Improved Historical Reconstructions of SST and Marine Precipitation Variations

Thomas M. Smith[1]
Richard W. Reynolds[2]
Phillip A. Arkin[3]
Viva Banzon[2]

1. NOAA/NESDIS/STAR SCSB and CICS, College Park, Maryland
2. NOAA/NESDIS/NCDC, Asheville, North Carolina
3. CICS/ESSIC/University of Maryland, College Park, Maryland

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)

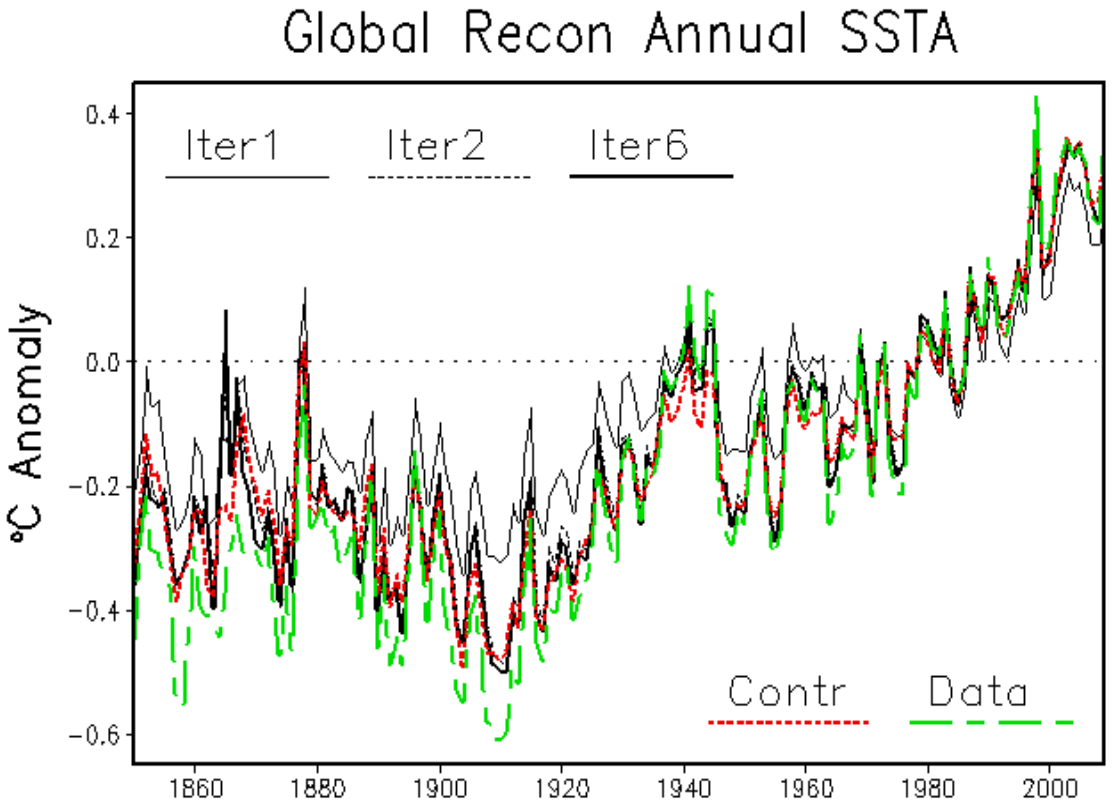
- 1st Iteration:
  - Rotated empirical orthogonal function (REOF) analysis of satellite-based SSTs
  - Satellite-based SSTs averaged annually 1982-2009 (30-years)
  - Use first 10 REOFs and annual-average HadSST2, reconstruct annual 1850-2009

