# AMV reprocessing activity for JRA-3Q at MSC/JMA

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1. Long term reanalysis and importance of AMV reprocessing
2. Overview of JRA-3Q (Japanese Reanalysis for Three Quarters of a Century)
3. Accuracy evaluation comparison between the reprocessed AMV for JRA-3Q and the others
4. Introduction of impact experiment results using reprocessed AMVs as input data
5. Summary

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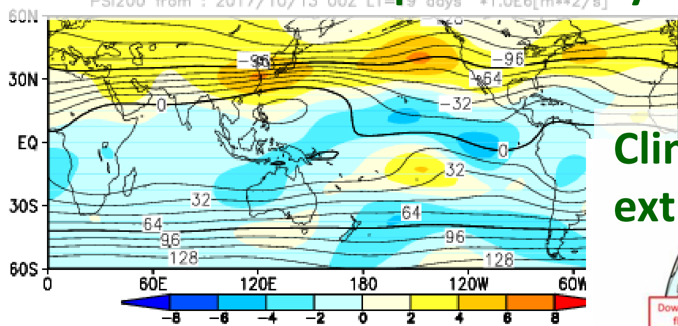
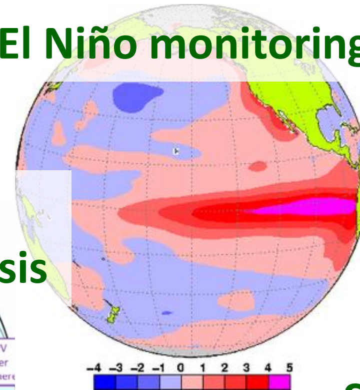
# Long-term Reanalysis

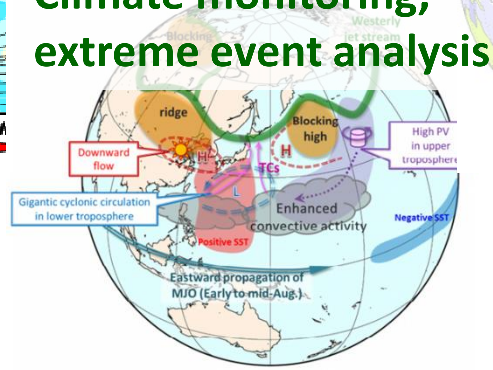
**Seasonal ensemble prediction system**



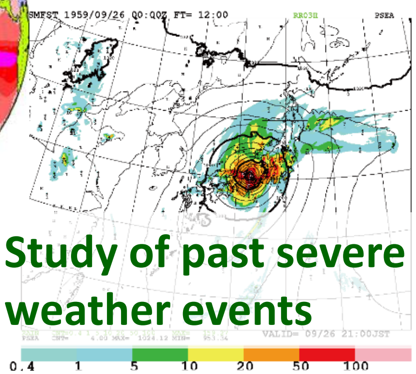

**El Niño monitoring**




**Climate monitoring, extreme event analysis**




**Study of past severe weather events**




**and many others**

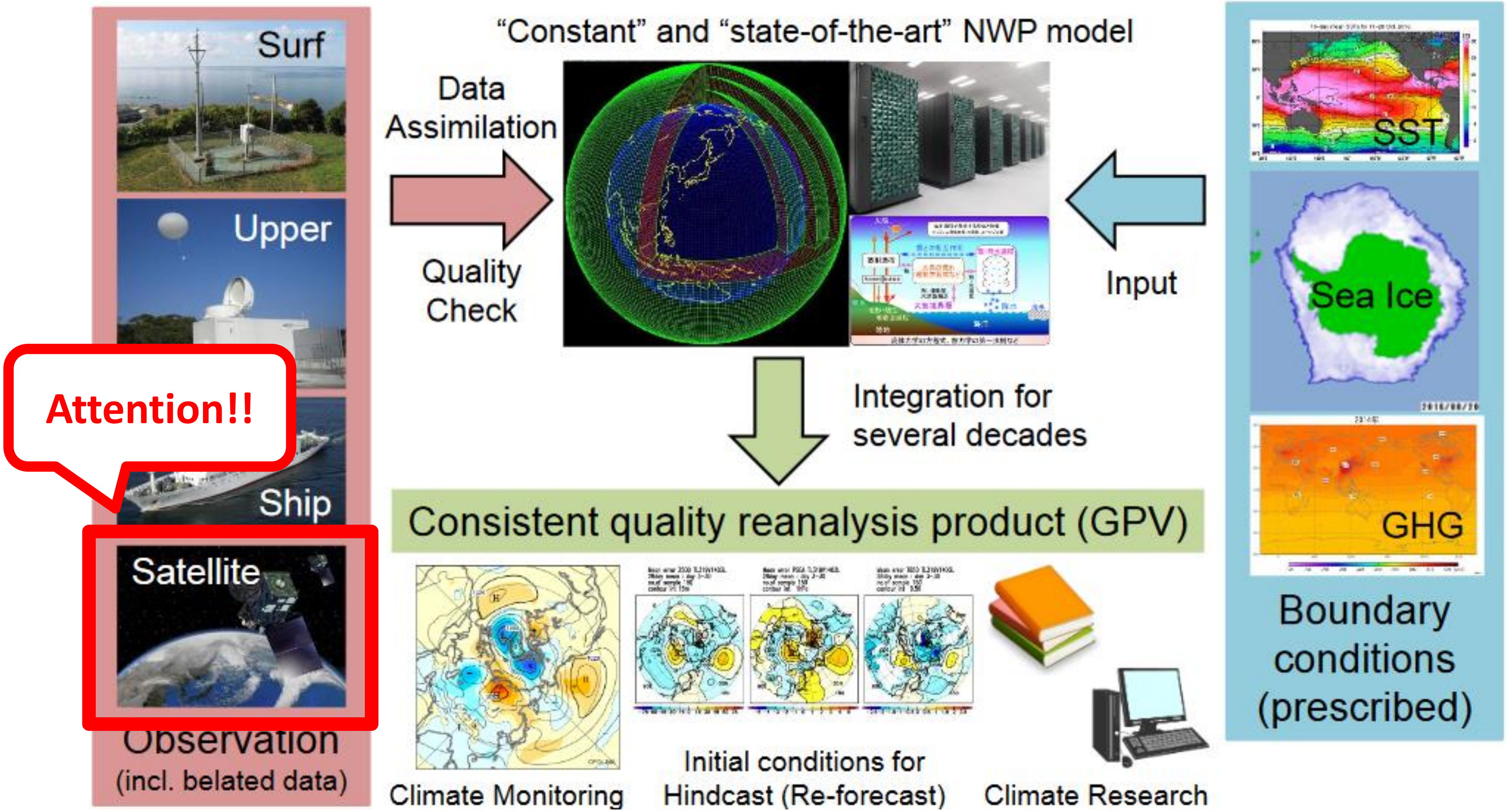
Climate related issues demand for **long-term homogeneous and high-quality datasets** to quantitatively assess past and current climates.

**(For examples of climate related issues)**
Climate research and seasonal forecasts, extreme weather analysis, climate monitoring, and so on...

**Existing analysis products are not homogeneous** due to improvements of assimilation systems and algorithms for deriving physical quantities from satellite data.

