Reconstructing ocean/sea-ice variability over the 1871-2010 period using NOAA 20th century Reanalysis

Steve Yeager

with thanks to Svetlana Karol

CESM Workshop, Breckenridge, June 18, 2015

NOAA CIRES Twentieth Century Reanalysis Version 2 (20CRv2)

- Global atmospheric reanalysis (1871-present) assimilating only surface pressure measurements, using observed SST and sea-ice boundary conditions (HadISST):

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RMetS
Royal Meteorological Society

Review Article
The Twentieth Century Reanalysis Project

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★ New version 2c (not used here!): "same model as version 2 with new sea ice boundary conditions from the COBE-SST2 (Hirahara et al. 2014), new pentad Simple Ocean Data Assimilation with sparse input (SODAsi.2, Giese et al. 2015) SST fields, and additional observations from ISPD version 3.2.9."

Motivation

- Develop mechanistic understanding of centennial-scale historical ocean/sea-ice variability (e.g. Lee et al. *GRL* 2011; Müller et al. *Clim Dyn* 2014; Lee et al. *Nature Geosci* 2015).
- Generate ocean/sea-ice initial conditions for CESM decadal prediction over multiple AMV cycles (e.g. Müller et al. *GRL* 2014).
- Gain new perspective/insights by comparing with traditional CORE-forced reconstructions (based on NCEP reanalysis).

Challenges

- Stability problems when shifting 2m air temp/humidity to 10m required imposing max(ζ)=1 (Large et al 1994)

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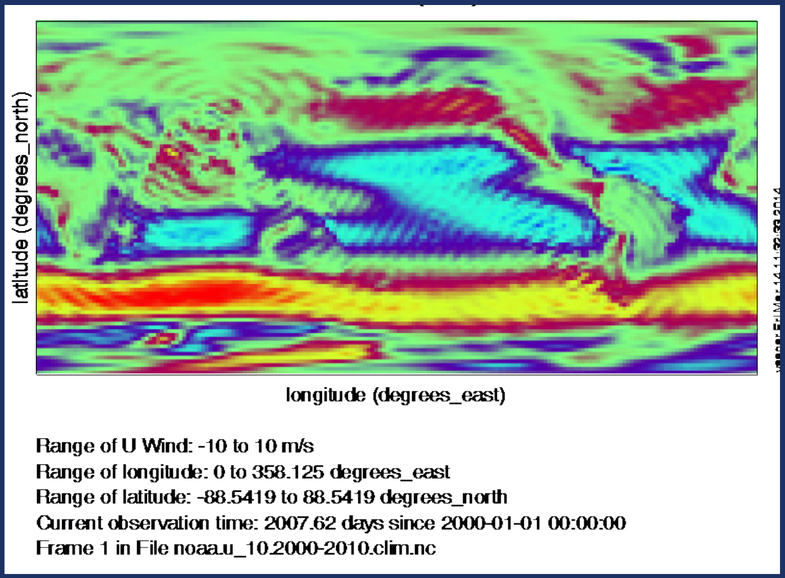
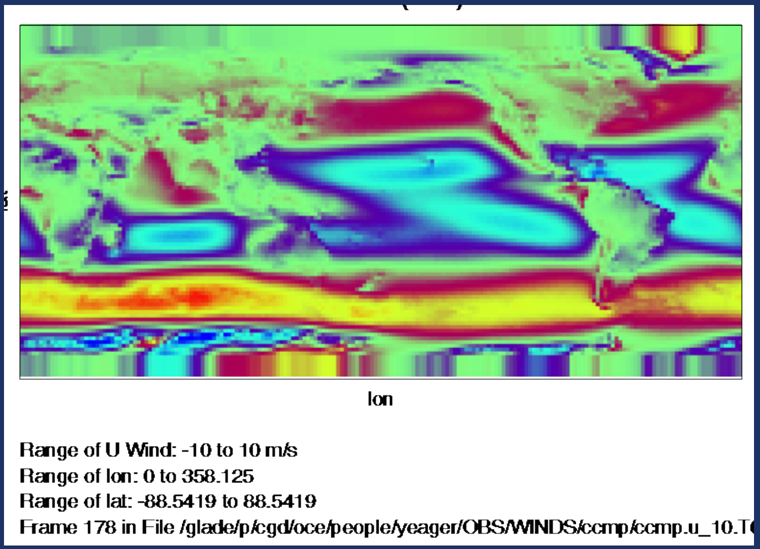
- Excessive Gibbs ringing in the wind field

10m zonal wind (2000-2010 clim)





20CRv2

CCMP

Challenges

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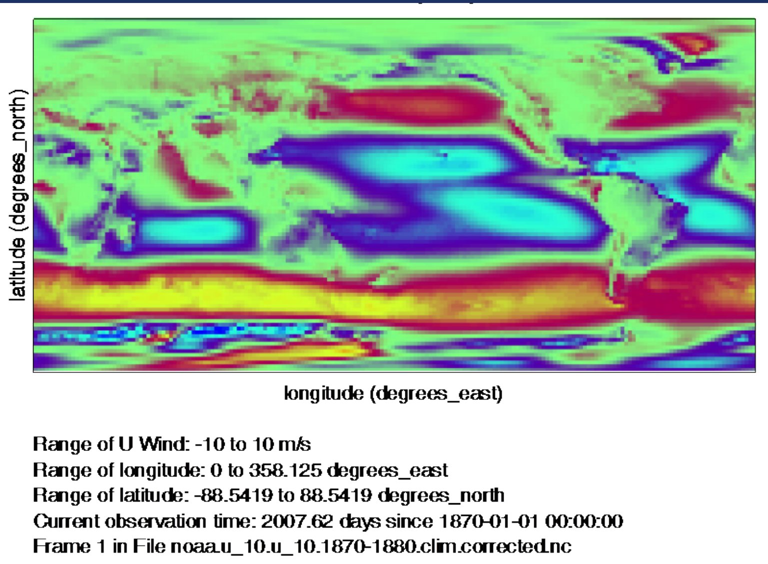
- Excessive Gibbs ringing in the wind field

10m zonal wind (1870-1880 clim)



➔ After removing bias
Δu(x,y) = 20CRv2-CCMP (2000-2010)
over 70°S-70°N

20CRv2

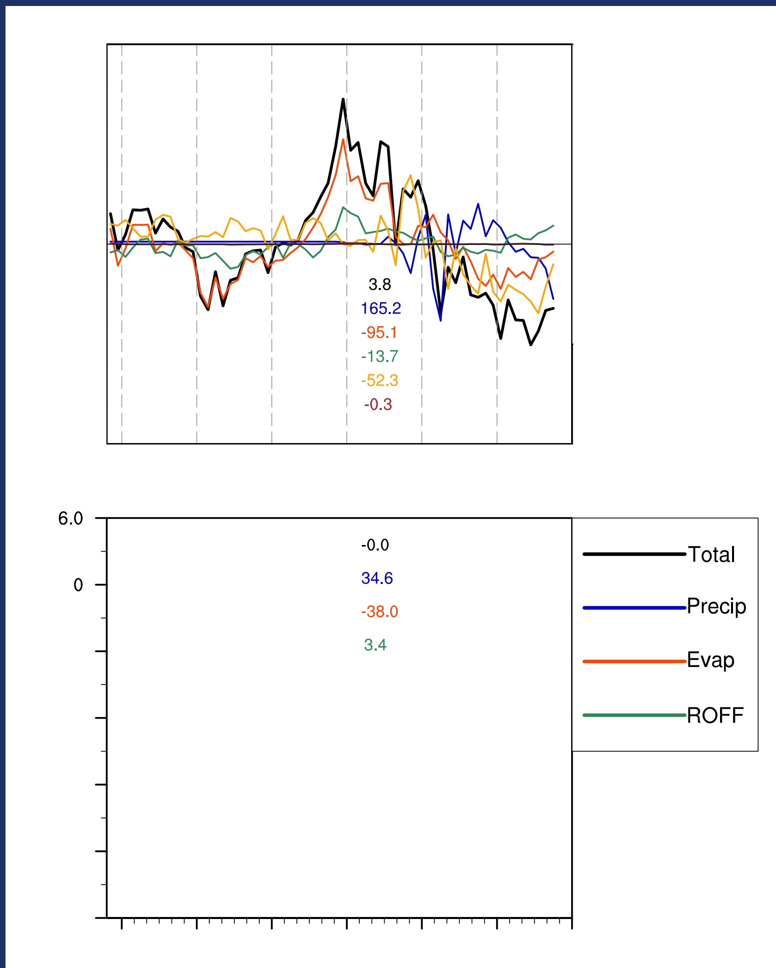
Challenges

- Stability problems when shifting 2m air temp/humidity to 10m required imposing $\max(\zeta)=1$ (Large et al 1994)
- Excessive Gibbs ringing in the wind field
- Excessive global air-sea heat/freshwater flux imbalances

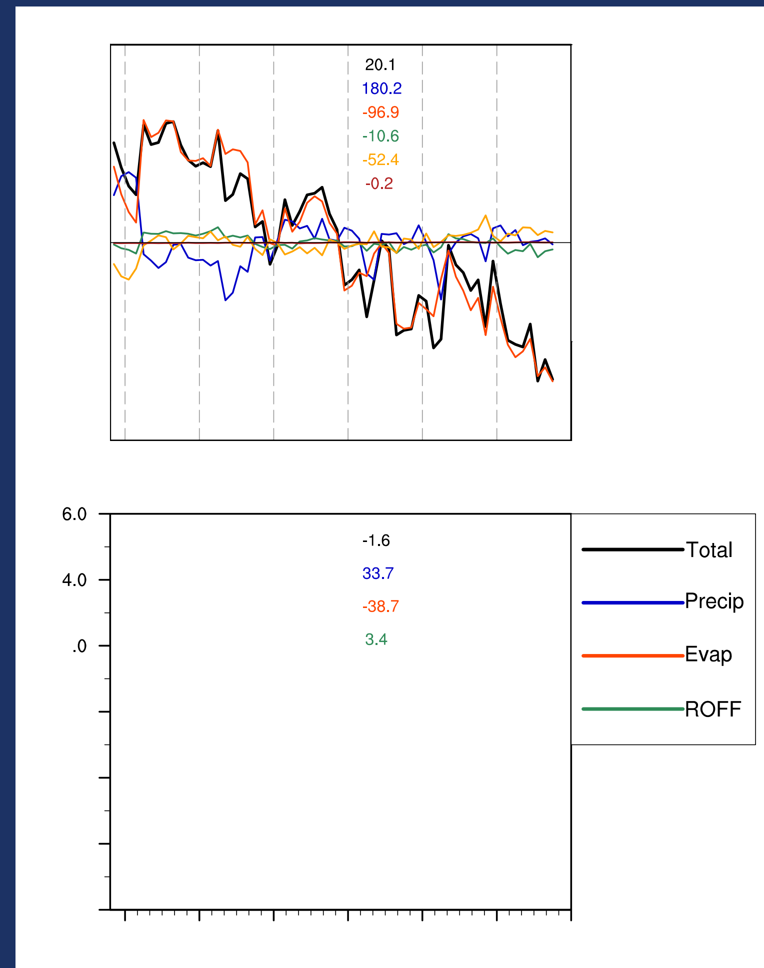
Global mean air-sea flux time series obtained by coupling to observed SST and sea-ice:

Heat

FW



CORE-II

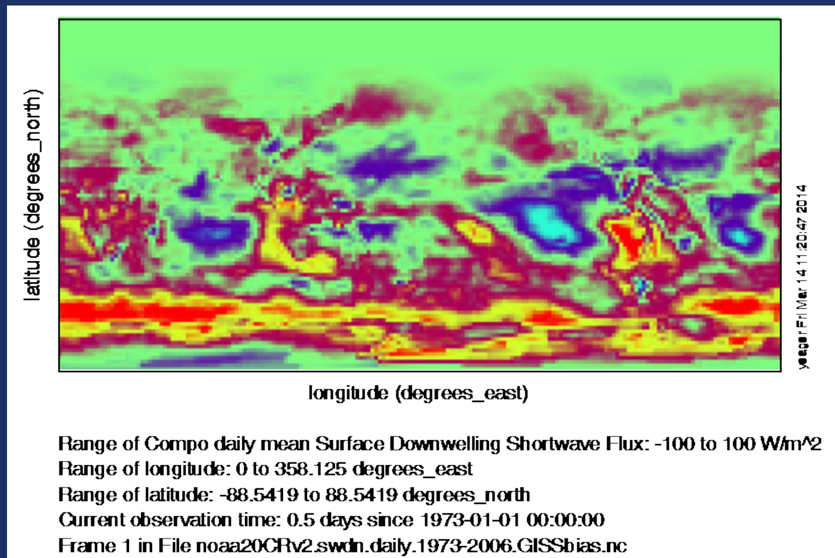


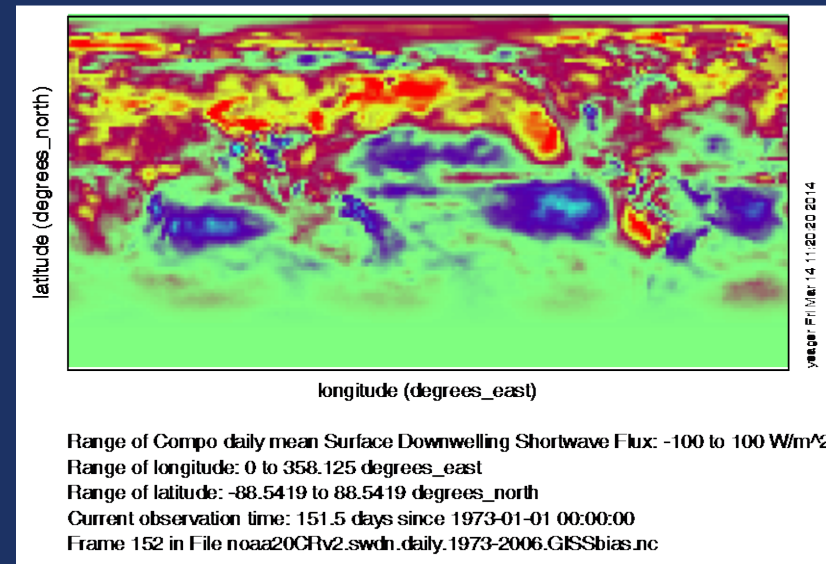
20CRv2 (raw)

Climatological bias relative to GISS (20CRv2 – GISS):

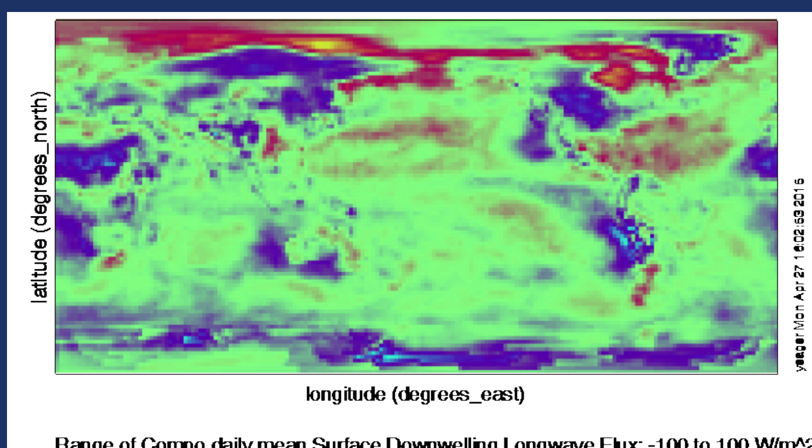
SH summer | NH summer

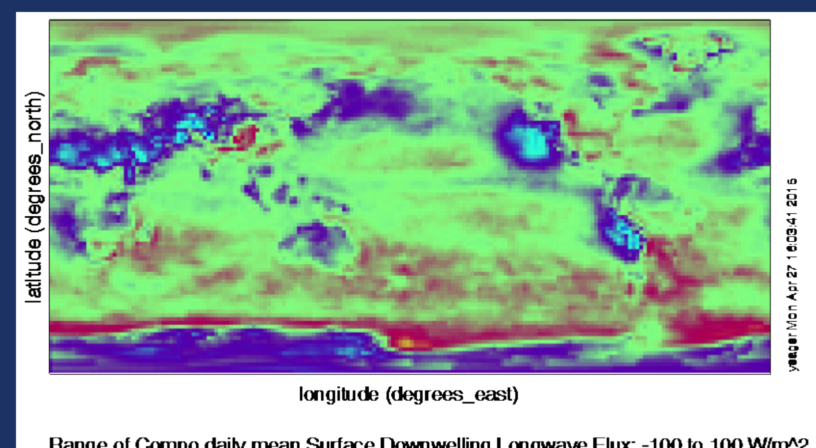
SWDN





LWDN



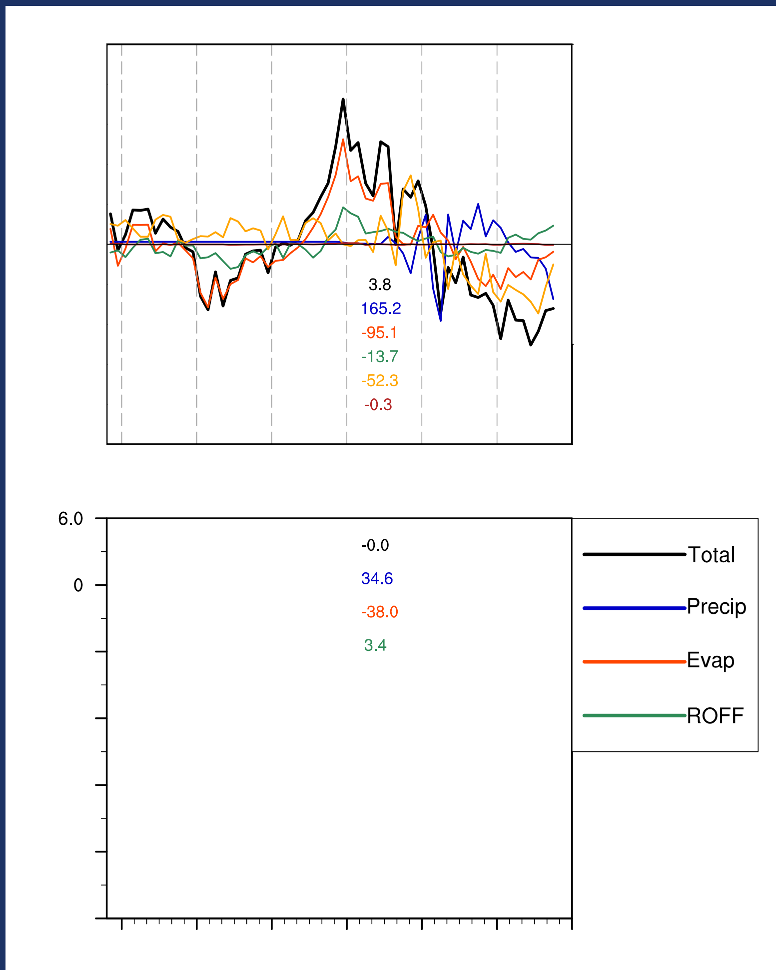


➔ removed climatological daily bias from 20CRv2: ΔSWDN(x,y,365), : ΔLWDN(x,y,365)

