

Appendix P4 Preliminary Texas Evaporation Trends Report

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Introduction and Purpose

The purpose of this preliminary report is to examine evaporation data from the Texas Water Development Board using the 1 degree quadrangle in Texas. Quadrangles are the smallest area for evaporation data calculated in 1 degree latitude and 1 degree longitude (Texas Water Development Board n.d.). The data for the quadrangle in Texas was collected by the Texas Water Development Board from the National Weather Service (NWS) and National Climatic Data Center (NCDC) (Texas Water Development Board n.d.). The quadrangle data is comprised of monthly and annual gross evaporation data from 1954 to 2007 (Texas Water Development Board n.d.). The data collected is an evaporation rate in the form of a ratio by which the change occurs from liquid to vapor (Purdue 2010).

Introduction to Evaporation

Matter on Earth exists in three states: solid, liquid and gas. The hydrologic (water) cycle is matter changing between these three states in the atmosphere, land and the bodies of water on Earth. The hydrologic cycle has no beginning or end as it recycles itself through evaporation and is redistributed on Earth as precipitation. Evaporation is the stage wherein water becomes gas by a form of energy, for example the heat of the sun. When air is hot, dry or during windy conditions, evaporation is the greatest. When the air is cooler with calm winds and humid conditions, evaporation will be at its lowest.

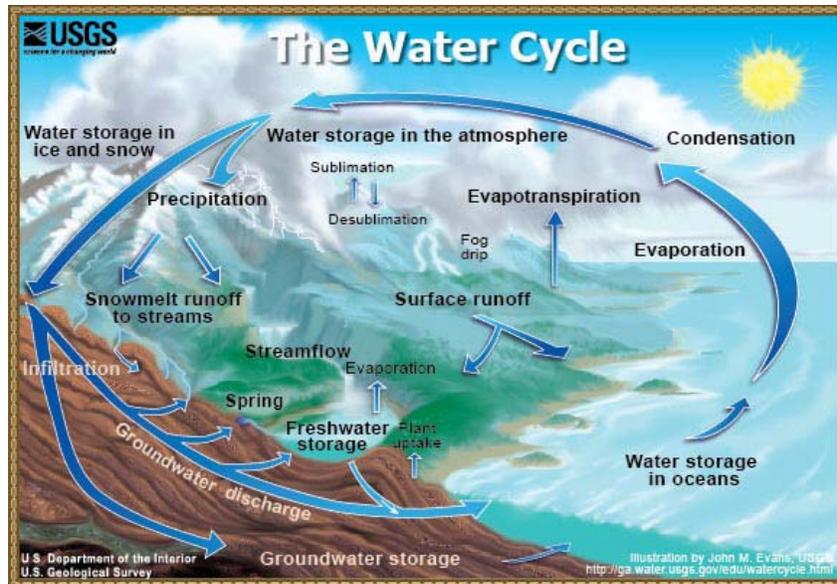


Figure 1 USGS Hydrological Cycle (USGS 2010)

The average rate of evaporation over the entire earth equals the rate of precipitation over the earth (Weather Street 2010). Evaporation requires both energy and moisture to convert water to vapor. In desert regions, temperatures are warmer and there are fewer bodies of water to generate evaporation and precipitation. “Eighty-eight percent of the water that is evaporated into the air comes from oceans that lie between 60° North and South latitude” (University of Wisconsin 2006). The tropical and subtropical areas are surrounded by oceans where it is warm and plenty of water is available for evaporation and precipitation.

Through evaporation, water becomes gas and enters the atmosphere. Transpiration takes place when plants absorb water from the earth and then release that water vapor through their leaves, stems, flowers and roots. The sum of evaporation and transpiration is evapotranspiration. Water is released into the atmosphere through transpiration. Plants breathe much like humans, releasing water vapor into the atmosphere; the term *transpire*

comes from the Latin root *spire*, which means *to breathe*. Transpiration rates depend on a number of factors, including energy, precipitation, soil type, wind, topography, temperature and humidity (Georgia USGS 2010).

Texas Climate

The Texas climate is as diverse as the topography of the state, with each season experiencing a contrast in temperature and precipitation. Precipitation during Texas winters decreases and is normally drier as compared to spring when there is increased rain and humidity. The Gulf of Mexico increases the movement of heat and moisture throughout the state. During the winter, typically more rain will fall than will be evaporated, allowing a greater supply of moisture.

