National Aeronautics and Space Administration
Goddard Institute for Space Studies

Science Briefs

Separating Natural from Anthropogenic Influences in Twentieth Century Climate Data Records

December 2008

Determining the human contribution to observed variations in Earth's climate is made more difficult by the fact that the climate system also varies naturally, due to interactions of different parts of the atmosphere with each other and with the underlying oceans. These natural variations exist on time scales of several years to decades. The shorter the time span of the data record, the more difficult it is to separate systematic changes due to human activities such as greenhouse gas emissions and the production of aerosol particles from natural variations.

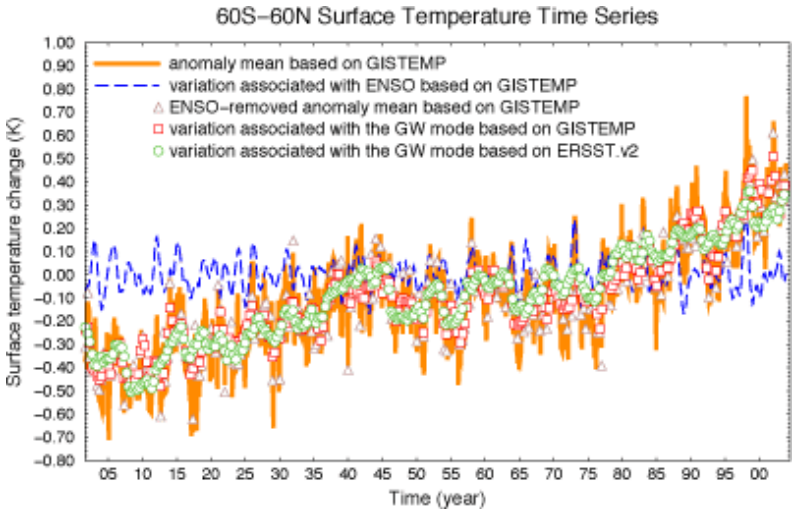


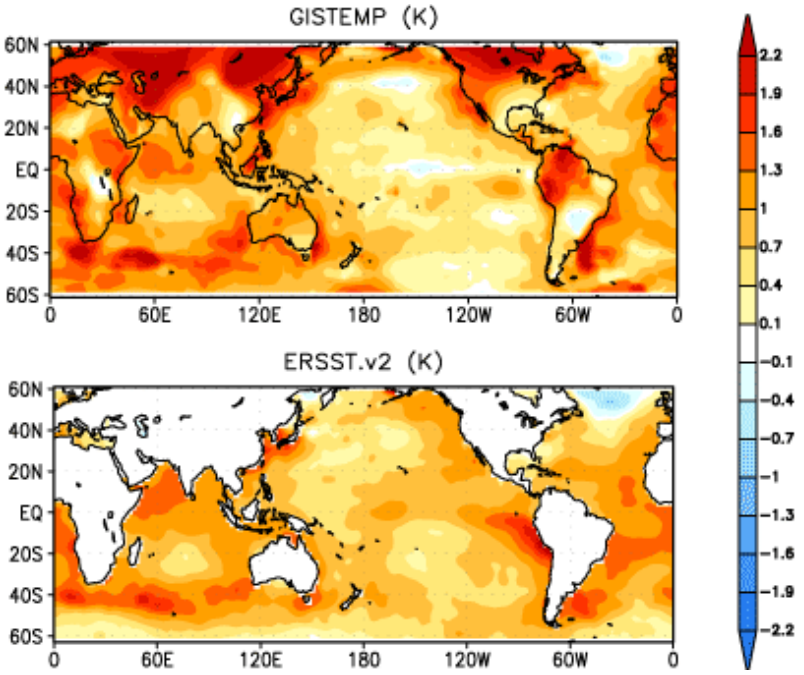
Figure 1. Changes in global surface temperature between 1900 and 2003 associated with the long-term global warming trend in two different datasets, GISTEMP and ERSST. The orange curve shows the temperature change in the GISTEMP data with all effects included. The blue dash-dot curve shows the contribution of El Niño-Southern Oscillation (ENSO) to the observed temperature fluctuations. The brown triangles show the temperature variations when the ENSO effect is subtracted from the original data. The red squares show the portion of the remaining variation that is associated with the long-term global warming trend in the GISTEMP data, and the green circles show the corresponding long-term global warming trend in the ERSST data. (Click for large GIF or PDF of figure.)