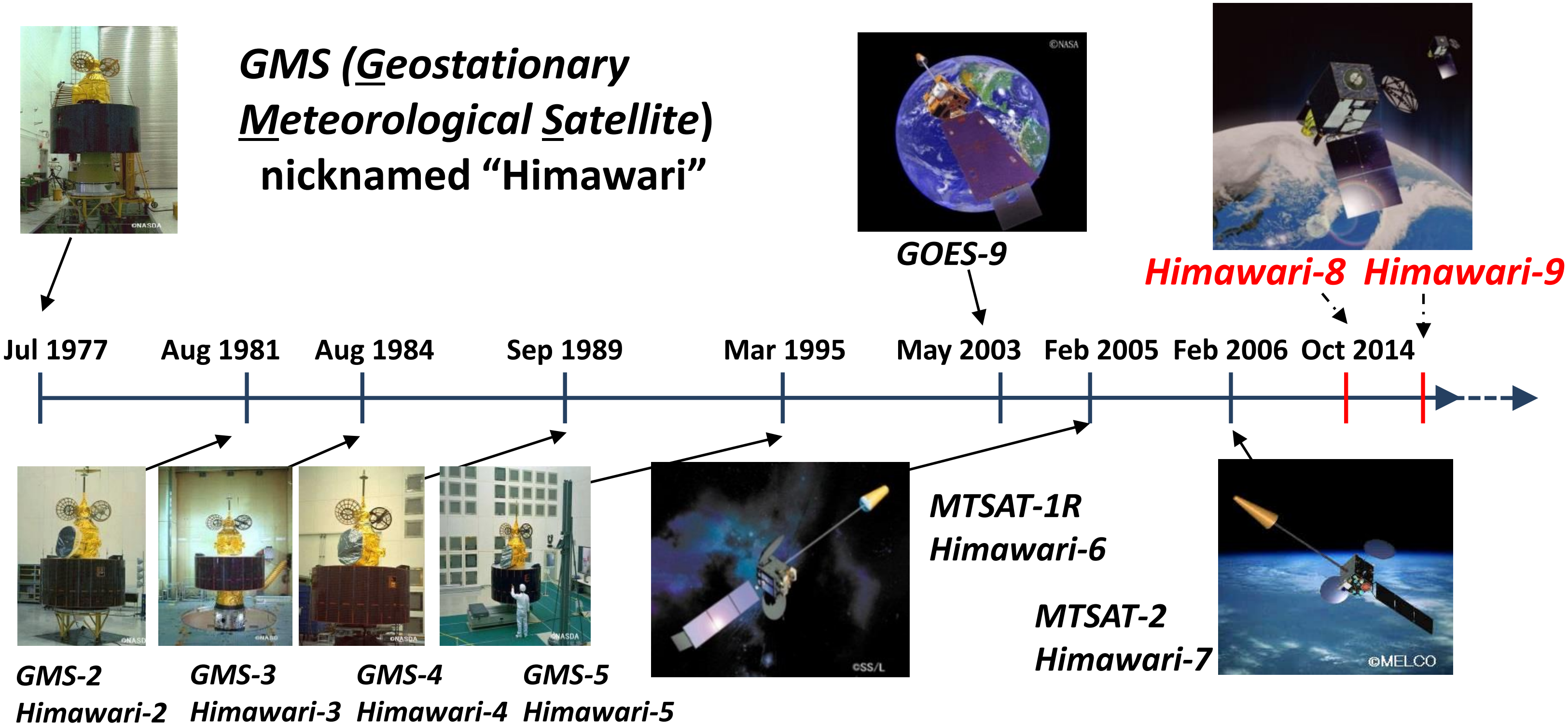
➡ **Long-term re-analysis required !!**

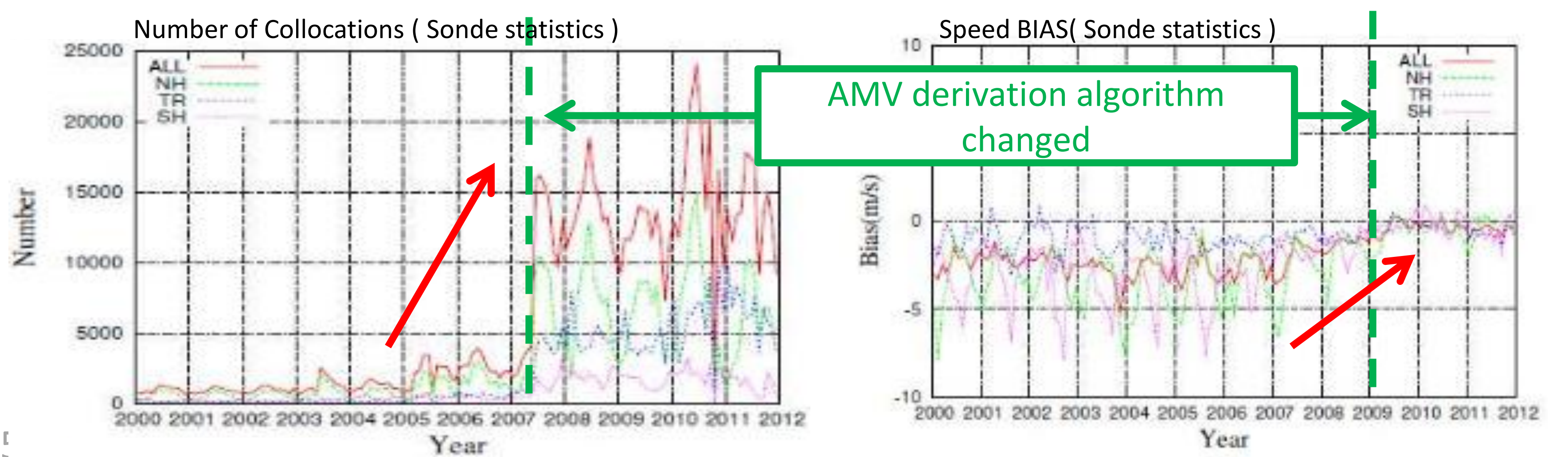
# Long-term Reanalysis




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.

# Importance of reprocessing for long-term reanalysis



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# The long-term re-analysis projects of JMA

- 1st **JRA-25**
  - By JMA and CRIEPI* (1979 to 2004, 26 years)
    * Central Research Institute fore Electric Power Industry
  - Near real-time extension using the same system (JCDAS) was conducted by JMA and terminated in February 2014
- 2nd **JRA-55**
  - By JMA (1958 to 2012, 55 years)
  - Near-real-time extension from 2013 to present
- 3rd **JRA-3Q**
  - Next project (currently conducting)

The Japanese Reanalysis for Three Quarters of a Century

**JRA Go! Go!**


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

“3” is pronounced as “San”.
3Q is called “San-kyu”
-> “Thank you”

# Overview of JRA-3Q

- **Reanalysis period**: **<u>1947 to present</u>**
- **Provisional specifications**
  - Resolution: 55 km, 60 layers (JRA-55) **-> 40 km, 100 layers (JRA-3Q)**
  - Incorporating many improvements from the operational NWP system
    - Overall upgrade of physical processes
    - New types of observation (ground-based GNSS, hyperspectral sounders)
  - Improved SST
    - COBE-SST2 (1-deg, up to 1985) & MGDSST (0.25 deg, from 1985 onward)
  - Improved observations
    - Observations newly rescued and digitised by ERA-CLIM and other projects
    - Improved satellite observations through reprocessing
    - JMA's own tropical cyclone bogus data
- **Production schedule**
  - Q3 2019: start production
  - **Q2 2021: complete production for the 1991 – 2020 normal period**
  - Q1 2022: complete production for the whole period

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# The algorithm used AMV reprocessing

## IR/WV bands for Height Assignment of AMV

AMV reprocessing for JRA-3Q using the latest algorithm for Himawari-8

Bands of the Advanced Himawari Imager (AHI) to be carried by Himawari-8/9

| Band Number | Central Wavelength (μm) | Spatial Resolution (km) |
|---|---|---|
| 1 | 0. 43−0. 48 | 1 |
| 2 | 0. 50−0. 52 | 1 |
| 3 | 0. 63−0. 66 | 0. 5 |
| 4 | 0. 85−0. 87 | 1 |
| 5 | 1. 60−1. 62 | 2 |
| 6 | 2. 25−2. 27 | 2 |
| 7 | 3. 74−3. 96 | 2 |
| 8 | 6. 06−6. 43 | 2 |
| 9 | 6. 89−7. 01 | 2 |
| 10 | 7. 26−7. 43 | 2 |
| 11 | 8. 44−8. 76 | 2 |
| 12 | 9. 54−9. 72 | 2 |
| 13 | 10. 3−10. 6 | 2 |
| 14 | 11. 1−11. 3 | 2 |
| 15 | 12. 2−12. 5 | 2 |
| 16 | 13. 2−13. 4 | 2 |