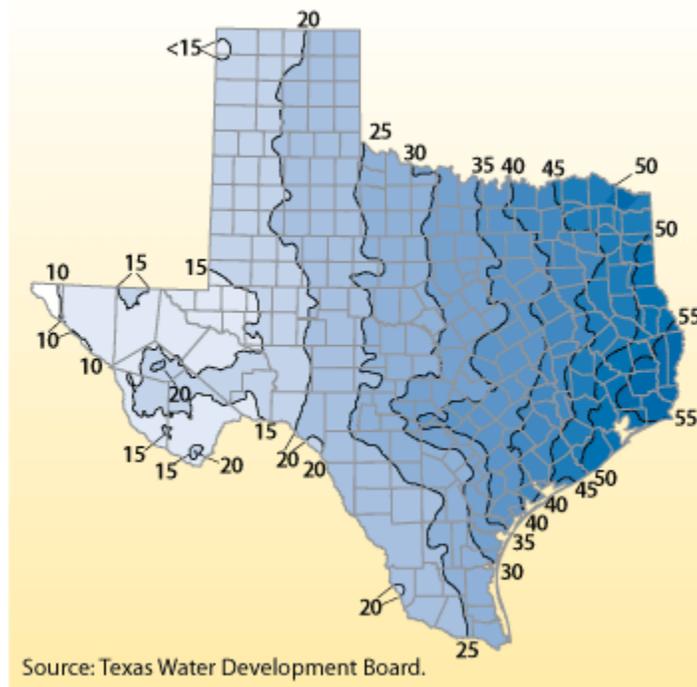


Figure 2 Average Annual Texas Precipitation (1971 to 2000) (State of Texas Comptroller n.d.)

In the winter, West Texas is drier than other parts of the state. Evaporation decreases because there is less heat energy and the sun is at a lower angle. Wind increases evaporation rates, but winds do not overcome the lower level of solar insolation. Cloud cover further decreases solar insolation, thereby lowering evaporation rates. Transpiration decreases dramatically because most plant life during the winter is either dead or dormant.

During the summer, temperatures are hot and dry and with a limited supply of moisture, evaporation rates increase. When summer brings rain the surface temperatures cool because the air mass is colder. The convective summer storms create an inflow and outflow of air masses. The inflow air mass is the warm, humid surface air. It is relatively buoyant and flows upward into the storm. Cooler air flows downward into the outflow. A primary reason storms tend to “pulse” is that the outflow, or cooler air, replaces the surface air stabilizing the atmosphere. Once the storm loses its inflow – which is the source of its energy and moisture – it starts to collapse.

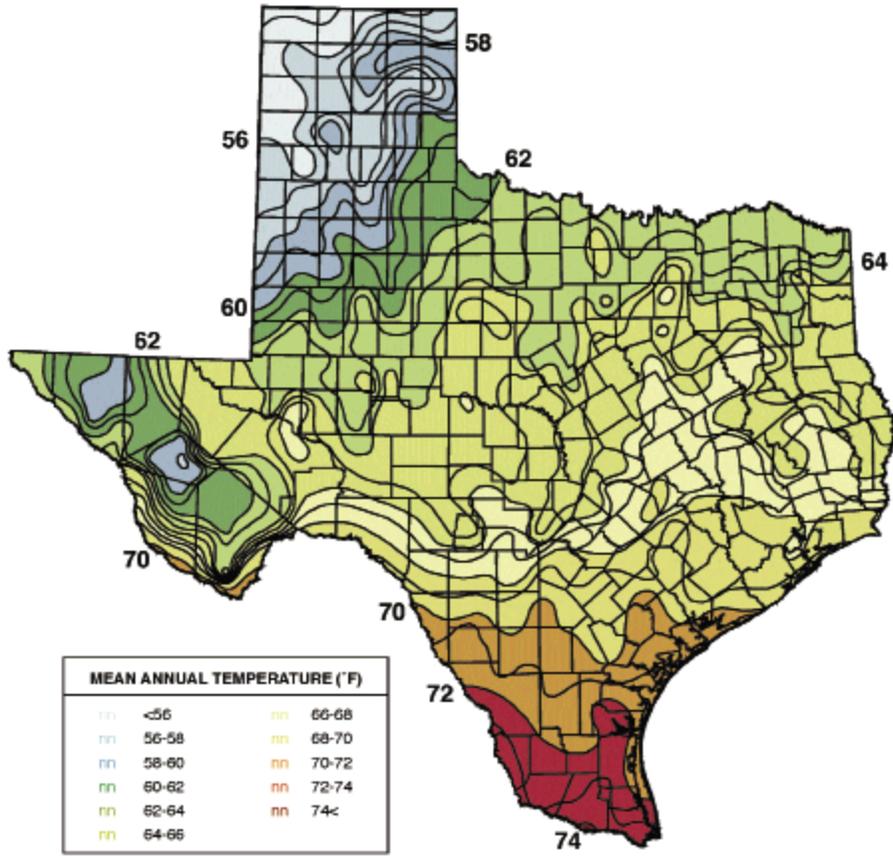


Figure 3 Texas Annual Mean Temperature 1961 to 1990 (SECO - Texas Comptroller 1994)

The terrain in Texas is rougher and the climate drier in the western portion of the state. The southern portion of the state is more humid and the terrain flatter towards the Gulf Coast. To further define Texas climates, the Koppen Climate Classification System map shows the definition between tropical climates and drier climates.