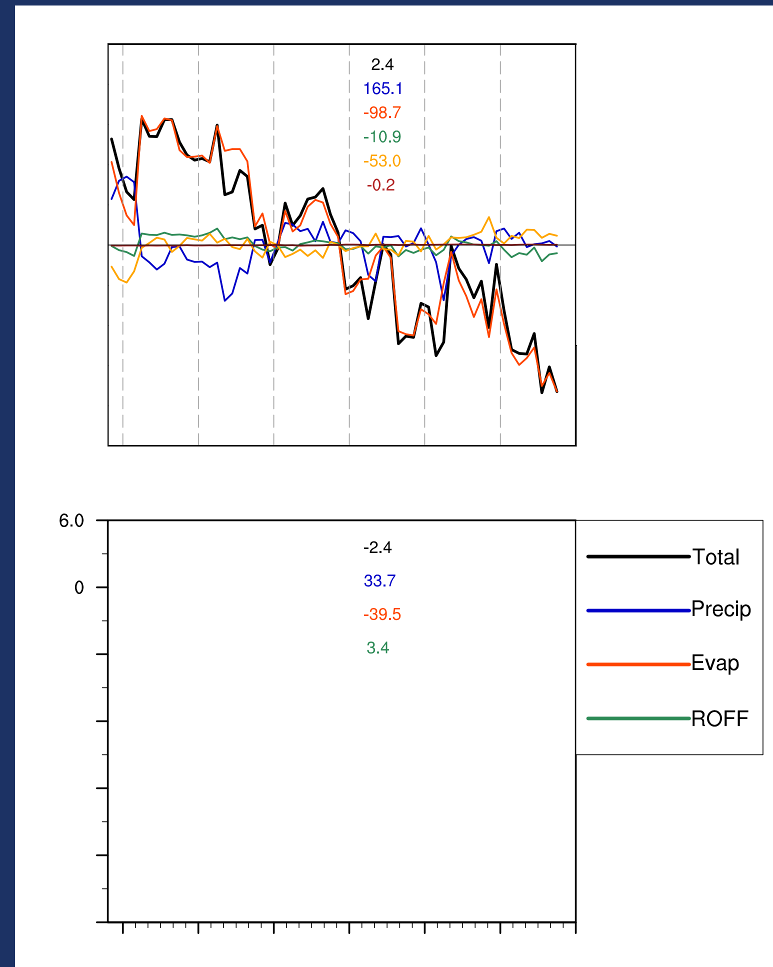
Global mean air-sea flux time series obtained by coupling to observed SST and sea-ice:

Heat

FW



CORE-II



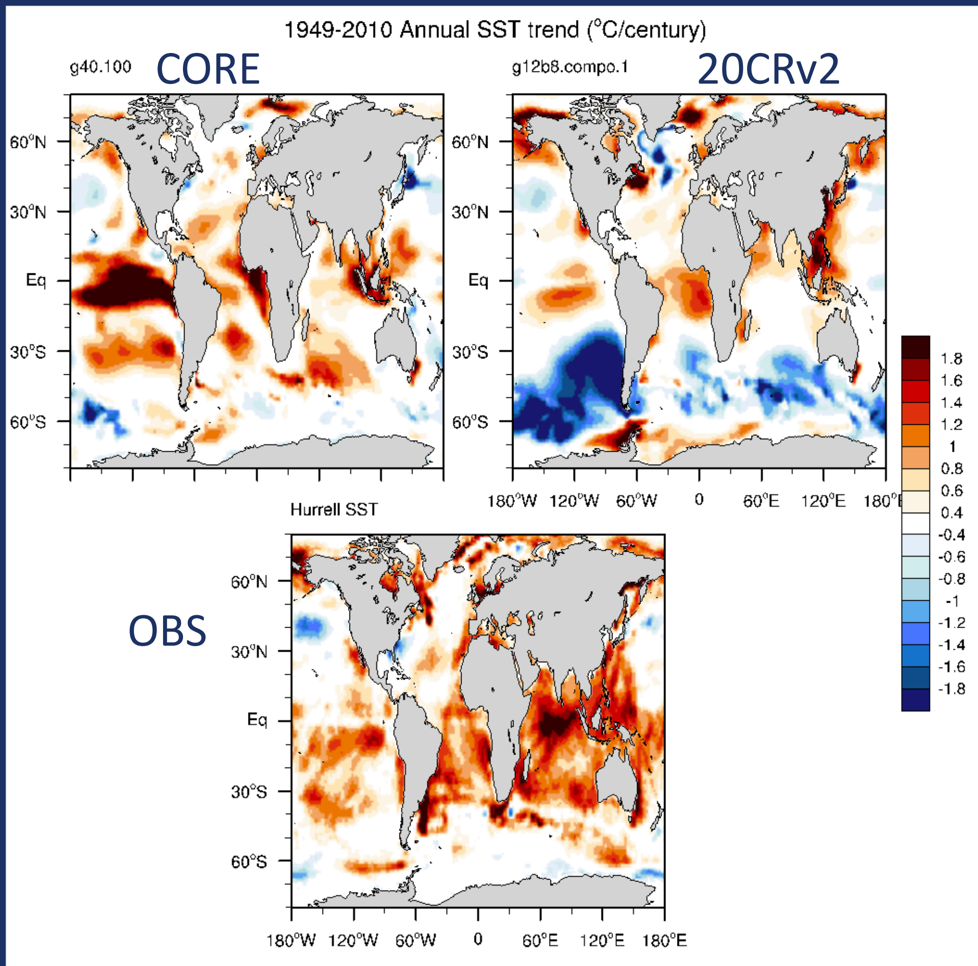
20CRv2 (adjusted winds/radiation)

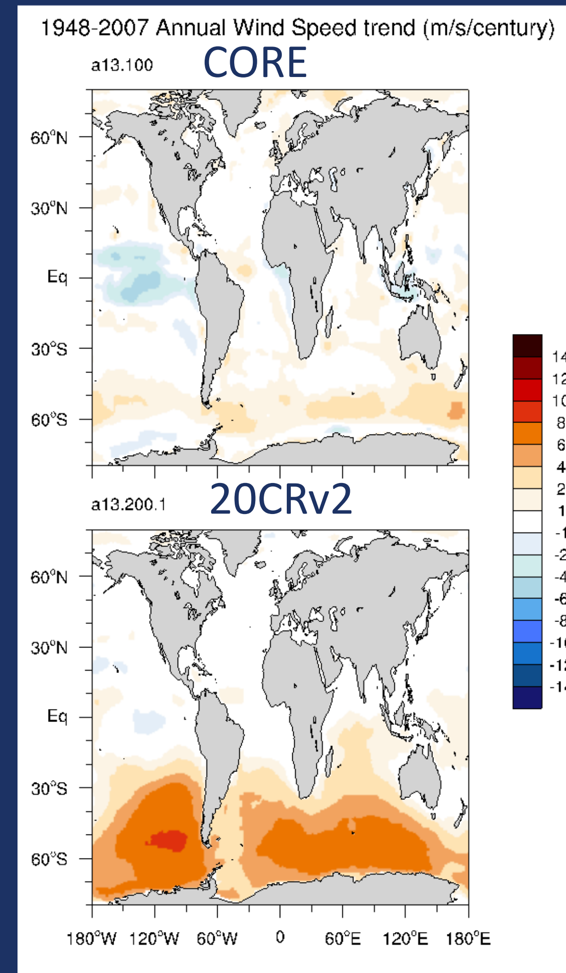
Challenges

- Stability problems when shifting 2m air temp/humidity to 10m required imposing $\max(\zeta)=1$ (Large et al 1994)
- Excessive Gibbs ringing in the wind field
- Excessive global air-sea heat/freshwater flux imbalances
- Correct treatment of ensemble (N=56) to avoid spurious wind speed trends

1948-2010 SST trend in “G” simulations:

1948-2007 10m wind speed trend:

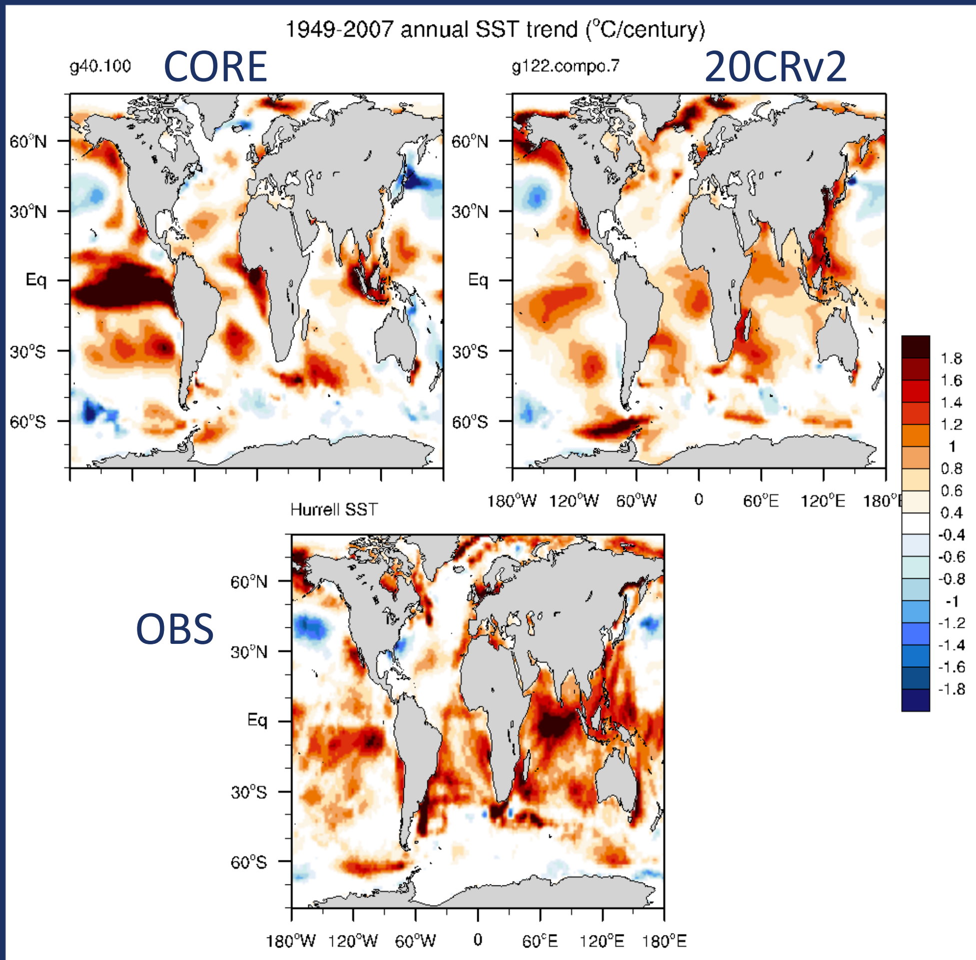




- <ws10> ≠ sqrt(<u10>2+<v10>2)
  = <sqrt(u102+v102)>

➔ Computation of <ws10> from full 20CRv2 ensemble & reformulation of datm/coupler to handle separate ws10 stream

1948-2010 SST trend in “G” simulations:



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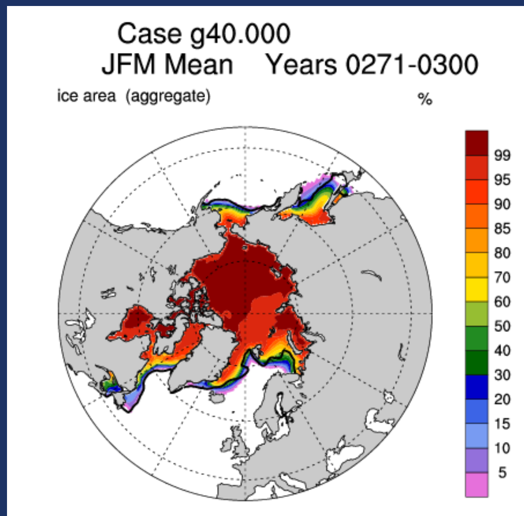
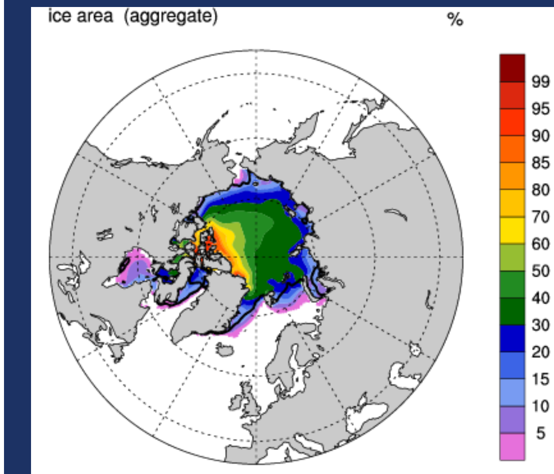
- Correct treatment of ensemble (N=56) to avoid spurious wind speed trends
- Large positive biases in polar air temp/humidity

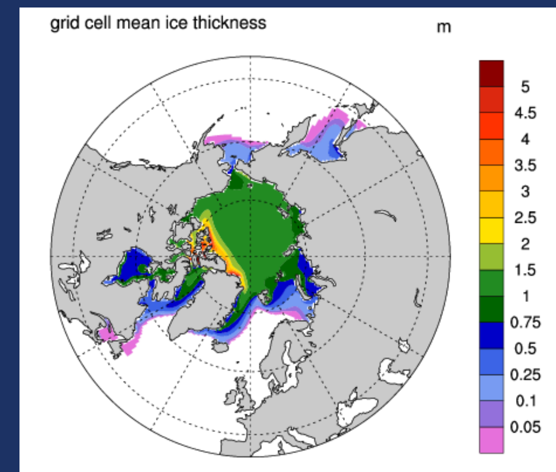
Arctic sea-ice after 5-cycle spinup (1948-2007 cycle):

JFM | JAS | ANN

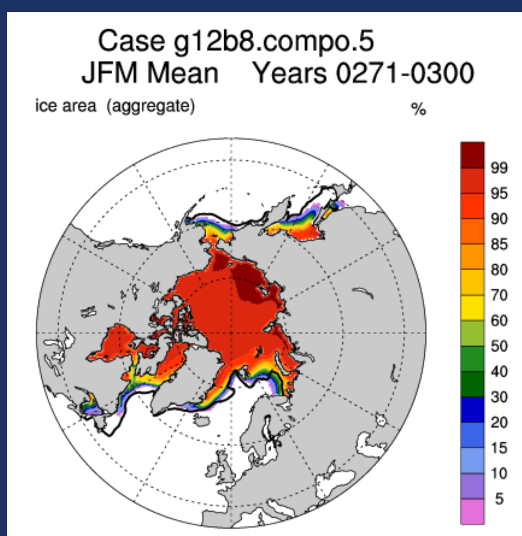
CORE

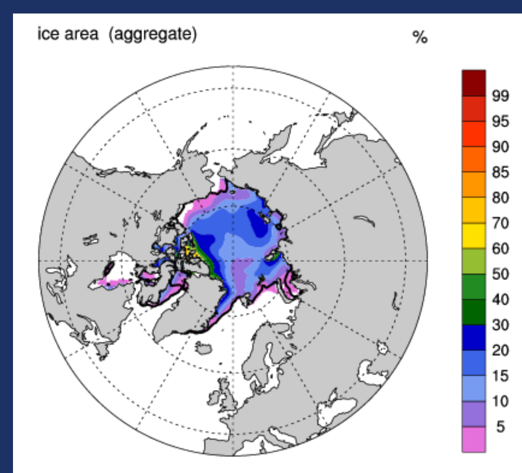


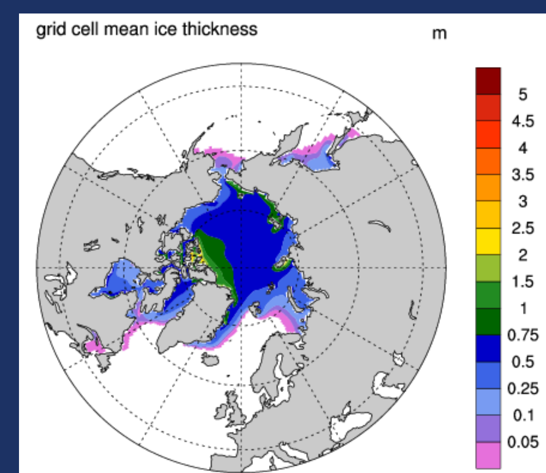




20CRv2





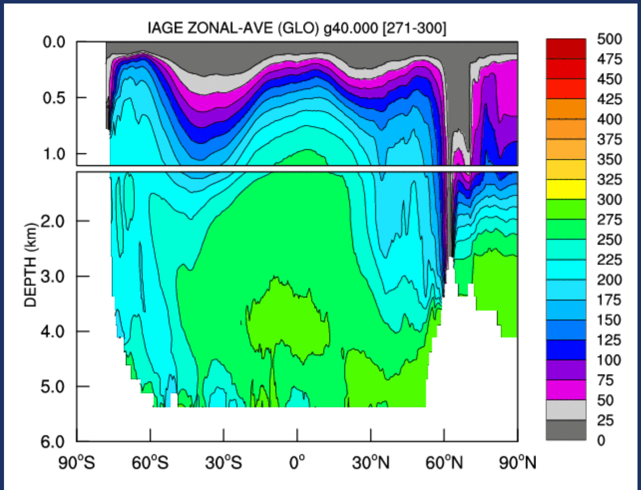


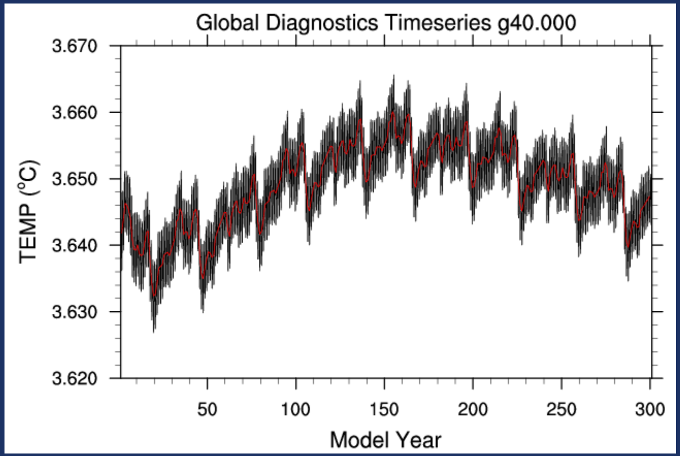
Poor SO ventilation (fresh bias) and substantial drift associated with sea-ice loss…

