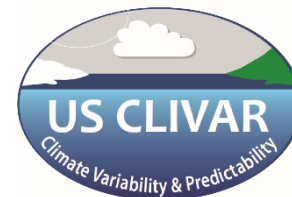
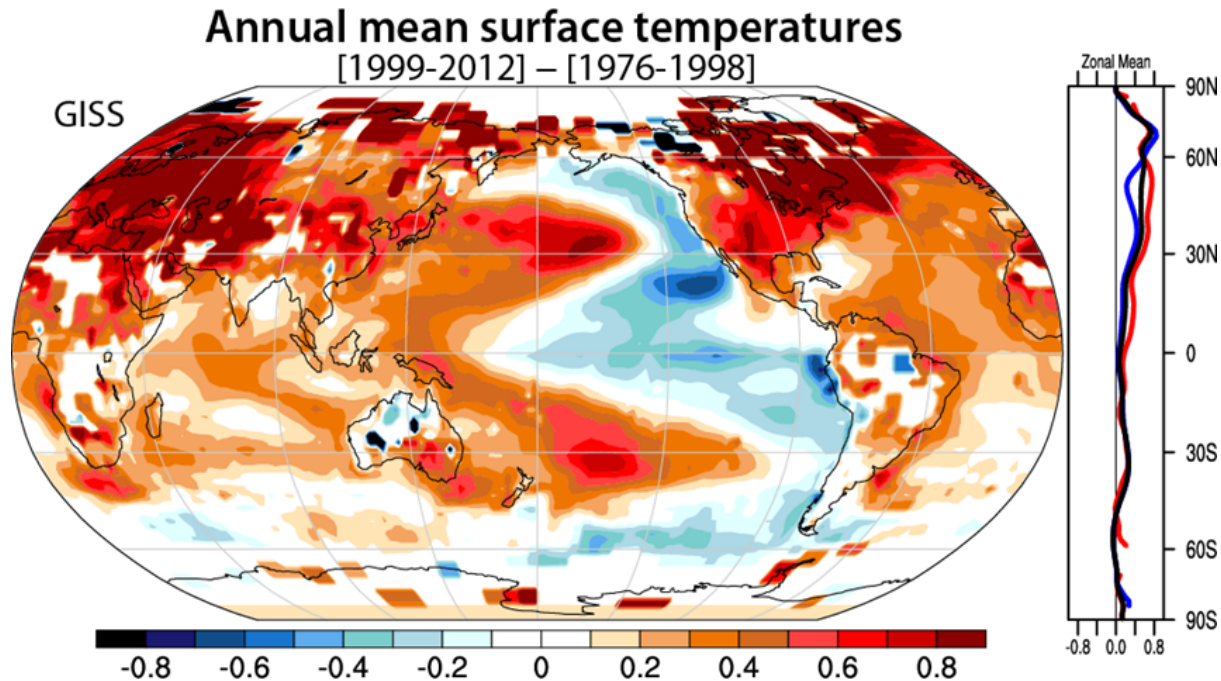
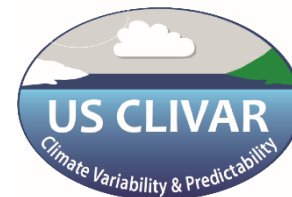
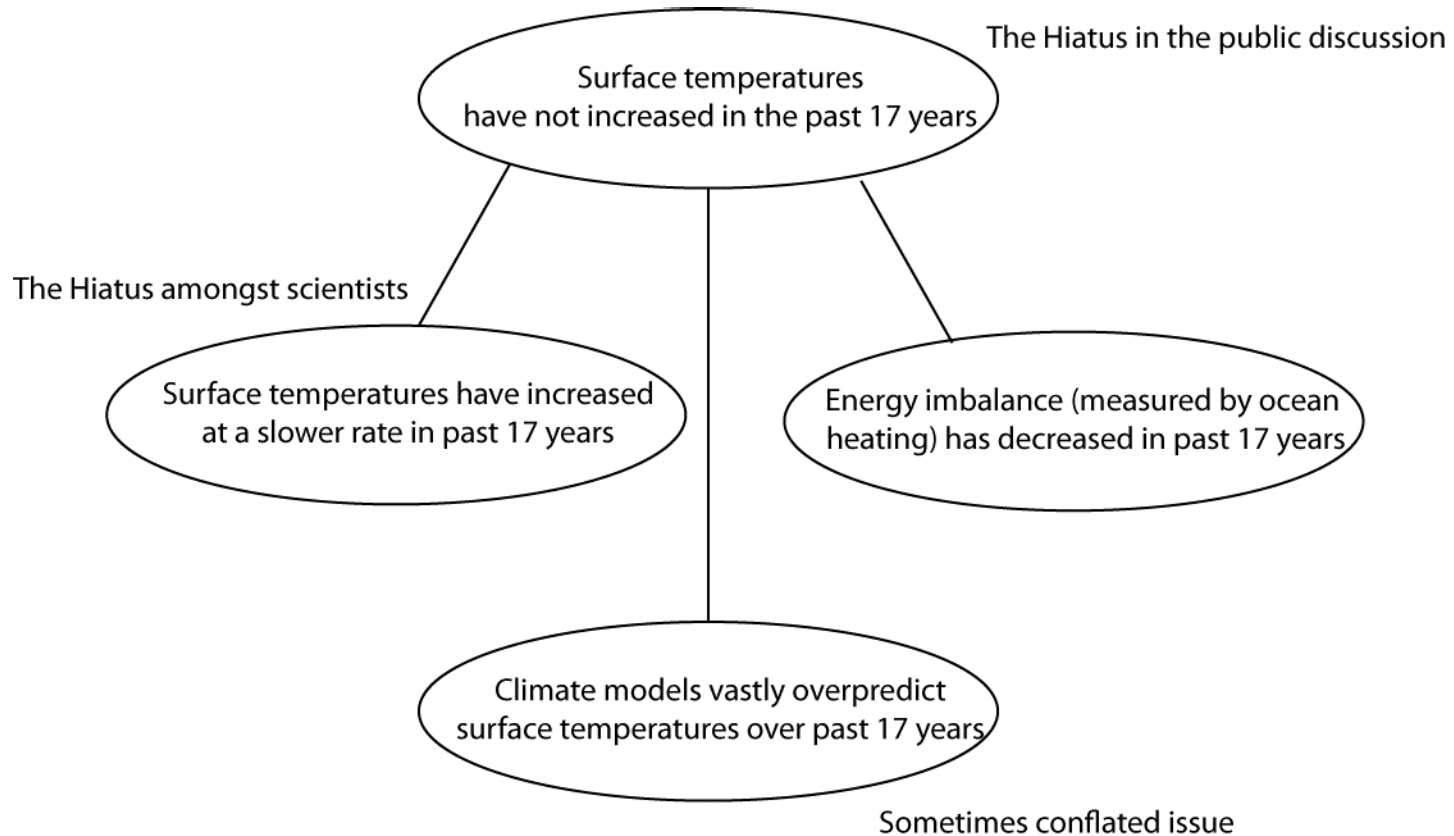


Lack of Evidence for a Slowdown in Global Temperature

Grant Foster, Tempo Analytics
John Abraham, University of St. Thomas

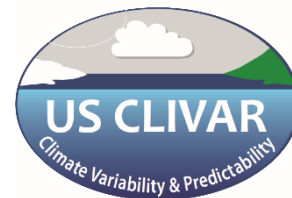


What is a Hiatus?

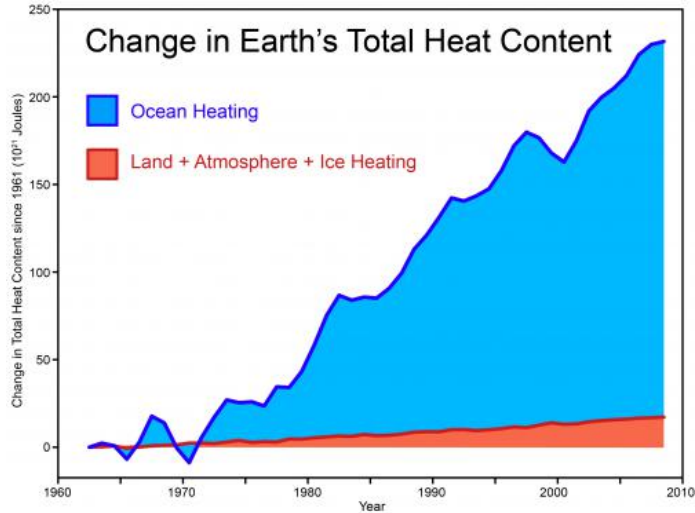


How is Earth's Energy Imbalance Measured?

