Extended Abstract

Improved historical Reconstructions of SST and Marine Precipitation Variations

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Since about 1980 both sea-surface temperature (SST) and oceanic precipitation have been sampled by satellites and monthly analyses are available base on satellite observations. Before that time there are only in situ SST observations and only island and land precipitation observations. To better evaluate climate variations in the pre-satellite period reconstructions of anomalies for those periods have been developed. Reconstructions are analyses that use statistics based on the satellite-era analyses with in situ data from the earlier periods to analyze variations in the pre-satellite period. Such reconstructions are needed for climate studies and to evaluate coupled climate models.

SST reconstructions have been produced for more than 15 years. The NOAA SST reconstruction is called the extended reconstruction of SST (ERSST). Here the ERSST method is used as the control and new iterative methods are tested in an attempt to produce better skill for the historical period. Data used are the Hadley Centre 5° monthly SST along with the number of individual observations used to form each 5° monthly average.

The ERSST method first performs large-scale spatial averaging to form large-scale monthly SST anomalies, which are then averaged annually. Those large-scale annual anomalies are next filtered over running 15-year periods to form an annual first guess SST anomaly. A set of spatial modes based on the satellite-period analysis is computed. Those spatial modes are used to analyze monthly increments from the first-guess analysis. The sum of the two forms the ERSST analysis. Testing was done to assign the optimum number of data needed to form the first guess anomalies and for including spatial modes used to adjust the first guess for the monthly analysis.

Iterative SST analyses were suggested by the Hadley Centre and modified here. They are used only for the annual first-guess analysis, and are intended to improve the skill of the first guess. First a set of 10 rotated empirical orthogonal functions (EOFs) are computed from the satellite-period analysis. Those EOFs are used to analyze the annual average anomalies for the entire historical period. The historical analysis is then adjusted by statistical re-injection of the historical annual average SSTs where they are available. A new set of 10 rotated EOFs is then computed using data from the entire historical period with the adjusted data and used to reanalyze the annual average anomalies for the historical period. The process is repeated until the historical analysis stabilizes. Using a limited number of modes ensures that noise from isolated re-injected data is minimized and only the large-scale variations are represented in the annual analysis.

In the first iteration only the satellite-period data are used for the EOFs, so the modes used for reconstruction are independent of the historical-period data. For that first iteration many of the historical variations may not be fully resolved because they are not sufficiently represented by the analysis EOF modes. In later iterations the historical-period data are included, which allows much better representation of historical variations. Several iterative methods are tested with different tuning. The first method (Iter Test 1) requires 5% variance sampling to include a mode for reconstruction and uses a constant noise/signal ratio in the data re-injection step. The next requires 10% variance sampling and uses a constant noise/signal ratio (Iter Test 2). That increases the skill compared to Iter Test 1 and eliminates some over-fitting in periods with sparse sampling. The third requires 10% variance sampling and uses noise/signal ratios inversely proportional to sampling (Iter Test 3), and improves the skill slightly compared to Iter Test 2.

Skill is demonstrated using cross-validation testing. The cross-validation testing used initial modes from the 1990-2009 satellite-based anomalies and analyzed data from 1982-1989 using the ERSST control methods and each of the iterative methods tested. Results clearly demonstrate that skill in the historical period can be improved using the iterative method (Fig. 1).

