



Instrument Operation and Software Guide

Operation Principles and Software Description for RPG standard single polarization radiometers (G5 series)



Applicable for
HATPRO, LHATPRO, TEMPRO, HUMPRO, LHUMPRO,
LWP, LWP-U90, LWP-U72-82, LWP-90-150,
Tau-225, Tau-225-350



Document Change Log

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11.07.2011	00/01	Work
20.07.2011	01/00	Release
30.01.2012	01/02	major revisions, new CAL.LOG format
17.09.2012	01/03	extended BRT files included
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30.09.2013	01/05	correction of *.VLT (new) file format description in Appendix A 17b
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28.03.2014	01/08	Boundary Layer Height (BLH) product added
17.06.2014	01/09	Data Server implementation
06.04.2015	01/10	Implementation of: RS displays in thermo-dynamic diagrams (TDDs: Skew-T,...) History display TDDs (-2h to -10h) Display of wind information in TDDs
11.11.2017	01/11	New file formats added (valid from software version 9.10)



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1. Scope of This Document

This document contains information about:

- Theory of operation, scientific background of profiling and IWV / LWP radiometers
- Complete software description



The methods and software features treated in this document apply to single-polarization radiometers of HATPRO types (profiling radiometers RPG-XXXPRO series), LWP multichannel radiometers (RPG-LWP-XXX series) and Tau/Tipping radiometers (RPG-Tau-XXX).

2. Theory of Operation

2.1 General Remarks

Atmospheric profiles of temperature, humidity, wind direction and speed are typically measured by radiosondes launched from facilities maintained by the national weather services. Their operation is expensive and requires extended logistics, and hence results in a poor spatial (several hundred kilometers at best) and temporal (about twice a day) coverage. Remote sensing of temperature and humidity profiles from satellites yields better spatial coverage especially over oceans and sparsely populated land areas, however, the obtained horizontal and temporal resolution is coarse. Due to their viewing geometry, the vertical resolution is good in the upper troposphere but deteriorates towards the surface. Because clouds strongly absorb in the infrared spectral region several satellite instruments (e.g. the Advanced Microwave Sounding Unit AMSU and the Special Sensor Microwave/Temperature SSM/T sounder) operate in the microwave region where clouds are semi-transparent. Profiling is achieved by measuring the atmospheric emission along the wings of pressure broadened rotational lines. The 60 GHz oxygen absorption complex is typically used for temperature profiling while the 183 GHz water vapor line is used for the humidity profile. Because the atmospheric opacity is high for both bands, the problem of the unknown surface emission is eliminated.

The usefulness of ground-based microwave radiometry for the retrieval of temperature and humidity profiles has been proven for quite some time [e.g. Westwater et al, 1965; Askne et al, 1986]. Due to the low maintenance requirements of microwave radiometers, continuous atmospheric profiles can be measured which have the highest vertical resolution close to the ground in the planetary boundary layer. This feature is extremely important for the evaluation of (and incorporation into) high resolution numerical weather forecast models of the future. Due to technical improvements and the intensifying search for alternatives to radiosondes, multi-channel microwave radiometers for the operational profiling of tropospheric temperature and humidity have been developed in the last few years [Del Frate et al, 1998; Solheim et al, 1998].

An additional advantage of ground-based microwave radiometers is their sensitivity to cloud liquid water. Over the land, passive microwave remote sensing is by far the most accurate method to measure the vertically integrated liquid water content (liquid water path, LWP) other than sporadic and expensive in-situ measurements from research aircraft. More than two decades ago [Westwater, 1978] two channel radiometers were shown to achieve high accuracy in the retrieved LWP and the integrated water vapour content (IWV).

In the last few years, further improvements to the LWP retrieval have been made by the inclusion of additional microwave channels [Bosisio and Mallet, 1998] and the combination of microwave radiometer measurements with other ground-based instrumentation [Han and Westwater, 1995]. The potential of deriving cloud liquid water profiles, rather than just the column amount, using multi-channel measurements has been suggested by Solheim et al. [1998].

Satellite based remote sensing of LWP over the oceans is a well established method [Grody, 1993], however, the inhomogeneous distribution of clouds within the satellites field of view (typical several kilometers), can lead to substantial errors (von Bremen, private communications). This effect has mostly been neglected for ground-based radiometers whose viewing geometry is often assumed to behave as a pencil beam although the spatial and temporal variability of clouds is high even on scales below the resolution of most radiometers [Rogers and Yau, 1989]. With a typical wavelength of about 1 cm, practical considerations about the antenna aperture size (about 20 cm) lead to half-power beam widths from 2° to 4° for conventional radiometers. These beam widths correspond to footprints of up to several 100 m at cloud base heights.

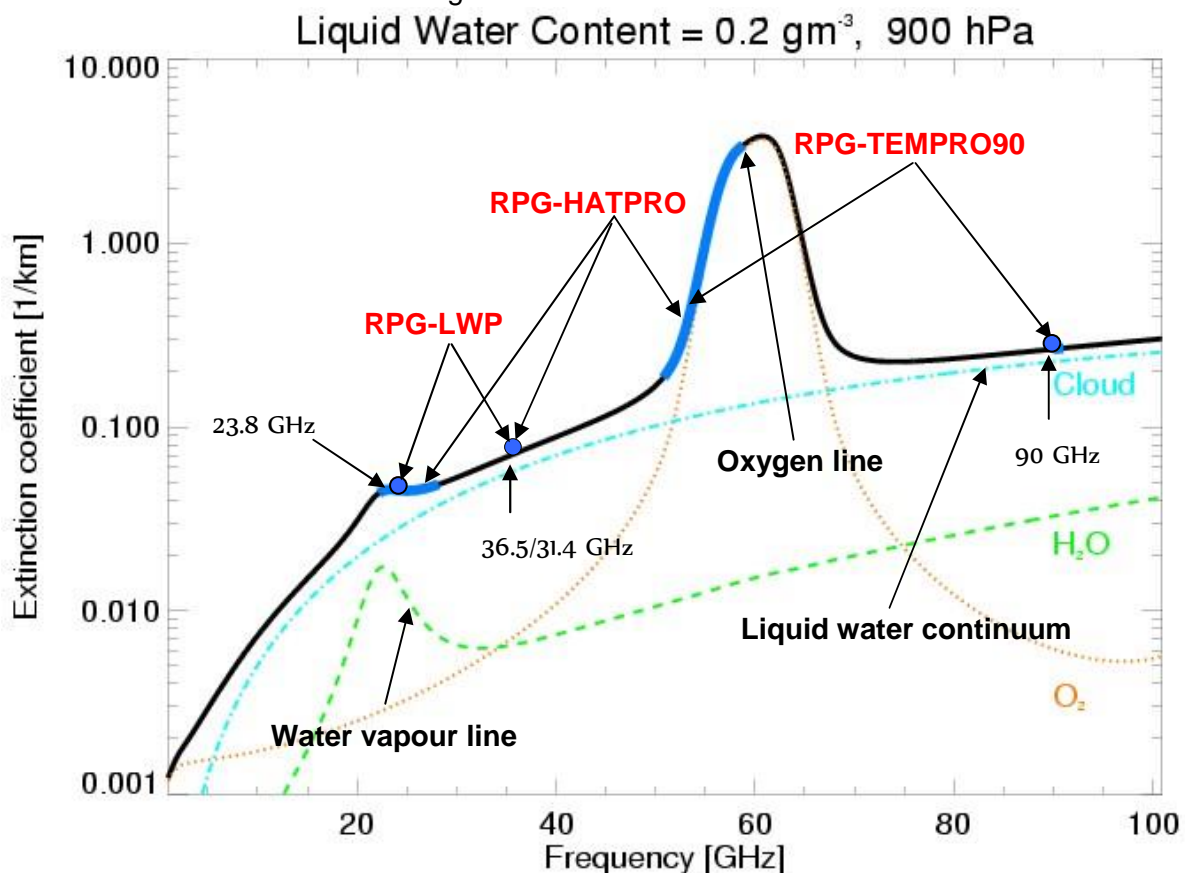


Fig.2.1: Atmospheric emission of liquid water, water vapour and oxygen. The frequency bands marked in blue are utilized by RPG's radiometers to derive LWP, IWV, Humidity and Temperature Profiles (full troposphere and boundary layer).

Atmospheric water vapor profile information is derived from frequency channels covering 6 GHz of the high frequency wing of the pressure broadened, relatively weak water vapor line (22-28 GHz). With a pressure broadening coefficient of about 3 MHz/hPa information between approx. 300 and 1000 hPa can be resolved with the spectral measurements. In the center of the oxygen absorption complex the atmosphere is optically thick and the measured radiation originates from regions close to the radiometer. For frequencies further away from the line center the atmosphere gets more transparent and the channels receive radiation which originates from regions more distant to the radiometer (see Fig.2.1). Due to the known

mixing ratio and the temperature dependence of the absorption coefficient of oxygen, information about the vertical temperature distribution is contained in the channels spanning the 8 GHz of the low frequency side.

For a ground based radiometer pointing to zenith, well defined weighting function peaks for each frequency are observed (see Fig.2.2b). If the elevation angle is lowered, (and hence the atmospheric path is increased), the peaks shift to lower altitudes. This demonstrates the radiometer's superiority in the retrieval of the planetary boundary layer temperature.

The cloud liquid water contribution to the microwave signal increases roughly with the frequency squared. It depends on temperature and is proportional to the third power of the particle radius. Therefore measurements at two channels, one influenced mainly by the water vapor line and one in the 30 GHz window region lead to good estimates of LWP and IWV [for example Westwater, 1978].

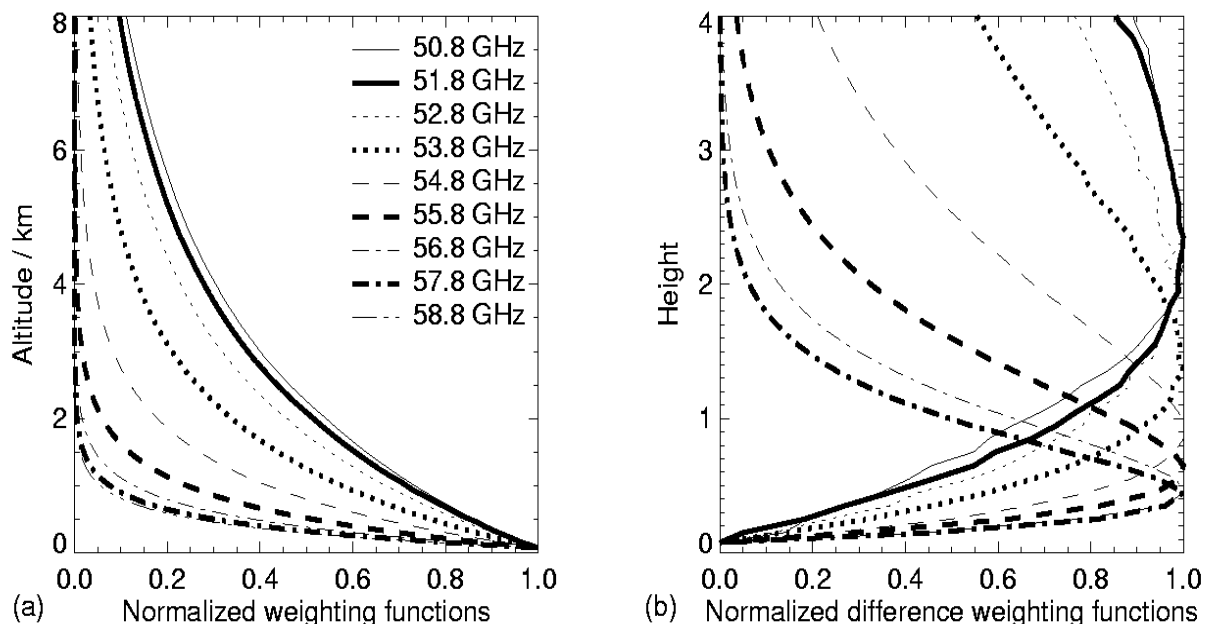


Fig.2.2: Weighting functions for the oxygen line complex channels.

2.2 Retrieval of Atmospheric Variables

Artificial neural networks (ANN) are increasingly used for the retrieval of geophysical parameters from measured brightness temperatures (for example Del Frate et al, 1999; Solheim et al, 1999; Churnside et al; 1994). They can easily adapt to nonlinear problems



such as the radiative transfer in the cloudy atmosphere. Additionally, input parameters of a diverse nature can be easily incorporated into neural networks.

We use a standard feed forward neural network [Jung et al., 1998] where the cost function is minimized employing the Davidon-Fletcher-Powell algorithm. The architecture of the ANN used for the retrieval includes an input layer consisting of simulated brightness temperatures for the PRG-HATPRO frequencies, a hidden layer with a certain number of neurons (nodes) and an output layer with the atmospheric variable of interest (LWP, IWV, temperature, or humidity profile). To derive the weights between the nodes of the different layers we generated a data set comprising about 15,000 possible realizations of the atmospheric state, which was divided into three subsets; the first for training, the second for generalization (finding the optimum number of iterations to avoid over fitting), and the third for evaluating the retrieval RMS. For each output parameter the optimal network configuration – number of nodes in the hidden layer, number of iterations and initial weight – was derived and the retrieval performance was evaluated using the third data subset. Generally, it can be stated that all algorithms developed show no systematic errors.

The data set is based on atmospheric profiles of temperature, pressure and humidity measured by radiosondes. In order to analyze profiles of cloud liquid water content (LWC) from the radio soundings, we chose a relative humidity threshold of 95 % as a threshold for the presence of clouds and calculated a modified adiabatic LWC-profile as proposed by Karstens et al. [1994]. Radiation transfer calculations were performed for each radio sounding using MWMOD [Simmer, 1994, Fuhrhop]. A random noise of 1 K was added to the resulting brightness temperatures to simulate radiometric noise. Realistic noise was also added to the other potential input parameters like the standard meteorological measurements (ground level temperature (T_{gr}), pressure (p_{gr}), relative humidity (q_{gr})) and the cloud base temperature (T_{cl}) as derived by an infrared radiometer (if provided).

It should be noted that a limitation to ANN algorithm, as to all statistical algorithms, is that they can only be applied to the range of atmospheric conditions, which is included in this data set. When extrapolations beyond the states included in the algorithm development are made, ANNs can behave in an uncontrolled way, while simple linear regressions will still give a reasonable, although erroneous, result. Quadratic regressions offer the robustness of a linear regression retrieval with the advantage to model nonlinearities much better than linear regressions. In many cases where unusual atmospheric conditions are likely the quadratic regression is the best choice.

2.3 TEMPRO / HATPRO / LHATPRO Operating Modes

The RPG-HATPRO (and related radiometers) supports two temperature profiling modes: Full troposphere profiling (frequency scan across the oxygen line) and boundary layer scanning (elevation scan @ 54.9 and 58 GHz). 22.4 GHz WVL humidity profiling is only available for the full troposphere mode (HATPRO) due to the lack of opaque

channels on the water vapour line at 22.4 GHz. The much more intense water vapour line at 183.31 GHz, observed by the RPG-LHATPRO, allows for a humidity profiling BL scanning mode.

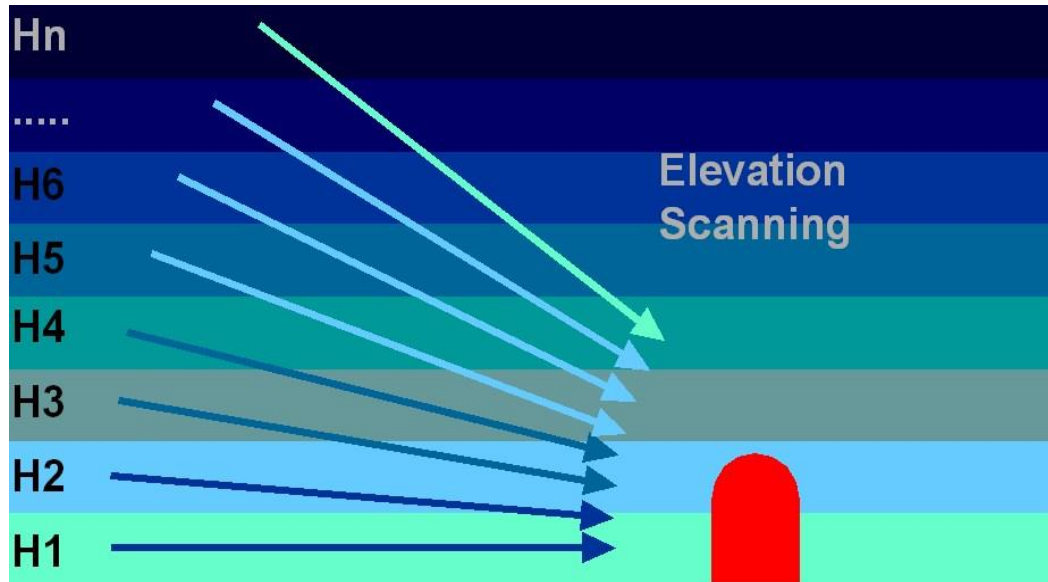


Fig.2.3: Elevation scanning technique used for boundary layer temperature profiling.

For boundary layer temperature profiling the radiometer beam is scanned in elevation between 5° and zenith (Fig.2.3). At the frequencies in use (54.9 GHz and 58 GHz) the atmosphere is optically thick. The frequencies weighting functions peak at 500 m (58 GHz) and 1000 m (54.9 GHz), see Fig.2.2. The receiver stability and accuracy has to be optimized due to the small brightness temperature variations that must be resolved in the elevation scanning method. In the RPG-HATPRO models the receiver's physical temperature is stabilized to better than 30 mK over the whole operating temperature range (-45°C to 50°C) to guarantee a high gain stability during measurements (>200 sec). The receiver noise temperature is minimized to be better than 700 K which optimizes the overall noise level.

2.4 Vertical Resolution

From the weighting functions corresponding to the various water vapour line and oxygen line profiling frequencies, the vertical resolution of the retrieval outputs can be derived:

- Tropospheric temperature profiles (0-10000 m): 200 m (<5000 m altitude), 400 m above, profile accuracy: +/- 0.6 K RMS (0-2000 m), +/- 1.0 K RMS (>2000 m)
- Boundary layer temperature profiles (0-1200 m), 30 m vertical resolution on the ground 50 m between 300-1200 m, profile accuracy: +/- 0.7 K RMS
- Tropospheric humidity profiles (0-5000 m), 200 m vertical resolution (0-2000 m), 400 m (2000 m – 5000 m), profile accuracy: +/- 0.4 g/m³ RMS



2.5 References

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3 Calibrations

Calibration errors are the major source of inaccuracies in radiometric measurements. The standard calibration procedure is to terminate the radiometer inputs with two absolute calibration targets which are assumed to be ideal targets, meaning their radiometric temperatures are equal to their physical temperature. This assumption is valid with reasonable accuracy as long as proper absorber materials are chosen for the frequency bands in use and barometric pressure corrections are applied to liquid coolants in the determination of their boiling temperature.

3.1 Absolute Calibration

A calibration target is considered to be an absolute standard when it is not calibrated by another standard. RPG's radiometers are shipped with two calibration targets of this category.

3.1.1 The Internal Ambient Temperature Calibration Target

RPG's profiling, LWP and tipping radiometers are equipped with an internal absolute ambient temperature calibration standard as shown in Fig.3.1. Other radiometer models, like the RPG-15-90, RPG-HALO-KV, RPG-HALO-119-90 and RPG-HALO-183 are using external ambient temperature targets.

The built-in ambient temperature load is one of the instrument's key components. The pyramidal absorber material is made from carbon loaded foam with low thermal capacity. The target is hermetically isolated by low and high density styrofoam with no exchange of air between the interior and environment (see Fig.3.1).

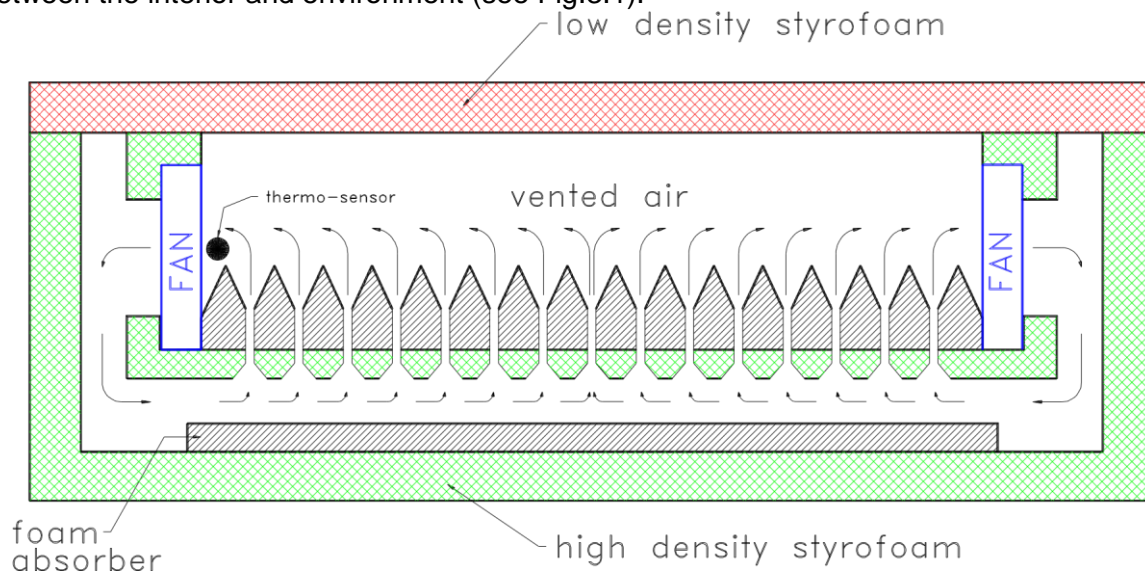


Fig.3.1: Ambient temperature target cross section (only profiling, LWP and tipping radiometers).

The air within the styrofoam box is dried with silica desiccant to avoid condensation of water on the inner styrofoam surfaces. Most important for the cancellation of thermal gradients



across the load is the closed cycle venting of the enclosed air as indicated in Fig.4.1. The foam absorber is perforated between the pyramids so that air from the bottom of the absorber can flow into the volume above the pyramids. The air flow is driven by four miniature fans which maintain a steady exchange of air and thus thermal equalisation of the absorber material.

For measuring the precise temperature of the internal calibration load the radiometer is equipped with gauged thermo-sensors offering a guaranteed absolute accuracy of ± 0.1 K. This accuracy is only realistic if the sensor is actively cooled to the air temperature inside the load which is achieved by placing the sensor into the stream of air close to one of the fans. This reduces the internal thermal gradient caused by the sensor's bias current. The top isolation plate is made from low density styrofoam with negligible microwave absorption at frequencies up to 100 GHz.

The major advantage of the ambient load is the fact that no active thermal stabilization by heaters or coolers is necessary. For a calibration load it is not essential to keep its temperature constant for all external thermal conditions but to know its precise physical temperature and to keep thermal gradients as small as possible (which is not achieved by heating or cooling the load from the bottom!). According to these requirements the described load is almost ideal. Furthermore the load has a minimized weight since it is mainly made of styrofoam and foam absorber.

For the radiometer models RPG-15-90, RPG-HALO-KV, RPG-HALO-119-90 and RPGHALO-183 an external ambient temperature target is used. Its physical temperature is measured by a certified thermometer, pushed into the foam pyramidal absorber.

3.1.2 External Liquid Nitrogen Cooled Calibration Target

Another absolute calibration standard is the liquid nitrogen cooled target that is attached externally to the radiometer box (see Fig.3.2). This standard - together with the internal ambient load - is used for the absolute calibration procedure. The cooled load is stored within a polystyrene container. 60 litres of liquid nitrogen is needed for one filling.

The boiling temperature of the liquid nitrogen and therefore the physical temperature of the cold load depends on the barometric pressure p . The radiometer's pressure sensor is read during absolute calibration to determine the corrected boiling temperature T_C according to the equation:

$$\ln\left(\frac{p}{1013.25 \cdot \text{mbar}}\right) = \frac{\Delta H}{R} \left(\frac{1}{77.35\text{K}} - \frac{1}{T_C} \right), \quad \text{Clausius - Clapeyron}$$

$T_0 = 77.36$ K is the boiling temperature at 1013.25 hPa, ΔH is the latent heat of liquid nitrogen and R is the universal gas constant.

The described cold target is used for all profiling, LWP and Tipping radiometers.

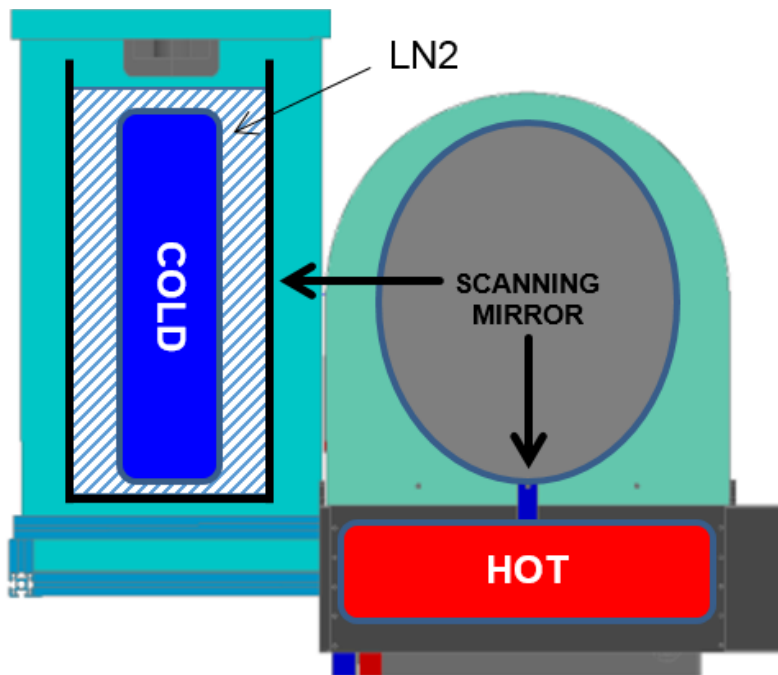


Fig.3.2: External cold load attached to the radiometer box.

3.1.3 General Remarks on Absolute Calibrations

After the system has been turned on, at least 30 minutes are required for warming up and stabilization of all receiver components. To ensure accurate measurements, an absolute calibration should be performed only after completed warm-up. It is recommended to repeat this calibration every 5 to 6 months of operation or after transportation of the system. This will recalibrate the built-in noise standards needed for the automatic regular calibration cycles.

3.1.3.1 System Nonlinearity Correction

A common simplification in the design of calibration systems for total power receivers is the assumption of a linear radiometer response. In this case a simple two point calibration (hot/cold) is sufficient to determine the system noise equivalent temperature (T_{sys} , offset noise) and system gain (G , slope of the linear response). Accurate noise injection measurements [2], [3] have shown that the assumption of linear system response is not valid in general. Calibration errors of 1-2 K have been observed at brightness temperatures in between the two calibration target temperatures. This system nonlinear behavior is mainly caused by detector diodes [1] needed for total power detection. Even in the well-defined square law operating regime (input power < -30 dBm) the detector diode is not an ideal element of perfect linearity. The noise injection calibration algorithm implemented in all RPG radiometers corrects for these nonlinearity effects.

The system nonlinearity is modelled by the following formula:

$$U = GP^\alpha, \quad 0.9 \leq \alpha < 1 \quad (1)$$

where U is the detector voltage, G is the receiver gain coefficient, α is a nonlinearity factor and P is the total noise power that is related to the radiometric brightness temperature T_R through the Planck radiation law:

$$P(T_R) \cong \frac{1}{\frac{h\nu}{e^{k_B T_R}} - 1}$$

(the proportionality factor is incorporated in G). T_R is the sum of the system noise temperature T_{sys} and the scene temperature T_{sc} .

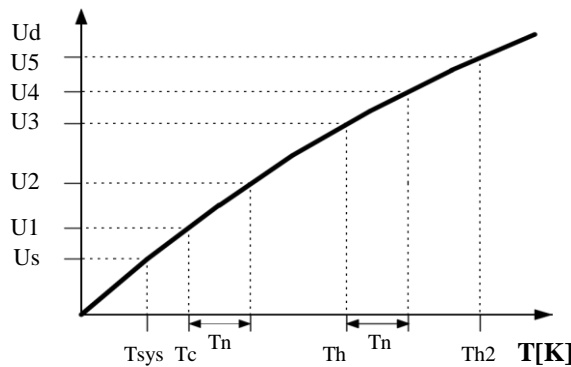


Fig.3.3: Detector response as a function of total noise temperature. T_{sys} is the system noise temperature, T_n the additionally injected noise, T_c the total noise when the radiometer is terminated with a cold load (e.g. liquid nitrogen cooled absorber) and T_h the corresponding noise temperatures for the ambient temperature load.

The problem is how to determine G , α and T_{sys} experimentally (three unknowns cannot be calculated from a measurement on two standards). A solution is to generate four temperature points by additional noise injection of temperature T_n which leads to four independent equations with four unknowns (G , α , T_{sys} and T_n) The procedure is illustrated in Fig.3.3:

During the calibration cycle the elevation mirror automatically scans the two absolute targets.

The initial calibration is performed with absolute standards and leads to the voltages $U1$ and $U3$. By injection of additional noise $U2$ and $U4$ are measured. For example $U2$ is given by

$$U_2 = G(P(T_{\text{sys}}) + P(T_{\text{cold}}) + P(T_n))^\alpha \quad (2)$$

T_{cold} is the radiometric temperature of the cold target. The evaluation of the corresponding equations for $U1$, $U3$ and $U4$ results in the determination of T_{sys} , G , α and T_n . It is important to notice that the knowledge of the equivalent noise injection temperature T_n is not needed for the calibration algorithm. It is only assumed that T_n is constant during the measurement of $U1$ to $U4$.

After finishing the procedure the radiometer is calibrated. With the four point calibration method also the noise diode equivalent temperature T_n is determined. Assuming a high radiometric stability of the noise injection temperature, following calibrations can use this secondary



standard (together with the built-in ambient temperature target) to recalibrate T_{sys} and G (considering α to be constant) without the need for liquid nitrogen.

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3.1.3.2 Avoiding Errors from Variable System Noise Temperature

All losses in the receiver system contribute to the system noise temperature. A significant system noise contribution is related to the receiver optics. A corrugated feedhorn operated at 90 GHz has a typical loss of $L=0.5$ dB. At a physical temperature of 300 K such a feedhorn contributes with 30 K to system noise according to the formula

$$T = T_0 \left(1 - \frac{1}{L}\right)$$

T_0 is the physical temperature of the horn. A change of the feedhorn's physical temperature from 0°C to 30°C leads to a system noise increase of 3 K which corresponds to an error in the absolute brightness temperature. For this reason the antenna has to be thermally stabilized together with the receivers.

The brightness temperature errors introduced by optics that are not thermally stabilized **cannot** be corrected by the implemented noise standard calibration because the noise source power enters the signal path behind the feedhorn and thus is not changed by a variable antenna temperature.

3.2 Noise Injection Calibration

G5 radiometers are equipped with a totally reworked data acquisition system. Its key feature is a 20 times faster channel sampling rate (4000 samples / sec / channel) which enables the receivers to efficiently take advantage of the noise injection system (noise adding radiometer). The G5 radiometer's calibration noise switching is fast enough to completely cancel 1/f receiver instabilities (non-white noise contributions). This implies that the radiometer's brightness temperature noise performance can be characterized by the ideal radiometer formula, meaning that the observed signal noise is reduced by the maximum rate when integrating on the sky or on calibration targets.

The new data acquisition system raises G5 radiometers to the category of precision instruments with brightness temperature accuracies of better than 0.1 K RMS. Allan variance measurements performed on the PT-V1 precision target have demonstrated a receiver stability of at least a few thousand seconds when operated in noise adding mode.

3.3 Gain Calibration (Relative Calibration)

Another calibration is the gain calibration method. It only corrects for gain drifts (G) but not for changes in system noise temperature T_{sys} . The receiver gain is most sensitive to even small changes in the physical temperature of the receiver components. During calibration the elevation mirror scans the built-in ambient temperature target (one calibration point only). With the assumption of constant T_{sys} the system gain can be recalibrated. The duration of the gain calibration is about 10 seconds. It is recommended to repeat it every 60 minutes.

3.4 Sky Tipping (Tip Curve)

Sky tipping (often referred to as tip curve calibration) is a calibration procedure suitable for those frequencies where the earth's atmosphere opacity is low (i.e. high transparency) which means that the observed sky brightness temperature is influenced by the cosmic background radiation temperature of 2.7 K. The humidity profiler channels are candidates for this calibration mode. High opacity channels like all temperature profiler channels >53 GHz are saturated in the atmosphere and must be calibrated by other methods.

Sky tipping assumes a homogeneous, stratified atmosphere without clouds or variations in the water vapor distribution. If these requirements are fulfilled the following method is applicable: The radiometer scans the atmosphere from zenith to around 14° in elevation and stores the corresponding detector readings for each frequency and angle. The path length for a given elevation angle α is $1/\sin(\alpha)$ times the zenith path length (defined as one "air mass"), thus the corresponding optical thickness should also be multiplied by this factor (if the atmosphere is stratified!).

When radiation of intensity I_ν (ν denotes a certain frequency) passes through an infinitely thin slice of gas, I_ν is reduced by dI_ν given as

$$dI_\nu = -I_\nu \kappa_\nu ds$$

where κ_ν is the absorption coefficient and includes all processes implying a loss of photons on the way down to the radiometer. Integration over a finite sheet of gas leads to:

$$-\int \frac{dI_\nu}{I_\nu} = -\int d \ln(I_\nu) = \int \kappa_\nu ds \quad \Rightarrow \quad I_\nu = I_\nu^0 \cdot e^{-\int \kappa_\nu ds}$$

I_ν^0 is the intensity before entering the sheet. The optical thickness is defined as:

$$\tau_\nu \equiv \int \kappa_\nu ds \quad \Rightarrow \quad I_\nu = I_\nu^0 \cdot e^{-\tau_\nu}$$

Spontaneous emission in the sheet increases the intensity. Atmospheric molecules perform rotational or vibrational transitions in the radiation field:

$$dI_\nu = \varepsilon_\nu ds$$

where ε_ν is the emission coefficient at frequency ν . The emission coefficient depends on pressure, temperature and chemical composition of the gas and has to be calculated quantum mechanically.

The total change of intensity for the infinitely thin gas sheet is then:

$$dI_\nu = \varepsilon_\nu ds - I_\nu \kappa_\nu ds \quad \Leftrightarrow \quad \frac{dI_\nu}{ds} = \varepsilon_\nu - I_\nu \kappa_\nu \quad \text{or} \quad \frac{dI_\nu}{d\tau_\nu} = \frac{\varepsilon_\nu}{\kappa_\nu} - I_\nu$$

We define the ratio ε / κ as the source function S . Then we get:

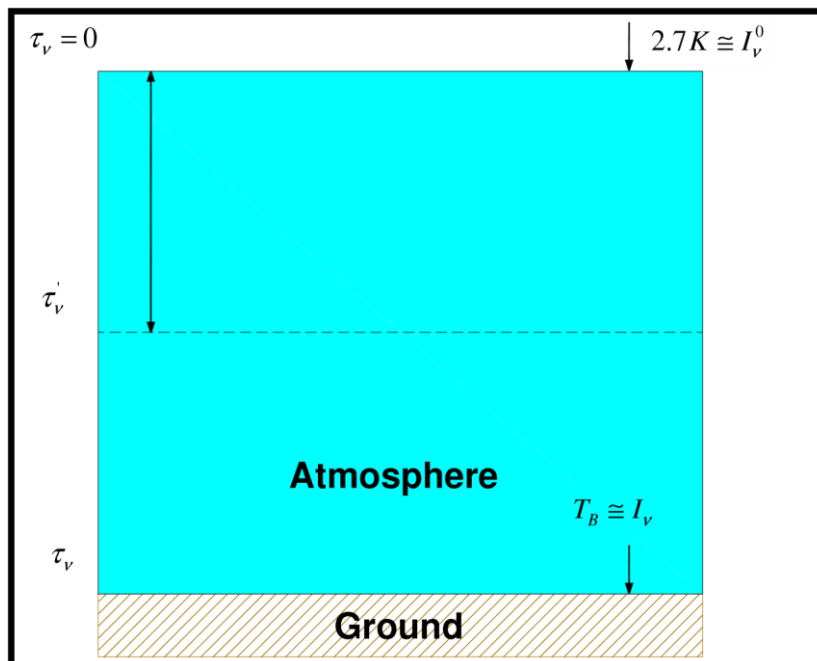
$$\left(\frac{dI_\nu}{d\tau_\nu} + I_\nu \right) \cdot e^{\tau_\nu} = S_\nu e^{\tau_\nu} \quad \Rightarrow \quad \frac{d}{d\tau_\nu} (I_\nu \cdot e^{\tau_\nu}) = S_\nu e^{\tau_\nu}$$

Integration leads to:

$$I_\nu(\tau_\nu) \cdot e^{\tau_\nu} - I_\nu^0 = \int_0^{\tau_\nu} S_\nu \cdot e^{\tau'_\nu} d\tau'_\nu \quad \text{where} \quad I_\nu^0 = I(\tau'_\nu = 0)$$

This is identical to the more common version of the radiative transfer equation:

$$I_\nu(\tau_\nu) = I_\nu^0 \cdot e^{-\tau_\nu} + \int_0^{\tau_\nu} S_\nu \cdot e^{-(\tau_\nu - \tau'_\nu)} d\tau'_\nu$$



A sheet of optical thickness τ_v absorbs a part of incident radiation I_v^0 and emits radiation at each position, which is partly absorbed by $(\tau_v - \tau_v')$. In order to obtain the intensity on the ground, we have to compute the integral along the whole line of sight through the gas, τ_v is the total optical thickness of the gas layer.

With the definition of the mean radiation temperature T_{mr} :

$$T_{mr} \equiv \frac{\int_0^{\tau_v} S_v \cdot e^{-(\tau_v - \tau_v')} d\tau_v'}{1 - e^{-\tau_v}}$$

the optical thickness is related to the brightness temperature by the equation:

$$\tau_v = \ln \left(\frac{T_{mr} - T_{B0}}{T_{mr} - T_B} \right)$$

T_{mr} is a mean atmospheric temperature in the direction θ , T_{B0} is the 2.7 K background radiation temperature and T_B is the brightness temperature of the frequency channel. The attenuation A in dB is related to τ_v by the following formula:

$$\tau_v = A \cdot \frac{\ln 10}{10}$$

T_{mr} is a function of frequency and is usually derived from radiosonde data. A sufficiently accurate method is to relate T_{mr} with a quadratic equation of the surface temperature measured directly by the radiometer.

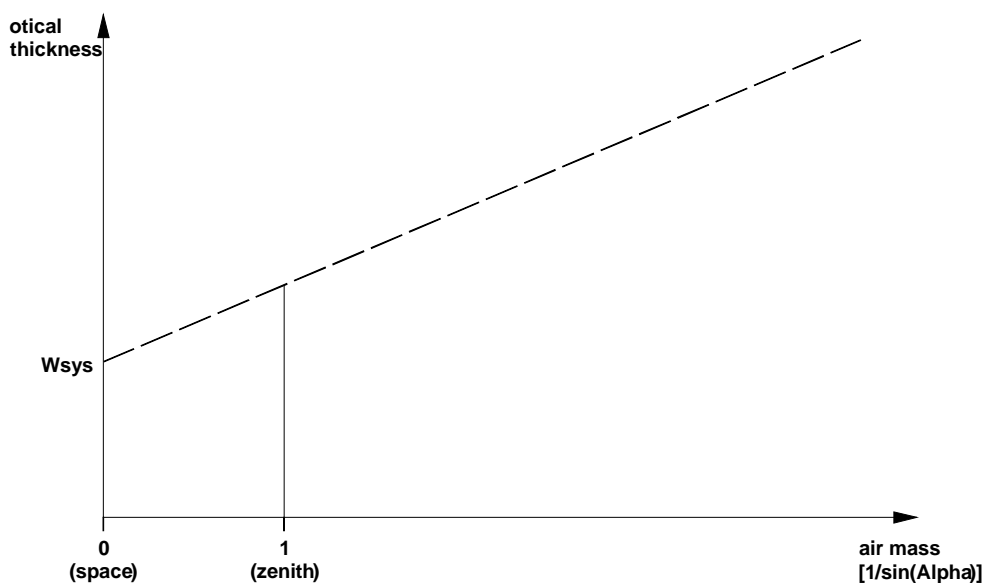


Fig.3.5: Extrapolation of tipping response to 2.7 K free space temperature.

The optical thickness as a function of air mass is a straight line (see Fig.3.5) which can be extrapolated to zero air mass. The detector reading U_{sys} at this point corresponds to a



radiometric temperature which equals to the system noise temperature plus 2.7 K: $U_{\text{sys}} = G \cdot (T_{\text{sys}} + 2.7 \text{ K})$. The proportionality factor (gain factor) G can be calculated when a second detector voltage is measured with the radiometer pointing to the ambient target with known radiometric temperature T_a . The sky tipping calibrates the system noise temperature and the gain factor for each frequency without using a liquid nitrogen cooled target.

The disadvantage of this method is that the assumption of a stratified atmosphere is often questionable even with clear sky conditions due to invisible inhomogeneous water vapour distributions (e.g. often observed close to coast lines). The built-in sky tipping algorithm investigates certain user selectable quality criteria to detect those atmospheric conditions that do not fulfil the calibration requirements. The most important criteria are:

- Linear correlation factor. This measures the correlation of the optical thickness samples (as a function of air mass) with a straight line. Typical linear correlation factor thresholds are >0.9995 . The linear correlation factor is not sensitive for the noise of the optical thickness samples caused by clouds etc.
- χ^2 -test. This measures the variance of the optical thickness samples relative to the straight line in Fig.3.5. Typical threshold values are <0.4 for a good quality calibration.

The tip curve calibration is considered to be the most accurate calibration method. The brightness temperatures acquired in the elevation scan are close to the scene temperatures measured during zenith observations.

3.5 Calibration Equations

Relation between detector voltages U_d and scene temperatures T_{sc} :

$U_d = G (T_{\text{sys}} + T_{\text{sc}})^{\text{Alpha}}$, for radiometers without Full Dicke Switching Mode (Type 1)

$U_d = G (T_{\text{sys}} + T_{\text{sc}})$, for radiometers with Full Dicke Switching Mode (Type 2)

System Noise Temperature T_{sys} , Noise Diode Temp. T_N and Gain G :

Absolute Calibrations (Hot / Cold): detector voltages on black body target (temperature $T_H = T_{\text{amb}}$): U_H , cold target (LN or Skydip, temperature T_C): U_C :

$Y = (U_H / U_C)^{1/\text{Alpha}}$, $T_{\text{sys}} = (T_H - Y * T_C) / (Y - 1)$, $0.95 < \text{Alpha} \leq 1$ (sec. 4.1.3.1), Type 1

$Y = (U_H / U_C)$, $T_{\text{sys}} = (T_H - Y * T_C) / (Y - 1)$, Type 2

$G = U_H / (T_{\text{sys}} + T_H)^{\text{Alpha}}$, Type 1

$G = U_H / (T_{\text{sys}} + T_H)$, Type 2

On black body target (T_{amb}), noise diode turned off: U_{-N} , noise diode turned on: U_{+N}

$T_N = (U_{+N} / G)^{1/\text{Alpha}} - T_{\text{sys}} - T_{\text{amb}}$, Type 1

$T_N = (U_{+N} - U_{-N}) / G$, Type 2

Type 2 only: Dicke Switch (DS) ON, radiometer pointing to amb. temp. target:

$\text{DelT} = U_{\text{DS}} / G - T_{\text{sys}} - T_{\text{DSp}}$,



Dicke Switch (DS) leakage (Type 2 only): DS ON, radiometer pointing to cold target: Alpha
 $= (T_{Dsp} + DeIT - (U_{DS} / G - T_{sys})) / (T_{Dsp} + DeIT - T_C)$

If a liquid nitrogen cooled target is used, the following correction has to be applied:

$T_C [K] = 77.36 - 8.2507e-3 * (1013.25 - P) + 1.9$, P in mbar, 1.9 K is correction for surface reflection on LN (n = 1.2)

Continuous full calibration on scene (Type 2 only): Noise Diode turned off: U_{-N} , noise diode turned on: U_{+N} , radiometers looking on scene temperature T_{sc} , Dicke switch turned ON (blocking scene), physical Dicke switch temperature T_{Dsp} :

$G = (U_{+N} - U_{-N}) / T_N$, $T_{sys} = U_{-N} / G - (T_{Dsp} + DeIT - Alpha * (T_{Dsp} - T_{sc}))$, Alpha= DS leakage (determined in absolute calibration)

Continuous noise switching on scene (Type 1 only): noise diode turned off: U_{-N} , noise diode turned on: U_{+N} (10 Hz), radiometers pointing to scene (temperature T_{sc}):

$D = (U_{+N} / U_{-N})^{1/Alpha} - 1$, $T_{sc} = (T_N - D * T_{sys}) / D$, $G = U_{-N} / (T_{sys} + T_{sc})^{Alpha}$
 Calibration on ambient temp. black body target (T_{amb}): $T_{sys} = (U_d / G)^{1/Alpha} - T_{amb}$

Type 1, no noise switching:


gain calibration on ambient temp. target (T_{amb}): $G = U_d / (T_{sys} + T_{amb})^{Alpha}$ noise
 calibration on ambient temp. target (T_{amb}):

$D = (U_{+N} / U_{-N})^{1/Alpha} - 1$, $T_{sys} = (T_N - D * T_{amb}) / D$, $G = U_{-N} / (T_{sys} + T_{amb})^{Alpha}$



4 Software Description

The following conventions are used in this software description:

- Messages generated by the program that have to be acknowledged are printed in red. Example: **Master Radiometer does not respond**
- Button labels are printed in green: **Cancel**
- Messages that have to be answered by **Yes** or **No** are printed in light blue: **Overwrite the existing file?**
- Labels produced by the software are printed in grey: **UTC**
- Names of group boxes are printed in blue. Example: **Radiometer Status** on the main screen.
- Names of tabs are printed in purple: **Sky Tipping**
- Names of menus are printed in black: **File Transfer**
- Labels of Entry-Boxes are printed in light blue: **Const. Elev. Angle**
- When a speed button shall be pressed, this is indicated by its symbol: 
- Hints to speed buttons are printed in brown: **Define Serial Interface**
- Selections from list boxes are printed in magenta: **Celsius**
- Selections from radio buttons or check boxes are printed in dark green: **COM1**
- File names are printed in orange: **MyFileName**
- Directory names are printed in dark blue: **C:\Programs\RPG-HATPRO**

4.1 Installation of Host Software

4.1.1 Hardware Requirements for Host PC


The hardware requirements for running the host PC (H-PC) software are:

- Pentium based PC, 1.0 GHz clock speed minimum
- 600 MB free RAM for software execution
- Ethernet interface for G4 models and higher (no need for serial interface)

4.1.2 Directory Tree

To operate the H-PC software without problems, a proper installation of the retrieval files (required to perform online calculations of atmospheric parameters like profiles, LWP, IWV etc.) is required.



By clicking on the desktop icon  the executable H-PC program **R2CH.EXE** is started (runs on Windows NT4.0®, Windows 2000®, Windows XP®, Windows Vista®, Windows 7®). On pre-installed PCs this file is located in **C:\RPG-XXX**, where 'XXX' stands for the radiometer model (e.g. HATPRO, TEMPRO, HUMPRO, LWP-U90, etc.). This directory path can be changed to any other path (in the following referred to as **MY_DIRECTORY\RPGXXX**). Of course the corresponding desktop link has to be modified accordingly.



In the case that the user wants (or has) to install the software himself the following steps should be performed:

- Start your Windows® operating system
- Start the Windows Explorer®
- Insert the Radiometer memory stick
- In Windows Explorer® click on the flash drive
- Click on the **RPG-XXX**-folder and drag the whole folder to **MY_DIRECTORY** (user selectable).

Example: If '**MY_DIRECTORY**' is the directory **D:\Programs** the complete tree should look like this:

```
D:
|---Programs
|   |---RPG-XXX
|   |   |---AGENTS
|   |   |---AUTO_MDF
|   |   |---AutoViewer
|   |   |---AUTO_RS
|   |   |---CONFIG
|   |   |---Data
|   |   |---Help
|   |   |---LICENSE
|   |   |---LOG
|   |   |---MDF_MBF
|   |   |---Radiometer PC
|   |   |---Retrievals
|   |       |---Attenuation
|   |       |---BINARY
|   |       |---HProfile
|   |       |---IWV
|   |       |---LWP
|   |       |---Miscellaneous
|   |       |---SPC
|   |       |---TMR
|   |       |---TProfile_BL
|   |       |---TProfile_TROP
|   |   |---TEMP
|   |   |---TRACKING
|   |   |---Translation
```

The **RPG-XXX**-directory contains (at least) the following files:

- **VCL50.BPL** : System library extension file (can be different in future releases)
- **VCLX50.BPL** : System library extension file (can be different in future releases)



- **BORLNDMM.DLL** : Dynamic link library, Memory Management functions (can be different in future releases)
- **CC3250MT.DLL** : Dynamic link library, Core functions (can be different in future releases)
- **NETCDF.DLL** : Dynamic link library, netCDF file format routines
- **NETCDF.LIB** : netCDF library file
- **R2CH.EXE** : Radiometer software
- **R2CH.CFG** : Radiometer software configuration file (in ...**CONFIG**)
- **RS.FMT** : Radiosonde file format archive (in ...**CONFIG**)

The **AUTO_MDF** subdirectory (this directory may be renamed) is used for Automatic MDF control. If this mode is activated, the software will inspect this directory for MDF or MBF files to be executed. The execution of MDFs by the radiometer can be controlled via simple file transfers this way.

The **AutoViewer** subdirectory (this directory may be renamed) is used to store the level 1 data files for measurement simulations. When running the Auto Viewer, these data files act as a data source that simulates a connected radiometer. While executing, the H-PC displays are looking as if a real measurement is running. This feature is useful for checking new program featured and retrievals or to illustrate the systems functionality without having a radiometer connected to the H-PC.

The radiometer configuration file and archive for radiosonde data formats is stored in **CONFIG**.

Data is reserved for measurement data files including user defined sub-directories or archiving sub-directories. Of course the user can create any other directory for his data file storage.

Help (must not be renamed) contains all RichText (*RTF) files for the help system.

In **LICENSE** you find the license ID for your radiometer. This is needed to get the unlimited license after all payment is done.

MDF_MBF directory is empty after installation and is intended for the Measurement Batch Files and Measurement Definition Files needed to initiate a measurement.

TRACKING is reserved for RINEX navigation files needed for the satellite tracking mode (see section 4.9.4.1).


Retrievals and its subdirectories should never be changed (renamed or deleted) since the software assumes to find all retrieval files here. The retrievals for humidity profiles are stored in **HProfile**, tropospheric retrievals for temperature profiling are stored in **TProfile_TROP** etc. When the user develops his own retrieval files he must store the retrieval in one of the 6 category directories.

The **Translation** subdirectory (must not be renamed!) stores the translation files needed for the multi-lingual system. The user may select one of the following languages: English, Chinese, German, Korean, French, Spanish or Italian.

Click into **MY_DIRECTORY\RPG-XXX** and locate **R2CH.EXE**. When clicking on this file with the right mouse button a list of actions is displayed. Select the 'Desktop (Create Shortcut)' option to generate an icon on the desktop.

The **RS.FMT** is an archive for radiosonde data formats. The user can extend this archive as described in 4.16.2.

4.2 Getting Started

When clicking on the desktop icon  to start the H-PC software **R2CH.EXE**, the following introduction window appears:

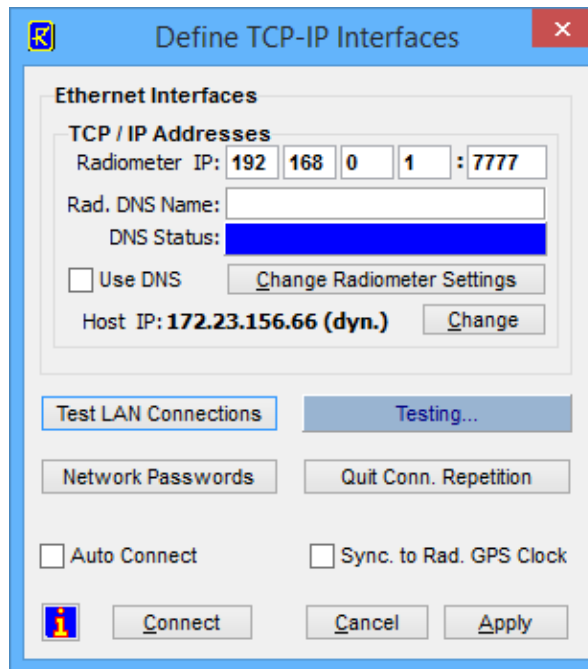


It displays the current version number, a few examples of instrument deployments, a list of supported RPG radiometer models and (in red) a hint to press <ESC> if you want to change some of the starting configuration settings (black arrow). By pressing <ESC> during software start, the user enters a menu where he can overwrite some settings of the automatically loaded configuration file **R2CH.CFG**. This can be very useful, e.g. when the H-PC software is configured for 'Auto Connect' in auto start mode but the user wants to change the IP address of host and/or radiometer PC.

4.2.1 Interfacing via Ethernet

If a data cable is installed between the H-PC and the radiometer (see Installation Manual), the user should select an Ethernet connection with IP and Gateway port definitions.

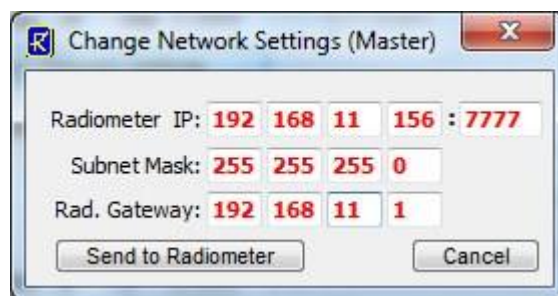
This is done by clicking  (**Define Serial / TCP-IP Interfaces**) which opens the menu below.



The R-PC is delivered with a certain fixed IP address (default: 192.168.0.1, port no.:7777) which can be altered later. For a first connection the user needs to enter this IP to the edit fields right to 'Radiometer IP:' (see encircled line above). The radiometer Gateway is set to the same address as the radiometer IP, which is needed for a peer-to-peer connection between the radiometer and the H-PC. A peer-to-peer connection is an Ethernet connection between two PCs without using a network in between.

In order to set up a peer-to-peer connection, the H-PC must have a fixed IP address as well and its gateway set to the same IP address.

For changing the radiometer IP and gateway, e.g. when the radiometer shall be connected to a network, click **Change Radiometer Settings** (a new menu pops up) and edit the fields to the desired numbers:

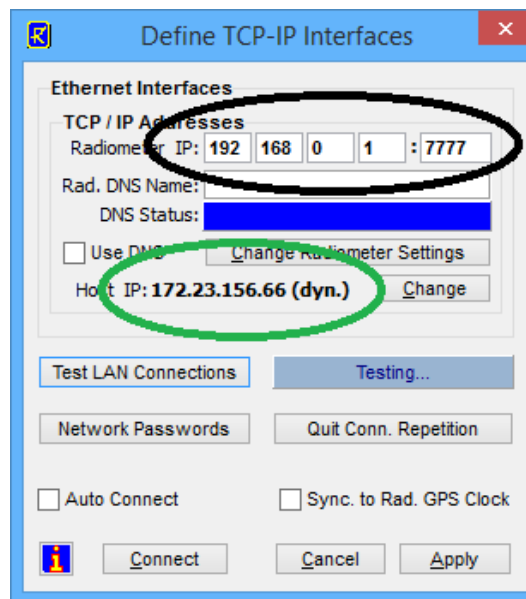


The red IP / gateway settings are sent to the radiometer by clicking **Send to Radiometer**. After new IPs have been successfully sent to the R-PC, it will be no longer reachable through the old IP / gateway addresses. In the case of a successful transfer of the new IP / gateway to the radiometer, the new IP is copied to the current IP fields automatically so that the H-PC can continue its connection to the radiometer. Then click **Connect**.

You may test the connection with **Test LAN Connections**. The H-PC will then try to get access to the R-PC via the specified IP address. If the connection is successful, the blue field will show **'STANDBY'**, otherwise **'Failed to connect!'**

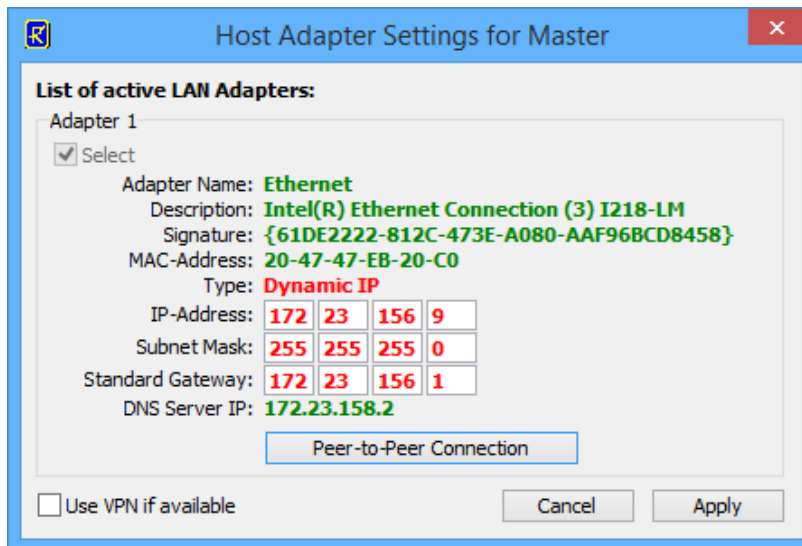
Example:

Consider a newly delivered radiometer with initial IP of 192.168.0.1, gateway of 192.168.0.1 and with port address 7777. In order to connect to this radiometer directly in a peer-to-peer connection, the radiometer communication cable must be connected **DIRECTLY** (not via a network) to the Ethernet connector of the H-PC. Without limitation of generality, let's assume the H-PC IP to be 172.23.156.66. In order to tell the H-PC to directly listen to the LAN interface (NOT via a network gateway), its gateway should also be set to 172.23.156.66 to enable a peer-to-peer connection. If the H-PC is configured this way, the user should modify the TCP-IP interface menu like this:



The black ellipse marks the R-PC's default IP and the green ellipse marks the H-PC IP setting.