1. Direct measurements from space, absorbed solar radiation, outgoing long wavelength radiation, net radiant flux.
 - Measurements are not absolutely accurate but can measure changes in time.
2. Measure energy storage on Earth.
 - A challenge to make adequate measurements of thermal reservoirs (oceans).
3. Climate models with specified forcings.

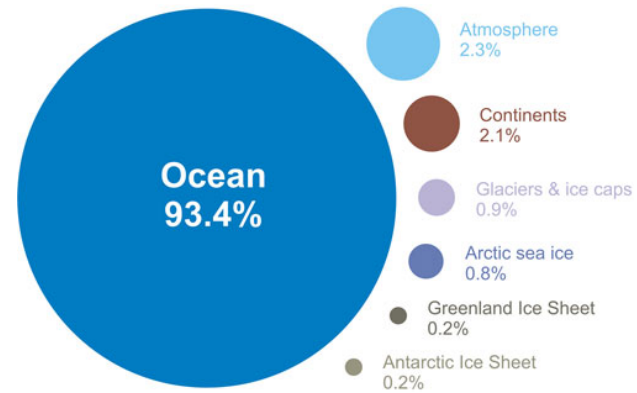


The Difficult Challenge – Measuring the Oceans

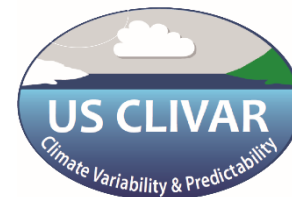


Nuccitelli et al, 2012

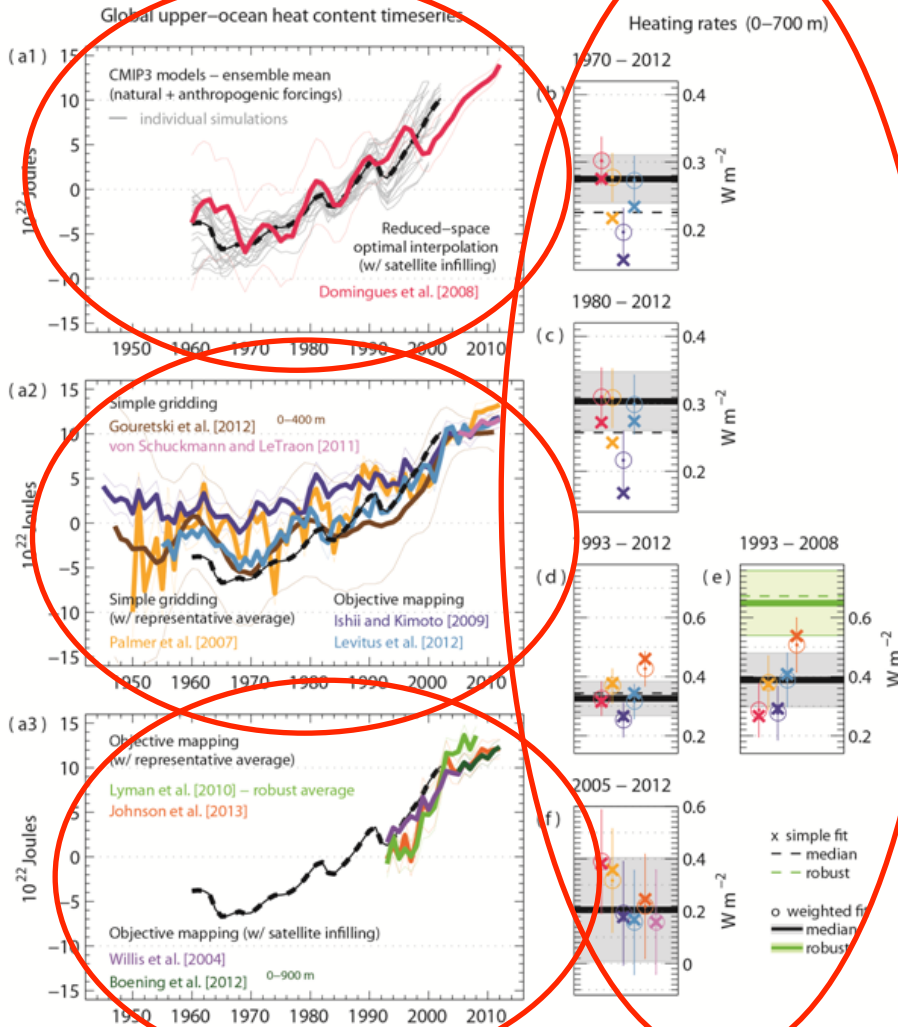
Where is global warming going?



SKS, 2014



Measuring Ocean Heating



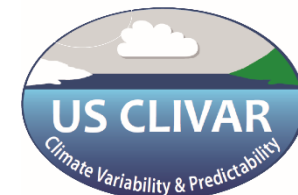
CMIP3 models and Domingues, 2008 estimates

Upper Oceans – various estimates, simple gridding

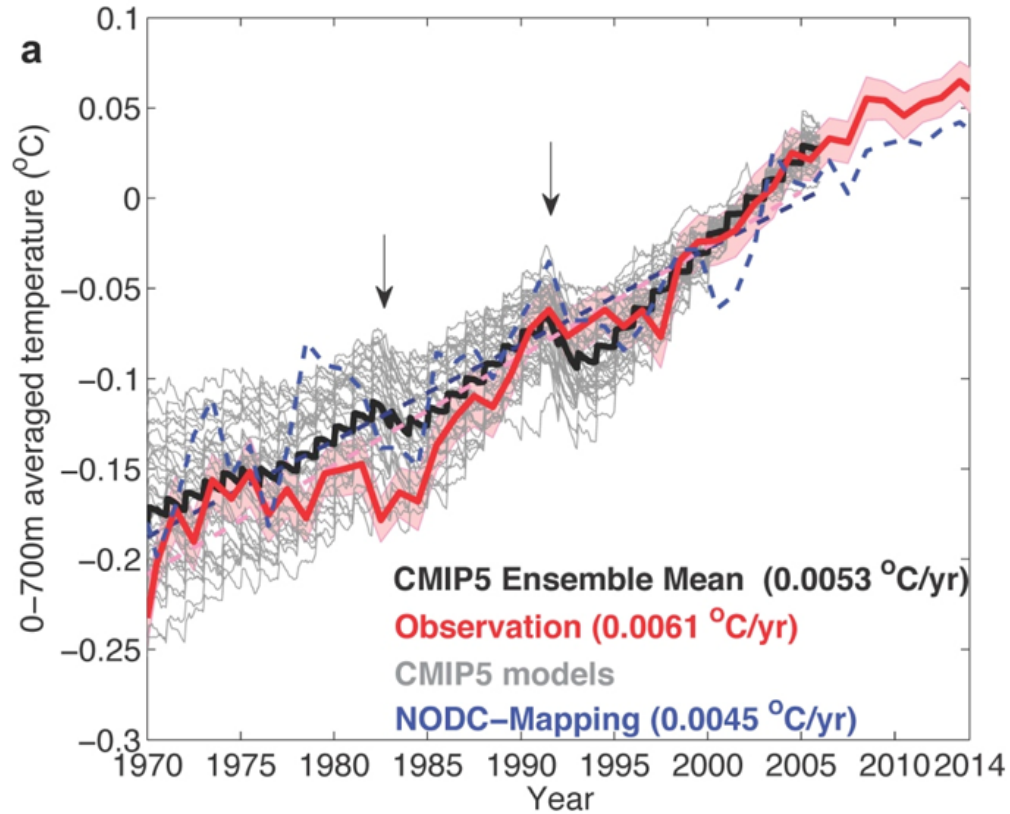
Upper Oceans – various estimates, mapping

