

An Overview of Decadal Climate Variability in the Historical Record

Clara Deser

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Boulder, CO USA

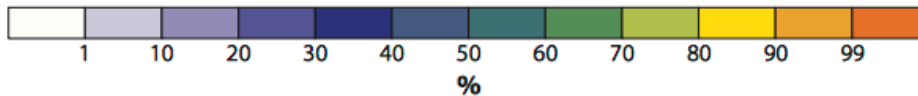
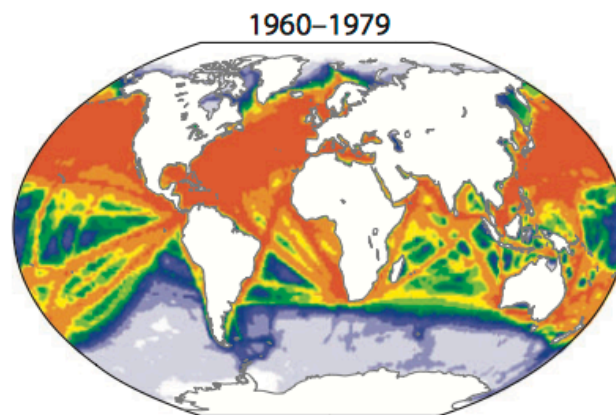
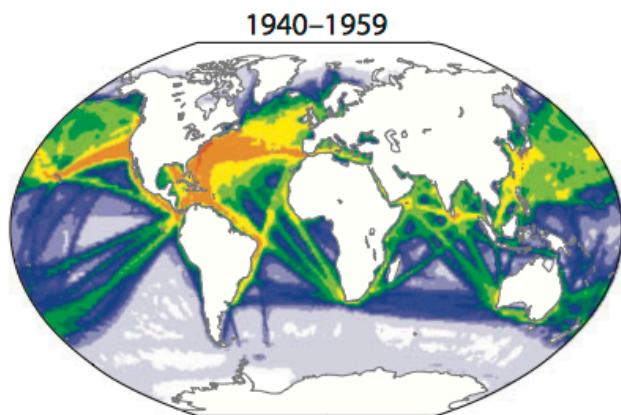
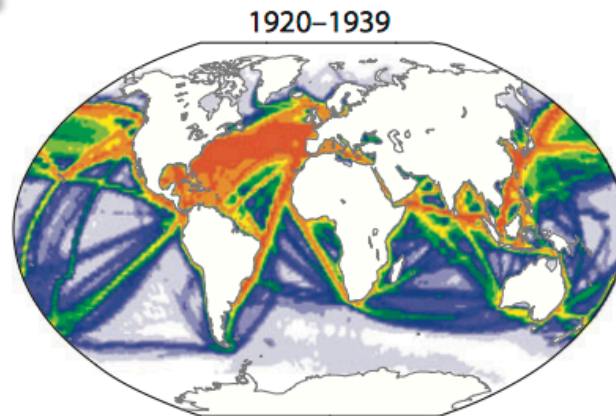
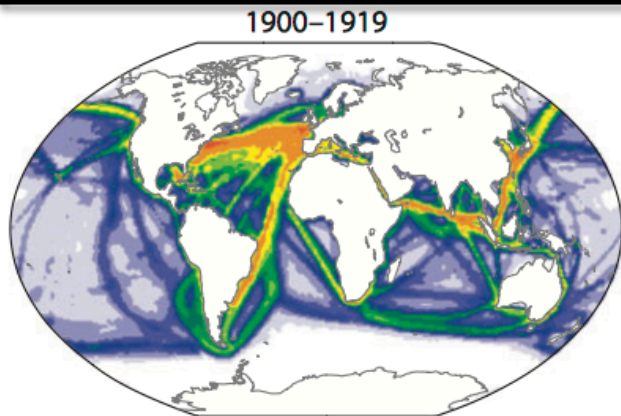
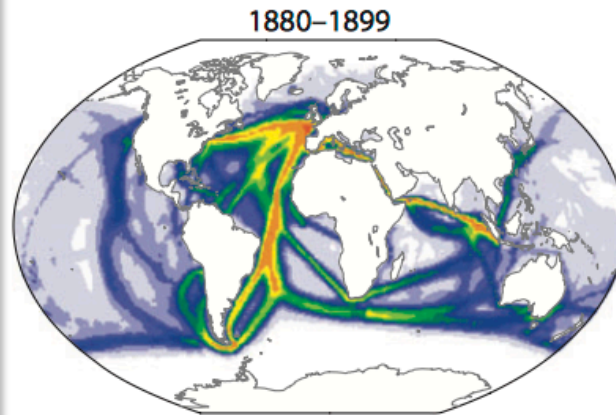
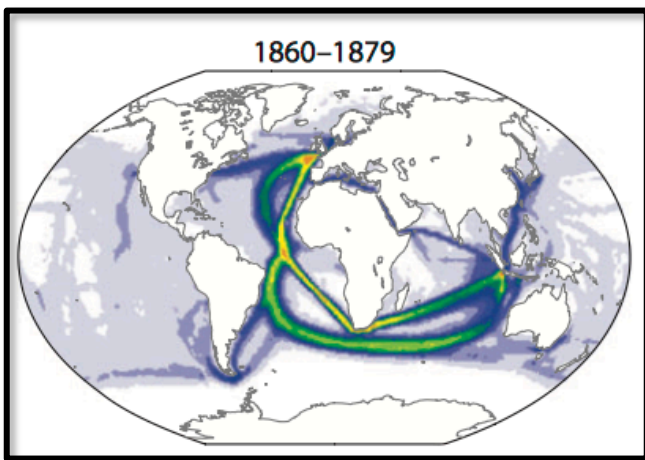
CLIVAR-ICTP International Workshop on Decadal Climate
Variability and Predictability: Challenge and Opportunity
Trieste, Italy 16-20 November 2015

- **Why do we care about DCV?**
 - Societal impacts
 - Adds uncertainty to climate projections
 - Confounds “detection and attribution” of past climate change
- **Challenges to defining and understanding DCV**
 - Patterns global in scale: difficult to sort out causal linkages
 - Sparse data, records short compared to time scales of interest
 - May be difficult to distinguish from a random process
 - A low-pass filtered time series will always show DCV, but it may not be physically meaningful.*
- **What are the main phenomena of DCV?**
 - Pacific/Indian Ocean
 - Atlantic Ocean
 - Southern Ocean

Data Coverage

International Comprehensive
Ocean-Atmosphere Data Set (ICOADS)

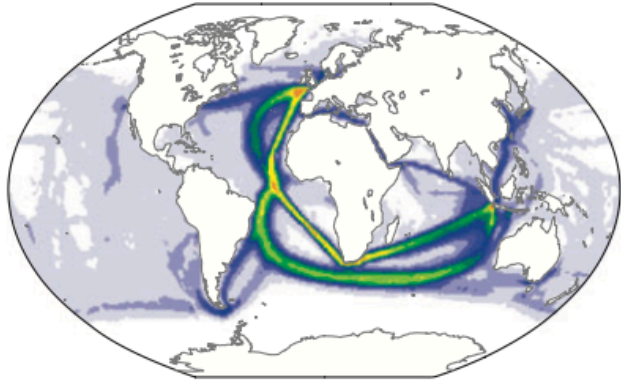
Merchant Ships



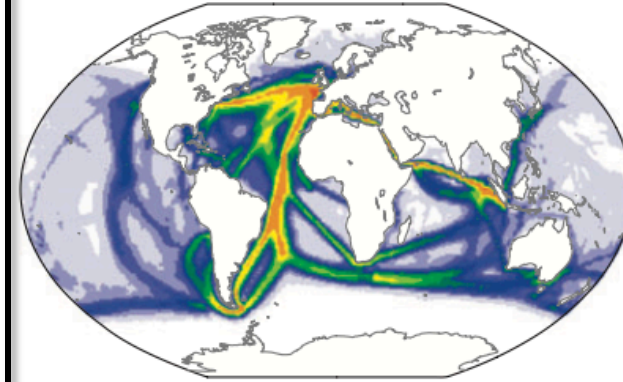
Percentage of months with ≥ 1 observation in a 20-year period

Deser et al. (2010)
Annual Reviews of Marine Sciences

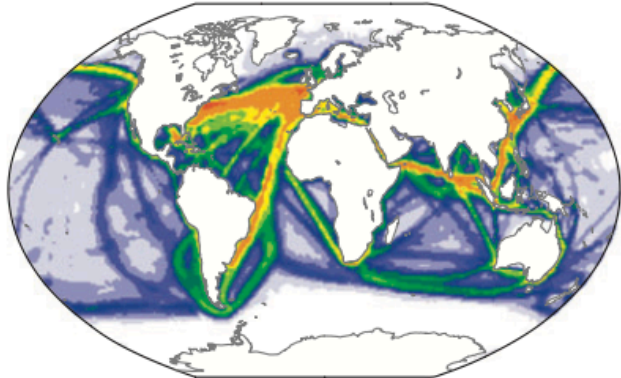
1860-1879



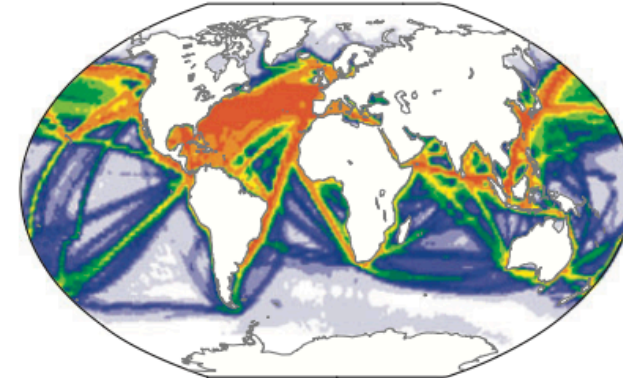
1880-1899



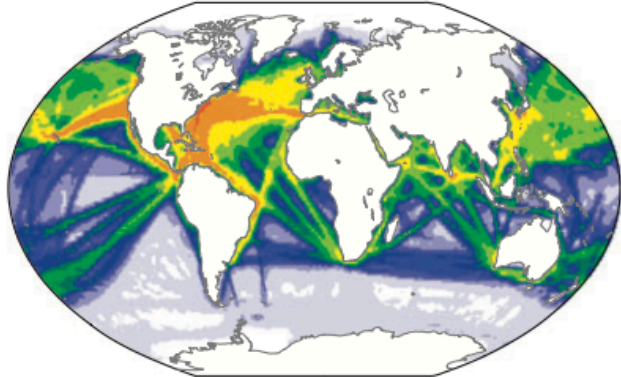
1900-1919



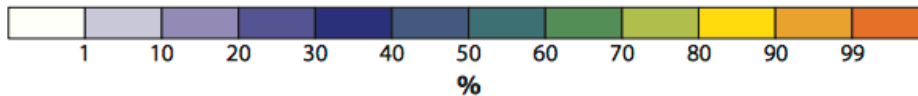
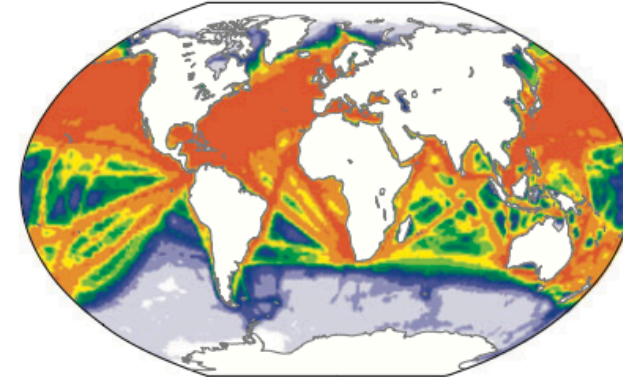
1920-1939



1940-1959



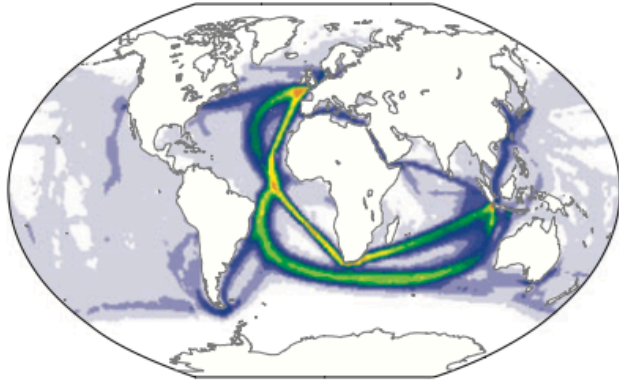
1960-1979



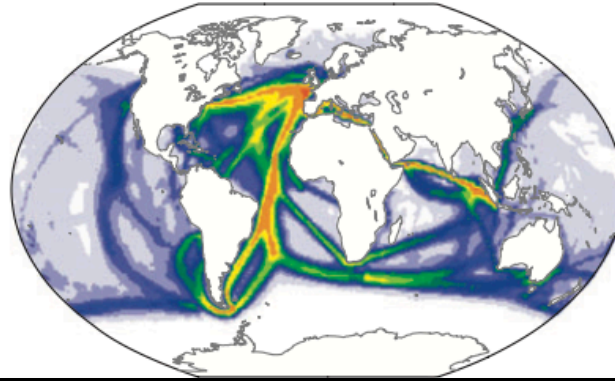
Percentage of months with ≥ 1 observation in a 20-year period

