IMPACT OF CLIMATE ON EASTERN U.S. WINE PRODUCTION

by

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ABSTRACT

IMPACT OF CLIMATE ON EASTERN U.S. WINE PRODUCTION

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This research addresses the gap in characterizing the climate structure in the eastern United States for suitability of winegrape growth. Even though all of the lower 48 contiguous states grow winegrapes and produce wine, most of the climate structure analyses have focused on the premium wine regions along the west coast (i.e, California, Washington, Oregon and Idaho). There has not been a comprehensive study on the climate structure in the remaining eastern states. This dissertation analyzes the eastern United States as a whole, to characterize the overall climate structure patterns. For this characterization, a comparative study of the four commonly used climate indices (i.e., Average Growing Season Temperature, Growing Degree Days, Heliothermal Index and Biologically Effective Degree Days), was performed using the Jan 1971 – 2000 PRISM 800-meter resolution dataset of climate temperature normals. Spatial temperature averages were created for the study area of 44 states and 58 American Viticultural Areas across the eastern United States. This study builds on current methodologies used to characterize premium wine regions in the western United States, and around the world. Results of this study created a comprehensive spatial analysis of site suitability for

winegrape growth using the four main climate indices for the eastern United States. Since there were many areas where these indices did not properly characterize a region as suitable for winegrape growth, a new index was developed, and used to assist in the characterization of the region. Lastly, the effects of climate change on the eastern US are analyzed using data from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report on Climate Change. Results of this study will make it possible to conduct more uniform climate-viticulture structure analyses.

Chapter 1

1. Introduction

This dissertation will use the four most common climate-viticulture indices to document the climate structure and suitability for viticulture (the science of the cultivation of grapevines) for the eastern United States (US). For this study, the eastern US is defined as the 44 states, which lie to the east of the west coast of the US. This excludes the states of California, Oregon, Washington State and Idaho, which is also referred to in this study as the premium wine regions of the US. Additionally, the study area also includes the subsequent 62 American Viticulture Areas (AVAs) which are found within the borders of those 44 states. These characterizations address the gap in the knowledge of the overall climate structure and suitability for viticulture throughout the eastern United States. Creating these datasets will allow for more uniform climate-viticulture comparisons to be performed on global scales.

In order to maintain uniformity with other climate-viticulture characterization studies in the western US (Jones et al 2009a), the 1971-2000 PRISM dataset was chosen. Using this type of dataset will create a true representation of the climate within the study area that the more commonly used data from climate station summaries can not provide. Station data only records data at one location, and does not capture the full climate of a particular area. Analyses of these characterizations will be performed to assess how each of the climate-viticulture indices describes the climate structure, and in cases where the indices do not fully capture the subtleties of an area, a new index will be created to more properly depict the climate in that region.

1.1 Importance of Climate

Climate is defined as the slowly varying aspects of the atmosphere-hydrosphere-land surface system (AMS Glossary, 2000). More simply, it describes the overall meteorological conditions in a particular region, and influences the activities that are associated in that particular region. For example, much of the United States (US) agriculture industry heavily relies on understanding and catering to particular regional climates to decide what type of crops to plant, and how to best manage their growth. The winegrape industry is no stranger to these types of management decisions, also heavily relying on how best to understand the climate within the grape growing region, and use it to their advantage (Jackson 2001; Jackson and Spurling 1988; Jackson and Schuster 1987; Jones 2006; Jones and Davis, 2000(a) and (b); Smart and Dry 1980; Tonietto and Carbonneau 2004; Van Leeuwen et. al, 2004; Winkler et al 1974).

There are many aspects of climate and geography that play an important role in viticulture. Temperature determines choice of cultivar (specific variety of plant of grapevine) to plant, length of growing season and ripening potential. Precipitation controls the seasonal water intake of the vine and determines if irrigation is necessary. Relative humidity can affect the susceptibility to certain diseases that the grapes may contract. In addition to climate parameters, geography parameters, such as latitude, altitude, slope and aspect, can also affect temperature and moisture parameters. Vineyards that are located in more northern latitudes, or higher altitudes, will have shorter growing seasons, however more northern latitudes have more daylight hours in the summer. Slope and aspect of the vineyard affects the amount of solar energy which is received and ability to drain away cold air and precipitation when necessary. All of these parameters play a significant role in many of the decisions that are made in regards to viticulture and vineyard management.

To make some of the initial vineyard management decisions easier, several climate-viticulture indices have been created over the years that have become standards for describing the climate in premium winegrape growing regions. The four most commonly used indices are: Growing Degree Days (GDD) (Amerine and Winkler, 1944; Winkler, et al. 1974), Heliothermal Index (HI) (Huglin, 1978), Biologically Effective Degree Days (BEDD) (Gladstones, 1992) and Average Growing Season Temperature (GSTavg) (Jones, 2006). These indices use temperatures (maximum, minimum and average) during the growing season to determine viticulture suitability of a particular region. This type of information is extremely useful to the grower initially, since it can determine what type of cultivar can grow in that climate, as well as knowing the length of the growing season.

Overall, the climate is one of the main factors that influence all terroir elements. Terroir is a French word that is the collective term integrating environmental (soil and climate), biological (variety and rootstock) and human factors (history and winemaking) that go into viticulture and enology (the science of making wines). These elements vary globally, from region to region.

It is not one single element of terroir that dominates the final outcome of the wine; however, temperature does play the strongest role. Winegrapes have been found to grow in a variety of different soil types, and in both wet and dry climates. Independently, each element of terroir contributes only a portion of the final wine character. It is necessary to have all of the elements of terroir work in harmony to produce the wine's characteristics (Bodin and Morlat 2006; Fanet 2004; Hancock 1999; Jones 2006; Van Leeuwen et. al, 2004; Vilanova et. al, 2007; White 2003).

1.2 Statement of Problem

In recent years, there have been several studies analyzing the climate-viticulture structure using high resolution datasets for premium wine regions in the Western US, Europe and Australia (Jones et al 2009a; Jones et al 2009b). These studies used similar datasets to the PRISM dataset which is used for this dissertation research, with the same temporal resolution, but slightly differing spatial resolution (400 m for western US and 1 km for

Europe and Australia). They were chosen because the continuous spatial coverage created a more realistic pattern of the climate in these study areas. Taking this approach allows more areas to be analyzed for viticulture suitability than past methods of analyzing point climate station data.

To create a complete climate-viticulture dataset for comparison studies, a similar analysis of the eastern US needs to be completed. However, this type of dataset does not exist. Instead, there are only site specific studies for individual states that give a summarization of vineyard site suitability (Boyer and Wolf 200; De Villers 1997; Fanet 2004; Jones 2001; Jones and Davis 2000; Jones and Hellman 2000,2003; Jones and Light 2001; Jones et. al, 2004, 2006; Magarey et al 1998; Shaulis and Dethier 1970; Watkins 1997; Wolf 1997; Wolf and Boyer 2003; Wolf and Poling 1995). Additionally, due to an increase in demand for opening new vineyards across the US, new growers have the need to understand the regional climate in their areas, so that they can properly set up their vineyard and choose the correct cultivars for their climate region.

Therefore, it is necessary to address this gap, and create global datasets of the most commonly used climate-viticulture indices. In doing so, this will address how appropriate these indices are for characterizing the climate in areas outside of where they were initially created. For example, the Winkler Growing Degree Day index (GDD) was found to be not very suitable for characterizing the climate structure for viticulture suitability in areas outside of California (Gladstones, 1992; Spellman, 1999; and Jones and Davis, 2000). Additionally, filling the gap in datasets will create an avenue for future comparison studies that are more realistic. Because of this type of study, growers in the eastern US will know how their climate compares to other global premium wine regions. This will help to make better vineyard management decisions, because new growers can follow the already established practices of the global premium wine regions that are comparable to their region.

1.3 Objective and Scope

The general objectives of this research are to analyze the climate structure throughout the Eastern US using the climate assessment methodologies that are most commonly used in climate-viticulture spatial studies. Additionally, a new index will be developed to address inadequacies in the current methodologies to properly depict the climate structure. The specific objectives of this research are as follows:

i) To document the climate structure of the study area by utilizing a high resolution dataset which will more accurately portray the subtleties of characteristics within the study area.

ii) To increase our understanding of the role that climate plays in non-traditional wine producing regions.

iii) To provide greater insight into current and future vineyard site suitability.

1.4 Organization of Dissertation

This dissertation consists of six chapters. In the first chapter, the issues and objectives of this research dissertation will be discussed. Methodologies of how this research will proceed and the data that will be used will also be outlined.

Chapter 2 consists of a literature review. Topics to be reviewed within this chapter are the role that climate parameters of temperature and moisture have on viticulture. Geography and topography, and the role that these parameters have on viticulture will also be examined in this chapter. Lastly, a review of the climate-viticulture indices and climate-viticulture classification studies will be discussed.

In Chapter 3, results of the application of each of the temperature based climate classification indices, for the overall eastern US, as well as state by state, will be discussed. Chapter 3 will begin with an overview of the history and current status of the wine industry in the study region. This is followed by a discussion of the US Koppen Classification, and the climate within these classifications, for the eastern US. Having an overview of how the eastern US is classified by the Koppen classification will create a baseline climate structure for the study area. Once this is accomplished, patterns of the four climate parameters will be summarized for the entire analysis region (i.e, the eastern US). These climate parameters are calculated according to the formulas listed in table 1, and will be evaluated on the basis of the maturity class levels which are also listed in this table.

Individual state and AVA classification analysis is documented in Appendix III. This analysis was performed also using the equations in Table 1. To assist in these classifications, percentages were generated from histograms of each AVA to illustrate the amount of area within the AVA which corresponds to a particular maturity class. Additionally, spatial statistics (i.e., quartile statistics), for the entire study area were calculated to illustrate ranges of maturity class. Both of these statistical tools represent the entire range of values for each index within each AVA and state, making no distinction between areas that are planted and areas that are not planted. Additionally, the range of values also makes no distinction between areas that can be planted, and areas that would never be planted due to elevation or otherwise owned or occupied lands, such as national and state parks.. For these situations, the spatial statistics can be used to determine the range that represents a particular area. These percentages and spatial statistics will help to determine the classification for each growing region.

Analysis of the performance of each of the indices will be evaluated in Chapter 4. Additionally, methodology for a new climate index will be introduced, and the performance will also be evaluated. Chapter 5 will provide a preliminary look at the evolution of the climate in the eastern US throughout the next 50 years. This will be done using one of the models from the AR4 IPCC report. Lastly, Chapter 6 will provide a summary and discussion of future directions.

Table 1: Summary of Climate Characteristic equations and ranking system.

Climate Parameter	Equation	Months to be calculated	Maturity Class Limits
Average Growing Season Temperature (GSTavg)	Σ ((Tmax+Tmin)/2)	April through October	Too Cool =< 13^0C Cool = 13^0C -15^0C Intermediate = 15^0C -17^0C Warm = 17^0C -19^0C Hot = 19^0C - 21^0C Very Hot = 21^0C -24^0C Too Hot = >24^0C
Growing Degree-Days (GDD)	Σ ((Tmax+Tmin)/2)-10°C)	April through October	Too Cool =< 1111 (Region I) 1111-1389 (Region II) 1389-1667 (Region III) 1667–1944 (Region IV) 1944-2222 (Region V) 2222-2500 (Region VI) 2500-2778 Too Hot >2778
Biologically Effective Degree-Days (BEDD)	Σ ((Tmax+Tmin)/2)-10°C)*k*DTR, where Tmax+Tmin has a 19°C upper limit, k = is a latitude coefficient that takes into account increasing daylengths from roughly 34° to 65° and DTR is the Diurnal Temperature Range (Tmax – Tmin)	April through October	Too Cool =< 1000 Very Cool 1000-1200 Cool 1200-1400 Temperate 1400-1600 Warm Temperate 1600-1800 Warm 1800-2000 Very Warm 2000-2200 Too Hot =>2200
Heliothermal Index (HI)	Σ ((Tavg-10°C) +(Tmax-10°C)/2)*k Adjusted for both latitude/daylength	April through September	Too Cool =< 1200 Very Cool 1200-1500 Cool 1500-1800 Temperate 1800-2100 Warm Temperate 2100-2400 Warm 2400-2700 Very Warm 2700-3000 Too Hot =>3000

1.5 Major Data Sources

1.5.1 Datasets

Various forms of data were used for this study. These are summarized in Table 2. Datasets that were used for current and future climate analysis were all obtained, or created, in a gridded format. Other industry data were obtained from sources found in online sources (see Appendix I). This data will be discussed in greater detail in this section.

For the climate classification analysis, two temperature normal datasets, maximum and minimum temperatures, were obtained for the conterminous US, from the PRISM group at Oregon State University (PRISM 2008). This dataset was created by the statistical model, PRISM (Parameter-elevation Regression on Independent Slopes Model). A detailed description of this model (i.e., methodology and verification comparisons) can be found in Daly (2008). This climate dataset is the official dataset of the USDA.

The basic methodology of PRISM uses a simple regression to calculate a linear relationship between climate (dependent variables) and elevation (independent variable) for each Digital Elevation Model (DEM) grid cell. To create a more realistic representation of the data, PRISM includes effects of physiographic features of the grid

Table 2: Summary of Datasets

Name	Description	Source
PRISM dataset	1971-2000 Climate normals (Maximum and Minimum temperature)	Oregon State University (PRISM 2008)
AVA boundary descriptions	Written description of boundary locations	TTB (CFR 2006)
State summary statistics	Statistics of area, population, other census data	ERSI ArcGIS dataset (ERSI 2009)
Wine and Viticulture industry data	State information of types of cultivars grown, wineries, production statistics, etc.	Websites from: state growers associations, state extension offices, wine tourism, etc. (See Appendix I)
State winery locations	Database of street addresses and latitude/longitude locations of Eastern US winery locations.	Websites from: state growers associations, state extension offices, wine tourism, etc. (See Appendix I)
Goddard Institute for Space Sciences–Atmosphere Ocean Model climate model (GISS-AOM)	Climate of the 20th Century experiment (20CM3) and 720 ppm stabilization experiment (SRES A1B) from the AR4 of the IPCC	Program for Climate Model Diagnosis and Intercomparison (PCMDI) at Lawrence Livermore National laboratory (PCMDI 2010)
US Historical Climatology Network	CO-OP station historical observations of Maximum and Minimum temperature (1950 – 2000)	National Climatic Data Center (NCDC 2010)

cells, such as proximity to water bodies, location and elevation, topography and orography features and vertical atmospheric layers. Ten thousand weather reporting stations were used as input into the regression, and were weighted based on similarities between physiographic features of the station and the grid cell. As the regression is calculated, the slope of the line changes as elevation changes per grid cell, due to the weighting methodology. The data are then interpolated onto 30 arc-second grids (~800 m). The resulting dataset is a spatial climate dataset of monthly temperature normals, (i.e., monthly maximum and minimum temperatures), for the time period of Jan 1971 – 2000.

As previously mentioned, the study region will be defined as the 44 states which are located to the east of the west coast. This excludes the states of California, Washington, Oregon and Idaho. Although all of the calculations will include all of the lower 48 states, to avoid creating artificial boundaries in the data, the analysis will only involve discussions of these 44 states. Additionally, only the AVA regions that lie within the boundaries of these 44 states will be analyzed. There are 62 of these areas.

To define the AVA regions that will be analyzed, it was necessary to obtain written descriptions of boundaries for the AVA regions. Written descriptions of each of the 62 AVA regions were obtained from the Alcohol and Tobacco Tax and Trade Bureau (TTB) (Code of Federal Regulations, 2006), and transposed into polygons representing each AVA. This created a gridded map which can be used in conjunction with the PRISM dataset, as a layer file. An image of this AVA region shapefile can be seen in Figure 1, in which the AVA region map is overlaid on top of the US states map. In this figure, the AVA regions are colored in blue. A list of these AVA regions and corresponding states can be found in Table 3. This list was compiled with data from online sources listed in Appendix I and digital datasets from the ArcGIS software listed in the next paragraph.

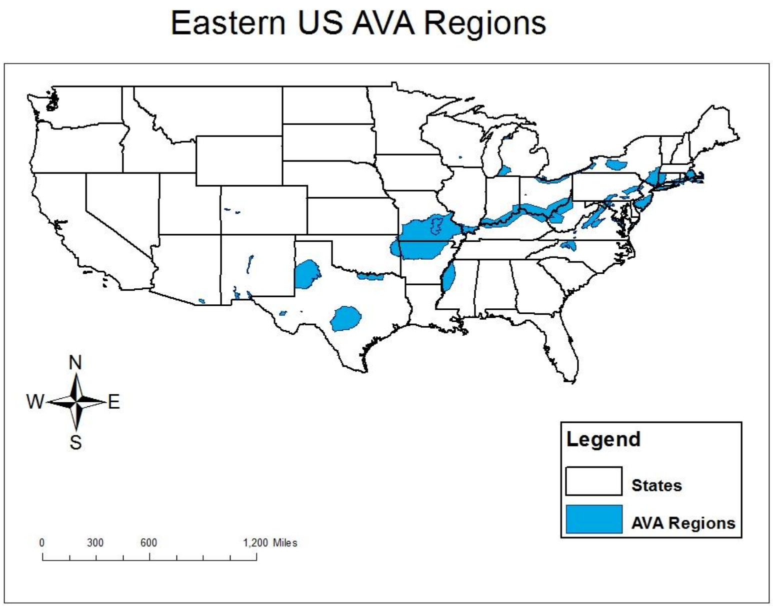


Figure 1: Eastern United States AVA regions. Data Source: TTB (CFR 2006)

Digital data, in the form of gridded shapefiles were obtained from Environmental Systems Research Institute, Inc. (ERSI, 2009). These gridded shapefiles contain data such as: state census data of demographic and size information, topographic and elevation files, transportation data, road and waterways locations, and state and county boundaries, and can be displayed as a layer file in ArcGIS. This dataset was used to calculate state area, elevation information, boundaries of AVAs, as well as other topographical information to locate features that would have a direct impact on the climate of a region (such as locations of lakes, rivers and mountains).

Wine and viticulture industry information was gathered from a variety of online sources, such as State Growers Associations and state winery websites (for a complete listing, see Appendix I). Information such as acreage planted, typical cultivars grown in a particular area, topographic information, and winegrape production was compiled from the websites and converted into formats that were compatible with ArcGIS. Location of estate wineries and vineyards were also compiled, and converted to latitude/longitude positions. These positions were used to create an ArcGIS point file, which was used as an additional layer for the climate analysis (See Figure 2).

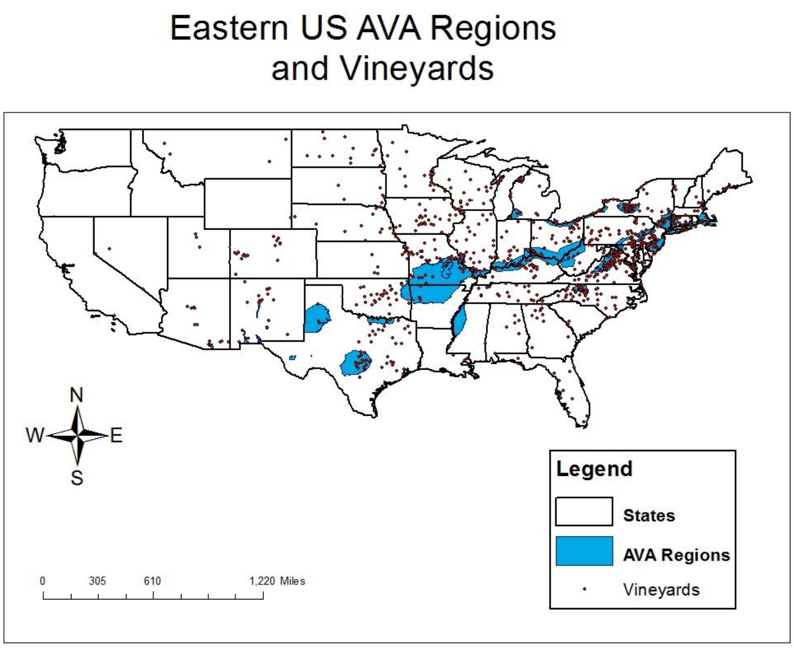


Figure 2: US Eastern Vineyard and Estate Winery Locations with AVA regions. Data Source: See Appendix I and TTB (CFR 2006)

Lastly, output from the Goddard Institute for Space Sciences – Atmosphere Ocean Model (GISS-AOM) climate model and historical observations from the US Historical Climatology Network (NCDC 2010) was used. The GISS-AOM was one of the climate models that was used to produce the 4th Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2007; PCMDI 2010). For this dissertation, the output will be used to describe historical and future trends in temperature. Historical temperature observations from the USHCN data, for the time period of 1950 – 2000, will be used as ground truth. This will be compared with the historical data from the GISS-AOM output. It should be noted that due to the grid cell size of the GISS-AOM data, that the closest GISS-AOM grid point was used for this analysis, and that some of the USHCN station locations may fall within the same GISS-AOM grid cell.

The GISS-AOM has a 4° x 3° horizontal resolution grid, with 12 atmospheric vertical layers and 16 ocean layers. The GISS-AOM does not use a flux adjustment. A more comprehensive description of the GISS-AOM model is available through the Program for Climate Model Diagnosis and Intercomparison (PCMDI) at Lawrence Livermore National laboratory (PCMDI 2010). For this study, the Climate of the 20th Century experiment (20CM3) was used to simulate historical climates, and the 720 ppm stabilization experiment (SRES A1B) was used to simulate future scenarios. The time periods of 1950 – 2000 will be evaluated for the 20CM3 dataset, and the years of 2020 – 2050 will be evaluated for the SRES A1B.

The US Historical Climatology Network (NCDC 2010) dataset will be used to show actual historical trends, for the time period of 1950 – 2000. Locations were chosen on the basis of proximity to larger concentrations of vineyards throughout winegrape growing regions in the eastern US. This dataset is a subset of the NOAA Co-Operative Observer Program (COOP) Network, and consists of historical observations of many different meteorological parameters. For this study, maximum and minimum temperatures will be evaluated.

1.5.2 Software

A Geographic Information System (GIS) will be used to create this climate classification. GIS technology has been proven to be a useful tool to organize and characterize many studies in the agriculture industry, as well as within the viticulture industry (Bowen et. al 2005; Boyer and Wolf 2000; Bramley and Hamilton 2004; Barmley and Proffitt 2003; Gordon 1997; Hartkamp et. al 1999; Jones 2001; Lamb and Bramley 2001, 2002; Morris 2001; Smith and Whigham 1999; Tamaluddin and Kamaruzaman 1999). It can be employed in such vineyard management tasks as monitoring variations within the vineyard, soil sampling, yield mapping and site specific management.

To create the GIS, the analysis software ArcGIS will be used (ERSI 2009). This is accomplished by using a series of digital maps overlays. Overlaying these maps reveal patterns in the data that might not be seen in a single map. In addition to creating analysis maps, ArcGIS can also be used for database management. Data can be gathered from various sources and merged into one large database. These databases can also be joined with the layer maps to reveal additional patterns in the data. This study will use ArcGIS in these capacities to organize and analyze spatial data and attribute data (i.e., temperature normal maps, AVA wine region maps, winery location map, topographic information, and elevation), through the use of layered maps, and developing spatial relationships among these layers.

In addition to analyzing spatial patterns with ArcGIS, the quantile statistics (i.e., minimum, 25%, median, 75% and maximum values) of climate data will also be analyzed statistically using the software package called "R" (Gentleman and Ihaka, 1997). This software was originally developed at the University of Auckland in the mid-1990s, and is similar to the software package, "S", developed at Bell Laboratories, now Lucent Technologies (Chambers, 1990). R was chosen for this study since it is an open source code, well documented and user-friendly, and provides all of the functionality of other statistical software packages that are not free open source code.

The Grid Analysis and Display System (GrADS) and the Interactive Data Language (IDL) were used to analyze the evolution of the future climate (GRADS/IGES 2010 and ITTVIS 2010). These software packages were used to perform temperature trend analysis within the study area. In addition to creating statistical trends, this software was also used to create graphics to further illustrate the evolution of the climate.

1.6 Principal Results

This dissertation has several key results, a climate-viticulture characterization of the eastern US, a new climate - viticulture characterization index based on the average growing season temperature in conjunction with the Koppen Classification scheme, and a preliminary look into the evolution of the climate over the next 50 years.

Climate-viticulture characterizations are documented for the 44 states and 62 AVAs that comprise the eastern US. This is done not only to create a starting point of how the standard climate-viticulture temperature indices characterize the climate in non-premium winegrape growing regions, but to investigate the validity of these standard indices. Results show that many areas are not properly characterized, since indications show that many areas are unsuitable for winegrape growth. As shown throughout this study, growth is already occurring in many of these regions.

A new index is proposed for characterizing climates in the eastern US. Current locations of vineyards are used to validate the usefulness of this index in characterizing climates. Analysis reveals that many of the areas where established vineyards are located correspond with maturity class levels that will support winegrape growth. This new index evaluates many of the areas that were once categorized as unsuitable by standard indices, now suitable for growth, therefore, it is a good indicator for climate-viticulture characterizations in the eastern US.

Finally, a preliminary analysis of the future climate in the eastern US is evaluated. This investigation evaluates one solution from the IPCC AR4 report. Implications of the changes predicted to occur are discussed.

Chapter 2

2. Literature Review

2.1 Vineyard Site Suitability Studies

Vineyard site suitability is concerned with matching the grape variety to the physical characteristics of the site, such as climate, elevation, slope, aspect, and soil (Jones et. al 2001), and is one of the most important factors in determining whether it is possible to establish a vineyard. Additionally, matching the combination of the optimum site to the grape variety will impact the success of the vineyard in terms of yield, quality of the wine and profitability (Wolf 1997). One of the most essential considerations in determining site suitability is the regional climate of the area where the vineyard will be located (Winkler et al 1974), and climate within the vineyard (Plocher and Parke 2001). It is a well known fact that winegrapes can be grown in a variety of soil types; however, climate is the limiting factor. If the climate is not conducive to winegrape growth, then the grapes will not mature properly thus affecting the end product.

A number of studies have been conducted over the years which focus on the premium global wine regions, such as Western United States, Europe and Australia, in order to assess the suitability of establishing and maintaining vineyards either by analyzing general climate aspects (Dry and Smart 1988; Gladstones 1992; Winkler et al 1974), or by investigating the overall terroir elements, such as climate, soils and viticultural practices (Bodin and Morlat 2006; Fanet 2004; Hancock 1999; Jones 2006; Van Leeuwen et. al, 2004; Vilanova et. al, 2007; White 2003).

Narrowing the geographic area, several studies have focused on the regional aspects of site suitability. The impacts of cooler climates have been investigated to understand how to adjust vineyard management techniques to obtain the maximum productivity (Jackson 2001; Jackson and Schuster, 2001; Plocher and Parke, 2001). In a 2000 study, Jones and Davis (2000a) examined the influence of climate in Bordeaux, France on grapevine phenology, composition and wine production. Additionally, Jackson and Cherry (1988) investigated seventy-eight locations throughout Europe, North America, Australia and New Zealand for site suitability on the basis of temperature and latitude.

To quantify the winegrape-growing climate regions worldwide, Tonietto and Carbonneau (2004) created a multicriteria climatic classification (MCC) system, based on 3 climate indices, the Heliothermal Index (HI), the Cool Night Index (CI) and the Dryness Index (DI). In this system, ninety-seven of the established premium winegrape growing regions were identified, and classified according to these indices. Examples of these already established premium grape-growing regions are France, Germany, Spain, Italy, Australia, New Zealand, Brazil, Argentina, Canada, South Africa and select parts of the US. These indices will be discussed in more detail in section 2.4. In 2007, Blanco-Ward et. al added to the initial regions by analyzing 39 more locations throughout the Mino River Valley of Spain using these same climate indices.

GIS has also been utilized on smaller scales studies, on the local level, to determine site suitability. This is done by analyzing the spatial characteristics of the various elements of terroir. As in the non-GIS studies, these studies evaluated a particular region for elements of vineyard site suitability, such as climate, topography and soils. Several studies have investigated site suitability throughout Oregon (Jones and Hellman 2000, 2001, 2003; Jones et. al 2004 and 2006). A similar study was conducted with the study region of the Okanagan and Similkameen Valleys in British Columbia (Bowen et al 2005). Lastly, only focusing on elements of soil and topographic characteristics, Watkins (1997) evaluated the Shenandoah Valley and Fiddletown AVAs in eastern California for elements of site suitability.

Also focusing on the local regions, many of the viticulture state extension offices produce guides for planting and determining site suitability specific to that state. These guides generally have broad overview of the factors that determine site suitability, as well as more specific information for the challenges of growing winegrapes in a particular region. Wolf (1997) discusses the specific climate, land characteristics and potential hazards that will be encountered in the state of Virginia. Similar guides can be found through many of the extension offices with similar information, such as Cornell Extension for New York State (Pool 2000), Ohio State University (Dami et. al 2005), Michigan State University Extension (Zabadal and Andersen 1997) and Texas A&M University (Hellman and Kamas 2007).

Synthesizing many of the areas evaluated in previous studies with new study areas, Jones et al (2009a and 2009b) addressed site suitability and climate characterizations in the premium global wine regions of the Western United State, Europe and Australia. In these studies, GIS and high resolutions temperature datasets were utilized to characterize the climate in the study region in terms of the standard climate indices (GDD, HI, BEDD and GSTavg). Again, these will be discussed in further detail in section 2.4. Doing this type of site suitability characterization produced the largest, most continuous coverage area of any site suitability study that has been produced so far.

2.2 Impacts of Temperature on Site Suitability

There is a common theme throughout all of the vineyard site suitability studies of evaluating the impacts of climate on the winegrape growing region. The climate parameters that have the greatest influence on the overall growth and survival of the grapevine are temperature, precipitation, and wind. Of these factors, temperature plays the most important role in the quality of the fruit, and the productivity of the vineyard (Amerine and Winkler 1944; Jackson 2001; Winkler et. al 1974). For example, it dictates what type of cultivars to plant, when the growing season will start, and how long it will last, when the vine will enter dormancy after the first frost, and minimum winter temperatures.

Temperature and solar radiation (also referred to as light intensity) also plays an essential role in the overall growth of the grapes (Buttrose et. al, 1971; Coombe 1987; Crippen and Morrison, 1986(a) and (b); Davidson Consulting, 2004; Ewart and Kliewer, 1977; Ewart et al, 1985; Hale and Buttrose 1974; Jackson 2001; Jackson and Spurling, 1988; Jackson and Lombard, 1993; Kliewer 1967, 1970 and 1977; Kobayashi et. al 1967; Lasko and Kliewer 1978; Van Leeuwen et al, 2004; Winkler et. al 1974). Temperature controls the composition and quality of the grape, by affecting the pigments in the grapeskins, as well as the sugars and acids within the grape. Solar radiation contributes to the overall growth of the plant.

The growing season is defined as the amount of days between the last 28°F day in the spring and the first 28°F day in the fall (Pool 2000). Although these limits define the actual growing season, vine shoot growth does not actually occur until temperatures reach 50°F (10°C) (Wolf 2008). Once vine shoot growth begins, temperature dictates how the cultivar and fruit will develop and mature. Each stage of growth must be significantly long enough, and at the correct temperature range, so that the berry can sufficiently develop, leading to proper growth rates and sizes. In general, the growing season should be greater than 170 days (Pool 2000).

The first stage of development is budbreak, which lasts approximately 5 to 7 weeks, depending on variety. The next stage is bloom, or grape flower cluster development, and lasts generally between 2 and 4 weeks. The third stage is veraison. At this stage, the winegrape changes color, the berries soften and there is an accumulation of sugars. This lasts between 5 and 8 weeks, and average mean temperature should range from 15°C to 21°C (59°F to 69.8°F) (Gladstones 1992). The last stage is harvest, and happens when the winegrape matures. (Jones and Davis 2000; Wolf 2008).

In general, plants need sunlight and warmth to grow. Solar radiation, in the form of sunlight, contributes to the growth of the plant by supplying the energy needed for photosynthesis to occur. Through photosynthesis, energy from the sun is absorbed into the green pigment in the leaves of the plant. With this energy, as well as Carbon Dioxide (CO_2) in the atmosphere, and water from the ground, the plant converts this energy into sugars, proteins, fats and other carbohydrates. These are necessary to begin and sustain the growth of the plant. (Winkler et. al 1974)

As the plant grows, it produces more leaves, making it possible to receive more sunlight, so that more photosynthesis can occur. This contribution of sunlight to growth is seen throughout the vineyard, during the growing season. As the canopy grows, leaves will continue to absorb more sunlight, producing more growth. If there is too much leaf area, then leaves will begin shading one another, and the plant will begin dying in spots, since it is not getting sunlight to all parts of the plant. Select pruning of the plant, and other canopy management techniques (i.e, trellis selection, shoot thinning and positioning, and vine spacing), can prevent this from happening (Smart and Robinson 1991; Wolf 2008)

Topography parameters, such as slope and aspect, can also affect the amount of sunlight the plant receives. Slope is defined as the inclination, or declination, that the land varies from the horizontal. This is usually expressed as a percentage. The aspect is defined as the compass direction that the slope faces. (Wolf 2008)

Vineyard slope and aspect can affect the development of the winegrape as well. Slope mainly influences the temperature changes in the vineyard and how moisture drains away from the vineyard. Additionally, slope can influence if the cooler air drains away from the vineyard, or becomes stagnant. If the slope is steep, cooler air will have more opportunity to drain down the hill. Flatter slopes allow cooler air to become trapped in the vineyard during periods of cooler temperatures in the early spring and late fall, creating a risk of damage to the winegrape. (Davidson Consulting, 2004; Gladstones 1992; Jackson 2001; Jackson and Schuster 1987; Jackson and Spurling 1988; Van Leeuwen et. al, 2004; Wolf 2008)

Aspect also influences the development and growth of the winegrape. It is important because it defines how much solar energy is available to the vines. Southward facing slopes receive more sunshine than northward facing slopes. Having a southward aspect will allow more photosynthesis to occur, allowing the plant to grow to their full potential. (Davidson Consulting, 2004; Gladstones 1992; Jackson 2001; Jackson and Schuster 1987; Jackson and Spurling 1988; Van Leeuwen et. al, 2004; Wolf 2008)

Many studies have been done on smaller scales to investigate the affects of temperature and sunlight on winegrape growth. These studies have looked at individual grapevines in varying degrees of temperature and light intensity. Then, results of these studies have been translated to larger scales, and applied to the vineyard scale.

There have been several studies that have investigated the quality of the fruit by mimicking the effects of select pruning of the canopy by growing grapevines under various levels of light intensity and temperature. In early studies, under controlled environments, Kliewer (1967, 1970) looked at the affects that temperature and light intensity had on coloration (anthocyanins) and concentration of acids on *V. Vinifera* winegrapes. Anthocyanin is the pigment that creates the red color in red, blue, purple and black grapes (Winkler et al, 1974). In these studies, the winegrape development was analyzed under high and low levels of temperature and light intensity.

Kliewer determined that under very high temperatures, greater than 30°C (86°F), anthocyanin synthesis completely slowed down in Cardinal winegrapes (large berries), but not in Pinot Noir winegrapes (small berries). However, there was a significant increase in the levels of anthocyanins at lower daytime temperatures, 20°C (68°F), at either light intensity. Coloration was also reduced at lower light intensities, at either temperature, however, more uniform coloration was found at lower temperatures.

Additionally, at high temperatures, the malic and tartaric acids, were significantly lower, at either light intensity, however, these acids were found to be generally higher when grown under low light intensities.

Temperatures also influence the composition of the sugars (Brix) and soluble solids found in the berry. The level of Brix determines the alcohol yield and the residual sugars (sweetness) in the wine. Higher temperatures during the growing season increases the level of Brix found in the berry.

In 1977, Kliewer further analyzed the affects of temperature and solar radiation on color and composition of Emperor grapes in both controlled environment and field conditions. Temperatures were set to 37°C (98.6°F) during the day and 32°C (89.6°F) during the night for the controlled environment, and 23.6°C (74.5°F) during the day and 17.1°C (62.85°F) during the night for the field conditions. Light intensities varied from full sun, partial sun to shaded conditions. He found that under the higher controlled temperatures, no anthocyanins were produced at either light intensities. Conversely, the field conditions produced considerable anthocyanins under either light intensities. Also at higher temperatures, there were no increases in soluble solids in Brix above the 12.9° level. Under the field conditions, there was an increase in soluble solids to 21° Brix. Lastly, anthocyanins and soluble solids were found to be the greatest under field conditions at higher light intensities.

To investigate the effects of light pruning, and trellis management, Ewart et. al (1985) found that using light pruning and a higher trellis system increased the growth of shoots and vines, which led to a slight increase in yield. The introduction of light pruning produced fewer shoots with clusters on the grapevine. This allowed the remaining shoots to receive more photosynthesis and have higher production rates.

Two studies by Crippen and Morrison (1986a and b) examined the effects that sun exposure had on Cabernet Sauvignon berries in terms of composition development and phenolic content. In these studies, berries were analyzed from both sun exposed and shaded locations within the canopy of the grapevine. In terms of compositional development, it was found that sun exposed berries had significantly higher concentrations of tartrates, malate, glucose and fructose (sugar content) than those berries that were shaded. Additionally, shaded berries were also found to be heavier due to the higher water content within the berry.

In terms of phenolic content, overall the concentrations of soluble phenols decreased over the growing season, while soluble phenols per berry increased during early berry growth, to maximum at the start of stage III, then decreasing after veraison for both shaded and sun exposed berries. Soluble phenols were also found to be significantly higher in the sun exposed berries. Additionally, the anthocyanin concentrations were also found to increase rapidly after veraison in the sun exposed berries, however, there were significantly lower concentrations found at harvest.

In addition to studies that look at the affects of the combination of light intensity and temperature, there have been many studies focusing on only temperature to determine how the fruit develops over time. Optimal temperature for photosynthesis is 25°C (77°F). Additionally, photosynthesis declines rapidly at temperatures in excess of 30°C (86°F). (Kriedemann 1968)

A number of the early temperature studies were conducted in a controlled environment. In 1967, Kobayashi et al (1967) examined the effects on day and night temperatures on yield and quality of Delaware grapes. To study the effects of nighttime temperatures, the temperatures were set at 15°C, 22°C, 27°C, and 35°C (59°F, 71.6°F, 80.6 , and 95°F, respectively) and daytime temperatures were kept at natural levels. To study the effects of daytime temperatures, the temperatures were set at 15°C, 20°C, 25°C, and 30°C (59°F, 68°F, 77°F, and 86°F, respectively) and nighttime temperatures were kept at 20°C (68°F). It was found that 22°C (71.6°F) was the most suitable day/night temperature combination for yield and quality. It was also found that temperatures greater than 30°C (86°F) were unsuitable for quality and yield. Additionally, it was also determined that berry temperatures were on an average 5-6°C above the ambient temperature because of greater absorption of solar radiation.

Buttrose et al (1971) investigated the effect of temperature on composition of Cabernet Sauvignon by varying the daytime temperature between 20°C (68°F) and 30°C (86°F), while keeping the nighttime temperature at 15°C (59°F). Growth was evaluated both before veraison and during ripening. Results of this study were consistent to results found in other light intensity and temperature studies. It was found that lower temperatures produced enhanced pigmentation and higher concentrations of malic acid. Conversely, higher temperatures produced an increase of 1.5° in Brix level. Lastly, there was no difference to be found in berry volume or concentrations of sugars and tartaric acid under differing temperatures.

Expanding on this study, Hale and Buttrose (1974) investigated the effects of temperature on the stages of development of Cabernet Sauvignon in a controlled environment. Temperatures for this study were allowed to vary from daytime temperatures of 18°C, 25°C and 35°C (64.4°F, 77°F, and 95°F, respectively), and nighttime temperatures of 13°C, 20°C and 30°C (55.4°F, 68°F, and 86°F, respectively). Stages I and II were found to be more sensitive to temperature than stage III. The highest temperatures were found to reduce the amount, size and duration of berry growth during stage I, and lengthened stage II by prolonging the onset of stage III. Also at the highest temperatures, total soluble solids were at their highest during stage I, and the lowest at stage II and III. The final berry weight was the lowest when temperatures were the highest; however, berry size was unaffected. When temperatures were at their lowest, maximum berry size was achieved more rapidly and acidity was at its highest.

In another controlled study, Ewart and Kliewer (1977) investigated the effects of controlled day and night temperatures on composition. For this study, temperatures were fixed at 25°C/10°C, 25°C/20°C, and 15°C/10°C (77°F/50°F, 77°F/68°F, and 59°F/50°F, respectively) for daytime/nighttime temperatures from one week before bloom until veraison. It was found that fruit set didn't differ between the temperature regimes, but, the number of seeds per berry was lower at lower temperatures.

Many of the worlds' premium wine regions are found in areas which are considered to have a cool climate. A cool climate is defined as an area where the mean temperature in the month before harvest is 15°C (59°F) or below. Some of these regions include areas of New Zealand, Germany, France and Oregon.

Cooler climates have a significant effect on the growth and maturity of the winegrape, and possess many challenges to viticulture. This type of climate produces grapes with lower sugar levels, higher acid levels, levels of pH that seldom too high and lower yields. Conversely, grapes produced in warmer climates, have higher sugar levels in the berries, which produces wines that have a higher alcohol content, low acid levels, high pH levels, and higher yields. (Jackson 2001)

Wines that are produced in cool climates often have less body than those produced in warmer climates, however, they are often considered fresher (due to the acidity), with a finer bouquet and aroma. Wines produced in warm regions, are more full-bodied in taste, less acidic and higher in alcohol. Cool regions produce more white wines, whereas warmer regions produced more red wines. (Jackson 2001)

There are several factors related to temperature that affect the speed of ripening that can be found in a cooler climate. As mentioned previously, temperature plays a major role in the speed of ripening. However, increases in temperature ranges don't necessarily equate to increases in ripening at the same speed. In other words, increase from 10°C (50°F) to 20°C (68°F) during the ripening period has a greater affect on the speed of ripening than increases from 25°C (77°F) to 35°C (95°F) (Jackson 2001). This is supported by the results from Kliewer (1967, 1970), Kriedemann (1986) and Kobayashi et al (1967), among others, who determined that higher temperature decreased the growth of the berry, the speed of ripening and quality of the fruit.

Temperatures in higher altitudes and latitudes can also have an affect of the speed of ripening. Winkler et. al (1974) found that maximum elevations for winegrape growth is 5000 – 6500 ft (1524 – 1981 m), since higher altitudes are generally cooler than surrounding lower elevations. In areas with extremely warm temperatures, higher altitudes can make up for found at lower latitudes (Van Leeuwen and Seguin 2006; Van Leeuwen et. al, 2004).

Higher latitudes also have an impact on temperatures throughout the growing season and during the ripening period. One concern in higher latitudes is cooler temperatures in the spring from bud break to bloom. If temperatures are cooler during this period, there will be a delay in budbreak, which will shorten the growing season. Cooler temperatures during bloom and shoot growth will slow down photosynthesis and delay the overall growth of the grapevine. Lastly, late spring frosts during budbreak, could cause the primary bud to die, and could decrease the overall productivity of the grapevine.

Although higher latitudes have more sunlight hours during the growing season, these areas are susceptible to early fall frost which cause the leaves to die, and fruits to complete the ripening process without fully developing (Jackson 2001; Plocher and Parke 2001).

Another major concern in a cool climate is temperature fluctuations during the winter and winter injury to the grapevine. Grapevines can acclimate to colder temperatures as long as the decrease in temperature happens over a long period of time. Sudden temperature drops can damage the vine since it is unprepared to handle freezing temperatures. As the temperature slowly drops, the vine produces suberin and callose, which slow, and eventually stop the flow of water from the roots to the trunks and canes. Because of this, periderm forms, and the canes turn from green to brown. If the temperature drops suddenly, these processes do not happen, and flow of water up the trunk into the canes is not stopped, causing the vines to burst as water is frozen in the trunk and canes. (Plocher and Parke 2001)

Sudden spikes in temperature in the winter or early spring can also cause injury similar to winter injury. Temperatures which warm above 0°C (32°F), such as a "January thaw", can cause the acclimation process to reverse. As temperatures return to more normal, colder temperatures, the vines can be injured in the same manner as described above. (Plocher and Parke 2001)

Minimum winter temperatures can also be a concern in the selection of cultivar. Temperatures during the growing season may indicate that the growing season is sufficiently warm enough, and long enough for a *V. Vinifera* to grow. However, minimum temperatures may be too cold for these varieties to survive throughout the winter. Many varieties of *V. Vinifera* can not withstand minimum temperatures below -15°C (Jackson 2001). However, there are many new French hybrid varieties which can withstand temperatures on average down to -26°C, and some even as low as -37°C, such as Marquette, Prairie Star and Brianna (Smiley 2008).

All of these temperature studies have brought out the importance of finding vineyard sites with either the most conducive climate on the larger scale, and/or a site which utilizes the maximum sunlight on the smaller scale. The results of these studies have indicated that different varieties respond differently to varying climates, due to characteristics of the grape (i.e., berry size or ripening length). Therefore, when analyzing site suitability, it is important to match the particular variety of grape to the growing season climate.

2.3 Additional Climate Parameters and Site Suitability

Moisture parameters, such as precipitation and relative humidity are also important for winegrape quality. Precipitation and soil moisture are critical factors in vine growth.

These climate parameters will be discussed briefly in this section, however, they are beyond the scope of this dissertation research.

Much research has shown that daily water intake is the most important factor to vine and fruit growth, throughout the season (Bravdo and Naor 1996; Fereres and Evans 2006; Matthews and Anderson, 1988; Netzer et. al, 2005; Ojeda et. al 2002, Winkler 1974). These studies have shown that it is important to monitor daily fluctuations of vine water status and soil moisture and temperature during the growing season, for effective irrigation management. This can be done with the use of hand held tools such as probes, tensiometers and lysimeters. Early in the growing season, it is necessary for soil moisture to be a certain background level for the vines to grow. This level is managed throughout the growing season, so that soil moisture levels do not exceed certain thresholds, and the vines are subjected to a certain amount of stress. (Bravdo and Hepner, 1987; Lascano et. al 1992; Lunt et. al, 2005; Monteiro and Lopes 2007; Ramos and Martinez-Casasnovas 2006; Riquelme and Ramos 2005; Williams et. al, 2003; Williams and Ayars 2005).

Precipitation and soil moisture can also play a role in the sugar levels in the fruit. Optimal annual precipitation is between 700 and 800 mm (Jackson and Lombard, 1993). Excesses in amounts of precipitation, or irrigation, have negative affects on growth as well (Jackson 2001). These excesses can cause ripening to be slower. By the addition of too much water into the plant, berries will become larger, decreasing the Brix level and the amount of anthocyanins (coloration) found in the berry, and increasing the acid levels. Additionally, heavy storms at the time of harvest can create situations where crops are harvested either too early, to avoid the addition of excessive amounts of precipitation, or too late, which would cause the berries to swell, and split due to the increase of water into the plant. (Conradie et al., 2002; Davidson Consulting, 2004; Jackson and Lombard, 1993)

Another factor to consider related to precipitation is the humidity of the region. Relative humidity also plays a role in the diseases that the fruit can contract (Dry and Smart 1988; Davidson Consulting, 2004). If the region is very humid, mold, fungus, botrytis and other diseases can form, and damage the crop. Sprays and powders can be used as effective methods of disease management, and can applied to the crop to combat this problem. Also, there are many varieties of cultivars that have a high disease resistance, such as the French Hybrid varieties of Kay Gray, Marquette and Prairie Star. Choosing one of these types of varieties can cut down problems with disease.

The last factor of climate that plays a minor role in climate conditions within the vineyard is wind (Gladstones 1992). Winds can have both positive and negative effects on the vineyard. Vineyards that have some exposure to mildly windy conditions benefit from the drying effects. On the positive side, wind can help to keep air circulating in the vineyard so that humidity levels are kept low, thus keeping diseases related to high humidity low as well. Additionally, it can assist in evapotranspiration by removing moister air, and replacing the air with drier air. As mentioned above, small amounts of vine water stress are helpful in producing fruit with high concentrations of Brix. Lastly, in the fall, wind can keep pockets of frost from settling in portions of the vineyard overnight. These pockets of frost will damage fruit, and decrease the yield. (Gladstones 1992; Jackson 2001; Winkler 1974)

On the negative side, high winds can break shoots from the vine, reduce growth and leaf size. It can also reduce stomatal density, leading to decreases in stomatal conductance and transpiration. High winds can also lead to decreases in photosynthesis and levels of Brix found in the berry. (Jackson 2001; Jackson and Lombard, 1993)

2.4 Review of Temperature based Climate Classification Indices

There are several common climate classifications indices used in the viticulture industry to determine site suitability. Mainly, these indices are based on the summation of average growing season temperature, since this is most important factor in growth of the cultivar and fruit. As mentioned before, grapes need at least a minimum temperature of 50°F before growth begins to occur, and needs at least 1200 degree days to attain full ripeness (van Leeuwen et al, 2007).

The first regional climate classifications began in the 1930's and 1940's, by Amerine and Winkler (1944). They created a methodology for categorizing California grape growing climate regions, based on temperature and heat summation, often referred to as the Heat Summation method or the Degree Day method. In this method, the mean monthly temperature above 50°F (1°C) is summed, and expressed in degree days. For example, if the mean for a particular day is 70°F, the summation is 20 degree days. These degree days are then summed for the entire season, from April 1 st to October 31st. Table 3 outlines how each Climatic Region is broken down according to degree days, and gives some examples of geographical locations of each Climatic Region.

Over the years, there have been several climate indices that have incorporated the biological aspects of the growing season such as sugar content, phenology and metabolism. Taking into account the length of day at the highest latitudes, Huglin (1978) created the Heliothermal Index (HI). This index uses daily temperatures, and a length of day coefficient to calculate an index to establish when the best potential sugar content of the grape can be found.

Derived from Winklers' Heat Summation method, the Biologically Effective Degree Day (BEDD) and the 19/10 Calculations (Gladstones 1992) are also commonly used to calculate degree days. In the BEDD method, the summation of degree days is limited to summations between 10°C and 19°C (66.2°F), and adjusts for latitude and daily temperature range. The 19/10 calculations differs from the BEDD method in that mean temperatures are truncated at 19°C, and a threshold of the maximum degree day summation is 279° for any given month.

Smart and Dry (1980) developed an index which was based on five climate parameters, average temperature in the hottest month, Continentality (difference between the temperature in the hottest month and the coldest month), total sunshine hours for the growing season (April – September for the Northern Hemisphere; October – March for the Southern Hemisphere), aridity (difference between total rainfall and evaporation), and average relative humidity during the growing season. Jackson and Cherry (1988), created a climate index based called the Latitude-Temperature Index (LTI). In this index, the latitude is subtracted from 60, and then multiplied by the mean temperature of the warmest month. This index was found to be comparable to Winkler's GDD. Also based on temperature, the Cool Night Index (CI), is based on the minimum air temperature in September (in the Northern Hemisphere) and in March (in the Southern

Hemisphere), which takes into account minimum temperatures during the ripening month (Tonietto 1999).

Table 3: Climatic Regions. Source: Winkler 1974.

Region	Heat Summation Range in degree days	Geographical Location Example
Climatic Region I	up to 2,500	California's Anderson Valley, Mendocino, Santa Clara and the Santa Cruz Mountains, France's Beaune and Bordeaux regions, Germany's Rhine region, Australia's Coonawarra region, and regions in the northeast US, such as Geneva, NY and Erie, PA
Climatic Region II	2,501 to 3,000	California's Napa, Monterey, and Sonoma Regions, Yakima Washington, Auckland New Zealand, and Santiago Chile
Climatic Region III	3,001 to 3,500	Mendocino, Monterey, Napa and Sonoma regions in California
Climatic Region IV	3,501 to 4,000	Fresno, Riverside, Sacramento, San Diego and San Joaquin regions in California
Climatic Region V	4,001 or greater	Sacramento, Fresno, San Bernardino and San Diego regions in California.

In a comparison study of the GDD and LTI, Jackson (2001) pointed out that each of these indices were effective for certain situations and appropriate to use to characterize the climate in the growing region, and ineffective for other situations, and inappropriate to use. The GDD was determined to be less reliable in cooler climates, whereas the LTI was found to be very effective for defining the climate in Winkler's Region I and II. The GDD was found to be fairly effective over the LTI for defining climates in Regions I – V. The LTI was found to overestimate suitability in higher altitudes. Both indices did not address the possibility of winter damage, and also tended to overestimate suitability for the northeastern United States.

In 2005, Jones developed an index based on the average growing season temperature (GSTavg) (Apr – Oct in the Northern Hemisphere; Oct – Apr in the Southern Hemisphere). This index linked the growing season temperate with the ability of a certain variety to mature. Climate maturity groupings were created based on overall climate, and varieties were placed within these maturity groups based on the range that they required for length of ripening. Further applications of this index were discussed in Jones (2006).

All of these climate classifications have a common theme of determining site suitability for a particular region of interest. Jackson (2001) points out that it is necessary to choose the correct index for the area where the vineyard will be established. Again, the key to choosing the correct site is to understand the climate of the region, and how to adapt vineyard planning and management strategies to have a successful vineyard.

Chapter 3

3. US Wine Industry and Climate Overview

3.1 US Wine Industry History and Current Status

The origins of winegrape growth in the US began before the first settlers arrived on the continent. Many of the native varieties of *Vitis Labrusca*, (Concord, Catawba, Niagara, etc) and *Vitis Riparia*, (Frontanac, etc), and *Vitis Rotundofolia*, (Scuppernong, Magnolia, etc), grew wild and prospered in their particular region. When the earliest settlers came to the eastern US in the 1500s and 1600s, they found these native growing grapes, and believed that European varietals could also be grown in the US. Many of the colonies began to import cuttings of *Vitis Vinifera* grapevines to the US, as well as exporting native *V. Labrusca* to Europe.

Many of the European *V. Vinifera* could not survive in the US. In the northern US, most of the *V. Vinifera* were unable to survive the cold weather. In the south, the climate was too humid, so disease was very common among the *V. Vinifera* winegrape crops. Lastly, many of the European varieties died because they lacked the necessary immunities against other diseases and pests, such as Phylloxera.

As the Midwest began to be settled, the various immigrant groups brought *V. Vinifera* native to their home country, but, these also did not survive due to disease and pests. Even with this setback, many of the states in the Midwest in the mid-1800s, such as Missouri, Indiana, Illinois, Michigan, Nebraska and Arkansas, had a thriving wine industry, producing thousands of gallons of wine per state with native varieties. Also during this time, work had begun in California, and other states, to develop grafted grapevines which were resistant to the Phylloxera bug. These grafted grapevines consisted of a European *V. Vinifera* grafted onto a native American rootstock. This grafting technique was so successful that when Phylloxera wiped out thousands of acres of grapevines in Europe (due to the importation of native American varieties into Europe), the US vineyards were able to help to rebuild many of the European vineyards by shipping grafted cuttings to Europe (Zraly 2008).

By the early 1900s, the US wine industry was flourishing, winning medals in many of the international competitions. Some of the top states in these competitions were California, New York, New Jersey, Ohio and Virginia. Despite the success that the wine industry was experiencing, the National Prohibition Act was passed in 1920. This act prohibited the "manufacture, sale, importation, exportation, transportation, delivery and possession of any intoxicating liquor for beverage purposes" (Zraly 2008).

There were a few loopholes in this law. The first was that the law allowed wines that were for sacramental or fortified wines purposes to be produced. Because of this, some of the larger producers found a way to produce a product that could be used in for church services or medicinal purposes. Additionally, the law allowed for every adult in a household to produce 200 gallons of fruit or grape juice. However, the law did not specify that this juice could not be in the concentrate form, which was the ideal form for making wine. This allowed bootleggers to obtain the juice concentrate and make it into wine. Eventually, the government did catch on, and this practice was put to an end. After that, grapevines stopped being cultivated, and the US wine industry came to a halt.

Prohibition finally ended in 1933, when the act was repealed. However, many of the states that had had large acreage of grapevines shifted to growing other crops. In the south, farmers switched to growing tobacco and cotton. In the Midwest, farmers switched to growing corn and beans. It would be another thirty to forty years before grapevines were replanted, and the wine industry would begin to grow again in the US.

In the last 10-15 years, the wine industry has acquired a better understanding of the role that regional climates play in the production of wine. This increase in understanding has prompted more vineyards to be opened in established winegrape growing regions, as well as regions that were once thought to be not able to sustain growing winegrapes. As a result, wine production has grown considerably over the last 10 years. According to a 2007 Department of Commerce study of year end production (Hodgen 2008), the number of wineries throughout the US has grown 81 percent, from 2668 in 1999 to 4867, in 2007.

A 2007 Wine Business Monthly study (Tinney 2007) further breaks these statistics down by separating “wineries” into virtual and bonded. A virtual winery is defined as a winery that produces at least one brand, and has its own winemaker and management. Virtual wineries are very similar in nature to bonded wineries, except that they must go to a bonded winery to actually make and bottle their wine. Because of the inclusion of both virtual and bonded wineries, the total number of wineries increased in the US to 5970. Of these 5970 wineries, 2923 are from California (49%), 507 from Washington (8.4%) and 364 from Oregon (6%), leaving 2176 wineries (36.4%) in the remaining 47 states. Many of these remaining 2176 wineries have well over 100 wineries, with New York having 270 (4.5%); Texas 151 (2.5%); Virginia, 149 (2.5%); and Pennsylvania, 142 (2.4%).

Although the major wine producing state is California, producing 90% (566.8 billion gallons) of the wine in the US in 2007, there are many states which have contributed to the remaining 10% of the wine production. New York, which is the third largest winegrape producing state, contributed to 2% (27.8 million gallons) of the total production of wine in 2007. Other significant contributors in 2007 were Florida, with 0.27% (1.7 million gallons), and New Jersey, 0.26% (1.6 million gallons). Table 3 and 5 provides a summary of AVA acreage data and state winery and production data for 2009, respectively. (See Appendix I for AVA data; US Dept of Treasury 2009; Wine Institute 2010)

Although most of this growth is seen in the premium wine regions of California, it can also be found on smaller scales throughout the US. Vineyards and estate wineries can be found in all of the 50 states (McKenney 2009). An estate winery is defined as a producer who makes wine grown from grapes grown on their property (Feldon, WSET). Many of these vineyards can be found within the boundaries of the American Viticultural Area (AVA), which is a designated winegrape growing region in the US, characterized by it's climate and geographical features, and defined by the Code of Federal Regulations, Alcohol and Tobacco Tax and Trade Bureau (TTB), US Department of Treasury (Code of Federal Regulations, 2006). These AVA regions are similar in nature to politically defined ecoregions, since each region has a similar climate, and grows similar cultivars (plant or grapevine), but, the boundaries are more based on map feature, or other physical boundary.

Although there are some newer emerging winegrape growing regions nationwide, some do not fall into within the AVA boundaries. These winery and vineyards are opening, in random locations, throughout the US. Some of these winery and vineyards can be found on abandon farms, existing farms that have converted their crop, or on newly acquired land. Additionally, some of these wineries are clustered together in location, and some are not. The patterns in locations are very random in nature. There may not be a definitive answer as to why these wineries have opened in these emerging regions, other than the fact that there may be some potential cash crop incentive to locate the winery in that particular location.

Because of the rising interest in US wine regions outside of the west, tourism in wine regions is also growing (Thach 2007). Many tourists visit wine regions across the US to tour wineries and vineyards, and attend wine festivals and shows. Although much of the tourism takes place in the better known regions, such as the Finger Lakes in New York, or Texas Hill Country, there is a fair amount of wine tourism that takes in the new emerging regions, such as Missouri, Virginia and Arizona. Wine Trails have been created in a number of states which lie outside of designated AVA regions, such as Maine, Pennsylvania, Nebraska, and Minnesota (Maine Winery Guild 2008; Nebraska Grape 2009; Pennsylvania Winery Association 2009; Three Rivers Wine Trail 2008). These Wine Trails draw thousands of visitors to these states to tour through the wine country, as well as other tourist attractions. This growth in tourism is very important and good for local economy of the region, since it injects money into existing businesses and promotes new business.

3.2 Evaluation of US Climate Indices Maps

As mentioned previously, this study will have a spatial coverage area of the all of the states in the contiguous US, with the exception of California, Oregon, Washington and Idaho. These states will be referred to as the "Western US". Before discussing the climate structure of the eastern US, a review of the Koppen Classification scheme in the eastern US will be discussed. This will be done to link the classifications to the climate patterns present in the eastern US.

3.2.1 Links between Koppen Classification Scheme and climate patterns

Figure 3 illustrates the Koppen classification of the US. This climate classification scheme uses the distributions of native vegetation to establish climate boundaries. It was first developed in 1918 due to the lack climate reporting stations, and has since been updated. There are five main climate groupings, Moist Tropical (A*), Dry (Bs*, Bw*), Moist with mild winters (Cs*, Cw*, Cf*), Moist with severe winters (Ds*, Dw*, Df*), Polar (E*, not shown) and Highland (H). (Ahrens, Idaho Climate Service)

In figure 3, from approximately 40°N - 50°N, east of the Rocky Mountains, there is a relatively zonal pattern, and a main categorization of Humid Continental Climate (Dfa, Dfb). This type of climate is broken down into two separate categories, Humid Continental with hot summers (Dfa) and Humid Continental with long cool summers (Dfb). These classifications are located throughout the northeast, north and central states and through the mid-Atlantic. The Dfb classification extends southward from the northeast, throughout the Appalachian Mountain range, due to the higher elevations. In both of these regions, precipitation is evenly distributed throughout the months of the year. The differences arise in the temperatures during the summer, and the frost-free growing season.

Hot summers are indicated by maximum temperatures exceeding 90°F (32°C) for long periods of time, and the length of the growing season is 5 to 6 months. This is due to the topography and climate patterns in this region. In between these mountain ranges, in the middle portion of the country, the topography has some rolling hills, but generally flattening out to the west of the Mississippi River. This region is referred to as the Great Plains, since it is mostly grassland. Surges of cold air moving south in the winter can move fairly far south, since there are no mountains to interfere with the airflow. Additionally, in the summer, warm, moist air from the Gulf of Mexico can flow fairly far north, for the same reasons. This causes extreme cold temperatures to be found fairly far south in the winter, and extreme hot temperatures fairly far north in the summer.

Long cool summers, such as those areas in the north central and northeast US, can also have maximum temperatures exceeding 95°F (35°C), but only for very short lengths of time. Frost free months only last 3 to 5 months, followed by a short fall, and winter temperatures that can fall below -22°F (-30°C), and can have temperatures routinely below 0°F (-18°C) for days and weeks at a time. Additionally, spring is also short, and there is a risk of late frosts, or even late snowstorms. (Ahrens)

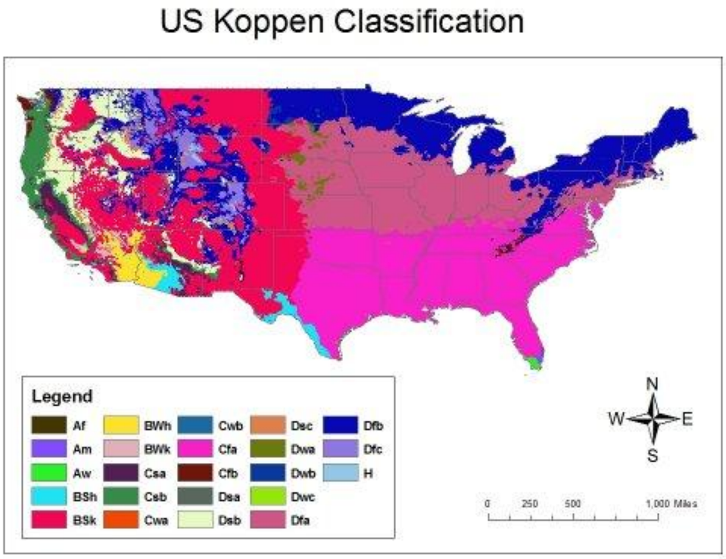


Figure 3: Koppen Classification for the United States. Data Source: Ahrens, Idaho Climate Service

Further south in the US lies the Humid Subtropical Climate classification (Cfa). This region stretches throughout most of the southern states which lie east of the Southern Rockies and desert southwest, from approximately 25°N - 40°N. In this region, summers are mostly hot and humid, due to the weather patterns transporting warm moist air northward from the Gulf of Mexico. Maximum temperatures routinely rise to over 90°F (32°C), with high dew points generally in the high 60s to low 70s (°F), thus producing very high relative humidity. Additionally, minimum temperatures during the summer are high as well, ranging between 70°F - 81°F (21°C - 27°C). Winter temperatures are mild, rarely dipping below freezing. Precipitation is also evenly distributed throughout the year as well. (Ahrens)

Located at the extreme southern tip of Florida lies the Tropical Moist Climate classification (Am, Aw). This region is generally located from the equator to approximately 15°N, but can be found as far north as 25°N. Temperatures are warm throughout the year, with a mean daily temperature above 64°F (18°C), and abundant rainfall.

Most of the western states have a Dry Climate classification (Bs*, Bw*). This region includes both arid and true desert climates. Precipitation in this region is very low, and often non-existent, allowing for very low relative humidity. In the lower latitudes in this region, maximum summer temperatures can easily range from 104°F - 113°F (40°C - 45°C). Minimum temperatures can fall generally below 77°F (25°C). This large diurnal temperature range is due to the low relative humidity. Winters are generally mild, sometimes dropping below freezing. In the middle latitudes in the Dry Climate, maximum temperatures are generally cooler than those found to the south, but can reach 104°F (40°C) in the summer. Winters are also much colder, often falling to -31°F (-35°C).

The last climate classification that can be found is the Highland Climate (H). This is found throughout the Rocky Mountains. This region is similar to a Polar Climate, which has low temperatures throughout the year, with temperatures in the warmest months around 50°F (10°C). These colder temperatures are mainly due to the high altitudes that can be found in this region.

3.2.3 Comparison of Climate Parameters for the US

A comparison of the spatial pattern for each of the four climate parameters for the entire US are shown in the figure 4. In these figures, cooler climates are represented by cooler colors of blue and green and warmer climates are represented by warmer colors of orange and red. White represents climates that are unsuitable for growing wine-grapes, either Too Cold or Too Hot. Areas outlined in the thicker black lines are the AVAs within the study area.

All four climate parameters reveal similar patterns due to the geography and overall climate structure of the US. This is verified through correlations of the median values of the indices within the AVAs, which shows that all the indices are highly correlated ($0.947 < r < 0.995$). The highest correlation is found between the GDD and GSTavg, where $r = 0.995$, meaning that these two indices are depicting similar features of the climate and geography of the US. The lowest correlations are between the BEDD and the other three indices ($r < 0.970$).

Examining the patterns closer reveal that east of the Rocky Mountains have a mostly zonal pattern, with lower indices in the northern part of the US, implying a shorter growing season, and higher indices found in the southern part of the US implying a longer growing season. In mountainous regions in the west the value of indices are based more on elevation. Higher elevations generally have lower indices, and lower elevation have generally higher indices.

Comparison of the climate indices patterns found along coastal regions in the Eastern US to those found in coastal regions along the west coast of the US reveal a much different pattern. Patterns along coastal regions on the west coast show indices increasing with distance from the Pacific Ocean. As mentioned before, lower SSTs are found along coastal regions of the Pacific Ocean than found along the Atlantic Ocean because of the California Current. The onshore flow tends to cool areas right along the coast, which is reflected by the climate indices being much lower directly along the west coast. The indices increase away from the coast where the influence of the ocean becomes less.

In addition to this ocean influence, climate indices patterns in the Western US, are similar to those found in the Rocky Mountain region. In the interior of CA, OR, WA and ID, the climate indices are also based on elevation. Similar to the Rocky Mountains and Southwest, lower indices are found at higher elevations, and higher indices are found at lower elevations.

Also revealed in these comparison maps are large areas throughout the entire US that are considered unsuitable for winegrape growth. As seen in Fig. 2, there are established vineyards located in many of these areas which are considered unsuitable for winegrape growth. Additionally, there are several AVAs that are also located within these unsuitable regions. This would imply that these indices may not fully capture the climate structure in these areas of the US, and that there are far more areas through out the US that are suitable for viticulture than the indices show.

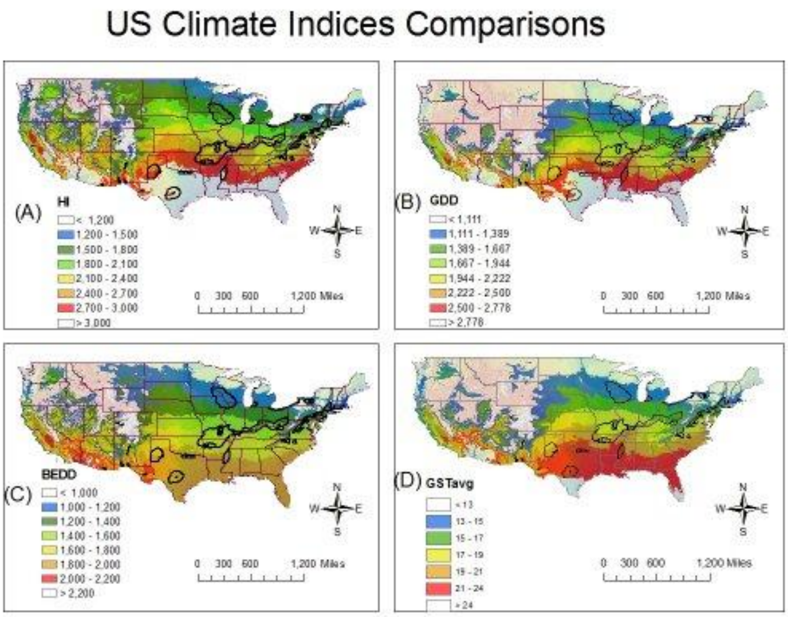


Figure 4: Maps of the four climate indices for the United States; (A) Heliothermal Index (HI), (B) Growing Degree Days (GDD), (C) Biologically Effective Degree Day (BEDD), and (D) Growing Season Average Temperature (GSTavg). Data Source: PRISM 2008.

Evaluating the individual indices show many similarities in characteristics of the AVAs within the maturity classes. For example, the AVAs with the lowest maturity classes are found in the Finger Lakes and Hudson River Range AVAs in New York, among the GDD, BEDD and GSTavg. The GSTavg also adds the Western Connecticut Highlands AVA to the list of lowest values. The outlier index, the HI, indicates that the Leelanau

Peninsula, in Michigan, as the AVA with the lowest maturity class. Highest maturity classes are also similar among the indices, designating the Texas Hill Country AVA, in Texas, as the AVA with the highest value among the GDD, GSTavg, and HI. The outlier is the BEDD, which indicates that the AVA with the highest maturity class is the Mesilla Valley, in Texas and New Mexico.

Other similarities arise from the spatial variability in the AVA. Many of the AVAs have little spatial variability, and are only characterized within one maturity class. This may be due to size of the AVA, climate structure, geographical features, or all of these factors together. These AVAs are Old Mission Peninsula (MI), Alexandria Lakes (MN), Rocky Knob (VA), Loramie Creek (OH), Augusta (MO) and Escondido Valley (TX). There is general agreement among the four indices with all of these AVAs, however the GSTavg adds additional AVAs to this list. All four indices are consistent in choosing the Sonoita AVA, in Arizona, as the AVA with the highest range of maturity classes.

Other important characteristics of the 62 AVAs are found within the elevation and spatial characteristics. There is a total of 131,023,395.2 acres (53,025,168 hectares) which are designated official AVAs in the eastern US. Of this acreage, the smallest AVA is the Isle St. George which is a sub-AVA of the Lake Erie AVA, and located on North Bass Island, OH, which has 882.2 acres (357 hectares) within its borders. Although a large portion of this AVA was once planted with many vineyards, only 38 acres (15.4 hectares) of planted vineyards remain. The largest AVA is the Ozark Mountain AVA, which has 34,024,858 acres (13,769,860 hectares), and contains 1213 acres (491 hectares) of vineyards.

There are seven AVAs which have a minimum elevation of 0 meters (m) above sea level, and rise in elevation from there. The lowest of these AVAs is Virginia's Eastern Shore, which has a range in elevation from 0 m to 16 m above sea level. The highest AVA is the West Elks AVA, in CO., which is 2119 m above sea level. There are three AVAs which have a range in elevation below 10 m, the lowest of which is Fennville AVA, in MI, which only has a range in elevation of 2 m. The AVA with the largest range is the Sonoita AVA, in AZ, which has a range in elevation of 1499 m. The median range in elevation is 213 m, which corresponds with the Western Connecticut Highlands AVA.

Appendix III contains summarizations of the climate structure and maturity class levels of each of the 62 AVAs, and the 44 states. This summary includes highlights of the current winegrape growing regions, and comparisons of the four standard indices, through the use of percentages from histograms and quartile statistics. Additionally, modifications to these standard indices are also summarized to achieve the proper categorization.

Percentages were generated by histograms of each AVA to illustrate the amount of area within the AVA which corresponds to a particular maturity class. Additionally, spatial statistics (i.e., quartile statistics), for the entire study area will be evaluated. These represent the entire range of values for each index within each AVA and state, making no distinction between areas that are planted and areas that are not planted. These percentages and spatial statistics will help to determine the classification for each growing region.

A few things should also be noted before beginning the discussion of the climate classifications of the AVAs and states. First, even though this is a discussion of the climate structure within the AVA, the patterns of these maturity classes extend well beyond the borders of the AVA, into other areas of the state. What this indicates is that suitability's found within the AVA also extend beyond the borders, which extends growing areas to outside the borders of the AVA to many areas within the state. Then, it should also be noted that the maturity classes really aren't comparable to each other. For example, the values of the indices for a "Cool" maturity class for the HI are not the same range of values as a "Cool" maturity class for the BEDD, even though the level of maturity class is the same.

Last, is should be noted that the number of vineyards are only approximate. Vineyards that are located just outside the boundaries of the AVAs can not be included within the AVA, even though they may be in very close proximity. There are several instances where there are a number of vineyards just outside the boundaries of the AVA, but, could not be included in the final acreage total for that AVA. Also, there may be growers which are not listed on the state Growers Association webpages, which sell their grapes to the local vineyards. These could not be included in the final numbers, either, since the names and contract information was not available. Therefore, the plus symbol "+" is indicated along with the number of vineyards in each state and AVA.

Chapter 4

4. Index Evaluation

4.1 Standard Climate-Viticulture Indices

4.1.1 Analysis

Results from the initial spatial analysis from previous chapters were first evaluated in terms of which index showed the most and least suitability. As expected, from the initial analysis of spatial patterns in chapter 3, the HI showed the most suitability out of all of the indices, indicating the largest geographic areas of suitability in 91% of the states, and 50% of the AVAs. The GSTavg also showed large geographic areas which were suitable for winegrape growth in 32% of the AVAs. The BEDD and GDD showed the least amount of geographic area which are considered suitable, 34% and 68% of the states, respectively, and 31% and 57% of the AVAs.

Error analysis was then performed to further evaluate the performance of the four standard indices, and confirm the results of the initial analysis. For this analysis, vineyard locations were matched with value of each individual index. Vineyard locations that were found to lie within the suitable range for winegrape growth scored a "0", and those lying outside the range scored a "1". Errors were tabulated for each region, as well as for the overall United States.

Of the four standard indices, the GSTavg performed the best, scoring a total of 30 errors overall for the entire US. The next lowest indices were the BEDD, with a score of 69 errors, and the HI, with a score of 122 errors. The GDD performed the worst of all the indices, with a total score of 242 errors for the entire US.

Evaluating the indices regionally revealed some similarities to the overall US. The HI had the lowest errors in both the Northeast and the Midwest. The latitude adjustment that is included in the calculation of this parameter could partly account for this. However, the GSTavg also had the lowest error in the Northeast, having an equivalent error score to the HI.

Conversely, the HI performed the worst in the South and West, accumulating the highest error scores of the four indices. In this instance, the latitude coefficient did not contribute to creating more areas of suitability. However, the BEDD had the lowest error scores for the South and the West, even though this index also includes the latitude coefficient term in the calculation of the index. The BEDD does include a Diurnal Temperature Range (DTR) term, which may have contributed to the lower error scores in these regions. In some areas of the south and the west, differences in daytime and nighttime temperatures can be very high, leading to a high DTR. This could cause the BEDD to be higher in these regions, implying more areas which are suitable for winegrape growth.

Overall, the GDD had errors on the high side, when compared to the other three indices. However, as mentioned in discussions of the other indices, this index did not have the highest in all of the regions. Overall, the GDD performed the worst in the Northeast and Midwest. This conclusion corresponds to the analysis by Jackson (2001), which also found the GDD not to be reliable in cool climates.

Further exploring the reasons for these errors of the GDD, BEDD and HI in cooler climates could be based on the temporal length which is used to calculate this index. Throughout many areas in the northern US, April average monthly temperatures are too cold to support budbreak. As mentioned in chapter 1, budbreak happens when temperatures are above 50°F (10°C). While April maximum monthly average temperatures reach 59°F (15°C) in the Northern, Midwestern and Western US, minimum monthly average temperatures are below 41°F (5°C), making monthly average temperatures in these regions below 50°F (10°C). These temperatures are very similar for the month of October, in these same regions.

In the calculation of these three indices (GDD, BEDD and HI), the first step is to calculate the differences of average growing season temperatures for the time period of April through October and 50°F (10°C), and then summed. The HI is the only index of the three that uses the time period of April through September. Since average monthly temperatures in regions of the Northern, Midwestern and Western US are below 50°F (10°C), these months will not accumulate any amount of degree day, and will only be able to accumulate degree days for the months of May through September. This leads to low heat accumulations in these regions, indicating large regions of unsuitability. Two of the indices, the BEDD and HI, compensate for these low heat accumulations by factoring in day length and diurnal temperature to raise heat accumulations and create more areas of suitability.

4.2 Proposed New Index

4.2.1 Variables included in the Index

Due to the performance of the majority of the standard four indices (with the exception of the GSTavg), as well as spatial patterns which revealed large areas which were unsuitable, a new index was created, the Modified-GSTavg index (Mod-GSTavg). This index builds upon the methodologies of the GSTavg. Additionally, this index uses the Koppen Classifications to determine the length of the growing season.

The Koppen Classification was chosen as an initial variable, and a method of separating the different climate types in the US. As mentioned in previous chapters, the Koppen Classification is based on regional temperature and humidity, and is one of the most widely used climate classification system (Peel et al 2007). For this index, climate zones throughout the US were divided into groups, based on length of growing season.

In creating this index, average monthly temperatures at the beginning and the end of the growing season were evaluated to determine which month typically begins and ends the growing season for all regions of the US. As mentioned above, monthly temperatures in both April and October are not conducive to winegrape growth in many parts of the US. Therefore, a portion of this index uses the growing season temperatures from May to September in the Northern, Midwestern and Western regions, instead of the standard April through October.

4.2.2 Methodology

Figure 111 outlines the methodology behind the Mod-GSTavg index. Initially, the Koppen Classification was divided into areas of long growing season (> 5 months), moderately long growing season (4-5 months), and short growing seasons (< 4 months). These were ranked by a score of 10, 7 and 3, for the respective growing season lengths. Then, the overall US is then put through a Boolean test which divides the US into either regions with the longest growing seasons, or the other two shorter growing season regions. For each of the tests, each region is given a score of "1" for a true score, and "0" for a false score. As a result of these tests, two separate files are generated, which separates the US into two distinct regions. For the file with regions that have the longest growing season, (Test >=9, in flowchart) a score of "1" for Koppen Classifications with the longest growing seasons, and a "0" for all other regions. Similarly, the file which contains the Koppen Classifications with shorter growing seasons (Test <= 8, in flowchart), a score of "1" is assigned to the shorter growing season classifications, and a "0" is assigned to all other areas.

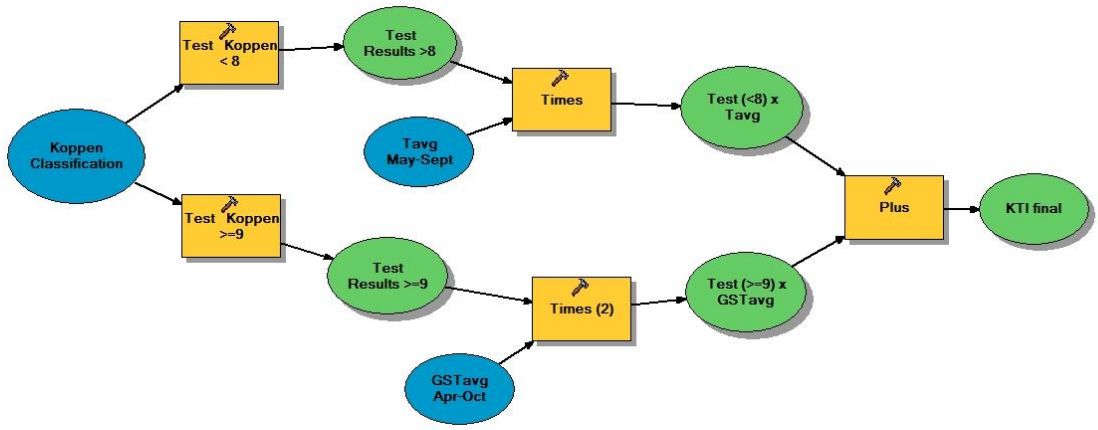


Figure 5: Flowchart of the Mod-GSTavg index

To create an overall growing season temperature map for the US, Test >=9 is then multiplied by the GSTavg (Apr – Oct). This produces a growing season temperature map, of mostly southern areas, where the growing season is > 5 months. Similarly, Test <= 8 is multiplied by the average growing season temperature map, however, this is only calculated for the months of May through September. The resulting map is a growing season temperature map for areas of shorter growing seasons, throughout the Midwest, West and Northeast. These two maps are then combined to produce a final map of growing season temperatures, which can then define areas of suitability.

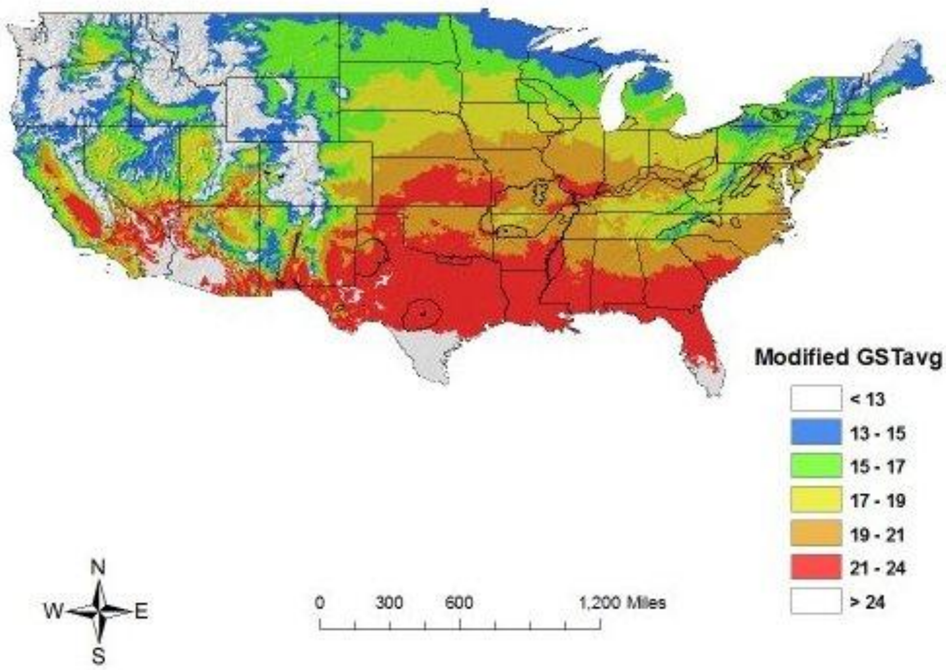


Figure 6: Mod-GSTavg displayed over US. Data Source: PRISM 2008

4.2.2 Analysis

Evaluating the spatial patterns for the Mod-GSTavg index, reveals a similar zonal pattern east of the Rocky Mountains, to the pattern seen in the standard four climate-viticulture indices. As expected, cooler temperatures are found in the northern US, and increase southward. Additionally, patterns throughout the Rocky Mountains are based on elevation, higher temperatures at lower elevations, and lower temperatures at higher elevations. This is also similar to the spatial patterns of the standard indices.

Some of the larger microclimates which are in close proximity to larger bodies of water are also seen in the Mod-GSTavg index. Regions bordered by the Great Lakes have warmer climates than inland areas. Areas which are in close proximity to major rivers and lakes also have warmer temperatures than surrounding areas, such as the Missouri River in Montana and North Dakota, or the Finger Lakes in New York.

Generally, the Mod-GSTavg index shows far more geographic area which is considered to be suitable for winegrape growth. This is due to the combination of the standard GSTavg along with shortened average growing season temperatures which are found in the Northern, Midwestern and Western regions in the US.

Figure 7 illustrates the differences between the new Mod-GSTavg index and the standard GSTavg difference. An increase of 2-3°C can be seen throughout most of the northern, central and western US. Additionally, there are small areas of +4°C seen in the north central US, throughout Wisconsin, Minnesota and North and South Dakota.

A closer inspection of the differences in these indices reveals that changes come from a better representation of the topographical and geographical features. Lower elevations, such as valleys show an increase in temperature, which creates a more pronounced spatial pattern highlighting warmer temperatures at lower elevations and cooler temperatures at higher elevations. This is much more evident in the western US, where elevations are much higher.

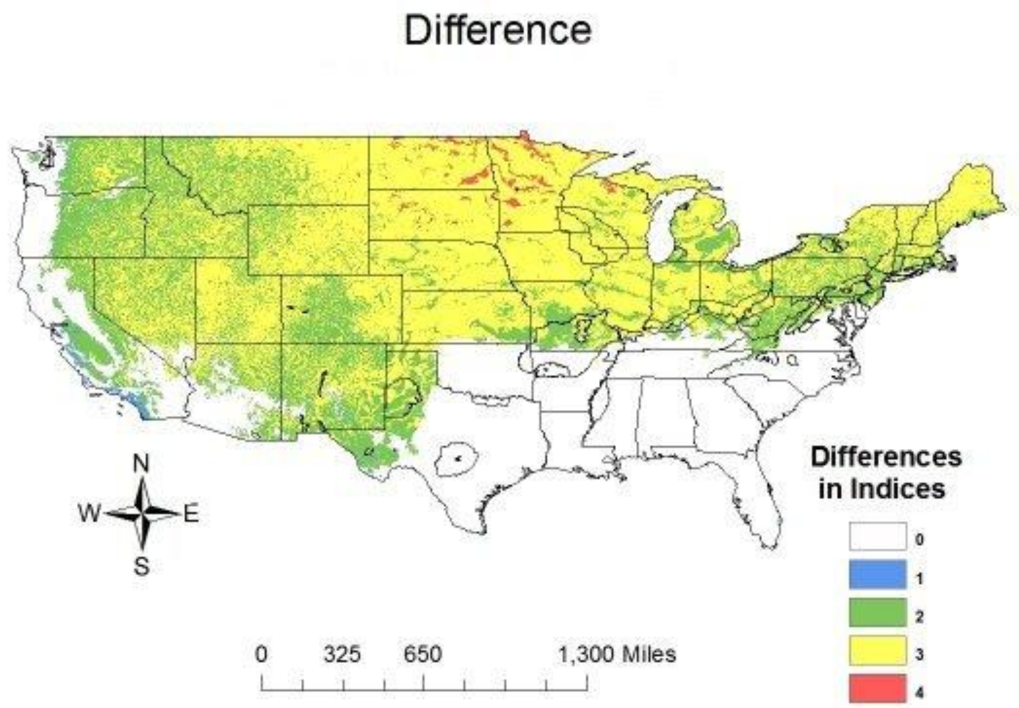


Figure 7: Differences in the GSTavg index and the new Mod-GSTavg index.

Along with elevations, effects from microclimates are more pronounced as well. Influences from major bodies of water are reflected as increases in temperature. This can be seen throughout the Great Lakes region, the Finger Lakes region and areas surrounding major rivers in the western US, such as the Missouri, Yellowstone, and

Platte Rivers. These increases in temperature correspond to many of the regions where winegrape growth is currently taking place.

Evaluating the median correlation coefficients for the five indices show that they are also highly correlated ($0.905 < r < 0.995$). The highest correlation is found between the GDD and GSTavg, where $r = 0.995$, meaning that these two indices are depicting similar features of the climate and geography of the US. The lowest correlations are between the BEDD and the Modified GSTavg (0.905), and the GSTavg and Modified GSTavg (0.905).

An error analysis, similar to the analysis performed on the standard climate-viticulture indices was performed on the new index. This index performed the best out of all of the climate-viticulture indices, with a score that was far lower than the other four indices. For the overall US, this index performed the best, having the lowest error score (14 errors, overall), as well as having the lowest error scores in the Northeast and Midwest. However, it was not the lowest in the South, having a score corresponding to the GSTavg, and in the West, having the second lowest error score.

Chapter 5

5. Climate Change Analysis

5.1 Overview

Up to this point, this research has focused on current and past climates in the eastern US in winegrape growing regions. It was established that winegrapes need a certain growing season temperature and length in order to grow and mature properly. Additionally, it was determined that there are other varietals that can be grown in the variety of climates found across the eastern US. However, it was not determined what would happen to these growing regions if the temperature changes as some of the future climate models predict, and how these changes would have any affect on the future winegrape industry in the eastern US.

In more recent years, there have been a few studies focusing on trends in factors affecting winegrape growth in premium winegrape growing regions. Evaluation of these trends is important because they indicate whether the growing season is warming, or lengthening, timing of the growing season, and frost occurrences. The earliest studies focusing on temperature trends in premium winegrape growing regions were Jones and Davis (2000), and Jones (1997). In these studies, factors such as trends in growing season temperature and length and timing of growing season were evaluated. They found that timing of phenological events, and the time interval between these events, were important in determining the quality of wine. Focusing primarily on the Bordeaux region in France, Jones and Davis (2000) determined that there were indications of trends toward earlier phenological events, a shortening of the time interval between these events, and longer growing seasons. As a result, they also found a significant trend towards an increase in vintage ratings, due to better composition quality of the winegrape.

Evaluating the overall warming of coastal California, Nemani et al (2001), analyzed Sea Surface Temperatures (SSTs) trends to determine what impact the rises in temperature has on the premium wine industry. In this study, it was determined that there have been moderate increases in annual temperature due to increases in SST and atmospheric water vapor. These increases translate to warmer winters and spring, increases in frost free periods, and a subsequent increase in the growing season

Further focusing on temperature trends, DeGaetano and Allen (2002), compiled a comprehensive review of temperature extremes, both cold and warm, using a subset of the U.S. Historical Climatology Network of stations. In this study, varying time periods were evaluated on the basis of temperature extremes, and the causes of the extremes. It was determined that the variability in warmer temperature extremes were caused by factors such as drought and urbanization and that there were significant decreases in the colder temperature extreme events.

Along with these few studies focusing on past temperature trends in premium wine regions, only a few studies have focused on future trends in these regions. As pointed out by Jones (2006), there is a certain threshold of temperatures where optimal ripening occurs, and if the temperature does not fall within the threshold, either too warm or too cool, ripening may not occur. If shifts in future temperature occur in premium winegrape growing regions, then, the premium varietals may not fall into the prescribed thresholds, thus creating a situation where these premium regions may not be able to grow these varietals anymore.

Two 2005 studies (Jones 2005; Jones et al 2005), focused on past and future trends in the premium wine regions both in the Western US and globally. Using the HadCM3 coupled atmospheric-ocean general circulation model, these studies focused mainly on growing season temperature averages, and how they are projected to change in the next 50 years. As in the previous trend studies, historical temperatures were shown to have increases from 1948 – 2002. Additionally, future temperatures showed increases of growing season warming on average of 1.7°C over the next 50 years (2000 – 2049). This warming trend could potentially have a negative impact on the growth and maturity of the winegrape, and subsequent wine style found in these regions.

In another climate change study, White et al (2006), used the RegCM3 regional climate model, to evaluate areas throughout the US on the basis of varietal tolerance to changes in temperature. This study was interested in determining which areas of the US would be more suitable for winegrape growth in the future. They concluded that future increases in extreme hot days (>35°C) would greatly restrict the areas where premium winegrape growth could occur by the late 21st century. This study indicates that only a few areas in the Northwest and Northeast may be the only areas suitable for premium winegrape growth by this time. As in the other climate change studies, if these indications occur, then the premium US wine industry will change in the future.

Lastly, a more comprehensive climate model analysis was conducted by Lobell et al (2006), using six of the climate from the 4th Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2007; PCMDI 2010). This study expanded the evaluation to not only included winegrape growth, but, included the impacts of temperature change projections for the major perennial crop yields in California. This study not only looked at the various climate change scenarios, but, also evaluated the economic impact of each of these scenarios using a variety of statistical crop models.

It was concluded that by the year 2050, yields will be reduced for these crops, creating economic losses. However, this study pointed out that there is much uncertainty in the amount of emissions that will be present in the future. Additionally, it is also uncertain how the agriculture industry in other countries will respond to the changing climate. Because of these conclusions, this study emphasizes that there is still time for adaptation of crops to the changing climate, as well as adaptation on the growers' part to choose cooler locations or alternative crops.

As in the first part of this dissertation research, a gap has been noticed in evaluating future temperature trends in the non-premium winegrape growing regions in the eastern US. Therefore, this chapter will begin to explore the scenarios of climate change in this region, by evaluating one of the climate models' projection. This will be a first look at the indications of the AR4 IPCC output. A more comprehensive study, such as that done by Lobell et al, using the six climate models with the best output datasets, is beyond the scope of this dissertation.

5.2 Data and Methodology

The data used for this portion of the study was the Goddard Institute for Space Sciences – Atmosphere Ocean Model (GISS-AOM) climate model. This model was used in the AR4 of the IPCC (IPCC 2007; PCMDI 2010). A description of this dataset can be found in section 1.5.1.

The GISS-AOM was chosen because it is one of six climate models which provide monthly output of daily minimum and maximum temperatures, as well as temperature for historical and future simulations. This model was also shown to have a fairly good correlation with observed globally averaged annual mean temperatures (0.82) and Northern Hemispheric average temperatures (0.71) for the time period of 1880 - 1999. Ensemble means were similar, 0.87 and 0.82, respectively (Zhou and Yu 2006).

In addition to the climate model, the US Historical Climatology Network (NCDC 2010) dataset will be used to show actual historical trends at various locations throughout winegrape growing regions in the eastern US. This dataset is a subset of the NOAA Co-Operative Observer Program (COOP) Network, and consists of historical observations of meteorological parameters. All observations have been corrected for instrument and location changes throughout the historical time period, as well as changes in recording practices. Locations for this study were chosen on the basis of proximity to areas of larger concentrations of vineyards, and the time period of 1950 – 2000 will be evaluated. A list of the names and physical locations can be found in Location List, below.

LOCATION LIST

City, State	U.S. HCN#	Latitude	Longitude	Elevation (m)
ALLEGAN 5NE, MI	200128	42.5800	-85.7892	228.6
ALLENTOWN AP, PA	360106	40.6508	-75.4492	118.9
ANNA 2 NNE, IL	110187	37.4814	-89.2344	195.1
ARCADIA, FL	080228	27.2181	-81.8739	9.1
BEDFORD, MA	190535	42.4833	-71.2833	48.8
BLANDING , UT	420738	37.6131	-109.4847	1854.7
BRIDGEHAMPTON, NY	300889	40.9464	-72.3067	18.3
BURLINGTON WSO AP, VT	431081	44.4681	-73.1503	100.6
CALHOUN RSCH STN, LA	161411	32.5133	-92.3478	54.9
CHARLOTTESVILLE 2W, VA	441593	38.0325	-78.5231	265.2
COLUMBUS , IN	121747	39.1978	-85.9211	189.3
COSHOCTON WPC PLT, OH	331890	40.2403	-81.8711	231.6
CRETE, NE	252020	40.6194	-96.9469	437.4

LOCATION LIST (CONTINUED)

City, State	U.S. HCN#	Latitude	Longitude	Elevation (m)
CROSBYTON, TX	412121	33.6517	-101.2450	917.4
DAHLONEGA, GA	092475	34.5292	-83.9900	475.5
DE FUNIAK SPRINGS 1, FL	082220	30.7244	-86.0939	74.7
ERIE WSO AP , PA	362682	42.0800	-80.1825	222.5
FALLON EXP STN, NV	262780	39.4572	-118.7811	1208.5
FALLS VILLAGE, CT	062658	41.9500	-73.3667	167.6
FRUITA, CO	053146	39.1653	-108.7331	1378.9
GARDINER, ME	173046	44.2203	-69.7889	42.7
GENEVA RSCH FARM, NY	303184	42.8767	-77.0308	218.8
INDIANOLA 2W, IA	134063	41.3656	-93.6481	287.1
JACKSON EXP STN, TN	404561	35.6214	-88.8456	121.9
KINSTON 7 SE, NC	314684	35.1967	-77.5433	7.3
LANCASTER 4 WSW, WI	474546	42.8278	-90.7889	317.0
LENOIR, NC	314938	35.9150	-81.5378	365.8
LOS LUNAS 3 SSW, NM	295150	34.7675	-106.7611	1475.2
MANDAN EXP STN, ND	325479	46.8128	-100.9097	533.4
MILFORD 2 SE, DE	075915	38.8983	-75.4250	10.7
MORA, MN	215615	45.8775	-93.3147	310.3
NEW BRAUNFELS, TX	416276	29.7192	-98.1189	208.8
NM ST UNI, LAS CRUCES NM	298535	32.2822	-106.7597	1182.9
OZARK 2, AR	035512	35.5125	-93.8683	253.0
PAULS VALLEY 4 WSW, OK	346926	34.7253	-97.2814	286.5
PRESCOTT, AZ	026796	34.5706	-112.4322	1586.5
RIVERTON, WY	487760	43.0308	-108.3742	1510.3
ROLLA UNI OF MISSOURI	237263	37.9572	-91.7758	355.7
SAINT IGNATIUS, MT	247286	47.3150	-114.0983	883.9
SCOTT CITY, KS	147271	38.4819	-100.9189	905.3
SUMMERVILLE 4W	388426	33.0367	-80.2325	19.8
TALLADEGA, AL	018024	33.4164	-86.1350	136.6
TOWANDA 1 S, PA	368905	41.7511	-76.4431	231.6
TUCSON WFO, AZ	028815	32.2292	-110.9536	742.2
WATERTOWN RGNL AP, SD	398932	44.9047	-97.1494	532.8
WOODSTOCK, MD	189750	39.3333	-76.8667	140.2

Using these datasets a variety of parameters were chosen to illustrate the affects of climate change on winegrape growth. These parameters were chosen either on the basis of their use in similar climate change studies, or created to illustrate additional changes. The parameters are listed in Table 9-2, along with the equations that were used in the calculations.

The first parameter chosen to illustrate climate change affects is the GSTavg, which is calculated similar to the methodology in chapters 3 of this dissertation. Next, Jan – Apr monthly average temperatures were chosen since White et. al (2006) showed that evaluating daily temperatures during this time period could indicate when the beginning of the growing season occurs. Lastly, trends in warming of the latter part of the growing season can also be seen during the ripening period (Aug 15th – Oct15th), as shown by Jones (2005).

Additional parameters were created on the basis of similar theories to those used in previous studies. Average temperatures for the time period of Oct – Dec were chosen to illustrate how the fall time period evolves, and if there are indications of a later harvest in certain regions. January minimum temperatures were chosen to evaluate winter minimum temperatures and possibilities that there could be enough warming in portions of the country where less winter damage to occur. August maximum temperatures were also chosen to be evaluated since this is the hottest month during the growing season. This parameter could determine if temperatures could reach a range that would be too hot to support winegrapes growth.

Table 4: Parameters for climate change analysis

Parameter	Equation	Months to be calculated
GSTavg	Σ ((Tmax+Tmin)/2)	April through October
Jan–Apr Average Temperature	Σ ((Tmax+Tmin)/2)	January through April
Aug – Oct Average Temperature	Σ ((Tmax+Tmin)/2)	August through October
Oct – Dec Average Temperature	Σ ((Tmax+Tmin)/2)	October through December
January Minimum Temperature	Σ Tmin/(number of years)	January
August Maximum Temperature	Σ Tmax/(number of years)	August

5.3 Results

A summary of the temperature trends can be found in Tables 5 - 10 in Appendix III, and Tables 11 – 16 in Appendix IV, for each of the parameters, using both the GISS-AOM and USHCN analysis, respectively. Plots of the trend analysis for both datasets are found in Appendix III (GISS-AOM) and Appendix IV (USHCN). Some locations have corresponding values; however, these may not be based on proximity to the matching location, but, may also be based on similar climate and topography.

The first parameter that was evaluated is the average growing season temperature (GSTavg). Lower trends indicate that there is not much change in growing season temperatures predicted out through 2050. Higher trends indicate more change predicted in the growing season temperatures.

The GISS-AOM data show the average trend in GSTavg is an increase of 1.99°C. Lowest trends are found in the northeast and north central US, with the lowest trend at Milford, DE (increase of 1.39°C). The highest trends are found in the southwest and southern plains, with the highest trend at New Mexico State University (increase of 2.9°C).

Evaluating the US as a whole with the GISS-AOM projections support the trends seen in the time series analysis (see fig 8, located at end of this chapter). Differences from 2000 to 2050 show increases in temperatures throughout the south and southwest, with the largest increases in Texas. Further supporting the time series analysis, show the least amount of temperature increases found throughout the northeast and north.

The USHCN trends from 1950 – 2000 reveal a different outcome. A portion of the trends are negative, indicating cooling in certain regions. These regions are located mostly in the south and southwest. The areas with the least amount of temperature change are also located in the south, with the lowest trend in temperature located at Los Lunas, NM, with a decrease in temperature of 0.00033°C. Higher trends are not specific to one region, however, the highest trend is found in Woodstock, MD, with an increase in temperature of 1.26°C.

Next, length of growing season was evaluated. To emulate this trend in length of growing season, the sum of monthly averages were taken for both the period of Jan –

Apr and Oct – Dec. Higher trends during the period of Jan – Apr indicate that spring temperatures are warming, and that that is the cause for the lengthening of the growing season. Similarly, higher trends during the period of Oct - Dec indicate that fall temperatures are warming, and lengthening of the growing season is the result.

The lowest trend in the GISS-AOM data for the time period of Jan – Apr was found in Milford, DE (increase of 0.5°C), and the highest found in Fruita, CO and St. Ignatius, MT (increase of 2.9°C). Overall, the lowest trends were found in the southeast and south central US. The highest trends were found in the southwest and northern Rockies, and parts of the northeast. On average, the trend for this period is an increase in temperature of 1.57°C. This is also seen in fig 9 (located at end of this chapter), which show some increases in temperature throughout the Rockies, south and southwest.

Evaluating the GISS-AOM Oct – Dec monthly averages also reveal an average temperature increase of 1.57°C. The lowest trend for the time period of Oct - Dec was found in Scott City, NE (increase of 1.2°C) and again in Milford, DE (increase of 1.24°C), and the highest found in Mora, MN (increase of 2.16°C). Again, the lowest trends were found in the southeast and southern plains. Also, the highest trends again were found in the northeast, northern Midwest and some in the northern plains. Fig 10 shows a mostly zonal pattern of change from 2000 to 2050, with higher changes found in the northern US, and the least amount of change in the south.

The USHCN data again reveal a different pattern than the GISS-AOM data. Unlike the GSTavg, the Jan – Apr time period has very few locations where there is a decrease in temperature, mostly located in the south and mid-Atlantic. For this period, the lowest trend was found at Dahlonega, GA, with a decrease of 0.11°C, and the highest at Mora, MN (4.3°C). Differing is the Oct – Dec time period which has almost half the trends showing decreases in temperature, mostly located in the northern and north central US. The least amount of temperature change is an increase in temperature of 0.0025°C at Erie, PA, and the greatest temperature change found at New Mexico State University (1.15°C).

To further evaluate changes in the growing season, the ripening period of August – October was analyzed. Overall, the GISS-AOM trend shows average temperature increases of 1.93°C. The lowest trends were found in Northeast and North central US, with the lowest trend found in Lancaster, WI, showing an increase in temperatures of 1.46°C during this period. The highest trends were found in the South and Southwestern US. The highest trend was found at New Mexico State University, which showed an increase in temperatures of 2.69°C. This is also supported by the pattern seen in Fig 11, which shows a bulls-eye of maximum temperature change similar to the GSTavg, located in the south and southwest, with a maximum centered over Texas.