**WV bands:** Including upper level information (bands 8–10)

**Window bands**: All level information (bands 13–15)

**CO2 band**: upper and middle level information (band 16)

**6 IR/WV bands** are simultaneously used in Himawari-8 algorithm

**Target Satellites of reprocessing for JRA-3Q**

- MTSAT-2 ( 2010-2015 )
- MTSAT-1R ( 2005-2010 )
- GOES-9 ( 2003-2005 )
- GMS-5 ( 1995-2003 )

Have water vapor images

# Confirmation of quality of the reprocessed AMV

**Period :** **January** 2008 (MTSAT-1R)

**Band :** IR (10.3 – 11.3 μm)

**Sonde statistics (against Sonde observation value)**

**O-B statistics (against JRA-55 analysis fields)**

- **Operational : AMV created by the operational algorithms**
- **JRA-55 : AMV created for JRA-55 project**

  **Upgraded from operational**
  - The height assignment schemes for IR and WV AMV are changed
  - Resizing target box
  - Expansion of AMV derivation region
- **JRA-3Q : AMV created by the latest algorithm**

  **Upgraded from JRA-55**
  - Target selection processing is designed to avoid correlated AMV errors.
  - Averaging of similarity surfaces is utilized for noise reduction in the tracking process.
  - The height assignment method uses maximum likelihood estimation.

# Sonde statistics (Statistics values)

MTSAT-1R (**January** 2008), Upper Layer (< 400hPa), without forecast QI (>85)

## Wind speed bias (m/s)

### Operational

| | ALL | NH | TROP | SH |
|---|---|---|---|---|
| Upper | -1.67 | **-3.32** | -0.12 | -1.66 |
| Middle | -2.55 | **-2.84** | 0.47 | 0.32 |
| Low | 1.51 | 1.74 | 1.44 | 1.10 |

### JRA-55

| ALL | NH | TROP | SH |
|---|---|---|---|
| -0.64 | **-1.22** | -0.28 | -0.73 |
| -1.88 | **-2.15** | -0.26 | 0.49 |
| 1.28 | 1.06 | 1.52 | 1.07 |

### JRA-3Q

| ALL | NH | TROP | SH |
|---|---|---|---|
| -0.03 | **-0.21** | 0.09 | -0.29 |
| 0.20 | **-0.32** | 0.81 | 1.40 |
| 0.88 | 0.22 | 1.78 | 0.34 |

## Root mean square vector difference

### Operational

| | ALL | NH | TROP | SH |
|---|---|---|---|---|
| Upper | 8.59 | 10.48 | 6.62 | 7.03 |
| Middle | 12.38 | 12.74 | 6.76 | 6.08 |
| Low | 7.29 | 8.01 | 6.44 | 4.89 |

### JRA-55

| ALL | NH | TROP | SH |
|---|---|---|---|
| 7.74 | 9.49 | 6.47 | 7.13 |
| 10.50 | 10.88 | 5.58 | 6.41 |
| 8.23 | 7.80 | 8.28 | 5.71 |

### JRA-3Q

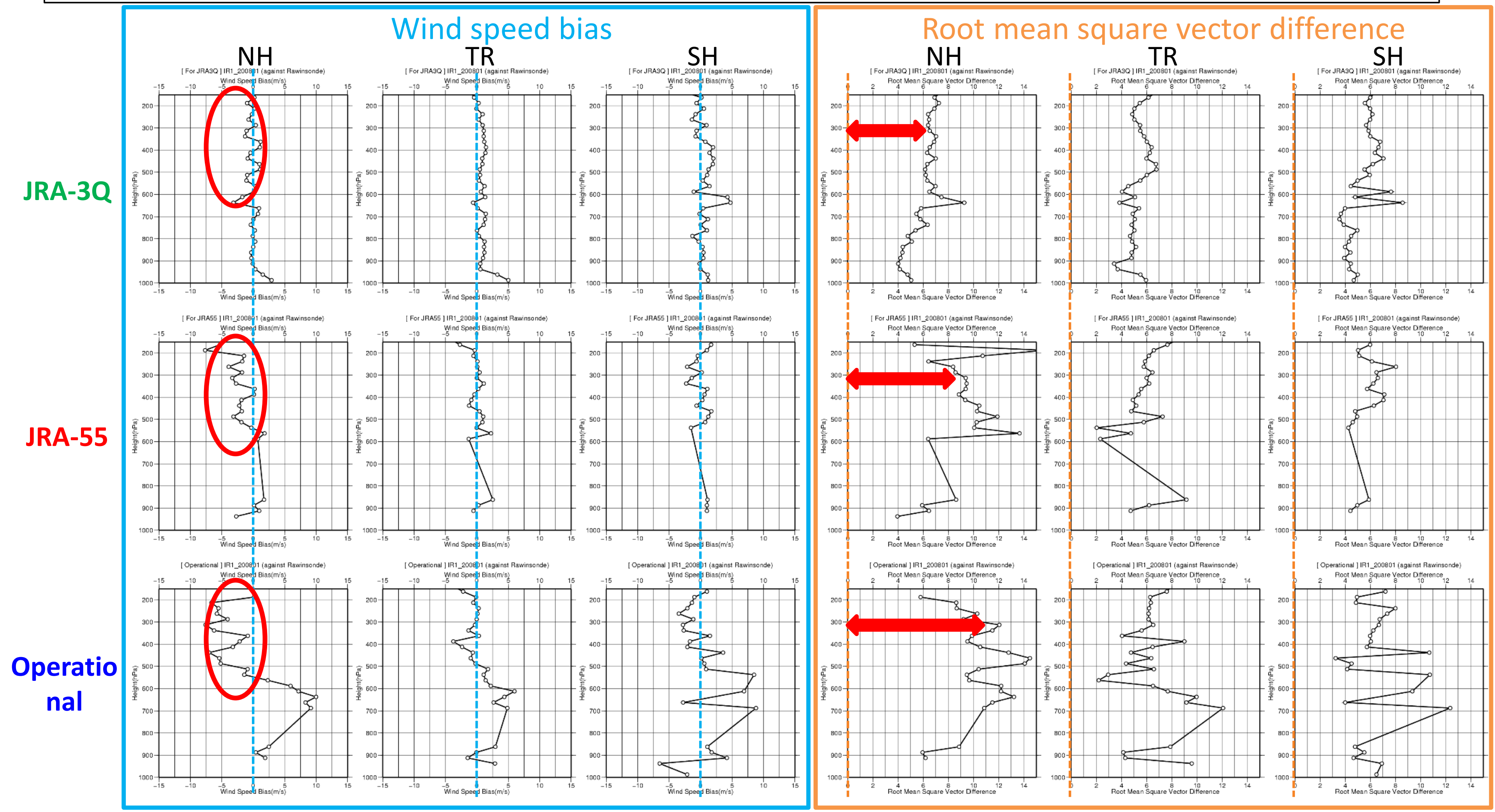
| ALL | NH | TROP | SH |
|---|---|---|---|
| **6.32** | **7.04** | **5.92** | **6.28** |
| **6.93** | **7.09** | 6.39 | **6.25** |
| **5.07** | **5.02** | **5.03** | **4.49** |

NH: Northern Hemisphere (N60-N20), TR: Tropical (N20-S20), SH: Southern Hemisphere (S20-S60)

**JRA-3Q**: For wind speed biases, the negative bias in the upper and middle layers of the northern hemisphere has improved, and Rmsvd has improved over the entire coverage.

