OMWG Meeting
Boulder, CO
Feb 9, 2016

Evaluation of CESM ocean-ice hindcast experiments forced by JRA55 data

Steve Yeager, Who Kim,
Justin Small, Gokhan Danabasoglu,
Bill Large, and Laura Landrum

NCAR, Boulder, Colorado, USA

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Outline

- What is JRA55?
- Experiment description
- Simulation spin-up
- Mean state characteristics
- Interannual variability

JRA55-based surface atmospheric data set for forcing ocean—sea-ice models

- Japanese 55-year Reanalysis (JRA55 or "JRA-GOGO") is a new atmospheric reanalysis from the Japan Meteorological Agency (JMA)
  - 1958-present, committed to near real-time updates
  - 55km resolution, 3-hourly data
  - Kobayashi et al, 2015, *J. Meteorol. Soc. Japan*, doi: 10.2151/jmsj.2015-001
- Bias adjustment needed for ocean/sea-ice modelling (as done for CORE and DRAKKAR projects) led by Hiroyuki Tsujino (JMA-MRI) as part of OMDP-JRA55 collaborative effort initiated at Jan2015 Grenoble meeting.
- Intended for use in "OMIP-phaseII" of CMIP6
- <u>Timeline</u>: version1.0 in mid-March; documentation of data set in June/July; documentation of CORE/JRA55 simulation comparison by end of year

- For detailed information, see presentations from Jan2016 OMDP meeting in Yokohama:

  http://www.clivar.org/omdp/japan2016

JRA55-based surface atmospheric data set for forcing ocean—sea-ice models

- *Version 0.0*: JRA-55 Product (when this name is useful)
- *Version 0.1*: Unadjusted JRA-55 on regular TL319 grid
  - Zonally interpolated from the (original) reduced TL319 grid
  - 2 m temp and humidity is shifted to 10 m using surface roughness of JRA-55 10 m values are adjusted for v0.2
- *Version 0.2*: Adjustment on version 0.1 (Mar 2015)
- ✓ *Version 0.3*: Revised adjustment (Dec 2015)
  - 2 m temp and humidity is adjusted on 2 m and then shifted to 10 m using LY09 formula
  - Adjustment is done essentially on v0.0
- *Version 0.4*: Very low temperature is cut-off around Antarctica

JRA55-based surface atmospheric data set for forcing ocean—sea-ice models

Summary of the adjustment method for v0.3 (Dec 2015) (After extensive discussions with collaborators)

	reference* data	adj*factor* based*on	Bme* dependency	spaBal* dependency*	How*is*the* factor*used
short wave	adjusted CERES[%]	mar2000-feb2015	monthly	(x,y) & constant	multiply
long wave	adjusted CERES[%]	mar2000-feb2015	monthly	(x,y) & constant	multiply
precipitation	CORE	1979-2008	monthly	(x,y) & constant	multiply
air temperature	JRA55-anl_surf[#] IABP-NPOLES	1979-1998	monthly	(x,y)	offset
specific humidity	JRA55-anl_surf[#]	1979-1998	monthly	(x,y)	multiply
wind speed	QuikSCAT* JRA55-anl_surf[#]	aug1999-oct2009	monthly	(x,y)	multiply
wind angle	QuikSCAT* JRA55-anl_surf[#]	aug1999-oct2009	monthly	(x,y)	offset

Red: change from v0.2

(%) CERES-EBAFv2.8 Surface (Kato et al. 2013)
(*) Remote Sensing Systems 0.25 x 0.25 data set version 4
(#) Screen level analysis of JRA55

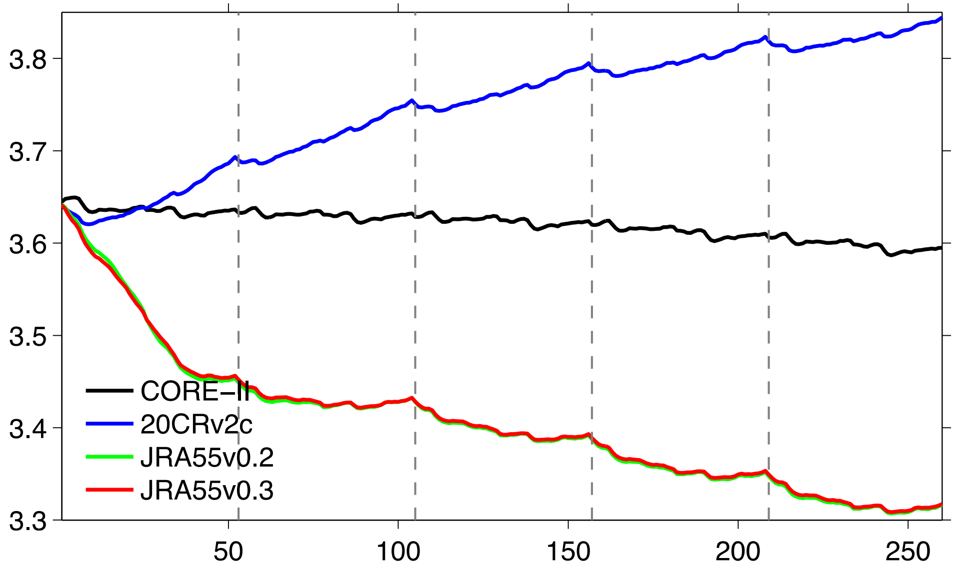
*Tsujino talk, Jan2016 OMDP meeting

POPCICE Ocean-ice Hindcast Experiments

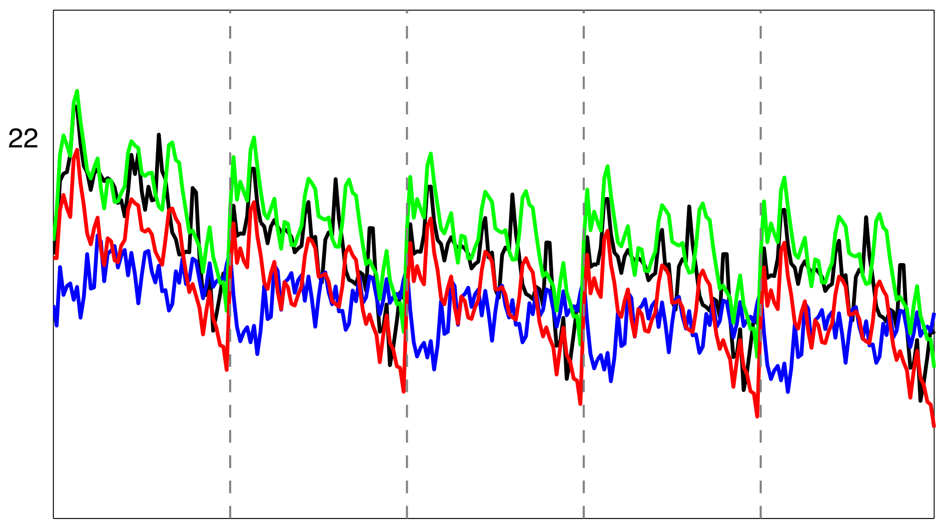
Experiment:	JRA55	CORE	20CR
Forcing data	JRA55v0.3	CORE.v2_iaf	20CRv2c
Forcing reference	Kobayashi et al., 2015, *JMSJ* Tsujino et al., 2015, pers.comm.	Large & Yeager, 2009, *Clim. Dyn.*	Compo et al., 2011, *QJRMS*
Downwelling radiation	JRA55v0.3 *	GISS ISCCP-FD *	20CRv2c *
Atmos. State (θ, q, ρ, **U**)	JRA55v0.3 *	NCEP *	20CRv2c *
Precipitation	JRA55v0.3 *	GPCP/CMAP/Serreze *	20CRv2c *
Forcing cycle	1958-2009 (52-year); 5 cycles	1958-2009 (52-year); 5 cycles	1958-2009 (52-year); 5 cycles
Initial Condition	PHC2; state-of-rest	PHC2; state-of-rest	PHC2; state-of-rest
Ocean Model	POP 1deg, 60lvl (CESM1.4)	POP 1deg, 60lvl (CESM1.4)	POP 1deg, 60lvl (CESM1.4)
Ice Model	CICE4 1deg (CESM1.4)	CICE4 1deg (CESM1.4)	CICE4 1deg (CESM1.4)
Ocean coupling frequency	daily	daily	daily
Salinity restoring	4-year	4-year	4-year
Continental Discharge	Dai et al. (2009)	Dai et al. (2009)	Dai et al. (2009)

Spin-up

Global–Mean Temperature & Salinity

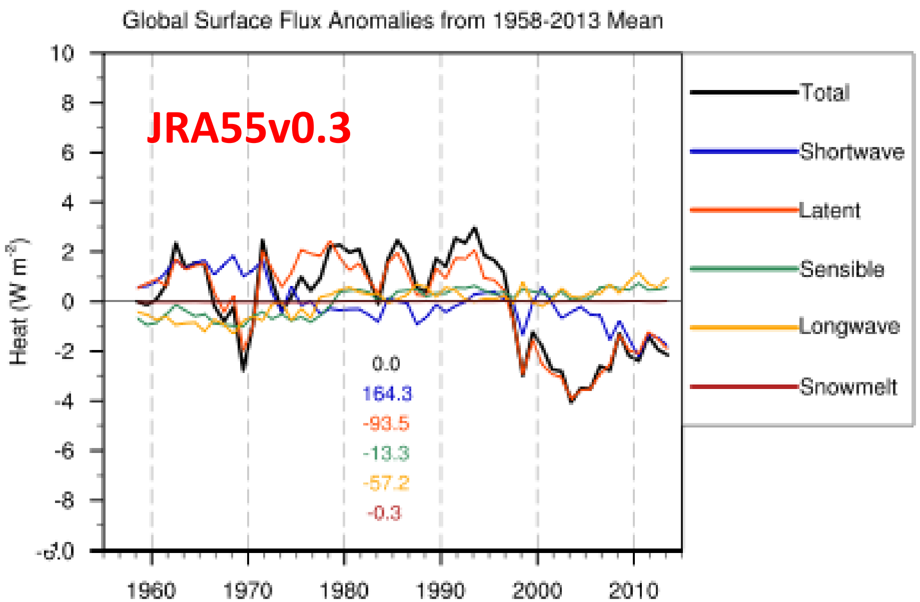


- Large, abrupt cooling in first JRA cycle; not seen in CORE
- Negative Temperature drift continues through 5th cycle

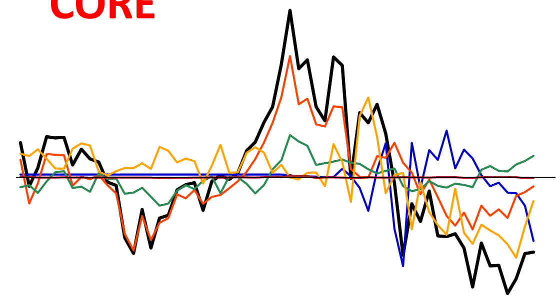


- Comparably small negative drift in Salinity (precip_factor corrects for FW imbalance)

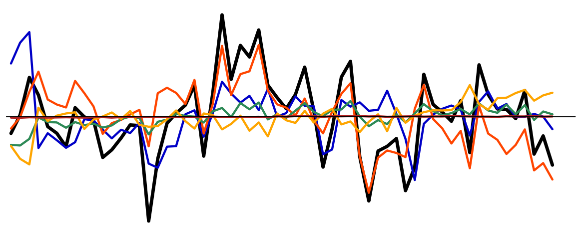
Global Heat Flux Analysis



CORE



20CRv2c



Global climatological heat flux (W/m^2) into the ocean when coupled to observed SST and sea ice fraction using LY09 bulk formulae:

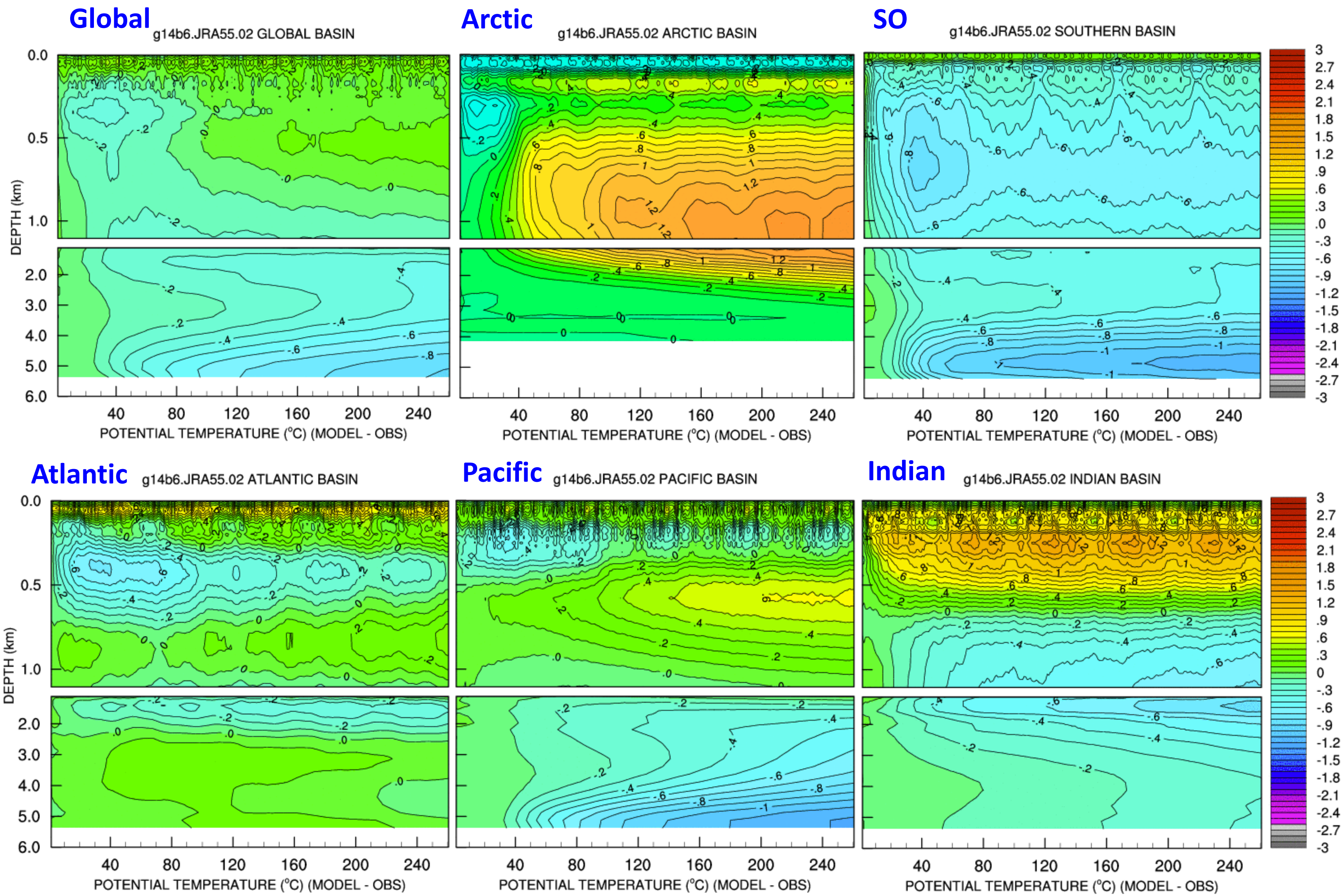
CORE: +3.6

JRA55v0.3: 0.0

20CRv2c: +0.1

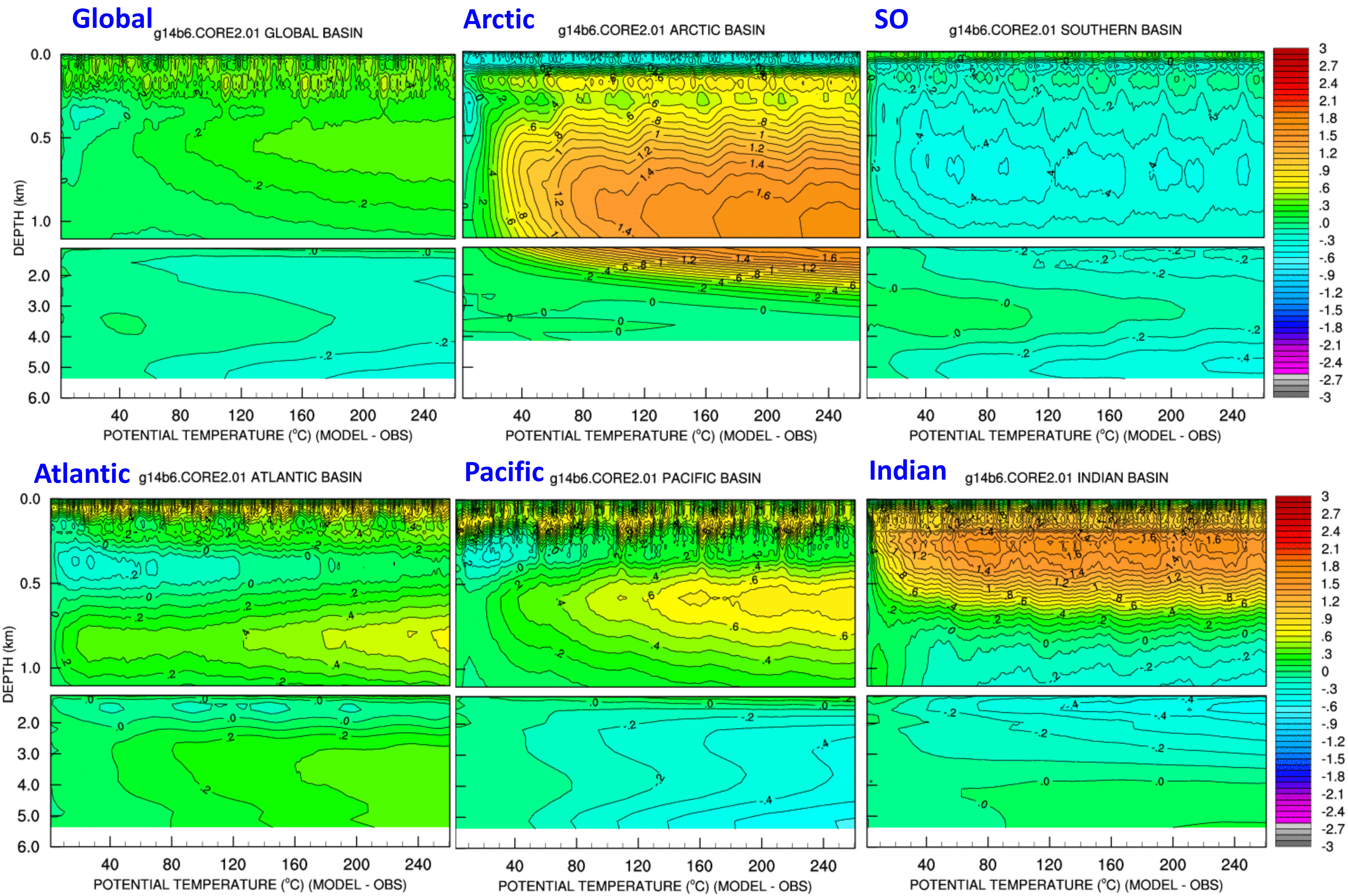
Horizontal Mean Temperature Diff from Obs.

