Multi-decadal climate variability in observed and modeled surface temperatures

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Introduction

Non-uniformity in the global warming trend is usually attributed to corresponding non-uniformities in the external forcing. Alternative hypothesis involves multi-decadal climate oscillations affecting the rate of global temperature change. **We use 20-th century observations of global surface temperature combined with analysis of coupled GCM simulations in an attempt to differentiate between the externally forced and natural aspects of the observed temperature variability.**

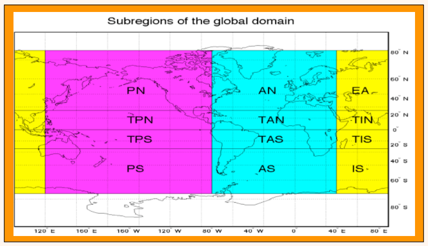

Fig. 1. The surface temperature record will be averaged within twelve sub-domains of the global domain corresponding to four latitude bands and Pacific, Atlantic, and Indian/Eurasian sectors, respectively.

Observational analysis

The time series (PCs) of the leading empirical orthogonal functions associated with multi-region surface temperature variability (see **Fig. 1**) are shown in **Fig. 2**, while the corresponding global patterns are displayed in **Fig. 3**. The leading PC represents non-uniform global warming trend (characterized by high cross-region temporal correlations); the next two time series, as well as the associated spatial patterns are in quadrature and strongly hint to a multi-decadal oscillation with a time scale of about 60–80 yrs.

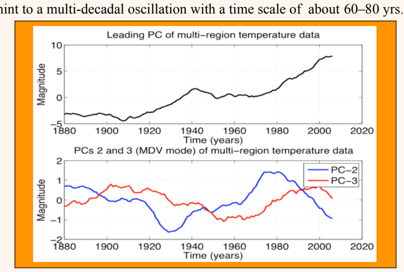

Fig. 2. Leading principal components of multi-region (see Fig. 1) surface temperature anomaly data based on Goddard Institute for Space Studies [GISS] data set [Hansen et al. 1999; Reynolds et al. 2002]): http://data.giss.nasa.gov/gistemp/.

Observed multi-decadal variability

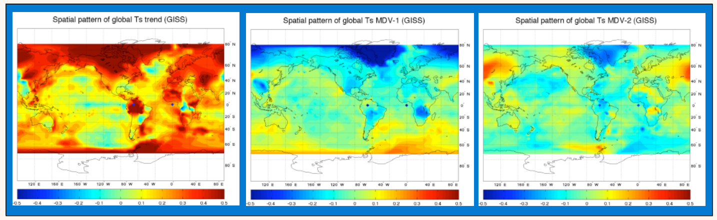

Fig. 3. Spatial patterns of three leading modes of the global surface temperature. The patterns characterizing multi-decadal variability with a period of 60–80 yrs have pronounced centers of action in Labrador and Weddell Seas – both are climatically important sites of deep-water formation. Variability is also fairly strong over eastern part of Eurasia.

Comparison with models

We have used for our analysis a 14-model ensemble from the IPCC data archive (multiple realizations of the 20-century climate for each model). We first computed, for each model, the single ensemble mean surface temperature time series by averaging over all available model runs. These time series were then averaged to get the multi-model ensemble mean temperature time series. The results for globally averaged temperature are shown in **Fig. 4**. The models do a good job in representing temperature variability, with notable exception of local troughs in 1910s and 70s and a crest around 1940. The regional deviations of simulated temperature from the observations (**Fig. 5**) are more pronounced and have a similar oscillatory structure in the Northern Hemisphere.

Time series of the leading EOF of multi-region data–model surface temperature difference, along with the corresponding spatial pattern, are shown in **Fig. 6**. The temperature difference appears to be dominated by an oscillation whose time scale and spatial pattern are not unlike those of the observed multi-decadal variability (**Figs. 2 and 3**). This suggests that the main difference between observed and simulated time series is the lack of multi-decadal signal presumably associated with natural climate variability. The ensemble-mean surface climate is thus interpreted as our best guess of climate response to external forcing dominated by anthropogenic sources.

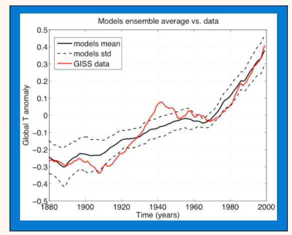

Fig. 4. Global temperature time series in models and data.

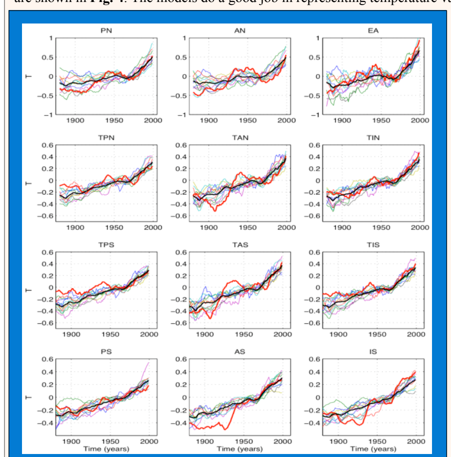

Fig. 5. Multi-region temperature variability in models and data (the index of a region is given in the caption of each panel). Light lines: individual model ensemble means (each line thus represents the average over 20-century climate realizations of the *same* model). Heavy black lines: average over all runs of all models (that is, average over the temperature time series represented by light lines). Heavy red lines: observed time series of surface temperature.

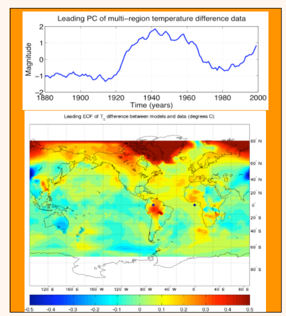

Fig. 6. The leading EOF of the difference between the observed multi-region surface temperature and models' ensemble mean time series. Note apparent similarities between the time scale (Fig. 2) and spatial pattern (Fig. 3) of observed multi-decadal variability and those of the models–data difference depicted here.

Discussion

Traditional interpretation of the decreasing global-mean surface temperature during the period of 1940–1970 is that it is due to tropospheric aerosols' cooling effect overweighting greenhouse-gas induced warming. Both types of forcing are incorporated in the model runs we have analyzed; yet, the simulated global temperature time series underestimates this local cooling trend (**Fig. 4**). Differences are even more pronounced in regional temperature averages (**Fig. 5**), with most amplitude in the Northern Hemisphere's Atlantic sector, *including the tropics*. We suggest that natural climate variability on a time scale of 60–70 yr may be partly responsible for the observed non-uniform trends (Schlesinger and Ramanakutty 1994; Delworth and Mann 2000).

The spatial pattern of multi-decadal signal in **Fig. 3** has a near-zero global average. The global-mean temperature trend is almost entirely accounted for by the leading PC of the multi-region data (**Fig. 2**); the latter PC, when linearly detrended, is a temperature anomaly whose apparent time scale is consistent with multi-decadal signal of PCs 2 and 3. We suggest that this anomaly is due, in part, to changes in the ocean uptake of CO_2 associated with multi-decadal natural signal.

References

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For further information

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