WORLD METEOROLOGICAL ORGANIZATION

JOINT MEETING OF
CBS EXPERT TEAM ON SURFACE-BASED REMOTELY-SENSED OBSERVATIONS
(Second Session)
AND
CIMO EXPERT TEAM ON OPERATIONAL REMOTE SENSING
(First Session)

(GENEVA, SWITZERLAND, 5-9 DECEMBER 2011)

CBS/ET-SBRSO-2 & CIMO/ET-ORS-1/Doc.5.3

(25.XI.2011)

ITEM: 5.3

Original: ENGLISH ONLY

RADAR WIND PROFILERS

Status of Operational Guidance and Regulatory Material

Guidance on Operational Wind Profilers

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Summary and Purpose of Document

This document presents an outline of the draft guidance material prepared by JMA, which is under the procedure to be published as IOM reports. The guidance describes, in particular, requirement for installation, quality management and the operation of the Wind Profiler Network of JMA (WINDAS).

ACTION PROPOSED

The meeting is invited to note the guidance material and consider that same applicable information could be reflected to the CIMO Guide (WMO-N0.8).

Guidance on Operational Wind Profilers

A draft guidance material prepared by JMA, which is under the procedure to be published as one of the IOM reports is briefly presented, with special emphasis on requirement for installation, quality management and the operation of the Wind Profiler Network of JMA, called WINDAS, for the joint CIMO/CBS expert team on Operational Remote-Sensing Geneva, December 2011.

1. Abstract of the guidance material

1.1 A wind profiler is a device that continually measures wind speed and direction in the upper air using radio waves. It plays an important role in monitoring atmospheric phenomena and providing initial values for numerical prediction models. Operational wind profiler networks are used around the world, including in the United States, Europe, and Japan. They have worked to improve the corresponding data quality management and advance the technologies that use this data.

1.2 First, the guidance focuses on the matters which should be considered (such as site location, radio frequency, and height and time resolution) on a new installation of wind profilers, based on the operational experience of the wind profiler network in Japan (hereinafter referred to as "WINDAS"). JMA introduced wind profilers in the 1.3 GHz band, after considering required height coverage, radio frequency allocation, and costs. Since the administration policy of radio frequency allocations could differ by countries, especially when choosing a radio frequency, it should be examined from a broad perspective. Moreover, environmental conditions of each observation station should be considered: for example, in Japan, a radome was introduced to some stations for protecting the equipment against snow cover in winter.

1.3 With regard to the parameters used in wind profilers, there are unfamiliar terms which are not usually used in weather radars, such as pulse compression or coherent integration. With a brief introduction to these terms, JMA describes the need to select the appropriate combination of observation parameters, some of which have a trade-off relationship between them.

1.4 To illustrate practical performance of wind profilers, the guidance provides the height coverage and the data acquisition rate in WINDAS. It also indicates that the observational data keeps adequate accuracy by comparing them with radiosondes and numerical weather predictions.

1.5 Wind profilers of each manufacturer, despite the same principles of observation, have different hardware configuration. Hence, the guidance introduces the equipment configuration in WINDAS as a reference. Despite unattended operation, WINDAS has operated stably for a long time throughout which the average operation rate is higher than 99%. This would owe much to the regular on-site inspection and maintenance of equipment. JMA also analyzes the cause of the failure, and summarize what attention should be paid to in advance.

1.6 The quality management is of much importance for the remote sensing, because more invalid data is usually mixed in than in situ measurements. The guidance describes in detail the techniques of quality control in WINDAS. Various quality management procedures are conducted at each phase of signal and data processing, in order not to output invalid data as far as possible. More than 1 % of the observation data is actually treated as invalid by these quality management processes.

1.7 Finally, the guidance briefly introduces some examples of utilization of the data. With the data of received signal intensity in addition to wind speed and direction, wind profilers can be used to monitor the various atmospheric phenomena.

