Technical report; TR-265

KNMI

Koninklijk Nederlands Meteorologisch Instituut

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De Bilt, 2004

Technical report = technisch rapport; TR-265

De Bilt, 2004

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Stageverslag [Student TU/e]

UDC: 551.501.771
(883)

ISSN: 0169-1708

ISBN: 90-369-2253-4

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Assessment of Data Quality of Water Vapor Measurements in Paramaribo

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Summary

This report presents the results of an investigation to improve data quality of water vapor measurements in Paramaribo (Surinam) during February/March 2004. Two types of water vapor sensors are used: a capacitive polymer sensor applied in the Vaisala RS80 and RS90 radiosondes and the Snow White (SW) chilled mirror hygrometer produced by Meteolabor AG. Two types of RS80 radiosondes are used: one using an A-Humicap polymer humidity sensor and one using a more sensitive H-Humicap sensor. The RS90 radiosonde uses two alternately heated H-Humicap sensors.

The RS80 radiosondes have been subject to a 100% relative humidity (RH) ground check before launch, using a specially designed calibration box. For the RS80-18LE and RS80-15GE (both A-Humicap) no significant bias in the RH data is found. One of the tests pointed at an increase of the bias with the age of the radiosonde. The RS80-15GHE (H-Humicap) radiosondes tested in Paramaribo, have an average wet bias of 4,1 ± 1,4 %, mainly caused by a calibration error.

Apart from a possible bias, all RS80 RH data agree well with the SW data in the lower troposphere (0-10 km). The SW data can be used as a reference up to the tropopause. If the RS80-15GHE RH data are corrected for their individual wet bias, better agreement with SW is reached. In the middle and upper troposphere RS80 RH data lose detail and are not reliable anymore.

Below -30 ^{o}C, the capacitance of the RS80 polymer humidity sensors becomes strongly temperature dependent, causing a dry bias. The RS80 (A- and H-Humicap) RH profiles are corrected for this behavior with formula's found in literature, showing better agreement with the SW profiles.

Finally, a comparison is made between ECMWF model output and the SW, RS80 and RS90 sounding data. Considering the large scale of the model output (1-degree longitude and 1-degree latitude), ECMWF profiles agree well with the sounding data in Paramaribo.

Contents

1 Introduction

Despite of its low and variable volume-mixing ratio (<0.03), water vapor plays an important role in the troposphere and the stratosphere. It is responsible for the precipitation (rain and snow) that forms an important part of our weather, it has significant radiative effects and in its ice phase it is associated with important chemical reactions that lead to the depletion of polar ozone. (1) (10) (11)

Accurate measurements of water vapour however, are still a challenge. This is because the vapour pressure decreases about five orders of magnitude from the surface to the tropopause and is very variable in time and space. World wide at about 50% of the sounding stations Vaisala RS80 radiosondes are used to measure relative humidity (RH), mostly equipped with so-called 'A-Humicap' humidity sensors. These sensors are able to accurately measure RH in the lower and middle troposphere (up to 10-12 km), although some corrections may be needed to avoid a bias. They fail at higher levels where the low temperatures (below $-30\ ^oC$) strongly decrease the accuracy. In a collaboration of KNMI [1] and MDS [2] an atmospheric observation program was started in 1998 in Paramaribo, Suriname. The weekly ozone soundings that are part of this program were made with A-Humicap RH sensors (until November 2003), and more recently with H-Humicap sensors (December 2003 and onward).

For measurements above the middle troposphere KNMI and MDS started a new project in cooperation with the SOWER [3] project in October 2002. For this project a "Snow White (SW)" dew/frost-point hygrometer for radiosonde application is used, produced by Meteolabor AG. This hygrometer is based on the well-known chilled mirror principle, which will be further explained in chapter 3. Between October 2002 and June 2003, eleven soundings have been performed during which a SW, a Vaisala RS80 radiosonde, and a Vaisala RS90 radiosonde were attached to the same balloon. The RS90 radiosonde uses two H-Humicap humidity sensors that are alternately heated and used for measurements, to dissolve contamination and icing of the sensors.

In this report three different experiments will be discussed. 1) A method to improve the accuracy of Vaisala RS80 radiosonde measurements will be tested. This method is based on an extra 100% RH ground check before launch. 2) Five SW soundings launched in Paramaribo in February/March 2004 will be discussed. During three of those SW soundings, old RS80 radiosondes using A-Humicap are compared with the new RS80 radiosondes using H-Humicap. 3) A comparison of the SW and radiosonde RH data with ECMWF model output is made.

Theory of water vapour and relative humidity calculations will be discussed in chapter 2 and the experimental setup will be given in chapter 3. In chapter 4 the results of the experiments will be discussed and chapter 5 consists of conclusions and recommendations.

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[1] Koninklijk Nederlands Meteorologisch Instituut

[2] Meteo Dienst Suriname

[3] Soundings of Ozone and Water in the Equatorial Region

2 Theory

Air consists amongst others of the gasses nitrogen, oxygen, water vapour, carbon dioxide, argon and ozone. Water vapour is the third most abundant compound with typical volume mixing ratios smaller than 0.03. As most compounds, water (H_2O) can exist in three phases: solid phase, liquid phase and vapour phase. The existence of the different phases depends on the pressure p and the temperature T as can be seen in figure 2.1.

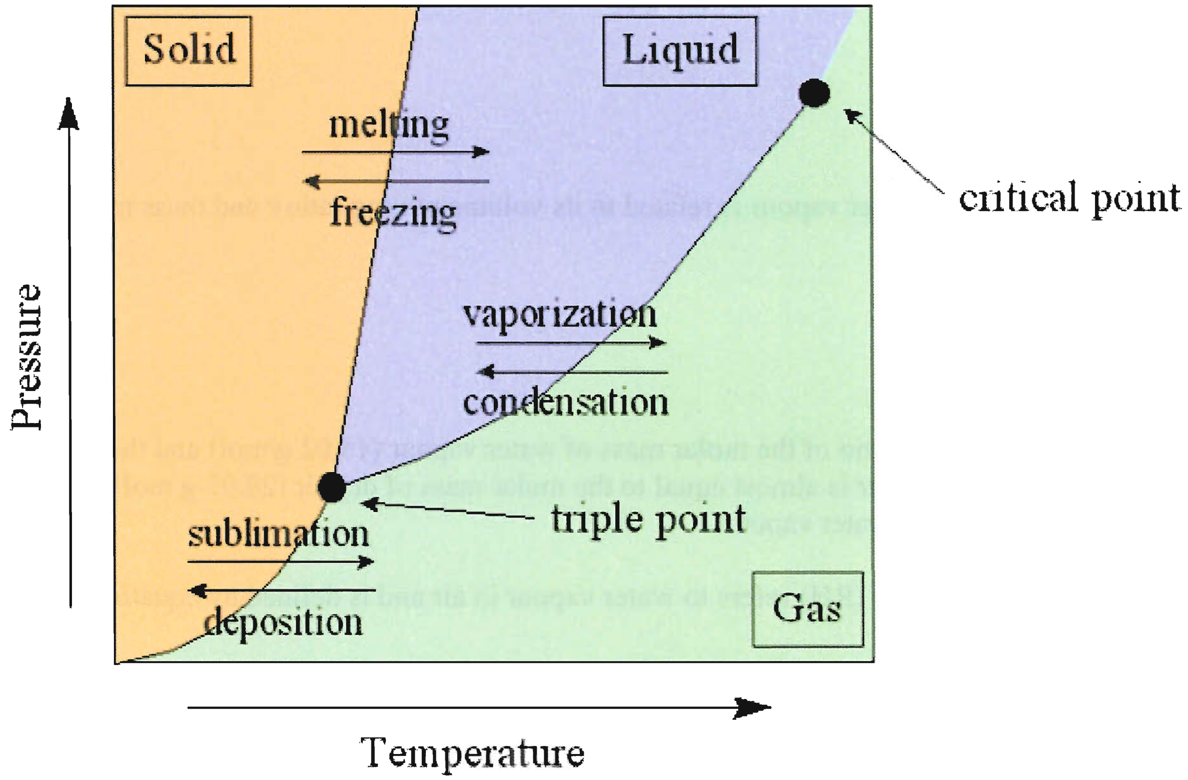

Figure 2.1: Phase diagram of water.

When the vapour phase is in equilibrium with the liquid phase, the volume is called saturated. The slope of the saturation vapour pressure p_s curve in figure 2.1 is given by the Clausius-Clapeyron equation:

$$\frac{dp_s}{dT} = \frac{\delta S}{\delta V} = \frac{L}{T\delta V} \qquad (2.1)$$

In this equation δS is the entropy gained as unit mass of water changes from liquid to vapour, δV is the increase of volume during this transition and L is the latent heat of vaporization per unit mass. Because the specific volume of the water vapour V_v is much larger than that of liquid water, δV is about equal to V_v. Using this and the ideal gas law (2.2), the Clausius-Clapeyron equation can be written in a more convenient way (2.3):

$$p = \frac{R^* T}{V_m} \qquad \text{and} \qquad \frac{R^*}{R_v} = \frac{V_m}{V_v}, \qquad (2.2)$$

$$\frac{dp_s}{dT} = \frac{Lp_s}{R_v T^2} \tag{2.3}$$

R^* is the universal gas constant, R_v is the specific gas constant for the vapour and V_m is the volume of one mole of gas. These considerations apply to pure water vapour, but can also be used for mixtures of water vapour and air by replacing the pressure by the partial pressure of water vapour *e*. If $e_s\ (T)$ stands for the saturation vapour pressure, equation (2.3) can be written as:

$$\frac{de_s}{dT} = \frac{Le_s}{R_v T^2} \tag{2.4}$$

The partial pressure of water vapour is related to its volume mixing ratio ν and mass mixing ratio μ as follows:

$$\nu = \frac{e}{p}, \qquad \mu = \varepsilon \frac{e}{p} \tag{2.5}$$

In this equation, ε is the ratio of the molar mass of water vapour (18.02 g/mol) and the molar mass of moist air. The latter is almost equal to the molar mass of dry air (28.97 g/mol) due to the small mixing ratio of water vapour.

The term relative humidity (RH) refers to water vapour in air and is defined by equation (2.6):

$$RH(T) = \frac{e}{e_s(T)} \tag{2.6}$$

The dew point T_d of a sample of air is the temperature to which air must be cooled at constant pressure, retaining its water vapour content, for it to become saturated. If the sample of air initially has vapour pressure *e*, then $e_s\ (T_d) = e$. If also e_s and the initial temperature T of the air are known, the RH is the ratio of $e_s\ (T_d)$ and $e_s\ (T)$. Sonntag (2) presented a numerical formula, derived from the Clausius-Clapeyron equation, to calculate the saturation vapour pressure with respect to water (2.7):

$$e_{sw}(T) = \exp(\frac{-6096{,}9385}{T} + 16{,}635794 - 0{,}02711193 \cdot T + 0{,}00001673952 \cdot T^2 + 2{,}433502 \cdot \ln T) \tag{2.7}$$

At temperatures below zero and in the presence of ice particles, the saturation vapour pressure has to be calculated with respect to ice, which results in a slightly different slope of the Clausius-Clapeyron equation as shown in figure 2.1. The equation Sonntag has presented for the case of saturation of water vapour relative to ice is given below (2.8):

$$e_{si}(T) = \exp(\frac{-6024{,}5282}{T} + 24{,}7219 + 0{,}010613868 \cdot T - 0{,}000013198825 \cdot T^2 - 0{,}49382577 \cdot \ln T) \tag{2.8}$$

In (2.7) and (2.8), e_s is given in hPa and T must be in Kelvin.

3 Experimental Setup

In the different experiments RS80 (A- and H-Humicap), RS90 radiosondes and the Snow White chilled-mirror hygrometer are used. In this chapter a description of the different instruments will be given. In Paramaribo also tests are done to improve the quality of the RS80 datasets. In addition to the 0% RH check that is currently done prior to the launch, an extra check at 100% RH is performed. Sections 3.1 and 3.2 describe the Vaisala RS80 and RS90 radiosonde respectively. Section 3.3 is about the Meteolabor AG Snow White chilled-mirror hygrometer. In section 3.4 the setup for the extra 100% RH ground check is explained.

3.1 Vaisala RS80 Radiosonde

The RS80 radiosonde is produced by a Finnish company named Vaisala. It is a package of 55x147x90mm, consisting of a circuit board and a water activated battery, covered with styrofoam for insulation. Connected to the circuit board are a sensor arm to measure PTU data (Pressure Temperature hUmidity) and a 403 MHz transmitter. The data are received by a ground station, consisting of a Vaisala DigiCORA II MW 15, connected to a computer. The Vaisala Humicap RH sensor is a thin-film capacitive sensor, using a highly porous polymer electrode, whose capacity depends on the amount of water vapour and the air temperature. There are two different polymer materials that are used in the sensors, the A-Humicap and the more accurate H-Humicap. More details about the PTU sensors are given in appendix A. Before flight, a ground check has to be performed during which the sensor is placed in a small chamber with a desiccant (keeping the RH at 0%). The PT data read on an external barometer and thermometer have to be inserted in the DigiCORA, together with the value of 0% RH. The software then corrects the measured profiles during the flight, by subtracting the differences measured during the ground check. The maximum sampling rate is 7 samples every 10 seconds.

3.2 Vaisala RS90 Radiosonde

This Vaisala radiosonde uses two H-Humicap polymer sensors that are alternately heated and used for measurements. This reduces the problems of icing and contamination of the polymer, improving the data quality. Furthermore the sensor arm is above the radiosonde body, instead of next to it, so the sensor arm encounters undisturbed air. Also the vertical resolution is improved, the RS90 can give one measurement of each variable per second, which is about once per 5 m during a normal balloon sounding.

3.3 Meteolabor AG Snow White Hygrometer

The Snow White (SW) hygrometer is produced by a Swiss company named Meteolabor AG. It continuously measures the dew/frost-point temperature during a balloon flight, using a 3x3mm mirror attached to the cold side of a Peltier element. A Peltier element consists of two layers of different metals and if a current is sent through a junction of these two layers, a temperature difference is generated between the two layers (a Peltier element is the reverse of a thermocouple). The hot side of the Peltier element is connected to an aluminum radiator, which is cooled by the air. During a flight a layer of condensate (dew or frost) is maintained on the mirror by cooling it below the outside temperature, till the dew/frost-point temperature is reached. The thickness of this layer is monitored using a lamp, an optical fiber and a phototransistor. The electric feedback circuit automatically controls the power of the Peltier cooler to maintain a constant layer of condensate on the mirror. The SW mirror is made of two thin metals (copper and constantan plated with gold) and is part of a thermocouple that in this way constantly measures the dew/frost-point temperature. The mirror, lamp and optical fiber are situated in a separated metal housing of 3x1x5 cm, which has a slit for air-intake. During the flights in Paramaribo in February/March, this metal housing has been adapted to improve the airflow on the mirror. Details of this adaptation are presented at http://wwwoa.ees.hokudai.ac.jp/people/fuji/sw/sw_nightmod/index.html by M. Fujiwara (EES, Hokkaido University). The sensor housing is equipped with a heater, which operates in cloud layers to avoid sensor icing and to make total water measurements. The SW hygrometer works with two ordinary dry-cell batteries, a 9V one for the lamp and the control circuit and a 1,5V one for Peltier element and the sensor-housing heater. (3) A schematic example of a hygrometer based on the chilled-mirror principle is shown in figure 3.1.

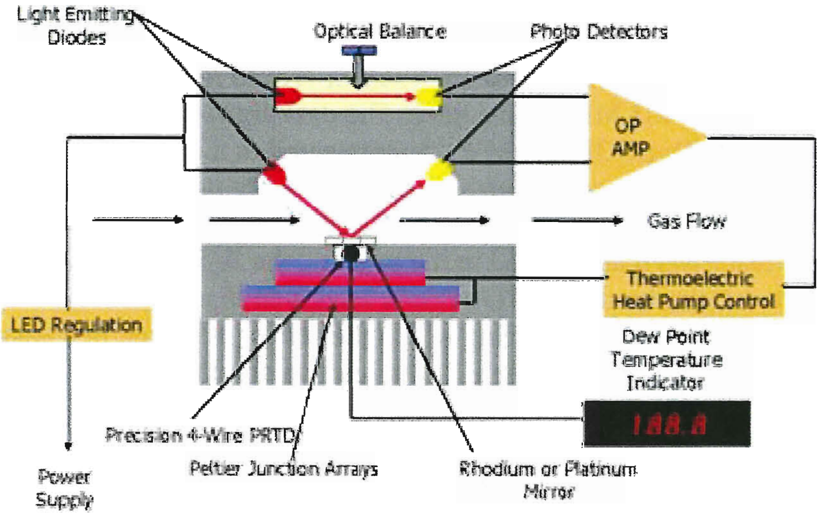

Figure 3.1: Principle of a chilled mirror hygrometer.

The SW hygrometer doesn't need any extra calibration and is produced ready for use. However, to be able to broadcast the SW data it has to be connected to a Vaisala RS80 radiosonde, because the SW itself doesn't have a transmitter. The connection to the RS80 is made through a TMAX-C interface which is already connected to the SW by Meteolabor AG. The RS80 circuit board has to be modified in such a way that the RS80 PTU data are first sent to the interface where the analog signal is converted to a digital one, after which it is sent to the RS80 transmitter, in combination with the SW data. More details about this modification are on http://wwwoa.ees.hokudai.ac.jp/people/fuji/sw/sw_surinam/rssoldr.html (M. Fujiwara). To receive the data at the ground, the following equipment is needed: Antenna with pre-amplifier, an ICOM IC-R8500 receiver, a Kantronics KAM'98 modem and a PC which can run MS-DOS (in Paramaribo a laptop is used) and which has a RS232C port. For the interpretation of the data, a software program STRATO.EXE (written by H. Vömel from Colorado university) is used, which makes real time plots of the data during a flight. More information about this program can be found at http://cires.colorado.edu/~voemel/strato/strato Together with this RS80-TMAX-C-SW combination a Vaisala RS90 radiosonde is connected to the balloon. A schematic view of the flight configuration is shown in figure 3.2. The gray parts in figure 3.2 are launched with a 1000 gr rubber balloon, the other parts are needed for receiving the data.

