ACCESS-OM: comparison between CORE-II and JRA-55 forcing for the CMIP6 Ocean Model

Intercomparison Project (OMIP)

Fabio Dias, C.M. Domingues, S.J. Marsland, N.L. Bindoff, S. Rintoul
Summary

- Model specifications
- Forcing details
- Results:
  - Global mean drifts
  - Surface and zonal mean biases
  - Meridional Overturning
  - Drake Passage transport
  - Seasonal MLD and ice extension
- Question about Ocean Heat Content
  - SST in ocean sea-ice models
  - Thermosteric comparison model x observation
Model specifications

- ACCESS-OM 2.0
- MOM5, CICE5, MATM, OASIS3.25 Coupler (Bi et al. 2013)
- Coarse grid 1° with:
  - tripolar Arctic North 65°N
  - equatorial refinement 1/3°
  - Mercator 0.25°-1° in southern hemisphere
- Ocean model:
  - 50 level z* coordinate
  - MDPPM advection scheme
  - Horizontal friction: isotropic Laplacian + biharmonic operator in WBC
  - Vertical mixing: KPP + tidal mixing param (Simmons et al. 2004) + background vertical diffusivity ($k_o = 1 \times 10^{-5} \text{ m}^2\text{s}^{-1}$) (reduced in equator)
  - Convection parametrised as enhancing vert. diff (Klinger, 1996)
  - Isoneutral diffusion (Redi, 1982) scheme modified from GM (Ferrari et al. 2010)
  - Submesoscale mixed layer restratification scheme (Fox-Kemper et al. 2011)
  - Overflow: Sigma transport scheme of Beckmann and Drescher (1997) + mixdownslope scheme (Griffies, 2009)
  - Surface salinity restoring with dt=15 days
Forcing details

- CORE-II Inter annual atmospheric state (Large and Yeager, 2009)
  - 1948 - 2007: 60 years
  - 112 x 94 grid cells
  - Using CORE protocol: cycle repeated 5 times = 300 yrs (Griffies et al, 2009b)

- JRA-55 based surface atmospheric data set (Tsujino et al 2015)
  - v0.4 (updating to v0.8 currently)
  - 1958 - 2015
  - 640 x 320 grid cells
  - Maintaining CORE-II inter annual runoff
  - run for 5 cycles until 2007 = 250 years

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Forcing details table

<table>
<thead>
<tr>
<th></th>
<th>CORE (cif version 2)</th>
<th>JRA55</th>
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<tbody>
<tr>
<td>Winds</td>
<td>6 hourly</td>
<td>3 hourly</td>
</tr>
<tr>
<td>Short wave radiation</td>
<td>Daily</td>
<td>3 hourly</td>
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<tr>
<td>Long wave radiation</td>
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<tr>
<td>Air temperature</td>
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<tr>
<td>Specific humidity</td>
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<td>3 hourly</td>
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<tr>
<td>Sea surface pressure</td>
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<tr>
<td>Precipitation</td>
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<td>3 hourly</td>
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<tr>
<td>River runoff</td>
<td>Monthly</td>
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</tr>
<tr>
<td>Period</td>
<td>1948-2009 (62yr)</td>
<td>1958-2014 (57yr)</td>
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</tbody>
</table>
Forcing details

Global mean forcing fields
Results

Volume-weighted global ocean potential temperature and salinity

Horizontally averaged annual mean global ocean anomalies of potential temperature

CORE-II

JRA-55
Surface biases: last 10 years - 1st year average
Sea Surface Temperature

CORE-II

JRA-55

SST Bias

SST Bias: CORE-II - JRA-55
Surface biases: last 10 years - 1st year average
Sea Surface Salinity

CORE-II

JRA-55

SSS Bias: CORE-II - JRA-55
Zonal mean temperature over last 10yr - 1sr yr avg

Initial condition

CORE-II

JRA-55

CORE-II - JRA-55
Zonal mean salinity over last 10yr - last cycle

Initial condition

CORE-II

JRA-55

CORE-II - JRA-55
Global and Atlantic MOC

CORE-II

JRA-55

Sv

Sv

Sv

Sv
Drake Passage transport
Average 1993-2007

Mixed Layer Depth - September

Core-II

JRA-55

Mixed Layer Depth - March

Core-II

JRA-55
Average March 1993-2007

Mixed Layer Depth

CORE-II

JRA-55

Ice thickness

CORE-II

JRA-55
Average March 1993-2007

Difference

Mixed Layer Depth

CORE-II - JRA-55


Ice thickness

Average March 1993-2007

Mixed Layer Depth

CORE-II

JRA-55

Ice proportion

CORE-II

JRA-55
Average March 1993-2007

Difference

Mixed Layer Depth

CORE-II - JRA-55

Ice proportion

CORE-II - JRA-55 ice proportion - March 1993-2007
Average September 1993-2007

Mixed Layer Depth

CORE-II

JRA-55

Ice thickness

CORE-II

JRA-55
Average September 1993-2007

Difference

Mixed Layer Depth

CORE-II - JRA-55


Ice thickness

CORE-2 - JRA-55 ice thickness - September 1993-2007
Average September 1993-2007

Mixed Layer Depth

CORE-II

JRA-55

Ice proportion

CORE-II

JRA-55
Average September 1993-2007

Mixed Layer Depth

Difference

CORE-II - JRA-55

Ice proportion

CORE-II - JRA-55 ice proportion - September 1993-2007
Questions arrises from the CORE-II paper on sea level (Griffies et al. 2014):

1) Why does SST not rise post-1980? Net heat flux near 0 W/m² suppress the increasing in SST during the IPO+ phase - as in coupled models.

