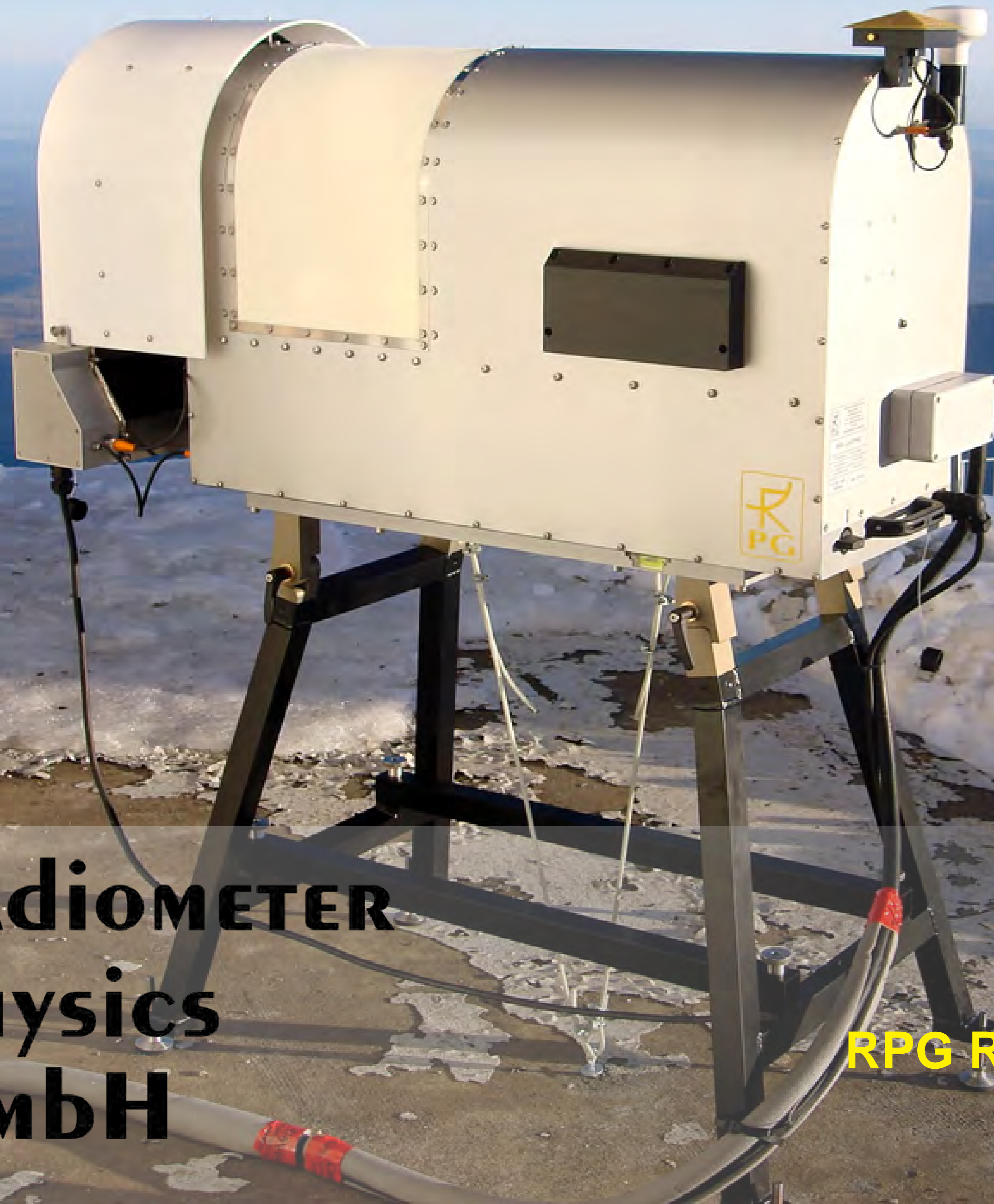


HATPRO – A Meteorological Observing System



**RADIOMETER
Physics
GmbH**

**Thomas Rose
Harald Czekała**

**RPG Radiometer Physics GmbH
Meckenheim, Germany**

What is HATPRO?

Direct detection passive microwave **H**umidity **A**nd **T**emperature **PRO**filer

- **(Passive) Microwave Radiometer:**
Measurement of atmospheric thermal emission in microwave spectrum
 - radiances converted into brightness temperature, e.g. the temperature of a black body with equivalent radiance
- **Direct detection:**
 - no down-conversion to low frequency IF bands
 - amplification at input frequency
 - filtering
 - detection (14 ch. parallel)
- **Dual-profiler:**
vertical profiles of temperature + humidity by using two gas-absorption
 - Water vapour line
7 channels (22.235 – 31.4 GHz)
 - Oxygen line complex
7 channels (51 – 58 GHz)



Working principle – Theory of operation

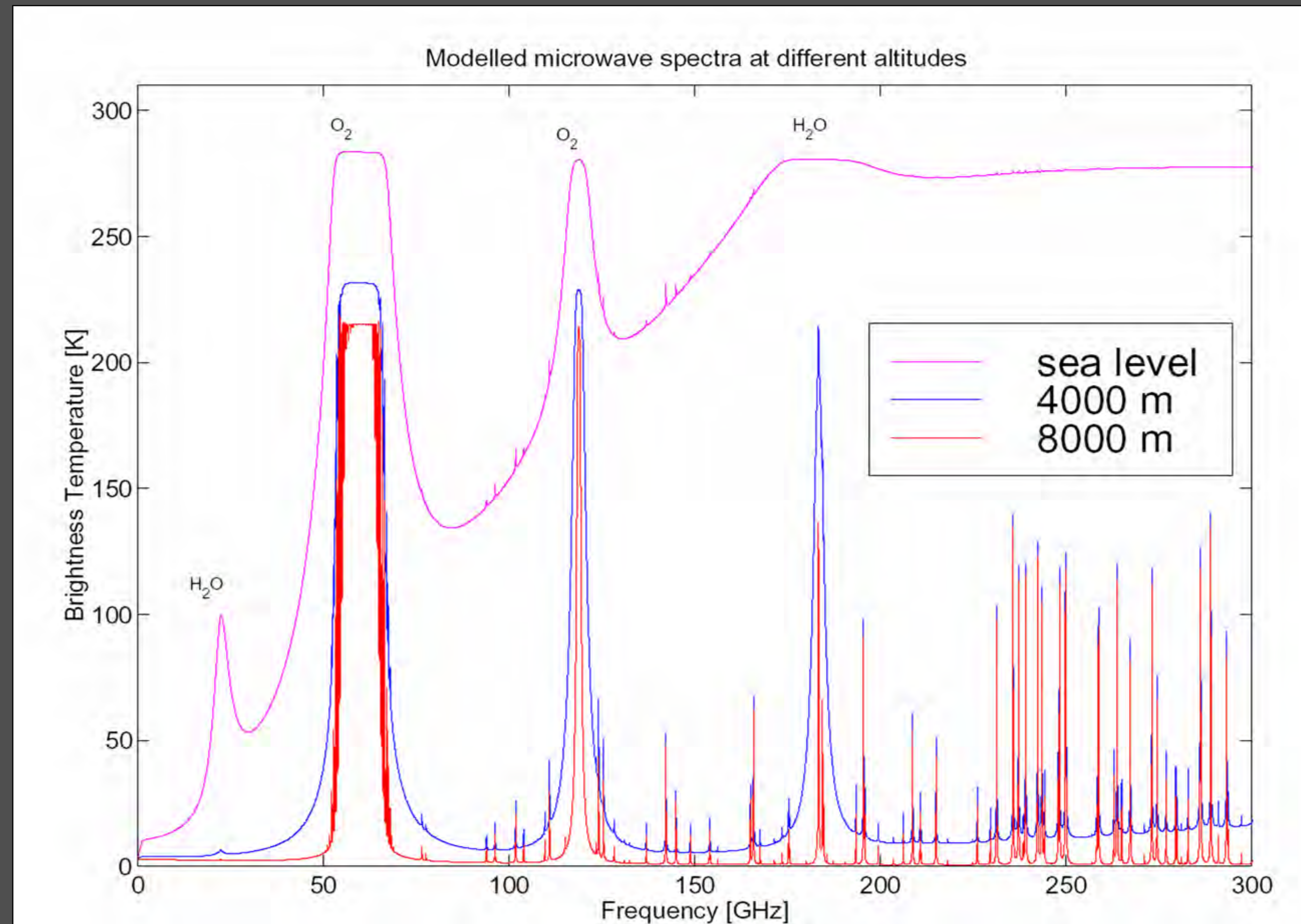
- **Passive** detection of microwave thermal radiation (not active!)
 - Emission (+absorption, scattering) from atmospheric components:
 - Gases (H₂O, O₂, N₂,... line emission)
 - Hydrometeors (clouds, precipitation, frequency dependent continuum)

- **Radiometric observation:**
Brightness temperatures

- at several fixed frequencies
- or several elevation angles

- **Meteorological Variables**
Calculated by retrievals

- Solving the „forward problem“ (radiative transfer for a given atmosphere)
- Inversion problem is ill-posed
- Data set statistics important

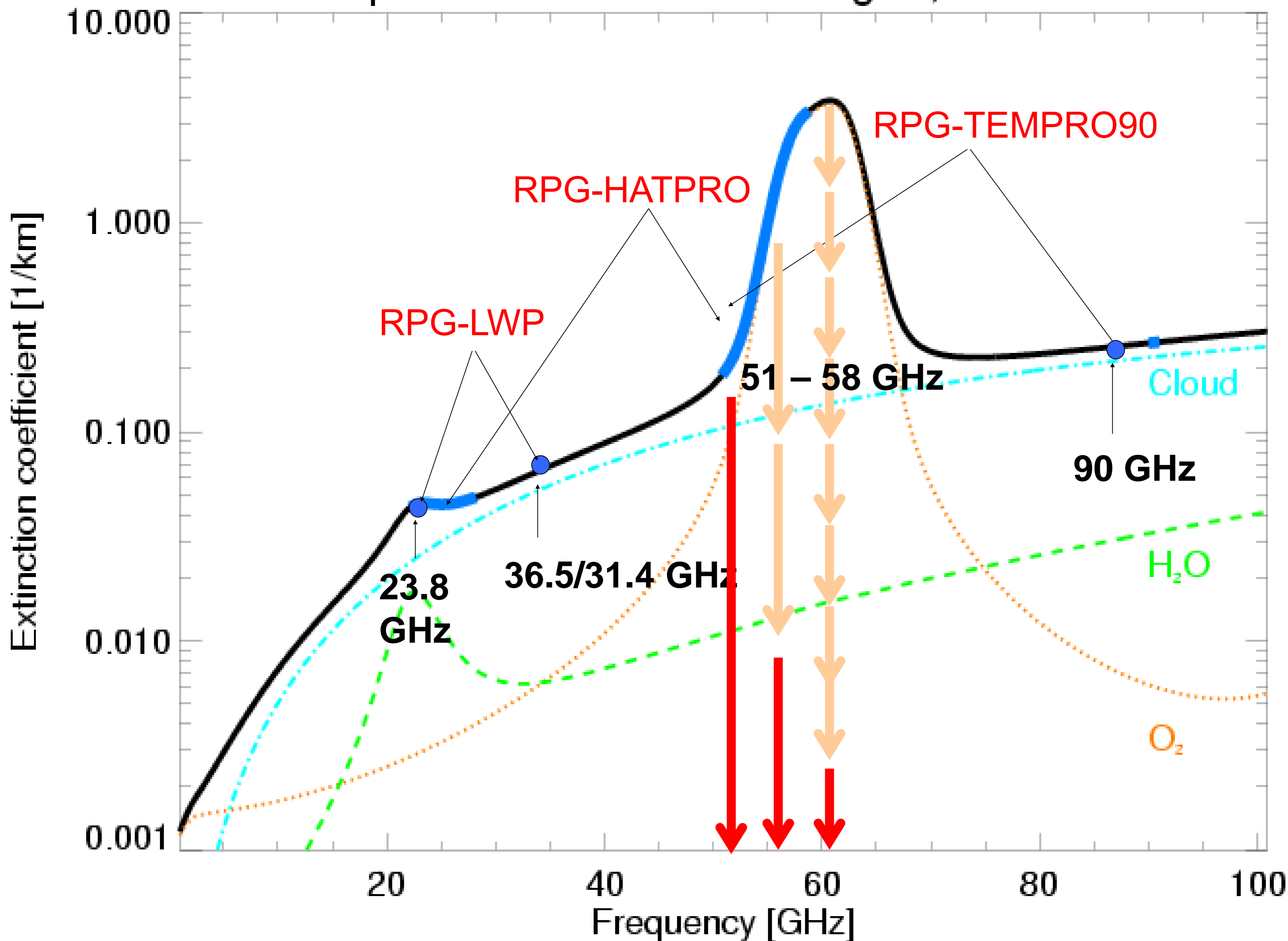


Frequencies of interest / data products

Meteorological Variables:

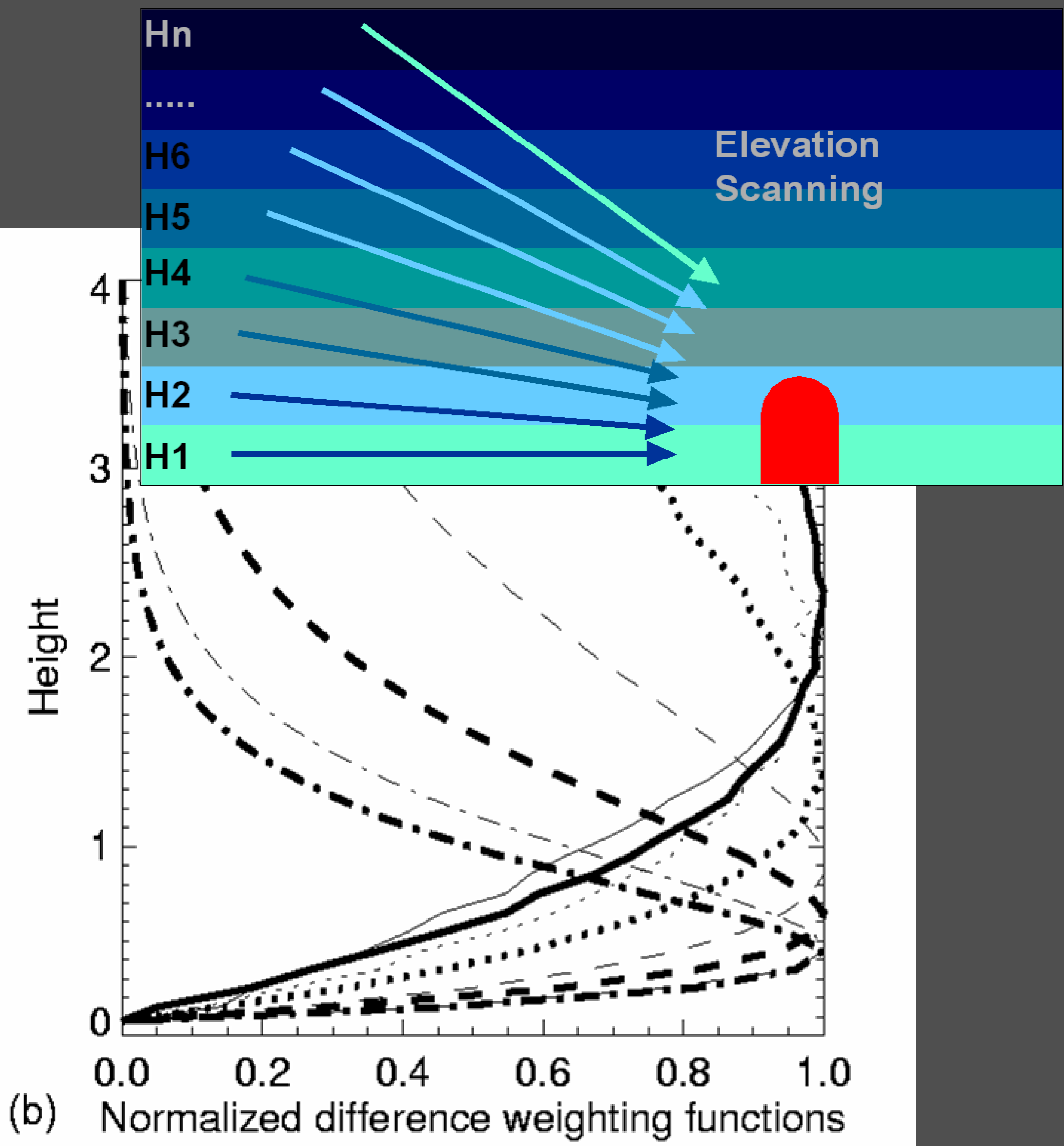
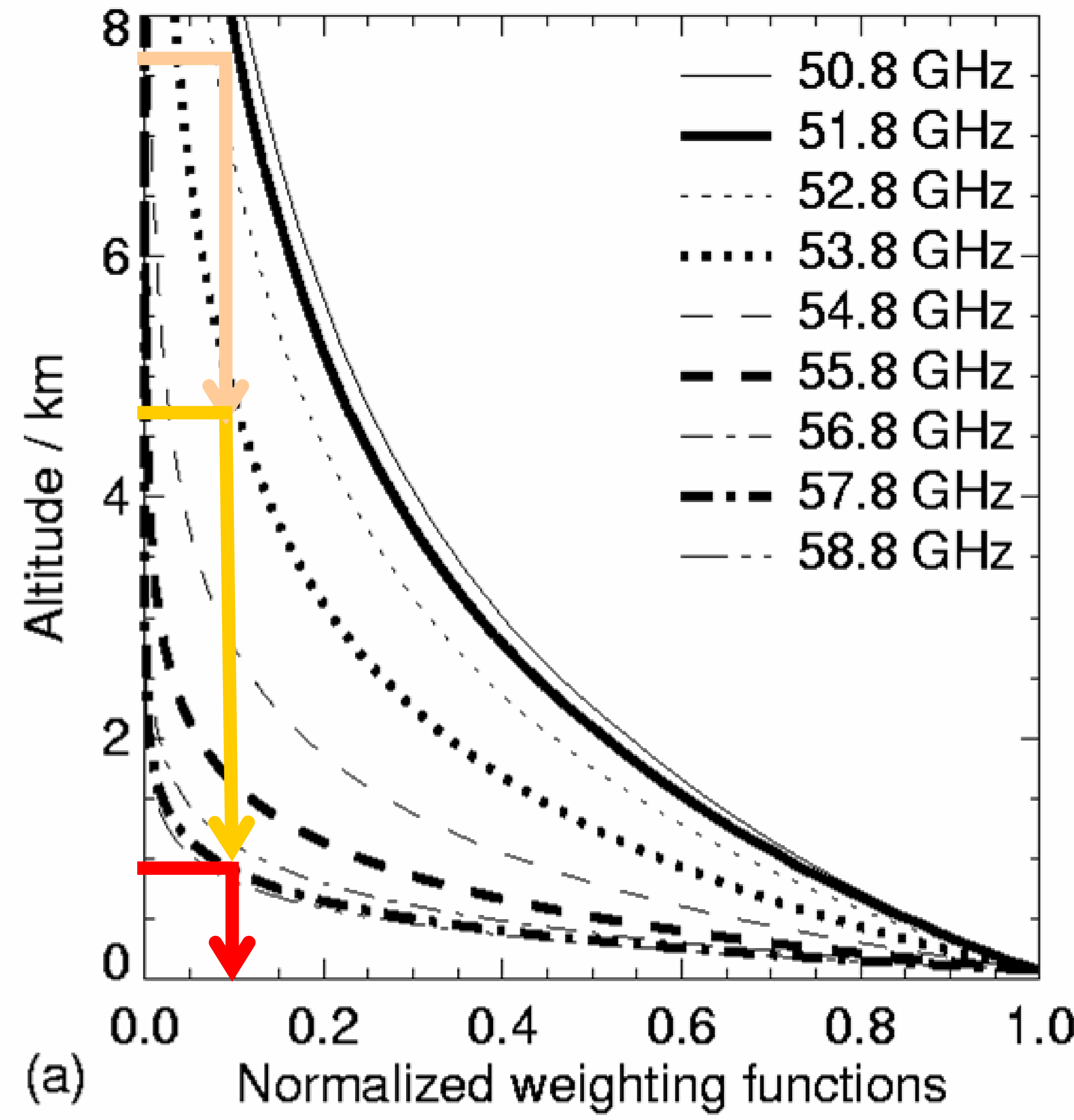
- Boundary layer Temperature profile (0 – 2 km)
- Tropospheric temperature profile (0 – 10 km)
- Absolute humidity profile
- Relative humidity profile
- Integrated water vapour (IWV, kg/m^2)
- Liquid water path (LWP, kg/m^2)
- LWC vertical profile (content, g/m^3)

Liquid Water Content = 0.2 gm^{-3} , 900 hPa

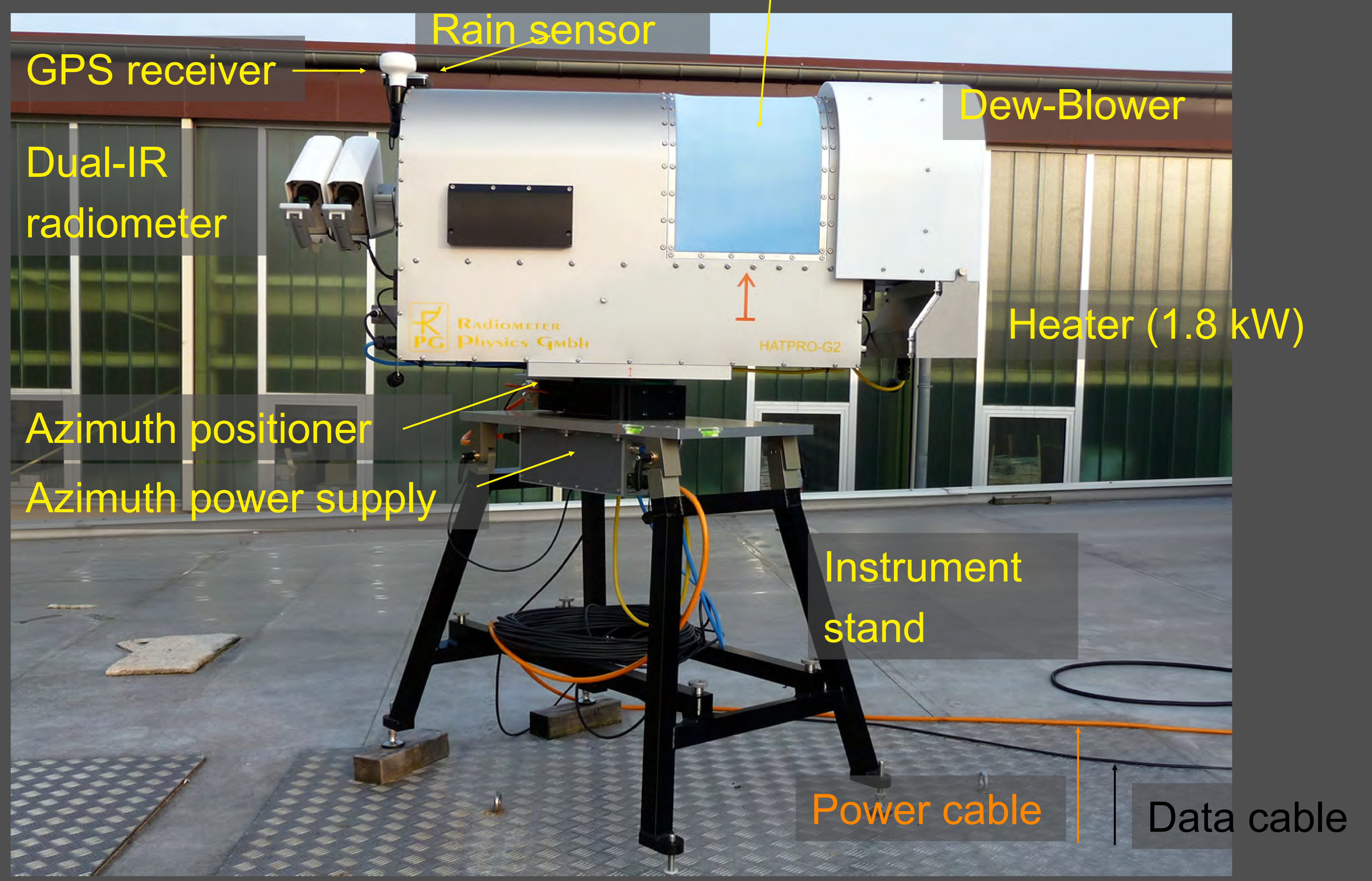


Vertical resolution: frequency dependence

54 to 58 GHz:
ideal for boundary layer
temperature profiling

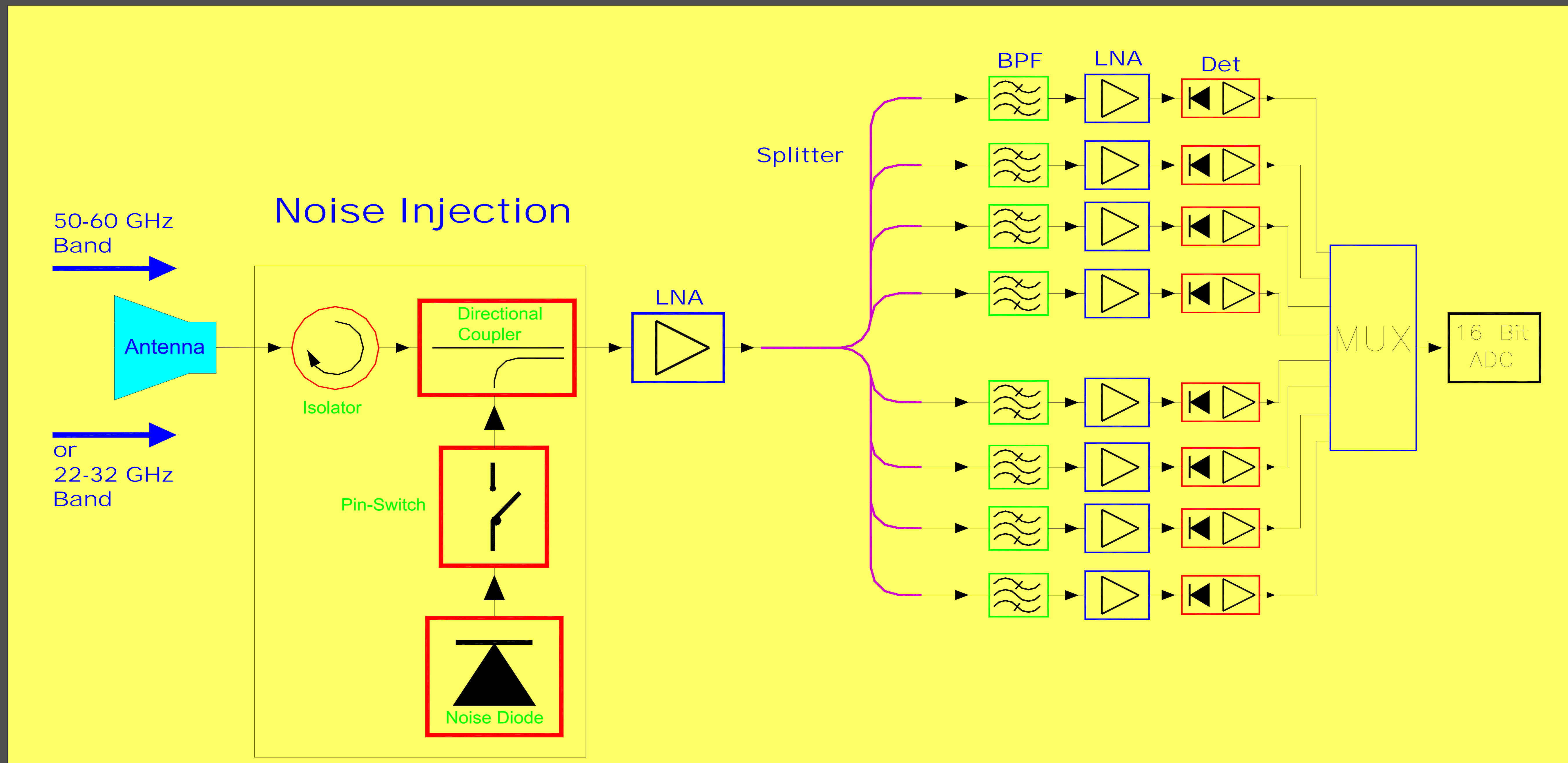


HATPRO – parts and components



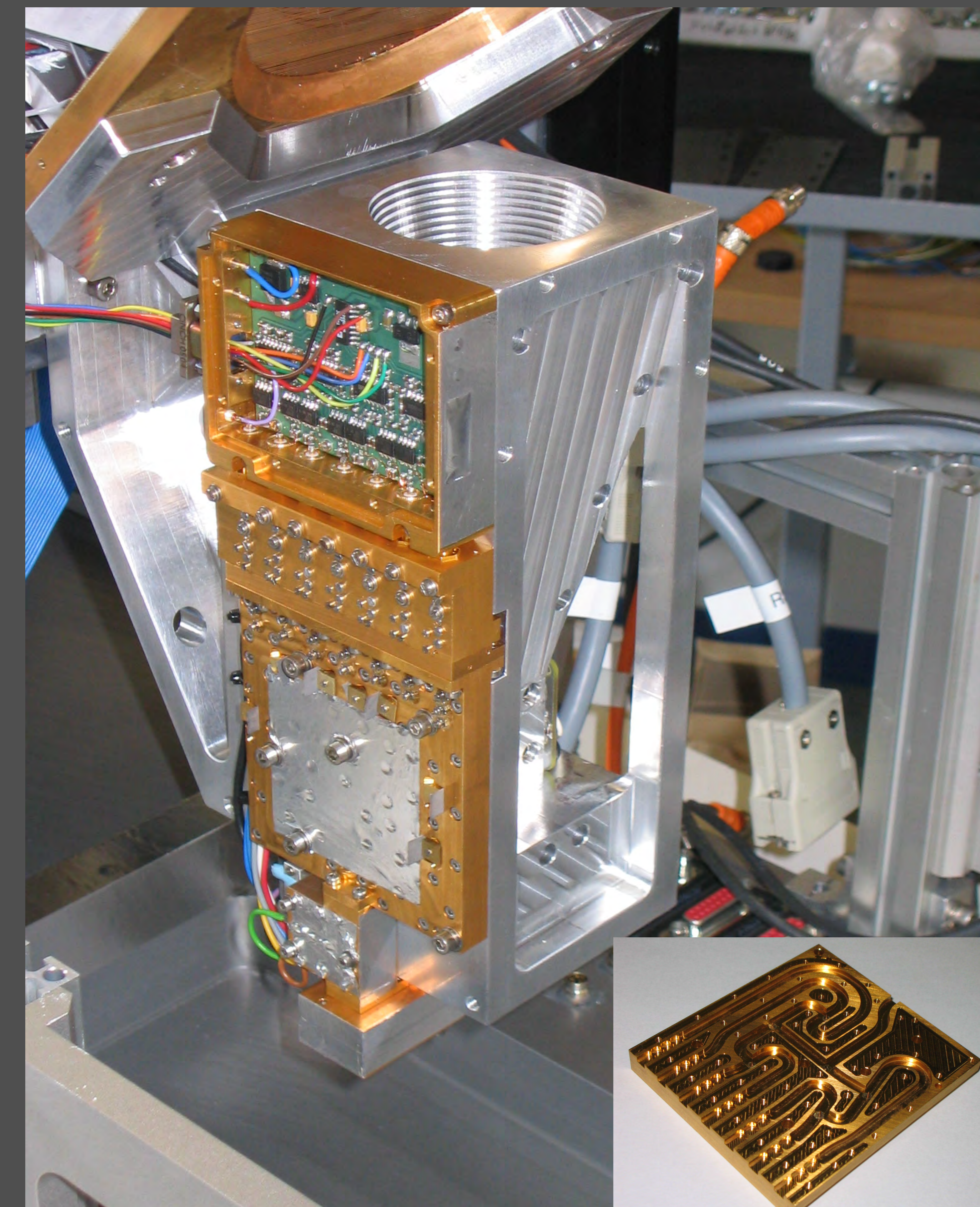
General Receiver Layout for Radiometers <100 GHz

Dual Profiler Direct Detection Filterbank Receivers based on MMIC Technology:



- sampling rate: ≥ 0.4 seconds
- with added Dicke switches: **auto-calibration receivers**
no black body calibrations required (e.g. the RPG-150-90)

RPG-HATPRO 7 Channel V-Band Receiver



Frequencies and bandwidth

22.24 GHz	51.26 GHz (230 MHz)
23.04 GHz	52.28 GHz (230 MHz)
23.84 GHz	53.86 GHz (230 MHz)
25.44 GHz	54.94 GHz (230 MHz)
26.24 GHz	56.66 GHz (650 MHz)
27.84 GHz	57.30 GHz (1000 MHz)
31.40 GHz	58.00 GHz (2000 MHz)

(at 20 to 30 GHz: 200 MHz bandwidth)

Receiver Noise Temperature

< 450 K < 700 K

„degrees of freedom“/significant de-cor.

Eigenvectors in (noisy) line shape

2 to max. 3 approx. 5

Auto-Calibration Devices:

Noise Injection + Magnetically switched
Isolarors (20 Hz Dicke Switching, ultra-stable)

Instrument details

Thermal stabilization: Two-stage system plus insulation \rightarrow 0.02 K stable op.