Some natural climate fluctuations like the seasonal cycle are simple to account for, since they occur on a well-known, fixed time scale. Other important natural climate influences like El Niño, the recurring warming of ocean waters in the tropical east-central Pacific Ocean, are more difficult to extract from climate datasets for two reasons. The warming does not occur at fixed time intervals, but ranges from 2-4 years. Furthermore, it can take 3-6 months for the effects in the east-central Pacific to be felt elsewhere around the globe, depending on how the circulation of the atmosphere communicates these effects to remote locations.

Scientists at the Goddard Institute for Space Studies and at the GSFC Global Modeling and Assimilation Office developed a technique to account for both the immediate effect of El Niño at its tropical Pacific source location, and its delayed effect elsewhere in the world. Once the El Niño contribution to climate variations is defined, it can be removed from a long-term climate data record, allowing longer-term climate variations to be documented. Even after this is done, some longer term natural variations remain, most notably a phenomenon called the Pacific Decadal Oscillation (PDO) that causes irregular shifts in the climate roughly every few decades. Fortunately, the spatial pattern of climate shifts due to the PDO is different from that associated with systematic human influences, and objective mathematical techniques can be used to separate them. The scientists applied this procedure to several 20th century surface temperature datasets, and also to late 20th century "reanalyses" that combine surface and satellite data with a numerical weather prediction model to produce a best estimate of variations in atmospheric temperatures and winds.

Figure 2. Spatial patterns of the long-term global warming contribution to the observed temperature trends in the GISTEMP (upper panel) and ERSST (lower panel) datasets. Orange and red colors represent warming and blue colors represent cooling over the period 1900-2003. (Click for large GIF or PDF of figure.)

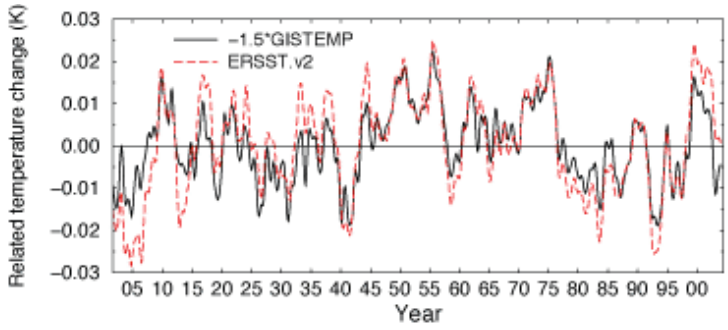
The analysis shows that the leading contributor to variations in surface temperature over the 20th century is a largely systematic upward trend in most locations that appears to be consistent with estimates of the effects of increasing greenhouse gas concentrations. A few locations over land exhibit weak cooling over this time, perhaps a signature of the effects of increasing aerosol particles due to combustion and biomass burning, or a result of changes in land use. The most notable new result is the finding that the tropical Pacific has warmed significantly more slowly (and maybe not at all near the equator) than the rest of the world over this time, a feature that is not captured by most climate models simulations of 20th century climate changes. This



slower warming of the tropical Pacific induces changes in the atmospheric circulation that can be seen in the reanalyses, but two different reanalysis products that incorporate different amounts of satellite data in different ways produce conflicting estimates of the change in circulation.

Aside from the long-term upward trend, the analysis captures the decadal natural fluctuations due to the PDO. A new finding that emerges from this analysis is that in addition to a well-known natural climate shift in 1976, another natural climate shift in the opposite direction apparently occurred in the mid-1990s. This latter climate shift makes it especially difficult to interpret trends seen in satellite or surface datasets that are only a decade or two in length, since an apparent upward trend in something like temperature may be partly anthropogenic and partly natural over a time period in which only one natural climate shift occurred.

Fortunately, by combining information about the spatial patterns of the anthropogenic and natural climate variations, it is possible to draw some conclusions. For example, an upward trend in ocean heat content from 1993-2003 has been interpreted by previous workers as a sign of anthropogenic influences that create an imbalance between the sunlight absorbed by the Earth and the heat it emits to space.



