The Correlation Between Temperature Anomaly and the Variation in Latitude of the Polar Jet Stream

Abstract

The initial question of whether or not the amount a planet is heated will change the behavior of streams of air in the upper atmosphere called jet streams drove this project to produce an interesting discovery. In my research, I found that the Polar Jet Stream on Earth is relatively unaffected by the minute changes in temperature and is mainly influenced by large scale seasonal temperature changes.

Images from NASA's GISS surface temperature analysis maps and the NEO database (Near Earth Observations) gave the temperature anomaly data used in this correlation study. NOAA's National Weather Service's Storm Prediction Center were used to produce the data describing the Polar Jet Stream activity. After plotting the data over 20 years starting in 2000, and making adjustments to how the data was used, a correlation coefficient of -.09 was found. Further analysis shows that the Polar Jet Stream activity does follow a trend similar to temperature but opposite: in the summer, activity is low when the temperature is high and in the winter, activity is high when the temperature is low. This is how the conclusion was made that airstreams may only be affected by large scale seasonal temperature changes. Although the initial hypothesis was not upheld by the results, fascinating discoveries were made.

Methodology

The dataset with information on land surface temperature anomaly was gathered from NASA's NEO (Near Earth Observations) as well as NASA's GISS surface temperature analysis maps. The data gives how much the land temperature deviates from the average in degrees Celsius. The observations were made using thermal infrared measurements collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard NASA's Terra satellite combined with OISST v2 which is a system of ships and buoys that collect temperature data in oceans. The Polar Jet Stream data was made by observing surface and upper air maps at 300mb provided by NOAA's National Weather Service's Storm Prediction Center. I then manually counted how many times The Polar Jet Stream dipped below 30° North and totaled the data by months. The data could be averaged by months and each month compared to that average to create an anomaly dataset. After plotting the data over 20 years, I improved my correlation by taking out the months June-August because during these months, the Polar Jet Stream is not active and will never dip below 30° North. I also switched my sources for the temperature dataset. Originally, I had a positive correlation, but because of the revisions to the data, I obtained a negative correlation which is more logical.

