Introduction to Reanalysis and JRA-55

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Outline

1. **Introduction to Reanalysis**
   - Basic dataset for climate services
   - Operational analysis
   - 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**

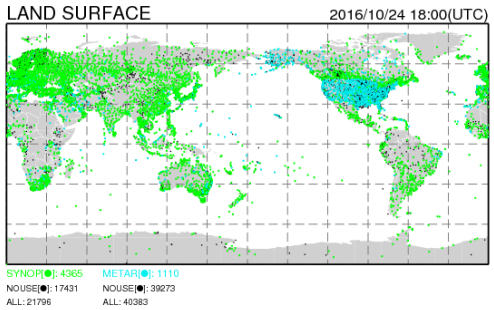
1. Introduction to reanalysis

- **For operational climate monitoring, we need dataset of…**
  1. covering the globe for several decades
  2. including as many meteorological variables as possible
  3. spatially and temporally consistent and highly qualified

- **In general, observation-alone is not enough to satisfy such conditions because the regions and variables are limited.**

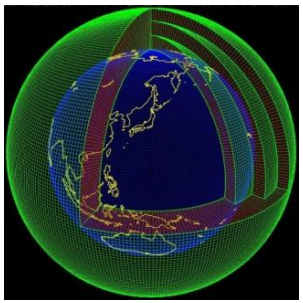
- **However, dynamically and physically consistent GPVs with various variables could be produced by incorporating observation data into the state of numerical weather prediction (NWP) model.**
  - This process, “Data Assimilation (DA)”, is a part of operational analysis cycle to estimate initial conditions for weather forecast.
  - Can dataset produced by long-term DA cycle satisfy the third condition??

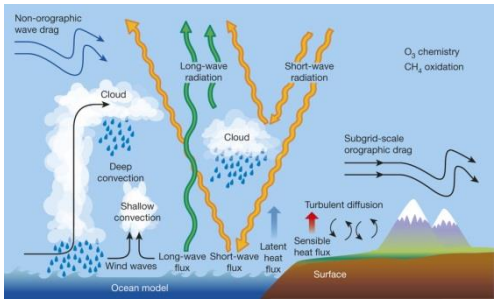
Observation (example)



Data Assimilation

Grid point and physical processes of NWP model



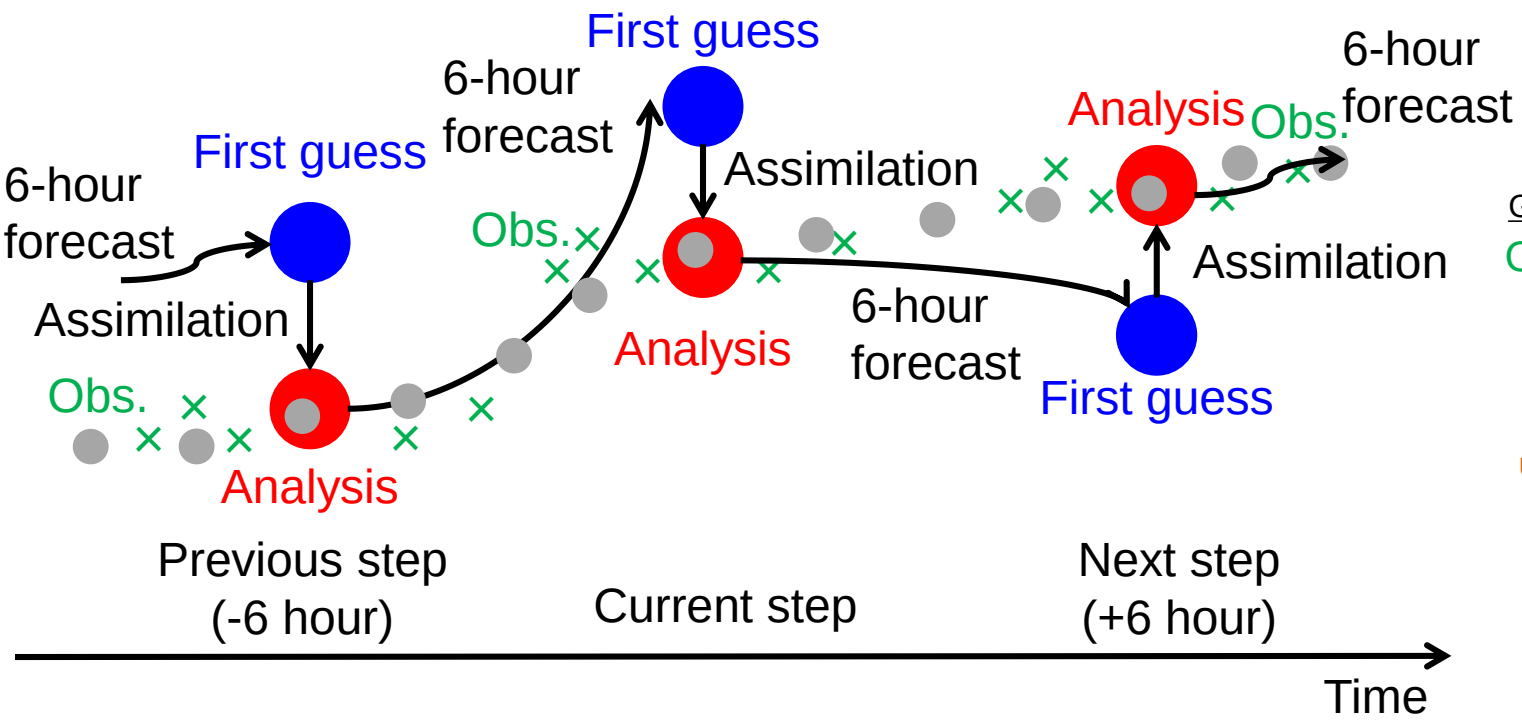


Bauer et al. (2015)

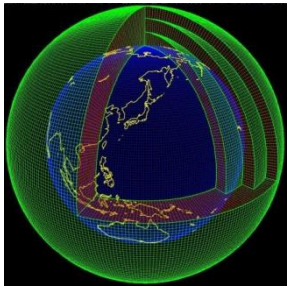
Operational analysis cycle

Schematic diagram of the operational analysis cycle

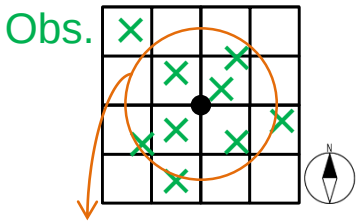
● Actual state of the atmosphere (unknown, but we want to know)



Forecast model



Grid points of the model



Supercomputer

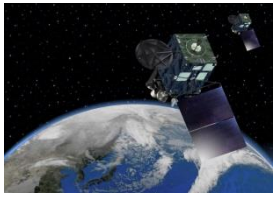
Observations (example)

Surface

Radiosonde

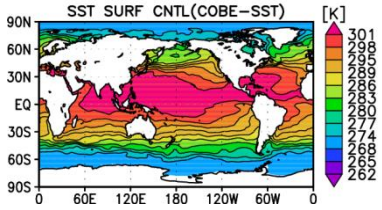
Ship

Satellite

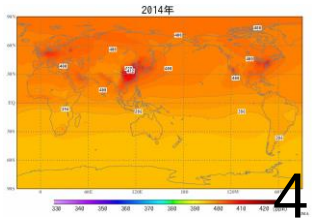


Boundary conditions (example)

