

The Correlation of Seismic Activity and Recent Global Warming

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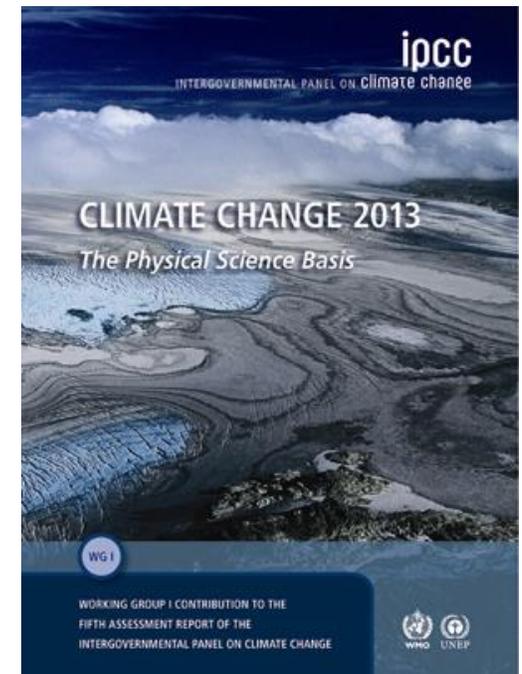
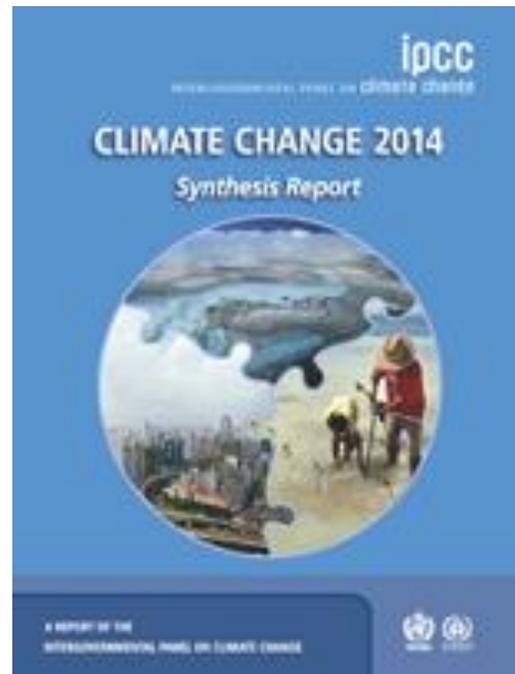
Abstract

The latest report from the Intergovernmental Panel on Climatic Change states with high confidence that the warming of global temperatures since 1901 has been driven by increased radiative forcing. The enhanced forcing is attributed to greenhouse gases of anthropogenic origin, and includes carbon dioxide, methane, and halocarbons. The Nongovernmental International Panel on Climatic Change has challenged these findings and concludes that the forcing from these gases is minimal and diminishing. They go on to say that modeling attempts of past and future climate states are inaccurate, and do not incorporate important solar inputs, such as magnetic strength and total irradiance. However, one geophysical variable that has been overlooked by both groups is geothermal flux. This study will show that increasing low-magnitude seismic activity, a proxy for increasing geothermal flux, is highly correlated with average global temperatures from 1979 to 2014 ($r = .775$). Multiple regression indicates that low-magnitude seismic frequency is a significant predictor of global temperatures ($P < .05$), but carbon dioxide concentrations do not significantly improve the explained variance ($P > .1$). A compelling case for geothermal forcing lies in the fact that 1) geothermal heat can trigger thermobaric convection and strengthen oceanic overturning, important mechanisms for transferring ocean heat to the overlying atmosphere, and 2) seismic activity is the leading indicator, while global temperature is the lagging indicator.

Keywords: climate change, seismic activity, geothermal forcing.

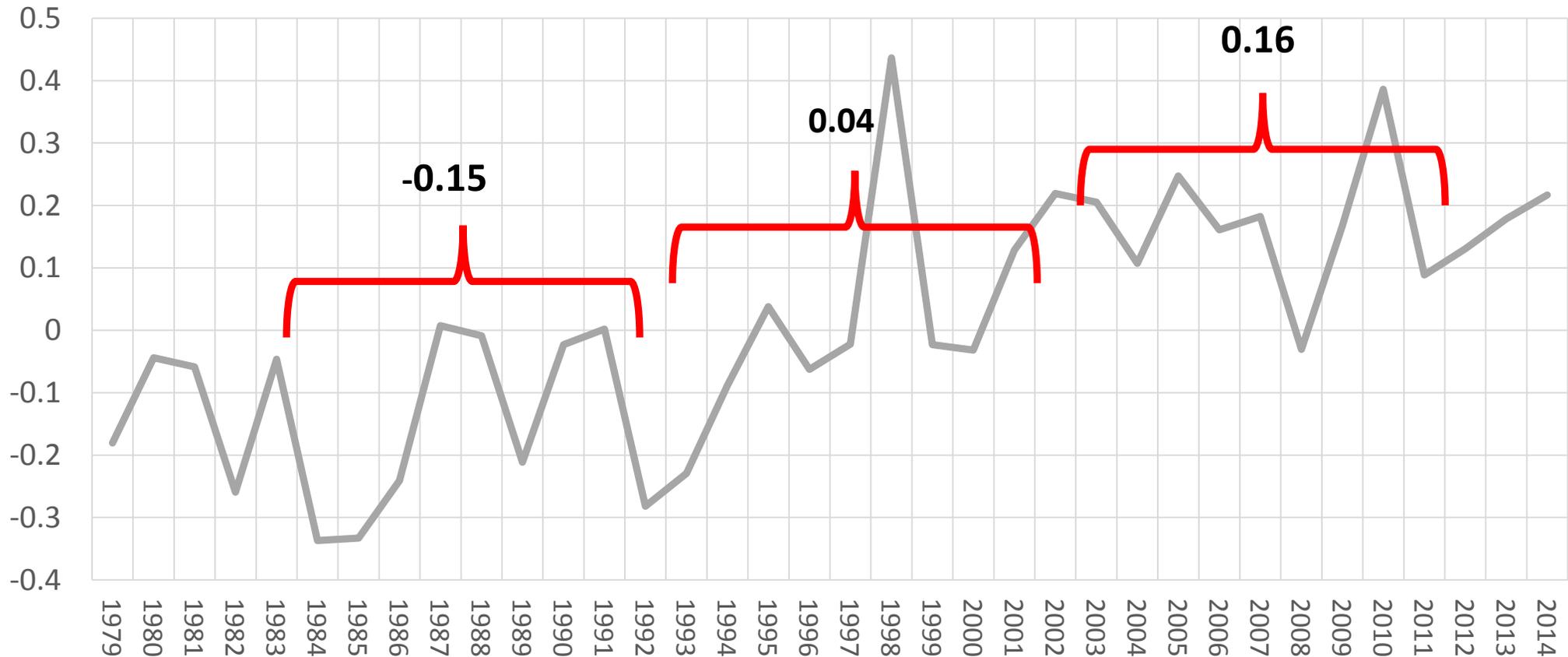
The Fifth Report of the IPCC states:

“Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.”



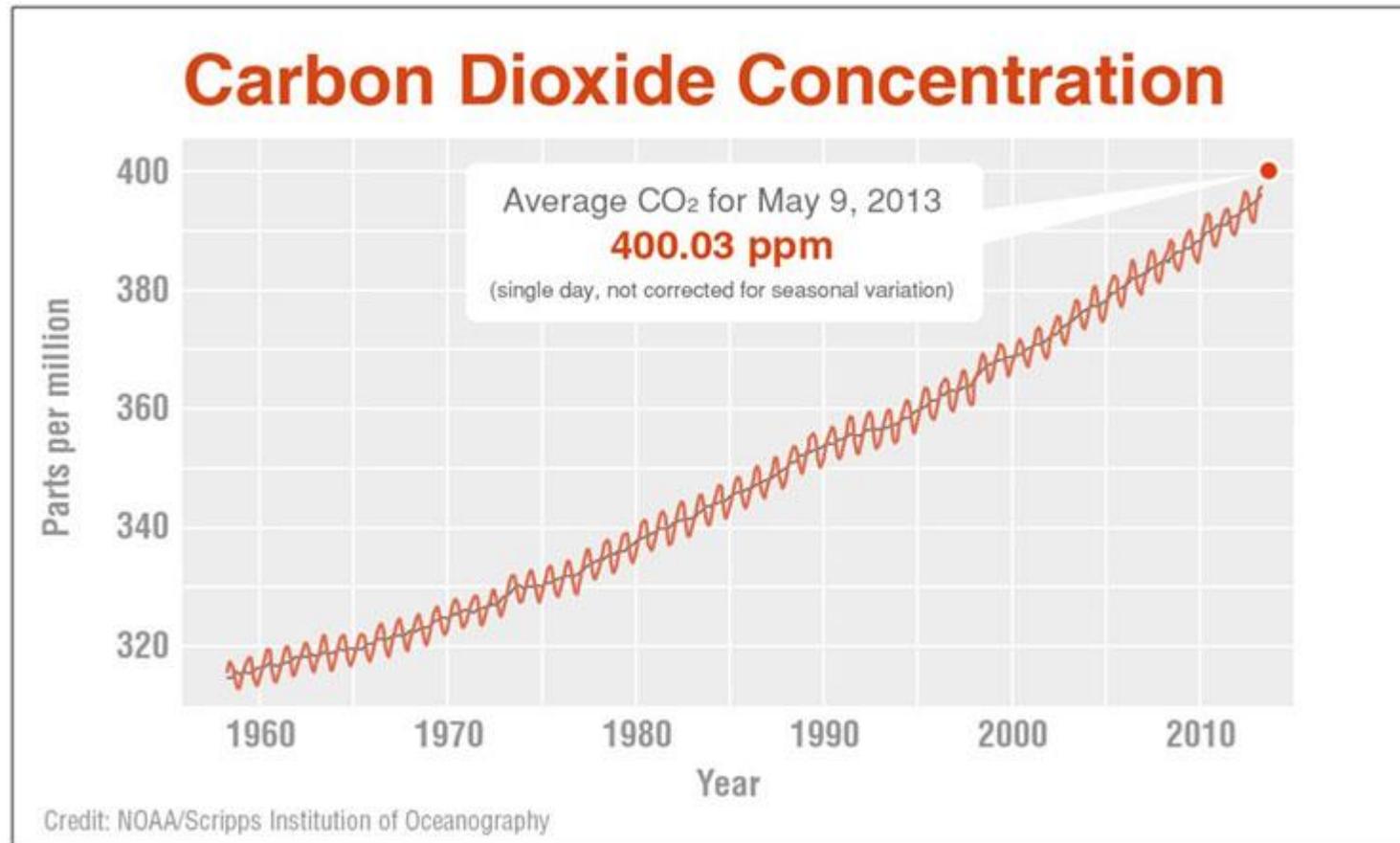
They add that:

“Each of the last three decades has been successively warmer at the Earth’s surface than any preceding decade since 1850. In the Northern Hemisphere, 1983–2012 was *likely* the warmest 30-year period of the last 1400 years (*medium confidence*).”



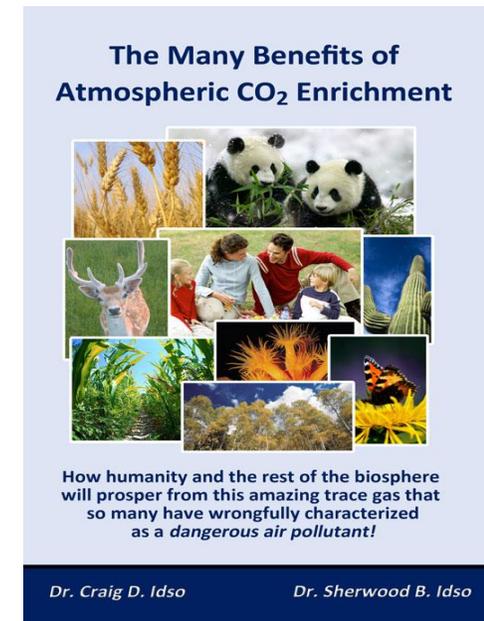
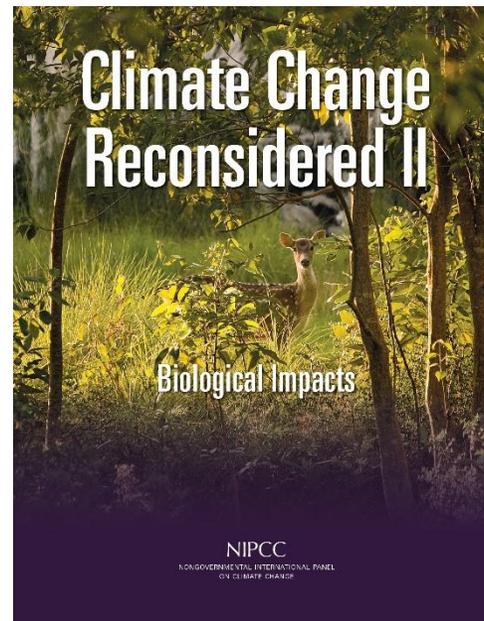
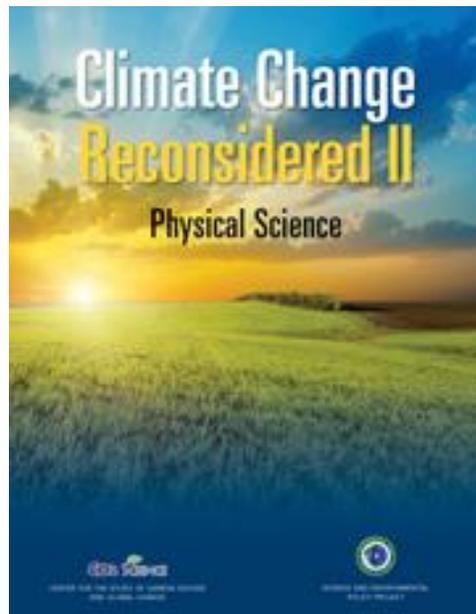
For causality, they cite the following:

“Total radiative forcing is positive, and has led to an uptake of energy by the climate system. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO₂ since 1750.”



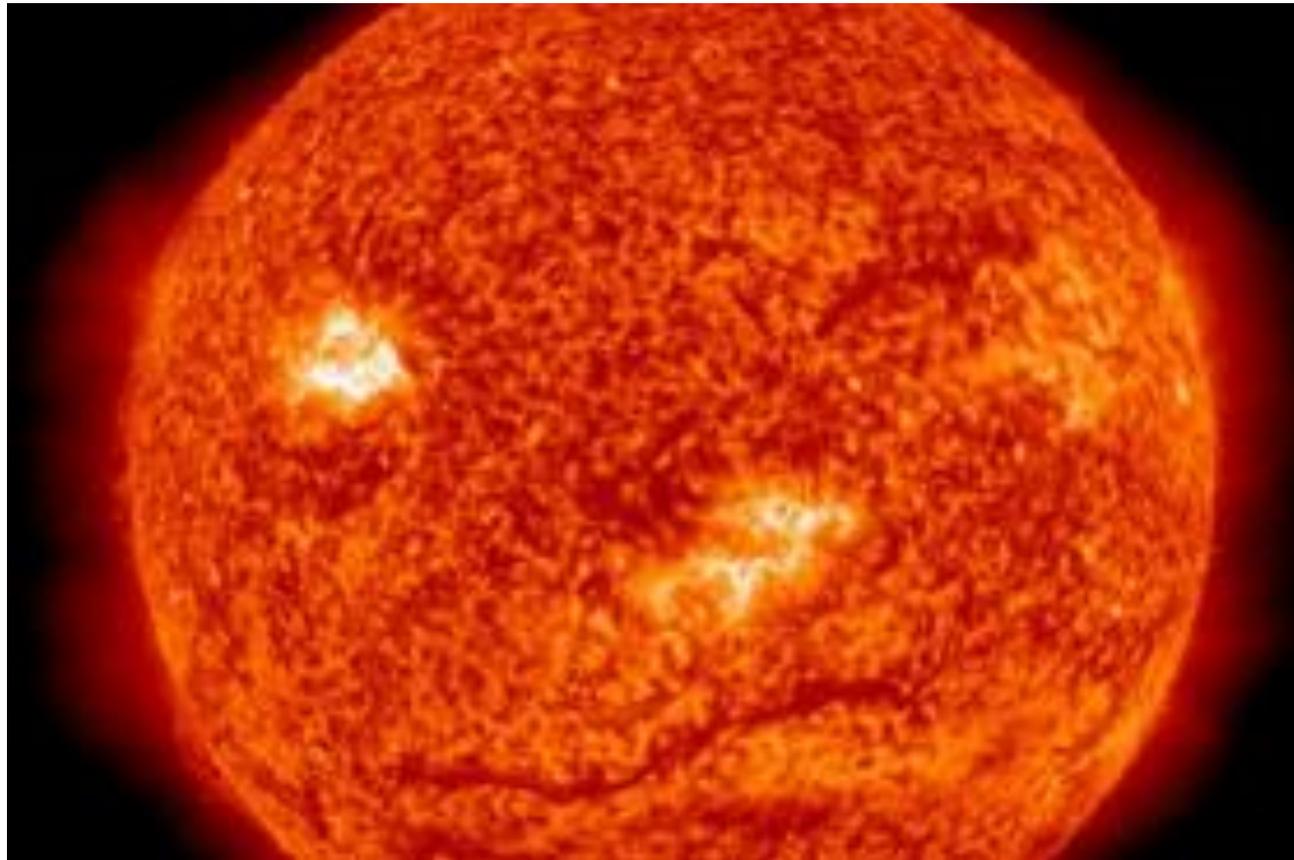
The Nongovernmental Panel on Climatic Change has a different perspective

“Any human global climate signal is so small as to be nearly indiscernible against the background variability of the natural climate system. Climate change is always occurring.”



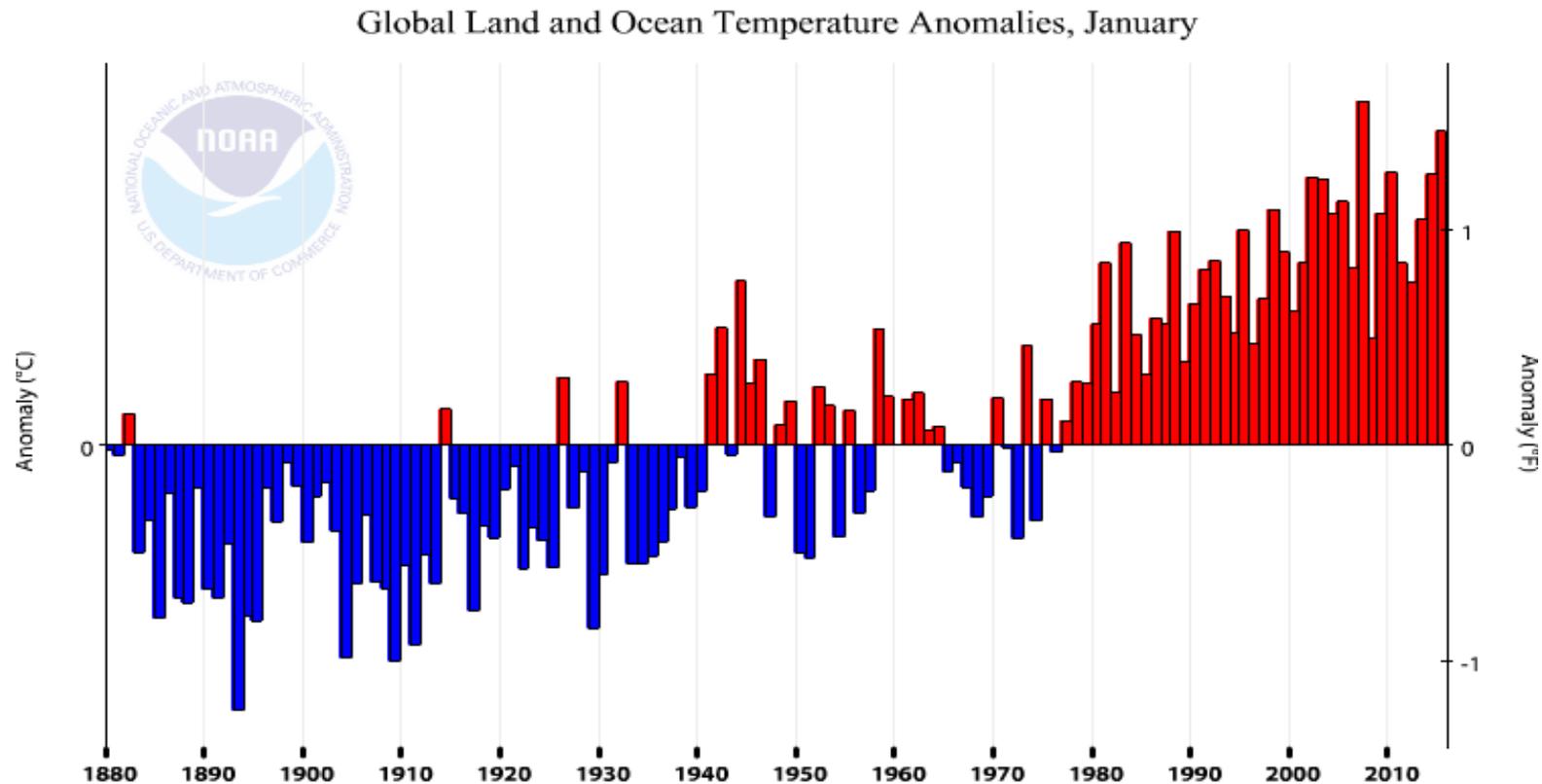
They further state:

“Solar forcing of temperature change is likely more important than is currently recognized.”