JRA55

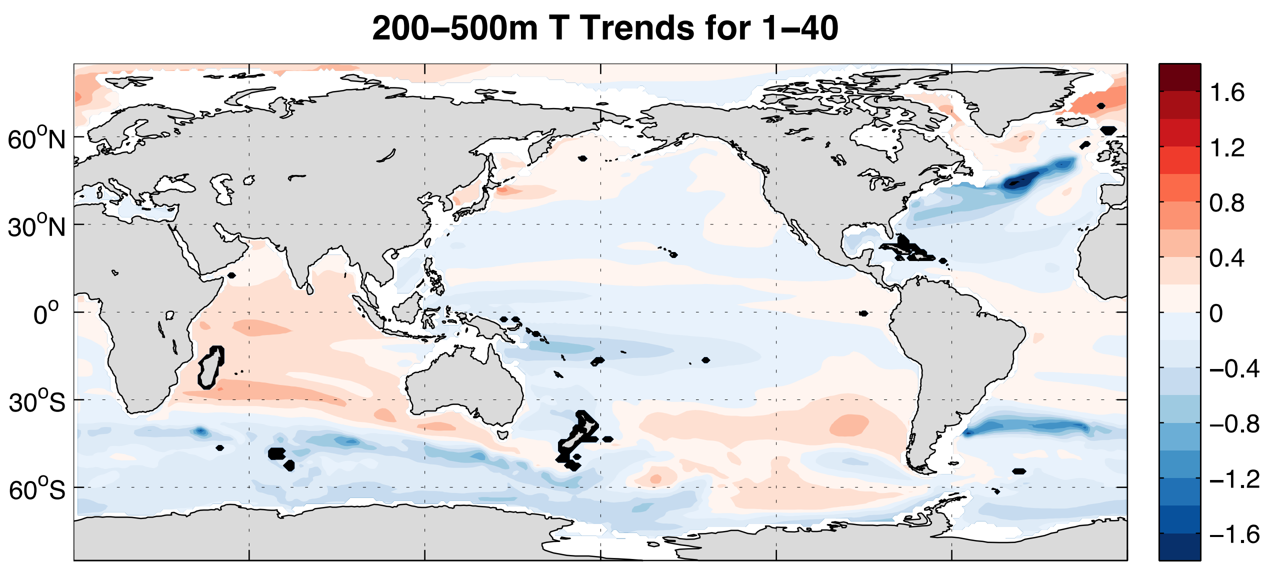


Horizontal Mean Temperature Diff from Obs.

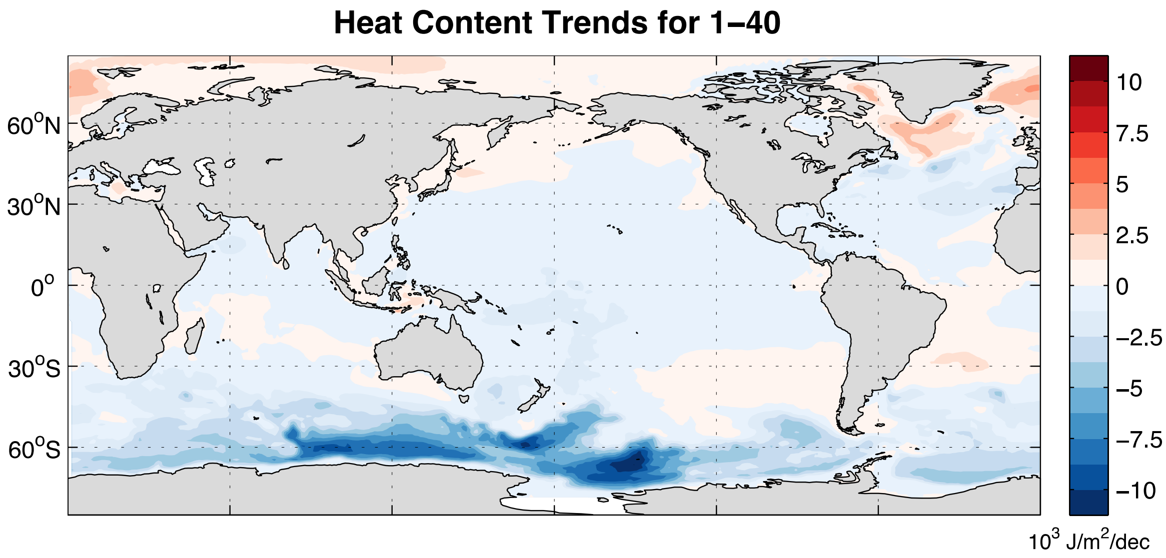
CORE



Heat Content Trends over simulation years 1-40 (JRA55)



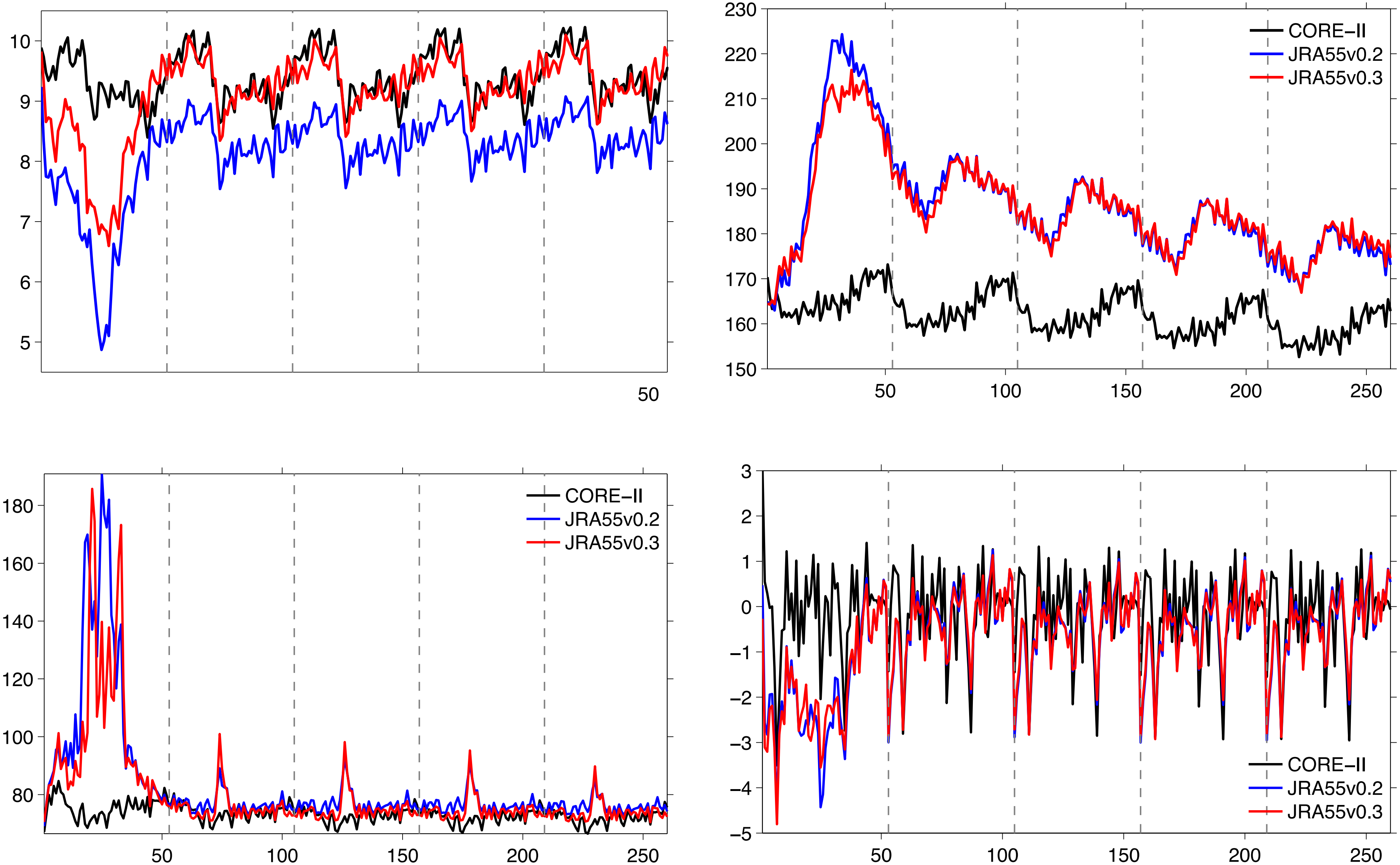
200-500m



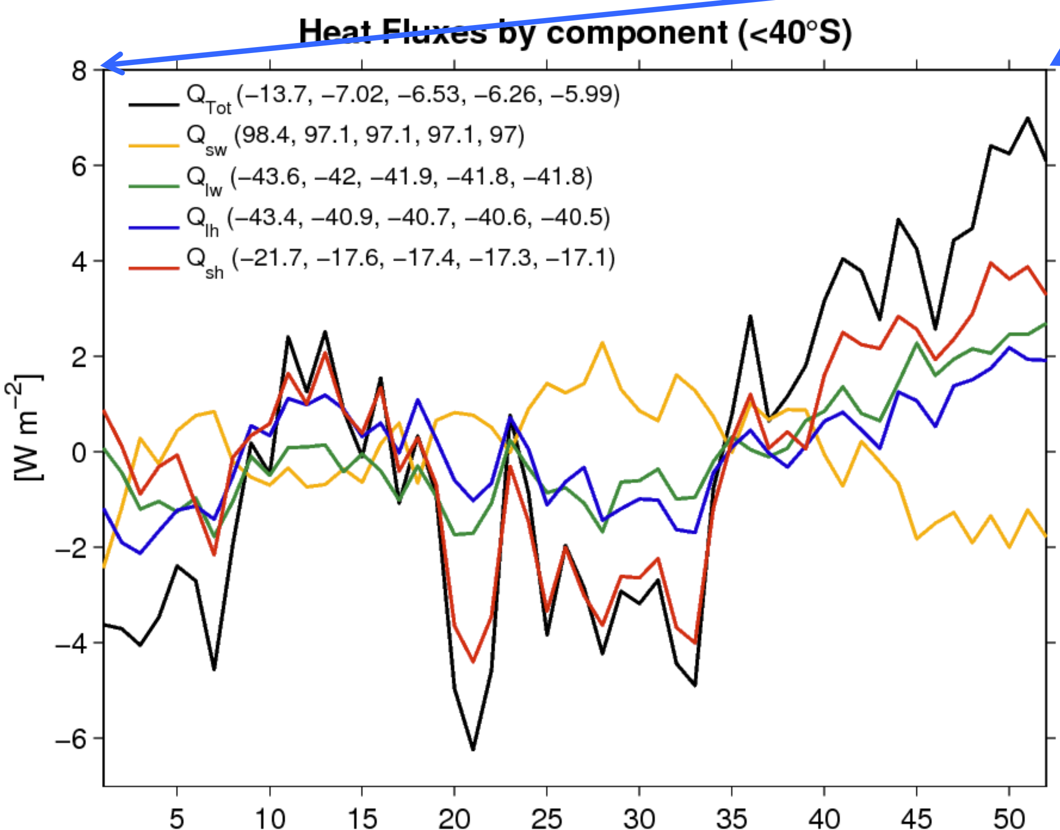
Full depth

Southern Ocean spinup

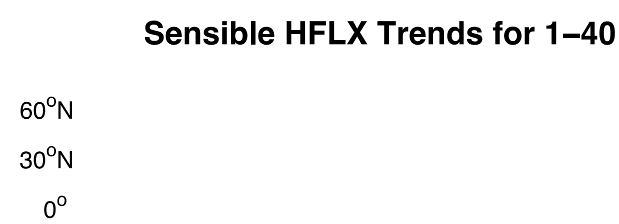
SH



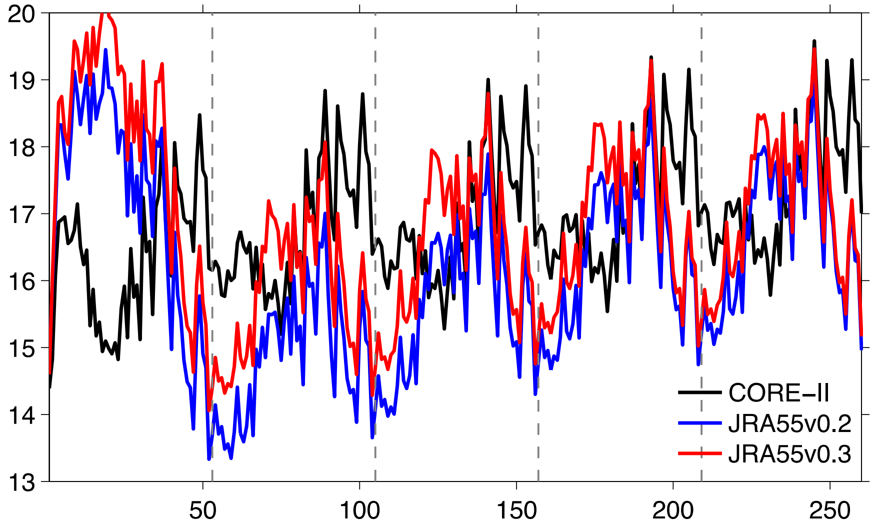
Southern Ocean spinup



Anomalously strong turbulent heat loss explains 1st cycle heat flux anomaly in Southern Ocean.



AMOC



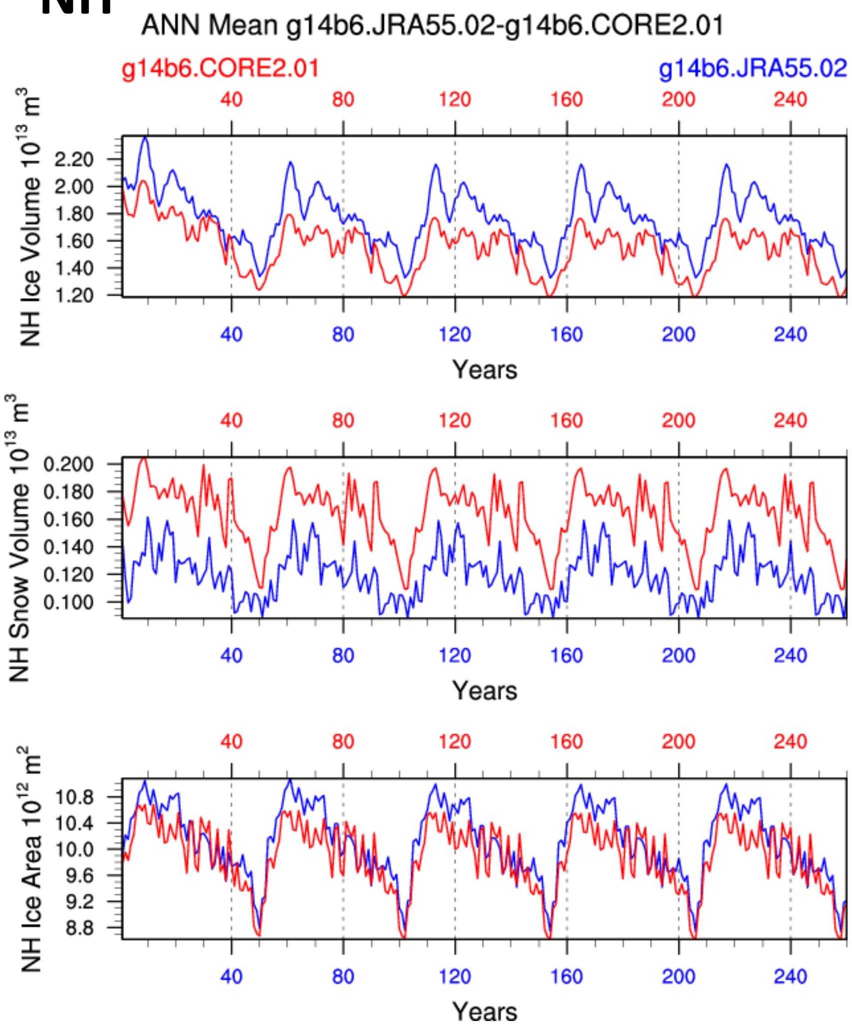
45°N

Sv

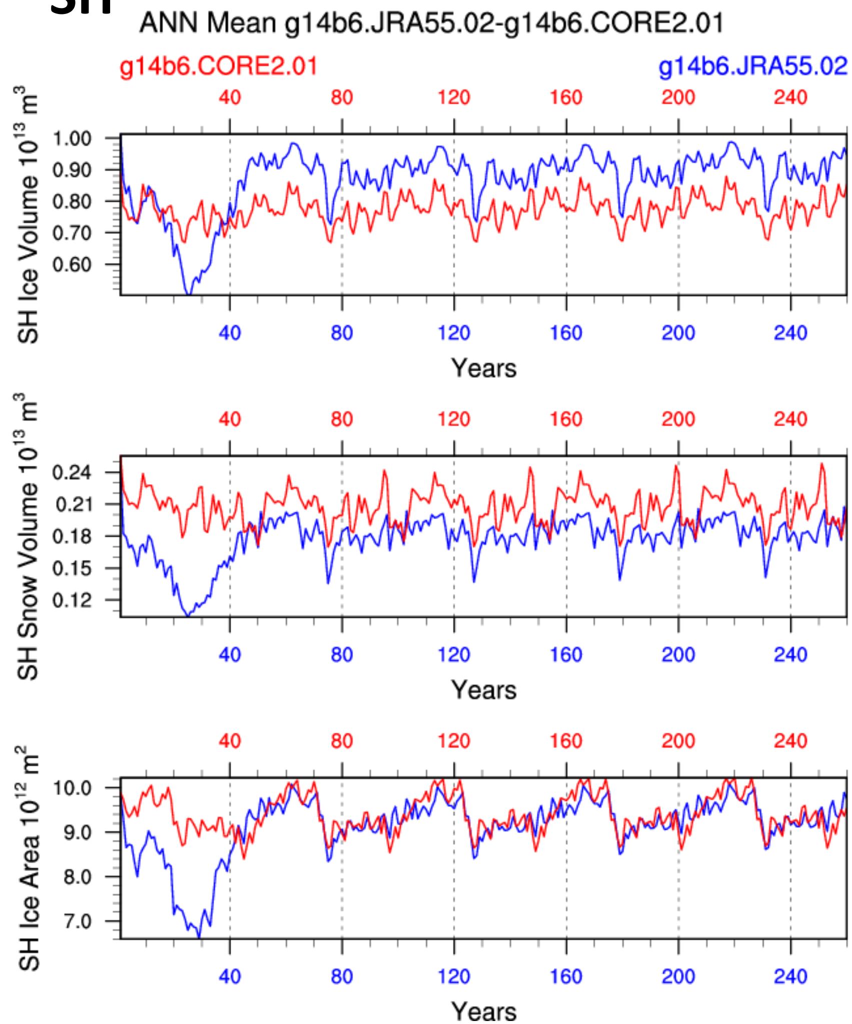
- Stable AMOC of comparable mean strength to CORE by 5th cycle

Annual Mean Sea Ice Time Series

NH



SH



- JRA55 yields higher ice volume & lower snow volume in both hemispheres

- ➔ Excessive cold drift in JRA55 hindcast appears related to collapse of Antarctic sea ice in 1st cycle; still under investigation (apparently wind-related)
- ➔ AMOC stabilizes at reasonable strength
- ➔ ACC is too strong
- ➔ Sea ice volume/area eventually stabilizes at good* levels in both hemispheres

*better than CORE

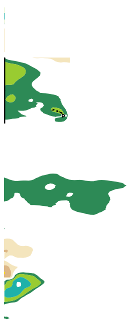
Mean State

(5th cycle, 1985-2009 climatology)