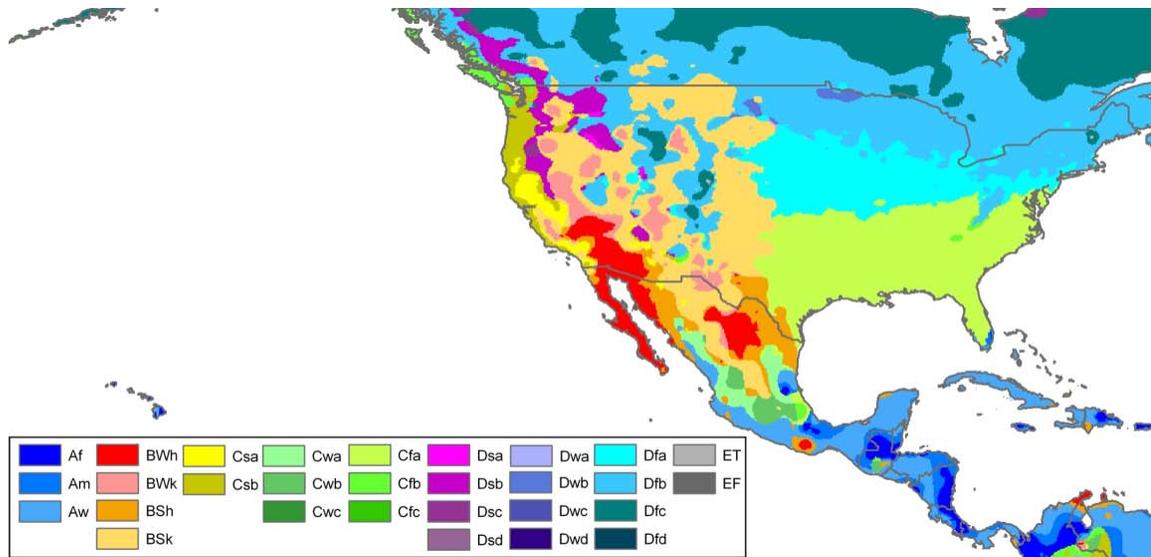


Figure 4 North-American Koppen Map (Wikipedia 2007)

The Koppen Climate Classification System was developed by Wladimir Koppen in the 1800's and modified throughout the years. The Koppen system is a complex modeling system that classifies climates according to temperature, rainfall and geographical locations. The Koppen Climate Classification is an identification system that uses letters to define various climates. There are 24 subcategories within the six major categories listed below.

- 1) A – Tropical
- 2) B – Deserts
- 3) C – Mesothermal or Mild Mid Latitudes
- 4) D – Continental or Severe Mid Latitudes
- 5) E – Polar
- 6) H – Highlands (this was added later)

(Gabler, Petersen and Trapasso 2008)

Texas is located mostly in the C Category of the Koppen Classification System Model, where the Gulf of Mexico brings warm and moist wind in from the south. In this classification, the climate is tropical in nature with warm and humid summers and mild winters. In the

winter, low pressure systems move down from the North, bringing occasional severe cold fronts. Convective thunderstorms are typical during the summer months. The general latitude for the C category is between 30 - 50 degrees North or South of the equator. According to the Koppen Classification System, West Texas falls in the B Category, which is dominated by dry climates. In dry climates, the potential for evaporation and transpiration will exceed precipitation. The general latitude for dry climates falls between 20 - 35 degrees North and South of the equator.

According to historical and projected data from the Census Bureau, the population in Texas will increase from 24.6 million inhabitants in 2010 to 33.3 million in 2030 (Census Bureau 2010). Texas is economically and culturally diverse and people are attracted to its mild climate. Texas is home to three cities each with over 1 million inhabitants – Houston, Dallas and San Antonio. Overall Texas is the 2nd largest state by population in the U.S. , behind California.

Texas has a favorable climate for food production and was ranked 2nd most productive state in agriculture in 2001, accounting for 32% of crops grown in the United States (City-Data 2010). Texas leads the country in cotton production and is home to a diversity of other crops. The large agricultural base demands large supplies of water for ranching and irrigating crops. “Approximately 80% of the irrigated land is supplied with water pumped from wells” (City-Data 2010). The added population will make it difficult for Texas to have enough water for agriculture, which represents more than three-fourths of the total land area of the state. An additional factor involved in pumping water from wells, is that more than half of the wells use natural gas as fuel, increasing irrigation costs as gas prices rise (City-Data 2010).