Ideal Age

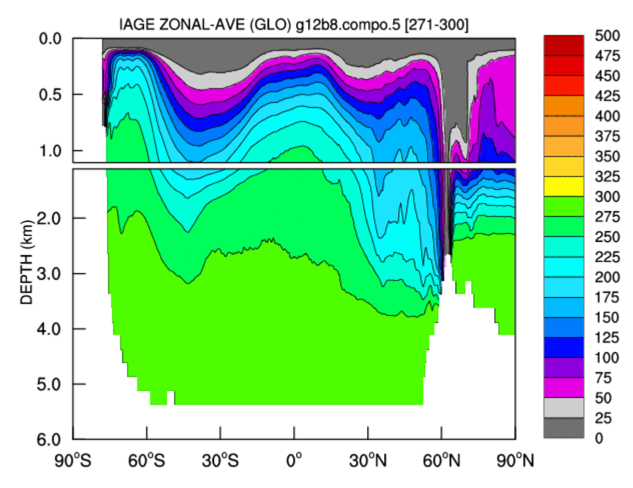
Global Ocean TEMP

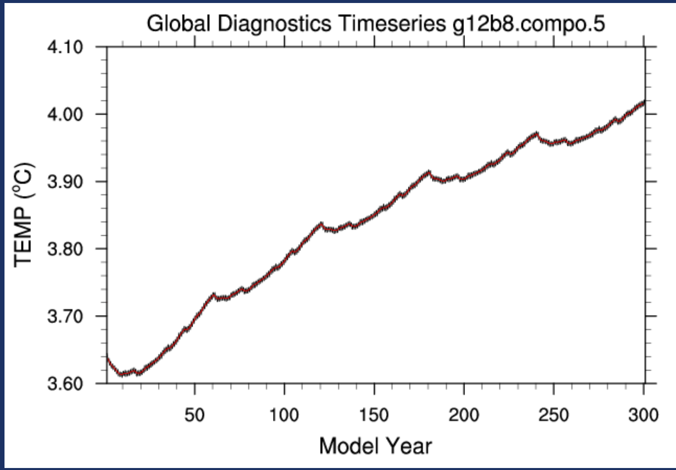
CORE





20CRv2

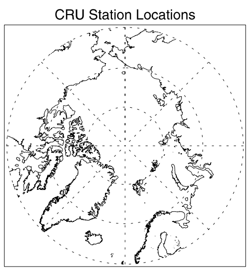


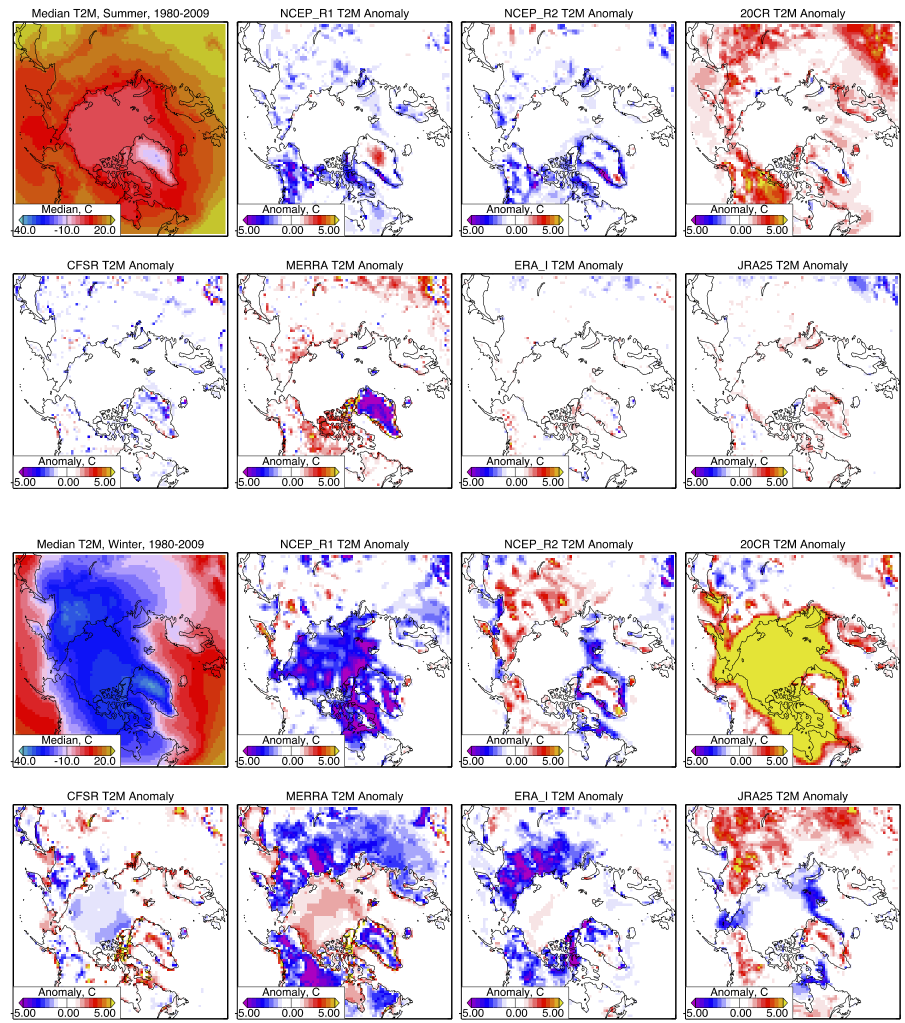


Evaluation of Seven Different Atmospheric Reanalysis Products in the Arctic*

R. LINDSAY, M. WENSNAHAN, A. SCHWEIGER, AND J. ZHANG

Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle, Washington



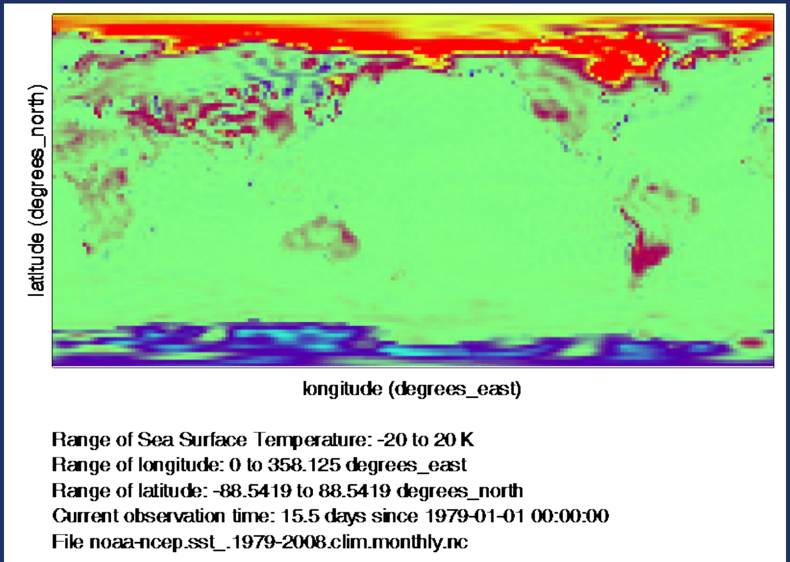


f each eight-
map set and the deviation from the median for each of the models is in the subsequent maps.

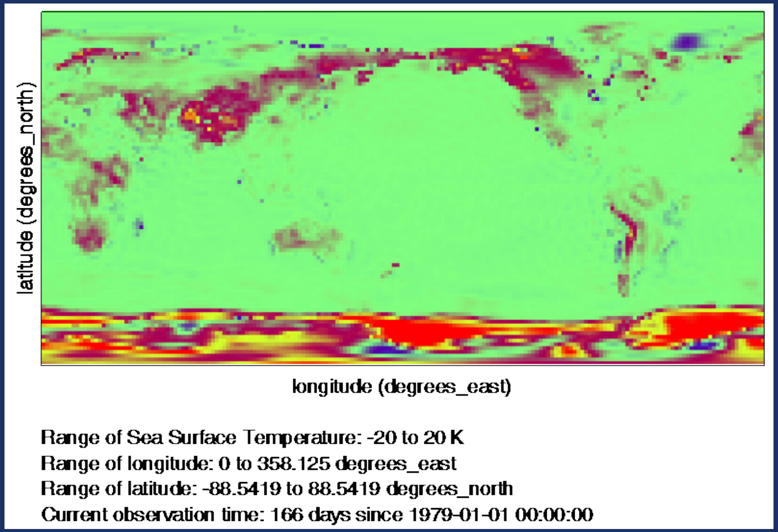
There is a problem with how sea ice is treated in the 20CR model, particularly in coastal regions where the sea ice concentration is often much less than observed. Compo et al. (2011) acknowledge the problem and report that it influences the lower tropospheric temperature structure in both polar regions, creating a warm bias compared to other reanalysis products during the cold seasons. As a result the 20CR is the most notable outlier for many of the variables considered but for others, particularly in the summer when the temperature difference is minimal, the ice concentration error is less significant and meaningful comparisons can be made.

Climatological bias relative to NCEP (20CRv2 – NCEP):

NH winter 10m air temperature



SH winter 10m air temperature



→ removed climatological 6-hourly air temperature <u>and humidity</u> bias from 20CRv2: $\Delta t10(x,y,1460)$, $\Delta q10(x,y,1460)$ poleward of 60^o

Challenges

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- Excessive Gibbs ringing in the wind field
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- Large positive biases in polar air temp/humidity
- AMOC stability

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- Correct treatment of ensemble (N=56) to avoid spurious wind speed trends
- Large positive biases in polar air temp/humidity
- AMOC stability

➔ 6-month salinity restoring timescale needed to prevent AMOC collapse when spinning up with pre-1900 forcing

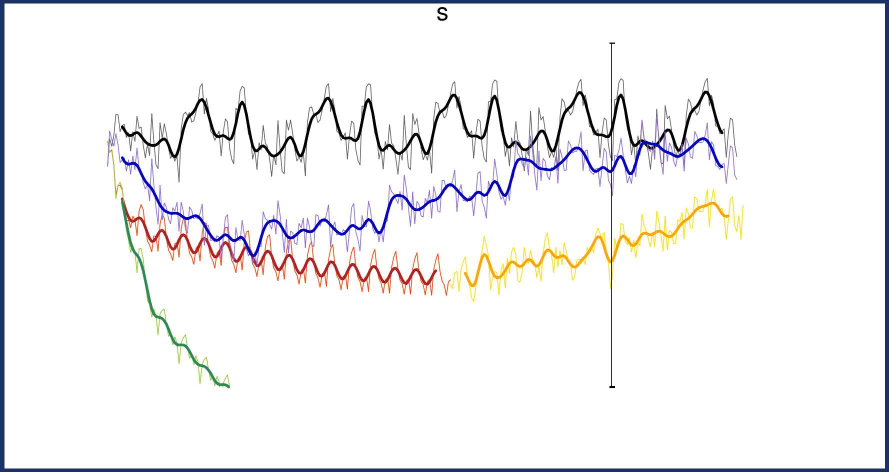
Results

- With:
  - Adjustments to 20CRv2: u10, v10, t10, q10, SWDN, LWDN
  - Correct treatment of ensemble mean ws10
  - Enhanced salinity restoring

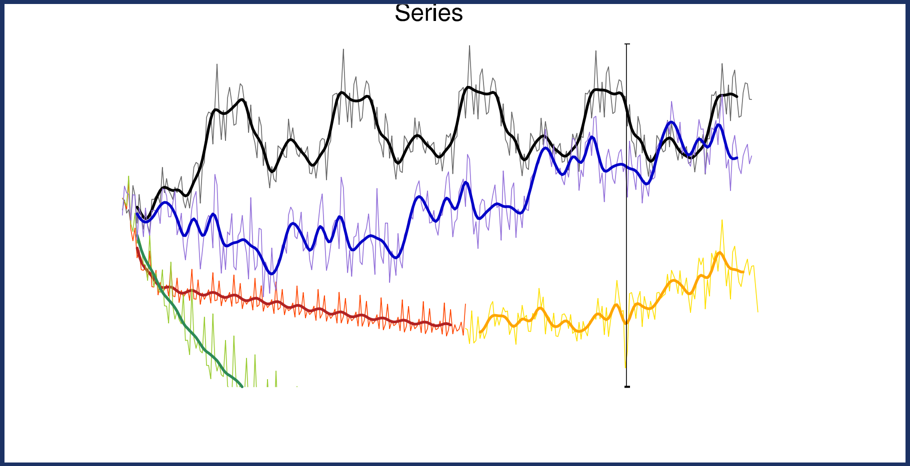
  can obtain reasonable ocean/sea-ice solution that is comparable to CORE

AMOC

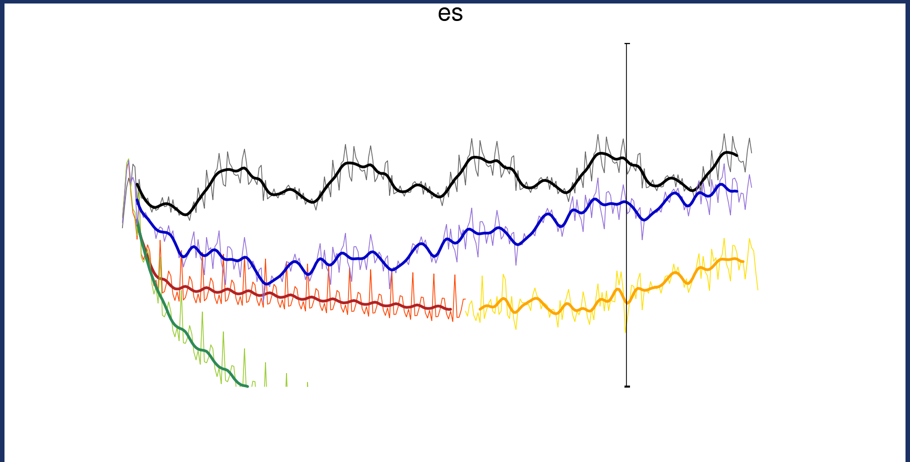
45^{o}N



35^{o}N



26.5^{o}N



CORE
(5 cycles 1948-2007)

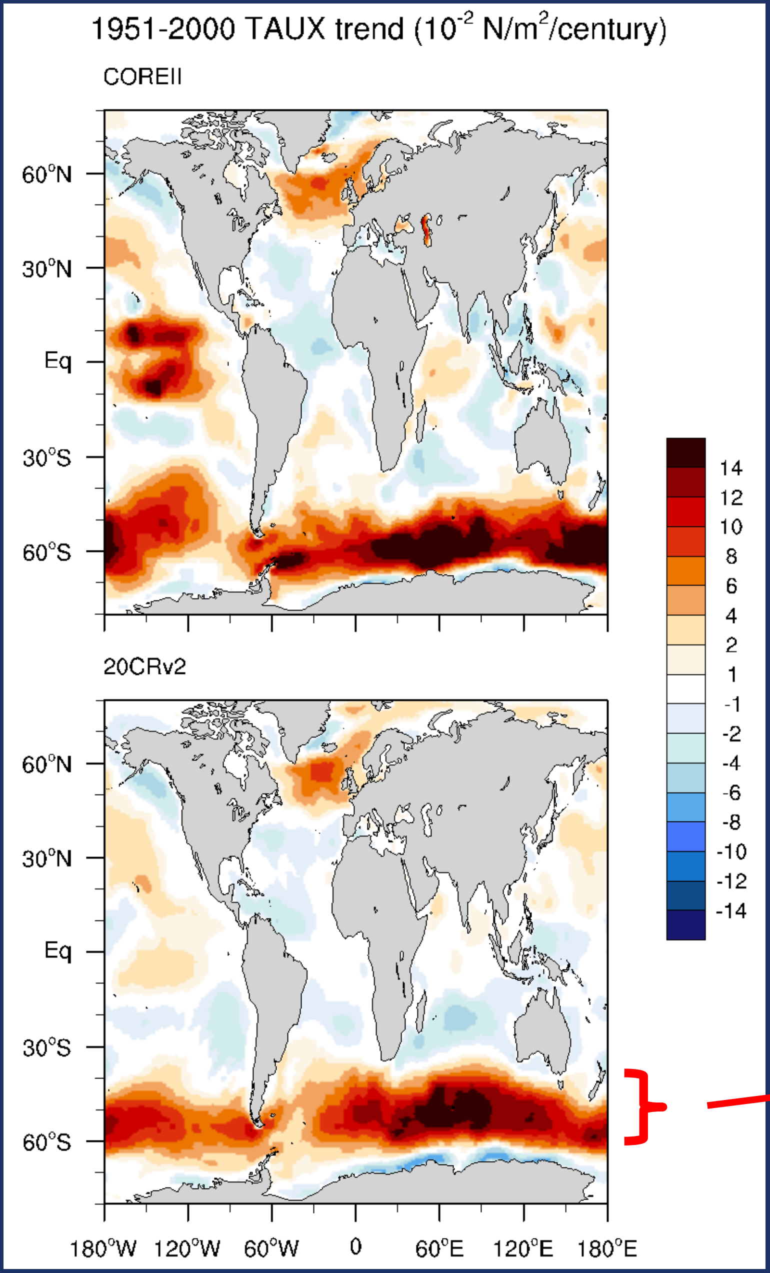
20CRv2
(5 cycles 1948-2007; all corrections; 4-year restoring)

20CRv2
(repeat 1871-1880 forcing; all corrections; 4-year restoring)

20CRv2
(repeat 1871-1880 forcing; all corrections; 6-month restoring)

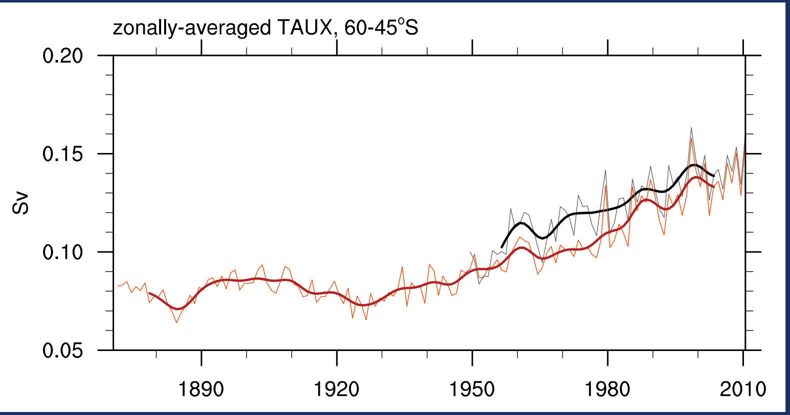
20CRv2
(1871-2010 forcing; all corrections; 6-month restoring)

Wind Stress

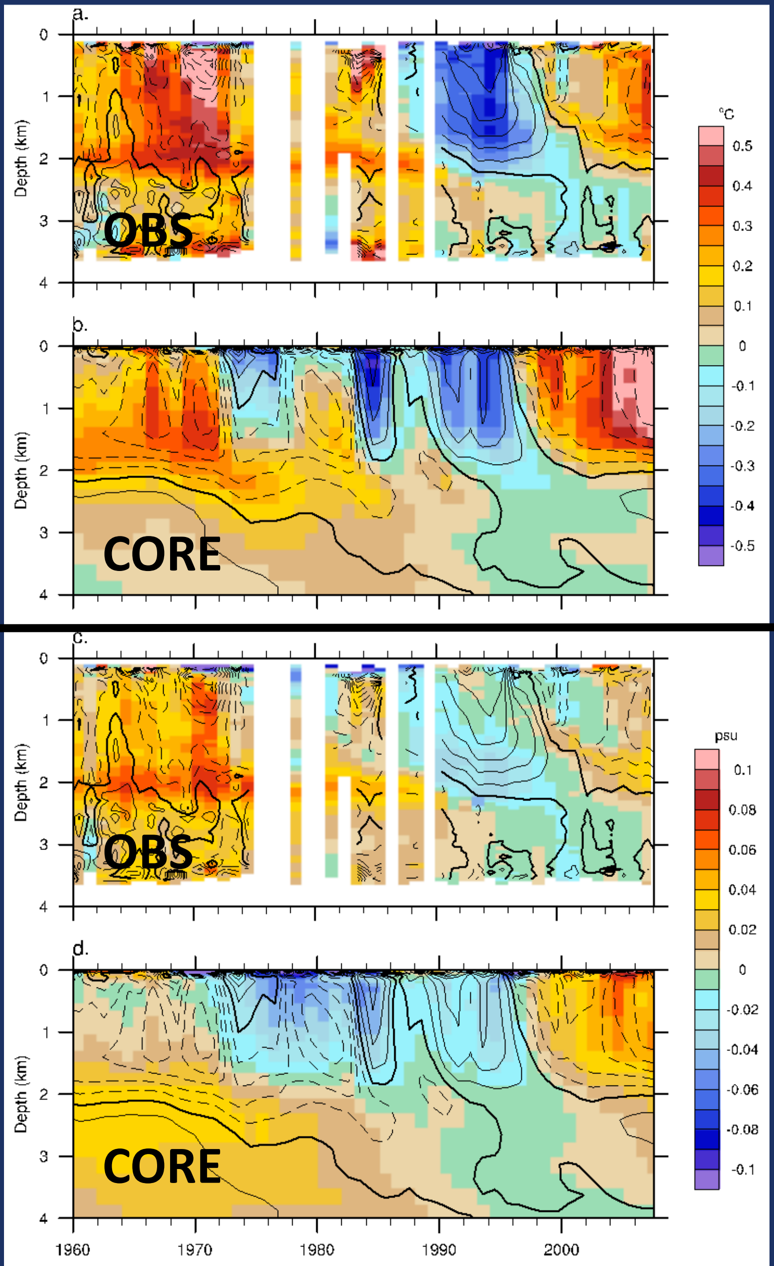


- ✓ Positive 20th century AMOC trend in 20CRv2 appears to be related to century-long increase in Southern Ocean wind stress (Lee et al., 2011)

- Is this trend plausible? Is the (parameterized) eddy overturning in the Southern Ocean too weak? Is N. Atlantic buoyancy forcing adequately represented?