SST

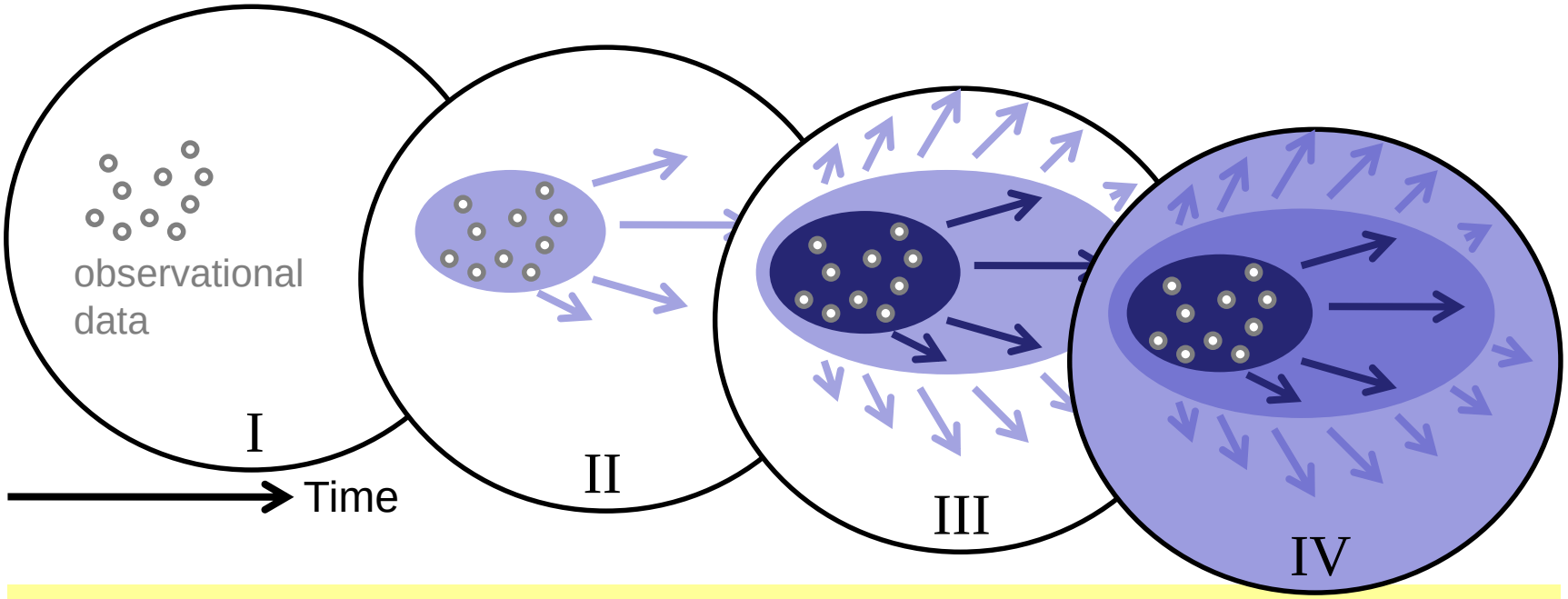


GHG (CO2)



Impacts of data assimilation

Schematic diagram of impacts of data assimilation



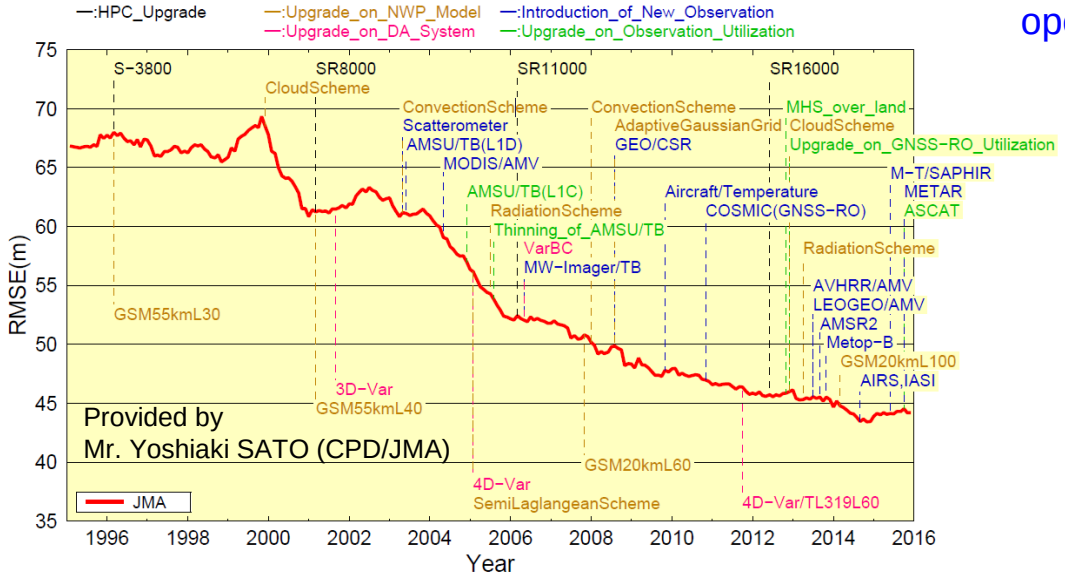
I. Un-uniformly distributed observations
II. The hatched area surrounding observations are analyzed with high quality. The high quality area extends thorough forecast.
III. In the next data assimilation, the deep colored area surrounding observations are analyzed with much higher accuracy. The higher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

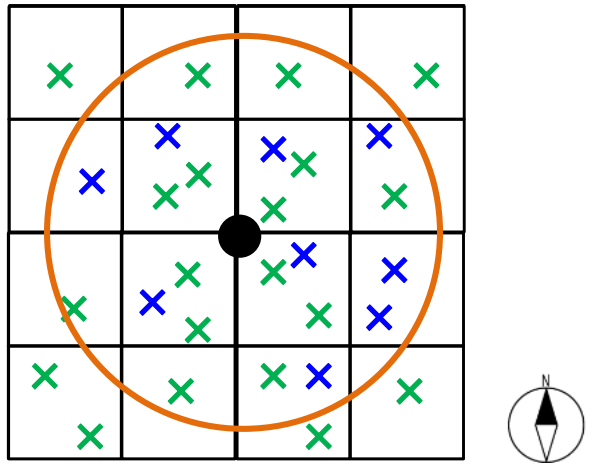
Comparison of the operational analysis and reanalysis

	Operational analysis	"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)



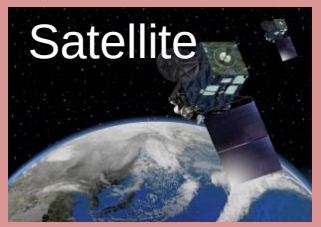
Obs. available at the time of operational analysis
Obs. which become available after the time of operational analysis (belated data)



