VAISALA RADIOSONDE RS41

White Paper
Ground Check Procedures

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CHAPTER 1
INTRODUCTION

Radiosonde ground check is an essential part of reliable sounding operations. With Ground Check Device RI41, each radiosonde is checked prior to launch to detect possible damages occurred, for example, during transportation, and to guarantee high measurement accuracy of PTU measurements. The applied technologies make this possible in an easy-to-use and maintenance-free way.

The first part of this document describes how radiosonde RS41 ground preparations are performed with Vaisala Ground Check Device RI41. From the operator's point of view, the preparation phase is extremely simple and user-friendly. Furthermore, as will be shown in the second part, by using RI41 in the preparations, the functionality and the measurement accuracy of the radiosonde are assured with high reliability.

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CHAPTER 2

GROUND PREPARATIONS USING VAISALA GROUND CHECK DEVICE RI41

In the following, the ground preparations are described in the execution order that is applied with Ground Check Device RI41 and Vaisala Sounding Systems MW41 and MW51.

Start-up

During storage, the electronics of Vaisala Radiosonde RS41 are in a completely inactive state. In the beginning of the ground preparations, the radiosonde is turned on and the status of basic functions is checked. In fact, whenever in power-on mode, the radiosonde continuously monitors its core functions, including PTU measurements, GPS processing, and flash memory operations. The functional status of the radiosonde is shown both with the LED indicator of the radiosonde (for detailed information, see the most recent version of RS41 User's Guide) and on the display of sounding system.

Start-up Procedure

The sounding system detects and automatically powers up the RS41 radiosonde when it is placed onto the Ground Check Device RI41. The RI41 device utilizes a wireless short-range (approximately 4 cm) radio frequency (RF) link for communication with RS41. During the preparation phase, the radiosonde telemetry transmitter is inactive. Instead, RS41 utilizes the RF excitation from the RI41 device for the data exchange. It is worth noting that the wireless link is used for data transfer only, that is, during the preparations RS41 is powered by its own battery.

As Radiosonde RS41 is powered up, the sounding system reads the radiosonde status and a set of radiosonde parameters. The user interface displays:

- *Transmitter status* (on/off)
- *Remaining radiosonde battery capacity* (minutes)
  If the battery capacity is low, MW41 displays a warning and it is recommended to change the batteries according to the instructions given in RS41 User's Guide.
- *Radiosonde status* (OK/error).
  This includes GPS initialization and correctness of parameters.

At any time during the ground preparations, the operator can change the following radiosonde parameters to preferred values:

- *Radiosonde transmitter frequency*
  Note 1: Applying the frequency change may take some time as it is conducted in-between the sensor checks.
  Note 2: The transmitter is set on in the final step of the ground preparations. Thus, the signal can be seen on the radio frequency display just after the preparations are ready. The transmitter sends data in pulsed mode, once per every second.
- *Optional criteria when to switch off radiosonde transmitter* (height and/or time)
- *Continue transmitting after balloon burst* (yes/no)
- *Additional sensors connected to RS41* (none/ozone/generic).
  Note: As the additional sensor interface of RS41 is activated, the LED indicator of the radiosonde blinks red whenever no additional sensor data is detected by the radiosonde. The LED turns green as soon as data is available.

Temperature Check

The temperature check with Ground Check Device RI41 enables reliable quality control combined with maintenance-free operation. During the check, readings from the actual temperature sensor are compared with the ones from the temperature sensor integrated on the humidity sensor chip.

The temperature measurement of Vaisala Radiosonde RS41 is based on platinum resistor technology which is known for its reference class stability. Regarding sounding preparations, the largest impact of this is that for RS41, a pre-flight fine-tuning of the temperature measurement is no longer applied. There are two reasons for this new approach: Firstly, as will be shown in the latter part of this document, the accuracy of the RS41 temperature measurement is practically unchanged during storage, and, thus, RS41 meets the highest quality standards of radiosonde users as such. Secondly, to set up and maintain a reference temperature measurement and conditions with better accuracy than those of the actual RS41 temperature measurement would be a challenge.