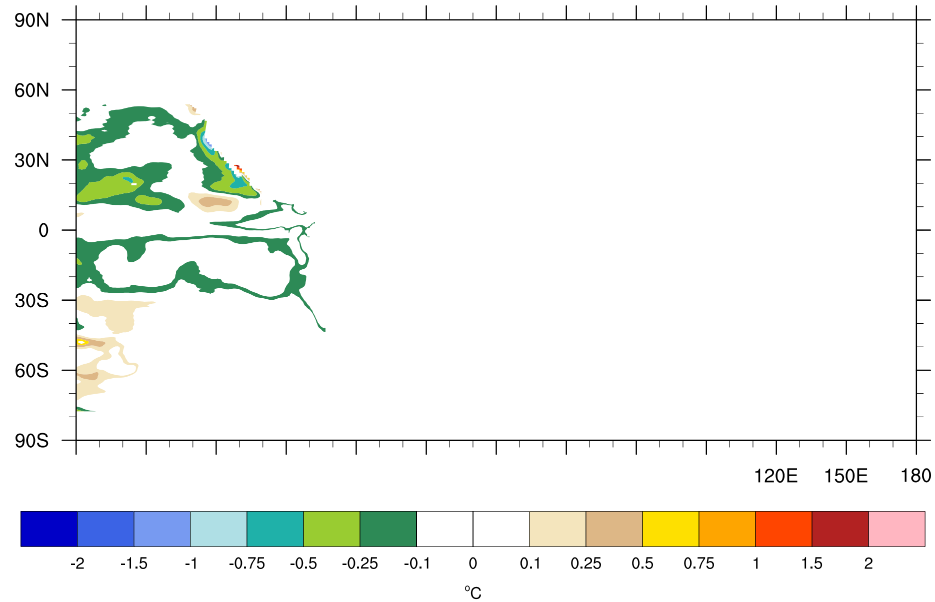
SST Bias

*OBS = Hurrell et al. 2008

JRA55



SST difference (JRA55 - CORE)



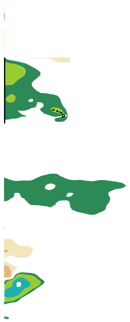
CORE

25 0 0.25 0.5 1 1.5 2 2.5 3

SST Bias

*OBS = Hurrell et al. 2008

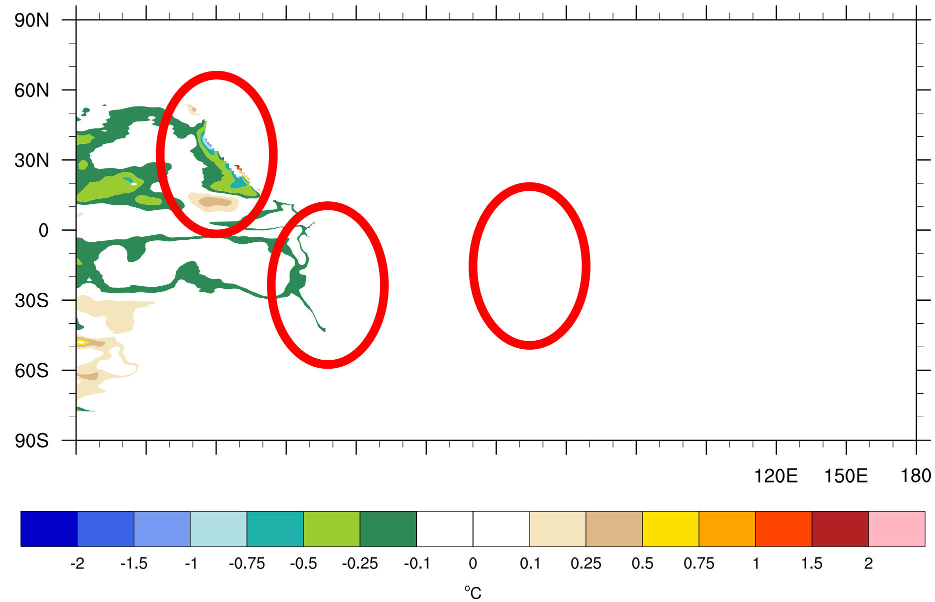
JRA55



CORE

25 0 0.25 0.5 1 1.5 2 2.5 3

SST difference (JRA55 - CORE)



- Largest bias reduction in eastern boundary upwelling regions
- Further improvements in tropical Pacific & Atlantic

SSS Bias

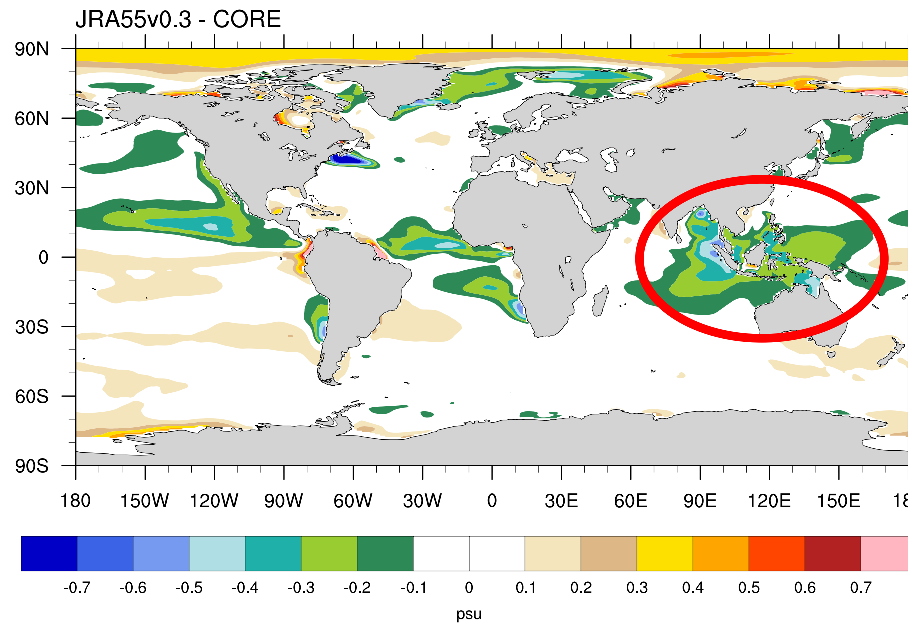
*OBS = PHC2

JRA55

CORE

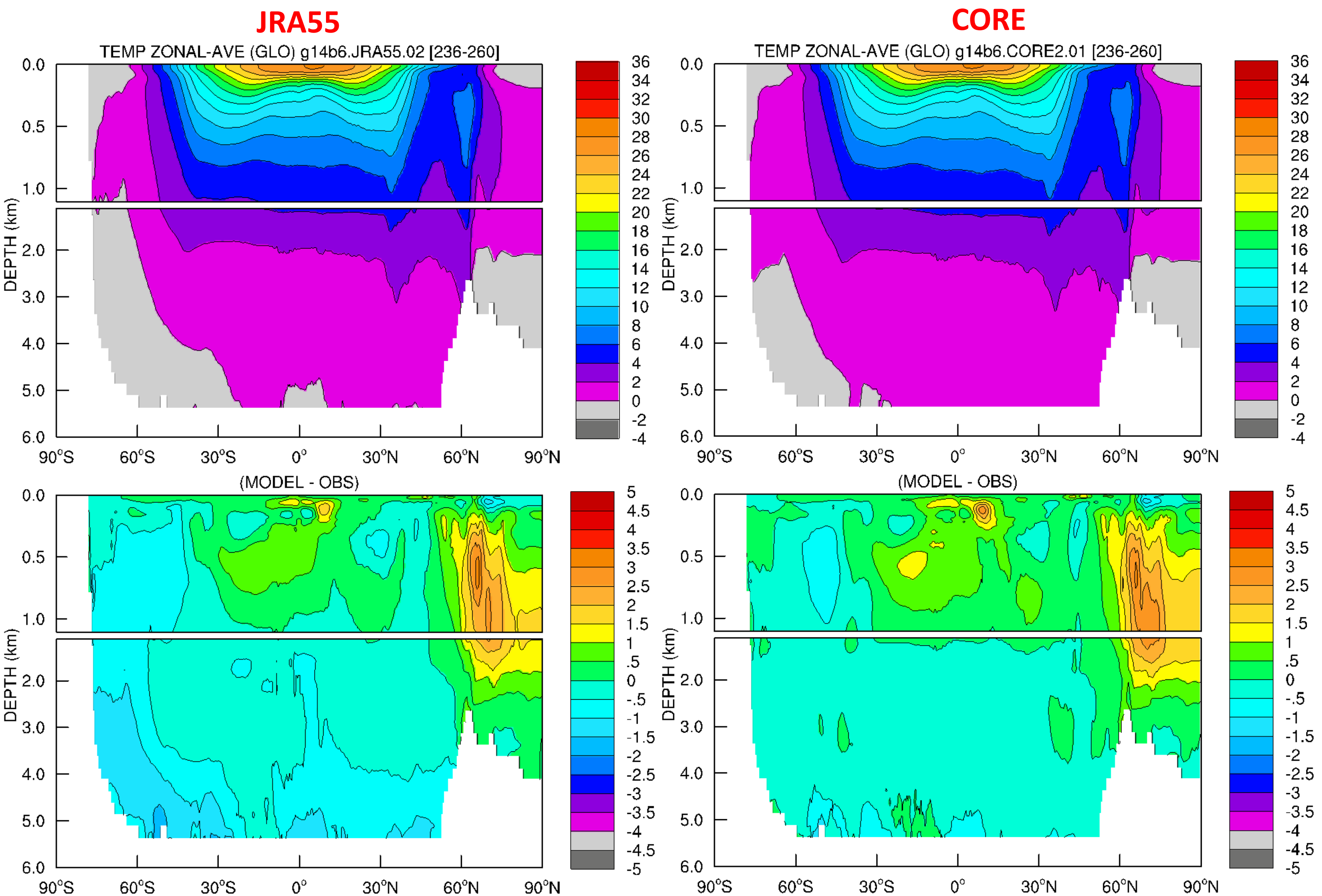
5 -0.25 -0.1 0 0.1 0.25 0.5 0.75 1 1.5 2

SSS difference (JRA55 - CORE)



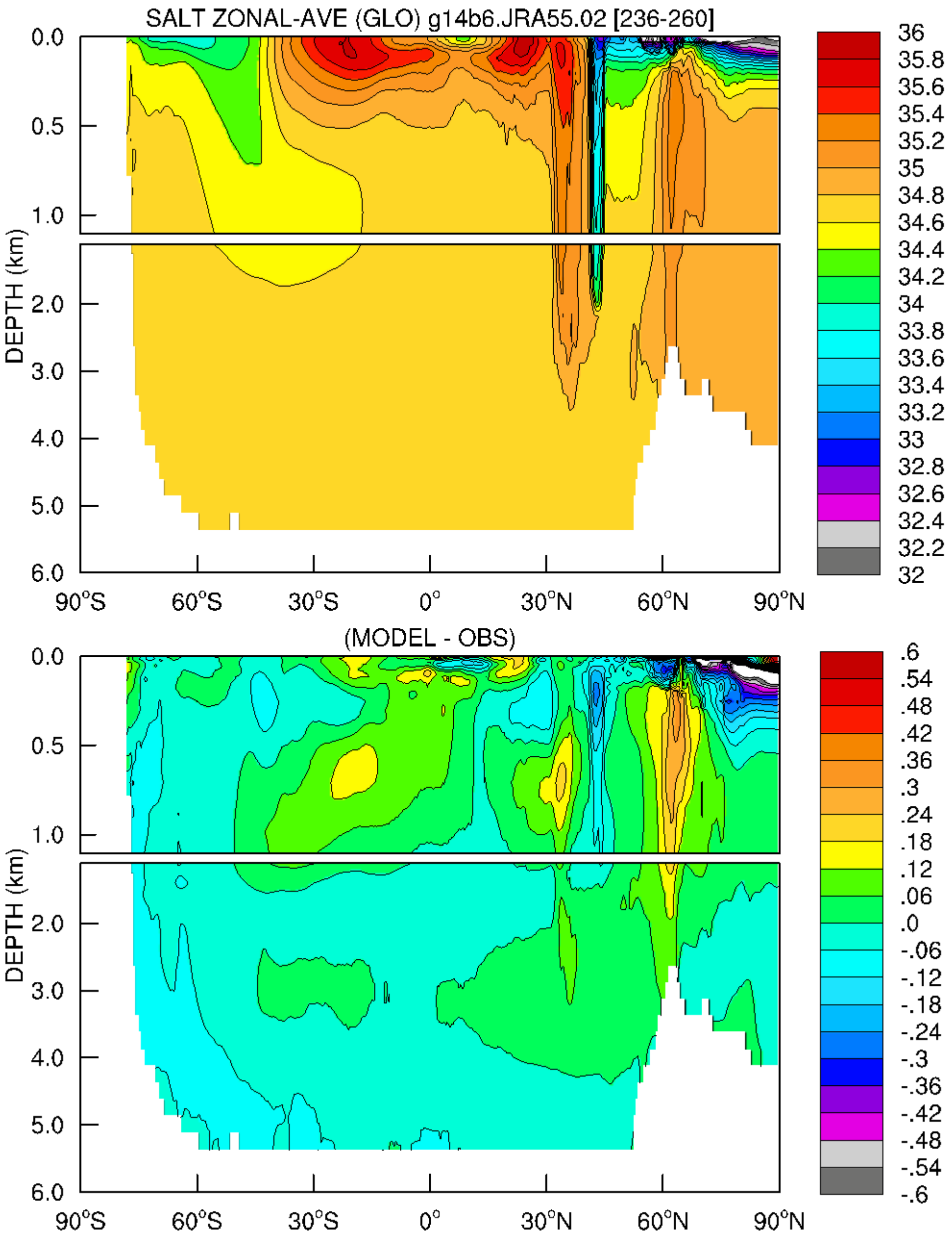
- Bias reduction in tropical Atlantic, tropical N. Pacific, Indian
- Bias increase in maritime continent and Arctic regions