Used for the analysis at ●

Summary of section 1 (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"

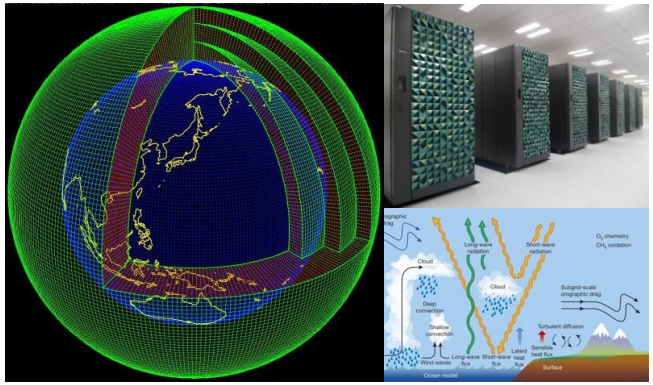


Observation
(incl. belated data)

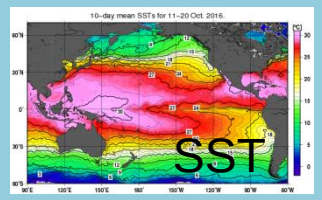
"Constant" and "state-of-the-art" NWP model

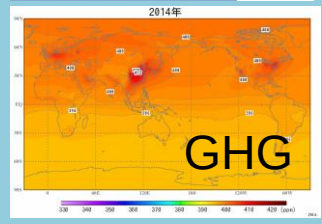
Data Assimilation

Quality Check



Input

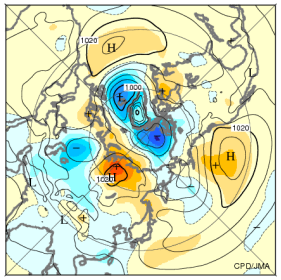




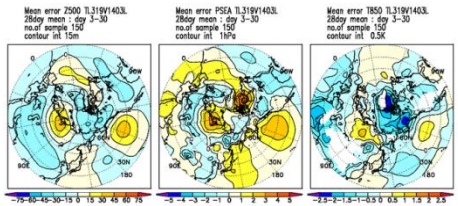
Boundary conditions (prescribed)

Integration for several decades

Consistent quality reanalysis product (GPV)



Climate Monitoring



Initial conditions for Hindcast (Re-forecast)

Climate Research

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

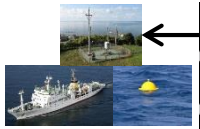
JRA-55 reanalysis system was extensively improved since JRA-25

	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)

Observational data for JRA-55 (1)

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

(image)



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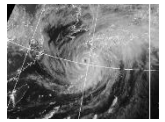
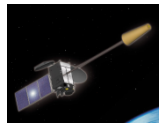
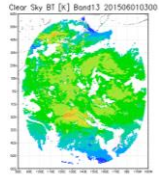
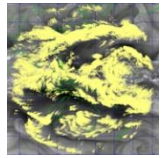
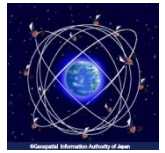










SYNOP, SHIP and BUOY

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

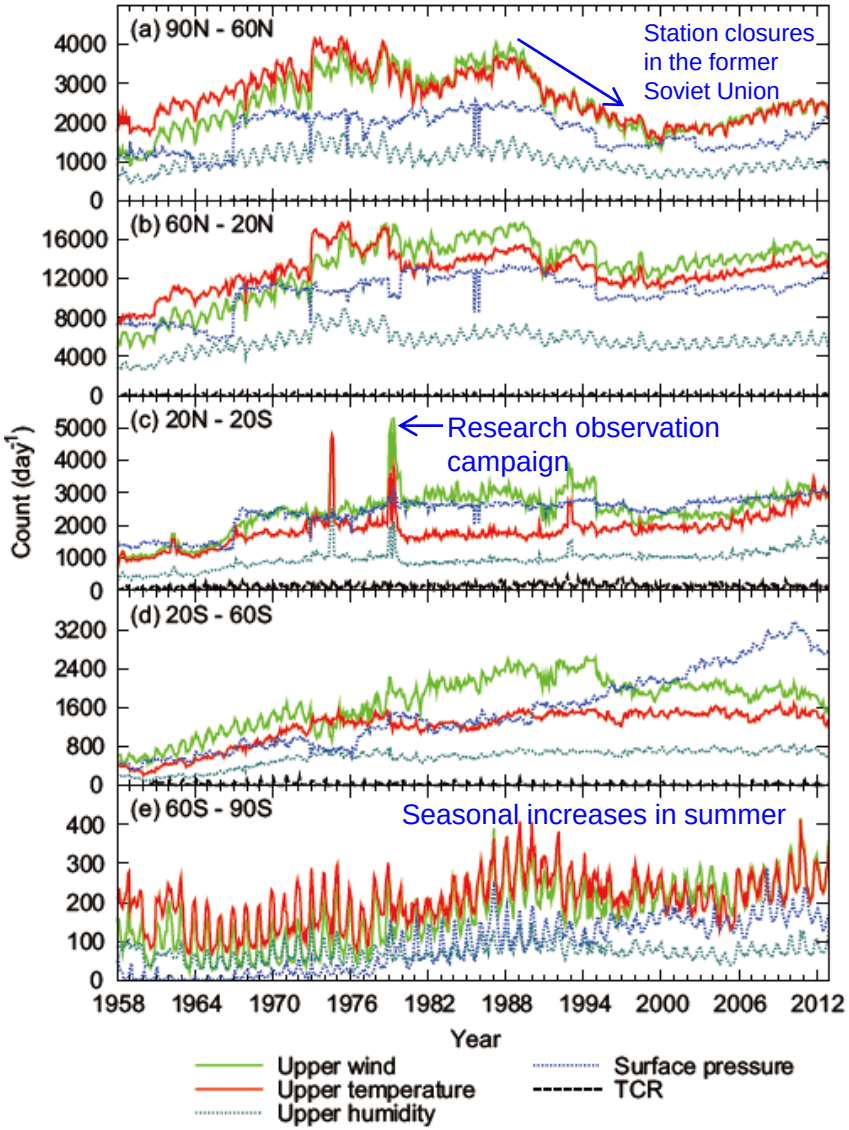
AMV: Atmospheric Motion Vectors

GNSS: Global Navigation Satellite System

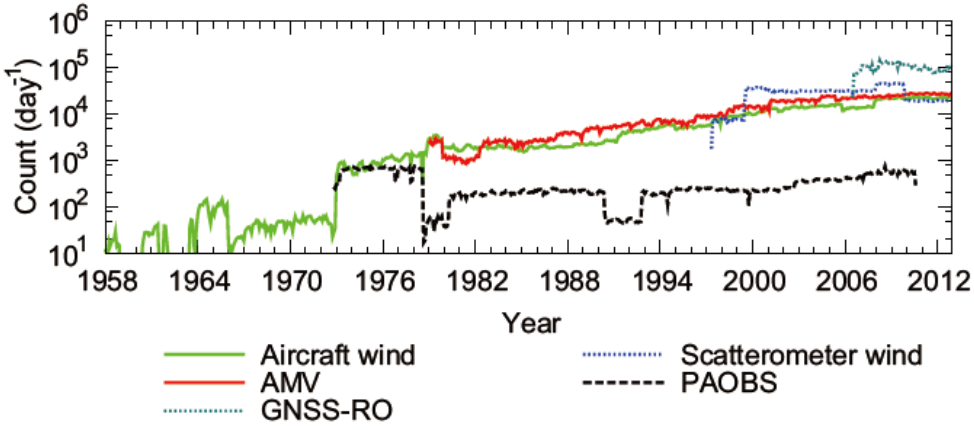
Observation data for JRA-55 (2)