Introduction

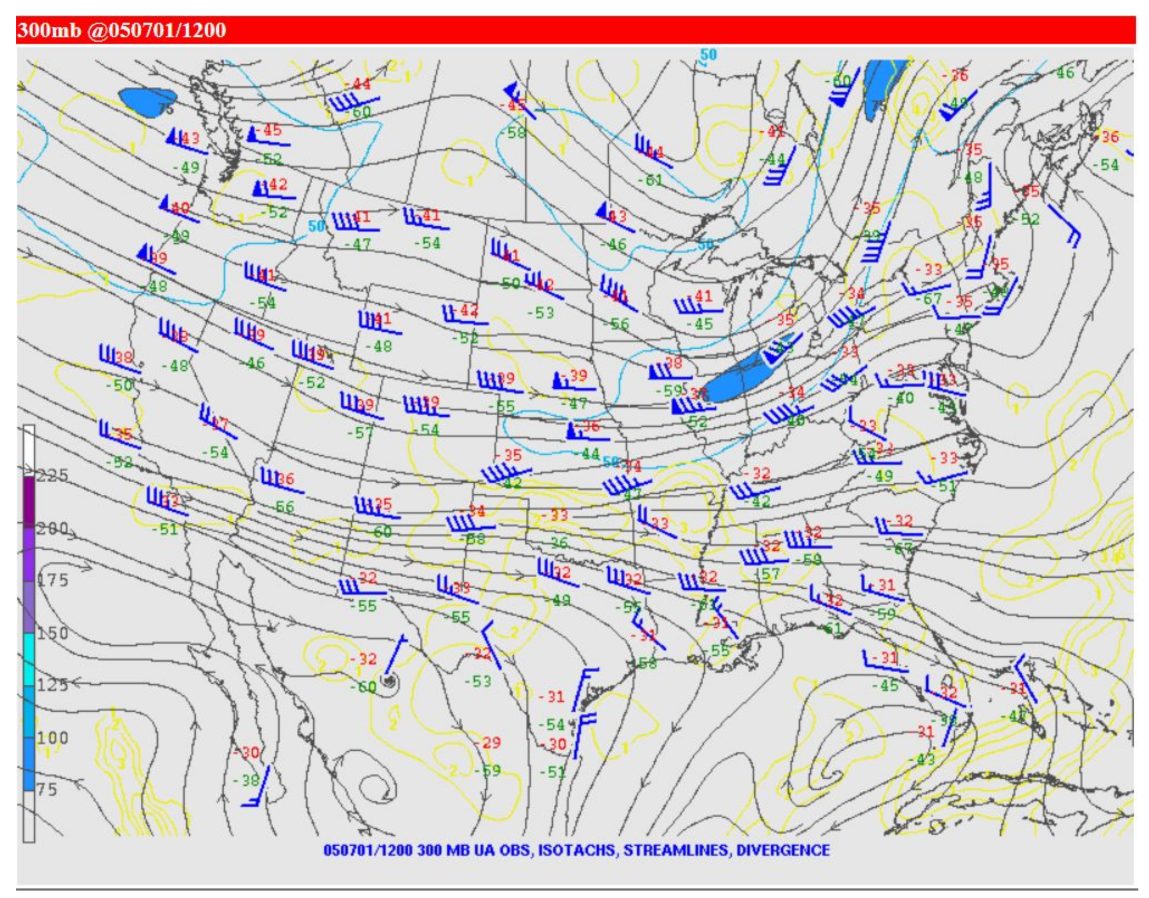
Many planets such as Venus, Mars, Saturn, and our Earth have "rivers of air" that flow through their atmospheres. These currents are called jet streams and are powered by heat whether it is solar radiation or heat from the planet's core, and the inertial effect that the spin of the planet has on the atmosphere, also known as the Coriolis Effect. In this study, Earth will be used as a model for how the dynamics of other plaent's airstreams behave because there is an abundant amount of information available on Earth's systems. The spheres that will be studied in this project are the heliosphere (solar radiation and heat) and the atmosphere (air cells and wind). The Polar Jet Stream is the northernmost stream and wraps around North America. It is the strongest of all the jet streams and its latitude varies, especially in recent years. The discovery of jet streams was a crucial development that helped with aviation and weather forecasting. Flying with the Polar Jet Stream can save fuel and help the plane travel faster. Analyzing the Polar Jet Stream is important for meteorologists because jet streams are extremely influential on large scale weather.

