Improved Historical Reconstructions of SST and Marine Precipitation Variations

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Introduction

• **Historical Reconstructions:**
  – Statistical analyses, use satellite-period statistics and historical data
  – Process similar for both SST and precipitation

• **Improved reconstructions:**
  – SST: New data and methods
  – Precip: Ocean-area reconstructions are being developed
1. Improved Iterative SST Anomaly Reconstruction

- Method suggested by Hadley Centre, modified and tested for annual SST
  - Compared to ERSST-like “control” method using the same data
  - Data: HadSST2 anoms w.r.t. 1961-1990, and bias adjusted (1850-2009)

- 1st Iteration:
  - Rotated empirical orthogonal function (REOF) analysis of satellite-based SSTs
  - Satellite-based SSTs averaged annually 1982-2009 (30-years)
  - Use first 10 REOFs and annual-average HadSST2, reconstruct annual 1850-2009

- More Iterations:
  - Use OI to re-inject annual HadSST2 into historical annual reconstruction
  - Compute new set of 10 REOFs from the adjusted full 160-year period
  - Use the new full-period REOFs to reconstruct
  - Repeat until reconstructions stabilize (check mean spatial variance change)

- Use iterative method for annual-average 1st guess, use fixed monthly increment modes for monthly analysis
Changes With Iterations

- Global averages
- 1\textsuperscript{st} Iteration anomalies weak
  - Satellite period EOFs partly resolve multi-decadal variations
- With more iterations average approaches control average
  - Note: large change in 1865 evaluated, iterative REOF was then tuned
Spatial Changes With Iterations

- Comparison of EOF1 from control and different iterations

  - 1\textsuperscript{st} iteration: weaker variations

  - Variations strengthen with iterations
Improved Tuning of Iterative REOF

- **Iterative test 1 (IT1):**
  - 5% sampling, constant noise/signal ratio for OI data re-injection
  - Almost no Pacific sampling in 1865, over fitting causes large anomaly for that year
  - 6 iterations to stabilize

- **Iterative test 2 (IT2):**
  - 10% sampling, constant noise/signal
  - Eliminates 1865 problem in IT1
  - 10 + iterations to stabilize

- **Iterative test 3 (IT3):**
  - 10% sampling, noise/signal varies with data sampling
  - 7 iterations to stabilize
The 1865 Problem

- Iterative test 1 creates an unsupported warm ENSO
- HadSST: almost no Pacific sampling
- Iterative test 3 filters out the ENSO
- Control 15-year filtering fills in with stronger anomalies from other years
Cross-Validation Correlations (1850-1899)

- Initial modes: 1990-2009
  - X-validation control uses these modes

- Data: 1982-1989
  - Repeat 8 years over historical period
  - Historical sub sampling
  - Add noise proportional to sampling in each 5 area
  - Analyze & compare to full data

- Control: best in tropics

- Iterative REOFs all resolve variations better, IT3 is best
SST Reconstruction Conclusions

• Iterative SST reconstructions improve the historical variations for annual average 1\textsuperscript{st} guess
  – Data re-injection makes reconstruction modes more dependent on historical period for better fits
  – Tuning of re-injection and limiting the number of modes filters out noise

• Test analysis produced using this 1\textsuperscript{st} guess and monthly increment modes to analyze monthly SSTs

• Improved method may be used in improved ERSST
2. Precipitation Anomaly Reconstructions (1900-2008)

• Satellite analyses available beginning 1979 (GPCP and others)

• A range of reconstructions tested on a 5 grid:
  – First, a direct monthly reconstruction using historical gauge analyses
  – Apparent problems inspired indirect annual reconstructions using CCA and historical SST and SLP analyses
  – Merged annual indirect, for multi-decadal ocean areas, with monthly direct, for interannual and shorter-period variations
  – Latest experiments: Annual-global direct reconstruction for 1st guess and monthly-global increment corrections, all based on gauge data

• A brief summary of methods and results is presented
Climate-Mode Regressions with **Monthly Direct Recon**: Consistent Interannual Variations with Different Gauge Data

**Against SOI**

- $\text{REOF(GHCN)}$ (SOI)
- $\text{REOF(GPCC)}$ (SOI)
- $\text{REOF(CRU)}$ (SOI)

**Against NAO (Dec-Mar)**

- $\text{REOF(GHCN)}$ (NAO)
- $\text{REOF(GPCC)}$ (NAO)
- $\text{REOF(CRU)}$ (NAO)

Problems

• Theory & most models say precipitation should increase with warming global temperatures
  – Monthly Recon EOF shows global decrease in 1st half of 20th century, increase in 2nd half
  – Sampling changes could be influencing multi-decadal signal

• Recon using CCA developed to use additional marine data
  – Uses correlation between precip and combined SST & SLP
  – Annual averages to concentrate on multi-decadal signal
  – Train in satellite period, use SST & SLP analyses since 1900
**1st CCA Mode**

- 2 Predictors (upper)
- Predictand (3rd panel)
- Time series for
  - CCA mode 1 (red, 1979-2004)
  - Ocean-area recon (1900-2008)
    - Solid black (associated with mode 1)
    - Dashed black (from all 8 modes)
- Most oceanic variations from 1st mode: ENSO-like
Near-Global Annual Recon CCA Comparisons Over Oceans

- **Ocean-Area Averages**
  - Consistent with GPCP base data
  - CCA Trend larger than ensemble AR4 model trend
  - CCA sensitive to 1970s SST climate shift
GPCP-Period Trends

- **GPCP trends**
  - Full (upper)
  - Filtered using recon EOF modes (middle)
  - Both show finer scales than CCA

- **CCA trend (lower)**
  - Trend over same period
  - Roughly similar to GPCP trends, but with larger spatial scales and stronger trends

- Apparent problem with the scales of CCA trends
How Many EOFs are Needed to Resolve GPCP Trends?

- Zonal trends over oceans in GPCP period (1979-2008)
- CCA resolution a problem in zonal averages (upper)
- Global-Annual EOF smoothing (lower)
  - 6 modes gets most of trend
  - 20 modes get nearly all
- Can annual average be reconstructed using global-annual EOF modes?
Global-Annual EOF Tests: Ocean Comparisons

• 20 mode global-annual EOF
  – GHCN only & GHCN + PSST (annual pseudo data from regression against SST)
  – No PSST: Global EOF multi-decadal change slightly weaker than RCCA
  – With PSST: The trend is stronger and spatial scales of the trend are larger
Cross-Val Testing

- Use annual GPCP data
  - 12 Global-annual EOFs (1989-2008)
  - Annual Recons 1979-1983
  - Historical grid from annual GHCN held constant for each 5-year test
  - Evaluate average statistics over each 5-year period

- Upper: Global spatial correlation and fraction of spatial variance
  - Correlation does not change greatly due to sampling changes
  - Decreases in correlation related to damping of variance (loss of modes)

- Lower: Global averages
  - Slight negative trend, mostly in tropics
  - Suggests that the positive trend in the analysis may be about 15% too weak
Conclusions

• Monthly historical reconstructions of both SST and P are possible beginning 1900 or earlier
  – Reconstructions are powerful tools for analysis of ocean-area large-scale variations
  – Using a first guess and then correcting increments makes reconstructions more effective

• Reconstructions can resolve most large-scale variations and can be useful for climate studies and model validation
  – Improved methods improve the resolution
  – Small scale variations (< roughly 1000 km) may not be resolved, especially for oceanic precipitation
  – All reconstructions have uncertainties

• There is a continued need to get the most and the best historical data for improved reconstructions
  – Understanding and being able to adjust for historical biases will continue to be a major issue