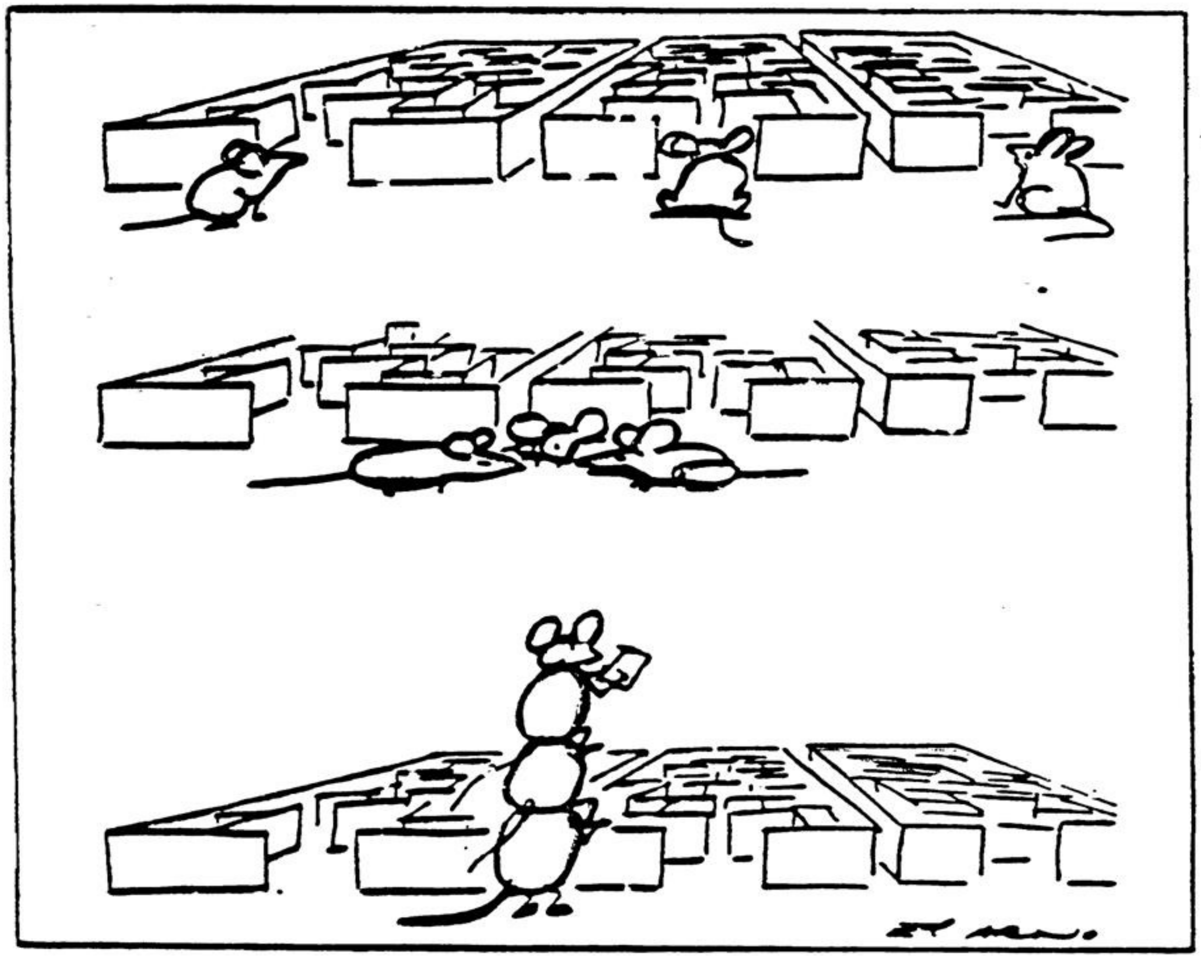
Multidecadal Climate Variability

Signal Propagation across the Northern Hemisphere

2012
Marcia Glaze Wyatt

How Something is Viewed Determines What Can be Seen!



P
E
R
S
P
E
C
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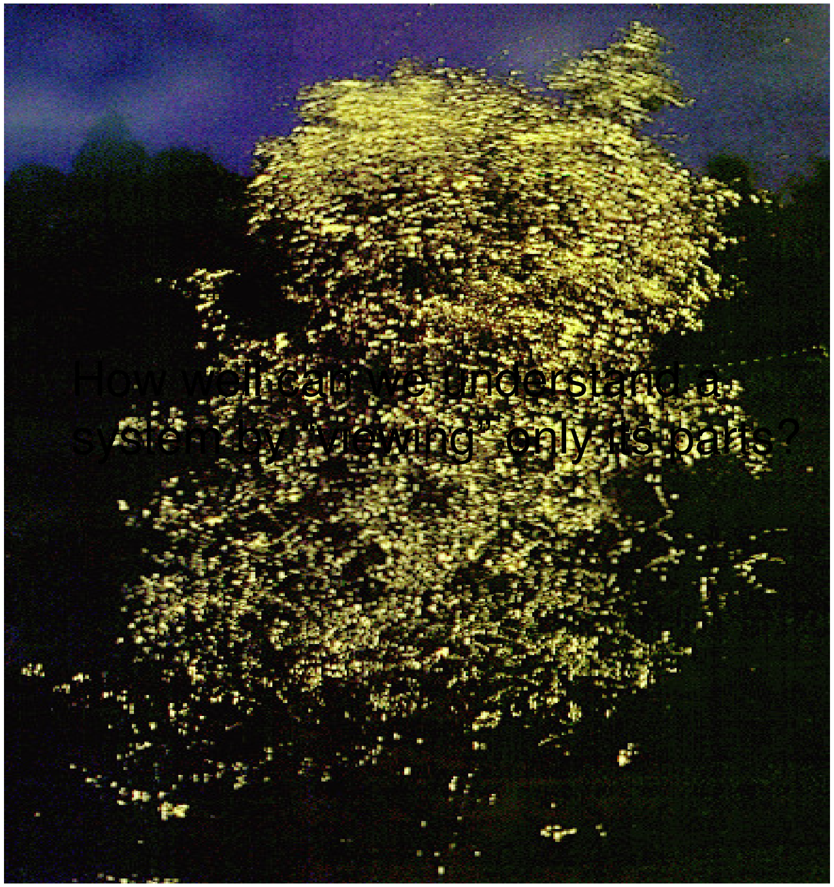
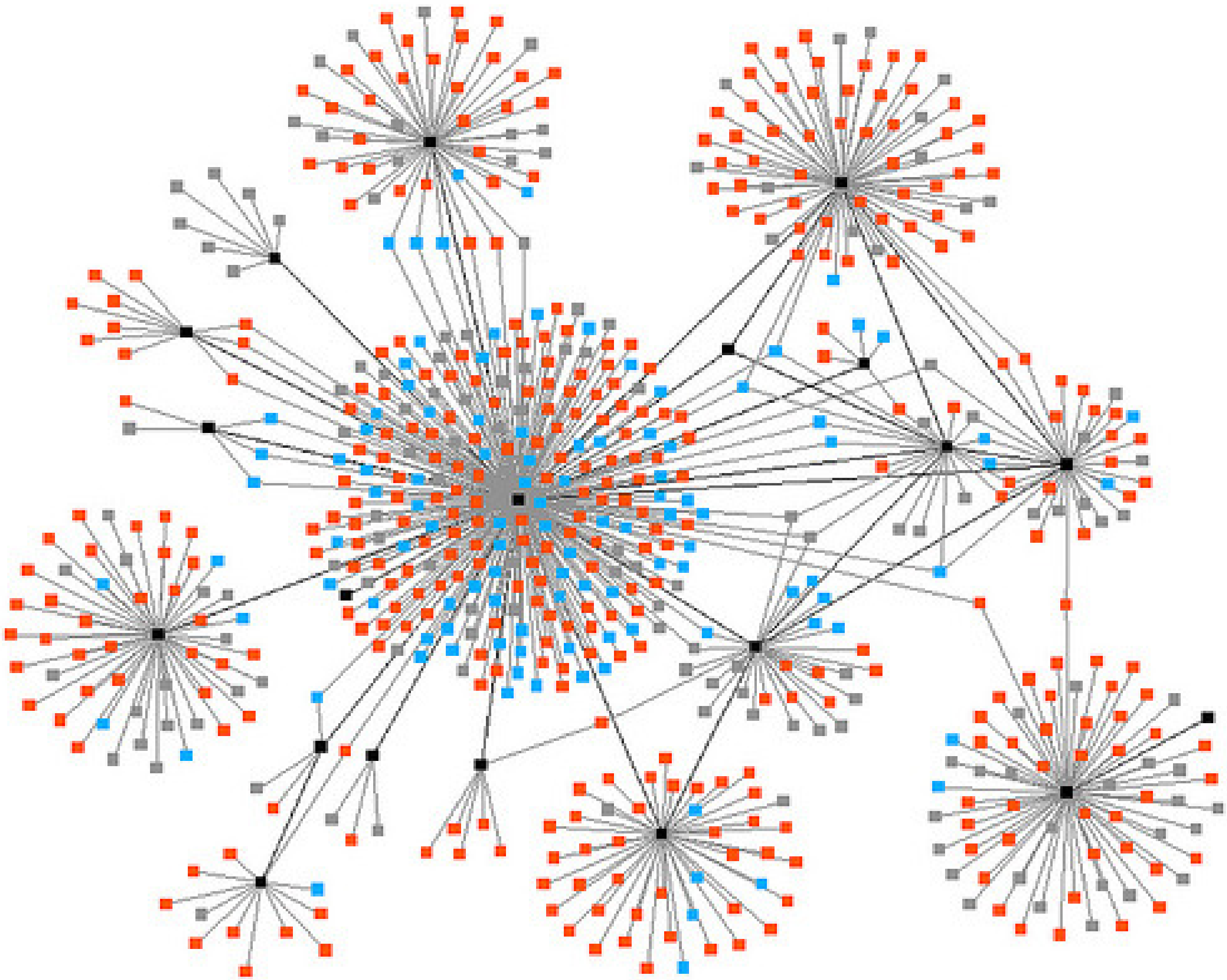
V
E

How well can we understand a system by “viewing” only its parts?