Zonal Mean Temperature

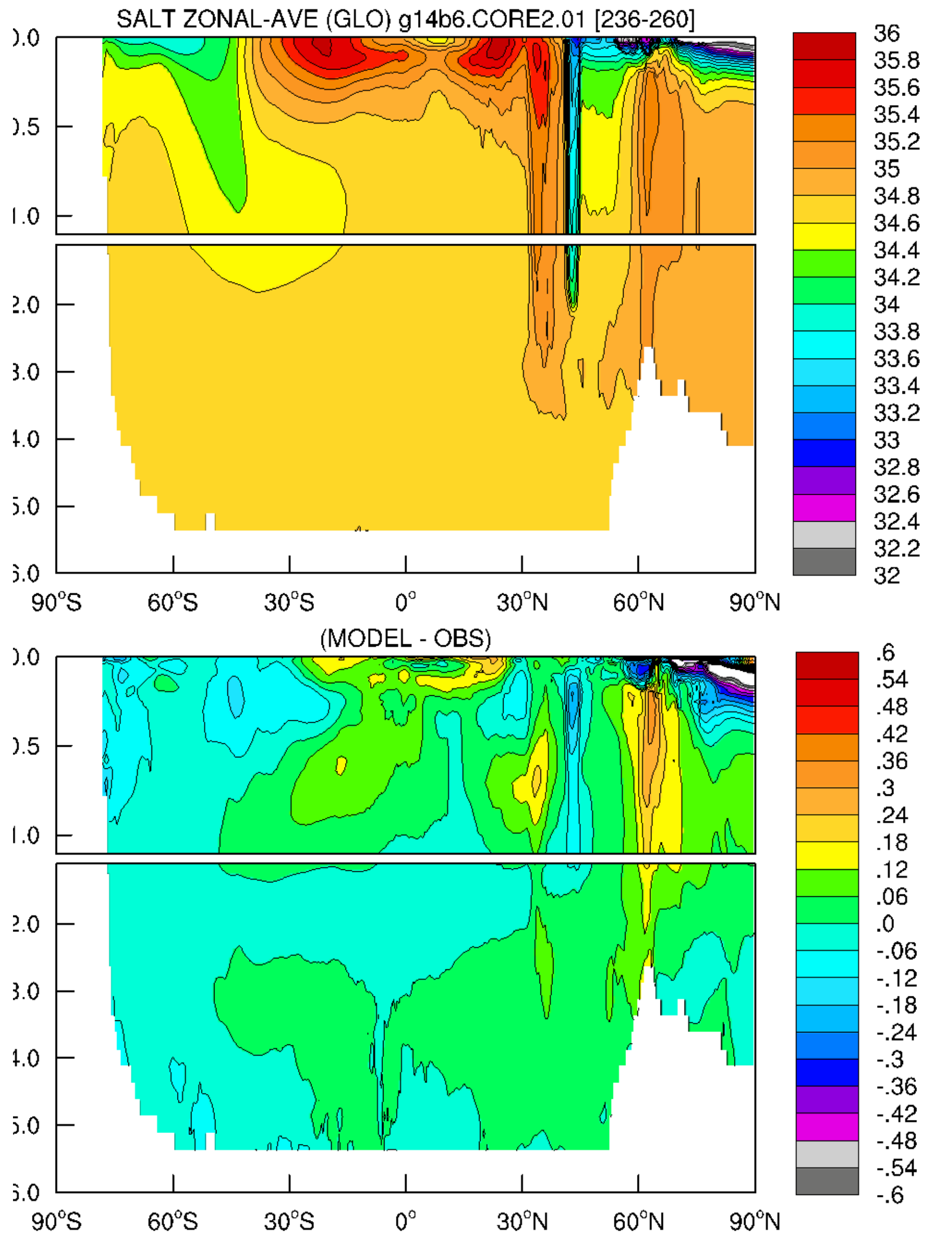


Zonal Mean Salinity

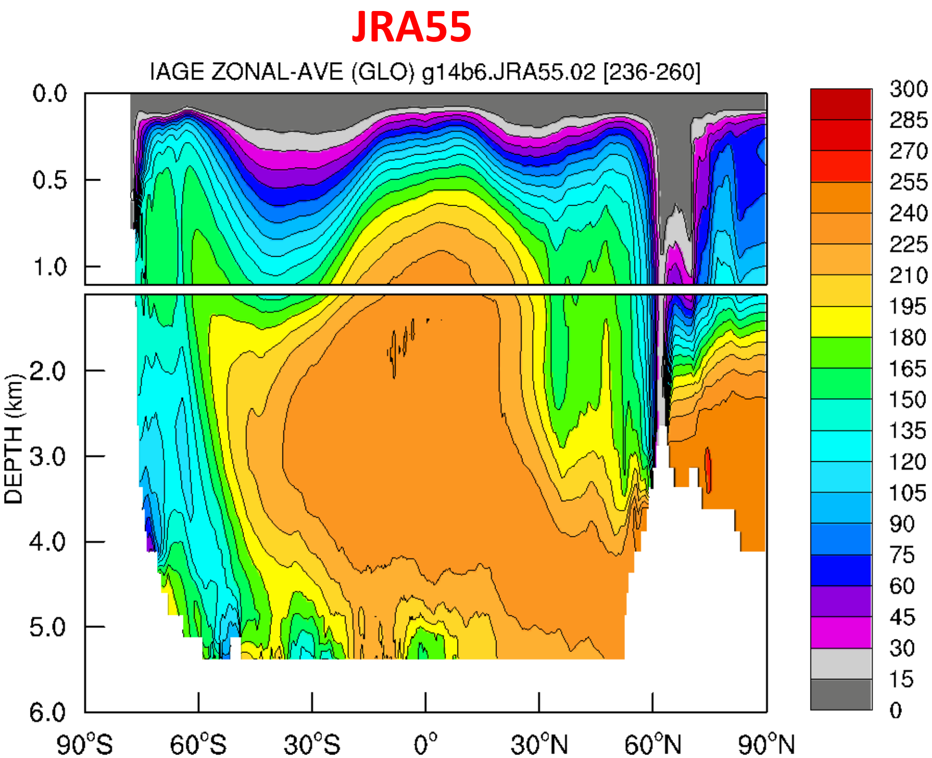
JRA55

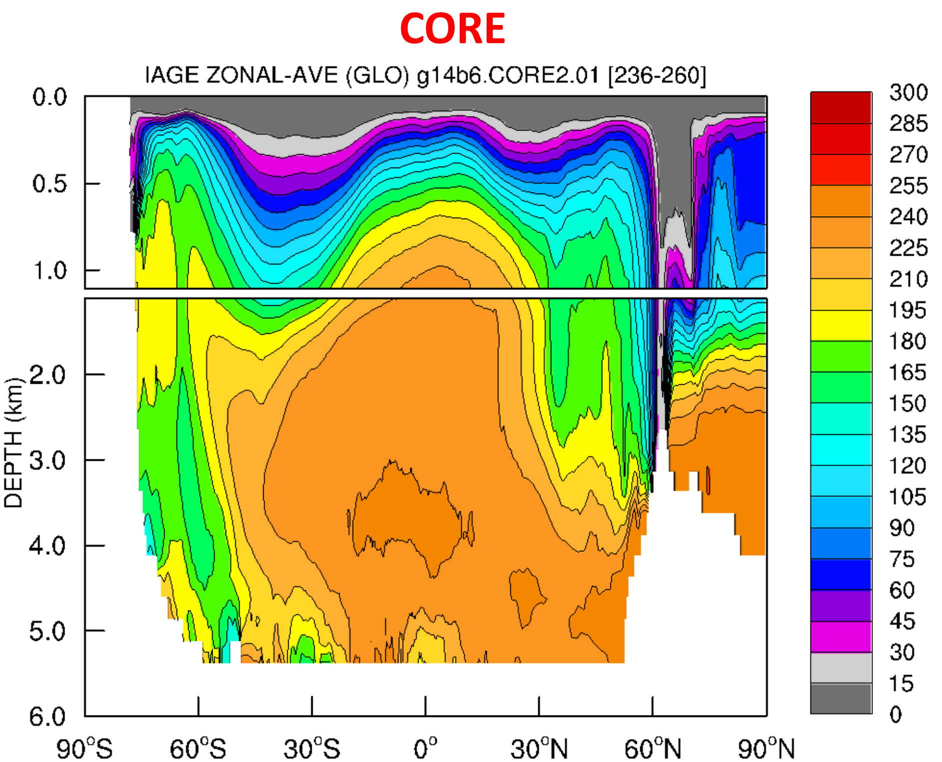


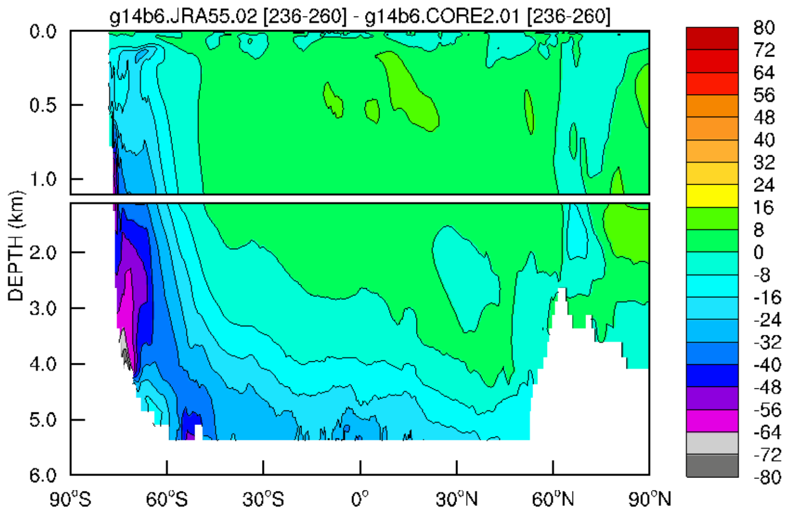
CORE



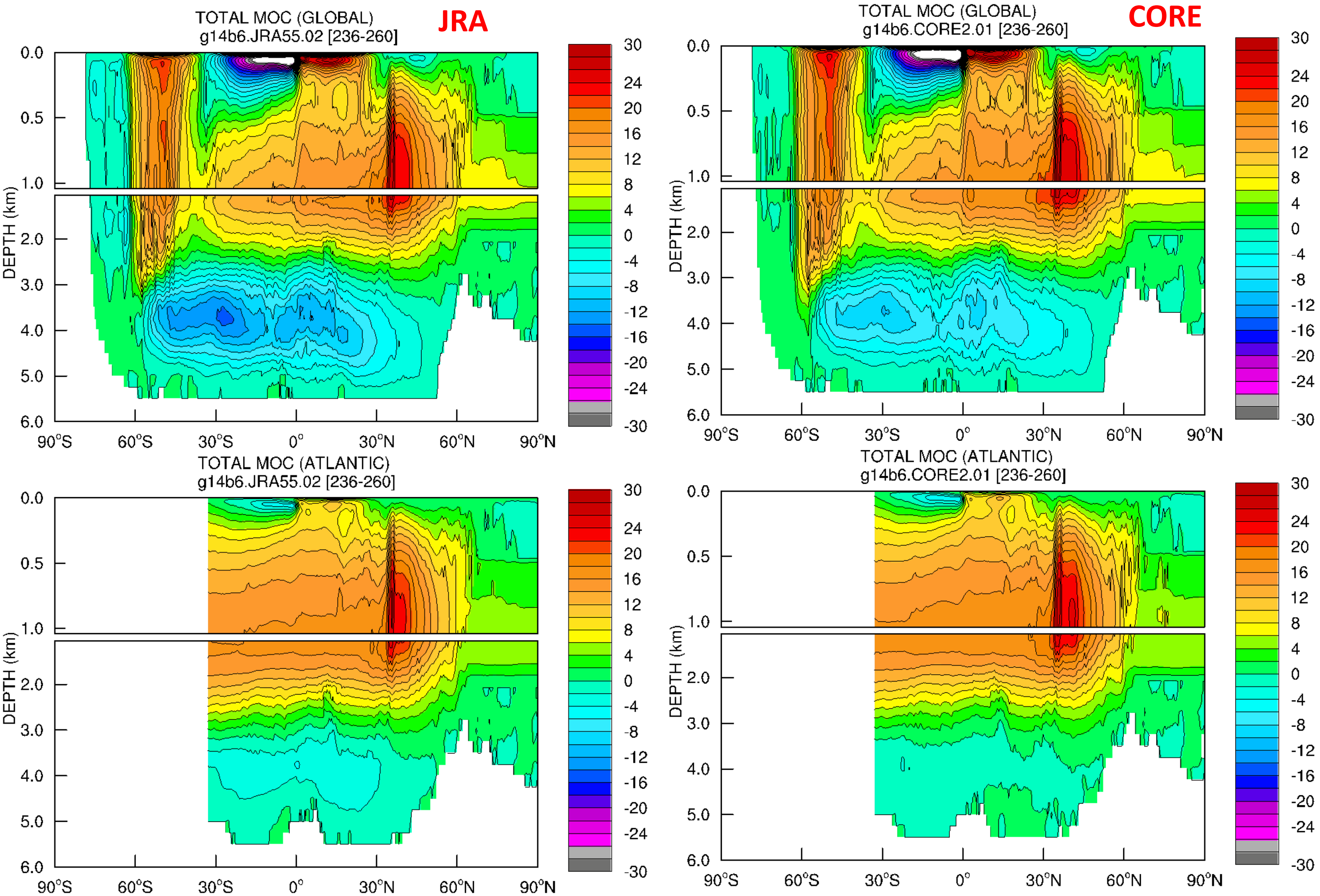
Zonal Mean IAGE



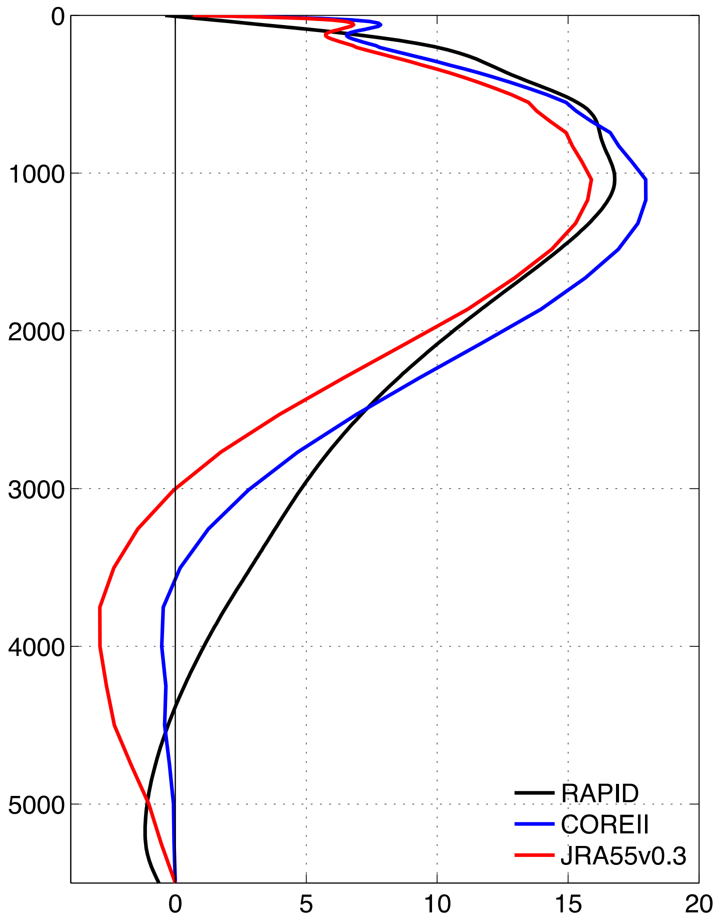


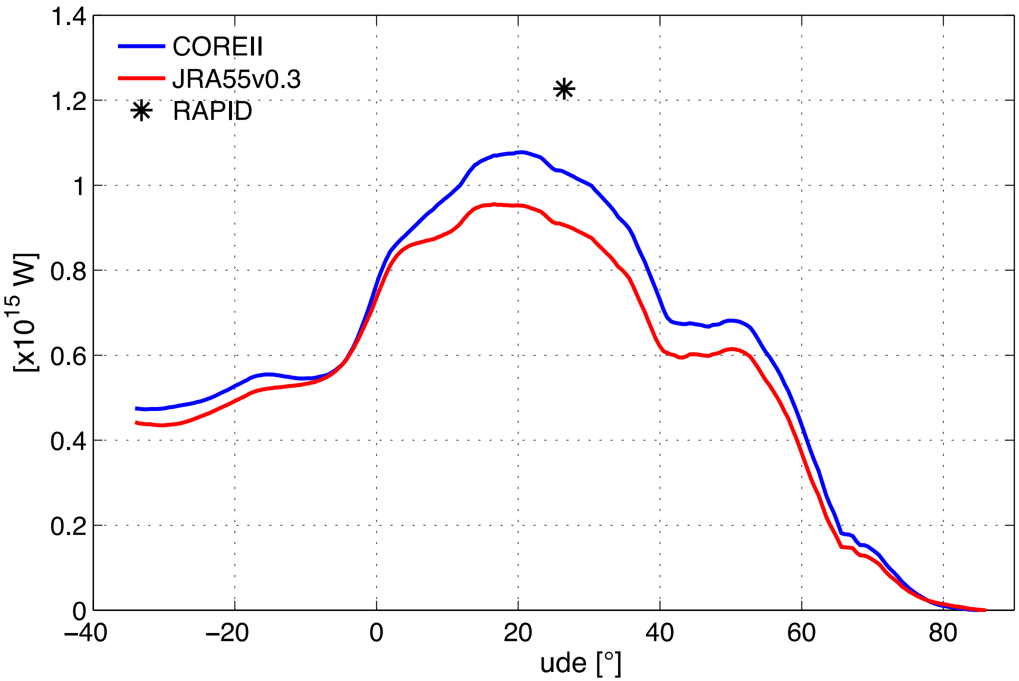


MOC


TOTAL MOC (GLOBAL)
g14b6.JRA55.02 [236-260]
JRA
TOTAL MOC (GLOBAL)
g14b6.CORE2.01 [236-260]
CORE
TOTAL MOC (ATLANTIC)
g14b6.JRA55.02 [236-260]
TOTAL MOC (ATLANTIC)
g14b6.CORE2.01 [236-260]
DEPTH (km)
0.0
0.5
1.0
2.0
3.0
4.0
5.0
6.0
90°S
60°S
30°S
0°
30°N
60°N
90°N
30
24
20
16
12
8
4
0
-4
-8
-12
-16
-20
-24
-30

AMOC and Heat Transport
(2005-2013 mean for both simulations and RAPID)

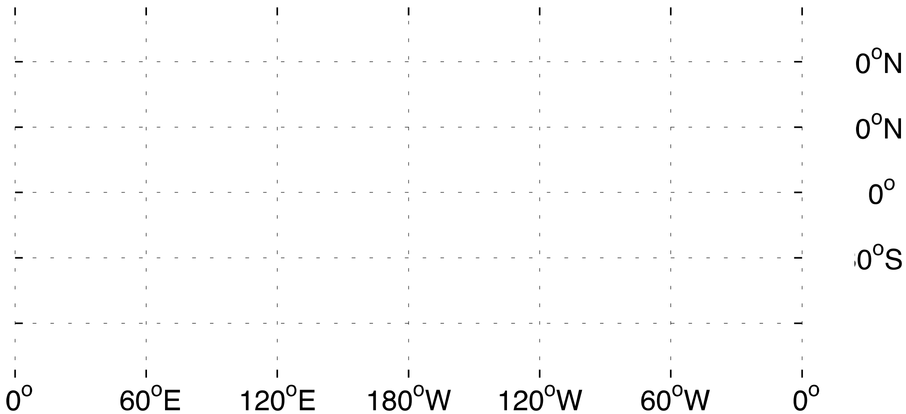




- AMOC profile compares less well with RAPID
- Atlantic heat transport too weak

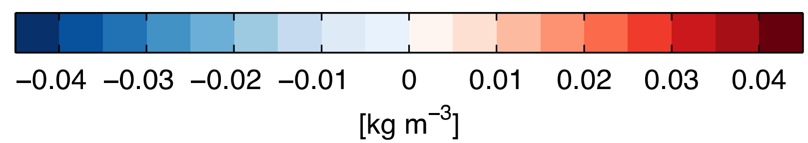
➔ Perhaps related to too vigorous AABW cell

MLD



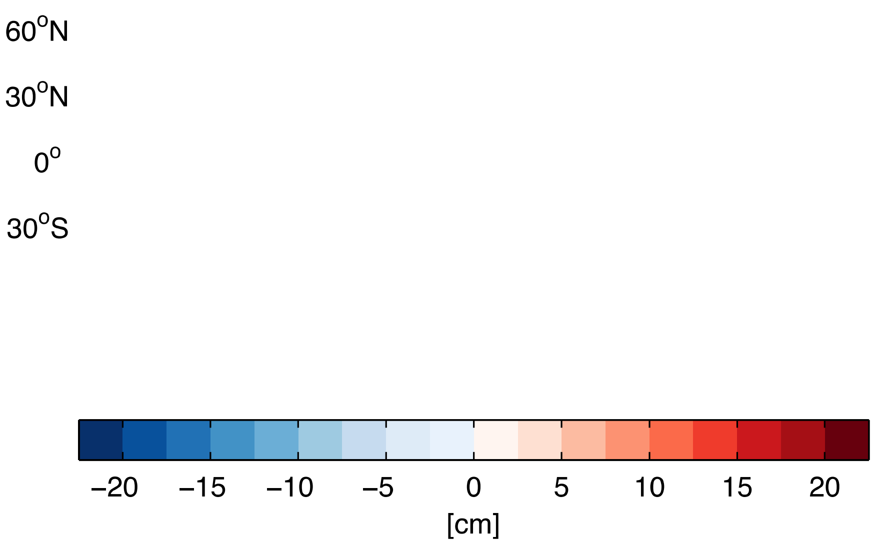
Density (>2000m)

