Improvements in the Upper-Air Observation Systems in Japan

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Abstract

Improvements in the upper-air observation systems are underway in Japan, such as replacement of conventional radars with Doppler radars and introduction of automatic balloon launchers (ABLs). In addition, experiments on ground-based microwave radiometer have been conducted for its operational use in Numerical Weather Prediction (NWP). GPS-derived integrated water vapor (IWV) processing on a near-real time basis is also in preparation for operational use.

1. Introduction

Japan Meteorological Agency (JMA) has started a project to enhance the performance of the upper-air observation network including the weather radar network, through introducing newly developed systems as well as improving existing systems, mainly aiming at prevention of disasters caused by mesoscale weather events. The project began in 2001 when a wind profiler network "WINDAS" was established to provide its data for NWP models (Ishihara et al., 2006). In the present paper we introduce the current status of the project, focusing on replacement of conventional weather radars with Doppler radars, deployment of ABLs, experiments of ground-based microwave radiometers for operational use, and preparation of the operational processing of GPS-derived integrated water vapor (IWV).

2. Replacement of conventional radars with Doppler radars

JMA is operating a weather radar network to make observation and nowcasting for precipitation over the whole country using three-dimensional radar echo data, and also eight Doppler weather radars at main airports to detect low-level wind shear. Replacing the conventional radars in the weather radar network with Doppler radars has been started in order to obtain wind data in precipitation and to provide them to the NWP models.

Impacts of Doppler radar data on NWP were examined through four-dimensional variational assimilation of the operational mesoscale model (MSM). Figure 1 is a result of the experiment (Ishikawa and Koizumi, 2006), showing that the forecast with the assimilation of Doppler velocity data predicts a heavy rainfall area more adequately than the forecast without the assimilation. Based on the effectiveness of Doppler velocity data evaluated by this experiment, a newly designed

Doppler radar, which extends observation range with triple-pulse repetition frequency and second-trip echo retrieval techniques, was installed in a Tokyo suburb in March 2006. Three more Doppler radars will start operation by March 2007 (see Figure 2).

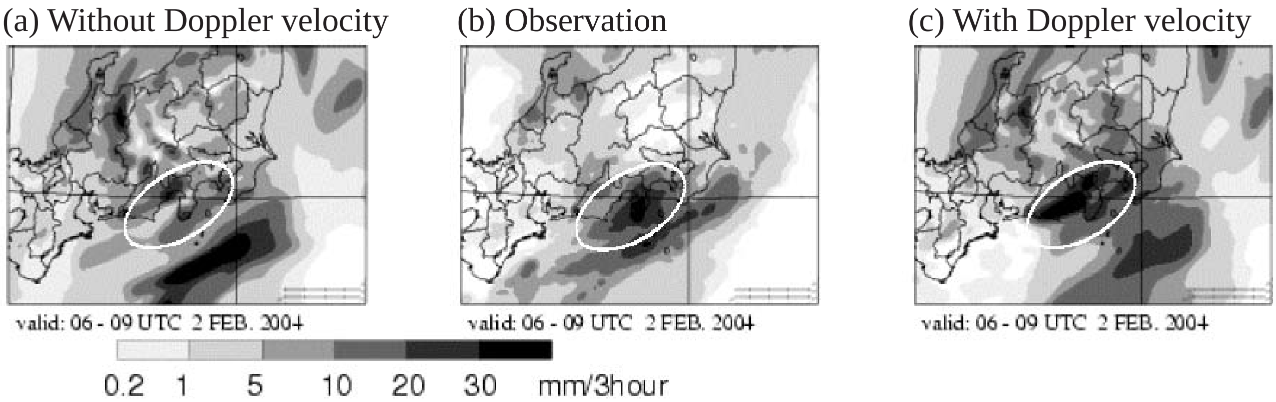

Fig. 1. Verification of 3-hour accumulated rainfall forecasts starting from 1800 UTC on 1 Feb 2004. (a) 12-15 hour forecast without the assimilation of Doppler velocity data, (b) observation, and (c) forecast with the assimilation (Ishikawa and Koizumi, 2006). Circles indicate heavy rainfall areas.