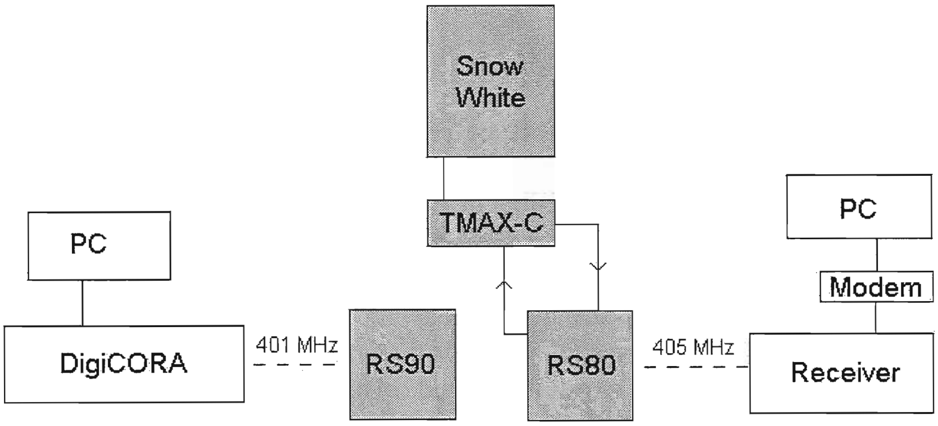

Figure 3.2: Schematic view of a flight configuration.

3.4 100% RH Ground Check.

Both types of Vaisala RS80 (A- and H-Humicap) are known to have a bias in their RH data at room temperature conditions. To check the size of this bias, experiments are done with a 100% ground check. For this purpose U. Leiterer (Deutscher Wetterdienst) constructed a metal calibration box, which is pictured schematically in figure 3.3.

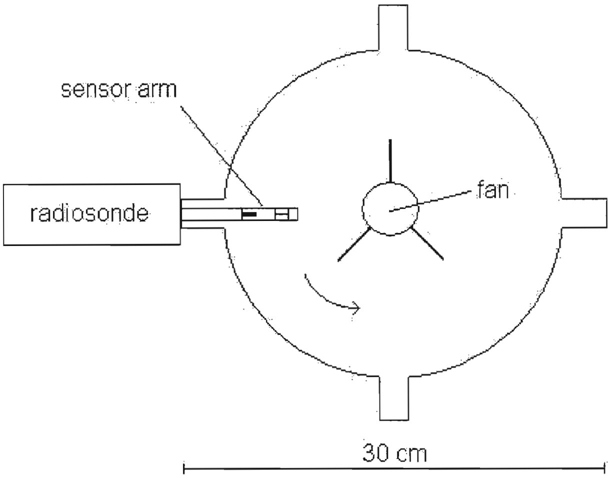

Figure 3.3: Calibration box for 100% RH ground check.

The fan is connected to a power supply (6V) and causes the air to flow around at approximately 5 m/s, roughly the same velocity as the rising speed of a balloon launch. A small layer of water (200 ml) inside the box is heated to about 10 degrees above room temperature, after which it slowly cools down again. The air above the water becomes saturated (100% RH) and the sensor arm of the radiosonde can be put inside the box. At the DigiCORA the RH given by the RS80 radiosonde can be seen and the correction in the RH data is made according to equation (3.1). RH_{corr} is the corrected and RH_m the measured relative humidity.

$$RH_{corr} = RH_m \frac{100}{RH_{m,100\%}} \tag{3.1}$$

4 Results

In this section the results of the different experiments are presented. In section 4.1, the results of the 100% RH ground check for the RS80 radiosondes are described. Section 4.2 discusses the combined Snow White, RS80 and RS90 soundings in Paramaribo during February/March 2004. Comparisons between SW and RS80H data are made and bias corrections are discussed. A-Humicap humidity sensors are compared to H-Humicap sensors and a few examples of possible temperature corrections are given. In section 4.3 a comparison of the SW and radiosonde RH data with ECMWF model output is made. All RH data in this report are given with respect to liquid water unless explicitly stated differently.

4.1 100% RH Ground Check

In the period of February/March 2004, 15 RS80 radiosondes were tested before launch at 100% RH, as described in section 3.4. The radiosondes were used for SW-soundings, O_3-soundings and also routine soundings only containing a RS80 radiosonde. Before launch the sensor arm of the radiosonde is put inside the calibration box for 10 minutes, after which the values of the pressure, temperature and RH are read at the DigiCORA. The average temperature in the calibration box during the 15 tests was 31,5 ± 0,7 °C and the average pressure was 1012,1 ± 1,4 hPa. When a routine 0% RH ground check is performed (see section 3.1), this is done before the 100% calibration. If no official ground check is performed at 0% RH before launch, the value of the 100% check is corrected manually afterwards by subtracting the difference between the measured RH at 0% RH and the real 0% RH. Table 4.1 lists the types of radiosondes that are tested, including the production date and the number of tested sondes. The production date can be retrieved from the serial number of the Vaisala radiosonde: the first number stands for the year of production, the next two numbers give the week of production. In the last column of table 4.1 the average RH is given, measured at 100% RH conditions.

Table 4.1: Results of the 100% RH ground check.

Type	Sensor type	Produced in	# of tests	RH at 100% RH (%)
RS80-15GHE	H-Humicap	2003, wk 37	9	104,1 ± 1,4
RS80-15GE	A-Humicap	2001, wk 7	3	100,3 ± 1,5
RS80-18LE	A-Humicap	2001, wk 27/ 2002, wk 52	3	94, 99 and 99

The average RH of the nine tested RS80-15GHE (H-Humicap) radiosondes at 100% RH is 104,1 ± 1,4 %, showing an average wet bias of 4,1%.
The three RS80-15GE (A Humicap) give an average RH of 100,3 ± 1,5 % at 100% RH (individual values of 99, 100 and 102%), showing no significant bias.
One of the RS80-18LE (A-Humicap) was produced in 2001 wk 27, giving a RH value of 94%; the other two (2002 wk 52) both give 99%, showing no significant bias.

At the Lindenberg (Germany) sounding station, 830 Vaisala RS80 routine soundings were investigated during the period of September 1994 to April 1995. (4) All the radiosondes used the A-Humicap polymer sensor. Before launch and after the routine ground check at 0% RH, the RH was checked with a well calibrated psychrometer (Assmann-type and/ or Rotronic-polymer-sensor). The result of these experiments was that within a humidity range of 40-100% RH, the RS80 radiosondes had an average dry bias of 4%, with a standard deviation of $\sigma = 2\%$.

A comparable research of 1460 RS80 radiosondes using A-Humicap, produced between 1991 and 1997, gives an average dry bias of 5,6%, with a standard deviation of $\sigma = 2\%$. (5)

From literature seven causes of measurement-errors for RS80 radiosondes are known. (6)(7) The different errors presented below are present in RS80A as well as in RS80H measurements, but the sizes differ for the different types of Humicap material.

1. Chemical contamination error: Due to outgassing of the packaging material of the radiosonde, non-water molecules occupy binding sites, reducing the ability of the polymer to absorb water molecules, causing a dry bias. Packing the sensor arm in a special low-outgassing plastic cover with a desiccant material inside solves this problem. This cover is placed on all RS80 radiosondes produced after May 2000.

2. Temperature dependence error: The relative humidity is derived from the measured sensor capacitance of the Humicap. This capacitance of the polymer sensor is apart from being dependent on the RH, also temperature dependent. A linear function of temperature is used for calibration of the radiosondes, while at low temperatures (below -30 °C) the temperature dependence is non-linear. This error is largest for the A-Humicap material. Below -40 °C the temperature dependence error dominates all other errors. At -70 °C the correction factor is 2,3 for the A-Humicap and 0,3 for the H-Humicap.

3. Basic calibration error: This error is caused by the fact that the manufacturer (Vaisala) does not calibrate the sensors individually, nor each production batch separately. Instead, a calibration model is used for each individual sensor, which is averaged over a large number of calibrated sensors from different production batches. This is a small effect, the 1 σ (68%) level lies within 2% RH and the 2 σ level lies within 4% RH, according to values given by Vaisala.

4. Sensor-arm-heating error: This error is caused only during the daytime in the first 40-60 s of a sounding, because the sensor-arm is heated due to exposure to sunlight. This gives a higher saturation vapour pressure, causing a dry bias. After 40-60 s the error disappears due to the ventilation of the sensor-arm. A temperature difference of 1 °C between the sensor-arm and the environment, gives a dry bias of about 4%.

5. Ground check error: Due to human errors, the RH value obtained at the ground check might not be taken at 0% RH. Causes might be using an old desiccant, not leaving the sensor in the box long enough to reach 0% RH, or a moist environment causing contamination from the outside inside the box.

6. Sensor aging error: Due to aging of the sensor, a dry bias develops. After two years of storage, this error can be 5% for the A-Humicap, after which it grows with 0,5% a year.

7. Time-lag error: Time response increases exponentially with decreasing temperatures.

The average wet bias (+4,1%) of the Paramaribo RS80-GHE data at ground level before launch can be the resultant of errors 1, 3, 5 and 6. If it is assumed that the chemical contamination error (1) has disappeared due to the better packing of the sensor and that no human errors are made (5), the bias is the resultant of the calibration-error for this production batch (serial no: 337......) and the sensor aging error. The average age of the sensors is only half a year, so the effect of sensor aging (6) is small. From the above it seems that a consistent calibration error (3) is responsible for this wet bias.

The dry bias (-6%) of the RS80-18LE produced in 2001 seems mainly to be caused by the sensor aging error (6). This is confirmed by the fact that both sensors of the same type produced at the end of 2002 only show a very small dry bias (-1%). However these sensors are of a different production batch, so a calibration error (3) might also be partly responsible for the bias. The fact that no significant bias is seen for the almost three-year-old RS80-15GE radiosondes might be explained by a wet calibration bias that is compensated by a dry bias caused by the sensor aging.

Comparisons to the biases found in literature are difficult, because the bias depends on production date (before or after May 2000 in relation to the contamination error), the age of the sonde when it was launched, and also a lot of other factors.

Bias corrections in the RS80-15GHE and the RS80-18LE RH profiles can be made, examples of this will be presented in section 4.2.

4.2 Snow White soundings in February/March 2004

In the period of February/March 2004, five Snow White hygrometers were launched at Paramaribo. Their flight configuration is given in figure 3.2. The radiosondes used to transmit the SW data were of the RS80-15GHE type (H-Humicap). During the last three flights the RS90 was replaced by an RS80-18LE (A-Humicap). Plots of the data obtained from these five flights are presented in appendix B. Plots of the same soundings, made by M. Fujiwara are presented at: http://wwwoa.ees.hokudai.ac.jp/~fuji/tmp/srnm/. In the text below the individual soundings will be discussed.

February 11:
The RH profiles for the first 25 km of this sounding, are presented in fig. 1a in Appendix B. In the plot the SW, RS80H and RS90 data are presented, as well as the ECMWF model forecast. Comparisons with the ECMWF model will be presented in section 4.3. In the lower troposphere (0-10 km, LT), SW, RS80H and RS90 profiles are quite similar. Between 6 and 9,5 km a very dry layer (<3% RH) is encountered in which the SW cannot reach frost-point-temperature. This can be seen from the extra housekeeping data that are taken during flight (not shown). The Peltier current shows a maximum (1,4 A), meaning that the cooling is insufficient to reach the frost-point-temperature. Also the phototransistor-voltage increases, showing increasing reflectivity of the mirror, meaning lost of condensate-coverage. (3)(8) The result is that RH values given by the SW in this layer are too high. The RS80 and RS90 H-Humicap humidity sensors can measure a minimum of 2% and 1% RH respectively. In the middle troposphere (10-15 km, MT), the RS80H profile starts diverging from the SW profile above a height of 10 km (-35 °C). This behavior is a combination of the time-lag-error and the temperature-dependence-error presented in section 4.1. However the profile still shows most

of the same shape as the SW profile, which can be taken as a reference profile up to the tropopause. (3)(8) The RS90 profile starts diverging from the SW profile above 12,5 km (-50 °C). In the upper troposphere and lower stratosphere (15-25 km, UT and LS), the RS80H and RS90 (also using H-Humicap) don't show any detail anymore and give a wet-bias compared to the SW profile. Between 18 and 20 km SW data are lost. From literature is known that in the LS the volume-mixing ratio of water vapor is about the same as around the tropopause (2-4 ppmv). With the increasing temperatures in the LS (thus increasing saturation mixing ratio), this means very deep frost-point-depressions, which can't be reached by the one-stage Peltier cooler of the SW (maximum of 20K frost-point-depression at tropical LS temperatures (3)). This means that the mirror would lose condensate coverage (increasing phototransistor voltage) and the Peltier current would reach a maximum. However, this maximum Peltier current and increasing phototransistor voltage is not seen in LS for this sounding, indicating suspiciously high mixing ratios of water vapor. A possible explanation for this is the lack of airflow at the mirror surface and icing of the mirror. To increase this airflow, all SW soundings in Paramaribo during February/March 2004 are performed without the sensor housing, as explained in section 3.3. However, this adaptation may not have been sufficient.

February 18:
The RH profiles for the first 25 km of this sounding, are presented in fig. 1b in Appendix B. In the LT, again the SW, RS80H and RS90 profiles are quite similar. Between 4,5 and 6 km a very dry layer (<3% RH) is encountered in which the SW cannot reach frost-point-temperature. Also a small wet bias is visible for the RS80H (+4% according to the 100% RH ground check) and the RS90 (not measured). In the MT, the RS80H and RS90 profiles both start diverging from the SW profile after a height of 13 km (-55 °C), also not following the shape of the SW profile anymore. In the UT all three sensors show ice-supersaturation, indicating high cirrus clouds. Time-lag errors however take away all the details in the RS80H and RS90 profiles.

February 25:
The RH profiles for the first 25 km of this sounding, are presented fig. 1c in Appendix B. In the plot SW and RS80H data are presented as well as the data obtained from an RS80-18LE (A-Humicap) instead of the RS90 during earlier flights. In the LT the shape of the SW and both RS80 profiles is similar, the RS80A showing a dry bias (-6% according to the 100% RH ground check) and the RS80H showing a wet bias (+3% according to the 100% RH ground check). With a correction in the data according to formula 3.1, the profiles in the lowest 6 km look like presented in fig. 1d in Appendix B. Now the profiles of both RS80 radiosondes show much better agreement with the SW profile, except when the RH changes very quickly with height. In these situations a time-lag-error is seen. In the MT, the RS80 profiles both start diverging from the SW profile above a height of 11,5 km (-45 °C), also not following all the details in the shape of the SW profile anymore. In the UT all details in both RS80 profiles are lost, also not showing the ice-supersaturation the SW detects there. In the UT and LS the RS80H gives much higher RH values than the RS80A. The extremely high values of SW RH around 16 km are unrealistic. In case of detection of an ice-cloud, the SW sensor housing is heated to prevent icing of the sensor. Therefore the mirror temperature no longer gives the frost-point temperature and the calculated RH is too high, indicated by a frost point temperature that is higher than the air temperature.

March 10:

The RH profiles for the first 25 km of this sounding, are presented in fig. 1e in Appendix B. In the LT, the SW and both RS80 profiles agree quite well, showing only very small biases. The bias measured at the 100% RH ground check was -1% for the RS80A and +2% for the RS80H. In the MT, both RS80 profiles start diverging from the SW profile after a height of 11,5 km (-45 °C) and fail to follow all the details in the shape of the SW profile. In the UT and LS all details in the RS80 profiles are lost, again the RS80H giving much higher RH values than the RS80A. For this flight a 1200 gr balloon was used in an attempt to increase the airflow on the mirror surface by increasing the rise-speed. The increase in rise-speed however was only 1,7 m/s (6,7 m/s instead of 5 m/s) and no improvement is seen in the Peltier current and phototransistor voltage.

March 17:

The RH profiles for the first 25 km of this sounding, are presented in fig. 1f in Appendix B. The behavior of the RS80 profiles is the same as described for the soundings above. The bias measured at the 100% RH ground check was -1% for the RS80A and +6% for the RS80H. A corrected profile for the lowest 4 km is presented in fig. 1g in Appendix B. For the RS80H profile the bias correction gives better agreement with the SW profile, however still showing a wet bias. The RS80A profile also shows a wet bias compared to the SW, the small correction only making this bias larger.

A-Humicap compared to H-Humicap:

In fig. 2 in Appendix B a comparison is shown for the three flights during which an RS80A radiosonde was launched simultaneously with an RS80H. From the plot can be seen that RS80H data show a wet bias relative to RS80A data in the LT, which is also seen from the 100 % RH ground check, discussed above. From the MT and above, both RS80 profiles lose detail, the H-Humicap showing much higher RH values than the A-Humicap.

Bias corrections:

Comparing the LT (0-10 km) RS80H data of the five flights in February/March 2004 with the SW data reveals a consistent wet bias. A plot of this comparison is presented in fig. 3a in Appendix B. Apart from this bias, the RS80H data and SW data show good agreement in the LT. If a bias correction is made for the four flights that had a 100 % RH ground check, very good agreement with the SW data is reached (fig. 3b in Appendix B).

In the MT (10-15 km) RS80H data show bad agreement with SW data (fig. 3c in Appendix B), again demonstrating the temperature dependence (TD) error in the RS80 data. Possible corrections for this TD error will be discussed below.

