Impact study of scatterometer winds on heavy rain forecast in the JMA’s regional forecast model

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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 and distribution of water vapor field is one of the important factors for accurate heavy rain forecast.
- Japan Meteorological Agency (JMA) operates global and regional numerical weather prediction (NWP) systems to support the short- to medium-range weather forecasts.
- JMA started to consider using HY-2B and -2C wind products(HSCAT winds) by OSI-SAF[1] in the operational global and regional data assimilation.
- The impact of using HSCAT winds have been verified by observing system experiments (OSEs) with the latest mesoscale NWP system of JMA.

2. Overview of Pre-Analysis Procedure

Flag check — Check provided flags (rain, land/sea, sea ice etc.) and reject flagged data

Gross error check — Reject large |O-B| data

Group QC — Reject large |O-B| averaged by an area including similar wind vector observation
Prevent over rejection in and around severe weather condition

Ambiguity removal — Select the closest wind to JMA’s forecast by median filter after nudging

Thinning — 0.5 deg x 0.5 deg box
Eliminate spatial observation error correlation
Reduce calculation cost
Overlapping data rejection

Fig.1 Pre-Analysis Procedure for Scatterometer Winds on JMA’s NWP Systems

This pre-analysis procedure is same as of operational pre-analysis procedure for ASCAT winds. This pre-analysis procedure is also applied to HSCAT wind products in this experiment.

3. Specification of the experiment

•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 mesoscale assimilation system of JMA [2]

•HSCAT assimilation experiment(TEST)
–HY-2B,C/HSCAT winds are added to operational assimilation datasets. As scatterometer winds, Metop-B,C/ASCAT and HY-2B,C/HSCAT are assimilated.
–Preprocessing system is unchanged from CNTL.

•Experiment and verification period
–Analysis : From 27 May 2023 to 15 Aug. 2023
–Forecast : From 1 Jun. 2023 to 15 Aug. 2023
–Statistical verification: From 1 Jul. 2023 to 31 Jul 2023

Summary

- JMA has tested the data assimilation of HY-2B and -2C wind product on the latest mesoscale NWP systems by OSEs.
- Assimilated data numbers of scatterometer has been increased approximately 1.5 times by using HSCAT winds.
- Assimilated HSCAT winds are consistent to the model and characteristics of bias and standard deviation are similar to ASCAT winds.
- Increasing of assimilated data leads improvement of first-guess field on surface and lower layer elements and forecast skills on surface features.
- By using of HSCAT winds, forecast of the heavy rain area distribution on the typhoon event shows improvements due to direct effect of assimilation and indirect effect through the analysis cycle.

4. Statistical result of OSEs

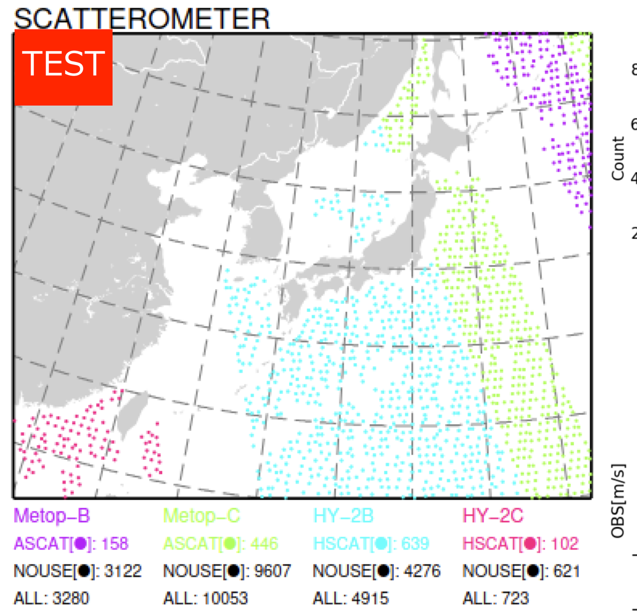

Fig.2 Data distribution of assimilated scatterometer data between 09 - 12 UTC 8 July 2023