Deser et al. (2010)
Annual Reviews of Marine Sciences

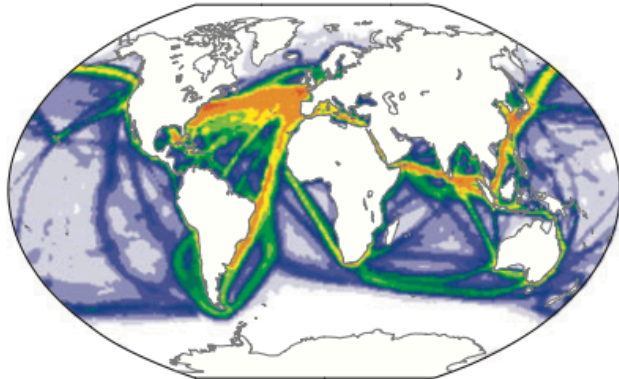
1860-1879



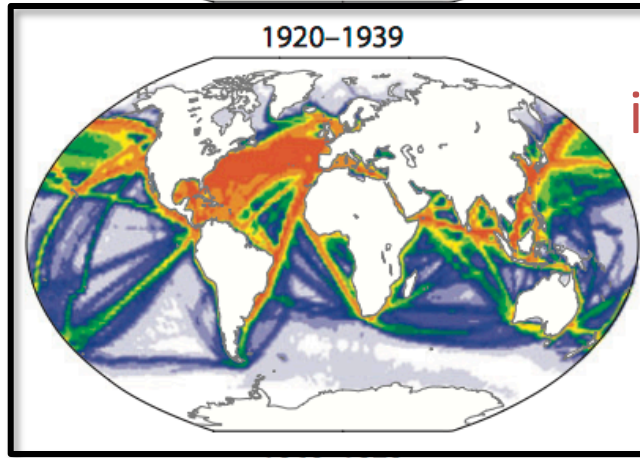
1880-1899



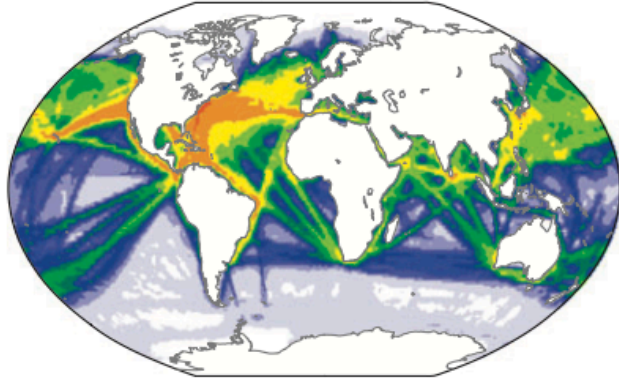
1900-1919



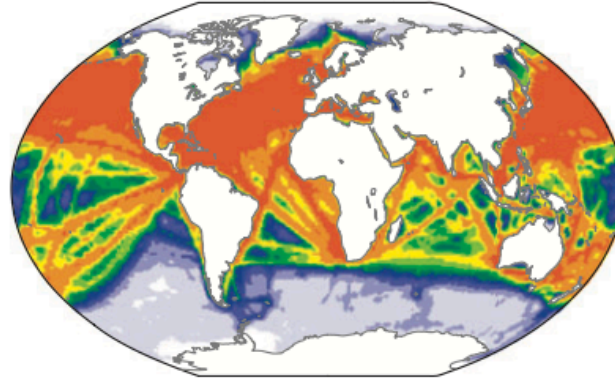
1920-1939



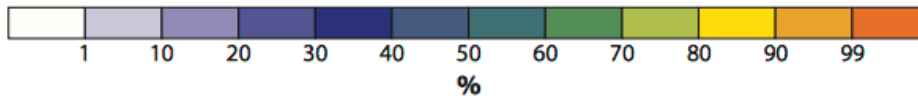
1940-1959



1960-1979

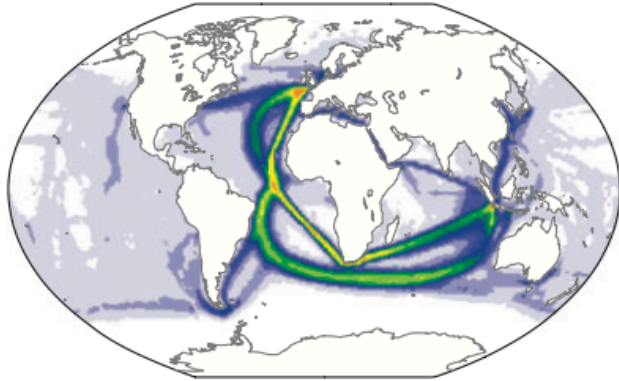


Percentage of months with ≥ 1 observation in a 20-year period

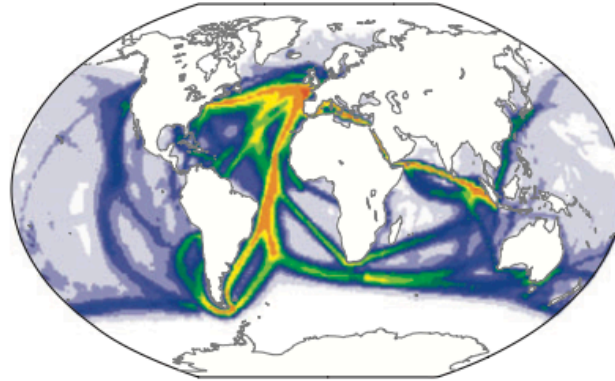


Deser et al. (2010)
*Annual Reviews of
Marine Sciences*

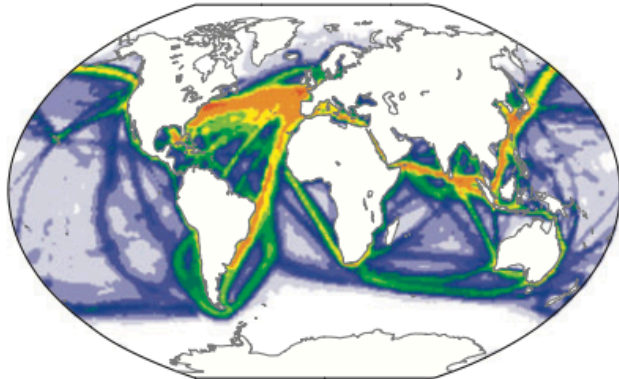
1860-1879



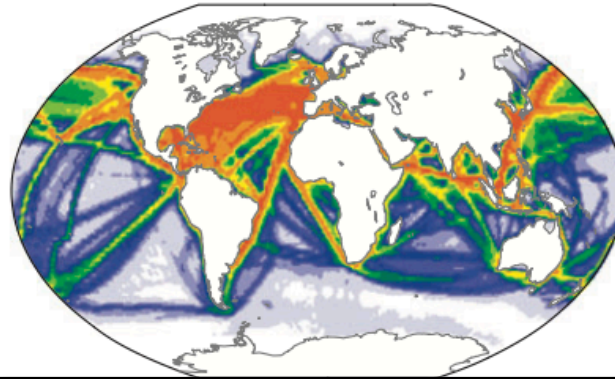
1880-1899



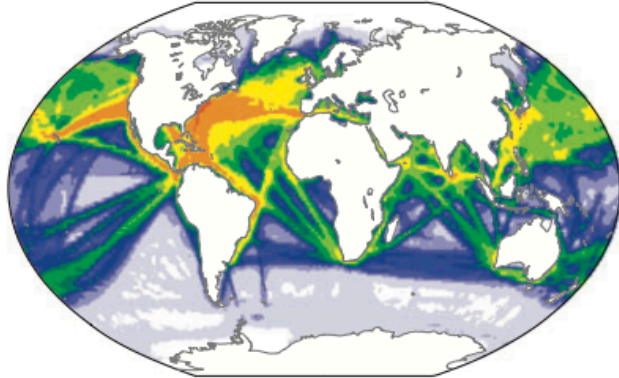
1900-1919



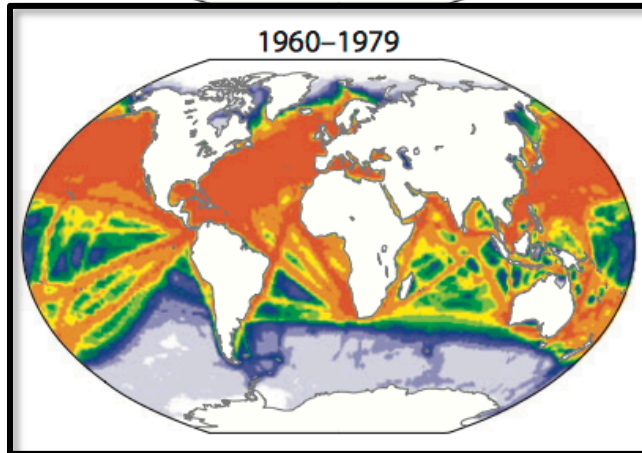
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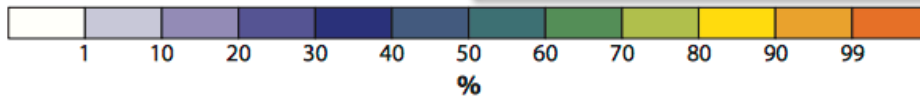
1940-1959



1960-1979



Percentage of months with ≥ 1 observation in a 20-year period



Deser et al. (2010)
*Annual Reviews of
Marine Sciences*



inform • compare • discover

An insider's view of data strengths and limitations | climatedataguide.ucar.edu

Schneider et al. *EOS* 2013

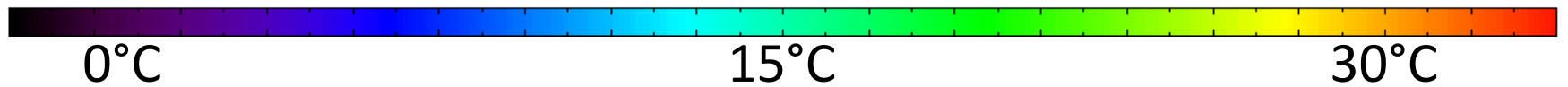
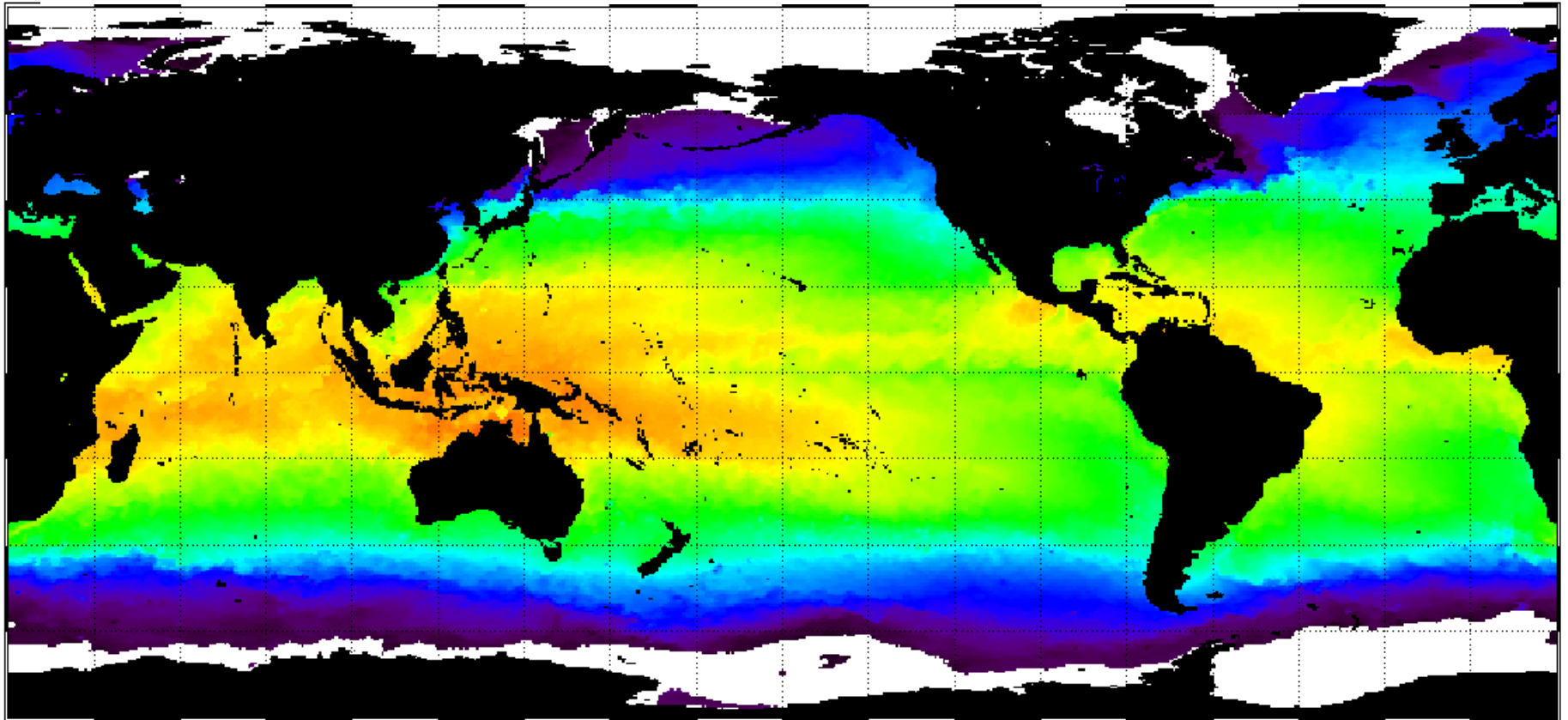
The “go-to” guide for information
on climate data sets by expert users

climatedataguide.ucar.edu

Defining Patterns of DCV

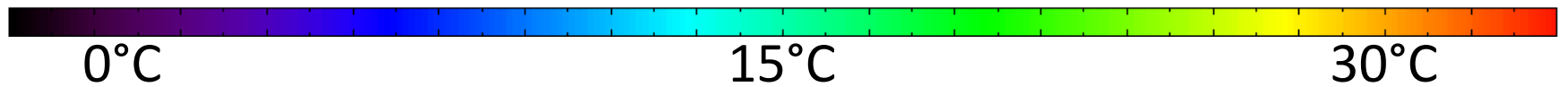
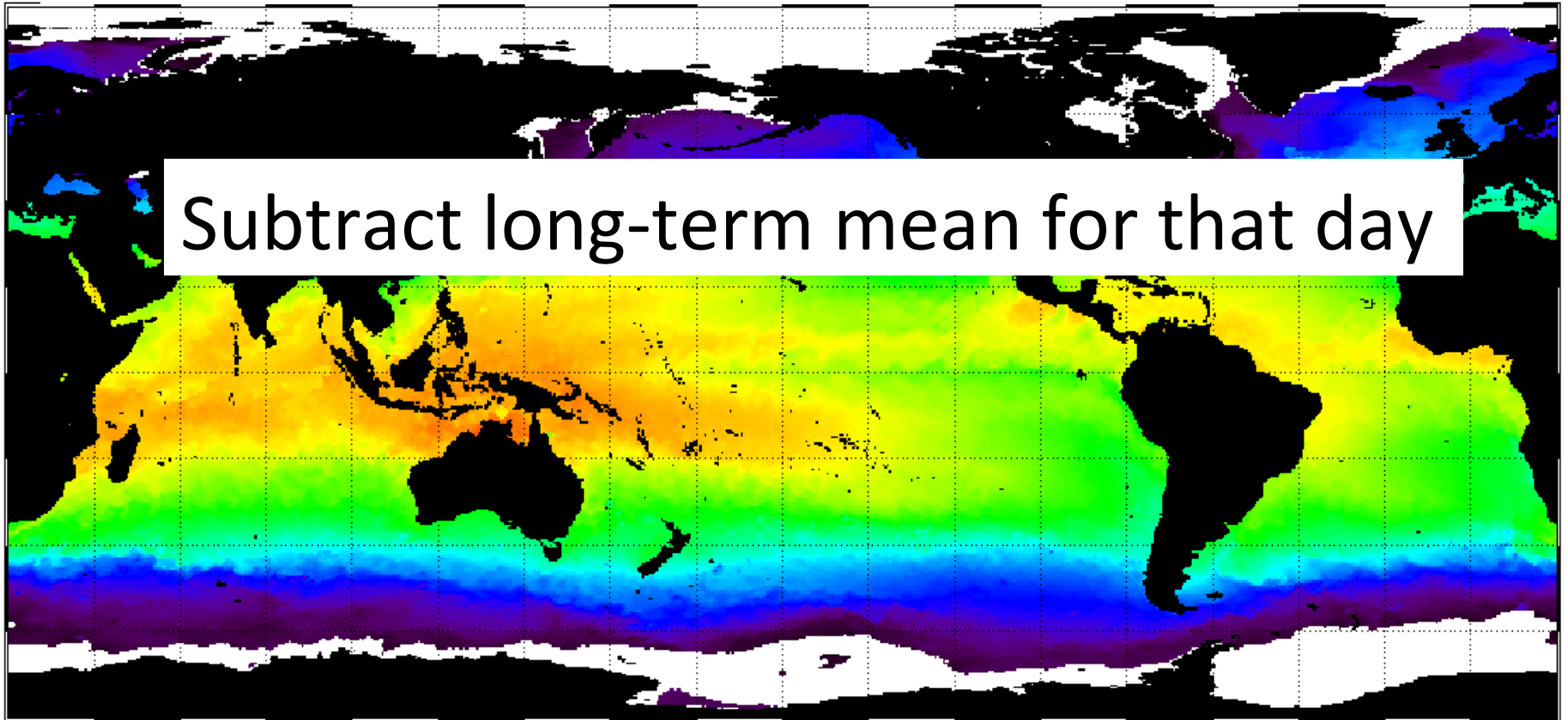


