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The Wind Profiler Network of the Japan Meteorological Agency

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1. INTRODUCTION

The Japan Meteorological Agency (JMA) established the operational Wind Profiler Network and Data Acquisition System (WINDAS) for the enhancement of capability to watch and predict severe weather in Japan. The network consists of thirty-one 1.3GHz wind profilers which are located across Japan and the Control Center at the JMA headquarters in Tokyo. 25 wind profilers started to be in operation in April 2001 and 6 profilers has been added by June 2003.

Characteristics and performance of the system and effect of the profiler data on numerical weather prediction of heavy rainfall are presented.

2. BACKGROUND AND OBJECTIVES OF WINDAS

Atmospheric radars originally developed in 1970s for the research of the mesosphere and stratosphere have been extensively applied to operational use for observations of the troposphere wind fields since 1990s as demonstrated by the Wind Profiler Demonstration Network (NOAA, 1994) and COST74/76 (Oakley et al, 2000). In Japan, more than ten profilers including the MU (middle and upper atmosphere) radar of Kyoto University are being operated for research use. The Meteorological Research Institute (MRI) of JMA started basic research on wind profilers in 1989. Through the research in MRI and evaluation of profilers data on the numerical weather prediction (NWP) models, JMA decided to install an wind profiler network (Ishihara and Goda, 2000). Considering the cost performance and the allocation condition of radio frequencies in Japan, 1.3GHz wind profilers were selected for the network.

The major aim of WINDAS is to obtain initial wind fields for the operational NWP models. Special role has been given to WINDAS to improve the performance of the mesoscale model (MSM) with the horizontal resolution of 10km to forecast severe rainfalls which often cause heavy damages due to floods and landslips in Japan. Although wind measurements using 1.3GHz wind profilers are restricted to the middle and lower troposphere, almost all the amount of water vapor is concentrated in the layers and then streams of moist air could be well depicted with the profiler data. WINDAS and MSM are the two major tools in JMA to predict mesoscale severe weather events.

The profiler data have been put onto the Global Telecommunication System(GTS) for global exchange on an operational basis since April 2002 and are also published in CD-ROM for general usage.

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3. SYSTEM AND CHARACTERISTICS OF WINDAS

As shown in Figure 1, the locations of 31 profilers were selected giving the high priority on observations in the middle and western Japan where heavy rain storms occur almost every year. The intervals of wind profiler sites are ranged from 67 to 262 km and 120 km on average over the four main islands of Japan.

The profilers of WINDAS were designed based on the technologies developed by the Radio Science Center for Space and Atmosphere(RASC) of the Kyoto University and were produced by the Mitsubishi Electric Corporation. The following points were paid much attention : 1)high transmitting power(1.8kW), 2)high antenna gain(33dB), 3)up-to date pulse compression technique (8-bit coding), 4)intense clutter fences to prevent ground clutter and interference with other radars, 5)semi-globe radomes against heavy snow accumulation, 6) automated data quality control, and 7)full remote operation of the profilers from the headquarters of JMA in Tokyo. Table 1 summarizes main characteristics of WINDAS.

4. SIGNAL/DATA PROCESSINGS AND DATA QUALITY CONTOROL

At each profiler site, vertical profiles of 10-minute averages of spectral moments on the five beams are measured, and U, V, W components of wind are sent every hour to the Control Center via the JMA exclusive telecommunication lines or public digital lines. The computer system of the Control Center makes quality control, and sends the data to the JMA central computer for numerical predictions by 20 minutes after each hour.

Signal processing as well as data quality control are the keys to keep profiler data high quality. The specific processes to WINDAS are the estimation of Doppler spectral moments using the Gaussian function fitting (Hashiguchi et al., 1995) and the quadratic surface check for U and V components (Sakota, 1997). The former has the advantage of obtaining spectral moments under the condition of low S/N ratio. The latter has effectively eliminate erroneous data based on continuity of U or V components on a time-height cross. One to two percents of the total amount of data has been rejected on average at the stage of the data quality control.