They conclude:

“Neither the rate nor the magnitude of the reported late twentieth century surface warming (1979–2000) lay outside the range of normal natural variability, nor were they in any way unusual compared to earlier episodes in Earth’s climatic history.”



To Summarize

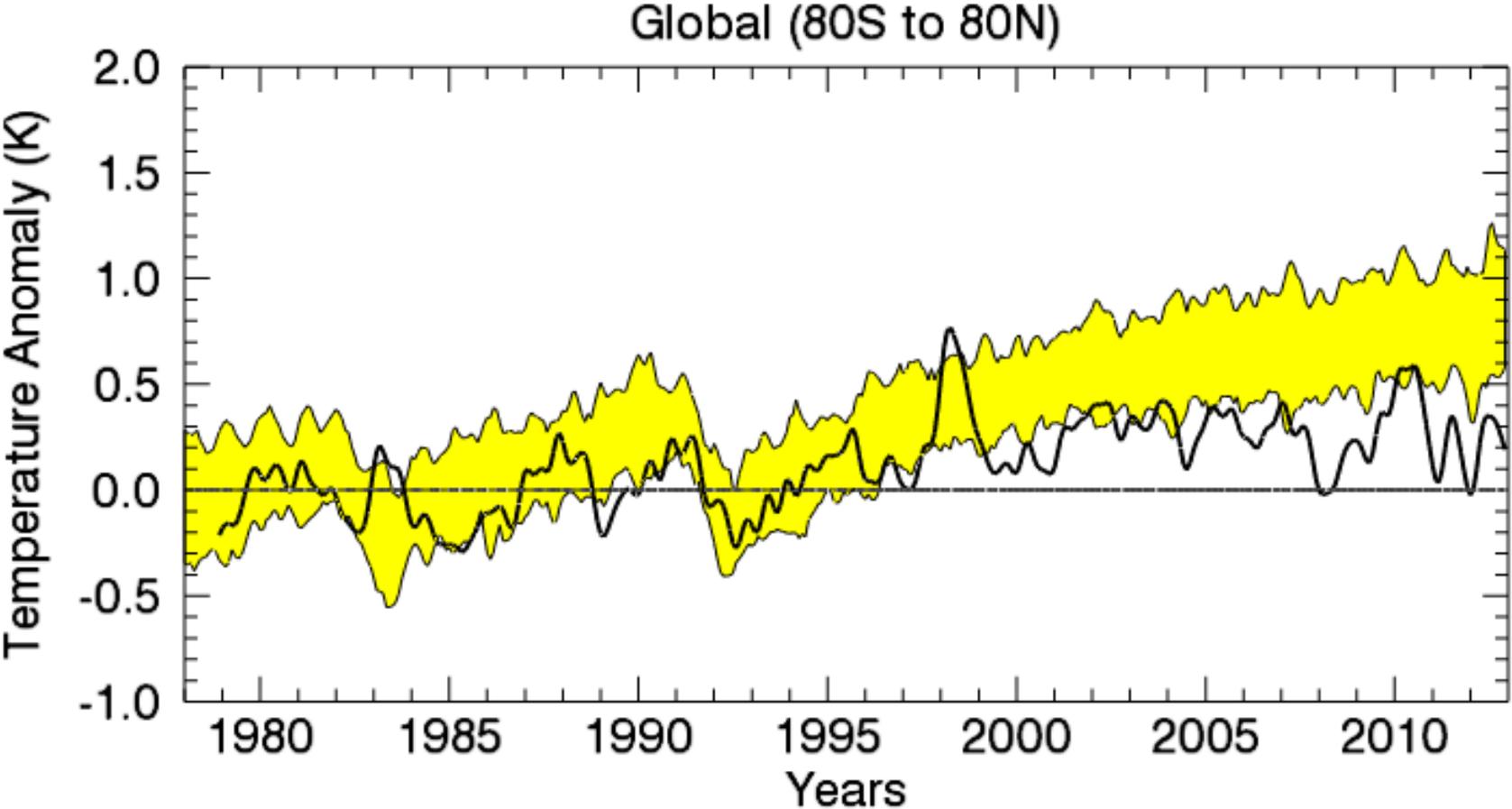
IPCC Arguments

- Global warming is a serious problem
- Recent warming is unprecedented
- Anthropogenic carbon dioxide is the driver
- We must act to ameliorate further warming

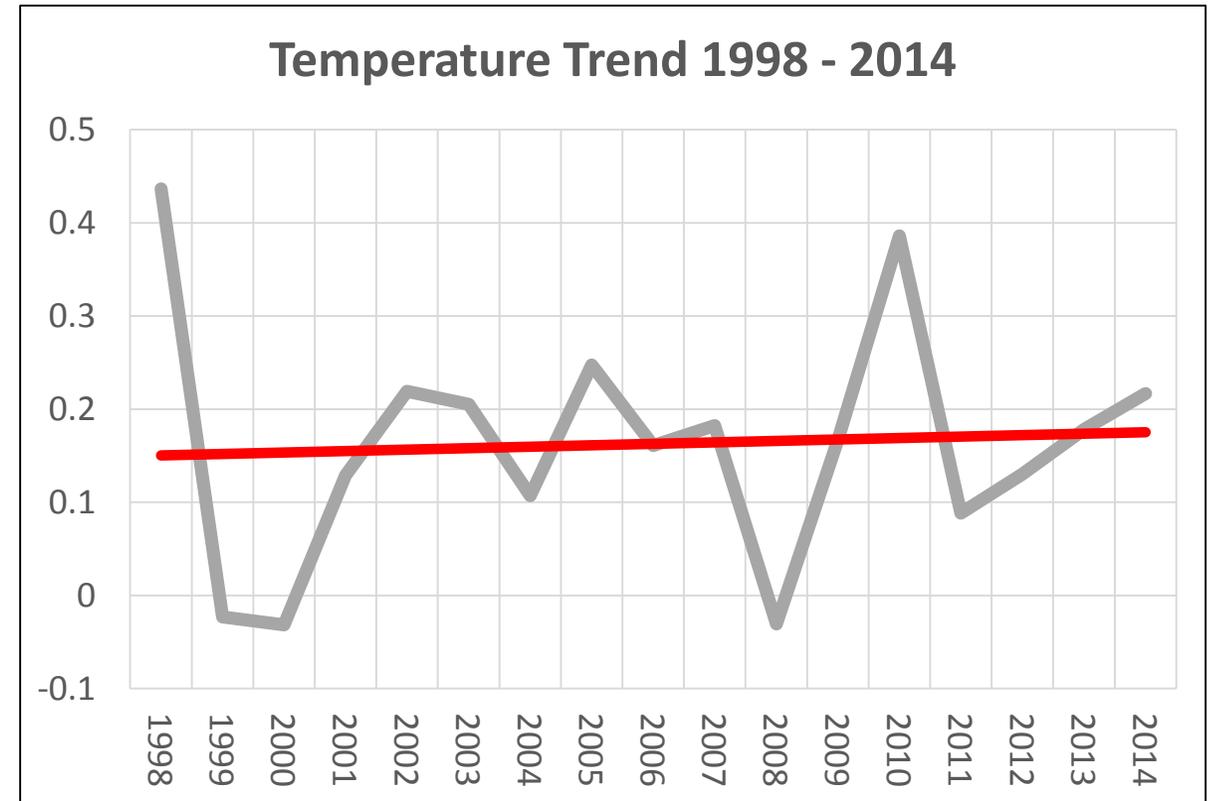
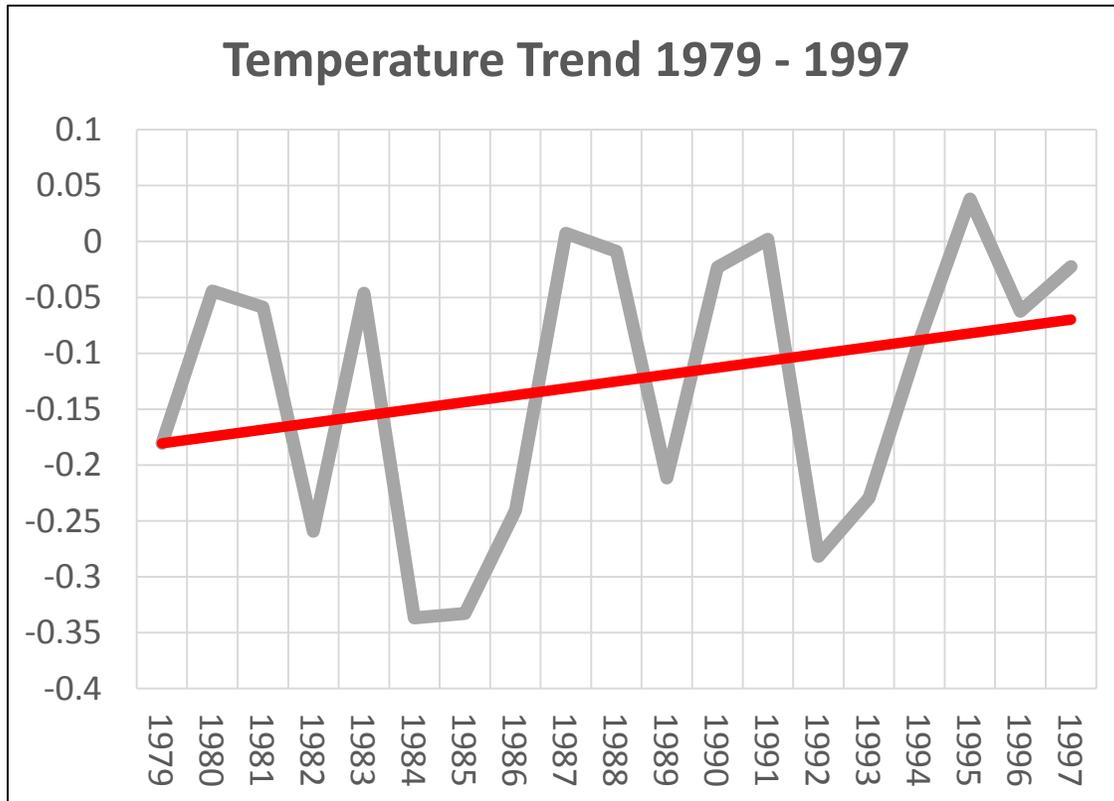
NIPCC Arguments

- Global warming is not a serious problem
- Recent warming is not unprecedented
- Natural variability/changing solar output is the driver
- We should attempt to adapt to further warming

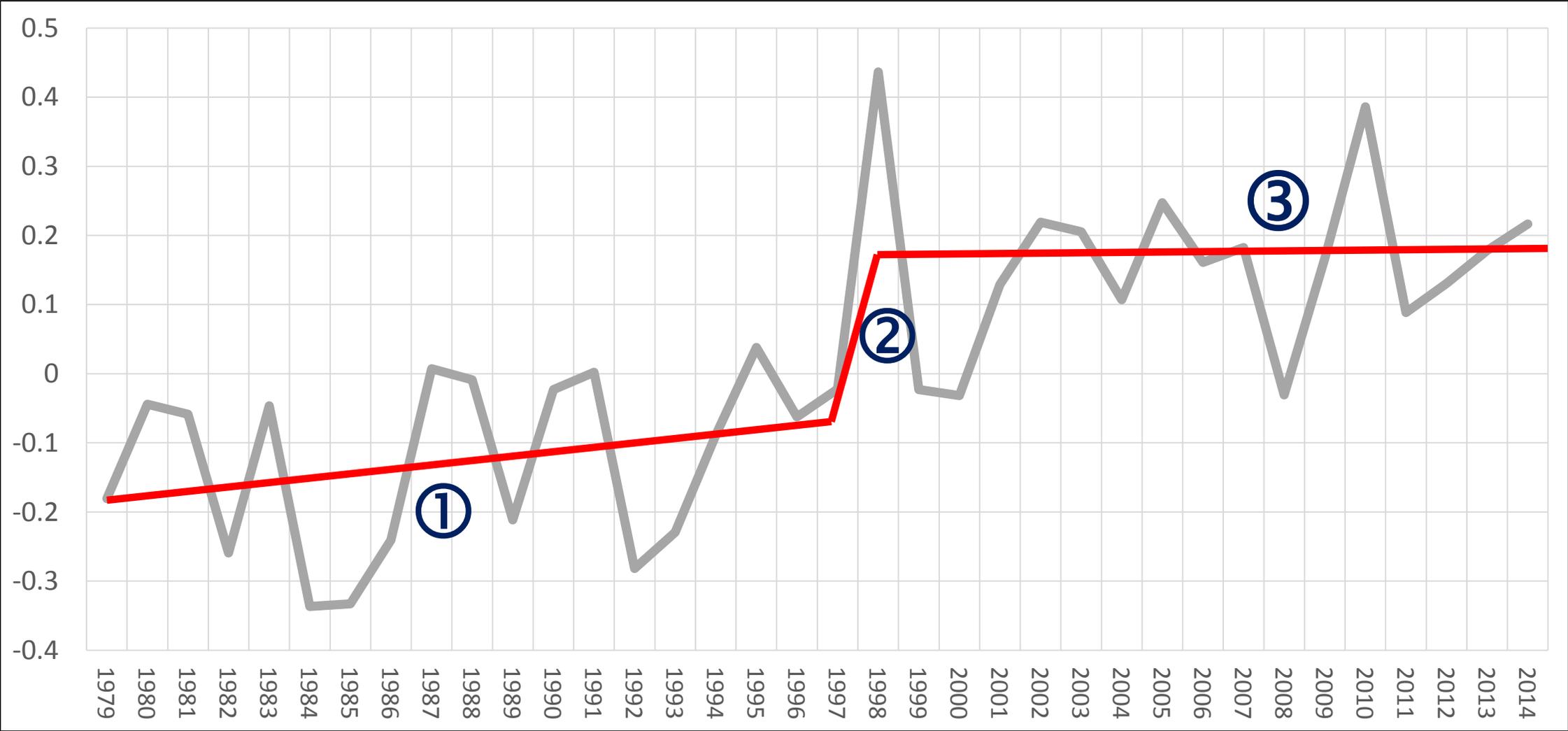
A powerful substantiation of the NIPCC claims is to be found in the differences between the actual global temperatures (black line, as measured by satellite) and the projected global temperatures (areas in yellow)



Further support for the NIPCC claims lies in the fact that global temperatures have not warmed since 1998.



Here is the full time series. Please note the three distinct segments: 1) Gradual warming from 1979 to 1997, 2) anomalously large warming during the 1997/1998 El Niño, 3) flattening temperatures since 1998.



Source: UAH, RSS

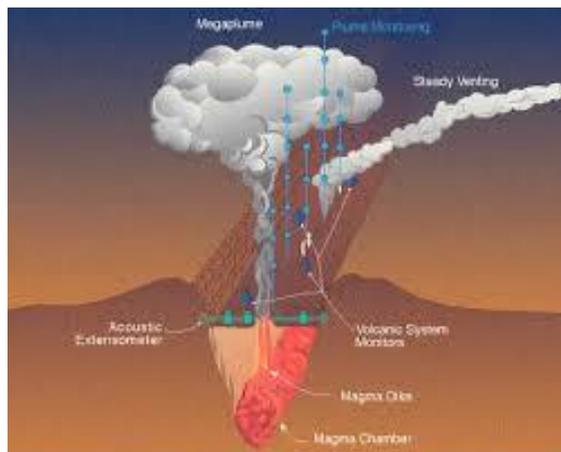
One planetary heat source that is absent from both the IPCC and NIPCC discussions is the flux of geothermal heat.



<http://science.howstuffworks.com/environmental/energy/geothermal-energy.htm>



<http://www.pmel.noaa.gov/eoi/nemo2001/background.html>

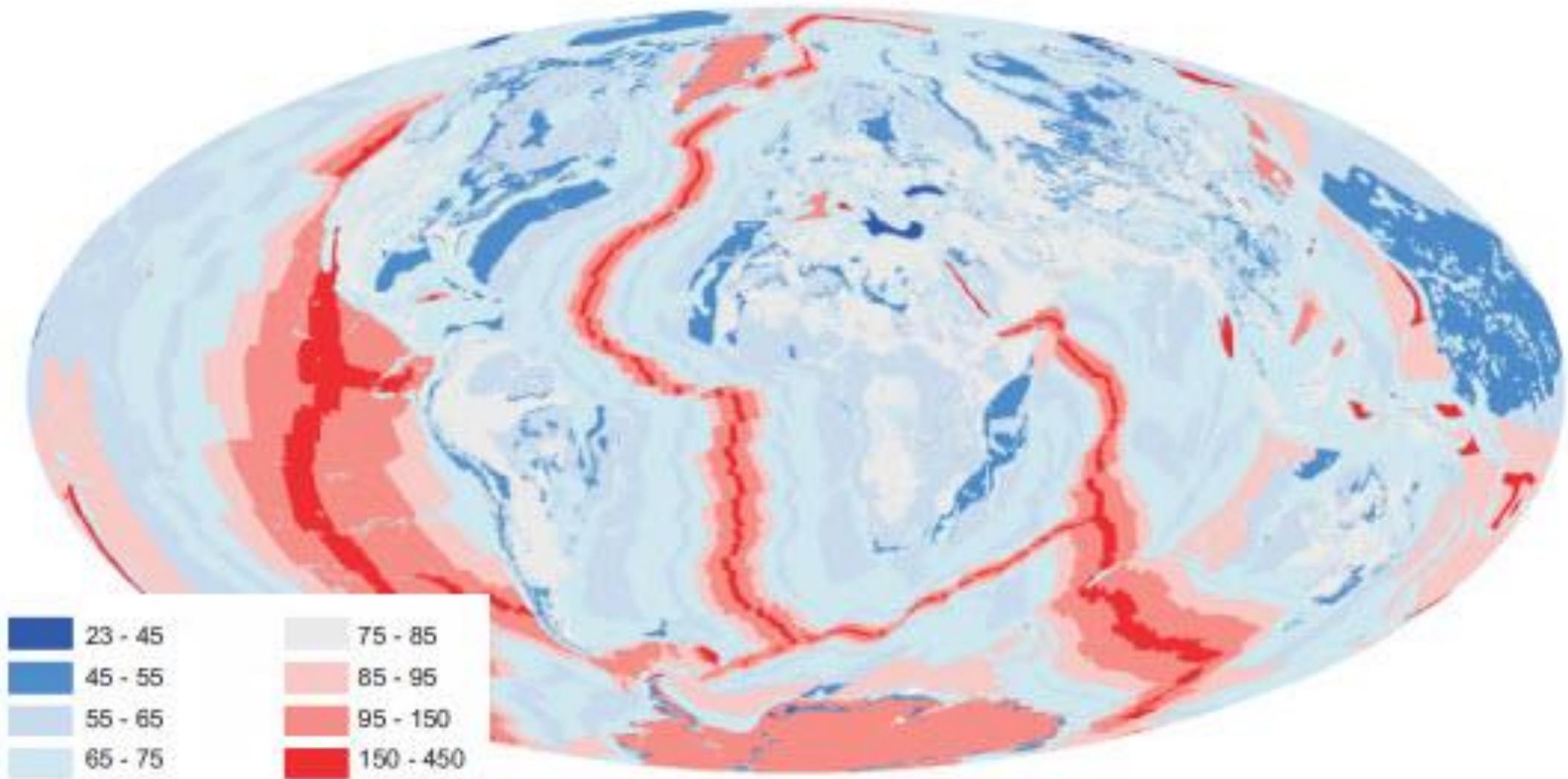


<http://www.pmel.noaa.gov/eoi/chemistry/plume.html>

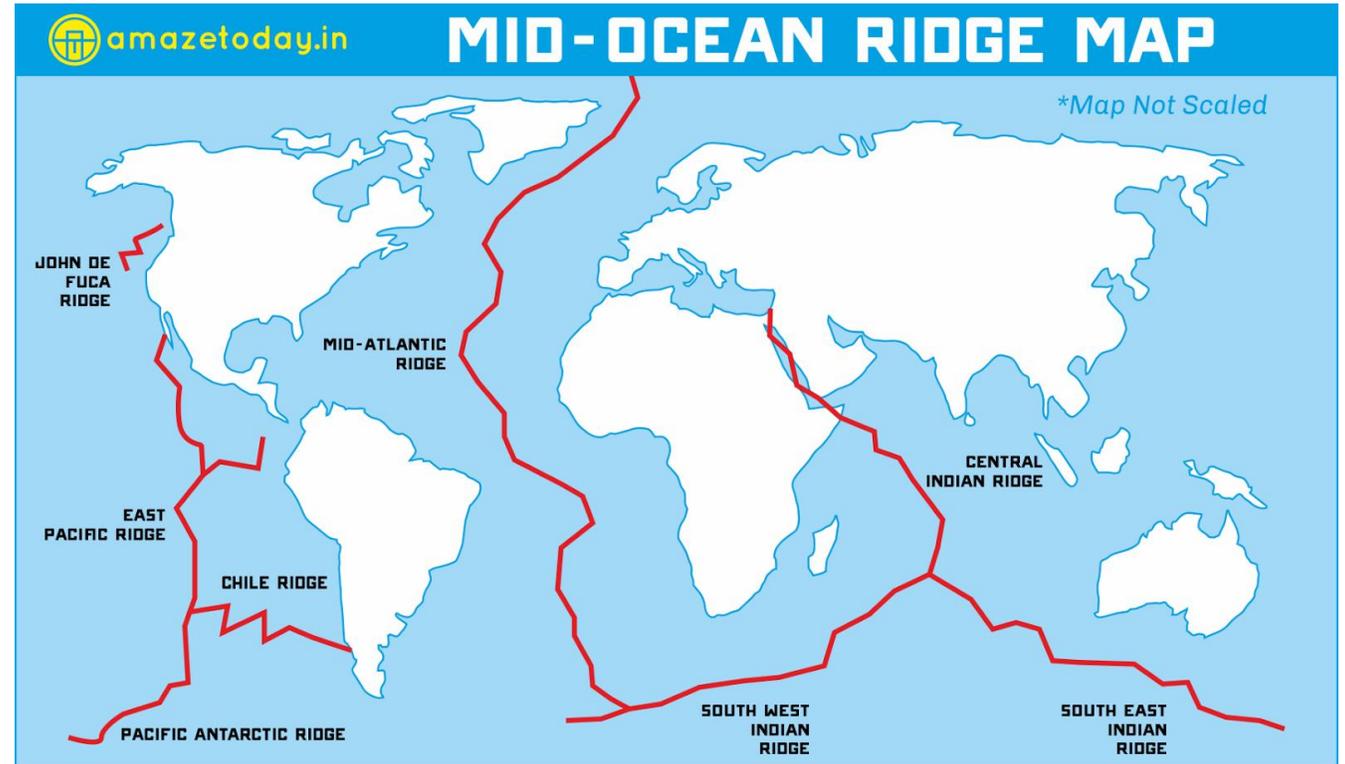
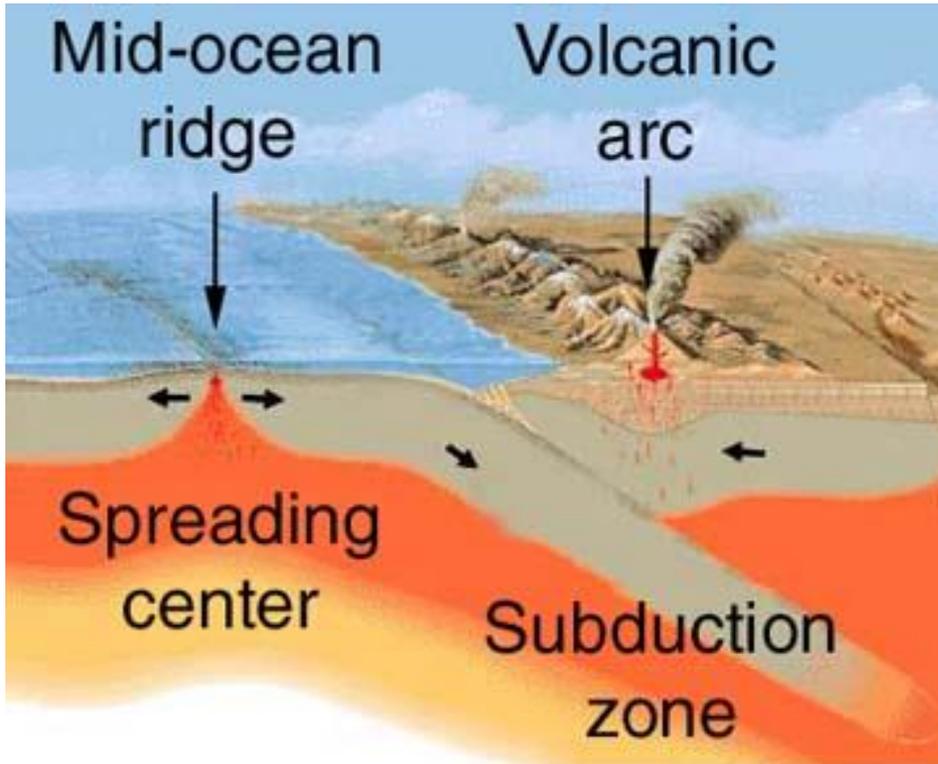