In order to modify the H-PC settings, click on the **Change** button and the following menu shows up (with possibly different settings):



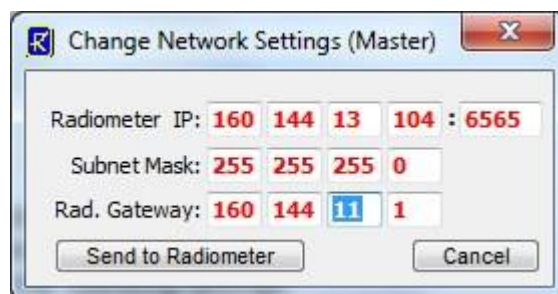
For establishing a peer-to-peer connection, click the **Peer-to-Peer Connection** button. The gateway address will be copied from the H-PC IP. Then click **Apply** and the H-PC will be ready to connect to the radiometer. By clicking on **Test LAN Connections**, the connection between H-PC and R-PC can be checked. If a connection can be established, the message **'STANDBY'** will be shown in the blue field.

Let us now assume, the user's administrator wants to connect the radiometer to a network with the following network settings:

IP: 160.144.13.104
Standard Gateway: 160.144.11.1
Port Address: 6565

The way to send this new configuration to the R-PC is the following:

1. Click on **Change Radiometer Settings**. The fields for the new radiometer IP and radiometer gateway are displayed in red. Edit these fields to the following settings:



2. Then click on **Send to Radiometer**. The settings in red are now transferred to the R-PC. If the radiometer has successfully changed its IP / gateway / port settings, a confirmation message is displayed.
3. After the IP / gateway / port numbers have been altered on the radiometer, it is not possible to connect to it anymore through a peer-to-peer connection. Therefore, connect the radiometer's communication line to the network.





4. Let us assume, the user's administrator has reserved the following network settings for the H-PC:

IP: 160.144.13.201

Standard Gateway: 160.144.11.1

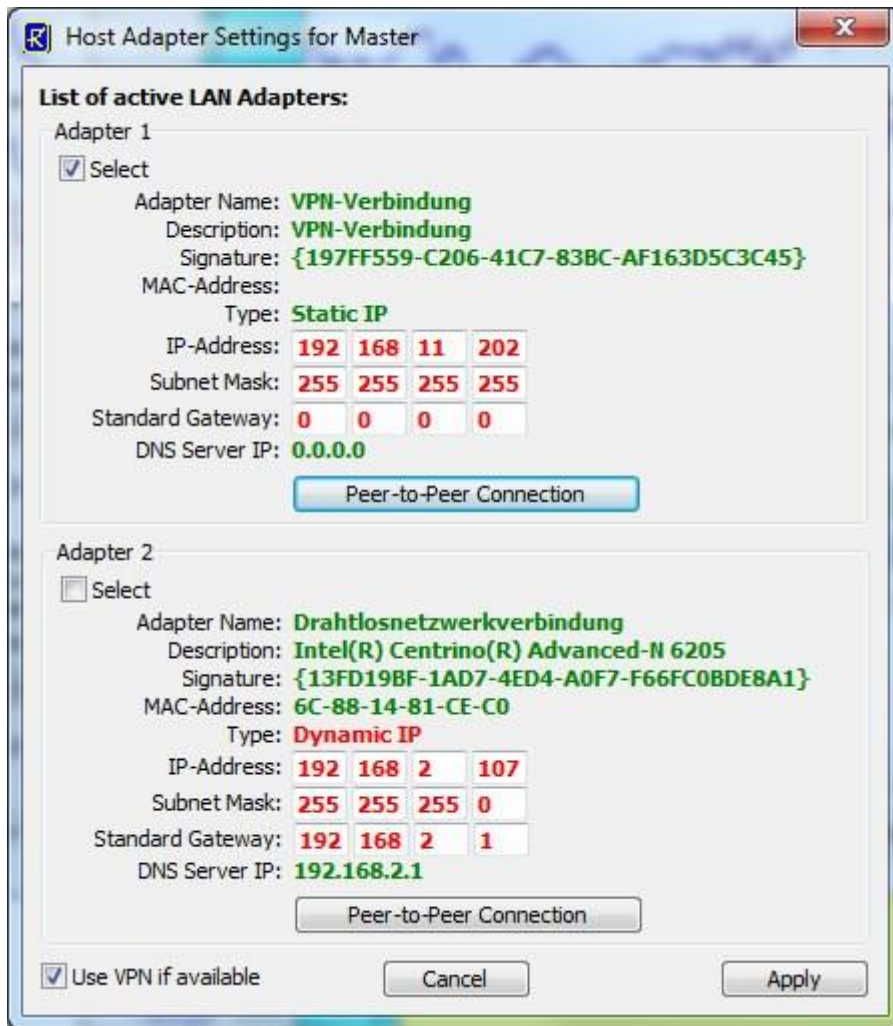
Modify the H-PC TCP/IP settings by clicking **Change** and enter the new settings. Confirm your changes with **Apply**. The H-PC then needs to be connected to the network as well. Now both, the R-PC and the H-PC, are properly connected to the network with specific unique addresses and a connection between the two can be established over the network (e.g. click on **Connect** to verify this). Click **Apply** in the **Define Serial / TCP-IP Interfaces** menu to save the new settings.

If **Auto Connect** is checked, the H-PC software automatically attempts to connect to the radiometer during the starting phase (if a data cable is detected). This feature enables an auto-startup function after a power failure of the H-PC. The radiometer embedded PC will automatically continue a measurement after a power failure when the power returns. To start the H-PC software automatically after reboot of the operating system, the **R2CH.EXE** should be entered into the OS Auto Start directory or an appropriate task should be defined in the schedule.

The radiometer status display can be disabled () or enabled () at any time. In general the display should be enabled because certain automatic tasks (like logging of all calibration activities) are only performed when the status display is enabled.

4.2.2.1 VPN Connections

If the H-PC is located far from the local network to which the radiometer is connected, the H-PC is typically using a VPN (Virtual Private Network) connection to the local network. This VPN connection is acting as a virtual adapter on the H-PC and can be inspected in the **Host Adapter Settings** menu. If you are not familiar of how to set up a VPN connection to a local network on your H-PC, please contact your network administrator.



The VPN service must be started on the Host-PC before it can be detected by the Host SW. By checking the **Use VPN if available** box, you can ensure that the H-PC will always prefer the VPN connection over other active adapters on the system. For a long term installation the VPN connection should be configured with re-dial option for the case that the VPN connection is interrupted. The Host-PC will then automatically reconnect to the radiometer as soon as the VPN becomes operational again.

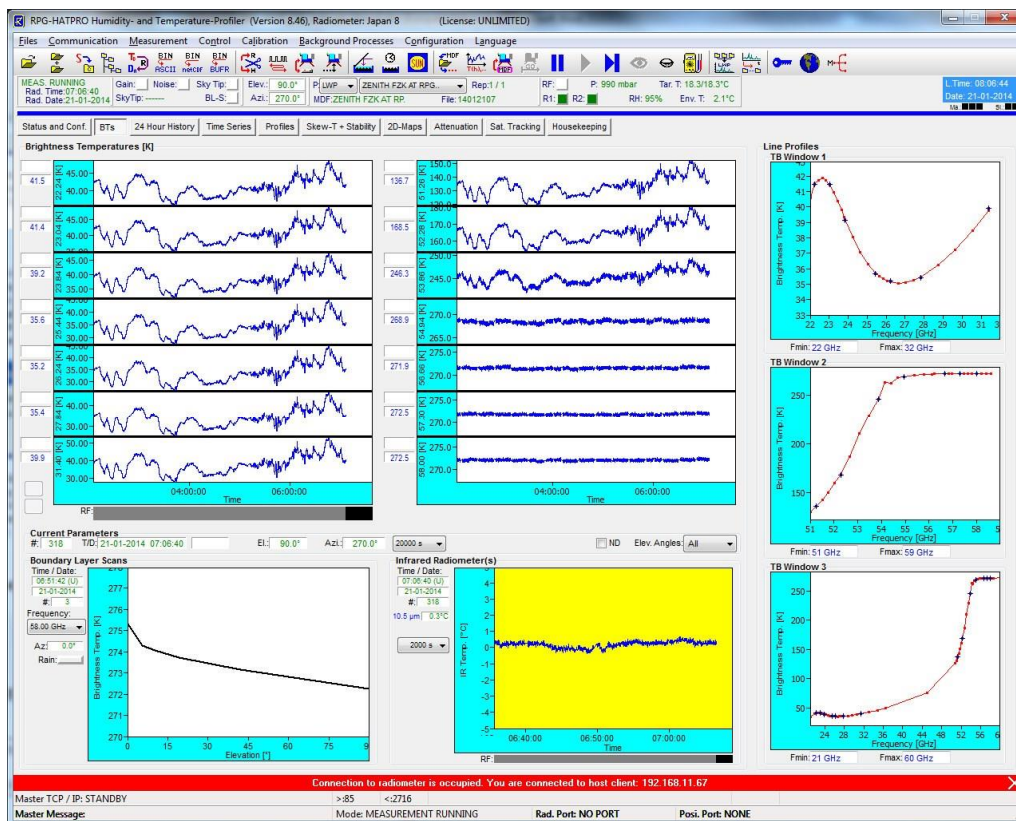
4.2.2.3 Multiple Clients

The R-PC connected to a H-PC is acting as a server, while the H-PC is the client. Every exchange of data packages is initiated by a H-PC request. The R-PC is permanently listening to its IP address and port for possible client requests. The H-PC is defined to be the **FIRST** client that connects to the radiometer. The radiometer then reserves its connection channel to this H-PC. Any other client requests from other IPs are rejected by the radiometer and a message is displayed to the new (secondary) client:



The connection of the secondary client is diverted from the radiometer to the H-PC. In this mode, the additional client can only download data files from the H-PC or inspect the current measurement status via the H-PC. But it is not authorized to change radiometer settings or to control a running measurement. The additional client is not allowed to have any direct data exchange with the radiometer.

The secondary client mode is indicated by a red bar on the bottom of the screen. In this mode the received data from the H-PC is not stored or archived.

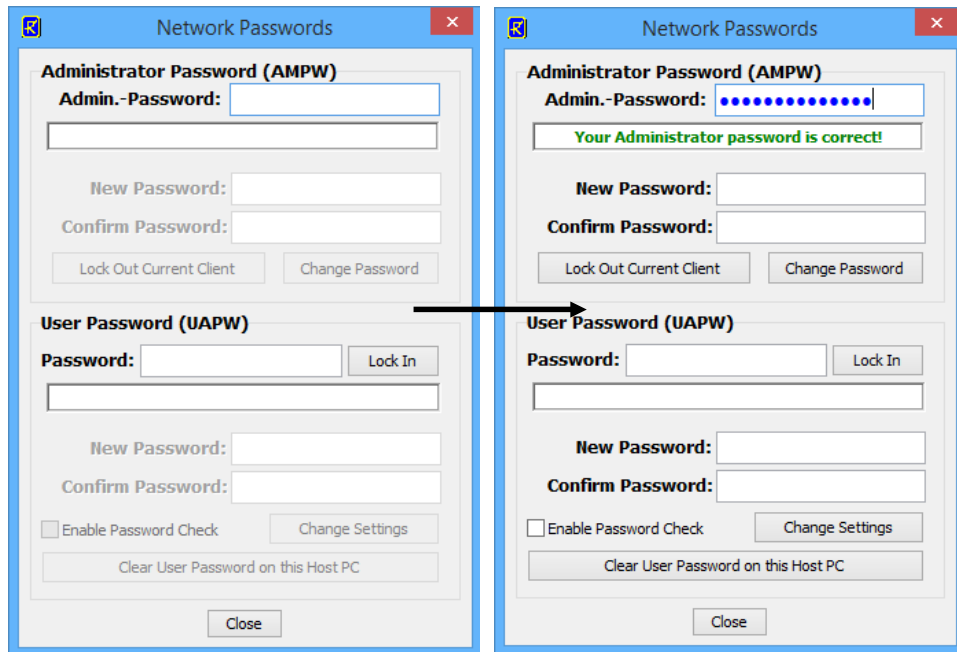


Secondary client mode data viewing.

4.2.2.4 Ethernet Passwords

When the radiometer becomes part of a network (not in a peer-to-peer connection), it acts as a server that will only allow one client (H-PC) to connect to it. In principle, any client, who uses a valid network address and knows the radiometer's IP address, can connect to the radiometer. Therefore, the radiometer is using a password control system in order to identify the access right of a particular client. This password is called a **User Access Password (UAPW)** and it is defined by a person with administrator rights, who should be a single IT person responsible for the network. Also the network administrator has a password called the **Administrator Password (AMPW)**.

When clicking **Network Passwords** from the **Define Serial / TCP-IP interfaces** menu, a menu opens for defining such passwords:



The menu appears in the way shown above (left), if the AMPW is already defined. In this case the fields to enter new passwords are disabled, until a valid AMPW is entered, which switches the menu to the status on the right. At radiometer delivery, the default AMPW is defined to be '**Administrator**'. The responsible network administrator should overwrite the AMPW as soon as possible when the radiometer has been assigned a valid IP address in a network. The network administrator is the only person who is authorized to set the UAPW and the password checking enable / disable.

A user who tries to connect to the radiometer with a valid UAPW (**Lock In** button) will be accepted if no other client is currently present. Otherwise he will be rejected and informed about the radiometer connection being occupied. Only the Administrator has the right to interfere in an established communication between the radiometer and a H-PC by clicking the **Lock Out Current Client** button. In this case the Administrator client becomes the new H-PC.

When an administrator has entered a valid AMPW, he can define a new UAPW or enable / disable password checking by the radiometer. Once a UAPW check is enabled and the UAPW has been defined by the administrator, a client must enter the UAPW when he



connects to the radiometer. Otherwise the access will be denied. If a client has entered the correct UAPW, the connection to the radiometer can be established (assuming the client is the first client) and the UAPW is stored on the client's disk so that a new entry of the UAPW is not required if the client tries to connect to the radiometer multiple times. The UAPW can be deleted from disk by **Clear User Password on this Host PC** to enforce the entry of the UAPW next time a user wants to access the radiometer again.

The UAPW entry cannot be over-ruled by an entry of the AMPW. When the UAPW entry is requested, only the correct UAPW is accepted. An administrator, who has forgotten the UAPW, can enter the correct AMPW and define a new UAPW or disable the password checking to get access to the R-PC.

For radiometers of generation 1-5 the **Network Passwords** menu is also needed to define access passwords for the data server (see chapter 4.26). The instrument responds to certain client requests in a network in order to allow for immediate data access and / or direct radiometer control. Also the termination and start of MDFs / MBFs can be automated by the data server control commands.

While the G4 and G5 radiometers are using the network passwords for both, the connection to the radiometer itself and the data server, G1 to G3 radiometers only need these passwords to access data via the data server.

4.3 Radiometer Status Information

The various status displays in the **Radiometer Status** group box are:


- **Software Version:** Indicates the version number of the R-PC software **RadPC.EXE** for reference (the H-PC software version is printed in the main window caption).
- **Instrument ID:** The radiometer identifies itself by sending the instrument ID to the HPC when a connection is established (e.g. **RPG-HATPRO**, **RPG-LWP**, **RPG-LWP-U**, etc.).
- **Controllers:** Lists the status of the two instrument controllers:
 - The **main controller** handles all communication activities between the R-PC and the radiometer hardware.
 - The **elevation stepper** controller generates the driving signals for the elevation scanning parabola mirror. It also provides the initialization procedure for moving the mirror to its index position at system power up.
 - The **cal stepper** controller is only implemented in certain radiometer models (e.g. RPG-DP150-90) with an internal calibration mirror but external elevation scanning.
 - The **IRR stepper** controller generates the driving signals for the elevation scanning IR radiometer (only with optional IR radiometer)
 - The **azimuth positioner** controller can be controlled directly from the radiometer. If the controller is connected to the radiometer's azimuth interface, the entry is 'responding'.
 - The radiometer uses an external weather station (Vaisala WXT536) which is equipped with temperature, humidity, barometric pressure, wind speed and wind direction sensors.
 - **Receivers:** Indicates the status of the installed receiver modules. From the radiometer model type, the H-PC determines the number of receiver modules and displays, which of them are responding or not.



- **GPS:** Indicates if a GPS clock is installed or not and the global position of the radiometer location (at least 5 GPS satellites have to be visible to provide this information). The radiometer time and date is directly derived from the GPS clock (if installed).

- **Infrared Radiometers:** If the optional infrared radiometer is installed, the infrared temperature is displayed here. This data can also be used as input for retrievals. In combination with the temperature profiles, the cloud base height is determined. The IR temperature provides a cloud flag.
- **Temperatures:** Four temperature sensors are implemented:
 - The **environmental** temperature sensor is located in the weather station.
 - The **ambient** temperature target sensor precisely measures the built-in calibration target temperature. The precision of that sensor is essential for ALL calibration procedures. Usually, two of these sensors are implemented to be able to generate an alarm in the case one of the sensors fails.
 - **Receiver1 / Receiver 2:** These temperature sensors reflect the physical temperatures of the receiver modules which are stabilized to an accuracy of < 0.03 K. Typical sensor readings are around 45°C. The thermal receiver stabilization is continuously monitored. If the receiver temperature is kept constant to within +/- 0.03 K, the status indicator on the right of the temperature display is green. If it turns to red the stability is worse than this threshold. In addition the actual stabilization values are listed. The color of the stability status indicator turns to yellow if not enough temperature samples have been collected to determine the stability.
- **Other Surface Sensors:** Five additional sensors are monitored:



- **Barometric Pressure:** The pressure sensor measures the barometric pressure in mbar (accuracy ± 1.0 mbar). The data is used in the determination of the precise boiling temperature of the liquid nitrogen coolant used in the external calibration target during absolute calibration.
- **Relative Humidity:** The sensor is located in the weather station. The data is used to control the dew blower fan speed when reaching a software predefined threshold. Its accuracy is $\pm 5\%$.
- **Rain Flag:** Status of the rain sensor. The flag is used to switch the dew blower speed and is stored with all measurement samples.
- **Wind speed and wind direction.**
- **Calibrations:** Here the status of automatic calibrations (gain calibration, noise calibration and sky tipping, see section 3) is monitored during measurements. All calibration data is automatically logged in the **CAL.LOG** file located in **MY_DIRECTORY\RPG-HATPRO**. The contents of that file can be inspected with the  command (described later).
- **Position:** The data displayed here is the current position of the **elevation** and **azimuth** scanners. Also displayed is the status of the boundary layer scan (see section 2.3).
- **Measurement:** During measurements, this group box displays details like **the file name** of the current measurement, when the measurement was **started** and when it will **end**, the **time reference** (UTC or local time), if **file backup** is enabled on the R-PC and the **batch repetition factor**.
- **Maintenance:** Displays how long the instrument has been in operation and when the last factory inspection was performed.
- **Liquid Nitrogen (LN2) Calibrations:** Displays a counter of the absolute calibrations. When the number of recommended target fillings is exceeded, an action item will appear accordingly.
- **Heater / Blower operation:** Displays information on the heater/blower operation.

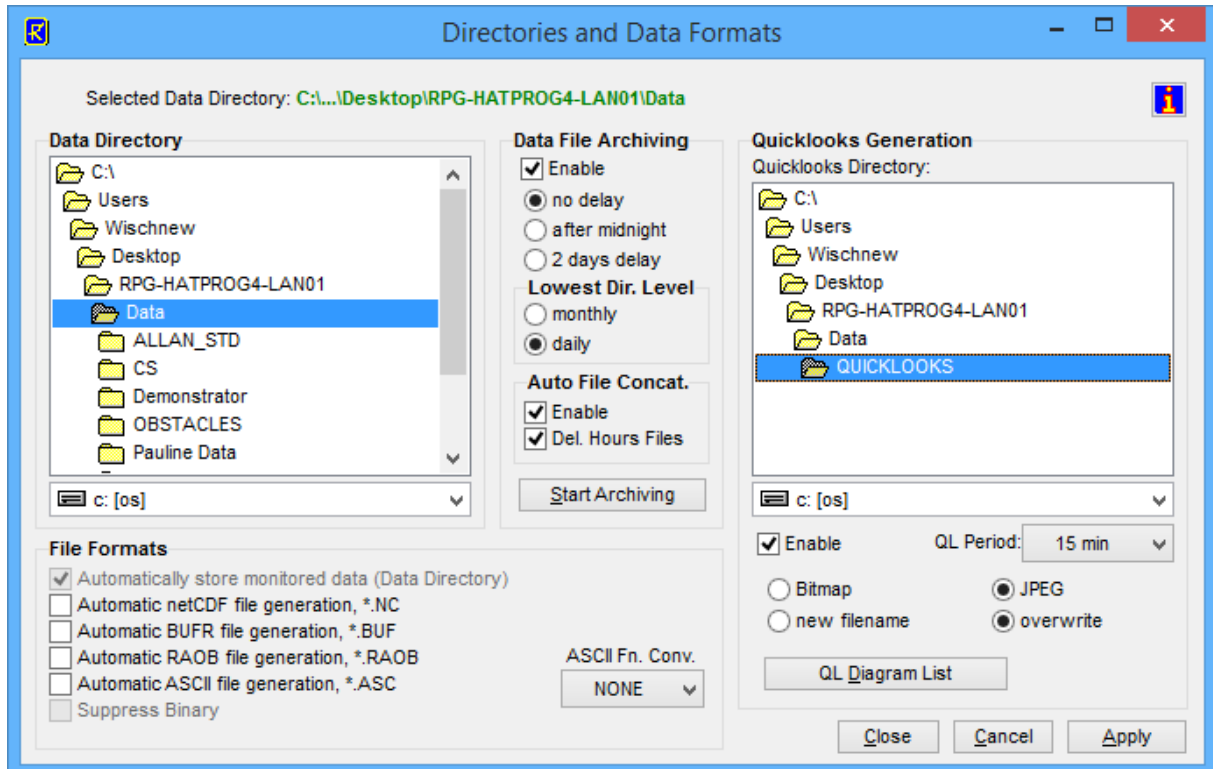
4.4 Data Storage Host Configuration

There are two different ways of data storage during measurements:

- Data files are stored on the R-PC by enabling the file backup option in the measurement definition file (MDF, explained later). The data transferred to the H-PC for online display are not stored by the H-PC. If the data files need to be inspected or further processed then they have to be transferred from the radiometer to the H-PC PC. The advantage of this storage mode is that once the measurement has started, the H-PC can be disconnected from the radiometer while the radiometer continues its operation. **In this mode it is important to transfer the data to the H-PC now and then because the memory on the R-PC has a limited capacity (how long you can store data in this mode depends on how many products you store).**
- If file backup on the R-PC is disabled and the data transferred to the H-PC this is stored by the H-PC in a predefined data directory. This is the most common operation mode for long term measurements because data files are transferred online from the radiometer to the H-PC. Of course the H-PC has to be permanently connected to the R-PC. When the H-PC is connected to a network it can regularly send the data files to an FTP server located far away from the measurement site. The file backup on the




radiometer is only used as a safety option for the case that the H-PC has a power failure or hard disk problem.



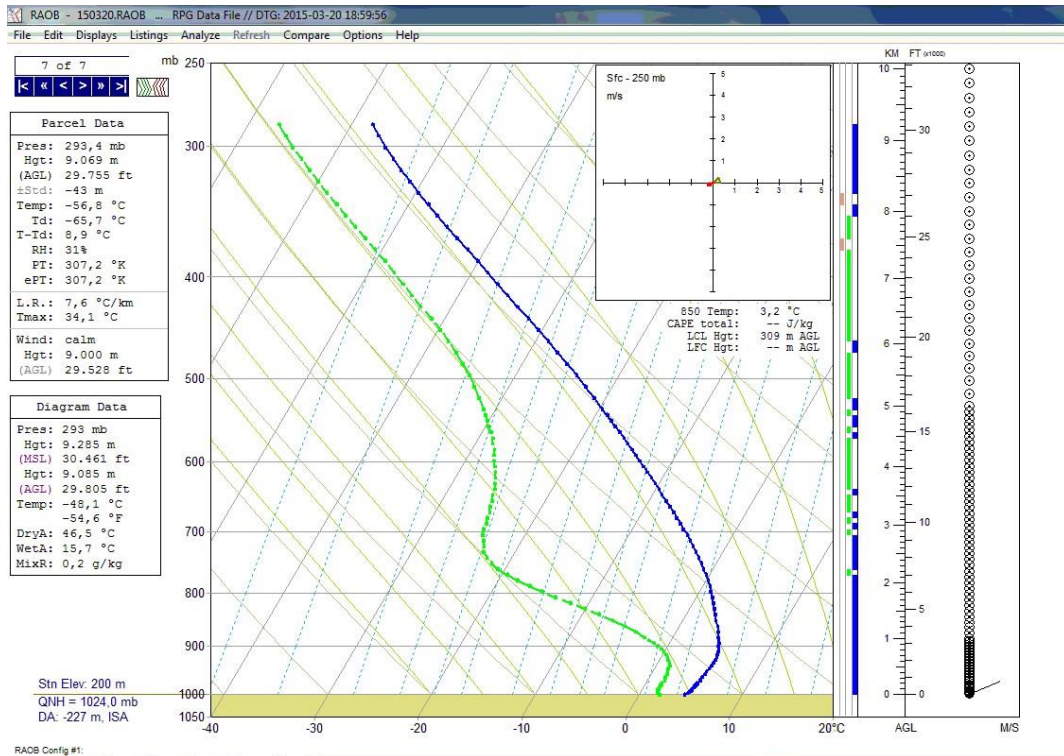
Directories and Data Formats Menu including data archiving.

The **Host Configuration** group box on the main screen displays the data storage details.

It is possible to change the settings by clicking  (**Define Directories**). The data storage directory is selected from the directory tree shown in **Data Directory**. In the same menu one can specify if an ASCII, netCDF or BUFR version of the data files (which are in binary format by default) shall be generated. ASCII and / or netCDF / BUFR files will then (if this option is selected) be stored to the same data directory as the binary files.

In addition, a RAOB file can be created, if the radiometer is capable of producing humidity and temperature profiles (RPG-HATPRO and RPG-LHATPRO). RAOB files are CSV format ASCII files that are compatible with the famous sounding software package RAOB® by Environmental Research Services (ERS), <http://www.raob.com/>, which is widely used by meteorologists. The RAOB file normally contains multiple soundings including liquid water profiles (LWC profiles).

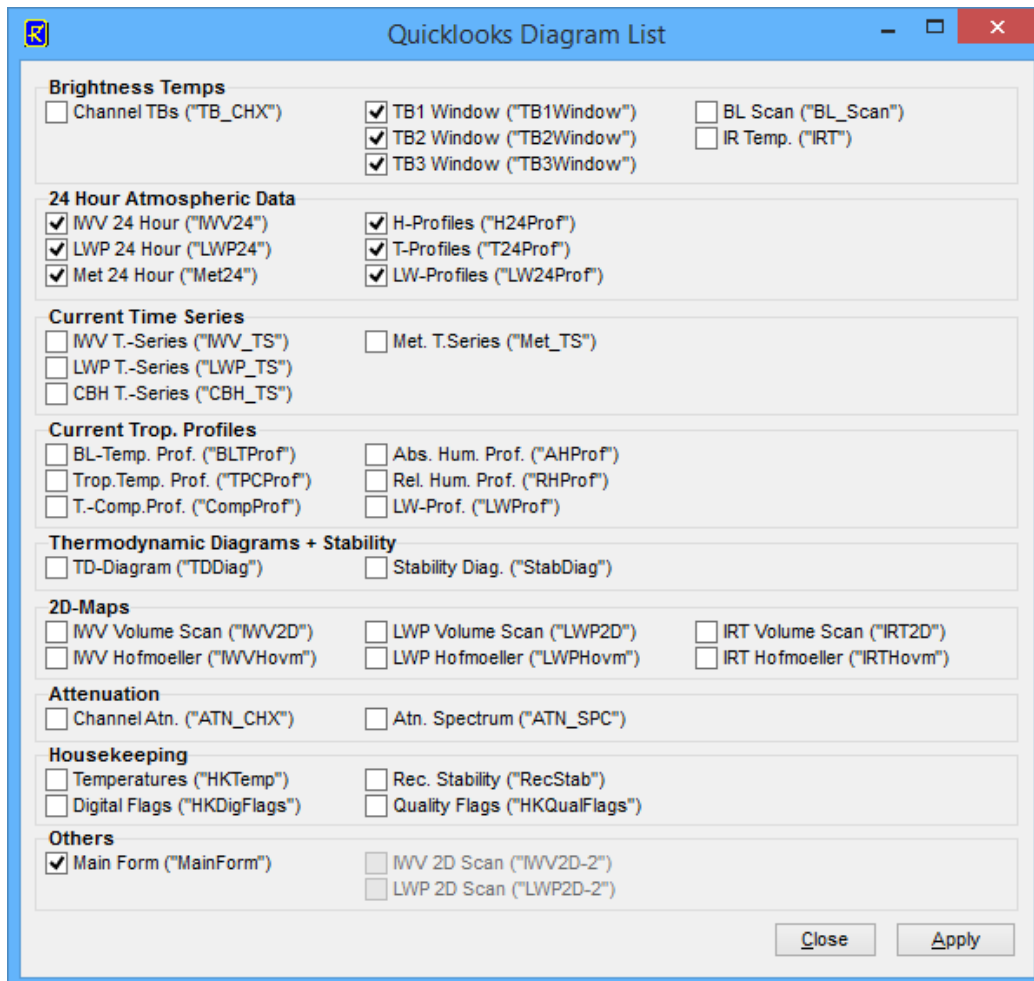
The RAOB file provided by RPG's host software avoids the necessity of an additional conversion software as required by other vendors. Also, RPG's RAOB file creation comes free of charge and is always included in the software package.



RPG-HATPRO profiles displayed by RAOB® (ERS), using automatically created RAOB data files.


Data archiving is a useful feature to prevent the data directory to be filled with ten thousands of files which may overload the operating system. MS operating systems cannot handle many (in the order of ten thousands) files in a single directory. If **Enable** is checked in the **Data File Archiving** group box, the software automatically creates sub-directories in the data directory and stores the data files according to the year, month and day they are generated. E.g. a file **08111623.LWP** would be stored in a directory **...RPG-HATPRO\Data\Y2008M11\D16** if **daily** is checked or in **...RPG-HATPRO\Data\Y2008M11** if **monthly** is checked. Automatic file concatenation to daily files can also be enabled (same feature as in section 4.13).

Quick-look files can be automatically created and stored to a separate directory. The file formats BMP and JPG are available. When clicking the **QL Diagram List** button, a list of graphics windows is displayed. Each of these windows can be enabled / disabled for quicklook file generation. When enabled, a certain graphics display is periodically (defined by **QL Period**) converted to a JPG or Bitmap file and stored to the quick-look directory.



QL diagram list which shows a list of graphics windows which can be selected for the quick-looks.

4.5 Exchanging Data Files

To get access to the radiometer directories, click  (**Exchange Data and System Files with the Radiometer**). The menu in Fig.4.2 will be displayed.

File transfer is necessary when backup data files need to be copied from the radiometer hard disk to the H-PC. If file backup is enabled for a measurement, the instrument stores all data files in its **Data** directory. It is possible to transfer complete directories (including sub-directories). This feature becomes beneficial when a lot of data has to be transferred from the radiometer's file backup to the H-PC.

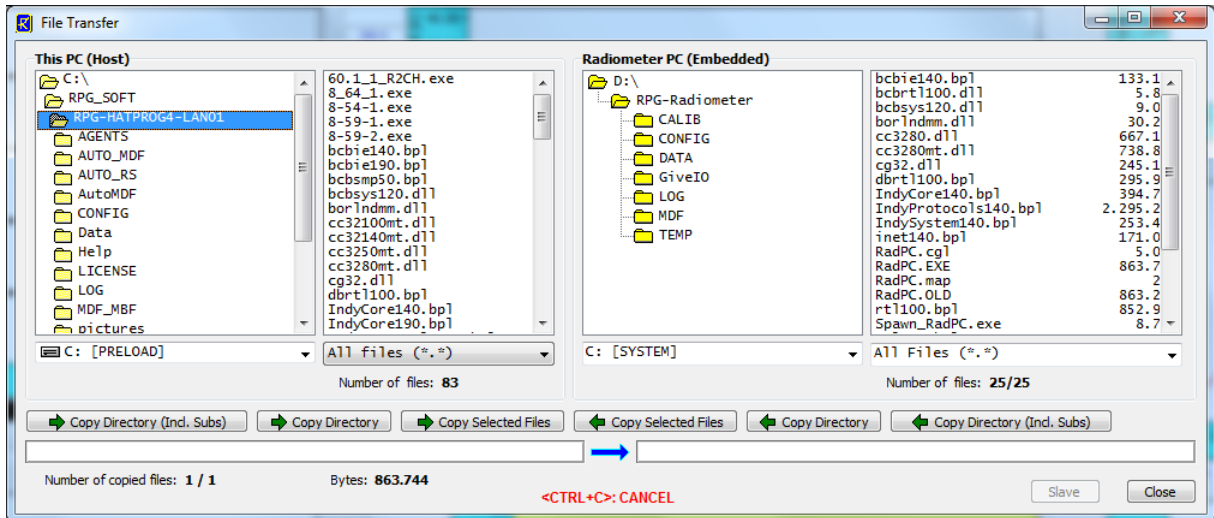
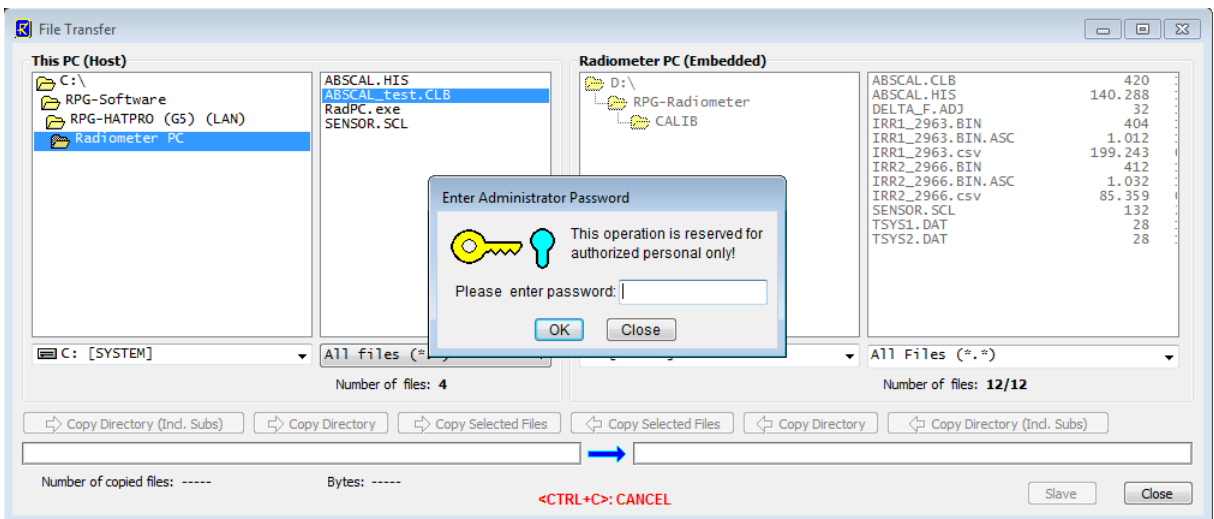



Fig.4.2: File transfer menu.

Files or directories can be deleted by marking them and clicking the right mouse button: From the displayed drop-down list the user may select '**Delete Selected Radiometer PC Files**' or '**Rename Radiometer PC File**'. These functions are also available for directories. Those buttons with green arrows pointing from left to right will move files / directories from the H-PC to the R-PC and those with a green arrow pointing from right to left will move files / directories from the radiometer to the host. If the user tries to send files to the '**RPG-Radiometer**' directory (the system directory), a password check is initiated:



The H-PC is asking for the entry of the Administrator password (AMPW) to complete the desired action. This will prevent unauthorized users to overwrite important files for the functionality of the R-PC.



Reading from the **RPG-Radiometer** directory is e.g. required when the absolute calibration history file shall be inspected. The file **ABSCAL.HIS** stores all absolute calibrations (including successful tip curve calibrations). Once copied to any directory on the H-PC hard

disk its contents can be browsed by the  (**Absolute Calibration History**) command (see section 4.6).



4.6 Inspecting Absolute Calibration History

As mentioned in section 4.4, the **ABSCAL.HIS** file located in the **RPG-Radiometer** directory on the R-PC stores all absolute calibration results. This also includes the successful tip curve calibrations. In order to inspect this calibration history, first copy **ABSCAL.HIS** from the

radiometer to the H-PC. Then press  (**Open Data Files**) and select  to open the **Absolute Calibration History** menu. Load the previously copied **ABSCAL.HIS** file with **Load History File** and the list of calibrations is displayed (see Fig.4.3).

The listed entries are incrementally numbered (preceded by #). The entry syntax is:

#calibration number: Receiver 1 cal. type / Receiver 2 cal. type, (date and time of Rec.1 calibration || date and time of Rec.2 calibration)

When an entry in the list is marked, **Delete Last Entries** removes all entries after the marked entry. This feature is useful to remove 'bad' calibrations from the list (typically the last calibration). With **Generate** a new calibration file **ABSCAL.CLB** is generated using the calibration numbers specified for receiver 1 and 2. If the modified **ABSCAL.CLB** file is copied to the system files directory (password protected) the radiometer will load the new calibration parameters from **ABSCAL.CLB** when **RadPC.EXE** boots up the next time. **Show Current Calibration** loads the newest calibration parameters from the radiometer (if connected).

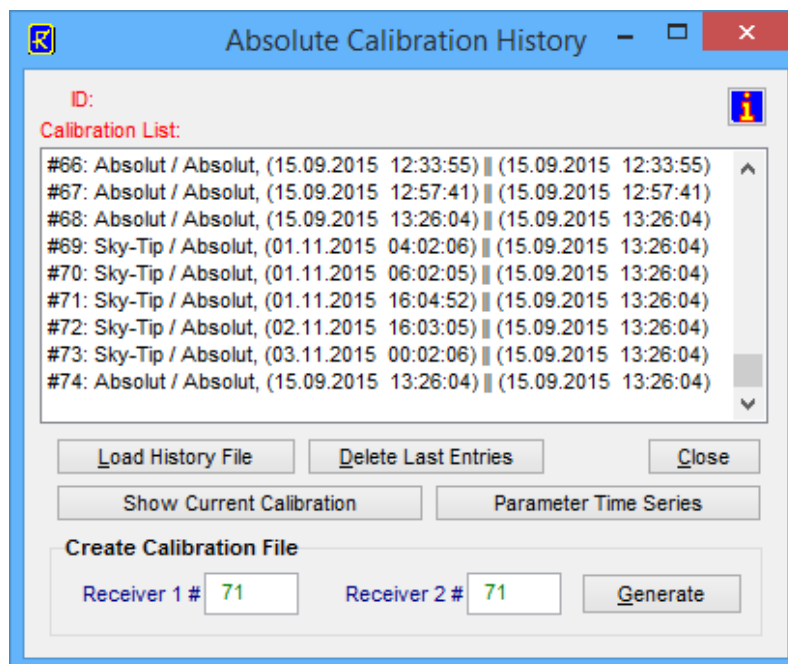


Fig.4.3: Loading the calibration log file **ABSCAL.HIS into the calibration history list.**

A double click on one of the entries opens the **Calibration Results** menu in Fig.4.4. For each receiver channel the four parameters G , T_{sys} , T_n and α (see section 3.1.3) are listed. In addition the calibration type, calibration time and physical temperature of calibration targets and the environmental temperature are displayed.

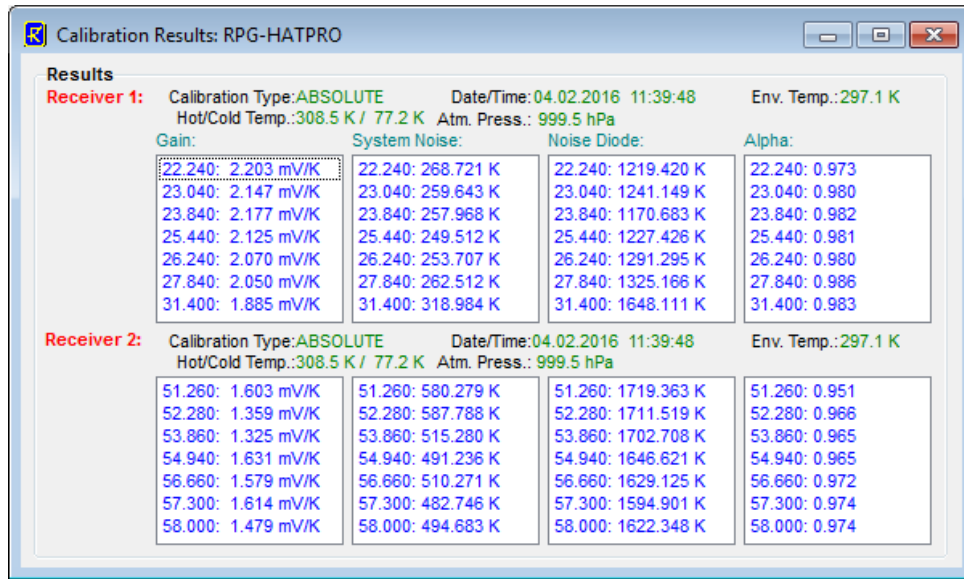


Fig.4.4: Display of absolute calibration parameters.

4.7 Inspecting Automatic Calibration Results

Automatic calibrations are those described in section 3.3, 3.4 and 3.5 (Gain, Noise, Tip Curve). These calibrations are performed automatically by the radiometer following the calibration settings in the MDF (see section 4.9). The **Radiometer Status** window on the main screen (if enabled) monitors automatic calibrations. The corresponding log file is **CAL.LOG**, located in **MY_DIRECTORY\RPG-HATPRO**

For inspecting this log file, click (**Display Automatic Calibration History**). The menu in Fig.4.5a appears. In the **Gain Calibrations** group box only gain parameters are displayed (the only parameter that is adjusted by this calibration type, see section 3.3) while also T_{sys} (**Tsys**) and T_n (**Tnoise**) are selectable in **Noise Calibrations** and **Sky Tipping Calibrations**. The user may zoom into the data by clicking on the graphics display (holding the left mouse button pressed) and dragging the mouse cursor to a second position. When the mouse button is released the new data window appears. **Zoom Out** reverts to the previous zoom. The time stamp of each calibration is marked by a dot. With and , this feature is toggled. All diagrams are synchronized (keeping the same time axis), if **Synchronize Diagrams** is active. Then zooming and zooming out is performed on all displays so that a common time axis is maintained. **Independent Diagrams** switches back to the non-synchronized display mode.

Below the **Sky Tipping Calibrations** data display, the successful calibrations are marked by a green bar while failed calibrations are marked in red (separately for receiver 1 and receiver 2). By clicking on one of these bars the tip curve calibration details are listed and a graphical display of the sky dip is shown (see Fig.4.5b).

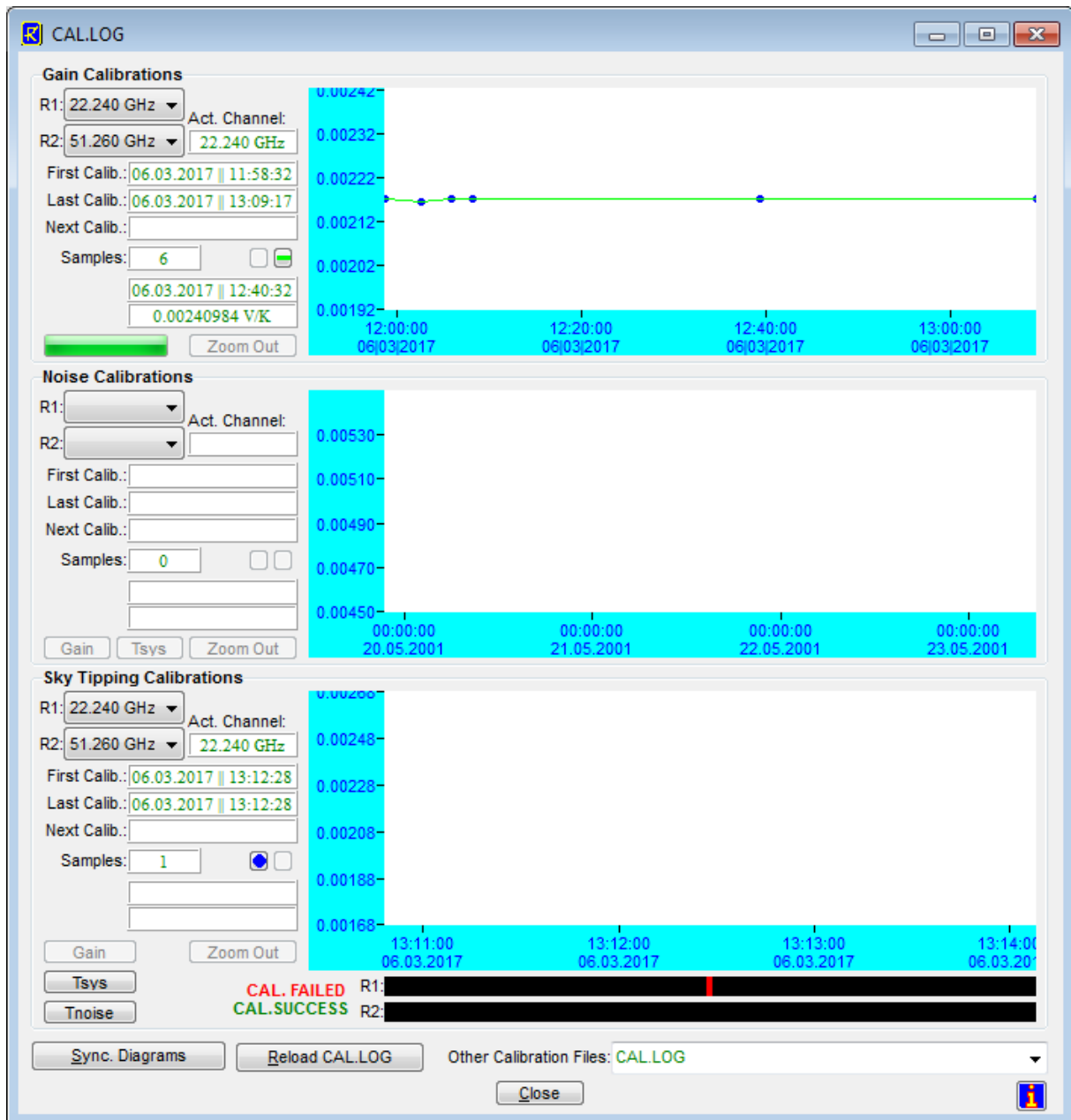


Fig.4.5a: Display of automatic calibration parameters.

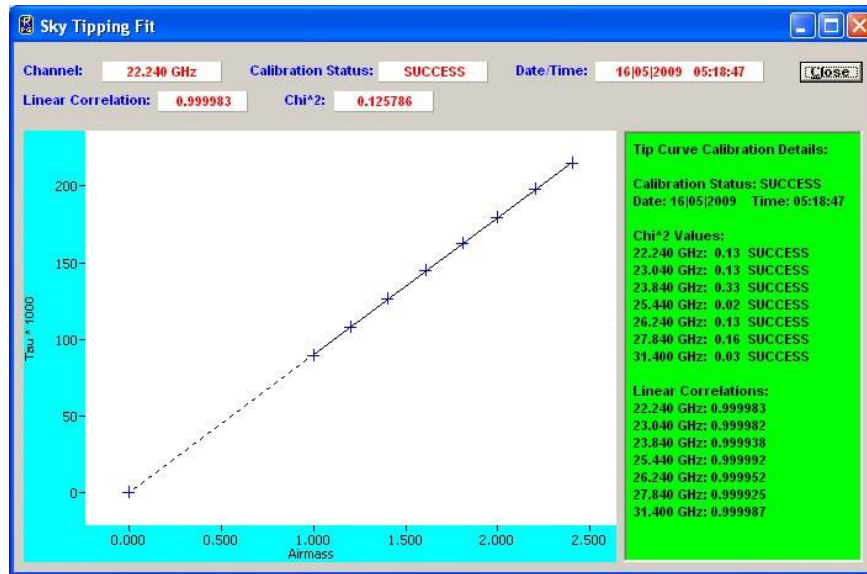
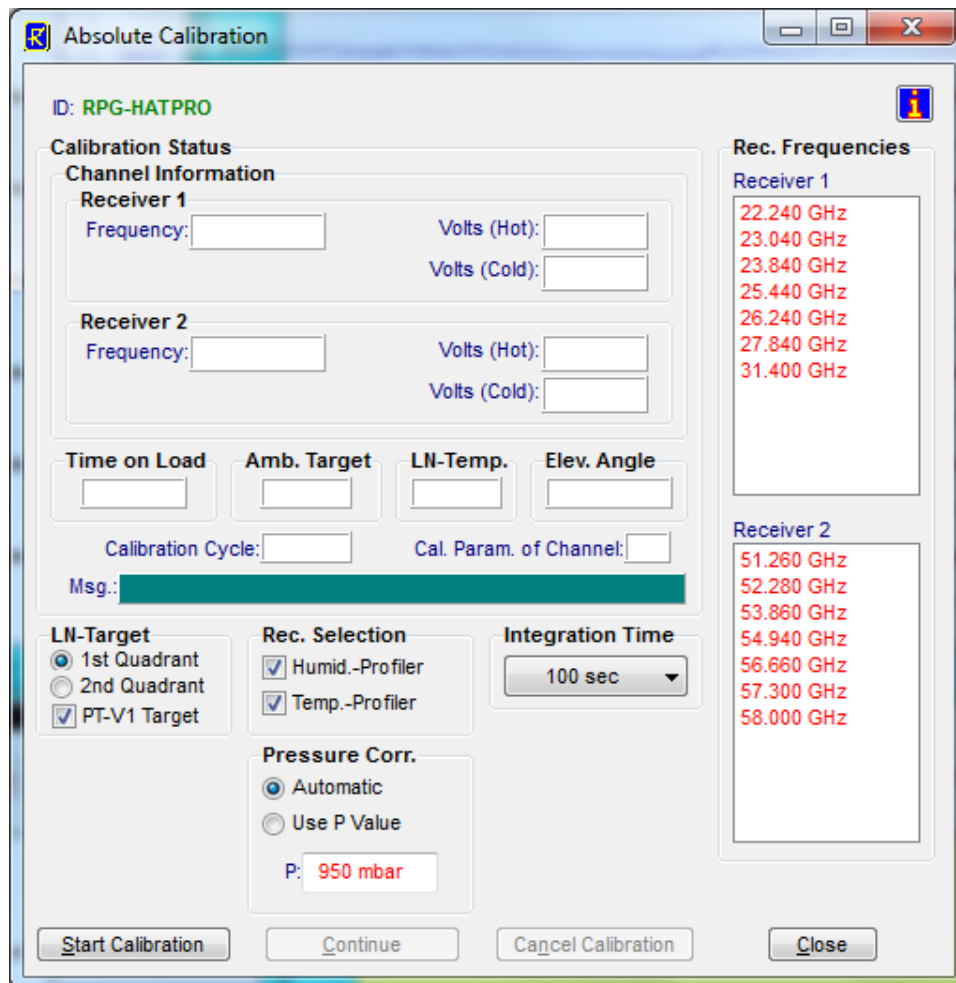


Fig.4.5b: Display of sky tipping fit and detailed result list.

4.8 Absolute Calibration



The 'Absolute Calibration' window is for device ID 'RPG-HATPRO'. It includes fields for Receiver 1 and 2 frequencies and voltages (Hot/Cold). Environmental settings include Time on Load, Amb. Target, LN-Temp., and Elev. Angle. Calibration Cycle and Cal. Param. of Channel are also adjustable. A message field is present.

LN-Target: 1st Quadrant, 2nd Quadrant, PT-V1 Target

Rec. Selection: Humid.-Profiler, Temp.-Profiler

Integration Time: 100 sec

Pressure Corr.: Automatic, Use P Value
P: 950 mbar


Rec. Frequencies:

- Receiver 1: 22.240 GHz, 23.040 GHz, 23.840 GHz, 25.440 GHz, 26.240 GHz, 27.840 GHz, 31.400 GHz
- Receiver 2: 51.260 GHz, 52.280 GHz, 53.860 GHz, 54.940 GHz, 56.660 GHz, 57.300 GHz, 58.000 GHz

Buttons: Start Calibration, Continue, Cancel Calibration, Close

Fig.4.6: Absolute calibration menu (profiling, LWP and tipping radiometers).



After setting up the external cold target as described in the Installation Manual, an absolute calibration is initiated by clicking  (**Perform Absolute Calibration**). The menu in Fig.4.6 is shown, if the connected instrument is a profiling, LWP or tipping radiometer.

When the absolute calibration menu is entered, the instruments frequency list is displayed in **Calibrated Frequencies**. The list contains the frequencies of both receivers that will be calibrated, if the related receivers are enabled for calibration (e.g. with **Humid. Profiler**, **Temp. Profiler** check boxes in **Receiver Selection**). The integration time T_i is selectable between **5 Seconds** and **300 Seconds** (**Integration Time** group box) and defines the integration time period for each calibrated channel. The total integration time is given by $T_{total} = 4 * T_i + 10$ because four integration cycles have to be passed according to section 3.1.3.1 (four point method) and calibration mirror movements take about 10 seconds.

For G5 radiometers select the PT-V1 precision target and an integration time of 100 seconds.

Start Calibration starts the absolute calibration procedure. During calibration, the current activity is displayed in the message line. When the integration on ambient target and K-band side of the target is completed the calibration will stop and the display will advise you to turn the PT-V1 precision target to V-band side. When clicking **Continue**, the display will advise you to wait some time for the target to dry before continuing the calibration. When the integration on both sides of the target is completed, the message **Calibration successful! Save?** and a display of the calibration parameters are shown. The user is prompted to confirm to save the calibration with **Continue** or to abort the calibration with **Cancel Calibration**. In the case of confirmation, the absolute calibration parameters are then stored to the R-PC's hard disk. Leave the calibration menu by clicking **Quit**.

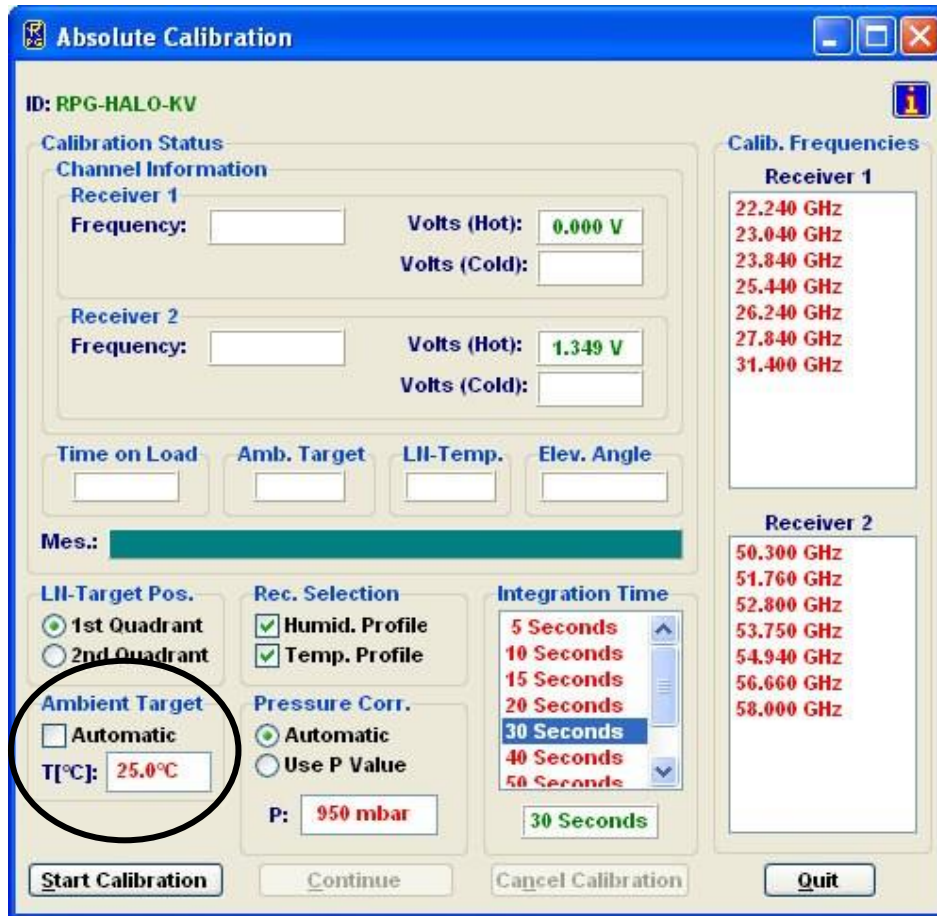



Fig.4.6b: Absolute calibration menu (RPG-15-90, RPG-HALO-KV, RPG-HALO-119-90 and RPG-HALO-183 models).

Code:	RPG-MWR-STD-SW	Principles of Operation & Software Guide (standard radiometers)	
Date:	17.06.2014		
Issue:	01/09		
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If the error message **No response to cold load. Calibration terminated!** appears, the cold target was probably not filled with liquid nitrogen or was not installed at all.

No noise diode response. Calibration terminated! indicates a malfunction of one of the noise sources. Contact RPG for help in this case.