Number of observations assimilated in JRA55 is continuously increasing

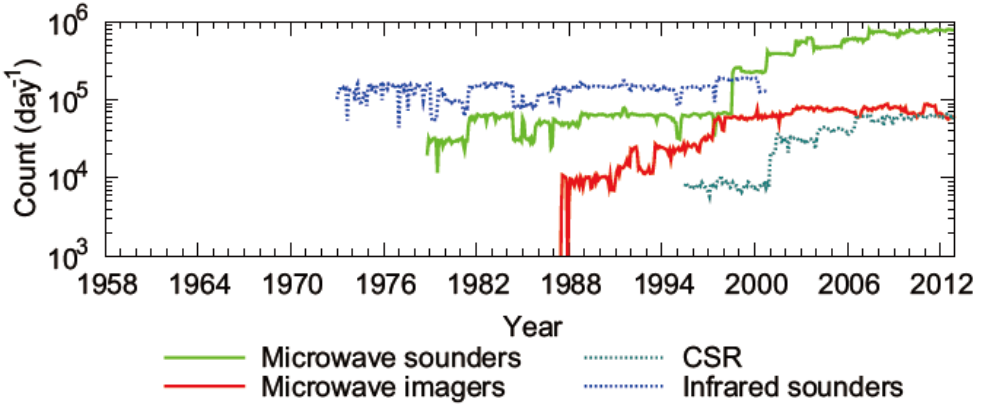
Conventional observation and TCRs



Aircraft an satellite winds, PABOS, and GNSS-RO



Various types of satellite radiances



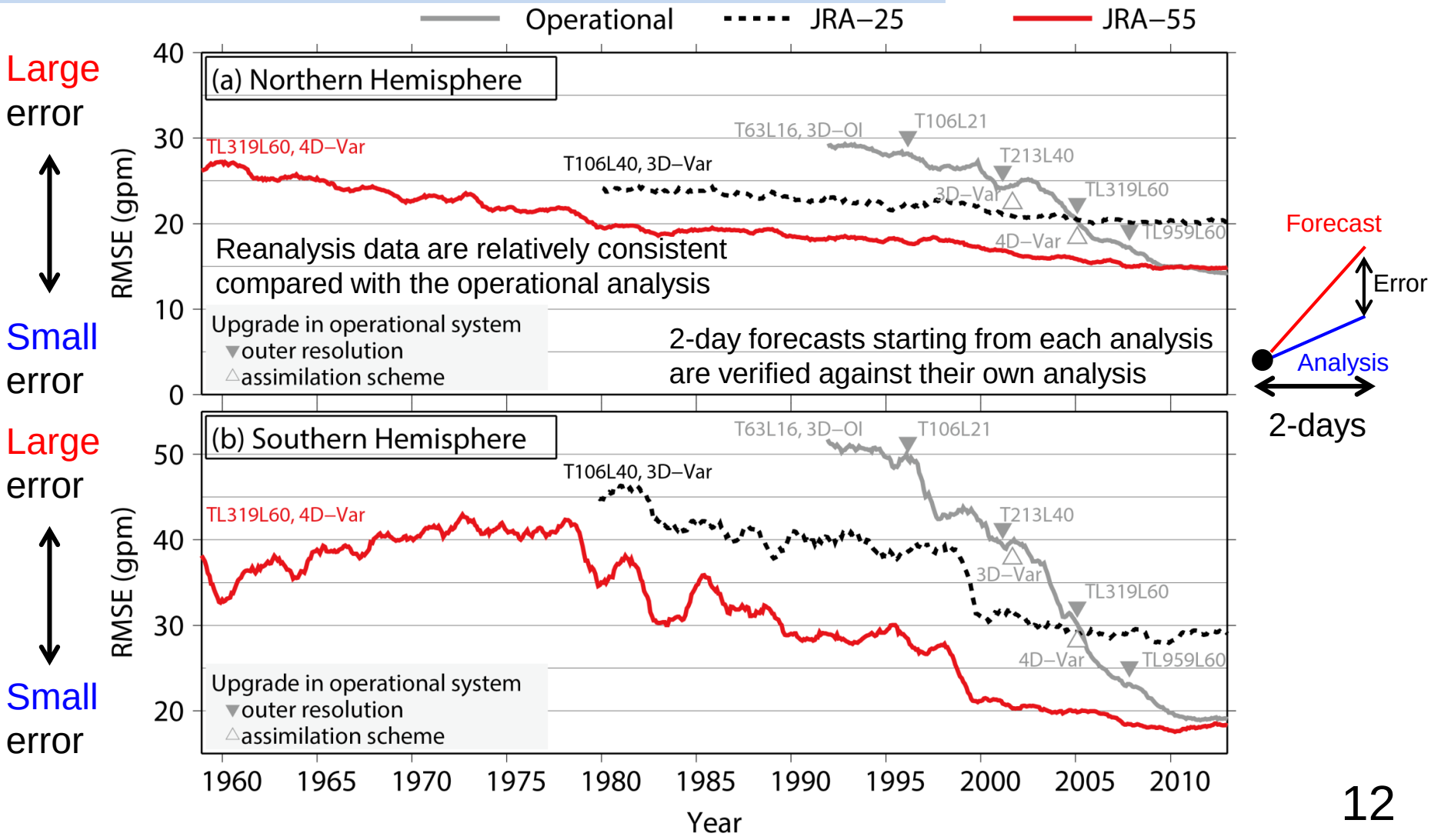
Unit: 1/day [Monthly mean counts]