JRA55v0.3 – COREII

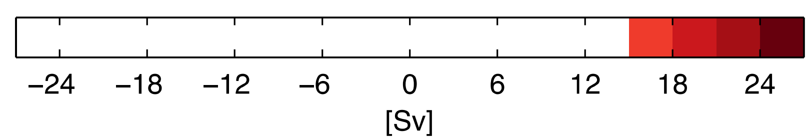


SSH

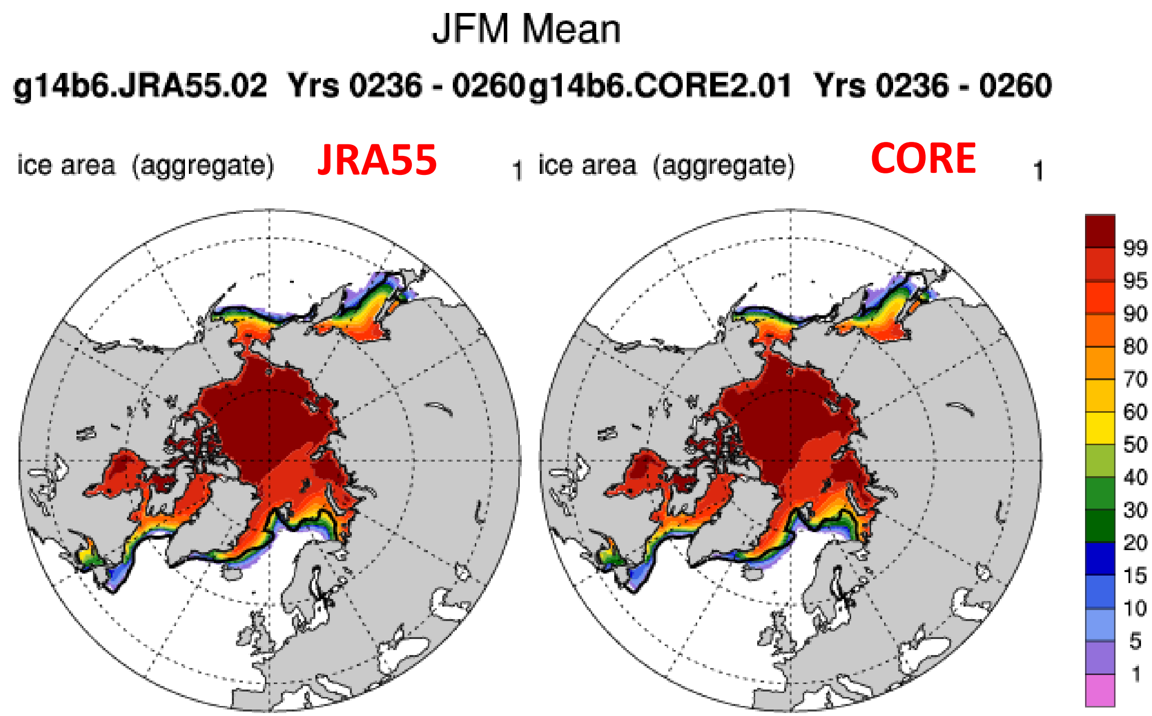
JRA55v0.3 – COREII

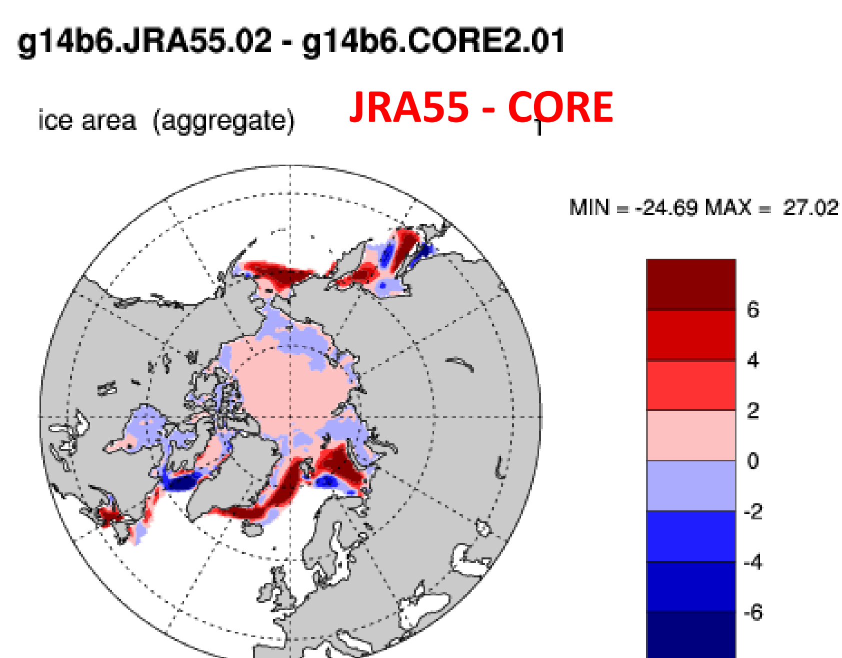


BSF



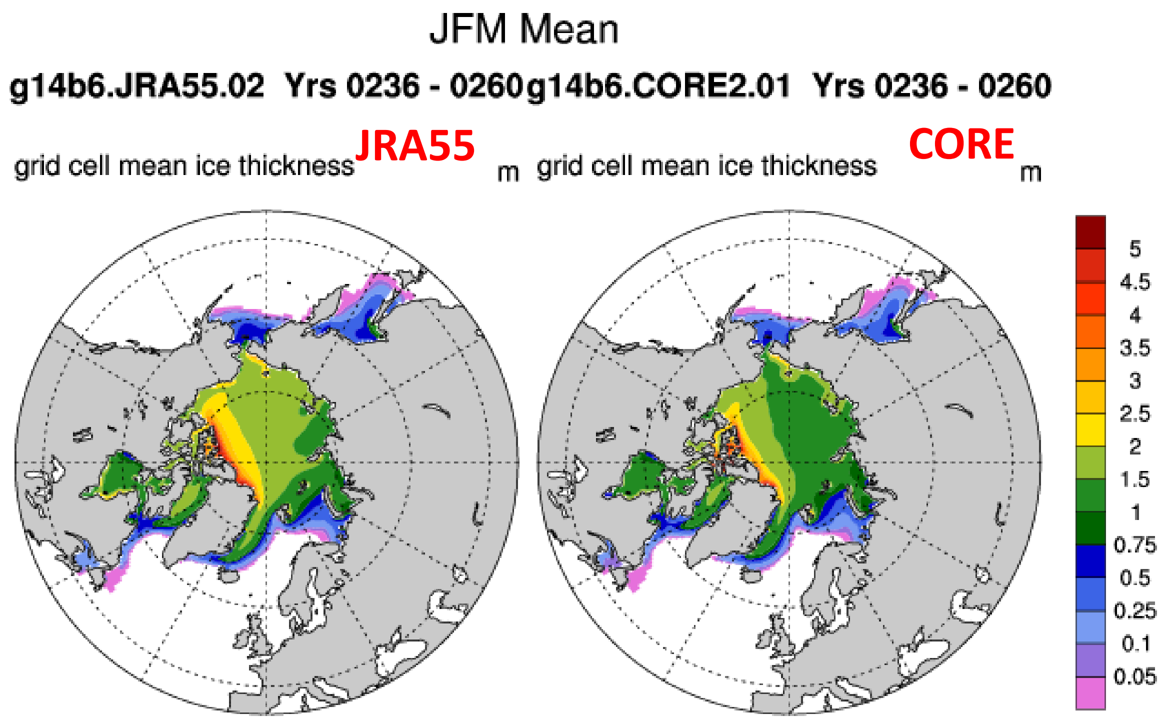
Winter NH Sea Ice Concentration



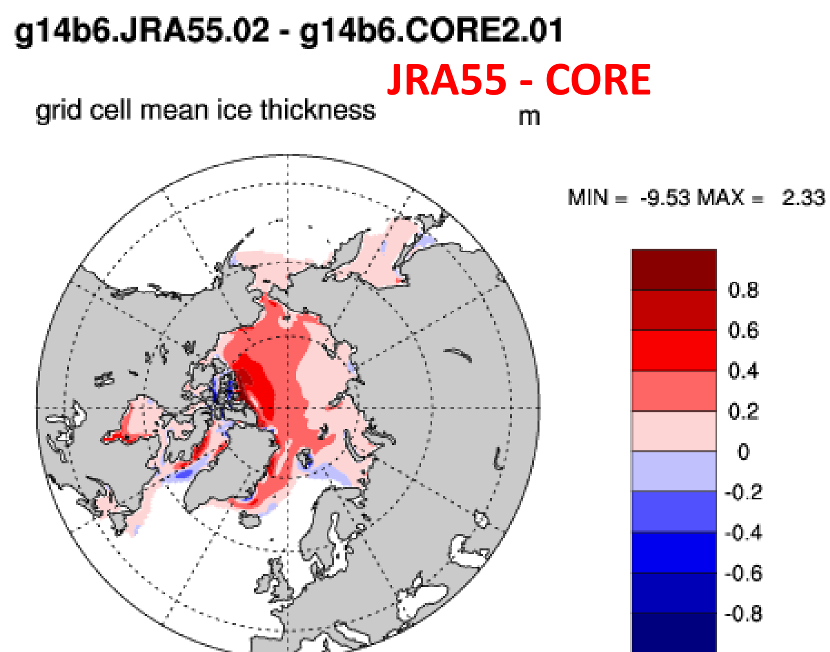


- Comparably good winter ice edge representation in Arctic, except for ice edge retreat in northern Labrador Sea

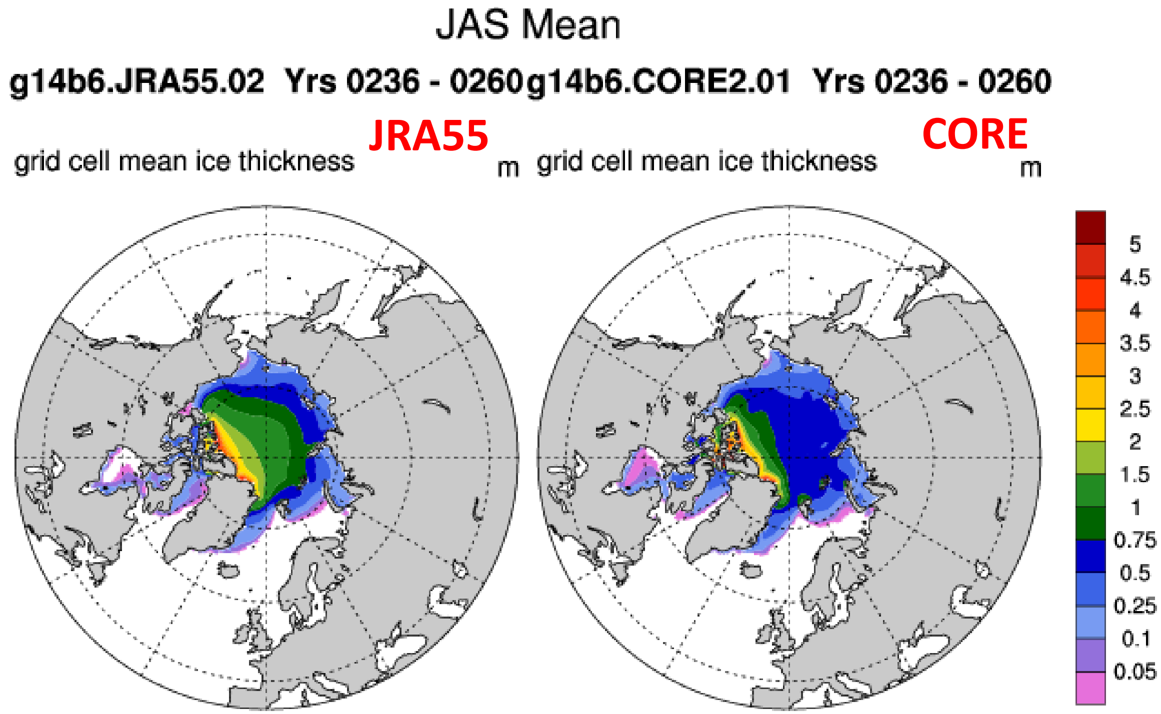
Winter NH Sea Ice Thickness



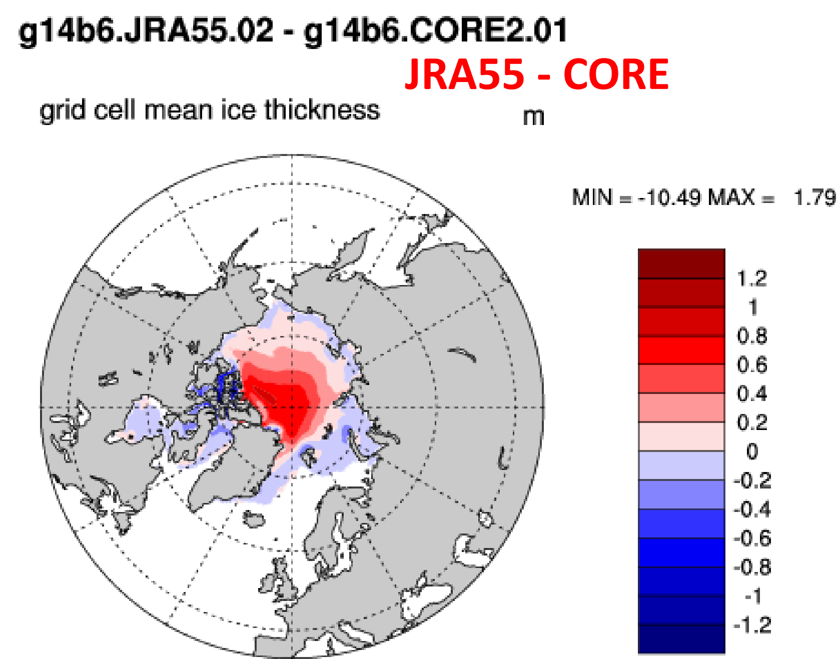
- ✓ Thicker winter sea ice with JRA55



Summer NH Sea Ice Thickness

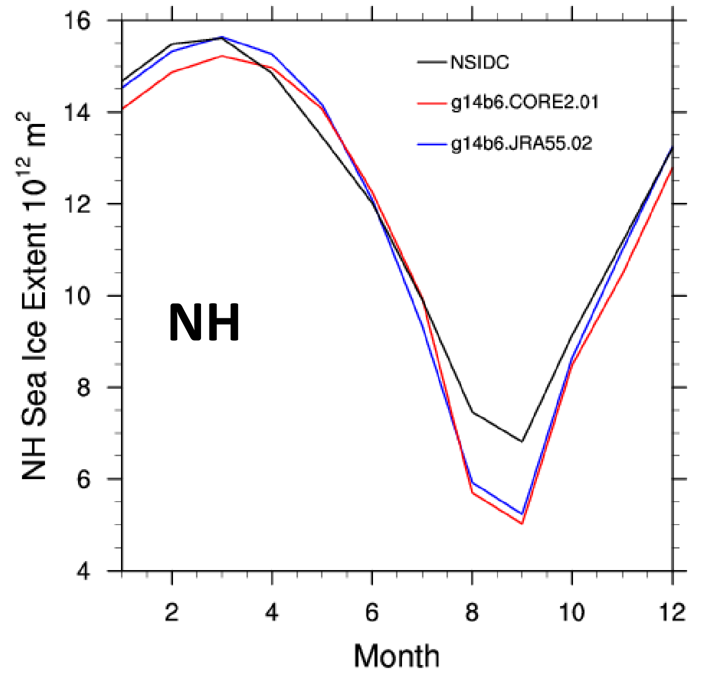


- ✓ Thicker summer sea ice with JRA55

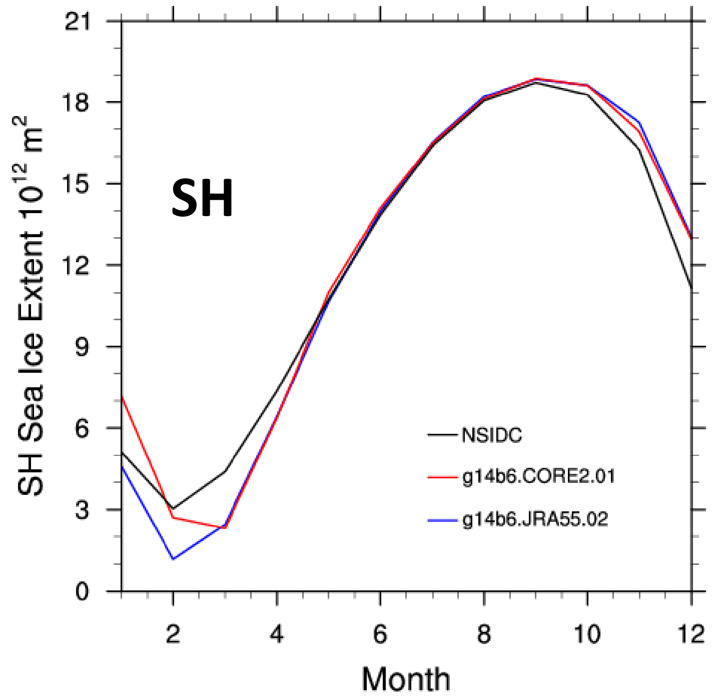


Seasonal Cycle of Sea Ice Extent

- Despite thicker ice, no improvement in summer SIE bias



- Improved timing of summer minimum, but mean summer SIE is worse

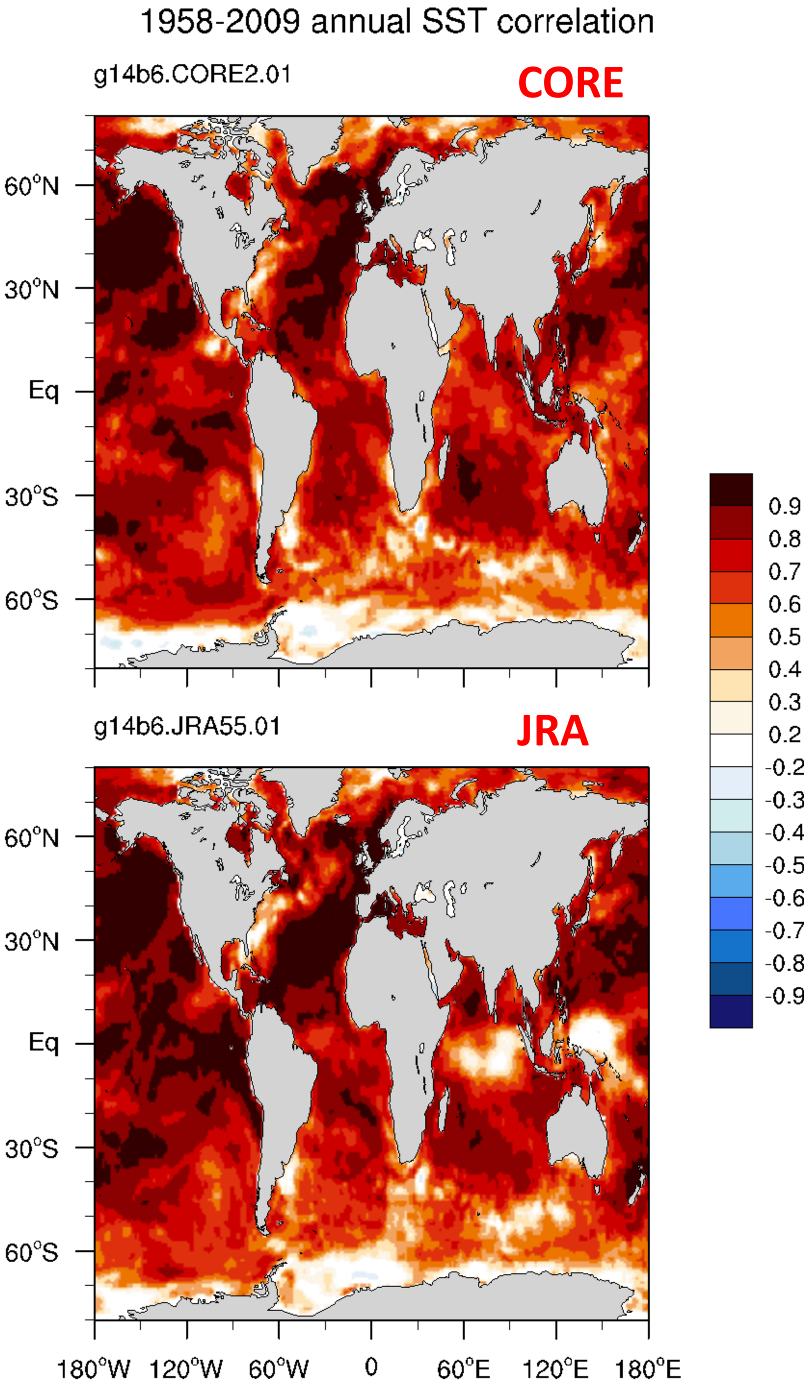


- ➔ Overall reduction of temperature bias in upper ocean with notable improvements in chronic SST warm bias in upwelling zones
- ➔ Slight degradation in upper ocean salinity bias, particularly in the vicinity of the Maritime Continent
- ➔ Abyssal waters too cold and fresh (spinup issue)
- ➔ AMOC stabilizes at reasonable (slightly weak) strength, but associated depth profile and heat transport are degraded (spinup issue?)
- ➔ ACC is too strong
- ➔ Encouraging improvements in sea ice simulation