Slopes, past four decades

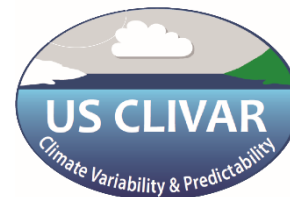
Abraham et al., 2013



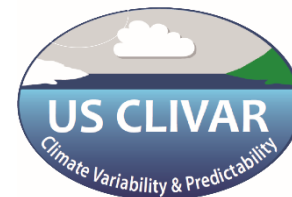
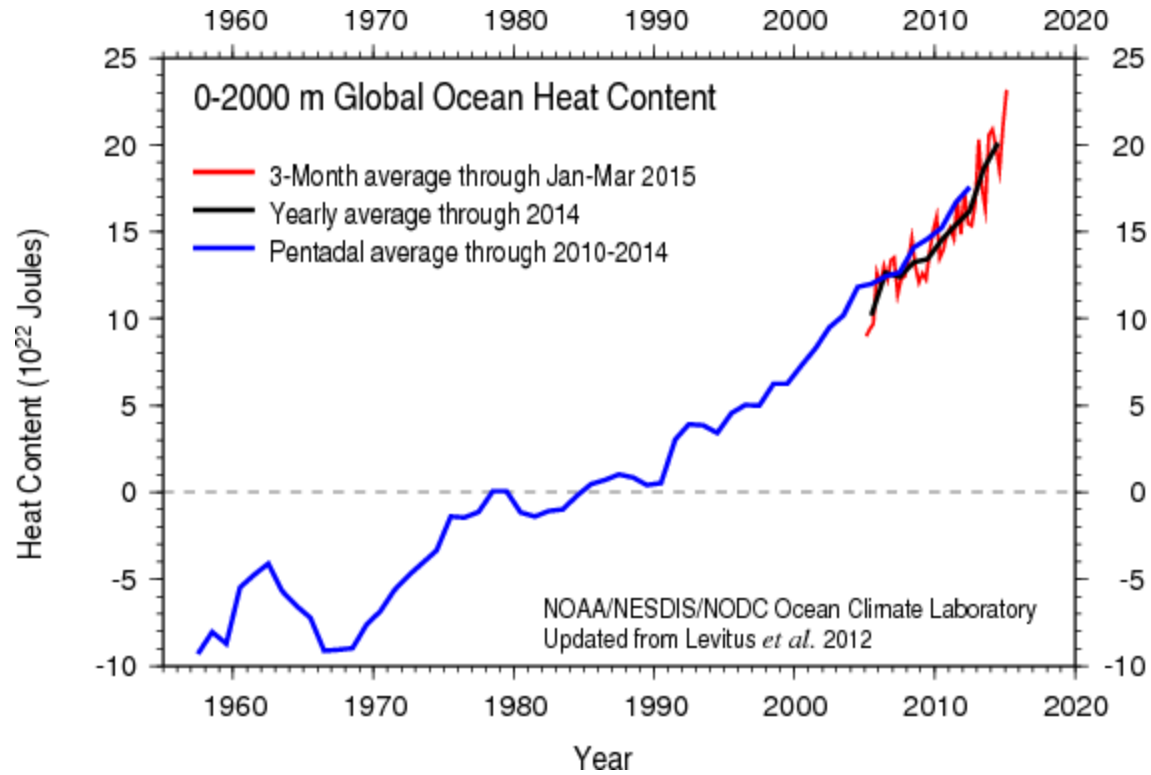
Measuring Ocean Heating



L. Cheng, et al., 2015

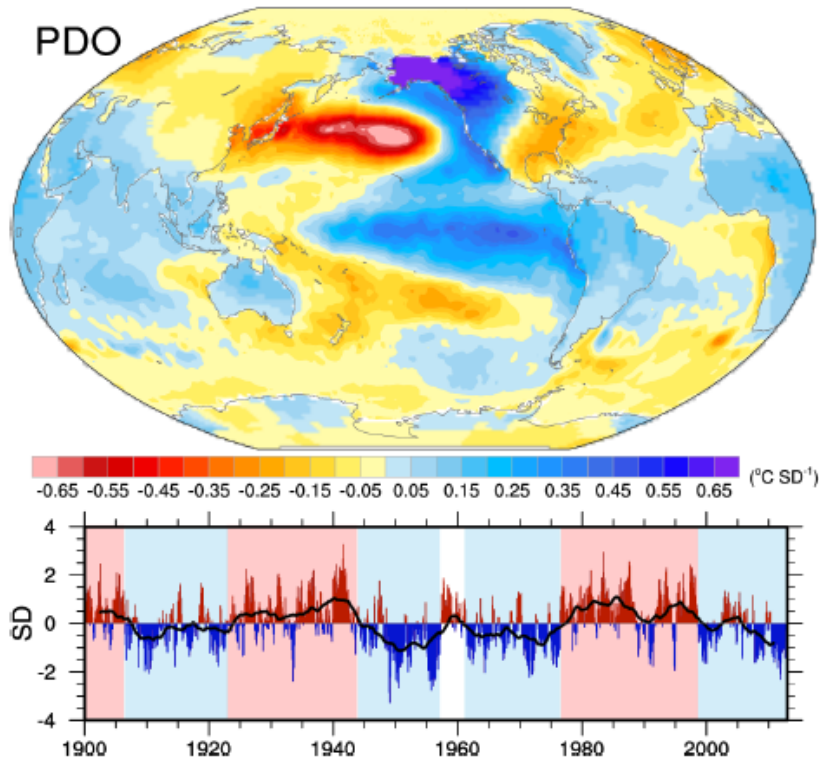


Most Recent Ocean Warming



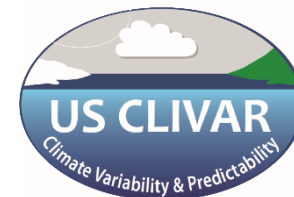
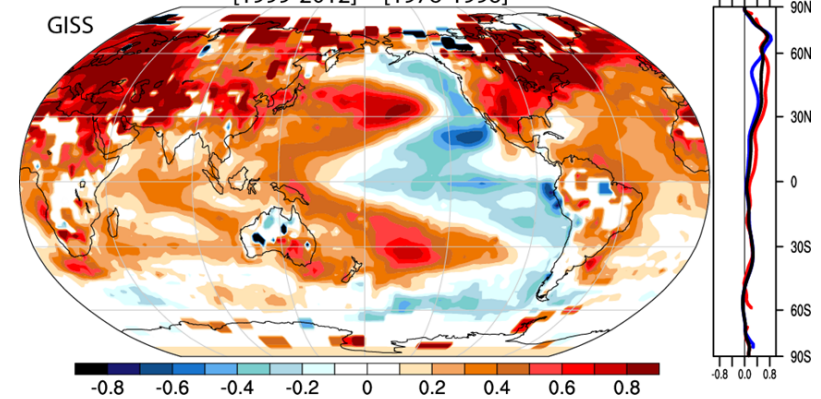
Why Has Deep-Ocean Heat Storage Increased?