# Sonde statistics (Vertical distribution)

MTSAT-1R (**January** 2008), Upper Layer (< 400hPa), without forecast QI (>85)




NH: Northern Hemisphere (N60-N20), TR: Tropical (N20-S20), SH: Southern Hemisphere (S20-S60)

**JRA-3Q**: Both wind speed bias and rmsvd are smaller than the others, especially, in wind speed biases, the negative bias in the upper layer on the northern hemisphere is closing 0. Additionally, the altitude change is also the smallest.

# Sonde statistics (Altitude distribution of zonal mean

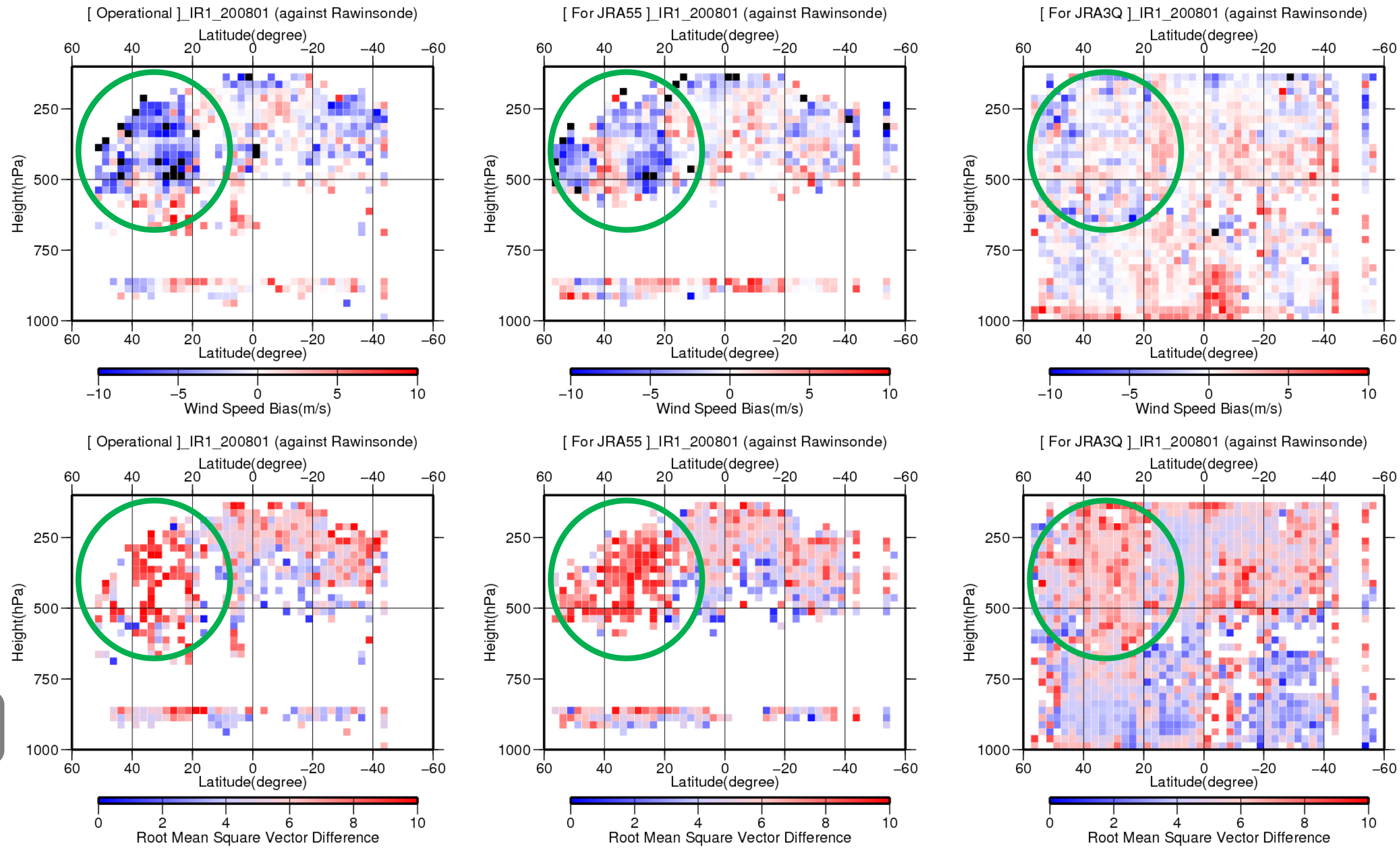
MTSAT-1R (**January** 2008), Upper Layer (< 400hPa), without forecast QI (>85)

**Operational** | **JRA-55** | **JRA-3Q**

Wind speed bias

White is better

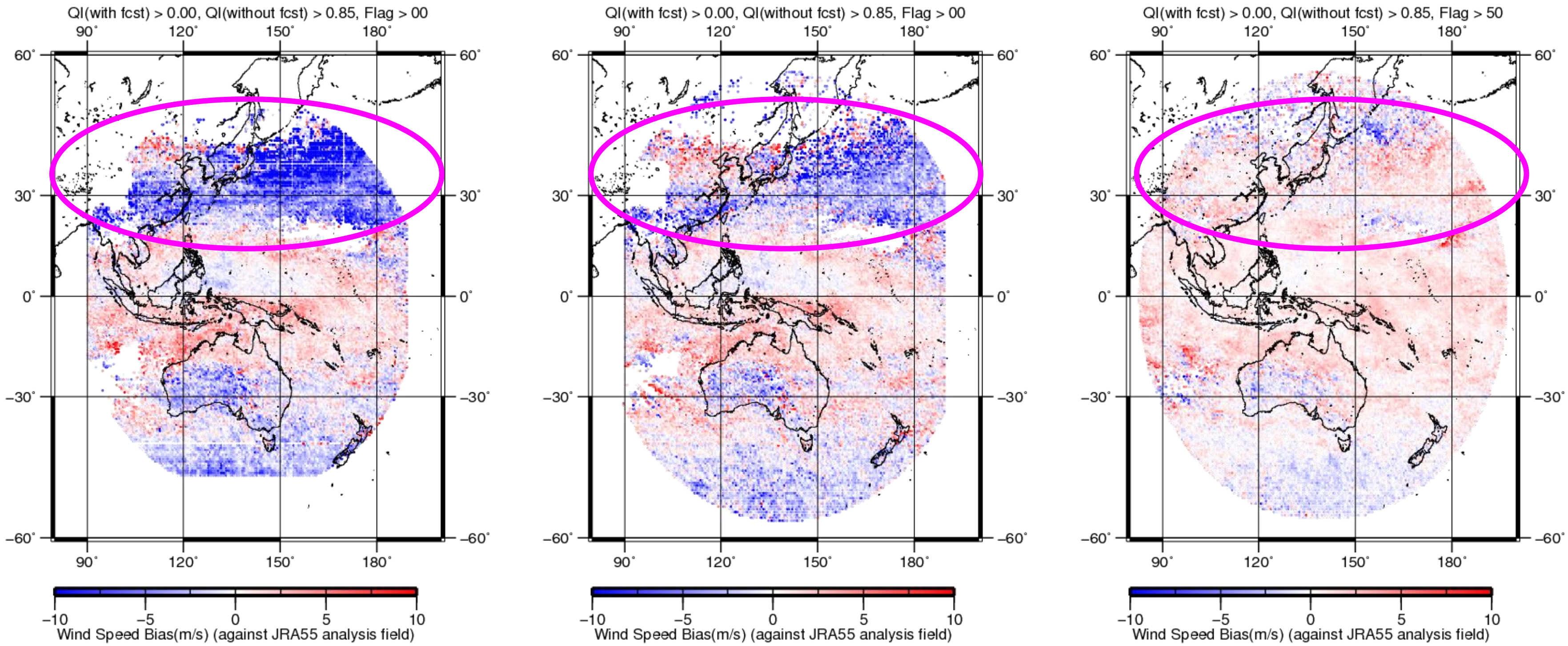
Blue is better




**JRA-3Q**: Coverage is wider than the others. Both wind speed bias and rmsvd are smaller than the others, and, it can be seen that the negative bias for wind speed in the upper layer on the northern hemisphere has improved.

