Spatial analysis of temperature and precipitation in Texas from historical data

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Introduction

- Our team decided to study the **GHCND** (*Global Historical Climatology Network daily*) dataset for Texas (*figure 1*), which is an integrated database of daily climate summaries from land surface stations across the globe.
- We decided to study three variables: **precipitation**, **minimum temperature** and **maximum temperature**.
- Some geostatistical methods were used such as the **kriging** techniques, which are interpolation techniques that can be used to interpret spatial data and it can be used to make predictions on spatial selected points.
- Furthermore, we made some comparisons among the means of three different periods of time (**1967-1973**, **1987-1993** and **2007-2013**) for all the previous variables.
- Notice that the datasets contain a different number of stations over different features and time periods (*table 1*).

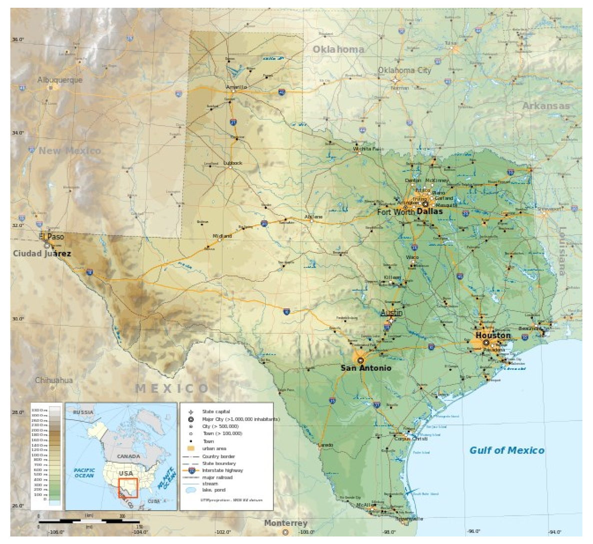

Figure 1.
State of **Texas**. Source: *Public domain data provided by the National Atlas of the United States of America.*

	67-73	87-93	07-13
TMAX	323	352	414
TMIN	323	352	414
PRCP	554	571	1226

Table 1.
Table with the **number of stations** for each different combination of variable and time period.

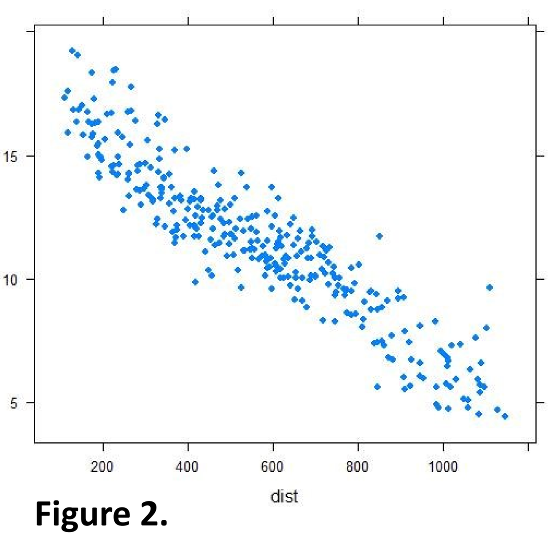

Figure 2.
Example of typical **scatterplot** between distance and temperature.

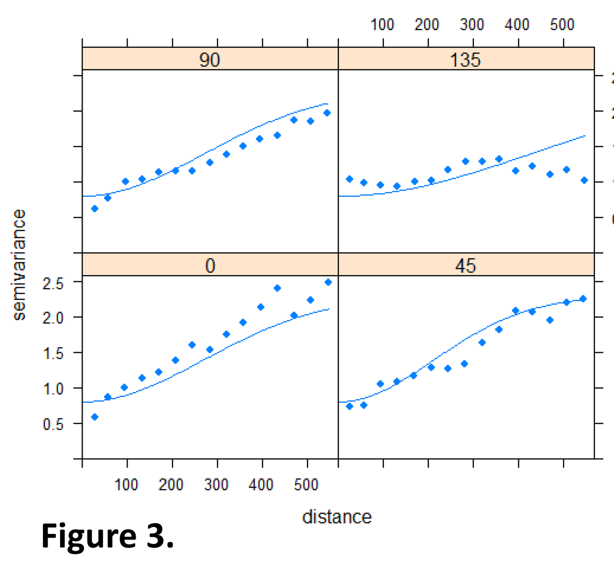

Figure 3.
Variograms of Tmin (~ Elevation + distance) showing different directions (0°, 45°, 90° and 135°) .