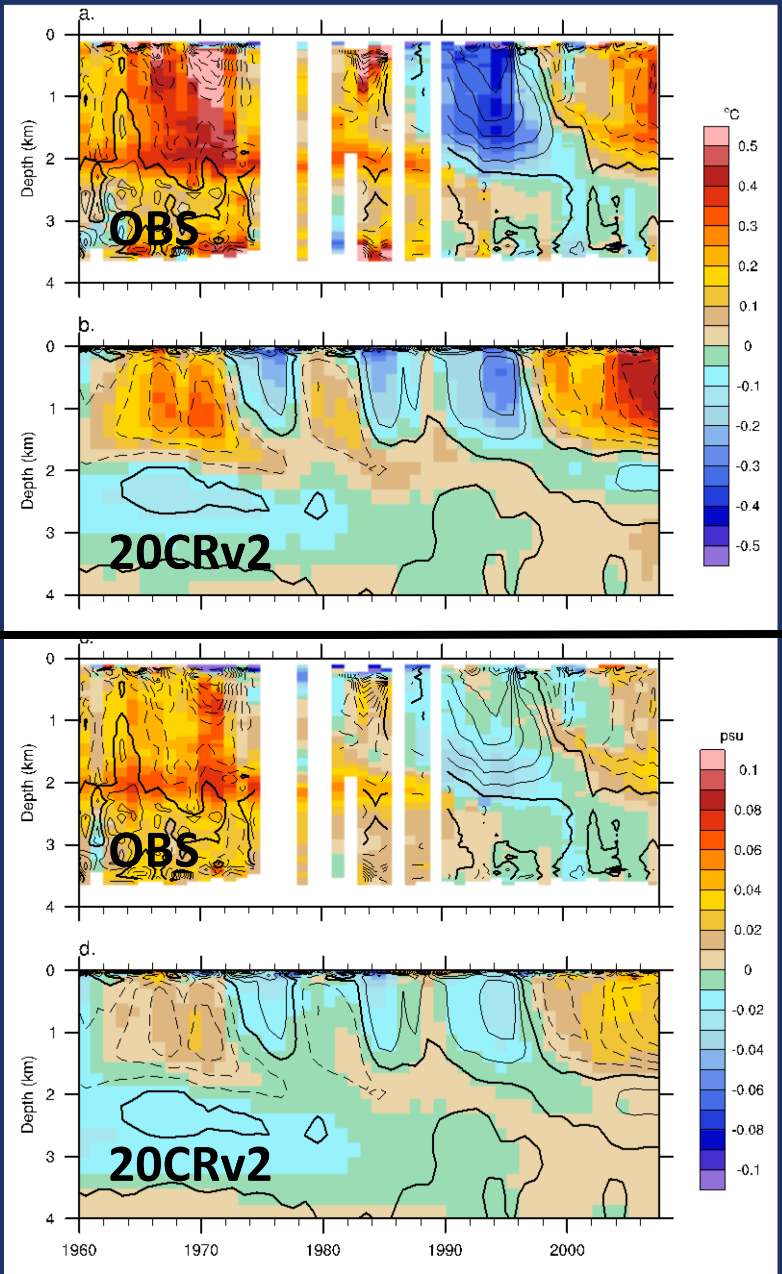


Labrador Sea hydrography



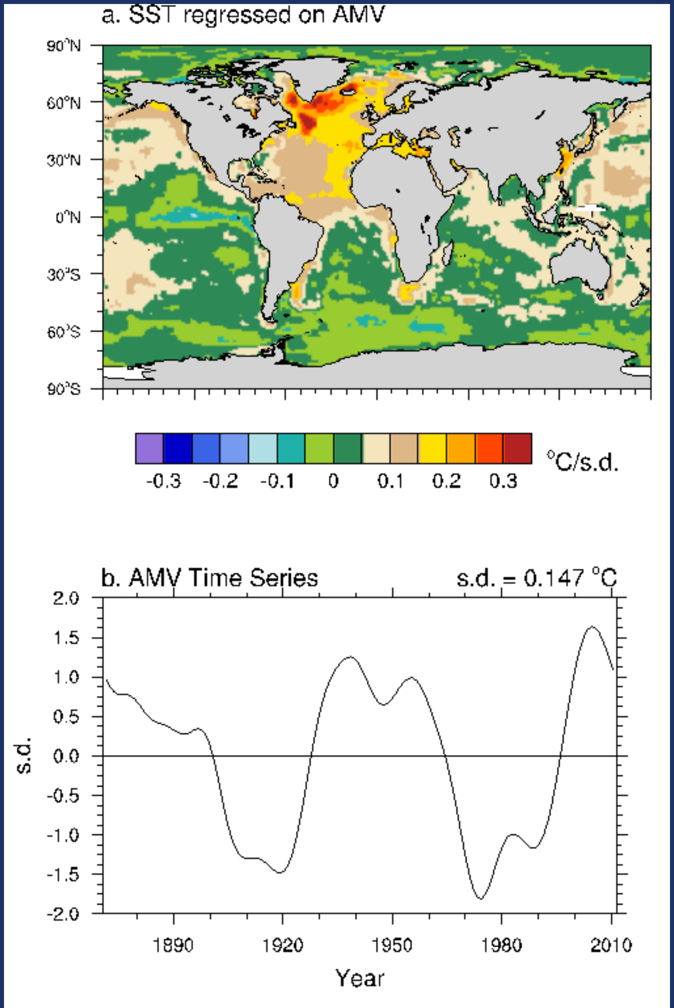
T (color)
σ (contour)

S (color)
σ (contour)

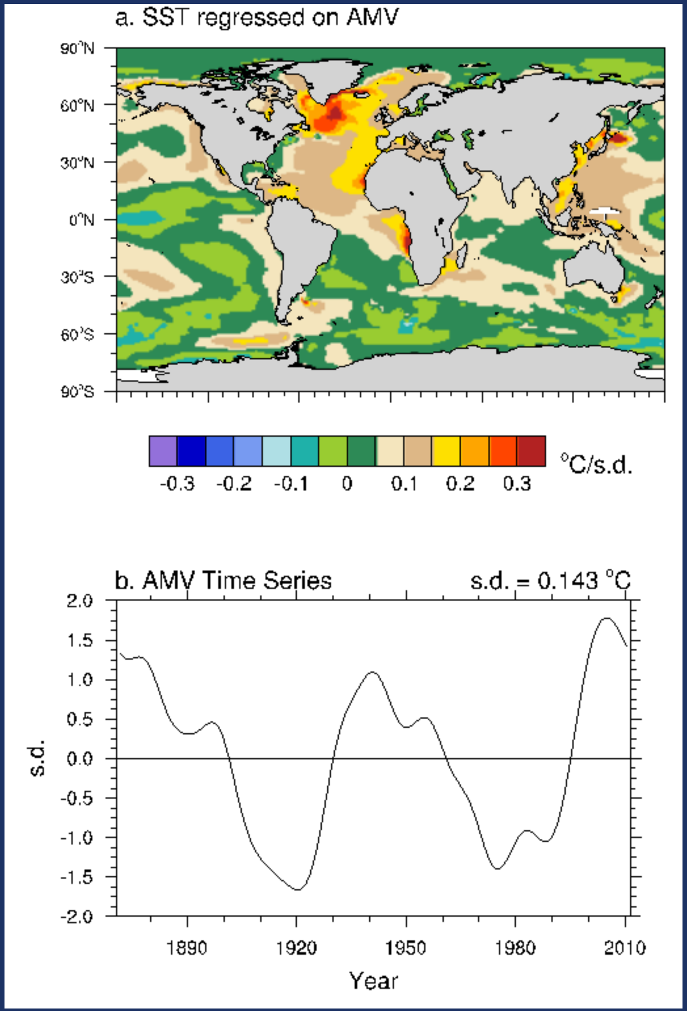


AMV

OBS

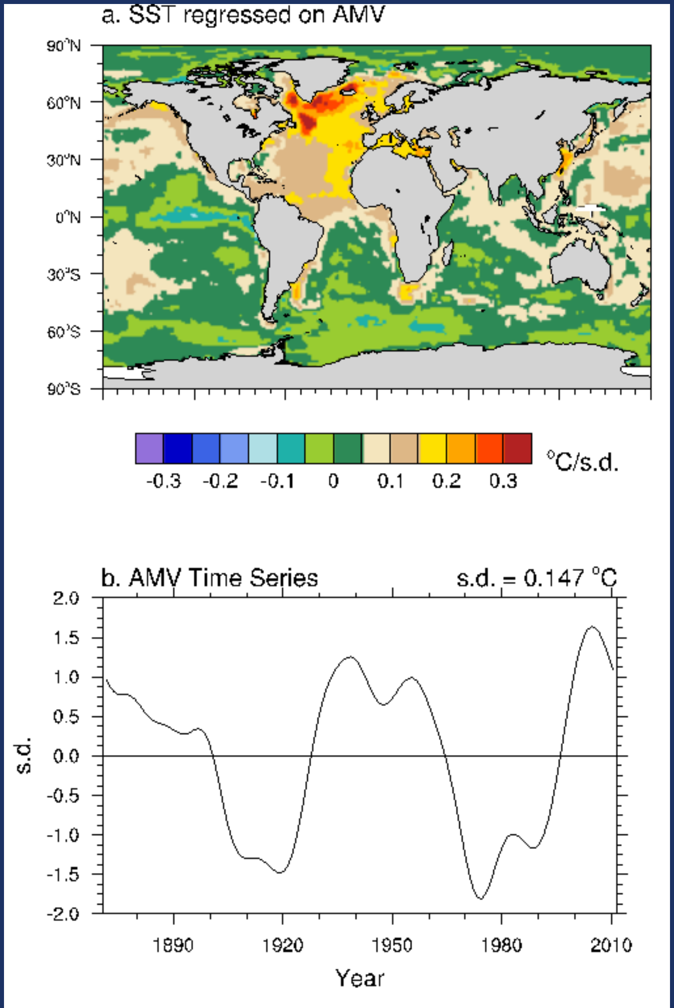


20CRv2

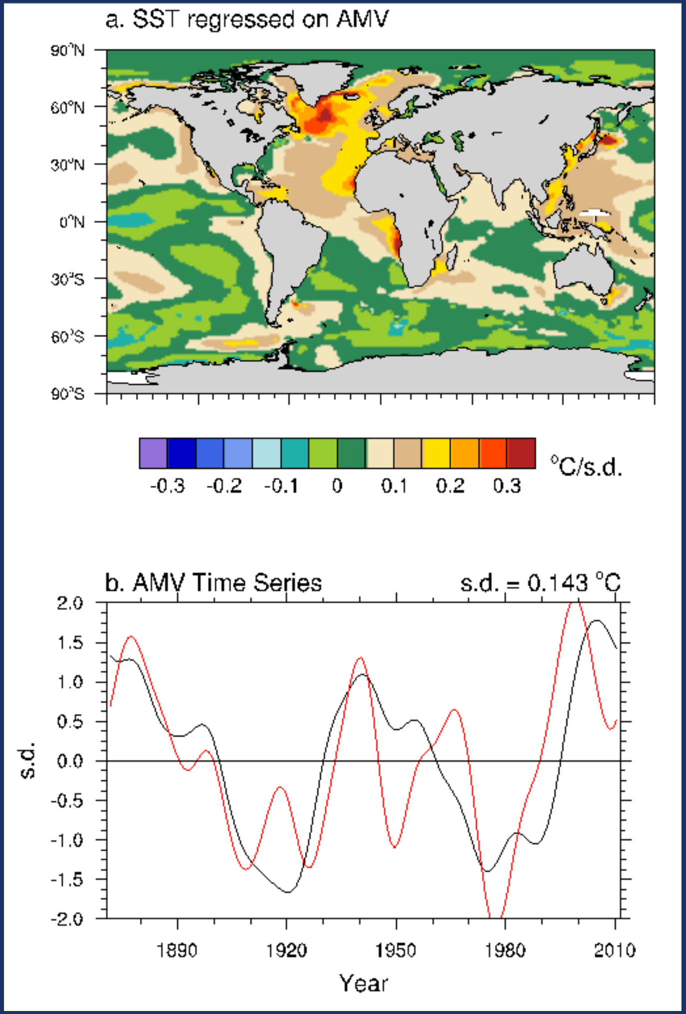


AMV

OBS



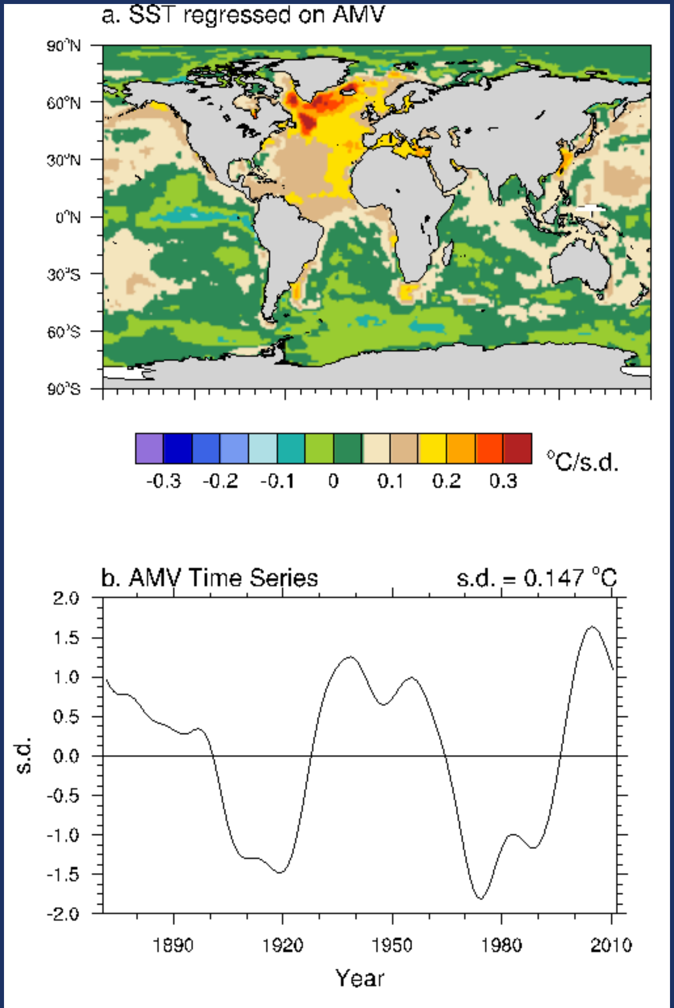
20CRv2



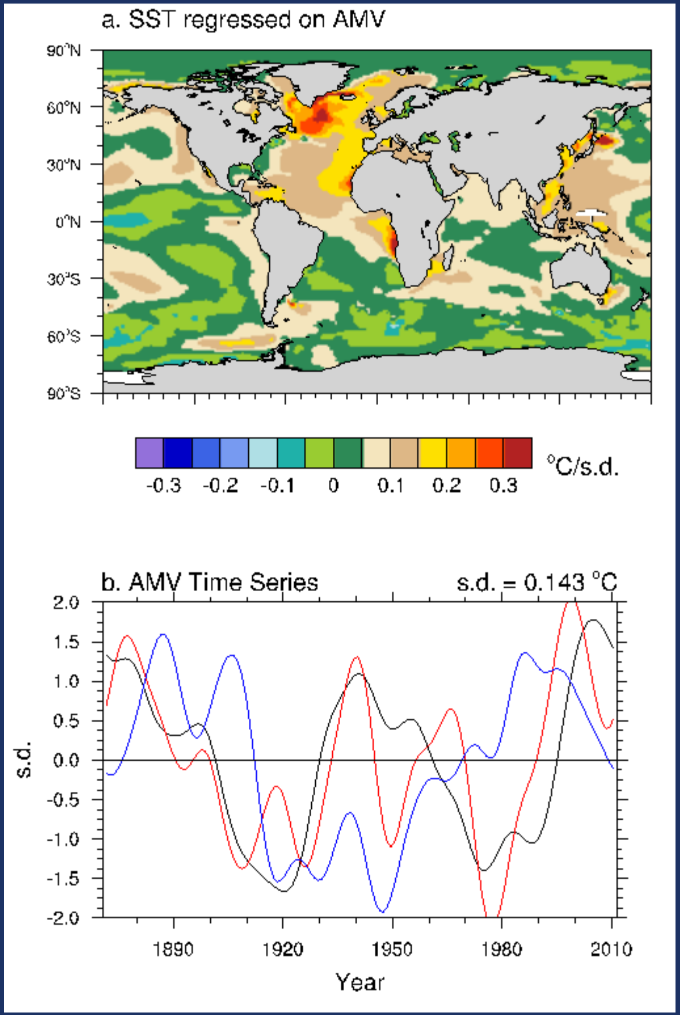
NHT (40-50ºN)

AMV

OBS



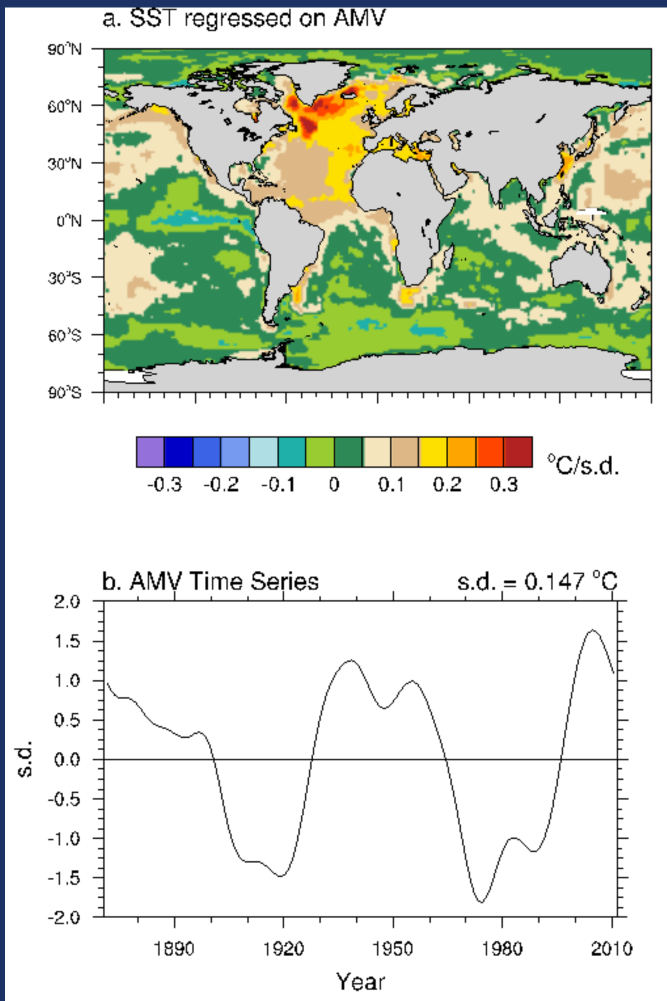
20CRv2



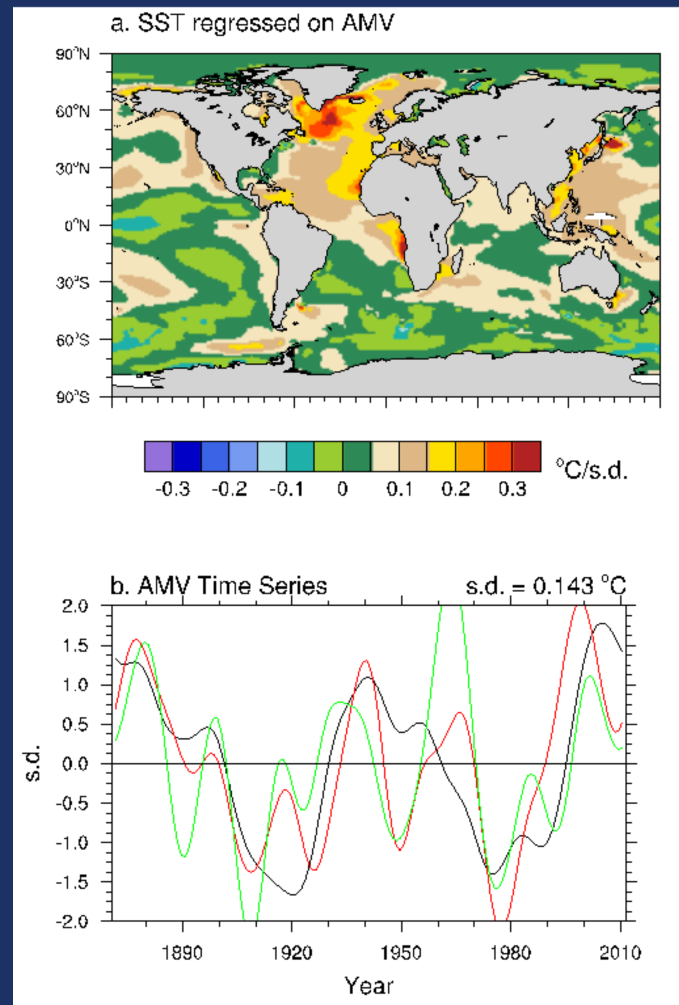
NHT (40-50°N)
MOC (40-50°N)

