Explaining the Record Warm 2007 Global Land Temperatures

NOAA CSI Team

The Observations

Globally averaged land temperatures for 2007 were the warmest since records began in 1880. The annual mean departure[1] was +0.64°C. Land temperatures were anomalously warm almost everywhere over the globe (Fig. 1, top panel) being particularly elevated over northern Eurasia. The few exceptions included cooler than normal temperatures over the west coast and southern regions of South America and northern Australia.

In contrast, global sea surface temperatures (SSTs) for 2007 were only the 9th warmest since records began in 1880, with an annual mean global average SST departure[1] of +0.12°C. Substantial portions of the world oceans were cooler than normal for 2007, in particular the east Pacific ocean from 60°N to 60°S (Fig. 1, bottom panel). This cooling was mostly a reflection of La Niña conditions that developed in the second half of 2007. By contrast, warm SSTs were widespread over all other ocean basins.

Formal detection and attibution studies, such as summarized in Chapter 9 of the Fourth Assessment Report of the Intergovernmental Panels on Climate Change (IPCC) have previously found that greenhouse gas forcing has very likely caused most of the observed global warming over the 50-year period 1956-2005. The analysis presented herein addresses factors contributing to the 2007 record land warmth, focusing on changes in event probability due to 2007 observed sea surface temperature conditions and estimated GHG forcing.

Link Between Ocean and Land Temperatures

To what extent was the record global land temperature of 2007 consistent with SST conditions? This connection is investigated with atmospheric general circulation model simulations forced with the monthly evolution of observed SSTs (so-called AMIP experiments). Simulations with three different models were performed, and for each an ensemble of 50 realizations was made. The multi-model ensemble averaged land surface temperature response in 2007 is also warm for virtually all locations (Fig. 2, top panel). Computed with respect to the 1971-2000 climatological mean of each model, the annual mean globally average land temperature departure was +0.26°C. This SST-forced signal is thus much less than the observed departure, suggesting that the SST forced signal, although of the same sign as the 2007 observed record land temperatures, was not the leading cause.

[1] *The observed global land surface temperature departures were calculated using the UK Meteorological Centre's HadCRUTEM3 global 5° gridded data. The departures were available for 2007 relative to a 1961-90 reference climatology, and we have adjusted those to a 1971-2000 climatology. The SST departures were calculated using the UK Meteorological Office's HadSST2 global 1° gridded data,*

relative to 1971-2000 reference. We calculate the global land average departure and SST departure using cosine weighting of grid boxes across the globe as a whole.

The distribution function of simulated globally averaged 2007 land surface temperature departures for each of the 150 runs is shown in Fig. 3, along with the distribution function of 150 members of the control runs that used 1971-2000 climatological SSTs. The following features of the AMIP distribution are noteworthy: (a) 145 of the 150 simulations for 2007 had a positive land surface temperature anomaly, (b) the spread of the distribution function (0.12°C standard deviation) is a measure of the influence of the internal atmospheric noise, indicating that internal atmospheric variability could also have been an important factor, (c) 2007 SSTs greatly elevated the chances that global land surface temperatures would be above normal, although no single run generated a departure as large as observed.

A larger model sample would be needed to better quantify the true statistical properties of these distribution functions. Our assessment nonetheless suggests that neither observed 2007 SST forcing nor internal atmospheric variability, either alone or in tandem, can explain the record warmth observed over land in 2007. These AMIP simulations did not include the effects of radiative forcing due to changes in atmospheric chemical composition; both the control and SST forced simulations used identical, climatological conditions for CO_2 and other anthropogenic trace gases. However, an indirect effect of greenhouse gas concentration changes is almost certainly included via the specification of the 2007 SSTs as lower boundary forcing.