For the radiometer models RPG-15-90, RPG-HALO-KV, RPG-HALO-119-90 and RPG-HALO-183 the absolute calibration menu looks slightly different:

It contains the additional box **Ambient Target** as marked in Fig.4.6b. As discussed in section

3.1, an external calibration target is used for models RPG-15-90, RPG-HALO-KV, RPGHALO-119-90 and RPG-HALO-183. The target temperature is measured manually by a precision thermometer and its value is entered in the edit box labelled **T[°C]**. It is important to uncheck **Automatic**, otherwise the radiometer will use its built-in environmental temperature sensor reading. During the calibration, messages in the message box are displayed that prompt the user to change the targets from ambient to cold target.

4.9 Defining Measurements

Before a measurement can be started, it has to be defined. The various measurement parameters are then stored in a MDF (**M**asurement **D**efinition **F**ile, extension **.MDF**). The radiometer is capable of processing multiple MDFs automatically which are combined in a MBF (**M**asurement **B**atch **F**ile, extension **.MBF**). The MBF is a batch file similar to DOS batch files but only intended to group MDFs. MBFs as well as single MDFs can be sent to the

radiometer (, section 4.10). The software automatically detects, which file type (MDF or MBF) was selected.

To enter the **Definition of Measurement and Calibration Parameters** menu, click  (**Define Measurement Parameter Files (MDF and MBF)**).

The measurement definition menu has several tab sheets (**Sky Tipping, Standard Calibrations, Products + Integration, Elevation Scanning, Timing + ... , MDF + MBF Storage**) which should be processed from left to right (see Fig.4.7).

4.9.1 Sky Tipping

The sky tipping (or tip curve) calibration is described in detail in section 3.4. Fig.4.7 shows the corresponding definition tab sheet.

The scanning angles listed in the **Scan Angles [DEG]** group box are predefined to give equidistant air mass samples in the sky tipping scan (the air mass is proportional to $1 / \sin(\alpha)$, see section 3.4). They can be modified by using **Add** and **Delete**, but it is recommended to only define angles $>14^\circ$. If the radiometer's horizontal view is blocked by obstacles, the lowest elevation angle should be adjusted appropriately but should not be $>30^\circ$ to maintain the calibration accuracy. In addition, the azimuth angle for the sky tipping direction is selected independently from other observation positions, if an azimuth positioner option is installed. The calibration reliability may be improved by checking **Bilateral Tipping** (**Timing** group box). With bilateral tipping, the radiometer scans the

elevation angles in both quadrants (main quadrant (marked by red arrow) and) to detect possible inhomogeneous water vapour distributions which might violate the requirements for a stratified atmosphere. Bilateral tipping assumes a free view to both observation sides between 20° and 90° elevation.

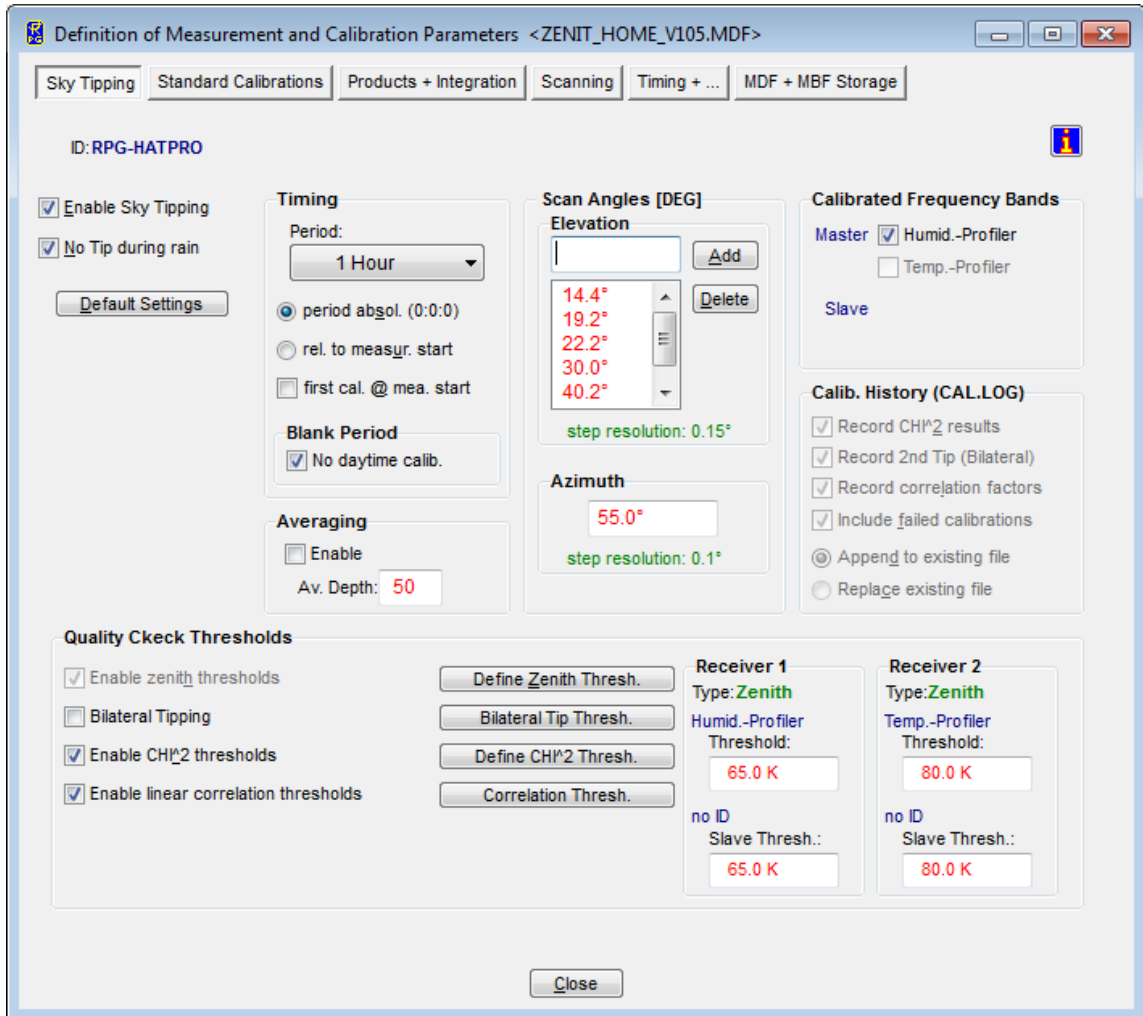


Fig.4.7: Measurement definition file menu, sky tipping tab sheet.

Sky Tipping is enabled by checking **Enable Sky Tipping**. The user can define how often a calibration shall be performed by selecting a period between **5 Minutes** and **24 Hours**. Practical periods are 2 to 24 hours because the radiometer gain is normally calibrated every 30 minutes by a gain calibration and continuously stabilized by rapid noise switching and a full parameter recalibration (including T_{sys} and T_n) is not required so frequently. A tip curve interrupts the measurement for more than three minutes, therefore the number of calibrations should be minimized.

Furthermore, it is possible to define the time of the first tip curve calibration in the measurement. By checking **period absol. (0:0:0)**, the calibration will start relative to midnight time, e.g. with a period of 6 hours and a measurement start at 3:00 pm the first calibration will take place at 6:00 pm, assuming that **first cal. @ mea. start** is not checked. If **rel. to measure. start** is checked, the calibration timing is relative to measurement start time. As explained in section 3.4, tip curve calibrations are only applicable for transparent channels. Receivers with opaque channels are automatically disabled for sky tipping.



Three quality checks (thresholds) are implemented:

- Zenith threshold. In the presence of clouds (which violate the assumption of a stratified atmosphere) the observed zenith brightness temperatures (BTs) are significantly higher than under clear sky conditions. The user can define a maximum BT level as a threshold for each receiver.
- Linear correlation factor. This measures the correlation of the optical thickness samples (as a function of air mass) with a straight line. Typical linear correlation factor thresholds are >0.9995 . The linear correlation factor is not sensitive to the sampling noise caused by clouds etc.
- χ^2 -test. This measures the variance of the optical thickness samples relative to the straight line. Typical threshold values are <0.3 for a good quality calibration.

With the *Define Zenith Thresh.*, *Define CHI² Thresh.* and *Correlation Thresh.* commands, the corresponding thresholds can be entered in the *Threshold Definition* group box.

The main purpose of a sky tipping calibration is to recalibrate the noise diode secondary standards (see section 3.2). The R-PC is capable of averaging successful sky tipping calibrations in order to avoid sudden calibration jumps in the calculated brightness temperatures (TBs). If calibration averaging is desired, the checkbox *Enable* in the 'Averaging' sub-menu should be checked. If enabled, the averager uses the number **Av. Depth** of successive calibrations in the averaging process. Reasonable values are in the range 40-100.

Default Settings resets all sky tip parameters to reasonable standard values, optimized for the specific instrument in use.

4.9.2 Standard Calibrations

On this tab sheet the user defines if and how often automatic gain calibrations and noise calibrations shall be performed.

Relative Calibrations (Gain Drifts): During gain calibrations, only the ambient target is scanned (one point calibration), which is the fastest calibration. Reasonable repetition periods are 30 minutes with 60 seconds integration time. The gain calibration does not correct for system noise temperature variations which are subject to long term drifts only.

Since G5 radiometers run with permanent rapid noise switching the right panel *Calibration with secondary standards (noise diode)* can be ignored.

Default Settings resets all standard calibration parameters to reasonable values, optimized for the specific instrument in use.

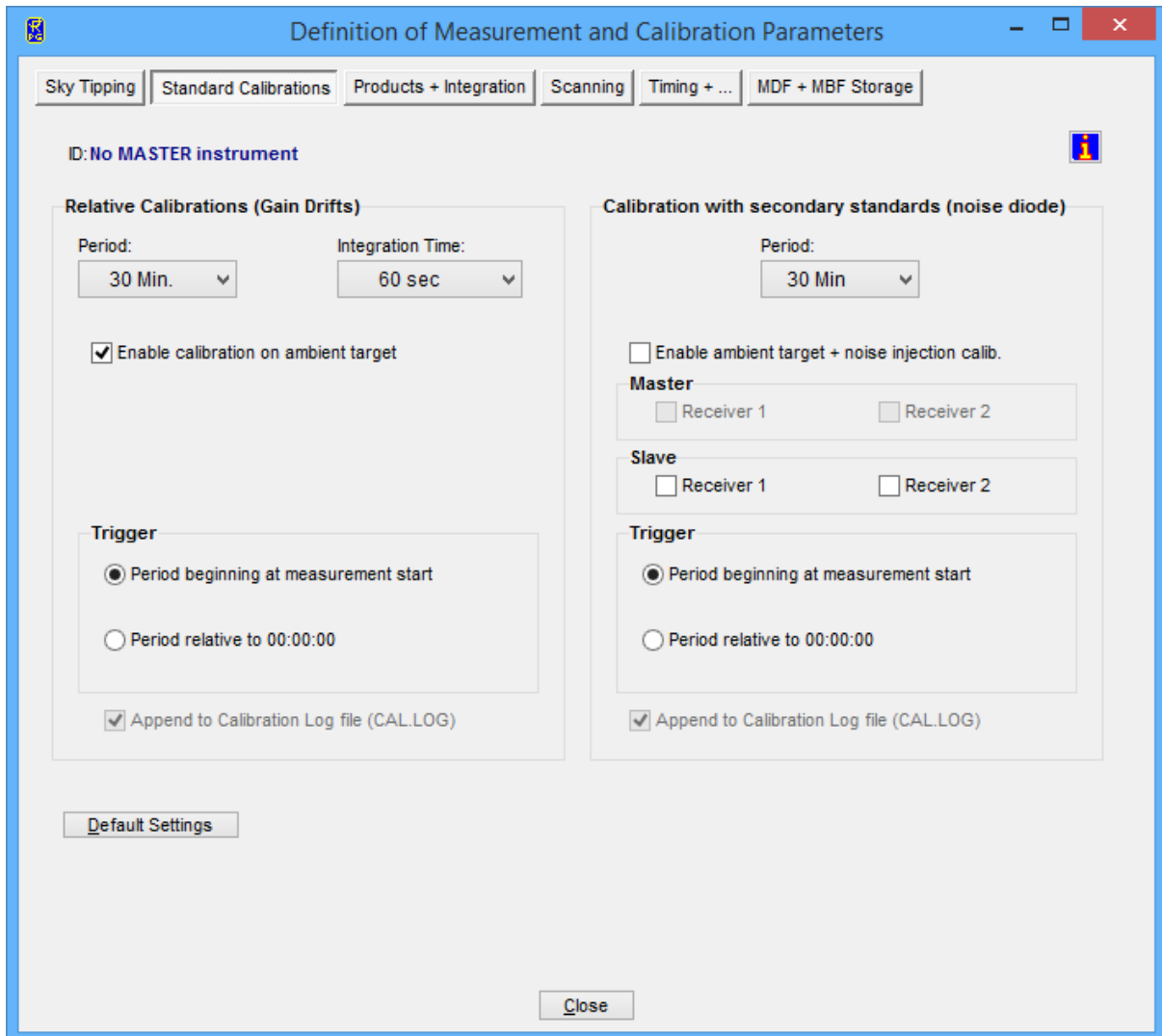


Fig. 4.8.: MDF standard calibration settings.

4.9.3 Products + Integration

On the *Products + Integration* sheet (see Fig.4.8) a selection of data products to be acquired and retrieved by the system during the execution of the MDF is defined. Only those products are enabled in the product list, which are compatible with the actual radiometer configuration, e.g. for a RPG-HUMPRO radiometer, all temperature profiling products are disabled. The product list is grouped into level 1 (brightness temperature data), level 2 (atmospheric data associated with a retrieval file) and others (Met-Station and housekeeping data).

For those products with associated retrieval files (level 2 products), one of the retrievals listed in the related list box needs to be selected. The entries of these boxes reflect the data base that is currently installed in the H-PC's retrieval directories, filtered to those retrievals that are compatible with the instrument hardware (e.g. the available frequency channels, etc.).



Example: When the MDF for a RPG-LWP radiometer (two channels, 23.8 / 31.4 GHz) is defined, the only retrievals that will be listed in the LWP retrieval list box are two channel retrievals designed for 23.8 and 31.4 GHz input. If the radiometer is the upgraded RPGLWP-U90, three channel retrievals are also listed, if they have been developed for 23.8 / 31.4 / 90 GHz channel sets.

When a retrieval file is marked in one of the list boxes, pressing the <RETURN> button opens a text window to display the retrieval file contents. A description of retrieval files and how to create them will be given in section 5. **Modifications of these files should be restricted to qualified personal only. Otherwise the modified retrieval algorithm may not work properly.**

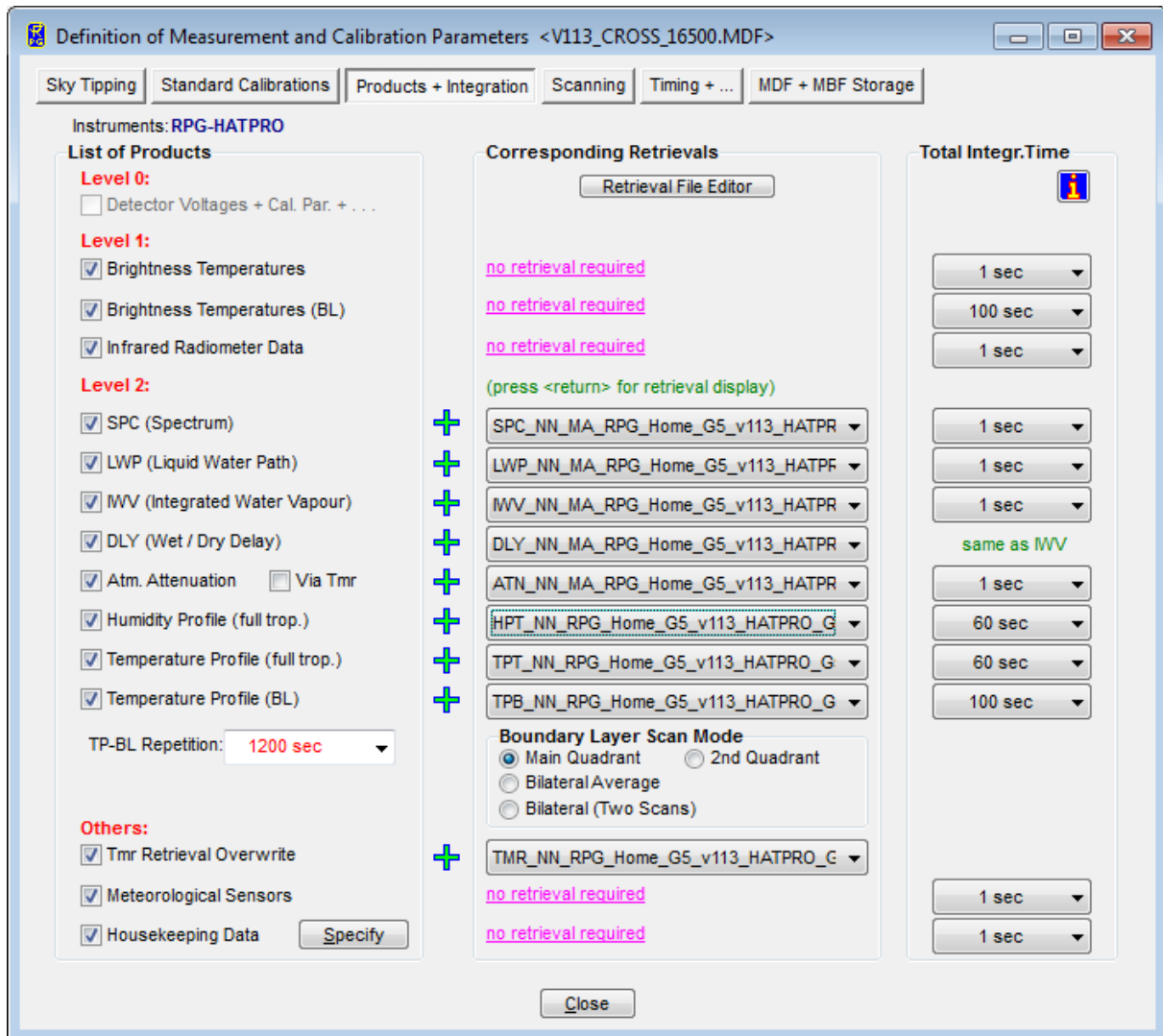


Fig.4.9: MDF product and retrieval selection menu.

For each enabled product a separate integration time can be selected. Only the setting for **Brightness Temp. (boundary layer)** and **Temperature Profile (boundary layer)** products has to be identical, because these products are closely related to each other. In fact the temperature profile is just a further processed product derived from the brightness temperatures of the boundary layer scan.

The user may define a customized T_{mr} (see section 3.4) retrieval and overwrite the default radiometer T_{mr} retrieval. If specified and checked, the new retrieval is used for sky tipping calibrations. For explanations on T_{mr} see section 3.4.

Boundary layer scans can be combined with full troposphere temperature profiling in a single measurement. If only boundary layer scans are required, the **CONTINUOUS** entry in the **TPBL Repetition** list box should be selected; only boundary layer profiling data, meteorological sensor data and infrared radiometer data (if an IRR is installed) will then be produced. All other selections in the TP-BL Repetition list box define a repetition period for boundary scans. After a BL scan has finished, the other products like LWP, full troposphere profiles etc. are generated and continued until the next BL period is initiated. Example: Define a TPBL repetition period of 1200 seconds and an integration time of 200 seconds for the **Temperature Profile (boundary layer)** product. At measurement start, a BL scan is carried out which takes about 200 seconds. The next scan will start 1000 seconds later. In the meantime the other selected products are processed.

The boundary layer scan is available in four different modes, selectable from the **Boundary Layer Scan Mode** box. The radiometer is usually scanning in the main quadrant (marked by a red arrow on the radiometer's housing underneath the microwave window) but it is possible to switch to the opposite quadrant (called 2nd quadrant). Two scans in both quadrants can be averaged and combined into a single BLB scan (Bilateral average). The two scans in the two quadrants can also be stored independently (Bilateral, two scans).

The **Housekeeping Data** product represents a summary of different parameters characterizing the instrumental state. These parameters are grouped into 6 categories. The monitoring of each category is selected by clicking the **Specify** button. The following menu pops up:



The detailed description of each category is given in appendix A18.

4.9.4 Scanning

Sometimes it is desirable to scan the radiometer's microwave beam in elevation and azimuth while taking measurement samples. The details for scanning are defined in the **Scanning** tab sheet.



4.9.4.1 Observation at Constant Elevation and Azimuth Angles

When **Constant Angles** is selected as the **Scan Type**, a constant elevation and azimuth angle is used for observations, specified in **Const. Elev. Angle** and **Const. Azi. Angle**. If a IR radiometer is installed, also the entry in **Const. IRR Angle** is used.

4.9.4.2 General Scans

If **General Scan** is selected, arbitrary elevation and azimuth scan patterns may be defined. When the optional azimuth scanner is not available, the radiometer ignores all azimuth angle definitions.

In the case that level 2 data products are selected in the product list (section 4.9.2), a retrieval conflict may occur with the defined scan pattern. E.g. humidity profiling retrievals are usually restricted to zenith observation elevation angles (90°) and therefore the retrieval output is not defined for other elevation directions. In **General Scan** MDFs, only those level 2 data products should be enabled, which are associated with multi-angle retrievals. A multiangle retrieval is identified by its file name. For example, in the retrieval file name **IWV_QR_MA_FZK.V1.RET** the sub-string ‘_MA’ indicates that this retrieval is capable of handling different elevation observation angles. The default retrieval set for some profiling (RPG-HATPRO, RPG-HUMPRO, RPG-LHATPRO) and LWP radiometers (RPG-LWP, RPGLWP-U90, RPG-LWP-U72-82) contain multi-angle IWV- and LWP-retrievals. Multi-angle retrievals for temperature and humidity profiling are currently under development. Thus only IWV, LWP, brightness temperature data (BRT, IRT) and MET products may be used in general scans.

It is recommended to set all integration times of the products acquired during general scans to 1 second. Otherwise, the scan will linger on each position for the maximum integration time selected in the products list!

The elevation mirror moves are subdivided into elementary scans from a start angle to a stop angle with a certain incremental angle and a given number of samples measured at each position. These scans are numbered as Scan#1, Scan#2,

The radiometer does not execute single scans but only frames of scans. Each frame has a start scan and a stop scan (these can be identical) which form a ‘loop’ of scans that may be repeated arbitrarily. The concept of having two levels of movement definitions allows for the definition of complex scan procedures.

A frame is defined by selecting one of the scans in the start scan list and then clicking on one in the stop scan list. After entering the repetition number, the frame is added (or inserted) to the frame list (**Add** or **Insert**). It is possible to edit a frame definition using the **Overwrite** command or to delete it with **Delete**. In addition, the frame start can be triggered to a certain time increment (if **Triggered** is checked). Three examples illustrate how a frame is executed:

- 1) Start: Scan#4, stop: Scan#6, repetitions: 3 ⇒
Scan#4,Scan#5,Scan#6,Scan#4,Scan#5,Scan#6,Scan#4,Scan#5,Scan#6
- 2) Start: Scan#4, stop: Scan#2, repetitions: 2 ⇒
Scan#4,Scan#3,Scan#2,Scan#4,Scan#3,Scan#2
- 3) Start: Scan#2, stop: Scan#2, repetitions: 1 ⇒
Scan#2

When an optional azimuth scanner is installed, a full 2D sky scan can be programmed by checking the **2D Scan** check box. In this case, the radiometer software interprets the given start- and stop-angles for elevation and azimuth as edge angles and performs a 2D scan within these limits. E.g. a full sky scan is defined by setting the elevation start angle to 9.0°, the elevation stop angle to 90.0° (a 9° increment angle produces 10 elevation steps at const. azimuth angle), the azimuth start angle to 0.0° and the azimuth stop angle to 350.0°

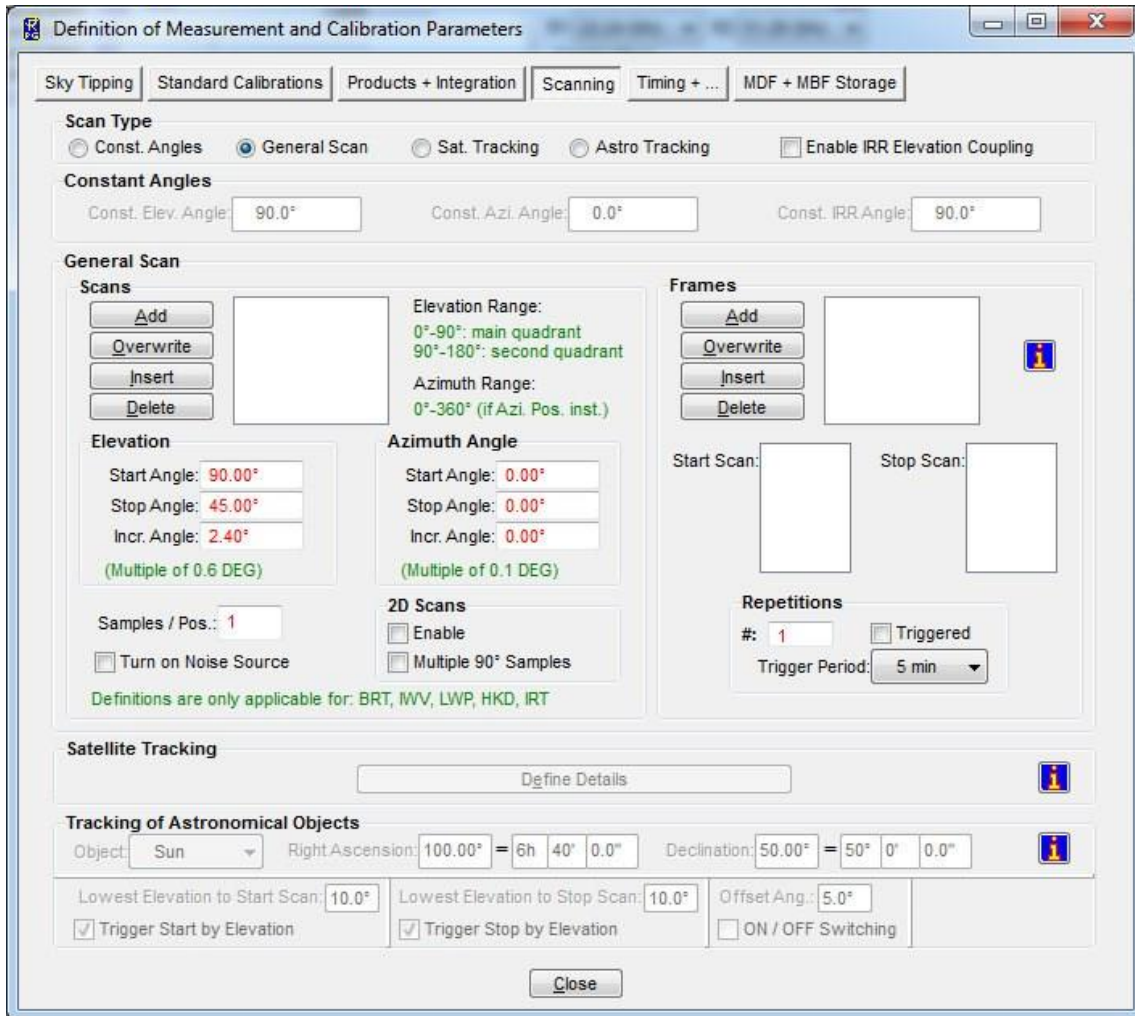


Fig.4.10.: MDF general scan settings.

(step increment 10°). This generates a measurement of 378 scan points with an angular resolution of 10° in azimuth and 9° in elevation. The radiometer sets the integration time to 0.4 seconds / sample to reduce the time needed for a full scan. The 'Samples / Pos.:' entry is ignored in this mode. The full scan in this example takes only about 7 minutes! High speed scanning is feasible due to the parallel architecture of the RPG radiometer's direct detection filter bank receivers described in the Technical Manual.

In the example above, the 90° elevation angle would be scanned 36 times if the **Multiple 90° Samples** check box is checked. This leads to redundant zenith samples that can be used to derive a time series of other products during full sky scanning (e.g. an LWP zenith time series). But it increases the time for a full scan due to redundant samples. If the scanning time shall be optimized, **Multiple 90° Samples** check box is unchecked (default setting). In this case the zenith scanning angle is only encountered once during a full sky



scan. When products with different integration times are selected for scanning, the radiometer adjusts all integration times to the maximum integration time in the products list.
Example:

A RPG-HATPRO radiometer is setup for scanning with the brightness temperature product (BRT, integration time: 10 sec.) and the IR temperature product (integration time: 5 sec.). Then the integration time during the scan will be 10 seconds (also for the IR temperature samples). After the definition of the start angle, stop angle and increment angle, the settings are stored as a scan with **Add**. Every scan in the scan list can be marked and overwritten with the current settings by using the **Overwrite** command. By clicking on a scan number in the scan list, the actual settings of that scan are displayed.

If the IRR motor driver option is installed, the infrared radiometer is moved synchronously together with the internal microwave elevation mirror, when **Enable IRR Elevation Coupling** is checked.

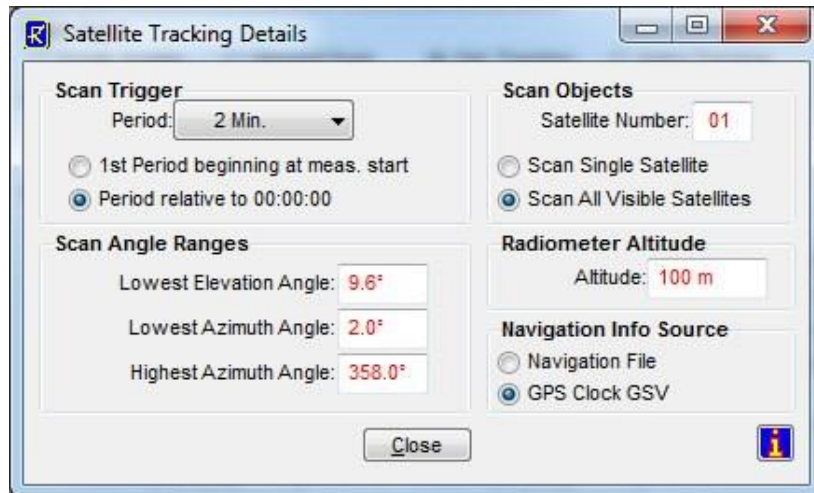
4.9.4.3 Satellite Tracking

Assuming the radiometer system is equipped with an azimuth scanner, the instrument can be run in satellite tracking mode by selecting **Satellite Tracking**.

In satellite tracking mode, the radiometer periodically scans a number of visible GPS or Galileo satellites and measures the wet delay component, LWP and attenuation in the line of sight to each of the satellites. The user should activate the products IWV, LWP, and Attenuation (ATN) in the MDF product list with identical integration time (typically one second). The system determines the satellite positions from a RINEX navigation file stored in the **TRACKING** subdirectory (see section 4.1.2) and its own GPS position. The azimuth scanner's 0.0° azimuth angle has to point to North direction (90° = West, 180° = South, 270° = East) to guarantee correct scanning positions. In **Define Details** the user can specify the tracking details.

The **Period** determines, in which time intervals the scan is repeated. In **Scan Objects** one specifies, if all visible satellites or just a single satellite shall be scanned. In the case of a single satellite, the satellite's number is given in **Satellite Number**. The angular scan range should be limited (e.g. in elevation) if not all sky directions are available due to obstacles.

RINEX navigation files are loaded from the European IGS FTP data server <ftp://igs.ensg.ign.fr/pub/igs/data/> and usually have the extension '.YYn' where YY stands for the year, e.g. '.08n' is a navigation file from 2008. For instance, the file <ftp://igs.ensg.ign.fr/pub/igs/data/2008/225/dlft2250.08n> is from Delft (dlft), day of the year 225 (August 12th). The RINEX navigation files are ASCII formatted files and contain the orbit information for all satellites of a certain navigation system like GPS or Galileo. The H-PC software periodically (every hour) checks if there is an updated RINEX file in the **TRACKING** subdirectory and automatically loads it if available. The software calculates the current positions from the information given in the RINEX files and the actual UTC time and the radiometer GPS position on earth.



Tracking data files are stored in binary format with extension '*.TRK'.

4.9.4.4 Astro Tracking

Assuming the radiometer system is equipped with an azimuth scanner, the instrument can be run in astro-tracking mode by selecting **Astro Tracking**. In this mode, the radiometer, assuming its azimuth zero position is well adjusted to north (see section 4.23), is capable of tracking any astronomical object, including sun, moon, planets and fixed stars or objects. If a fixed star is selected from the object list, the right ascension and declination of the objects has to be entered. Start and stop times of the scan can be triggered by the standard trigger options already discussed or by a minimum object elevation angle.

4.9.5 Timing + ...

Start time, end time and time reference are important parameters for a measurement setup. The time reference is set to UTC or local time which is UTC + time shift [h]. The radiometer determines UTC from a GPS clock reading which is synchronized to the radiometer's real time clock (RTC) every 10 minutes.

There are two ways of triggering a measurement: Immediately after launching the MDF or at a certain time and date. Using a start time before the current time is equivalent to an immediate start. If the measurement start is triggered to a certain time, the check boxes **Ignore Date** and **Ignore Hour** allow for a date or hour independent triggering. This is particularly useful in a repeated multiple MDF batch measurement, where MDFs are repeated multiple times. A triggering to a certain date / time would trigger the MDF only once but not repeatedly. E.g. if **Ignore Hour** is checked (assuming **Triggered** mode is activated) and the 'Start Time' entry is set to 22|36|15, the measurement is triggered to 00:15:00, 01:15:00, 02:15:00, ..., ignoring the current date and hour. If a more frequent trigger is required, one can use the **Raster** feature combined with a raster period. E.g. if a start time of 22|36|15 is defined in combination with raster mode and a raster period of 10 minutes, the trigger sequence is: 22|36|15, 22|46|15, 22|56|15, 23|06|15 etc.

Two options are available for measurement termination. In LIMITED mode the user can set a duration or termination time. If the stop time is before the start time, the measurement duration is adjusted to 100 seconds.



In the case that the measurement has a well-defined end time (automatic measurement termination, LIMITED mode) the radiometer needs a filename for storing backups. The user may enter any filename not longer than 8 characters. The H-PC also uses this filename when it is operated in automatic storage mode. If measurement timing is set to UNLIMITED mode the radiometer automatically generates filenames deduced from the actual time and date and ignores the measurement filename entry.

In UNLIMITED mode the measurement is terminated manually. A new filename is generated every X hours where X is selected from the *Filename Interval* list box. The file format is one of 14 possible versions given in the *Name Convention* list box. In the format string HH=hours, DD=days, MM=month and YY=year are taken from the actual time and date. During measurement, this filename is also transmitted to the H-PC, which uses it for file storage of monitored data (assuming the H-PC is operated in *Enable File Backup* mode).

Since the temperature and humidity environmental sensors respond quickly to changes of the corresponding parameters (caused by turbulence in the vicinity of the radiometer) it is often desirable to smooth the temperature and relative humidity data samples. This is important if retrievals are utilizing the meteorological sensors, but the detailed surface turbulence at the radiometer location is not of interest and would only lead to noisy retrieval results if not filtered. In *Data Smoothing* a 10 minutes LIFO filter is activated to smooth the environmental temperature and humidity readings.

Another feature is the enabling of a file backup on the embedded PC. When *Enable File Backup* is checked, all product files will be automatically stored in the radiometer's data directory. This is usually done for safety reasons because the standard mode of measurements is to enable automatic data storage on the H-PC (online monitored data). Without monitoring the data on the H-PC and only storing it on the radiometer as backup, the user will sooner or later have to transfer the data from the R-PC to the H-PC using the *Transfer Data and System Files* menu.

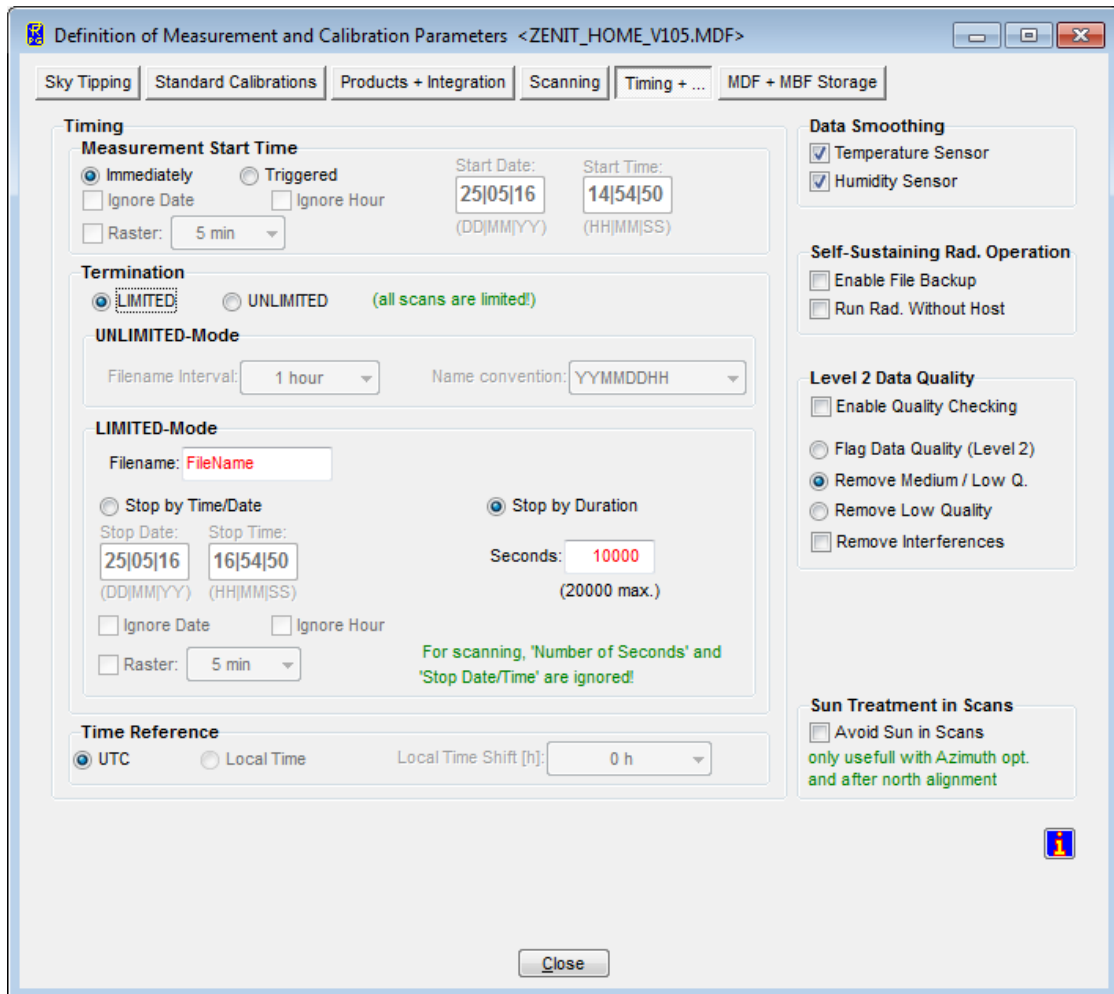


Fig.4.11: Timing+... definition menu.

For the RPG-HATPRO, RPG-TEMPRO, RPG-HUMPRO and RPG-LHATPRO, the R-PC performs quality checks on the water vapour and oxygen lines measured in zenith mode and during boundary layer scans. These tests include the detection of possible external interferences or reduced quality level 2 data caused by intensive rain. The program generates a quality flag and information for the possible reason of a reduced quality. This information is coded into the rain flag of each sample (see Appendix A). More information about quality checking can be found in appendix A18. The radiometer can be configured to filter low and medium quality samples and is capable of interpolating the brightness temperature of channels affected by external interference. In **Level 2 Data Quality** there are three options for filtering level 2 data (retrieved atmospheric data). The **Flag Data Quality (Level 2)** option does not filter the level 2 data according to the quality level but flags each data sample in the rain flag byte as described in appendix A. With the option **Remove Medium / Low Q.**, medium and low quality samples are not transmitted by the radiometer. In this case, the sample sent to the H-PC is the repeated latest high quality sample. The filter **Remove Low Quality** will only remove the worst quality level data and transmits high and medium quality data. If the radiometer detects a possible interference problem (an external signal interferes with one of the receiving channels), it can automatically remove the interference signal from the spectral line by interpolating between adjacent channels. This function is enabled by checking **Remove Interferences**.



Another feature is the blanking or avoiding of the sun position during scanning observations and sky tipping. This implies the availability of the azimuth scanner option and a GPS clock and that the azimuth table is precisely aligned according to the procedure described in section 4.23. If **Avoid Sun in Scans** is checked, the radiometer will determine the sun position on the sky automatically when performing full sky scans, azimuth scans (Hovmöller plots) or sky tipping calibrations. If the sun position is encountered, the radiometer sidesteps this position by about 6° to avoid unrealistic brightness temperatures in transparent channels.

4.9.6 MDF + MBF Storage

It is possible to send a *single* MDF **directly** to the radiometer. Multiple MDFs are packed into a MBF (measurement batch file). The concept is similar to the Scan/Frame relationship for scanning.

The MDFs in a batch file are executed sequentially in the order they are listed in the MDF list (see Fig.4.10). The batch repetition number has the same meaning as the frame repetition factor for scanning: The MDF list forms a loop, which is repeated an arbitrary number of times. This offers the user a flexibility of combining different measurement tasks, which would otherwise not be compatible in a single MDF, e.g. if one wants to do a scanning measurement (not possible with retrieved products) followed by a temperature profiling measurement (a retrieved product) and repeat this 100 times, the solution is to define two different MDFs, one for scanning and one for temperature profiling and combine them in a batch file with a repetition factor of 100. The only restriction for MDF definitions in multi-MDF batches is that the UNLIMITED mode must be avoided.

It is a good practice to store all MDFs in one directory (e.g. ...**RPG-HATPROWDF-MBF**). All MDFs in the selected directory are listed in the box in the lower right corner. From this list, the user may select each MDF he wants to add or insert to the MDF batch list by dragging the desired MDFs to the MDF batch list box. MDFs may also be deleted from the MDF batch list by dragging it to the waste bin. Store your measurement batch files (MBFs) in a single directory (like ...**RPG-HATPROWDF-MBF**).

If file backup is enabled in the MDFs and the batch repetition factor is >1, there is only one filename for each MDF available. The data of successive executions of a certain MDF in the batch loop is stored to a single file. Each time the MDF is repeated in the loop, its measurement data is appended to the file.

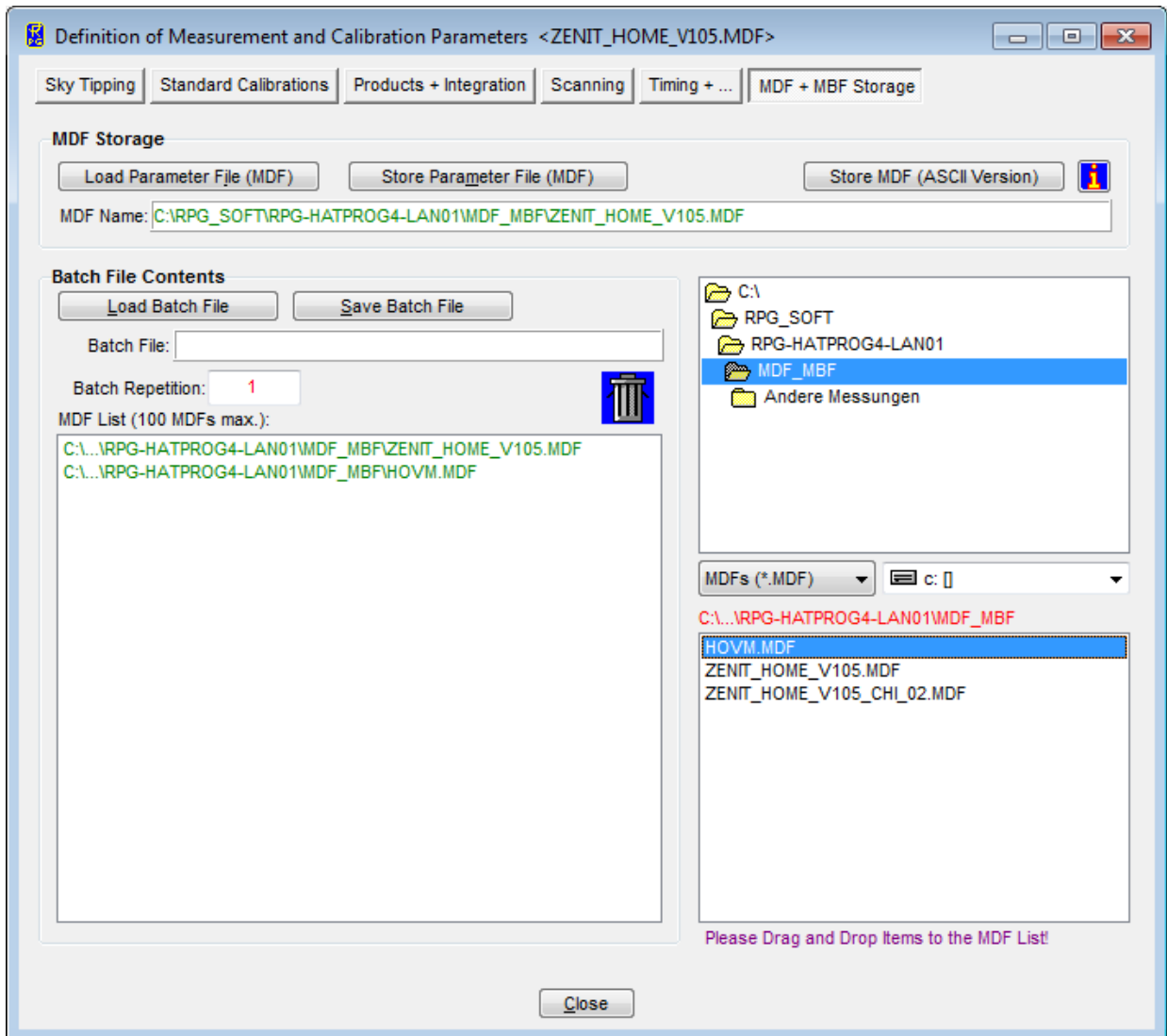



Fig.4.12: Batch file configuration menu.

4.10 Sending a MDF / MBF to the Radiometer

MDFs and MBFs can be sent to the radiometer (assuming the H-PC is connected to it) from the **Send Measurement Configuration** menu by clicking .

When an MDF or MBF is loaded (**Load MDF/MBF File**), its contents and repetition factor are displayed. In addition some pre-checks are performed, e.g. correct radiometer configuration, frequency list consistency, etc. A variety of other checks ensure that no erroneous command data is sent.

When the consistency check of a MDF is finished, the test result is displayed in the **Check List**. The batch can only be sent to the radiometer if all consistency checks have finished with the status OK. Then the MBF is transmitted with **Send**.

The H-PC 'remembers' the directory where MDFs and MBFs are stored from a previous **Load MDF/MBF File**. This directory is marked in red and its content is listed below the directory label. In the list, MDFs are separated from MBFs by a dashed line. Dragging a file from the list and dropping it on the radiometer image on the right is equivalent to the **Send**

command. If **Auto Go** and **Auto Send** are both checked, the MDF or MBF is sent, the **Send Measurement Configuration** menu is closed and the measurement is automatically started.

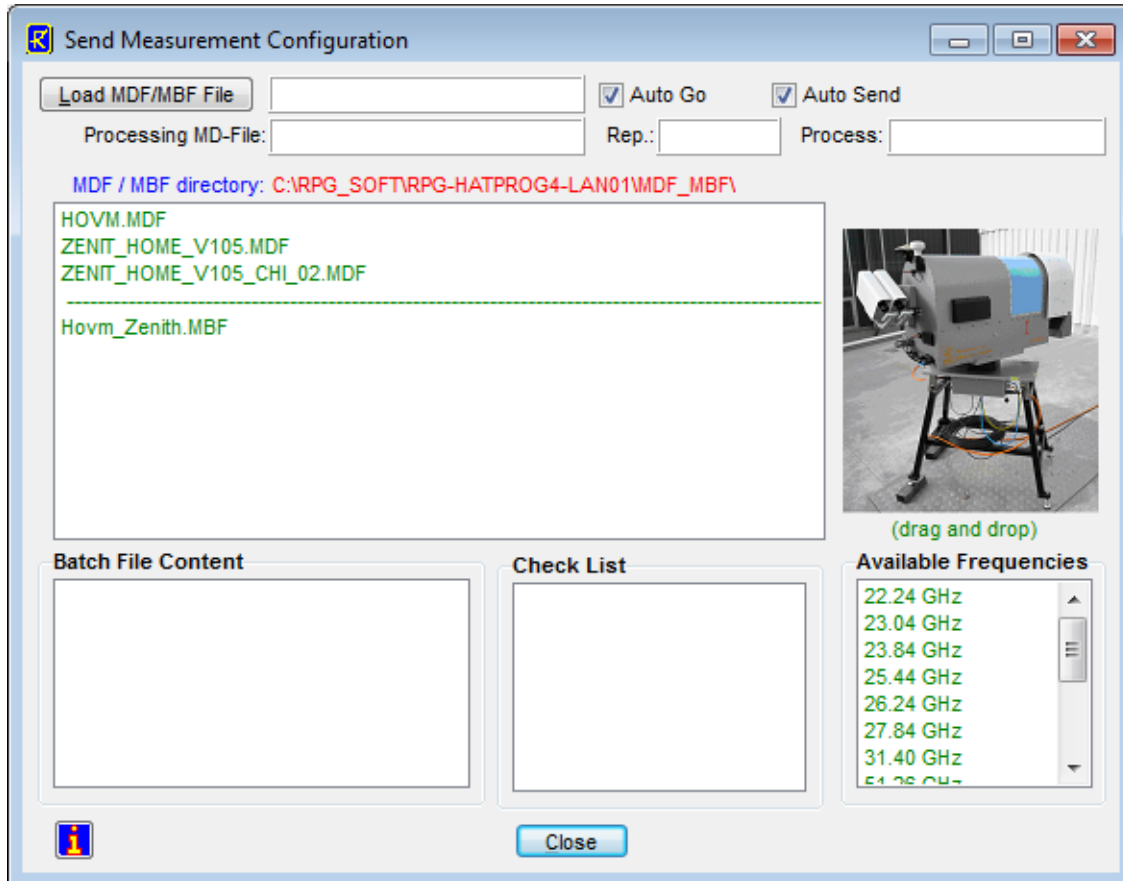



Fig.4.13.: Send measurement configuration menu.

4.11 Commanding a Measurement Process

When a valid MDF / MBF has been transmitted to the instrument the following functions are enabled:




(Start Processing MDF/MBF)

If **Auto Go** is disabled in section 4.10, the MDF or MBF is now stored on the radiometer's embedded PC, but the radiometer software remains in STANDBY mode as long as  is not executed. The status line entry changes to "MEASUREMENT RUNNING..." after clicking



(**Halt Running MDF/MBF**)

A running measurement can be halted any time. This might be useful when e.g. the user wants to manually change the elevation angle. The status bar display switches to

“MEASUREMENT HALTED” and the manual control button (, discussed later) is enabled (among other commands) which offers manual control over elevation stepper and other radiometer features.

(**Continue Interrupted MDF/MBF**)





Used to continue a halted measurement. The status bar display changes back to “MEASUREMENT RUNNING” and the manual control button is disabled.

(**Terminate Running MDF/MBF**)

This command terminates the execution of the currently running measurement. The radiometer switches to STANDBY mode and is ready to receive the next MDF/MBF.

4.12 Monitoring Data

The easiest way to perform a measurement is:

- Define a MDF (or multiple MDFs  included in a MBF) ().
- Send the MDF or MBF to the radiometer ().
- Start the MDF or MBF on the radiometer ().

The monitoring of the products that were selected in the MDF is automatically activated and the measured data is displayed. Since the data is transmitted online from the radiometer to the H-PC, no additional file transfer is required.

The data display is grouped into different tag fields that can be individually selected.

4.12.1 Status and Configuration Display

This group includes the status display of the radiometer and measurement information like the current processed MDF, current data filename, activation status of file backup, start and end time, etc. In a second box, the settings for the automatic calibrations are displayed (**Automatic Calibration Timing**). These settings, like calibration period and integration time, can be changed ‘on the fly’. Each calibration is performed automatically but there is the possibility to enforce a calibration by clicking the associated **Execute Calibration** button.

While a measurement is running, the MDFs of an executed measurement batch (MBF) are listed in the MDF list combo-box within the **Measurement** display-box. In the case that only a single MDF is executed, the MDF name is listed there as a single entry.



Each individual MDF is related to its separate set of retrieval files it needs to derive level 2 data (atmospheric data). The names of the currently executed MDF retrieval files are listed in a separate Retrievals combo-box.

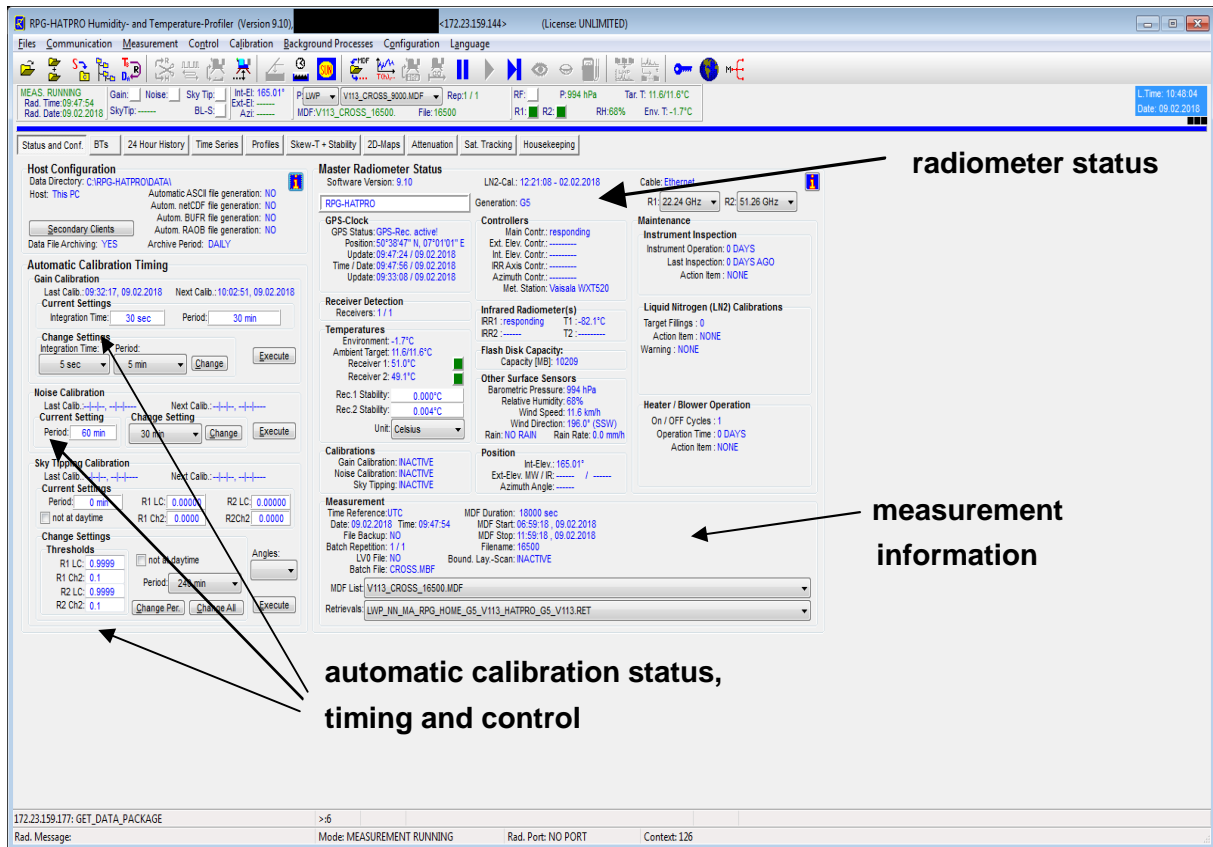


Fig.4.11a: Radiometer status, measurement configuration and automatic calibration display.

4.12.2 Brightness Temperatures (BTs) Display

All brightness temperatures, at both microwave and IR frequencies, are displayed in this group.

The display includes the time series of each available microwave and IR channel, the boundary layer scan information and the line profiles, if applicable (e.g. water vapour and oxygen lines). The three **TB Windows 1-3** each show a subset of the microwave channels that is defined by entering the **Fmin** and **Fmax** of the displayed frequency range.

Within the **Boundary Layer Scans** display-box, the displayed BL TB scan frequency can be selected from the **Frequency** combo-box. During a BL-scan, all available radiometer channels are monitored and stored into the related BLB file.

The time axis spread of the radiometer channel time series TBs can be changed by selecting a different time axis period from the time axis selection box.



The Host software stores the last 50.000 samples of data in a ring buffer, so that almost a full day of TB data is simultaneously visible when a time axis spread of 100.000 seconds is selected.

