Data denial experiments of scatterometer winds in the JMA's global data assimilation system

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1. Introduction

- In Japan, heavy rainfall events related to fronts or typhoons often cause water-related disasters during warm season. Realistic representation of wind convergence zone and distribution of water vapor field on the lower-level of troposphere is one of the important factors for accurate heavy rain forecast.
- Ocean Wind Vectors(OWVs) retrieved from microwave scatterometer onboard polar-orbiting satellites provide global, spatially continuous data on wind speed and direction twice a day without being affected by cloud cover.
- As input data for numerical weather prediction (NWP) systems, scatterometer-derived OWVs provide directly improvement of the accuracy of near-surface wind analyses. Indirectly, these improvements can enhance the representation of lower-level temperature fields, moisture distributions, and surface pressure fields, which contribute to better precipitation forecasts.
- In recent years, the assessment of the impact of assimilating scatterometer winds has largely focused on comparing conditions before and after the introduction of new satellite data in JMA. The direct effect of scatterometer winds to the data assimilation system has not been examined for a long time, particularly with using the present NWP systems.
- In this study, we conducted denial experiments of OWVs to examine the impact of the assimilating the data on the present global NWP system.

2. Specification of the experiment

Table 1. Experiment and verification period

	Summer	Winter
Analysis	From 10 Jun. 2023 to 11 Aug. 2023	From 10 Dec. 2022 to 11 Feb. 2023
Forecast	From 20 Jun. 2023 to 11 Aug. 2023	From 20 Dec. 2022 to 11 Feb. 2023
Statistical verification	From 1 Jul. 2023 to 31 Jul 2023	From 1 Jan. 2023 to 30 Jan. 2023

Control experiment (CNTL)

Same as Jun. 2023 operational assimilation datasets are used. As scatterometer winds, Metop-B,C/ASCAT winds are assimilated. Same as of Jun. 2023 global assimilation system of JMA [1]

Data denial experiment (TEST)

Metop-B,C/ASCAT winds are not assimilated. Except for scatterometer, same as Jun. 2023 operational assimilation datasets are used.

Experiment and verification period are shown on the table1.

3. Result of denial experiment(statistical result)

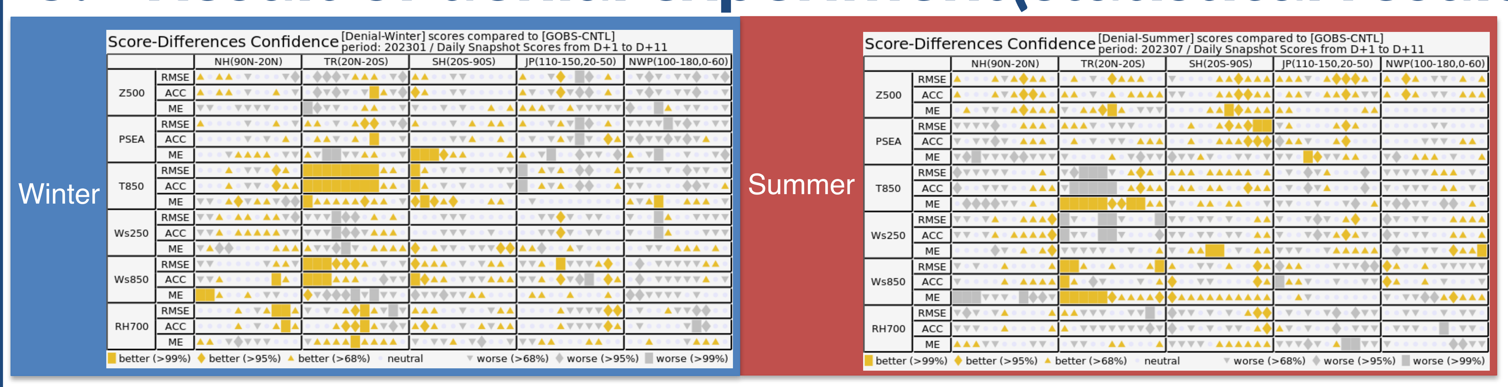

Fig. 1. Significance level of the differences in forecast scores of summer (right) and winter (left) experiments. Yellow sign means the improvement of forecast score and gray sign means the degradation of forecast score.