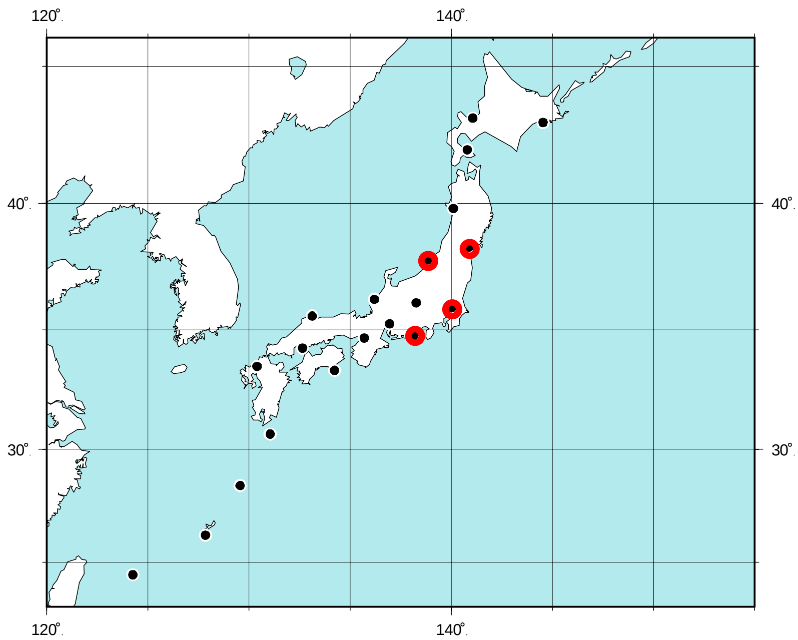

Fig. 2. JMA weather radar network (as of March 2007). Large red circles indicate Doppler radars.

3. Deployment of automatic balloon launchers (ABLs)

Figure 3 shows 18 radiosonde observation sites operated by JMA. The installation of ABLs is in progress at the sites on isolated islands as listed in Table 1. The ABL systems were designed to be operable under severe wind conditions (up to $25ms^{-1}$). ABLs at Hachijojima, Minamidaitoijima and

Ishigakijima are currently operating; remote operation from the JMA Headquarters is being planned.

Table 1. ABLs of the Japan Meteorological Agency

Station (year of installation)		Manufacturer	ABL	Radiosonde	Ground Equipment
47678	HACHIJOJIMA (2003)	VAISALA	AUTOSONDE	RS92-AGP	DigiCORA III
47945	MINAMIDAITOJIMA (2005)	VAISALA	AUTOSONDE	RS92-AGP	DigiCORA III
47918	ISHIGAKIJIMA (2006)	MEISEI	ARS	RS-01GM	RD-01G
47909	NAZE (2007)	MEISEI	ARS	RS-01GM	RD-01G

At the initial stage of the operation at Hachijojima, balloon launchings sometimes failed because balloons stuck to the inside wall of the radiosonde launcher due to heavily humid condition and strong wind. Also, sometimes balloons were not smoothly inflated in the balloon launcher under strong wind conditions. In order to avoid these troubles, the following improvements were made: a balloon cartridge was tilted, a funnel-shaped ring was attached to the orifice of the cartridge for smooth inflation, and a honeycomb-shaped rectifier was attached to the air vent in the bottom of the launcher to avoid oscillation of balloons under strong wind conditions. Parachute built-in balloons are used at Ishigakijima, and an unmanned hydrogen generator system will be in operation at Naze.

