

# Diagnosis of Cause(s) for 2007 U.S. Precipitation Extremes

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The NOAA Climate Attribution Team, led by Dr. Martin Hoerling, investigated the causes of below average precipitation in both the southwestern and southeastern U.S. in 2007. This team calls themselves “Climate Scene Investigators,” (CSI) because they try to understand and explain anomalous climatic behavior as it evolves. They also assess seasonal climate predictors and evaluate the reasons for seasonal forecast success and failure. The CSI team includes scientists from the NOAA Earth System Research Lab in Boulder, CO, other NOAA research labs across the U.S., and also NOAA’s Climate Prediction Center in Washington D.C.

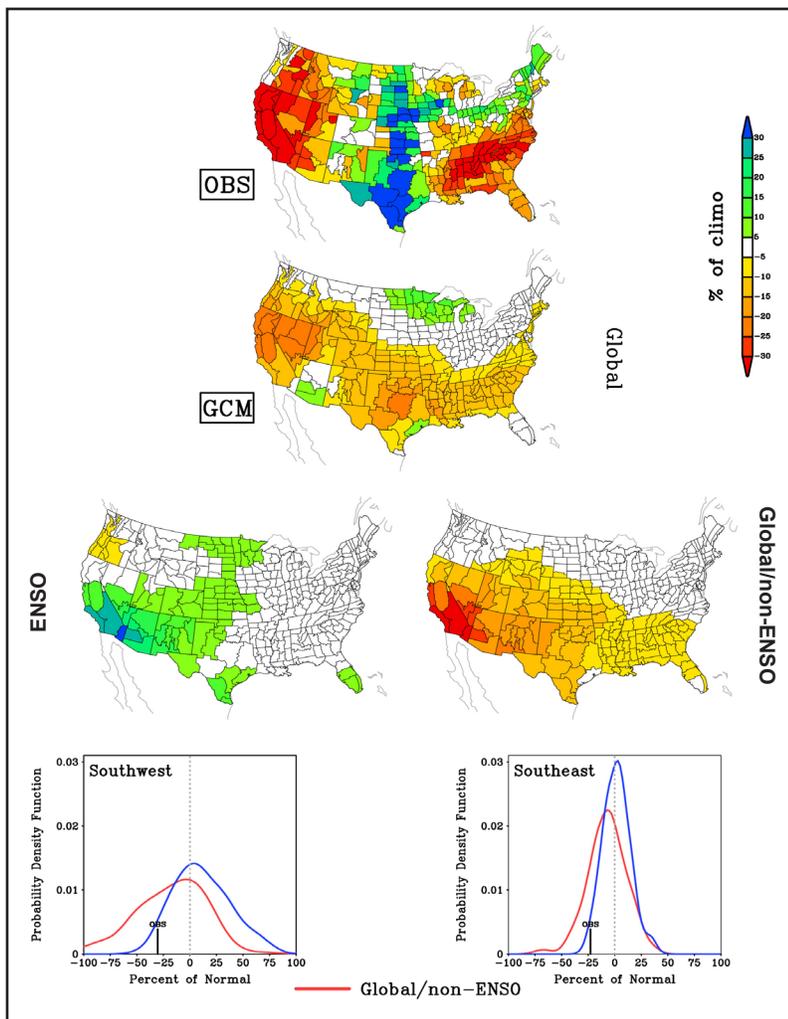
This article describes an effort by the CSI team to determine if below average precipitation in 2007 can be attributed to sea surface temperature (SST) anomalies. Since there was a strong El Niño in the winter/spring of 2007 and a La Niña beginning in late summer 2007, the team wanted to see if they could attribute the precipitation anomalies to the SST anomalies in the Tropical Pacific Ocean (i.e. the ENSO region). They analyzed SSTs in both the ENSO region and other regions including the Indian Ocean, the North Pacific and North Atlantic Oceans. As this article shows, the team found that it is unlikely that ENSO played a role in the US droughts of 2007. However, they found the atmosphere to have been sensitive to SST anomalies in other parts of the world oceans during 2007, and that was a factor in the U.S. dryness.

## Investigating global ocean influences on 2007 U.S. precipitation

For the contiguous United States (U.S.), large deficits in annually averaged (January-December) precipitation occurred in the Southwest and the Southeast regions (Fig. 1, top). There, accumulated annual departures have exceeded -30% of the 1971-2000 climatologies. Below normal precipitation was a remarkably persistent feature of the 2007 climate conditions in these two regions; all seasons during 2007 yielded abnormally low precipitation.

