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Comparing GPS and Loran-C windfinding performance

Vaisala Radiosonde RS92 Validation Trial at Prague-Libus

The Czech Hydrometeorological Institute (CHMI) plans to start using Vaisala Radiosondes RS92 and the Vaisala DigiCORA® Sounding System MW21 at its Prague-Libus aerological station. Striving to ensure the highest possible data quality and homogeneity of the time series, the CHMI carried out a validation trial of the Loran-C and GPS windfinding models of the RS92 and of the sounding system MW21 during the period May 26 - June 6, 2003.



The Czech Hydrometeorological Institute's sounding station at the Prague-Libus observatory,

Short history of the Czech aerology

The first experimental aerological measurements with radiosondes started in 1946 at the Ruzyně airport in Prague. Since then, many substantial changes have taken place. The location of the aerological station, sensors and radiosondes, the procedures for handling the radiosondes, the total aerological system and software have all been changed at least once. The Prague-Libus aerological station (50.02°N, 14.45°E, 304 m, WMO ID: 11520) started operating officially in 1970 when the new observatory was inaugurated. The basic parameters - pressure, temperature, humidity (PTU) and wind profiles - were measured at 00 and 12 UTC to start with, and only wind was

measured at 06 and 18 UTC. However, in 1974, the observations were extended to cover all parameters four times a day. In 1978, the observational schedule was enhanced with ozone soundings, which took place all year round until 1982. Since then, the Prague-Libus station has measured the vertical profiles of ozone three times per week from January to April.

The Vaisala DigiCORA® Sounding System MW11 was installed at the Prague-Libus station in 1991, which started to use Vaisala Radiosondes RS80 in January 1992. The introduction of the new ground equipment and new radiosondes was the most important milestone in aerological measurement in the Czech Republic. The new very accurate radiosondes, together

with the automation of post-flight data processing, improved the data quality to a high level.

In 1994, the Prague-Libus station extended its scope to radioactivity measurements and started to measure vertical profiles of beta and gamma activity. In 2000, the schedule of radioactivity soundings was changed from once-a-month to once every four months (in January, April, July and October). Since the beginning of 1999, Vaisala Radiosondes RS90 have been

used for routine soundings at the Prague-Libus station, but a transition to the recently introduced Vaisala Radiosondes RS92 and the DigiCORA® Sounding System MW21 is being planned.

Validation trial aims

The accuracy of radiosonde measurement is very important to meteorologists, not only for numerical weather forecasts, but also in aviation. It is therefore vital to determine the effect of ra-

A balloon with Vaisala Radiosondes RS90 and RS92 with Loran-C windfinding suspended about 1 m below a bamboo rig ready for release at Prague-Libus, Czech Republic. From the left: Mr. Cernoch and Mrs. Skrivankova.

diosonde change and to evaluate the differences in data brought about by a transition to a new radiosonde type is of crucial importance. A comparison of “old” and “new” radiosondes is a useful source of such information. The main aim of the validation trial at Prague-Libus was to evaluate radiosonde sensor performance. However, the data transmission of both of Vaisala’s sounding systems - the MW11 and MW21 - was tested too.

Test setup

The Prague-Libus comparison test consisted of 33 dual soundings. On every flight, two types of radiosondes were suspended about 1 meter below a bamboo rod, approximately 60 m below a single balloon. In most cases, the comparison soundings were made at 06, 12 and 18 UTC (WMO standard sounding times). For the Loran-C windfinding comparison, the RS92-KL radiosondes were compared with the RS90-AL, while the RS92-SGP radiosondes were launched together with the RS80-15G to compare the GPS windfinding. The MW11 ground equipment collected the data from the RS80 and RS90 radiosondes, whereas the MW21 was used to process the RS92 data.

The calibration of the RS92-SGP was checked in the field immediately prior to launch. The RS80-15G and the RS90-AL calibrations were also checked. At



the time of testing, the Ground Check Set GC25 was under development and could not yet be used for the RS92-KL.

Data processing

Data were processed using edited 5-second data on the MW11 and MW21. Vertical profiles of pressure, temperature, humidity and wind were compared. Direct differences computed on a time

scale were used as the “first” step check on the data. The software developed for WMO radiosonde intercomparison (Radio and Ozone Comparison and Evaluation Software Package) was used as an additional validation step. The RS92 data were used as the reference and were checked against the corresponding values on the RS80 or RS90. Vertical profiles of pres-

sure, temperature, humidity and wind differences were analyzed on a pressure scale. Figures 1 and 2 show the RS80 vs. RS92 and RS90 vs. RS92 mean pressure differences. Temperature and humidity differences are shown in figures 3, 4 and 5, 6 respectively. The wind direction and wind speed comparison is presented in figures 7, 8 and 9, 10.