- 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

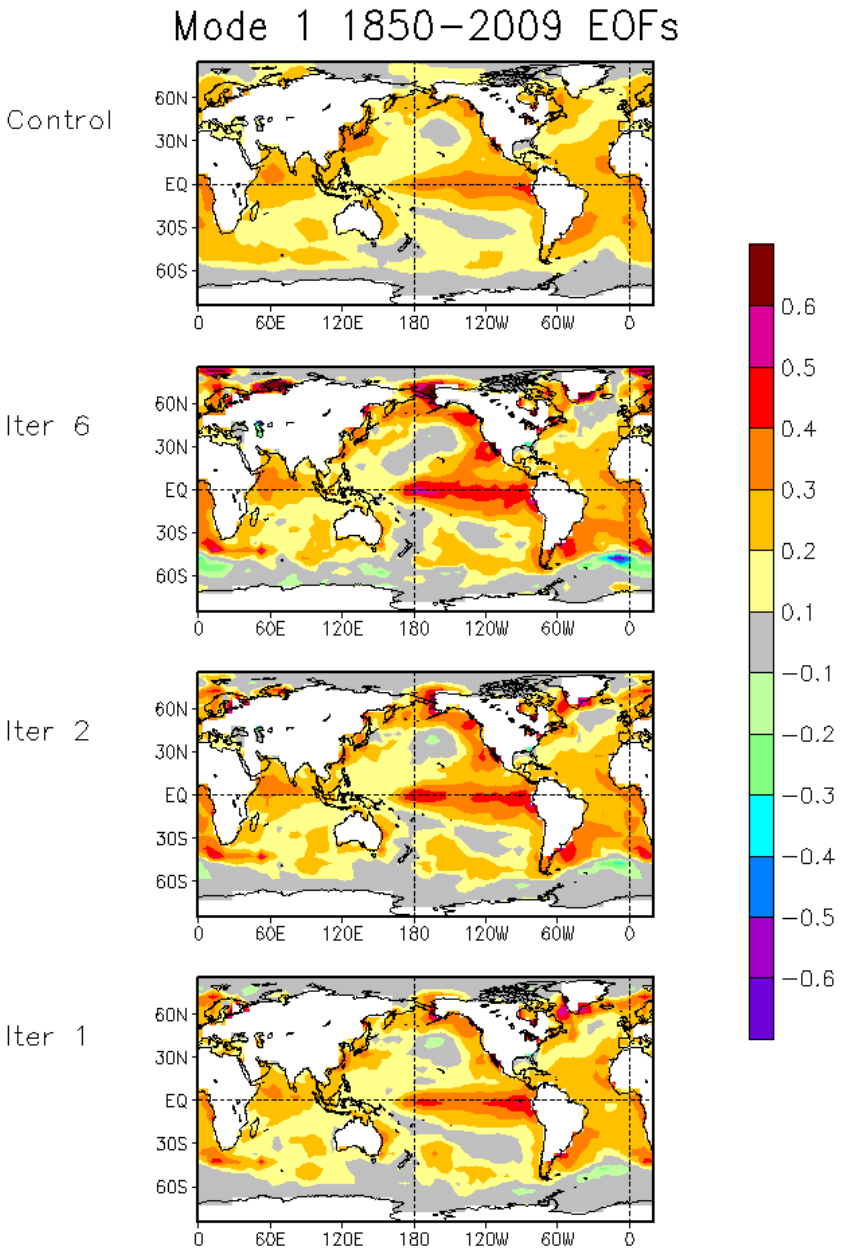
Changes With Iterations

- Global averages
- 1st 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

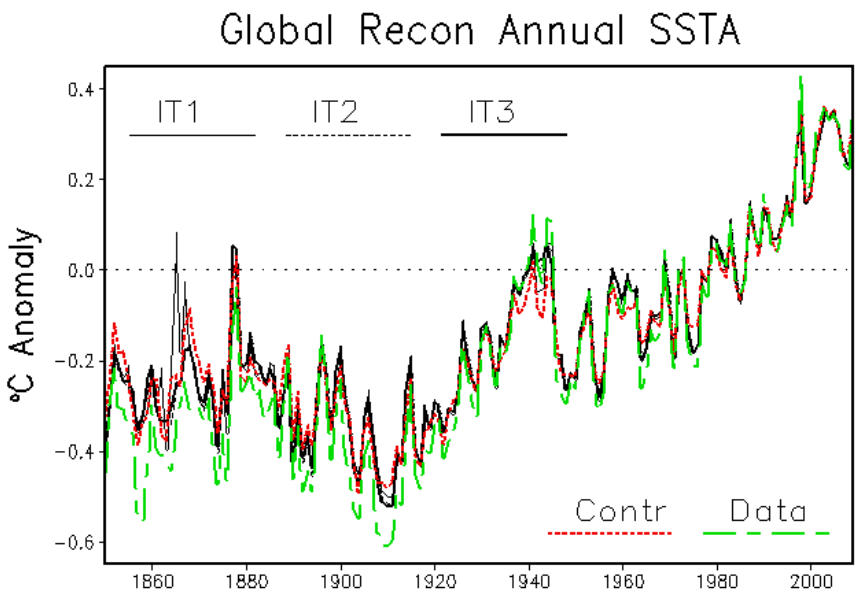
- Comparison of EOF1 from control and different iterations
- 1st iteration: weaker variations
- Variations strengthen with iterations

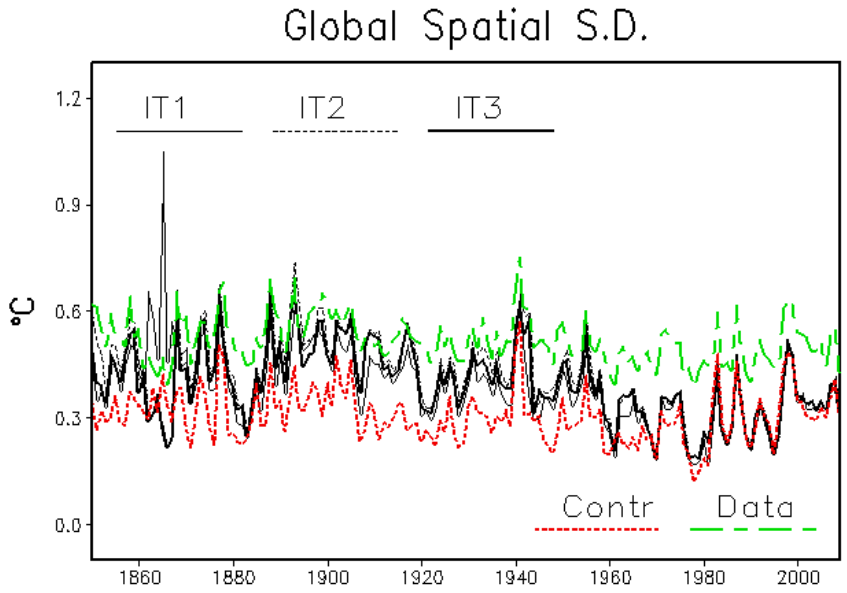


Cooperative Research Programs (CoRP)
Satellite Climate Studies Branch (SCSB)