Temperature difference per st. dev. PDO

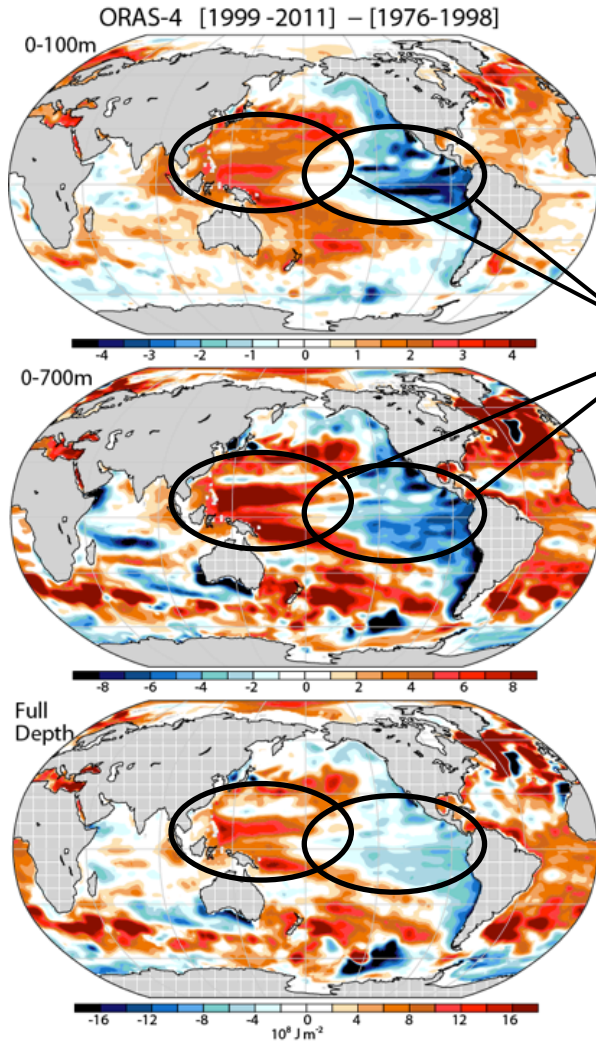


Trenberth et al., 2014

Annual mean surface temperatures
[1999-2012] - [1976-1998]



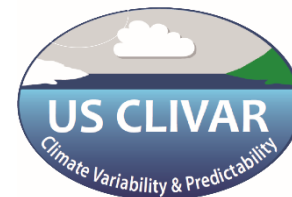
Why Has Deep-Ocean Heat Storage Increased?



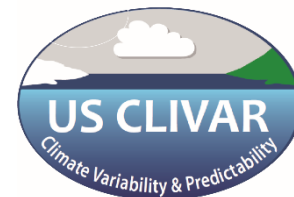
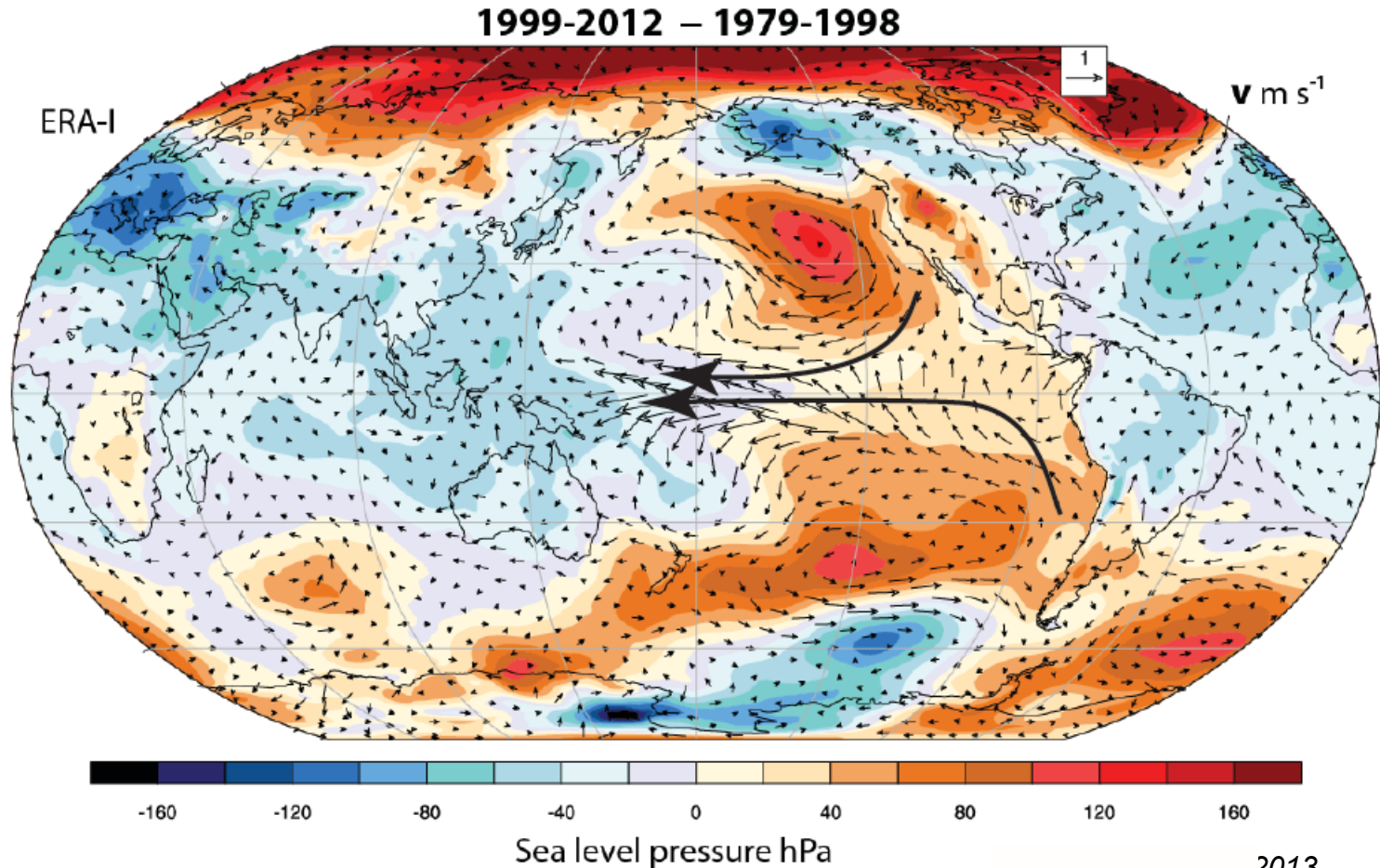
Comparison of ocean heat content for different water layers.

Waters in the Eastern Pacific have gotten colder

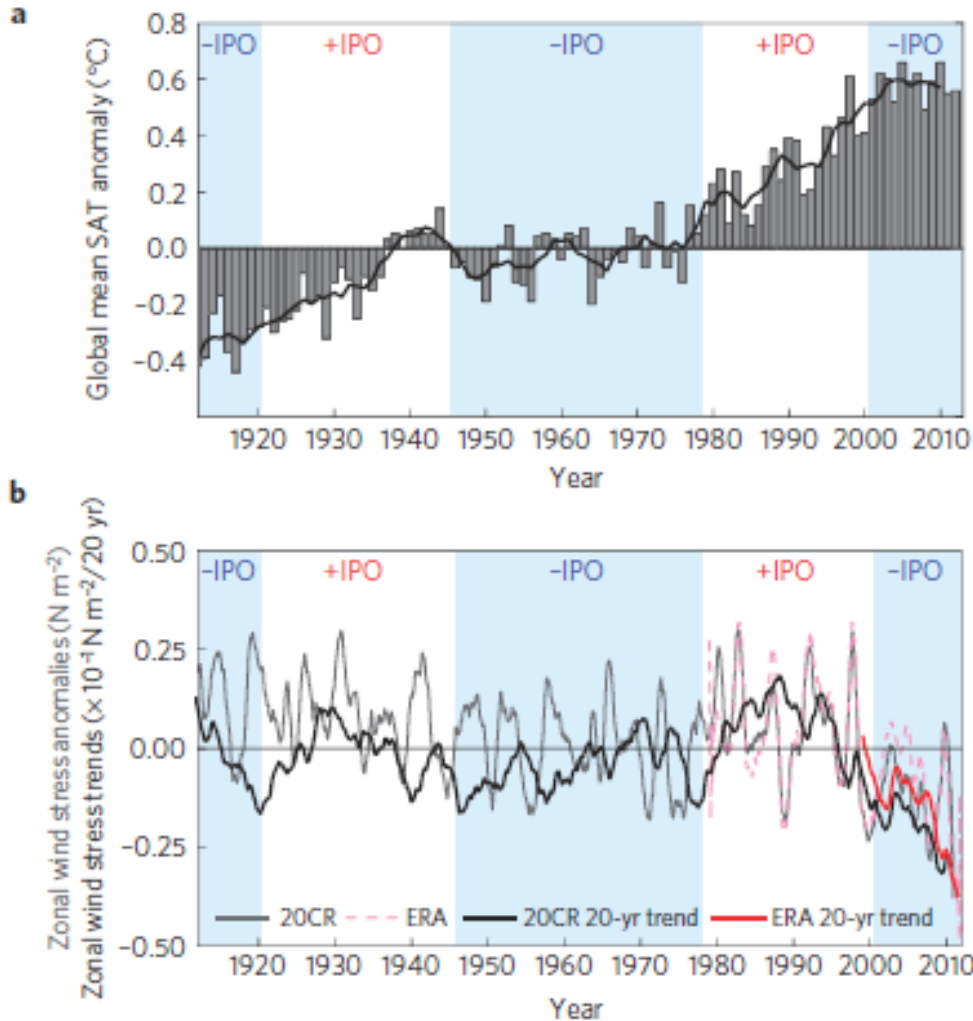
Waters in the Western Pacific have gotten warmer