http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/how-geothermal-energy-works.html#.ViJdZsJdFLM

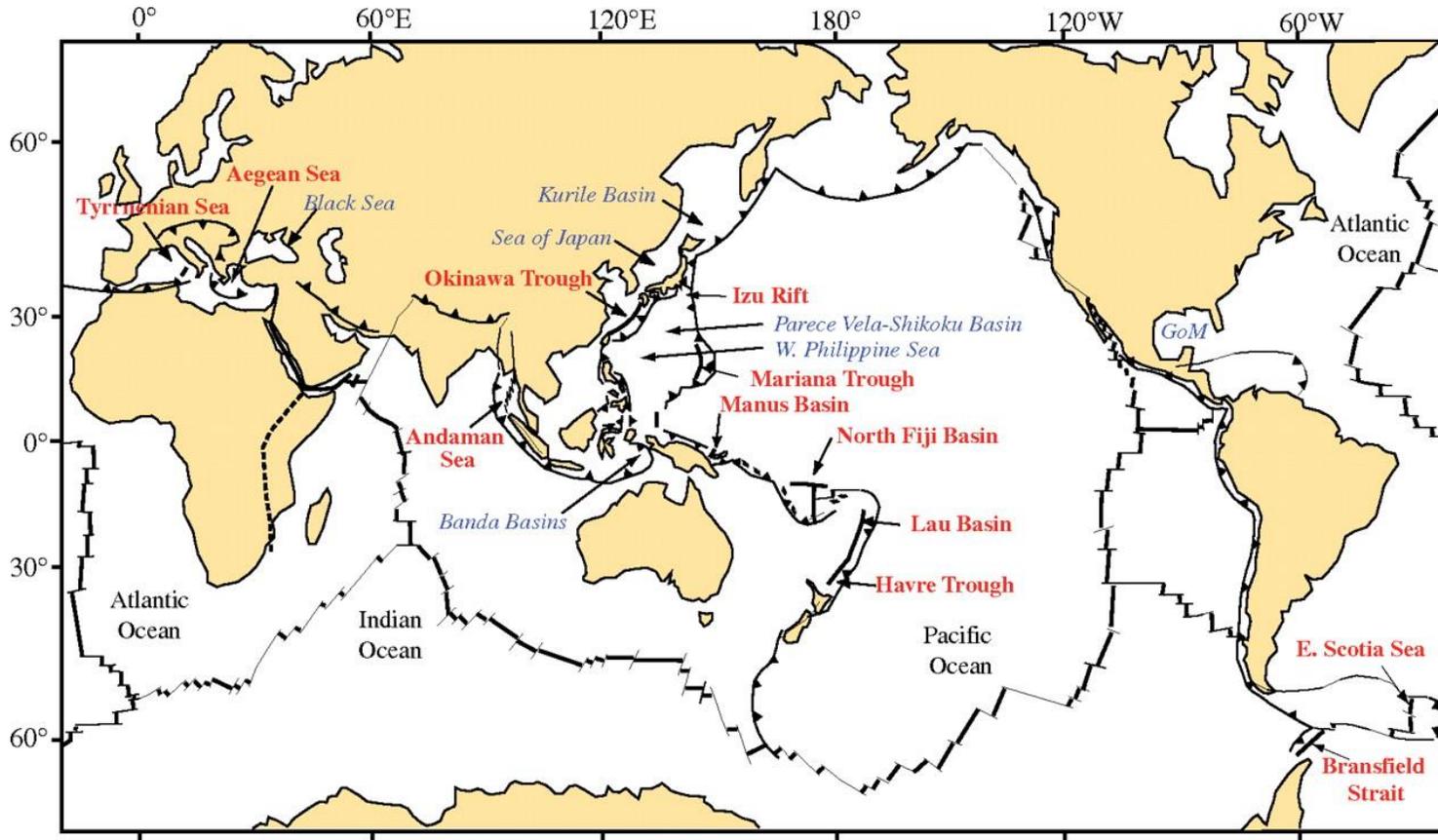
As this data indicates, most geothermal flux occurs along divergent plate boundaries.



This includes the globe's mid-ocean ridges ...

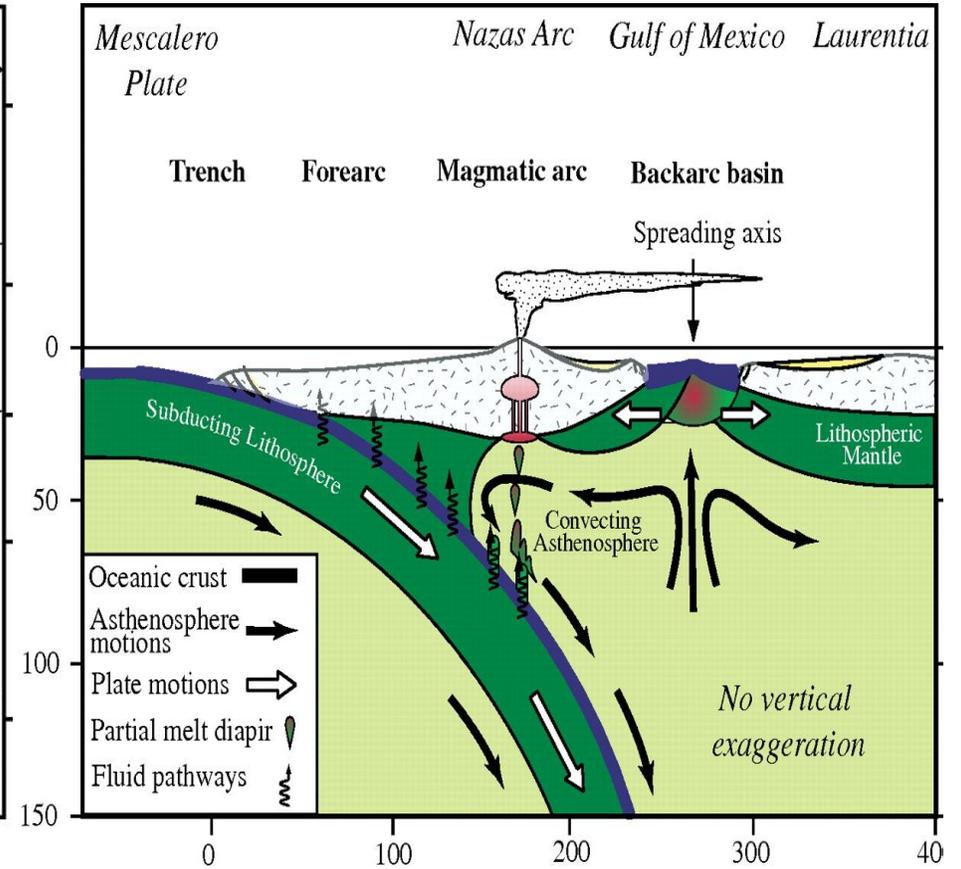


Along with the globe's back-arc basins

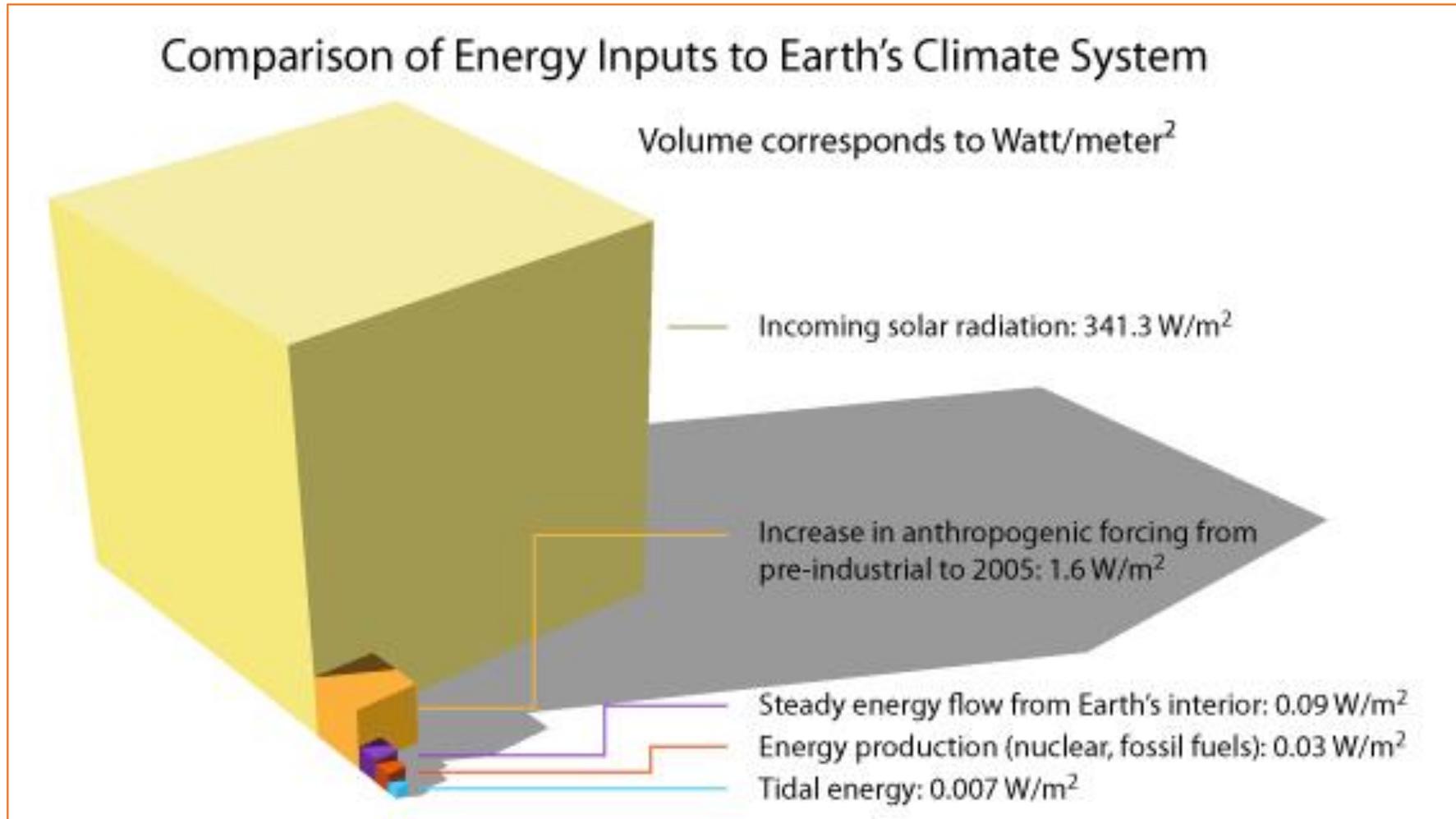


Active Backarc & Intraarc Basins

Extinct Backarc Basins



The reason geothermal is absent from these analyses is because of its low magnitude, relative to other sources.



To directly quote from the website “Skeptical Science” it is stated:

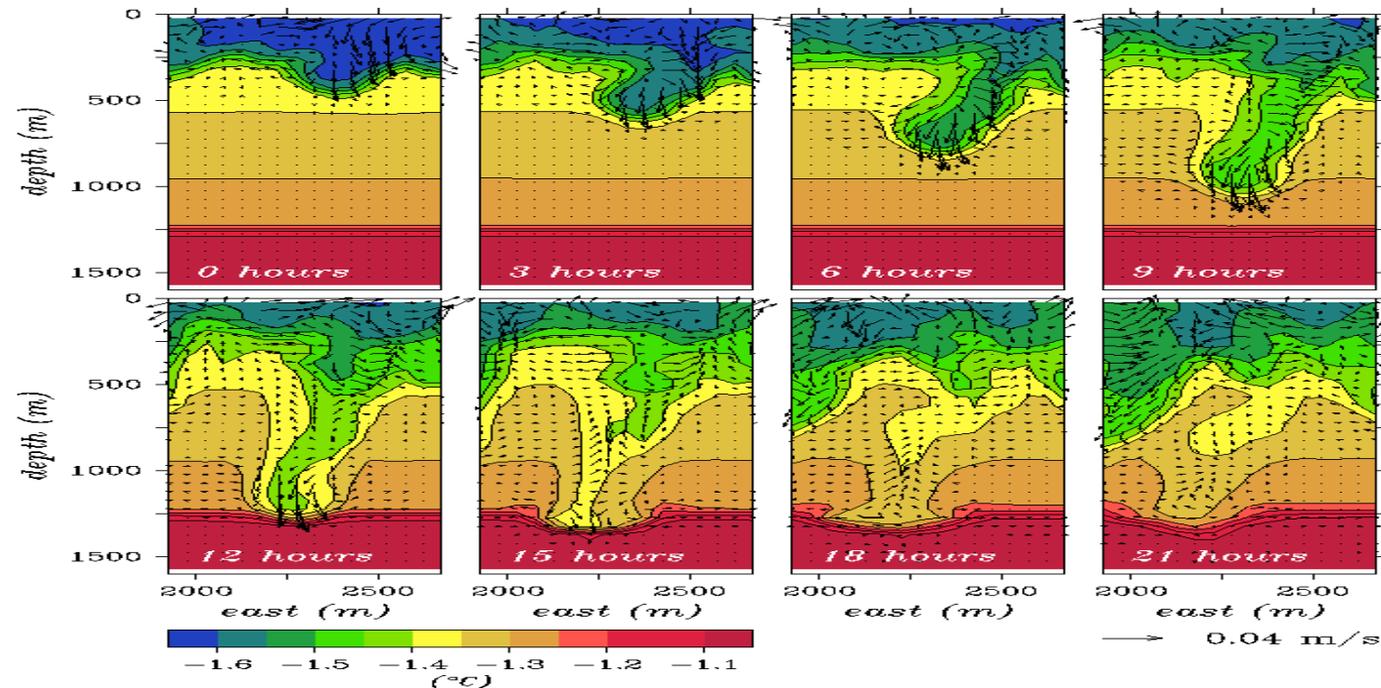
“What The Science Says:

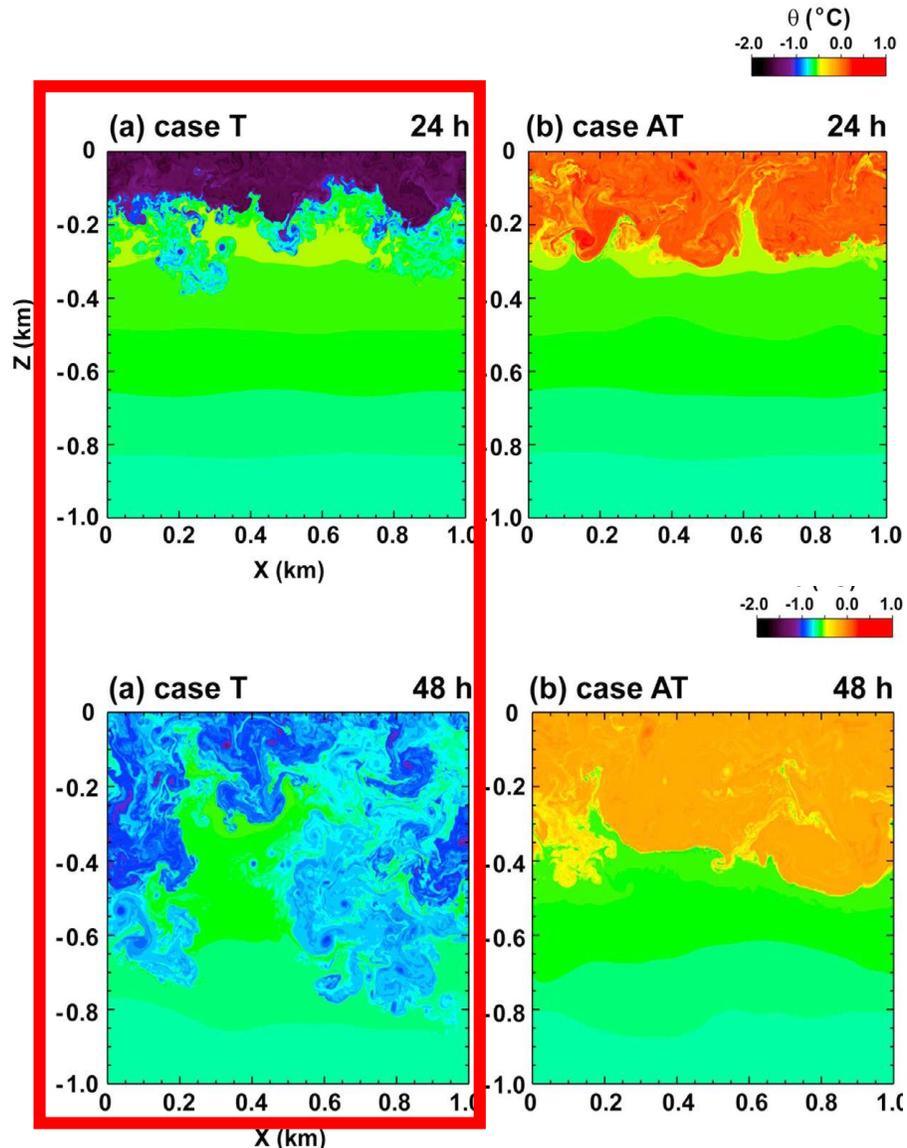
The flow of energy outwards from the interior of the Earth is 1/10,000th of the size of the energy flow from the Sun.

Furthermore, over the past few million years, the heat flow from deep in the Earth has also remained very steady compared to other climatic factors. Heat from the bowels of the Earth does not influence climate in any significant way.”

Despite a relatively small thermal load, geothermal heating warms the ocean deep water and can trigger thermobaric convection, a mechanism where heat is transferred to the ocean surface from lower layers. As Carmack et al. state (Carmack, E.C., W. J. Williams, S. L. Zimmermann, and F. A. McLaughlin, 2012: The Arctic Ocean warms from below. *Geophysical Research Letters*, 39, doi: 10.1029/2012GL050890):

“...as temperatures within the bottom layer increase, ... vertical motions may be sufficient to trigger intermittent thermobaric overturning cells. ... (G)eothermal heating warms and stirs the bottom layer.”