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

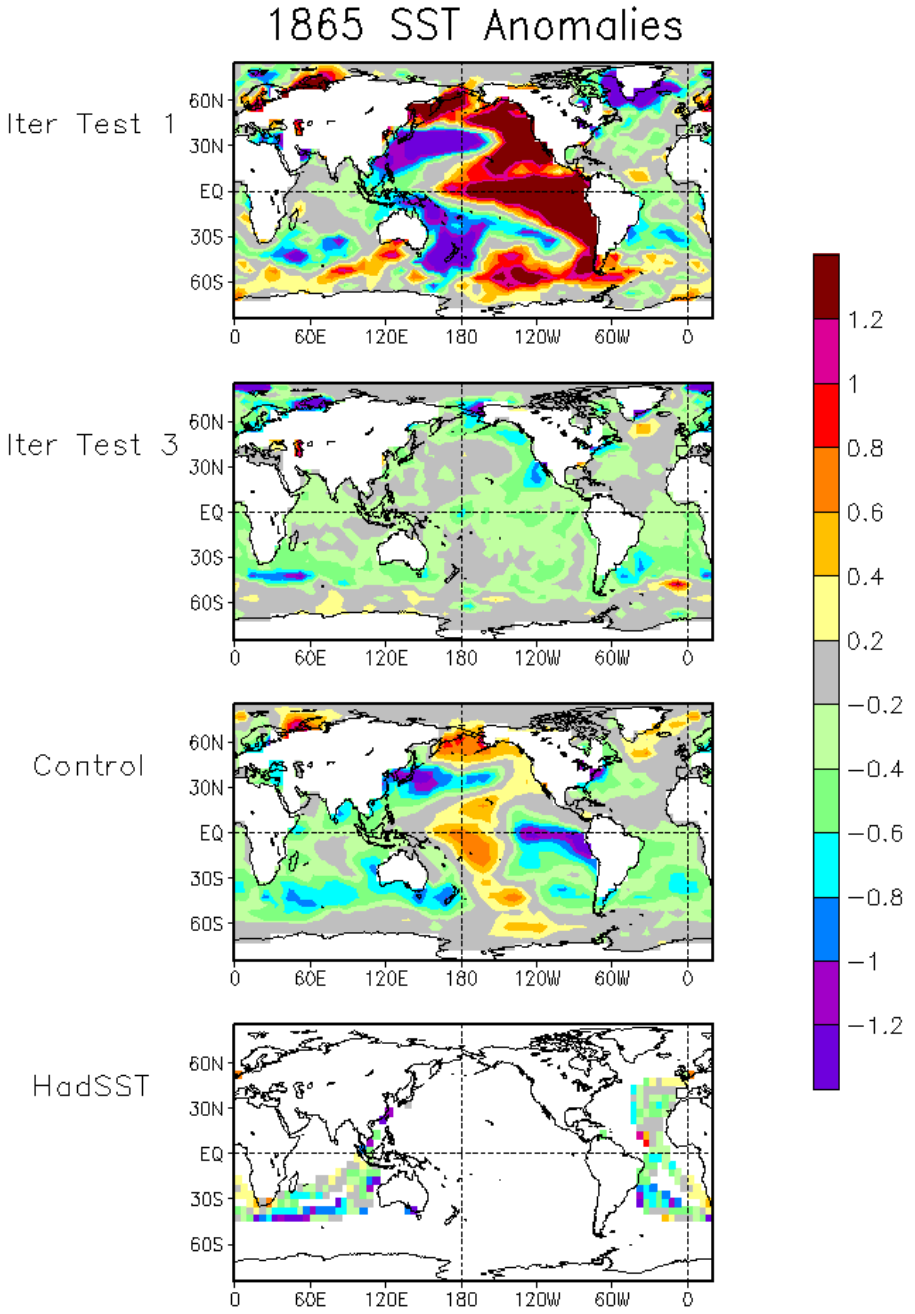




Cooperative Research Programs (CoRP)
Satellite Climate Studies Branch (SCSB)

