Comparing Climate Model Temperature Fields to Historical Observations

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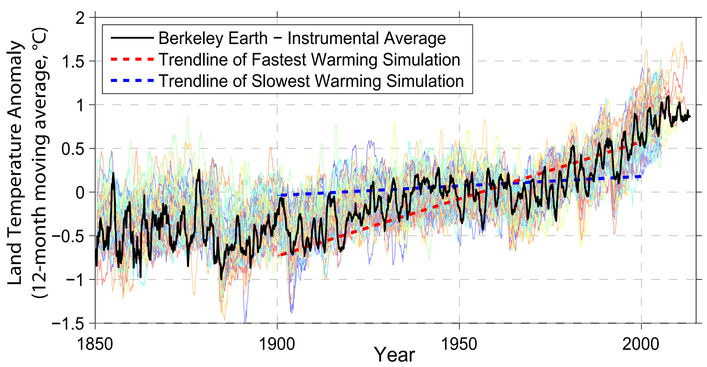
Introduction

Climate models are an essential tool for predicting future climate changes. However, not all models are created equal, and the accuracy of climate models needs to be tested against historical conditions in order to determine which models perform well or poorly. Here we compare 43 simulations of historical temperature change from the Coupled Model Intercomparison Project Phase 5 (CMIP5) to instrumentally derived surface temperature fields from Berkeley Earth (Rohde et al. 2013), NOAA NCDC (Smith et al. 2008), NASA GISS (Hansen et al. 2010), and Hadley / CRU (Morice et al. 2012).

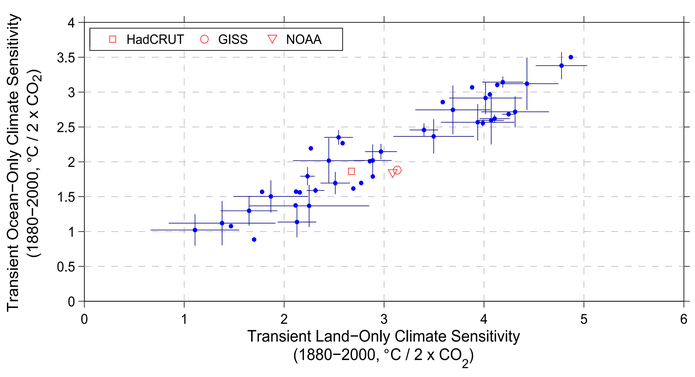
The inherently chaotic properties of weather imply that climate models will never reproduce the exact history of Earth's weather. Nonetheless, by looking at long-term characteristics of models, aggregate statistical properties, and variations across perturbed model runs, it should be possible to characterize the simulated climate of each model. These properties are compared to similarly calculated characteristics from each of the instrumentally estimated climate fields.

Comparison of Land-Average Temperature in 43 Historical Climate Models to Instrumental Observations



Average surface air temperature over land relative to a 1951-1980 baseline. When viewed as large scale averages, it is easy to believe that most models are similar, and yet during the twentieth century, the fastest warming climate model showed more than six times the rate of warming as the slowest responding model.

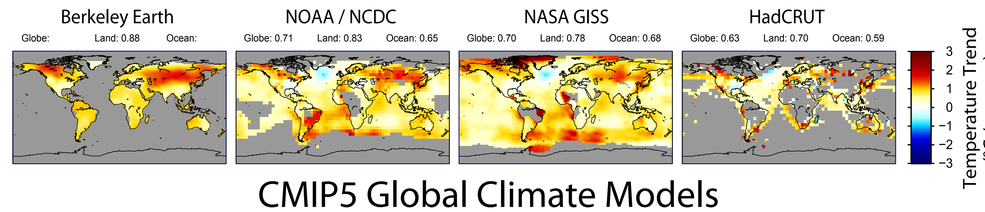
Implied Climate Sensitivity during Historical Period



