

Diagnosing 2007 U.S. precipitation extremes

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Forget “CSI: Crime Scene Investigations,” the television show that uses ubiquitous fingerprints, DNA, and gunshot residue to catch crooks. There’s another CSI, and this one uses computer simulations, data, and atmospheric science for some sleuthing of its own: to uncover the reasons behind anomalous climatic behavior as it evolves.

Climate Scenes Investigators (CSI) recently focused on the causes of below-average precipitation in 2007 in the southwestern and southeastern United States to determine if those conditions can be attributed to sea surface temperature (SST) anomalies. After some climatic detective work, the team turned up some surprising findings.

Calendar Year 2007

Precipitation Departures

CSI is the nickname for the National Oceanic and Atmospheric Administration (NOAA) Climate Attribution Team. Led by Martin Hoerling, a NOAA meteorologist, the CSI team includes scientists from the NOAA Earth System Research Lab in Boulder, Colorado, other NOAA research labs across the U.S., and NOAA’s Climate Prediction Center in Washington D.C. The scientists also assess seasonal climate predictors and evaluate the reasons for seasonal forecast success and failure.

A strong El Niño in the winter/spring of 2007 and a La Niña beginning in late summer 2007 gave the CSI team an opportunity to try to link below-average precipitation in the Southwest and Southeast to the SST anomalies in the Tropical Pacific Ocean, the region of the El Niño Southern Oscillation (ENSO). ENSO is the term currently

used by scientists to describe periodic basin-wide changes in air-sea interaction in the equatorial Pacific Ocean; El Niño/La Niña is the oceanic component, and the Southern Oscillation is the atmospheric component. The term El Niño refers to a sustained warming of SSTs across a broad region of the eastern and central tropical Pacific Ocean and tends to be associated with drier winters in the Pacific Northwest and wetter winters in the southwestern United States. The opposite is generally associated with La Niña events.

The team analyzed SSTs in both the ENSO region and other regions, including the Indian, North Pacific, and North Atlantic oceans. While the team concluded that it is unlikely that ENSO played a role in the U.S. droughts of 2007, the scientists found the atmosphere to have been sensitive to SST anomalies in other parts of the world oceans that year, and that that was a factor in the U.S. dryness.

Investigating global ocean influences on 2007 U.S. precipitation

For the contiguous U.S., large deficits in annually averaged (January–December) precipitation occurred last year in the Southwest and the Southeast regions (Figure 1, top). In those regions, accumulated annual departures from average have exceeded -30 percent of the 1971–2000 average precipitation. 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 SST conditions (as opposed to SSTs in the ENSO region and



the oceans mentioned above), the scientists ran three different atmospheric climate models with the monthly varying global 2007 SSTs. For these so-called GOGA (Global Ocean-Global Atmosphere) runs, fifty separate simulations were conducted for each model. Figure 1 (middle panel) shows the average precipitation anomaly (departure from average) for all model simulations compared to the long-term average global SSTs. A dry pattern emerges over much of the southern U.S.

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

Additional simulations indicate this dry pattern was very unlikely the result of ENSO variability. Lingering El Niño conditions during winter and 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 degrees north to 20 degrees south, 160 degrees east to the South American coast only, while average SSTs were specified elsewhere over the world oceans. For these so-called EPOGA (East Pacific Ocean-Global

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Atmosphere) runs, fifty separate simulations were again conducted for each model. Although drought conditions were observed in reality, the simulation results indicated a strong wet pattern over the Southwest (Figure 1, bottom left). This simulated wet pattern was 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 pattern failed to emerge during 2007, and it appears very unlikely that ENSO was a contributing factor to the droughts that year.

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. The team estimated the effect of the non-ENSO region SST influence, or forcing, by constructing the GOGA-EPOGA, subsequently referred to as global/non-ENSO. This analysis provided one estimate for the SST-forced signal from the ocean conditions outside of the tropical eastern Pacific.

The global/non-ENSO results (Figure 1, bottom right) revealed a strong U.S. precipitation sensitivity to this non-ENSO region forcing. In particular, dry conditions occurred 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 overwhelmed the east Pacific-induced wet signal. Thus, the modest U.S. drying that emerged in response to the full global SST conditions of 2007 (Figure 1, middle) appears to reflect the cancellation between two different SST influences: a wet ENSO