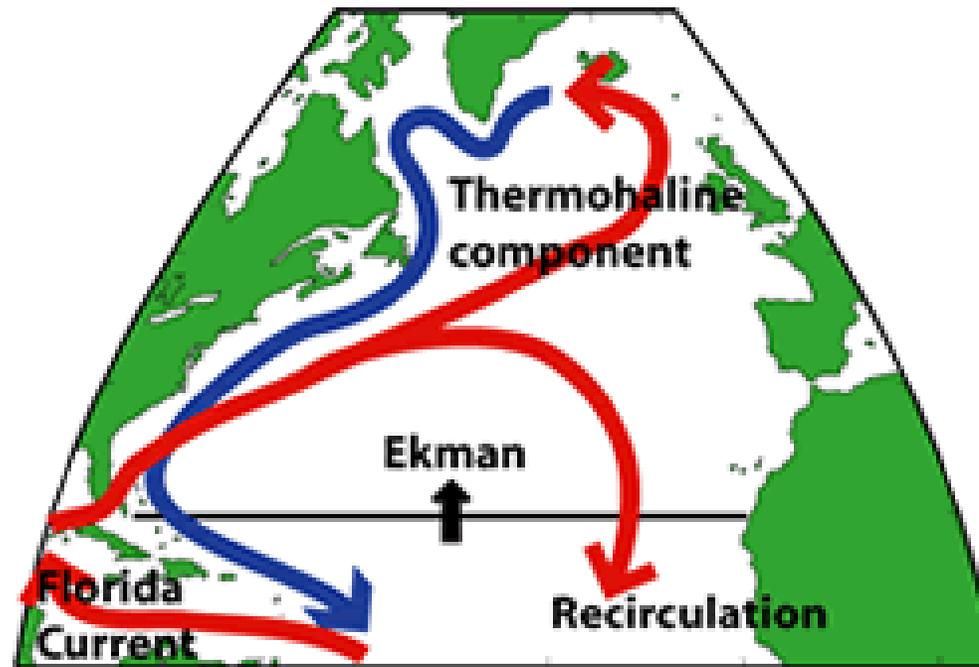
Akitomo (Two types of thermobaric deep convection possible in the Greenland Sea, K. Akitomo, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, C08012, doi:10.1029/2010JC006635, 2011) goes on to state that:

“Thermal-like plumes induced by the thermobaric instability destroy the thermocline (halocline) and transport the cold and less-saline mixed layer water into the warm and more-saline underlying layer. Then the underlying water ascends to push the thermocline (halocline) up until it disappears at the sea surface. It takes only a few days for the thermocline (halocline) to disappear without sea-ice cover.”

Geothermal heating of the bottom waters also strengthens the overturning circulation of the oceans. As Adkins et al. point out:

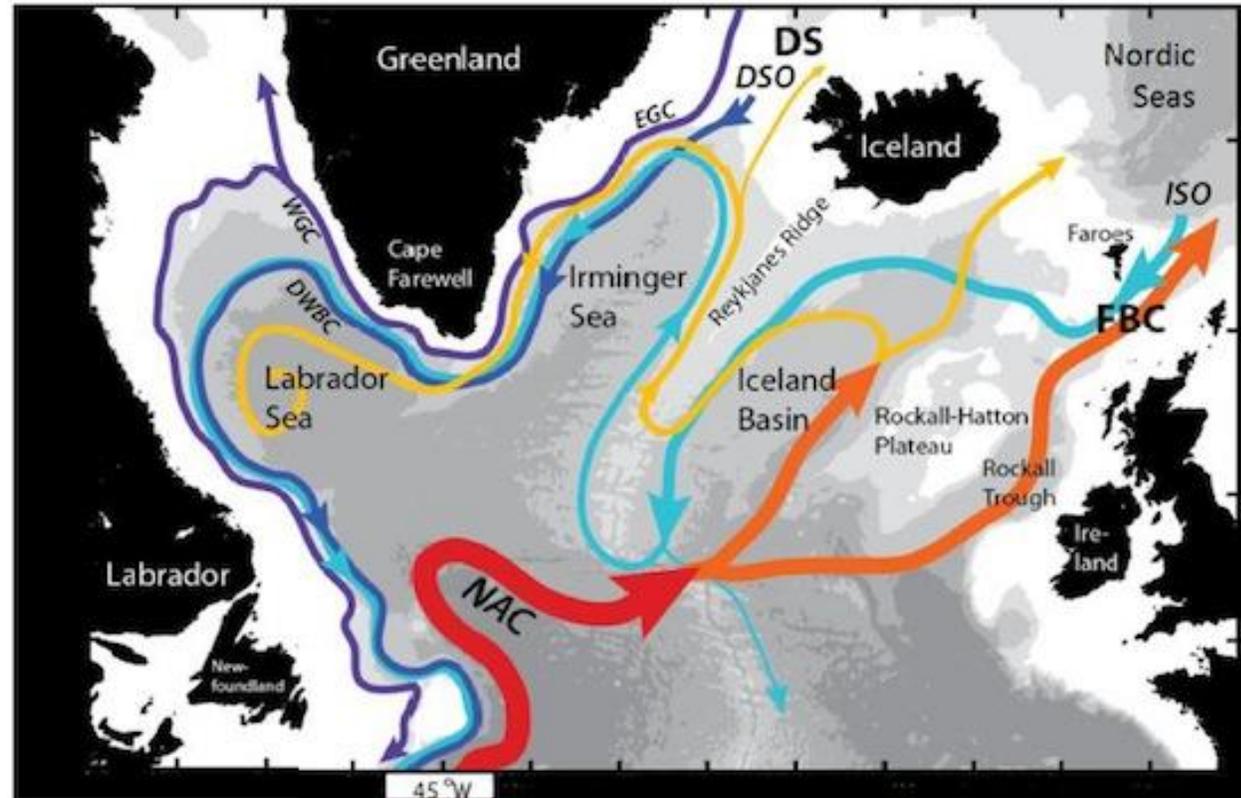
“In modern ocean studies, there is an increasing awareness of the effect of geothermal heating on the overturning circulation.”

(Adkins, J.F., A.P. Ingersoll, and C. Pasquero, 2005: Rapid climate change and conditional instability of the glacial deep ocean from the thermobaric effect and geothermal heating. *Quaternary Science Reviews*, 24, 581-594, doi: 10.1016/j.quasirev.2004.11.005.)



Hofmann and Morales Maqueda note that bottom-water heating strengthens the Atlantic Meridional Overturning Circulation (AMOC) and, in the process, warms the North Atlantic Deep Western Boundary Current by as much as 1.5° C.

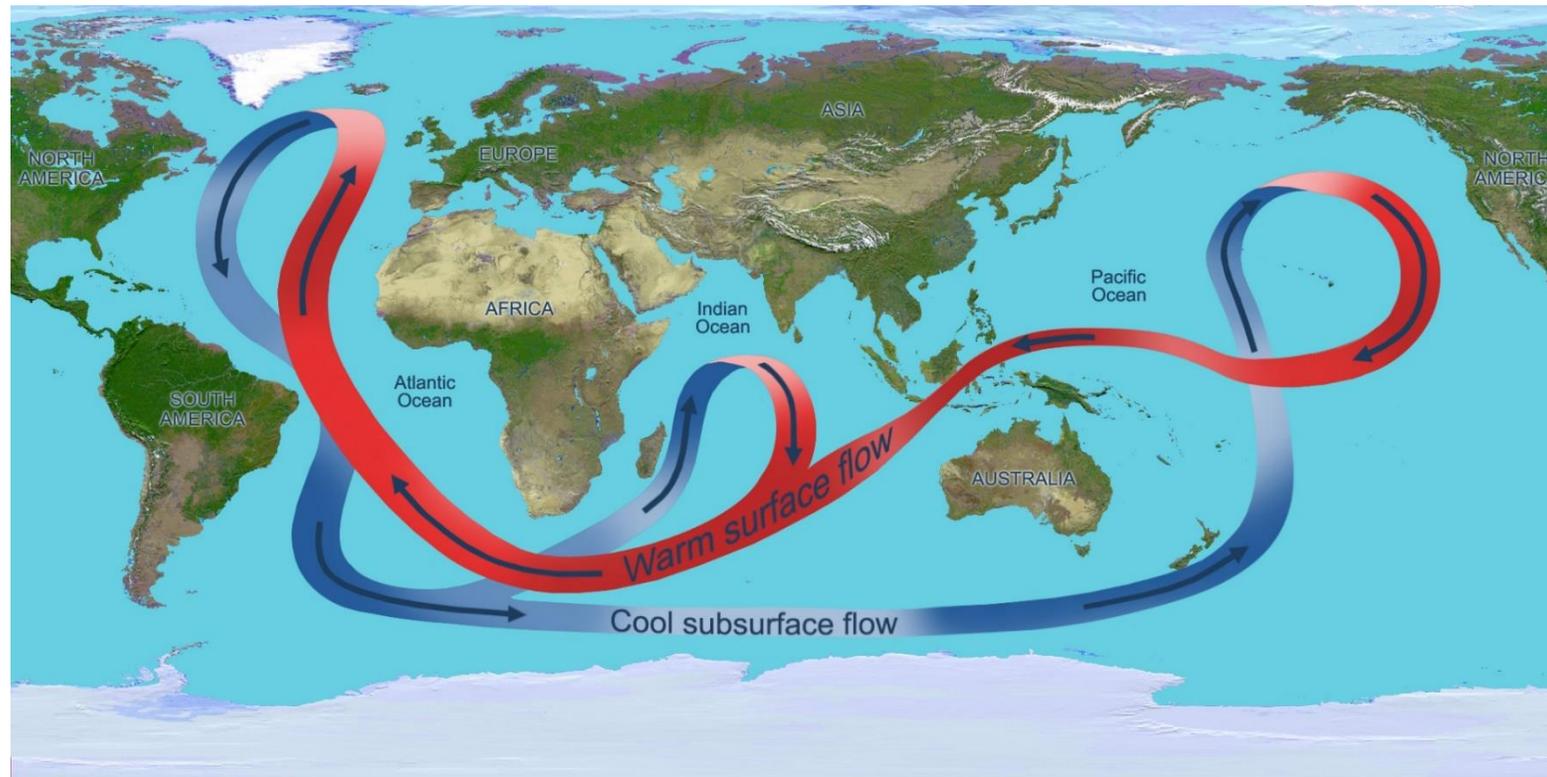
(Hofmann, M., and M. A. Morales Maqueda, 2009: Geothermal heat flux and its influence on the oceanic abyssal circulation and radiocarbon distribution. *Geophysical Research Letters*, 36, doi: 10.1029/2008GL036078.)



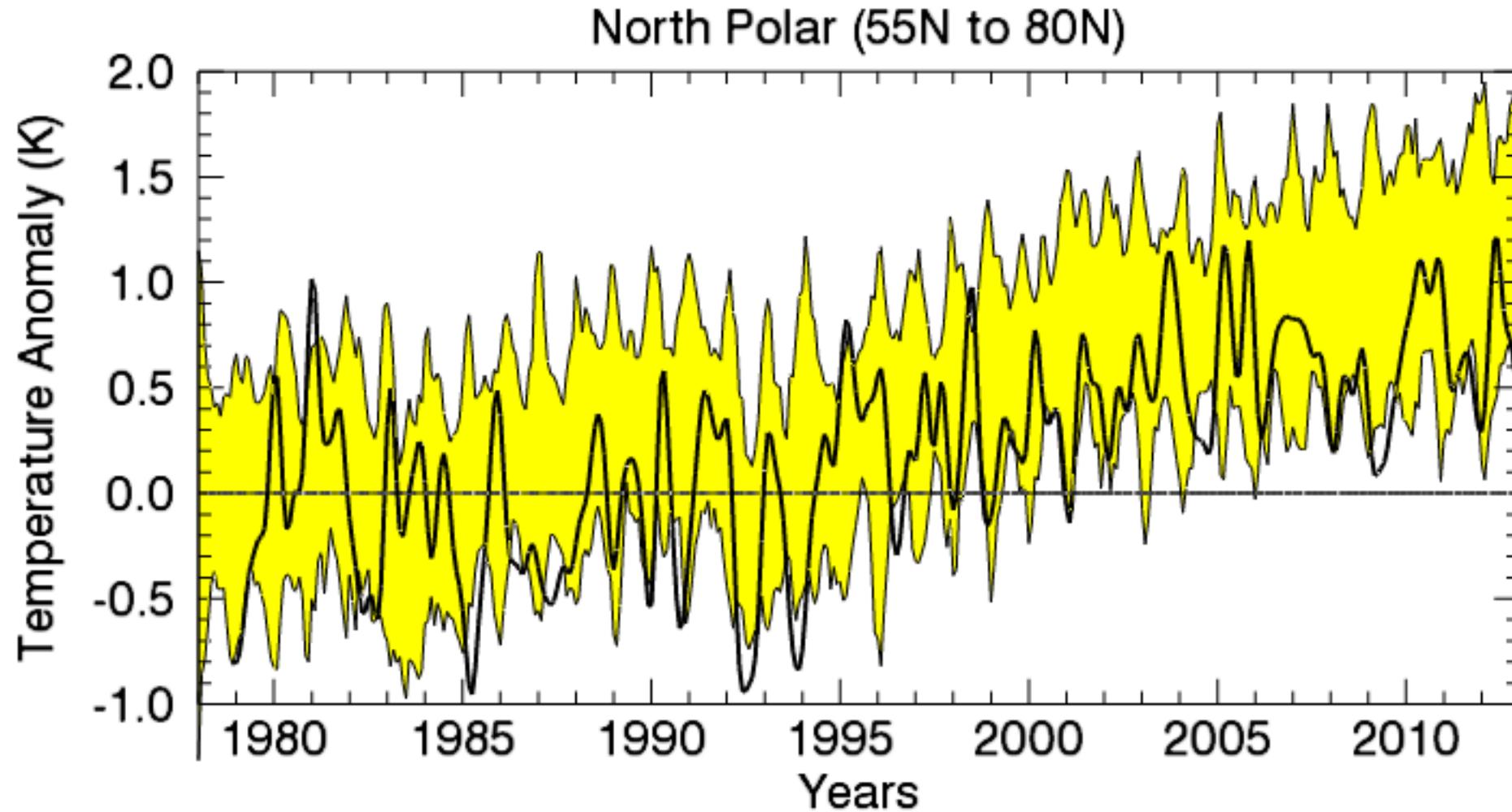
Josh Willis of the Jet propulsion Laboratory sees significant strengthening of AMOC since 1993. *That strengthening accelerates the flow of heat into the Arctic.* In a NASA press release he states:

“This overturning is one part of the vast conveyor belt of ocean currents that move heat around the globe... (and there is) evidence that the circulation had sped up about 20 percent from 1993 to 2009.”

(<http://www.nasa.gov/topics/earth/features/atlantic20100325.html>).

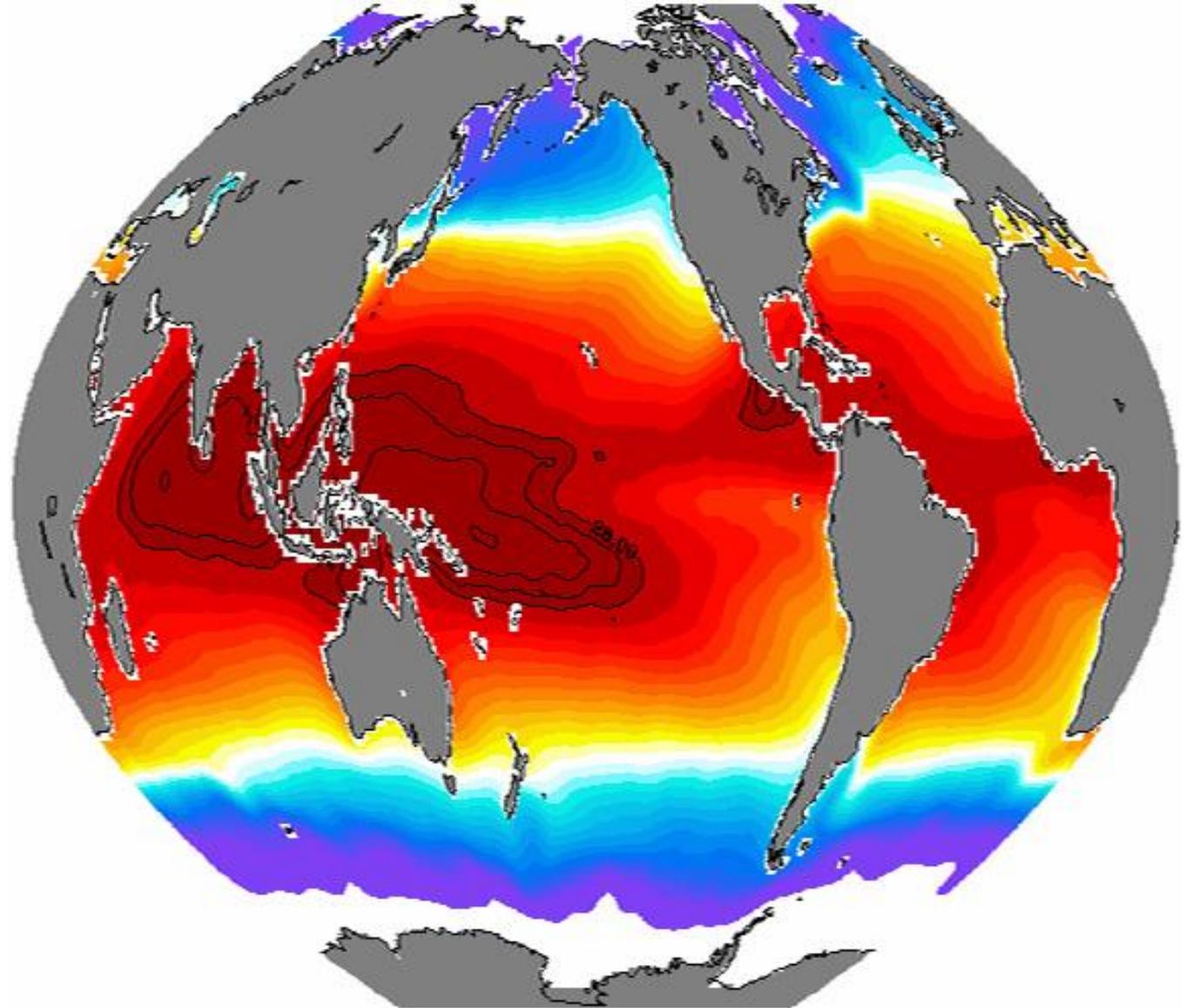


This correlates well with the “Arctic Amplification” phenomenon that has characterized recent warming.



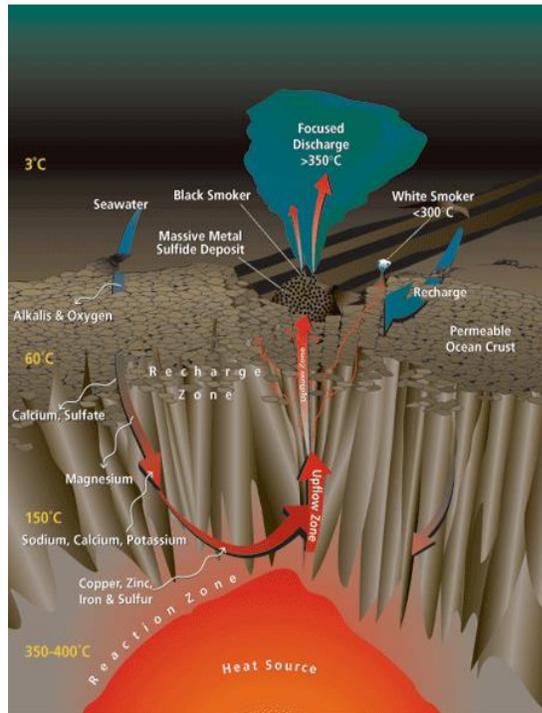
In the Pacific sector, a study by Adcroft et al. shows that geothermal heating leads to a 25% increase in Antarctic bottom water overturning strength and heats the Pacific by roughly 0.5°C.

(Adcroft, A., J.R. Scott, and J. Marotzke, 2001: Impact of geothermal heating on the global ocean circulation. *Geophysical Research Letters*, 28, 1735-1738, doi: 10.1029/2000GL012182)



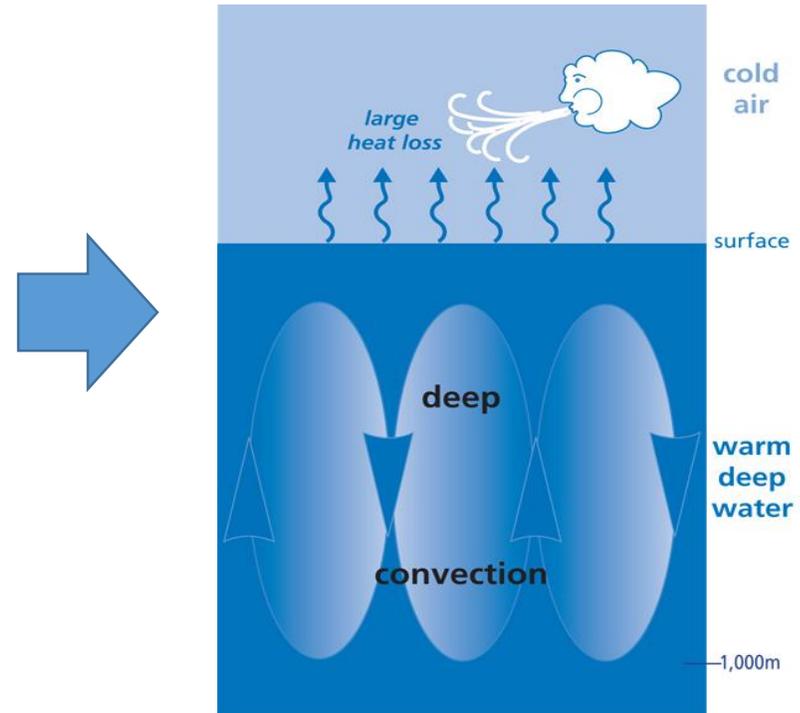
Based on these emerging lines of evidence, we will test the hypothesis:

Increasing
geothermal flux



<http://www.whoi.edu/oceanus/v2/article/images.do?id=2401>

Releases more
ocean heat



<http://www.whoi.edu/oceanus/feature/ocean-conveyors-pump-switches-back-on>

Causing global
temperatures to rise



<http://www.dreamstime.com/royalty-free-stock-photography-global-warming-image3545967>

When we talk “global temperatures” we need to understand that there are a number of datasets that attempt to estimate global temperatures. There are five commonly used datasets, three of which are based on surface temperature readings and two of which are based on satellite estimates of the lower troposphere.

