

# Pacific Basin ensemble SST field reconstructions from marine paleoproxy data

Michael N. Evans (University of Maryland – College Park)  
mnevans@geol.umd.edu

Alexey Kaplan (Lamont-Doherty Earth Observatory, Columbia University)  
alexeyk@ldeo.columbia.edu

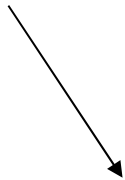
*Thanks: Richard Seager, Amy Clement, Konrad Hughen, Natalie Goodkin, Henning Kuhnert, Rosanne D'Arrigo, Rob Wilson, Ed Cook, Jason Smerdon, Kim Cobb, Joelle Gergis, Brendan Buckley, Pavla Fenwick, Anthony Fowler*

## Outline

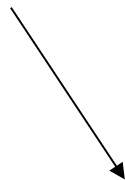
- Ensemble reduced space optimal interpolation scheme.
- Results:
  - Skill and uncertainty.
  - Comparison: SST and drought reconstructions.

# Long-term hydroclimate variations in western North America: Tropical Pacific forcing?

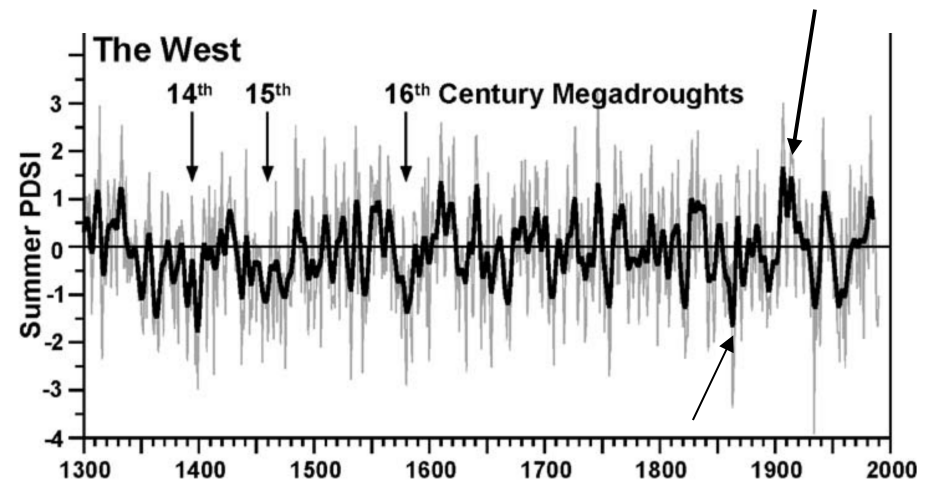
SST reconstructions



AGCM



Drought reconstructions



Cook et al. 1999, 2004; Stahle et al., 2007; Seager et al 2007, 2008

# Methodology

- *SVD-based, low-dimensional paleodata calibration*
- *Ensemble-OI climate field reconstruction*
  - *fit to error-weighted calibrated proxies and truncated description of modern SST variance*
  - *Ensemble generated from multivariate random normal error sampling*
  - *Error variance + signal variance  $\sim$  constant over time*
- *Diagnostics*
  - *Correlation and error fields*
  - *NINO34 SST anomaly index*
  - *Composites from drought and pluvial intervals*

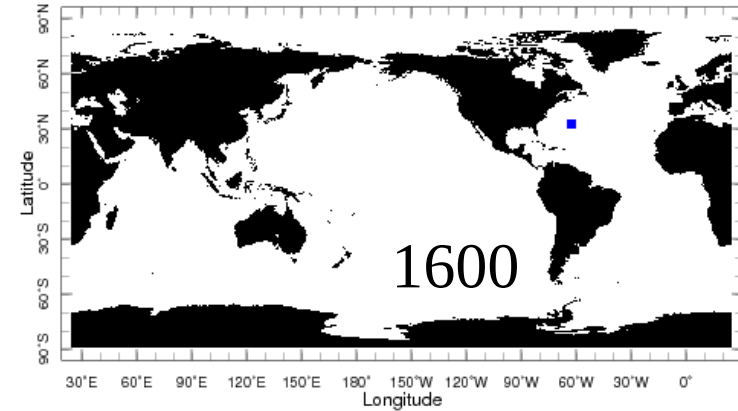
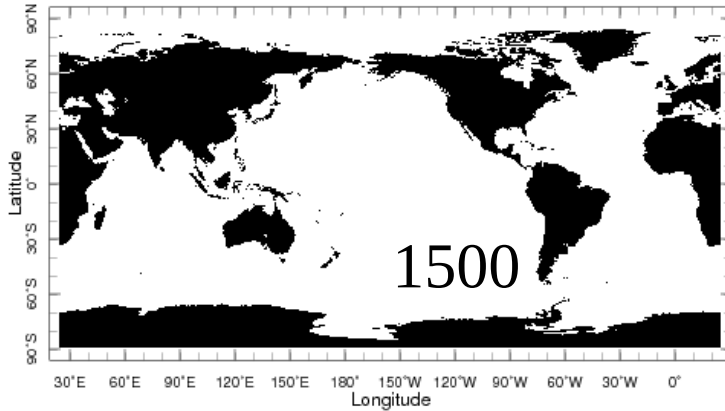
# Paleo data set: 73 marine proxies