To sum up the key points, the accuracy of RS41 temperature measurement after storage is at a very high level and the application of a ground check correction could lead to cases where the measurement accuracy is deteriorated due to the applied correction. In the case of RS41 temperature measurement, both the best accuracy and user-friendliness are achieved leaving the ground check correction undone.

It is worth emphasizing that the check for proper function of the temperature measurement is still an important part of the ground preparations - the secondary temperature sensor integrated on the RS41 humidity sensor chip makes the detection of a faulty sensor unit possible in an effortless way.

Temperature Check Procedure

Shortly after the start-up, the sounding system commands Radiosonde RS41 to start the temperature check. During the check, RS41 compares the temperature readings of the actual temperature sensor with the temperature sensor integrated on the humidity sensor chip.

After the check, the user interface displays status information for the operator. The temperature check results in numbers, and, as all other relevant information of the preparation phase, is saved in a file named *soundingqualityreport_yyyymmdd_hhmm_N.txt* found in the *C:\\Messages* folder, by default. If the temperature check fails, that is, the temperature readings deviate more than a pre-set limit, 3°C as a default, the sounding system displays the observed difference, terminates the preparation process, and asks for the operator to change the radiosonde. Also the LED indicator of RS41 starts to blink red as a sign of the error status of the radiosonde. The pre-set rejection limit is set to a level that is strict enough to detect possible breakages of radiosonde sensors or failures of circuit board components and, at the same time, the limit is loose enough to avoid false alarms due to uncontrolled environmental conditions during the check.

Humidity Check

The humidity check procedures with Ground Check Device RI41 involve new technical solutions designed for reliable performance and for maintenance-free operation. The RS41 humidity check consists of two main steps – the sensor reconditioning phase and the zero humidity check.

In the recondition phase, the sensor is heated to remove possible contaminants that could affect the measurement results. Exposure to contaminants may cause a slight degradation of the sensitivity of the humidity sensor. That is why applying the reconditioning heating improves the consistency of identifying layers of saturated water vapor in the sounding profile, that is, it facilitates precise cloud layer detection.

In connection with the reconditioning heating phase, the humidity sensor is also checked and then corrected against a dry humidity condition. Specifically, the dry reference condition of the new zero humidity check is generated in open air by heating the sensor using the integrated heating element on the sensor chip. The procedure utilizes the commonly known behavior of relative humidity: relative humidity decreases towards zero humidity level as the temperature rises high enough. This advanced humidity check method has been proven to produce results at a level of consistency that is hard to maintain in operations with the conventional method, in which the correction is based on a dry condition generated with desiccants. The improvement in the RS41 humidity check accuracy has been achieved by eliminating the limitations related to the use of a dry reference condition: the gradually fading drying capacity of the desiccants and the careful maintenance activities the desiccants involve.

Humidity Check Procedure

When the temperature check phase has finished, the sounding system commands Radiosonde RS41 to start reconditioning heating, which, together with the adjacent cooling time, lasts for approximately four minutes. The user interface shows the remaining heating and cooling phase times during the procedure. If, for some reason, the reconditioning temperature has not reached a high enough level, the the sounding system display as well as the LED indicator of RS41 both point out the status of the radiosonde as erroneous. After the reconditioning period, the sounding system calculates and reports the zero humidity check results and shows the related radiosonde status. If the humidity check correction is out of the pre-set limits, ±2% RH as a default, the preparation procedure is terminated and the operator is asked to change the radiosonde to a new one. The error status of the radiosonde is also indicated by the blinking red LED indicator of Radiosonde RS41.

Pressure Check

In case radiosonde model RS41-SGP is used, the pressure sensor measurement is also checked during the ground preparations. The silicon pressure sensor used in RS41-SGP is characterized by its stability and robustness. However, to ensure the best accuracy of the measurements after transportation and storage, the normal procedure is to compare and adjust the pressure measurement against a reference barometer before the sounding.