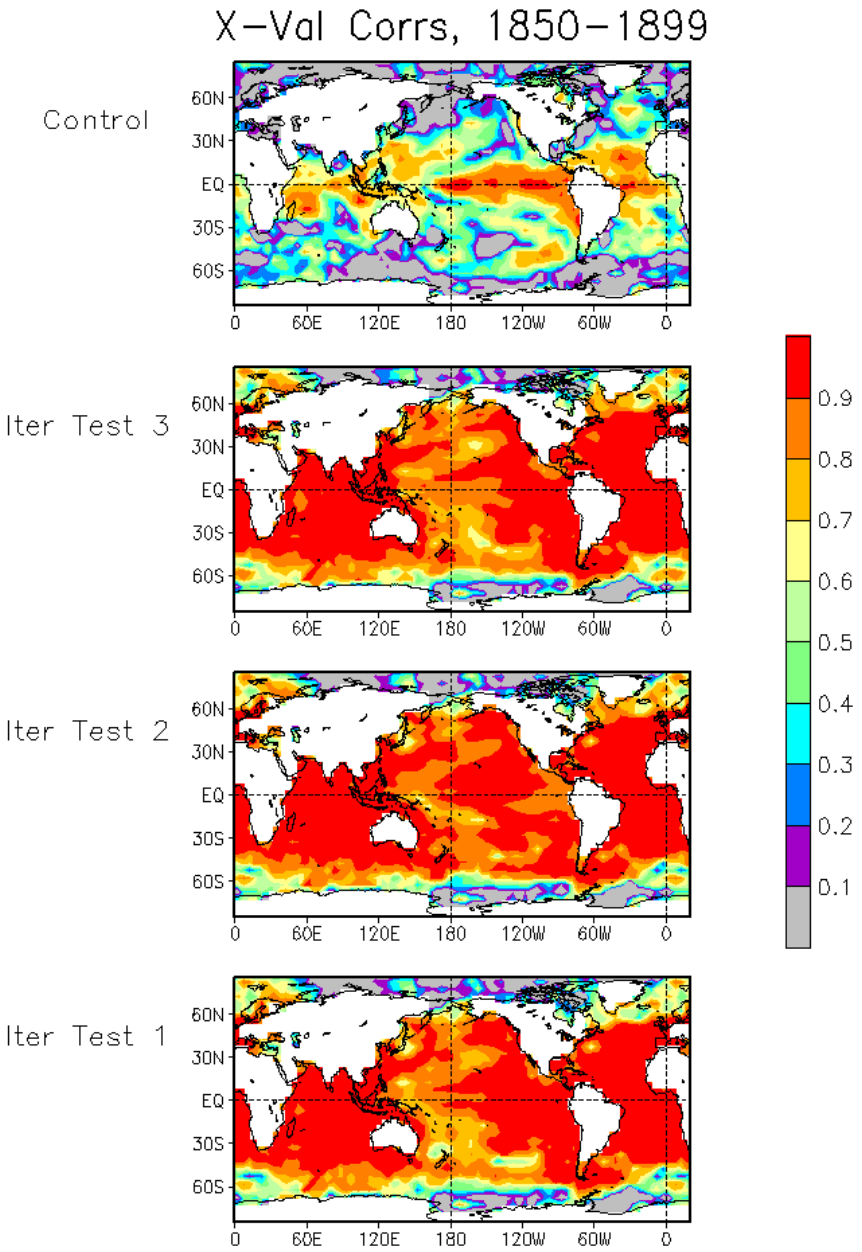
The 1865 Problem

- 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 1st 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 1st guess and monthly increment modes to analyze monthly SSTs

- Improved method may be used in improved ERSST

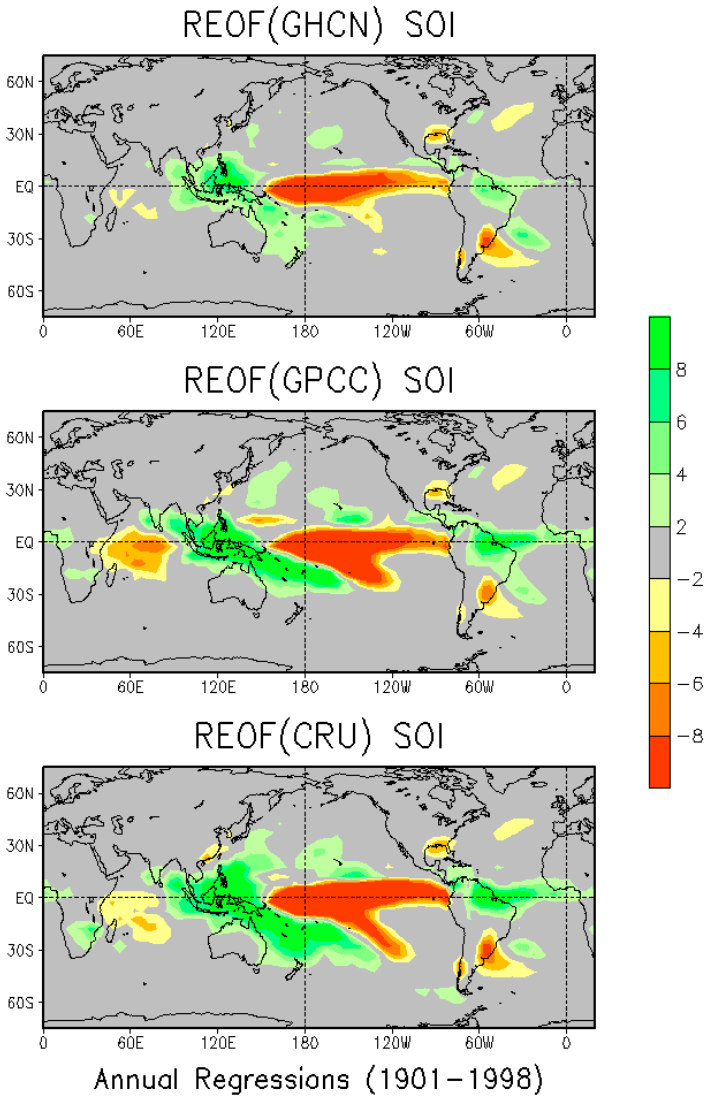
2. Precipitation Anomaly Reconstructions (1900-2008)