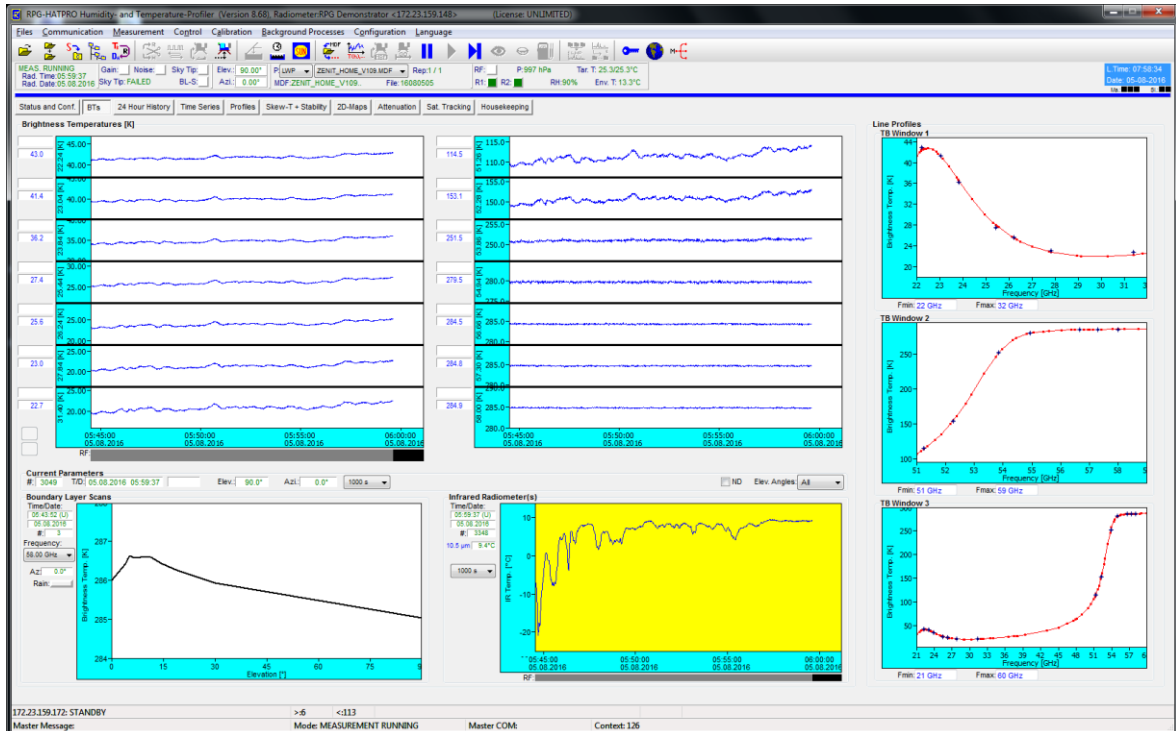


Fig.4.11b: Brightness temperature information.

4.12.3 24 Hours History Display

A 24 hours history of IWV, LWP, meteorological sensors and profiles is continuously updated in this data group display.

The IWV, LWP and sensor data displays can be individually changed to a 3, 6, 12 or 24 hours history (click one of the **3 / 6 / 12 / 24** buttons). With the **R** button, the user may reset the time series by deleting the data ring buffer. By checking the **N** check-box, the IWV / LWP data is displayed as normalized to zenith angle. This feature only affects observations performed under non-zenith elevation angles.

The **Met Surface Sensors** display may be changed between P / T / H (pressure / temp. / humidity) and WS / WD / RR (wind speed / wind direction / rain rate) by clicking the **W / P-T** buttons.

In the profiles boxes (**Relative Humidity**, **Temperature Profiles**, **Liquid Water Profiles**), colour scales, vertical axis limits and contour values may be changes for data monitoring.

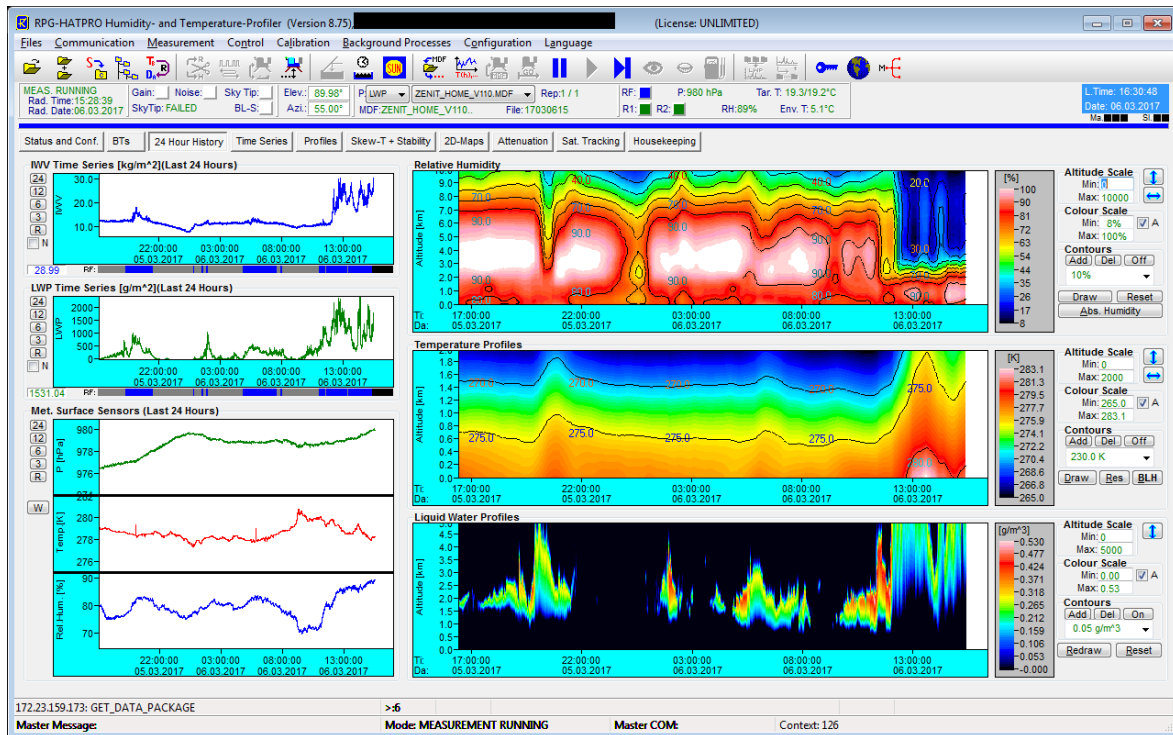




Fig.4.11c: 24 hours data history display.

The humidity profile window has a selection button for alternatively displaying absolute or relative humidity.

The temperature profile window offers an additional display for boundary layer height, which can be toggled on/off with **BLH**. The stable boundary layer is indicated in white colour, while the instable boundary layer is plotted in magenta. For details of how the BL height is computed, please refer to chapter 4.16.5.

As with all 2D colour plots, horizontal cuts (time series) and vertical cuts (profiles) can be plotted from the profile history displays. Simply click on  (for profile) or  (for time series) to activate the related cursor and move it over the diagram. Then click on a position from where you want the profile or time series and it will be displayed in a separate window.

4.12.4 Time Series Display

This group includes time series of liquid water path (LWP), integrated water vapour (IWV), cloud base height (CBH) and the surface sensors (temperature, rel. humidity, barometric pressure, wind speed, wind direction and rain rate). CBH data is available for all temperature profiling radiometer models (RPG-HATPRO, RPG-TEMPRO, RPG-LHATPRO) if the IRR option is installed. LWP, IWV and CBH are retrieved data products and are therefore quality checked. The quality level (High, Medium, Low) and the possible reason for reduced data quality is shown below the time series charts. All time series include a rain flag display. Each window displays the current reference time, date, sample number, sample value, retrieval type (if applicable) and cursor position (when the mouse cursor is moved into the display area).

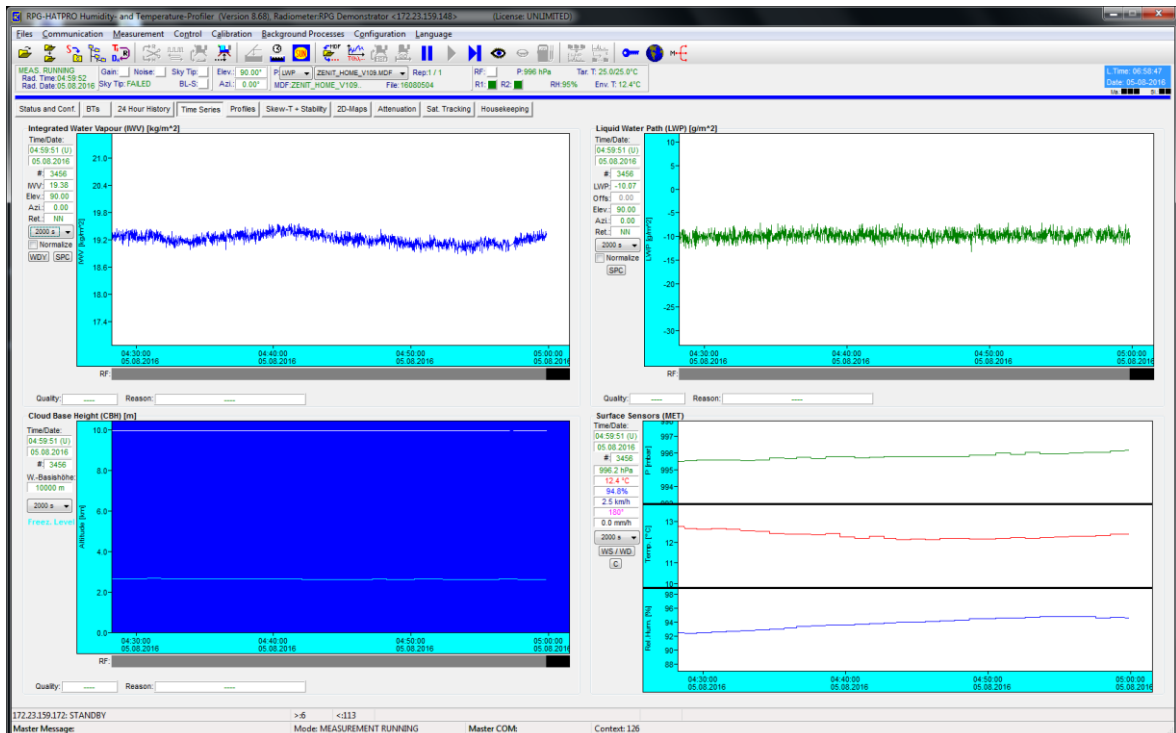


Fig.4.11d: Time series of atmospheric data like IWV, LWP, cloud base height and sensor data (wind speed and wind direction in this case).

4.12.5 Profiles Display

The group summarizes all available profiles. There are three temperature profile displays, one for the boundary layer scan (TPB) with high vertical resolution (range 0-2000 m), one for the zenith observation (TPC, full troposphere profile with coarser resolution in the boundary layer) and one for the composite profile (CMP.TPC). The composite temperature profile is a combination of the high vertical resolution boundary profile and the full troposphere profiles. Both profiles are linked together at the 1200 m altitude level by applying a cubic-spline fit. The temperature profiles are in blue colour while the dew point temperature profiles are in green. Dew point information is only available (and displayed), if the radiometer is equipped with a humidity profiler. Absolute humidity and dew point temperature are only different versions of the same information content. Like with all temperature displays, the temperature axis can be scaled to Celsius, Fahrenheit or Kelvin.

On the bottom of the screen the diagrams for absolute humidity (HPC), relative humidity and the liquid water profile (LPR) are shown. The LPR data product is automatically generated when the products LWP, IWV and IRT are selected in the MDF product list and a retrieval for the maximum LWC is installed in the LWP retrieval directory (must have the same retrieval filename as the LWP retrieval but starting with 'LWM' instead of 'LWP'). X-axis: LWC-density [g/m^3], Y-axis: altitude [m].

Additionally, the boundary layer height and freezing level is marked on the profile displays.

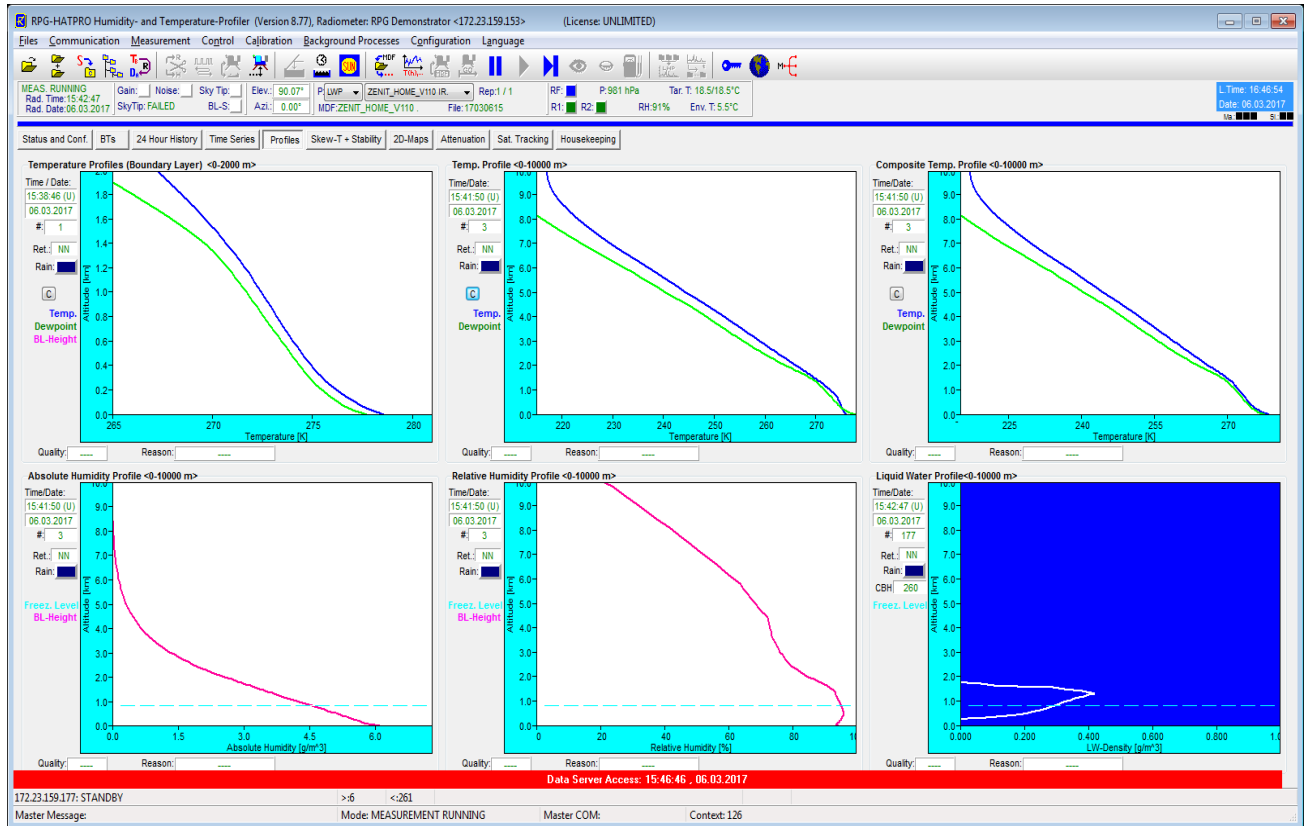


Fig.4.11e: Atmospheric profiles display.

4.12.6 Thermodynamic Diagrams / Stability Index Display

This group presents a thermodynamic diagram (Skew-T, Tephigram, Stüve diagram or Emagram) display which is often used by meteorologists to analyse the atmospheric state. The diagram is only active during measurements of RPG-HATPRO or RPG-LHATPRO radiometers, which provide the profile data required for this analysis.

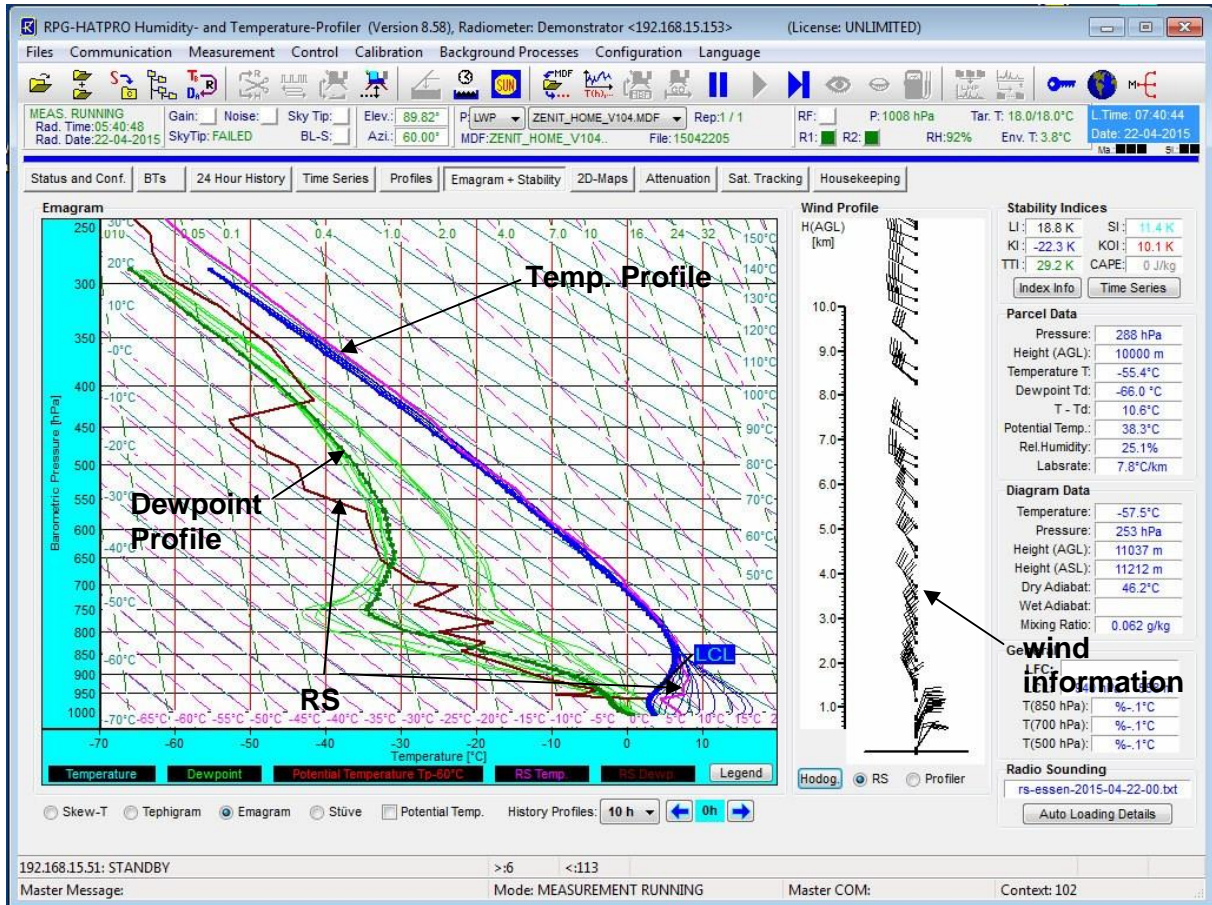


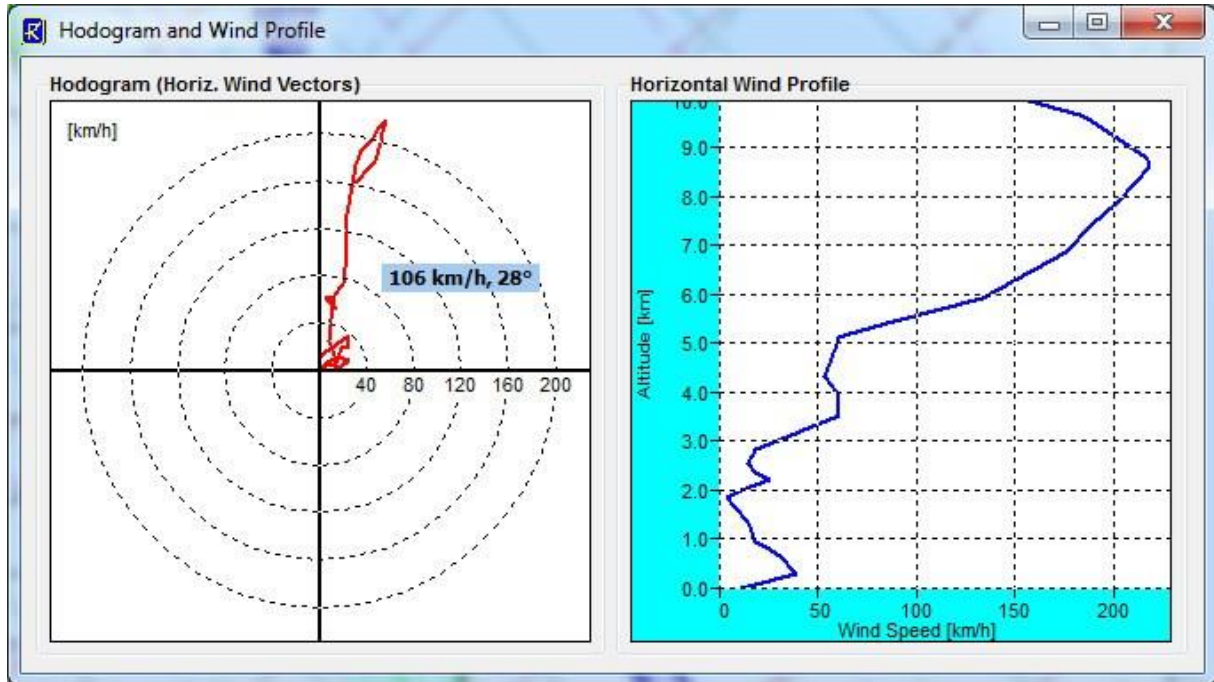
Fig.5.11f: Thermodynamic Diagram / Wind Info / Stability Index display.

The diagram is organized very similarly and delivers the same data analysis as presented in the famous sounding software package RAOB® by Environmental Research Services (ERS), <http://www.raob.com/>, which is widely used by meteorologists.

The user may select between the most common 4 diagram types **Skey-T**, **Tephigram**, **Stüve** or **Emagram**, by selecting it from one of the radio buttons on the bottom of the screen.

The radiometer's temperature profiles are plotted in **blue**, the dew point profiles in **green**. When radio soundings are automatically loaded (see section 4.12.6.1), the RS temp. is plotted in **magenta** and the RS dewpoint profile in **brown** (see Fig. 5.11f).

To the right of the thermodynamic diagram (TDD) the wind information is displayed. The user can select between the radio sounding wind profile (**RS** radio button) or the profile of a wind profiler connected to the radiometer (**Profiler** radio button). If a wind profiler is not present, the surface wind measured by the radiometer is plotted. Additional wind plots are available by clicking the **Hodog.** button. A new window is opened, displaying a hodograph (horizontal wind vector diagram) and a wind speed profile.



Hodograph and horizontal wind speed profile.

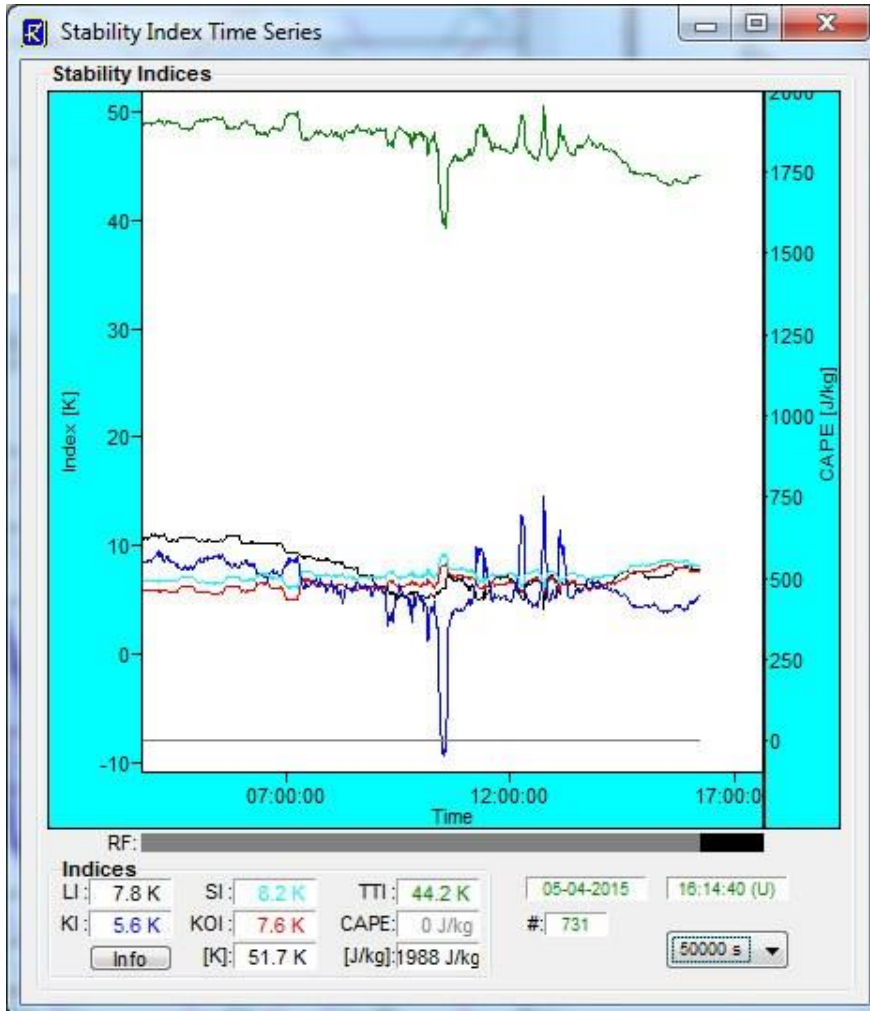
The **Legend** button presents a window explaining the TDD coloured lines and wind symbols:

Bft.	Symbol	Description	m/s	km/h	knts.
0		calm	0 - 0.2	<1	<0.6
1		light draught	0.3 - 1.5	1 - 5	0.6 - 3.0
2		light breeze	1.6 - 3.3	6 - 11	3.1 - 6.1
3		weak breeze	3.4 - 5.4	12 - 19	6.2 - 10.6
4		moderate breeze	5.5 - 7.9	20 - 28	10.7 - 15.6
5		brisk breeze	8.0 - 10.7	29 - 38	15.7 - 20.9
6		strong wind	10.8 - 13.8	39 - 49	21.0 - 26.9
7		stiff wind	13.9 - 17.1	50 - 61	27.0 - 33.5
8		stormy wind	17.2 - 20.7	62 - 74	33.6 - 40.7
9		storm	20.8 - 24.4	75 - 88	40.8 - 48.4
10		heavy storm	24.5 - 28.4	89 - 102	48.5 - 56.0
11		hurricane-like storm	28.5 - 32.6	103 - 117	56.1 - 64.3
12		hurricane	32.7 - more	118 - more	64.4 - more

By running the cursor over the TDD, the **Parcel Data** and **Diagram Data** are updated on the right side of the wind diagram. The parcels (corresponding to the retrieval's altitude layers) are indicated as little dots along the T- and Tp-profiles.

Six of the most common stability indices (lifted index (LI), K-index (KI), KO-index, Showalter index (SI), CAPE index, total totals index (TTI)) are monitored in the upper right corner.

A definition of a certain index is listed by double-clicking on one of the index panels. A time series of each index is available with **Time Series**:



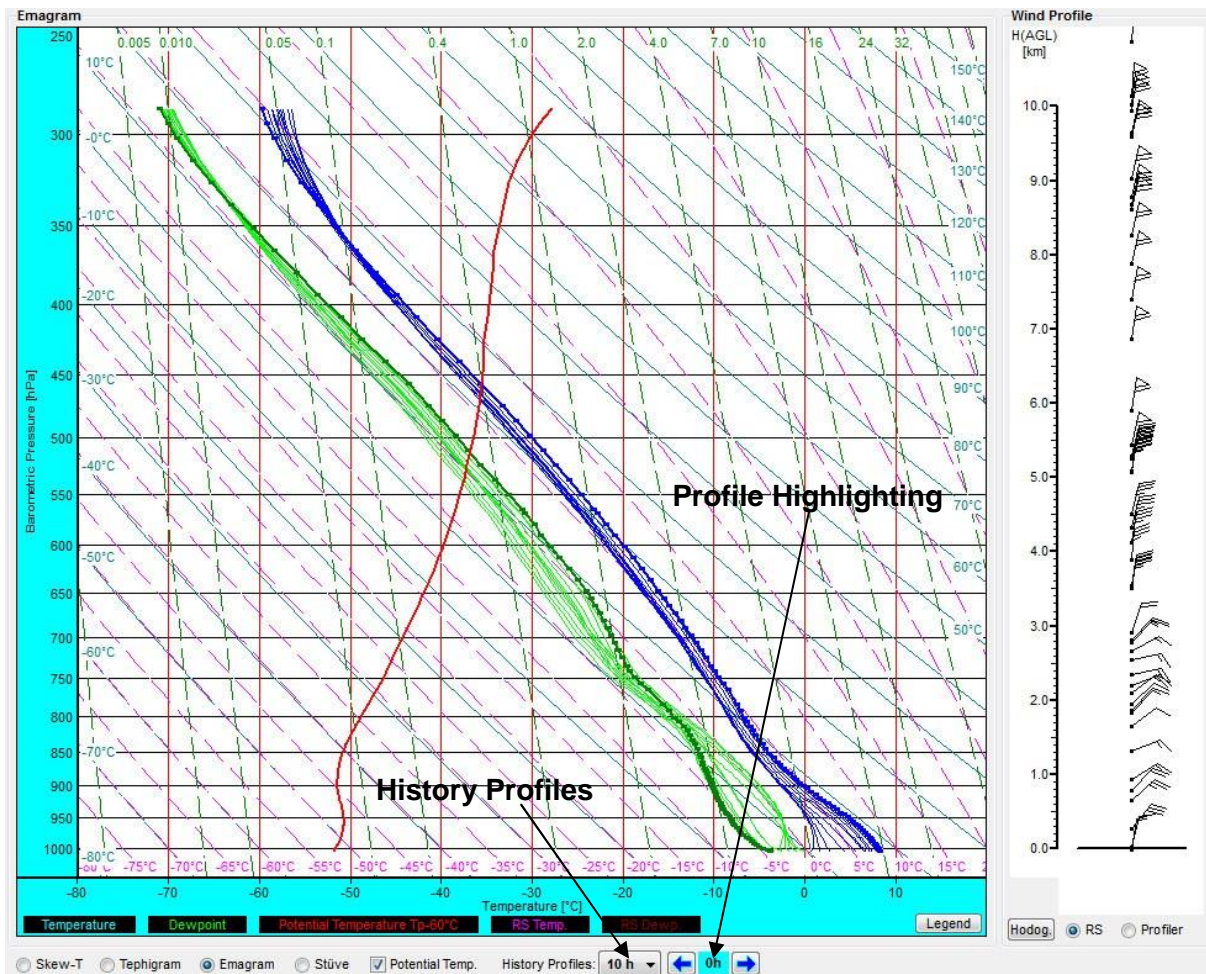
The stability indices are stored in files of extension '.STA'.

Other useful information like the LCL (Lifted Condensation Level) and LFC (Level of Free Convection) is marked on the TDD. When the **Potential Temp.** check-box is checked, the potential temperature, shifted by -60°C to be plotted within the diagram, is added to the TDD in red colour. It contains valuable information about the stability of the atmospheric layers (see definition of KO-index).



The potential temperature is given by:

$$T_p = T \left(\frac{p_0}{p} \right)^{R_a / C_p}$$

p_0 is the reference pressure (1000 mbar), R_a is the gas constant for dry air (287 J / kg K), C_p is the specific heat capacity at constant pressure (1004 J / kg K).



Example of a 10 hours History Profile display.

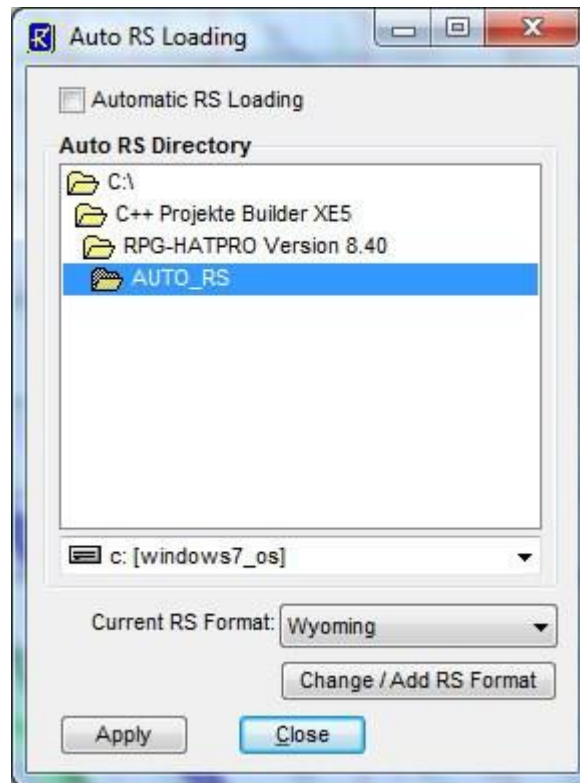
Below the TDD, the user may select the **History Profiles** period (between 2h and 10h). If this feature is selected, the T- and Tp-profiles of the last few hours are also displayed, giving an impression of the variability of the atmospheric state over time. The time pitch between the profiles is one hour. Therefore, a 10h period will display the profiles of the last 10 hours. When clicking on one of the  or  buttons, a member of these profiles is highlighted.

4.12.6.1 Automatic Loading of Radio Soundings

The Host software allows the automatic loading and display of radio soundings. In order to activate this feature, click the **Auto Loading Details** button within the Radio Sounding box. The **Auto RS Loading** menu will be shown. When checking **Automatic RS Loading**, auto loading is activated. The directory, from which the radio sounding file is imported, is defined in the **Auto RS Directory** box.

Because there is no unified format for radio soundings, the format needs to be selected from the **Current RS Format** combo-box. If a new format has to be defined, click **Change**

/ Add RS Format. The menu described in section 4.16.2 pops up to extend the RS format data base.



RS auto loading menu.

The Auto-RS-directory is scanned every 10 seconds for a new radio sounding file. If a file is detected, it is automatically loaded and displayed in the TDD and the RS wind profile is updated accordingly. The currently loaded RS filename is listed in the **Radio Sounding** box. After loading, the RS file is removed from the Auto-RS-directory to avoid ambiguities with new files that are stored to the directory sequentially.

4.12.7 Attenuation Display

This display is similar to the brightness temperature diagram and monitors the time series of atmospheric attenuation. The vertical axis unit is dB as the standard unit for attenuation parameters. The attenuation is only calculated for the microwave channels. The standard attenuation retrievals are applicable for all elevation angles and can be used in scanning mode.

The displays can be toggled between Tau in Neper and attenuation in dB.

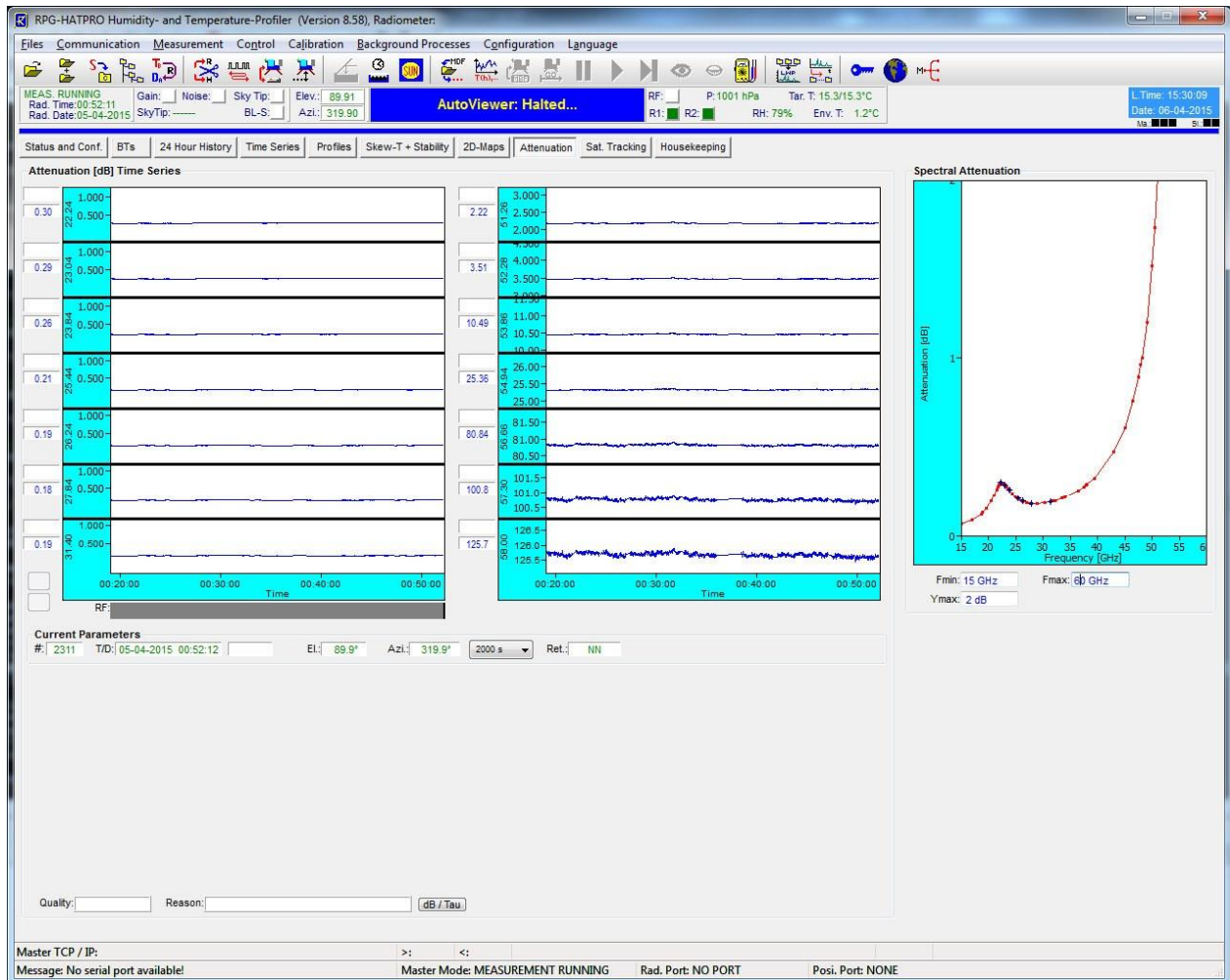


Fig.4.11g: Atmospheric attenuation display.

4.12.8 Satellite Tracking Display

If satellite tracking is enabled in the running MDF, the scanned satellite information, like satellite number, navigation file, satellite elevation and azimuth position, wet path delay, LWP and atmospheric attenuation along the line of sight are listed for each scan.

4.12.9 Housekeeping Display

Data like GPS position, receiver stability, system temperatures (ambient target, receiver temperatures), flash memory capacity, quality flags and system status flags are monitored. By clicking the **Legend** button, the colour codes for the different flags are listed. An ALARM



indicator warns the user if a systematic problem with the radiometer has occurred. A detailed description of housekeeping flags is given in appendix A18.

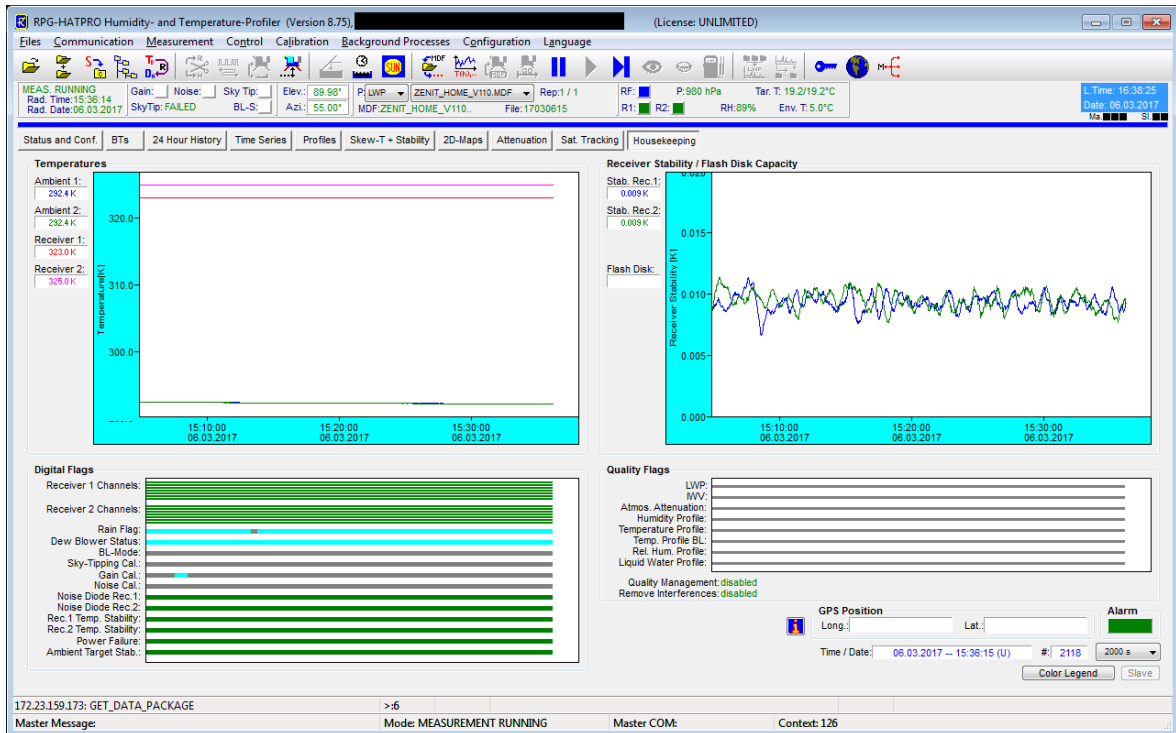



Fig.4.11h: Housekeeping data display.

4.13 Concatenate Data Files

In UNLIMITED termination mode, the radiometer periodically generates new data filenames (e.g. every hour). It is often desirable to concatenate data files of the same type (*.LWP, *.TPC etc.) to form bigger files (e.g. 24 hour files). This is possible by clicking  (**Concatenate Data Files**) which opens the menu in Fig.4.12. A set of filenames is selected from the list and then concatenated to a single file with **Generate Concatenated File**. All files in a certain directory can be automatically concatenated to daily files by using the **Generate Daily Files** command. Optionally, the original hourly files can be deleted, if the appropriate checkbox is checked.

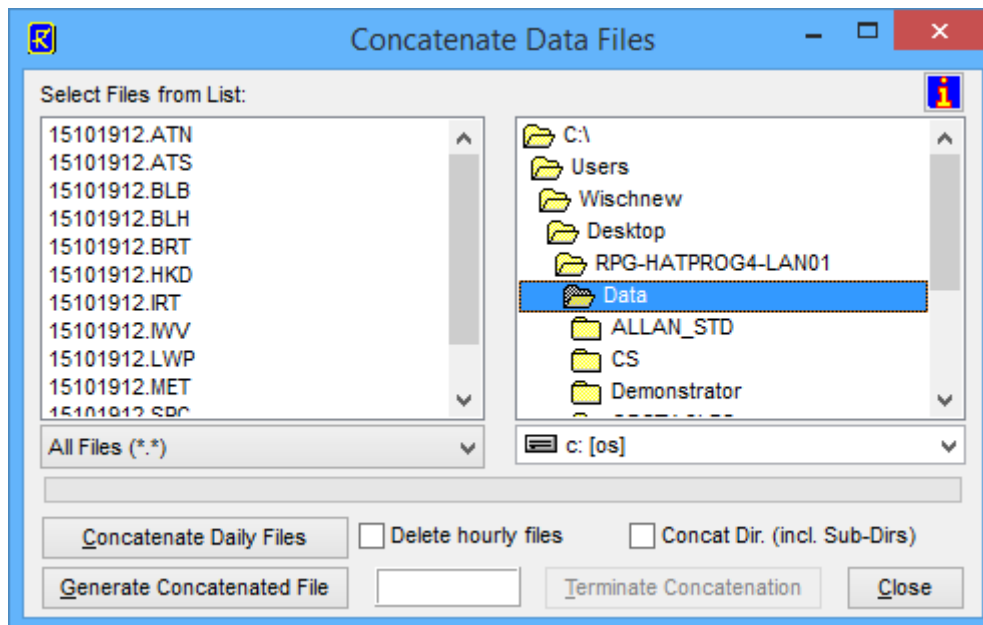


Fig.4.12: Concatenating data files.

4.14 Cutting Connection




(Cut Connection to Radiometer)

If the user wants to disconnect the H-PC from the interface cable or turn off the radiometer after having been connected this command should be used first. It ensures that all communication activities between H-PC and R-PC are disabled so that the H-PC will not crash after disconnection.

4.15 Data Post Processing

Files of products that are based on retrievals (LWP, IWV, profiles) can be generated by combining brightness temperature files, meteorological sensor files and corresponding retrieval files. The frequencies specified in a retrieval file (see section 5) must match the frequency information in the BT (Brightness Temperature) file.

Example: An LWP retrieval requires BT information at 23.8 and 31.4 GHz and input from a temperature sensor and humidity sensor. A RPG-HATPRO radiometer provides this information in a **BRT** file. The calculation of the LWP data is performed in the **Transform**

Brightness Temperature Data to Atmospheric Data menu (click ). Fig.4.13 shows an example. The file **100520.MET** (click on the filename in the list) is combined with the BRT file **100520.BRT** (click on the filename in the list), both recorded at the same time and date, by applying the retrieval information of the **HPT_QR_FZK_V1.RET** file. **Generate Humidity Profile** performs a consistency check (frequency matching, additional sensor matching) and generates a new **.HPT** file.

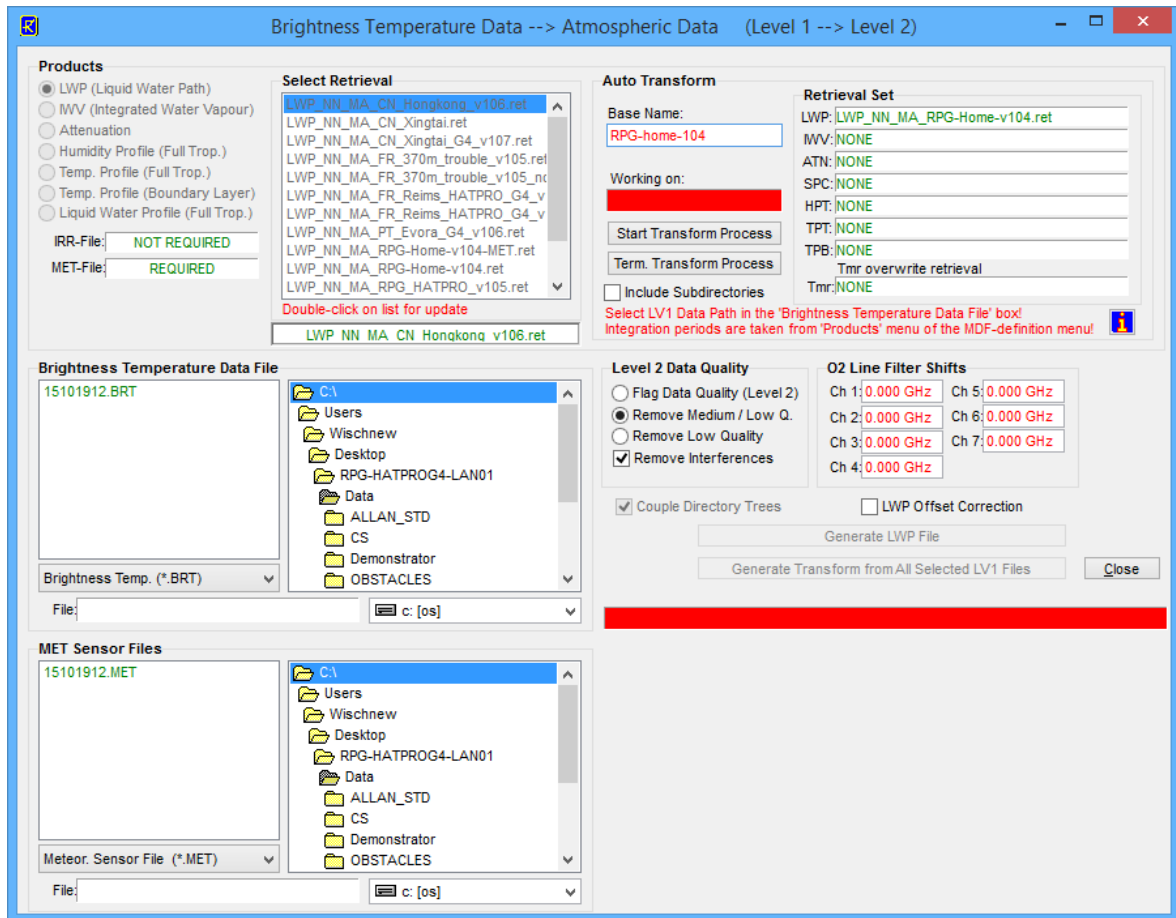


Fig.4.13: Generate level 2 data (atmospheric data like LWP, IWV or profiles) from associated BT and sensor data files.

When a humidity profile **MyFile.HPC** is created, the software first looks for a RHP retrieval (relative humidity retrieval) file associated with the selected HPT retrieval file in order to generate relative humidity profiles in addition to absolute humidity profiles. If an RHP retrieval is not found, the H-PC automatically looks for a **MyFile.COM.TPC** file (in the same directory as the BRT file is located) containing a composite temperature profile chart (see section 4.16.3).

If this file is found, relative humidity profiles are calculated by combining the absolute humidity profiles (calculated from the **MyFile.BRT** brightness temperatures) and the temperature profiles in **MyFile.COM.TPC**. The relative humidity profiles are then appended to the absolute humidity profile information in **MyFile.HPC**. If **MyFile.COM.TPC** is not found, the software looks for a **MyFile.TPC** located in the same directory as **MyFile.BRT** and uses the temperature profiles of this file to create the relative humidity information. Only if neither **MyFile.COM.TPC** nor **MyFile.TPC** is found, the **MyFile.HPC** exclusively contains absolute humidity profiles. The **Rel. Hum.** Button in the **Display Absolute Humidity Profiles** menu is then disabled when loading the **MyFile.HPC**.

A very sophisticated feature is the Auto Transform function of this menu (upper right corner). The requested retrievals are all selected from the list (green entries). Then the level 1 data source (brightness temperature data and MET data) is selected from the **Brightness Temperature Data File** box. By clicking the **Start Transform Process** button,



the whole data directory is processed to level 2 data (atmospheric data). In **Base Name** a preceding name for the resulting level 2 data files can be defined. When checking the **Include Subdirectories** checkbox, the level 1 directory with all of its subdirectories is processed. This feature is very useful when processing archived data that is organized in a directory tree.


4.16 Data Display Menus


For each measurement data product a display window is available. Click on the open button



and select a product from the pull down list. Then load a product data file. Fig.4.14a is an example of a boundary layer temperature profile chart. All data display menus indicate start time, end time, time reference, duration, and retrieval algorithm (for retrieval products).

One may zoom into the data by pressing the left mouse button in the display area and drag the mouse to a different position (mouse button still pressed) to define a rectangle (indicated by a black frame). For zooming back click **Zoom Out**.

For coloured maps as profile charts and brightness temperature charts, by clicking **Select Profile** and moving the mouse into the display area the cursor changes its appearance (). When clicking on the display area, another window is opened showing the line profile or profile at the time point corresponding to the cursor position (see Fig. 4.14b). A right mouse button click exits the profile selection mode.

By clicking on **Time Series** and moving the mouse into the display area, the cursor changes its appearance (). When clicking on the display area, another window is opened showing the time series related to a certain altitude or frequency. A right mouse button click exits the time series selection mode.

Brightness temperature data files always contain the elevation angle information for each sample. The elevation angle display can be toggled (**Show Angles, Blank Angle**).

You can enter contour values in the profile charts (with **Add** and **Del**) to be plotted as lines in the colored display. With **Redr** (Redraw) the display is updated according to the newest contour list. The contour lines are turned on and off with **On** and **Off**.

Most display menus can be stretched in size (resized) by positioning the mouse on the menu window edge and drag it to the desired position. The display is then adjusted in size.

All display menus show the time series of measured data with a rain flag stored for each sample in the data file. This flag is indicated underneath the data plot labelled with **RF**. During rain events, the flag is colored in blue, otherwise in gray.

Profile and line charts display a legend with a color code bar. By clicking on the dark grey shaded area of the legend the sub-menu in Fig.4.15 pops up. When **Auto Scaling** is checked the program automatically uses the minimum and maximum numbers for the color axis limits. When **Auto Scaling** is turned off, these limits are taken from the two entry lines labeled with **Color-Axis Min** and **Color-Axis Min**. Exiting this menu with **OK** will initiate a new plot with different colour coding

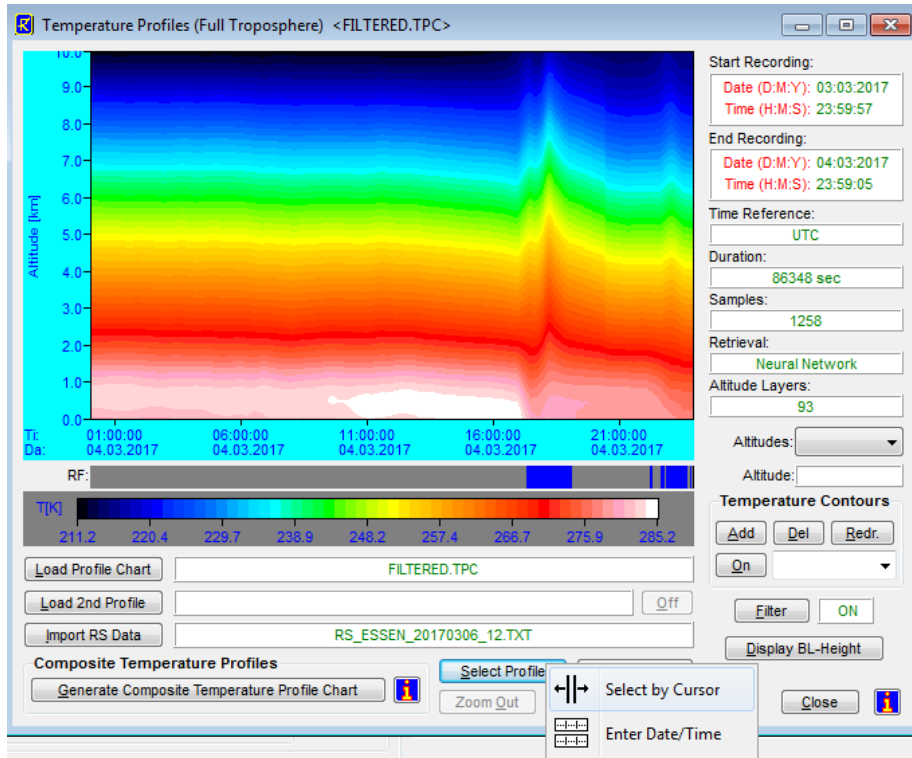


Fig.4.14a: Temperature profile chart window.

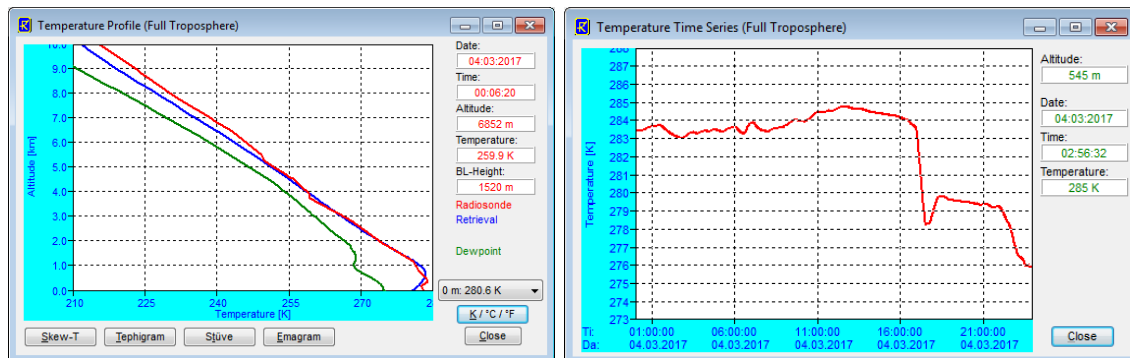


Fig.4.14b: Temperature profile (with radio sonde comparison) and time series plots.



Fig.4.15: Colour code bar scaling menu.

The profile display windows (like the one in Fig.4.14b) offer a similar feature. By doubleclicking on the display area in these windows a similar menu like in Fig.4.15 is

displayed which allows for automatic or manual scaling of the temperature and humidity axis' in these menus.

Another type of data display is the scalar type time series like LWP, IWV, meteorological sensors, infrared radiometer temperature or stability indices (Fig.4.16). No colour code is required because the data type is scalar instead of a vector (e.g. a profile). The **Display Stability Indices** menu has a special information feature. By double-clicking on one of the index labels a text file is shown with information about the index definition and thresholds for severe weather conditions.



Fig.4.16: Stability index display. Information about a certain index can be obtained by double-clicking on the index label.

4.16.1 Data filters

Most data displays offer a filter function sub-menu accessed by clicking **Filter**. The window in Fig.4.17 appears. The filter can be turned on/off by checking/unchecking **Enable Filter**.

Three filter flags can be selected:

Interpolate Rain Samples: This filter linearly interpolates the data samples taken during rain events by using the two 'no rain' samples before and after the rain event. E.g. the water vapour line channels are very sensitive to droplets on the microwave radome or shutter blocking. The acquired data will not be useful in this situation and can be overwritten by this filter.

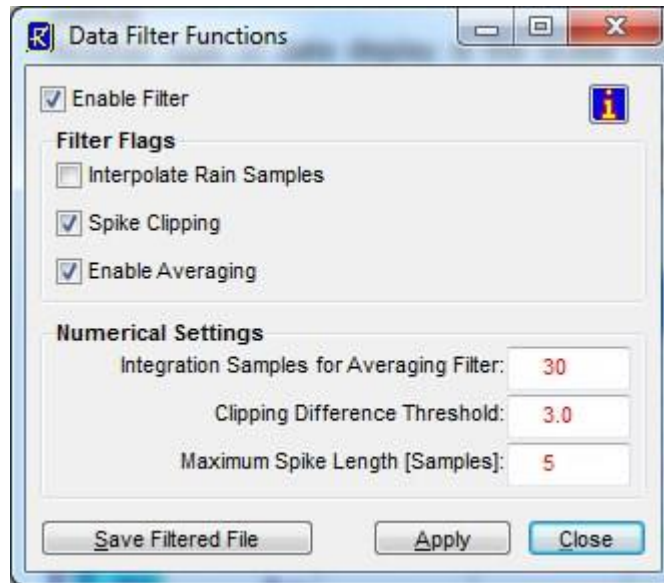


Fig.4.17: Filter functions sub-menu.