Again, the USHCN data reveal different patterns. Many locations in the south, central plains and southwest have decreases in temperature. The least amount of temperature change shows an increase in temperatures at Geneva, NY, of 0.0094°C. Conversely, temperature increases are seen in these regions as well, with additional locations found in the north. The location with the most change is a decrease in temperature of 1.3°C at Crosbyton, TX.

The next parameter to be evaluated is the minimum Jan temperatures. On average, January minimum temperatures are predicted to increase 1.5°C. The lowest trend in the GISS-AOM data is found in Kinston, NC (increase of 0.18°C), and the highest trend is found in Bedford, MA/Gardiner, ME (increase of 3.14°C). Overall, lower trends are found in the southeast and south central US, and higher trends can be found in the northern and central Rockies, and in the northeast.

Evaluating the US as a whole supports the pattern found in the time series as well. Fig 12 (located at end of this chapter) shows little change in temperatures in the southern portion of the US and small changes throughout the Rockies. The majority of changes are found throughout the northeast and northern US.

Again, the USHCN data shows many locations throughout the north and north central US that have decreases in temperature for the time period of 1950 - 2000. The lowest trend is found in Charlottesville, VA, which shows an increase in temperature of 0.00017°C. Higher trends are found throughout the south, southwest and north central plains, with the most warming occurring at Watertown, SD (5°C).

Lastly, evaluating the August maximum temperatures with the GISS-AOM data, it can be seen that the average temperature changes are an increase of 2.14°C. The lowest trend is found in Mora, MN (increase of 1.3°C), and the highest trend is an increase in temperature of 3.44°C, found at New Mexico State University. Overall, lower trends are found throughout the northeast, northern Rockies and Plains. The highest trends are found in the southeast, southern central US and southern plains.

Evaluating the US as a whole, again reveals a similar pattern to that found in the GSTavg and Aug – Oct monthly average. There is also a bulls-eye found over the southern and southwestern US, with slightly higher temperatures than seen in the other two parameters, which is seen in Fig 13 (located at end of this chapter). Again, the largest temperature change is found in Texas. The least amount of temperature change is found throughout the northeast and northern US.

Again, the USHCN data reveals that half the stations show a decrease in temperature for the time period of 1950 - 2000. These decreases in August maximum temperatures are found in the south, southwest and central plains, with a few locations in the northeast, although some of these stations in these areas also show increases in temperature. The least amount of change in temperature is located at Fruita, CO, which shows a decrease in temperature of 0.00051°C. The most amount of temperature change is found at Crete, NE, which shows a decrease in temperature of 2.57°C.

5.4 Discussion

Evaluating the GISS-AOM model output against the actual historical data from the USHCN dataset reveal that some of the historical trends may not have been fully captured in the model output. This is seen by the number of stations which indicate cooling of temperatures, instead of an overall warming trend. However, if absolute values of the trends alone were evaluated, the two datasets show similar regions where maximum and minimum changes will occur.

Evaluating the GISS-AOM output alone also shows a number of things. First, the growing season is not going to become longer in the south, but, average growing season temperatures are projected to increase, especially in the latter part of the growing season, (Aug – Oct). This is evident by August maximum temperatures increasing over time, along with growing season temperatures also increasing. In addition to this, portions of the southeast, southern plains and southwest indicate that there may be temperatures that will become too hot to support winegrape growth, such as those seen in Fig. 13 (located at end of this chapter).

Next, the trends suggest that the growing season in portions of the US will increase over time. In the northeast, southwest and portions of the Rockies, temperature trends suggest that there will be some warming of winter and springtime temperatures (Jan – Apr), thus lengthening the growing season (see Fig 9, located at end of this chapter). What this indicates is that bud break could occur earlier in these regions in the future, and that there may be less risk of frost in the spring months.

Similar trends were found in the fall to early winter temperatures (Oct – Dec) in the northeast and north. This indicates that temperatures in these regions could stay more conducive to winegrape ripening further into the fall. Extending the growing season in the fall would allow for alternative varietals with longer ripening periods to be planted, later harvest dates, as well as less of a risk of killing frosts in the fall.

In addition to lengthening the growing season, warming of winter temperatures also indicate that regions of the US will be less susceptible to winter kill of the grapevine. Future trends of January minimum temperatures (Fig 12, located at end of this chapter), show increases throughout the north and northeast. The -10°C in this figure has moved further north, above the Canadian border by 2050 in the northeast, indicating warming in the northeast. If this trend occurs, it could allow for alternative varietals to be planted, which are less cold hardy than what is planted currently, and even allow for *V. Vinifera* to be planted.

Lastly, these temperature trends also indicate that many of the areas across the eastern US who are currently considered as unsuitable for winegrape growth, may be more acceptable for winegrape growth in the future. As pointed out in the first portion of this dissertation, these areas are already producing winegrapes which are suitable for that region. If these temperature trends hold true, then, these regions could begin exploring the option of planting more premium *V. Vinifera* varietals, and could move towards becoming premium regions.

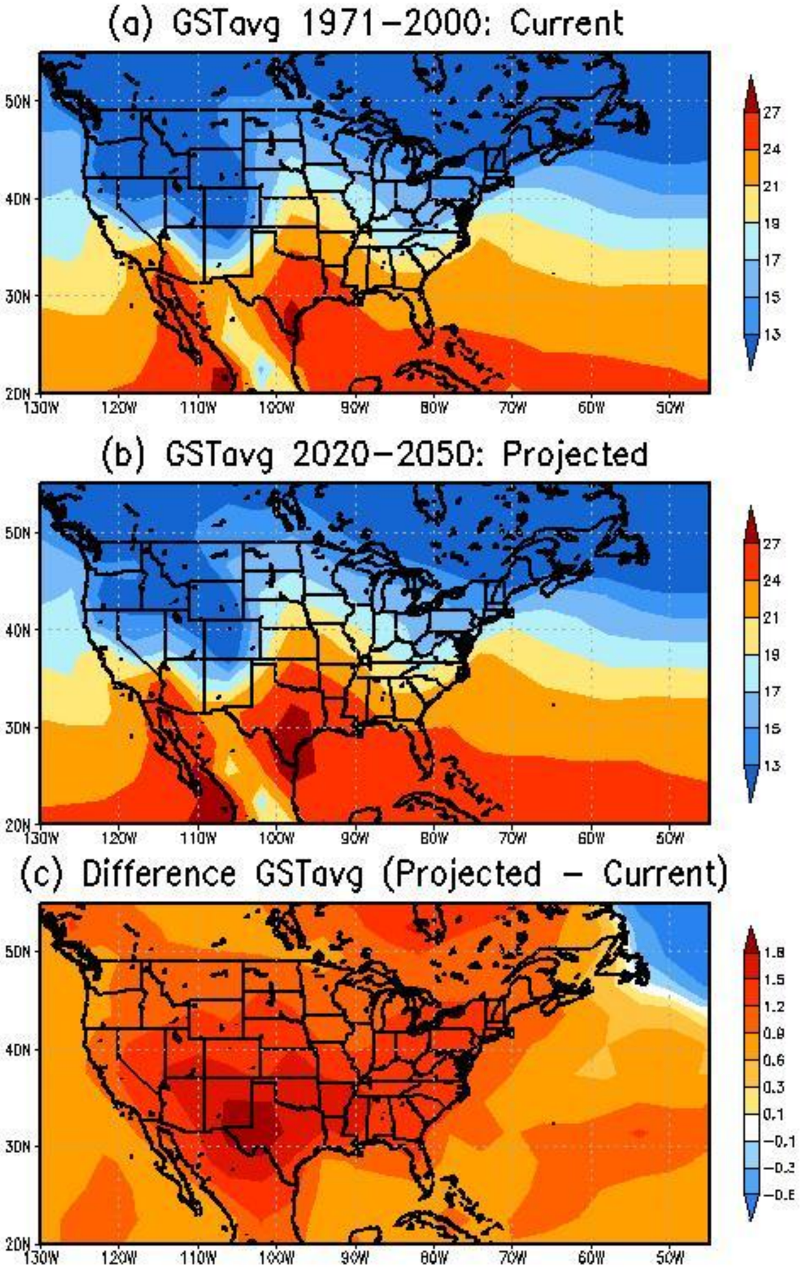


Figure 8:(a) GSTavg (Apr – Oct) for the time period of 1971 – 2000; (b) GSTavg (Apr – Oct) for the time period of 2020 – 2050; (c)Difference in GSTavg (2050 Projection – 2000 Current). Data Source: GISS-AOM.

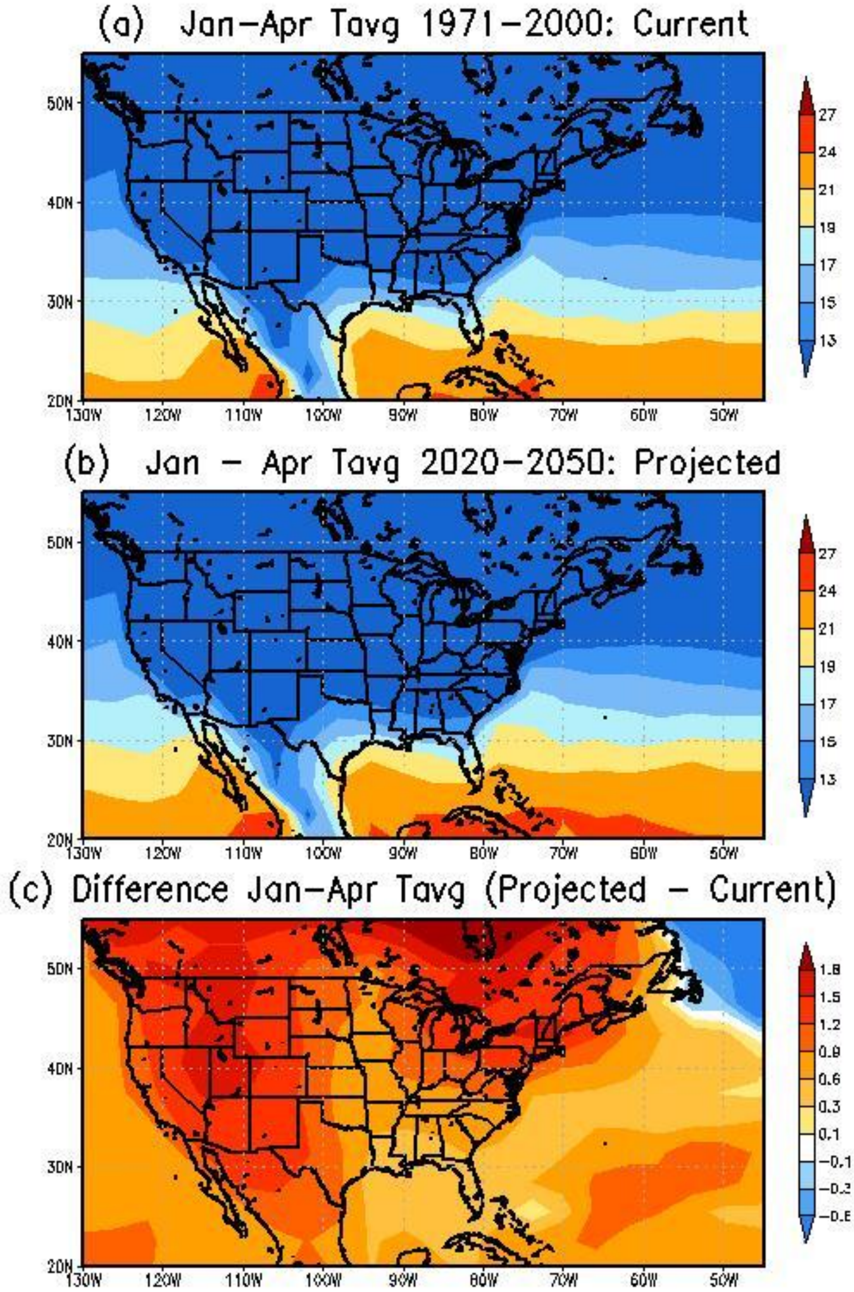


Figure 9:(a) Jan - Apr Average Temperature for the time period of 1971 – 2000; (b) for the time period of 2020 – 2050; (c) Difference in Jan – Apr Average (2050 Projection – 2000 Current). Data Source: GISS-AOM.

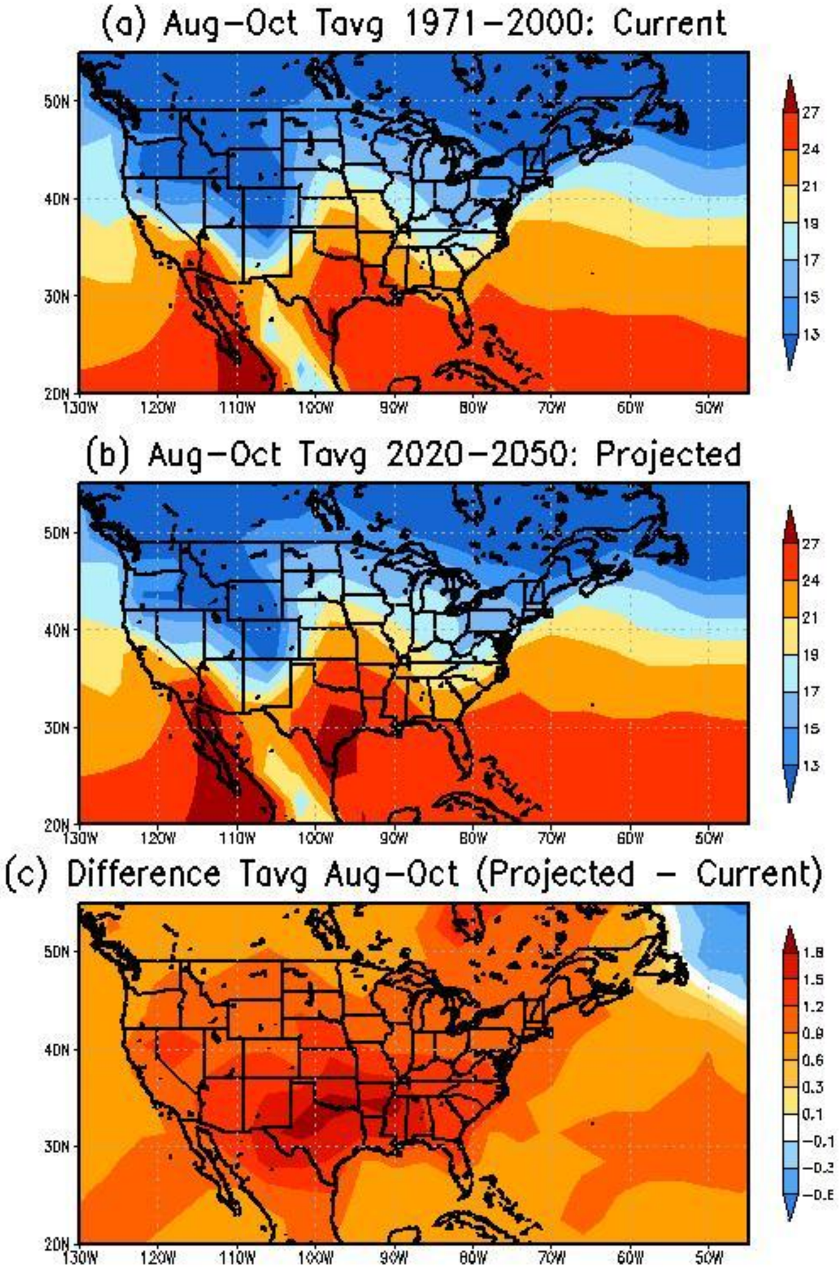


Figure 10: (a) Aug - Oct Average Temperature for the time period of 1971 – 2000; (b) for the time period of 2020 – 2050; (c) Difference in Aug – Oct Average (2050 Projection – 2000 Current). Data Source: GISS-AOM.

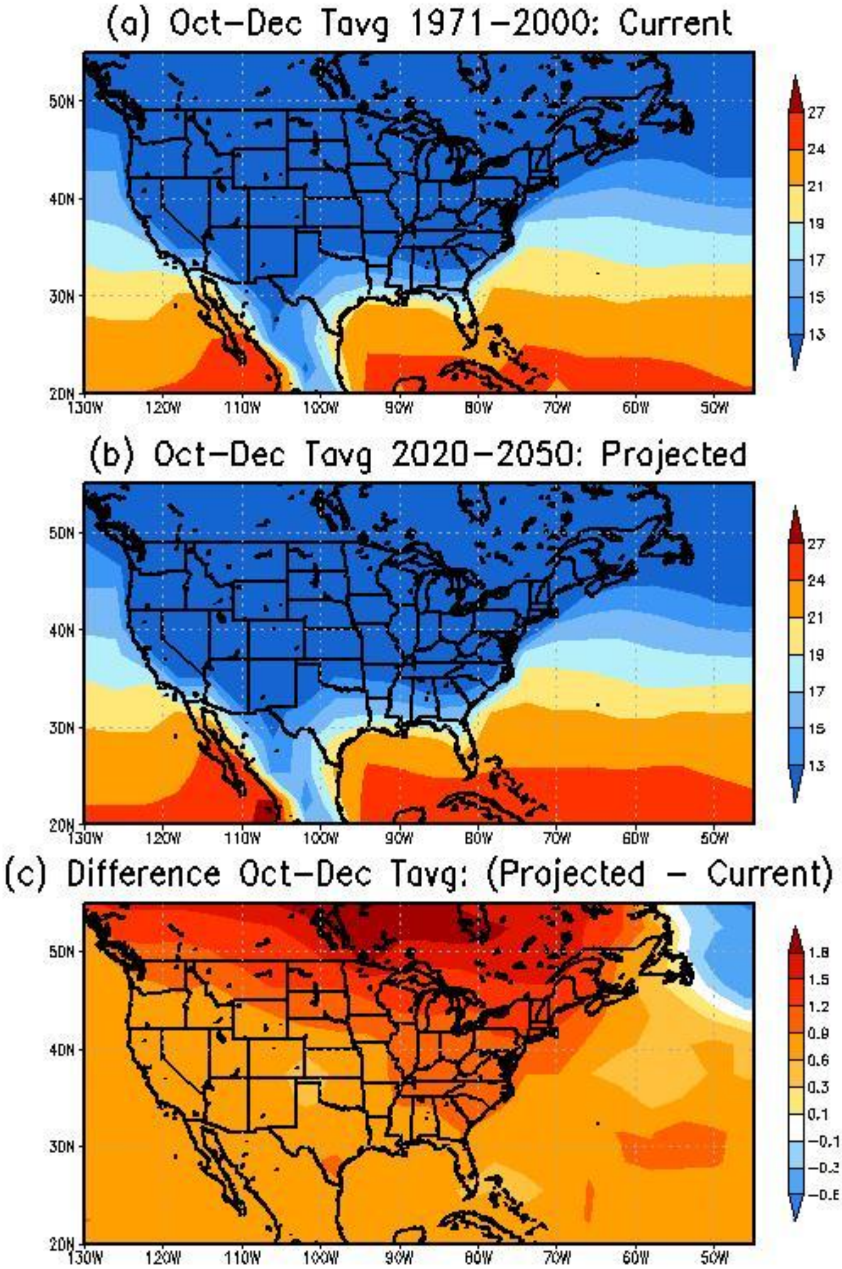


Figure 11: (a) Oct - Dec Average Temperature for the time period of 1971 – 2000; (b) for the time period of 2020 – 2050; (c) Difference in Oct - Dec Average (2050 Projection – 2000 Current). Data Source: GISS-AOM.

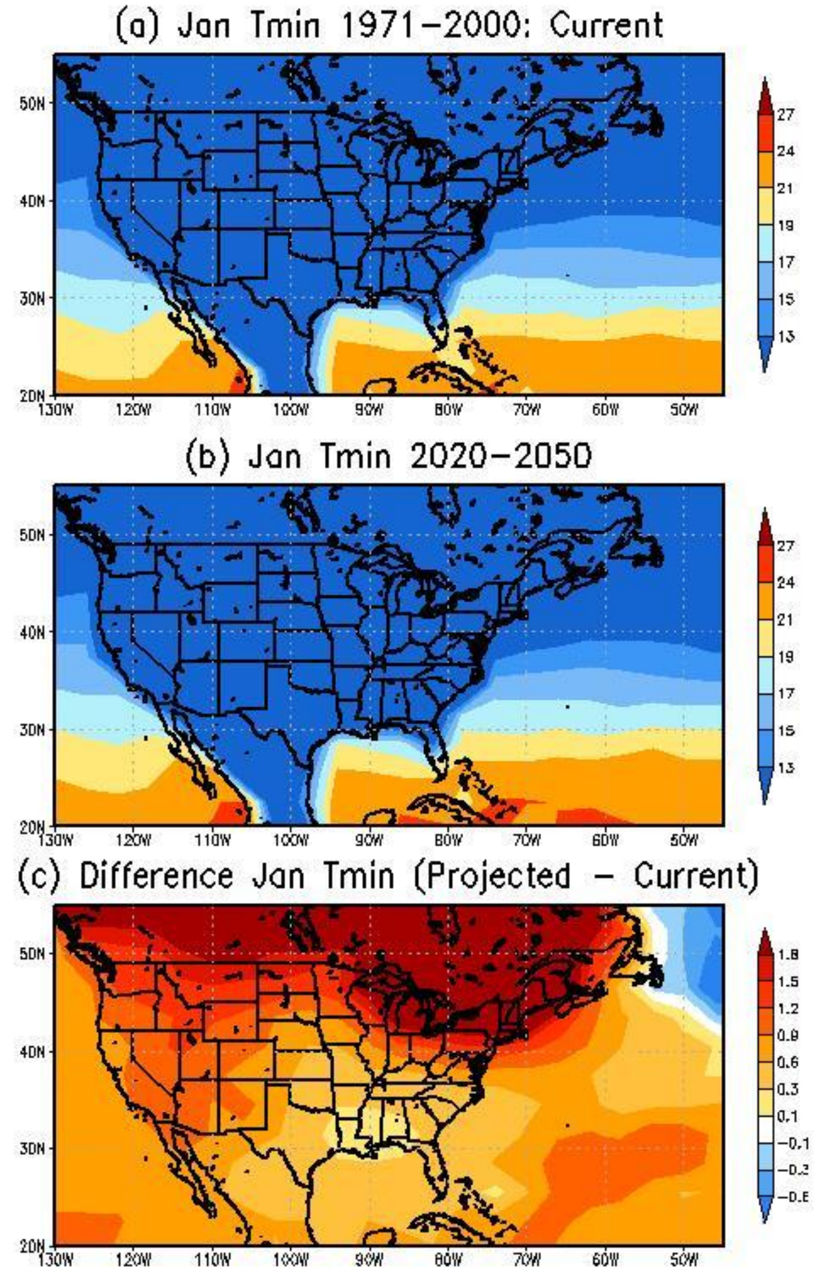


Figure 12: (a) January Minimum Temperature for the time period of 1971 – 2000; (b) for the time period of 2020 – 2050; (c) Difference in January Minimum Temperature (2050 Projection – 2000 Current). Data Source: GISS-AOM

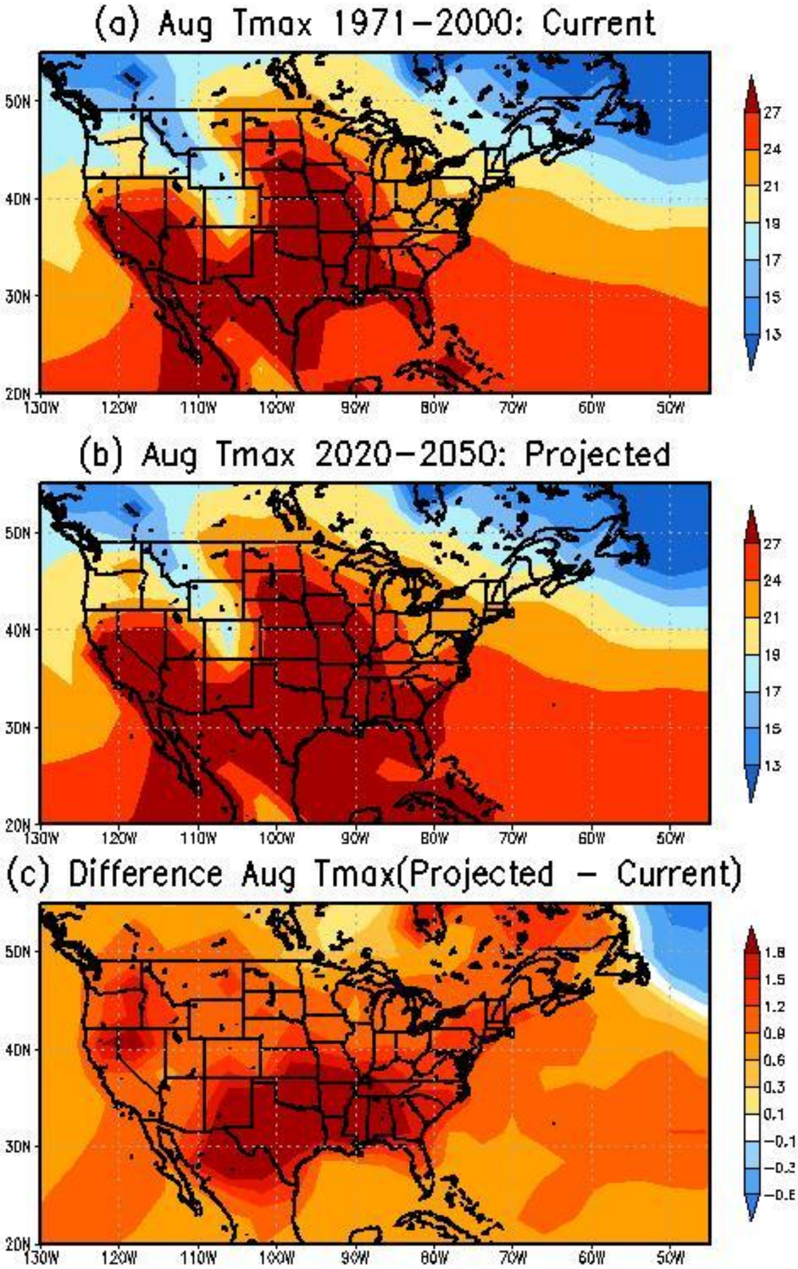


Figure 13: (a) August Maximum Temperature for the time period of 1971 – 2000; (b) for the time period of 2020 – 2050; (c) Difference in August Maximum Temperature (2050 Projection – 2000 Current). Data Source: GISS-AOM

Chapter 6

6. Summary and Conclusion

The objective of this dissertation research was to analyze and document the climate structure of the non-premium winegrape growing regions throughout the eastern US. This was achieved by using the PRISM monthly temperature maximum and minimum dataset.

6.1 Conclusions

This research had three main goals:

iv) To document the climate structure of the study area by utilizing a high resolution dataset which will more accurately portray the subtleties of characteristics within the study area.

v) To increase our understanding of the role that climate plays in non-traditional wine producing regions.

vi) To provide greater insight into current and future vineyard site suitability.

6.1.1 Documenting climate structure

The first goal of this study was to evaluate and document the climate structure in winegrape growing regions throughout the eastern US. This was accomplished through the use of a high resolution dataset of 30 year monthly averages of temperature maximum and minimum, the PRISM dataset. This dataset has an 800m resolution, which was able to capture the details of each of the regions that were analyzed.

The climate structure was evaluated by using four of the most common climate-viticulture indices, the GSTavg, HI, BEDD and GDD. It was found that aside from the GSTavg, the three other most common indices did not fully capture the entire climate structure in the eastern US. These three indices categorized many of the regions throughout the eastern US either as unsuitable for winegrape growth, or having very low growing season temperatures, which implies that winegrapes would not grow and mature properly.

To overcome the shortcomings of the three common indices, a new temperature based index was created, called the Modified-GSTavg. This index was based on the initial methodologies of the GSTavg, in that the average growing season temperature was evaluated. However, this index deviates from the GSTavg, since it takes into account that areas of the US have varying growing seasons. Since the growing season is not standard throughout the US, the Koppen Classification was employed to provide insight into the length of growing season. This allowed the US to be divided into regions where the growing season was shorter or longer, or started later and ended earlier. It was felt that this was a more realistic approach to evaluating the suitability of a region.

Finally, the four most common indices were documented. This research has created a concise documentation of how the indices categorize each AVA and state in the non-traditional growing regions of the eastern US, and have assembled this analysis into a single document. For this documentation, the original maturity class categorization was evaluated, and in some cases, was modified based on physical reasons. These reasons were also documented, along with the final maturity class categorization.

6.1.2 Role of the climate

The second goal of this study was to increase the understanding of the role that climate plays in the eastern US in determining length of the growing season, and success of the growth of the winegrape. It was determined that the more common indices don't fully capture the overall climate in certain regions in the eastern US. Other factors must be taken into consideration when evaluating the overall climate.

Results from this study showed that there are several factors that play an important role in the final climate of a region. First, topography and physical features influence temperatures by altering the atmospheric flow, modifying temperatures and creating microclimates. It can be seen from the successful vineyards in the north central US, that the strong seasonal southerly flow from the Gulf of Mexico, creates an environment that is conducive to winegrape growth. This type of seasonal weather pattern allows temperatures to rise in the Midwest to a temperature that allows the winegrapes to mature properly, and overcome the shortened growing season. In addition to the modifications produced by seasonal weather patterns, many of the physical features, such as large water bodies, have a great influence on altering temperatures, and creating more conducive environments to winegrape growth. These features create microclimates that raise temperatures, and allow the winegrapes to mature fully.

Understanding how the climate is modified by these factors is the first step in understanding how the climate influences the final vineyard management planning and decisions. Familiarity with the growing environment of a particular region can lead to correct decisions of what type of cultivars to plant, and how to best manage the vineyard throughout the season. Finally, this understanding will provide a foundation for success in productivity of the vineyard.

6.1.3 Insight into current and future site suitability

The last goal of this study was to provide greater insight into current and future vineyard site suitability. Each categorization provided a greater understanding of the current suitability for winegrape growth in a particular region. As discussed in the previous section, current suitability is based on the climate of a region. So, documenting the current climate has provided insight into the suitability of a region.

The initial evaluation of the GISS-AOM climate model provided some insight into future site suitability in the eastern US. As expected, some regions are forecasted to warm in the next 50 years, and have a more favorable environment during the growing season. However, forecasts for other regions showed little change to the current climate. If these forecasts do verify to some extent, then small changes in temperature could produce regions where alternative, more premium varietals could be grown.

6.2 Future directions

Several questions have arisen from this research, which provide opportunity for future research directions. The first direction would be to evaluate additional climate models to gain more insight into the evolution of growing season temperatures in the eastern US. This research only evaluated the output from one climate model. To thoroughly evaluate the predicted changes, the output from more models will need to be analyzed.

Another direction of future research could be in the subject of climate variability in the eastern US. Since the baseline climate has been documented, then, it is possible to investigate the impact that variability of the climate has on the growing season in these areas. For example, the influence of an El Nino event could be examined for impacts on the growing season, as well as impacts during the dormant, winter season. Investigating climate variability, and understanding the implications, could assist growers in planning for the upcoming season.

The last direction of future research that could be undertaken is expanding the categorizations to include a precipitation categorization. This could be accomplished two different ways, or a combination of the two. A precipitation index could be created to document typical rainfall in a particular region. This would be done using the same approach as this current study, evaluating each state and AVA on the basis of total monthly precipitation during the growing season. Or, an evaluation of precipitation patterns throughout the entire eastern US, could be documented, either based on monthly average precipitation, or evaluating typical storm tracks.

Expanding this research in any of these directions could provide valuable insight into vineyard establishment, and site suitability. Applying climate science to vineyard management issues is a relatively new topic that has not been thoroughly explored. Investigating topics, such as these, will provide a necessary understanding of the environment for the vineyard to be productive and successful.

Appendix I: Wine association website listing

Alabama Wineries and Grape Growers Association, 2008. Retrieved from http://www.alabamawines.net/default.asp

Arizona Wine Growers Association, 2009. Retrieved from http://arizonawine.org/

Coastal Wine Trail of Southeastern New England. 2009. Retrieved from http://www.coastalwinetrail.com/

Connecticut Vineyard and Winery Association. Connecticut Wine Trail 2010. Retrieved from http://www.ctwine.com/

Colorado Wine Industry Development Board, 2007. Retrieved from http://www.coloradowine.com/

Florida Grape Growers Association – FGGA, 2010. Retrieved from http://www.fgga.org/

Garden State Wine Growers Association, 2010. Retrieved from http://www.newjerseywines.com/

Illinois Grape Growers and Vintners Association, 2010. Retrieved from http://www.illinoiswine.com/

Indiana Wine Grape Council, 2010. Wineries of Indiana. Retrieved from http://www.indianawines.org/

Iowa Wine Growers Association, 2008. Retrieved from http://iowawinegrowers.org/

Kansas Grape Growers and Winemakers Association, 2010. Retrieved from http://kansasgrapesandwines.com/

Kentucky Wines, 2010. Retrieved from http://www.kentuckywine.com/

Leelanau Peninsula Vintners Association, 2009. Retrieved from http://www.lpwines.com/

Maine Winery Guild, 2010. The Maine Wine Trail. Retrieved from http://www.mainewinetrail.com/

Maryland Wineries Association, 2010. Retrieved from http://www.marylandwine.com/

Massachusetts Department of Agricultural Resources, 2010. Wineries webpage. Retrieved from http://www.mass.gov/agr/massgrown/wineries.htm

Michigan Grape and Wine Industry Council, 2008. Retrieved from http://www.michiganwines.com/

Minnesota Grape Growers Association, 2010. Retrieved from http://www.mngrapes.org/

Montana State Government Department of Commerce, 2010 Montana Wineries. Retrieved from http://www.madeinmontanausa.com/Wineries.asp

Nassau Valley Vineyard, 2010. Retrieved from http://www.nassauvalley.com/

Nebraska Winery and Grape Growers Association, 2010. Vintage Nebraska. Retrieved from http://www.nebraskawines.com/

New Hampshire Winery Association (NHWA), 2010. Retrieved from http://www.nhwineryassociation.com/

New Mexico Wine Growers Association, 2010. Retrieved from http://www.nmwine.com/

New York Wines and Grape Foundations. Uncork New York, 2010. Retrieved from http://www.uncorkny.com/

North Carolina Winegrowers Association, 2010. Retrieved from http://www.ncwinegrowers.com/

North Carolina Wine Trails, 2010. Retrieved from http://www.visitnc.com/itineraries/wine

North Dakota Grape Growers Association, 2010. Retrieved from http://www.ndgga.org/

Ohio Wine Association, 2010. Retrieved from http://www.ohiowines.org/

Oklahoma Grape Growers and Wine Makers Association, 2004. Retrieved from http://www.oklahomawines.org/

Pennsylvania Winery Association, 2009. Retrieved from http://www.pennsylvaniawine.com/Wineries.aspx

South Carolina's Information Highway, 2010. SC Grapes and Vineyards. Retrieved from http://www.sciway.net/bus/wine.html

South Dakota State University, Agriculture Experiment Station. Viticulture in South Dakota, 2010. Retrieved from http://sdgrapes.sdstate.edu/wineries.cfm

Table Mountain Vineyards, Wyoming. Retrieved from http://www.tablemountainvineyards.com/

Tennessee Farm Winegrowers Association, 2010. Retrieved from http://www.tennesseewines.com/

Ten Spoon Winery, 2010. Retrieved from http://www.tenspoonwinery.com/Vineyard_Story.html

Texas Department of Agriculture/Wine Division, 2010. Retrieved from http://www.gotexanwine.org/

Three Rivers Wine Trail of Minnesota, 2008. Retrieved from http://www.threeriverswinetrail.com/

University of Arkansas Division of Agriculture Enology and Viticulture Program, Wine Industry of Arkansas, 2010. Retrieved from http://www.uark.edu/depts/ifse/grapeprog/winetrail/wineries.htm

Vermont Brewers Association, 2010. Retrieved from http://www.vermontbrewers.com/

Virginia Wine Association, 2010. Virginia Wine. Retrieved from http://www.virginiawine.org/

Weekend Wineries, 2007. The Essential Guide to American Wineries. Retrieved from http://www.weekendwinery.com/Wineries/

Wine and Grape Board of Missouri, 2010. Missouri Wines. Retrieved from http://www.missouriwine.org/default.htm

Winegrowers Association of Georgia, 2009-2010. Retrieved from http://www.georgiawine.com/

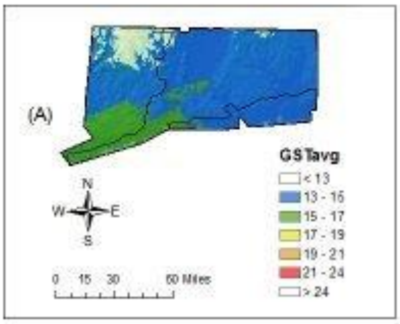
Wine Trails USA, 2010. Retrieved from http://www.winetrailsusa.com/

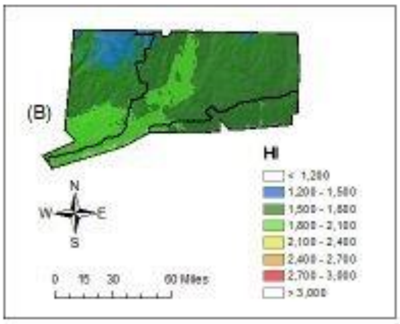
Wisconsin Winery Association, 2010. Retrieved from http://www.wiswine.com/

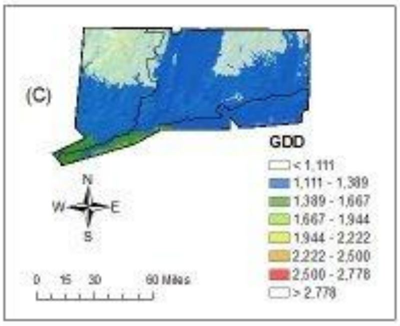
Appendix II: State and AVA Climate Indices Analysis

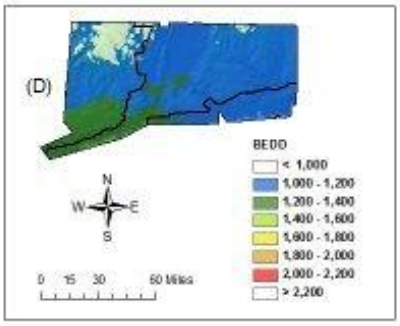
Northeast

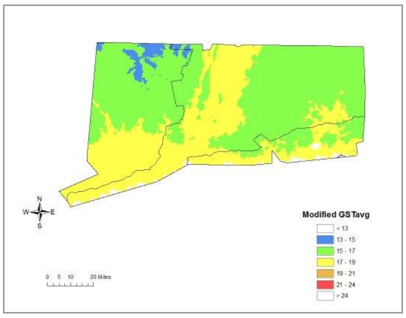
Connecticut











Highlights:

- 4977 square miles
- 825 planted acres (333.87 hectares)
- 25+ commercial vineyards
- Rank 26th in US production (113,767 gal/yr)
- 2 AVAs within the borders (Western Connecticut Highlands, SE New England)
- Elevation range:152 m to 725.4m
- Dfa and Dfb Koppen Classification

- Most common *V. Vinifera* varietals grown in Connecticut are Chardonnay, Cabernet Franc, Merlot and Riesling, and French Hybrid varietals of Seval Blanc, Vidal Blanc, Cayuga, Saint Croix, Vignoles, and Foch

Climate indices original characterization:
GSTavg: Too Cool; Cool; Intermediate
HI: Very Cool; Cool; Temperate
GDD: Too Cool; Very Cool, Cool
BEDD: Too Cool; Very Cool (Region I), Cool (Region II)
Modified GSTavg: Cool, Intermediate

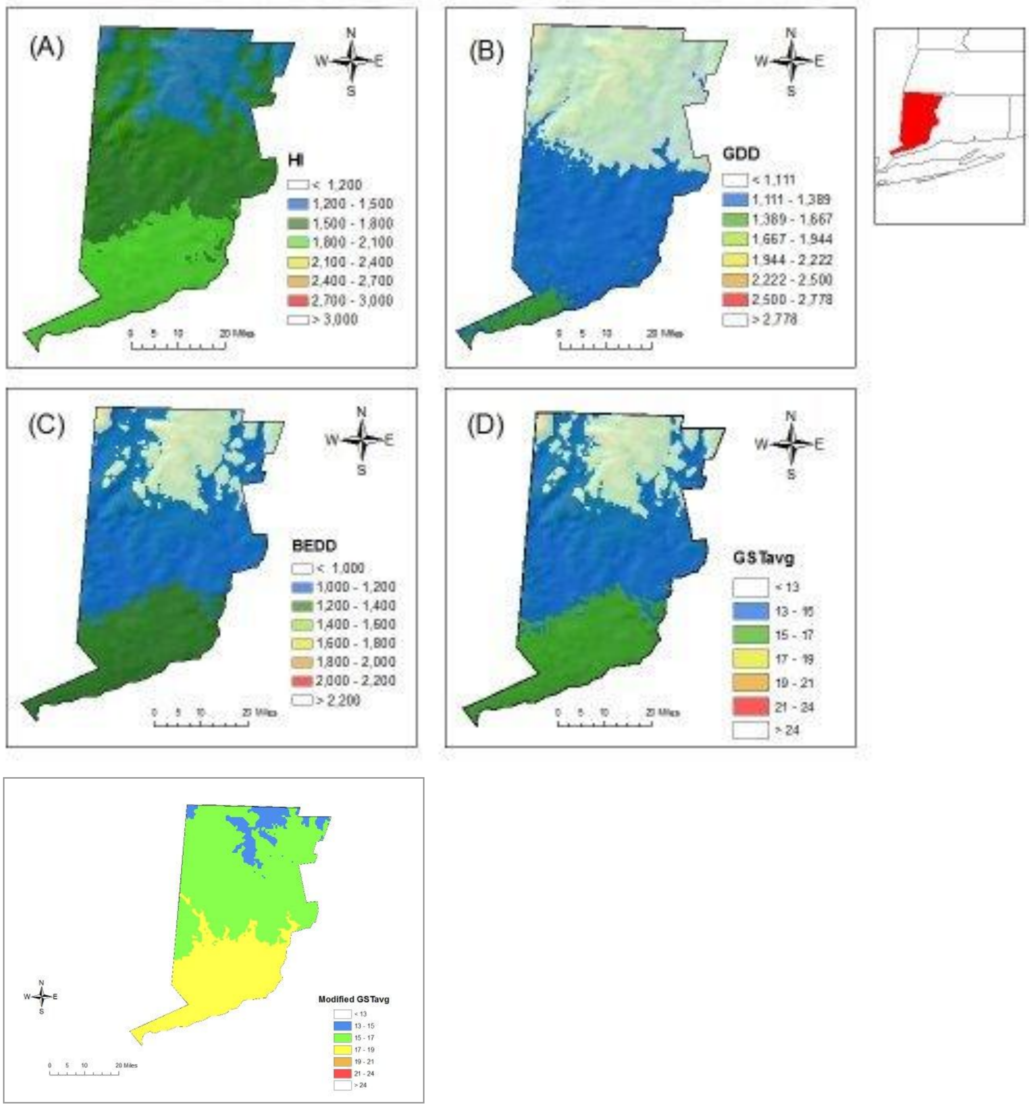
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	13	14	15	15	16
HI	1321.3	1632.1	1695.3	1790.9	1942.3
GDD	858	1134	1195	1287	1471
BEDD	880.5	1074.7	1114.5	1169.9	1315.2
Modified GSTavg	18	21	23	26	29

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Cool to Intermediate (25% to Maximum quartile range)
HI: Cool to Temperate (25% to Maximum quartile range)
GDD: Very Cool (Region I) to Cool (Region II) (25% to Maximum quartile range)
BEDD: Very Cool to Cool (25% to Maximum quartile range)
Modified GSTavg: Cool to Intermediate (Full quartile range)

Western Connecticut Highlands AVA



Highlights:

- 1,025,696.4 acres (415,099.3 hectares)
- 355 acres planted acres (143.67 hectares)
- Vineyards size ranging from 3 acres (1.21 hectares) to 175 acres (70.8 hectares)
- 11+ commercial vineyards
- Elevation range:28 m to 607 m (median value of 213 m)

Climate indices original characterization:
GSTavg: Too Cool (22%); Cool (52%); Intermediate (26%)
HI: Very Cool (20%); Cool (53%); Temperate (27%)
GDD: Too Cool (50%); Very Cool, Region I (46%); Cool, Region II (4%)
BEDD: Too Cool (20%); Very Cool (54%); Cool (26%)
Modified GSTavg: Cool (6%); Intermediate (59%); Warm (35%)

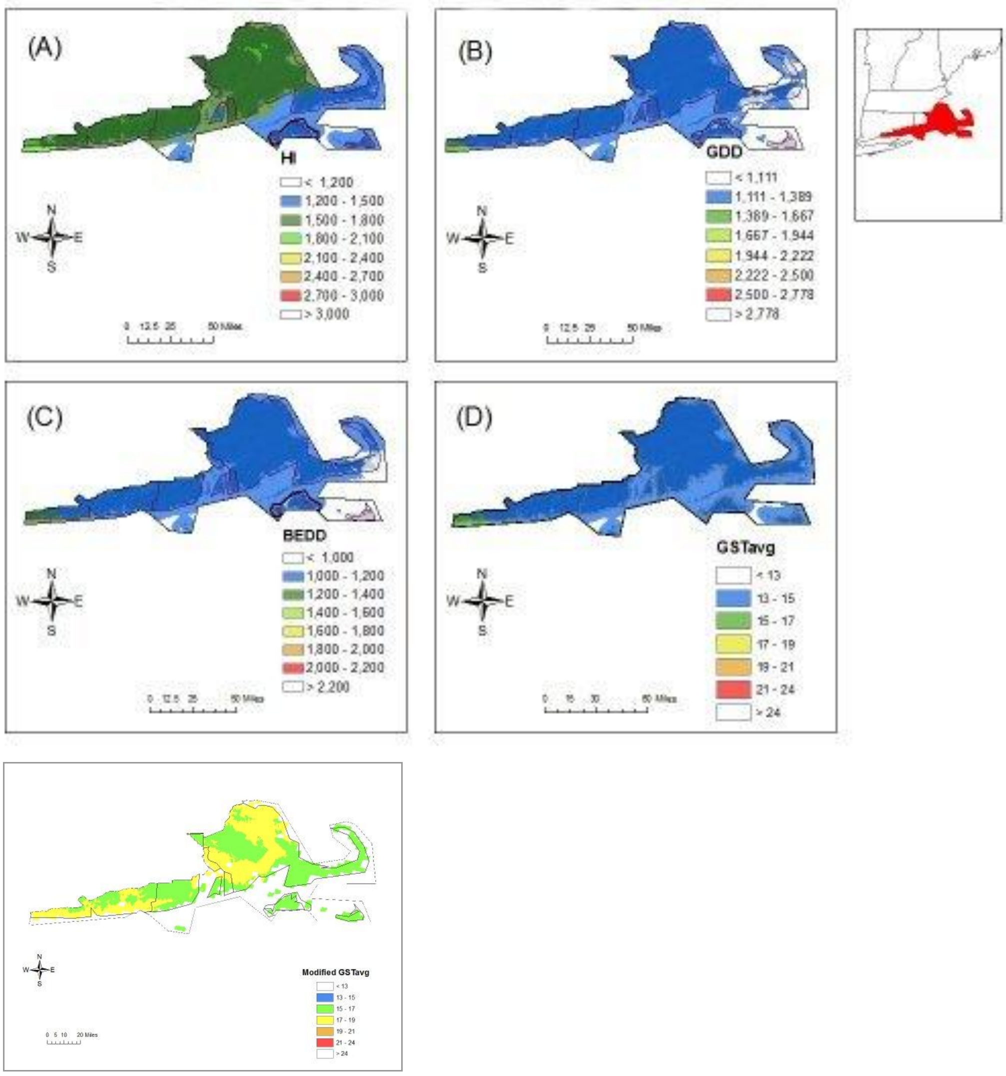
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	12	14	14	16	16
HI	1321	1509	1603	1850	1943
GDD	828	1011.25	1103	1348	1410
BEDD	850	1032	1098	1221	1254
Modified GSTavg	19	20	21	22	23

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations or State Forest lands, where it is unsuitable for planting

Final characterization:
GSTavg: Cool to Intermediate (25% to Maximum quartile range)
HI: Very Cool to Temperate (full range)
GDD: Very Cool, Region I to Cool, Region II (Median to Maximum quartile range)
BEDD: Very Cool to Cool (Median to Maximum quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Southeastern New England AVA



Highlights:

- 3,269,858 total acres (1,323,311.5 hectares)
- Encompasses 3 states (CT, RI and MA)
- 491 planted acres (198.7 hectares)
- Vineyard size ranges from 2 acres (0.81 hectares) to 140 acres (56.7 hectares)
- 17+ commercial vineyards
- Elevation range: 0 m to 157 m (median value of 26m)

Climate indices original characterization:
GSTavg: Cool (98%); Intermediate (2%)
HI: Very Cool (35%); Cool (63%); Temperate (2%)
GDD: Too Cool (10%); Very Cool, Region I (88%); Cool, Region II (2%)
BEDD: Too Cool (12%); Very Cool (87%); Cool, Region II (1%)
Modified GSTavg: Intermediate (57%); Warm (43%)

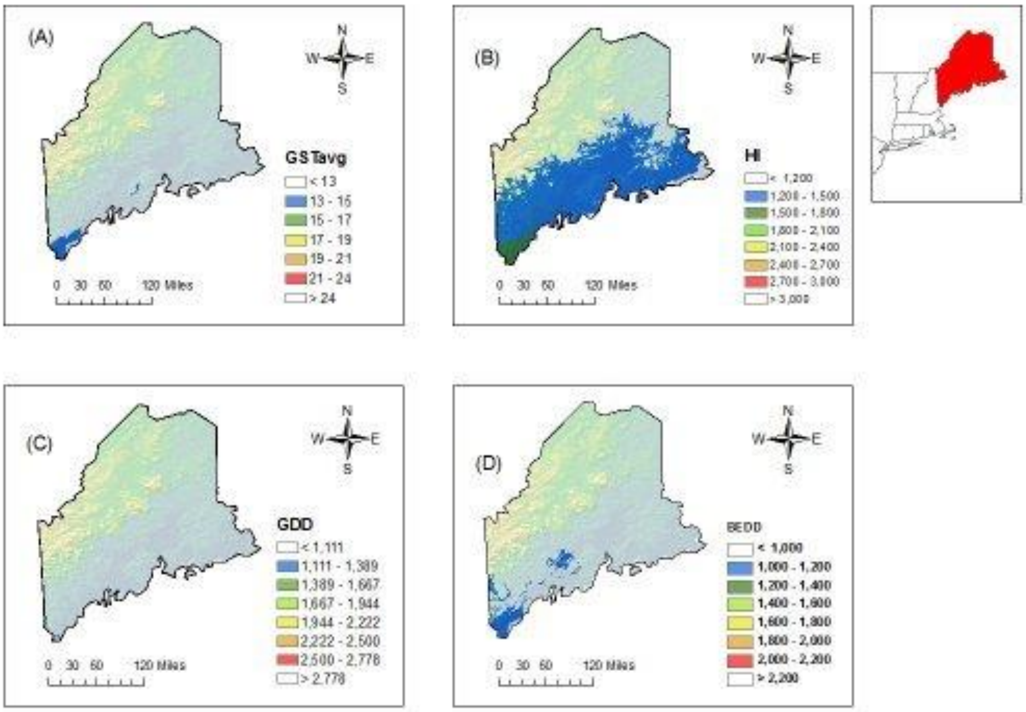
Quartile Statistics:

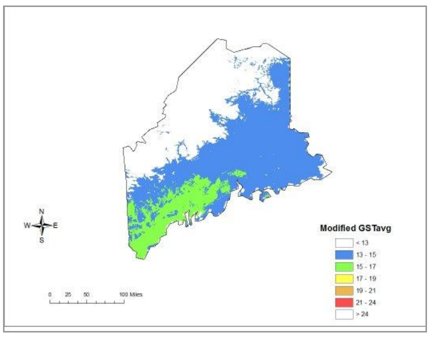
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	15	15	15	16
HI	1,285	1,444	1,540	1,667	1,850
GDD	1011	1164	1195	1256	1471
BEDD	860	1041	1122	1161	1285
Modified GSTavg	20	21	21	22	23

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Cool to Intermediate (Full quartile range)
HI: Very Cool to Temperate (Full quartile range)
GDD: Too Cool to Cool (Full quartile range)
BEDD: Too Cool to Cool (Full quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Maine





Highlights:

- 32,162 square miles
- 25 planted acres (hectares)
- 5 commercial vineyards
- Ranked 34th in US production (35,193 gal/yr)
- Elevation range: 0 m to 1605.7 m
- Dfb Koppen Classification

- Most common winegrapes grown are French Hybrids, such as Cayuga and Foch and native American variety, Concord.

<u>Climate indices original characterization:</u>
GSTavg: Too Cool; Cool
HI: Very Cool; Cool
GDD: Too Cool; Very Cool, Region I
BEDD: Too Cool; Very Cool
Modified GSTavg: Too Cool, Very Cool, Cool, Intermediate

Quartile Statistics:

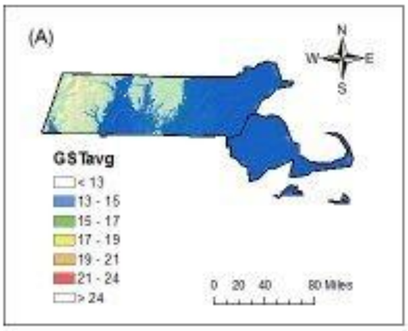
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	7	10	11	12	14
HI	605.1	1025.3	1178.0	1335.4	1644.1
GDD	247	553	675	828	1134
BEDD	256.4	583.9	708.1	887.6	1087.9
Modified GSTavg	14	21	24	27	31

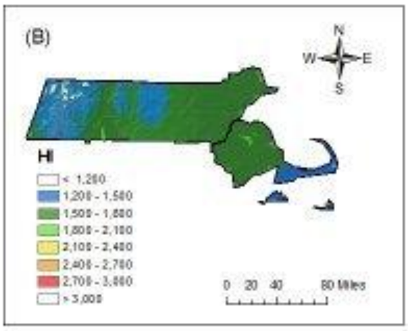
<u>Factors affecting alteration of characterizations:</u>
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

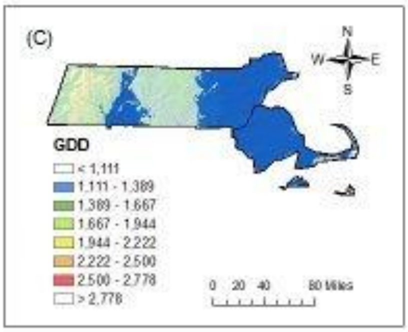
<u>Final characterization:</u>
GSTavg: Cool (Maximum quartile range)
HI: Cool (Maximum quartile range)
GDD: Very Cool (Maximum quartile range)
BEDD: Very Cool (Maximum quartile range)
Modified GSTavg: Very Cool to Intermediate (Full quartile range)

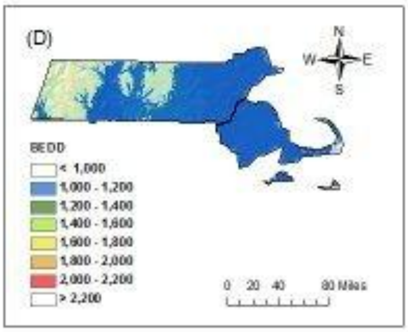
** Range of quartile statistics for standard indices may not fully capture climate structure of the state **

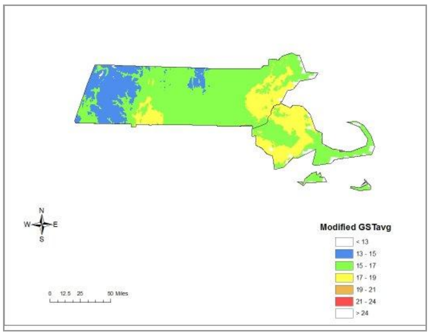
Massachusetts











Highlights:

- 8,173 square miles
- 433 planted acres (hectares)
- 12+ commercial vineyards
- Ranks 25th in US wine production (158,905 gal/yr)
- Two AVAs within state borders (SE New England and Martha's Vineyard)
- Elevation range: 0 m to 1062.8 m

- Dfa and Dfb Koppen Classification
- Most common *V. Vinifera* varietals grown are Chardonnay, Pinot Noir, Pinot Blanc, Pinot Gris, Riesling, and Gewurztraminer, and French Hybrid varietals of Vidal Blanc, and Cayuga.

Climate indices original characterization:
GSTavg: Too Cool; Cool
HI: Very Cool; Cool, Temperate
GDD: Too Cool; Very Cool, Region I
BEDD: Too Cool; Very Cool
Modified GSTavg: Cool, Intermediate, Warm

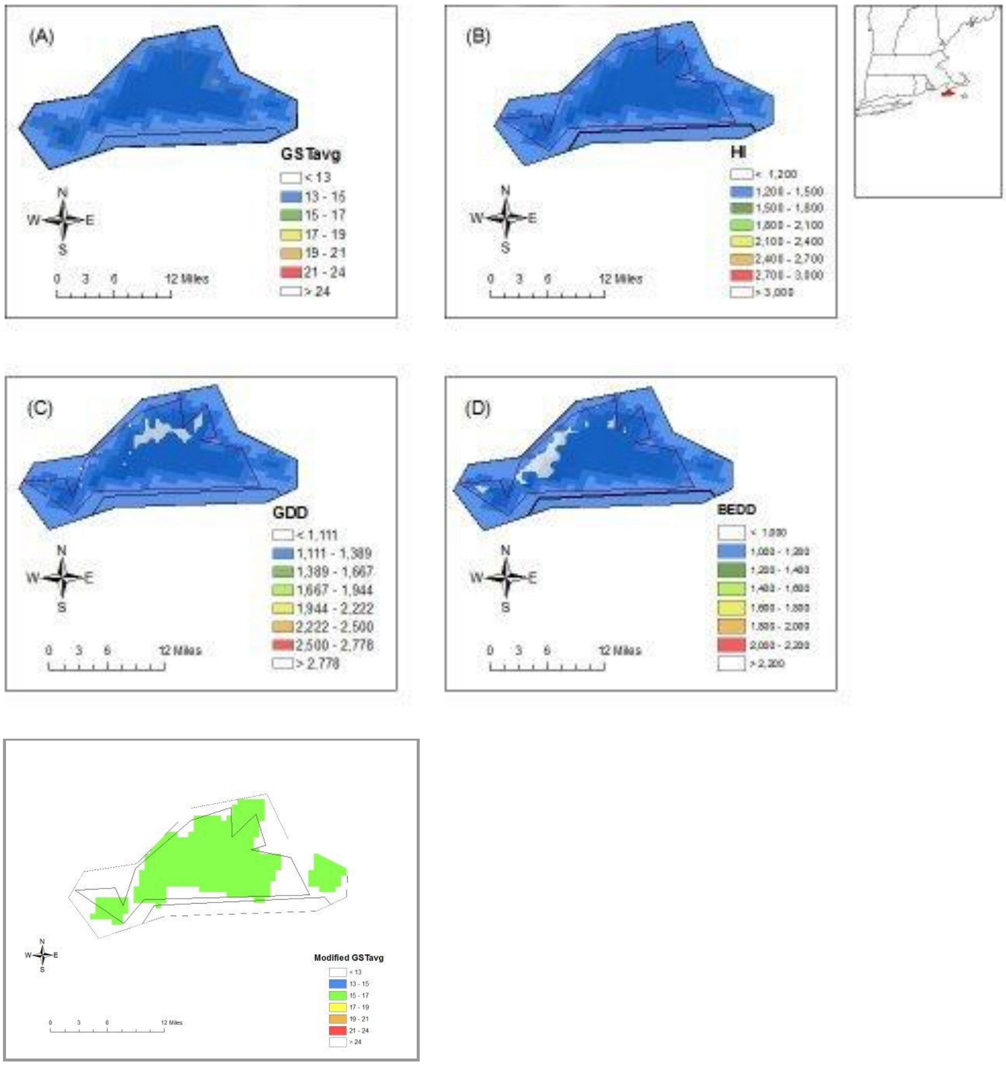
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	12	13	14	15	15
HI	1197.5	1442.6	1573.4	1667.9	1822.9
GDD	705	981	1134	1195	1317
BEDD	725.3	976.6	1078.7	1130.3	1195.6
Modified GSTavg	18	21	24	26	30

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Very Cool to Cool (Median to Maximum quartile range)
HI: Very Cool to Temperate (25% to Maximum quartile range)
GDD: Very Cool, Region I (Median to Maximum quartile range)
BEDD: Very Cool (Median to Maximum quartile range)
Modified GSTavg: Cool to Warm (Full quartile range)

Martha’s Vineyard AVA



Highlights:

- 117,387 total acres (47,506.5 hectares)
- No planted acres
- Last estate winery closed in 2008 due to hurricane damage
- Elevation range: 0m to 72m (median value 11m)

Climate indices original characterization:
GSTavg: Cool (100%);
HI: Very Cool (100%)
GDD: Too Cool (6%); Very Cool, Region I (94%);
BEDD: Too Cool (8%); Very Cool (92%)
Modified GSTavg: Intermediate (100%)

Quartile Statistics:

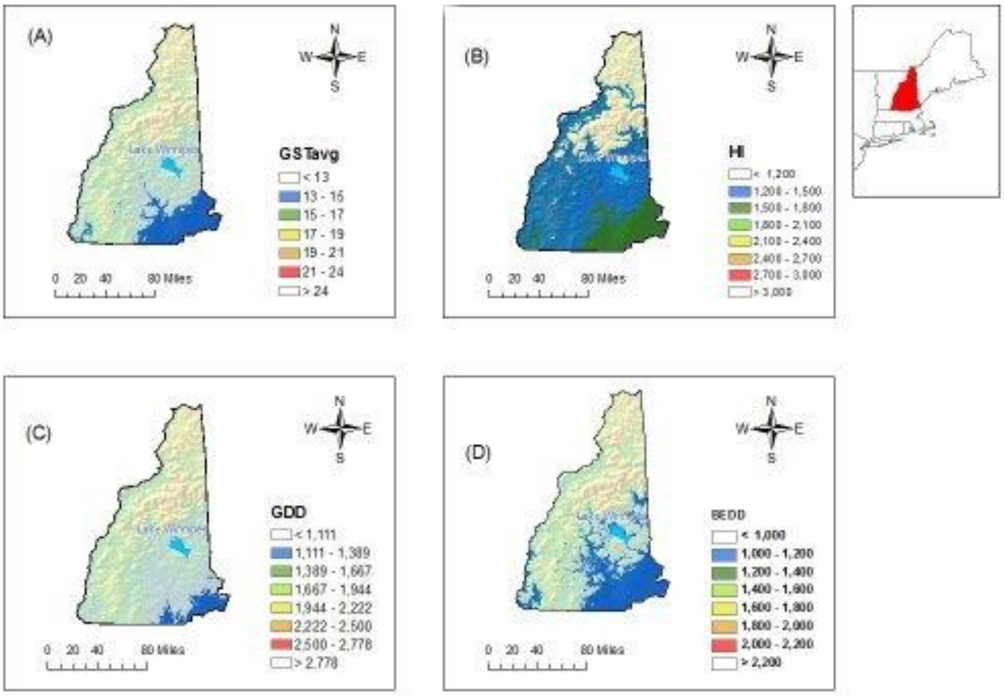
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	14	15	15	15
HI	1,412	1,442	1,443	1,443	1,444
GDD	1103	1134	1164	1164	1164
BEDD	998	1025	1091	1091	1099
Modified GSTavg	21	21	21	21	21

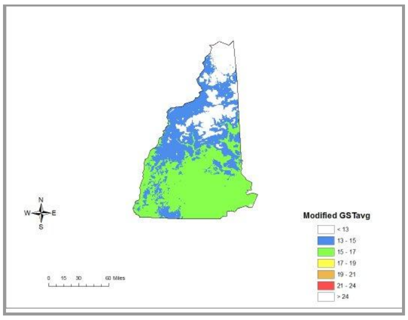
Factors affecting alteration of characterizations:

- Productive vineyards in past years

Final characterization:
GSTavg: Cool (Median to Maximum quartile range)
HI: Cool (Median to Maximum quartile range)
GDD: Very Cool (Median to Maximum quartile range)
BEDD: Very Cool (Median to Maximum quartile range)
Modified GSTavg: Intermediate (Full quartile range)

New Hampshire





Highlights:

- 9,260 square miles
- 43 planted acres (17.4 hectares)
- 6+ commercial vineyards
- Production data not documented
- Elevation range: 0 m to 1916.6 m
- Dfa, Dfb and Dfc Koppen Classification
- Most common varieties are the French hybrids, Marechal Foch and Seyval.

Climate indices original characterization:
GSTavg: Too Cool; Cool
HI: Very Cool; Cool, Temperate
GDD: Too Cool; Very Cool, Region I
BEDD: Too Cool; Very Cool
Modified GSTavg: Too Cool, Cool, Intermediate

Quartile Statistics:

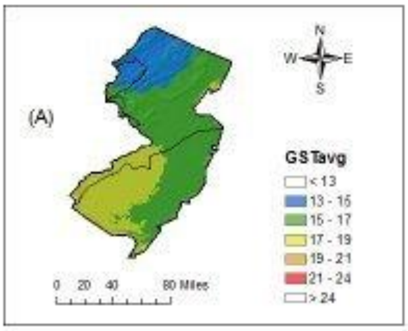
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	7	11	13	13	15
HI	382	1172	1395	1486	1673
GDD	185	675	889	981	1164
BEDD	169	698	938	1003	1126
Modified GSTavg	18	20	24	26	30

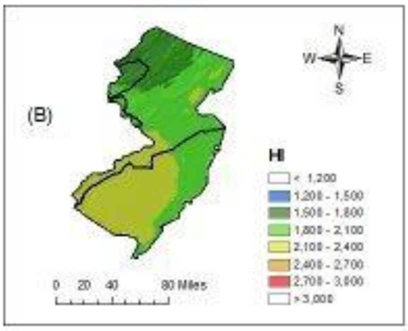
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

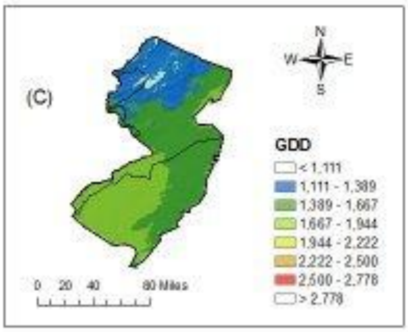
Final characterization:
GSTavg: Cool (Maximum quartile range)
HI: Cool (Maximum quartile range)
GDD: Very Cool, Region I (Maximum quartile range)
BEDD: Very Cool (Maximum quartile range)
Modified GSTavg: Cool to Intermediate (Full quartile range)

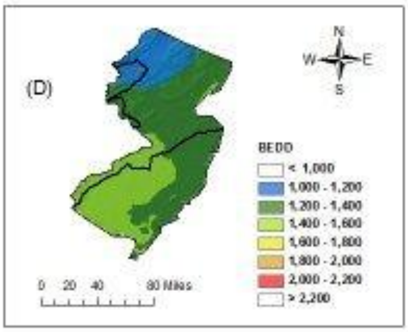
** Range of statistical values for standard indices may not fully capture the climate structure of the state.**

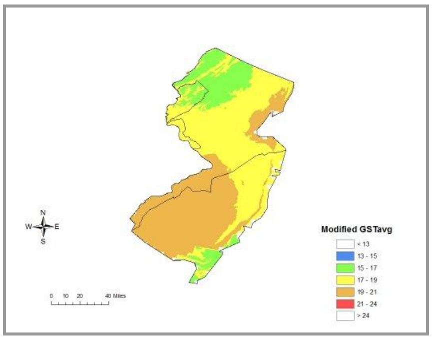
New Jersey











Highlights:

- 7,508 square miles
- 792 planted acres (320.5 hectares)
- 33+ commercial vineyards
- 3 AVAs (Outer Coastal Plain, Central Delaware Valley and Warren Hills)
- Ranks 6th in US production (1,457,652 gal/yr)
- Elevation range: 0 m to 549.6 m

- Dfa and Dfb Koppen Classification
- Most common *V. Vinifera* varieties grown are Cabernet Sauvignon, Cabernet Franc, Chardonnay, Reisling, Merlot, Pinot Gris, Viognier and French Hybrid varieties of Chambourcin and Vidal Blanc.

Climate indices original characterization:
GSTavg: Cool, Intermediate, Warm
HI: Cool, Cool, Temperate, Warm Temperate
GDD: Too Cool; Very Cool, Region I, Cool, Temperate
BEDD: Very Cool, Cool, Temperate
Modified GSTavg: Intermediate, Warm, Hot

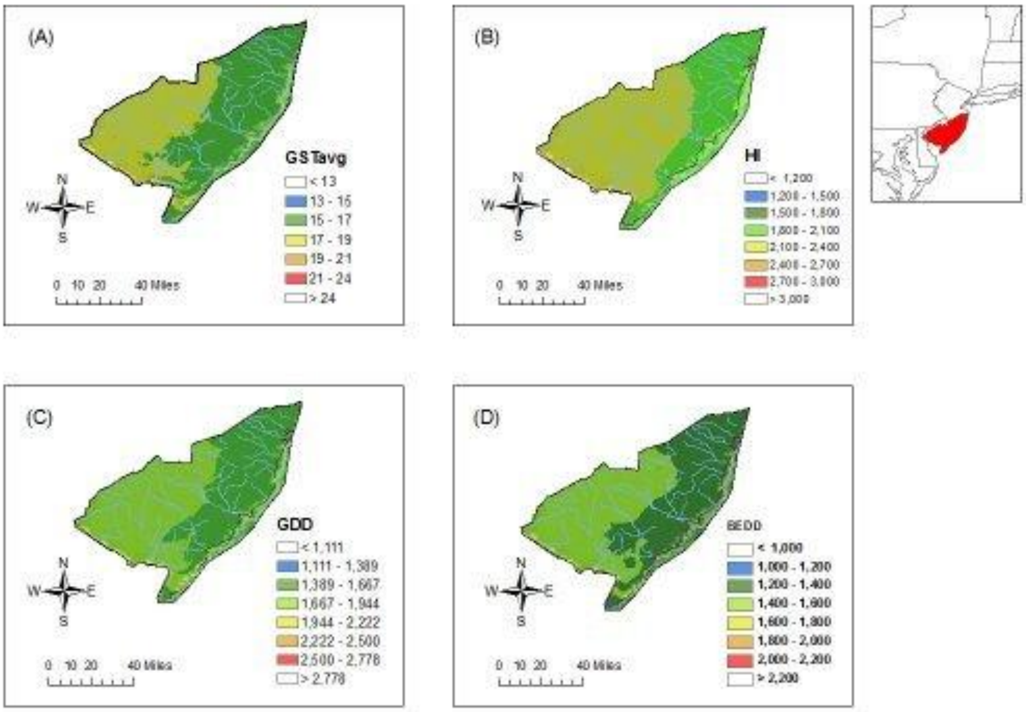
Quartile Statistics:

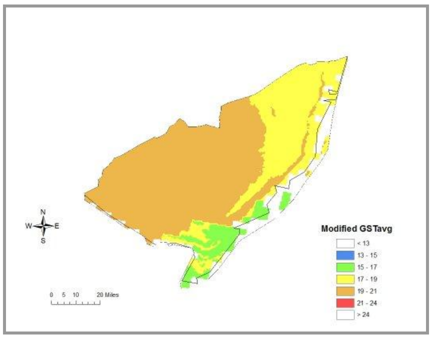
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	16	17	18	19
HI	1566	1902	2061	2211	2308
GDD	1072	1409	1592	1716	1930
BEDD	1065	1270	1345	1405	1497
Modified GSTavg	17	21	22	26	29

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, or in National Parks or recreational areas, where it is unsuitable for planting

Final characterization:
GSTavg: Intermediate to Warm (25% to Maximum quartile range)
HI: Temperate to Warm Temperate (25% to Maximum quartile range)
GDD: Cool, Region II to Temperate, Region III (25% to Maximum quartile range)
BEDD: Cool to Temperate (Median to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (Full quartile range)

Outer Coastal Plain AVA





Highlights:

- 2,377,774.2 total acres (962,285.2 hectares)
- 472 planted acres (191 hectares)
- Vineyard size ranges from 1 acres (0.4047 hectares) to 80 acres (32.4 hectares)
- 23+ commercial vineyards
- Elevation range: 0 m to 61m (median value of 19m)

Climate indices original characterization:
GSTavg: Intermediate (57%); Warm (43%);
HI: Temperate (41%); Warm Temperate (59%);
GDD: Cool (49%); Temperate (51%);
BEDD: Cool (50%); Temperate (50%);
Modified GSTavg: Intermediate (8%); Warm (29%); Hot (63%)

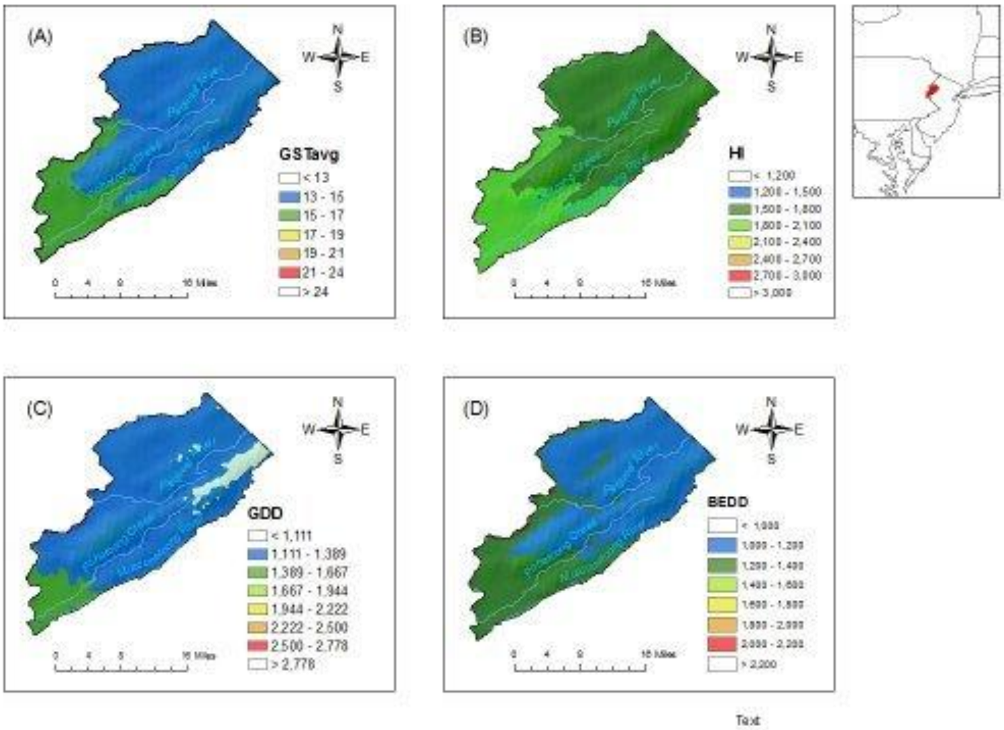
Quartile Statistics:

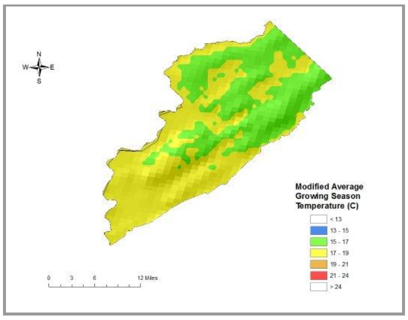
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	17	17	17	18	19
HI	1840	2058	2178	2242	2307
GDD	1532	1593	1685	1746	1930
BEDD	1255	1356	1401	1433	1497
Modified GSTavg	21	23	24	24	25

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Intermediate to Warm (Full quartile range)
HI: Temperate to Warm Temperate (Full quartile range)
GDD: Cool, Region II to Temperate, Region III (Full quartile range)
BEDD: Temperate (Median to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (Full quartile range)

Warren Hills AVA





Highlights:

- 189,853 total acres (76,833.5 hectares)
- 19 planted acres (7.7 hectares)
- Vineyard size ranges from 8 acres (3.2 hectares) to 11 acres (4.5 hectares)
- 2+ commercial vineyards
- Elevation range: 87 m to 351m (median value of 179m)

<u>Climate indices original characterization:</u>
GSTavg: Cool (74%); Intermediate (26%)
HI: Cool (70%); Temperate (30%)
GDD: Too Cool (6%); Very Cool, Region I (84%); Cool (10%);
BEDD: Very Cool (61%); Cool (39%)
Modified GSTavg: Intermediate (53%); Warm (47%)

Quartile Statistics:

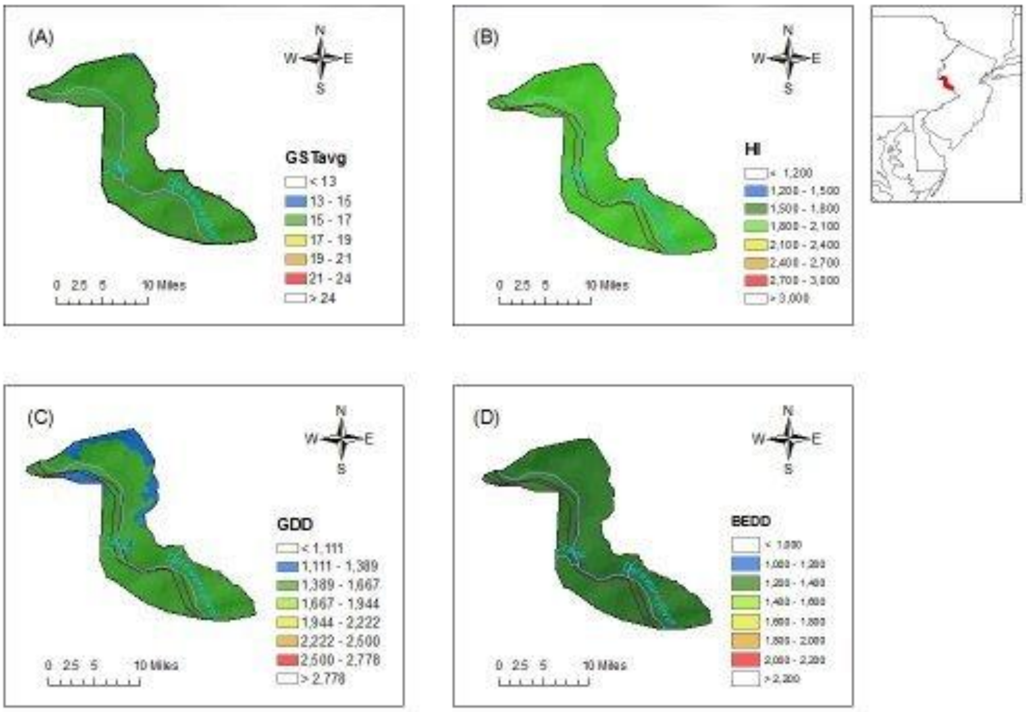
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	15	15	15.5	16
HI	1536	1723	1753	1862	2000
GDD	1042	1195	1225	1348	1470
BEDD	1042	1139	1173	1247	1351
Modified GSTavg	21	22	22	22	23

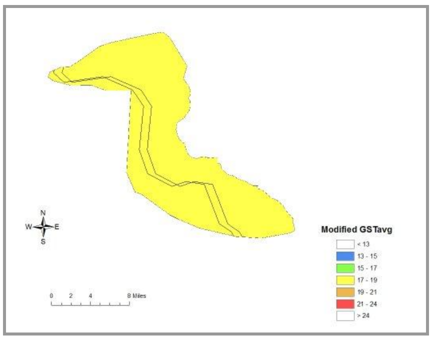
<u>Factors affecting alteration of characterizations:</u>

- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

<u>Final characterization:</u>
GSTavg: Cool to Intermediate (Full quartile range)
HI: Cool to Temperate (25% to Maximum quartile range)
GDD: Very Cool, Region I to Cool, Region II (Median to Maximum quartile range)
BEDD: Very Cool to Cool (Median to Maximum quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Central Delaware Valley AVA





Highlights:

- 92,190.5 total acres (37,309.5 hectares)
- 86 planted acres (34.8 hectares)
- Vineyard size ranges from 8 acres (3.2 hectares) to 78 acres (31.6 hectares)
- 2+ commercial vineyards
- Elevation range: 24 m to 225m (median value of 94m)

<u>Climate indices original characterization:</u>
GSTavg: Cool (1%); Intermediate (99%)
HI: Temperate (100%)
GDD: Very Cool, Region I (15%); Cool (85%);
BEDD: Cool (100%)
Modified GSTavg: Warm (100%)

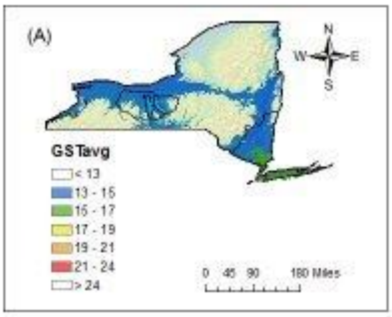
Quartile Statistics:

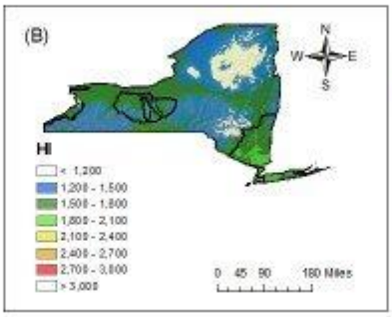
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16	16	16	17	17
HI	1907	1937	1938	2032	2063
GDD	1379	1409	1409	1532	1532
BEDD	1257	1258	1266	1320	1336
Modified GSTavg	23	23	23	23	23

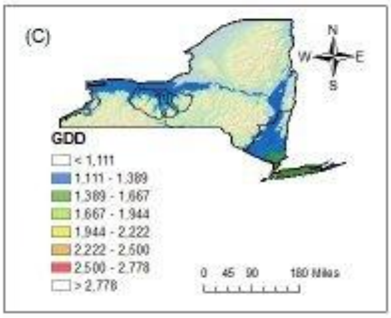
<u>Factors affecting alteration of characterizations:</u>
- Already established productive vineyards
- Many areas suited for crop farming

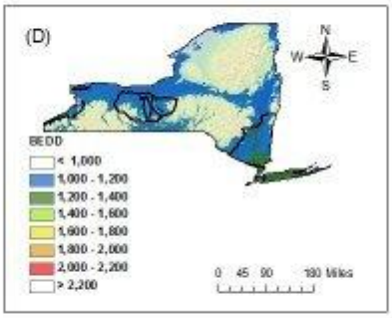
<u>Final characterization:</u>
GSTavg: Cool to Intermediate (Full quartile range)
HI: Temperate (Full quartile range)
GDD: Cool, Region II(25% to Maximum quartile range)
BEDD: Cool (Full quartile range)
Modified GSTavg: Warm (Full quartile range)

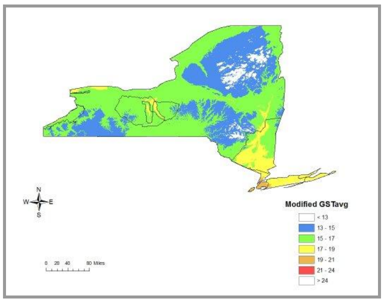
New York











Highlights:

- 48,562 square miles
- 7617 planted acres (320.5 hectares)
- 163+ commercial vineyards
- Ranks 3rd in US production (26,174,092 gal/yr)
- 5 AVAs and 4 sub-AVAs (AVAs: Finger Lakes, Lake Erie, Niagara Escarpment, Long Island, Hudson River Region; sub-AVAs: Cayuga Lake, Seneca Lake, North Fork of Long Island, The Hamptons, Long Island)

- Elevation range: 0 m to 1628.8 m
- Dfa and Dfb Koppen Classification
- Most common *V. Vinifera* varietals grown are Cabernet Sauvingon, Chardonnay, Cabernet Franc, Merlot, and Pinot Noir, French Hybrid varietals of Seval Blanc, Vidal Blanc, Traminette, and Niagara, and the native American varietal, Concord.

Climate indices original characterization:
GSTavg: Too Cool, Cool, Intermediate
HI: Too Cool, Very Cool, Cool, Temperate
GDD: Too Cool; Very Cool, Region I; Cool, Region II
BEDD: Very Cool; Cool
Modified GSTavg: Too Cool, Cool, Intermediate, Warm, Hot

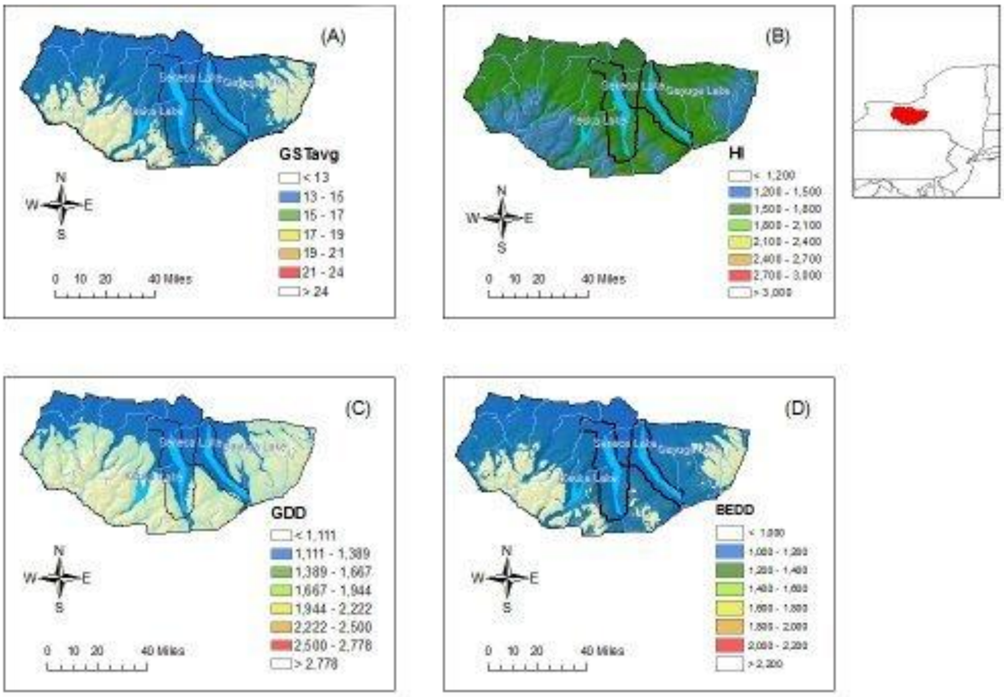
Quartile Statistics:

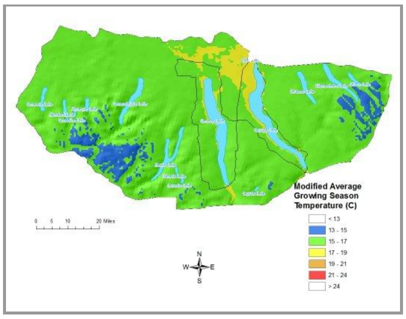
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	7	12	13	14	18
HI	508	1328	1478	1591	2067
GDD	185	828	980	1103	1716
BEDD	191	872	984	1077	1385
Modified GSTavg	17	21	23	26	30

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes characterizations found at higher elevations, or in National Parks or recreational areas, where it is unsuitable for planting

Final characterization:
GSTavg: Cool to Warm (75% to Maximum quartile range)
HI: Cool to Temperate (75% to Maximum quartile range)
GDD: Very Cool, Region I to Temperate, Region III (75% to Maximum quartile range)
BEDD: Very Cool to Cool (75% to Maximum quartile range)
Modified GSTavg: Cool to Hot (Full quartile range)

Finger Lakes AVA





__Highlights:__
- 2,216,174 total acres (896,885.6 hectares)
- 4135 planted acres (1673.4 hectares)
- Vineyard size ranges from 2 acres (0.81 hectares) to 75 acres (30.4 hectares)
- 45+ commercial vineyard
- 2 sub-AVAs (Seneca Lake and Cayuga Lake)
- Elevation range: 123 m to 653 m (median value of 308 m)

Climate indices original characterization:
GSTavg: Cool (73%); Too Cool (27%)
HI: Very Cool (25%); Cool (75%);
GDD: Too Cool (60%); Very Cool, Region I (40%)
BEDD: Very Cool (80%); Too Cool (20%)
Modified GSTavg: Cool (6%); Intermediate (86%); Warm (8%)

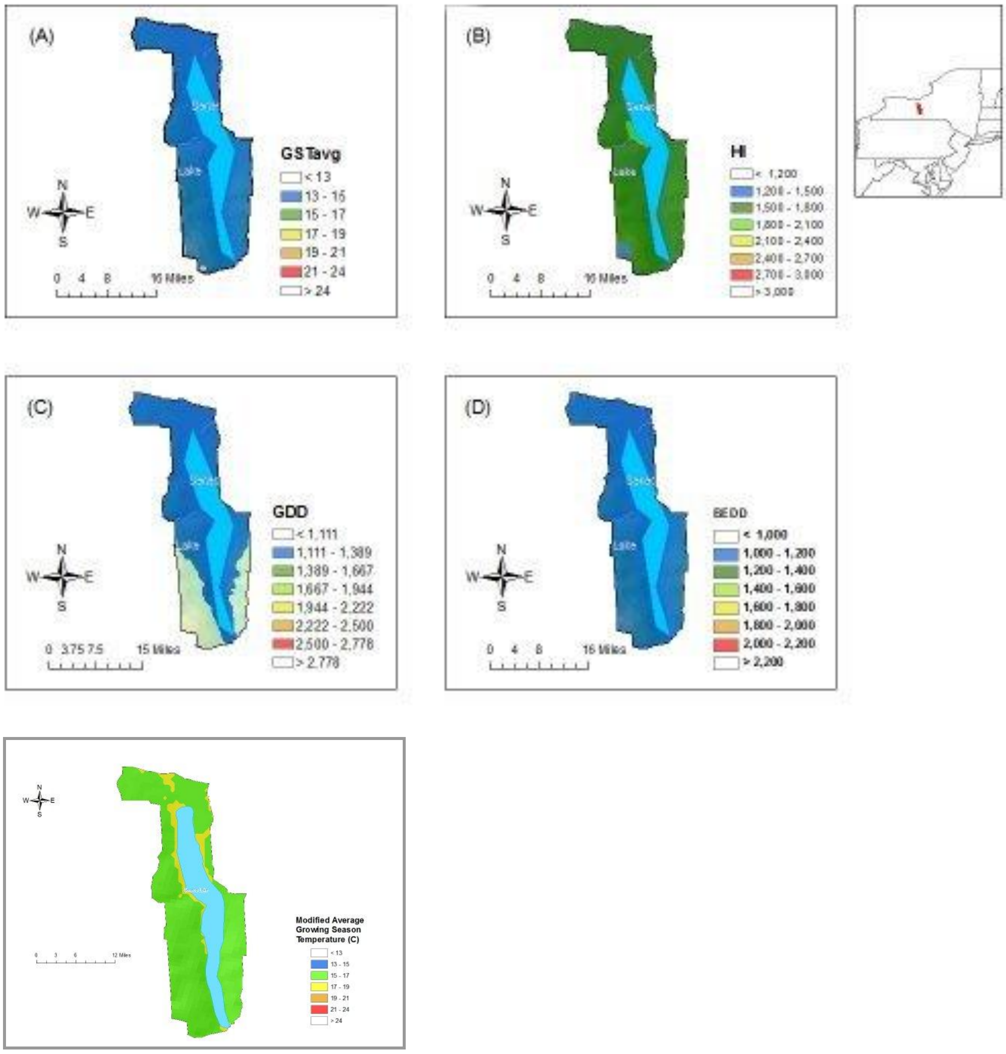
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	12	13	14	14	15
HI	1260	1458	1514	1670	1735
GDD	766	980	1011	1164	1225
BEDD	788	1007	1009	1103	1166
Modified GSTavg	19	20	21	21	22

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Cool (75% to Maximum quartile range)
HI: Cool (75% to Maximum quartile range)
GDD: Very Cool, Region I(75% to Maximum quartile range)
BEDD: Very Cool (75% to Maximum quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Seneca Lake sub-AVA



Highlights:

- 196,465.4 total acres (79,509.5 hectares)
- 1386 planted acres (560.9 hectares)
- Vineyard size ranges from 5 acres (2 hectares) to 250 acres (101.2 hectares)
- 28+ commercial vineyards
- Elevation range: 151 m to 510m (median value of 195m)

<u>Climate indices original characterization:</u>
GSTavg: Cool (100%)
HI: Too Cool (1%); Cool (97%); Temperate (2%)
GDD: Too Cool (23%); Very Cool, Region I (77%); Cool (85%);
BEDD: Very Cool (100%)
Modified GSTavg: Intermediate (71%); Warm (29%)

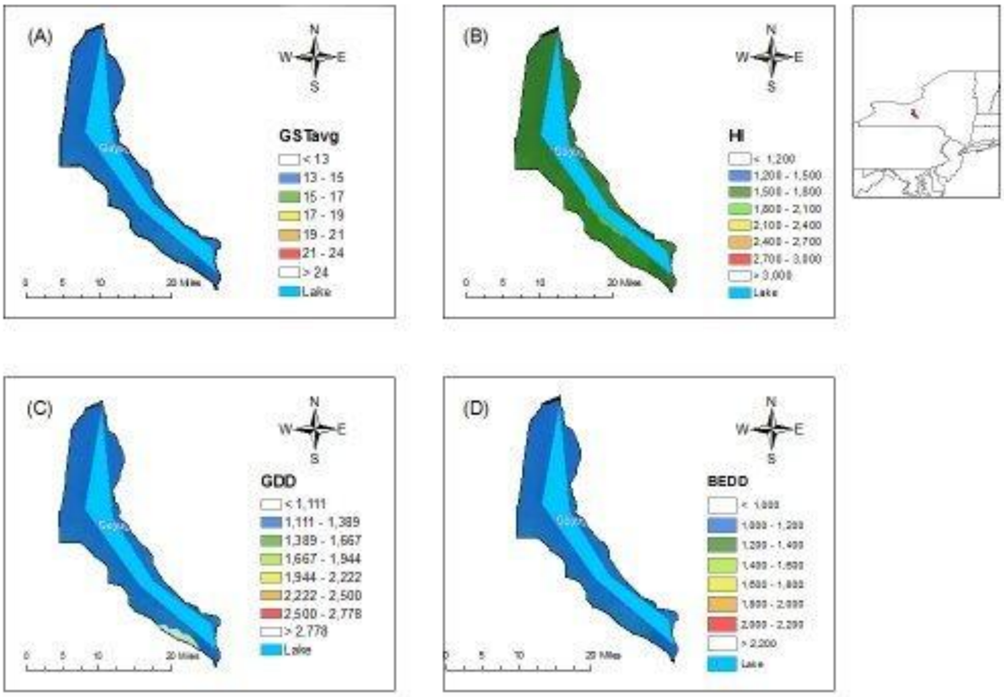
Quartile Statistics:

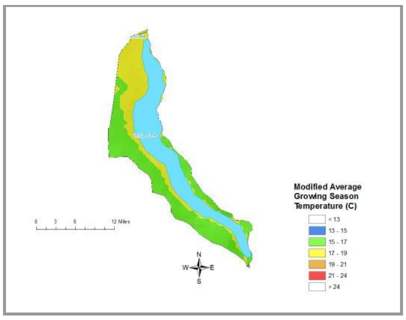
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	14	15	15	15
HI	1512	1615	1671	1733	1796
GDD	1011	1111	1164	1217	1286
BEDD	1008	1089	1103	1156	1196
Modified GSTavg	20	21	21	22	22

<u>Factors affecting alteration of characterizations:</u>
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

<u>Final characterization:</u>
GSTavg: Intermediate (75% to Maximum quartile range)
HI: Cool to Temperate (75% to Maximum quartile range)
GDD: Very Cool, Region I(75% to Maximum quartile range)
BEDD: Very Cool (75% to Maximum quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Cayuga Lake sub-AVA





Highlights:

- 116,331 total acres (47,079.2 hectares)
- 303 planted acres (122.6 hectares)
- Vineyard size ranges from 29 acres (11.7 hectares) to 70 acres (28.3 hectares)
- 8+ commercial vineyards
- Elevation range: 123 m to 332m (median value of 141m)

Climate indices original characterization:
GSTavg: Cool (100%)
HI: Cool (95%); Temperate (5%)
GDD: Too Cool (3%); Very Cool, Region I (97%)
BEDD: Very Cool (100%)
Modified GSTavg: Intermediate (45%); Warm (55%)

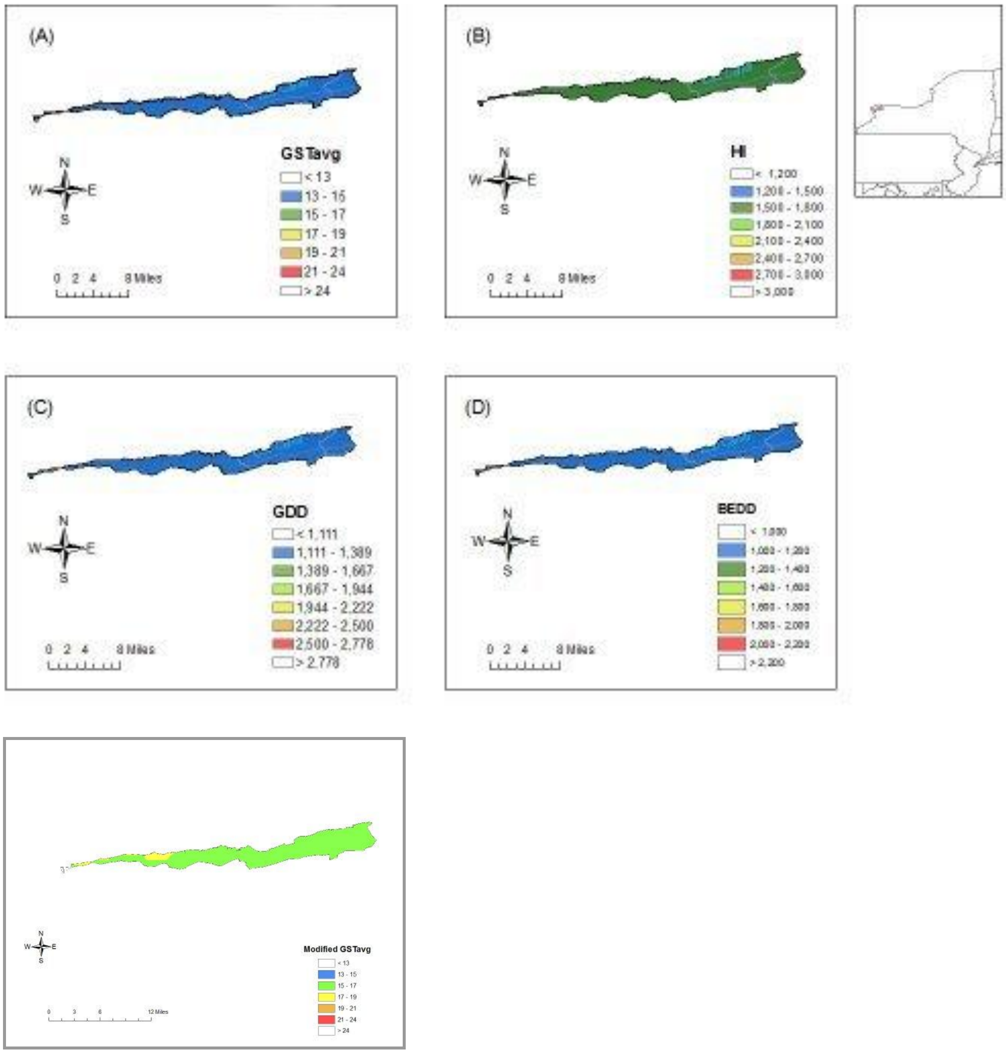
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	15	15	15	15
HI	1638	1670	1734	1735	1827
GDD	1133	1164	1225	1225	1317
BEDD	1101	1102	1165	1166	1196
Modified GSTavg	21	22	22	22	22

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Cool to Intermediate (75% to Maximum quartile range)
HI: Cool to Temperate (75% to Maximum quartile range)
GDD: Very Cool, Region I(75% to Maximum quartile range)
BEDD: Cool (75% to Maximum quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Niagara Escarpment AVA



Highlights:

- 29,502.5 total acres (11,939.7 hectares)
- 59 planted acres (23.9 hectares)
- Vineyard size ranges from 2 acres (0.81 hectares) to 50 acres (20.2 hectares)
- 3+ commercial vineyards
- Elevation range: 119 m to 186m (median value of 148m)

<u>Climate indices original characterization:</u>
GSTavg: Cool (100%)
HI: Cool (100%)
GDD: Too Cool (3%); Very Cool, Region I (97%)
BEDD: Very Cool (100%)
Modified GSTavg: Intermediate (80%); Warm (20%)

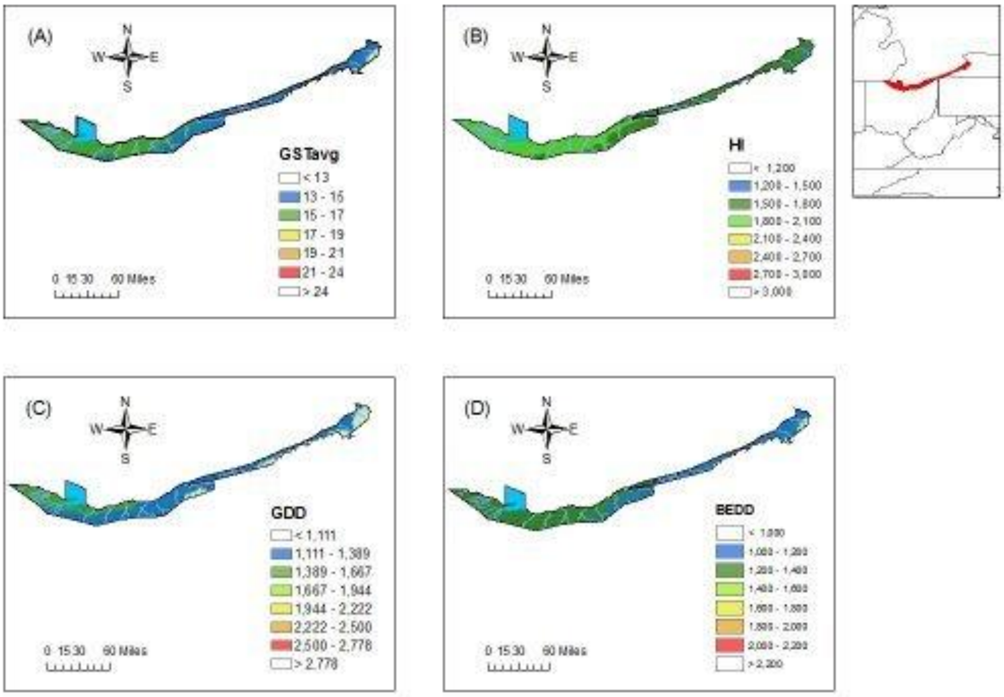
Quartile Statistics:

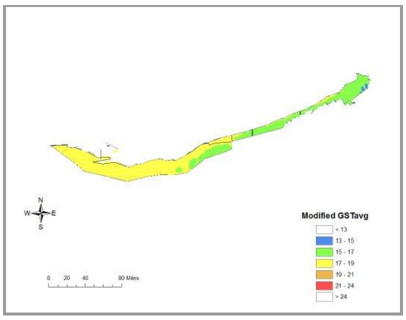
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	14	14	15	15
HI	1642	1673	1673	1673	1704
GDD	1164	1164	1164	1194	1195
BEDD	1089	1104	1104	1104	1135
Modified GSTavg	21	21	21	22	22

<u>Factors affecting alteration of characterizations:</u>
None

<u>Final characterization:</u>
GSTavg: Cool (Full quartile range)
HI: Cool (Full quartile range)
GDD: Very Cool, Region I(Full quartile range)
BEDD: Very Cool (Full quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Lake Erie AVA