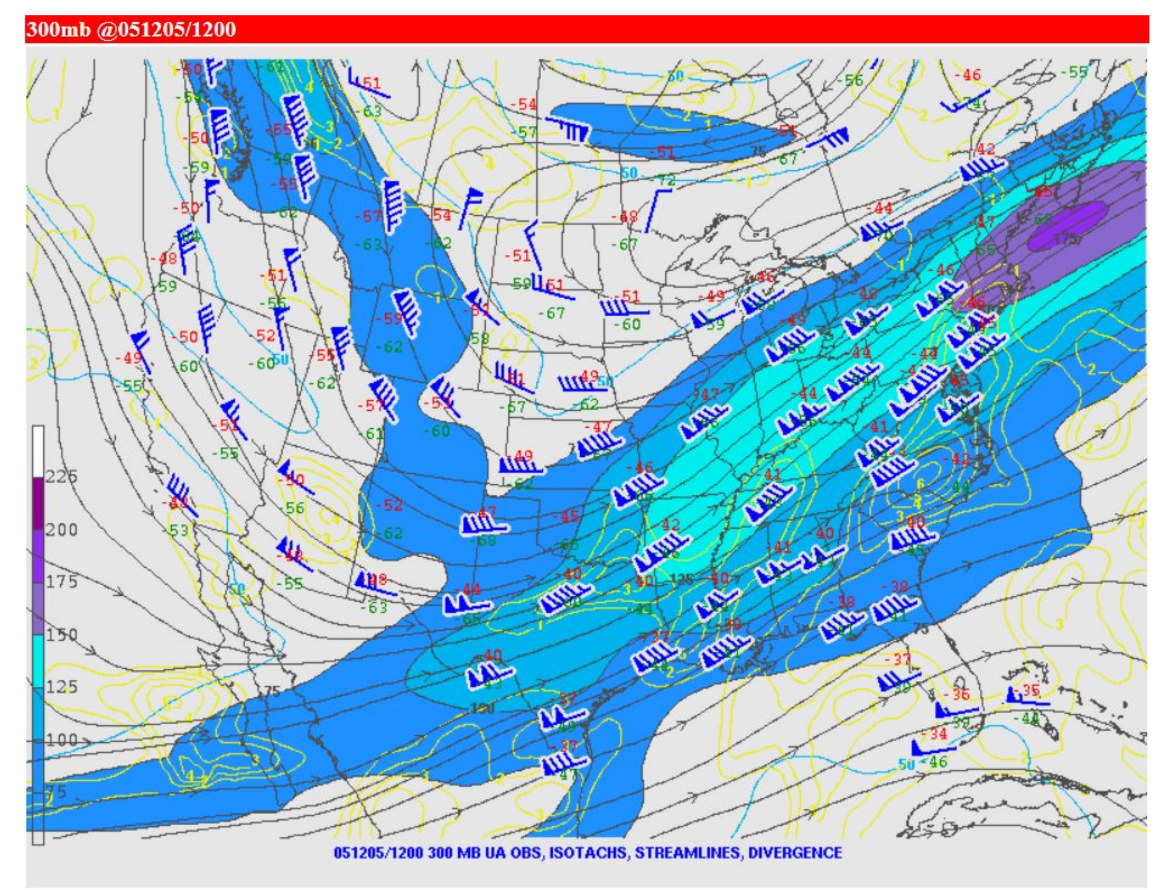
Over the course of the year, the Polar Jet Stream will vary in latitude; in the winter, it moves more south and in the summer, it travels north. I will be studying how strong the relationship between temperature and the variation in latitude of the Polar Jet Stream is and if other planet's varriating/stable jet streams can be explained by the same factors. This will be done by observing temperatures over the Northern hemisphere and the latitude shifts of the Polar Jet Stream over North America over a 20 year period.

The Earth's atmosphere is comprised of three air cells that form the jet streams. As the sun heats the air at the equator, it begins to rise. At this point, the Coriolis Effect comes into play: As the Earth spins on the axis, the equator travels faster than the poles. The air over the equator maintains its momentum and as it starts to move north towards the poles, its relative speed is faster than the earth below. The result is that as the air moves farther north, the easterly wind speeds increase. Next, as the air begins to cool, it sinks around 30 degrees North. This forms the Hadley Cell. The Polar and Ferrel Cells are formed when the air around 50-60 degrees North diverges as it rises to the tropopause. Some of the air travels north and sinks at the pole, forming the Polar cell. The rest of the air that rises around 60 degrees North travels south and meets with air traveling from the equator and sinks at 30 degrees. This forms the Ferrel cell. The jet streams are located at the tropopause along the corners of the air cells: the intersection between the troposphere and stratosphere approximately 30,000–39,000 ft above sea level where the airflow is divided. Jet Streams form at the tropopause because the stratosphere and troposphere have different densities and temperatures: in these areas air does not flow into between the two air masses but is deflected by the Coriolis Effect and flows along the boundaries, creating high wind speeds. The Polar Stream carries air from the North Pole into North America. During the winter, it is located relatively south (25-40 degrees North), bringing in colder temperatures.

