The Impact of AMOC on Arctic Sea-ice Variability

Salil Mahajan[1], Rong Zhang[2], Thomas L. Delworth[2], Shaoqing Zhang[2], Anthony J. Rosati[2] and You-Soon Chang[2]

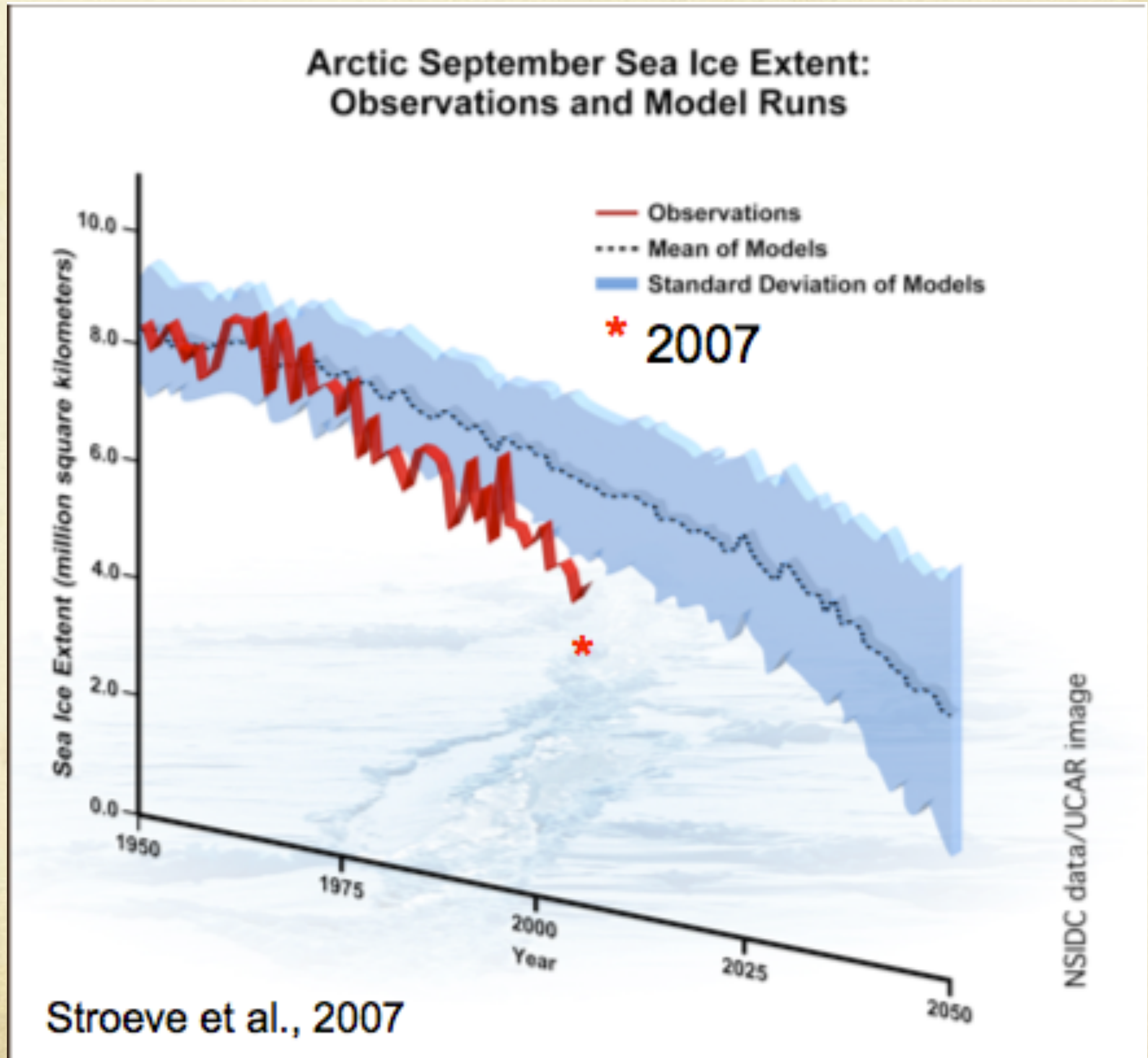
[1]Oak Ridge National Laboratory, Oak Ridge, Tennessee
[2]Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey

Conclusions and Caveats

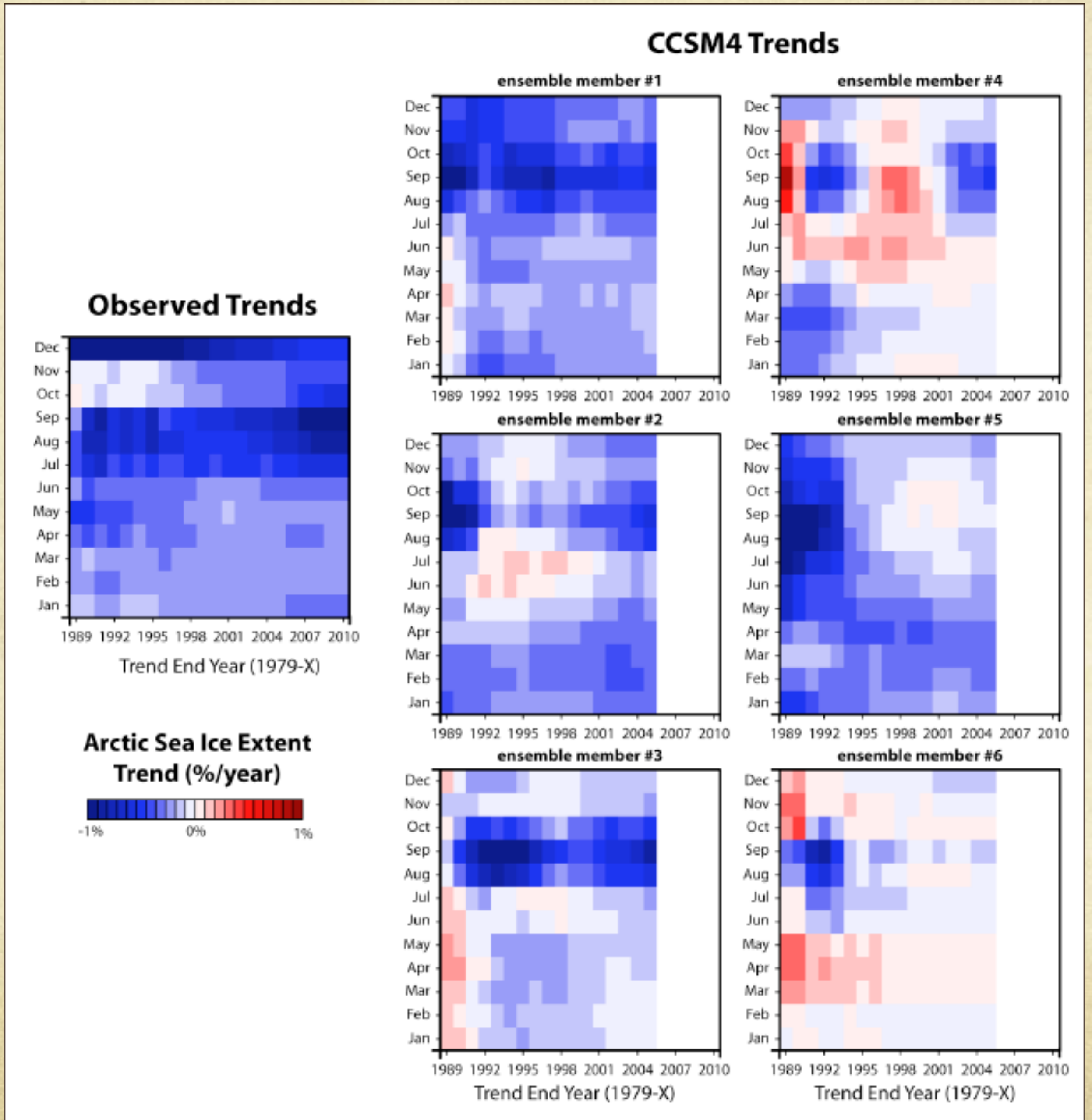
- GFDL CM2.1 unforced simulation shows that AMOC can significantly modulate Arctic sea-ice on decadal/multi-decadal scales.
- The spatial pattern of AMOC associated Arctic variability in GFDL CM2.1 is similar to the observed trend in the Winter season.
- AMOC seems to have little impact on Pacific sector of the Arctic in GFDL CM2.1, where the observed decline is the strongest in the summer.
- AMOC fingerprints suggest that the AMOC has been strengthening in the past few decades.
- A strengthening AMOC could have contributed to the observed decline in the Arctic Sea-ice in the Winter, but not in the summer based on GFDL CM2.1 results.
- AR2 model of AMOC fingerprints predicts a decline of the AMOC in the coming years, suggesting a weakening of the decrease in Arctic sea-ice.
- The above results are based on GFDL CM2.1 and 50 years of observational data.

