Operational Use of Shipborne GNSS-derived Precipitable Water Vapor in JMA's Mesoscale NWP System

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1. Introduction

The Japan Meteorological Agency (JMA) places high priority on improving accuracy in numerical weather prediction (NWP) for heavy rainfall.

Water vapor advection from seas in the lower atmosphere sometimes causes heavy rainfall, and NWP accuracy of heavy rainfall depends in good part on the precision of related fields as an initial condition. Although data assimilation is effective in improving initial field accuracy, water vapor observation networks for sea areas are not sufficient as those over land.

Ikuta et al. (2022) described improved prediction of heavy rainfall via assimilation of shipborne GNSS-derived precipitable water vapor (PWV) data (Shoji et al. 2017). Real-time PWV data from meteorological observation vessels for targeted areas and times also support operational NWP accuracy.

Against this background, JMA began assimilating shipborne PWV data in its mesoscale NWP system on August 31 2021. This report gives an overview of related experiments.

2. Shipborne PWV data and quality control

Shipborne PWVs are provided from two JMA observation vessels and four Japan Coast Guard vessels (as of March 2021) in near-real time.

Ground-based PWVs derived from the GNSS Earth Observation Network System (GEONET) of Geospatial Information Authority of Japan (analyzed from observation on the same principle as shipborne PWVs) have been used in mesoscale analysis since 2009 (Ishikawa 2010). Accordingly, equivalent quality control and data thinning are used for shipborne PWV data.

3. Assimilation experiments

Observing system experiments were conducted to evaluate the effects of shipborne PWV data assimilation on mesoscale analysis and forecasting. The control experiment (CNTL) had the same configuration as the operational JMA mesoscale NWP system as of May 2021, and the test experiment (TEST) was the same as CNTL except for the assimilation of shipborne PWVs. The experiments covered the period from June 1 to July 15 2021, which included several heavy rainfall events.

4. Shipborne PWV data quality

Figure 1 shows observation-minus-background (O-B) histograms of ground-based and shipborne PWVs. Table 1 presents mean and standard deviations of O-B and data counts of PWVs observed during the experimental period. The mean O-B of shipborne PWVs is slightly negative, while its absolute value is around the same as that of ground-based PWVs (approx. 10^{-1} mm). In Fig. 2's time sequence of shipborne PWV observation values, outliers are appropriately removed in gross error data rejection and other quality control processes.

5. Effects on analysis and forecasting

Several improved rainfall forecast cases were seen in TEST, as exemplified in the precipitation distribution of Fig. 3. Here, the initial condition water vapor field shows clear changes from assimilation of shipborne PWVs. The gradient PWV field gradient in the initial TEST condition is steeper near the shipborne PWV observation location (Fig. 4). Similar initial condition changes are seen in other improvements.

4. Summary

Shipborne PWV data quality is comparable to that of ground-based PWV data, and improved precipitation prediction from assimilation was observed. Excessive data rejection in quality control was seen in some cases, generally when there was a large discrepancy between the observed PWV and the NWP model's first-guess PWV. Further investigation on shipborne PWV usage and development for more appropriate quality control procedure are necessary toward the effective use of PWV data.

References

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Table 1. Shipborne and ground-based PWV: observations, mean values and standard deviations (Std) of O-B.

	Mean[mm]	Std[mm]	Number
ground-based PWV	0.29	2.50	1256145
shipborne PWV	-0.72	2.63	15562

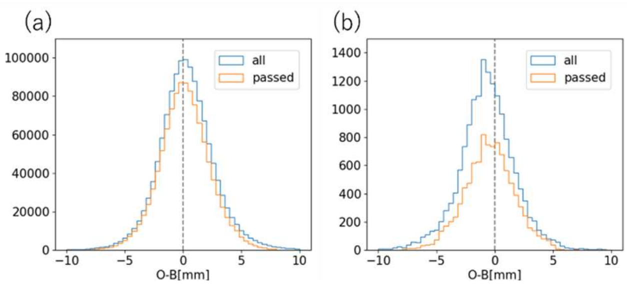

Figure 1. O-B histograms of (a) ground-based and (b) shipborne PWVs (blue: all data; orange: quality-controlled)