At the early stages of the operation of WINDAS, ground clutter disturbed the wind measurement at several profiler sites. Enhancement of the performances of the clutter fences and improvement of the zero-Doppler velocity rejection in Doppler spectra in the data processing have almost solved the problem. Clutters from aircrafts or side robes of the antenna radiation occasionally appear, but they cause little troubles on the wind measurements.

The significant wind measurement error results from migrating birds. The erroneous data appear mostly in the night of spring and autumn under the fair weather conditions as well as in the profiler networks of U.S. and of Europe (Wilczak et al,1995 ; Engerbart and Gorsdorf 1997). The wind measurement deviations due to migrating birds extended to 90 degree in direction and 10 m/s in speed for the most pronounced case. In October 2001 when birds actively migrated over about half of the profiler sites, 12% of the total amount of WINDAS data were contaminated by birds. Echoes from migrating birds had been rejected by monitoring spectrum width during December 2001 to March 2003. The new algorithm, in which Doppler spectra with intense signal power are eliminated before the incoherent integration, has been developed and was introduced in the signal processor of the profilers in March 2003. The algorithm has recovered atmospheric signal from nearly half of birds-contaminated echoes.

5. DATA QUALITY AND IMPACT ON NWP MODELS

The wind profilers of WINDAS have four options in vertical resolutions: 100, 200, 300 and 600m corresponding to four pulse lengths. The longer pulse length has better height coverage, but the less vertical resolution. Data availability for each height resolution examined prior to the operation. Data availabilities of 50% in 100, 200, 300m height resolution were 3.0 km, 5.4 km and 6.4 km, respectively. Considering these height coverages, we selected the height resolution of 300m as the default operation mode in WINDAS. 300m is a sufficient height resolution for producing initial values of the current NWP models.

Signal power of 1.3GHz wind profilers highly depends on the amount of water vapor in the middle and lower troposphere. Figure 2 shows the monthly total means of height coverage at all the profiler sites from June 2001 to April 2002. The height coverages of WINDAS are 6 to 7 km in summer and at 3 to 4 km in winter and they have reached the original goal of JMA.

The measurement accuracy of WINDAS was evaluated by comparisons with the model forecast winds in June and July 2001. RMSEs of profiler winds from model winds as well as those between rawinsonde winds are shown in Figure 3. There is no significant difference between profiler winds and rawinsonde winds in the RMSEs. This means that the accuracy in the wind measurement of WINDAS is comparable to that in rawinsonde observation.

The data of WINDAS have been used as an initial value in all the NWP models operated in JMA since June 2001. The 4-dimensional variational data assimilation (4D-VAR) started to be in operation in MSM in April 2002. 4D-VAR makes the best use of the potential of profiler data because of the capability of continuous measurement of upper-air winds. Figure 4 illustrates a result of an impact experiment made by MSM using WINDAS data with the 4D-VAR for a severe rain storm occurred in June 2001 (Tada, 2001, private communications) . The profiler data and the 4D-VAR well improved the accuracy of the location of the severe rain storm in MSM.

6. PERFORMANCE IN OPERATION

In order to evaluate the reliability of the operation of WINDAS, the percentage of data received in real-time at the Control Center were examined. The monthly total means over all the sites have been over 98.8% since May 2001. This indicates that stable operation of the system has been accomplished

7. CONCLUSIONS

JMA has operated the wind profiler network for tow years and the profiler data are effectively used in real-time for numerical weather prediction. Issues on ground clutter and migrating birds have been practically solved. Retrieval of vertical water vapor from signal power and spectrum width of profilers will be one of the future plans.