A network’s ultimate expression is not merely a sum total of its parts.



Viewing Climate as a Network



Network = a collection of interacting "parts"

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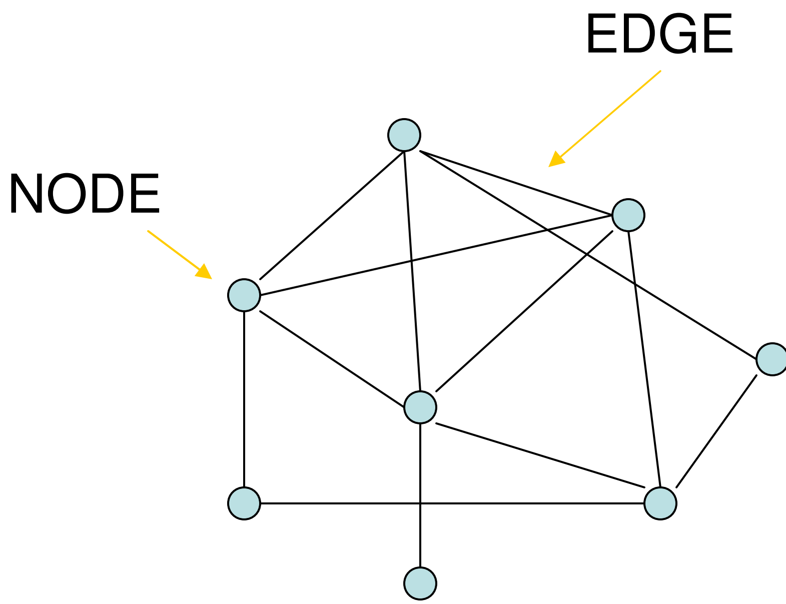
NETWORKS:

Communication
Stability



Number of edges = Node-degree

In its simplest form, a network is a collection of nodes joined by edges

Physics Today Nov '08

Each Node = Self-Sustained "Oscillator"

Self-sustained Oscillators Can be
Synchronized

SYNCHRONIZATION

Individual Self-Sustained “Oscillators”

Interact

Adjust

Share Tempo

Self-Organizing

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COMMUNICATION
STABILITY

Network of "Parts"

COMMUNICATION
STABILITY

Network of "Parts"

WITH

SELF-ORGANIZING

"Parts" are self-sustained oscillators

COMMUNICATION
STABILITY

Network of “Parts”

WITH

SELF-ORGANIZING

“Parts” are self-sustained oscillators

<u>ADD</u>

Local coupling between oscillators

SIGNAL PROPAGATION

Beyond Synchrony

"**Stadium-Wave Signal**"

Local Coupling →Signal Propagation

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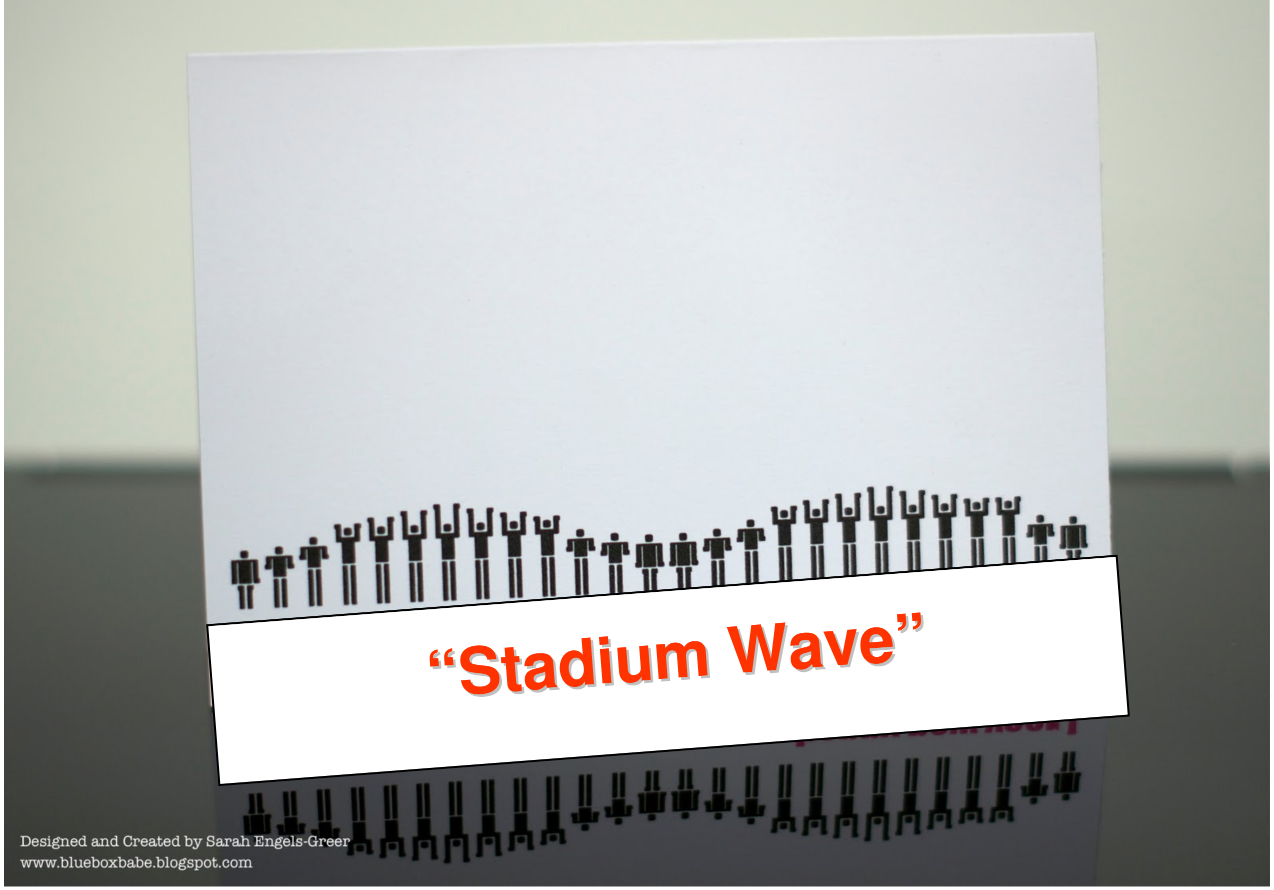
Hypothesis

Climate as a Stadium Wave:



Propagation of a low-frequency climate-signal through a network of atmospheric, Ice, and oceanic self-sustained oscillating indices

Instrumental data
20th century

I

Proxy data

1700-2000

II

Data Sets for testing the Stadium-Wave Signal

III

CMIP3 model
data
20thc
Pre-industrial

Methods

DJFM all indices

document

STEP ONE:

20th c

mechanism

STEP TWO:

Proxy

1700-2000 **history**

STEP THREE

Modeled
20thc
pre-ind

Signal simulation

1st Order
Linearly Detrend
13y Smooth

2nd Order
M-SSA
Significance Tests

"original 8"

"complementary 7"

3rd Order
M-SSA
Correlations
Significance Tests

"extended data set"

"dynamic" proxies

3rd Order
M-SSA
Correlations
Significance Tests

"conventional"proxies

2nd Order
M-SSA
Significance Tests

CMIP3 data

Methods

DJFM all indices

1st Order
Linearly Detrend
13y Smoothed

"original 8"

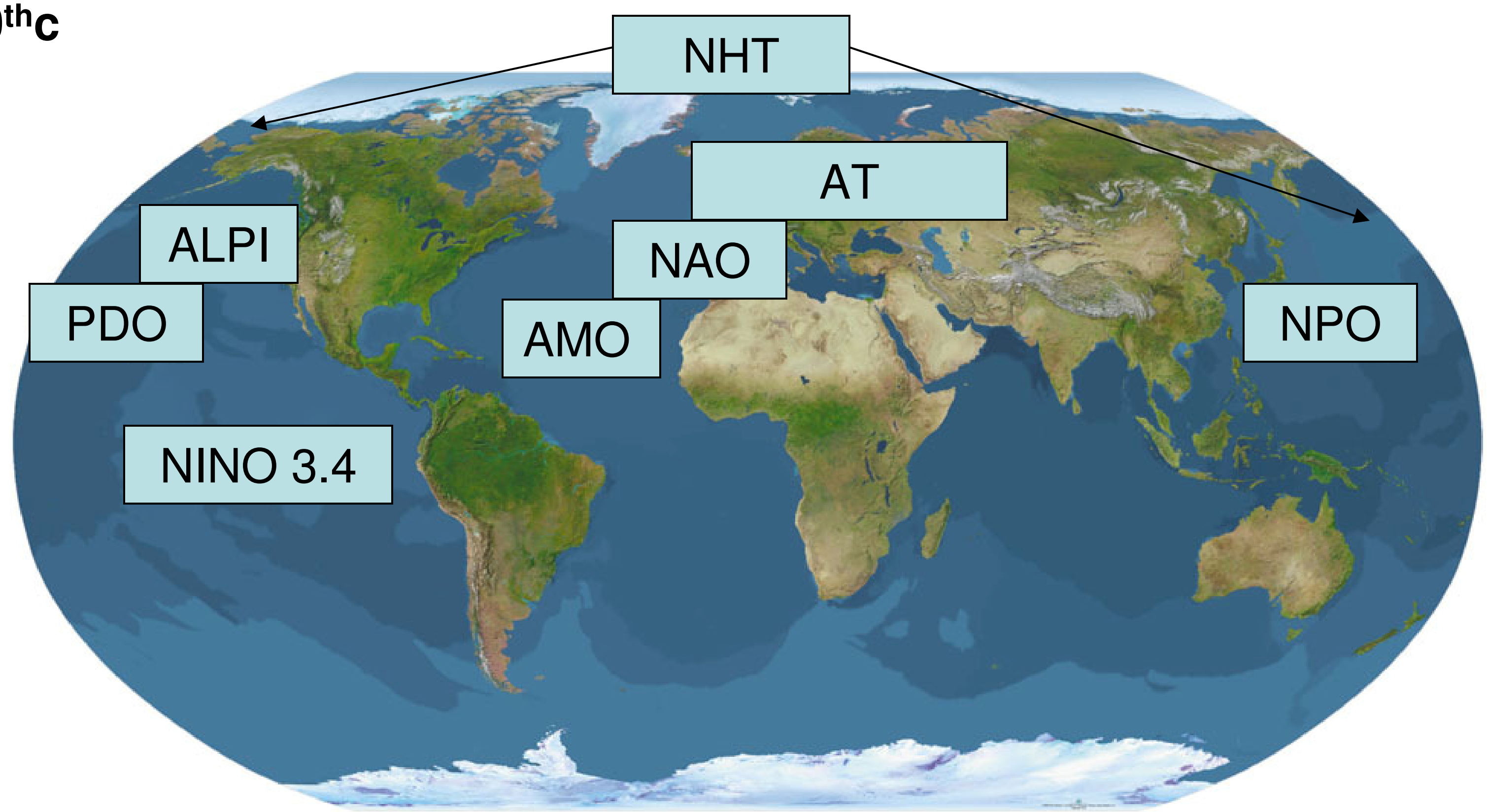
Indices:

NHT, AMO, AT, NAO, NINO3.4, NPO, PDO, ALPI

document

STEP ONE:

20thc



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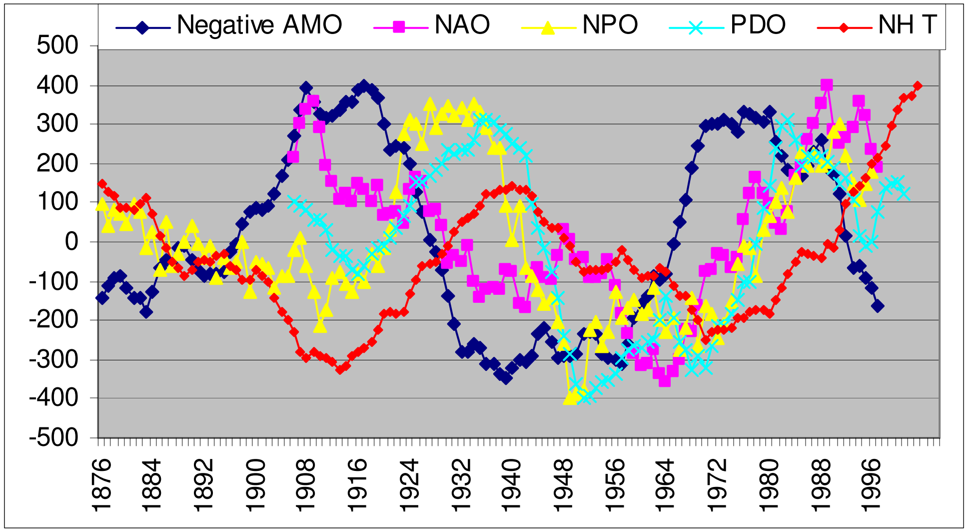
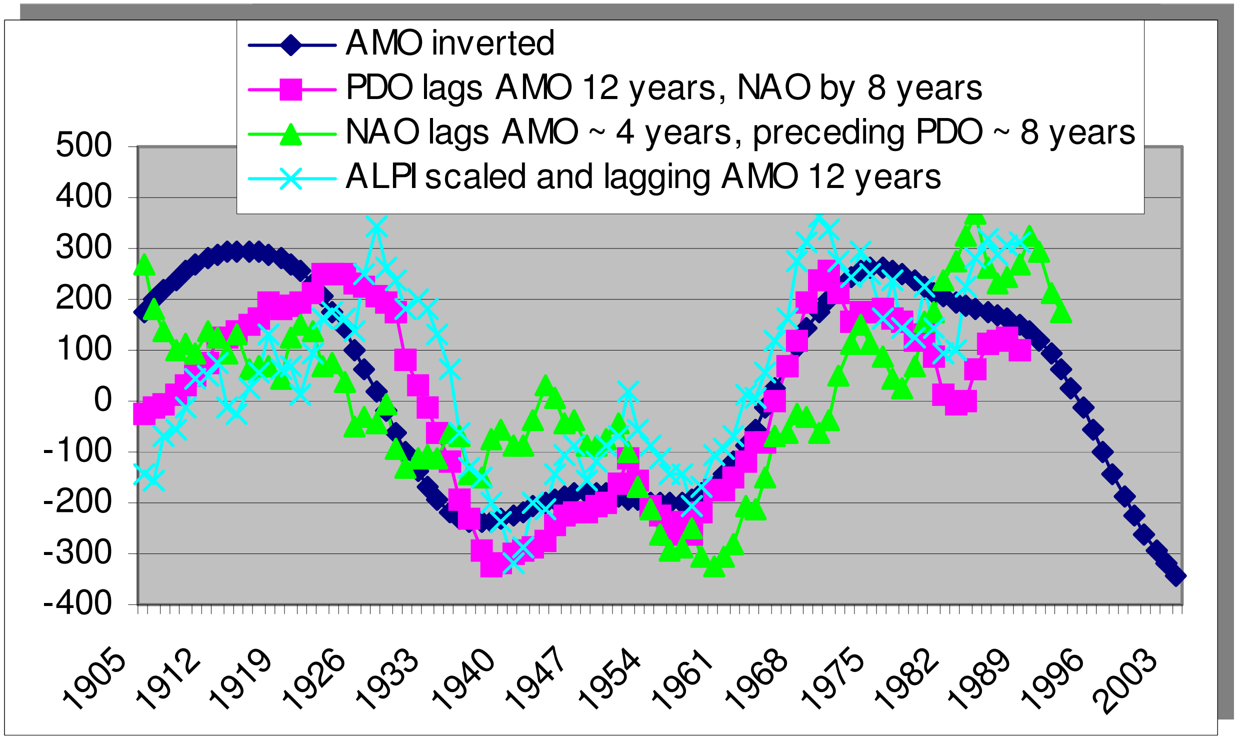
“Real Time” timeseries:
+NHT, -AMO, NAO, NPO, PDO



A ‘mess’, yet lagged, synchronized relationships suggested, prompting further investigation

Random Red-Noise? or Coherent Signal?

-AMO (4y) +NAO (8y) +PDO (4y) +ALPI



- Lagged correlations of multidecadal signal in various indices
- Conclude possibility of signal
- Need tool that detects lagged relationships

Methods

DJFM all indices

document

STEP ONE:

20th c

1st Order
Linearly Detrend
13y Smooth

2nd Order
M-SSA
Significance Tests

"original 8"

NHT, AMO, AT, NAO, NINO3.4, NPO, PDO, and ALPI

detrended & normalized prior to processing

Multichannel Singular Spectrum Analysis

Propagating Signals

1) Individual Time Series Extended
2) Covariance Matrix
3) Shared Variability
4) Plot means of mode variance

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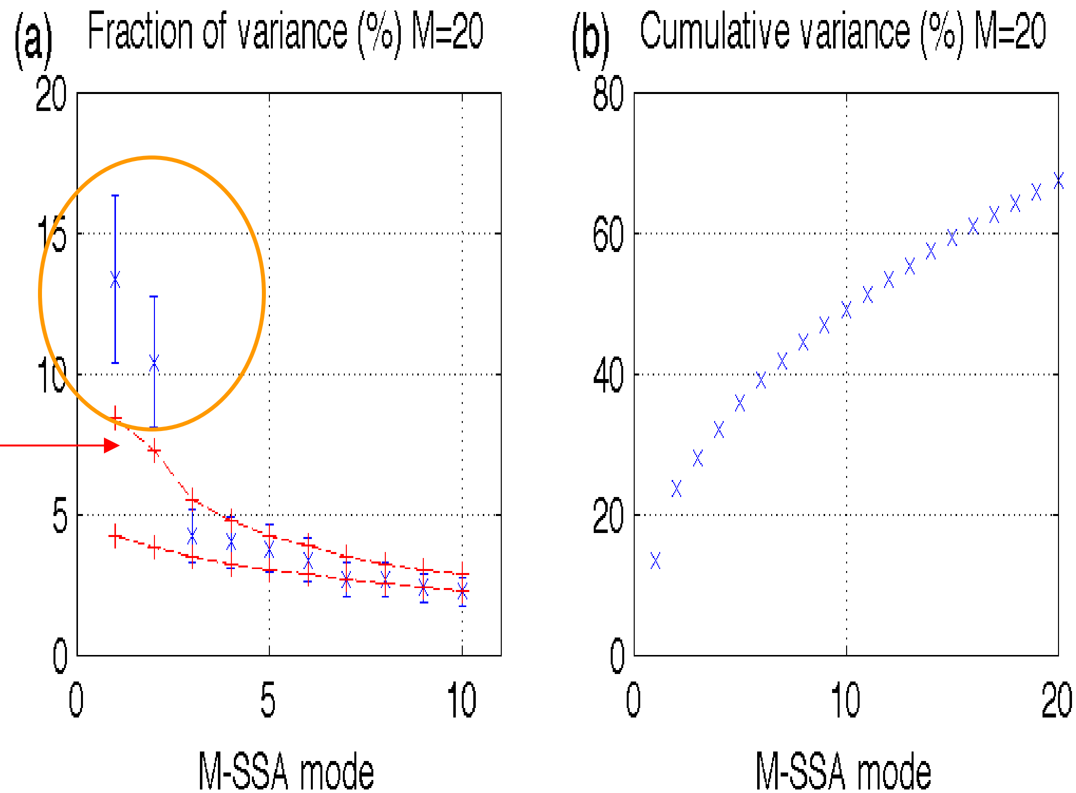
M-SSA Plots

Random variance unlikely for this leading pair; upper red dashed line outlines the corresponding surrogate spectra generated by red-noise model.