Temperature corrections:

From 70 comparison flights with a specially developed RS90 research radiosonde (using the method of standardized frequencies (9)) and a RS80A radiosonde (produced between 1991 and 1997), a temperature dependent correction for the RH values of the RS80A radiosondes has been derived. (5) Together with the measured bias at 100% RH this resulted in the following formula for correction of the RS80A humidity data:

$$U_{corr} = U_{ms} + \left[\Delta U_{gc}(100\%) \cdot \frac{U_{ms}}{100\%} \right] + \left(0{,}005 \cdot t^2 + 0{,}112 \cdot t + 0{,}404 \right) \cdot$$

$$\left(\frac{U_{ms} + \Delta U_{gc}(100\%) \cdot \frac{U_{ms}}{100\%}}{U(t,100\%ice) - \left(0{,}005 \cdot t^2 + 0{,}112 \cdot t + 0{,}404\right)} \right) \qquad \text{(4.1 RS80A)}$$

In this formula U_{ms} is the measured RH with the RS80A, $\Delta U_{gc}(100\%)$ is the correction obtained from the 100% ground check, t is the temperature in °C and $U(t, 100\%\ ice)$ is the RH of ice-saturation, calculated with the formula of Sonntag (formula 2.8). The temperature correction part of equation 4.1 is only used for temperatures below -12 °C.

For the RS80H an immediately applicable temperature correction formula is available in the literature. From one study however (6) a temperature correction model can be derived. This study presents corrections for RS80A and H soundings above the tropical western Pacific Ocean during 1992 and 1993. Temperature correction values for the RS80A and H are presented, obtained from laboratory experiments at different temperatures. Plotting the correction values against temperature gives the following bias and temperature corrections for the measured RH values:

$$U_{corr} = U_{ms} \cdot \frac{100\%}{\left(U_{ms} + \Delta U_{gc}(100\%)\right)} \cdot \left[1 + \left(0{,}0006 \cdot t^2 + 0{,}0203 \cdot t\right)\right] \qquad \text{(4.2 RS80A)}$$

$$U_{corr} = U_{ms} \cdot \frac{100\%}{\left(U_{ms} + \Delta U_{gc}(100\%)\right)} \cdot \left[1 + \left(0{,}00007 \cdot t^2 + 0{,}0016 \cdot t\right)\right] \qquad \text{(4.3 RS80H)}$$

The temperature correction part of equation 4.2 and 4.3 is only used for temperatures below -30 °C. Formulas 4.1 to 4.3 are only accurate for the RS80 production batches they were derived from but can give an indication of the sizes of possible temperature corrections for the RS80 soundings in Paramaribo during February/March 2004. For the sounding of February 25, the corrections are presented in fig. 4a in Appendix B. Although the profiles of the RS80 radiosondes still don't show any detail in UT and LS, they show much better agreement with the SW profile. With formula 4.2 and 4.3 even ice-supersaturation is detected. From fig. 4b in Appendix B can be seen that in the UT especially formula 4.2 and 4.3 give profiles for the RS80A and H that are in better agreement with the SW profile. However no detail is seen and in the LS the RH values obtained with these formulas don't make much sense. Some more examples of temperature corrections are given in fig. 4c-4e in Appendix B, showing that ice-supersaturation in the UT is not always reached with the temperature corrections. If the SW data are used as a reference, formula 4.2 gives a better correction for the RS80A data than formula 4.1.

4.3 Comparisons of the Paramaribo soundings to ECMWF model output

The ECMWF model forecasts and analyzes meteorological variables such as pressure, temperature and RH on a worldwide scale. For an area of 1-degree latitude and 1-degree longitude around Paramaribo, the model output on pressure levels for the first 25 km of height is compared to the sounding data of 16 SW, RS80 and RS90 soundings between October 2002 and March 2004. All of the SW soundings are launched around 22.30 UTC and take about 1 hour and 30 minutes to reach 30 km of height. The ECMWF model was available every six hours, so data of 0.00 UTC next day are used to compare to the SW and radiosonde data. In fig. 1a-1k in Appendix C all ECMWF, SW, RS80 and RS90 profiles of flights between October 2002 and June 2003 are presented. All the ECMWF profiles in Appendix C are analyzed profiles unless stated differently. The profiles of flights in February/March 2004 are presented in fig. 1a, 1b, 1c, 1e and 1f in Appendix B. All the ECMWF profiles in Appendix B are 48-hour forecasted profiles unless stated differently. The thick black line in the plots represents the ECMWF model output. It should be noted that the ECMWF model works with layers, increasing in thickness from 50 m at ground level to more than 1 km at 25 km of height. Therefore the RH values in the plots actually represent the average RH value for each layer and the data points are taken for the middle of each layer.

In general the analyzed ECMWF profiles in Appendix C are in good agreement with the SW and radiosonde profiles. Some details in the RH profile however, are not given by the ECMWF model. For example, at 17 October 2002 and 28 February 2003 high clouds (10-18 km) that are measured, are not given by the model. The reason for this is that the ECMWF model gives RH values for a large area and the soundings only report local values, just one small cloud is enough to detect ice-supersaturation while the rest of the area may be totally clear. At 29 January 2003 the ECMWF model gives a very dry layer (RH = 3%) above 5 km and after encountering this layer the SW mirror dries up and isn't able to recover condensate again, like predicted in literature. (8) This might point to using the ECMWF model forecasts to predict dry layers and maybe not to perform a SW sounding on such a day. At 18 February 2004 (fig. 1b in Appendix B) however, a very dry layer is predicted (<5% RH) between 2,5 and 10 km of height but from the sounding data is seen that this layer is only small and condensate is recovered again. A fact that should be noted is that all SW soundings were performed in relatively dry conditions because precipitation has a bad influence on SW data. Therefore, the ECMWF model output for rainy days isn't evaluated by these soundings.

Not only are the ECMWF profiles averaged over a large area, they are also averaged in height, so thin clouds are cancelled out in this average. To give a better comparison between the ECMWF model output and sounding data, SW profiles can be averaged for the layers of the ECMWF. An example of an averaged SW profile in comparison to the ECMWF profile is presented in fig. 2 in Appendix C, for the sounding at 18 October 2002. The original SW profile was very spiky, the averaged profile shows good agreement with the ECMWF model output, filtering out rapid changes of RH with height.

For the soundings in February/March 2004, the SW profiles are averaged and also the ECMWF forecasts are compared to the ECMWF analyses. Plots of these comparisons are presented in fig. 5a-5c in Appendix B. Keeping in mind that the model uses a grid of 1-degree longitude and 1-degree latitude, the analyzed ECMWF profiles generally agree well with the averaged SW profiles. The difference between the ECMWF forecast and analysis however, can be quite large. For 18 February 2004, the ECMWF model forecasts a layer of very dry air between 2,5 and 10 km of height. From the SW data and the ECMWF analysis, is seen that only three small dry layers between 5 and 11 km are present. The ECMWF analysis shows good agreement with the SW up to 15 km. The model however didn't predict ice-supersaturation near the tropopause. By definition, the ECMWF model is limited to a maximum RH of ice-saturation. In the plot of 18 February 2004 the dotted green line shows the influence of the delay time of the SW sensor. The RS80 temperature sensor has a very small delay time (1-2s), the SW takes longer to stabilize (negligible at +20 °C, 10 s at -30 °C and 80 s at -60 °C). If the delay time is taken into account, a small shift of the SW profile is seen.

5 Conclusions and Recommendations

From the results of the 100% RH ground check is seen that a consistent bias in the RS80 RH data can be detected and corrected in the RH profiles. The existence of a bias and the size of it mainly depend on the production batch of the radiosondes. Radiosondes from the same production batch give comparable biases. However it should be noted that for the RS80-15GE and RS80-18LE (both A-Humicap), only three radiosondes were tested, a very small number to draw conclusions. The average wet bias in the RS80-15GHE data found from nine different radiosondes is a more reliable result and seems to be consistent for the whole production batch. The bias in RS80 data is mainly caused by the age of the sensor, in combination with a calibration error, which is different for each production batch. Considering that it is only 15 minutes extra work for the operators, continuation of the 100% RH ground check is recommended if the radiosonde data in the first 10 km of height are of interest. For further use of the 100% ground check an operation manual (in Dutch) is presented in Appendix D.

The SW RH profiles can be used as reference profiles if a comparison is made with the RS80 and RS90 data. RS80 data are in reasonable agreement with SW data to a height of about 12 km (air temperature of -50 °C). A time-lag error is seen because the RS80 humidity sensors need more time to stabilize than the SW chilled-mirror, therefore missing some details if RH changes rapidly with height. From 12-14 km, the RS80 profiles still show some detail however giving different absolute RH values than the SW and above 14 km no detail is seen in the RS80 data. This behavior is consistent with earlier comparisons between SW and RS80, found in literature. (3) RS90 profiles show about the same behavior, but perform better in detection of ice-supersaturation. If the RS80-15GHE data in the LT are corrected for their individual wet bias, better agreement with the SW data is reached.

Below -30 °C, the capacitance of the RS80 polymer humidity sensors becomes strongly temperature dependent, causing a dry bias. The RS80 profiles can be corrected for this behavior with formulas found in literature. The correction in the middle and upper troposphere gives results in better agreement with the SW profiles. If ice-supersaturation is present however, this is not always reached with the corrections. In the lower stratosphere the corrections are of no use, giving much too high RH values for the RS80 radiosonde data. The problem with the temperature corrections is that they can only be derived from large numbers of tests. Therefore the corrections suggested in literature are always for old radiosonde production batches. Changes in the production and calibration process cause the corrections to be slightly different for newer radiosondes. However, the correction gives a good indication of what is possible. When enough SW sounding data are available, the temperature correction model can be fit to these data and this fit can be applied to the radiosonde RH observations of the same soundings in Paramaribo.

Comparison of ECMWF analyzed profiles with SW and radiosonde data shows a very good agreement, considered the fact that the model predicts the RH for a large area. This might be caused by the usage of the Cayenne soundings (about 400 km east from Paramaribo) in the analysis. The forecasted ECMWF RH profiles show a less layered structure than the observed profiles and the ECMWF analysis.

6 Acknowledgements

This report would not have been possible without the very good facilities provided by the KNMI and great help of the people from the working group of Atmospheric Composition, especially my supervisor Gé Verver. Also I would like to thank C. Becker and the operator group from MDS for their great hospitality and their very good cooperation. U. Leiterer (Deutscher Wetterdienst) is acknowledged for making available the metal calibration box for the calibration tests. Many thanks also to M. Fujiwara (EES, Hokkaido University) for the good cooperation and the great assistance.

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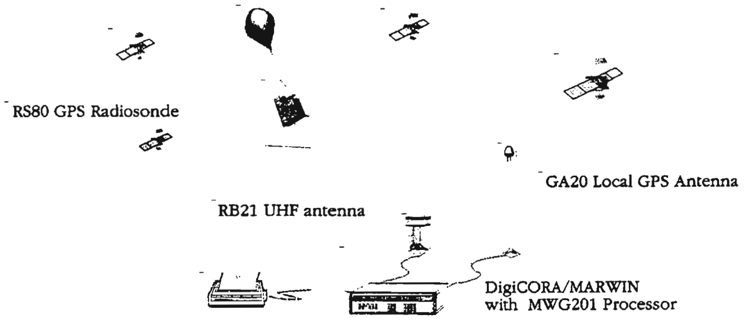
Appendix A: Specifications of the RS80 and RS90 radiosondes



CODELESS GPS RECEIVER

Number of channels:	Digital, 8 channels
Radiosonde downlink:	Digital, 1200 baud
Temporal resolution:	0.5 s
Fixed station (with SA on, PDOP < 4):	
Wind measurement accuracy:	0.2 m/s RMS
Mobile sounding station, without RTCM differential correction (with SA on PDOP <4):	
Wind measurement accuracy:	0.5 m/s RMS

PTU TRANSDUCER

Sampling rate:	7 samples/10 s for each parameter
Calibration data content:	Polynomial for each sensor with checksum
Calibration data format:	8-channel paper tape
Sensor references:	Low and high range
Battery:	Water-activated
Voltage:	19 V

DIMENSIONS AND WEIGHT

Dimensions excl. antenna:	55 mm by 155 mm by 125 mm
Weight, battery activated:	approximately 330 g

TRANSMITTER

Transmitter type	RS80-15G	RS80-30G
Frequency, nominal	403 MHz	403 MHz
Tuning range	400–406 MHz	400–406 MHz
Drift (max during flight)	±300 kHz	±5 kHz
Output power (nominal)	200 mW	100 mW
CCIR emission type	F9D	F9D
Modulation	FM	FM
PTU modulation frequency	7–10 kHz	0.7–1.0kHz

METEOROLOGICAL SENSORS

PTU sensors are individually factory-calibrated.

Pressure	BAROCAP® Capacitive aneroid
Measuring range:	1060 hPa to 3 hPa (mb)
Resolution:	0.1 hPa
Accuracy:	
Reproducibility[1]:	0.5 hPa
Repeatability[2]:	0.5 hPa
Temperature	THERMOCAP® Capacitive bead
Measuring range:	+60°C to - 90°C
Resolution:	0.1°C
Accuracy:	
Reproducibility[1]:	0.2°C up to 50 hPa, 0.3°C for 50-15 hPa, 0.4°C above 15 hPa level
Repeatability[2]:	0.2°C
Lag:	< 2.5 s (6 m/s flow at 1000 hPa)
Humidity	HUMICAP® thin film capacitor
Measuring range:	0 to 100 % RH
Resolution:	1 % RH
Lag:	1 s (6 m/s flow at 1000 hPa, +20°C)
Accuracy:	
Reproducibility[1]:	<3 % RH
Repeatability[2]:	2 % RH

1) Data based on WMO International Radiosonde Comparison Phases I, II, and III (WMO/TD no 195 and 451)

2) Standard deviation of differences between two successful calibrations

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B330en 1997-06

RS80

Technical Information

CE

METEOROLOGICAL SENSORS

Temperature	**F- THERMOCAP® capacitive wire**
Measuring range	+60 °C to -90 °C
Response time (63.2 %, 6m/s flow)	
1000 hPa	0.2 s
10 hPa	0.5 s
Resolution	0. 1 °C
Accuracy	
Repeatibility (*	0.1 °C
Uncertainty in sounding (**	0.5 °C
Reproducibility in sounding (***	
1080 - 100 hPa	0.2 °C
100 - 20 hPa	0.2 °C

Humidity	**H- HUMICAP® thin film capacitor,** heated twin-sensor design
Measuring range	0 to 100 % RH
Resolution	1 % RH
Response time	
6 m/s, 1000 hPa, +20°C	<0.5 s
6 m/s, 1000 hPa, -40 °C	<20 s
Accuracy	
Repeatability (*	2 % RH
Uncertainty in sounding (**	5% RH
Reproducibility in sounding (***	2 % RH

Pressure	**BAROCAP ® silicon sensor**
Measuring range	1080 hPa to 3hPa
Resolution	0.1 hPa
Accuracy	
Repeatability (*	
1080 - 100 hPa	0.4 hPa
100 - 3 hPa	0.4 hPa
Uncertainty in sounding (**	
1080 - 100 hPa	1.5 hPa
100 - 3 hPa	0.7 hPa
Reproducibility in sounding (***	
1080 - 100 hPa	0.5 hPa
100- 3 hPa	0.3 hPa

PTU SENSOR UNIT

PTU sensors are individually factory calibrated with measurement electronics

Sampling rate	1 sample /second
Calibration data format options	8-channel paper tape EEPROM Floppy disk

DIMENSIONS AND WEIGHT

Radiosonde body dimensions	150 mm by 90 mm by 50 mm
Weight, battery activated,with unwinder	approximately 290 g

BATTERY

Water activated battery	19 V
Operation time	135 min

*) standard deviation of differences between two successive repeated calibrations, k = 2 confidence level

**) 2-sigma (95,5 %) confidence level (k=2), cumulative uncertainty including:
- repeatability
- long-term stability
- effects due to measuring conditions
- dynamic effects (such as response time)
- effects due to measurement electronics

***) standard deviation of differences, in twin soundings divided by $\sqrt{2}$

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RS90

Appendix B: Profiles of SW soundings in Paramaribo during February/March 2004

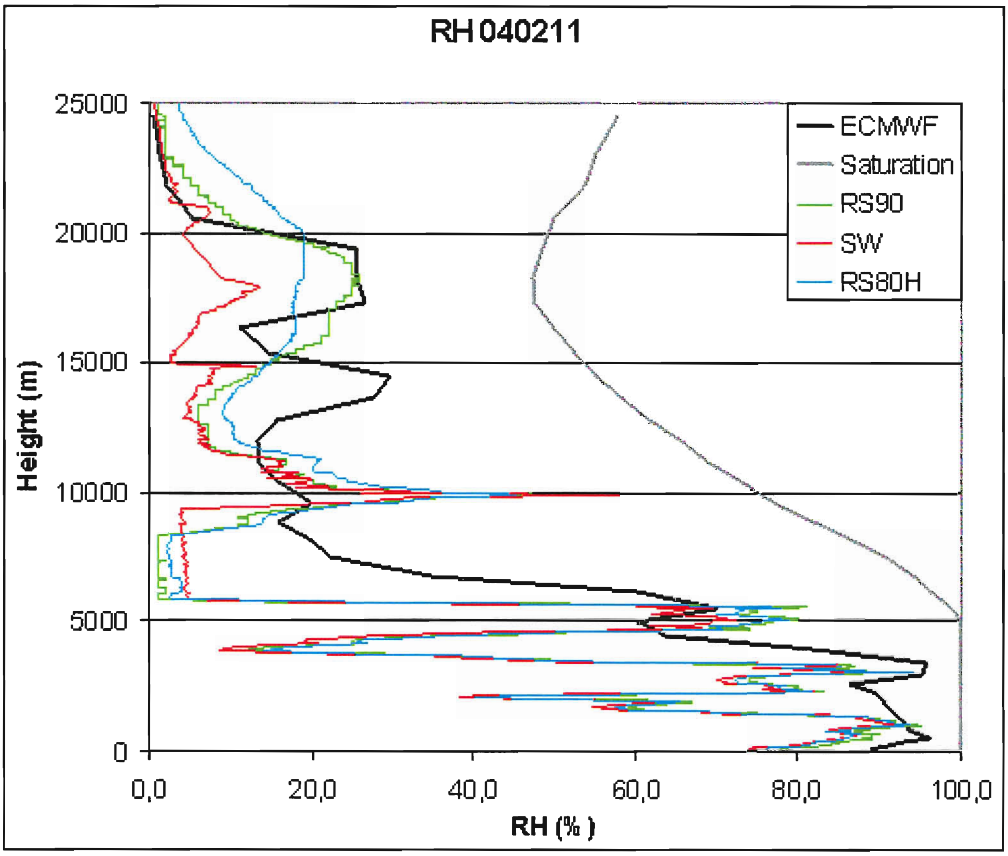

Fig. 1a and 1b: Profiles of RH measured by SW (red line), RS90 (green line) and RS80H (blue line) and ECMWF model forecast (black line).