1st stage: 0.2 K

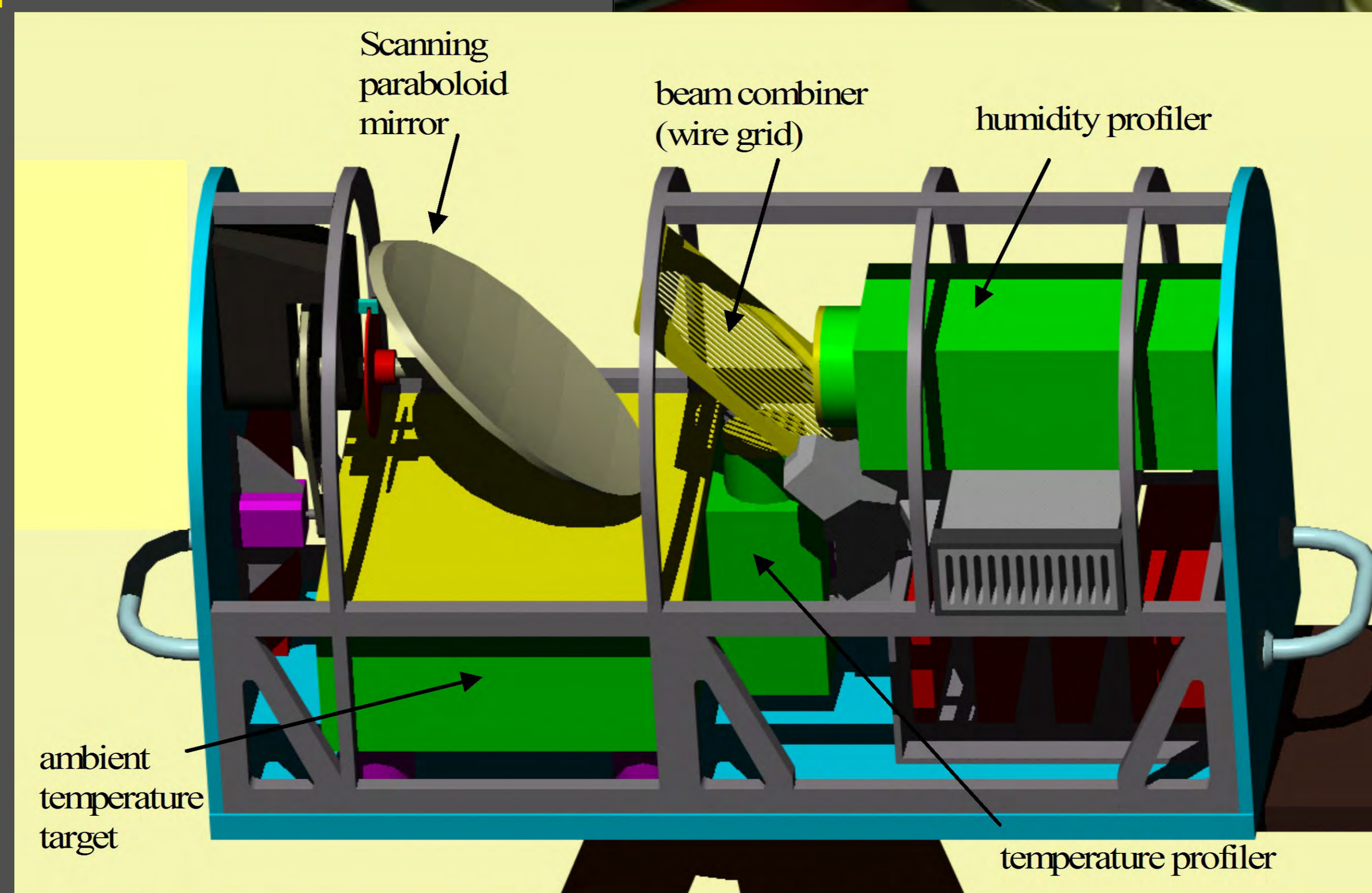
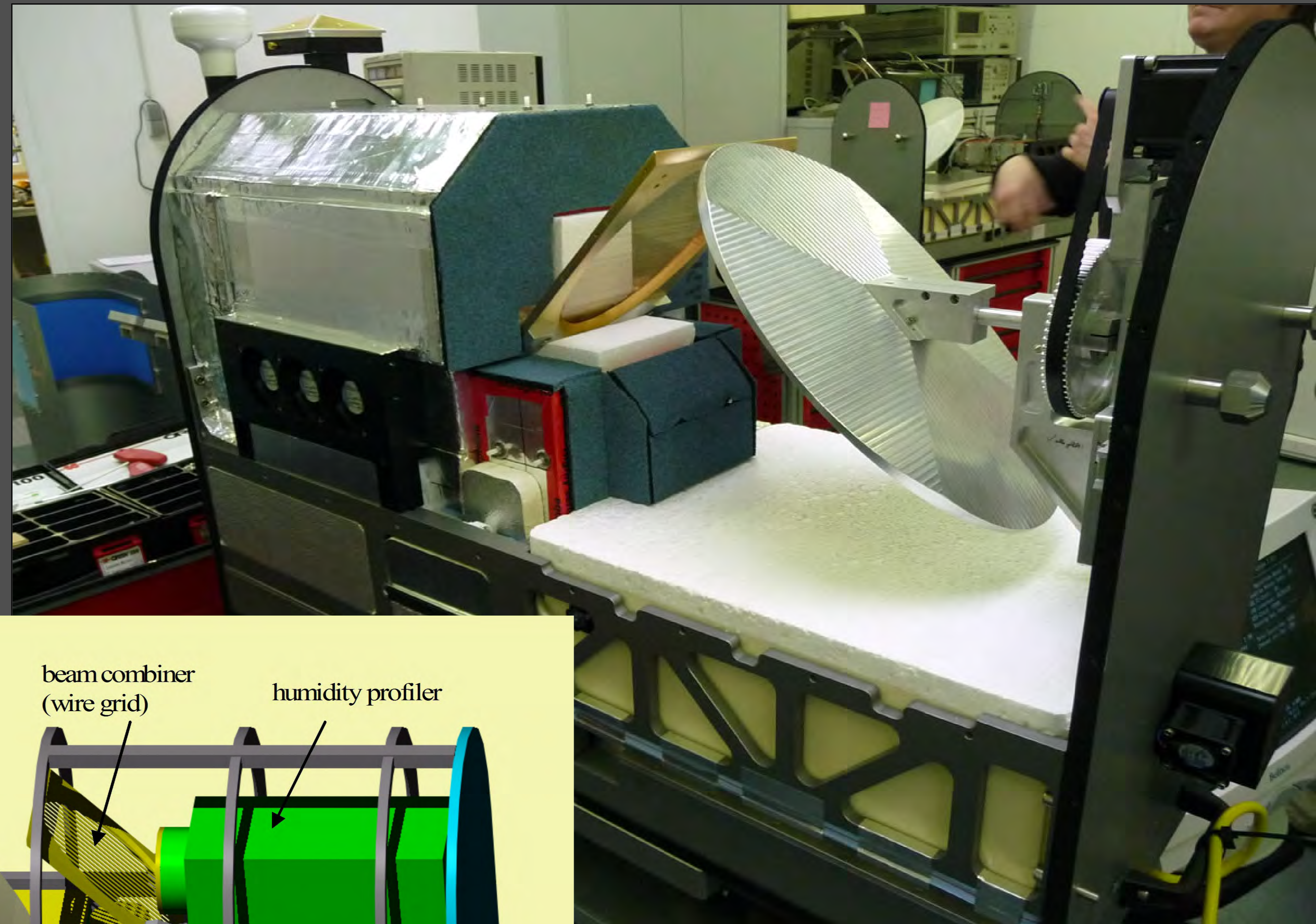
2nd stage: < 30 mK

Primary scan mirror:

300 mm off-axis
paraboloid

Results in 1.8° beam

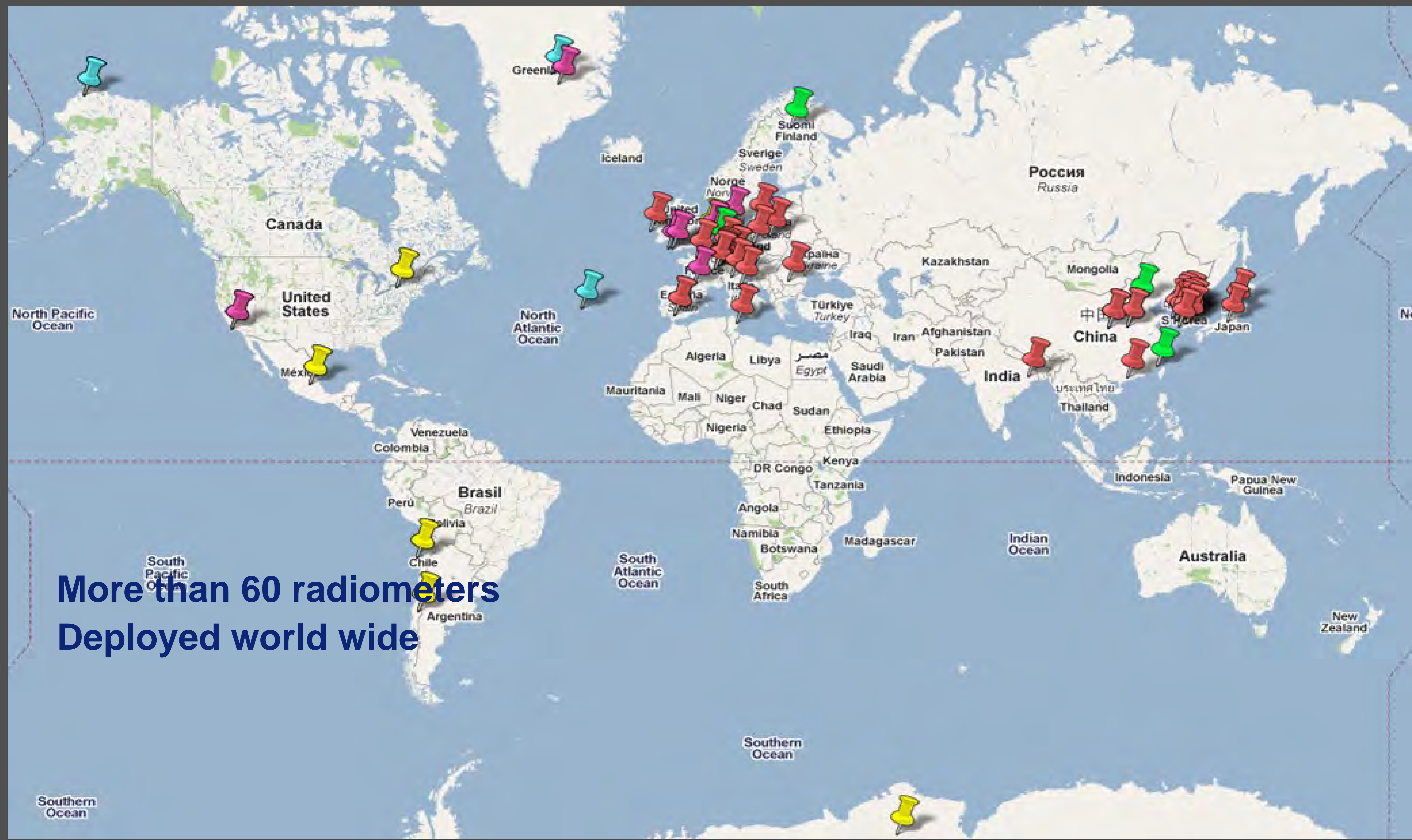
\rightarrow Elevation-scans
at 5.4° possible



HATPRO Highlights

- Direct detection
 - No out of band RFI
 - enables parallel acquisition and individual filter bandwidth
- Parallel detection of all channels („Filterbank“ vs. Synthesizer)
 - rapid scans, reduced calibration time, 100% duty cycle
 - mandatory for full-sky scans (faster than the sky is changing)
- Individual Filter bandwidth
 - mandatory for Boundary layer temperature profiling (explained later)
- Large primary reflector (optics)
 - Small beam, required for BL-T-profile
- Steerable IR-radiometers
 - Small beam, required for BL-T-profile
- Blower/Heater → effectively removes rain, snow, dew, fog, ...
- Fibre optical control → lightning protection, up to 1400m line
- GPS clock → Time reference, satellite tracking
- IR radiometer suite → Cloud base height / LWP sensing

Deployment Examples (1)



More than 60 radiometers
Deployed world wide

Deployment examples (2)

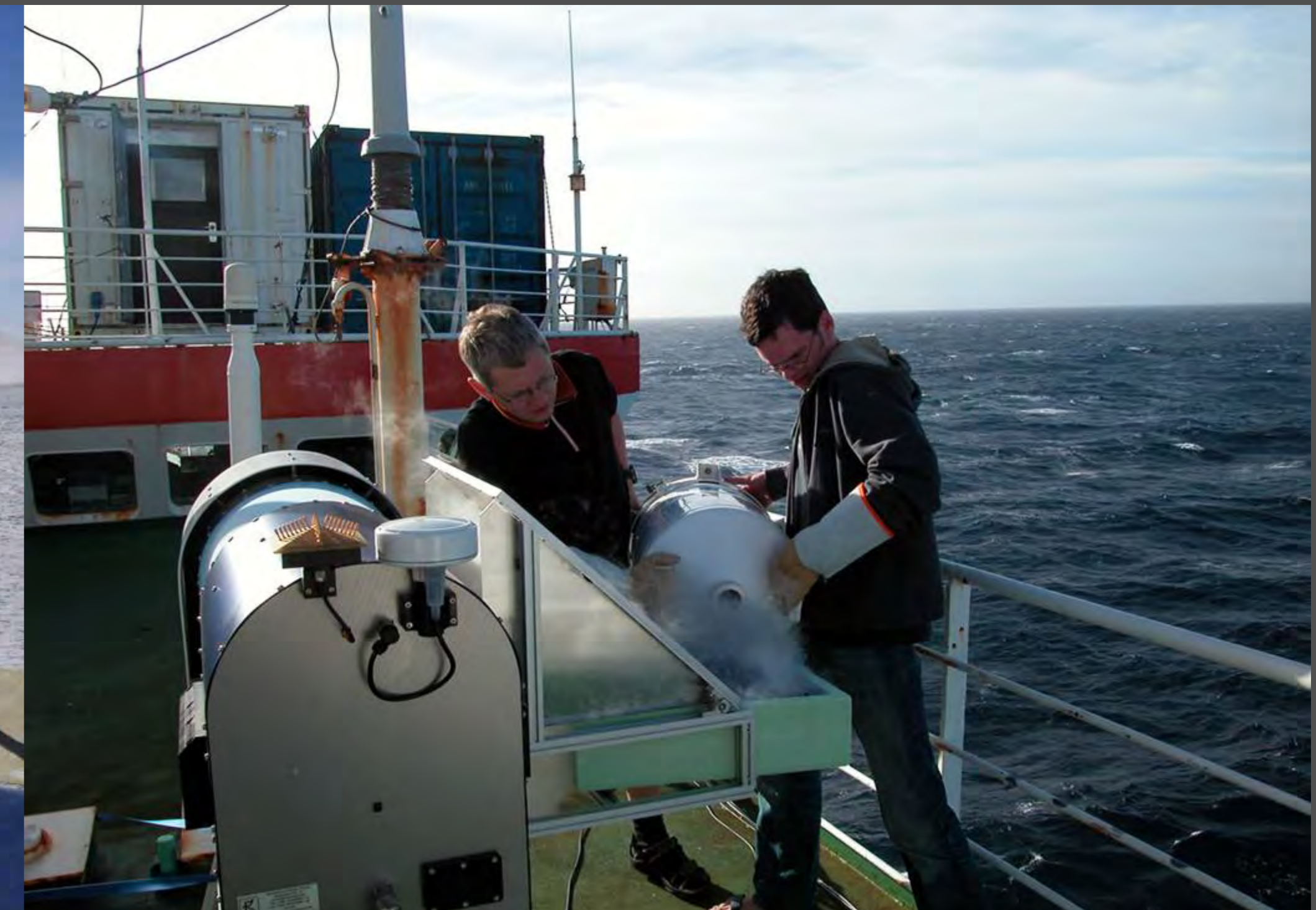
Today: delivery of approx. 20 standalone multi-channel radiometers per year



Lampedusa, Italy
(humid, hot, salty)



Dome-C, Antarctica
(3.300m, -25 to -80 °C)



Research Vessel "Polarstern"
(Atlantic Ocean)



ALMA site, Chile
(5.500m above sea level)



Zugspitze, Germany
(2.800m, -35 °C, 250km/h wind)

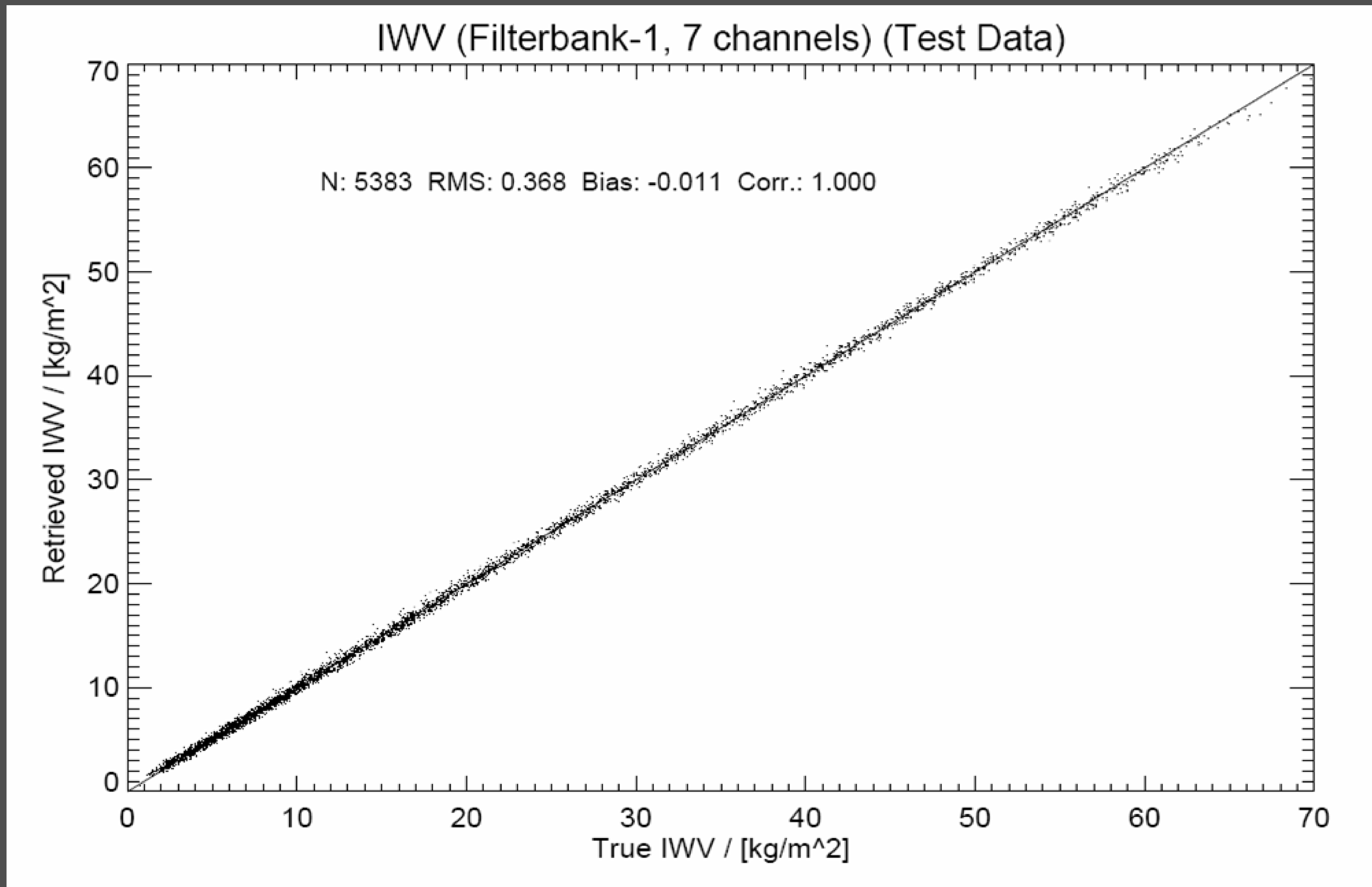


AMMA campaign, Benin
(West-Africa, hot climate, dust)

Reference Customers (selected)

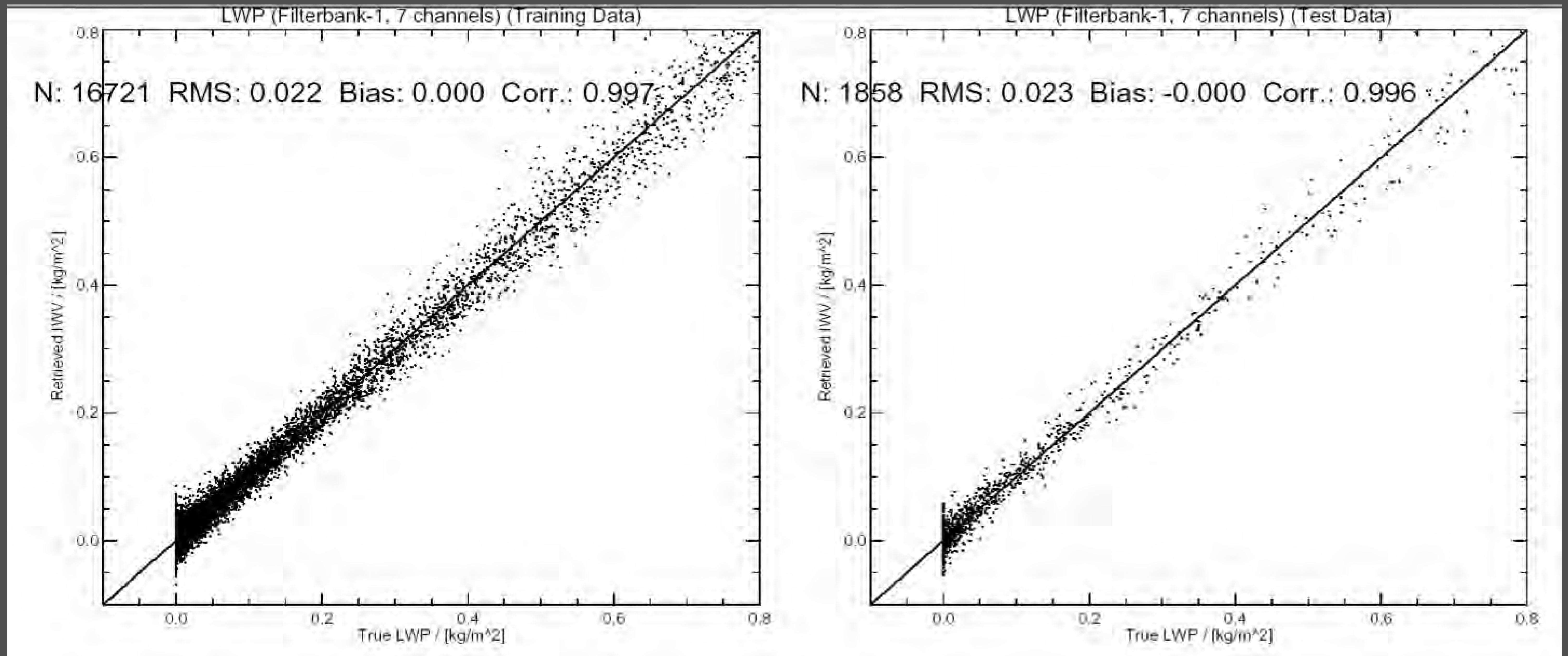
- ARM (Atmospheric Radiation Monitoring program, USA – 2 units)
- KMA (Korean weather service, 9 units)
- CNRS (France – 2 units)
- UK Met Office (2 units)
- KNMI (The Netherlands weather service)
- Meteo Swiss (4 units)
- Polish weather service (3 units)
- Italian weather services (3 units)
- University of Cologne (4 units)
- FZK Karlsruhe, Germany
- Aerospace Corp, Los Angeles, USA
- Univ. Madison, Wisconsin, USA (2 units)
- Univ. Salford, UK

IWV Retrieval – Korea, Incheon



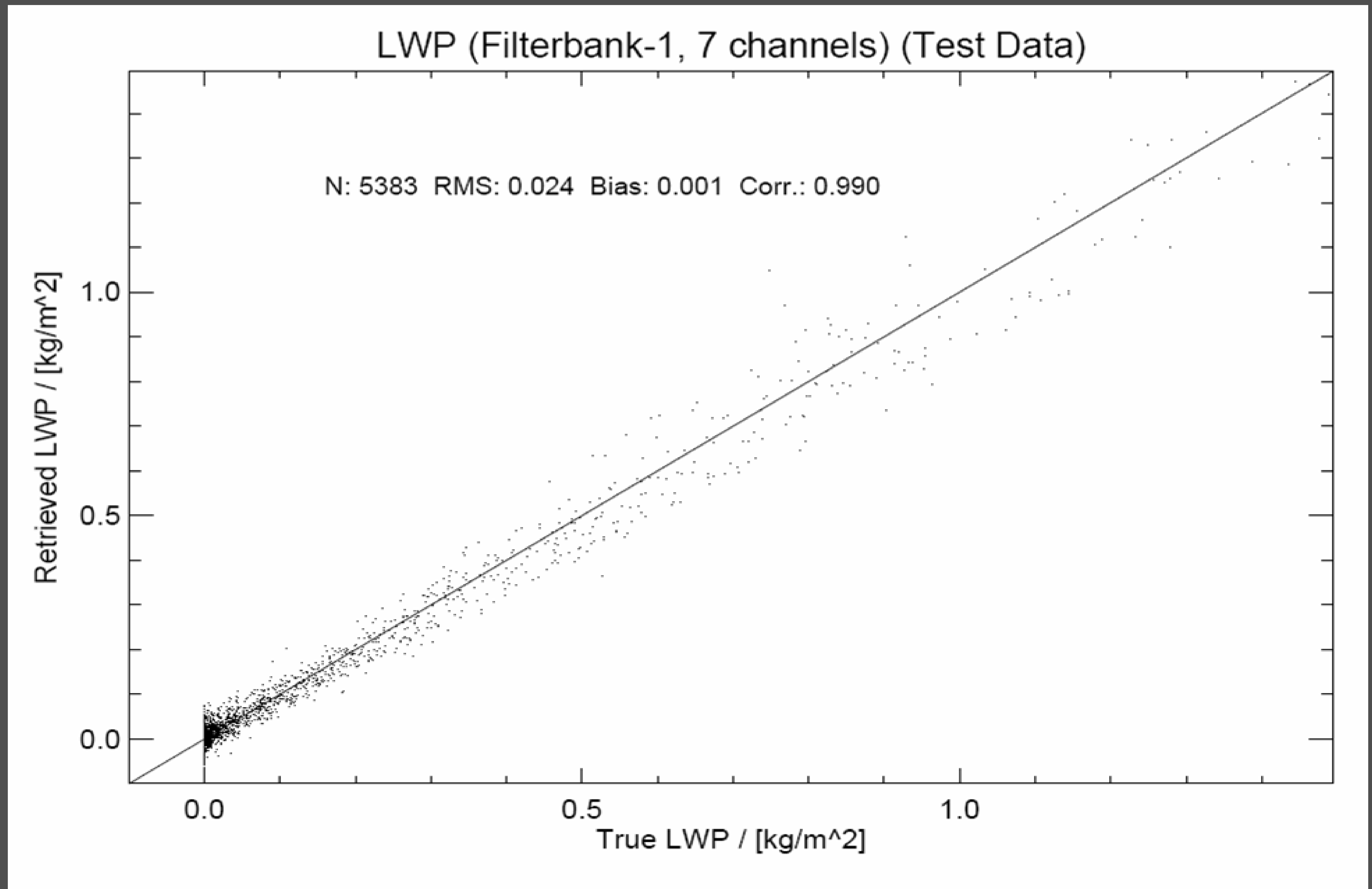
18000 Profiles, 12600 Training, 5400 Test

LWP Retrieval

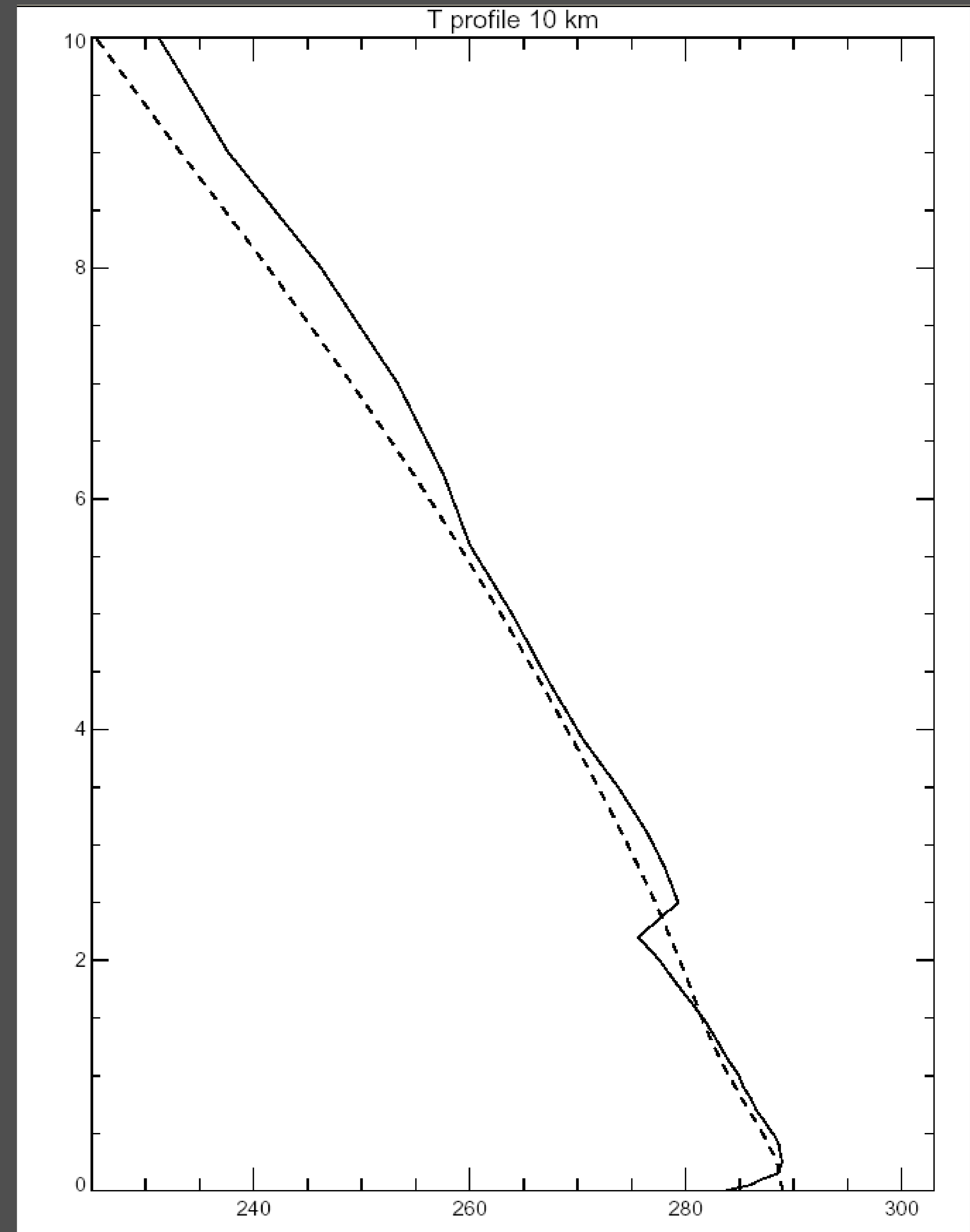
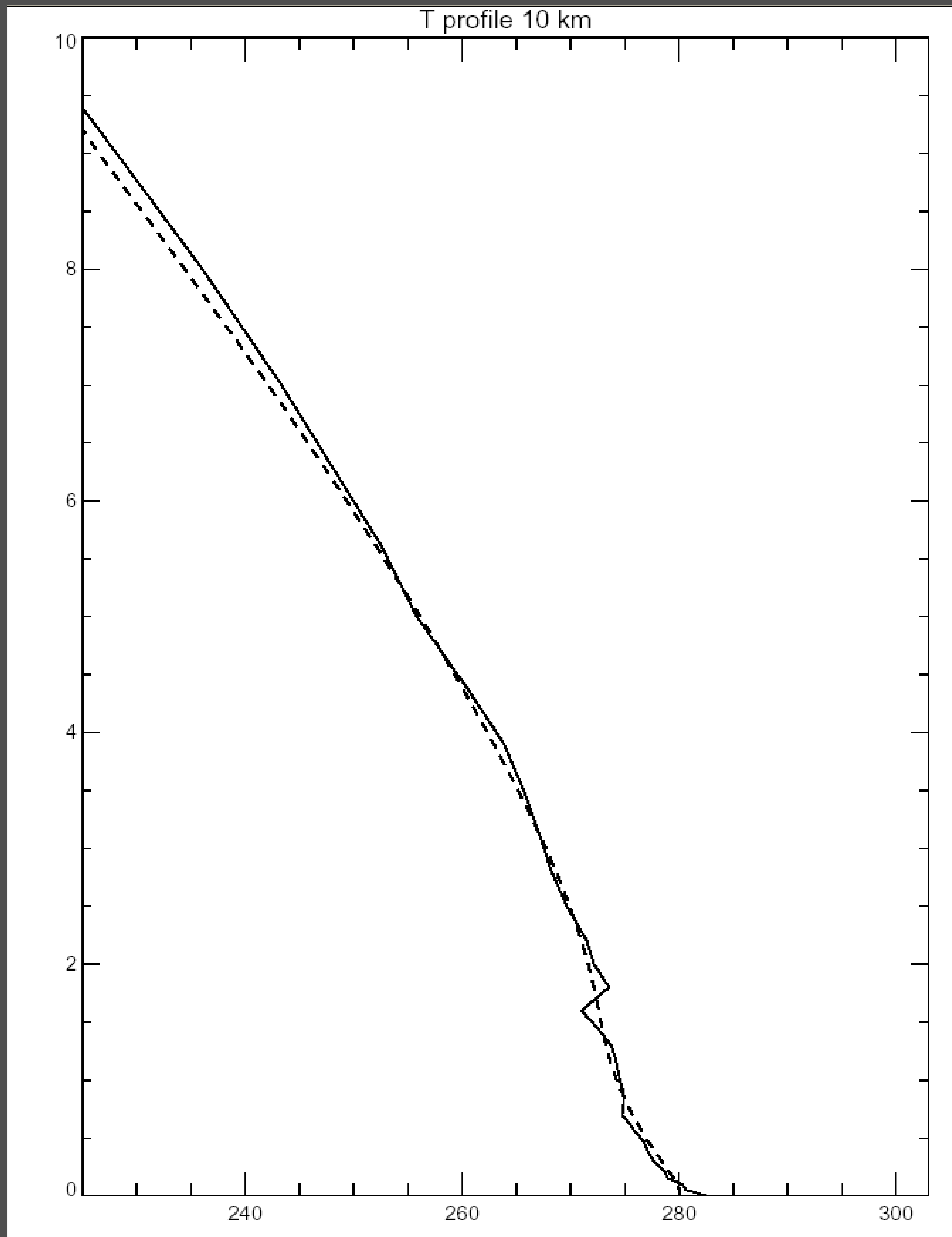