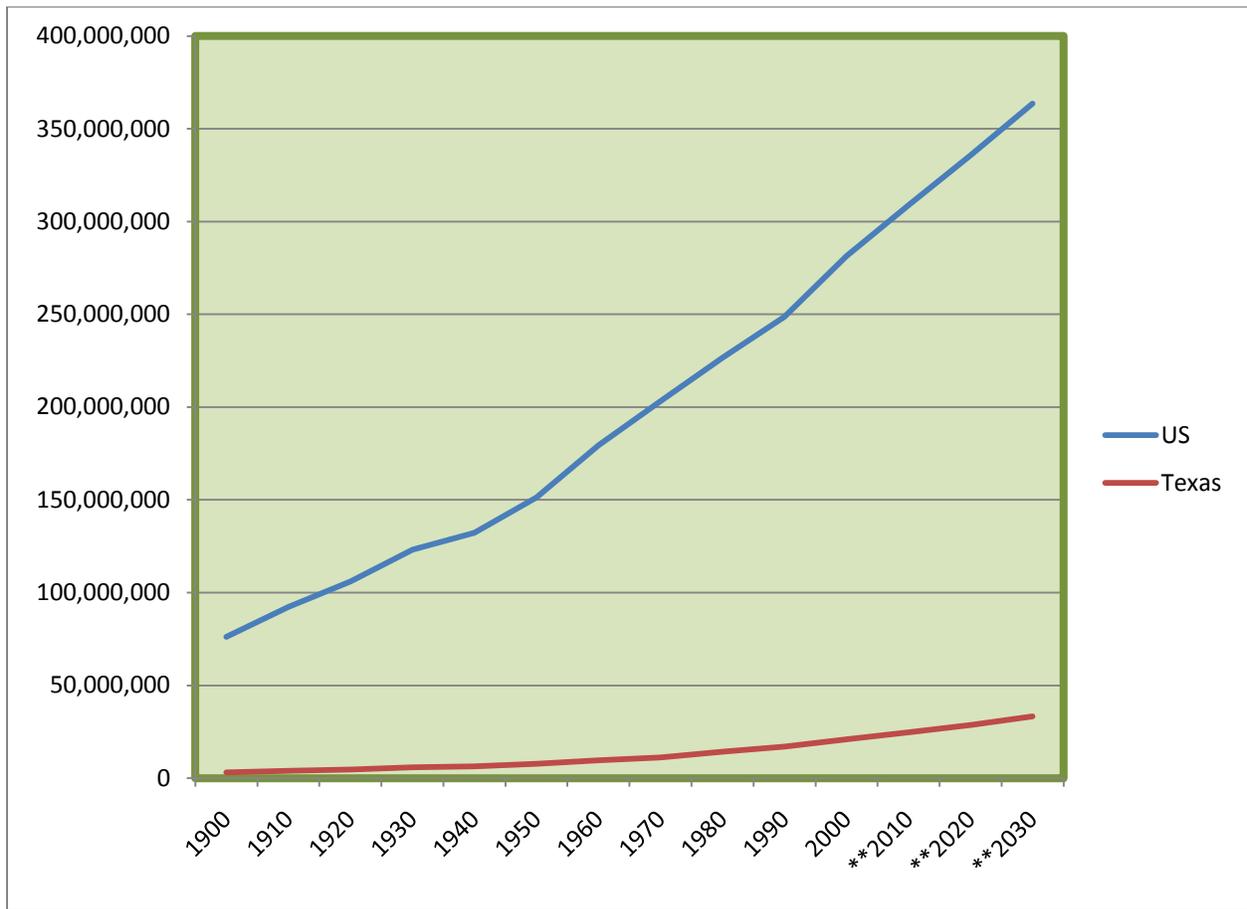


Figure 5 US and Texas Population Trend and Predictions (Census Bureau 2010)

The Physical State of Texas

Texas is located in the south central part of the United States, from Latitude 36 to 25 North to South and Longitude 93 to 106 East to West. Texas is the largest state in the lower 48, and is second only to Alaska in land area. The total Texas land and water area totals 268,581 square miles. Although it is the second largest state in the US, Texas occupies only about 7% of the total land of the country (Texas Almanac 2010). Beginning at sea level at the Gulf of Mexico, elevation levels rise to over 8,000 feet in the Guadalupe Mountains in the western

portion of the state. Texas extends north in the high plains of the panhandle bordering Oklahoma and New Mexico. To the south, the international border with Mexico and the Rio Grande extend to the Gulf of Mexico. West Texas begins at El Paso, bordering New Mexico to the west and Mexico to the south. East Texas, also known as the Pineywoods, borders Arkansas to the North East and Louisiana directly to the east. There is a major gradient in precipitation patterns across the state, with very wet conditions in the Eastern portion of the state and dry, arid conditions in the Western portion.



Figure 6 Texas Geographical Regions (Texas Parks and Wildlife 2007)

Texas is divided into 7 regions for this document using the Texas Parks and Wildlife Geographic Regions: the Panhandle Plains, Big Bend Country, Hill Country, South Texas Plains, Gulf Coast, Prairies and Lakes and Pineywoods. Defining the geographical regions of Texas is challenging because there are many factors, such as natural features and the cultural and political characteristics that divide the state according to spatial distribution. The seven

geographic regions of the state are expanded upon in the following section (Texas Parks and Wildlife 2007).

Big Bend Country

The Big Bend Country in West Texas is made up of deserts, plateaus and Texas' only mountain range. Big Bend Country is hot and dry during the day and cool at night. The mountains are cooler at the top where precipitation falls from the clouds. To the south of Big Bend, the Rio Grande borders Mexico and is one of the longest rivers in North America. The Big Bend region is named for the bend in the Rio Grande. The rainfall in this region ranges from 8-20 inches per year. The average Net-Evaporation rate is between 52 - 68 inches.

Gulf Coast

The Gulf Coast of South Texas is made up of marshes, estuaries, barrier islands and bays. There is a great deal of water in the Gulf Coast Region because the area is flat and does not drain well. In addition, there are many streams and rivers flowing to the Gulf. South of Brownsville, the area extends to the Louisiana border. The Gulf Coast is home to myriad species of plants and animals. The average rainfall for this region ranges from 40-60 inches per year. The average Net Evaporation rate is between 16 - 28 inches.