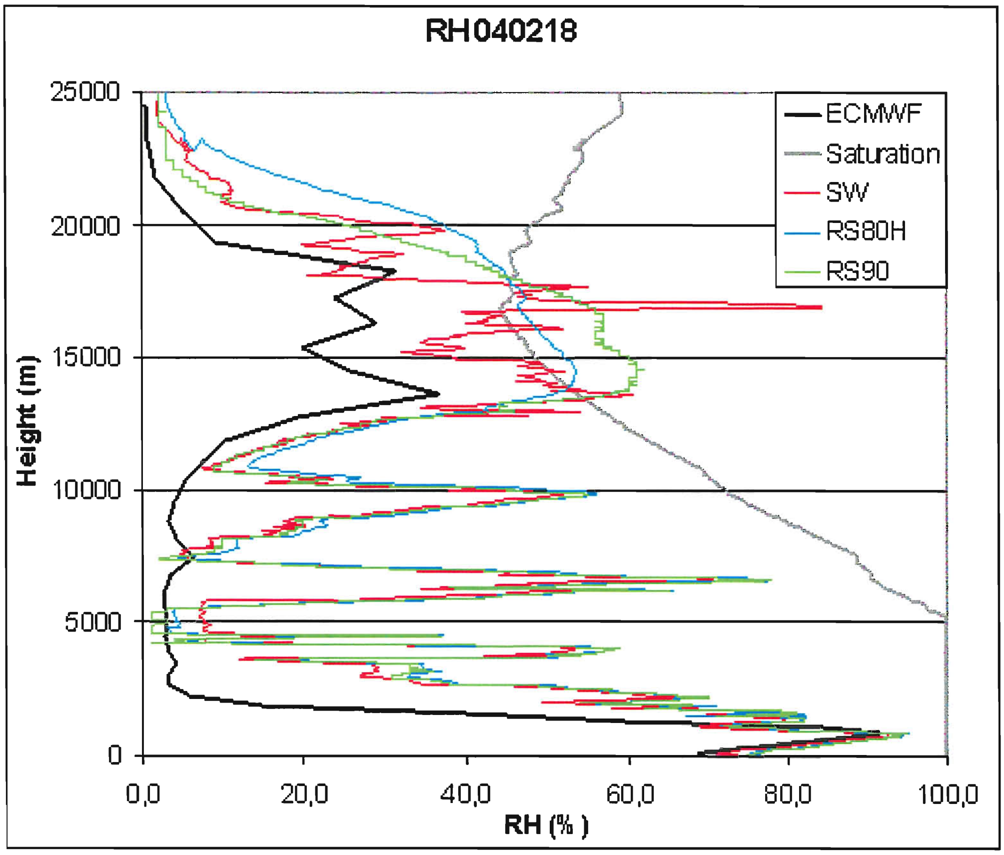

Fig. 1b

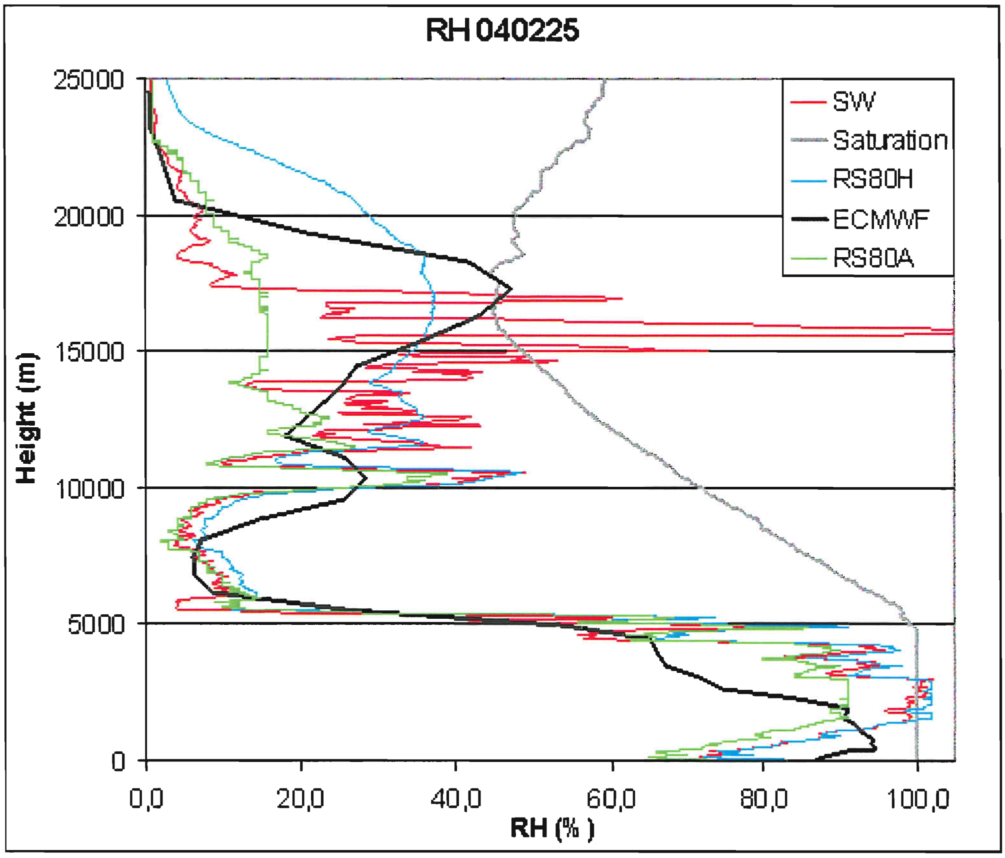

Fig. 1c, 1e and 1f: Profiles of RH measured by SW (red line), RS80A (green line) and RS80H (blue line) and ECMWF model forecast (black line).

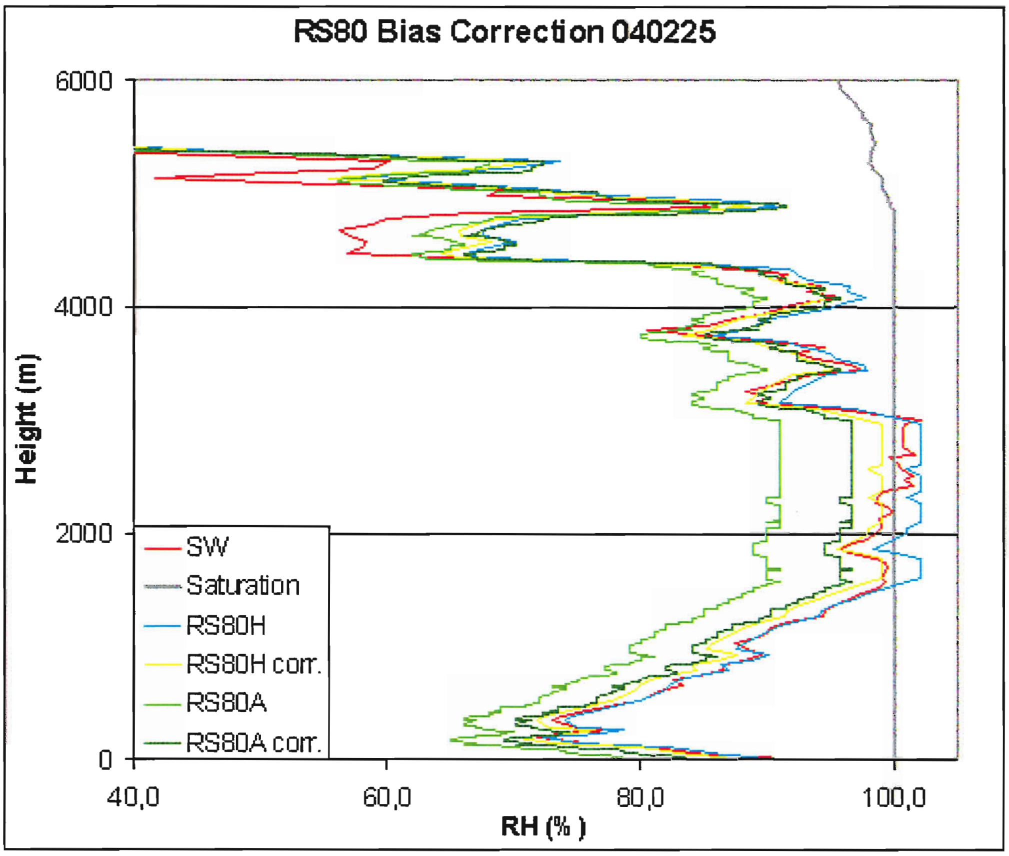

Fig. 1d, 1g: Bias corrections for RS80H (yellow line) and RS80A RH profiles (dark green line).

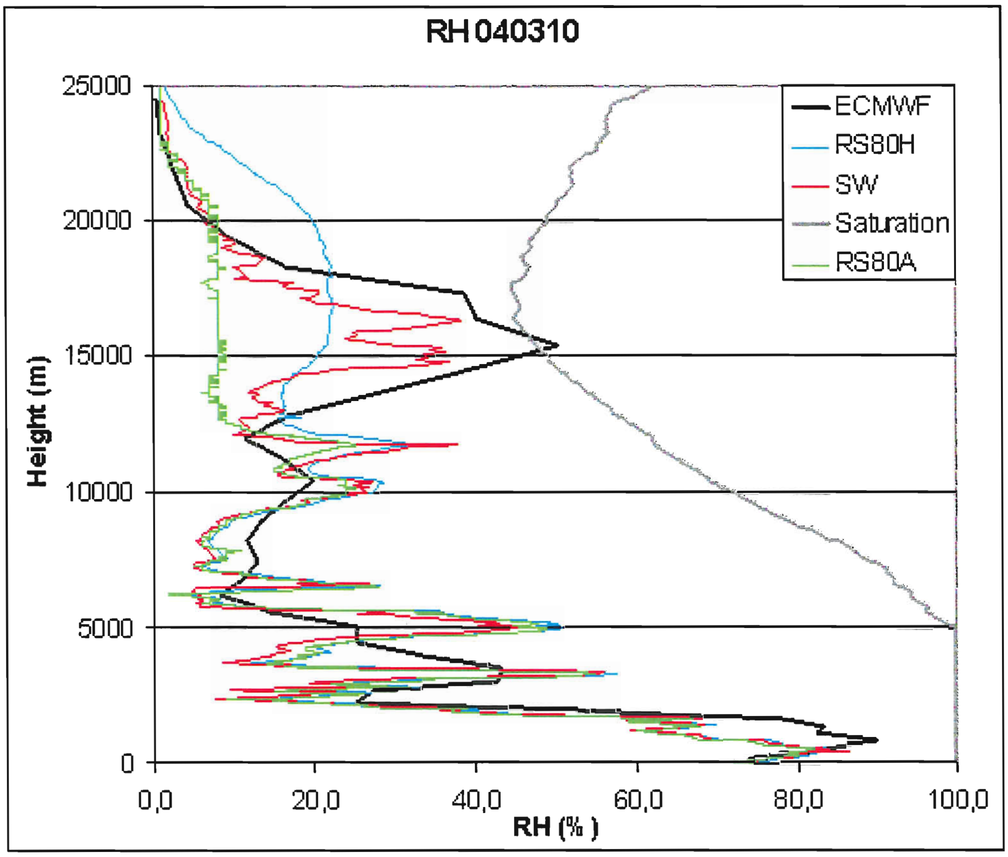
RH 040310
25000
20000
15000
10000
5000
0
Height (m)
0,0
20,0
40,0
60,0
80,0
100,0
RH (%)
ECMWF
RS80H
SW
Saturation
RS80A

Fig. 1 e

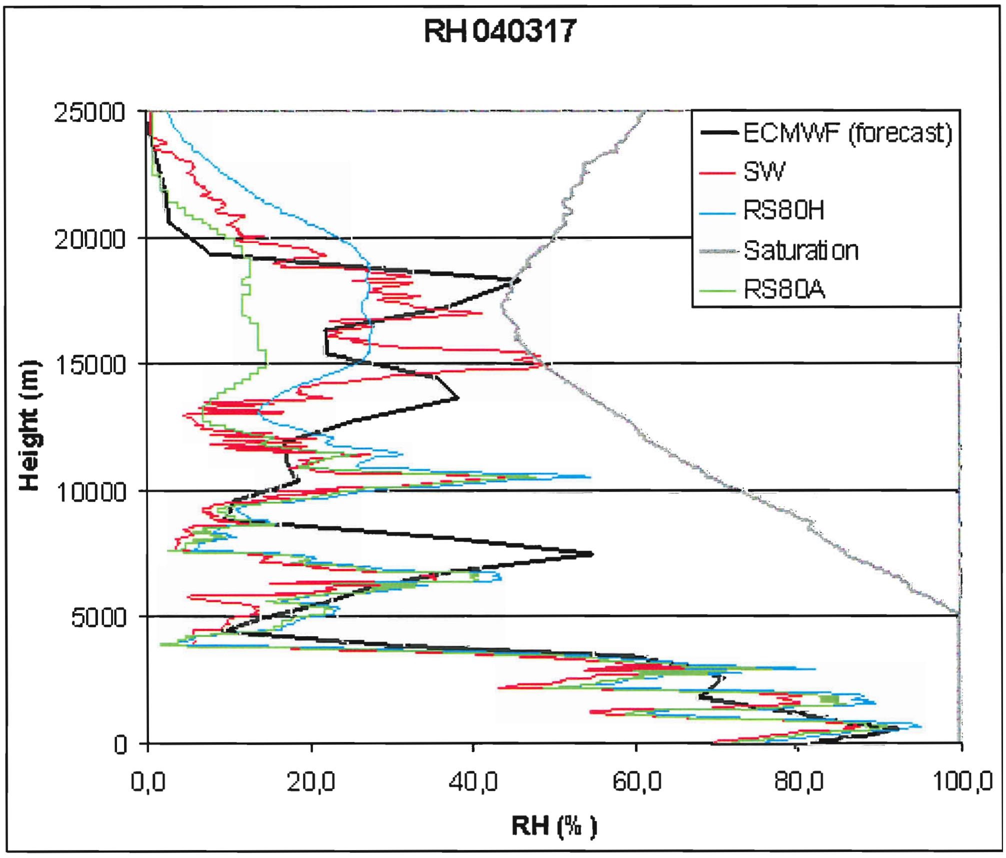
RH 040317
25000
20000
15000
10000
5000
0
Height (m)
0,0
20,0
40,0
60,0
80,0
100,0
RH (%)
ECMWF (forecast)
SW
RS80H
Saturation
RS80A