# O-B statistics (Wind Speed Bias)

MTSAT-1R (**January** 2008), Upper Layer (< 400hPa), without forecast QI (>85)




**Operational** ( m/s )

| | ALL | NH | TROP | SH |
|---|---|---|---|---|
| Upper | -0.91 | **-5.19** | 0.80 | -1.28 |
| Middle | -0.92 | -3.50 | 2.18 | 3.27 |
| Low | 1.12 | 1.13 | 0.88 | 1.49 |

**JRA-55** ( m/s )

| ALL | NH | TROP | SH |
|---|---|---|---|
| -0.15 | **-2.50** | 0.67 | -0.42 |
| -1.31 | -2.84 | 1.26 | -0.06 |
| 0.84 | 0.77 | 0.76 | 0.99 |

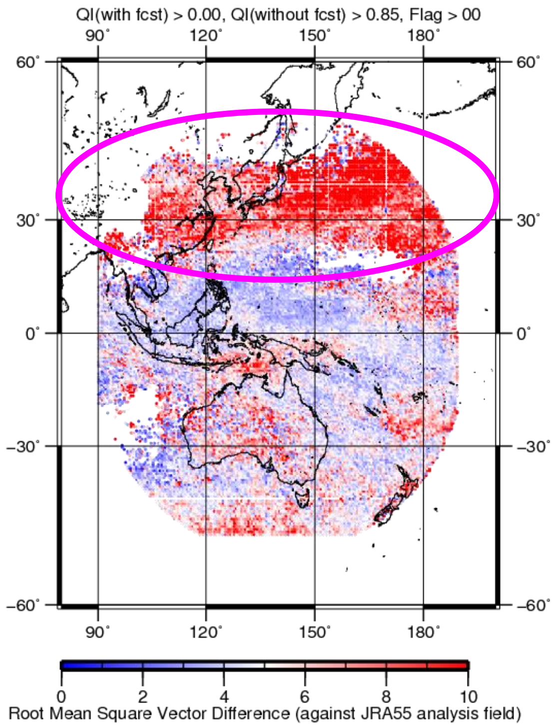
**JRA-3Q** ( m/s )

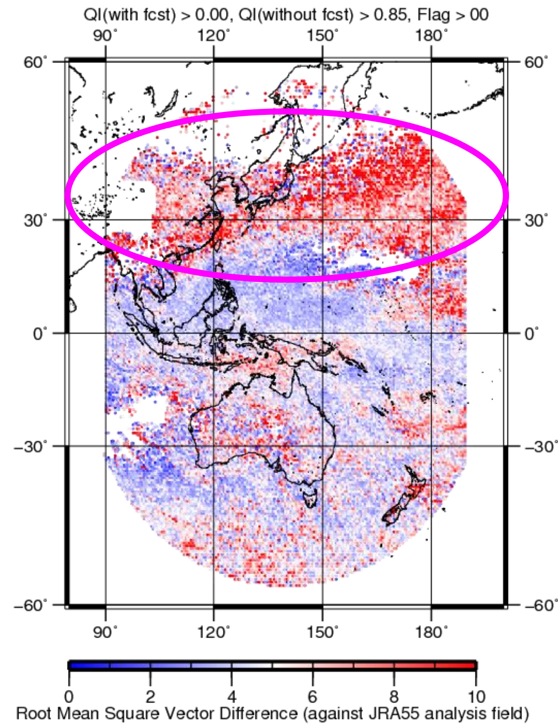
| ALL | NH | TROP | SH |
|---|---|---|---|
| 0.72 | **0.69** | 0.85 | 0.20 |
| 1.41 | 0.39 | 2.26 | 1.16 |
| 0.40 | 0.48 | 0.49 | 0.18 |

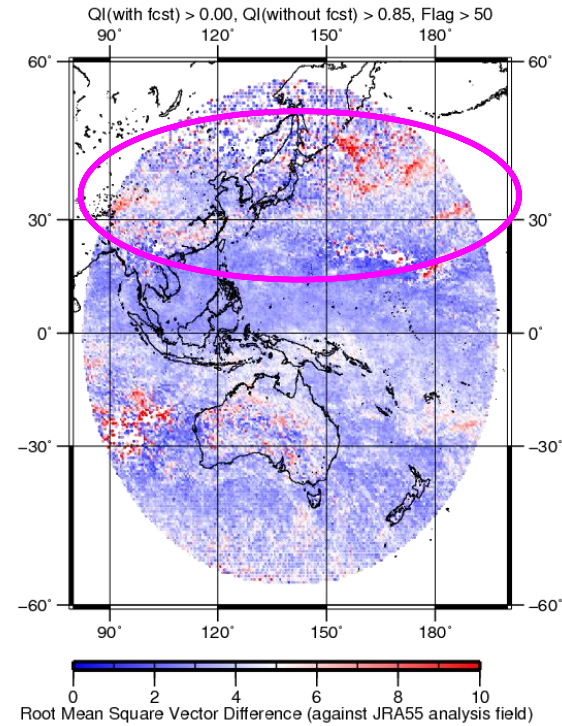
**JRA-3Q**: Coverage is **wider** than the others and wind speed bias is **spatially uniform** over the entire coverage, especially, the negative bias near a jet stream in the northern hemisphere has **changed to positive** significantly.

# O-B statistics (Root Mean Square Vector Difference)

MTSAT-1R (**January** 2008), Upper Layer (< 400hPa), without forecast QI (>85)




**Operational**

| | ALL | NH | TROP | SH |
|---|---|---|---|---|
| Upper | 7.65 | 11.91 | 5.53 | 6.61 |
| Middle | 11.69 | 12.95 | 7.18 | 9.77 |
| Low | 6.15 | 5.48 | 6.86 | 4.84 |

**JRA-55**

| | ALL | NH | TROP | SH |
|---|---|---|---|---|
| Upper | 6.47 | 9.28 | 5.41 | 6.24 |
| Middle | 8.85 | 10.65 | 5.89 | 6.68 |
| Low | 6.08 | 5.13 | 7.48 | 4.62 |

**JRA-3Q**

| | ALL | NH | TROP | SH |
|---|---|---|---|---|
| Upper | **4.33** | **4.73** | **4.22** | **4.45** |
| Middle | **5.67** | **4.98** | **6.20** | **5.23** |
| Low | **2.79** | **2.87** | **2.77** | **2.67** |

**JRA-3Q**: Coverage is **wider** than the others and root mean square vector difference is **spatially uniform** and **close 0** over the entire coverage, especially, the errors near a jet stream in the northern hemisphere has **improved** significantly.

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# The period of impact experiments

| Name of satellite | AMVs for comparison | Winter experiment | Summer experiment |
|---|---|---|---|
| MTSAT-2 | Operational AMVs | From $10^{th}$ Jan. 2012 to $11^{th}$ Mar. | From $10^{th}$ Jul. 2012 to $11^{th}$ Sep. |
| GOES-9 | AMVs for JRA-55 | Form $10^{th}$ Dec. 2003 to $11^{th}$ Feb. 2004 | From $10^{th}$ Jul. 2003 to $11^{th}$ Sep. |
| GMS-5 | AMVs for JRA-55 | Form $10^{th}$ Dec. 1999 to $11^{th}$ Feb. 2000 | From $10^{th}$ Jul. 1999 to $11^{th}$ Sep. |

To decide whether to use reprocessed AMVs for JRA-3Q, JRA team conducted impact experiments on each satellite for above periods.