(68 corals\*, 5 sclerosponges, ~44 distinct sites)

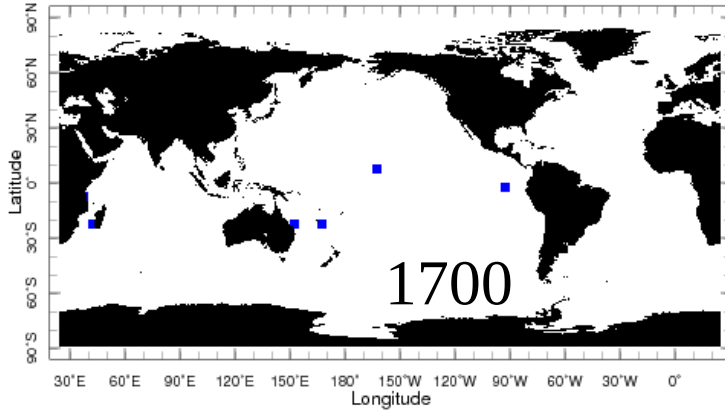
<u>proxy type</u>	<u>“process model”</u>	<u>number</u>
• $\delta^{18}\text{O}$	$f(T, \delta^{18}\text{O}_{\text{sw}})$	55
• Sr/Ca	$f(T, \text{Sr}/\text{Ca}_{\text{sw}})$	8
• Mg/Ca	$f(T, \text{Mg}/\text{Ca}_{\text{sw}})$	1
• Ba/Ca	$f(T, \text{Ba}/\text{Ca}_{\text{sw}}) \sim \text{nutrients/upwelling}$	1
• Density	$f(T, \Phi, \text{nutrients})$	1
• Extension rate	$f(T, \Phi, \text{nutrients})$	2
• Calcification rate	$\rho * \text{extension rate}$	1(71)
• Luminescence	$f(S)$	4

*e.g. Weber and Woodhead, 1972; deVilliers et al. 1994; Barnes and Lough, 1990; Lough and Barnes, 1997; Barnes et al. 2003). Data from: WDC-A for Paleoclimatology (2007-2008), H. Kuhnert, N. Goodkin and K.Hughen, pers. comm. 2007*