Hill Country

The Hill Country is located in central Texas. As its name implies, the Hill Country is made of rolling hills. There are several important geologic areas within the Hill Country, namely the Edwards Plateau. The Edwards Plateau has many hidden caves, where fractures in the rock allow water to seep into the aquifer. There are many springs in the Edwards Plateau region,

including the San Marcos Springs. The San Marcos Springs are located on the campus of Texas State University at Aquarena Springs, where Glass Bottom Boats float over the San Marcos Springs on Spring Lake. Enchanted Rock State Park is a central location within the Hill country, and is known for its large granite domes, comprising one of the largest batholiths in the state. The unique dome formations are also known for the minerals they contain. The rainfall for this region ranges from 14 - 34 inches per year. The average Net Evaporation rate is between 16 - 32 inches.

Panhandle

The Panhandle is a narrow strip that resembles the handle of a pan. Oklahoma is just to the north and New Mexico directly to the west. The area lies on a high, flat plateau and is mostly flat grassland with few trees. The eastern side of the Panhandle contains more rolling hills and increased rainfall. This region is unique because of the deep canyons it contains that have been carved by rivers, such as the Palo Duro Canyon as well as Caprock Canyon. The rainfall for the region ranges from 15 - 28 inches per year.

Pineywoods

The Pineywoods are named for the pines found in the region of East Texas. The terrain is mostly rolling hills with wet bottomlands that grow hardwood trees like pines, elm, mesquite and ash. The border to the east is mostly along the Louisiana border with a small area bordering Arkansas in the North East portion of the state. The rainfall for the region ranges from 40 - 52 inches per year. The average Net-Evaporation rate is between 16 - 32 inches.

Prairies and Lakes

The Prairies and Lakes region is in northern Texas. The fertile soil in this region has brought farming and ranching to the area. This area is known for the dinosaurs found within a dinosaur park in the Glen Rose area called Dinosaur Valley State Park, where a large collection of dinosaur footprints can be found. The rainfall for the region ranges from 26 - 40 inches per year. The average Net-Evaporation rate is about 41 inches.

South Texas Plains

The South Texas Plains is located to the south of the Hill Country and extends Southeast to the Gulf. The area is fairly flat and dry with brush, grasses, mesquite and cacti. There are some lakes in the region, including “resacas” or oxbows that were at one time part of the Rio Grande River. The Rio Grande Valley is a subtropical environment and is very humid. Birds are attracted to the area and it is a well known region for bird watching. The rainfall for the region ranges from 20 - 32 inches per year. The average Net-Evaporation rate is between 16 - 28 inches.

Evaporation Data

Evaporation data in Texas is not as readily available as precipitation data. The Texas Water Development Board (TWDB) has gathered data from collection sites operated by both the TWDB and the National Weather Service (NWS). Historical Evaporation data is available from 1954 to 2007 and organized through quadrangle data maps. Studying and analyzing evaporation data is important for calculating rain for crops and drinking water.

Evaporation data can be used for planning population centers, future water projections, businesses, agriculture and municipal water management. As the state of Texas increases in population there will be greater demands on the already limited water resources.

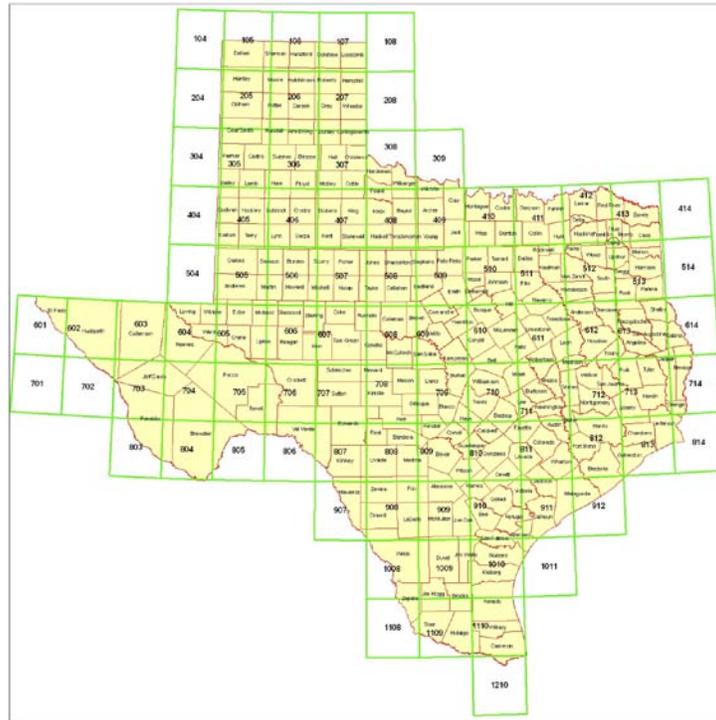


Figure 2 TWDB Evaporation Quadrangles (Texas Water Development Board n.d.)

Data Methods

TWDB has published evaporation data on its website and has the data available in several formats: tables, columns, statistics, and graphs. There are a total of 92 quadrangles on the map, covering the years from 1954 to 2007. A Quadrangle is the smallest evaporation area to calculate, and its measurement size is 1 degree latitude by 1 degree longitude.