Sea Surface Temperature 29 December 2011



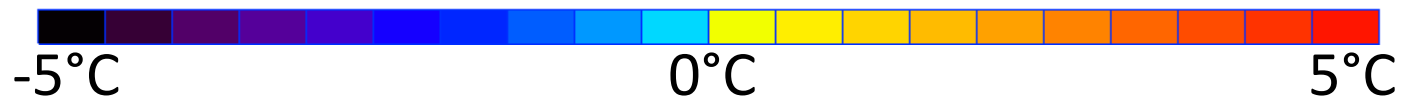
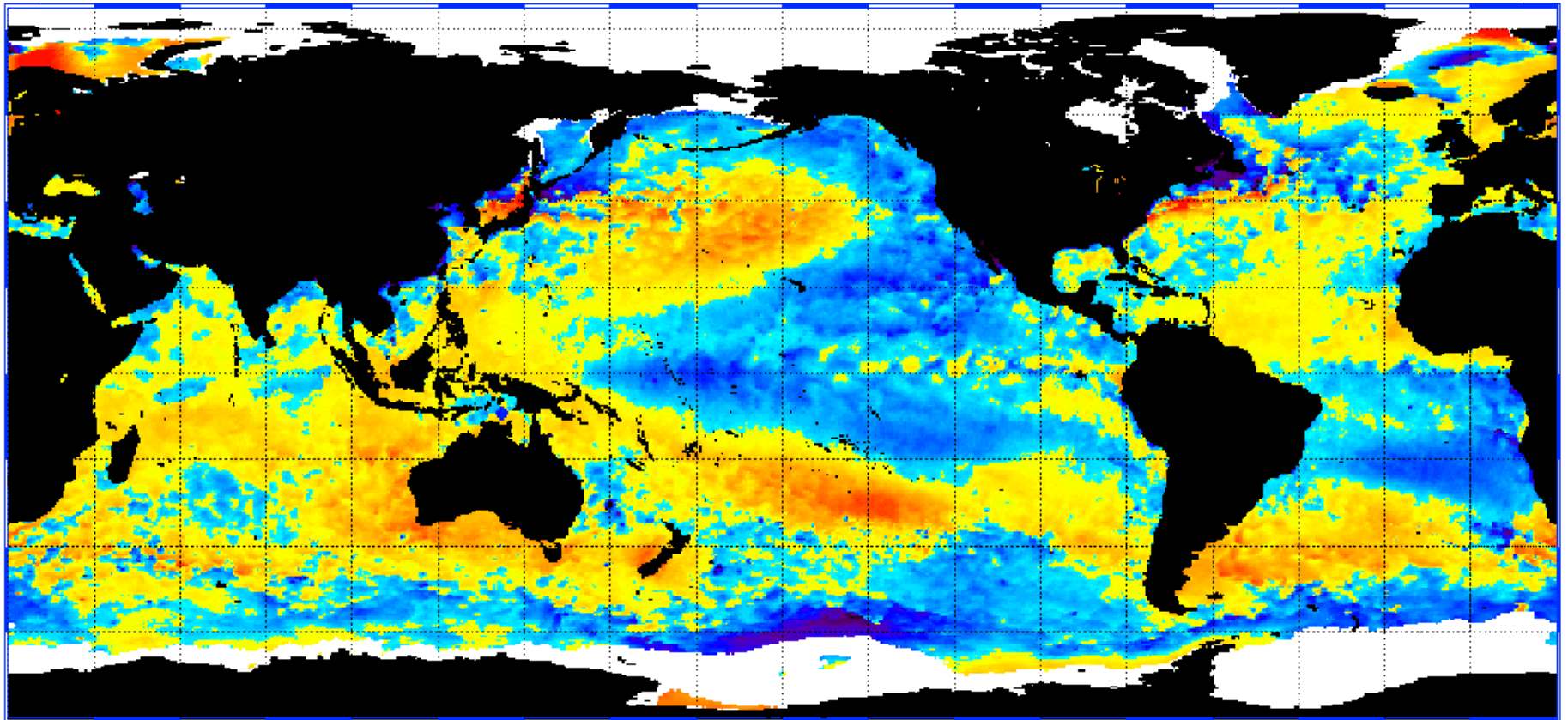
Sea Surface Temperature 29 December 2011

Subtract long-term mean for that day



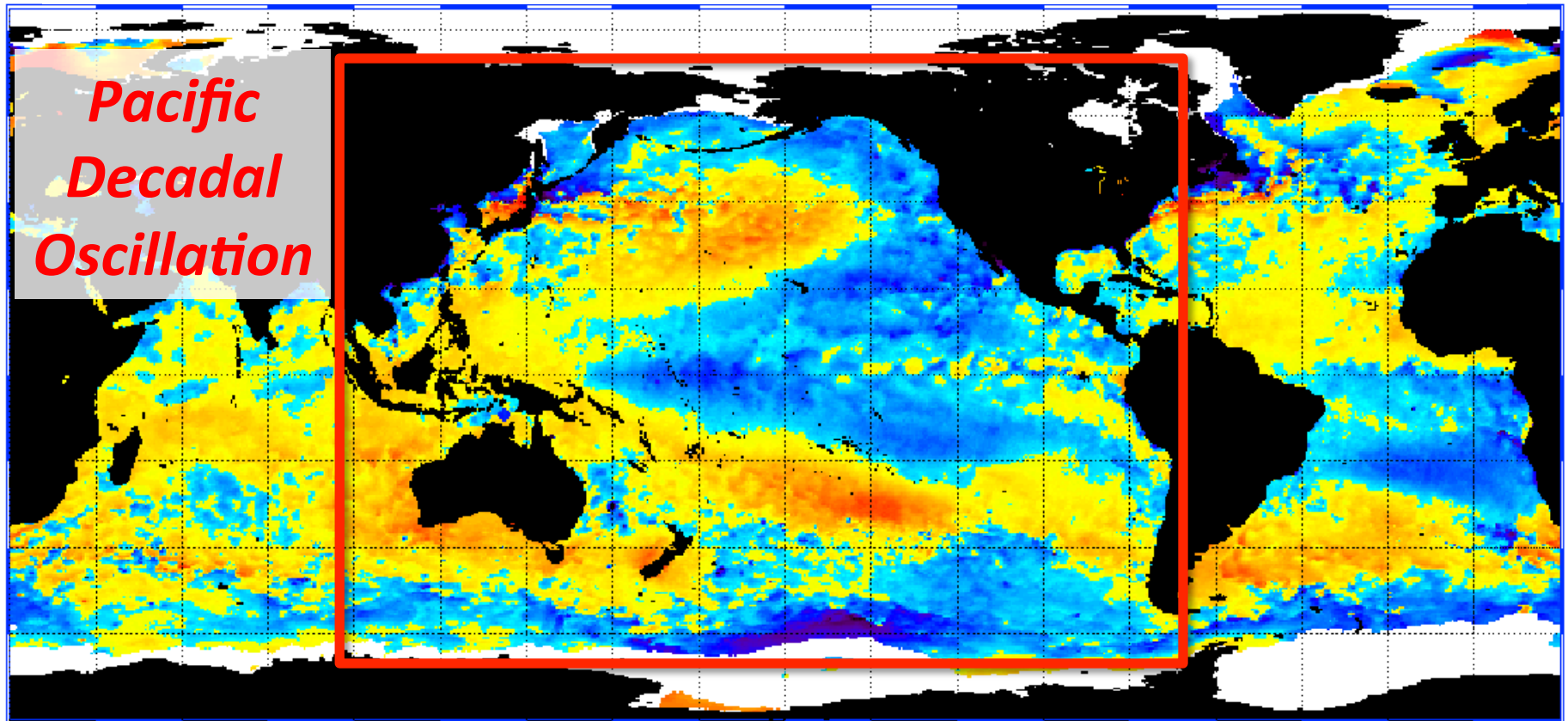
Sea Surface Temperature Anomaly

29 December 2011



Sea Surface Temperature Anomaly

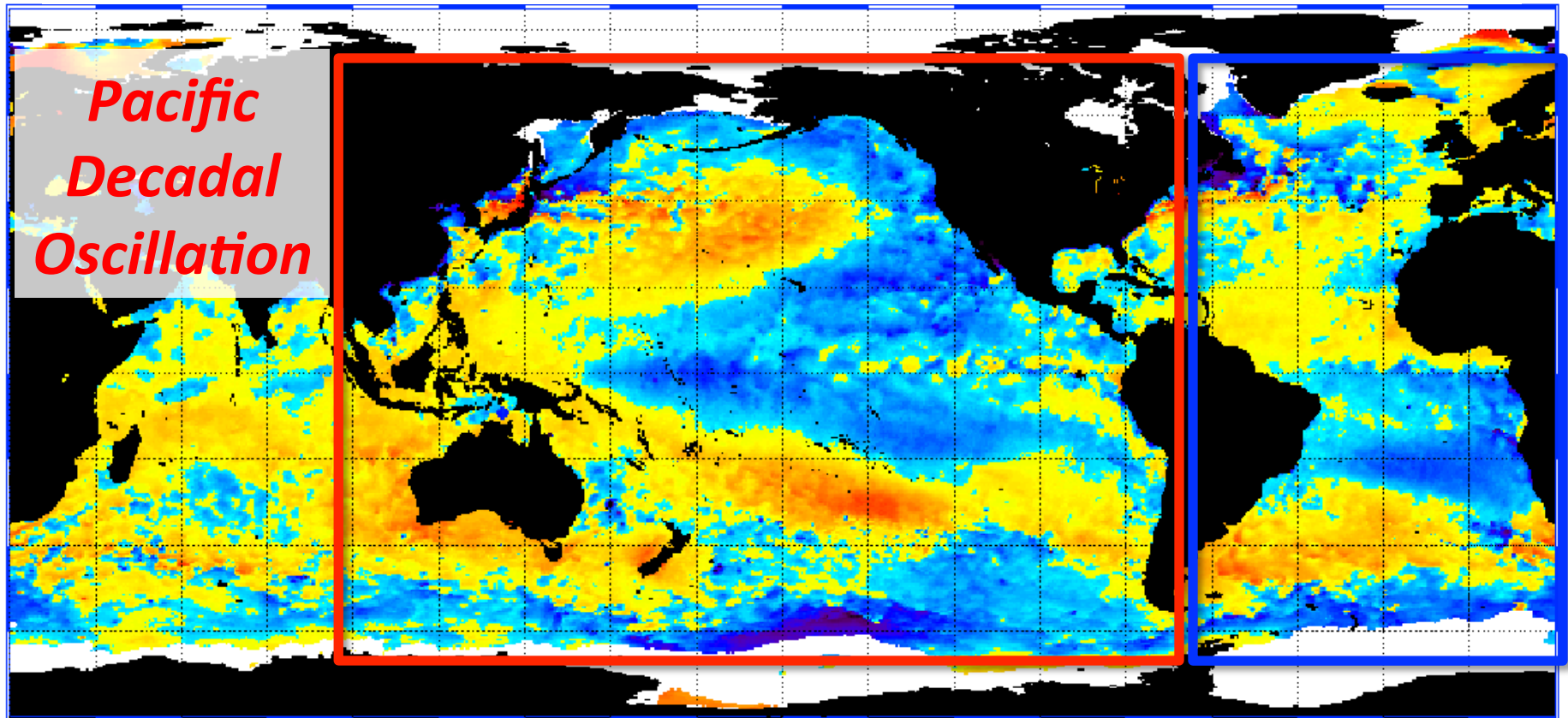
29 December 2011



Large-scale organization

Sea Surface Temperature Anomaly

29 December 2011



Large-scale organization

Pacific DCV

HadISST

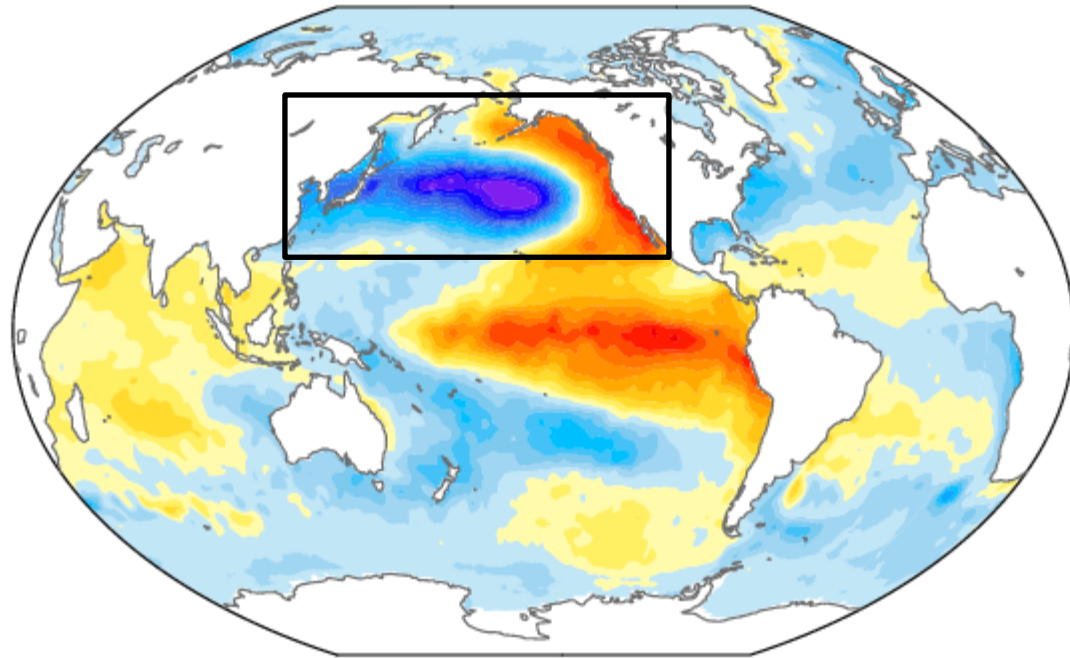
1870-2014

EOF1 of monthly SST*

* global mean SST subtracted

Mantua et al., 1997; Zhang et al., 1997; Power et al., 1999;
Folland et al., 2002; Chen and Wallace, 2015; Newman et al., 2015