Next

Introduction of the winter experiment for reprocessed MTSAT AMVs

(as an example of all experiments)

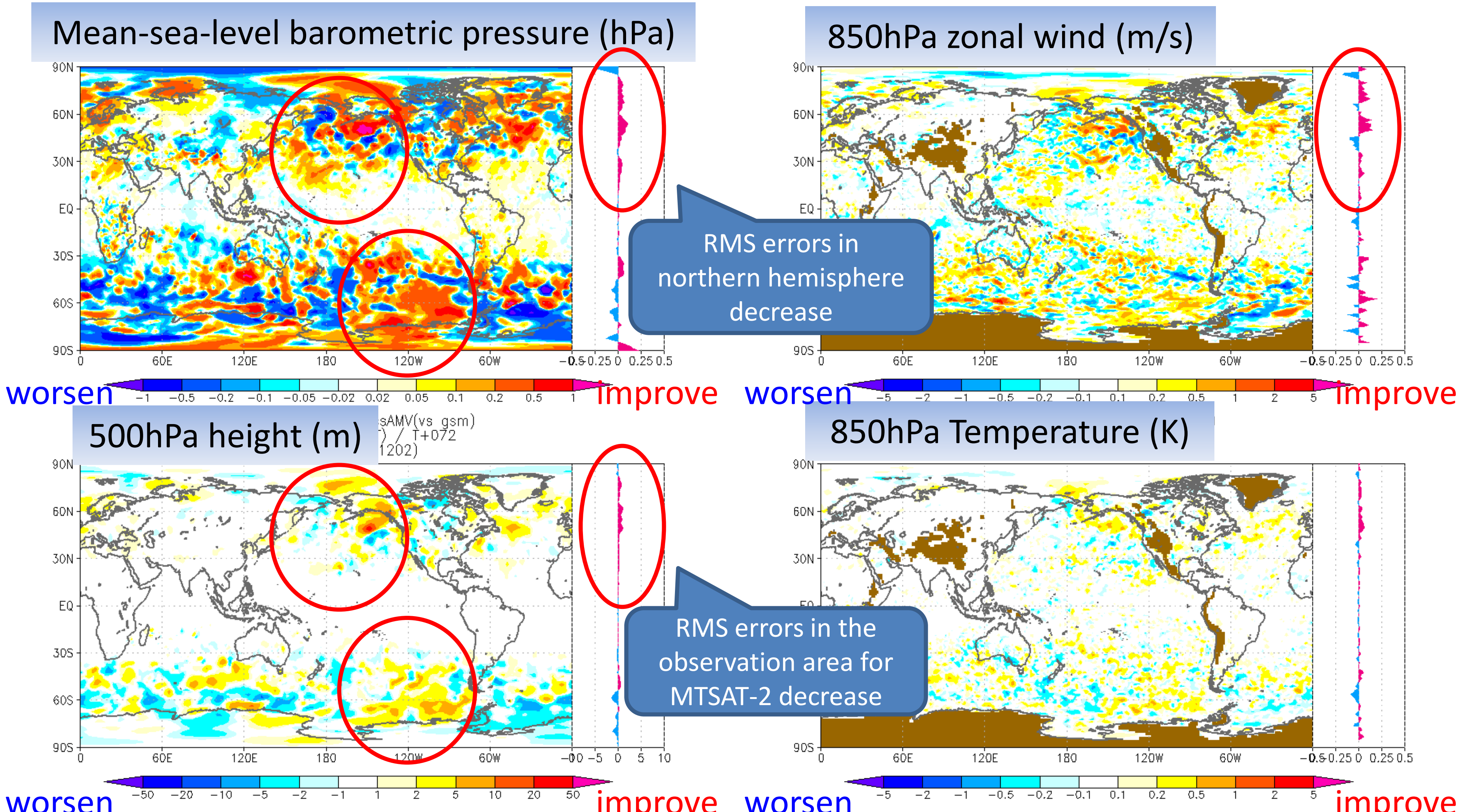
* Meaning of CNTL and TEST appearing from next slide

CNTL: the data using the operational AMBs

TEST: the data using the reprocessed AMVs for JRA-3Q

# The difference of RMS errors for three days forecast (CNTL-TEST)
## of the winter experiment for MTSAT-2

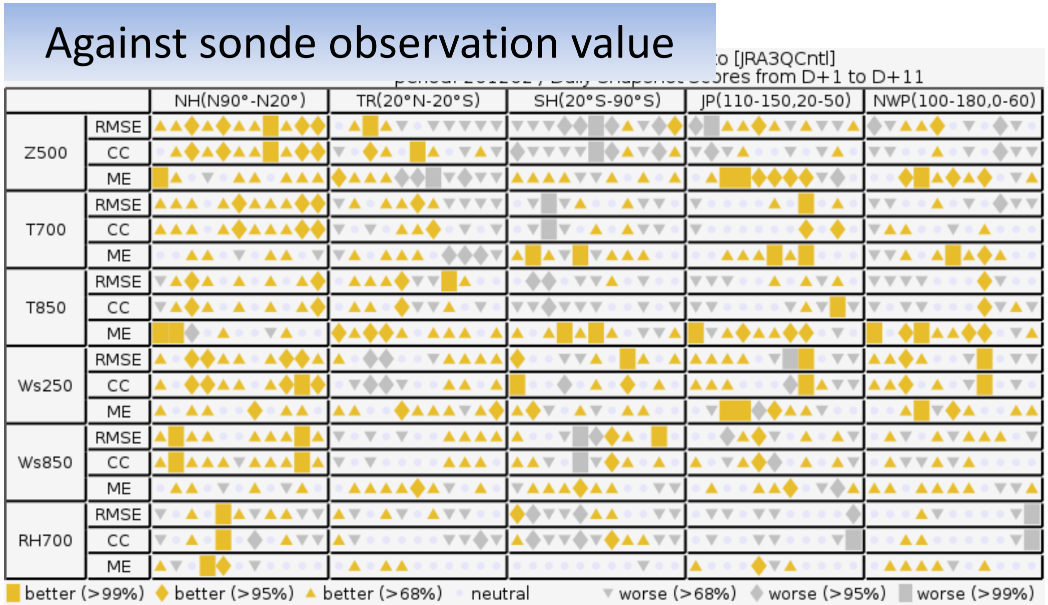
The forecast error decreases not only zonal wind, but also mean-sea-level barometric pressure and height, especially in the northern hemisphere, there are big improvements.