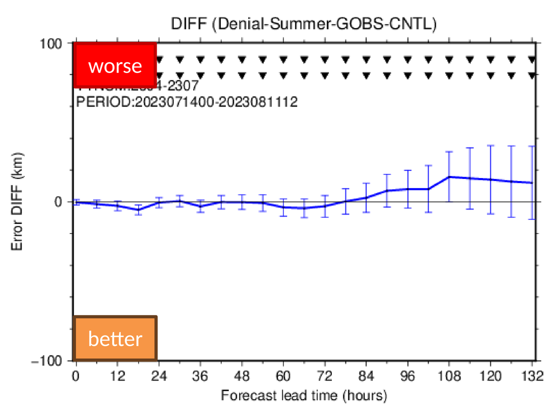

Fig. 2. Statistical typhoon position error difference of summer experiments.

Fig. 1 shows the significance level of the differences in forecast scores of the global forecast model. Forecast skill was assessed through verification against analysis. In this experiment, results of forecast score become generally neutral. Result of Northern Hemisphere on summer experiment shows some degradation of lower layer elements. Number of assimilated other lower-tropospheric data such as Atmospheric Motion Vectors (AMVs) were increased (>10%, not shown).
Since the verification in this study was conducted against the experiment's own analysis, the CNTL experiment that is the amount of correction applied to the first guess was smaller may have been at an advantage.

Fig. 2 shows the differences in typhoon track forecast errors during the summer experiment. This validation is compared with the reference to JMA best-track data and validated region is Northwestern Pacific. Although some deterioration in track forecasts was observed in the later forecast stages, the early stages showed mostly neutral results.