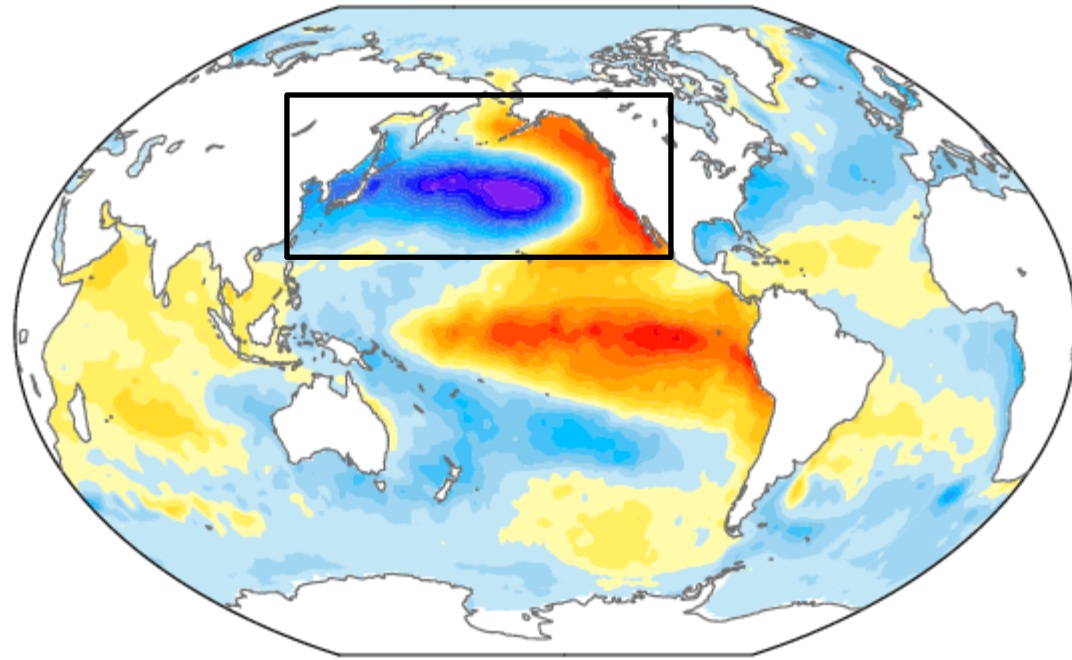
North Pacific
25%



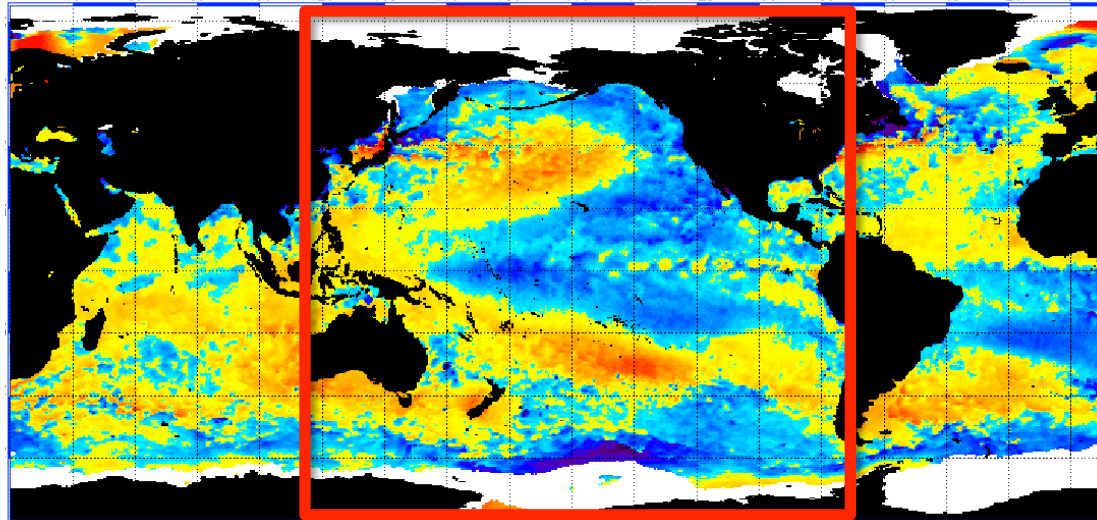
Global
regression
map on PC
time series



North Pacific
25%

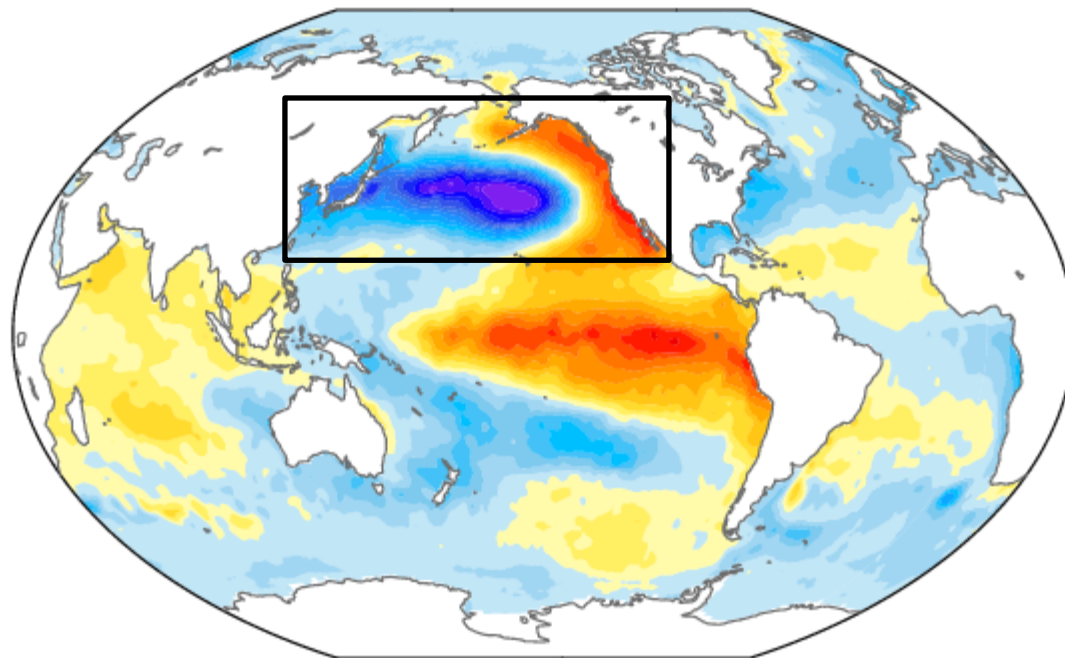


Global
regression
map on PC
time series



29 December
2011

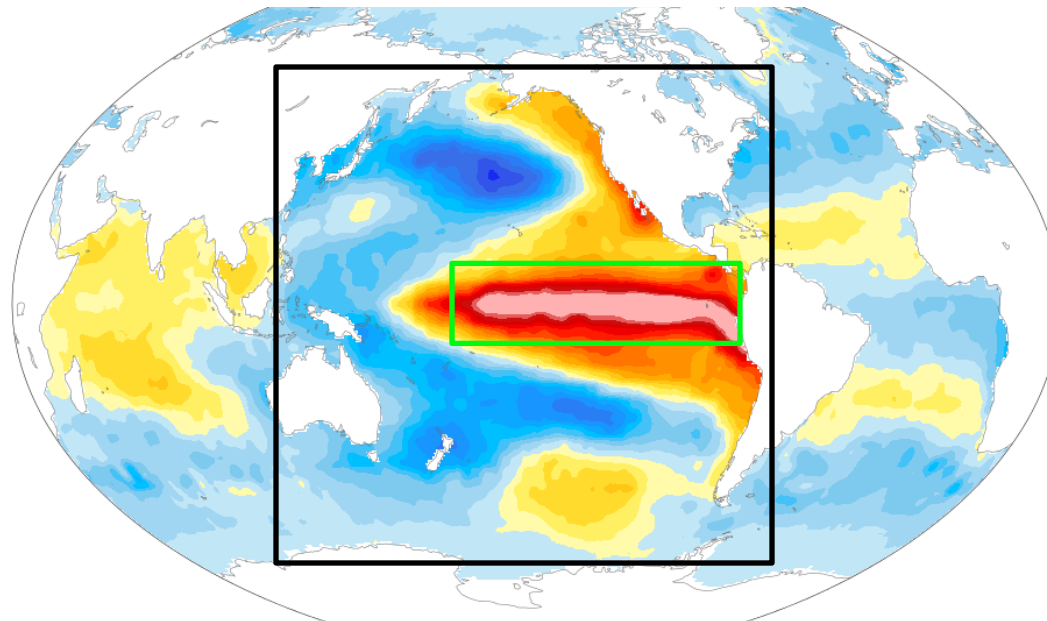
North Pacific
25%



Global
regression
map on PC
time series

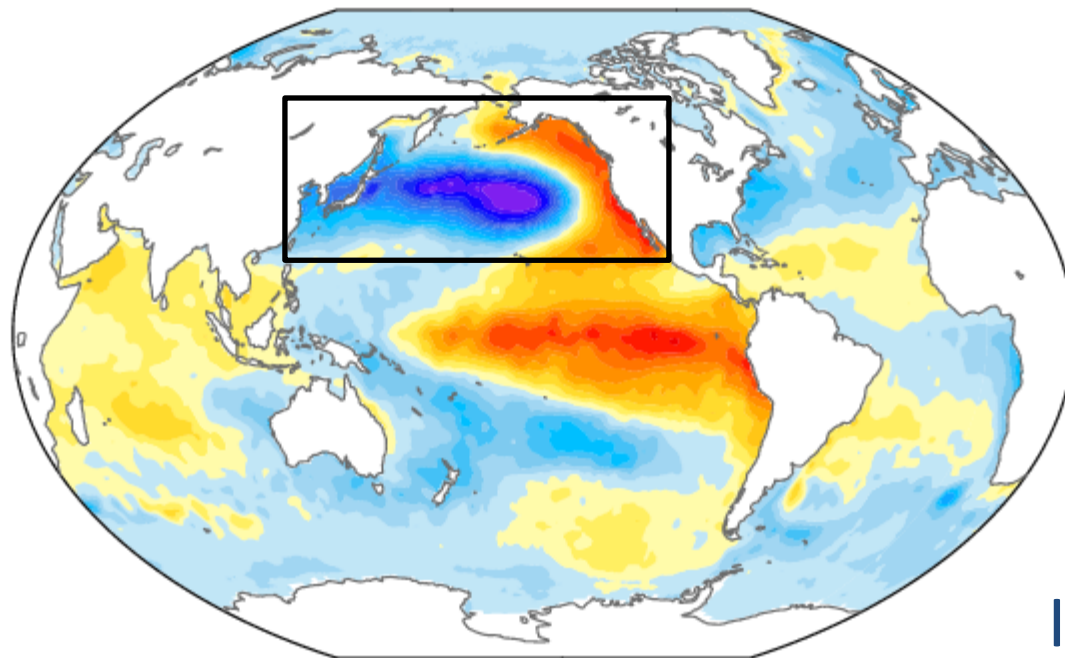


Pan Pacific
31%



ENSO

North Pacific
25%

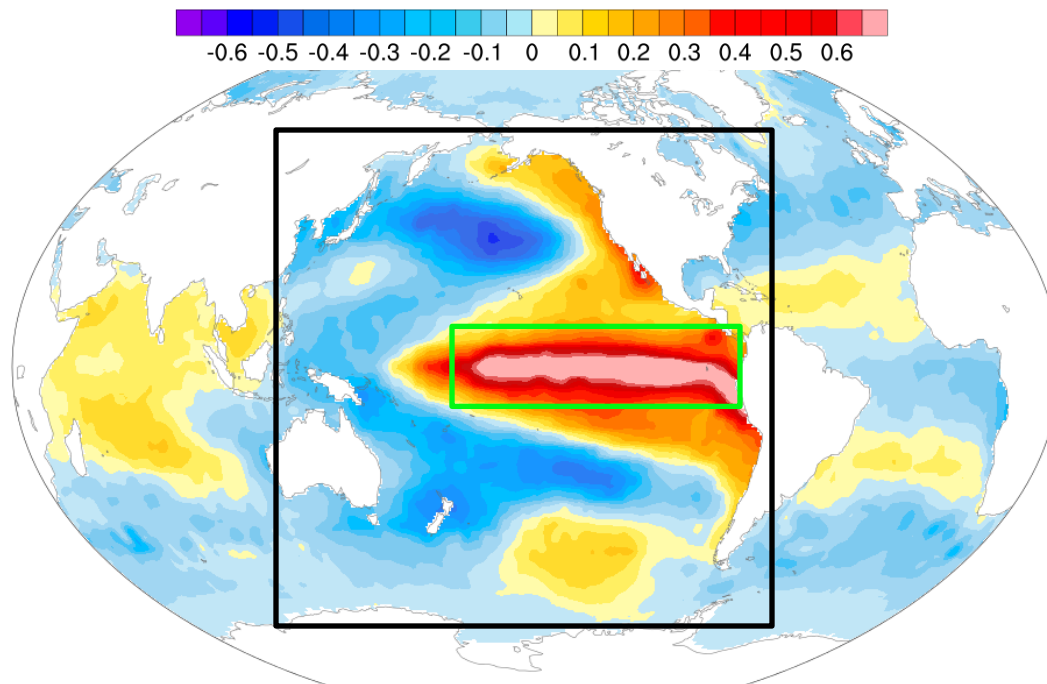


Pacific
Decadal
Oscillation
(ENSO-like)



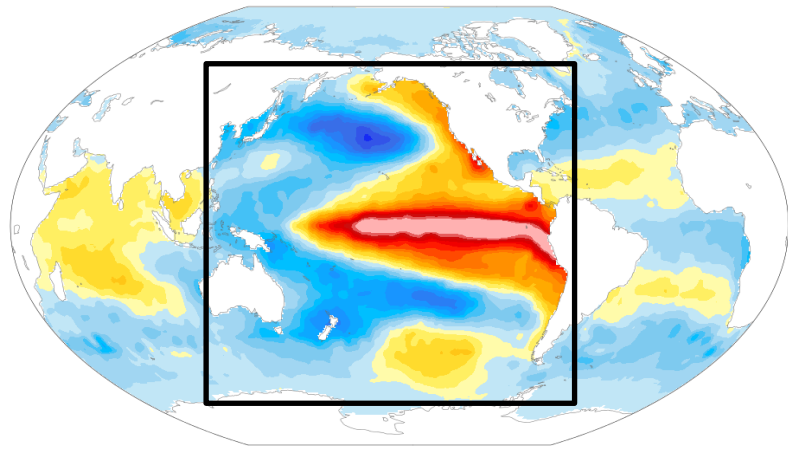
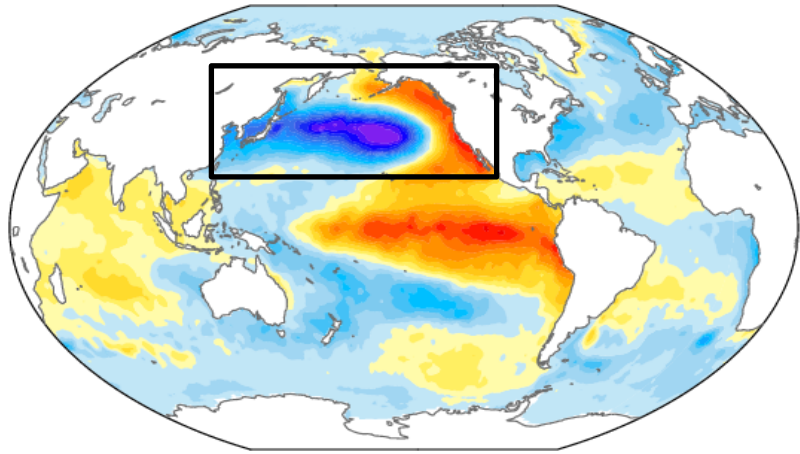
Interdecadal
Pacific
Oscillation