Basic performance (1): forecast scores

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

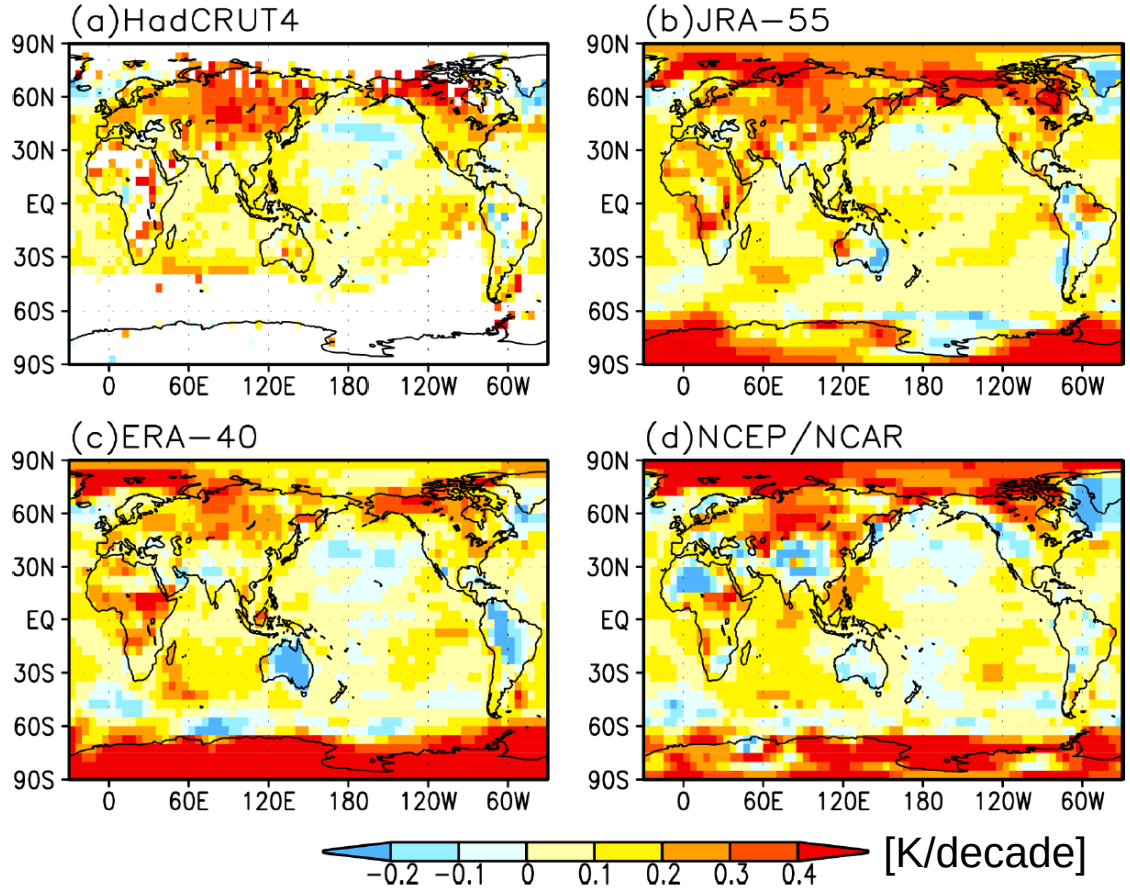
*Average over the extratropics



Basic performance (2): Tropospheric temperature

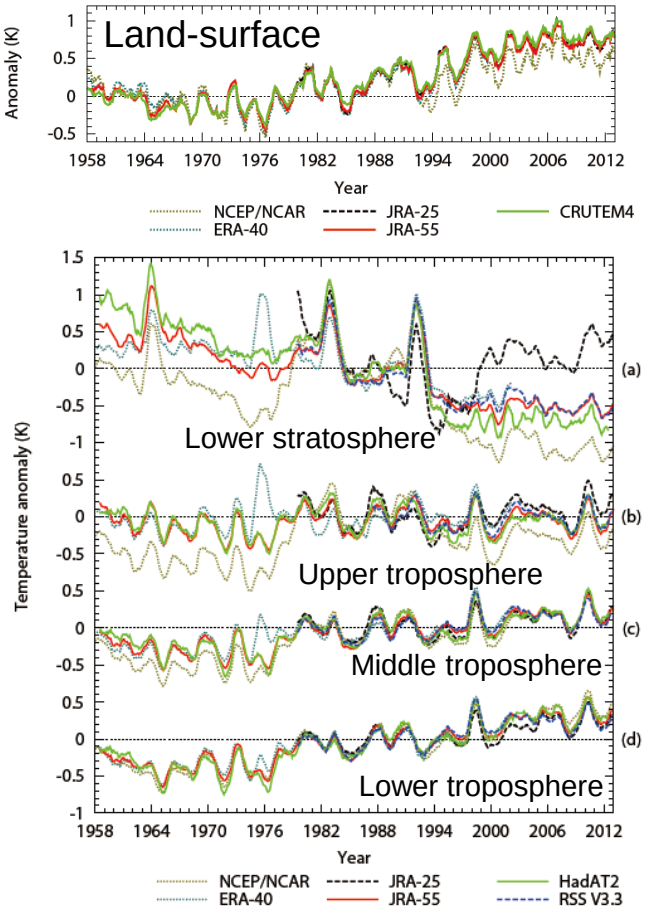
Long-term trends and variation of temperature in the land-surface and troposphere are well reproduced by JRA-55 reanalysis