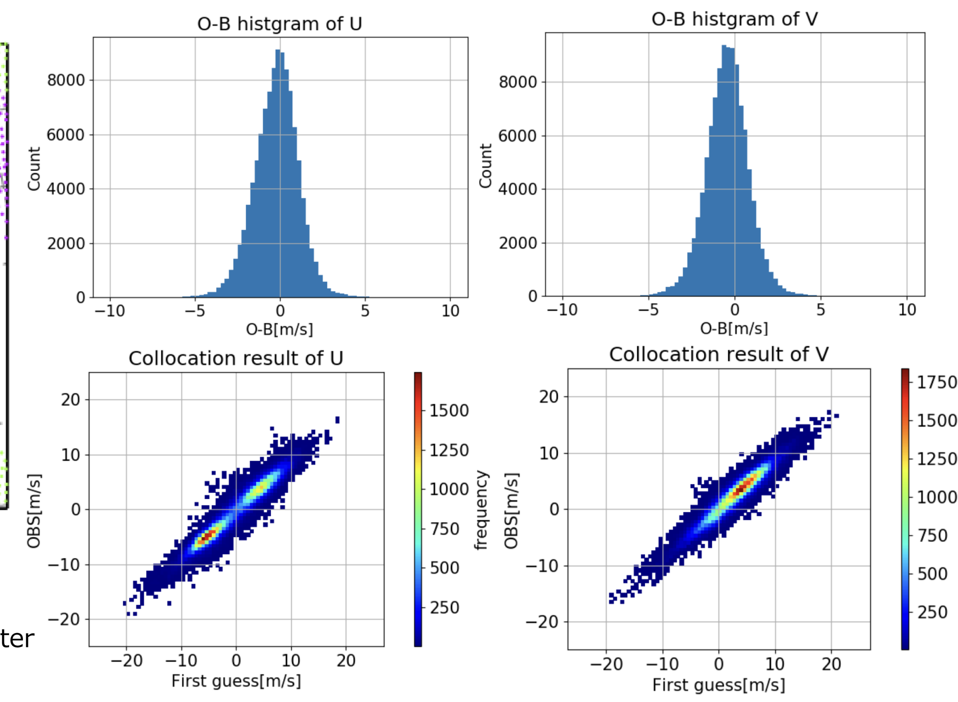

Fig.3 O-B histogram and collocation result of HSCAT winds on Mesoscale analysis

HSCAT	U	V
Data num	108420	
Bias(m/s)	-0.219	-0.426
STDV(m/s)	1.320	1.253

ASCAT	U	V
Data num	162662	
Bias(m/s)	-0.207	-0.324
STDV(m/s)	1.326	1.374

Table 1 Statistics of HSCAT and ASCAT winds on the TEST experiment

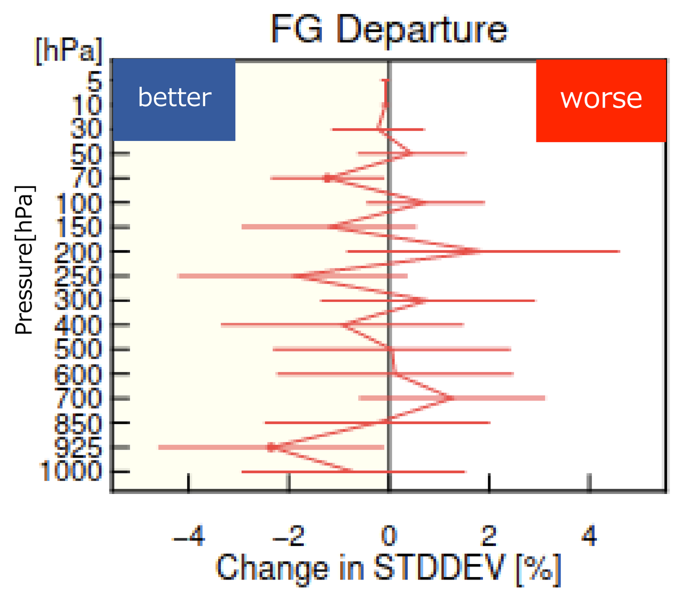

Fig.4 Change in standard deviation of the first guess departure compared to wind speed profile of radiosonde