Pan Pacific
31%

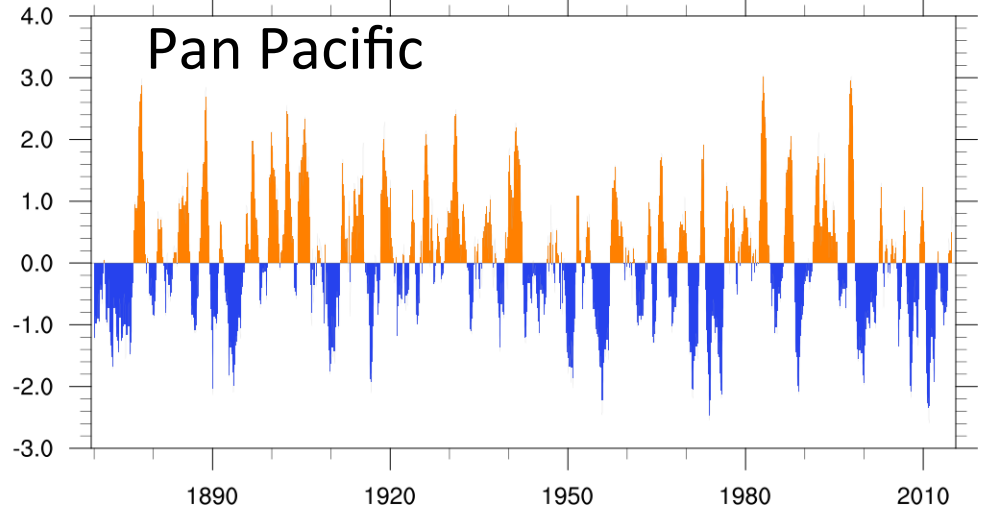
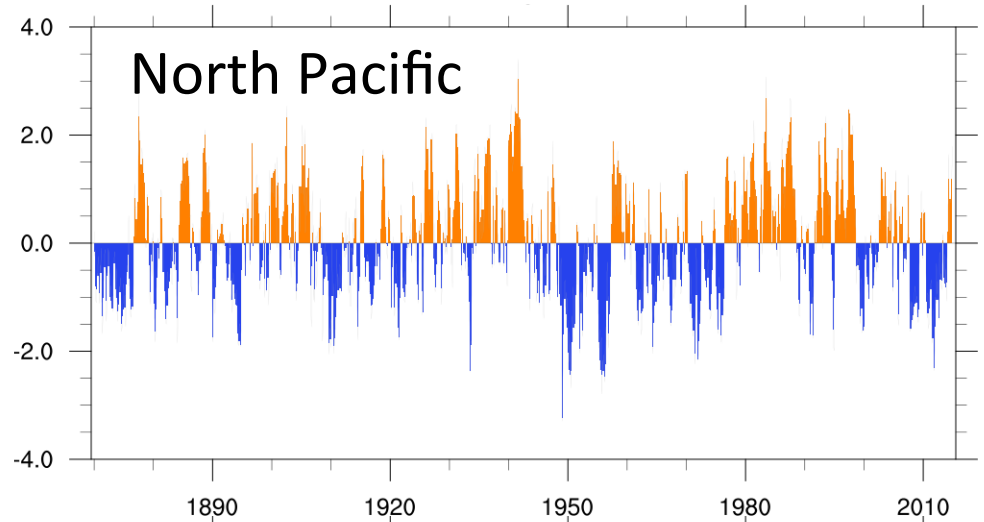


ENSO

EOF

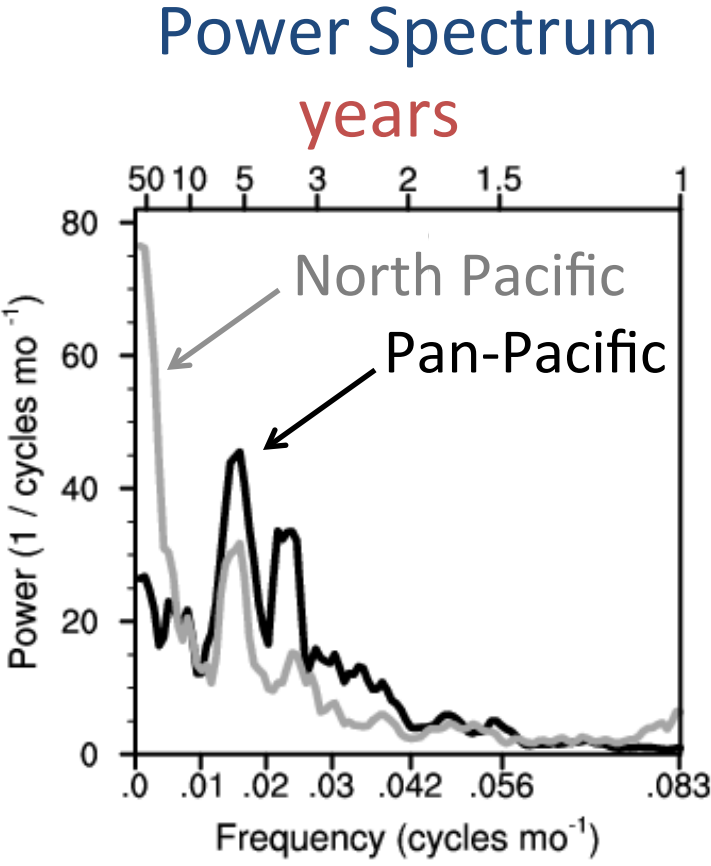


Principal Component

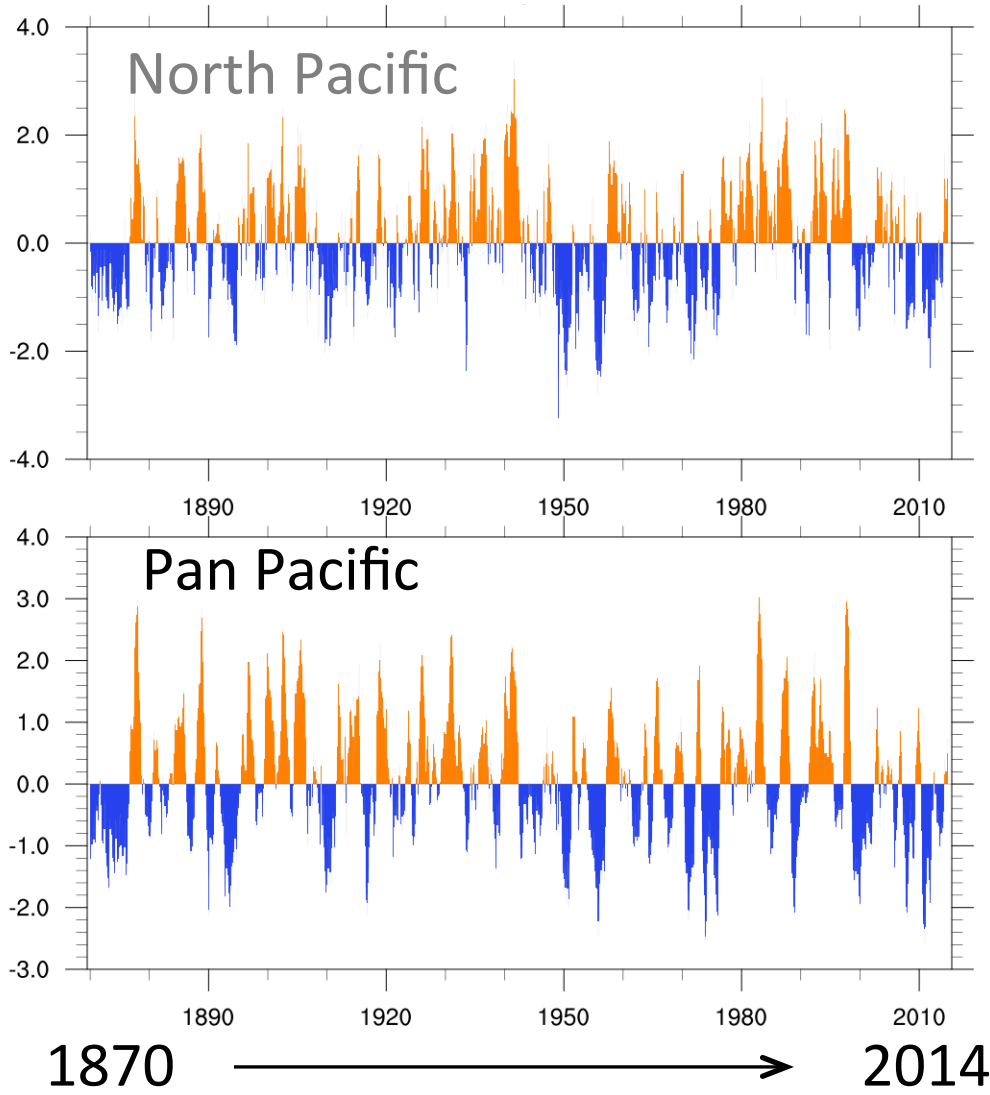


1870 \longrightarrow 2014

Principal Component



Deser et al. (2012)
Journal of Climate



1870 → 2014

Atlantic DCV

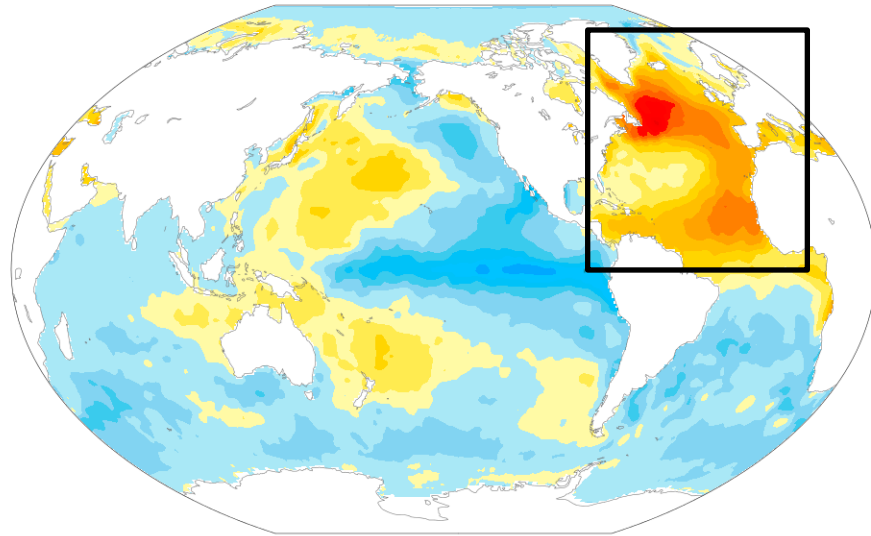
HadISST

1870-2014

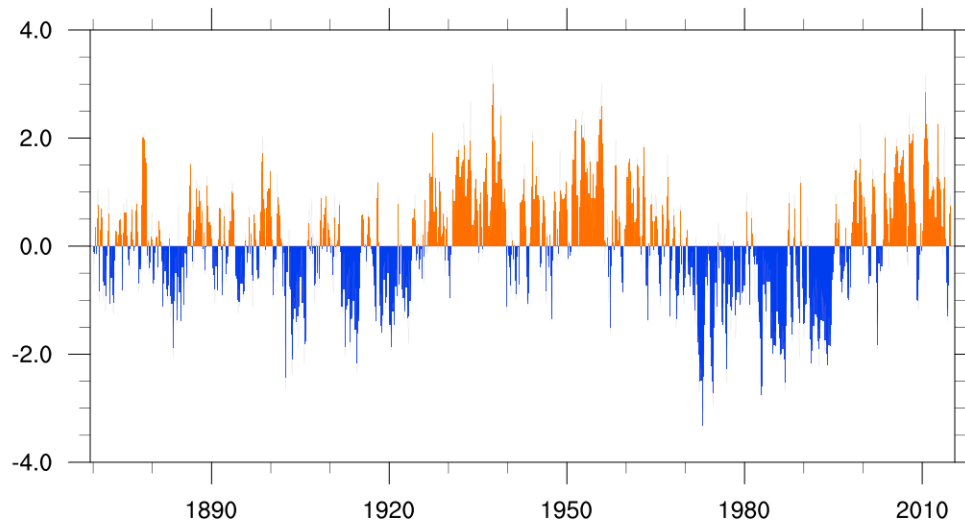
North Atlantic SST*

* global mean SST subtracted

Deser and Blackmon, 1993; Kushnir, 1994; Delworth and Mann, 2000;
Trenberth and Shea, 2006; Ting et al., 2009

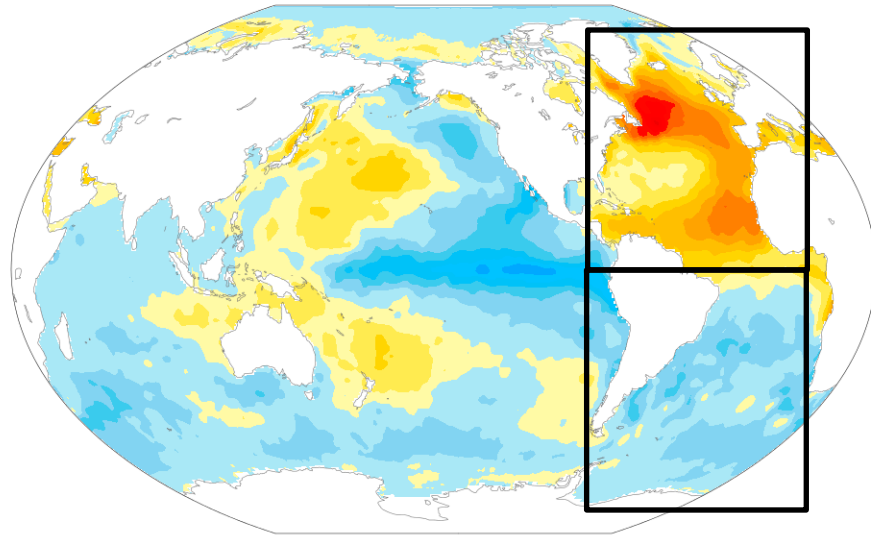


Global regression
map on North
Atlantic SST*

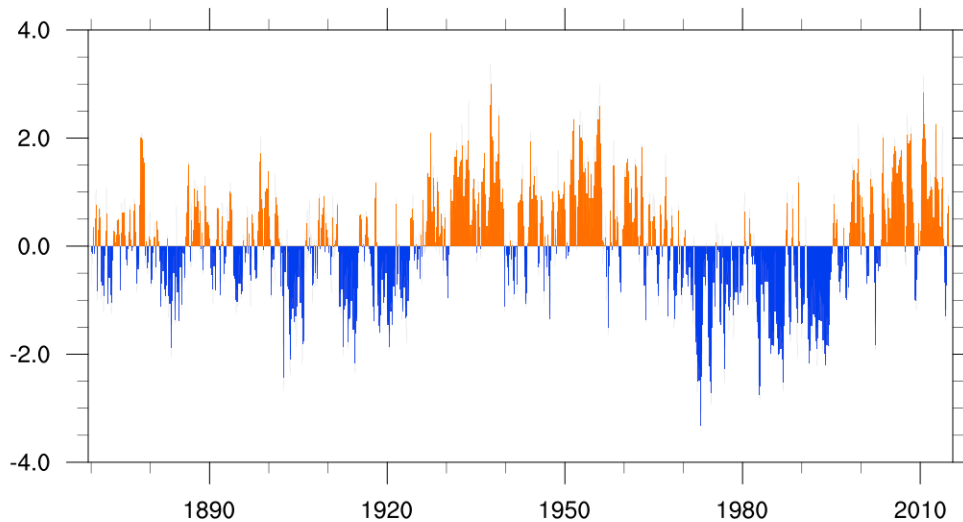
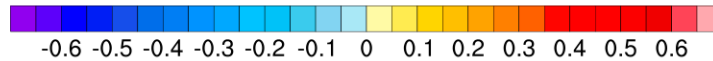