At the end of the trial, ►



Mr. Cernoch performing pre-flight preparations for the RS92.

the heights of standard pressure levels 500, 300, 200, 100 and 50 hPa were compared against the ALADIN model analysis (see table 1). The ALADIN (Aire-Limitée Adaptation Dynamique développement International) is a numerical model of the atmosphere developed by an international team working mainly at Météo-France. The results calculated by the ALADIN model are used for the short-range weather forecasting in the CHMI's weather service while the Prague-Libus station uses the ALADIN forecast of heights of standard pressure levels as a quality check routine.

Test results

As expected, there were bigger differences between the PTU values measured by the RS80 and the RS92 sensors than between those of the RS90 and RS92. The differences in pressure measurements between the RS92 and RS80 originate mainly from the different pressure sensors in these two radiosonde types. The RS80 is equipped with an aneroid BAROCAP® pressure sensor while the RS92 and RS90 are equipped with a silicon BAROCAP® pressure sensor. The aneroid sensor is known to have a positive pres-

sure bias as its internal temperature changes from a higher to a colder temperature [1]. Near the ground the RS92 indicated lower pressures than the RS80. In the stratosphere, the average difference between the RS92 and RS80 pressure measurement was about -0.4 hPa (see fig. 1).

The ground check pressure correction was performed only for the RS90-AL, which can be one of the reasons for the difference in pressure measurement from the RS92 and RS90. The average difference between the RS92 and RS90 pressure measurement was about -0.3 hPa (see fig. 2).

The differences between temperature observations for the RS92 and RS80, presented in fig. 3, are in line with the results of the RS90 radiosonde test in Vienna [2] and with the Met Office RS90 temperature sensor evaluations [3]. A small warm bias in the RS80 temperature measurement was seen in the troposphere. In the stratosphere, the faster RS92 temperature sensor response together with the differences in the radiation corrections between RS92 and RS80 resulted in an increasing deviation of the temperature profile. The RS92 temperature sensor is the same as in the RS90. Consequently, the differences in temperature measure-

ment were mostly between -0.1°C and 0.1°C up to the 20-hPa pressure level. The increase of bias above the 20-hPa level (see fig. 4) would require a more comprehensive testing.

The heated H-HUMICAP® is a fast, defrosting humidity sensor used in the RS90 and RS92 radiosondes, while the RS80 employs an earlier version of the A-HUMICAP®, which has no heating. The big differences in humidity profiles from between the RS92 and RS80 are caused by the RS80 humidity sensor's problems at temperatures below -40°C (see fig. 5). The H-HUMICAP heated humidity sensor can correctly measure higher humidity at cold temperatures than the A-HUMICAP can. Figure 6 shows the variability in the RS92 and RS90 humidity measurements. The RS90-AL radiosonde was reconditioned prior to the flight, whereas the RS92-KL was not. The differences in humidity measurements were between -2.5 % and 2.5%. The Ground Check Set GC25 will enable the RS92-KL to be operated with a reconditioning procedure, which is expected to decrease the deviation in humidity measurements caused by chemical contaminants, for example.

The Prague-Libus station

Figure 1. RS80-RS92 pressure differences mean value and standard deviation (blue RS92, red RS80).

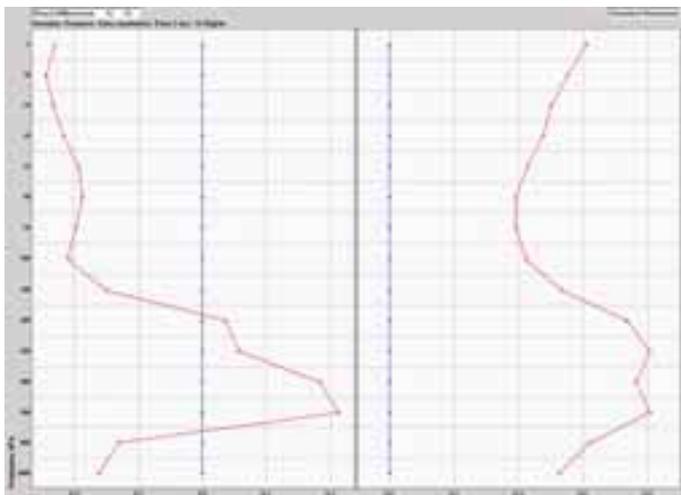
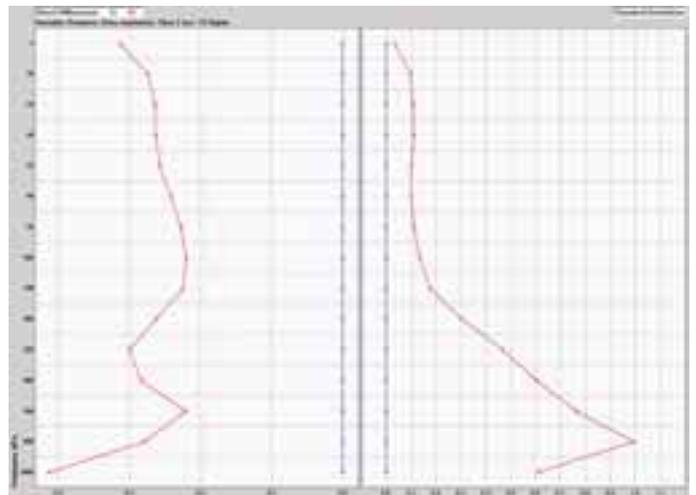