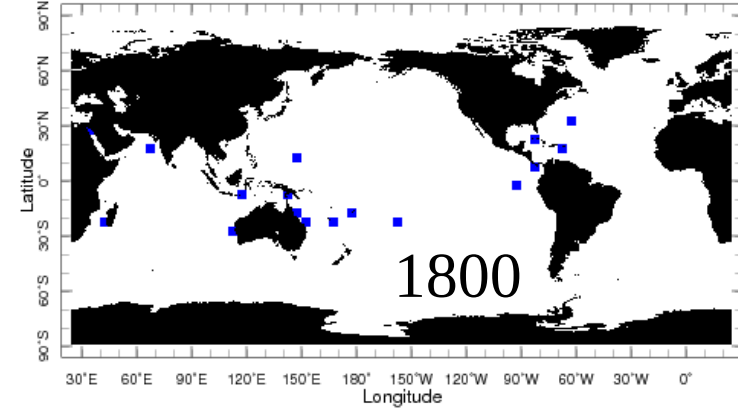
# Proxy data availability: 1500-1950



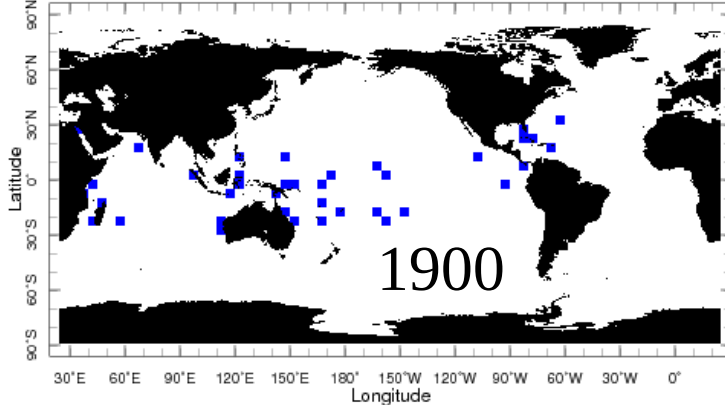
Apr 1499 - Mar 1500



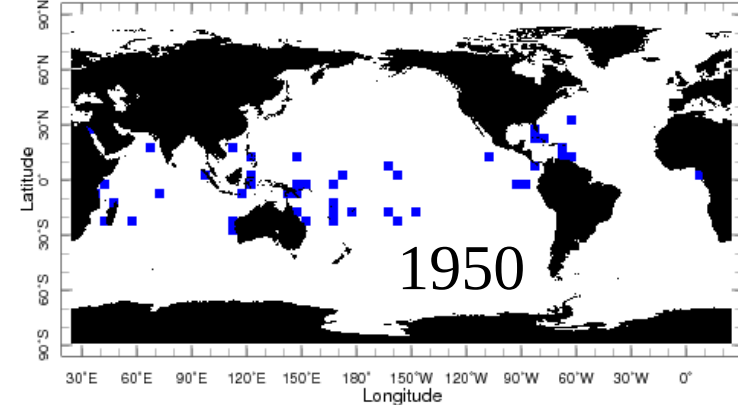
Apr 1599 - Mar 1600



Apr 1699 - Mar 1700



Apr 1799 - Mar 1800



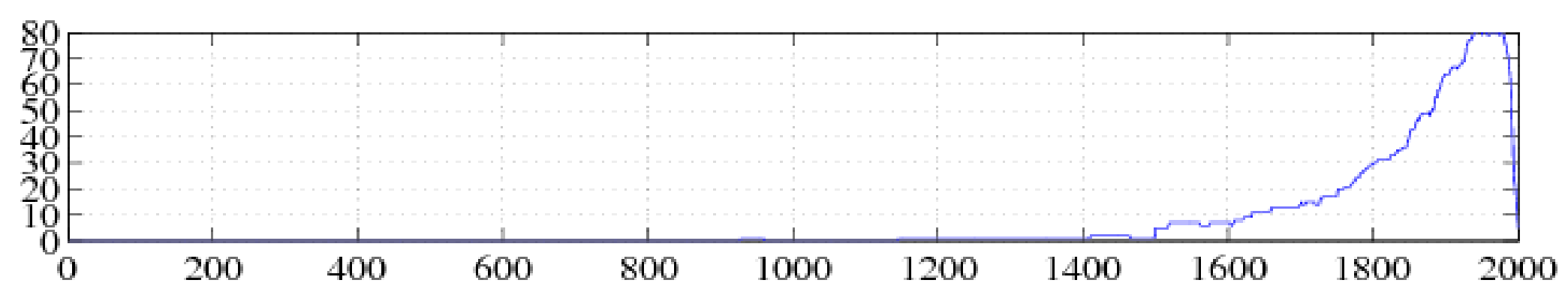
Apr 1899 - Mar 1900

Apr 1949 - Mar 1950

*WDC-A for Paleoclimatology, 2007-2011 and unpublished data contributors*

# Parameters

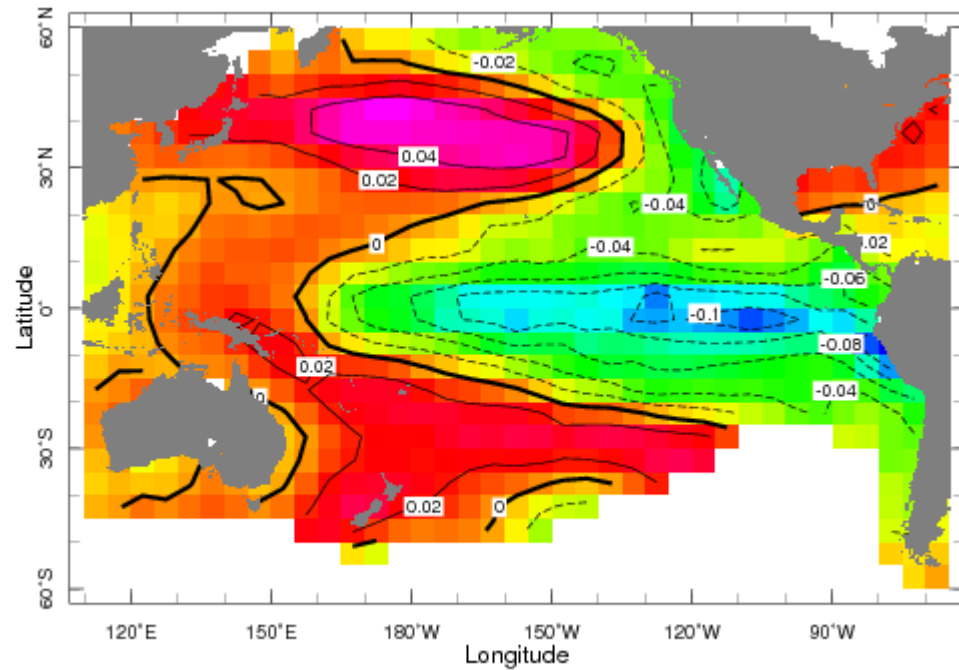
- Target climate field: latitude-weighted Pacific Basin SST, April-March averages, all latitudes, 110E-65W
- SST field space reduction: 95% of variance retained in 30 patterns
- Proxy preprocessing: standardization to calibration period mean + variance
- Proxy calibration period: 1923-1990; validation period: 1856-1922
- Number of calibrated patterns: 2
- Ensemble realizations performed: 100
- Reconstruction interval: 1-2000