- Customer: University Salford, UK
- 18580 high-resolution radio sondes
- Rainy conditions included
- RMS für cloud-only LWP smaller than shown above

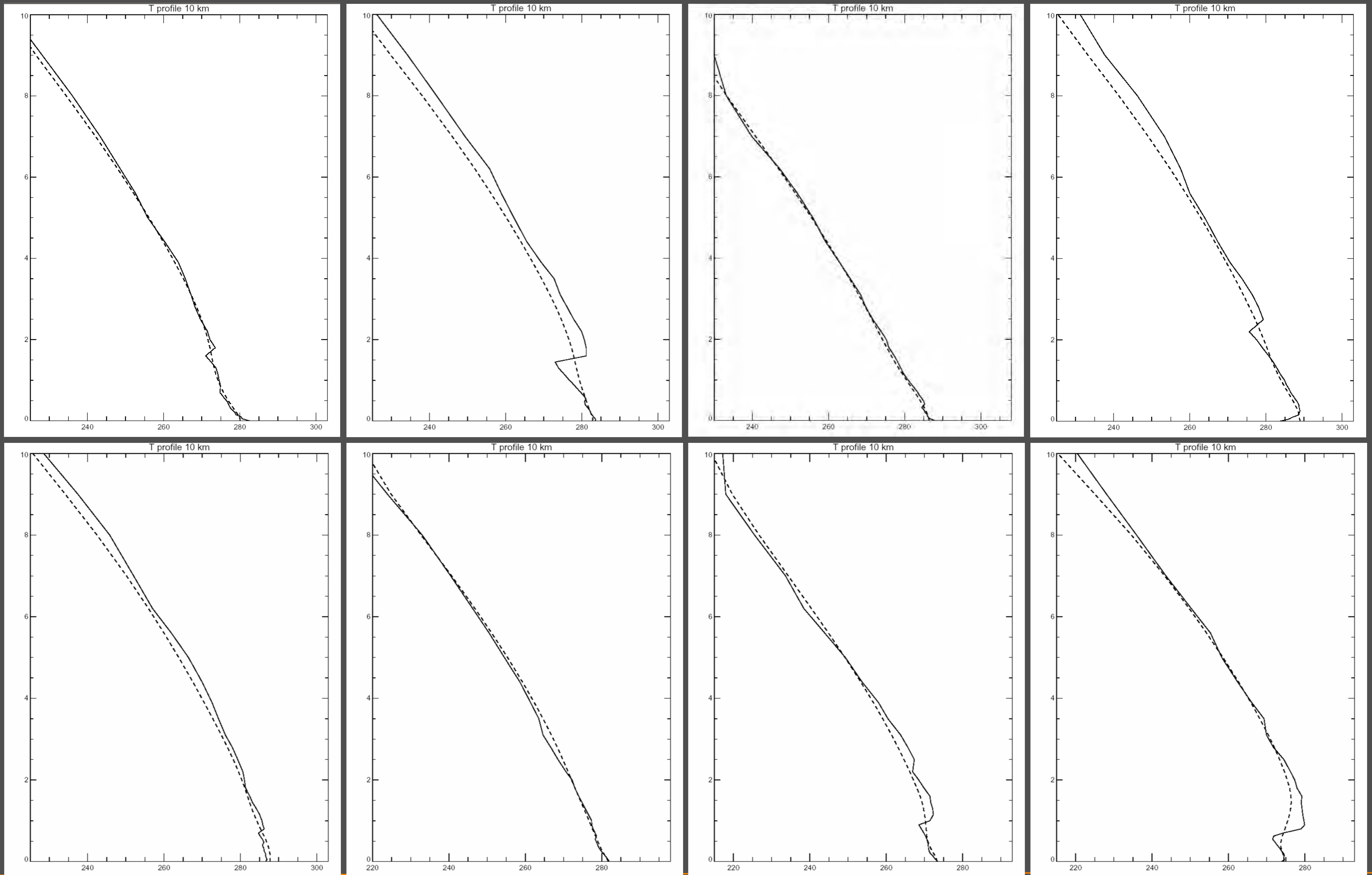
LWP Retrieval - Korea



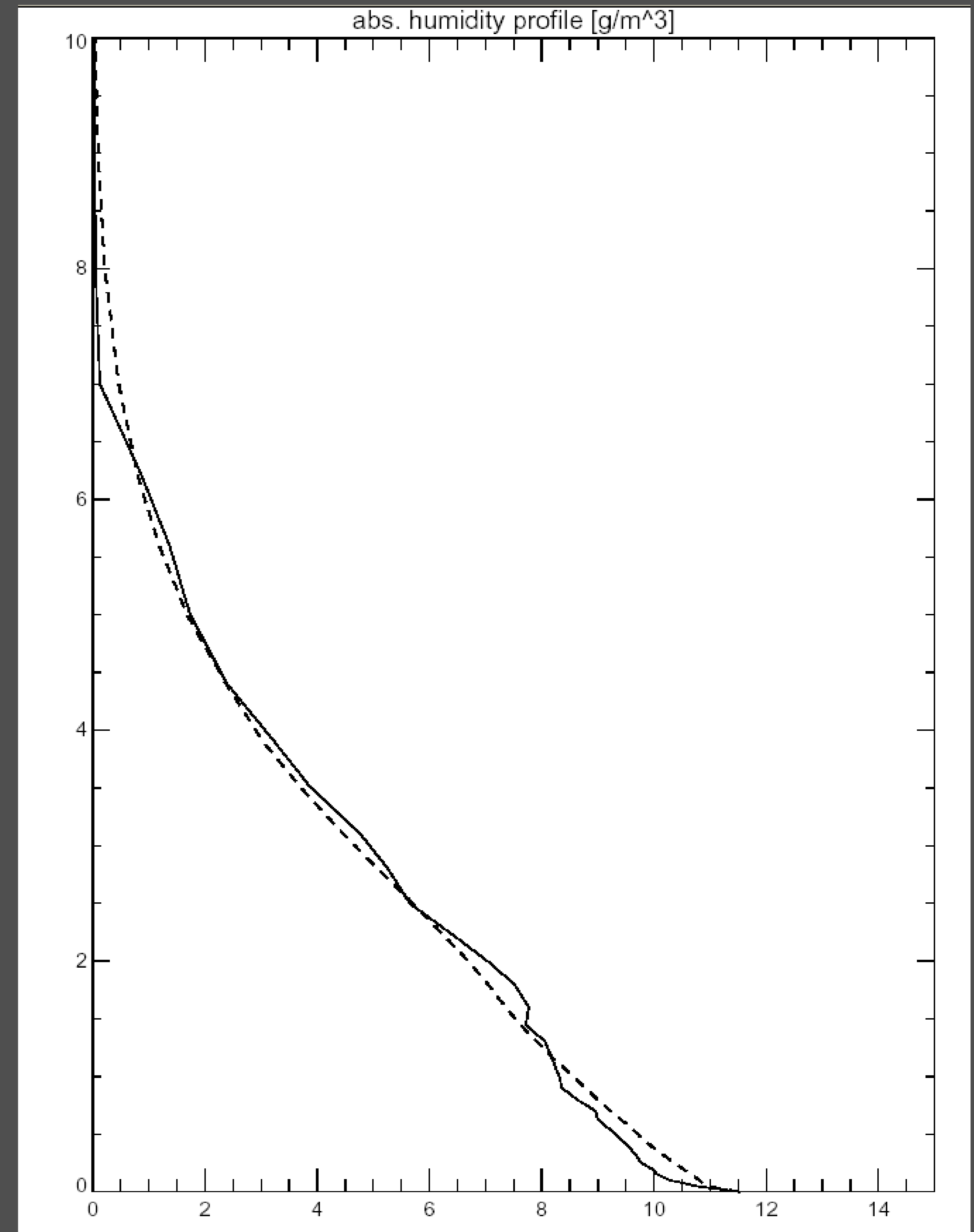
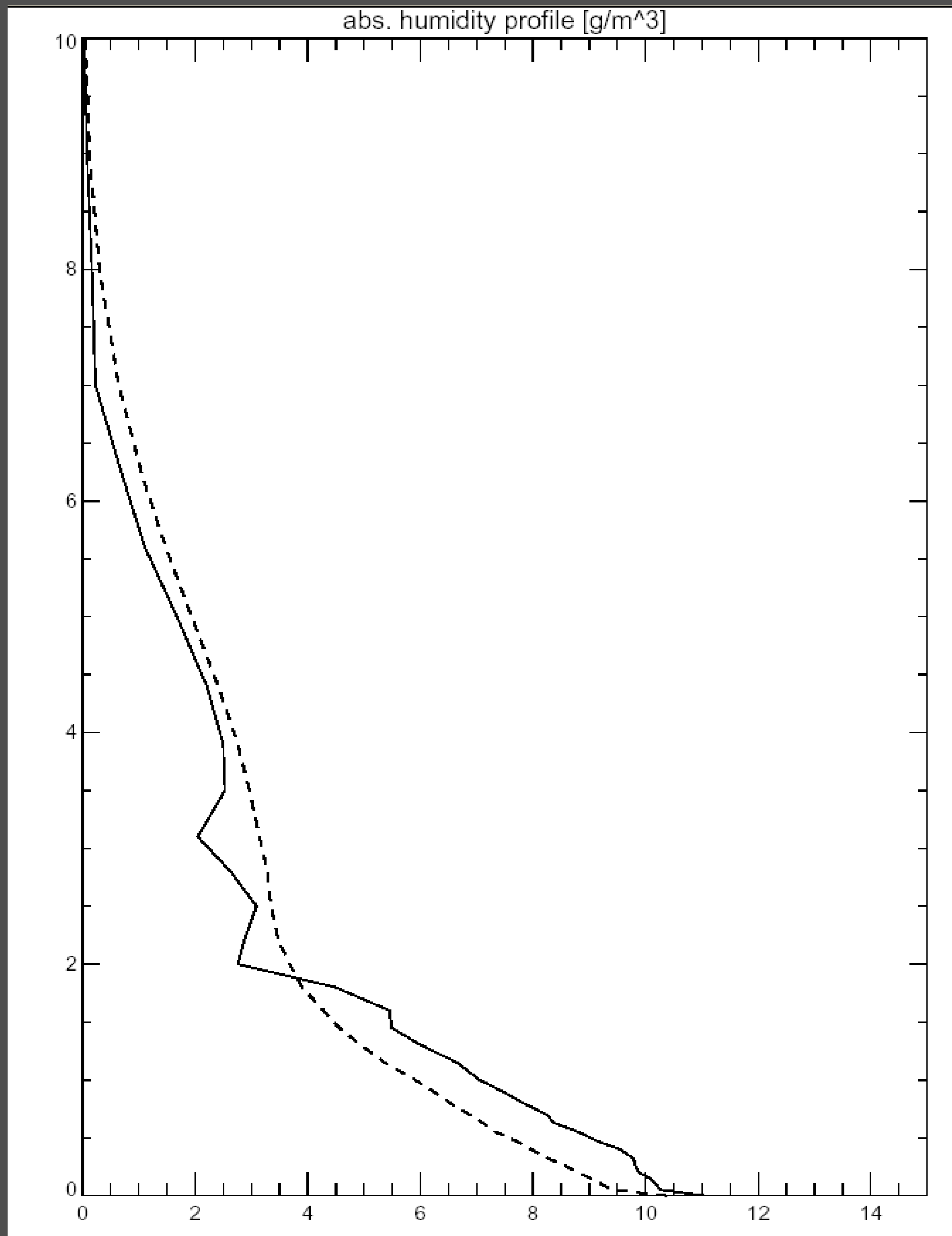
Vertical profiles (temperature, 10 km)



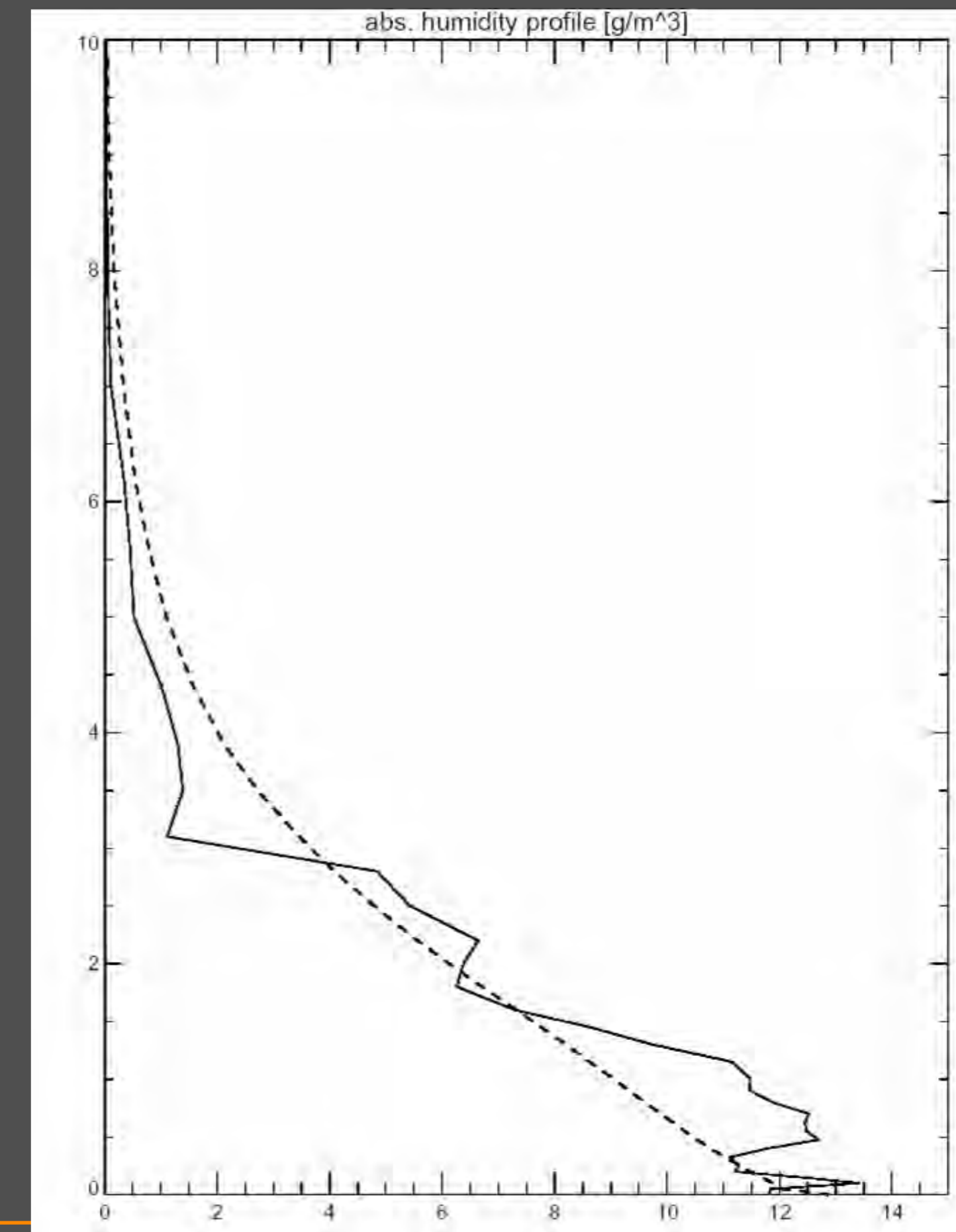
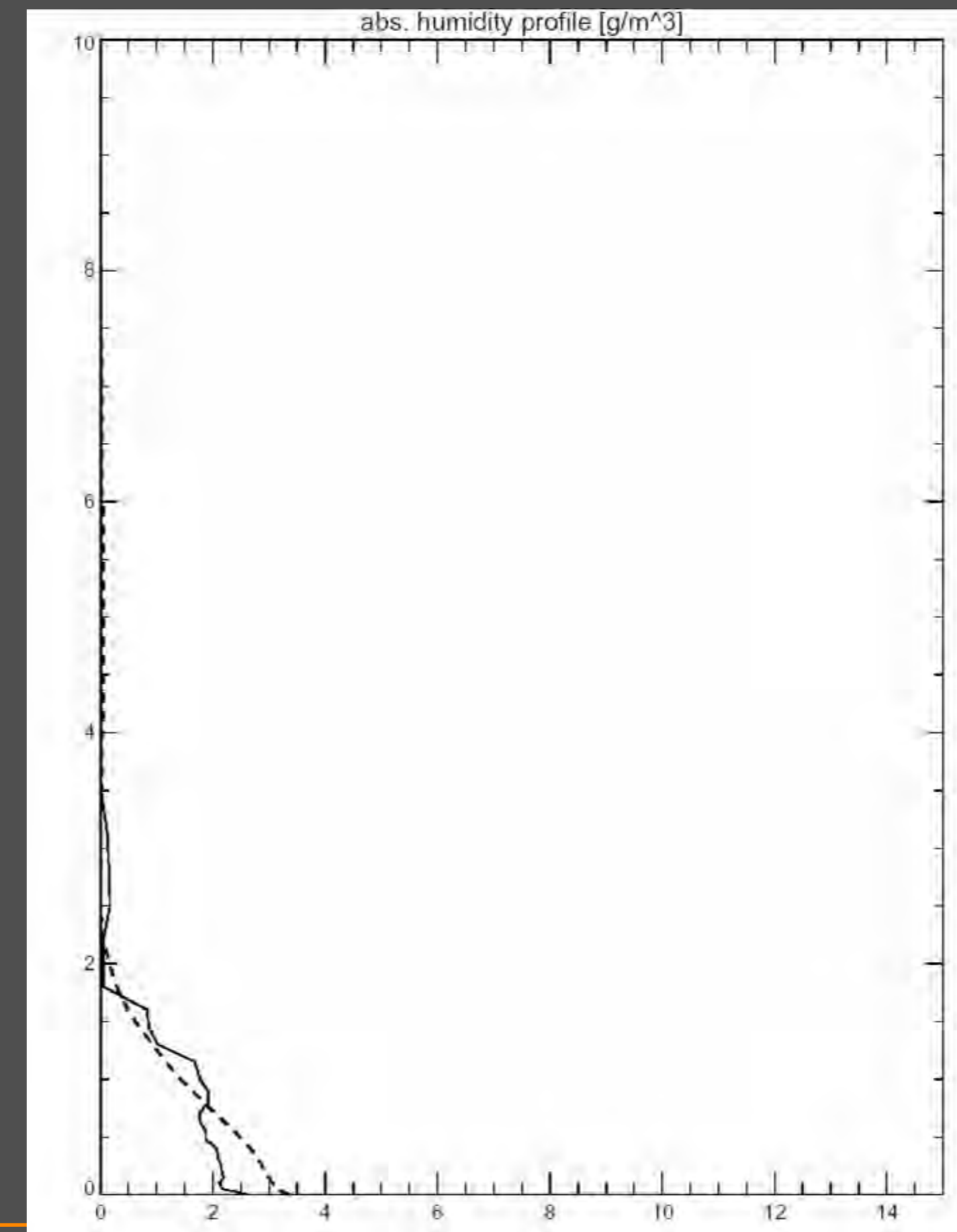
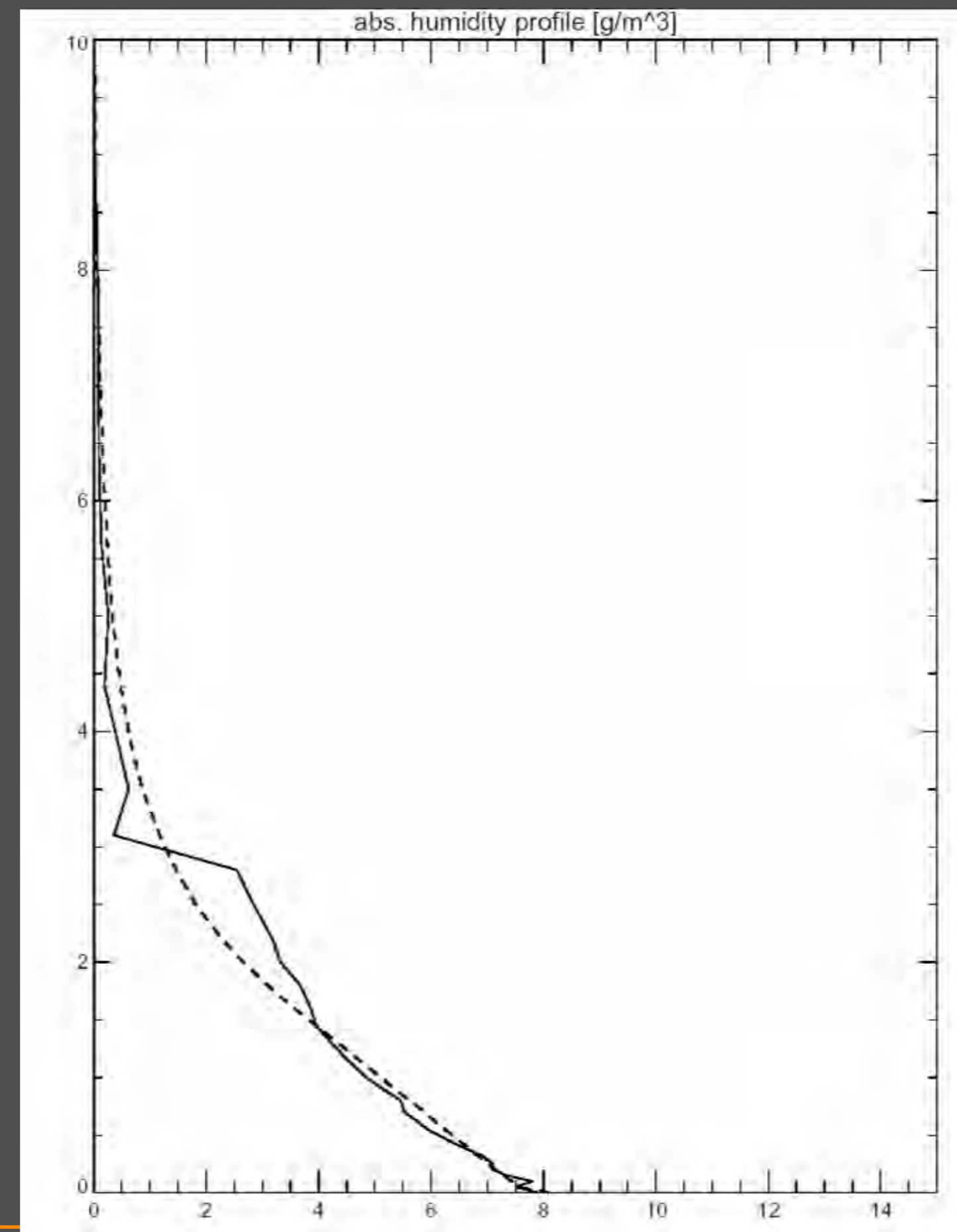
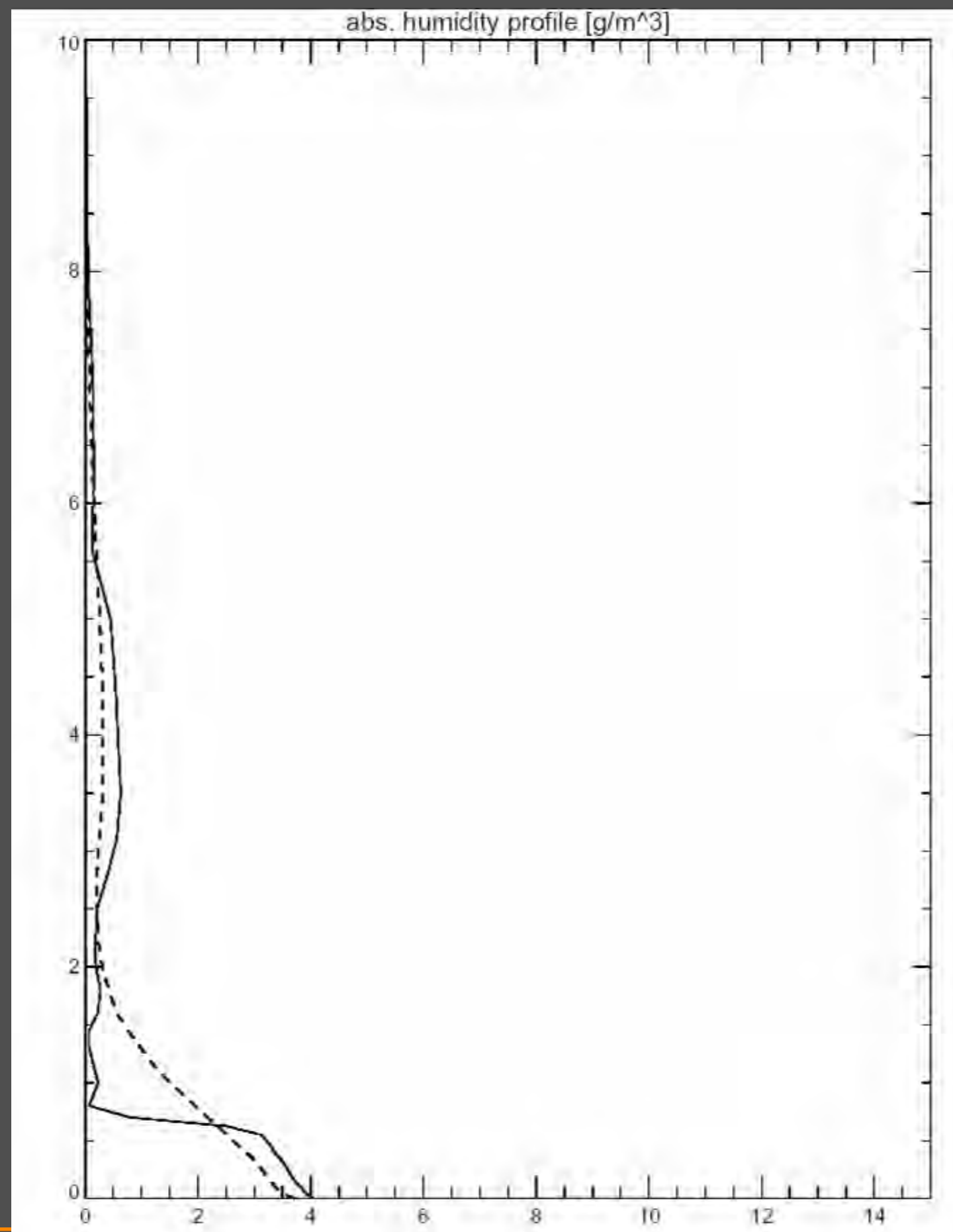
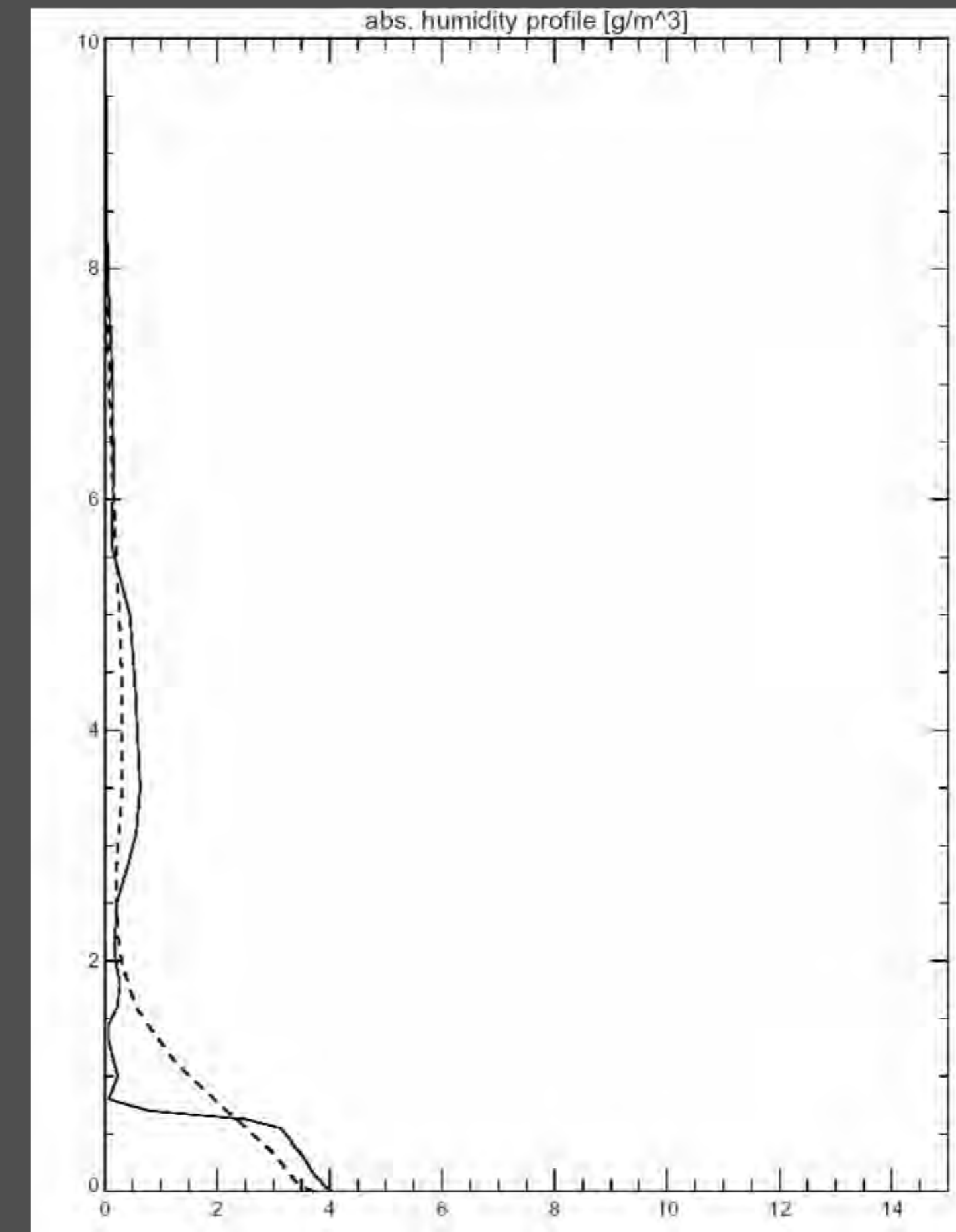
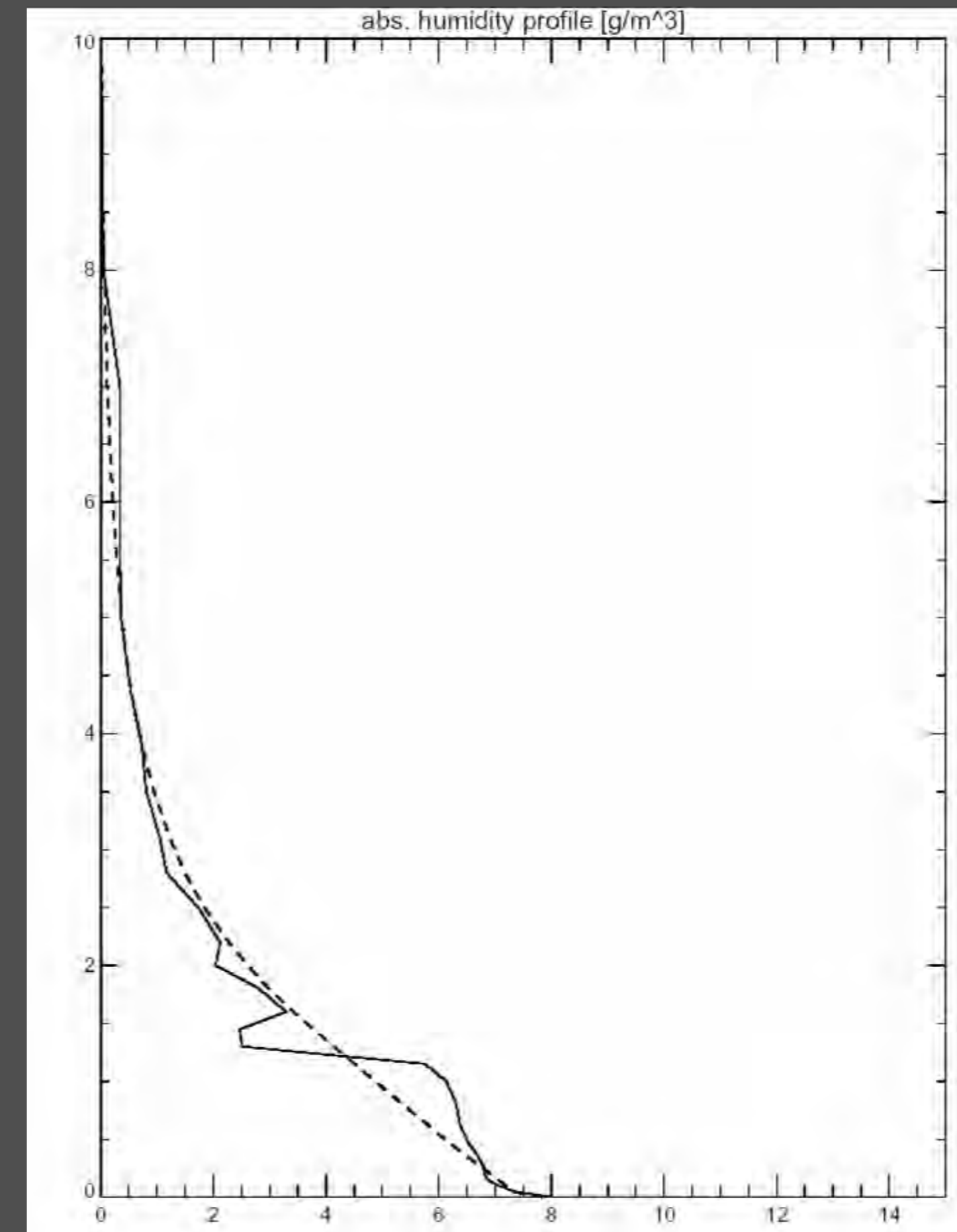
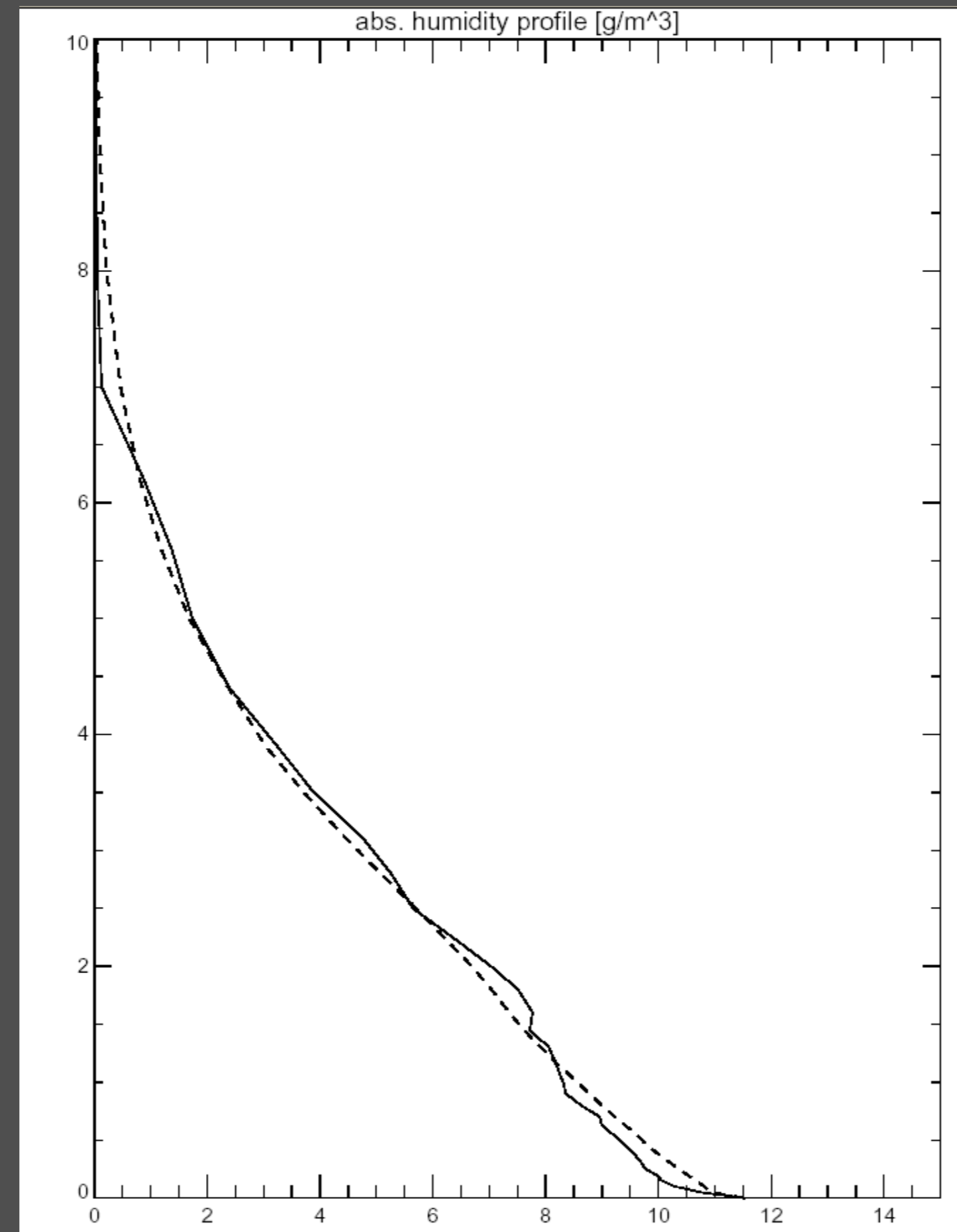
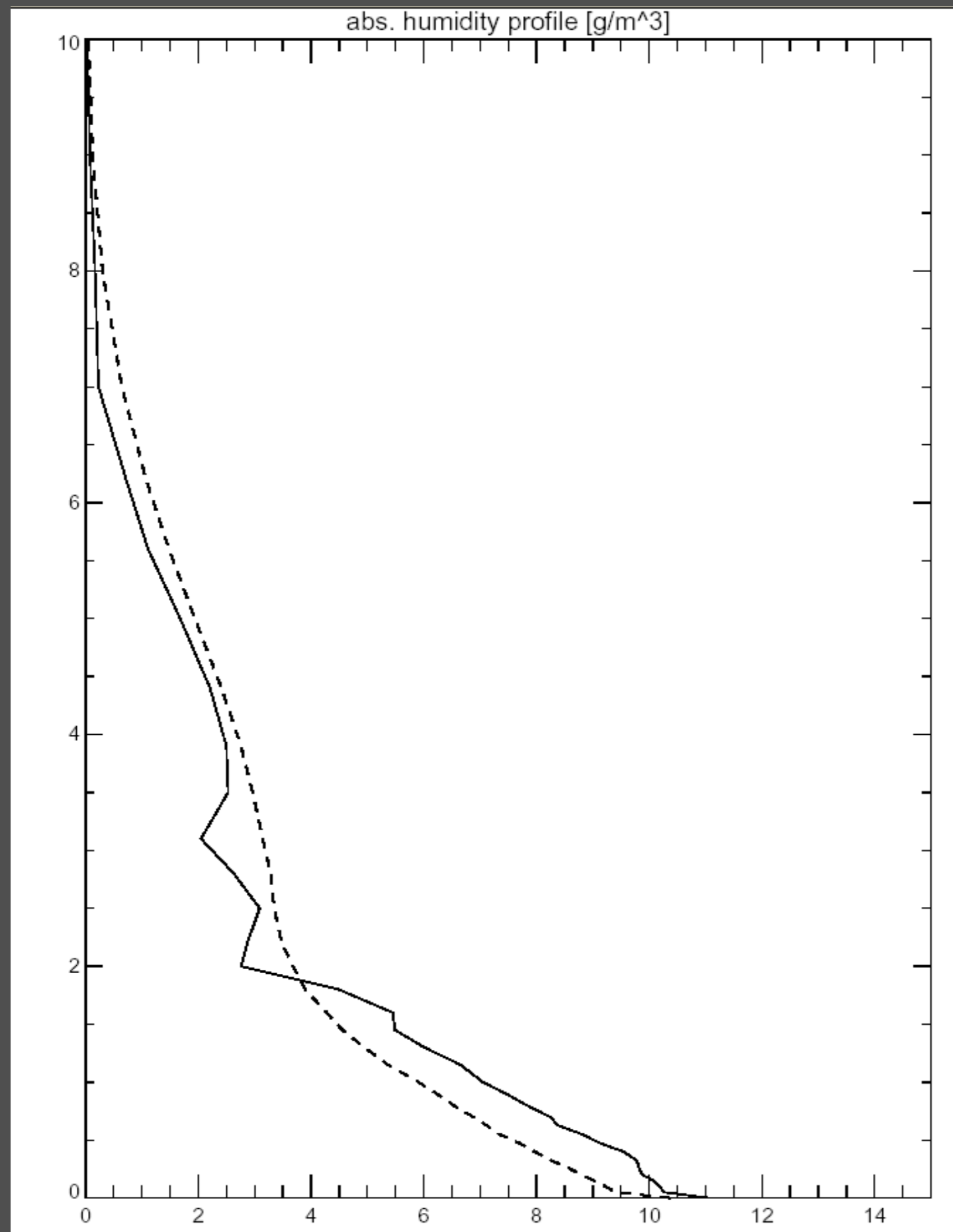
Vertical profiles (temperature, 10 km)