Highlights:

- 2,453,804 total acres (993,054.5 hectares)
- Encompasses 3 states (NY, PA and OH)
- 1787planted acres (723.2 hectares)
- Over 40,000 total acres (16,188 hectares) of grapevines in AVA; largest grape growing region outside of CA
- Vineyard size ranges from 1 acre (0.4047 hectares) to 200 acres (80.9 hectares)

- 41+ commercial vineyards
- Elevation range: 174 m to 497 m (median value

Climate indices original characterization:
GSTavg: Too Cool (3%); Cool (46%); Intermediate (51%)
HI: Very Cool (4%); Cool (45%); Temperate (51%)
GDD: Too Cool (2%); Very Cool, Region I (37%); Cool, Region II (61%)
BEDD: Too Cool (13%); Very Cool (59%); Cool, Region II (28%)
Modified GSTavg: Cool (0.5%); Intermediate (34%); Warm (65%); Hot (0.5%)

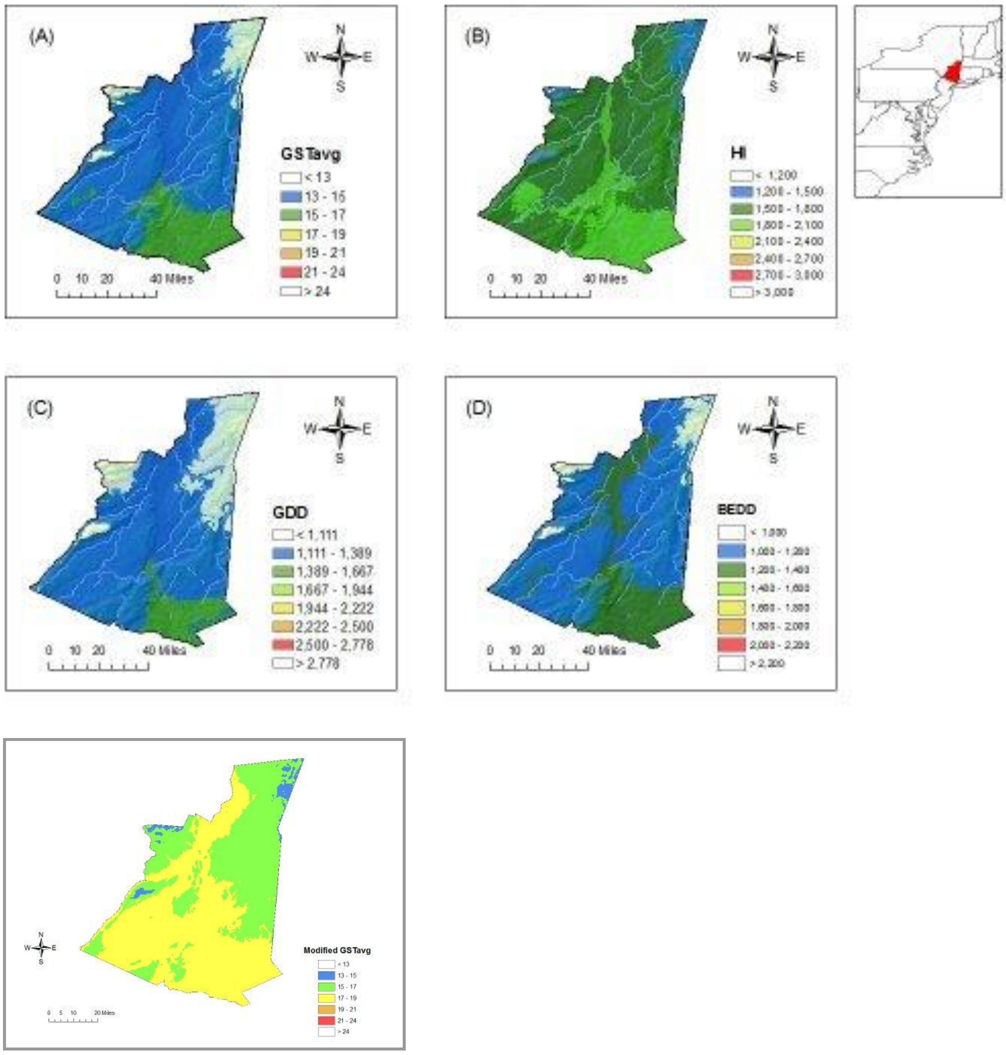
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	13	15	16	16	17
HI	1355	1666	1804	1882	2071
GDD	858	1195	1348	1409	1562
BEDD	883	1131	1222	1254	1318
Modified GSTavg	19	21	22	23	23

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Intermediate (Median to Maximum quartile range)
HI: Temperate (Median to Maximum quartile range)
GDD: Cool, Region II (75% to Maximum quartile range)
BEDD: Cool (Median to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (Full quartile range)

Hudson River Region AVA



Highlights:

- 2,411,549.2 total acres (975,954 hectares)
- 294 planted acres (119 hectares)
- Vineyard size ranges from 4 acres (1.6 hectares) to 70 acres (28.3 hectares)
- 17+ commercial vineyards
- Elevation range:8 m to 901m (median value 156m)

Climate indices original characterization:
GSTavg: Too Cool (8%); Cool (74%); Intermediate (18%)
HI: Too Cool (1%); Very Cool (5%); Cool (67%); Temperate (27%)
GDD: Too Cool (20%); Very Cool, Region I (70%); Cool, Region II (10%)
BEDD: Too Cool (6%); Very Cool (67%); Cool (27%)
Modified GSTavg: Cool (2%); Intermediate (43%); Warm (55%)

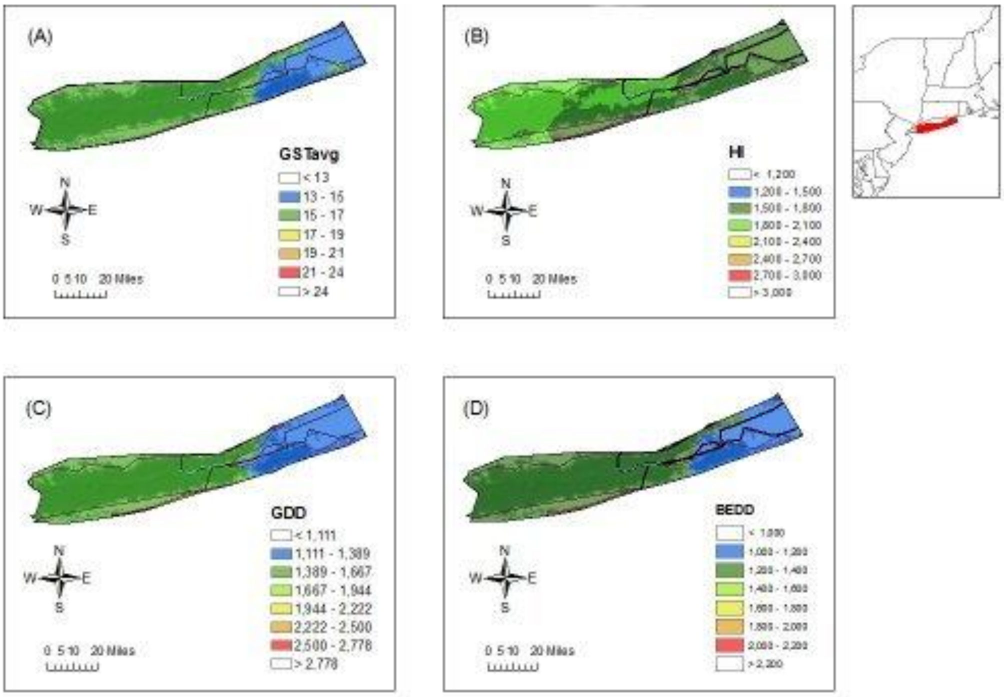
Quartile Statistics:

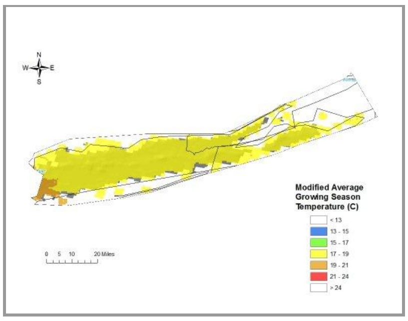
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	12	14	15	15	17
HI	1258	1667	1757	1792	2068
GDD	766	1134	1225	1256	1532
BEDD	787	1116	1160	1201	1316
Modified GSTavg	19	21	22	22	23

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Cool to Intermediate (25% to Maximum quartile range)
HI: Cool to Temperate (Median to Maximum quartile range)
GDD: Very Cool, Region I to Cool, Region II (Median to Maximum quartile range)
BEDD: Cool (75% to Maximum quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Long Island AVA





Highlights

- 1,275,473 total acres (516,183.9 hectares)
- 2021 planted acres (817.9 hectares)
- Vineyard size ranges from 3 acres (1.2 hectares) to 425 acres (172 hectares)
- 34+ commercial vineyards
- 2 sub-AVAs (North Fork of Long Island and The Hamptons)
- Elevation range:0 m to 94m (median value 17m)

Climate indices original characterization:
GSTavg: Cool (54%); Intermediate (46%)
HI: Cool (25%); Temperate (75%)
GDD: Very Cool, Region I (30%); Cool, Region II (70%)
BEDD: Very Cool (26%); Cool (74%)
Modified GSTAvg: Warm (97%); Hot (3%)

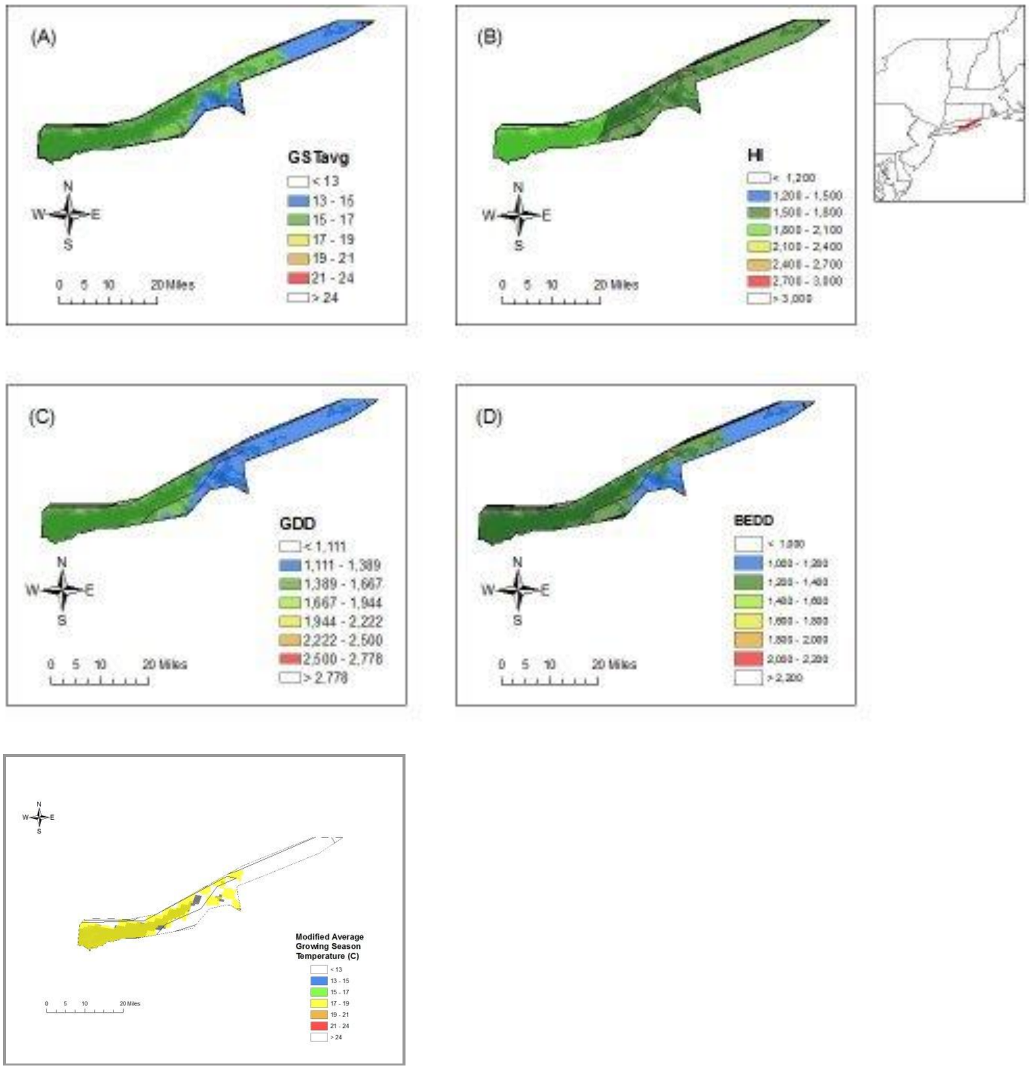
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	16	16	16	17
HI	1536	1753	1816	1848	2002
GDD	1256	1440	1470	1501	1624
BEDD	1052	1256	1275	1283	1376
Modified GSTavg	22	23	23	23	24

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Cool to Intermediate (Full quartile range)
HI: Cool to Temperate (Full quartile range)
GDD: Very Cool to Cool (Full quartile range)
BEDD: Very Cool to Cool (Full quartile range)
Modified GSTAvg: Warm to Hot (Full quartile range)

North Fork of Long Island sub-AVA



<u>**Highlights:**</u>

- 196,694.4 total acres (79,602.2 hectares)
- 1749 planted acres (707.8 hectares)
- Vineyard size ranges from 4 acres (1.6 hectares) to 425 acres (172 hectares)
- 29+ commercial vineyards
- Elevation range:10 m to 15m (median value 10m)

<u>Climate indices original characterization:</u>
GSTavg: Cool (30%); Intermediate (70%)
HI: Cool (66%); Temperate (34%)
GDD: Very Cool, Region I (33%); Cool, Region II (67%)
BEDD: Very Cool (50%); Cool (50%)
Modified GSTavg: Warm (100%)

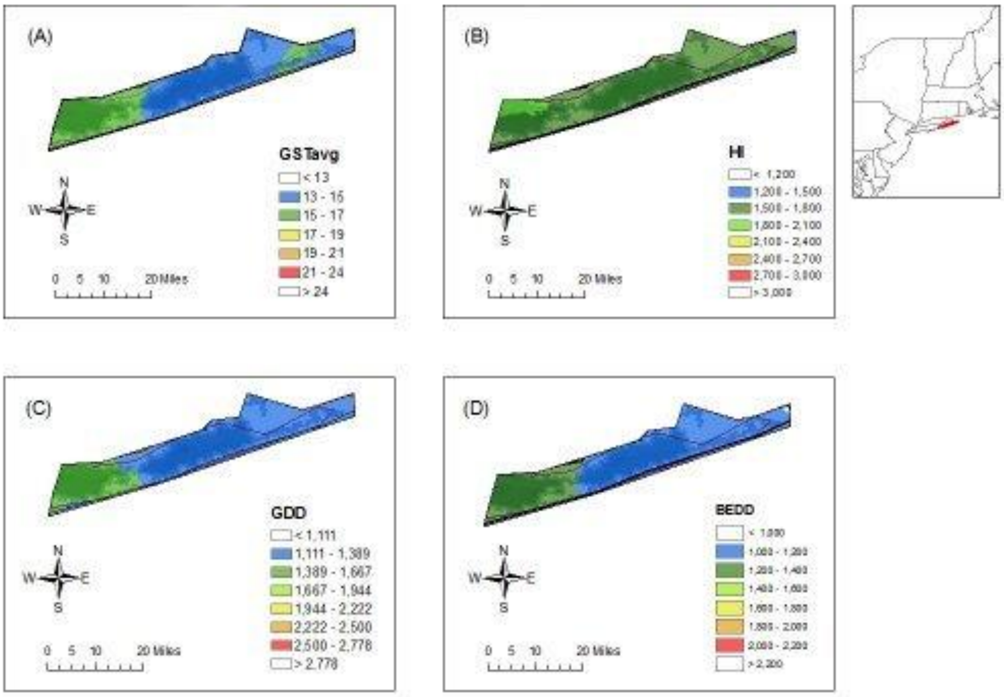
Quartile Statistics:

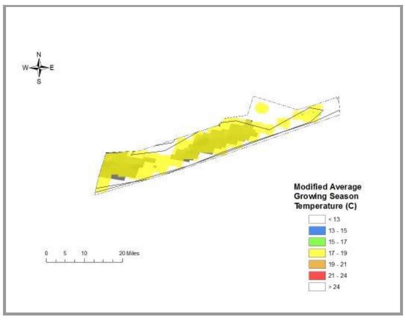
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	15	16	16	16
HI	1567	1615	1692	1848	1848
GDD	1287	1302.5	1409	1440	1471
BEDD	1144	1172	1260	1283	1315
Modified GSTavg	22	22	22	23	23

<u>Factors affecting alteration of characterizations:</u>
- Already established productive vineyards
- Many areas suited for crop farming

<u>Final characterization:</u>
GSTavg: Cool to Intermediate (Full quartile range)
HI: Cool to Temperate (Median to Maximum quartile range)
GDD: Cool, Region II (Median to Maximum quartile range)
BEDD: Cool (Median to Maximum quartile range)
Modified GSTavg: Warm (Full quartile range)

The Hamptons, Long Island sub-AVA





Highlights:

- 251,205 total acres (101,662.7 hectares)
- 217 planted acres (87.8 hectares)
- Vineyard size ranges from 67 acres (27.1 hectares) to 150 acres (60.7 hectares)
- 2+ commercial vineyards
- Elevation range:0 m to 94m (median value 17m)

Climate indices original characterization:
GSTavg: Cool (62%); Intermediate (38%)
HI: Cool (94%); Temperate (6%)
GDD: Very Cool, Region I (68%); Cool, Region II (32%)
BEDD: Very Cool (74%); Cool (26%)
Modified GSTavg: Warm (100%)

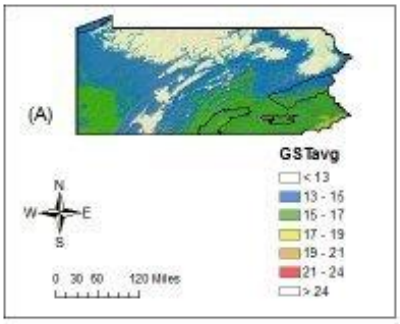
Quartile Statistics:

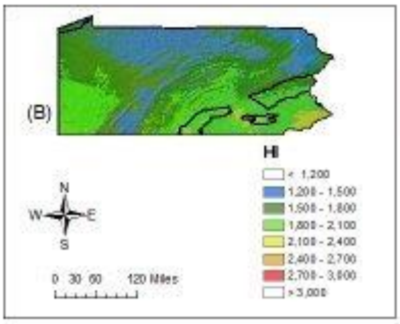
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	15	15	16	16
HI	1504	1566	1597	1691	1848
GDD	1225	1287	1317	1401.5	1440
BEDD	1006	1146	1159	1250	1283
Modified GSTavg	22	22	22	22	23

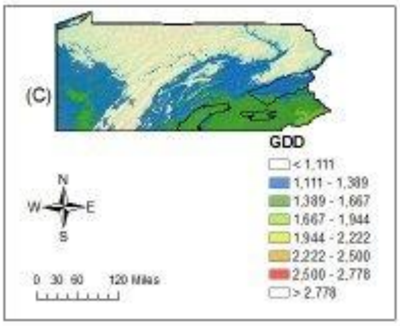
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

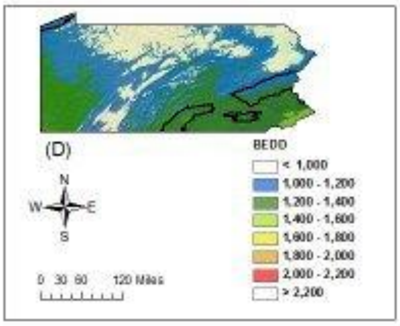
Final characterization:
GSTavg: Cool to Intermediate (Full quartile range)
HI: Cool to Temperate (Median to Maximum quartile range)
GDD: Cool, Region II (75% to Maximum quartile range)
BEDD: Cool (75% to Maximum quartile range)
Modified GSTavg: Warm (Full quartile range)

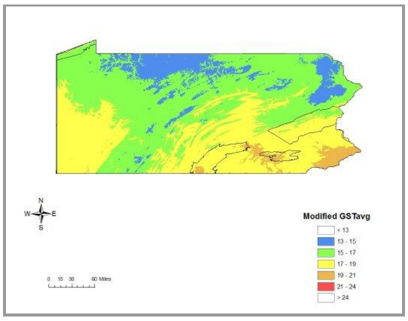
Pennsylvania











<u>Highlights:</u>

- 45,360 square miles
- 1599 planted acres (647.1 hectares)
- 80+ commercial vineyards
- Ranks 13th in US production (845,334 gal/yr)
- 5 AVAs within border of state (Lake Erie, Cumberland Valley, Central Delaware Valley, Lancaster Valley, Lehigh Valley)
- Elevation range: 0 m to 979.3 m

- Dfa and Dfb Koppen Classification
- Most common *V. Vinifera* varietals are Cabernet Sauvingon, Chardonnay, Cabernet Franc, Merlot, and Pinot Gris; French Hybrid varietals of Seval Blanc, Vidal Blanc, Chambourcin, Traminette and Niagara, and the native American varietal, Concord.

Climate indices original characterization:
GSTavg: Too Cool; Cool; Intermediate; Warm
HI: Very Cool; Cool; Temperate; Warm Temperate
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III
BEDD: Too Cool; Very Cool; Cool; Temperate
Modified GSTavg: Cool, Intermediate, Warm, Hot

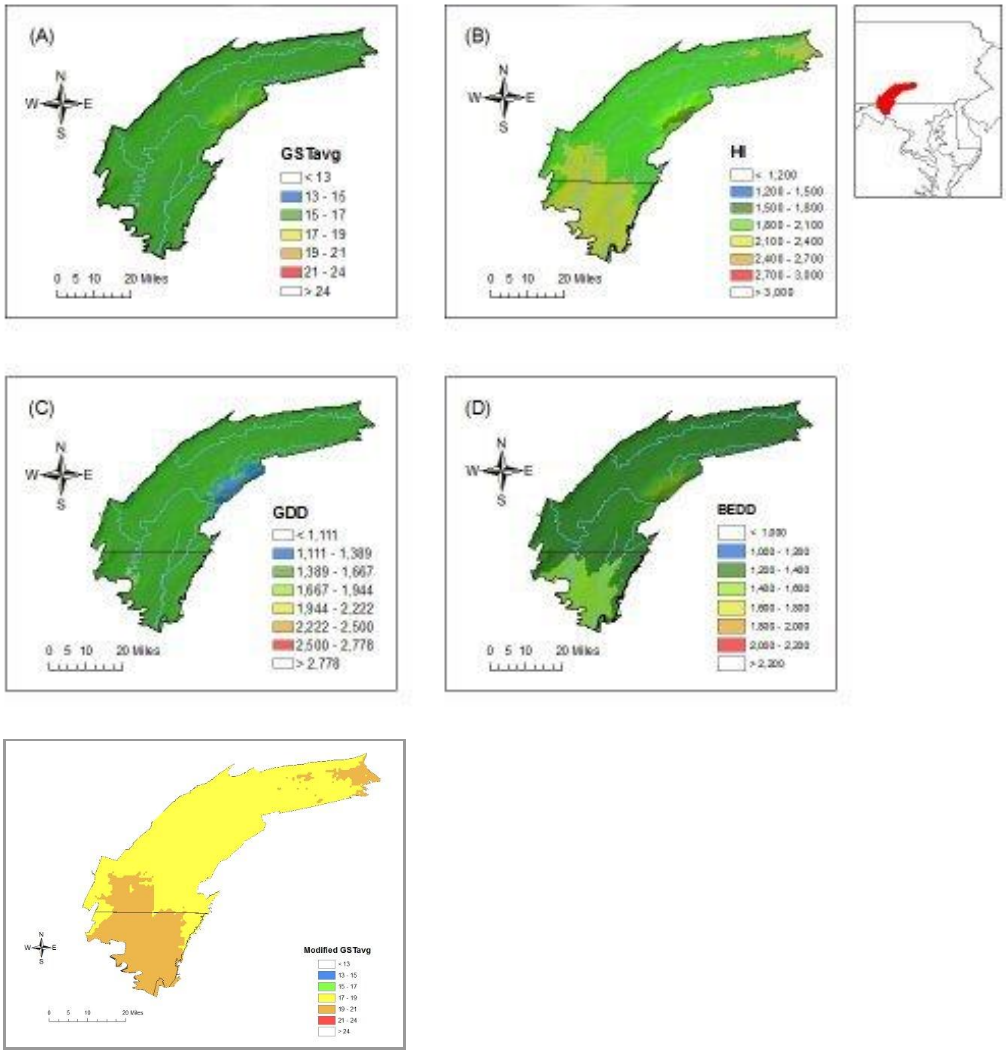
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	12	13	14	16	19
HI	1224	1474	1629	1876	2308
GDD	736	980	1133	1348	1930
BEDD	754	1004	1113	1241	1498
Modified GSTavg	18	21	22	25	30

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Cool to Warm (Median to Maximum quartile range)
HI: Cool to Warm Temperate (Median to Maximum quartile range)
GDD: Very Cool, Region I to Temperate, Region III (Median to Maximum quartile range)
BEDD: Very Cool to Temperate (Median to Maximum quartile range)
Modified GSTavg: Cool to Hot (Full quartile range)

Cumberland Valley AVA



Highlights:

- 833,843 total acres (337,456.3 hectares)
- no commercial vineyards
- Elevation range: 94 m to 613m (median value of 183m)

Climate indices original characterization:
GSTavg: Cool (0.2%); Intermediate (99.8%)
HI: Cool (1%); Temperate (68%); Warm Temperate (31%)
GDD: Very Cool, Region I (6%); Cool, Region II (93%); Temperate (1%)
BEDD: Very Cool (1%); Cool (84%); Temperate (15%)
Modified GSTavg: Warm (64%); Hot (36%)

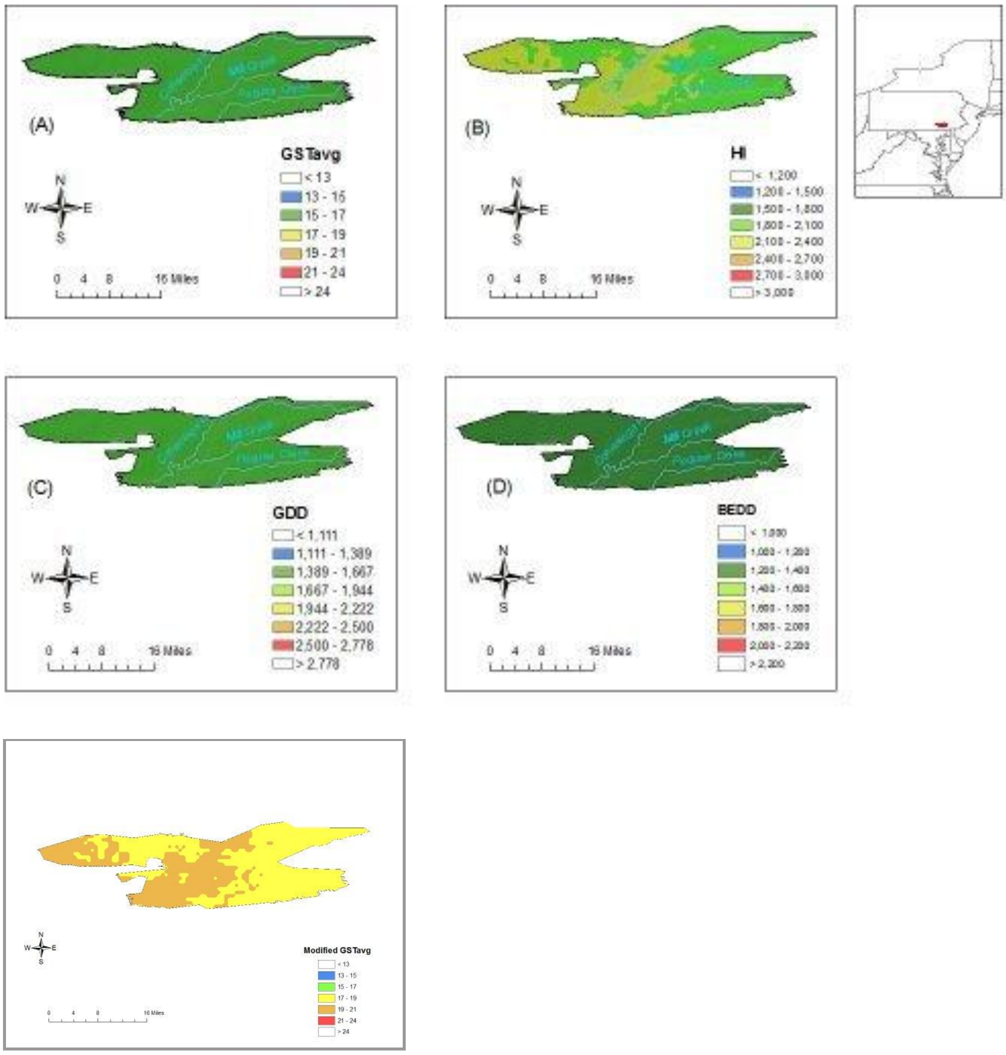
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16	16	17	17	17
HI	1779	2028	2061	2120	2211
GDD	1348	1470	1532	1593	1653
BEDD	1217	1279	1312	1371	1463
Modified GSTavg	22	23	23	24	24

Factors affecting alteration of characterizations:
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Cool to Intermediate (Full quartile range)
HI: Temperate to Warm Temperate (25% to Maximum quartile range)
GDD: Cool, Region II to Temperate, Region III (25% to Maximum quartile range)
BEDD: Cool to Temperate (Full quartile range)
Modified GSTavg: Warm to Hot

Lancaster Valley AVA



Highlights:

- 210,326.3 total acres (85,119 hectares)
- 51 planted acres (20.6 hectares)
- Vineyard size ranges from 4 acres (1.6 hectares) to 47 acres (19 hectares)
- 2+ commercial vineyards
- Elevation range: 91 m to 186m (median

Climate indices original characterization:
GSTavg: Intermediate (100%)
HI: Temperate (61%); Warm Temperate (39%)
GDD: Cool (100%);
BEDD: Cool (100%)
Modified GSTavg: Warm (41%), Hot (59%)

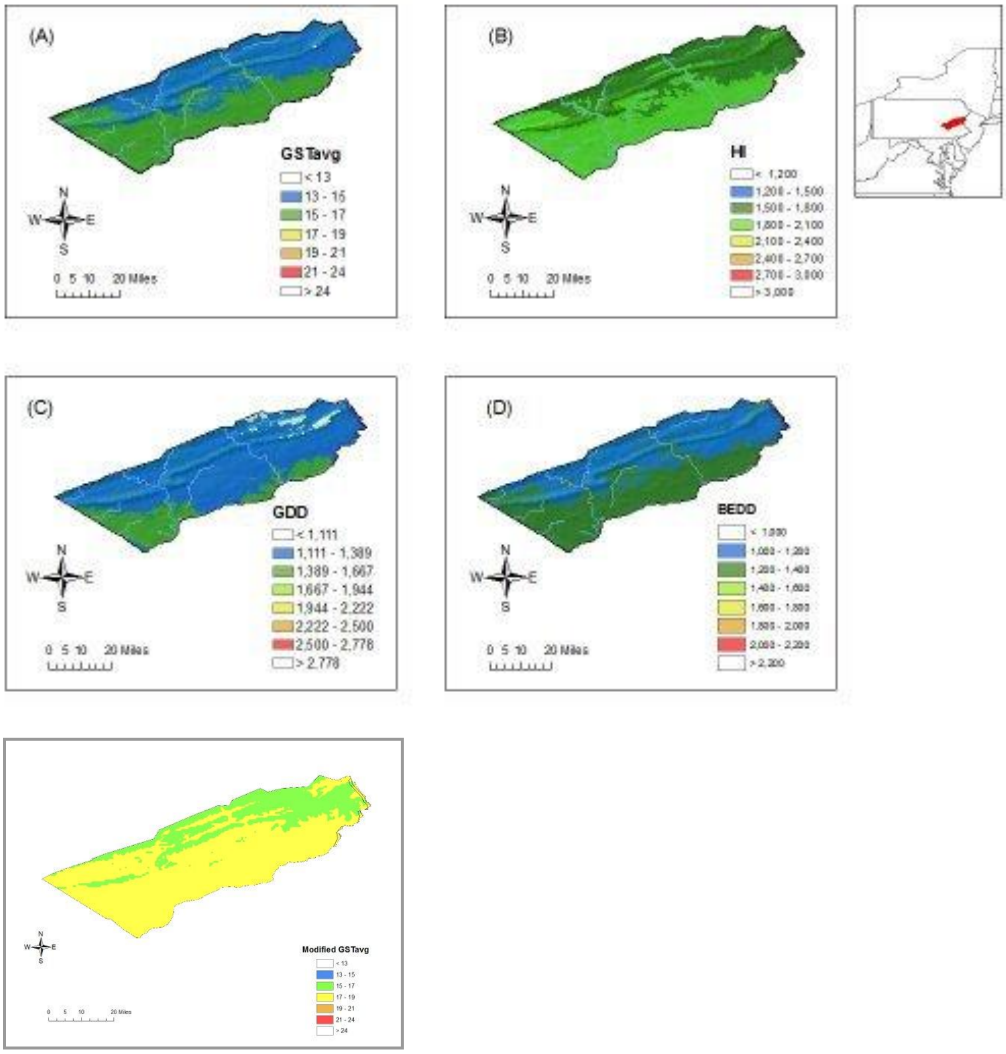
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	17	17	17	17	17
HI	2059	2060	2091	2122	2122
GDD	1501	1532	1562	1593	1593
BEDD	1280	1311	1311	1342	1343
Modified GSTavg	23	23	24	24	24

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Intermediate (Full quartile range)
HI: Temperate to Warm Temperate (Full quartile range)
GDD: Cool, Region II (Full quartile range)
BEDD: Cool (Full quartile range)
Modified GSTavg: Warm to Hot (Full quartile range)

Lehigh Valley AVA



Highlights:

- 1,042,439.8 total acres (421,875.4 hectares)
- 182 planted acres (73.7 hectares)
- Vineyard size ranges from 3 acres (1.2 hectares) to 70 acres (28.3 hectares)
- 8+ commercial vineyards
- Elevation range: 75 m to 486m (median value of 188m)

<u>Climate indices original characterization:</u>
GSTavg: Cool (51%); Intermediate (49%)
HI: Cool(46%); Temperate (54%)
GDD: Too Cool (4%); Very Cool, Region I (76%); Cool, Region II (20%);
BEDD: Very Cool (48%); Cool (52%)
Modified GSTavg: Intermediate (27%); Warm (73%)

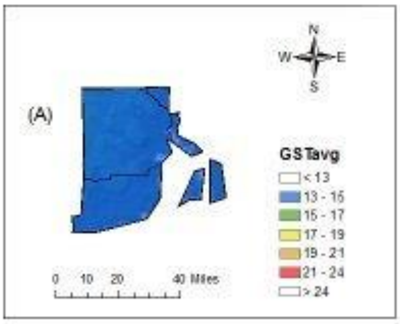
Quartile Statistics:

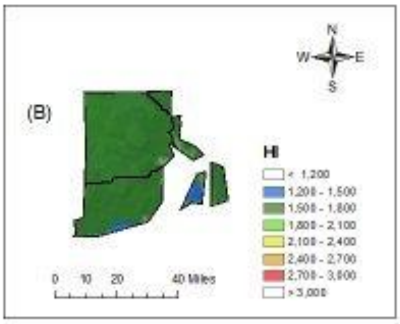
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	15	15	16	16
HI	1504	1722	1814	1907	2001
GDD	1011	1195	1287	1379	1471
BEDD	1003	1151	1187	1250	1306
Modified GSTavg	21	22	22	22	23

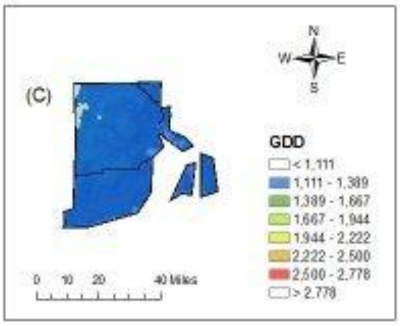
<u>Factors affecting alteration of characterizations:</u>
- Already established productive vineyards
- May areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

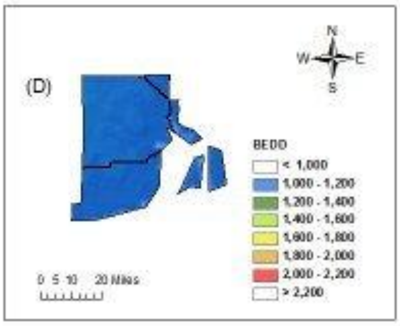
<u>Final characterization:</u>
GSTavg: Intermediate (Median to Maximum quartile range)
HI: Temperate (Median to Maximum quartile range)
GDD: Very Cool, Region I to Cool, Region II(75% to Maximum quartile range)
BEDD: Cool (75% to Maximum quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

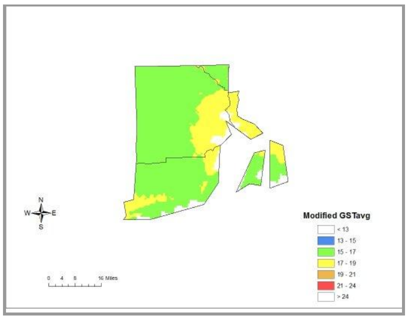
Rhode Island











Highlights:

- 1,045 square miles
- 117 planted acres (47.4 hectares)
- 5+ commercial vineyards
- Rank 37th in US production (no data)
- 1 AVAs within the borders (SE New England)
- Elevation range: 0 m to 247.5 m
- Dfa and Dfb Koppen Classification

- Most common *V. Vinifera* varietals grown are Chardonnay, Cabernet Franc, and Gewurztraminer, and French Hybrid varietals of Seyval Blanc and Vidal Blanc.

<u>Climate indices original characterization:</u>
GSTavg: Cool
HI: Very Cool; Cool
GDD: Too Cool; Very Cool
BEDD: Very Cool
Modified GSTavg: Intermediate, Warm

Quartile Statistics:

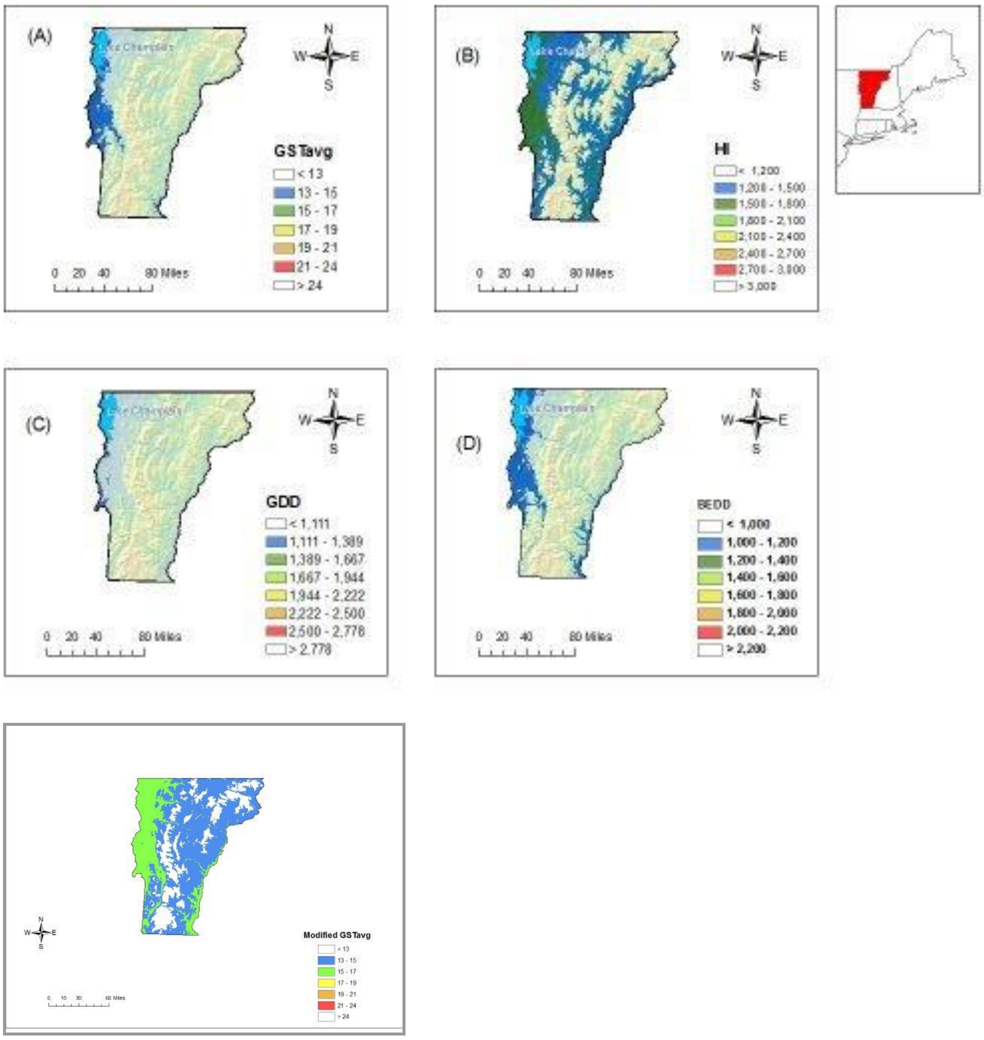
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	15	15	15	15
HI	1474	1633	1664	1673	1727
GDD	1072	1164	1195	1233.5	1287
BEDD	1068	1098	1111	1155	1184
Modified GSTavg	20	20	25	26	27

<u>Factors affecting alteration of characterizations:</u>
- Already established productive vineyards
- Many areas suited for crop farming

<u>Final characterization:</u>
GSTavg: Cool (Full quartile range)
HI: Very Cool to Cool (Full quartile range)
GDD: Too Cool to Very Cool (Region I)
BEDD: Very Cool (Full quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

** Range of statistical values for standard indices may not fully capture the climate structure within the state.

Vermont



<u>**Highlights:**</u>

- 9,603 square miles
- 86 planted acres (34.8 hectares)
- 6+ commercial vineyards
- Production data not documented
- Elevation range: 29 m to 1339 m
- Dfa and Dfb Koppen Classification
- Most common varietals grown are the *V. Vinifera* varietal, Riesling, and French Hybrid varietals, Cayuga and Vidal Blanc

Climate indices original characterization:
GSTavg: Too Cool; Cool
HI: Too Cool, Very Cool; Cool
GDD: Too Cool; Very Cool, Region I
BEDD: Too Cool; Very Cool
Modified GSTavg: Cool, Intermediate

Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	9	11	12	13	15
HI	667	1107	1237	1398	1708
GDD	339	613	736	889	1195
BEDD	350	635	775	935	1169
Modified GSTavg	18	21	23	26	30

Factors affecting alteration of characterizations:

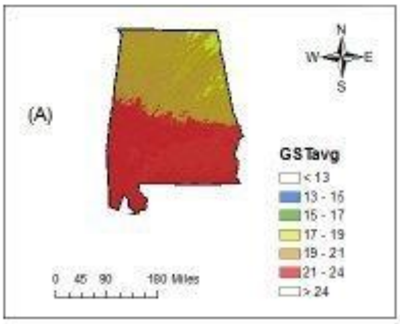
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

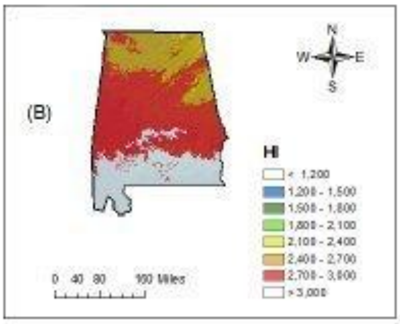
Final characterization:
GSTavg: Cool (Maximum quartile range)
HI: Very Cool (Maximum quartile range)
GDD: Very Cool, Region I (Maximum quartile range)
BEDD: Very Cool (Maximum quartile range)
Modified GSTavg: Cool to Intermediate (Full quartile range)

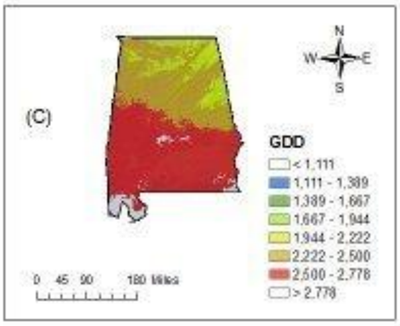
** Range of statistical values for standard indices may not fully capture the climate structure of the state.**

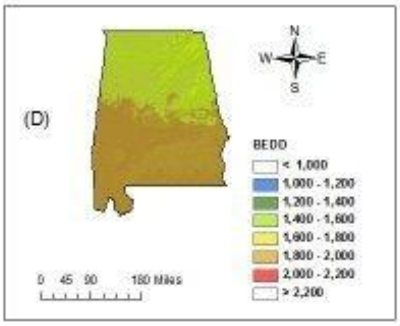
South

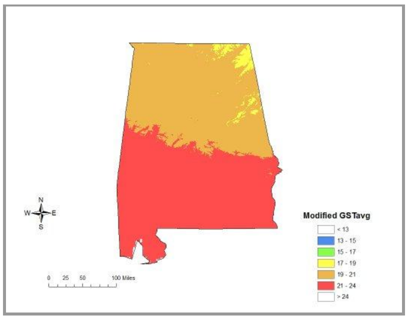
Alabama











Highlights:

- 51,716 square miles
- 113 planted acres (45.7 hectares)
- 6+ commercial vineyards
- No production data
- Elevation range: 0 m to 733.7m
- Cfa Koppen classification

- Most common varietals grown are the French Hybrid varietals of Norton (Cynthiana), Chambourcin and Villard, and the native American varietals, Scuppernong and Muscadine

Climate indices original characterization:
GSTavg: Warm; Hot, Very Hot
HI: Warm Temperate; Warm; Very Warm; Too Hot
GDD: Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI; Too Hot
BEDD: Temperate; Warm Temperate; Warm
Modified GSTavg: Warm, Hot, Very Hot

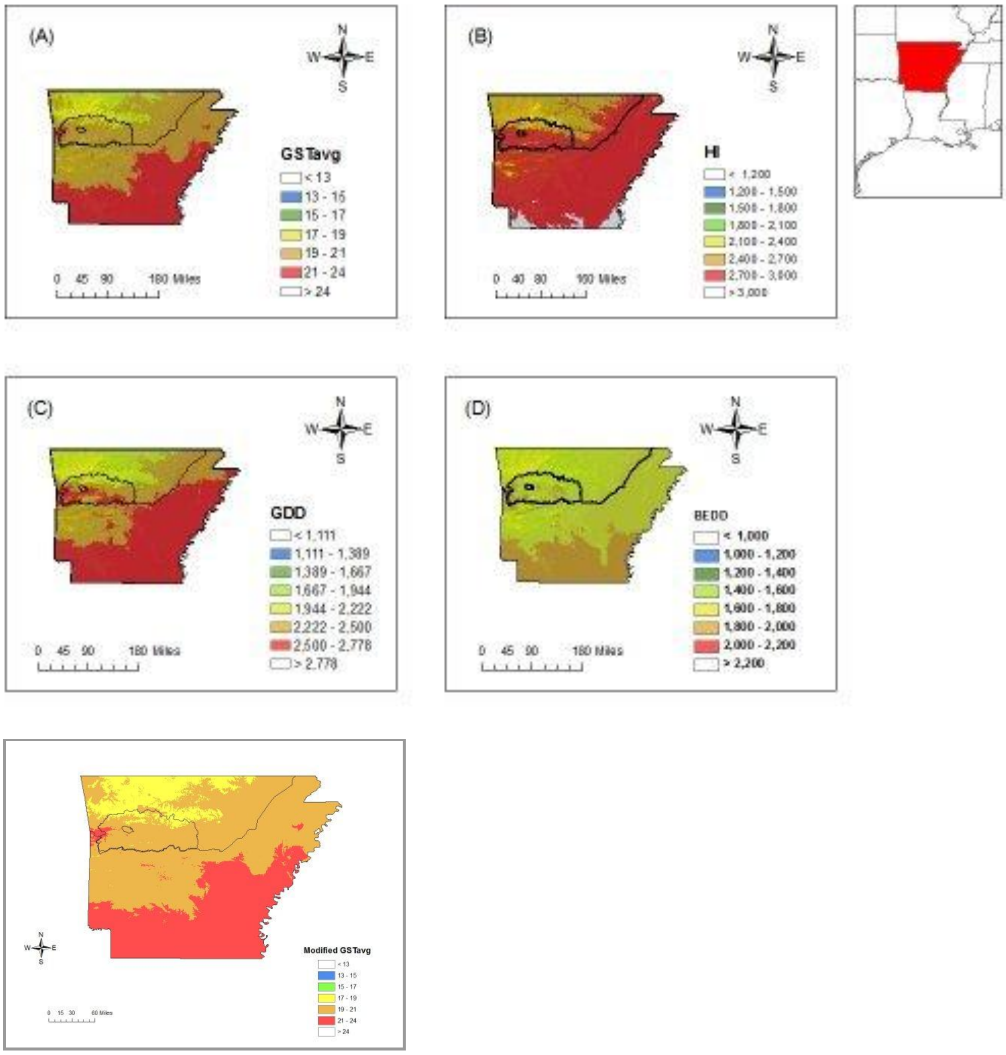
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	19	20	22	22	23
HI	2362	2724	2902	3023	3144
GDD	1928	2326	2570	2692	2967
BEDD	1566	1746	1819	1873	1988
Modified GSTavg	9	19	21	25	30

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Warm to Very Hot (Full quartile range)
HI: Warm Temperate to Too Hot (Minimum to 75% quartile range)
GDD: Temperate to Too Hot (Full quartile range)
BEDD: Temperate to Warm (Full quartile range)
Modified GSTavg: Warm to Very Hot (25% to maximum quartile range)

Arkansas



<u>**Highlights:**</u>

- 52,913 square miles
- 496 planted acres (200.7 hectares)
- 6+ commercial vineyards
- 1 AVA and 2 sub-AVA (Ozark MT, Altus sub-AVA, Arkansas MT sub-AVA
- 42nd in production (no data)
- Elevation range: 0 m to 839 m
- Cfa and Dfa Koppen classification

- Most common *V. Vinifera* varietals grown are Chardonnay, Cabernet Sauvignon, and Zinfandel; French Hybrid varietals of Norton and Niagara, and the native American varietals, Concord and Muscadine

<u>Climate indices original characterization:</u>
GSTavg: Warm; Hot, Very Hot
HI: Warm Temperate; Warm; Very Warm; Too Hot
GDD: Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI
BEDD: Temperate; Warm Temperate; Warm
Modified GSTavg: Warm, Hot, Very Hot

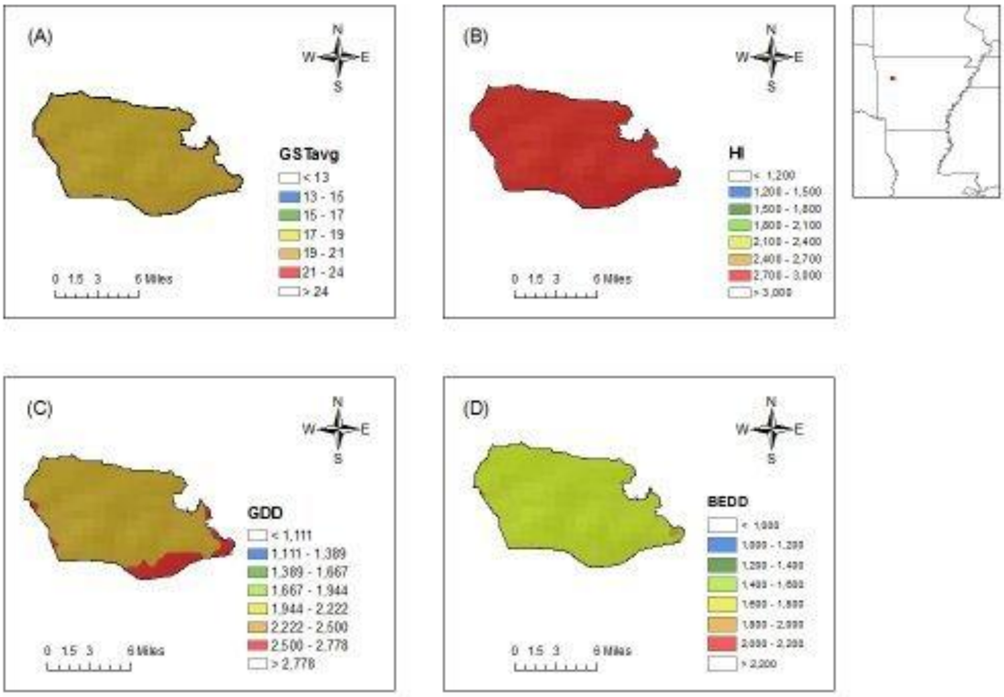
Quartile Statistics:

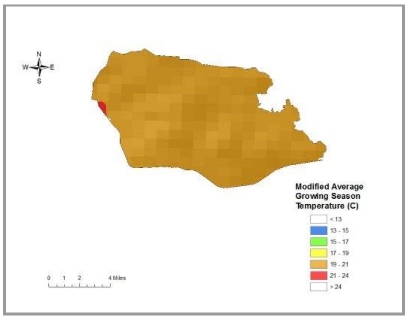
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	18	20	21	22	22
HI	2218	2738	2878	2939	3056
GDD	1868	2325	2508	2601	2754
BEDD	1539	1733	1780	1807	1866
Modified GSTavg	8	19	22	25	29

<u>Factors affecting alteration of characterizations:</u>
- Already established productive vineyards
- Many areas suited for crop farming

<u>Final characterization:</u>
GSTavg: Warm to Very Hot (Full quartile range)
HI: Warm Temperate to Very Warm (Minimum to 75% quartile range)
GDD: Temperate to Very Warm (Full quartile range)
BEDD: Temperate to Warm (Full quartile range)
Modified GSTavg: Warm to Very Hot (25% to maximum quartile range)

Altus sub-AVA





Highlights:

- 46,089 total acres (18,652.2 hectares)
- 56 planted acres (22.7 hectares)
- Vineyard size ranges from 20 acres (8 hectares) to 36 acres (14.6 hectares)
- 2+ commercial vineyards
- Elevation range:106 m to 238m (median value 169m)

Climate indices original characterization:
GSTavg: Hot (99%);Very Hot (1%)
HI: Very Warm (100%)
GDD: Warm, Region V (86%); Very Warm, Region VI (14%)
BEDD: Warm Temperate (100%)
Modified GSTavg: Hot (100%)

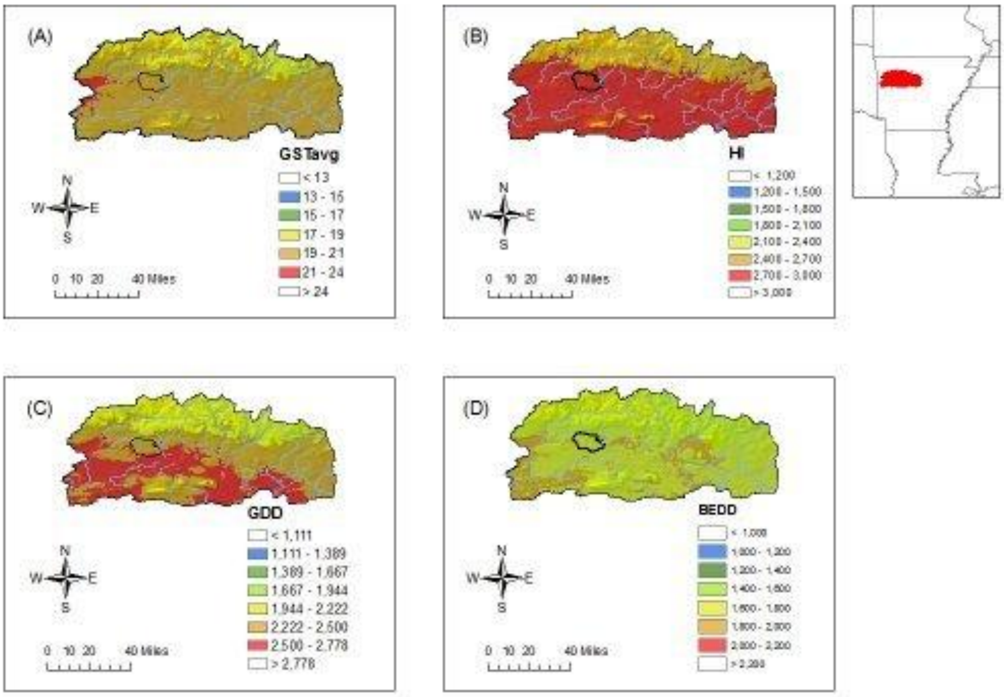
Quartile Statistics:

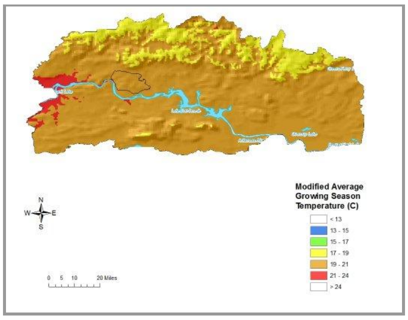
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	21	21	21	21	21
HI	2767	2767	2767	2812	2858
GDD	2387	2387	2387	2432.5	2478
BEDD	1731	1735	1739	1765	1792
Modified GSTavg	25	25	25	25	25

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Hot to Very Hot (Full quartile range)
HI: Very Warm (Full quartile range)
GDD: Warm to Very Warm (Full quartile range)
BEDD: Warm Temperate (Full quartile range)
Modified GSTavg: Hot (Full quartile range)

Arkansas Mountain sub-AVA





Highlights:

- 2,932,531.4 total acres (1,186,795.5 hectares)
- 484 planted acres (196 hectares)
- Vineyard size ranges from 3 acres (1.2 hectares) to 225 acres (91 hectares)
- 5+ commercial vineyards
- Elevation range:100 m to 159 m (median value 127m)

<u>Climate indices original characterization:</u>
GSTavg: Warm (15%); Hot (82%);Very Hot (3%)
HI: Warm (24%); Very Warm (72%)
GDD: Temperate, Region III, (3%); Warm Temperate, Region IV (21%); Warm, Region V (43%); Very Warm, Region VI (33%)
BEDD: Temperate (7%); Warm Temperate (79%); Warm (14%)
Modified GSTavg: Warm (14%); Hot (83%); Very Hot (3%)

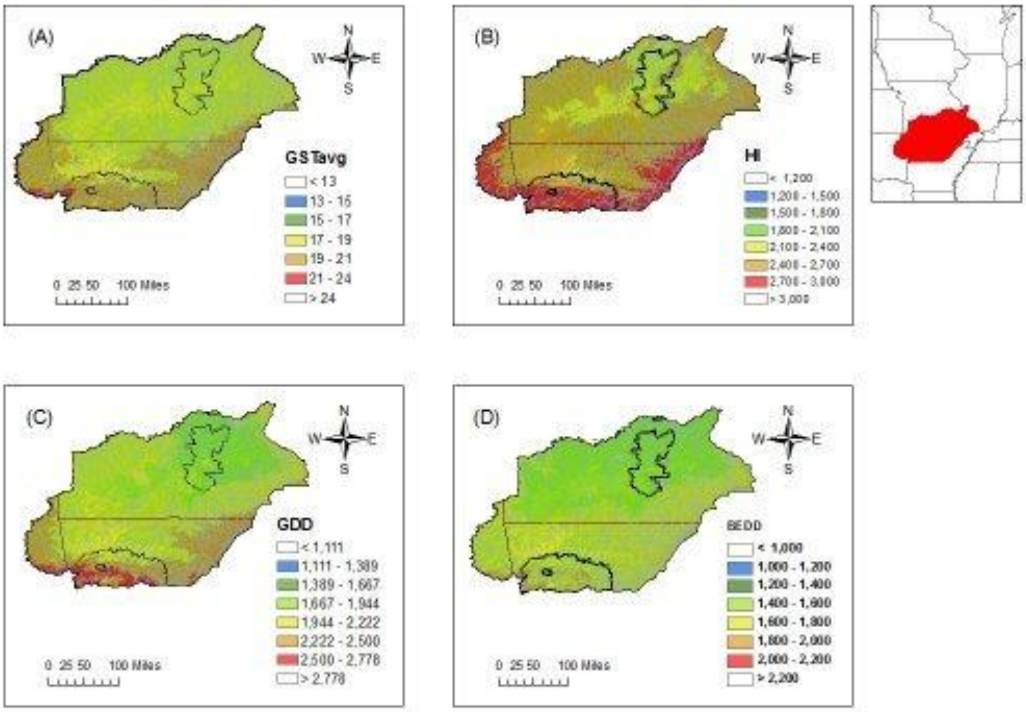
Quartile Statistics:

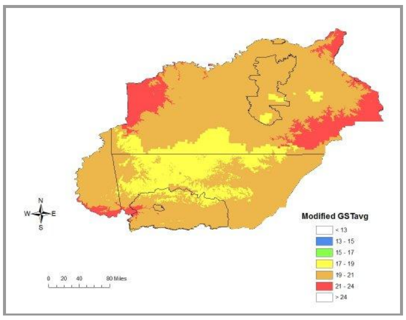
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	18	20	21	21	22
HI	2186	2637	2796	2888	2921
GDD	1807	2204	2417	2509	2571
BEDD	1478	1690	1780	1799	1823
Modified GSTavg	23	25	25	25	26

<u>Factors affecting alteration of characterizations:</u>
None

<u>Final characterization:</u>
GSTavg: Warm to Very Hot (Full quartile range)
HI: Warm to Very Warm (Full quartile range)
GDD: Temperate, Region III to Very Warm, Region VI (Full quartile range)
BEDD: Temperate to Warm (Full quartile range)
Modified GSTavg: Warm to Very Hot (Full quartile range)

Ozark Mountain AVA





Highlights:

- 34,024,532 total acres (13,769,728 hectares)
- 1407 planted acres (569.4 hectares)
- Vineyard size ranges from 1 acres (.4047 hectares) to 225 acres (91 hectares)
- 43+ commercial vineyards
- Elevation range: 63 m to 772m (median value 275m)

Climate indices original characterization:
GSTavg: Warm (68%); Hot (31%);Very Hot (1%)
HI: Warm (65%); Warm Temperate (17%); Very Warm (18%)
GDD: Temperate, Region III (24%); Warm Temperate, Region IV (53%); Warm, Region V (19%), Very Warm, Region VI (4%)
BEDD: Temperate (42%); Warm Temperate (56%), Warm (2%)
Modified GSTavg: Warm (17%); Hot (71%); Very Hot (12%)

Quartile Statistics:

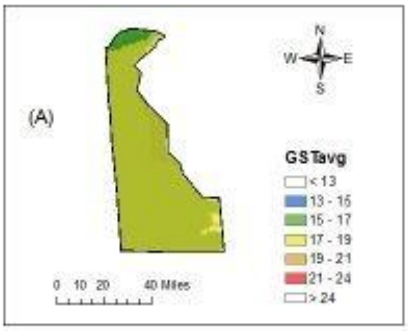
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	18	19	19	20	22
HI	2189	2414	2498	2592	2951
GDD	1776	1930	2021	2143	2601
BEDD	1449	1567	1609	1666	1823
Modified GSTavg	22	24	25	25	27

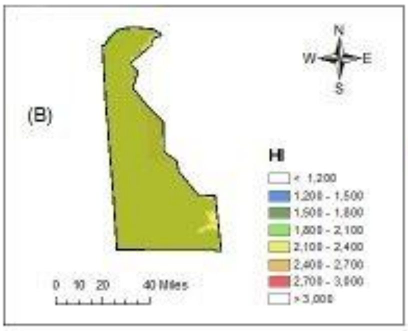
Factors affecting alteration of characterizations:

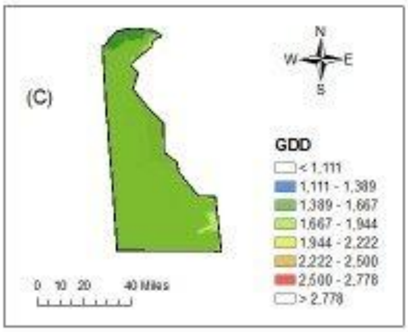
- Coolest maturity class located in National Forest

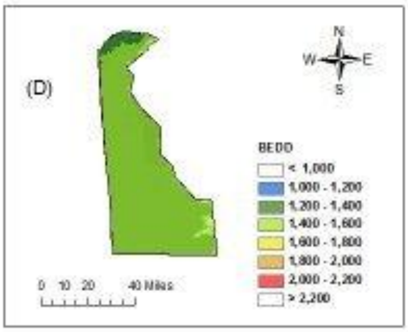
Final characterization:
GSTavg: Warm to Very Hot (Full quartile range)
HI: Warm to Very Warm (Full quartile range)
GDD: Temperate, Region III to Very Warm, Region VI (Full quartile range)
BEDD: Temperate to Warm (25% to Maximum quartile range)
Modified GSTavg: Warm to Very Hot (Full quartile range)

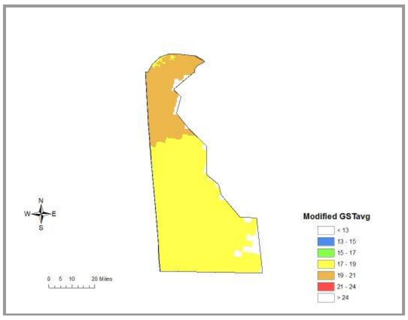
Delaware











Highlights:

- 2,055 square miles
- 24 planted acres (9.7 hectares)
- 2+ commercial vineyards
- Rank 50th in US production (no data)
- Elevation range: 0 m to 136.6 m
- Dfa and Cfa Koppen Classification

- Most common *V. Vinifera* varietals grown are Chardonnay, Cabernet Sauvignon, and French Hybrid varietals of Seval Blanc and Chambourcin

Climate indices original characterization:
GSTavg: Intermediate; Warm
HI: Temperate, Warm Temperate
GDD: Cool, Region II; Temperate, Region III
BEDD: Cool; Temperate
Modified GSTavg: Warm, Hot

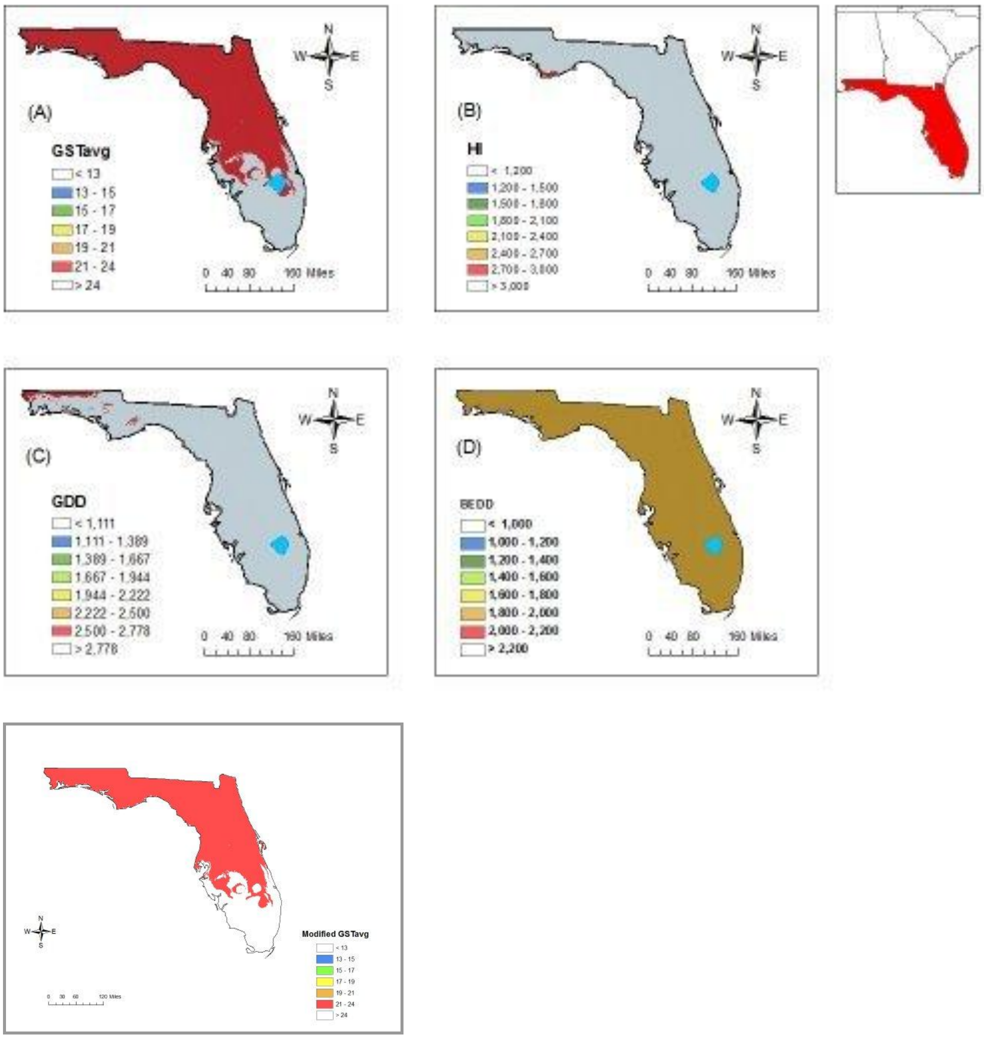
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	17	18	18	18	18
HI	2090	2243	2300	2329	2359
GDD	1563	1798.75	1837	1838	1898
BEDD	1341	1433	1461	1480	1522
Modified GSTavg	18	20	22	25	29

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Cool characterizations found along microclimate of Delaware River

Final characterization:
GSTavg: Intermediate to Warm (Full quartile range)
HI: Temperate to Warm Temperate (Full quartile range)
GDD: Temperate (Region III) (25% to Maximum quartile range)
BEDD: Temperate (25% to Maximum quartile range)
Modified GSTavg: Warm to Hot (Full quartile range)

Florida



Highlights:

- 55,815 square miles
- 555 planted acres (224.6 hectares)
- 40+ commercial vineyards
- Ranked 5th in production (1,745,715 gal/yr)
- Elevation range: 0 m to 105.2 m
- Cfa, Af, Am and Aw Koppen classification

- Most common varietals grown are the native American varietals, Muscadine, Carlos and Noble

Climate indices original characterization:
GSTavg: Very Hot, Too Hot
HI: Very Warm; Too Hot
GDD: Very Warm, Region VI; Too Hot
BEDD: Warm Temperate; Warm
Modified GSTavg: Very Hot, Too Hot

Quartile Statistics:

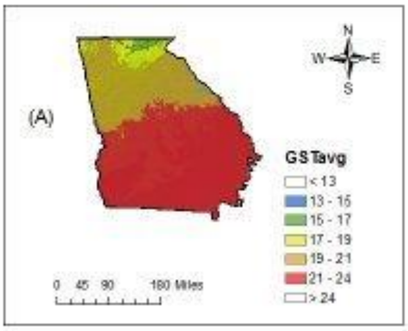
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	22	23	24	25	26
HI	2961	3174	3235	3297	3540
GDD	2691	2936	3119	3211	3517
BEDD	1743	1919	1926	1941	1988
Modified GSTavg	8	20	21	24	30

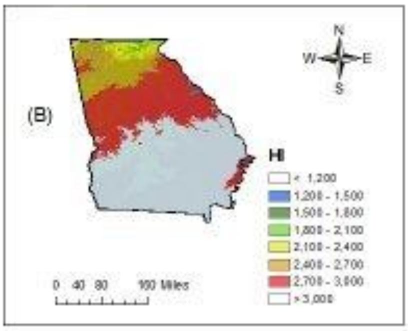
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

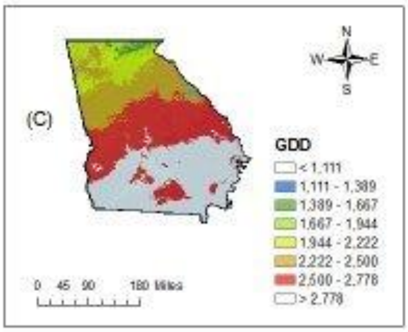
Final characterization:
GSTavg: Very Hot (Minimum to Median quartile range)
HI: Very Warm (Minimum quartile range)
GDD: Very Warm (Minimum quartile range)
BEDD: Warm Temperate to Warm (Full quartile range)
Modified GSTavg: Hot to Too Hot (25% to maximum quartile range)

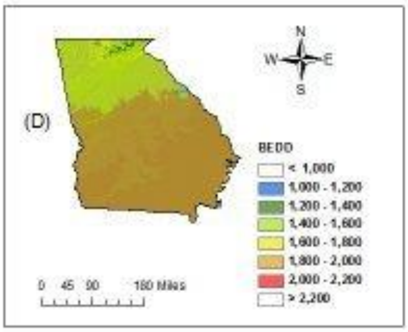
** Range of statistical values may not fully capture the climate structure of the state for HI and GDD indices**

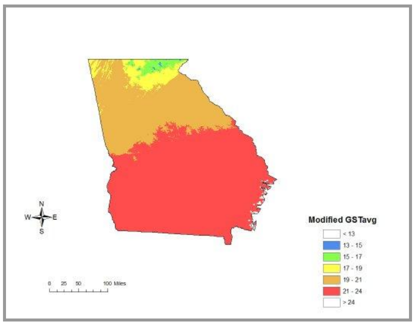
Georgia











Highlights:

- 58,629 square miles
- 840 planted acres (340 hectares)
- 19+ commercial vineyards
- Ranked 24th in US production (183,226 gal/yr)
- Elevation range: 0 m to 1458.2 m
- Cfa and Dsc Koppen classification

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- Most common *V. Vinifera* varietals grown are Chardonnay, Cabernet Franc, Cabernet Sauvginon, Merlot and is the largest producer of the native American varietal, Muscadine.

Climate indices original characterization:
GSTavg: Intermediate; Warm; Hot, Very Hot
HI: Cool; Temperate; Warm Temperate; Warm; Very Warm; Too Hot
GDD: Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI; Too Hot
BEDD: Very Cool; Cool; Temperate; Warm Temperate; Warm
Modified GSTavg: Cool, Intermediate, Warm, Hot, Very Hot

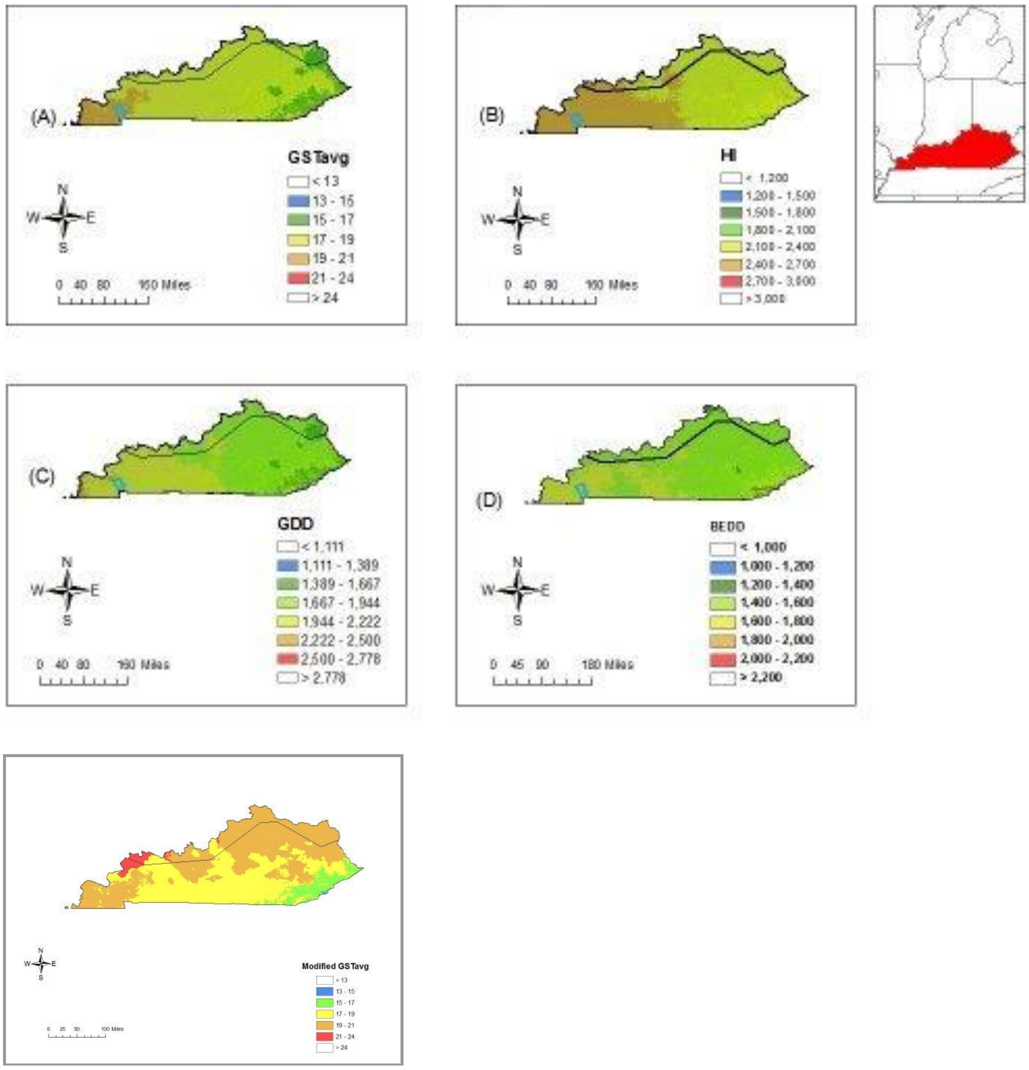
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	21	22	23	24
HI	1689	2784	3023	3085	3236
GDD	1164	2417	2722	2813	2998
BEDD	1168	1769	1866	1927	1987
Modified GSTavg	8	19	21	23	28

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Intermediate to Very Hot (Full quartile range)
HI: Cool to Too Hot (Minimum to Median quartile range)
GDD: Very Cool to Very Warm (Minimum to Median quartile range)
BEDD: Very Cool to Warm (Full quartile range)
Modified GSTavg: Intermediate to Very Hot (Full quartile range)

Kentucky



Highlights:

- 40,320 square miles
- 268 planted acres (340 hectares)
- 26+ commercial vineyards
- Ranked 7th in US production (1,373,539 gal/yr)
- Elevation range: 78.3 m to 1263.4 m
- Dfa, Cfa and Dsc Koppen classification

- Most common *V. Vinifera* varietals grown are Cabernet Sauvignon, Cabernet Franc, Reisling, Viognier and Merlot, and French Hybrid varietals of Vidal Blanc, Chambourcin, Norton (Cynthiana), Chardonel and Traminette.

Climate indices original characterization:
GSTavg: Intermediate; Warm; Hot
HI: Cool; Temperate; Warm Temperate; Warm
GDD: Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V
BEDD: Very Cool; Cool; Temperate; Warm Temperate
Modified GSTavg: Intermediate, Warm, Hot, Very Hot

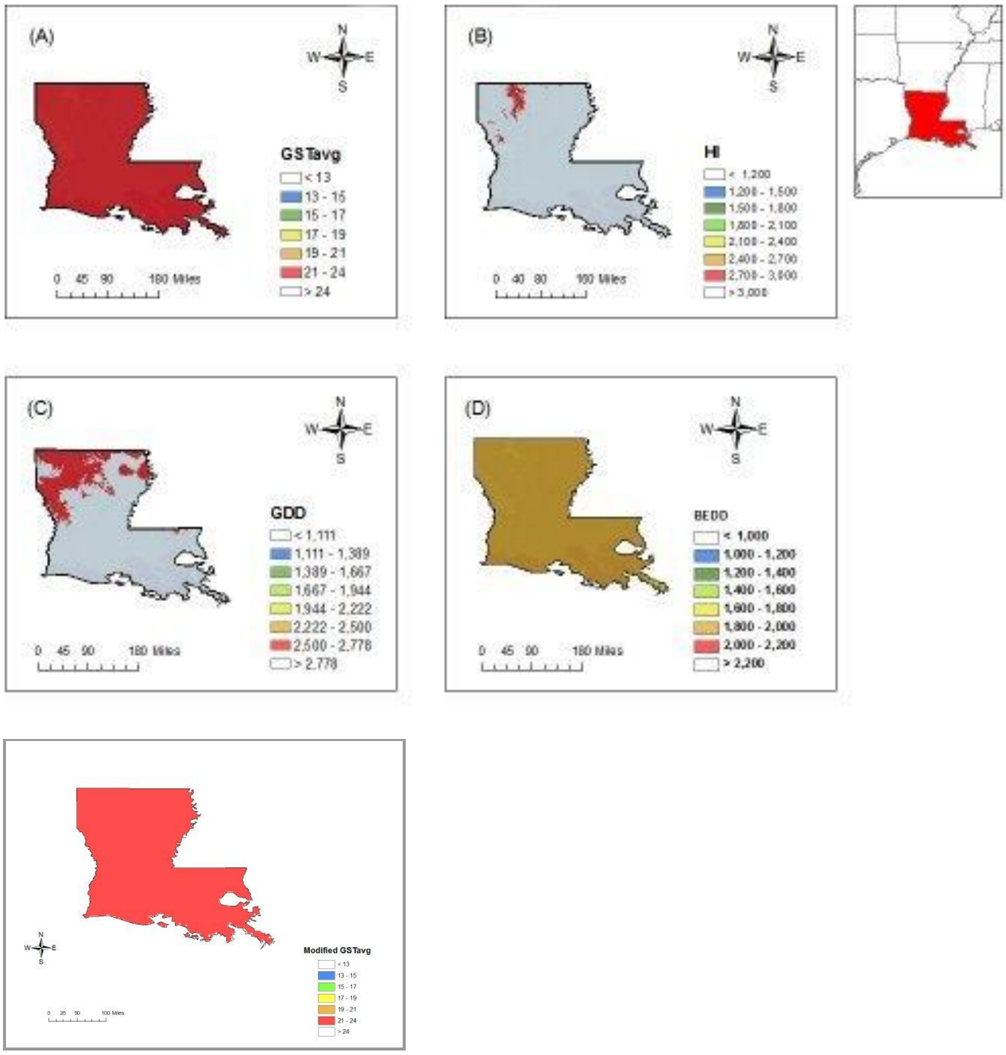
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	18	18	19	20
HI	1728	2258	2356	2472	2688
GDD	1194	1745	1867	2020	2265
BEDD	1143	1497	1547	1593	1684
Modified GSTavg	8	19	21	23	30

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations where it is unsuitable to plant

Final characterization:
GSTavg: Intermediate to Hot (Full quartile range)
HI: Warm Temperate to Warm (25% to Maximum quartile range)
GDD: Temperate, Region III to Warm, Region V (25% to Maximum quartile range)
BEDD: Temperate to Warm Temperate (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Very Hot (25% to Maximum quartile range)

Louisiana



Highlights:

- 45,836 square miles
- 111 planted acres (hectares)
- 5+ commercial vineyards
- No production data
- 1 AVA (Mississippi Delta AVA)
- Elevation range: 0 m to 163m
- Cfa Koppen classification

- Most common varietals grown are the French Hybrid varietals of Niagara, Blanc du Bois and Norton, and the native American varietal, Muscadine.

Climate indices original characterization:
GSTavg: Very Hot, Too Hot
HI: Very Warm; Too Hot
GDD: Very Warm, Region VI; Too Hot
BEDD: Warm Temperate; Warm
Modified GSTavg: Very Hot

Quartile Statistics:

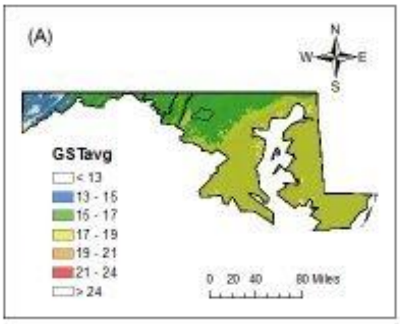
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	22	23	23	23	25
HI	2963	3055	3114	3146	3236
GDD	2631	2784	2876	2967	3212
BEDD	1750	1881	1904	1926	1949
Modified GSTavg	9	19	22	25	29

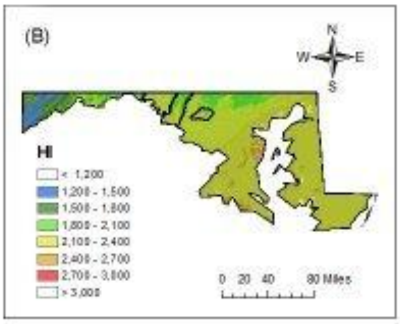
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

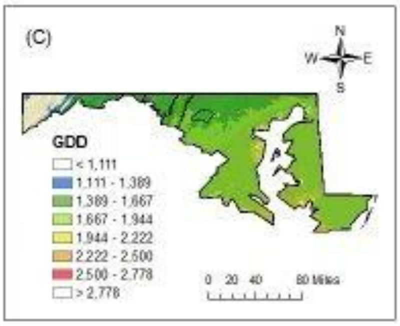
Final characterization:
GSTavg: Very Hot (Minimum to Median quartile range)
HI: Warm Temperate to Too Hot (Minimum to Median quartile range)
GDD: Very Warm, Region VI to Too Hot (Minimum to Median quartile range)
BEDD: Warm Temperate to Warm (Full quartile range)
Modified GSTavg: Very Hot (25% to Maximum quartile range)

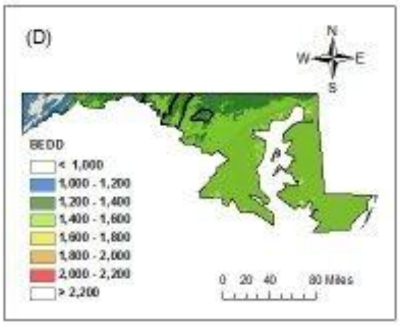
The range of statistical values for the standard indices may not fully capture the climate structure of the state for all the indices.

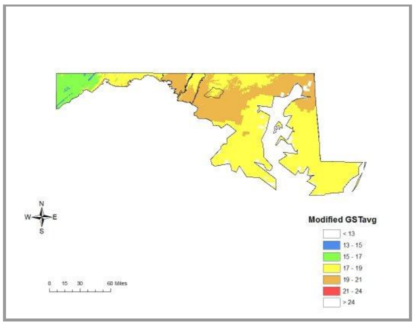
Maryland











Highlights:

- 9,740 square miles
- 285 planted acres (115.3 hectares)
- 20+ commercial vineyards
- Ranks 20th in US production (305,375 gal/yr)
- 3 AVAs (Catoctin, Linganore, and Cumberland Valley)
- Elevation range: 0 m to 1024 m
- Cfa, Dfa and Dfb Koppen Classification

- Most common *V. Vinifera* varietals grown are Chardonnay and Cabernet Sauvignon, and French Hybrid varietals of Seval Blanc, Vidal Blanc and Chambourcin.

Climate indices original characterization:
GSTavg: Too Cool; Cool; Intermediate; Warm
HI: Very Cool; Cool; Temperate; Warm Temperate; Warm
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV
BEDD: Too Cool; Very Cool; Cool; Temperate; Warm Temperate
GSTavg: Intermediate, Warm, Hot

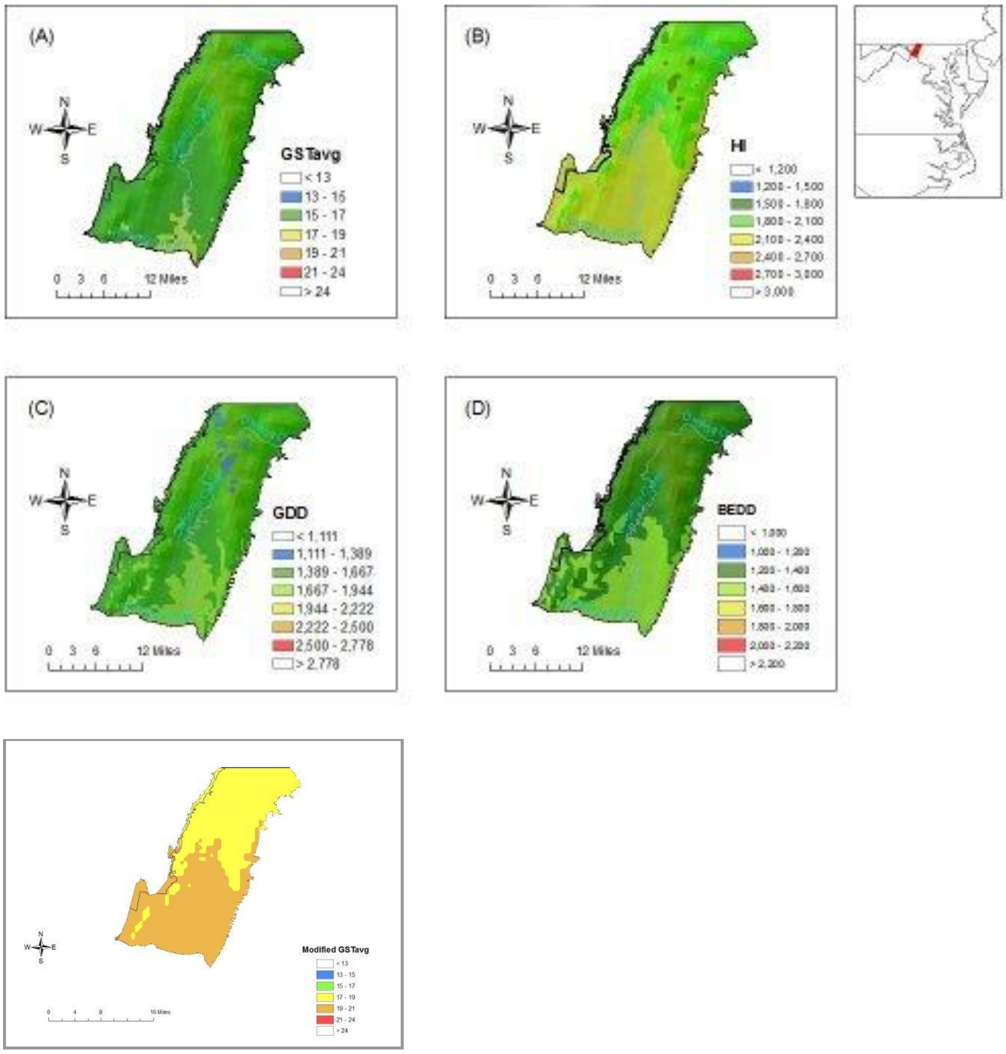
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	13	17	18	18	19
HI	1342	2148	2271	2358	2543
GDD	889	1623	1777	1898	2112
BEDD	905	1371	1463	1521	1622
Modified GSTavg	18	20	22	25	29

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest characterizations found at higher elevations, or in National or State Parks or recreational areas, where it is unsuitable for planting

Final characterization:
GSTavg: Intermediate to Warm (25% to Maximum quartile range)
HI: Warm Temperate to Warm (25% to Maximum quartile range)
GDD: Temperate, Region III to Warm Temperate, Region IV (Median to Maximum quartile range)
BEDD: Temperate to Warm Temperate (Median to Maximum quartile range)
GSTavg: Intermediate to Hot (Full quartile range)

Catoctin AVA



Highlights:

- 196,118.3 total acres (79,369 hectares)
- No commercial vineyards
- Elevation range: 90 m to 596 m (median value of 250 m)

Climate indices original characterization:
GSTavg: Intermediate (94%); Warm (6%)
HI: Cool (2%); Temperate (41%); Warm Temperate (57%)
GDD: Very Cool, Region I (4%); Cool, Region II (73%); Temperate, Region III (23%)
BEDD: Cool (61%); Temperate (39%)
Modified GSTavg: Warm (50%); Hot (50%)

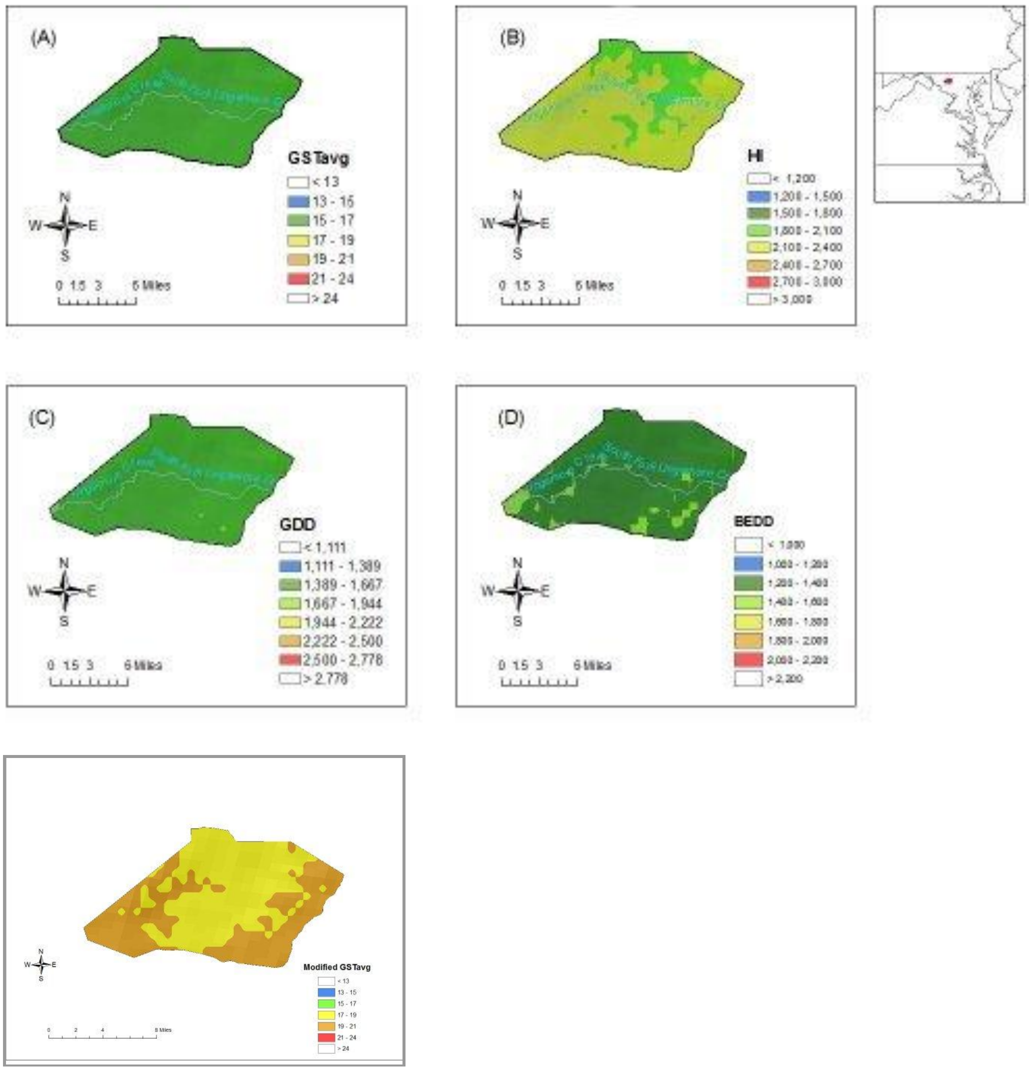
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	16.5	17	17	17
HI	1653	1995	2148	2178	2210
GDD	1256	1485.5	1623	1668.5	1684
BEDD	1170	1325	1371	1417	1455
Modified GSTavg	23	23	24	24	24

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Intermediate to Warm (Full quartile range)
HI: Temperate to Warm Temperate (25% to Maximum quartile range)
GDD: Cool, Region II to Temperate, Region III (Median to Maximum quartile range)
BEDD: Cool to Temperate (Median to Maximum quartile range)
Modified GSTavg: Warm to Hot (Full quartile range)

Linganore AVA



Highlights:

- 61,385.5 total acres (24,842.7 hectares)
- 3+ commercial vineyards
- 107 planted acres (43.3 hectares)
- Vineyard size ranges from 3 acres (1.2 hectares) to 23 acres (9.3 hectares)
- Elevation range: 92 m to 248 m (median value of 159 m)

Climate indices original characterization:
GSTavg: Intermediate (100%)
HI: Temperate (26%); Warm Temperate (74%)
GDD: Cool, Region II (99%); Temperate, Region III (1%)
BEDD: Cool (78%); Temperate (22%)
Modified GSTavg: Warm (33%); Hot (67%)

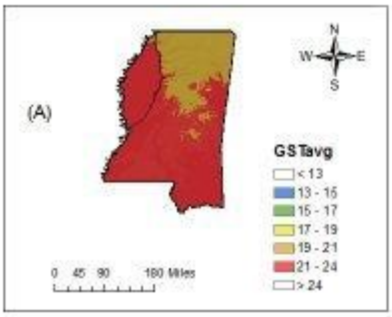
Quartile Statistics:

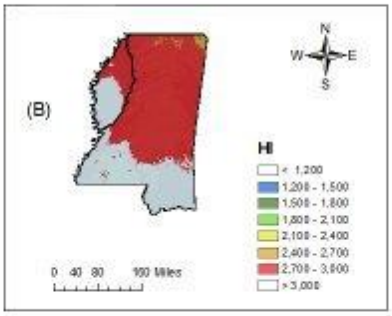
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	17	17	17	17	17
HI	2087	2088	2088	2118	2148
GDD	1563	1563	1563	1593	1623
BEDD	1340	1347	1348	1386	1393
Modified GSTavg	23	23	23	23	24

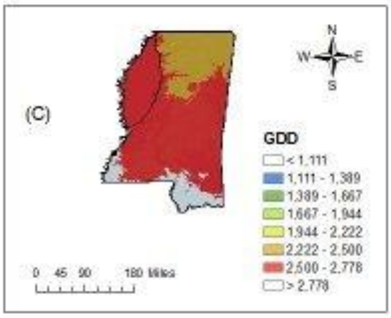
Factors affecting alteration of characterizations:
None

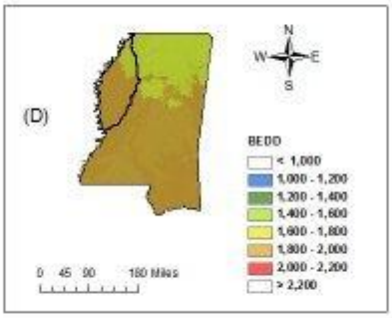
Final characterization:
GSTavg: Intermediate (Full quartile range)
HI: Temperate to Warm Temperate (Full quartile range)
GDD: Cool, Region II to Temperate, Region III (Full quartile range)
BEDD: Cool to Temperate (Full quartile range)
Modified GSTavg: Warm to Hot (Full quartile range)

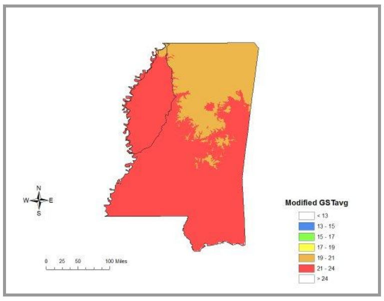
Mississippi











Highlights:

- 47,619 square miles
- 147 planted acres (hectares)
- 2+ commercial vineyards
- 1 AVA (Mississippi Delta AVA)
- Ranked 40th in US production (no data)
- Elevation range: 0 m to 246 m
- Cfa Koppen classification
- Most common varietal grown is Muscadine.

Climate indices original characterization:
GSTavg: Hot, Very Hot
HI: Warm; Very Warm; Too Hot
GDD: Warm, Region V; Very Warm, Region VI; Too Hot
BEDD: Warm Temperate; Warm
Modified GSTavg: Very Warm, Hot

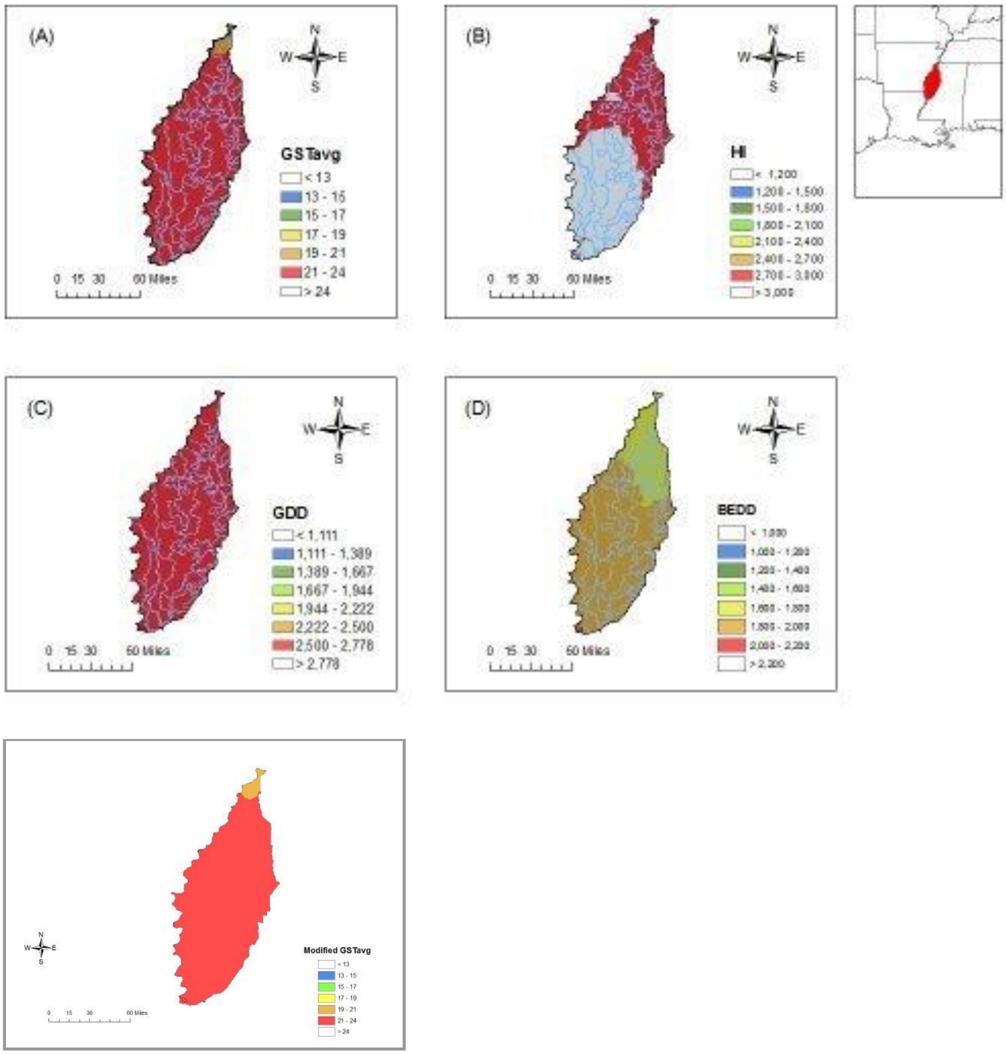
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	20	21	22	22	23
HI	2668	2875	2963	3054	3206
GDD	2264	2539	2631	2753	2967
BEDD	1704	1791	1835	1888	1987
Modified GSTavg	9	20	22	24	30

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Hot to Very Hot (Full quartile range)
HI: Warm to Very Warm (Minimum to Median quartile range)
GDD: Warm, Region V to Very Warm, Region VI (Minimum to 75% quartile range)
BEDD: Warm Temperate to Warm (Full quartile range)
Modified GSTavg: Very Warm to Hot (25% to maximum quartile range)

Mississippi Delta AVA



Highlights:

- 4,111,226.3 total acres (1,663,813.3 hectares)
- No commercial vineyards
- Elevation range: 22 m to 83m (median value 38 m)

Climate indices original characterization:
GSTavg: Hot (2%);Very Hot (98%)
HI: Very Warm (47%); Too Hot (53%)
GDD: Very Warm, Region VI (100%)
BEDD: Warm Temperate (22%); Warm (78%)
Modified GSTavg: Hot (3%); Very Hot (97%)

Quartile Statistics:

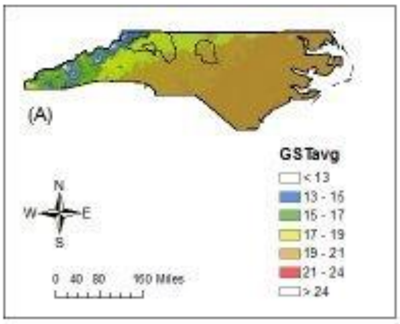
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	21	22	22	22	23
HI	2912	2964	3028	3055	3085
GDD	2540	2631	2692	2754	2784
BEDD	1750	1813	1820	1843	1888
Modified GSTavg	25	26	26	26	27

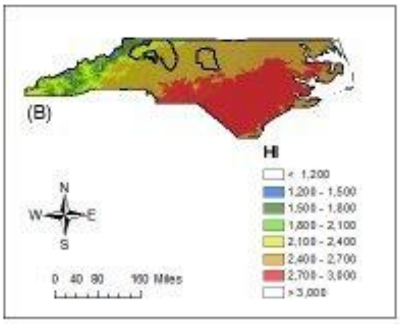
Factors affecting alteration of characterizations:

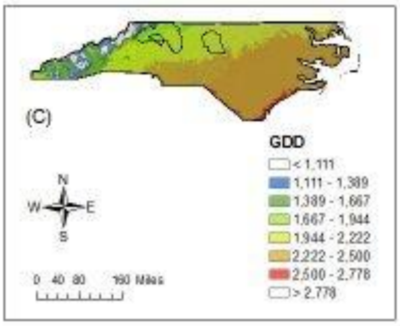
- Already established productive vineyards
- Many areas suited for crop farming

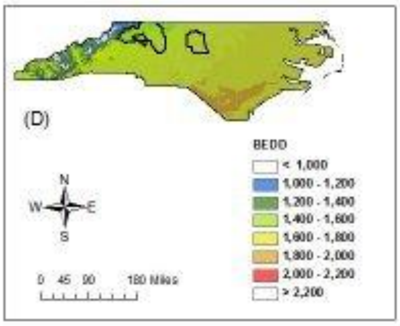
Final characterization:
GSTavg: Hot to Very Hot (Full quartile range)
HI: Very Warm to Too Hot (Minimum to Median quartile range)
GDD: Very Warm, Region VI (Full quartile range)
BEDD: Warm Temperate to Warm (Full quartile range)
Modified GSTavg: Hot to Very Hot (Full quartile range)

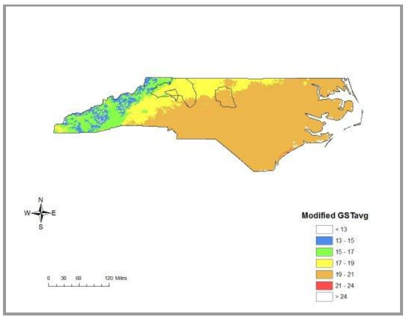
North Carolina











Highlights:

- 49,048 square miles
- 1881 planted acres (761.2 hectares)
- 67+ commercial vineyards
- Ranked 9th in US production (1,173,296 gal/yr)
- Elevation range: 0 m to 2037.3 m
- Cfa, Dsc and Dfb Koppen classification

- Most common *V. Vinifera* varietals grown are Chardonnay, Cabernet Sauvignon, Merlot, Cabernet Franc, and Viognier, and the native American varietal, Scuppernong.

