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PRESENTATIONS ON RECENT NATIONAL TESTS/COMPARISONS

Recent Tests and Comparisons of Radiosonde Operated by Japan Meteorological Agency

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Summary and purpose of document

This document provides the status report on the upper-air observations and information on recent comparisons of radiosondes operated by the Japan Meteorological Agency

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Action proposed

The meeting is invited to note and comment on the information contained in the report and take actions on the issues raised in the report, as appropriate

Recent tests and comparisons of radiosonde operated by Japan Meteorological Agency

1. Upper-air observations of the Japan Meteorological Agency

The Japan Meteorological Agency (JMA) operates 18 upper-air stations. Four marine research vessels of JMA make upper-air observations on the open sea away from the coast of Japan using the ASAP systems. Upper-air observation is also made at the Syowa station in the Antarctic.

Six stations in the JMA radiosonde network and the Antarctic station are registered into the GCOS Upper-air Network(GUAN), and according to the GCOS recommendation, high altitude observations up to 5 hPa are performed once a day at Tsukuba and the Antarctic station. At four stations in Japan and the Antarctic station, direct measurements of vertical distribution of ozone are made using ozone sondes once every week.

The Meisei RS2-91 radiosondes with radio-direction wind finding system had been used at all 18 stations till March 2002. The Meisei RS-01G GPS radiosondes started to be used at Minamitorishima Island (47991), which is an isolated island in the Northwestern Pacific, from April 2002. The operation use of the Sippican MARK-2A GPS radiosonde was started in April 2003 at Chichijima Island (47971), which is located 800 km to the south from Tokyo. In accordance with the start of operation of an Vaisala “Autosonde” system on Hachijojima Island (47678), which is located 300 km to the south from Tokyo, Vaisala RS80-15GA GPS radiosonde had been used from June 2003 and they were replaced to the Vaisala RS92-AGP GPS radiosonde in January 2004.

16 stations except Minamitorishima Island and Chichijima Island had operated rawin observations (wind soundings) twice a day in accordance with erquirements from numerical weather prediction and aviation weather services. An wind profiler network “WINDAS” started to be in operational in Japan in April 2001. WINDAS consists of 31 sets of 1.3 GHz wind profilers and is measuring upper-winds over Japan every 10 minutes up to the levels of 6.5 km in summer and to 3.5 km in winter. It was confirmed that the transition from rawin data to wind profiler data did not decrease the accuracy of numerical weather forecasting by observing system experiments with the mesoscale numerical model. The rawin observations were finished on March 2004.

This report chronologically presents the outline of tests and comparisons concerning upper-air observations operated in JMA since 1993.

2. Radiosonde intercomparison Phase IV at Tsukuba, Japan

WMO International Radiosonde Comparison Phase IV was made at the Aerological Observatory at Tsukuba, Japan from February 15 to March 12, 1993. As reported to Instruments and Observing Methods REPORT (Green Stripe) No.59 of CIMO, two types of radiosondes of Japan, two types of Finland, and three types of the U.S. participated in the comparison.

3. Temperature compensation of the relative humidity sensor of Meisei RS2-91

The various reports of CIMO including the report on the radiosonde international comparison Phase IV have shown that the improvement in accuracy of relative humidity (RH) sensors was difficult compared with other measurement elements.

The radiosonde international comparison Phase IV showed that dry bias in RH measurements occurred in Meisei RS2-91 radiosondes due to the change of sensitivity of the RH sensor during storage in rooms for several months. A new type of capacitive thin-film sensor was adopted to Meisei RS2-91 in July 1999 and the dry bias error was canceled as a result. However, the new RH sensor indicated wet bias at temperatures below 0 degree C because the calibration of the RH sensors in the manufacturing process was made at room temperatures.

The temperature dependency of the RH sensors was carefully tested using a humidity-temperature chamber for calibrating RH at various temperatures with a chilled-mirror hygrometer under room pressures. The test showed that there were –2 % of RH bias at +20 degrees C, +2 % at 0 degree C, and +7 % at -30 degrees C in the RH sensors. From the results, the correction of raw RH values (RH') into true RH values (RH") at temperatures from –40 to 0 degrees C was started from February 2003 using the following quadratic equation.

$$RH'' = RH' - 2.02 \times 10^{-3} T^2 - 1.68 \times 10^{-1} T + 2.86$$

The probability in which error of RH measurements enter less than 5 %, which is the accuracy requirement of GOS for upper-air observations, has been improved from 54 % before the correction to 99 % after making the correction.

Nakamura et al. (2004) compared the precipitable water vapor (PWV)s obtained from the delay of GPS signals with the PWVs estimated from to the Meisei RS2-91 radiosondes. The amount of PWVs obtained from RS2-91 well agreed to the GPS derived PWVs. This study also demonstrated that the PWVs from Vaisala RS80-15GA GPS radiosondes were 3-4 mm smaller those of the GPS derived PWVs, which result conformed to the dry bias of Vaisala RS80 series.