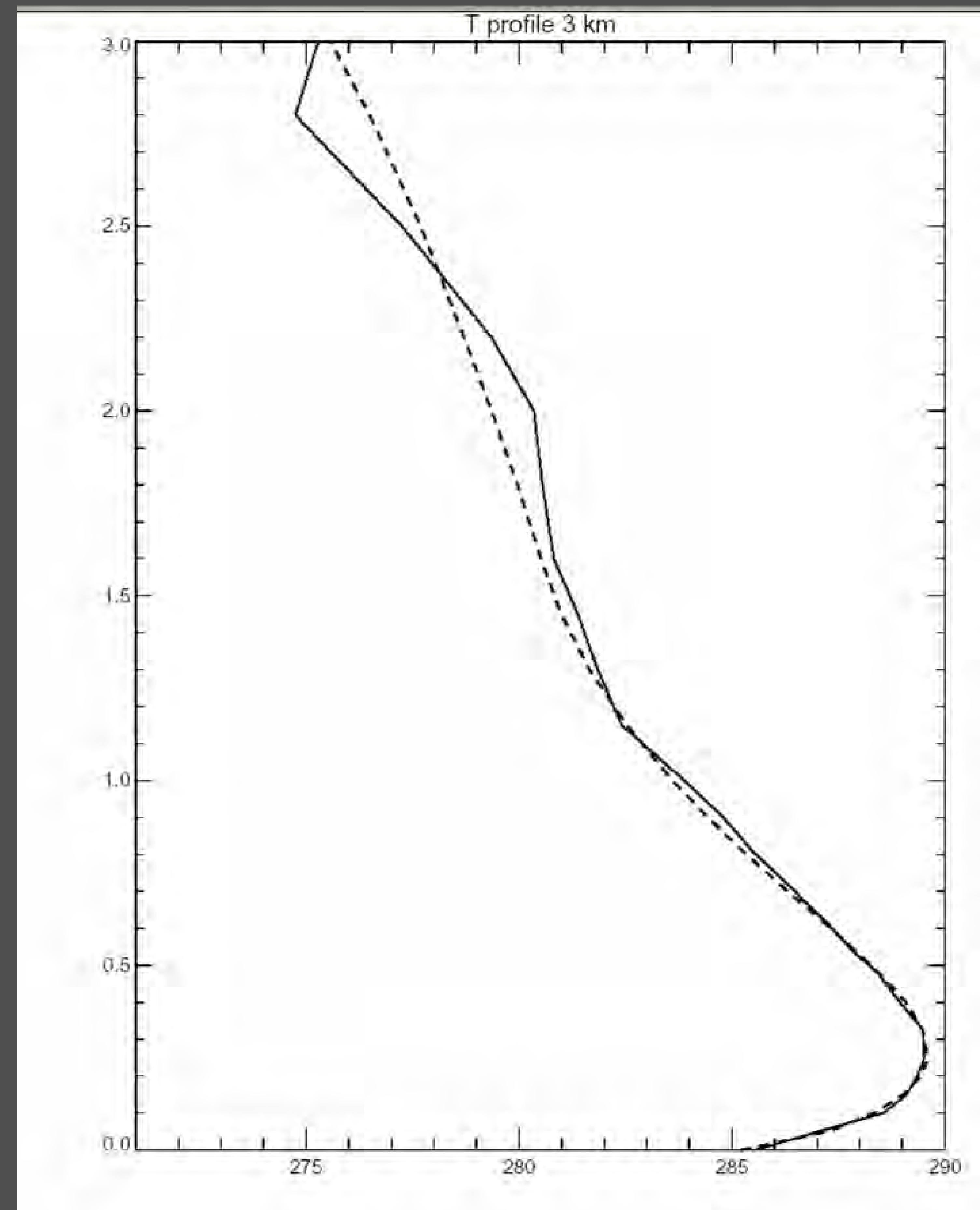
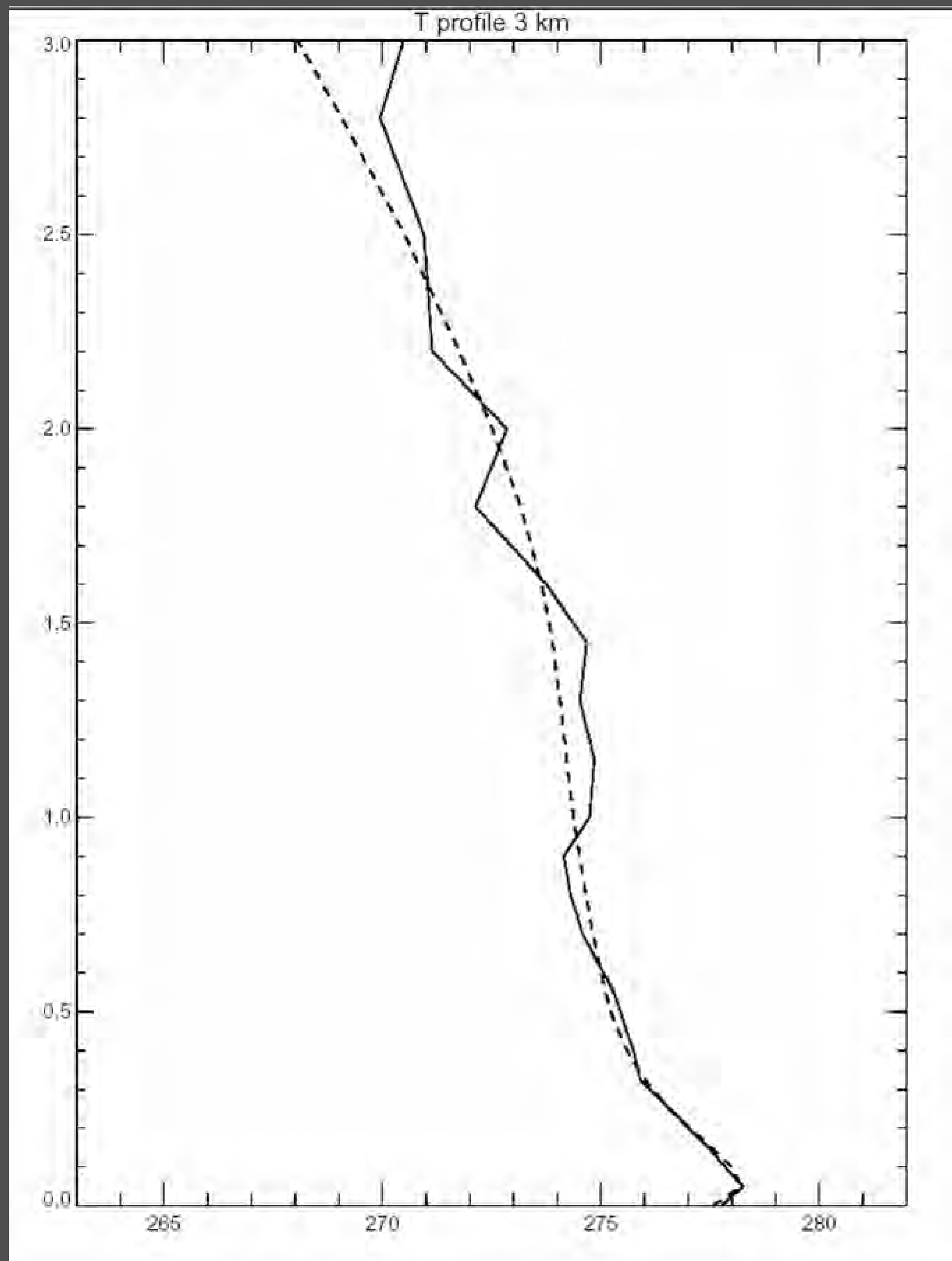
Vertical profiles (absolute humidity, 10 km)



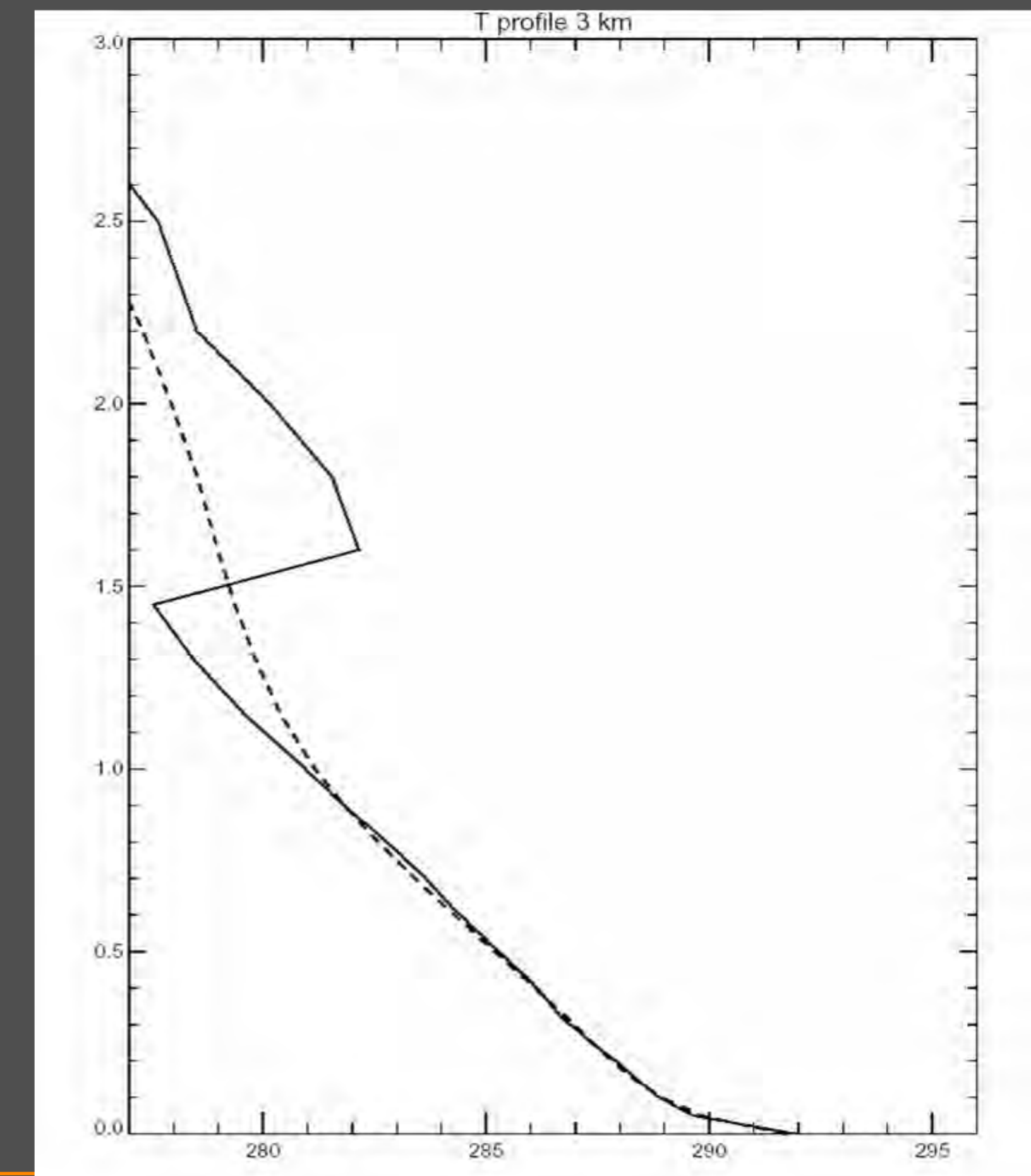
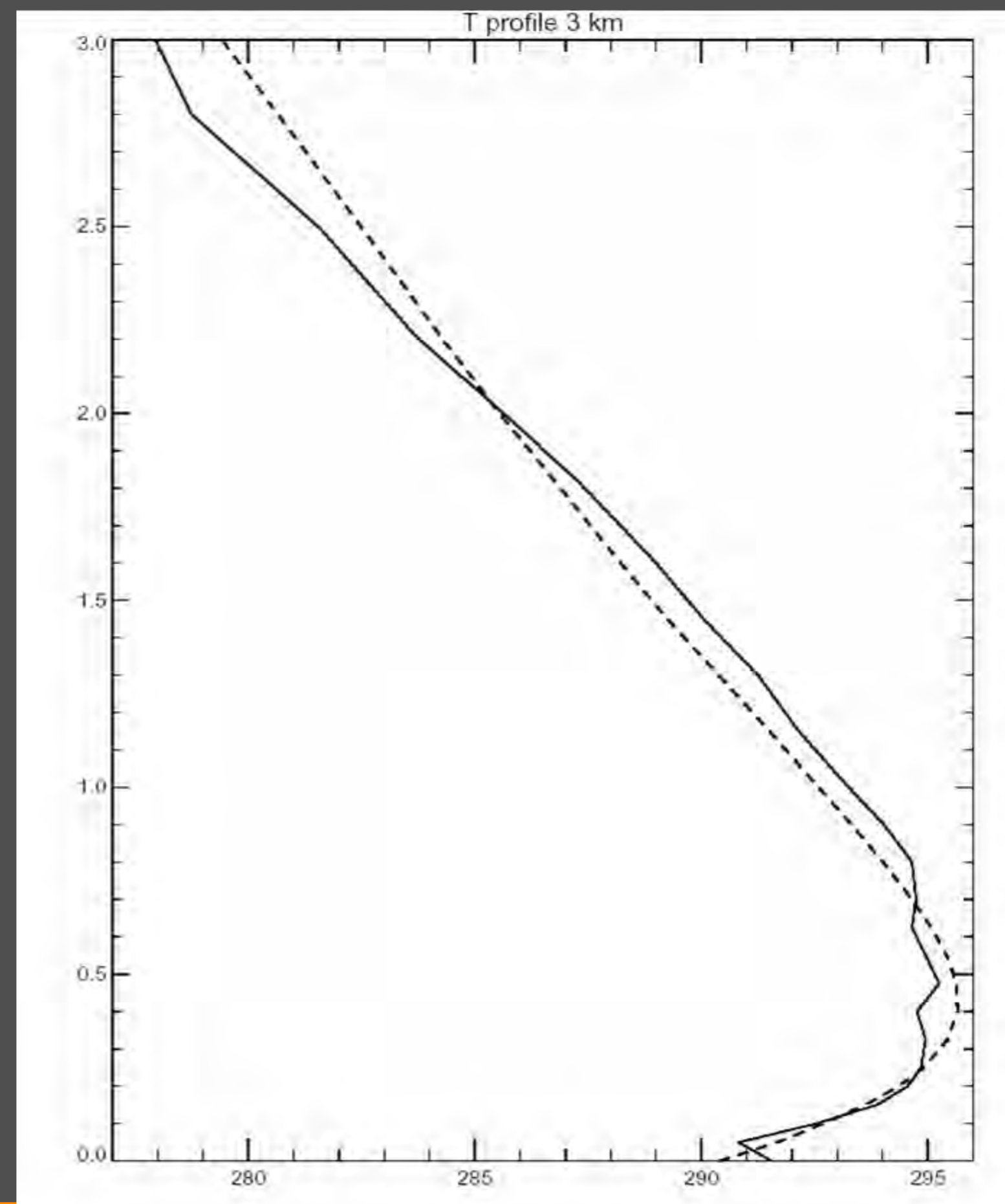
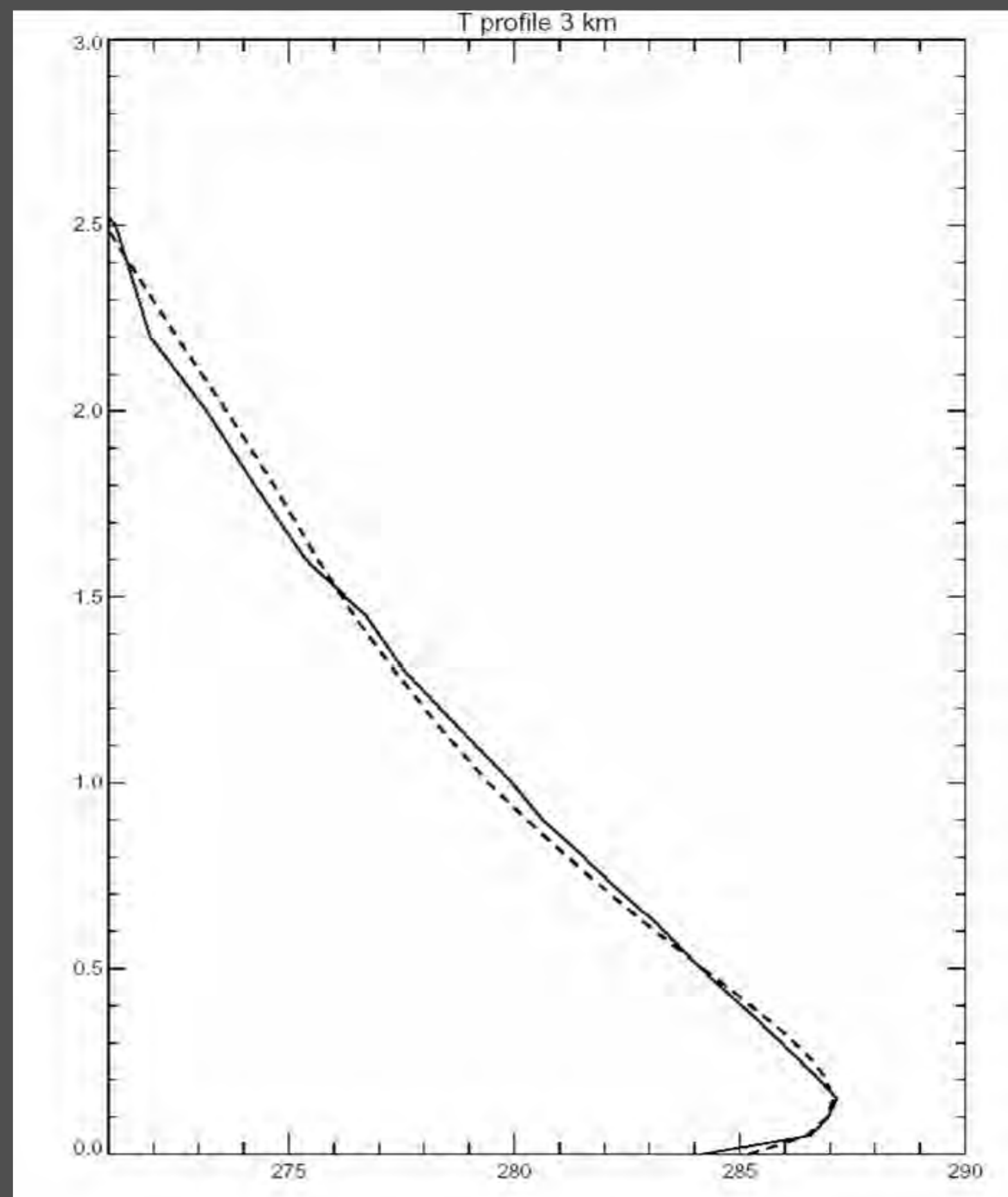
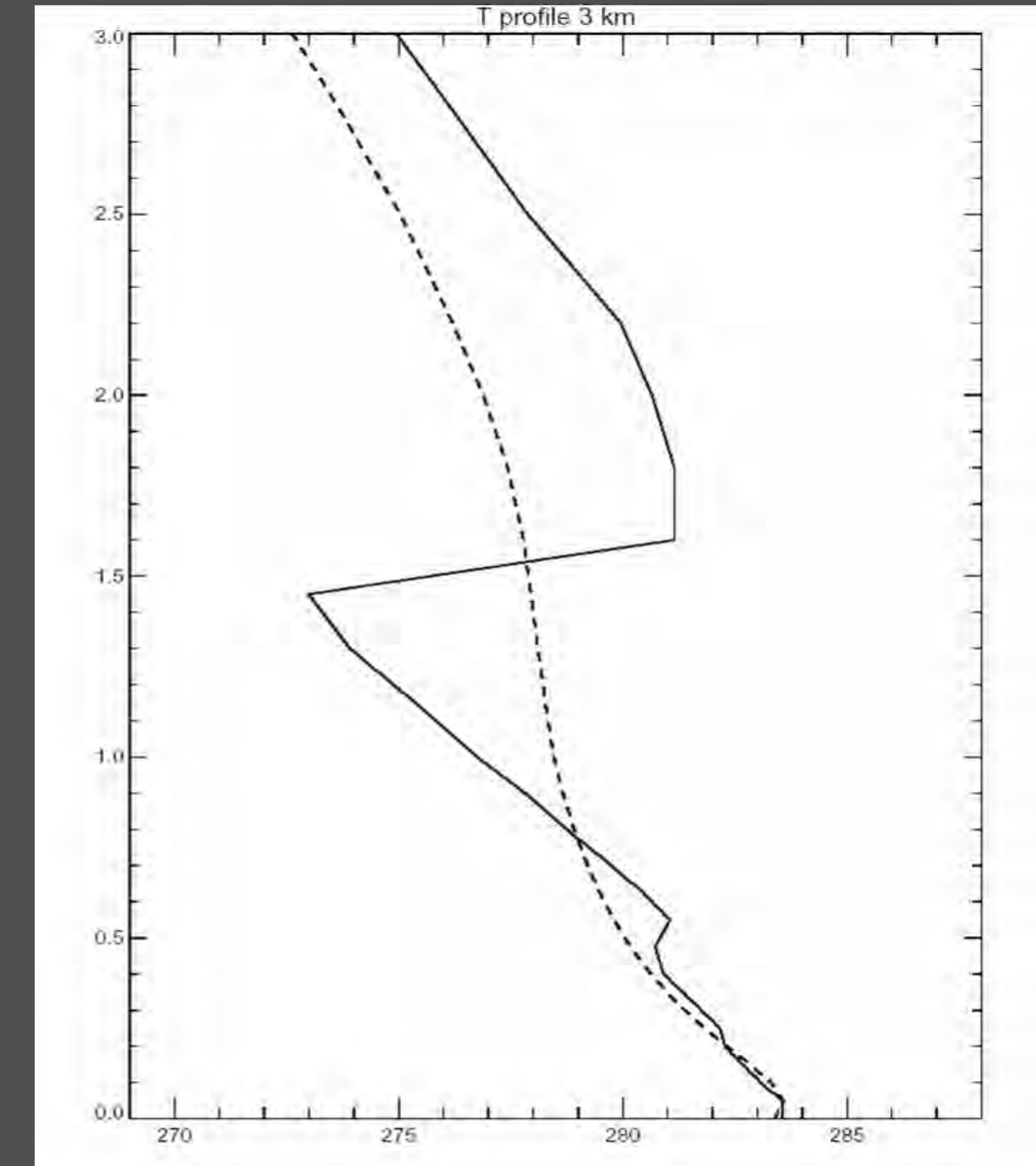
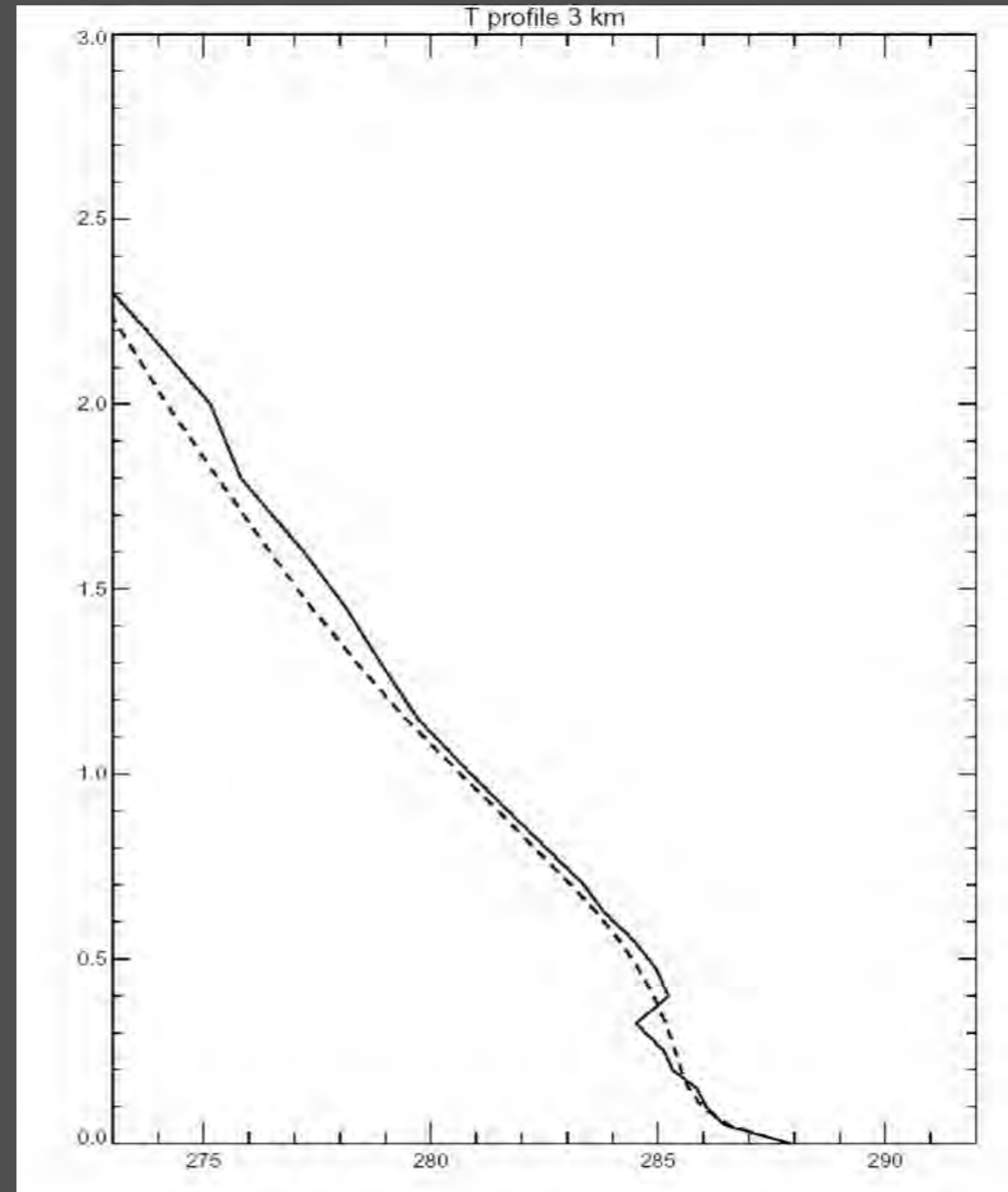
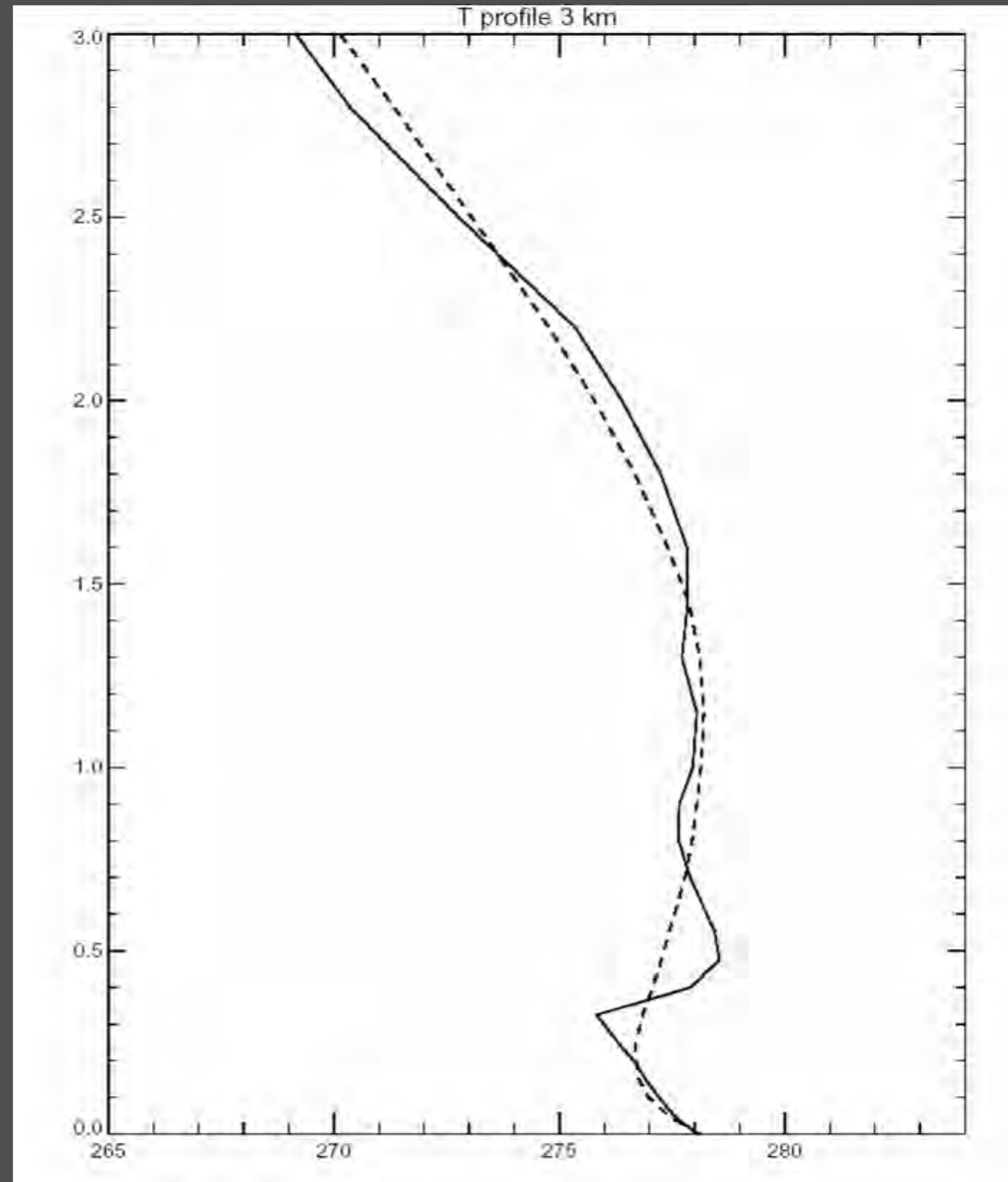
Vertical profiles (absolute humidity, 10km)