- 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

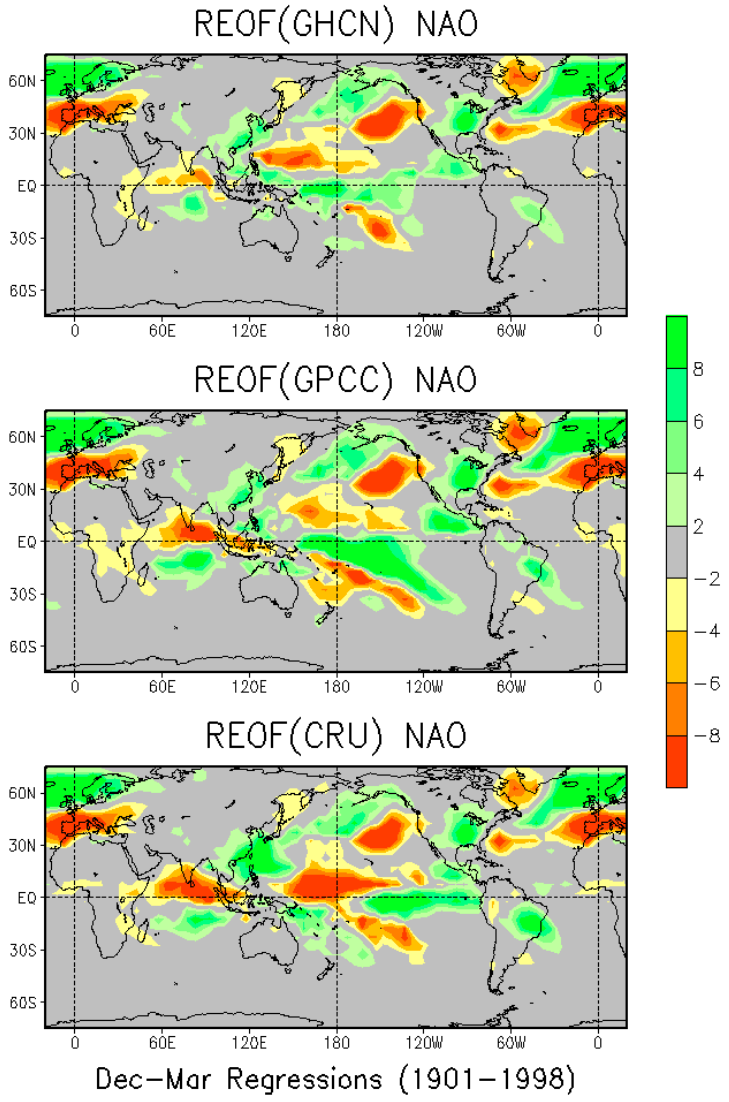
10

Climate-Mode Regressions with Monthly Direct Recon: Consistent Interannual Variations with Different Gauge Data

Against SOI



Against NAO (Dec-Mar)



Problems

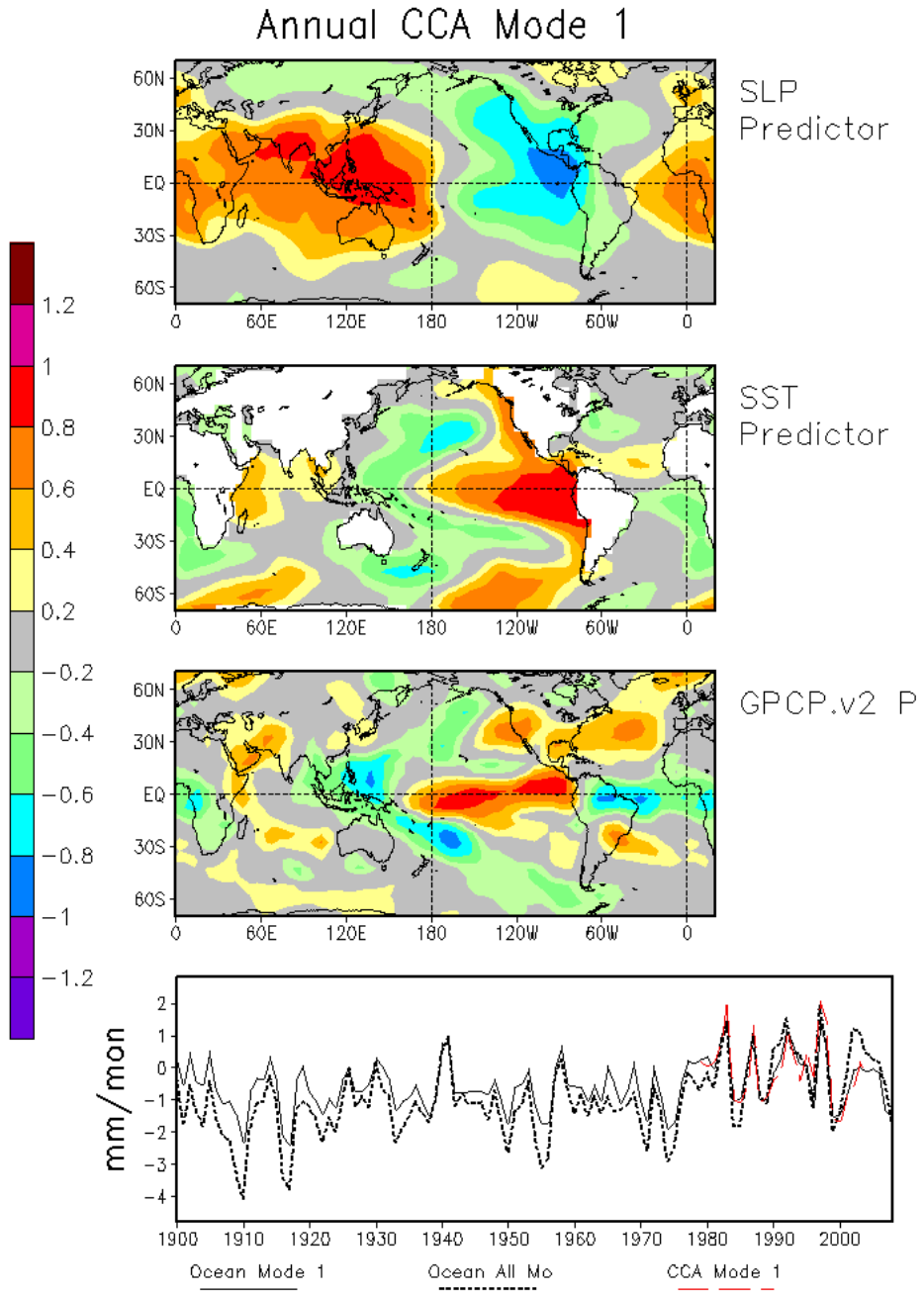
- Theory & most models say precipitation should increase with warming global temperatures
  - Monthly Recon EOF shows global decrease in 1st half of 20th century, increase in 2nd half
  - Sampling changes could be influencing multi-decadal signal
- Recon using CCA developed to use additional marine data
  - 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