Motivation

- CMIP3 models forced with GHG not capturing observed Arctic sea-ice decline
- A strong role for decadal/multi-decadal natural variability
- AMOC is the largest source of decadal/multi-decadal variability

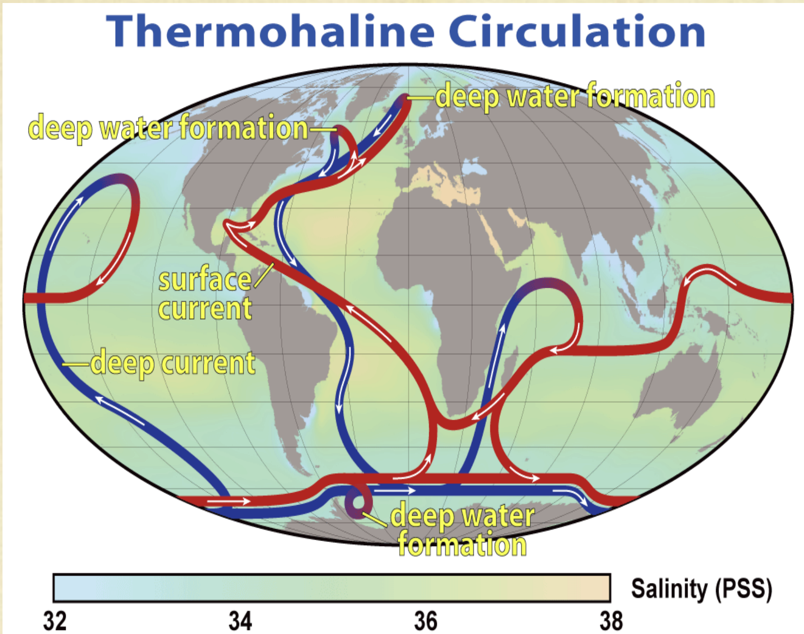


Motivation



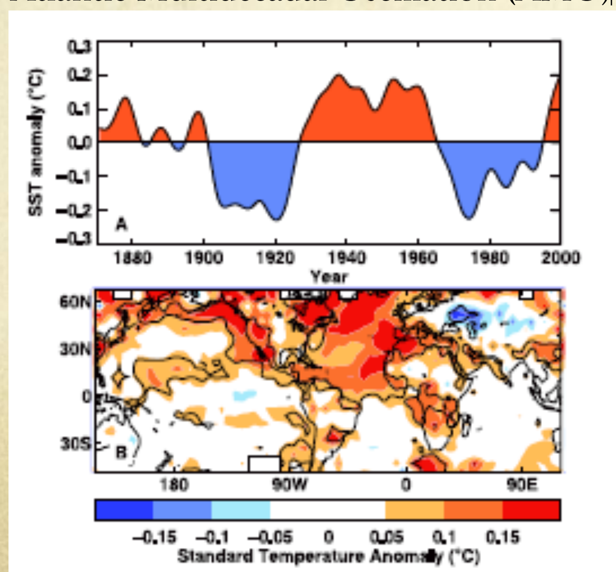
Jennifer Kay, WCRP, 2011
(Kay et al., 2011)

Background: AMOC

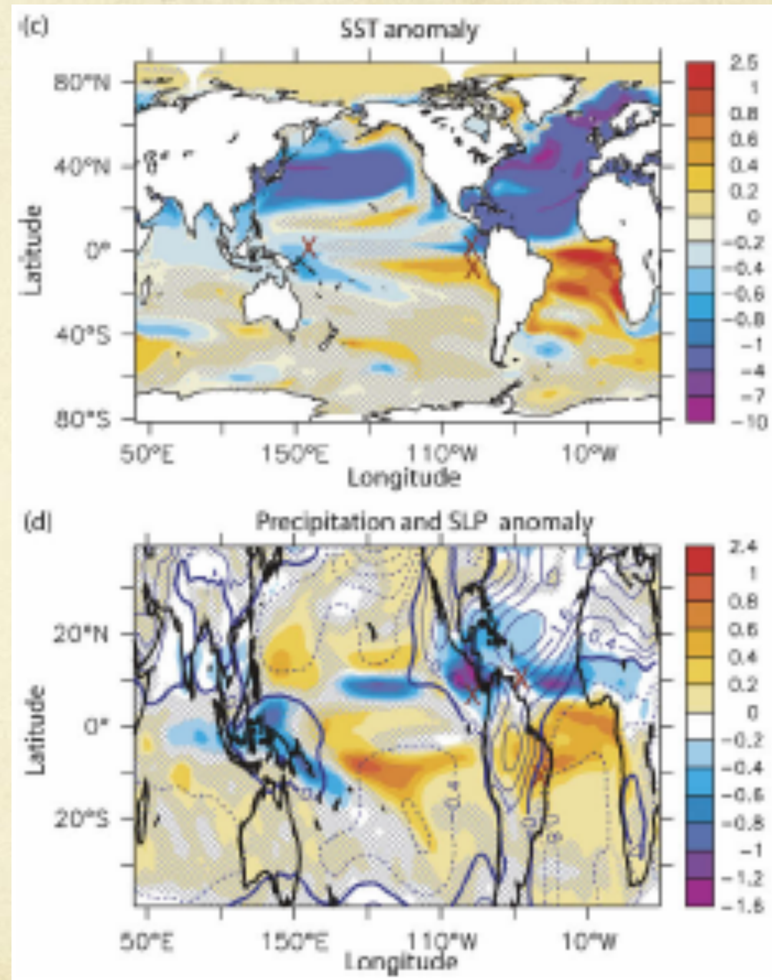


Courtesy: NASA

Atlantic Multidecadal Oscillation (AMO)



Knight et al. (2005)



Zhang and Delworth (2006)

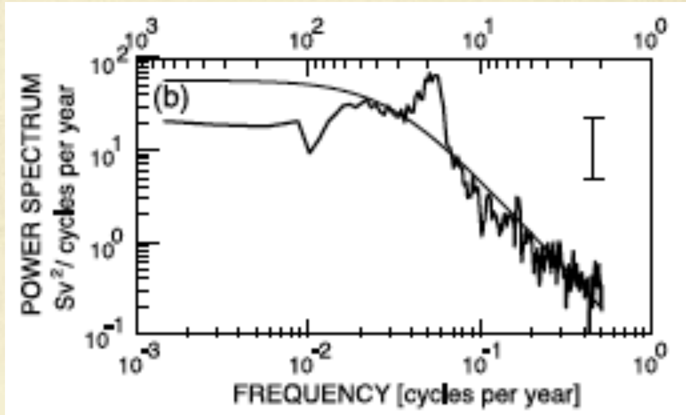
Data and Model

- Observations:
  - NSIDC sea-ice concentration 1979-2008 (*Cavalieri et al. 1996, updated 2008*)
  - Zakharov Arctic sea-ice extent (EXT) 1900-1999 (*Zakharov et al. 1997*)
  - NANSEN Surface Air Temperature (SAT) (*Kuzmina et al. 2008*)
  - Levitus optimally interpolated ocean temperature data 1955-2009
  - AVISO DUACS altimetry SSH data 1993-2008

- Models:
  - GFDL CM2.1 pre-industrial 1000-year long segment
  - GFDL Coupled Data Assimilation (CDA) (*Zhang 2007*):
    - Incorporates Argo Array data 2001-2008