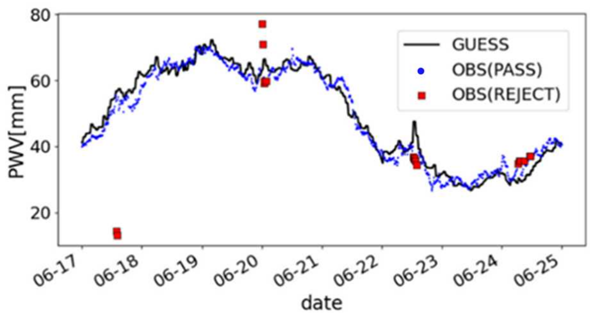

Figure 2. Ship-borne PWVs observed by JMA's Ryofu-maru vessel from 17 June to 25 June 2021 (black: background; blue: quality-controlled: red: rejected in quality control).

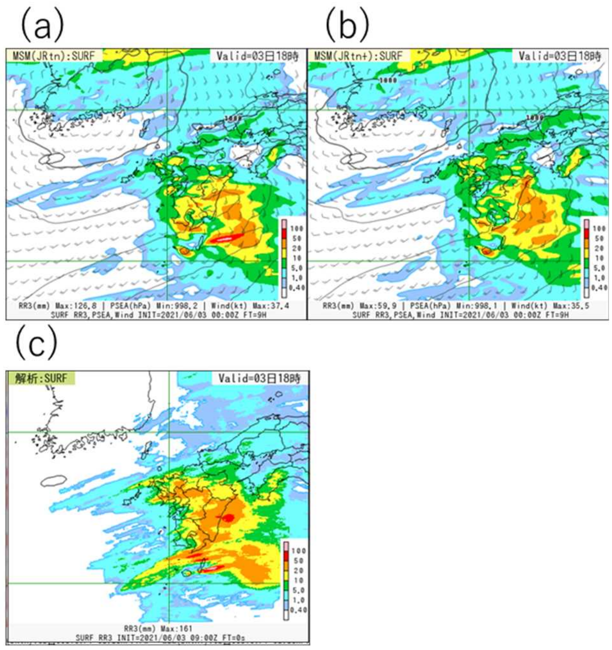

Figure 3. 3-hour accumulated precipitation at 09 UTC on June 3 2021. (a) TEST (9-hour forecast range), (b) CNTL (9-hour forecast range) (c) Radar rain-gauge analyzed precipitation.

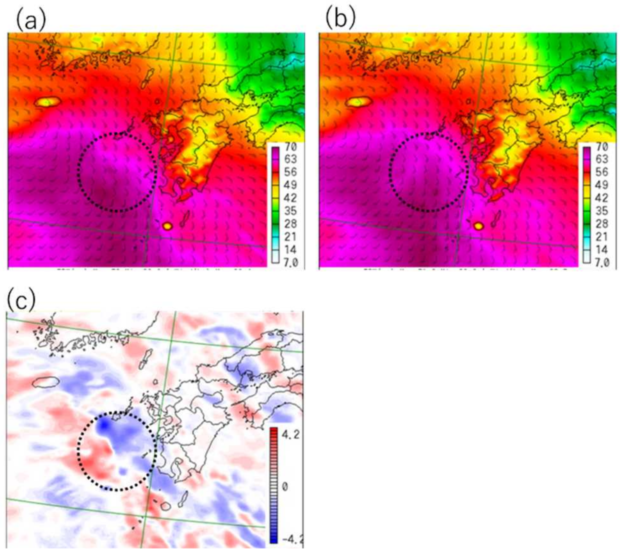

Figure 4. PWV in initial conditions at 00 UTC on June 3 2021. (a) TEST, (b) CNTL, (c) TEST-CNTL. Units are mm.