The sounding system can be configured to automatically use a pressure reference value from RI41-B, a version of the ground check device with a high-precision barometer, or the reference pressure value can be fed manually according to a preferred reference barometer. After the check, all readings in the radiosonde pressure profile are corrected according to the relation of the reference pressure and the radiosonde pressure readings measured during the ground check.

Procedure when Using RS41-SGP and RI41-B

After the humidity check phase has finished, the sounding system starts reading pressure and temperature readings both from the radiosonde and from the reference barometer of RI41-B. As the measurements have stabilized, the sounding system stores and displays the pressure readings. If the values deviate more than a pre-set limit, 3 hPa as a default, the preparation procedure is terminated and the operator is asked to change the radiosonde to a new one. In case a manually fed barometer value is applied, the sounding system suspends the preparation process and asks the operator to check the given reference pressure value, and then either to correct the reference pressure value or to stop the sounding preparations, and to change the radiosonde to a new one.

Procedure when Using RS41-SG

If the radiosonde model RS41-SG reporting GPS-derived pressure is used, pressure calculation is initialized in the preparation phase according to the station height settings of the sounding system and the reference barometer in use.

Table 1. Summary of applied checks and fine-tuning corrections during the ground preparations. Radiosonde version RS41-SGP includes a pressure sensor, while RS41-SG determines pressure based on GPS measurements.

	RS41- SGP Check	RS41- SGP Fine-tuning	RS41-SG Check	RS41-SG Fine-tuning
Temperature	Done	N/A	Done	N/A
Humidity	Done	Done	Done	Done
Pressure	Done	Done	N/A	N/A

Parameter Updates and Setting the Transmitter on

After the sensor checks have been successfully passed, the final stage of the ground preparations process is to:

- Update radiosonde parameters according to the operator's inputs and ground check results.
- Tune the RF telemetry transmitter to the chosen frequency and set the transmitter on.

Surface Observations and Meta Data

As the sounding system has detected the launch of the radiosonde, the user interface shows a surface observations display. The surface observations can be configured to be automatically filled in according to a weather station observations. Also in this case, the readings can be edited manually. Moreover, cloud observations can be recorded on the same display as well. And, finally, there is a text field for free-form meta data notes that are saved to the sounding quality report.

Storing the Ground Preparation Data

All the information related to the ground preparation phase along with the meta data of the sounding is saved in a file named *soundingqualityreport_yyyymmdd_hhmm_N.txt* found in the *C:\\Messages* folder, by default. The sounding quality report contains:

- Radiosonde type, software version, calculation version of the radiosonde, serial number, type of applied height, and pressure (GPS/P sensor)
- Ground equipment station name, software version, ground check device type, ground check device hardware and software versions
- Ground check results: Observed differences for the temperature measurements, and results from the comparisons against reference measurements for humidity and pressure measurements
- Sounding information including terminating altitude, reason for termination, reason for possible sounding failure, balloon release time, duration of the sounding, average ascent rate, STD level heights, and sounding status
- Surface level observations: Pressure, temperature, humidity, wind direction, wind speed, sea water temperature
- Special group input: WMO cloud group, special group 1, special group 2, ASAP status
- Sounding notes: Text format meta data added by the operator
- GPS status: tracked satellite average count

Ground Check Procedures when Using Vaisala Unmanned Sounding System AUTOSONDE® AS15 or AS41, and RS41 Radiosondes

With Vaisala Unmanned Sounding System AUTOSONDE® AS15 and AS41 it is possible to perform 24 and 60 consecutive soundings, respectively, without any user involvement. As an AUTOSONDE® is operating, temperature, humidity, and pressure measurement functions of each radiosonde are ground checked just before the balloon launch. The checks utilize procedures that are identical with those in manual launches (Table 1). These reliable ground check operations are enabled by the automated, maintenance-free ground check functions of the RS41 radiosonde.

