Lab 14: Differences in Regional Climate: Why Do Two Cities Located at the Same Latitude and Near a Body of Water Have Such Different Climates?

Introduction

Weather describes the current atmospheric conditions at a particular location. *Climate,* in contrast, is the aggregate or typical weather for a particular location over a long period of time. People often describe the climate of a region by reporting average temperatures and rainfall by month or by season. Cities located at higher latitudes (i.e., farther from the equator) experience greater changes in day length and Sun angle over the course of a year. These cities, as a result, have greater seasonal temperature differences than cities that are located closer to the equator. It is therefore not surprising that cities located at different latitudes often have very different climates. Cities located at the same latitude, however, can also have very different climates. A good example of this phenomenon is seen when we look at the climates of San Francisco, California, and Norfolk, Virginia (see figure below).

Locations of San Francisco and Norfolk

San Francisco is located on the coast of the Pacific Ocean at 37.7° N latitude. It has mild summers and winters; the average high temperature between 1945 and 2017 has been 17.1°C (62.8°F) for July and 9.7°C (49.4°F) for January. San Francisco is very dry, averaging 19.7 inches of rain per year from 1946 to 2017. According to the Köppen Climate Classification System (the most widely used system for classifying the world's climates), San Francisco has a temperate Mediterranean climate with warm summers (denoted Csb in the Köppen system). In contrast, Norfolk, which is located on the Atlantic Ocean at 36.9° N latitude, has hot summers and mild winters. The average high temperature between 1945 and 2017 has been 30.9°C (87.6°F) in July and 9.5°C (49.1°F) in January. Between 1945 and 2017, Norfolk has averaged 46.4 inches of rain a year. Norfolk has a humid subtropical climate (Cfa) based on the Köppen classification system. In summary, San

Francisco and Norfolk have very different temperature and precipitation patterns throughout the year even though they are located at similar latitudes. To understand why these two cities have such different temperature and precipitation patterns, we must consider all the different factors that can affect the climate of a region.

There are at least six important factors to consider when someone attempts to explain a difference in two or more regional climates:

- *Latitude,* as noted earlier, determines changes in day length and sun angle throughout the year.
- *Elevation,* which is the height of an area above sea level. Generally, as elevation increases, temperature decreases.
- *Proximity to a large body of water.* Land heats up and cools down faster than water. Water can also store more heat energy than land. This makes the climate of a region that is located near a large body of water, such as an ocean, more moderate because the water absorbs extra heat energy during the summer and releases heat into the air during winter.
- *The nature of nearby ocean currents.* Ocean currents move large amounts of water with different properties to different locations across the Earth. Winds, tides, and differences in water temperature and salinity at different locations in the ocean affect the path an ocean current follows over time.
- *The direction and strength of prevailing winds.* Winds can move air masses with specific properties from a source region to a different region. In the Northern Hemisphere, winds tend to blow from west to east (westerly winds) in the mid- latitudes and northeast to southwest between the Tropic of Cancer and the equator.
- *Local topography*. The presence of absence of a mountain in a region, for example, can affect precipitation patterns and therefore climate.

These six factors can help us understand why there are different climates at different locations around the globe. Yet, some of them may or may not be useful when we need to explain the different temperature and precipitation patterns observed in cities such as San Francisco and Norfolk. The two cities, as noted earlier, have much in common. San Francisco and Norfolk are located at similar latitudes, at an elevation slightly above sea level, and are near an ocean but on different coasts. You will therefore need to learn more about the nature of nearby ocean currents, the nature of any prevailing winds in these regions, and the local topography around these cities to figure out why these two cities have such different climates. Next, you will put all these pieces of information together to develop a conceptual model that not only explains the different climates in San Francisco and Norfolk but can also explain differences in the climates of other cities that are located at similar latitudes.

Your Task

Develop a conceptual model that you can use to explain the temperature and precipitation patterns in San Francisco and Norfolk. Your conceptual model must reflect what we know about the various factors that can affect climate, patterns, and systems and system models. To be considered valid or acceptable, you should be able use your conceptual model to not only explain why San Francisco and Norfolk have different climates but also to predict the temperature and precipitation patterns of several other pairs of cities that are located at similar latitudes on Earth.