Link Between Greenhouse Gas Emissions and Land Temperatures

To what extent was the record global land temperature of 2007 consistent with the greenhouse gas forcing? For this analysis the coupled model simulations that participated in the IPCC Fourth Assessment are well suited. The so-called CMIP archive of such model data that we used include 22 coupled atmosphere-ocean models and a total ensemble size of 48 simulations for 2007. These runs used projected GHG and aerosol concentrations based on a business-as-usual scenario (A1B) extended from the historical climate of the 20th Century runs that ended in 1999. Results for 2007 are not expected to depend crucially on scenario assumptions. The 2007 land surface and SST averaged across all 48 model simulations is shown in Fig. 2 (bottom panel) and Fig. 4, respectively. Warm surface temperature departures (relative the CMIP model climatologies of 1971-2000) occur over all land and ocean points.

The magnitude of the land surface warmth is appreciably greater in the CMIP ensemble than in the AMIP ensemble, particularly over Eurasia and North America, where CMIP results are also in better agreement with the intensity of observed warmth. The annual mean globally average land temperature departure was +0.40°C, and suggests that GHG forcing was a leading cause for the 2007 record land temperatures. The comparison with results from the AMIP runs suggests that at least one pathway by which GHG forcing raised land temperature was via their influence on the observed SSTs that on average were warmer, though we have not yet performed a formal detection/attribution study for the GHG signal in 2007 global SSTs.

The distribution function of simulated globally averaged land surface temperature departures for each of the 48 runs is shown in Fig. 3 (bottom panel) . Superimposed is the distribution of all CMIP simulated global land surface temperatures during the reference period of 1971-2000, comprising 1440 samples (30 years x 48 runs). The following features of the CMIP distribution are noteworthy: (a) 47 of the 48 simulations for 2007 had a positive land surface temperature anomaly; (b) a few runs generated 2007 departures larger than the record observed warmth; and (c) the spread of the distribution function (0.21°C standard deviation) is appreciably larger than the AMIP spread. Regarding points (a) and (b), it is apparent that the GHG forcing in the models by the year 2007 had greatly elevated the chances that global land surface temperatures would be above normal, which very likely applies also in the real world. Regarding (c) possible reasons for the increased spread include the larger number of CMIP models, which samples a wider range of model sensitivity, and also the fact that each CMIP simulation is free to generate its own internal SST variability, thereby increasing the variance in surface boundary forcing, and increasing the internal noise influence over land as well.

Summary

The diagnosis presented above seeks to explain the record 2007 global land surface temperature. The text uses subjective language to interpret the likelihood that certain conditions were caused by certain forcings, but at this point these should be viewed as a <u>*qualitative*</u>, expert assessment.

<u>Regarding the factors responsible for the record land warmth of 2007, this assessment suggests the following:</u>

1. *The observed SST conditions of 2007 forced a warming of global land temperatures, though the magnitude of the contribution was too small to explain the record land warming.*

2. *Greenhouse gas forcing was the likely principal factor raising global land temperatures in 2007, as the CMIP3 models that include positive GHG forcing through 2007 are much more consistent with the observed 2007 warmth than the models for the control period (1971-2000) . The observed <u>record</u> land warmth was larger than the multi-model mean response of the CMIP3 models with GHG forcing, however.*

3. *The increase of global land surface temperatures from an ensemble of CMIP3 model integrations, extended to 2007, suggests that GHG forcing*

has substantially elevated the probability of a record global land surface temperature, as occurred in 2007. Based on model studies, we found a nearly 100-fold increase in the probability of land temperatures exceeding the 2007 observed +0.64°C record...from a less than 0.1% chance for 1971-2000 conditions, to a 10% probability by 2007, under the IPCC A1B forcing scenario.