4. Comparisons of Vaisala RS80-15GA with Meisei RS2-91

For reducing the difficulty for posting staffs to remote islands for upper-air observations, JMA had determined the plan to use Autosonde systems stations on remote islands. The first Autosonde system was installed on Hachijojima Island, and was started to be in operational in June, 2003. Vaisala Oyj. took charge of manufacture of the Autosonde system and supply of radiosondes. Meisei Inc. has made the installation and maintenance of the system.

At the early stage of the plan, JMA had requested the use of RS92-AGP which is the newly developed Vaisala GPS radiosondes instead of Vaisala RS80-15GA due to their dry bias of the RH sensor and high probability of wind measurement missing which was presented by Elms (2001) and other WMO reports. From the reason that RS92-AGP radiosondes were incapable to be fitted to the Autosonde system during the manufacturing term, however, RS80-15GA started to be used from June 2003.

In advance of the start of operation of the Autosonde system, 30 times of comparisons were performed between Meisei RS2-91 which had been used as the JMA standard radiosondes and Vaisala RS80-15GA. The comparisons were made at 00UTC (daytime) and 12UTC(night) from February 20 to March 13, 2003 at Tsukuba. The results of the comparisons are summarized as follows:

(1) Temperature
- From the surface to 500hPa, there is little difference between RS80-15GA and RS2-91 both in daytime and in night.
- In the layer of 150-100 hPa, the temperatures of RS80-15GA showed 0.2-0.4 degree C higher than those of RS 2-91 in daytime.
- From 500 to 40 hPa, RS80-15GA showed 0.1-0.5 degree C lower temperature than those of RS2-91 in night.
- At altitude higher than the 15hPa level, RS80-15GA measured higher temperature than RS2-91 both in daytime and in night. The temperature difference increased as the altitude was increased.
- One possible cause of these differences is that data processing of infrared-radiation compensation is made (RS80-15GA) or not (RS2-91) in temperature measurements.

(2) Relative humidity
- RS80-15GA showed 2 to 7 % lower RH values both in daytime and night at all the height.
- Measurement of RH below -40 degrees C is not performed in Japan due to low accuracy of RH sensors.

(3) Geopotential height
- In daytime, in the troposphere RS80-15GA showed the heights 1-5 m lower than those of RS2-91. In the stratosphere, the height of RS80-15GA become higher than the height of RS2-91 as increasing altitude in accordance with the deviation of temperature described above. The difference of height between the radiosondes was 40 m at 5 hPa.
- In night, the heights measured by RS80-15GA were lower than those by RS2-91 at all the altitudes except at 5 hPa, and the greatest deviation of height was 12 m at 70 hPa.

(4) Wind

The differences of wind were less than 2 m/s in east-west components and less than 1 m/s in north-south components.

5. Wind measurement missing in RS80-15GA

On Hachijyojima Island, wind measurement missing frequently occurred immediately after starting the upper-air observation with RS80-15GA.

(1) Data measuring rate

The rate of soundings in which wind measurement missing occurred were ranged from 18 to 60 % from June to October 2003, which rate were further larger values than the rate which JMA had estimated for at the beginning of the operation of RS80-15GA (Elms, 2002).

(2) Cause of the wind measurement missing

JMA, Meisei Inc. and Vaisala Oyj. collaborated in making various examinations to reveal the cause. As probable causes of the wind data missing, we supposed three factors : reduction of electric power of a battery due to low temperature around the tropopause, influences of the electric-magnetic waves from some satellites and mechanical oscillation of radiosondes lifting aloft. The true cause, however, was not specified, and we concluded that the data missing came from the fundamental weakness of codeless GPS radiosondes.

(3) Replacement to RS92-AGP radiosondes

We agreed in September 2003 that RS80-15GA would be replaced to the code-correlatad GPS radiosonde, Vaisala RS92-AGP, after making modification of the Autosonde system. The observations using RS92-AGP radiosondes were started from January 2004.

6. Comparisons of Vaisala RS92-AGP with Meisei RS2-91

After we had determined to replace RS80-15GA into RS92-AGP, 30 times of comparisons were performed between Vaisala RS92-AGP and Meisei RS2-91. The comparisons were made at 00 UTC (daytime) and 12 UTC (night) from November 25 to December 12, 2003 at Tsukuba. The results of the comparisons are summarized as follows:

(1) Temperature

The differences of temperature between the radiosondes were from -0.2 to +0.4 degree C on the average.

(2) Pressure

The differences of pressure between the radiosondes were from –1.2 to +0.5 hPa on the average.

(3) Relative humidity

The differences of RH between the radiosondes were from –1. to +1.5 % on the average.

(4) Wind

The differences of wind speed between the radiosondes were from –1.2 to +1.5 m/s on the average.