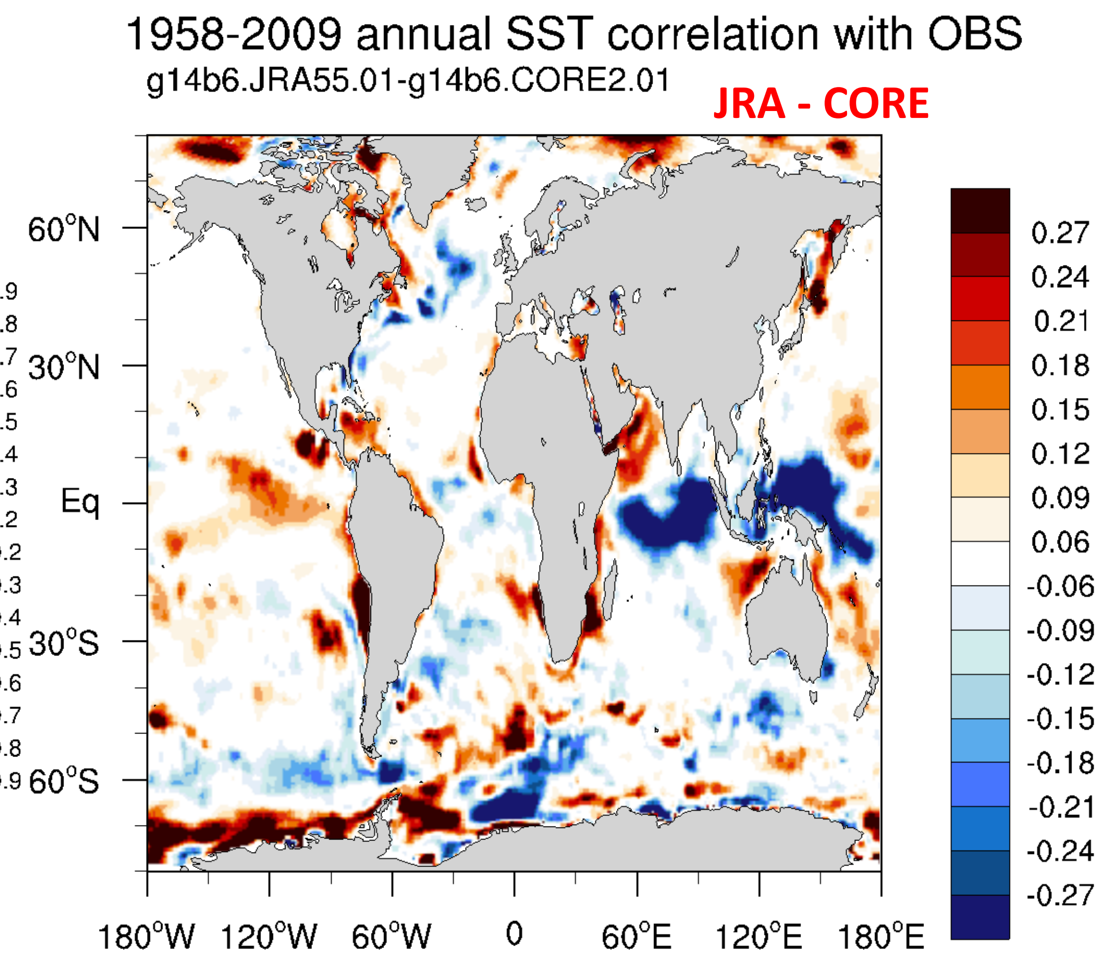
Interannual Variability

(5th cycle, 1985-2009)

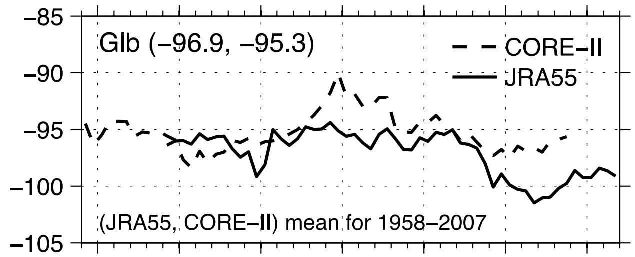
SST Skill



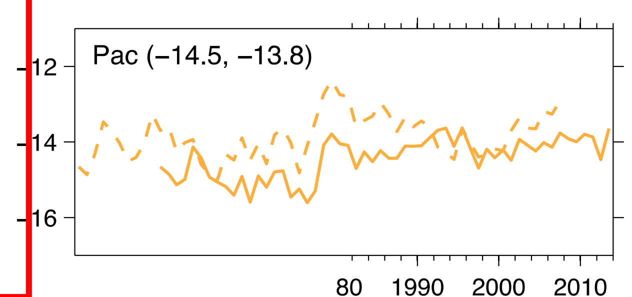
Difference



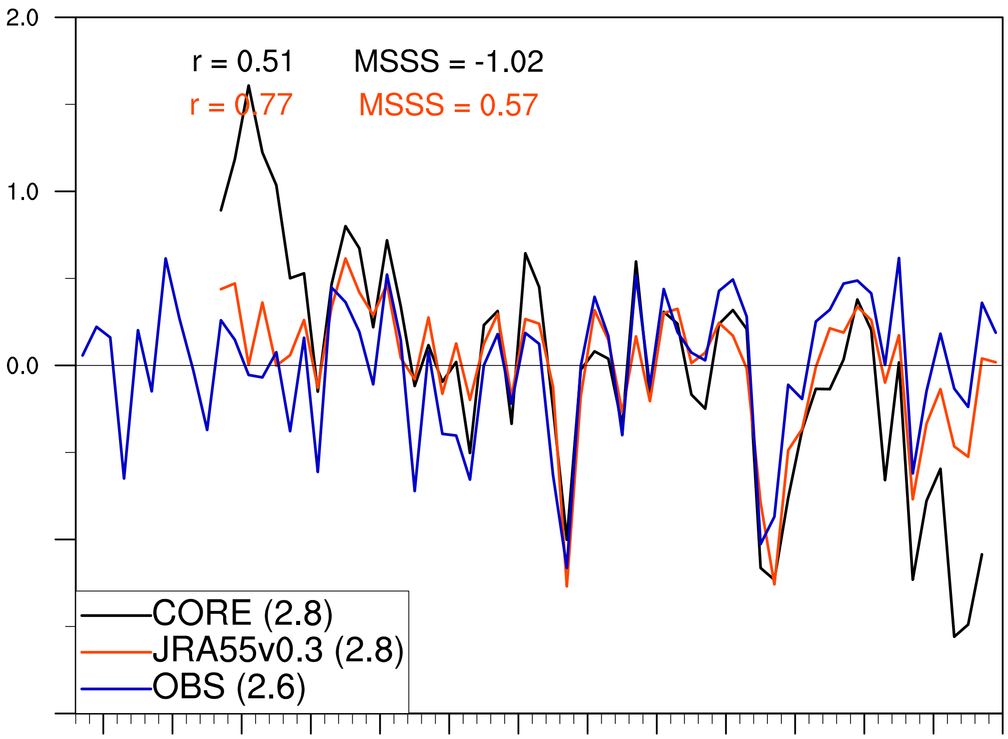
Turbulent Heat Flux Comparison

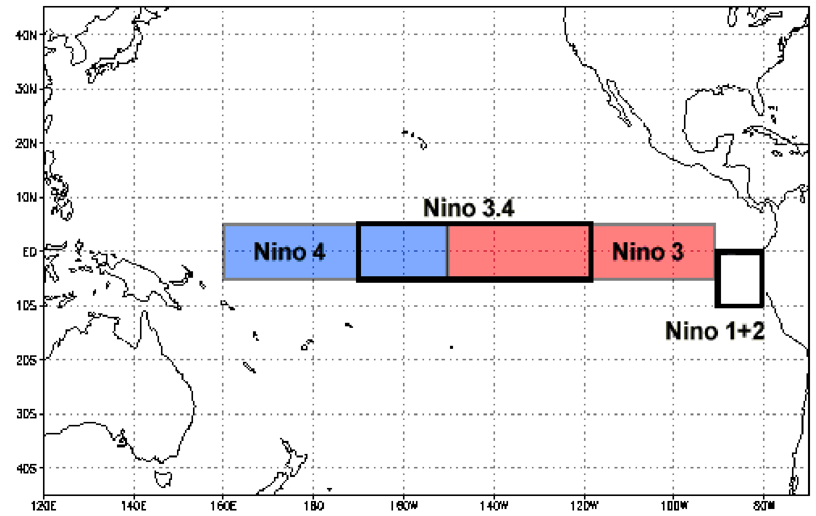


- ✓ The mean values are smaller in JRA55 for all basins
- ✓ Discrepancy is most obvious in the Atlantic Latent heat flux: the ~1980 peak is absent in JRA55
- ✓ ~ 1980 peak is more or less found in all basins in CORE-II
- ✓ The abrupt drop in the global mean is largely due to the IO



Tropical Pacific Zonal SST Gradient (Nino4 – Nino3)

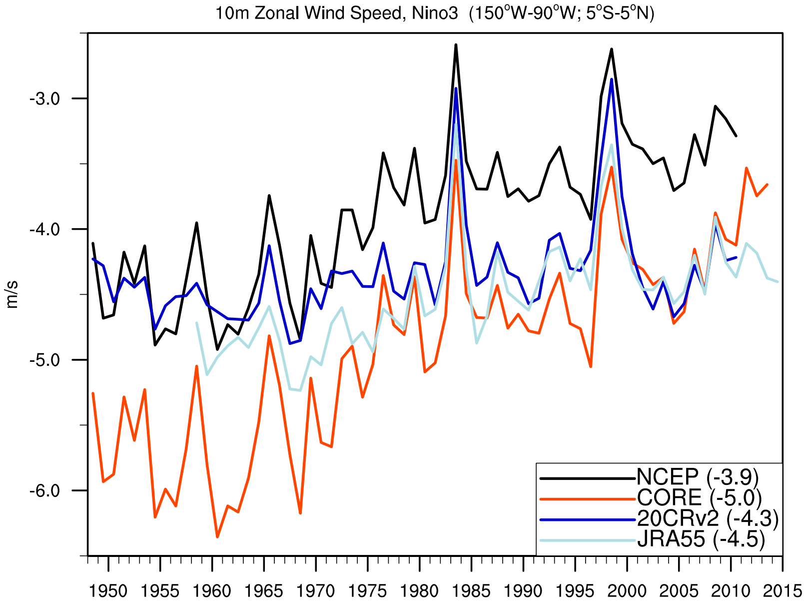


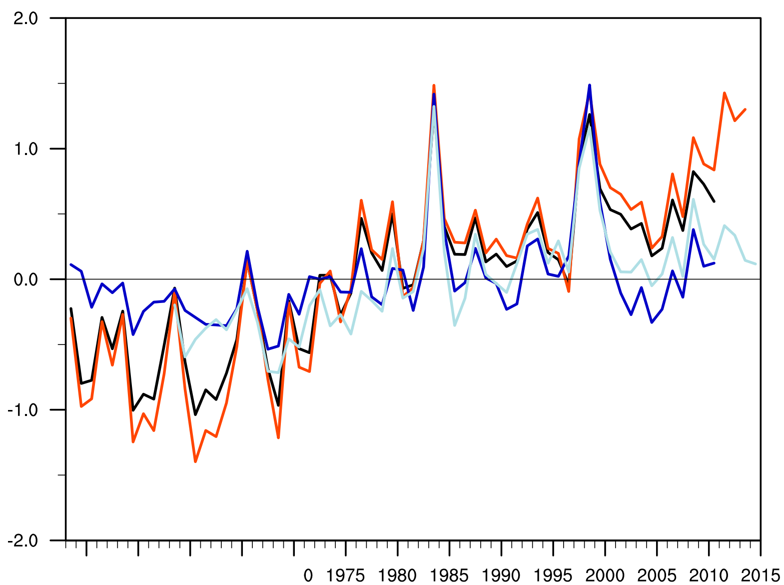


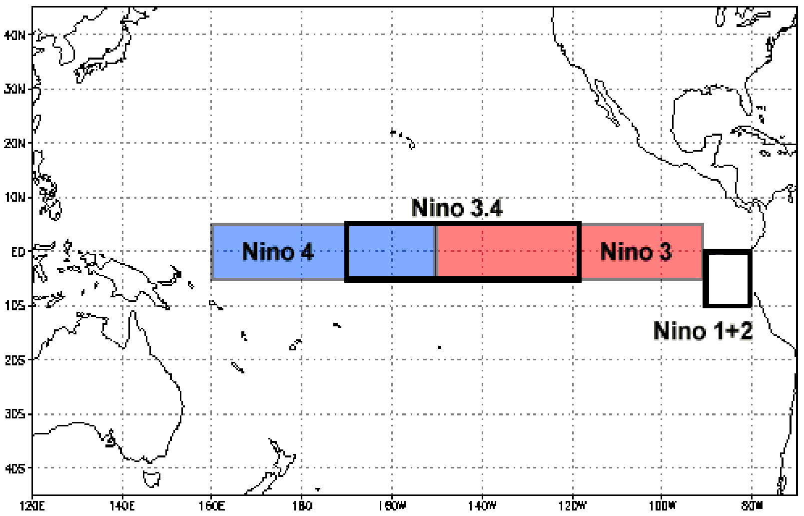
- Spurious ΔSST trend in CORE contributes to poor ENSO skill in CORE-initialized decadal prediction runs

✓ Much better simulation with JRA55

Equatorial Pacific Zonal Wind



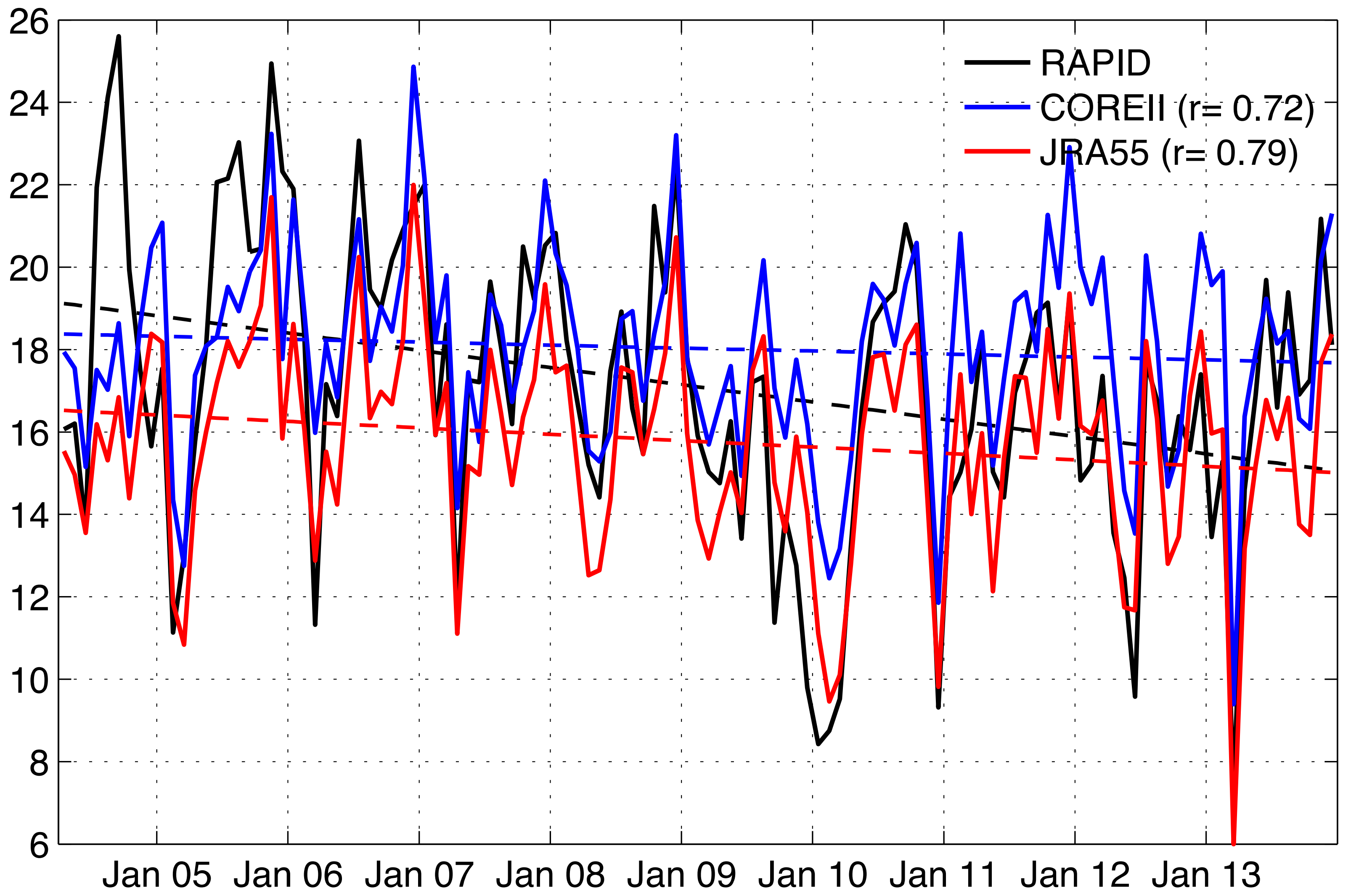




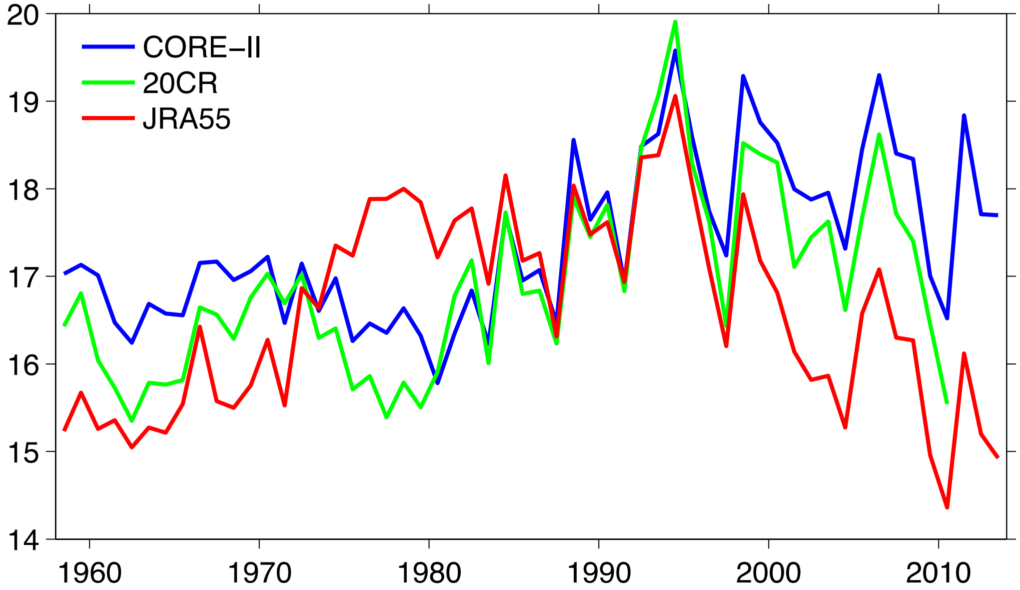
- Spurious ΔSST trend in CORE contributes to poor ENSO skill in CORE-initialized decadal prediction runs