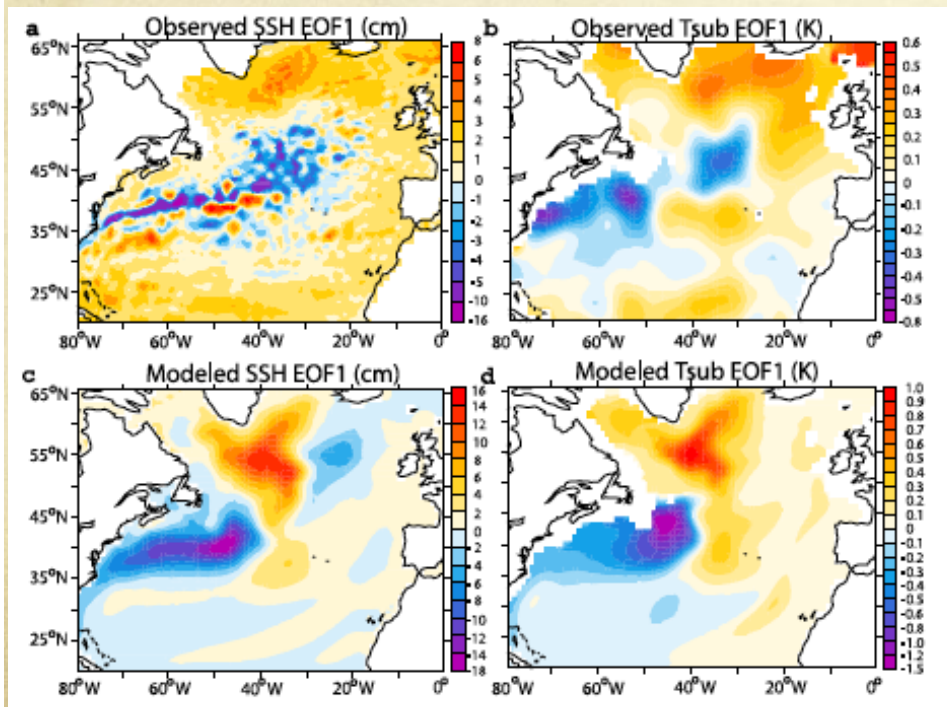
GFDL CM2.1 Simulated AMOC

AMOC index Spectrum

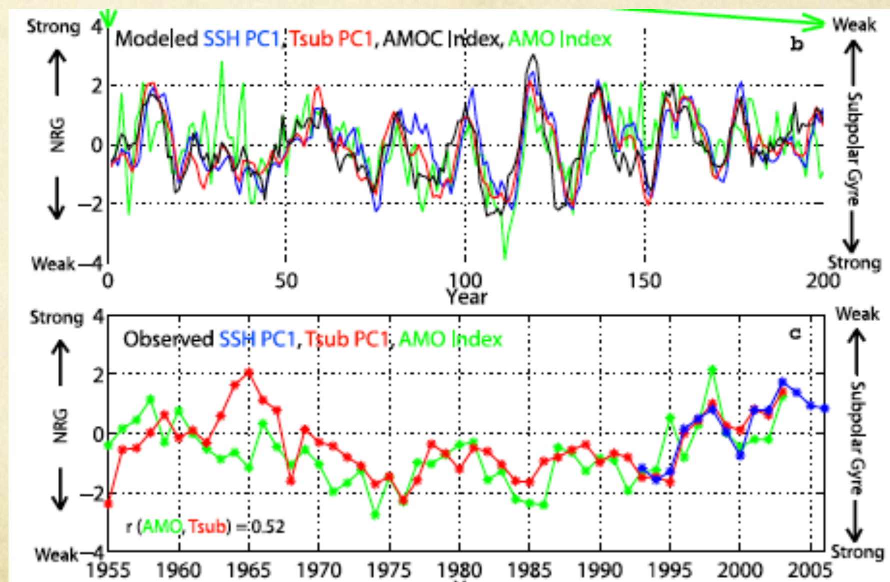


Msadek et al. 2010, GRL

AMOC Fingerprints



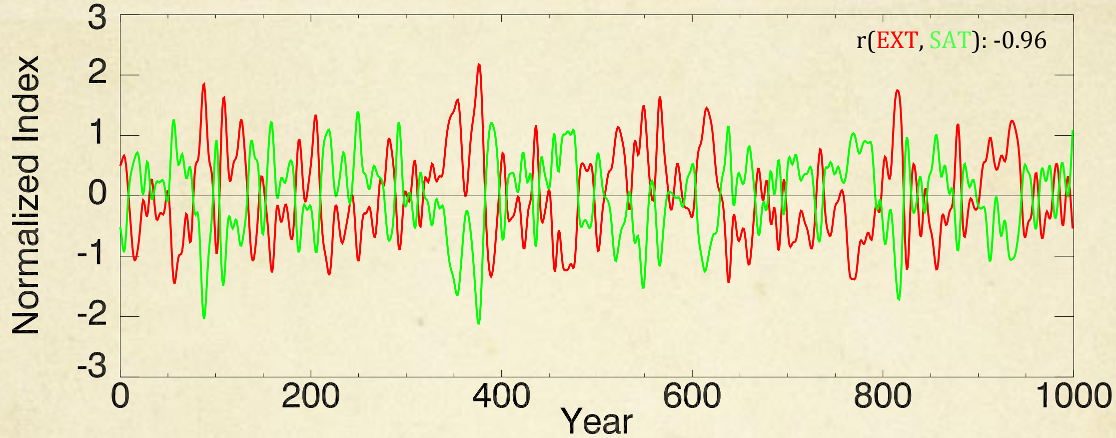
Time Series: AMOC index, SSH, Tsub, AMO



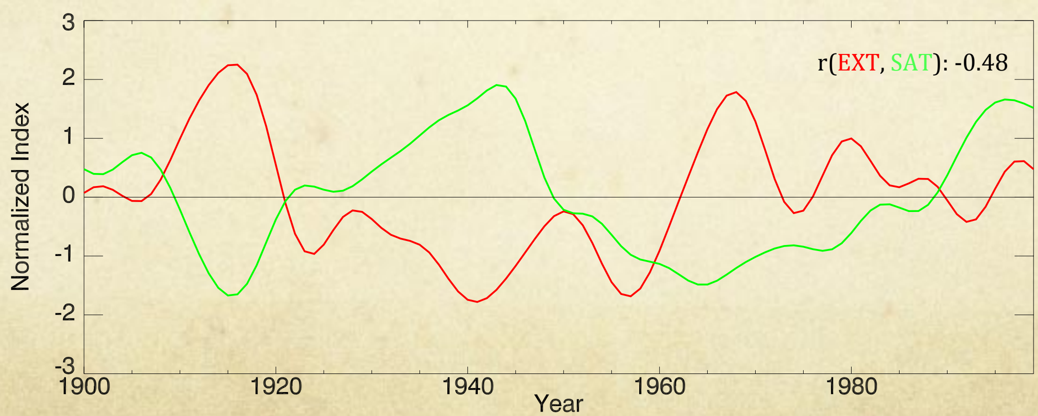
Zhang 2008, GRL

Arctic sea-ice and surface air temperature

a. GFDL CM2.1 Arctic Surface Air Temperature (SAT) and Sea-ice Extent (EXT)

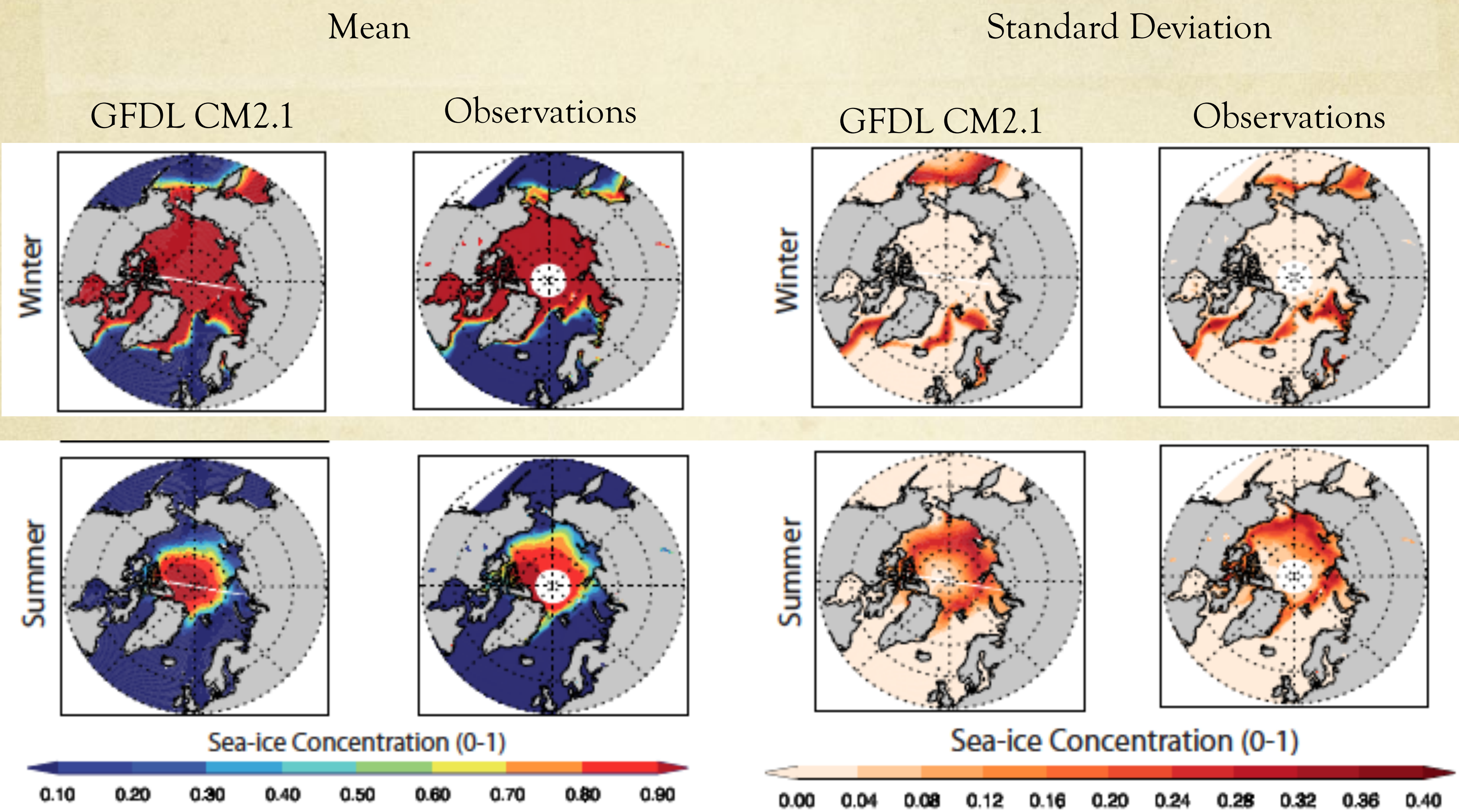


b. Observed Arctic Surface Air Temperature (SAT) and Sea-ice Extent (EXT)



Mahajan et al (2011)