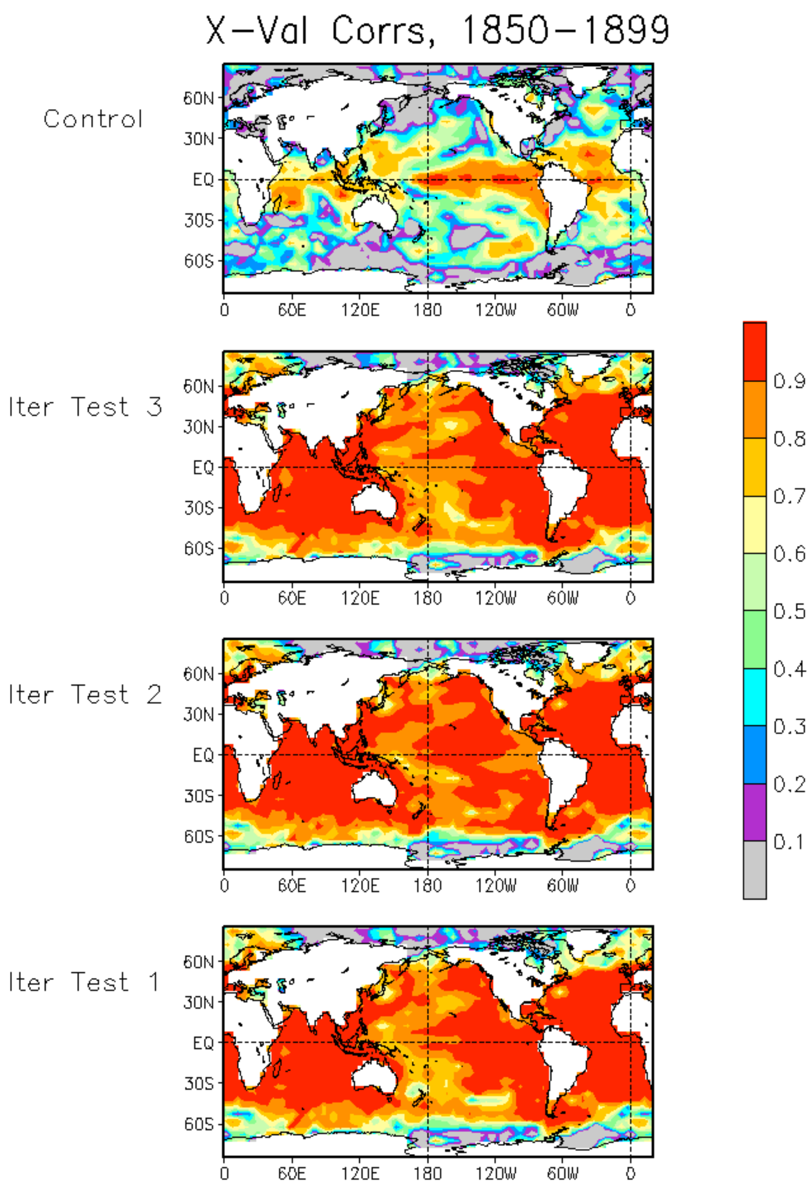

Figure 1. Cross validation correlation of SST reconstructions from the control method and tests of three iterative methods for annual averages over 1850-1899.

More recently precipitation reconstructions have been produced for the period beginning 1900. Precipitation is sampled over land for the extended period by networks of gauges, but there is almost no oceanic sampling before the satellite period. Understanding oceanic precipitation is important because it is an important component of the global climate system and it is predicted to change with a warming earth.

Changes in oceanic and land precipitation can influence each other and they should both be understood if we are to have a clear understanding of what may happen in the future.

The first precipitation reconstruction used monthly EOF anomaly modes to reconstruct the monthly anomalies from monthly gauge data. The EOFs and base statistics for all the precipitation analyses discussed here are computed from the Global Precipitation Climatology Project (GPCP) merged satellite and in situ data. That analysis represented interannual and shorter period variations consistently and in agreement with our understanding based on the shorter period. However, there were some inconsistencies in the multi-decadal variations in that analysis for the period before 1950. To improve the multi-decadal signal a canonical correlation analysis (CCA) was developed to reconstruct annual averages from correlations with historical SST and sea-level pressure (SLP). The CCA gave oceanic precipitation multi-decadal changes consistent with the theoretical and model understanding that it would increase with warming temperatures. However, the CCA spatial trend patterns that are much larger than those from the satellite-based analyses, suggesting potential problems with that analysis. The monthly EOF analysis and the annual CCA analysis were combined by replacing the oceanic multi-decadal signal of the EOF analysis with that from the CCA. The resulting analysis is called the Merged analysis.