<u>Climate indices original characterization:</u>
GSTavg: Too Cool; Cool; Intermediate; Warm; Hot, Very Hot
HI: Too Cool; Cool; Temperate; Warm Temperate; Warm; Very Warm
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI
BEDD: Too Cool; Cool; Temperate; Warm Temperate; Warm
Modified GSTavg: Cool, Intermediate, Warm, Hot, Very Hot

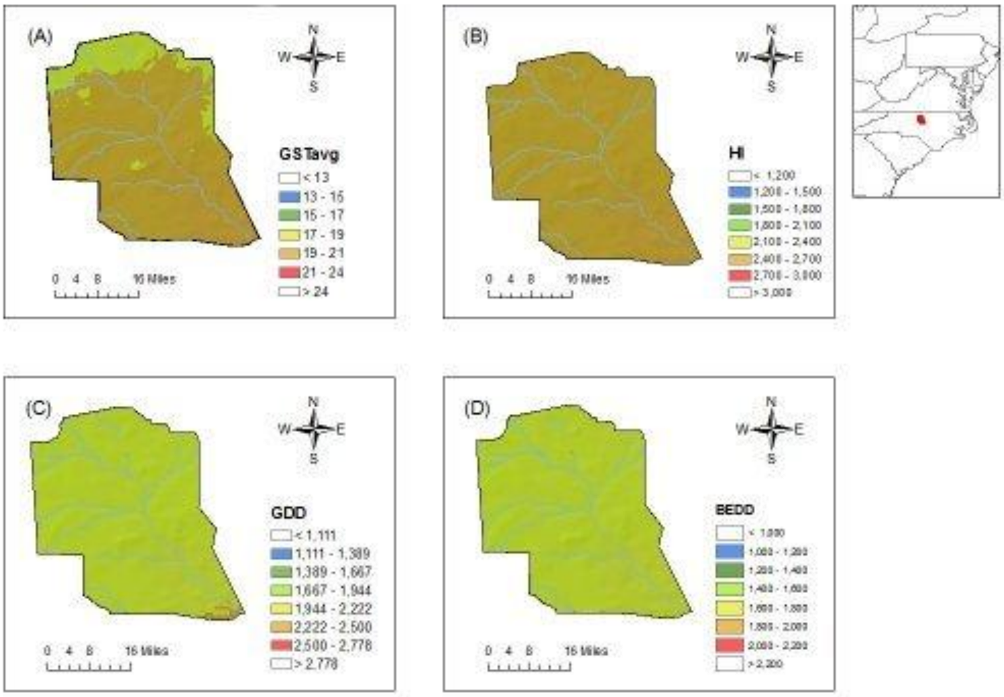
Quartile Statistics:

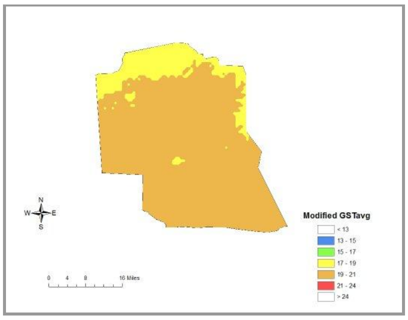
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	12	19	20	21	21
HI	925	2498	2645	2763	2910
GDD	613	2051	2234	2387	2540
BEDD	564	1626	1707	1755	1835
Modified GSTavg	13	20	22	25	30

<u>Factors affecting alteration of characterizations:</u>
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

<u>Final characterization:</u>
GSTavg: Warm to Very Hot (25% to Maximum quartile range)
HI: Warm to Very Warm (25% to Maximum quartile range)
GDD: Warm Temperate, Region IV to Very Warm, Region VI (25% to Maximum quartile range)
BEDD: Warm Temperate to Warm (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Very Hot (25% to maximum quartile range)

Haw River Valley AVA





Highlights:

- 614,899 total acres (248,849.6 hectares)
- 25 planted acres (10.1 hectares)
- Vineyard size ranges from 2 acres (0.8 hectares) to 12 acres (4.9 hectares)
- 2+ commercial vineyards
- Elevation range: 96 m to 272m (median value 201m)

<u>Climate indices original characterization:</u>
GSTavg: Warm (15%); Hot (85%)
HI: Warm (100%)
GDD: Warm Temperate, Region IV (99%); Warm, Region V (1%)
BEDD: Warm Temperate (100%)
Modified GSTavg: Warm (20%); Hot (80%)

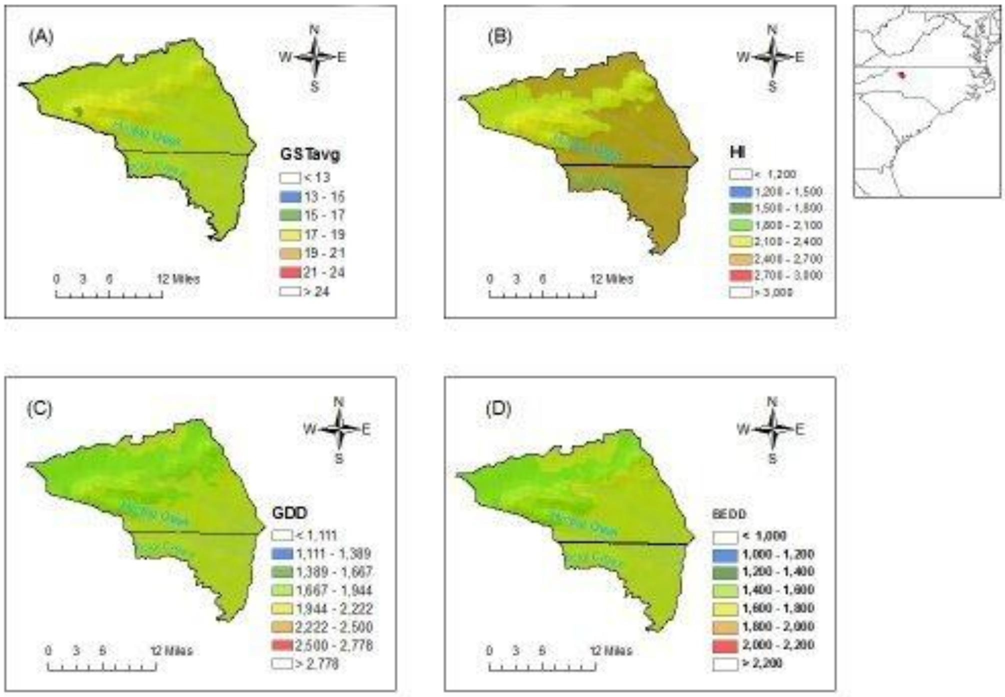
Quartile Statistics:

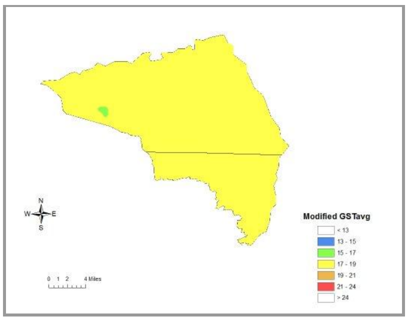
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	19	20	20	20	20
HI	2465	2571	2615	2616	2646
GDD	2020	2143	2173	2173	2234
BEDD	1610	1689	1694	1695	1717
Modified GSTavg	23	24	24	24	24

<u>Factors affecting alteration of characterizations:</u>
None

<u>Final characterization:</u>
GSTavg: Warm to Hot (Full quartile range)
HI: Warm (Full quartile range)
GDD: Warm Temperate to Warm (Full quartile range)
BEDD: Warm Temperate (Full quartile range)
Modified GSTavg: Warm to Hot (Full quartile range)

Swan Creek AVA





<u>Highlights:</u>

- 146,986.3 total acres (59,485.4 hectares)
- 76 planted acres (30.8 hectares)
- Vineyard size ranges from 10 acres (4 hectares) to 43 acres (17.4 hectares)
- 4+ commercial vineyards
- Elevation range: 224 m to 522m (median value 329m)

Climate indices original characterization:
GSTavg: Intermediate (1%); Warm (99%)
HI: Warm Temperate (27%); Warm (73%)
GDD: Temperate, Region III (40%); Warm Temperate, Region IV (60%);
BEDD: Temperate (31%); Warm Temperate (69%)
Modified GSTavg: Warm (100%)

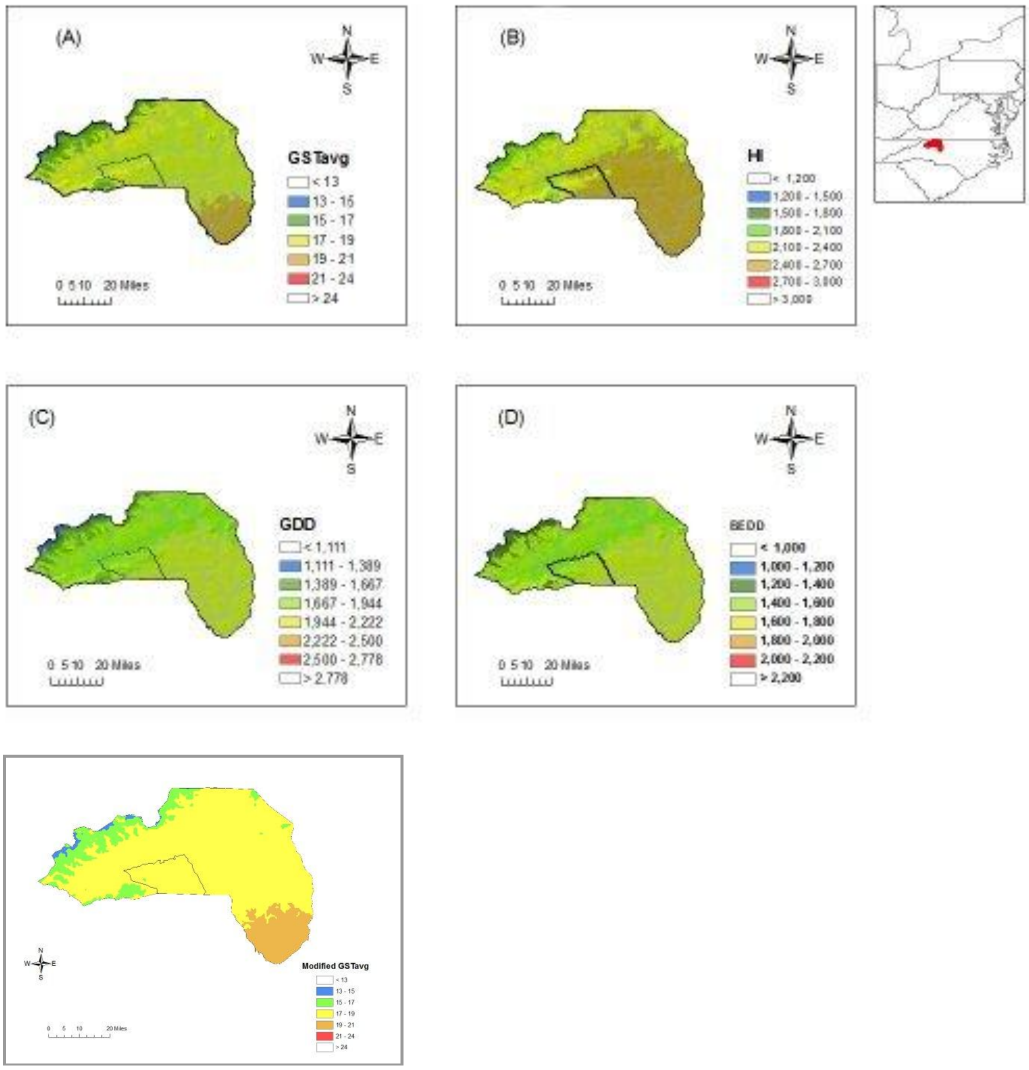
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	19	19	19	19	19
HI	2464	2479	2495	2510	2525
GDD	1990	1990	1990	2020.5	2051
BEDD	1610	1614	1618	1645	1671
Modified GSTavg	23	23	23	23.5	24

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Intermediate to Warm (Full quartile range)
HI: Warm Temperate to Warm (Full quartile range)
GDD: Temperate to Warm Temperate (Full quartile range)
BEDD: Temperate to Warm Temperate (Full quartile range)
Modified GSTavg: Warm (Full quartile range)

Yadkin Valley AVA



Highlights:

- 1,431,964 total acres (579,515.8 hectares)
- 611 planted acres (247.3 hectares)
- Vineyard size ranges from 2 acres (0.8 hectares) to 152 acres (61.5 hectares)
- 23+ commercial vineyards
- Elevation range: 201 m to 1087m (median value 334m)

<u>Climate indices original characterization:</u>
GSTavg: Cool (1%); Intermediate (11%); Warm (77%)
HI: Cool (1%); Temperate (7%); Warm Temperate (40%); Warm (52%); Hot (11%)
GDD: Very Cool, Region I (3%); Cool, Region II (8%); Temperate, Region III (45%); Warm Temperate, Region IV (44%);
BEDD: Very Cool (1%); Cool (5%); Temperate (46%); Warm Temperate (48%)
Modified GSTavg: Cool (2%); Intermediate (12%); Warm (78%); Hot (8%)

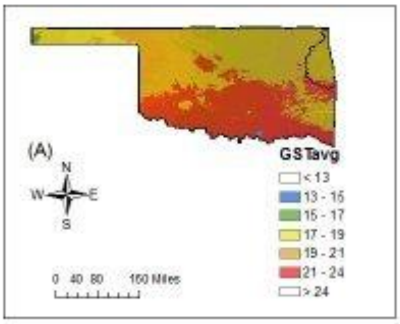
Quartile Statistics:

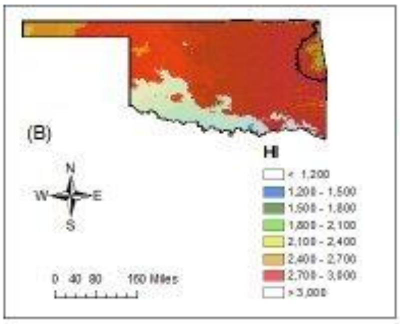
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	18	18	19	20
HI	1789	2282	2403	2495	2616
GDD	1226	1745	1898	2020	2173
BEDD	1204	1527	1588	1649	1702
Modified GSTavg	21	22	23	23	24

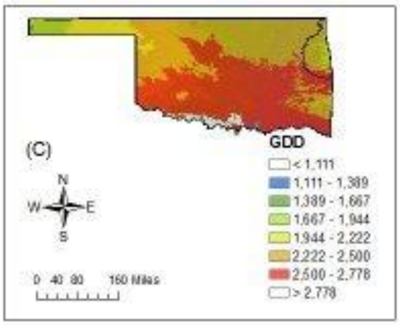
<u>Factors affecting alteration of characterizations:</u>
- Coolest maturity classes found at higher elevations where planting is unsuitable.

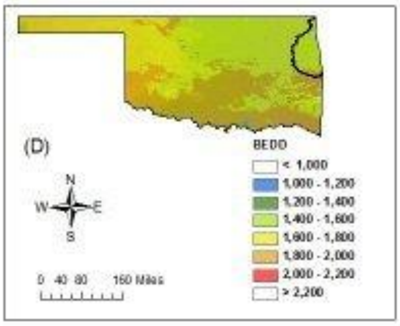
<u>Final characterization:</u>
GSTavg: Cool to Warm (Full quartile range)
HI: Warm Temperate to Hot (25% to Maximum quartile range)
GDD: Temperate, Region III to Warm Temperate (25% to Maximum quartile range)
BEDD: Temperate to Warm Temperate (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (Full quartile range)

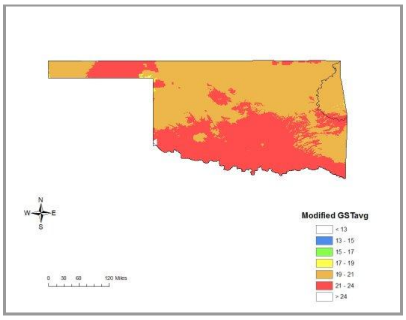
Oklahoma











Highlights:

- 70,003 square miles
- 295 planted acres (hectares)
- 38+ commercial vineyards
- Ranked 33rd in US production (37,104 gal/yr)
- Elevation range: 88.1 m to 1515.8m
- Cfa and Dfc Koppen classification

- Most common *V. Vinifera* varietals grown are Chardonnay, Vignoles, Shiraz and Zinfandel, and the French Hybrid varietal, Cynthiana.

Climate indices original characterization:
GSTavg: Intermediate; Warm; Hot, Very Hot
HI: Warm Temperate; Warm; Very Warm; Too Hot
GDD: Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI
BEDD: Temperate; Warm Temperate; Warm
Modified GSTavg: Hot, Very Hot

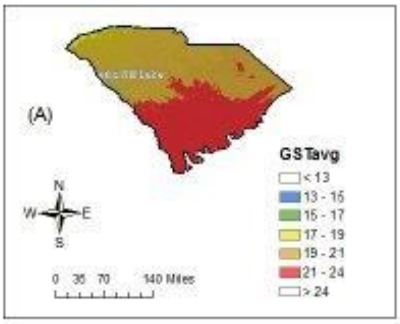
Quartile Statistics:

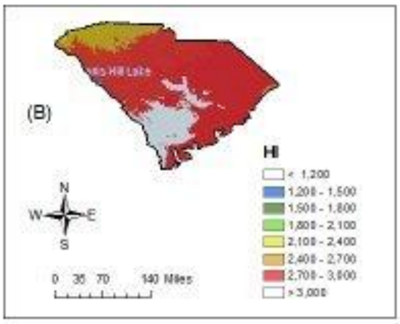
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	17	21	21	22	23
HI	2285	2833	2910	2970	3252
GDD	1593	2387	2480	2601	2846
BEDD	1504	1743	1778	1814	1919
Modified GSTavg	11	19	22	25	32

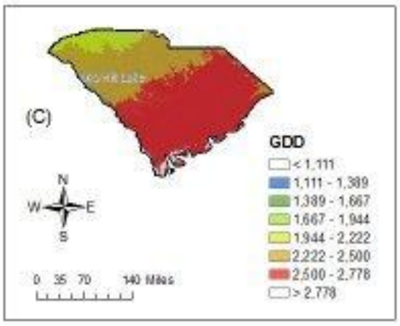
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

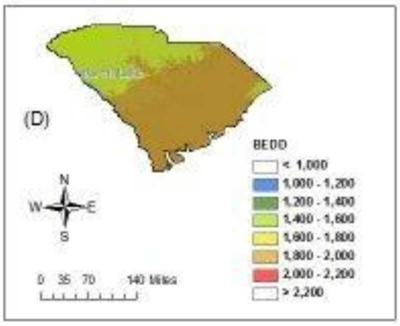
Final characterization:
GSTavg: Intermediate to Very Hot (Full quartile range)
HI: Warm Temperate to Very Warm (Minimum to 75% quartile range)
GDD: Cool to Very Warm, Region VI (Minimum to 75% quartile range)
BEDD: Temperate to Warm (Full quartile range)
Modified GSTavg: Hot to Very Hot (25% to maximum quartile range)

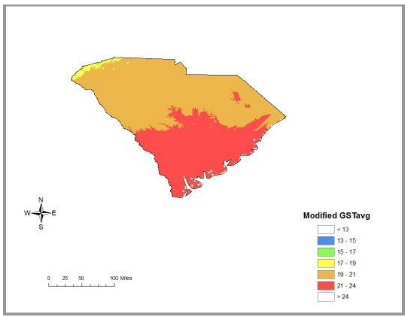
South Carolina











Highlights:

- 30,867 square miles
- 47 planted acres (19 hectares)
- 4+ commercial vineyards
- No production data
- Elevation range: 0 m to 1085m
- Cfa and Dsc Koppen classification

- Most common varietals grown are the French Hybrid varietals of Vidal Blanc and Chambourcin, and the native American varietal, Scuppernong.

Climate indices original characterization:
GSTavg: Warm; Hot, Very Hot
HI: Warm Temperate; Warm; Very Warm; Too Hot
GDD: Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI; Too Hot
BEDD: Temperate; Warm Temperate; Warm
Modified GSTavg: Warm; Hot, Very Hot

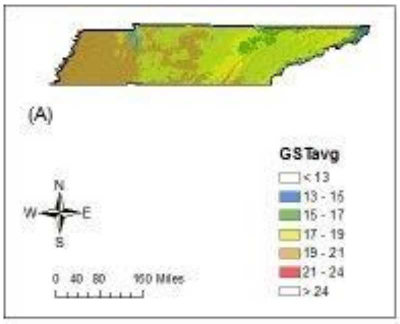
Quartile Statistics:

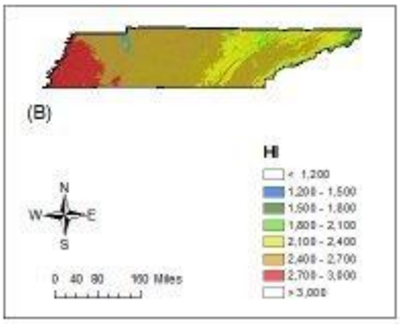
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	17	21	21	22	23
HI	2149	2790	2878	2963	3115
GDD	1653	2417	2540	2631	2784
BEDD	1505	1764	1808	1843	1919
Modified GSTavg	12	20	22	24	30

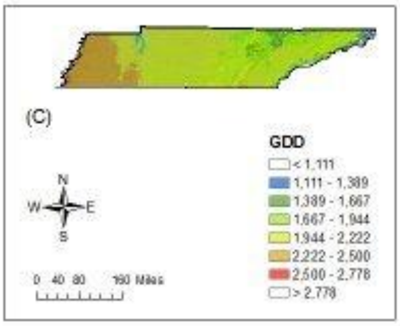
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

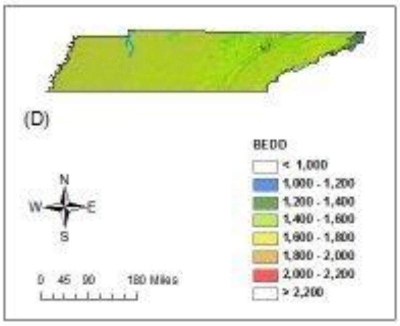
Final characterization:
GSTavg: Warm to Very Hot (Full quartile range)
HI: Warm Temperate to Very Warm (Minimum to 75% quartile range)
GDD: Cool to Too Hot, Region VI (Full quartile range)
BEDD: Temperate to Warm (Full quartile range)
Modified GSTavg: Warm to Very Hot (25% to maximum quartile range)

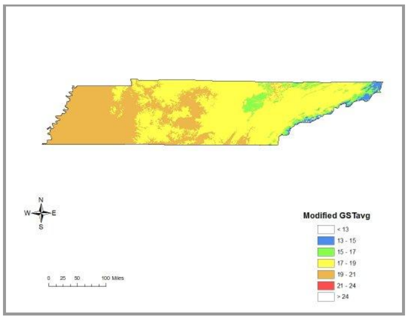
Tennessee











Highlights:

- 42,092 square miles
- 286 planted acres (115.7 hectares)
- 24+ commercial vineyards
- Ranked 21st in US production (204,607 gal/yr)
- Elevation range: 54.3 m to 2024.8 m
- Cfa, Dsc, Dfa and Dfb Koppen classification

- Most common *V. Vinifera* varietals grown are Chardonnay and Nebbiolo; French Hybrid varietals of Seyval Blanc, Chambourcin; and the native American varietal, Muscadine.

Climate indices original characterization:
GSTavg: Cool; Intermediate; Warm; Hot
HI: Very Cool; Cool; Temperate; Warm Temperate; Warm; Very Warm
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI
BEDD: Too Cool; Cool; Temperate; Warm Temperate
Modified GSTavg: Cool; Intermediate; Warm; Hot

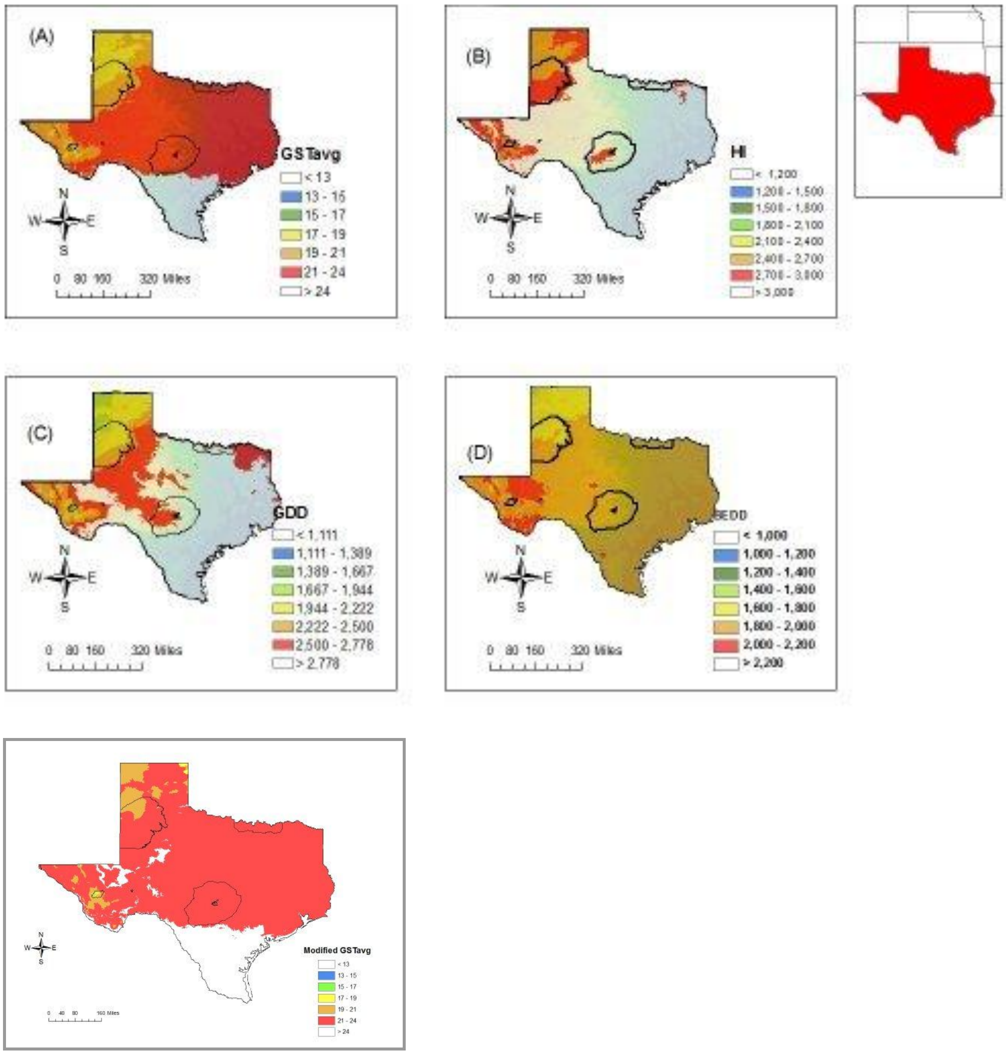
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	13	19	19	20	21
HI	1386	2402	2524	2614	2921
GDD	888	1928	2081	2173	2540
BEDD	894	1595	1639	1688	1775
Modified GSTavg	9	19	21	23	30

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, state and national parks, and recreational areas where it is unsuitable for planting

Final characterization:
GSTavg: Warm to Hot (25% to Maximum quartile range)
HI: Warm Temperate to Very Warm (25% to Maximum quartile range)
GDD: Temperate, Region III to Very Warm, Region VI (25% to Maximum quartile range)
BEDD: Temperate to Warm Temperate (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (25% to Maximum quartile range

Texas



Highlights:

- 264,436 square miles
- 2446 planted acres (hectares)
- 79+ commercial vineyards
- 5 AVAs and 2 sub-AVAs (AVAs: Texas Hill Country, Texas Davis Mountains, Texoma, Mesilla Valley, Escondido Valley; sub-AVAs: Bell Mountain, Fredericksburg in Texas Hill Country)
- Ranked 15th in US production (624,997 gal/yr)
- Elevation range: 0 m to 2,666.7 m

- Cfa, Dfc, Af, Bsh, and Csb Koppen classification
- Most common *V. Vinifera* varietals grown are Sangiovese, Tempranillo and Syrah.

Climate indices original characterization:
GSTavg: Intermediate; Warm; Hot, Very Hot, Too Hot
HI: Temperate; Warm Temperate; Warm; Very Warm; Too Hot
GDD: Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI; Too Hot
BEDD: Cool; Temperate; Warm Temperate; Warm; Very Warm; Too Hot
Modified GSTavg: Hot, Very Hot, Too Hot

Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16	22	23	24	27
HI	1834	3054	3147	3268	4030
GDD	1439	2661	2815	3029	3670
BEDD	1347	1874	1919	1942	2216
Modified GSTavg	8	19	23	25	32

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Intermediate to Very Hot (Minimum to 75% quartile range)
HI: Temperate to Too Hot (Minimum to 25% quartile range)
GDD: Cool to Too Hot (Minimum to 75% quartile range)
BEDD: Cool to Too Hot (Full quartile range)
Modified GStavg: Hot to Too Hot (25% to 75% quartile range)

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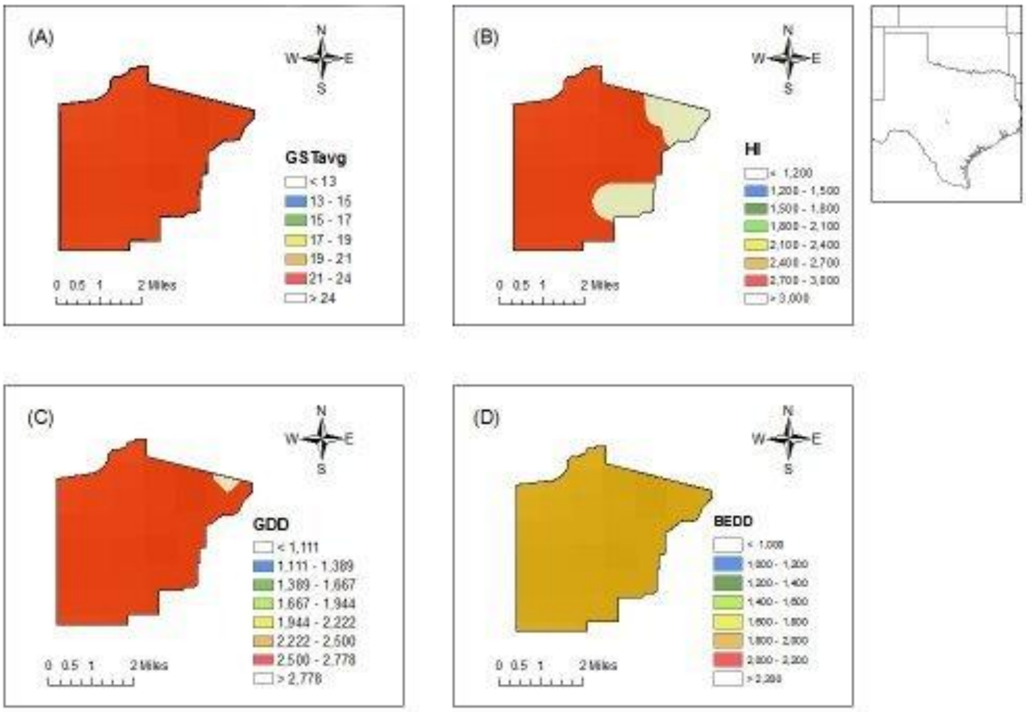
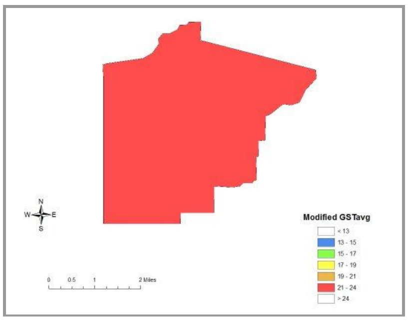
Bell Mountain sub-AVA





Highlights:

- 7,360 total acres (2978.6 hectares)
- 33 planted acres (13.4 hectares)
- 1+ commercial vineyards
- Elevation range:513 m to 572m (median value 540m)

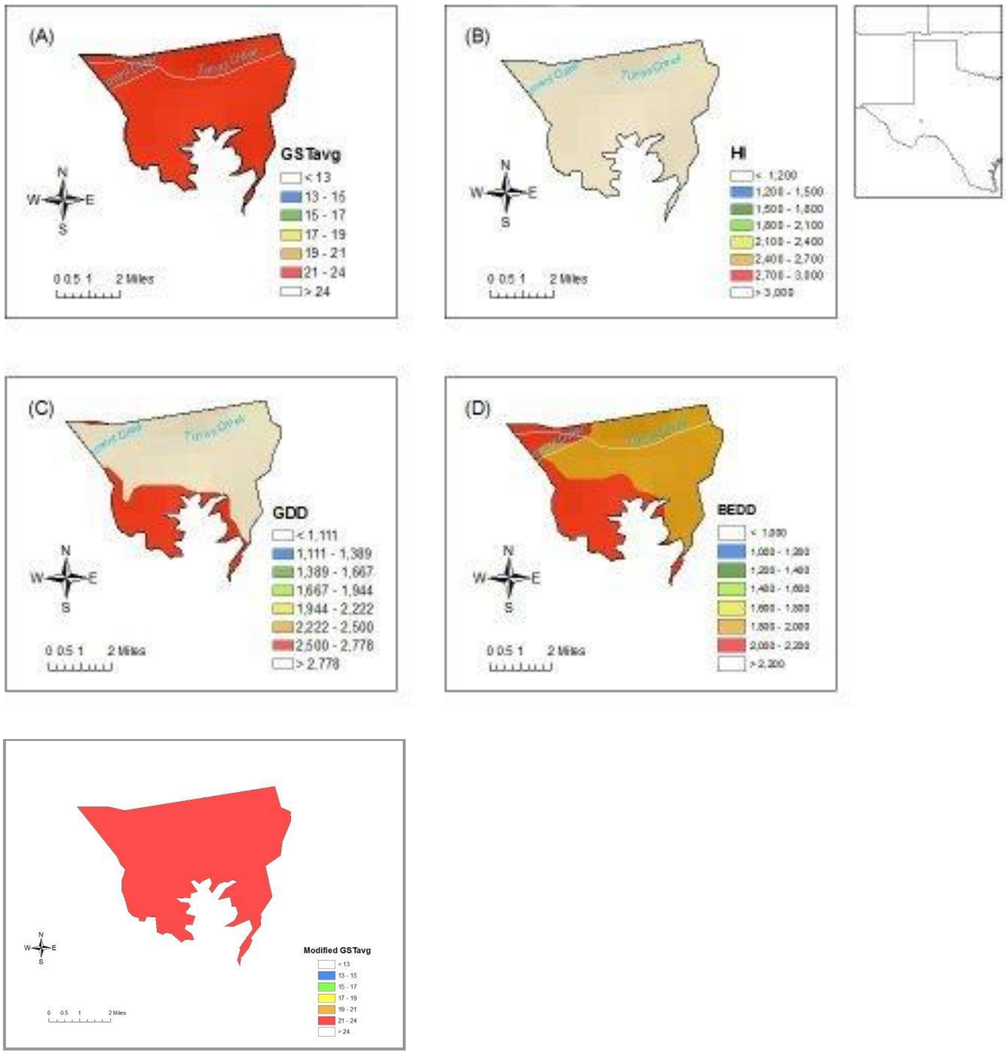
Climate indices original characterization:
GSTavg: Very Hot (100%)
HI: Very Warm (87%); Too Hot (13%)
GDD: Very Hot, Region VI (100%)
BEDD: Warm (100%)
Modified GSTavg: Very Hot (100%)

Quartile Statistics:
Unable to be calculated due to size.

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Very Hot (Full quartile range)
HI: Very Warm to Too Hot (Full quartile range)
GDD: Very Hot (Full quartile range)
BEDD: Warm (Full quartile range)
Modified GSTavg: Very Hot

Escondido Valley AVA



Highlights:

- 11,304.3 total acres (4,575 hectares)
- No commercial vineyards
- Elevation range:813 m to 943m (median value 854m)

Climate indices original characterization:
GSTavg: Very Hot (100%)
HI: Too Hot (100%)
GDD: Very Warm, Region VI (27%); Too Hot (73%)
BEDD: Warm (63%); Very Warm (37%)
Modified GSTavg: Very Hot (100%)

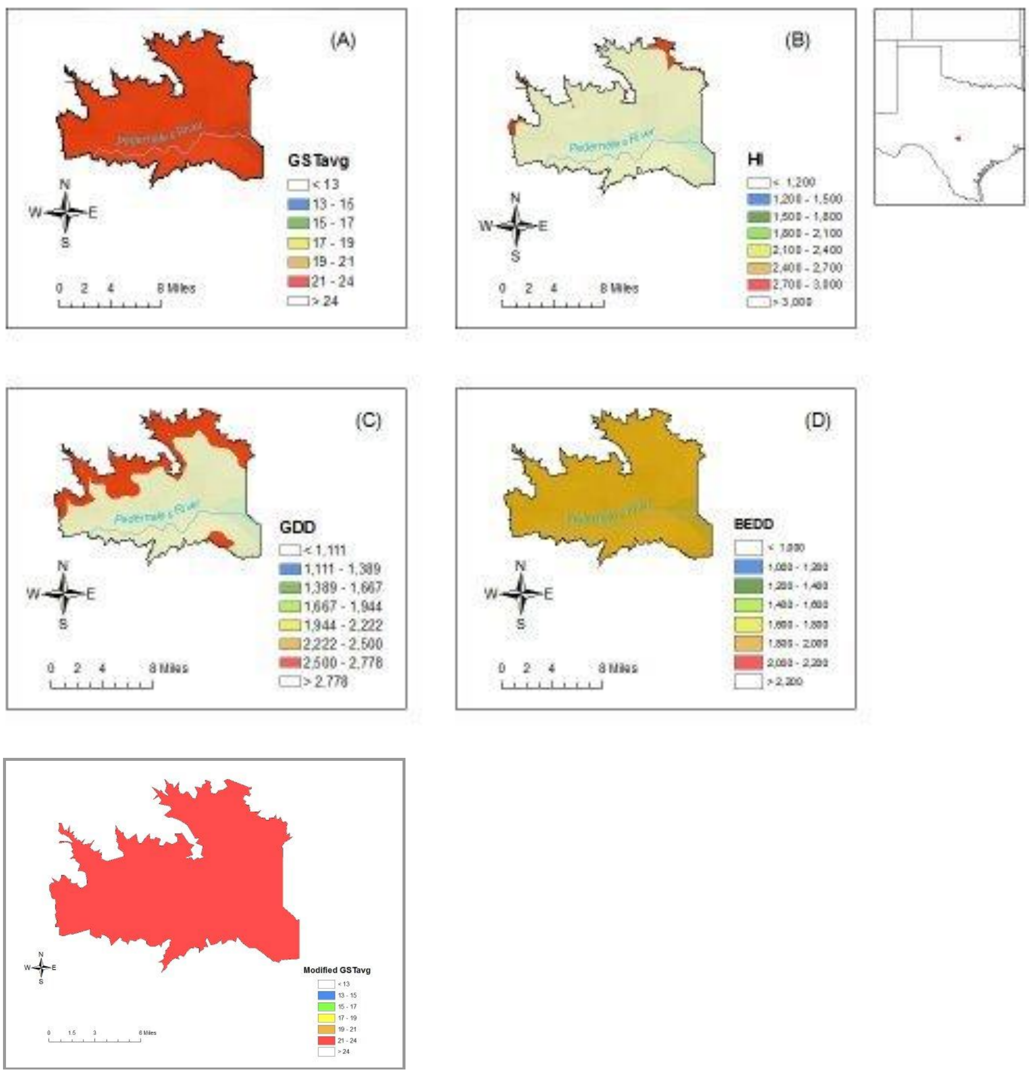
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	23	23	23	23	23
HI	3268	3268	3268	3268	3268
GDD	2815	2815	2815	2815	2815
BEDD	1995	1995	1995	1995	1995

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Very Hot (Full quartile range)
HI: Too Hot (Full quartile range)
GDD: Very Warm to Too Hot (Full quartile range)
BEDD: Warm to Very Warm (Full quartile range)
Modified GSTavg: Very Hot (quartile statistics could not be calculated)

Fredericksburg in Texas Hill Country sub-AVA



Highlights:

- 66,576.2 total acres (26,943.4 hectares)
- No commercial vineyards
- Elevation range:454 m to 555m (median value 505m)

Climate indices original characterization:
GSTavg: Very Hot (100%)
HI: Very Warm (8%); Too Hot (92%)
GDD: Very Warm, Region VI (25%); Too Hot (75%)
BEDD: Warm (100%)
Modified GSTavg: Very Hot (100%)

Quartile Statistics:

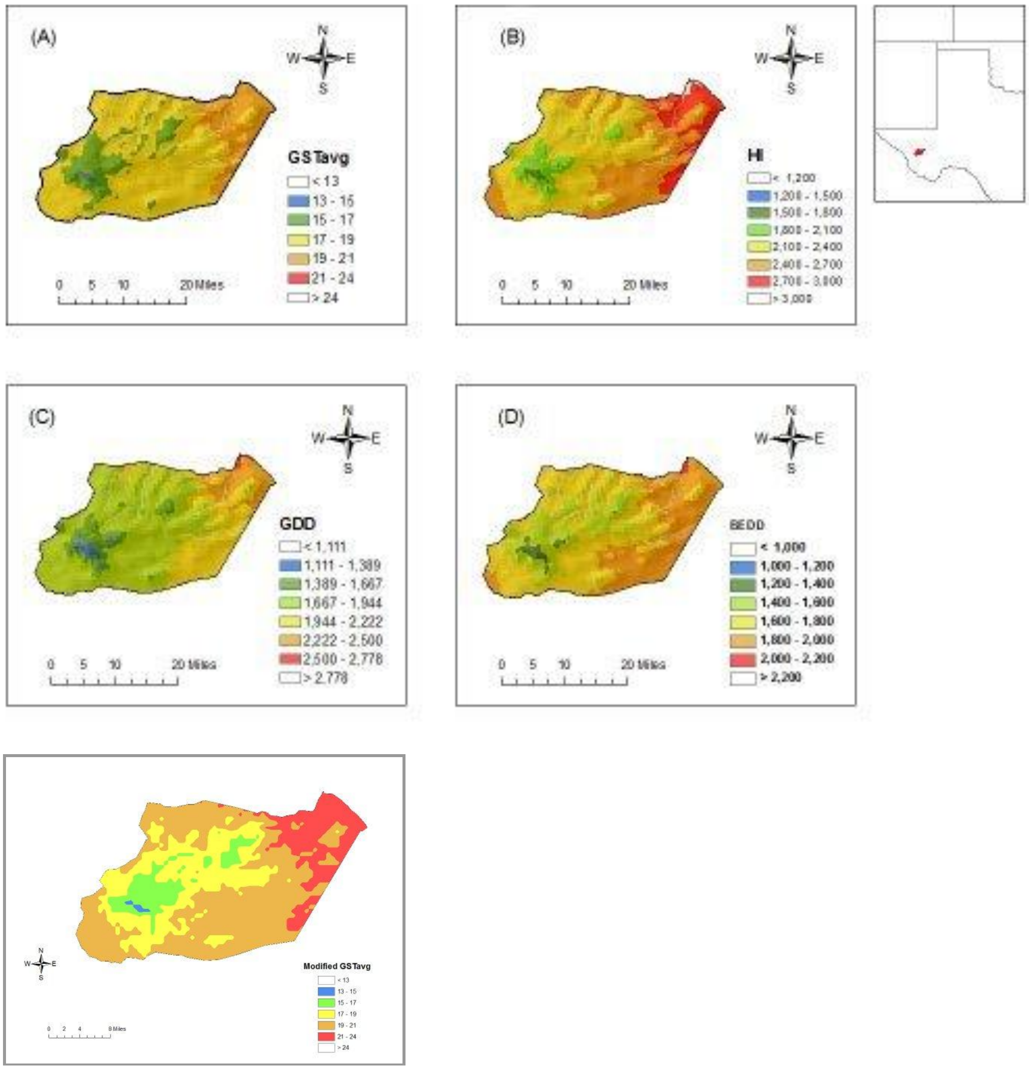
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	22	23	23	23	23
HI	2962	3085	3085	3085	3085
GDD	2661	2791.75	2815	2815	2815
BEDD	1888	1917	1934	1934	1934

Factors affecting alteration of characterizations:

- Sub-AVA of larger AVA where the largest concentration of vineyards in Texas are located.

Final characterization:
GSTavg: Very Hot (Full quartile range)
HI: Very Warm to Too Hot (Minimum to 25% quartile range)
GDD: Very Warm, Region VI to Too Hot (Minimum to 25% quartile range)
BEDD: Warm (Full quartile range)
Modified GSTavg: Very Hot (quartile statistics could not be calculated)

Texas Davis Mountain AVA



Highlights:

- 309,298 acres (125,173 hectares)
- No commercial vineyards
- Elevation range: 1158 m to 2338 m (median value of 1737 m)

Climate indices original characterization:
GSTavg: Intermediate (16%); Warm (68%); Hot (16%)
HI: Cool (2%); Temperate (6%); Warm Temperate (47%); Warm (34%); Very Warm (11%)
GDD: Very Cool, Region I (2%); Cool, Region II (6%); Temperate, Region III (60%); Warm Temperate, Region IV (22%); Warm, Region VI (9%); Very Warm, Region VI (1%)
BEDD: Cool (2%); Temperate (20%); Warm Temperate (46%); Warm (31%); Very Warm (1%)
Modified GSTavg: Intermediate (4%); Warm (31%); Hot (46%); Very Hot (19%)

Quartile Statistics:

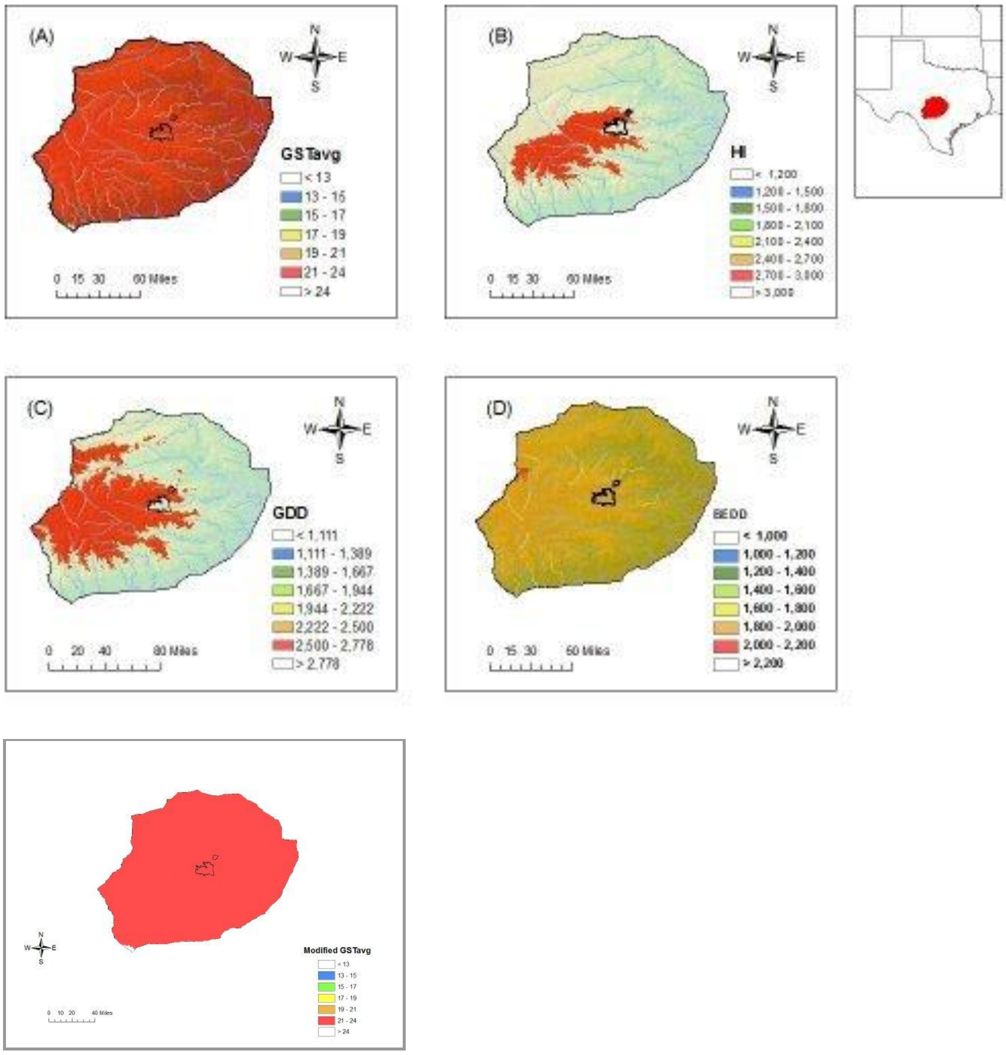
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16	18	18	19	21
HI	1772	2260	2413	2534	2932
GDD	1316	1744	1806	2019	2387
BEDD	1316	1606	1728	1812	1965
Modified GSTavg	21	23	24	25	26

Factors affecting alteration of characterizations:

- Coolest maturity classes are found at higher elevations where it is unsuitable for planting

Final characterization:
GSTavg: Intermediate to Hot (Full quartile range)
HI: Cool to Very Warm (Full range)
GDD: Temperate, Region III to Very Warm, Region VI (25% to Maximum quartile range)
BEDD: Warm Temperate to Warm (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Very Hot (Full quartile range)

Texas Hill Country AVA



Highlights:

- 9,327,982.4 total acres (3,775,034.5 hectares)
- 416 planted acres (168.4 hectares)
- Vineyard size ranges from 2 acres (0.8 hectares) to 58 acres (23.5 hectares)
- 26+ commercial vineyards
- 1 sub-AVA (Fredericksburg in Texas Hill Country)
- Elevation range:143 m to 733m (median value 454m)

Climate indices original characterization:
GSTavg: Very Hot (99.7%); Too Hot (0.3%)
HI: Very Warm (16%); Too Hot (84%)
GDD: Very Warm, Region VI (29%); Too Hot (71%)
BEDD: Warm (99%); Very Warm (1%)
Modified GSTavg: Very Hot (100%)

Quartile Statistics:

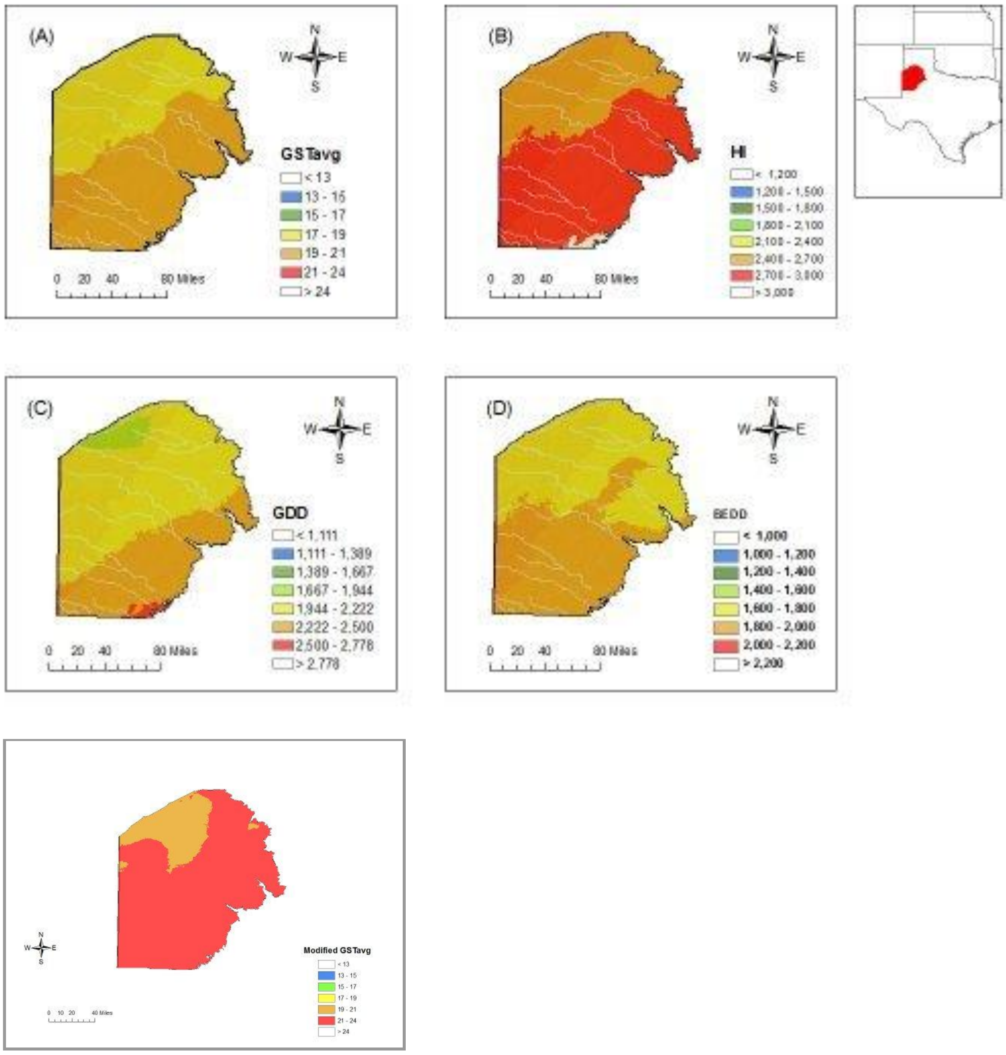
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	22	22	23	23	25
HI	2901	3085	3145	3237	3481
GDD	2570	2753	2815	2967	3211
BEDD	1858	1919	1934	1949	2026

Factors affecting alteration of characterizations:

- Largest concentrations of vineyards in Texas are located in this AVA.

Final characterization:
GSTavg: Very Hot (Minimum to 75% quartile range)
HI: Very Warm to Too Hot (Minimum to 25% quartile range)
GDD: Very Warm, Region VI to Too Hot (Minimum to 75% quartile range)
BEDD: Warm to Very Warm (Full quartile range)
Modified GSTavg: Very Hot (quartile statistics could not be calculated)

Texas High Plains AVA



Highlights:

- 8,964,353.2 acres (3,627,873.7 hectares)
- 83 planted acres (33.6 hectares)
- Vineyard size ranges from 7 acres (2.8 hectares) to 35 acres (14.2 hectares)
- 4+ commercial vineyards
- No commercial vineyards
- Elevation range: 763 m to 1268 m (median value of 1056 m)

Climate indices original characterization:
GSTavg: Warm (43%); Hot (57%)
HI: Warm (38%); Very Warm (61%); Too Hot (1%)
GDD: Temperate, Region III (4%); Warm Temperate, Region IV (60%); Warm, Region VI (34%); Very Warm, Region VI (2%)
BEDD: Warm Temperate (51%); Warm (49%)
Modified GSTavg: Hot (18%); Very Hot (82%)

Quartile Statistics:

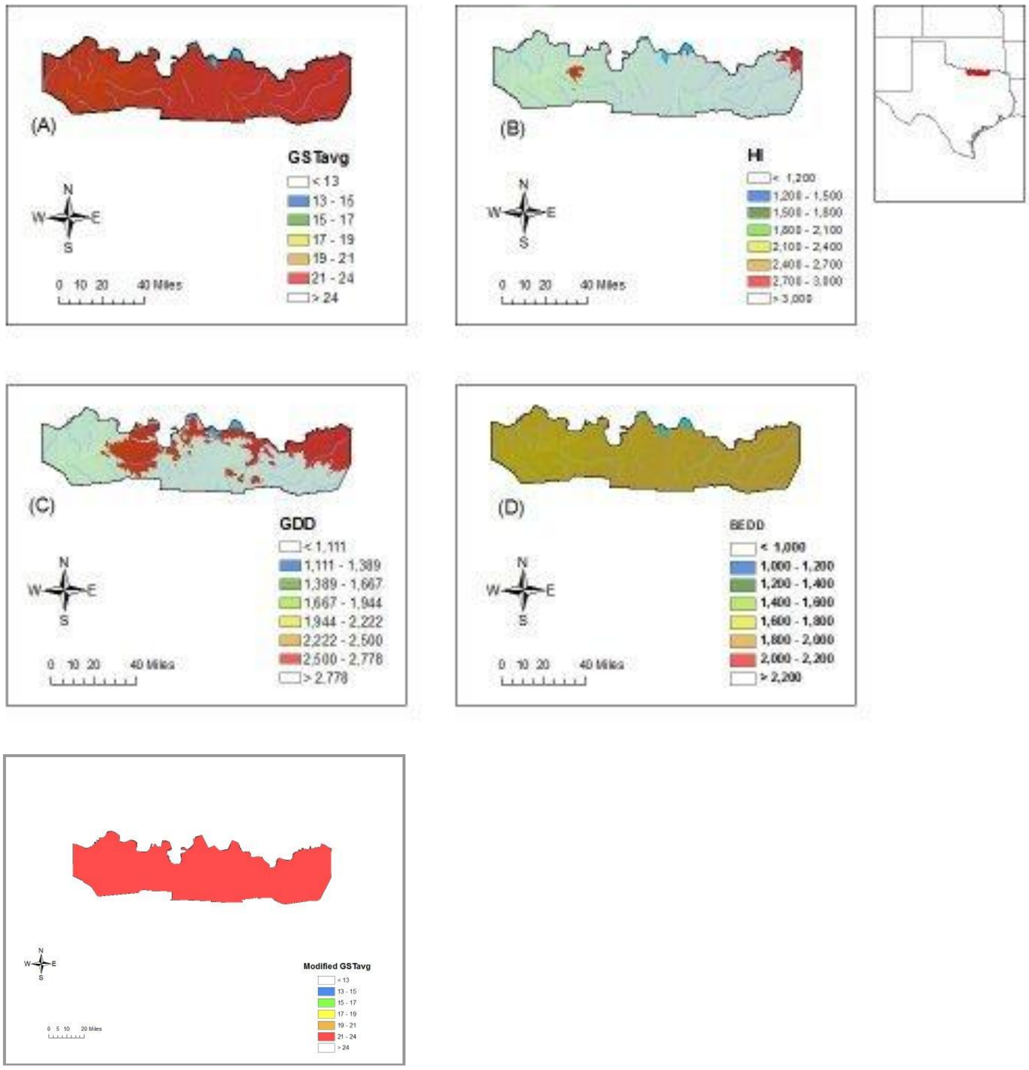
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	18	19	20	20	21
HI	2515	2669	2727	2815	3055
GDD	1867	2051	2143	2264	2540
BEDD	1671	1762	1800	1851	1934
Modified GSTavg	25	26	26	27	28

Factors affecting alteration of characterizations:

- Established vineyards within AVA borders

Final characterization:
GSTavg: Warm to Hot (Minimum to 75% quartile range)
HI: Warm to Very Warm (Minimum to 75% range)
GDD: Temperate, Region III to Very Warm, Region VI (Full quartile range)
BEDD: Warm Temperate to Warm (Full quartile range)
Modified GSTavg: Hot to Very Hot (Full quartile range)

Texoma



Highlights:

- 2,151,625.4 total acres (870,762.8 hectares)
- 48 planted acres (19.4 hectares)
- Vineyard size ranges from 3 acres (1.2 hectares) to 15 acres (6 hectares)
- 6+ commercial vineyards
- Elevation range:134 m to 393m (median value 228m)

Climate indices original characterization:
GSTavg: Very Hot (100%)
HI: Very Warm (4%); Too Hot (96%)
GDD: Very Warm, Region VI (27%); Too Hot (73%)
BEDD: Warm (100%);
Modified GSTavg: Very Hot (100%)

Quartile Statistics:

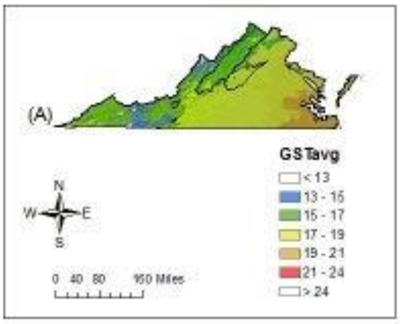
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	22	22	23	23	23
HI	2998	3059	3089	3092	3152
GDD	2662	2755	2785	2785	2846
BEDD	1807	1823	1844	1867	1883
Modified GSTavg	26	27	27	27	27

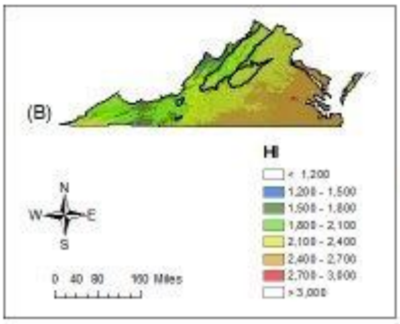
Factors affecting alteration of characterizations:

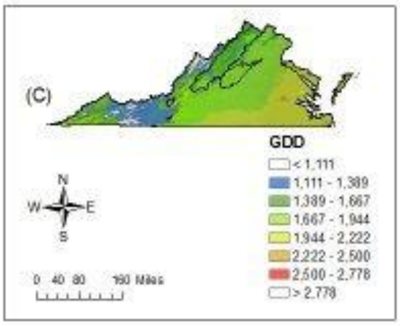
- Established vineyards located within this AVA.

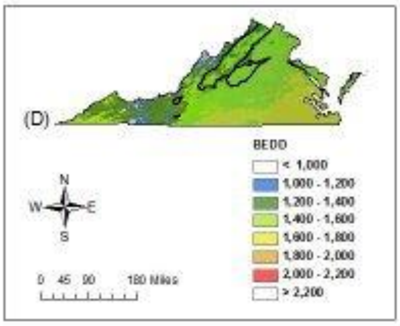
Final characterization:
GSTavg: Very Hot (Full quartile range)
HI: Very Warm to Too Hot (Minimum to 25% quartile range)
GDD: Very Warm, Region VI to Too Hot (Minimum to 25% quartile range)
BEDD: Warm (Full quartile range)
Modified GSTavg: Very Hot (Full quartile range)

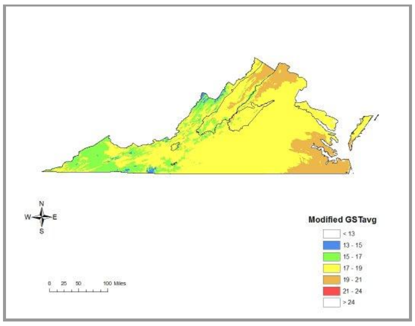
Virginia











Highlights:

- 39,820 square miles
- 2779 planted acres (1124.7 hectares)
- 122+ commercial vineyards
- Ranked 10th in US production (1,164,580 gal/yr)
- 6 AVAs (Shenandoah Valley, Northern Neck George Washington Birthplace, Monticello, North Fork of Roanoke, Rocky Knob, Virginia's Eastern Shore)
- Elevation range: 0 m to 1746.2 m

- Cfa, Dsc, Dfa and Dfb Koppen classification
- Most common *V. Vinifera* varietals grown are Chardonnay, Cabernet Franc, Merlot, Petite Verdot and Viognier, and French Hybrid varietals of Vidal Blanc, Chambourcin and Traminette.

Climate indices original characterization:
GSTavg: Too Cool; Cool; Intermediate; Warm; Hot
HI: Too Cool; Cool; Temperate; Warm Temperate; Warm; Very Warm
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III
BEDD: Too Cool; Cool; Temperate; Warm Temperate
Modified GSTavg: Cool; Intermediate; Warm; Hot

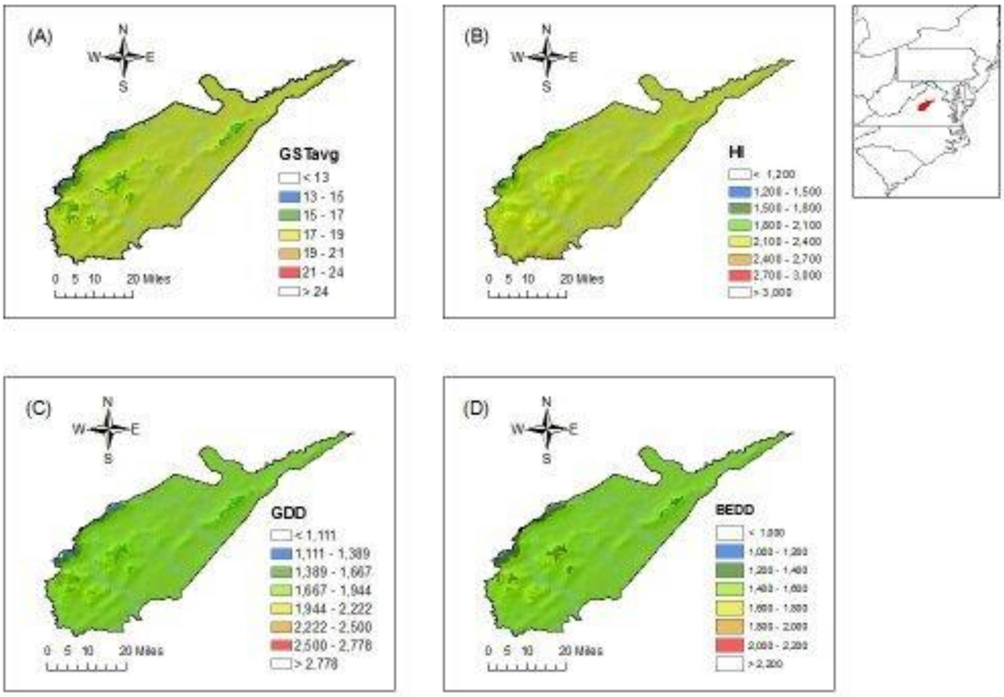
Quartile Statistics:

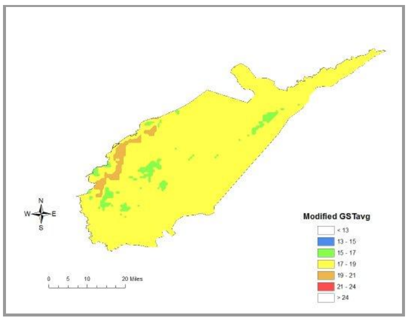
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	12	17	18	19	20
HI	1175	2052	2321	2442	2720
GDD	705	1531	1807	1990	2265
BEDD	731	1393	1522	1602	1714
Modified GSTavg	11	20	22	25	29

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Warm to Hot (25% to Maximum quartile range)
HI: Temperate to Very Warm (25% to Maximum quartile range)
GDD: Cool, Region II to Temperate, Region III (Median to Maximum quartile range)
BEDD: Temperate to Warm Temperate (Median to Maximum quartile range)
Modified GSTavg: Cool to Hot (Full quartile range)

Monticello AVA





Highlights:

- 741,437.3 total acres (300,059.7 hectares)
- 694 planted acres (280.9 hectares)
- Vineyard size ranges from 3 acres (1.2 hectares) to 220 acres (89 hectares)
- 21+ commercial vineyards
- Elevation range:91 m to 1063m (median value 182m)

Climate indices original characterization:
GSTavg: Cool (1%); Intermediate (7%); Warm (92%)
HI: Cool (1%); Temperate (3%); Warm Temperate (93%); Warm (3%)
GDD: Very Cool, Region I (2%); Cool, Region II (5%); Temperate, Region III (93%)
BEDD: Very Cool, Region I (1%); Cool (5%); Temperate (94%)
Modified GSTavg: Intermediate (4%); Warm (93%); Hot (3%)

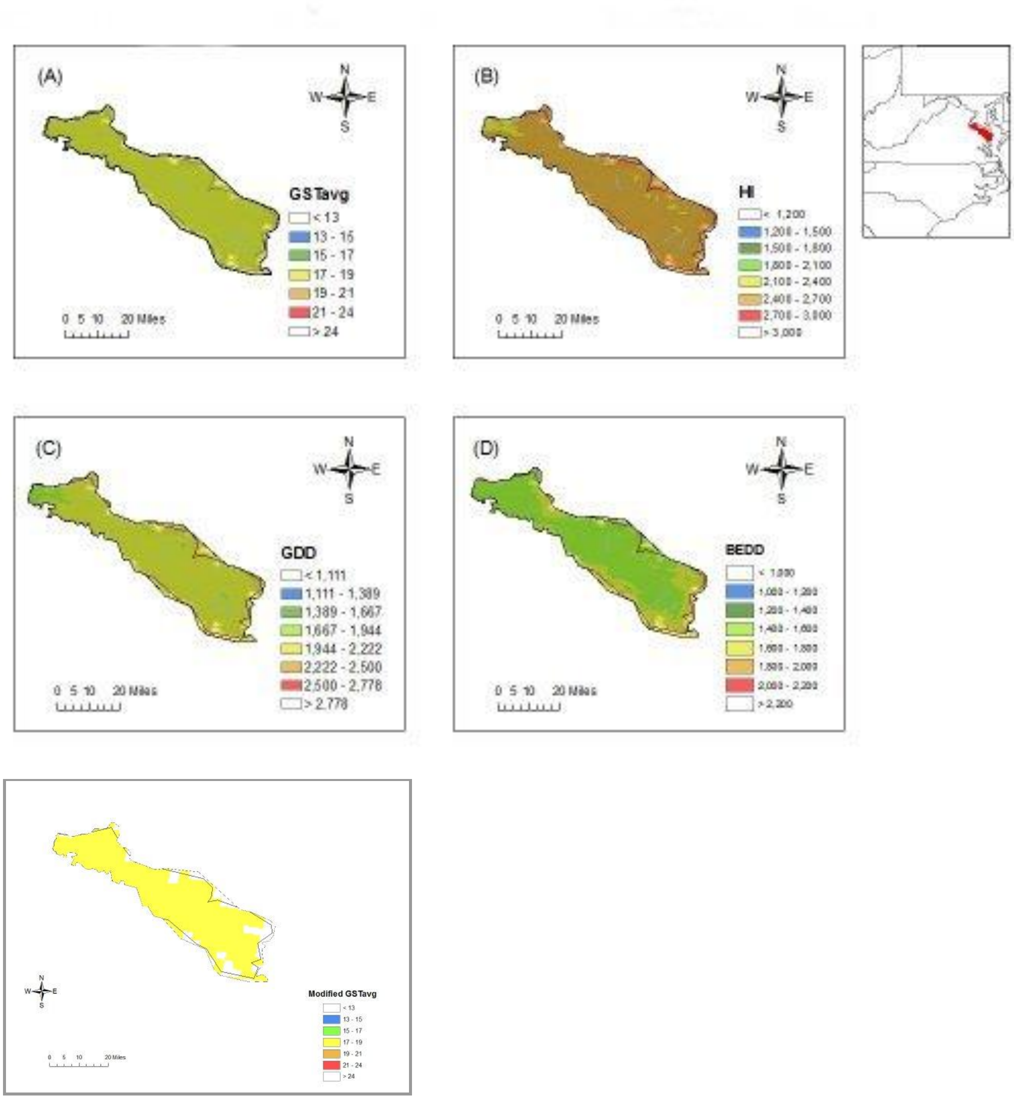
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16	18	18	18	18
HI	1953	2264	2323	2324	2445
GDD	1409	1776	1807	1807	1897
BEDD	1240	1511	1518	1526	1586
Modified GSTavg	22	22	22	22	24

Factors affecting alteration of characterizations:
- Coolest maturity classes found at higher elevations

Final characterization:
GSTavg: Cool to Warm (Full quartile range)
HI: Coo to Warm (Full quartile range)
GDD: Warm Temperate to Warm (25% to Maximum quartile range)
BEDD: Temperate (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (Full quartile range)

Northern Neck George Washington Birthplace AVA



Highlights:

- 674,564 total acres (272,996 hectares)
- 107 planted acres (43.3 hectares)
- Vineyard size ranges from 5 acres (2 hectares) to 65 acres (26.3 hectares)
- 6+ commercial vineyards
- Elevation range: 0 m to 55m (median value 18m)

Climate indices original characterization:
GSTavg: Warm (100%)
HI: Warm Temperate (5%); Warm (95%);
GDD: Temperate, Region III (4%); Warm Temperate, Region IV (96%)
BEDD: Temperate (70%); Warm Temperate (30%)
Modified GSTavg: Warm (100%)

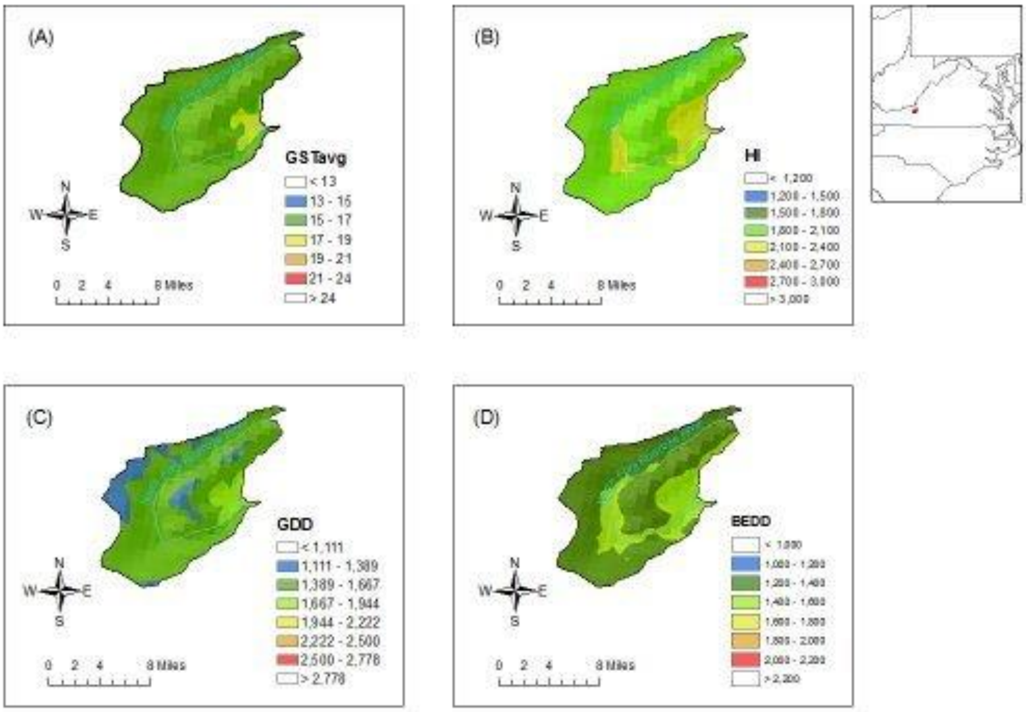
Quartile Statistics:

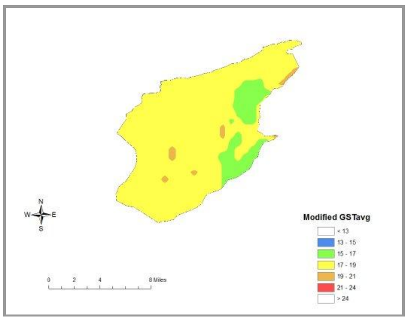
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	18	19	19	19	19
HI	2357	2419	2449	2480	2543
GDD	1867	1991	2036.5	2052	2112
BEDD	1497	1575	1589	1611	1622
Modified GSTavg	23	23	23	23	23

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Warm (Full quartile range)
HI: Warm Temperate to Warm (Full quartile range)
GDD: Temperate to Warm Temperate (Full quartile range)
BEDD: Temperate to Warm Temperate (Full quartile range)
Modified GSTavg: Warm (Full quartile range)

North Fork of Roanoke AVA





Highlights:

- 56,575 total acres (22,896 hectares)
- 21 planted acres (8.5 hectares)
- 1+ commercial vineyards
- Elevation range: 398 m to 802m (median value 570m)

Climate indices original characterization:
GSTavg: Intermediate (94%); Warm (6%)
HI: Temperate (74%); Warm Temperate (26%)
GDD: Very Cool, Region I (19%); Cool, Region II (74%); Temperate, Region III (7%)
BEDD: Cool (72%); Temperate (28%)
Modified GSTavg: Intermediate (83%); Warm (17%)

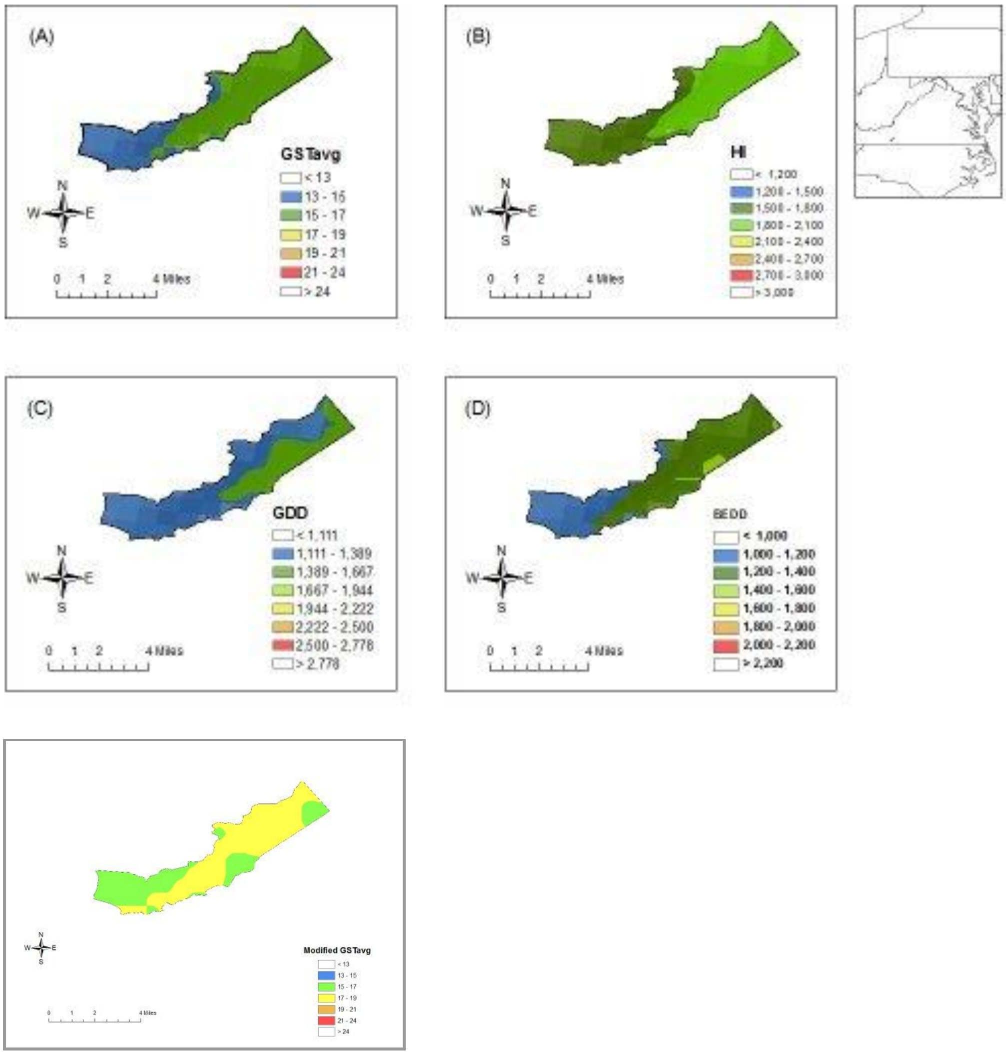
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16	16	16	17	17
HI	1917	1949	1980	2011	2102
GDD	1378	1440	1471	1501	1592
BEDD	1276	1315	1354	1377	1414
Modified GSTavg	22	23	23	23	23

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Intermediate to Warm (Full quartile range)
HI: Temperate to Warm Temperate (Full quartile range)
GDD: Very Cool to Temperate (Full quartile range)
BEDD: Cool to Temperate (Full quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Rocky Knob AVA



Highlights:

- 9,199.6 total acres (3723 hectares)
- No commercial vineyards
- Elevation range:550 m to 1007m (median value 835m)

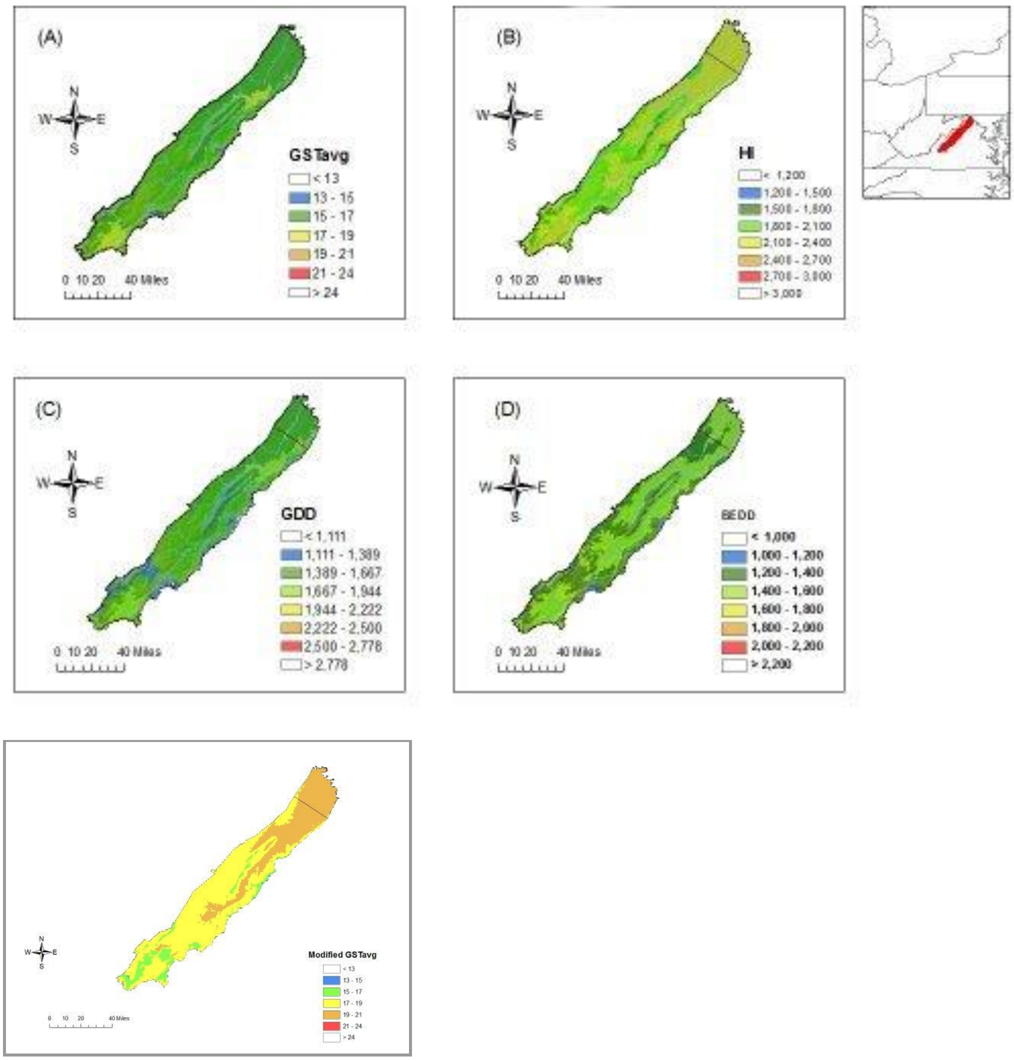
Climate indices original characterization:
GSTavg: Cool (36%); Intermediate (64%)
HI: Cool (46%); Temperate (52%); Warm Temperate (2%)
GDD: Very Cool, Region I (73%); Cool, Region II (27%)
BEDD: Very Cool (57%); Cool (36%); Temperate (7%)
Modified GSTavg: Intermediate, Warm (Percentages could not be calculated)

Quartile Statistics:
Could not be calculated due to size of AVA.

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Cool to Intermediate (Full quartile range)
HI: Cool to Warm Temperate (Full quartile range)
GDD: Very Cool to Cool (Full quartile range)
BEDD: Very Cool to Temperate (Full quartile range)
Modified GSTavg: Intermediate to Warm

Shenandoah Valley AVA



Highlights:

- 2,327,323 acres (941,867.6 hectares)
- 300 acres planted acres (121.4 hectares) ranging in size from 2 – 100 acres (0.8 – 40.5 hectares)
- 15+ commercial vineyards
- Elevation range: 121 m to 1139 m (median value of 379 m)

Climate indices original characterization:
GSTavg: Cool (6%); Intermediate (86%); Warm (8%)
HI: Cool (6%); Temperate (39%); Warm Temperate (54%)
GDD: Very Cool, Region I (15%); Cool, Region II (73%); Temperate, Region III (12%)
BEDD: Very Cool (4%); Cool (40%); Temperate (55%)
Modified GSTavg: Cool (0.5%); Intermediate (9.5%); Warm (57%); Hot (33%)

Quartile Statistics:

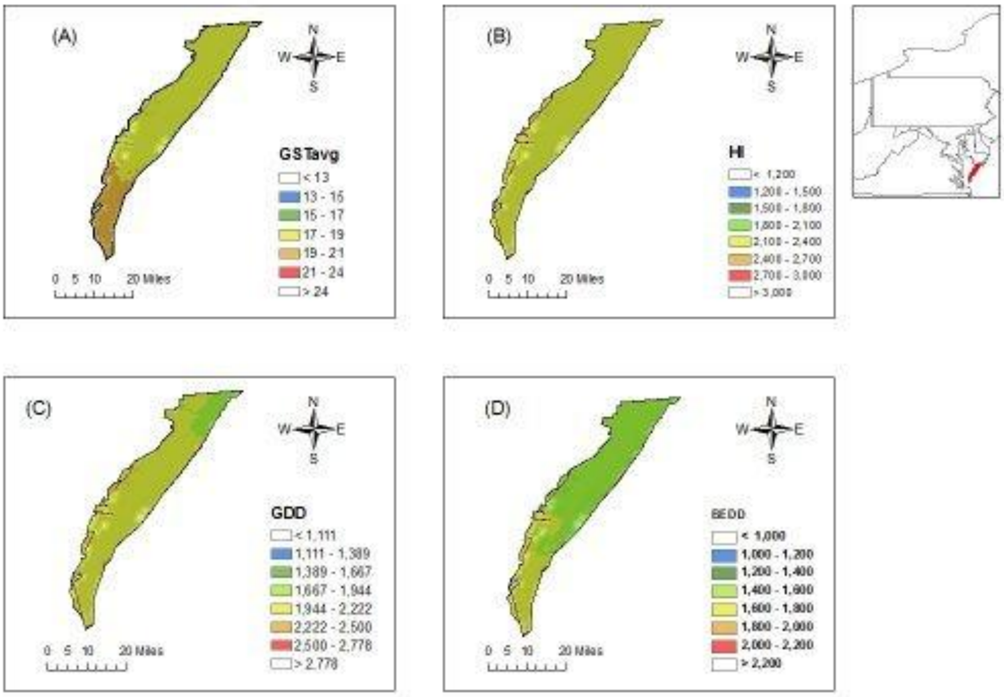
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	17	17	17	18
HI	1429	2048	2114	2205	2415
GDD	980	1501	1562	1638	1867
BEDD	995	1375	1402	1445	1593
Modified GSTavg	21	23	23	24	24

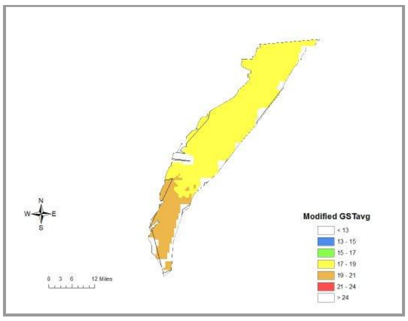
Factors affecting alteration of characterizations:

- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes are found at higher elevations where it is unsuitable for planting

Final characterization:
GSTavg: Intermediate to Warm (25% to Maximum quartile range)
HI: Temperate to Warm Temperate (25% to Maximum range)
GDD: Cool, Region II to Temperate, Region III (Median to Maximum quartile range)
BEDD: Temperate (Median to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (Full quartile range)

Virginia’s Eastern Shore AVA





Highlights:

- 331,764.8 total acres (134,265.2 hectares)
- 42 planted acres (17 hectares)
- Vineyard size ranges from 4 acres (1.6 hectares) to 20 acres (8 hectares)
- 4+ commercial vineyards
- Elevation range: 0 m to 16m (median value 6m)

Climate indices original characterization:
GSTavg: Warm (79%); Hot (21%)
HI: Warm Temperate (100%)
GDD: Temperate, Region III (11%); Warm Temperate, Region IV (89%)
BEDD: Temperate (72%); Warm Temperate (28%)
Modifed GSTavg: Warm (82%); Hot (18%)

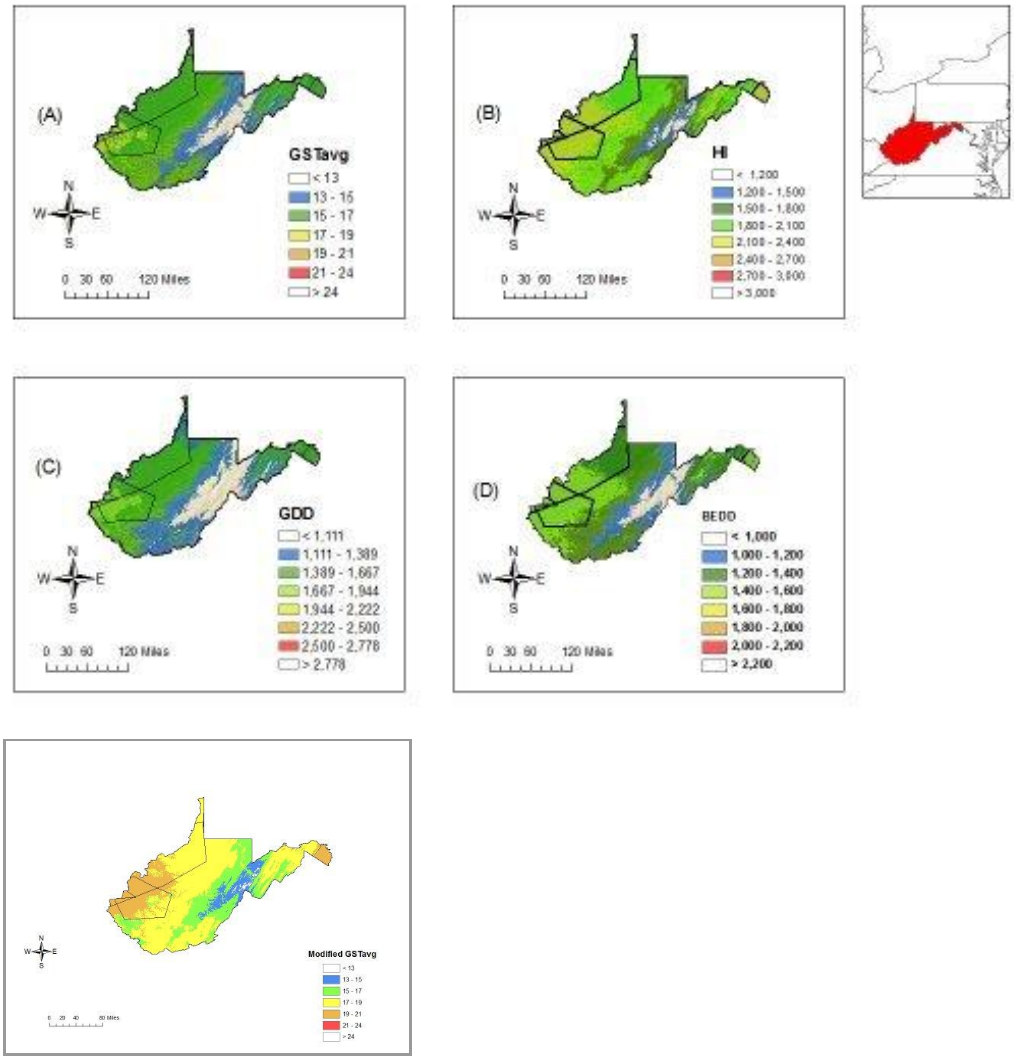
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	19	19	19	19	20
HI	2168	2261	2351	2381	2383
GDD	1929	1990	2021	2112	2143
BEDD	1465	1534	1550	1603	1626
Modified GSTavg	23	23	23	23.5	24

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Warm to Hot (Full quartile range)
HI: Warm Temperate (Full quartile range)
GDD: Temperate to Warm Temperate (Full quartile range)
BEDD: Temperate to Warm Temperate (Full quartile range)
Modifed GSTavg: Warm to Hot (Full quartile range)

West Virginia



Highlights:

- 24,229 square miles
- 147 planted acres (59.5 hectares)
- 15+ commercial vineyards
- Ranked 32nd in US production (51,746 gal/yr)

- 3 AVAs within states' borders (Kanawha River Valley, Ohio River Valley and Shenandoah Valley)
- Elevation range: 73.2 m to 1482.2 m
- Cfa, Dfa and Dfb Koppen classification
- Most common *V. Vinifera* varietals grown are Chardonnay, Reisling and Pinot Noir, and French Hybrid varietals of Seval Blanc, Vidal Blanc, Cayuga, Chancellor, Chambourcin, Niagara and Foch.

Climate indices original characterization:
GSTavg: Too Cool; Cool; Intermediate; Warm
HI: Too Cool; Cool; Temperate; Warm Temperate
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III
BEDD: Too Cool; Cool; Temperate
Modified GSTavg: Too Cool; Cool; Intermediate; Warm, Hot

Quartile Statistics:

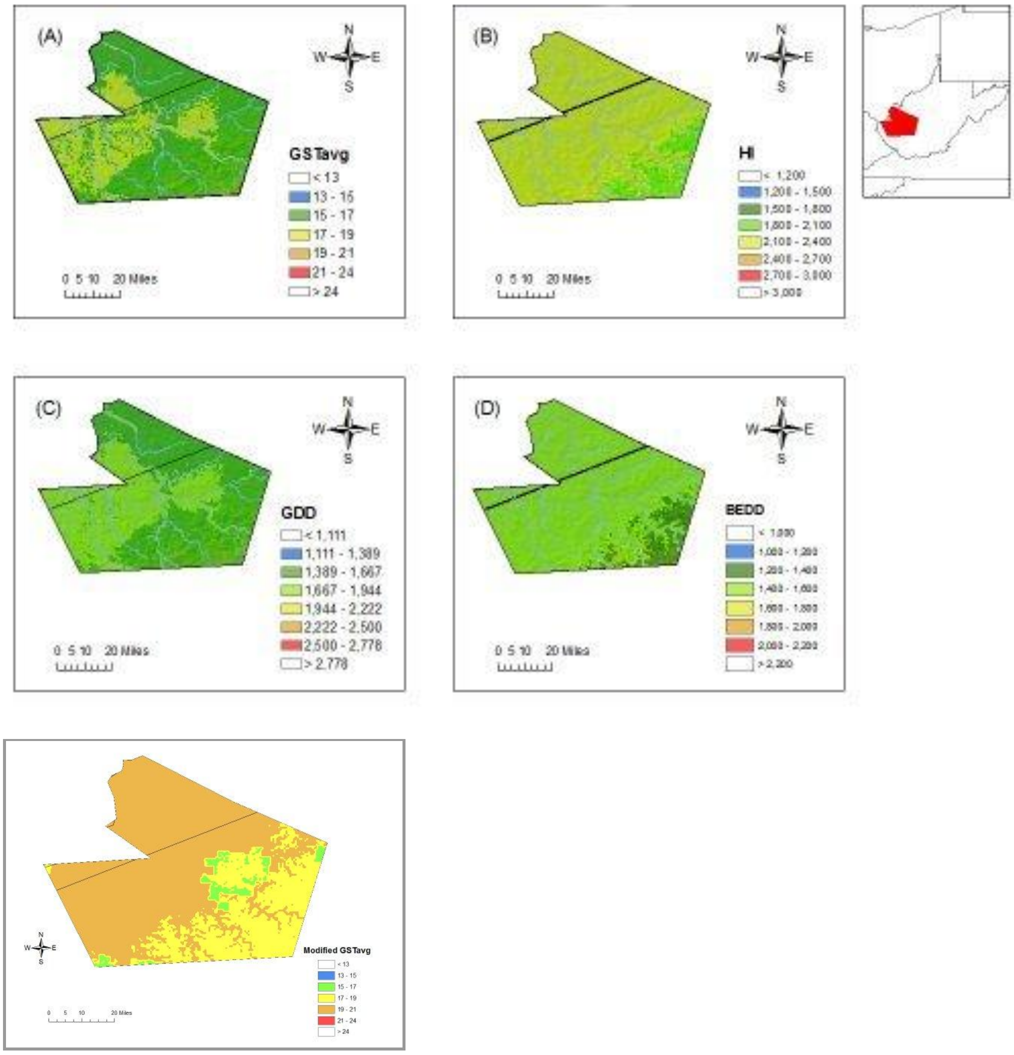
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	10	15	16	17	18
HI	841	1745	2011	2138	2326
GDD	399	1195	1409	1562	1776
BEDD	406	1177	1327	1414	1581
Modified GSTavg	18	20	22	25	30

Factors affecting alteration of characterizations:

- Already established productive vineyards
- Many areas suited for crop farming
- Coolest characterizations found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Intermediate to Warm (25% to Maximum quartile range)
HI: Temperate to Warm Temperate (25% to Maximum quartile range)
GDD: Cool, Region II to Warm Temperate, Region IV (Median to Maximum quartile range)
BEDD: Cool to Temperate (Median to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (Full quartile range)

Kanawha River Valley AVA



Highlights:

- 1,762,205 total acres (713,164.4 hectares)
- 7 planted acres (2.8 hectares)
- 1+ commercial vineyards
- Elevation range: 183 m to 629m (median value of 273m)

Climate indices original characterization:
GSTavg: Intermediate (70%); Warm (30%)
HI: Temperate (10%); Warm Temperate (90%)
GDD: Cool, Region II (57%); Temperate (43%)
BEDD: Cool (10%); Temperate (90%)
Modified GSTavg: Intermediate (4%); Warm (27%); Hot (69%)

Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16	17	17	18	18
HI	1891	2140	2232	2234	2295
GDD	1348	1562	1653	1714	1776
BEDD	1241	1405	1458	1497	1558
Modified GSTavg	22	23	24	24	24

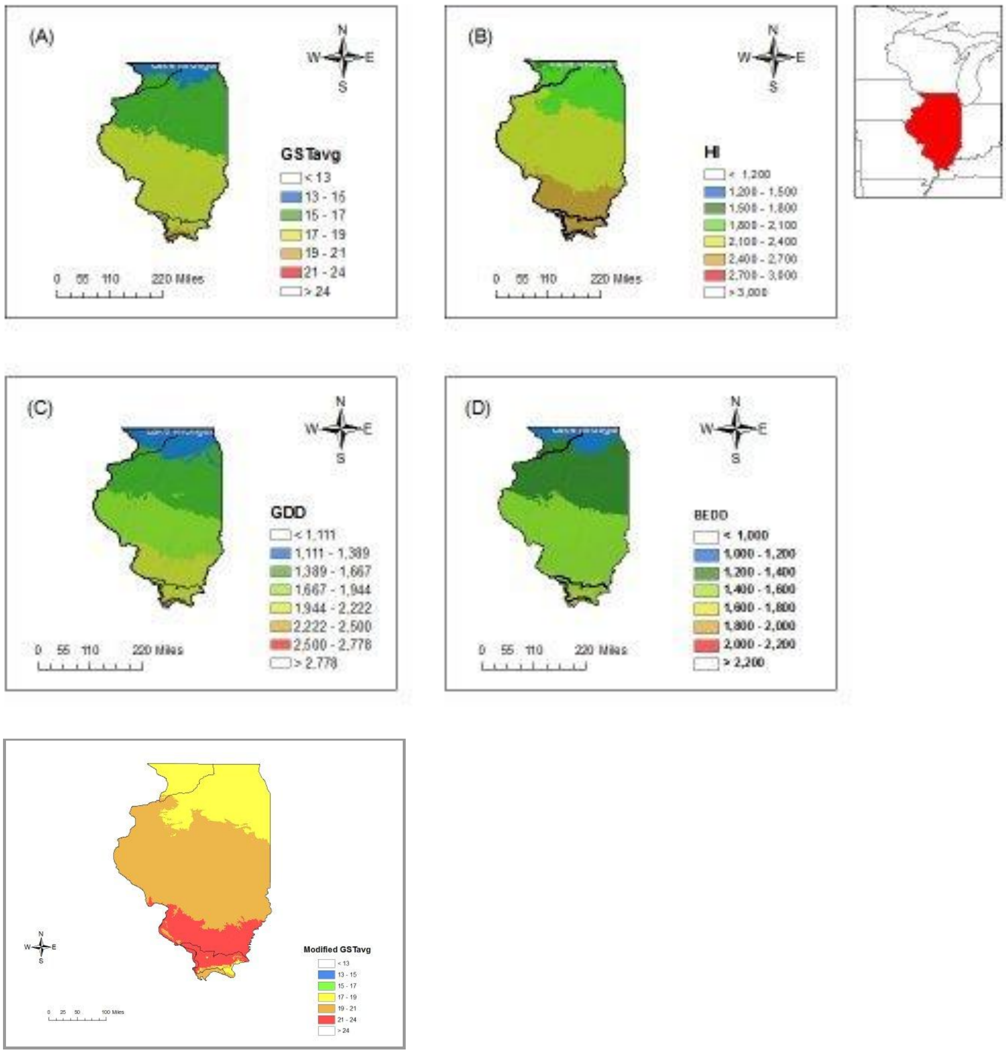
Factors affecting alteration of characterizations:

- Coolest maturity classes are found at higher elevations, where it is unsuitable for planting

Final characterization:
GSTavg: Intermediate to Warm (Full quartile range)
HI: Temperate to Warm Temperate (Full quartile range)
GDD: Cool, Region II to Temperate (Median to Maximum quartile range)
BEDD: Temperate (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (Full quartile range)

Mid-West

Illinois



Highlights:

- 56,299 square miles
- 698 planted acres (282.5 hectares)
- 49+ commercial vineyards
- 2 AVAs (Upper Mississippi River Valley and Shawnee Hills)
- Ranks 19th in US production (391,676 gal/yr)
- Elevation range: 85 m to 376.4 m
- Cfa, Dfa and Dfb Koppen Classification

- Most common winegrapes grown are French Hybrid varietals of Seval Blanc, Vidal Blanc, Chambourcin, Chardonel, Traminette, Norton and Foch.