The results of the comparison described above shows that the accuracy of RH measurement was greatly improved in RS92-AGP as compared with that of RS80-15GA.

As well as the improvement of RH measurement with RS92-AGP, the availability of wind measurement by RS92-AGP has been 100 % since the start of the observation using the radiosondes. The problem of wind measurement missing was resolved.

In addition, RS92-AGP has experienced sudden shifts twice in temperature measurement, and once in RH measurement during two months since January 2004. They are supposed to be due to bugs on the data processing software in the digiCORA III.

7. Comparisons among Sippican MARK-2A, Meisei RS-01G and RS2-91

The newly deployed GPS radiosondes, Sippican MARK-2A on Chichijima Island and Meisei RS-01G on Minamitorishima Island were compared with Meisei RS2-91 twice in December 2002. The differences between Meisei RS-01G and RS2-91 are wind measurement methods (Code-correlated GPS in RS-01G and radio-direction wind finding in RS2-91) and pressure measurements (calculation from temperature and geopotential height derived from GPS in RS-01G and Aneroid capsule in RS2-91), and the same types of sensors of temperature and RH are used in RS-01G and RS2-91.

As few comparisons were made, statistical analysis is not available. Case studies on the comparisons shows that there were no particular differences in measurements of temperature, geopotential height and wind. The differences of RH between MARK-2A and RS-01G (RS2-91) was from –10 to +10 % below the 8 km level and more than +10 % values were seen above the 8 km level. The difference in the RH measurements possibly came from the difference of methods of RH measurement (carbon sensor in MARK-2A and capacitive thin-film sensor in RS-01G and RS2-91).

The time series of geopotential heights at 100 hPa from radiosondes and those of first guesses from 6-hour numerical forecasting before and after the replacement from RS2-91 to RS-01G on Minamitorishima Island was examined. Large deviation of geopotential heights occurred for one week just after the change of radiosondes due to some software bugs in the RS-01G system. After debugging, the deviation turned out to be very small as before the replacement. Small deviation of geopotential heights between the values of MARK-2A on Chichijima Island and the first guesses of the numerical forecasts are also seen.

Since there are few comparison data, the conclusion could not be obtained, but both MARK-2A and RS-01G are measuring in accuracy at least equivalent to that of RS2-91 except the humidity measurement by MARK-2A.

8. Operation of the Autosonde system

The operation of the Autosonde system was started in June, 2003. The failure rates of upper-air observations with the system in each month has been from 0 to 4 %. The operation has been smoothly made except the problem of wind data missing previously described and the following problems concerning burst of balloons.

- Under the strong wind at the time of typhoon approach, two balloons burst inside the balloon launcher of the Autosonde system.
- When the Autosonde system was in dense fog, the inner wall of the balloon launcher was wetted with water. Inflating balloons were stuck on the inner wall of the balloon launcher, and spread over the bottom of the balloon launcher instead of being lifted upward. Some projections around the radiosonde tray equipped on the bottom accordingly made the balloon burst. The bursts of balloons occurred 5 times in June 2003 when Japan was in the rainy Baiu-season.

The following improvements were made in collaboration with the staff of the Hachijyojima station, Meisei Inc. and Vaisala Oyj., and the problems have been resolved as a result.

- In order to stop the inflow of large amount of air through the bottom of the balloon launcher under strong wind, openings in the bottom were closed.
- A net was installed on the inner wall of the balloon launcher to prevent balloons being stuck. We also installed a handmade tube with a diameter of 10cm and a length of 40 cm beside the balloon tray, and set a balloon into the tube before putting hydrogen in balloons.

9. Summary and future plans

JMA has largely changed the upper-air observations of Japan since 2001 as seen in the adoption of several types of GPS radiosondes, an Autosonde system, and the start of operation of a wind profiler network. The following issues and future plans will be discussed on :

- Installation of the Autosonde systems to the stations on remote islands will be promoted. The second Autosonde system of JMA will start to be in operational on Minamidaito Island (47945) in March 2005.
- Costs of GPS radiosondes should be reduced in order to extend the use GPS radiosondes and the Autosonde systems.
- Concerning RH measurements, RS92-AGP, RS-01G and RS2-91 have accuracies to meet requirement of CIMO. JMA will continue to monitor the performances and accuracies in RH measurements of the radiosondes.
- JMA will be also checking the RH sensor of MARK-2A carefully.
- Extension of numerical forecasting and climate monitoring will require radiosondes with more accuracy and reaching higher altitudes. JMA should have plans for study and development of the next generation radiosondes with CIMO and manufactures.
- In order to increase the accuracy of watching and numerical forecasting for disastrous atmospheric systems, such as mesosocale heavy rainfalls, more amount of upper-air observation data are needed. Newly developing methods and observation systems such as GPS precipitable water vapor, microwave radiometers, ACARS and AMDAR data, water vapor profile derived wind profilers, should be studied to establish their operational uses.

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