Boundary Layer Temperature Profiles



Boundary Layer Temperature Profile

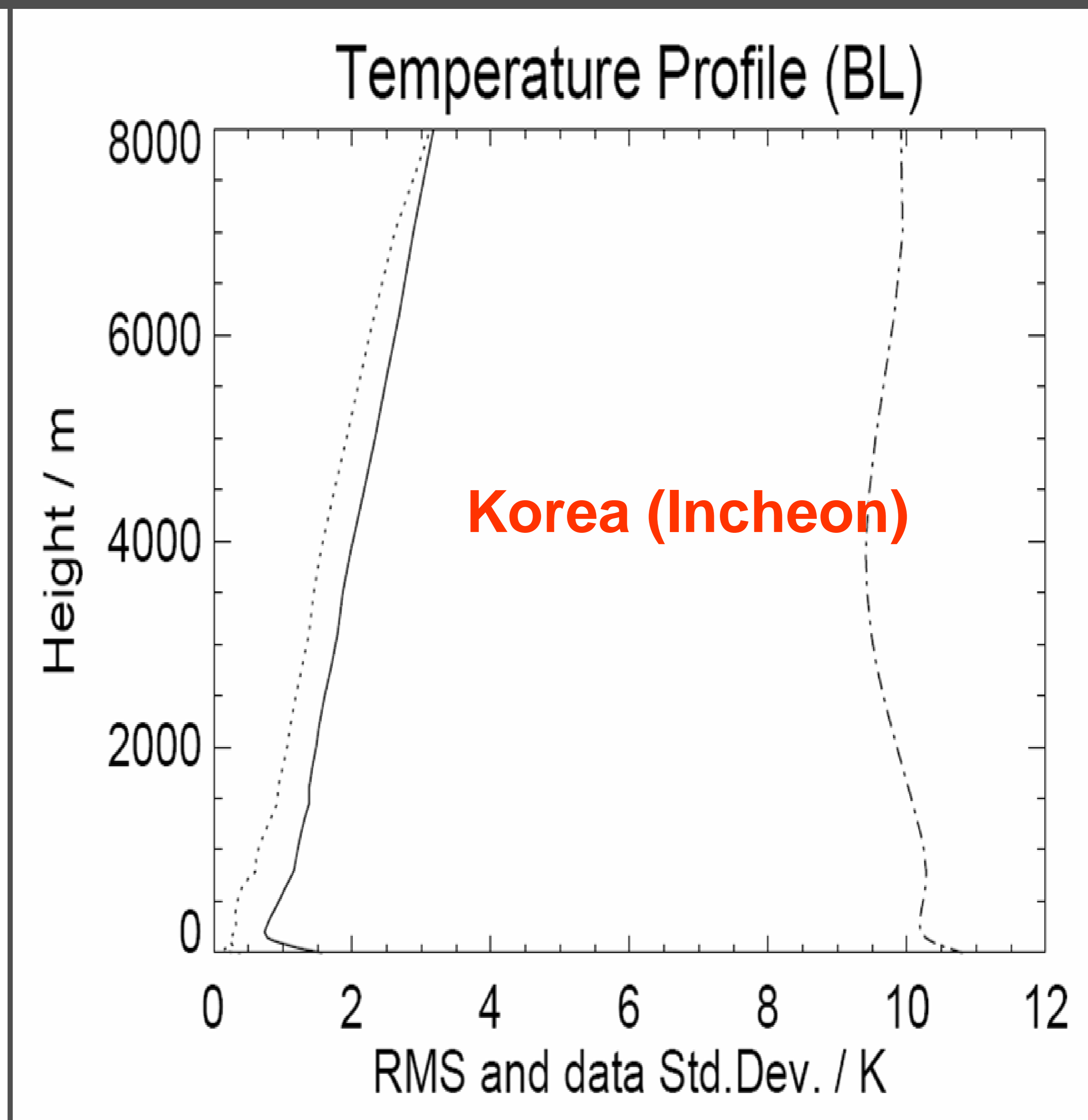
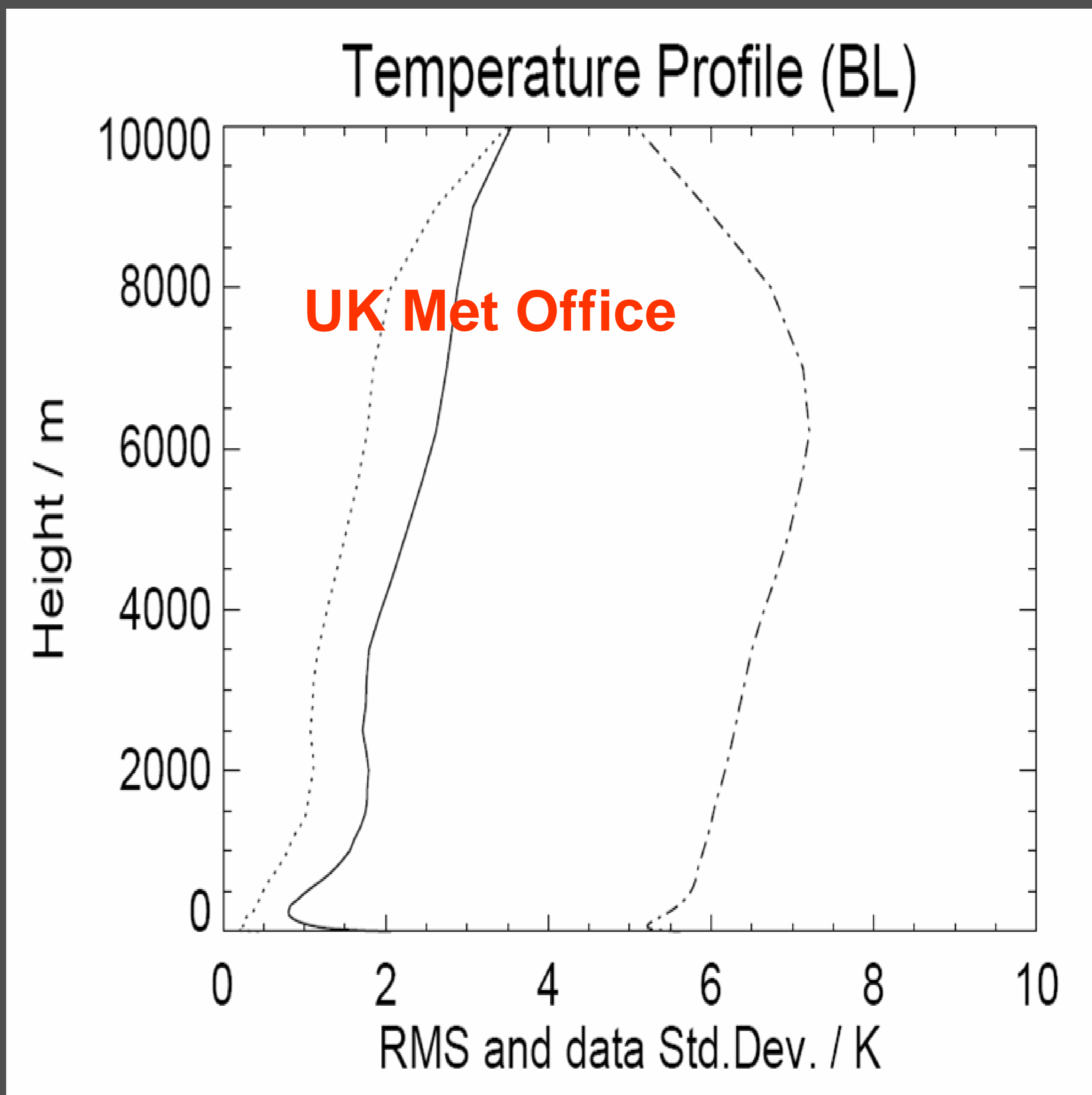


Temperature Profiles: RMS

dotted lines: boundary layer / elevation scanning

solid lines: full troposphere

dash-dotted: std.dev. from data set

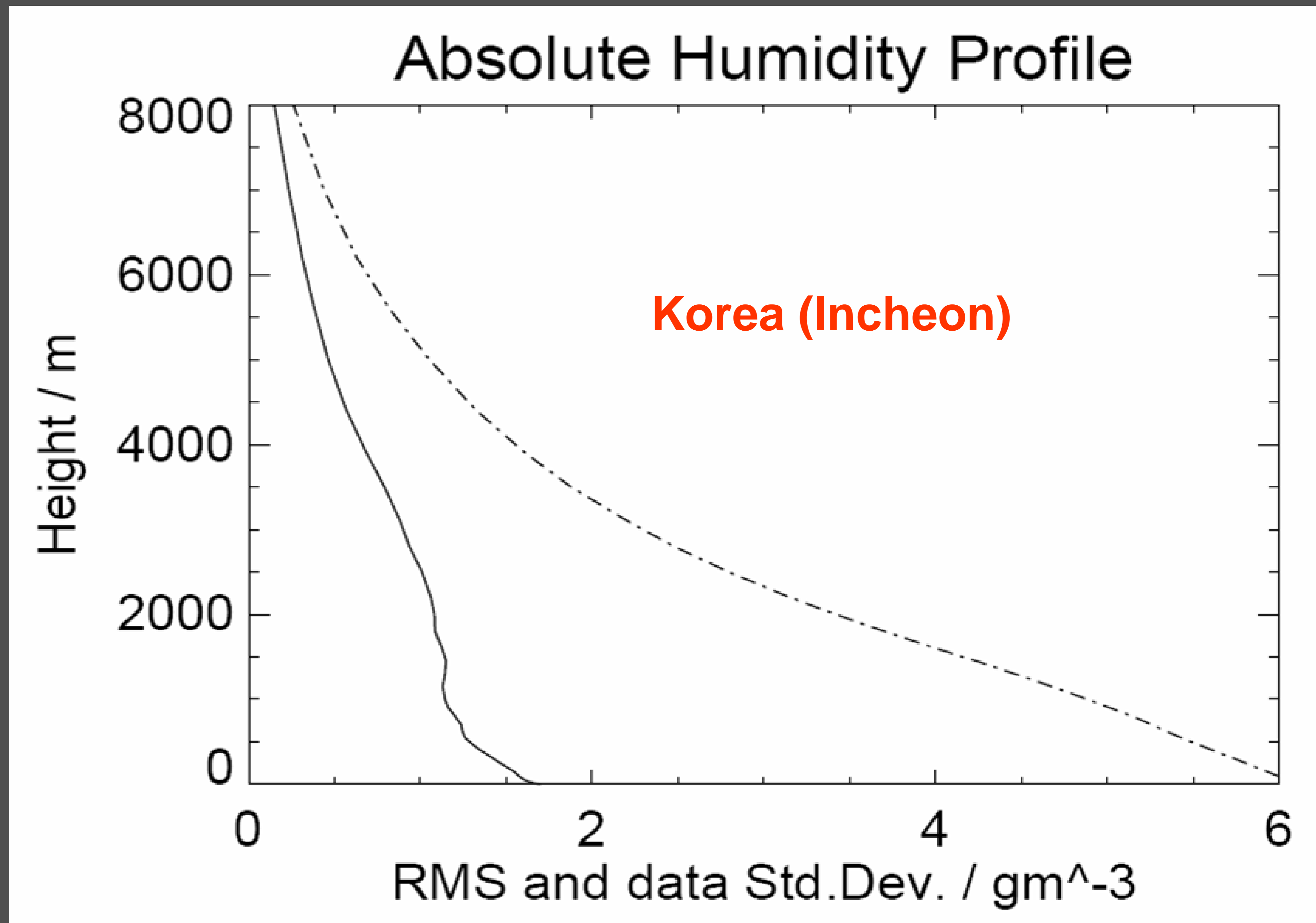


Absolute Humidity Profile: RMS

dotted lines: boundary layer / elevation scanning

solid lines: full troposphere

dash-dotted: std.dev. from data set

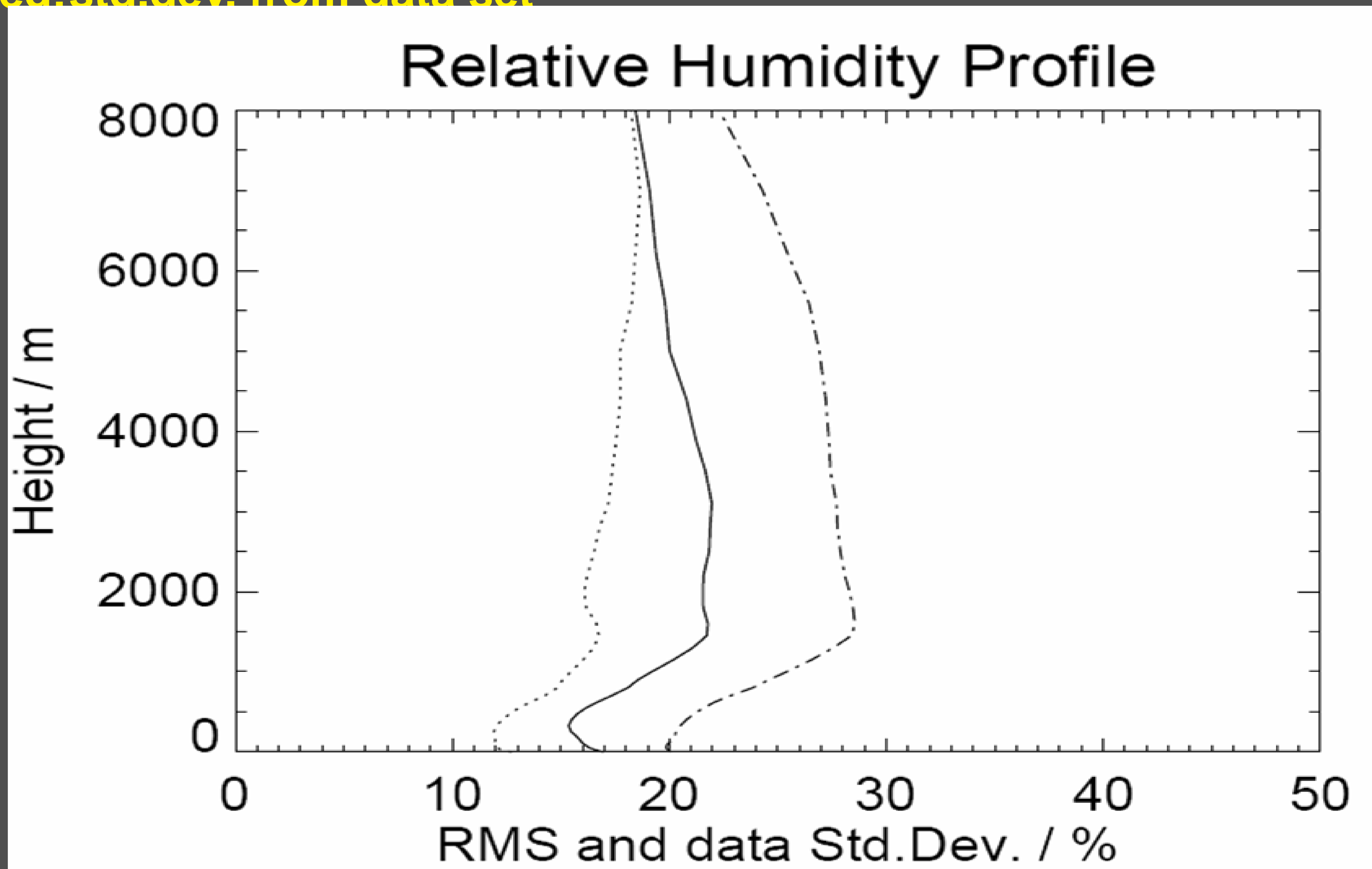


Relative Humidity Profile: RMS

dotted lines: boundary layer / elevation scanning

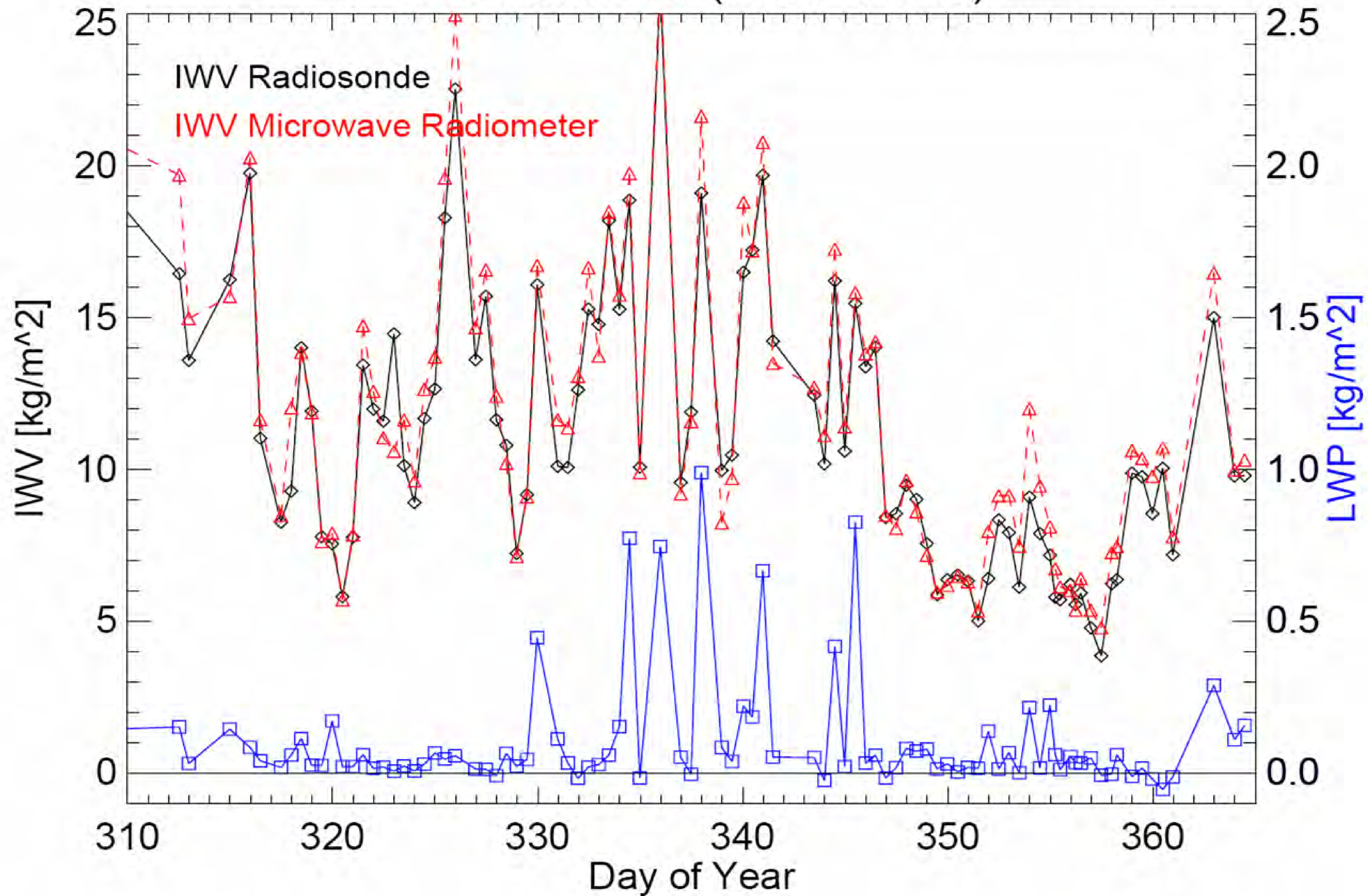
solid lines: full troposphere

dash-dotted: std.dev. from data set

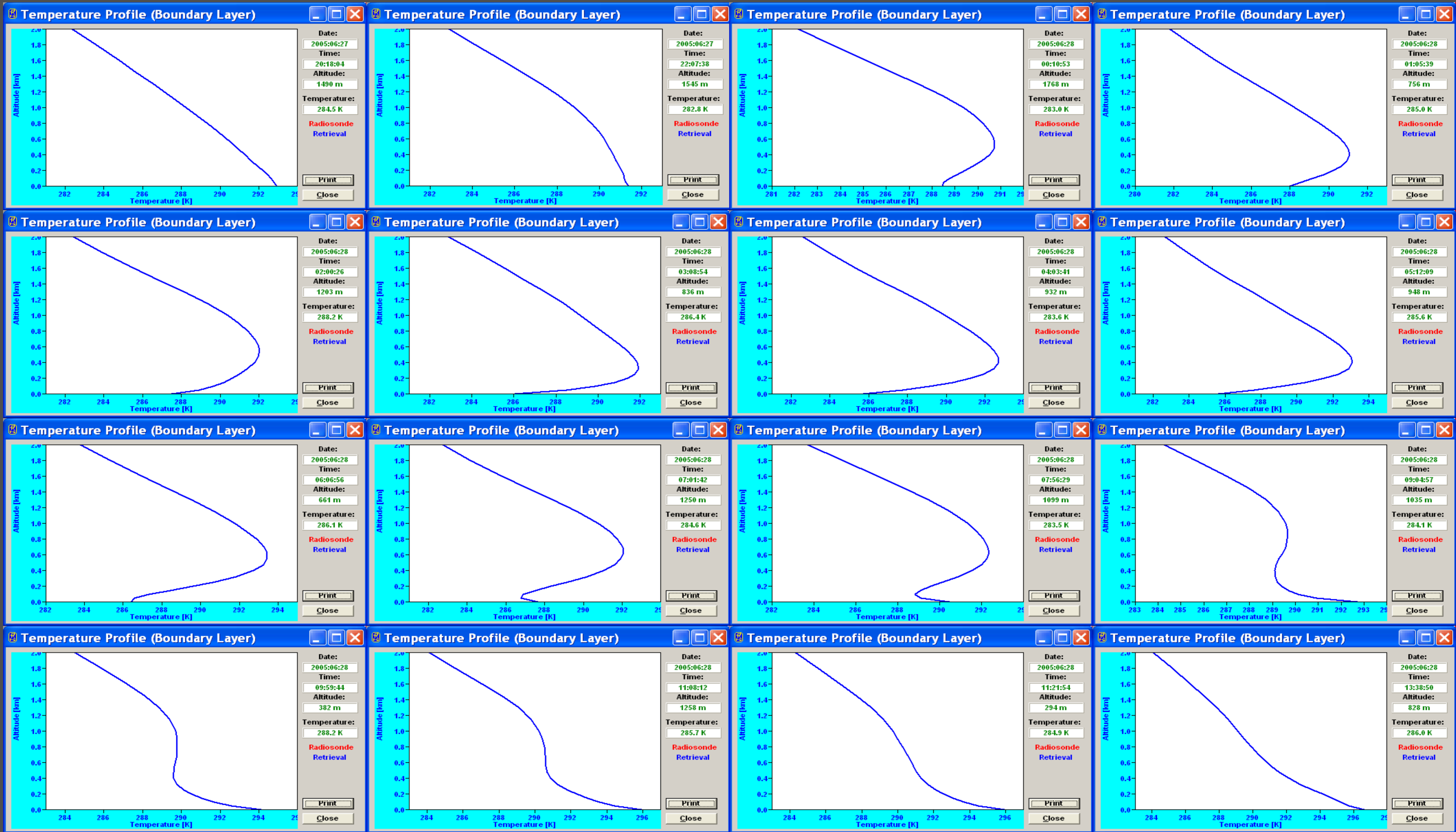


Measurement examples

IWV Retrieval (2007-11.12)

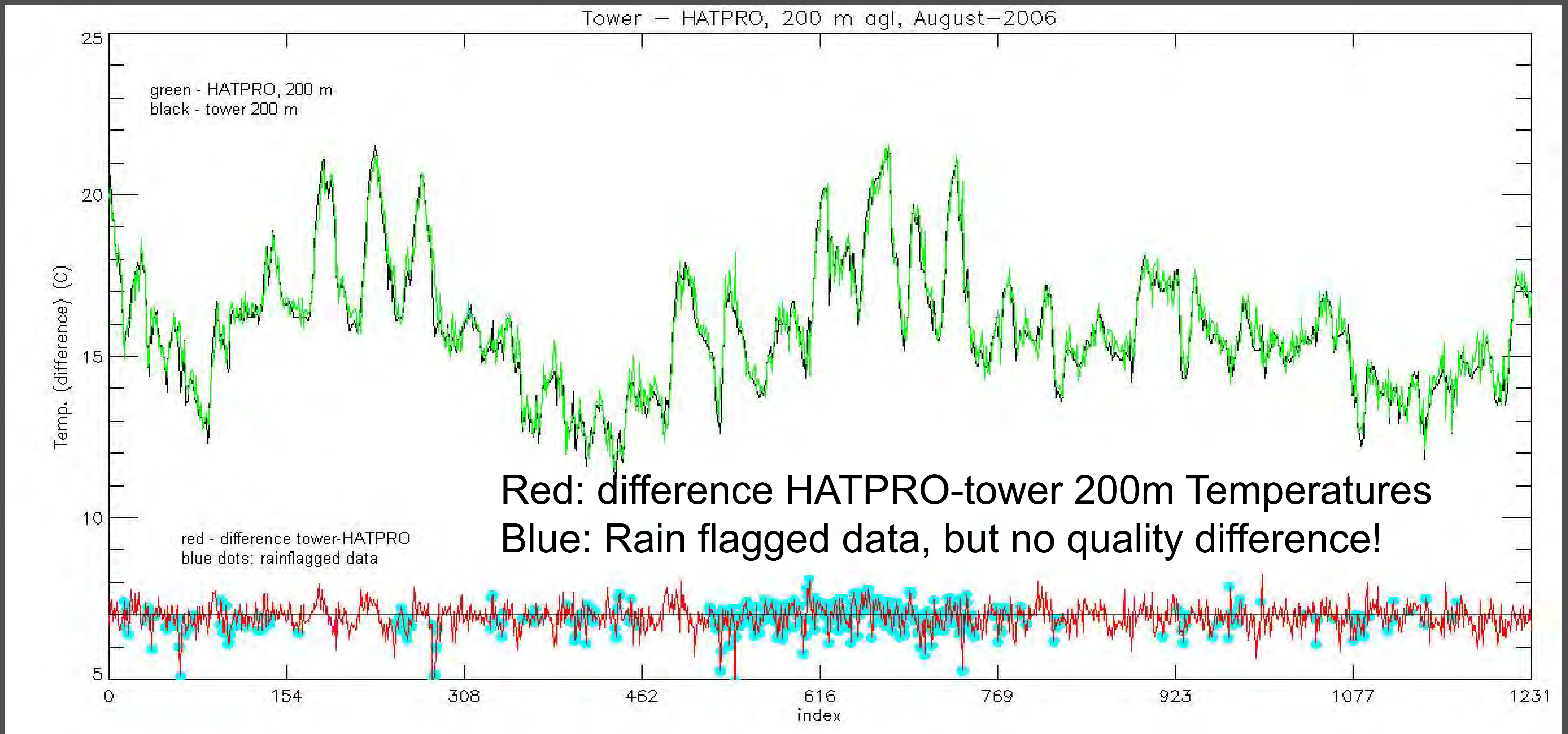


Time series of temperature inversion



Measurements: 200m temperature at KNMI mast

- Comparison of HATPRO 200 m temperature measurements
- (in BL mode) with meteorological tower temperature sensor readings
- in the same altitude (coutesy of Henk Klein-Baltink, KNMI, Neatherlands):



Measurements: spatial and temporal information

The spatial and temporal evolution of integrated water vapour content (IWV), sky-temperature (IR) and liquid water path (LWP) are visualized by Time-Azimuth-(Hovmöller) Diagrams

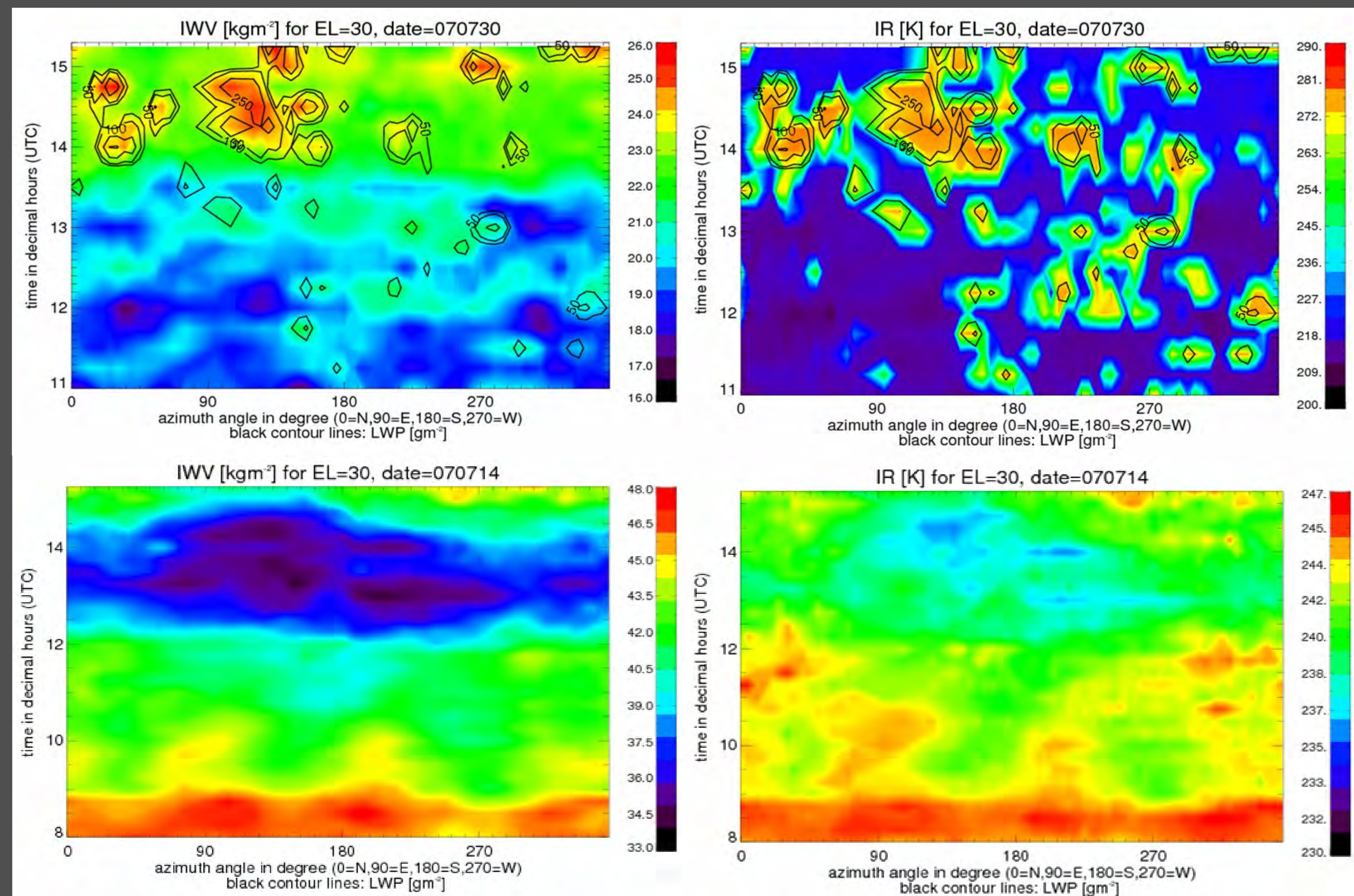
horizontal axis:

azimuth angle

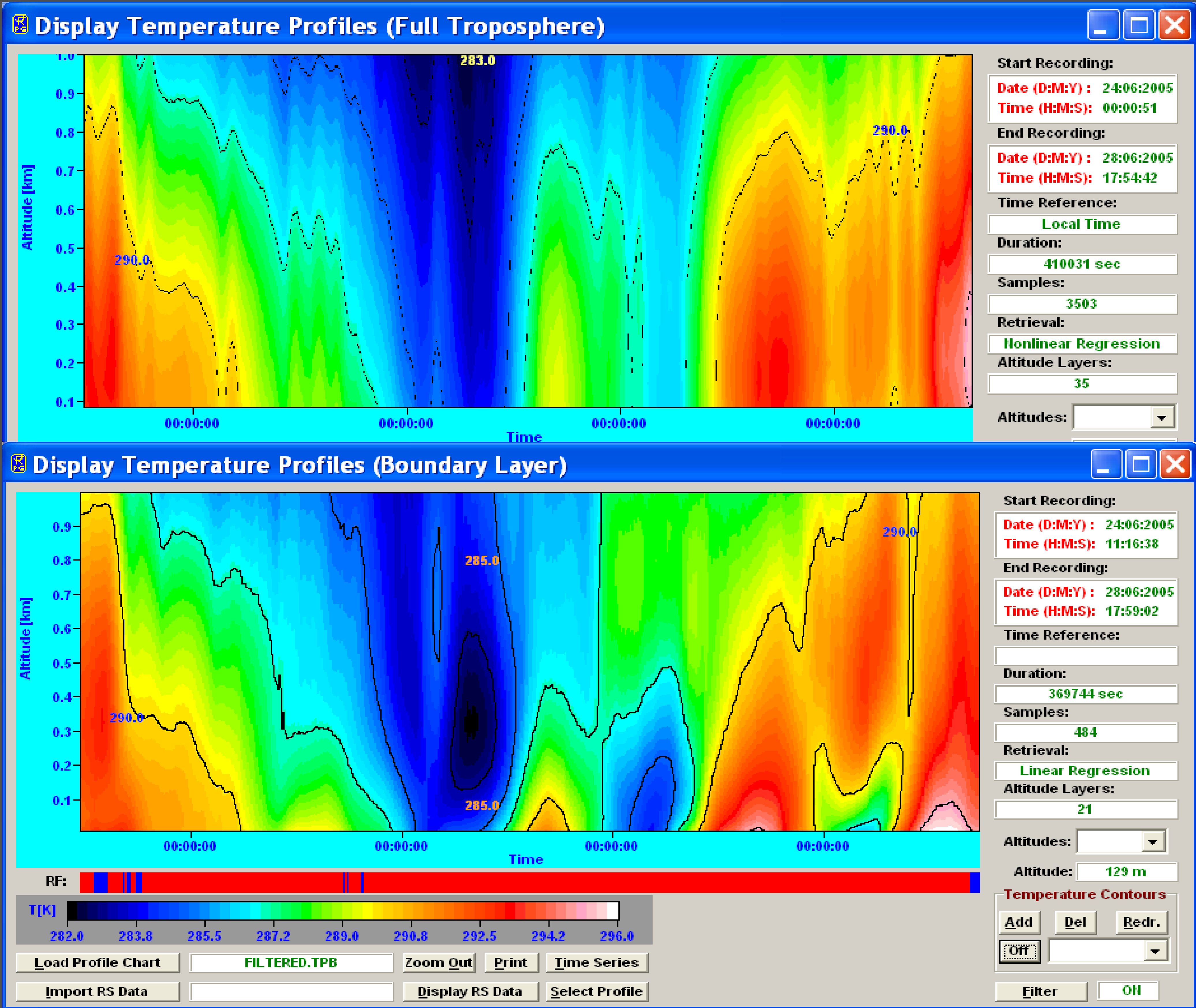
Vertical axis:

Time / hours

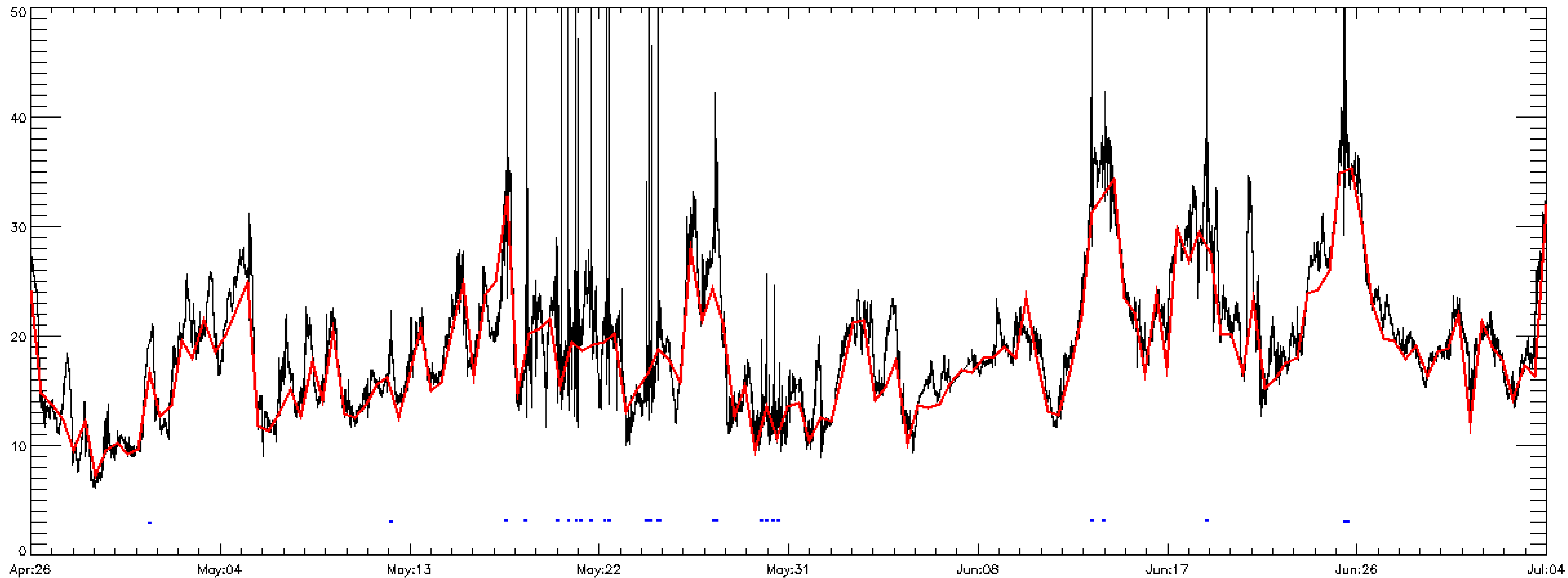
(courtesy of Stefan Kneifel, University of Cologne).



Comparison of T-profiles: full zenith vs. Boundary layer mode



IWV at Cabauw, KNMI



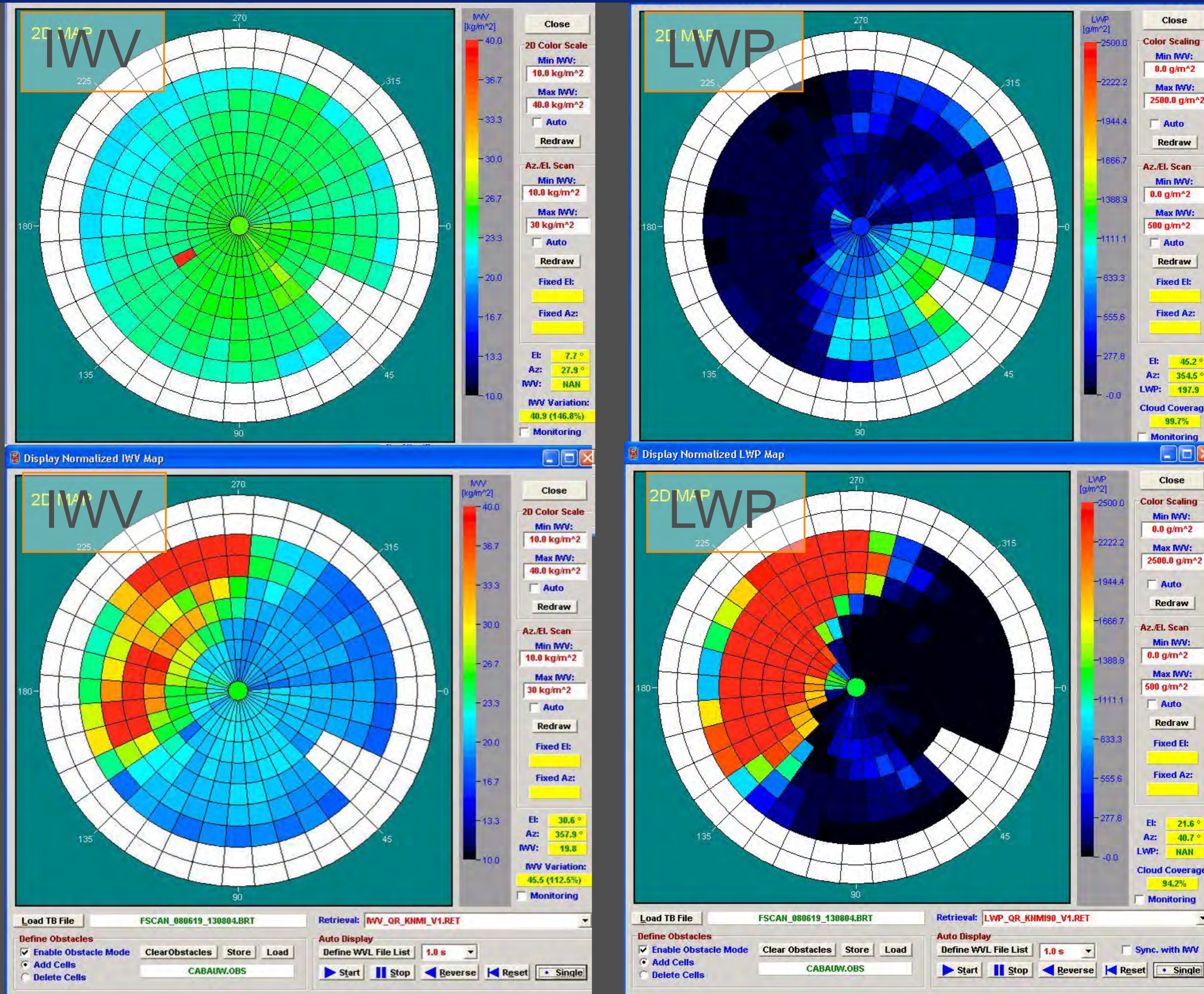
IWV time series over one month (KNMI, May 2006).

140 radio soundings (26. April to 4. July, Cabauw, KNMI).

Radiosonds: Vaisala RS-92.

No-Rain RMS: 0.43 kg/m², Bias: 0.05 kg/m²

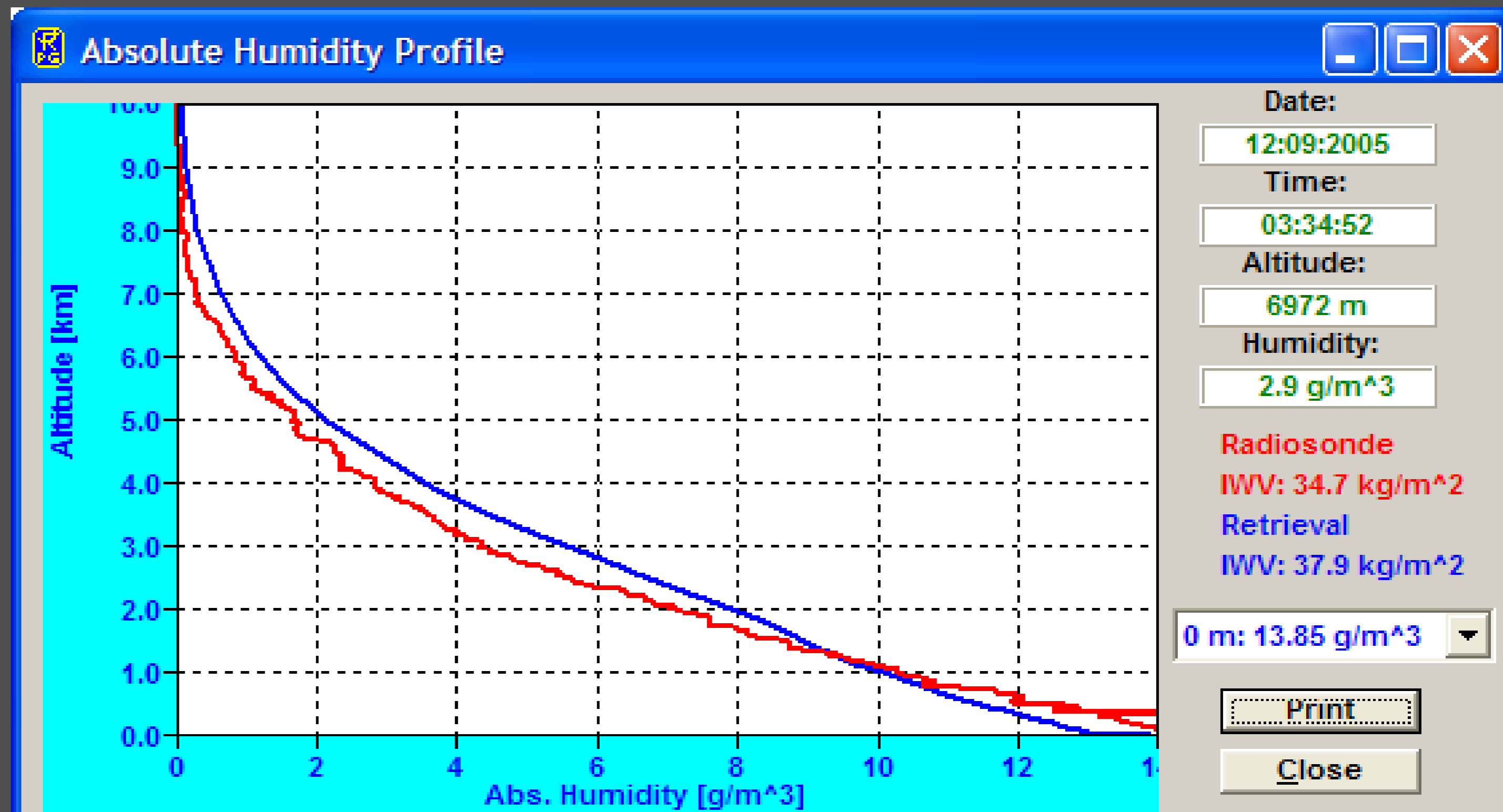
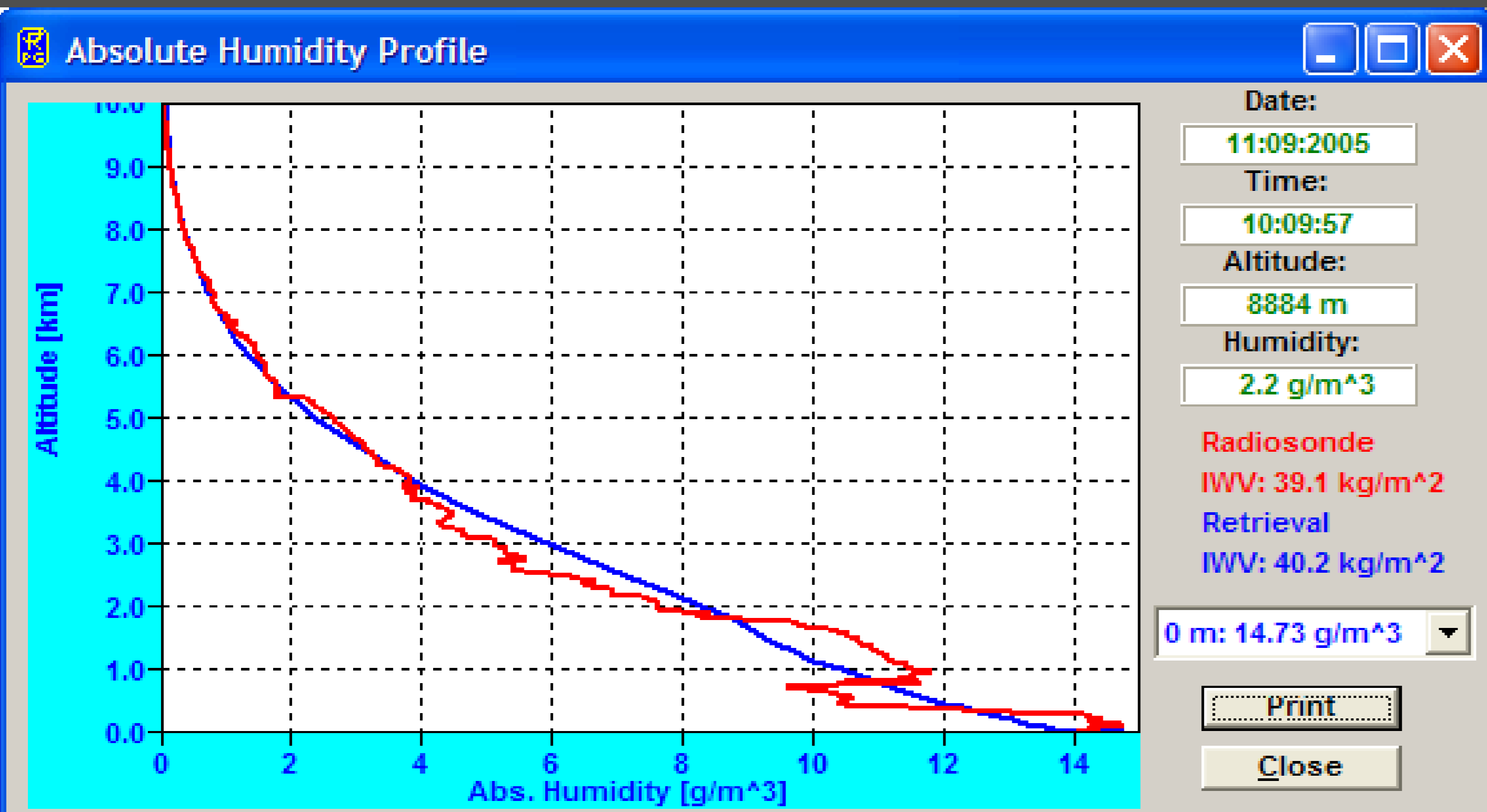
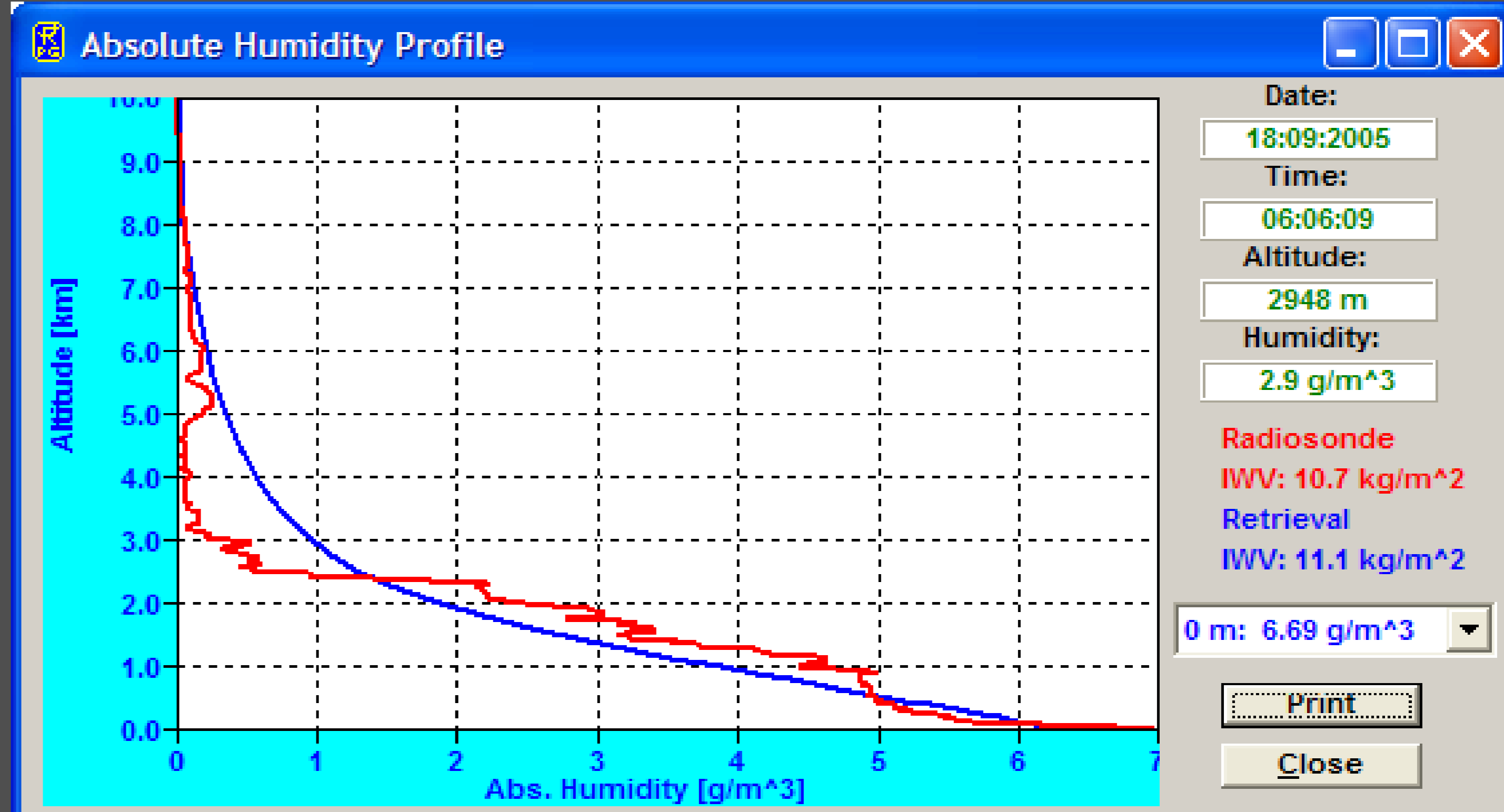
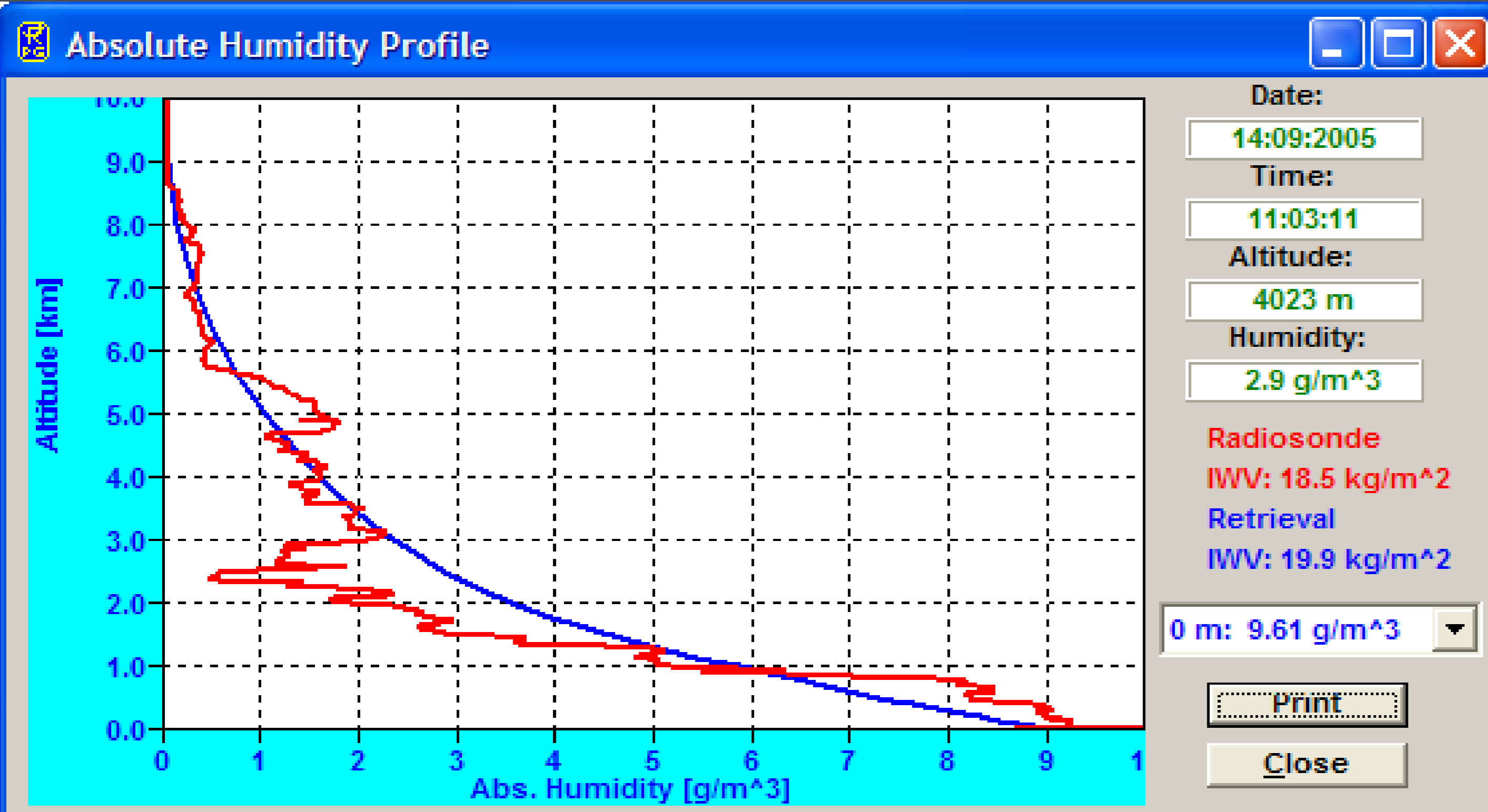
2D full sky scans

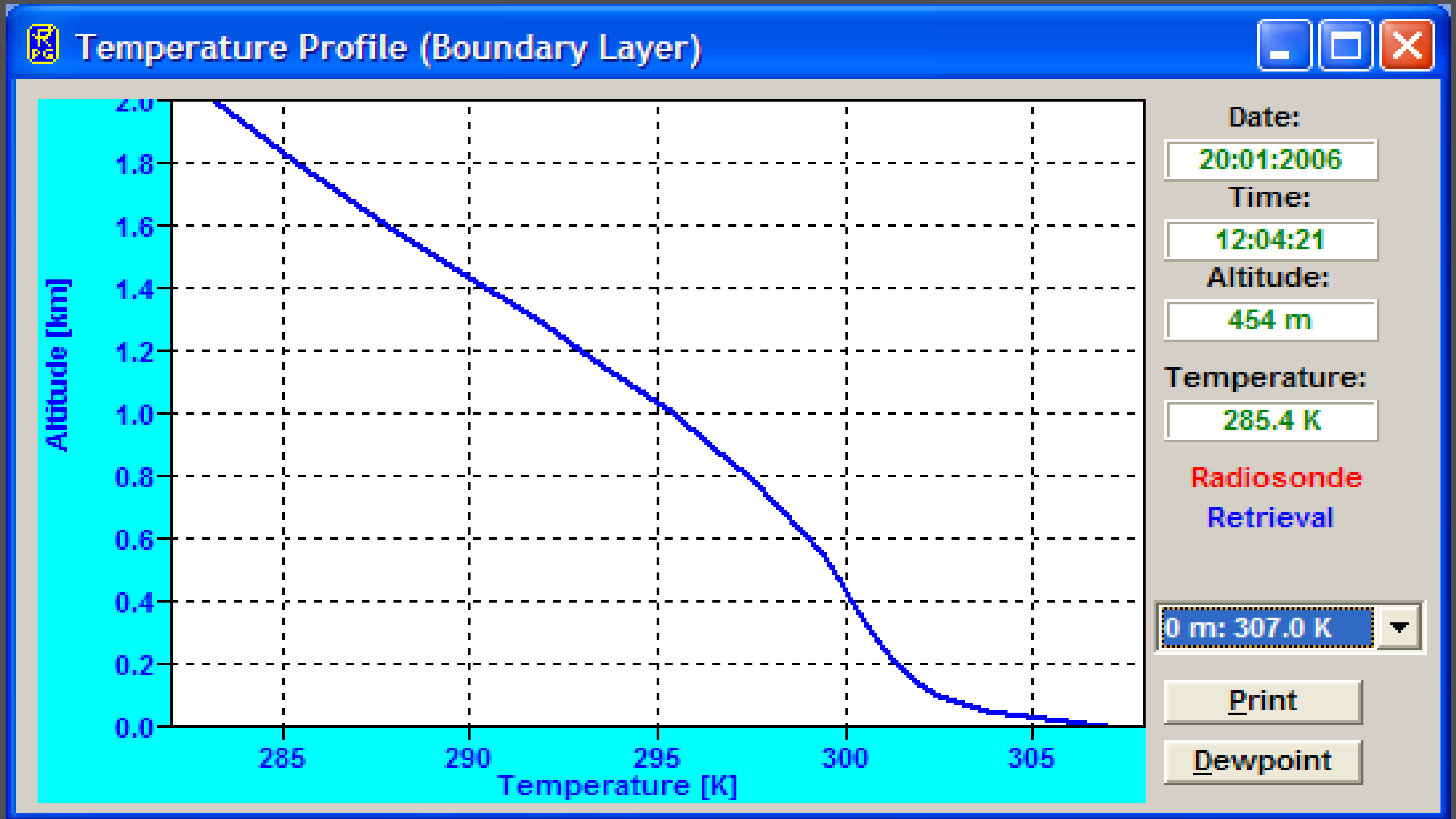


- Homogeneous IWV
- Cloud cover (LWP signal) in lower right quadrant
- Advection of frontal system from upper left
- Response in IWV and LWP

- Sky scan takes 5 minutes with 320 samples
- Software feature for automatic sun-tracking / north-alignment
- Satellite tracking possible, either GPS-info or orbit data files

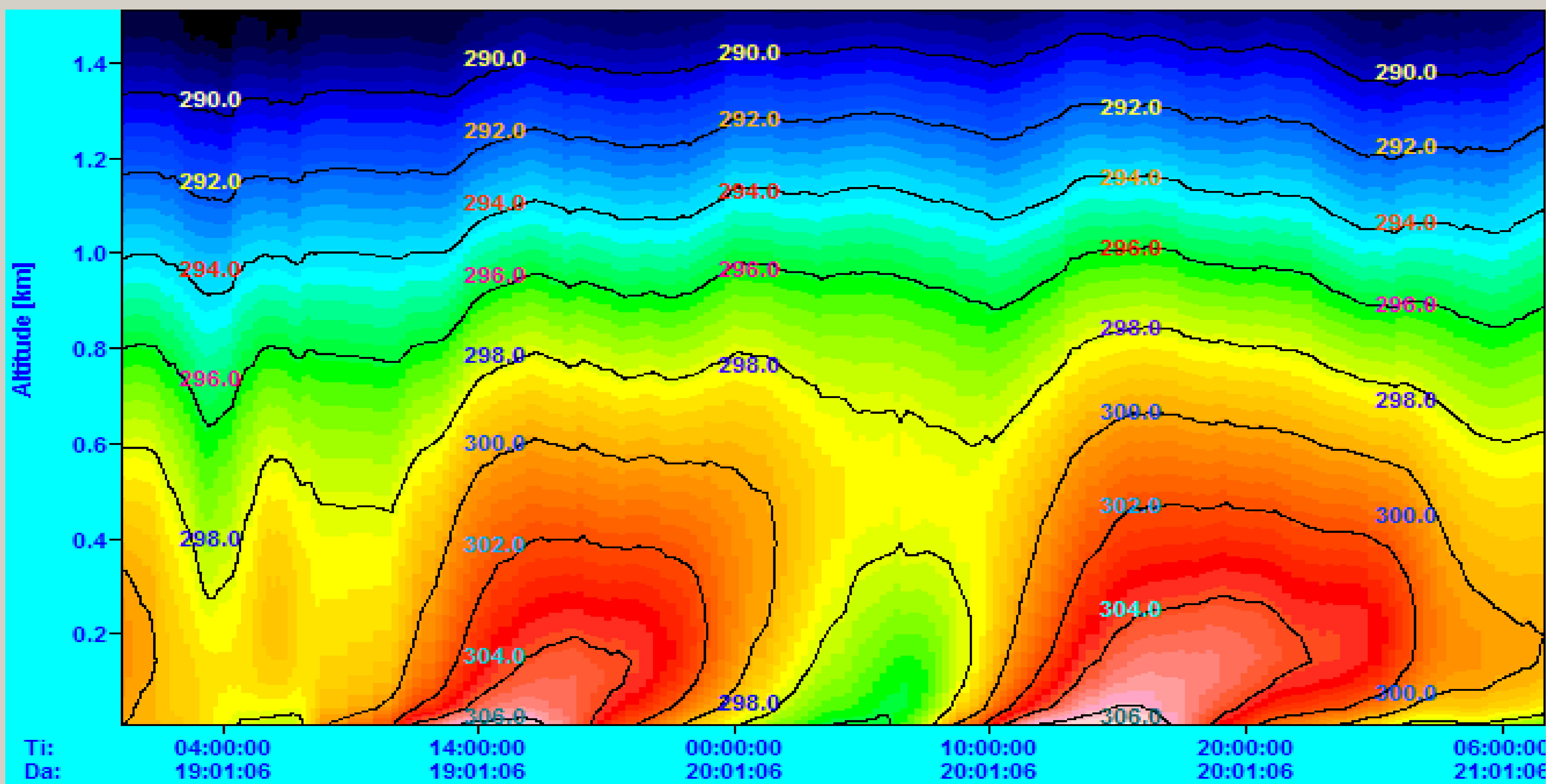
Absolute Humidity Vertical Profile



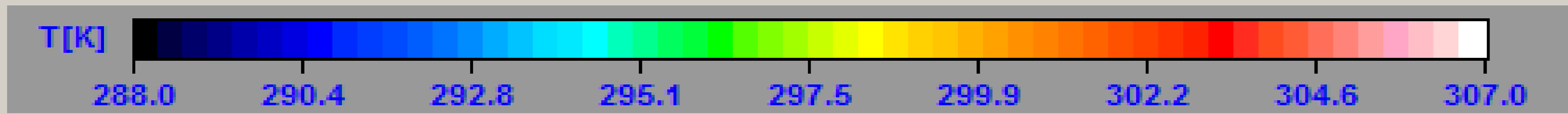


Boundary Layer temperature profile

Display Temperature Profiles (Boundary Layer)