Spike Clipping: This filter eliminates sharp spikes in the data caused by blocking the microwave window during the measurement (e.g. by human beings, birds etc.). The maximum spike length measured in samples can be defined in **Maximum Spike Length [Samples]** and a clipping threshold is entered in **Clipping Difference Threshold** to distinguish the spike from general noise.

Enable Averaging: Noise on the data may be reduced by this filter. It generates the mean value of the number of samples given in **Integration Samples for Averaging Filter**. These samples are centered around the filter sample.

When pressing **Apply** the filter with its new settings is executed. The resulting filtered data file can be stored with the **Save Filtered File** command.

4.16.2 Import Radiosonde Files

The temperature and humidity profile display menus offer a feature for loading radiosonde data files to directly compare with the radiometer data (**Import RS Data**). When a radiosonde file is loaded and the RS display toggle button shows **Display RS Data**, the radiosonde data is displayed in red as an additional plot when a profile is selected like in Fig.4.18:

By clicking the **Import RS Data** button in a profile map window, one enters the **Radiosonde File Format** sub-menu in Fig.4.19a. Radiosonde data files (usually available in ASCII format) come in a variety of different file formats.

A typical example is shown in Fig.4.19b. Usually the file starts with a header containing information about the station (e.g. station number) and a definition of the data columns and their units. The data is listed in columns separated by blanks, commas etc.

Before loading such a file one has to define in which columns the program can find the three important data types Altitude, Temperature and Humidity (wind speed and wind direction are optional). The user may set the right column numbers in the **Radiosonde File Format** submenu. For instance, in the ASCII file in Fig.4.19b the altitude column number is 2, the temperature column is 3, the rel. humidity is listed in column 5, wind speed in column 8 and wind direction in column 7.

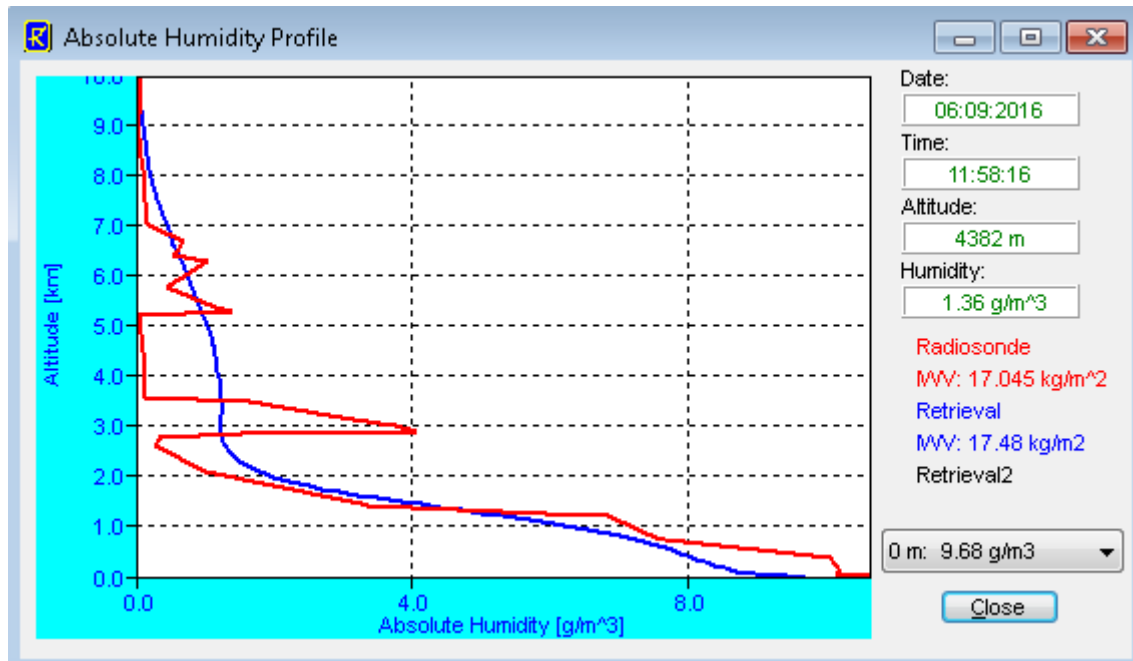


Fig.4.18: Absolute humidity profile with radiosonde data in red.

Available altitude units are m, km, hPa and Pa. Sometimes the altitude is not stored in m or km but as the barometric pressure (e.g. mbar or hPa or Pa).

Units for the temperature are °C, K, F or °C*10. The last unit is sometimes used to keep the column data format as an integer number (e.g. 12.3°C is written as 123).

Because wind speed and wind direction are optional (not mandatory) data columns, the wind information reading may be turned off by setting the wind speed column number to zero.

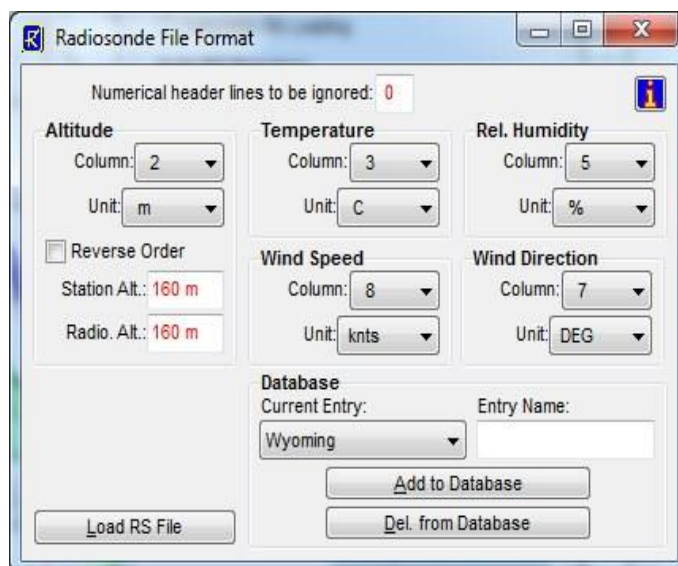


Fig.4.19a: Radiosonde file format definition and file loading.

Units for relative humidity are %, 0-1 or Dpt. The most common unit is % but rel. humidity is sometimes expressed by a number between 0 and 1. A less frequent unit is Dpt

(dewpoint, expressed in the same unit as for the temperature column) and the rel. humidity has to be computed from that number and the temperature reading.

PRES hPa	HGHT m	TEMP C	DWPT C	RELH %	MIXR g/kg	DRCT deg	SKNT knot	THTA K	THTE K	THTV K
1000.0	60									
990.0	153	21.6	11.6	53	8.73	220	6	295.6	321.1	297.1
983.0	214	20.4	10.4	53	8.11	218	6	295.0	318.7	296.4
925.0	729	15.2	9.2	67	7.95	200	8	294.9	318.1	296.3
898.0	978	12.9	8.6	75	7.84	205	10	295.0	317.9	296.4
890.0	1053	12.2	8.4	77	7.81	190	12	295.0	317.9	296.4
867.0	1273	10.2	7.8	85	7.71	227	13	295.1	317.7	296.5
862.0	1321	9.8	7.5	85	7.60	235	14	295.3	317.5	296.6
850.0	1438	9.0	6.8	86	7.34	235	14	295.6	317.1	296.9
818.0	1756	7.4	3.8	78	6.18	226	16	297.1	315.5	298.2
799.0	1949	5.7	3.1	84	6.03	220	17	297.3	315.2	298.3
790.0	2042	4.8	2.8	87	5.96	223	18	297.3	315.1	298.4
773.0	2219	4.4	1.3	81	5.48	230	19	298.7	315.2	299.7
750.0	2465	3.8	-0.7	72	4.87	225	18	300.7	315.6	301.6
748.0	2487	3.7	-0.8	73	4.85	225	17	300.8	315.6	301.6
729.0	2695	2.3	-1.7	75	4.65	245	17	301.5	315.8	302.4

Fig.4.19b: Typical radiosonde data file format (ASCII). Units are m, °C and %.

Furthermore there are radiosonde file formats with reversed order, meaning that the highest altitude sample is listed first. In this case one has to check the **Reverse Order** checkbox. For ground level correction it is useful to define the radiosonde station altitude (**Station Alt.**) and radiometer altitude (**Radio. Alt.**).

All settings can be stored in a database (file **RS.FMT** in the home directory) by clicking **Add to Database**; do not forget to define an entry name first. Each entry is listed in the **Current Entry** list box and can be deleted from the database with **Delete from Database**.

Once all parameters for the file definition are entered, the radiosonde file can be loaded with **Load RS File**.

4.16.3 Generate Composite Temperature Profiles

A special feature is available in the **Display Temperature Profiles (Full Troposphere)** menu. Usually the menu is used to display ***.TPC** files which were created in zenith observation mode. As discussed in section 2.3, the zenith observation mode leads to much coarser vertical profile resolution in the boundary layer compared to the BL (**B**oundary **L**ayer) mode but works best for altitudes >2000 m. Thus it is desirable to combine the observations of both modes into a single data file. When a **MyFile.TPC** file is loaded to the **Display Temperature Profiles (Full Troposphere)** menu and a **MyFile.TPB** file is located in the same directory as the **MyFile.TPC**, a **MyFile.COM.TPC** file is generated when clicking the **Generate Composite Temperature Profile Chart** button. This file contains a composite temperature profile combined from the two **MyFile.TPC** and **MyFile.TPB** files. The temperature values below 1200 m altitude are identical in **MyFile.COM.TPC** and **MyFile.TPB** and the same is true for the temperature values above 2000 m which are identical in **MyFile.COM.TPC** and **MyFile.TPC**. In the altitude range 1200 m to 2000 m the **MyFile.COM.TPC** file temperature values are generated from a cubic spline fit to match both profiles in **MyFile.TPC** and **MyFile.TPB** smoothly. The cubic spline interpolation



ensures that the first and second derivative of the fit match precisely the two profiles from which it has been generated.

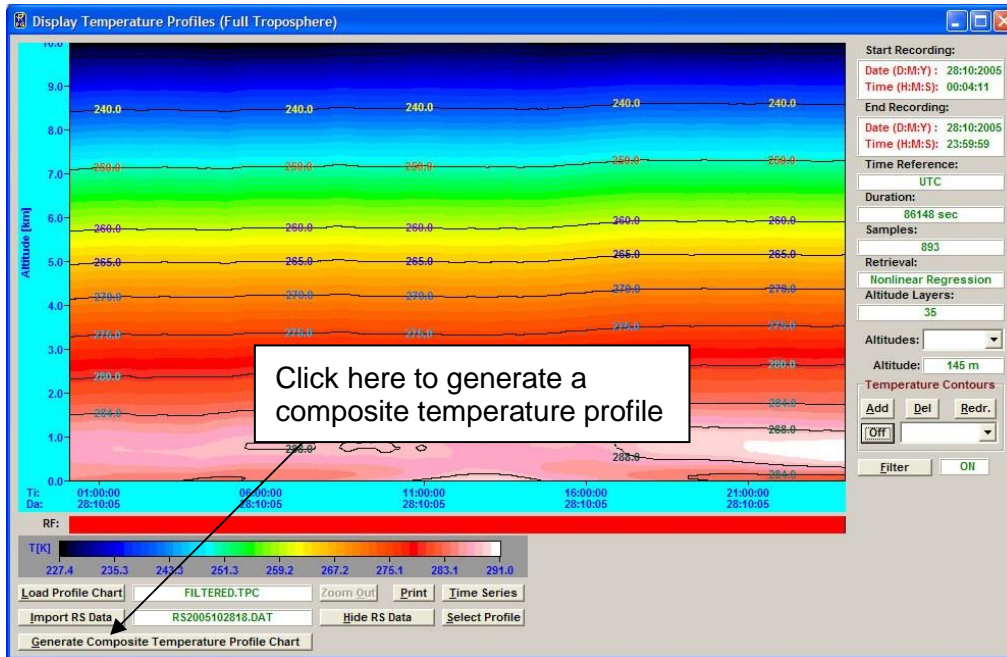


Fig.4.20a: How to create a composite temperature profile chart.

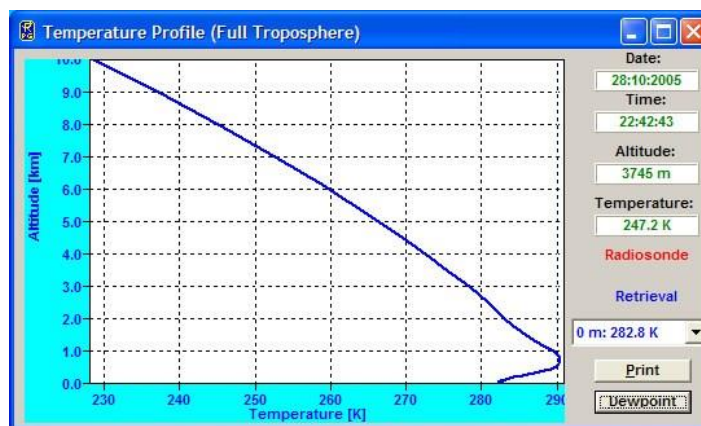


Fig.4.20b: Example of a composite temperature profile.

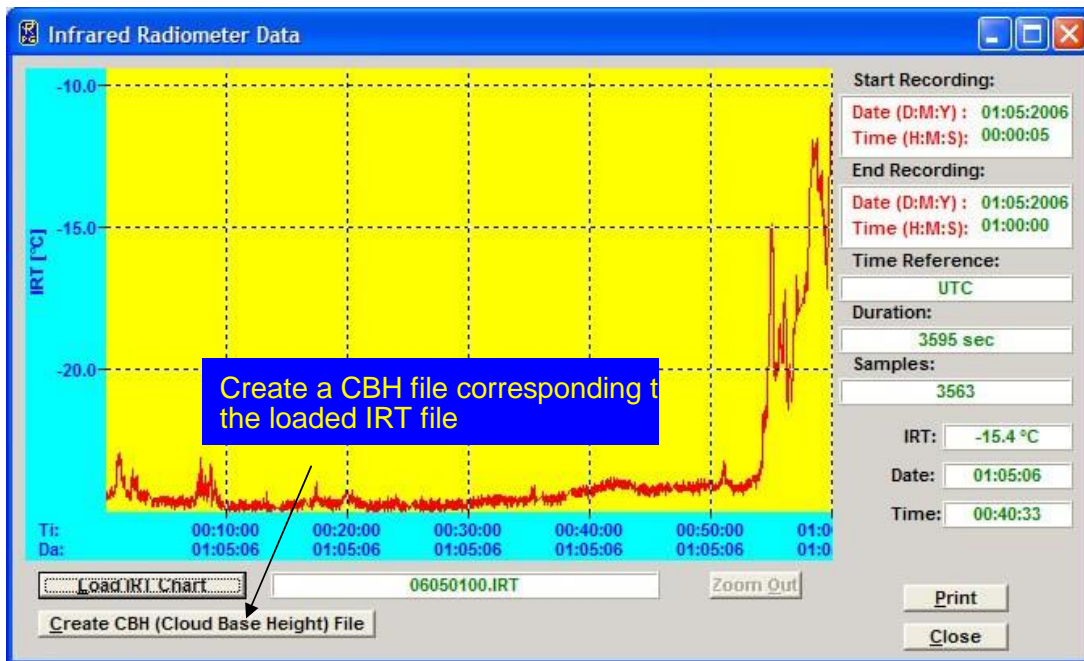
The file structure of the composite profile chart is identical to the *.TPC files which is indicated by the same file extension. Consequently the composite file can also be displayed in the **Display Temperature Profiles (Full Troposphere)** menu or converted to ASCII file format with the same tool as all other *.TPC files.

4.16.4 Generate Cloud Base Height Charts

When the infrared radiometer option is installed, the RPG-TEMPRO, RPG-HATPRO and RPG-LHATPRO can measure the cloud base height by identifying the infrared radiometer temperature with the physical temperature of the cloud base (if any) and deriving the height of the cloud by using the temperature profile. The embedded R-PC automatically generates

the cloud base height charts (*.CBH) when infrared radiometer data is acquired and temperature profile data is available. The same holds for the H-PC when it monitors IR data and temperature profiles. Even though a post-processing is possible, which means a manual generation of a *MyName.CBH* file from a *MyName.IRT* + *MyName.TPC* or *MyName.CMP.TPC* file. The *MyName.CMP.TPC* file (if available) is always preferred over the *MyName.TPC* file because the composite temperature profiles are more accurate than those derived from zenith observations only.

The manual post-processing of IRT and TPC data is performed in the IR data display window as shown below.



4.16.5 Boundary Layer Height

When the radiometer performs boundary layer scanning during a measurement in order to derive temperature profiles with high vertical resolution (*.TPB), the software automatically creates a boundary layer height file (*.BLH). The algorithm used to calculate the BLH is the following:

1. Calculation of the potential temperature for each altitude of a temperature profile:

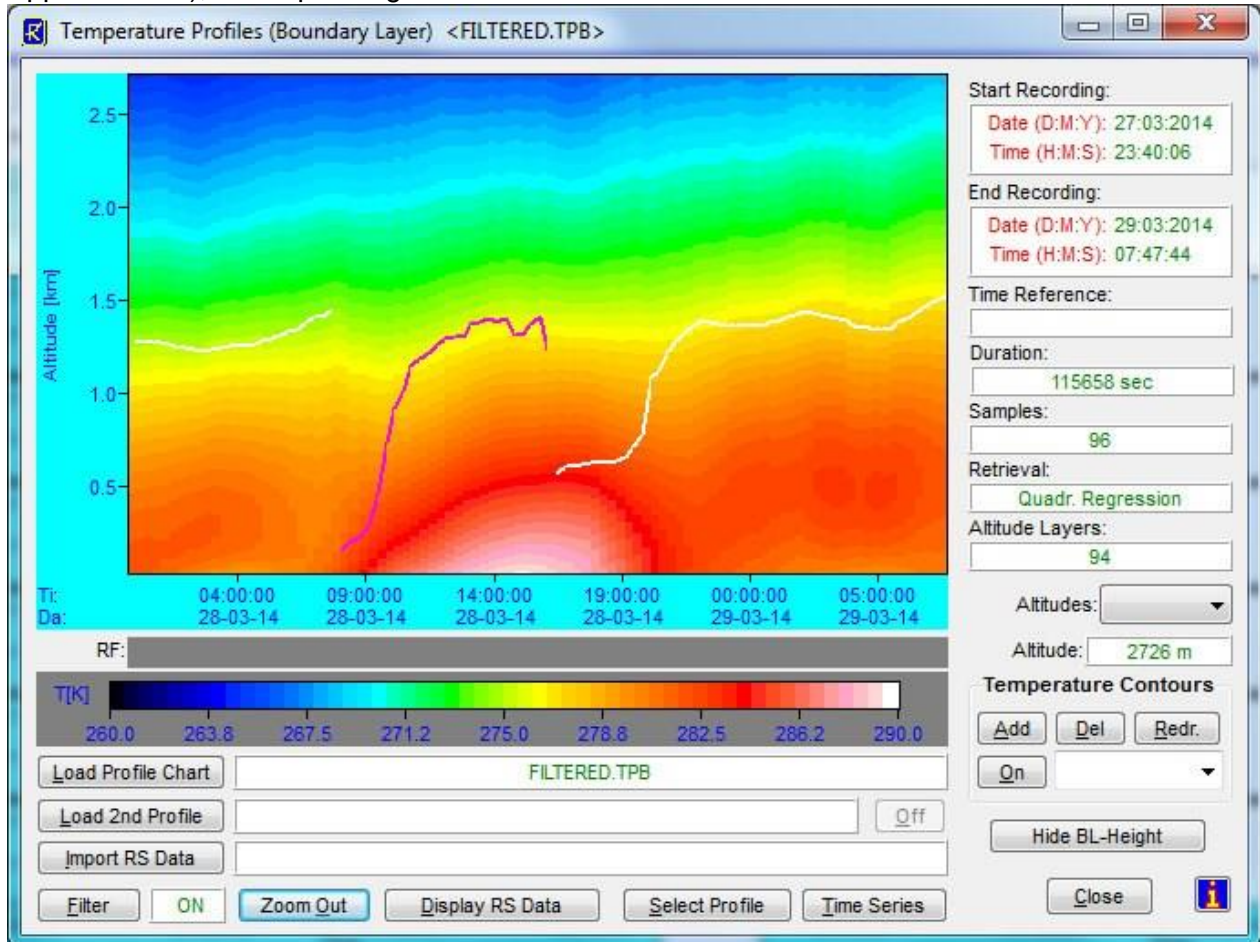
$$\Theta = T \cdot \left(\frac{p_0}{p} \right)^{R/c_p}$$

p_0 = reference pressure, p = pressure at altitude layer, R = ideal gas constant, c_p = specific heat capacity at constant pressure.

2. Checking of Parcel condition $\Theta(z_2) < \Theta(z_1)$ for $z_2 > z_1$. This region represents the mixing layer. The BLH is the altitude where $\Theta(\text{BLH}) = \Theta(0)$ (magenta line in figure below, representing instable condition, mixing layer).
3. If the Parcel condition is not fulfilled, the derivative of $\Theta(z)$ is calculated ($\Theta'(z)$). If a minimum of $\Theta'(z)$ exists, two possibilities may occur:
 - a. $\Theta'(z_{\min}) \geq 0$: BLH = z_{\min} (white line in figure below, stable layer)

- b. $\Theta'(z_{\min}) < 0$: The BLH is the height above z_{\min} , where $\Theta'(\text{BLH}) = 0$ (white line in figure below, stable layer, often accompanied by inversions).

In all other cases the BLH is set to zero. The BLH is stored in a separate data file (see Appendix A17), corresponding to a *.TPB file.




Stable BL (white) and instable mixing layer (magenta).

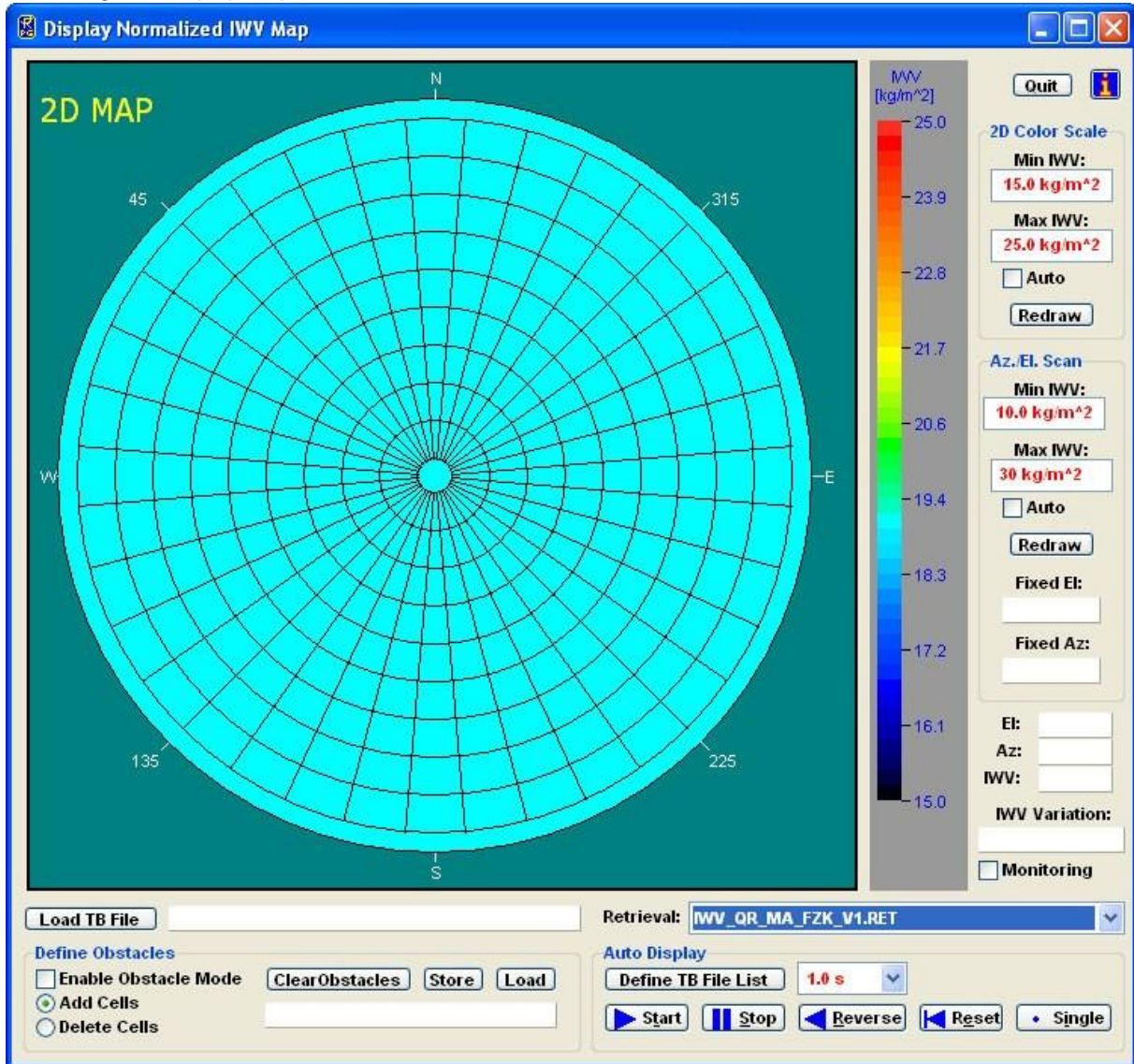
4.16.6 Housekeeping Data Display

When housekeeping data is displayed, six different display windows are available, corresponding to the six data categories System Temperatures, Receiver Stability, GPS Position, Quality Flags, System Status Flags and Flash Memory.

For more details on these data types please refer to Appendix A17. After a HKD file has been loaded, one can display each of the data types by clicking the related display button. A colour legend explains the meaning of the different colour codes in the Quality Flags and Status Flags displays.

4.16.7 Full Sky Scanning Displays

By selecting the '2D IWV Map' () command from the Files => Open Files list, the following menu pops up:

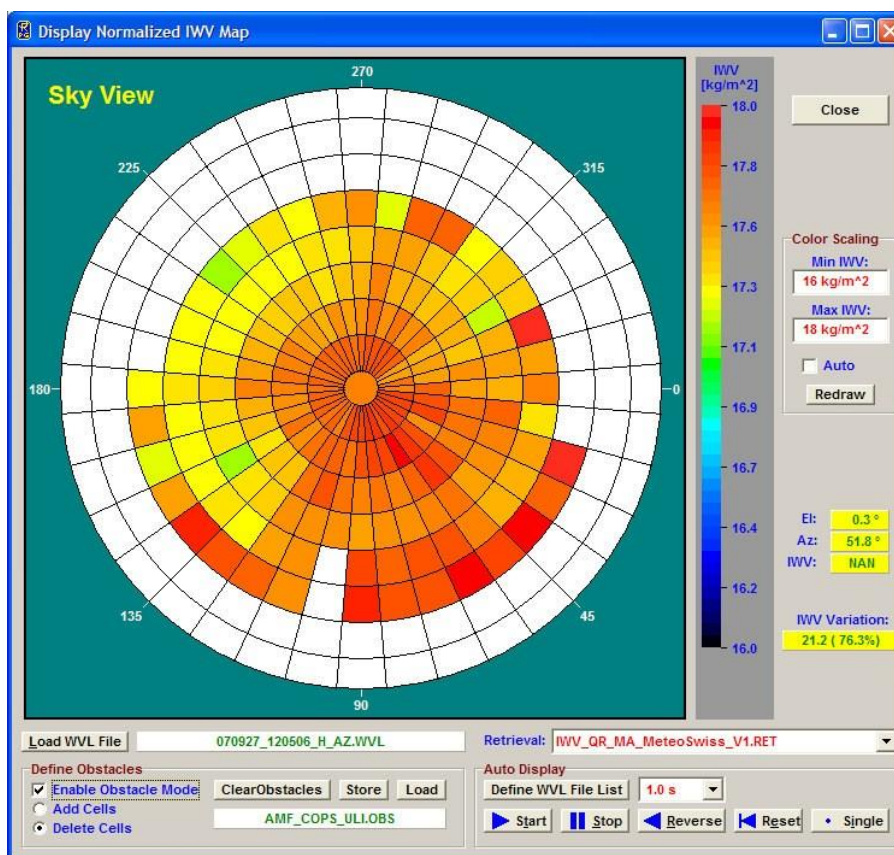


This menu displays normalized IWV data (IWV divided by airmass) that has been measured using the 2D scanning feature described in section 4.9.4. The central cell corresponds to the zenith observation angle and the data cells located at the edge of the diagram are related to horizontal observations. The numbers around the circle identify the azimuth angle (technical angle counted counter clockwise) and the sky directions N, E, S, W are marked for clarity. The instrument 0° azimuth angle corresponds to north direction.

IWV is a level 2 data product which requires a retrieval file that contains the required coefficients. In a full sky scan the radiometer changes the observation elevation angle, thus a multi-angle IWV retrieval is required for a correct evaluation of the scan data. In the display above, the retrieval file name is **IWV_QR_MA_FZK_V1.RET**. The 'MA' term indicates that the IWV retrieval is a multi-angle retrieval. If the user is selecting a retrieval developed for constant observation angles, a warning message will be issued. In order to display IWV data in this menu, one has to load a *.BRT data file by clicking the **Load TB**

File button. After loading a data file, the specified retrieval is automatically applied to convert the brightness temperature data to IWV data.

Close to the horizon the radiometer beam is often blocked by obstacles and at 0° elevation angle the beam is influenced by ground radiation. Therefore, it is desirable to define an 'obstacle' pattern to mark those cells that are not relevant due to beam blocking. To do so, the **Enable Obstacle Mode** check box has to be checked and blocking cells can be defined by toggling the enter mode with **Add Cells** or **Delete Cells** and clicking on the relevant cell in the diagram. The result might look like:

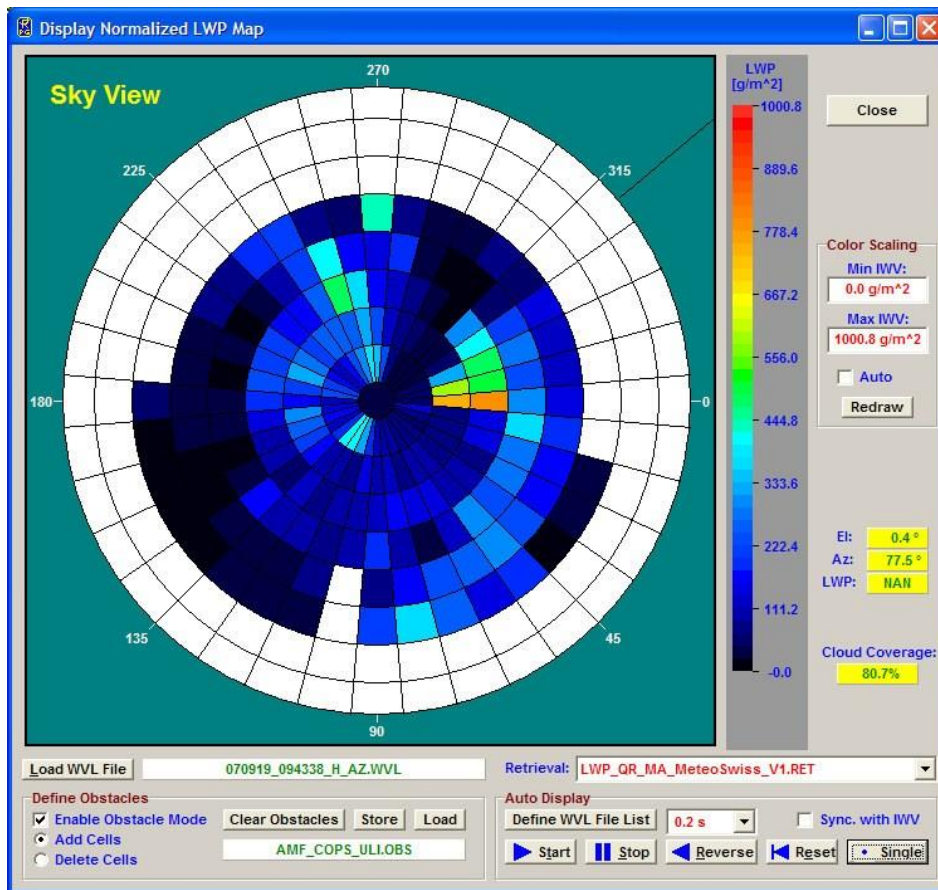


Once a cell is marked as blocked (white colour), the cell's data content is no longer be taken into account for calculations like the displayed 'IWV Variation'. When the cursor is located on a blocked cell, the data content displayed on the right of the diagram is showing 'NaN' which means Not A Number. The obstacle pattern definition can be stored and loaded using the **Store** and **Load** commands.

The colour range for the IWV display is adjusted in the **Colour Scaling** box. For the example above the IWV variation over the full sky is about 1 kg/m².

The full sky scanning feature is typically used every 10 or 15 minutes to monitor changes of the water vapour distribution. Each scan is automatically stored in a separate data file. A 'movie' of the IWV evolution can be displayed by defining the list of *.BRT full sky scanning brightness temperature files with **Define WV File List**. A separate menu opens where the user may select multiple files for auto display. The **Start** button starts the sequence and **Stop** halts it. With **Reverse** the file sequence is processed in reversed


chronological order and **Reset** jumps to the first data file of the list. When the auto display is halted by pressing **Start**, a manual file display progression can be performed by successively clicking **Single**. In auto display mode the pausing interval between successive data file displays can be adjusted by selecting a different time from the combo box.



LWP map indicating cloud coverage.

A similar full sky display diagram is available for LWP data. If the IWV display is also activated, the LWP display is synchronized to the IWV display by checking the **Sync. with IWV** checkbox. Then the file list defined in the IWV full sky display menu is used for both diagrams and the auto display is controlled by the IWV **Auto Display** commands.

4.17 Manual Radiometer Control

When the H-PC is connected to the instrument and the R-PC is in STANDBY- or HALTED-mode, the manual control functions are enabled. Click  (**Manual Radiometer Control**) to enter the **Diagnostics and manual control** menu in Fig.4.21. The reason of implementing these functions is mainly for diagnostic purposes. When a radiometer is assembled, every single electronic component must be tested. The receivers' long term stability is checked for several weeks by monitoring the detector voltages. However, some of the diagnostic functions are also useful for other tasks.

4.17.1 Elevation / Azimuth

The **Elevation / Azimuth** tab sheet is used (for instance) to change the observation angle during a measurement in HALTED mode. If **Reset Position** is checked the stepper is reset to its original position after leaving the diagnostics menu. If the user wishes to keep the new position he must uncheck **Reset Position**.

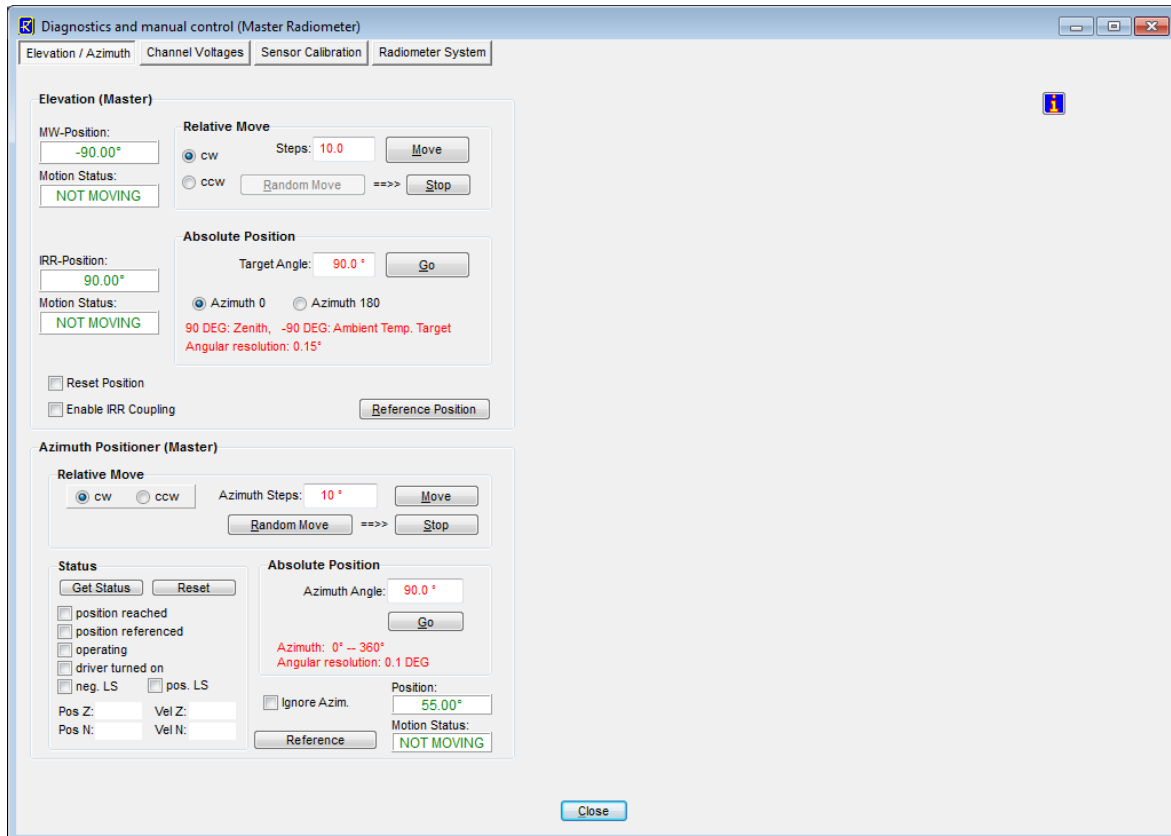


Fig.4.21: The stepper / azimuth scanner control tab sheet.

Elevation stepping positions can be set relative in stepper units (600 units correspond to a full turn) or absolute in DEG. Since the stepper can move to both quadrants of the microwave window, the azimuth angle flips from 0° to 180° when the mirror crosses the zenith direction. The absolute elevation stepper positions are as follows:

- Zenith: +90°
- Horizontal: 0°
- Ambient target: -90°

The angular stepper resolution is 0.6°. The azimuth value of 180° is usually not used (only in Sky Tipping Bilateral Mode). The angle range elevation 0-90°, azimuth=0° is the **active quadrant** and is marked on the outside radiometer housing by a **red arrow**. The **Azimuth** sub-window is only visible if an azimuth controller is connected to the H-PC or R- PC. The same holds for the infrared radiometer elevation sub-window which is only shown if the motorized IRR option is installed.

4.17.2 Channel Voltages

The **Channel Voltages** tab sheet is the main diagnostics tool (Fig.4.22).

Each of the four acquisition channels (not to be mixed up with receiver channels!) can be configured to sample one of the following data sources:

- Receiver 1 detector voltage (1:1)
- Receiver 2 detector voltage (1:1)
- Receiver 1 board temperature ($T = \text{voltage} * 100$ [K])
- Receiver 2 board temperature ($T = \text{voltage} * 100$ [K])
- Ambient target temperature ($T = \text{voltage} * 100$ [K])
- Environmental temperature ($T = \text{voltage} * 100$ [K])
- Barometric pressure ($P = \text{voltage} * 1000$ [mbar])
- Rel. humidity ($H = \text{voltage} * 100$ [%])

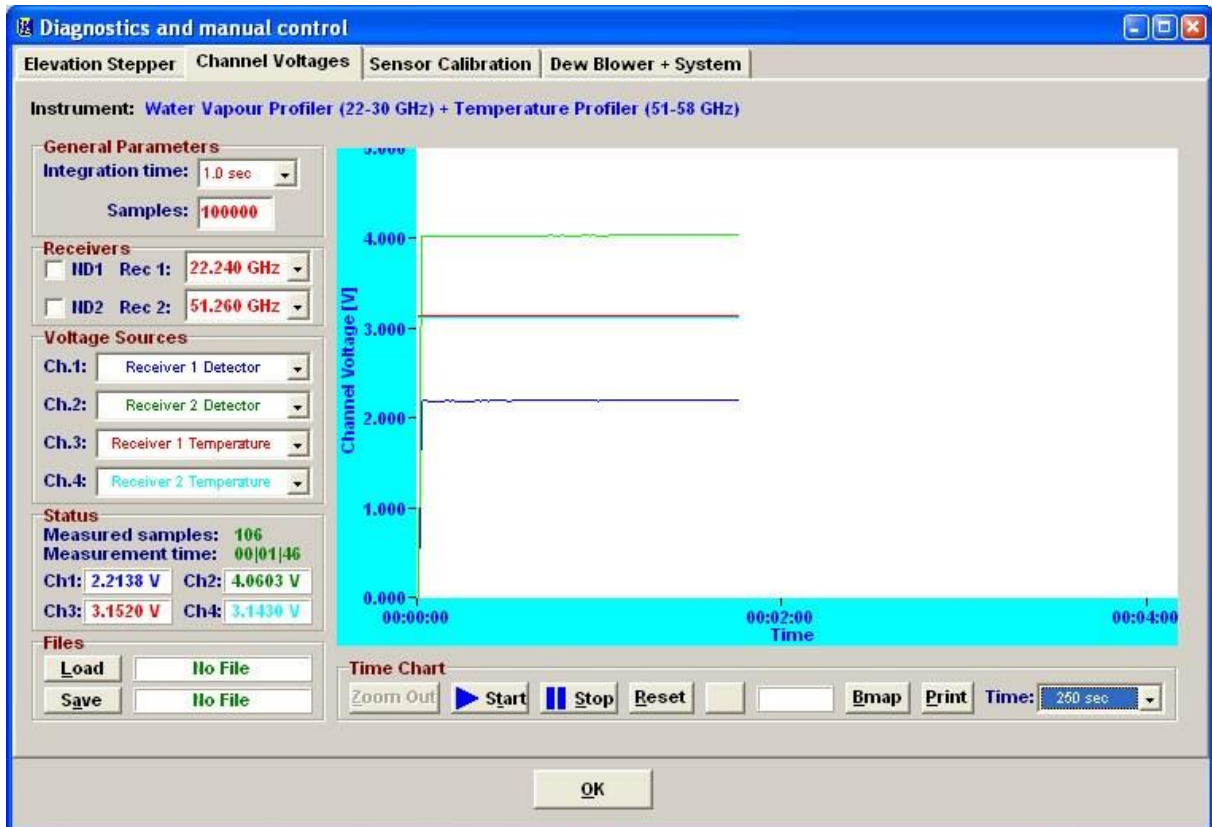


Fig.4.22: Channel voltages tab sheet.

The sample integration time and maximum number of samples are set in **General Parameters**.

While sampling detector voltages, one can manually turn the noise diodes on and off to check for a correct noise source operation (**ND1** and **ND2**). The detector voltage display can be switched to each receiver channel by selecting its frequency from the related fixed frequency list boxes (**Rec 1** and **Rec 2**).



The channel readings are displayed graphically and also in the **Status** frame. Data zooming is possible. After the sampling is halted (**Stop**), a ruler function becomes available to measure the precise voltage at a certain time (⇕).

Reset clears the acquisition display and sets the Y-axis to +5 V (maximum).

4.17.3 Sensor Calibration

This tab sheet is needed to calibrate the thermal sensors, pressure sensor, humidity sensor and infrared sensor. It is not intended for user purposes. The sensor calibration must be performed by qualified personal only and is done before the radiometer delivery.



Fig.4.23: Sensor calibration tab sheet.



4.17.4 Radiometer System

The tab sheet in Fig.4.24 comprises a manual toggle for switching the dew blower's speed to low and maximum (**Speed Toggle** button bottom left) which is intended for testing the blower's and heater's functionality.

A useful feature is the **Restart Radiometer Software** function. When an update of the radiometer software has been performed by transferring a new **RadPC.EXE** file to the radiometer's system file directory, a software reset is required to run the new software version. When clicking on the **Reset Radiometer PC** button a warning message is displayed.

The **Reload Configuration + Shifts** function sends a configuration inquiry to the radiometer which is then displayed in the **Radiometer Configuration** box. The information shown summarizes all specific hardware settings related to the radiometer model and equipment. A modification of these parameters is critical and password protected.

Power Failure Handling can be disabled (**Clear Recovery Mode**) or enabled (**Set Recovery Mode**). When enabled, the power failure handling automatically restarts the measurement on the radiometer after a power failure. When disabled, the radiometer returns to STANDBY mode after the power failure.

It is possible to manually set the radiometer time and date with the **Set Radiometer Time / Date** function after entering the new time and date to the 6 edit boxes in the **Set Time / Date** group box. The current GPS clock time can be read with **Read GPS Time / Date**. A list of visible GPS satellites, together with their individual elevation and azimuth locations, is shown after clicking **GPS Satellite Vectors**.

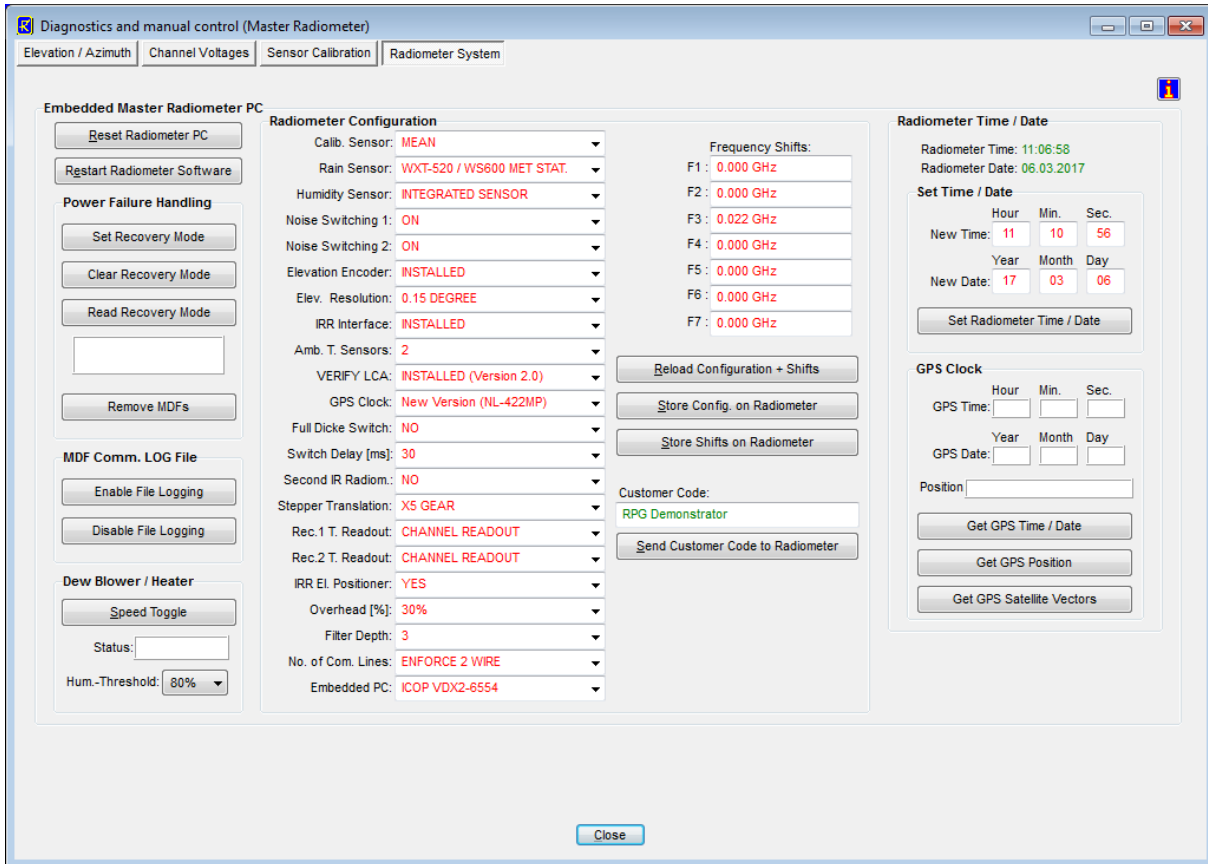


Fig.4.24: Manual control of radiometer configuration, recovery mode, dew blower speed and GPS clock.

4.18 Transform Data Files to ASCII, netCDF and BUFR Format

The standard data file format is binary (file structures listed in Appendix A) because it is more compact than other formats. In the case that a human readable format is required, the binary

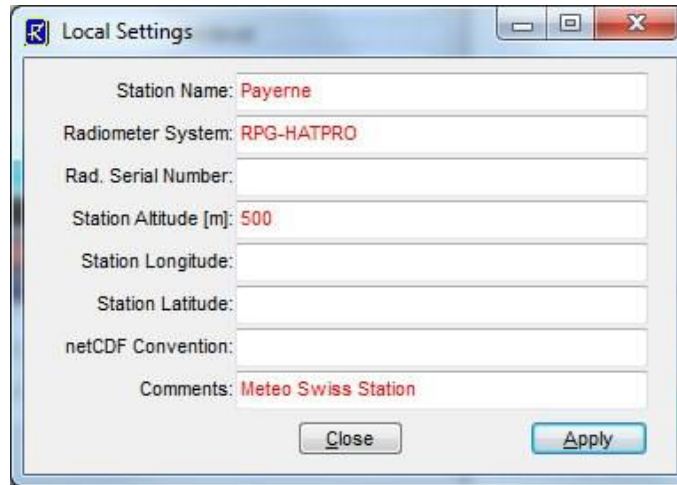
files can be transformed to ASCII. When using the `ASCII` command (**Transform Data Files to ASCII Format**), a binary data file is converted to an ASCII file. The file name of the new file is the binary file name with appended '.ASC', e.g. the humidity profile binary format file **MyFileName.HPC** is converted to **MyFileName.HPC.ASC**.

Beside this manual ASCII file generation, it is possible to automatically store data in ASCII format during the monitoring process (active measurement). See section 4.4 for details.

Examples of ASCII files are described in Appendix B.

Other frequently used data formats are the netCDF and BUFR format developed for archiving atmospheric data. The manual conversion of a binary file to a netCDF or BUFR file is performed with `nc` or `bufr`. The file extension of the converted file is '.NC' ('.BUF' respectively) like in **MyFileName.HPC.NC** (**MyFileName.HPC.BUF** respectively) Automatic conversion to netCDF and / or BUFR formats during measurements is activated in the **Define Directories and Data Formats** menu. Additional useful information added to the netCDF and BUFR file's


global attribute list can be entered by clicking . The **Define Local Settings** menu pops up:



The specified information strings are then added to each netCDF file global attribute list. The 'Station Name' is also added to each BUFR message as a 32 byte character string.

4.19 Auto Viewer

The H-PC software can be used as a measurement data monitor, even if the H-PC is not connected to a radiometer. In this case the data source is a Source Directory, to which data files are transferred. A possible scenario could be a PC that is regularly receiving data files from a server. With the Auto Viewer function, this PC can be configured to show the measurement data samples, contained in the data files, in the same way as if it would receive data from a radiometer in a measurement. It is also possible to define a target directory to store the data files as hourly files. After all data samples of a source file have been displayed, the file is automatically deleted from the Source Directory.

Fig.4.25 shows the **Auto Viewer Setup** menu that can be entered by clicking . It lists the auto viewer's Source Directory where it looks for data files to be displayed. In addition the Target Directory can be defined where the results of the auto viewer process are stored if **Store to Archive** is checked.

The **Product Scan List** summarizes the selected products to be scanned from the Source Directory. The display speed is set between original speed (one sample per second) up to 200 times faster.

The Viewer is activated by clicking **Start Viewer**, halted by clicking **Halt Viewer** and terminated with **Terminate Viewer**. The user can activate the generation of ASCII, netCDF or BUFR format data files by checking the respective format(s) in the **Data Directory Menu**.

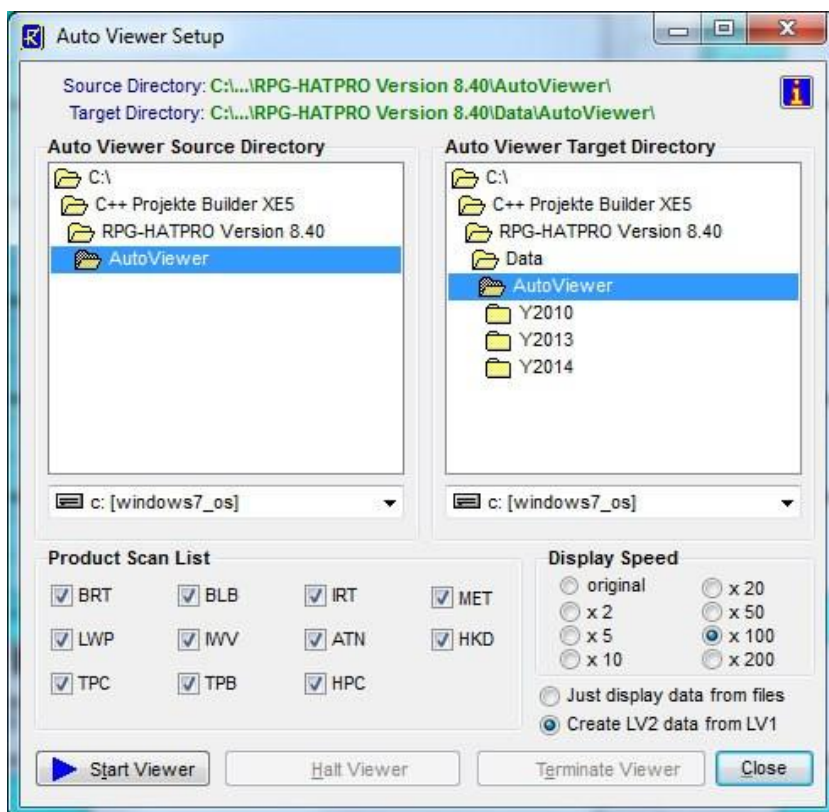



Fig.4.25: Auto Viewer Setup menu.

4.20 Current Sample Files

During measurements data files are automatically generated on an hourly basis when UNLIMITED mode is selected. This implies that data updates are available with a delay of 60 minutes maximum when the files are remotely downloaded from the H-PC (e.g. by an ftp server). Sometimes it is desirable to get updates more frequently. This is realized in the following way:

Enter the **Define Continuous File Generation of Current Samples** menu (). A product list is displayed as shown in Fig.4.26. For each product a separate file interval is defined. This interval determines the file length of the current samples file. E.g. with a file interval of 10 minutes for BRT, a new file **CSYYMMDDHHmm.BRT** is created every 10 minutes (YY=Year, MM=Month, DD=Date, HH=Hour, mm=Minute of the date / time centred to the current CS file interval) and stored to the directory shown in the **File Directory** box to the left. The data in the current data files is averaged by selecting a shifting average number (measured in samples). Integration times / sample and retrievals are taken from the MDF products definition menu.

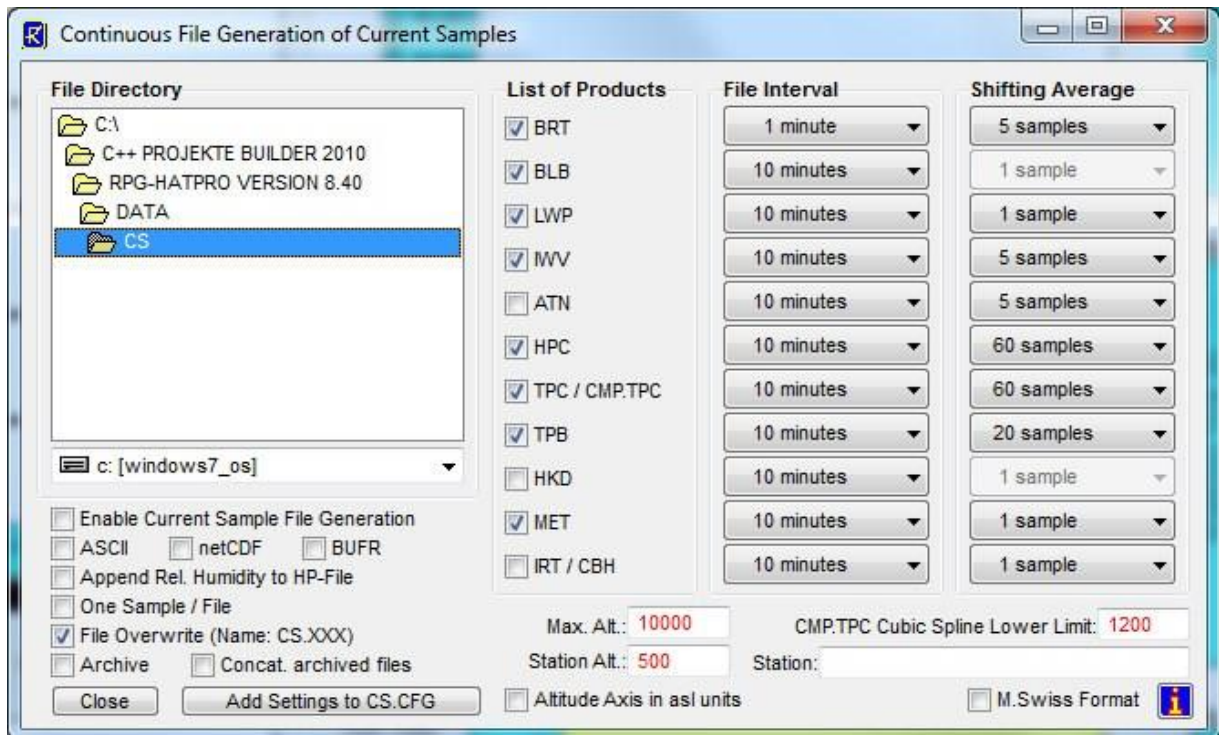


Fig.4.26: Current Samples menu showing the product list with individual file repetition and shift average settings.