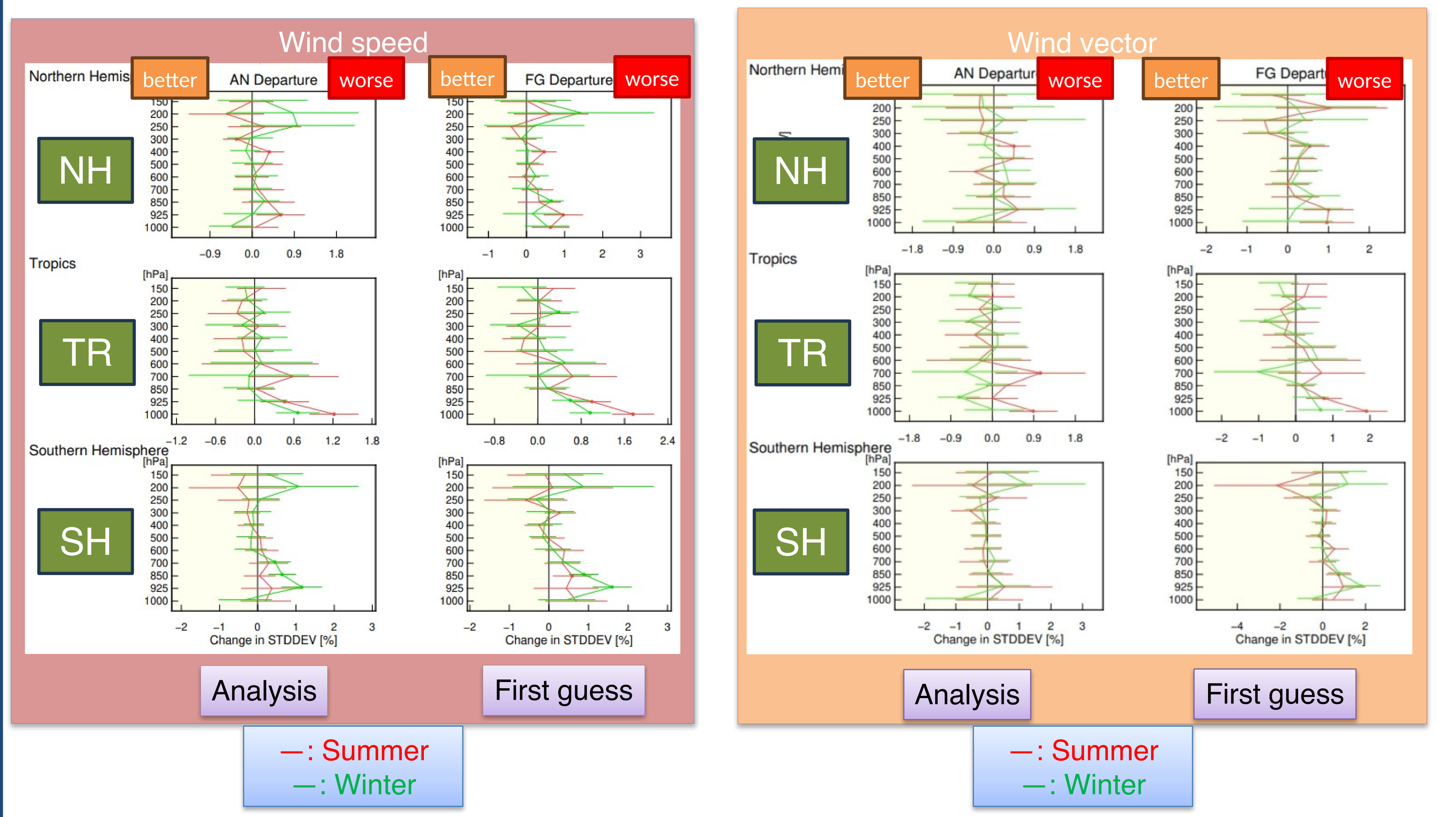

Fig. 3 shows that, in the denial experiment(TEST), degradation of consistency between the analysis (and first guess) and AMV observations are shown for both wind speed and wind direction, particularly in the lower layer.

A similar tendency was observed for other wind-related observations (e.g., radiosondes and aircraft observation; not shown).

In addition, degradation in consistency with observations was also evident in environmental parameters such as relative humidity, temperature, and sea-level pressure, especially in the middle to lower layers of the atmosphere.

Fig. 3. Change in normalized standard deviation(STDDEV) of the analysis and first-guess departure.
$(STDDEV_{BASE} - STDDEV_{CNTL})/STDDEV_{CNTL})$ for AMV wind observations(Red: Summer, Green: Winter) Error bars represent 95% confidence intervals, and dots are statistically significant.