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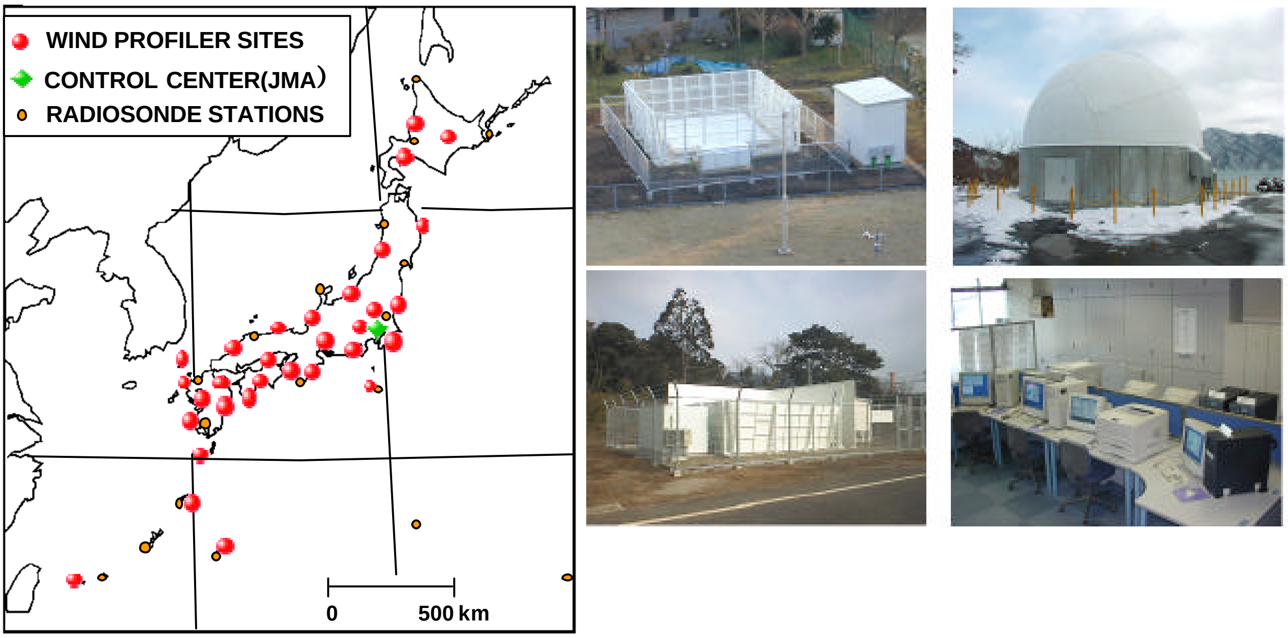

Figure 1. The locations of WINDAS and photos of the wind profiler sites and the Control Center.

Table 1. Characteristcs of wind profilers of WINDAS .

Frequency	1357.5 MHz
Antenna	coaxial colinear arrays with gain of 33dB and size of 4m x 4m
Peak Power	1.8 kW
Beam width	4 °
Beam configuration	5 beams
Pulse length	0.67, 1.33, 2.00, 4.00 μ s
PRF	5, 10, 15, 20 kHz
Side robe level	-40dB or -60dB (at elevation angles of 0 - 10 °)
Basic data	Doppler moments every 1 minute
Distributed data	U,V,W-components of wind, S/N ratio, & data quality flag every 10 minutes

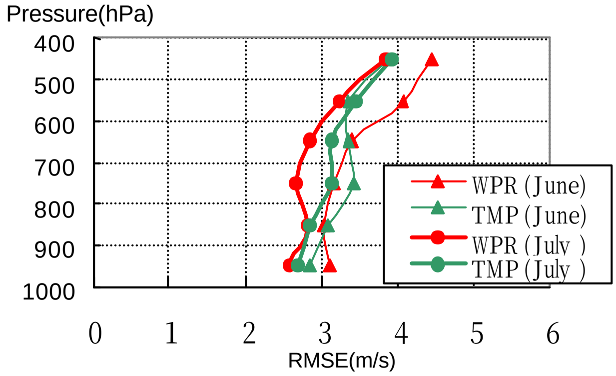

Figure 3. Vertical distributions of RMSEs of profiler winds (WPR) from winds by mesoscale model(MSM) and those of radiosondes winds (TMP). u-components of winds in June and July 2001 are examined.