Fig. 1f

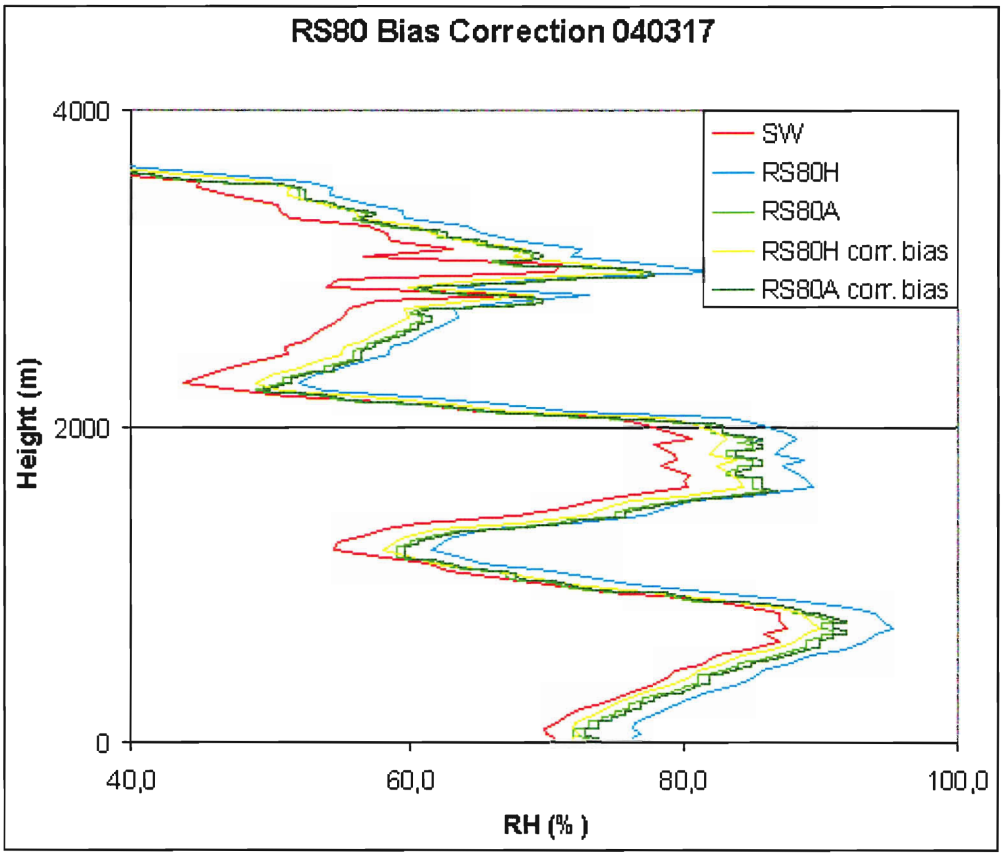

Fig. 1g

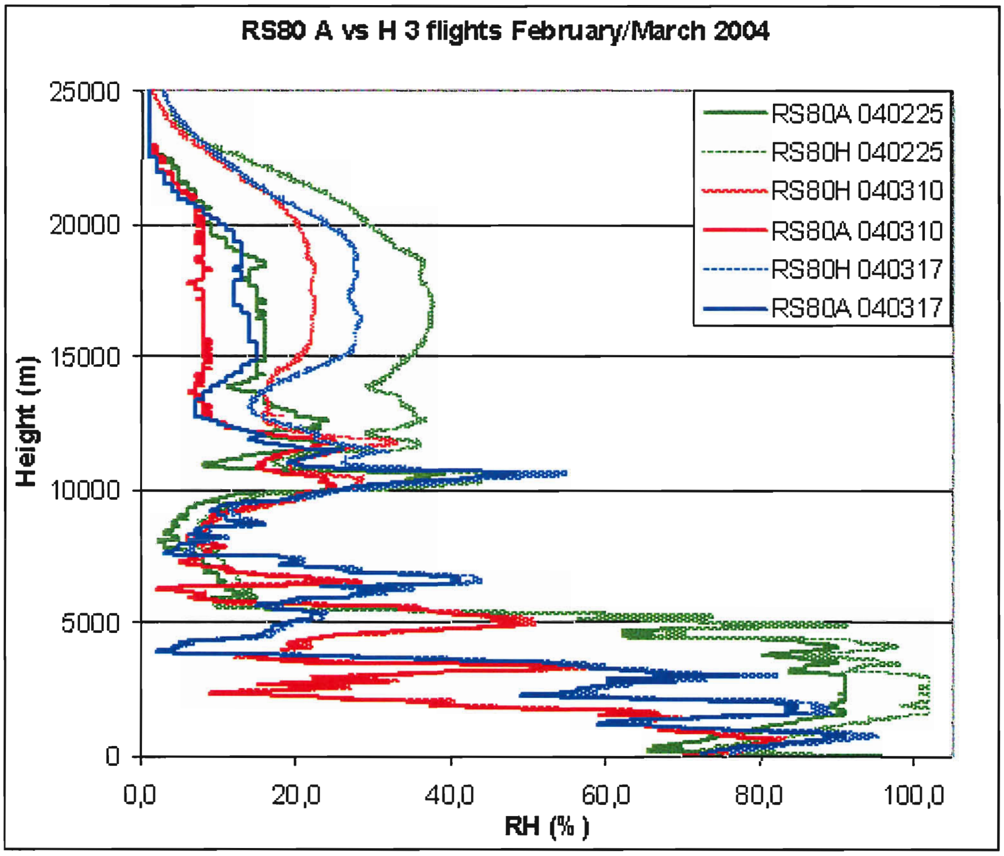

Fig. 2: Direct comparison between RS80 A- and H-Humicap RH profiles during simultaneous soundings.

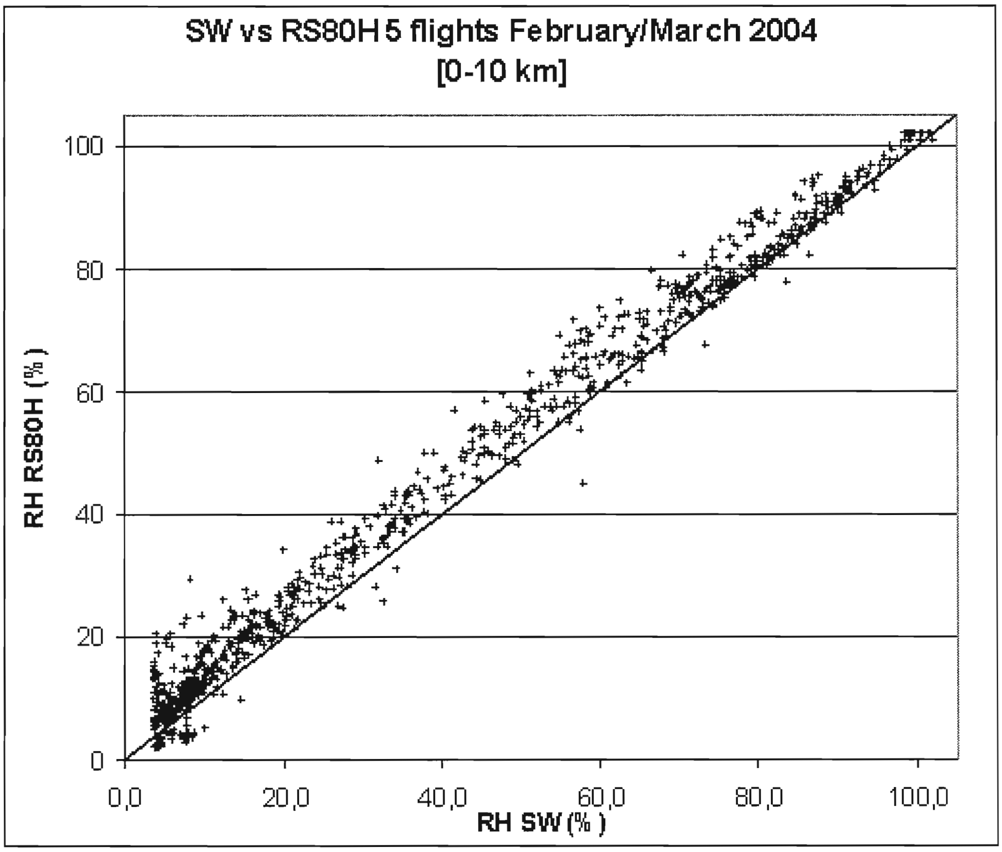

Fig 3a: RS80H RH data compared to SW data during simultaneous soundings for the lower troposphere (0-10 km).

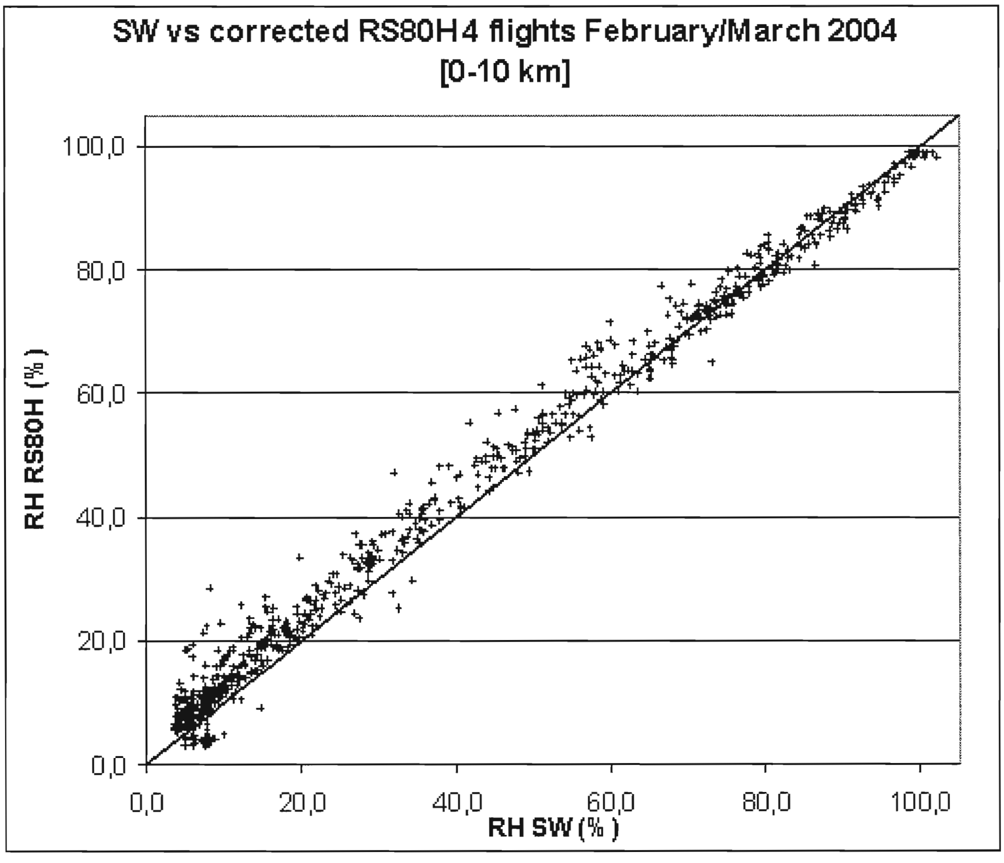

Fig 3b: RS80H RH data compared to SW data during simultaneous soundings after bias-corrections, for the lower troposphere (0-10 km).

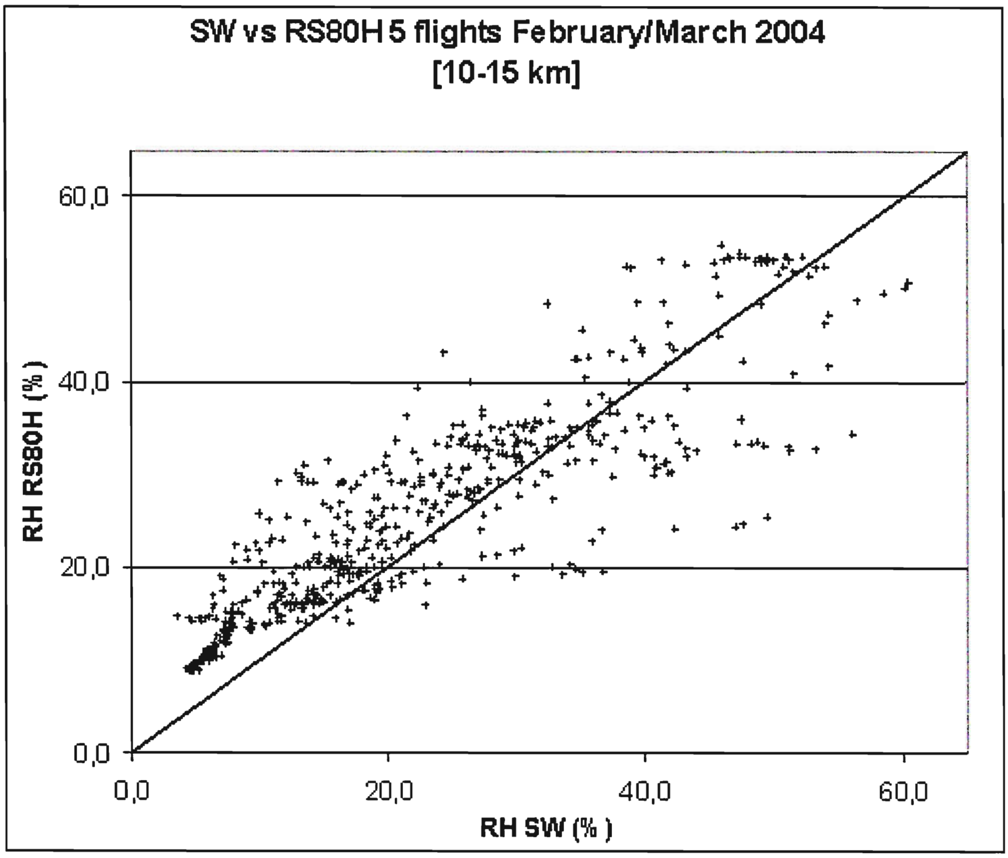

Fig 3c: RS80H RH data compared to SW data during simultaneous soundings for the middle troposphere (10-15 km).

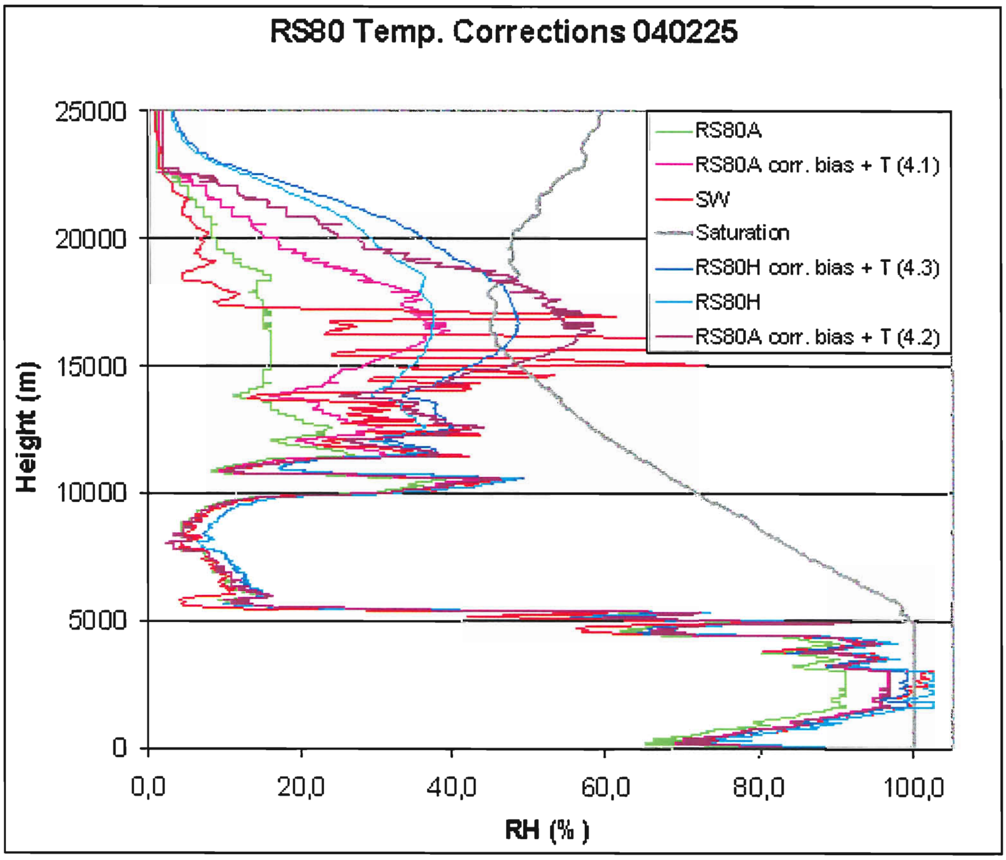

Fig. 4a, 4b, 4c: Bias and temperature corrections for RS80H (dark blue line) and RS80A RH profiles (pink and purple lines).

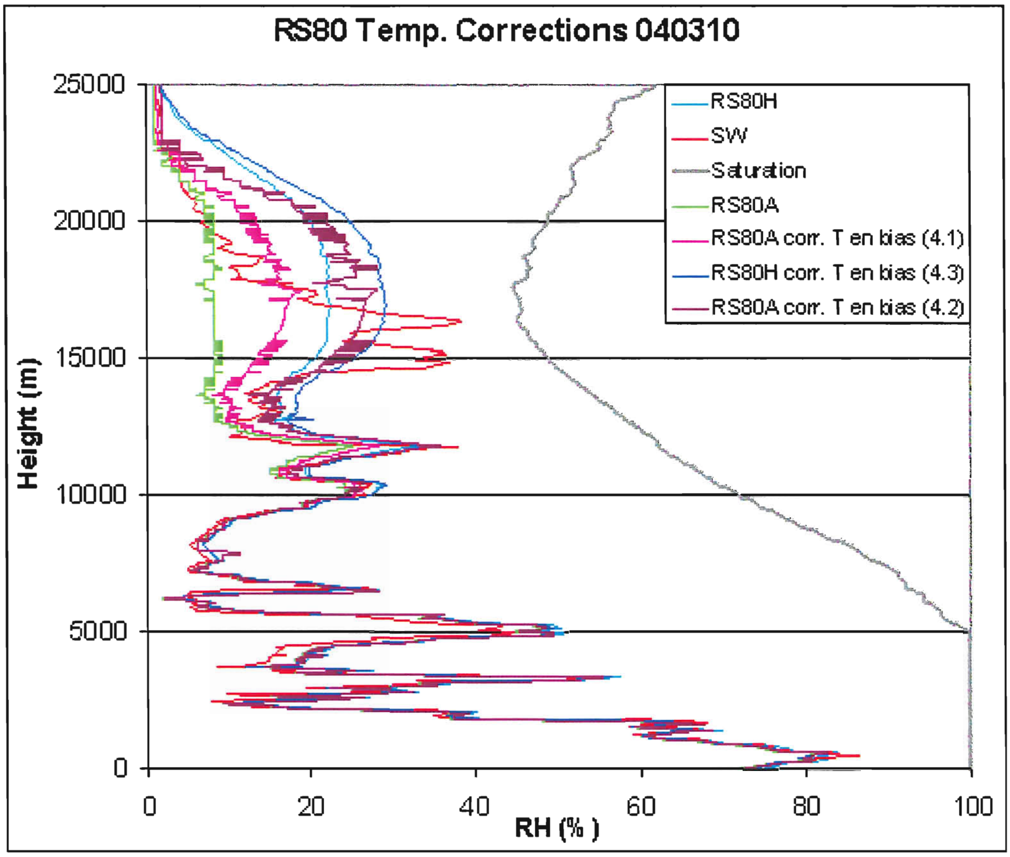
RS80 Temp. Corrections 040310
Height (m)
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
RH (%)
RS80H
SW
Saturation
RS80A
RS80A corr. T en bias (4.1)
RS80H corr. T en bias (4.3)
RS80A corr. T en bias (4.2)

