



Introduction to Reanalysis and JRA

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1. Introduction to Reanalysis

- 1.1 Required dataset for climate monitoring
- 1.2 Approaches for producing climate dataset
- 1.3 Reanalysis for climate monitoring

2. Introduction to JRA-55 reanalysis

- 2.1 Data assimilation system and forecast model
- 2.2 Basic performance

3. JMA's next reanalysis: JRA-3Q

4. Other topics

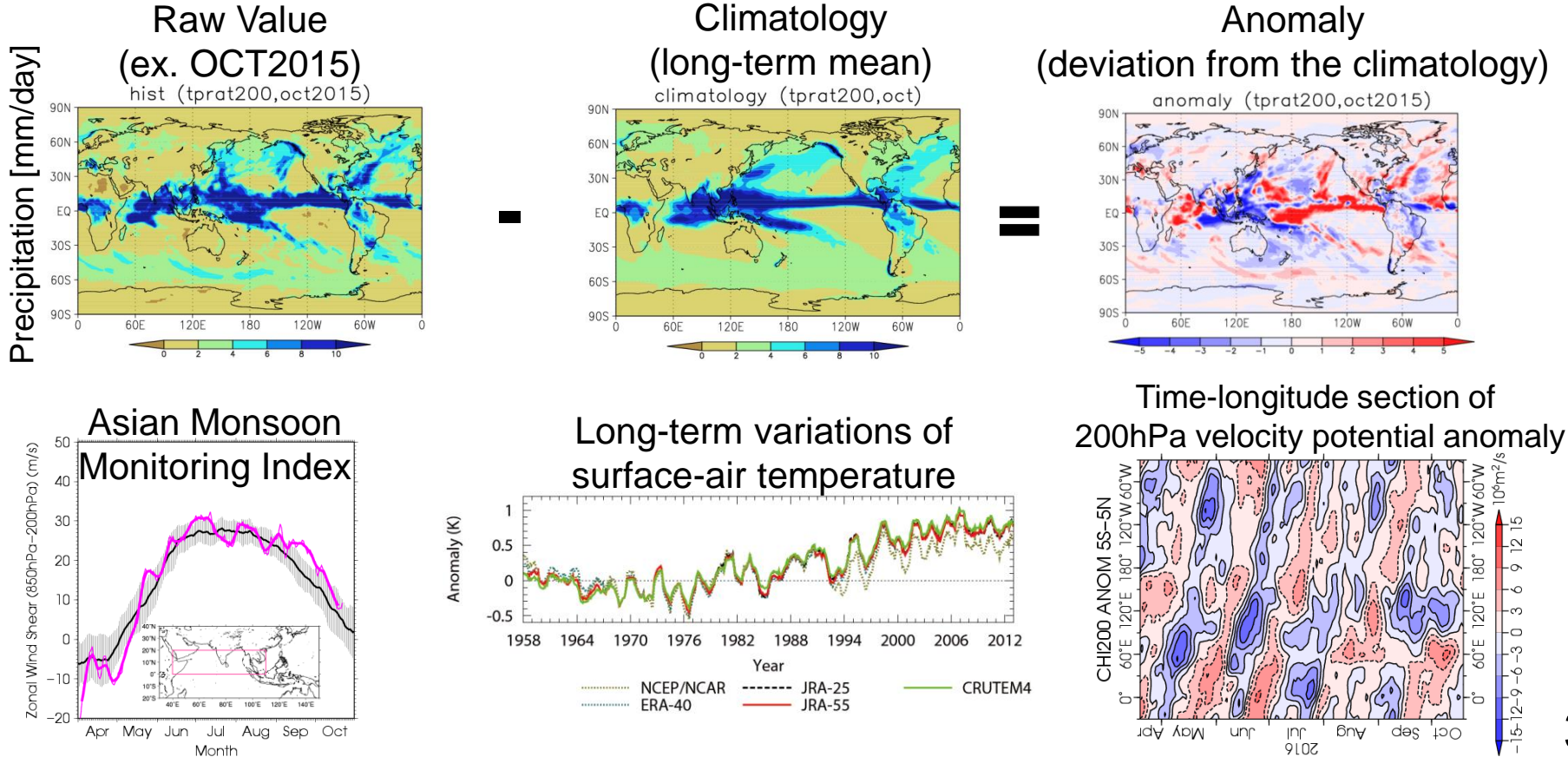
- 4.1 JRA-55 family: JRA-55C and JRA-55AMIP
- 4.2 JRA-55 homepage and Atlas

1.1 Required dataset for climate monitoring

■ As basis for climate monitoring, climate dataset should be...

1. Covering the globe for several decades
2. Including as many variables and time scales as possible
3. Spatially and temporally consistent and highly qualified

Examples of climate monitoring

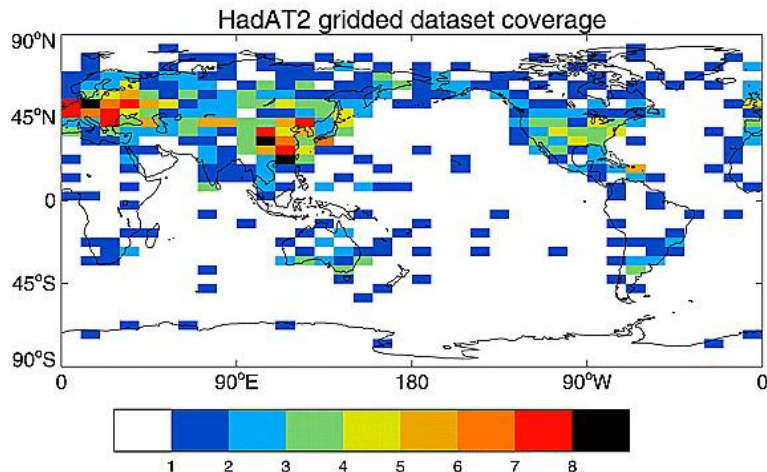


1.2 Approaches for producing climate dataset (1/4)

Approach (1): Using observational data only

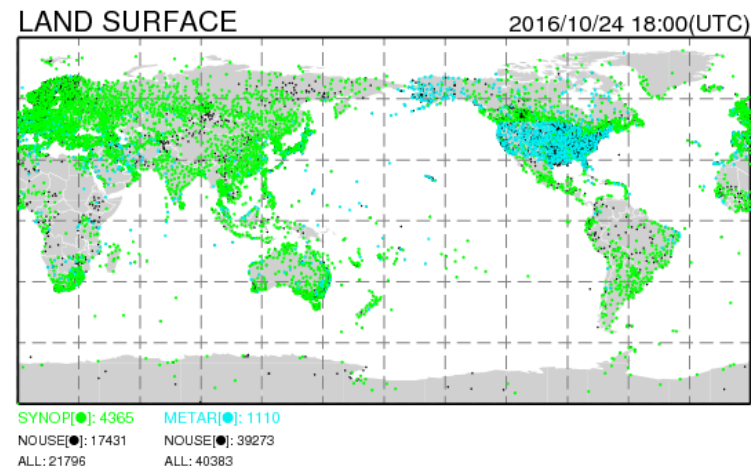
- Historical in-situ surface and upper observational data have been accumulated for several decades or a century in many organizations
 - High quality climate dataset can be generated at the observation station and surrounding region
 - However, the regions and variables are limited...
- ➔ Observation-alone is not suitable for (general) climate monitoring (though it is useful for some specific purposes)

Radiosonde data number for each grid



Thorne et al. 2005

Distribution of surface observation (example)



1.2 Approaches for producing climate dataset (2/4)

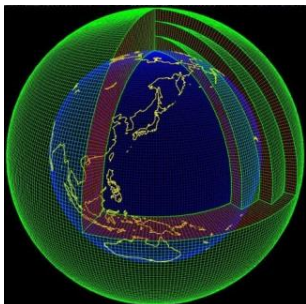
Approach (2): Using Global Circulation Model (GCM)

- Numerical integration of the basic equations of atmosphere using GCM and supercomputer

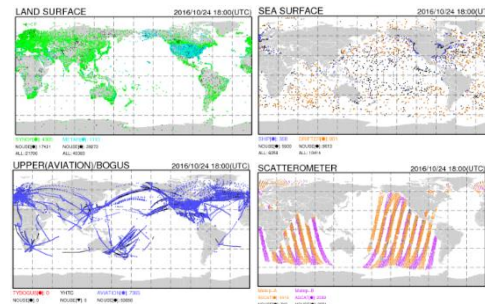
- Grid Point Values (GPVs) with many kind of variables are generated based on consistent dynamics and physics of the model
- However, calculation by model-alone is not enough to produce dataset with high accuracy...

- ➔ Modification of the model outputs by observational data is needed (this process is called “Data Assimilation(DA)”, a part of **operational analysis cycle** to estimate the initial condition for short-range NWP)
- ➔ Climate dataset can be produced by long-term DA cycle??

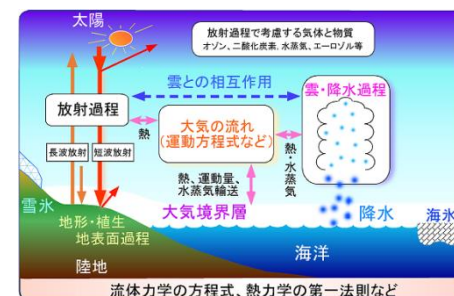
Distribution of grid points



Observational data (ex.)



Schematics of the atmospheric process

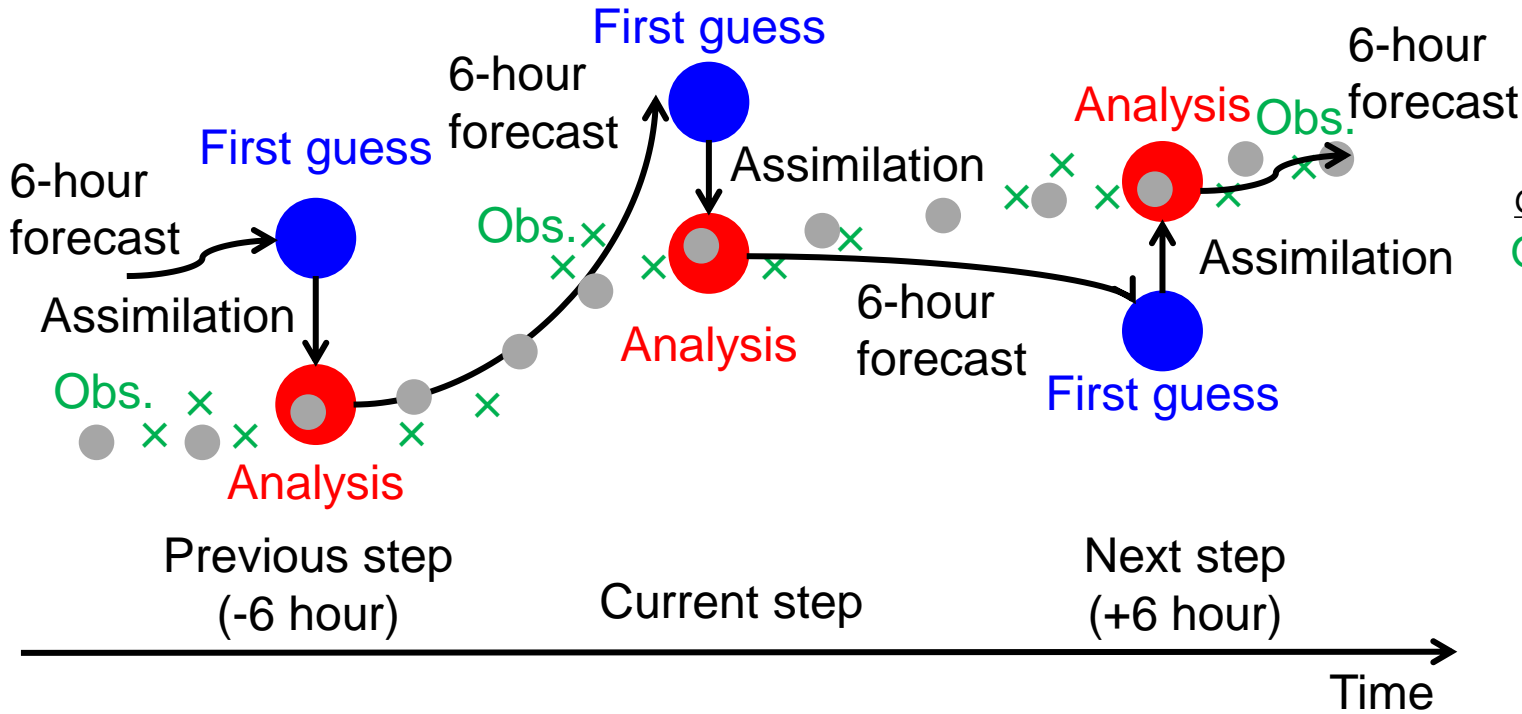


Dynamics
Radiation
Cloud etc.

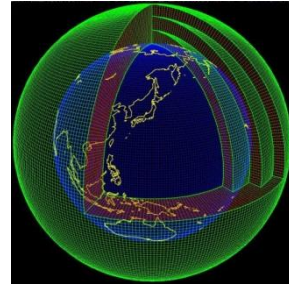
1.2 Approaches for producing climate dataset (3/4)

Schematic diagram of the operational analysis cycle

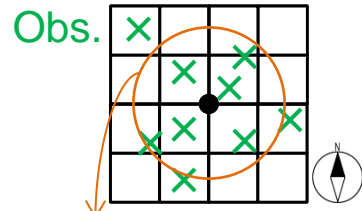
- Actual state of the atmosphere (unknown, but we want to know)



Forecast model



Grid points of the model



Supercomputer



Observations (example)

Surface

Radiosonde

Ship

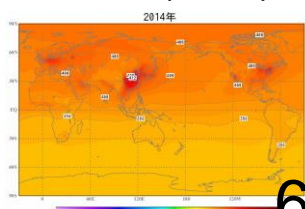
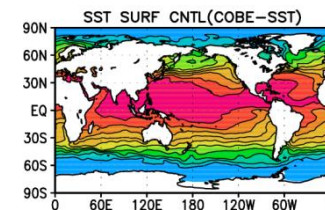
Satellite



Boundary conditions (example)

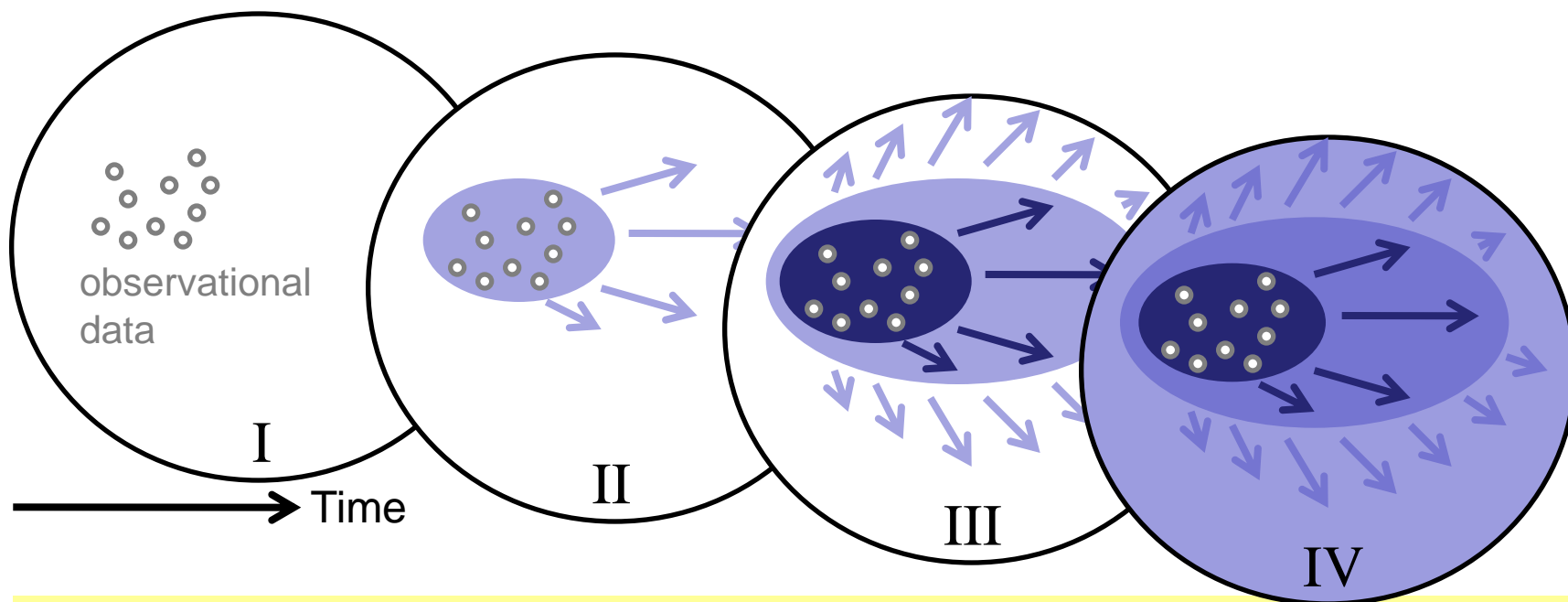
SST

GHG (CO₂)



1.2 Approaches for producing climate dataset (4/4)

Schematic diagram of impacts of data assimilation



- I. Un-uniformly distributed observations
- II. The hatched area surrounding observations are analyzed with high quality. The high quality area extends through forecast.
- III. In the next data assimilation, the deep colored area surrounding observations are analyzed with much higher accuracy. The higher quality area extended further by the next forecast.
- IV. The repetition of data assimilation and forecast is called “Data Assimilation cycle”. DA cycle plays very important role to keep a certain level of high quality even in the area with no/less observational data.

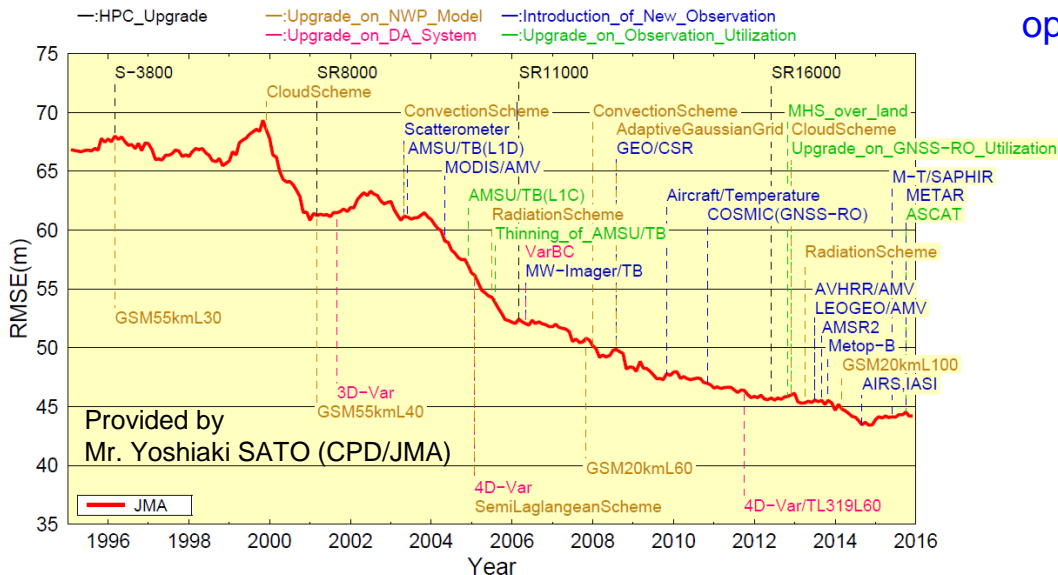
1.3 Reanalysis for climate monitoring (1/2)

Comparison of the operational analysis and reanalysis

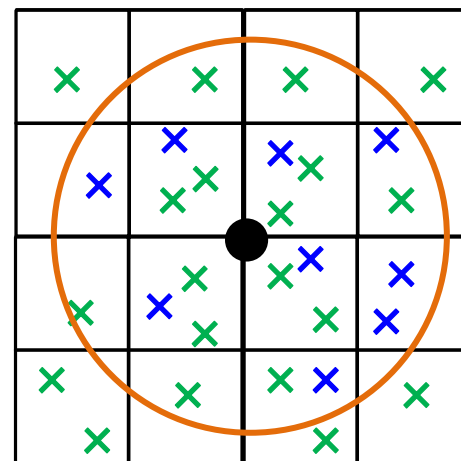
* as possible

	Operational analysis	“Re” analysis
Model and DA system	Occasionally changes (to improve forecast skills)	Constant and the latest* (to assure consistency and accuracy)
Observation data	Belated data are not used (because time for operational NWP is limited)	Belated data can be included (which may lead to improve the quality)
Period	The same as that of the model (not covering long-period)	Can be extended to past (depends on the obs. availability)

RMSE of forecast errors for Z500 in the northern hemisphere
(with information of model improvements)



Obs. available at the time of operational analysis
Obs. which become available after the time of operational analysis (belated data)



Used for the analysis at ●

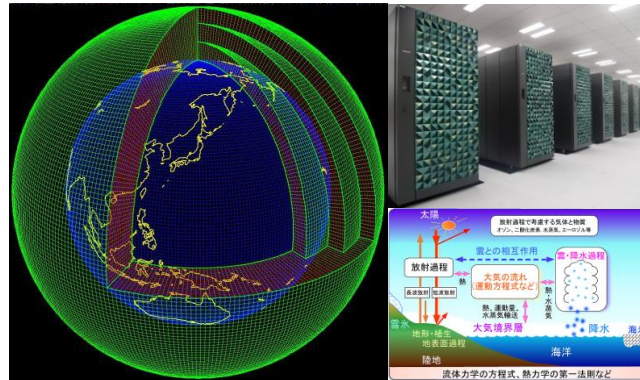


1.3 Reanalysis for climate monitoring (2/2)

Reanalysis: “analysis of the past atmospheric conditions using a constant, state-of-the-art NWP model and data assimilation system with the latest observation to produce a high-quality, spatially and temporally consistent dataset”

“Constant” and “state-of-the-art” NWP model

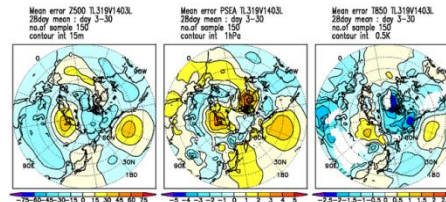
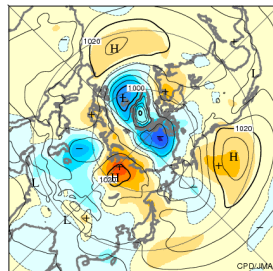
Data Assimilation
Quality Check



Input

Integration for several decades

Consistent quality reanalysis product (GPV)



Climate Monitoring

Initial conditions for Hindcast (Re-forecast)

Climate Research



Surf



Upper

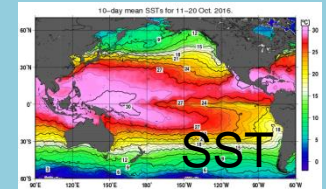


Ship

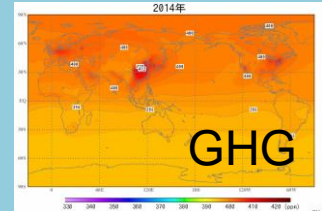


Satellite

Observation
(incl. belated data)



2016/08/20



Boundary conditions
(prescribed)

2. Introduction to JRA-55 reanalysis

- 1st **JRA-25** (Onogi et al. 2007)
 - By JMA and CRIEPI* (1979-2004)
 - *Central Research Institute for Electric Power Industry
 - Near real-time extension using the same system (JCDAS) was conducted by JMA and terminated in February 2014



- 2nd **JRA-55** (Kobayashi et al. 2015)
 - By JMA (1958-2012)
 - The first reanalysis which covers more than 50 years since 1958 with 4D-VAR data assimilation system
 - Real time analysis after 2013 to present



In Japanese, “5” is pronounced as “Go”.

2.1 JRA-55 reanalysis system

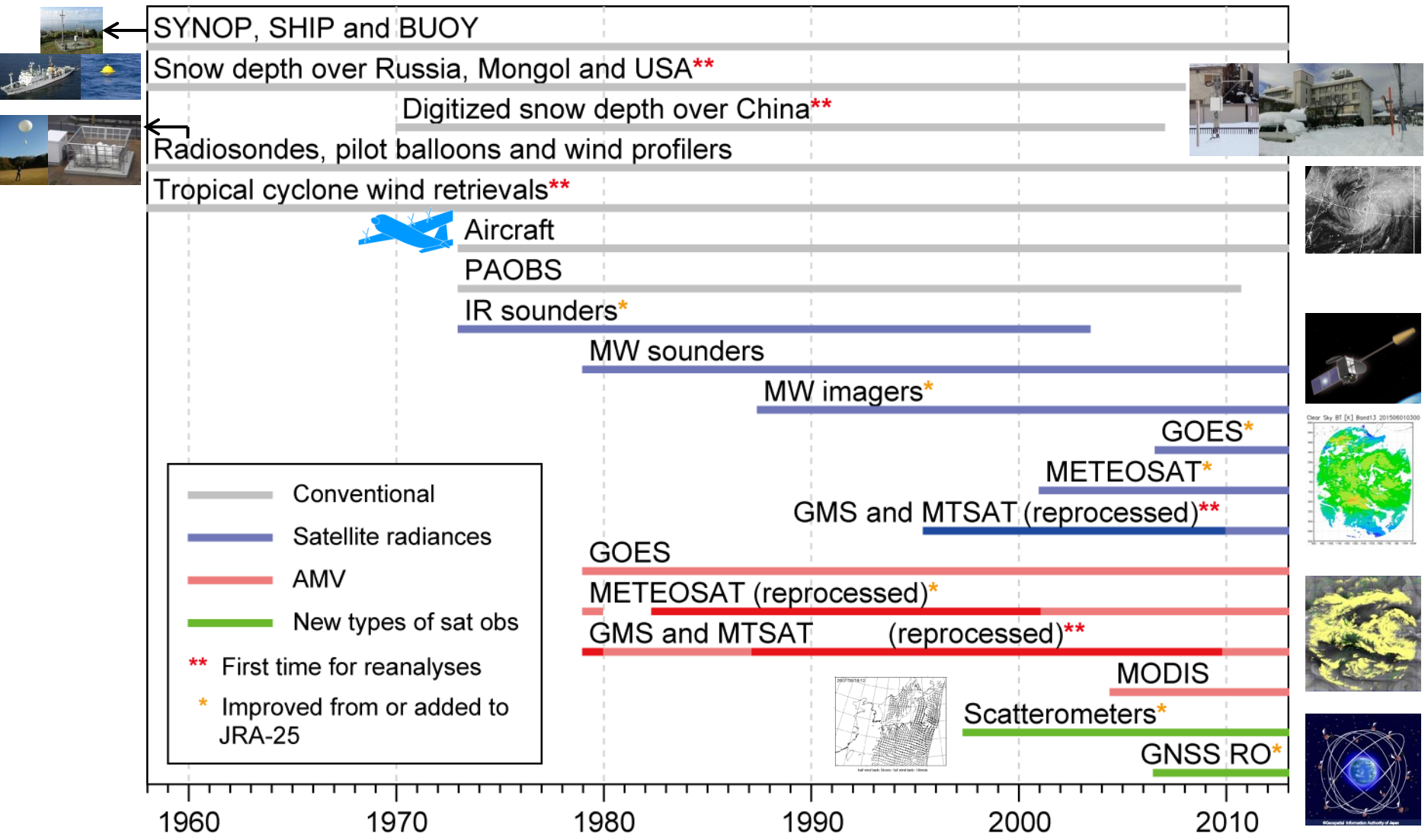
JRA-55 reanalysis system was extensively improved since JRA-25

	JRA-25	JRA-55
Period	1979-2004 (26 years)	1958-2012 (55 years)
NWP system	As of Mar. 2004	As of Dec. 2009
Resolution	T106L40 (~110km) <i>(top layer at 0.4 hPa)</i>	TL319L60 (~55km) <i>(top layer at 0.1 hPa)</i>
Advection scheme	Eulerian	Semi-Lagrangian
Assimilation scheme	3D-Var	4D-Var <i>(with T106 inner model)</i>
Bias correction (satellite radiance)	Adaptive method (Sakamoto et al. 2009)	Variational Bias Correction (Dee et al. 2009)
GHG concentrations	Constant at 375 ppmv (CO ₂)	Annual mean data are interpolated to daily data (CO ₂ ,CH ₄ ,N ₂ O)

2.2 Observational Data for JRA-55 (1/2)

Newly available and improved past observations are included in JRA-55

(image) (image)



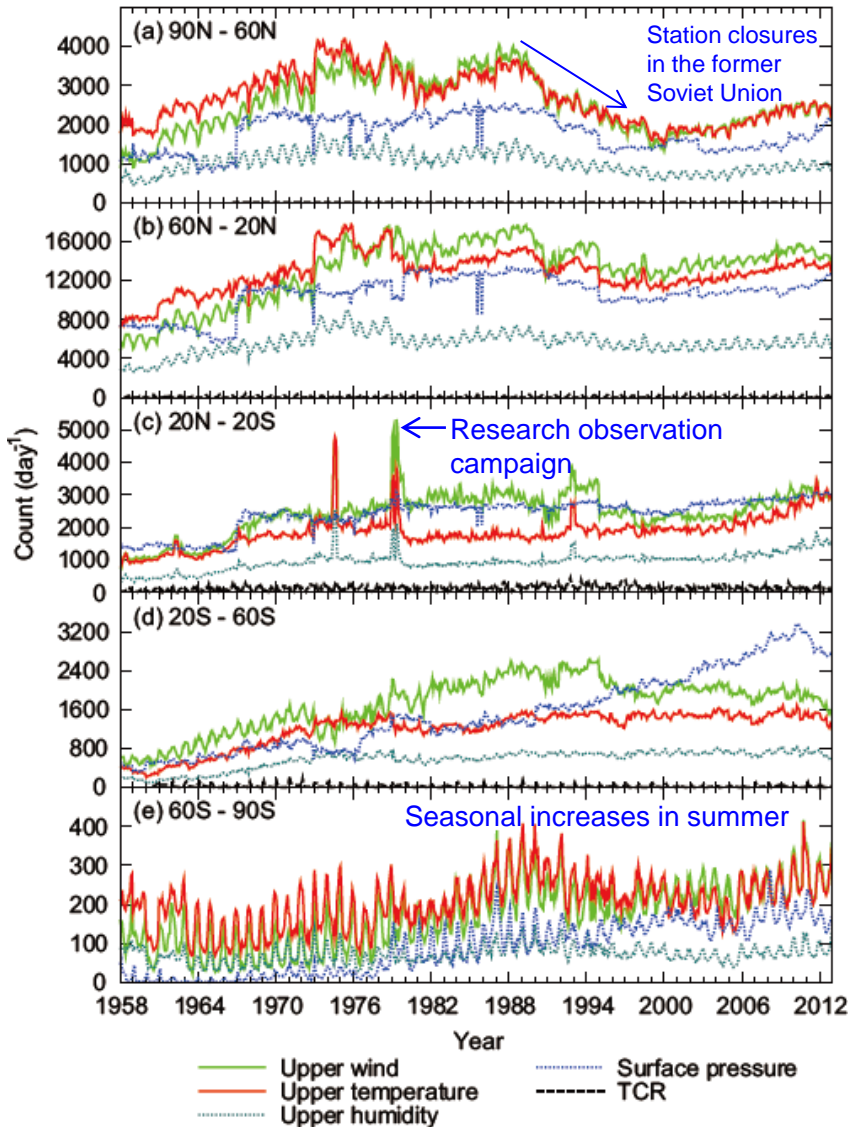
AMV: Atmospheric Motion Vectors

GNSS: Global Navigation Satellite System

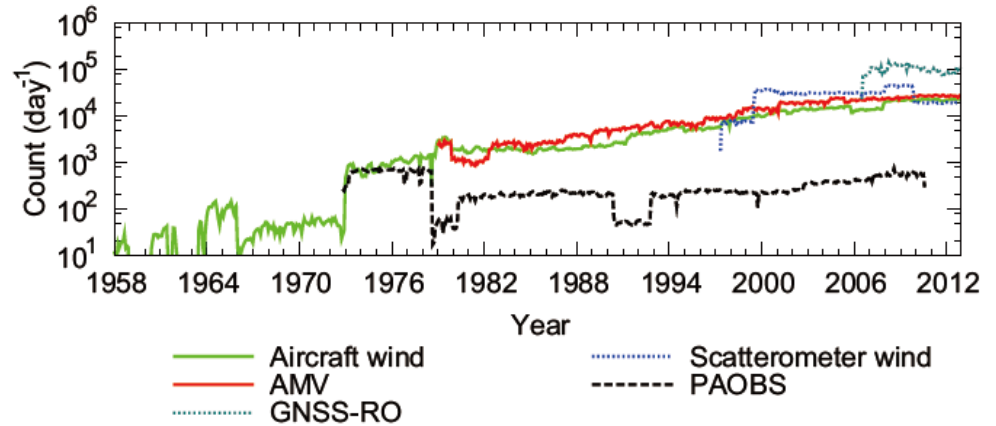
2.2 Observation data for JRA-55 (2/2)

Number of observations assimilated in JRA55 is continuously increasing

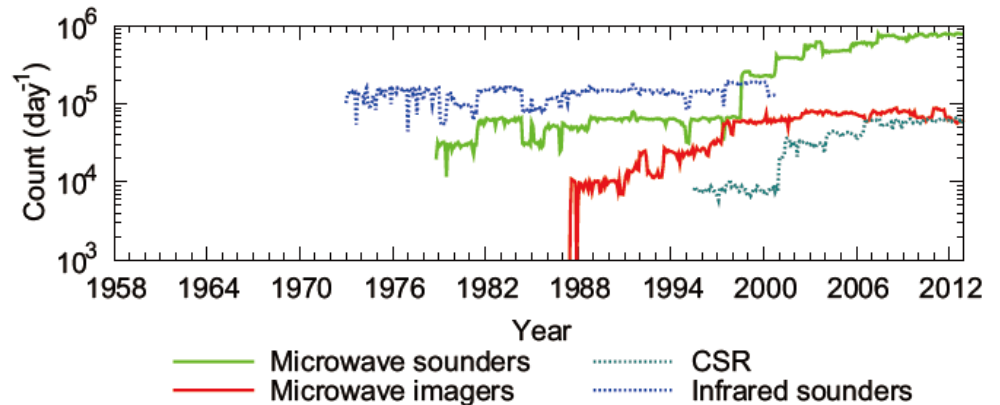
Conventional observation and TCRs



Aircraft and satellite winds, PABOS, and GNSS-RO



Various types of satellite radiances



Kobayashi et al. (2015, JMSJ)

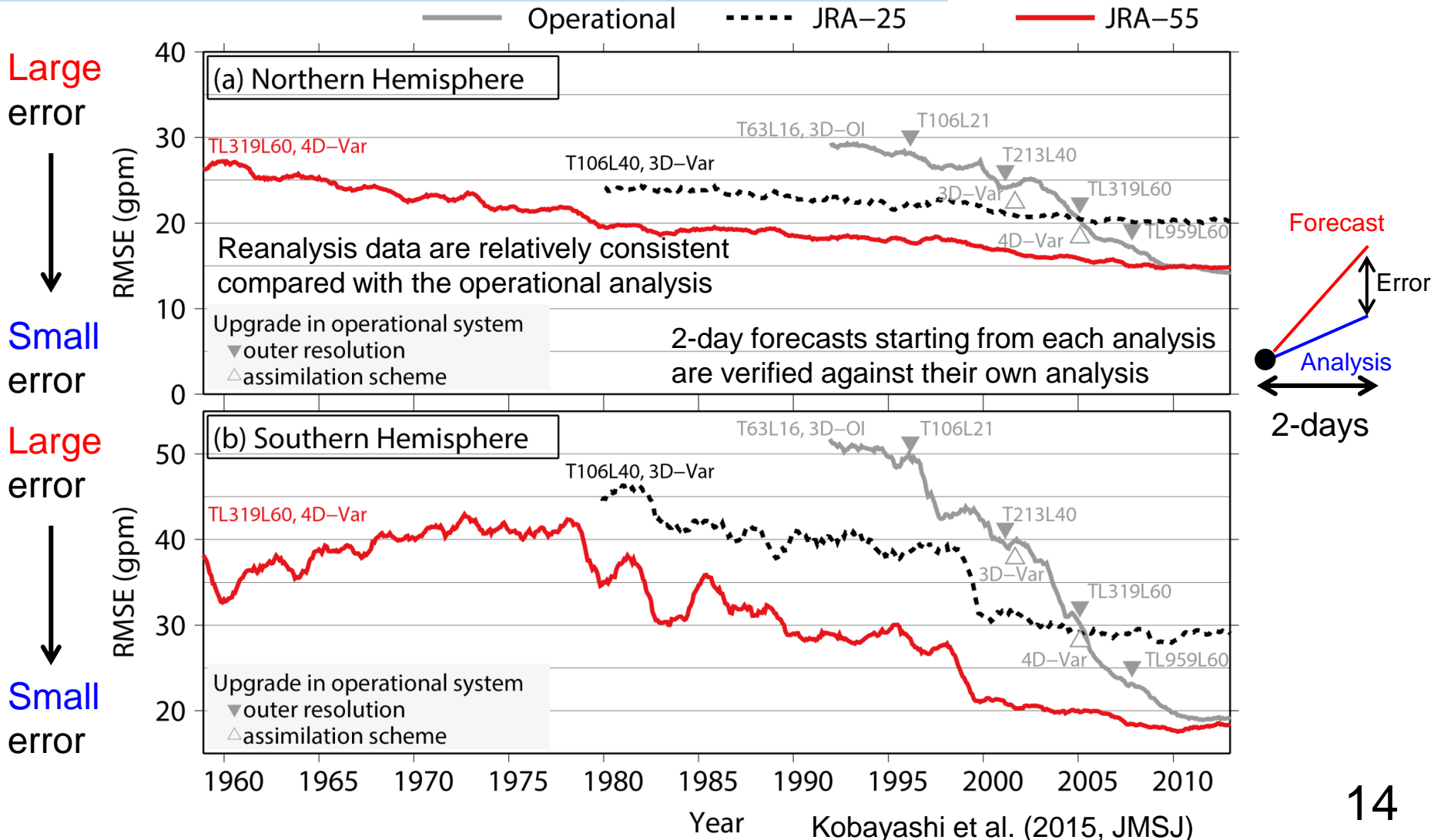
Unit: 1/day [Monthly mean counts] 13

2.2 Basic performance (1/6)

The forecast scores of the JRA-55 system are considerably better than those of the JRA-25 due to new observational data and improvements of the DA system

RMSEs of 2-day forecasts of the geopotential height at 500hPa

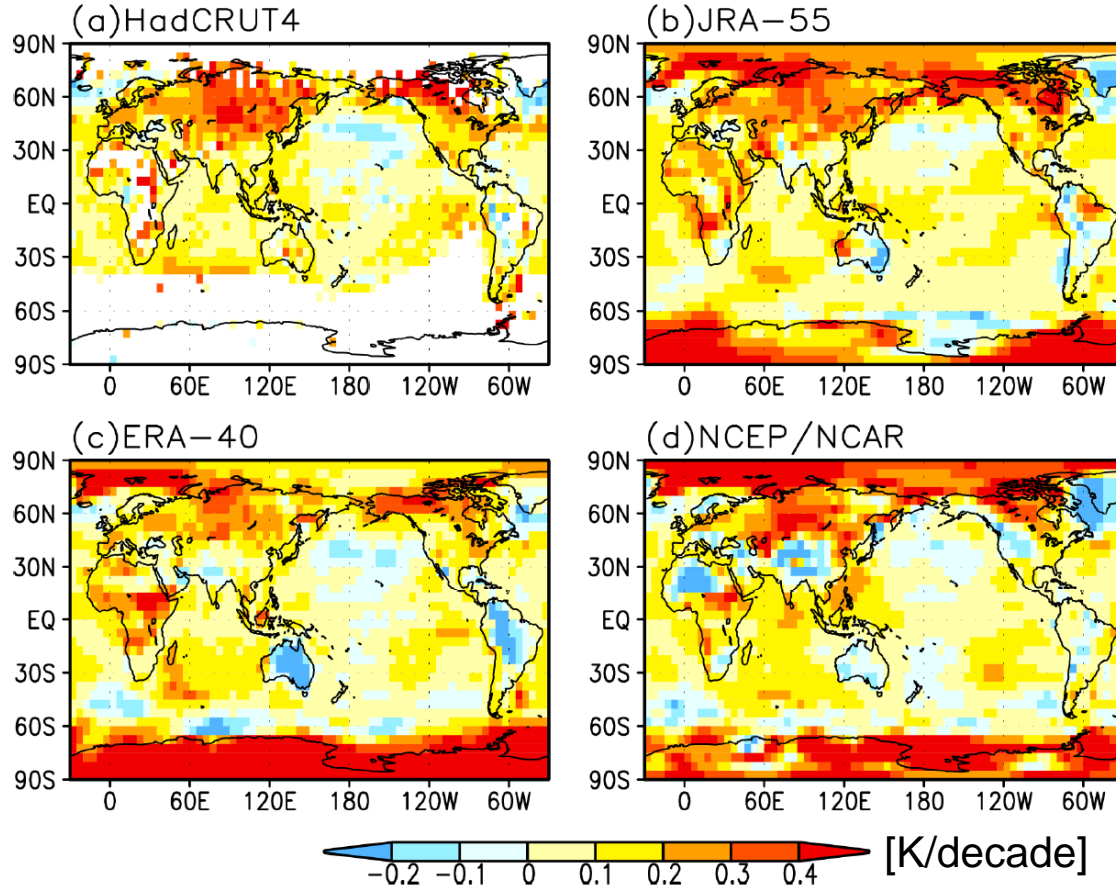
*Average over the extratropics



2.2 Basic Performance (2/6): Temperature in the troposphere

Long-term trends and variation of temperature in the land-surface and troposphere are well reproduced by JRA-55 reanalysis

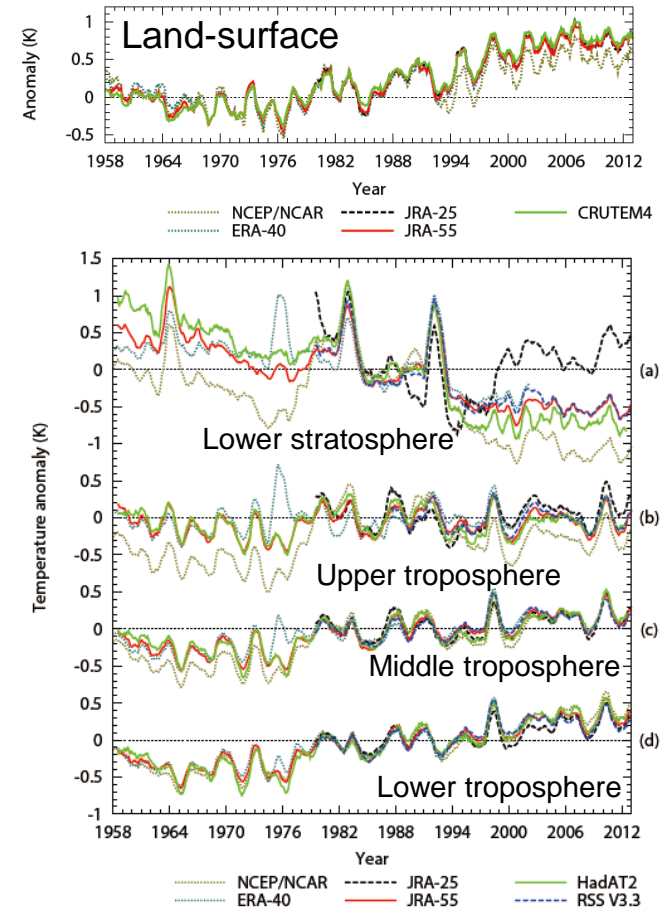
Surface air temperature trends from 1958 to 2001



Reanalysis data were re-gridded to 5x5 resolution

Harada et al. (2016, JMSJ) and Kobayashi et al. (2015, JMSJ)

Monthly temperature anomalies averaged over the globe

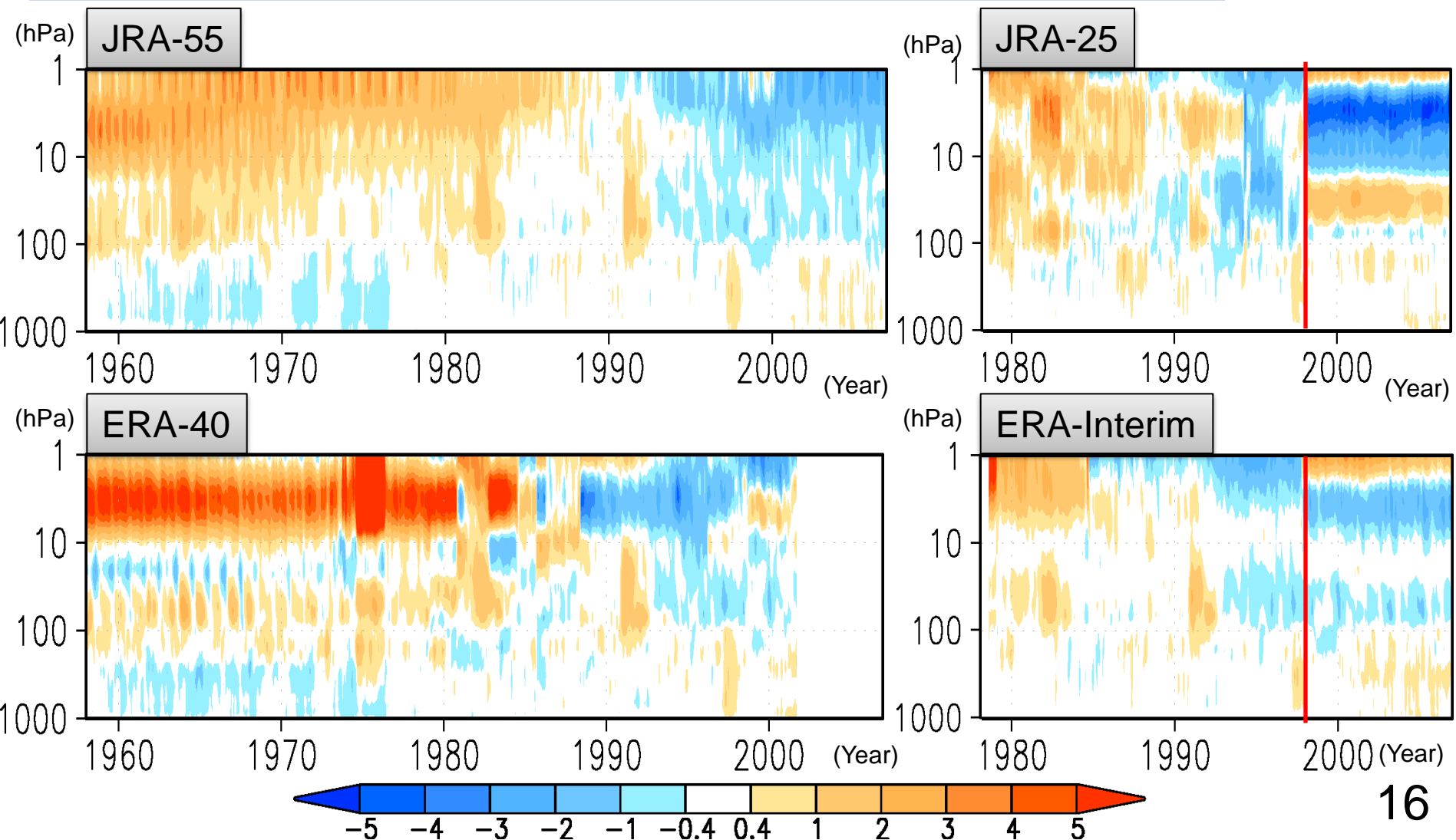


12-month running mean

2.2 Basic Performance (3/6): Temperature in the stratosphere

Cold bias in the stratosphere, one of the major problems of JRA-25, is extensively reduced in JRA-55 due to the revision of longwave radiation scheme

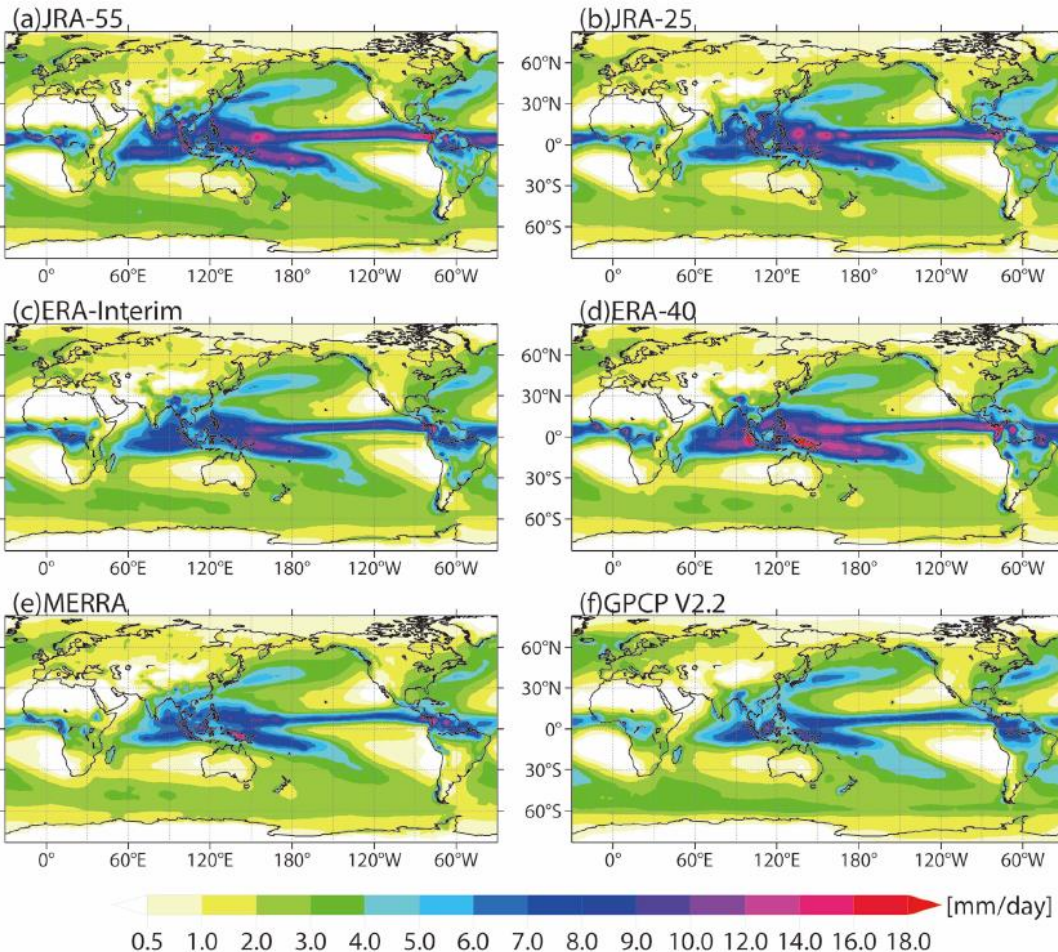
Time-height sections of global mean temperature anomalies (1980-2001 mean)



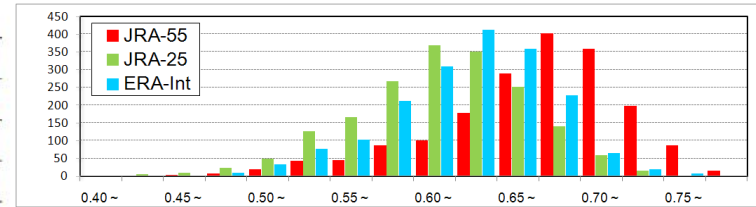
2.2 Basic Performance (4/6): Precipitation

JRA-55 well reproduce the precipitation in middle and high latitude
 Spatial pattern of daily precipitation in the tropics are well reproduced by JRA-55

Annual mean precipitation averaged over 1980-2001

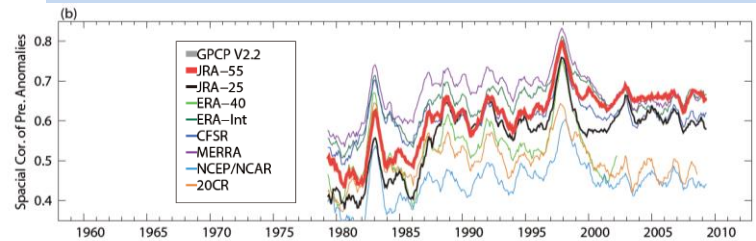


Frequency of spatial correlation of daily precipitation against TRMM



Small Correlation **Large**
 Region: 22S-22N
 Period: 1998-2009, May-Sep.

Spatial correlation of monthly precipitation anomaly against GPCP

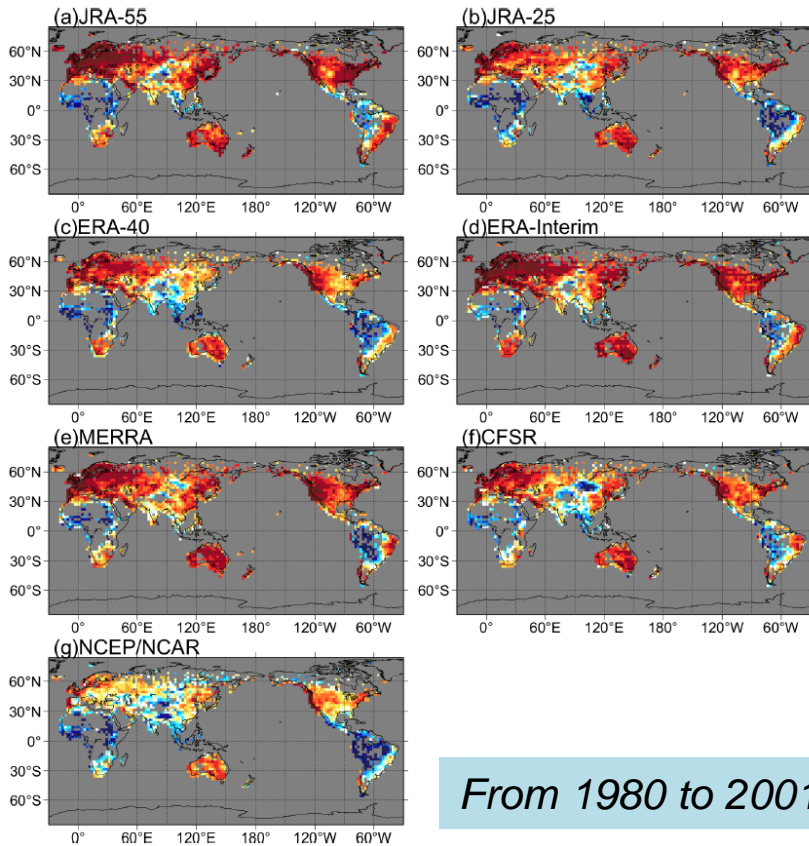


Year
 Region: Global
 12-month running mean

2.2 Basic performance (5/6): Precipitation over land

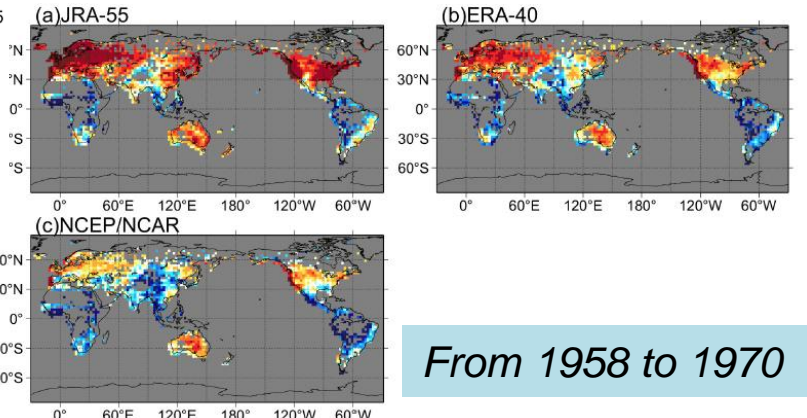
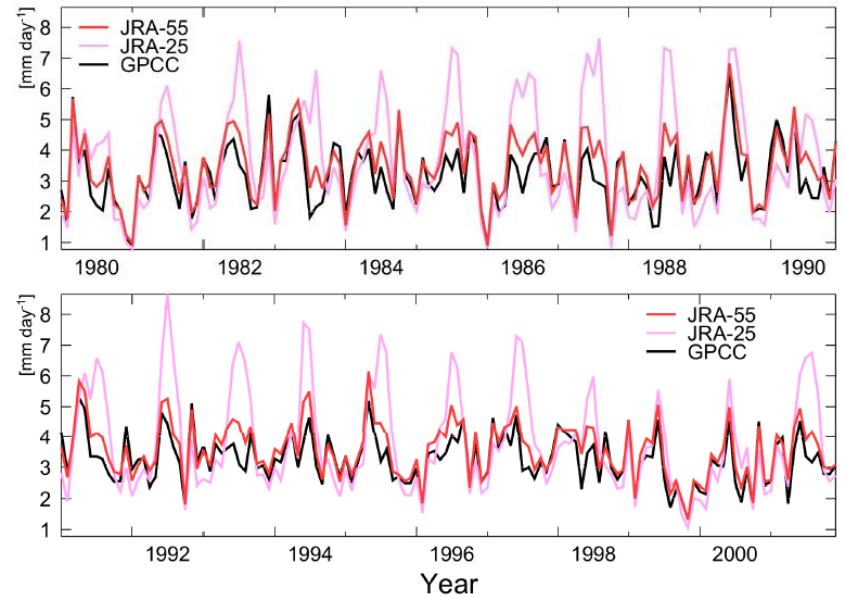
Precipitation estimated by JRA-55 is consistent with the GPCP results. Representation of precipitation over extra-tropical land is of high quality throughout the reanalysis period.

Temporal correlation coefficients of monthly precipitation anomaly with GPCP



From 1980 to 2001

Time series of monthly mean precipitation averaged over 30-40N, 80-100W

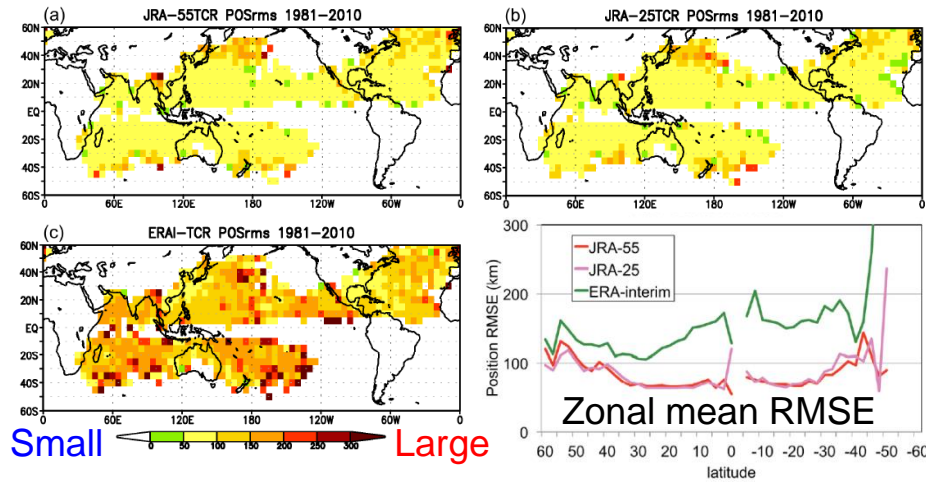


From 1958 to 1970

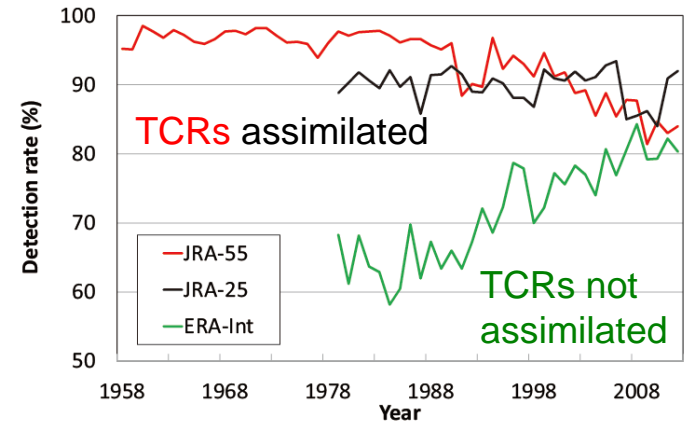
2.2 Basic Performance (6/6): Tropical cyclones

Spatial pattern and intensity of TCs are well represented by JRA-55. However, artificial decreasing trends were detected due to bugs in TCRs...

RMSE of TC position with respect to the best track

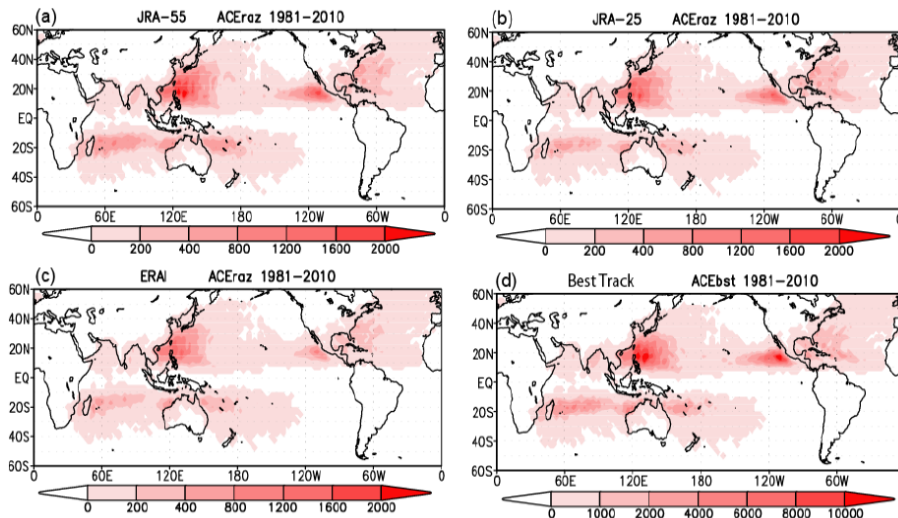


Global detection rates of tropical cyclones



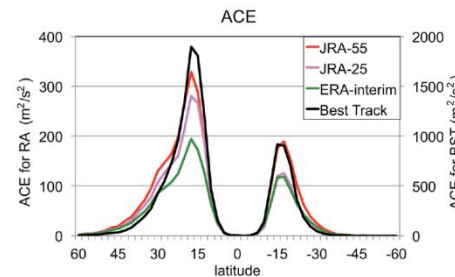
Artificial decreasing trends of JRA-55 due to TCRs bug??

Accumulated cyclone energy (ACE)



Case study of individual TC: OK
Analysis of long-term TC trends: NG

Zonal mean ACE



Summary of JRA-55

- **Forecast model and data assimilation system for JRA-55**
 - Extensively improved from those for JRA-25
(e.g., resolution, 4D-VAR, advection scheme and physical schemes)
- **Observational data for JRA-55**
 - Improved in both quality and quantity from JRA-25
(e.g., many reprocessed satellite data, newly available data)
- **JRA-55 has been improved from JRA-25. For example...**
 - Reduction of Cold bias in the stratosphere
 - Reduction of the dry bias in the Amazon basin (not shown)
 - Increase of spatial temporal consistency
- **Problems to be addressed (→The next reanalysis)**
 - Dry bias in the upper and lower troposphere
 - Warm (cold) bias in the upper (lower) troposphere
 - Unrealistic long-term trends in tropical cyclones

3. The next Japanese reanalysis: JRA-3Q

- **JRA-3Q** (Japanese Reanalysis for Three Quarters of a Century)

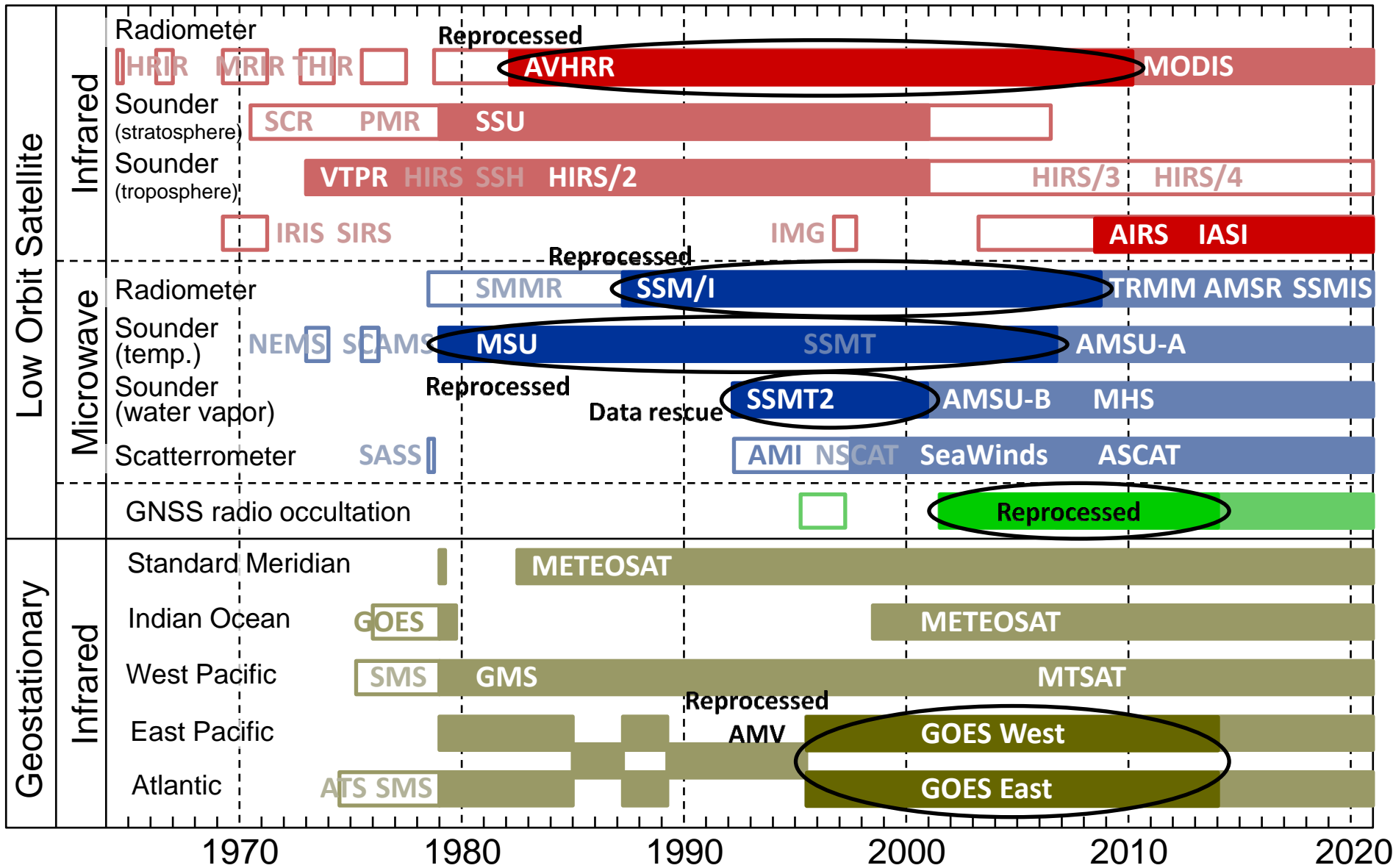
In Japanese, “3” is pronounced as “San”.
San-Q → San-kyuu → Thank you ☺

- **Provisional specifications**

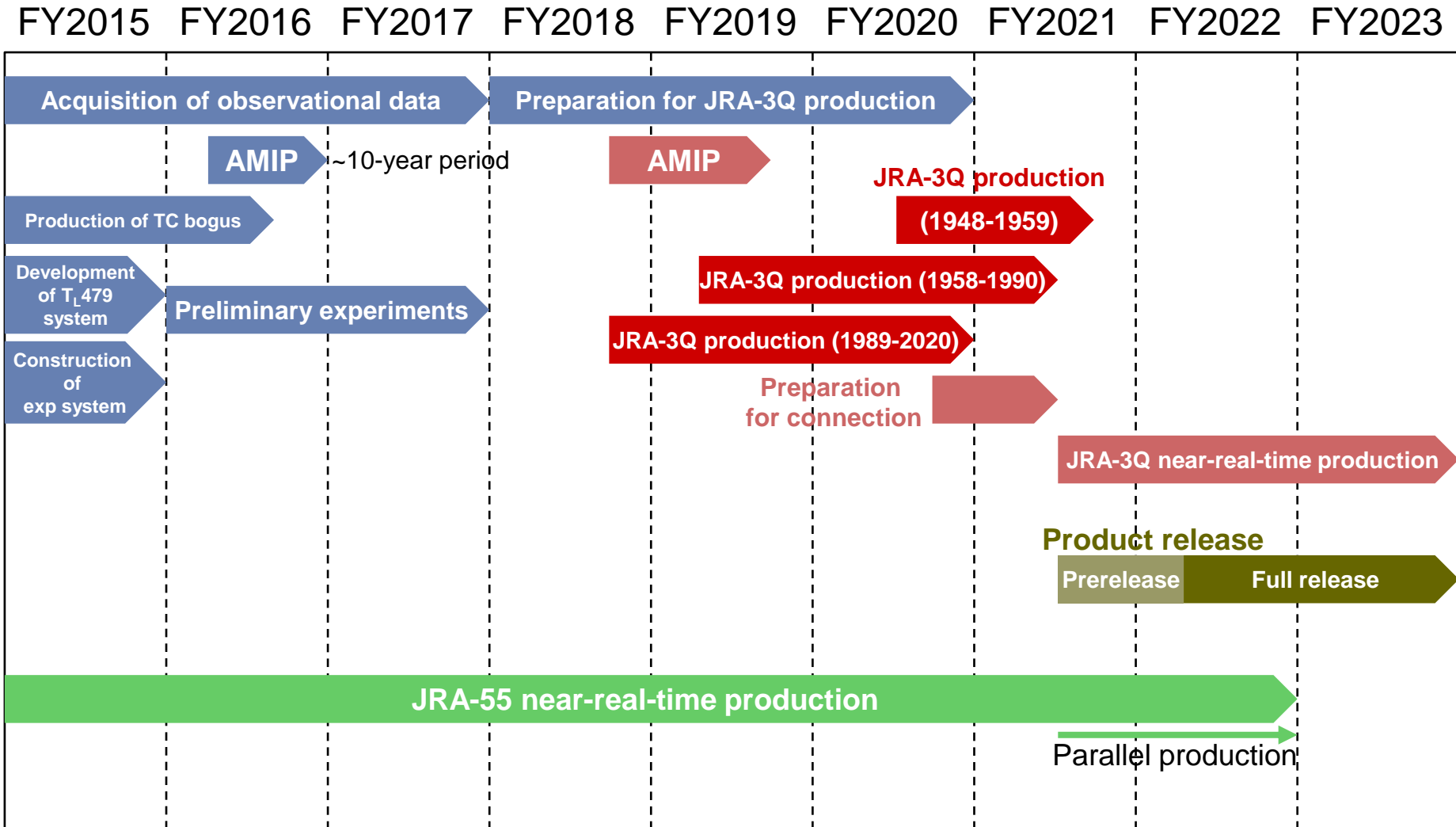
- Higher resolution: T_L319L60 -> T_L479L100
 - 40 km in horizontal, 100 layers up to 0.01 hPa in vertical
- Extending the reanalysis period back in time
 - Atmospheric reanalysis from 1948 (planned) to present
- New boundary conditions and forcing fields
 - COBE-SST2 (from the beginning to 1981)
 - MGDSST (satellite-based SST from 1982 onward)
- New observations
 - Observations newly rescued and digitized by ERA-CLIM et al.
 - Improved satellite observations through reprocessing
 - JMA’s own tropical cyclone bogus

Satellite observing systems for JRA-3Q (plan)

Thin Color shadings: used for JRA-55, Others: not used
 Thick Color shadings: will be used for JRA-3Q



Schedule for JRA-3Q (plan)



4.1 JRA-55 family

Subsets of JRA-55, JRA-55C and JRA55-AMIP, are useful for investigating impacts of changing observing systems on the quality of reanalysis

- **JRA-55** (JMA, S. Kobayashi et al. 2015)
 - Reanalysis **with full observing system**
- **JRA-55C** (MRI/JMA, C. Kobayashi et al. 2014)
 - Reanalysis **with only conventional observations**
- **JRA-55AMIP** (MRI/JMA)
 - Reanalysis **without any observations**

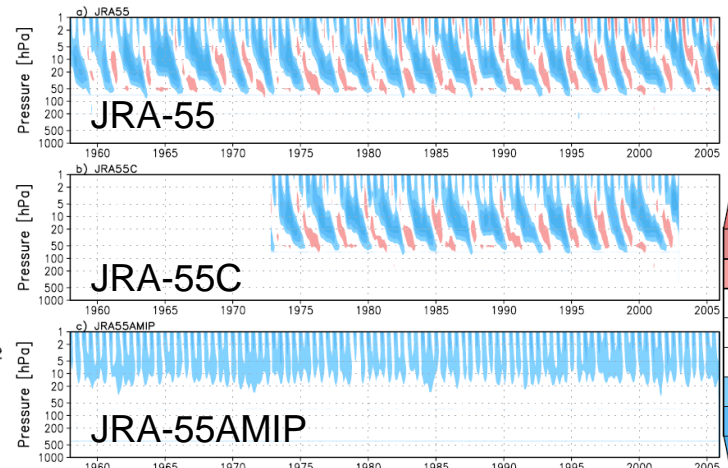
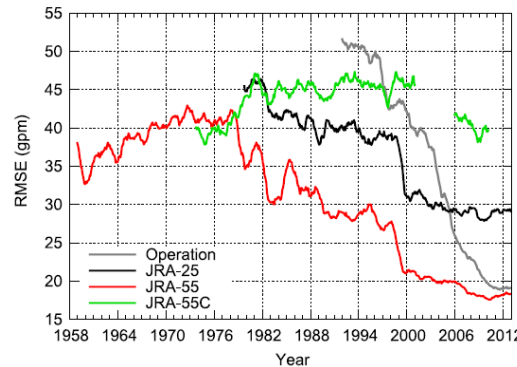
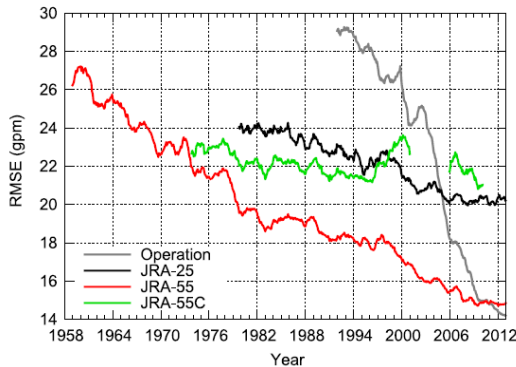
Surface
Radiosondes
TCR
Wind profilers

RMSEs of 2-day forecasts of the geopotential height at 500hPa for NH (left) and SH (right)

Time-height section of equatorial (5S-5N) zonal mean zonal wind

a) Z500 forecasts, Northern Hemisphere, FT=48

b) Z500 forecasts, Southern Hemisphere, FT=48



Kobayashi et al. (2014, SOLA)

4.2 JRA-55 Homepage and Atlas (1)

Basic information of JRA-55 is provided from JMA's homepage. Registered users can download JRA-55 products from the JDDS*.

http://jra.kishou.go.jp/JRA-55/index_en.html

*JMA Data Dissemination System

JRA project Japanese >>

JRA-55 – the Japanese 55-year Reanalysis

> News > About > Usage > Manual > Quality Issues > Contact

Application JRA-55 Atlas

About

Basic information of JRA-55 including background, references, and leaflets

JRA-55
The Japanese 55-year Reanalysis

OUTLINE
In response to the success of JRA-25, JMA continued the second Japanese global reanalysis, called JRA-55. The project involved comprehensive global atmospheric reanalysis based on four-dimensional variational analysis (4D-Var) for the first half of the 20th century (1958-2005). As a result, the new reanalysis based on JRA-55 has been significantly improved in terms of consistency of temporal analysis is also better than that of previous reanalysis products. The high quality and long term JRA-55 data provided are suitable for studies on climate change and multi-decadal variability as well as for the monitoring of severe climate systems.

DATA ASSIMILATION SYSTEM
The data assimilation system is based on JMA's operational reanalysis of December 2005, and is called JRA-55. The system includes a revision of the radiation scheme and the introduction of an 800-mb and horizontal flow correction (HFC) for satellite radiances. These updates significantly reduce model biases, enhance the diurnal consistency of analysis fields, and improve the handling of satellite radiances.

PRODUCT AVAILABILITY
JRA-55 reanalysis and JRA-55MPP are provided as various extra JRA-55 products. Highlight the impact of observational systems and model biases. JRA-55 is suitable for studies of climate variability and model diagnostic variability. Available in a high-resolution dataset covering an extended period.

JRA-55 FAMILY
JRA-55 observational and JRA-55MPP are provided as various extra JRA-55 products. Highlight the impact of observational systems and model biases. JRA-55 is suitable for studies of climate variability and model diagnostic variability. Available in a high-resolution dataset covering an extended period.

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Manual

Guides on JRA-55 products

JRA-55 Product Users' Handbook

Model grid data

Climate Prediction Division
Global Environment and Marine Department
Japan Meteorological Agency
March 2014

JRA-55 Product Users' Handbook

1.25-degree latitude/longitude grid data

Climate Prediction Division
Global Environment and Marine Department
Japan Meteorological Agency
September 2013

→ JRA Data User Application

Applicants must first accept the [Terms and Conditions of Use for JRA Products](#).
By registering, applicants are considered to have agreed to the conditions of data use.

Please fill out the fields below in **English**.

Name: Full name

Affiliation: Indicate the full organization name. Applicants who have retired or resigned from the organization should indicate their former affiliation. (e.g., Climate Prediction Division of the Japan Meteorological Agency)

Nation of affiliation: Country only (e.g. Japan, USA, UK)

E-mail address: In principle, an email address with an affiliation-specific domain name is required.

Purpose of use: Indicate the purpose in detail. Simply stating "study" or "research" is not acceptable. (e.g., Research on tropical cyclone intensity/tracks and water circulation)

OK

A response will be sent to the email address provided within a few days.

JRA-55 dataset including JRA-55 family are also available from the collaborative organizations

- <http://dias-dss.tkl.iis.u-tokyo.ac.jp/ddc/viewer?ds=JRA55&lang=en>
- <http://gpvjma.ccs.hpcc.jp/~jra55/index.html>
- <http://rda.ucar.edu/datasets/ds628.0/>

DIAS
Data Integration & Analysis System

University of Tsukuba
Center for Computational Sciences

NCAR UCAR

Research Data Archive
Computational & Information Systems Lab

4.2 JRA-55 Homepage and Atlas (2)

Climate maps for various meteorological variables are provided by the JRA-55 Atlas.

http://jra.kishou.go.jp/JRA-55/index_en.html

JRA project Japanese >>

JRA-55 – the Japanese 55-year Reanalysis

> News > About > Usage > Manual > Quality Issues > Contact

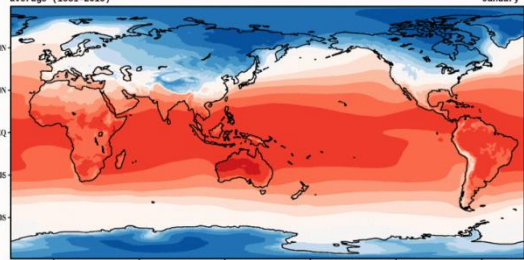
Application **JRA-55 Atlas**

<http://ds.data.jma.go.jp/gmd/jra/atlas/en/index.html>

Surface climatologies

Temperature (surface 2m level) | color 2

average (1981-2010) **2 meter temperature** January



JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC ANN MAM JJA SON DJF

JAN

You can download figures and text data

Figure legends

Select a month/season to download | JAN

[png figure](#) [eps figure](#) [text data](#)

JRA project > JRA-55 > JRA-55 Atlas Japanese >>

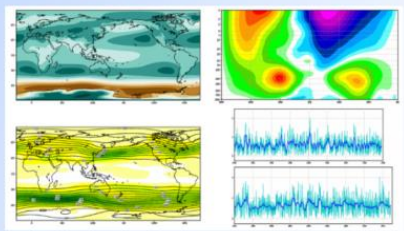
JRA-55 Atlas

This page shows a compilation of climate maps produced with the Japanese 55-year Reanalysis (JRA-55; a high-quality comprehensive climate dataset covering the last half-century).

The JRA-55 Atlas provides climate maps for a variety of meteorological variables ranging from basic metrics such as surface temperature and wind to technical considerations for climate research. It is expected to be widely useful in research and education.

JRA-55 Atlas

Climate maps by the Japanese 55-year Reanalysis

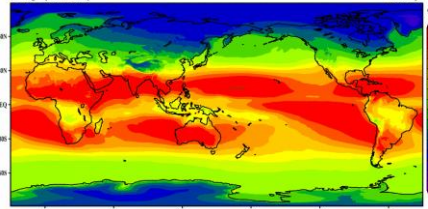


- How to use
- Notices
- Display climate map
 - Surface elevation and vegetation
 - Surface climatologies
 - Surface and top-of-atmosphere climatologies
 - Column climatologies
 - Isobaric climatologies
 - Isentropic climatologies
 - Time-series representations
- Commentary and material
 - Production method
 - Download in PDF format

[JRA-55 Atlas home](#)

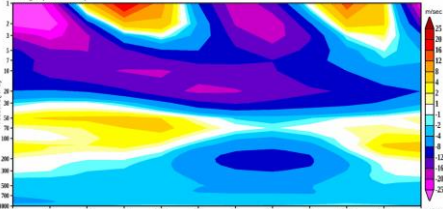
Horizontal distribution

Top of atmosphere net thermal radiation January



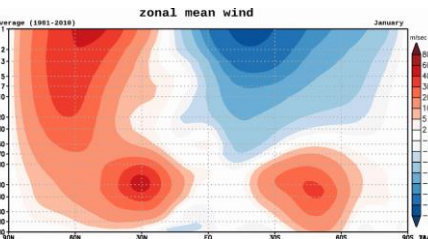
Time-height section

Annual cycle of equatorial zonal mean u-wind



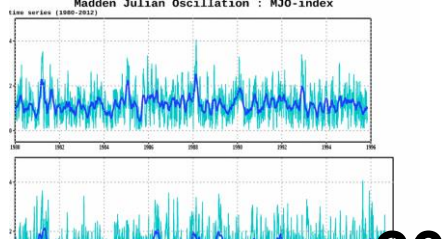
Latitude-height section

zonal mean wind January



Time series of index

Madden Julian Oscillation : MJO-index



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- **Reanalysis**

- Analysis of the past atmospheric conditions using a constant, state-of-the-art NWP model and data assimilation system with the latest observation data
- Need to produce a high-quality, spatially and temporally consistent dataset for climate monitoring

- **JRA-55**: the latest reanalysis by JMA

- Improved NWP system and newly available observational data are used to produce consistent climate dataset from 1958 onward
- Spin-offs (JRA-55C and AMIP) for evaluating impacts of observation
- Dataset and basic figures are available from the JMA's HP

- **JMA-3Q**: the next reanalysis by JMA

- Currently in preparation to produce higher quality and more consistent dataset for climate monitoring

References

● [S. Kobayashi et al. \(2015\)](#)

- ❑ Kobayashi, S., Y. Ota, Y. Harada, A. Ebita, M. Moriya, H. Onoda, K. Onogi, H. Kamahori, C. Kobayashi, H. Endo, K. Miyaoka, and K. Takahashi, 2015: The JRA-55 Reanalysis: General specifications and basic characteristics. *J. Meteor. Soc. Japan*, 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. \(2016\)](#)

- ❑ Harada, Y., H. Kamahori, C. Kobayashi, H. Endo, S. Kobayashi, Y. Ota, H. Onoda, K. Onogi, K. Miyaoka, and K. Takahashi, 2016: The JRA-55 Reanalysis: Representation of atmospheric circulation and climate variability, *J. Meteor. Soc. Japan*, 94, 269-302, doi:10.2151/jmsj.2016-015.
- ❑ https://www.jstage.jst.go.jp/article/jmsj/94/3/94_2016-015/article

● [C. Kobayashi et al. \(2014\)](#)

- ❑ Kobayashi, C., H. Endo, Y. Ota, S. Kobayashi, H. Onoda, Y. Harada, K. Onogi, and H. Kamahori, 2014: “**Preliminary results of the JRA-55C**, an atmospheric reanalysis assimilating conventional observations only”, *SOLA*, **10**, 78-82, doi:10.2151/sola.2014-016
- ❑ https://www.jstage.jst.go.jp/article/sola/10/0/10_2014-016/article