To assess whether such dryness was related to global sea surface temperature (SST) conditions, three different atmospheric climate models (NCEP-GFS, NCAR-CCM3, and GFDL-AM2.1, with nominal resolution of ~200 km) were forced with the monthly varying global 2007 SSTs. For these so-called GOGA (Global Ocean-Global Atmosphere) runs, 50 separate realizations were conducted for each model. Figure 1 (middle panel) shows the multi-model ensemble mean precipitation anomaly (% of climatology) computed relative to control simulations that had used climatological global SSTs of 1971-2000. A dry signal emerges over much of the southern U.S.; the departures are about -10% in the 150-member average, compared

Calendar Year 2007 Precipitation Departures



**Figure 1.** The U.S. 2007 annually averaged (January-December) precipitation departures expressed as % of the 1971-2000 climatologies for observations (top), for simulations based on global SST forcing (middle, contour interval half as for OBS), for simulations based on tropical east Pacific SST forcing (bottom left, same contour interval as for OBS), and for simulations based on global SST forcing excluding the tropical east Pacific (global/non-ENSO; bottom right, same contour interval as for OBS). The probability distribution functions of regional precipitation departures of the individual 150-member runs for the ENSO forced (blue curve) and global/non-ENSO forced regions (red curve) are shown for the Southwest U.S. (left) and the Southeast U.S. (right). Observed 2007 annual precipitation departures are shown by vertical gray bar.

to the -30% observed (contour interval of the GOGA run results is half that of OBS).

## Did ENSO cause the U.S. droughts of 2007?

Additional simulations indicate this dry signal was very unlikely the result of ENSO variability. Lingering El Niño

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conditions during winter/early spring 2007 were replaced by a La Niña event in late summer 2007. In a further suite of runs, SSTs were specified over the region 20°N-20°S, 160°E to the South American coast only, while climatological SSTs were specified elsewhere over the world oceans. For these so-called EPOGA (East Pacific Ocean-Global Atmosphere) runs, 50 separate realizations were again conducted for each model. A strong wet signal occurs over the Southwest (Fig. 1, bottom left), opposite to the drought conditions observed. The simulated wet signal is especially strong during winter/spring 2007 when El Niño conditions prevailed, and is also consistent with historical observations that reveal ENSO impacts to be largest during that time of year. Clearly, the expected wet signal failed to emerge during 2007; and it appears very unlikely that ENSO was a contributing factor to the droughts of 2007.

### Did other ocean conditions contribute to U.S. droughts of 2007?

The principal anomalies in global SSTs during 2007, outside the ENSO region, were warmth in the tropical Indian and Atlantic Oceans, and warmth across much of the extratropical North Pacific and North Atlantic Oceans. We estimate the effect of the “non-ENSO region” SST forcing by constructing the differences “GOGA-EPOGA” (subsequently referred to as global/non-ENSO). To the extent that the U.S. response can be viewed as the linear superposition of signals from various ocean forcings, this analysis is one estimate for the SST forced signal from the ocean conditions outside of the tropical eastern Pacific.

The global/non-ENSO results (Fig. 1, bottom right) reveal a strong U.S. precipitation sensitivity to this non-ENSO region forcing. In particular, a dry signal occurs along the entire southern tier of states, having a maximum percentage reduction in precipitation over the Southwest akin to the observed anomalies. Over the U.S. as a whole, this dry signal overwhelms the east Pacific induced wet signal. Thus, the modest U.S. drying emerging in response to the full global SST conditions of 2007 (Fig. 1, middle) appears to reflect the cancellation between two different SST influences; a wet ENSO effect and a stronger drying effect due to non-ENSO SST conditions.

### What was the changed likelihood of U.S. dryness given ocean conditions of 2007?

To quantify the extent to which the observed U.S. precipitation extremes were statistically consistent with SST forcing during 2007, Figure 1 also shows probability distribution functions (PDFs) of the individual 150-member annual precipitation anomalies for the Southwest (left panel; averages of California, Nevada, Utah, Arizona, Colorado, and New Mexico) and for the Southeast (right panel; averages of Arkansas, Alabama, Louisiana, Mississippi, Georgia, Tennessee, Florida, and the Carolinas). Two PDFs are compared, one drawn from the sampled population of runs forced by the ENSO-region 2007 SSTs only (blue curve), and the other drawn from the the sample population of runs forced with global/non-ENSO region 2007 SSTs (red curve).



Consistent with the spatial plots, a distinct shift toward increasingly dry probabilities under the influence of global/non-ENSO SSTs occurs over the Southwest and Southeast U.S..

A simple ranking of all ENSO forced runs reveals that only 3% and 2% of runs were as dry as observed over the Southwest and Southeast, respectively. By comparison, for the effect of global/non-ENSO SSTs, 22% and 15% of runs were as dry as observed over the Southwest and Southeast, respectively. There is thus a 8-fold increase in the probability of drying having the severity observed over both the Southwest and Southeast during 2007 due to the effect of global/non-ENSO region SSTs versus the effect of ENSO region forcing alone.

### Summary

The diagnosis presented above provides some attribution of key features of the observed 2007 U.S. climate conditions. The text uses subjective language to interpret the likelihood that certain conditions were caused by certain forcings, but at this point that should be viewed as a *qualitative*, expert assessment.

Regarding the anomalously low precipitation within the U.S. Southwest and Southeast regions, this assessment suggests the following:

- The extreme low precipitation was inconsistent with east tropical Pacific SST variability during 2007, and thus was very unlikely caused by the ENSO cycle occurring during January-December 2007. We estimate less than a 5% probability that the observed dryness was consistent with climate conditions driven from the tropical east Pacific in 2007.
- An SST-induced dry signal did exist in 2007, spanning much of the southern U.S., and originated from SST conditions outside the tropical Pacific. This dry signal overwhelmed the ENSO wet signal, and we estimate a large increase in the probability of U.S. drying having intensities as large as observed in 2007 due to such a global SST influence.