Fig. 4b

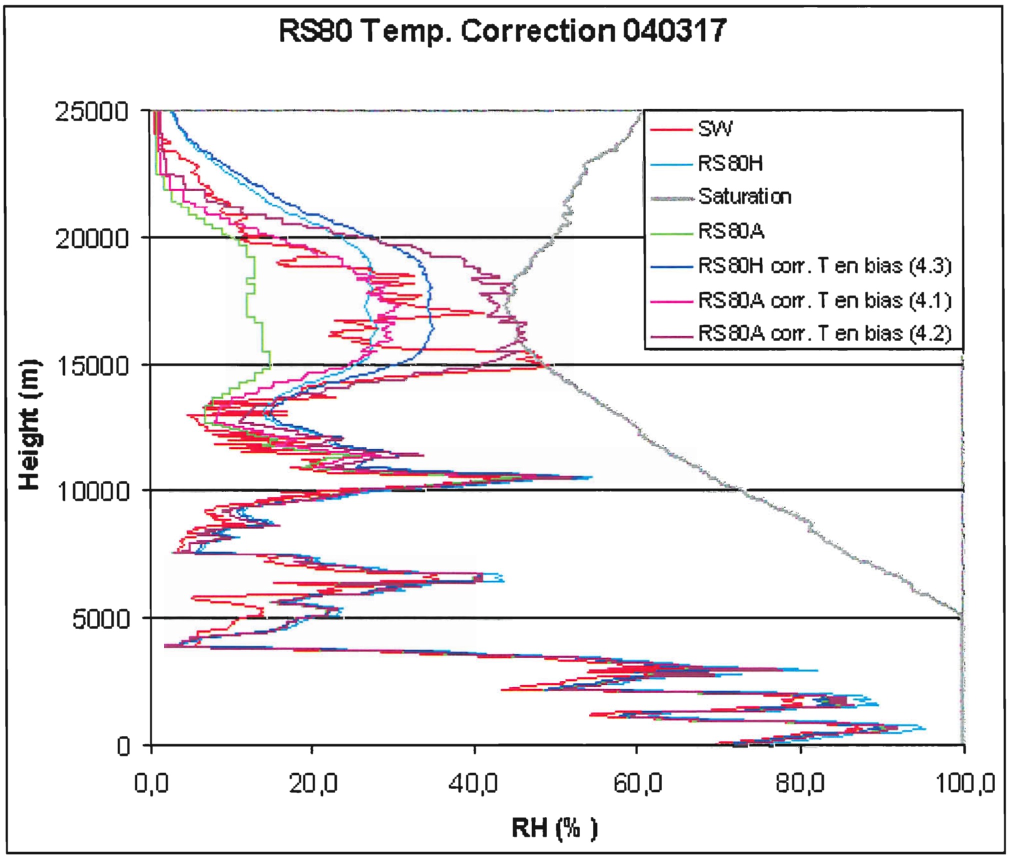
RS80 Temp. Correction 040317
Height (m)
25000
20000
15000
10000
5000
0
0,0
20,0
40,0
60,0
80,0
100,0
RH (%)
SW
RS80H
Saturation
RS80A
RS80H corr. T en bias (4.3)
RS80A corr. T en bias (4.1)
RS80A corr. T en bias (4.2)

Fig. 4c

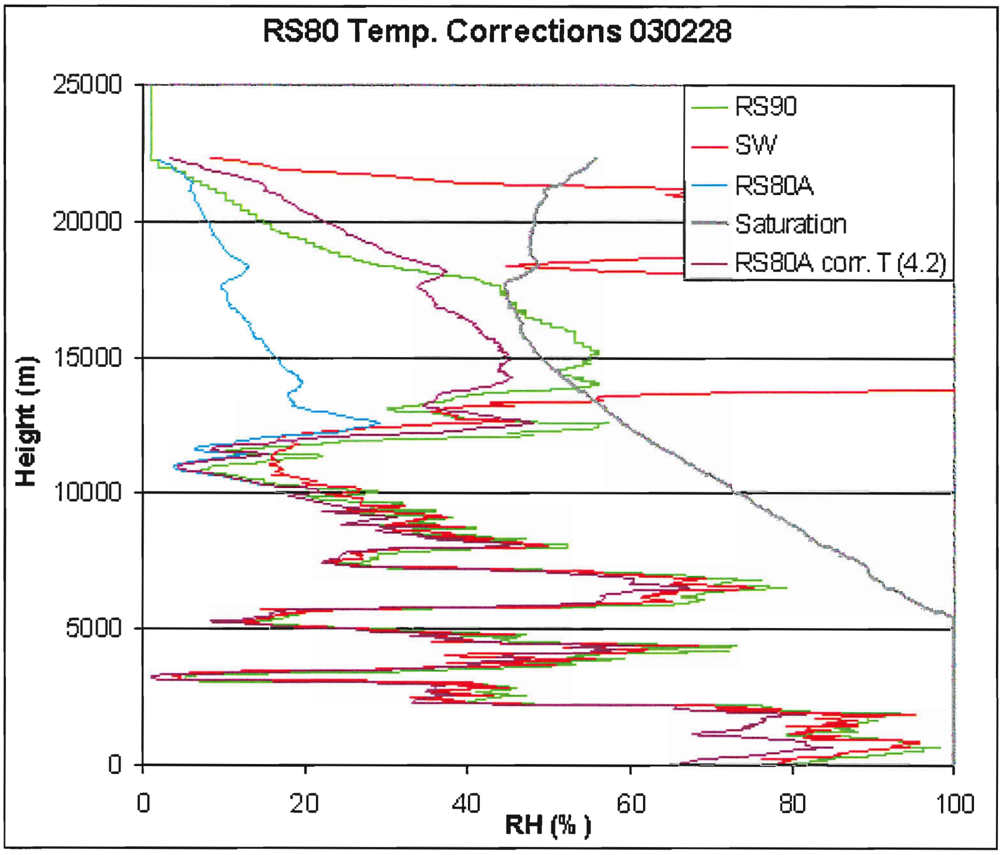

Fig. 4d and 4e: Temperature correction for RS80A RH profile (purple line).

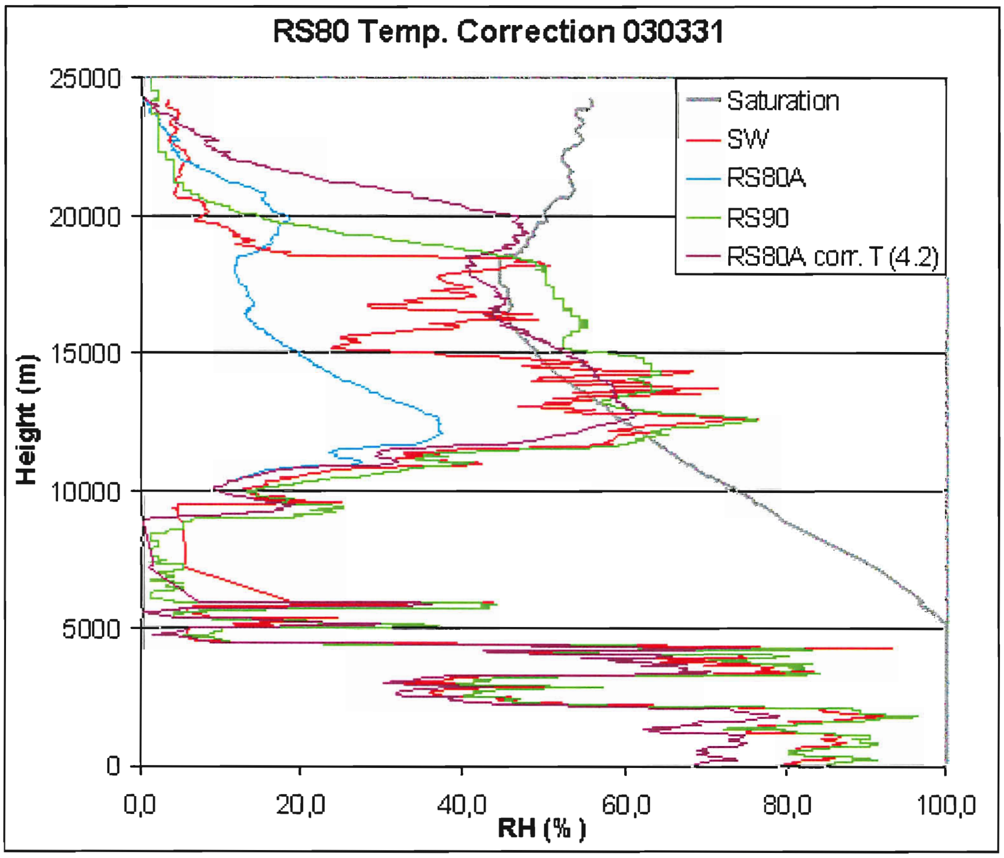

Fig. 4e

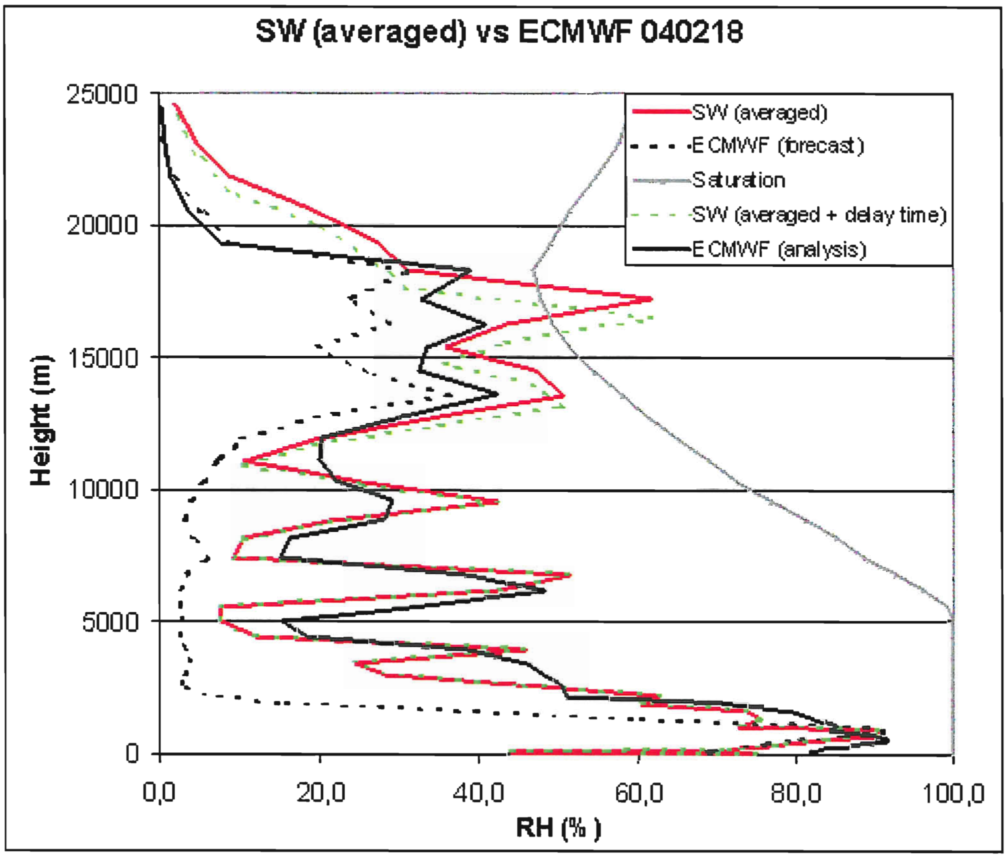

Fig. 5a, 5b and 5c: Averaged SW RH profile compared to the ECMWF model RH profiles (dotted black line: forecast and solid black line: analysis).

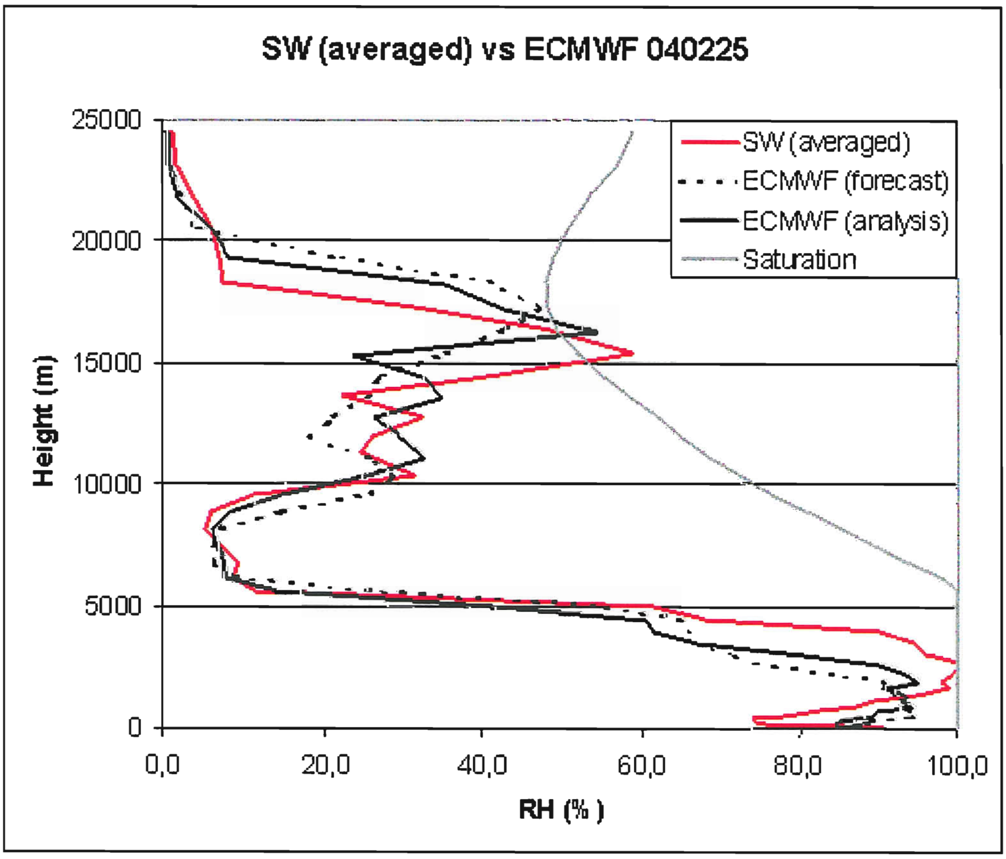

Fig. 5b

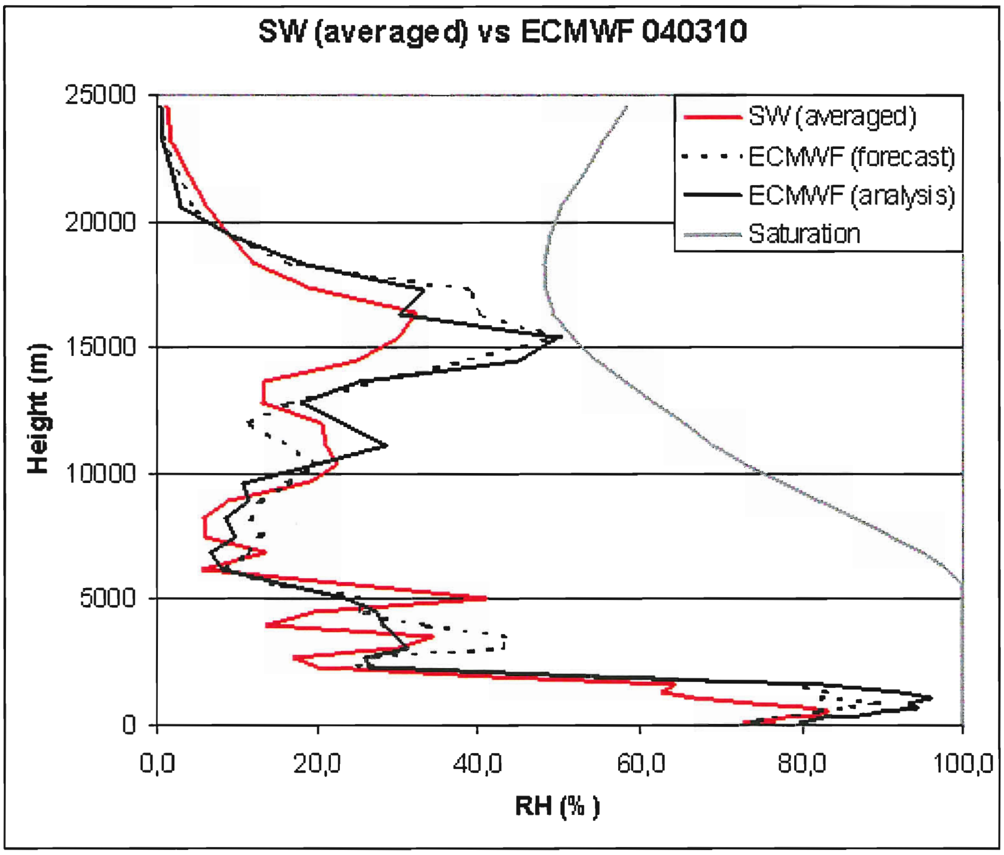
SW (averaged) vs ECMWF 040310
SW (averaged)
ECMWF (forecast)
ECMWF (analysis)
Saturation
Height (m)
25000
20000
15000
10000
5000
0
0,0
20,0
40,0
60,0
80,0
100,0
RH (%)

Fig. 5c

Appendix C: SW, RS80 and RS90 humidity profiles October 2002 to June 2003

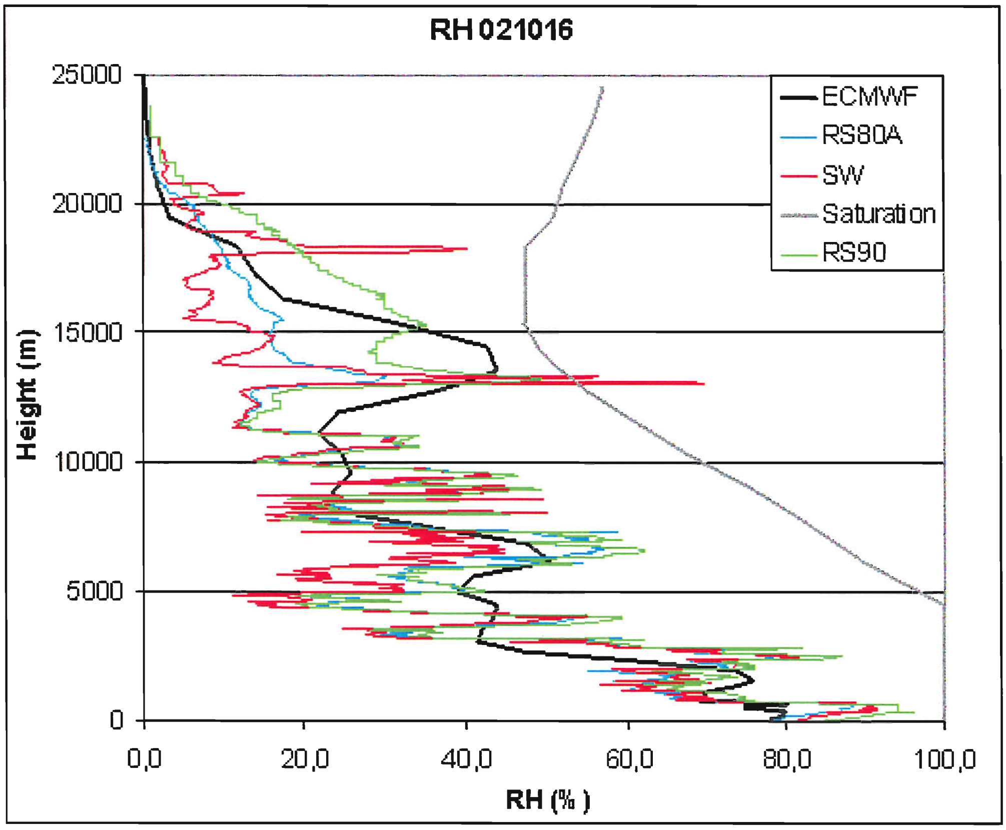

Fig. 1a, 1b and 1d-1k: RH Profiles measured by SW (red line), RS90 (green line), RS80A (blue line) and ECMWF model analysis (black line).