Surface air temperature trends from 1958 to 2001



Reanalysis data were re-gridded to 5x5 resolution

Monthly temperature anomalies averaged over the globe

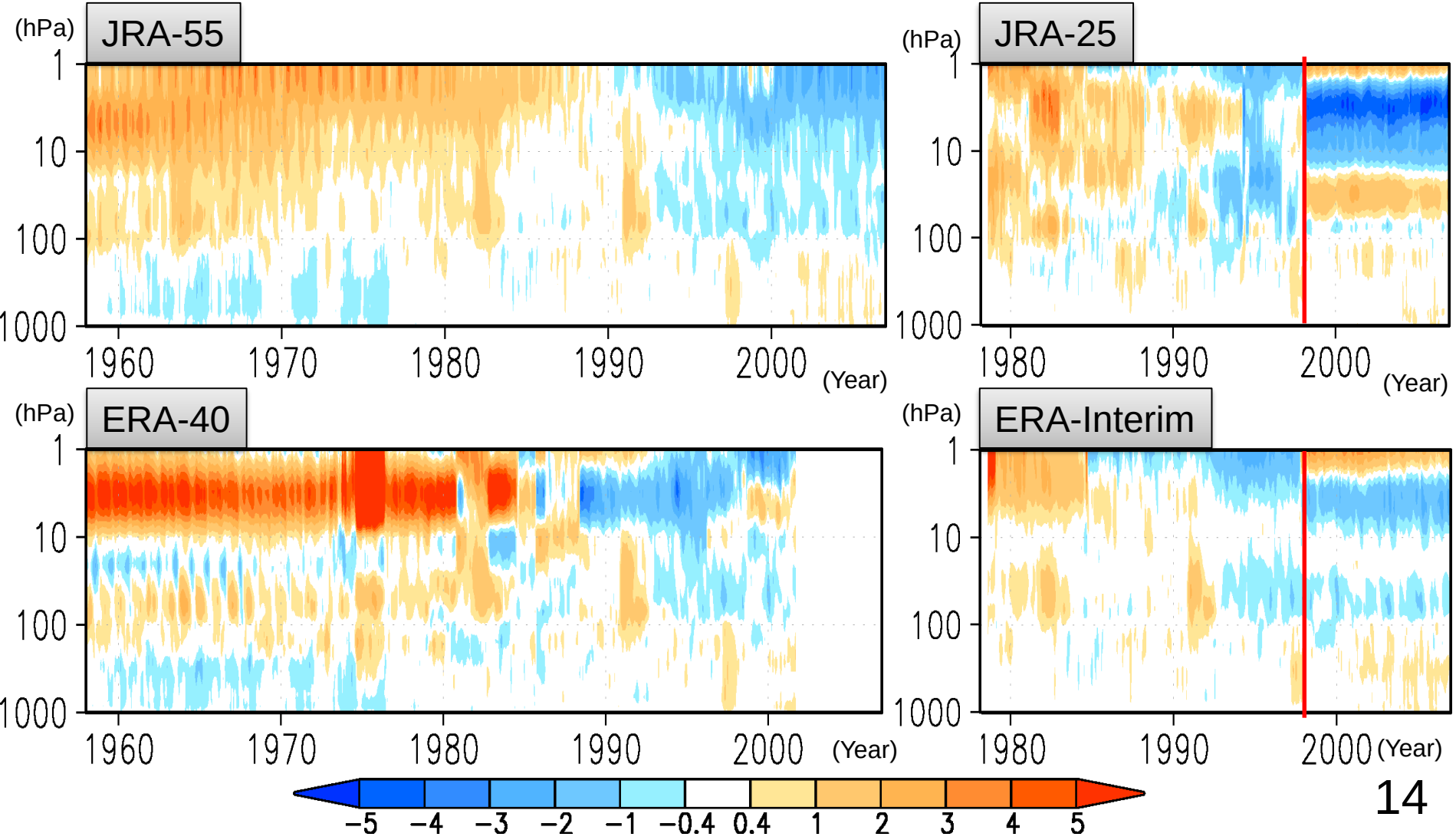


12-month running mean

Basic performance (3): 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

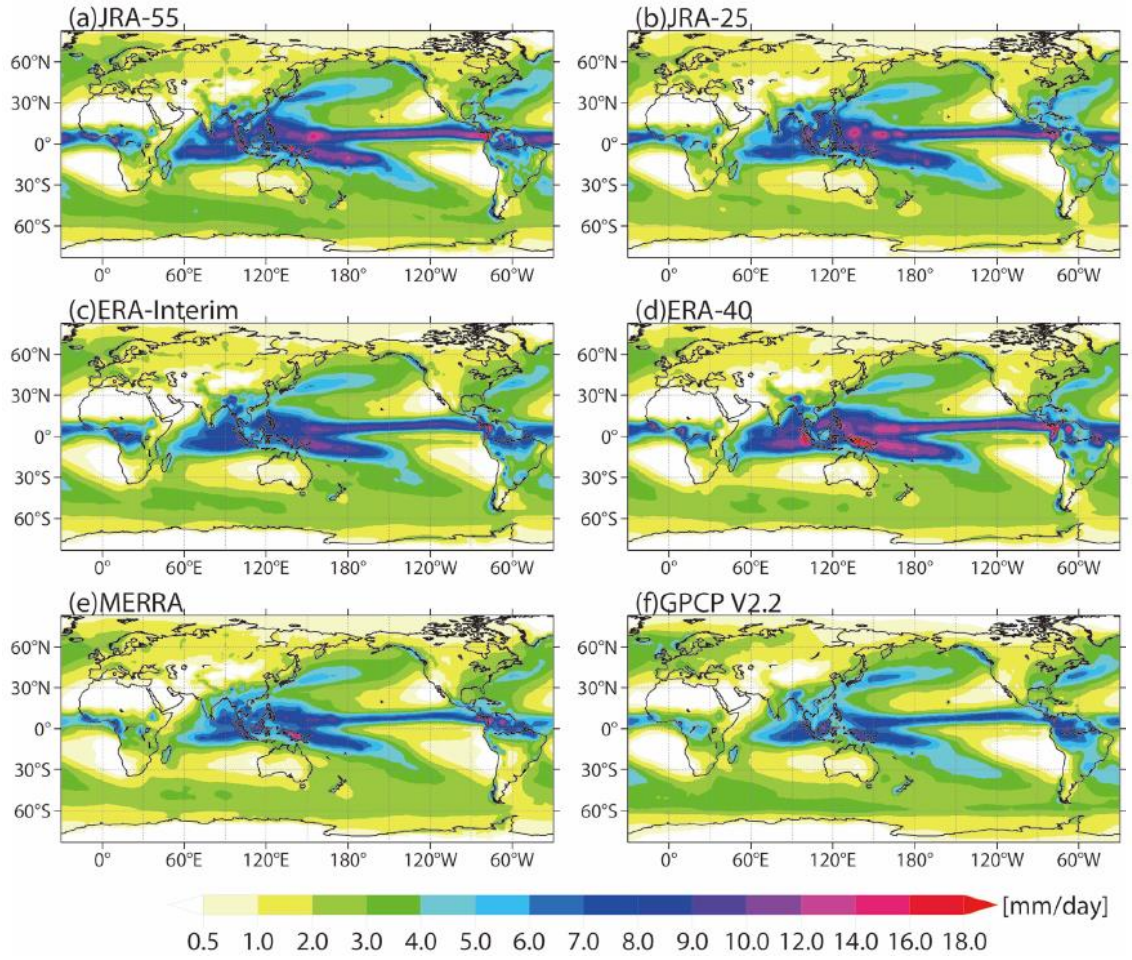
Time-height sections of global mean temperature anomalies (1980-2001 mean)



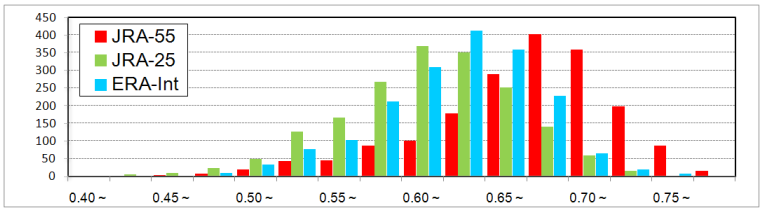
Basic performance (4): Precipitation

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



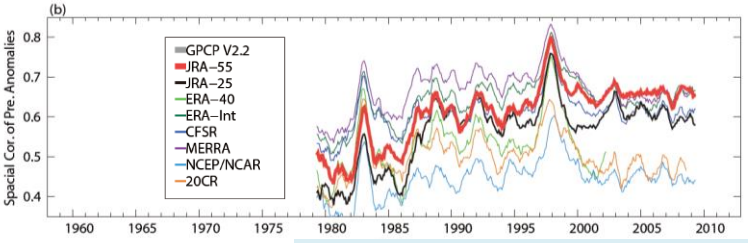
Frequency of spatial correlation of daily precipitation against TRMM



Small Correlation Large

Region: 22S-22N
Period: 1998-2009, May-Sep.