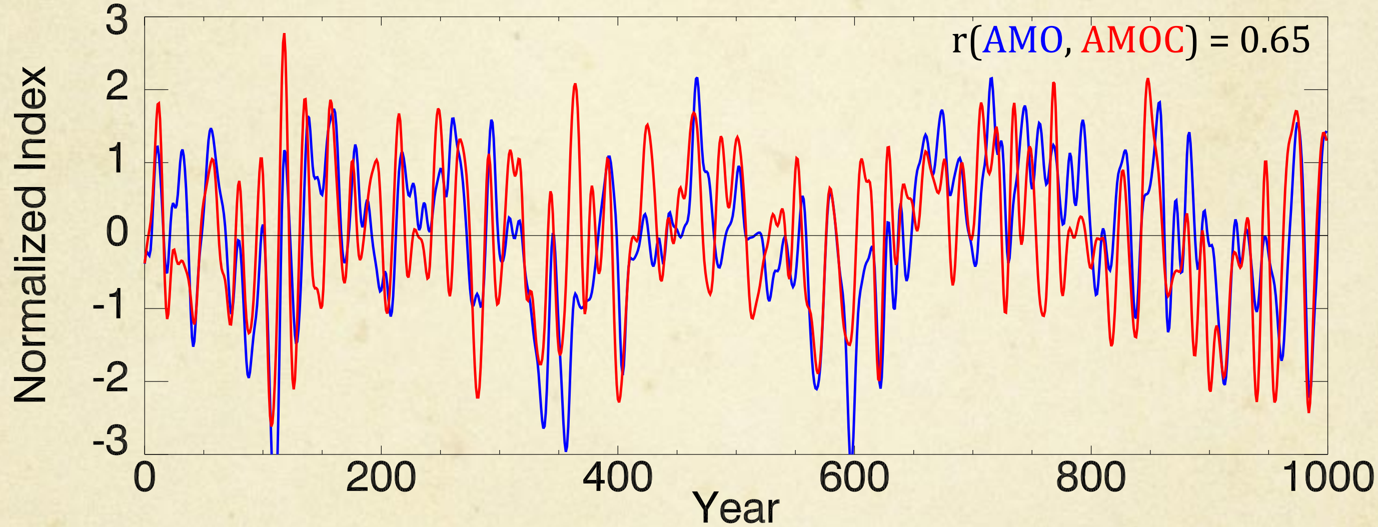
Simulated Arctic Sea-ice



Mahajan et al (2011)

AMOC and AMO

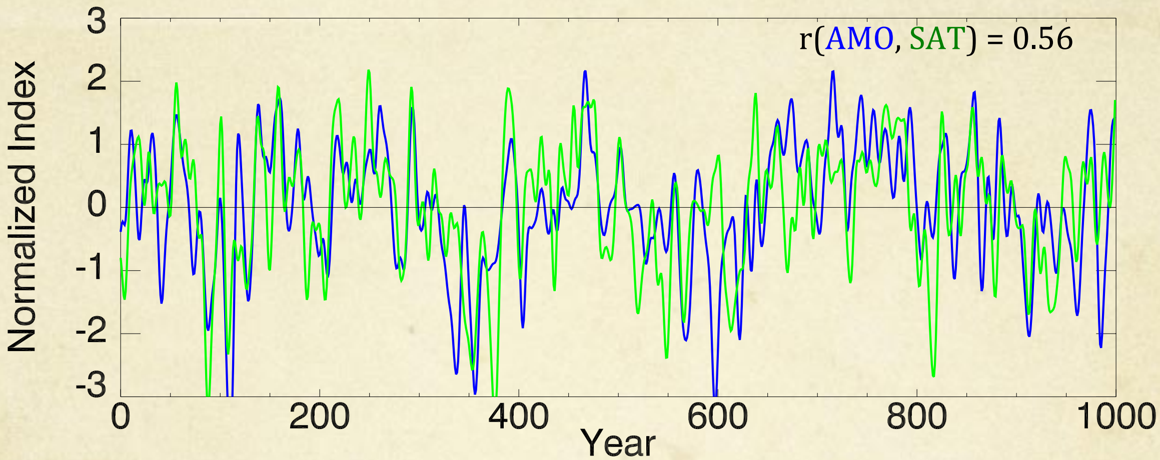
a. Time-series: AMO index and AMOC index



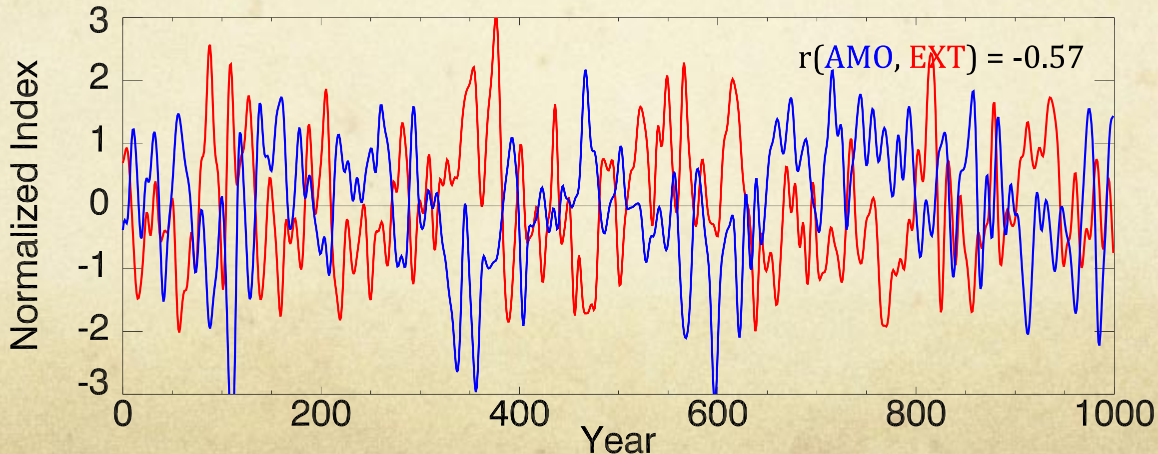
Mahajan et al (2011)

AMO and Arctic

b. Time-series: AMO index and Arctic Surface Air Temperature (SAT)

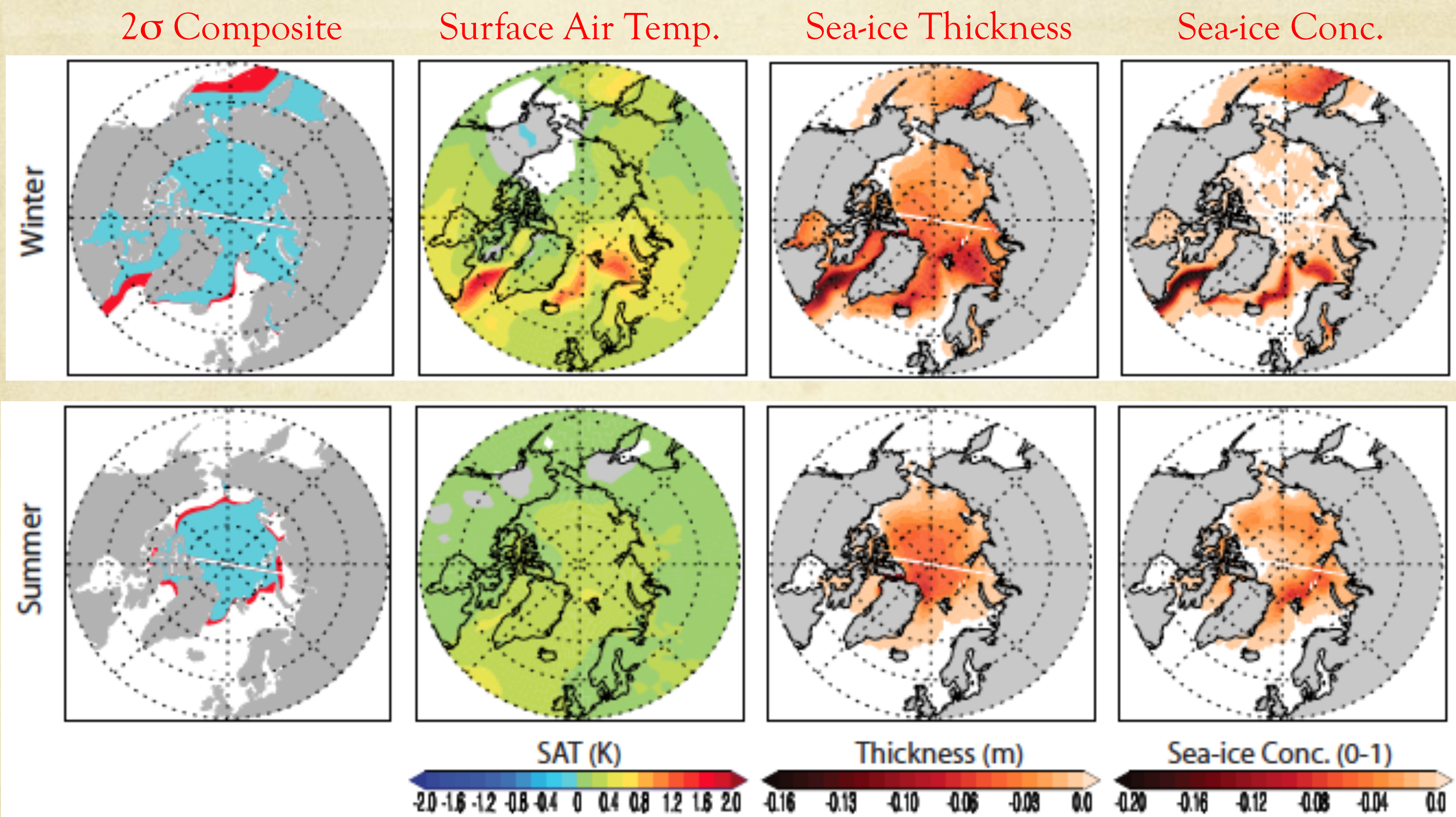


c. Time-series: AMO index and Arctic sea-ice extent (EXT)