Surface Temperature Estimates:

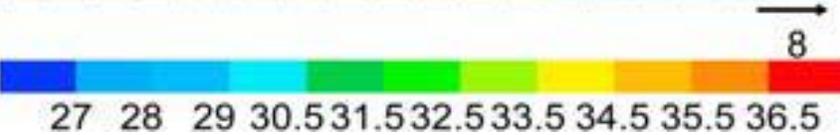
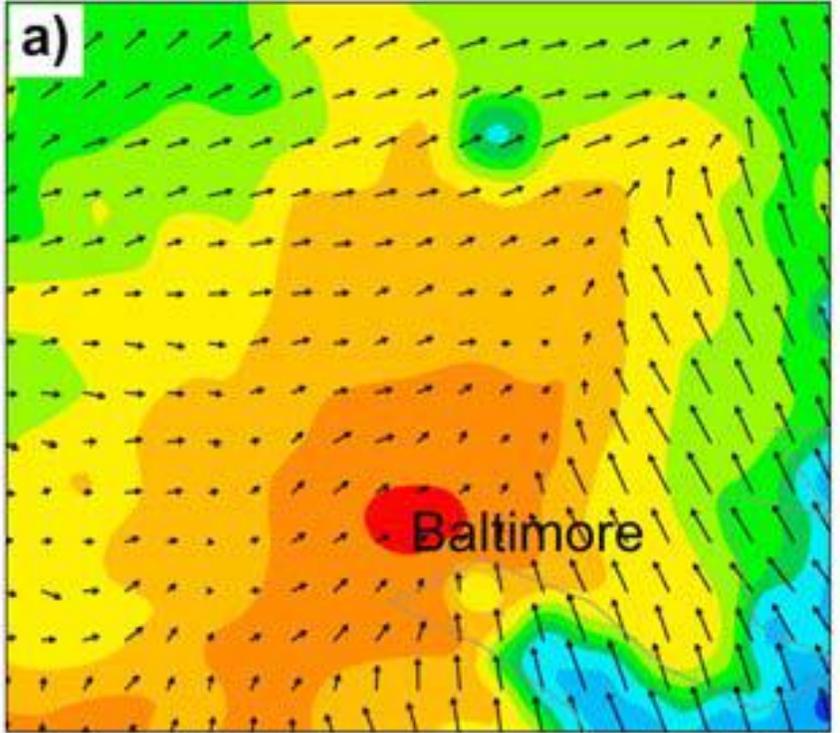
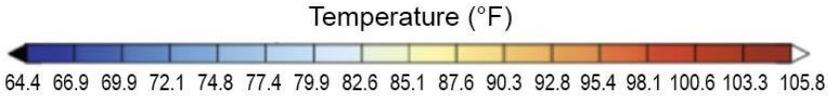
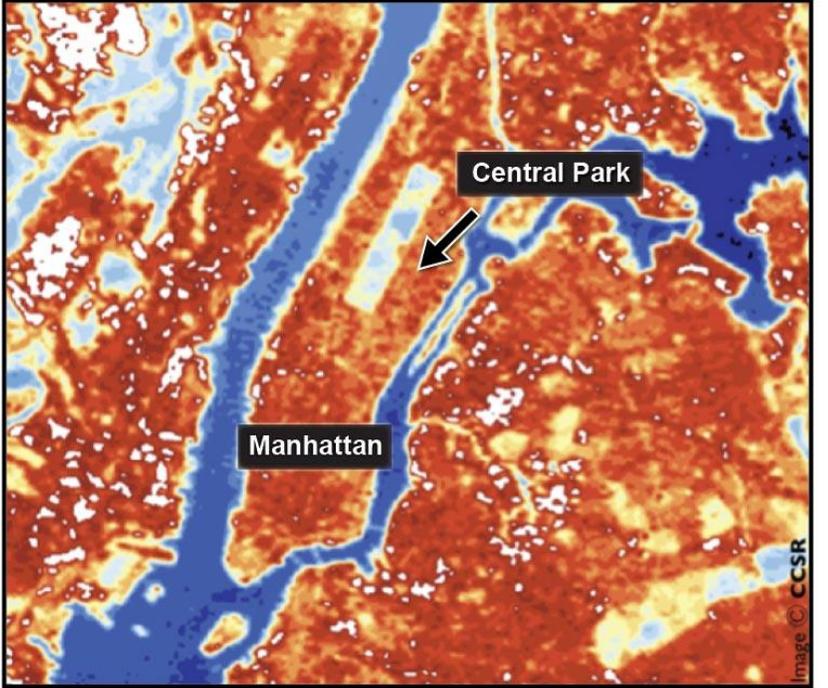
- National Climate Data Center/Global Historical Climate Network
- Goddard Institute for Space Studies
- Had CRUT4

Satellite Estimates:

- University of Alabama – Huntsville (UAH)
- Remote Sensing Systems (RSS)

By some estimates, the satellite data is the “gold standard” as the surface data contain many problems, to include urban heat island effects

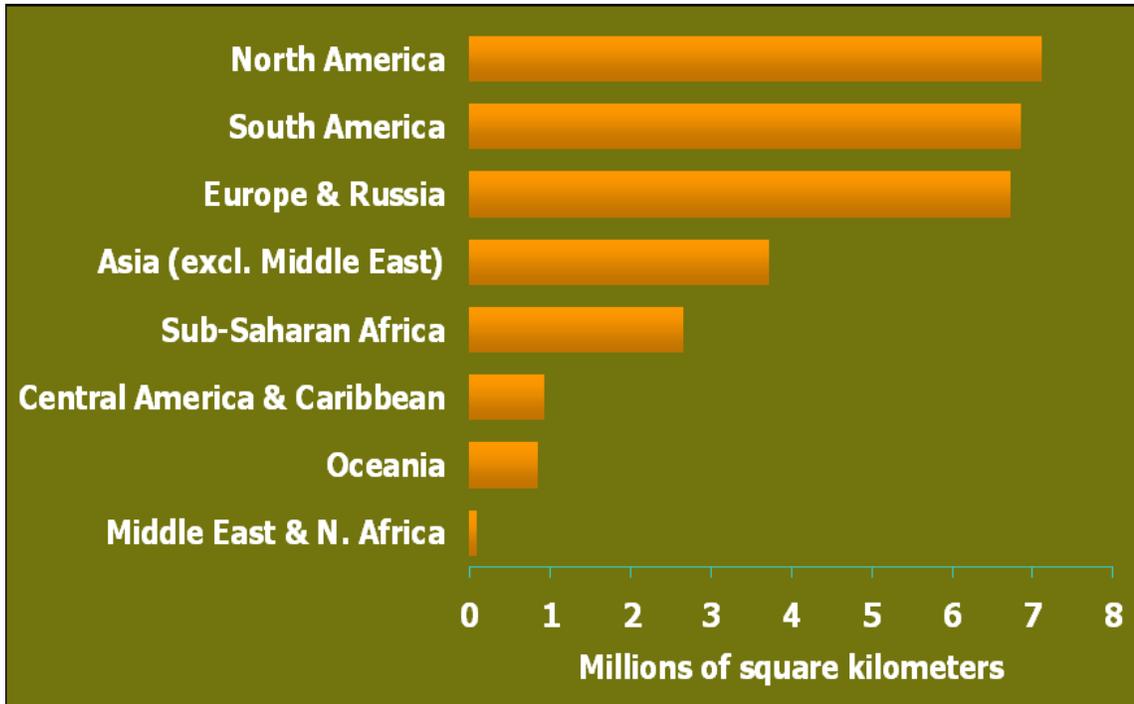
Urban Heat Island



<http://nca2014.globalchange.gov/report/regions/northeast>

<http://onlinelibrary.wiley.com/doi/10.1029/2009GL041082/pdf>

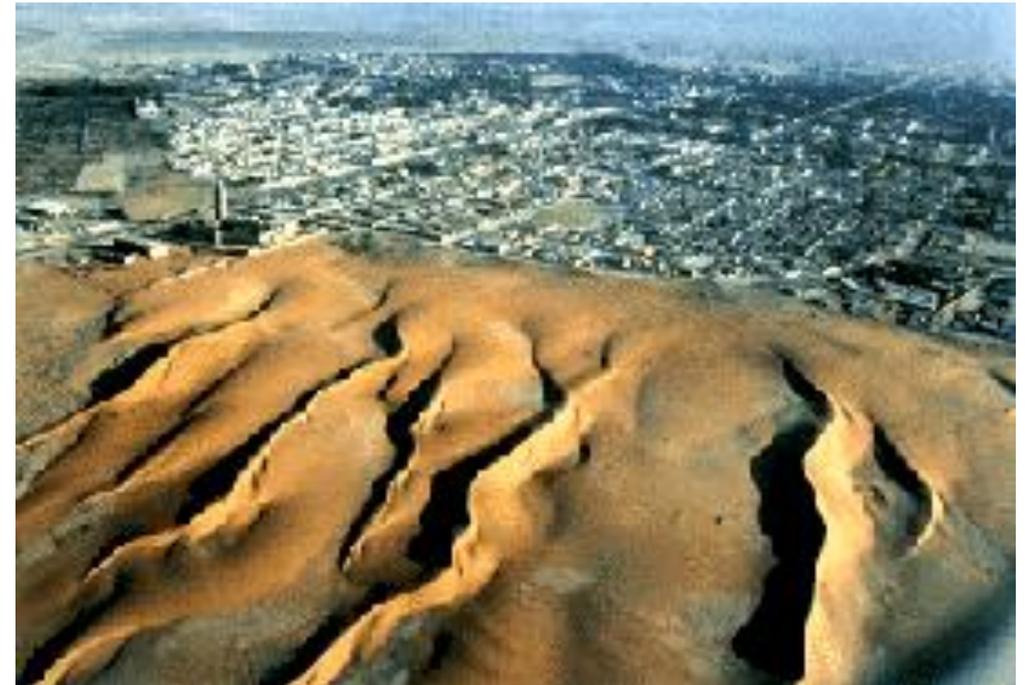
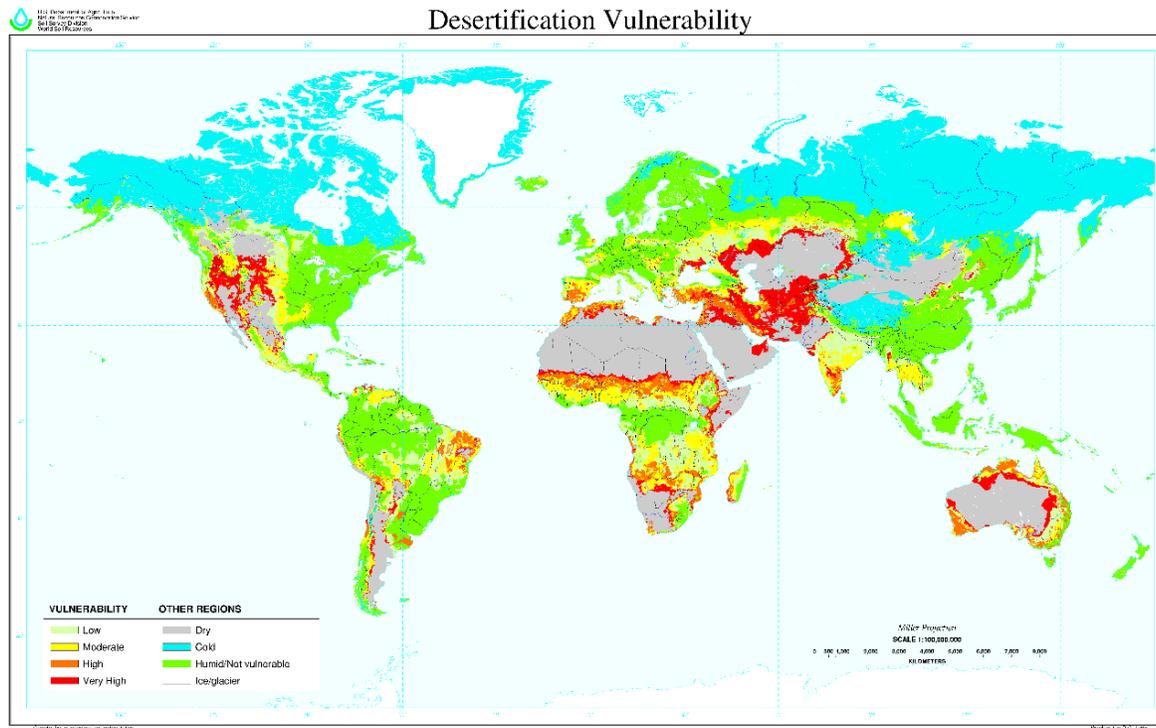
Deforestation effects



<http://www.globalchange.umich.edu/globalchange2/current/lectures/deforest/deforest.html>

<https://sites.psu.edu/sputteringspeechspace/2013/11/21/rc10-amazon/>

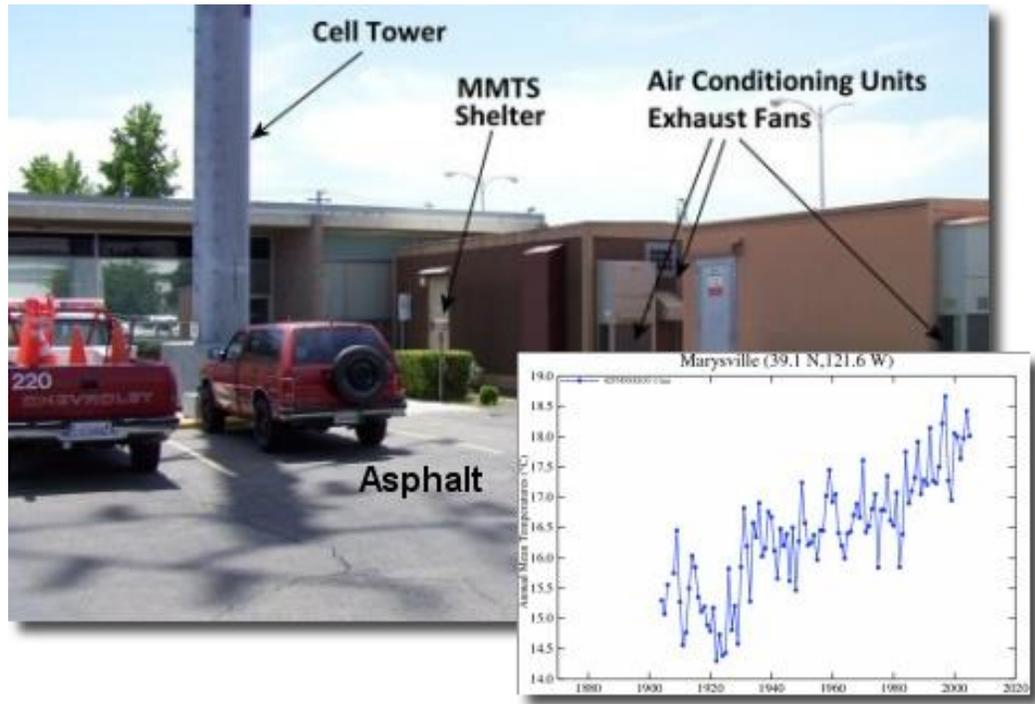
Effects of desertification



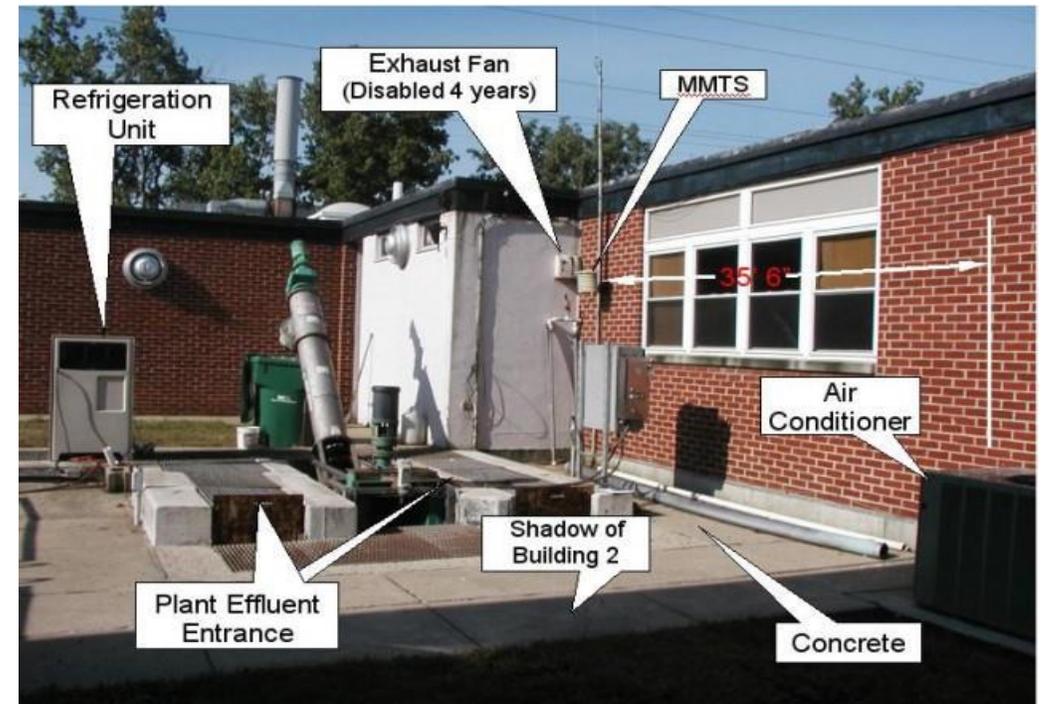
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/use/maps/?cid=nrcs142p2_054003

<http://pubs.usgs.gov/gip/deserts/desertification/>

Poor instrument siting

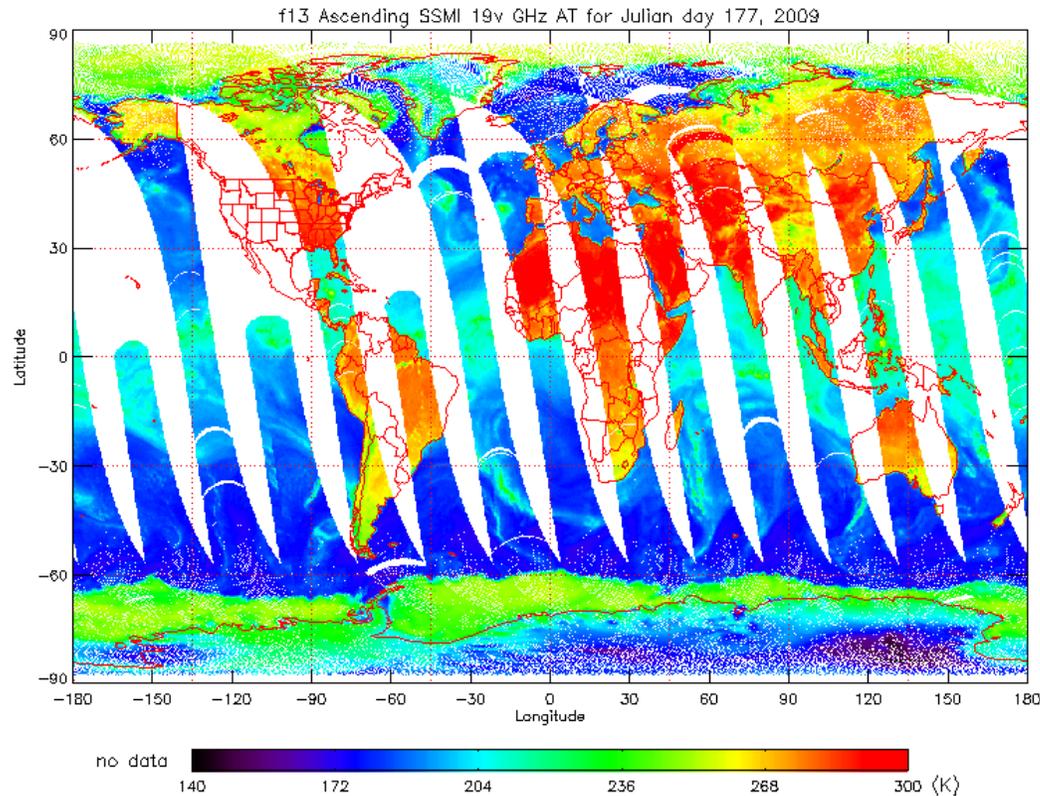


<http://wattsupwiththat.com/2012/07/30/my-response-to-ncdcs-op-ed-in-the-new-york-times/>

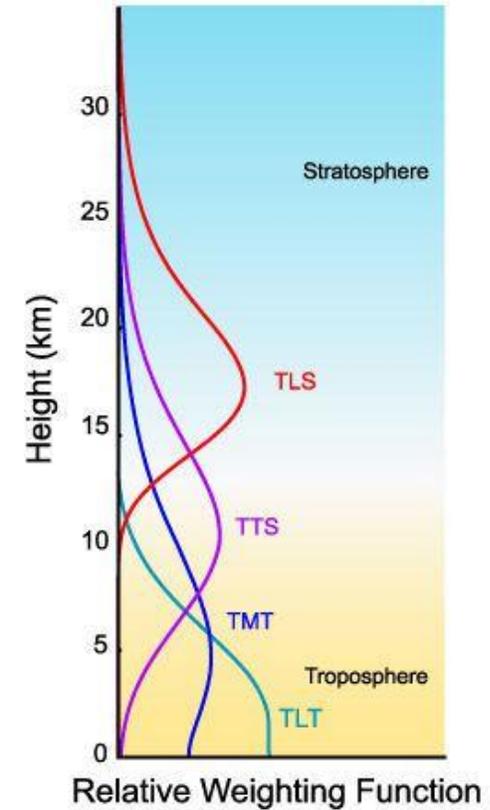


<http://globalwarmingsolved.com/2013/11/summary-has-poor-station-quality-biased-u-s-temperature-trend-estimates/>

Additionally, satellites have 97% to 98% global coverage whereas surface data is relatively spotty. The satellite data also agree well with radiosonde data.