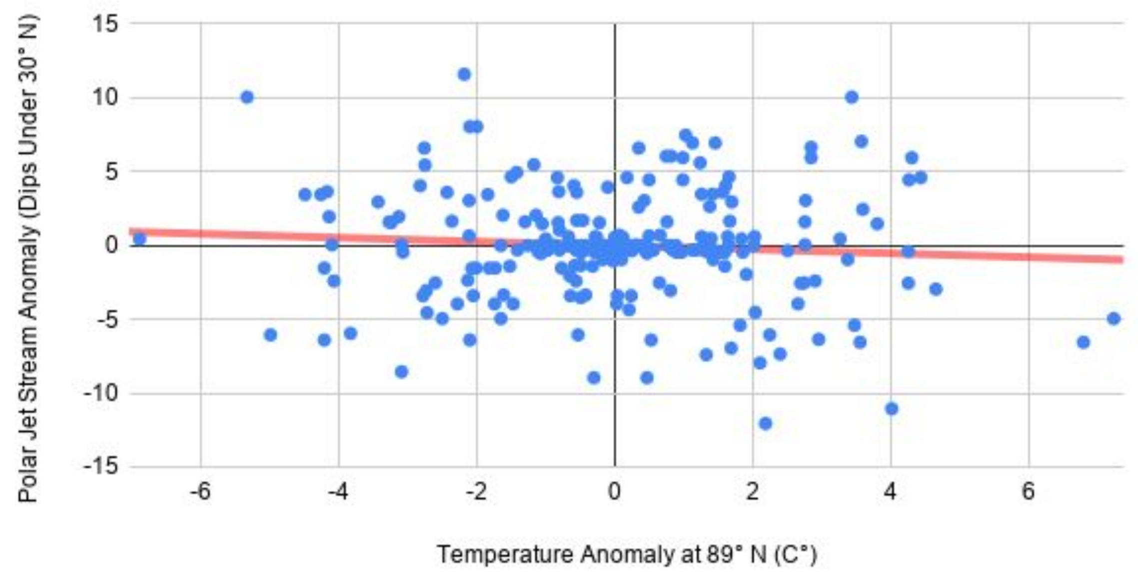
Temperature on Earth can be easily explained by how the planet is tilted on its axis. Because the planet is tilted 23.5 degrees from the vertical, the northern hemisphere will be exposed to longer hours of direct sunlight in the summer months (June-September). The same will happen in the southern hemisphere (December-March). The greater amounts of direct sunlight causes warmer temperatures. This heat powers the wind on Earth to circulate in air cells as explained before. Sunlight in turn helps create the air cells that form the jet streams, however, determining why the jet streams vary in latitude is not as easily explained.

In recent years, scientists have noticed that the Polar Jet Stream of Earth has moved farther. In previous years, it was observed to be more steady, but now it fluctuates north and sound by almost 10 degrees. This may be because of climate change, specifically absorption of heat by the oceans. Much of the heat that the planet receives from the sun is stored in water. This could drive the jet streams to behave unexplainably and migrate north and south more often. Temperature on other planets such as Mars or Venus work similar to Earth: their heat is solar powered. Solar Radiation is sent to these planets from the sun and depending on the composition and thickness of the atmosphere, heat can get trapped inside. This may have an effect on the planets jet stream and drive it to behave differently. Other planets, such as the Gas Giants, are too far from the sun and are primarily internally powered by their core. This will affect the formation of jet streams and could potentially cause a more stable, non-meandering jet stream. In this study, I will be investigating the link between the the varriating latitudes of the Polar Jet Stream and the change in temperature over the course of the year. I will use my findings as a tool of comparison for other planets in the solar system. I hypothesize that if a planet's jet streams that are powers by internal heat, they will be more uniform and less varring. If they are powered by solar radiation, they will vary as the planet moves through its seasons.