Climate indices original characterization:
GSTavg: Cool, Intermediate, Warm, Hot
HI: Cool, Temperate, Warm Temperate, Warm
GDD: Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V
BEDD: Very Cool, Cool, Temperate, Warm Temperate
Modified GSTavg: Warm, Hot, Very Hot

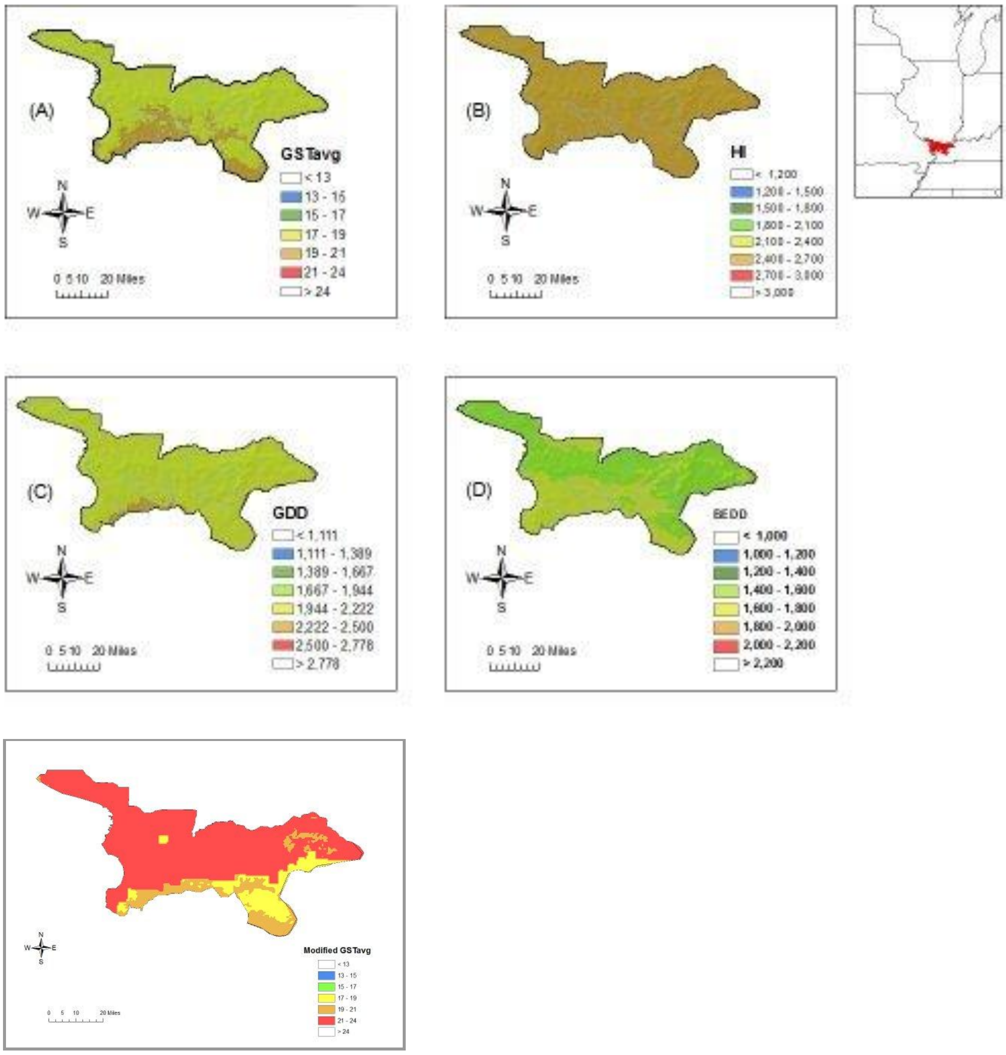
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	17	18	18	20
HI	1637	2067	2245	2360	2689
GDD	1225	1531	1714	1867	2265
BEDD	1131	1291	1409	1499	1687
Modified GSTavg	9	20	22	25	30

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Cool to Hot (Full quartile range)
HI: Cool to Warm (Full quartile range)
GDD: Cool, Region II to Warm, Region V (25% to Maximum quartile range)
BEDD: Cool to Warm Temperate (25% to Maximum quartile range)
Modified GSTavg: Warm to Very Hot (25% to Maximum quartile range)

Shawnee Hills AVA



Highlights:

- 1,443,864.4 total acres (440,090 hectares)
- 225 planted acres (68.6 hectares)
- Vineyard size ranges from 2 acres (0.8 hectares) to 150 acres (45.7 hectares)
- 12+ commercial vineyards
- Elevation range: 91 m to 283m (median value 147m)

Climate indices original characterization:
GSTavg: Warm (81%);Hot (19%)
HI: Warm (100%)
GDD: Warm Temperate, Region IV (96%); Warm, Region V (4%)
BEDD: Temperate (53%); Warm Temperate (47%)
Modified GSTavg: Warm (10%); Hot (16%); Very Hot (74%)

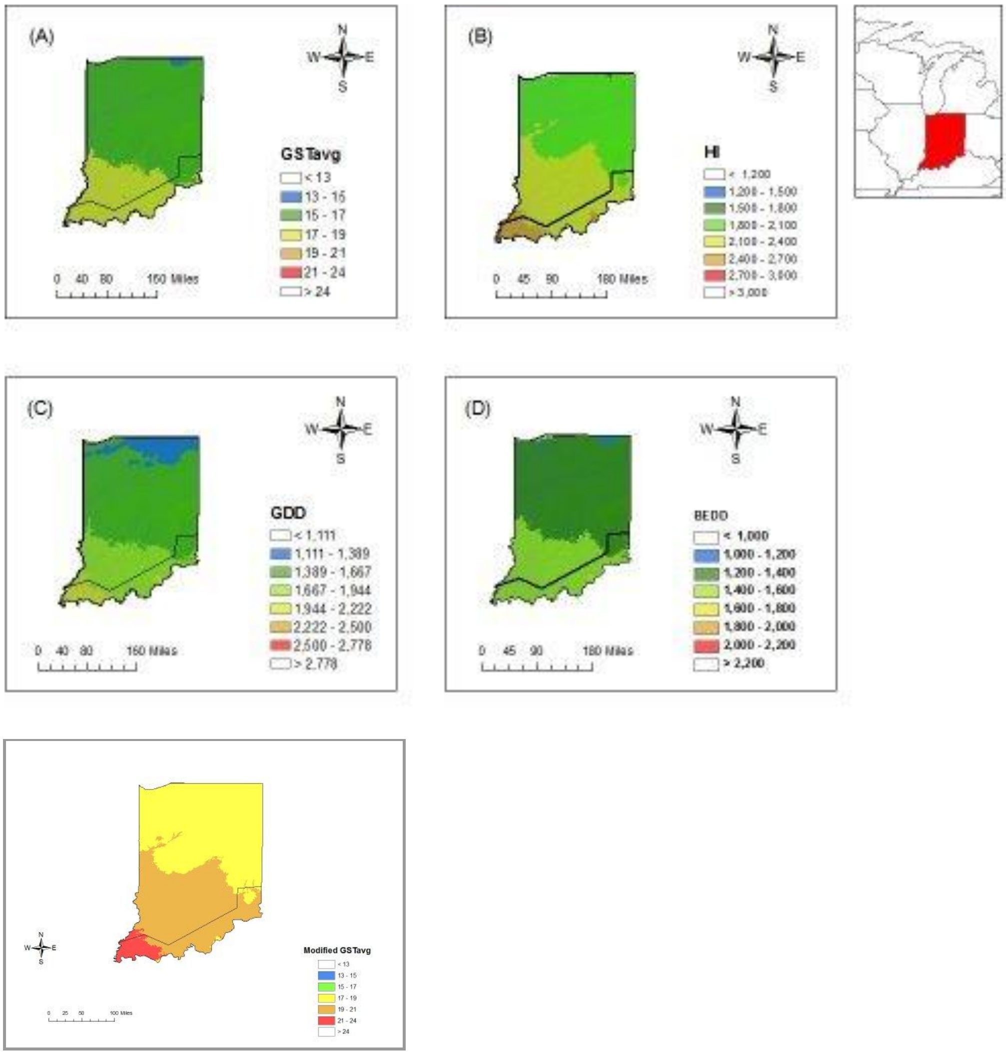
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	19	19	19	19	20
HI	2414	2506	2507	2537	2660
GDD	1959	2051	2051	2082	2235
BEDD	1577	1579	1588	1610	1680
Modified GSTavg	23	24.25	26	26	26

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Warm to Hot (Full quartile range)
HI: Warm (Full quartile range)
GDD: Warm Temperate to Warm (Full quartile range)
BEDD: Temperate to Warm Temperate (Full quartile range)
Modified GSTavg: Warm to Very Hot (Full quartile range)

Indiana



<u>**Highlights:**</u>

- 36,400 square miles
- 225 planted acres (91.1 hectares)
- 26+ commercial vineyards
- 1 AVA (Ohio River Valley)
- Ranks 14^{th} in US production (767,816 gal/yr)
- Elevation range: 97.5 m to 383 m

- Cfa, Dfa and Dfb Koppen Classification
- Most commonly grown are French Hybrid varietals of Seval Blanc, Vidal Blanc, Chambourcin, Chardonel, Traminette and Foch.

Climate indices original characterization:
GSTavg: Cool, Intermediate, Warm
HI: Cool, Temperate, Warm Temperate, Warm
GDD: Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV
BEDD: Very Cool, Cool, Temperate, Warm Temperate
Modified GSTavg: Intermediate, Warm, Hot

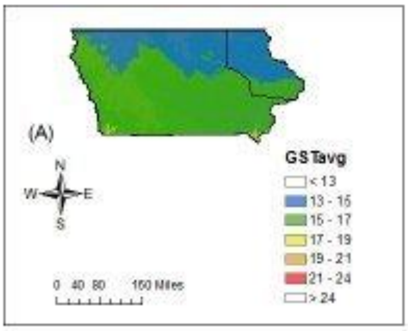
Quartile Statistics:

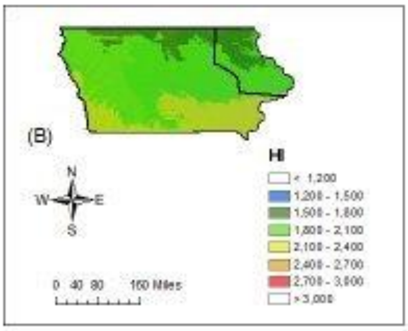
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	16	17	18	19
HI	1790	1942	2060	2267	2512
GDD	1256	1409	1531	1776	2051
BEDD	1161	1254	1296	1471	1619
Modified GSTavg	8	19	21	24	30

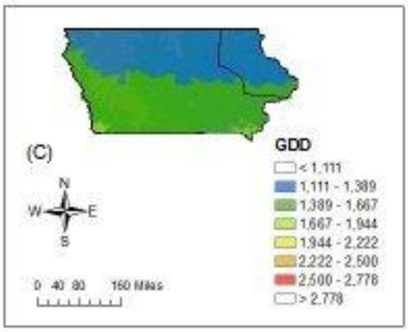
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

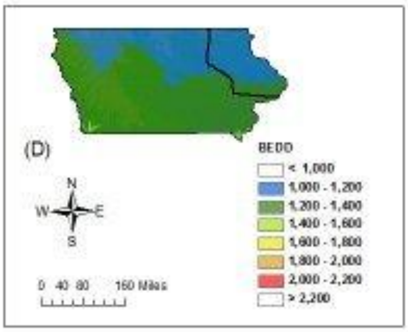
Final characterization:
GSTavg: Cool to Warm (Full quartile range)
HI: Cool to Warm (Full quartile range)
GDD: Cool, Region II to Warm Temperate, Region IV (25% to Maximum quartile range)
BEDD: Cool to Warm Temperate (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (25% to Maximum quartile range)

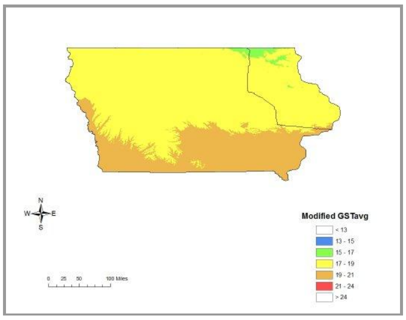
Iowa











Highlights:

- 56,258 square miles
- 281 planted acres (113.7 hectares)
- 41+ commercial vineyards
- Ranks 23rd in US production (234,466 gal/yr)
- Elevation range: 85 m to 146 m
- Dfa and Dfb Koppen Classification

- Most common varietals that are grown in are French Hybrid varietals, such as La Crosse, La Crescent, Edelweiss, Saint Croix, Frontenac, Marquette, and Foch.

Climate indices original characterization:
GSTavg: Cool, Intermediate, Warm
HI: Cool, Temperate, Warm Temperate
GDD: Very Cool, Region I; Cool, Region II; Temperate, Region III
BEDD: Very Cool, Cool, Temperate
Modified GSTavg: Intermediate, Warm, Hot

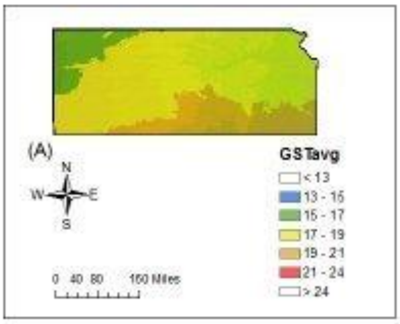
Quartile Statistics:

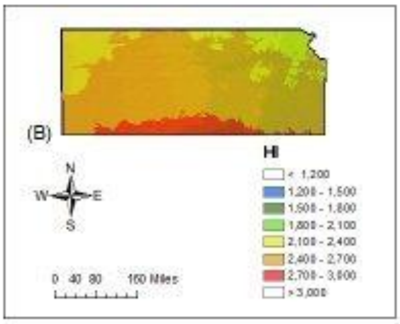
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	15	16	17	18
HI	1674	1857	1979	2097	2314
GDD	1164	1317	1409	1532	1807
BEDD	1105	1175	1242	1287	1469
Modified GSTavg	9	19	22	25	30

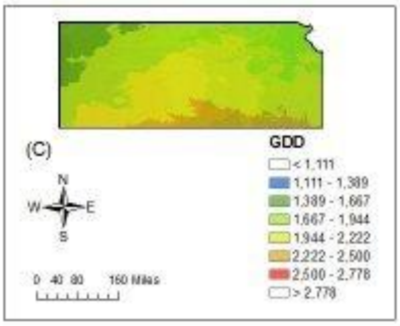
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

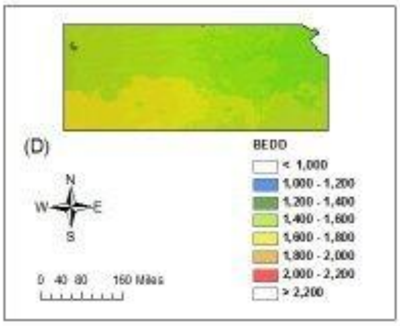
Final characterization:
GSTavg: Cool to Warm (Full quartile range)
HI: Cool to Warm Temperate (Full quartile range)
GDD: Cool, Region II to Temperate, Region III (Median to Maximum quartile range)
BEDD: Cool to Temperate (Median to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (25% to Maximum quartile range)

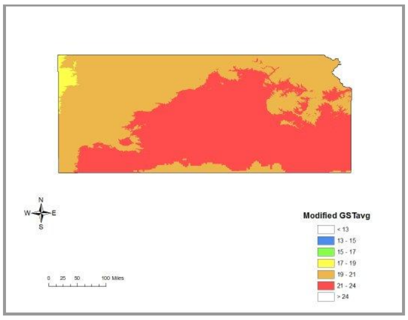
Kansas











<u>Highlights:</u>

- 82,197 square miles
- 188 planted acres (76.1 hectares)
- 10+ commercial vineyards
- and Shawnee Hills)
- Ranks in US production (69,583gal/yr)
- Elevation range: 207 m to 1231 m
- Dfa, Dfc and Dwa Koppen Classification

- Most commonly grown *V. Vinifera* are Cabernet Franc and Syrah; French Hybrid varietals, such as Chambourcin, Cynthia (Norton), Sevyal and Tramminette, and American varietals Concord and Niagara

Climate indices original characterization:
GSTavg: Intermediate, Warm, Hot
HI: Warm Temperate, Warm, Very Warm
GDD: Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V
BEDD: Cool, Temperate, Warm Temperate
Modified GSTavg: Warm, Hot, Very Hot

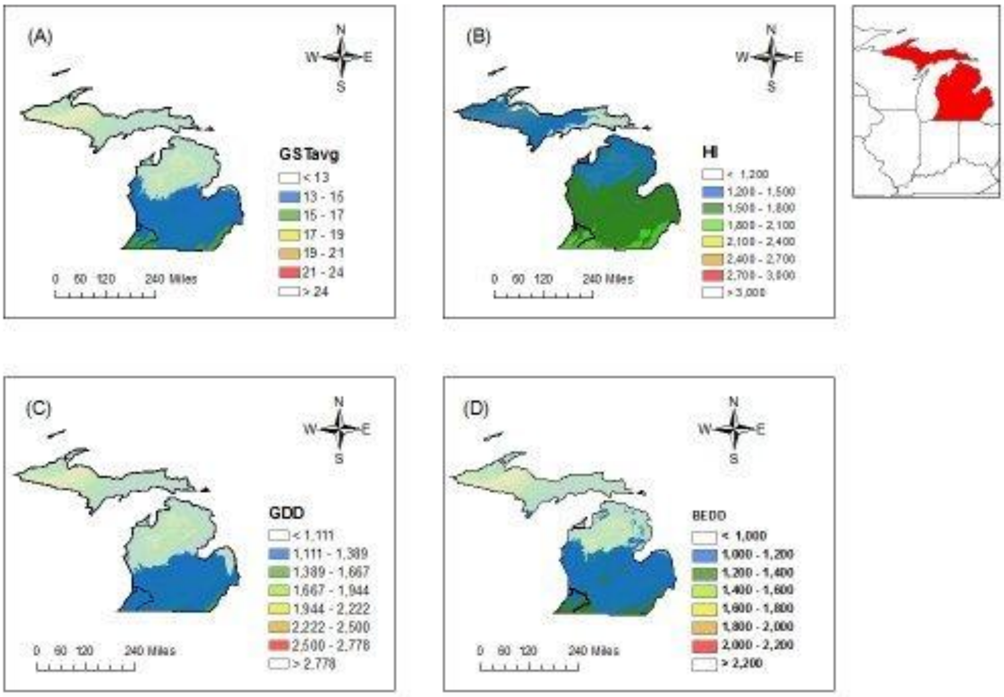
Quartile Statistics:

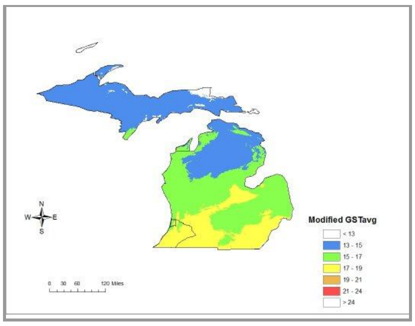
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16	18	19	19	21
HI	2116	2428	2521	2632	2935
GDD	1440	1838	1961	2083	2419
BEDD	1382	1511	1561	1632	1792
Modified GSTavg	10	19	22	24	31

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Intermediate to Hot (Full quartile range)
HI: Warm Temperate to Very Warm (Full quartile range)
GDD: Temperate, Region III to Warm, Region V (25% to Maximum quartile range)
BEDD: Temperate to Warm Temperate (25% to Maximum quartile range)
Modified GSTavg: Warm to Very Hot (25% to Maximum quartile range)

Michigan





Highlights:

- 57,899 square miles
- 1825 planted acres (738.6 hectares)
- 46+ commercial vineyards
- 3 AVAs and 1 sub-AVA (AVAs: Lake Michigan Shore, Old Mission Peninsula, Leelanau Peninsula; sub-AVA: Fennville)
- Ranked 12th in US production data (1,063,561)
- Elevation range: 174 m to 603.2 m

- Dfa and Dfb Koppen Classification
- Most common *V. Vinifera* varietals grown are Reisling, Pinot Gris/Grigo, Cabernet Franc, and Gewurztraminer, and French Hybrid varietals of Vidal Blanc, Concord and Niagara.

Climate indices original characterization:
GSTavg: Too Cool; Cool, Intermediate
HI: Too Cool, Very Cool, Cool, Temperate
GDD: Too Cool; Very Cool, Region I; Cool, Region II
BEDD: Too Cool; Very Cool, Cool
Modified GSTavg: Cool, Intermediate, Warm

Quartile Statistics:

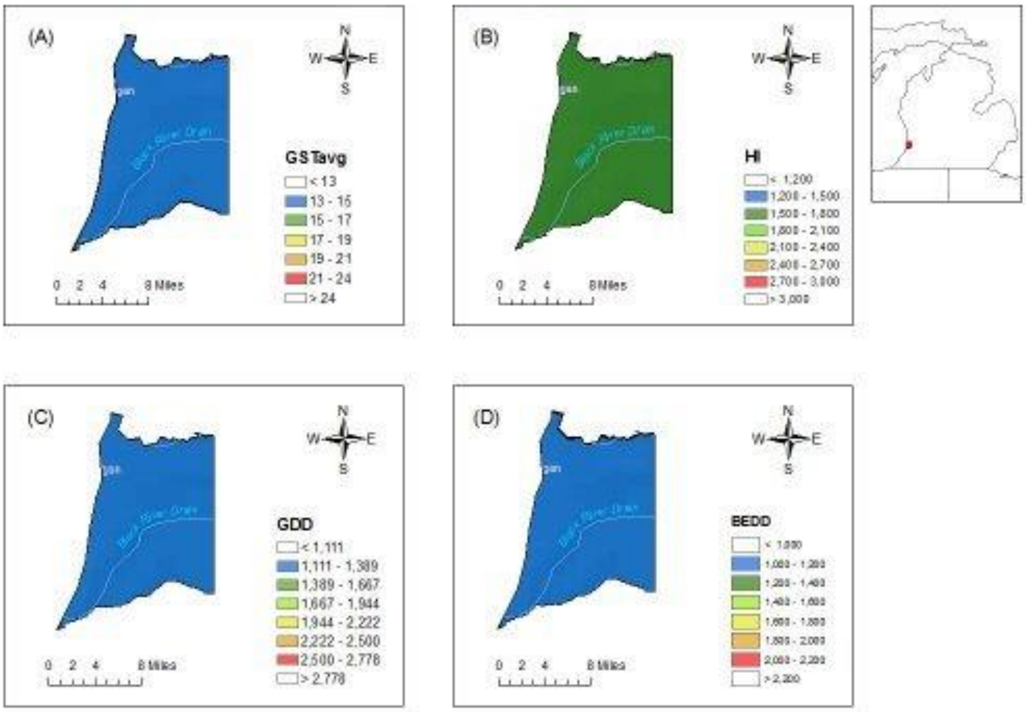
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	10	12	13	15	16
HI	837	1309	1496	1702	2041
GDD	461	767	919	1194	1531
BEDD	461	844	1003	1133	1287
Modified GSTavg	8	19	21	23	30

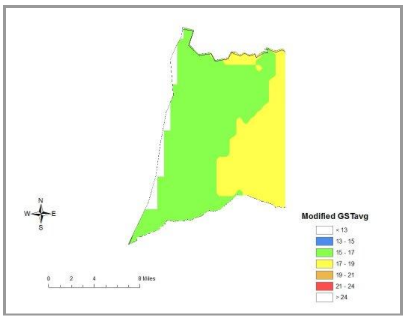
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Cool to Intermediate (75% to Maximum quartile range)
HI: Cool to Temperate (75% to Maximum quartile range)
GDD: Very Cool, Region I to Cool, Region II (75% to Maximum quartile range)
BEDD: Very Cool to Cool (75% to Maximum quartile range)
Modified GSTavg: Cool to Warm (Minimum to 75% quartile range)

** Range of statistical values for the standard indices may not fully capture the climate structure of the state.**

Fennville sub-AVA





Highlights:

- 73,038 total acres (29,558.5 hectares)
- 136 planted acres (55 hectares)
- Vineyard size ranges from 60 acres (24.3 hectares) to 76 acres (30.8 hectares)
- 2+ commercial vineyards
- Elevation range: 181 m to 183 m (median value of 182m)

<u>Climate indices original characterization:</u>
GSTavg: Cool (100%);
HI: Cool (100%);
GDD: Very Cool, Region I (100%);
BEDD: Very Cool (100%)
Modified GSTavg: Intermediate (80%); Warm (20%)

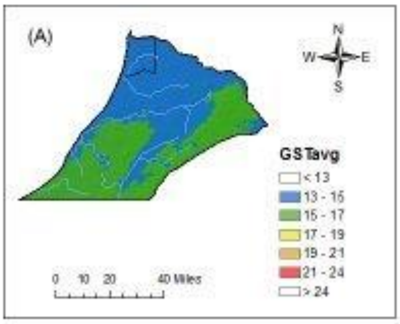
Quartile Statistics:

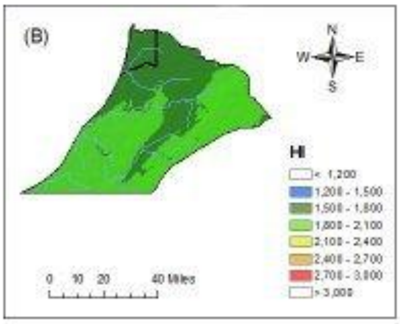
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	15	15	15	15
HI	1605	1670	1700	1731	1764
GDD	1164	1195	1224	1225	1255
BEDD	1102	1134	1163	1164	1164
Modified GSTavg	21	21	21	22	22

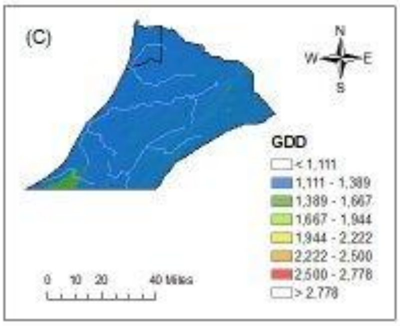
<u>Factors affecting alteration of characterizations:</u>
None

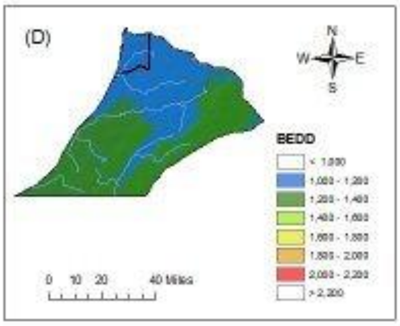
<u>Final characterization:</u>
GSTavg: Cool (Full quartile range)
HI: Cool (Full quartile range)
GDD: Very Cool (Full quartile range)
BEDD: Very Cool (Full quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

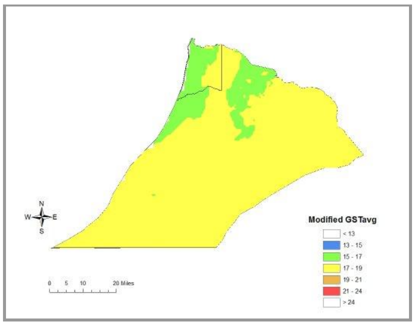
Lake Michigan Shore AVA











Highlights:

- 1,315,459 total acres (532,366.3 hectares)
- 964 planted acres (390 hectares)
- Vineyard size ranges from 5 acres (2 hectares) to 500 acres (202.4 hectares)
- 10+ commercial vineyards
- Elevation range: 176 m to 308 m (median value of 227m)

Climate indices original characterization:
GSTavg: Cool (53%); Intermediate (47%)
HI: Cool (41%); Temperate (59%)
GDD: Very Cool, Region I (98%); Cool, Region II (2%)
BEDD: Very Cool (44%); Cool (56%)
Modified GSTavg: Intermediate (14%), Warm (86%)

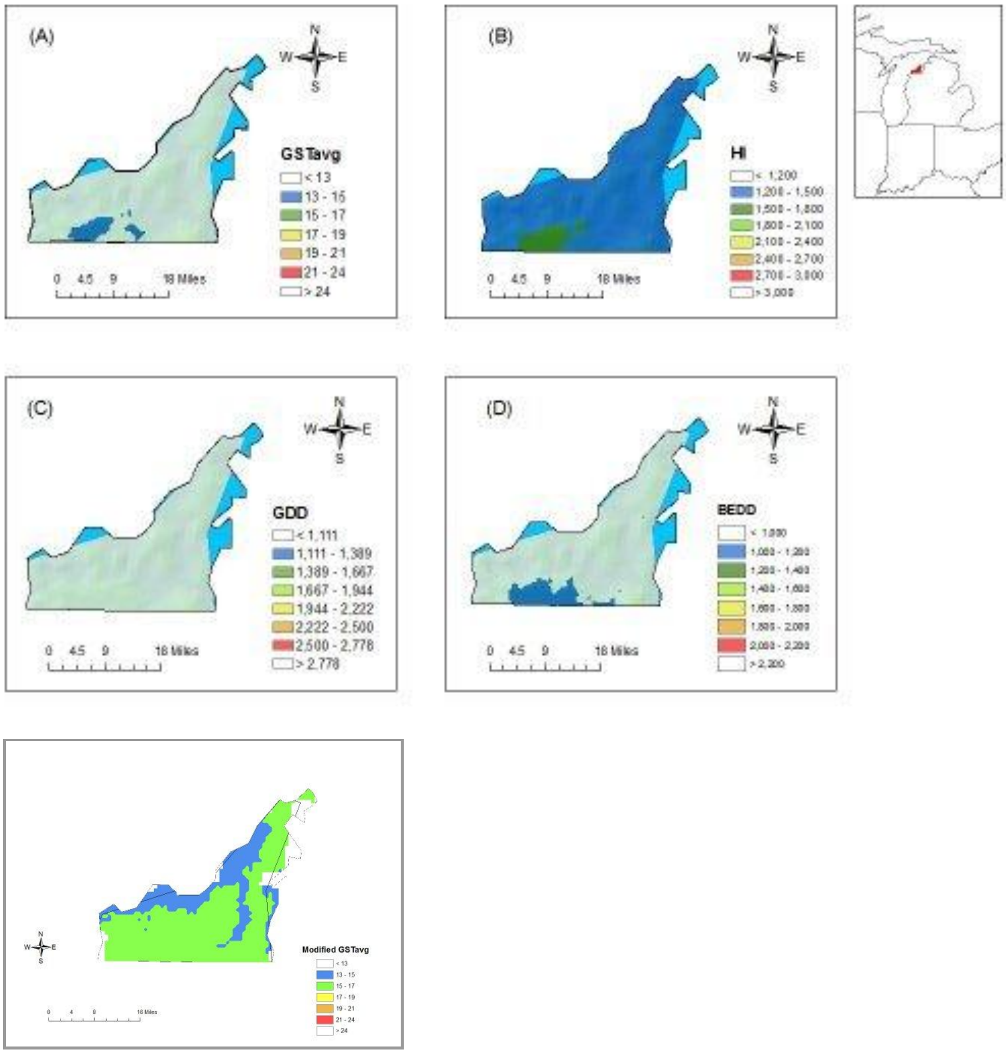
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	15	15	16	16
HI	1542	1762	1826	1856	1945
GDD	1164	1255	1318	1348	1439
BEDD	1101	1179	1224	1225	1287
Modified GSTavg	21	22	22	22	23

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Cool to Intermediate (Full quartile range)
HI: Cool to Temperate(Full quartile range)
GDD: Very Cool to Cool (Full quartile range)
BEDD: Very Cool to Cool (Full quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Leelanau Peninsula AVA



Highlights:

- 210,326.3 total acres (85,119 hectares)
- 409 planted acres (165.5 hectares)
- Vineyard size ranges from 3 acres (1.2 hectares) to 100 acres (40.5 hectares)
- 15+ commercial vineyards
- Elevation range: 176 m to 331 m (median value of 222m)

Climate indices original characterization:
GSTavg: Too Cool (95%); Cool (5%);
HI: Very Cool (95%); Cool (5%);
GDD: Too Cool (100%);
BEDD: Too Cool (90%); Very Cool (10%)
Modified GSTavg: Cool (23%); Intermediate (77%)

Quartile Statistics:

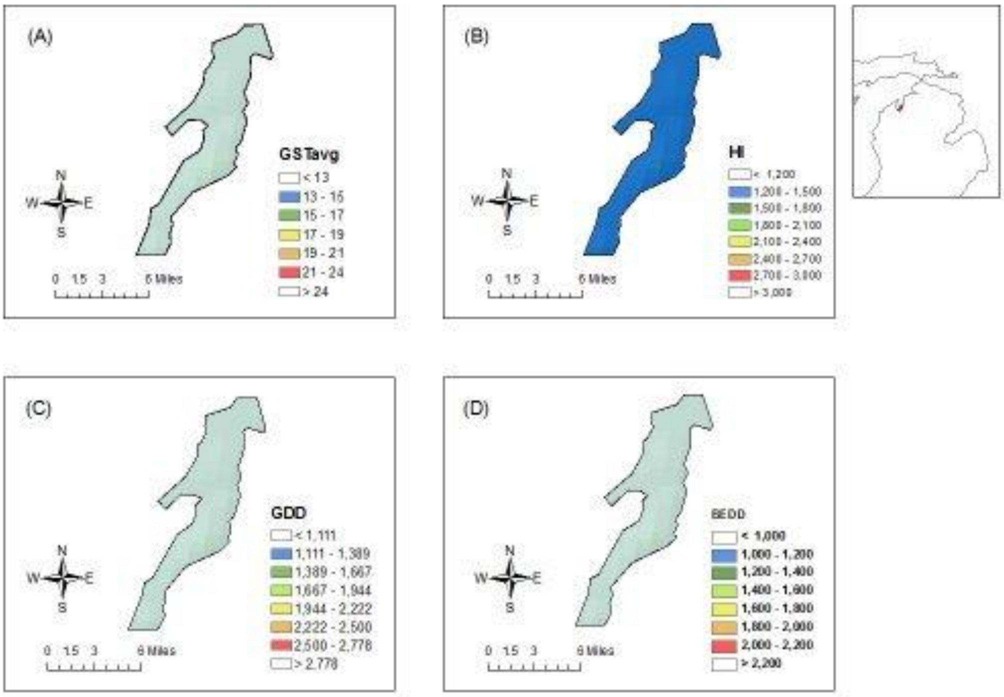
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	13	13	13	13	14
HI	1240	1382	1400	1462	1525
GDD	888	888.5	919	950	1011
BEDD	906	918	953	962	1032
Modified GSTavg	20	20	20	20	20

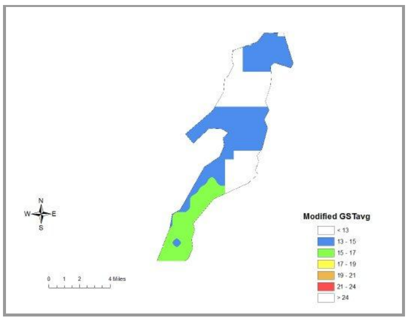
Factors affecting alteration of characterizations:
- Already established vineyards within this AVA.

Final characterization:
GSTavg: Cool (Maximum quartile range)
HI: Cool (Maximum quartile range)
GDD: Too Cool (Maximum quartile range)
BEDD: Very Cool (Maximum quartile range)
Modified GSTavg: Cool to Intermediate (Full quartile range)

** The range of statistical values for standard indices may not fully capture the climate structure of the AVA.

Old Mission Peninsula AVA





Highlights:

- 18,991.5 total acres (7,686 hectares)
- 55 planted acres (22.3 hectares)
- Vineyard size ranges from 24 acres (9.7 hectares) to 31 acres (12.5 hectares)
- 2+ commercial vineyards
- Elevation range: 177 m to 243 m (median value of 202m)

Climate indices original characterization:
GSTavg: Too Cool (100%);
HI: Very Cool (100%);
GDD: Too Cool (100%);
BEDD: Too Cool (100%)
Modified GSTavg: Too Cool, Cool, Intermediate (statistics unable to be calculated)

Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	13	13	13	13	13
HI	1366	1366	1367	1367	1367
GDD	858	858	858	858	858
BEDD	890	890	890	890	891
Modified GSTavg	19	19.25	19.5	19.75	20

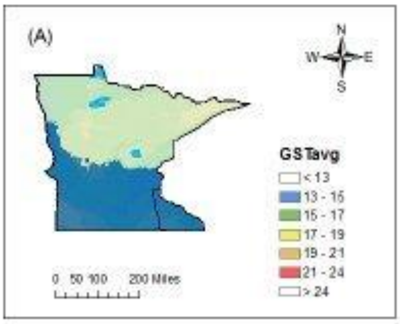
Factors affecting alteration of characterizations:

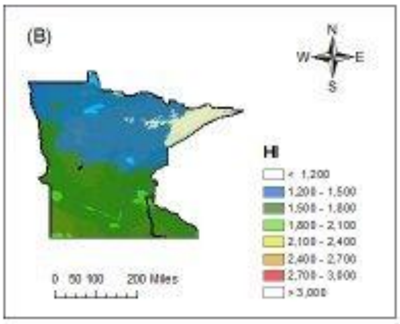
- Already established vineyards located within this AVA.

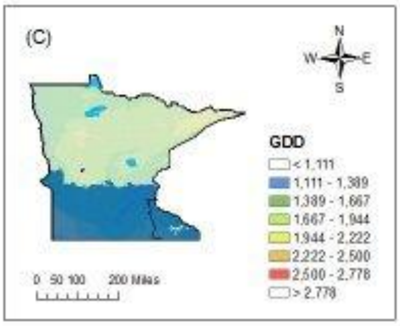
Final characterization:
GSTavg: Cool (Maximum quartile range)
HI: Cool (Maximum quartile range)
GDD: Very Cool (Maximum quartile range)
BEDD: Very Cool (Maximum quartile range)
Modified GSTavg: Cool to Intermediate (Full quartile range)

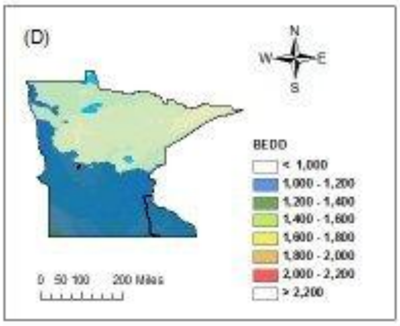
** The range of statistical values for standard indices may not fully capture the climate structure of the AVA.

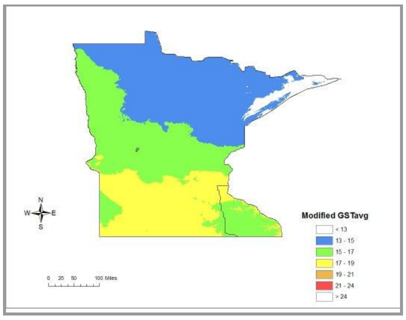
Minnesota











Highlights:

- 84,520 square miles
- 240 planted acres (97.1 hectares)
- 20+ commercial vineyards
- 2 AVAs (Upper Mississippi River Valley and Alexandria Lakes)
- Ranked 34th in US production (35,193 gal/yr)
- Elevation range: 183 m to 701 m
- Dfa and Dfb Koppen Classification

- Most commonly grown are French Hybrid varietals of La Crescent, Saint Croix, Frontenac, Frontenac Gris, Marquette, and Prairie Star.

Climate indices original characterization:
GSTavg: Too Cool; Cool
HI: Too Cool; Very Cool; Cool; Temperate
GDD: Too Cool; Very Cool, Region I
BEDD: Too Cool; Very Cool; Cool
GSTavg: Too Cool; Cool, Intermediate, Warm

Quartile Statistics:

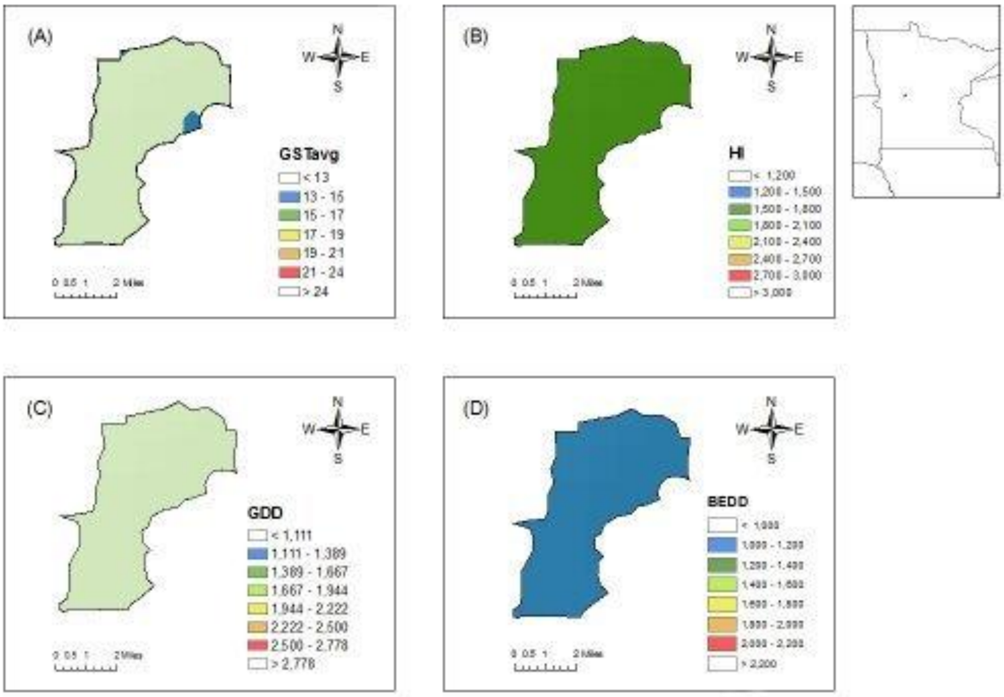
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	9	12	13	14	15
HI	741	1314	1480	1688	1865
GDD	401	767	951	1164	1317
BEDD	390	847	989	1122	1213
Modified GSTavg	8	19	22	25	30

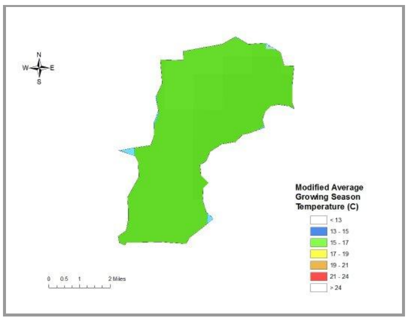
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Cool (75% to Maximum quartile range)
HI: Cool to Temperate (75% to Maximum quartile range)
GDD: Very Cool (75% to Maximum quartile range)
BEDD: Very Cool (75% to Maximum quartile range)
GSTavg: Too Cool to Warm (Full quartile range)

** Range of quartile statistics for standard indices may not fully capture climate structure of the state **

Alexandria Lakes AVA





Highlights:

- 8,936.2 total acres (3,616.5 hectares)
- No commercial vineyards
- Elevation range: 425 m to 441 m (median value of 430m)

Climate indices original characterization:
GSTavg: Too Cool (95%); Cool (5%)
HI: Cool (100%);
GDD: Too Cool (100%);
BEDD: Very Cool (100%)
Modified GSTavg: Intermediate (100%)

Quartile Statistics:

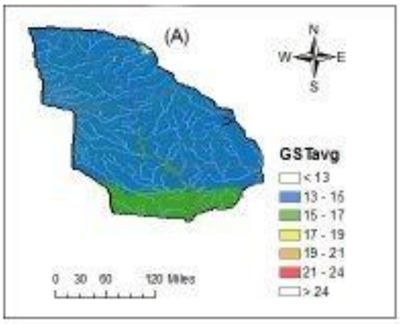
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	13		13		14
HI	1596				1596
GDD	1073		1073		1073
BEDD	1021		1021		1021

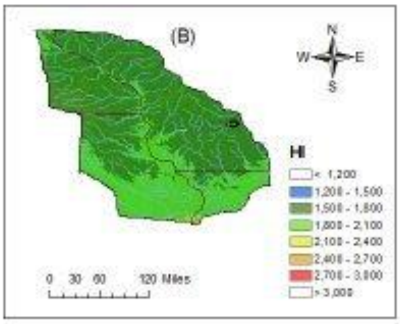
Factors affecting alteration of characterizations:
- Established vineyards located in close proximity to AVA.

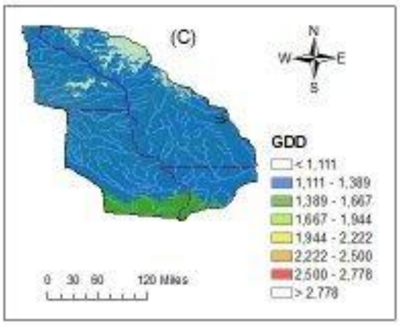
Final characterization:
GSTavg: Cool (Maximum quartile range)
HI: Cool (Maximum quartile range)
GDD: Too Cool (Maximum quartile range)
BEDD: Very Cool (Maximum quartile range)
Modified GSTavg: Intermediate (quartile statistics could not be calculated)

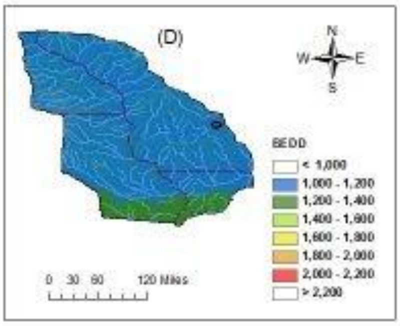
** Range of quartile statistics for standard indices may not fully capture climate structure of the AVA **

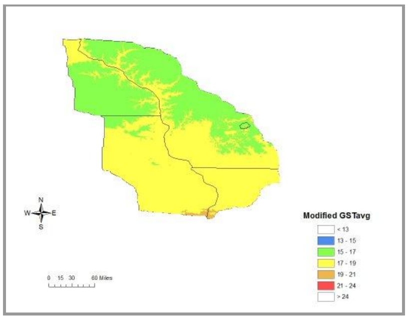
Upper Mississippi River Valley AVA











Highlights:

- 19,159,466.4 total acres (7,753,836 hectares)
- 397 planted acres (160.7 hectares)
- Vineyard size ranges from 1 acres (0.4047 hectares) to 80 acres (32.4 hectares)
- 32+ commercial vineyards
- Encompasses 4 states (MN, WI, Ill and IA)
- Elevation range: 176 m to 462m (median value of 295m)

<u>Climate indices original characterization:</u>
GSTavg: Cool (87%); Intermediate (13%)
HI: Cool (67%); Temperate (32%); Warm Temperate (1%)
GDD: Too Cool (6%); Very Cool, Region I (87%); Cool (7%);
BEDD: Very Cool (89%); Cool (11%)
Modified GSTavg: Intermediate (40%); Warm (59.5%); Hot (0.5%)

Quartile Statistics:

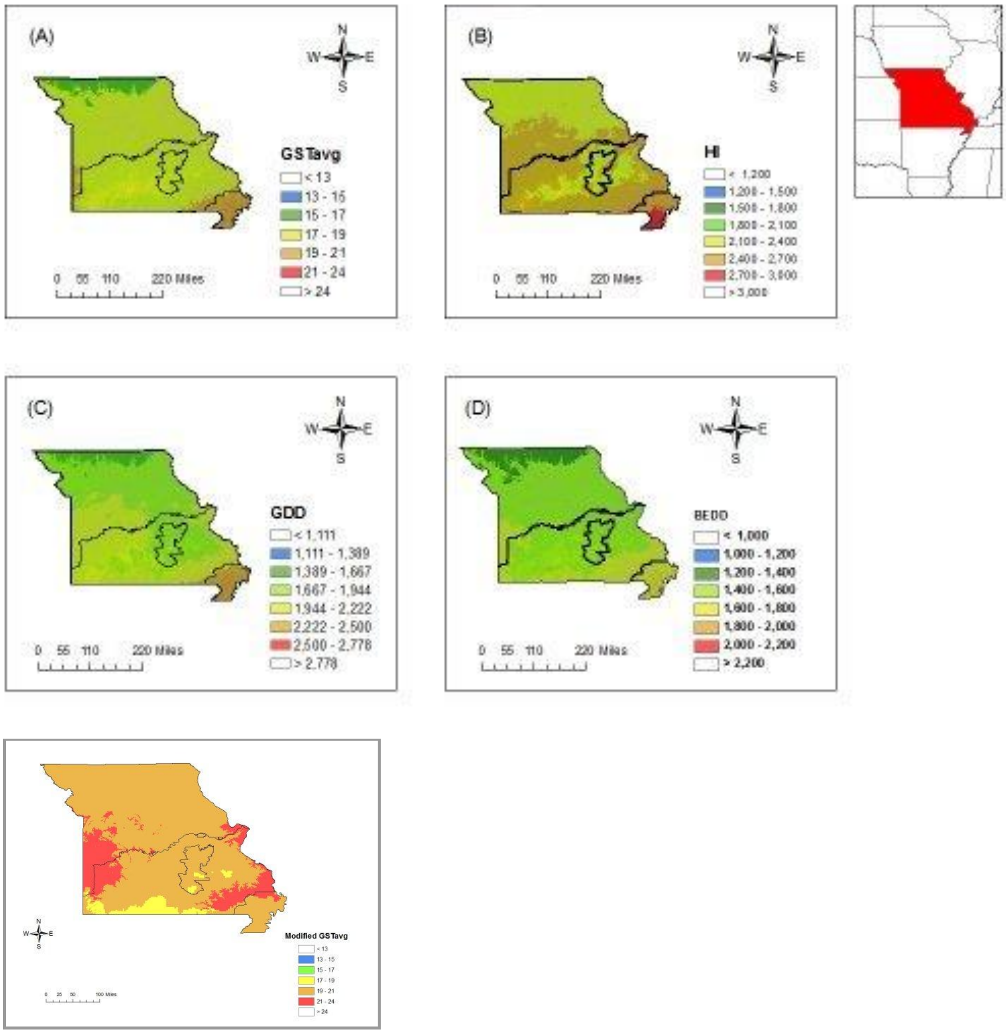
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	13	14	15	15	17
HI	1492	1678	1734	1829	2134
GDD	981	1164	1225	1287	1593
BEDD	984	1108	1156	1167	1349
Modified GSTavg	20	21	22	22	24

<u>Factors affecting alteration of characterizations:</u>

- Already established productive vineyards
- Many areas suited for crop farming

<u>Final characterization:</u>
GSTavg: Cool to Intermediate (Full quartile range)
HI: Cool to WarmTemperate (Full quartile range)
GDD: Very Cool, Region I to Cool, Region II (25% to Maximum quartile range)
BEDD: Very Cool to Cool (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Missouri



Highlights:

- 69,833 square miles
- 1499 planted acres (606.7 hectares)
- 92+ commercial vineyards
- 4 AVAs (Ozark Mountain, Ozark Highlands, Hermann and Augusta)
- Ranks 8th in US production (1,218,286 gal/yr)
- Elevation range: 70.1 m to 540.1 m
- Cfa and Dfa Koppen Classification

- Most common varietals which are grown are French Hybrid varietals, such as Seyval Blanc, Vidal Blanc, Catawba, Chambourcin, Chardonel, Vignoles, and Norton/Cynthiana, the official state grape. Also grown is the American varietal, Concord.

Climate indices original characterization:
GSTavg: Intermediate, Warm, Hot
HI: Warm Temperate, Warm, Very Warm
GDD: Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V
BEDD: Cool, Temperate, Warm Temperate
GSTavg: Warm, Hot, Very Hot

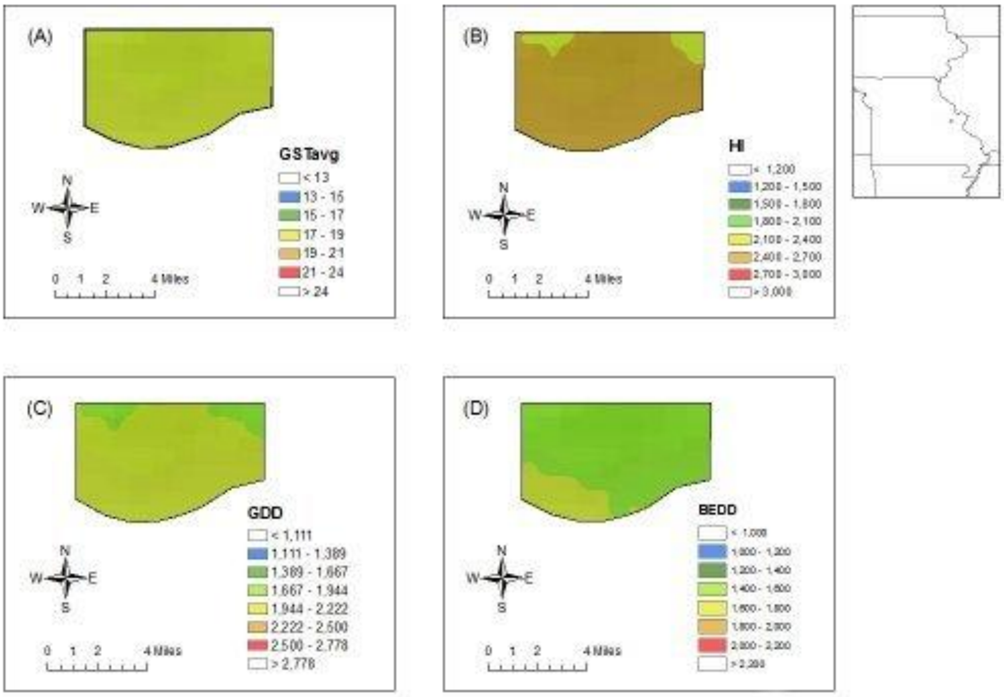
Quartile Statistics:

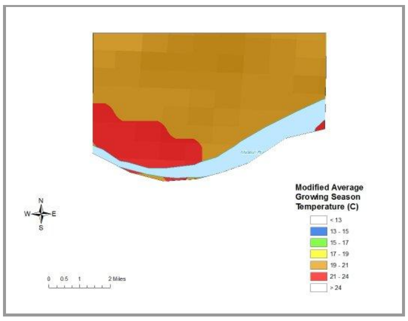
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	17	18	19	19	21
HI	2124	2339	2417	2485	2865
GDD	1562	1838	1929	2021	2479
BEDD	1313	1485	1545	1592	1751
Modified GSTavg	8	19	22	25	29

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Intermediate to Hot (Full quartile range)
HI: Warm Temperate to Very Warm (Full quartile range)
GDD: Temperate, Region III to Warm, Region V (25% to Maximum quartile range)
BEDD: Temperate to Warm Temperate (25% to Maximum quartile range)
GSTavg: Warm to Very Hot (Minimum to Median quartile range)

Augusta AVA





Highlights:

- 16,185 total acres (6,550 hectares)
- 147 planted acres (59.5 hectares)
- Vineyard size ranges from 10 acres (4 hectares) to 77 acres (31.2 hectares)
- 3+ commercial vineyards
- Elevation range:139 m to 237m (median value 165m)

Climate indices original characterization:
GSTavg: Warm (100%)
HI: Warm Temperate (8%); Warm (92%)
GDD: Temperate, Region III (10%); Warm Temperate, Region IV (90%)
BEDD: Temperate (23%); Warm Temperate (77%)
Modified GSTavg: Hot (100%)

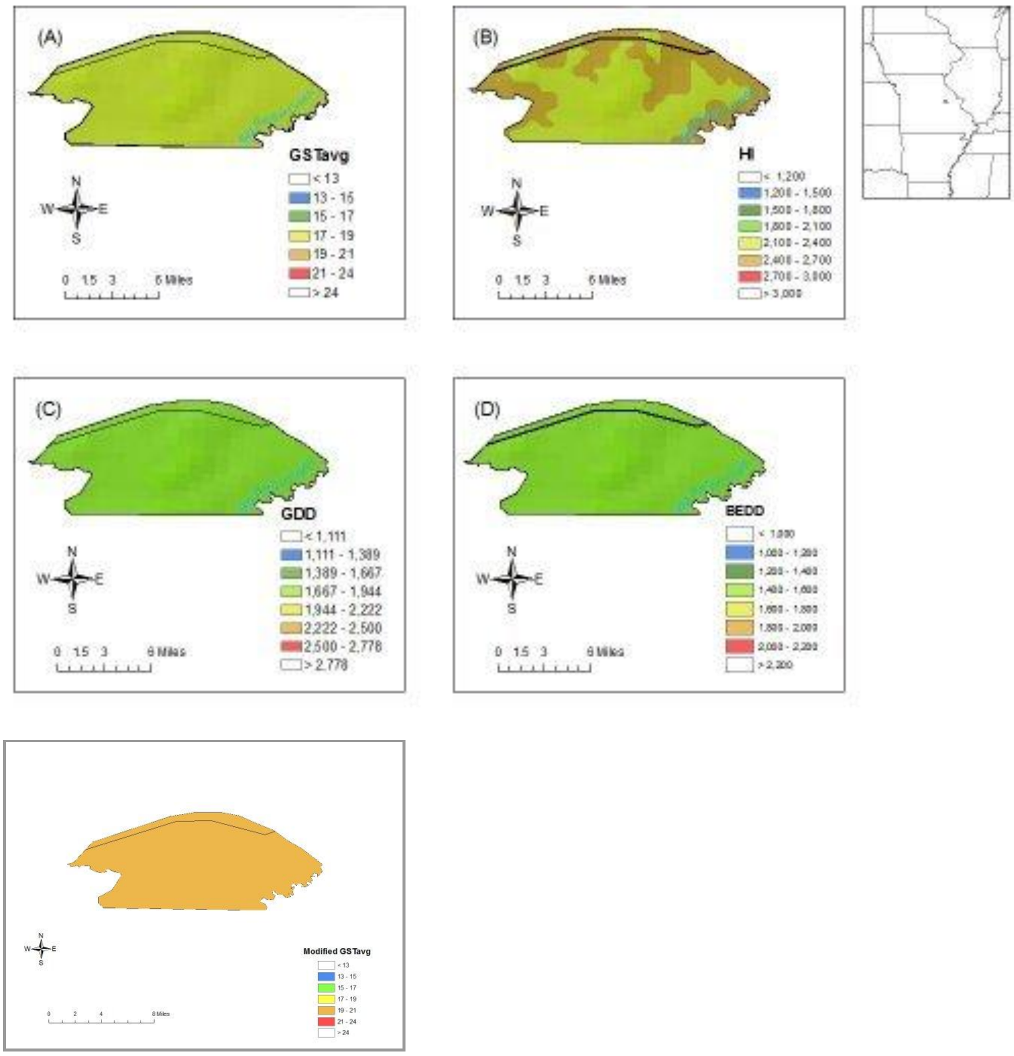
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	19	19	19	19	19
HI	2483	2483	2483	2483	2483
GDD	2020	2020	2020	2020	2020
BEDD	1575	1575	1575	1575	1575
Modified GSTavg	25	25	25	25	25

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Warm (Full quartile range)
HI: Warm Temperate to Warm (Full quartile range)
GDD: Temperate to Warm Temperate (Full quartile range)
BEDD: Temperate to Warm Temperate (Full quartile range)
Modified GSTavg: Hot (Full quartile range)

Hermann AVA



Highlights:

- 50,578 total acres (20,468.9 hectares)
- 255 planted acres (103.2 hectares)
- Vineyard size ranges from 6 acres (2.4 hectares) to 175 acres (70.8 hectares)
- 5+ commercial vineyards
- Elevation range:156 m to 236m (median value 195m)

<u>Climate indices original characterization:</u>
GSTavg: Warm (100%)
HI: Warm Temperate (64%); Warm (36%)
GDD: Temperate, Region III (100%)
BEDD: Warm Temperate (100%)
Modified GSTavg: Hot (100%)

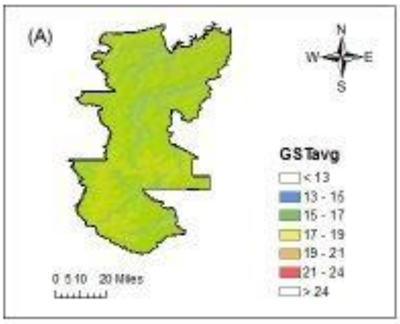
Quartile Statistics:

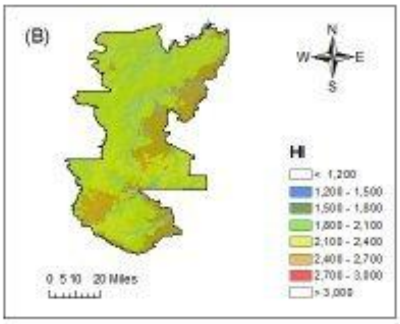
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	18	18	18	18	19
HI	2360	2390	2423	2423	2452
GDD	1868	1868	1868	1899	1929
BEDD	1498	1521	1530	1537	1582
Modified GSTavg	25	25	25	25	25

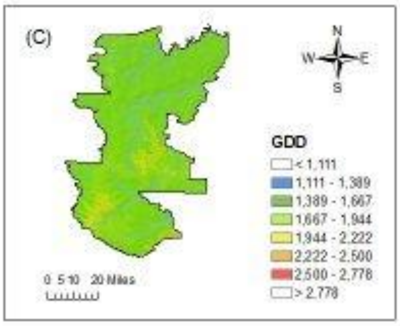
<u>Factors affecting alteration of characterizations:</u>
None

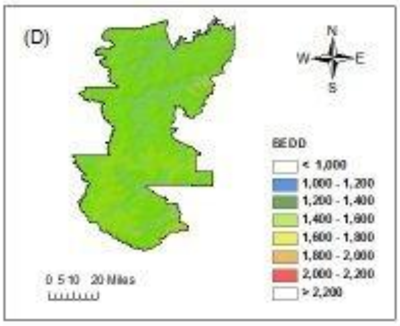
<u>Final characterization:</u>
GSTavg: Warm (Full quartile range)
HI: Warm Temperate to Warm (Full quartile range)
GDD: Temperate (Full quartile range)
BEDD: Warm Temperate (Full quartile range)
Modified GSTavg: Hot (Full quartile range)

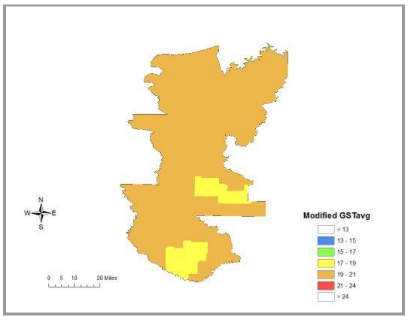
Ozark Highlands AVA











Highlights:

- 1,789,823.3 total acres (724,341.5 hectares)
- 235 planted acres (95 hectares)
- Vineyard size ranges from 5 acres (2 hectares) to 200 acres (81 hectares)
- 5+ commercial vineyards
- Elevation range:186 m to 448m (median value 321m)

Climate indices original characterization:
GSTavg: Warm (100%)
HI: Warm Temperate (74%); Warm (26%)
GDD: Temperate, Region III (96%); Warm Temperate, Region IV (4%)
BEDD: Temperate (92%); Warm Temperate (8%)
Modified GSTavg: Warm (10%); Hot (90%)

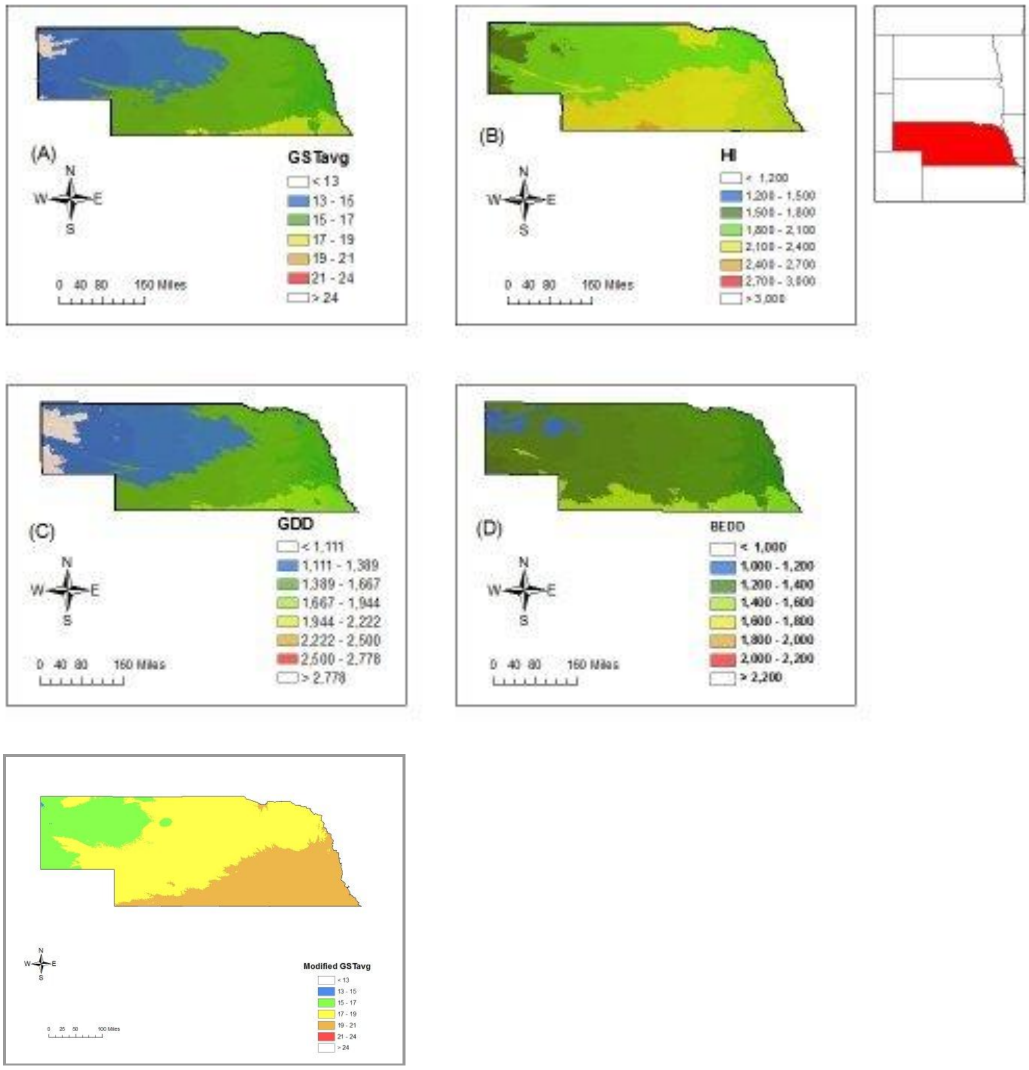
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	18	18	18	18	19
HI	2325	2356	2381	2411	2504
GDD	1807	1838	1868	1899	2021
BEDD	1488	1542	1554	1571	1630
Modified GSTavg	22	25	25	25	25

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Warm (Full quartile range)
HI: Warm Temperate to Warm (Full quartile range)
GDD: Temperate to Warm Temperate (Full quartile range)
BEDD: Temperate to Warm Temperate (Full quartile range)
Modified GSTavg: Warm to Hot (Full quartile range)

Nebraska



Highlights:

- 77,330 square miles
- 1147 planted acres (464.2 hectares)
- 26+ commercial vineyards
- Ranks 27th in US production (107,142 gal/yr)
- Elevation range: 256 m to 1599 m
- Dfa, Dwa and Dfc Koppen Classification

- Most commonly grown are cold hardy French Hybrids such as La Crosse, Edelweiss, Saint Croix, Foch and Seyval Blanc.

Climate indices original characterization:

GSTavg: Too Cool, Cool, Intermediate, Warm, Hot
HI: Cool, Temperate, Warm Temperate, Warm
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV
BEDD: Very Cool, Cool, Temperate
Modified GSTavg: Intermediate, Warm, Hot

Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	13	15	16	17	18
HI	1545	1956	2073	2191	2436
GDD	889	1257	1409	1593	1869
BEDD	1029	1272	1319	1363	1526
Modified GSTavg	11	19	23	25	32

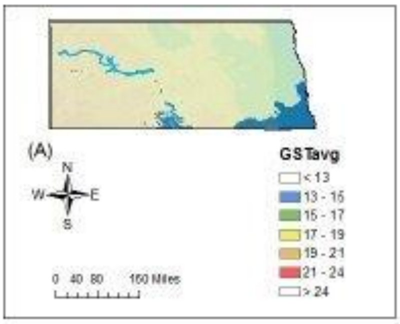
Factors affecting alteration of characterizations:

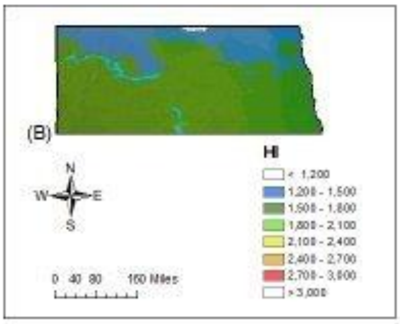
- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes found at higher elevations where it is unsuitable for planting

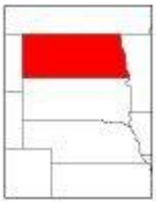
Final characterization:

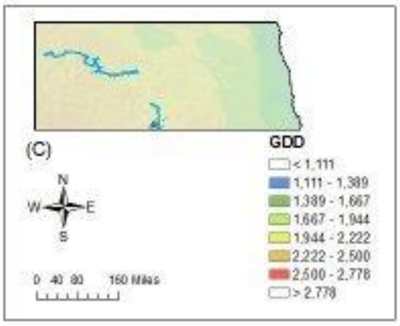
GSTavg: Intermediate to Hot (25% to Maximum quartile range)
HI: Temperate to Warm (25% to Maximum quartile range)
GDD: Cool, Region II to Warm Temperate, Region IV (75% to Maximum quartile range)
BEDD: Cool to Temperate (75% to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (25% to Median quartile range)

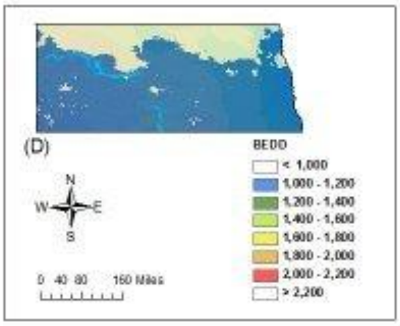
North Dakota

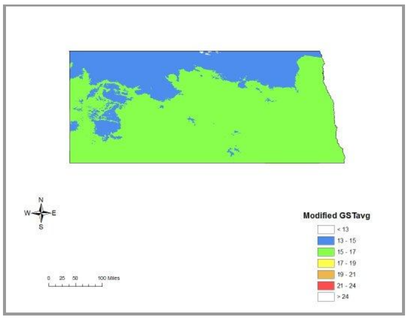












Highlights:

- 70,812 square miles
- 28 planted acres (11.3 hectares)
- 3+ commercial vineyards
- No production data
- Elevation range: 229 m to 1068.6 m
- Dfa, Dfb, Dfc and Dwb Koppen Classification

- Most commonly grown are cold hardy French Hybrid varietals are Frontenac and Prairie Star.

Climate indices original characterization:
GSTavg: Too Cool; Cool
HI: Too Cool; Very Cool; Cool; Temperate
GDD: Too Cool; Very Cool, Region I
BEDD: Too Cool; Very Cool; Cool
GSTavg: Cool, Intermediate

Quartile Statistics:

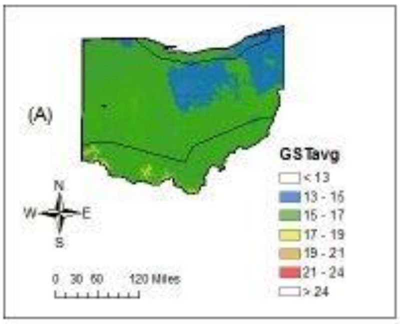
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	10	12	13	13	14
HI	1068	1512	1576	1634	1886
GDD	554	890	951	982	1196
BEDD	600	991	1038	1080	1246
Modified GSTavg	10	19	23	25	32

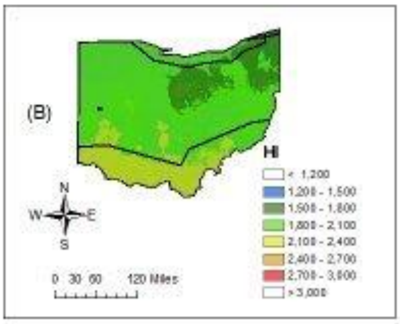
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

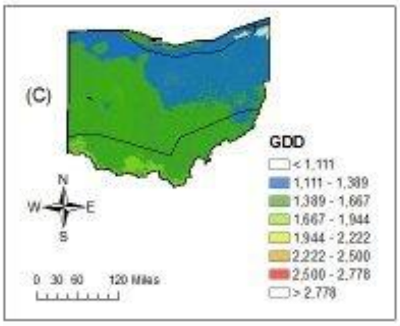
Final characterization:
GSTavg: Cool (75% to Maximum quartile range)
HI: Cool to Temperate (25% to Maximum quartile range)
GDD: Too Cool to Very Cool (75% to Maximum quartile range)
BEDD: Too Cool to Very Cool (75% to Maximum quartile range)
GSTavg: Cool to Intermediate (Minimum to Median quartile range)

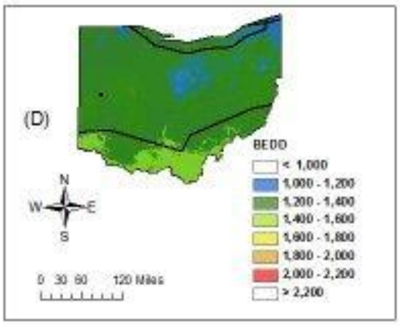
** Range of quartile statistics for standard indices may not fully capture climate structure of the state **

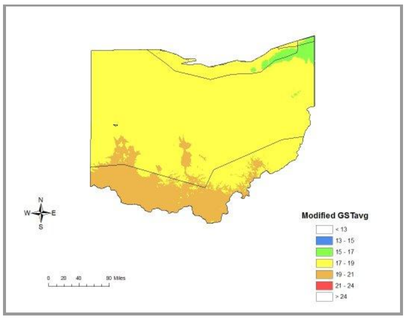
Ohio











Highlights:

- 41,194 square miles
- 978 planted acres (395.8 hectares)
- 109+ commercial vineyards
- 5 AVAs (Ohio River Valley, Kanawha River Valley, Isle St. George, Grand River Valley and Lake Erie)
- Ranks 11th in US production (1,101,873 gal/yr)
- Elevation range: 139 m to 472.4 m

- Dfa and Dfb Koppen Classification
- Most common *V. Vinifera* varietals grown are Reisling, Pinot Gris, Chardonnay, Cabernet Franc, Cabernet Sauvignon; French Hybrid varietals of Vidal Blanc, Chambourcin, Niagara and Catawba; and the native American varietal, Concord.

Climate indices original characterization:
GSTavg: Cool, Intermediate, Warm
HI: Cool, Temperate, Warm Temperate, Warm
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III
BEDD: Very Cool, Cool, Temperate, Warm Temperate
Modified GSTavg: Intermediate, Warm, Hot

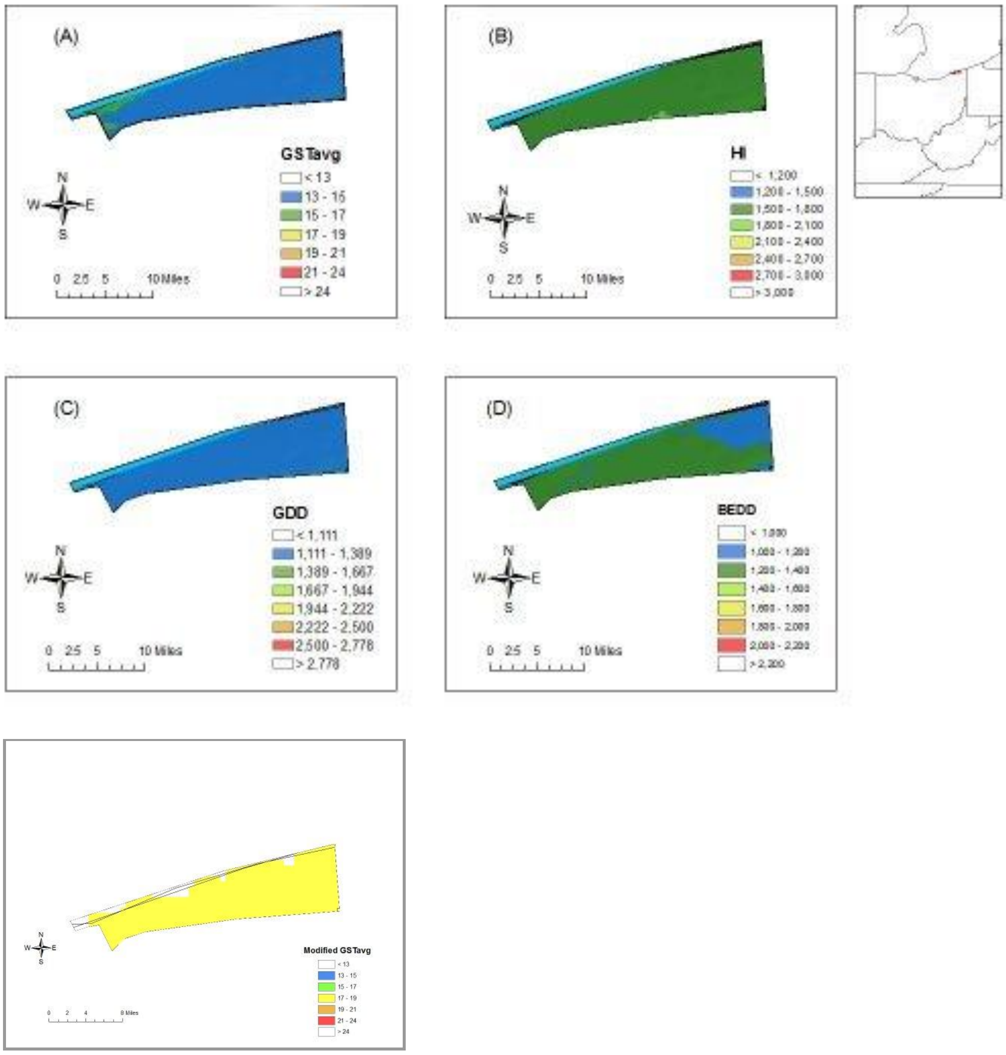
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	16	16	17	18
HI	1570	1874	1940	2055	2421
GDD	1071	1348	1409	1501	1837
BEDD	1067	1222	1265	1339	1605
Modified GSTavg	9	20	21	24	29

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Cool to Warm (Full quartile range)
HI: Cool to Warm (Full quartile range)
GDD: Cool, Region II to Temperate, Region III (75% to Maximum quartile range)
BEDD: Cool to Warm Temperate (75% to Maximum quartile range)
Modified GSTavg: Intermediate to Hot (25% to 75% quartile range)

Grand River Valley AVA



Highlights:

- 68,093.6 total acres (27,557.5 hectares)
- 178 planted acres (72 hectares)
- Vineyard size ranges from 3 acres (1.2 hectares) to 112 acres (45.3 hectares)
- 4+ commercial vineyards
- Elevation range:174 m to 258m (median value 200m)

Climate indices original characterization:
GSTavg: Cool (91%); Intermediate (9%)
HI: Cool (99%); Temperate (1%)
GDD: Very Cool, Region I (97%); Cool, Region II (3%)
BEDD: Very Cool (26%); Cool (74%)
Modified GSTavg: Warm (100%)

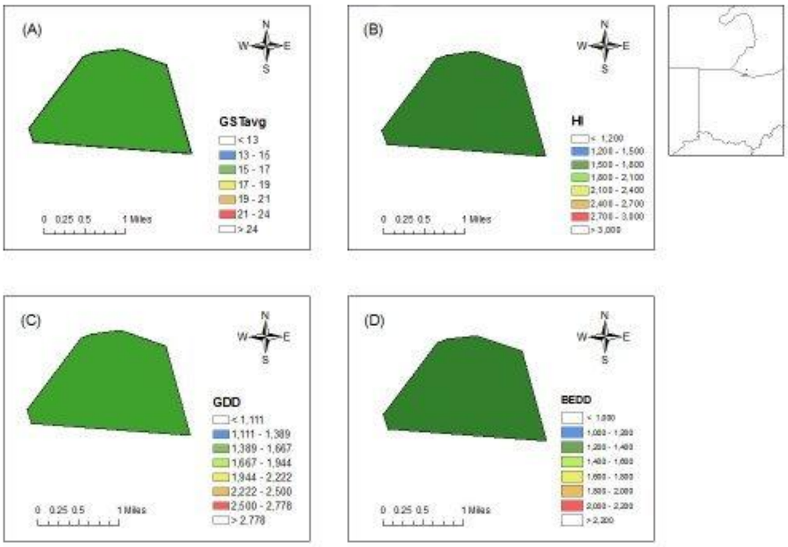
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	15	15	15	16
HI	1696	1727	1727	1751	1789
GDD	1255	1262.75	1286	1286	1348
BEDD	1193	1193	1208	1224	1256
Modified GSTavg	22	22	22	22	22

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Cool to Intermediate (Full quartile range)
HI: Cool to Temperate (Full quartile range)
GDD: Very Cool, Region I to Cool, Region II (Full quartile range)
BEDD: Very Cool to Cool (Full quartile range)
Modified GSTavg: Warm (Full quartile range)

Isle St. George AVA



<u>Highlights:</u>

- 882.2 total acres (357 hectares)
- 38 planted acres (15.4 hectares)
- 1+ commercial vineyards
- Elevation range: 176 m to 179 m (median value of 177 m)

<u>Climate indices original characterization:</u>
GSTavg: Intermediate (100%)
HI: Cool (100%)
GDD: Cool, Region II (100%)
BEDD: Cool (100%)
Modified GSTavg: Warm

**Note: Graphic and statistics for Modified GSTavg did not properly calculate this AVA.

Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16		16		16
HI	1758				1790
GDD	1470		1501		1501
BEDD	1210				1217

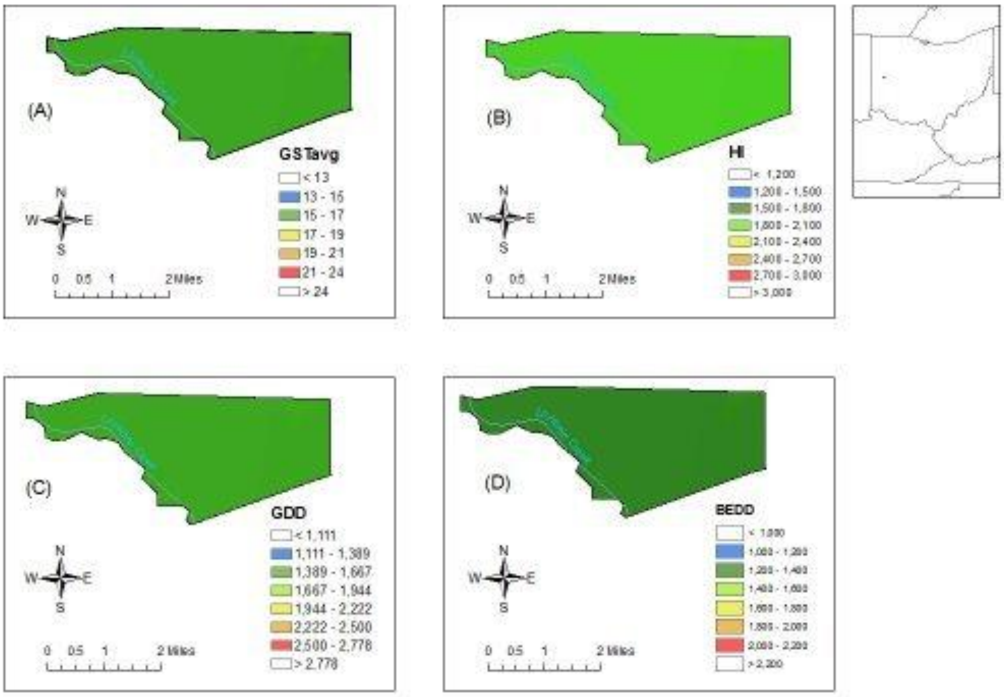
Factors affecting alteration of characterizations:

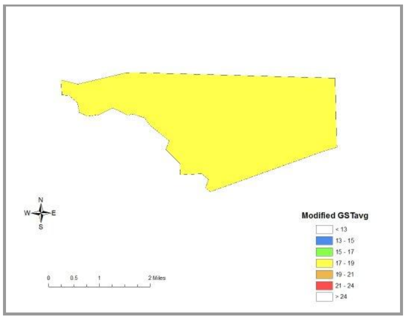
None

Final characterization:

GSTavg: Intemediate (Full quartile range)
HI: Cool (Full quartile range)
GDD: Cool (Full quartile range)
BEDD: Cool (Full quartile range)
Modified GSTavg: Warm

Loramie Creek AVA





Highlights:

- 3,779.4 total acres (1,529.5 hectares)
- No commercial vineyards
- Elevation range: 289 m to 304 m (median value of 290 m)

Climate indices original characterization:
GSTavg: Intermediate (100%)
HI: Temperate (100%)
GDD: Cool, Region II (100%)
BEDD: Cool (100%)
Modified GSTavg: Warm (100%)

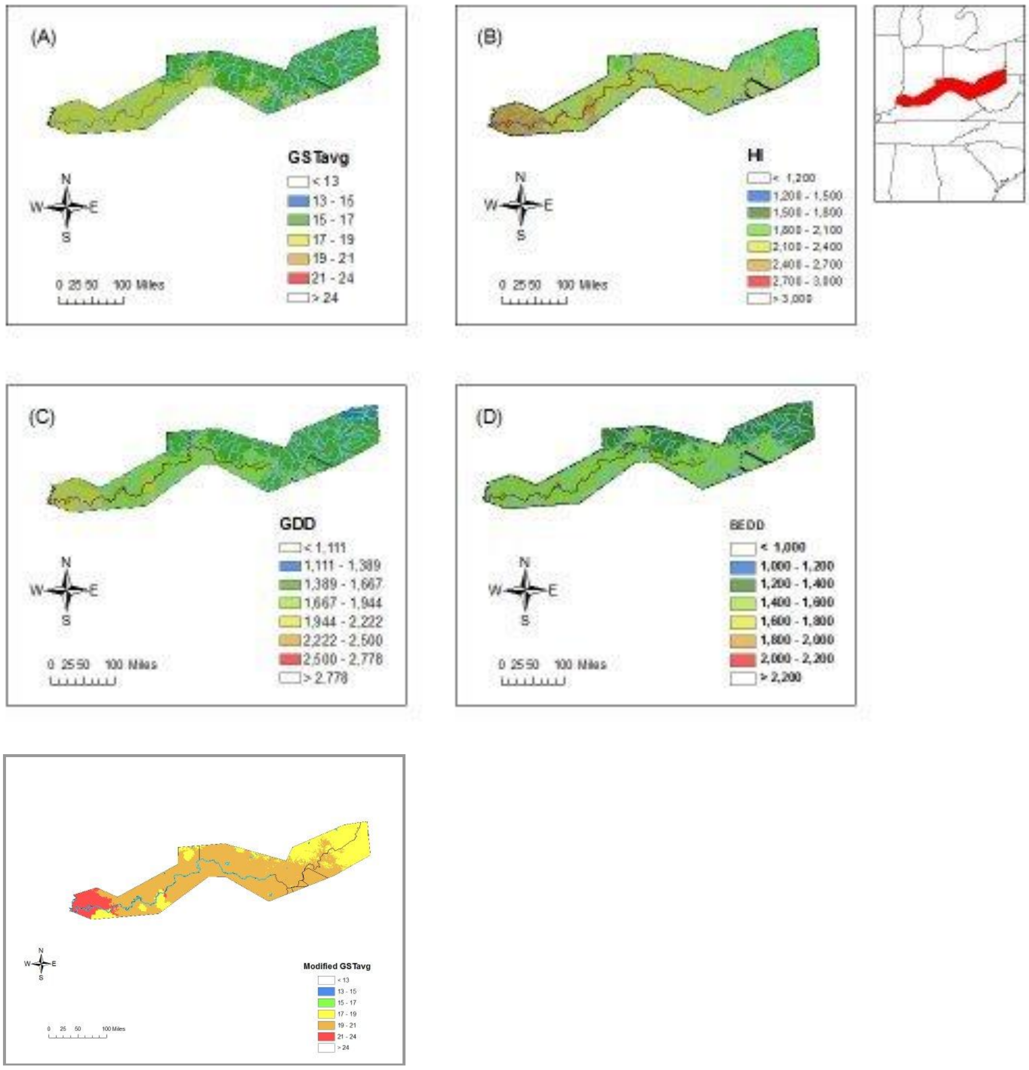
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16		16		16
HI	1937				1937
GDD	1409		1409		1409
BEDD	1249				1250

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Intemediate (Full quartile range)
HI: Temperate (Full quartile range)
GDD: Cool (Full quartile range)
BEDD: Cool (Full quartile range)
Modified GSTavg: Warm (quartile statistics could not be calculated)

Ohio River Valley AVA



Highlights:

- 16,670,078.8 total acres (6,746,381 hectares)
- 313 planted acres (126.7 hectares)
- Vineyard size ranges from 2 acres (0.8 hectares) to 70 acres (28.3 hectares)
- 25+ commercial vineyards
- Elevation range: 115 m to 426m (median value of 243m)

Climate indices original characterization:
GSTavg: Intermediate (55%); Warm (45%)
HI: Temperate (19%); Warm Temperate (68%); Warm (13%)
GDD: Too Cool (6%); Very Cool, Region I (3%); Cool (47%); Temperate, Region III (37%); Warm Temperate, Region IV (13%)
BEDD: Cool (31%); Temperate (67%); Warm Temperate (2%)
Modified GSTavg: Warm (26%); Hot (66%); Very Hot (8%)

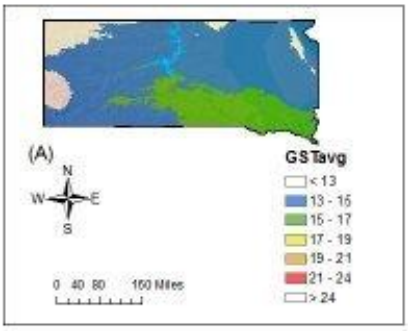
Quartile Statistics:

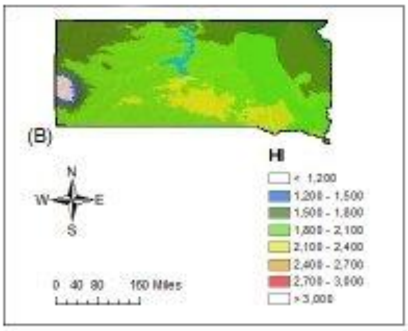
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	17	17	18	19
HI	1808	2117	2235	2356	2512
GDD	1286	1593	1668.5	1867	2051
BEDD	1239	1376	1458	1519	1634
Modified GSTavg	22	24	24	25	26

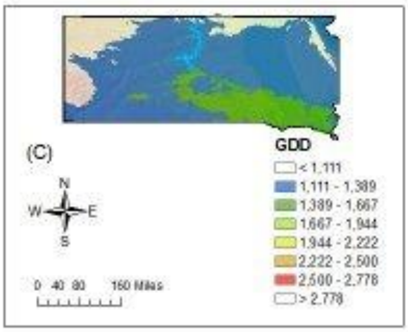
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

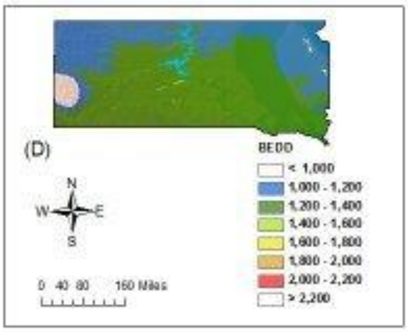
Final characterization:
GSTavg: Intermediate to Warm (Full quartile range)
HI: Temperate to Warm (Full quartile range)
GDD: Temperate, Region III to Warm Temperate, Region IV (Median to Maximum quartile range)
BEDD: Temperate to Warm Temperate (Median to Maximum quartile range)
Modified GSTavg: Warm to Very Hot (Minimum to Median quartile range)

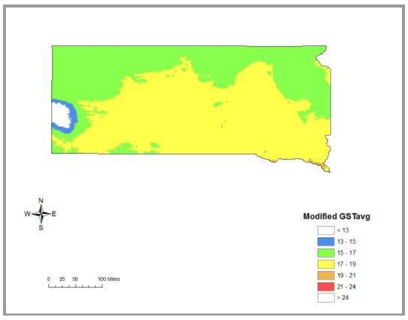
South Dakota











Highlights:

- 77,195 square miles
- 213 planted acres (11.3 hectares)
- 8+ commercial vineyards
- Ranked 31st in US production (63,453 gal/yr)
- Elevation range: 294 m to 2207.4 m
- Dfa, Dfb, Dfc, Dwa and Dwb Koppen Classification

- Most commonly grown are cold hardy French Hybrids such as Frontenac, Foch and Seyval Blanc and Baltica.

Climate indices original characterization:
GSTavg: Too Cool; Cool, Intermediate
HI: Too Cool; Very Cool; Cool; Temperate, Warm Temperate
GDD: Too Cool; Very Cool, Region I; Cool, Region II
BEDD: Too Cool; Very Cool; Cool, Temperate
Modified GSTavg: Too Cool; Cool, Intermediate, Warm

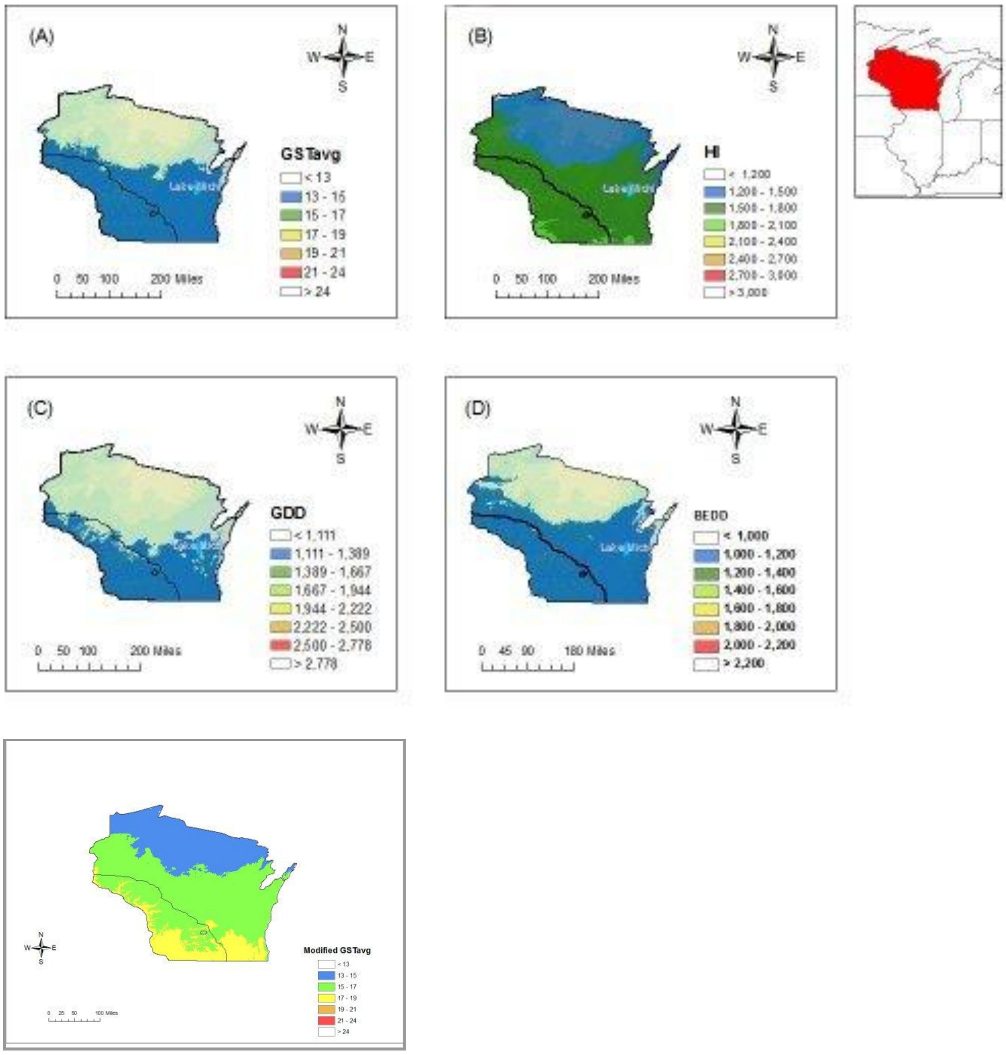
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	8	14	15	15	17
HI	793	1753	1879	2023	2277
GDD	309	1134	1227	1348	1563
BEDD	442	1149	1227	1296	1449
Modified GSTavg	12	19	23	25	32

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Cool to Intermediate (25% to Maximum quartile range)
HI: Cool to Warm Temperate (25% to Maximum quartile range)
GDD: Very Cool, Region I to Cool, Region II (75% to Maximum quartile range)
BEDD: Cool (75% to Maximum quartile range)
Modified GSTavg: Too Cool to Warm (Minimum to Median quartile range)

Wisconsin



<u>**Highlights:**</u>

- 56,088 square miles
- 445 planted acres (180.1 hectares)
- 30+ commercial vineyards
- 2 AVAs (Upper Mississippi River Valley and Lake Wisconsin)
- Ranked 18th in US production (424,270 gal/yr)
- Elevation range: 177 m to 594.7 m
- Dfa and Dfb Koppen Classification

- Most commonly grown varietal is the cold hardy, Foch.