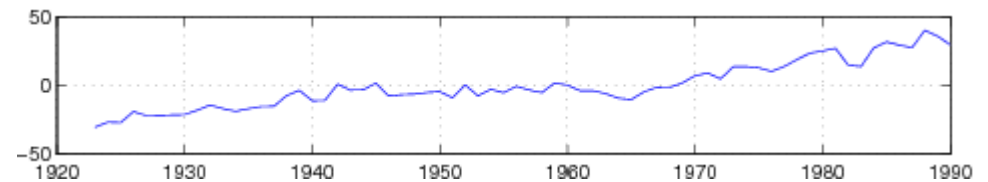
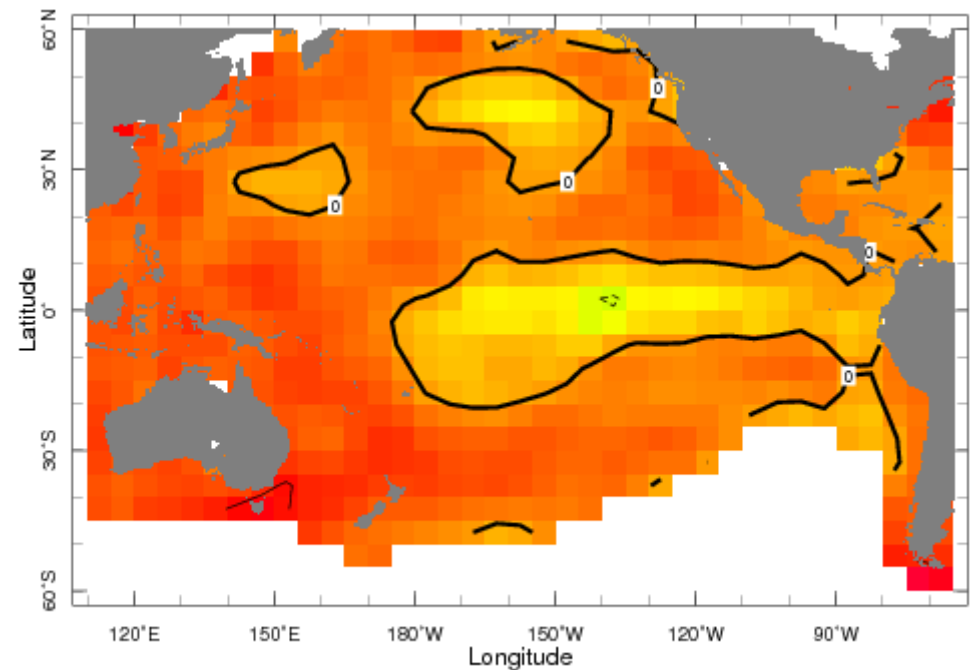
*Kaplan et al. 1997, 1998, 1999; Evans et al. (1998, 2000, 2001, 2002);  
Evans and Kaplan (2011) in prep*