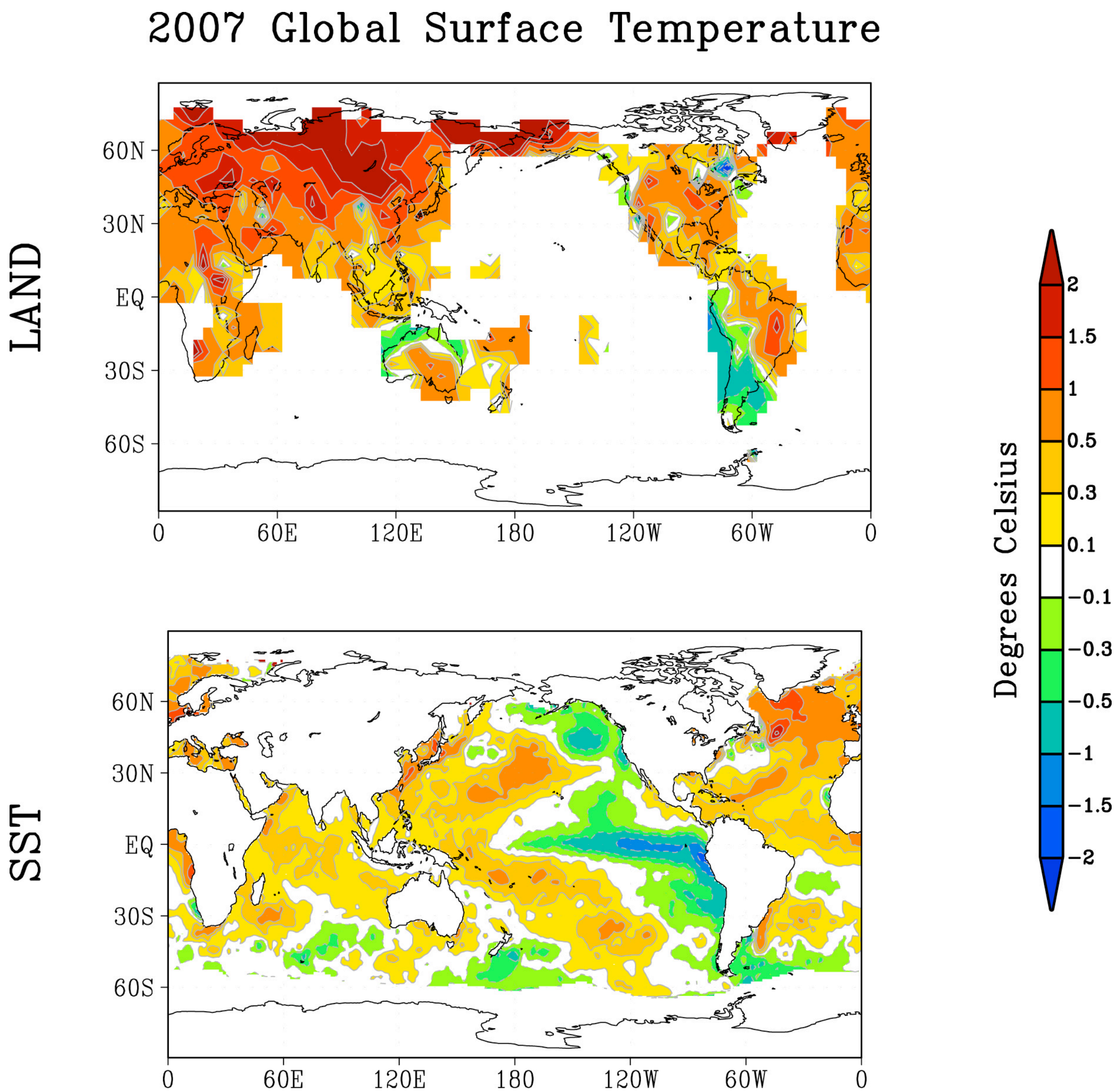

Figure 1. *Observed 2007 annuallly averaged land surface temperature departures (top), and sea surface temperature departures (bottom). Reference is 1971-2000 climatology.*