Spatial correlation of monthly precipitation anomaly against GPCP



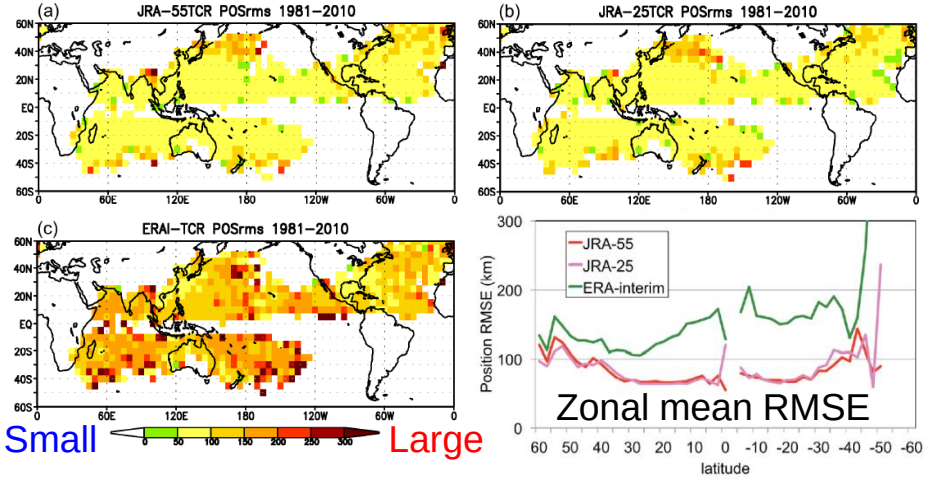
Year

Region: Global
12-month running mean

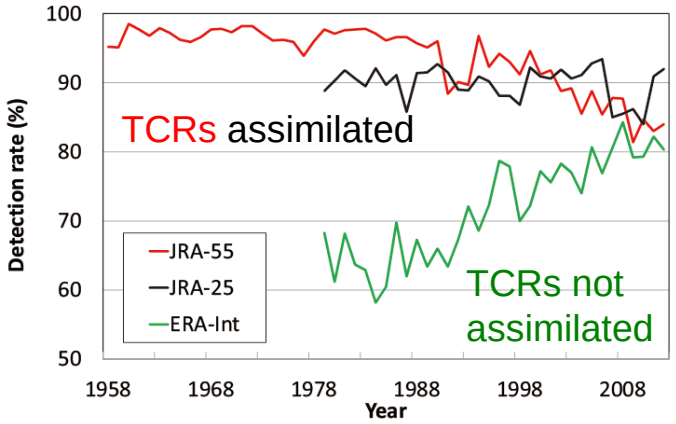
Basic performance (5): Tropical cyclones

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



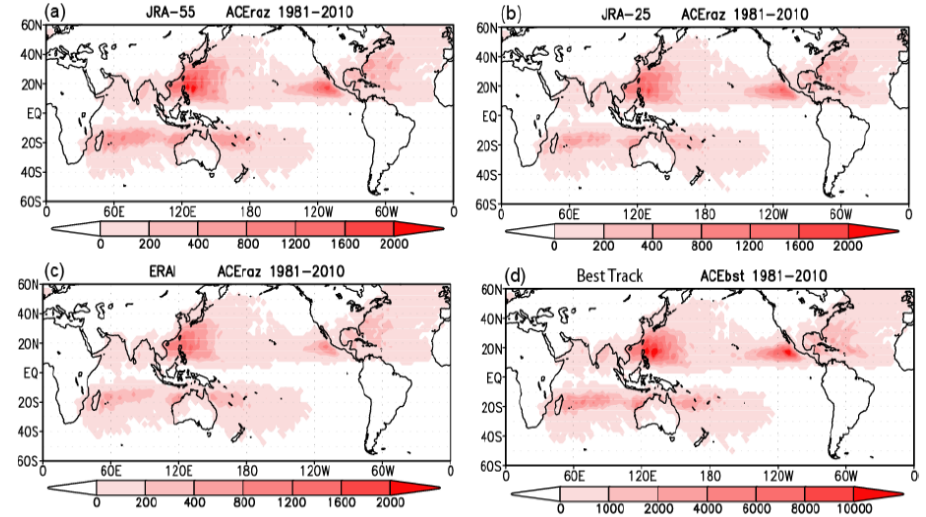
Global detection rates of tropical cyclones



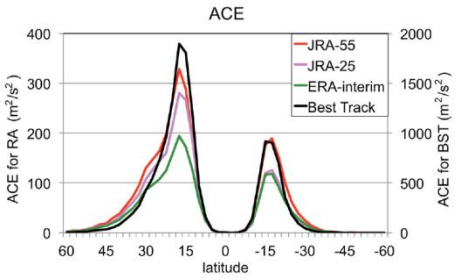
Artificial decreasing trends of JRA-55 due to TCRs bug??

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

Accumulated cyclone energy (ACE)



Zonal mean ACE



Summary of section 2 (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 significantly improved from JRA-25**
  - 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

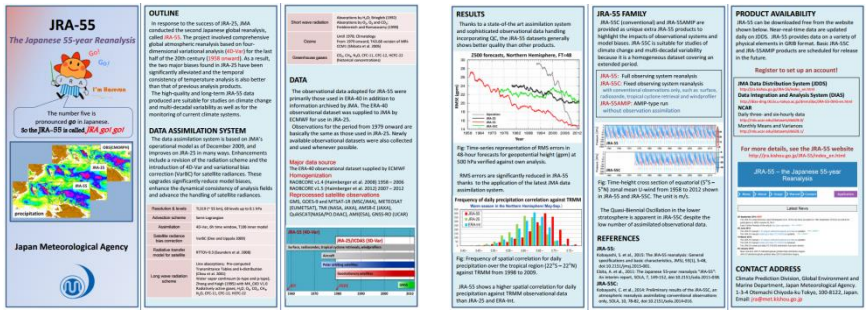
JRA-55 homepage and user application

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

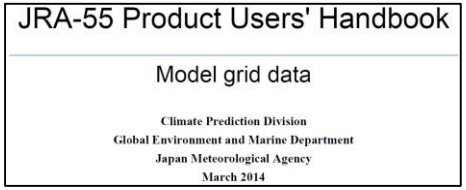
http://jra.kishou.go.jp/JRA-55/index_en.html