The current sample file generation is activated by checking **Enable Current Sample File Generation**. The **CSYYMMDDHhmm.XXX** file format is identical to the standard binary file format of the products. Automatic ASCII file generation is enabled with **Add ASCII File**. For CS Files the relative humidity can be blocked to be appended to absolute humidity files by un-checking **Append Rel. Humidity to HP-File**.

If **One Sample / File** is activated, the program stores only the latest sample of a file interval in the CS-file. The only exception is the *.HKD CS file which is not affected by this flag.

When checking **File Overwrite (Name:CS.XXX)**, the program does not use the **CSYYMMDDHhmm.XXX** file convention. Instead, only **CS.XXX** file names are created, overwriting older files by the newest one.

When both 'Temperature Profiles (full troposphere)' and 'Temperature Profiles (boundary layer)' are selected from the list of products, a **CS.COM.TPC** file is automatically produced.

This file contains a composite temperature profile combined from the two **CS.TPC** and **CS.TPB** files. The temperature values below 1200 m altitude are identical in **CS.COM.TPC** and **CS.TPB** and the same holds for the temperature values above 2000 m which are identical in **CS.COM.TPC** and **CS.TPC**. In the altitude range 1200 m to 2000 m, the **CS.COM.TPC** file temperature values are generated from a cubic spline fit to smoothly join both profiles in **CS.TPC** and **CS.TPB**. The cubic spline interpolation ensures that the first and second derivatives are continuous with the two original profiles.

4.21 The License Manager

RPG's radiometers are delivered with a preliminary limited license of 30 days. Without activating an unlimited license, the radiometer stops operation when the limited license is expired. The common procedure to avoid this is the following:

Invoke the **License Manager** by clicking the  button. The menu in Fig.4.32 pops up.

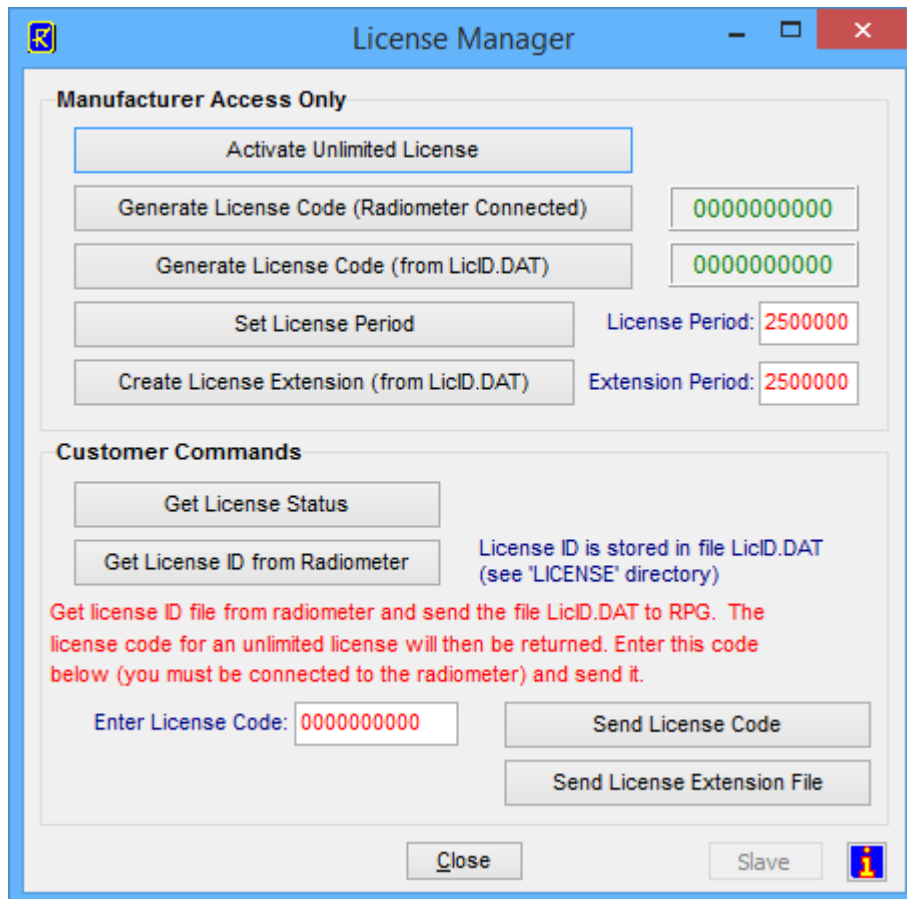


Fig.4.32 : License manager menu.


The user retrieves license status information with the **Get License Status** command. The license type (limited or unlimited) as well as the expiration date and time will be displayed. In order to obtain an unlimited license, the following steps have to be performed:

1. Connect to the radiometer and click the **Get License ID from Radiometer** button. The license ID code is then written to the file 'LicID.DAT' stored in the radiometer root directory (the directory where R2CH.EXE is located).
2. Send the 'LicID.DAT' file to RPG (by e-mail to remotesensing-service@radiometer-physics.de). Then the 10 digit license code will be returned (also by e-mail).
3. Enter the 10 digit license code into the edit box in the license manager and click Send License Code. The license manager will inform the user if the unlimited license installation was successful or not. If not successful, please contact RPG again.

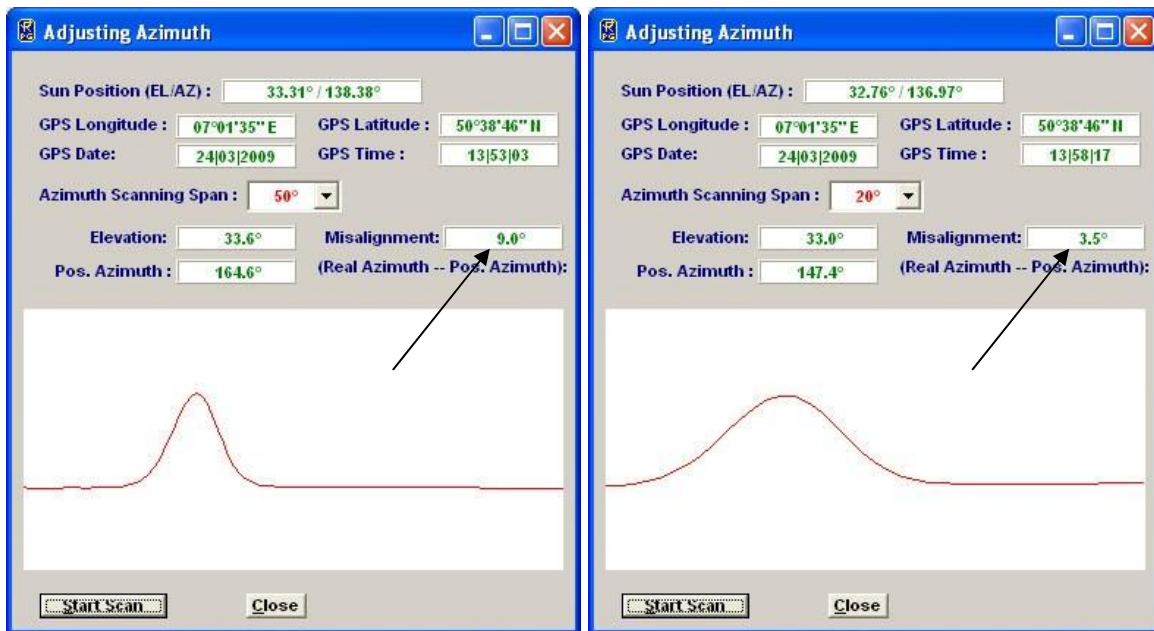


4.22 Adjusting Azimuth Positioner Direction

The H-PC software includes the possibility of precisely adjusting the azimuth scanner's zero index position to North direction. This is useful for volume scans or when different instruments shall be aligned to the same scanning directions. The described method assumes that the instrument stand is horizontally aligned (see Installation Manual).

The azimuth adjustment menu is entered with the  command, as shown in Fig.4.33. The H-PC software calculates the sun position in elevation and azimuth from the GPS position and UTC time available from the GPS clock. The radiometer stand should be pre-adjusted so that the azimuth scanner's zero position is pointing to North with an accuracy of better than 30°. This can be easily achieved with a standard low cost compass.

The user should start the adjustment procedure with a relatively wide azimuth scanning span (e.g. $\geq 50^\circ$) and start the scan (click **Start Scan**) as shown in the upper left corner of Fig.4.33. After the scan is finished, the misalignment between the real north direction and the scanner's north direction is printed in the 'Misalignment' box. A positive misalignment indicates that the stand is directed towards the West and should be rotated eastwards. In an iterative process like indicated in Fig.4.33, the stand's orientation can be adjusted to the real North with an accuracy of better than 0.5°.



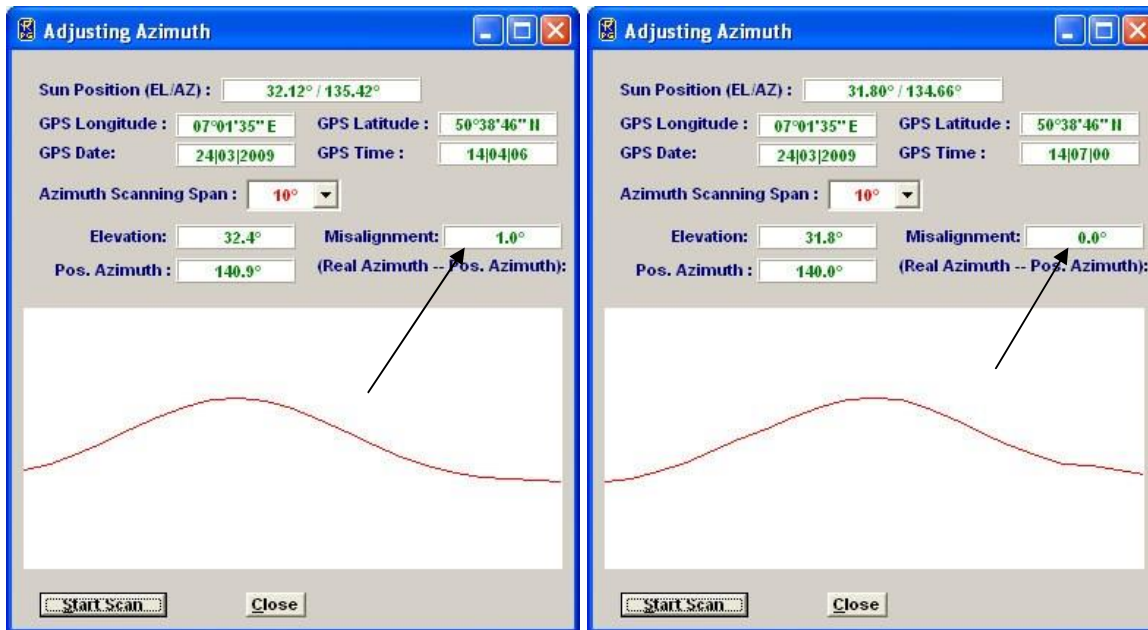



Fig.4.33: Azimuth angle adjustment using the sun position.

The radiometer uses the detector voltage of the first channel of receiver 1, if present (e.g. the 22.24 GHz channel in a RPG-HATPRO radiometer), otherwise it takes the first channel of receiver 2 (e.g. in the RPG-TEMPRO radiometer).

4.23 Software Updates

Assumption: You want to install a new radiometer software version (RadPC.EXE) on the embedded R- PC and a new version of R2CH.EXE on the H-PC.

1. Step: Save the old software versions

- a) Create a directory to save the old software versions (e.g. C:\MyPath \SAVE).
- b) Connect the H-PC to the radiometer and enter the File Transfer Menu (, Fig.4.34b). On the left side (H-PC) browse to the directory for saving the files (e.g. C:\MyPath\SAVE) and on the right side (R-PC) mark the file 'RadPC.EXE' in the 'RPG-Radiometer' Directory (see fig.4.34b). Then click **Copy Selected Files** to initiate the copy process.
- c) Locate the R2CH.EXE file in the MyPath\ RPG-HATPRO directory and copy this file to the C:\MyPath \SAVE directory (by using the Operating System Explorer).

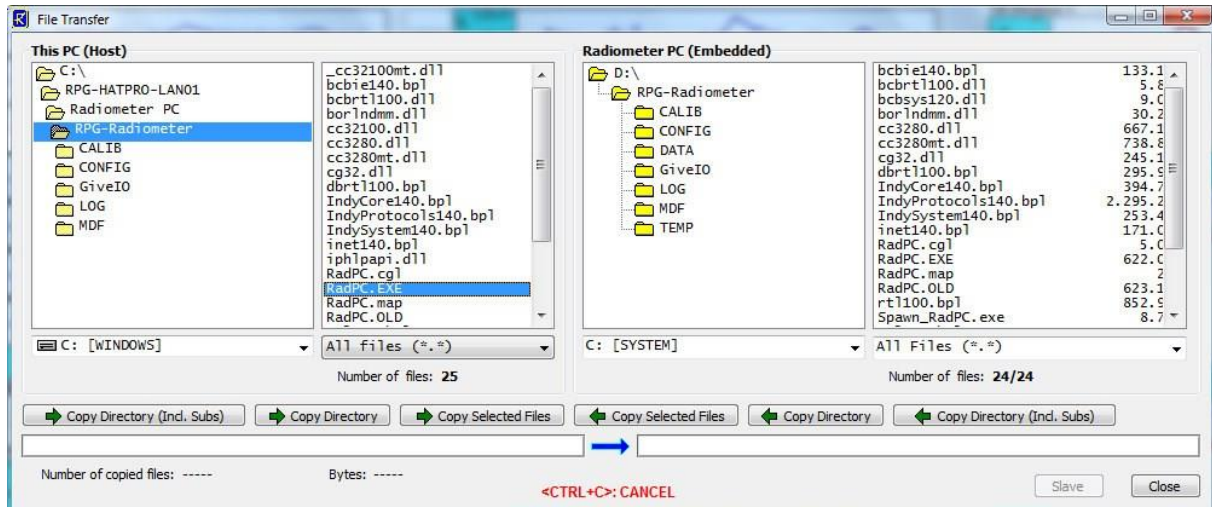




Fig.4.34b: File Transfer Menu (G4 radiometers)

2. Step: Overwrite the old versions by the new ones

- a) Copy the new version of RadPC.EXE (the R-PC software) on an arbitrary directory on your hard disk (e.g. MyPath\RPG-HATPRO\Radiometer PC). Then enter the file transfer menu in Fig.4.34b and browse to that directory. Mark the RadPC.EXE file in the file list and copy it to the 'RPG-Radiometer' directory on the R-PC (click **Copy Selected Files**). Because you are now going to overwrite a file in the radiometer's System Files Directory (which is password protected for write access) a password entry window pops up. Please enter the Administrator password.
- e) Restart the radiometer software to make the new RadPC.EXE the running version. You can do this by
 - entering the Manual Control Menu () and selecting the "Radiometer System" tag. Click **Restart Radiometer Software** and confirm the command with 'YES'. Wait for about 1 minute to give the restart process time enough to finish.
- f) Terminate R2CH.EXE and overwrite the old R2CH.EXE in MyPath\ RPG-HATPRO with the new version.
- g) Execute R2CH.EXE to start the new H-PC version and reconnect to the radiometer with .

The software upgrade is finished. You can confirm the successful upgrade by reading the software version numbers of both, the embedded R-PC (see main window radiometer status display) and the H-PC (see main window caption).

4.24 Automatic E-Mail Warning Messages

While a measurement is running, several events that may occur are of major interest for the user. These events could be:

- Hardware malfunction of a radiometer component
- Freezing of the Host software for unknown reason
- A user has forgotten to click the **Continue** button when pausing the measurement
- The Host has lost the connection to the radiometer

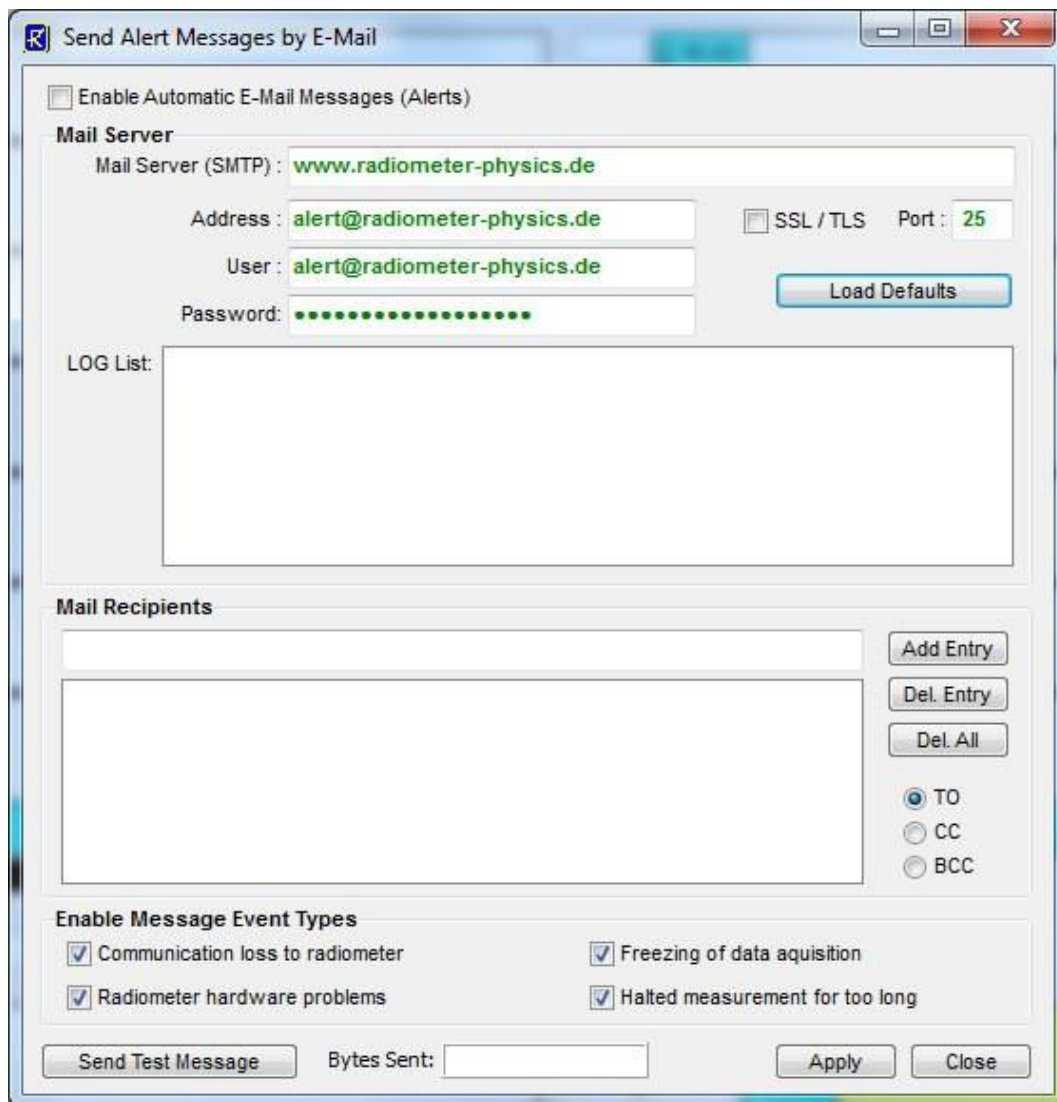



Fig.4.35: Menu for defining automatic E-Mail warning messages.

The host SW offers the possibility to send automatic e-mails to pre-defined addresses via a built-in SMTP server. Click  to enter the SMTP server menu.

The first step is to define the SMTP server details. The user may configure a server of his choice (enter the server, a user address with user and password and the port number for the



server) or simply click **Load Defaults** to use the RPG mail server for this purpose (indicated in Fig.4.35).

Then enter the address of a mail recipient as a message target and add it to the mail list (**Add Entry**). Before adding an address, the copy status may be selected (TO, CC, BCC). The message types can be enabled or disabled separately. Mail server settings, the mailing list and event types are stored permanently by clicking **Apply**.

The communication may be tested by sending a test message (**Send Test Message**). Automatic e-mails must be enabled by checking **Enable Automatic E-Mail Messages (Alerts)**.

4.25 Data Server

In some applications an immediate data access is required (within seconds) so that the concept of 'Current Sample Files' (section 4.20) is not sufficient, even when a file period of one minute is selected. The solution is to communicate with the data server of the host software via Ethernet.

The following assumes that the host PC is connected to a network and is assigned a valid IP address (IP-A). The data server can be reached through port no 7000, thus **IP-A : 7000**.

A data stream sent to the server starts with a single byte representing the command to be executed by the server. This is the list of currently implemented commands (data transfer commands in blue, MDF commands in red and control commands in green):

Code	Description
170	SEND_LEV1_DATA : Request to send the current level 1 data (brightness temp. data)
171	SEND_LEV2_DATA : Request to send the current level 2 data (atmospheric data)
172	SEND_HKD_DATA : Request to send housekeeping data
173	SEND_RAD_STAT : Request to send the radiometer status information
174	SEND_MET_DATA : Request to send surface sensor data
175	DS_TERM_MEAS : Terminates the currently running measurement
176	DS_START_MEAS : Starts a new MDF / MBF
177	DS_SET_FLAGS : Specifies operation flags
178	DS_MOV_EL_AZ : Point the radiometer beam(s) to a certain elevation and azimuth angle
179	DS_TAKE_SAMP : Measures a one second sample and calculates LV2 data
180	DS_CLR_RET_TABLE : Deletes all entries in retrieval table
181	DS_SEL_RET: Selects a retrieval into retrieval table
182	DS_RUN_CAL: Starts an automatic calibration (1P, 2P, Sky Tipping)
183	DS_UPDATE_STAT: Updates radiometer status information
184	DS_UPDATE_HKD: Updates housekeeping data sample

Table 4.1: List of data server commands



The command byte is followed by a 4 byte password code (PWC). The PWC represents the user password defined on the radiometer PC (can be set by the Administrator, see section 4.2.2.4). The PWC is calculated the following way:

1. The password is first converted to uppercase
2. The PWC is then the sum of the ASCII code of each character multiplied by the square of its position in the password

Example: The User Password shall be 'RadUser'. Then the PWC is:

$$PWC = 1 * 'R' + 4 * 'A' + 9 * 'D' + 16 * 'U' + 25 * 'S' + 36 * 'E' + 49 * 'R' = 10891$$

With 'R' = 82 (ASCII code of character R), etc.

The PWC must be sent as little endian (least significant byte first), which is the standard for Microsoft operating systems. The correct byte sequence for a level 2 data request with user password 'RadUser' would be (decimal): 171 139 42 0 0.

If there is no user password activated on the radiometer PC, the PWC is not evaluated by the server and can be an arbitrary 4 byte integer number. Note, that even in this case an arbitrary 4 byte PWC must be sent (for example four zero bytes).

When a user password is activated, the PWC will be evaluated. Does the PWC match the user password code on the radiometer, the server responds with the repetition of the command code (if the command code represents a valid command) followed by the requested data block. If the PWC does not match, the server only responds with the PW_ERROR byte (0xFF = 255). When an invalid command code is sent, the server responds with a single INVALID_COM (0xFD = 253) byte.

When a valid command byte followed by the correct PWC was sent to the server, the first response byte is the command byte (as a confirmation) followed by the data block which is described in the following sections.

4.25.1 SEND_LEV1_DATA command (170)

This command is used to retrieve the current brightness temperature data samples. The data block is structured as follows:

Variable Name	Type	# Bytes	Description
TotLength	int	4	Total length of the data block in bytes
Flags	byte	1	the byte codes the availability of different level 1 data types. If the corresponding bit is set (=1), the data type is available: Bit 1: BRT Bit 2: SPC Bit 3: BLB Bit 4: IRT
Length(1)	int	4	length of the following BRT block in bytes
BRT_Time(1)	int	4	time of BRT sample (seconds since 1.1.2001, 00:00:00)
BRT_RF(1)	char	1	rain flag of BRT sample
BRT_NoFrq ⁽¹⁾	int	4	number of BRT channels



BRT_EI ⁽¹⁾	float	4	elevation angle [DEG]
BRT_Az ⁽¹⁾	float	4	azimuth angle [DEG]
BRT_Frq[] ⁽¹⁾	float	4 x BRT_NoFrq	array of frequency channels [GHz]
BRT_TBs[] ⁽¹⁾	float	4 x BRT_NoFrq	array of brightness temperatures [K]
Length ⁽²⁾	int	4	length of the following SPC block in bytes
SPC_Time ⁽²⁾	int	4	time of SPC sample (seconds since 1.1.2001, 00:00:00)
SPC_RF ⁽²⁾	char	1	rain flag of SPC sample
SPC_NoFrq ⁽²⁾	int	4	number of spectrum channels
SPC_EI ⁽²⁾	float	4	elevation angle [DEG]
SPC_Az ⁽²⁾	float	4	azimuth angle [DEG]
SPC_Frq[] ⁽²⁾	float	4 x SPC_NoFrq	array of frequency channels in spectrum [GHz]
SPC_TBs[] ⁽²⁾	float	4 x SPC_NoFrq	array of brightness temperatures in spectrum [K]
Length ⁽³⁾	int	4	length of the following BLB block in bytes
BLB_Time ⁽³⁾	int	4	time of BLB sample (seconds since 1.1.2001, 00:00:00)
BLB_RF ⁽³⁾	char	1	rain flag of BLB sample
BLB_NoFrq ⁽³⁾	int	4	number of channels in BL scan
BLB_NoAng ⁽³⁾	int	4	number of angles in BL scan
BLB_Az ⁽³⁾	float	4	azimuth angle [DEG] of BL scan
BLB_Frq[] ⁽³⁾	float	4 x BLB_NoFrq	array of frequency channels in BL scan [GHz]
BLB_Ang[] ⁽³⁾	float	4 x BLB_NoAng	array of angles in BL scan [DEG]
BLB_TBs[] ⁽³⁾	float	4 x BLB_NoFrq x BLB_NoAng	array of brightness temperatures in BL scan. List of scanned TBs for each channel [K]
Length ⁽⁴⁾	int	4	length of the following IRT block in bytes
IRT_Time ⁽⁴⁾	int	4	time of IRT sample (seconds since 1.1.2001, 00:00:00)
IRT_RF ⁽⁴⁾	char	1	rain flag of IRT sample
IRT_NoChn ⁽⁴⁾	int	4	number of IRT channels
IRT_EI ⁽⁴⁾	float	4	elevation angle [DEG]
IRT_Az ⁽⁴⁾	float	4	azimuth angle [DEG]
IRT_TBs[] ⁽⁴⁾	float	4 x IRT_NoChn	array of IR brightness temperatures [°C]

⁽¹⁾ only if Bit 1 of Flags byte is set, ⁽²⁾ only if Bit 2 of Flags byte is set ⁽³⁾ ⁽⁴⁾ only if Bit 3 of Flags byte is set, only if Bit 4 of Flags byte is set

The '**Length**' parameter can be used to efficiently skip over data that is not of interest. For instance, if only the IR temperature shall be loaded and all four data types are available (coded in the Flags byte), the BRT block can be skipped by reading its **Length** and adding it to the current data stream pointer. This will lead to the position of the SPC block **Length**



parameter. Reading it and adding this value to the current data stream pointer will lead to the position of the BLB **Length** parameter and so on.

Please note that the data blocks for BRT, SPC, BLB and IRT are only present in the data stream if the corresponding bit in the **Flags** byte is set to 1, as indicated by the footnotes in the structure table.

4.25.2 SEND_LEV2_DATA command (171)

This command is used to retrieve the current atmospheric data samples. The data block is structured as follows:

Variable Name	Type	# Bytes	Description
TotLength	int	4	Total length of the data block in bytes
Flags	word	2	the WORD codes the availability of different level 2 data types. If the corresponding bit is set (=1), the data type is available: Bit 1: LWP, liquid water path Bit 2: IWV, integrated water vapour Bit 3: CBH, cloud base height Bit 4: BLH, BL height Bit 5: TPB, BL temp. profile Bit 6: TPC, zenith temp. profile Bit 7: HPC, absolute humidity profile Bit 8: RHP, rel. humidity profile Bit 9: LPR, cloud liquid profile Bit 10: ATN, attenuation of meas. chan. Bit Bit 11: ATS, spectrum attenuation Bit 12: HOV, Hovmöller conical scan Bit 13: M2D, 2D scan Bit 14: TRK, satellite tracking Bit 15: DLY, wet / dry delay
Length ⁽¹⁾	int	4	length of the following LWP block in bytes
LWP_Time ⁽¹⁾	int	4	time of LWP sample (seconds since 1.1.2001, 00:00:00)
LWP_RF ⁽¹⁾	char	1	rain flag of LWP sample
LWP_EI ⁽¹⁾	float	4	elevation angle [DEG]
LWP_Az ⁽¹⁾	float	4	azimuth angle [DEG]
LWP ⁽¹⁾	float	4	LWP value [g/m ²]
Length ⁽²⁾	int	4	length of the following IWV block in bytes



IWV_Time ⁽²⁾	int	4	time of IWV sample (seconds since 1.1.2001, 00:00:00)
IWV_RF ⁽²⁾	char	1	rain flag of IWV sample
IWV_EI ⁽²⁾	float	4	elevation angle [DEG]
IWV_Az ⁽²⁾	float	4	azimuth angle [DEG]
IWV ⁽²⁾	float	4	IWV value [kg/m ²]
Length ⁽³⁾	int	4	length of the following CBH block in bytes
CBH_Time ⁽³⁾	int	4	time of CBH sample (seconds since 1.1.2001, 00:00:00)
CBH_RF ⁽³⁾	char	1	rain flag of CBH sample
CBH ⁽³⁾	float	4	CBH value [m]
Length ⁽⁴⁾	int	4	length of the following BLH block in bytes
BLH_Time ⁽⁴⁾	int	4	time of BLH sample (seconds since 1.1.2001, 00:00:00)
BLH_RF ⁽⁴⁾	char	1	rain flag of BLH sample
BLH ⁽⁴⁾	float	4	BLH value [m]
Length ⁽⁵⁾	int	4	length of the following TPB block in bytes
TPB_Time ⁽⁵⁾	int	4	time of TPB sample (seconds since 1.1.2001, 00:00:00)
TPB_RF ⁽⁵⁾	char	1	rain flag of TPB sample
TPB_No ⁽⁵⁾	int	4	number of altitude layers
TPB_Alt[] ⁽⁵⁾	float	4 x TPB_No	array of altitudes [m]
TPB_Ts[] ⁽⁵⁾	float	4 x TPB_No	array of temperatures at alt. levels
Length ⁽⁶⁾	int	4	length of the following TPC block in bytes
TPC_Time ⁽⁶⁾	int	4	time of TPC sample (seconds since 1.1.2001, 00:00:00)
TPC_RF ⁽⁶⁾	char	1	rain flag of TPC sample
TPC_No ⁽⁶⁾	int	4	number of altitude layers
TPC_Alt[] ⁽⁶⁾	float	4 x TPC_No	array of altitudes [m]
TPC_Ts[] ⁽⁶⁾	float	4 x TPC_No	array of temperatures at alt. levels
Length ⁽⁷⁾	int	4	length of the following HPC block in bytes
HPC_Time ⁽⁷⁾	int	4	time of HPC sample (seconds since 1.1.2001, 00:00:00)
HPC_RF ⁽⁷⁾	char	1	rain flag of HPC sample
HPC_No ⁽⁷⁾	int	4	number of altitude layers
HPC_Alt[] ⁽⁷⁾	float	4 x HPC_No	array of altitudes [m]
HPC_H[] ⁽⁷⁾	float	4 x HPC_No	array of abs. humidity [g/m ³]
Length ⁽⁸⁾	int	4	length of the following RHP block in bytes
RHP_Time ⁽⁸⁾	int	4	time of RHP sample (seconds since 1.1.2001, 00:00:00)
RHP_RF ⁽⁸⁾	char	1	rain flag of RHP sample
RHP_No ⁽⁸⁾	int	4	number of altitude layers



RHP_Alt[] ⁽⁸⁾	float	4 x RHP_No	array of altitudes [m]
RHP_RH[] ⁽⁸⁾	float	4 x RHP_No	array of rel. humidity [%]
Length ⁽⁹⁾	int	4	length of the following LPR block in bytes
LPR_Time ⁽⁹⁾	int	4	time of LPR sample (seconds since 1.1.2001, 00:00:00)
LPR_RF ⁽⁹⁾	char	1	rain flag of LPR sample
LPR_No ⁽⁹⁾	int	4	number of altitude layers
LPR_Alt[] ⁽⁹⁾	float	4 x LPR_No	array of altitudes [m]
LPR [] ⁽⁹⁾	float	4 x LPR_No	array of liquid content [g/m ³]
Length ⁽¹⁰⁾	int	4	length of the following ATN block in bytes
ATN_Time ⁽¹⁰⁾	int	4	time of ATN sample (seconds since 1.1.2001, 00:00:00)
ATN_RF ⁽¹⁰⁾	char	1	rain flag of ATN sample
ATN_No ⁽¹⁰⁾	int	4	number of channels
ATN_El ⁽¹⁰⁾	float	4	elevation angle [DEG]
ATN_Az ⁽¹⁰⁾	float	4	azimuth angle [DEG]
ATN_Frq[] ⁽¹⁰⁾	float	4 x ATN_No	array of frequency channels [GHz]
ATN [] ⁽¹⁰⁾	float	4 x ATN_No	array of attenuations [dB]
Length ⁽¹¹⁾	int	4	length of the following ATS block in bytes
ATS_Time ⁽¹¹⁾	int	4	time of ATS sample (seconds since 1.1.2001, 00:00:00)
ATS_RF ⁽¹¹⁾	char	1	rain flag of ATS sample
ATS_No ⁽¹¹⁾	int	4	number of channels
ATS_El ⁽¹¹⁾	float	4	elevation angle [DEG]
ATS_Az ⁽¹¹⁾	float	4	azimuth angle [DEG]
ATS_Frq[] ⁽¹¹⁾	float	4 x ATS_No	array of frequency channels [GHz]
ATS [] ⁽¹¹⁾	float	4 x ATS_No	array of attenuations [dB]
Length ⁽¹²⁾	int	4	length of the following HOV block in bytes
HOV_Time ⁽¹²⁾	int	4	time of HOV sample (seconds since 1.1.2001, 00:00:00)
HOV_No ⁽¹²⁾	int	4	number of samples in Hovmöller scan
HOV_El ⁽¹²⁾	float	4	elevation angle [DEG] of Hovmöller sc.
HOV_StaAz ⁽¹²⁾	float	4	azimuth start angle [DEG]
HOV_StpAz ⁽¹²⁾	float	4	azimuth stop angle [DEG]
HOV_IncAz ⁽¹²⁾	float	4	azimuth increment angle [DEG]
HOV_Msk ⁽¹²⁾	byte	1	flag byte for availability of: Bit 1: IWV scan Bit 2: LWP scan Bit 3: IRT scan
HOV_IWV ⁽¹²⁾	float	4 x HOV_No	array of IWVs in scan (only if Bit 1 in HOV_Msk is set)



HOV_LWP ⁽¹²⁾	float	4 x HOV_No	array of LWPs in scan (only if Bit 2 in HOV_Msk is set)
HOV_IRT ⁽¹²⁾	float	4 x HOV_No	array of IRTs in scan (only if Bit 3 in HOV_Msk is set)
Length ⁽¹³⁾	int	4	length of the following M2D block in bytes
M2D_Time ⁽¹³⁾	int	4	time of M2D sample (seconds since 1.1.2001, 00:00:00)
M2D_No ⁽¹³⁾	int	4	number of samples in M2D scan
M2D_StaEI ⁽¹³⁾	float	4	elevation start angle [DEG]
M2D_StpEI ⁽¹³⁾	float	4	elevation stop angle [DEG]
M2D_IncEI ⁽¹³⁾	float	4	elevation increment angle [DEG]
M2D_StaAz ⁽¹³⁾	float	4	azimuth start angle [DEG]
M2D_StpAz ⁽¹³⁾	float	4	azimuth stop angle [DEG]
M2D_IncAz ⁽¹³⁾	float	4	azimuth increment angle [DEG]
M2D_Msk ⁽¹³⁾	byte	1	flag byte for availability of: Bit 1: IWV scan Bit 2: LWP scan Bit 3: IRT scan
M2D_IWV ⁽¹³⁾	float	4 x M2D_No	array of IWVs in scan (only if Bit 1 in M2D_Msk is set)
M2D_LWP ⁽¹³⁾	float	4 x M2D_No	array of LWPs in scan (only if Bit 2 in M2D_Msk is set)
M2D_IRT ⁽¹³⁾	float	4 x M2D_No	array of IRTs in scan (only if Bit 3 in M2D_Msk is set)
Length ⁽¹⁴⁾	int	4	length of the following TRK block in bytes
TRK_Time ⁽¹⁴⁾	int	4	time of TRK sample (seconds since 1.1.2001, 00:00:00)
TRK_RF ⁽¹⁴⁾	char	1	rain flag of TRK sample
TRK_Typ ⁽¹⁴⁾	char	1	satellite type (e.g. 'G' for Galileo)
TRK_No ⁽¹⁴⁾	int	4	satellite number
TRK_EI ⁽¹⁴⁾	float	4	satellite elevation angle [DEG]
TRK_Az ⁽¹⁴⁾	float	4	satellite azimuth angle [DEG]
TRK_Del ⁽¹⁴⁾	float	4	path wet delay [mm]
Length ⁽¹⁵⁾	int	4	length of the following DLY block in bytes
DLY_Time ⁽¹⁵⁾	int	4	time of IDLY sample (seconds since 1.1.2001, 00:00:00)
DLY_RF ⁽¹⁵⁾	char	1	rain flag of DLY sample
IDLY_EI ⁽¹⁵⁾	float	4	elevation angle [DEG]
DLY_Az ⁽¹⁵⁾	float	4	azimuth angle [DEG]
IDLY_WET ⁽¹⁵⁾	float	4	Wet delay [mm]
DLY_DRY ⁽¹⁵⁾	float	4	Dry delay [mm]

⁽ⁱ⁾ only if Bit i of Flags word is set



4.25.3 SEND_HKD_DATA command (172)

This command is used to retrieve the current housekeeping data sample. The data block is structured as follows:

Variable Name	Type	# Bytes	Description
TotLength	int	4	Total length of the data block in bytes
Available	byte	1	=0: no HKD sample available =1: HKD sample available
HKD_Time	int	4	time of HKD sample (seconds since 1.1.2001, 00:00:00)
HKD_Alarm	byte	1	=0: no alarm, =1: alarm condition
Flags	byte	1	the byte codes the availability of different HKD types. If the corresponding bit is set (=1), the HKD type is available: Bit 1: GPS coordinates Bit 2: system temperatures Bit 3: temp. stability Bit 4: flash disk capacity Bit 5: quality flags Bit 6: digital flags
HKD_Long ⁽¹⁾	float	4	GPS longitude
HKD_Lat ⁽¹⁾	float	4	GPS latitude
HKD_Amb1T ⁽²⁾	float	4	temp. of ambient target sensor 1 [K]
HKD_Amb2T ⁽²⁾	float	4	temp. of ambient target sensor 2 [K]
HKD_Rec1T ⁽²⁾	float	4	temp. of receiver 1 [K]
HKD_Rec2T ⁽²⁾	float	4	temp. of receiver 2 [K]
HKD_Rec1St ⁽³⁾	float	4	temp. stability of receiver 1 [K]
HKD_Rec2St ⁽³⁾	float	4	temp. stability of receiver 2 [K]
HKD_DskCap ⁽⁴⁾	int	4	free flash disk capacity [MB]
HKD_Qual ⁽⁵⁾	int	4	quality flag DWORD (see appendix A19)
HKD_Dig ⁽⁶⁾	int	4	digital status flag DWORD (see appendix A19)

⁽¹⁾ only if Bit 1 of Flags byte is set, ⁽²⁾ only if Bit 2 of Flags byte is set ⁽³⁾

⁽⁴⁾ only if Bit 3 of Flags byte is set, only if Bit 4 of Flags byte is set ⁽⁵⁾

⁽⁶⁾ only if Bit 5 of Flags byte is set, only if Bit 6 of Flags byte is set

4.25.4 SEND_RAD_STAT command (173)

This command is used to retrieve the current radiometer status. The data block is structured as follows:



Variable Name	Type	# Bytes	Description
TotLength	int	4	Total length of the data block in bytes
RAD_Time	int	4	radiometer time (seconds since 1.1.2001, 00:00:00)
RAD_Stat	byte	1	=0: STANDBY =1: measurement running =2: calibrating =3: measurement halted =4: absolute calibration running =14: astro tracking active =15: waiting for trigger =100: BREAK detected
Cal_Stat	byte	1	Bit 1: BL scan ON/OFF Bit 2: 1-point calibration ON/OFF Bit 3: 2-point calibration ON/OFF Bit 4: sky tipping ON/OFF
Axis_Stat	byte	1	Bit 1: int. elev. axis moving ON/OFF Bit 2: IRR elev. axis moving ON/OFF Bit 3: local azim. axis moving ON/OFF Bit 4: host azim. axis moving ON/OFF Bit 5: ext. elev. axis moving ON/OFF
MW_Int_EI	float	4	internal elevation angle [DEG]
MW_Ext_EI	float	4	external elevation angle [DEG]
IRR_EI	float	4	IRR elevation angle [DEG]
Azimuth	float	4	azimuth angle [DEG]
BatFn_Len ⁽¹⁾	int	4	length of batch filename (including string end char 0)
BatFn[] ⁽¹⁾	char	BatFn_Len	batch filename char array
MDFFn_Len ⁽¹⁾	int	4	length of current MDF filename (including string end char 0)
MDFFn[] ⁽¹⁾	char	MDFFn_Len	current MDF filename char array
MeasFn_Len ⁽¹⁾	int	4	length of measurement filename (including string end char 0)
MeasFn[] ⁽¹⁾	char	MeasFn_Len	measurement filename char array
BatRep ⁽¹⁾	int	4	total number of batch repetitions
CurrBatRep ⁽¹⁾	int	4	current batch repetition
FileBackup ⁽¹⁾	char	1	file backup ON/OFF
MeasStaTime ⁽¹⁾	int	4	measurement start time
MeasStpTime ⁽¹⁾	int	4	measurement stop time

⁽¹⁾ only if RAD_Stat is 1 / 2 / 3 / 14 / 15



4.25.5 SEND_MET_DATA command (174)

This command is used to retrieve the surface sensor data. The data block is structured as follows:

Variable Name	Type	# Bytes	Description
TotLength	int	4	Total length of the data block in bytes
Available	byte	1	=0: no MET sample available =1: MET sample available
MET_Time	int	4	time of MET sample (seconds since 1.1.2001, 00:00:00)
MET_RF	char	1	rain flag of MET sample
MET_No	int	4	number of surface sensors
MET_P	float	4	surface barometric pressure [hPa]
MET_T	float	4	surface temperature [K]
MET_RH	float	4	surface rel. humidity [%]
MET_WS	float	4	surface wind speed [km/h]
MET_WD	float	4	surface wind direction [DEG]
MET_RR	float	4	surface rain rate [mm/h]

4.25.6 DS_TERM_MEAS command (175)

This command terminates the currently running MDF / MBF. The server responds in the following way:

Variable Name	Type	# Bytes	Description
RetStat	byte	1	=0xFA (251): operation success =0xFB (252): no success

If the return status byte **RetStat** = 252 (no success), there is currently no measurement running to be terminated.

4.25.7 DS_START_MEAS command (176)

This command starts a new measurement MDF / MBF if the radiometer is in STANDBY mode. Because the command requires the definition of a MDF / MBF filename, the command structure is extended compared to the commands described so far. The command structure is as follows:

Variable Name	Type	# Bytes	Description
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ComByte	byte	1	=176
PWC	integer	4	password code
PathLen	integer	4	length of the following path string in bytes (including termination zero byte)
PathStr	char	PathLen	Path string to MDF / MBF on host PC

If **PathStr** is just the name of a MDF / MBF file (like 'Zenith_Home_V87.MDF'), the file path is assumed to be the default MDF / MBF directory (...\\RootDir\MDF_MBF). If the MDF / MBF is located in a different directory, the full path needs to be specified in **PathStr**, for instance C:\MyMDFs\ Zenith_Home_V87.MDF.

The server responds in the following way:

Variable Name	Type	# Bytes	Description
RetStat	byte	1	=0xFA (251): operation success =0xFB (252): no success

If the return status byte **RetStat** = 252 (no success), the reason could be one of the following:

- the radiometer is not in STANDBY mode
- the path or MDF / MBF filename does not exist

4.25.8 Elementary control commands

This class of commands allows the user to control the radiometer by elementary commands (marked in green in Table 4.1). This means that no MDF / MBF is started but the processing of pointing the radiometer beam and taking samples, starting automatic calibrations, defining retrieval files, etc. is all performed by individual commands. Control commands assume that the radiometer is in STANDBY mode and not running a measurement. If the radiometer is in a different mode, the control commands are ignored. While samples are acquired by control commands, the data is NOT stored to the host PC's file archive system or backed up on the radiometer PC. The user is fully responsible for retrieving the data samples by using the blue command set of Table 4.1.

4.25.8.1 DS_SET_FLAGS command (177)

This command sets flags on the radiometer PC, if the radiometer is in STANDBY mode. The command structure is extended as follows:

Variable Name	Type	# Bytes	Description
ComByte	byte	1	=177
PWC	integer	4	password code
Flags	byte	1	Flags: Bit 1: IRR coupling ON / OFF (1 / 0)

The server responds in the following way:



Variable Name	Type	# Bytes	Description
RetStat	byte	1	=0xFA (251): operation success =0xFB (252): no success

If the return status byte **RetStat** = 252 (no success), the radiometer is not in STANDBY mode.

4.26.8.2 DS_MOV_EL_AZ command (178)

This command starts a pointing to a different elevation and azimuth direction, if the radiometer is in STANDBY mode. Because the command requires the definition of an elevation and azimuth angle, the command structure is extended as follows:

Variable Name	Type	# Bytes	Description
ComByte	byte	1	=178
PWC	integer	4	password code
TargetEl	float	4	New elevation position [DEG]
TargetAz	float	4	New azimuth position [DEG]
WaitFlag	char	1	=0: the server returns BEFORE movements have finished =1: the server returns AFTER movements have finished

If the **WaitFlag** is OFF (=0), the user must query the movement status with calls to **SEND_RAD_STAT** commands (173), in order to make sure that the movement has finished before a **DS_TAKE_SAMP** command is issued. If the movement is not finished when a **DS_TAKE_SAMP** command is executed, the sample is integrated at an intermediate position, but not at the final position **TargetEl** / **TargetAz**.

Note that the **WaitFlag** = 1 functionality is only available for radiometers of generation G4 or higher. If the host PC communicates with the radiometer via RS-232 interface, the server always returns BEFORE the movements have finished.

The server responds in the following way:

Variable Name	Type	# Bytes	Description
RetStat	byte	1	=0xFA (251): operation success =0xFB (252): no success

If the return status byte **RetStat** = 252 (no success), the radiometer is not in STANDBY mode.

4.26.8.3 DS_TAKE_SAMP command (179)



This command takes a measurement sample, if the radiometer is in STANDBY mode. The command structure is as follows:

Variable Name	Type	# Bytes	Description
ComByte	byte	1	=179
PWC	integer	4	password code

Before the first sample is taken, the **DS_CLR_RET_TABLE** command (180) should be executed to initialize the retrieval table (it turns off all level 2 products). Then a list of required retrieval files should be defined by subsequent **DS_SEL_RET** commands (181). This list is then used in the following calls to **DS_TAKE_SAMP** to generate the corresponding level 2 products (atmospheric data) which can be inspected by **SEND_LEV2_DATA** (171). The **DS_TAKE_SAMP** command also updates the surface sensor data reading, so that a **SEND_MET_DATA** command (174) will return the newest surface sensor data.

The server responds in the following way:

Variable Name	Type	# Bytes	Description
RetStat	byte	1	=0xFA (251): operation success =0xFB (252): no success

If the return status byte **RetStat** = 252 (no success), the radiometer is not in STANDBY mode.

4.26.8.4 DS_CLR_RET_TABLE command (180)

This command clears the retrieval table, if the radiometer is in STANDBY mode. Retrieval table entries are performed by the **DS_SEL_RET** command (181). For each successful retrieval entry, the server will generate the corresponding level 2 data sample each time the **DS_TAKE_SAMP** command (179) is issued. The level 2 data sample can then be retrieved by the **SEND_LEV2_DATA** command (171).

The server responds in the following way:

Variable Name	Type	# Bytes	Description
RetStat	byte	1	=0xFA (251): operation success =0xFB (252): no success

If the return status byte **RetStat** = 252 (no success), the radiometer is not in STANDBY mode.

4.26.8.5 DS_SEL_RET command (181)

This command performs an entry in the retrieval table, if the radiometer is in STANDBY mode. For each successful retrieval entry, the server will generate the corresponding level 2 data sample each time the **DS_TAKE_SAMP** command (179) is issued. The level 2 data sample can then be retrieved by the **SEND_LEV2_DATA** command (171). The command structure is as follows:



Variable Name	Type	# Bytes	Description
ComByte	byte	1	=181
PWC	integer	4	password code
RetLen	int	4	Length of retrieval filename (including termination zero character)
RetFn	char	RetLen	Length of retrieval filename

The specified retrieval file must be installed in the retrieval directory tree on the Host PC. Otherwise the server will respond with a return status of 252 (no success).

The server responds in the following way:

Variable Name	Type	# Bytes	Description
RetStat	byte	1	=0xFA (251): operation success =0xFB (252): no success

If the return status byte **RetStat** = 252 (no success), the reason could be one of the following:

- the radiometer is not in STANDBY mode
- the specified retrieval file does not exist
- the specified retrieval file exists but it is not compliant to the radiometer's resources (e.g. the frequency table)
- the specified retrieval file exists but its format is not correct
- the specified retrieval is a TPB retrieval (BL temperature profile). This profile type is not allowed in direct command mode.

4.26.8.6 DS_RUN_CAL command (182)

This command performs one of the three automatic calibrations (Relative (1P), Noise Injection (2P) and Sky Tipping (SKD), if the radiometer is in STANDBY mode. For each successful retrieval entry, the server will generate the corresponding level 2 data sample each time the **DS_TAKE_SAMP** command (179) is issued. The level 2 data sample can then be retrieved by the **SEND_LEV2_DATA** command (171). The command structure is as follows:

Variable Name	Type	# Bytes	Description
ComByte	byte	1	=181
PWC	integer	4	password code
CalType	char	1	=1: 1P calibration =2: 2P calibration =3: SKD calibration
IntTime₍₁₎	int	4	integration time for 1P / 2P calibrations



RecEn2P⁽²⁾	char	1	=1: only receiver 1 is calibrated =2: only receiver 2 is calibrated =3: both receivers are calibrated
Chi^2Th[]⁽³⁾	float	2 x 4	Chi² thresholds for receiver 1 / 2
LincTh[]⁽³⁾	float	2 x 4	linear correlation thresholds for receiver 1 / 2
SKDAzi⁽³⁾	float	4	azimuth position for sky tipping

⁽¹⁾ Only if **CalType** = 1/2

⁽²⁾ Only if **CalType** = 2

⁽³⁾ Only if **CalType** = 3

When a calibration is started, the user should control its status by subsequent calls to **DS_UPDATE_STAT** (183) and **SEND_RAD_STAT** (173) commands. If a calibration has not been finished, a new data sample should not be started by **DS_TAKE_SAMP** (179) and the radiometer's elevation or azimuth axis should not be moved by **DS_MOV_EL_AZ** (178). The server responds in the following way:

Variable Name	Type	# Bytes	Description
RetStat	byte	1	=0xFA (251): operation success =0xFB (252): no success

If the return status byte **RetStat** = 252 (no success), the radiometer is not in STANDBY mode.

4.26.8.7 DS_UPDATE_STAT command (183)

When a measurement is running (initiated by an MDF) the radiometer status information, which can be inspected by the **SEND_RAD_STAT** command (173), is automatically updated by the measurement process. But when an elementary control command is issued, the radiometer has to be in STANDBY mode and no measurement process is executed. In the case the radiometer is directly commanded by elementary control commands (in STANDBY mode), the **DS_UPDATE_STAT** command (183) needs to be executed BEFORE the **SEND_RAD_STAT** command. Otherwise the status information returned by **SEND_RAD_STAT** will not reflect the current status.

The server responds in the following way:

Variable Name	Type	# Bytes	Description
RetStat	byte	1	=0xFA (251): operation success =0xFB (252): no success

If the return status byte **RetStat** = 252 (no success), the radiometer is not in STANDBY mode.

4.26.8.8 DS_UPDATE_HKD command (184)

When a measurement is running (initiated by an MDF) the radiometer status information, which can be inspected by the **SEND_HKD_DATA** command (172), is automatically updated by the measurement process. But when an elementary control command is issued, the



radiometer has to be in STANDBY mode and no measurement process is executed. In the case the radiometer is directly commanded by elementary control commands (in STANDBY mode), the **DS_UPDATE_HKD** command (184) needs to be executed BEFORE the **SEND_HKD_DATA** command. Otherwise the housekeeping data returned by **SEND_HKD_DATA** will not reflect the current data.

The server responds in the following way:

Variable Name	Type	# Bytes	Description
RetStat	byte	1	=0xFA (251): operation success =0xFB (252): no success

If the return status byte **RetStat** = 252 (no success), the radiometer is not in STANDBY mode.

5. Retrievals

5.1 Retrieval Algorithms

In order to estimate atmospheric parameters (such as liquid water path or the humidity profile) from the radiometer data, a suitable mathematical algorithm has to be found. A statistical regression between observed atmospheric (meteorological) data and the corresponding instrument data (brightness temperatures in different channels and additional information provided by temperature, pressure, and humidity sensors within the instrument) is a widely used solution for this task, although other methods (physical retrievals) are also known to yield good results.

5.1.1 General remarks

Gathering such simultaneously observed calibration data for a specific instrument at a specific site leads to long delays before the instruments ability to deliver atmospheric data is established. Statistical reliability calls for an observation period of several years, preferably more then one decade. During this time the atmosphere would need to be measured on a regular basis (twice a day), which also adds to the costs and impracticability. A faster approach will not use real data from the actual instrument but databases of meteorological observations. Such (radio sounding) measurements are recorded for weather prediction by many stations throughout the whole world, thus covering a vast range of climates and different weather conditions. The corresponding radiometer data needs to be calculated by radiative transfer models. This simulation is called forward modelling because the dependent data (the observable brightness temperatures) are calculated from the independent atmospheric variables. Any method or algorithm that is able to invert this process and calculate the independent variables from the dependent observations is called Retrieval.

Statistical retrieval methods use a training data set to derive a multi-linear regression, quadratic regression or an artificial neural network fit (which essentially is a form of nonlinear multivariate regression). The coefficients of this regression will be applied to the radiometer measurements in order to calculate actual atmospheric variables. Quality control of the retrieval algorithms is, in general, performed in two ways: After using the training data set for establishing the regression coefficients we apply the retrieval to a second data set, the test data. This data set must not be contained in the training data. Comparing the retrieved results with the known "real" results from the test data allows for a thorough statistical evaluation in terms of bias error, RMS, correlation etc. In addition, the operational algorithms have to be



tested with measurement campaigns where the atmospheric state is actually measured by independent instrumentation.

5.1.2 Data source and applicability

The amount and quality of the input data is crucial for the quality of the designed algorithm. Since a statistical algorithm can (when applied to real data) only cope with input data that is in the range represented by the training data, we need a sufficient number of samples. At least 10 years of data with two observations per day are needed to describe the natural variation of the atmosphere. Smaller time series might be missing some extreme situations which do not occur every year.

Besides the length of the time series the geographical sampling is of major importance. If only one time series which is taken at one single station is used to derive the algorithm, then the algorithm may only be used at this specific location. Moving the radiometer to another geographical position with different weather conditions or even different altitudes above sea level will have a negative impact on the retrieval quality.

By using a multitude of weather stations for the regression data base, the algorithms will be applicable to a variety of different locations. Furthermore the larger number of input data will contribute to the overall quality of the product.

5.1.3 Data quality processing and reformatting

Raw data comes in form of radiosonde data (also known as radio soundings). Such measurements contain air pressure, ambient temperature, and relative humidity at different vertical positions. Some types of radio soundings also contain wind speed and direction, but this information is not used in our type of algorithms. The number of levels (vertical resolution) typically is in the range of 10 to 20 levels up to several thousand levels.

The following steps have to be performed with the data:

1. Quality control: Depending on the data source the data may contain measurement errors, inconsistent data, and missing data. Missing data in one level leads to rejection of only that level. We check for the following error conditions and reject the sounding:
 - Increasing height in subsequent levels
 - Increasing pressure with height
 - Temperatures larger than 330 K or smaller than 210 K (190 K at larger heights)
 - Pressure larger than 1050 hPa
 - Pressure smaller than 1 Pa, surface pressure smaller than 500 hPa
 - Height larger than 70 km or smaller than -200 m
2. Applicability checks:
 - At least a 10 km height is reached with temperature and pressure information
 - At least -30 °C is reached with valid humidity information
 - At least 10 levels are present in the sounding
 - For some retrievals we reject raining clouds. These are detected by a threshold LWC larger than 3.5 g/m².
3. Reformatting: The soundings are stored in a common data format, but without interpolating or changing the data.



5.1.4 Cloud processing

From the sounding data we calculate further atmospheric parameters connected to clouds and rain. A cloud detection scheme reads the temperature and humidity vertical profiles and determines whether a cloud exists in a level or not. The criteria for cloud existence are a threshold relative humidity (usually 95 %) together with a temperature warmer than 243.15 K. These thresholds can be varied.

A second stage processing calculates the amount of liquid water (LWC, liquid water content) within each layer based on the modified adiabatic water content. This number is something like an upper limit of how much water can be present in a cloud layer with respect to the current atmospheric situation.