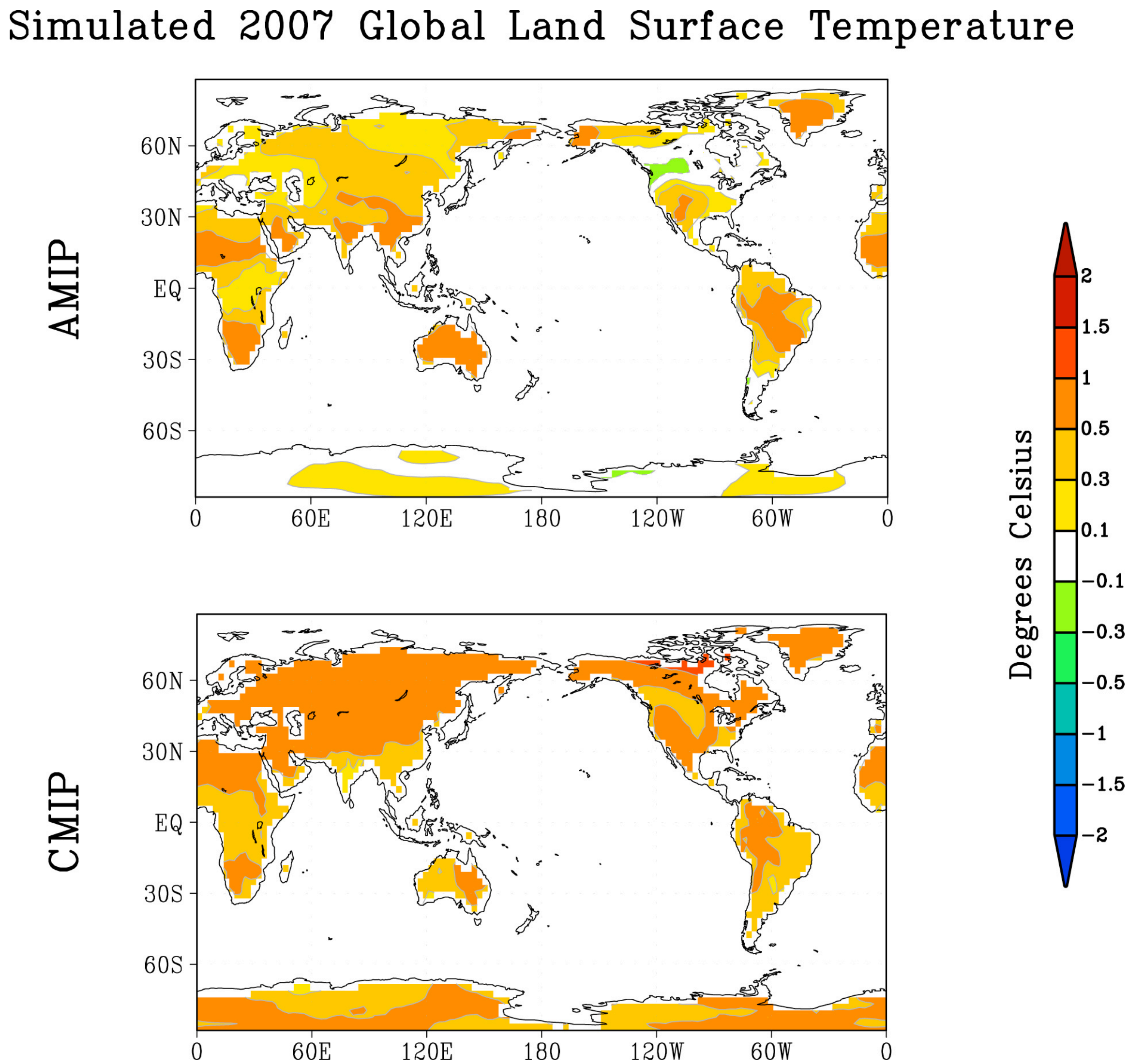

Figure 2. *Simulated 2007 annually averaged land surface temperature departure based on AMIP ensmeble (top), and CMIP ensemble (bottom) experiments. Reference is 1971-2000 model climatologies. AMIP refers to atmospheric climate models forced with the monthly varying observed 2007 global sea surface temperatures. CMIP refers to coupled ocean-atmosphere climate models forced with estimated 2007 greenhouse gas concentrations. See text for details on model runs.*