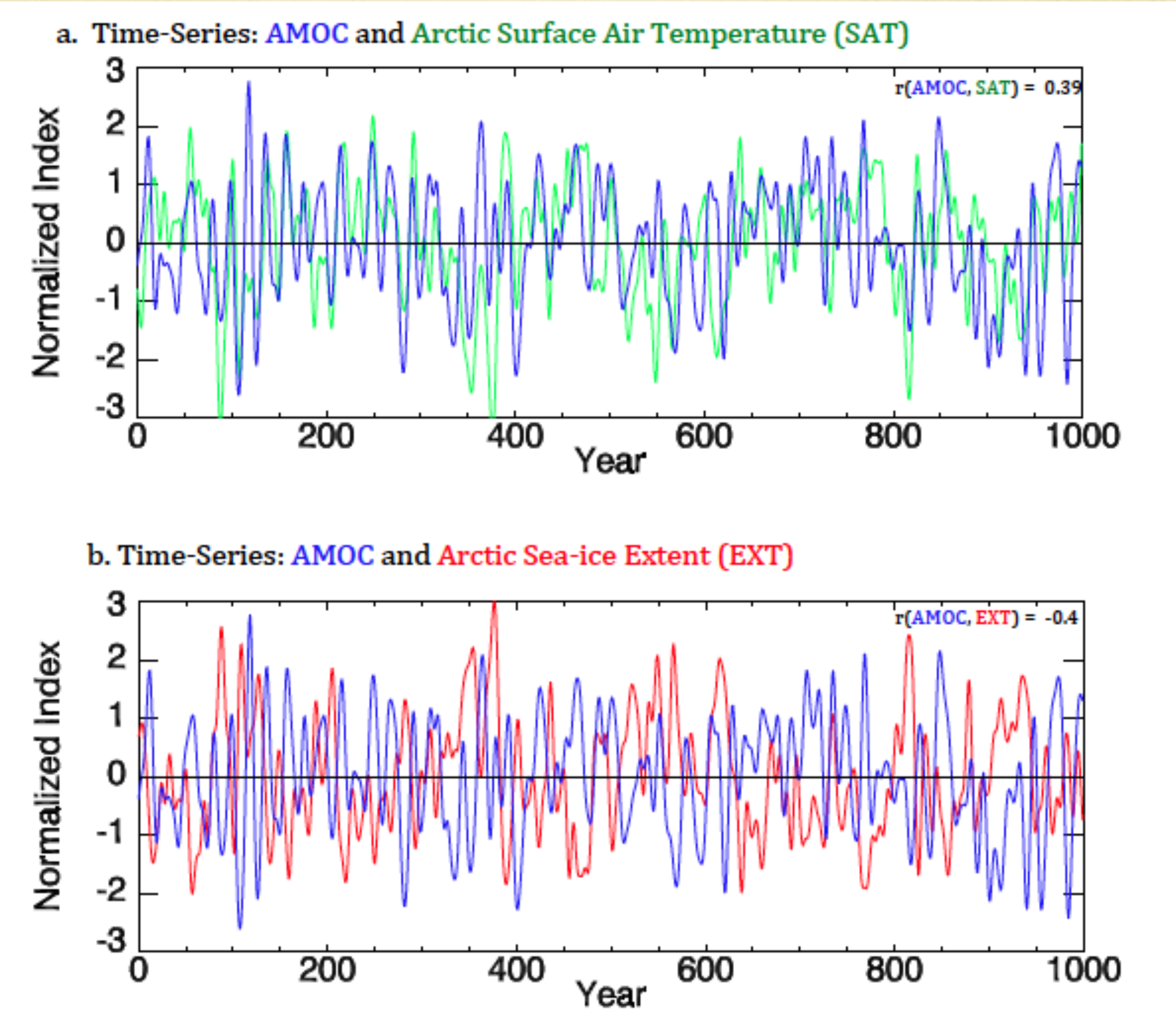
Mahajan et al (2011)

AMO and Arctic



Mahajan et al (2011)

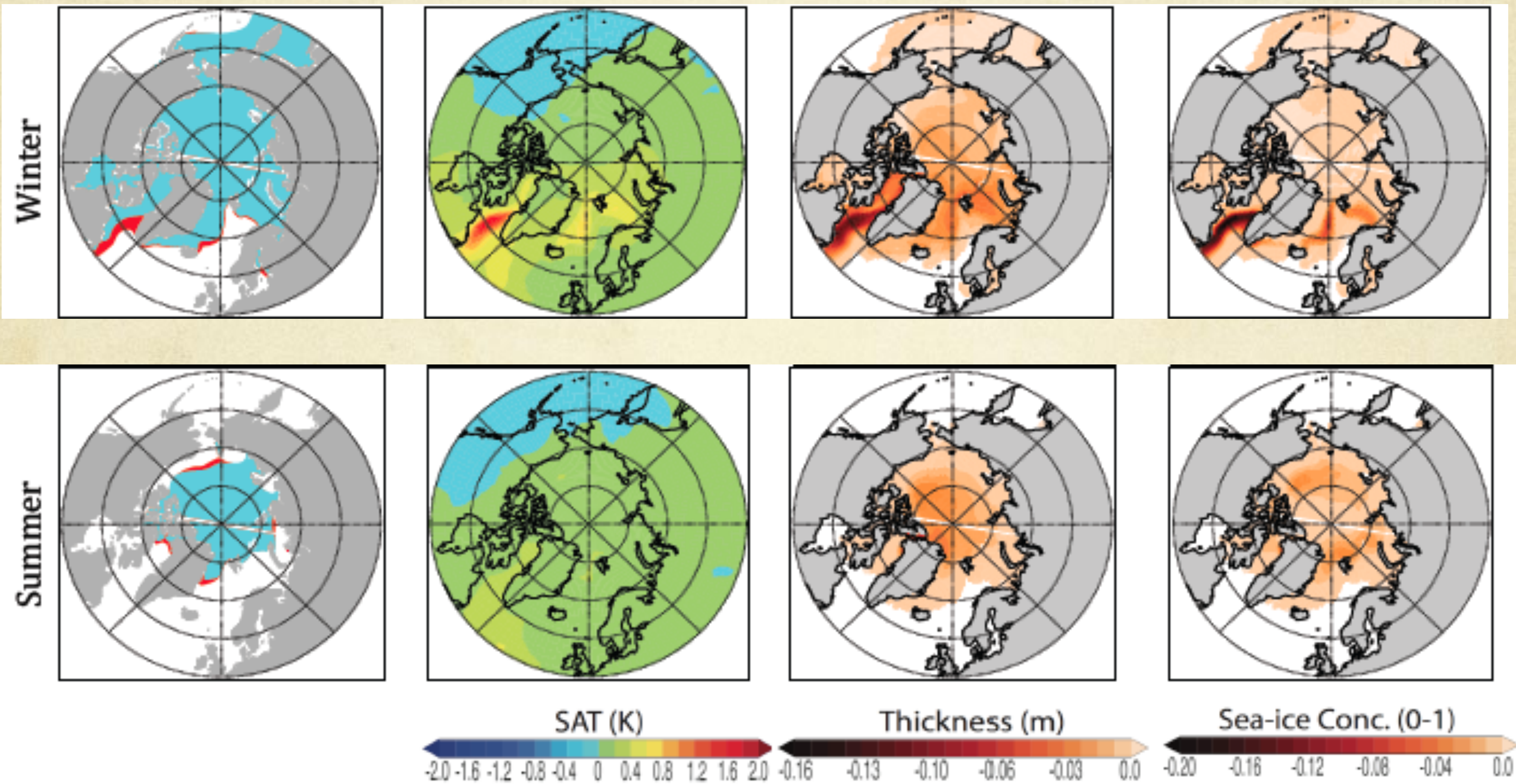
Simulated AMOC and Arctic



Mahajan et al (2011)