AMV

OBS



20CRv2

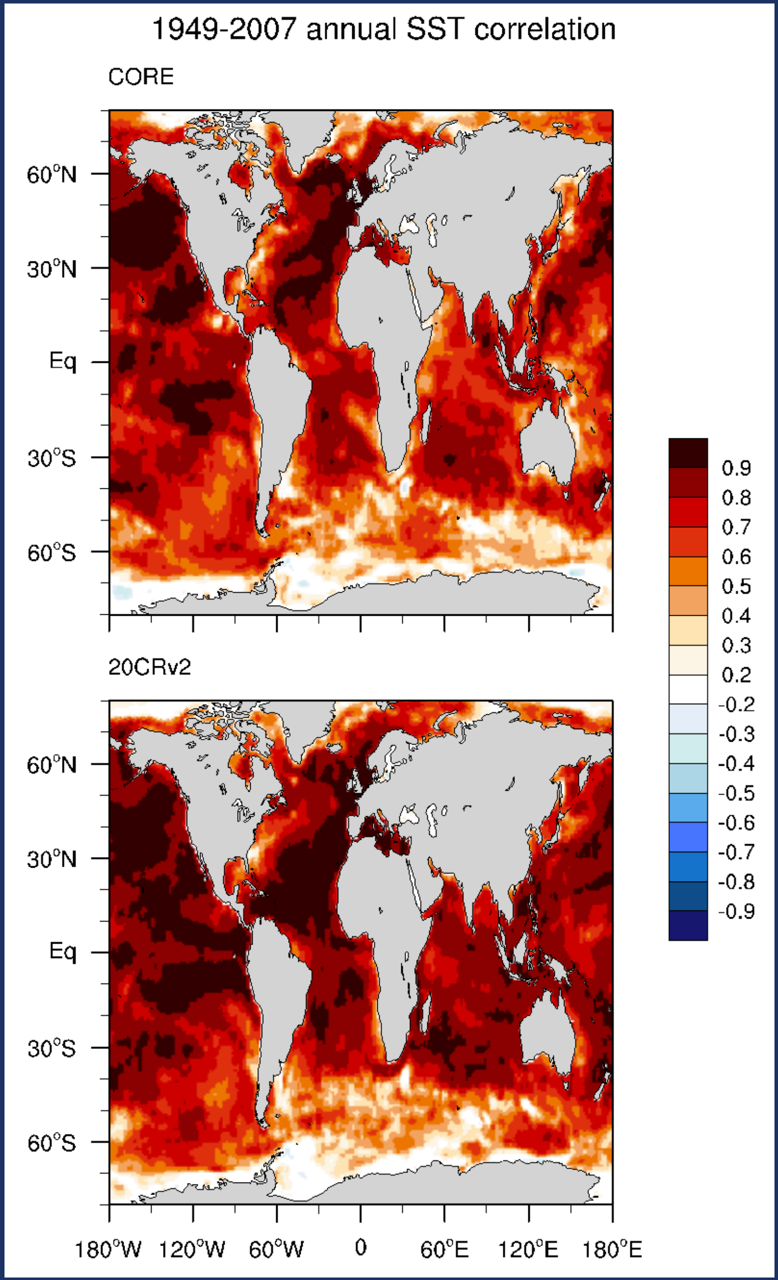


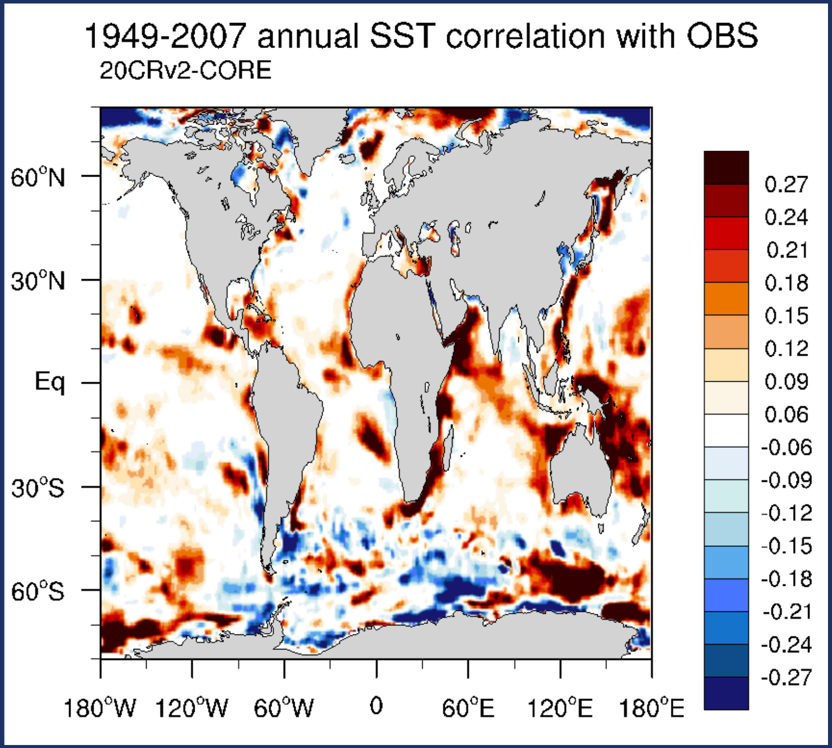
NHT (40-50°N)
BSF (40-50°N, 50-35°W)

SST

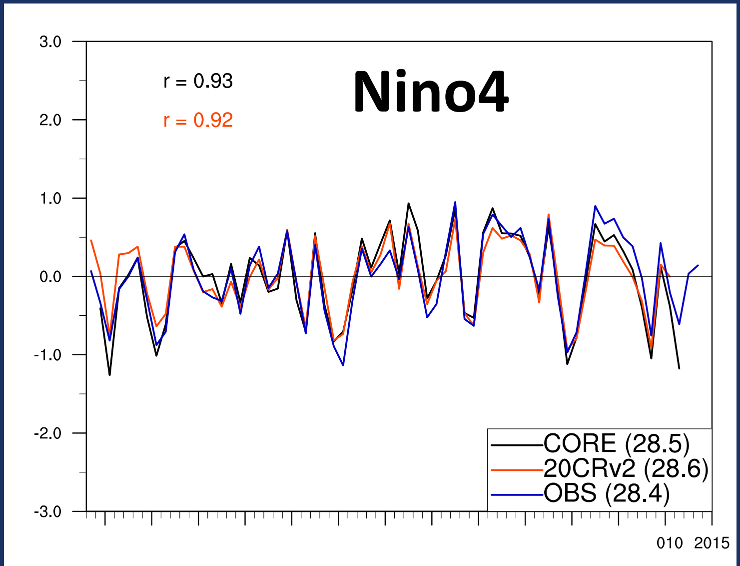
CORE

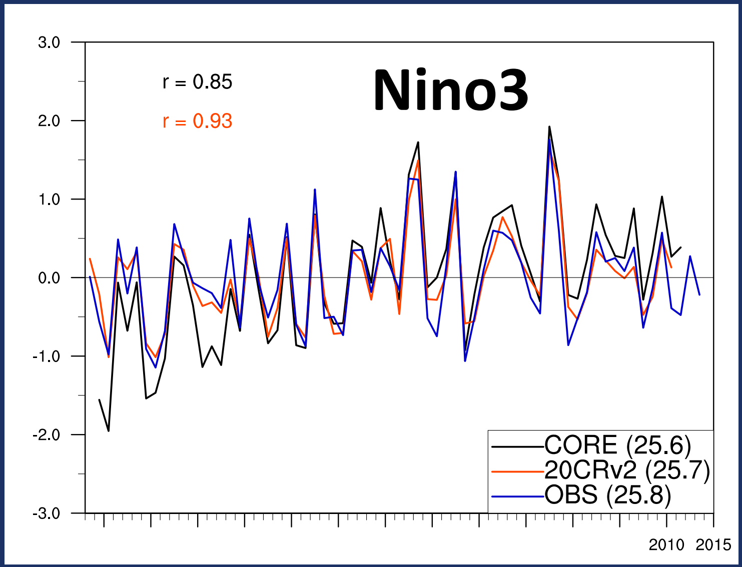
20CRv2

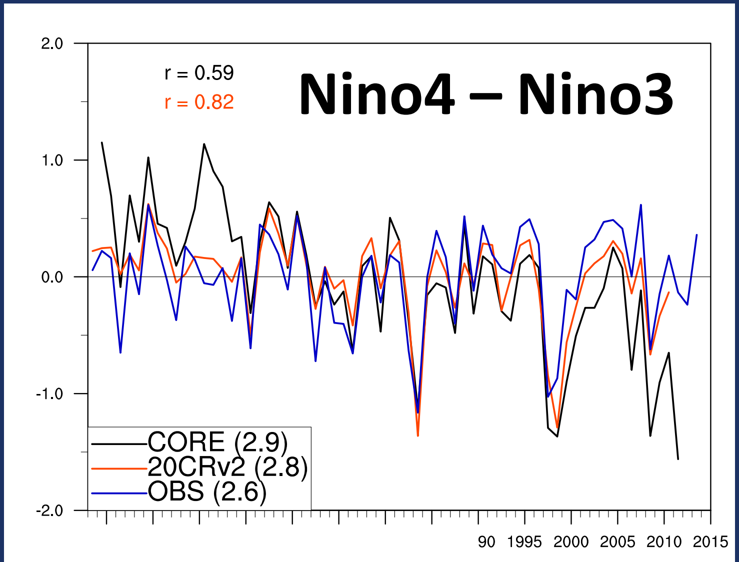


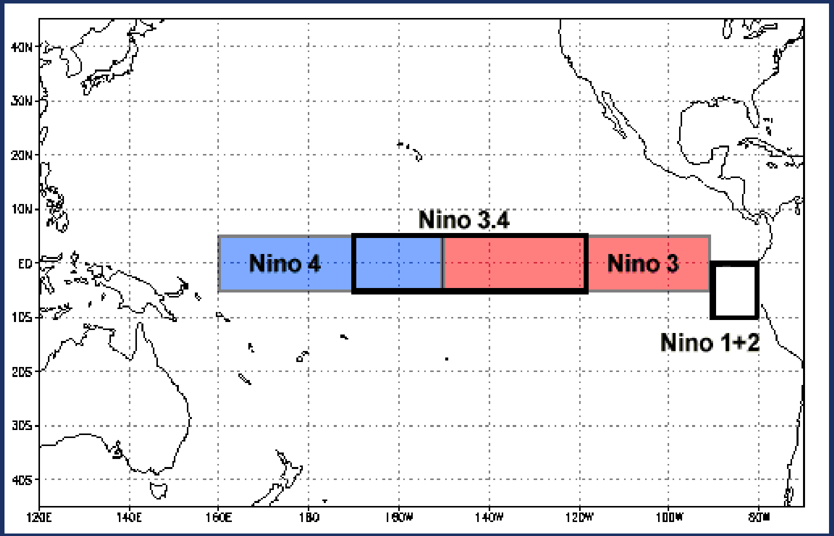


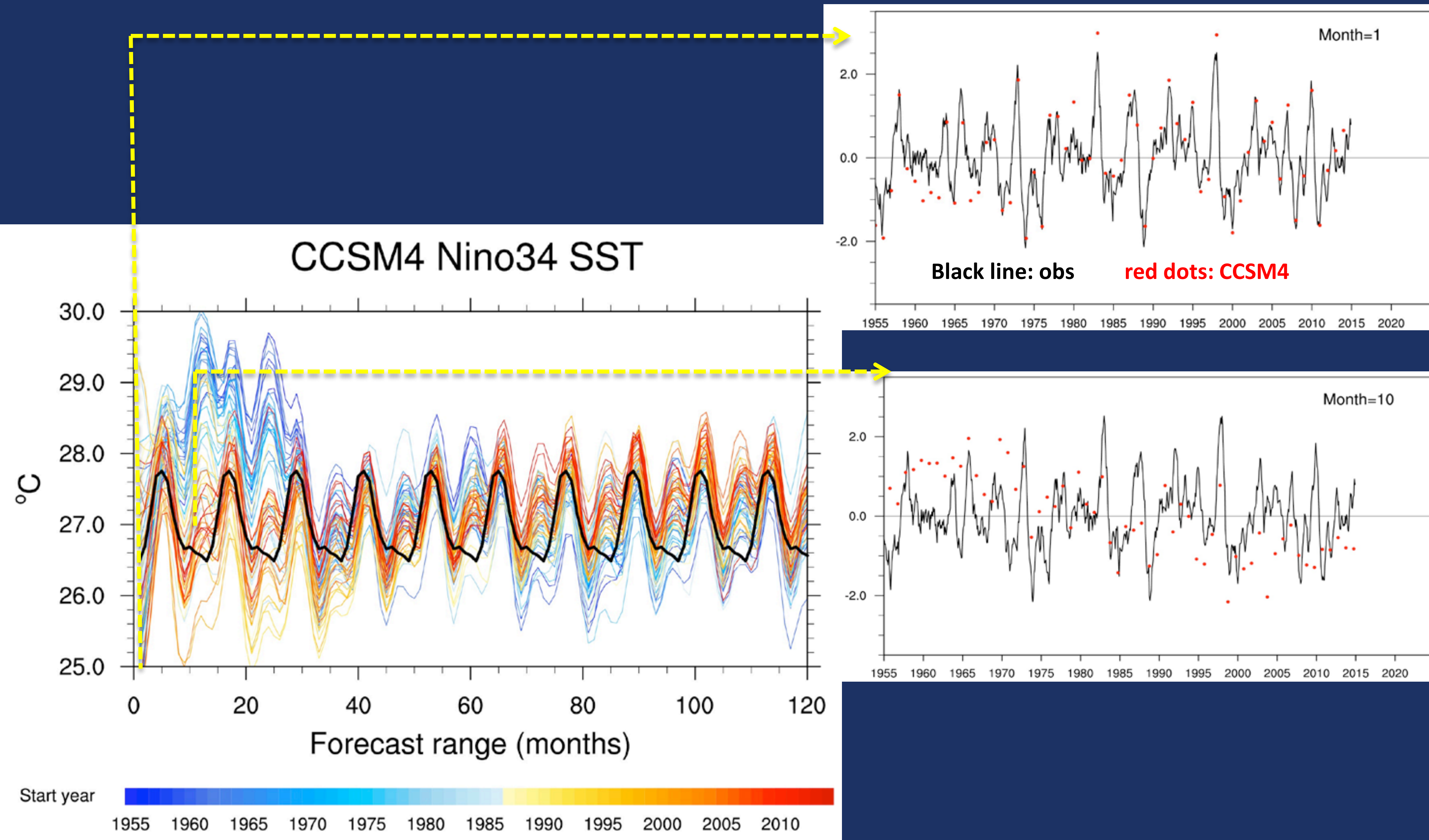
Equatorial Pacific SST











courtesy Haiyan Teng

Conclusions

- With:
  - Adjustments to 20CRv2: u10, v10, t10, q10, SWDN, LWDN
  - Correct treatment of ensemble mean ws10
  - Enhanced salinity restoring

  can obtain reasonable 20CRv2 ocean/sea-ice solution that is comparable to CORE

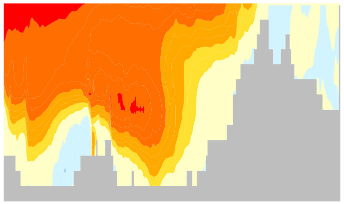
- Preliminary AMOC analysis suggests that N. Atlantic buoyancy forcing is too weak in 20CRv2, with Southern Ocean winds driving a large positive trend over the 20th century.

- Observed AMV fluctuations from 1871-present are skillfully reproduced, with hints that ocean dynamical changes are playing a role.

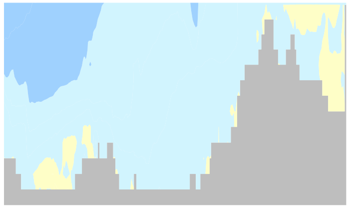
- 20CRv2 shows more realistic SST variability than CORE in low latitudes, notably in the Equatorial Pacific. This highlights potential issues with wind variability in CORE ➔ important implications for CESM decadal prediction.

