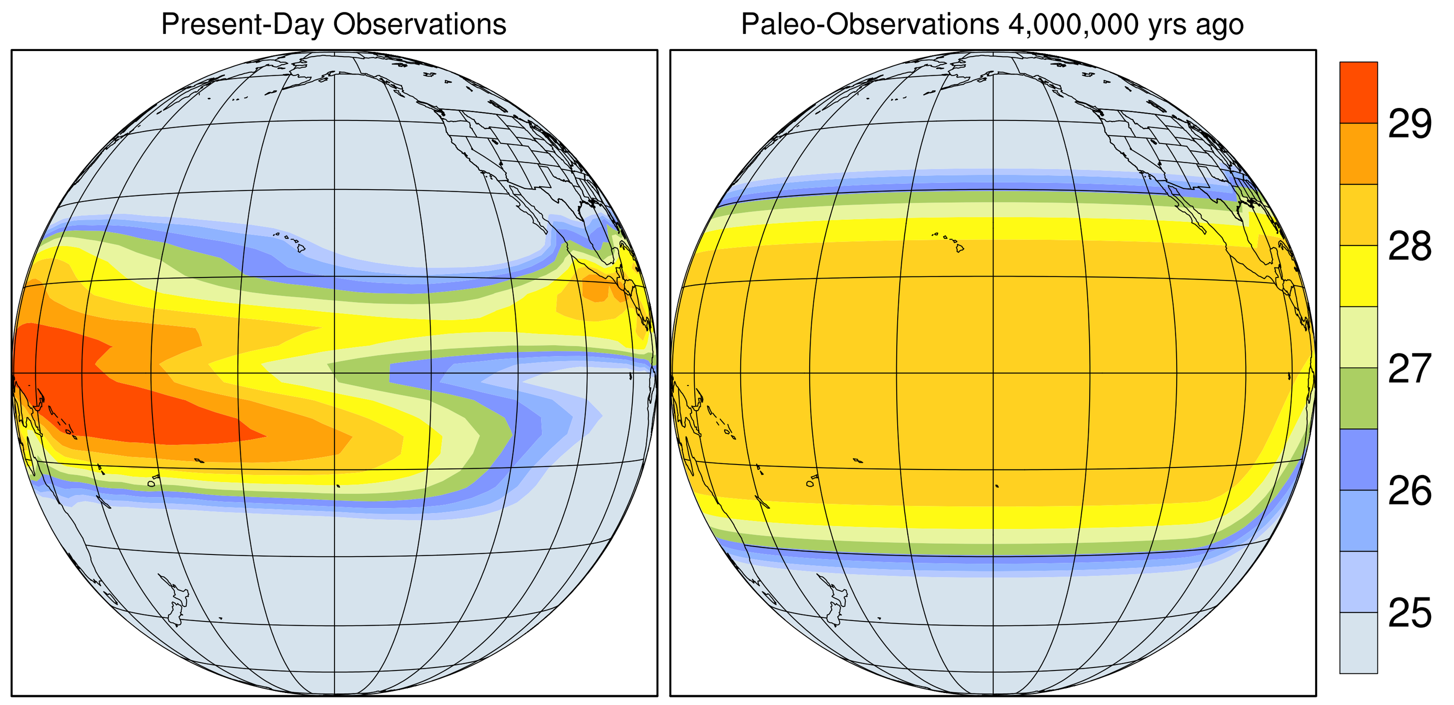
# Simple Measures of Structural Climate Change


## Chris Brierley

UCL Department of Geography, University College London, c.brierley@ucl.ac.uk


## Motivation

Paleo-observations for the early Pliocene (4 million years ago) show a warm world, with $CO_2$ levels a little higher than preindustrial. Yet, there was a different structure of tropical sea surface temperatures (SST).