Atlantic
Multi-decadal
Oscillation

1870 → 2014



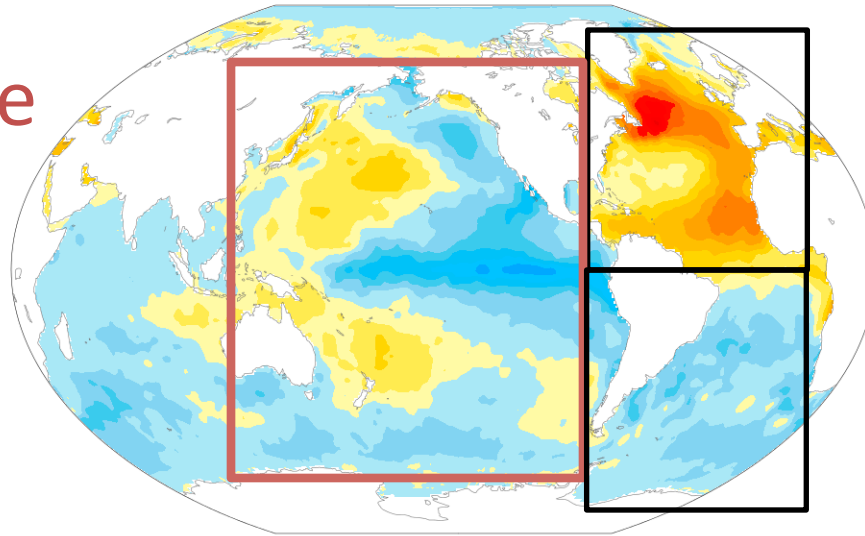
Global regression
map on North
Atlantic SST*



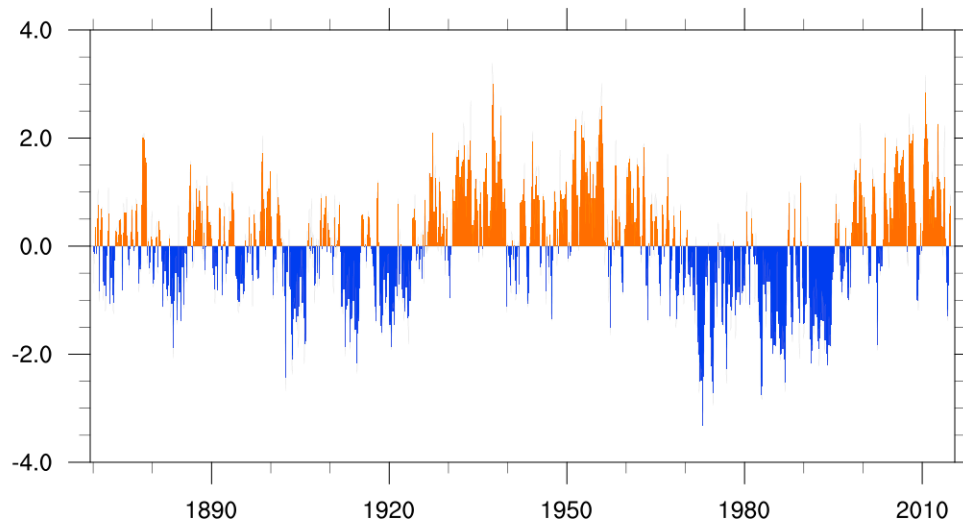
Atlantic
Multi-decadal
Oscillation

1870 → 2014

PDO-like

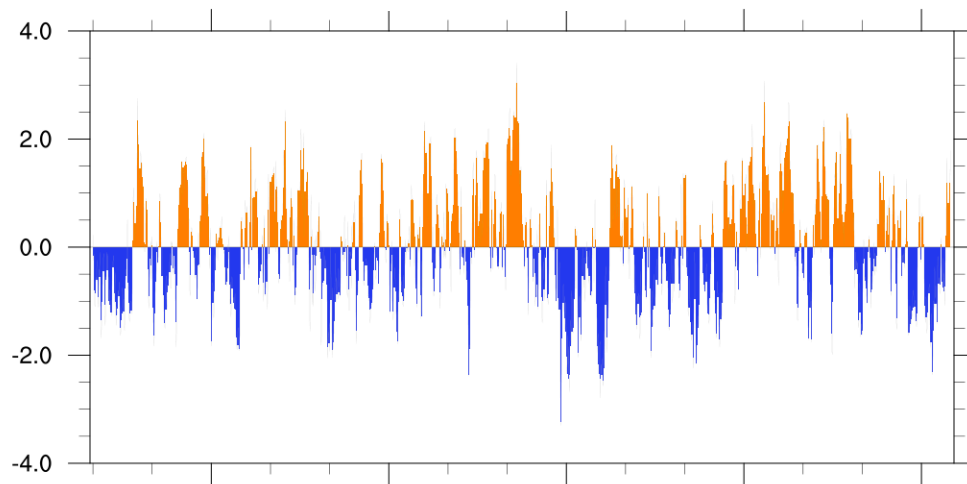


Global regression map on North Atlantic SST*



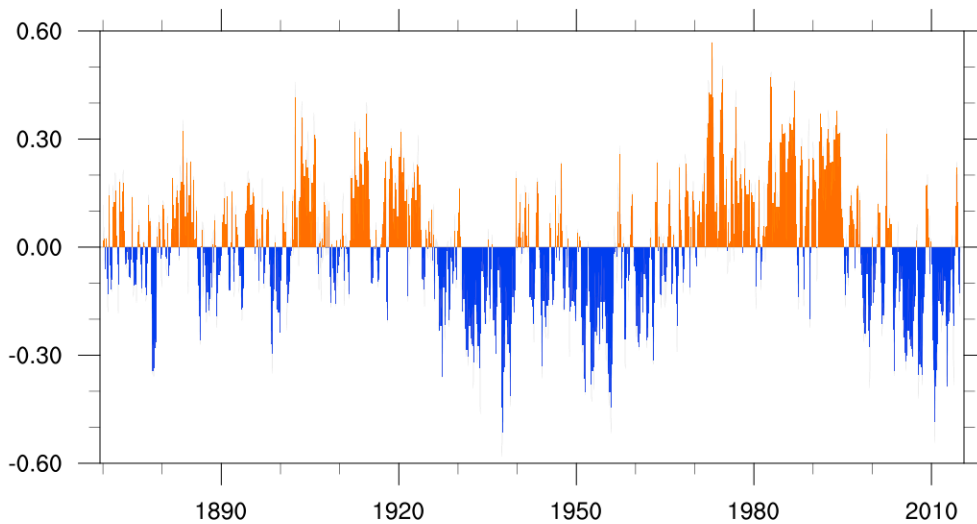
Atlantic Multi-decadal Oscillation

1870 → 2014



+ PDO

?



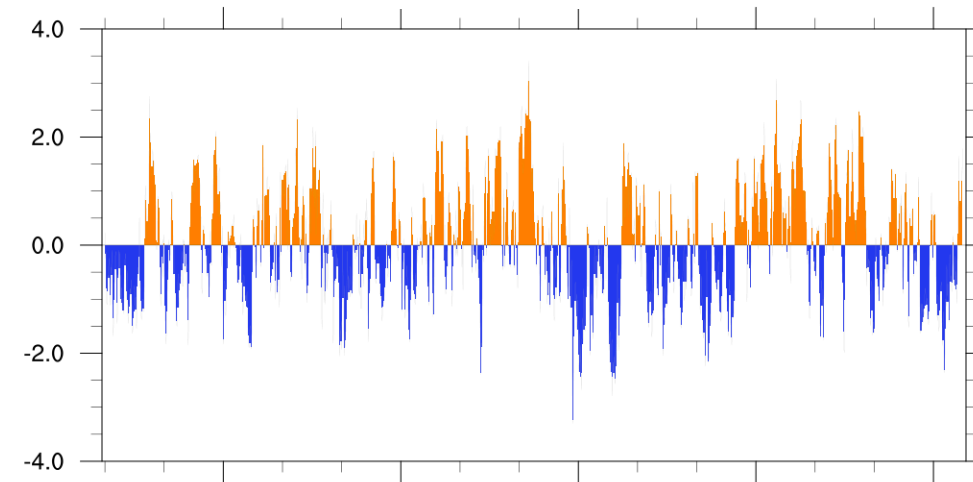
- AMO

1870



2014

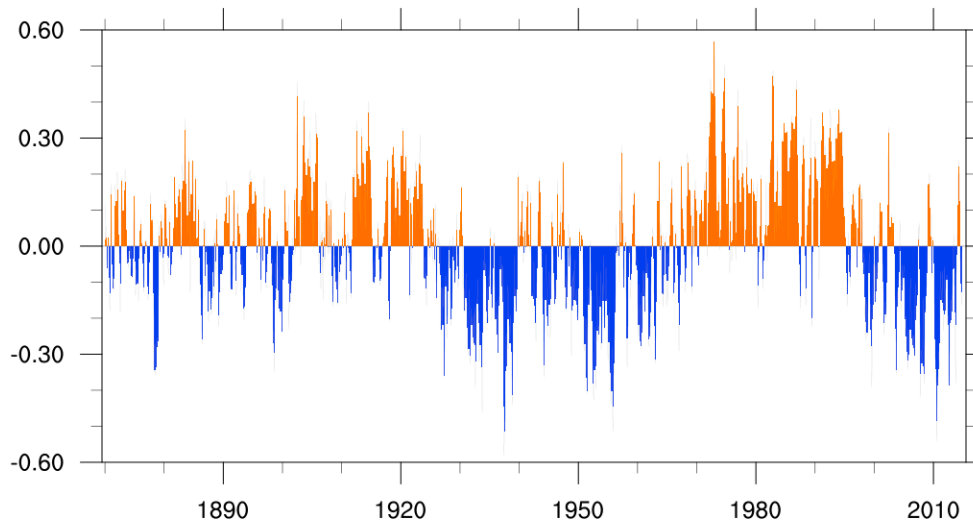
R = - 0.5
AMO leads
PDO by
10-20 years



+ PDO

?