AMOC

Raw AMOC EOFs

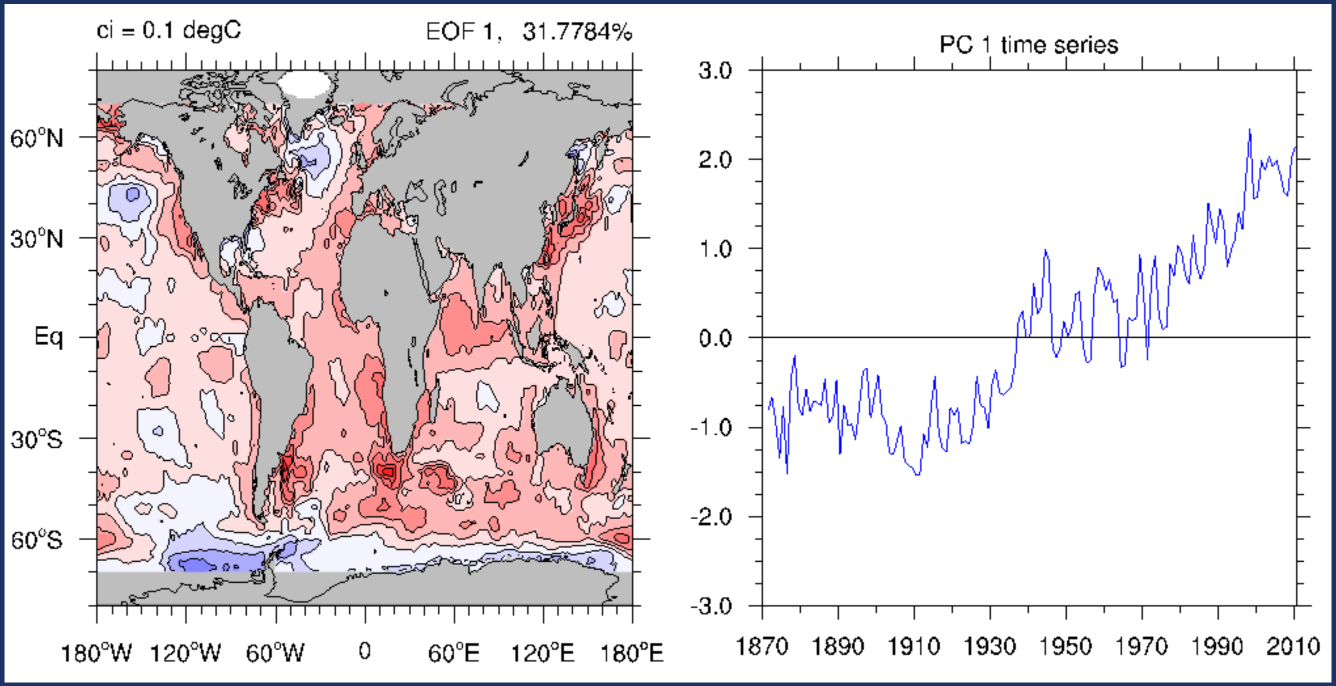


detrended AMOC EOFs



SST
EOF 1

OBS



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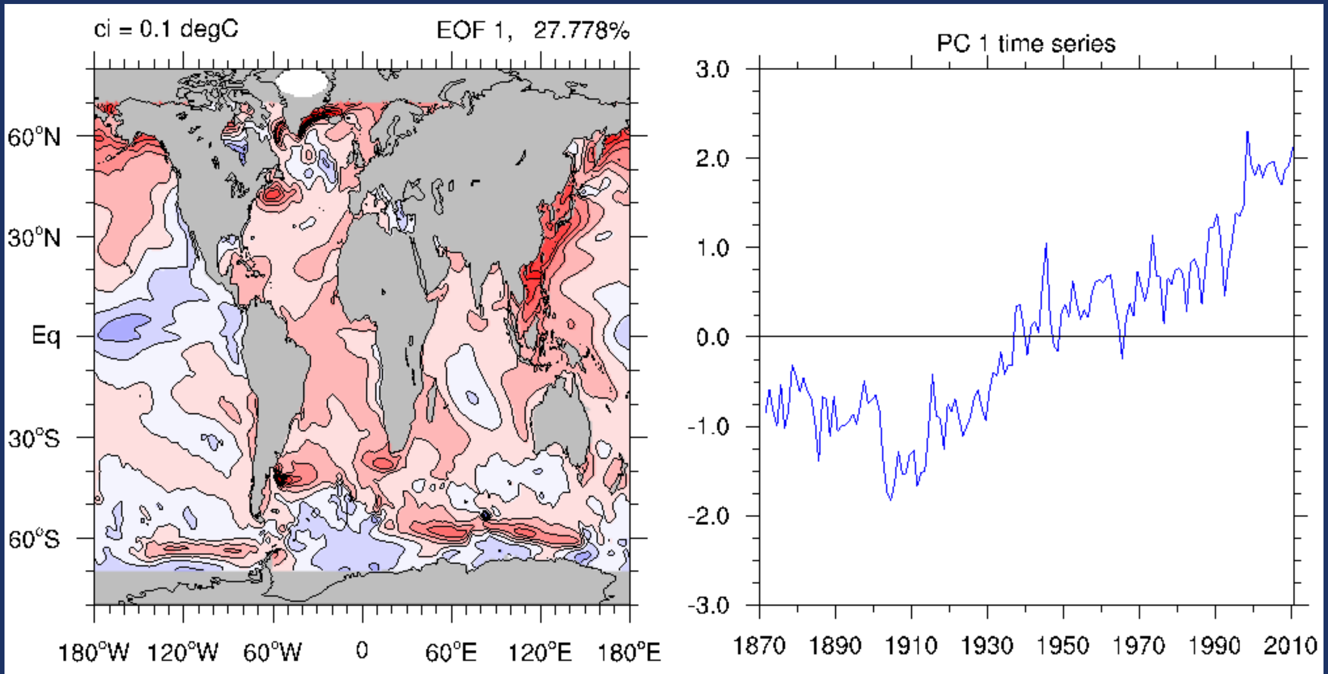

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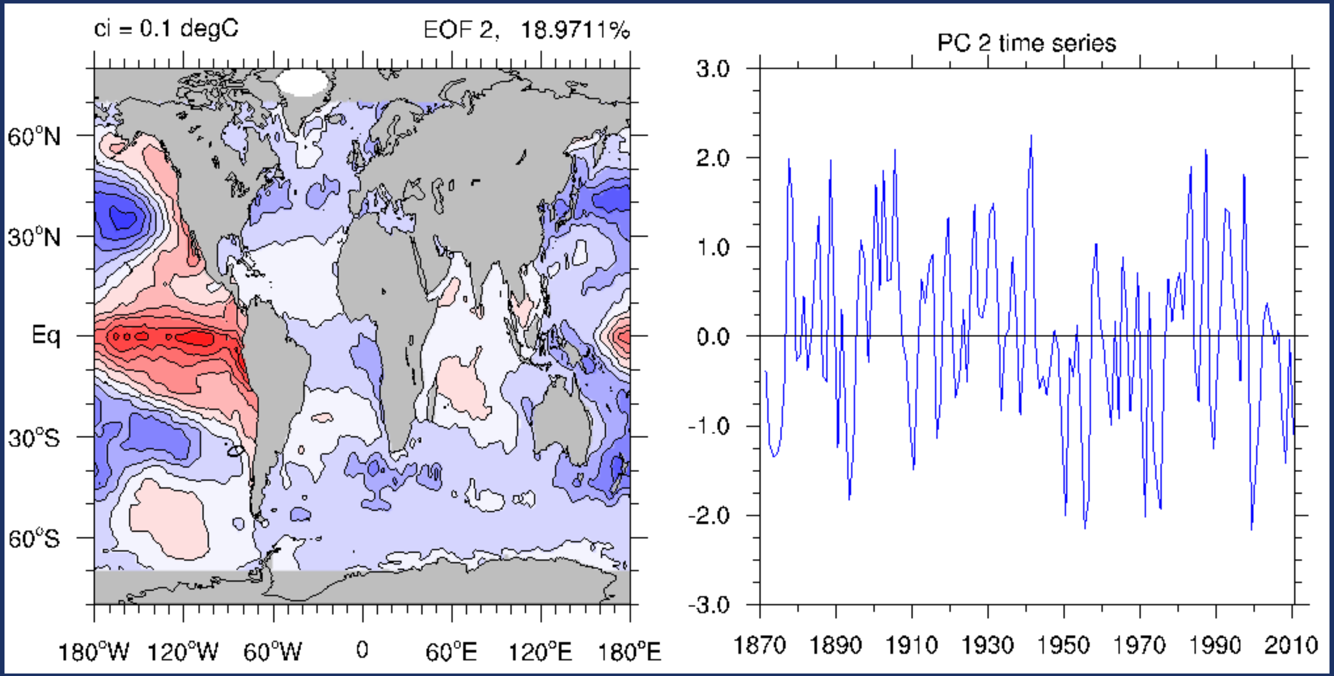

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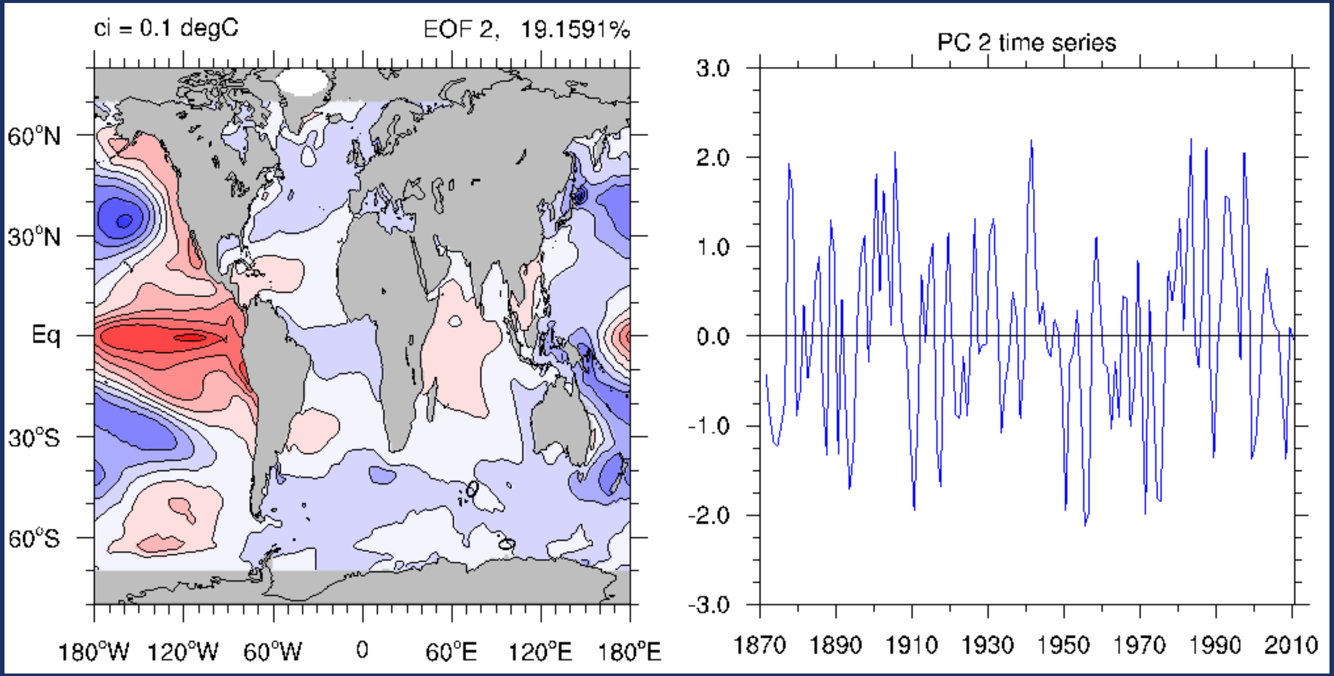

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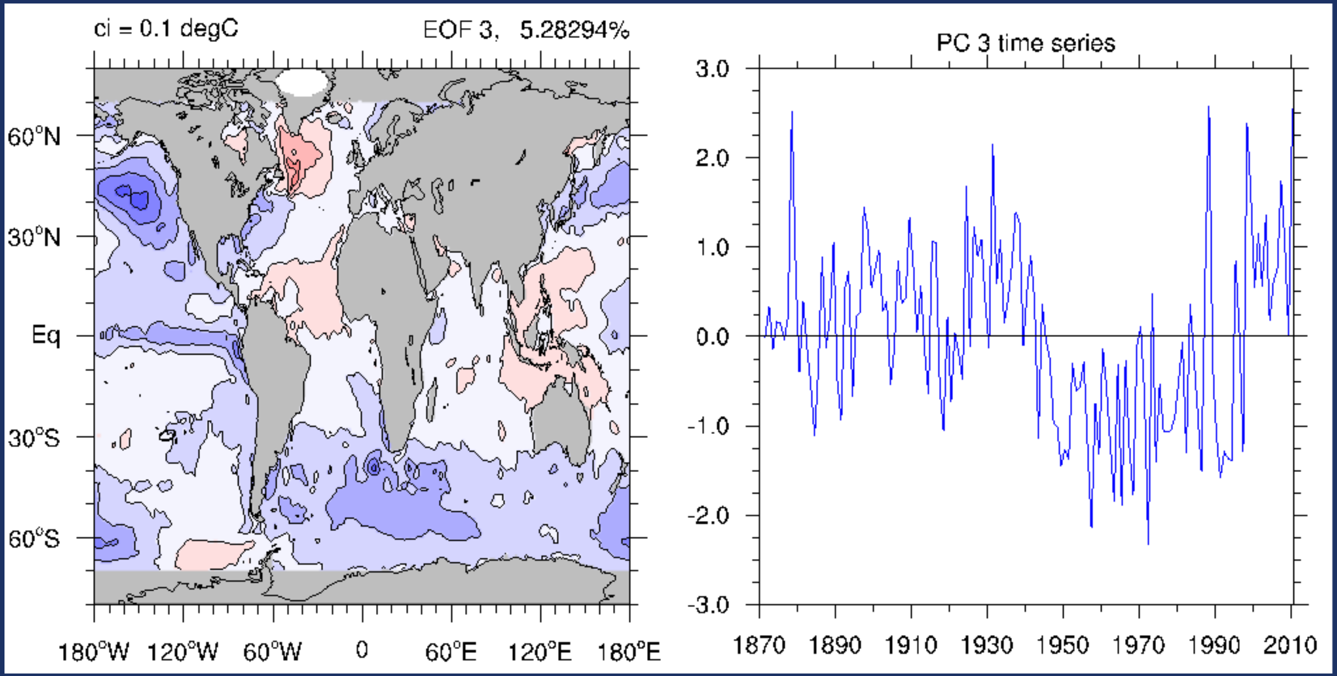

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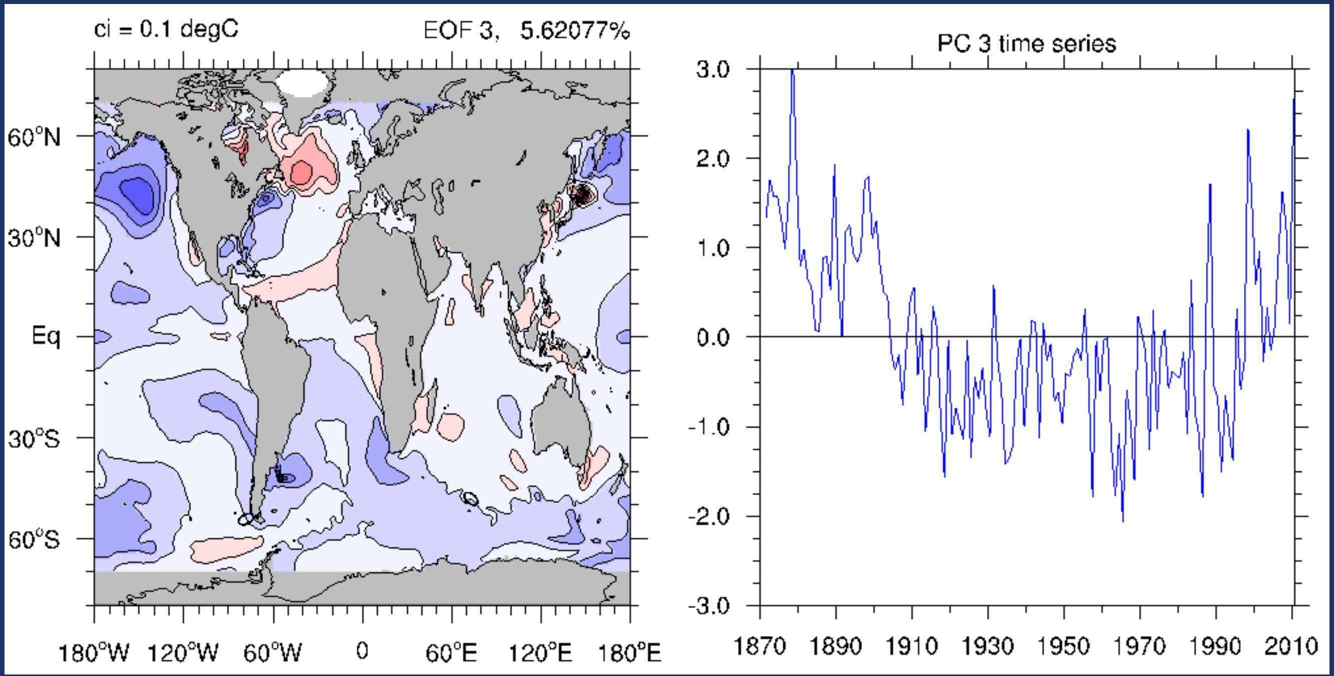

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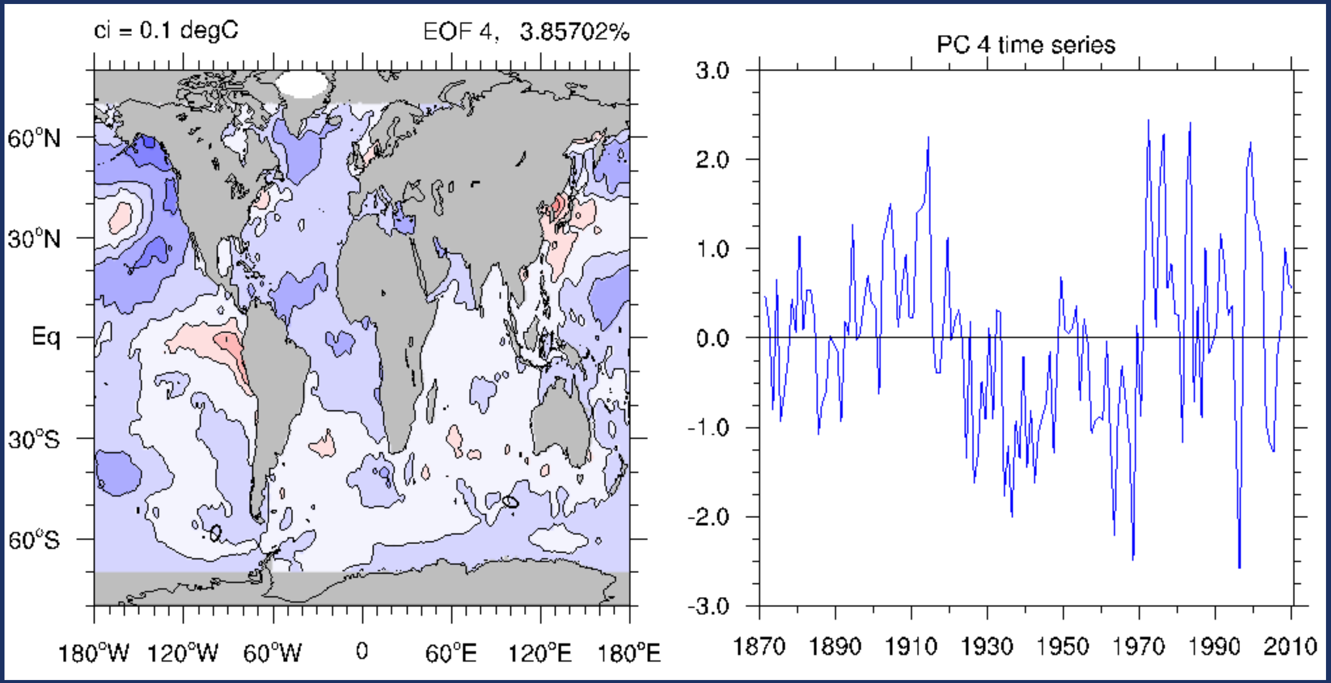

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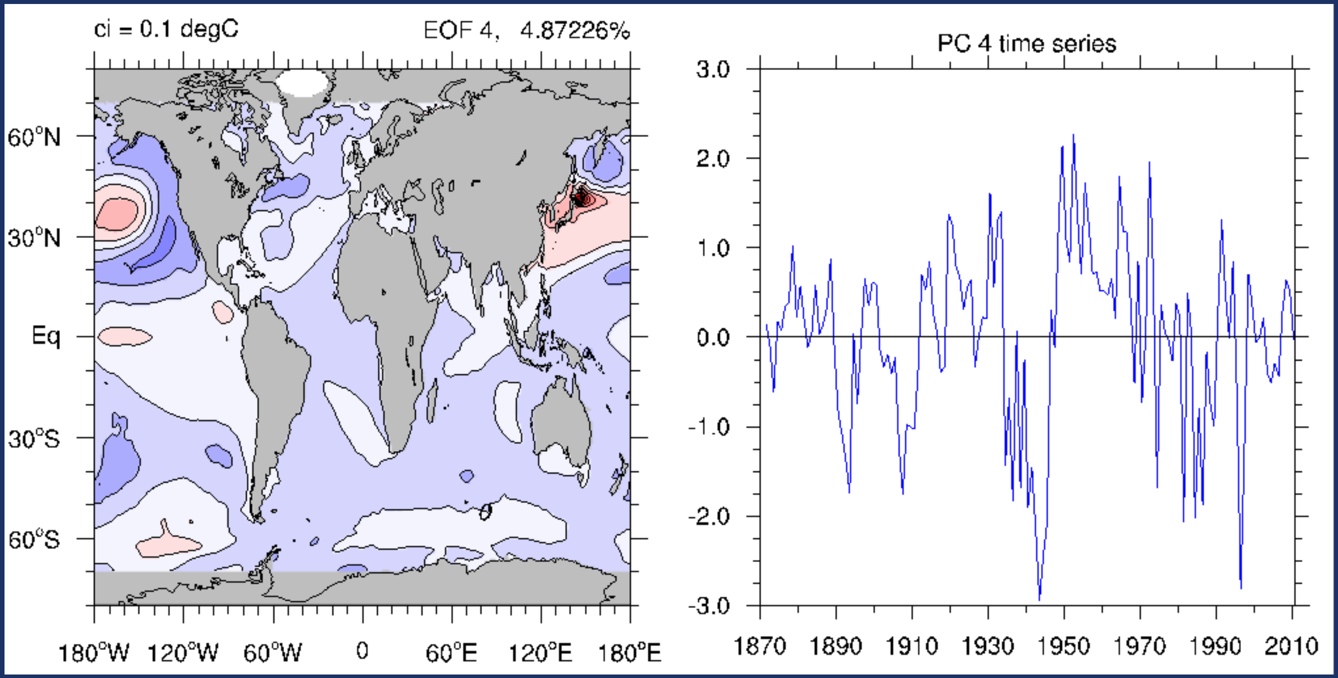

