JRA-55 based data set for Driving Ocean - sea ice model (JRA55-do)

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1. Background (Why do we switch to JRA-55)

• **CORE (and OMIP)** is a common facility that supports ocean and climate modelers to perform hindcast simulations of the past Ocean-Sea ice climate variability

• To study recent climate extreme events (e.g., Arctic sea ice reduction, GW hiatus, 2015-16 El Nino, ...) using Ocean-Sea ice models, the forcing data set should be preferably kept up to date

• The current data set (Large and Yeager 2009, hereinafter LY09) was produced more than ten years ago (in 2004), having been updated only to 2009

• LY09 is based on the NCEP/NCAR reanalysis (~200 km horizontal resolution) and may not be suitable for simulations that employ high horizontal resolutions
**Project to produce a dataset based on JRA-55**

- JRA-55 (Kobayashi et al. 2015) is a modern long-term reanalysis using high-resolution (~55 km) model and updated assimilation techniques.

- Japanese group started to consider producing a JRA-55 based data set *tailored* for driving ocean-sea ice models (JRA55-do). The key feature is to base all necessary elements on JRA-55, which makes the data set *self-contained* and easy to be *kept up-to-date*.

- The idea found support from OMDP. OMDP-JRA55 collaboration started, aiming to form the basis for Version 2 of CMIP6/OMIP simulations.

- Errors of JRA-55 are evaluated and adjustment (bias correction) methods are examined (*eight test versions have been produced eventually*) in the last two years (2014-2015) so that the data set deserves wide use.

- Taking into account of the feedback received at the Yokohama meeting (Jan 2016), version 1 (first official version) is now near completion.
2. Strategy on producing JRA55-do

**Atmospheric states: JRA-55 (Kobayashi et al. 2015, JMSJ)**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>1958-2012, continued on the JMA operation and products are provided real-time (to 2023 at longest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model resolution</td>
<td>TL319 (~ 55 km, reduced gaussian grid), L60</td>
</tr>
<tr>
<td>Assimilation method</td>
<td>4D-Var (T106 resolution)</td>
</tr>
<tr>
<td>Lower boundary condition</td>
<td>COBESST (Ishii et al. 2005, 1x1 daily)</td>
</tr>
<tr>
<td>Output interval for surface fluxes</td>
<td>3-hourly average from 3 or 6 hour forecast (00-03, 03-06,...)</td>
</tr>
<tr>
<td>- downward short/long wave</td>
<td></td>
</tr>
<tr>
<td>- precipitation</td>
<td></td>
</tr>
<tr>
<td>Marine meteorological variables</td>
<td>Snap shot of 3 or 6 hr forecast (03,06,...)</td>
</tr>
<tr>
<td>- 10m wind</td>
<td></td>
</tr>
<tr>
<td>- 2m temperature/specific humidity</td>
<td></td>
</tr>
<tr>
<td>- sea level pressure</td>
<td></td>
</tr>
</tbody>
</table>

**JRA-55 family**

- **JRA-55**: All available observational data are used
- **JRA-55C**: Only conventional observations are used (no satellite, aircraft)
- **JRA-55AMIP**: Long-term free-run of the atmospheric model
River run-off to the ocean: JRA-55 + CaMa-Flood

River model: “Catchment-based Macro-scale Floodplain model”
(CaMa-Flood; Yamazaki et al. 2011#)

Forcing: Run-off from a land surface model of JRA-55

✓ Production
  - CaMa-Flood will be run operationally near-real time
  - Run-off of JRA-55 is adjusted relative to Dai et al. (2009)

✓ River run-off data
  - Horizontal resolution : 0.25° x 0.25°
  - Time interval : daily
  - Unavailable around Antarctica:
    → Time-invariant, annual mean climatology taken from CORE
    → Monthly climatology of iceberg melt by Merino et al. (2016)

✓ Support data for mapping to the ocean model grid are also provided

Period-wise adjustment (separation into three periods)

- Separation point #1: Year 1973
  - Inclusion of Vertical Temperature Profile Radiometer (VTPR)
  - Separating point between JRA-55 and JRA-55C

