The JRA-55 Reanalysis: General specifications and basic characteristics

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on behalf of the JRA-55 reanalysis group

Japan Meteorological Agency

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• Kazutoshi ONOGI 35 min. → 40 min.
  – The JRA-55 Reanalysis: General specifications and basic characteristics

• Yayoi HARADA 35 min. → 30 min.
  – Representation of atmospheric circulation and climate variability in the JRA-55 reanalysis
Contents

1. JRA-55 (JRA Go! Go!)
   - general specifications
   - basic characteristics
2. JRA-55 family
3. Ocean reanalysis and forecast using JRA-55 in CPD/JMA
4. JRA-55 data availability, DSJRA-55 and Next reanalysis plan
• The second Japanese global reanalysis conducted by JMA
• The first comprehensive global atmospheric reanalysis that applies 4D-Var to the last half century
# JRA-55 Reanalysis system

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<thead>
<tr>
<th></th>
<th><strong>JRA-25</strong></th>
<th><strong>JRA-55</strong></th>
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<tr>
<td>Reanalysis years</td>
<td>1979-2004 (26 years) +2005-2014.1 (JCDAS)</td>
<td>1958-2012 (55 years) + 2013-present</td>
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<td>Equivalent operational NWP system</td>
<td>As of Mar. 2004</td>
<td>As of Dec. 2009</td>
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<tr>
<td>Resolution</td>
<td>T106L40 (~110 km) (\text{top layer at 0.4 hPa})</td>
<td>TL319L60 (~55 km) (\text{top layer at 0.1 hPa})</td>
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<tr>
<td>Advection Scheme</td>
<td>Eulerian</td>
<td>Semi-Lagrangian</td>
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<td>Assimilation scheme</td>
<td>3D-Var</td>
<td>4D-Var ((\text{with T106 inner model}))</td>
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<td>Bias correction (satellite radiance)</td>
<td>Adaptive method (\text{(Sakamoto and Christy 2009)})</td>
<td>Variational Bias Correction (\text{(Dee and Uppala 2009)})</td>
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<tr>
<td>GHG concentrations</td>
<td>Constant at 375 ppmv ((\text{CO}_2))</td>
<td>Annual mean data are interpolated to daily data ((\text{CO}_2, \text{CH}_4, \text{N}_2\text{O}))</td>
</tr>
</tbody>
</table>

**GHG concentrations**

- Constant at 375 ppmv \((\text{CO}_2)\)
- Annual mean data are interpolated to daily data \((\text{CO}_2, \text{CH}_4, \text{N}_2\text{O})\)
Observational data

- The major data source
  - The ERA-40 observational dataset supplied by ECMWF

- Homogenization
  - Radiosonde Observation Correction using Reanalyses (RAOBCORE) v1.4 (Haimberger et al. 2008)

- Reprocessed satellite observations
  - GMS, GOES-9 and MTSAT-1R (MSC/JMA)
    - Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring
  - METEOSAT (EUMETSAT), TMI (NASA and JAXA), AMSR-E (JAXA), QuikSCAT (NASA/PO.DAAC), AMI (ESA), GNSS/RO (UCAR)

Chronology of types of observational data assimilated in JRA-55
Number of observations assimilated (Global)

Number of data assimilated (conventional)

Number of data assimilated (aircraft, satellite)

Count (month)

Count (month)

logarithmic scale

- Surface pressure
- Upper Tmp
- Upper RH
- Upper wind
- TCR wind
- Aircraft wind
- PAOBS
- IR sounders
- MW sounders
- MW imagers
- CSR
- GEO wind
- LEO wind
- Scat wind
- GNSS RO

FGGE
JRA-55 has significant moistening increments above 850 hPa and drying increments below it.

The moistening increments in the upper and middle troposphere tend to increase as the number of observations from satellite humidity channels increases.

The model has dry bias in middle troposphere and moist bias in lower troposphere. The biases are reduced in data assimilation. Increased satellite data works effectively.
Humidity observations during the early years are only radiosondes, whereas those during the recent years consist of many kinds of satellites as well as radiosondes.

The patterns of precipitable water increments look quite different especially over the oceans.
Precipitation

Reanalyses vs. GPCP (1980~2008)

JRA-55 - GPCP

JRA-25 - GPCP

ERA-Interim - GPCP

CFSR - GPCP

ERA-40 - GPCP

MERRA - GPCP

[mm/day]

18.0
14.0
10.0
6.0
4.0
2.0
1.0
0.5
0.2
0.1
-0.1
-0.2
-0.5
-1.0
-2.0
-4.0
-6.0
-10.0
-14.0
-18.0
Global annual mean energy balance at the TOA values (upper table) and at the surface values (lower table) from JRA-25 and JRA-55 are for the period 2002–2008, whereas those from Wild et al. (2013) represent present-day climate conditions at the beginning of the 21st century with their uncertainty ranges in parentheses.

<table>
<thead>
<tr>
<th>TOA (W m⁻²)</th>
<th>Wild et al. (2013)</th>
<th>JRA-25</th>
<th>JRA-55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incoming solar</td>
<td>340 (340, 341)</td>
<td>341</td>
<td>341</td>
</tr>
<tr>
<td>Solar reflected</td>
<td>100 (96, 100)</td>
<td>95</td>
<td>100</td>
</tr>
<tr>
<td>Thermal outgoing</td>
<td>239 (236, 242)</td>
<td>255</td>
<td>251</td>
</tr>
<tr>
<td>Residual (downward)</td>
<td>–7.9</td>
<td>–10.0</td>
<td>–10.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface (W m⁻²)</th>
<th>Wild et al. (2013)</th>
<th>JRA-25</th>
<th>JRA-55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar down</td>
<td>185 (179, 189)</td>
<td>197</td>
<td>189</td>
</tr>
<tr>
<td>Solar reflected</td>
<td>24 (22, 26)</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>Solar absorbed surface</td>
<td>161 (154, 166)</td>
<td>172</td>
<td>164</td>
</tr>
<tr>
<td>Solar absorbed atmosphere</td>
<td>79 (74, 91)</td>
<td>75</td>
<td>77</td>
</tr>
<tr>
<td>Residual (downward)</td>
<td>0.6 (0.2, 1.0)</td>
<td>–11.6</td>
<td>–11.2</td>
</tr>
<tr>
<td>Thermal down</td>
<td>342 (338, 348)</td>
<td>327</td>
<td>338</td>
</tr>
<tr>
<td>Thermal up</td>
<td>397 (394, 400)</td>
<td>399</td>
<td>400</td>
</tr>
<tr>
<td>Sensible heat</td>
<td>20 (15, 25)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Evaporation</td>
<td>85 (80, 90)</td>
<td>91</td>
<td>93</td>
</tr>
</tbody>
</table>
Anomalies from the mean temperature at each pressure level for years 1980 to 2001 of each reanalysis, JRA-55, ERA-40, JRA-25 and ERA-Interim, respectively.
Long term trend of maximum wind of tropical cyclones

JRA-55 has weakening trend of tropical cyclones’ maximum wind but no such trend is seen in observations and JRA-25. We found the TC bogus wind data assimilated in JRA-55 have unrealistic weakening trend. The weakening trend is not truth.
Quality of JRA
Forecast [FT=48] Scores
RMSE of Z500 for N.H. and S.H. [gpm]

N.H.

S.H.

a) Z500 forecasts, Northern Hemisphere, FT=48

b) Z500 forecasts, Southern Hemisphere, FT=48

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2. JRA-55 Family

JRA-55  JRA-55C  JRA-55AMIP
JRA-55 family

- **JRA-55 (JMA)**
  - Full observing system reanalysis

- **JRA-55C (MRI/JMA)**
  - Fixed observing system reanalysis
  - Using conventional observations only
    - surface, radiosondes, *tropical cyclone retrievals* and windprofilers
      - The TC wind weakening problem is also found in JRA-55C.

- **JRA-55AMIP (MRI/JMA)**
  - AMIP type run (with no observations assimilated)

- Providing a range of products using the common base NWP system for investigating impact of changing observing systems and model biases
Differences and ACCs of Z500
QBO reproducibility

Equatorial (5S-5N) zonal mean U wind component (m/s)
Quality of JRA
Forecast [FT=48] Scores
RMSE of Z500 for N.H. and S.H. [gpm]
Quality of JRA Forecast [FT=48] Scores

RMSE of Z500 for N.H. and S.H. [gpm]

N.H.

a) Z500 forecasts, Northern Hemisphere, FT=48

S.H.

b) Z500 forecasts, Southern Hemisphere, FT=48
JRA-55 Summary

• Advantages
  – Results of quality assessment have suggested that many of deficiencies in JRA-25 have been diminished or reduced in JRA-55.
  – Temporal consistency of temperature analysis of JRA-55 has the best performance with few jumps among the reanalyses.
  – Inter-comparison among the “JRA-55 family” provides an opportunity for quantitative assessment regarding representation of climatic trends and low-frequency variations.

• Deficiencies
  – Unexpected unrealistic weakening trend of tropical cyclone maximum winds.
  – Some parameters of energy budget still have biases.
  – Snow depths at part of coastal grid points are abnormal.
3. Ocean reanalysis and forecast using JRA-55 in CPD/JMA

Ocean forecast (JMA/MRI-CPS2) & Ocean reanalysis (MOVE-G2) forced by JRA-55
Ocean Model long-term forecast
Equatorial cross sections for climatic water temperature

✓ Low temperature bias (sea surface) and high temperature bias (thermocline) are reduced.

- Against subsurface analysis (Ishii and Kimoto, 2009)
- Average for 24 years from 1980 to 2003
- Forced atmospheric boundary: JRA-55 for New model, JRA-25 for Old model

Courtesy of T. Yasuda
Observational in situ data for ocean reanalysis

Time series of used data (Temperature, Salinity)
Data were taken from WOD09 and GTSSP
Ocean Reanalysis
Equatorial OHC Time-Longitude cross sections
(Hovmueller diagram)

✓ High temperature bias seen before 1980’s is diminished.

MOVE-G2(Move-G2(v1401A))
MOVE-G(Move-G(Rtn))

JRA-55
(JRA55/Merged)

JRA-25
(JRA25/Merged)

Diff (ERA-40+cor.

JRA-25 - MOVE-G

ERS-40+cor.

MOVE-G2 - MOVE-G
4. JRA-55 data availability, DSJRA-55, and Next reanalysis plan
**JRA-55 data availability**

JMA  [http://jra.kishou.go.jp/](http://jra.kishou.go.jp/)

DIAS* [http://dias-dss.tkl.iis.u-tokyo.ac.jp/acc/storages/filelist/dataset:204](http://dias-dss.tkl.iis.u-tokyo.ac.jp/acc/storages/filelist/dataset:204)

NCAR* Daily 3-Hourly and 6-Hourly Data [http://rda.ucar.edu/datasets/ds628.0/](http://rda.ucar.edu/datasets/ds628.0/)


NASA ESGF (ANA4MIPS, under major revision, coming soon, the same grid system with other reanalyses and CMIP data)

ECMWF (in preparation; probably become available in the latter half of 2016)

Univ. of Cantabria (Spain, in preparation)

*All JRA-55 data are available, and JRA-55C and JRA-55AMIP data are also available from DIAS and NCAR.
DSJRA-55

- Regional Downscaling using JRA-55 (completed)
- 5km resolution, around Japan region, using JMA’s operational mesoscale model (NHM) as of 2012.
- 55 years from 1958 to 2012 (not to present)
- The data may become available from DIAS.
  - Schedule has not been determined yet.
- Reference (coming soon)
References

• S. Kobayashi et al. (2015)
  – “The JRA-55 Reanalysis: General Specifications and Basic Characteristics”
    • JMSJ, 2015, 93, 5-48, doi:10.2151/jmsj.2015-001
    • https://www.jstage.jst.go.jp/article/jmsj/93/1/93_2015-001/_article

• Harada et al. (submitted to JMSJ, to be published in 2016)
  – "The JRA-55 Reanalysis: Representation of atmospheric circulation and climate variability"

• C. Kobayashi et al. (2014)
  – Chiaki Kobayashi, H.Endo, Y.Ota, S.Kobayashi, H.Onoda, Y.Harada, K.Onogi and H.Kamahori
  – “Preliminary Results of the JRA-55C, an Atmospheric Reanalysis Assimilating Conventional Observations Only"
    • https://www.jstage.jst.go.jp/article/sola/10/0/10_2014-016/_article
New Japanese Reanalysis plan

• **JRA-3Q** (JRA Thank you)
  – Japanese Reanalysis for Three Quarters of a century

• **Provisional specifications**
  – Atmospheric reanalysis from 1948? to present
  – Resolution: T₄₇₉L₁₀₀, top level at 0.01 hPa
  – 4D-Var with VarBC
  – State-of-the-art JMA operational global model
    • Improved physics (radiation, boundary layer, land surface, ...)
  – **New SST and sea ice**
    • COBE-SST2 (from the beginning to 1981)  1.0 X 1.0 deg.
    • MGDSST (satellite-based SST from 1982 onward)  0.25 X 0.25 deg.

• **Aiming at starting production by FY2018**
• New observations
  – Improved tropical cyclone retrieval winds
  – Conventional observations newly rescued and digitised by the ERA-CLIM project etc.
  – New satellite data
    • Reprocessed GOES winds
    • AVHRR polar winds
    • SSM/T-2 radiances
    • Hyper-spectral sounder radiances
    • GNSS-RO bending angles
    • ...
Thank you!
Backup slides
Annual Global Energy Balance

Statistics period:

Trenberth et al., 2011: 
*J. Climate, 24, 4907–4924*
Global mean temperature trend compared with independent observation datasets

SSU (K) 75S - 75N mean

MSU (K) 82.5S – 82.5N mean

Anomalies for each dataset were defined relative to their own monthly means over 1980-1994 (left) and 1979-1988 (right).
Number and spatial distribution of Radiosonde Observations for JRA-55C

Horizontal distribution of radiosonde temperature observation

a) Yearly nOBS (per day) 500hPa TEMP T 1958–2012

Vertical distribution of radiosonde temperature observation for 1960’s, 1980’s and 2000’s
In JRA-55, WV increments increase above 850hPa and decrease below 850hPa.
The increments increase in recent years owing to enhancement of satellite observing systems.
GMS/MTSAT reprocessing at JMA/MSC

- JMA’s contribution to SCOPE-CM and reanalysis
  - **SCOPE-CM**: Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring

- The reprocessed AMVs and CSRs are provided to the Japanese 55-year Reanalysis (JRA-55)
The number of AMVs assimilated in JRA-55

**Meteosat 0 degree**

**GOES West**

**Indian Ocean**

**GOES East**

**GMS/MTSAT**

“New” reprocessed data will be available for future reanalyses.

- CIMSS has recently reprocessed GOES AMVs from 1995 to mid 2013.
- Reprocessing of AMV/CSR/ASR is underway in the framework of SCOPE-CM phase 2 project (2014-2018)
<table>
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<tr>
<th></th>
<th>RT model</th>
<th>Emissivity model (ocean)</th>
<th>Improvements from previous RT models</th>
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<tr>
<td>JRA-25</td>
<td>(TOVS) RTTOV-6</td>
<td>IR: ISEM MW: FASTEM-1</td>
<td><em>RTTOV-6</em></td>
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<td></td>
<td>(ATOVS) RTTOV-7</td>
<td>IR: ISEM MW: FASTEM-2</td>
<td><strong>Addition of IR emissivity model for ocean</strong></td>
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<tr>
<td>JRA-55</td>
<td>RTTOV-9</td>
<td>IR: ISEM MW: FASTEM-3</td>
<td><em>RTTOV-7</em></td>
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<td><strong>Change to transmittance computations (RTTOV-7 predictors)</strong></td>
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<td><strong>Inclusion of cosmic background radiation</strong></td>
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<td><em>RTTOV-8</em></td>
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<td><strong>Change to transmittance computations (RTTOV-8 predictors)</strong></td>
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<td><strong>Microwave scattering code (not activated for JRA yet)</strong></td>
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<td><em>RTTOV-9</em></td>
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<td><strong>Change to transmittance computations (RTTOV-9 predictors)</strong></td>
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<td><strong>Improvements to the atmospheric path length computation</strong></td>
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<td><em>RTTOV-10</em></td>
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<td><strong>Land surface emissivity atlases</strong></td>
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<td><strong>Refinements in LBL and layering for coefficient generation</strong></td>
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<td><em>RTTOV-11</em></td>
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<td><strong>Variable GHG</strong></td>
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<td><strong>HIRS shifted spectral response</strong></td>
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<td><strong>SSU with variable cell pressure</strong></td>
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<td></td>
<td><strong>etc.</strong> From <a href="https://nwpsaf.eu/deliverables/rtm/">https://nwpsaf.eu/deliverables/rtm/</a></td>
</tr>
</tbody>
</table>
A sealing problem caused cell pressures to increase during storage on the ground and then to decrease after launch.

Time series for “effective” cell pressures deduced from the frequency of oscillation of the modulator cell

Values are adjusted to best fit to the Met Office’s 6-monthly estimates.