2. Requirements for Installation of Wind Profilers

2.1 Site Location

The following five points were laid down as rules for the selection of wind profiler installation points from the perspective of (1) utilization of observation data, (2) operation of equipment, and (3) installation cost.

[1] The primary purpose of installing a wind profiler is to use its observation data as the initial values for meso-scale NWP models in order to improve the prediction results for meso-scale phenomena with horizontal scales of 100 km or more. Thus, wind profilers will be installed around Japan so that the average spatial interval becomes 100 km when combined with the current upper-air sounding network which uses radiosondes.

[2] Wind profilers will not be installed in general at radiosonde observation points, because the highest possible density for the observation network is achieved by combining wind profilers with the current radiosonde observation network.

[3] Wind Profilers will be installed in high concentrations in those areas that have a possibility of becoming upstream regions of areas with heavy rain and snow. This is so that observations can be made of the movements of the humid airflows that play an especially important role in generating and sustaining heavy rain and snow.

[4] Wind profilers will be installed in high concentrations in areas where major weather-related disasters have occurred in recent years or in the past, and in densely populated areas.

[5] In order to ensure that observation data are representative, wind profilers will not be installed near steep terrain that would not be expressed in meso-scale NWP models.

JMA selected a shortlist of points based on the above requirements and determined the final installation points after examining interference with other radio stations and obtaining the final approval to use radio waves from the radio wave administration authorities.

The interval between observation points in the conventional upper-air sounding network using radiosondes was 300 to 350 km. However, the addition of the wind profiler observation network makes the average interval between observation points 120 to 150 km. Figure 1 shows the installation points of the wind profilers and the radiosonde observation points. The intervals between observation points largely satisfy the 100 km horizontal resolution recommended for wind profiler networks by the WMO (WMO, 1997).

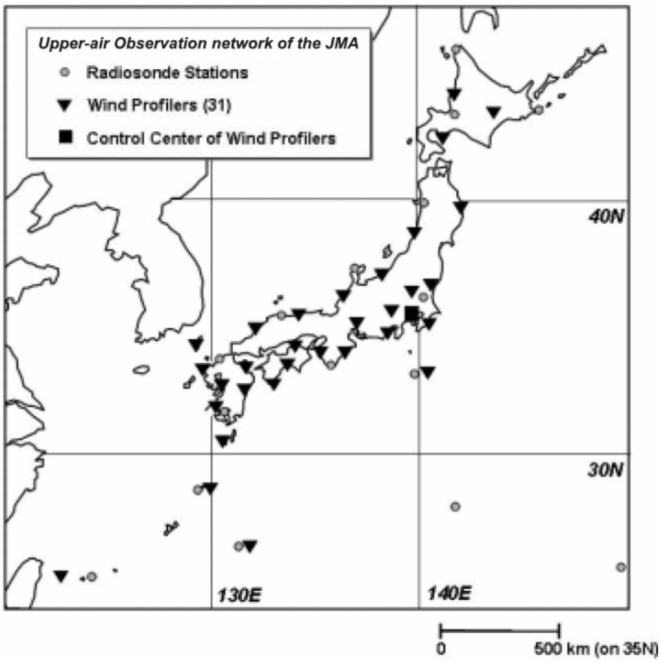

Fig.1 Site locations of the wind profilers of the WINDAS and radiosonde stations of the JMA.

2.2 Radio Frequency

Wind profilers are roughly divided into three categories depending on the frequency of the radio waves used: the 50 MHz band, the 400 MHz band and the 1.3 GHz band (900 MHz band in some countries). The available observation altitude varies depending on the radio frequency used.

The 400 MHz band has the advantage of being able to observe up to about 15 km altitude. 404 MHz was formerly permitted around the world as a frequency for wind profilers. However, the only permissible frequency came to be 449 MHz to avoid interference with the frequency of the Search And Rescue Satellite Aided Tracking (SARSAT) System. The 50 MHz band has more height coverage. On the other hand, it requires larger area and more costs for installation. Typical characteristics of wind profilers with each frequency band are summarized by the WMO (WMO, 2008).