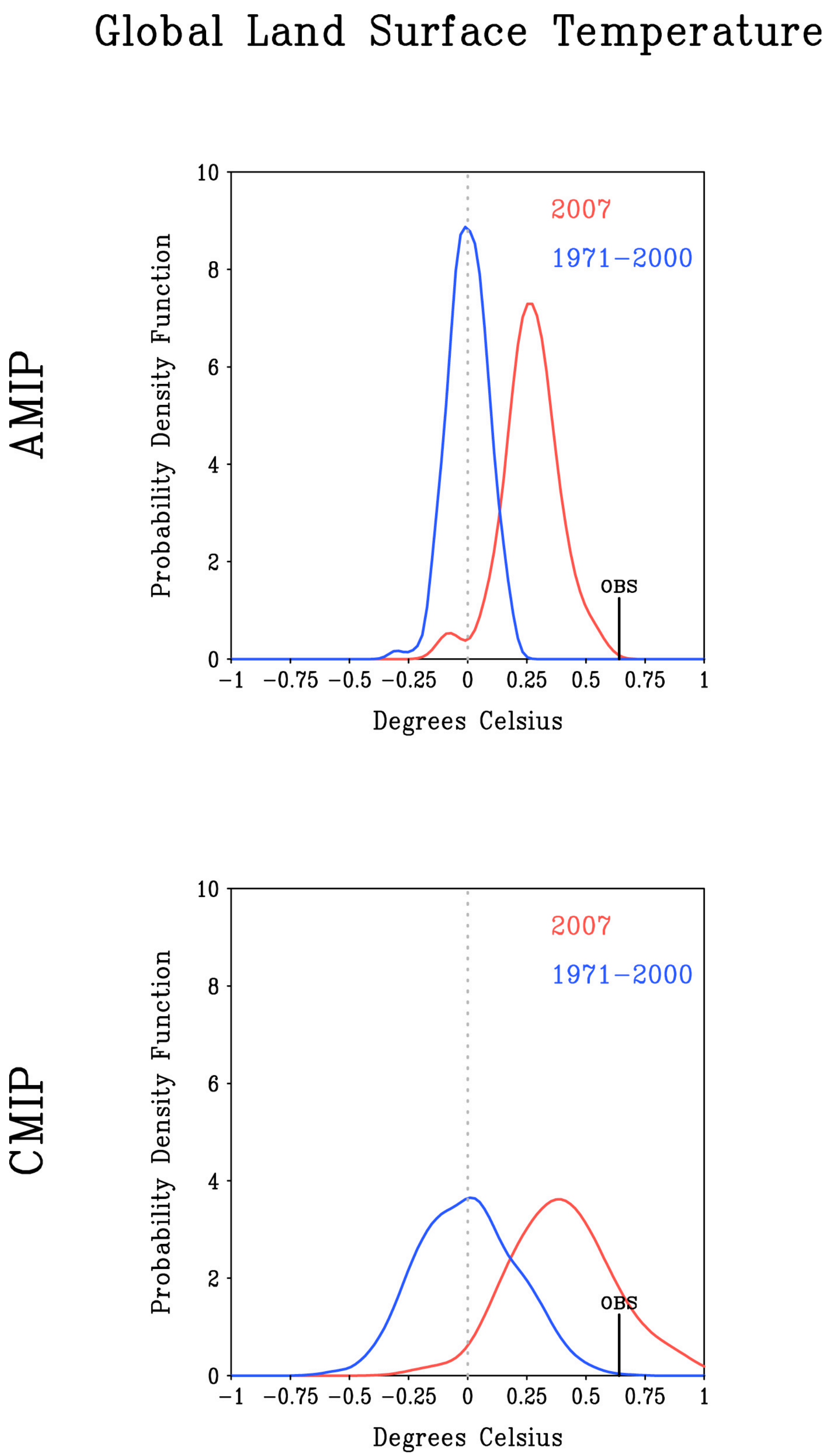

Figure 3. *Probability distribution functions (PDFs) of the simulated gloablly averaged 2007 annual land surface temperatures based on individual 150 AMIP runs (top, red), and the individual 48 CMIP runs (bottom, red) . The PDFs of simulated gloablly averaged annual land surface temperatures during the reference period of 1971-2000) are shown for y the blue PDFs. The observed gloablly averaged 2007 annual land surface temperature departure of +0.64°C plotted by vertical tic mark*