Pacific Pressure and Winds

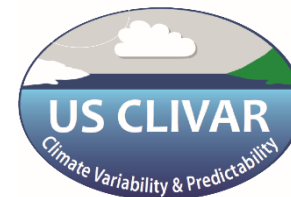


Pacific Oscillation, Temperatures, and Winds

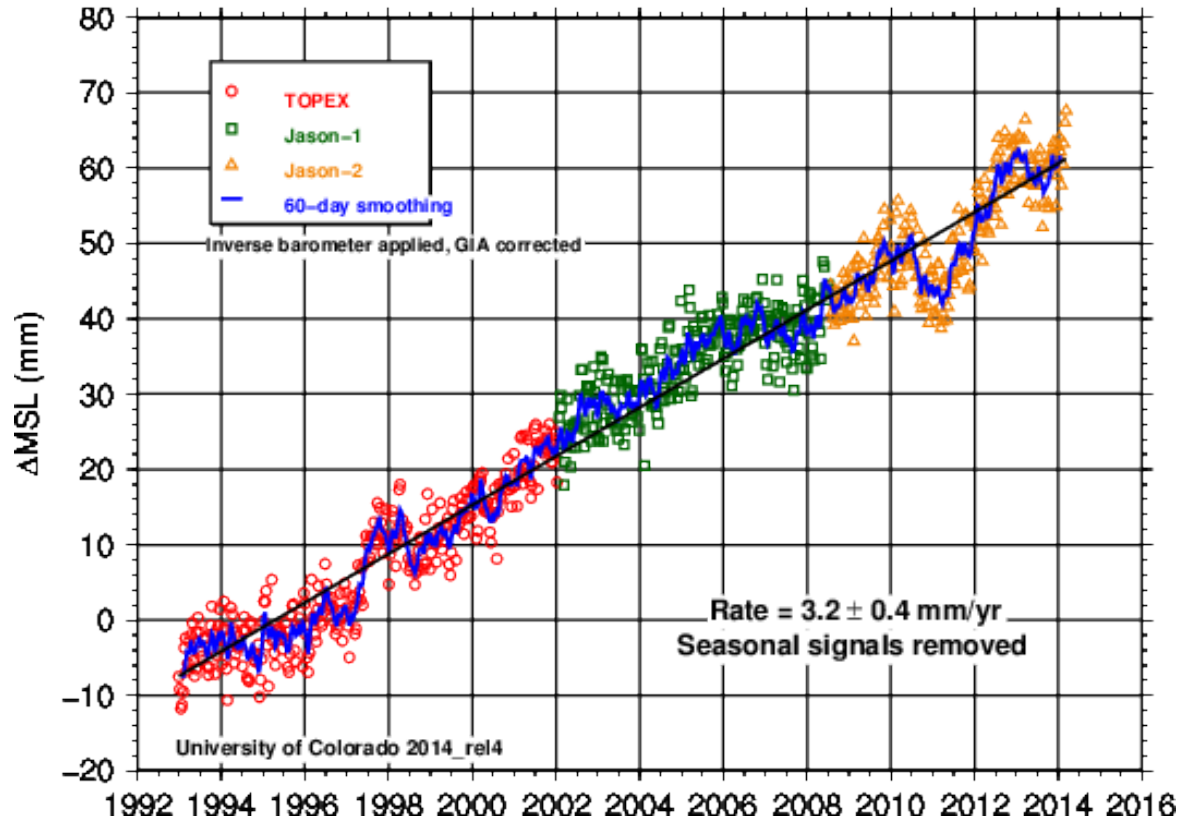


Is this natural internal variability? Is it partly caused by human-induced climate change?