In Japan, it is impossible to use wind profilers with a 400 MHz band, because 449 MHz was already allocated to medical telemetering. Therefore, the 1.3 GHz band wind profilers were adopted for WINDAS, because the most important objective was to conduct detailed observation of the flow of the lower atmosphere, which is strongly related to heavy rain and snow. Aspects related to cost were also taken into account in this decision. In the conventional categorization, a wind profiler with the 1.3 GHz-band was called “boundary layer radar”, and its highest observation altitude used to be two to three kilometers. WINDAS, however, has improved observation capabilities with expanding antenna sizes, increasing transmission power, and adopting technologies such as pulse compression, while still using the frequency of conventional boundary layer radar; its highest observation altitude was nine kilometers and the annual average for the highest observation altitude was around five kilometers.

2.3 Height and Time Resolution

In general, the height resolution is determined by the pulse width which is one of the observation parameters. The height resolution in WINDAS has set to 300 m, although 100m is recommended below 2km for regional NWP models (WMO, 2010). This is because JMA's current data assimilation system for the meso-scale model (4-Dimensional Variational data assimilation: 4D-Var) (JMA, 2007) requires observation data free of vertical error correlations, and therefore higher resolution is not needed.

WINDAS performs observation of wind speed and direction every minute and calculates ten-minute averages. At first, the ten-minute average was calculated from ten-minute Doppler velocity averages along each beam direction. However, it was found that a more precise ten-minute average was able to be calculated stably from one-minute values, and therefore this method was adopted.

By selecting these height and time resolution, it is possible, in addition to be used for NWP models, to monitor the change of wind aloft when a front passes, and the strength of vertical wind shear.

2.4 Others

Of the conditions to be considered when installing wind profilers, Dibbern et al. (2003) provides detailed descriptions on the following points.

- Clutter prevention
- Interference of radio waves
- Problems of sound wave noise when using RASS (Radio Acoustic Sounding System; this system consists of a wind profiler and a few speakers, and can observe the virtual temperature profile.(Marshall et al., 1972; Matuura et al., 1986))
- Corrosion prevention (prevention of salt damage)
- Improvement of lightning resistance

Besides the above points, the following must also be considered as conditions for installing wind profilers.

- Secure power sources
- Secure ways to transmit data
- Prevention of snow accumulation in snowy areas

3. Quality Management

3.1 Background of Quality Management

Because wind profilers measure the wind by receiving faint radio waves, they are vulnerable to influences such as non-atmospheric scattering and noise, so that the observations obtained may often include erroneous values. Therefore, it is necessary to perform quality management on the observation data.

Quality management at observation stations
<Signal processing>
•Removal of bird echo
•Removal of ground clutter
<Applicable to one-minute values>
•Spectrum width check
•Homogeneity check in the wind field
<Applicable when producing ten-minute averages>
•Consensus average

Quality management at Control Center
<Applicable to ten-minute averages>
•Quadric surface approximation check
•Vertical shear check
•Manual quality management

Fig.2 Overview of quality management in WINDAS

3.2 Quality Management at Observation Stations

3.2.1 Removal of ground clutter

(Hardware Measures)

The antennas of the wind profilers are designed to minimize side-lobes and metal fences (clutter fences) of two meters in height are installed in order to physically block the side-lobes.

(Software Measures)

The digital signal processors first calculates the slope of the spectrum curves around zero Doppler velocity, and identifies the curve as ground clutter if its slope exceeds a certain threshold, removing it and connecting the ends of the two remaining curves to give a spectrum curve with the terrain echo excluded.

3.2.2 Spectrum width check

The normal spectrum width is from 2 to less than 3 m/s, and significantly larger or smaller values are likely indications that scattering due to objects other than the atmosphere or precipitation particles is being observed. If the spread of the distribution exceeds a previously determined threshold, the data (the one-minute value) is classified as invalid by this quality management. Data exhibiting extreme deviation is removed by the spectrum width check using thresholds of 0.3 m/s or 0.4 m/s as the lower limit and 9.0 m/s as the upper limit.

