Overview of Met Office Intercomparison of Vaisala RS92 and RS41 Radiosondes

Camborne, United Kingdom, 7th – 19th November 2013

David Edwards, Graeme Anderson,
Tim Oakley, Peter Gault

12/02/14

Vaisala staff launching a 4 radiosonde rig used in this report from the rotating balloon shed at the Met Office site in Camborne.

Note: This is an overview version of the complete intercomparison report. Please see the complete report for further details of all aspects of the results discussed.

Executive Summary

30 trial ascents were launched during November 2013 from the Met Office radiosonde station in Camborne to compare the performance of RS92 and RS41 radiosondes. Each ascent used 2x RS92 and 2x RS41 radiosondes and was launched by Vaisala staff under Met Office supervision. The RS92 software and model versions were the same as those used in the *WMO Intercomparison of high quality radiosonde systems, Yangjiang, China, 2010*.

All hardware and consumables apart from helium were provided by Vaisala. The design of the trial was agreed by both parties and follows the methodology of WMO intercomparisons (see *Guide to Meteorological Instruments and Methods of Observation).* The Met Office was contracted by Vaisala to provide an independent report from the data produced by the trial. The report and all statistical analysis were completed by Met Office staff.

In previous intercomparisons, synchronising the times of each radiosonde during each ascent had to be completed manually. In this trial, Vaisala used the GPS times for each radiosonde to synchronise all 4 datasets. This is a novel approach and reduces the impact of variability due to time synchronisation errors.

Throughout the trial at Camborne, the RS41 radiosonde performed very similarly to the RS92, but several key differences and improvements were observed.

No significant consistent temperature differences were observed between the RS41 and RS92. The temperature observations of the RS41 are more precise and less susceptible to the problems caused by moisture contamination when exiting cloud than the RS92, including wet-bulb effects. In the wet-bulb events observed during this trial, the RS41 radiosondes demonstrated a significant improvement in performance relative to the RS92.

Some slight consistent differences in humidity were observed between the RS41 and RS92. The humidity measurements of the RS41 are more precise and should be less prone to moisture contamination and solar radiation correction errors than the RS92.

The GPS derived wind speeds and directions calculated by the RS41 are consistent with the performance of the RS92.

The GPS derived heights observed by the RS41 are consistent with the performance of the RS92, but demonstrate greater precision.

Relative to pressure derived heights observed by the RS92, GPS derived heights from both the RS92 and RS41 demonstrate significantly improved precision and potentially greater accuracy. This will have an impact on standard TEMP and BUFR output data files if GPS derived altitudes are used, as pressure is then also calculated from GPS derived altitudes.

Important:

As there was no scientific reference system used in this intercomparison, it was not possible to know which radiosonde model made the most accurate measurements. However, the use of two of each type of radiosonde allowed analysis of their flight-by-flight precision – the consistency of measurement of each radiosonde. Also, the impact of known effects on radiosonde data including those listed below enabled an assessment of relative data quality between the two radiosonde models:

- Evaporative cooling of moisture contamination from temperature sensors (referred to as ‘wet-bulbing’ or ‘the wet-bulb effect’)
- Sensor response time changes with temperature
- Contamination of humidity sensors by moisture

Overall conclusions

Radiosonde systems

The RS92 and RS41 radiosondes were both very reliable throughout the trial period in Camborne. The quantity of missing data was very low and the typical duration of missing data was no longer than 2 seconds at any point throughout the ascent from both radiosonde models. There were no instances of in-flight telemetry failures or sensor failures. All 4 sets of hardware and software were very reliable with no problems occurring.

Overall temperature and humidity

The RS41 demonstrates several differences and improvements in the observation of temperature and humidity relative to the RS92. It is not possible to determine which radiosonde provided more accurate measurements due to the lack of a reference system, but the reduction in the impact of known temperature and humidity phenomena should improve the data quality of the RS41 relative to the RS92, and may improve accuracy as a result.