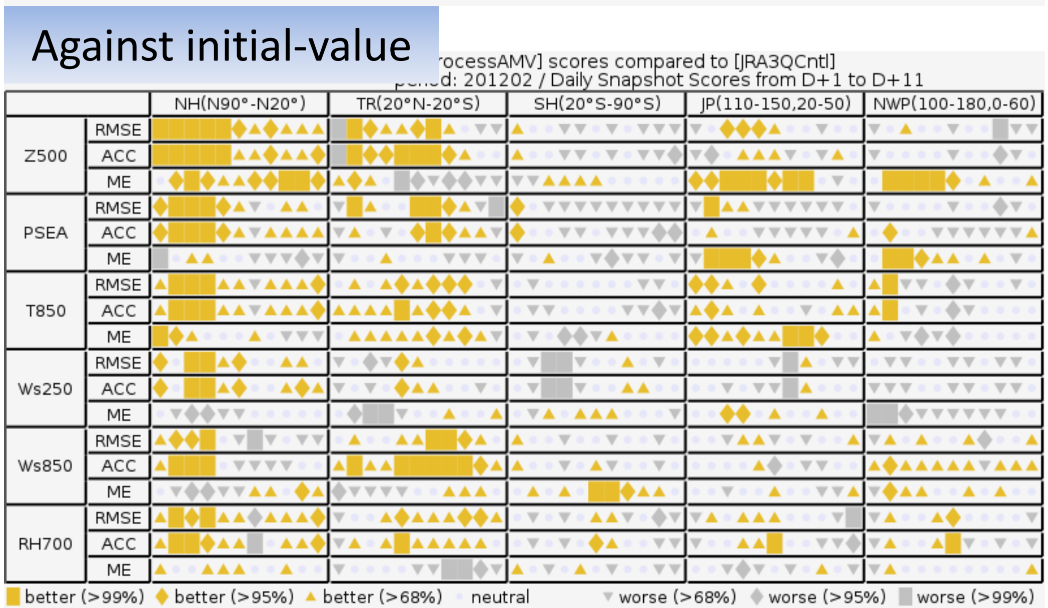



These are differences of three days forecast RMS errors. * CNTL: operational AMVs, TEST: reprocessed AMVs for JRA-3Q

The left figure shows the difference of RMS errors (CNTL-TEST), the right one shows the zonal mean.

# Score cards of the winter experiment for MTSAT-2




Yellow means improvement, Gray means worsen.

- Both against first-guess and sonde score clearly improve for early forecast in northern hemisphere.
  - 250hPa wind, 850hPa wind
  - 500hPa height、mean-sea-level barometric pressure, 850hPa Temperature, 700hPa relative humidity
- 850hPa wind score against first-guess also improve in tropical.
- 500hPa height and mean-sea-level barometric pressure score against first-guess improve in Japanese area which is the observation area for MTSAT-2

# Summary of impact experimental results

**MTSAT (against operational AMVs)**

- Number of assimilation usage increases below 950hPa.
- FG departure decrease above 500hPa.

**Winter experiment**

- A jet stream speed increase in mid latitudes of northern hemisphere.
- The forecast error decreases not only zonal wind, but also mean-sea-level barometric pressure and height, especially in the northern hemisphere.
- The forecast error decreases in Japanese area which is the observation

**GOES-9 (against JRA-55 analysis fields)**

- Number of assimilation usage increases below 950hPa, but slightly decreases above 850hPa.
- FG departure decrease.

**Winter experiment**

- The forecast error decreases not only zonal wind, but also mean-sea-level barometric pressure and height in the southern hemisphere.

**GMS-5 (against JRA-55 analysis fields)**

- Number of assimilation usage increases below 950hPa, but slightly decreases above 850hPa.
- FG departure decrease.

**Winter experiment**

- The forecast error decreases not only zonal wind, but also mean-sea-level barometric pressure and height in the northern hemisphere.
- The forecast error decreases in Japanese area which is the observation

**Common to all experiments**

**Summer experiment** - Mostly neutral

JRA team is currently conducting JRA-3Q using the reprocessed AMVs for JRA-3Q !!

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# Summary

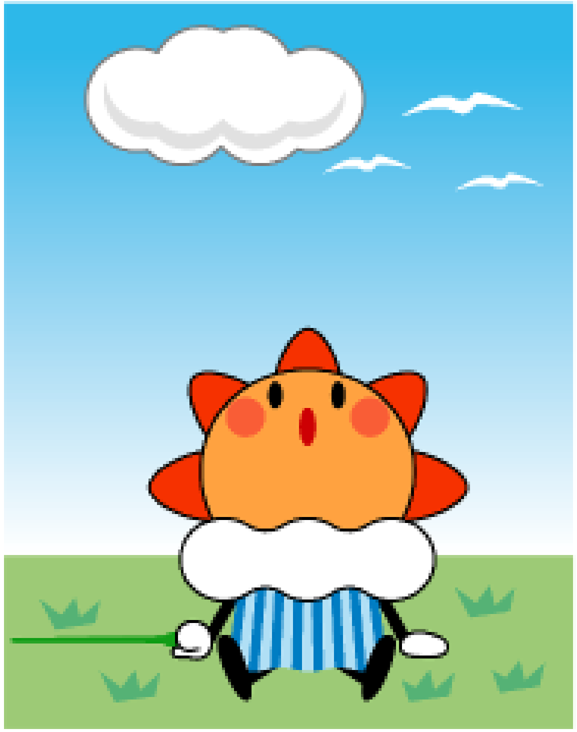
1. **Long term reanalysis and importance of AMV reprocessing**
2. **Overview of JRA-3Q (Japanese Reanalysis for Three Quarters of a Century)**
3. **Quality evaluation comparison between the reprocessed AMV for JRA-3Q and the others**

We showed that the quality of the reprocessed AMVs for JRA-3Q is better than that of the existing AMVs by confirming the statistics against JRA-55 analysis fields and sonde observation values.

4. **Introduction of impact experiment results using reprocessed AMVs as input data**

In the winter experiment using each reprocessed AMV, JRA team confirmed that the forecast errors decreased, and they are currently conducting JRA-3Q using the reprocessed AMVs for JRA-3Q.

# Thank you for your time!!



# Reference


Meteorological Satellite Center Technical Note

March 2017, No.62 (The author is Mr. Shimoji of JMA)

“**Introduction to the Himawari-8 Atmospheric Motion Vector Algorithm**”

- http://www.data.jma.go.jp/mscweb/technotes/msctechrep62-4.pdf

Meteorological Satellite Center Technical Note

February 2023, No.58 (The author is Mr. Hayashi and Mr. Shimoji of JMA)

“**Atmospheric Motion Vectors Derivation Algorithm**” (Japanese)

- https://www.data.jma.go.jp/mscweb/technotes/msctechrep58-1.pdf

TCC Training Seminar ( 14 NOV. 2016 )

“**Introduction to Reanalysis and JRA**” ( The author is Mr. Harada of JMA )

- https://ds.data.jma.go.jp/tcc/tcc/library/library2016/lectures/7_Introduction_to_Reanalysis_and_JRA.pdf