The above algorithms produce multi-layered clouds with several sounding levels in each cloud layer. The total amount of water (LWP, liquid water path) is calculated by integrating all cloud layers.

5.1.5 Angle and frequency selection

Prior to radiative transfer calculations the frequencies and elevation angles have to be selected. While the frequencies are mostly determined by the type of the retrieval, the angles have to be selected to meet the user requirements. Each observation angle needs its own set of retrieval coefficients. Those coefficients depend strongly on the observation angle and cannot be interpolated.

5.1.6 Radiative Transfer calculations

In order to calculate simulated brightness temperatures from the sounding data we have to know the interaction parameters of matter with microwave radiation (absorption and scattering coefficients) at every position and every frequency that might be considered in one retrieval algorithm. Based on gas absorption models, the mass absorption coefficients are set up in every layer according to the pressure, humidity, and temperature. Cloud water adds absorption proportional to its mass with a temperature dependent absorption coefficient. At frequencies below 100 GHz the scattering at cloud droplets can be neglected. Rain clouds are not considered in the retrieval generation.

This subsection is not yet finished and still under preparation.

5.1.7 Retrieval grid and type of regression

This subsection is under preparation.

5.1.8 Algorithm performance

This subsection is under preparation.

Some users might be able to perform their own radiative transfer calculations and have access to a huge data set of radiosondes. A sophisticated design tool for the generation of



system conform retrieval files is implemented in the “Files + Integration” tab sheet of the measurement definition window (see Fig.4.8). The **Define Retrieval File**-command activates the retrieval design window of Fig.5.1.

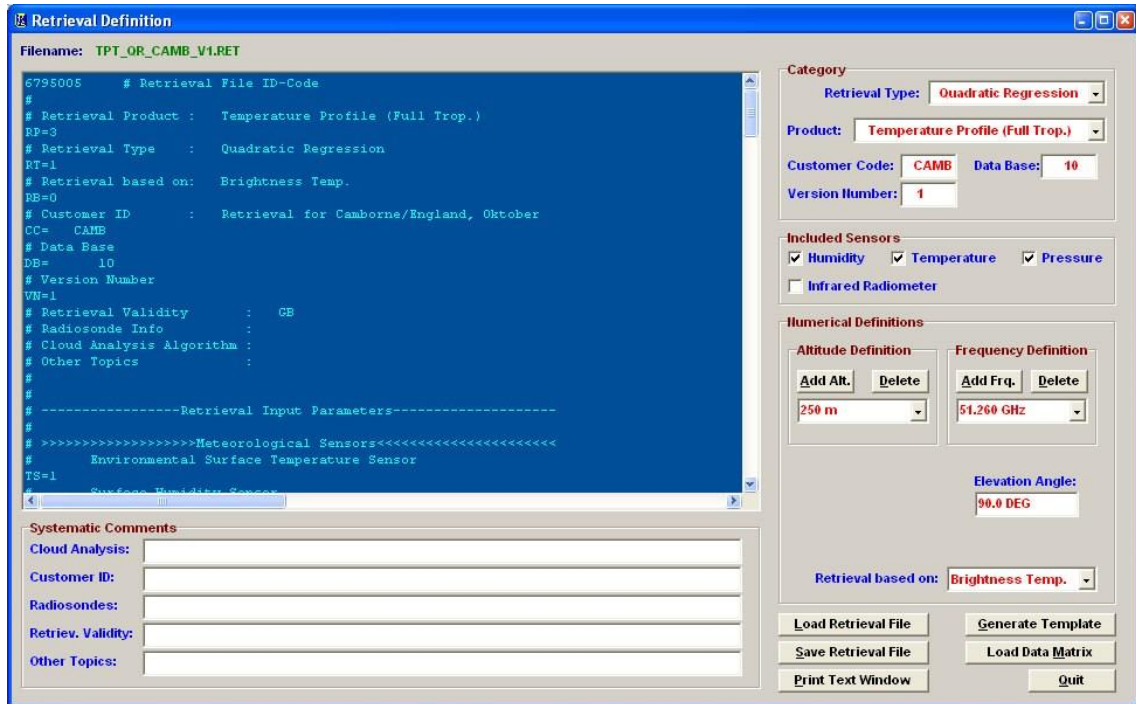


Fig.5.1: Retrieval file editor.

5.1.9 File Format

All retrieval files have the extension “.RET” to distinguish them from other file types. The first three characters of the file name indicate the retrieval product. For version 1.1 six products are implemented: TPT (temperature profile, troposphere), HPT (humidity profile, troposphere), LWP, IWV, ATN (Atmospheric Attenuation) and TPB (temperature profile, boundary layer). The next section (sections are separated from each other by the “_” character) of the file name is reserved for the retrieval type. Possible retrieval types are: LR (linear regression), QR (quadratic regression) and NN (neural networks). The third section contains the customer code and the fourth section represents the version number. The file name sections are summarized in the editor’s “Category”-frame. The data base identifier is not used for the file name but is stored into the retrieval file for future purposes.

5.2 Retrieval File Structure

With the **Load Retrieval File**-button load the “TPT_QR_JAP_1_V1.RET”-file from the “...\\2CH\\RETRIEVALS\\TPROFILE_TROP”-directory. Retrieval files are text files which can be edited by any editor that does not insert any control codes or other characters that do not belong to the text. The content of the loaded retrieval file is displayed in the blue editor window.

The file starts with an identification code (6795005) utilized by R2CH to detect nonconformities caused by future changes in the file format. Comments are preceded by the “#” character. All other text lines contain relevant data needed for the retrieval computation routines (2CH).



The continue character “:” at the beginning of a line indicates that this line belongs to the same parameter as the previous line. The continue code is used in the definition of matrices to add rows to a matrix.

A parameter code of 2 characters followed by a “=” character (no spaces!) specifies the meaning of the data that follows the “=” sign. The codes for the retrieval category are:

- ‘RP=’: Retrieval product. 0: LWP, 1: IWV, 2: Attenuation, 3: temperature profile (troposphere), 4: temperature profile (boundary layer), 6: humidity profile (troposphere) (mandatory parameter).
- ‘RT=’: Retrieval type. 0: linear regression, 1: quadratic regression, 2: neural network (mandatory).
- ‘CC=’: Customer code (mandatory parameter).
- ‘DB=’: Data Base
- ‘VN=’: Version number (mandatory parameter).

These codes must precede all other codes (except for the retrieval basis ‘RB=’).

Some retrievals include the surface sensor data as input parameters beside the brightness temperature data. In the “Included Sensors”-frame the retrieval designer checks the sensors he is going to include in his retrieval. The associated codes are:

- ‘TS=’: Temperature sensor. 0: sensor not used for retrieval, 1: sensor used (mandatory parameter).
- ‘PS=’: Pressure sensor. 0: sensor not used for retrieval, 1: sensor used (mandatory parameter).
- ‘HS=’: Humidity sensor. 0: sensor not used for retrieval, 1: sensor used (mandatory parameter).
- ‘IS=’: Infrared radiometer. 0: sensor not used for retrieval, 1: sensor used (mandatory parameter).

A neural network retrieval parameter is the number of intermediate knots (hidden knot layer). The associated parameter is:

- ‘NK=’: Number of intermediate knots (Neural Network only)

The presence of these codes in the retrieval file is mandatory.

Some retrieval designers prefer the optical thicknesses as input parameter instead of brightness temperatures. The code is:

- ‘RB=’: Retrieval basis. 0: brightness temperatures, 1: optical thicknesses (mandatory parameter).

All retrievals are based on microwave frequency channels. The frequency list must be preceded by:

- ‘FR=’: Frequency list [GHz] (mandatory parameter).

All observations are performed at certain elevation angles:

- ‘AG=’: Elevation angle list (mandatory parameter).



Those retrievals that produce data at certain altitudes (humidity and temperature profiles) must have an altitude parameter specified:

'AL=': Altitude list [m]

All other parameters are specific for the retrieval type.

5.2.1 Linear Regressions

As was discussed before a linear regression retrieval calculation has the following structure:

$$Out_i = OS_i + \sum_{sensors} SL_{ij} * Sr_j + \sum_{freq} TL_{ij} * Tb_j$$

where Out_i is the i -th retrieval output parameter (e.g. the temperature at altitude A_i), OS_i is the retrieval offset parameter for Out_i , Sr_j is the surface sensor reading of the j -th checked sensor (the sequence is: TS, HS,PS,IS), SL_{ij} is the corresponding linear coefficient, Tb_j is the brightness temperature or optical thickness at the j -th frequency and TL_{ij} is the corresponding linear coefficient. The surface sensor readings are measured in K (Temperature), % (Humidity), Pa (Barometric Pressure) and °C (Infrared Temperature). All brightness temperatures are measured in K.

The parameters in the retrieval file are:

- 'OS=': offset matrix (same unit as Out_i)
- 'SL=': linear sensor coefficient matrix
- 'TL=': linear brightness temperature coefficient

5.2.2 Quadratic Regressions

A quadratic regression retrieval calculation has the following structure:

$$Out_i = OS_i + \sum_{sensors} SL_{ij} * Sr_j + \sum_{freq} TL_{ij} * Tb_j + \sum_{sensors} SQ_{ij} * Sr_j^2 + \sum_{freq} TQ_{ij} * Tb_j^2$$

where Out_i is the i -th retrieval output parameter (e.g. the temperature at altitude A_i), OS_i is the retrieval offset parameter for Out_i , Sr_j is the surface sensor reading of the j -th checked sensor (the sequence is: TS, HS,PS,IS), SL_{ij} is the corresponding linear coefficient and SQ_{ij} is the corresponding quadratic coefficient, Tb_j is the brightness temperature or optical thickness at the j -th frequency with TL_{ij} is the corresponding linear coefficient and TQ_{ij} is the corresponding quadratic coefficient. The surface sensor readings are measured in K (Temperature), % (Humidity), Pa (Barometric Pressure) and °C (Infrared Temperature). All brightness temperatures are measured in K.



The parameters in the retrieval file are:

- 'OS=': offset matrix (same unit as Out_i)
- 'SL=': linear sensor coefficient matrix
- 'SQ=': quadratic sensor coefficient matrix
- 'TL=': linear brightness temperature coefficient
- 'TQ=': quadratic brightness temperature coefficient

5.2.3 Neural Networks

The parameters for the neural network retrieval calculation are:

- 'IM=': input coefficient matrix
- 'OM=': output coefficient matrix

The structure of these matrices can be derived from a template neural network file (see chapter below).

5.3 Retrieval File Templates

The user does not have to enter all these parameters by hand but instead defines his retrieval input and output parameters by filling the list boxes and check boxes in the retrieval editor. In addition, five comment lines may be entered for customer related information etc. By clicking on the "Generate Template"-button the editor text window is initialized with a syntactically correct retrieval file comprising all settings and numerical data is filled with zeros.

The user must generate a text file which contains the retrieval coefficients in the same row and column order as required for the template. Then this coefficient file can be loaded with the "Load Data Matrix"-button and a second editor text window is opened containing this file. The user then copies and pastes the matrices from his coefficient file editor into the retrieval file editor text window. This concept ensures that the retrieval file syntax remains correct.

Appendix A (File Formats)

A1a: LWP-Files (*.LWP), (version 1)

Variable Name	Type	# Bytes	Description
LWPCode	int	4	LWP-File Code (=934501978)
N	int	4	Number of recorded samples
LWPMin	float	4	Minimum of recorded LWP values
LWPMax	float	4	Maximum of recorded LWP values
LWPTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
LWPRetrieval	int	4	0: lin. Reg., 1 : quad. Reg., 2: Neur. Net.
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)



LWP_1	float	4	LWP sample 1 [g/m ²]
LWPAng_1 ⁽²⁾	float	4	LWP angles 1 [DEG]
...
...
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
LWP_N	float	4	LWP sample N [g/m ²]
LWPAng_N ⁽²⁾	float	4	LWP angles N [DEG]

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18) ⁽²⁾

Angle is coded in the following way: Ang=sign(EI) * (|EI|+1000*Az), -90°<=EI<100°, 0°<=Az<360°. If EI>=100°, the value 1000.000 is added to Ang and EI in the formula is EI100°. Example: EI=138.5°, Az=267.4°, Ang=1267438.5

A1b: LWP-Files (*.LWP), (version 2)

Variable Name	Type	# Bytes	Description
LWPCode	int	4	LWP-File Code (=934501000)
N	int	4	Number of recorded samples
LWPMin	float	4	Minimum of recorded LWP values
LWPMax	float	4	Maximum of recorded LWP values
LWPTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
LWPRetrieval	int	4	0: lin. Reg., 1 : quad. Reg., 2: Neur. Net.
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
LWP_1	float	4	LWP sample 1 [g/m ²]
ANG_1 ⁽²⁾	float	4	LWP angles 1 [DEG]
...
...
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
LWP_N	float	4	LWP sample N [g/m ²]
ANG_N ⁽²⁾	int	4	LWP angles N [DEG]

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18) ⁽²⁾



(2) Angles are coded in the following way: first 5 decimal digits is azimuth * 100, last 5 decimal digits is elevation * 100, sign of ANG is sign of elevation.

Example 1: elevation = 145.30°, azimuth = 310.45° → ANG is 1453031045

Example 2: elevation = -90.00°, azimuth = 12.32 → ANG is -900001232

A2a: IWV-Files (*.IWV), (version 1)

Variable Name	Type	# Bytes	Description
IWVCode	int	4	IWV-File Code (=594811068)
N	int	4	Number of recorded samples
IWVMin	float	4	Minimum of recorded IWV values
IWVMax	float	4	Maximum of recorded IWV values
IWVTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
IWVRetrieval	int	4	0: lin. Reg., 1 : quad. Reg., 2: Neur. Net.
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
IWV_1	float	4	IWVsample 1 [kg/m ²]
IWVAng_1 ⁽²⁾	float	4	IWV angles 1 [DEG]
...
...
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
IWV_N	float	4	IWV sample N [kg/m ²]
IWVAng_N ⁽²⁾	float	4	IWV angles N [DEG]

(1) The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18) (2)

Angle is coded in the following way: Ang=sign(EI) * (|EI|+1000*Az), -90°<=EI<100°, 0°<=Az<360°. If EI>=100°, the value 1000.000 is added to Ang and EI in the formula is EI100°. Example: EI=138.5°, Az=267.4°, Ang=1267438.5

A2b: IWV-Files (*.IWV), (version 2)

Variable Name	Type	# Bytes	Description
IWVCode	int	4	IWV-File Code (=594811000)
N	int	4	Number of recorded samples
IWVMin	float	4	Minimum of recorded IWV values
IWVMax	float	4	Maximum of recorded IWV values
IWVTimeRef	int	4	Time reference (1: UTC, 0: Local Time)



IWVRetrieval	int	4	0: lin. Reg., 1 : quad. Reg., 2: Neur. Net.
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
IWV_1	float	4	IWVs sample 1 [kg/m ²]
ANG_1 ⁽²⁾	int	4	IWV angles 1 [DEG]
...
...
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
IWV_N	float	4	IWV sample N [kg/m ²]
ANG_N ⁽²⁾	int	4	IWV angles N [DEG]

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18) ⁽²⁾

⁽²⁾ Angles are coded in the following way: first 5 decimal digits is azimuth * 100, last 5 decimal digits is elevation * 100, sign of ANG is sign of elevation.

Example 1: elevation = 145.30°, azimuth = 310.45° → ANG is 1453031045

Example 2: elevation = -90.00°, azimuth = 12.32 → ANG is -900001232

A3a: ATN-Files (*.ATN), (version 1)

Variable Name	Type	# Bytes	Description
ATNCode	int	4	ATN-File Code (=7757564)
N	int	4	Number of recorded samples
ATNTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
ATNRetrieval	int	4	0: lin. Reg., 1 : quad. Reg., 2: Neur. Net., 3: Tmr based retrieval
FreqAnz	int	4	# of recorded frequencies
Freqs[i]	float	4 x FreqAnz	Frequencies [GHz]
ATNMin[]	float	4 x FreqAnz	Minimum of recorded ATN values
ATNMax[]	float	4 x FreqAnz	Maximum of recorded ATN values
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
ATN_1[]	float	4 x FreqAnz	ATN sample 1 (Attenuation [dB])
ANG1 ⁽²⁾	float	4	Observation angles, sample 1
...
...
...



T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
ATN_N[]	float	4 x FreqAnz	ATN sample N (Attenuation [dB])
ANGN ⁽²⁾	float	4	Observation angles, sample N

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18) ⁽²⁾

Angle is coded in the following way: Ang=sign(EI) * (|EI|+1000*Az), -90°<=EI<100°, 0°<=Az<360°. If EI>=100°, the value 1000.000 is added to Ang and EI in the formula is

EI100°. Example: EI=138.5°, Az=267.4°, Ang=1267438.5

A3b: ATN-Files (*.ATN), (version 2)

Variable Name	Type	# Bytes	Description
ATNCode	int	4	ATN-File Code (=7757000)
N	int	4	Number of recorded samples
ATNTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
ATNRetrieval	int	4	0: lin. Reg., 1 : quad. Reg., 2: Neur. Net., 3: Tmr based retrieval
FreqAnz	int	4	# of recorded frequencies
Freqs[i]	float	4 x FreqAnz	Frequencies [GHz]
ATNMin[]	float	4 x FreqAnz	Minimum of recorded ATN values
ATNMax[]	float	4 x FreqAnz	Maximum of recorded ATN values
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
ATN_1[]	float	4 x FreqAnz	ATN sample 1 (Attenuation [dB])
ANG1 ⁽²⁾	int	4	Observation angles, sample 1
...
...
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
ATN_N[]	float	4 x FreqAnz	ATN sample N (Attenuation [dB])
ANGN ⁽²⁾	int	4	Observation angles, sample N

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18)

⁽²⁾ Angles are coded in the following way: first 5 decimal digits is azimuth * 100, last 5 decimal digits is elevation * 100, sign of ANG is sign of elevation.



Example 1: elevation = 145.30°, azimuth = 310.45° → ANG is 1453031045

Example 2: elevation = -90.00°, azimuth = 12.32 → ANG is -900001232

A4a: BRT-Files (*.BRT), (version 1)

Variable Name	Type	# Bytes	Description
BRTCode	int	4	BRT-File Code (=666666 or 666667 for SPC files)
N	int	4	Number of recorded samples
BRTTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
FreqAnz	int	4	# of recorded frequencies
Freq[]	float	4 x FreqAnz	Frequencies [GHz]
BRTMin[]	float	4 x FreqAnz	Minimum array of recorded BRT values
BRTMax[]	float	4 x FreqAnz	Maximum array of recorded BRT values
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
BRT_1[]	float	4 x FreqAnz	Br. Temp. array sample 1 [K]
ANG_1 ⁽¹⁾	float	4	Elevation/Azimuth angle of sample 1 (DEG)
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N	char	1	Rainflag of sample N (0: no rain, 1: rain)
BRT_N[]	float	4 x FreqAnz	Br. Temp. sample N, frequency 1 [K]
ANG_N ⁽¹⁾	float	4	Elevation/Azimuth angle of sample N (DEG)

⁽¹⁾

Angle is coded in the following way: ANG=sign(Elevation) * (|Elevation|+1000*Azimuth)

A4b: BRT-Files (*.BRT), (version 2)

Variable Name	Type	# Bytes	Description
BRTCode	int	4	BRT-File Code (=666000 or 667000 for SPC files)
N	int	4	Number of recorded samples
BRTTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
FreqAnz	int	4	# of recorded frequencies
Freq[]	float	4 x FreqAnz	Frequencies [GHz]
BRTMin[]	float	4 x FreqAnz	Minimum array of recorded BRT values
BRTMax[]	float	4 x FreqAnz	Maximum array of recorded BRT values
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
BRT_1[]	float	4 x FreqAnz	Br. Temp. array sample 1 [K]
ANG_1 ⁽¹⁾	int	4	Elevation/Azimuth angle of sample 1 (DEG)
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)



RF_N	char	1	Rainflag of sample N (0: no rain, 1: rain)
BRT_N[]	float	4 x FreqAnz	Br. Temp. sample N, frequency 1 [K]
ANG_N ⁽¹⁾	int	4	Elevation/Azimuth angle of sample N (DEG)

⁽¹⁾ Angles are coded in the following way: first 5 decimal digits is azimuth * 100, last 5 decimal digits is elevation * 100, sign of ANG is sign of elevation.

Example 1: elevation = 145.30°, azimuth = 310.45° → ANG is 1453031045

Example 2: elevation = -90.00°, azimuth = 12.32 → ANG is -900001232

A5a: MET-Files (*.MET), Meteorological Sensors (old version)

Variable Name	Type	# Bytes	Description
METCode	int	4	MET-File Code (=599658943)
N	int	4	Number of recorded samples
METMinP	float	4	Minimum of recorded pressure values
METMaxP	float	4	Maximum of recorded pressure values
METMinT	float	4	Minimum of environmental temp. values
METMaxT	float	4	Maximum of environmental temp. values
METMinH	float	4	Minimum of recorded rel. humidity values
METMaxH	float	4	Maximum of recorded rel. humidity values
METTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
MET_1(0)	float	4	Pressure value sample 1 [mbar]
MET_1(1)	float	4	Temp. value sample 1 [K]
MET_1(2)	float	4	Rel. humidity value sample 1 [%]
...
MET_N(0)	float	4	Pressure value sample N [mbar]
MET_N(1)	float	4	Temp. value sample N [K]
MET_N(2)	float	4	Rel. humidity value sample N [%]

A5b: MET-Files (*.MET), Meteorological Sensors (new version)

Variable Name	Type	# Bytes	Description
METCode	int	4	MET-File Code (=599658944)
N	int	4	Number of recorded samples
AddSensors ⁽¹⁾	char	1	8 bit field for additional sensors
METMinP	float	4	Minimum of recorded pressure values
METMaxP	float	4	Maximum of recorded pressure values
METMinT	float	4	Minimum of environmental temp. values



METMaxT	float	4	Maximum of environmental temp. values
METMinH	float	4	Minimum of recorded rel. humidity values
METMaxH	float	4	Maximum of recorded rel. humidity values
...	float	8*# of add. sensors	Minimum and Maximum values of additional sensors
METTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
MET_1(0)	float	4	Pressure value sample 1 [mbar]
MET_1(1)	float	4	Temp. value sample 1 [K]
MET_1(2)	float	4	Rel. humidity value sample 1 [%]
...	float	4*# of add. sensors	sample 1 of additional sensor values
...
MET_N(0)	float	4	Pressure value sample N [mbar]
MET_N(1)	float	4	Temp. value sample N [K]
MET_N(2)	float	4	Rel. humidity value sample N [%]
...	float	4*# of add. sensors	sample N of additional sensor values

⁽¹⁾ Additional sensors bit field: Bit0 (LSB): wind speed (km/h), Bit1: wind direction [°], Bit2: Rain Rate. If corresponding bit is 1, the additional sensor exists, otherwise it does not.

A6: OLC-Files (*.OLC), Oxygen Line Chart

Variable Name	Type	# Bytes	Description
OLCCode	int	4	OLC-File Code (=955874342)
N	int	4	Number of recorded samples
OLCMin	float	4	Minimum of recorded OL-Brt. values
OLCMax	float	4	Maximum of recorded OL-Brt. values
OLCTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
FreqAnz	int	4	# of recorded frequencies in oxygen line
Freq[i]	float	4 x FreqAnz	Frequencies [GHz]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
O2_BRT_1(i)	float	4 x FreqAnz	Brightness Temp. of oxygen line [K], sample 1
ANG1 ⁽¹⁾	float	4	Observation angles, sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N	char	1	Rainflag of sample N (0: no rain, 1: rain)



O2_BRT_N(i)	float	4 x FreqAnz	Brightness Temp. of oxygen line [K], sample N
ANGN ⁽¹⁾	float	4	Observation angles, sample N

⁽¹⁾ Angle is coded in the following way: ANG=sign(Elevation) * (|Elevation|+1000*Azimuth)

A7: TPC-Files (*.TPC), Temperature Profile Chart (Full Trop.)

Variable Name	Type	# Bytes	Description
TPCCode	int	4	TPC-File Code (=780798065)
N	int	4	Number of recorded samples
TPCMin	float	4	Minimum of recorded temperature values
TPCMax	float	4	Maximum of recorded temperature values
TPCTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
TPCRetrieval	int	4	0: lin. Reg., 1 : quad. Reg., 2: Neural Network
AltAnz	int	4	# of altitude layers
Alts[i]	int	4 x AltAnz	Altitudes [m]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
TP_1(i)	float	4 x AltAnz	Temperature Profile [K], sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
TP_N(i)	float	4 x AltAnz	Temperature Profile [K], sample N

⁽¹⁾The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18)

A8: TPB-Files (*.TPB), Temperature Profile Chart (Boundary Layer)

Variable Name	Type	# Bytes	Description
TPBCode	int	4	TPB-File Code (=459769847)
N	int	4	Number of recorded samples
TPBMin	float	4	Minimum of recorded temperature values
TPBMax	float	4	Maximum of recorded temperature values
TPBTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
TPBRetrieval	int	4	0: lin. Reg., 1 : quad. Reg., 2: Neural Network
AltAnz	int	4	# of altitude layers
Alts[i]	int	4 x AltAnz	Altitudes [m]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)



TP_1(i)	float	4 x AltAnz	Temperature Profile [K], sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
TP_N(i)	float	4 x AltAnz	Temperature Profile [K], sample N

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18)

A9: WVL-Files (*.WVL), Water Vapour Line Chart

Variable Name	Type	# Bytes	Description
WVLCode	int	4	WVL-File Code (=456783953)
N	int	4	Number of recorded samples
WVLMin	float	4	Minimum of recorded WVl-Brt. values
WVLMax	float	4	Maximum of recorded WVl-Brt. values
WVLTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
FreqAnz	int	4	# of recorded frequencies in WV line
Freq[i]	float	4 x FreqAnz	Frequencies [GHz]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
WVL_BRT_1(i)	float	4 x FreqAnz	Brightness Temp. of WV line [K], sample 1
ANG1 ⁽¹⁾	float	4	Observation angle, sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N	char	1	Rainflag of sample N (0: no rain, 1: rain)
WVL_BRT_N(i)	float	4 x FreqAnz	Brightness Temp. of WV line [K], sample N
ANGN ⁽¹⁾	float	4	Observation angle, sample N

⁽¹⁾ Angle is coded in the following way: $Ang = \text{sign}(EI) * (|EI| + 1000 * Az)$, $-90^\circ \leq EI < 100^\circ$, $0^\circ \leq Az < 360^\circ$. If $EI \geq 100^\circ$, the value 1000.000 is added to Ang and EI in the formula is $EI - 100^\circ$. Example: $EI = 138.5^\circ$, $Az = 267.4^\circ$, $Ang = 1267438.5$

A10(1): HPC-Files (*.HPC), Humidity Profile Chart (without RH)

Variable Name	Type	# Bytes	Description
HPCCode	int	4	HPC-File Code (=117343672)
N	int	4	Number of recorded samples
HPCMin	float	4	Minimum of recorded abs. humidity values
HPCMax	float	4	Maximum of recorded abs. humidity values
HPCTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
HPCRetrieval	int	4	0: lin. Reg., 1: quad. Reg., 2: Neural Network
AltAnz	int	4	# of altitude layers



Alts[i]	int	4 x AltAnz	Altitudes [m]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
HP_1(i)	float	4 x AltAnz	Humidity Profile [g/m ³], sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
HP_N(i)	float	4 x AltAnz	Humidity Profile [g/m ³], sample N

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18)

A10(2): HPC-Files (*.HPC), Humidity Profile Chart (including RH)

Variable Name	Type	# Bytes	Description
HPCCode	int	4	HPC-File Code (=117343673)
N	int	4	Number of recorded samples
HPCMin	float	4	Minimum of recorded abs. humidity values
HPCMax	float	4	Maximum of recorded abs. humidity values
HPCTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
HPCRetrieval	int	4	0: lin. Reg., 1 : quad. Reg., 2: Neural Network
AltAnz	int	4	# of altitude layers
Alts[i]	int	4 x AltAnz	Altitudes [m]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
HP_1(i)	float	4 x AltAnz	Abs. Humidity Profile [g/m ³], sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
HP_N(i)	float	4 x AltAnz	Abs. Humidity Profile [g/m ³], sample N
RHMin	float	4	Minimum of recorded rel. humidity values [%]
RHMax	float	4	Maximum of recorded rel. humidity values [%]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
HP_1(i)	float	4 x AltAnz	Rel. Humidity Profile [%], sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
HP_N(i)	float	4 x AltAnz	Abs. Humidity Profile [%], sample N

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18)



A11: LPR-Files (*.LPR), Liquid Water Profile Chart

Variable Name	Type	# Bytes	Description
LPRCode	int	4	LPR-File Code (=4567)
N	int	4	Number of recorded samples
LPRMin	float	4	Minimum of recorded LW-density
LPRMax	float	4	Maximum of recorded LW-density
LPRTIMERef	int	4	Time reference (1: UTC, 0: Local Time)
LPRRetrieval	int	4	0: lin. Reg., 1 : quad. Reg., 2: Neural Network
AltAnz	int	4	# of altitude layers
Alts[i]	int	4 x AltAnz	Altitudes [m]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
LWD_1(i)	float	4 x AltAnz	LW-density profile [g/m ³], sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
LWD_N(i)	float	4 x AltAnz	LW-density profile [g/m ³], sample N

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18)

A12a: IRT-Files (*.IRT), (version 1)

Variable Name	Type	# Bytes	Description
IRTCode	int	4	IRT-File Code (=671112495)
N	int	4	Number of recorded samples
IRTMin	float	4	Minimum of recorded IRT values
IRTMax	float	4	Maximum of recorded IRT values
IRTTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
IRT_1	float	4	Infrared temperature [°C], sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N	char	1	Rainflag of sample N (0: no rain, 1: rain)
IRT_N	float	4	Infrared temperature [°C], sample N



A12b: IRT-Files (*.IRT), (version 2)

Variable Name	Type	# Bytes	Description
IRTCode	int	4	IRT-File Code (=671112496)
N	int	4	Number of recorded samples
IRTMin	float	4	Minimum of recorded IRT values
IRTMax	float	4	Maximum of recorded IRT values
IRTTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
FreqAnz	int	4	# of recorded IRRs
Freq[]	float	4 x FreqAnz	Wavelengths [µm]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
IRT[]_1	float	4 x FreqAnz	Infrared temperatures [°C], sample 1
ANG_1 ⁽¹⁾	float	4	Elevation/Azimuth angle of sample 1 (DEG)
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N	char	1	Rainflag of sample N (0: no rain, 1: rain)
IRT[]_N	float	4 x FreqAnz	Infrared temperatures [°C], sample N
ANG_N ⁽¹⁾	float	4	Elevation/Azimuth angle of sample N (DEG)

⁽¹⁾ Angle is coded in the following way: $Ang = \text{sign}(El) * (|El| + 1000 * Az)$, $-90^\circ \leq El < 100^\circ$, $0^\circ \leq Az < 360^\circ$. If $El \geq 100^\circ$, the value 1000.000 is added to Ang and El in the formula is $El - 100^\circ$. Example: $El = 138.5^\circ$, $Az = 267.4^\circ$, $Ang = 1267438.5$

A12c: IRT-Files (*.IRT), (version 3)

Variable Name	Type	# Bytes	Description
IRTCode	int	4	IRT-File Code (=671112000)
N	int	4	Number of recorded samples
IRTMin	float	4	Minimum of recorded IRT values
IRTMax	float	4	Maximum of recorded IRT values
IRTTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
FreqAnz	int	4	# of recorded IRRs
Freq[]	float	4 x FreqAnz	Wavelengths [µm]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
IRT[]_1	float	4 x FreqAnz	Infrared temperatures [°C], sample 1
ANG_1 ⁽¹⁾	int	4	Elevation/Azimuth angle of sample 1 (DEG) Elevation in [-90,180], Azimuth in [0,360]
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)



RF_N	char	1	Rainflag of sample N (0: no rain, 1: rain)
IRT[]_N	float	4 x FreqAnz	Infrared temperatures [°C], sample N
ANG_N ⁽¹⁾	int	4	Elevation/Azimuth angle of sample N (DEG) Elevation in [-90,180], Azimuth in [0,360]

⁽¹⁾ Angles are coded in the following way: first 5 decimal digits is azimuth * 100, last 5 decimal digits is elevation * 100, sign of ANG is sign of elevation.

Example 1: elevation = 145.30°, azimuth = 310.45° → ANG is 1453031045

Example 2: elevation = -90.00°, azimuth = 12.32 → ANG is -900001232

A13a: BLB-Files (*.BLB), (version 1)

Variable Name	Type	# Bytes	Description
BLBCode	int	4	BLB-File Code (=567845847)
N	int	4	Number of recorded samples
BLBMin[]	float	14*4	Minimum of recorded BLB values (14 channels, 22.24-31.4, 51.3-58)
BLBMax[]	float	14*4	Maximum of recorded BLB values (14 channels, 22.24-31.4, 51.3-58)
BLBTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
Nf	int	4	No. of frequencies (14)
Freq[]	float	Nf*4	Frequencies [GHz]
Nang	int	4	No. of scanning angles (without 0°)
Ang[]	float	Nang*4	Scanning elevation angles [DEG], without 0°
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF/Mode_1	char	1	Rainflag/Mode of sample 1. Bit1=0: no rain, Bit1=1: rain; Bit2/3=0/0: 1 st Quadrant Scan, Bit2/3=1/0: 2 nd Quadrant Scan, Bit2/3=0/1: Averaged Two Quadrant Scan
BT1_1[]	float	(Nang+1)*4	BTs for channel 1 (22.4 GHz) at different angles (starting with zenith), sample 1, the temperature at 0° is added to each scan (surface sensor)
...
BT14_1[]	float	(Nang+1)*4	BTs for channel 14 (58 GHz) at different angles (starting with zenith), sample 1, the temperature at 0° is added to each scan (surface sensor)
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF/Mode_N	char	1	Rainflag/Mode of sample N. Bit1=0: no rain, Bit1=1: rain; Bit2/3=0/0: 1 st Quadrant Scan, Bit2/3=1/0: 2 nd Quadrant Scan, Bit2/3=0/1: Averaged Two Quadrant Scan



BT1_N[]	float	(Nang+1)*4	BTs for channel 1 (22.4 GHz) at different angles (starting with zenith), sample N, the temperature at 0° is added to each scan (surface sensor)
...
BT14_N[]	float	(Nang+1)*4	BTs for channel 14 (58 GHz) at different angles (starting with zenith), sample N, the temperature at 0° is added to each scan (surface sensor)

A13b: BLB-Files (*.BLB), (version 2)

Variable Name	Type	# Bytes	Description
BLBCode	int	4	BLB-File Code (=567845848)
N	int	4	Number of recorded samples
Nf	int	4	No. of frequencies
BLBMin[]	float	4*Nf	Minimum of recorded BLB values
BLBMax[]	float	4*Nf	Maximum of recorded BLB values
BLBTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
Freq[]	float	Nf*4	Frequencies [GHz]
Nang	int	4	No. of scanning angles (without 0°)
Ang[]	float	Nang*4	Scanning elevation angles [DEG], without 0°
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF/Mode_1	char	1	Rainflag/Mode of sample 1. Bit1=0: no rain, Bit1=1: rain; Bit6/7=0/0: 1 st Quadrant Scan, Bit6/7=1/0:2 nd Quadrant Scan, Bit6/7=0/1: Averaged Two Quadrant Scan, Bit6/7=1/1: Two Independent Scans
BT1_1[]	float	(Nang+1)*4	BTs for channel 1 at different angles (starting with zenith), sample 1, the temperature at 0° is added to each scan (surface sensor)
...
BTNf_1[]	float	(Nang+1)*4	BTs for channel Nf at different angles (starting with zenith), sample 1, the temperature at 0° is added to each scan (surface sensor)
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF/Mode_N	char	1	Rainflag/Mode of sample N. Bit1=0: no rain, Bit1=1: rain; Bit6/7=0/0: 1 st Quadrant Scan, Bit6/7=1/0:2 nd Quadrant Scan, Bit6/7=0/1: Averaged Two Quadrant Scan, Bit6/7=1/1: Two Independent Scans



BT1_N[]	float	(Nang+1)*4	BTs for channel 1 at different angles (starting with zenith), sample N, the temperature at 0° is added to each scan (surface sensor)
...
BTNf_N[]	float	(Nang+1)*4	BTs for channel Nf at different angles (starting with zenith), sample N, the temperature at 0° is added to each scan (surface sensor)

A14: STA-Files (*.STA), Stability Indices

Variable Name	Type	# Bytes	Description
STACode	int	4	STA-File Code (=454532)
N	int	4	Number of recorded samples
STAMin[]	float	4	Minimum of recorded indices
STAMax[]	float	4	Maximum of recorded indices
STAIndexList	int	6*4	Flag for each index (1: Index present in file, 0: Index not present in file). Sequence: LI, KO, TTI, KI, SI, CAPE
STATimeRef	int	4	Time reference (1: UTC, 0: Local Time)
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
STA1_1	float	4	LI-sample 1 (if STAIndexList[0]=1)
...
STA1_6	float	4	CAPE-sample 1 (if STAIndexList[5]=1)
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
STAN_1	float	4	LI-sample N (if STAIndexList[0]=1)
...
STAN_6	float	4	CAPE-sample N (if STAIndexList[5]=1)

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18)

A15a: Structure of Calibration Log-File (CAL.LOG), old version

Variable Name	Type	# Bytes	Description
STACode	int	4	CAL.LOG -File Code (=657644)
N_Gain	int	4	Number of recorded gain cal. samples



N_Noise	int	4	Number of recorded noise cal. samples
N_SkyTip	int	4	Number of recorded tip curve cal. samples
N_CH_Rec1	int	4	Number of receiver 1 channels
N_CH_Rec2	int	4	Number of receiver 2 channels
Frequ[]	float	4* ChanNo	Frequencies of Rec1 and Rec2
CalType1	int	4	Type of calibration sample 1 (0=gain, 1=noise, 2=tip curve results, 3=tip curve with full fit information)
CalTime1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
TipCurveStat1	int	4	Status of tip curve calibration (only if CalType1=2 or 3), 3 = FAILED, 2 = SUCCESS
Gain1[]	float	4* ChanNo	Gains of calibration sample 1
Tsys1[]	float	4* ChanNo	system noise temps of calibration sample 1 (only if CalType1=1 or CalType1=2 or CalType1=3)
LinCorr1[]	float	4* ChanNo	Linear correlations for calibration sample 1 (only if CalType1=2 or 3)
ChiSqr1[]	float	4* ChanNo	Chi square factors for calibration sample 1 (only if CalType1=2 or 3)
NoiseTemp1[]	float	4* ChanNo	Noise source temperatures for calibration sample 1 (only if CalType1=2 or 3)
SkyTipAngAnz1	int	4	Number of sky tip for calibration sample 1 (only if CalType1=3)
Airmass1[]	float	4* SkyTipAngAnz1	Airmass array (only if CalType1=3)
Rec1Enable	int	4	1=Skydip enabled for Receiver 1, 0=disabled
Rec2Enable	int	4	1=Skydip enabled for Receiver 2, 0=disabled
SkyDipUs1[i][j] i=0, ..., N_CH_Rec1-1 j=0, ..., SkyTipAngAnz1	float	4* N_CH_Rec1* (SkyTipAngAnz1+1)	Sky dip detector voltages (only if CalType1=3). For each frequency the det. Voltage is given at all angles. The last entry is the voltage on the hot target



TauSuccess1[]	int	4* N_CH_Rec1	Flag that indicates if the Tau calculation during the skydip was successful (0=no, 1=yes, 2=yes, also skydip successful) (only if CalType1=3)
TauArr1[0][j]	float	4* SkyTipAngAnz1	Tau array for channel 1 (only if CalType1=3 and TauSuccess1[0]=1)
LinFit1A[0]	float	4	Linear Fit parameter A (offset) for channel 1 (only if CalType1=3 and TauSuccess1[0]=1)
LinFit1B[0]	float	4	Linear Fit parameter B (slope) for channel 1 (only if CalType1=3 and TauSuccess1[0]=1)
...
TauArr1[N_CH_Rec1-1][j]	float	4* SkyTipAngAnz1	Tau array for last channel (only if CalType1=3 and TauSuccess1[N_CH_Rec1-1]=1)
LinFit1A[N_CH_Rec1-1]	float	4	Linear Fit parameter A (offset) for channel 1 (only if CalType1=3 and TauSuccess1[N_CH_Rec1-1]=1)
LinFit1B[N_CH_Rec1-1]	float	4	Linear Fit parameter B (slope) for last channel (only if CalType1=3 and TauSuccess1[N_CH_Rec1-1]=1)
...
CalTypeN	int	4	Type of calibration sample N (0=gain, 1=noise, 2=tip curve)
CalTimeN	int	4	Time of sample N (# of sec. since 1.1.2001)
TipCurveStatN	int	4	Status of tip curve calibration (only if CalTypeN=2), 3=FAILED, 2=SUCCESS
GainN[]	float	4* ChanNo	Gains of calibration sample 1
TsysN[]	float	4* ChanNo	system noise temps of calibration sample N (only if CalTypeN=1 or CalTypeN=2)
LinCorrN[]	float	4* ChanNo	Linear correlations for calibration sample N (only if CalTypeN=2)
ChiSqrN[]	float	4* ChanNo	Chi square factors for calibration sample N (only if CalTypeN=2)



NoiseTempN[]	float	4* ChanNo	Noise source temperatures for calibration sample N (only if CalTypeN=2)
SkyTipAngAnzN	int	4	Number of sky tip for calibration sample N (only if CalType1= 3)
AirmassN[]	float	4* SkyTipAngAnzN	Airmass array (only if CalType1=3)
Rec1Enable	int	4	1=Skydip enabled for Receiver 1, 0=disabled
Rec2Enable	int	4	1=Skydip enabled for Receiver 2, 0=disabled
SkyDipUsN[i][j] i=0, ... , N_CH_Rec1-1 j=0, ... , SkyTipAngAnzN	float	4* N_CH_Rec1* (SkyTipAngAnzN+1)	Sky dip detector voltages (only if CalType1=3). For each frequency the det. Voltage is given at all angles. The last entry is the voltage on the hot target, sample N
TauSuccessN[]	int	4* N_CH_Rec1	Flag that indicates if the Tau calculation during the skydip was successful (0=no, 1=yes, 2=yes, also skydip successful) (only if CalType1=3), sample N
TauArrN[0][j]	float	4* SkyTipAngAnzN	Tau array for channel 1 (only if CalType1=3 and TauSuccessN[0]=1)
LinFit1A[0]	float	4	Linear Fit parameter A (offset) for channel 1 (only if CalType1=3 and TauSuccessN[0]=1)
LinFit1B[0]	float	4	Linear Fit parameter B (slope) for channel 1 (only if CalType1=3 and TauSuccessN[0]=1)
...
TauArr1[N_CH_Rec1 - 1][j]	float	4* SkyTipAngAnzN	Tau array for last channel (only if CalType1=3 and TauSuccessN[N_CH_Rec1 - 1]=1)
LinFit1A[N_CH_Rec1 - 1]	float	4	Linear Fit parameter A (offset) for channel 1 (only if CalType1=3 and TauSuccessN[N_CH_Rec1 - 1]=1)
LinFit1B[N_CH_Rec1 - 1]	float	4	Linear Fit parameter B (slope) for last channel (only if CalType1=3 and TauSuccessN[N_CH_Rec1 - 1] =1)

with $N = N_Gain + N_Noise + N_SkyTip$ and $ChanNo = N_CH_Rec1 + N_CH_Rec2$.



A15b: Structure of Calibration Log-File (CAL.LOG), new version

Variable Name	Type	# Bytes	Description
STACode	int	4	CAL.LOG -File Code (=657645)
T1	int	4	time of first sample
Tn	int	4	time of latest sample
N_Gain	int	4	Number of recorded gain cal. samples
N_Noise	int	4	Number of recorded noise cal. samples
N_SkyTip	int	4	Number of recorded tip curve cal. samples
N_CH_Rec1	int	4	Number of receiver 1 channels
N_CH_Rec2	int	4	Number of receiver 2 channels
Frequ[]	float	4* ChanNo	Frequencies of Rec1 and Rec2
CalType1	int	4	Type of calibration sample 1 (0=gain, 1=noise, 2=tip curve results, 3=tip curve with full fit information)
CalTime1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
TipCurveStat1	int	4	Status of tip curve calibration (only if CalType1=2 or 3), 3 = FAILED, 2 = SUCCESS
Gain1[]	float	4* ChanNo	Gains of calibration sample 1
Tsys1[]	float	4* ChanNo	system noise temps of calibration sample 1 (only if CalType1=1 or CalType1=2 or CalType1=3)
LinCorr1[]	float	4* ChanNo	Linear correlations for calibration sample 1 (only if CalType1=2 or 3)
ChiSqr1[]	float	4* ChanNo	Chi square factors for calibration sample 1 (only if CalType1=2 or 3)
NoiseTemp1[]	float	4* ChanNo	Noise source temperatures for calibration sample 1 (only if CalType1=2 or 3)
SkyTipAngAnz1	int	4	Number of sky tip for calibration sample 1 (only if CalType1= 3)
Airmass1[]	float	4* SkyTipAngAnz1	Airmass array (only if CalType1=3)
Rec1Enable	int	4	1=Skydip enabled for Receiver 1, 0=disabled
Rec2Enable	int	4	1=Skydip enabled for Receiver 2, 0=disabled



SkyDipUs1[i][j] i=0, ... , N_CH_Rec1-1 j=0, ... , SkyTipAngAnz1	float	4* N_CH_Rec1* (SkyTipAngAnz1+1)	Sky dip detector voltages (only if CalType1=3). For each frequency the det. Voltage is given at all angles. The last entry is the voltage on the hot target
TauSuccess1[]	int	4* N_CH_Rec1	Flag that indicates if the Tau calculation during the skydip was successful (0=no, 1=yes, 2=yes, also skydip successful) (only if CalType1=3)
TauArr1[0][j]	float	4* SkyTipAngAnz1	Tau array for channel 1 (only if CalType1=3 and TauSuccess1[0]=1)
LinFit1A[0]	float	4	Linear Fit parameter A (offset) for channel 1 (only if CalType1=3 and TauSuccess1[0]=1)
LinFit1B[0]	float	4	Linear Fit parameter B (slope) for channel 1 (only if CalType1=3 and TauSuccess1[0]=1)
...
TauArr1[N_CH_Rec1-1][j]	float	4* SkyTipAngAnz1	Tau array for last channel (only if CalType1=3 and TauSuccess1[N_CH_Rec1-1]=1)
LinFit1A[N_CH_Rec1-1]	float	4	Linear Fit parameter A (offset) for channel 1 (only if CalType1=3 and TauSuccess1[N_CH_Rec1-1]=1)
LinFit1B[N_CH_Rec1-1]	float	4	Linear Fit parameter B (slope) for last channel (only if CalType1=3 and TauSuccess1 [N_CH_Rec1-1] =1)
...
CalTypeN	int	4	Type of calibration sample N (0=gain, 1=noise, 2=tip curve)
CalTimeN	int	4	Time of sample N (# of sec. since 1.1.2001)
TipCurveStatN	int	4	Status of tip curve calibration (only if CalTypeN=2), 3=FAILED, 2=SUCCESS
GainN[]	float	4* ChanNo	Gains of calibration sample 1
TsysN[]	float	4* ChanNo	system noise temps of calibration sample N (only if CalTypeN=1 or CalTypeN=2)
LinCorrN[]	float	4* ChanNo	Linear correlations for calibration sample N (only if CalTypeN=2)



ChiSqrN[]	float	4* ChanNo	Chi square factors for calibration sample N (only if CalTypeN=2)
NoiseTempN[]	float	4* ChanNo	Noise source temperatures for calibration sample N (only if CalTypeN=2)
SkyTipAngAnzN	int	4	Number of sky tip for calibration sample N (only if CalType1= 3)
AirmassN[]	float	4* SkyTipAngAnzN	Airmass array (only if CalType1=3)
Rec1Enable	int	4	1=Skydip enabled for Receiver 1, 0=disabled
Rec2Enable	int	4	1=Skydip enabled for Receiver 2, 0=disabled
SkyDipUsN[i][j] i=0, ... , N_CH_Rec1-1 j=0, ... , SkyTipAngAnzN	float	4* N_CH_Rec1* (SkyTipAngAnzN+1)	Sky dip detector voltages (only if CalType1=3). For each frequency the det. Voltage is given at all angles. The last entry is the voltage on the hot target, sample N
TauSuccessN[]	int	4* N_CH_Rec1	Flag that indicates if the Tau calculation during the skydip was successful (0=no, 1=yes, 2=yes, also skydip successful) (only if CalType1=3), sample N
TauArrN[0][j]	float	4* SkyTipAngAnzN	Tau array for channel 1 (only if CalType1=3 and TauSuccessN[0]=1)
LinFit1A[0]	float	4	Linear Fit parameter A (offset) for channel 1 (only if CalType1=3 and TauSuccessN[0]=1)
LinFit1B[0]	float	4	Linear Fit parameter B (slope) for channel 1 (only if CalType1=3 and TauSuccessN[0]=1)
...
TauArr1[N_CH_Rec1-1][j]	float	4* SkyTipAngAnzN	Tau array for last channel (only if CalType1=3 and TauSuccessN[N_CH_Rec1-1]=1)
LinFit1A[N_CH_Rec1-1]	float	4	Linear Fit parameter A (offset) for channel 1 (only if CalType1=3 and TauSuccessN[N_CH_Rec1-1]=1)
LinFit1B[N_CH_Rec1-1]	float	4	Linear Fit parameter B (slope) for last channel (only if CalType1=3 and TauSuccessN[N_CH_Rec1-1]=1)



A16: CBH-Files (*.CBH), Cloud Base Height

Variable Name	Type	# Bytes	Description
CBHCode	int	4	CBH-File Code (=67777499)
N	int	4	Number of recorded samples
CBHMin	float	4	Minimum of recorded CBH values
CBHMax	float	4	Maximum of recorded CBH values
CBHTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1 ⁽¹⁾	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
CBH_1	float	4	Cloud base height [m], sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N ⁽¹⁾	char	1	Rainflag of sample N (0: no rain, 1: rain)
CBH_N	float	4	Cloud base height [m], sample N

⁽¹⁾ The rain flag is an 8 bit array: MSB 000yyxxr LSB, r = rain information (0= no rain, 1=raining) xx = quality level (0=not evaluated, 1=high, 2=medium, 3=low), yy = reason for reduced quality (see appendix A18)

A17: BLH-Files (*.BLH), Boundary Layer Height

Variable Name	Type	# Bytes	Description
BLHCode	int	4	BLH-File Code (=1777786)
N	int	4	Number of recorded samples
BLHMin	float	4	Minimum of recorded BLH values
BLH Max	float	4	Maximum of recorded BLH values
BLHTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
BLH_1 ⁽¹⁾	float	4	Boundary layer height [m], sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
RF_N	char	1	Rainflag of sample N (0: no rain, 1: rain)
BLH_N ⁽¹⁾	float	4	Boundary layer height [m], sample N

⁽¹⁾ If the BLH is positive, it refers to a stable boundary layer (most likely with temp. inversion). When BLH is negative, its absolute number refers to an instable mixing layer height (Parcel condition is fulfilled, see section 4.16.5).



A18a: VLT-Files (*.VLT), Channel Voltage File (old version)

Variable Name	Type	# Bytes	Description
CBHCode	int	4	VLT-File Code (=362118746)
N	int	4	Number of recorded samples
IntTimeIndex	int	4	Integration time index (0:1sec, 1:2sec, 2:5 sec, 3:10sec, 4:20sec, 5:30sec, 6:60sec)
DiagSource[0..3]	int	4x4	Type array for the four acquisition channels; 0=disabled, 1=receiver 1 voltage data, 2=receiver 2 voltage data, 3=ambient target temp., 4=env. temp, 5=rec. 1 temp., 6=rec. 2 temp., 7=bar. Pressure, 8=rel. humidity
DataSample1, DiagSource[0]	float	4 or 7x4	Data for sample 1 (7 floats in the case of data type =1/2, one float in all other cases)
DataSample1, DiagSource[1]	float	4 or 7x4	Data for sample 1 (7 floats in the case of data type =1/2, one float in all other cases)
DataSample1, DiagSource[2]	float	4 or 7x4	Data for sample 1 (7 floats in the case of data type =1/2, one float in all other cases)
DataSample1, DiagSource[3]	float	4 or 7x4	Data for sample 1 (7 floats in the case of data type =1/2, one float in all other cases)
Time1	int	4	Time in seconds after measurement start of sample N
...
DataSampleN, DiagSource[0]	float	4 or 7x4	Data for sample N (7 floats in the case of data type =1/2, one float in all other cases)
DataSampleN, DiagSource[1]	float	4 or 7x4	Data for sample N (7 floats in the case of data type =1/2, one float in all other cases)
DataSampleN, DiagSource[2]	float	4 or 7x4	Data for sample N (7 floats in the case of data type =1/2, one float in all other cases)
DataSampleN, DiagSource[3]	float	4 or 7x4	Data for sample N (7 floats in the case of data type =1/2, one float in all other cases)
TimeN	int	4	Time in seconds after measurement start of sample N

A18b: VLT-Files (*.VLT), Channel Voltage File (new version)

Variable Name	Type	# Bytes	Description
CBHCode	int	4	VLT-File Code (=362118747)
N	int	4	Number of recorded samples
IntTimeIndex	int	4	Integration time index (0:1sec, 1:2sec, 2:5 sec, 3:10sec, 4:20sec, 5:30sec, 6:60sec)
SlaveRecord	int	4	=0: no Slave radiometer data recorded, =1: Slave radiometer data recorded
R1FAnz	int	4	Receiver 1 number of frequencies



Rec1Freqs[]	float	R1FAnz x4	Receiver 1 frequencies [GHz]
R2FAnz	int	4	Receiver 2 number of frequencies
Rec2Freqs[]	float	R2FAnz x4	Receiver 2 frequencies [GHz]
SIR1FAnz	int	4	If SlaveRecord =1: Slave Receiver 1 number of frequencies
SIRec1Freqs[]	float	SIR1FAnz x4	If SlaveRecord =1: Slave Receiver 1 frequencies [GHz]
SIR2FAnz	int	4	If SlaveRecord =1: Slave Receiver 2 number of frequencies
SIRec2Freqs[]	float	SIR2FAnz x4	If SlaveRecord =1: Slave Receiver 2 frequencies [GHz]
DiagSource[0..3]	int	4x4	Type array for the four acquisition channels; 0=disabled, 1=receiver 1 voltage data, 2=receiver 2 voltage data, 3=ambient target temp., 4=env. temp, 5=rec. 1 temp., 6=rec. 2 temp., 7=bar. Pressure, 8=rel. humidity
DataSample1, DiagSource[0]	float	4 or R1FAnz/R2FAnz x4	Data for sample 1 (R1FAnz/R2FAnz floats in the case of data type =1/2, one float in all other cases)
DataSample1, DiagSource[1]	float	4 or R1FAnz/R2FAnz x4	Data for sample 1 (R1FAnz/R2FAnz floats in the case of data type =1/2, one float in all other cases)
DataSample1, DiagSource[2]	float	4 or R1FAnz/R2FAnz x4	Data for sample 1 (R1FAnz/R2FAnz floats in the case of data type =1/2, one float in all other cases)
DataSample1, DiagSource[3]	float	4 or R1FAnz/R2FAnz x4	Data for sample 1 (R1FAnz/R2FAnz floats in the case of data type =1/2, one float in all other cases)
Time1	int	4	Time in seconds after measurement start off sample 1
...
DataSampleN, DiagSource[0]	float	4 or R1FAnz/R2FAnz x4	Data for sample N (R1FAnz/R2FAnz floats in the case of data type =1/2, one float in all other cases)
DataSampleN, DiagSource[1]	float	4 or R1FAnz/R2FAnz x4	Data for sample N (R1FAnz/R2FAnz floats in the case of data type =1/2, one float in all other cases)
DataSampleN, DiagSource[2]	float	4 or R1FAnz/R2FAnz x4	Data for sample N (R1FAnz/R2FAnz floats in the case of data type =1/2, one float in all other cases)
DataSampleN, DiagSource[3]	float	4 or R1FAnz/R2FAnz x4	Data for sample N (R1FAnz/R2FAnz floats in the case of data type =1/2, one float in all other cases)



TimeN	int	4	Time in seconds after measurement start of sample N
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A19: HKD-Files (*.HKD), Housekeeping Data File

Variable Name	Type	# Bytes	Description
HKDCode	int	4	HKD-File Code (=837854832)
N	int	4	Number of recorded samples
HKDTimeRef	int	4	Time reference (1: UTC, 0: Local Time)
HKDSelect ⁽¹⁾	int	4	Selects the recorded data groups of this file
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
Alarm_1 ⁽²⁾	char	1	Alarm flag of sample 1 (0: ok, 1: alarm)
Longitude_1 ⁽³⁾	float	4	GPS longitude of sample 1 (only if bit 1 of HKDSelect is set to '1')
Latitude_1 ⁽³⁾	float	4	GPS latitude of sample 1 (only if bit 1 of HKDSelect is set to '1')
T[0,...,3]_1	float	4x4	Temperatures of sample 1. T[0]=ambient target sensor 1, T[1]=ambient target sensor 2 (if present), T[2]=humidity profiler receiver(1), T[3]=temperaure profiler receiver(2) (only if bit 2 of HKDSelect is set to '1'), unit [K]
Stab[0,1]_1	float	2x4	Temperature stability of receiver 1 and 2 (only if bit 3 of HKDSelect is set to '1'), unit [K]
Flash_1	int	4	Remaining flash memory (only if bit 4 of HKDSelect is set to '1'), unit [kBytes]
Quality_1 ⁽⁴⁾	int	4	Quality flags of sample 1 (only if bit 5 of HKDSelect is set to '1')
Status_1 ⁽⁵⁾	int	4	Status flags of sample 1 (only if bit 5 of HKDSelect is set to '1')
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
Alarm_N ⁽²⁾	char	1	Alarm flag of sample N (0: ok, 1: alarm)
Longitude_N ⁽³⁾	float	4	GPS longitude of sample N (only if bit 1 of HKDSelect is set to '1')
Latitude_N ⁽³⁾	float	4	GPS latitude of sample N (only if bit 1 of HKDSelect is set to '1')
T[0,...,3]_N	float	4x4	Temperatures of sample N. T[0]=ambient target sensor 1, T[1]=ambient target sensor 2 (if present), T[2]=humidity profiler receiver(1), T[3]=temperaure profiler receiver(2) (only if bit 2 of HKDSelect is set to '1'), unit [K]
Stab[0,1]_N	float	2x4	Temperature stability of receiver 1 and 2 (only if bit 3 of HKDSelect is set to '1'), unit [K]



Flash_N	int	4	Remaining flash memory (only if bit 4 of HKDSelect is set to '1'), unit [kBytes]
Quality_N ⁽⁴⁾	int	4	Quality flags of sample N (only if bit 5 of HKDSelect is set to '1')
Status_N ⁽⁵⁾	int	4	Status flags of sample N (only if bit 5 of HKDSelect is set to '1')

⁽¹⁾ **HKDSelect:** Only the first byte of this integer value is used for selection of data groups. The meaning of the various bit settings of this byte is the following:

- Bit 1: When this bit is set to '1', the GPS-position (longitude, latitude) is recorded in this file, otherwise not.
- Bit 2: When this bit is set to '1', the temperature data is recorded in this file, otherwise not. Bit 3: When this bit is set to '1', the receiver stability data is recorded in this file, otherwise not.
- Bit 4: When this bit is set to '1', the remaining flash memory is recorded in this file, otherwise not.
- Bit 5: When this bit is set to '1', quality flags are recorded in this file, otherwise not.
- Bit 6: When this bit is set to '1', status flags are recorded in this file, otherwise not.