The RS41 is not at risk of a systematic bias being introduced by the application of incorrect ground check calibrations to the humidity or temperature measurements, which is possible with the RS92 using the GC25 ground check. This should improve the overall accuracy of temperature and humidity measurements operationally. The RS41 temperature and humidity sensors are still tested for faults before launch in the RI41 ground check. Additionally, the RS41 humidity sensor is reconditioned using its integrated heating element. This also generates a 0% humidity reference point which the sensor is correct to before launch. The consistency of RS41 measurements without the application of ground check corrections against independent references gives confidence in the factory or internal calibrations during this trial.

Temperature

The temperature observations of the RS41 are more precise and less susceptible to the problems caused by moisture contamination when exiting cloud than the RS92. No consistent temperature differences were observed between the RS41 and RS92 when measured over 10^{o}C bands.

- During this trial the average flight-by-flight differences of RS41_1 and RS41_2 temperatures relative to RS92_1 were within ±0.1^{o}C at night and ±0.2^{o}C during the day to 1 standard deviation when measured in 10^{o}C bands.

The precision of the RS92 and RS41 temperature sensors can be estimated based on the standard deviations of average flight-by-flight differences between the radiosonde pairs of each type:

- The standard deviation of RS92_1 vs. RS92_2 temperatures were within ±0.3^{o}C at night and ±0.2^{o}C during the day to 1 standard deviation when measured in 1 km bands.
    - Note: the RS92 night-time standard deviations are smaller (within ±0.1^{o}C) than the daytime standard deviations except in the lower troposphere where moisture contamination caused a localised increase in standard deviations to over ±0.2^{o}C.
- The standard deviation of RS41_1 vs. RS41_2 temperatures were within ±0.1^{o}C at night and ±0.2^{o}C during the day to 1 standard deviation when measured in 1 km bands.

Moisture contamination events still cause a slight degradation of RS41 precision (increase in standard deviations from approximately ±0.01^{o}C to ±0.05^{o}C at night), but the impact is much smaller in magnitude that on RS92 precision (from approximately ±0.05^{o}C to ±0.22^{o}C at night). In the wet-bulbing situations observed during this trial, the RS41 radiosondes demonstrated a significant improvement in performance relative to the RS92.

Changing from the RS92 to the RS41 operationally may improve the measurement accuracy of temperature and will provide more precise temperature measurements, reducing total temperature measurement uncertainty.

Humidity

The humidity measurements of the RS41 are more precise and should be less prone to moisture contamination than the RS92, especially in the upper troposphere and stratosphere. The RS92 applies solar radiation corrections to humidity based on calculated solar angle, which is a potential source of error. The RS41 calculates humidity based on the temperature measured by the separate temperature sensor integrated into its humidity sensor. This removes the need for the application of a solar radiation correction, which eliminates that potential source of error.

Some slight consistent differences were observed between the RS41 and RS92 of approximately 1-2%. The key differences were the greater humidity measured by the RS92 after the tropopause relative to the RS41 and the greater humidity measured by the RS41 below the tropopause. The impact of these differences would be small operationally, but may be measureable in the climate record of a station.

During this trial:

- The average flight-by-flight differences for of RS41_1 and RS41_2 humidities relative to RS92_1 were within ±1.0% at night and ±2.6% during the day to 1 standard deviation when measured in 10^{o}C bands.

The precision of the RS92 and RS41 humidity sensors can be estimated based on the standard deviations of average flight-by-flight differences between the radiosonde pairs of each type.

- The standard deviation of RS92_1 vs. RS92_2 humidities were within ±0.7% at night and ±1.3% during the day when measured in 10^{o}C bands.
- The standard deviation of RS41_1 vs. RS41_2 humidities were within ±0.3% at night and ±0.6% during the day to 1 standard deviation when measured in 10^{o}C bands.

GPS derived wind and altitude

The GPS derived wind components calculated by the RS41 were consistent with the performance of the RS92 and showed very similar precision.

During this trial:

- The average flight-by-flight differences of RS41_1 and RS41_2 wind components relative to RS92_1 were within ±0.2m/s at all heights to 1 standard deviation throughout the trial when measured in 1 km bands.

The precision of the RS92 and RS41 wind components can be estimated based on the standard deviations of average flight-by-flight differences between the radiosonde pairs of each type.