Figure 2. RS90-RS92 pressure differences mean value and standard deviation (blue RS92, red RS90).



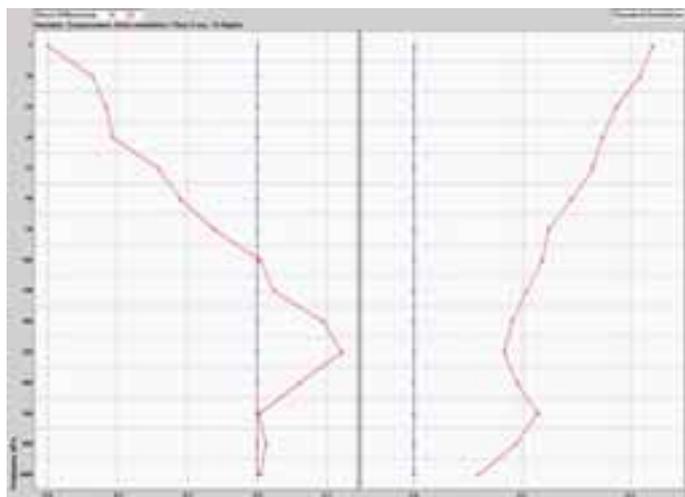


Figure 3. RS80-RS92 temperature differences mean value and standard deviation. (blue RS92, red RS80).

performs most regular wind measurements with the RS90-AL radiosonde with Loran-C windfinding. If weather conditions are bad and there are disturbances of the Loran-C signals, the RS80-15G with GPS windfinding is used. Therefore, both the Loran-C and the GPS models of radiosondes were tested. Very low wind prevailed nearly all the time during the validation trial. The MW11 ground system was less sensitive than the MW21. When the signal quality was low, the MW11 system produced more interpolated wind data than the MW21. Consequently, the differences in

wind direction and speed for the Loran-C radiosondes were bigger than with the GPS windfinding. The wind measurements obtained with GPS windfinding were more consistent. Figure 7 presents the wind direction bias between the RS92-SGP and the RS80-15G. The differences in wind speed measurement were between -0.1 m/s and 0.1 m/s (see figure 8). A comparison of the RS92-KL and RS90-AL wind direction and wind speed data is presented in figures 9 and 10. The wind speed differs between -0.1 m/s and 0.4 m/s.

The height differences of a particular sounding did not ex-

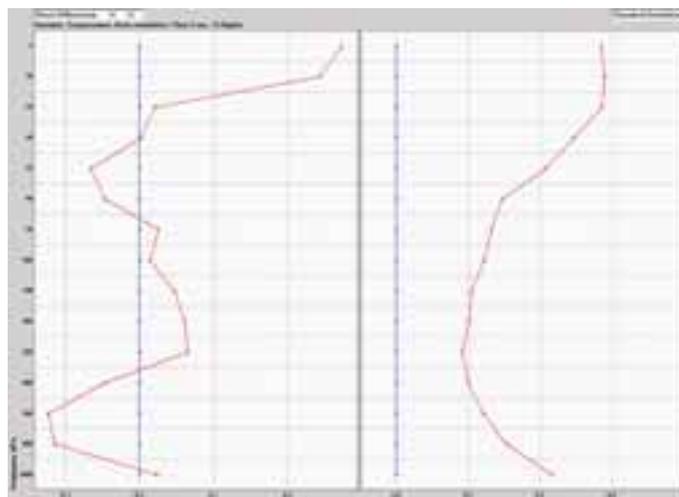


Figure 4. RS90-RS92 temperature differences mean value and standard deviation (blue RS92, red RS90).

ceed 30 m until 100 hPa and 40 m until 50 hPa in relation to the ALADIN numerical model. Table 1 shows the mean values and standard deviations on 500, 300, 200, 100 and 50 hPa standard pressure levels.