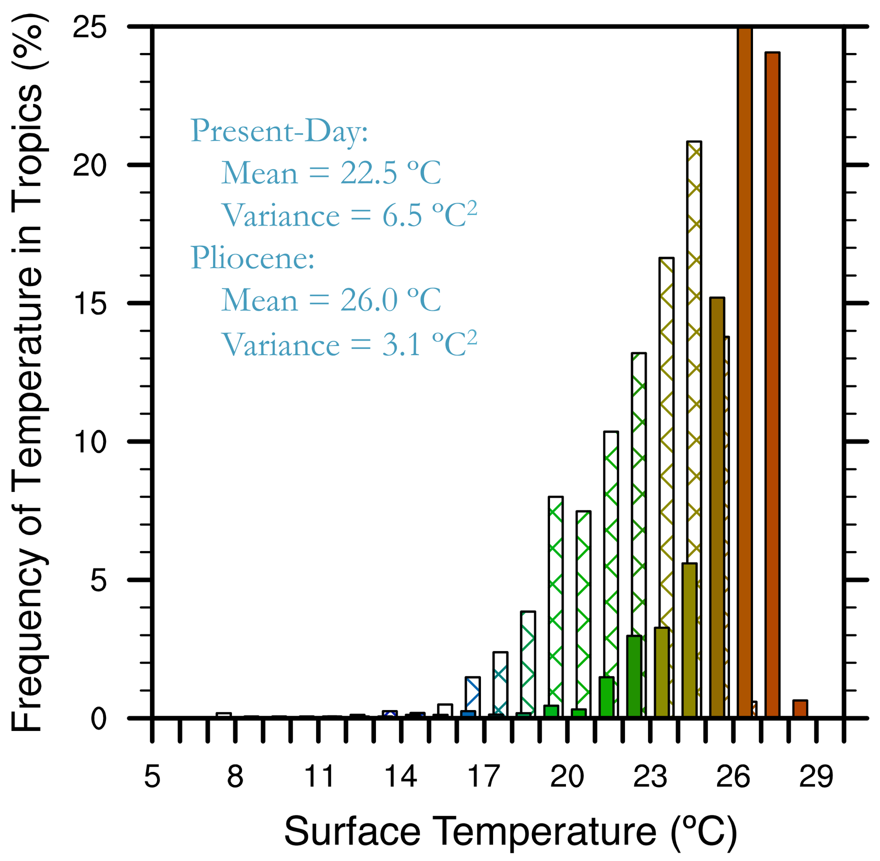



*Annual mean SST in the Tropical Pacific (in °C): (left) at present and (right) in the early Pliocene (after Brierley et al., 2009)*

Our recent paper (Fedorov *et al.*, 2013) compared five explanations of this state against three critical features:

- Minimal increase in the warmpool temperature
- Weak gradients along the Equator
- Smaller meridional temperature gradients

The Pliocene had weak SST gradients in the tropics, so saw less spread in its distribution (right). We used the tropical variance to quantify how well hypotheses explained changes in the gradients. Is this metric useful in other situations?




*Tropical surface temperature histograms from models forced by (solid) Pliocene and (hatched) present-day SSTs*


References

Brierley, C. M. *et al.* (2009). Greatly expanded tropical warm pool and weakened Hadley circulation in the early Pliocene. *Science*, 323, 1714–1718.

Fedorov, A. V. *et al.* (2013). Patterns and mechanisms of Early Pliocene warmth. *Nature*, 496, 43-49.