- Separation point #2: Year around 1998
  - Large improvement in the forecast score (inclusion of ATOVS)
  - Increase of precipitation, decline of SW radiation of JRA-55 wrt JRA-55C
  - Scatterometer wind started to be assimilated to JRA-55 in May 1997
## Reference data and how they are used for adjustment

<table>
<thead>
<tr>
<th>reference data</th>
<th>availability for deriving adj factor</th>
<th>time dependency (climatological)</th>
<th>spatial dependency</th>
<th>How is the factor used</th>
</tr>
</thead>
<tbody>
<tr>
<td>short wave CERES adjusted relative to buoys</td>
<td>2000-2015</td>
<td>monthly</td>
<td>(x,y) &amp; constant</td>
<td>multiply</td>
</tr>
<tr>
<td>long wave CERES</td>
<td>2000-2015</td>
<td>monthly</td>
<td>(x,y) &amp; constant</td>
<td>multiply</td>
</tr>
<tr>
<td>precipitation CORE</td>
<td>1979-2009</td>
<td>monthly</td>
<td>(x,y) &amp; constant</td>
<td>multiply</td>
</tr>
<tr>
<td>air temperature Ensemble mean@ IABP-NPOLES JRA55anl_surf &amp; JRA55anl_surf</td>
<td>1980-2014 1979-1998 (over sea ice)</td>
<td>monthly</td>
<td>(x,y)</td>
<td>offset</td>
</tr>
<tr>
<td>specific humidity Ensemble mean@ JRA55anl_surf &amp; JRA55anl_surf</td>
<td>1980-2014 (over sea ice)</td>
<td>monthly</td>
<td>(x,y)</td>
<td>multiply</td>
</tr>
<tr>
<td>wind speed RSS-QuikSCAT* RSS-SSM/I# JRA55anl_surf &amp; JRA55anl_surf</td>
<td>1999-2009 1988-1998 (to fill data gap)</td>
<td>annual</td>
<td>(x,y)</td>
<td>multiply</td>
</tr>
<tr>
<td>wind angle RSS-QuikSCAT* JRA55anl_surf &amp; JRA55anl_surf</td>
<td>1999-2009 (to fill data gap)</td>
<td>annual</td>
<td>(x,y)</td>
<td>offset</td>
</tr>
</tbody>
</table>

(@) Ensemble mean of 7-reanalyses: JRA55anl, MERRA2, ERA-interim, NCEP-CFSR, NCEP-R1, NCEP-R2, 20CRv2
(* Remote Sensing Systems 0.25 x 0.25 data set version 4
(# Remote Sensing Systems SSM/I wind speed product version 7, adjusted relative to RSS-QuikSCAT
(& JRA55anl_surf (JRA55anl; screen level analysis based on 2D-OI) is used to fill data over sea ice and land)
Addition of “anomaly” of CORE relative to adjusted JRA-55 T&Q for 1958-1978

Adjustment factor for this period is determined by comparing JRA-55C(*) of later years with:
- **T&Q**: ensemble mean of reanalyses (1980-1996)
- **Winds**: SSM/I after adjusted wrt QuikSCAT (1988-1996)
- **Prec**: CORE (1979-1996)

Adjustment relative to:
- **T&Q**: ensemble mean of reanalyses (1980-1996)
- **Winds**: SSM/I after adjusted wrt QuikSCAT (1988-1996)
- **Prec**: CORE (1979-1996)

Adjustment relative to:
- **T&Q**: ensemble mean of reanalyses (1999-2014)
- **Winds**: QuikSCAT (1999-2009)
- **Prec**: CORE (1999-2009)

Addition of “anomaly” of CORE relative to adjusted JRA-55 T&Q for 1958-1978

- Adjustment factors do not change within each period
- Smooth transition of adjustment factors between periods

(*) Note:
- **JRA-55** (1958-present): All available observational data are used
- **JRA-55C** (1958-2012): Only conventional observations are used (no satellite, aircraft)
- **JRA-55** and **JRA-55C** are common for 1958-1972
3. Evaluation and adjustment for raw JRA-55 (JRA55-raw)
Ref: Ensemble mean of reanalysis products for T&q

\[ JRA55anl, \ MERRA2, \ ERA-interim, \ NCEP-CFSR, \ NCEP-R1, \ NCEP-R2, \ 20CRv2 \]
available for Jan1980 - Dec2014

Weighting factor for grid-wise ensemble average
(reduced contribution from low-resolution products)

\[
\begin{array}{ccc}
\text{x 1.0} & \text{x 0.5} \\
\text{JRA55anl} & \text{NCEP-R1} \\
\text{MERRA2} & \text{NCEP-R2} \\
\text{ERA-interim} & \text{20CRv2} \\
\text{NCEP-CFSR} & \\
\end{array}
\]

Contribution from the minimum (1st) and the maximum (7th) member
is further reduced in half

For land and on sea ice, \text{JRA55anl} is adopted instead of ensemble average
(to minimize difference between JRA55-raw)

Josey et al. (2014): “blobs” around buoys for several reanalysis products,
not found in JRA55-raw
Air temperature and Specific humidity (2 m) averaged over the global ocean

Ensemble mean
JRA55anl
MERRA2
ERA-interim
NCEP-CFSR
NCEP-R1
NCEP-R2
20CRv2

JRA55-raw is the cold outlier
Adjustment (offset) factor for the raw JRA55 (JRA55‐raw) air temperature

1958-1972
(a) T2m offset factor 1958–1972 (v0.8)
(b) T2m offset factor over sea ice 1958–1972 (v0.8)

1973-1996
(c) T2m offset factor 1973–1996 (v0.8)
(d) T2m offset factor over sea ice 1973–1996 (v0.8)

1999-2015
(e) T2m offset factor 1999–2015 (v0.8)
(f) T2m offset factor over sea ice 1999–2015 (v0.8)

✓ Cold bias in low to mid latitudes
✓ Warm bias over Arctic Sea Ice (adjusted wrt IABP-NPOLES)
Adjustment (multiplication) factor for JRA55-raw specific humidity (*after* temperature adjustment)

Specific humidity is shifted with air temperature adjustment by keeping relative humidity, then adjusted wrt the reference data

1958-1972  
1973-1996  
1999-2015

✓ JRA-55’s atmospheric model is known to have moist bias over sea surface
Additional adjustment for T&q (1/3):
Smooth transition of T&q around marginal sea ice zone

- Because atmospheric model of JRA-55 does not allow partial sea ice cover, transition of air temperature is abrupt in the marginal sea ice zone. Air temperature over sea ice is smoothed with several passes of 5-point filter using values over sea water or monthly mean area fraction of COBESST sea ice distribution greater than 0.99
Additional adjustment for T&q (2/3)
Cut-off of extremely low air temperature around Antarctica

- For the Antarctic region, we followed the adjustment employed by Large and Yeager (2004) for the CORE data set: Extremely low temperatures are cut off by using a sinusoidal fits to observed monthly minimum temperature as a function of latitude south of 60°S. To achieve smooth transition, cut-off is applied to 50°S using minimum value at 60°S.
**Additional adjustment for T&q (3/3)**

Use JRA-55 uses monthly climatology for sea ice for 1958-78, time series of monthly difference of T&q between the adjusted JRA-55 and CORE (CORE minus adjusted JRA-55) for latitudes higher than 40N or 50S is smoothed and then added to the adjusted JRA55 field for 1958-1978.

(a) T10m change by CORE  
FEB 1958–78  

(b) T10m change by CORE  
AUG 1958–78
Adjustment for Vector Wind

Reference data

- Remote sensing systems (RSS) QuikSCAT v4 (1999-2009) for both speed and direction
- RSS wind speed v7 (1988-2015) based on SSMI for pre-QSCAT period
- Gaps of satellite products are filled with JRA55anl_srf
- JRA55 winds are converted to those at neutral stability before they are blended or compared with satellite products

Wind speed adjustment is based on annual mean climatology

wind angle adjustment (annual mean) is based on CEOF analysis on time series of monthly mean field. If the first mode (the co-varying mode) does not...
Adjustment (multiplication) factor for JRA55‐raw wind speed

1958‐1972

1973‐1996

1999‐2015

Zonal mean wind speed over the ocean

CORE
JRA55‐raw
JRA55‐do
RSS‐QuikSCAT

RE wind is strong (weak) wind
mid (low) latitude

JRA55‐raw
Adjustment (offset) factor for JRA55-raw wind angle (positive counter-clockwise)
Diagnosed annual mean wind stress curl

A55-raw

A55-do

and Chelton (2008)
Adjustment of short and long wave radiation

ERES-EBAFv2.8 Surface (Mar2000-Feb2015) (Kato et al. 2013) used as the reference data for downward radiation adjustment

- Both SW and LW radiation are compared with buoy measurements before they are used as a reference data as LY09 did for ISCCP-FD
- Short wave radiation is adjusted (next slide) before it is used as a reference data
- Long wave radiation is used as the reference data without modification
Reduction of CERES SW radiation as a function of latitude (profile is given at the bottom slide: \( \text{CERES}_{\text{adj}} / \text{CERES} \))

- **Zonal mean downward SW over the ocean**
- **Max 10% reduction over sea ice**
Adjustment (multiplication) factor for JRA55-raw downward SW / LW radiation
Downward radiation zonally averaged over the ocean

**Short wave**

**Long wave**

Small (large) downward SW in low (high) latitudes for JRA55-raw
Adjustment for precipitation

Multiplication factor for JRA55-raw precipitation (ref: CORE)

1958-1972
1973-1996
1999-2015

Zonally averaged precipitation over the ocean
Additional adjustment on precipitation over Mediterranean

Black = GPCC (around Mediterranean)

\[ \text{Red: CORE, Red: JRA55-do} \]

\[ \text{Black = GPCC(around Mediterranean)} \times \text{CORE(1979-96 mean)} / \text{GPCC(1979-96 mean)} \]

To estimate precipitation over Mediterranean for 1958-1978 (unavailable from CORE), GPCC precipitation around Mediterranean is multiplied by the ratio between CORE (integrated over entire Mediterranean) and GPCC (integrated over coastal stations).
Finalizing adjustment

Application of globally constant adjustment factor to downward SW/LW and precipitation to achieve global balance.

After the period-dependent, local adjustments, a globally uniform, time-invariant factor (=0.98789) is applied (reduction by 1.12%) to both downward SW/LW to achieve global heat flux balance for 1988-2007.

Residual is intended to be about 2 W/m² (warming of the ocean), because heat will be lost owing to sea ice processes and temperature difference between precipitation and evaporation.

Similarly, a constant factor (=1.024288) is applied (enhancement by 2.43%) to precipitation, so that E-P equals river run-off, which has been calibrated to be 1.22 Sv for 1988-2007. Minor contribution from sublimation over sea ice is also taken into account.
Time series of global mean
JRA55-raw, JRA55-do, CORE

surface heat flux

(a) Net short wave
(b) Net long wave
(c) Latent heat flux
(d) Sensible heat flux
(e) TOTAL surface heat flux

surface fresh water flux

Evaporation
Precipitation

Net SW
Net LW
latent
sensible

$10^9$ [kg/sec]

E-P (= Run off minus Sublimation)
Adjustment on run-off data

Annual time-scale

Major 39 rivers and 6 rivers with vast basin, a
5-yr Lanczos window) JRA-55 run-off
and (orange and black in the upper panel) is
filtered by 5-yr Lanczos window) to fit
the river discharge of Dai et al. (2009) (red).

Annual time-scale

Major 39 rivers, width and depth are tuned so
that the morphology of seasonal variability fits with Dai et al. (2009).

Run-off to the river from land of JRA-55. (orange)
filtered by 5-yr Lanczos window. (Red) River run-off to the
Dai et al. (2009). (Green) GPCP regressed wrt Dai et al. (2009)
river run-off after 2007 to be used as a reference. (Blue) Low
filtered by 5-yr Lanczos window.