Summary

The differences between PTU values measured by the RS92 and the RS90 are smaller than the variance between the RS92 and the RS80 PTU measurements. The RS92 radiosonde performs better than the RS80 and is comparable with the RS90. Pre-flight preparation of the RS92 is more convenient.

An EEPROM for calibration coefficients is placed on the motherboard.

It was found that interferences from local transmissions immediately before or during a launch are a possible reason for the gaps found in the RS80 GPS wind measurements at the Prague-Libus station. A television tower is near the station. Upgrading to the RS92 with GPS windfinding, which is less susceptible to this type of interference, should improve the wind measurement and reduce the failure rate.

The MW21 frequency analyzer, windfinding system ►

Figure 5. RS80-RS92 humidity differences mean value and standard deviation (blue RS92, red RS80).

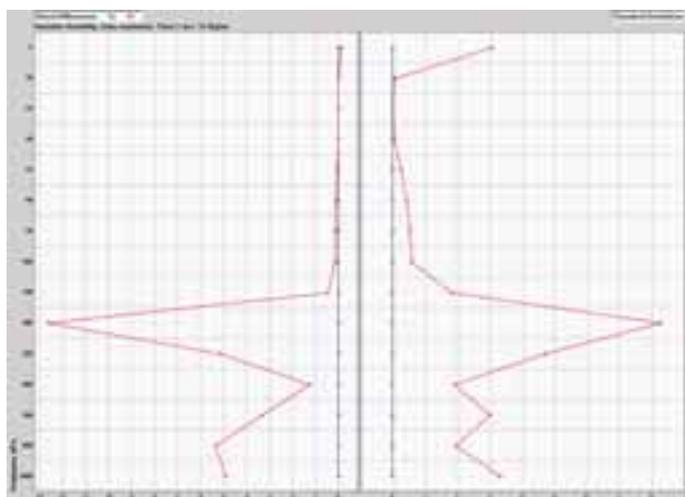
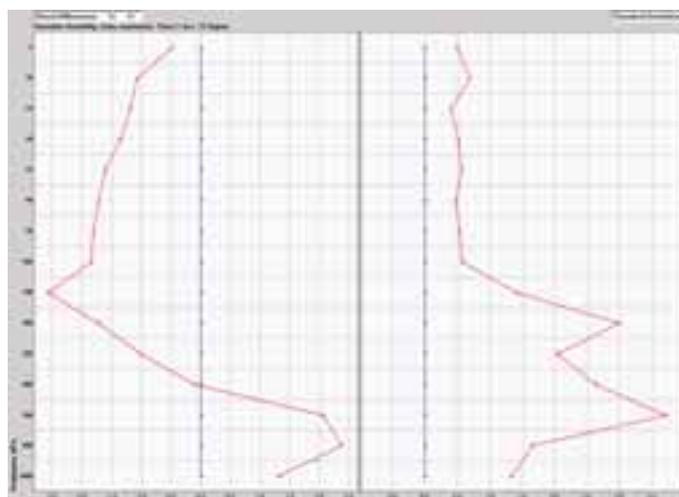


Figure 6. RS90-RS92 humidity differences mean value and standard deviation (blue RS92, red RS90).



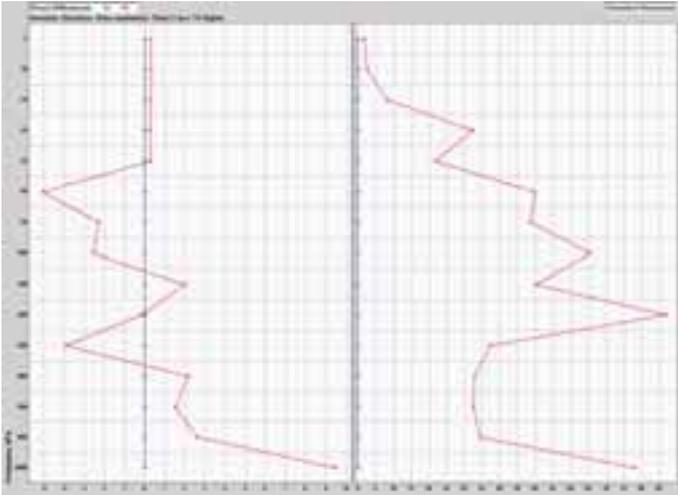


Figure 7. RS80-RS92 wind direction differences mean value and standard deviation (blue RS92, red RS80).