## Variance

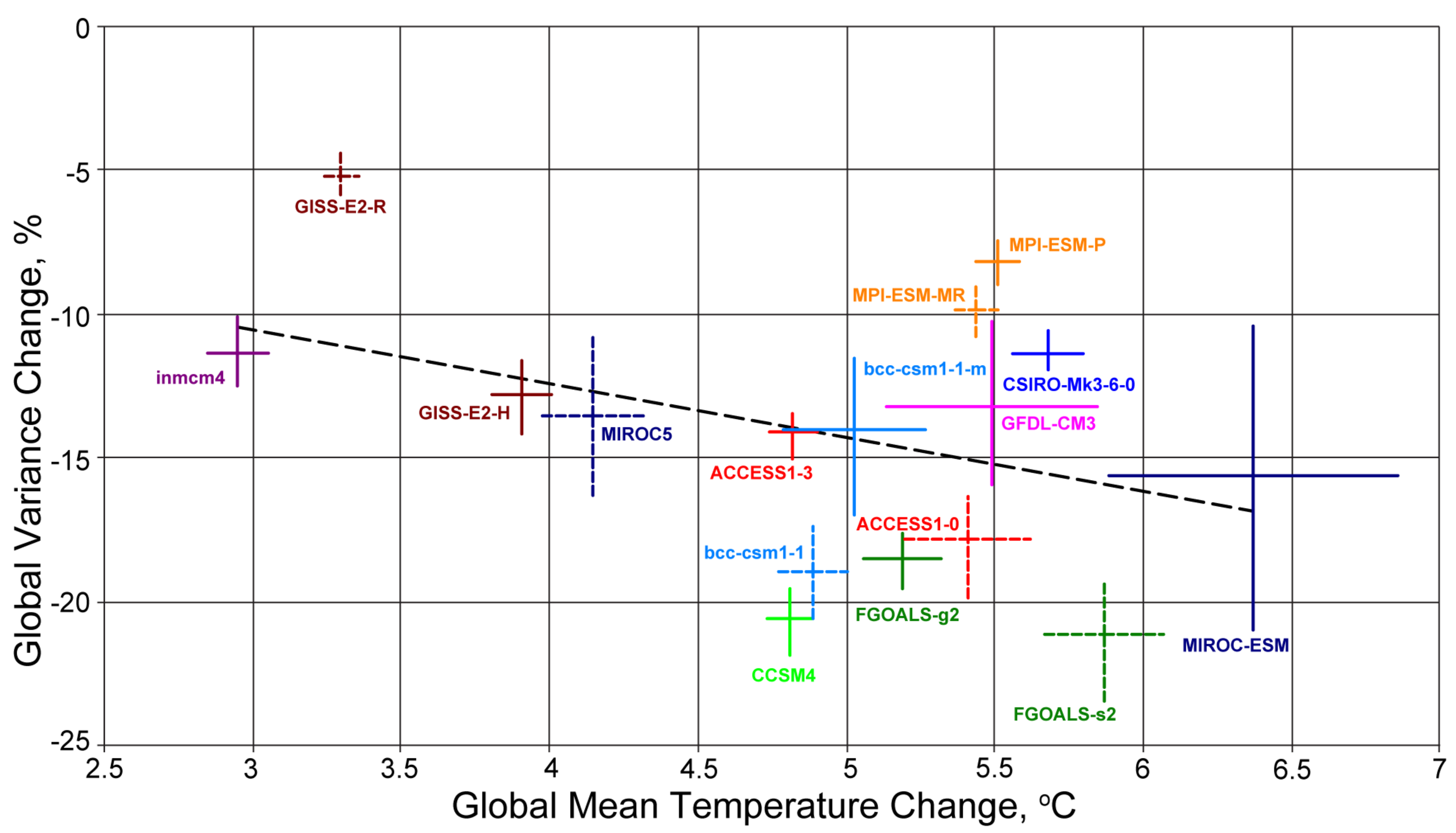
Surface temperature changes both temporally and spatially. A common metric of climate change is the change in the space-averaged, time-averaged surface temperature (i.e. global mean temperature). It is logical for the second most basic description to be the change in spatial variance of the time-averaged temperatures.

The frequency distribution of surface temperatures has a long, cold tail coming from high altitude/latitudes.

The variance depends on a model's orography and resolution - much more so than the mean. So I express changes as a percentage of the preindustrial variance.

