Climate Change Over Past and Recent Solar Minima

Christopher Maloney

Mentors: Tom Woods, Odele Coddington, Andrew Kren, and Peter Pilewskie

Abstract

The Earth’s atmosphere is a vastly complex system which is affected by both human influence and natural climate effects. One natural forcing component is our sun’s contribution to climate. It is well known that the sun provides the majority of the energy for the Earth and that variability of the total solar irradiance (TSI) during the 11 year solar cycle affects our climate. Historically the sun’s variability has been the primary input to climate change, but within the past 100 years, the sun’s contribution has been diminished by the growing impact of mankind’s industrialization. This study attempts to quantify the solar forcing on tropospheric climate change over the past 35 years so that we could better understand our own human impact on global warming. We use a linear regression model with forcing parameters of TSI, anthropogenic warming, volcanic aerosol, and El Niño-Southern Oscillation (ENSO) components. Our focus is upon regions including the entire planet, the northern hemisphere, the United States, and central to eastern United States. We also took a seasonal approach to mitigate the large annual variations associated with Earth’s orbit. Our main period of interest is the difference in temperature between this most recent low solar minimum (2007-2009) and the previous solar minimum in 1996. Our results suggest a 0.1 K or less cooling in surface temperature during the recent low solar minimum on the global and northern hemisphere spatial scales. Our model results are much less accurate for the smaller regions due to an increase in temperature variability, possibly due to dynamical effects such as the North Atlantic Oscillation (NAO). It appears that more forcing components are needed in the model, or a different model is needed, to properly study the smaller regions (USA and central to eastern United States).

Results

Our Temperature data and Model fit plots provide us with the overall influence of the four components used in our linear regression. Each domain is represented by a graph for the Dec-Jan-Feb season where the purple diamonds represents the temperature data and the red line is our regression model’s best fit.

Note that the temperature data variability increases dramatically as the domain size decreases. This results in a poorer fitting model. The regression plots below confirm this trend as correlation decreases. For example, in the right bottom plot the TSI shows the greatest variability and volcanic aerosols show a warming effect where we would expect cooling.

Results continued

Our model shows the low solar minimum spanning (2007-2009) appears to have caused slightly colder temperature in 2009 than in 1996 by about 0.02 degrees (K) (shown in the chart below). We can test this by seeing a decrease in global and northern hemisphere domains. The smaller USA and central to eastern United States domains do also exhibit cooling, but their correlation values are too low to expect accurate results.

Methods

Similar to (Lean and Rind 2008) we used the method of linear regression to isolate the TSI contribution to temperature change between the 2007-2009 solar minimum and the 1996 minimum.

- Linear regression equation:

  \[ Temp = A + B \cdot \text{Time} + C \cdot \text{[Atlantic-ENSO data]} + D \cdot \text{[ENSO data]} + E \cdot \text{[Volcanic data]} \]

To produce the linear regression we include four main climate impacting components; Anthropogenic, TSI, ENSO, and Volcanic Aerosols.

It is clear from our model that Anthropogenic forcing is the greatest contributor to the overall warming trend our atmosphere has been experiencing over the past 35 years. Volcanic aerosols have the second largest impact. Both TSI and ENSO have smaller and less obvious contributions to temperature change. Our analysis provides acceptable results in large spatial scales such as the entire planet and the northern hemisphere, but becomes inadequate in smaller regions due to large temperature variability, presumably stemming from regional dynamics.

References


Temperature data and Volcanic Aerosol geots from following NOAA and NASA websites:

ENSO: www.cpc.ncep.noaa.gov/papers/aodx.xls

Volcanic Aerosol: http://climate.noaa.gov/volcanic/20070827Volcanic_Aerosol.html

Temperature Data can be downloaded here: http://www.cdc.noaa.gov/DataSources/metadata.shtml

It is an interactive weather data from tdb.net/index.html