Operational Use of Surface Humidity Observations in JMA's Mesoscale NWP Systems

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1. Introduction

Water vapor in the lower troposphere has a significant influence on the occurrence and development of torrential rainfall caused by stationary linear mesoscale convective systems. Accordingly, assimilation of observation data that capture the inflow of lower-tropospheric water vapor is critical for the enhancement of torrential-rain forecasting. In this context, the Japan Meteorological Agency (JMA) observes screen-level relative humidity nationwide at SYNOP weather observation sites, and assimilates the results into its Local NWP System (JMA, 2023). To help clarify the characteristics of such vapor, the Agency incorporates hygrometers in its Automated Meteorological Data Acquisition System (AMeDAS) on a national basis, and has observed relative humidity since 2021. Assimilation of these observation data is expected to enhance the representation of lower-tropospheric water vapor and precipitation forecast accuracy.

JMA began operational assimilation of surface humidity data from the AMeDAS and SYNOP observation stations in its Mesoscale NWP system in March 2023. This paper describes data quality and related effects on precipitation forecasts.

2. Quality control (QC) for surface humidity data

The QC algorithm for AMeDAS surface humidity data is based on the existing process for SYNOP surface humidity data in JMA's local NWP system, where conventional humidity data are used. In addition, we introduced the dynamic QC and space consistency checking (Onogi 1998) for humidity observation in this algorithm. Observation errors and other factors for QC are recalculated from the results of observation minus background (O-B).

As AMeDAS does not collect the surface pressure data necessary for conversion of observed relative humidity to specific humidity (a variable in the assimilation system), surface pressure from the first guess (background) is used as an alternative.

3. Quality of new surface humidity data

Statistical comparison was conducted between AMeDAS humidity data and the already-established SYNOP data, including mean and standard deviations of O-B, for the period from August to December 2022. The results showed that AMeDAS data exhibit a wet bias to SYNOP data in summer, but the difference was smaller than standard O-B deviation. The statistics also showed sufficient quality for AMeDAS humidity data assimilation. However, the O-B statistics suggested that dry bias in the first guess to surface humidity observation is still present in summer, while surface humidity prediction accuracy with the Meso-Scale Model (MSM) was significantly improved for March 2022 (Sawada et al. 2022).

4. Effects on analysis and prediction

To evaluate the effects of the new humidity observation data on the Mesoscale NWP system, numerical experiments have been conducted based on the system since March 2022 (CNTL) with surface humidity observation data (TEST) for July 2021 and January 2022. Data assimilation resulted in a statistically significant improvement in surface humidity forecasts for both summer and winter (Fig. 1). For precipitation prediction, improvement was particularly pronounced where surface humidity observation data were assimilated upstream of heavy-rainfall areas. For 15 UTC on July 15 2022 as the initial MSM forecast time, accuracy for heavy precipitation improved in the 12-hour forecast because the assimilation of surface humidity data increased upstream precipitable water vapor (PWV) values, and vapor from these areas flowed to rainy areas (Fig. 2).

5. Summary

In relation to JMA's introduction of new hygrometers for AMeDAS sites all over Japan, this study clarified that the produced surface humidity data was of sufficient quality for assimilation. The introduction of these data for AMeDAS and SYNOP stations also improved forecast accuracy for surface humidity and precipitation in the Mesoscale NWP system. JMA began assimilation of these data in March 2023.

References

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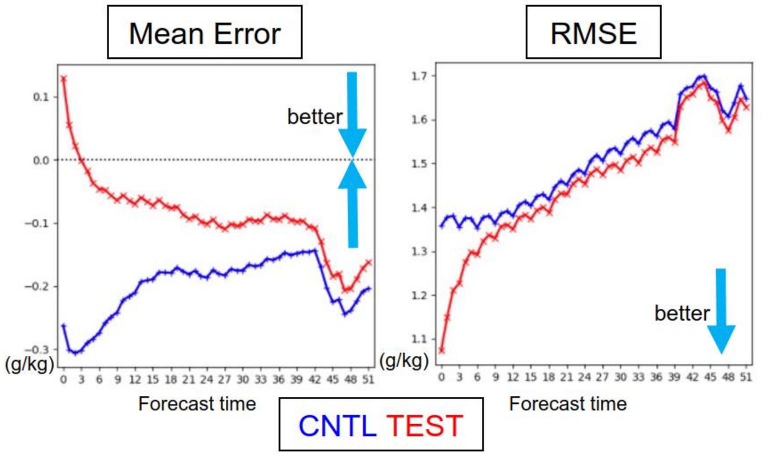

Figure 1. Mean errors and RMSEs for observation of specific humidity [g/kg] over the experimental period of July 1 – 31 2021. Blue lines: CNTL; red lines: TEST.

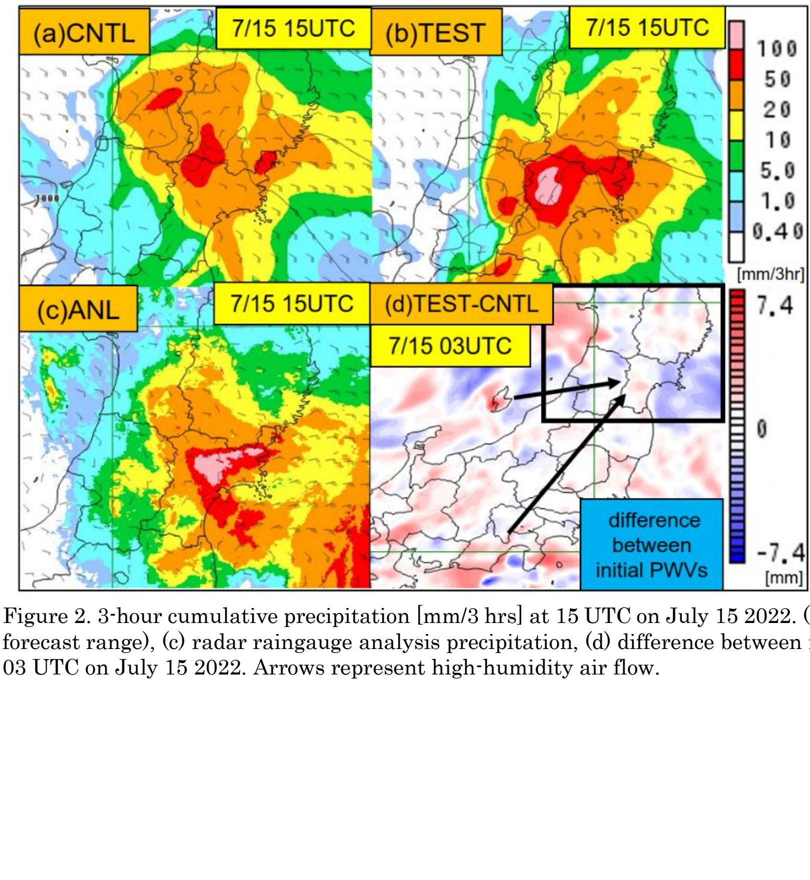

Figure 2. 3-hour cumulative precipitation [mm/3 hrs] at 15 UTC on July 15 2022. (a) TEST (9-hour forecast range), (b) CNTL (9-hour forecast range), (c) radar raingauge analysis precipitation, (d) difference between initial conditions of PWV [mm] (TEST – CNTL) at 03 UTC on July 15 2022. Arrows represent high-humidity air flow.