Climate indices original characterization:
GSTavg: Too Cool; Cool; Intermediate
HI: Too Cool; Very Cool; Cool; Temperate
GDD: Too Cool; Very Cool, Region I
BEDD: Too Cool; Very Cool; Cool
Modified GSTavg: Cool; Intermediate, Warm

Quartile Statistics:

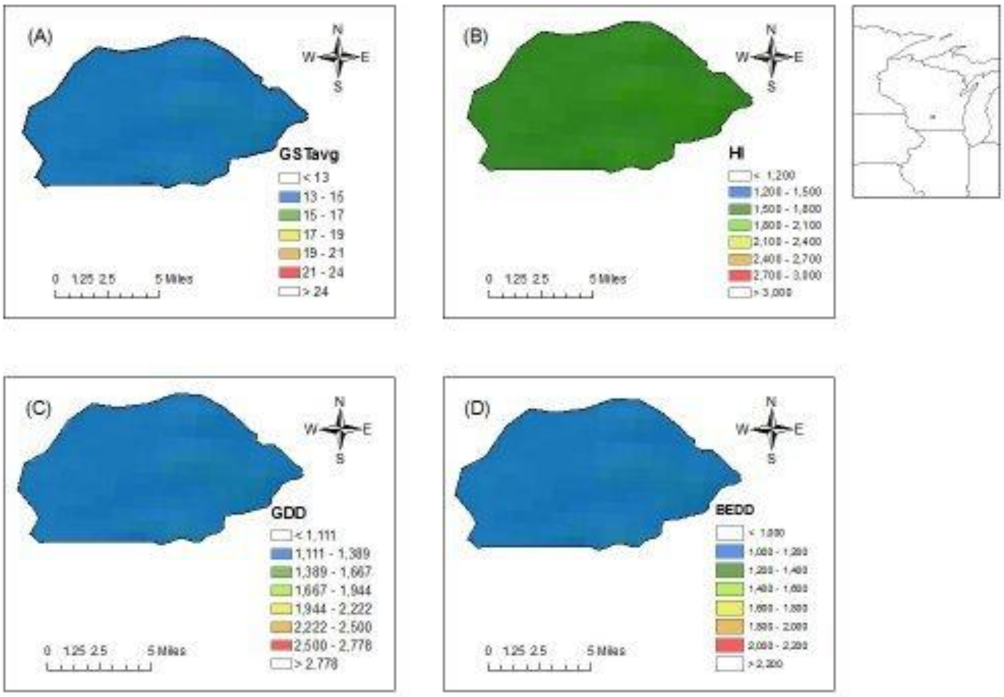
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	11	12	14	14	16
HI	1089	1401	1556	1673	1893
GDD	674	858	1042	1164	1348
BEDD	712	932	1056	1105	1206
Modified GSTavg	7	20	22	25	30

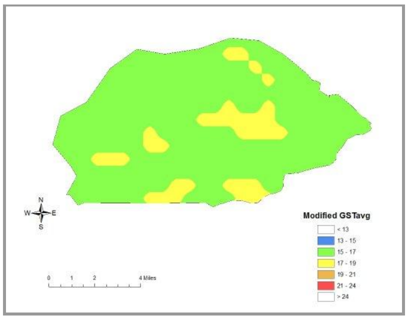
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Cool to Intermediate (75% to Maximum quartile range)
HI: Cool to Temperate (75% to Maximum quartile range)
GDD: Very Cool (75% to Maximum quartile range)
BEDD: Very Cool (75% to Maximum quartile range)
Modified GSTavg: Cool to Warm (Minimum to Median quartile range)

** Range of quartile statistics for standard indices may not fully capture climate structure of the state **

Lake Wisconsin AVA





Highlights:

- 33,387 total acres (13,511.7 hectares)
- 27 planted acres (11 hectares)
- 1+ commercial vineyards
- Elevation range: 232 m to 340 m (median value of 286m)

Climate indices original characterization:
GSTavg: Cool (100%);
HI: Cool (100%);
GDD: Very Cool, Region I (100%);
BEDD: Very Cool (100%)
Modified GSTavg: Intermediate, Warm (Percentages could not be calculated)

Quartile Statistics:

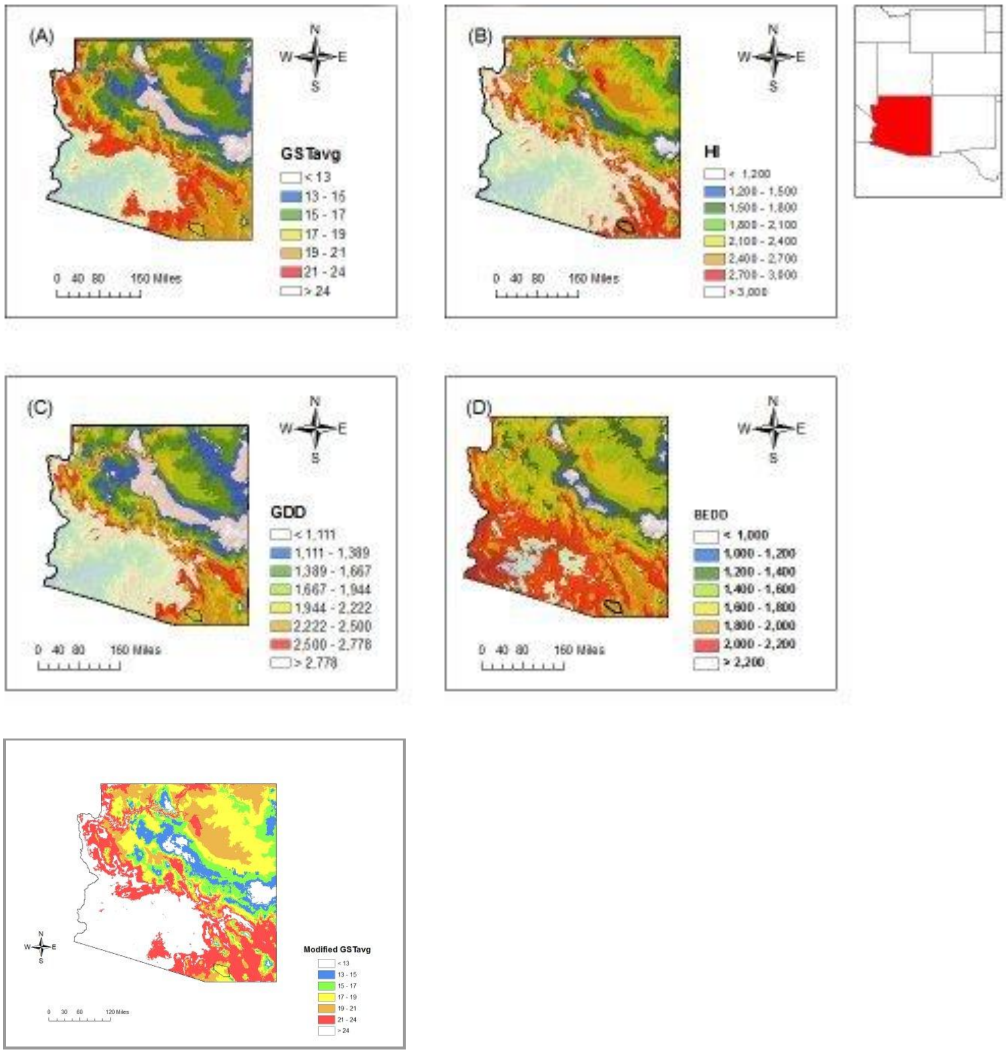
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	14	14	14	14.5	15
HI	1674	1674	1674	1690	1705
GDD	1164	1164	1164	1179	1194
BEDD	1105	1105	1105	1120	1136
Modified GSTavg	21	21	21	21	21

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Cool (Full quartile range)
HI: Cool (Full quartile range)
GDD: Very Cool (Full quartile range)
BEDD: Very Cool (Full quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

West

Arizona



Highlights:

- 113,713 square miles
- 951 planted acres (282.5 hectares)
- 37+ commercial vineyards
- 1 AVA (Sonoita)
- Ranks 30th in US production (69,280 gal/yr)
- Elevation range: 16.8 m to 3850.5 m
- Dfb, Dsb, Csa, Csb, Bsh and Bwh Koppen Classification

- Most commonly grown *V. Vinifera* varietals are Cabernet Sauvignon, Pinot Noir, Viognier, and Sauvignon Blanc

Climate indices original characterization:
GSTavg: Too Cool, Cool, Intermediate, Warm, Hot, Very Hot, Too Hot
HI: Too Cool, Very Cool, Cool, Temperate, Warm Temperate, Warm, Very Warm, Too Hot
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI; Too Hot
BEDD: Too Cool; Very Cool, Cool, Temperate, Warm Temperate, Warm, Very Warm, Too Hot
Modified GSTavg: Too Cool, Cool, Intermediate, Warm, Hot, Very Hot, Too Hot

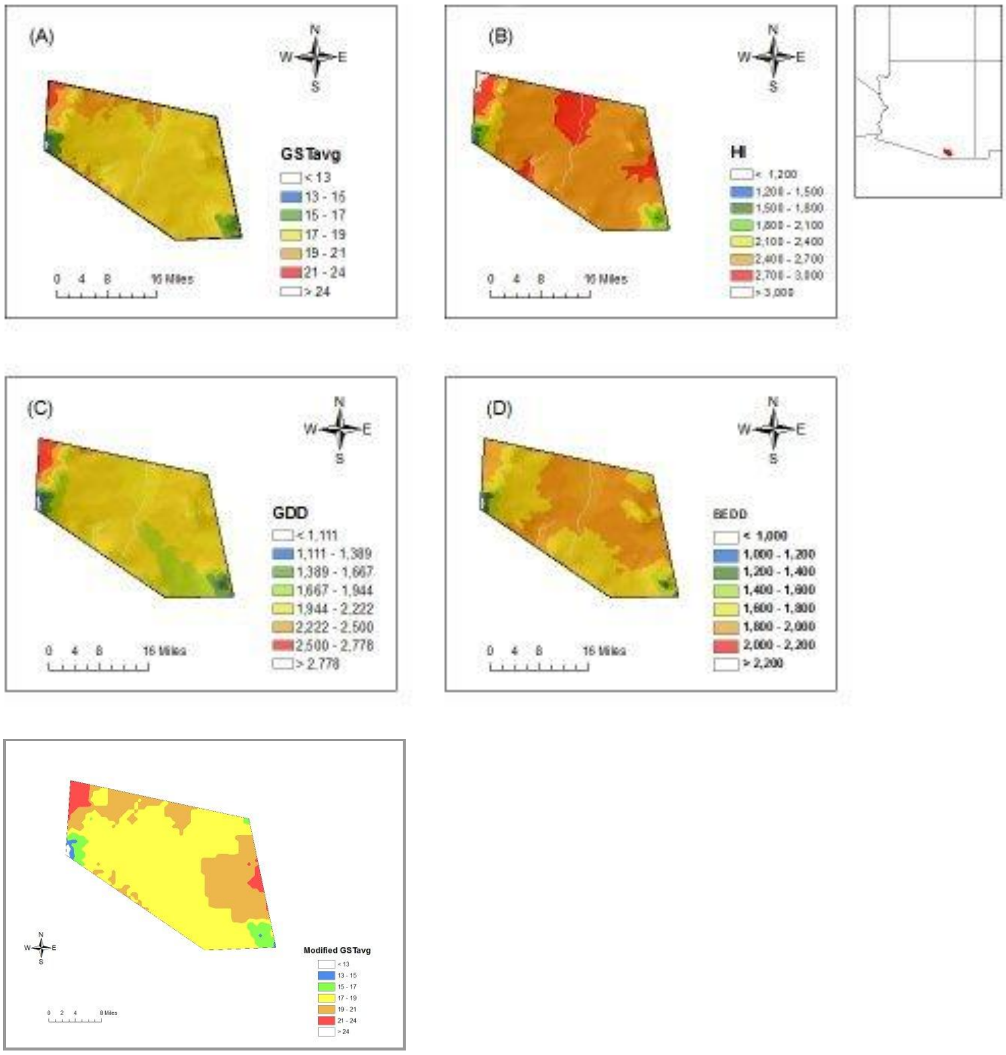
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	6	16	19	24	28
HI	338	2169	2677	3573	4264
GDD	31	1409.25	2081	3122	3916
BEDD	115	1509	1774	2080	2261
Modified GSTavg	8	20	22	25	30

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Coolest maturity classes are found at higher elevations, or in National Parks or recreational areas, where it is unsuitable for planting

Final characterization:
GSTavg: Intermediate to Very Hot (25% to 75% quartile range)
HI: Warm Temperate to Too Hot(25% to 75% quartile range)
GDD: Cool, Region II to Too Hot (25% to 75% quartile range)
BEDD: Temperate to Too Hot (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Very Hot (25% to Maximum quartile range)

Sonoita AVA



Highlights:

- 287,967.6 total acres (116,540.5 hectares)
- 267 planted acres (108 hectares)
- Vineyard size ranges from 10 acres (4 hectares) to 80 acres (32.4 hectares)
- 10+ commercial vineyards
- Elevation range: 1165 m to 2664m (median value of 1517m)

Climate indices original characterization:
GSTavg: Very Cool (0.25%); Cool (0.5%); Intermediate (4%); Warm (82%); Hot (12%); Very Hot (1.25%)
HI: Very Cool (0.25%); Cool (2%); Temperate (2%); Warm Temperate (8%); Warm (73%); Very Warm (15%); Too Hot (0.75%)
GDD: Very Cool, Region I (1%); Cool, Region II (3%); Temperate, Region III (18%); Warm Temperate, Region IV (44%); Warm, Region V (32%); Very Warm, Region VI (2%)
BEDD: Cool (1%); Temperate (4%); Warm Temperate(44%), Warm (51%);
Modified GSTavg: Warm (65%); Hot (35%)

Quartile Statistics:

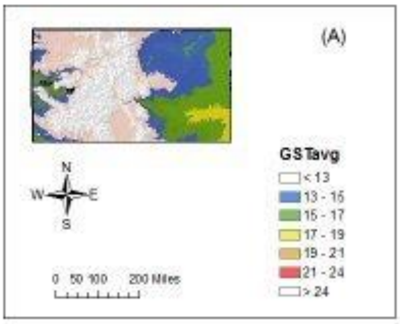
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	16	19	19	19	22
HI	1771	2564	2596	2626	3083
GDD	1285	1989	2110	2111	2722
BEDD	1285	1766	1835	1858	1965
Modified GSTavg	20	23	23	24	28

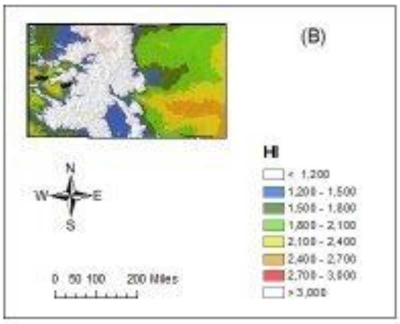
Factors affecting alteration of characterizations:

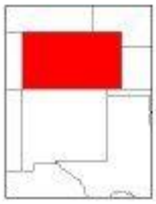
- Already established productive vineyards
- Coolest maturity classes are found at higher elevations and federal and state lands, where it is unsuitable for planting

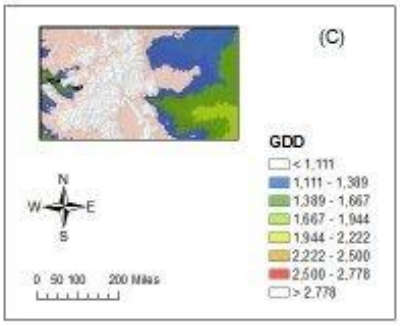
Final characterization:
GSTavg: Intermediate to Very Hot (Full quartile range)
HI: Warm to Too Hot (25% to maximum quartile range)
GDD: Warm Temperate, Region IV to Very Warm, Region VI (25% to maximum quartile range)
BEDD: Warm (Median to Maximum quartile range)
Modified GSTavg: Warm to Hot (Minimum to 75% quartile range)

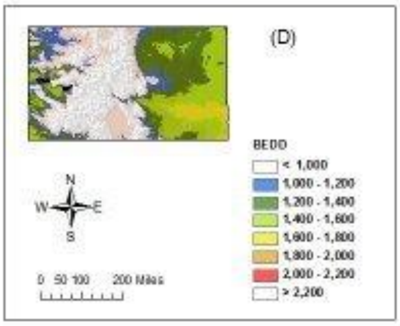
Colorado

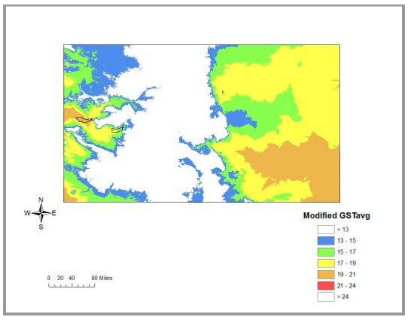












<u>Highlights:</u>

- 104,101 square miles
- 651 planted acres (263.5 hectares)
- 84+ commercial vineyards
- 1 AVA (Sonoita)
- Ranks 22nd in US production (262,621 gal/yr)
- Elevation range: 1010 m to 4401.3 m

- Dfa, Dfb, Dfc, Dsb, and H Koppen Classification
- Most common *V. Vinifera* varietals grown are Chardonnay, Cabernet Sauvignon, Merlot, Syrah and Reisling.

Climate indices original characterization:
GSTavg: Too Cool, Cool, Intermediate, Warm, Hot
HI: Too Cool, Very Cool, Cool, Temperate, Warm Temperate, Warm
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV
BEDD: Too Cool; Very Cool, Cool, Temperate, Warm Temperate
Modified GSTavg: Too Cool, Cool, Intermediate, Warm, Hot

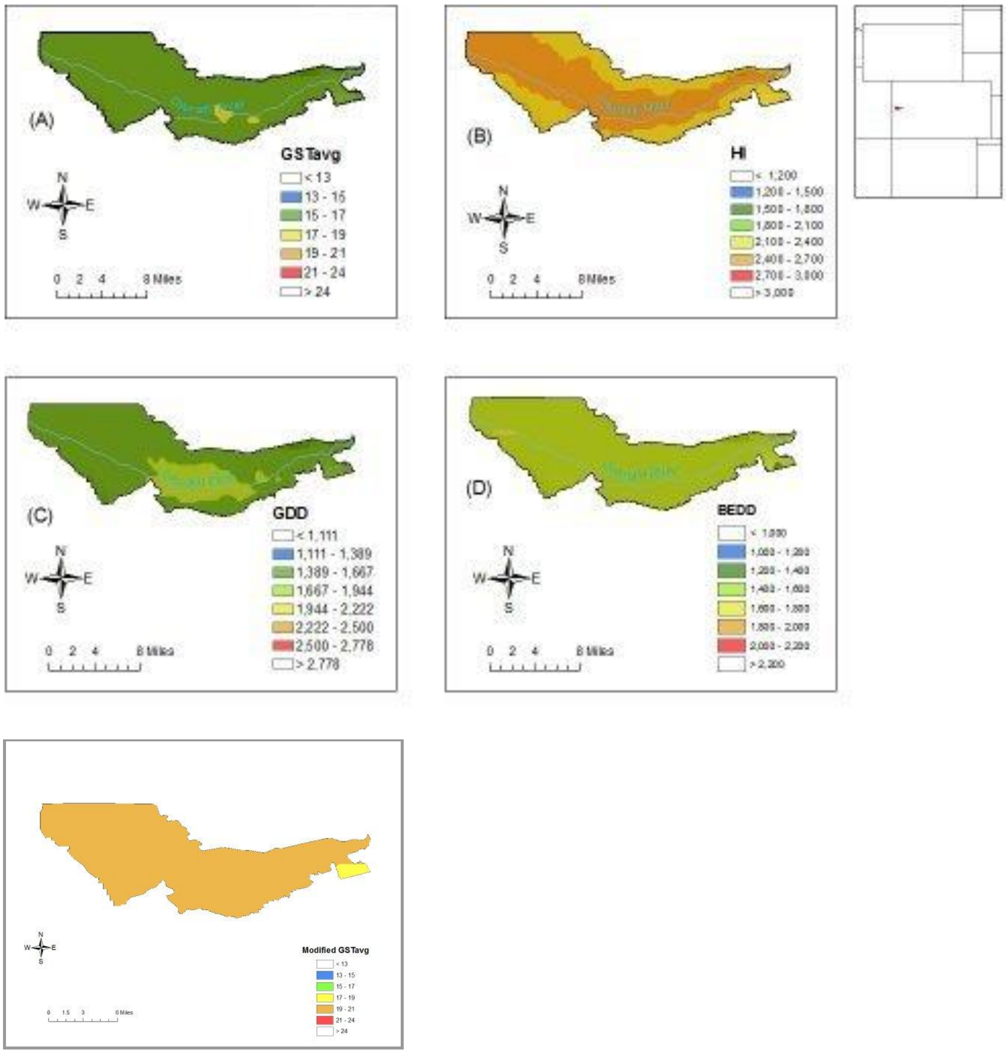
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	0	9	13	15	19
HI	0	935	1583	2042	2634
GDD	0	369	920	1287	1929
BEDD	-8	569	1130	1398	1716
Modified GSTavg	11	19	23	26	33

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Coolest maturity classes are found at higher elevations, or in National and State Parks, Federal Lands or wildlife preserves, where it is unsuitable for planting

Final characterization:
GSTavg: Cool to Hot (Median to Maximum quartile range)
HI: Cool to Warm (Median to Maximum quartile range)
GDD: Very Cool, Region I to Warm Temperate (75% to Maximum quartile range)
BEDD: Cool to Warm Temperate (75% to Maximum quartile range)
Modified GSTavg: Cool to Hot (Minimum to Median quartile range)

Grand Valley AVA



Highlights:

- 75,149 total acres (30,412.8 hectares)
- 384 planted acres (155.4 hectares)
- Vineyard size ranges from 1 acres (0.4047 hectares) to 115 acres (46.5 hectares)
- 17+ commercial vineyards
- Elevation range:1524 m to 1696m (median value 1524m)

Climate indices original characterization:
GSTavg: Intermediate (98%); Warm(2%)
HI: Warm Temperte (45%); Warm (55%)
GDD: Cool, Region II (83%); Temperate, Region III (17%)
BEDD: Cool (0.25%); Temperate (99%); Warm Temperate (0.75%)
Modified GSTavg: Hot (100%)

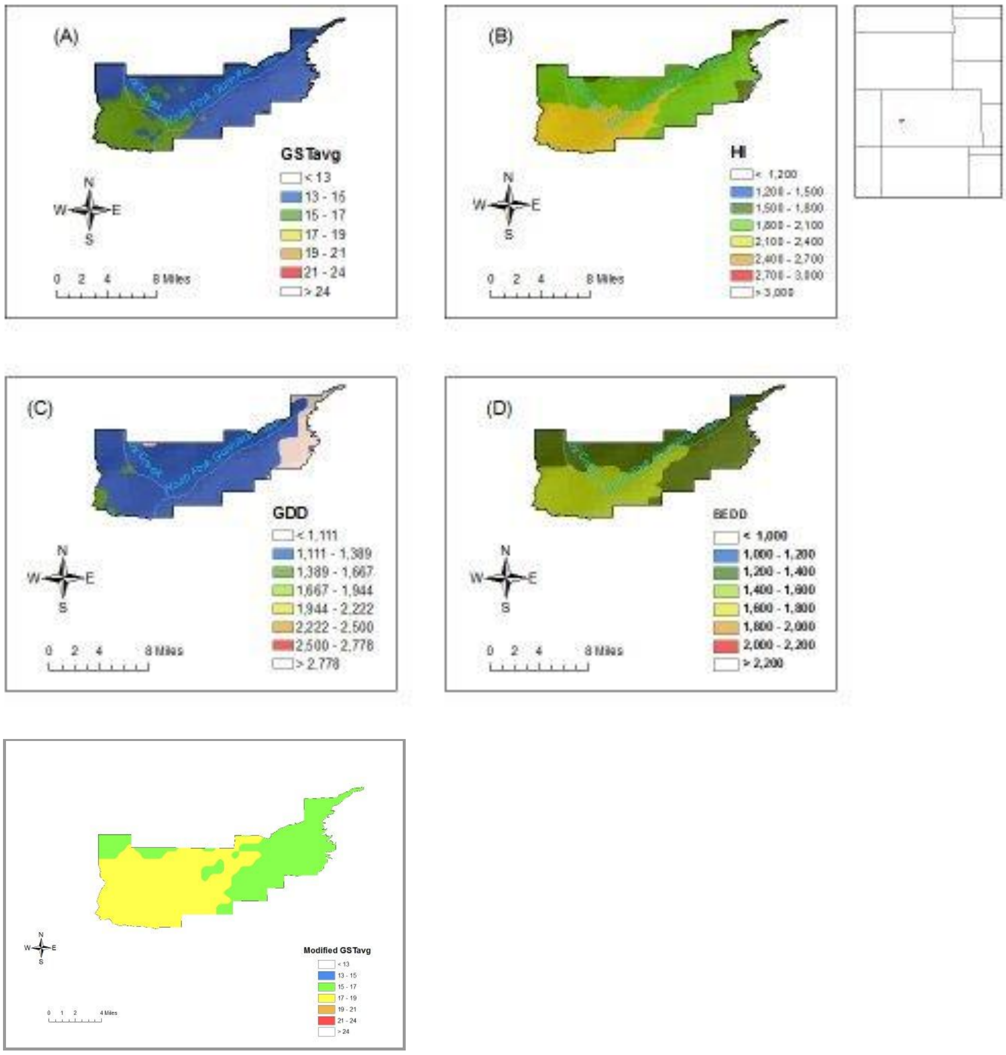
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	17	17	17	17	17
HI	2365	2380	2395	2426	2427
GDD	1593	1624	1624	1639	1654
BEDD	1490	1520	1550	1562	1590
Modified GSTavg	24	24	24	24	24

Factors affecting alteration of characterizations:
None

Final characterization:
GSTavg: Intermediate to Warm (Full quartile range)
HI: Warm Temperate to Warm (Full quartile range)
GDD: Cool to Temperate (Full quartile range)
BEDD: Cool to Warm Temperate (Full quartile range)
Modified GSTavg: Hot (Full quartile range)

West Elks AVA



Highlights:

- 48,191.2 total acres (19,503 hectares)
- 48 planted acres (19.4 hectares)
- Vineyard size ranges from 4 acres (1.6 hectares) to 30 acres (12.1 hectares)
- 4+ commercial vineyards
- Elevation range: 1614 m to 2119m (median value of 1739m)

Climate indices original characterization:
GSTavg: Cool (74%); Intermediate (26%)
HI: Cool (5%); Temperate (58%); Warm Temperate(37%)
GDD: Too Cool (14%); Very Cool, Region I (84%); Cool (2%);
BEDD: Very Cool (2%); Cool (58%); Temperate (40%)
Modified GSTavg: Intermediate (75%); Warm (25%)

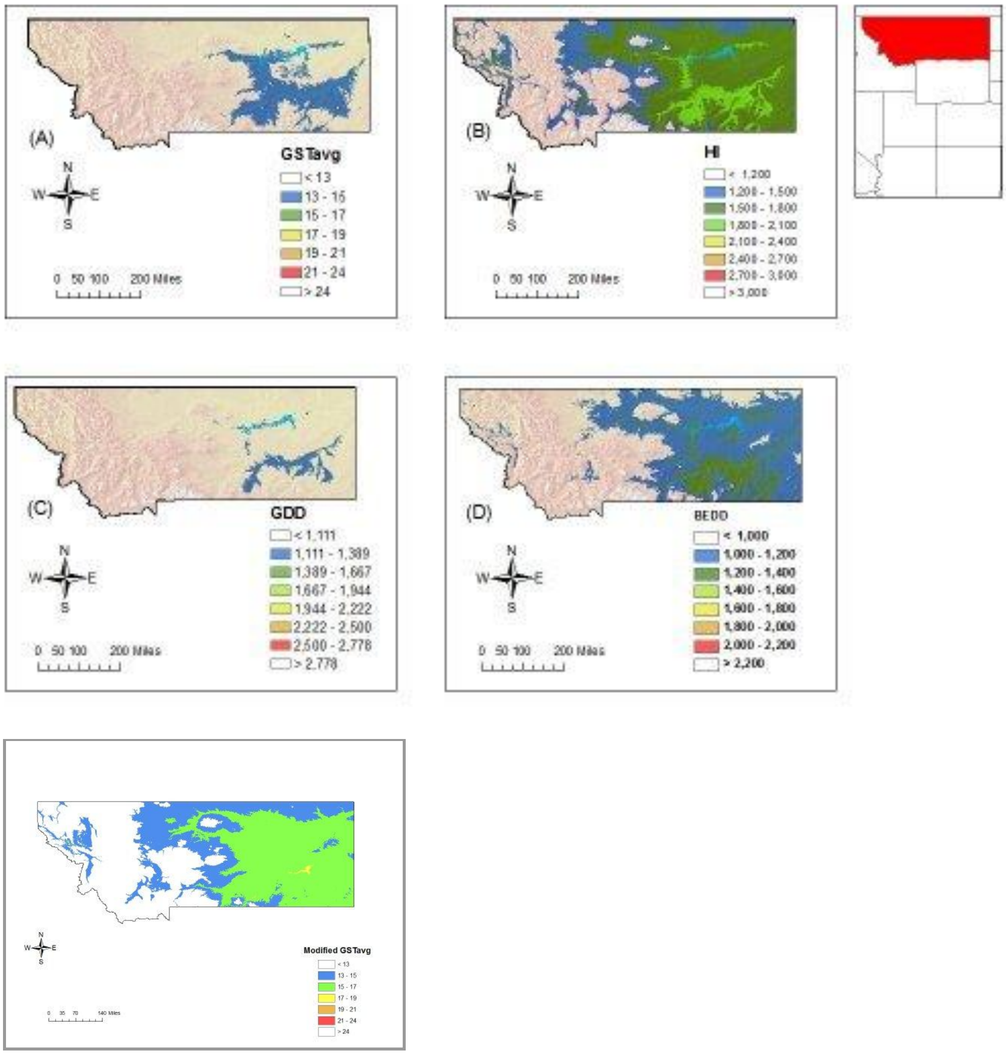
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	15	15	15	15.5	16
HI	2021	2052	2083	2114	2145
GDD	1195	1241	1287	1302	1317
BEDD	1379	1406	1433	1441	1448
Modified GSTavg	21	21.5	22	22	22

Factors affecting alteration of characterizations:
- Already established productive vineyards

Final characterization:
GSTavg: Cool to Intermediate (Full quartile range)
HI: Cool to Warm Temperate (Full quartile range)
GDD: Very Cool, Region I to Cool, Region II (75% to Maximum quartile range)
BEDD: Temperate (25% to Maximum quartile range)
Modified GSTavg: Intermediate to Warm (Full quartile range)

Montana



Highlights:

- 147,245 square miles
- 31 planted acres (12.5 hectares)
- 3+ commercial vineyards
- 35th in US production (20,025 gal/yr)
- Elevation range: 549 m to 3901 m
- Dfa, Dfb, Dfc, Dsb and Dsc Koppen Classification

- Most common varietals grown are *V. Vinifera*, such as Pinot Noir, Pinot Gris, Chardonnay and Gewurtztriminer, and cold hardy French Hybids grown, such as Frontanec, Leon Millot, Foch and St. Croix.

Climate indices original characterization:
GSTavg: Too Cool; Cool
HI: Too Cool; Very Cool; Cool; Temperate
GDD: Too Cool; Very Cool, Region I
BEDD: Too Cool; Very Cool; Cool
GSTavg: Too Cool; Cool, Intermediate

Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	-1	9	12	13	15
HI	0	994	1455	1673	2041
GDD	0	401	768	982	1258
BEDD	-127	565	971	1127	1382
Modified GSTavg	10	19	22	25	34

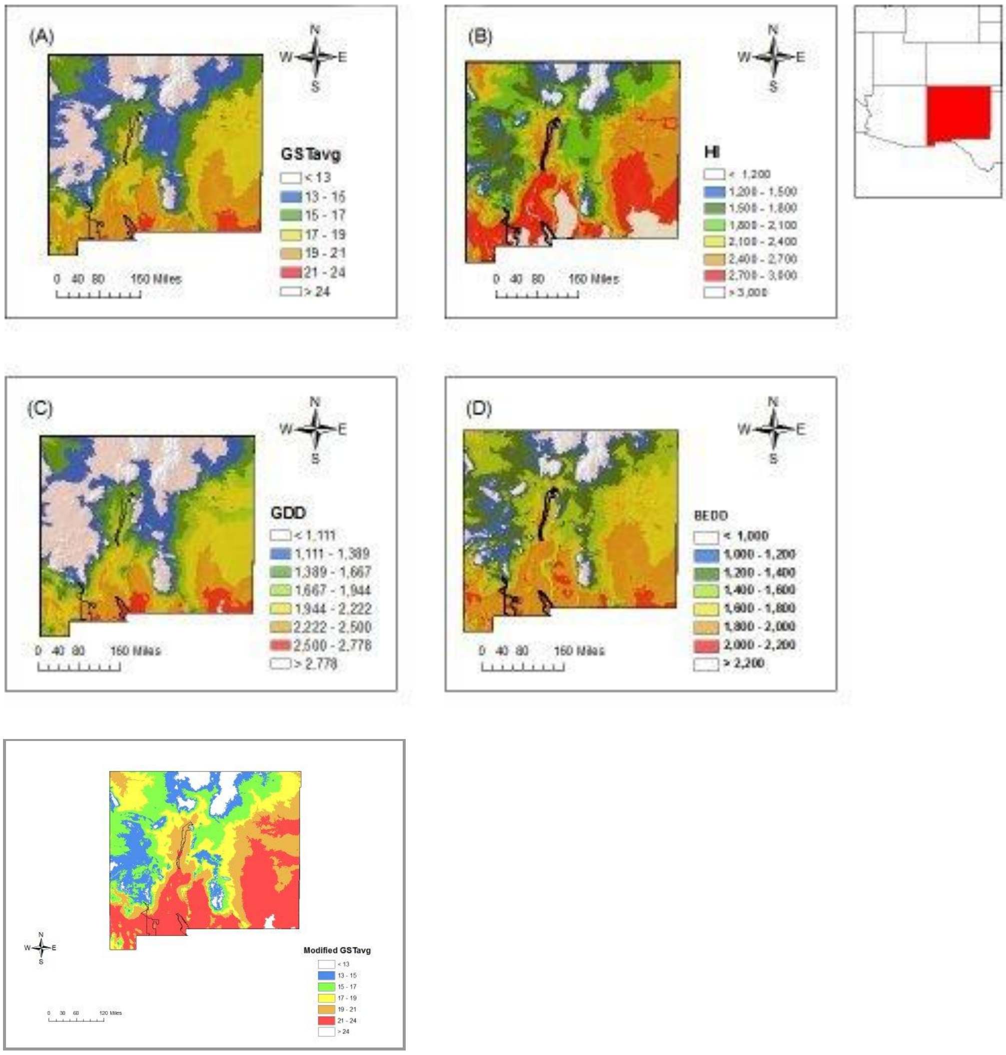
Factors affecting alteration of characterizations:

- Already established productive vineyards
- Many areas suited for crop farming
- Coolest maturity classes are found at higher elevations, or in National and State Parks, Federal Lands where it is unsuitable for planting

Final characterization:
GSTavg: Cool (Maximum quartile range)
HI: Cool to Temperate (75% to Maximum quartile range)
GDD: Very Cool (Maximum quartile range)
BEDD: Very Cool (Maximum quartile range)
GSTavg: Cool to Intermediate (Minimum to Median quartile range)

** Range of quartile statistics for standard indices may not fully capture climate structure of the state **

New Mexico



Highlights:

- 121,757 square miles
- 951 planted acres (282.5 hectares)
- 37+ commercial vineyards
- 3 AVA (Middle Rio Grande Valley, Mimbres Valley, Mesilla Valley)
- Ranks 30th in US production (69,280 gal/yr)
- Elevation range: 866 m to 4011.5 m

- Dfa, Dfb, Dfc, H, Dsb, Dsc, Csa and Csb Koppen Classification
- Most common *V. Vinifera* varietals grown are Chardonnay, Cabernet Sauvignon, Johannisberg Riesling, Merlot, Pinot Noir, Sauvignon Blanc and Zinfandel.

Climate indices original characterization:
GSTavg: Too Cool, Cool, Intermediate, Warm, Hot, Very Hot
HI: Too Cool, Very Cool, Cool, Temperate, Warm Temperate, Warm, Very Warm, Too Hot
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI; Too Hot
BEDD: Too Cool; Very Cool, Cool, Temperate, Warm Temperate, Warm, Very Warm
Modified GSTavg: Too Cool, Cool, Intermediate, Warm, Hot, Very Hot, Too Hot

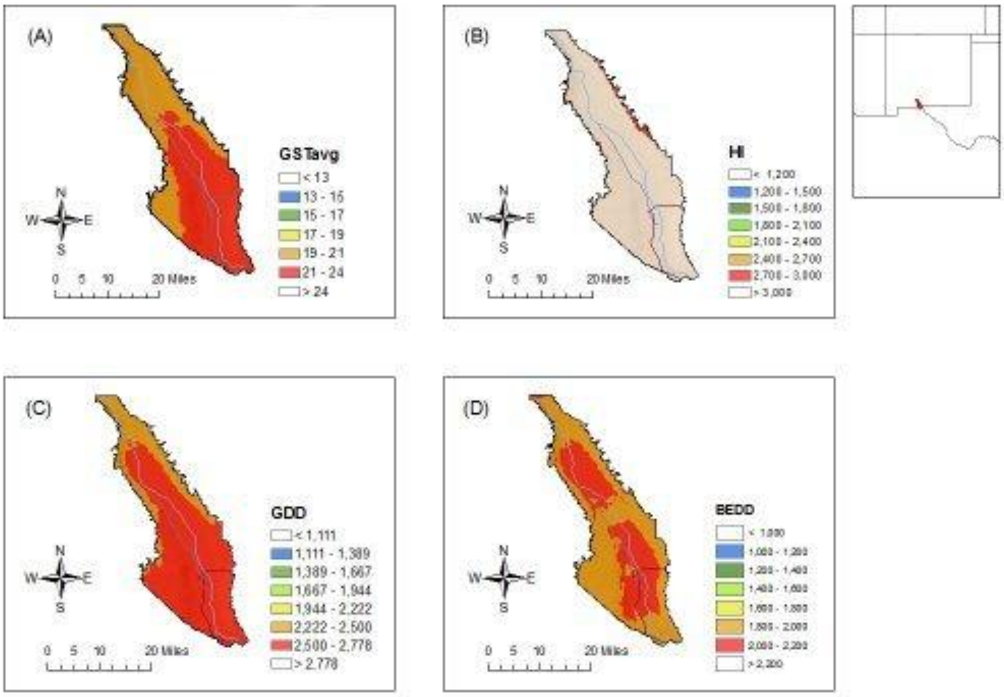
Quartile Statistics:

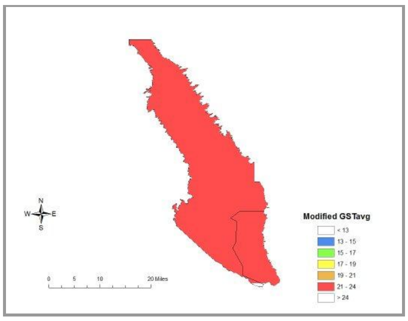
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	5	14	17	19	23
HI	248	1783	2242	2695	3390
GDD	0	1041	1501	2051	2845
BEDD	23	1286	1553	1813	2079
Modified GSTavg	11	19	23	25	34

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Coolest maturity classes are found at higher elevations, or in National or State Parks, where it is unsuitable for planting

Final characterization:
GSTavg: Intermediate to Very Hot (Median to Maximum quartile range)
HI: Warm Temperate to Too Hot (Median to Maximum quartile range)
GDD: Warm Temperate, Region IV to Too Hot (75% to Maximum quartile range)
BEDD: Temperate to Very Warm (Median to Maximum quartile range)
Modified GSTavg: Intermediate to Very Hot (Minimum to 75% quartile range)

Mesilla Valley AVA





Highlights:

- 293,770.8 total acres (118,889 hectares)
- 35 planted acres (14.2 hectares)
- Vineyard size ranges from 2 acres (0.8 hectares) to 25 acres (10 hectares)
- 4+ commercial vineyards
- Elevation range: 1148 m to 1323 m (median value of 1198 m)

__Climate indices original characterization:__
GSTavg: Hot (45%); Very Hot (55%)
HI: Very Warm (5%); Too Hot (95%)
GDD: Warm, Region V (22%); Very Warm, Region VI (78%)
BEDD: Warm (62%); Very Warm (38%)
Modified GSTavg: Very Hot (100%)

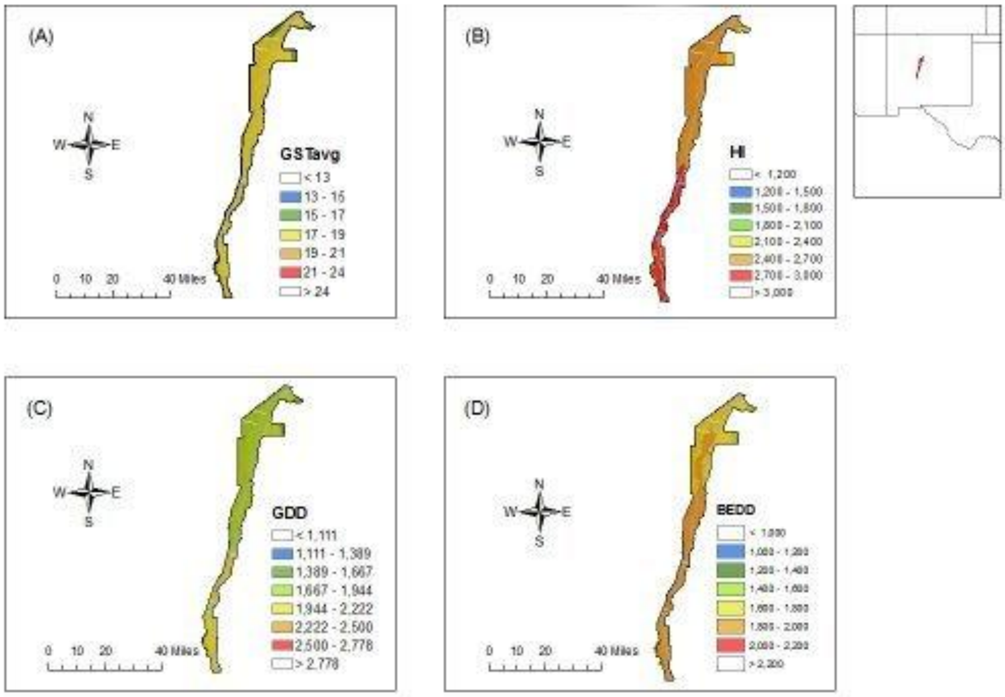
Quartile Statistics:

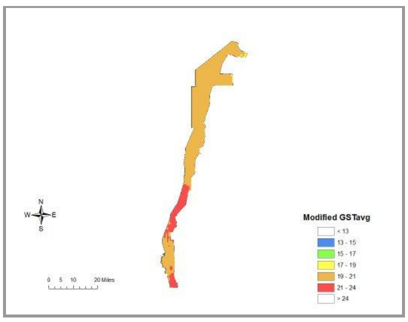
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	21	21	21	22	22
HI	2993	3054	3115	3176	3207
GDD	2386	2479	2539	2631	2692
BEDD	1926	1950	1988	2003	2033
Modified GSTavg	27	27	28	28	28

__Factors affecting alteration of characterizations:__
- Already established productive vineyards

__Final characterization:__
GSTavg: Hot to Very Hot (Full quartile range)
HI: Very Warm to Too Hot (Minimum to 25% quartile range)
GDD: Warm, Region V to Very Warm, Region VI (Full quartile range)
BEDD: Warm to Very Warm (Full quartile range)
Modified GSTavg: Very Hot (Full quartile range)

Middle Rio Grande Valley AVA





Highlights:

- 310,926.6 total acres (125,832 hectares)
- 205 planted acres (83 hectares)
- Vineyard size ranges from 3 acres (1.2 hectares) to 180 acres (72.8 hectares)
- 5+ commercial vineyards
- Elevation range:1390 m to 1870m (median value 1497 m)

<u>Climate indices original characterization:</u>
GSTavg: Intermediate (5%); Warm (95%)
HI: Warm Temperate (4%); Warm (71%); Very Warm (25%)
GDD: Cool, Region II (2%); Temperate, Region III (71%); Warm Temperate, Region IV (27%)
BEDD: Temperate (3%); Warm Temperate (37%); Warm (60%)
Modified GSTavg: Hot (96%); Very Hot (4%)

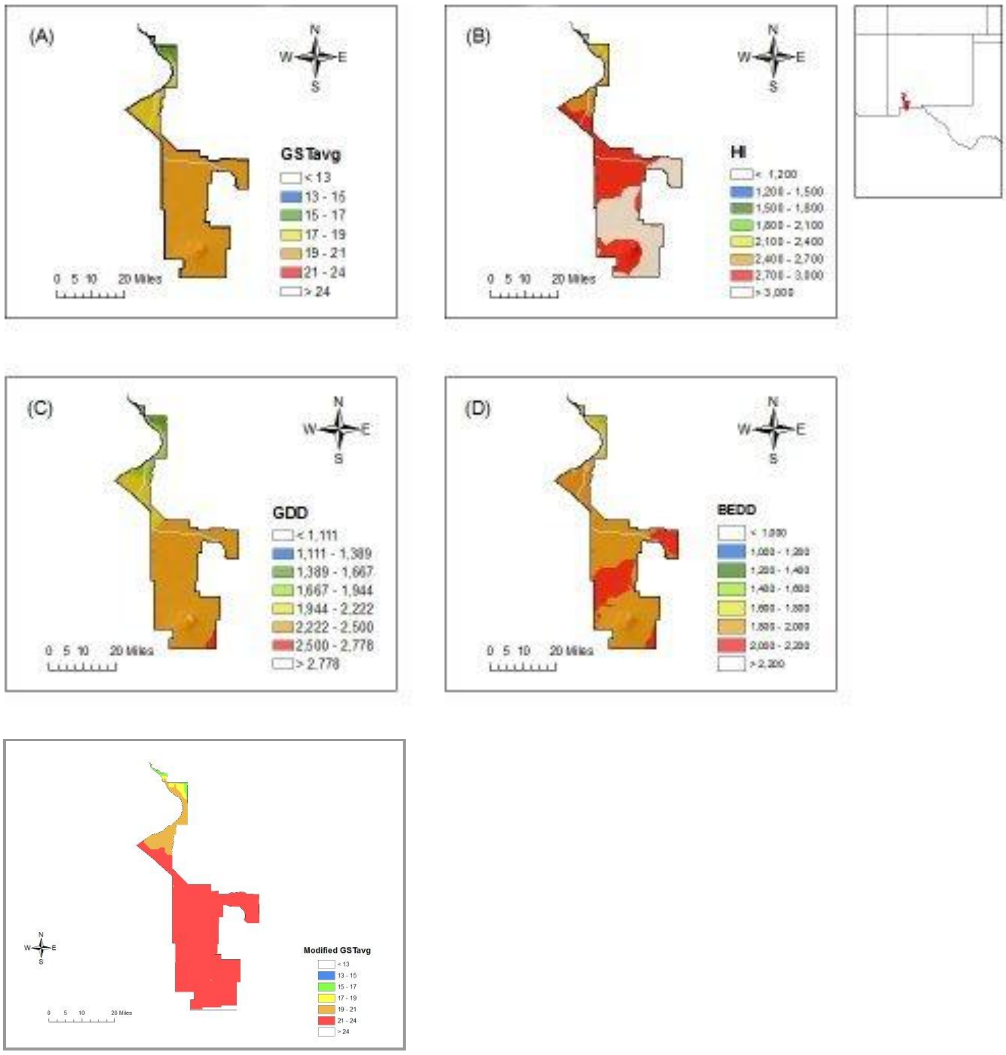
Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	18	18	18	19	19
HI	2365	2550	2638	2694	2880
GDD	1714	1791	1837	1958	2081
BEDD	1605	1753	1804	1837	1962
Modified GSTavg	23	25	25	25	26

<u>Factors affecting alteration of characterizations:</u>
None

<u>Final characterization:</u>
GSTavg: Intermediate to Warm (Full quartile range)
HI: Warm Temperate to Very Warm (Full quartile range)
GDD: Cool to Warm Temperate (Full quartile range)
BEDD: Temperate to Warm (Full quartile range)
Modified GSTavg: Hot to Very Hot (Full quartile range)

Mimbres Valley AVA



Highlights:

- 444,847.3 total acres (180,029.7 hectares)
- 228 planted acres (92.3 hectares)
- Vineyard size ranges from 28 acres (11.3 hectares) to 200 acres (81 hectares)
- 2+ commercial vineyards
- Elevation range:1233 m to 1923m (median value 1309 m)

Climate indices original characterization:
GSTavg: Intermediate (3%); Warm (13%); Hot (84%)
HI: Warm Temperate (3%); Warm (9%); Very Warm (46%); Hot (42%)
GDD: Cool, Region II (3%); Temperate, Region III (6%); Warm Temperate, Region IV (10%); Warm, Region V (79%); Very Warm, Region VI (2%)
BEDD: Temperate (1%); Warm Temperate (5%); Warm (70%); Very Warm (24%)
Modified GSTavg: Warm (3%); Hot (13%); Very Hot (84%)

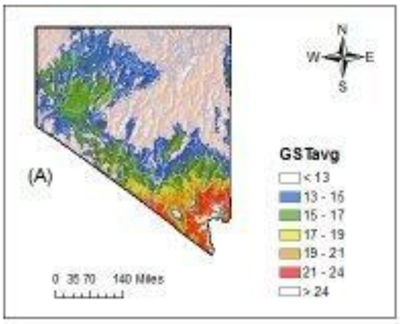
Quartile Statistics:

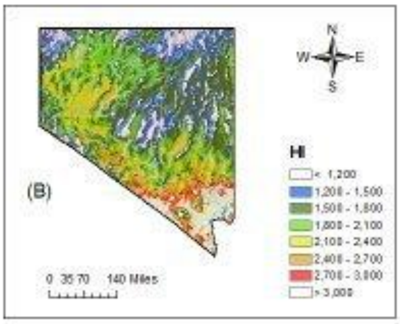
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	19	20	21	21	21
HI	2688	2933	2993	3054	3085
GDD	1989	2265	2356	2417	2448
BEDD	1850	1934	1980	1995	2011
Modified GSTavg	25	27	27	27	27

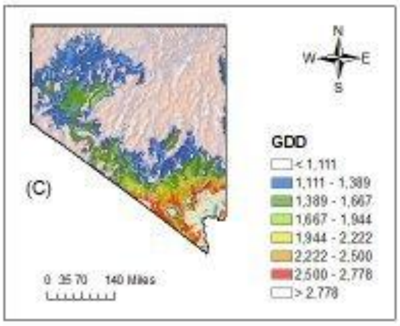
Factors affecting alteration of characterizations:
- Already established productive vineyards

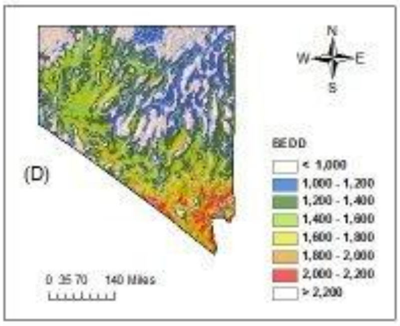
Final characterization:
GSTavg: Intermediate to Warm (Full quartile range)
HI: Warm Temperate to Very Warm (Minimum to Median quartile range)
GDD: Cool to Warm Temperate (Full quartile range)
BEDD: Temperate to Warm (Full quartile range)
Modified GSTavg: Warm to Very Hot (Full quartile range)

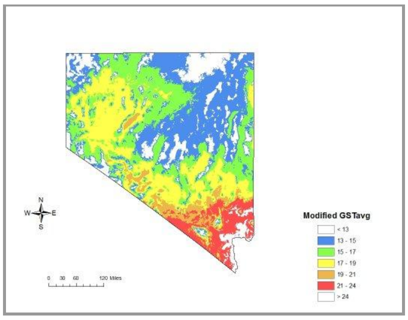
Nevada











Highlights:

- 110,670 square miles
- 37 planted acres (15 hectares)
- 3+ commercial vineyards
- No production data
- Elevation range: 146 m to 4007.2 m
- Dfb, Dfc, Dsb, Bwh and Aw Koppen Classification

- Most common *V. Vinifera* varietals grown are Chardonnay, Cabernet Sauvignon, and Merlot

Climate indices original characterization:
GSTavg: Too Cool, Cool, Intermediate, Warm, Hot, Too Hot
HI: Too Cool, Very Cool, Cool, Temperate, Warm Temperate, Warm, Very Warm, Too Hot
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI; Too Hot
BEDD: Too Cool; Very Cool, Cool, Temperate, Warm Temperate, Warm, Very Warm, Too Hot
Modified GSTavg: Too Cool, Cool, Intermediate, Warm, Hot, Too Hot

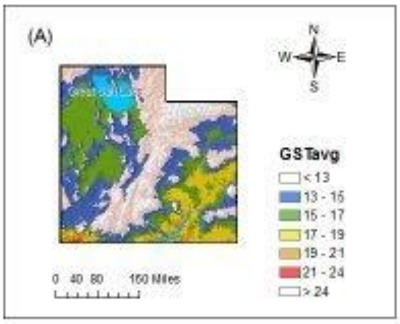
Quartile Statistics:

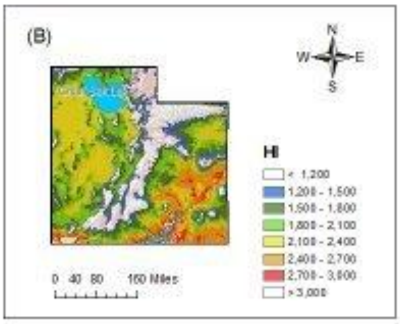
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	4	12	14	16	27
HI	158	1473	1750	2130	4213
GDD	0	767	1042	1349	3825
BEDD	-8	1015	1225	1469	2228
Modified GSTavg	10	19	22	25	29

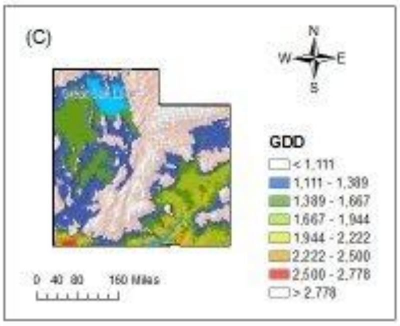
Factors affecting alteration of characterizations:
- Already established productive vineyards
- Coolest maturity classes are found at higher elevations, or in National or State Parks, where it is unsuitable for planting

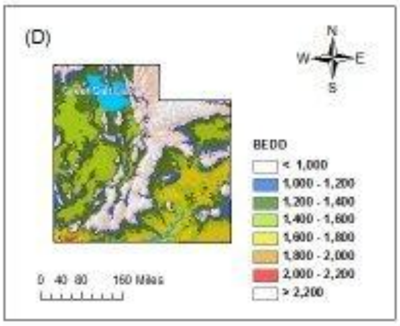
Final characterization:
GSTavg: Cool to Too Hot (Median to Maximum quartile range)
HI: Cool to Too Hot(Median to Maximum quartile range)
GDD: Cool, Region II to Too Hot (75% to Maximum quartile range)
BEDD: Temperate to Too Hot (75% to Maximum quartile range)
Modified GSTavg: Cool to Too Hot (Full quartile range)

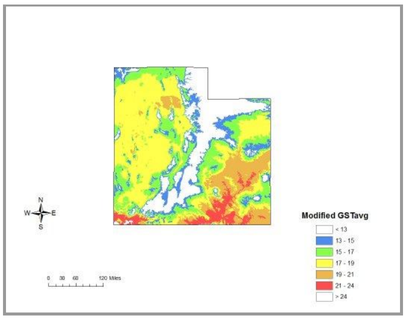
Utah











Highlights:

- 84,872 square miles
- 29 planted acres (11.7 hectares)
- 3+ commercial vineyards
- No production data
- Elevation range: 610 m to 4123 m
- Dfa, Dfb, Dfc and Dsb Koppen Classification

- Most common *V. Vinifera* varietals grown are Chardonnay, Cabernet Sauvignon, Pinot Noir, Merlot, Chenin Blanc and Gewurztraminer

<u>Climate indices original characterization:</u>
GSTavg: Too Cool, Cool, Intermediate, Warm, Hot, Very Hot
HI: Too Cool, Very Cool, Cool, Temperate, Warm Temperate, Warm, Very Warm, Too Hot
GDD: Too Cool; Very Cool, Region I; Cool, Region II; Temperate, Region III; Warm Temperate, Region IV; Warm, Region V; Very Warm, Region VI
BEDD: Too Cool; Very Cool, Cool, Temperate, Warm Temperate, Warm, Very Warm
Modified GSTavg: Too Cool, Cool, Intermediate, Warm, Hot, Very Hot

Quartile Statistics:

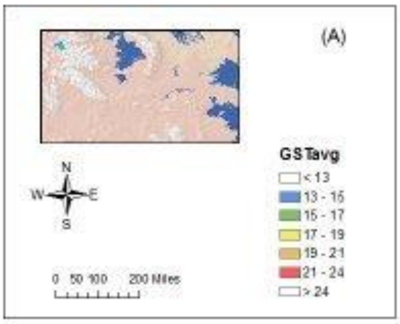
INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	0	12	15	16	22
HI	0	1427	1948	2214	3428
GDD	0	797	1226	1441	2755
BEDD	31	938	1285	1446	2099
Modified GSTavg	8	20	22	25	30

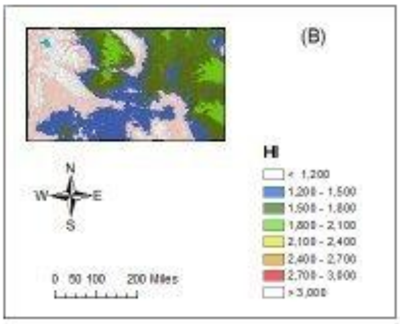
<u>Factors affecting alteration of characterizations:</u>

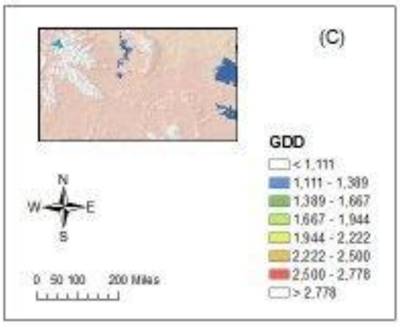
- Already established productive vineyards
- Coolest maturity classes are found at higher elevations, or in National or State Parks, where it is unsuitable for planting

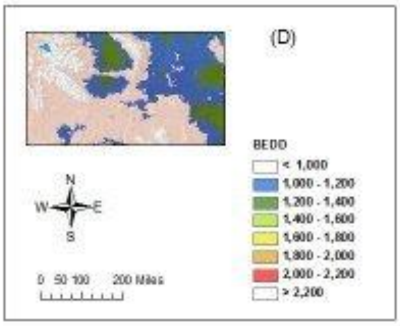
<u>Final characterization:</u>
GSTavg: Intermediate to Very Hot (Median to Maximum quartile range)
HI: Temperate to Too Hot (Median to Maximum quartile range)
GDD: Cool, Region II to Very Warm (75% to Maximum quartile range)
BEDD: Temperate to Very Warm (Median to Maximum quartile range)
Modified GSTavg: Intermediate to Very Hot (Full Quartile range)

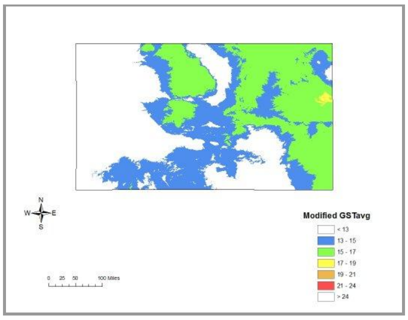
Wyoming











Highlights:

- 97,803 square miles
- 11 planted acres (4.5 hectares)
- 2+ commercial vineyards
- No production data
- Elevation range: 945 m to 4207.5 m
- Dfb, Dfc, Dsb, Dsc and H Koppen Classification

- Mostly commonly grown winegrapes are cold hardy French Hybrid varietals, such as Frontenac, Frontenac Gris, Marchael Foch and Marquette

Climate indices original characterization:
GSTavg: Too Cool; Cool
HI: Too Cool; Very Cool; Cool; Temperate
GDD: Too Cool; Very Cool, Region I
BEDD: Too Cool; Very Cool; Cool
Modified GSTavg: Too Cool; Cool, Intermediate

Quartile Statistics:

INDEX	MINIMUM	25%	MEDIAN	75%	MAXIMUM
GSTavg	0	9	11	13	15
HI	0	947	1353	1640	1997
GDD	0	401	706	921	1258
BEDD	-69	610	914	1116	1398
Modified GSTavg	9	19	23	25	33

Factors affecting alteration of characterizations:
- Already established productive vineyards
- Many areas suited for crop farming

Final characterization:
GSTavg: Cool (75% to Maximum quartile range)
HI: Cool to Temperate (75% to Maximum quartile range)
GDD: Very Cool (Maximum quartile range)
BEDD: Very Cool (Maximum quartile range)
Modified GSTavg: Cool to Intermediate (Minimum to Median quartile range)

** Range of quartile statistics for standard indices may not fully capture climate structure of the state **

Appendix III: GISS-AOM Trend Analysis

Table 5: Summary of average growing season temperature (GSTavg) trends (Apr – Oct) for the time period 1950 – 2000. Data source: GISS-AOM.

Name of Location	GSTavg Trends (Apr - Oct)
Milford	1.3906
Mora	1.4534
Lancaster	1.4619
Mandan	1.5825
Allegan	1.5962
Erie	1.6681
Indianola	1.7126
Geneva	1.7258
Bedford	1.7321
Gardiner	1.7321
Allentown	1.7385
Bridgehampton	1.7385
Watertown	1.7495
Towanda	1.7671
Woodstock	1.7671
Burlington	1.7692
Columbus	1.7703
Arcadia	1.7936
Coshocton	1.8014
Charlottesville	1.8222
Riverton	1.84731
Kinston	1.9113
Fallon	1.9288
Dahlonega	1.959
Lenoir	1.959
Summerville	1.959
DeFuniak	1.9606
Talladega	2.002
Anna	2.0293
Rolla	2.0293
Scott City	2.0366
Fruita	2.04431
St. Ignatius	2.04431
Crete	2.0938
Calhoun	2.2419
Prescott	2.2587
New Braunfels	2.3143
Tucson	2.3827
Falls Village	2.3997
Jackson	2.4174
Blanding	2.4259
Ozark	2.5204
Crosbyton	2.657
Pauls Valley	2.678
Los Lunas	2.6928
New Mexico State Uni	2.9042

Table 6: Summary of average temperature trends of January – April temperatures for the time period 1950 – 2000. Data source: GISS-AOM

Name	Jan – Apr Average Temperature Trends
Milford	0.5015
DeFuniak	0.5542
Arcadia	0.6556
Calhoun	0.7985
Talladega	0.80891
Kinston	0.8139
Jackson	0.8553
Dahlonega	0.87598
Lenoir	0.87598
Summerville	0.87598
Ozark	1.0084
Charlottesville	1.03903
Anna	1.07534
Rolla	1.07534
Indianola	1.0864
Mora	1.27044
Columbus	1.33943
Pauls Valley	1.3593
New Braunfels	1.3698
Lancaster	1.406136
Coshocton	1.40927
Allentown	1.41578
Bridgehampton	1.41578
Towanda	1.428624
Woodstock	1.428624
Crete	1.43576
Watertown	1.4475
Crosbyton	1.75097
Allegan	1.81602682
Mandan	1.82345
Scott City	1.85048
Tucson	1.9348
Erie	1.94626
Geneva	1.969761
New Mexico State University	2.03061
Burlington	2.03152
Bedford	2.1178013
Gardiner	2.1178013
Los Lunas	2.24268
Prescott	2.2849
Riverton	2.44885
Fallon	2.69151
Falls Village	2.76779
Blanding	2.81429
Fruita	2.9035461
St. Ignatius	2.9035461

Table 7: Summary of average temperature trends of August - October temperatures for the time period 1950 – 2000. Data source: GISS-AOM

Name	Aug – Oct Average Temperature Trends
Lancaster	1.4552
Milford	1.4862
Allegan	1.508
Erie	1.5086
Mora	1.5184
Geneva	1.5482
Bedford	1.5756
Gardiner	1.5756
Burlington	1.5788
Allentown	1.6384
Bridgehampton	1.6384
Towanda	1.6746
Woodstock	1.6746
Indianola	1.6999
Coshocton	1.7055
Columbus	1.717
Riverton	1.7176
Charlottesville	1.7341
Fruita	1.7506
St. Ignatius	1.7506
Arcadia	1.8235
Scott City	1.8276
Mandan	1.8355
Watertown	1.8561
Blanding	1.967
Kinston	1.9689
Dahlonega	2.0284
Lenoir	2.0284
Summerville	2.0284
Anna	2.0579
Rolla	2.0579
DeFuniak	2.058
Crete	2.0848
Talladega	2.087
Prescott	2.1183
Tucson	2.1602
New Braunfels	2.1916
Calhoun	2.2328
Fallon	2.2423
Los Lunas	2.3284
Crosbyton	2.4317
Falls Village	2.4704
Ozark	2.487
Pauls Valley	2.5249
Jackson	2.5446
New Mexico State University	2.696

Table 8: Summary of average temperature trends of October - December temperatures for the time period 1950 – 2000. Data source: GISS-AOM

Name	Oct – Dec Average Temperature Trends
Scott City	1.20151
Milford	1.241
Calhoun	1.2423
DeFuniak	1.266
Ozark	1.3237
Arcadia	1.3276
Pauls Valley	1.3327
Crosbyton	1.33514
Indianola	1.33994
Talladega	1.40924
Kinston	1.4174
Crete	1.42068
Fruita	1.432721
St. Ignatius	1.432721
Dahlonega	1.433
Lenoir	1.433
Summerville	1.433
Jackson	1.4478
Charlottesville	1.46731
Blanding	1.47965
Anna	1.49037
Rolla	1.49037
Falls Village	1.491048
Fallon	1.52698
Riverton	1.530942
Prescott	1.5327
Los Lunas	1.55625
Coshocton	1.57958
Columbus	1.58156
Tucson	1.6469
New Braunfels	1.6646
Towanda	1.68073
Woodstock	1.68073
Watertown	1.6942
Erie	1.72626
Allegan	1.73894
Lancaster	1.74944
Allentown	1.76216
Bridgehampton	1.76216
New Mexico State University	1.8108
Geneva	1.83278
Mandan	1.88728
Burlington	2.00418
Bedford	2.05073
Gardiner	2.05073

Mora	2.16718

Table 9: Summary of trends of January Minimum temperatures for the time period 1950 – 2000. Data source: GISS-AOM.

Name	Jan Minimum Temperature Trends
Kinston	0.18018
DeFuniak	0.3205
Milford	0.3698
Dahlonega	0.45907
Lenoir	0.45907
Summerville	0.45907
Charlottesville	0.535811
Talladega	0.55332
Arcadia	0.5616
Indianola	0.71054
Jackson	0.77172
Calhoun	0.80153
Anna	0.90488
Rolla	0.90488
Coshocton	1.02538
Ozark	1.03186
Crete	1.07605
Watertown	1.11219
Towanda	1.14573
Woodstock	1.14573
Columbus	1.15057
New Braunfels	1.15911
Pauls Valley	1.18879
Allentown	1.33101
Bridgehampton	1.33101
Mora	1.5596
Crosbyton	1.56014
Tucson	1.57324
New Mexico State University	1.581561
Lancaster	1.62739
Scott City	1.745032
Los Lunas	1.90163
Mandan	1.94242
Riverton	2.14658
Fruita	2.1714
St. Ignatius	2.1714
Prescott	2.28179
Blanding	2.58221
Falls Village	2.68452
Allegan	2.71589
Fallon	2.743117
Geneva	2.8592
Burlington	2.90975

Erie	3.09082
Bedford	3.13511
Gardiner	3.13511

Table 10: Summary of trends of August Maximum temperatures for the time period 1950 – 2000. Data source: USHCN Maximum and Minimum dataset.

Name	Aug Maximum Temperature Trends
Mora	1.2995
Riverton	1.4168
Lancaster	1.4366
Bedford	1.4643
Gardiner	1.4643
Burlington	1.523
Geneva	1.5647
Fruita	1.5849
St. Ignatius	1.5849
Erie	1.6064
Milford	1.6082
Watertown	1.6211
Allegan	1.6323
Mandan	1.6649
Indianola	1.7027
Allentown	1.7281
Bridgehampton	1.7281
Prescott	1.7326
Towanda	1.783
Woodstock	1.783
Blanding	1.8161
Coshocton	1.8261
Scott City	1.8621
Crete	1.8999
Charlottesville	1.9449
Arcadia	1.9636
Columbus	1.9749
Tucson	2.1562
Kinston	2.3527
Fallon	2.3714
Dahlonega	2.473
Lenoir	2.473
Summerville	2.473
DeFuniak	2.6276
New Braunfels	2.7472
Los Lunas	2.7704
Talladega	2.8124
Anna	2.8757
Rolla	2.8757
Falls Village	2.9577
Calhoun	2.9996

Pauls Valley	3.0743
Ozark	3.1149
Crosbyton	3.3674
Jackson	3.4091
New Mexico State University	3.4384

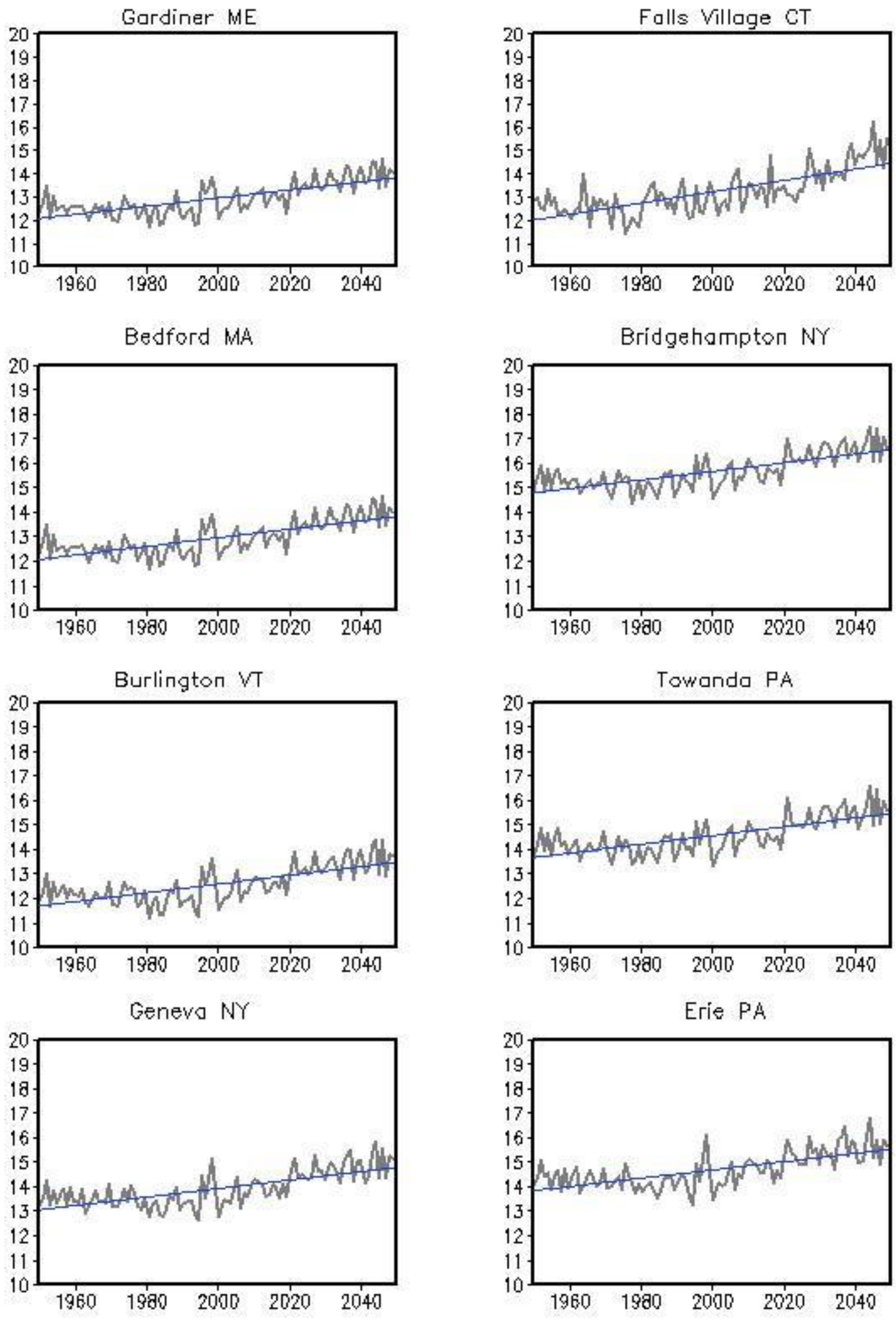


Figure 1: Growing Season Temperature Averages (April – October) for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

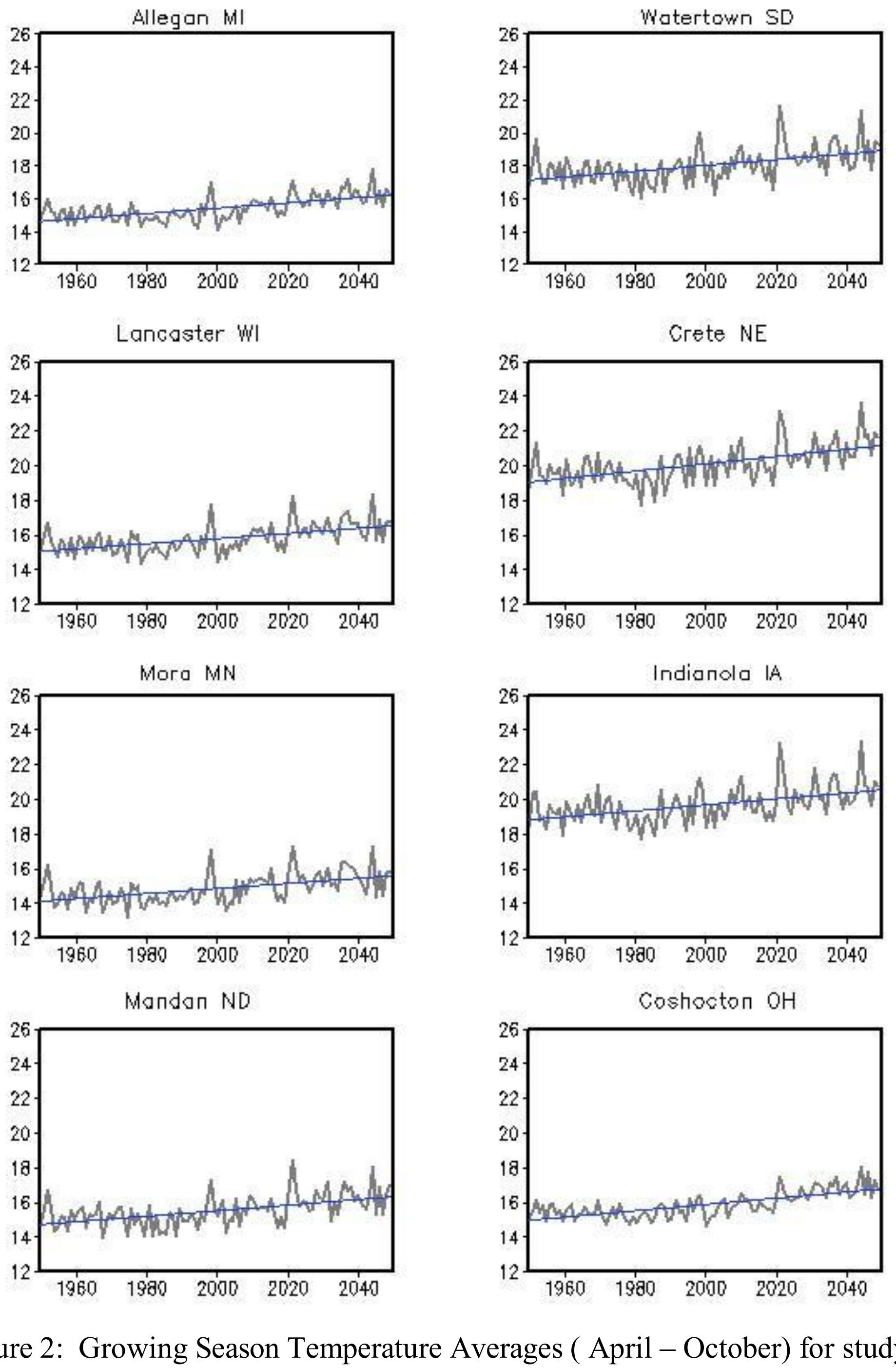


Figure 2: Growing Season Temperature Averages (April – October) for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

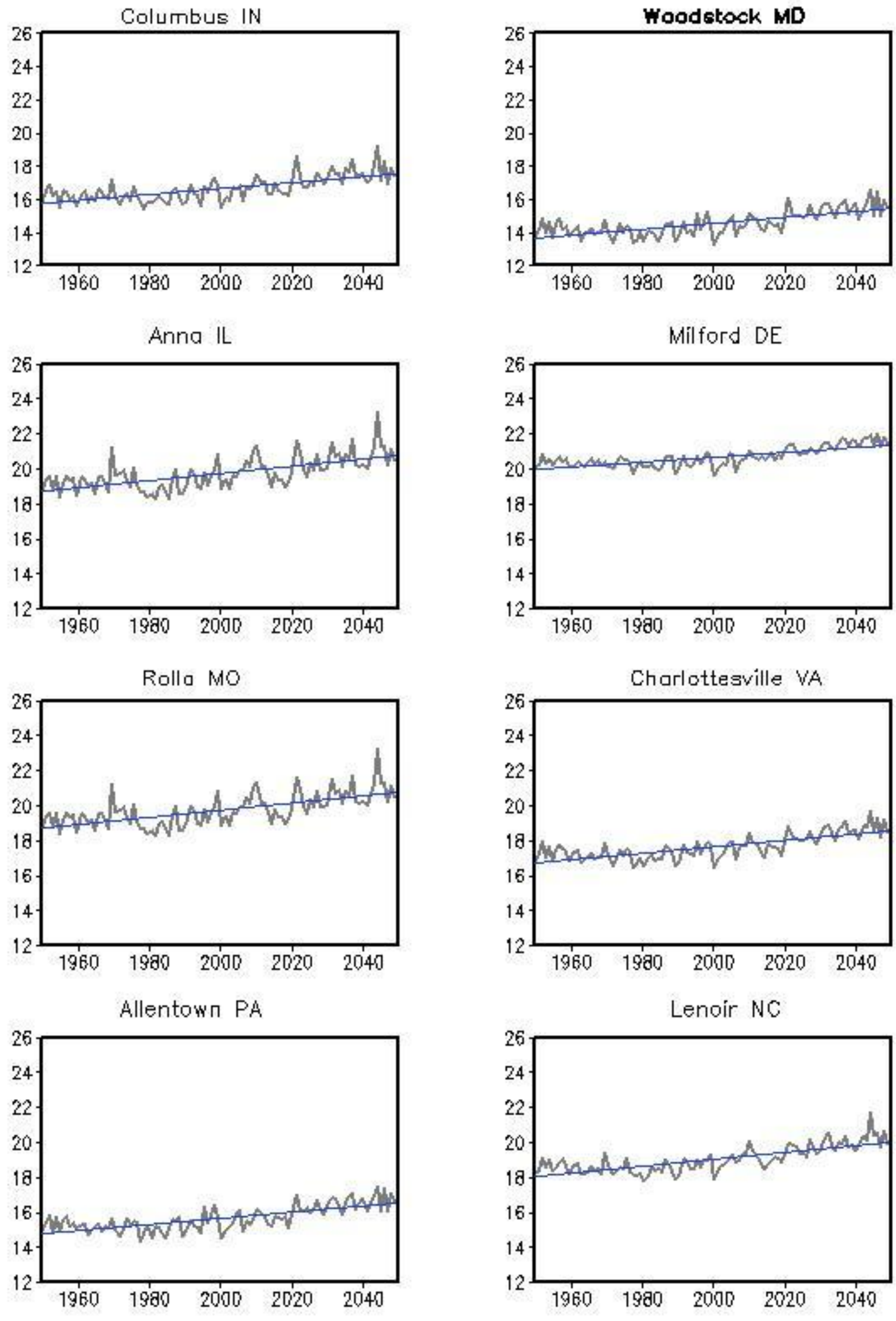


Figure 3: Growing Season Temperature Averages (April – October) for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

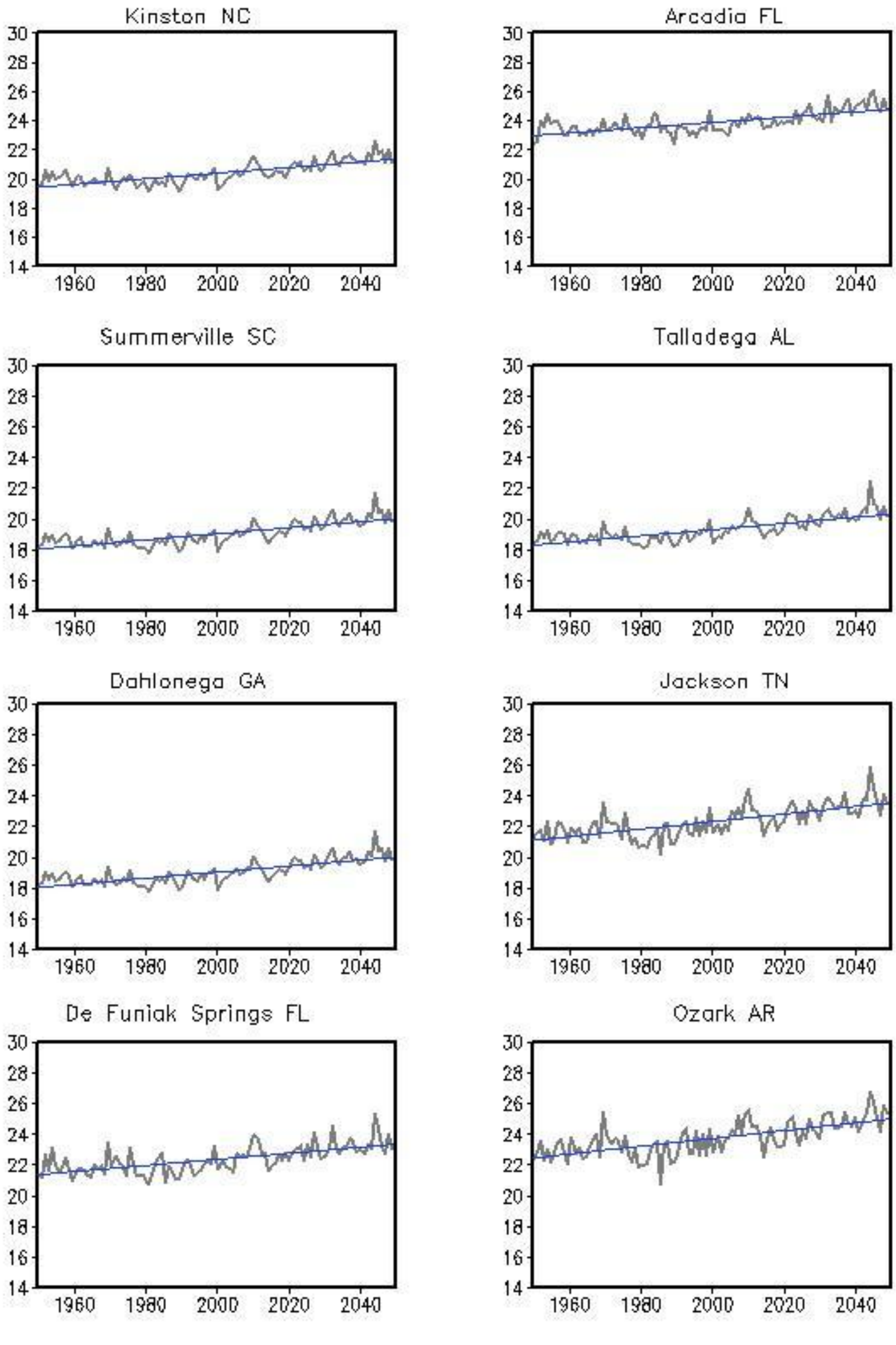


Figure 4: Growing Season Temperature Averages (April – October) for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

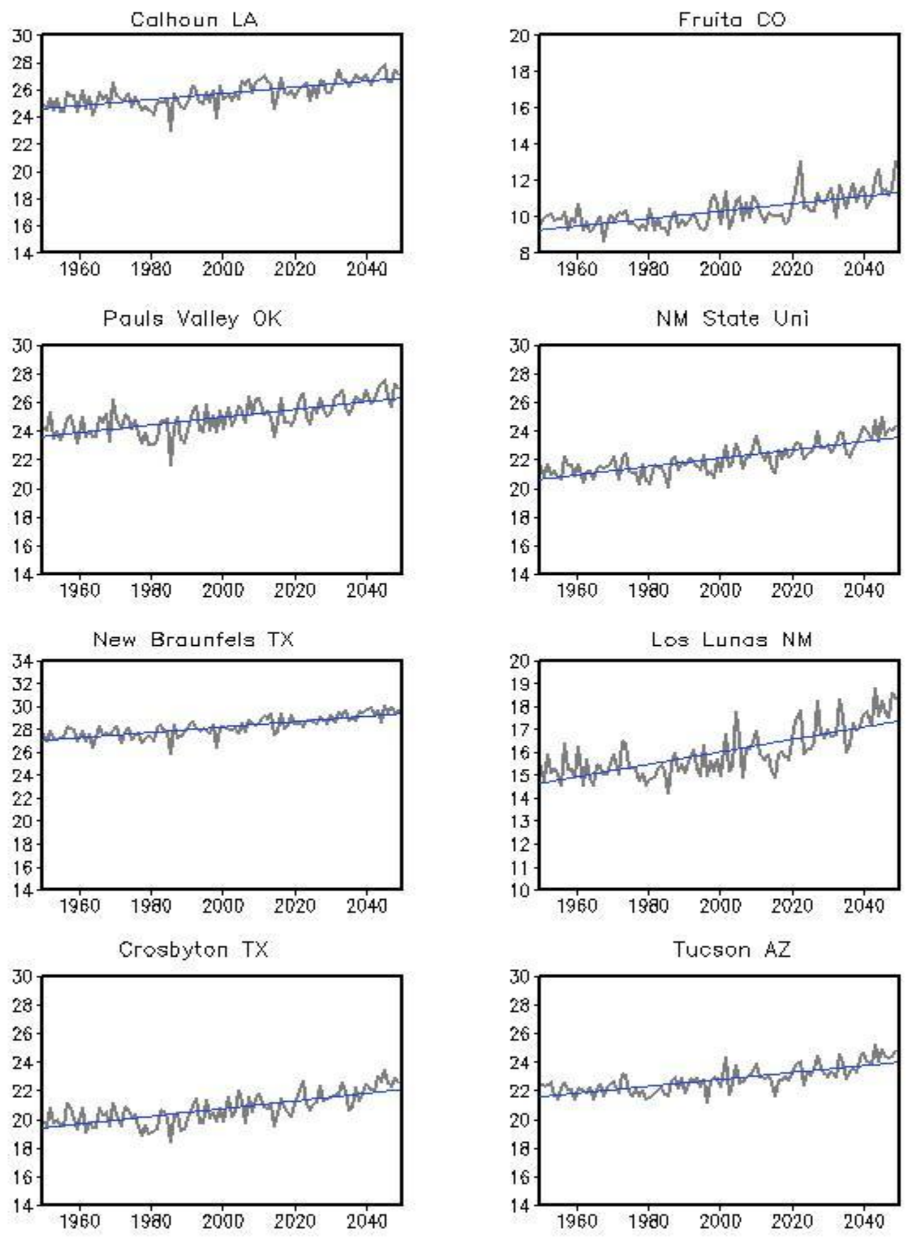


Figure 5: Growing Season Temperature Averages (April – October) for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

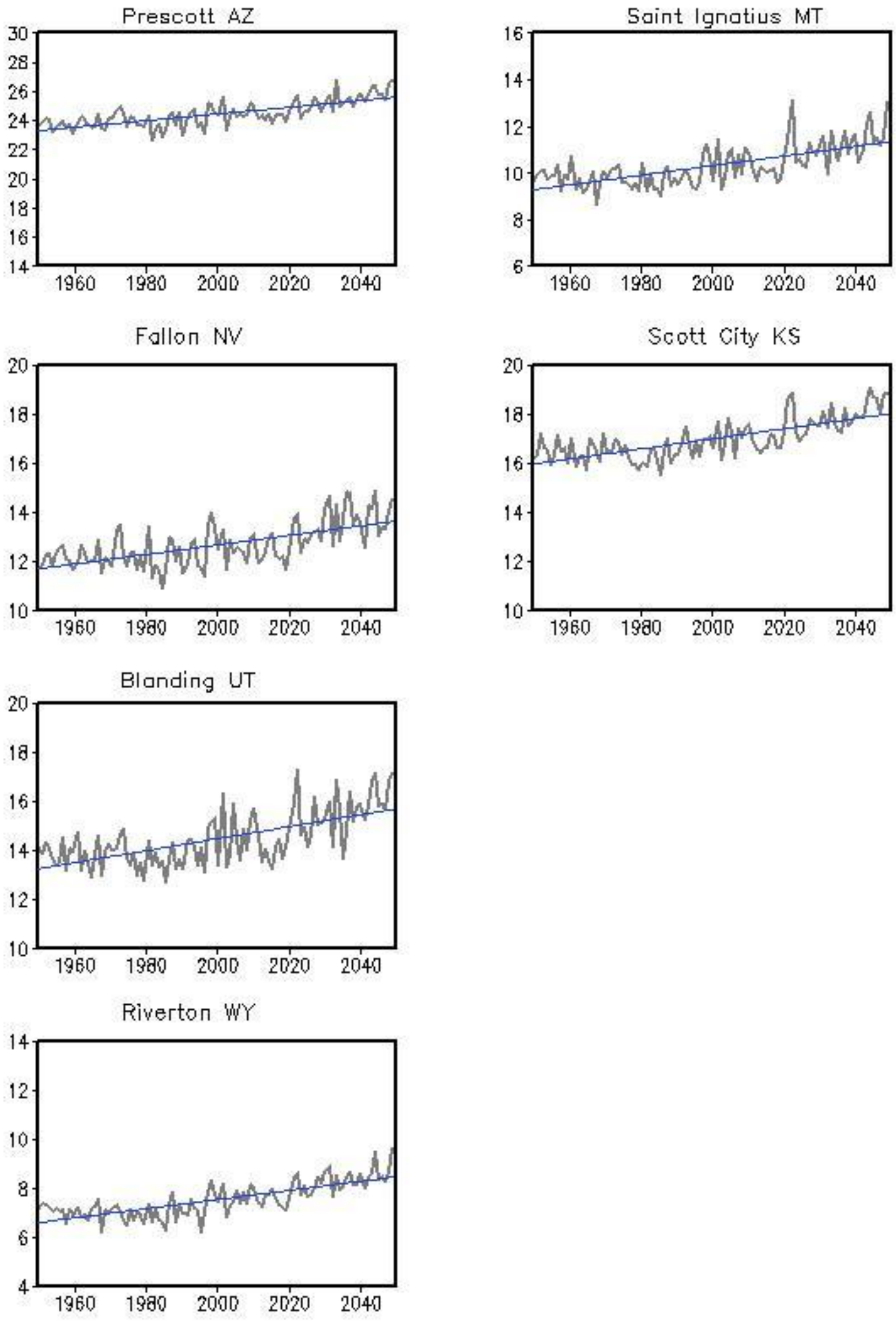


Figure 6: Growing Season Temperature Averages (April – October) for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