The evaporation data begins in 1954, not 1940 as does state precipitation data, because the system of collection and equipment changed. The two methods generated vastly different coefficients; therefore a decision was made to leave out evaporation rates prior to 1954.

The evaporation data from TWDB was used in SPSS Statistical software to determine the trends. The average annual and seasonal evaporation rates were calculated for each grid and a GIS map pinpointed the grids with the appropriate data. In analyzing evaporation data, it is important to notice patterns and examine statistically significant changes in the Texas climate. Analyzing statistical changes could point to patterns of significant trends.

Results

Surface water is an area of major water loss through evaporation from rivers, lakes and reservoirs, with weather being the chief variable. Knowing the crop evapotranspiration rates allows farmers to apply the right amount of water to crops without wasting resources.

A simple technique to directly measure water evaporation involves the use of an evaporation pan, which measures the interaction between solar radiation, temperature, humidity and wind. Because this is a small scale model, it cannot be an exact replication of the real data from the watershed, known as lake evaporation. Pan evaporation is proportional to actual evaporation on lakes and other moist surfaces. For this report, the data is based on Pan Evaporation and will be used for evaluating possible trends in Texas evaporation.

The pans used in pan evaporation data collection have had various designs and their results have varied historically as seen in the TWDB data, partially due to changes in pan design. Historically, the pan evaporation data has been used to estimate actual evaporation in non-

moist environments. The pan evaporation data was not intended for this purpose. Consistency is needed in pan design and data collection for a precise historical trend analysis.

The GIS mapped data is used in the following analysis for each region related to Figure 8 to show the quadrangles that are statistically significant. If the area is not statically significant the maps in Figures 9 to 13 will show no data.

Regions	Annual	Spring	Summer	Fall	Winter
Panhandle	↑	↑	↑	↑	↑
Big Bend	↓	↓	↓	↓	↔
Hill Country	↓	↔	↓	↔	↑
Prairies and Lakes	↓	↔	↓	↔	↑
Pineywoods	↑	↔	↑	↑	↑
Gulf Coast	↑	↑	↑	↑	↑
South Texas	↓	↓	↓	↓	↔

Figure 3 Statistically Significant Evaporation by Region

Summary of Results Statewide

- Evaporation increases statewide in winter, whereas during the other seasons it increases in the Panhandle and Gulf Coast.
- The annual GIS map in Figure 9 and the table in Figure 8 show a positive trend in the Panhandle, Pineywoods and Gulf Coast regions, but a negative trend throughout the rest of the state.

Summary of Results by Region

- Panhandle region evaporation increased every season and the annual evaporation trend also increased.
- The Big Bend region's evaporation decreased every season with the exception of winter when there were signs of positive and negative evaporation.
- The Hill Country region did not show signs of statistically significant changes in the spring, with evaporation decreasing in the summer, and an increase in the winter and mixed positive and negative results in the fall.
- The Prairies and Lakes region evaporation increased in the spring and winter with mixed results in the fall, but evaporation was lower in the annual and summer data.
- The Pineywoods were annually statistically significant in all seasons except spring, which contained both negative and positive results across the region.
- The Gulf Coast region overall was statistically significant with positive evaporation throughout the seasons and annually.
- The South Texas region was statistically significant annually and during all seasons except in Spring when both negative and positive results were achieved across the region.