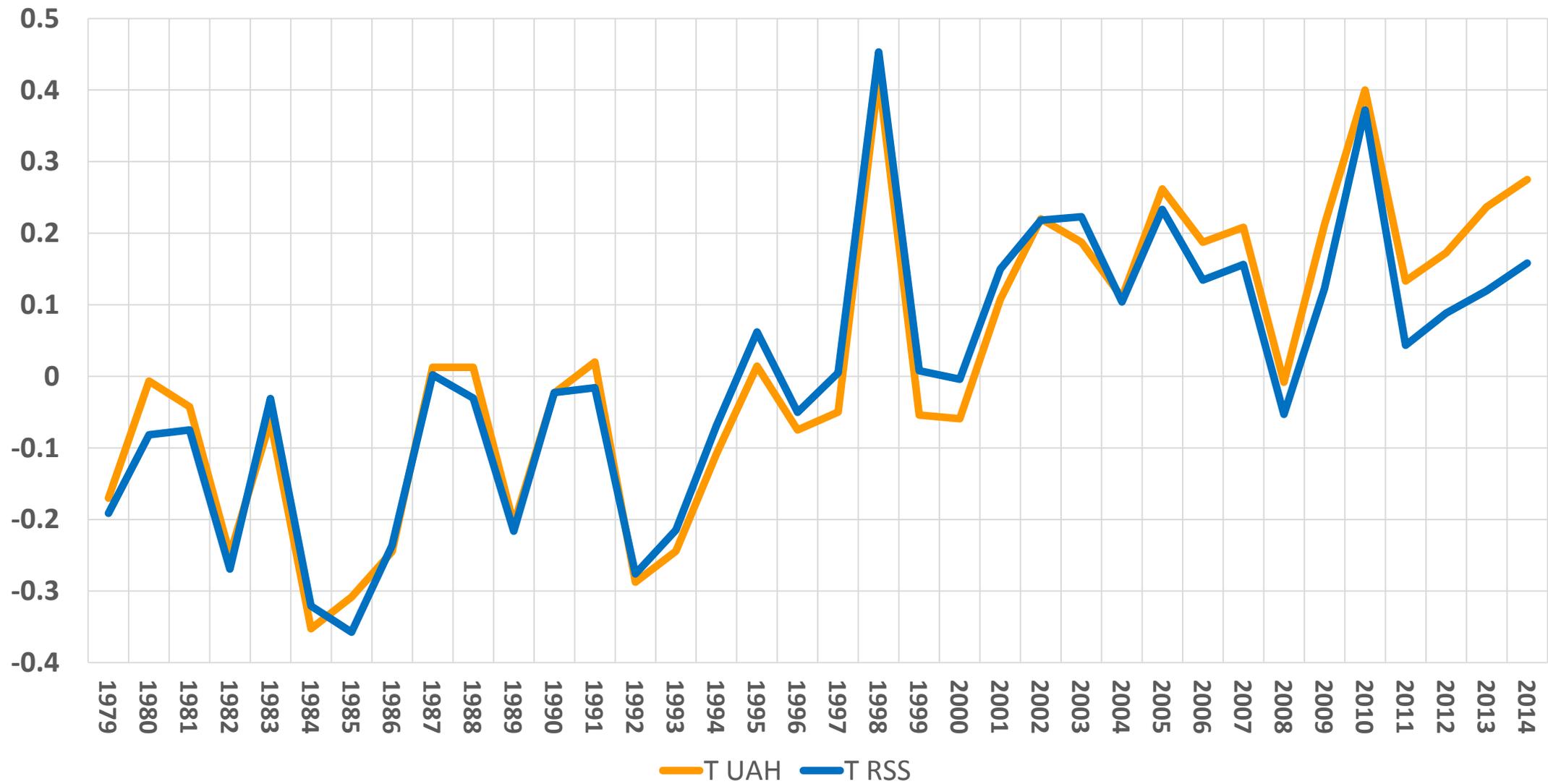


<https://catalog.data.gov/dataset/noaa-climate-data-record-cdr-of-ssm-i-and-ssmis-microwave-brightness-temperatures-rss-version-7>



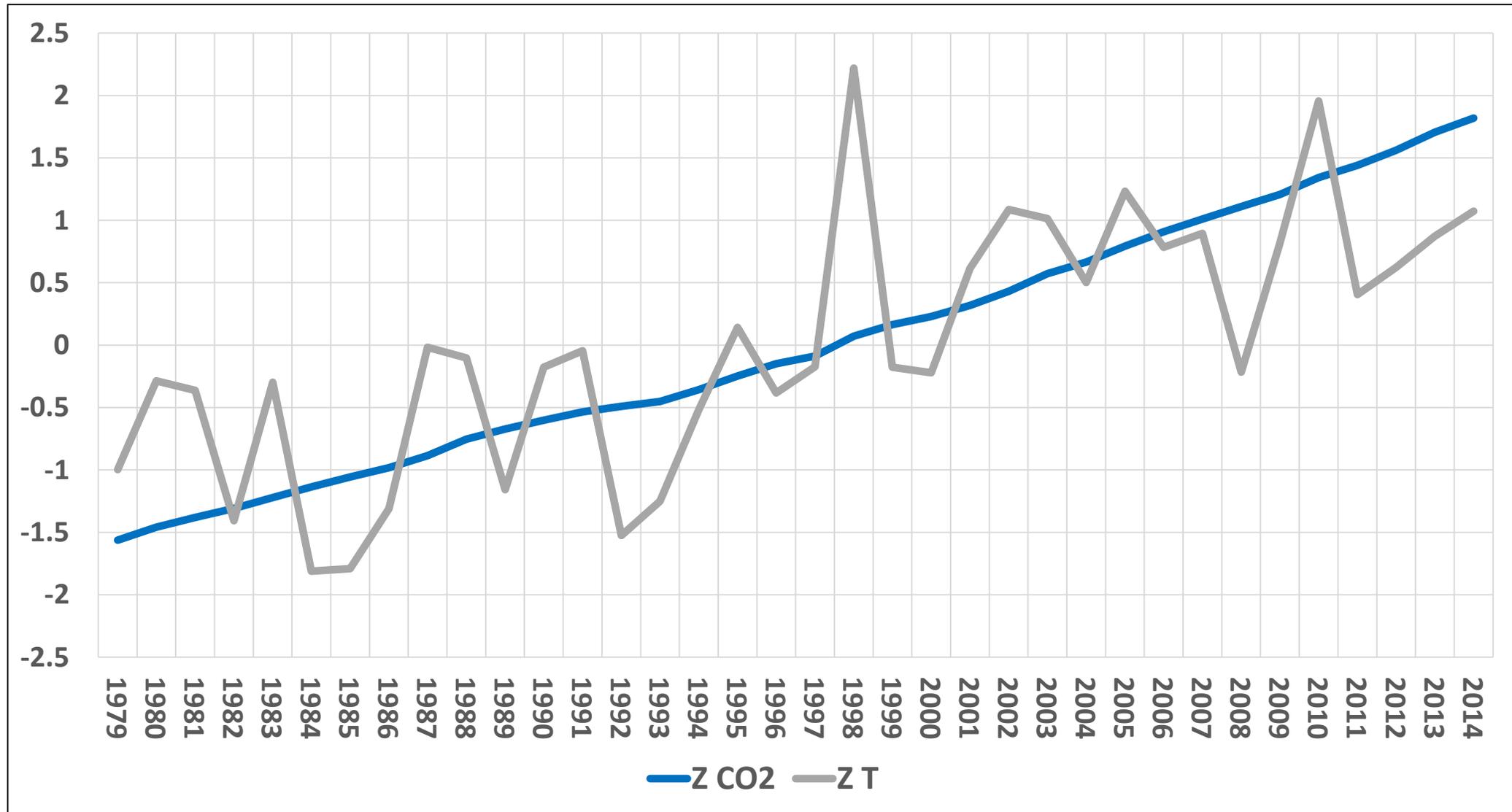
<https://noconsensus.wordpress.com/2009/01/23/bifurcated-temperature-trend/>

These are the UAH and RSS data sets for the lower troposphere.



Source: UAH, RSS

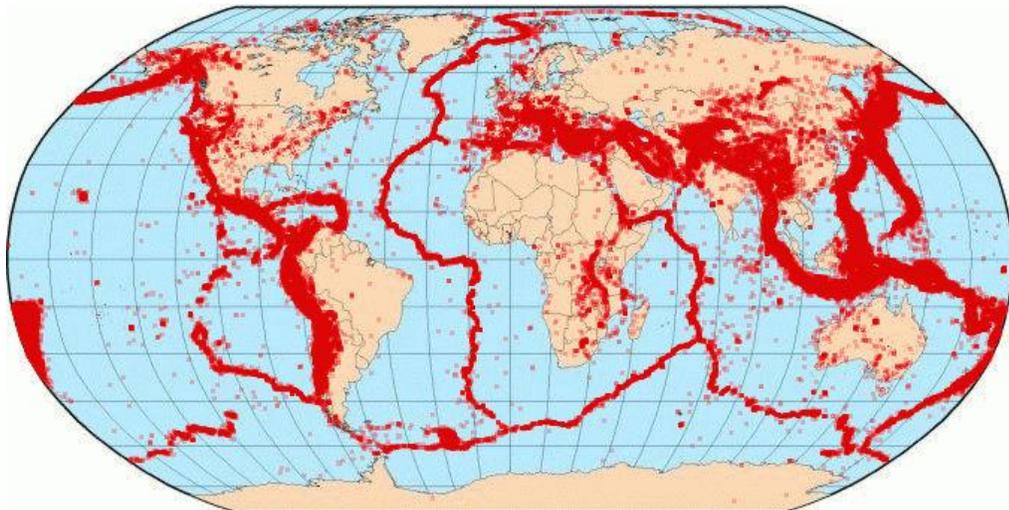
This shows CO2 plotted against the blended satellite data. The correlation between atmospheric CO2 and lower tropospheric temperatures is .719.



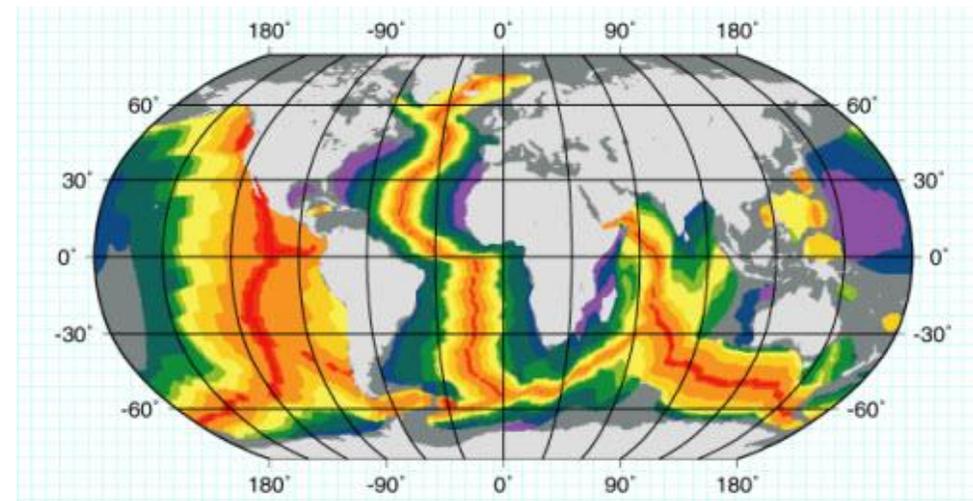
In order to assess changes in geothermal flux, seismic activity is used as a proxy. According to Libby and Libby:

“High geothermal heat fluxes correlate with enhanced seismicity, and with faulting, upwelling, and enhanced productivity of bio-organic material, phosphoritic and uranium bearing rocks, and sediments containing hydrocarbons.”

(Libby, L. M., and W.F. Libby, 1974: Geographical coincidence of high heat flow, high seismicity, and upwelling, with hydrocarbon deposits, phosphorites, evaporites, and uranium ores. *Proceedings National Academy of Sciences*, 71, 3931-3935, doi: 10.1073/pnas.71.10.3931)



<https://www.flickr.com/photos/btard/4438692900>

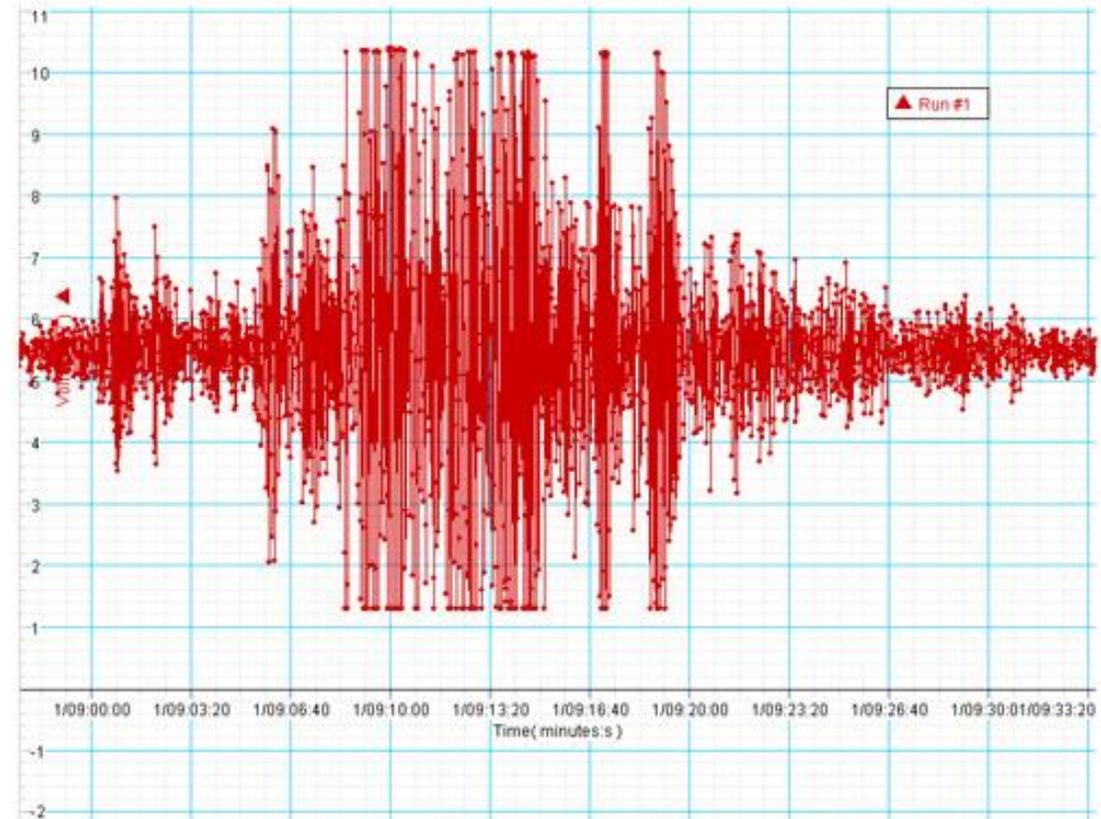


<http://www.skepticalscience.com/heatflow.html>

Spreading zone seismic events are predominantly low magnitude events (1 – 3), with maximum magnitudes of 6 (Searle, R., 2013: *Mid-Ocean Ridges*. Oxford University Press, 330 pp). Although the global seismic network captures a smaller percentage of these low magnitude events, seismic activity in the 4.0 – 4.4 range (MAG4/4.4) yields some remarkable results.