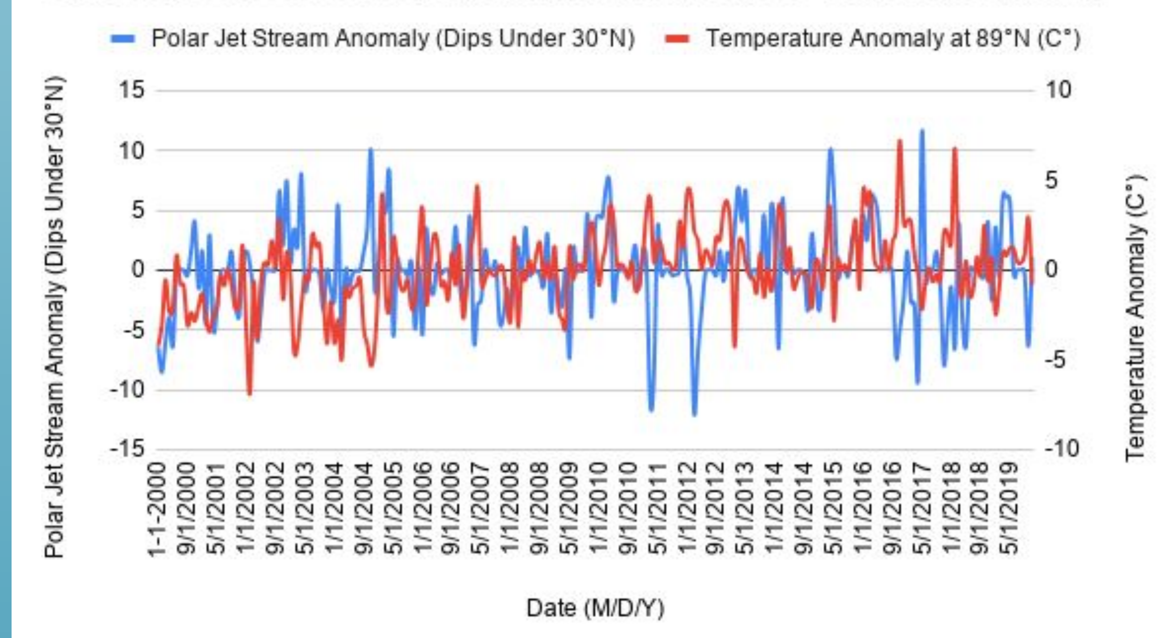




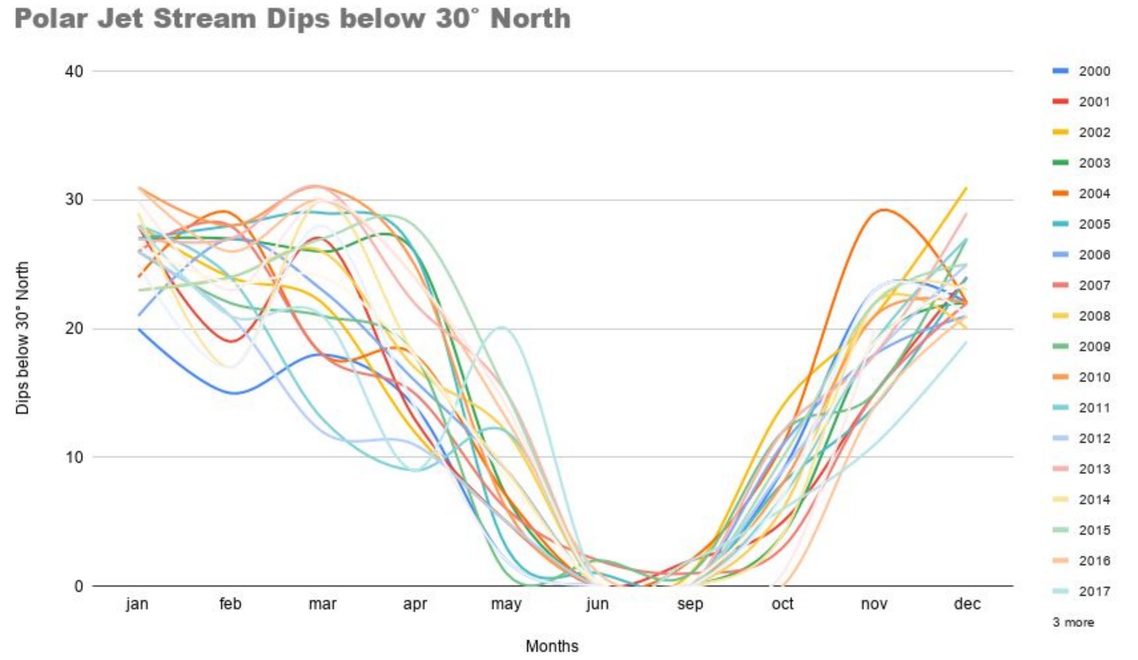
Correlation Between Polar Jet Stream Anomaly and SurfaceTemperature Anomaly