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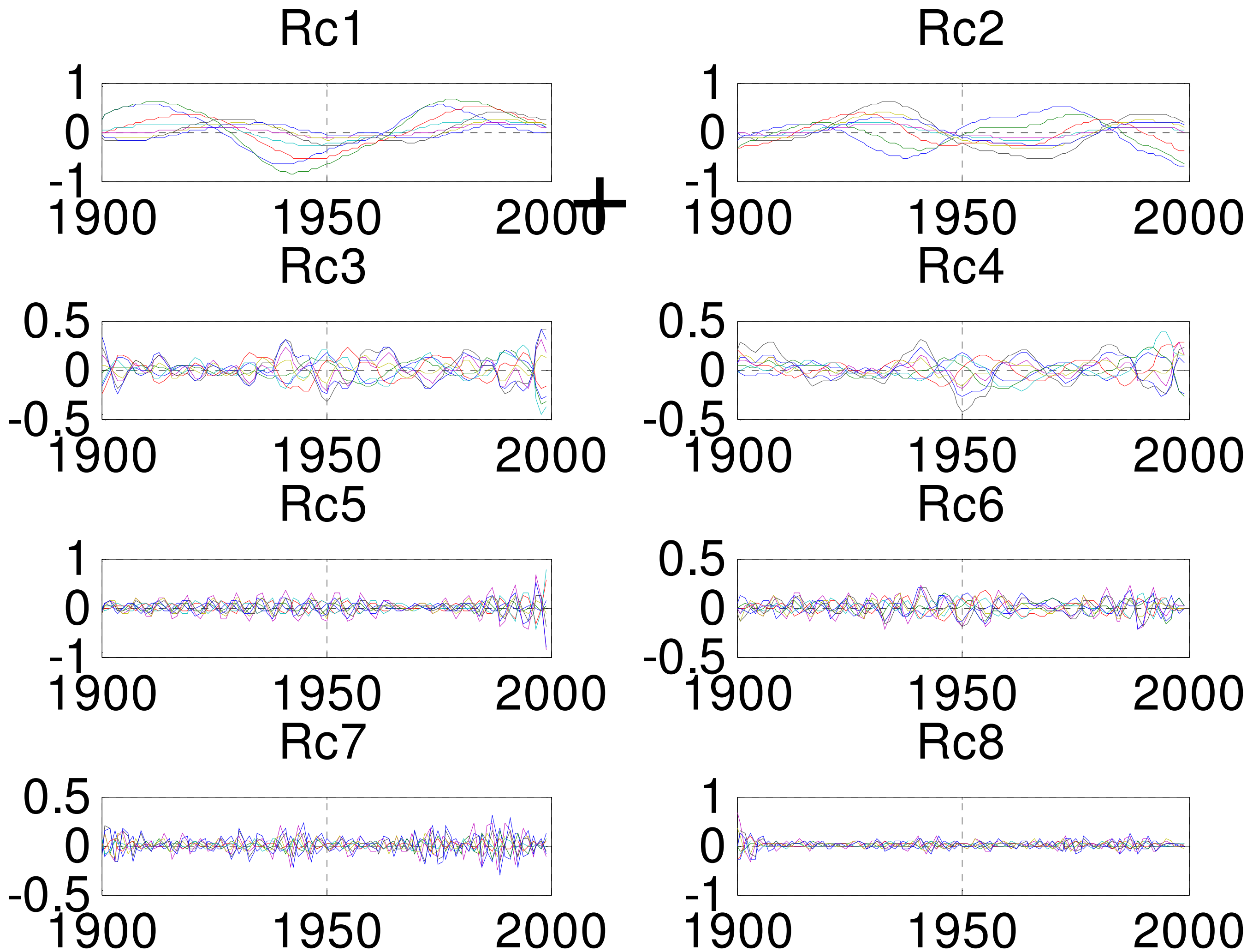
RCs for Modes of Variability



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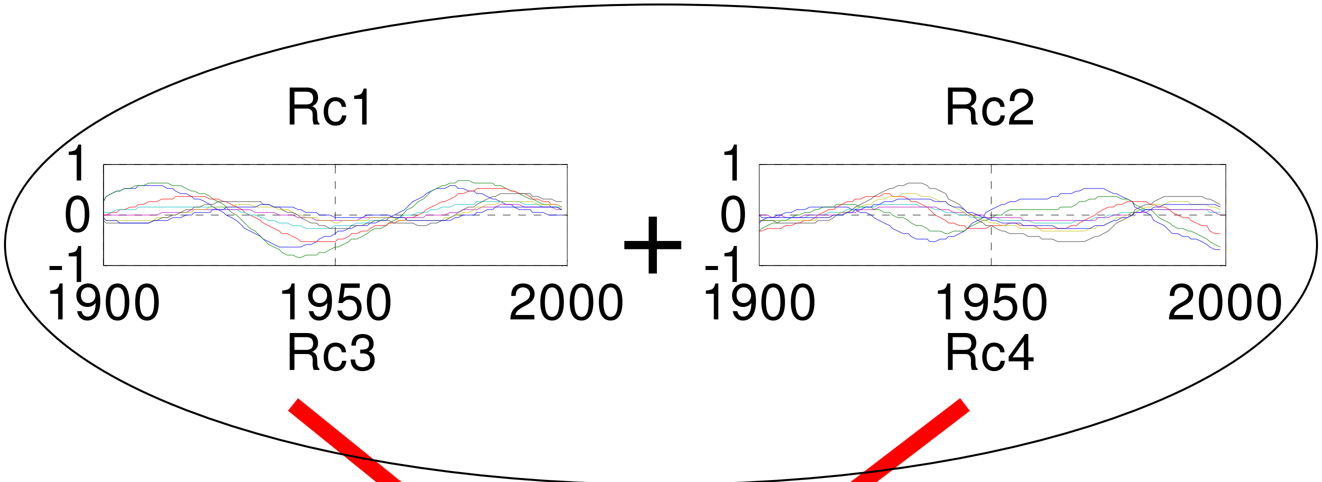
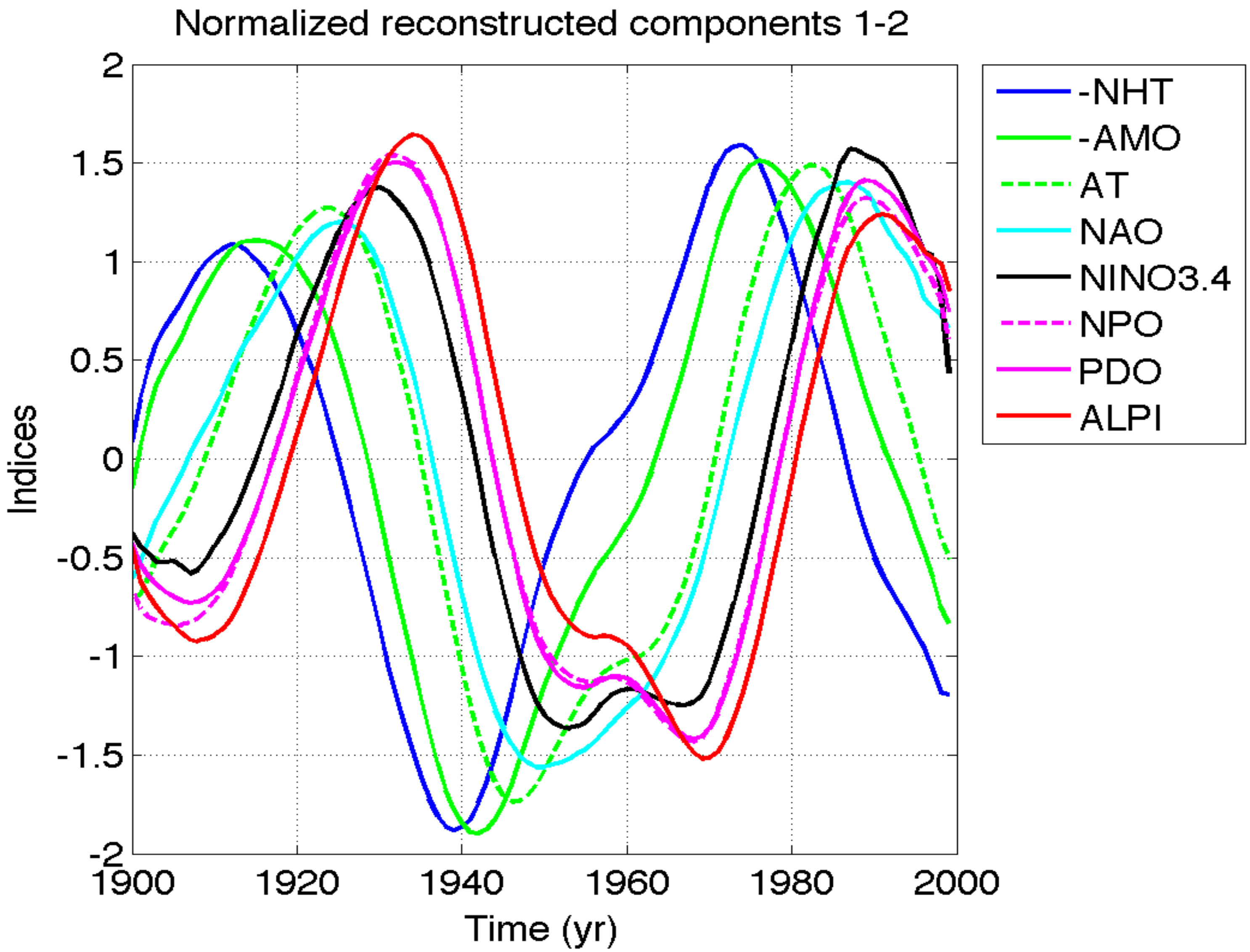
RCs for Modes of Variability



The leading two modes of
variability, together, are
the ‘stadium-wave’ signal.

