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Math 145: Intro to Chaos Theory
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Chaotic Weather in Santa Cruz

The idea of the project was to predict what Santa Cruz's weather would be like using the characteristics of other cities. We collected data in the form of averages for temperature, pressure, and precipitation in the respective cities for months of the year over a 10-year period. The cities chosen were limited to cities that were well documented with historical data on the three variables we assumed to have the largest effect on the outcome variable of temperature in Santa Cruz. The cities chosen as determinants of Santa Cruz weather were Salinas, Monterey, and San Jose.

The first step we took towards creating this project was collecting the data. We used a website called Wunderground which was helpful for recording monthly averages dating back to 2007. A key factor that we thought of including, but decided not to for the sake of difficulty in representing it in the regression analysis, was wind speed and direction. We thought to include it because it would help to capture the pattern in which the temperature, pressure, and precipitation of surrounding cities could influence Santa Cruz. We ultimately did not include this variable because of the inaccurate data that was available for such a long period of time and also because it would be difficult to properly account for in an ordinary least squares regression analysis.

After collecting the data, we used a program called Stata to compute the ordinary least squares regression analysis. Using Excel, we were easily able to create variables for the change in average temperature, pressure, and precipitation from month to month. By regressing the change in temperature of the respective cities on the change in the temperature, pressure, and precipitation of surrounding cities, we were able to observe the effect that variation in the surrounding cities would have on the target city. We created regressions using each city's change in temperature as the outcome determined by the initial values from the surrounding cities to account for the specific example of Santa Cruz's weather affecting San Jose's weather, and vice versa. Our regressions were linear in their components for the sake of simplicity in the dynamical system. The dynamical system is indeed complex for the reason of forward and reverse connections between cities and their observable characteristics. If temperature in single city changes, the pressure and precipitation will surely change because of the change in temperature. The same holds true for the cases where pressure is the initial value that changes, and for the case where precipitation changes initially.

After finding the linear components that were weighted differently with regards to the variation in the changes of temperature, pressure, and precipitation for respective cities, we used NetLogo to model this dynamical system. Using the Dynamical Systems Modeler, we created in-flows to each city's temperature, which were linked to their determinants as discussed above (pressure and precipitation for that city, along with the pressure, precipitation, and temperature of the surrounding cities). The initial values for our dynamical system were the average pressures, temperatures, and precipitations of the respective cities for the last recorded month (April 2017).

The expressions for the in-flows were given by the regression equations we found using Stata. By using the 10-year data to find the coefficients, and plugging in the initial values from the previous month, we are then making the assumption that the next month (May 2017) is determined by the trends of the previous months' weather patterns from the 10-year period conditioned on the data for the averages from April 2017.

The NetLogo program could run infinitely many iterations of the dynamical system, plugging new values into the temperatures, pressures, and precipitations of the respective cities to be linked back to their effects on the surrounding cities in the next iteration. The model we used had a great deal of interconnectivity between all the cities as shown in the System Dynamics Modeler screenshot. The graph shows that the predicted weather for Santa Cruz would decrease to unlivable conditions in about a week, and would continue to fall below 0 degrees Fahrenheit with great speed. The conditions would change again drastically towards a much higher temperature that is well above livable conditions, predicting the temperature to be far above 100 degrees Fahrenheit. To recap, the beginning stages of the model predict that there is a basin of attractive points towards a very low temperature for Santa Cruz. The bifurcations become more abundant and the attractive points become more extreme with subsequent iterations switching from very low to very high and back to low attractive points representing temperatures in Santa Cruz. The process repeats indefinitely, each time flipping its trajectory in a smaller increment of time from the extreme attractors.

The statistically significant determinants of the change in Santa Cruz temperature were the change in Santa Cruz precipitation, the change in Monterey temperature, the change in Monterey pressure, and the change in San Jose temperature. Although these had the largest effect for determining the predicted change in Santa Cruz's temperature, our model still has a long way to go in terms of creating accurate representations of reality of what is observed in reality. May of 2017 was not characterized by the subzero temperatures that our model predicted it to be. We can confirm that although this model may not be accurate, it does provide insight as to the existence of a relationship being present between surrounding cities and the city of interest.

One error that our model doesn't account for is using the historical data to predict the future. The historical data can help to give us an idea of a trend that may be re-occurring, but is in no way the true determinant of what it would take to predict the weather in Santa Cruz. There are numerous omitted variables that are causing large amounts of bias in our model. This project sheds light on the complexity of predicting weather even just a couple of miles away for a short period of time. Cloud formation, elevation, humidity, distance from ocean, terrain type, population density, daylight hours, and CO_2 levels are just a few variables that come to mind that could have an impact on determining what the weather in any given city will be like on a certain day. This project opened me up to the subject of meteorology and the study of atmospheric patterns as a complex dynamical system involving many intricate and sensitive variables interacting with one another.