⁽²⁾ **Alarm:** The alarm flag is activated in the following cases:

- interference or failure of a channel that is used in one of the retrievals
- thermal receiver stability not sufficient for measurement
- noise diode failure of one of the receivers
- ambient target thermal sensor not stable

⁽³⁾ **GPS longitude / latitude format:** (-)DDDMM.mmmm, longitude is negative: West of 0-meridian, latitude is negative: South of equator. 'DDD' is measured in degrees (0-180 for longitude, 0-90 for latitude), 'MM' is measured in minutes ('), 'mmmm' is the decimal fraction of 'MM'. Example: longitude = -12245.50 means 122°45'30" West, latitude -3321.25 means 33°21'15" South.

⁽⁴⁾ **Quality Flags:** This 4 byte unsigned integer is subdivided into 8 groups of 4 bits:

```

MSB  yyxx  yyxx  yyxx  yyxx  yyxx  yyxx  yyxx  yyxx
LSB  LP    STA  TPB   TPC  HPC  DLY  IWV  LWP

```

Each group represents the quality flags of a certain level 2 product (retrieved data). The 'xx' bits are coded in the following way:

- 'xx' = 0: this level 2 product is not evaluated for quality control
- 'xx' = 1: highest quality level
- 'xx' = 2: reduced quality
- 'xx' = 3: low quality. This sample should not be used.

The 'yy' bits are coding the possible reasons for reduced or low quality sampling:

- 'yy' = 0: unknown
- 'yy' = 1: possible external interference on a receiver channel or failure of a receiver channel that is used in the retrieval of this product.
- 'yy' = 2: LWP too high. At high rain rates the scattering on rain drops can mask the water vapour line completely and no humidity profiling or IWV determination is possible. Also the temperature profiling may be affected when the oxygen line channels are all saturated due to droplets.
- 'yy' = 3: free for future use.

⁽⁵⁾ **Status Flags:**



- Bit 1-7: status flags for channel 1 to 7 of the humidity profiler receiver. When a bit is set '1', the corresponding channel is ok, otherwise the channel has a malfunction.
- Bit 8: not used
- Bit 9-15: status flags for channel 1 to 7 of the temperature profiler receiver. When a bit is set '1', the corresponding channel is ok, otherwise the channel has a malfunction.
- Bit 16: not used
- Bit 17: rain flag. '1' means raining, '0' = no rain
- Bit 18: dew blower speed status. '1' = high speed mode, '0' = low speed mode
- Bit 19: BL-mode flag. '1' = boundary layer scanning active, '0' = BL-mode not active
- Bit 20: '1' = sky tipping calibration running, '0' = not active
- Bit 21: '1' = gain calibration running (using internal ambient target), '0' = not active
- Bit 22: '1' = noise calibration running, '0' = not active
- Bit 23: '1' = noise diode of humidity profiler ok, '0' = noise diode not working
- Bit 24: '1' = noise diode of temperature profiler ok, '0' = noise diode not working
- Bits 25,26: receiver 1 (humidity profiler) thermal stability. '0' = unknown, not enough data samples recorded yet, '1' = stability ok, '2' = not sufficiently stable
- Bits 27,28: receiver 2 (temperature profiler) thermal stability. '0' = unknown, not enough data samples recorded yet, '1' = stability ok, '2' = not sufficiently stable
- Bit 29: power failure flag. '1' = a power failure has occurred recently. When a new MDF has been started automatically after a power failure, the '1' flag is kept for 1000 seconds and switching back to '0' afterwards. '0' = no power failure occurred.
- Bit 30: ambient target stability: Some radiometers are using two ambient target temperature sensors for monitoring the target's physical temperature. When the temperature readings of these two sensors differ by more than 0.3 K, the flag turns to '1'. '0' = sensors ok.
- Bit 31: noise diode status: '0' = noise diode is turned off for the current sample, '1' = noise diode is turned on for the current sample.

A20: ABSCAL.HIS, Absolute Calibration History File

Variable Name	Type	# Bytes	Description
HISCode	int	4	HIS-File Code (=39583209)
N	int	4	Number of calibration entries
EntryLen1	int	4	Length of entry #1 in bytes
Radiometer-ID1	int	4	1=TEMPRO, 2=HUMPRO, 3=HATPRO, 4=RPG-15-90, 5=LHATPRO, 6=RPG-150-90, 7= RPG-36-90, 8=RPG-LWP, 9=RPG-LWPU90, 10 =RPG-DP150-90, 11=HALO-KV, 12=HALO-183, 13=HALO-119-90
Cal1Type1	int	4	Calibration type receiver 1, entry #1 (0: no calibration, 1: Abs. Cal. With LN, 2:Skydip calibration)
Cal2Type1	int	4	Calibration type receiver 2, entry #1 (0: no calibration, 1: Abs. Cal. With LN, 2:Skydip calibration)
T1_1	int	4	Time of calibration receiver 1 , entry #1 (# of sec. since 1.1.2001)



T2_1	int	4	Time of calibration receiver 2 , entry #1 (# of sec. since 1.1.2001)
ATemp1_1	float	4	Ambient temperature receiver 1, entry #1 [K]
ATemp2_1	float	4	Ambient temperature receiver 2, entry #1 [K]
P1_1	float	4	Barom. pressure receiver 1, entry #1 [mbar]
P2_1	float	4	Barom. pressure receiver 2, entry #1 [mbar]
HLTemp1_1	float	4	Hotload temp. receiver 1, entry #1 [K]
HLTemp2_1	float	4	Hotload temp. receiver 2, entry #1 [K]
CLTemp1_1	float	4	Coldload temp. receiver 1, entry #1 [K]
CLTemp2_1	float	4	Coldload temp. receiver 2, entry #1 [K]
Spare[5]	float	4x5	20 spare bytes, entry #1
NRec1Ch	int	4	Number of receiver 1 channels, entry #1
ChF1[1... NRec1Ch]	float	4x NRec1Ch	Frequencies of receiver 1, entry #1
NRec2Ch	int	4	Number of receiver 2 channels, entry #1
ChF2[1... NRec2Ch]	float	4x NRec2Ch	Frequencies of receiver 2, entry #1
Calibrated1[]	int	4x(NRec1Ch+ NRec2Ch)	Calibration flags for all channels, entry #1 (0=no calibrated, 1=calibrated)
Gain1[]	float	4x(NRec1Ch+ NRec2Ch)	Receiver gains for all channels, entry #1 [V/K]
NoiseT1[]	float	4x(NRec1Ch+ NRec2Ch)	Noise diode temperature for all channels, entry #1 [K]
TSys1[]	float	4x(NRec1Ch+ NRec2Ch)	System noise temperature for all channels, entry #1 [K]
Alpha1[]	float	4x(NRec1Ch+ NRec2Ch)	Non-linearity factors for all channels, entry #1
...
EntryLenN	int	4	Length of entry #N in bytes
Radiometer-IDN	int	4	1=TEMPRO, 2=HUMPRO, 3=HATPRO, 4=RPG-15-90, 5=LHATPRO, 6=RPG-150-90, 7= RPG-36-90, 8=RPG-LWP, 9=RPG-LWPU90, 10 =RPG-DP150-90, 11=HALO-KV, 12=HALO-183, 13=HALO-119-90
Cal1TypeN	int	4	Calibration type receiver 1, entry #N (0: no calibration, 1: Abs. Cal. With LN, 2:Skydip calibration)
Cal2TypeN	int	4	Calibration type receiver 2, entry #N (0: no calibration, 1: Abs. Cal. With LN, 2:Skydip calibration)
T1_N	int	4	Time of calibration receiver 1 , entry #N (# of sec. since 1.1.2001)



T2_N	int	4	Time of calibration receiver 2 , entry #N (# of sec. since 1.1.2001)
ATemp1_N	float	4	Ambient temperature receiver 1, entry #N [K]
ATemp2_N	float	4	Ambient temperature receiver 2, entry #N [K]
P1_N	float	4	Barom. pressure receiver 1, entry #N [mbar]
P2_N	float	4	Barom. pressure receiver 2, entry #N [mbar]
HLTemp1_N	float	4	Hotload temp. receiver 1, entry #N [K]
HLTemp2_N	float	4	Hotload temp. receiver 2, entry #N [K]
CLTemp1_N	float	4	Coldload temp. receiver 1, entry #N [K]
CLTemp2_N	float	4	Coldload temp. receiver 2, entry #N [K]
Spare[5]	float	4x5	20 spare bytes, entry #N
NRec1Ch	int	4	Number of receiver 1 channels, entry #N
ChF1[1... NRec1Ch]	float	4x NRec1Ch	Frequencies of receiver 1, entry #N
NRec2Ch	int	4	Number of receiver 2 channels, entry #N
ChF2[1... NRec2Ch]	float	4x NRec2Ch	Frequencies of receiver 2, entry #N
Calibrated1[]	int	4x(NRec1Ch+ NRec2Ch)	Calibration flags for all channels, entry #N (0=not calibrated, 1=calibrated)
GainN[]	float	4x(NRec1Ch+ NRec2Ch)	Receiver gains for all channels, entry #N [V/K]
NoiseTN[]	float	4x(NRec1Ch+ NRec2Ch)	Noise diode temperature for all channels, entry #N [K]
TSysN[]	float	4x(NRec1Ch+ NRec2Ch)	System noise temperature for all channels, entry #N [K]
AlphaN[]	float	4x(NRec1Ch+ NRec2Ch)	Non-linearity factors for all channels, entry #N

A21a: LV0-Files (*.LV0), Level Zero (Detector Voltages) Files (old)

Variable Name	Type	# Bytes	Description
LV0Code	int	4	LV0-File Code (=111111)
N	int	4	Number of samples
MasterID ⁽¹⁾	int	4	ID number of Master Radiometer
SlaveID ⁽¹⁾	int	4	ID number of Slave Radiometer
TimeRef	int	4	Time Reference (0=Local, 1=UTC)
FreqNo	int	4	Number of Frequencies
Freqs[]	float	4*FreqNo	Frequencies [GHz]
Longitude	float	4	GPS longitude (refer to FN (3), HKD-files)
Latitude	float	4	GPS latitude (refer to FN (3), HKD-files)
Alpha ⁽²⁾ []	float	4*FreqNo	Alpha calibration parameters
DelT ⁽³⁾ []	float	4*FreqNo	DelT calibration Parameters [K]



T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
Ud_1[]	float	4*FreqNo	Detector Voltages [V] of sample 1
Elevation_1	float	4	Elevation Angle [°] of sample 1
Azimuth_1	float	4	Azimuth Angle [°] of sample 1
MaTambient_1	float	4	Black Body Temperature [K] of Master radiometer, sample 1
MaDigFlags_1	int	4	Digital Flags of Master radiometer, sample 1, refer to FN (5) of HKD-files
SITambient_1	float	4	Black Body Temperature [K] of Slave radiometer, sample 1 (only if SlaveID ≠ 0)
SIDigFlags_1	int	4	Digital Flags of Slave radiometer, sample 1, refer to FN (5) of HKD-files (only if SlaveID ≠ 0)
G_1[]	float	4*FreqNo	Gain calibration parameters [V/K], sample 1
Tsys_1[]	float	4*FreqNo	System Noise Temperature calibration parameters Tsys [K], sample 1
Tn_1[]	float	4*FreqNo	Noise Diode Temperature calibration parameters Tn [K], sample 1
Tenv_1	float	4	Environmental Temperature [K] of sample 1
P_1	float	4	Barometric Pressure [mbar] of sample 1
RH_1	float	4	Relative Humidity [%] of sample 1
IRT_1	float	4	Infrared Radiometer Temperature [°C] of sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
Ud_N[]	float	4*FreqNo	Detector Voltages [V] of sample N
Elevation_N	float	4	Elevation Angle [°] of sample N
Azimuth_N	float	4	Azimuth Angle [°] of sample N
MaTambient_N	float	4	Black Body Temperature [K] of Master radiometer, sample N
MaDigFlags_N	int	4	Digital Flags of Master radiometer, sample N, refer to FN (5) of HKD-files
SITambient_N	float	4	Black Body Temperature [K] of Slave radiometer, sample N (only if SlaveID ≠ 0)
SIDigFlags_N	int	4	Digital Flags of Slave radiometer, sample N, refer to FN (5) of HKD-files (only if SlaveID ≠ 0)
G_N[]	float	4*FreqNo	Gain calibration parameters [V/K], sample N
Tsys_N[]	float	4*FreqNo	System Noise Temperature calibration parameters Tsys [K], sample N
Tn_N[]	float	4*FreqNo	Noise Diode Temperature calibration parameters Tn [K], sample N
Tenv_N	float	4	Environmental Temperature [K] of sample N
P_N	float	4	Barometric Pressure [mbar] of sample N
RH_N	float	4	Relative Humidity [%] of sample N



IRT_N	float	4	Infrared Radiometer Temperature [°C] of sample N
-------	-------	---	--

A21b: LV0-Files (*.LV0), Level Zero (Detector Voltages) Files (new)

Variable Name	Type	# Bytes	Description
LV0Code	int	4	LV0-File Code (=111112)
N	int	4	Number of samples
MasterID ⁽¹⁾	int	4	ID number of Master Radiometer
SlaveID ⁽¹⁾	int	4	ID number of Slave Radiometer
TimeRef	int	4	Time Reference (0=Local, 1=UTC)
FreqNo	int	4	Number of Frequencies
Freqs[]	float	4*FreqNo	Frequencies [GHz]
IRFreqNo	int	4	Number of IRRs
IRRWLs[]	float	4*IRFreqNo	IRR wavelengths [µm]
Longitude	float	4	GPS longitude (refer to FN (3), HKD-files)
Latitude	float	4	GPS latitude (refer to FN (3), HKD-files)
Alpha[] ⁽²⁾	float	4*FreqNo	Alpha calibration parameters
DelT[] ⁽³⁾	float	4*FreqNo	DelT calibration Parameters [K]
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
Ud_1[]	float	4*FreqNo	Detector Voltages [V] of sample 1
Elevation_1	float	4	Elevation Angle [°] of sample 1
Azimuth_1	float	4	Azimuth Angle [°] of sample 1
MaTambient_1	float	4	Black Body Temperature [K] of Master radiometer, sample 1
MaDigFlags_1	int	4	Digital Flags of Master radiometer, sample 1, refer to FN (5) of HKD-files
SITambient_1	float	4	Black Body Temperature [K] of Slave radiometer, sample 1 (only if SlaveID ≠ 0)
SIDigFlags_1	int	4	Digital Flags of Slave radiometer, sample 1, refer to FN (5) of HKD-files (only if SlaveID ≠ 0)
G_1[]	float	4*FreqNo	Gain calibration parameters [V/K], sample 1
Tsys_1[]	float	4*FreqNo	System Noise Temperature calibration parameters Tsys [K], sample 1
Tn_1[]	float	4*FreqNo	Noise Diode Temperature calibration parameters Tn [K], sample 1
Tenv_1	float	4	Environmental Temperature [K] of sample 1
P_1	float	4	Barometric Pressure [mbar] of sample 1
RH_1	float	4	Relative Humidity [%] of sample 1
IRT[]_1	float	4*IRFreqNo	Infrared Radiometer Temperatures [°C] of sample 1
...
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
Ud_N[]	float	4*FreqNo	Detector Voltages [V] of sample N



Elevation_N	float	4	Elevation Angle [°] of sample N
Azimuth_N	float	4	Azimuth Angle [°] of sample N
MaTambient_N	float	4	Black Body Temperature [K] of Master radiometer, sample N
MaDigFlags_N	int	4	Digital Flags of Master radiometer, sample N, refer to FN (5) of HKD-files
SITambient_N	float	4	Black Body Temperature [K] of Slave radiometer, sample N (only if SlaveID ≠ 0)
SIDigFlags_N	int	4	Digital Flags of Slave radiometer, sample N, refer to FN (5) of HKD-files (only if SlaveID ≠ 0)
G_N[]	float	4*FreqNo	Gain calibration parameters [V/K], sample N
Tsys_N[]	float	4*FreqNo	System Noise Temperature calibration parameters Tsys [K], sample N
Tn_N[]	float	4*FreqNo	Noise Diode Temperature calibration parameters Tn [K], sample N
Tenv_N	float	4	Environmental Temperature [K] of sample N
P_N	float	4	Barometric Pressure [mbar] of sample N
RH_N	float	4	Relative Humidity [%] of sample N
IRT[]_N	float	4*IRFreqNo	Infrared Radiometer Temperatures [°C] of sample N

(1) ID number coding: 0=no rad., 1=RPG-TEMPRO, 2=RPG-HUMPRO, 3=RPG-HATPRO, 4=RPG-15-90, 5=RPR-LHUMPRO, 6=RPG-150-90, 7=RPG-36-90, 8=RPG-DP150-90

(2) Alpha Parameter: Non-Linearity Parameter for radiometer which are not operated in Full-Dicke Switching mode (Dicke Switching + Noise Switching) like RPG-TEMPRO, RPG-HUMPRO, RPG-HATPRO, RPG-LHUMPRO, RPG-3690, RPG-DP150-90
Dicke Switch Leakage for radiometers that are operated in Full-Dicke Switching mode (Dicke Switching + Noise Switching) like RPG-150-90, RPG-15-90 and RPG-HATPRO-U

(3) DelT Parameter: Difference between radiometric (T_{DSr}) and physical (T_{Dsp}) Dicke Switch temperature: $DelT = T_{DSr} - T_{Dsp}$, only relevant for Full Dicke Switching radiometers

Notes on Calibrations

Relation between detector voltages U_d and scene temperatures T_{sc} :

$U_d = G (T_{sys} + T_{sc})^{Alpha}$, for radiometers without Full Dicke Switching Mode (Type 1) $U_d = G (T_{sys} + T_{sc})$, for radiometers with Full Dicke Switching Mode (Type 2)

System Noise Temperature T_{sys} , Noise Diode Temp. T_N and Gain G :

Absolute Calibrations (Hot / Cold): detector voltages on black body target (temperature $T_H = T_{amb}$): U_H , cold target (LN or Skydip, temperature T_C): U_C :

$Y = (U_H / U_C)^{1/Alpha}$, $T_{sys} = (T_H - Y * T_C) / (Y - 1)$, $0.95 < Alpha <= 1$ (sec. 4.1.3.1), Type 1



$$Y = (U_H / U_C), T_{sys} = (T_H - Y * T_C) / (Y - 1), \text{ Type 2}$$

$$G = U_H / (T_{sys} + T_H)^{\text{Alpha}}, \text{ Type 1}$$

$$G = U_H / (T_{sys} + T_H), \text{ Type 2}$$

On black body target (T_{amb}), noise diode turned off: U_{-N} , noise diode turned on: U_{+N}

$$T_N = (U_{+N} / G)^{1/\text{Alpha}} - T_{sys} - T_{amb}, \text{ Type 1}$$

$$T_N = (U_{+N} - U_{-N}) / G, \text{ Type 2}$$

Type 2 only: Dicke Switch (DS) ON, radiometer pointing to amb. temp. target:

$$\text{DelT} = U_{DS} / G - T_{sys} - T_{DSp},$$

Dicke Switch (DS) leakage (Type 2 only): DS ON, radiometer pointing to cold target: Alpha = $(T_{DSp} + \text{DelT} - (U_{DS} / G - T_{sys})) / (T_{DSp} + \text{DelT} - T_C)$

If a liquid nitrogen cooled target is used, the following correction has to be applied:

$$\ln\left(\frac{p}{1013.25 \cdot \text{mbar}}\right) = \frac{\Delta H}{R} \left(\frac{1}{77.35 \text{K}} - \frac{1}{T_C} \right), \text{ Clausius - Clapeyron}$$

$T_0 = 77.36 \text{ K}$ is the boiling temperature at 1013.25 hPa, ΔH is the latent heat of liquid nitrogen and R is the universal gas constant.

Continuous full calibration on scene (Type 2 only): Noise Diode turned off: U_{-N} , noise diode turned on: U_{+N} , radiometers looking on scene temperature T_{sc} , Dicke switch turned ON (blocking scene), physical Dicke switch temperature T_{DSp} :

$G = (U_{+N} - U_{-N}) / T_N$, $T_{sys} = U_{-N} / G - (T_{DSp} + \text{DelT} - \text{Alpha} * (T_{DSp} - T_{sc}))$, Alpha = DS leakage (determined in absolute calibration)

Continuous noise switching on scene (Type 1 only): noise diode turned off: U_{-N} , noise diode turned on: U_{+N} (10 Hz), radiometers pointing to scene (temperature T_{sc}):

$$D = (U_{+N} / U_{-N})^{1/\text{Alpha}} - 1, T_{sc} = (T_N - D * T_{sys}) / D, G = U_{-N} / (T_{sys} + T_{sc})^{\text{Alpha}}$$

$$\text{Calibration on ambient temp. black body target } (T_{amb}): T_{sys} = (U_d / G)^{1/\text{Alpha}} - T_{amb}$$

Type 1, no noise switching:

gain calibration on ambient temp. target (T_{amb}): $G = U_d / (T_{sys} + T_{amb})^{\text{Alpha}}$ noise calibration on ambient temp. target (T_{amb}):

$$D = (U_{+N} / U_{-N})^{1/\text{Alpha}} - 1, T_{sys} = (T_N - D * T_{amb}) / D, G = U_{-N} / (T_{sys} + T_{amb})^{\text{Alpha}}$$

Important general note:

Be aware that at low brightness temperatures $T_b < 10 \text{ K}$ and high frequencies $> 50 \text{ GHz}$ you have to apply the Planck transformation, NOT the Rayleigh-Jeans approximation. The detector voltage is in general proportional to the received power but not to a brightness temperature as assumed by the Rayleigh-Jeans approximation. Therefore a T_{br} calculated by Rayleigh-Jeans (the formalism used above) has to be converted to a Planck T_{bp} brightness temperature by the following formula:

$$T_{BP} = \frac{Ff}{\ln\left(\frac{Ff}{T_{BR}} + 1\right)}, \text{ with } Ff = f[\text{Hz}] \cdot \frac{h}{k_B}$$



A22: TRK-Files (*.TRK), Satellite Tracking File

Variable Name	Type	# Bytes	Description
TRKCode	int	4	TRK-File Code (=683403)
N	int	4	Number of recorded samples
FreqAnz	int	4	# of recorded frequencies (ATN)
Freq[]	float	4 x FreqAnz	Frequencies [GHz], ATN
SatType_1	char	1	Satellite type, e.g. "G" for GPS-Sat., sample 1
SatNo_1	char	1	Satellite number, sample 1
RF_1	char	1	Rainflag of sample 1 (0: no rain, 1: rain)
T_1	int	4	Time of sample 1 (# of sec. since 1.1.2001)
EL-ANG_1	float	4	Elevation angle of sample 1 (DEG)
AZ-ANG_1	float	4	Azimuth angle of sample 1 (DEG)
WET_DLY_1	float	4	Wet Delay of sample 1 (mm)
LWP_1	float	4	LWP of sample 1 (g/m ²)
ATN[]_1	float	4 x FreqAnz	Attenuations [dB] of sample 1
...
SatType_N	char	1	Satellite type, e.g. "G" for GPS-Sat., sample N
SatNo_N	char	1	Satellite number, sample N
RF_N	char	1	Rainflag of sample N (0: no rain, 1: rain)
T_N	int	4	Time of sample N (# of sec. since 1.1.2001)
EL-ANG_N	float	4	Elevation angle of sample N (DEG)
AZ-ANG_N	float	4	Azimuth angle of sample N (DEG)
WET_DLY_N	float	4	Wet Delay of sample N (mm)
LWP_N	float	4	LWP of sample N (g/m ²)
ATN[]_N	float	4 x FreqAnz	Attenuations [dB] of sample N

A23: BUFR (Version 3.0) File Format

The H-PC software is capable of data file transformations from binary (Appendix A1-A20) to ASCII (see Appendix B), netCDF and BUFR. While netCDF is a real self-explaining format (and therefore does not require any further information for decoding), BUFR is a descriptor table based format which requires the definition of local descriptors (user defined) in the case that certain data items in the file are not listed in the WMO Table B.

The local descriptors used in the H-PC software version are listed in Table A21.1. In order to fulfil the BUFR regulations, these special descriptors are preceded by the data description operator 2 06 YYY, where YYY is the length of the local described data element in bits. E.g. the section 3 entry of a BUFR message for an atmospheric attenuation sample (refer to table A21.1), which is represented by a local descriptor, would be 2 06 016 0 21 193 (or in hex: 86



10 15 C1). The 2 06 016 operator allows a BUFR decoder software, which has no access to the information in Table A21.1, to skip the sample in the data section 4, because the operator contains its length of 16 bits.

F	X	Y	Name	Unit	Scale	Reference	Data Width [Bits]
0	14	192	IR radiometer wavelength	m	7	0	8
0	14	193	microwave frequency	Hz	-7	0	16
0	21	192	cloud liquid content	kg/m ³	6	0	16
0	21	193	atmospheric attenuation	dB	2	-10000	16

Table A21.1: Host software local descriptors.

The H-PC software changes the data width of all WMO Table B entries, which are not compatible with an integer number of a full byte (8 or 16 bits). E.g. the data width of the 'MWR water vapour content' (this is the IWV) 0 13 096 from 14 bits (Table B) to 16 bits. This is more efficient for programming and decoding of the data segment. Nowadays, extreme bit saving is not an issue anymore and additional bits, even if not used, can improve the readability of the data segment significantly.

All data files contain a 32 character 'Station Name' as the first entry in the data section 4 (descriptor 0 01 19). This name is taken from the 'Station Name' entry of the **Define Local Settings** menu (see section 5.18). Also the time reference is defined in all files (descriptors 0 08 025 0 26 003).

Each data item (single value or profile) is preceded by a date / time and rain flag (RF). This block of information is defined by the following descriptors:

0 04 001	Year (12 bit)
0 04 002	Month (4 bits)
2 01 127 0 04 003 2 01 000	Day (reduced from 6 to 5 bits)
0 04 004	Hour (5 bits)
0 04 005	Minutes (6 bits)
0 04 006	Seconds (6 bits)
0 20 029	Rain Flag (2 bits code table)

This sums up to a total of 40 bits = 5 bytes.

The general rule is that all data lists of single parameters (like frequency lists, altitude lists, temperature profile, humidity profile, etc.) are coded by simple replication descriptors, e.g.:

1 01 xxx 0 10 002 :	a list of xxx altitudes (e.g. in profile BUFR files)
1 01 xxx 0 12 101 :	a list of xxx dry-bulb temperatures (a temp. profile)
1 02 xxx 2 06 016 0 21 192	a list of xxx atmospheric attenuations (local descriptor)
1 03 xxx 2 01 129 0 13 003 2 01 000	a list of xxx rel. humidity values (data width extended from 7 to 8 bits)

For the replication of blocks of parameters in the data section 4, the 'Delayed Replication' mechanism is used:

Example of an absolute humidity data set replication:



1 15 000 0 31 002	delayed replication of 15 descriptors (16 bit replication factor in data section)
0 04 001	Year (12 bit)
0 04 002	Month (4 bits)
2 01 127 0 04 003 2 01 000	Day (reduced from 6 to 5 bits)
0 04 004	Hour (5 bits)
0 04 005	Minutes (6 bits)
0 04 006	Seconds (6 bits)
20 029	Rain Flag (2 bits code table)
05 039	39 replications of the next 5 descriptors
01 137	data width extended by 9 bits (from 7 to 16)
2 02 130	scale extended by 2 bits (from 3 to 5)
0 13 005	vapour density in kg/m ³
2 02 000 2 01 000	back to Table B settings

This delayed replication (16 bit number given in section 4) is representing the collection of data samples in the file. The 'Number of Data Subsets' in bytes 5-7 of section 3 is not used for this replication (and therefore set to 1), because this would replicate ALL descriptors of the section and not only a part of it. But the data file structure required here consists of a data header (e.g. station name, time reference, list of altitudes in a profile) which should not be repeated, followed by a repeated (the number of samples) block of descriptors defining each data sample (e.g. time, RF, profile of water vapour density (list), observation angles). In all profile BUFR messages, the sequence of items in the altitude list corresponds to the sequence of items in the repeated data list. E.g. in the example above, the HPC.BUF file has a list of altitudes in the data header and repeated lists of water vapour density. The first altitude in the header list refers to the first vapour density data item in the repeated list. The altitude layers are constant throughout the whole data set and do not have to be repeated for each sample. This is why they are stored in the data header of section 4.

For more details about the coding of BUFR messages, please refer to WMO's FM 94 BUFR 'Guide to WMO Table Driven Code Forms', available from the WMO website's download area.

Appendix B (ASCII File Formats)

Fig.B1 shows an example of an ASCII data file structure (LWP). All ASCII files start with a header giving information about the number of samples in the file, Minimum and Maximum values of the measured or retrieved quantities for scaling purposes, the time reference (UTC or local time) and the type of retrieval if any (0 = linear regression, 1 = quadratic regression, 2 = neural network). Comments are preceded by '#'. Each sample line starts with the date and time (Ye = Year, Mo = Month, Da = Day, Ho = Hour, Mi = Minute, Se = Second) this sample was measured followed by the rain flag (0 = no rain, 1 = raining). All data columns are separated by ',' from each other. Each line ends with CR/LF.


```

050409.lwp.ASC - Editor
Datei Bearbeiten Format Ansicht ?
# LWP File
7177 # Number of Samples
-55.6 # Minimum LWP in File
605.3 # Maximum LWP in File
1 # Time Reference (1=UTC, 0=Local)
1 # Retrieval Algorithm (0=LR, 1=QR, 2=NN)
# Ye , Mo , Da , Ho , Mi , Se , Rain Flag , LWP [g/m^2]
05 , 04 , 09 , 04 , 00 , 01 , 0 , -23.6
05 , 04 , 09 , 04 , 00 , 02 , 0 , -22.8
05 , 04 , 09 , 04 , 00 , 04 , 0 , -22.8
05 , 04 , 09 , 04 , 00 , 05 , 0 , -27.5
05 , 04 , 09 , 04 , 00 , 06 , 0 , -25.8
05 , 04 , 09 , 04 , 00 , 08 , 0 , -18.9
05 , 04 , 09 , 04 , 00 , 09 , 0 , -21.3
05 , 04 , 09 , 04 , 00 , 11 , 0 , -26.2
05 , 04 , 09 , 04 , 00 , 12 , 0 , -21.2
05 , 04 , 09 , 04 , 00 , 13 , 0 , -26.8
05 , 04 , 09 , 04 , 00 , 15 , 0 , -20.6
05 , 04 , 09 , 04 , 00 , 16 , 0 , -17.8
05 , 04 , 09 , 04 , 00 , 18 , 0 , -31.9
05 , 04 , 09 , 04 , 00 , 19 , 0 , -25.1
05 , 04 , 09 , 04 , 00 , 21 , 0 , -22.9
05 , 04 , 09 , 04 , 00 , 22 , 0 , -26.3
05 , 04 , 09 , 04 , 00 , 23 , 0 , -23.3
05 , 04 , 09 , 04 , 00 , 25 , 0 , -29.7
05 , 04 , 09 , 04 , 00 , 26 , 0 , -26.3
05 , 04 , 09 , 04 , 00 , 28 , 0 , -19.5
05 , 04 , 09 , 04 , 00 , 29 , 0 , -32.0
05 , 04 , 09 , 04 , 00 , 31 , 0 , -21.0
05 , 04 , 09 , 04 , 00 , 32 , 0 , -27.1

```

Fig.B1: LWP ASCII data file structure.

Fig.B2 is an example of a temperature profile ASCII file. The header contains additional information about the number of altitude levels and the altitudes in m. The altitude levels are designated with H1, H2, ... The data lines are a sequence of temperature values corresponding to these levels.

```

050429.TPC.ASC - Editor
Datei Bearbeiten Format Ansicht ?
# TPC File
841 # Number of Samples
235.6 # Minimum Temperature in File
301.8 # Maximum Temperature in File
0 # Time Reference (1=UTC, 0=Local)
0 # Retrieval Algorithm (0=LR, 1=QR, 2=NN)
36 # Number of Altitude Levels
0, 50, 100, 150, 200, 250, 325, 400, 475, 550, 625, 700, 800, 900, 1000, 1150, 1300, 1450, 1600, 180
# Ye , Mo , Da , Ho , Mi , Se , Rain Flag , T(H1) [K] , T(H2) [K] , ... , T(Hn) [K]
05 , 04 , 29 , 00 , 01 , 24 , 0 , 299.4 , 298.9 , 298.4 , 298.2 , 297.9 , 297.7 , 297.4 , 297.1 , 29
05 , 04 , 29 , 00 , 02 , 48 , 0 , 299.2 , 298.6 , 298.1 , 297.9 , 297.5 , 297.3 , 297.0 , 296.8 , 29
05 , 04 , 29 , 00 , 07 , 41 , 0 , 299.4 , 299.0 , 298.5 , 298.2 , 297.9 , 297.6 , 297.3 , 297.0 , 29
05 , 04 , 29 , 00 , 09 , 05 , 0 , 299.3 , 299.0 , 298.5 , 298.2 , 297.9 , 297.6 , 297.3 , 297.0 , 29
05 , 04 , 29 , 00 , 10 , 29 , 0 , 299.2 , 299.0 , 298.6 , 298.3 , 298.0 , 297.7 , 297.4 , 297.0 , 29
05 , 04 , 29 , 00 , 11 , 54 , 0 , 299.4 , 299.3 , 298.9 , 298.5 , 298.2 , 297.9 , 297.6 , 297.2 , 29
05 , 04 , 29 , 00 , 13 , 18 , 0 , 299.1 , 298.9 , 298.5 , 298.2 , 297.9 , 297.7 , 297.4 , 297.1 , 29
05 , 04 , 29 , 00 , 15 , 23 , 0 , 299.1 , 298.9 , 298.5 , 298.2 , 297.9 , 297.6 , 297.3 , 297.0 , 29
05 , 04 , 29 , 00 , 16 , 47 , 0 , 299.2 , 298.9 , 298.5 , 298.2 , 297.9 , 297.6 , 297.2 , 296.9 , 29
05 , 04 , 29 , 00 , 18 , 11 , 0 , 299.2 , 299.0 , 298.6 , 298.2 , 297.9 , 297.6 , 297.3 , 296.9 , 29
05 , 04 , 29 , 00 , 19 , 35 , 0 , 299.1 , 299.0 , 298.6 , 298.3 , 298.0 , 297.7 , 297.4 , 297.0 , 29
05 , 04 , 29 , 00 , 20 , 59 , 0 , 299.0 , 298.9 , 298.5 , 298.2 , 297.9 , 297.6 , 297.3 , 297.0 , 29
05 , 04 , 29 , 00 , 22 , 23 , 0 , 299.2 , 299.0 , 298.5 , 298.2 , 297.9 , 297.6 , 297.3 , 296.9 , 29
05 , 04 , 29 , 00 , 24 , 27 , 0 , 299.3 , 299.0 , 298.6 , 298.3 , 298.0 , 297.7 , 297.4 , 297.0 , 29
05 , 04 , 29 , 00 , 25 , 51 , 0 , 299.3 , 299.0 , 298.5 , 298.3 , 297.9 , 297.6 , 297.3 , 297.0 , 29
05 , 04 , 29 , 00 , 30 , 45 , 0 , 299.3 , 299.1 , 298.7 , 298.4 , 298.1 , 297.8 , 297.5 , 297.1 , 29
05 , 04 , 29 , 00 , 32 , 50 , 0 , 299.3 , 299.3 , 298.9 , 298.6 , 298.3 , 298.0 , 297.7 , 297.3 , 29
05 , 04 , 29 , 00 , 34 , 14 , 0 , 299.3 , 299.2 , 298.8 , 298.4 , 298.1 , 297.9 , 297.5 , 297.2 , 29
05 , 04 , 29 , 00 , 35 , 39 , 0 , 299.4 , 299.3 , 298.9 , 298.6 , 298.3 , 298.0 , 297.7 , 297.4 , 29
05 , 04 , 29 , 00 , 37 , 03 , 0 , 299.6 , 299.6 , 299.2 , 298.9 , 298.6 , 298.3 , 298.0 , 297.6 , 29
05 , 04 , 29 , 00 , 38 , 27 , 0 , 299.7 , 299.7 , 299.3 , 299.0 , 298.7 , 298.4 , 298.1 , 297.7 , 29

```




Fig.B2: TPC profile ASCII data file structure.

The brightness temperature data file in Fig.B3 specifies the frequency list in the header instead of altitudes. The data lines list the brightness temperatures related to these frequencies and end with the observation elevation angle for the sample.

```

050429.OLC.ASC - Editor
Datei Bearbeiten Format Ansicht ?
# OLC File
50427 # Number of Samples
130.6 # Minimum Brightness Temp. in File
302.5 # Maximum Brightness Temp. in File
0 # Time Reference (1=UTC, 0=Local)
7 # Number of Frequencies
51.26 , 52.28 , 53.86 , 54.94 , 56.66 , 57.30 , 58.00 # Frequencies
# Ye , Mo , Da , Ho , Mi , Se , Rain Flag , BT(F1) [K] , BT(F2) [K] , ... , BT(Fn) , Ang [DEG]
05 , 04 , 29 , 00 , 00 , 01 , 0 , 262.62 , 272.65 , 290.41 , 295.21 , 297.45 , 297.55 , 297.35 , 90.00
05 , 04 , 29 , 00 , 00 , 02 , 0 , 261.91 , 270.95 , 289.81 , 295.22 , 297.21 , 297.40 , 297.43 , 90.00
05 , 04 , 29 , 00 , 00 , 03 , 0 , 262.06 , 271.77 , 290.60 , 296.33 , 297.87 , 298.02 , 297.72 , 90.00
05 , 04 , 29 , 00 , 00 , 04 , 0 , 262.15 , 269.88 , 289.40 , 295.37 , 296.84 , 297.47 , 297.58 , 90.00
05 , 04 , 29 , 00 , 00 , 06 , 0 , 260.65 , 269.02 , 289.88 , 295.34 , 297.99 , 298.70 , 298.46 , 90.00
05 , 04 , 29 , 00 , 00 , 07 , 0 , 260.11 , 269.14 , 289.59 , 295.04 , 297.64 , 297.89 , 297.15 , 90.00
05 , 04 , 29 , 00 , 00 , 09 , 0 , 262.02 , 268.99 , 290.40 , 295.66 , 298.06 , 297.42 , 297.76 , 90.00
05 , 04 , 29 , 00 , 00 , 10 , 0 , 260.34 , 272.79 , 290.16 , 296.21 , 298.05 , 297.81 , 297.25 , 90.00
05 , 04 , 29 , 00 , 00 , 12 , 0 , 260.64 , 265.77 , 291.06 , 295.45 , 298.16 , 298.41 , 297.92 , 90.00
05 , 04 , 29 , 00 , 00 , 13 , 0 , 260.05 , 269.64 , 290.08 , 295.38 , 298.11 , 298.38 , 297.38 , 90.00
05 , 04 , 29 , 00 , 00 , 14 , 0 , 259.72 , 268.99 , 287.61 , 295.92 , 297.06 , 297.48 , 297.55 , 90.00
05 , 04 , 29 , 00 , 00 , 15 , 0 , 258.74 , 270.65 , 289.71 , 295.72 , 298.38 , 298.00 , 297.96 , 90.00
05 , 04 , 29 , 00 , 00 , 18 , 0 , 258.92 , 269.13 , 290.69 , 295.18 , 297.04 , 297.88 , 297.65 , 90.00
05 , 04 , 29 , 00 , 00 , 19 , 0 , 258.87 , 267.83 , 291.08 , 296.20 , 297.91 , 297.76 , 297.87 , 90.00
05 , 04 , 29 , 00 , 00 , 20 , 0 , 258.25 , 266.92 , 288.93 , 295.39 , 296.42 , 297.37 , 297.08 , 90.00

```

Fig.B3: OLC brightness temperature ASCII data file structure.

Fig.B4 is an example for a meteorological surface sensor data file (MET). Here the header lists minimum and maximum values for each sensor type.

In Fig.B5 the file contains both the absolute and relative humidity chart. The latter is preceded by the minimum and maximum relative humidity values in the appended chart.

```

050429.MET.ASC - Editor
Datei Bearbeiten Format Ansicht ?
# MET File
65687 # Number of Samples
999.8 # Minimum Pressure value in File [mbar]
1003.8 # Maximum Pressure Value in File [mbar]
297.2 # Minimum Temperature value in File [K]
303.1 # Maximum Temperature value in File [K]
79.6 # Minimum Rel. Humidity value in File [%]
93.2 # Maximum Rel. Humidity in File [%]
0 # Time Reference (1=UTC, 0=Local)
# Ye , Mo , Da , Ho , Mi , Se , Rain Flag , P [mbar] , T [K] , H [%]
05 , 04 , 29 , 00 , 00 , 00 , 0 , 1003.2 , 300.3 , 92.1
05 , 04 , 29 , 00 , 00 , 01 , 0 , 1003.2 , 300.3 , 92.1
05 , 04 , 29 , 00 , 00 , 02 , 0 , 1003.2 , 300.3 , 92.1
05 , 04 , 29 , 00 , 00 , 03 , 0 , 1003.2 , 300.3 , 92.1
05 , 04 , 29 , 00 , 00 , 05 , 0 , 1003.2 , 300.3 , 92.2
05 , 04 , 29 , 00 , 00 , 06 , 0 , 1003.2 , 300.3 , 92.2
05 , 04 , 29 , 00 , 00 , 07 , 0 , 1003.1 , 300.3 , 92.2
05 , 04 , 29 , 00 , 00 , 09 , 0 , 1003.2 , 300.3 , 92.2
05 , 04 , 29 , 00 , 00 , 11 , 0 , 1003.2 , 300.3 , 92.2
05 , 04 , 29 , 00 , 00 , 12 , 0 , 1003.2 , 300.3 , 92.2
05 , 04 , 29 , 00 , 00 , 13 , 0 , 1003.2 , 300.3 , 92.2
05 , 04 , 29 , 00 , 00 , 14 , 0 , 1003.1 , 300.3 , 92.2
05 , 04 , 29 , 00 , 00 , 16 , 0 , 1003.2 , 300.3 , 92.3

```

Fig.B4: MET meteorological sensor ASCII data file structure.

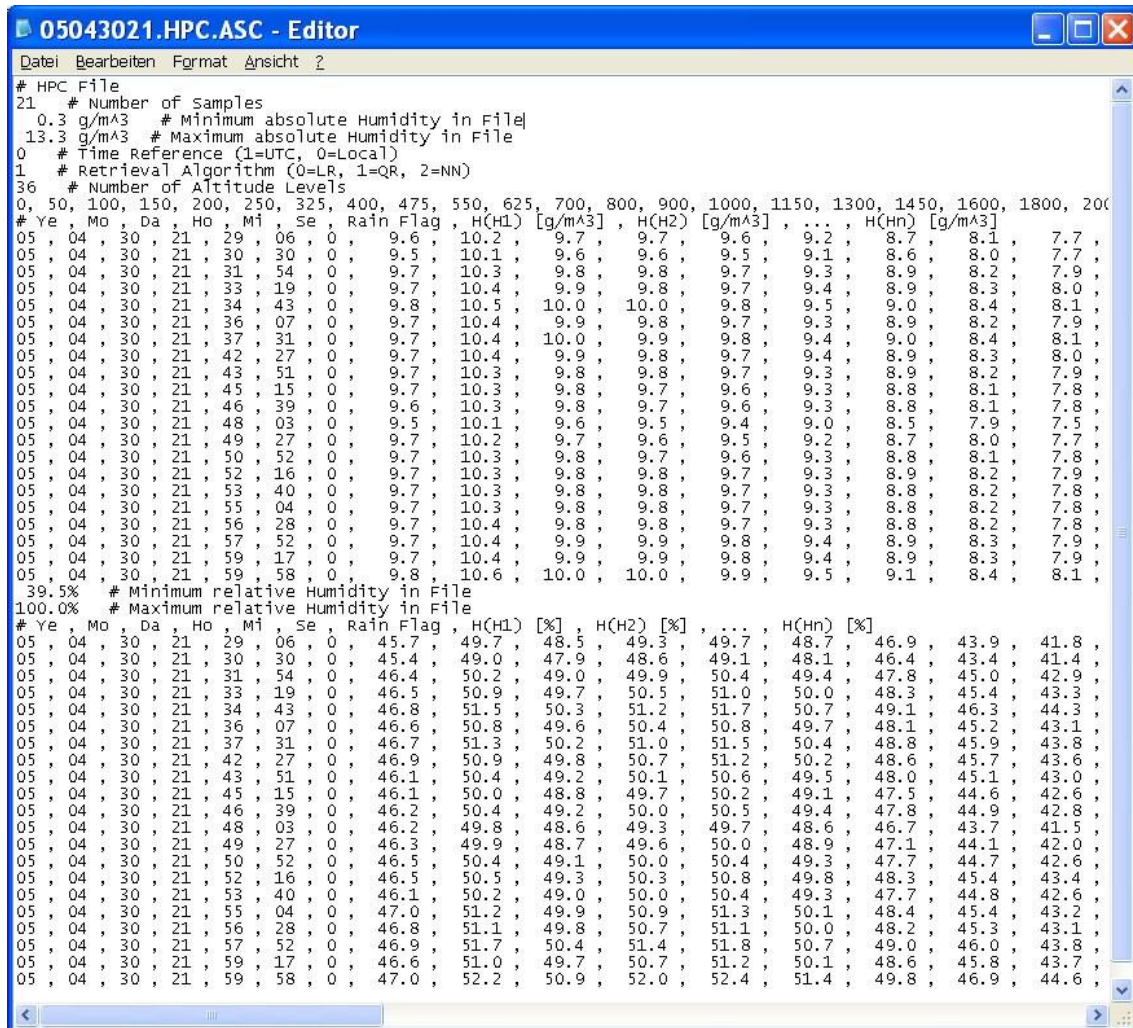
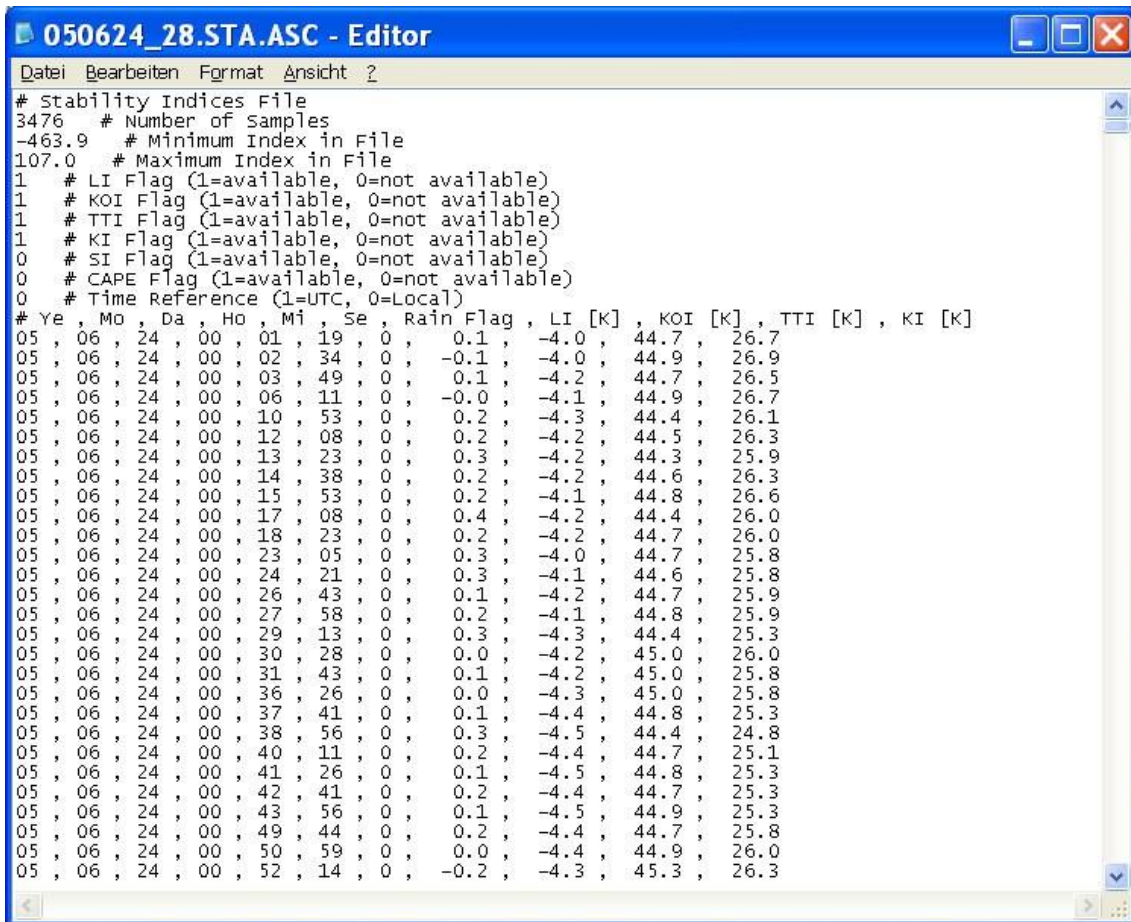


Fig.B5: HPC humidity profile ASCII data file structure with appended relative humidity chart.



```

# Stability Indices File
3476 # Number of Samples
-463.9 # Minimum Index in File
107.0 # Maximum Index in File
1 # LI Flag (1=available, 0=not available)
1 # KOI Flag (1=available, 0=not available)
1 # TTI Flag (1=available, 0=not available)
1 # KI Flag (1=available, 0=not available)
0 # SI Flag (1=available, 0=not available)
0 # CAPE Flag (1=available, 0=not available)
0 # Time Reference (1=UTC, 0=Local)
# Ye , Mo , Da , Ho , Mi , Se , Rain Flag , LI [K] , KOI [K] , TTI [K] , KI [K]
05 , 06 , 24 , 00 , 01 , 19 , 0 , 0.1 , -4.0 , 44.7 , 26.7
05 , 06 , 24 , 00 , 02 , 34 , 0 , -0.1 , -4.0 , 44.9 , 26.9
05 , 06 , 24 , 00 , 03 , 49 , 0 , 0.1 , -4.2 , 44.7 , 26.5
05 , 06 , 24 , 00 , 06 , 11 , 0 , -0.0 , -4.1 , 44.9 , 26.7
05 , 06 , 24 , 00 , 10 , 53 , 0 , 0.2 , -4.3 , 44.4 , 26.1
05 , 06 , 24 , 00 , 12 , 08 , 0 , 0.2 , -4.2 , 44.5 , 26.3
05 , 06 , 24 , 00 , 13 , 23 , 0 , 0.3 , -4.2 , 44.3 , 25.9
05 , 06 , 24 , 00 , 14 , 38 , 0 , 0.2 , -4.2 , 44.6 , 26.3
05 , 06 , 24 , 00 , 15 , 53 , 0 , 0.2 , -4.1 , 44.8 , 26.6
05 , 06 , 24 , 00 , 17 , 08 , 0 , 0.4 , -4.2 , 44.4 , 26.0
05 , 06 , 24 , 00 , 18 , 23 , 0 , 0.2 , -4.2 , 44.7 , 26.0
05 , 06 , 24 , 00 , 23 , 05 , 0 , 0.3 , -4.0 , 44.7 , 25.8
05 , 06 , 24 , 00 , 24 , 21 , 0 , 0.3 , -4.1 , 44.6 , 25.8
05 , 06 , 24 , 00 , 26 , 43 , 0 , 0.1 , -4.2 , 44.7 , 25.9
05 , 06 , 24 , 00 , 27 , 58 , 0 , 0.2 , -4.1 , 44.8 , 25.9
05 , 06 , 24 , 00 , 29 , 13 , 0 , 0.3 , -4.3 , 44.4 , 25.3
05 , 06 , 24 , 00 , 30 , 28 , 0 , 0.0 , -4.2 , 45.0 , 26.0
05 , 06 , 24 , 00 , 31 , 43 , 0 , 0.1 , -4.2 , 45.0 , 25.8
05 , 06 , 24 , 00 , 36 , 26 , 0 , 0.0 , -4.3 , 45.0 , 25.8
05 , 06 , 24 , 00 , 37 , 41 , 0 , 0.1 , -4.4 , 44.8 , 25.3
05 , 06 , 24 , 00 , 38 , 56 , 0 , 0.3 , -4.5 , 44.4 , 24.8
05 , 06 , 24 , 00 , 40 , 11 , 0 , 0.2 , -4.4 , 44.7 , 25.1
05 , 06 , 24 , 00 , 41 , 26 , 0 , 0.1 , -4.5 , 44.8 , 25.3
05 , 06 , 24 , 00 , 42 , 41 , 0 , 0.2 , -4.4 , 44.7 , 25.3
05 , 06 , 24 , 00 , 43 , 56 , 0 , 0.1 , -4.5 , 44.9 , 25.3
05 , 06 , 24 , 00 , 49 , 44 , 0 , 0.2 , -4.4 , 44.7 , 25.8
05 , 06 , 24 , 00 , 50 , 59 , 0 , 0.0 , -4.4 , 44.9 , 26.0
05 , 06 , 24 , 00 , 52 , 14 , 0 , -0.2 , -4.3 , 45.3 , 26.3

```

Fig.B6: Stability indices ASCII data file structure.

B1 Housekeeping ASCII file format

Fig.B7 shows the ASCII version of a HKD file (housekeeping data). The explanations for the abbreviations in the legend line are the following:

- **Ye, Mo, Da, Ho, Mi, Se:** Year, Month, Day, Hour, Minute and Second of the sample time
- **AF:** Alarm flag, refer to Appendix A17
- **GPS Long:** GPS Longitude
- **GPS Lat.:** GPS latitude
- **TAmb1:** temperature of ambient target sensor 1 • **TAmb2:** temperature of ambient target sensor 2
- **TRec1:** temperature of receiver 1 (humidity profiler)
- **TRec2:** temperature of receiver 2 (temperature profiler)
- **SRec1:** stability of receiver 1
- **SRec2:** stability of receiver 2
- **Flash D:** remaining flash disk capacity
- **QF LWP, ..., QF LPR:** quality flags of LWP, ..., LPR (liquid profile)
- **HP CH:** humidity profiler channel status flags, refer to A17



- **TP CH:** temperature profiler channel status flags, refer to A17
- **RF:** rain flag, refer to A17
- **DB:** dew blower speed status, refer to A17
- **BLM:** boundary layer mode status, refer to A17
- **SCa:** skydip calibration status, refer to A17
- **GCa:** gain calibration status, refer to A17
- **NCa:** noise calibration status, refer to A17
- **ND1:** noise diode receiver 1 status, refer to A17
- **ND2:** noise diode receiver 2 status, refer to A17
- **R1St:** receiver 1 stability status, refer to A17
- **R2St:** receiver 2 stability status, refer to A17
- **PF:** power failure status, refer to A17
- **TarSt:** ambient target stability status, refer to A17

```
07081416.HKD.ASC - Editor
Datei Bearbeiten Format Ansicht ?
# HKD File
2996 # Number of Samples
0 # Time Reference (1=UTC, 0=Local)
1 # 0=GPS position not recorded, 1=GPS position recorded
1 # 0=receiver / ambient temperatures not recorded, 1=receiver / ambient temperatures recorded
1 # 0=receiver stability not recorded, 1=receiver stability recorded
1 # 0=Flash Disk capacity not recorded, 1=Flash Disk capacity recorded
1 # 0=quality flags not recorded, 1=quality flags recorded
1 # 0=instrument status flags not recorded, 1=instrument status flags recorded
#Ye,Mo,Da,Ho,Mi,Se,AF, GPS Long., GPS Lat., TAMB1,TAMB2,TREc1,TREc2,SREc1,SREc2,Flash D,QF LWP,QF IWV,QF
07,08,14,16,00,08,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.003,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,10,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.003,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,11,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.003,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,12,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,13,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,13,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,16,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,17,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,18,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,19,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,19,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,22,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,23,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.000,0238784, 0000 , 0000 , C
07,08,14,16,00,24,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,24,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,26,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,28,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,29,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,29,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,31,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,32,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,34,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,35,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,35,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,37,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,38,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,40,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,41,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
07,08,14,16,00,41,0, 701.5922, 5038.7744,313.8, 0.0,311.3,313.6,0.002,0.001,0238784, 0000 , 0000 , C
```

Fig.B7: HKD ASCII sample file.