Methods

- Collecting, filtering and filling missing values of data from Texas GHCND stations.
- Modelling spatial dependence through **variogram** models.
- Analysing **Ordinary** and **Universal Kriging** with emphasis on elevation and distance from the sea.
- **LOO Cross-Validation.**
- Analysing trends of temperature and precipitations.
- Creating maps for each feature with Kriging over different time periods.

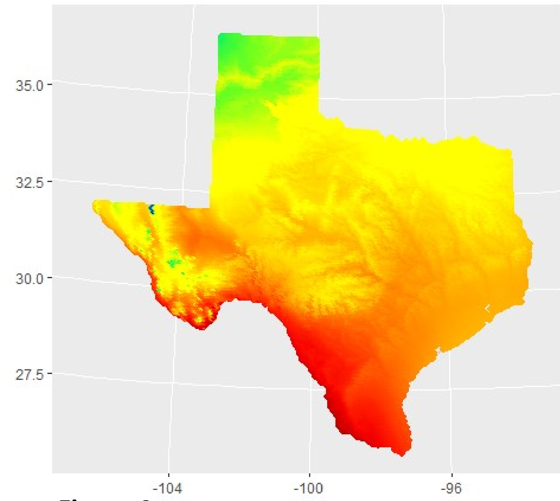

Figure 4.
Maximum Temperature predictions **1967-1973** using UK with best model (~ **elevation**)

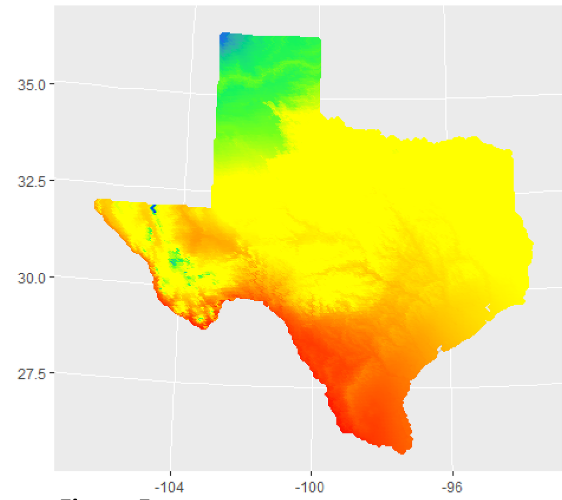

Figure 5.
Maximum Temperature predictions **1987-1993** using UK with best model (~ **elevation**)

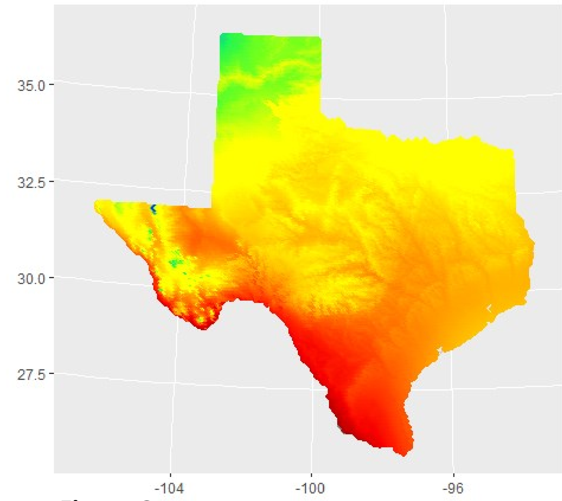

Figure 6.
Maximum Temperature predictions **2007-2013** using UK with best model (~ **elevation**)

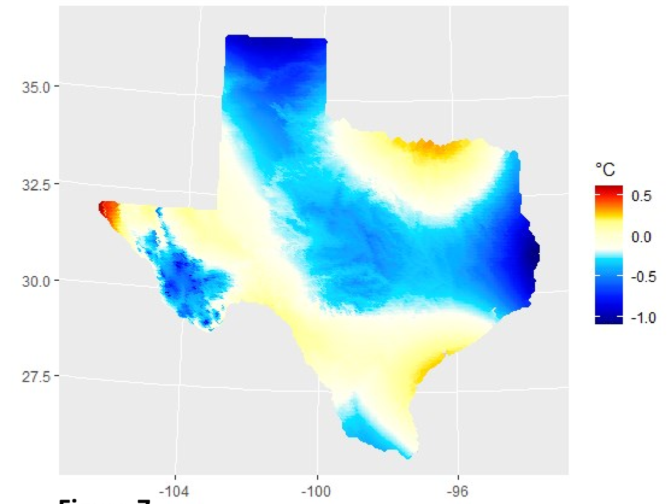

Figure 7.
Maximum Temperature comparison of the predictions between the periods 1967-1973 and 1987-1993 using UK with best model (~ **elevation**)