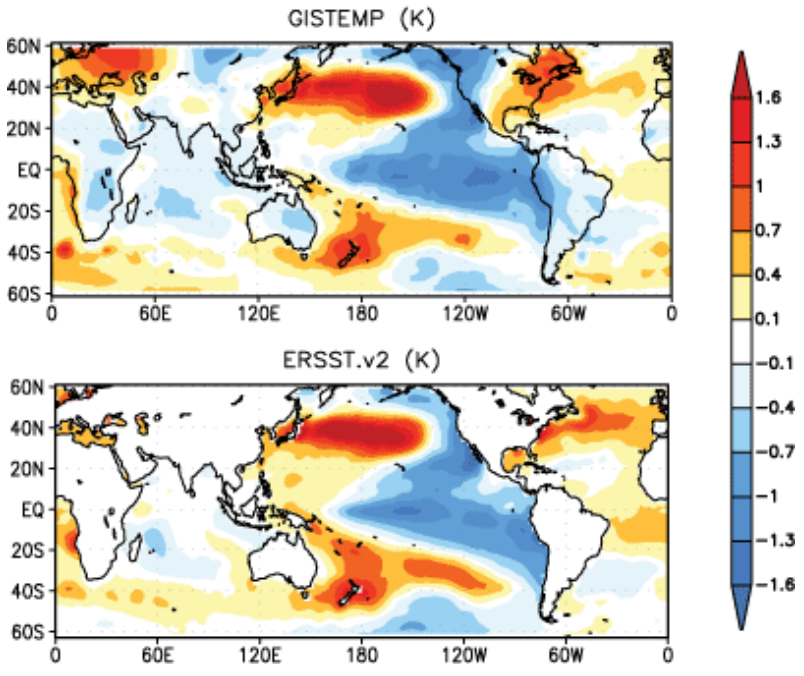


Figure 3. Upper panel: Changes in global surface temperature over the period 1900-2003 associated with the Pacific Decadal Oscillation (PDO) in the GISTEMP and ERSST datasets. Middle and lower panel: Spatial patterns of surface temperature change due to the PDO in both datasets. Orange and red colors represent warming and blue colors represent cooling. (Click for large GIF or PDF of figure.)

At first glance the PDO shift in the mid-1990s might call such an interpretation into question. However, the spatial pattern of the PDO includes warming in some places and cooling in others; in fact, changes consistent with the PDO can be seen in the geographic pattern of observed ocean heat content changes. But in the global mean these warming and cooling changes nearly offset each other, so the overall upward trend in observed ocean heat content can only be explained by anthropogenic effects, which exhibit warming almost everywhere. On the other hand, satellite-observed changes in absorbed sunlight and emitted heat in the tropics over the period 1985-2000, which appear to have caused a strengthening of the tropical atmospheric circulation, could in principle be either anthropogenic or natural in origin.

By examining the spatial pattern of both types of climate variation, the scientists found that the anthropogenic global warming signal was relatively spatially uniform over the tropical oceans and thus would not have a large effect on the atmospheric circulation, whereas the PDO shift in the 1990s consisted of warming in the tropical west Pacific and cooling in the subtropical and east tropical Pacific, which would enhance the existing sea surface temperature difference and thus intensify the circulation. Thus, it can be concluded that the observed 15-year trend in radiative imbalance of the tropics is probably a signature of natural rather than anthropogenic climate variations.

Reference

Chen, J., A.D. Del Genio, B.E. Carlson, and M.G. Bosilovich, 2008: The spatiotemporal structure of twentieth-century climate variations in observations and reanalyses. Part I: Long-term trend. *J. Climate*, **21**, 2611-2633, doi:10.1175/2007JCLI2011.1.

Chen, J., A.D. Del Genio, B.E. Carlson, and M.G. Bosilovich, 2008: The spatiotemporal structure of twentieth-century climate variations in observations and reanalyses. Part II: Pacific pan-decadal variability. *J. Climate*, **21**, 2634-2650, doi:10.1175/2007JCLI2012.1.

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