An Overview of Decadal Climate Variability in the Historical Record

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

Percentage of months with \( \geq 1 \) observation in a 20-year period
Percentage of months with ≥ 1 observation in a 20-year period

Deser et al. (2010)
Annual Reviews of Marine Sciences
Percentage of months with $\geq 1$ observation in a 20-year period

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

Subtract long-term mean for that day
Sea Surface Temperature Anomaly
29 December 2011
Sea Surface Temperature Anomaly
29 December 2011

Large-scale organization

Pacific Decadal Oscillation
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
Pacific Decadal Oscillation (ENSO-like)

North Pacific
25%

Pan Pacific
31%

Interdecadal Pacific Oscillation
Deser et al. (2012)
Journal of Climate
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
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
$R = -0.5$

AMO leads PDO by 10-20 years.
Southern Ocean DCV

Global regression on Southern Ocean SST

See also: Fan et al. 2014; Latif et al., 2013; Li et al., 2014
See also: Fan et al. 2014; Latif et al., 2013; Li et al., 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
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Issues and Challenges for Understanding DCV in the Historical Record

- 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

- Global connectivity: difficult to sort out causal linkages
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Need for a combined approach using observations, paleo-climate records and modeling
Thank you
Simple Stochastic Climate Model

\[ \frac{dT}{dt} = \frac{Q_{\text{net}}}{(\rho C_p H)} - bT \]

Forcing (W m\(^{-2}\))

\( Q_{\text{atm}} \)

White noise

\( H = 50 \text{m} \)

\( H = 500 \text{m} \)

\( T_{\text{ocean}} \)

Red noise

1 year to 60 years

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

Time

50 years

5 years
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