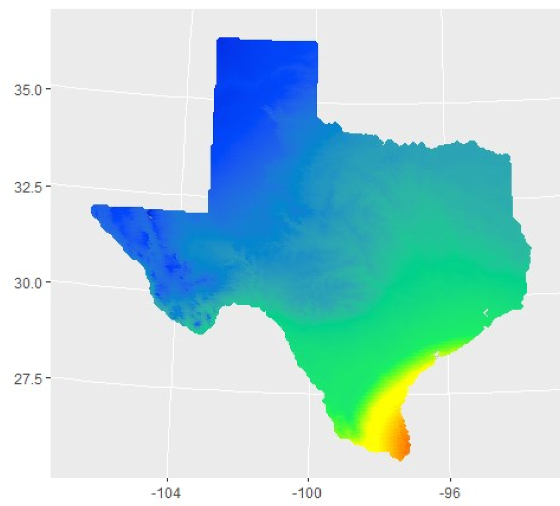

Figure 8.
Minimum Temperature predictions **1967-1973** using UK with best model (~ **elevation**)

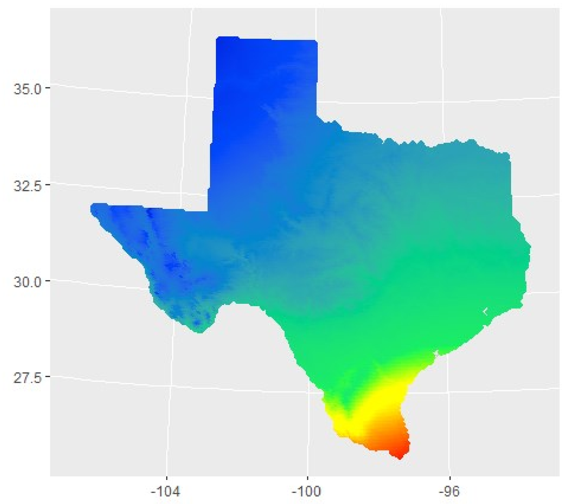

Figure 9.
Minimum Temperature predictions **1987-1993** using UK with best model (~ **elevation**)

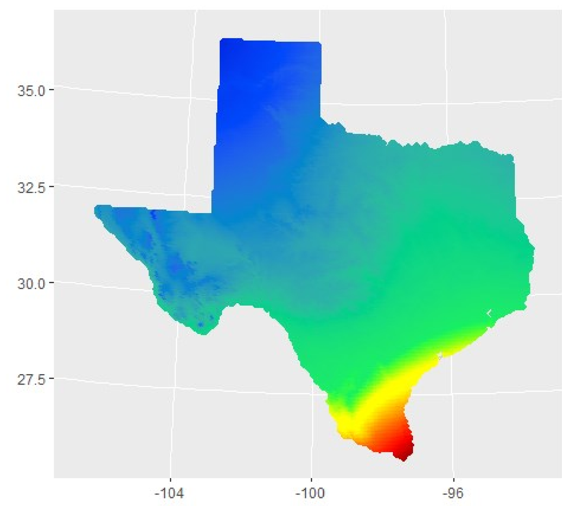

Figure 10.
Minimum Temperature predictions **2007-2013** using UK with best model (~ **elevation**)