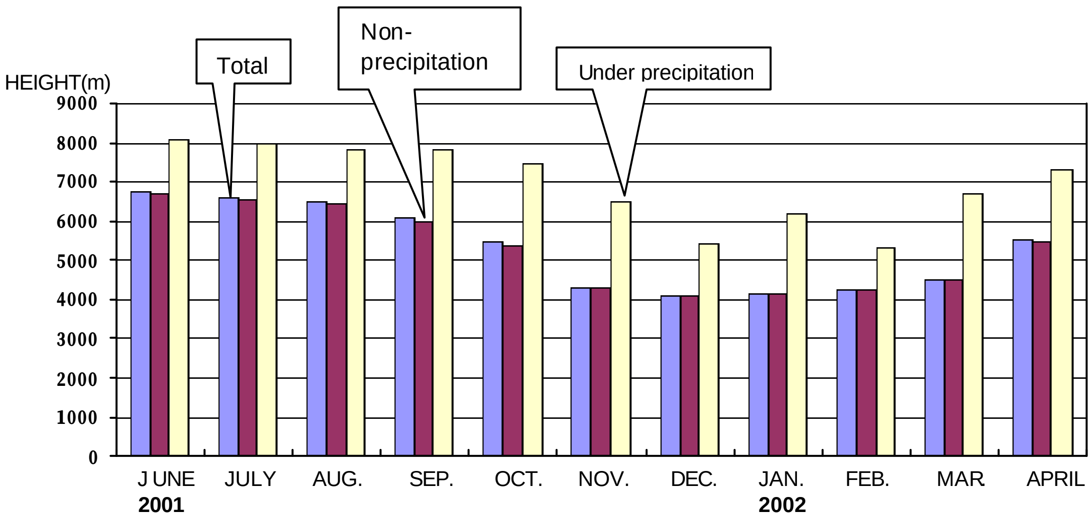

Figure2. Monthly total means of height coverage for 25 wind profilers of WINDAS.

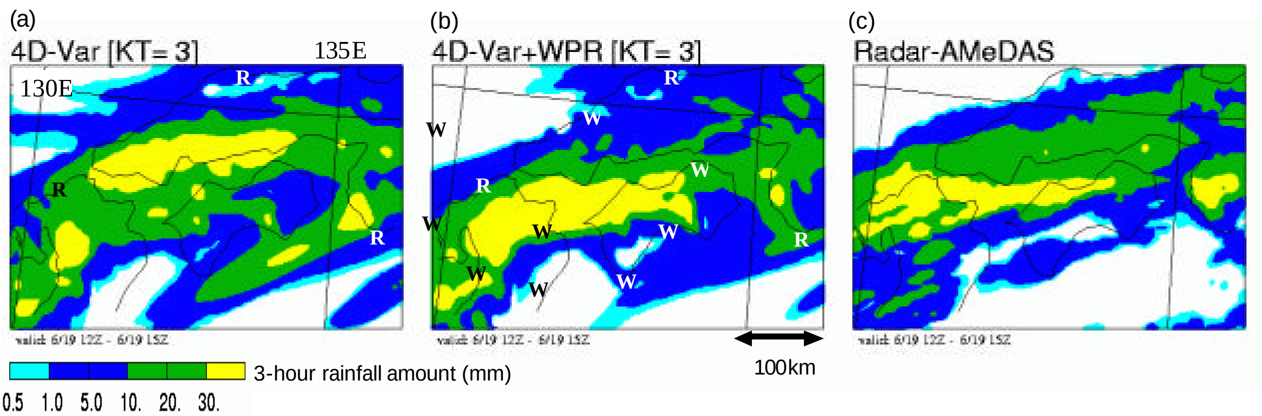

Figure 4. Results of an observing system experiment on comparison between forecasts by the mesoscale model (MSM) and observations for 3-hour rainfall amount. The initial time is 12UTC on 19 June 2001. (a) forecasts from MSM and 4D-VAR without profiler data but radiosonde data, (b) forecasts from MSM and 4D-VAR with both profiler data and radiosonde data, and (c) rainfall amount observed by radars and rain gauges during 12 to 15UTC. 'R's in (a) and (b) indicate the locations of the radiosonde sites and 'W's in (b) the locations of the wind profiler sites.