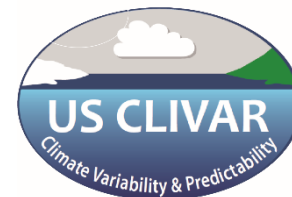
England et al., 2014



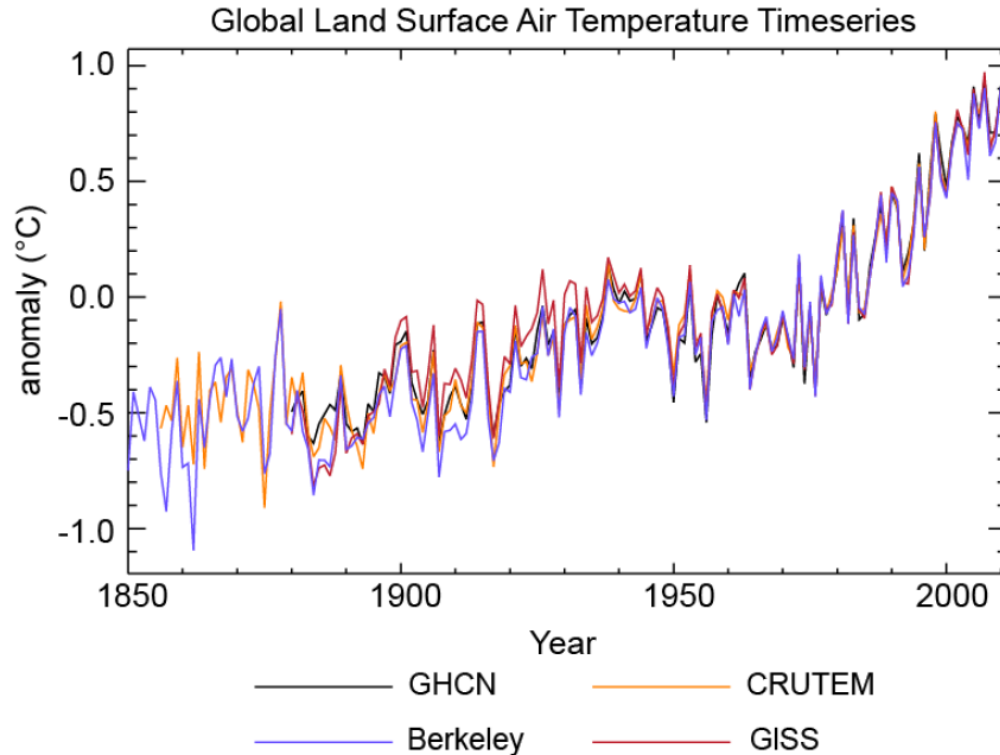
Global Sea Level – Also no Hiatus



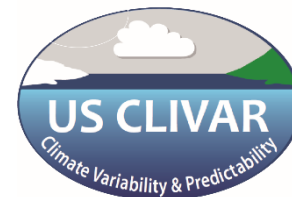
Sea level rise, Univ. Colorado



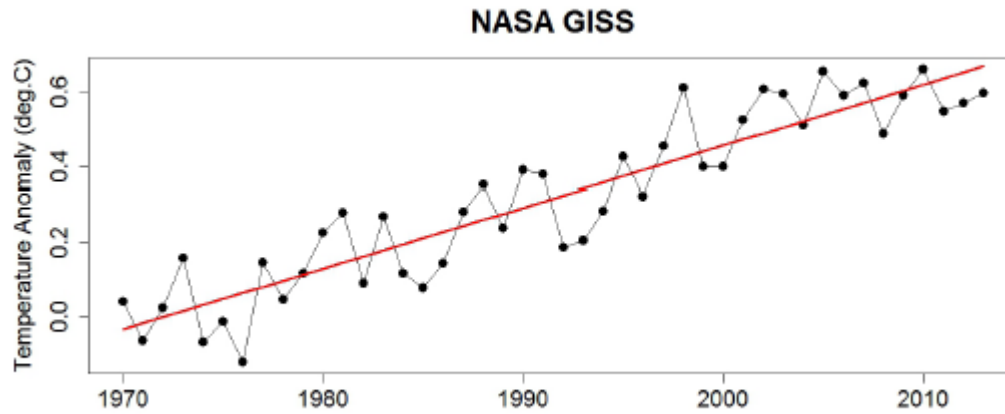
Surface Temperatures have Slowed



Four different surface temperature datasets

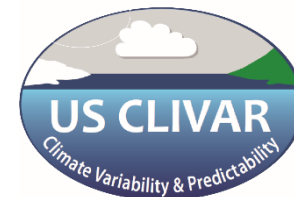
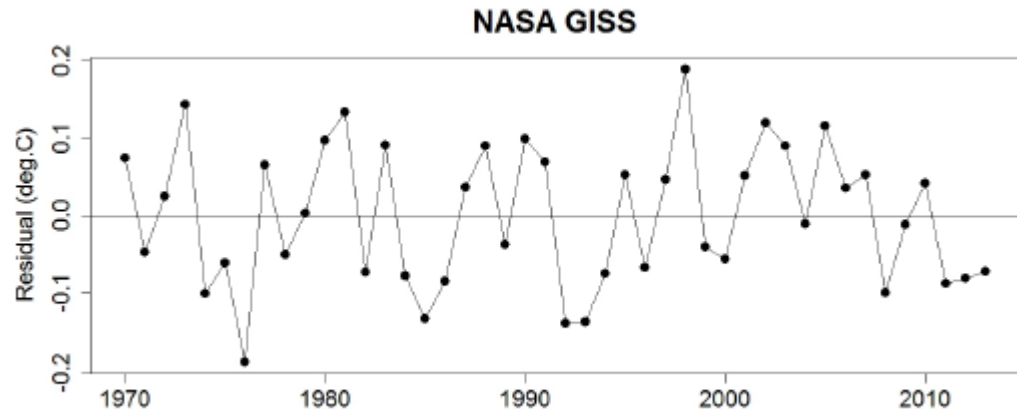


Is There Really a Slowdown in The Surface Temps?



NASA GISS LOTI (1970-2013)

NASA GISS
Residuals (1970-2013)



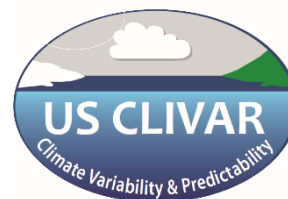
Is There Really a Slowdown?

A Change-Point Analysis is performed on the residuals from 1970-2013. This tests all reasonable changes in slope over the time period, selects best fit, and provides statistical significance.

The best fit included a slope change in 2006 (raw p value = 0.074) which does not meet the standard for statistically significant.

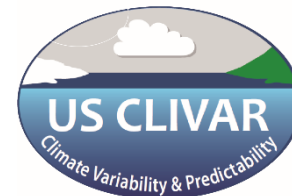
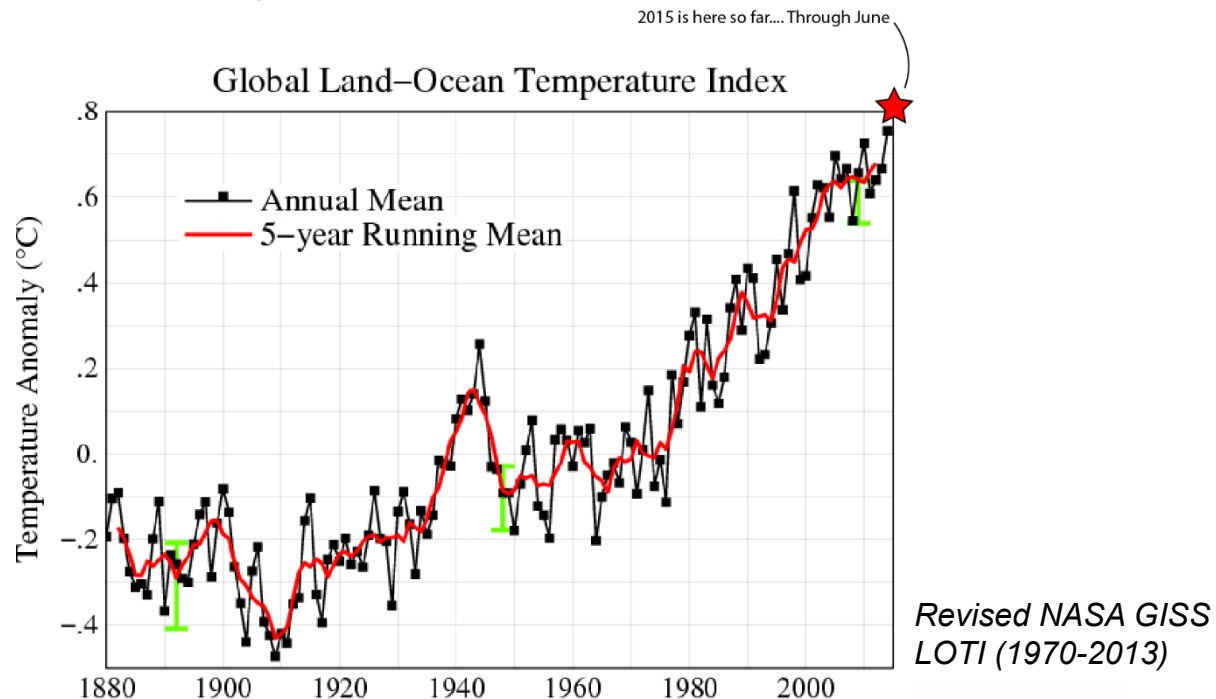
Other patterns were then investigated (polynomial fits to residuals up to degree 10) but no statistically significant trends found.

Finally, years were binned into segments (from 3 to 20 year) and an analysis of variance was performed (ANOVA). Once again, none of the attempts yielded significant results.

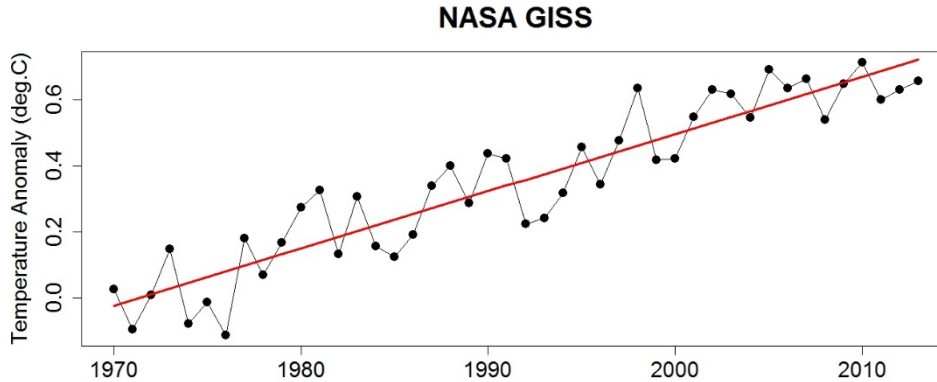


Is There Really a Slowdown?

In July 2015, NASA GISS revised its sea surface temperature product (ERSST v. 4) from NCDC. It includes updated data from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS), changes to quality control procedures, new in-filling procedures, updated bias adjustments from ship measurements using HadNMAT2, Buoy temperature improvements, among others.