# Calibrated patterns

pattern 1: 69% covariance



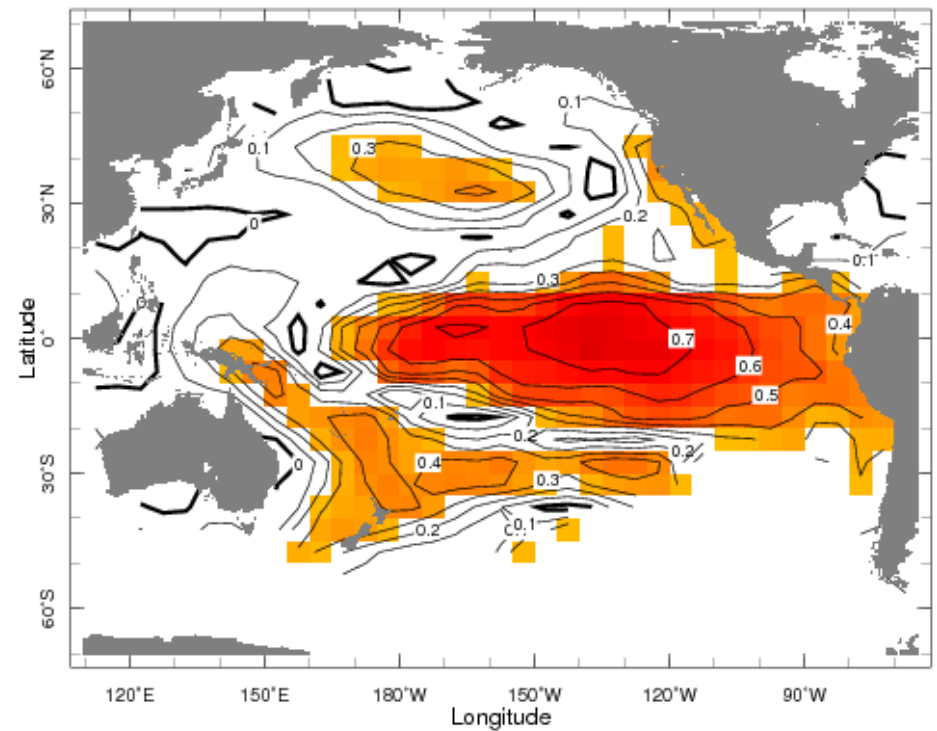
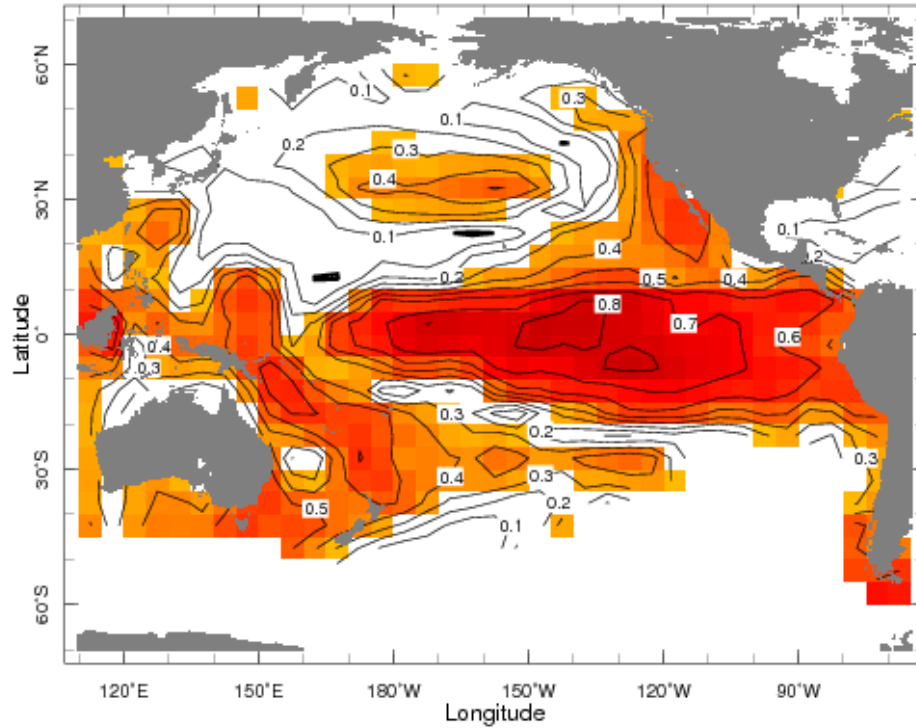
pattern 1: 14% covariance