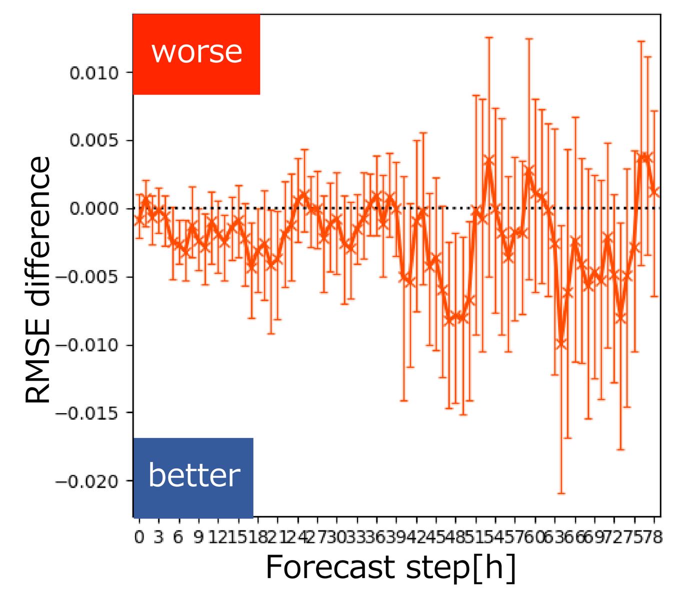

Fig.5 Change in RMSE of 10m wind speed forecast compared to SYNOP and AMeDAS observation

Assimilated data distribution (Fig.2) shows increase of scatterometer assimilation area coverage by using HSCAT wind product in the specific time. TEST experiment shows that HSCAT wind product (cyan and pink) cover the coverage of the pacific ocean. HY-2 series satellite path through the regional analysis area at different time from Metop series satellite due to difference of the orbit. It causes difference of passing time over the regional analysis region therefore time slots that assimilated scatterometer dataset exist are also increased.

Investigation of data quality of HSCAT winds (Fig.3) shows that HSCAT wind product is consistent to the model and characteristics of bias and standard deviation (STDV) are similar to ASCAT winds(Table 1). Statistics of assimilation also show that assimilated data number of scatterometer has increased approximately 1.5 times. By adding HSCAT winds, accuracy of first-guess field on test experiment becomes better than control experiment especially wind field(Fig. 4).

Verification of forecast (Fig.5) shows improvements of forecast skills on surface wind field. Forecast skills of other surface features such as surface pressure, mixing ratio, temperature(not shown) also shows improvements.

5. Case study of Typhoon event (Typhoon Khanun 2023)

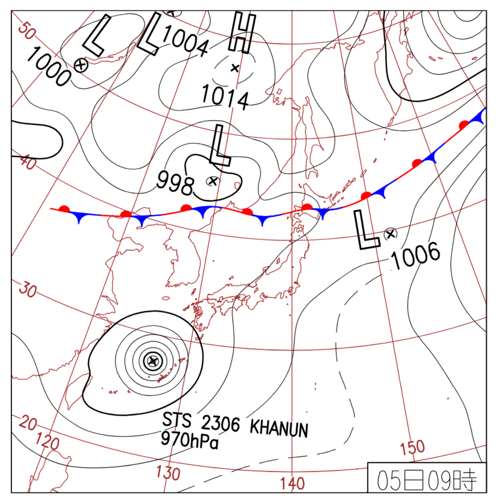

Fig.6 Surface analysis chart at 00UTC on 5th Aug. 2023. Typhoon Khanun is shown on the Okinawa islands.