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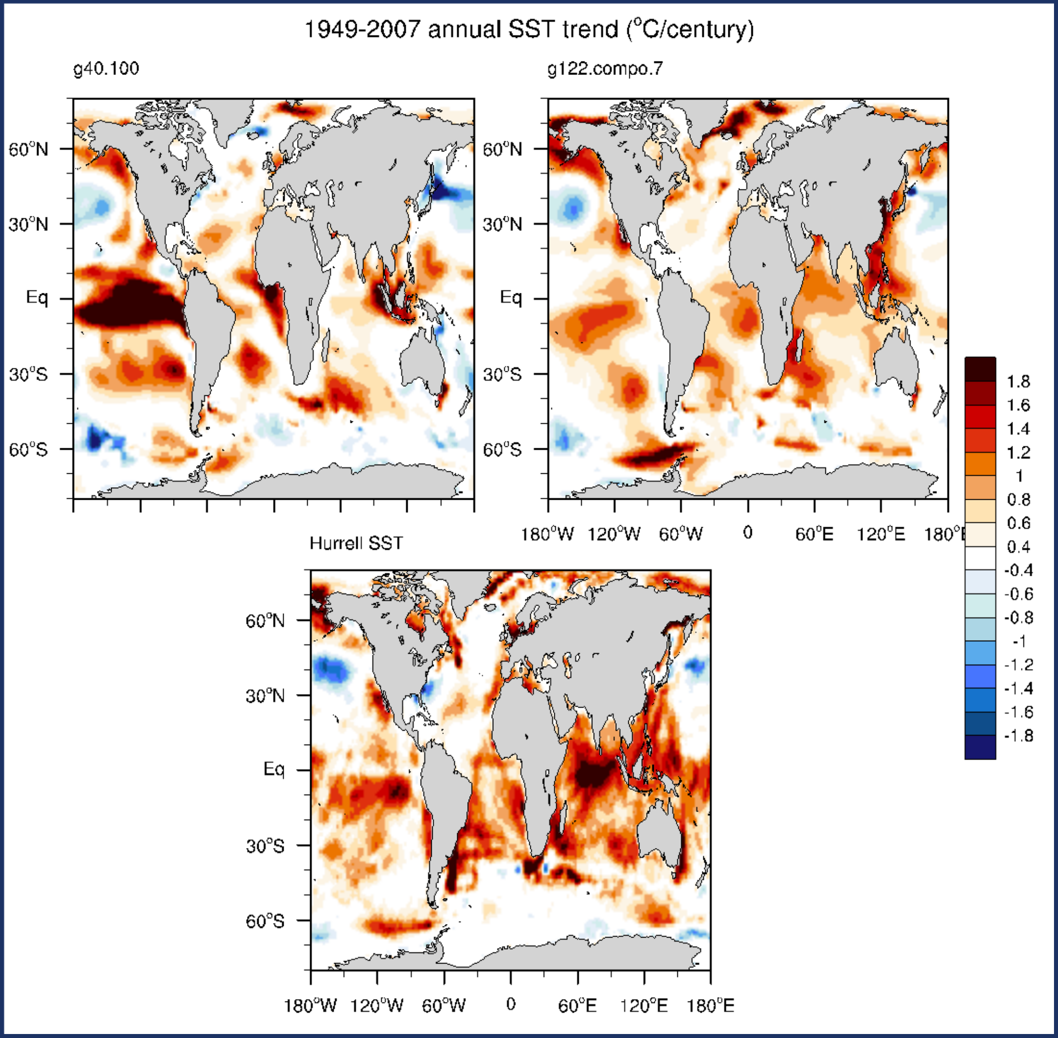

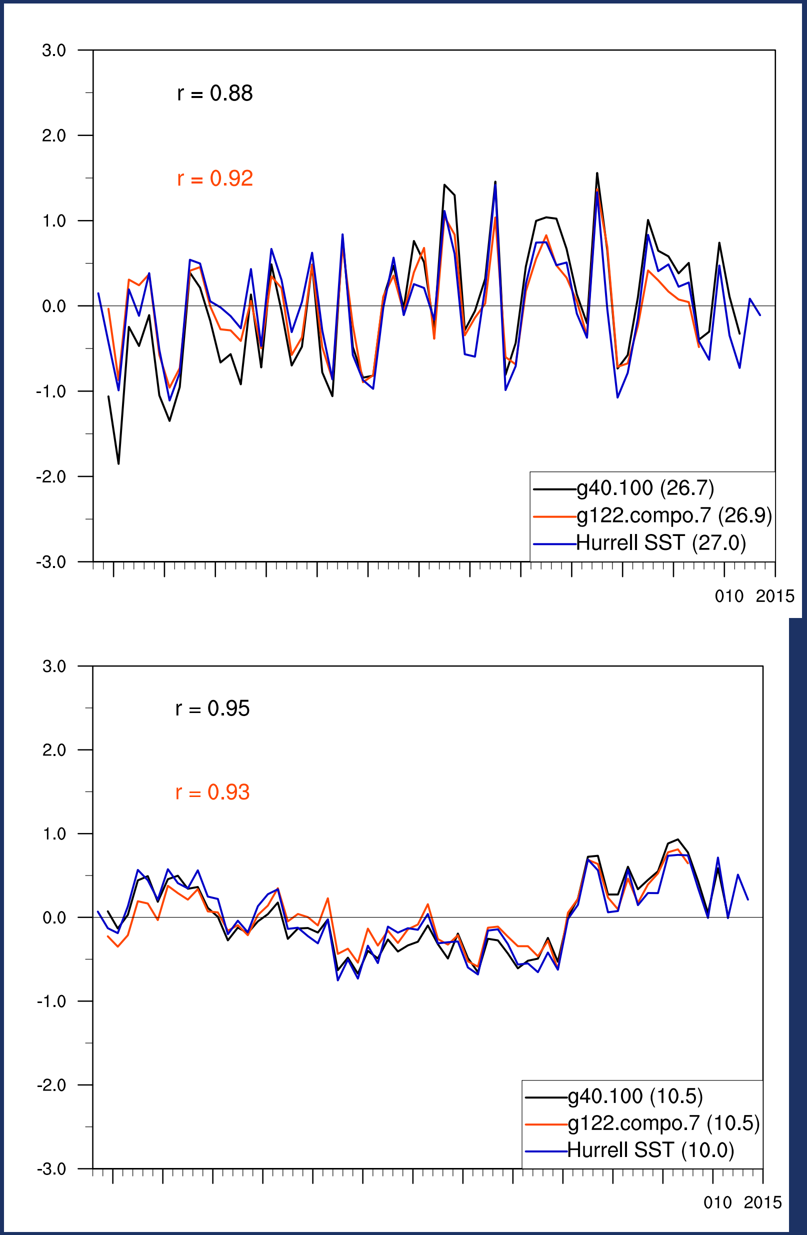

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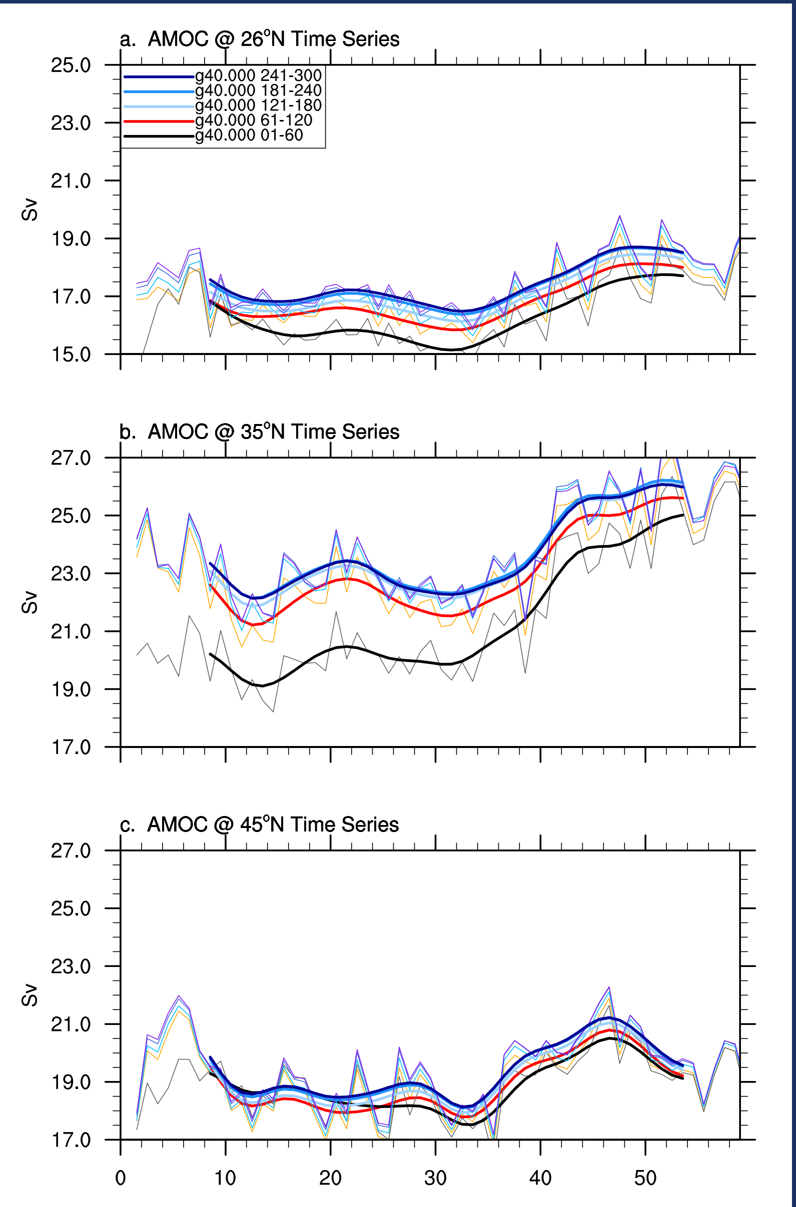

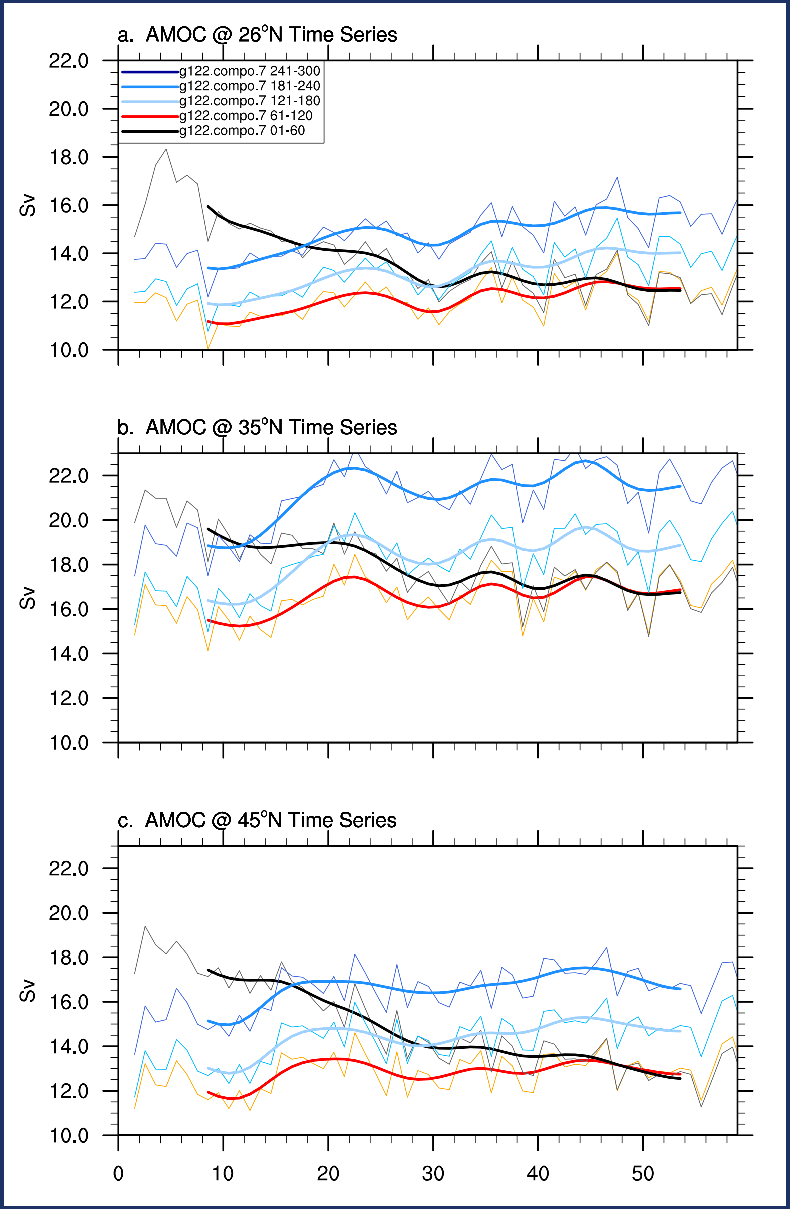

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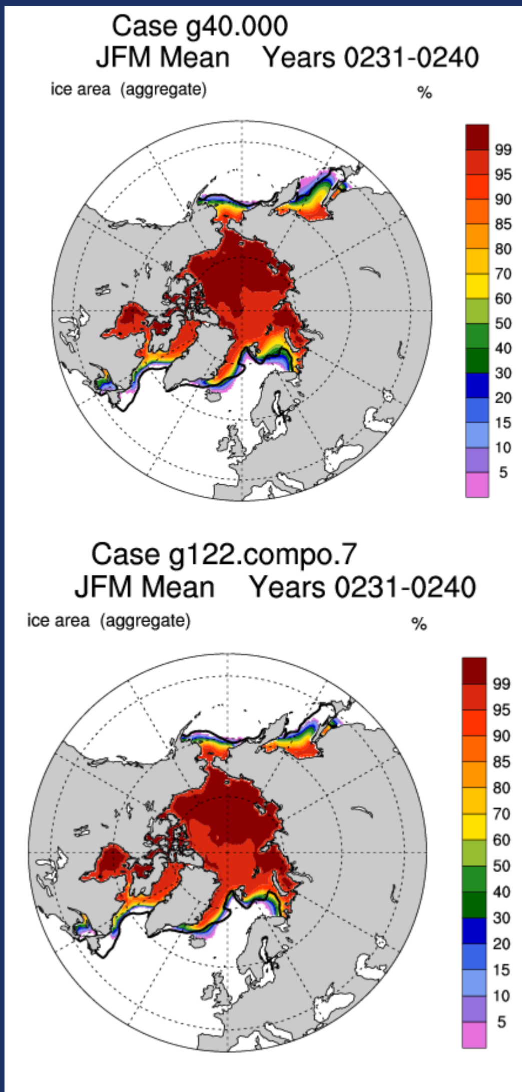

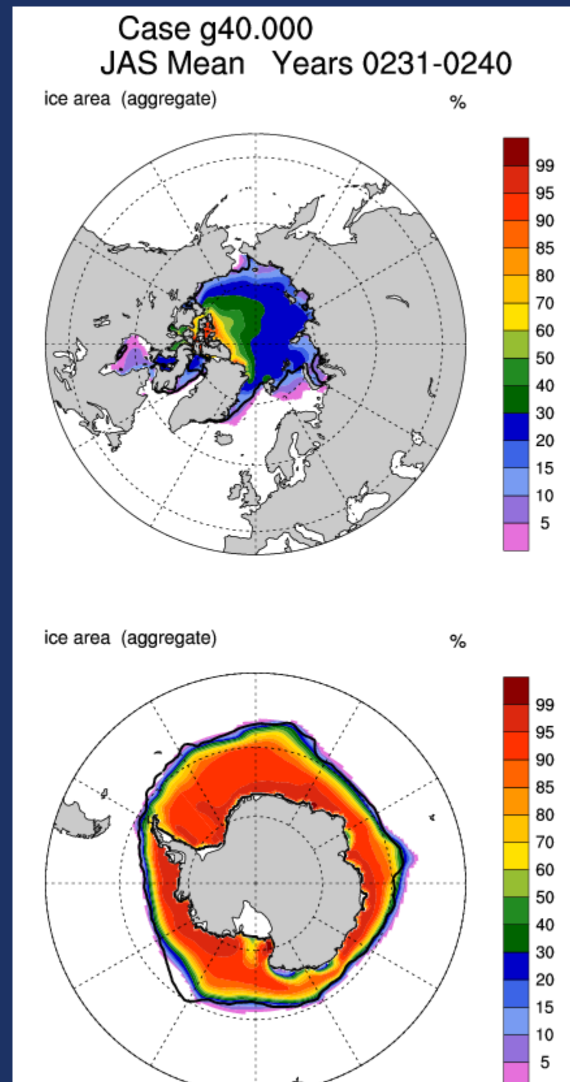

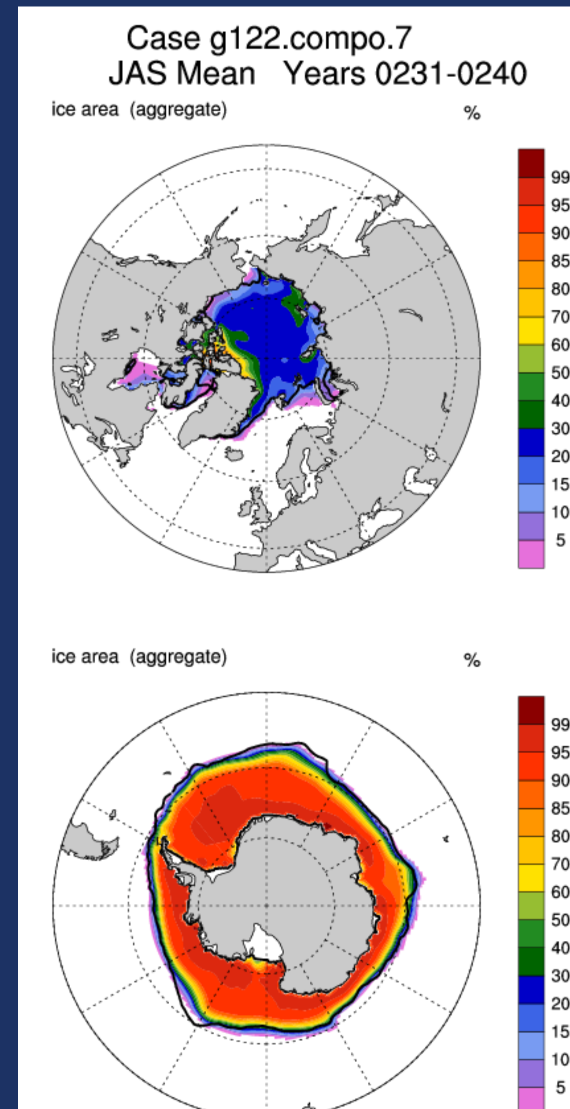

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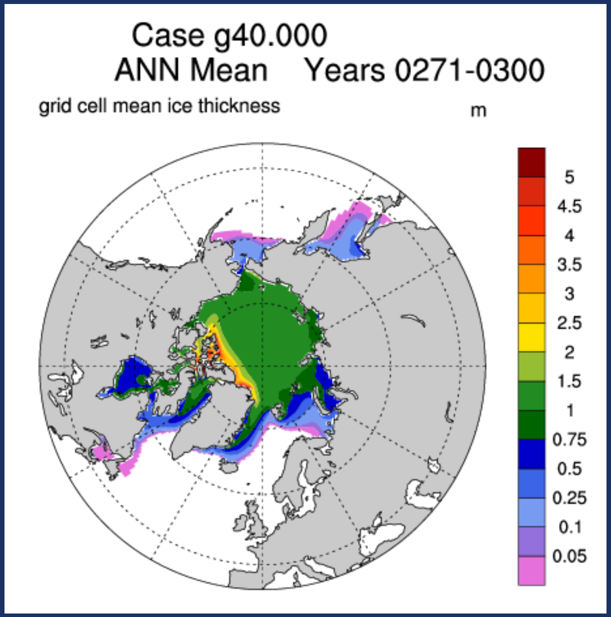