12

NOAA Satellites and Information
National Environmental Satellite, Data, and Information Service

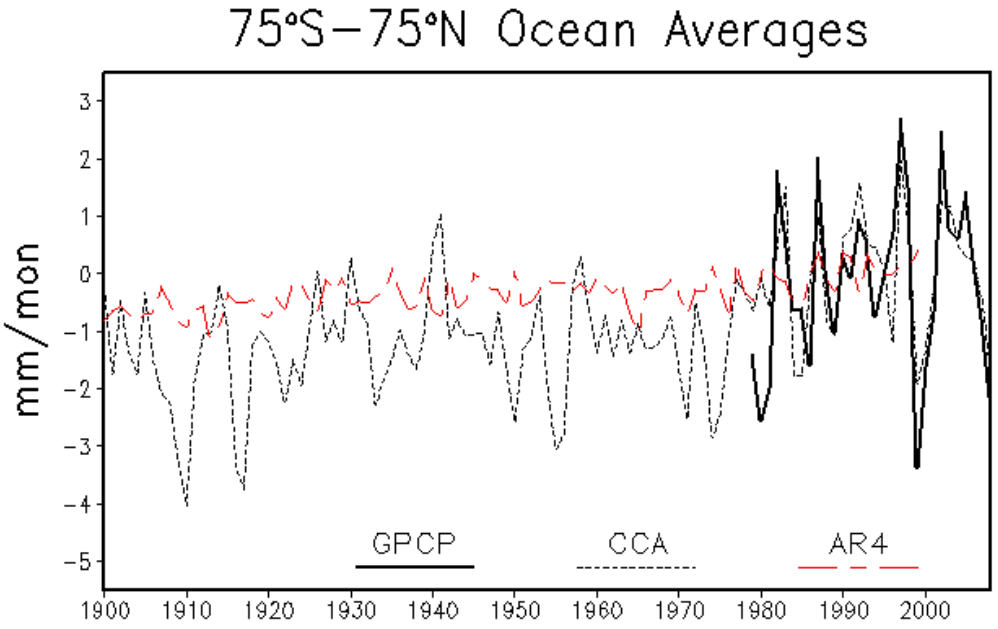
1st CCA Mode

- 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



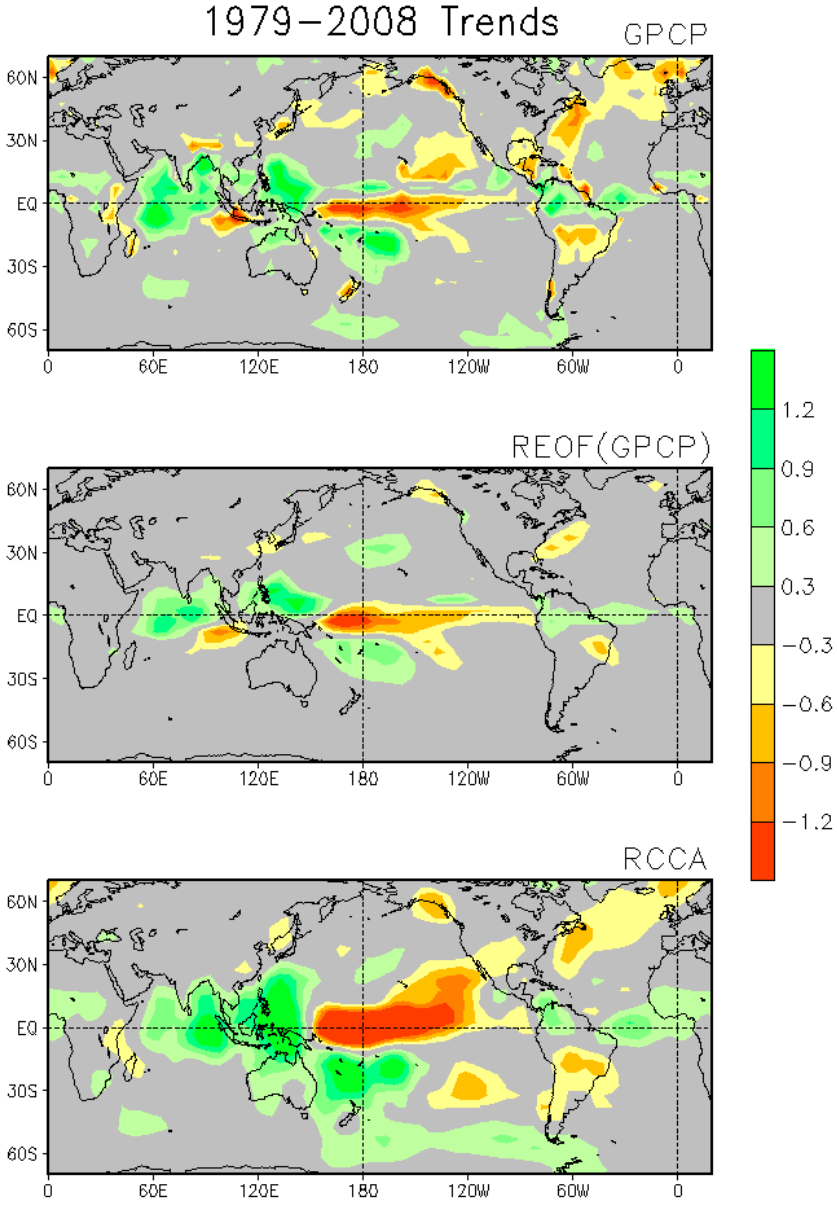
Near-Global Annual Recon CCA Comparisons Over Oceans