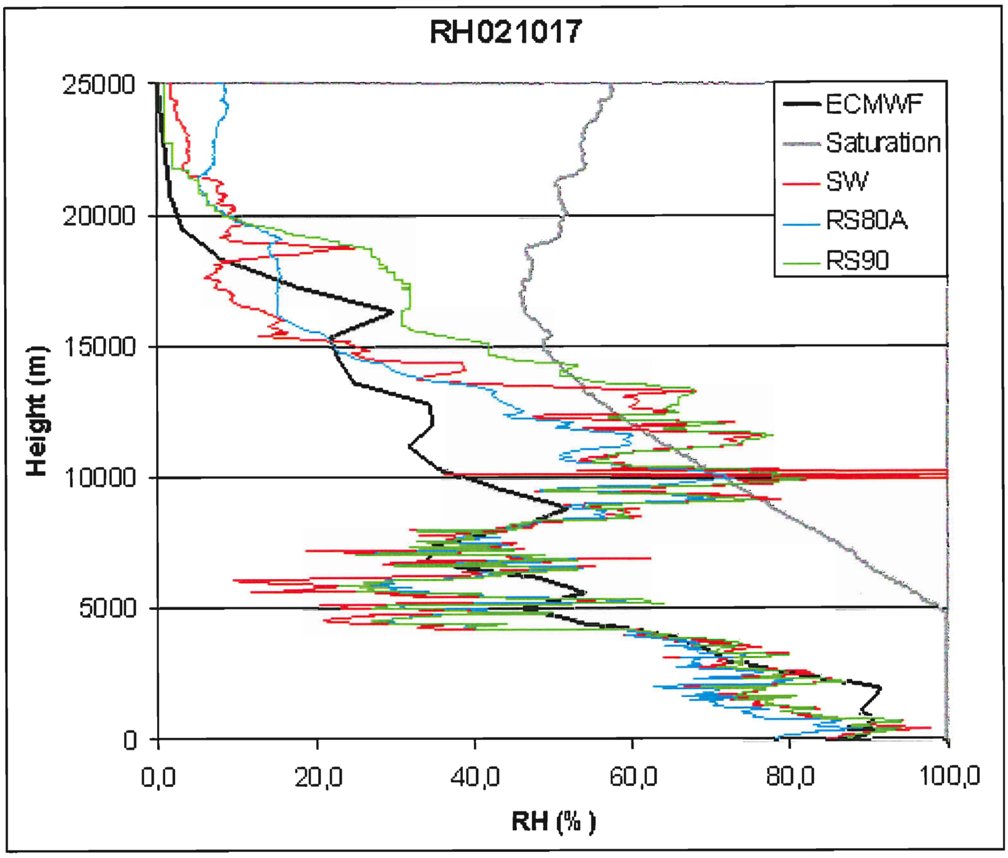
RH021017
Height (m)
25000
20000
15000
10000
5000
0
0,0
20,0
40,0
60,0
80,0
100,0
RH (%)
ECMWF
Saturation
SW
RS80A
RS90

Fig. 1b

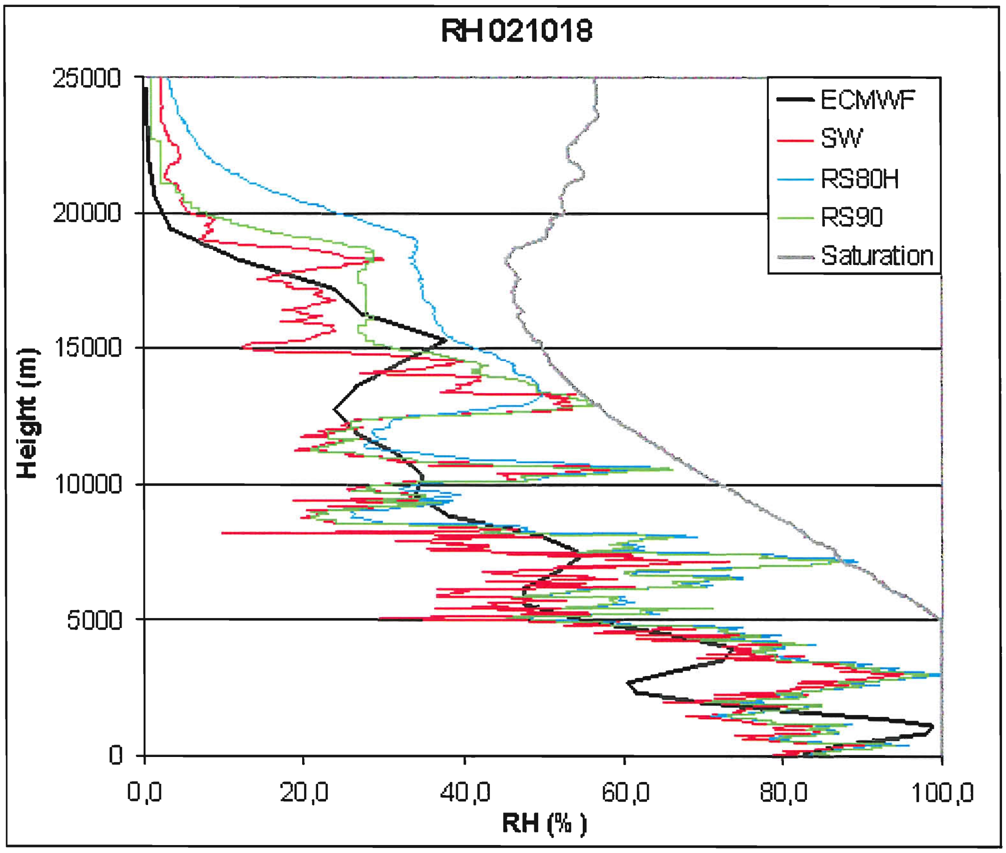

Fig. 1c: RH Profiles measured by SW (red line), RS90 (green line), RS80H (blue line) and ECMWF model analysis (black line).

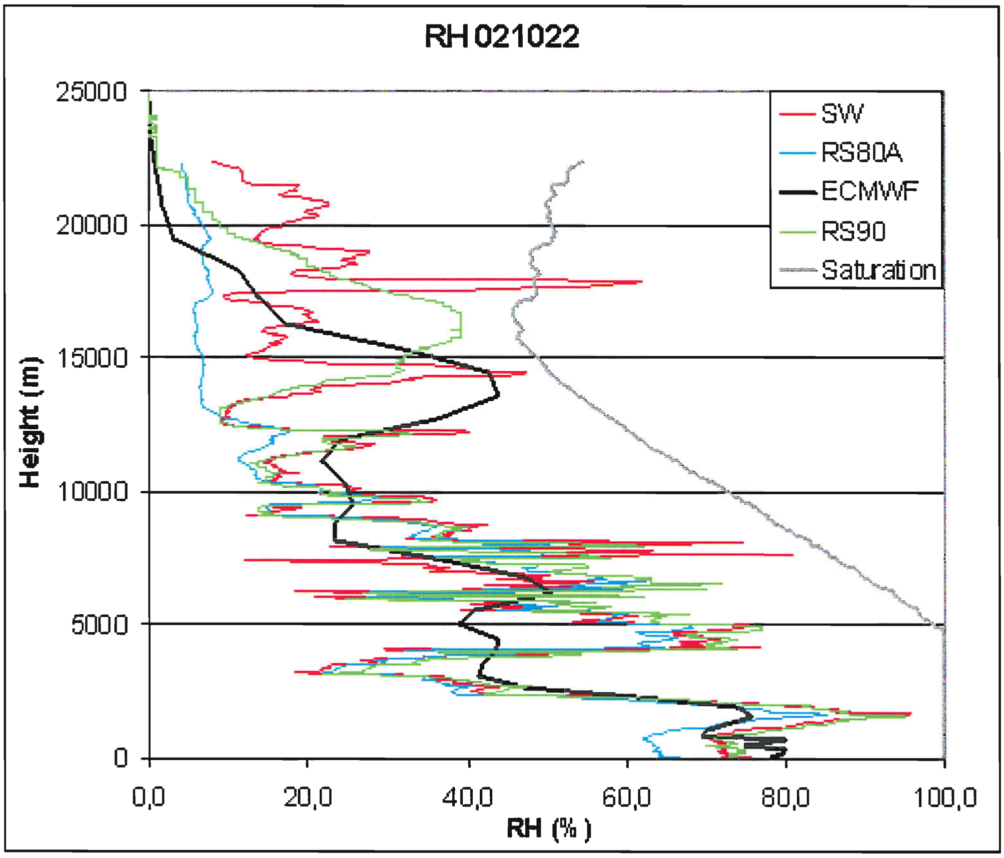

Fig. 1d

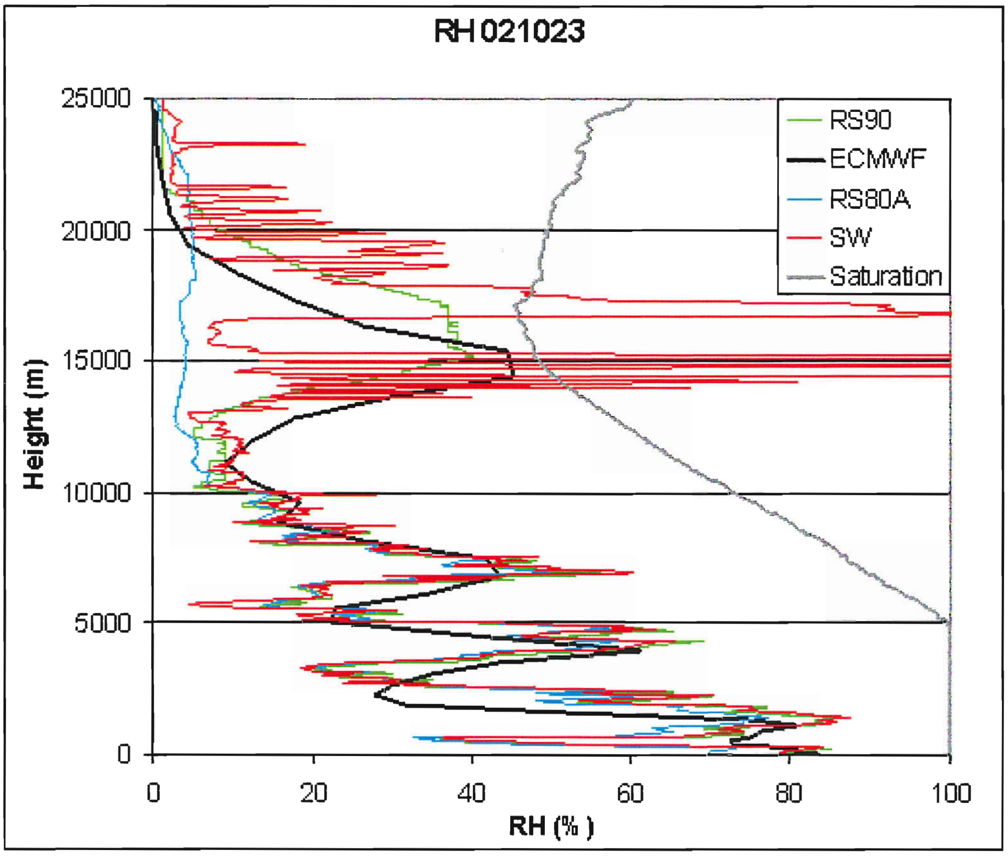
RH 021023
25000
20000
15000
10000
5000
0
Height (m)
0
20
40
60
80
100
RH (%)
RS90
ECMWF
RS80A
SW
Saturation

Fig. 1e

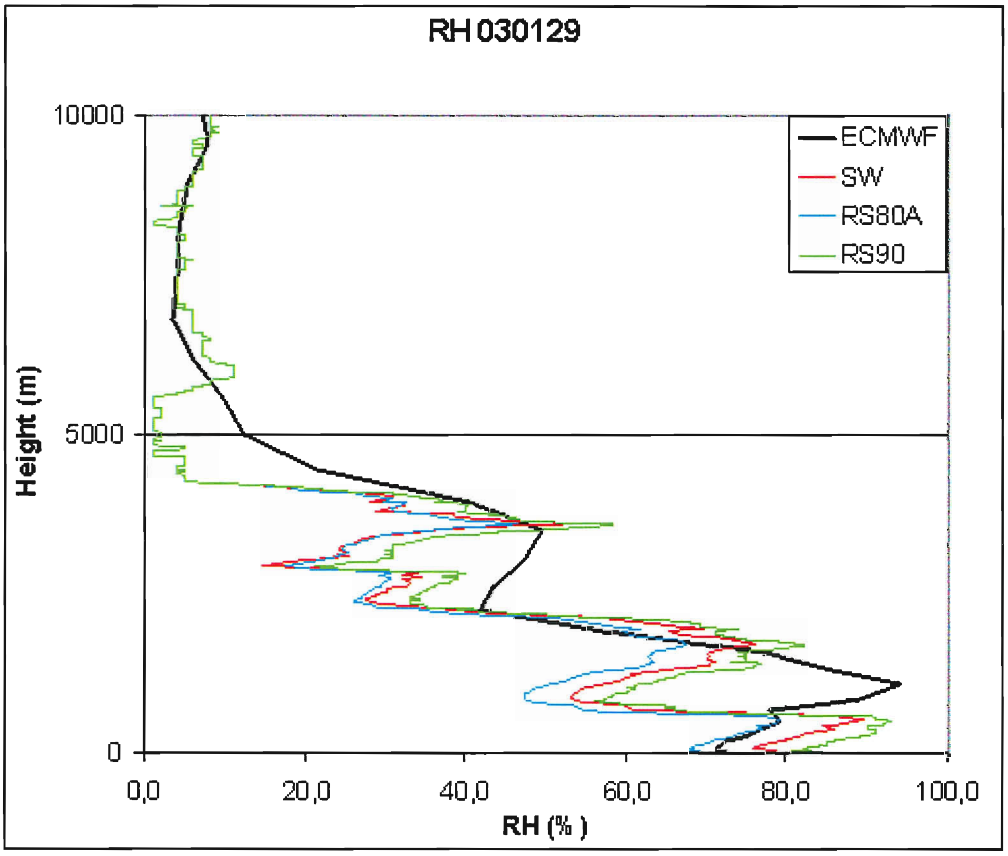
RH 030129
10000
5000
0
Height (m)
0,0
20,0
40,0
60,0
80,0
100,0
RH (%)
ECMWF
SW
RS80A
RS90