- AMO

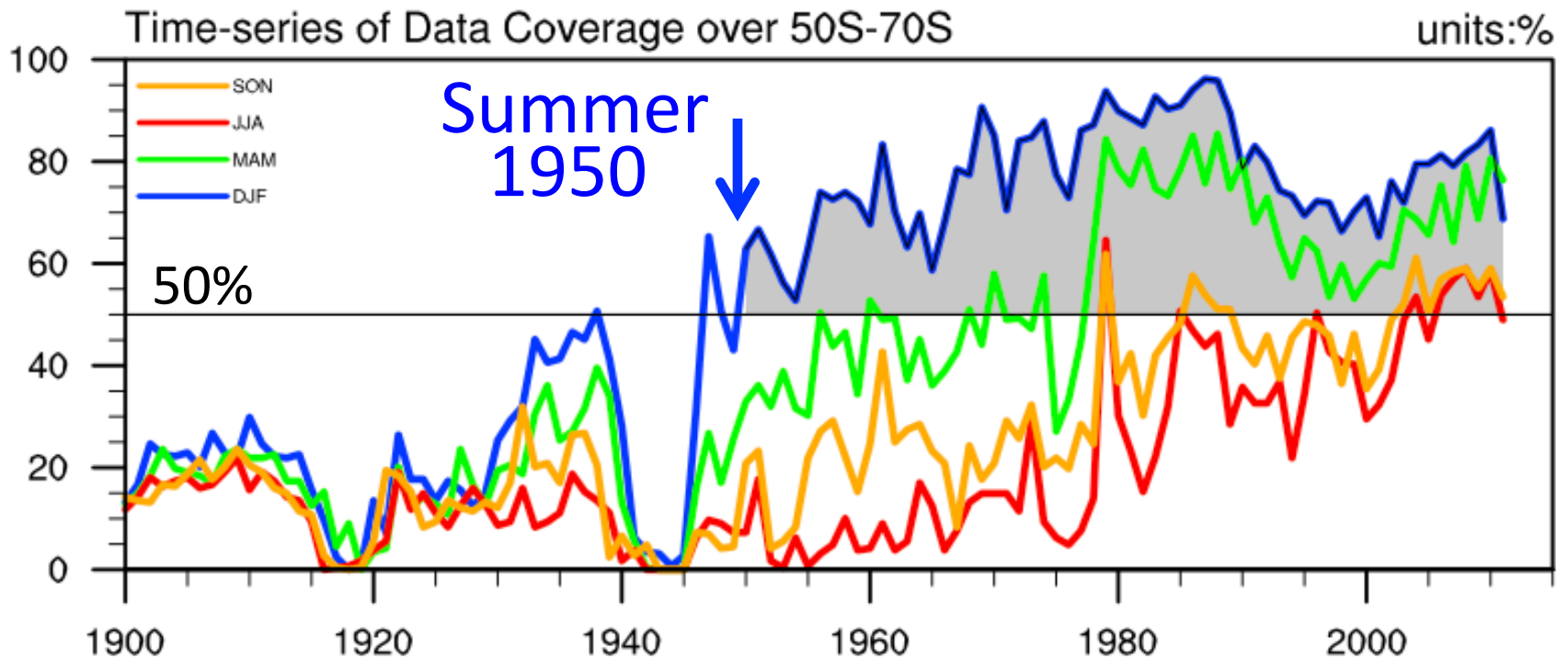


1870

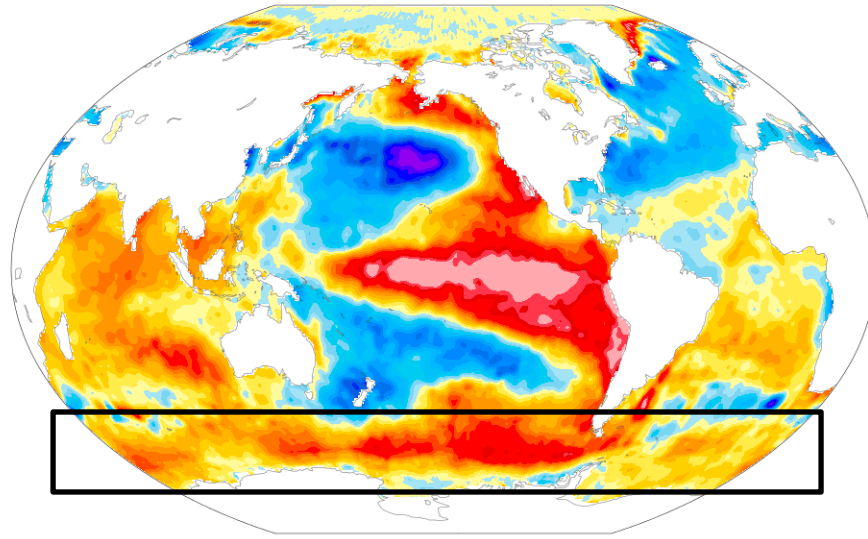


2014

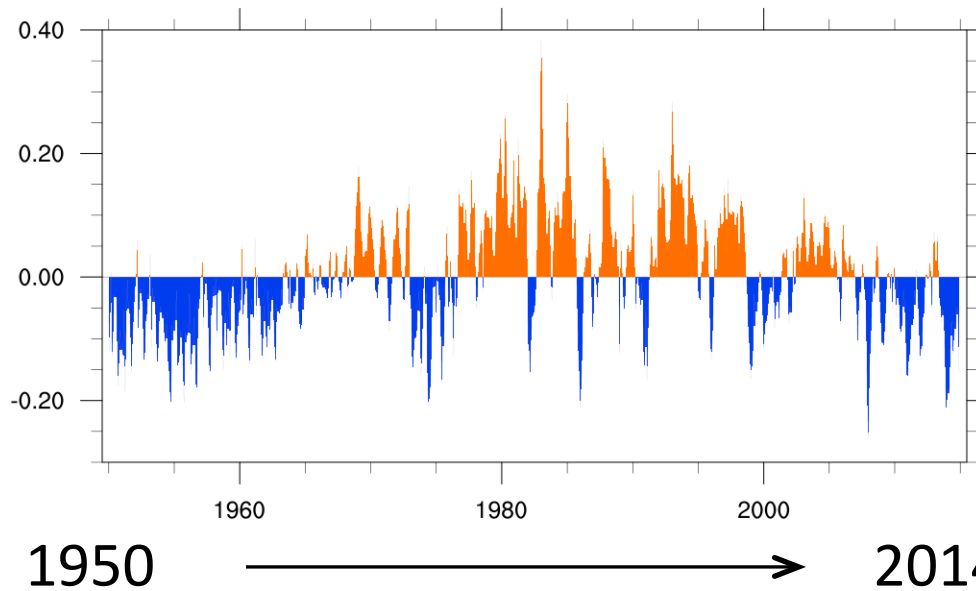
Southern Ocean DCV



Fan et al., *Geophys. Res. Lett.* 2014

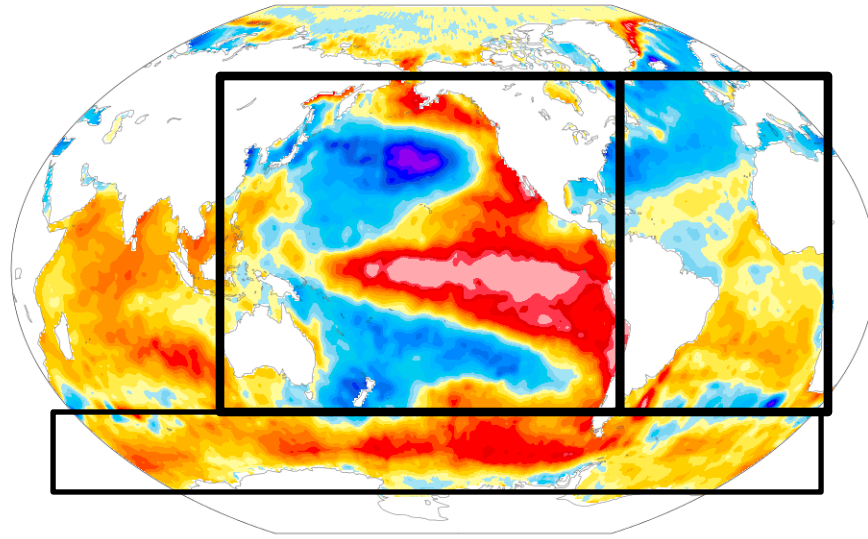


Global regression
on Southern
Ocean SST

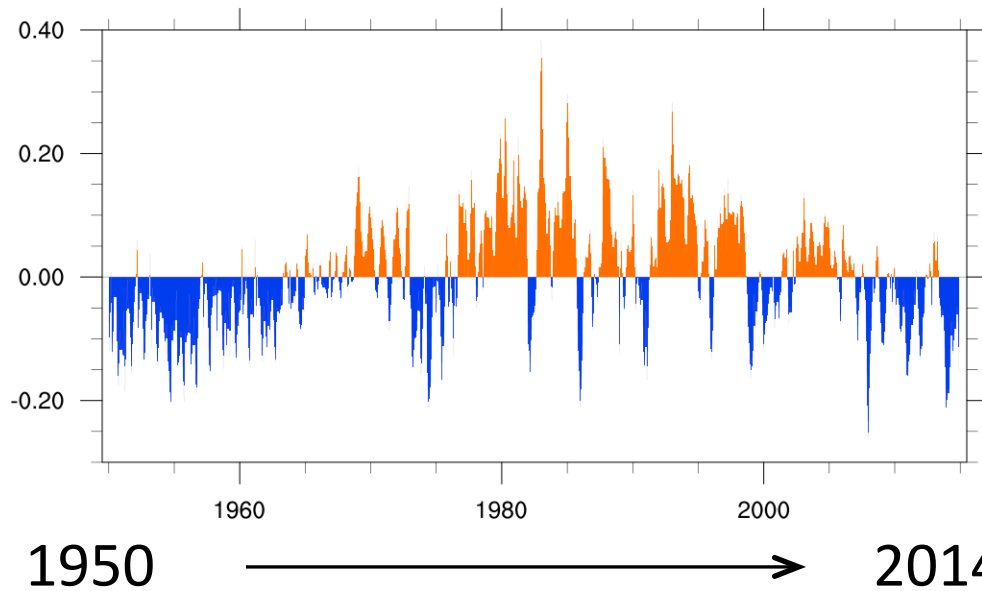


Southern
Ocean SST

See also: Fan et al. 2014; Latif et al., 2013; Li et al., 2014

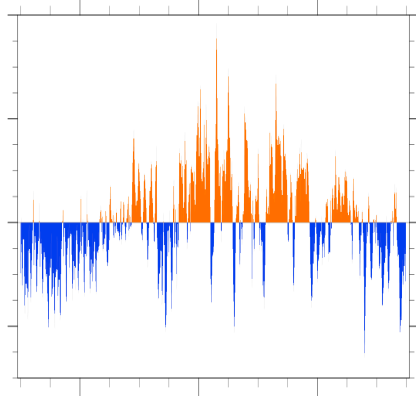


Global regression
on Southern
Ocean SST

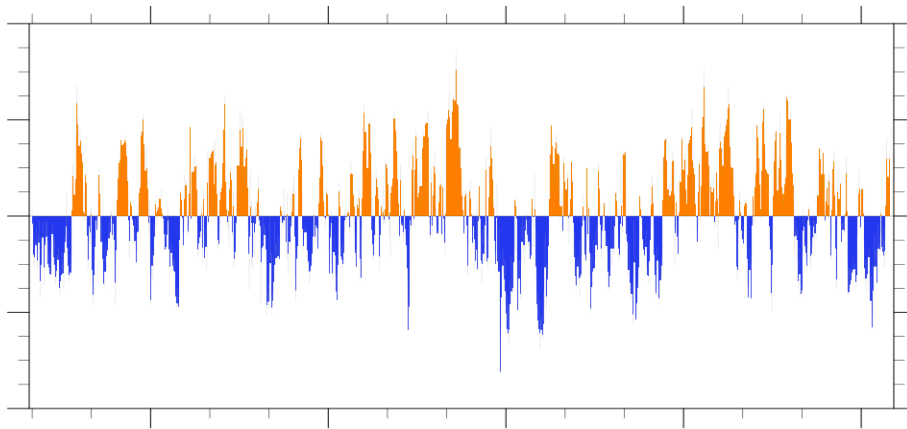


Southern
Ocean SST

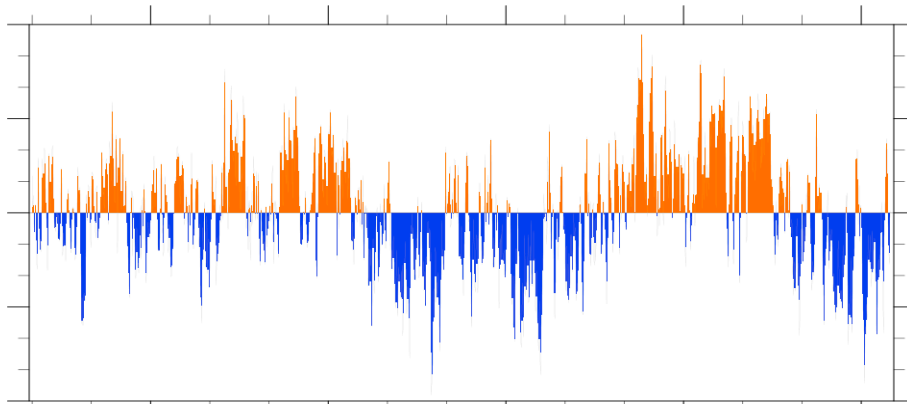
See also: Fan et al. 2014; Latif et al., 2013; Li et al., 2014



+ SO



+ PDO



- AMO

1870 \longrightarrow 2014

Additional Background on DCV

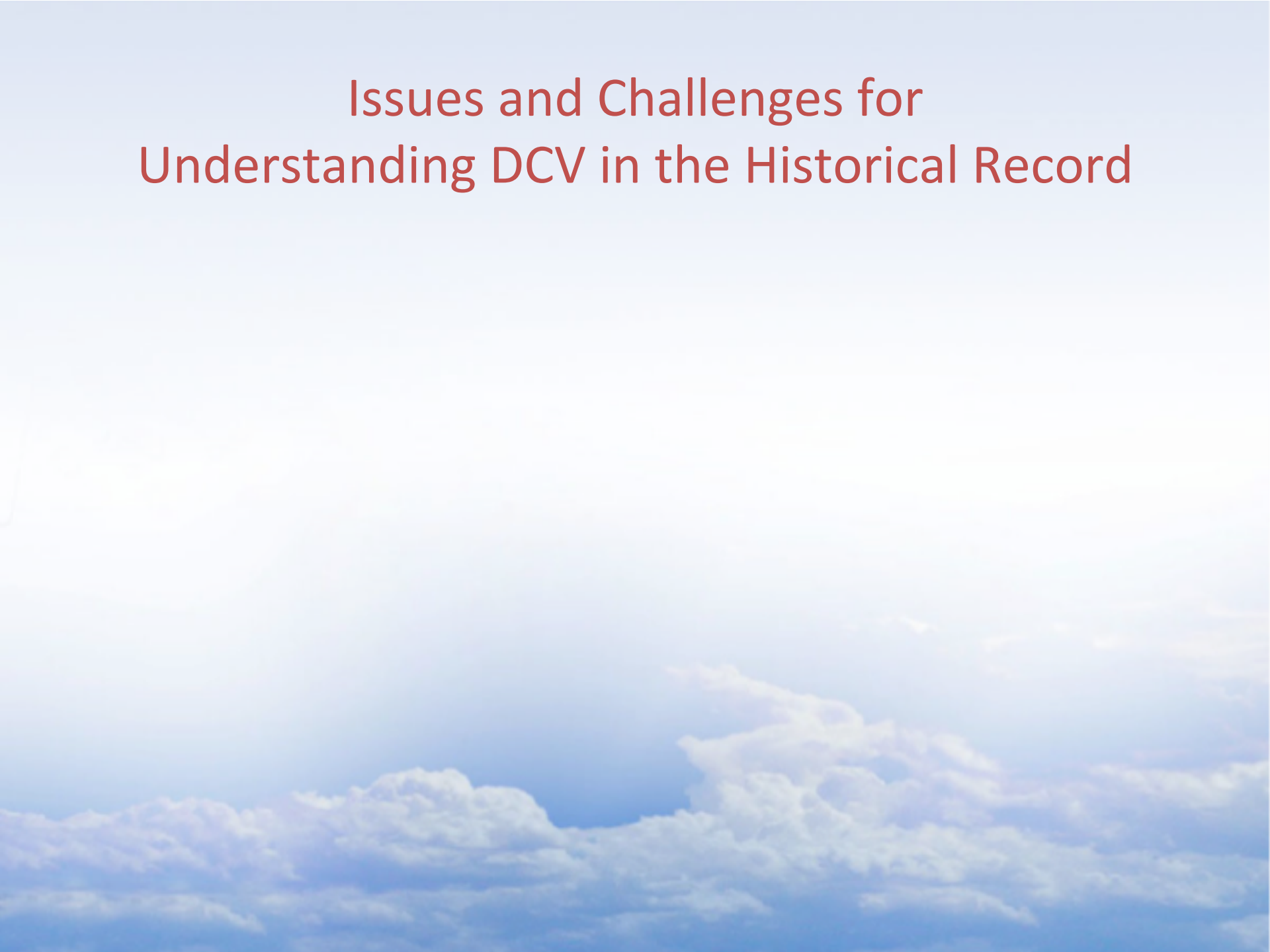
Climate Change: Multi-decadal and Beyond

World Scientific Series on Asia-Pacific Weather and Climate Vol. 6

Editors: Chang, Ghil, Latif and Wallace (2016)