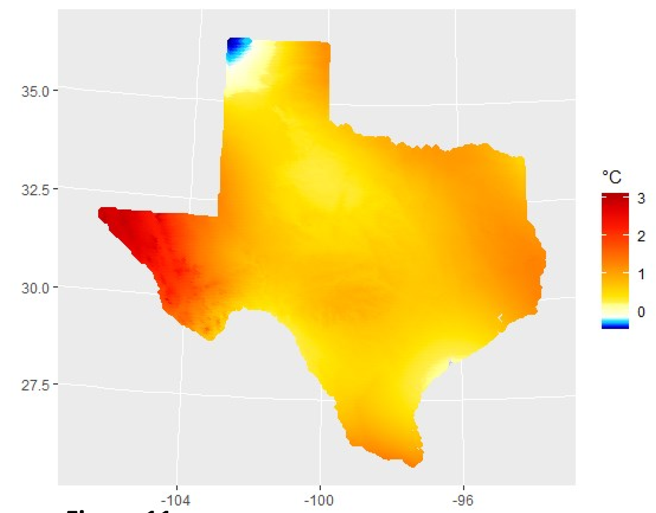

Figure 11.
Minimum Temperature comparison of the predictions between the periods 1967-1973 and 2007-2013 using UK with best model (~ **elevation**)

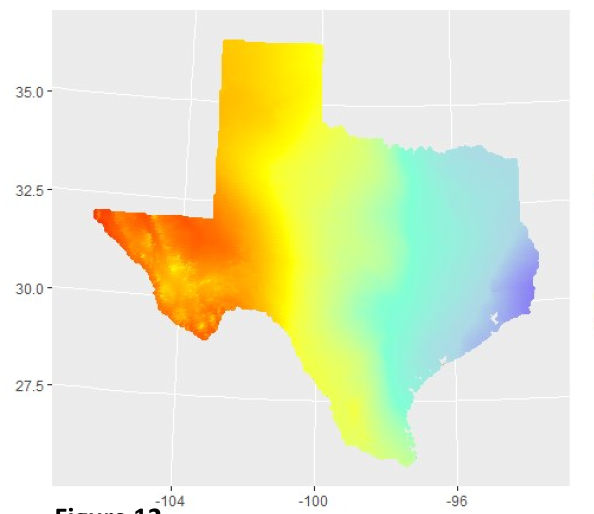

Figure 12.
Precipitation predictions **1967-1973** using UK with best model (~ **elevation**)

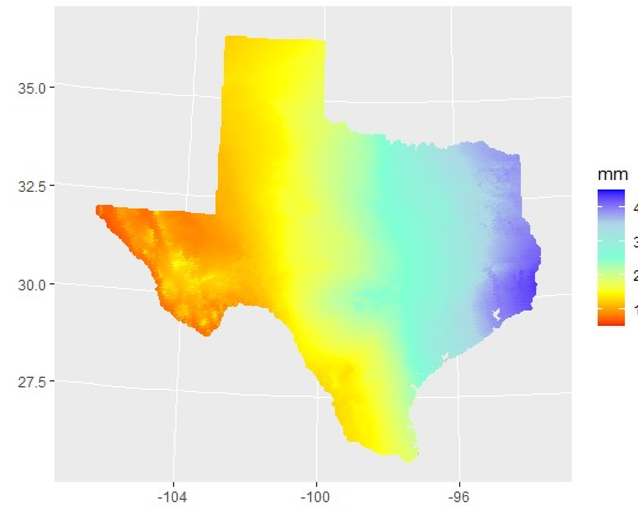

Figure 13.
Precipitation predictions **1987-1993** using UK with best model (~ **elevation**)

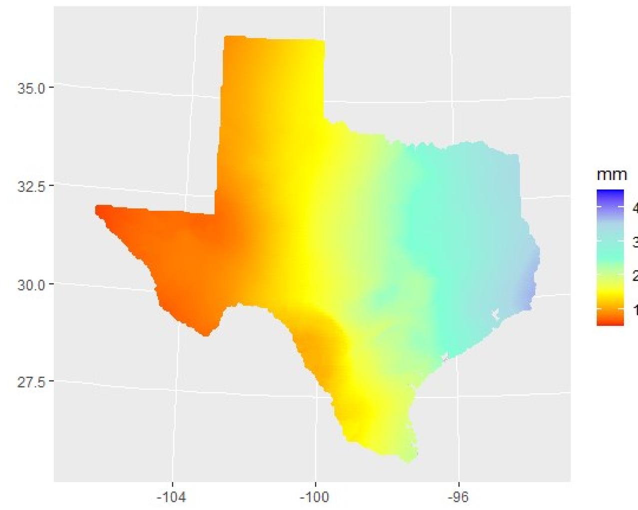

Figure 14.
Precipitation predictions **2007-2013** using OK with best model (~ **1**)