The guiding question of this investigation is: ***Why do two cities located at the same latitude and near a body of water have such different climates?***

Materials

You may use any of the following materials during your investigation:

- U.S. Climate Data. You can access this website, which includes detailed climate data and the location of most major U.S. Cities, at www.usclimatedata.com/climate/ united-states/us
- Wind rose data from the National Oceanic and Atmospheric Administration (NOAA). You can access this database, which includes monthly wind speed and direction information for 237 U.S. cities, at www.climate.gov/maps-data/dataset/ monthly-wind-rose-plots-charts.
- *Earth: A Global Map of Wind, Weather, and Ocean Conditions.* You can access this interactive animated map that shows current wind speeds and direction for the entire planet at https://earth.nullschool.net.
- *My NASA Data*. You can access this database, which includes information about ocean surface temperatures and the average wind speed and direction by month over the entire year, at https://mynasadata.larc.nasa.gov.
- *State of the Ocean* (SOTO). You can access this visualization tool, which includes information about current and past ocean currents and changes in surface temperature, through the NASA Jet Propulsion Laboratory Physical Oceanography Distributed Active Archive Center at https://podaac.jpl.nasa.gov. Click on "Data Access" and "SOTO (State of the Ocean)" to open the visualization tool.

Getting Started

The first step in developing a conceptual model that explains differences in the temperature and precipitation patterns of San Francisco and Norfolk is to collect information about seasonal changes in temperature and precipitation in both cities. This information can be found at the U.S. Climate Data website. Be sure look for any patterns that you can use to help develop your conceptual model. Next, you can learn about the prevailing winds at each location using data provided by the NOAA wind rose website and the Earth: A Global Map of Wind, Weather, and Ocean Conditions website (which provides real-time data you can use). You can also access data about ocean temperatures and wind patterns by using the My NASA data. The final website, SOTO, will allow you to visualize a variety of ocean characteristics on a map of the world.

To learn more about how prevailing winds affect climate, you must first determine what type of data you need to collect, how you will collect it, and how you will analyze it.

To determine *what type of data you need to collect,* think about the following questions:

- What are the boundaries and components of the system you are studying?
- How do the components of the system interact with each other?
- When is this system stable, and under which conditions does it change?
- What could be the underlying cause of this phenomenon?
- What type of measurements or observations will you need?
- What types of patterns could you look for in the available data?

To determine *how you will collect your data,* think about the following questions:

- What conditions need to be satisfied to establish a cause-and-effect relationship?
- How can you describe the components of the system quantitatively?
- What measurement scale or scales should you use to collect data?
- What type of comparisons will you need to make?
- How will you keep track of and organize the data you collect?

To determine *how you will analyze your data,* think about the following questions:

- What types of patterns might you look for as you analyze your data?
- How could you use mathematics to document a difference between conditions?
- What type of comparisons and calculations will you need to make?
- What type of graph could you create to help make sense of your data?

Once you feel you have gathered sufficient data and identified important patterns about how oceans and prevailing winds affect climate, your group can develop a conceptual model that can be used to explain why San Francisco and Norfolk have such different climates. To be valid or acceptable, your conceptual model must be able to explain why San Francisco and Norfolk have such different seasonal temperatures, and why San Francisco and Norfolk have such different rain patterns.

The last step in your investigation will be to generate the evidence that you need to convince others that your conceptual model is valid or acceptable. To accomplish this goal, you will use your model to predict the temperature and precipitation patterns in several additional cities. These cities should be ones that you have not looked up before but are located at similar latitudes on different coasts. Some good pairs of cities to compare are

- San Diego, California, and Charleston, South Carolina;
- Portland, Oregon, and Bangor, Maine;
- Eureka, California, and New York City; and
- Santa Monica, California, and Wilmington, North Carolina.

You can also attempt to show how using a different version of your model or making a specific change to a portion of your model will make your model inconsistent with data you have or the facts we know about climate. Scientists often make comparisons between different versions of a model in this manner to show that a model is valid or acceptable. If you are able to use your conceptual model to make accurate predictions about the climates of other cities or if you are able show how your conceptual model explains the climates of different cities better than other conceptual models, then you should be able to convince others that it is valid or acceptable.

Report

Once you have completed your research, you will need to prepare an investigation report that consists of four sections (be sure to have section headings):

1. Introduction: Give some background information on the topic. Explain what question you were trying to answer and include a hypothesis. (Background info, research question and hypothesis)
2. Procedure: What did you do during your investigation and why did you conduct your investigation in this way? (How you collected and analyzed data)
3. Data: Include a data table and/or graph to show your results. Be sure to include a title for your table or graph with labels for the variables.
4. Conclusion: What is your argument? (Claim - Evidence - Reasoning)

Your report should answer these questions in two pages or less. The report must be typed, and any diagrams, figures, or tables should be embedded into the document. Type your report on Google Docs (12 point font, double-spaced) and share it with your teacher. Your report will be graded based on the rubric in the class syllabus.