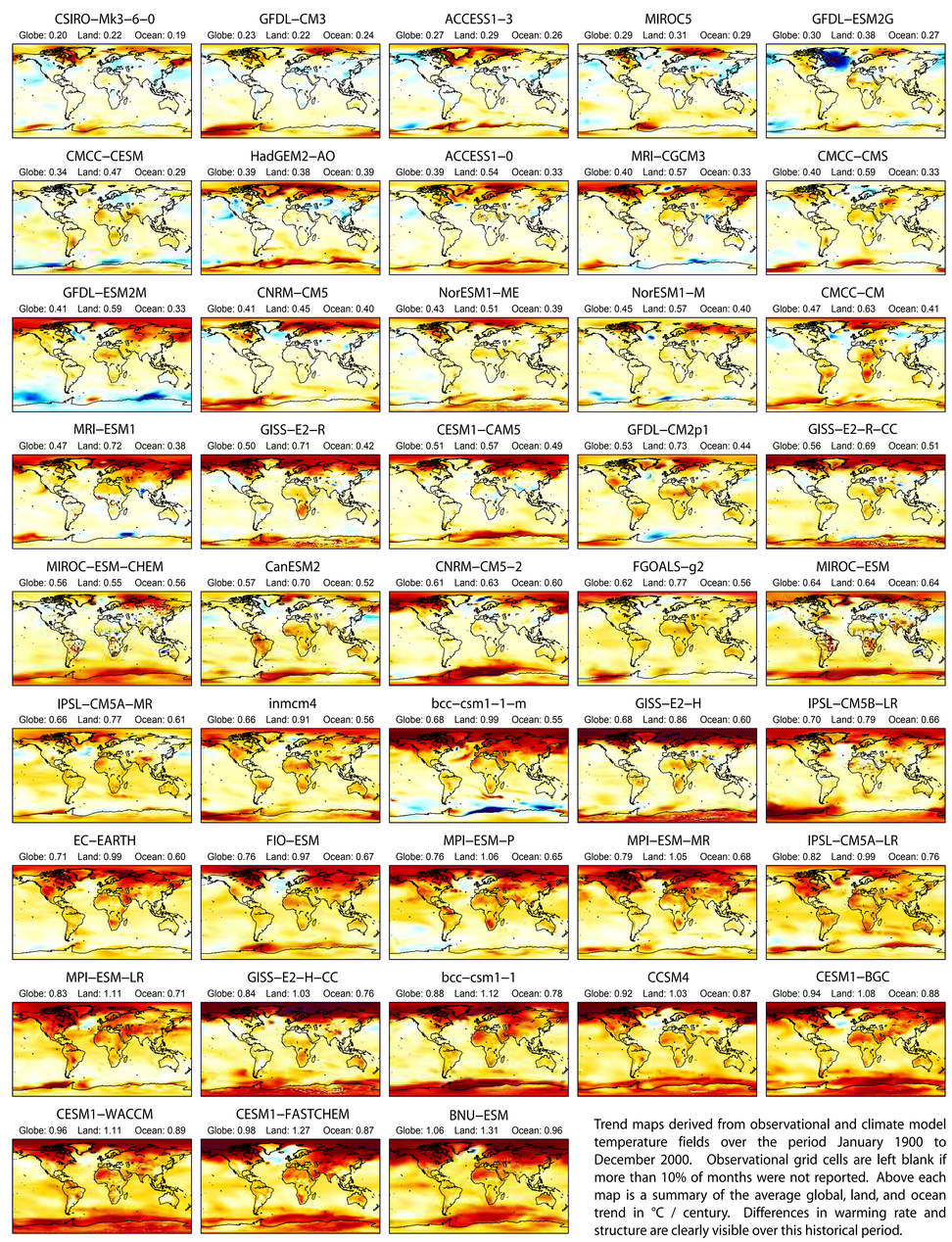
During the historical period a wide range of climate sensitivities are implied from climate models (blue dots), indicating considerable model uncertainty about the temperature response to greenhouse gas forcing. Variations across model runs are indicated with horizontal and vertical bars. These show that the range of responses cannot solely be attributed to model internal variability. The climate model sensitivities, though spanning a wide range, do frame the sensitivities implied from the historical temperature fields.