4. Changes in the mean analysis field

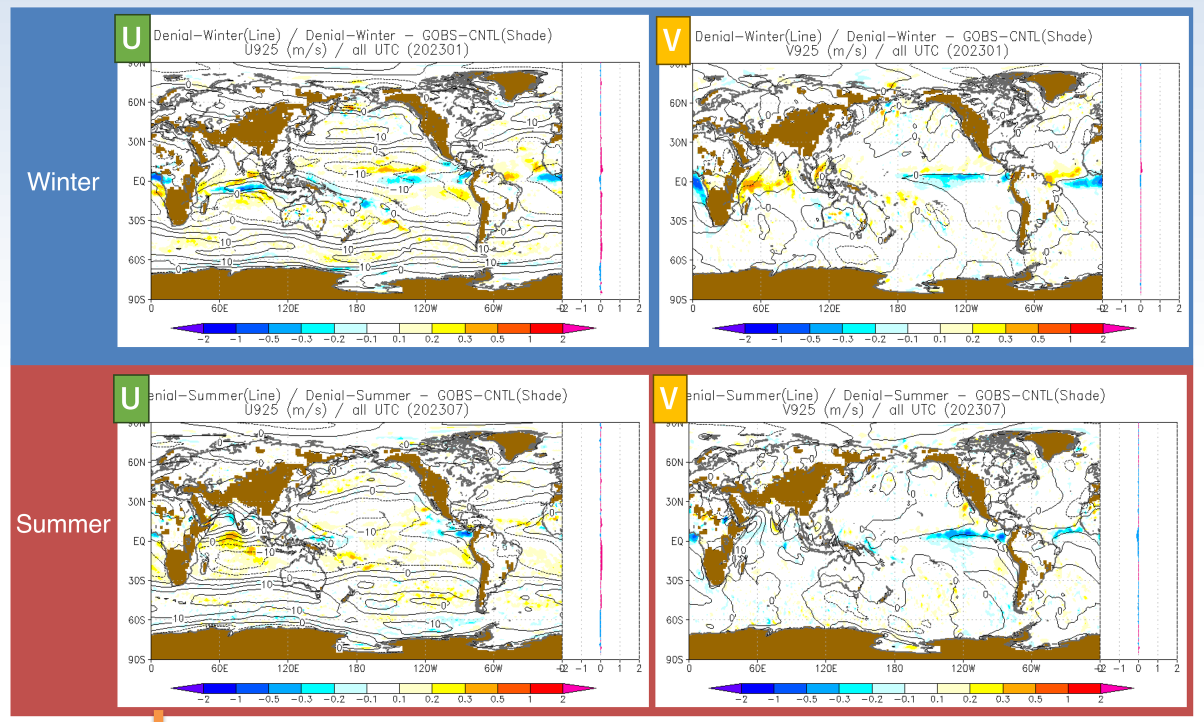

Fig. 4. Change in the mean analysis field of 925 hPa wind(U, V).

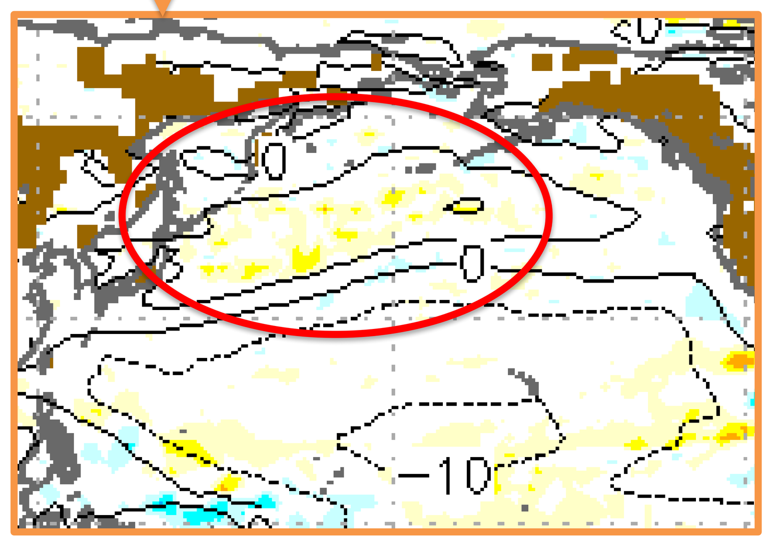

Fig. 5. Change in the mean analysis field of 925 hPa wind(U) around Japan area on the summer experiment.

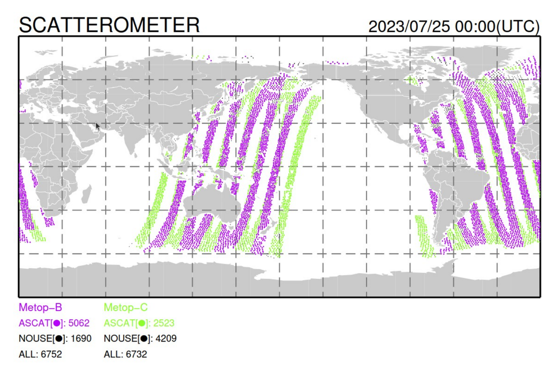

Fig. 6. Data coverage of assimilated scatterometer data in the CNTL experiment at 00UTC on 25th Jul.2023

