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

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

NCAR, Boulder, Colorado, USA
Outline

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• Simulation spin-up
• Mean state characteristics
• Interannual variability
## POPCICE Ocean-ice Hindcast Experiments

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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 climatological heat flux (W/m²) 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.

Global: g14b6.CORE2.01 GLOBAL BASIN

Arctic: g14b6.CORE2.01 ARCTIC BASIN

SO: g14b6.CORE2.01 SOUTHERN BASIN

Atlantic: g14b6.CORE2.01 ATLANTIC BASIN

Pacific: g14b6.CORE2.01 PACIFIC BASIN

Indian: g14b6.CORE2.01 INDIAN BASIN
Heat Content Trends over simulation years 1-40 (JRA55)

200–500m T Trends for 1–40

Heat Content Trends for 1–40

200-500m

Full depth
Anomalous strong turbulent heat loss explains 1st cycle heat flux anomaly in Southern Ocean.
AMOC

- Stable AMOC of comparable mean strength to CORE by 5th cycle
Annual Mean Sea Ice Time Series

- 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
→ 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

Mean = -0.010, RMS = 0.555

CORE

Mean = 0.041, RMS = 0.585

SST difference (JRA55 - CORE)
SST Bias

*OBS = Hurrell et al. 2008

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

*OBS = PHC2*

**SSS difference (JRA55 - CORE)**

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

**JRA55**
TEMP ZONAL-AVE (GLO) g14b6.JRA55.02 [236-260]

**CORE**
TEMP ZONAL-AVE (GLO) g14b6.CORE2.01 [236-260]

**MODEL - OBS**
Zonal Mean IAGE
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
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 Arctic sea ice with JRA55

JFM Mean

\[ \text{g14b6.JRA55.02 Yrs 0236 - 0260} \quad \text{g14b6.CORE2.01 Yrs 0236 - 0260} \]

grid cell mean ice thickness

JRA55 \_m \quad \text{grid cell mean ice thickness} \quad \text{CORE} \_m

\[ \text{g14b6.JRA55.02 - g14b6.CORE2.01} \]

grid cell mean ice thickness \_m

MIN = -9.53 MAX = 2.33
Summer NH Sea Ice Thickness

Thicker Arctic sea ice with JRA55

"The JRA55 data set does result in thicker summer sea ice compared to the CORE (this is a step in the right direction), although even the JRA summer sea ice is still too thin."

-- Laura Landrum (NCAR)
Seasonal Cycle of Sea Ice

- Despite thicker ice, no improvement in NH summer sea ice extent bias

- Improved timing of summer minimum in SH
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, particularly in NH
Interannual Variability
(5th cycle, 1985-2009)
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
• 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 26.5°N

Monthly AMOC Max at 26.5°N

RAPID (r = 0.72)
COREII (r = 0.72)
JRA55 (r = 0.79)
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

OBS

CORE

20CRv2c

JRA55v0.3
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 (early 1970s)

- Flux analysis (using same observed SST & sea ice extent data) shows large (~100 W/m²) 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?
Southern Ocean 10m air temperature

1979–2007 Mean

COREII

JRA55v0.2

JRA55v0.3


Latitude [°]

1.6

1.2

0.8

0.4

0

-0.4

-0.8

-1.2

-1.6

-70

-65

-60

-55

Latitude [°]
Antarctic Circumpolar Current

Drake Passage Transport

Zonal Wind Stress Average (60°S−40°S)
NH Sea Ice

- Very comparable winter sea ice extent variability over the satellite era
- Summer sea ice extent variability is more realistic in JRA55 (thicker winter ice)
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 JRA55 buoyancy forcing.
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Thank you.
Monthly AMOC Max at 26.5°N

Monthly Northward Heat Transport at 26.5°N
Turbulent Heat Flux Comparison

- 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)

JRA55

CORE–II
Labrador Sea Winter Heat Flux Differences (early 1970s)

- From hindcast simulations:
Spinup Sensitivity Runs

Temperature

Sea-Ice Extent (Southern Hemisphere)