<http://www.edu.pe.ca/gulfshore/Archives/Earthquakes/seismo.htm>

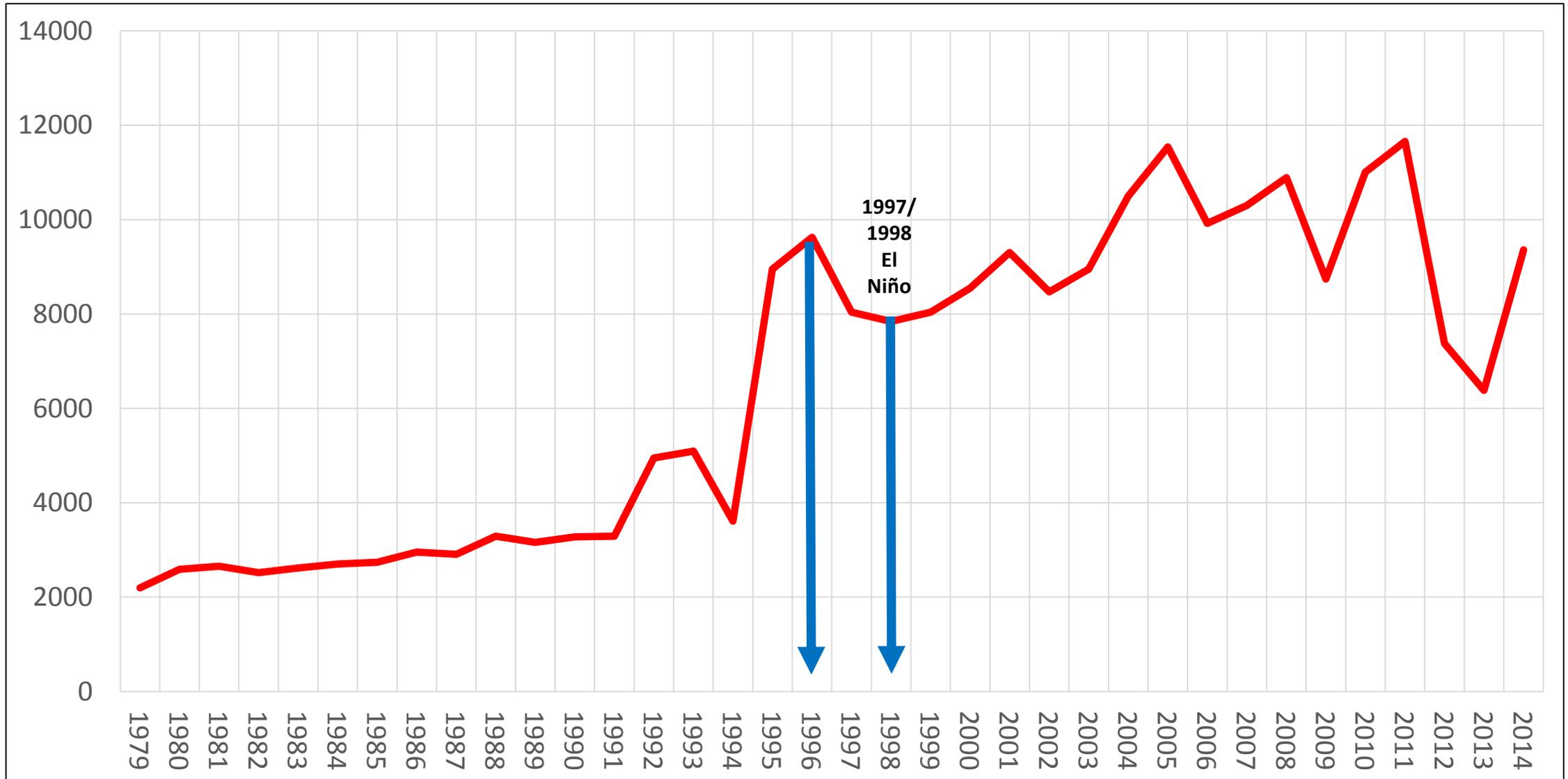


<http://science.uniserve.edu.au/school/Seismograph/datalogger/>

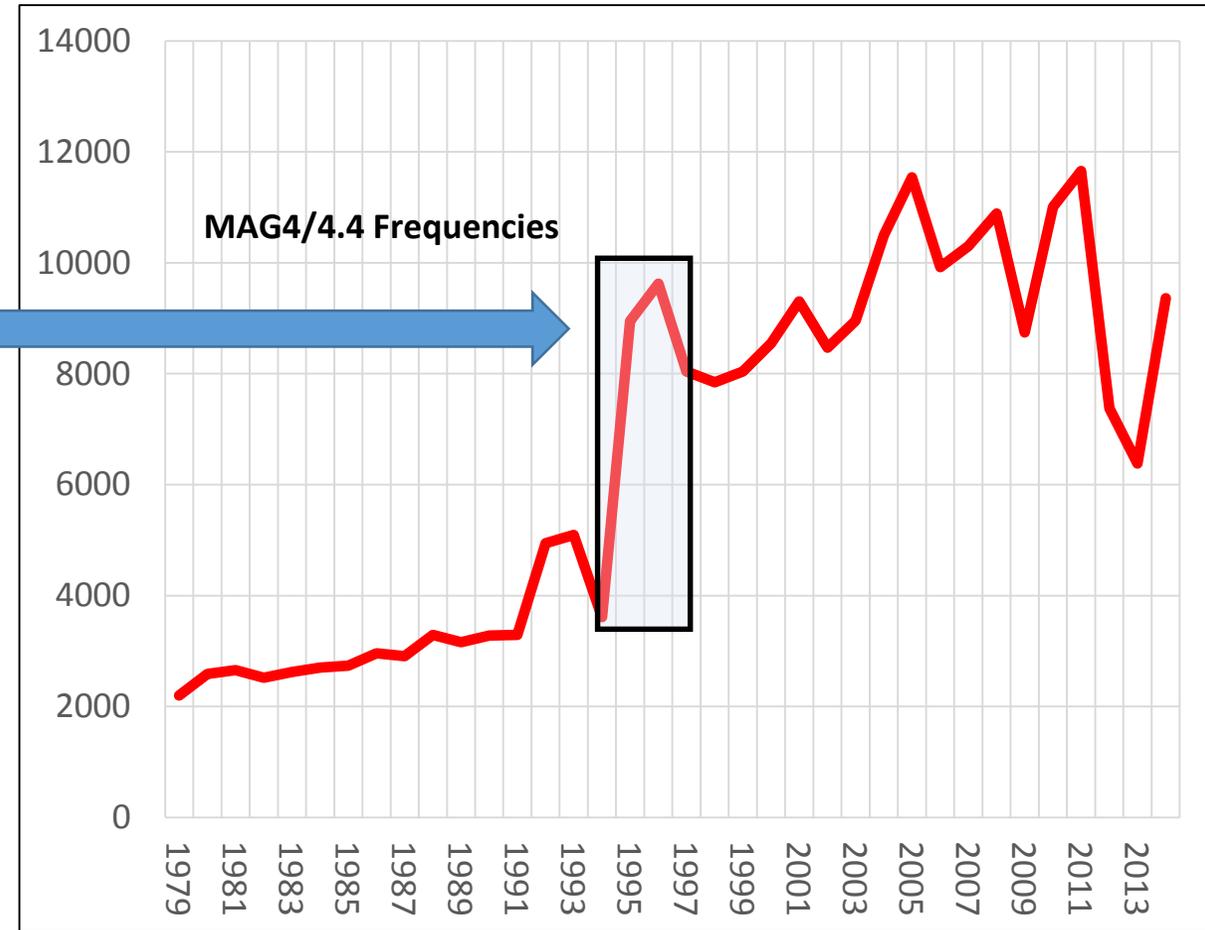
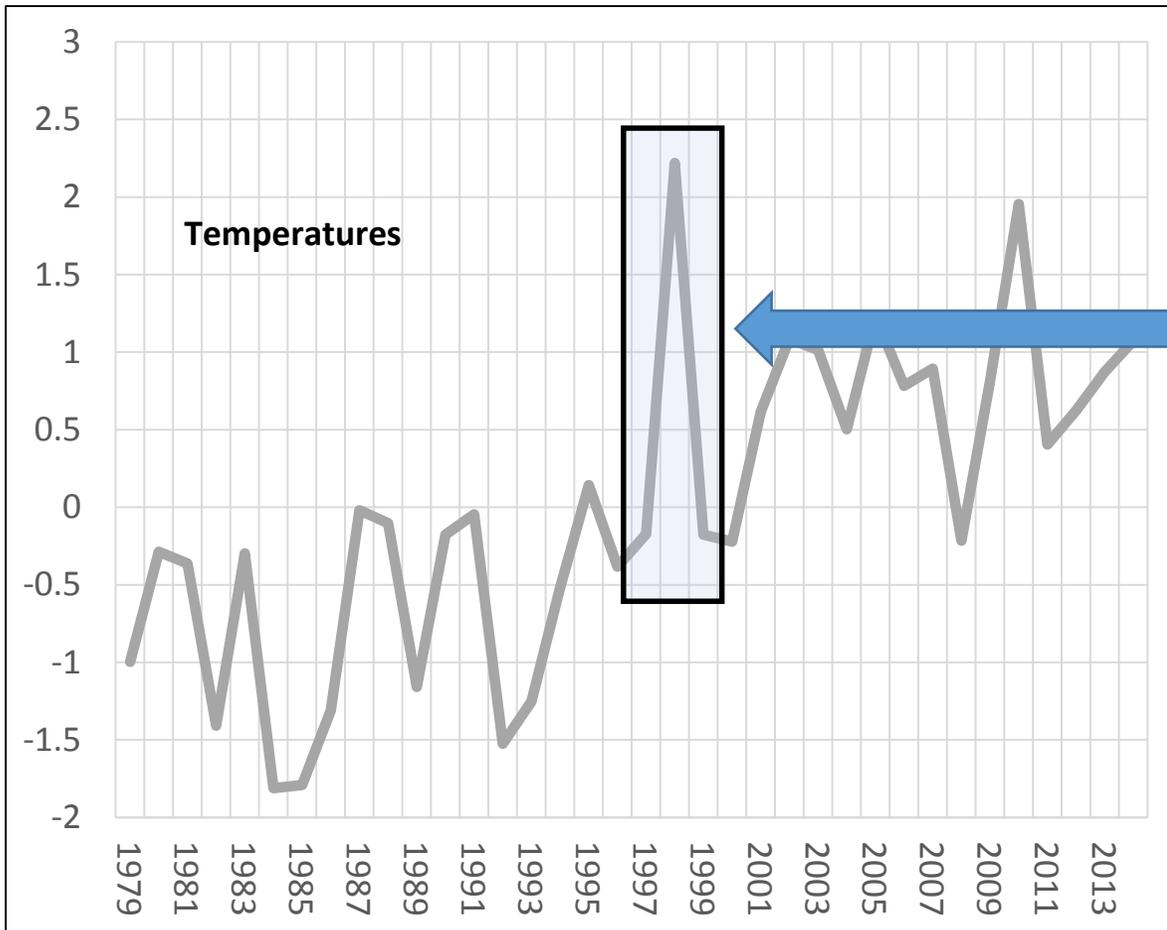
A sampling of High Geothermal Flux Areas (HGFA) from 1994 to 1996 reveals that these areas experienced a nearly *600% increase in MAG4/4.4 activity.*

HGFA Earthquake Frequency, MAG4/4.4			
	<u>1994</u>	<u>1996</u>	<u>% Increase</u>
Fiji	60	292	387%
Mariana	22	99	350%
Papua	78	464	495%
Banda	9	78	767%
Biak	0	168	N/A
Mid Atlantic Ridge	12	117	875%
	181	1,218	573%

These are the global frequencies for MAG4/4.4 events. As with the HGFA data, we see a huge jump in MAG4/4.4 frequencies 2 years prior to the record-setting 1997/1998 El Niño.



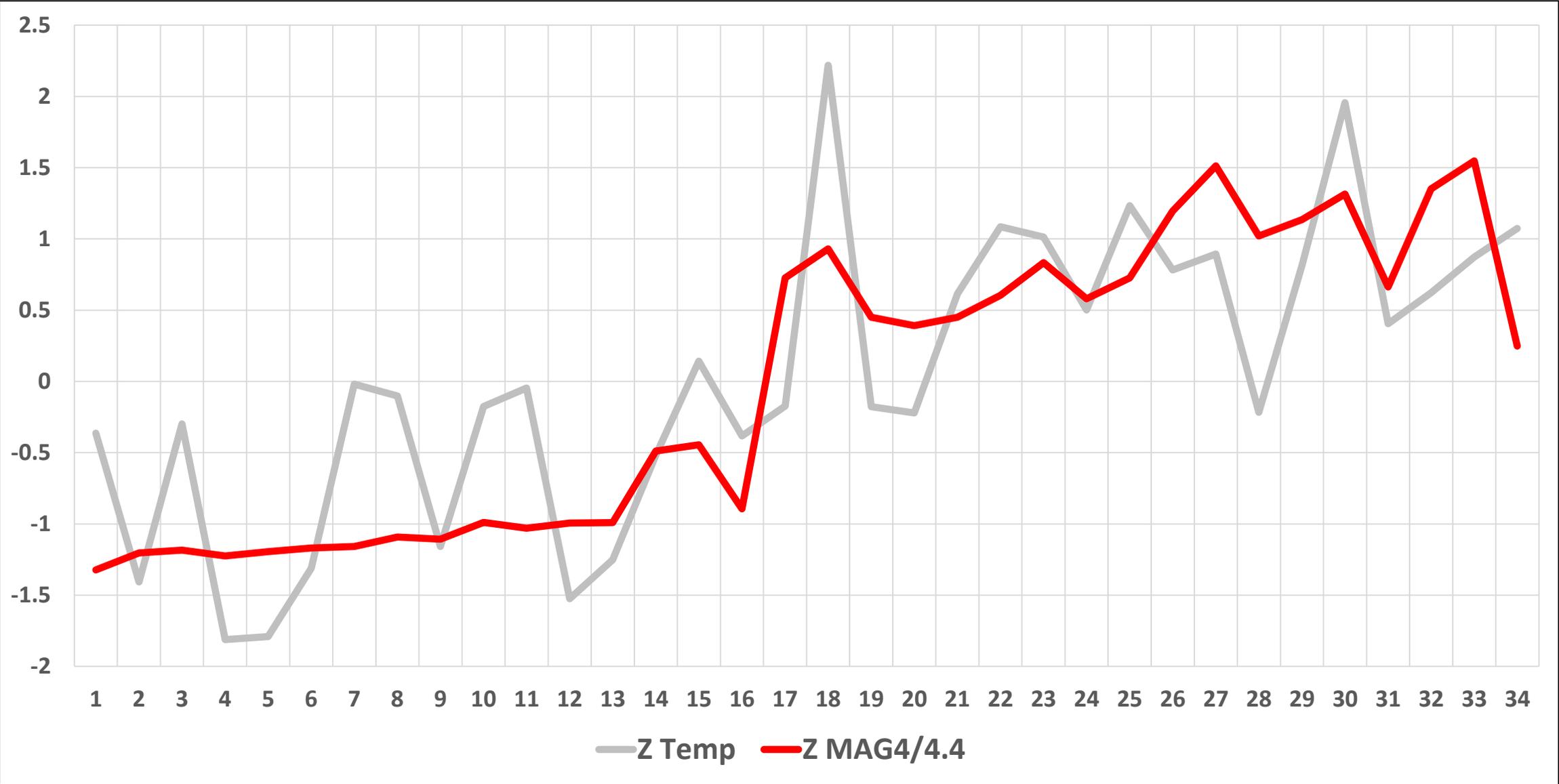
This is a significant find in that it suggests a time-lagged, seismic “amplifier” for the 1997 – 1998 El Niño, the largest El Niño on record. We can call this **SIENA**, for **S**eismically **I**nduced **E**l Niño **A**mplification.



Source: UAH, RSS

http://ds.iris.edu/wilber3/find_event

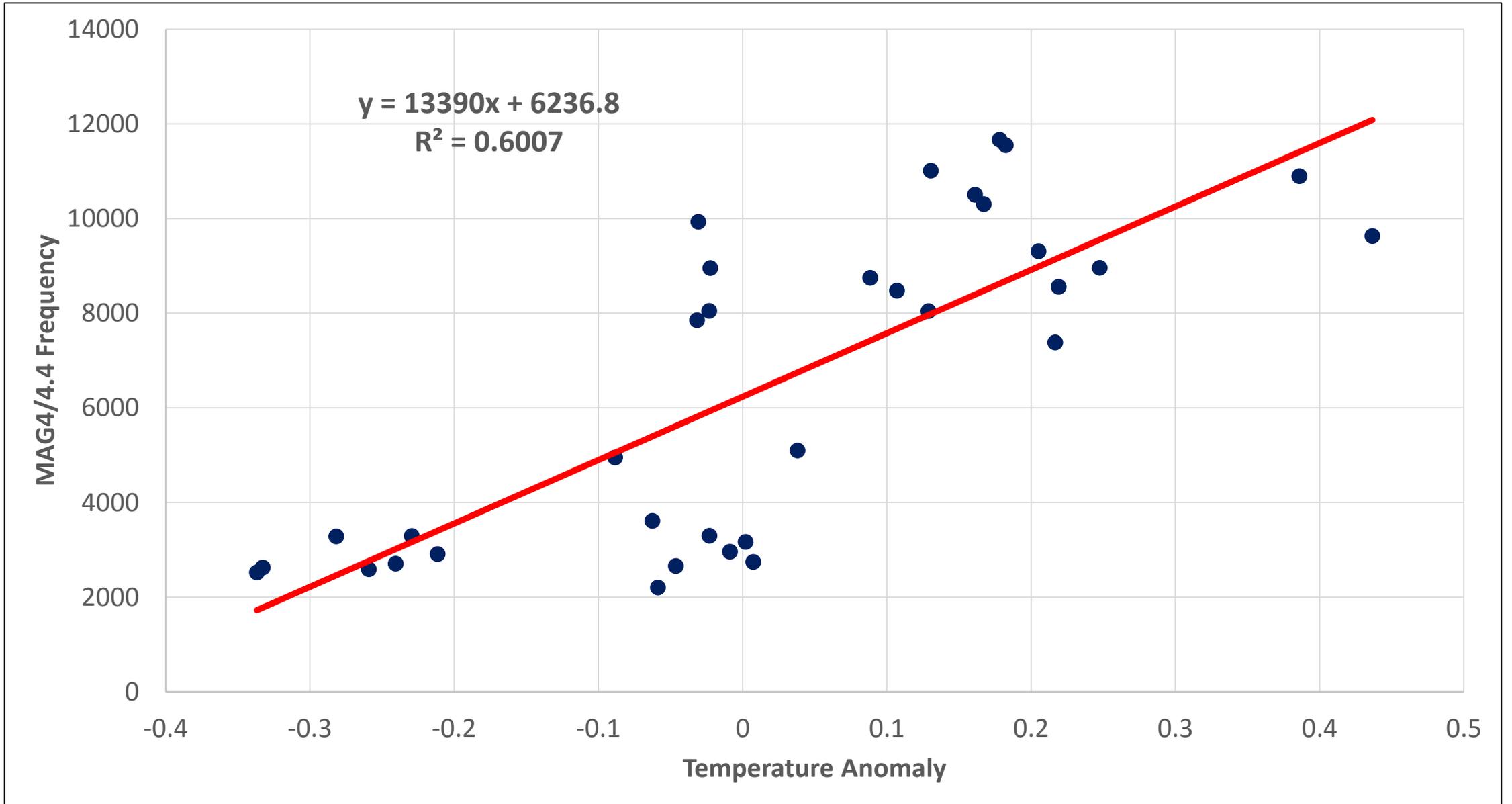
Fitting the MAG4/4.4 data to the lag adjusted (2 years) satellite temperatures (z - scores are displayed) reveals a remarkably good fit. In fact, the correlation is .775, higher than the CO2/temperature correlation (.719).



Source: UAH, RSS

http://ds.iris.edu/wilber3/find_event

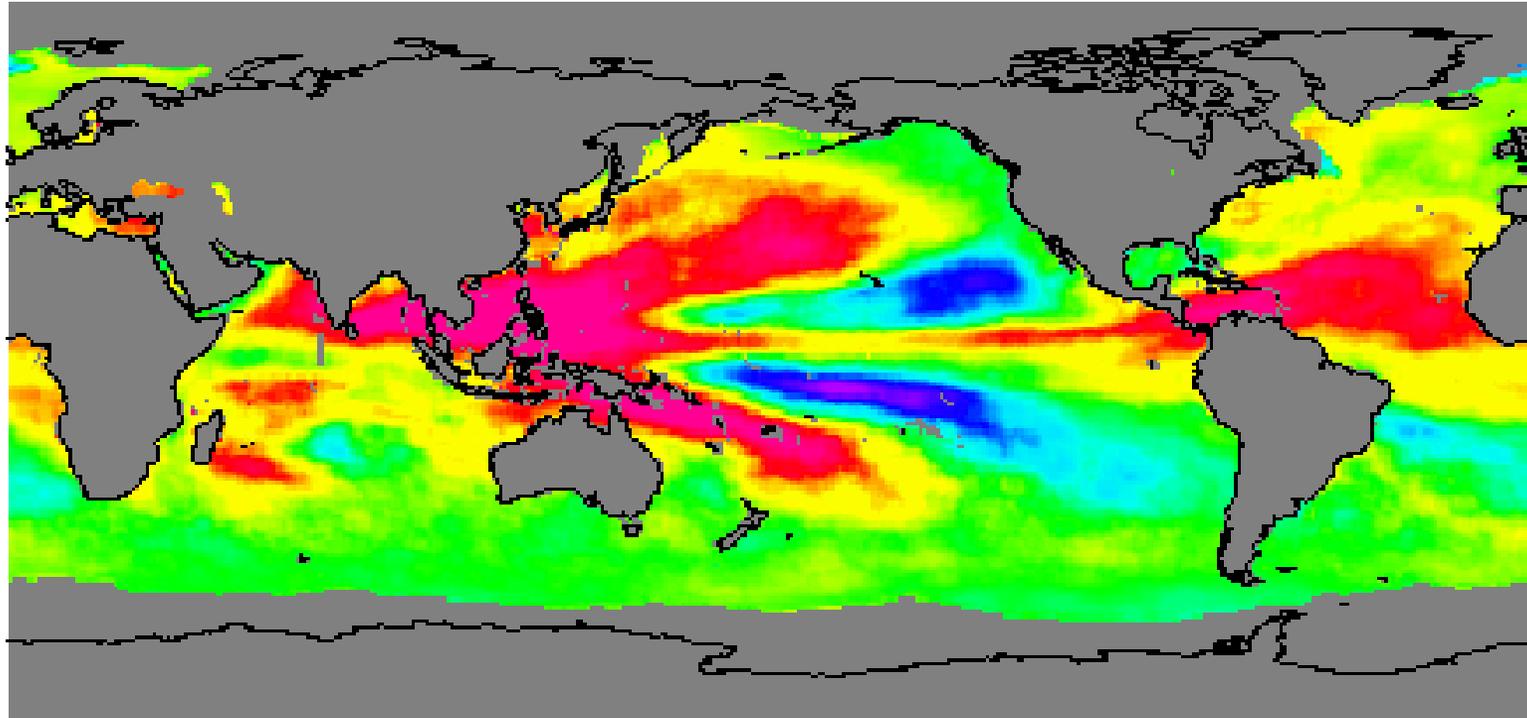
The correlation between MAG4/4.4 and temperature is *statistically significant at the .001 level* ($P=7.40712E-08$). The Durbin-Watson test yields a statistic of 2.1, indicating no significant autocorrelation.



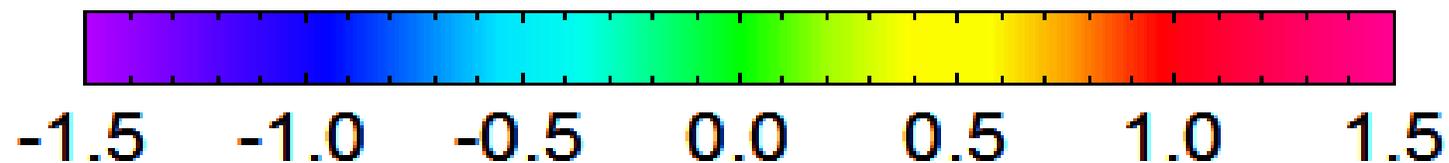
Multiple regression analysis reveals that MAG4/4.4 frequency is a significant predictor of global temperatures. CO2 does not significantly add to the explained variance and *is dropped from the analysis.*

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.776807447							
R Square	0.603429809							
Adjusted R Square	0.577844636							
Standard Error	0.126303054							
Observations	34							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	2	0.752481959	0.376240979	23.585136	5.9424E-07			
Residual	31	0.494526305	0.015952461					
Total	33	1.247008264						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.719033789	0.964167761	-0.745755893	0.4614327	-2.6854669	1.247399323	-2.685466901	1.247399323
EQ 4-4.4	3.86732E-05	1.48657E-05	2.601503757	0.0141024	8.3544E-06	6.8992E-05	8.35438E-06	6.8992E-05
CO2	0.001325869	0.002859893	0.463608008	0.6461674	-0.0045069	0.00715866	-0.004506921	0.00715866