- 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

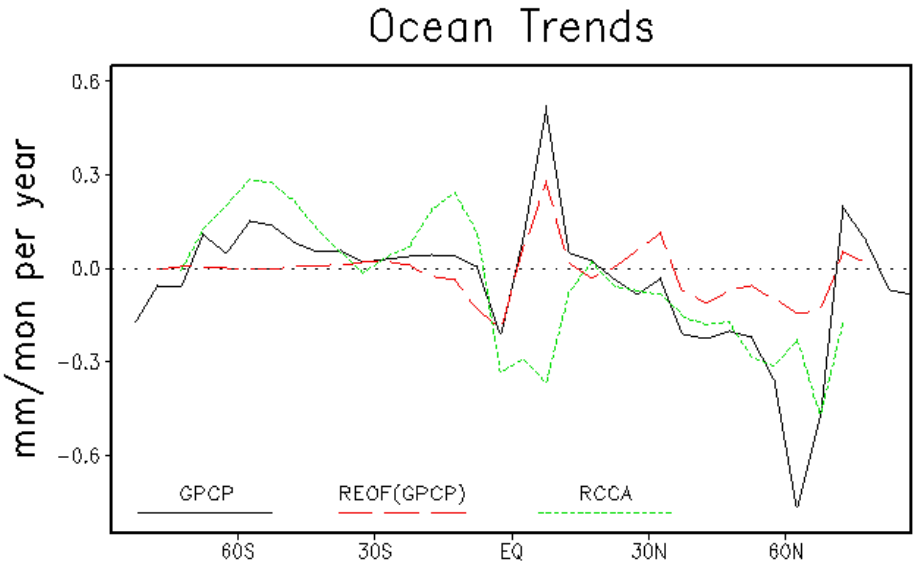
- GPCP trends
  - Full (upper)
  - Filtered using recon EOF modes (middle)
  - Both show finer scales than CCA
- CCA trend (lower)
  - Trend over same period
  - Roughly similar to GPCP trends, but with larger spatial scales and stronger trends
- Apparent problem with the scales of CCA trends

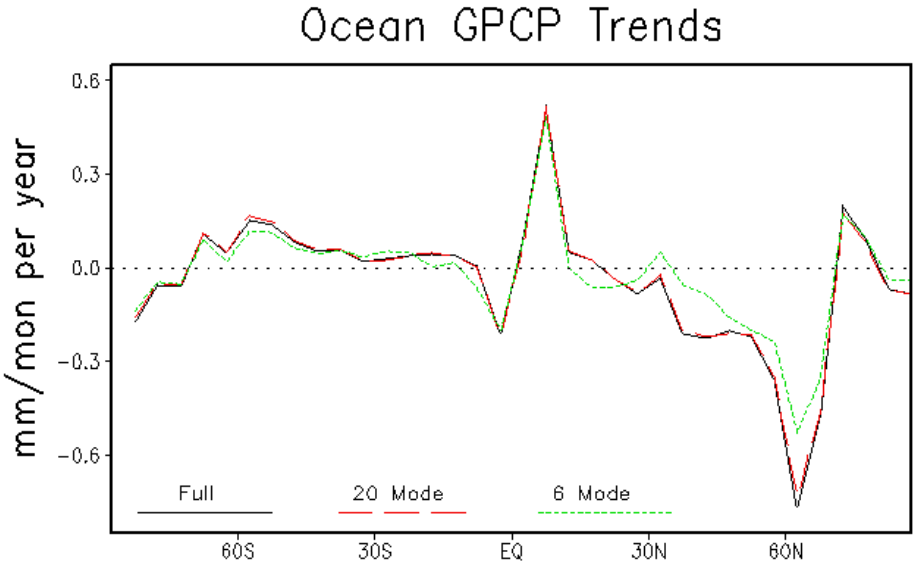


15

How Many EOFs are Needed to Resolve GPCP Trends?