Climate as a "Stadium Wave"



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Methods

DJFM all indices,
where possible

document

STEP ONE:

20^{th}c

mechanism

1st Order
Linear Detrend
13y Smooth

2nd Order
M-SSA
Significance Tests

"original 8"

"complementary 7"

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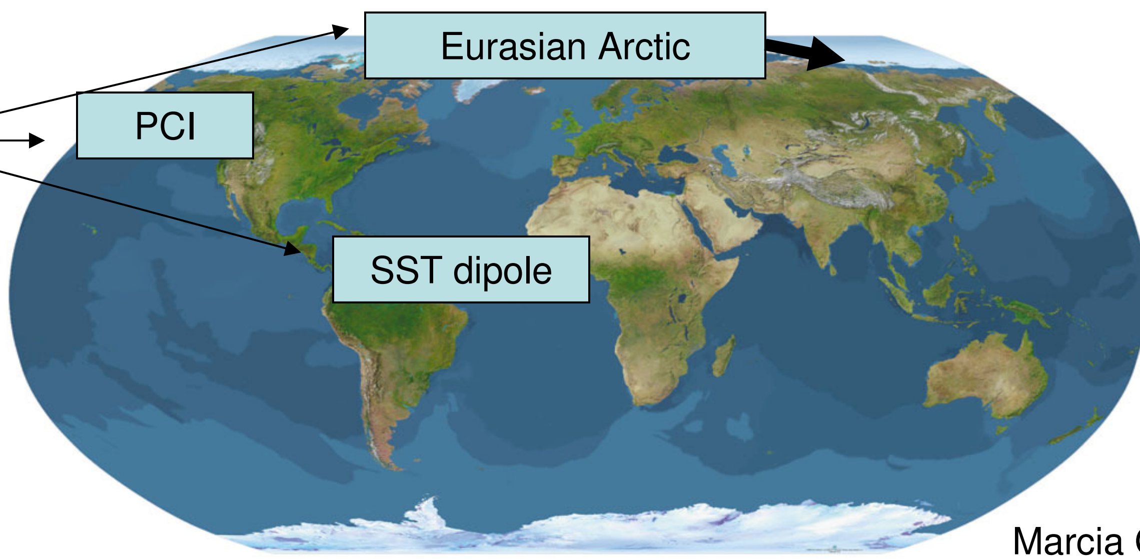
"extended data set"

Added
indices



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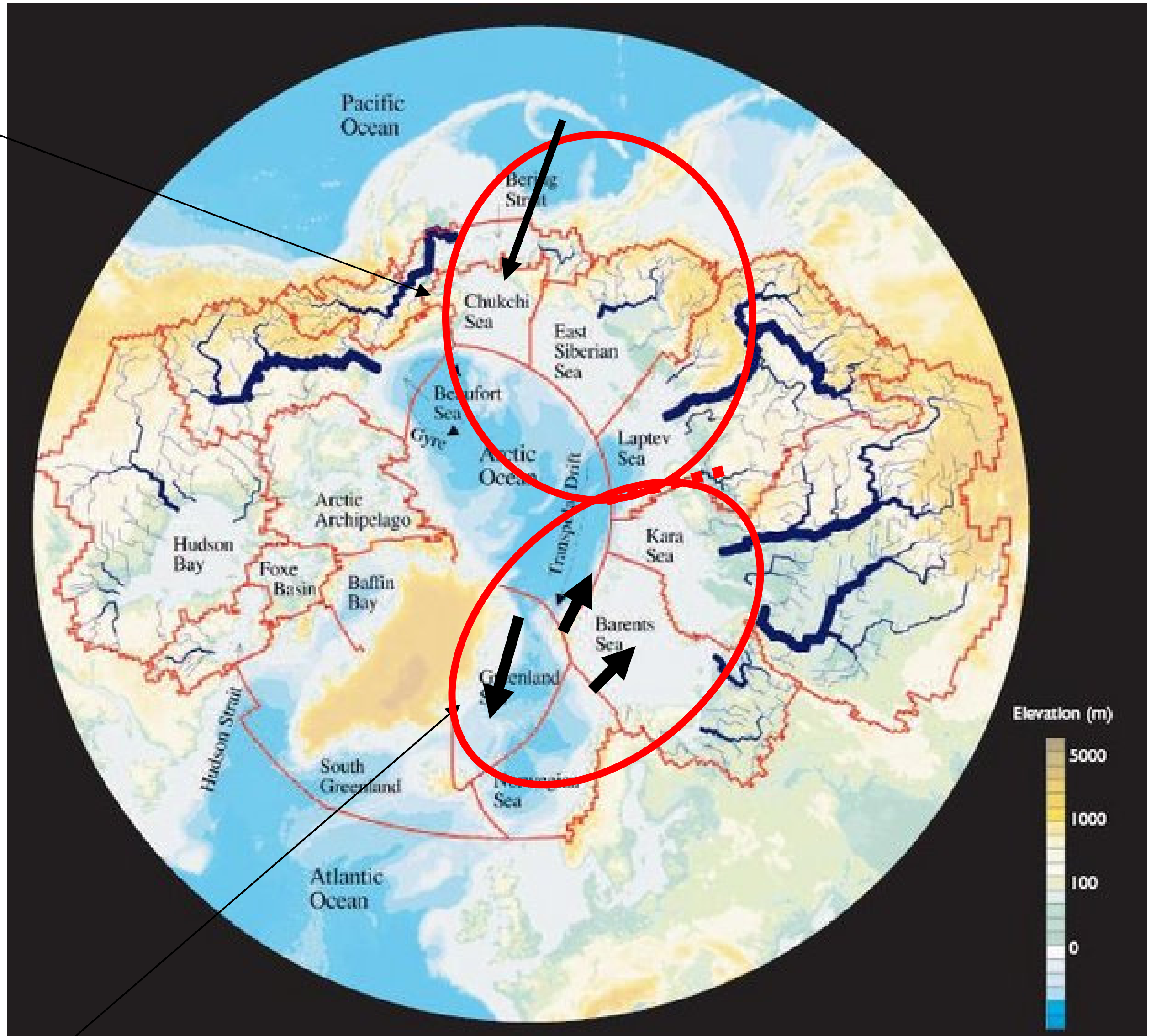
Eurasian Arctic Shelf Seas

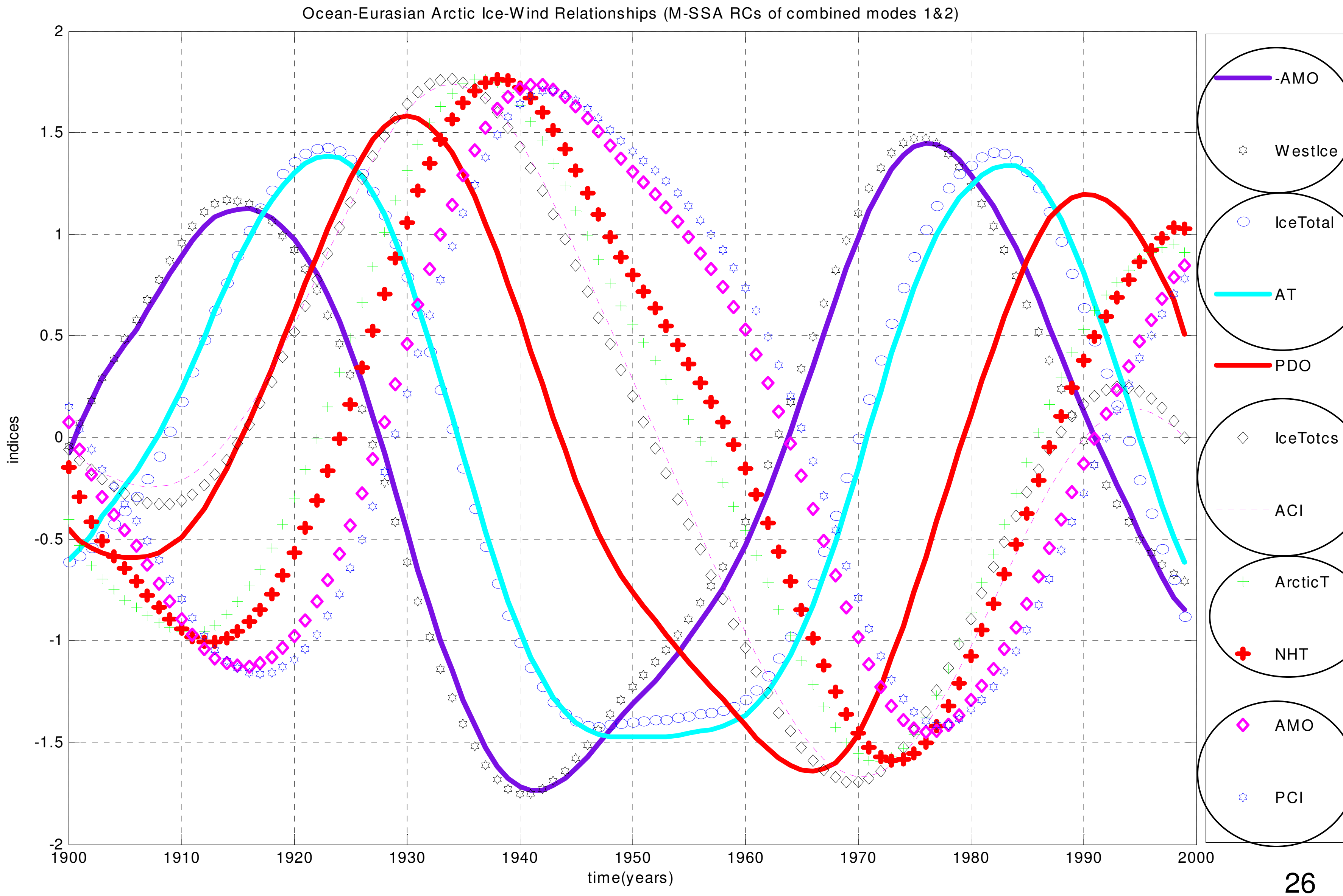
"East Ice"