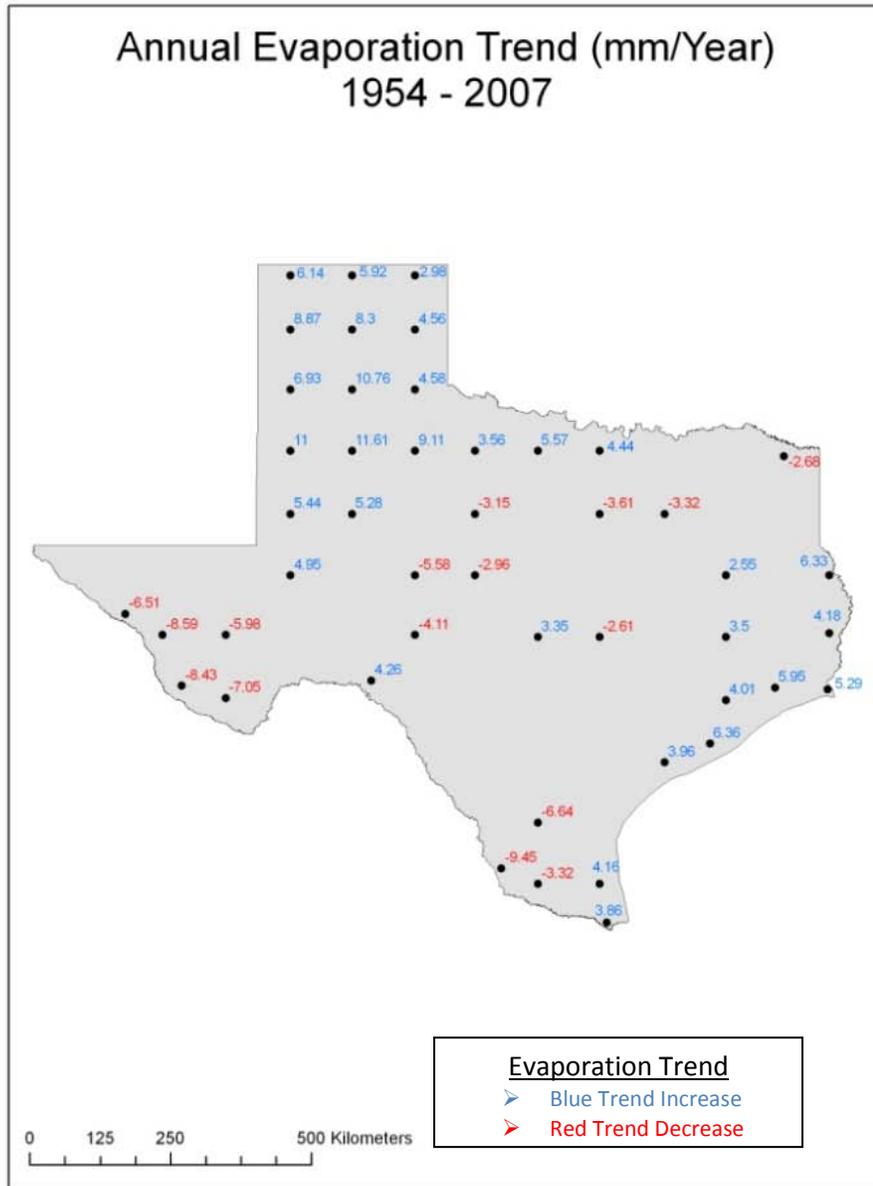


Figure 9 GIS Map – Annual Evaporation Historical Trend



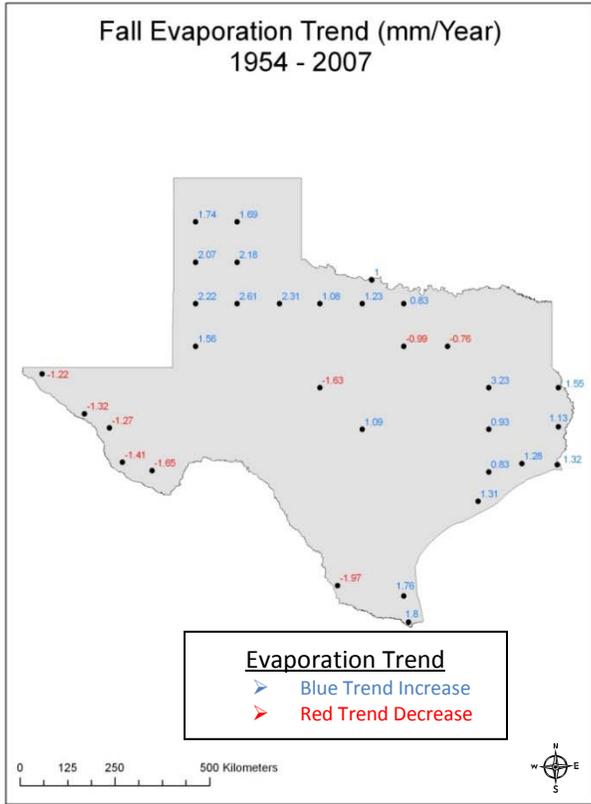


Figure 10 GIS Map – Fall Season Evaporation Trend

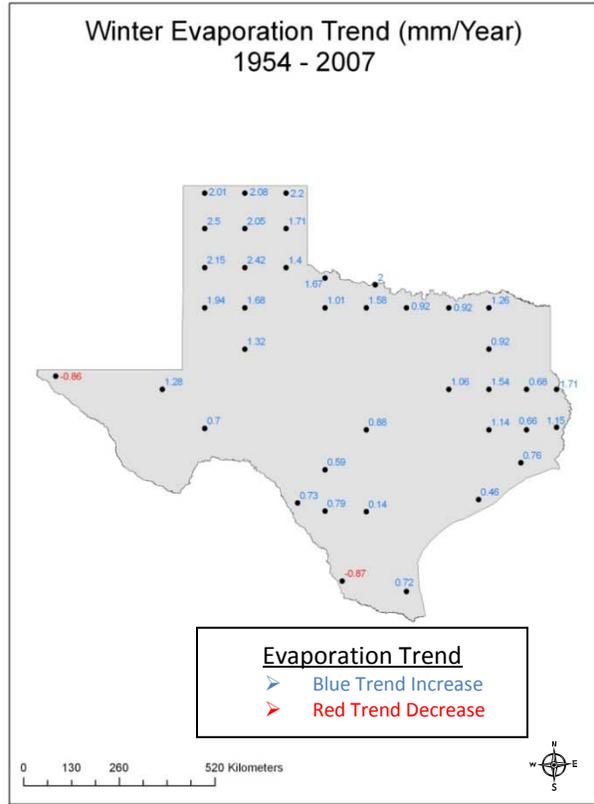


Figure 11 GIS Map - Winter Season Evaporation Trend

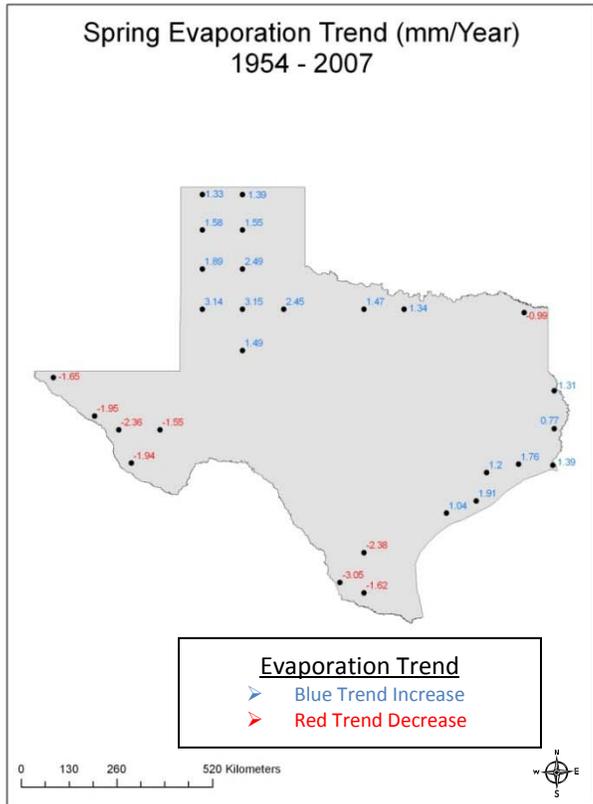


Figure 12 GIS Map - Spring Season Evaporation Trend

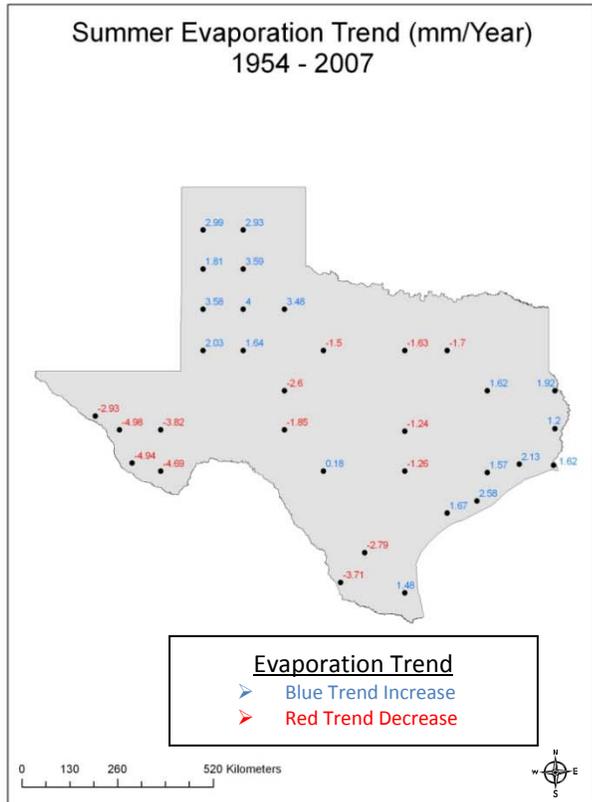


Figure 13 GIS Map - Summer Evaporation Trend

Conclusion

There is a heated debate within the scientific and political fields over climate change. Adding to the confusion, during extreme weather events people argue this as evidence of global warming. Data supporting the factors of global warming with factual representation presented in a format that is easily understood will bring a new understanding to this issue.

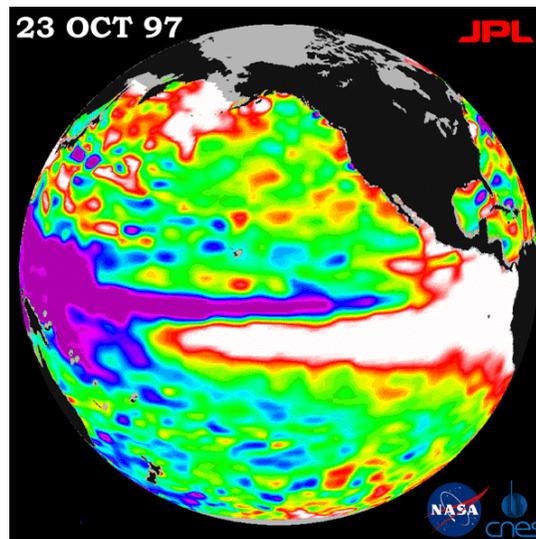


Figure 14 El Nino October 1997 (white represents warm water and purple cold water (NASA 1997))

Observed average global temperatures have increased over the past 50 years, although pan evaporation rates have been decreasing in this time, thus leading to the pan evaporation paradox (Shem, Jian and He 2003). Further study is needed to discern the reason that the pan evaporation trend is moving in the opposite direction of what is expected from historical temperatures. The study should include research into the impact of La Nina and El Nino on climate. Collection of data for trend analysis should be processed the same way for each observation and the same at every station.

Determining the rate through exactly the same methods during the observed dates is essential; otherwise the data can become skewed. If the data is unreliable, the method of collection must

be reexamined to be consistent across the board, but if the data is reliable and the evaporation paradox exists, it is difficult to explain the trend in the hydrological cycle (Shem, Jian and He 2003).

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