# Ensemble average skill

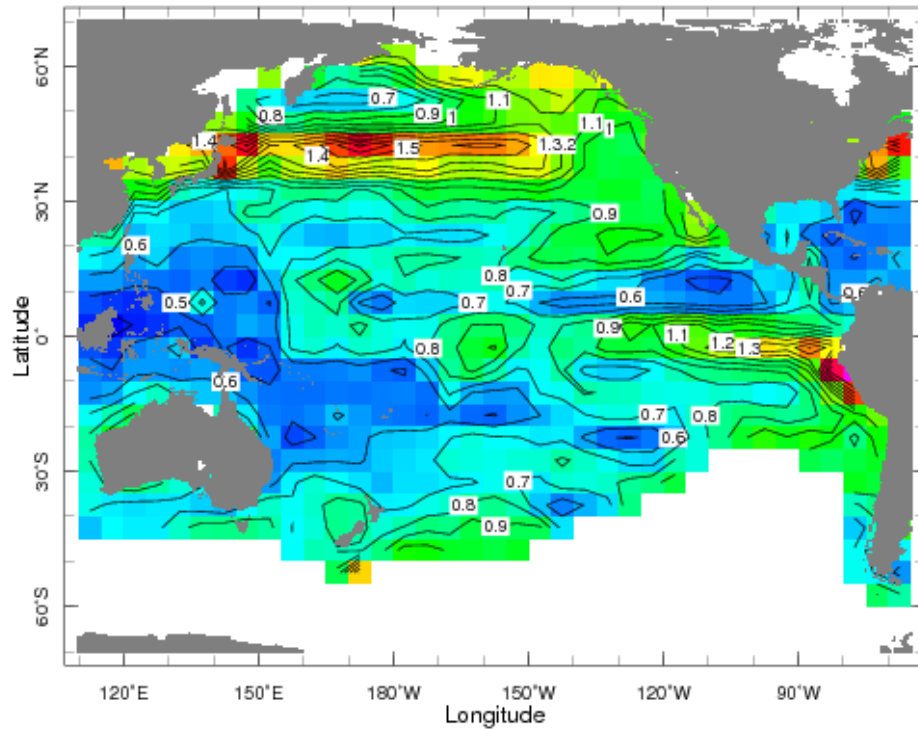
calibration period: 1923-1990

validation period: 1856-1922

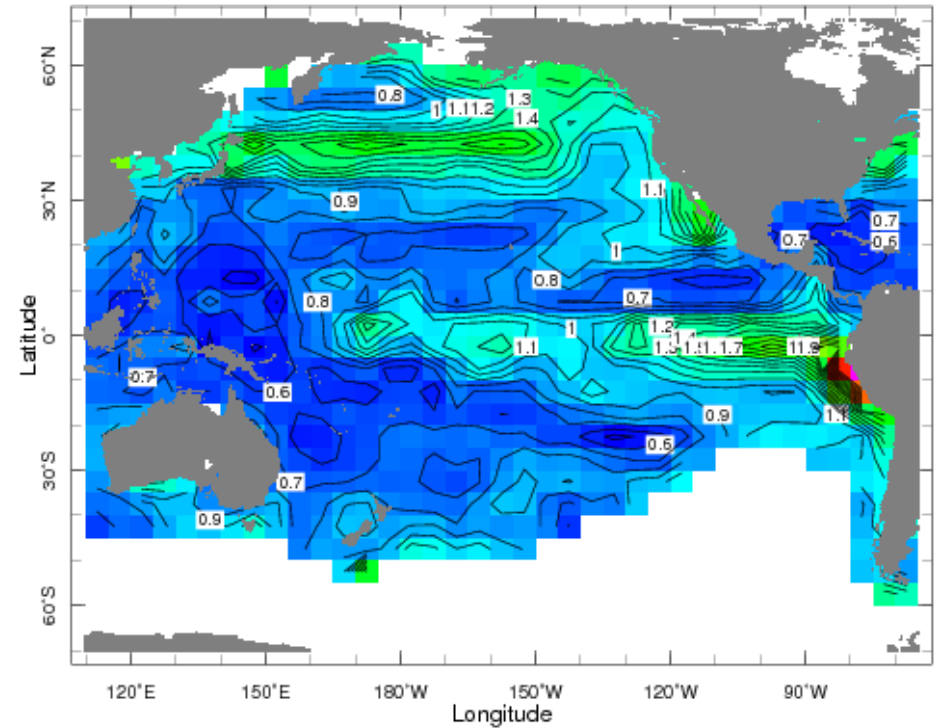


# Ensemble average reconstruction error

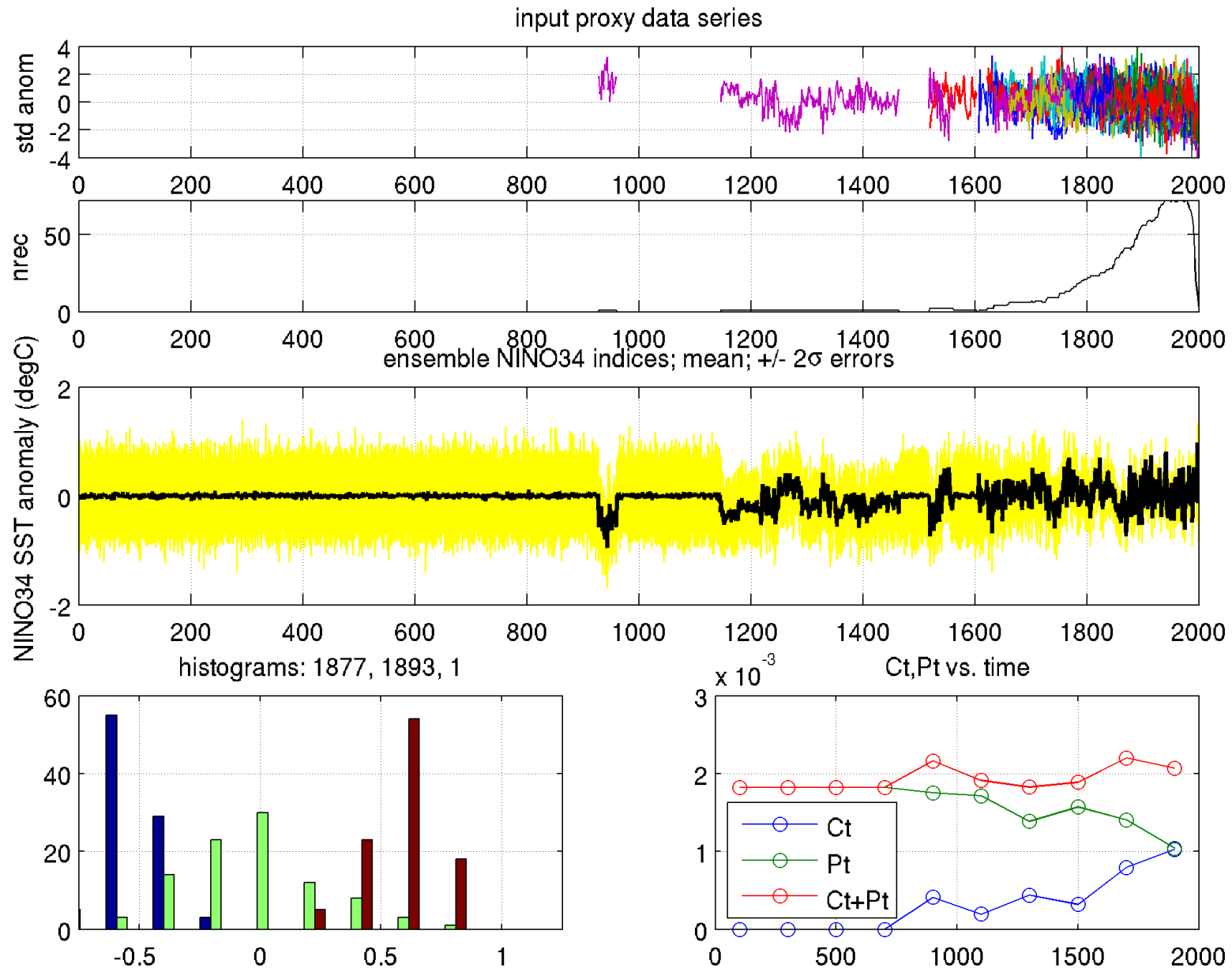
RMS SST K98, cal. pd.: 1923-1990



RMS SST rec., val. pd.: 1856-1922



# Reconstructed NINO34



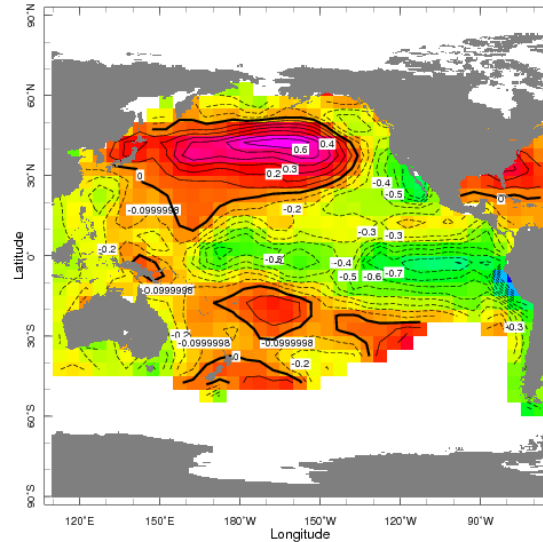
# Long-term hydroclimate variations in western North America: Tropical Pacific forcing?