2) Drift in global thermometric sea level in CORE simulations does not show good agreement with observations until 1993. Why?
1) SST does not rise post-1980: net heat flux near 0 W/m² suppress the increasing in SST during the IPO+ phase - as seems in coupled models
Griffies hypothesis: lack of longwave feedback

Post-1980 in CORE-II atmospheric state:

- SAT rise leading reduction in sensible cooling (+1 W/m²)
- Air humidity rise - increasing in latent heat flux (+2.5 W/m²)
- Balanced by Longwave heating decrease the same amount
2) Drift in global thermometric sea level in CORE simulations does not show good agreement with observations until 1993. Why?
Ocean Heat Content

a) OHC: CORE-2
- 0-300m
- 0-700m
- 700-2000m
- >2000m
- Total

b) OHC: JRA-55
- 0-300m
- 0-700m
- 700-2000m
- >2000m
- Total
Ocean Heat Budget
Tendencies - avg 1993-2007

CORE-II

Global Ocean

Southern Ocean

Atlantic Ocean

Pacific Ocean

Indian Ocean

Global-mean heat convergences [°C/yr]

Depth [m]

--- net tendency
Ocean Heat Budget
Tendencies - avg 1993-2007

JRA-55

Global Ocean

Southern Ocean

Atlantic Ocean

Pacific Ocean

Indian Ocean

Global-mean heat convergences [°C/yr]

Depth [m]
Objective: To investigate ocean heat uptake and transport in the ACCESS-CORE-II and JRA-55 forcing for the CMIP6 Ocean Model Coordinated Ocean-ice Reference Experiments (CORE-II):

Horizontally integrated heat budget:
\[ \sum_{x,y} dA \left[ \partial_t (C_p \Theta \rho dz) = -C_p \Delta_k \left[ \rho \Theta w + \rho F^Z \right] + \delta_{k,1} Q_{surf} \right] \]

- Increase in total OHC after 1993 similar to observations (Griffies et al. 2014)
- Global average potential temperature drift - small in JRA-55.
- Post-80's all basins show warming. Post-90's warming is more pronounced and leads to a shallower positive temperature anomaly of the global ocean in the Southern Ocean.
- The Pacific Ocean plays an important role in this warming trend.
- Between forcing products, they impact directly the upper 100 m due to vertical cooling from advection and subgrid scale processes, and by boundary fluxes. This decomposition of ocean heat tendency is useful for surface coupler components and for understanding the contributions of the different processes to the heat budget at each level in the water column.

**Next steps:**
- Runoff is secondly important for the net surface boundary heating – this is to be studied in the next CMIP6 models.
- precipitation-evaporation warms it.
- The forcing of the ocean model is important to its performance and to the reliability of the simulation.

**Figure 5:** Global balance above 100 m dominated by SW penetration, nonlocal KPP, submesoscale, isoneutral diffusion, and vertical advection.

**Figure 2:** Global-mean heat convergences for the CMIP6 Ocean Model Intercomparison Project (OMIP) for the ACCESS-OM under both CORE-II and JRA-55 forcing.
Increase in total OHC after 1993 similar to observations (Griffies et al., 2014). Decrease in total OHC prior to 1990 largely due to deep ocean.

**Motivation:** To help understand model spread in surface warming and sea level rise.

**Objective:** To investigate differences in Ocean Heat Uptake and redistribution in the ACCESS-OM study comparing CORE-II and JRA-55 forcings. The Pacific Ocean plays an important role on this warming trend. The contribution of individual terms to the global heat budget is similar between cooling (KPP, submesoscale, isoneutral diffusion) and warming (from vertical advection (warms) and eddy GM parametrisation (cools). The global volume of the surface grid cell, \( v_{surf} \), is distributed throughout the full depth. Hence, variability in the averaged surface area-averaged, depth-integrated heating tendency is distributed throughout the full depth.

**Horizontally integrated heat budget:**

\[
\sum_{x,y} dA \left[ \partial_t (C_p \Theta dz) = -C_p \Delta_k \left( \rho w \Theta + \rho F_z \right) + \delta_{k,1} Q_{surf} \right]
\]

**JRA-55**

**Global ocean**

**Southern Ocean**

**Atlantic Ocean**

**Pacific Ocean**

**Indian Ocean**

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- **net tendency**
- **advection of mean**
- **submeso eddy param**
- **KPP nonlocal + SW pen**
- **meso eddy param**
- **neutral diffusion param**
- **vert diffusion**
- **advection + meso param**
References:

- Simmons, H. L., S. R. Jayne, L. C. St.Laurent, and A. J. Weaver, 2004: Tidally driven mixing in a numerical model of the ocean general circulation. Ocean Modell., 6, 245–263
- Tsujino et al. 2015: JRA-55 based surface atmospheric data set for driving Ocean-Sea ice models versions 0.3 and 0.4.
Thanks!