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CHAPTER 3

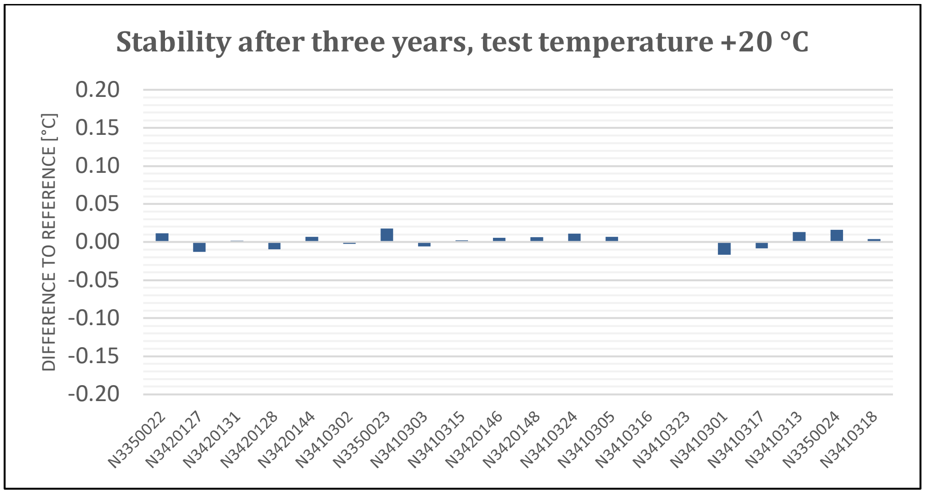
ACCURACY OF VAISALA RADIOSONDE RS41 AFTER STORAGE AND GROUND PREPARATIONS

In this chapter, long period storage test results are presented for the RS41 radiosonde with EPS (expanded polystyrene) covers. Also tests related to the effects of varying conditions during the ground preparation are shown. The results demonstrate that the high-measurement performance of RS41 is assured using the automated preparation procedures of Ground Check Device RI41 controlled by Sounding System MW41 or MW51.

Temperature

The ground check procedure of RS41 temperature measurement is basically a functionality check, and, thus, it does not result in any corrections to be applied in the measurement. That is why, in this context, a simple stability test best describes the measurement performance after storage.

The RS41 radiosondes under the test were factory-calibrated and packed according to standard manufacturing procedures of RS41 production. The radiosondes were stored in outdoor temperature and humidity conditions at Vaisala's factory area in Finland in an unheated shelter-type warehouse. The stability test results of twenty radiosondes after a three-year storage period are shown in Figure 1.



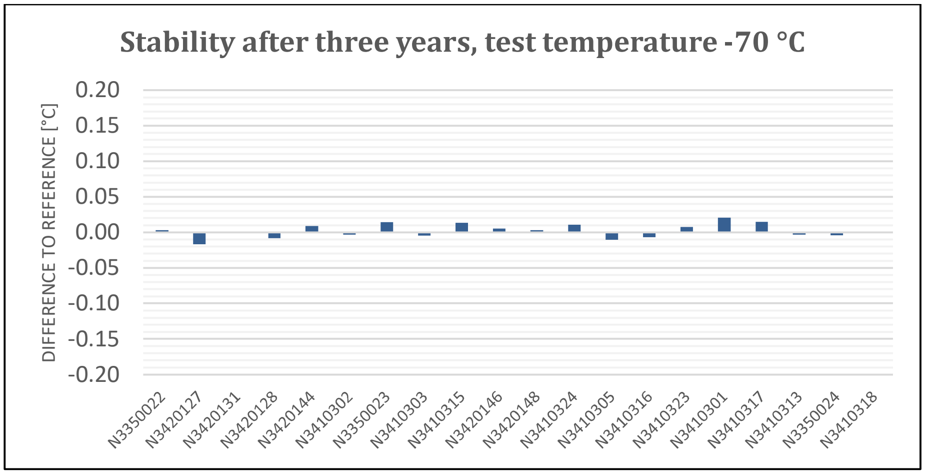


Figure 1. Stability test results of RS41 temperature measurement in two test temperatures after three years of storage. The measurement uncertainty of the test system was 0.07 °C (k=2).