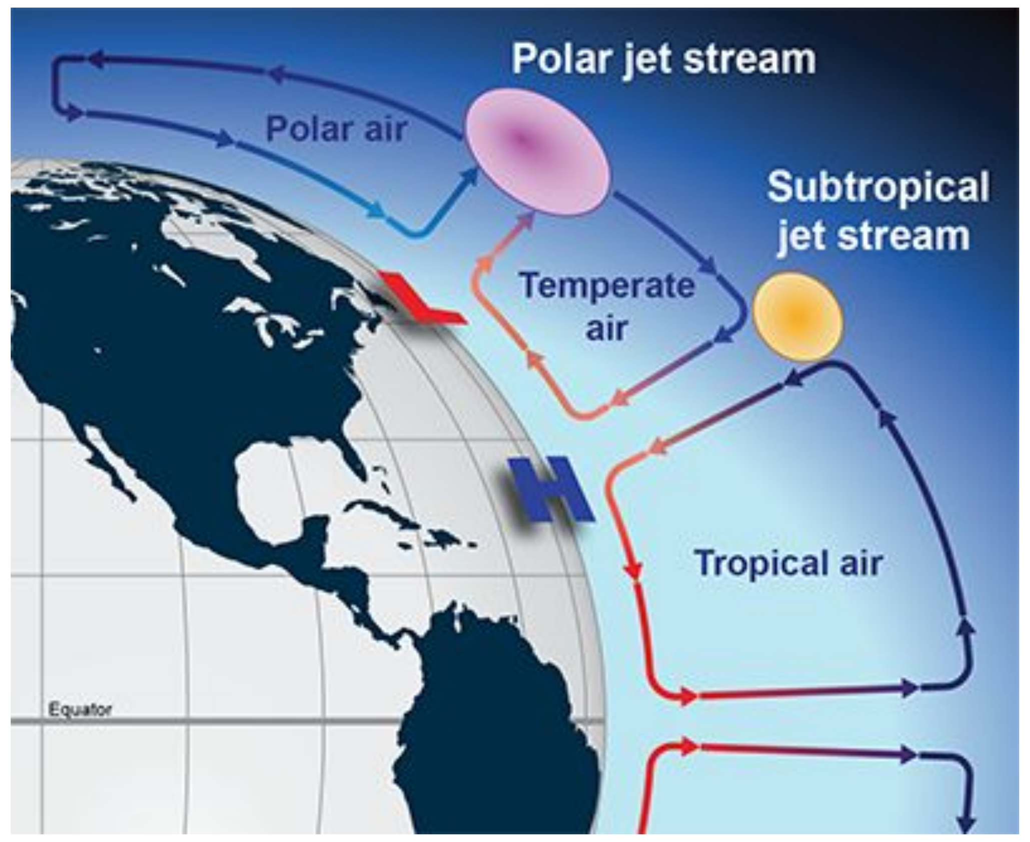


Correlation Between Polar Jet Stream Anomaly and Surface Temperature Anomaly



Polar Jet Stream Dips below 30° North





Findings

Data Sets	R values	R^2 values
Greenland Temperature Anomaly and PJS Dips	0.0637032796	0.004058107831
Greenland Winter Temperature Anomaly and PJS Dips	0.07104778451	0.005047787684
North Pole Temperature Anomaly 1950-81 and PJS Dips	0.326131914	0.1063620253
North Pole Winter Temperature Anomaly 1950-81 and PJS Dips	0.05562452825	0.003094088143
North Pole Temperature Anomaly 1950-81 and PJS Anomaly	-0.06879773796	0.004733128748
North Pole Winter Temperature Anomaly 1950-81 and PJS Anomaly	-0.05687086556	0.003234295349
North Pole Temperature Anomaly 2000-19 and PJS Dips	-0.02090693512	0.000437099936
North Pole Temperature Anomaly 2000-19 and PJS Anomaly	-0.09211142164	0.008484513996
North Pole Winter Temperature Anomaly 2000-19 and PJS Anomaly	-0.06157330399	0.003791271765

Discussion

In order to find the relationship between a planet's temperature and behavior of its airstreams, temperature anomaly and variation in the latitude of the Polar Jet Stream on Earth was compared in a correlation study. During the winter, the Polar Jet Stream fluctuates around the northern hemisphere usually dipping below 30° North about 20 times per month. In the summer, however, the jet stream rarely strays from the more northern regions of the planet. The drive of the airstream system is the surface temperature of Earth. The sun heats the planet and causes convection cells of air in the atmosphere which direct the jet streams. In the months of October-March, the northern hemisphere will experience colder temperatures which causes the Polar Jet Stream to be more active, but according to the data the temperature anomaly has little effect on the Polar Jet Stream anomaly: The general temperature of the air has a large effect but the small temperature anomalies have little effect.

The connection between temperature anomaly and jet stream anomaly had a correlation coefficient of $r = -.09$. Although the effect was small, this means that the more the temperature anomaly was (negative), the more the Polar Jet Stream dipped below 30°N. One of the correlations I obtained was $r = .33$, but this was most likely an extreme coincidence because it does not make sense with the data or general observations. It is not logical that there is a more positive temperature anomaly, the jet stream will vary in latitude. This can be backed up by the data in the summer months of the northern hemisphere - there is little to no activity of the Polar Jet Stream during these months. The coefficient of determination for this r value is .0008.