SST reconstructions

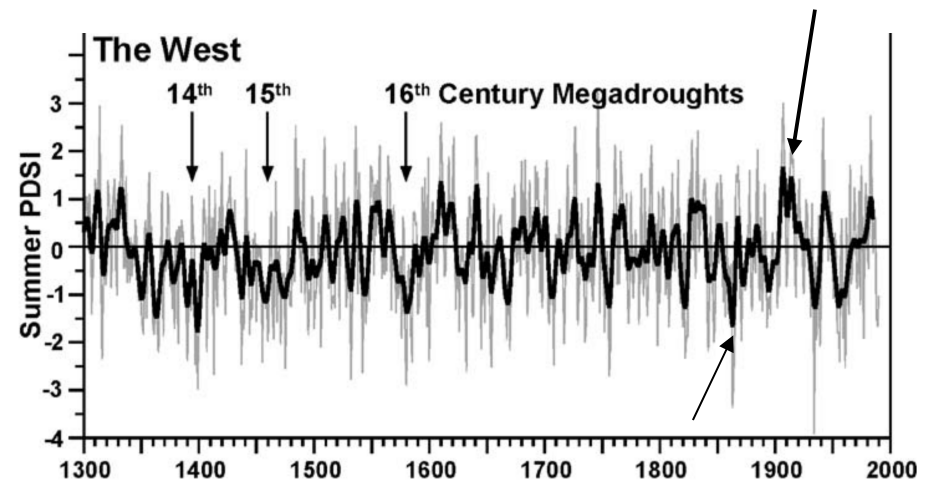
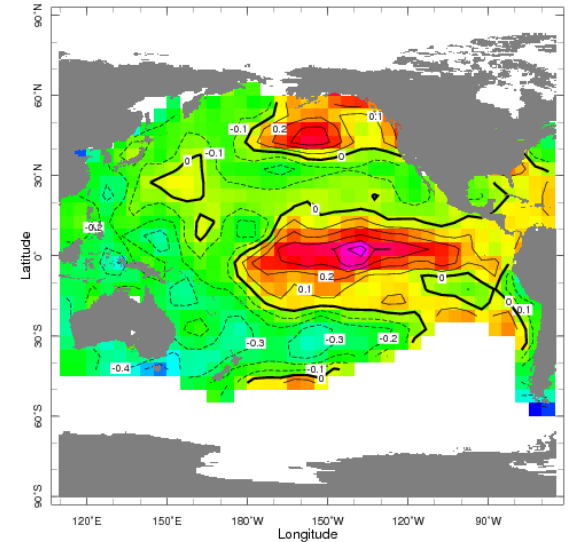
AGCM

Drought reconstructions

1850-1860 average



1901-1916 average



Cook et al. 1999, 2004; Stahle et al., 2007; Seager et al 2007, 2008

# Beta results via Ingrid

data: crec11 allt\_marine - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://kalman.ldeo.columbia.edu:81/expert/(/home/mevans/crec07/pacrec11/base/crec11.in)/read Google

Most Visited UMD/Web of Sci IRI/LDEO Data Library TerpNav Pedestrian ... The World Clock Mee... NAS Geol Dir

data: crec11 allt\_marine

A.Kaplan's data server / Kalman

Using B.Blumenthal's Data Library Software

Introduction Questions & Answers

alexeyk at ldeo dot columbia dot edu

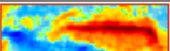

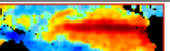
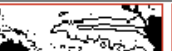
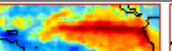
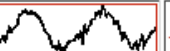
Dataset Search

crec11 allt\_marine[ nreal X Y | T] M M M M

nreal T X Y

expert (/home/mevans/crec07/pacrec11/base/crec11.in) readfile .allt\_marine

OK reset

NEW Views       old Viewer

Data Selection Filters Data Files Tables

(/home/mevans/crec07/pacrec11/base/crec11.in) readfile allt\_marine

served from kalman.ldeo.columbia.edu

## crec11 allt\_marine

crec11 allt\_marine.

### Grids

*nreal*  
grid: /nreal (unitless) ordered (1.) to (100.) by 1. N= 100 pts :grid

*Time*  
grid: /T (months since 1960-01-01) ordered (Apr 0001 - Mar 0002) to (Apr 2000 - Mar 2001) by 12. N= 2000 pts :grid

*Longitude*  
grid: /X (degree\_east) periodic (112.5E) to (67.5W) by 5. N= 37 pts :grid

*Latitude*  
grid: /Y (degree\_north) ordered (87.5S) to (87.5N) by 5. N= 36 pts :grid

### Other Info

missing value  
Done

# Summary

- The OI-ensemble reconstruction algorithm allows us to create a set of SST forcing fields with uniform total variance, yet also represent the true change in uncertainty as the paleodata become sparser with time.
- Results suggest the 16<sup>th</sup> century drought in western North America was driven by ENSO cold phase conditions – forced AGCM experiments can be used to investigate the mechanisms. Two quasi-independent mechanisms for multiyear subtropical droughts may exist.
- Climate field reconstruction uncertainties are probably a function of at least sampling network, frequency, proxy type, and calibration. Validation of proxies/reconstructions as true representations of climate remains an outstanding challenge.