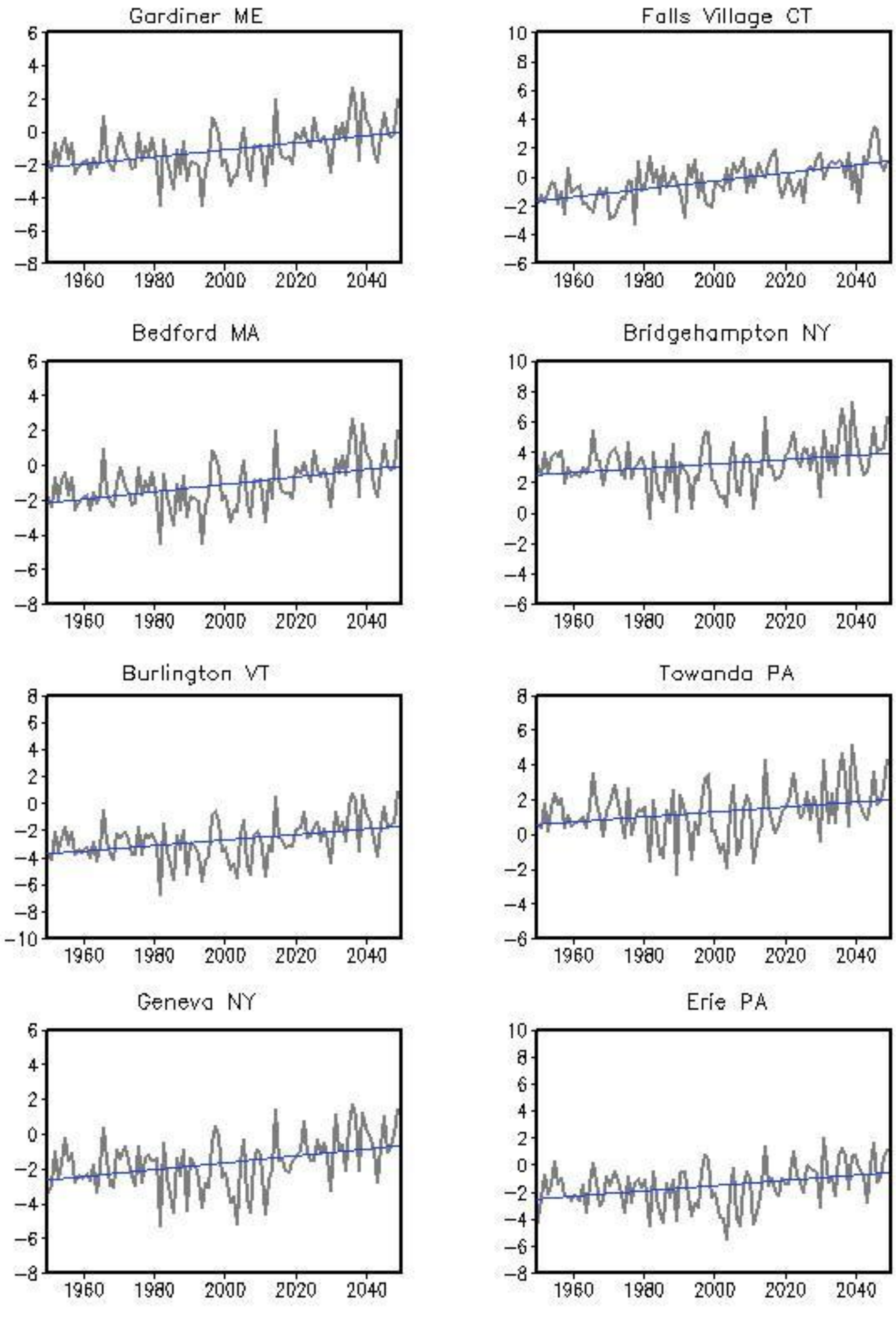


Figure 7: January – April Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

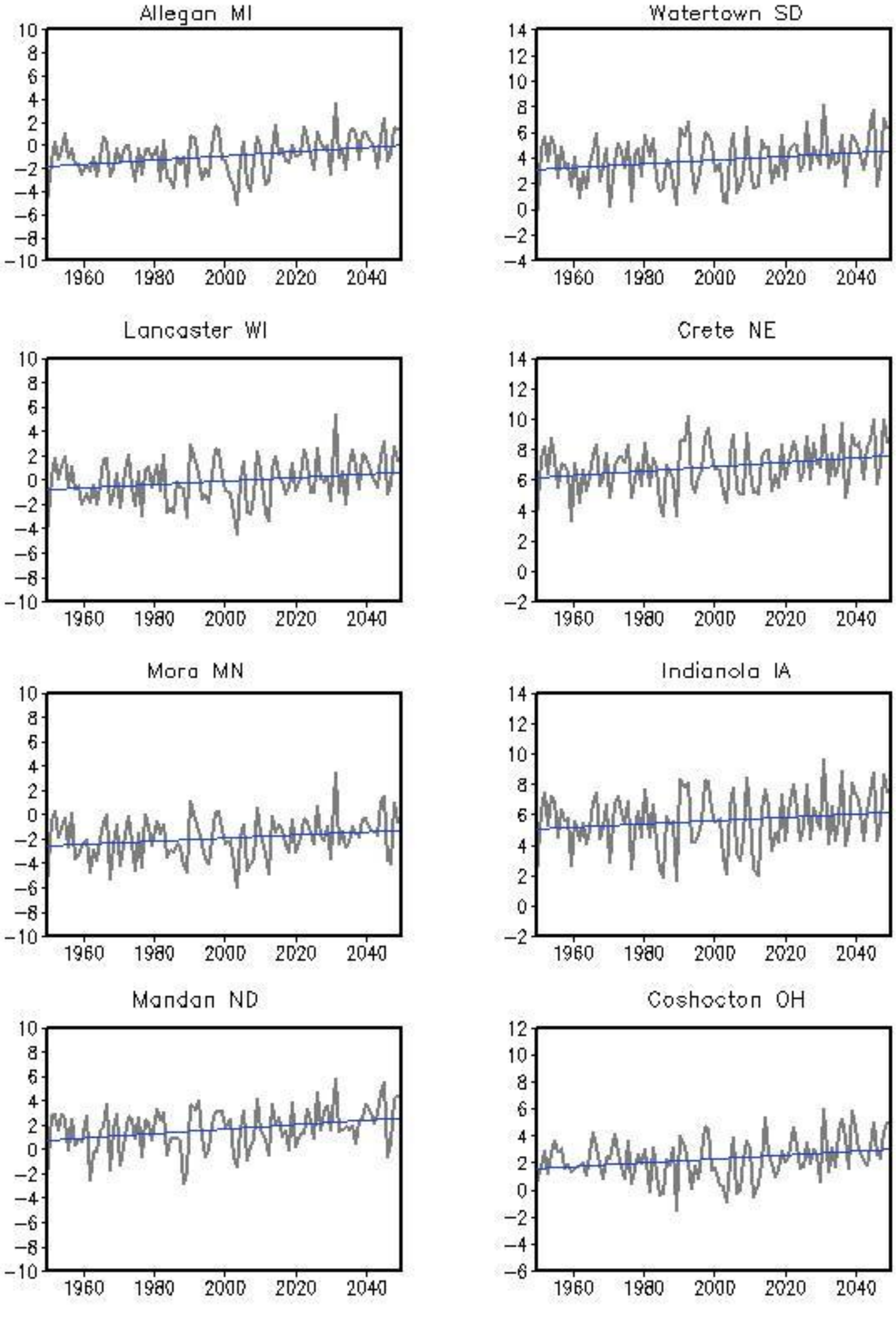


Figure 8: January – April Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

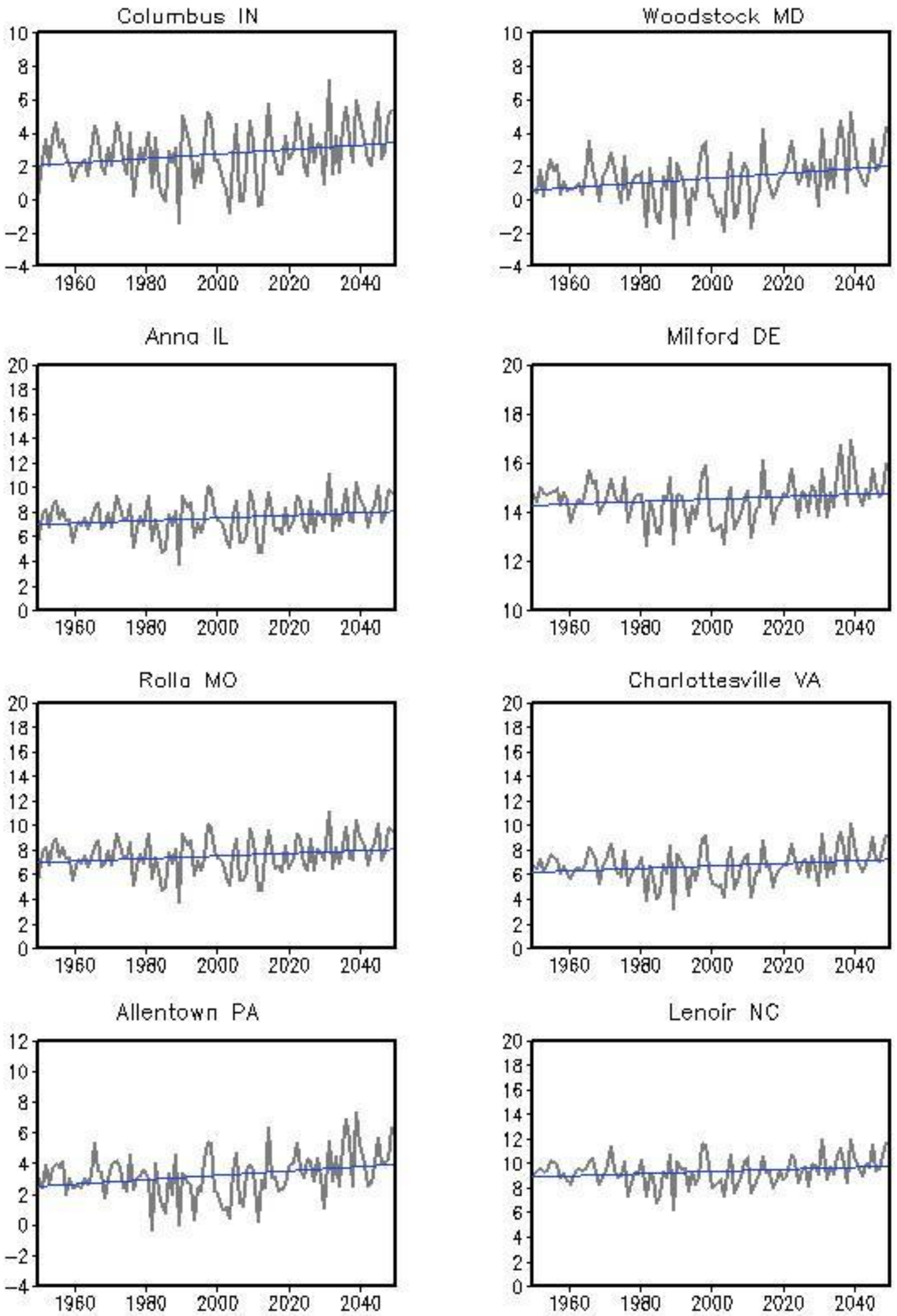


Figure 9: January – April Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

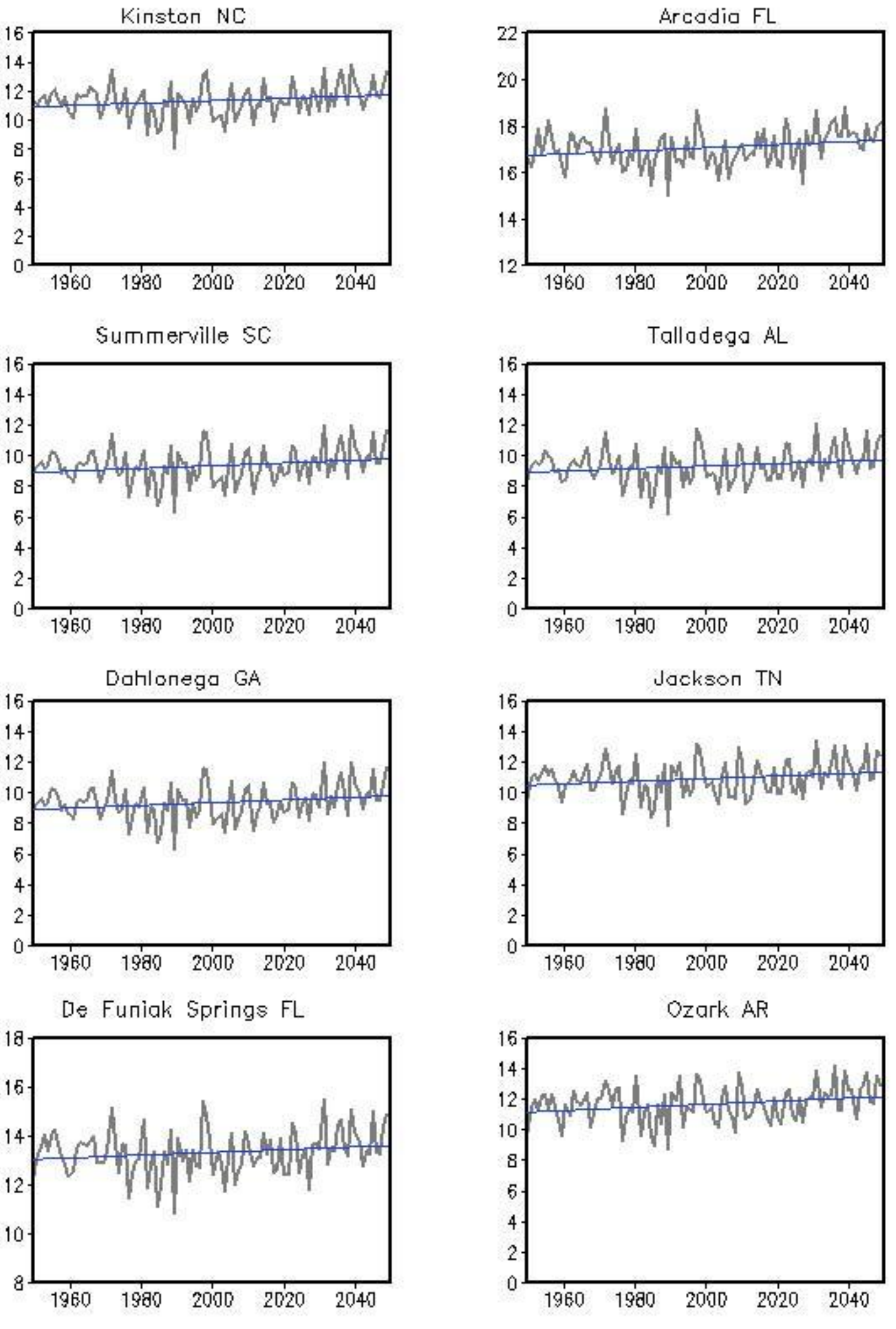


Figure 10: January – April Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

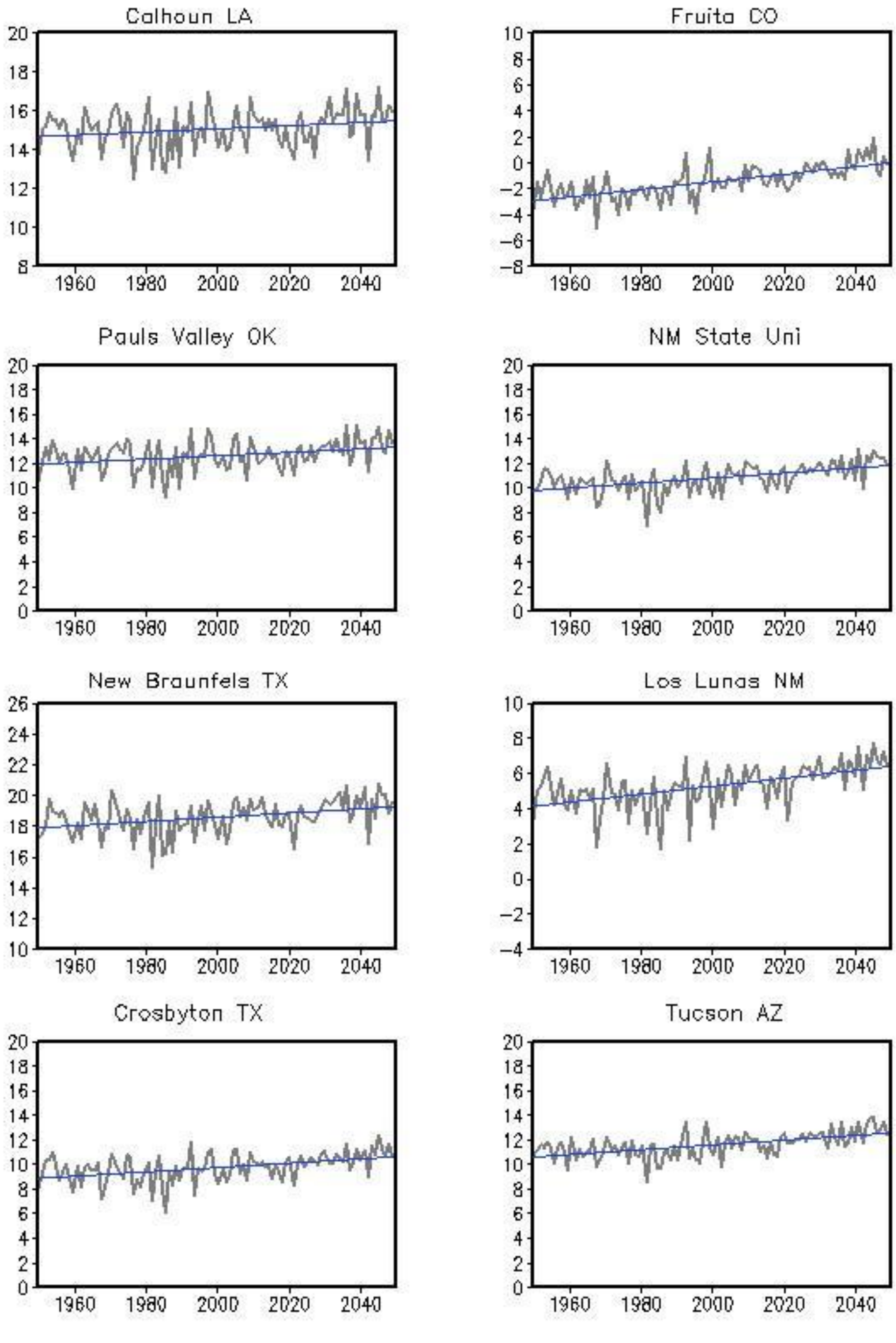


Figure 11: January – April Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

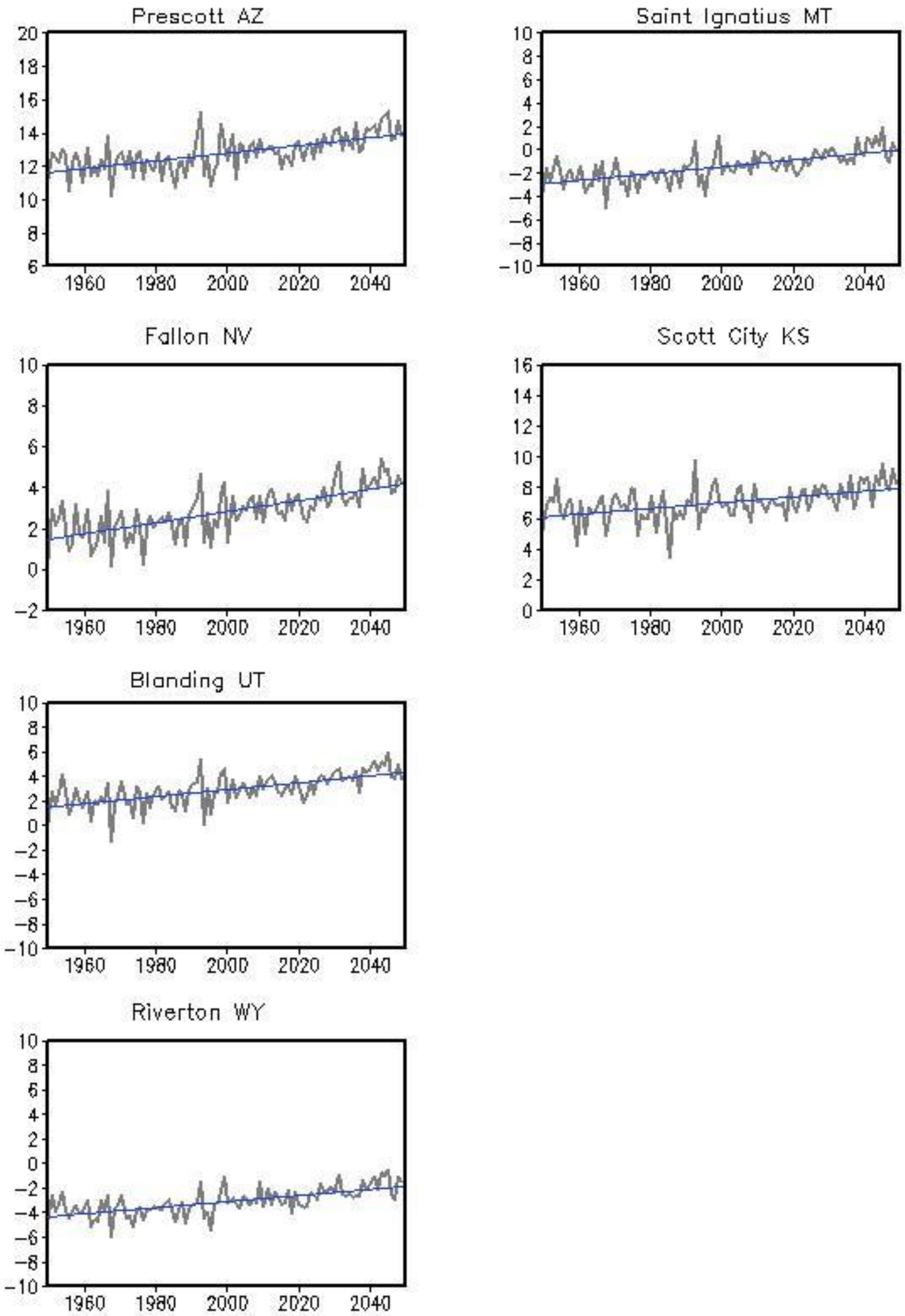


Figure 12: January – April Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

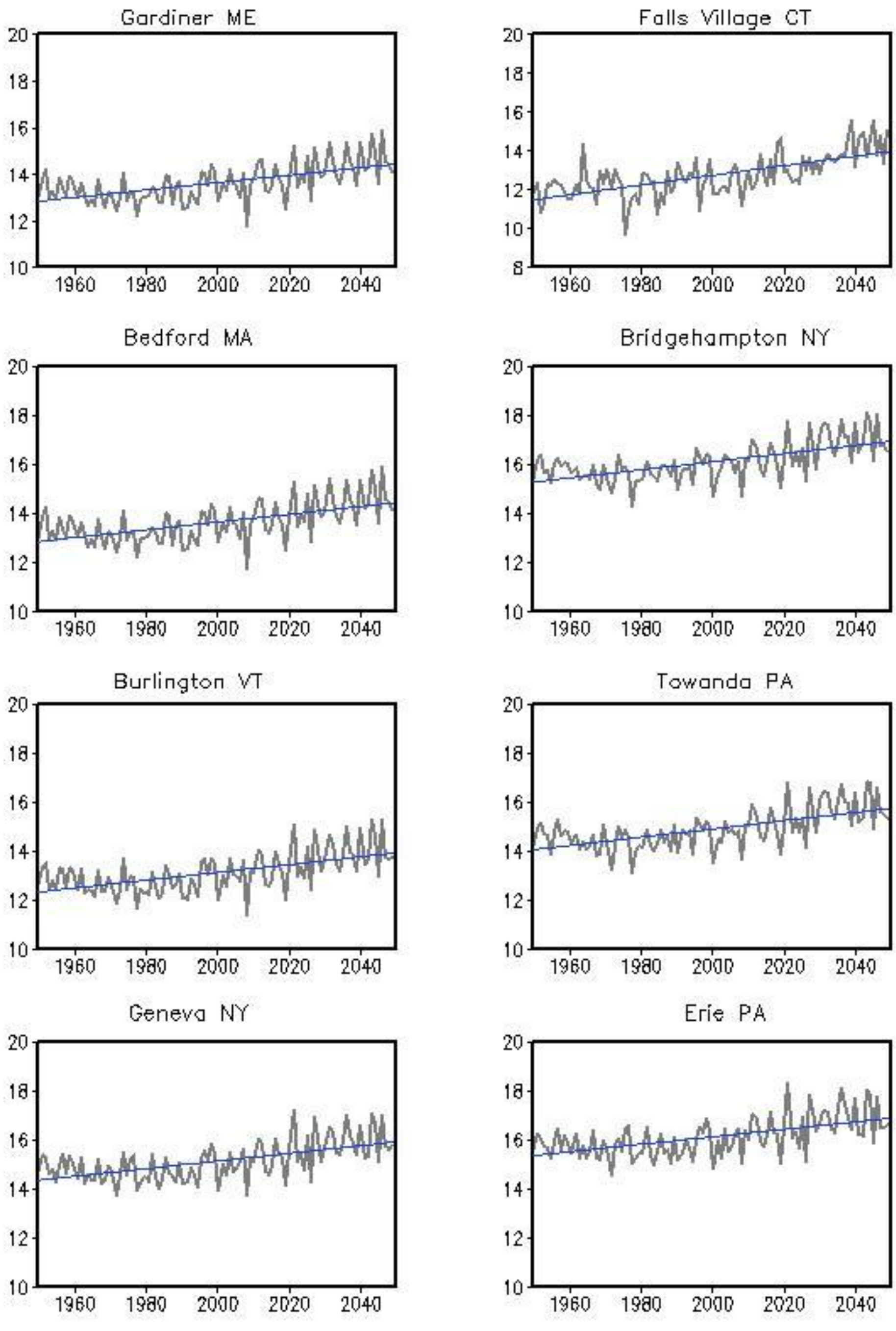


Figure 13: August - October Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

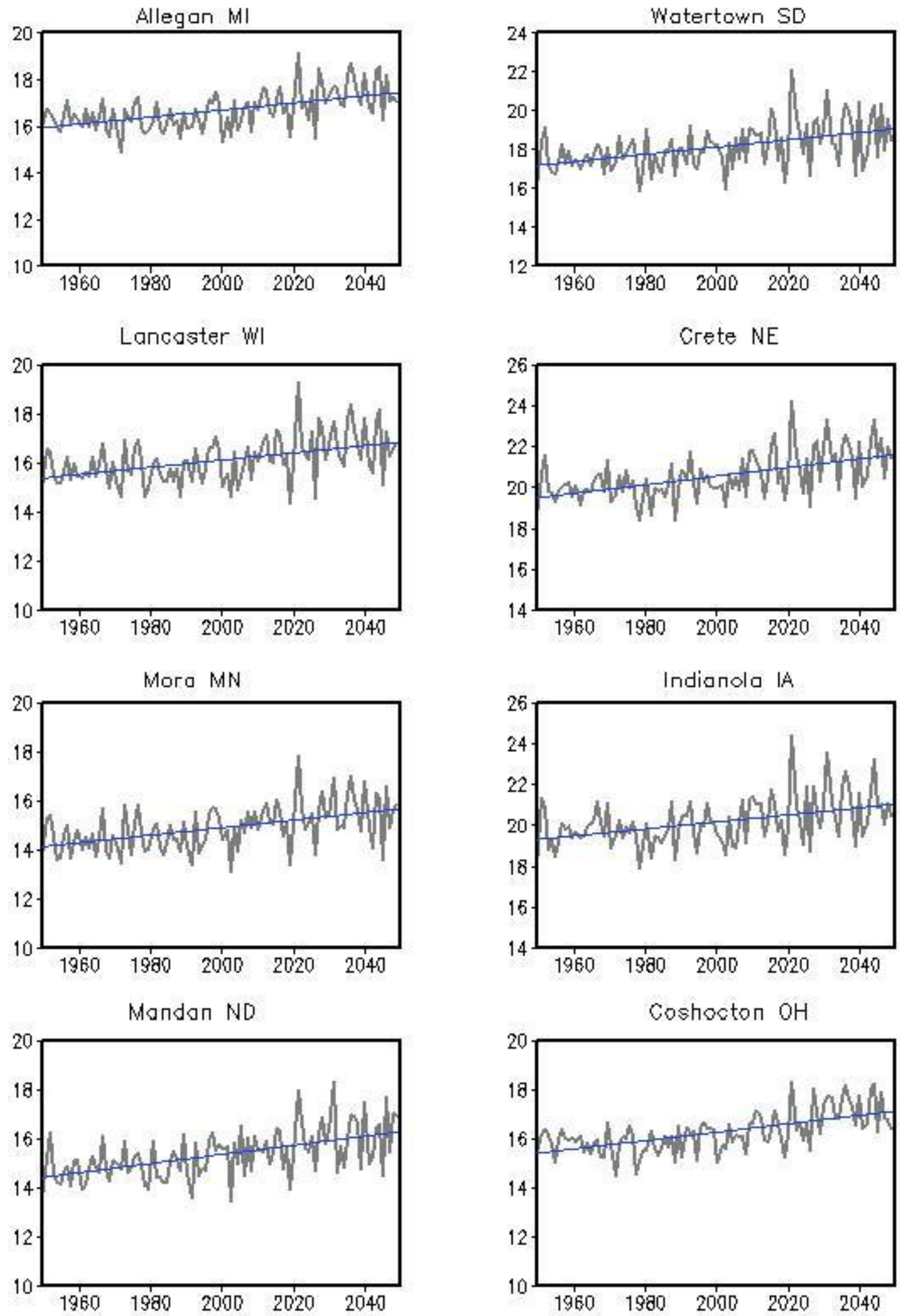


Figure 14: August - October Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

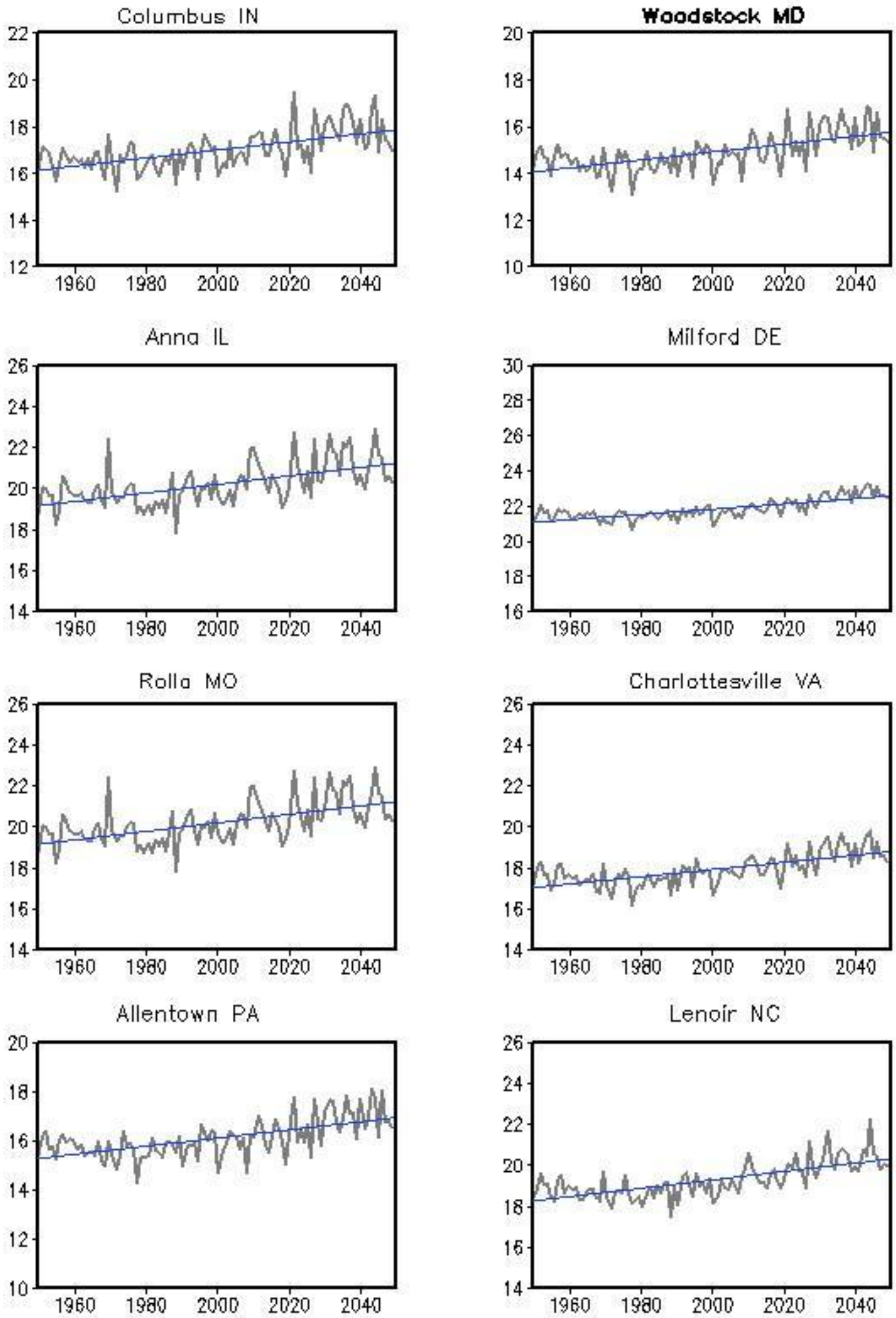


Figure 15: August - October Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

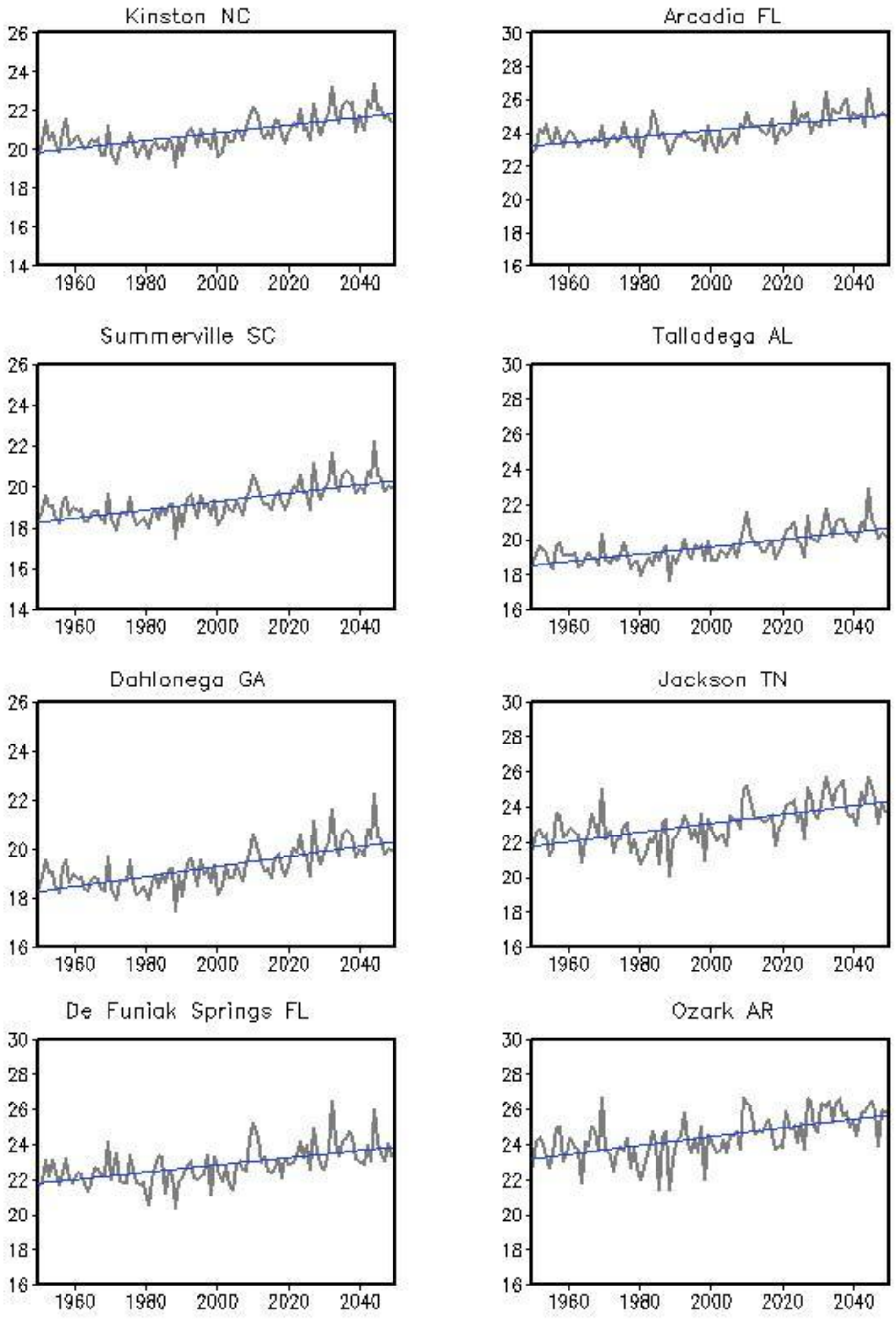


Figure 16: August - October Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

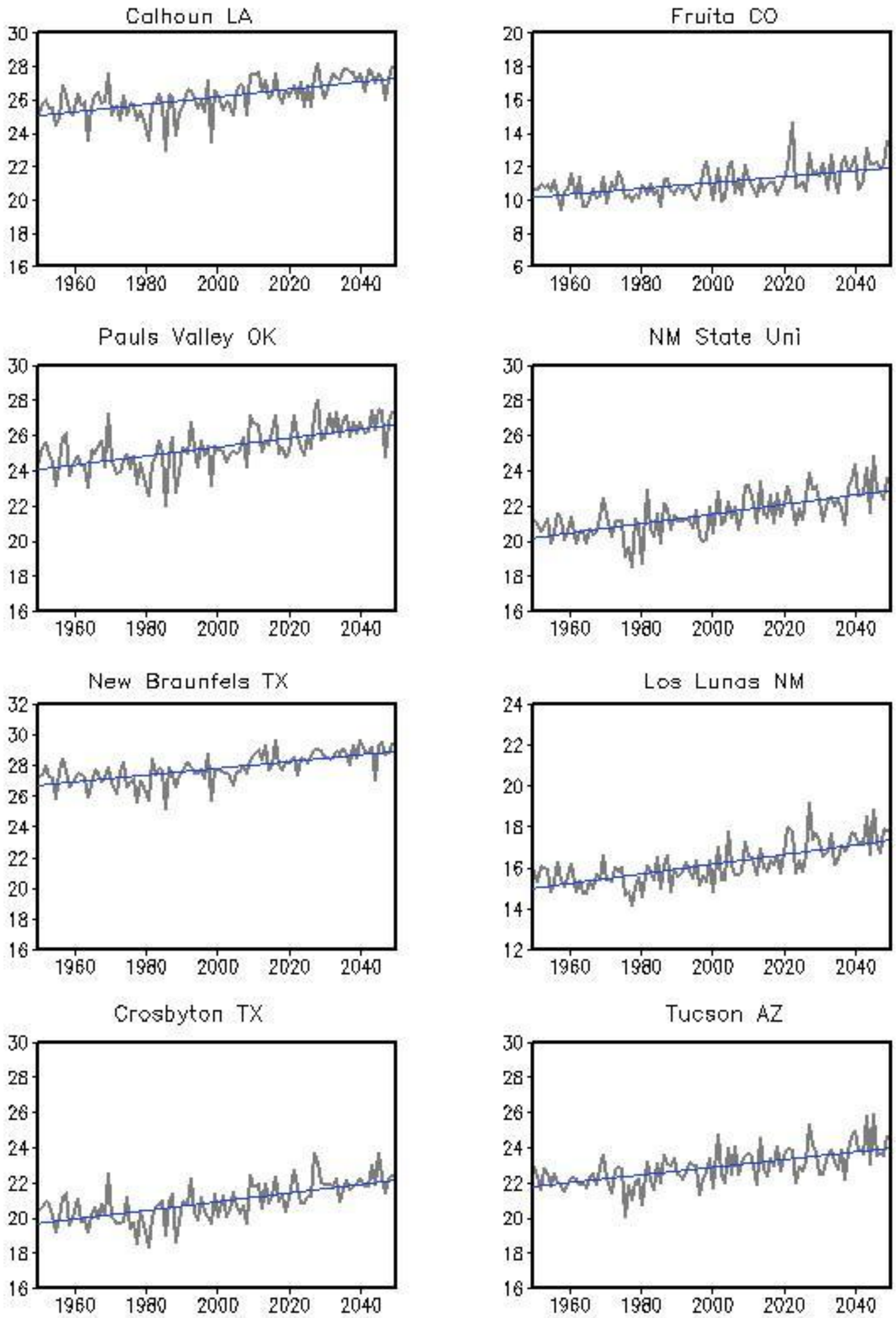


Figure 17: August - October Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

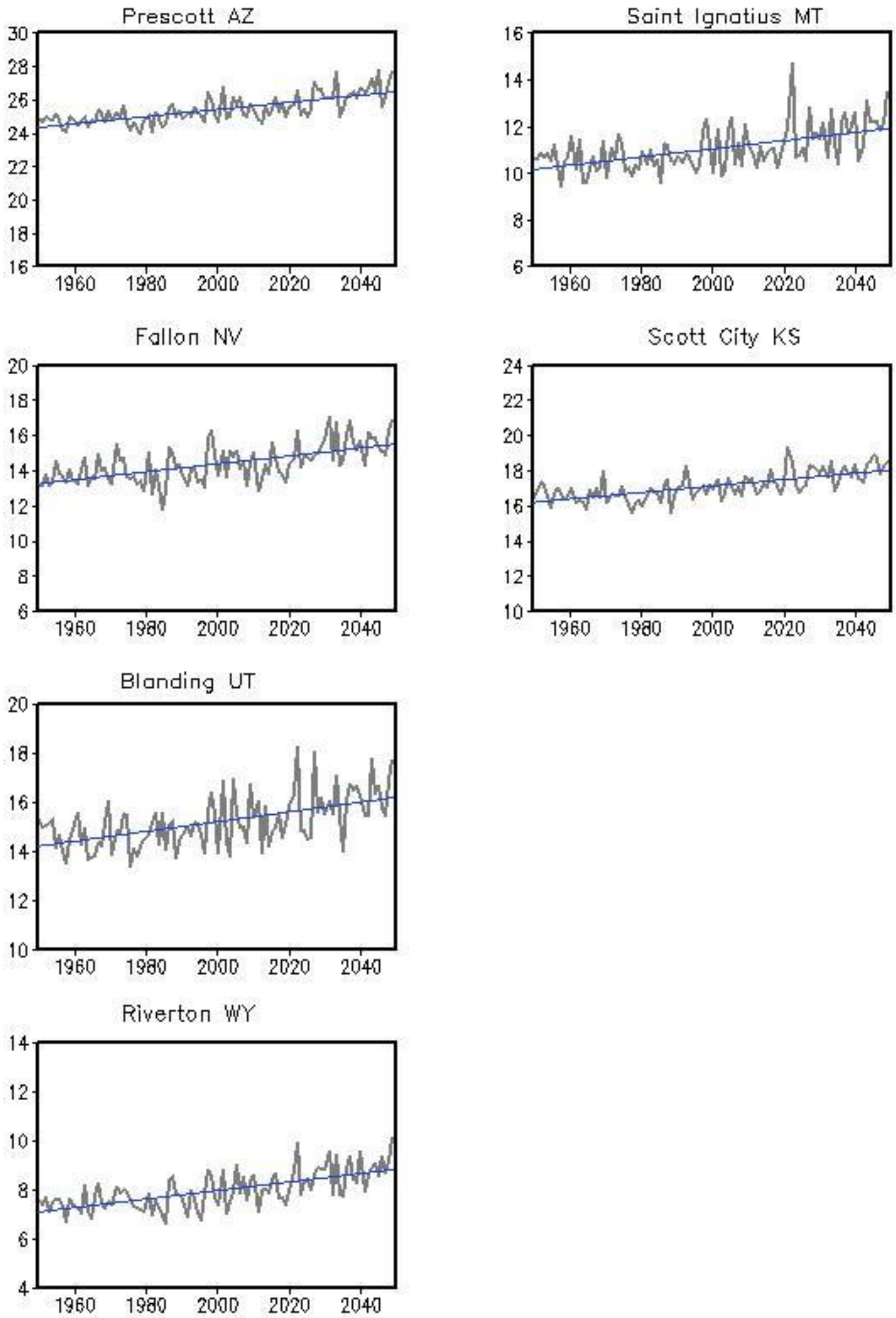


Figure 18: August - October Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

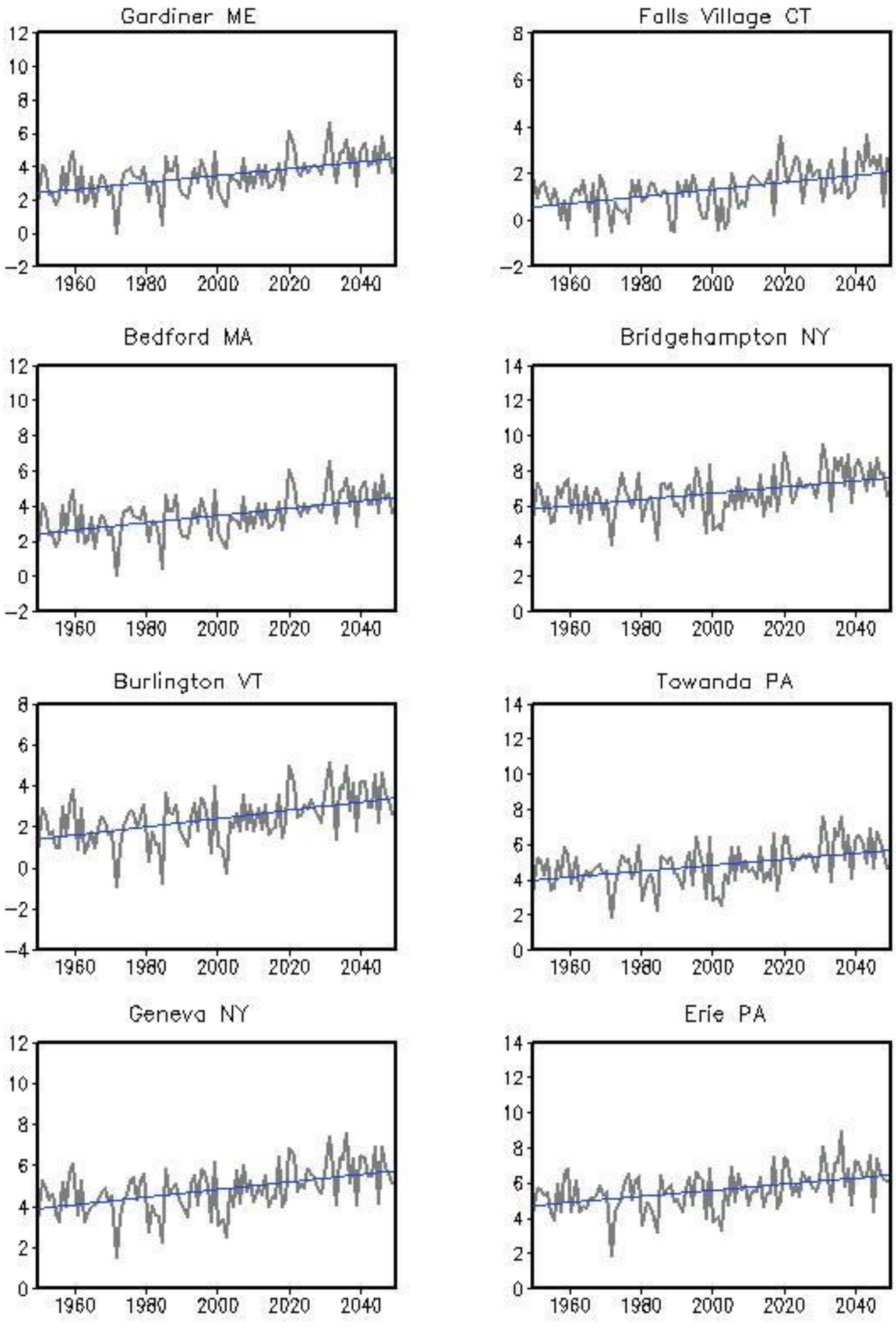


Figure 19: October – December Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

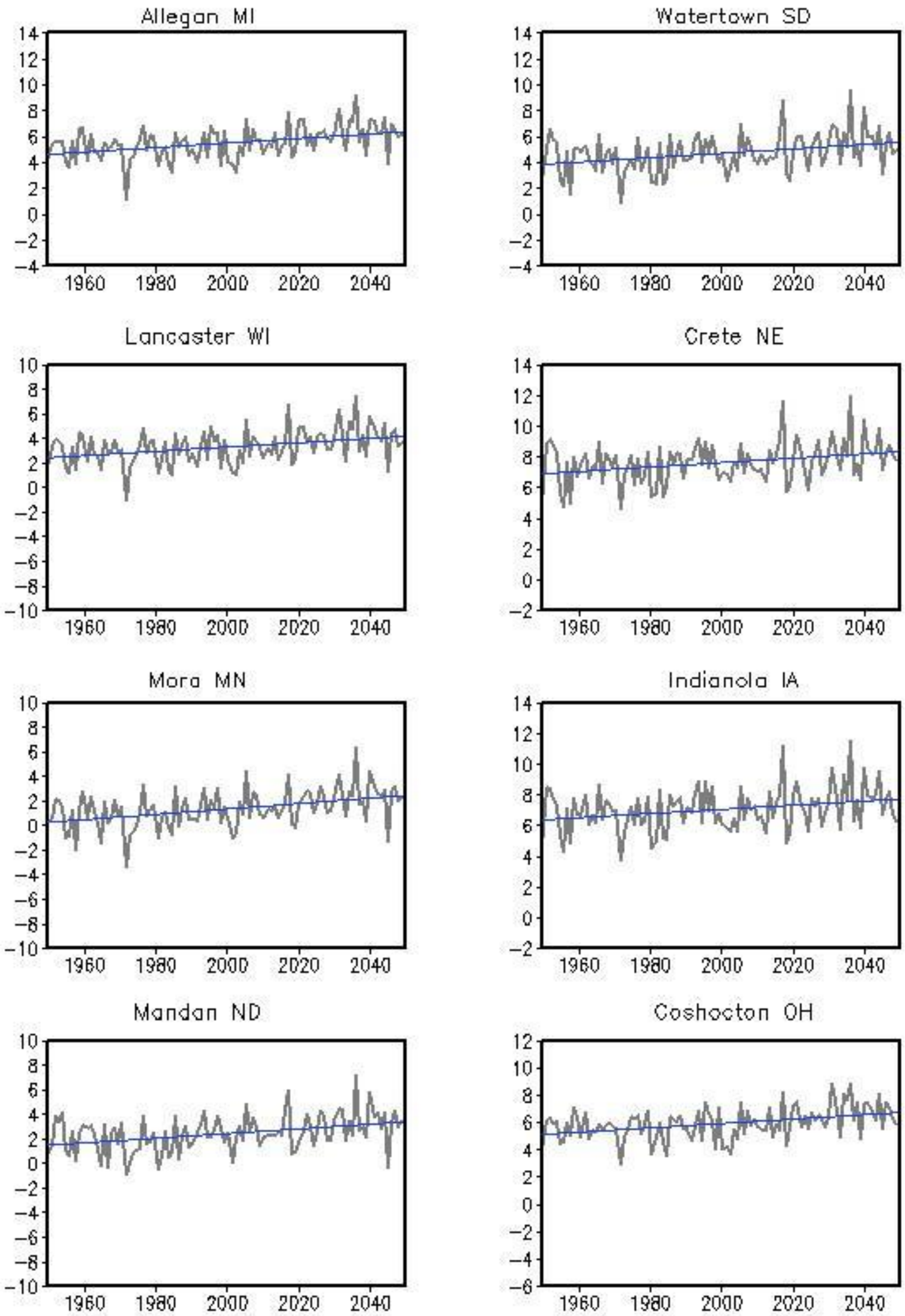


Figure 20: October – December Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

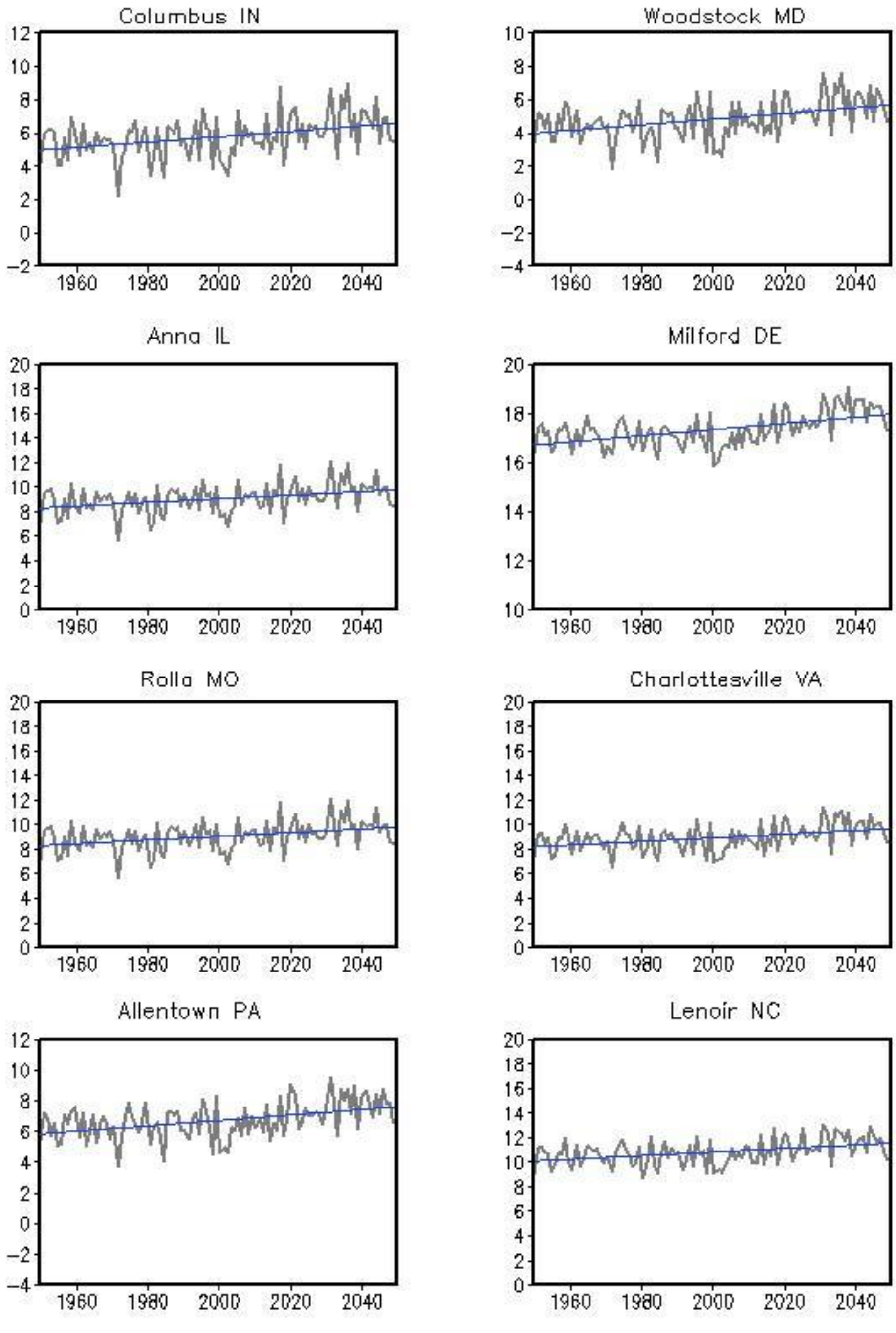


Figure 21: October – December Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

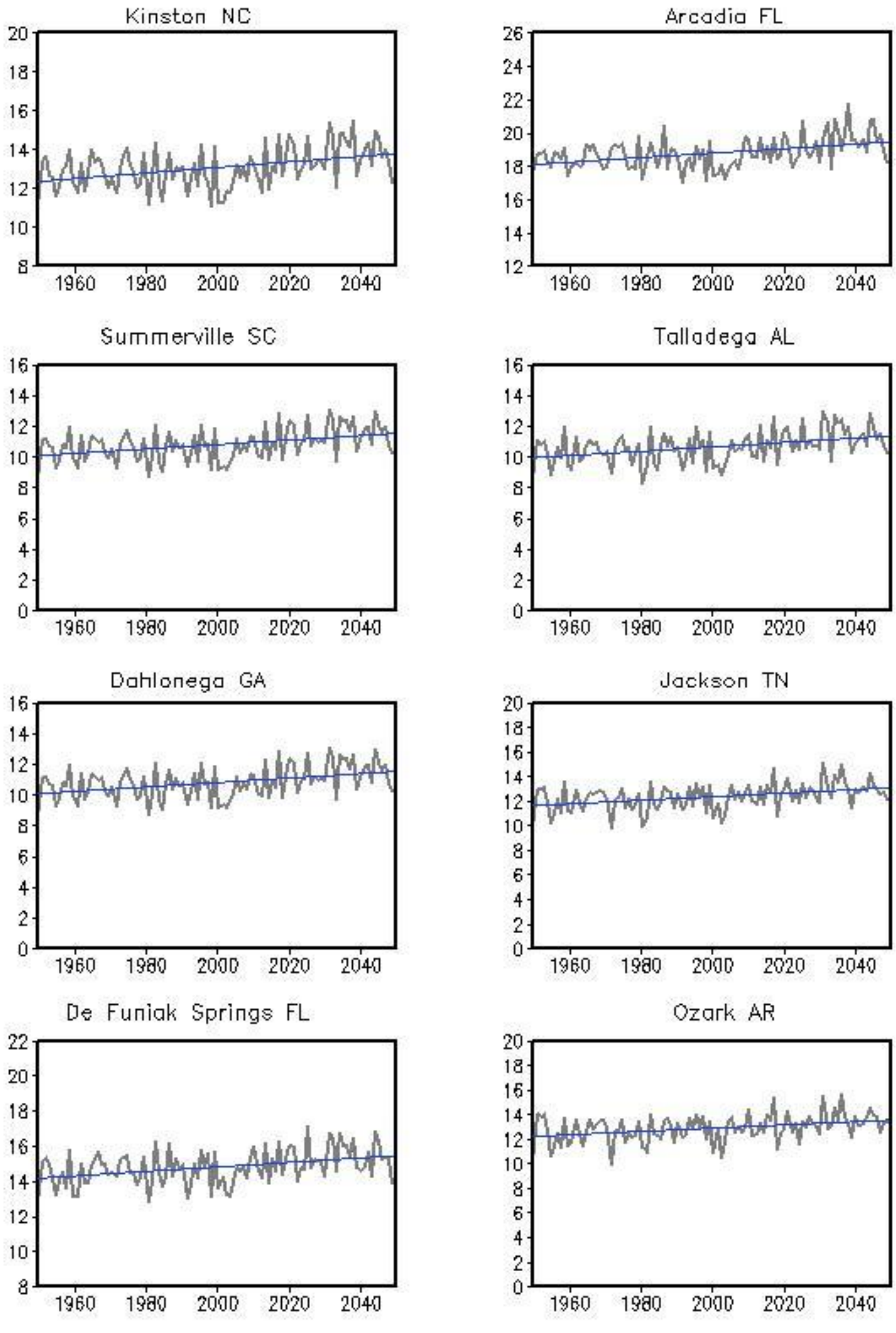


Figure 22: October – December Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

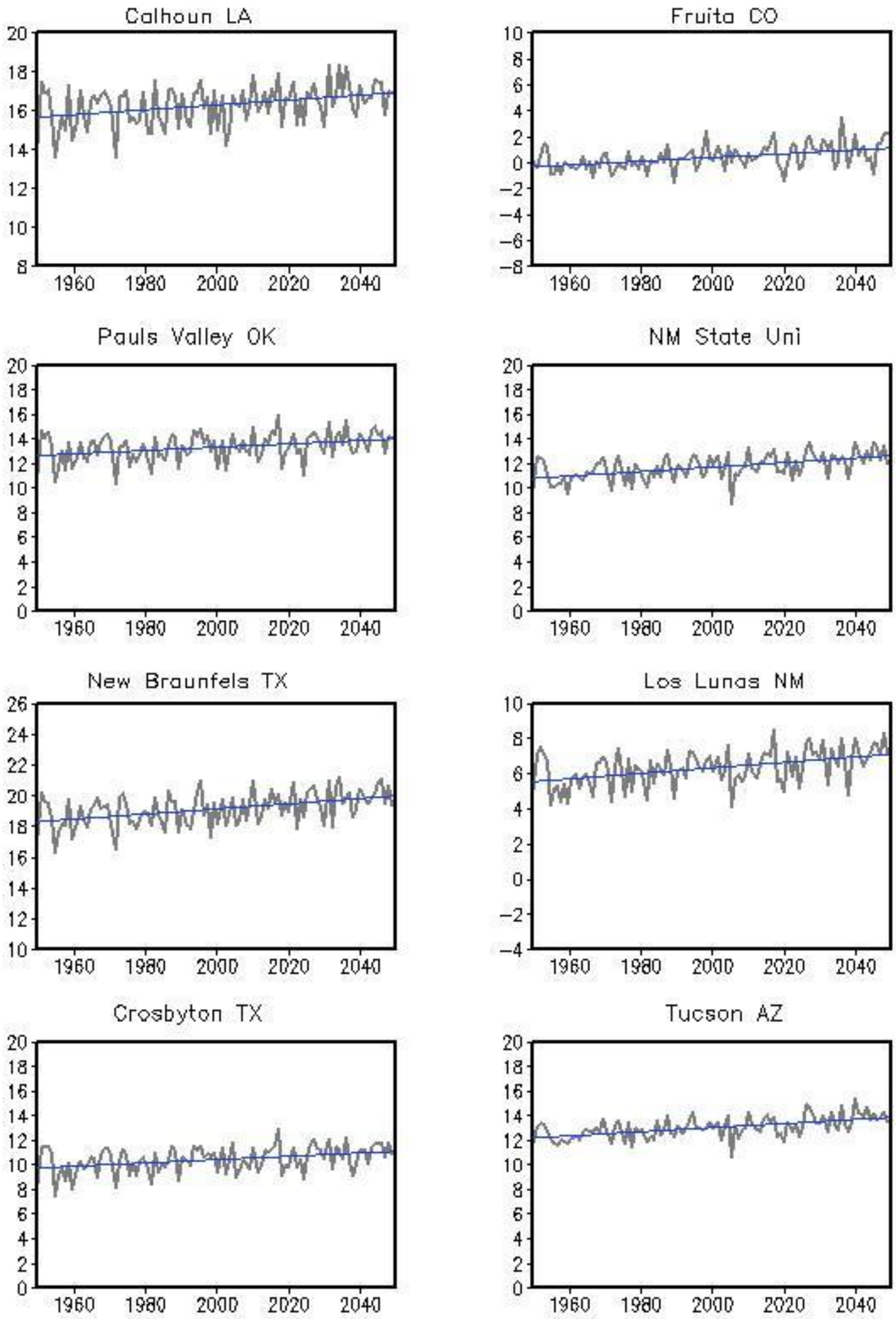


Figure 23: October – December Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

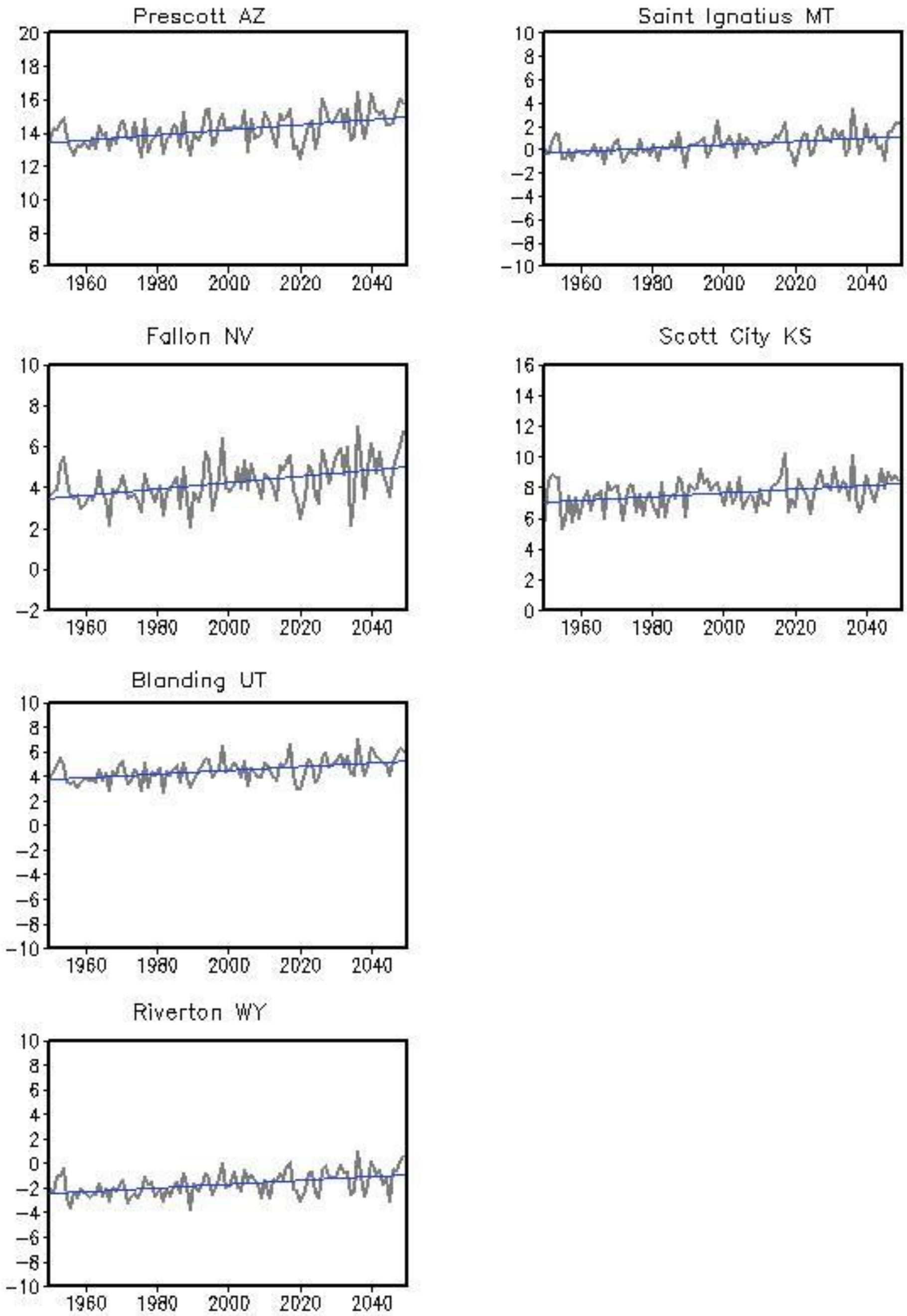


Figure 24: October – December Average temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

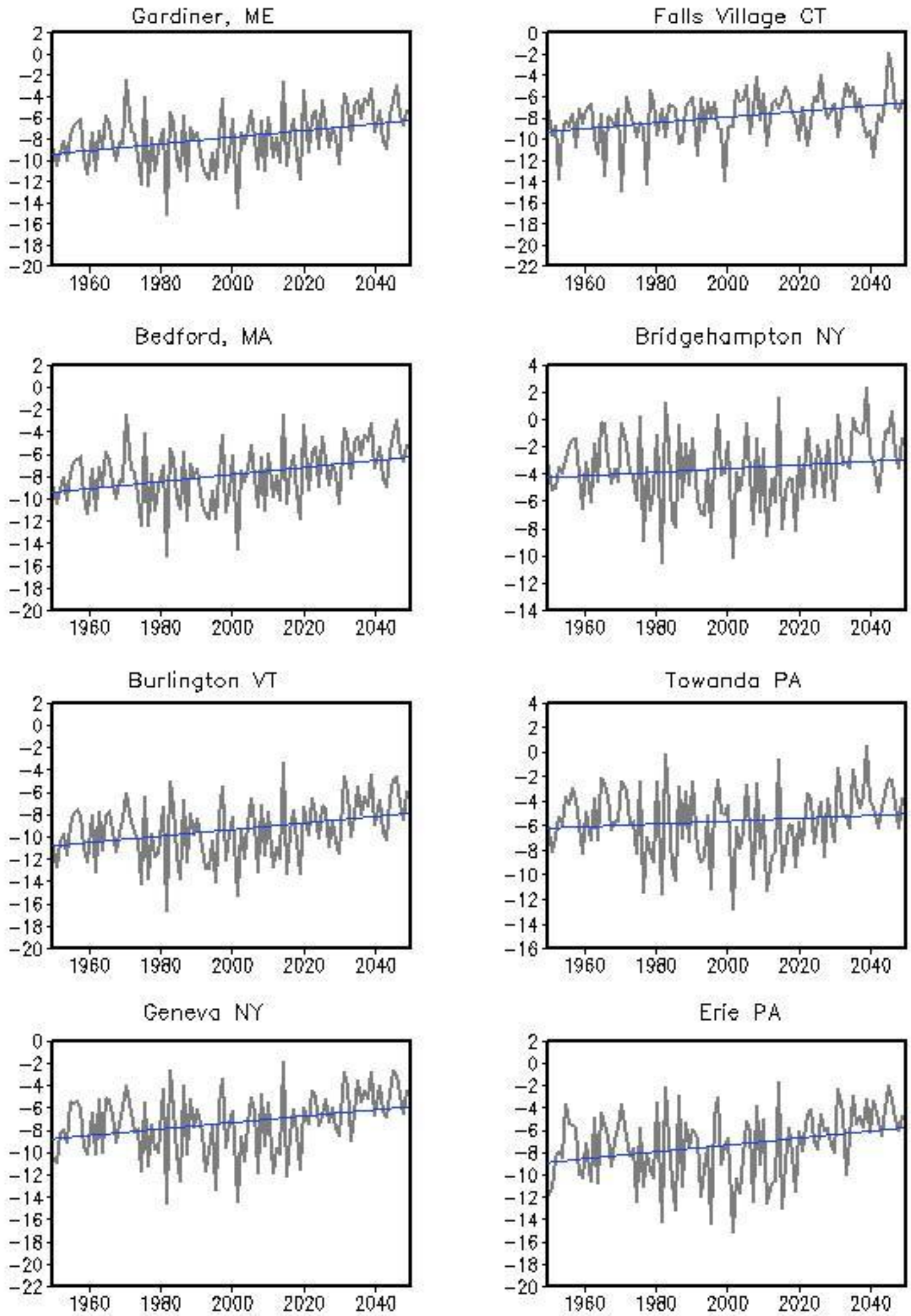


Figure 25: January Minimum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

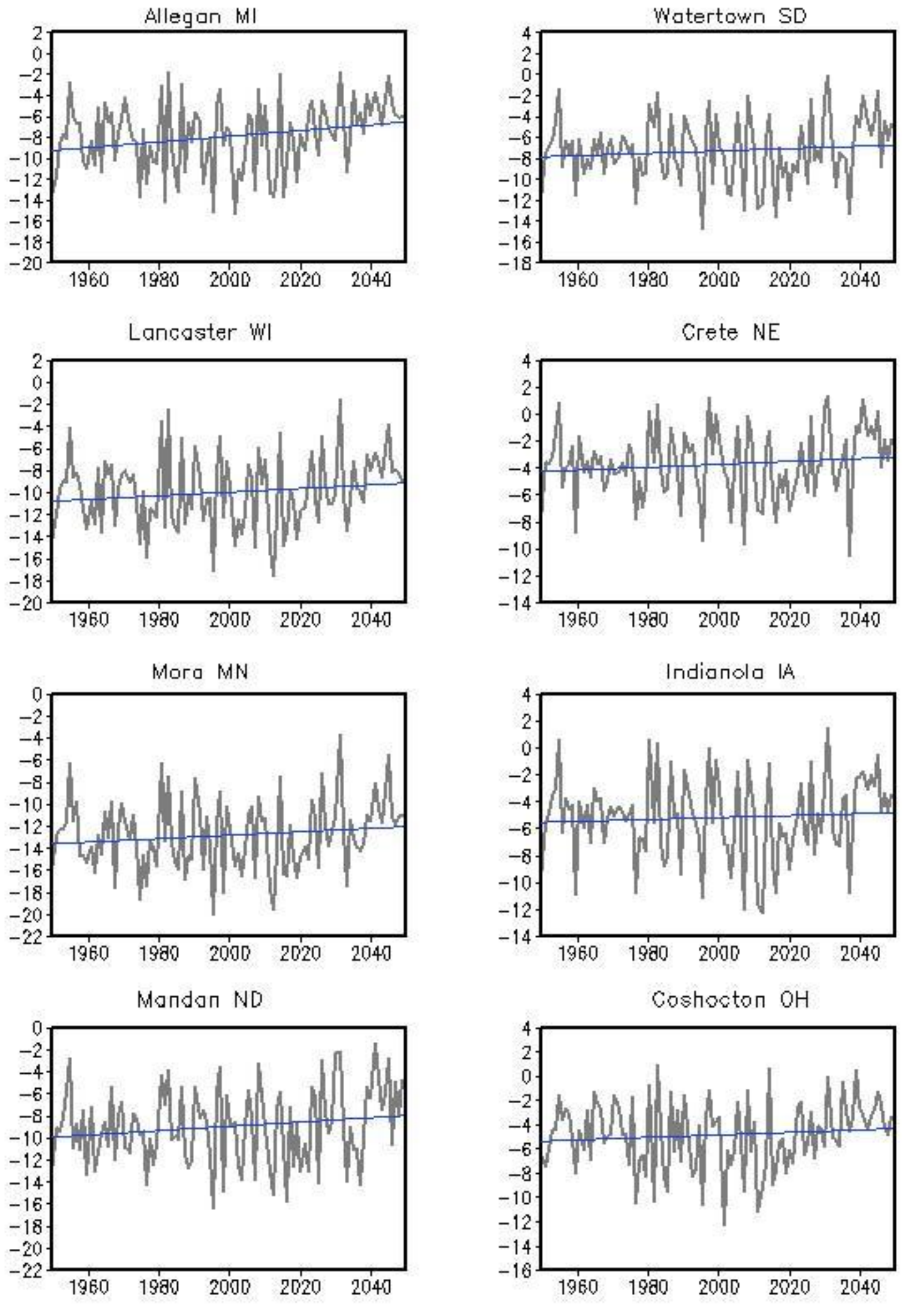


Figure 26: January Minimum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

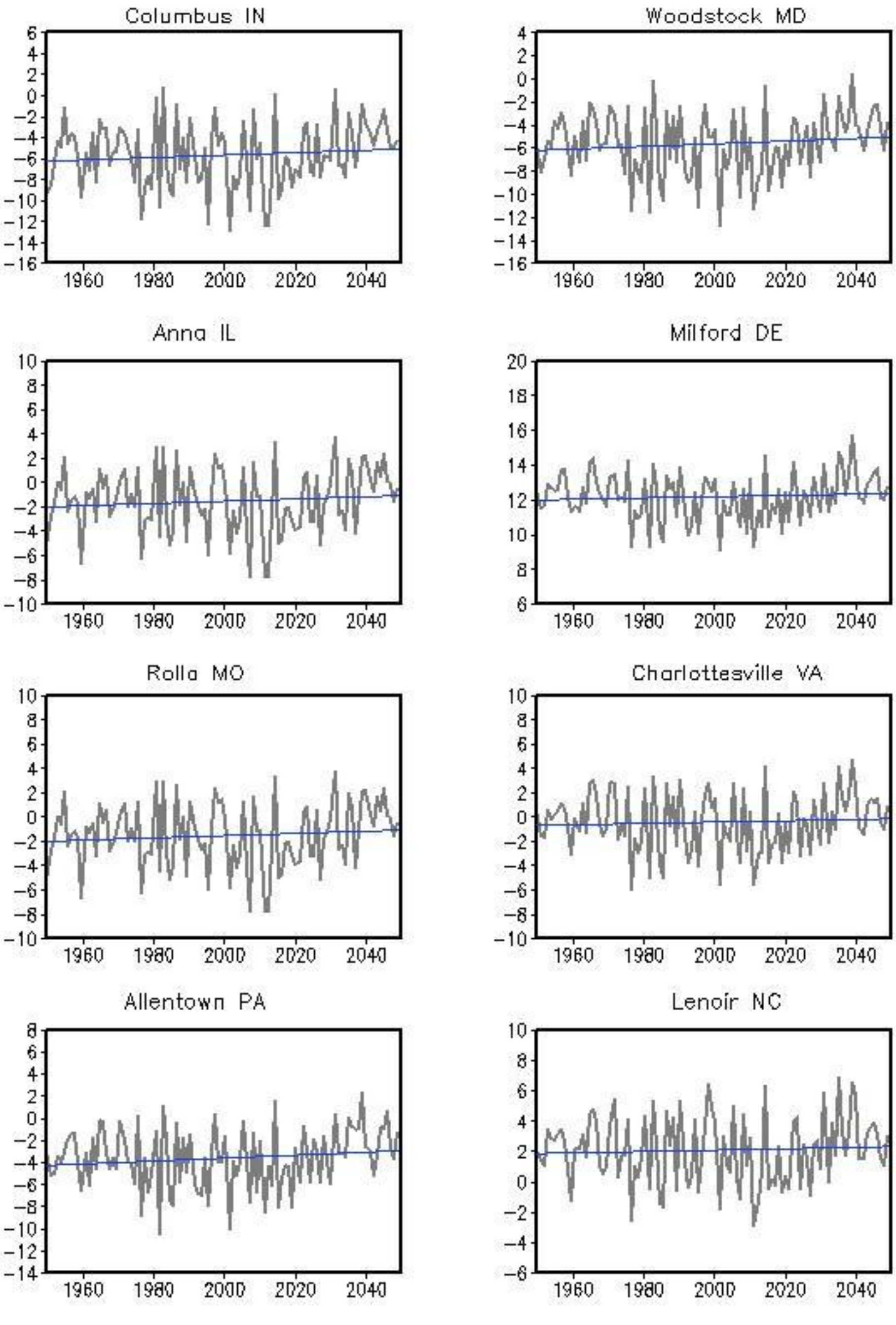


Figure 27: January Minimum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

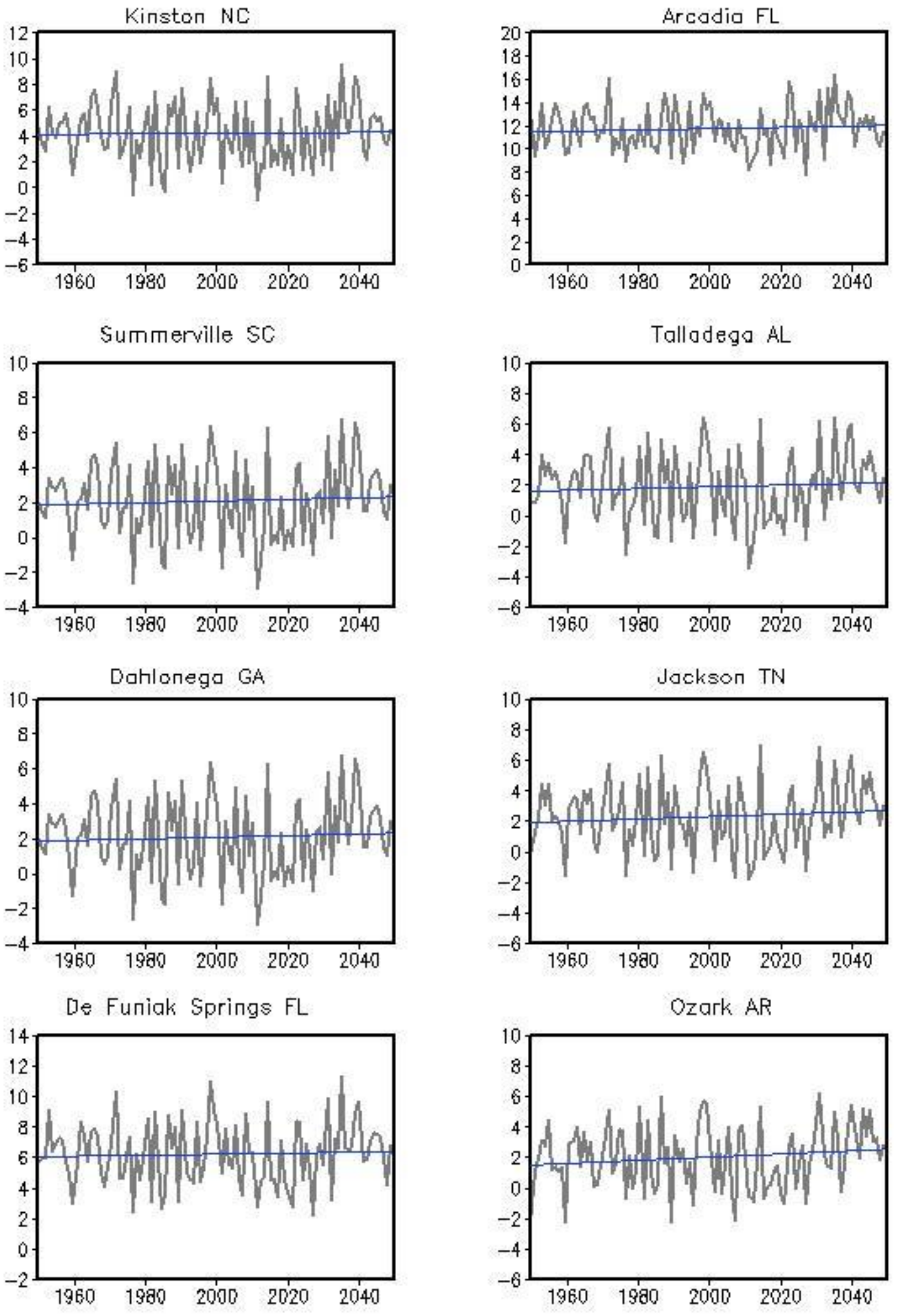


Figure 28: January Minimum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

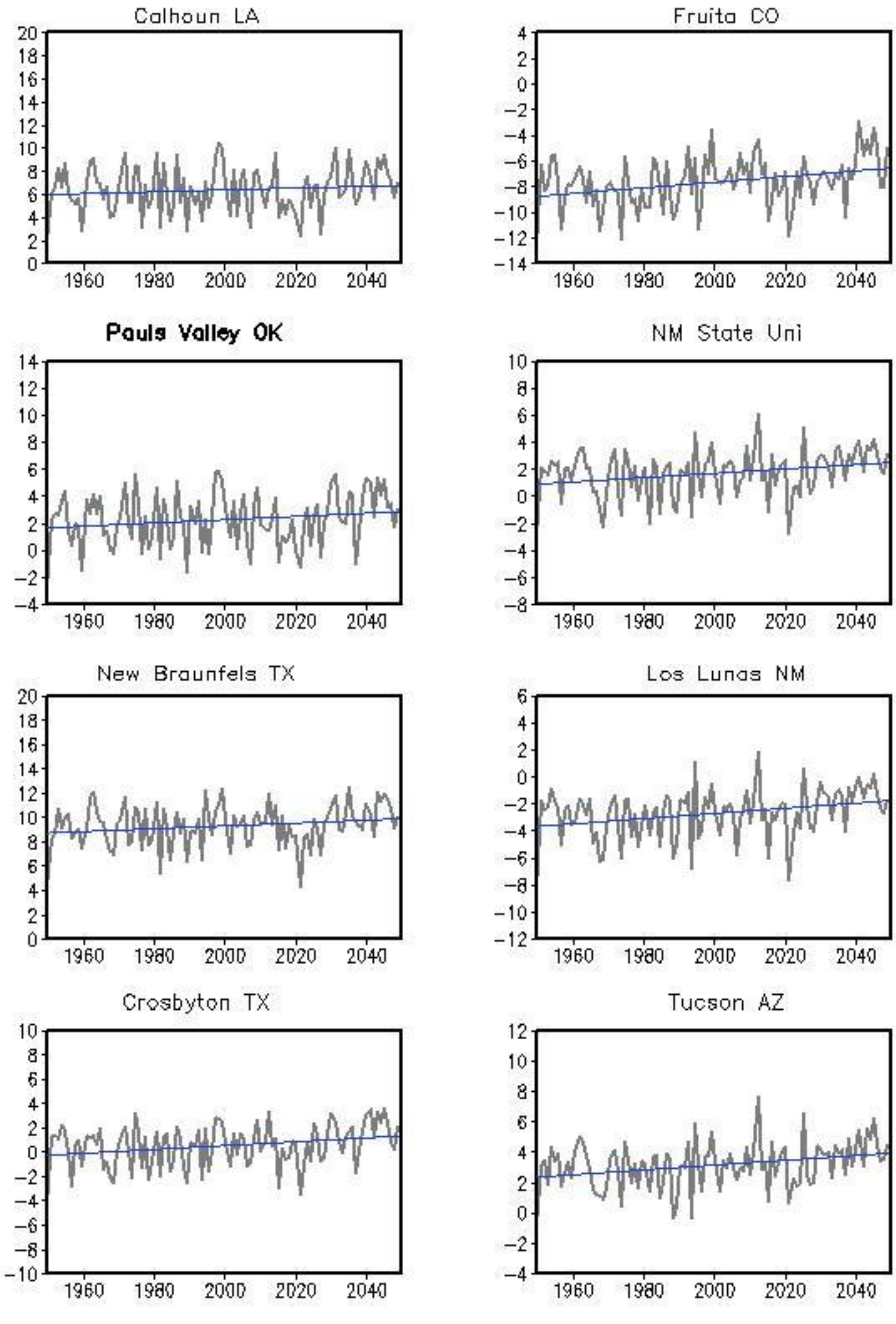


Figure 29: January Minimum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

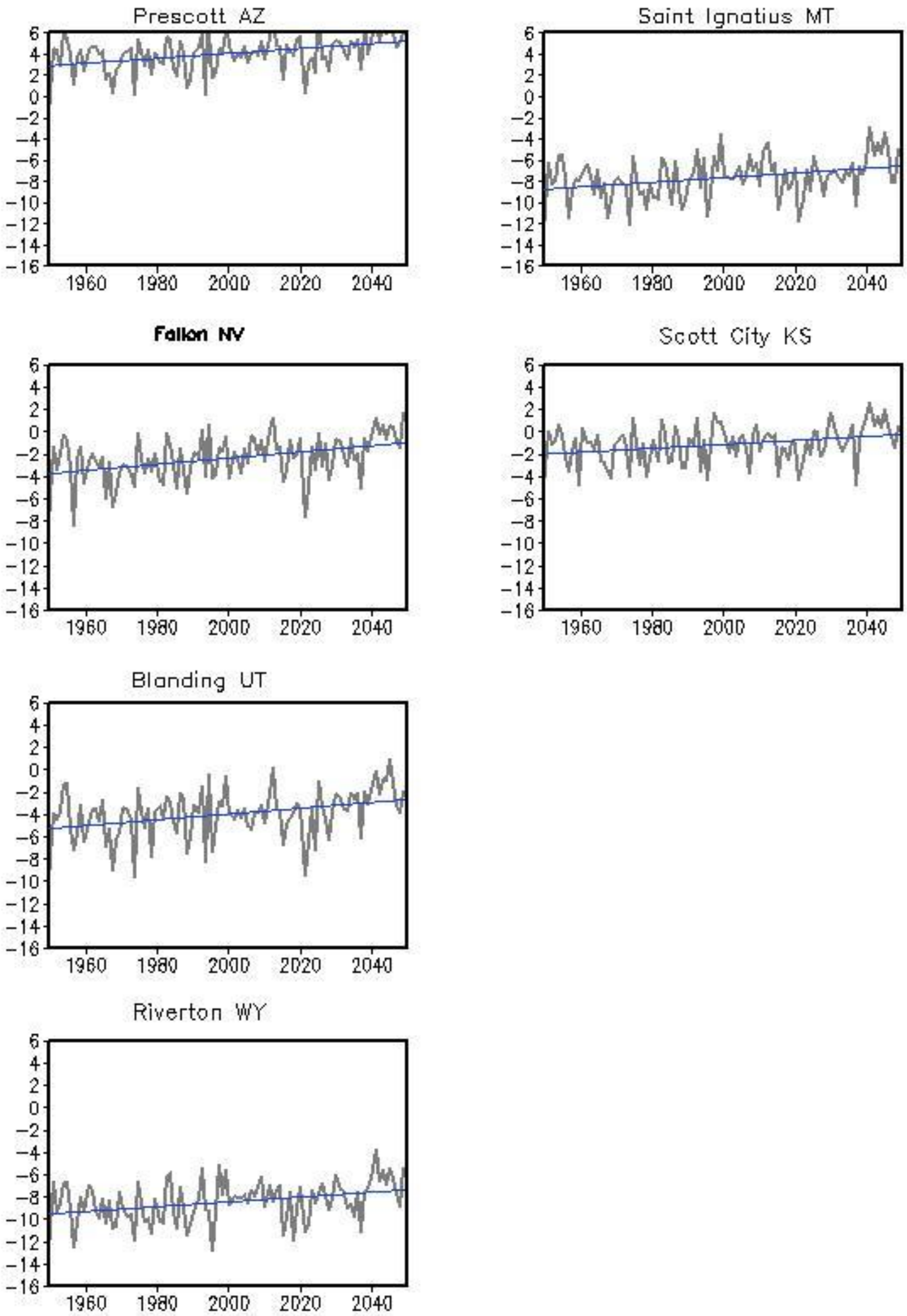


Figure 30: January Minimum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

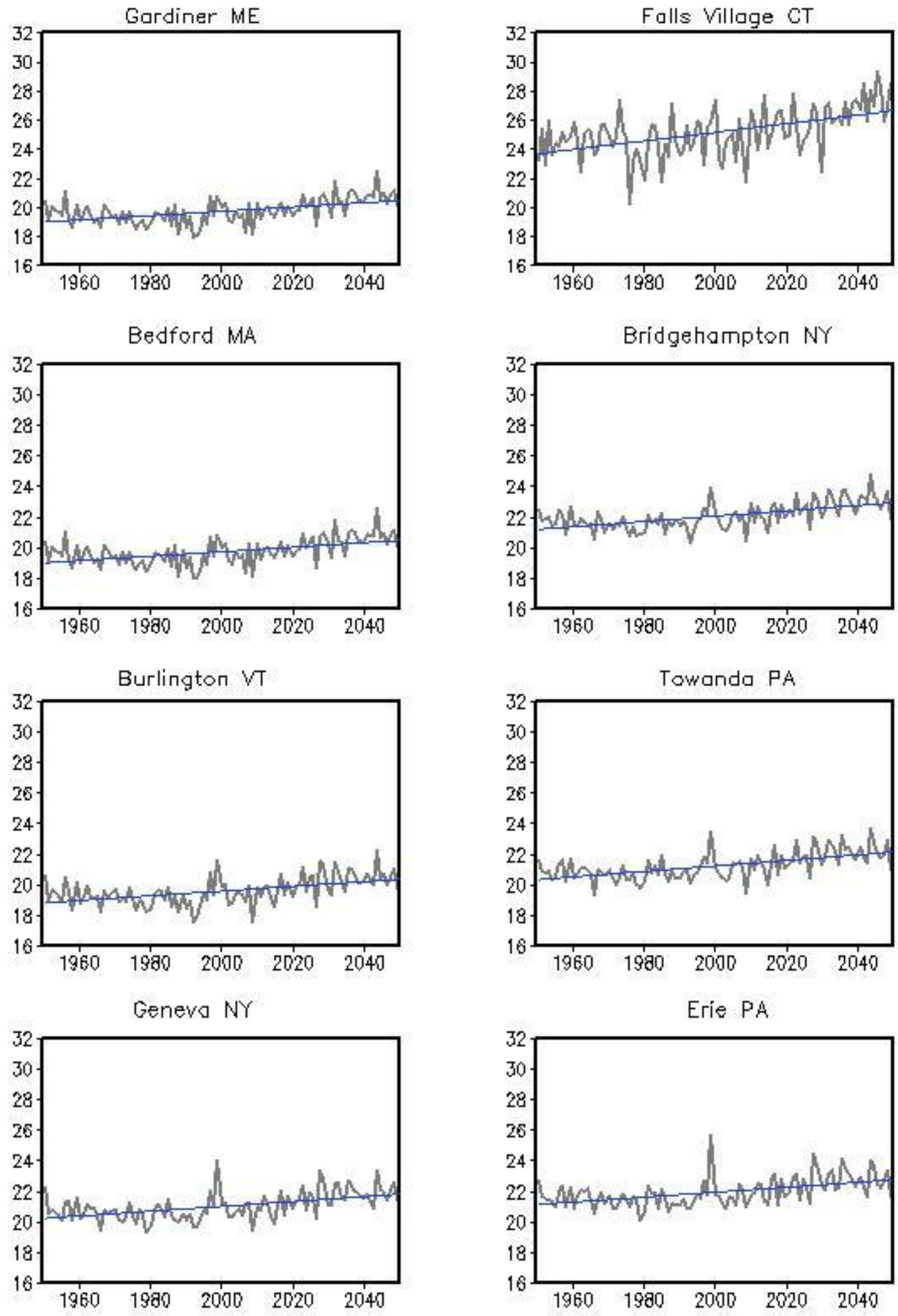


Figure 31: August maximum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

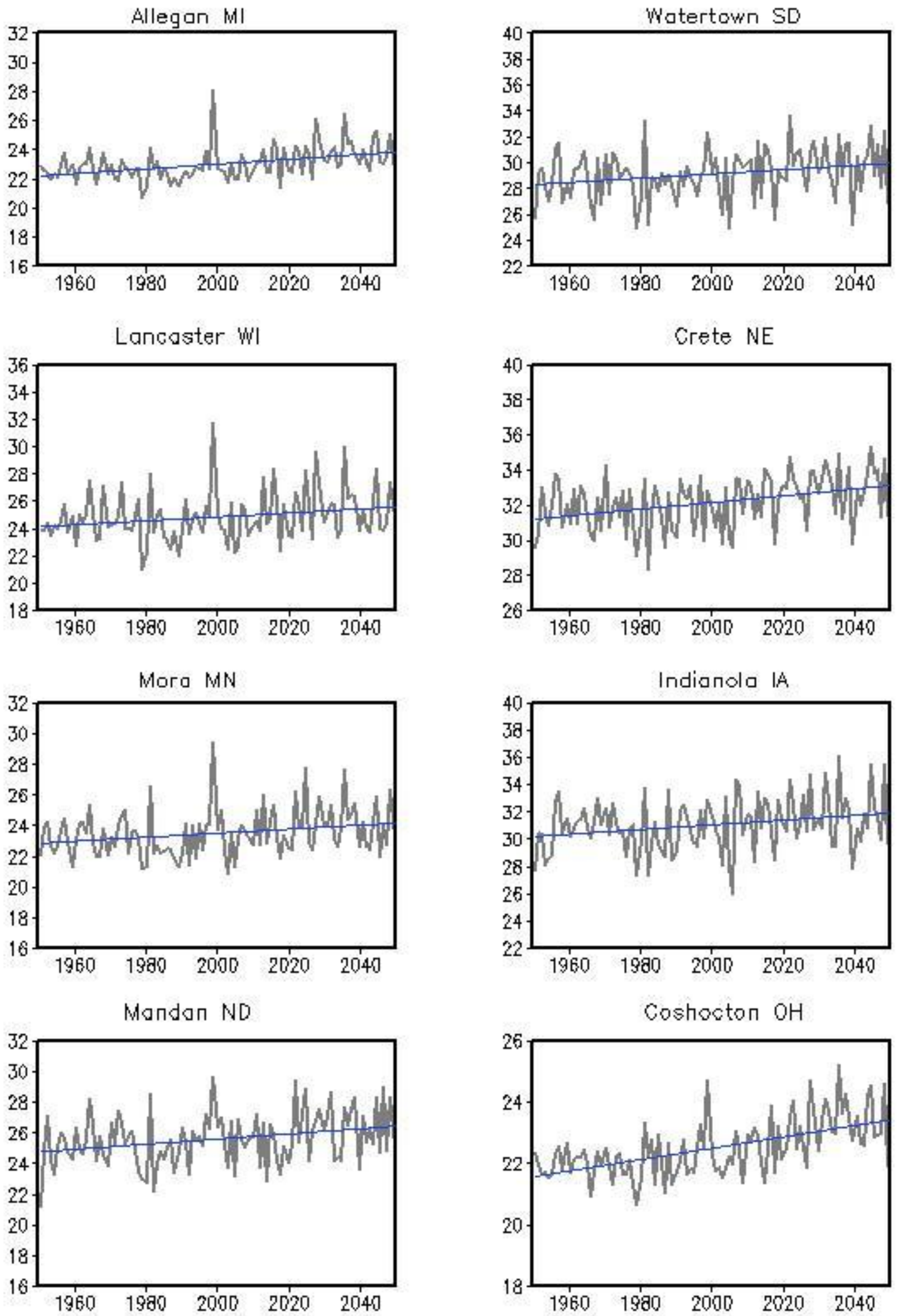


Figure 32: August maximum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

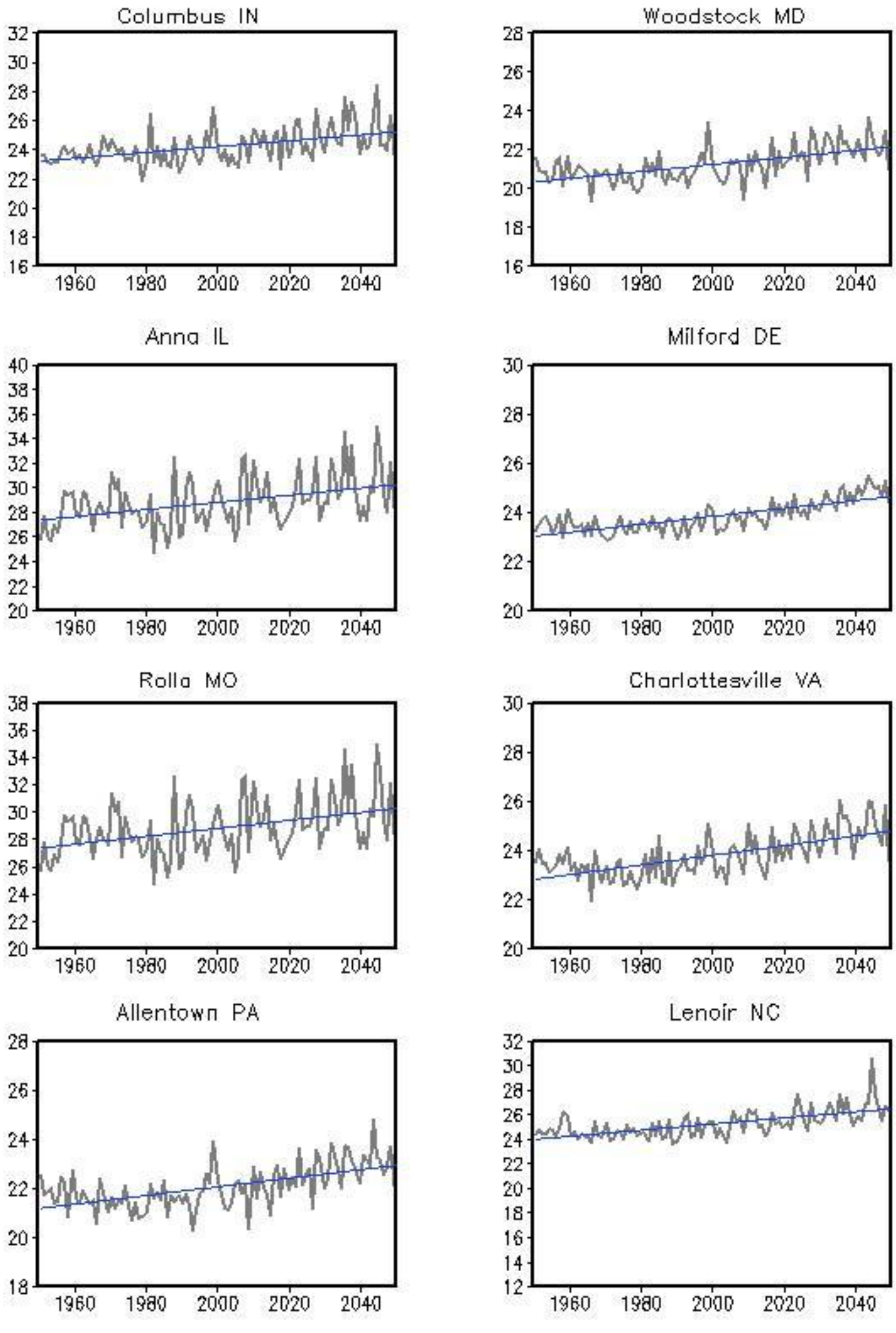


Figure 33: August maximum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

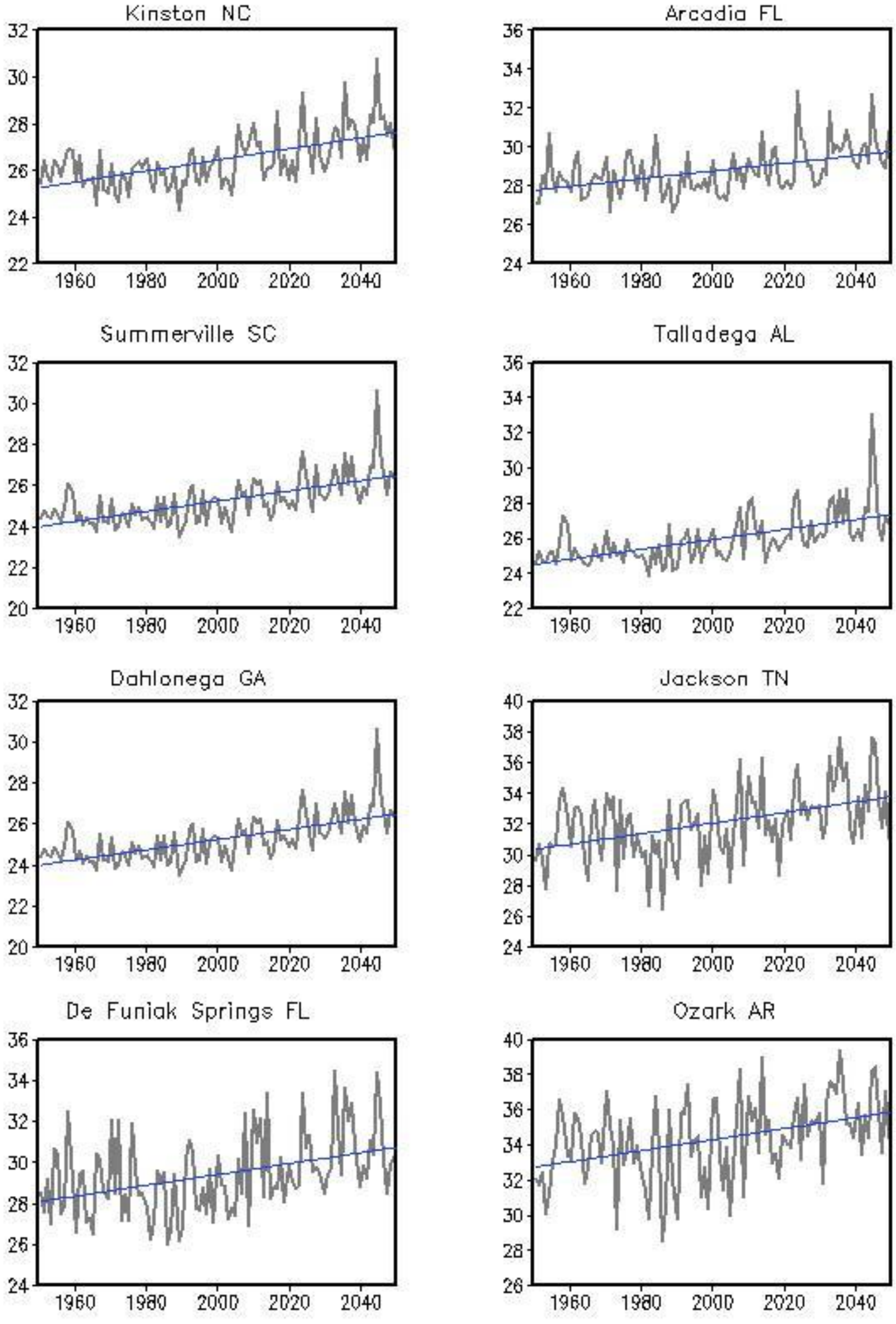


Figure 34: August maximum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

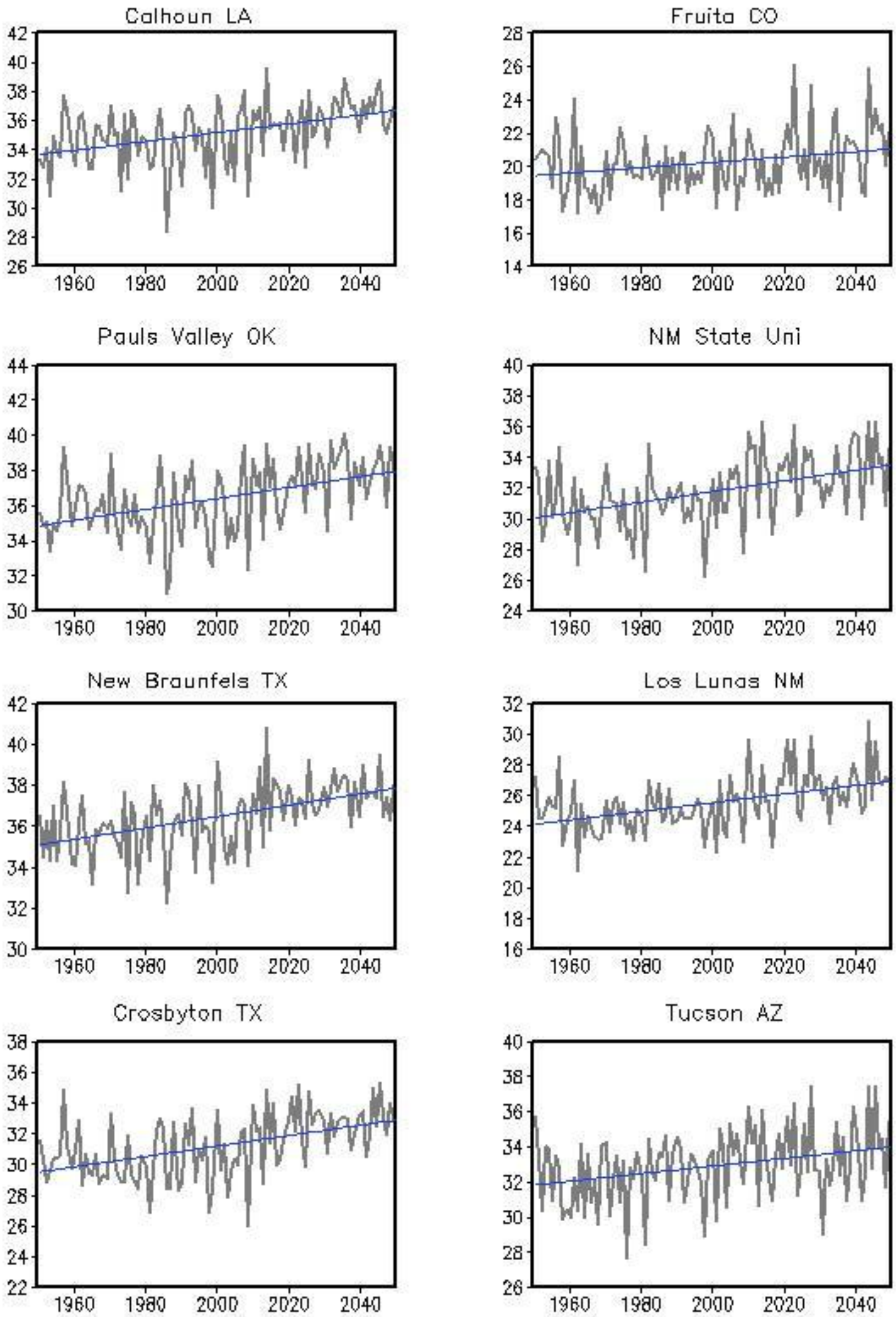


Figure 35: August maximum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

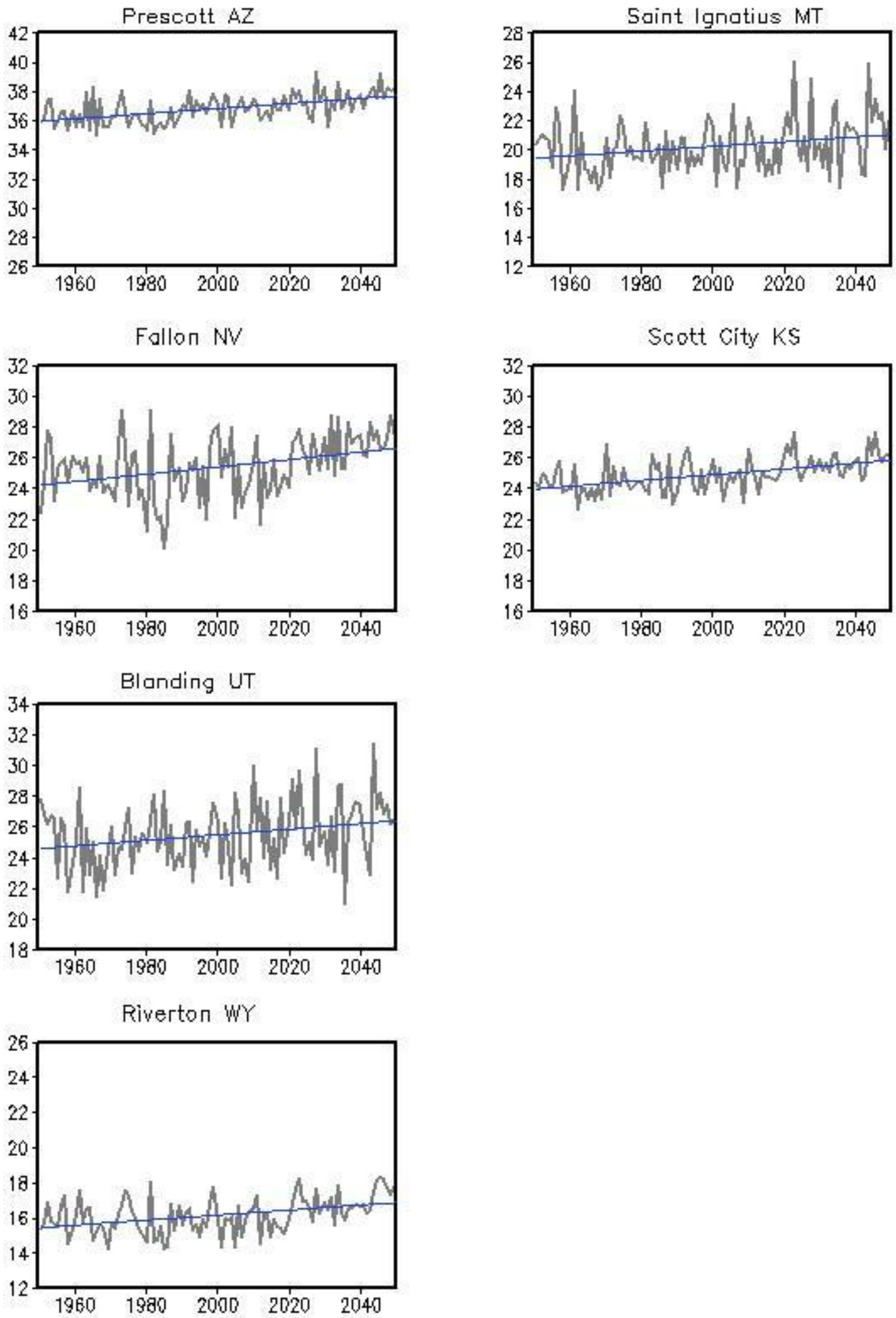


Figure 36: August maximum temperatures for study locations using GISS CGCM 3°x 4° grid cells for the time period 1950 - 2050.

Appendix IV: USHCN Trend Analysis

Table 11: Summary of average growing season temperature (GSTavg) trends (Apr – Oct) for the time period 1950 – 2000. Data source: USHCN Maximum and Minimum dataset.

Station Name	GSTavg Trends (Apr - Oct)
Dahlonega	-1.23124
Ozark	-0.803856
Anna	-0.701397
Crete	-0.684412
Crosbyton	-0.472342
Kinston	-0.442936
Indianola	-0.309555
Pauls Valley	-0.263023
Coshocton	-0.24324
Calhoun	-0.239372
Jackson	-0.196705
Arcadia	-0.139479
Riverton	-0.12043
Talladega	-0.0518723
Mandan	-0.03475
DeFuniak	-0.0264893
Los Lunas	-0.000333786
Geneva	0.017662
Summerville	0.0374165
Rolla	0.0401402
Charlottesville	0.0668678
Towanda	0.0895424
Burlington	0.100247
Gardiner	0.106506
Tucson	0.188484
St. Ignatius	0.26395
Bedford	0.283905
New Mexico State University	0.296721
Allentown	0.305786
Columbus	0.334354
Fallon	0.338909
Allegan	0.340972
Milford	0.402159
Lenoir	0.429615
Falls Village	0.436674
Fruita	0.437653
Erie	0.451738
Blanding	0.483057
Scott City	0.567604
Lancaster	0.655706
Watertown	0.662933
Bridgehampton	0.850609
New Braunfels	0.900009
Mora	0.902508
Prescott	1.03204
Woodstock	1.2556

Table 12: Summary of average temperature trends of January – April temperatures for the time period 1950 – 2000. Data source: USHCN Maximum and Minimum dataset.

Station Name	Jan – Apr Average Temperature Trends
Arcadia	-0.50277
Anna	-0.48201
DeFuniak	-0.29819
Charlottesville	-0.00161
Dahlonega	0.010739
Gardiner	0.072997
Calhoun	0.086927
Crosbyton	0.100153
Lenoir	0.106035
Ozark	0.167937
Geneva	0.31936
Summerville	0.466444
Kinston	0.519184
Coshocton	0.554182
Jackson	0.556818
New Braunfels	0.600018
Columbus	0.62118
Milford	0.661888
Tucson	0.669638
Pauls Valley	0.732994
Burlington	0.755745
Rolla	0.773092
Riverton	0.843346
Talladega	0.85651
Bedford	1.00611
Fallon	1.05846
Erie	1.08109
Scott City	1.08115
Towanda	1.12517
Allentown	1.1282
Los Lunas	1.13803
Allegan	1.17693
New Mexico State University	1.28291
Woodstock	1.34844
Falls Village	1.3524
Crete	1.35946
Lancaster	1.51781
Blanding	1.60615
Bridgehampton	1.64616
Prescott	1.84777
St. Ignatius	2.33279
Indianola	2.33325
Fruita	2.47562
Watertown	3.28068
Mandan	3.70932
Mora	4.31232

Table 13: Summary of average temperature trends of August - October temperatures for the time period 1950 – 2000. Data source: USHCN Maximum and Minimum dataset.

Station Name	Aug – Oct Average Temperature Trends
Crosbyton	-1.30834
Crete	-0.936245
Lancaster	-0.905697
Anna	-0.626976
Jackson	-0.481947
Coshocton	-0.423124
Indianola	-0.414557
Dahlonega	-0.392101
Calhoun	-0.39201
Kinston	-0.362598
Ozark	-0.349754
New Mexico State University	-0.174135
Mora	-0.160073
Charlottesville	-0.0923214
Mandan	-0.0905476
Pauls Valley	-0.053894
Allegan	-0.0479116
Geneva	0.00936031
Watertown	0.0167532
Burlington	0.0285311
Arcadia	0.0476761
Bedford	0.0511389
Tucson	0.101162
Rolla	0.131359
Allentown	0.152866
Los Lunas	0.161312
Blanding	0.17371
Towanda	0.188294
Erie	0.246752
Riverton	0.253003
St. Ignatius	0.287813
Columbus	0.290497
Summerville	0.307671
Gardiner	0.346447
DeFuniak	0.434217
Falls Village	0.451902
Scott City	0.46026
New Braunfels	0.512291
Prescott	0.526436
Fruita	0.528072
Fallon	0.590752
Talladega	0.661312
Milford	0.755713
Bridgehampton	0.827824
Lenoir	0.846428

Woodstock	1.15661

Table 14: Summary of average temperature trends of October - December temperatures for the time period 1950 – 2000. Data source: USHCN Maximum and Minimum dataset.

Station Name	Oct – Dec Average Temperature Trends
Ozark	-0.92734
Watertown	-0.88336
Crete	-0.86158
Crosbyton	-0.80268
Burlington	-0.69387
Fallon	-0.49181
Anna	-0.47898
Bridgehampton	-0.44893
Lancaster	-0.41803
Calhoun	-0.40356
Riverton	-0.39641
Indianola	-0.38673
Geneva	-0.35112
Bedford	-0.34919
Mandan	-0.34738
Scott City	-0.2969
St. Ignatius	-0.27034
Falls Village	-0.24129
Gardiner	-0.20783
Columbus	-0.08319
Mora	-0.0789
Allentown	-0.0309
Allegan	-0.01301
Erie	0.002465
Towanda	0.077286
Los Lunas	0.082992
Rolla	0.135414
Blanding	0.142232
Tucson	0.20499
Prescott	0.289495
Dahlonega	0.323616
Charlottesville	0.399052
Fruita	0.428469
Arcadia	0.431057
Lenoir	0.453264
DeFuniak	0.514896
Kinston	0.590578
Jackson	0.744722
Milford	0.762573
Coshocton	0.790543
New Braunfels	0.791689
Woodstock	0.798386
Pauls Valley	0.85347
Summerville	0.940437
Talladega	1.11734
New Mexico State University	1.14454

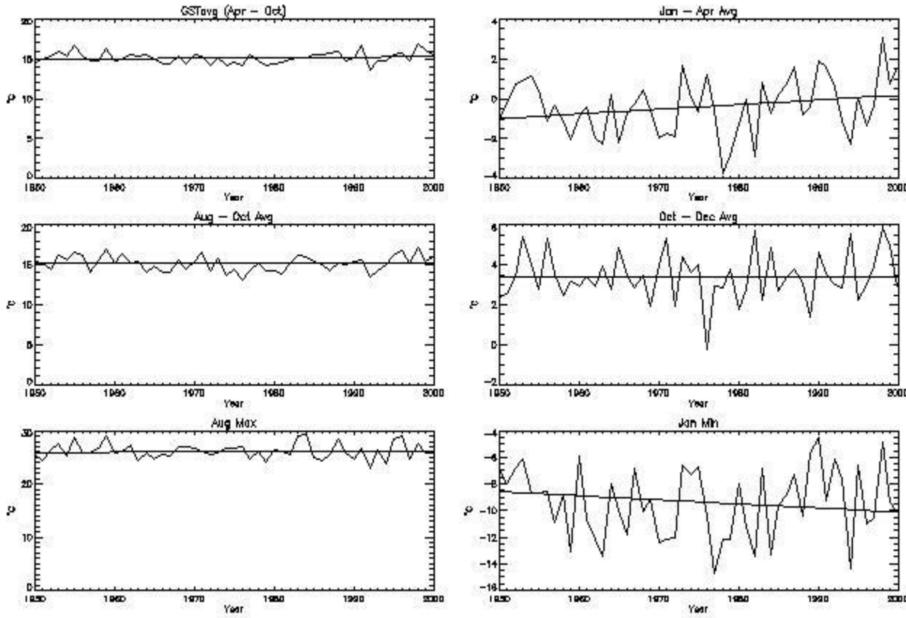
Table 15: Trends of January Minimum temperatures for the time period 1950 – 2000. Data source: USHCN Maximum and Minimum dataset.

Station Name	Jan Minimum Temperature Trends
Allegan	-1.53695
Gardiner	-1.38836
Geneva	-0.950409
Coshocton	-0.664959
Arcadia	-0.505011
Anna	-0.339689
Towanda	-0.309837
Crosbyton	-0.229986
Calhoun	-0.156112
Bedford	-0.150349
Falls Village	-0.085557
Burlington	-0.0733156
Columbus	-0.00205612
Charlottesville	0.000168085
DeFuniak	0.0881021
Lenoir	0.101116
Allentown	0.111685
Rolla	0.259535
Summerville	0.267986
Dahlonega	0.30653
Erie	0.360174
Jackson	0.406235
Tucson	0.460171
Riverton	0.467909
Woodstock	0.561007
New Mexico State University	0.729824
Bridgehampton	0.749895
Lancaster	1.00196
Pauls Valley	1.013
Los Lunas	1.24437
Milford	1.30167
Blanding	1.40636
Indianola	1.51762
Crete	1.8728
New Braunfels	1.88708
Fallon	1.94412
Kinston	2.03152
Prescott	2.45835
Scott City	2.50961
St. Ignatius	2.65798
Ozark	2.68339
Talladega	2.78127
Mora	3.1353
Mandan	3.24046
Fruita	4.48038
Watertown	4.99507

Table 16: Summary of trends of August Maximum temperatures for the time period 1950 – 2000. Data source: USHCN Maximum and Minimum dataset.