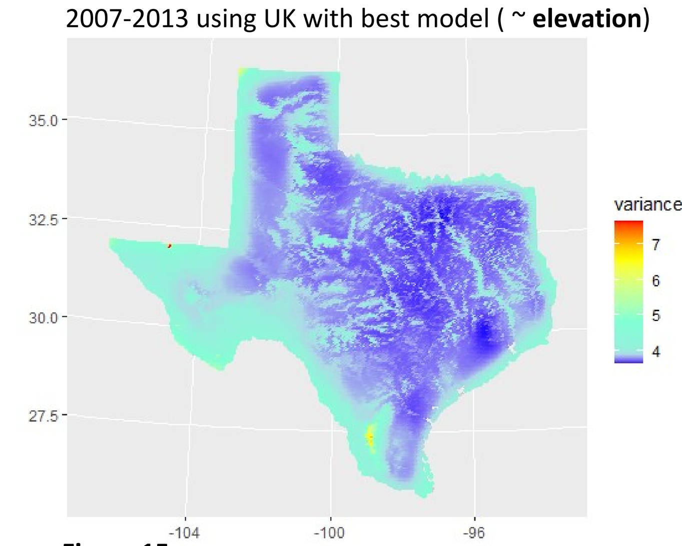

Figure 15.
Precipitation variation 1967-1973 using OK with best model (~ **elevation**)

	67-73	87-93	07-13
OK	0.89	1.05	1.01
Elev	0.65	0.69	0.61
Sqrt(elev)	0.75	0.81	0.76
Log(elev)	0.86	1.03	1.02
Dist	0.85	1.03	1.03
Sqrt(dist)	0.85	1.04	1.03
Elev+dist	0.64	0.69	0.6

Table 2.
Table of the **RMSE** of the **Maximum Temperature** over the three different time periods (1967-1973, 1987-1993 and 2007-2013) and different models.

	67-73	87-93	07-13
OK	1.01	1.06	1.07
Elev	0.84	0.93	0.97
Sqrt(elev)	0.85	0.94	0.98
Log(elev)	0.86	0.99	1
Dist	0.89	0.97	1.01
Sqrt(dist)	0.88	0.96	1.02
Elev+dist	0.84	0.93	0.97

Table 3.
Table of the **RMSE** of the **Minimum Temperature** over the three different time periods (1967-1973, 1987-1993 and 2007-2013) and different models.

	67-73	87-93	07-13
OK	1.8	2.21	3.65
Elev	1.57	2.02	3.61
Sqrt(elev)	1.61	2.05	3.57
Log(elev)	1.72	2.14	3.6
Dist	1.64	2.11	3.66
Sqrt(dist)	1.66	2.09	3.63
Elev+dist	1.55	2	3.61

Table 4.
Table of the **RMSE** of the **Precipitation** over the three different time periods (1967-1973, 1987-1993 and 2007-2013) and different models.

Results

- An exploratory analysis showed us dependence between the variables of interest with both elevation and distance from the sea (see example in *figure 2*).
- Using the previous results, variogram models were constructed taking into account anisotropy of the phenomenon (*figure 3*).
- The best variograms were **Gaussian models**, whose parameters fitted the data.
- Different Kriging methods yield different results, which were analysed **through LOO Cross-Validation** (see *tables 2,3* and *4*).
- In general, **Universal Kriging** with elevation seems to be the best model for temperature having the smallest **RMSE.**
- More complex models with both elevation and distance don't explain much more variability than simpler models.
- So, we chose simpler models with only one effect and in particular elevation because it performs better.

Conclusions

- To sum up, **maximum temperature** data decreased in most parts of Texas between 1967 and 1993, while it increased between 1993 and 2013 causing a return to previous years' levels (*figure 4,5,6* and *7*). In fact, these results reflect the 1989-1990 Cold Wave that hit the region (*reference 1*).
- The **minimum temperature** has increased all over the state and the temperature is an important indicator of the impact of the global warming. (*figure 8,9,10* and *11*).
- **Precipitation** data is hard to gauge because of its unpredictability, but we observed some trends: a rise in the precipitation from 1967 to 1993 and a serious scarcity of rain that hit the whole state in recent decades (*figure 12, 13* and *14*).
- Interestingly the **variance of the precipitation** is higher around rivers and mountains (*figure 15*).
- In general, it seems that **precipitations** are mostly prevalent in the eastern part, while the western side is much more arid.

References

Ref.1 National Weather Service US