## Global Variance

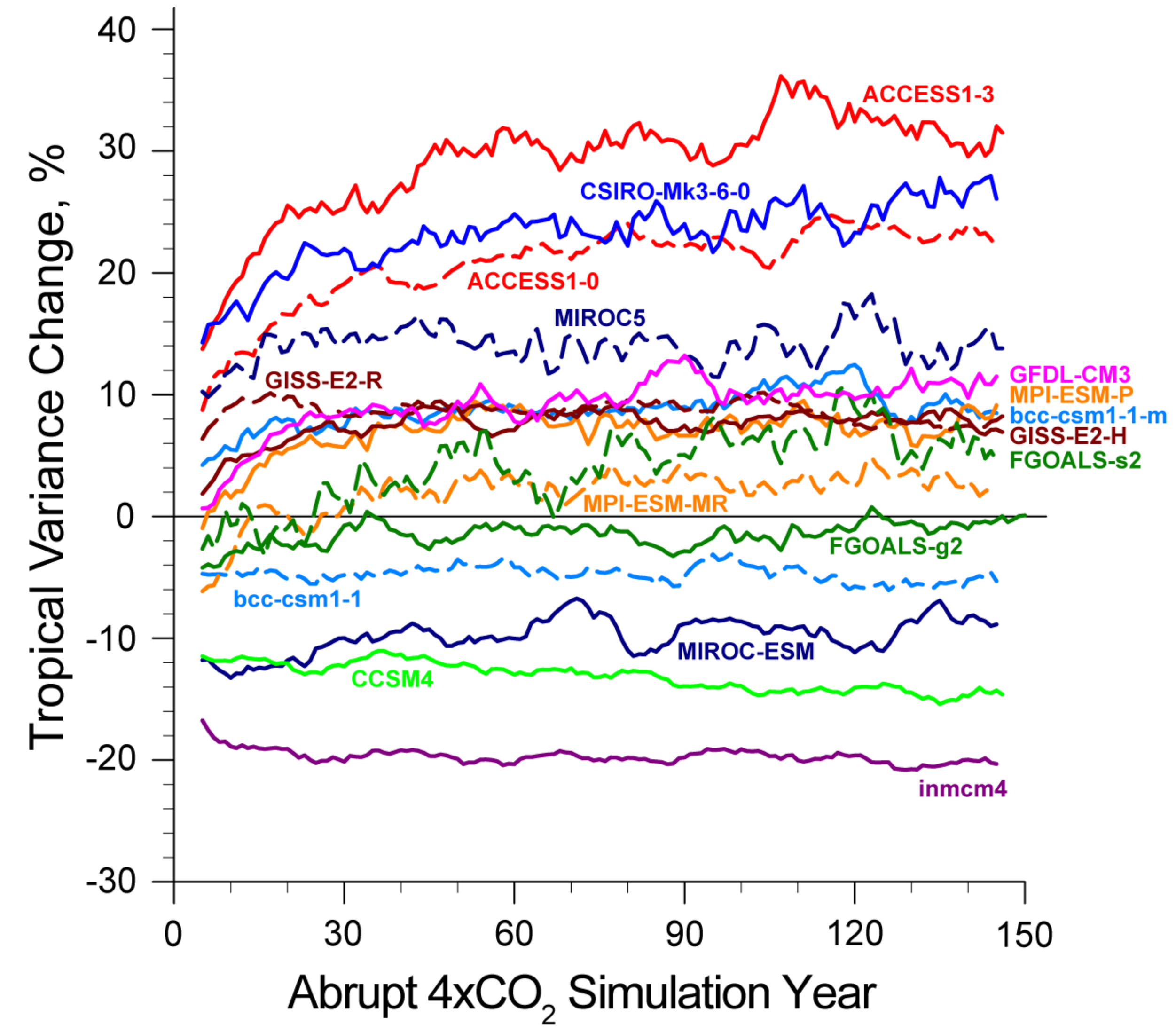
As the world warms, the variance in global surface temperatures reduces ($r = -0.39$, $p = 0.13$). This reflects the fact that cold regions warm disproportionately under climate change. Variance change is a spatially broader metric than polar amplification and does not need a mean change; but it is less intuitive to interpret.




*Changes in global mean and variance of surface temperatures in response to increased $CO_2$ (final 25 years of CMIP5 abrupt 4x$CO_2$ runs). Error bars represent 90% confidence interval based on 25 year normal internal variability throughout the preindustrial control runs*

## Tropical Variance

There are some large percentage changes in variance, in part because temperature varies less throughout the Tropics. There is little consensus amongst the CMIP5 models on the sign of the change in tropical variance.




*Percentage change in tropical (30°S-30°N) variance seen during the abrupt 4x$CO_2$ simulations (after decadal smoothing)*

## Summary

- ***Variance is the second moment of a distribution, behind the mean.***
- ***Global means are ubiquitous in climate literature, yet spatial variances are not.***
- ***Change in temperature variance may be a useful metric of tropical climate change***
- ***Models show large changes in tropical variance under increasing $CO_2$ - but without a consistent sign.***