✓ Much better simulation with JRA55

Monthly AMOC Time series at 26.5ºN



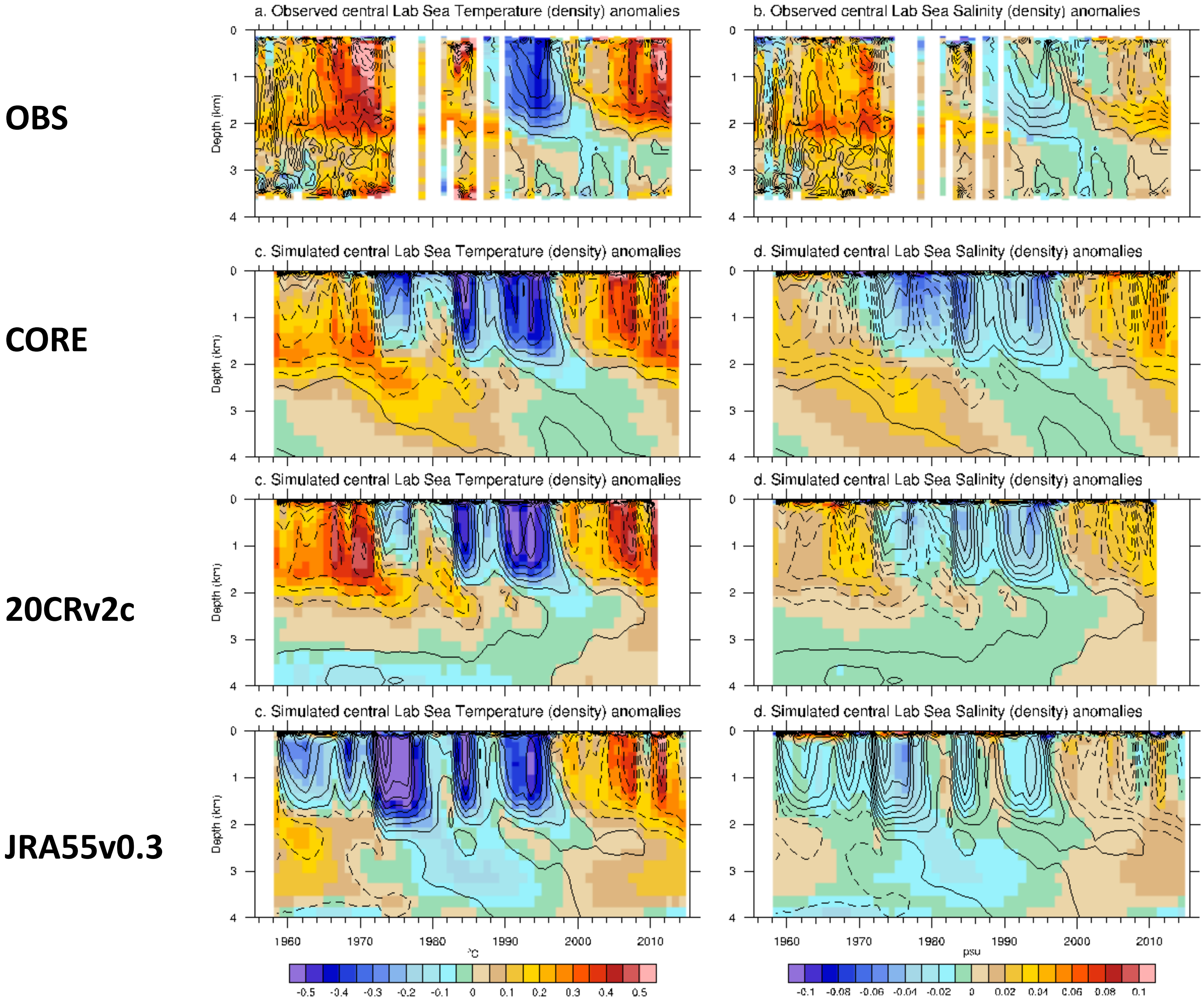
Annual AMOC Time series



- AMOC variability in CORE & 20CR is very similar; JRA55 gives different low-frequency variability

- 1970->mid-1990s trend is positive in CORE & 20CR, negative in JRA55

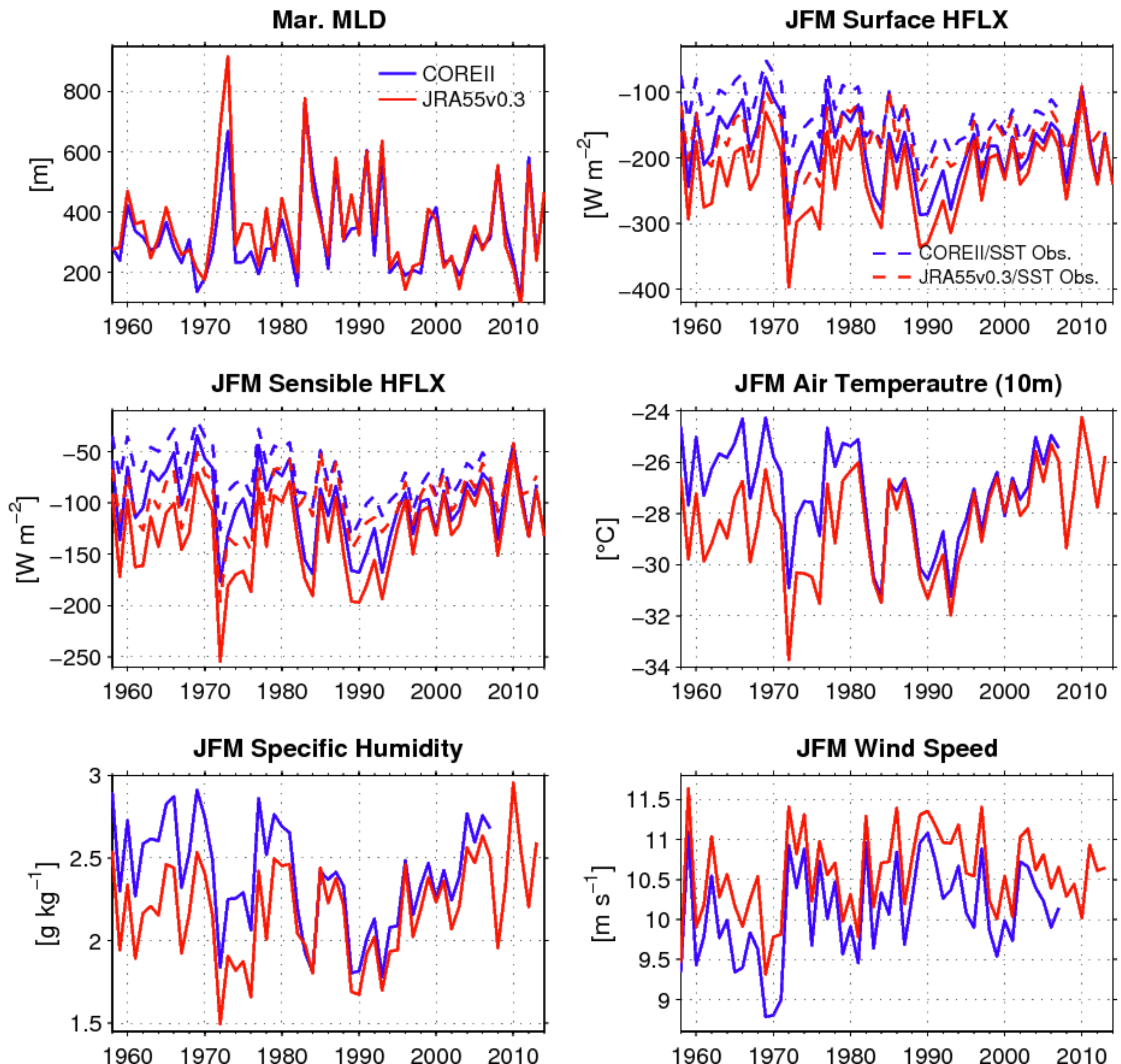
Annual Labrador Sea Hydrography Time series



Labrador Sea (52-60°N, 60-44°W) Time Series

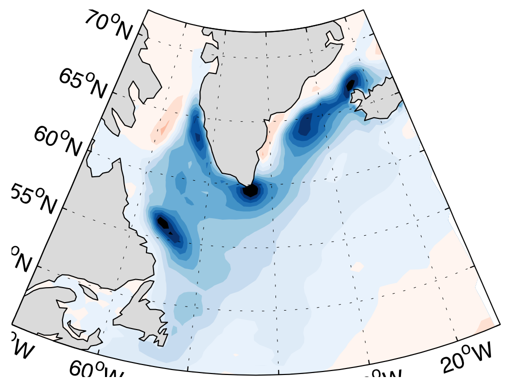
- Deep convection actually *stronger* in JRA55 particularly in 1970s (so weaker AMOC is **not** due to weaker NH buoyancy forcing!)
- Related to stronger turbulent heat flux forcing (much colder, drier air prior to ~1980), and consistently stronger winds

★ Why do JRA55 and CORE(NCEP) surface air properties over the Atlantic DWF regions diverge so dramatically prior to 1980?

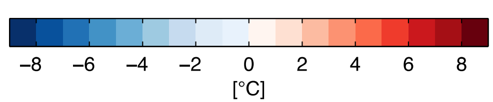


Labrador Sea Winter Heat Flux Differences (1972-78)

- Flux analysis (using same observed SST & sea ice extent data) shows large (~100 W/m^2) winter flux differences associated with air temperature difference along the winter sea ice edge
- Perhaps related to different (pre-satellite) sea ice boundary conditions used in the different reanalyses??
- Might Southern Ocean spinup issues also be related to sea ice boundary conditions in the JRA55 reanalysis?



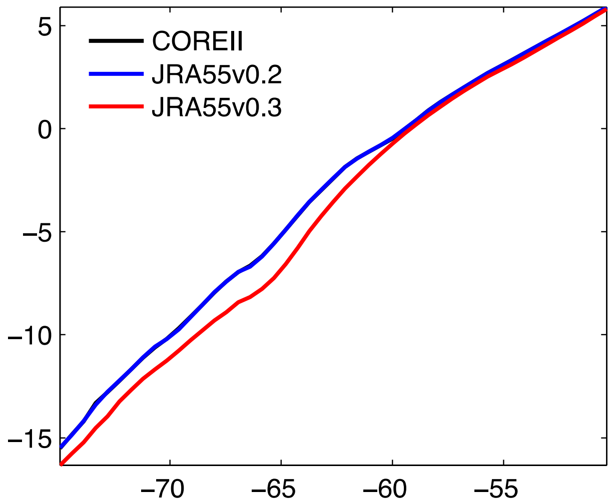
ir Temp.

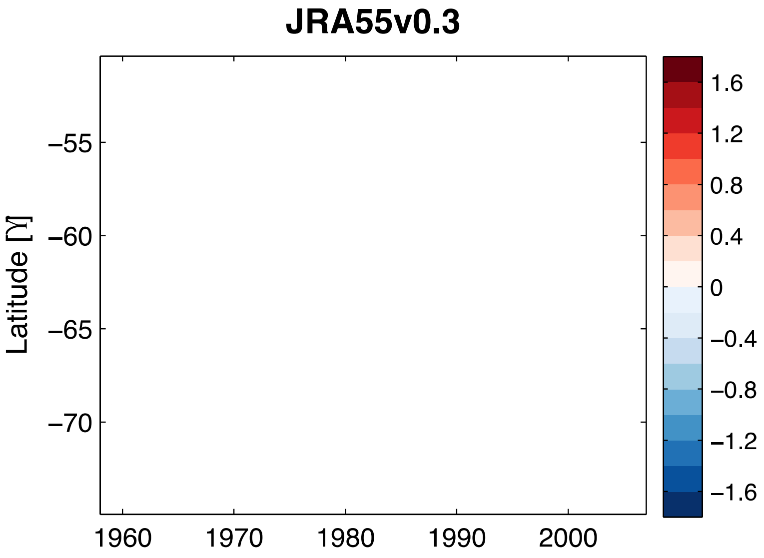


JRA55 – CORE

magenta (JRA55 SIE)
Black (NCEP SIE)

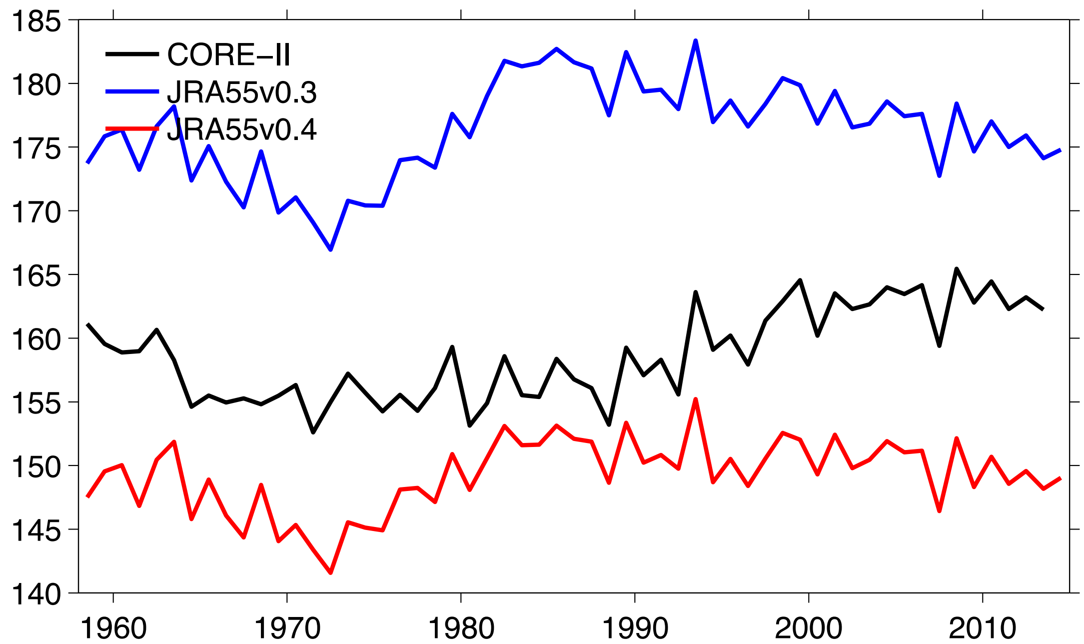
Southern Ocean 10m air temperature

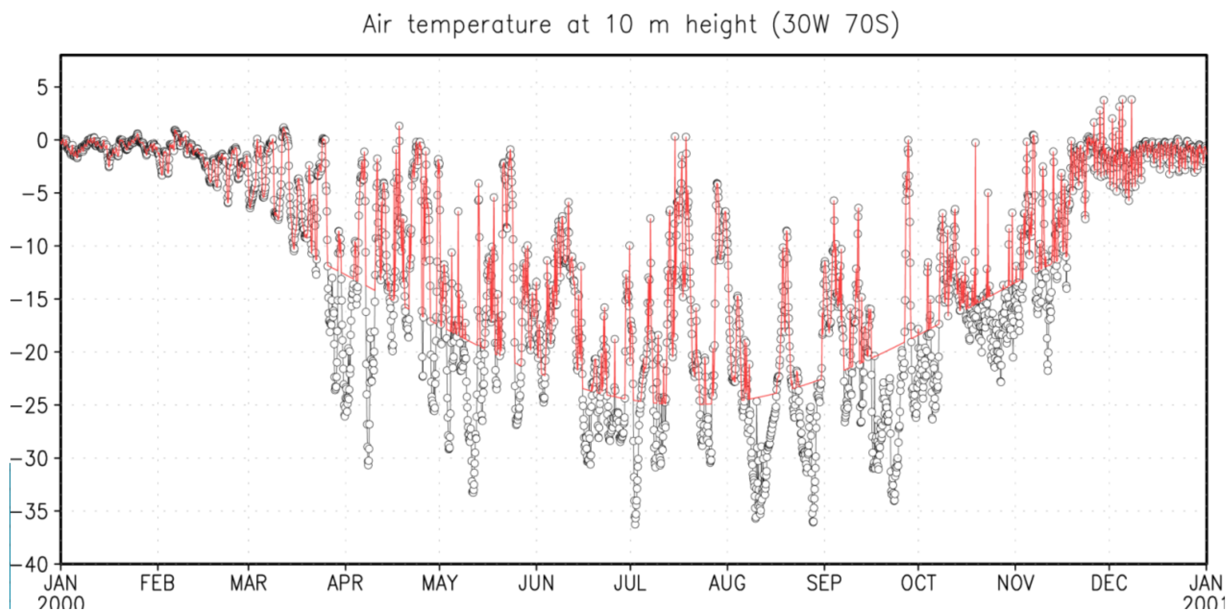




Antarctic Circumpolar Current

- V0.4 (lower bound on Antarctic air temp, as in CORE) yields weaker mean ACC and reduced 1970s spinup

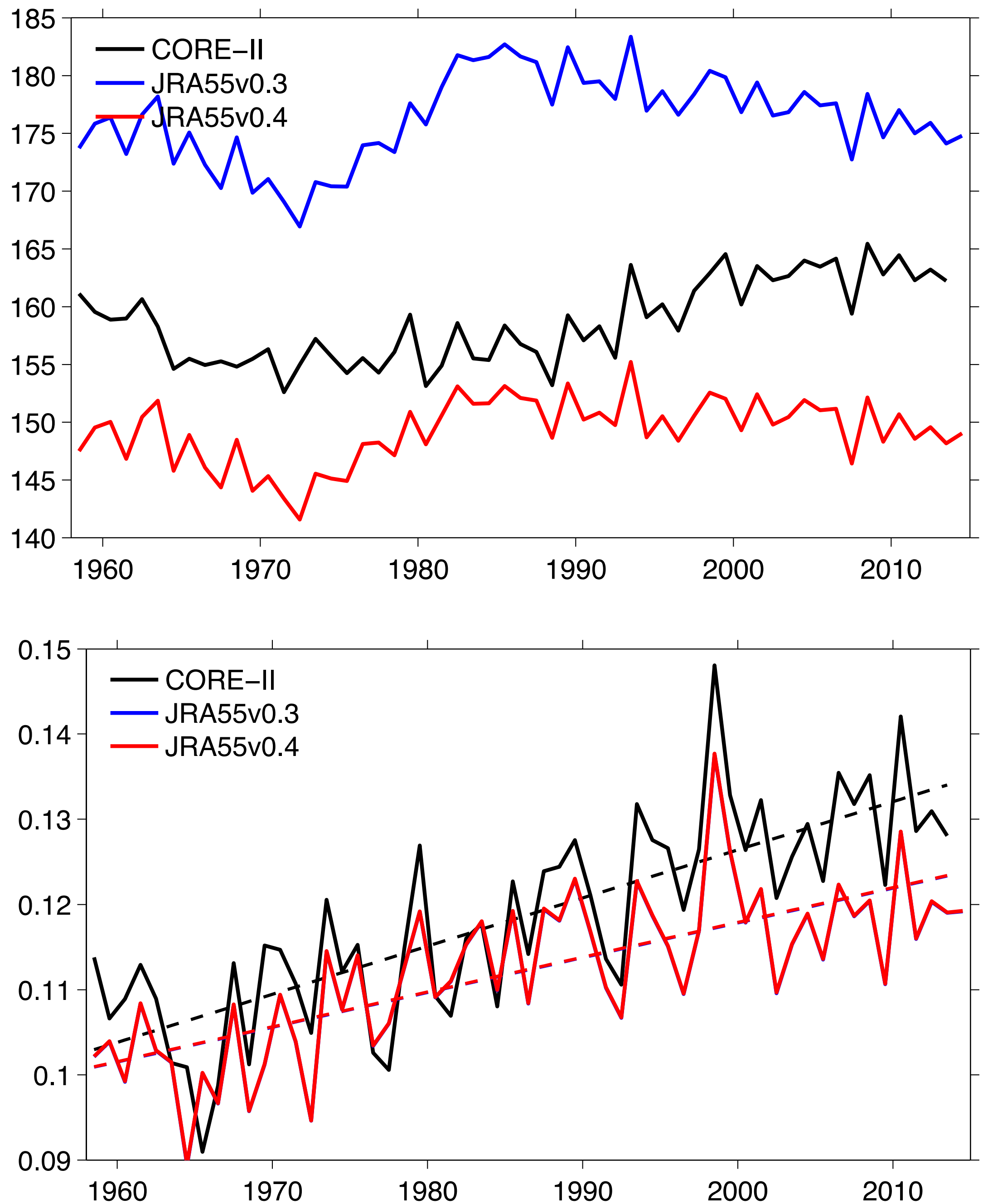




Black: v0.3
Red: v0.4

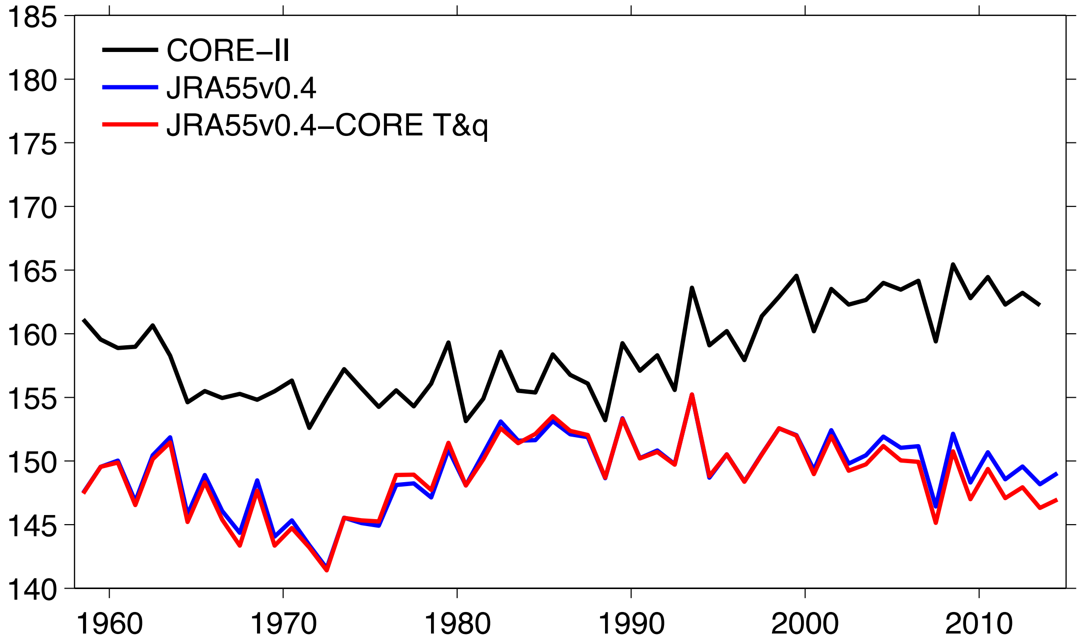
Antarctic Circumpolar Current

- V0.4 (lower bound on Antarctic air temp, as in CORE) yields weaker mean ACC and reduced 1970s spinup
- ACC variability still differs from CORE despite similar TAUX trend