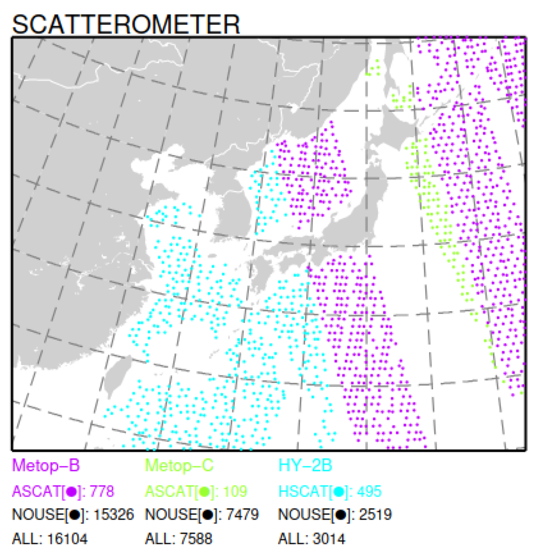

Fig.7 Data distribution of assimilated scatterometer data between 09 - 12 UTC 5 Aug. 2023

Typhoon Khanun 2023(Fig.6) caused heavy rainfall event on Okinawa. Kumejima-island AMeDAS station observed 245 mm/day on 5th Aug. 2023. In the TEST experiment, HY-2B was assimilated around western area of the Pacific Ocean and East China Sea on 12UTC analysis(Fig.7).
On the forecast step 6h from 12UTC on 5th Aug., comparison with Radar-Raingauge Analyzed Precipitation(R/A) indicates that TEST experiment shows more consistent distribution of typhoon rainfall compared to CNTL(Fig.8).

Fig.8 shows that forecast of distribution on typhoon related area of surface wind field and surface pressure field are also different between CNTL and TEST.

To separate the causes of these differences into those due to direct effect of the initial analysis and those due to indirect effect through the assimilation cycle, an additional experiment which uses the same first guess as TEST but HSCAT winds are not assimilated(TEST2) was conducted.

Right panel of Fig.9 shows the difference between TEST and TEST2 (TEST-TEST2) forecast fields(T+6) for EPT on 925hPa. It indicates direct effect of assimilation causes difference mainly around fringe of the typhoon area because HSCAT winds are not assimilated around central part of typhoon due to strong wind speed.
Left panel of Fig.9 also shows the difference between TEST and CNTL(CNTL-TEST) forecast fields(T+6) for EPT on 925hPa. Differences between TEST and CNTL include direct effect of assimilation and indirect effect through the analysis cycle. Compared to right panel, it indicates indirect effect through the analysis cycle affects to central part of typhoon area.

Therefore, Fig.9 shows that both of effect of improvement through the assimilation cycle and direct effect of assimilated datasets play an important role for the difference between TEST and CNTL on this typhoon event.