Temperature Trend (1900-2000)

Observational Reconstructions



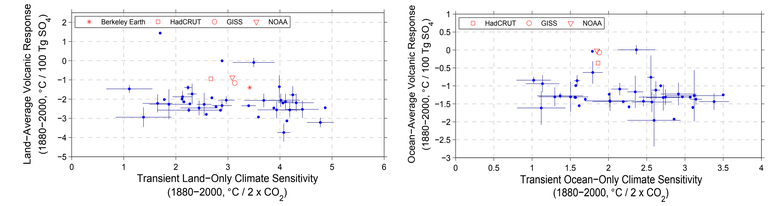
CMIP5 Global Climate Models



Trend maps derived from observational and climate model temperature fields over the period January 1900 to December 2000. Observational grid cells are left blank if more than 10% of months were not reported. Above each map is a summary of the average global, land, and ocean trend in °C / century. Differences in warming rate and structure are clearly visible over this historical period.

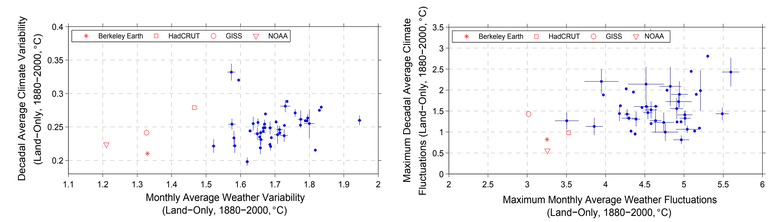
Response to Historical Volcanic Forcing

Nearly all climate models show a larger globally-averaged response to volcanic forcing than implied from the changes observed in historical instrumental temperature fields.



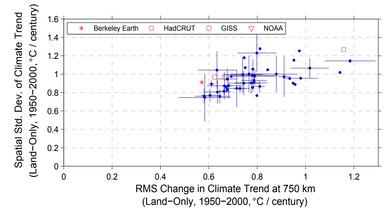
Weather and Climate Fluctuations

On monthly time scales, the temperature fields in all models show greater variability due to weather over land than is observed with direct instrumentation. On decadal time scales the internal climate variability of the models is more similar on average to the internal variability of the instrumental fields; however, most models have regions with decadal variability that exceeds the highest decadal variability seen in observations.



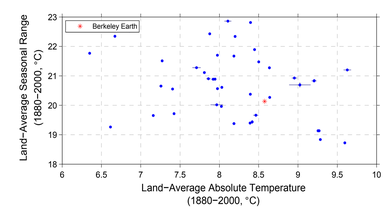
Smoothness of Trend Fields

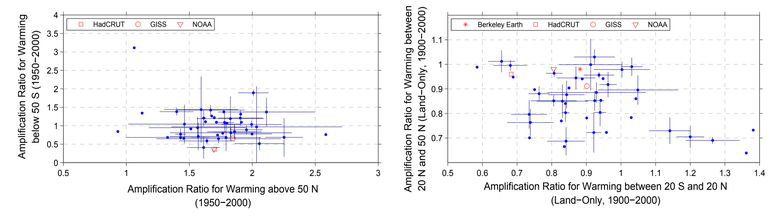
When considering nearby locations, instrumental temperature trend fields tend to be somewhat smoother than the typical model.



Absolute Average and Seasonality

Models exhibit considerable dispersion regarding Earth's absolute average temperature and mean seasonal range.



Regional Amplification of Climate Change

Models exhibit a wide range of possible values for Arctic amplification of climate change, though the mean value is near observations; however, most models expect more Antarctic warming than has been observed. Compared to the median model, observational data suggests faster warming in the Northern mid latitudes and slower warming near the Equator. Models that suggest amplified warming at the equator are inconsistent with existing observations.