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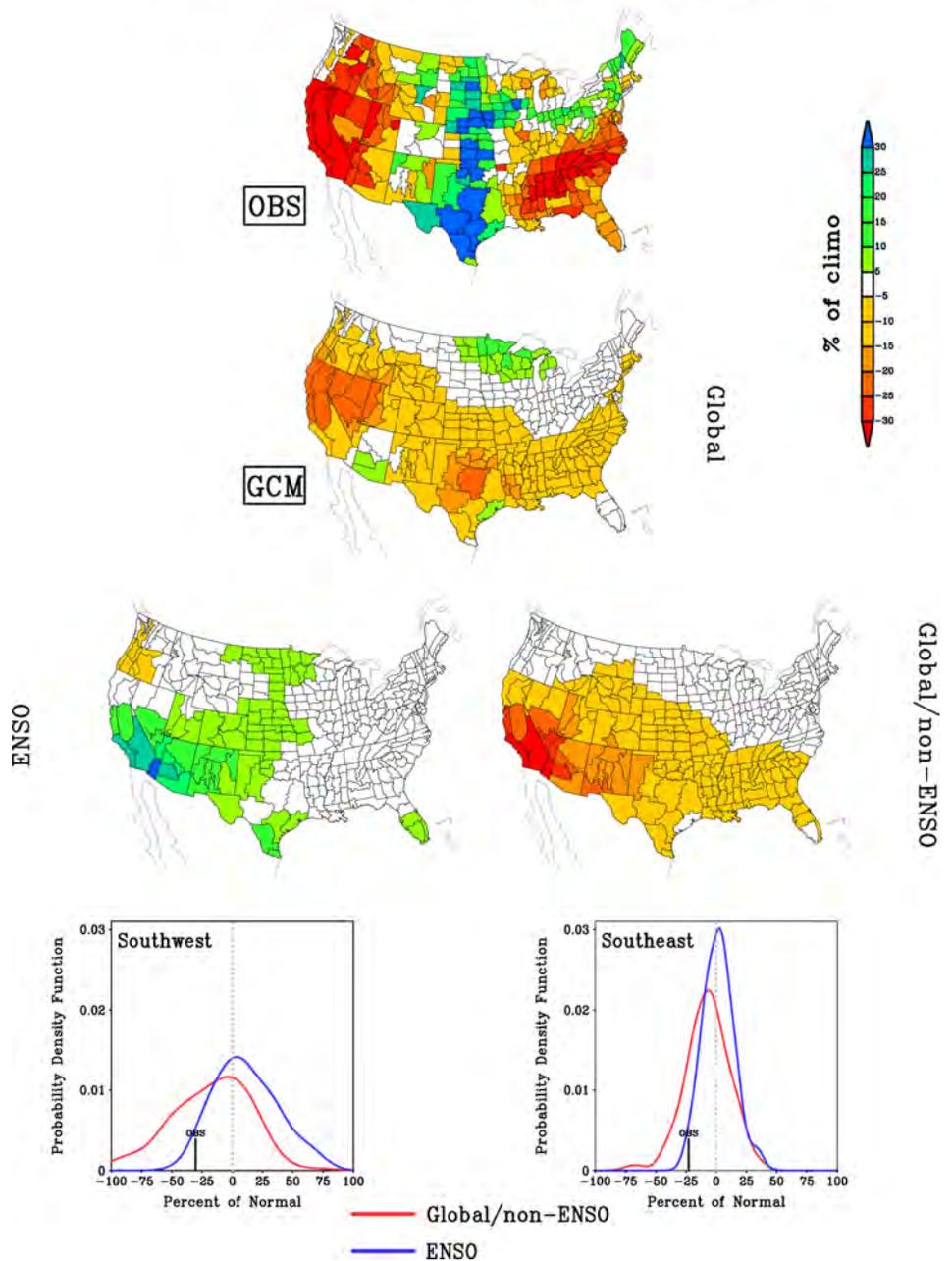


Figure 1. The U.S. 2007 annually averaged (January–December) precipitation departures expressed as a percent of the 1971–2000 climatologies for observations (top), for simulations based on global SST forcing (middle, contour interval half as for OBS), for simulations based on tropical east Pacific SST 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.

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effect and a stronger drying effect due to non-ENSO SST conditions.

In other words, the models indicated that the conditions in the world oceans—but not in the central Pacific—swamped the ENSO signal in 2007. Those results are surprising because the scientific community generally has tended to associate El Niño events with a wet southwestern United States, but that is not what occurred.

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, two probability density functions are compared (Figure 1, bottom), one drawn from the sampled population of runs forced by the ENSO-region 2007 SSTs only (blue curve), and the other drawn from 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 southwestern and southeastern United States.

A simple ranking of all ENSO-forced runs reveals that only 3 percent and 2 percent of runs were as dry as observed over the Southwest and Southeast, respectively. By comparison, for the effect of global/non-ENSO SSTs, 22 percent and 15 percent of runs were as dry as observed over the Southwest and Southeast, respectively. There is thus an eight-fold increase in the probability that drying, with the severity observed over both the Southwest and Southeast during 2007, was 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. The team estimated there is less than a 5 percent probability that the observed dryness was consistent with climate conditions driven from the tropical east Pacific in 2007.
- An SST-induced dry signal existed 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; the team estimated 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.

** A full list of the Climate Attribution team members is available at <http://www.cdc.noaa.gov/CSI/>.*

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Related Links

Visit the links listed below for more information on the CSI Team, their affiliates, and for information on climatological conditions discussed in the accompanying article.

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NOAA El Niño Page
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NOAA Climate Prediction Center
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NOAA El Niño Educational Sites
<http://www.elnino.noaa.gov/edu.html>

CLIMAS Glossary of Climate Terms
<http://www.climas.arizona.edu/forecasts/glossary.html>

The International Research Institute for Climate and Society (IRI) ENSO Forecast
<http://iri.columbia.edu/climate/ENSO/currentinfo/figure3.html>

USGS Information on El Niño
<http://walrus.wr.usgs.gov/elnino/>

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<http://www.wrcc.dri.edu/>