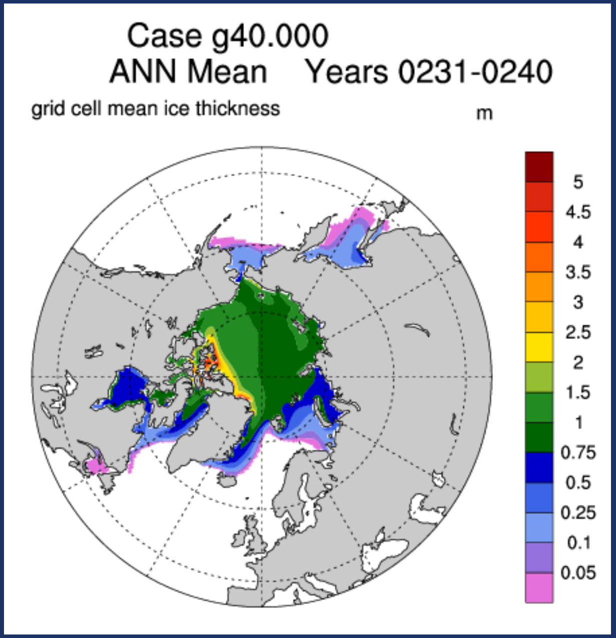

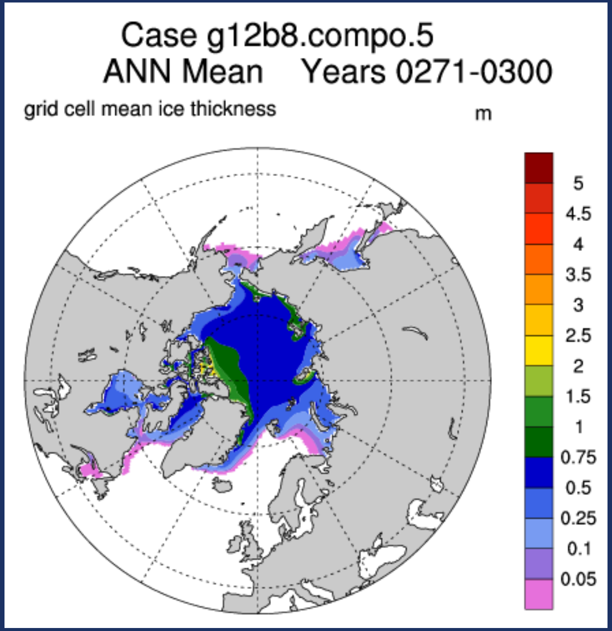

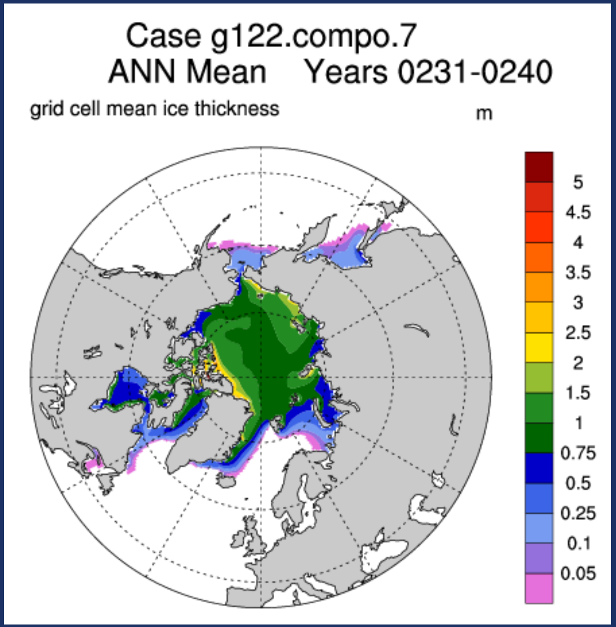

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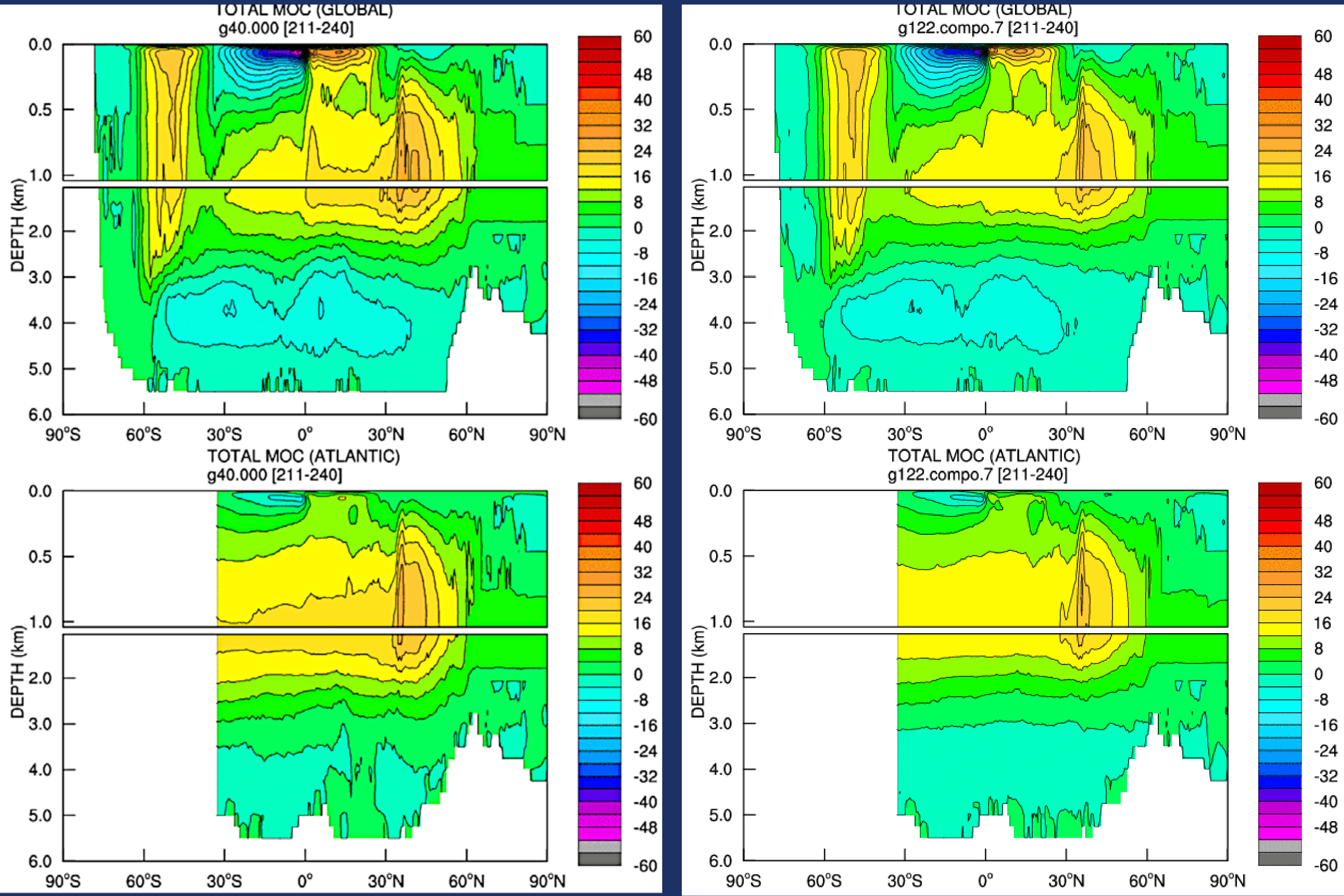

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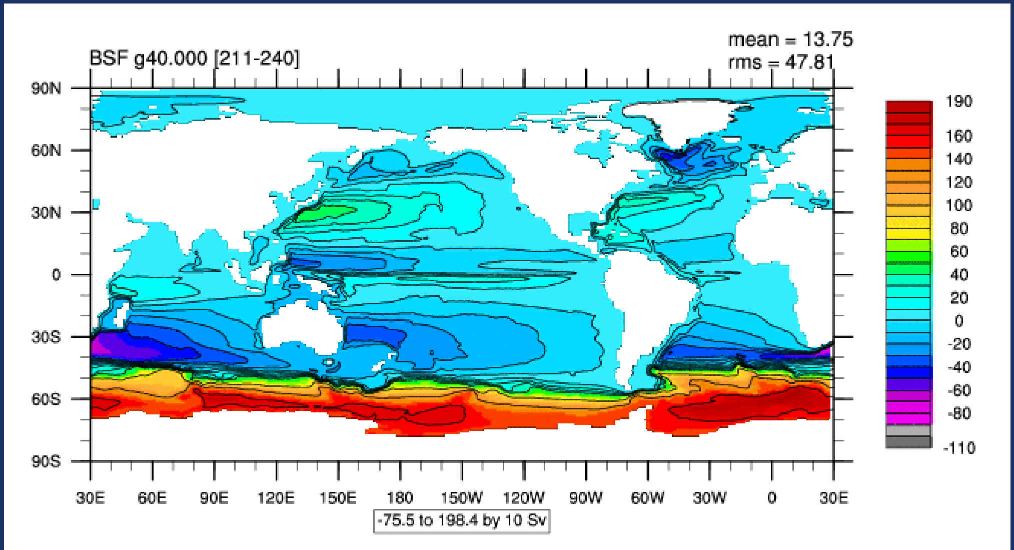

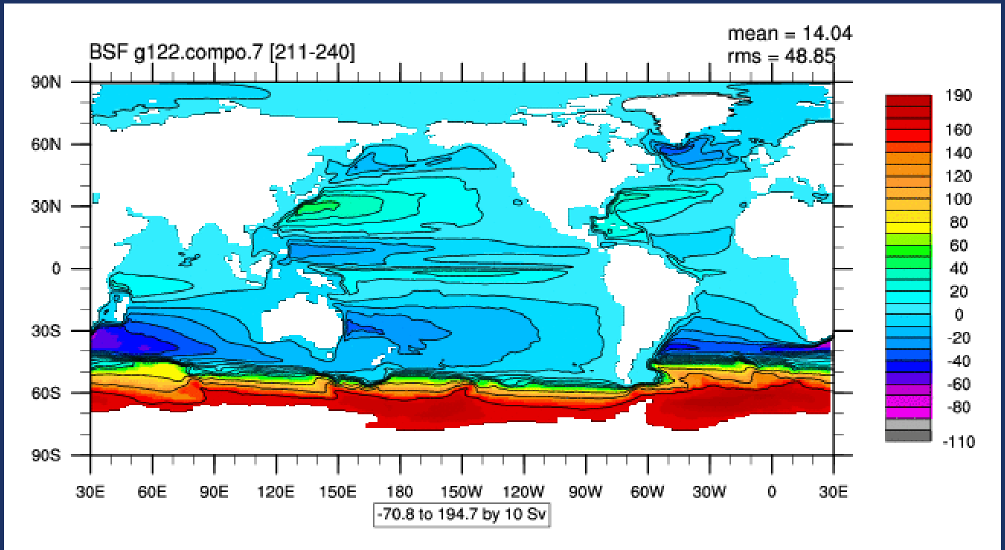

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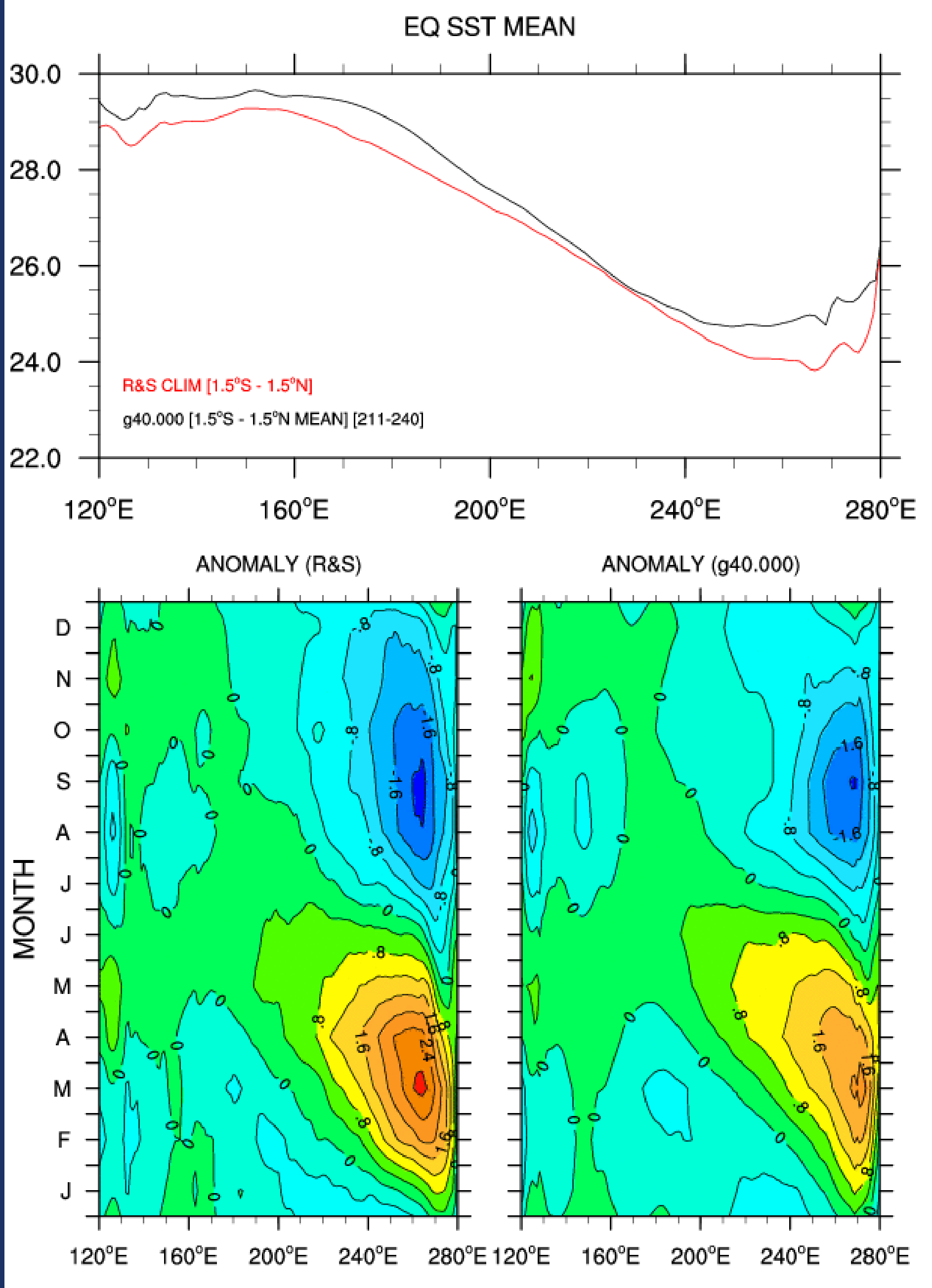

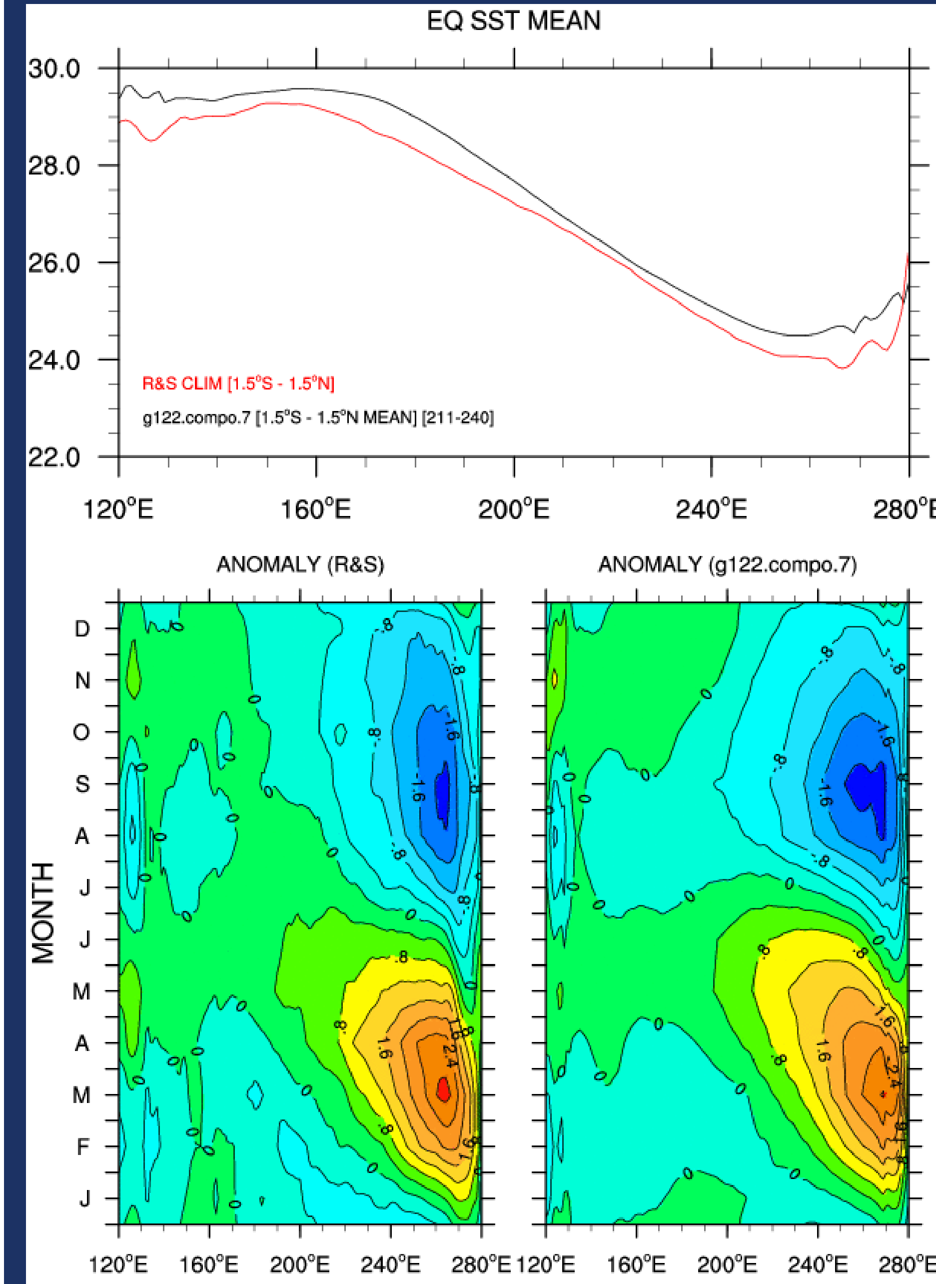

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