Ti: 04:00:00 14:00:00 00:00:00 10:00:00 20:00:00 06:00:00
 Da: 19:01:06 19:01:06 20:01:06 20:01:06 20:01:06 21:01:06



Start Recording:
 Date (D:M:Y) : 19:01:2006
 Time (H:M:S) : 00:00:10

End Recording:
 Date (D:M:Y) : 21:01:2006
 Time (H:M:S) : 07:57:28

Time Reference:

Duration:

Samples:

Retrieval:

Altitude Layers:

Altitudes:

Altitude:

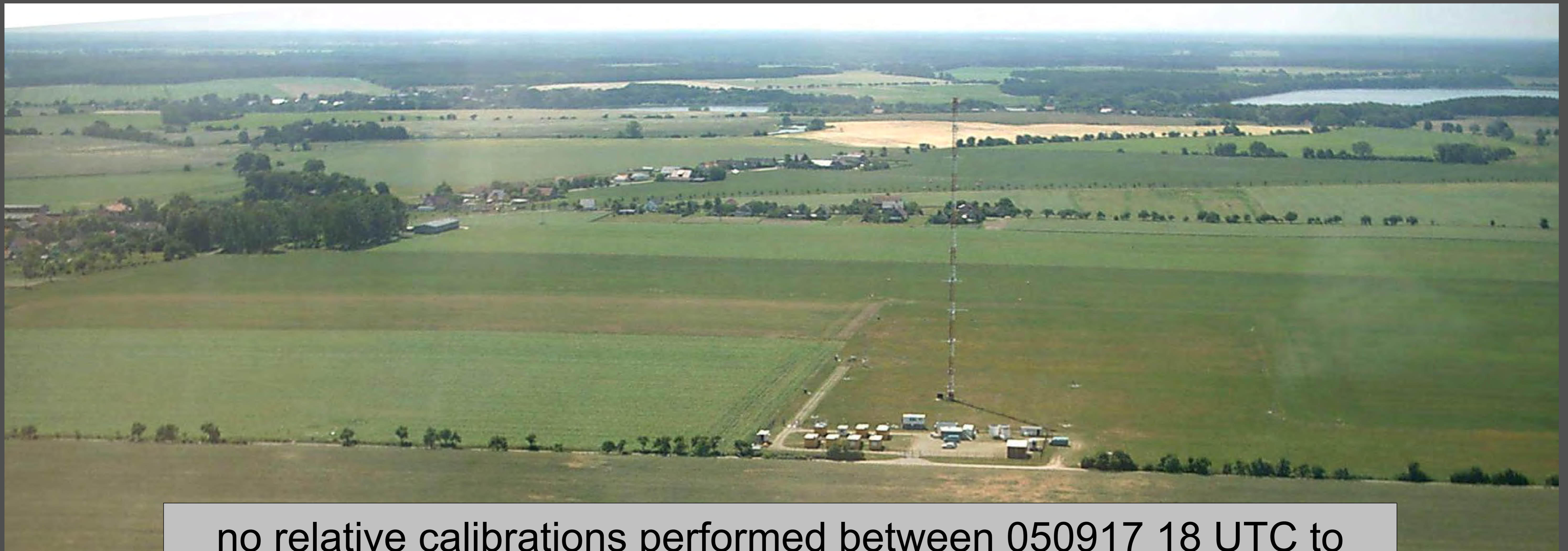
Temperature Contours

HATPRO observations at Falkenberg

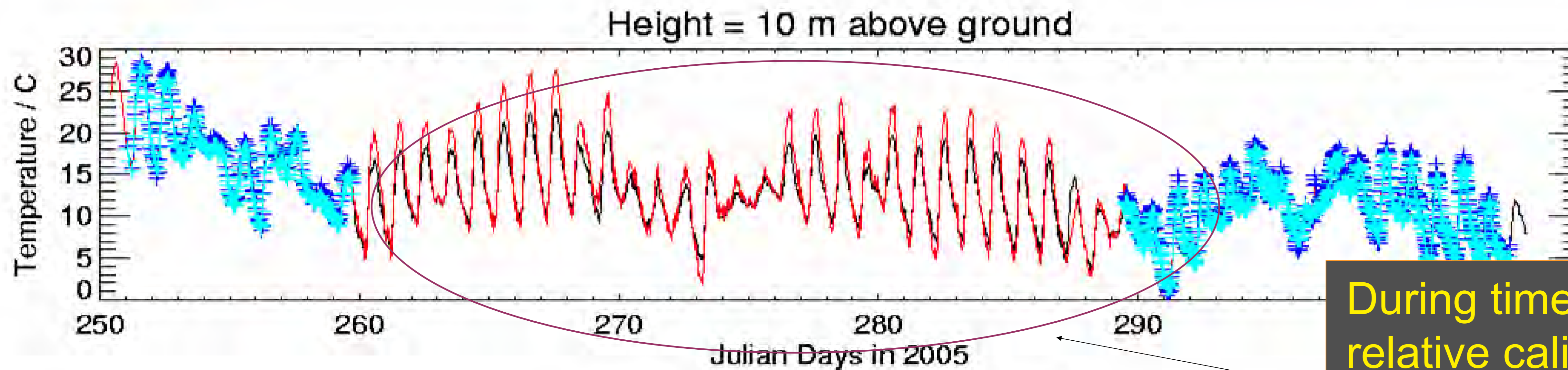
Start: 8 Sep 2005 9 UTC
Stop: 1 Nov 2005 7 UTC
Latitude: 52.17 N
Longitude: 14.12 E
Altitude: 73 m

Retrievals:

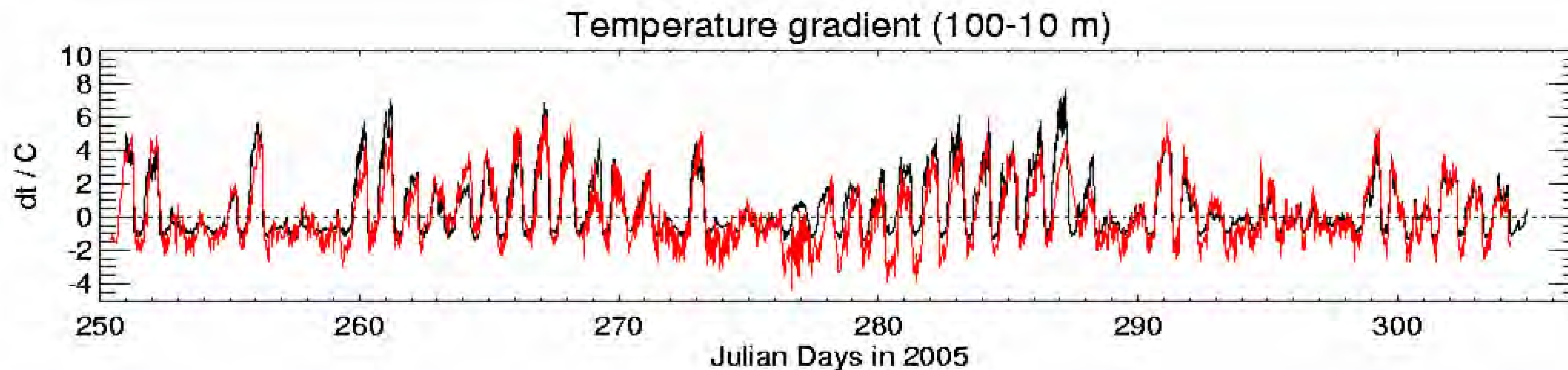
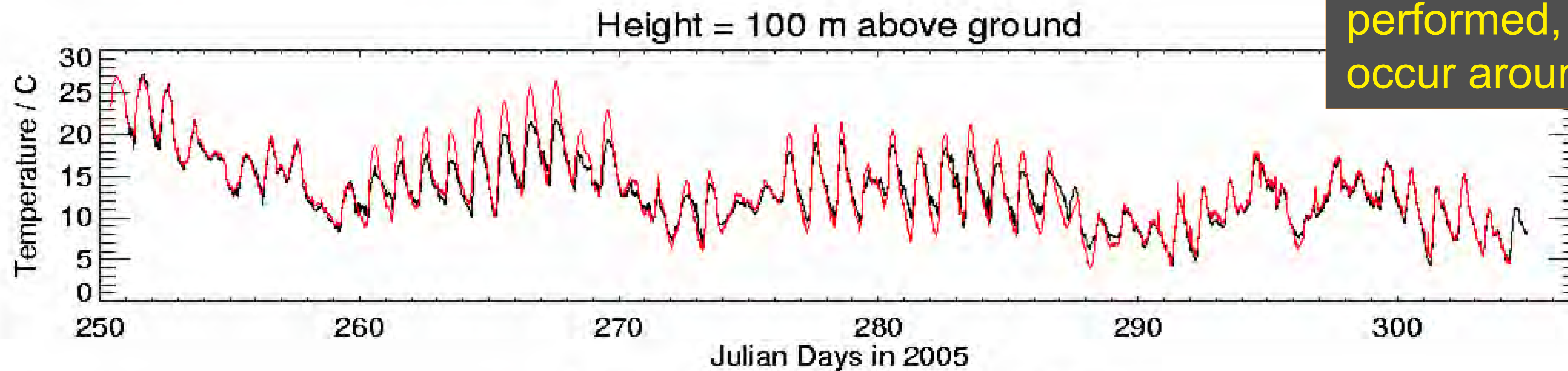
- Salford RS data base from UK > 14000
- Rosenkranz absorption model R98
0.1 K noise level assumed
- BLB: 5 Angle til 17 Oct, 6 afterwards



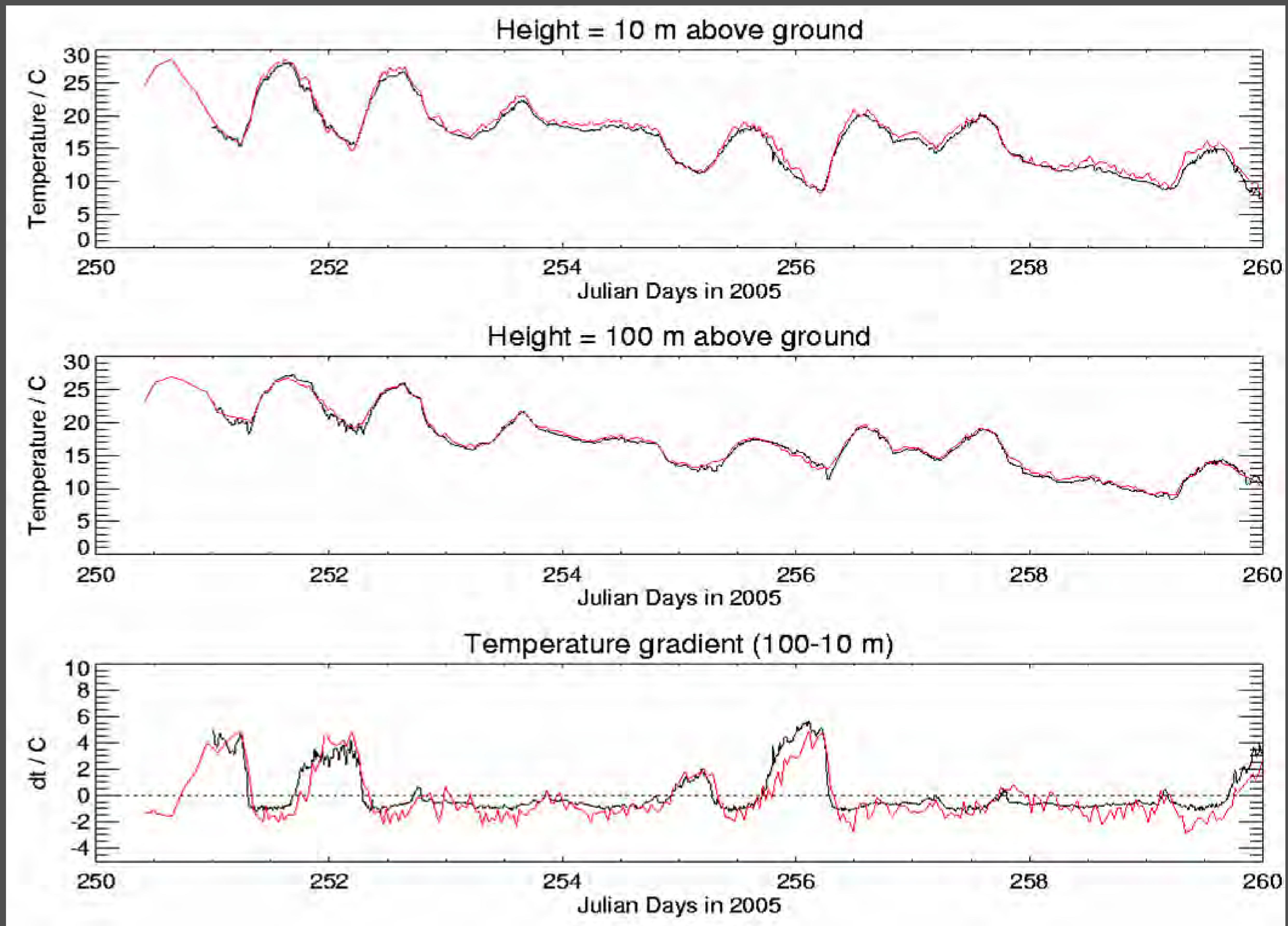
no relative calibrations performed between 050917 18 UTC to
051017 12 UTC due to failure of GPS clock



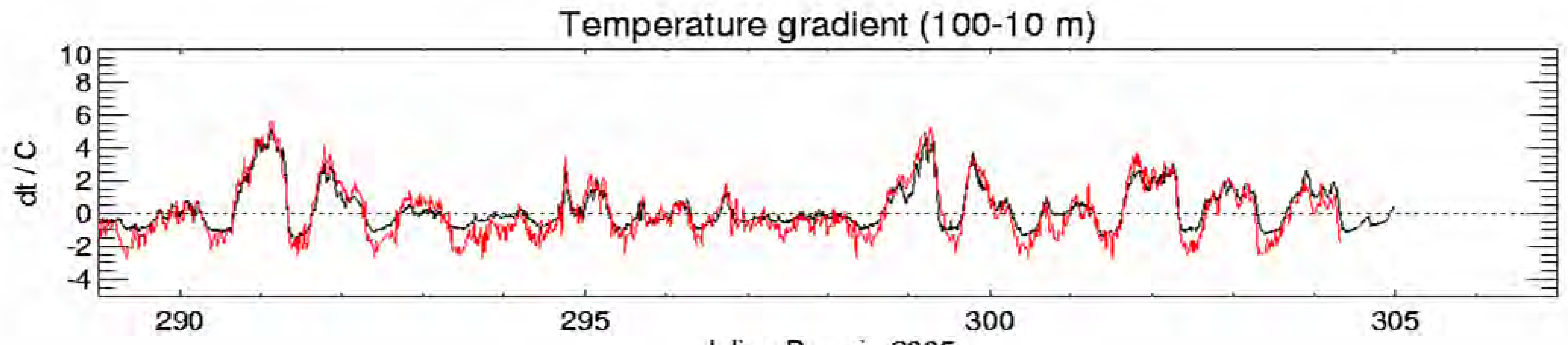
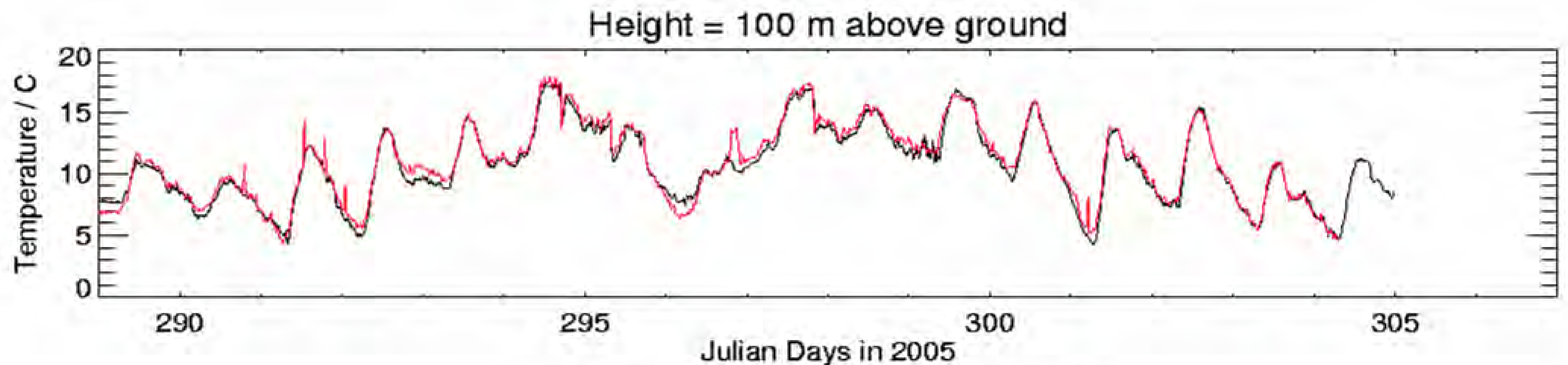
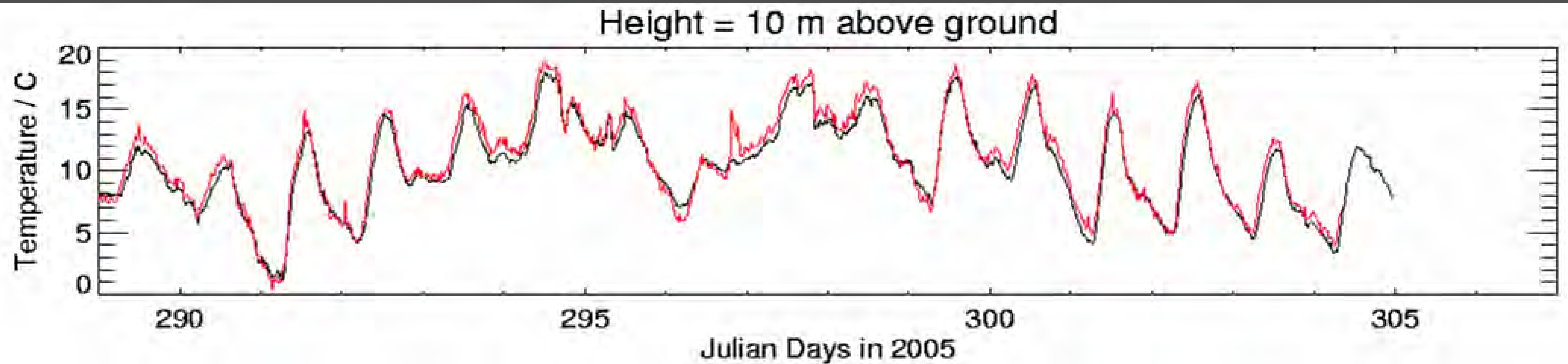
During time when no relative calibrations were performed, largest deviations occur around noon



Comparison with 99 m Mast (Zoom)

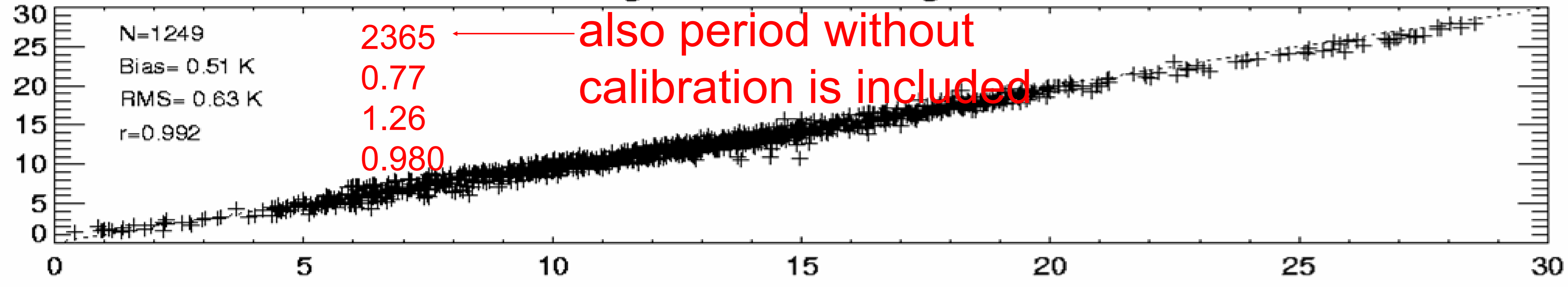


Comparison with 99 m Mast (Zoom)

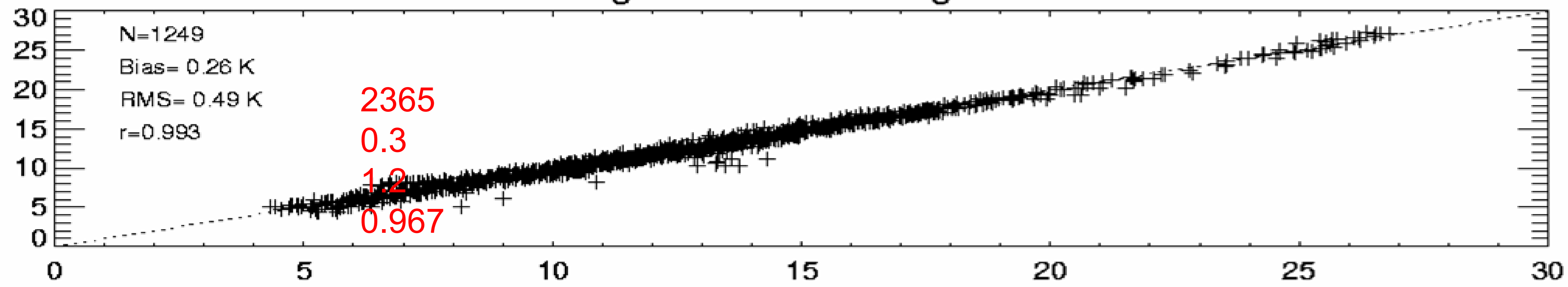


Comparison with 99 m Mast

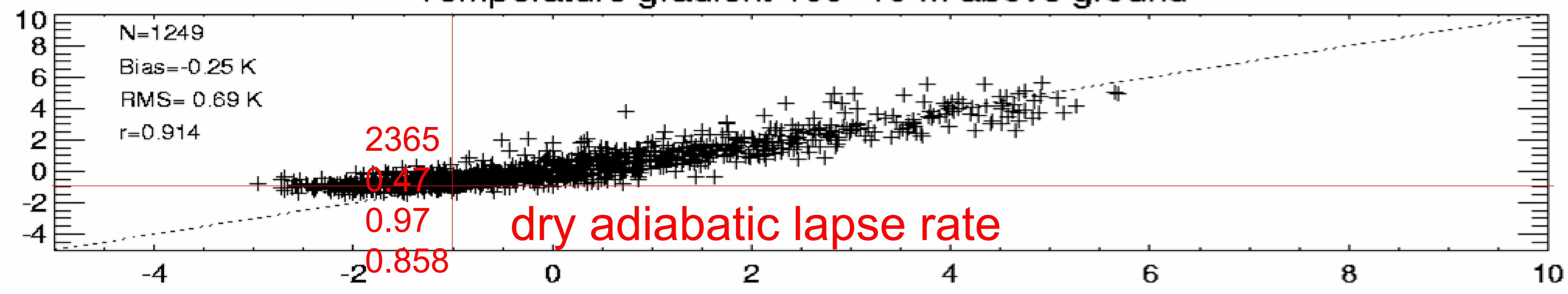
Height = 10 m above ground



Height = 100 m above ground

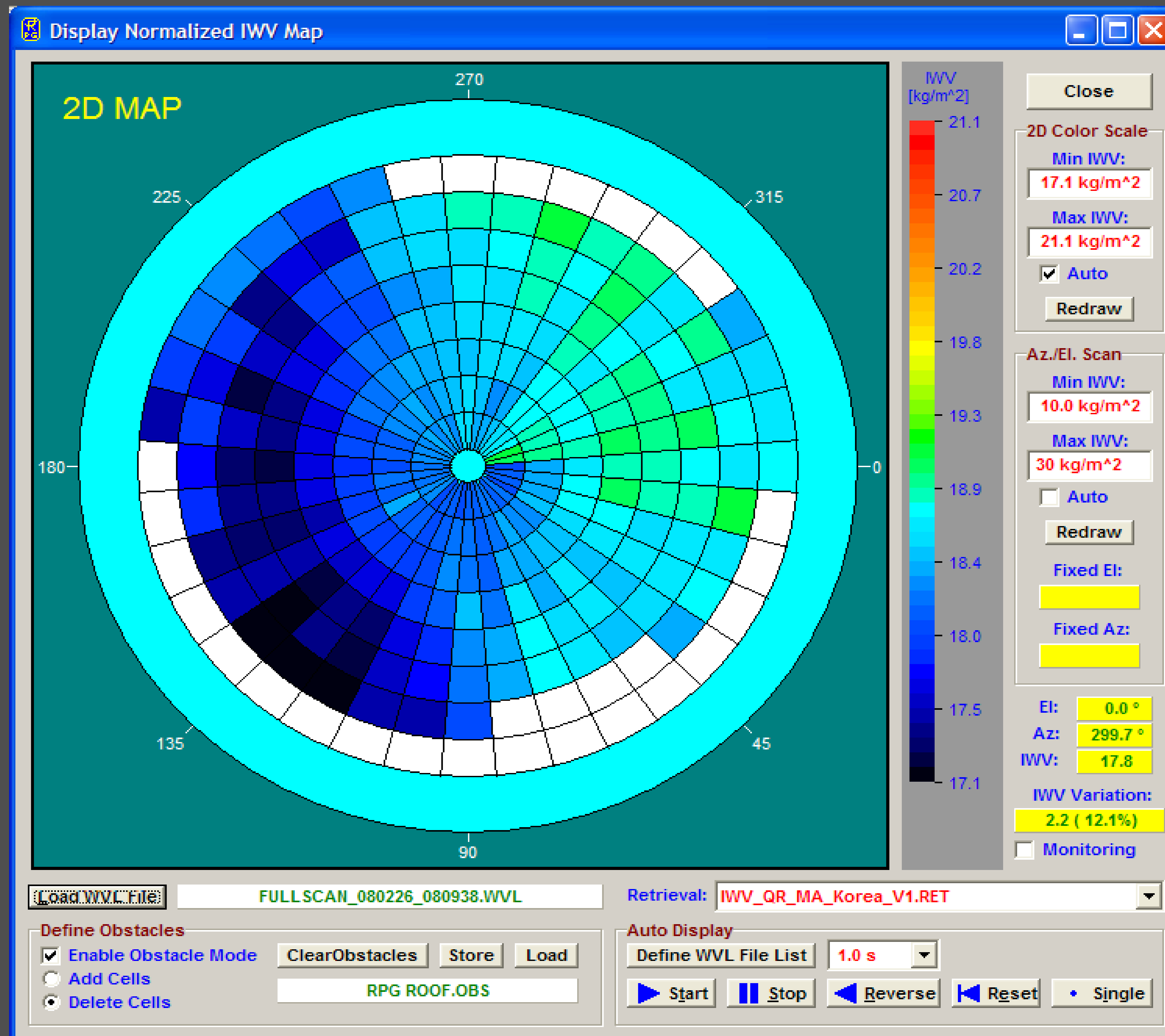


Temperature gradient 100 -10 m above ground

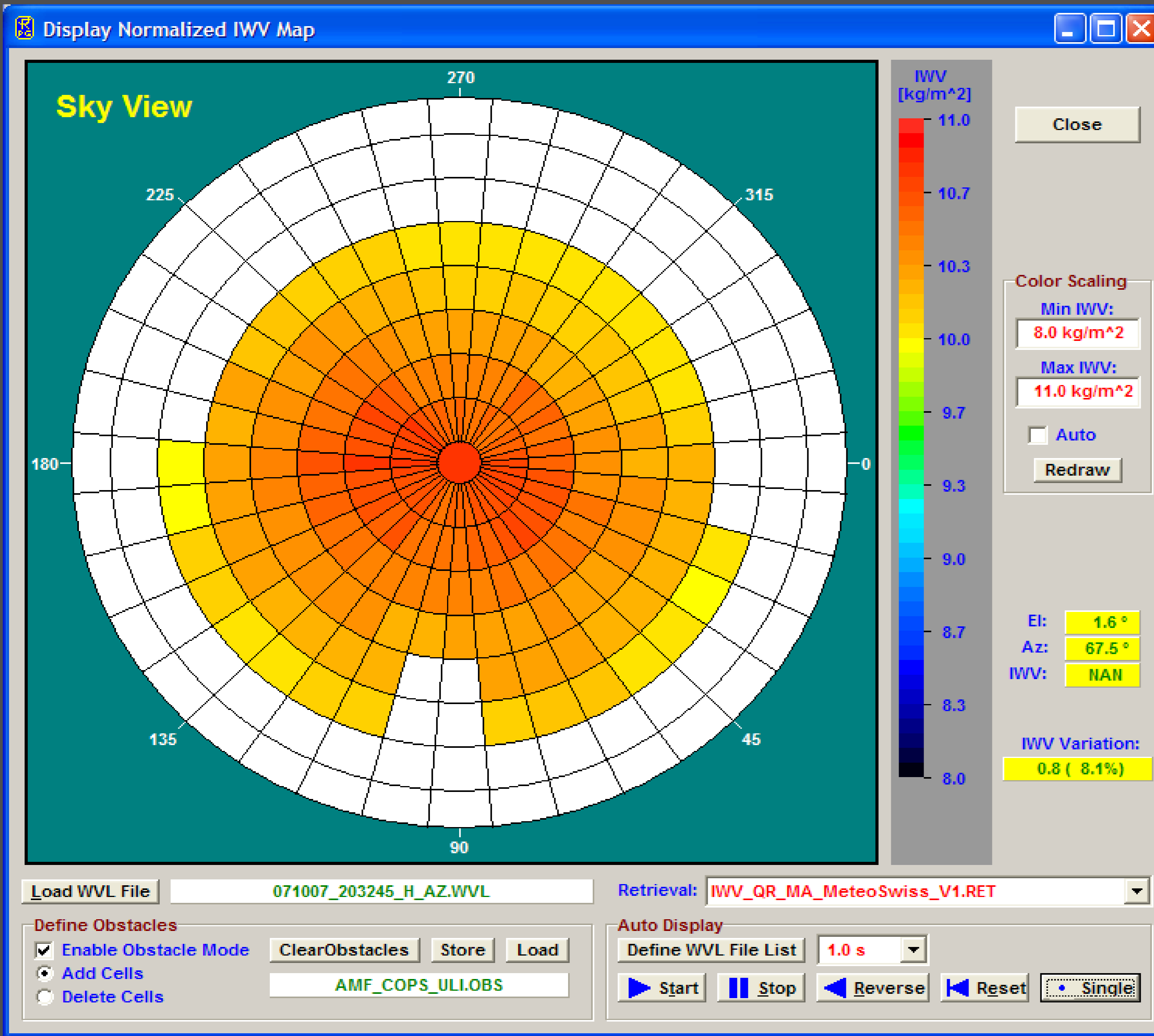


2D Humidity Scanning

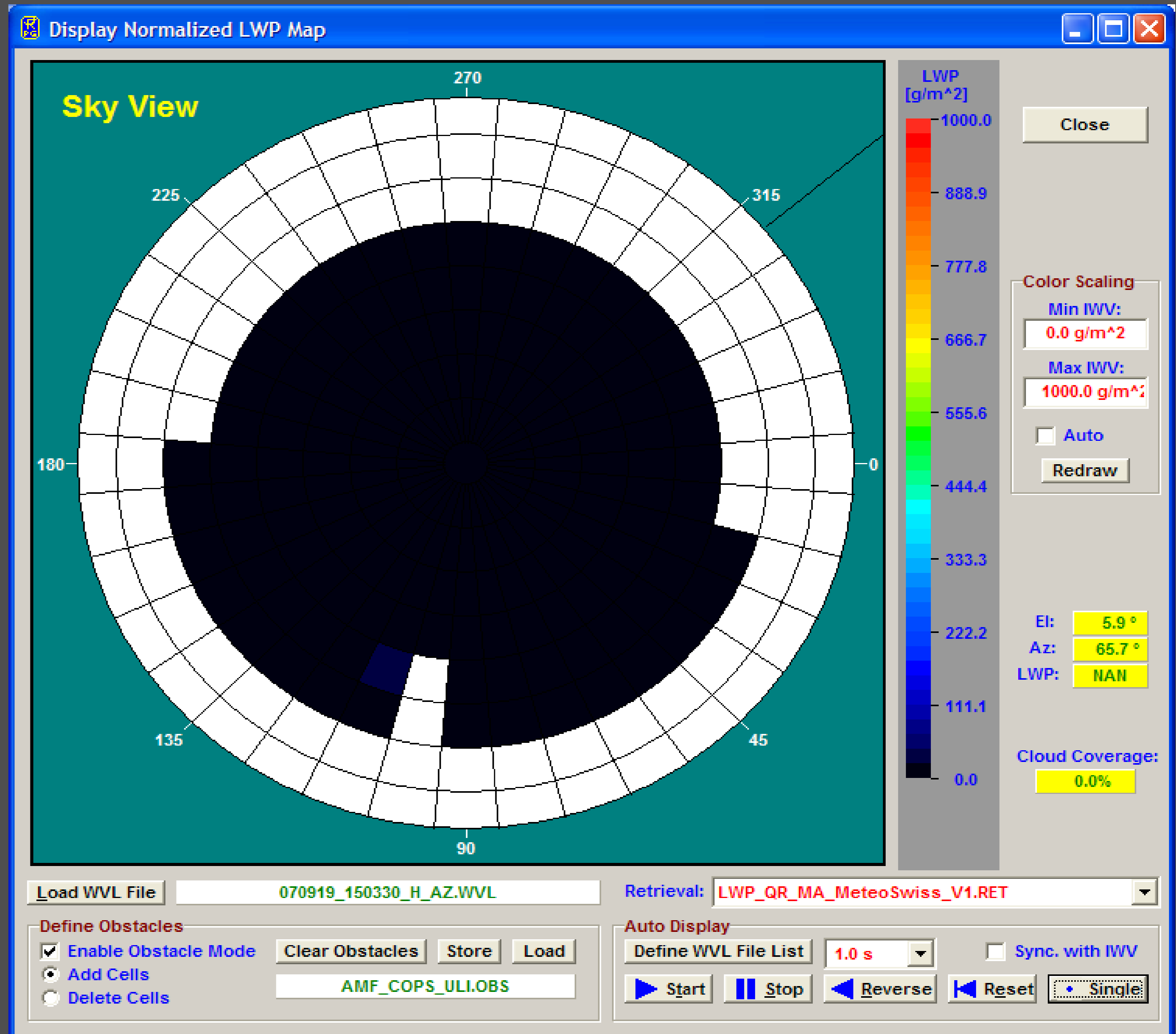
Example of 12 %
IWV variation
(with ATPROP
instrument during
test phase at RPG)