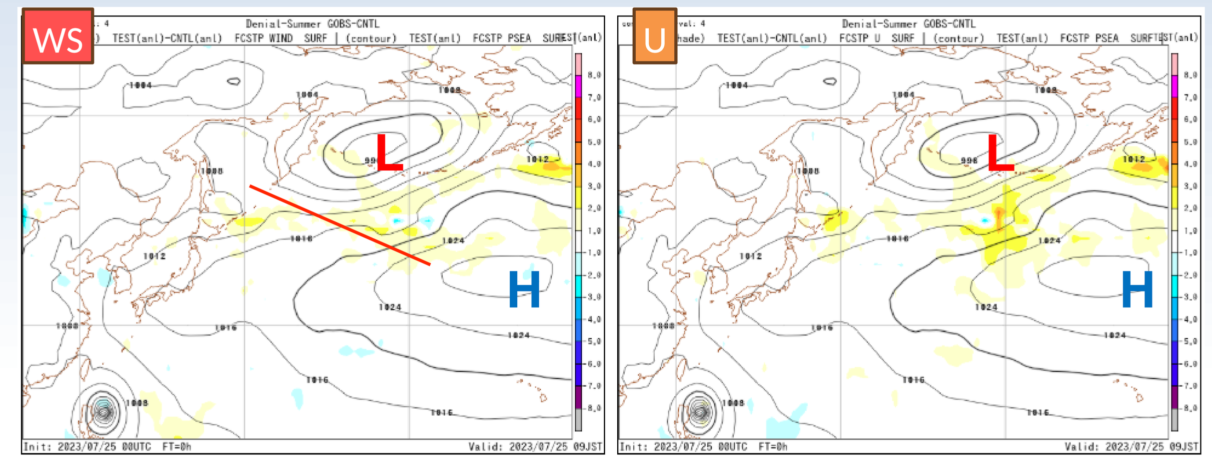

Fig. 7. Change in the analysis field of surface wind(WS, U) around Japan area at 00UTC on 25th Jul. 2023.
Yellow shade shows enhancement of wind on the denial experiment.
Black contour shows sea surface pressure of TEST experiment.

Fig. 4 shows the spatial distribution of change in the mean analysis field of 925 hPa winds. Resulting from the assimilation of scatterometer OWVs are found over the low- and high-latitude regions of the Pacific Ocean, as well as in equatorial regions of the Indian and Atlantic Oceans. Relatively large changes are seen over the area extending from east of Japan to the Aleutian Islands.

Fig. 5 is a zoomed-in view of the mean analyzed U-component wind field from the summer experiment shown in Fig. 4, focusing on the area from east of Japan to the Aleutian islands.
As indicated by the red circles, the U-component is strengthened east of Japan in the denial experiment.
In the CNTL experiment, scatterometer ocean surface wind data were assimilated in this area (Fig. 6).
This implies that the assimilation of scatterometer ocean surface winds tends to adjust the forecast model zonal winds east of Japan toward weaker values.

To further analyze the area with changes in zonal winds identified in Fig. 5, Fig. 7 presents the surface wind field (wind speed and U-component) from the analysis field at 00 UTC on July 25, 2023.

The region shaded in yellow, where winds are strengthened in the denial experiment, is located near the boundary of a high-pressure system over the North Pacific.

This result shows that the scatterometer ocean surface winds weakened the surface wind field around the high-pressure system over the North Pacific.

According to satellite-based observations over the ocean southwest of the Aleutian Islands, located near the boundary of a high-pressure system shown in Fig. 7, cloud analysis techniques using satellite imagery [2] indicate the presence of widespread stratocumulus clouds and stratus clouds (Fig. 8).
The occurrence of these stratocumulus clouds suggests the presence of a low-level temperature inversion layer [3].

On the right side of Fig. 9, which presents a cross-section along the red line shown in Fig. 7 indicates that the region where the lower-level winds were weakened in the CNTL experiment across the area where the inversion layer extends.
Whether the changes in the analysis fields in this experiment actually led to improved consistency with the real atmospheric state will be investigated in future work.

