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

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Outline

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

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-phasell” of CMIP6

Timeline: 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:
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 LYO9 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)

<table>
<thead>
<tr>
<th></th>
<th>reference data</th>
<th>adj*factor based on</th>
<th>Bme* dependency</th>
<th>spaBal* dependency*</th>
<th>How is the factor*used</th>
</tr>
</thead>
<tbody>
<tr>
<td>short wave</td>
<td>adjusted CERES%</td>
<td>mar2000-feb2015</td>
<td>monthly</td>
<td>(x,y) &amp; constant</td>
<td>multiply</td>
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<tr>
<td>long wave</td>
<td>adjusted CERES%</td>
<td>mar2000-feb2015</td>
<td>monthly</td>
<td>(x,y) &amp; constant</td>
<td>multiply</td>
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<tr>
<td>precipitation</td>
<td>CORE</td>
<td>1979-2008</td>
<td>monthly</td>
<td>(x,y) &amp; constant</td>
<td>multiply</td>
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<tr>
<td>air temperature</td>
<td>JRA55-ansl_surf* IABP-NPOLES</td>
<td>1979-1998</td>
<td>monthly</td>
<td>(x,y)</td>
<td>offset</td>
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<tr>
<td>specific humidity</td>
<td>JRA55-ansl_surf*</td>
<td>1979-1998</td>
<td>monthly</td>
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<tr>
<td>wind speed</td>
<td>QuikSCAT*</td>
<td>aug1999-oct2009</td>
<td>monthly</td>
<td>(x,y)</td>
<td>multiply</td>
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<tr>
<td>wind angle</td>
<td>QuikSCAT*</td>
<td>aug1999-oct2009</td>
<td>monthly</td>
<td>(x,y)</td>
<td>offset</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Experiment:</th>
<th>JRA55</th>
<th>CORE</th>
<th>20CR</th>
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<tbody>
<tr>
<td>Forcing data</td>
<td>JRA55v0.3</td>
<td>CORE.v2_iaf</td>
<td>20CRv2c</td>
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<tr>
<td>Downwelling radiation</td>
<td>JRA55v0.3 *</td>
<td>GISS ISCCP-FD *</td>
<td>20CRv2c *</td>
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<tr>
<td>Atmos. State (θ, q, ρ, U)</td>
<td>JRA55v0.3 *</td>
<td>NCEP *</td>
<td>20CRv2c *</td>
</tr>
<tr>
<td>Precipitation</td>
<td>JRA55v0.3 *</td>
<td>GPCP/CMAP/Serreze *</td>
<td>20CRv2c *</td>
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<tr>
<td>Forcing cycle</td>
<td>1958-2009 (52-year); 5 cycles</td>
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<tr>
<td>Initial Condition</td>
<td>PHC2; state-of-rest</td>
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<td>Ocean Model</td>
<td>POP 1deg, 60lvl (CESM1.4)</td>
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<tr>
<td>Ice Model</td>
<td>CICE4 1deg (CESM1.4)</td>
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<td>Ocean coupling frequency</td>
<td>daily</td>
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<tr>
<td>Salinity restoring</td>
<td>4-year</td>
<td>4-year</td>
<td>4-year</td>
</tr>
</tbody>
</table>
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

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.

JRA55

Global

Arctic

SO

Atlantic

Pacific

Indian
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

10^9 J/m^2/dec
Southern Ocean spinup

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

Sensible HFLX Trends for 1–40
• Stable AMOC of comparable mean strength to CORE by 5\textsuperscript{th} 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 (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

CORE

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

1958-2009 annual SST correlation with OBS

JRA - CORE
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 26.5°N
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 (1972-78)

- 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
Antarctic Circumpolar Current

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

- 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...
• 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

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

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

$Q_{lh}$ Trend (1986-2005)
Labrador Sea Winter Heat Flux Differences (1972-78)

- From hindcast simulations:
Southern Ocean Winter Heat Flux Differences (1972-78)
Southern Ocean Winter Heat Flux Differences (1972-78)

Difference (JRA55-COREII) From Hindcast Simulations
Spinup Sensitivity Runs