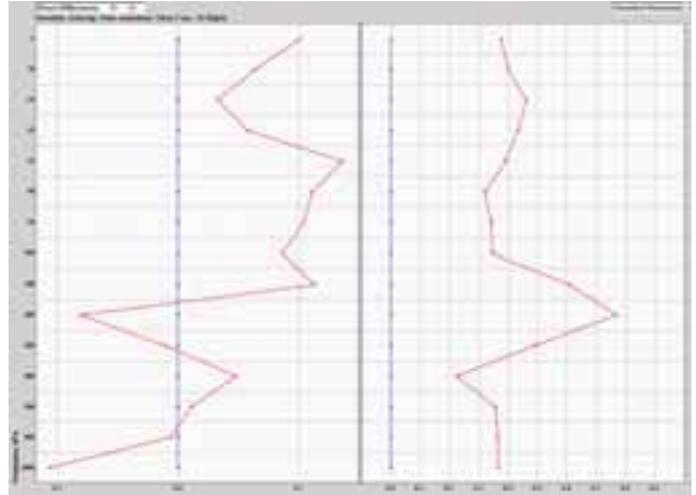


Figure 8. RS80-RS92 wind speed differences mean value and standard deviation (blue RS92, red RS80).

status display and thermodynamical diagrams are very useful tools from for the user. Improved signal processing leads to better utilization of wind measurement. The MW21 produces less interpolated wind data than the MW11.

The transition from the RS90 to the RS92 should not significantly affect the consistency of upper-air measurement at Prague-Libus. On the contrary, it is expected that the data quality and availability will improve. The validation trial demonstrated the good performance of the MW21 together with the RS92 radiosondes. ●

GPS radiosonde versus ALADIN model heights				
	RS80-15G	(n=14)	RS92 SGP	(n=14)
P[hPa]	Mean [m]	STD dev. [m]	Mean [m]	STD dev. [m]
500	-6,4	7	-6	6,4
300	-7,4	10,1	-3,4	8,7
200	-10,9	9,6	-3,4	5,9
100	-15,9	10,9	-6,7	7,3
50	-21,8	10,1	-12,3	9,3
LORAN radiosonde versus ALADIN model heights				
	RS90-AL	(n=14)	RS92 KL	(n=14)
P[hPa]	Mean [m]	STD dev. [m]	Mean [m]	STD dev. [m]
500	-5,4	8,9	-7	7,2
300	-2,4	8,1	-2,7	6,6
200	1	11,3	2,4	8,2
100	-6,2	12,4	-3,5	10,6
50	-12,7	14,5	-9,4	12,9

Table 1. Height differences (radiosonde - ALADIN model) on the standard pressure levels 500, 300, 200, 100 and 50 hPa.

References

- [1] Smout, R., Elms, J., Lyth, D., Nash, J., 2001: Met Office RS90 Pressure Sensor Evaluations. New Technology in Upper-air Observations report.
- [2] Finne, M., 1998: Promising Pilot Test Results of the New RS90 Radiosonde in Vienna. Vaisala News, 147, 8-10.
- [3] Smout, R., Elms, J., Lyth, D., Nash, J., 2001: Met Office RS90 Temperature Sensor Evaluations. New Technology in Upper-air Observations report.

Figure 9. RS90-RS92 wind direction differences mean value and standard deviation (blue RS92, red RS90).

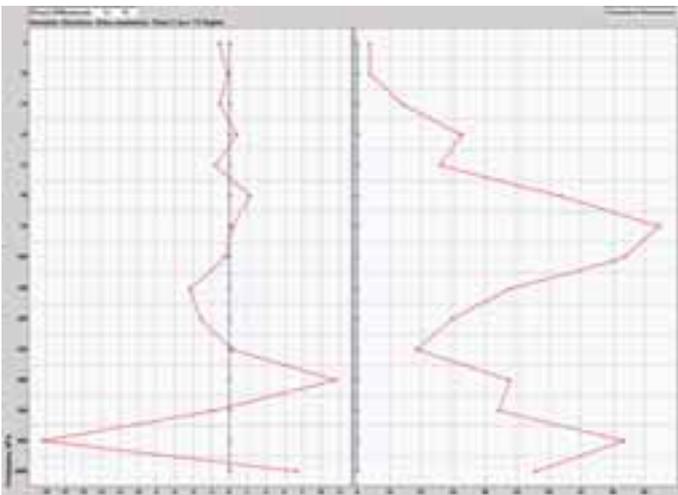


Figure 10. RS90-RS92 wind speed differences mean value (blue RS92, red RS90).