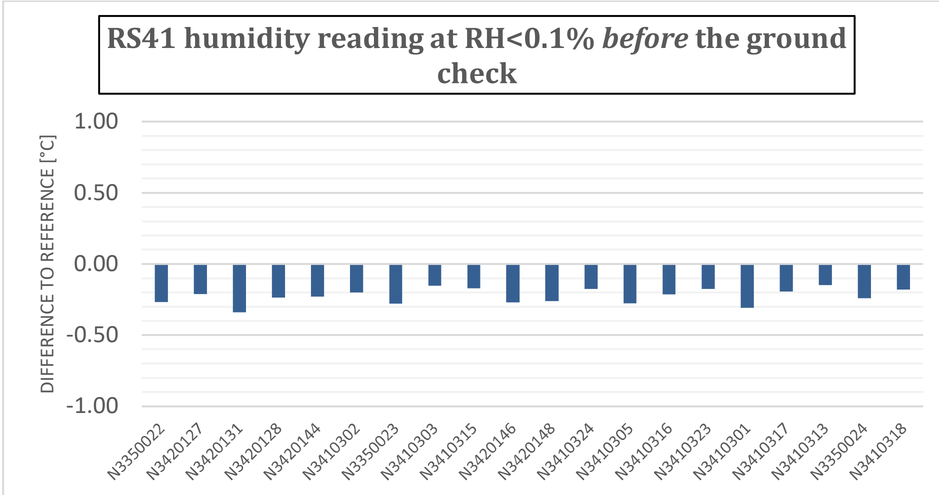
At both test temperatures, +20 °C and -70 °C , the difference to a platinum resistor reference sensor averaged 0.00 °C with a standard deviation of 0.01 °C. It is thus obvious that the results of RS41 temperature measurements are within the test system measurement uncertainty, which was 0.07 °C, applying a coverage factor of two.

The main observation summarizing the temperature test results is that there was no detectable drift found after the three-year storage period. In other words, RS41 temperature measurement retains its high accuracy also in a long-lasting storage. Furthermore, it is well justified to conclude, that for RS41, a mere functionality check in the ground preparation phase guarantees a reliable temperature measurement performance during the sounding.

Humidity

When using Vaisala Ground Check Device RI41 in the RS41 ground preparations, the humidity measurement ground check consists of reconditioning of the sensor, followed by the zero humidity correction, as explained in more detail in the first chapter.

The humidity measurement tests were conducted by using the same set of radiosondes as in the temperature tests. The twenty radiosondes were first measured at room temperature, in a dry, RH<0.1%, nitrogen atmosphere before the ground check. In this phase, the readings of the radiosondes averaged -0.23 %RH, with a standard deviation of 0.05 %RH. After that, the reconditioning and the humidity check procedures were applied in room air, and the measurements in dry conditions were repeated. Now, the average of reading was 0.13 %RH with a standard deviation of 0.03 %RH. Lastly, measurements were conducted in saturated humidity conditions generated with a Standard Humidity Chamber by Dr. Schulz & Partner GmbH. In these conditions the average reading was 99.4 %RH with a standard deviation 0f 0.3 %RH. The RS41 humidity measurement results after three years of storage are presented in Figure 2 and Figure 3 on the next pages.