3.2.3 Homogeneity check in the wind field

WINDAS wind profilers usually calculate horizontal wind and vertical flow based on the Doppler velocity observed in the five beam directions (the vertical direction and the north, south, east and west directions at an elevation angle of 80 degrees). The observed horizontal wind speed is correct when there are no precipitation particles, or when the precipitation particles are evenly distributed. However, when precipitation particles are present only on one side of the beam, the observed horizontal wind speed differs from the actual value. To reject these abnormal values, the method first checks whether the wind field is homogeneous (whether the individual beam values can be treated equally) before producing one-minute values of wind vector based on the Doppler velocity in the beam direction. If the quality is found to be acceptable in the check, the system calculates the wind vector.

3.2.4 Consensus average

The consensus average is used to obtain the ten-minute averages based on the one-minute values. The method is to calculate the average after removing values that deviate to an extreme extent from the overall average.

The ability of consensus averaging to remove extreme values and its average production rate (the ratio of cases in which an average is produced) vary depending on the consensus numbers and the threshold of ΔV. JMA adjusted the thresholds in actual operation in accordance with the results of the simulation at operational wind profilers.

3.2.5 Removal of echo from migratory birds

JMA found that the strength of the bird echo was not constant; it showed large fluctuations within short time intervals (intervals of around 0.4 seconds). Using the characteristics of the bird echo, JMA set up the signal processor to recognize it as the presence of bird echo in micro-time segments and remove the data. And the one-minute value of the received spectrum could be produced using the received spectra without bird echo.

By making use of the difference in time variation between the received power for bird echo and that for precipitation echo, it is possible to remove bird echo only and to prevent precipitation removal. JMA set up the following two methods as the algorithm for the all-weather automatic operation, to determine a received power threshold for the removal of data:

(1) the absolute method in which a previously determined value is applied as the threshold, and

(2) the relative method which adds a previously determined bias value to the smallest received power value observed in the previous hour and uses the sum as the threshold.

The absolute method and relative method are selected in accordance with the difference between the largest and smallest values of received power. The absolute method is used when the difference is large, because it is likely that bird echo is occurring. Conversely, the relative method is used when the difference is small, because precipitation echo might be occurring.

3.3 Quality Management at Control Center

3.3.1 Quadric surface approximation check

The quadric surface approximation check is a method to approximate wind component values (north-south component and east-west component) by a three-dimensional quadric surface where the X axis represents time, the Y axis altitude and the Z axis wind component, and to identify data that deviates by a certain distance from the quadric surface as invalid data.

3.3.2 Vertical shear check

Vertical shear check is a quality management procedure which focuses on data at a given point and time and categorizes it as “invalid” when the adjacent data indicates a wind speed in the vertical direction having a shear that exceeds a certain value.

3.3.3 Manual quality management

As part of quality management at the Control Center, observation officers perform visual checking of the values after the data has been processed in automatic quality management, the main part of which is quadric surface approximation checking. In this visual checking process, the observation officers manually revise quality management information when necessary (manual quality management).

3.3.4 Quality management status at Control Center

The average ratios for management categories for all data obtained since July 17, 2001, when automatic quality management started in operation, to January 31, 2002 are as follows.

“Automatically marked invalid”:	1.3% (of all data)
“Manually marked invalid”:	0.2% (of all data)
“Manually marked valid”:	0.1% (of all data)

4. The Control Center of WINDAS

The Control Center is installed in the headquarters of JMA and equipped with servers, data monitors, and operation monitors. Officers are assigned to the Control Center around the clock to monitor data input/output and the condition of the devices, to operate devices by remote control and to conduct data quality management (Figure 3).

4.1 Servers

The servers control communication with the individual observation stations, the NWP system, and the GTS server. They collect one-minute values and ten-minute average values every ten minutes from the individual stations and stored them. The collected ten-minute wind averages are sent to the NWP system and the GTS lines every 10 minute and every one hour, respectively, in the Binary Universal Form for the Representation of meteorological data (BUFR).