Station Name	Aug Maximum Temperature Trends
Crete	-2.56638
Coshocton	-2.31396
Crosbyton	-2.2859
Indianola	-1.82125
Columbus	-1.50615
Dahlonega	-1.38585
Jackson	-1.35406
Geneva	-1.19195
Kinston	-1.166
Anna	-1.04025
Scott City	-0.98629
Towanda	-0.92772
Watertown	-0.84483
Riverton	-0.78388
Ozark	-0.67139
Los Lunas	-0.55128
Mandan	-0.49937
Lancaster	-0.35115
Charlottesville	-0.21205
Rolla	-0.20114
New Braunfels	-0.15099
Erie	-0.12037
Talladega	-0.00209
Fruita	-0.00051
Pauls Valley	0.003262
Woodstock	0.124414
Allegan	0.124653
Milford	0.167686
Arcadia	0.19286
Summerville	0.193958
Allentown	0.230526
Lenoir	0.296219
Burlington	0.395611
Bedford	0.519823
Mora	0.628902
Gardiner	0.755047
Fallon	0.836628
Blanding	0.879322
Bridgehampton	0.921982
Falls Village	1.00058
Calhoun	1.05417
New Mexico State University	1.11258
DeFuniak	1.15313
Tucson	1.15614
Prescott	1.51179
St. Ignatius	2.32459

(a)



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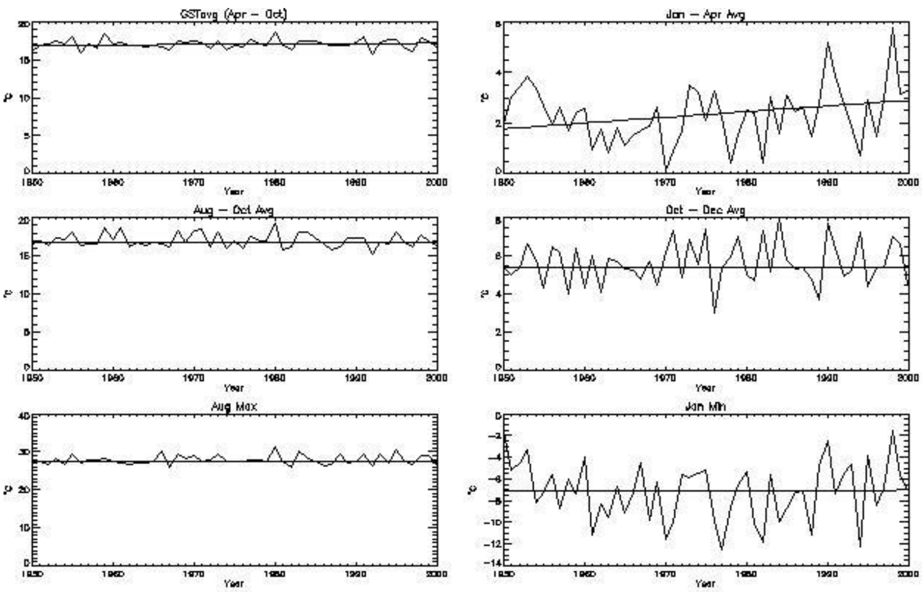
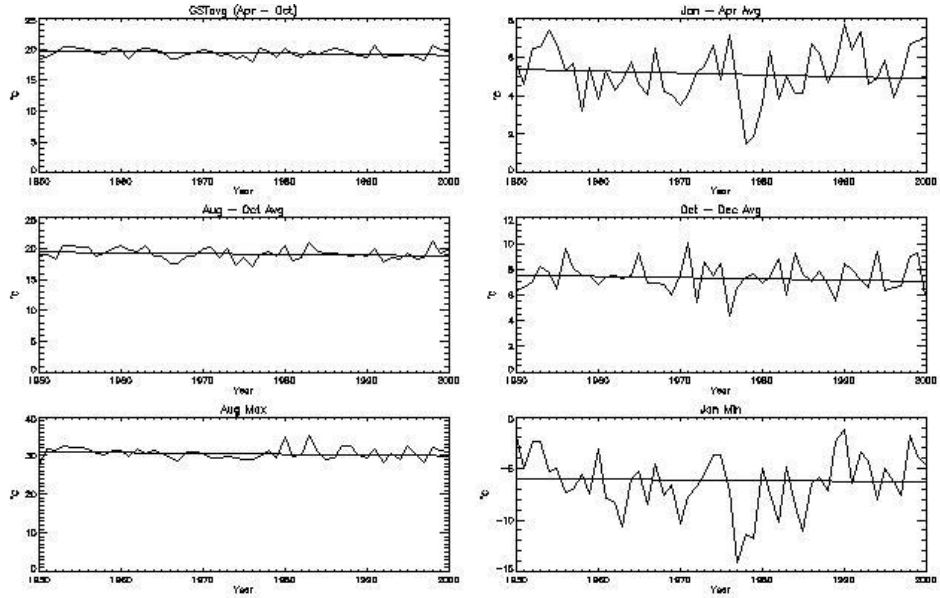


Fig. 1: Time series plots for USHCN station, (a) Allegan, MI; (b) Allentown, PA. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



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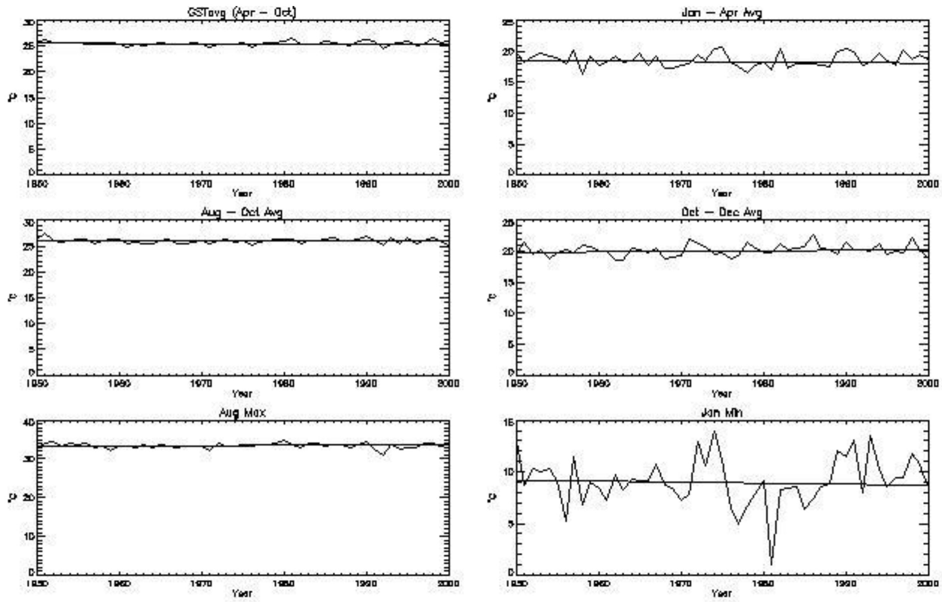
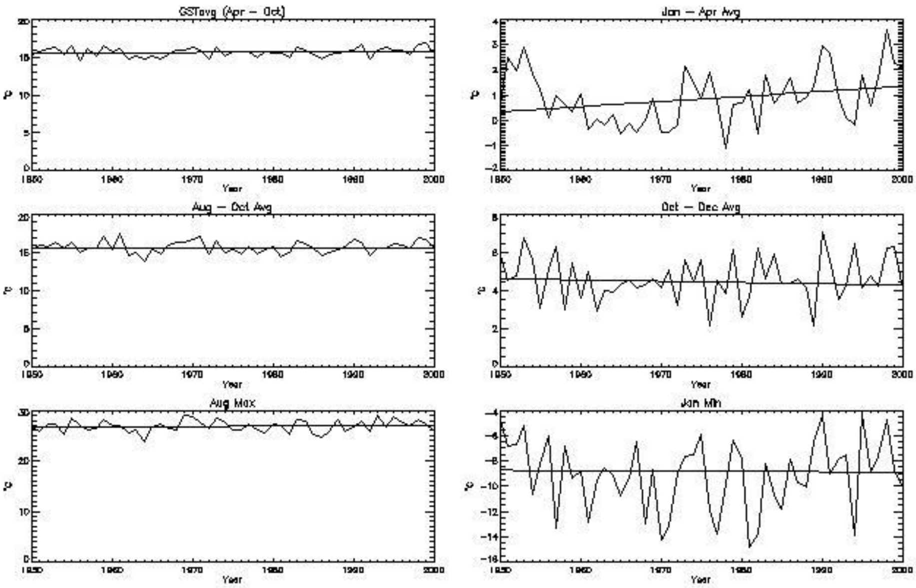


Fig. 2: Time series plots for USHCN station (a) Anna, Ill; (b) Arcadia, FL . Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



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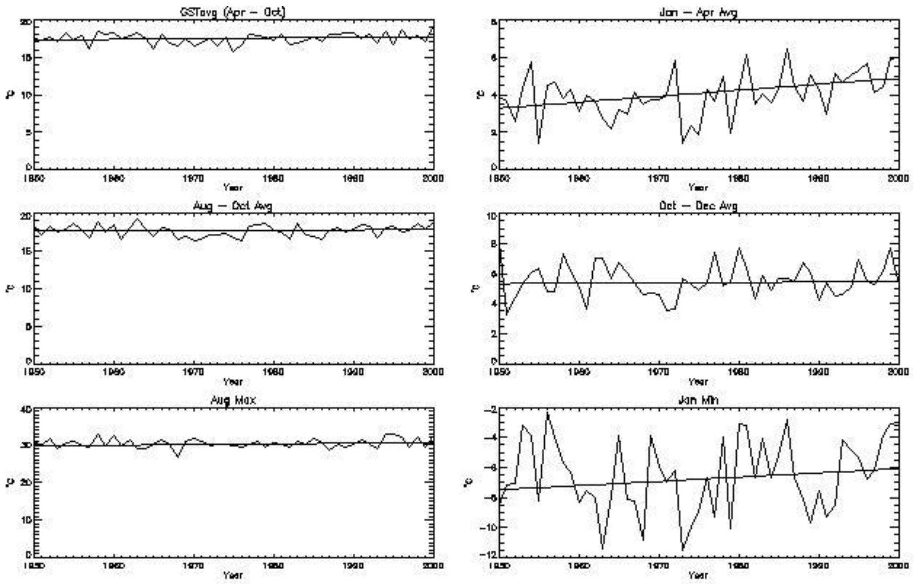
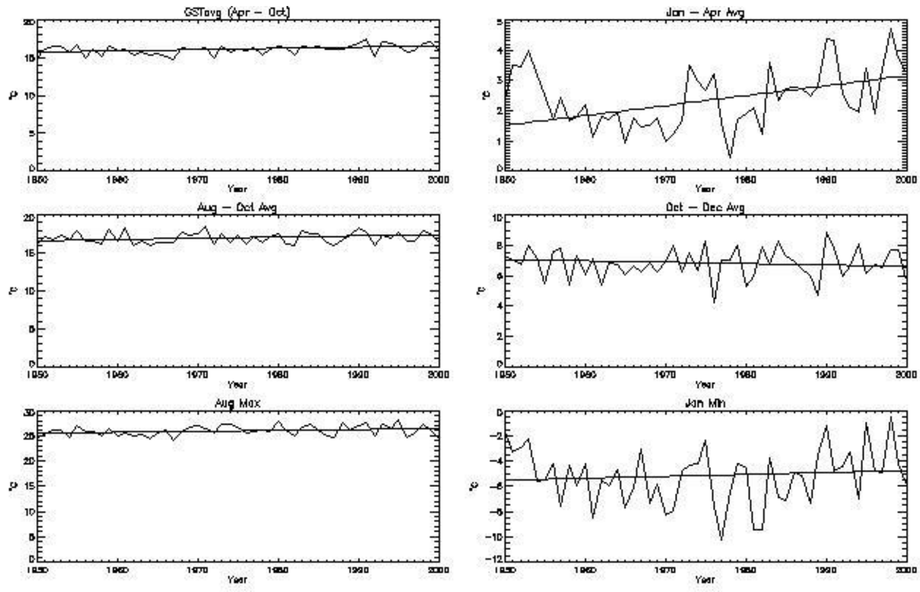


Fig. 3: Time series plots for USHCN station: (a) Bedford, MA; (b) Blanding, UT . Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

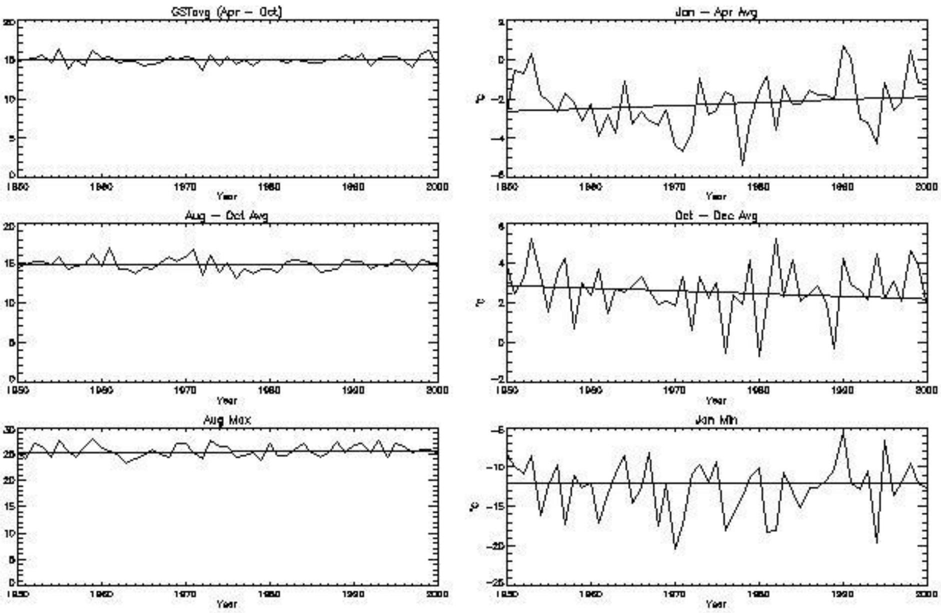
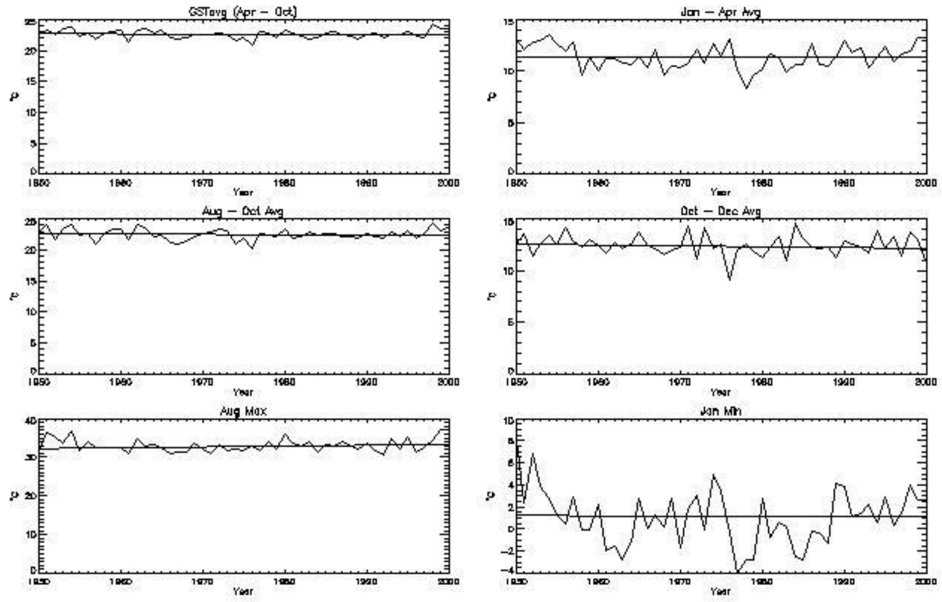


Fig. 4: Time series plots for USHCN station: (a) Bridgehampton, NY; (b) Burlington, VT . Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

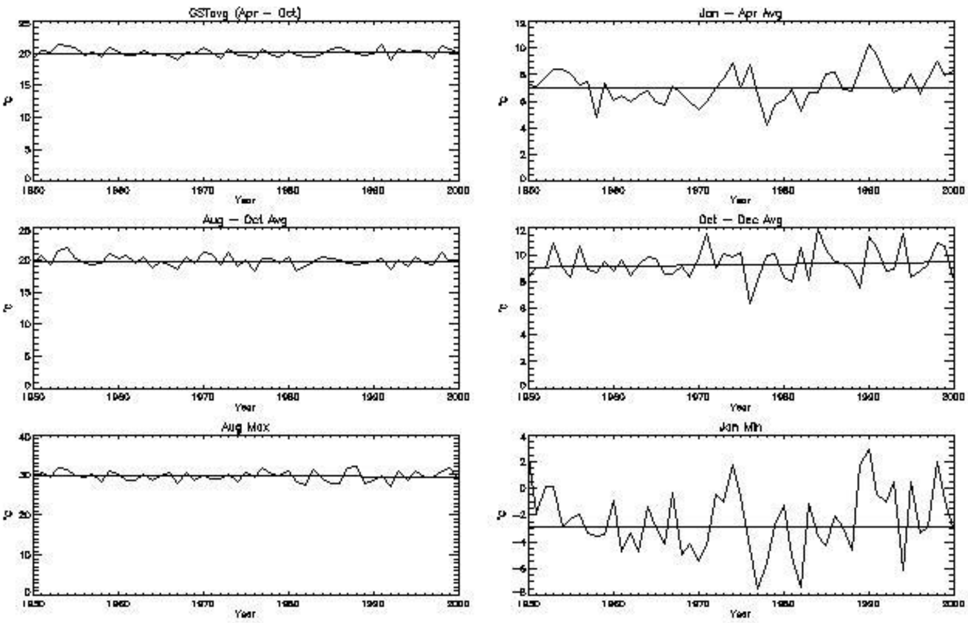
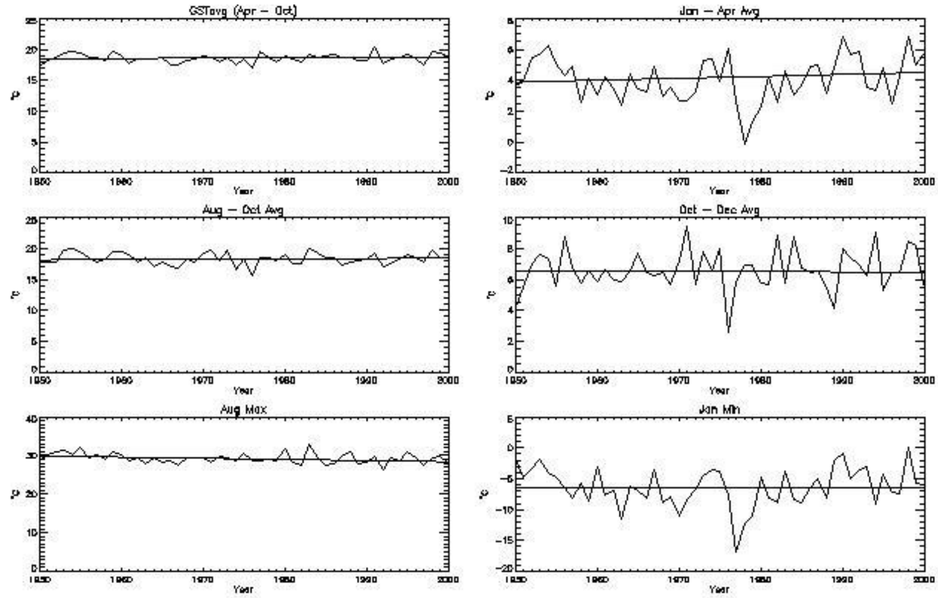


Fig. 5: Time series plots for USHCN station: (a) Calhoun, LA; (b) Charlottesville, VA. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

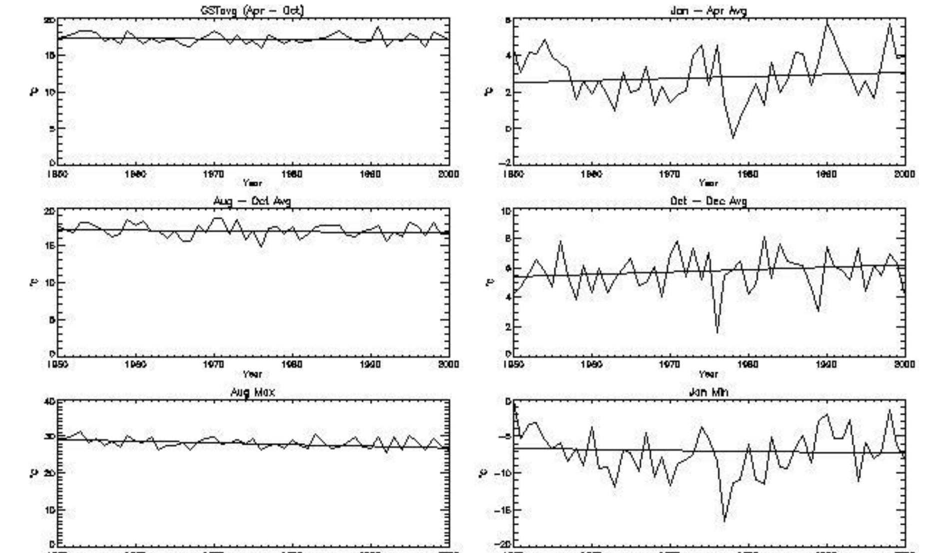
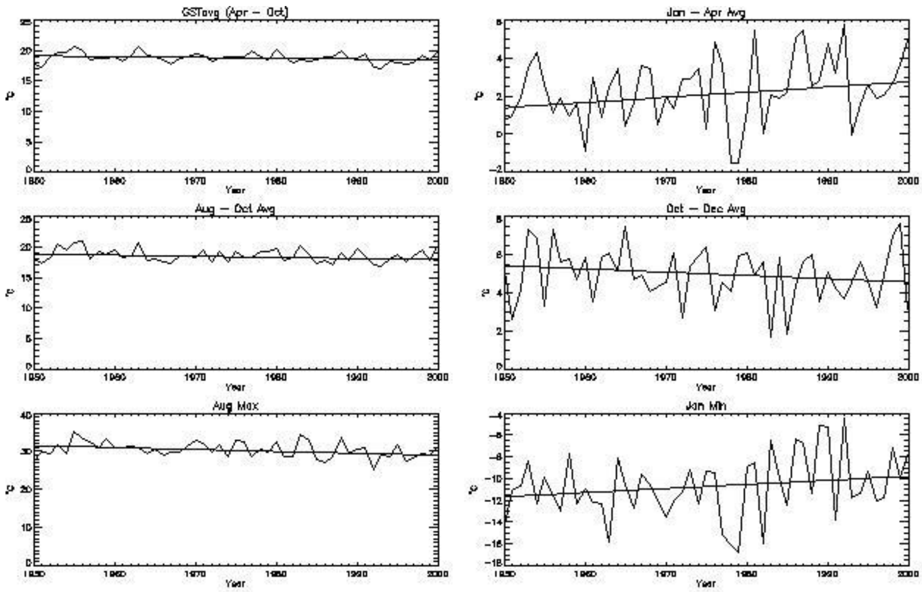


Fig. 6: Time series plots for USHCN station: (a) Columbus, IN (b) Coshocton, OH . Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

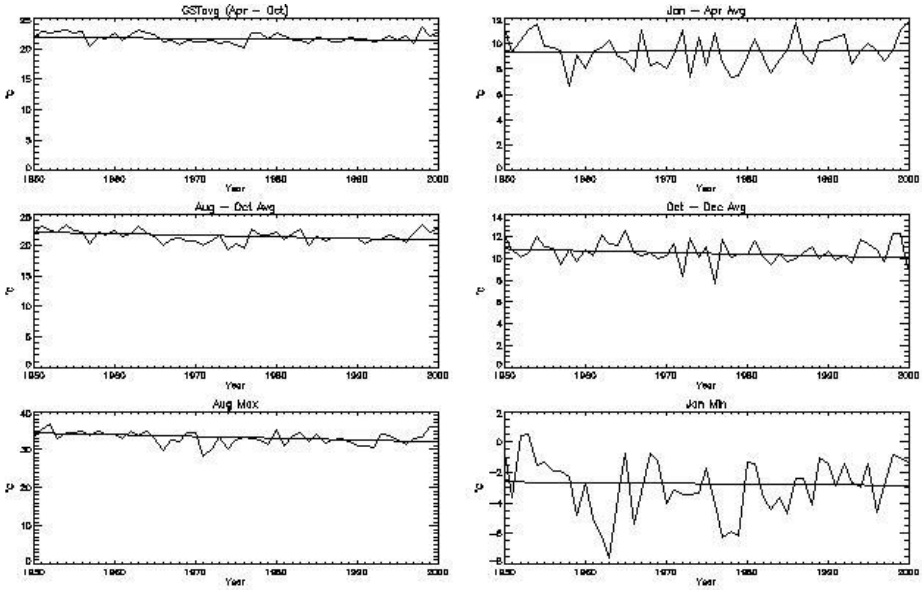
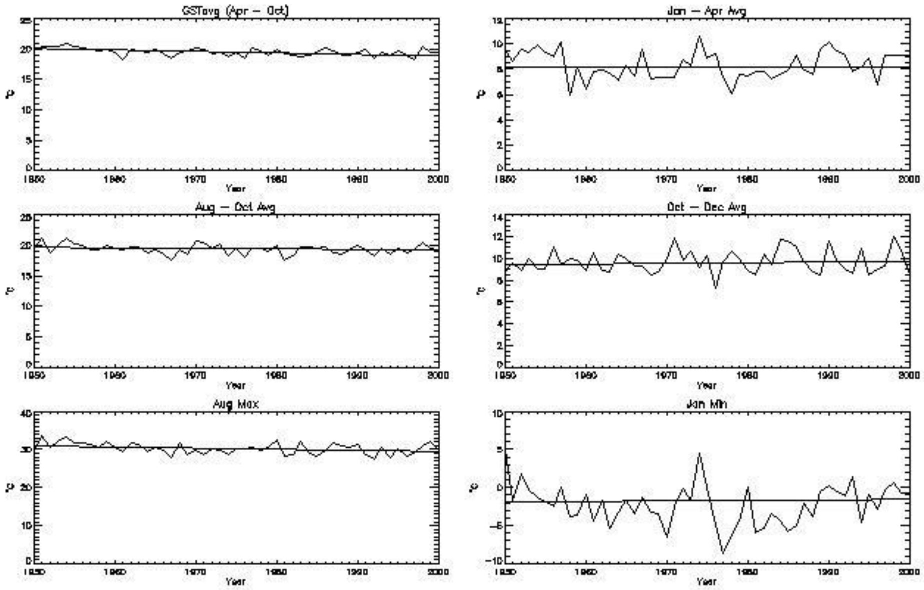


Fig. 7: Time series plots for USHCN station: (a) Crete, NE; (b) Crosbyton, TX. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

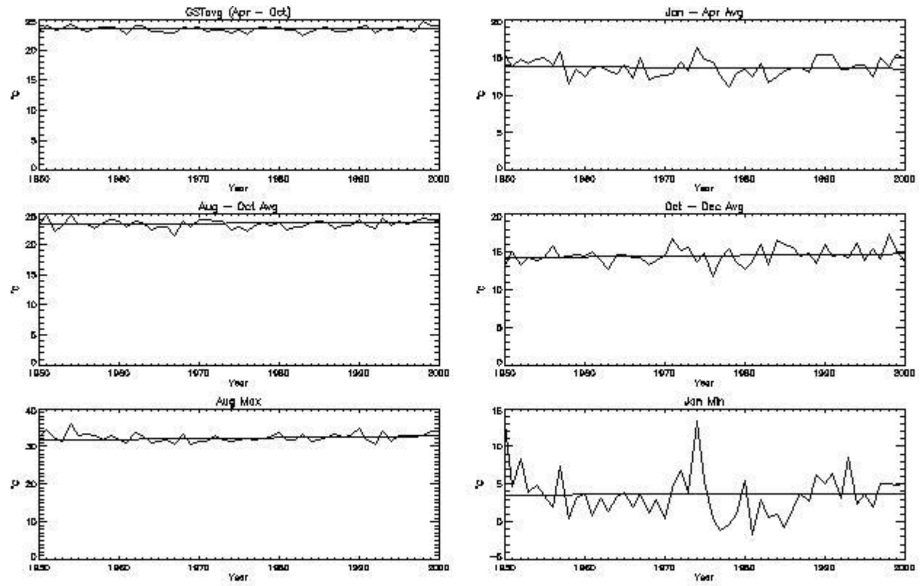
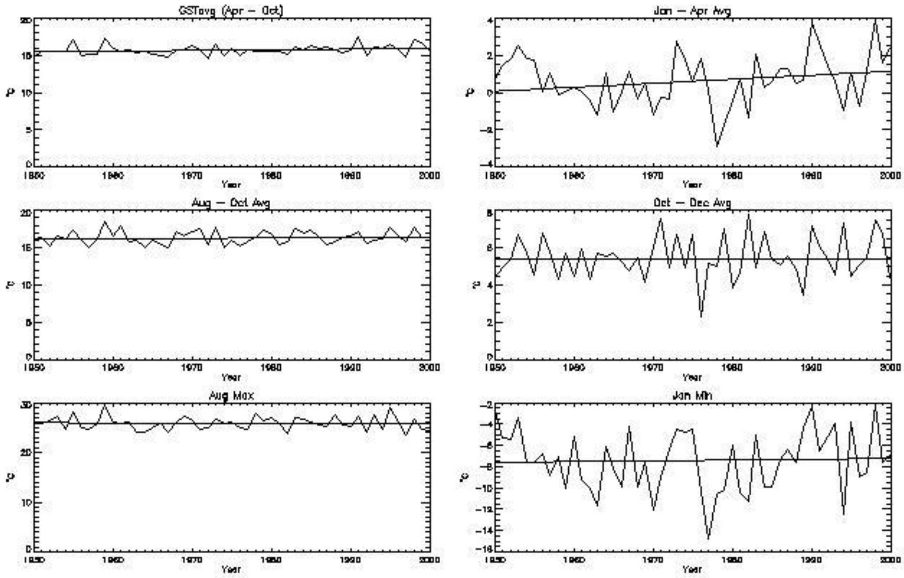


Fig. 8: Time series plots for USHCN station: (a) Dahlonega, GA; (b) De Funiak Springs, FL. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

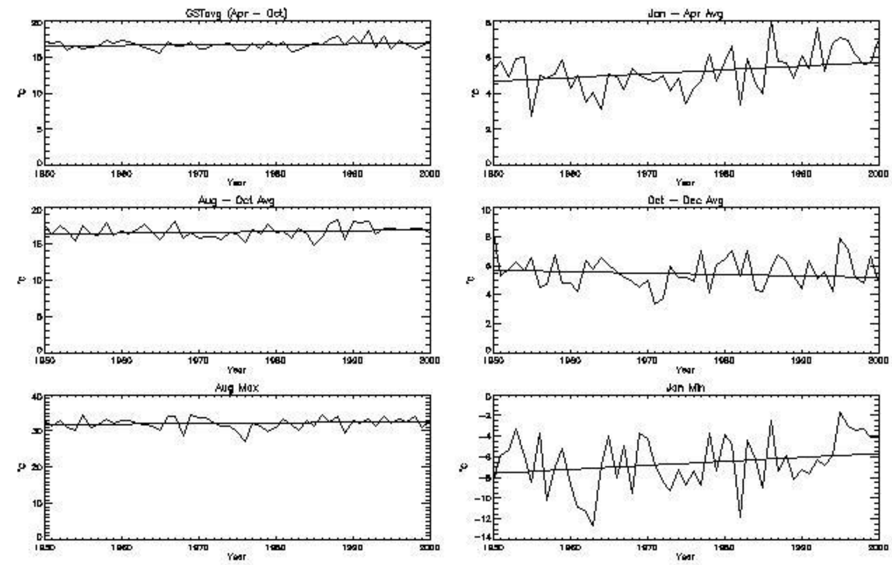
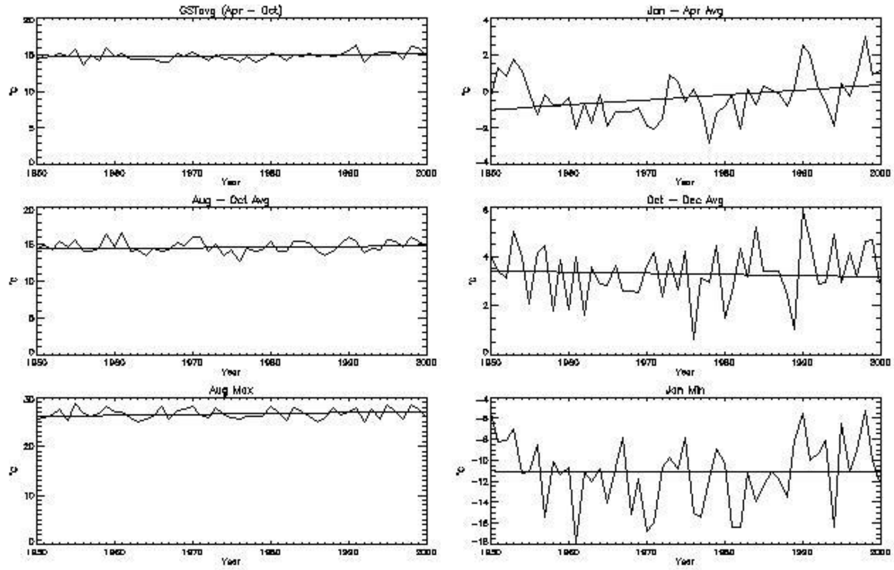


Fig. 9: Time series plots for USHCN station: (a) Erie, PA; (b) Fallon, NV. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



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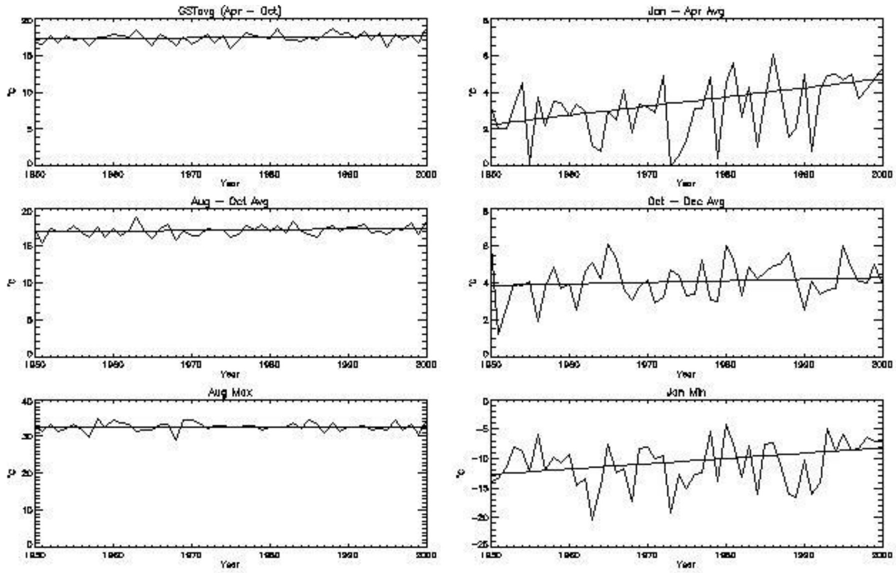
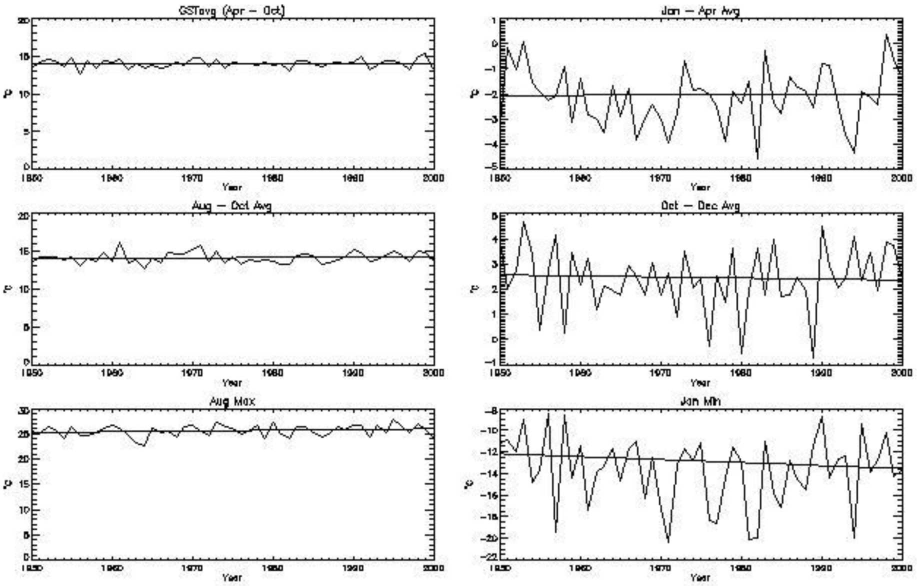


Fig. 10: Time series plots for USHCN station: (a) Falls Village, CT; (b) Fruita, CO. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

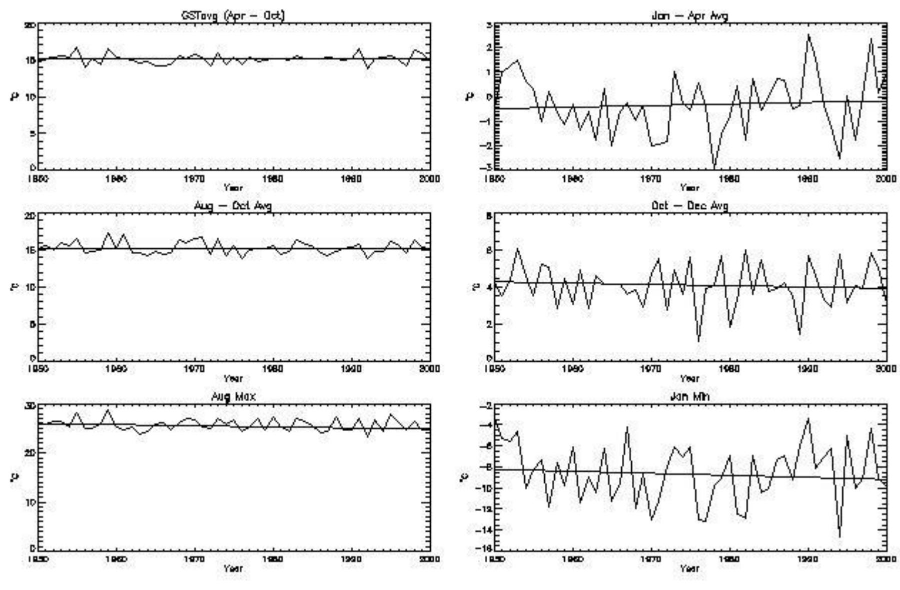
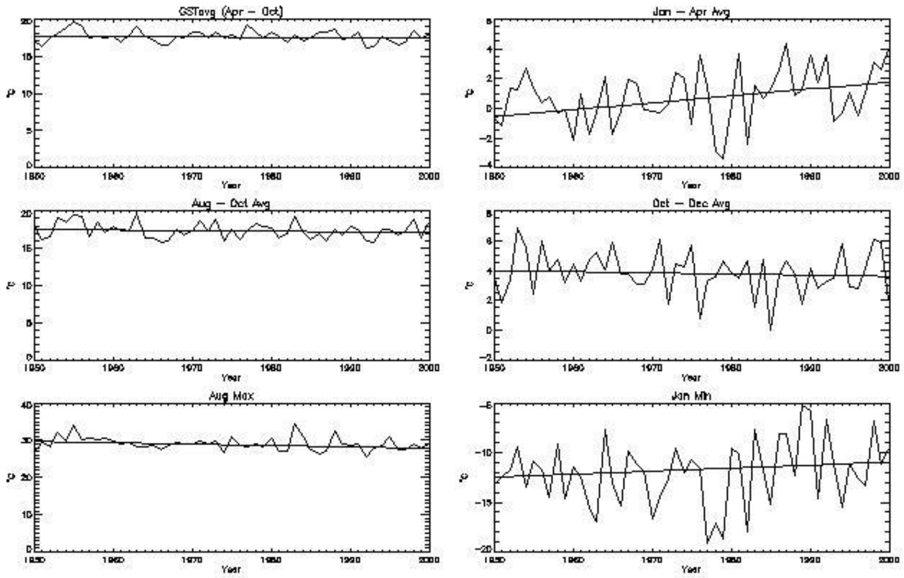


Fig. 11: Time series plots for USHCN station: (a) Gardiner, ME; (b) Geneva, NY. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



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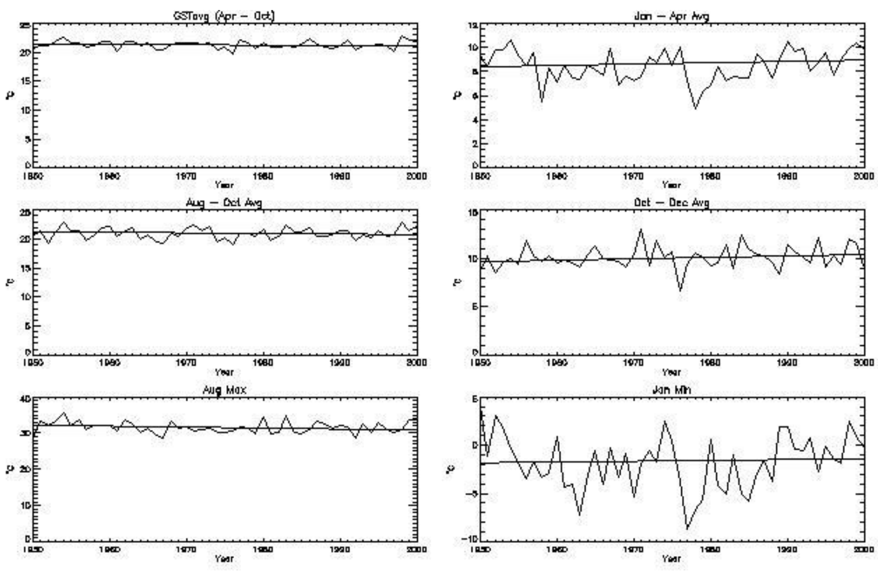
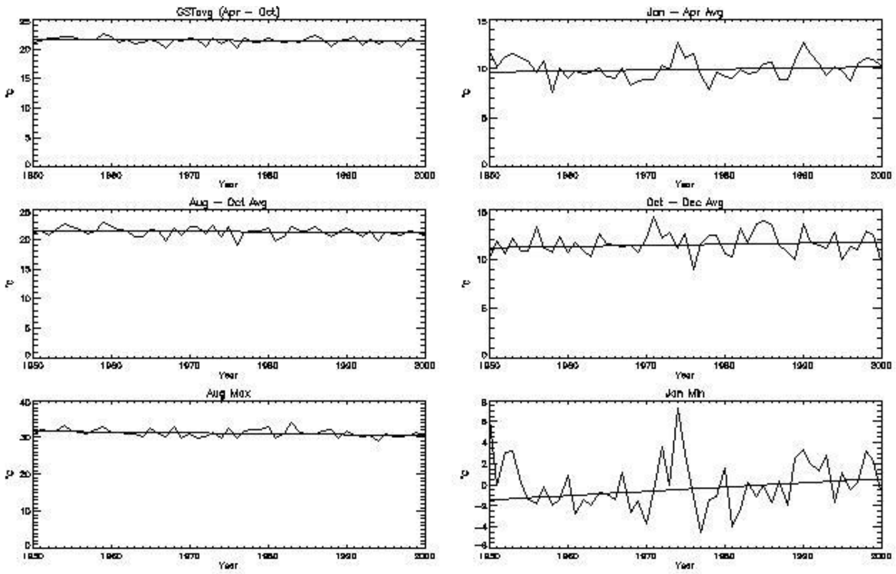


Fig. 12: Time series plots for USHCN station: (a) Indianola, IA; (b) Jackson, TN. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

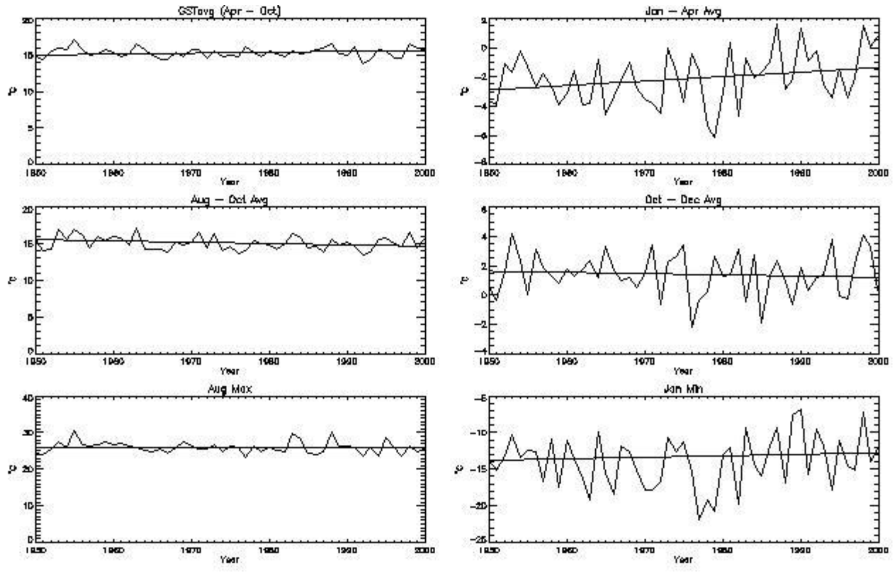
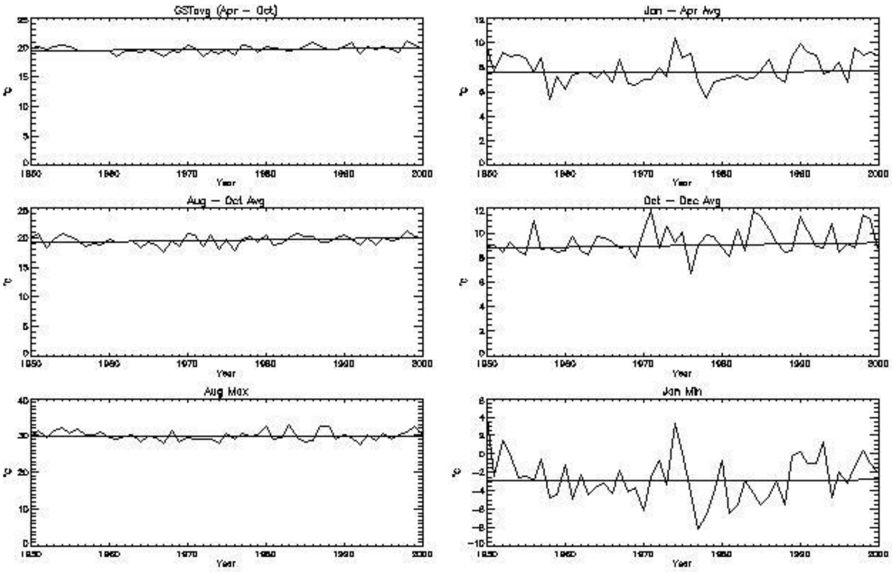


Fig. 13: Time series plots for USHCN station: (a) Kinston, NC; (b) Lancaster, WI . Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



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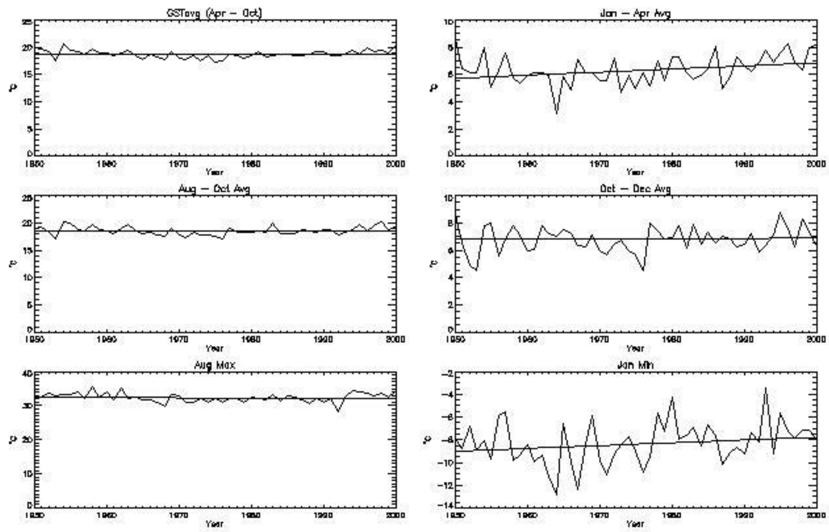
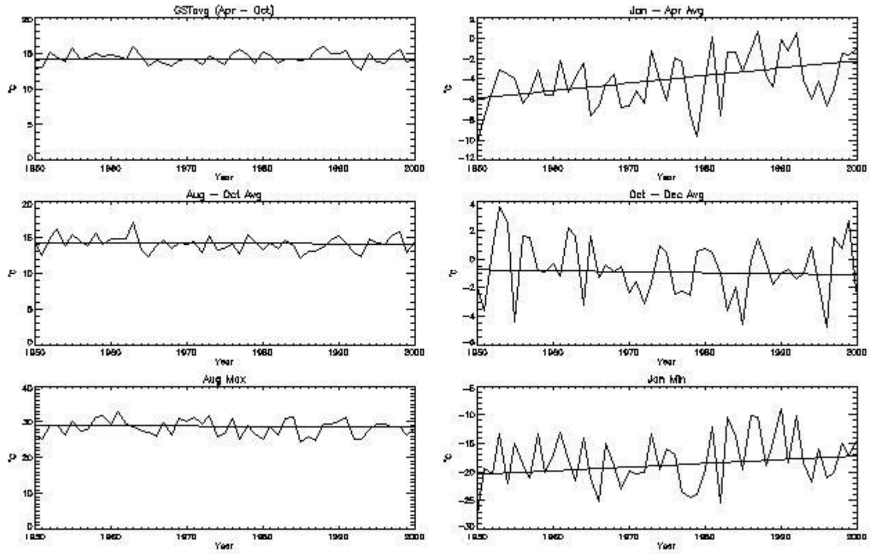


Fig. 14: Time series plots for USHCN station: (a) Lenoir, NC; (b) Los Lunas, NM. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

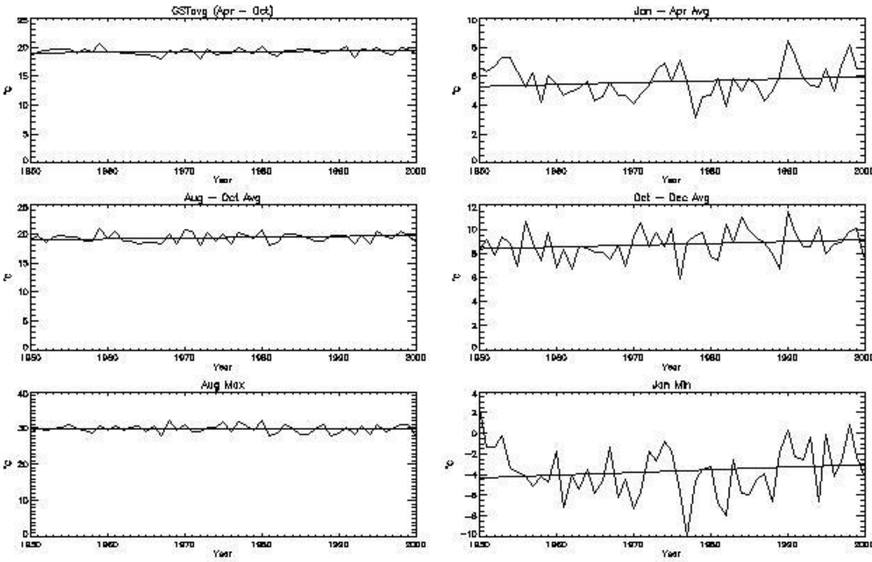
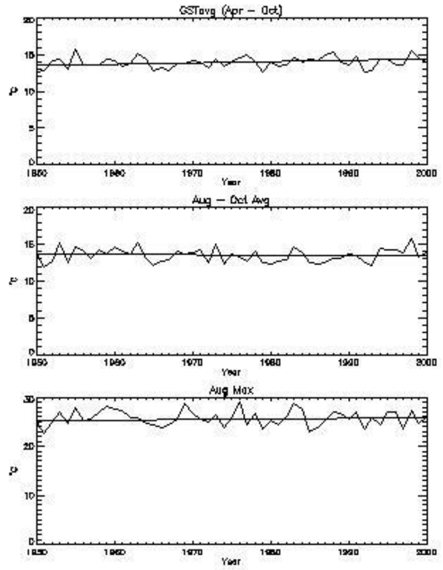


Fig. 15: Time series plots for USHCN station: (a) Mandan, ND; (b) Milford, DE. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

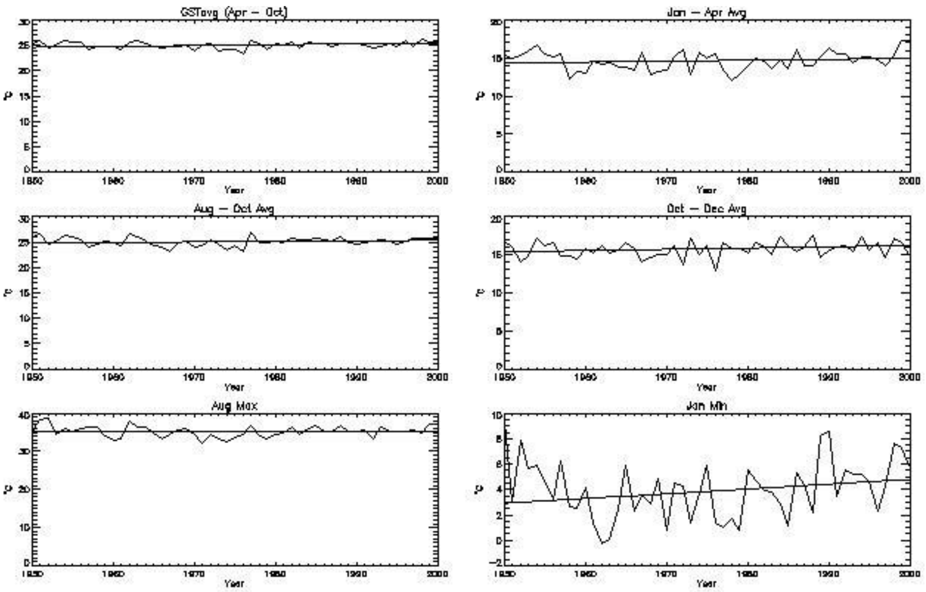
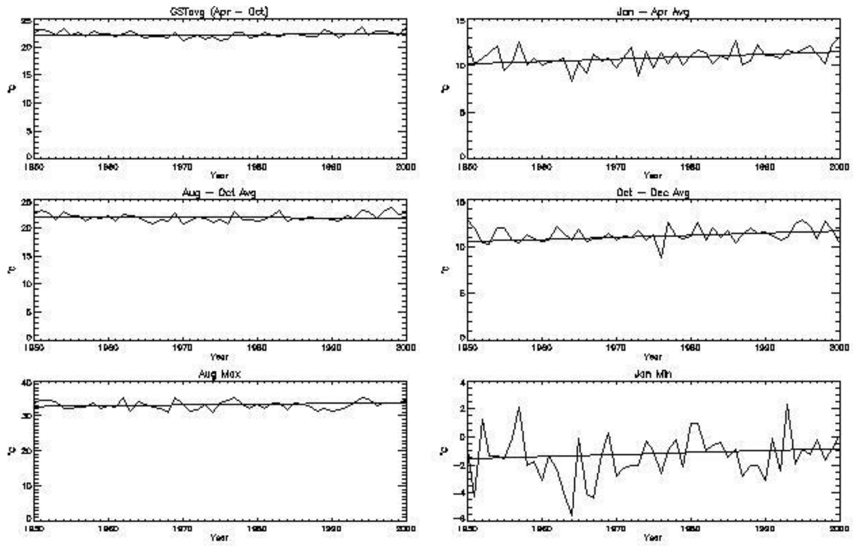


Fig. 16: Time series plots for USHCN station: (a) Mora, MN; (b) New Braunfels, TX. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

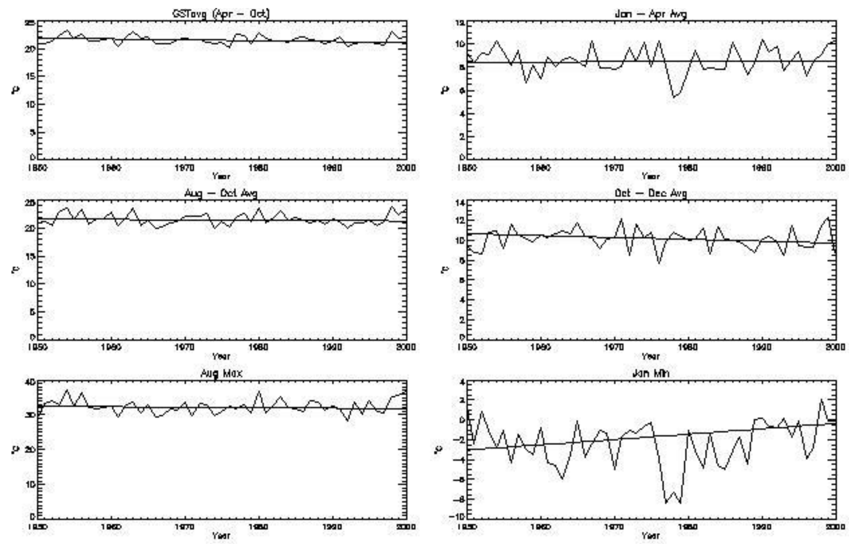
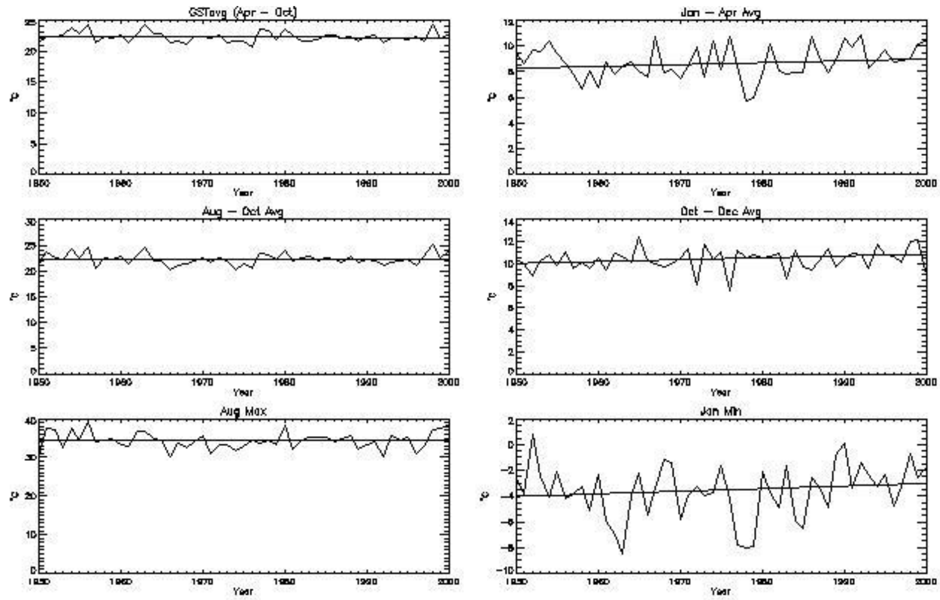


Fig. 17: Time series plots for USHCN station: (a) New Mexico State University, Las Cruces, NM (b) Ozark, AR. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

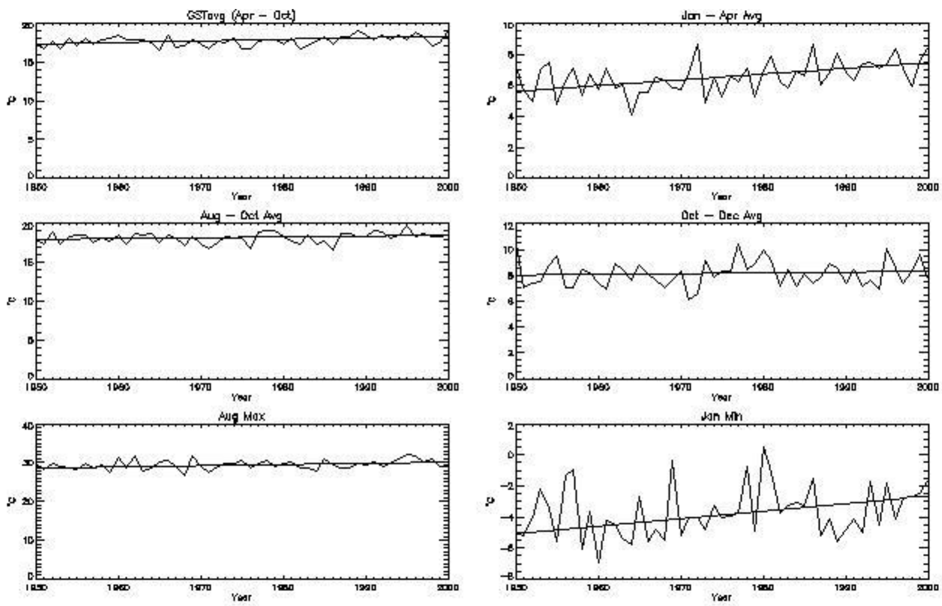
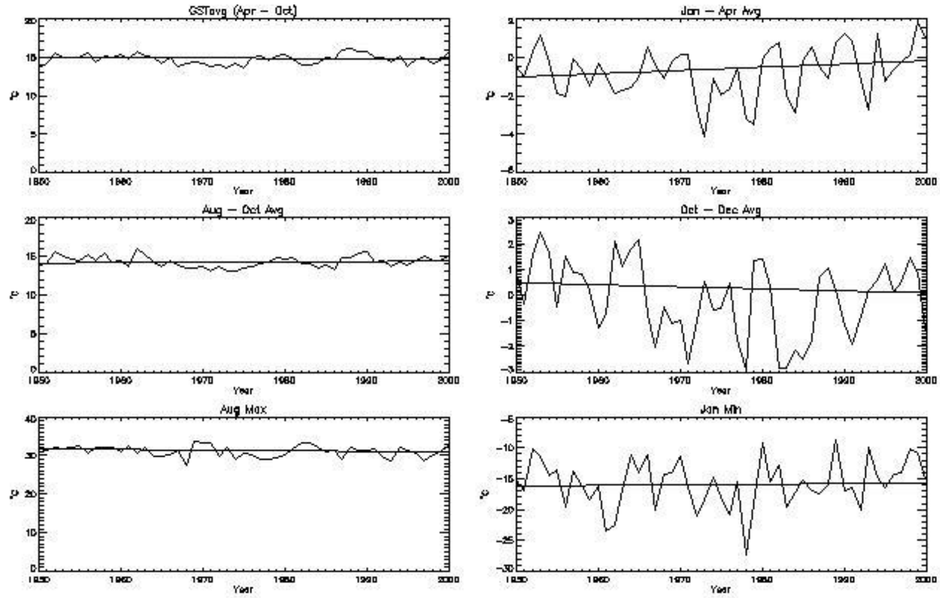


Fig. 18: Time series plots for USHCN station: (a) Pauls Valley, OK; (b) Prescott, AZ. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

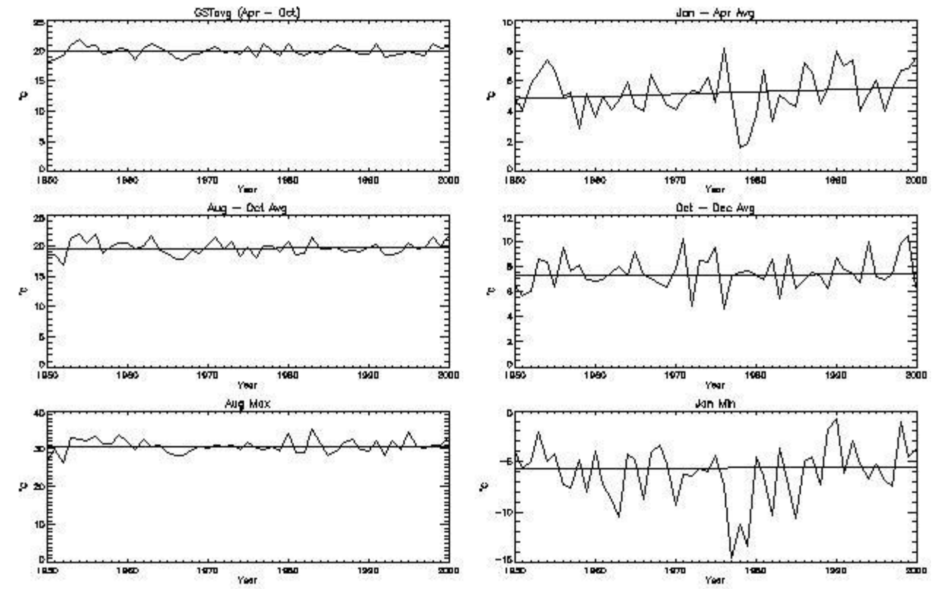
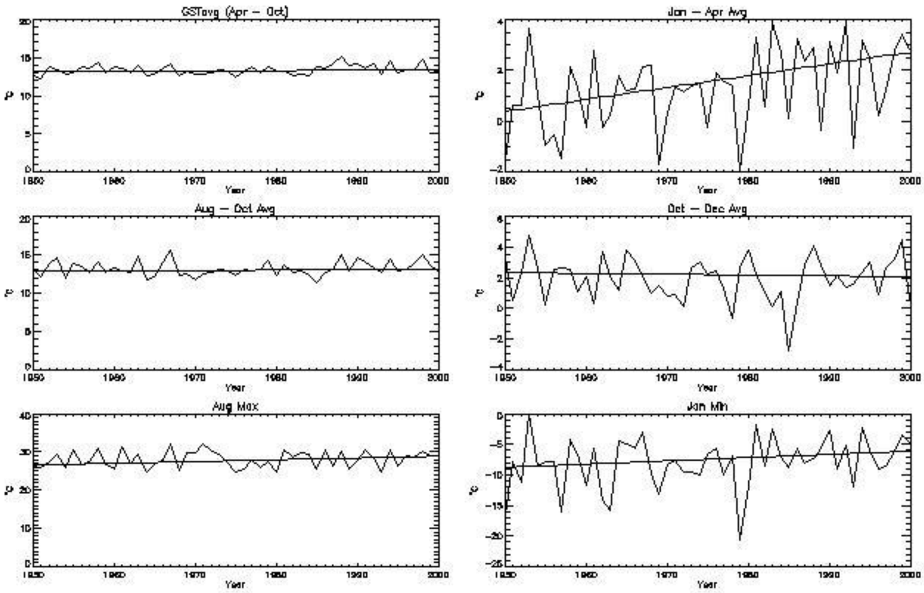


Fig. 19: Time series plots for USHCN station: (a) Riverton, WY; (b) University of MO, Rolla, MO . Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

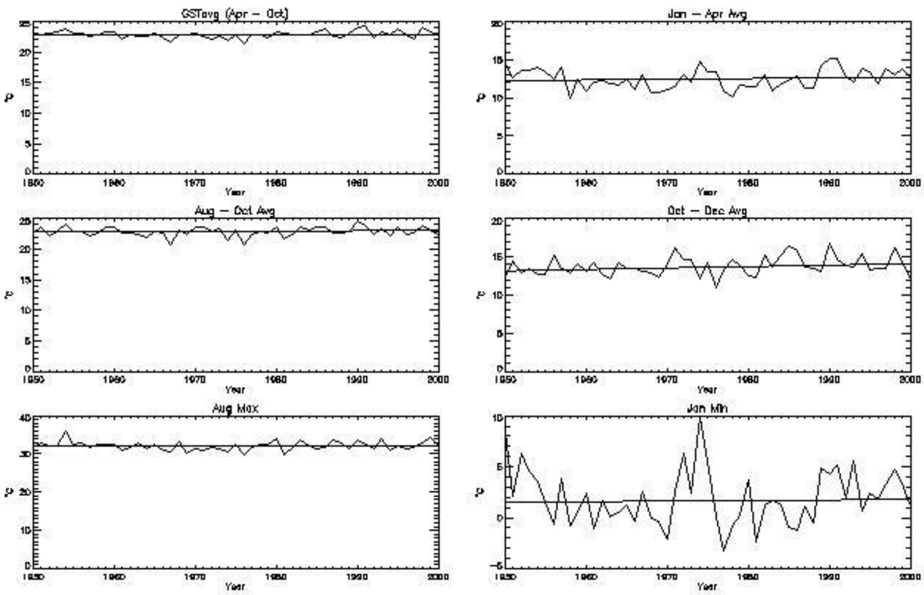
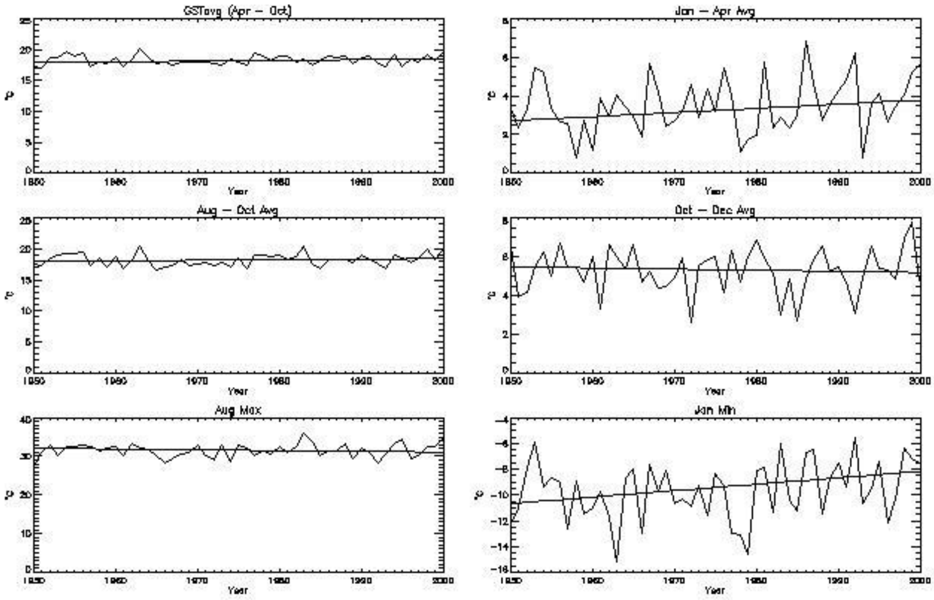


Fig. 20: Time series plots for USHCN station: (a) Saint Ignatius, MT; (b) Summerville, SC. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

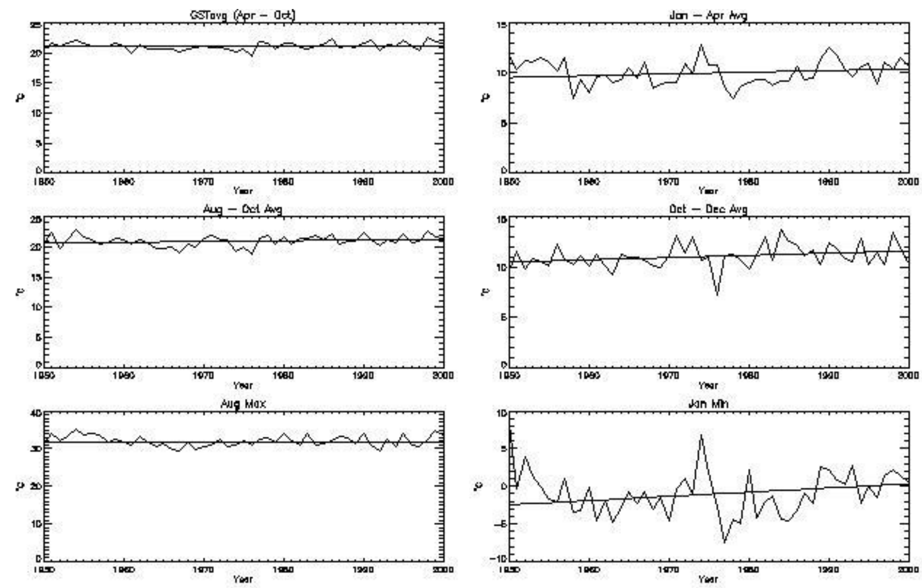
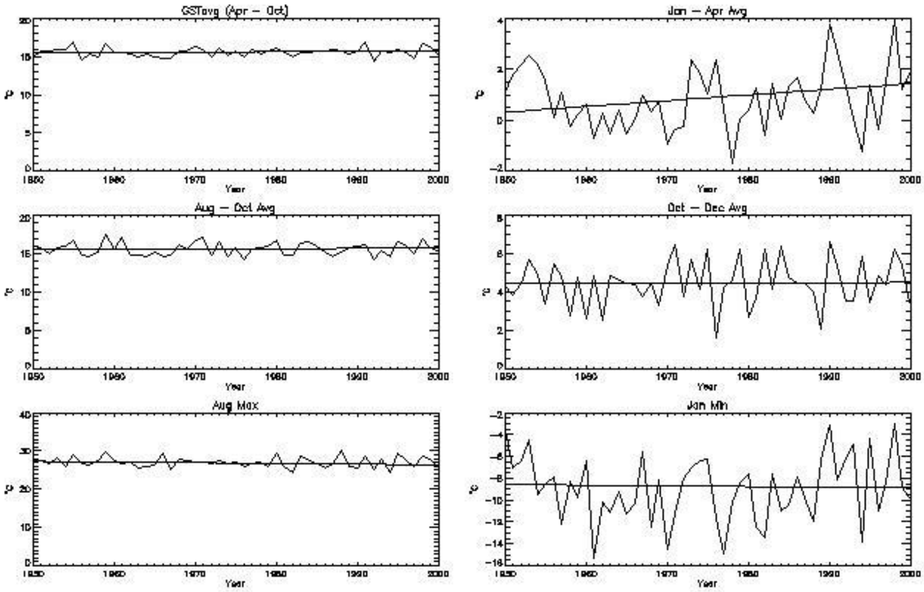


Fig. 21: Time series plots for USHCN station: (a) Scott City, KS; (b) Talladega, AL. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

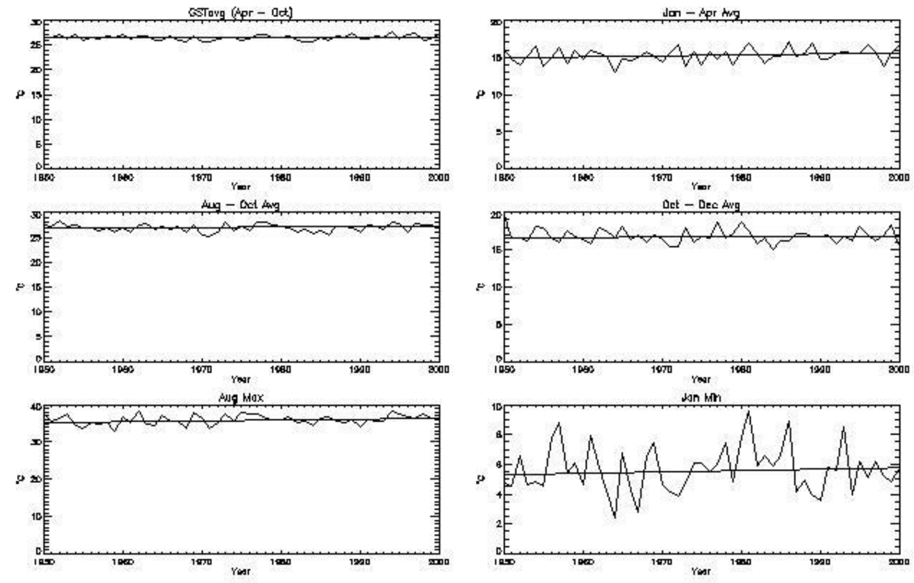
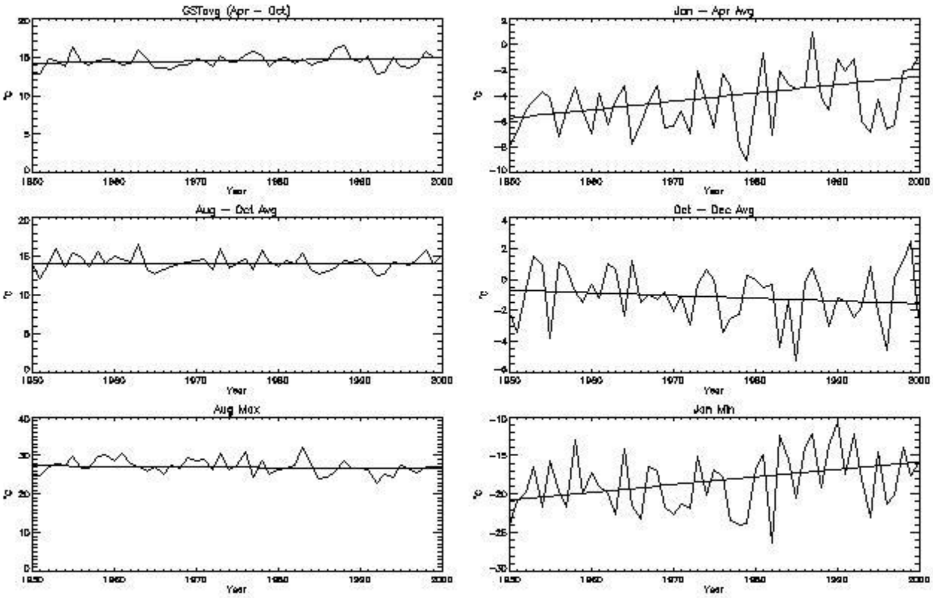


Fig. 22: Time series plots for USHCN station: (a) Towanda, PA; (b) Tucson, AZ. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

(a)



(b)

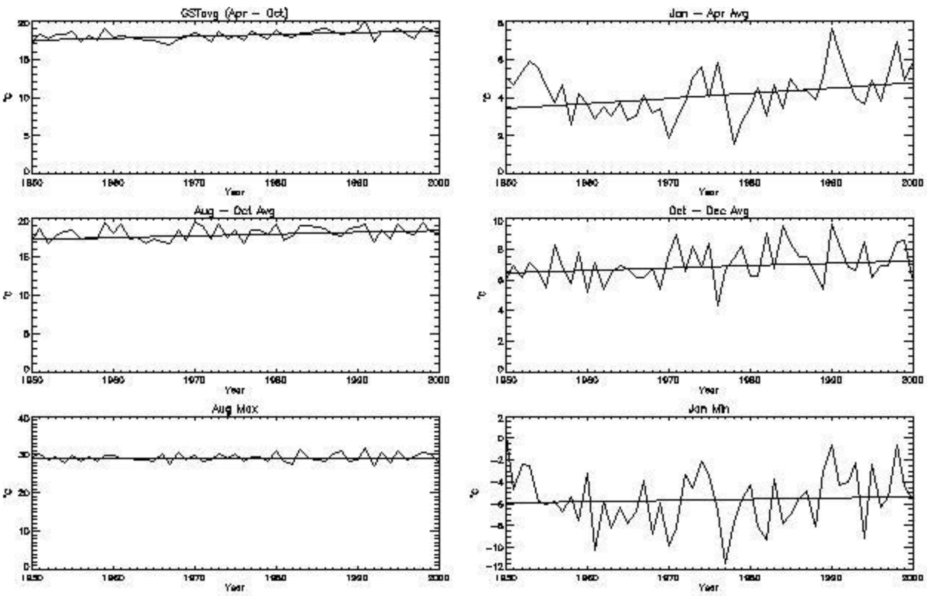


Fig. 23: Time series plots for USHCN station: (a) Watertown, SD; (b) Woodstock, MD. Data source: USHCN Temperature Monthly Maximum and Minimum for the time period of 1950 – 2000.

References

References

Allmon, W. D., W. D. and R M. Ross, 2007. Finger Lakes Geology. In *Ithaca is Gorges: A Guide to the Geology of the Ithaca Area*. The Paleontological Research Institution. Retrieved from http://www.priweb.org/ed/finger_lakes/nystate_geo1.html

Amerine, M.A. and A.J. Winkler. 1944. Composition and quality of musts and wines of California grapes. Hilgardia, 15:493-675.

Code of Federal Regulations (CFR9.1) Title 27--"American Viticultural Area – Part 9". Alcohol, Tobacco Products and Firearms. 2006. Retrieved from http://www.access.gpo.gov/nara/cfr/waisidx_06/27cfr9_06.html

Azevedo, P.V. , J. M. Soares, VdPRd Silva, Bbd Silva, T. Nascimento, 2008. Evapotranspiration of ''Superior'' grapevines under intermittent irrigation. *Agric. Water Manage.*, **Vol. 95**, **no. 3**, p. 301-308.

Bergqvist, J. ,N. Dokoozlian and N. Ebisuda, 2001. Sunlight Exposure and Temperature Effects on Berry Growth and Composition of Cabernet Sauvignon and Grenache in the Central San Joaquin Valley of California. *Am. J. Enol. Vitic.* **Vol 52**. p 1-7.

Blanco-Ward, D., J. M. Garcia Queijeiro and G.V. Jones, 2007. Spatial Climate Variability and Viticulture in the Miño River Valley of Spain. V*itis*, 46(2) 63-70.

Bodin, F. and R. Morlat, 2006 . Characterization of viticultural terroirs using a simple field model based on soil depth I. Validation of the water supply regime, phenology and vine vigour, in the Anjou vineyard (France). *Plant and Soil*, **Vol. 281**, p.37–54.

Bowen, P. 2006. Tech Tools Reveal *Terroir*. **Wines & Vines.** Retrieved from **http://www.winesandvines.com/**

Bowen, P.A., C.P. Bogdanoff, B.F. Estergaard, S.G. Marsh, K.B. Usher, C.A.S. Smith and G. Frank. 2005. Geology and Wine 10: Use of Geographic Information System Technology to Assess viticulture Performance in the Okanagan and Similkameen Valleys, British Columbia. *Geoscience Canada*, **Vol 32, no 4**, p 161 - 176.

Boyer, J. and T. Wolf, 2000, GIS and GPS aid the exploration of viticultural potential in Virginia: *Vineyard and Winery Management*, Nov/Dec 2000, p. 48-54.

Boyer, J. and T. K. Wolf, 2000. "Development and preliminary validation of a Geographical Information System approach to vineyard site suitability assessment in Virginia." 11 p. In: Proceedings of the 5th International Symposium on Cool Climate Viticulture and Oenology, 16-20 January 2000,Melbourne, Aust.

Bramley, R.G.V. and R.P. Hamilton, 2004. Understanding variability in winegrape production systems: 1. Within vineyard variation in yield over several vintages. *Australian Journal of Grape and Wine Research* 10, 32–45, 2004.

Bramley, R.G.V. and A.P.B. Proffitt, 2003. Being profitable – a case study of precision viticulture from Margaret River. *The Australian & New Zealand Grapegrower & Winemaker* 84-87.

Bravdo B and A. Naor, 1996. Effect of water regime on productivity and quality of fruit and wine. *Acta Hort,* **Vol. 427**, p. 15–26.

Bravdo, B.A. and Y. Hepner, 1987. Irrigation management and fertigation to optimize grape composition and vine performance. In: Proceedings of the Symposium on Grapevine Canopy and Vigor Management. *Acta Hortie*, **Vol. 206**, p. 49-67.

Buttrose, M. S., C. R. Hale, and W. M. Kliewer, 1971. Effect of temperature on the composition of Cabernet Sauvignon berries. *Am. J. Enol. Vitic.* **Vol. 22**, p 71-75.

Chambers, J., 1976. Bell Labs. The S System. Retrieved from http://cm.bell-labs.com/cm/ms/departments/sia/S/index.html

"Climate" Glossary of Meteorology. CD-ROM. 2nd Ed. Boston, Mass: American Meteorological Society, 2000.

Conradie, W.J., Carey, V.A., Bonnardot, V., Saayman, D., Schoor van, L.H., 2002. Effect of different environmental factors on the performance of Sauvignon blanc grapevines in the Stellenbosch/Durbanville districts of South Africa. I. geology, soil, climate, phenology and grape composition. South African J. Enol. Vitic. 23 (2), 79–91.

Commbe, B.G., 1987. Influence of temperature on composition and quality of grapes. In: Proceedings of the Symposium on Grapevine Canopy and Vigor Management. Acta Hortie 206, 23-35.

Crippen, D.D., and J.C. Morrison, 1986(a). The effects of sun exposure on the compositional development of Cabernet Sauvignon berries. *Am. J. Enol. Vitic.* **Vol. 37**, p. 235-242.

Crippen, D.D., and J.C. Morrison, 1986(b). The effects of sun exposure on the phenolic content of Cabernet Sauvignon berries during development. *Am. J. Enol. Vitic.* **Vol. 37**, p. 243-247.

Dami, I., B. Bordelon, D. C. Ferree, M. Brown, M. A. Ellis, R. N. Williams, and D. Doohan, 2005. Midwest grape production guide. Bulletin 919. Columbus, Ohio. The Ohio St. Univ. Retrieved from http://ohioline.osu.edu/b919/

Davidson Viticultural Consulting Services. Adelaide Hills Wine Region Profile. Australia, 2004.

DeGaetano, A.T. and R.J. Allen, 2002. Trends in Twentieth-Century Temperature Extremes across the United States. *J. Climate*, **15**, 3188-3205.

De Villiers F. S., 1997, The use of Geographic Information System (GIS) in the selection of wine cultivars for specific areas by using temperature climatic models: in Proceedings, XXII Congrès de la Vigne et du Vin, December, 1997, Buenos Aires, Argentina.

Dry, P.R. and R. E. Smart, 1988. Vineyard Site Selection, In “Viticulture Volume 1: Resources in Aurtralia”, edited by Coombe, B.G. and Dry, P.R. Aurtralian Industrial Publishers, Underdale, South Australia.

Ewart, A. J. W., C. J. Brien, R. Soderland, and R. E. Smart, 1985. Effects of light pruning, irrigation and improved soil management on wine quality of the *Vitis vinifera* cv. Riesling. *Vitis,* **Vol. 24**. p. 209-217.

Ewart, A., and W. M. Kliewer, 1977. Effects of controlled day and night temperatures and nitrogen on fruit-set, ovule fertility, and fruit composition of several wine grape cultivars. *Am. J. Enol. Vitic.*, **Vol. 28**, p 88-95.

Fanet, J., 2004. *Great Wine Terroirs*. Berkeley: University of California press.

Fereres, E. and R. G. Evans, 2006. Irrigation of fruit trees and vines: an introduction. *Irrig Sci*, **Vol. 24**, p. 55–57.

Gentleman, R. and R. Ihaka, 1997. The R Project for statistical Computing, University of Auckland. Retrieved from http://www.r-project.org/

Gladstones, J. 1992. *Viticulture and Environment*. Winetitles, Adelaide, Australia. 310 pp.

Gordon, D.A., 1997. Vineyard and winery management: a case study in GIS implementation. In: ESRI International User Conference, San Diego, California, USA.

GrADS Online Documentation, 2010. Retrieved from http://grads.iges.org/grads/gadoc/index.html

Hale, C. R., and M. S. Buttrose, 1974. Effect of temperature on ontogeny of berries of *Vitis vinifera* cv. Cabernet Sauvignon. *J. Am. Soc. Hortic. Sci*. **Vol. 99**, p. 390-394.

Hancock, J. 1999. Feature review. *Terroir. The role of geology, climate, and culture in the making of French wines* by J.E. Wilson, 1998. *Journal of Wine Research* 10:43-49.

Hartkamp, A.D., White, J.W., Hoogenboom, G., 1999. Interfacing Geographic Information Systems with agronomic modelling: a review. *Agron. J.*, **Vol. 9, no. 5**, p. 761–772.

Hellman, E. and J. Kamas 2007. Texas A&M University Texas Cooperative Extension. Vineyard Site Assessment. Retrieved from http://winegrapes.tamu.edu/grow/siteassessment.html

Huglin, P., 1978. Nouveau mode d'évaluation des possibilities héliothermiques d'un milieu viticole. In: Proceedings of the Symposium International sur l'ecologie de la Vigne. Ministère de l'Agriculture et de l'Industrie Alimentaire, Contança, pp. 89–98.

ITT Visual Information Solutions, Image Processing and Data Analysis, 2010. Retrieved from http://www.ittvis.com/default.aspx

Jackson, D., 2001. *Climate: Monographs in Cool Climate Viticulture – 2*. Wellington: Daphne Brasell Associates LTD with Gypsum Press.

Jackson, D.I. and P. B. Lombard, 1993. Environmental and Management Practices Affecting Grape Composition and Wine Quality- A Review. *Am. J. Enol. Vitic.*, **Vol. 44, No. 4.** 409-430

Jackson and Spurling (1988) "Climate and Viticulture in Australia" Chapter 4 in Viticulture (Volume 1: Resources) Coombe B.G. and Dry P.R. Eds. Winetitles Adelaide

Jackson, David, and D. Schuster. 1987. The Production of Grapes & Wine In Cool Climates. Butterworths of New Zealand (Ltd), Wellington, New Zealand.

Jones, G.V. 2006. Climate and Terroir: Impacts of Climate Variability and Change on Wine. *Fine Wine and Terroir - The Geoscience Perspective.* Macqueen, R.W., and Meinert, L.D., (eds.), Geoscience Canada Reprint Series Number 9, Geological Association of Canada, St. John's, Newfoundland, 247 pages.

Jones, G.V., 2005. Climate Change in the Western United States Grape Growing Regions. *Acta Horticulturae* (ISHS), 689:41-60

Jones, G. V., 2001. Using GIS/GPS Technology to Assess Viticultural Status and Potential in the Rogue Valley AVA. Proceedings from the 115th Annual Meeting of the Oregon Horticultural Society, Portland, Oregon, January 2001.

Jones, G. V. and R. E. Davis, 2000(a). 'Climate influences on grapevine phenology, grape composition, and wine production and quality for Bordeaux, France', *Am. J. Viti. Enol.* **51**, 249–261.

Jones, G. V., and R. E. Davis, 2000(b). Using a synoptic climatological approach to understand climate/viticulture relationships. *Inter. J. Clim*. **Vol. 20**, p. 813-837.

Jones, G. V. and E. Hellman, 2003, *Site Assessment and Oregon Winegrowing Regions*: in "Oregon Viticulture" Hellman, E. (ed.), 5th Edition, Oregon State University Press, Corvallis, Oregon, p 44-50, 51-69.

Jones, G. V., and E. Hellman. 2000. *Oregon Viticulture, Site assessment*, ed., E.W. Hellman, Oregon State University, pp 44-50.

Jones, G.V., P. Nelson, and N. Snead, 2004, Modeling Viticultural Landscapes: A GIS Analysis of the Terroir Potential in the Umpqua Valley of Oregon. *GeoScience Canada*, **Vol. 31, no. 4**, p. 167-178.

Jones, G.V., A.A. Duff, and J.M. Myers, 2006. Modeling Viticultural Landscapes: a GIS Analysis of the Viticultural Potential in the Rogue Valley of Oregon. Proceedings of the VIth Terroir Congress, Bordeaux and Montpellier, France. July 3-7, 2006

Jones, G.V., Duff, A.A., and A. Hall (2009a). Updated analysis of climate-viticulture structure and suitability in the western United States. Proceedings of the 16th International GiESCO Symposium, Davis, California. July 12-16, 2009.

Jones, G.V., M. Moriondo, B. Bois, A. Hall, and A. Duff. (2009b): Analysis of the spatial climate structure in viticulture regions worldwide. Le Bulletin de l'OIV 82(944,945,946):507-518.

Jones, G. V. and S. Light, 2001, Site Characteristics of Vineyards in the Rogue and Applegate Valley American Viticultural Areas. Open Report to the Oregon Wine Board and the Rogue Chapter of the Oregon Winegrape Growers Association. 55 pp.

Kliewer, W.M., 1970. Effect of day temperature and light intensity on coloration of Vitis vinifera L. grapes. *J. Amer. Soc. Hort. Sci*., **Vol. 95 no. 6**, p. 693- 697.

Kliewer, W.M., 1967. Effect of day temperature and light intensity on concentration of malic and tartaric acids in Vitis vinifera L. grapes. *J. Amer. Soc. Hort. Sci*. **Vol. 96, no. 3**, p. 372-377.

Kliewer, W.M., 1977. Influence of temperature, solar radiation, and nitrogen on coloration and composition of Emperor grapes. *Am. J. Enol. Vitic*. **Vol. 28**, p. 96-103.

Kobayashi, A., T. Fukushima, T. Nii, and K. Harada, 1967. Studies on the thermal conditions of grapes. VI. Effects of day and night temperatures on yield and quality of Delaware grapes. *J. Jap. Soc. Hort. Sci*., **Vol. 36**, p. 1-7.

Kriedmann, P.E., 1968. Photosynthesis in vine leaves as a function of light, intensity, temperature and leaf age. *Vitis*, **Vol. 7**, p. 213-220.

Lamb, D.W. and Bramley, R.G.V., 2001. Managing and monitoring spatial variability in vineyard variability. *Natural Resource Management*, **Vol. 4**, p. 25-30

Lamb, D.W. and Bramley, R.G.V., 2002. Precision viticulture – tools, techniques and benefits. Blair, R.J., Williams, P.J. and Hoj, P.B. (Eds) 'Proceedings of the 11th Australian Wine Industry Technical Conference'. Winetitles, Adelaide, p.91- 97.

Lang, L., 1996. Geotechnology use grows in California's agriculture community. *Earth Observ. Mag*. **Vol. 5**, p. 16–20.

Lascano, R.J., Baumhardt, Lipe, W.N., 1992. Measurement of water flow in young grapevines using the stem heat balance method. *Amer. J. Enol. Viticult*. **Vol. 43, no. 2**, 159–165.

Lakso, A.N., and W.M. Kliewer, 1978. The influence of temperature on malic acid metabolism in grape berries. II. Temperature responses of net dark CO2 fixation and malic acid pools. *Am. J. Enol. Vitic*. **Vol. 29, no. 3**, p. 145-149.

Lobell, D.B., C.B. Field, K.N. Cahill and C. Bonfils, 2006. Impacts of future climate change on California perennial crop yields: Model projections with climate and crop uncertainties. *Ag. and Forest Meteo.*, **141**, 208-218.

Lunt, I.A., S.S. Hubbard and Y. Rubin, 2005. Soil Moisture content estimation using ground-penetrating radar reflection data. *J. Hydrol.,* **Vol. 307**, 254-269.

Magarey, R.D., Seem, R. C. and DeGloria, S.D., 1998, Prediction of vineyard site suitability: *Grape Research News*, **Vol.. 9, no. 1**, p. 1, 2. Retrieved from http://www.nysaes.cornell.edu/pp/faculty/seem/magarey/Vinesite/vinesite.htm

Maine Winery Guild, 2008. The Maine Wine Trail. http://www.mainewinetrail.com

Matthews, MA and M.M. Anderson, 1988. Fruit ripening in grapes (Vitis vinifera L.): responses to seasonal water deficits. *Am J Enol Vitic*, **Vol. 39, no. 3**, p. 313–320.

Monteiro, A., Lopes, C.M., 2007. Influence of cover crop on water use and performance of vineyard in Mediterranean Portugal. Agric. Ecosyst. Environ. Vol. 121, no. 4, p. 336–342.

Morlat, R. and F. Bodin, 2006. Characterization of viticultural terroirs using a simple field model based on soil depth – II. Validation of the grape yield and berry quality in the Anjou vineyard (France). *Plant and Soil*. **Vol. 281**, p. 55–69.

Morris, J., 2001. Precision Viticulture – A Mechanized Systems Approach. *Proceedings: ASEV/ES Symp Cool Clim Oenol and Vitic Inst, Ontario*, p 103-110.

McKenney, A., Feb. 2009. Number of U.S. Wineries Tops 6,100. Wine Business Monthly, http://www.winebusiness.com.

Nebraska Grape, Wine, Beer, B&B and Agri-Tourism Promotional Groups, 2009. Retrieved from http://www.vintagenebraska.org/wine_trails.htm

Nemani, R.R., M.A. White, D.R. Cayan, G.V. Jones, S.W. Running, J.C. Coughlan and D.L. Peterson, 2001. Asymmetric warming over coastal California and its impact on the premium wine industry. *Clim. Res.*, **Vol. 19**, 25-34.

Netzer, Y., C. Yao, M. Shenker, S. Cohen, B. Bravdo, A. Schwartz, 2005. Water consumption of 'Superior' grapevines grown in a semiarid region. *Acta Hortic. (ISHS)* **Vol. 689**, p. 399–406.

Ojeda H., C. Andary, E. Kraeva, A. Carbonneau, A. Deloire, 2002. Influence of pre- and postveraison water deficit on synthesis and concentration of skin phenolic compounds during berry growth of vitis vinifera cv. Shiraz. *Am J Enol Vitic*, **Vol. 53, no. 4**, p. 261–267

Peacoock, W.L., Christensen, L.P., Andris, H.L., 1987. Development of drip irrigation schedule for average-canopy vineyards in San Joaquin Valley. *Am. J. Enol. Viticult*. **Vol. 38 no. 1**, p. 113–119.

PRISM Group, 2008. Oregon State University. Retrieved from http://prism.oregonstate.edu/

Pool, R., 2000. Cornell University. Retrieved from http://www.nysaes.cornell.edu/hort/faculty/pool/NYSite-Soils/SiteSelection.html

Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National laboratory, 2010. Retrieved from http://www-pcmdi.llnl.gov/

Ramos, M.C., Martı´nez-Casasnovas, J.A., 2006. Impact of land levelling on soil moisture and runoff variability in vineyards under different rainfall distributions in a Mediterranean climate and its influence on crop productivity. *J. Hydrol.,* **Vol. 312, no. 1**, p. 131–146.

Riou, Ch., Becker, N., Sotes Ruiz, V., Gomez-Miguel, V., Carbonneau, A., Panagiotou, M., Calo, A., Costacurta, A., Castro de, R., Pinto, A., Lopes, C., Carneiro, L., Climaco, P., 1994. Le déterminisme climatique de la maturation du raisin: application au zonage de la teneur em sucre dans la communauté européenne. Office des Publications Officielles des Communautés Européennes, Luxembourg, 322 pp.

Riquelme, F.J.M. and A. B. Ramos, 2005. Land and water use management in vine growing by using geographic information systems in Castilla-La Mancha, Spain. *Ag. Water Mgt.*, **Vol. 77**, p. 82–95

Robert, P.C, 2000. Site specific management of the twenty-first centurty. *HortTech*. **Vol. 10**, p. 448-451.

Shaulis, N. and Dethier, B., 1970, New York site selection for wine grapes: New York State Horticultural Society, Proceedings, v. 115, p. 288-294.

Smart, R. E., and P. R. Dry. 1980. A climatic classification for Australian viticultural regions. *Australian Grapegrower and Winemaker*, **Vol. 17**, p. 8-16.

Smith, L., Whigham, P., 1999. Spatial aspects of vineyard management and wine grape production. In: Annual Colloquium of the Spatial Information Research Centre, University of Otago, Dunedin, New Zealand.

Tamaluddin, S., Kamaruzaman, J., 1999. Remote sensing and geographic information systems technology for field implementation in Malaysian agriculture. In: Seminar on Repositioning Agriculture Industry in the Next Millenium, Serdang, Selangor, Malaysia.

Thach, L., Aug. 2007. Trends in Wine Tourism. Wine Business Monthly, Retrieved from http://www.winebusiness.com.

Tinney, M., Feb 2007. Review of the Industry: Number of U.S. Wineries Tops 5,900. Wine Business Monthly. Retrieved from http://www.winebusiness.com.

Tonietto, J., 1999. Les macroclimats viticoles mondiaux et l'influence du mésoclimat sur la typicité de la Syrah et du Muscat de Hambourg dans le sud de la France: méthodologie de caráctérisation. Thèse Doctorat. Ecole Nationale Supérieure Agronomique, Montpellier, 233 pp.

Tonietto, J., Carbonneau, A. , 2004. A multicriteria climatic classification system for grape-growing regions worldwide. *Ag. And Forest Meteor.*, **124**, p 81 - 97.

United States Department of Agriculture, National Agricultural Statistics Service, (USDA-NASS), 2010. Retrieved from http://www.agcensus.usda.gov/

United States Department of Commerce, Census Bureau. US Wine Industry 2008. Washington, D.C., 2008.

United States Department of Commerce, National Climatic Data Center (NCDC), 2010. The USHCN Version 2 Serial Monthly Dataset. Retrieved from http://www.ncdc.noaa.gov/oa/climate/research/ushcn/

United States Department of Treasury. Alcohol and Tobacco Tax and Trade Bureau. Alcohol Statistics. Retrieved from http://www.ttb.gov/statistics/alcohol_stats.shtml

Van leeuwen, C., B. Bois, P. Pieri and J-P. Gaudillere, 2007. Climate as a Terroir Component. *Congress On Clim. And Viti.,* Zaragoza, 10-14 April 2007.

Van Leeuwen, C., P. Friant, X. Chone, O. Tregoat, S. Koundouras and D. Dubourdieu, 2004. Influence of Climate, Soil and Cultivar on Terroir. *Am. J. Enol. Vitic*., **55:3**, 207 – 217.

Van Leeuwen, C. and G. Seguin, 2006. The Concept of Terroir in Viticulture. Journal of Wine Research, 2006, Vol. 17, No. 1, pp. 1–10

Vilanova, M. , S. Zamuz, F. Vilarino and C. Sieiro, 2007. Effect of *terroir* on the volatiles of *Vitis vinifera* cv. Albarino. *J Sci Food Agric,* **Vol. 87**, p.1252–1256.

Watkins, R. L. 1997. Vineyard site suitability in Eastern California. ***GeoJournal*** 43.3: 229–239.

White, M.A, N.S. Diffenbaugh, G.V. Jones, J.S. Pal and F. Giorgi, 2006. Extreme heat reduces and shifts United States premium wine production in the 21 st century. *Proc. Natl. Acad. Sci*. **103**, 11217-11222.

White, R.E., (2003): *Soils for Fine Wines*. Oxford: Oxford University Press.

Williams, L.E., Phene, C.J., Grimes, D.W., Trout, T.J., 2003. Water use of mature Thompson Seedless grapevines in California. *Irrig. Sci*., **Vol. 22, no. 1**, p. 11–18.

Williams, L.E., Ayars, J.E., 2005. Grapevine water use and the crop coefficient are linear functions of the shaded area measured beneath the canopy. *Agric. Forest Meteorol*. **Vol. 132, no. 1**, p. 201–211.

Winkler, A.J., J.A. Cook, W.M. Kliewer and L.A. Kider, 1974. *General Viticulture*. 2nd ed. Berkeley: University of California Press.

Wine Institute, 2010. *A Signature California Industry: California Wine Brochure*. Retrieved from http://www.wineinstitute.org

Wolf, T.K. (editor), 2008, *Wine Grape Production Guide fro Eastern North America*. Ithaca: Cooperative Extension Natural Resource, Agriculture and Engineering Service. 336 pp.

Wolf, T. K., 1997, Site Selection for Commercial Vineyards: Virginia Agricultural Experiment Station, Winchester, Virginia, Publication n. 463-016.

Wolf, T. K., and J. D. Boyer. 2003. **Vineyard Site Selection**. Publication Number 463-020, Virginia Polytechnic Institute and State University, Blacksburg, VA. Retrieved from http://www.ext.vt.edu/pubs/viticulture/463-020/463-020.html.

Wolf, T. K., and E. B. Poling. 1995. The Mid-Atlantic Winegrape Grower's Guide. North Carolina Cooperative Extension Service, NC State University, Raleigh, NC.

Zabadal, T.J., and J.A. Andersen, 1997. **Vineyard Establishment I, Preplant Decisions.** Bull. E-2644, MSU Bulletin Office, Michigan State University, East Lansing, MI. Retrieved from http://web1.msue.msu.edu/msue/imp/modfr/26449701.html

Curriculum Vitae

Rosalyn F. MacCracken received her Bachelor of Science in Applied Mathematics from Bowie State University (Bowie, MD) in 1994. She received her Master of Science in Meteorology from University of Maryland in 1998. She was employed as a contractor to NOAA's Climate Prediction Center and National Environmental Satellite, Data and Information Service before joining George Mason University as a Graduate Research Assistant and Ph.D. student in 2002. Rosalyn presently spends most of the year in Granville Summit, PA, where she operates a vineyard with her husband, Robert.