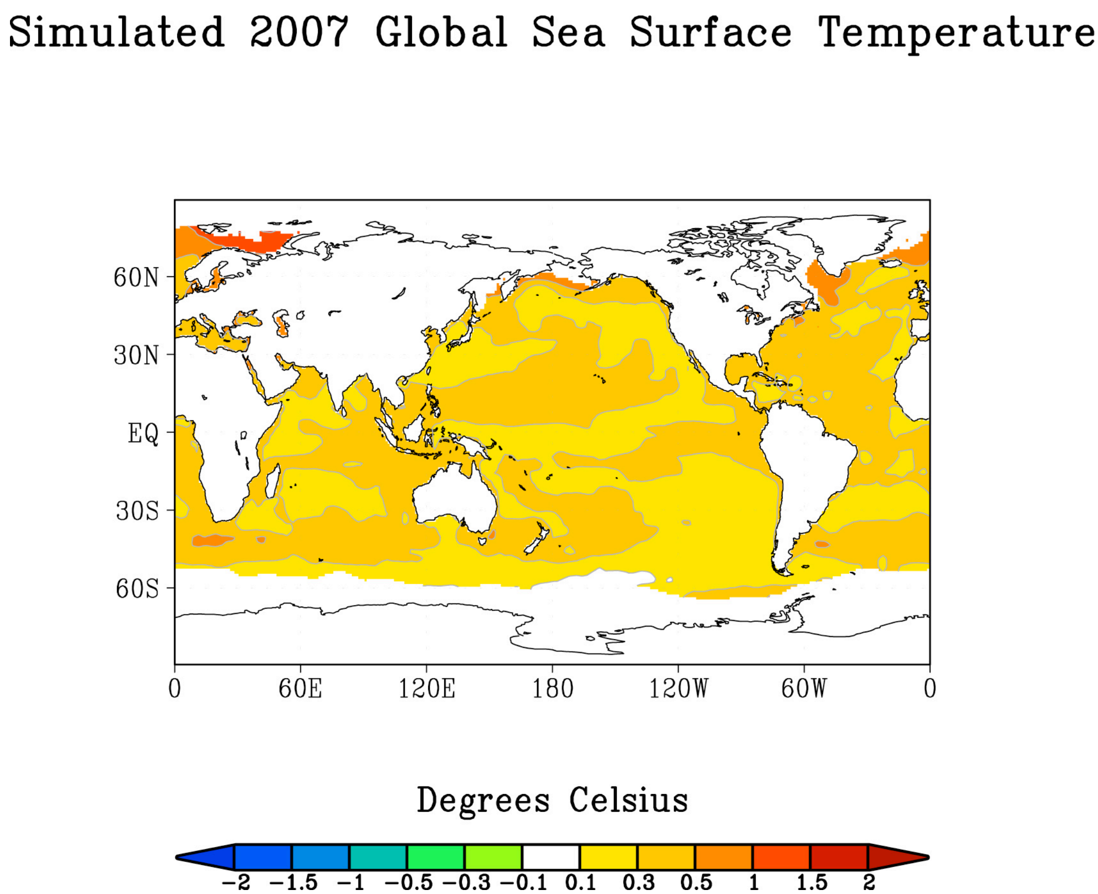

Figure 4. *Simulated 2007 annually averaged sea surface temperature departure based on CMIP experiments. Reference is 1971-2000 model climatologies.*