- The standard deviations of RS92_1 vs. RS92_2 wind components were within ±0.2m/s throughout the trial when measured in 1 km bands.
- The standard deviations of RS41_1 vs. RS41_2 wind components were within ±0.1m/s throughout the trial when measured in 1 km bands.

The GPS derived altitudes observed by the RS41 were consistent with the performance of the RS92, but demonstrated greater precision.

- The standard deviations of RS92_1 vs. RS92_2 altitude differences were < ±1.8m throughout the trial when measured in 1 km bands.

- The standard deviations of RS41_1 vs. RS41_2 altitude differences were < ±0.8m throughout the trial when measured in 1 km bands.

Changing from the RS92 to the RS41 operationally should not result in any operational difference for GPS wind or altitude.

Pressure derived altitude vs. GPS derived altitude

Relative to pressure derived altitude observed by the RS92, GPS derived altitude from both the RS92 and RS41 demonstrate significantly improved precision and potentially greater accuracy.

The precision of pressure derived altitude decreased very significantly with height during this trial. The precision of the RS92_1P and RS92_2P altitudes can be estimated based on the standard deviations of average flight-by-flight differences between the radiosonde pairs of each type.

Note: RS92_1P and RS92_2P were the same radiosondes as RS92_1 and RS92_2, but the data was rerun using DigiCORA software to use pressure rather than GPS derived altitudes.

During this trial:

- The average flight-by-flight altitude differences of RS92_1P and RS92_2P were within 10m up to 14 km, increasing to 25m up to 33 km when measured in 1 km bands.
- The standard deviations of RS92_1P vs. RS92_2P altitude differences were ±10m at 14 km increasing to ±90m at 30 km when measured in 1 km bands.
- The average flight-by-flight differences between RS92_1P and the RS92 and RS41 radiosondes using GPS derived altitudes were within 10m up to 14 km, increasing to 50m up to 33 km when measured in 1 km bands.

Using GPS rather than pressure derived altitudes should improve the precision and possibly the accuracy of temperature, humidity and wind measurements. This is due to the increased uncertainty in pressure derived altitude relative to GPS derived altitude.

If GPS derived altitude is selected in the Vaisala software, then pressure is calculated from GPS derived altitude, rather than measured by the pressure sensor. Extra care must be taken to ensure that the ground data is correct when using GPS altitude derived pressure.

Overall

During this trial, the RS92 and RS41 both offered very similar levels of performance across all parameters, with the RS41 demonstrating improved measurement precision for temperature, humidity and height. The RS41 demonstrated performance improvements for temperature and humidity which should improve measurement accuracy.

The most significant performance improvement seen during this trial was the reduction in the impact of ‘wet-bulb’ moisture contamination on the temperature measurements of the RS41 relative to the RS92.

References

Nash, J., R. Smout, T. Oakley, B. Pathack and S. Kurnosenko (2006), WMO Intercomparison of High Quality Radiosonde Systems, Vacoas, Mauritius, 2-25 February 2005, Final Report. *World Meteorological Organization*

Nash, J., T. Oakley, H. Vömel, and W. Li (2011), WMO Intercomparison of High Quality Radiosonde Systems, Yangjiang, China, 12 July–3 August 2010. *World Meteorological Organization, Instruments and Observing methods, report No. 107*

Vaisala (2013), Vaisala Radiosonde RS41-SG datasheet in English, B211321EN-A, *Vaisala*, available on (2014/01/31) http://www.vaisala.com/Vaisala%20Documents/Brochures%20and%20Datasheets/RS41_Datasheet.pdf

Vaisala (2013), Vaisala Radiosonde RS92-SGP datasheet in English, B210358EN-F, *Vaisala*, available on (2014/01/31) http://www.vaisala.com/Vaisala%20Documents/Brochures%20and%20Datasheets/RS92SGP-Datasheet-B210358EN-F-LOW.pdf

World Meteorological Organisation (2012), Guide to Meteorological Instruments and Methods of Observation, WMO-No. 8, 2008 edition updated in 2010. *World Meteorological Organization, WMO-No. 8*

Met Office
FitzRoy Road, Exeter
Devon EX1 3PB
United Kingdom

Tel: 0870 900 0100
Fax: 0870 900 5050
enquiries@metoffice.gov.uk
www.metoffice.gov.uk