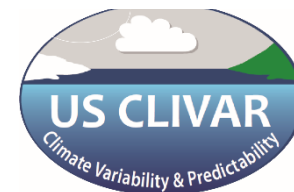
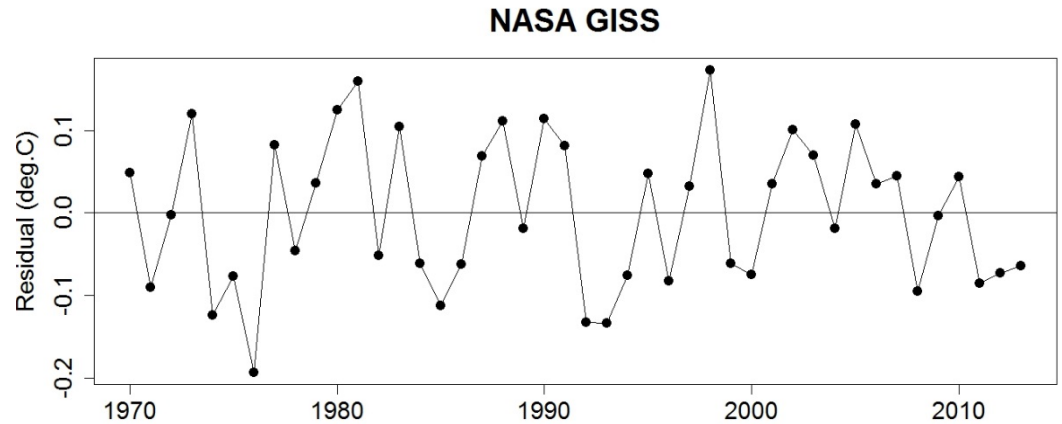


Is There Really a Slowdown?



Revised NASA GISS LOTI (1970-2013)

Revised NASA GISS
Residuals (1970-2013)

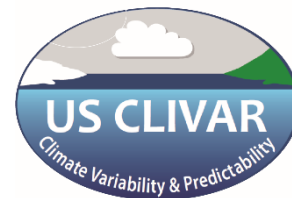


Is There Really a Slowdown?

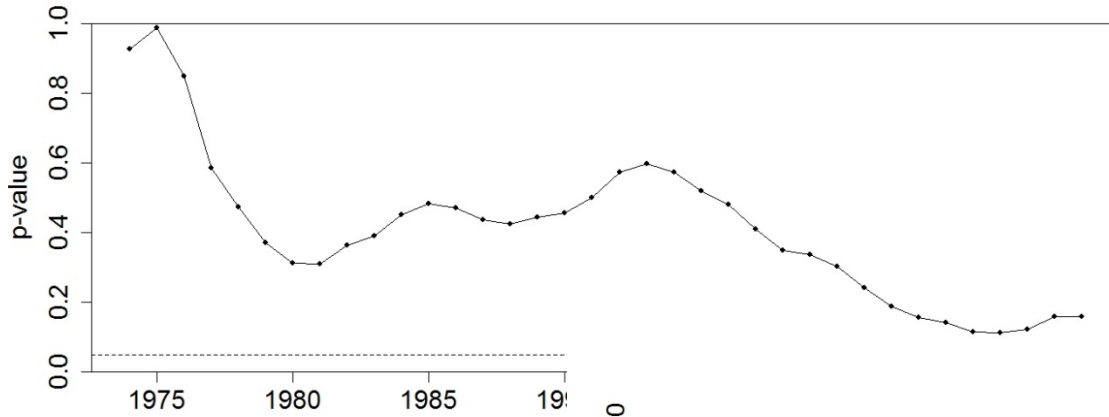
The best fit included a slope change (p value = 0.113) which does not meet the standard for statistically significant.

Other patterns were then investigated (polynomial fits to residuals up to degree 10) but no statistically significant trends found (minimum p = 0.18).

Finally, years were binned into segments (from 3 to 20 year) and an analysis of variance was performed (ANOVA). Once again, none of the attempts yielded significant results, (minimum p value 0.425).

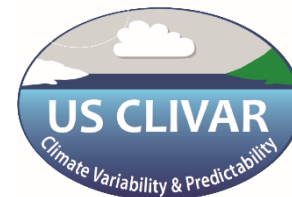
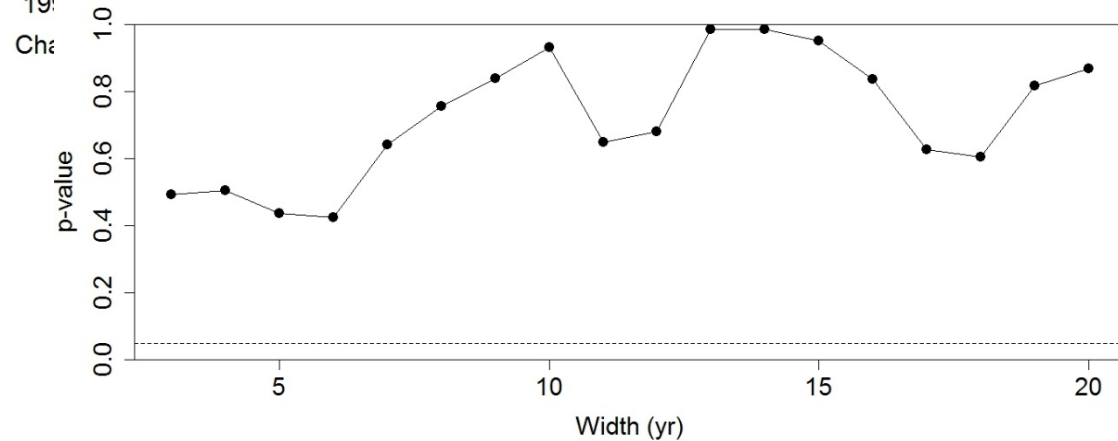


Is There Really a Slowdown?

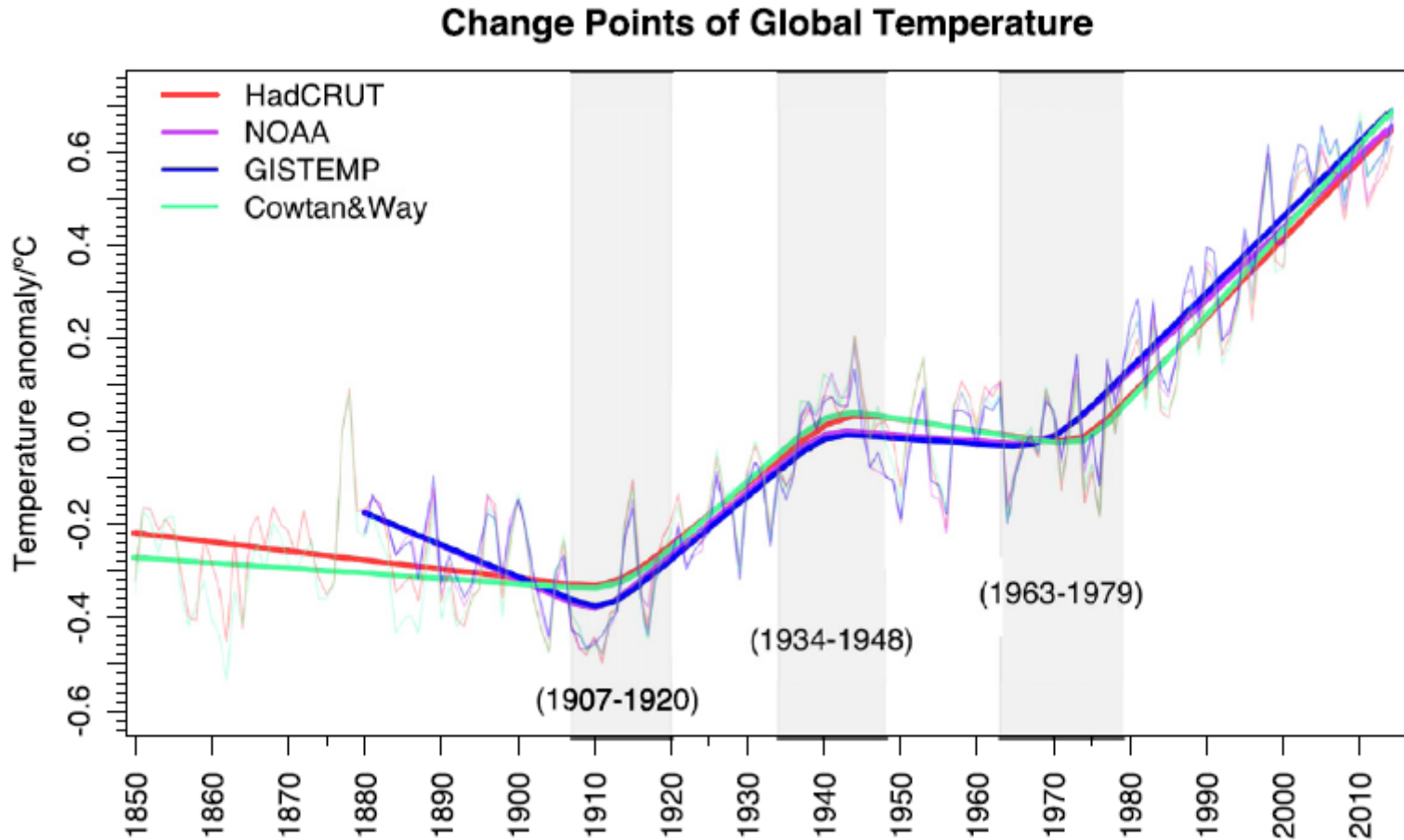


P values for slope change at different years

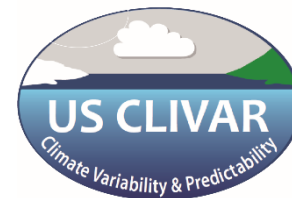
P values for bin duration, ANOVA



Is There Really a Slowdown?