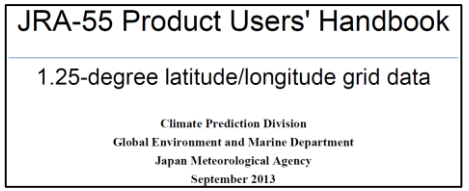
*JMA Data Dissemination System

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



Manual — *Guides on JRA-55 products*





JRA-55 and related dataset 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

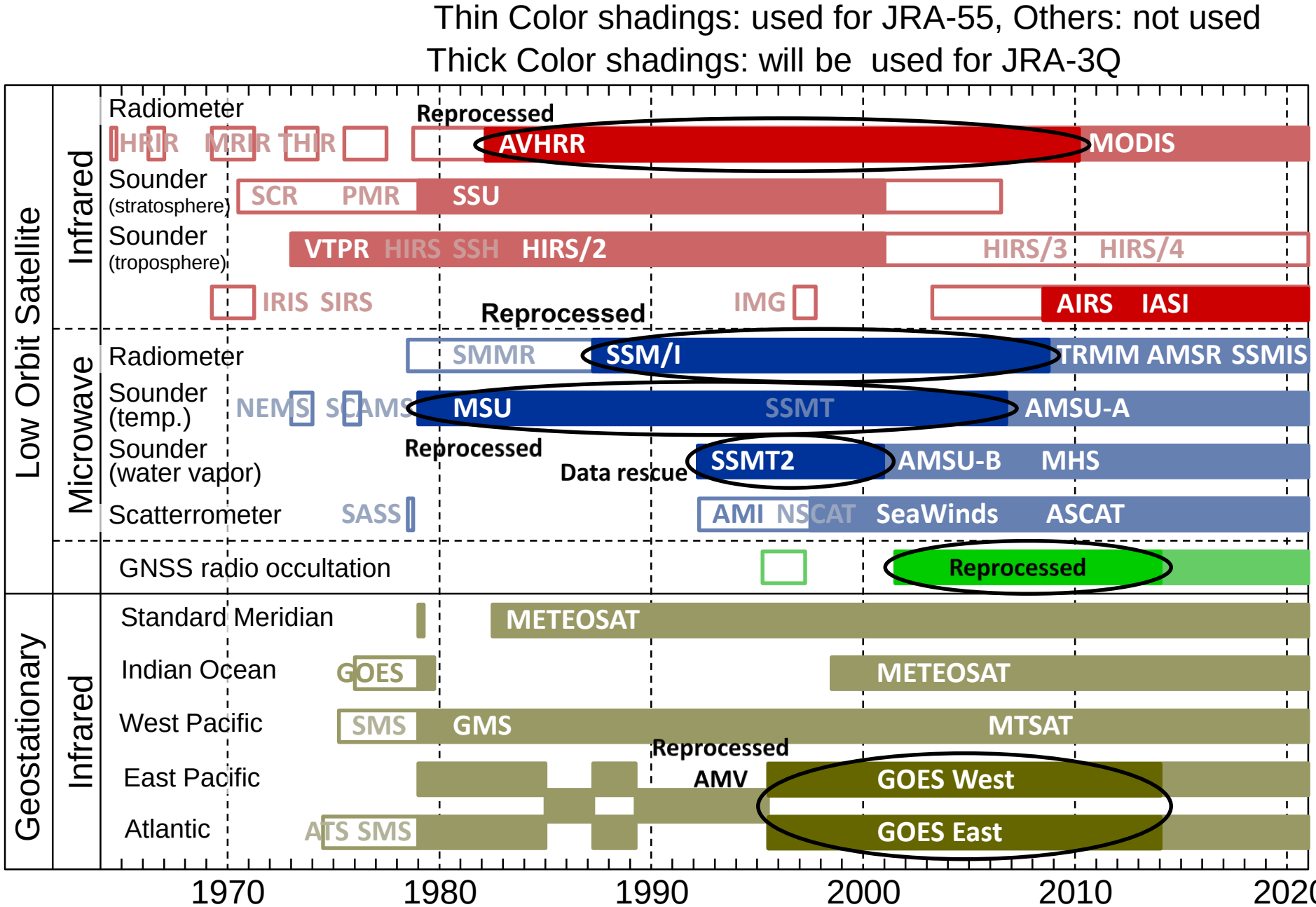
3. The next Japanese reanalysis: JRA-3Q

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

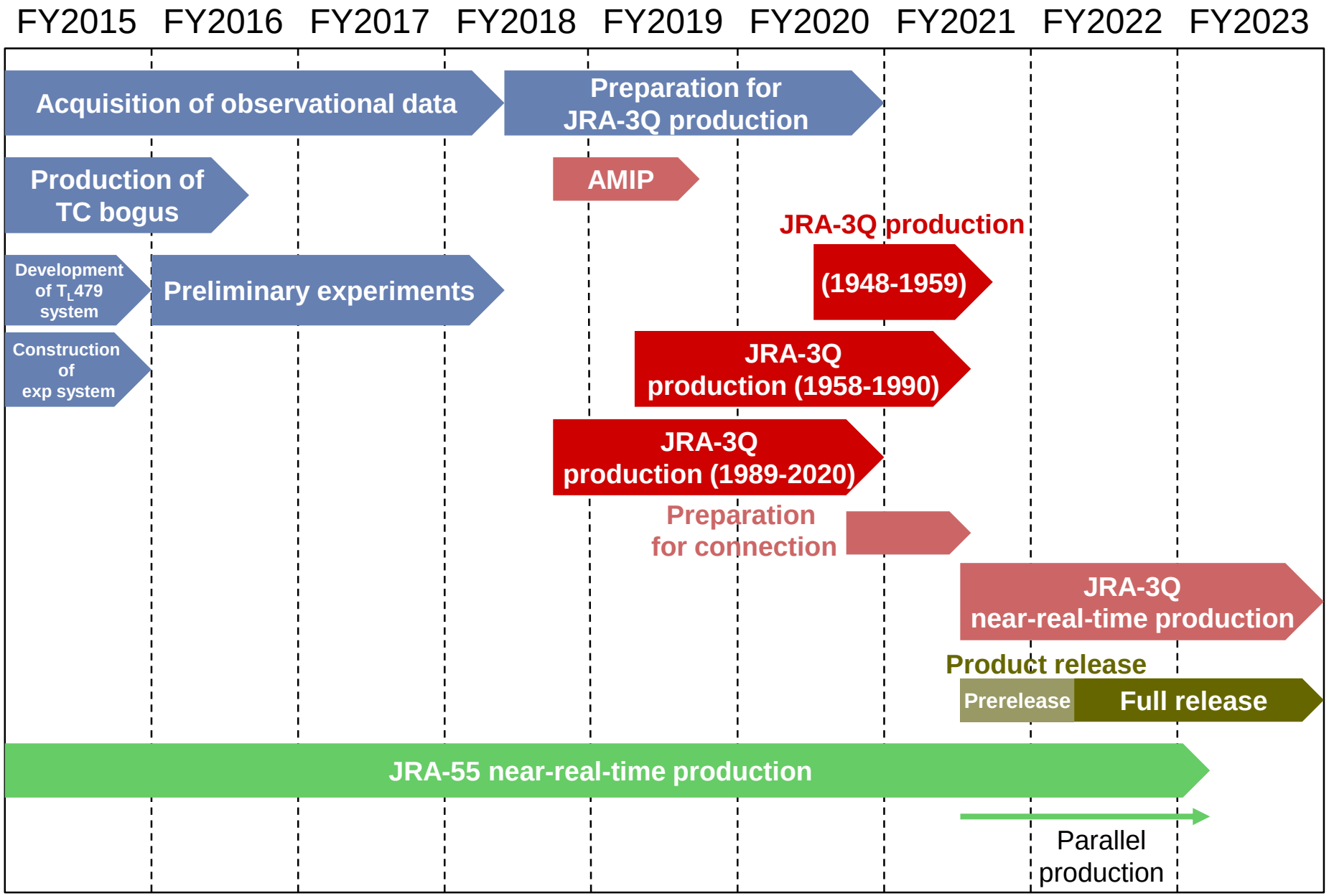
In Japanese, “3” is pronounced as “San”.
San-Q ➔ San-kyuu ➔ Thank you ☺

- **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 1947 to present
  - New boundary conditions and forcing fields
    - COBE-SST2 (1 deg., up to 1985)
    - MGDSST (0.25 deg. from 1985 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)



Schedule for JRA-3Q (plan)



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

- JMA-3Q: the next reanalysis by JMA
  - Currently in preparation to produce higher quality and more consistent dataset for climate monitoring