The servers have a redundant configuration, consisting of the main and sub-systems in the headquarters of JMA. In addition, a back-up system is installed in remotely-located Meteorological Observatory in case of total failure of the systems in the headquarters due to, for example, earthquake.

4.2 Data monitors

The data monitors are equipped with functions to display the time-altitude cross sections of ten-minute averages, received signal intensity, and spectrum width stored on the server, and to allow observers to manually run quality control check, in which defect flags are added for the values judged as erroneous.

4.3 Operation monitors

The operation monitors display the monitoring status on the screen, showing the condition of the individual observation stations and transmit control and data request signals to individual observation stations. Condition monitoring information (housekeeping information) includes information on normal/abnormal operation of individual devices, status regarding the opening/closing of station doors, room temperature, and the condition of the power breakers. The control signals include signals to start/stop devices, start/stop radio wave emissions, and restart the data processor.

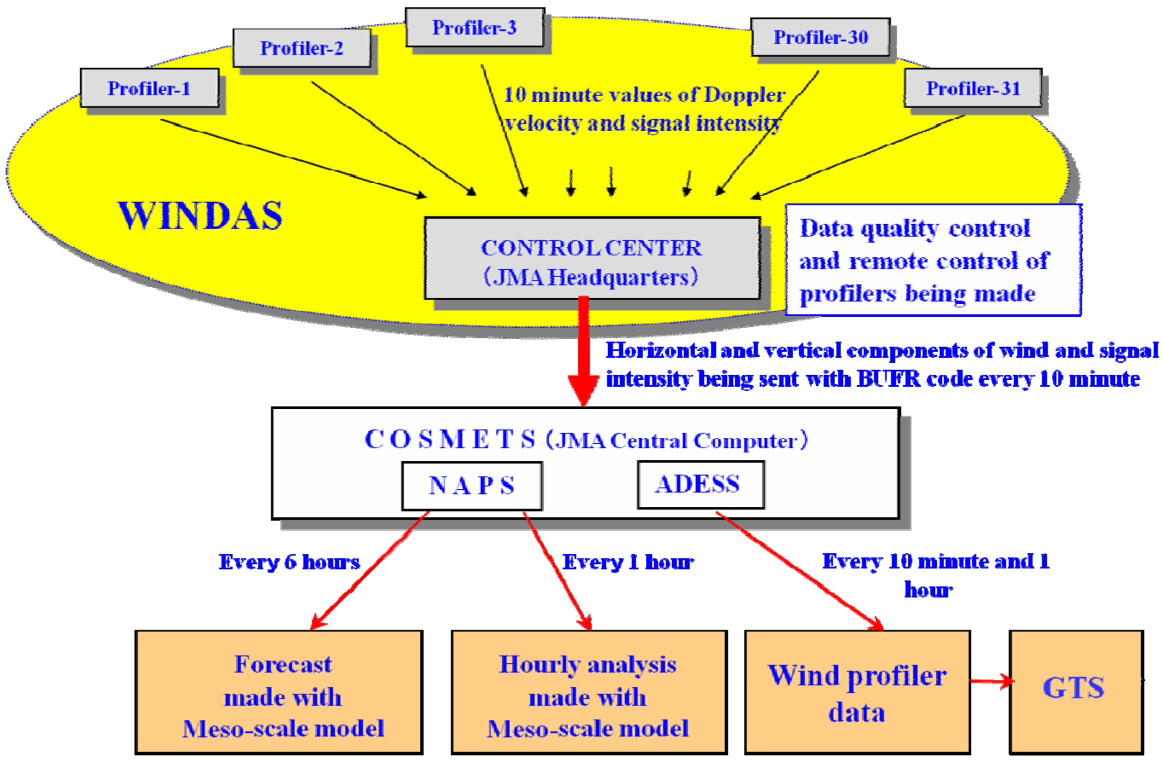

Fig.3 WINDAS data flow

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