Changes in Temperature and Snowfall in the Midwestern United States

Research Question: Has the Northern Plains experienced a significant increase in snowfall while the Southern Plains has experienced a significant decrease in snowfall during the years 1970-2010, as claimed in the article? Do we also observe shortening snow seasons as well as an increase in temperature over this time period, as described by the article?

Background:

Article: https://weather.com/safety/winter/news/2020-02-05-snow-season-shorter-us-climate-central-study

The article claims the following:

- Parts of the Northern Plains have seen more snow since the 1970's.
- Overall snowfall declines in the Southern Plains from the 1970's-2010's.
- Warmer temperatures are taking a toll on snowfall.
- Snow-seasons in the U.S. are shortening.

While we already know that the northern parts of the United States experience more snowfall than the Southern parts of the United States, this article claims that the amount of snowfall that northern regions receive has increased since the 1970's, while it has decreased in Southern regions since the 1970's. This result is interesting, since we would expect warmer temperatures to take a toll on snowfall across the United States; however, the article notes: "One possible explanation is that a warmer climate is allowing these normally cold areas to experience more snowy days with temperatures close to 32 degrees rather than well below freezing. Higher temperatures allow for more water vapor, which in turn supports heavier snow if conditions are otherwise favorable". The article also claims that snow-seasons in the United States are shortening, and we would like to examine if that is in direct response to a warming climate.

Experimental Design

The Northern Plains consist of the following states: North Dakota, South Dakota, Minnesota, Iowa, and Nebraska, while the Southern Plains consist of the following states: Texas, Oklahoma, and Kansas. We will model and analyze the snowfall, snow season, and temperature trends in these regions over the time period from 1970-2010. We will then use the appropriate statistical trend test to acquire evidence to either support or refute the various aforementioned claims made in this article. As we have already seen from Professor Freund's previous work, we can use PCA analysis to compute the eigenvectors and their coefficients for the pre-existing snow depth (SNWD) data. We would like to perform a similar analysis on snowfall (SNOW) data. By modelling the coefficients for the eigenvectors relating to the snow seasons, we can determine if the snow seasons are getting shorter or longer over time, and we can compute the correlation between shortening snow seasons and an increase in temperature using Pearson's correlation to summarize the relationship between the two variables. Overall, this results in an analysis that is informative of qualitative trends in snow seasons over space and over time.

Summary of Experimental Design

1. Extract snowfall and temperature data for all stations in states in both the Northern and Southern Plains which have collected snowfall and temperature data for every year from 1970 to 2010.
2. Compute the mean and standard deviation of snowfall and temperature across the years 1970 to 2010. Use PCA on snowfall (SNOW) data to compute coefficients corresponding to snow season length eigenvectors for each region for each year. Use a 10-year moving average window for analysis, since we are interested in long term trends.
3. Perform statistical tests to compare snowfall, temperature, and snow season length in 2010's to snowfall, temperature, and snow season length in 1970's; these tests will generate evidence to either support or refute the claims made in the article.
4. Additional step: PCA can also be used to provide further insight, for example, whether the variation in snowfall and temperature from the 2010's is caused by the same features as the variation in snowfall from the 1970's.

Data Wrangling

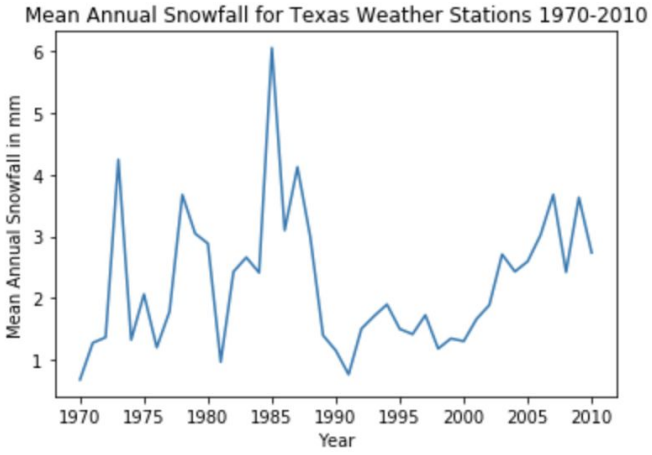
Collect all data for the following:

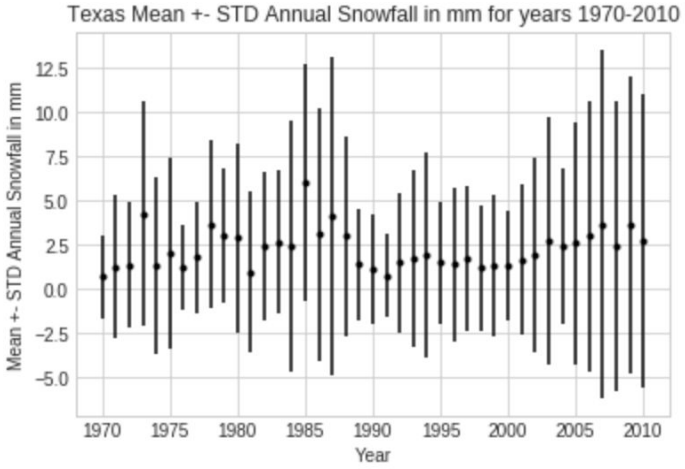
-Regions: Northern and Southern Plains
-States: North Dakota, South Dakota, Minnesota, Iowa, Nebraska, Texas, Oklahoma, Kansas
-Timeframe: 1970-2010
-Dependent Variables to consider: Snowfall, Snow Season Length, Temperature
-Variables from dataset: Snowfall (SNOW), Snow depth (SNWD), Number of days snow fell (DASF), Temperature (TOBS), Min/Max Temperature (TMIN, TMAX)
-Stations: All stations which have all data present (non-null values) for all years from 1970-2010

Exploratory Data Analysis:

An exploratory data analysis was performed on one state from each region to begin with. Texas was chosen for the Southern Plains while North Dakota was chosen for the Northern Plains, since the two were the farthest north and south from each other in each region. Further analysis will need to be performed across the entire regions. Since we are interested in long term trends and the exploratory data analysis has shown these slices of data to have a high level of variance, a next step for exploratory data analysis would be to look at 10-year running averages of the snowfall data for each region.

Texas Mean Annual Snowfall and Mean +- STD Annual Snowfall in mm for years 1970-2010:





North Dakota Mean Annual Snowfall and Mean +- STD Annual Snowfall in mm for years 1970-2010: