Introduction to Reanalysis and JRA-55

Yuki KOSAKA

Climate Prediction Division,
Japan Meteorological Agency

Outline

1. Introduction to Reanalysis

- Basic dataset for climate services
- Comparison b/w operational analysis and reanalysis

2. Introduction to JRA-55 reanalysis

- Data assimilation system and forecast model
- Basic performance
- JRA-55 homepage and user application

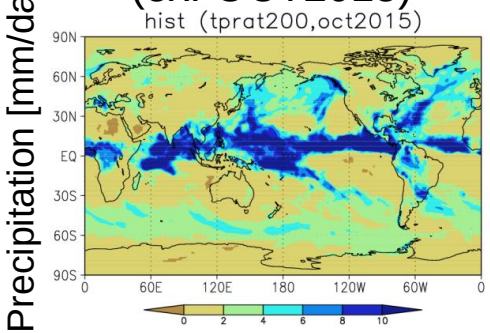
3. JMA's next reanalysis: JRA-3Q

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

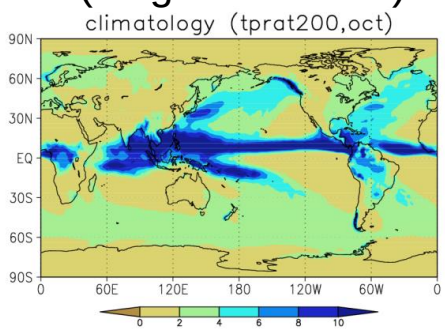
Examples of climate monitoring

Raw Value
(ex. OCT2015)



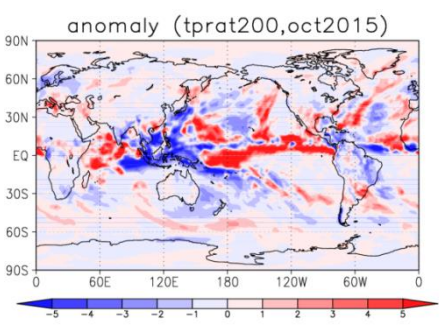
-

Climatology
(long-term mean)

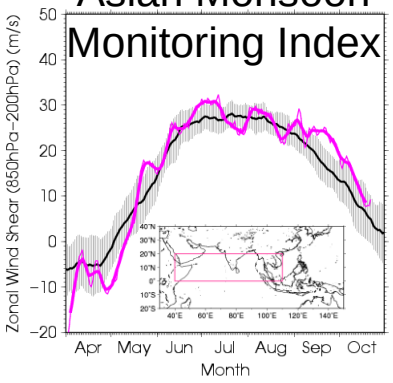


=

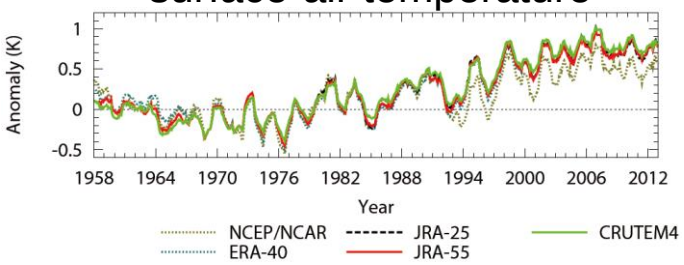
Anomaly
(deviation from the climatology)



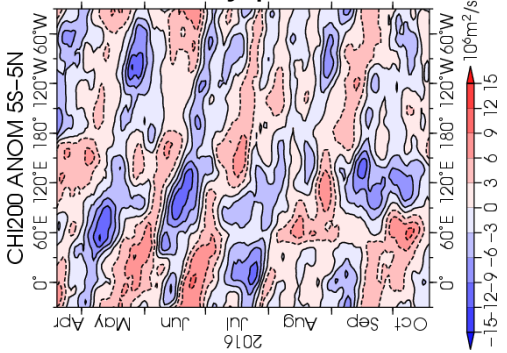
Asian Monsoon
Monitoring Index



Long-term variations of
surface-air temperature



Time-longitude section of
200hPa velocity potential anomaly



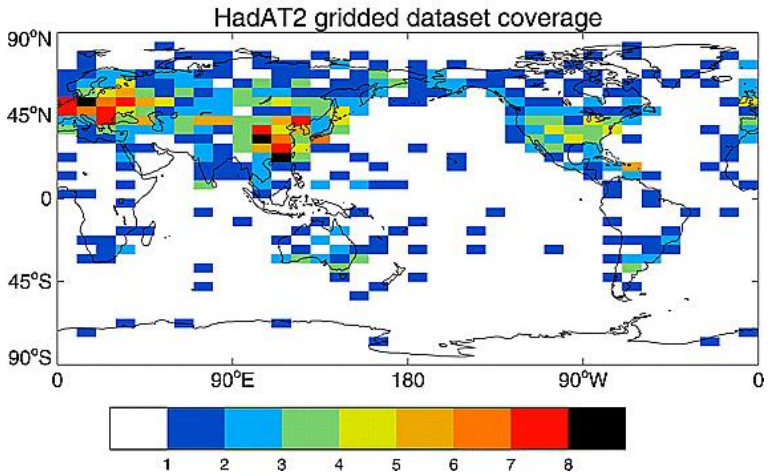
1.2 Approaches for producing climate dataset (1/4)

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…

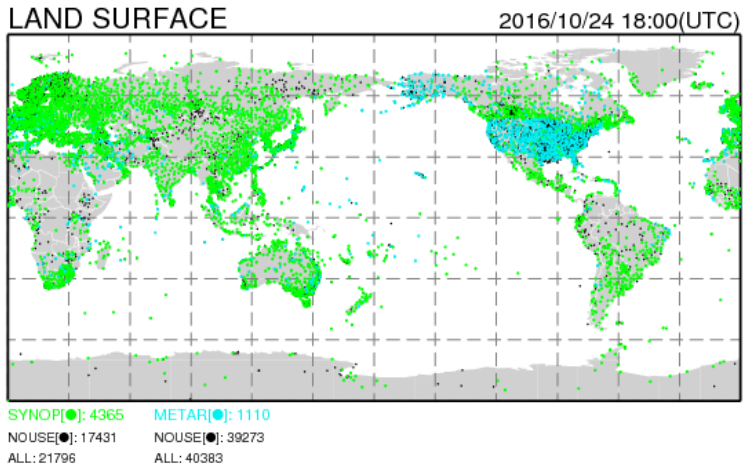
➔Observation-alone is not suitable for (general) climate monitoring (though it is useful for some specific purposes)

Radiosonde data number for each grid



Thorne et al. 2005

Distribution of surface observation (example)



1.2 Approaches for producing climate dataset (2/4)

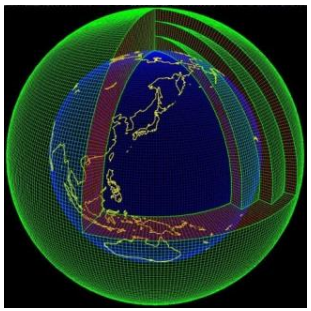
Approach (2): Using Global Circulation Model (GCM)

- 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…

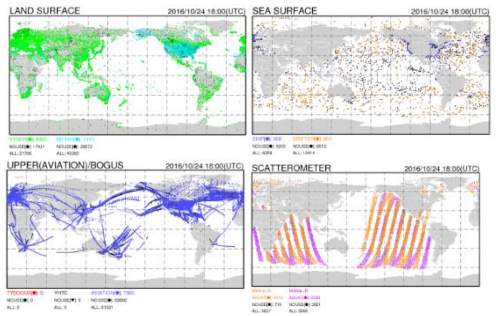
➔Modification of the model outputs by observational data is needed (this process is called “Data Assimilation(DA)”, a part of **operational analysis cycle** to estimate the initial condition for short-range NWP)

➔Climate dataset can be produced by long-term DA cycle??

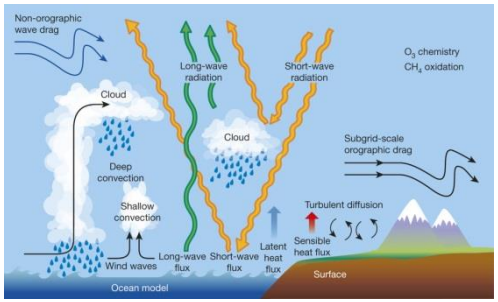
Distribution of grid points



Observational data (ex.)



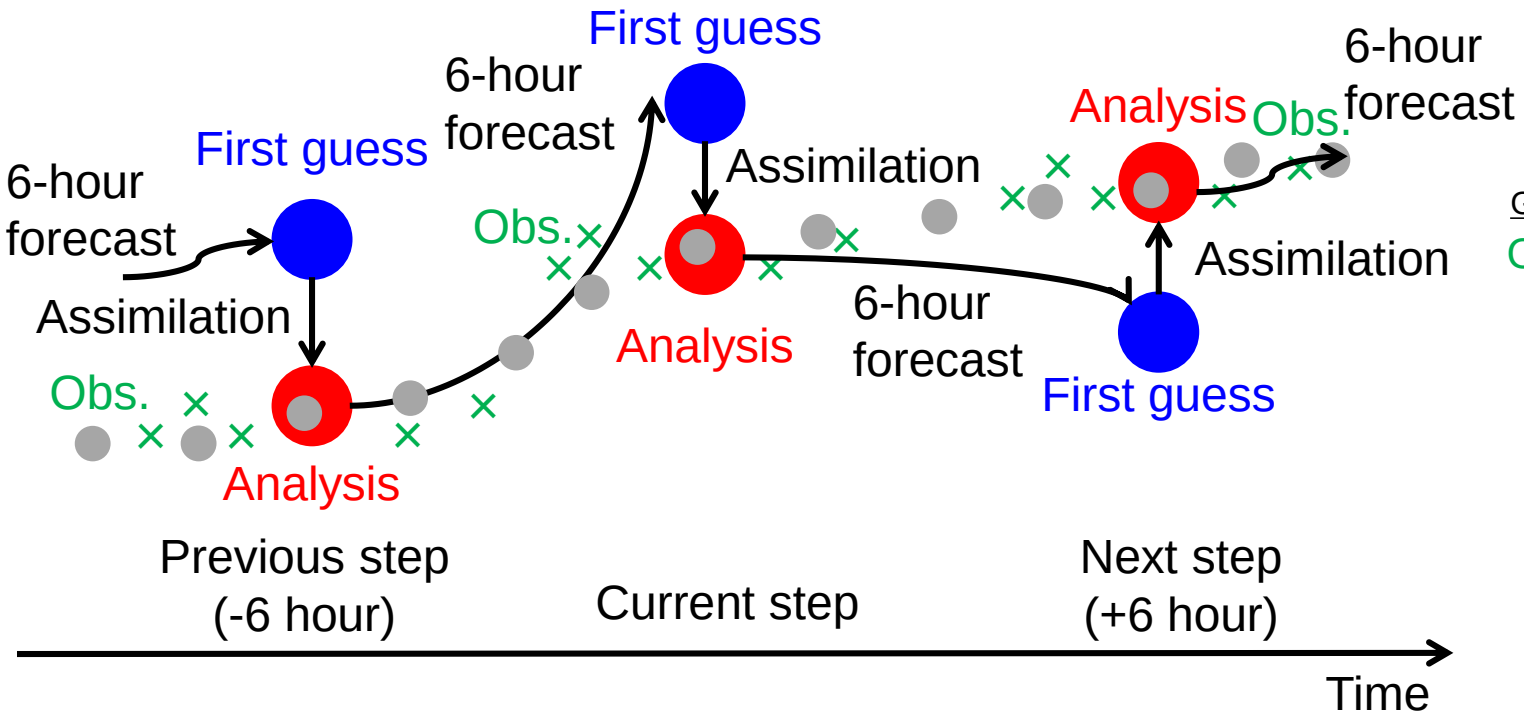
Schematics of the atmospheric process



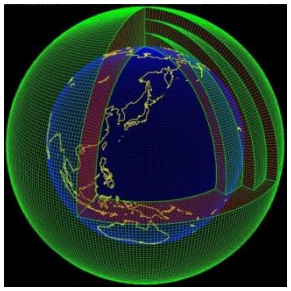
Bauer et al. (2015)

Data assimilation

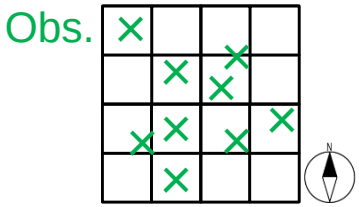
Schematic diagram of the data assimilation cycle



Forecast model



Grid points of the model



Supercomputer

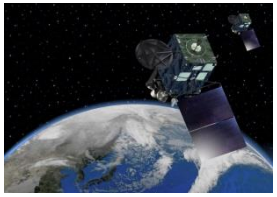
Observations (example)

Surface

Radiosonde

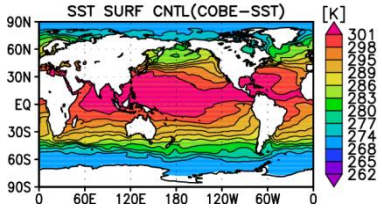
Ship

Satellite

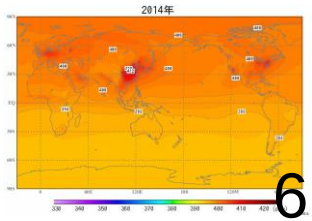


Boundary conditions (example)

SST

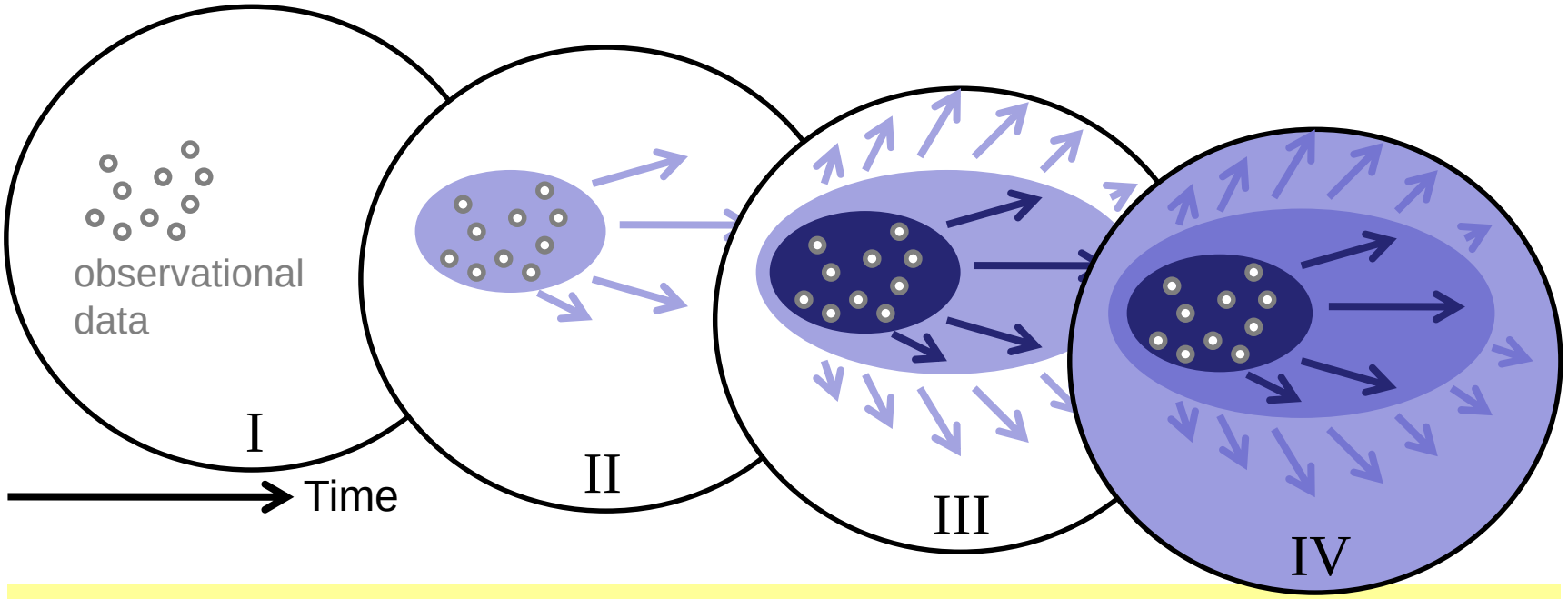


GHG (CO2)



Impacts of data assimilation

Schematic diagram of impacts of data assimilation



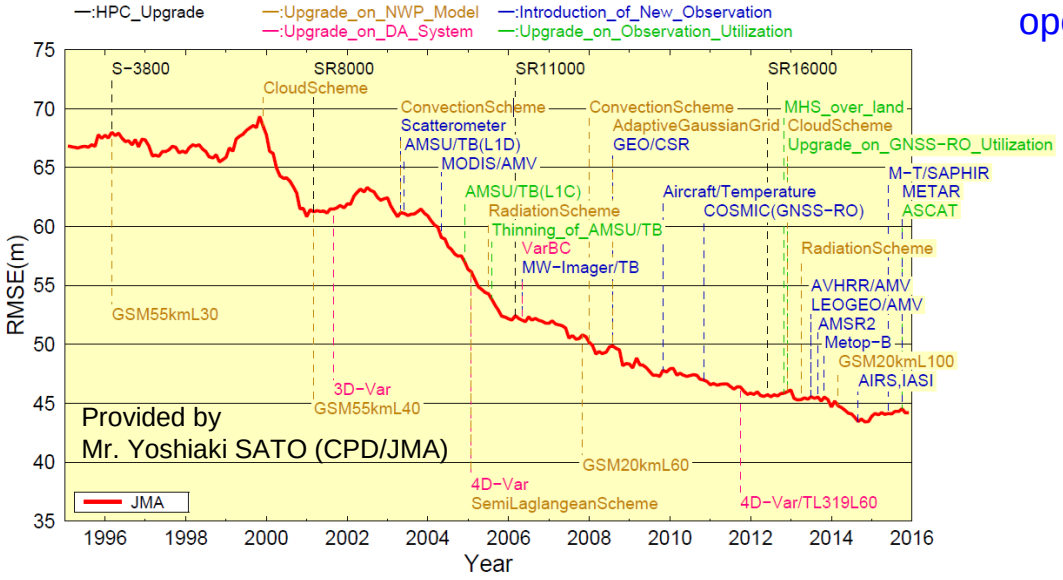
I. Un-uniformly distributed observations
II. The hatched area surrounding observations are analyzed with high quality. The high quality area extends thorough forecast.
III. In the next data assimilation, the deep colored area surrounding observations are analyzed with much higher accuracy. The higher 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.

Operational analysis and Reanalysis

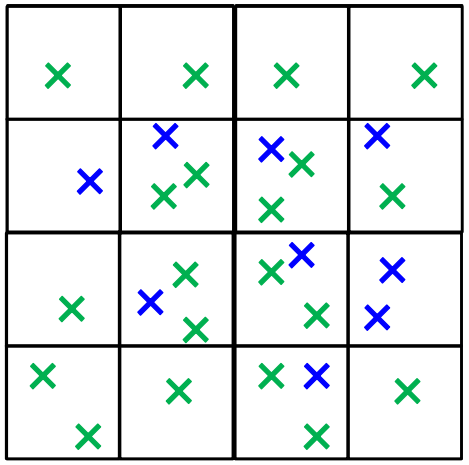
Comparison of the operational analysis and reanalysis

	Operational analysis	Reanalysis
Model and DA system	Upgraded with time (to improve forecast skills)	Constant and the latest* (to assure consistency and accuracy)
Observation data	Delayed data can't be used (because time for operational NWP is limited)	Delayed data are included (which may lead to improve the quality)

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

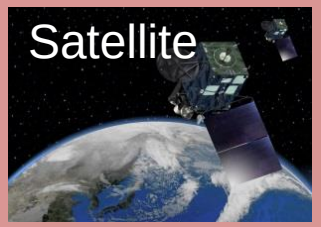


Obs. available at the time of operational analysis
Obs. which become available after the time of operational analysis (delayed data)



Reanalysis

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”

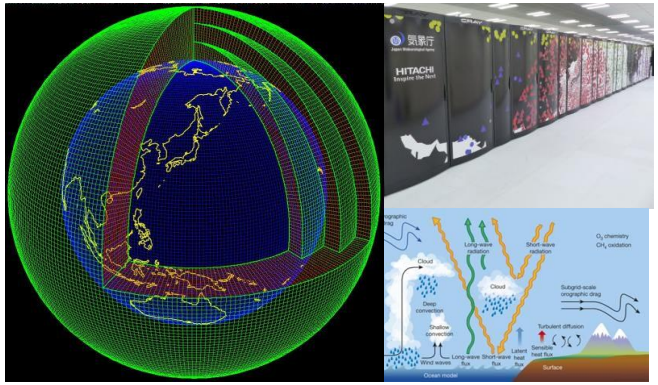


Observation
(incl. belated data)

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

Data Assimilation

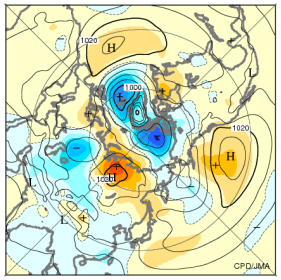
Quality Check



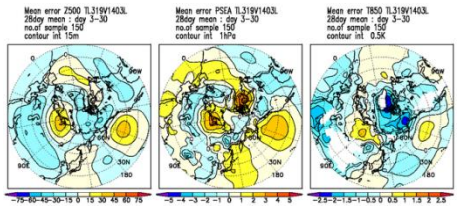
Input

Integration for several decades

Consistent quality reanalysis product (GPV)

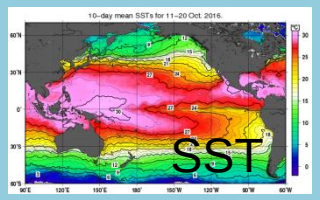


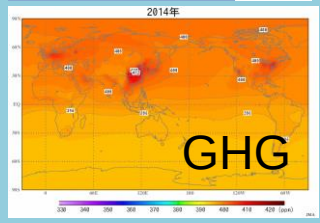
Climate Monitoring



Initial conditions for Hindcast (Re-forecast)

Climate Research



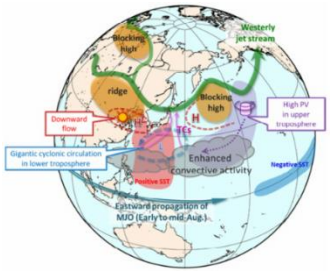


Boundary conditions (prescribed)

Utilization of reanalysis data

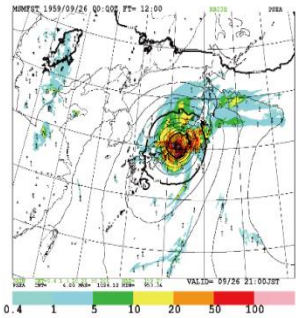
(1) Operational seasonal forecasting and climate monitoring at JMA

- Development and verification of seasonal ensemble prediction system
- Climate system monitoring, extreme event analysis



(2) Other operational uses at JMA

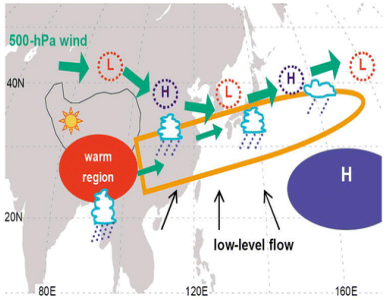
- Development of various models
- Study of past severe weather events



(example)
Re-analysis/forecast of typhoon Vera project: ReVera
(Reanalysis data were used for initial condition of meso-scale model)

(3) Fundamental research

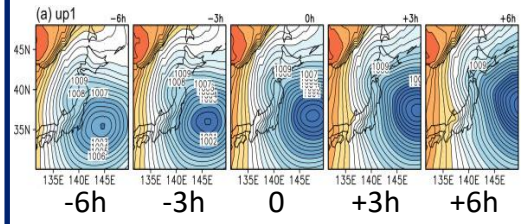
- Fundamental data for academic research in meteorology, climatorogy, and oceanography



(example)
Large-Scale Dynamics of the Meiyu-Baiu Rainband: EnvironmentalForcing by the Westerly Jet
(Sampe and Xie 2010, *J. Climate*)

(4) Applied research

- Input data for various applications fields such as agricultural meteorology and renewable energy



(example)
Impacts of synoptic circulation patterns on wind power ramp events in East Japan
(Ohba, Kadokura and Nohara 2016, *Renew. Energ.*)

2. Introduction to JRA-55

- 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

JRA Go! Go!

In Japanese, "5" is pronounced as "Go".

JRA-55 reanalysis system

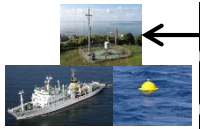
JRA-55 reanalysis system was extensively improved since JRA-25

	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) *(top layer at 0.4 hPa)*	**TL319L60 (~55km)** ***(top layer at 0.1 hPa)***
Advection scheme	Eulerian	**Semi-Lagrangian**
Assimilation scheme	3D-Var	**4D-Var** ***(with T106 inner model)***
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 (CO2,CH4,N2O)

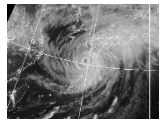
Observation data for JRA-55 (1)

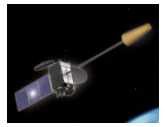
Newly available and improved past observations are included in JRA-55

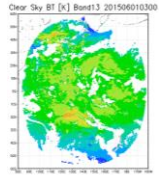
(image)

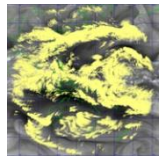


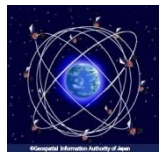
(image)











SYNOP, SHIP and BUOY

Snow depth over Russia, Mongol and USA**

Digitized snow depth over China**

Radiosondes, pilot balloons and wind profilers

Tropical cyclone wind retrievals**

Aircraft

PAOBS

IR sounders*

MW sounders

MW imagers*

GOES*

METEOSAT*

GMS and MTSAT (reprocessed)**

GOES

METEOSAT (reprocessed)*

GMS and MTSAT (reprocessed)**

MODIS

Scatterometers*

GNSS RO*

Conventional

Satellite radiances

AMV

New types of sat obs

** First time for reanalyses

* Improved from or added to JRA-25

1960 1970 1980 1990 2000 2010

Year

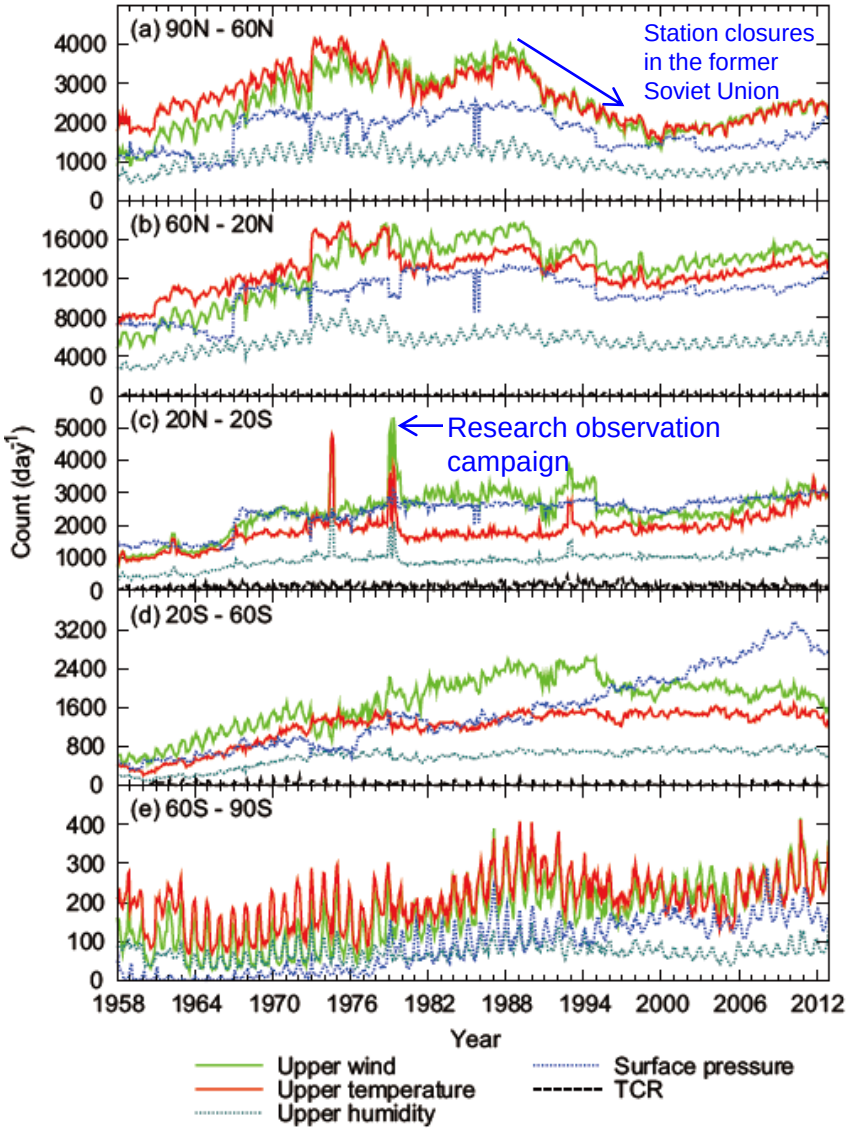
AMV: Atmospheric Motion Vectors

GNSS: Global Navigation Satellite System

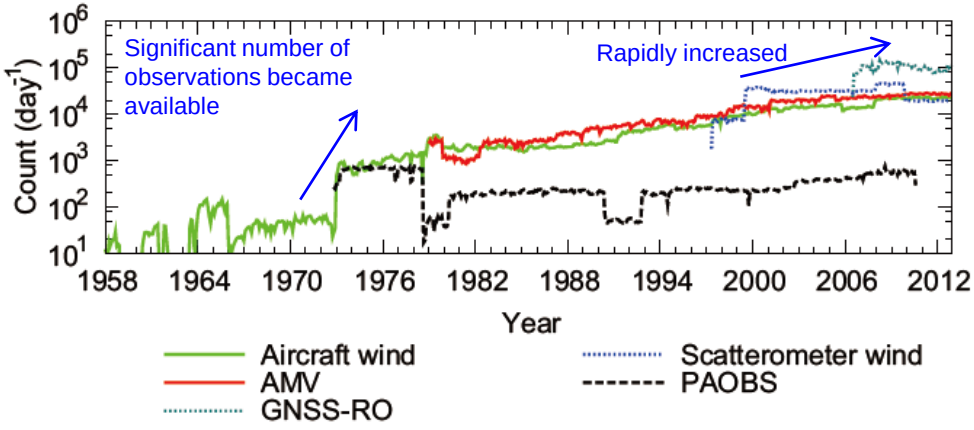
Observation data for JRA-55 (2)

Number of observations assimilated in JRA-55 is continuously increasing

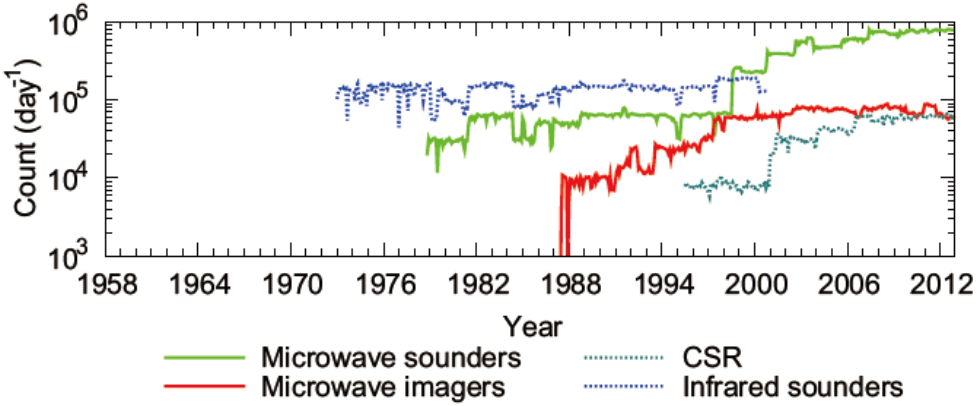
Conventional observation and TCRs



Aircraft and satellite winds, PAOBS, and GNSS-RO



Various types of satellite radiances



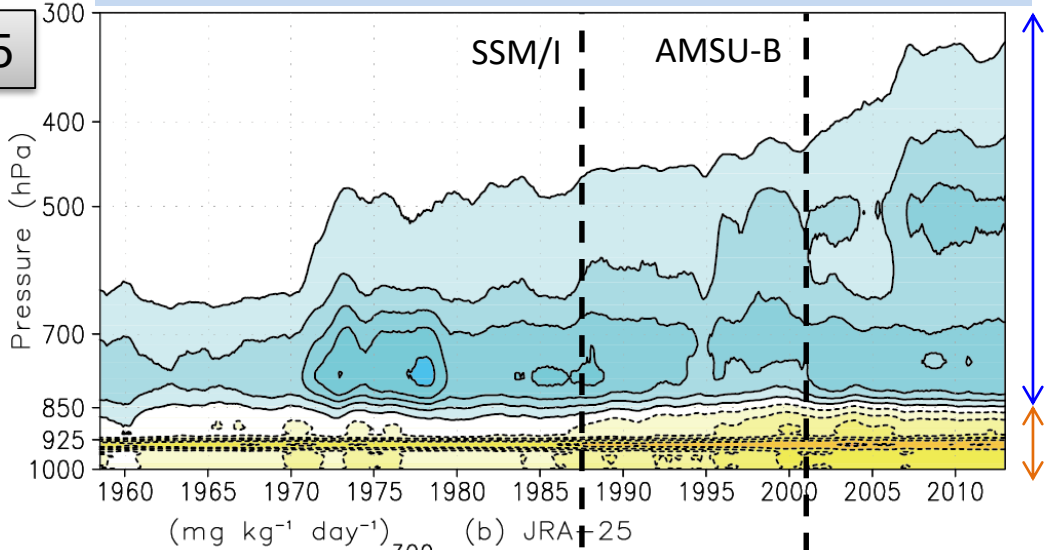
Unit: 1/day [Monthly mean counts]

Basic performance (1): Analysis increments

Temporal consistency of analysis is improved compared to JRA-25.
JRA-55 has moistening increments above 850hPa and drying increments below it.

*Time-height sections of global mean specific humidity increments**

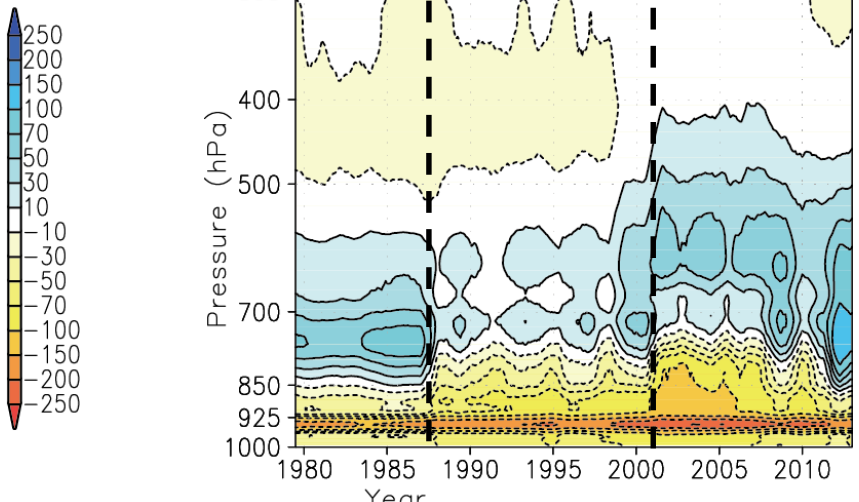
JRA-55



Moistening increments (dry bias)

Drying increments (moist bias)

JRA-25



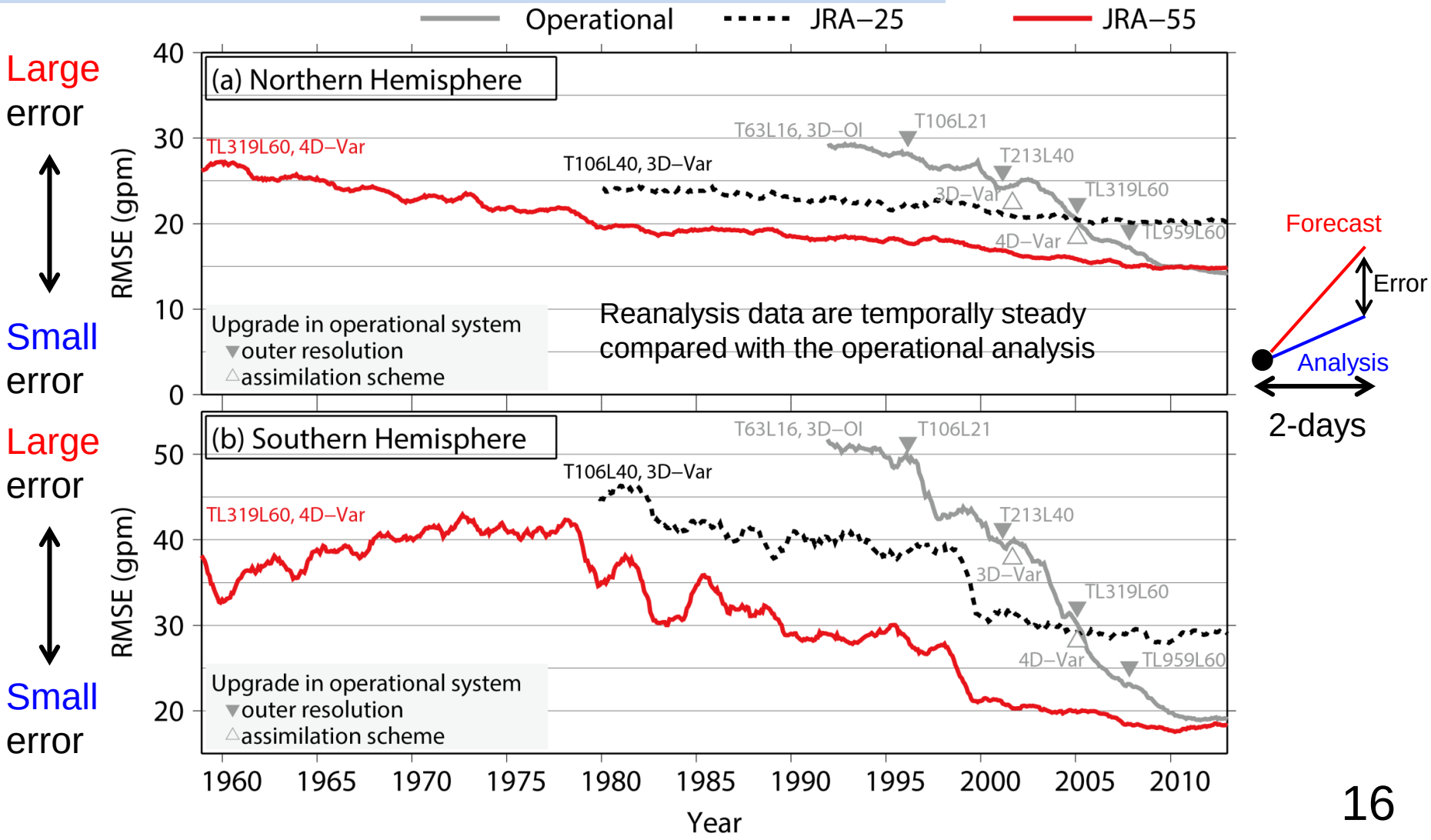
*Increment
= Analysis – First guess

Basic performance (2): forecast scores

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

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

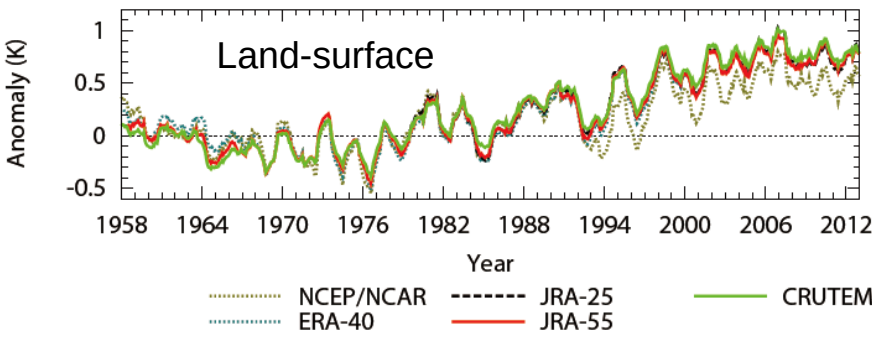
*Average over the extratropics



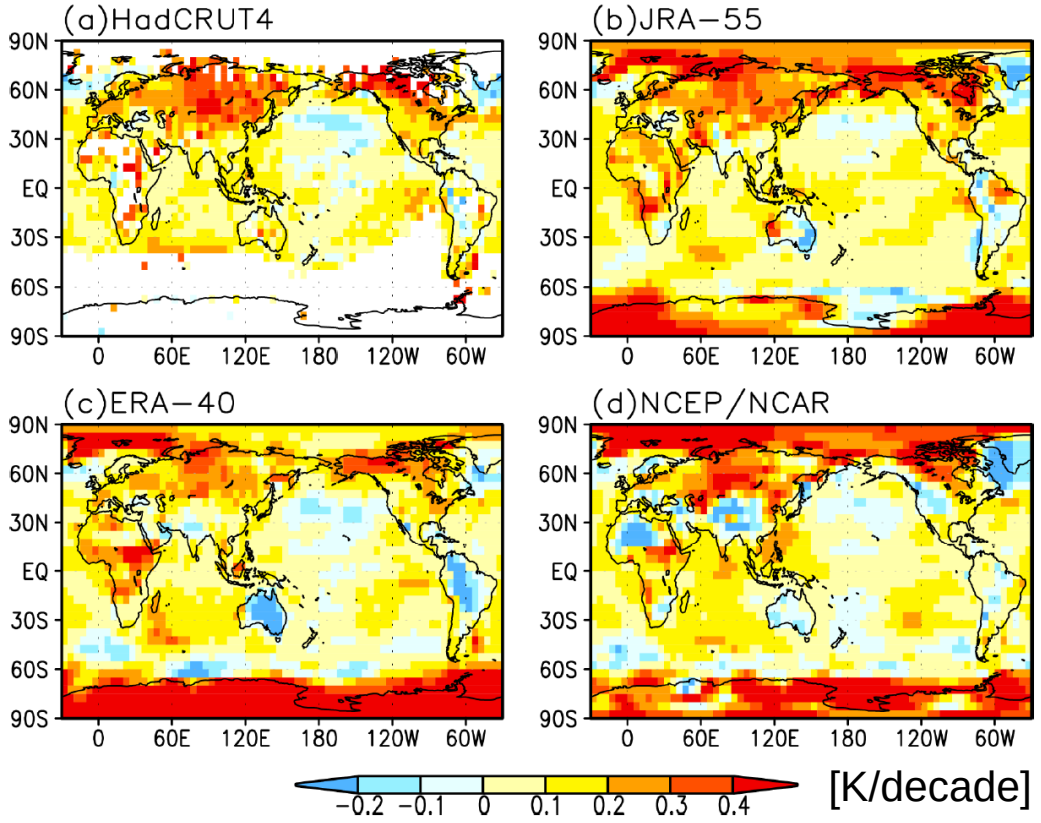
Basic characteristics (1): Surface temperature

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

12-month running mean temperature anomalies averaged over the globe



Surface air temperature trends from 1958 to 2001

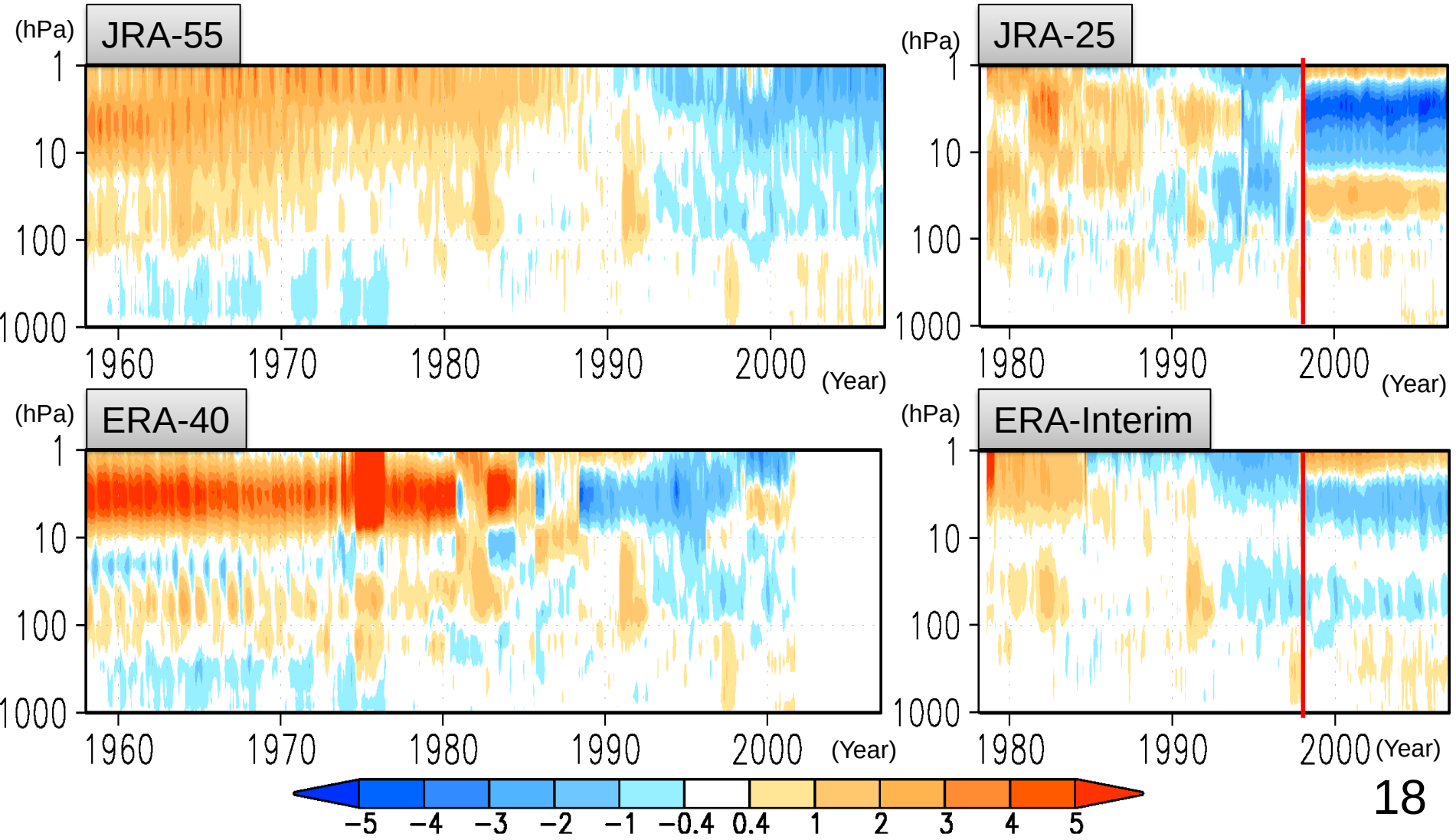


Reanalysis data were re-gridded to 5x5 resolution

Basic characteristics (2): Stratospheric temperature

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

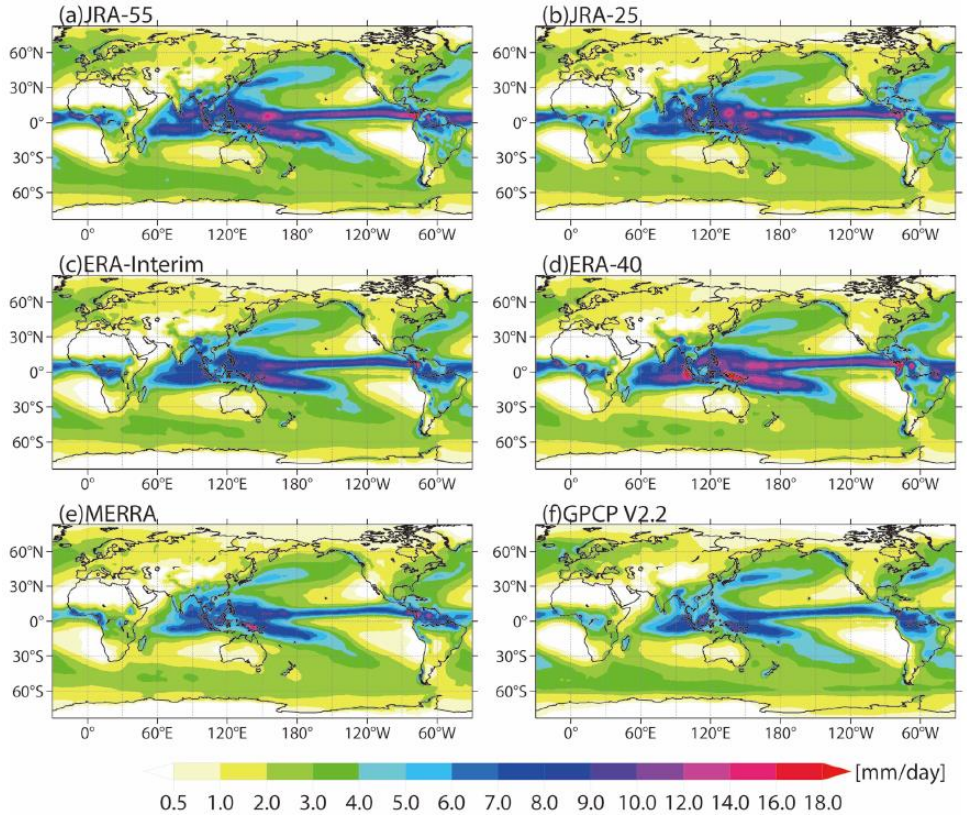
Time-height sections of global mean temperature anomalies (1980-2001 mean)



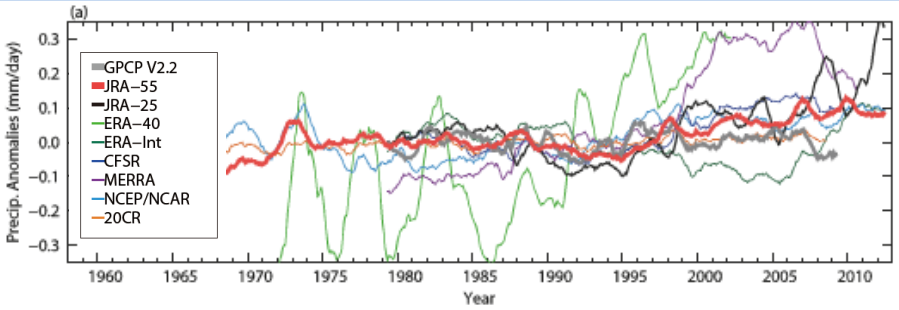
Basic characteristics (3): Precipitation

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

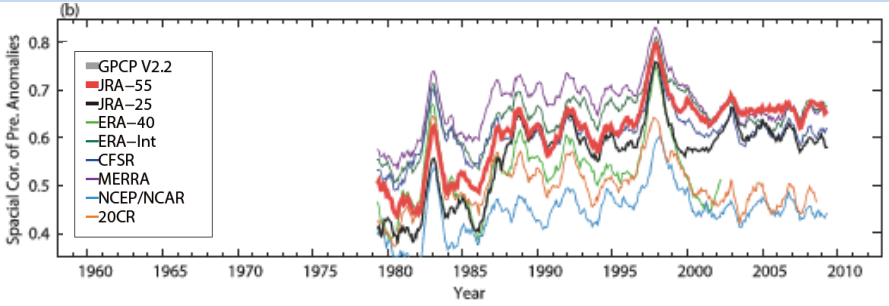
Annual mean precipitation averaged over 1980-2001



Global monthly mean precipitation anomalies from reanalyses and GPCP



Spatial correlation of monthly precipitation anomaly against GPCP



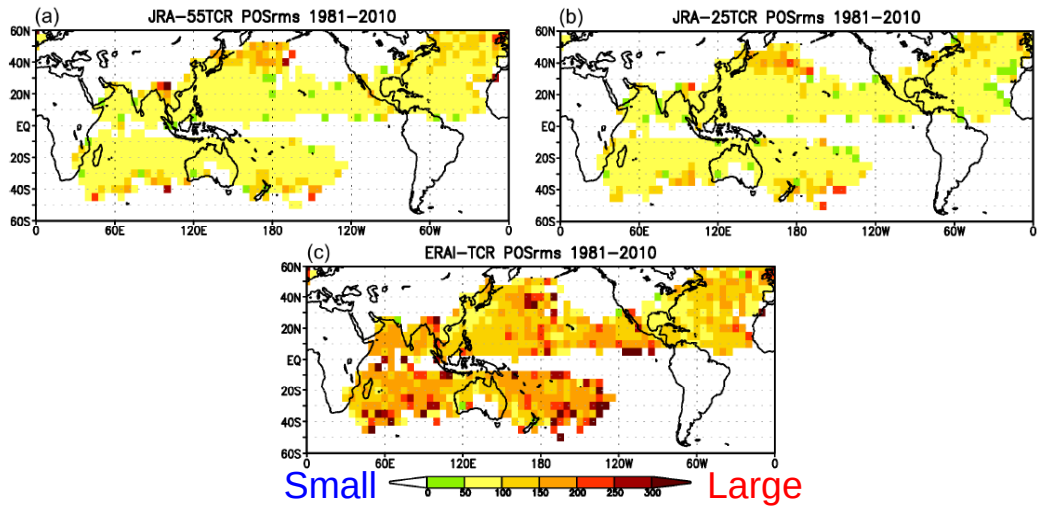
Year

Region: Global
12-month running mean

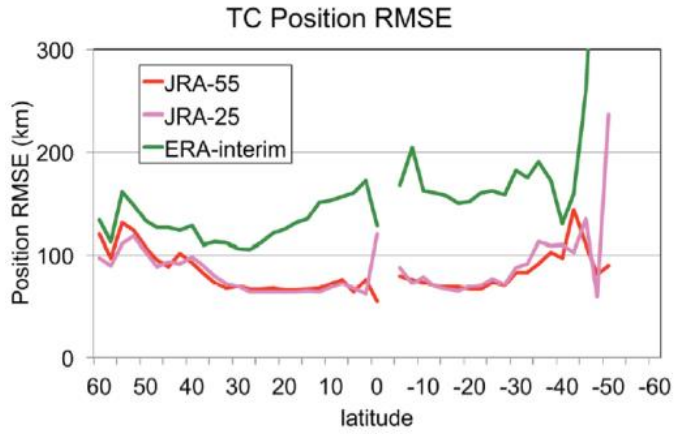
Basic characteristics (4): Tropical cyclones

Position of TCs is well represented in JRA-55.
However, detection rates of TCs show artificial decreasing trends in JRA-55.

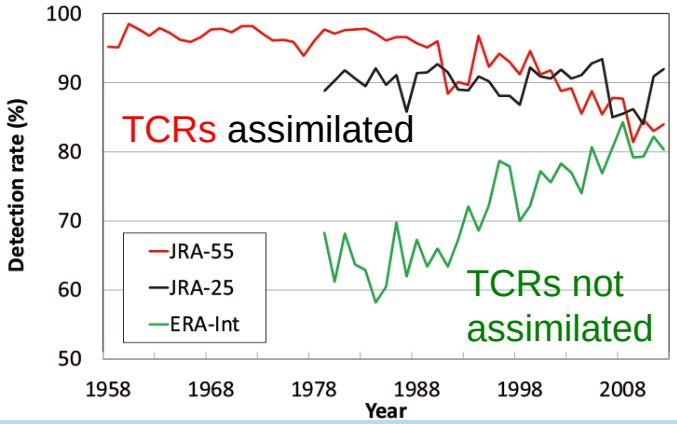
Distribution of RMSE of TC position with respect to the best track



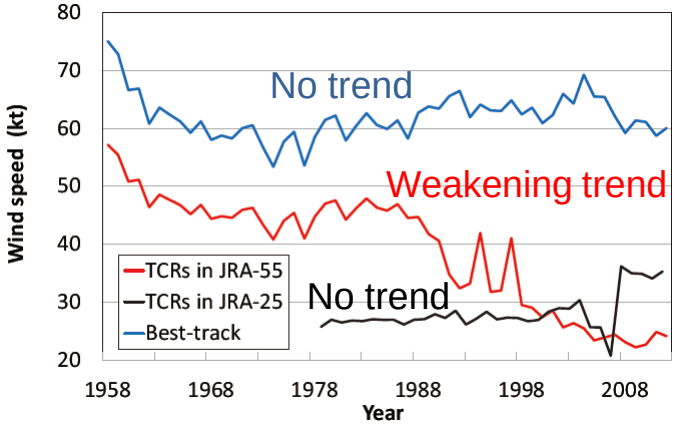
Zonal mean of the RMSE of TC position



Global detection rates of tropical cyclones



Global mean wind speed of the TCRs assimilated in JRA-25 and JRA-55



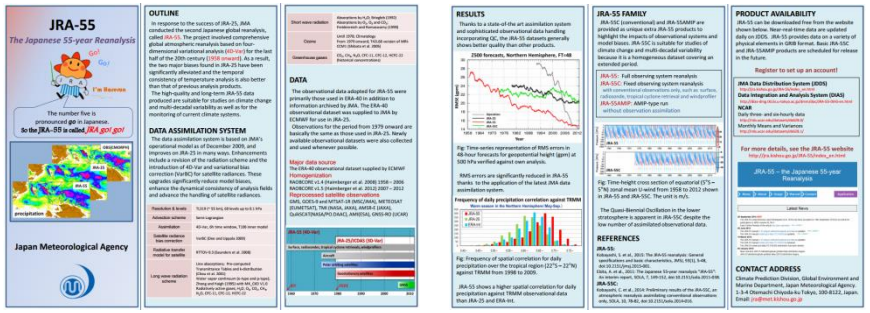
JRA-55 homepage and user application

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

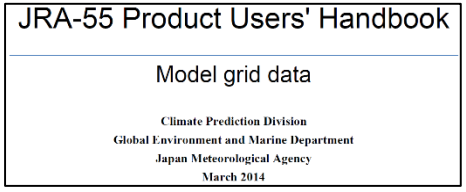
http://jra.kishou.go.jp/JRA-55/index_en.html

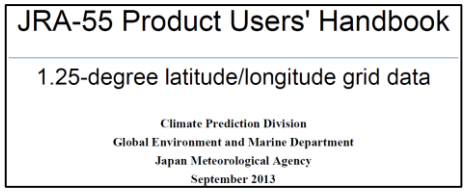
*JMA Data Dissemination System

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



Manual — *Guides on JRA-55 products*





JRA-55 dataset is 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

Improvements and problems of JRA-55

- **JRA-55 has significantly improved from JRA-25**
  - Reduction of cold bias in the stratosphere
  - Reduction of the dry bias in the Amazon basin
  - Increase of spatial temporal consistency

- **Problems to be addressed (➔The next reanalysis)**
  - Dry bias in the upper and middle 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**
  - Extending the reanalysis period back in time
    - Atmospheric reanalysis from 1947 to present
  - Higher resolution: T_L319L60 -> T_L479L100
    - 40 km in horizontal, 100 layers up to 0.01 hPa in vertical
  - Incorporating many improvements from the operational NWP system
    - Overall upgrade of physical processes
    - New types of observation (ground-based GNSS, hyperspectral sounders)
  - Improved boundary conditions and forcing fields
    - COBE-SST2 (1 deg., until to the mid 1980s)
    - MGDSST (0.25 deg. from the mid 1980s onward)
  - Improved observations
    - Observations newly rescued and digitized by ERA-CLIM et al.
    - Improved satellite observations through reprocessing
    - JMA’s own tropical cyclone bogus

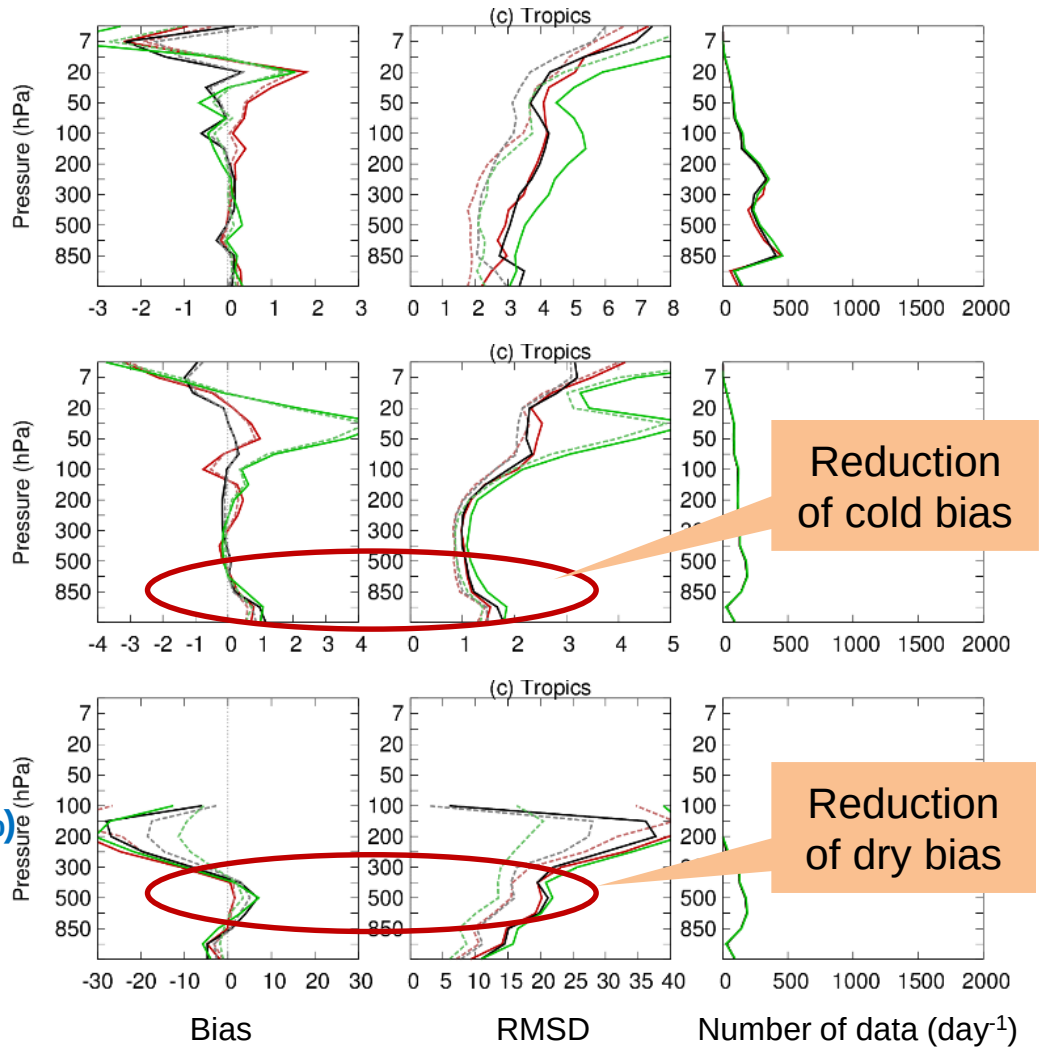
Statistics of radiosonde (Nov 1990 to Oct 1991)

Consistency between JRA-3Q reanalysis and radiosonde improved from JRA-55 in tropics.

Zonal wind (m/s)

Temperature (K)

Relative humidity (%)



Reduction of cold bias

Reduction of dry bias

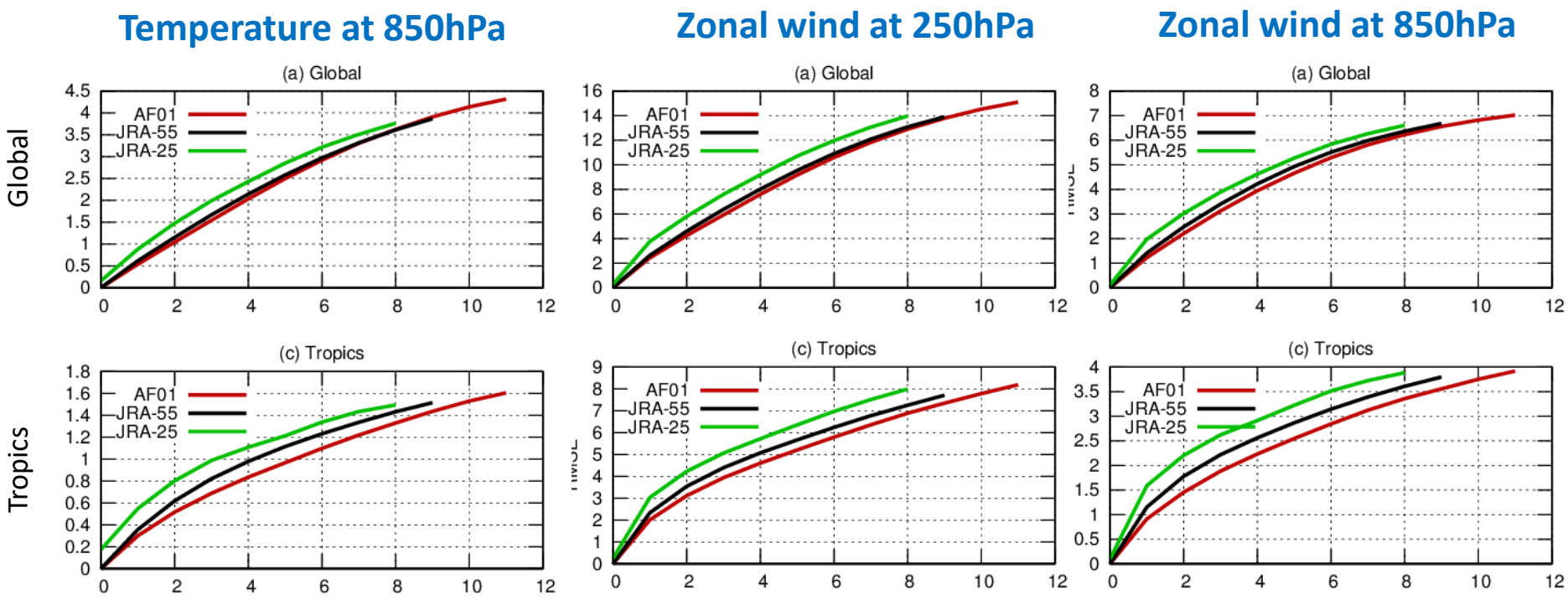
JRA-3Q
Observation－First guess
Observation－Analysis

JRA-55
Observation－First guess
Observation－Analysis

JRA-25
Observation－First guess
Observation－Analysis

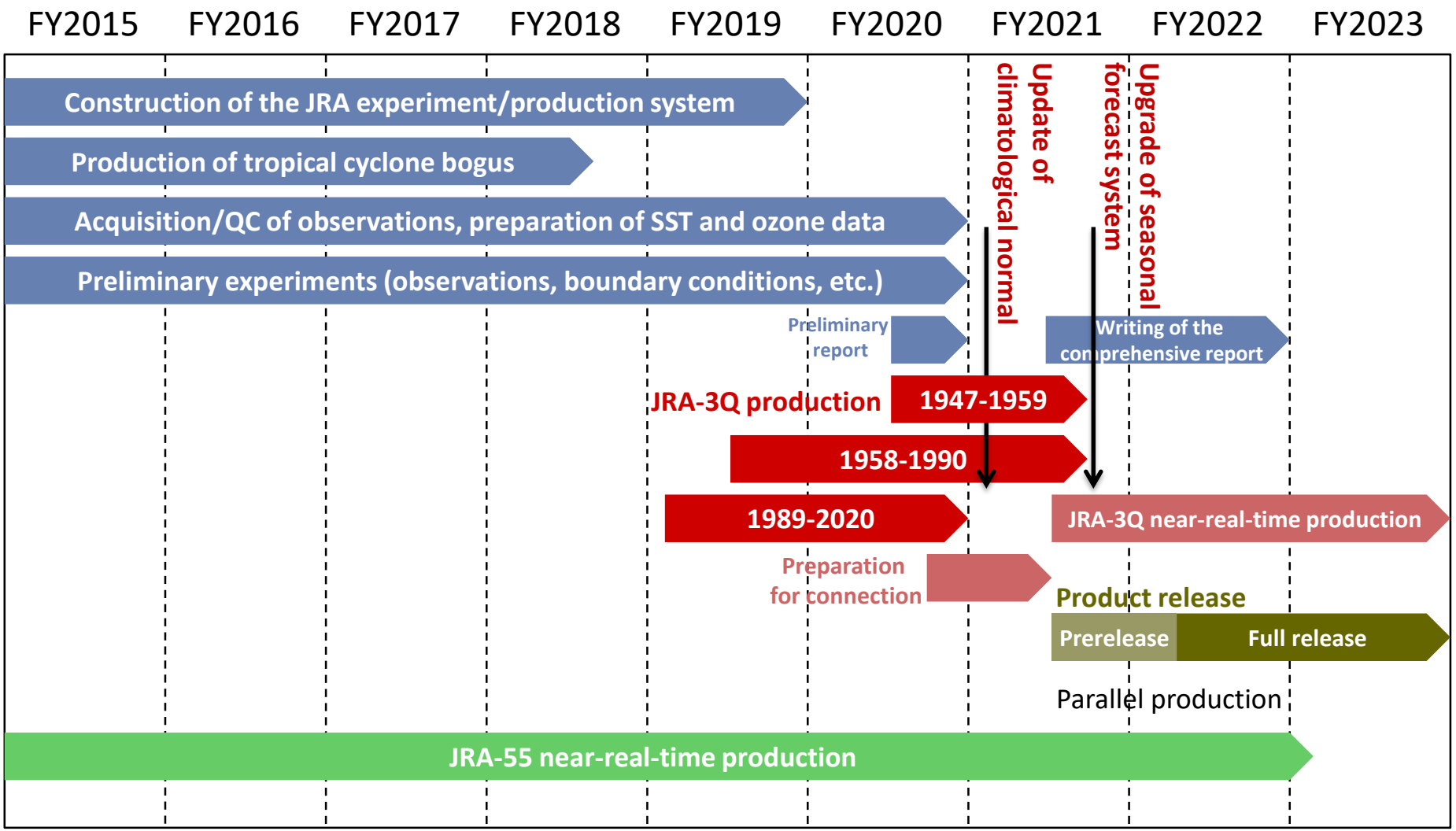
Forecast scores (Nov 1990 to Oct 1991)

The forecast scores of the JRA-3Q system are better than those of the JRA-55 especially in tropics.



JRA-3Q JRA-55 JRA-25

Production schedule (as of Nov 2019)



The Japanese financial year (FY) runs from 1 April to 31 March.

Summary

- 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
  - Production of a high-quality, spatially and temporally consistent dataset is vital for operational 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
  - Registered users can download JRA-55 products from the JDDS

- JRA-3Q: the next reanalysis by JMA
  - Started producing higher quality and more consistent dataset for climate monitoring


Thank you...
3(san) Q
...for
your
attention!