There are multiple factors that affect airstreams and although temperature anomaly does play a part, there may be too many other aspects to obtain a strong correlation between these two variables. It is obvious that there is a connection between the general temperature of the surface and the latitude change of the jet stream because in the summer there is little to no activity, but in the winter, it dips up and down in latitude the majority of the season. However, small changes in temperature (the anomaly) does not have a large enough effect on the jet stream.

Because the correlation was not strong does not mean that the results are any less significant. The data used was given in anomalies therefore, it can show the robustness of the system: it is relatively unaffected by minute changes in the temperature. This could explain why the Jet Stream is affected by long term seasonal weather and not day-to-day changes.

In order to establish a better correlation, other aspects of the atmosphere should be researched such as the temperature and density aspects of the atmosphere. This could have an effect on the winds in the upper atmosphere that is strong enough to be related to the meandering of the jet stream. It is also important to not just look at the Polar Jet Stream but the Sub-Tropical Stream as well. Because it is closer to the equator it is possible that temperature could have more of an impact: the surface of the Earth near the equator is exposed to more sunlight and therefore is warmer.

One of the largest sources of error that I suspect is human inaccuracy made by myself. It is very possible that I could have made a mistake while studying and recording jet stream data. I had to look through an image for every day for 20 years and record what I had seen. If I had misrecorded a piece of data, it would skew that months data by a factor of up to 10% per value depending on the month (if one month was more likely to have a larger number of dips such as the winter months, it would be less of an error).

Acknowledgements

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