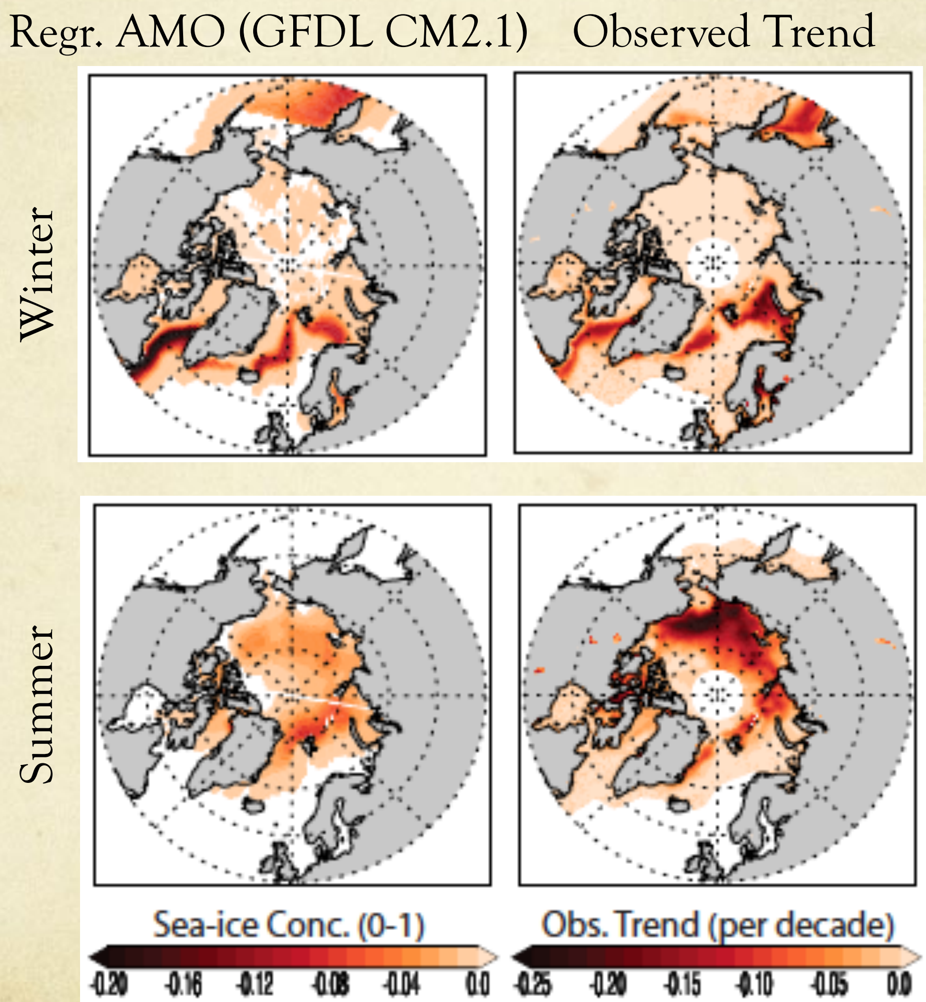
Simulated AMOC and Arctic

2σ Composite | Surface Air Temp. | Sea-ice Thickness | Sea-ice Conc.



Mahajan et al (2011)

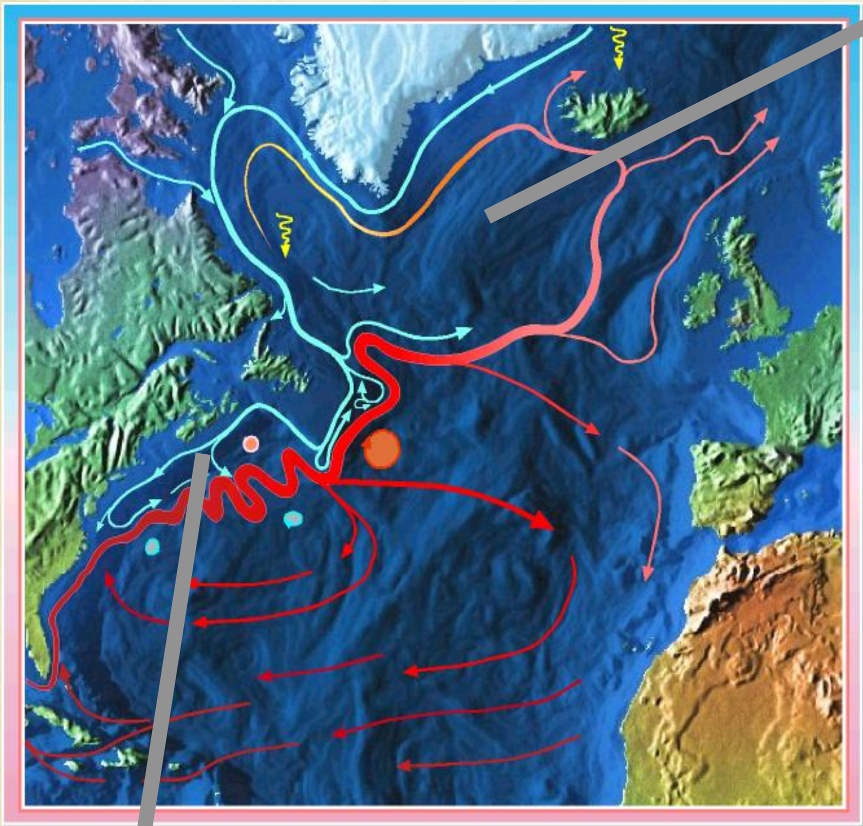
Observed Sea-ice Trend 1979-2009



Mahajan et al (2011)

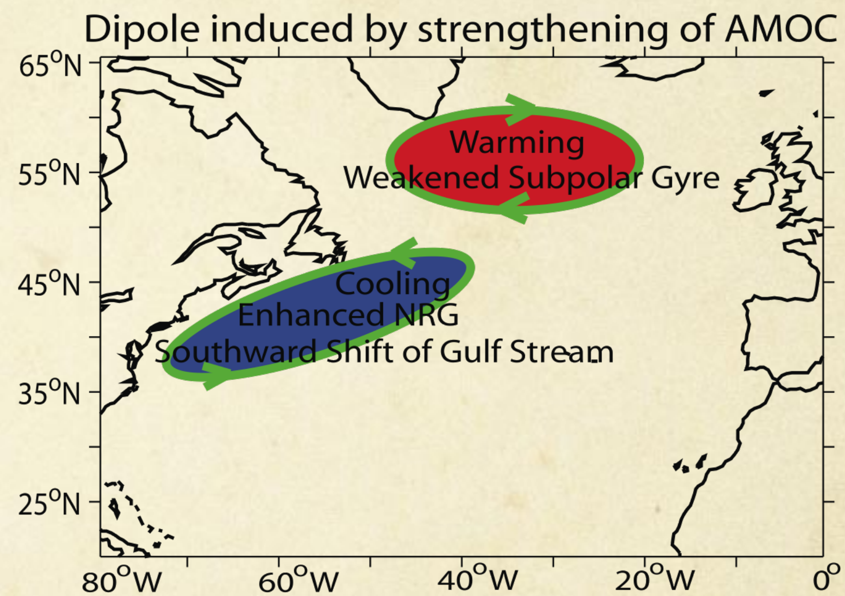
AMOC Fingerprints

Subpolar Gyre



Courtesy: http://www.mar.dfo-mpo.gc.ca

North Atlantic Currents

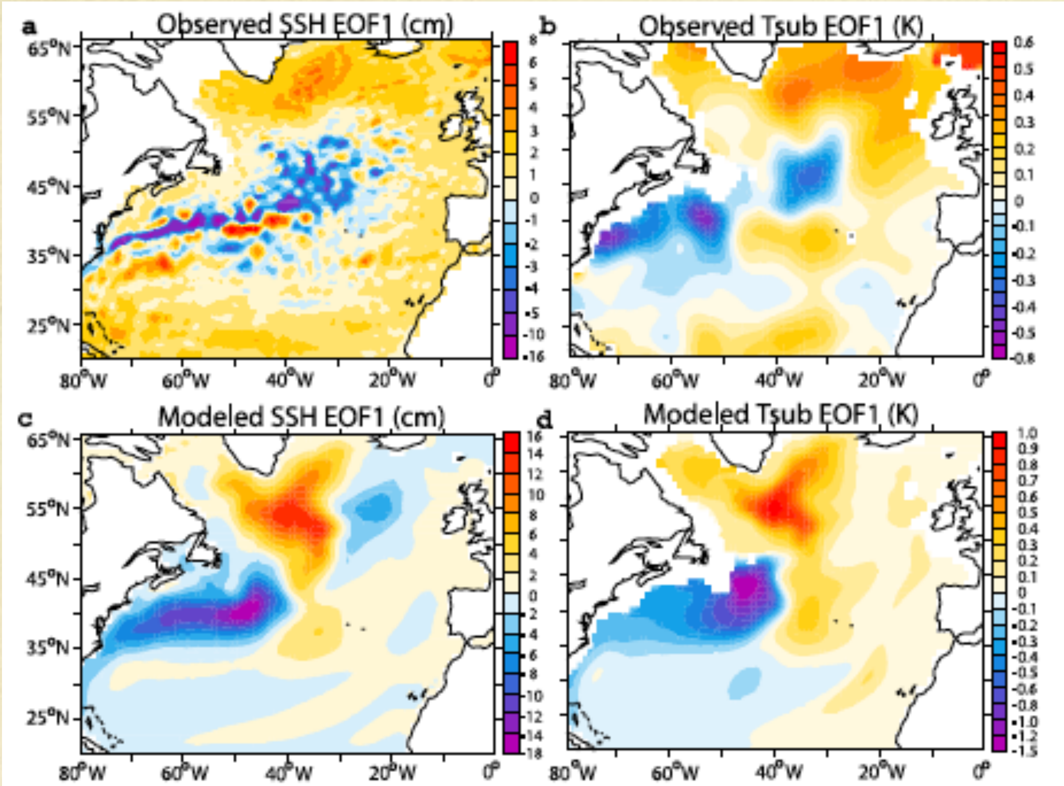


Zhang (2008)

Northern Recirculation Gyre (NRG)