River run-off to the ocean calculated by CaMa-
Interannual variability of basin-wise river run-off to the ocean (Units: Sverdrups)
5. Plans and ToDos

- Update near real-time (once a month)
- Make the dataset available from ESG
- Write a citable document(s) ASAP
- Run-off around Antarctica and Greenland
  - Blank data around Antarctica
  - Offer options (CORE, iceberg melt) to users
Supplemental materials
Main feature of “JRA55-do” version 1

• All elements are based on forecast phase of JRA-55 (Kobayashi et al. 2015)

• Long period (1958-present), high resolution (55 km, 3 hourly)

• Surface atmospheric states of JRA-55 (except for SLP) are adjusted relative to reference datasets

• Time-dependent adjustment (1958-72, 1973-97, 1998-present) based on shifts in the quality of data

• Continental river discharge is provided by running a river model using run-off from land surface component of JRA-55

• Global balance of surface heat and freshwater fluxes

• Updated near real-time. Will be made available from ESG
Additional adjustments

• T&q are smoothed in the marginal sea ice region, because JRA-55 does not allow partial sea ice cover

• Extremely low air temperature is cut off around Antarctica (as in CORE)

• For 1958-1978, when JRA-55 uses monthly climatology for sea ice distribution, time series of monthly difference of T&q between the adjusted JRA-55 and CORE for latitudes higher than 40°N or 50°S is added to the adjusted JRA-55 field

• Precipitation on Mediterranean for 1958-1978 is adjusted based on GPCC precipitation

• Downward fluxes are adjusted to achieve global balance of surface heat and freshwater fluxes under observed sea surface temperature (1988-2007)
Time series of global mean
Diagnosed annual mean WSC (NH)

JRA55-raw

JRA55-do

Risien and Chelton (2008)
Diagnosed annual mean WSC (SH)

Curl tau annual mean [x 1e-7 N/m] (v1_1) [Nov.1999–Oct.2009]

Curl tau annual mean [x 1e-7 N/m] (v0_8) [Nov.1999–Oct.2009]

Curl tau annual mean [x 1e-7 N/m] (SCOW) [Sep.1999–Oct.2009]
Diagnosed annual mean Sverdrup stream function in the northern hemisphere (JRA55-do)
Comparison of diagnosed annual mean Sverdrup stream function in the North Pacific
Zonal mean eastward wind stress over the Southern Ocean

JRA55-raw
JRA55-do
CORE
Support data for river run-off
Support data for mapping river run-off data to ocean model grid

Support data
- Direction of river (1/60 x 1/60) (flwdir.bin)
  This gives the downstream (next) grid point by index (N=1, NE=2, E=3,..., NW=8) starting from the headwater

Headwater position for river run-off to the ocean (1/4 x 1/4) (waterhead_xy.bin)
  This gives position (x,y) on 1/60 x 1/60 degree grid of the headwater for the grid point where non-zero river run-off to the ocean exist.
An example on the detection of river mouth

1. Search the flow path of a river downstream from its headwater.
   The first intersection with the model’s coast line is decided to be the river mouth.

2. You may search river mouth for the model further downstream.
Evaluation of CERES radiation
Bias of CERES-EBAF 2.8 surface downward shortwave radiation relative to Buoys

- CERES has positive bias in the tropics except for the Equator
- CERES should be reduced by...
CERES-EBAF 2.8 surface downward long wave

bias

CERES downward LW and Bias from buoy (annual mean)

CERES should be reduced by...

CERES downward LW (shade) and Bias correction in percent

CERES LW radiation will not be adjusted: Used as a reference as it is
Evaluation of CERES radiation in high latitudes (SH)

\[(\text{CERES} - \text{OBS}) / (\text{CERES} + 10 \text{ W m}^{-2}) \times 100\]

**downward short wave**
- SY0 (69S, 39.58E)
- GVN (70.65S, 351.75E)

**downward long wave**
- SY0 (69S, 39.58E)
- GVN (70.65S, 351.75E)
Evaluation of CERES radiation in high latitudes (NH)

(CERES – OBS) / (CERES) x 100

downward short wave  

• Up to 10% reduction of downward short wave radiation over sea ice will be necessary

• No adjustment for downward long wave radiation
Implied Meridional Heat Transport