# Element of the statistics

RMSVD : Root mean square vector difference

$$RMSVD = \sqrt{\frac{1}{N}\sum_{i,r=1}^{N}[(u_i - u_r)^2 + (v_i - v_r)^2]}$$

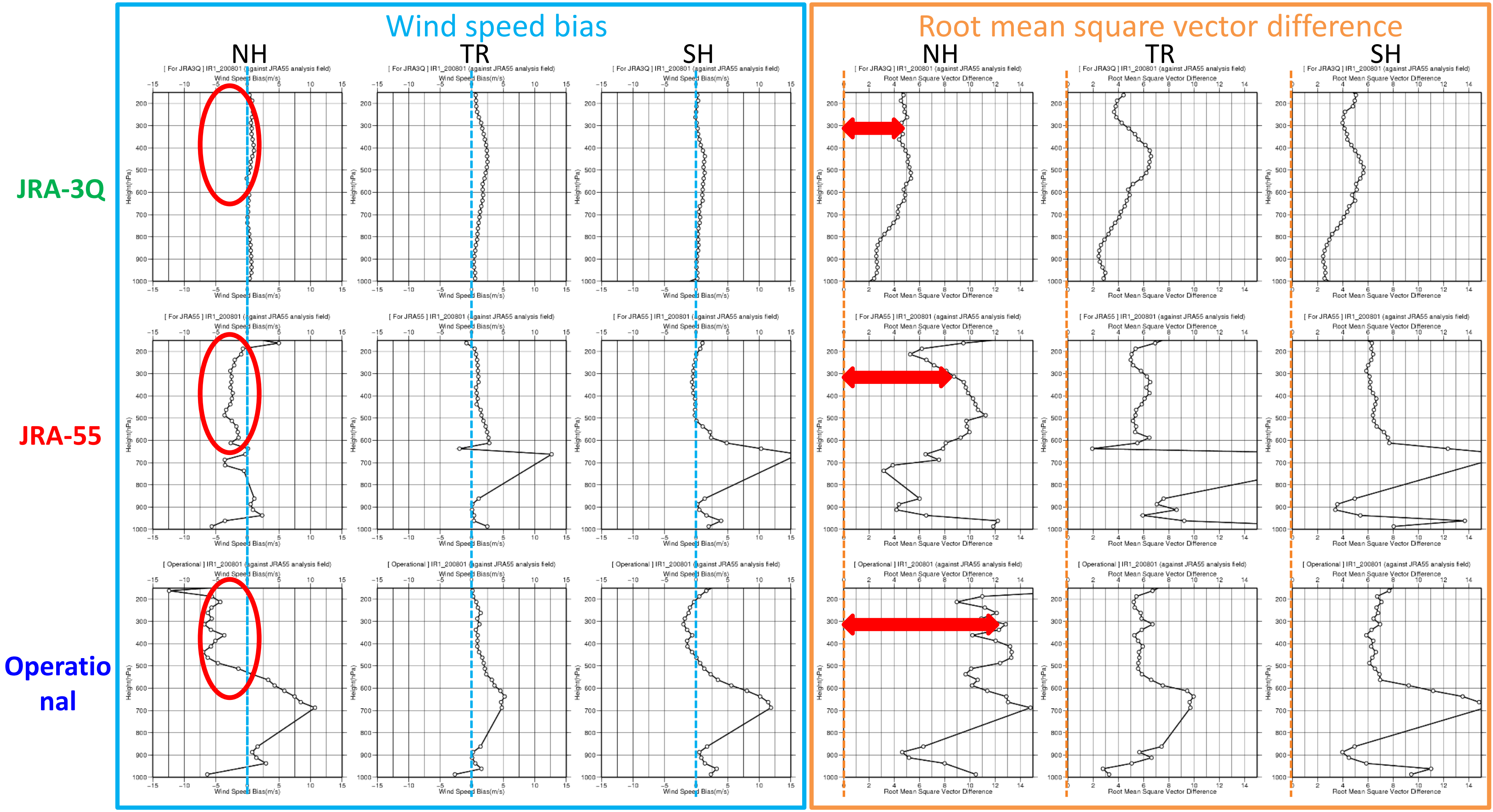
BIAS : Wind speed bias

$$BIAS = \frac{1}{N}\sum_{i,r=1}^{N}[\sqrt{{u_i}^2 + {v_i}^2} - \sqrt{{u_r}^2 + {v_r}^2}]$$

$X_i$ : AMV element, $X_r$ : Model element

# O-B statistics (Altitude distribution)

MTSAT-1R (January 2008), Upper Layer (< 400hPa), without forecast QI (>85)




NH: Northern Hemisphere (N60-N20), TR: Tropical (N20-S20), SH: Southern Hemisphere (S20-S60)

**JRA-3Q**: Both wind speed bias and rmsvd are smaller than the others, especially, in wind speed biases, the negative bias in the upper layer on the northern hemisphere is closing 0. Additionally, the altitude change is also the smallest.

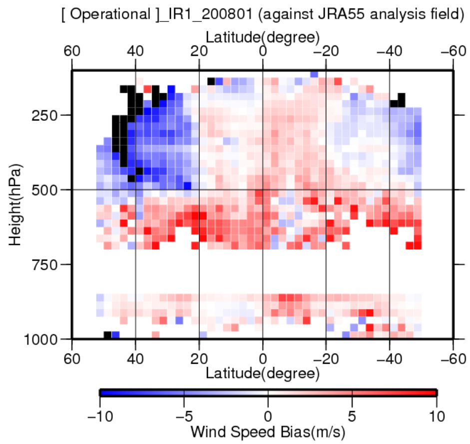
# O-B statistics (Altitude distribution of zonal mean)

MTSAT-1R (January 2008), Upper Layer (< 400hPa), without forecast QI (>85)

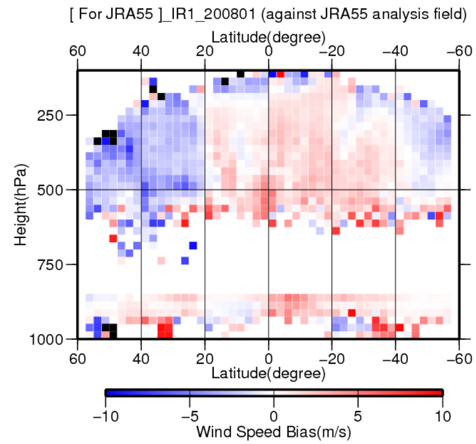
Wind speed bias

White is better

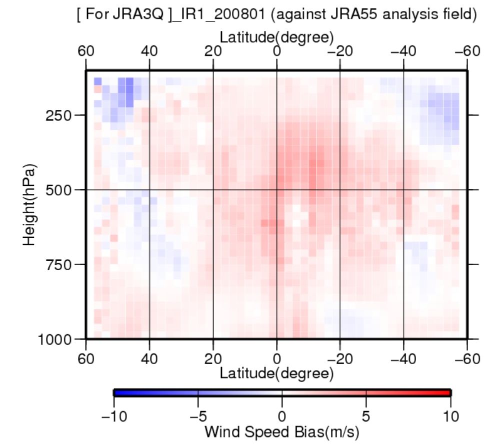
Operational




JRA-55

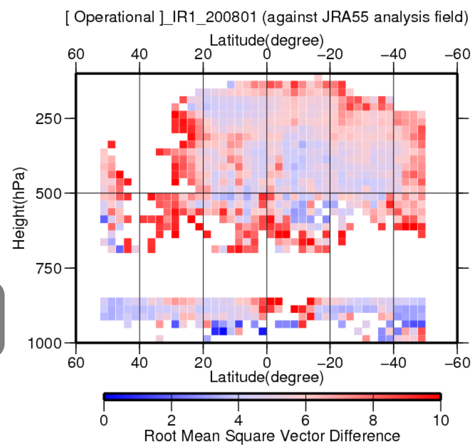


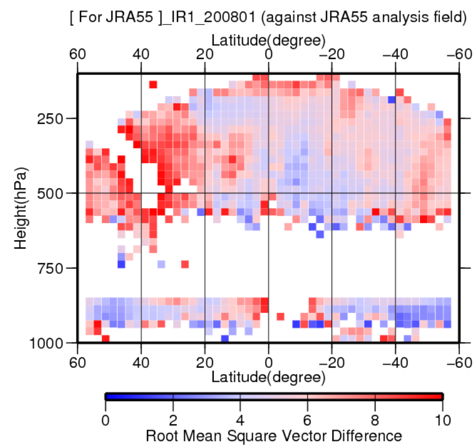

JRA-3Q

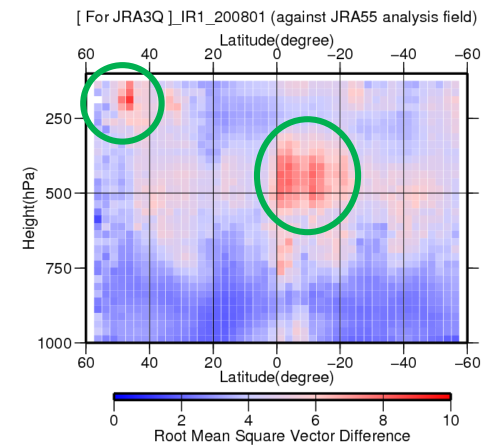



Root mean square vector difference

Blue is better




**JRA-3Q**: Coverage is wider than the others. Wind speed bias is spatially uniform over the entire coverage. Rmsvd has improved in a wide range, but it's large in the middle layer on the tropic and in the upper layer on the north pole.