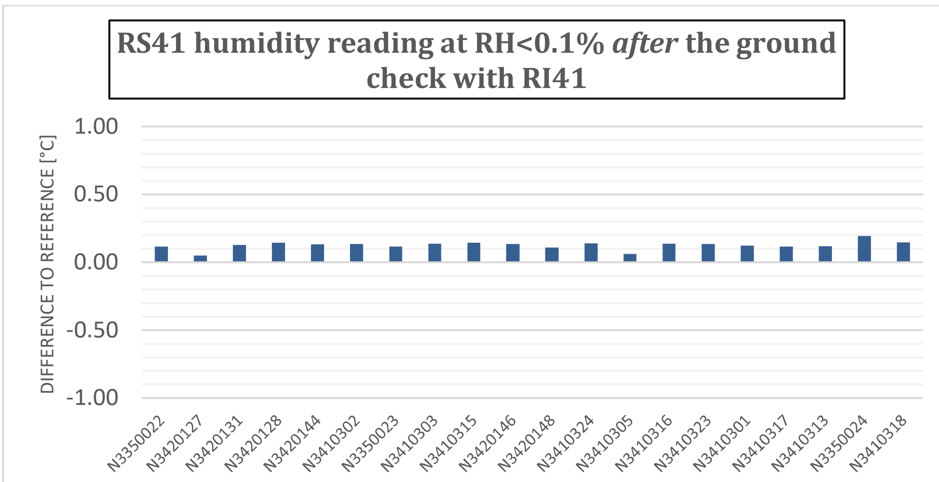


Figure 2. Stability test results of RS41 humidity measurement after three years of storage before and after ground check. The readings averaged over 30 seconds in dry conditions without ground preparation procedures (top), and with the recondition heating and zero humidity check applied, dry conditions (bottom). The humidity level at the dry test condition was below 0.1 % RH.

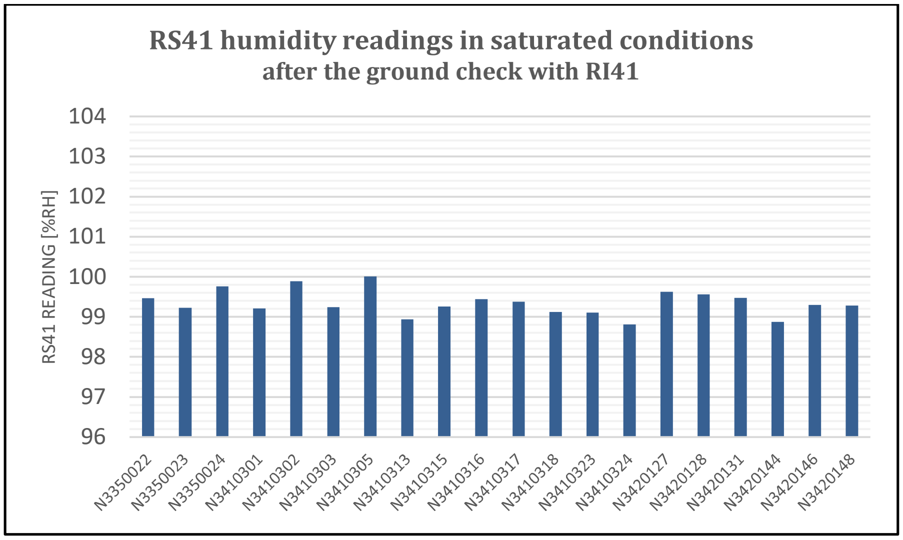
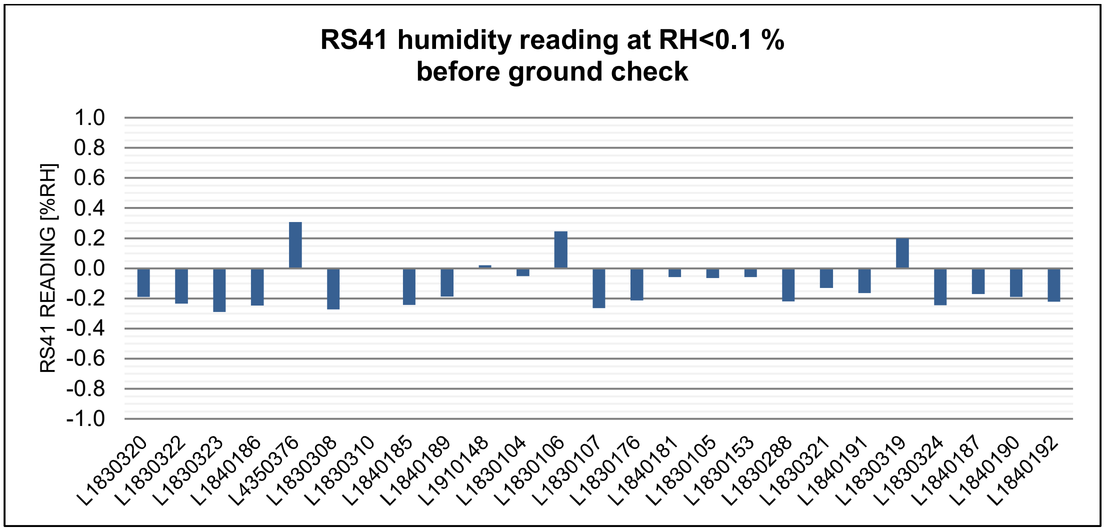