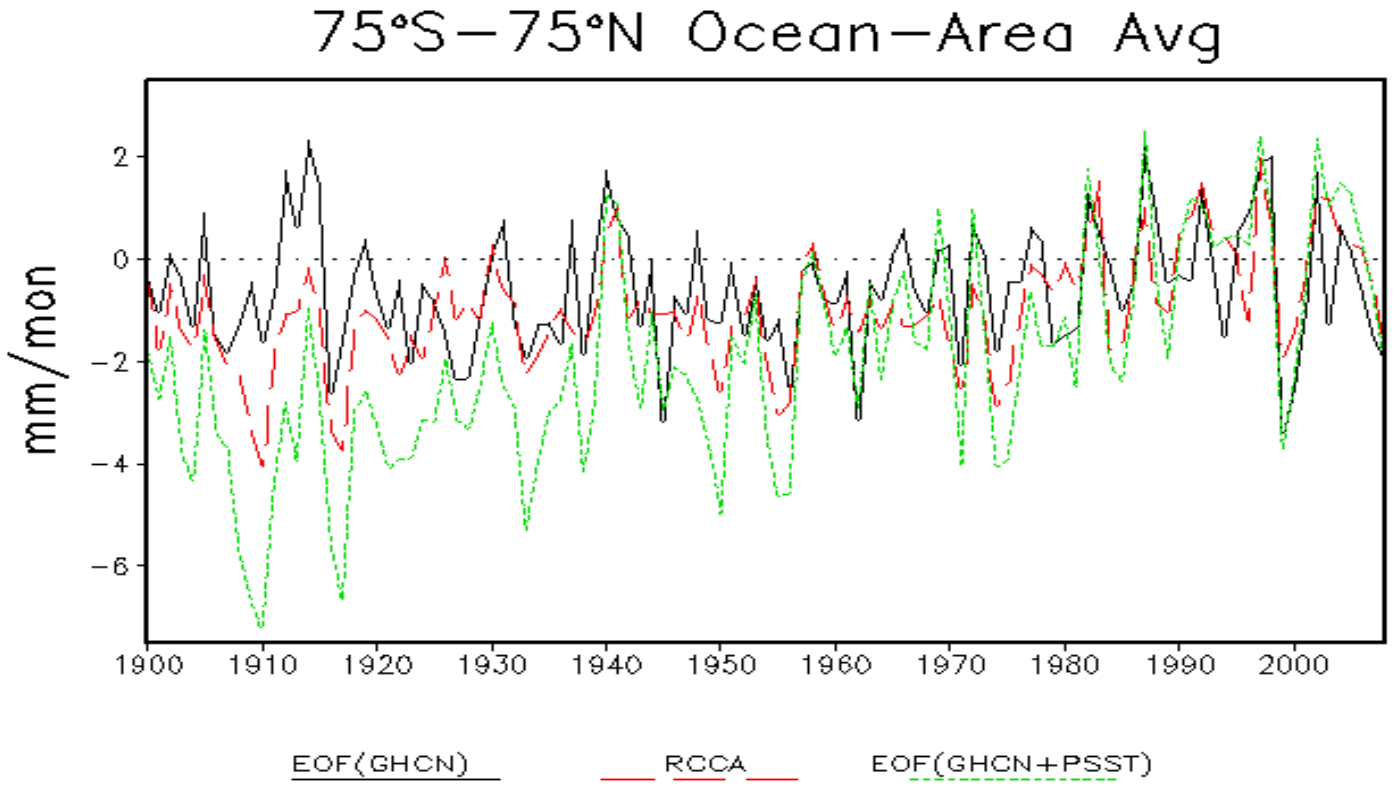
- Zonal trends over oceans in GPCP period (1979-2008)
- CCA resolution a problem in zonal averages (upper)
- Global-Annual EOF smoothing (lower)
  - 6 modes gets most of trend
  - 20 modes get nearly all
- Can annual average be reconstructed using global-annual EOF modes?





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



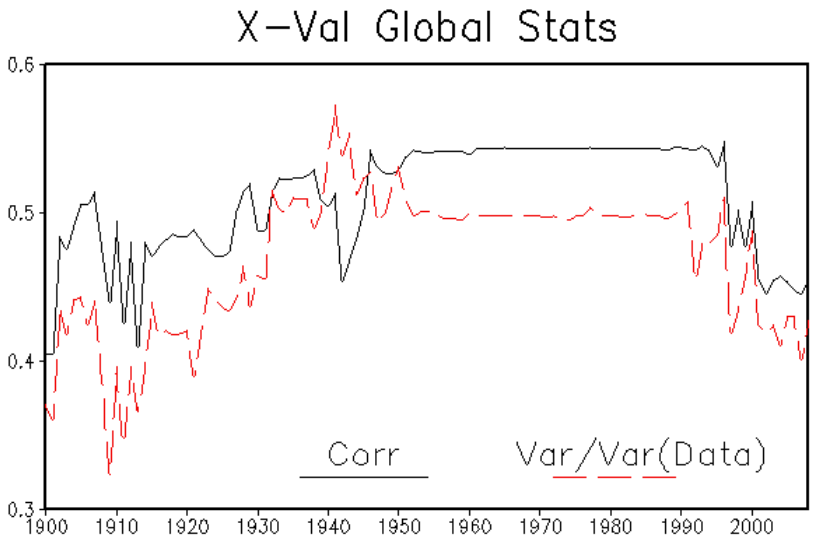
17

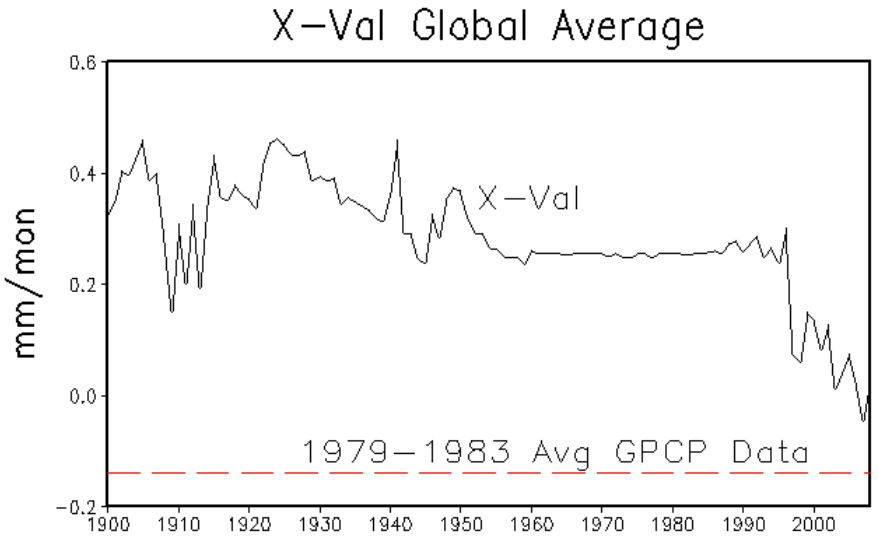
Cross-Val Testing

- 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

19