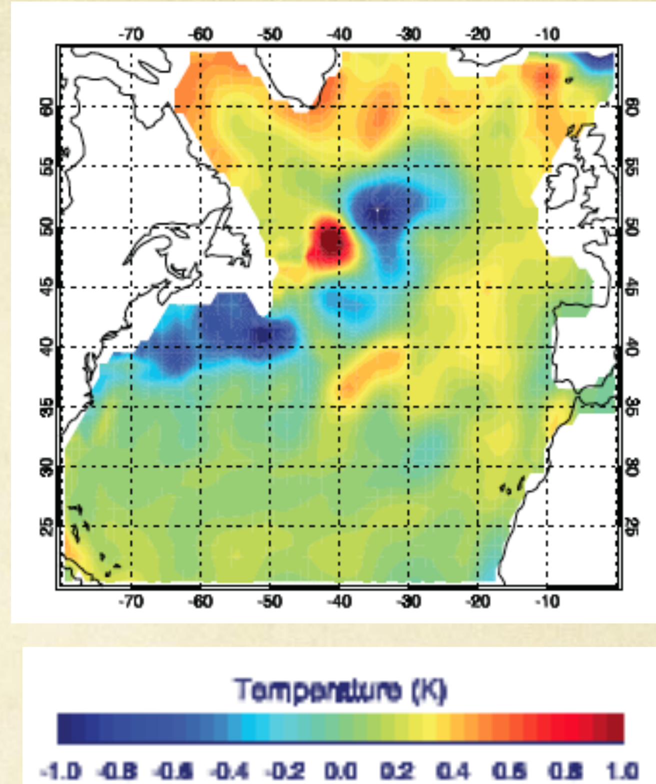
AMOC Fingerprints

Spatial Pattern



Zhang (2008)

CDA



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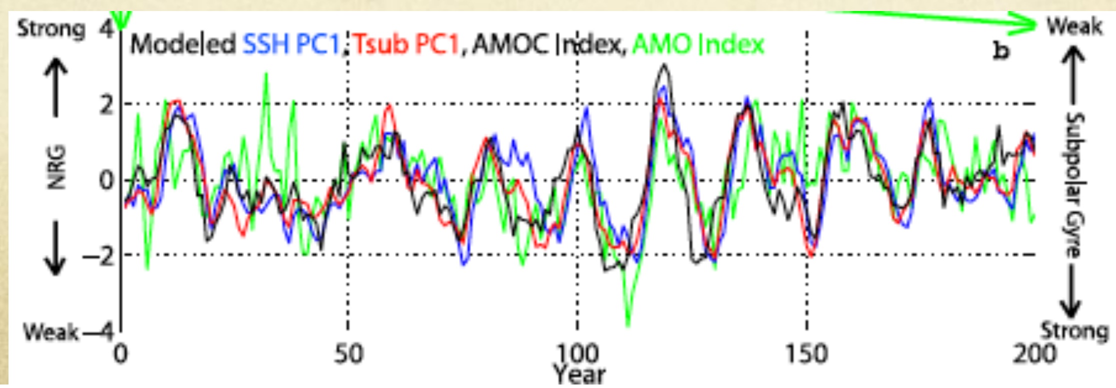
Time-series



Zhang (2008)

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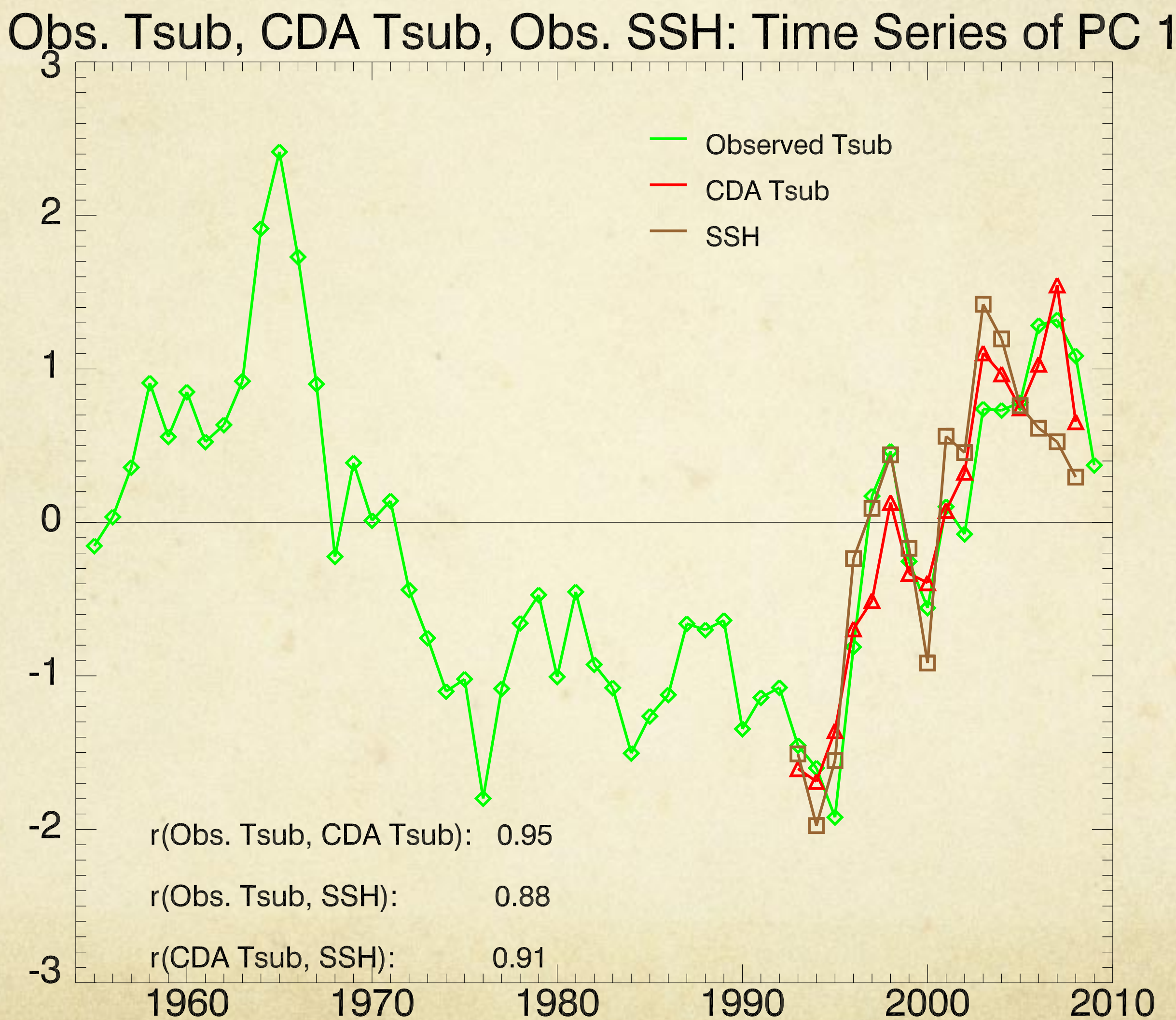

Mahajan et al (2011)

Statistical Prediction

Strategy:

1. Model fingerprints time-series using Auto-Regressive (AR) models

AR2 model (SBC criterion):

$$x(t) = ax(t\text{-}1) + bx(t\text{-}2) + e(t)$$

2. Estimate AR model parameters from observed Tsub timeseries and make predictions
3. Use the same model to predict SSH and CDA Tsub timeseries