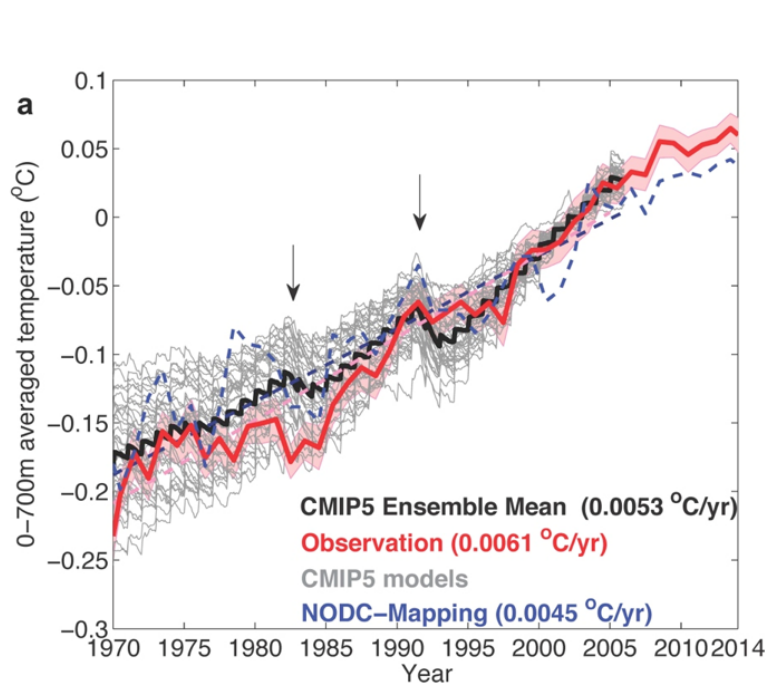


Cahill et al., 2015 “we conclude that the term “hiatus” or “Pause” cannot be statistically justified”

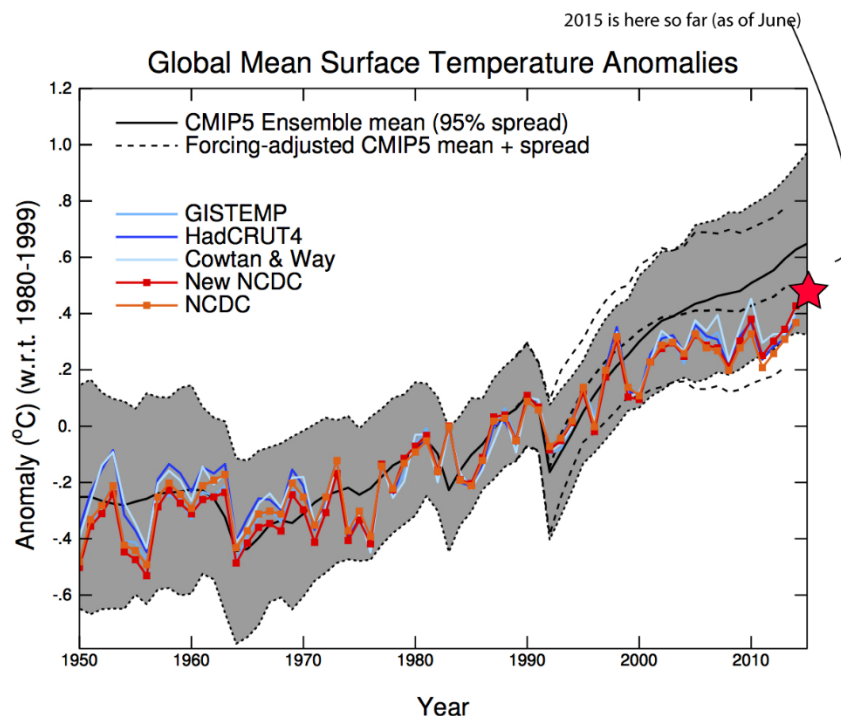


What About Climate Models

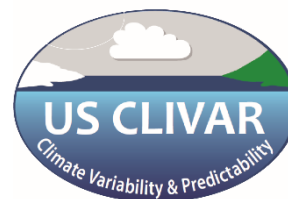
Much attention has been given to how well models (especially CMIP3 and CMIP5) match observations. In some cases models under-predict change (ice loss and ocean heating).



Cheng et al., 2015

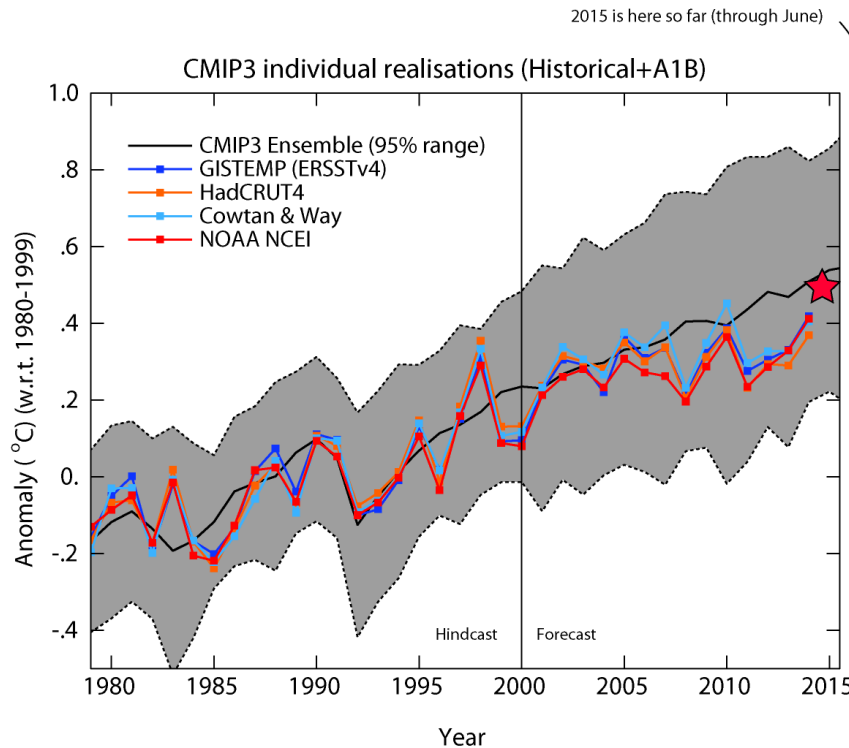


Modified from Schmidt et al., 2014

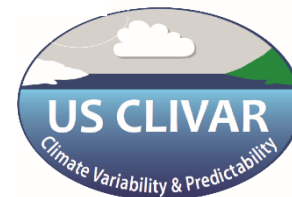


What About Climate Models

Much attention has been given to how well models (especially CMIP3 and CMIP5) match observations. In some cases models under-predict change (ice loss and ocean heating).



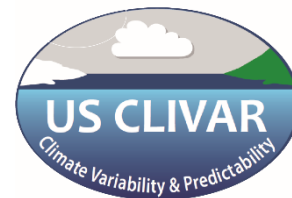
Modified from G. Schmidt



Is There Really a Slowdown?

If we include the years 2014 and 2015, the lack of a slowdown is even more compelling.

There is no pause, there was no pause....



Thank you....

John Abraham
University of St. Thomas
jpabraham@stthomas.edu