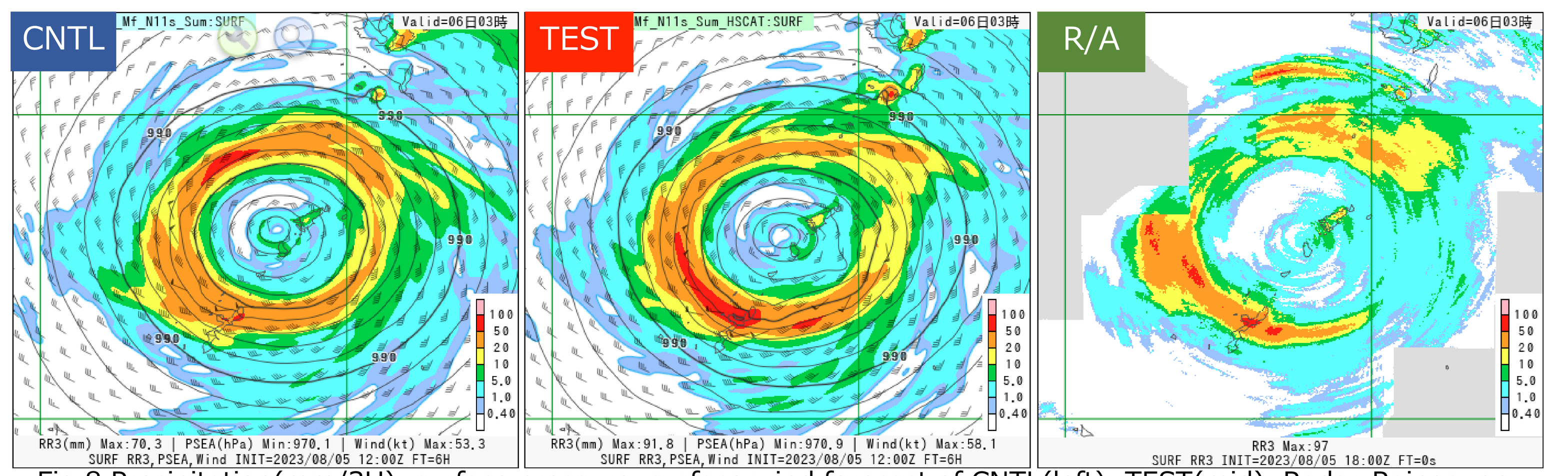

Fig.8 Precipitation(mm/3H), surface pressure, surface wind forecast of CNTL(left), TEST(mid), Radar-Raingauge Analyzed Precipitation(mm/3H)(right) on forecast step 6h. Valid time is 18 UTC 5 Aug. 2023

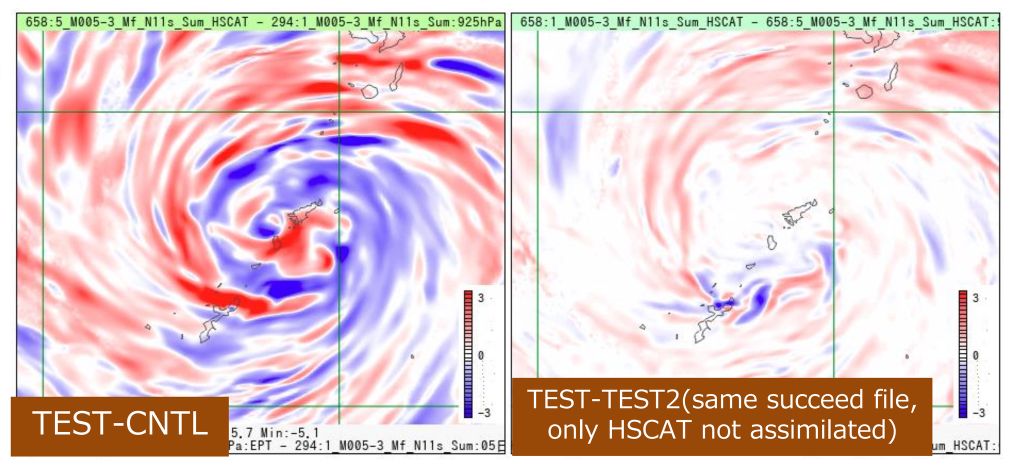

Fig.9 Difference of EPT(925hPa) forecast field on forecast step 6h. Initial time is the 12UTC 5 Aug. 2023.

Reference

[1] OSI SAF, 2021: HSCAT Winds at 25 km Swath Grid - Hai Yang 2B, EUMETSAT SAF on Ocean and Sea Ice, DOI: 10.15770/EUM_SAF_OSI_NRT_2000. http://doi.org/10.15770/EUM_SAF_OSI_NRT_2000
[2] 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