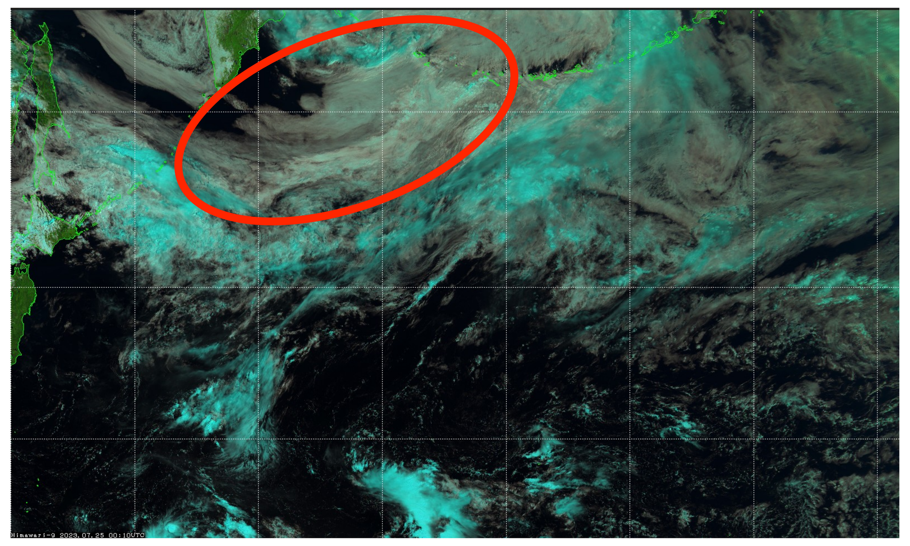

Fig.8. Day Natural RGB imagery of Himawari-9 satellite at 00UTC on 25th Jul. 2023.
Cyan color region indicate ice cloud and snow or sea ice covered area. White color region indicate water cloud.

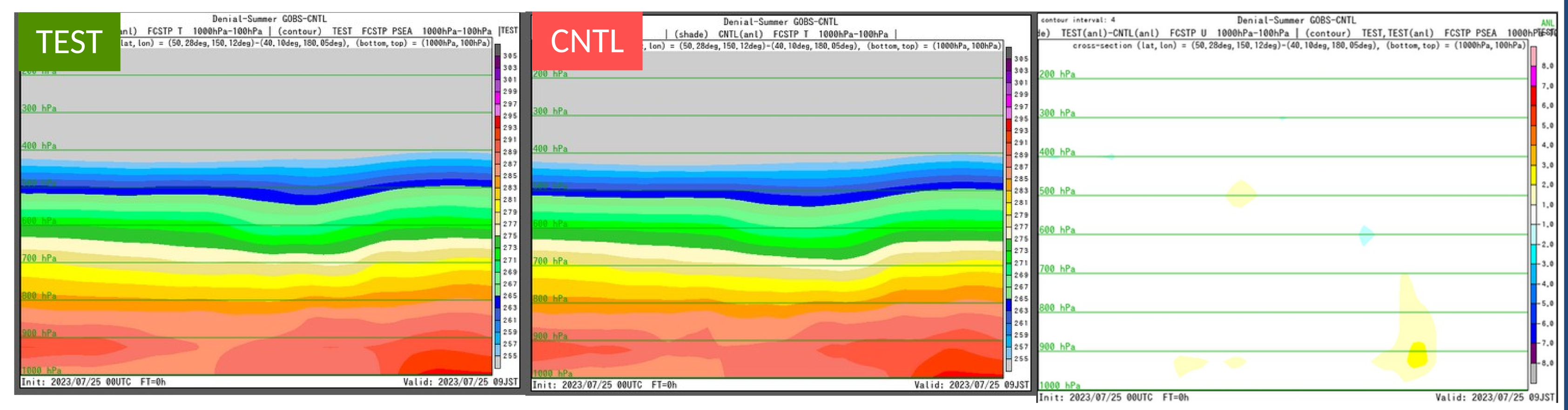

Fig.9. Vertical cross-section field of temperature(left, mid) and difference of U-component wind(TEST-CNTL) at 00UTC on 25th Jul. 2023(right).

Summary

- In this study, a denial experiment of scatterometer OWVs was conducted using the JMA's global NWP system, as a preliminary investigation to evaluate the impact on analysis and forecasts.
- While the forecast impact was generally neutral in this period. Analysis fields, particularly the lower-level winds and environmental parameters, showed degraded statistical consistency with observations.
- In the summer case, changes were seen in the near-surface zonal wind along the boundary of a high-pressure system over the northern Pacific, and it was shown that the representation of the low-level inversion layer was enhanced.

Reference

[1] Japan Meteorological Agency, 2024: Outline of the operational numerical weather prediction at the Japan Meteorological Agency. https://www.jma.go.jp/jma/jma-eng/jma-center/nwp/outline2024-nwp/index.htm

[2] Meteorological Satellite Center of JMA, 2024: Utilization of Meteorological Satellite Data in Cloud Analysis. Meteorological Satellite Center Technical Note, SP

[3]Wood,R.and C.S.Bretherton,2006： On the relationship between stratiform low cloud cover and lower tropospheric stability. J.Climate,19,6425-6432.