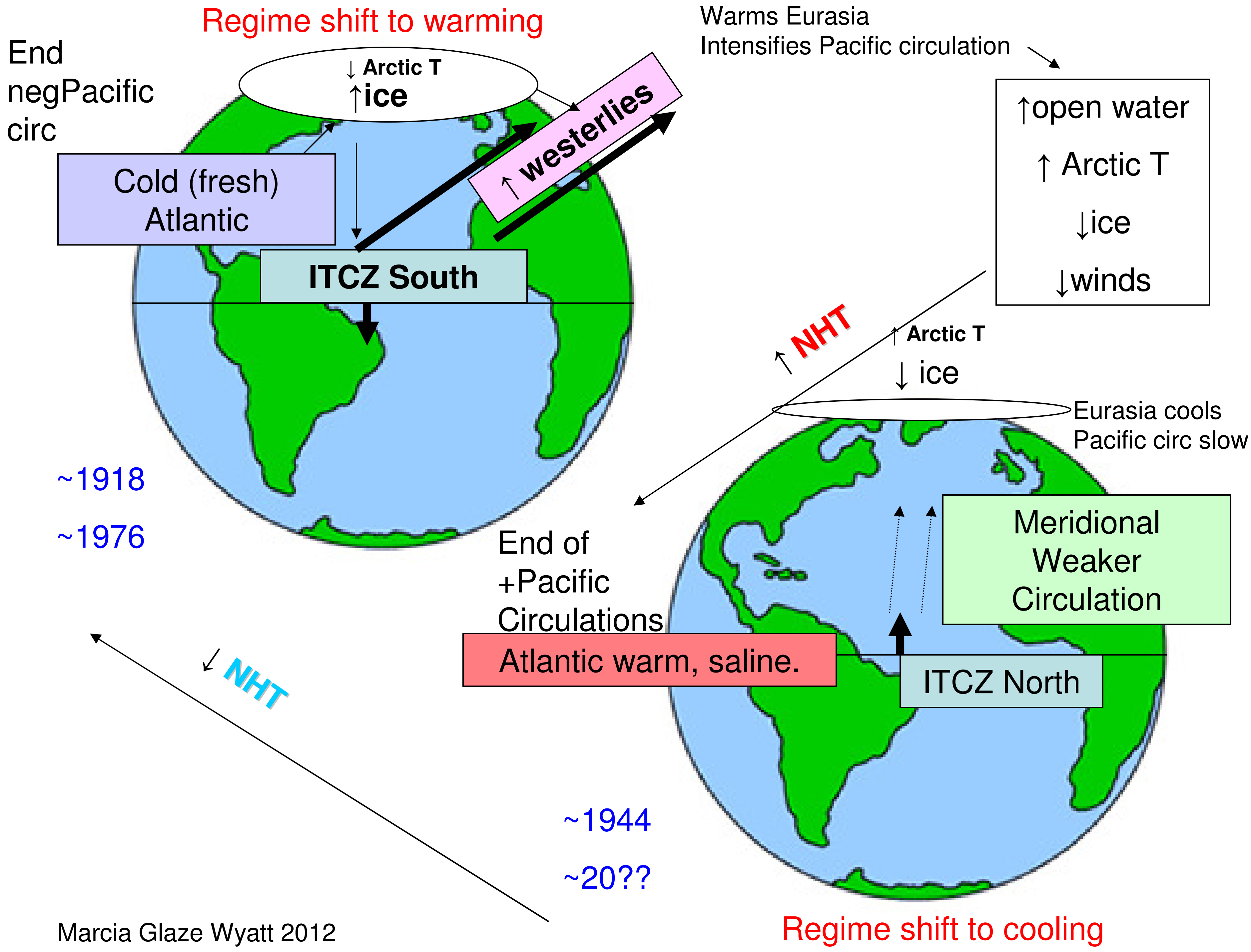
"Total Ice"



"West Ice"

Ocean-Ice-Atmosphere Interactions





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Methods

STEP ONE:

20thc

document

1st Order
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mechanism

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"extended data set"

STEP TWO:

1700-2000

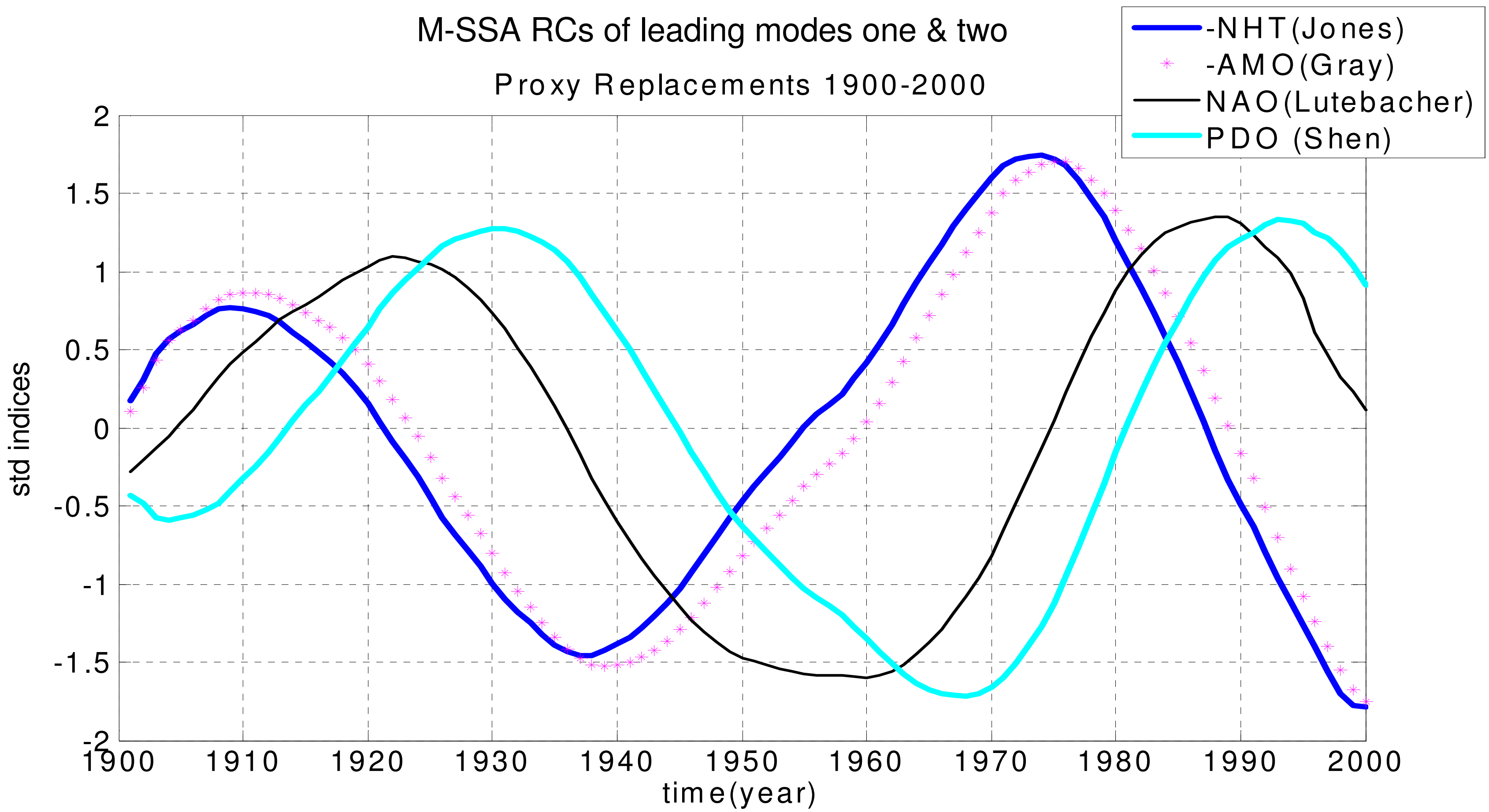
history

3rd Order
M-SSA
Correlations
Significance Tests

"conventional"**proxies**

- Tree rings
- isotope ratios from ice, corals
- historical documentation

“Conventional” Proxy Replacements 1900 to 2000



Statistically Significant p<5%

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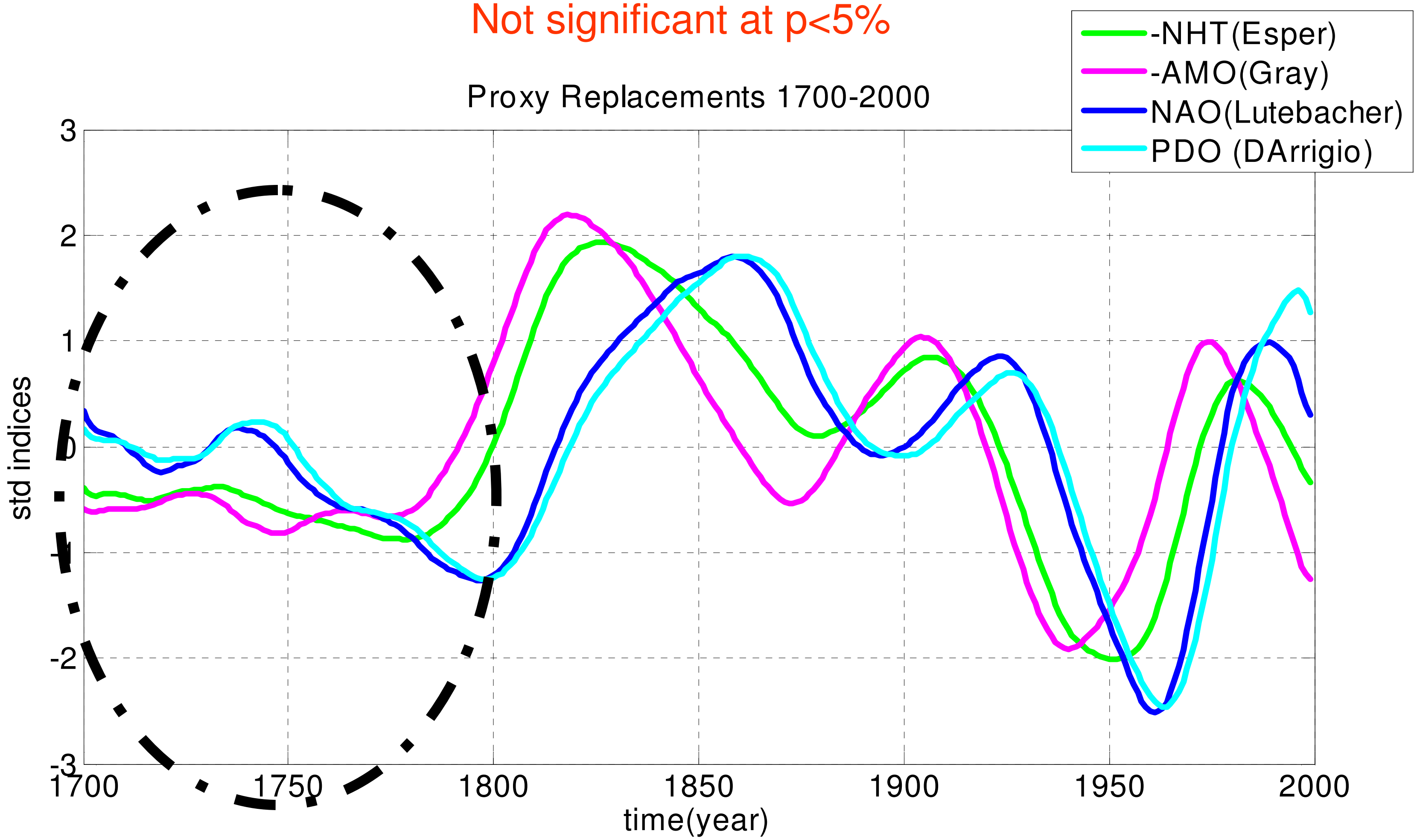
Proxy Replacement 1700 to 2000

