GRUAN: A reference data product for the Vaisala RS92 radiosonde

Ruud Dirksen[1], Michael Sommer[1], Christoph von Rohden[1], Franz Immler[2]

[1]GRUAN Lead Centre, Deutscher Wetterdienst, Lindenberg, Germany
[2]European Commission, Brussels, Belgium

Website: www.gruan.org
Email: gruan.lc@dwd.de
Data: www.gruan.org/data

Introduction

The first reference radiosonde data product of the GCOS Reference Upper Air Network (GRUAN) is based on Vaisala RS92 measurements of temperature, humidity, wind and pressure. These data follow the requirements of GRUAN that were outlined by Immler et al. (2010). Reference measurements are traceable to SI units or accepted standards, include an uncertainty analysis, are documented in accessible literature, and are validated (e.g. by inter-comparisons). The main features of the RS92 data product are that the profiles are retrieved from calibrated raw data (DigiCora III data base files, DC3DB), which are corrected for all known biases using correction algorithms that are described in peer-reviewed literature. Furthermore, a comprehensive uncertainty analysis is made, including an assessment of the uncertainty of the corrections. The dominant source of RS92 measurement errors is solar radiation, which causes temperature biases and humidity dry biases.

Radiation experiments

Radiative heating of sensors by the sun causes a significant warm bias during daytime measurements. This systematic radiation bias was measured using a vacuum chamber with a fused silica window containing two RS92 sondes. One is periodically exposed to direct sunlight, while the other -reference- sensor is in the shade. Measurements are taken at different pressures, ventilation speeds and solar intensities. The increase in temperature due to solar heating is calculated from the difference between the exposed and the dark sensor. Fig. 1 shows the temperature error as a function of actinic flux, pressure, and ventilation.

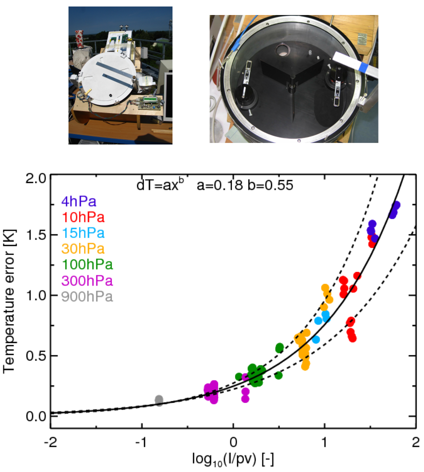

Figure 1: Vacuumchamber for determining the solar radiation error (top).
Solar radiation error for the RS92 temperature measurement versus a scaled parameter comprising actinic flux, pressure and ventilation speed (bottom).

Temperature

Temperature measurements are corrected for solar heating using a correction scheme that is based on lab measurements (Radiation Experiments) and on a radiative transfer model to estimate the actinic flux impinging on the sensor.

The uncertainty analysis (Fig. 4) includes the uncertainty of the (re)calibration and the uncertainty of the radiation correction, including radiation model, ventilation and orientation of the sensor. The largest uncertainty is due to the orientation of the temperature sensor wire.

Daytime RS92 twin-soundings are used to evaluate the uncertainty in the GRUAN temperature measurements (Fig. 2), which shows that the GRUAN uncertainty estimate tends to under-estimate the actual uncertainty in the temperature measurements. Further work has to reveal whether this is due to an incomplete correction model or an unknown error source.

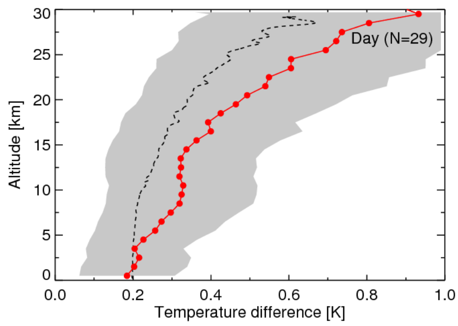

Figure 2: Uncertainty of GRUAN RS92 temperature measurements determined from daytime twin soundings performed at Lindenberg. Dashed line represents the estimated uncertainty profile, the red trace represents the mean of the difference of GRUAN profiles. The grey band represents the standard deviation of the measured temperature differences.

Additional ground check

The standard humidity chamber (Fig. 3) contains saturated air (100 %RH), thus providing SI traceable references for temperature and humidity. Ventilation ensures uniform humidity and temperature as well as a flight-representative ventilation speed. Each RS92 is subjected to a manufacturer-independent ground check in the SHC prior to launch. The SHC ground check at 100 %RH is better suited to reveal batch dependent variations, or potential sensor issues than the Vaisala prescribed ground check at 0 %RH.

Humidity

The humidity measurements are corrected for the solar radiation bias, the time-lag of the sensor, which becomes significant at cold temperatures, and a temperature dependent calibration correction. The total uncertainty of the humidity is about 2 %RH in the lower troposphere and reaches values of more than 5 %RH in the upper troposphere (Fig. 4). In the stratosphere the estimated uncertainty (1 %RH) equals, or exceeds, the humidity measured by the RS92. Therefore, for accurate measurements of stratospheric water vapor reference instruments employing other techniques, e.g. frostpoint or optical luminescence hygrometers, are required.

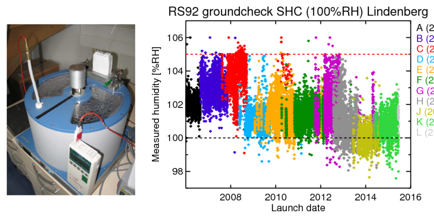

Figure 3: Standard humidity chamber (left).
Vaisala RS92 relative humidity measured in the standard humidity chamber at Lindenberg. Colors indicate production year (right).

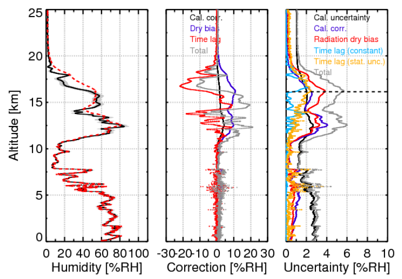

Figure 4: RS92 humidity profile measured at Yangjiang, July 2010. Left panel: GRUAN processed profile (black) + estimated uncertainty (grey), raw measurement data (red).
Middle panel: corrections for various error sources applied to the profile.
Right panel: uncertainty profiles of various components.
The largest corrections, and their associated uncertainties, occur around the UTLS (>12km), with sensor time lag and radiation dry bias as dominant corrections.

Humidity validation

Intercomparison with a frostpoint hygrometer reference instrument (Fig. 5) shows that the GRUAN RS92 water vapour measurements agree within 20%, although systematic biases occur around -40°C for daytime and nighttime measurements.

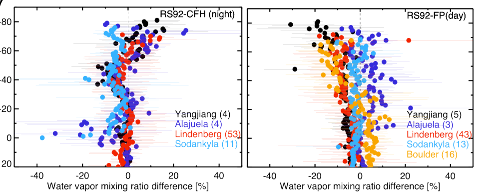

Figure 5: Comparison of tropospheric humidity profiles from GRUAN RS92 and coincident frost point (FP) hygrometer data. Left: daytime soundings, right: nighttime soundings.Color represents the measurement-site. For Boulder only daytime soundings are available. The circles represent the RS92-FP difference relative to FP humidity, the bars indicate the statistical uncertainty in the data.

References

Dirksen, R.J. et al., Atmos. Meas. Tech., 7, 4463-4490, 2014.

Immler, F.J. et al.. Atmos. Meas. Tech., 3, 1217–1231, 2010.

GRUAN RS92 dataproduct: doi:10.5676/GRUAN/RS92-GDP.2