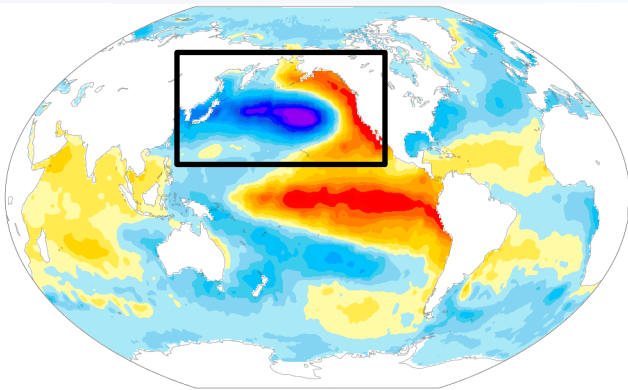
23 chapters on a wide-range of topics

Issues and Challenges for Understanding DCV in the Historical Record

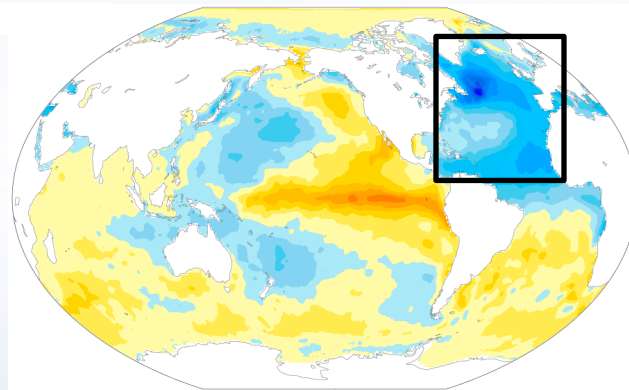


Issues and Challenges for Understanding DCV in the Historical Record

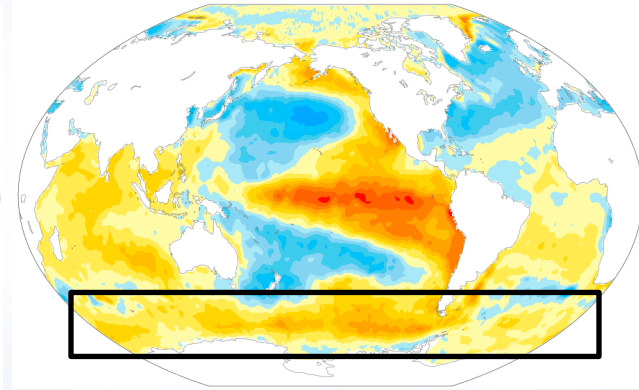
Pacific



Atlantic

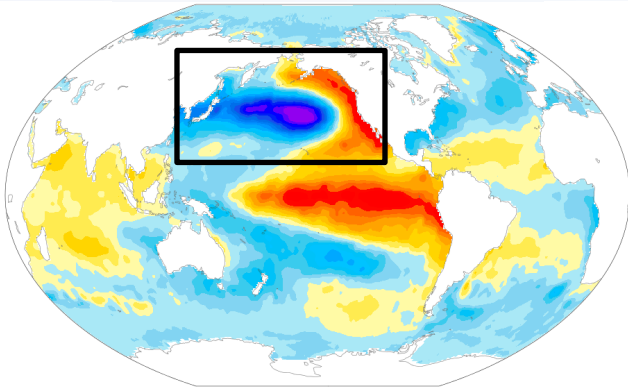


Southern Ocean

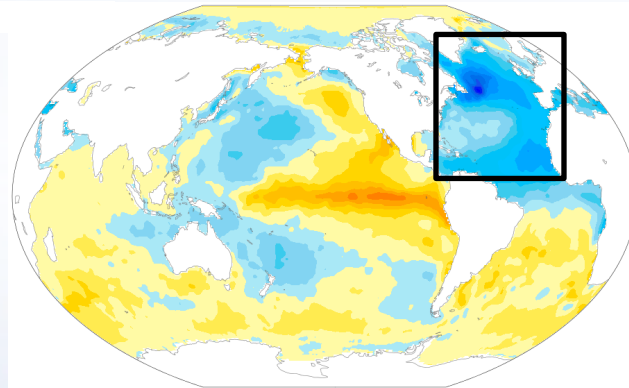


Issues and Challenges for Understanding DCV in the Historical Record

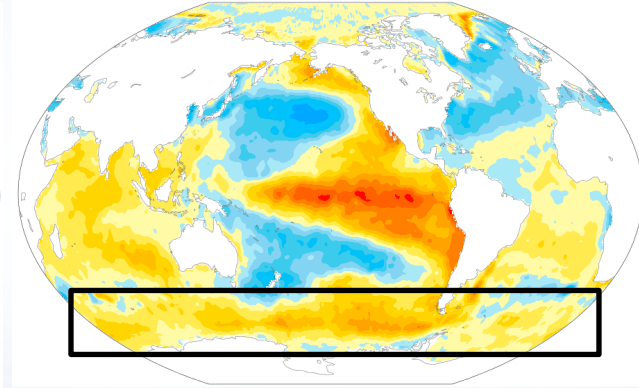
Pacific



Atlantic



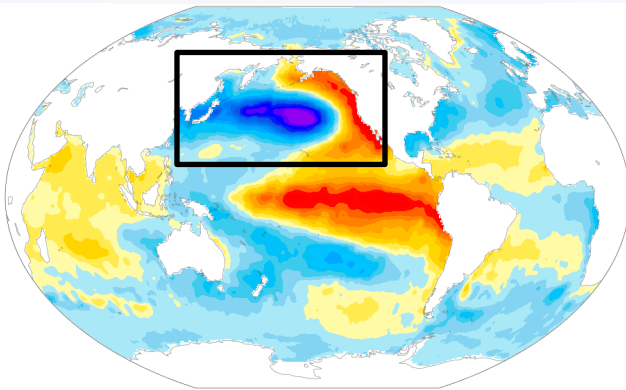
Southern Ocean



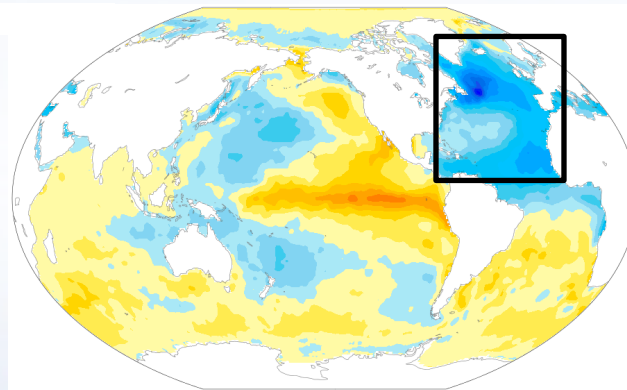
- Global connectivity: difficult to sort out causal linkages
- Sparse data and short records: robustness, mechanisms
- Random (red noise) vs. deterministic processes

Issues and Challenges for Understanding DCV in the Historical Record

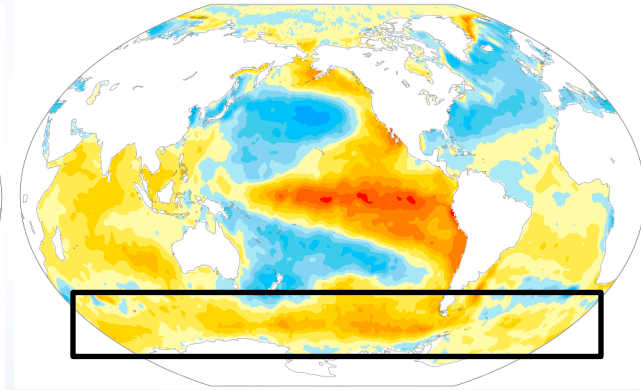
Pacific



Atlantic



Southern Ocean



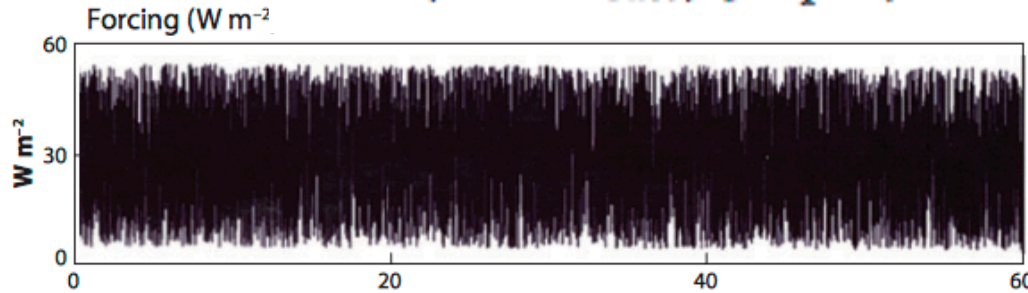
- Global connectivity: difficult to sort out causal linkages
- Sparse data and short records: robustness, mechanisms
- Random (red noise) vs. deterministic processes
- Need for a combined approach using observations, paleo-climate records and modeling

Thank you

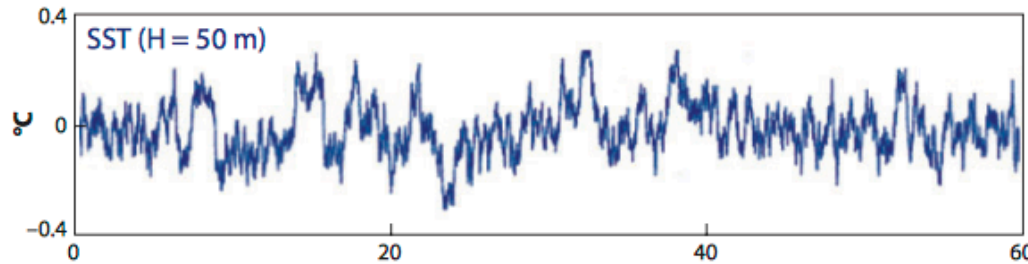


Simple Stochastic Climate Model

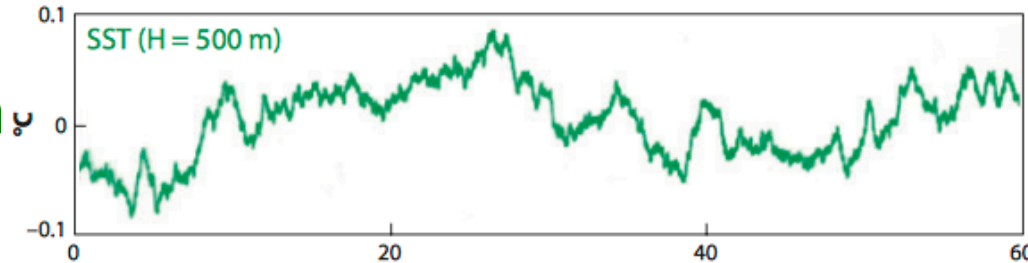
$$\partial T / \partial t = Q_{net} / (\rho C_p H) - bT$$



White noise Q_{atm}



$H = 50m$



$H = 500m$

1 —————> 60
years

Red noise T_{ocean}

AMO Mechanisms

- Natural mode of oscillation of the Atlantic Ocean's thermohaline circulation
- Stochastically forced by atmospheric buoyancy fluxes
- Coupling with NAO?
(response vs. feedback)
- Impact on PDO?

Delworth and Greatbatch, 2000; Raible et al., 2001; Chelliah and Bell, 2004; Dima and Lohmann, 2007; and many others

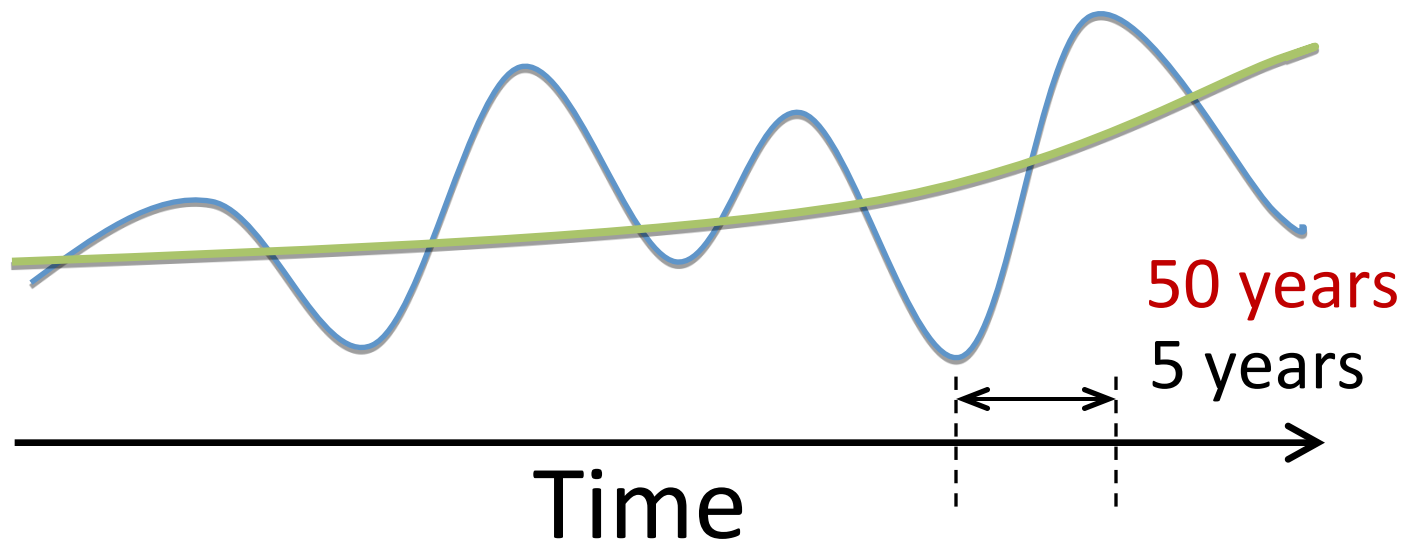
PDO Mechanisms

- Tropical Indo-Pacific SST variability (thermodynamic/dynamic)
- Atmospheric Teleconnections (tropics to extra-tropics)
- North Pacific ocean mixed layer response (heat fluxes, Ekman currents, entrainment/re-emergence mechanism)
- North Pacific wind-driven gyre response (oceanic Rossby waves)
- Timescale: Red noise; **~ 20,50 year cycles?**

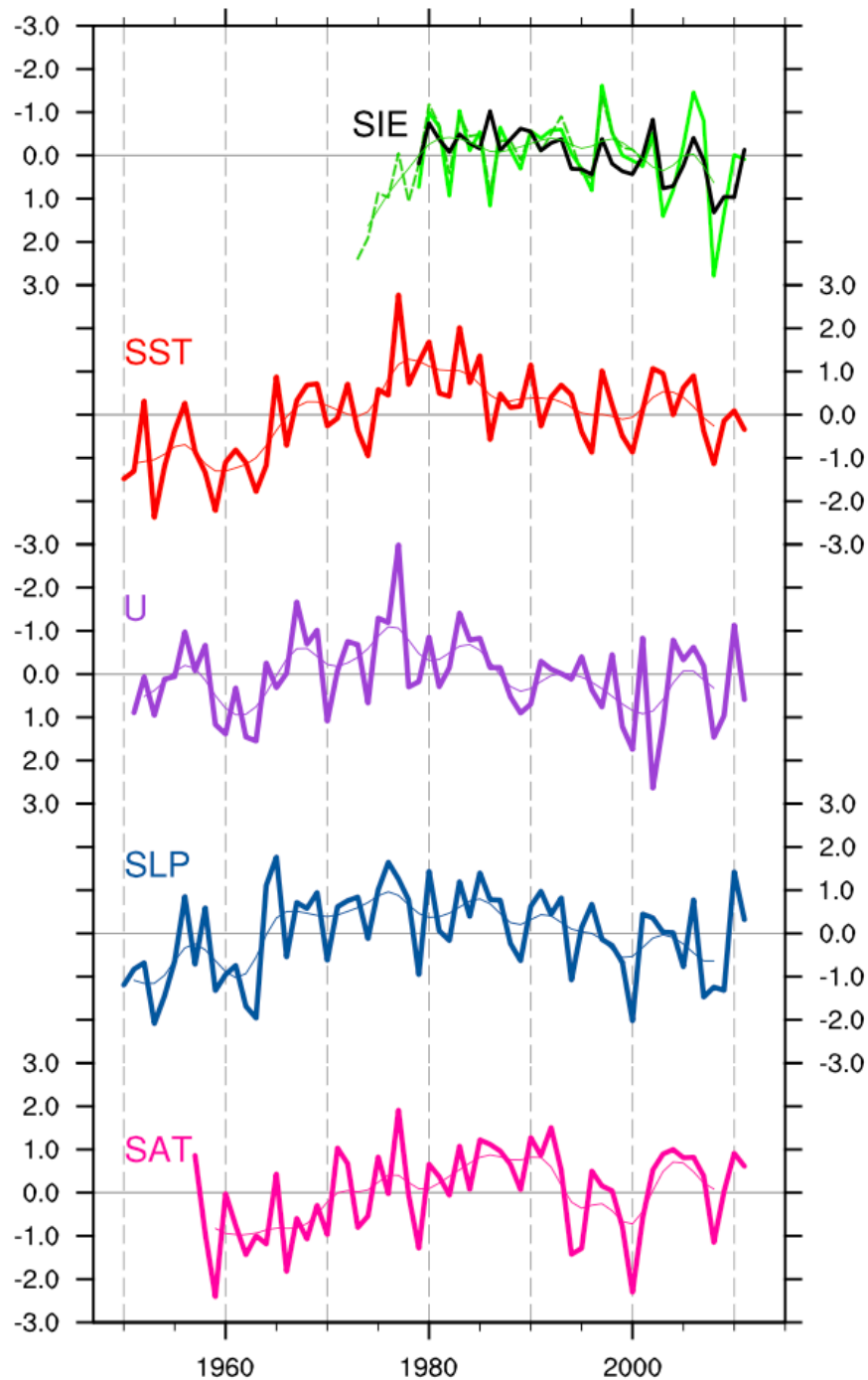
Alexander, 2009; Deser et al., 2010; Clement et al., 2011;
Newman et al. (2015) Superposition of processes – not one phenomenon

Unforced Climate Variability

Forced Climate Change



Southern Ocean DCV



Fan et al. 2014
Geophys. Res. Lett.

Defining Patterns of DCV

Objective methods, subjective choices

- Empirical Orthogonal Function Analysis
- Empirical Mode Decomposition
- One-point Correlation Analysis
 - *Spatial Domain*
 - *Time period*
 - *Spatial and temporal filtering*
- Epoch Differences