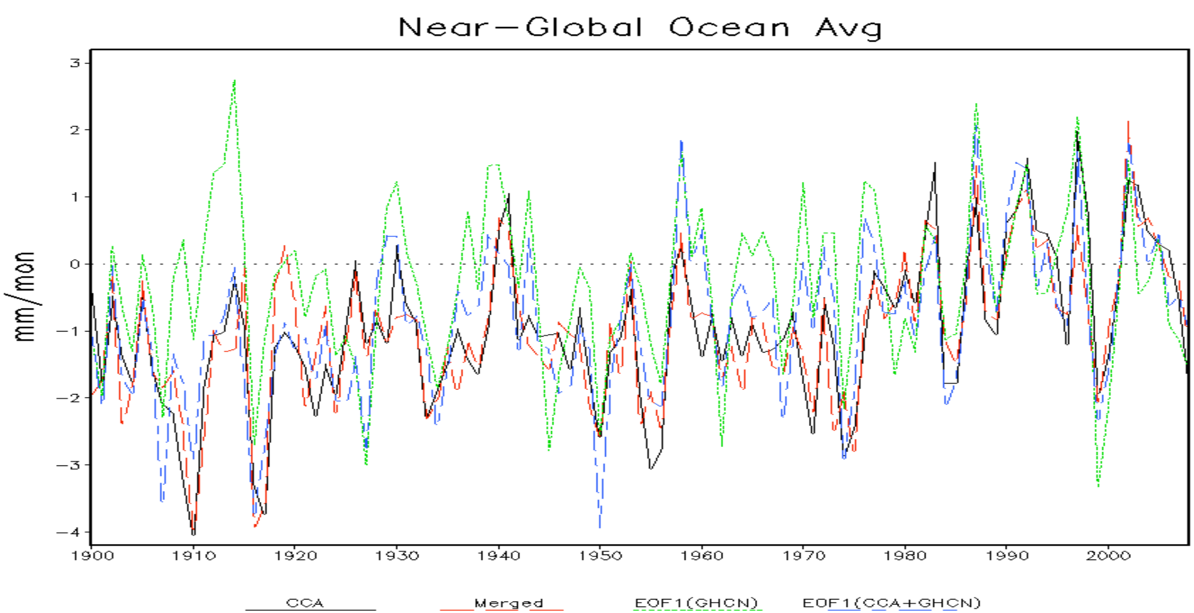

Figure 2. Ocean-area averages of reconstructed precipitation using the indicated methods.

The possible problems with the CCA spatial resolution were addressed with another reconstruction. This reconstruction first produces an annual first guess by analyzing data using a set of 20 global annual-average anomaly EOFs. Monthly anomaly increments from that first guess are then analyzed using a set of 40 global anomaly increment EOFs. The analysis, called EOF1, is produced by combining the first guess and increment analyses. For the increment analysis only GHCN gauge anomaly increments are used, but two types of first guess analyses are tested. One uses only GHCN annual anomalies, and the other uses both ocean-area CCA and GHCN annual anomalies.

As expected, averages over ocean areas are similar for CCA and the Merged reconstructions (Fig. 2). Averages increase over time with SST warming, and the CCA and Merged also indicate a slight shift in the mid 1970s when there was a climate shift in the Pacific SSTs. The EOF1 using only GHCN gauges, called EOF1(GHCN), also has a positive trend over the analysis period, but the trend is much weaker than the CCA trend. This qualitative consistency with an analysis based only on gauge data is encouraging, but it does not tell which estimate is most correct. Evaluation is difficult because for the GPCP period (since 1979) all the reconstructions tend have similar ocean-area averages. Trends of the EOF1(GHCN) have spatial scales more similar to the GPCP spatial scales in the overlap period, suggesting that it better resolves spatial scales of the multi-decadal variations. The EOF1 analysis using both oceanic CCA and GHCN for the first guess, called EOF1(CCA+GHCN), retains the stronger multi-decadal signal of the CCA. Maps of the EOF1(CCA+GHCN) trends show that the trend patterns resemble the EOF1(GHCN) trends but have larger magnitudes. Because it retains information from historical SST and SLP and also adjusts the scales of multi-decadal variations to better match those of the GPCP, the EOF1(CCA+GHCN) reconstruction method may be superior to the others.

Research is continuing with precipitation reconstruction to better validate methods and estimate errors for the reconstructions. Presently the merged analysis has been documented and is available to users at http://cics.umd.edu/~tsmith/PR/PR.html.