Fig. 1f

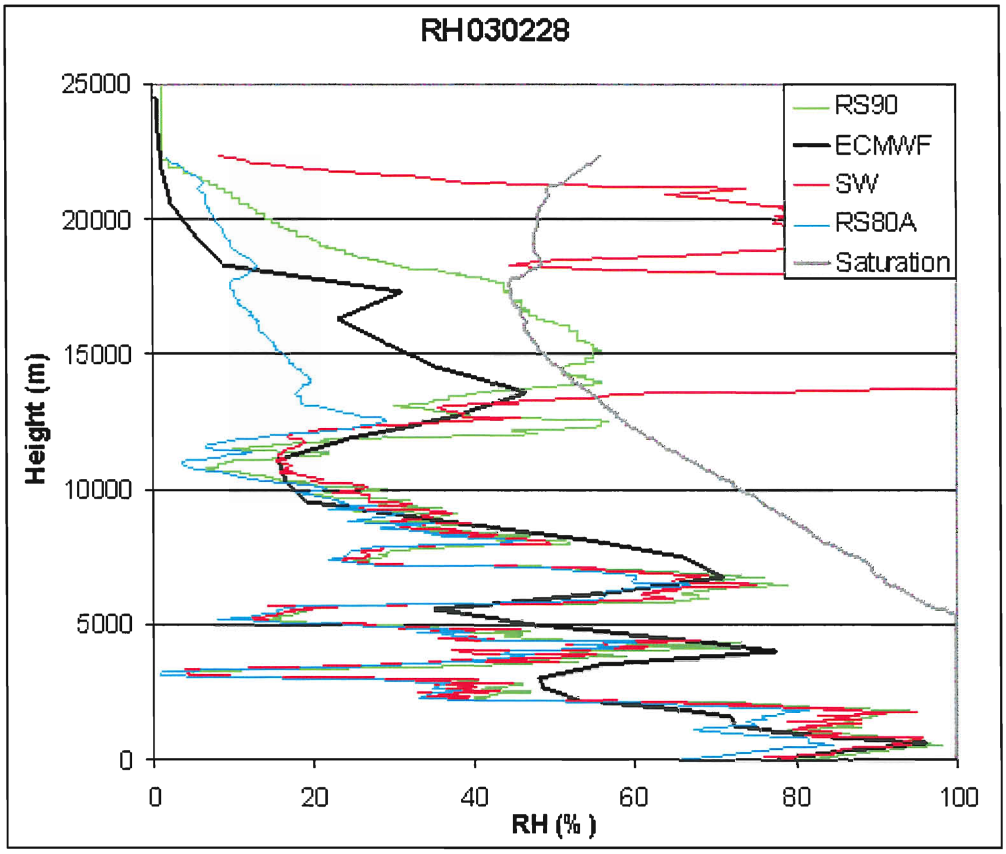
RH030228
RS90
ECMWF
SW
RS80A
Saturation
Height (m)
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
RH (%)

Fig. 1g

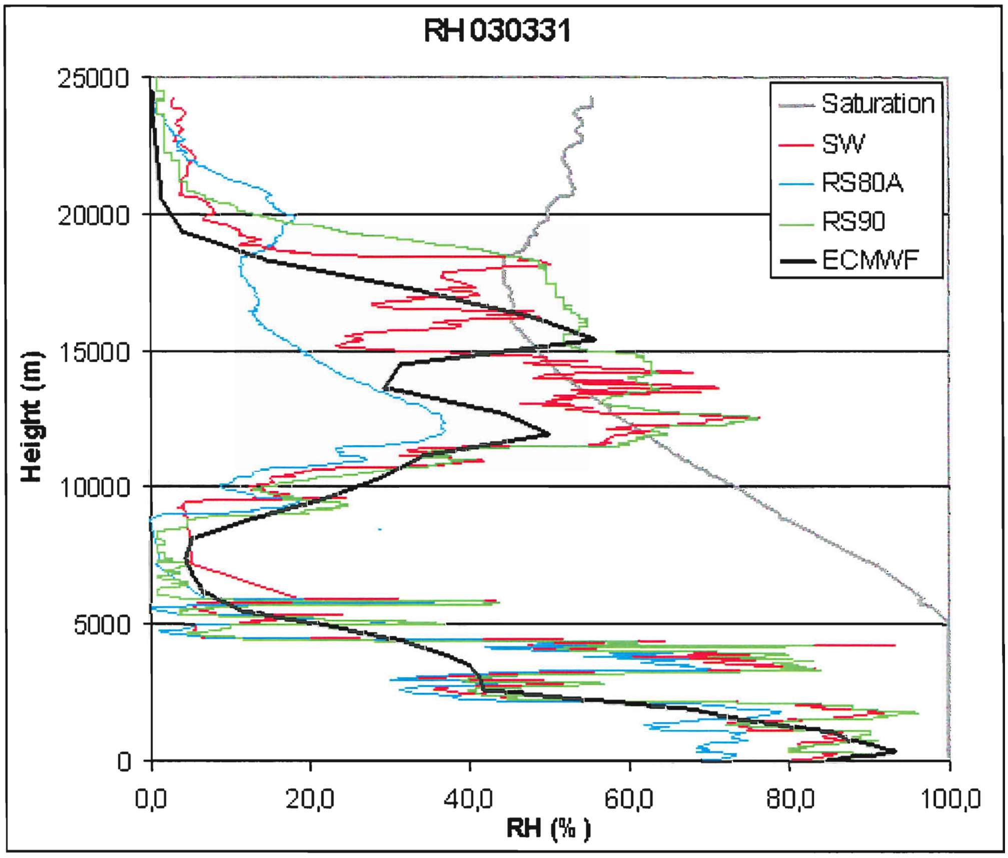
RH030331
Saturation
SW
RS80A
RS90
ECMWF
Height (m)
25000
20000
15000
10000
5000
0
0,0
20,0
40,0
60,0
80,0
100,0
RH (%)

Fig. 1h

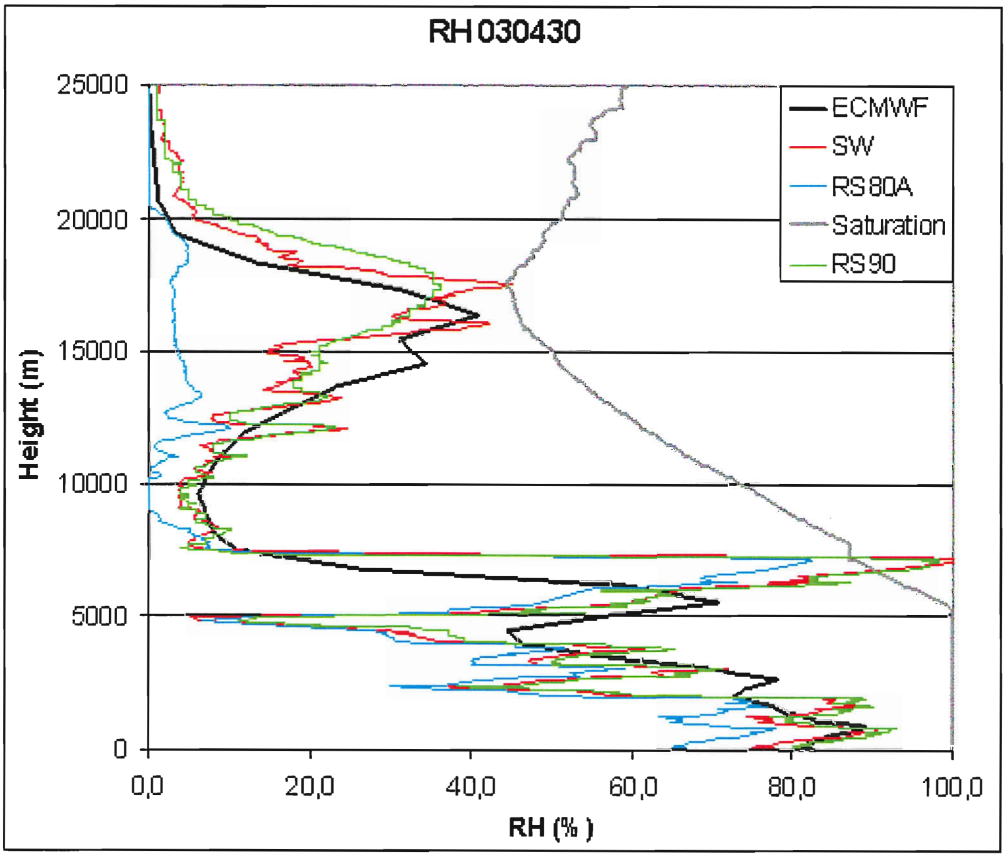
RH 030430
25000
20000
15000
10000
5000
0
Height (m)
0,0
20,0
40,0
60,0
80,0
100,0
RH (%)
ECMWF
SW
RS80A
Saturation
RS90

Fig. 1i

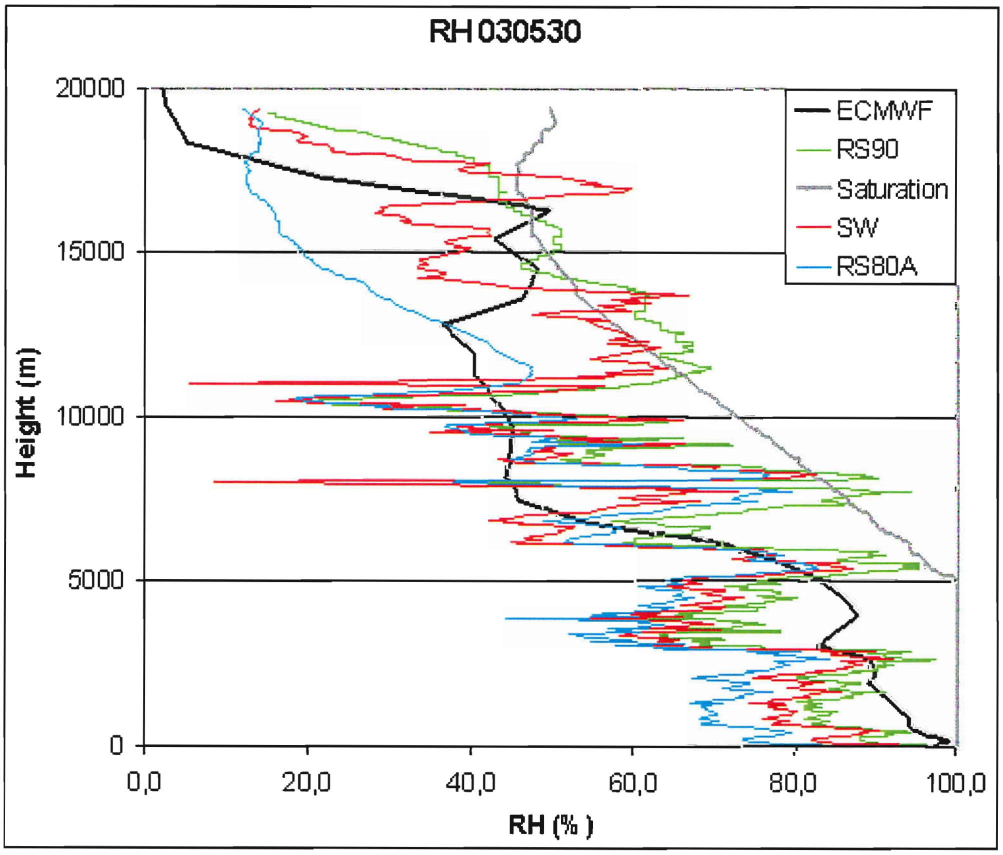
RH 030530
20000
15000
10000
5000
0
Height (m)
0,0
20,0
40,0
60,0
80,0
100,0
RH (%)
ECMWF
RS90
Saturation
SW
RS80A

Fig. 1j

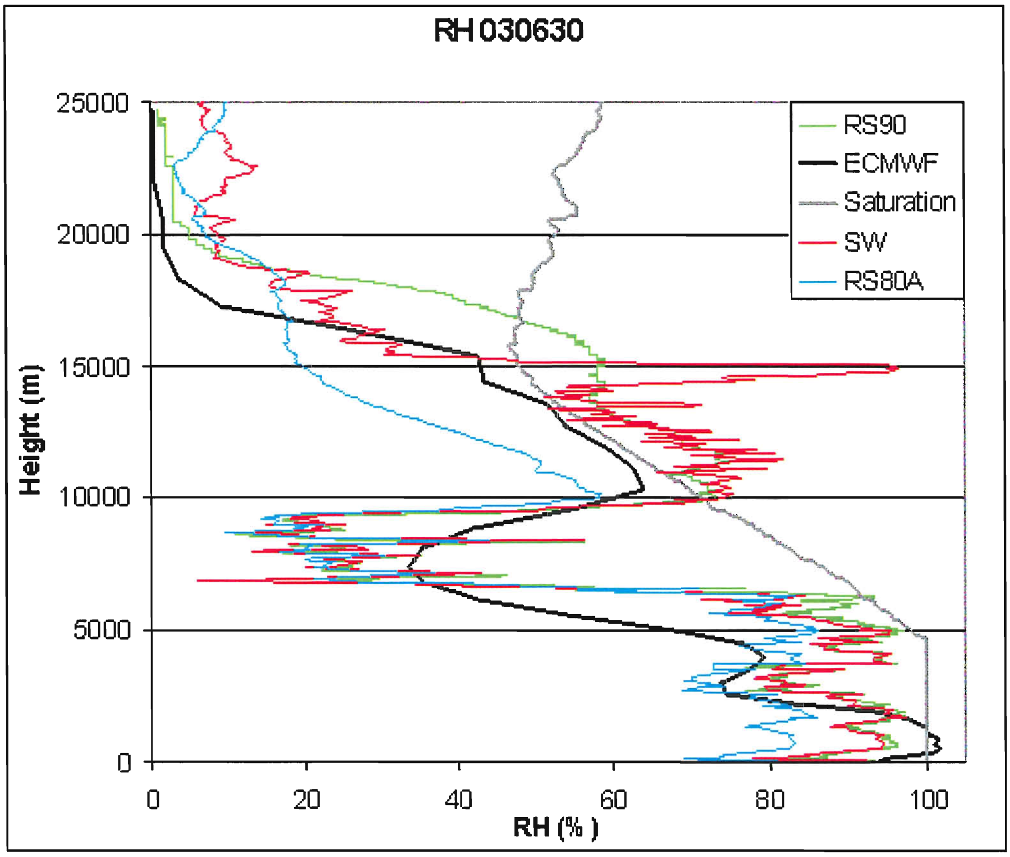

Fig. 1k

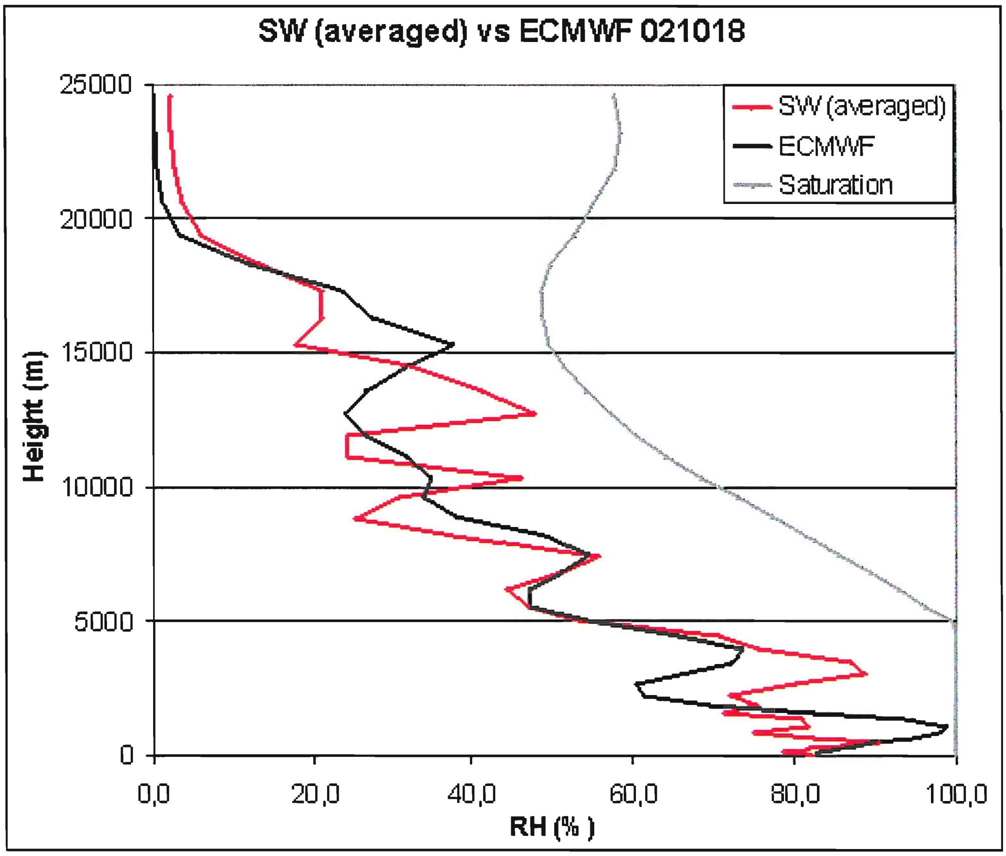

Fig. 2: Averaged SW RH profile (red line) compared to the ECMWF model analysis RH profile (black line).

Appendix D: Handleiding voor de 100% RH ijking van de Vaisala RS80

Benodigdheden:
- -Kookplaatje
- -IJkings apparaat
- -Voeding (6V)
- -Maatbeker

Is de groundcheck van de RS80 gedaan? (moet ja zijn)

Stap 1
Vul het ijkings apparaat met 200ml water, plaats het op het kookplaatje en zet het kookplaatje op stand LOW. Zet dit na 30 seconden weer uit.
(temperatuur van de lucht in de box is nu ongeveer 30-35 °C)

Stap 2
Plaats de sensor-arm van de RS80 in het ijkings apparaat, met de RS80 zo dicht mogelijk tegen de opening aan en maak deze zo nodig vast met tape. (een stukje piepschuim van 1cm dikte onder de RS80 plaatsen helpt ook) Sluit de ventilator aan op 6V, de propellor gaat nu draaien. (pas op dat de propellor de sensor-arm niet raakt) Het apparaat zo 10 minuten laten staan en wachten tot de temperatuur onder de 32 °C is gezakt.

Stap 3
Lees de waarde van de relatieve vochtigheid af op de Digicora en noteer deze.

P.S. Als geen groundcheck is gedaan, noteer dan wel de waarde van de RH bij 0% RH in de box met de silica-bolletjes.

Datum	Type RS80	Serienr.	p (hPa)	T (deg C)	RH bij 100% (%)