Figure 3. Stability test results of RS41 humidity measurement in saturated conditions after three years of storage followed by the ground check with RI41 device.. The readings averaged over 30 seconds. The saturated test condition was generated with a Standard Humidity Chamber.

With the RI41 device, the ground check correction for humidity is defined in ambient office air by the zero humidity check procedure. The prevailing temperature and humidity conditions at the office may vary for several reasons, thus, it is important that the zero humidity check performs consistently at a wide range of office conditions. To verify this, the following laboratory test was conducted. In the beginning of the test, a set of twenty-five factory-calibrated radiosondes were measured at room temperature, in a dry, RH<0.1%, nitrogen atmosphere. Then, the set of radiosondes was divided into five sub-groups, for which the zero humidity check was done in different conditions: In an “unheated dry office”: T=10.5°C / RH=24%, “heated office at winter time”: T=20.3°C / RH=22%, “normal office”: T=20.4°C / RH=50%, “damp office” T=20.4°C / RH=90%, and in an “office without air-conditioning in the tropics”: T=29.9°C / RH=89.9%. And as a final step to evaluate the accuracy of the applied humidity check correction, the radiosondes were re-measured in the dry nitrogen atmosphere. The results are shown in Figure 4 on the next page.



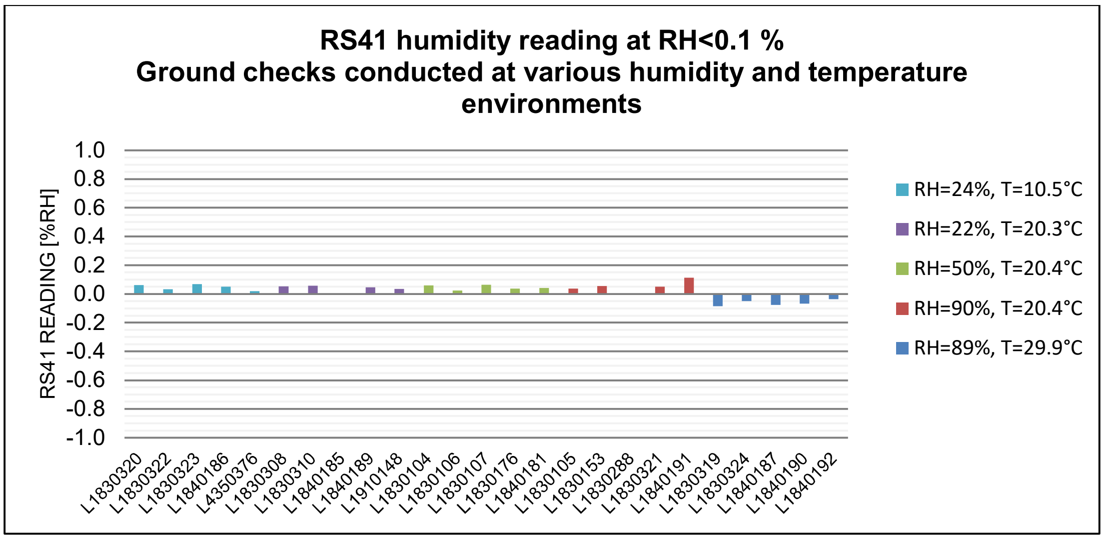


Figure 4. Accuracy of the RS41 humidity check correction performed at a wide range of office conditions. Test radiosondes' humidity readings in a dry (RH<0.1%) nitrogen atmosphere before the humidity check (top), and after the zero humidity checks were conducted in five different conditions (bottom).