Hindcasts

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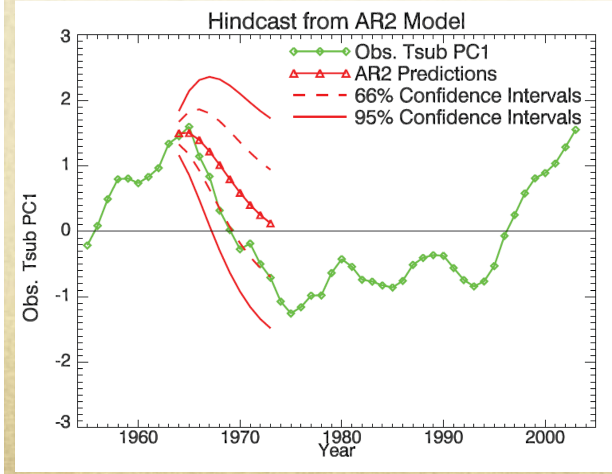
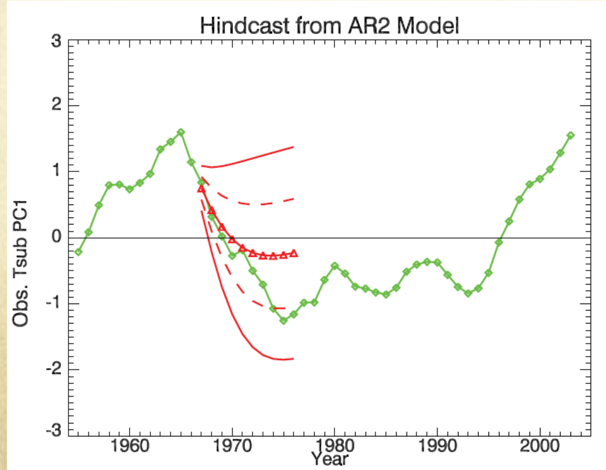
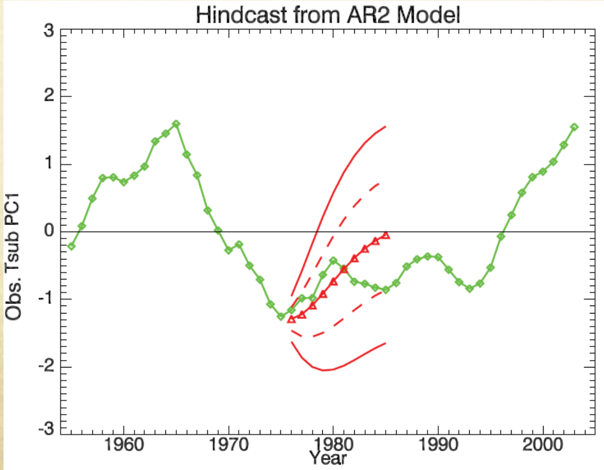
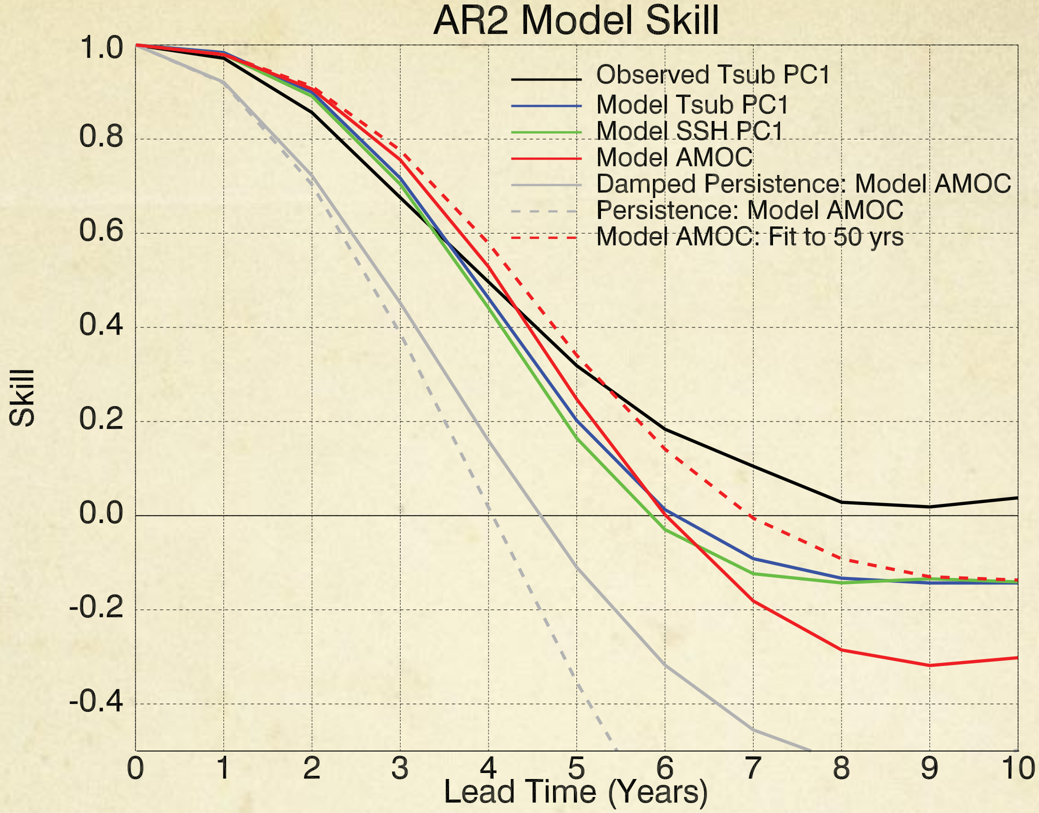






AR2 Validation



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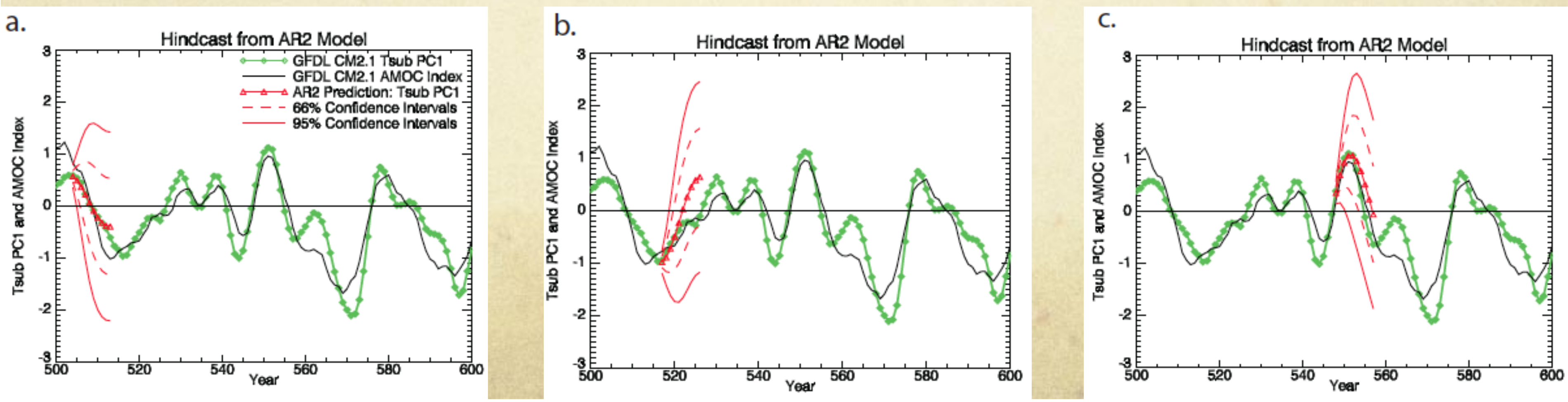
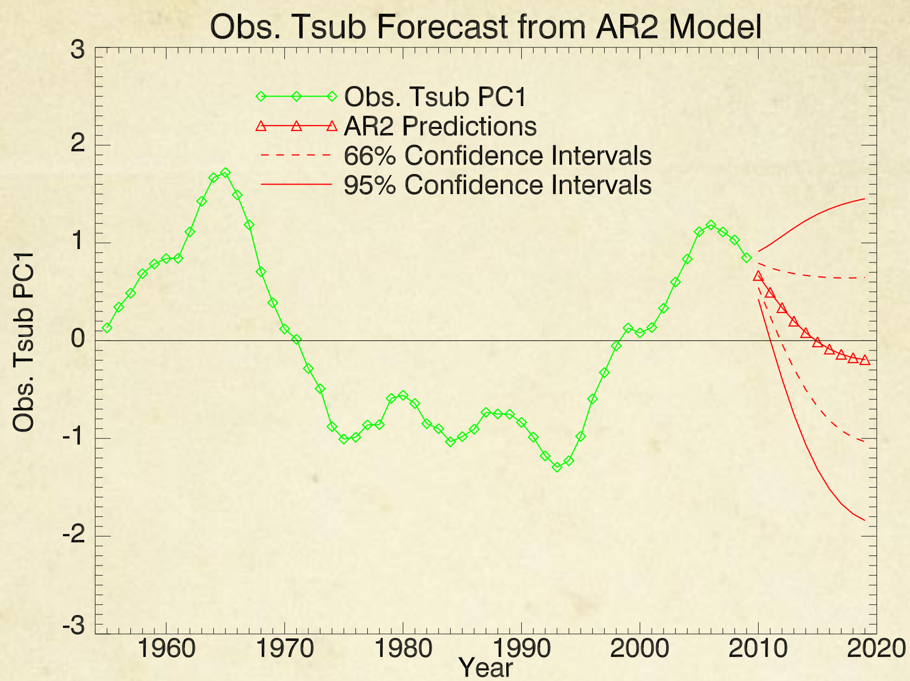


AMOC Forecasts



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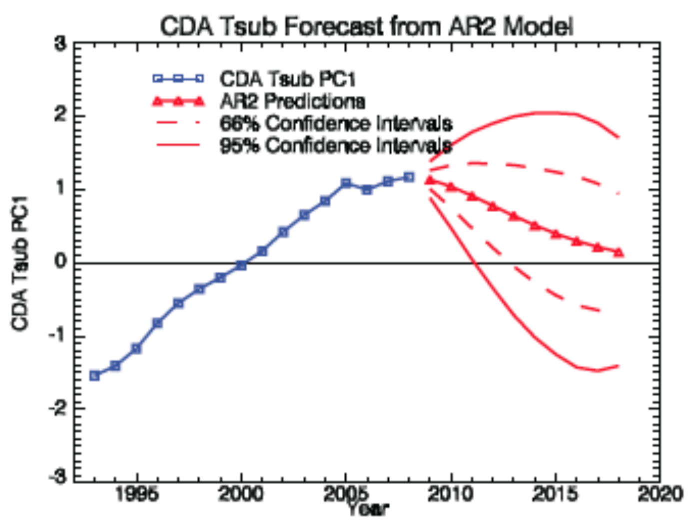

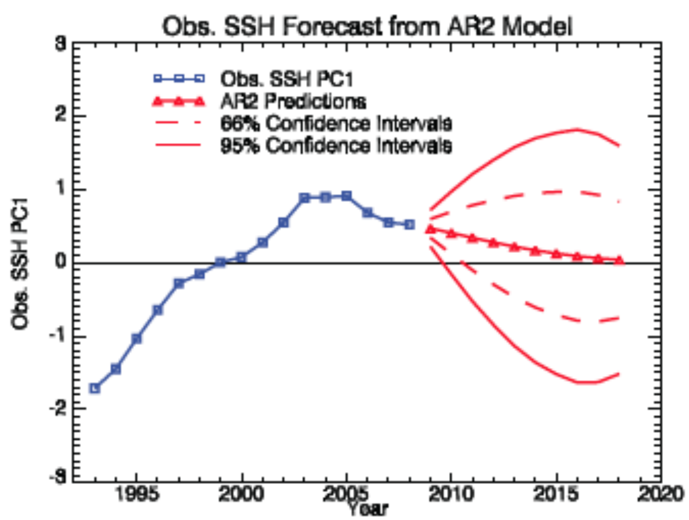

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