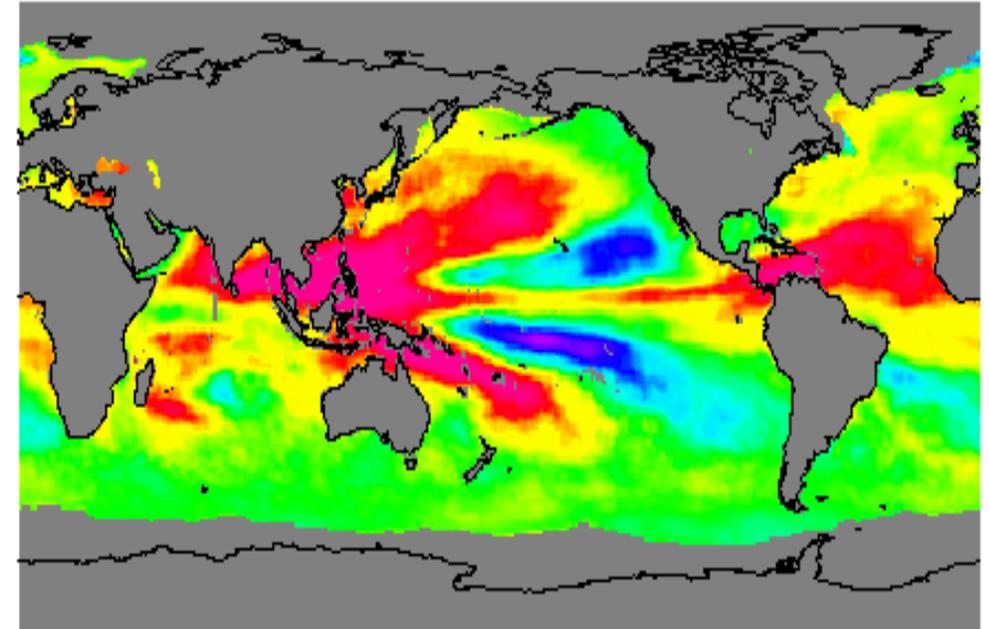
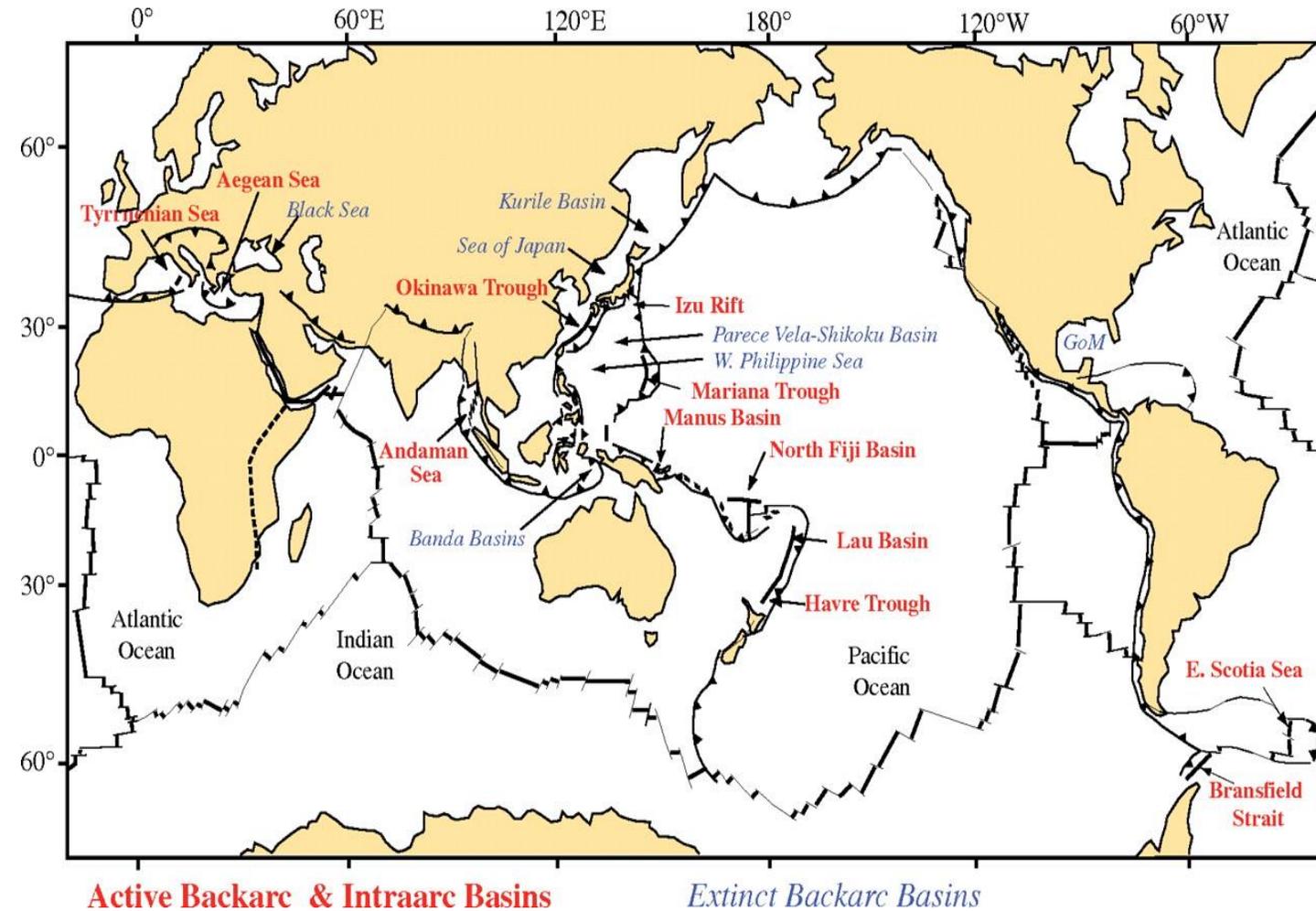
Other lines of evidence support the geothermal flux/recent warming link. This image, produced by Remote Sensing Systems, shows the pattern of recent water vapor increases across the globe.



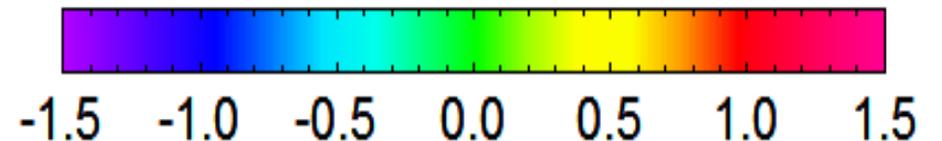
Trend in Water Vapor, 1988-2012 (mm/decade)



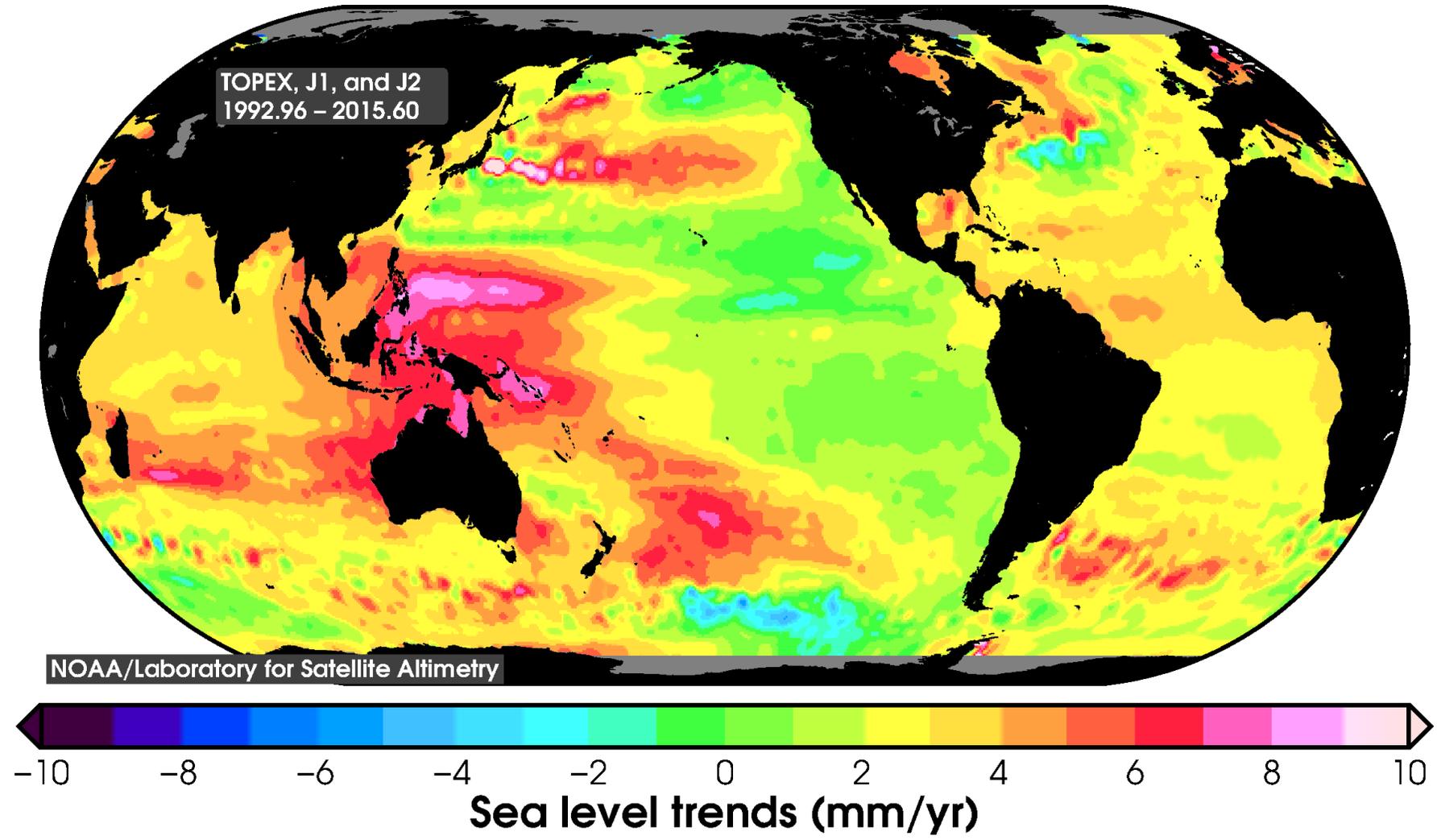
The spatial pattern closely resembles the distribution of the globe's HGFA. It is sound geophysical reasoning to conclude that a warmer, more buoyant water column will have higher evaporation rates.



Trend in Water Vapor, 1988-2012 (mm/decade)

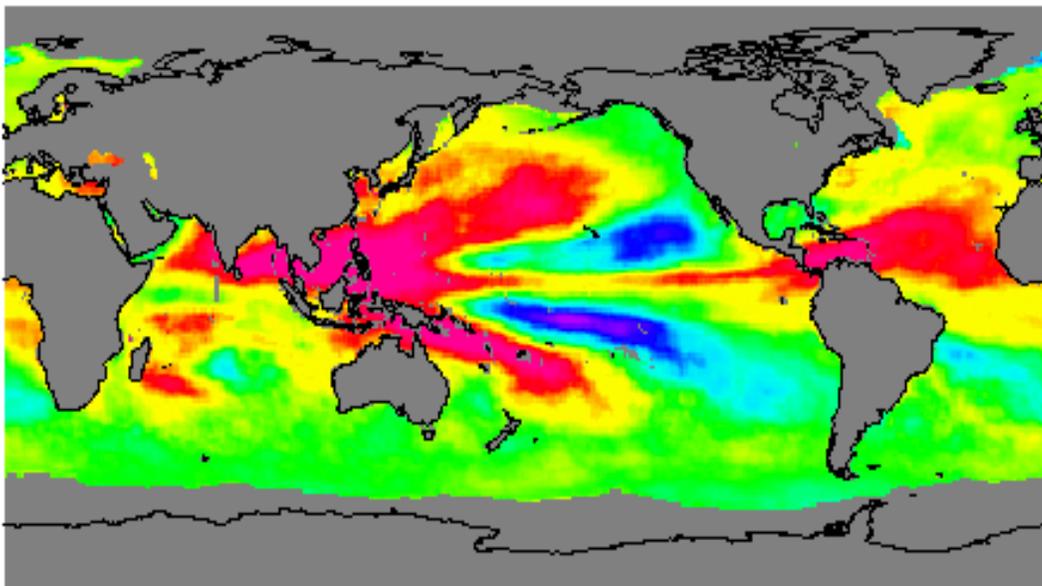


This sea level rise map from NOAA shows a similar spatial pattern. We can logically deduce that convective plumes will expand the water column, causing sea levels to rise in these areas.

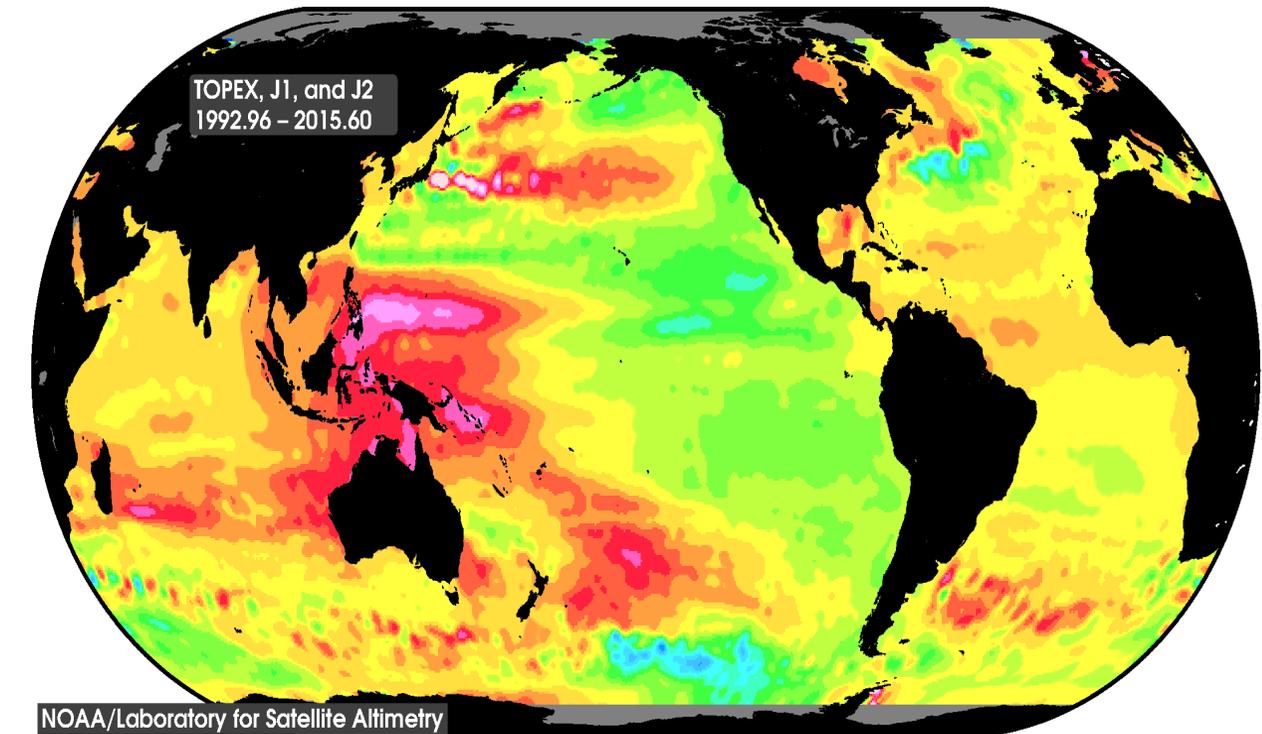
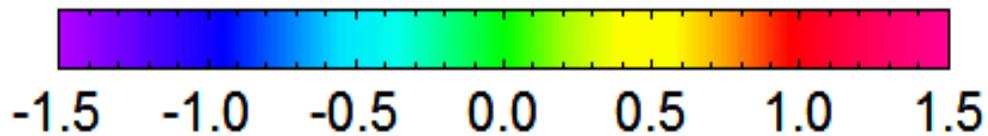


http://www.star.nesdis.noaa.gov/sod/lisa/SeaLevelRise/slr/map_txj1j2_wysiwyg.png

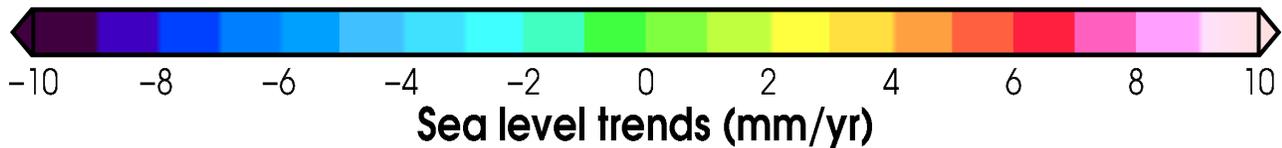
Here we have placed sea level rise and the water vapor increase maps side by side. Both are well-explained by increasing geothermal flux. Despite this seemingly good fit, anthropogenic CO2 is (still) cited as the “driver” of these anomalies in the literature.



Trend in Water Vapor, 1988-2012 (mm/decade)



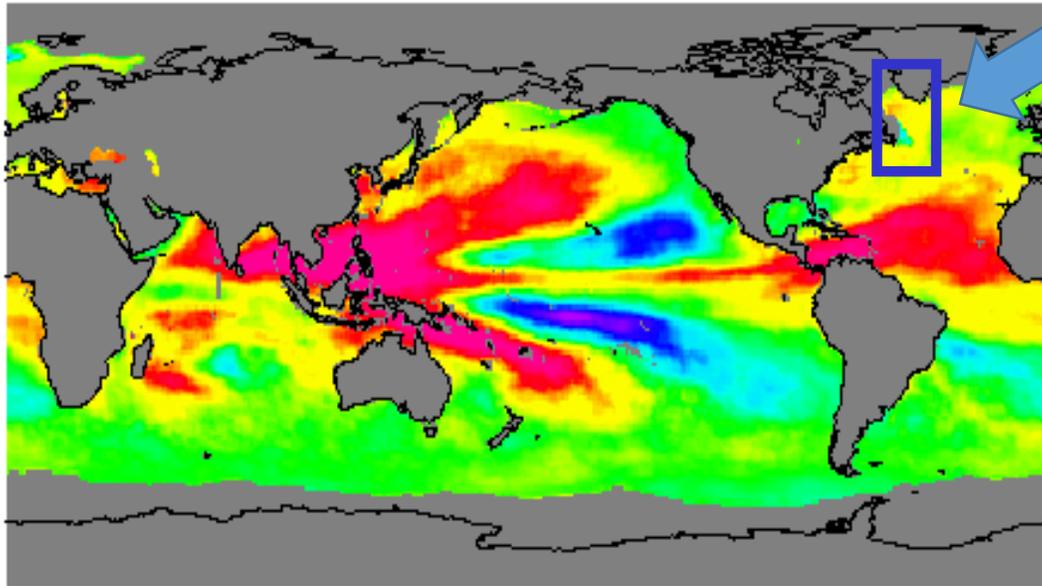
NOAA/Laboratory for Satellite Altimetry



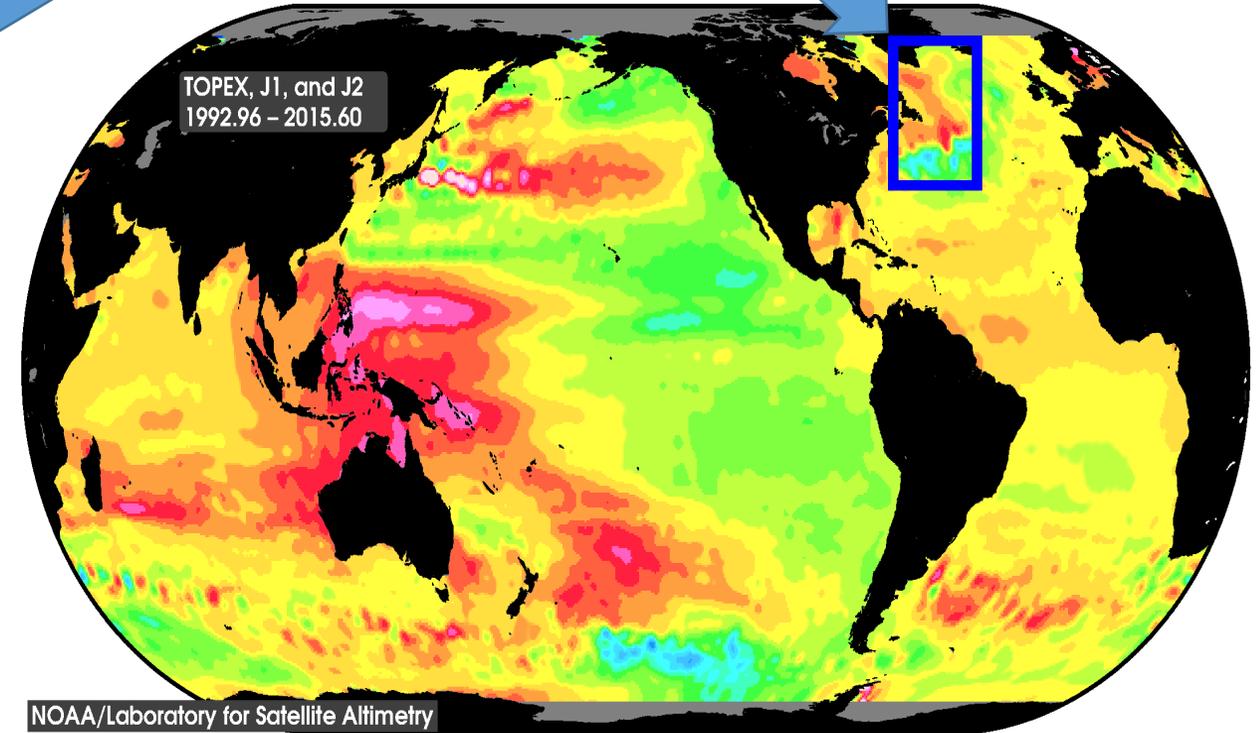
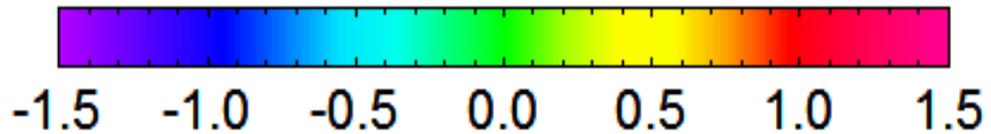
<http://www.remss.com/research/climate#Atmospheric-Temperature>

http://www.star.nesdis.noaa.gov/sod/lsa/SeaLevelRise/slr/map_txj1j2_wysiwyg.png

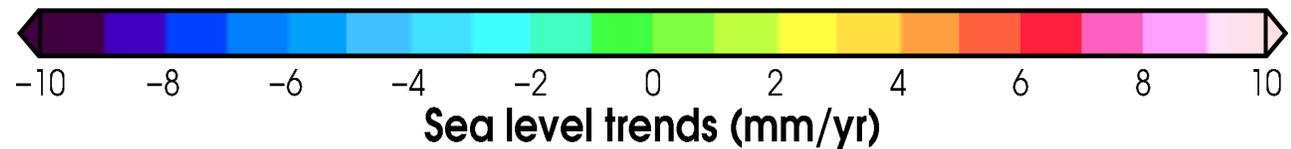
Notice the response of the Western Boundary Current cited earlier.



Trend in Water Vapor, 1988-2012 (mm/decade)



NOAA/Laboratory for Satellite Altimetry



"Scientists still do not appear to understand sufficiently that all earth sciences must contribute evidence toward unveiling the state of our planet It is only by combing the information furnished by ***all the earth sciences*** that we can hope to determine 'truth' here.... Further, we have to be prepared always for the possibility that each new discovery, no matter what science furnishes it, may modify the conclusions we draw."

Alfred Wegener. *The Origins of Continents and Oceans* (4th edition, 1929)

