Climate Change Over Past and Recent Solar Minima

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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 troposphere 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).

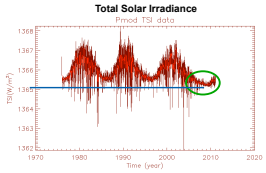
Methods

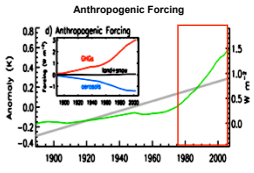
Similar to (Lean and Rind 2008) we used the method of linear regression to isolate the TSI contribution to temperature change between the 2007-2009 solar minimum and the 1996 minimum.

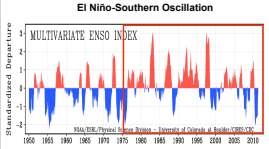
- Linear regression equation:

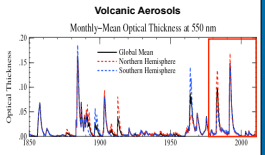
Temp = A + B*time + C*[Esol-Emin]+ D*[ENSO data] + V*[Volcanic data]

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





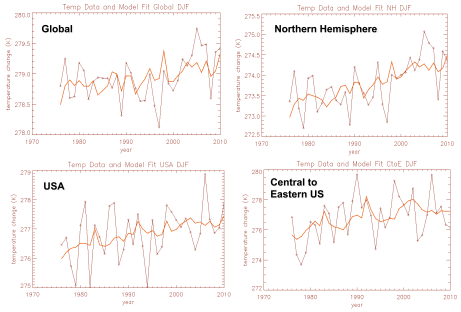




Results

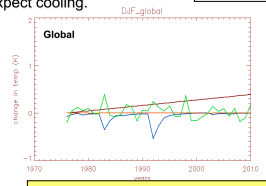
Our Temperature data and Model fit plots provide us with the overall influence of the four components used in our linear regression. Each domain is represented by a graph for the Dec-Jan-Feb season where the purple diamonds represents the temperature data and the red line is our regression model's best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

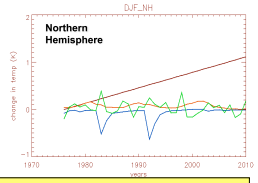
Note that the temperature data variability increases dramatically as the domain size decreases. This results in a poorer fitting model. The regression plots below confirm this trend as correlation decreases. For example, in the bottom right plot the TSI shows too large of variability and Volcanic aerosols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



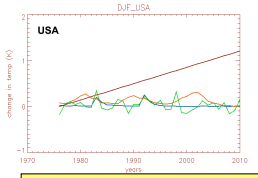
LEGEND

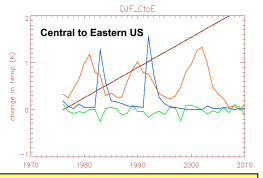
TSI Anthropogenic Volcanic ENSO





Model Correlation = 0.53 | Model Correlation = 0.65





Model Correlation = 0.42 | Model Correlation = 0.48

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.

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) (exhibited in the chart below). We can only make this statement with confidence for the global and northern hemisphere domains however. 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.

Domains	Dec-Jan-Feb	Mar-Apr-May	Jun-Jul-Aug	Sep-Oct-Nov	Annual Average
Global (degrees K)	0.00078	-0.03	-0.046	-0.018	-0.022
Northern Hemisphere (degrees K)	-0.03	-0.051	-0.032	0.021	-0.019

*Note: Included in this chart is a annual average of all of the seasons.

The below chart shows the coefficient values per season for each regression component in the Global domain. Also shown are the components correlation values and the error in the annual coefficient values.

Global	Coefficient Values				Corresponding Correlation			
Seasons	Anthro	Volcanic	TSI	ENSO	Anthro	Volc	TSI	ENSO
DJF	0.011	-3.7	-0.0029	0.14	0.37	-0.21	-0.081	0.237
MAM	0.037	-3.8	0.11	0.11	0.81	-0.28	-0.22	-0.011
JJA	0.034	-3.8	0.17	-0.02	0.82	-0.43	-0.28	-0.28
SON	0.041	-2.5	0.066	-0.001	0.91	-0.37	-0.38	-0.29
Annual	0.031	-3.6	0.081	0.042	0.83	-0.4	-0.26	-0.23
Error in Annual Values:	13%	48%	126%	156%				

Conclusion

Our results show that solar forcing has a small impact on tropospheric temperature changes in comparison to other forcing such as Anthropogenic and volcanic aerosols. It is also clear that our method is limited in the models ability to accurately portray smaller regions. There are possible solutions to this issue such as adding region specific temperature forcing dynamics to the regression model. For example, in our "Temperature data & Model Fit" graphs in the center results panel, there is a quasi-two year oscillation in the temperature data which is not being accounted for by our model in the USA and central to eastern United States domain. This oscillation could be accounted for by quasi-two year oscillations specific to that region such as the North Atlantic Oscillation (NAO), or stratospheric Quasi-Biannual Oscillations (QBO's) in the stratosphere.

Our study also shows support for the (Lean, Rind 2008) and (Lockwood, Harrison, Woollings, Solanki 2010) papers from which we based our study upon. Our linear regression model produced similar results to (Lean, Rind 2008), as well as faced similar difficulties in smaller regions. Like Lockwood et. all, we found a small cooling effect in the winter season, and we found our central to eastern United States results correlated well with the Europe results (regions are affected by many of the same dynamics such as the NAO).

References

- Lean, J, & Rind, D. (2008). How natural and anthropogenic influences alter global and regional surface temperatures: 1889 to 2006. *Geophysical Research Letters*, *35*. Retrieved from http://www.agu.org/pubs/crossref/2008/2008GL034864.shtml doi: 10.1029/2008GL034864

- Lockwood, M, Harrison, R G, Woollings, T, & Solanki, S K. (2010). Are cold winters in europe associated with low solar activity?. *Environmental Research Letters*, *5*. Retrieved from IOPscience.iop.org doi: 10.1088/1748-9326/5/2/024001

Temperature data and, ENSO and Volcanic Aerosol graphs obtained from following NOAA and NASA websites:

ENSO: www.esrl.noaa.gov/psd/enso/mei/

Volcanic Aerosol: http://data.giss.nasa.gov/modelforce/strataer/

Temperature Data can be downloaded here: ftp://ftp.cdc.noaa.gov/Datasets/ncep.reanalysis/

Information on the reanalysis data is found here: http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html