The test results demonstrate that the humidity correction, defined by the zero humidity check, keeps its accuracy on a high level in a very wide range of office conditions. The condition-wise grouped means of humidity readings in the dry reference condition ranges from -0.06 to +0.05 %RH, with an inter-group standard deviation of 0.05 %RH.

The conclusion from the stability tests and from the humidity check tests of the RS41 radiosonde is that the ground preparation procedures conducted with Vaisala Ground Check Device RI41 restore the measurement performance to its original level. The new humidity check procedure of RS41 is robust and user-friendly, and, thus, it results in accurate corrections and consistent measurement performance in operational use.

Pressure

Stability of the pressure measurement has been evaluated in storage tests partly separate from the previously presented temperature and humidity measurement stability tests. In the first test, 32 pressure sensor units were stored inside RS41 radiosonde covers and a foil packaging for a period of one year. The storage area was in an outdoor shelter corresponding to a typical long-term storage conditions at a sounding station. In the second test, 15 pressure sensor units were stored inside RS41 radiosonde covers and a foil packaging for two years in typical office conditions. And finally, for the three years stability test, a set of 20 units were stored in an outdoor shelter, as in the first test.

Figure 5 presents the observed drift in pressure measurements averaged over relevant temperature conditions, comparing deviations to a calibrated reference before and after the storage period. The measurement uncertainty of the reference barometer ranges from 0.23 hPa at the lowest pressures to 0.34 hPa at ground-level pressures, when applying a coverage factor of two.

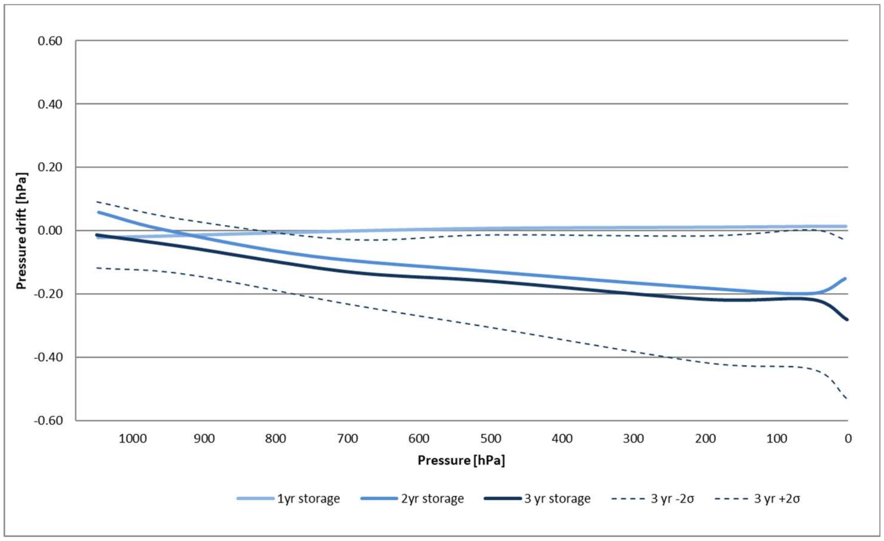


Figure 5. Mean drift in RS41-SGP pressure after one-year (light blue), two-year (blue) and three-year (dark blue) storage in radiosonde foil packaging. The two-sigma dispersion of results after three-year storage is indicated by thin dashed lines.

The test results show that the pressure sensor has excellent stability. Even the three-year test exhibits mean drifts within 0.3 hPa, with standard deviations of approximately 0.1 hPa.

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