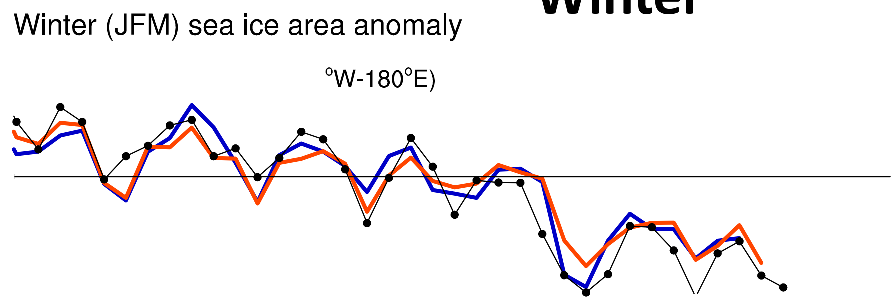
Sensitivity to atmospheric temp & humidity

- New experiment: repeat 5th cycle of JRA55v0.4 but using CORE air temp & humidity
- JRA55 variability in Southern Ocean appears to be strongly influenced by wind-driven Ross Sea polynya in 1970s ➔ very different buoyancy forcing of ocean
- JRA55 variability in the N. Atlantic changes character with different temp & humidity



NH Sea Ice

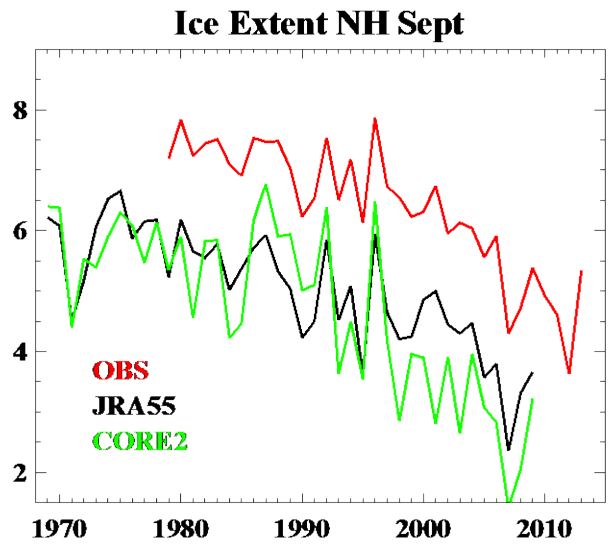
Winter



- Very comparable winter sea ice extent variability over the satellite era

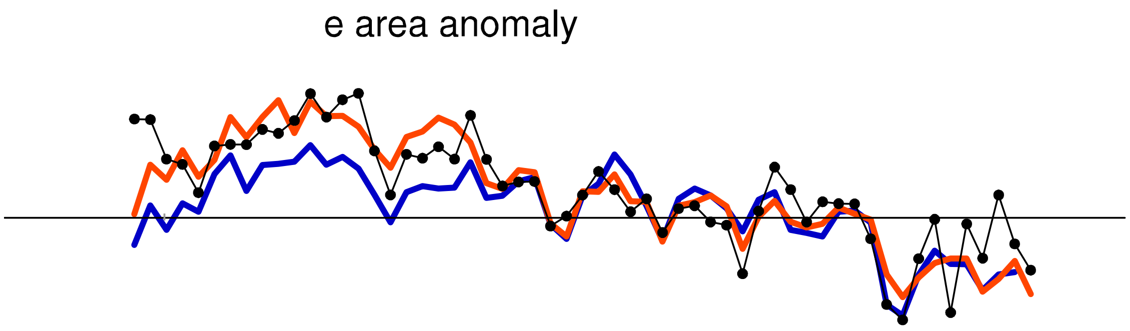
- Summer sea ice extent variability is more realistic in JRA55 (thicker winter ice)

Summer



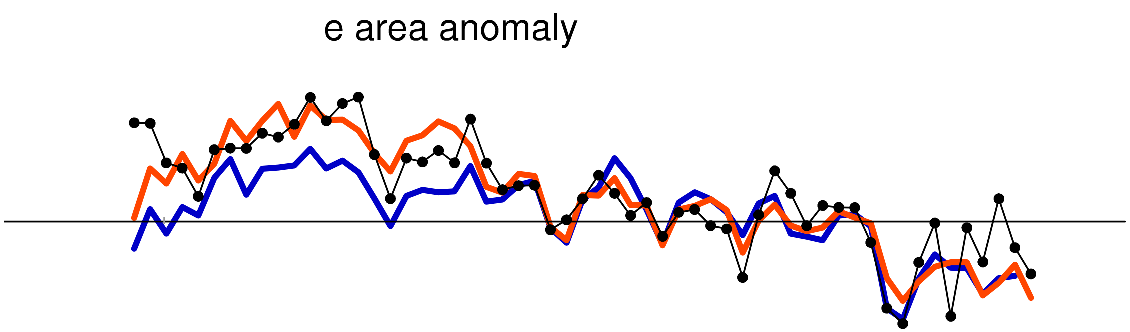
NH Winter Sea Ice

- Large differences in winter sea ice extent in the pre-satellite era
- JRA55 seems to do better than CORE, but…



NH Winter Sea Ice

- Large differences in winter sea ice extent in the pre-satellite era
- JRA55 seems to do better than CORE, but…

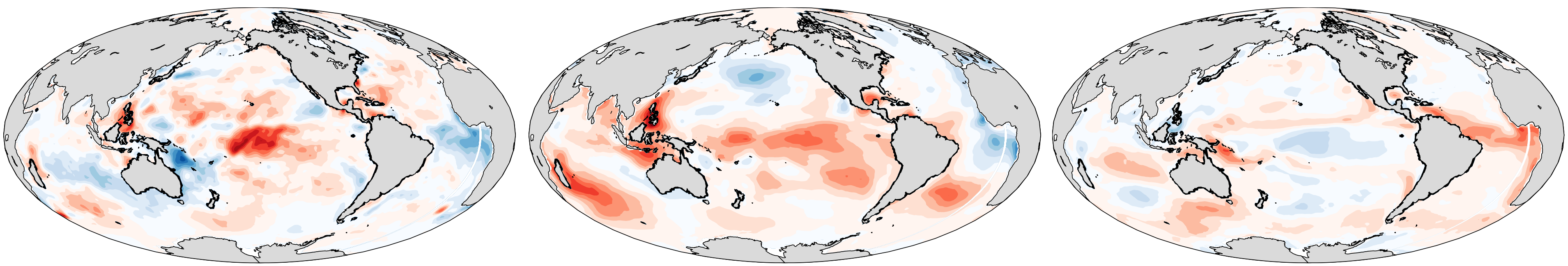


- ➔ Preliminary analysis with POPCICE suggests that the realism of simulated ocean/ice interannual variability can be improved in many respects by moving from CORE to JRA55
- ➔ Very promising improvements in skill relative to obs in SST (except Maritime Continent), wind-driven MOC, & sea ice
- ➔ HOWEVER, there are important outstanding questions regarding the fidelity of multidecadal ocean/ice variability driven by high latitude buoyancy forcing

- ➔ Work is ongoing to address these & other issues for JRA55v1.0

Turbulent Heat Flux Comparison

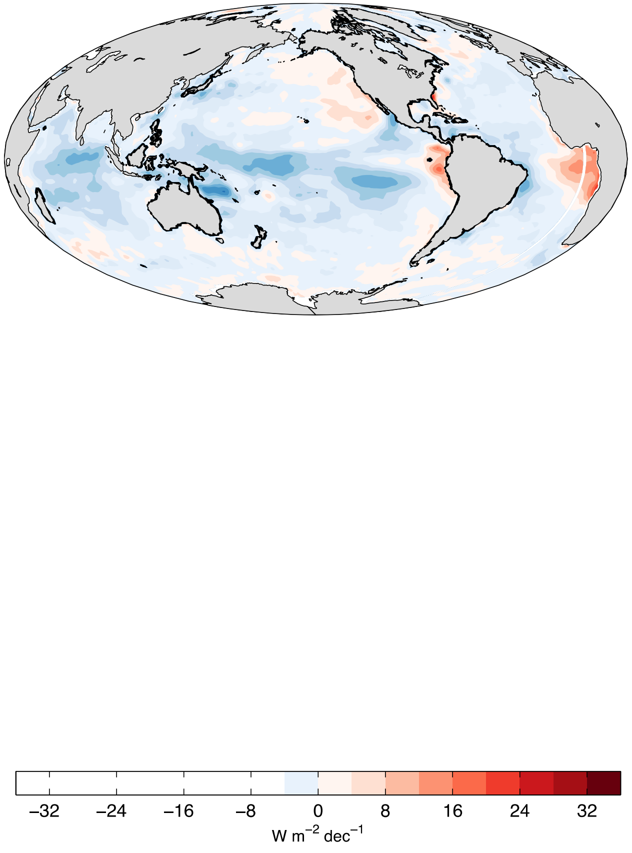
Q_{lh} Trend (1961-1980) | q_{10m} Trend (1961-1980) | $|U_{10m}|$ Trend (1961-1980)



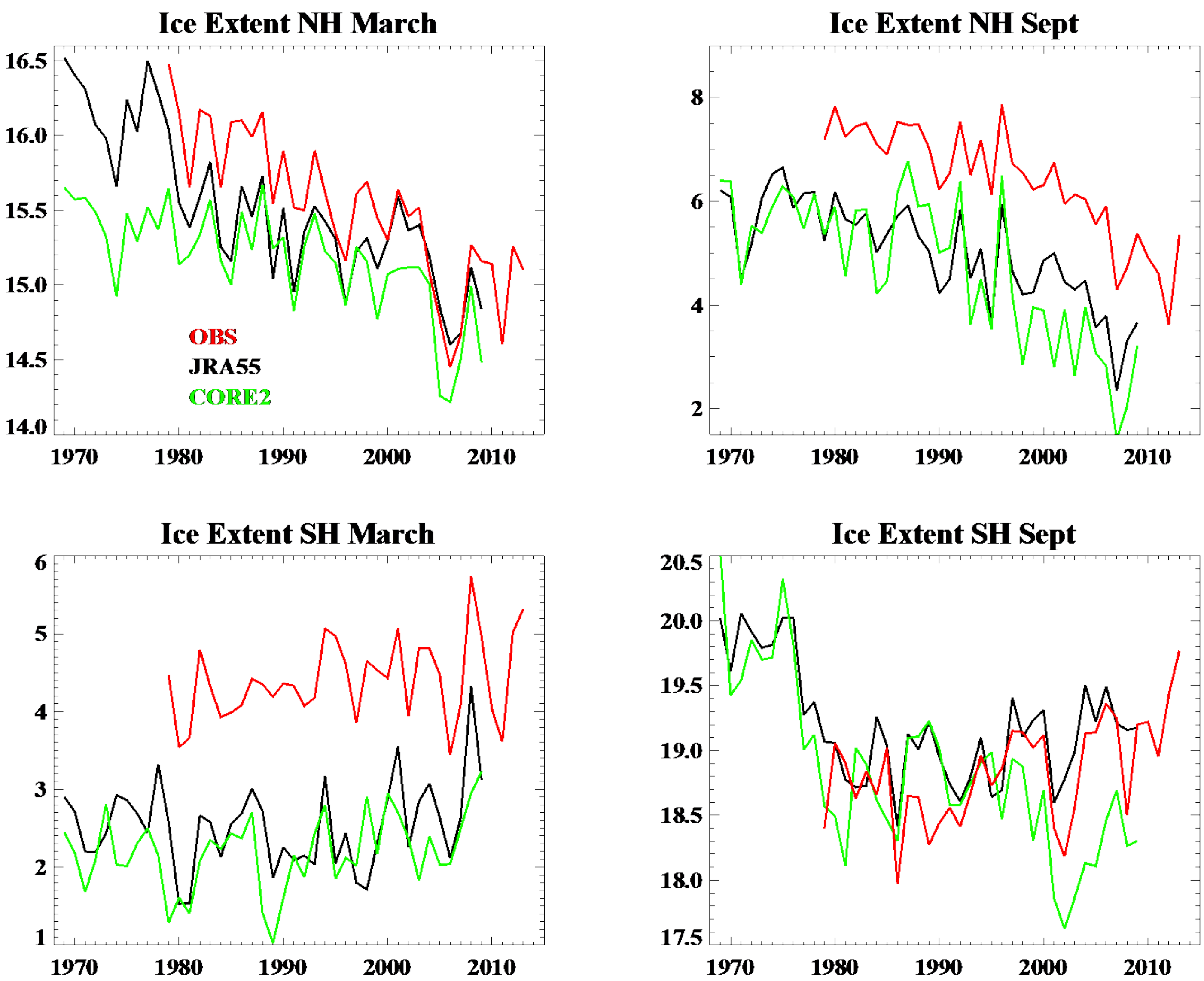
- ✓ Apparently, the different low-frequency variability in Q_{lh} is due to opposite trend in the South Atlantic, especially off the west coast of the Africa
- ✓ which is related to the opposite trend of both specific humidity and wind speed.

Turbulent Heat Flux Comparison

Q_{lh} Trend (1986-2005)



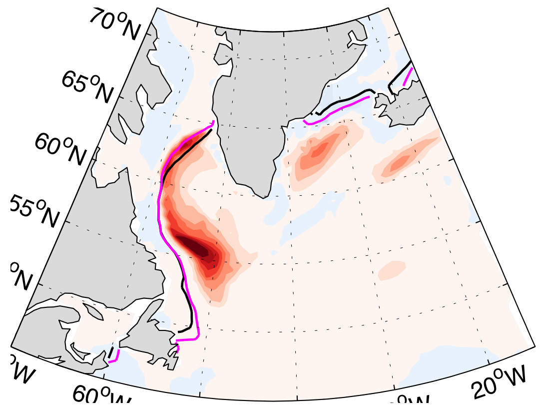
NH Winter Sea Ice

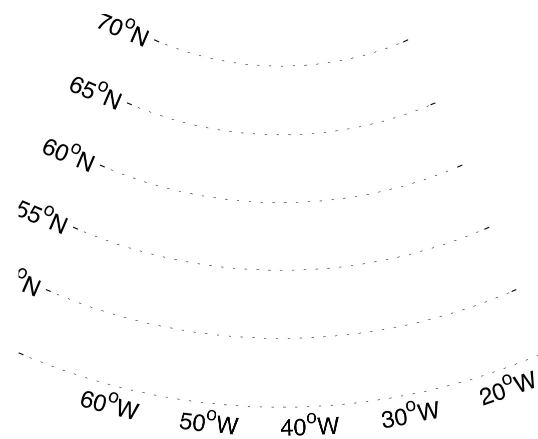


JRA55 - CORE

Labrador Sea Winter Heat Flux Differences (1972-78)

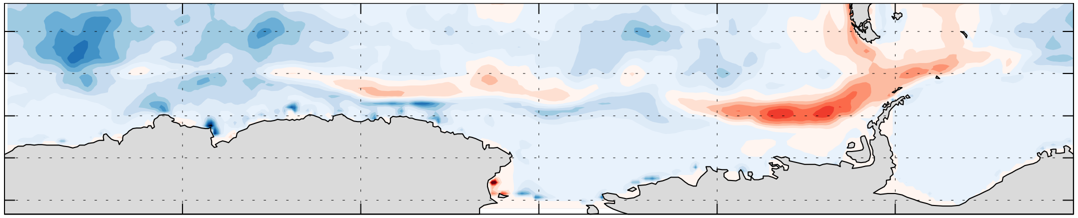
- From hindcast simulations:





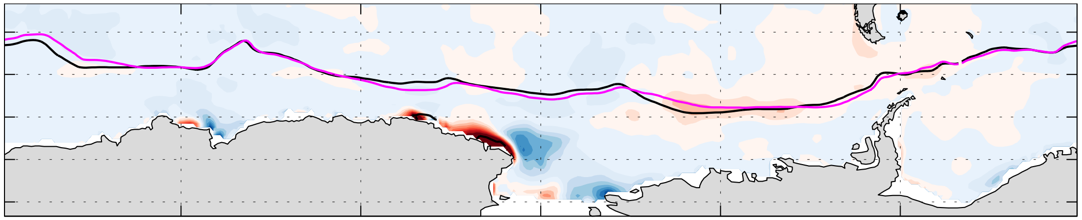
Southern Ocean Winter Heat Flux Differences (1972-78)

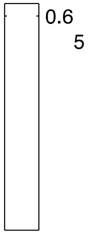
rom Forcing



Southern Ocean Winter Heat Flux Differences (1972-78)

Difference (JRA55-COREII) From Hindcast Simulations





Spinup Sensitivity Runs