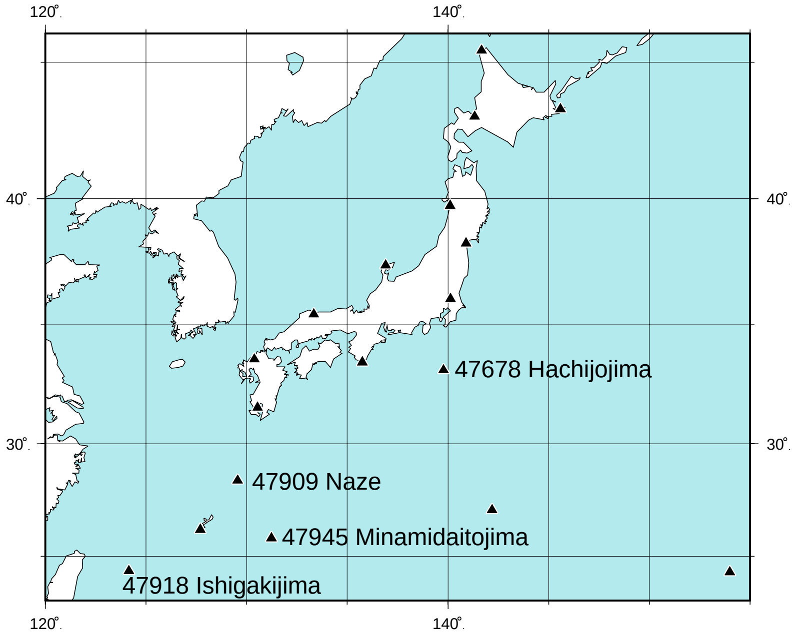

Fig. 3. JMA radiosonde upper-air observation sites.

4. Experiments of ground-based microwave radiometers for operational use

JMA has started experimenting operational use of ground-based microwave radiometers data in assimilation to NWP. A microwave radiometer, Radiometrics TP/WVP-3000 (Ware et al., 2003) was experimentally operated in the mid-latitude (Tsukuba: 36.0N, 140.1E) from April to May 2006, and in the subtropics (Naha: 26.2N, 127.7E) from June to July 2006. Figure 4 shows profiles of temperature and water vapor obtained from TP/WVP-3000 at 2305 UTC (under strong rain condition) and 2345 UTC (under light rain condition), on 9 June 2006 at Naha, as well as those from radiosonde at 2400 UTC. Nash (2005) reported that radiometer measurements were reliable in drizzle or light rains, whereas our experiment found that the radiometer measurements (with a rainfall mitigation system) showed good accuracy in temperature and water vapor profiles even in a strong rain condition. Another field experiment is underway using TP/WVP-3000 and Radiometer Physics GmbH HATPRO (Rose et al., 2005), in order to obtain data at higher latitudes in winter. An impact experiment on NWP is also underway using the data obtained from those field experiments.

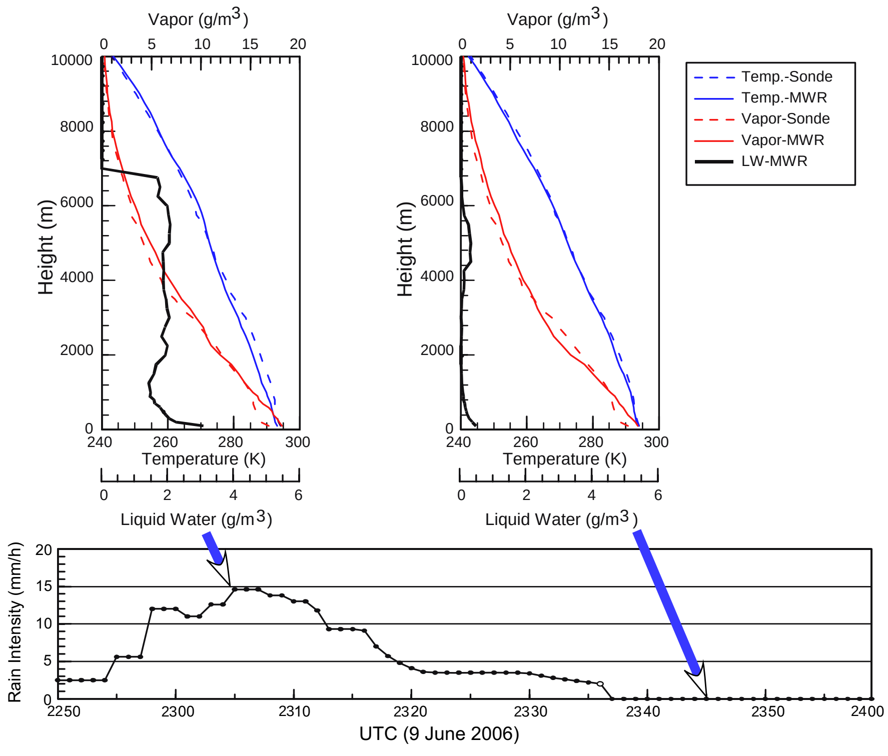

Fig. 4. Vertical profiles of temperature (blue solid lines), water vapor (red solid lines) and liquid water content (black thick lines) obtained from the microwave radiometer TP/WVP-3000 at 2305 UTC (upper left) and 2345 UTC (upper right) on 9 June 2006 at Naha. Profiles observed by radiosonde at 2400 UTC are also depicted in broken lines. Rainfall intensity from 2250 UTC to 2400 UTC is shown at the bottom.