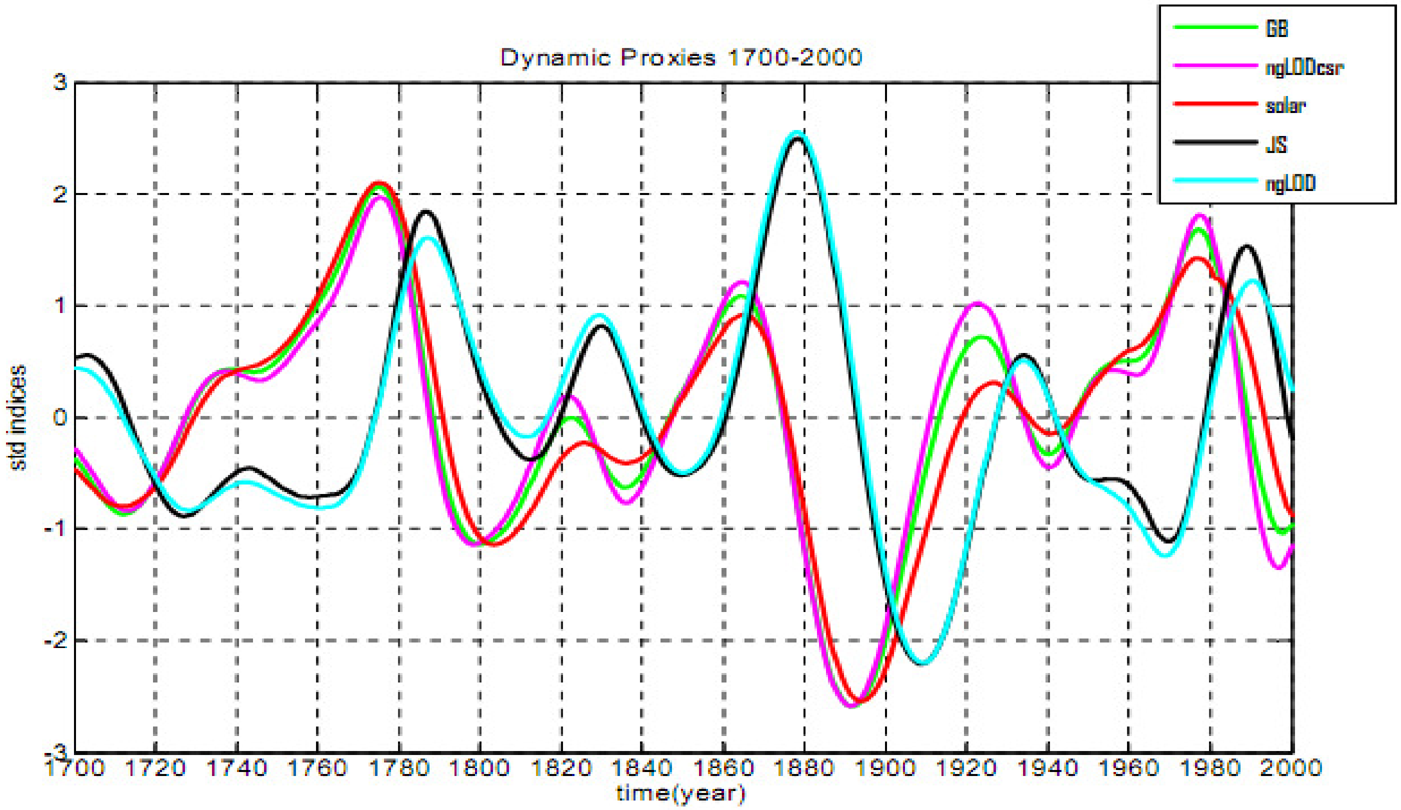
M-SSA RCs of leading modes one and two

Not significant at p<5%



For the interval 1850 to 2000, statistical significance p<5%, but not for longer time series of these proxies, which are inherently 'noisy'.

Using Alternate Proxy Data: 1700-2000



See text for explanation of these proxy indices

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Methods

DJFM all indices

STEP ONE:

20th c

document

1st Order
Linear Detrend
13y Smooth

2nd Order
M-SSA
Significance Tests

"original 8"
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mechanism

3rd Order
M-SSA
Correlations
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"extended data set"

STEP TWO:

1700-2000

history

3rd Order
M-SSA
Correlations
Significance Tests

"conventional"proxies

STEP THREE

20thc
pre-ind

Signal simulation

2nd Order
M-SSA
Significance Tests

CMIP3 data

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RC Number	Group	Periodicity	Model	Experiment	Run	Significant with Annual Sampling	Significant with Sampling @ 5y Running Mean	Comments Related to Signal Propagation or Other Behavior
1	single	~70y	CCCMA_cgcm3	20c	1	yes	no	
1,2	pair	bi-annual	CNRM_cm3	20c	1	yes	no	
3	single	~25y	CNRM_cm3	20c	1	yes	no	
3	single	subdecadal	CSIRO_mk3	20c	1	yes	no	
5	single	subdecadal	CSIRO_mk3	20c	1	yes	no	
6,7	pair	bi-annual	CSIRO_mk3	20c	1	yes	no	
1	single	~70y	CSIRO_mk3	20c	1	no	yes	
1,2	pair	~35y	*GFDL_2_0	20c	1	marginal	yes	no propagation
1,2	pair	~35	GFDL_2_1	20c	3	no	marginal	no propagation
1	single	100y	IAP_fgoals_1_0_g	20c3m	1	yes	yes	
2,3	pair	biannual	IAP_fgoals_1_0_g	20c3m	1	yes	no	non-stationary behavior
1	single	interannual	MIUB_echo_g	20c	2	yes		
1	single	~60y	MIUB_echo_g	20c	2		yes	
2	single	~60y	MIUB_echo_g	20c	2	yes	no	
3	single	~25y	MIUB_echo_g	20c	2	yes	no	
3	single	~55y	UKMO_hadcm3	20c	1	marginal	no	
1	single	~50y	CNRM_cm3	control	1	no	marginal	
2	single	~25y	CSIRO_mk3	control	1	no	yes	
1	single	~55 to 75y	GFDL_2_0	control	1	n/a	yes	
2	single	~25y	GFDL_2_0	control	1	n/a	yes	

No “Stadium Wave” Signal Detected in CMIP

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Summary

- **Hypothesis**: Low-frequency climate signal propagates across NH
- **Tested** : M-SSA cornerstone of analysis techniques
  - 20th century Instrumental Data
    - Documentation of Signal
    - Explore Mechanism
  - Proxy Data: 1700-2000
    - Probe History
  - CMIP3 Model-Generated Data: 20thc and pre-industrial
    - Model Reproduction?
- **Results**:
  - A statistically significant low-frequency climate signal propagates through network of indices 20thc
    - Ocean-ice-atmospheric coupling
  - Proxies show signal: 1850 (significant) and to 1700 (with statistical uncertainty)
  - Models do not reproduce signal

Interpretation/Thoughts

- <u>Step One 20th Century Instrumental Data</u>
  - Statistics can not “prove”.
  - Need mechanism.
  - Literature support for “links”
    - Highlight deep, interactive ocean
    - COA position, migration
    - Western-boundary currents/extensions
- <u>Step Two: 1700-200 Proxy Data</u>
  - Not statistically significant prior to 1850:
    - Could mean no signal
    - Could mean proxy data too noisy
- <u>Step Three: model-generated Data</u>
  - No signal with statistical significance, frequency, or propagation characteristics of stadium-wave signal
    - Critical links not well-modeled:
      - COAs
      - Sea-ice, especially motion and export
      - Western-boundary currents

Outstanding Questions:

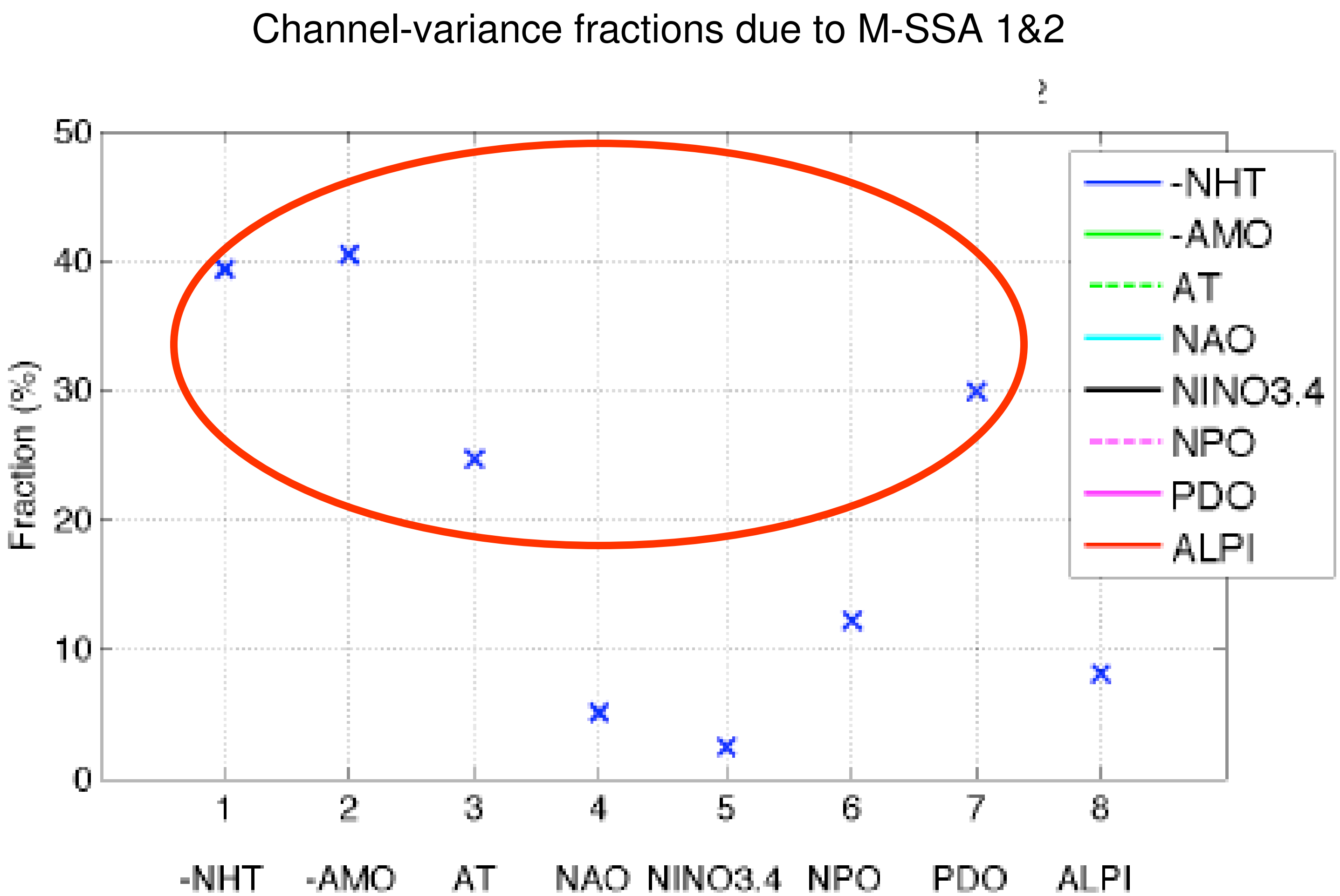
- What explains the signal's absence of statistical significance in proxy data prior to1850?
- Does sea ice influence the climate signal's sensitivity?
- Why do models not simulate the signal?

Signal Propagation & Synchronized Networks

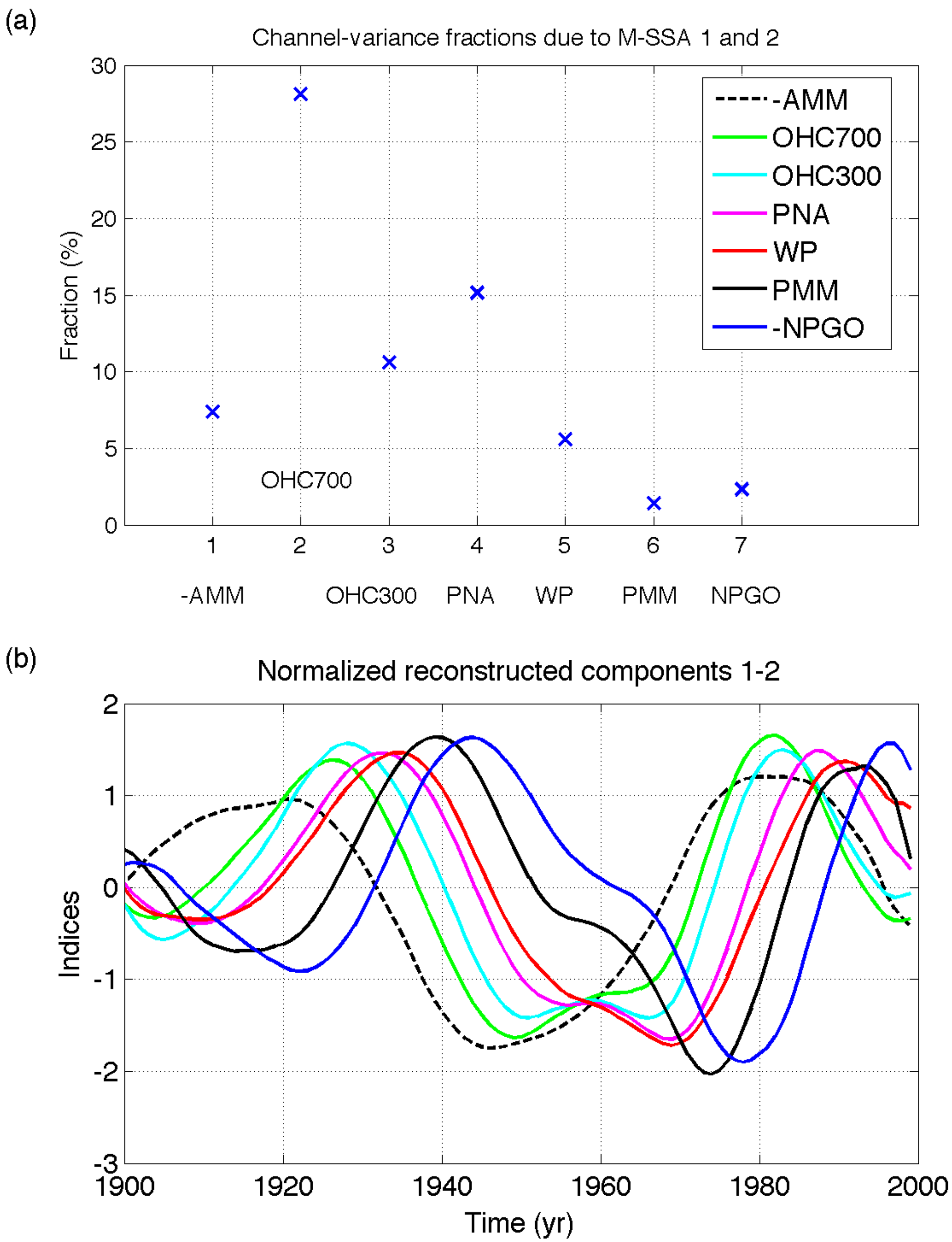
THE END

Miscellaneous
Extras follow

Channel-Fraction of Raw-Index Variance



How much variability in an index can be “explained” by the M-SSA signal?



7 Indices added to Index Network

Note: infill of gapped data via MSSA.

See text.

Running Conclusion

(Step One: 2nd order analysis)

- **Statistical Results**
  - Climate signal documented
  - Significance 95%
- **Speculation**
  - Tempo
  - Feedback
- **Cautionary Note**
- **Next Step:**
  - **Explore Mechanism**

Methods

DJFM all indices,
where possible

STEP ONE:

20th c

document

mechanism

1st Order
Linear Detrend
13y Smooth

2nd Order
M-SSA
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"original 8"

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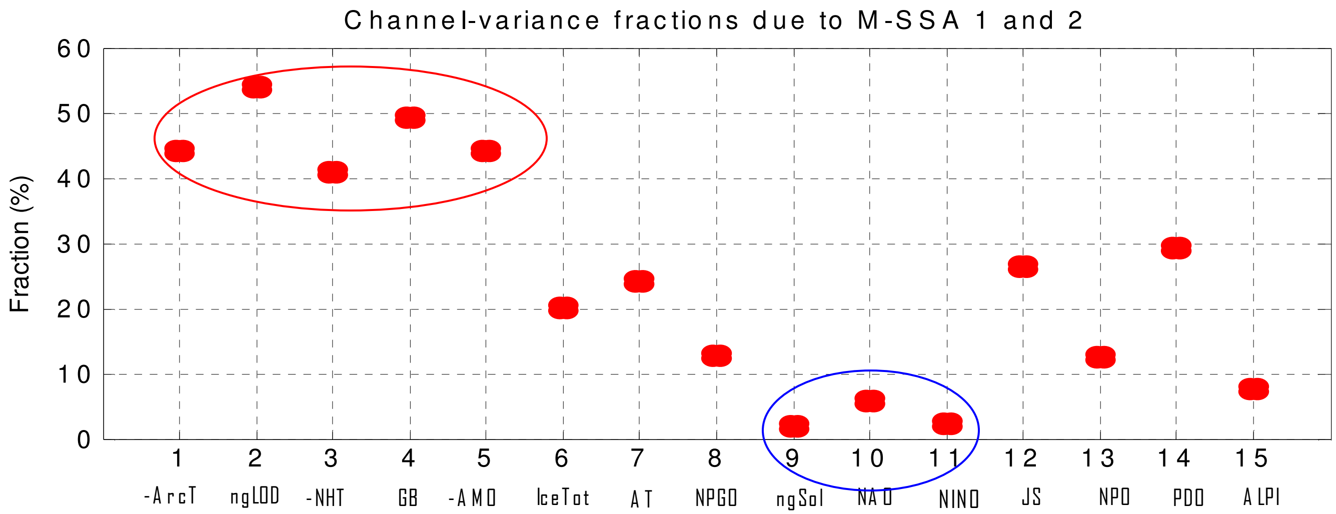
Added Indices:

Arctic T

Eurasian Arctic Shelf sea ice

Atlantic SSTA Dipole

Pacific Circulation Index (PCI),



Channel-Fraction Variance of Select Indices from Original plus Arctic Variables and Proxies

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Running Conclusion:
(Step One: 3rd order analysis)

- **Eurasian Arctic Sea Ice**
  - Relationship with Atlantic
  - Relationship with Winds
- **ITCZ Migrations**
  - Max NHT, Min Sea Ice, North ITCZ
  - Min NHT, Max Sea Ice, South ITCZ
- **Pacific feedback to Atlantic**
  - Pacific Anomaly Trend and AMO
- **Next Step:**
  - Probe History

Running Conclusion

(Step Two: 3rd order analysis)

- 20thc stadium wave
  - All proxies
- 1850-2000
  - Significant (not shown)
- Prior to 1850
  - "Signal", yet amplitude, frequency modifications
  - Significance not identified
    - No signal? Or diminished quality of proxy data? Or other?
- Next Step:
  - Model-Data Simulations

Running Conclusion

(Step Three: 2nd order analysis)

- No stadium wave signal in Model Data
- Speculation on reason
  - Signal could be random
  - Models could have deficiencies
    - Sea-ice
    - COAs
    - Western-boundary currents