5. Operational GPS-derived IWV Processing

Research and technical development for derivation of IWV from GPS meteorology has been made in the Meteorological Research Institute (MRI) of JMA (Seko et al., 2004), and the technique is now in the operational stage. The technique uses data from GEONET (GPS Earth Observation NETwork), a GPS network operated by the Geographical Survey Institute, the Ministry of Land, Infrastructure and Transport, Japan. In GEONET, approximately 1,200 GPS receivers are arrayed throughout Japan to monitor crustal deformation with an average distance of 20 km. The operational processing of IWV derivation using GEONET has been planned by JMA but not started because the information on orbits and clocks of GPS satellites are not available in realtime. MRI has developed a near-real time processing scheme using ultra-rapid information and GPS clocks corrected by the accurate clock of an International Global Navigation Satellite System Service (IGS) station, and has ascertained that the processing provides enough accuracy of IWV for assimilation to NWP (Shoji and Kunii, 2006).

Effect of horizontal IWV flux on rainfall nowcasting for several hours ahead has been examined (Yoshimoto et al., 2006). Figure 5 is an example of IWV flux obtained by using surface winds from the JMA's automatic weather station (AWS) network (AMeDAS) and GPV-derived IWV from GEONET. Among the radar echo cells shown by solid ellipse at 0500 UTC, only the cells with IWV convergences developed one hour later, while those with divergences decayed. On the other hand, radar echo suddenly appeared at 06 UTC in areas where no echo had been detected but there were IWV convergences (as shown by a dotted ellipse) one hour before. This example illustrates that IWV flux estimated with GPS might be a useful tool for precipitation nowcasting.

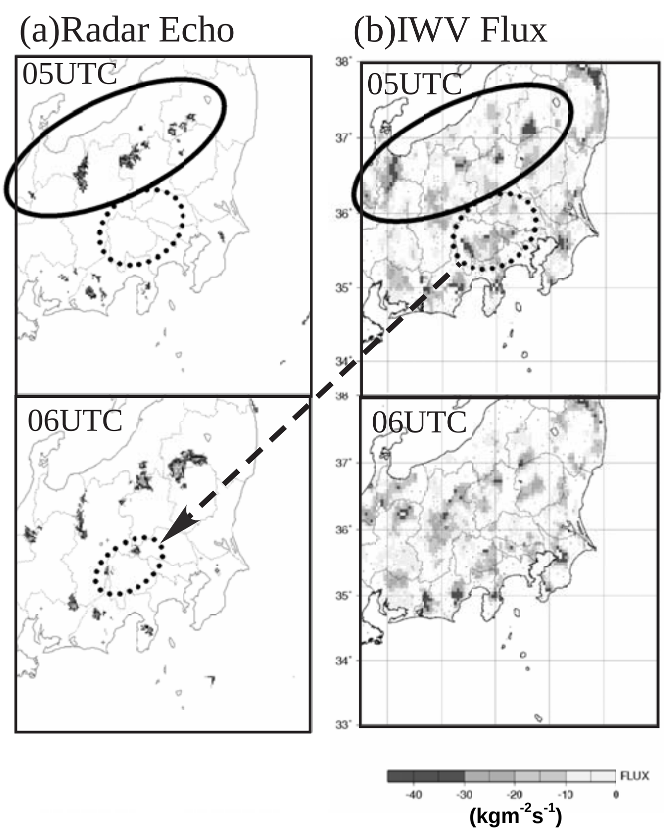

Fig. 5. Patterns of radar echo and IWV flux obtained by using surface winds from the AWS network and GPS-derived IWV from GEONET.

6. Summary

The project of improving the upper-air observation systems is underway in Japan, mainly aiming at prevention of disasters due to mesoscale weather events. In the project, Doppler radars equipped with a sophisticated technique are replacing conventional radars, and automatic balloon launchers are being deployed. Besides, operational uses of new remote sensing technologies such as ground-based microwave radiometers and near real-time GPS-derived IWV processing are currently being examined.

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