Full Sky Scans (IWV and LWP)



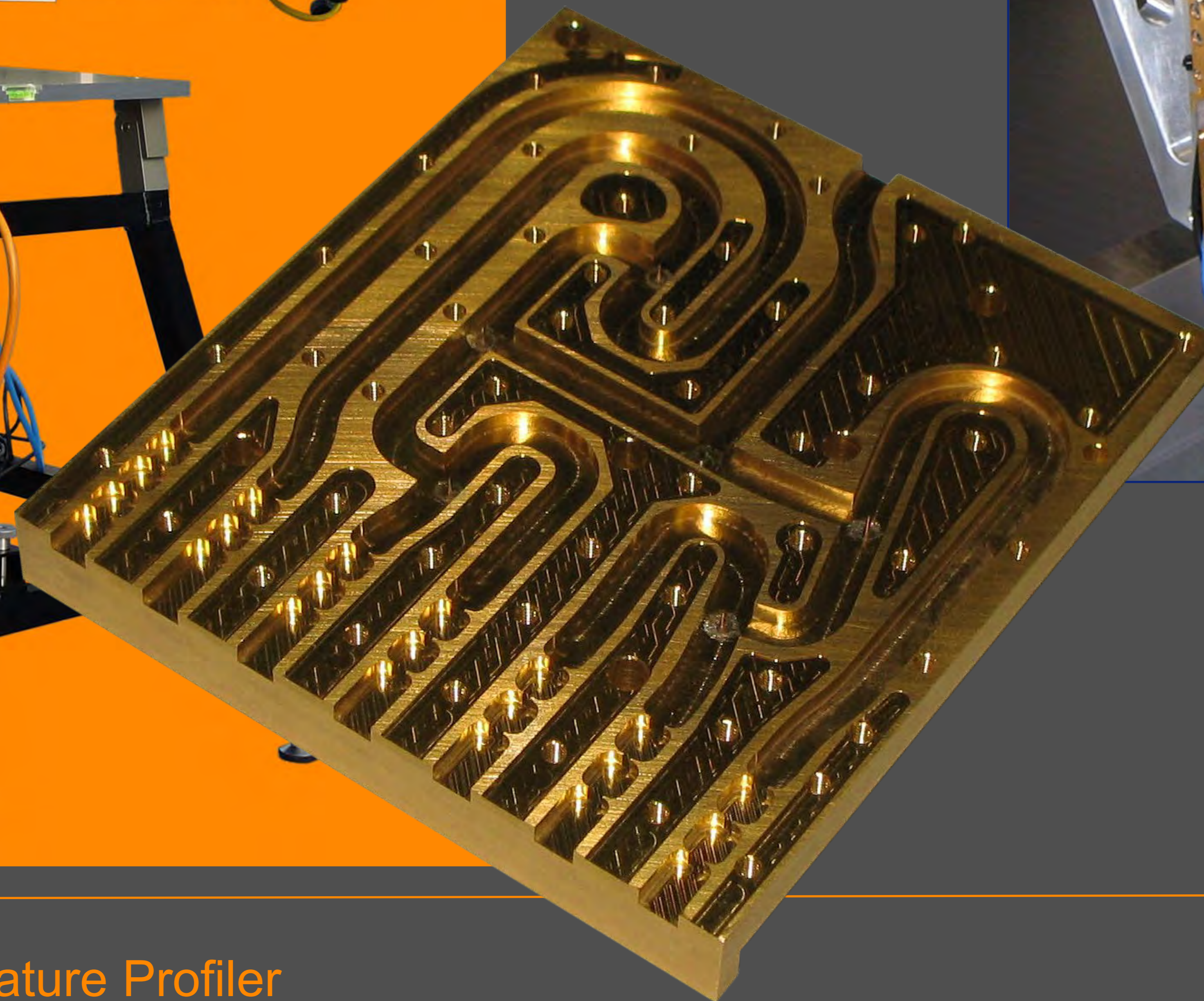
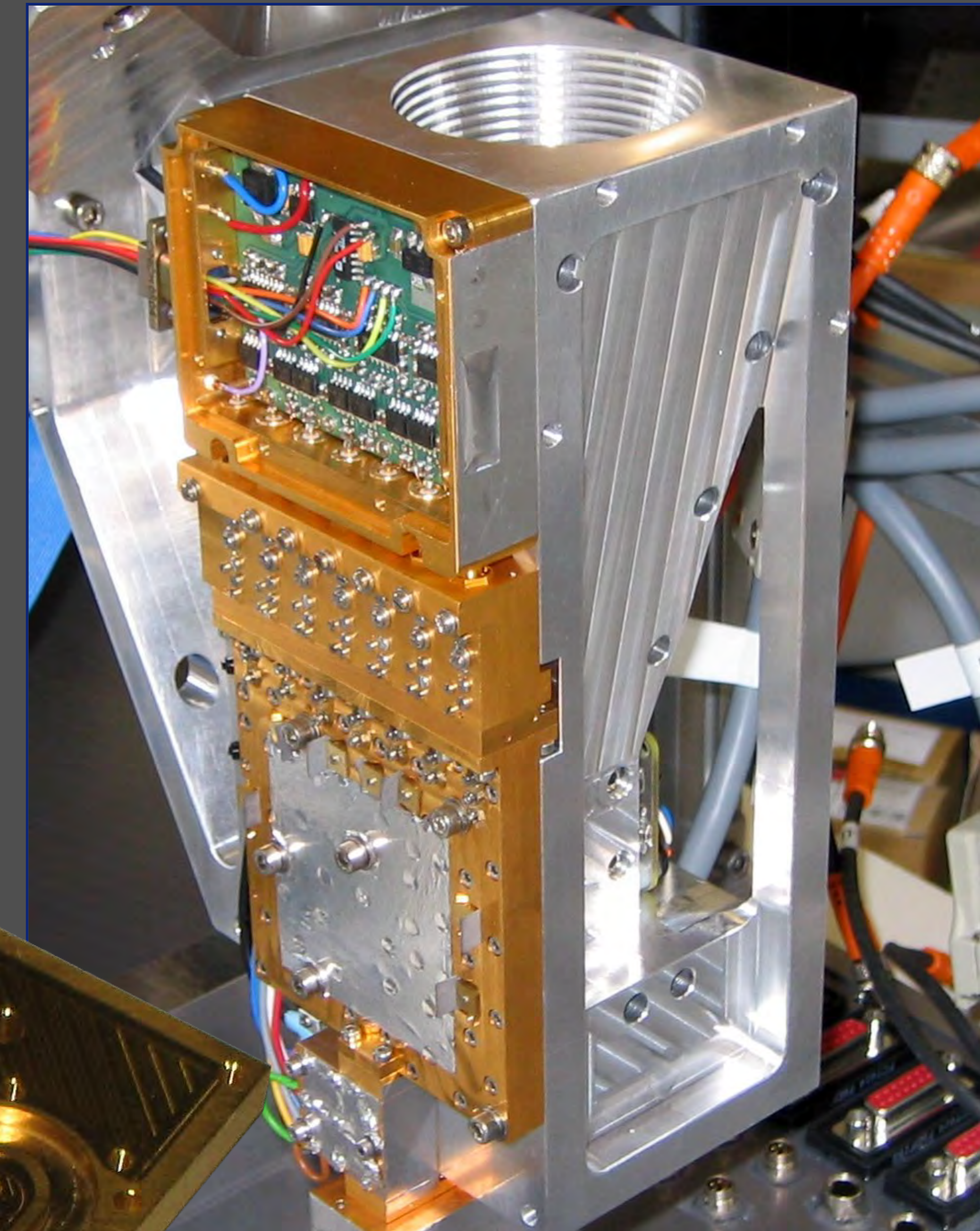
IWV Sky Map



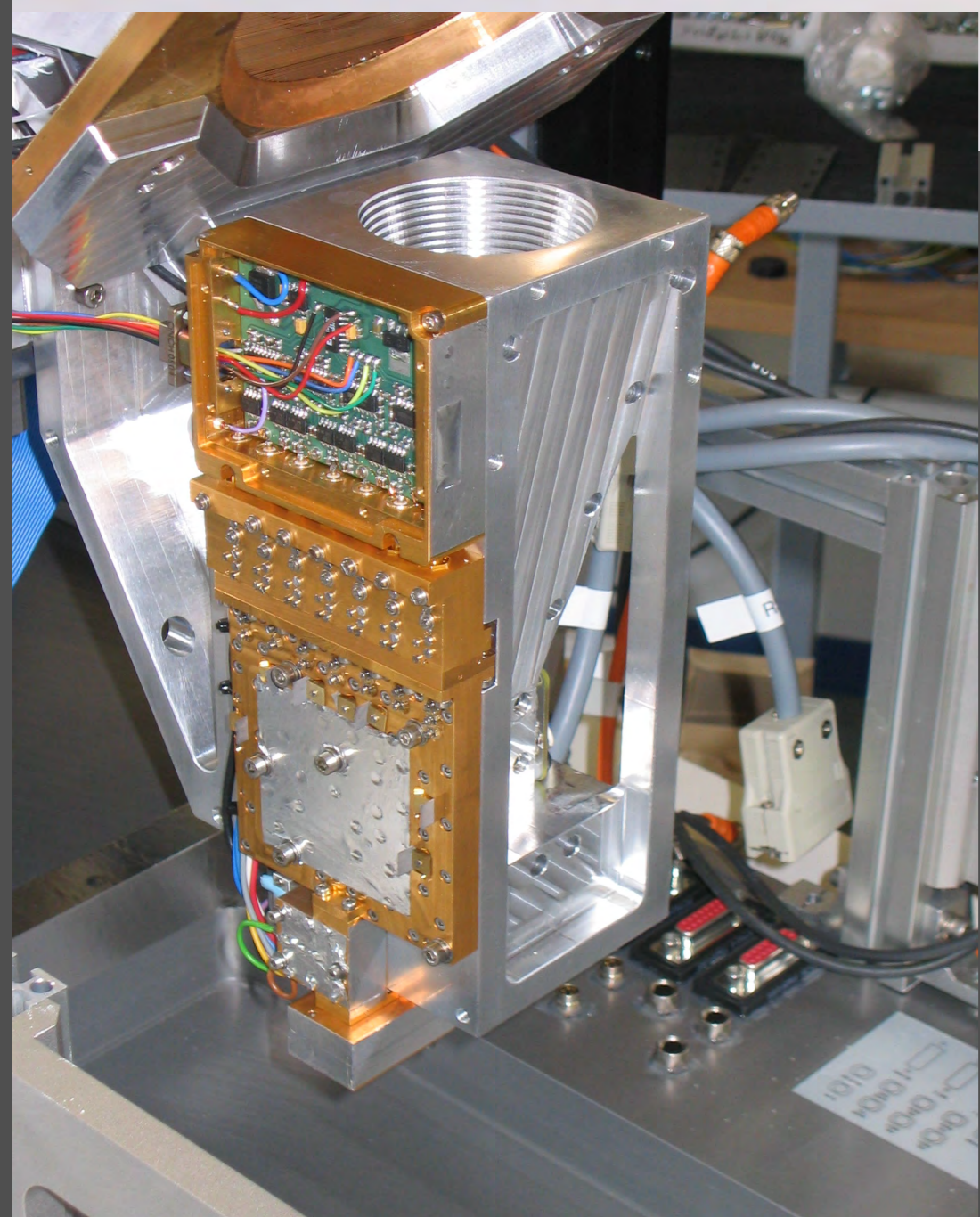
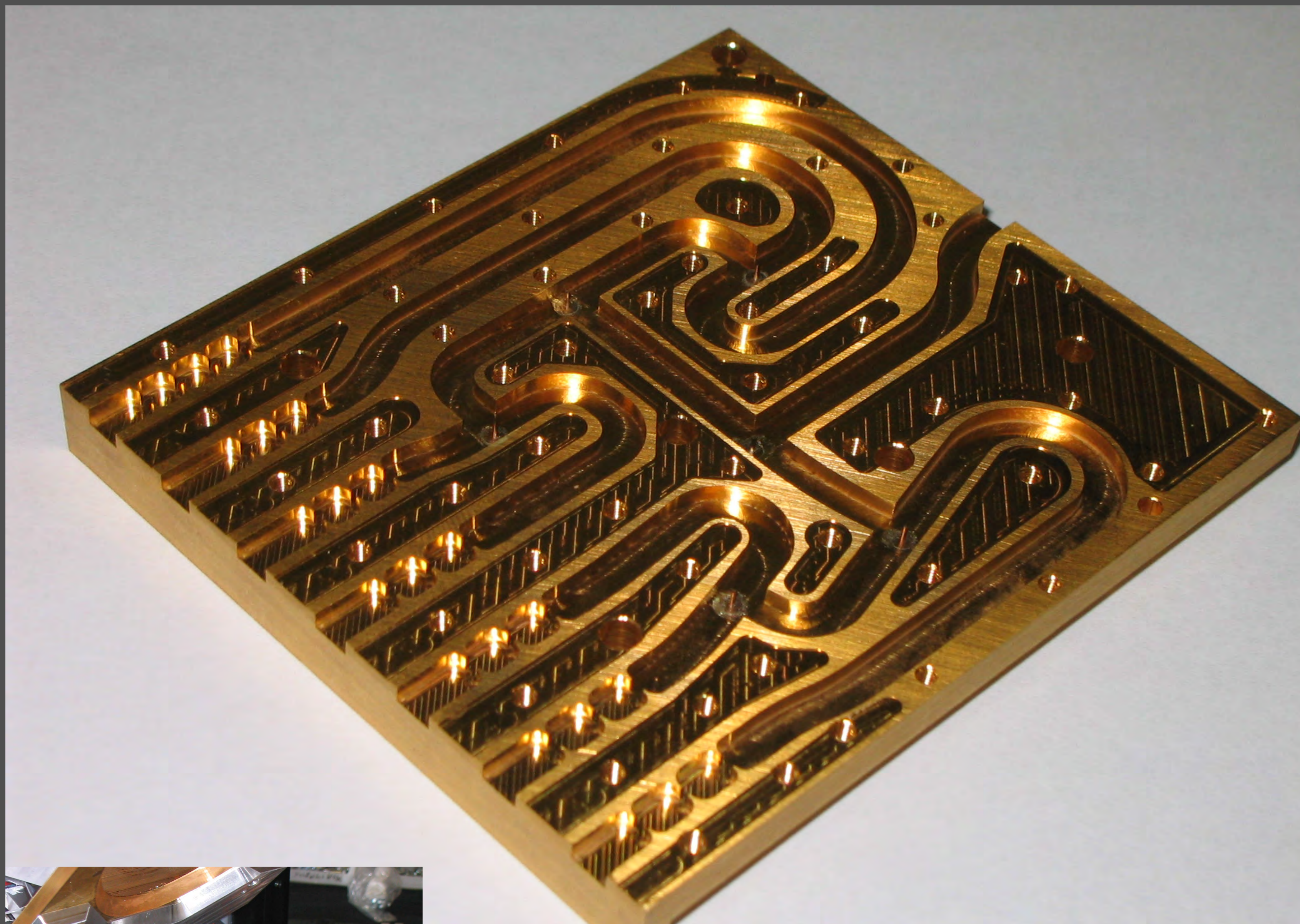
LWP Sky Map

Courtesy of
Ulrich Löhnert, Institute for Geophysics and Meteorology, Univ. Cologne

Detailed description of the instrument



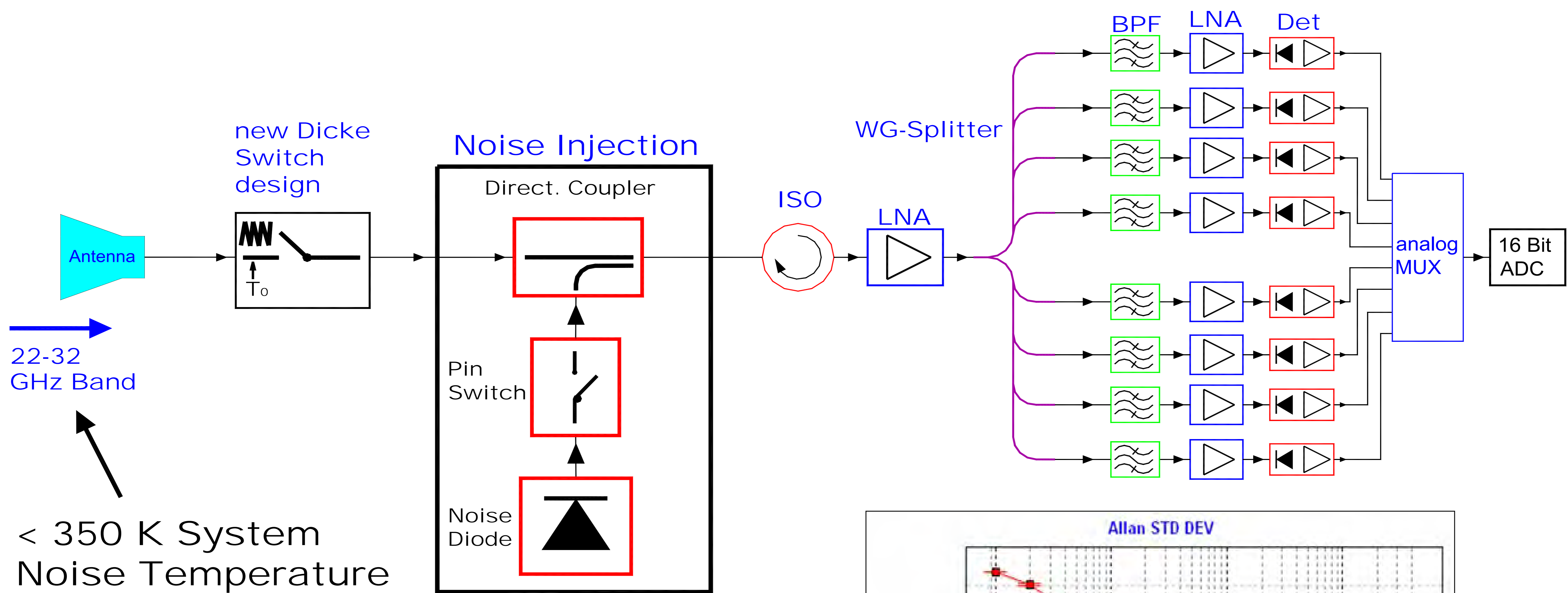
RPG-HATPRO Filter characterization



Quality control:

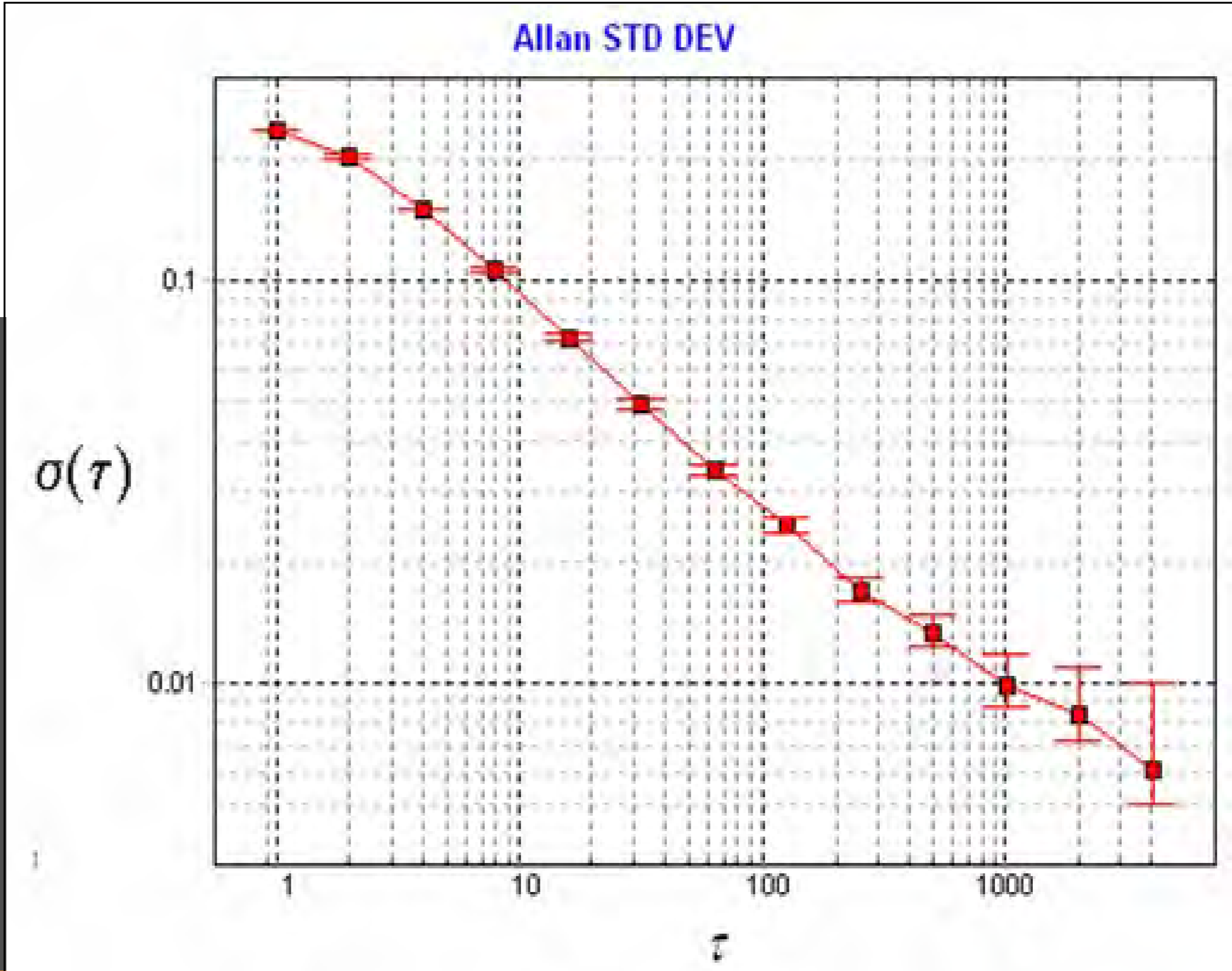
- Receivers are thermo-cycled
- Filters are characterized at precise stabilization temperature
- System characterized by injection of swept frequency signal (vector network analyzer)
- Bandpasses measured on-line
- Filters are then fine-tuned
- Center frequency deviation smaller than 0.0005 GHz
- RPG-HATPRO is the **only** radiometer on the market with full characterisation of filter spectra from optical input to digital output!

Auto-calibration receivers: Frontend Layout



22-32 GHz Band

< 350 K System Noise Temperature



- Switch, coupler, and isolator all in front of LNA (or mixer)
- Allan Variance test: decrease of variance until 4.000 s

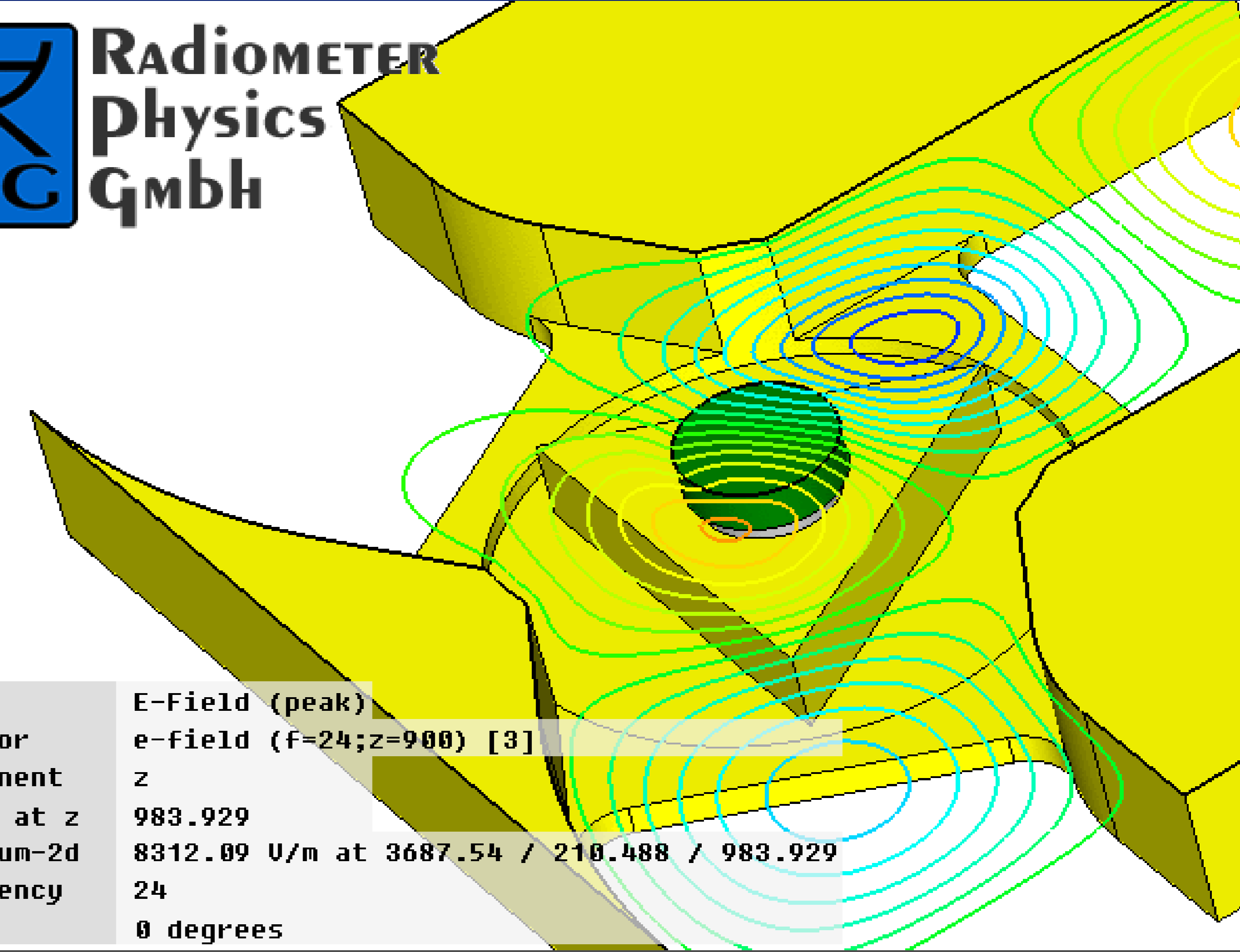
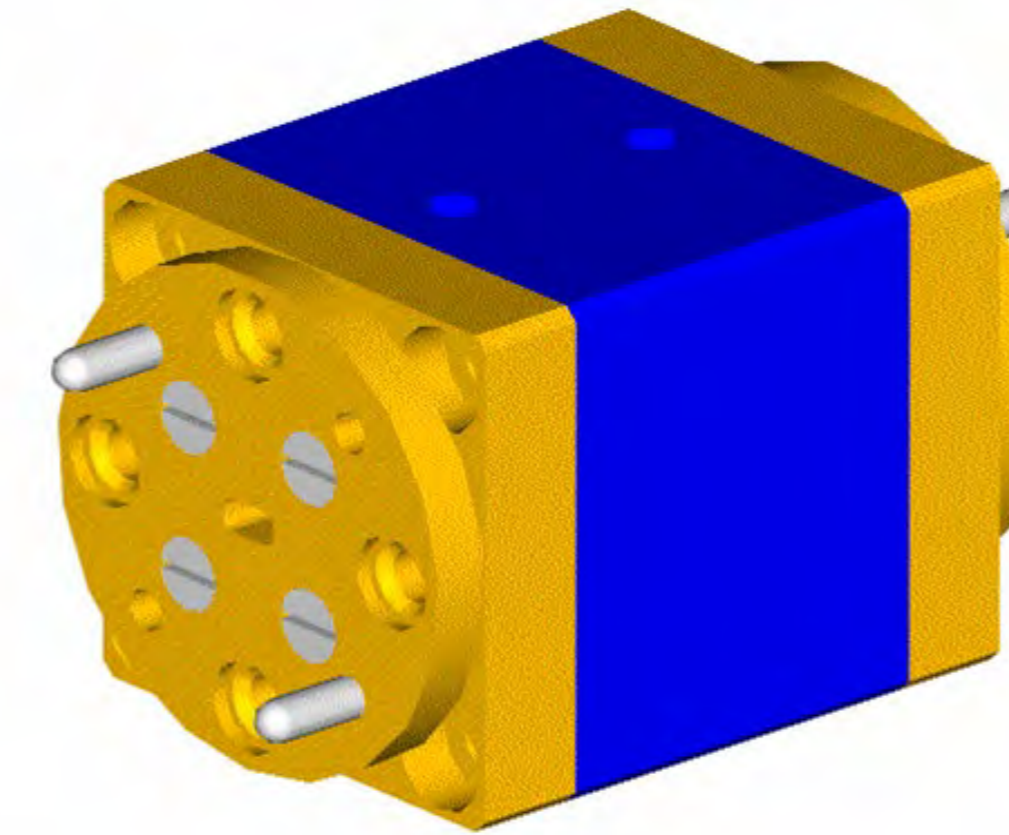
(Switchable Isolators)

Two types:

- Y-junction and
- Faraday Isolators (also used for power levelling)

All devices optimised to

- Low transmission loss
- Low insertion loss
- High isolation



Frequency [GHz]	Waveguide	Transm. Loss	I/O Match	Isolation when off	Switching Speed
18 – 26	WR-42	< 0.25 dB	< -22 dB	> 25 dB	< 20 Hz
22 – 32	WR-34	< 0.30 dB	< -20 dB	> 25 dB	< 40 Hz
20 – 33	WR-34-F	< 0.50 dB	< -20 dB	> 35 dB	< 40 Hz
50 – 75	WR-15	< 0.35 dB	< -18 dB	> 27 dB	< 40 Hz
50 – 75	WR-15-F	< 0.50 dB	< -18 dB	> 35 dB	< 40 Hz
75 – 110	WR-10	< 0.40 dB	< -18 dB	> 27 dB	< 40 Hz
75 – 110	WR-10-F	< 1.00 dB	< -18 dB	> 35 dB	< 40 Hz

Gain linearity correction with 4-point calibration

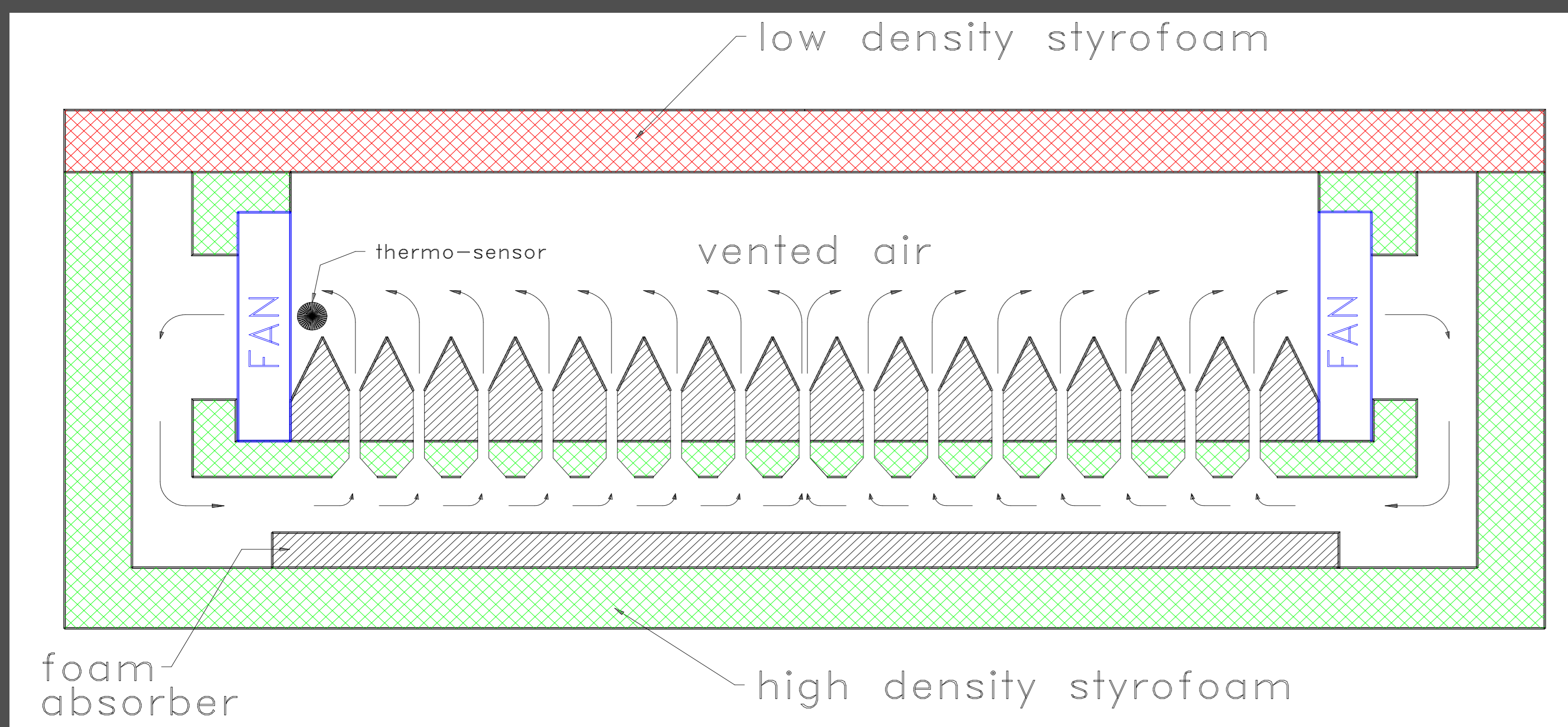
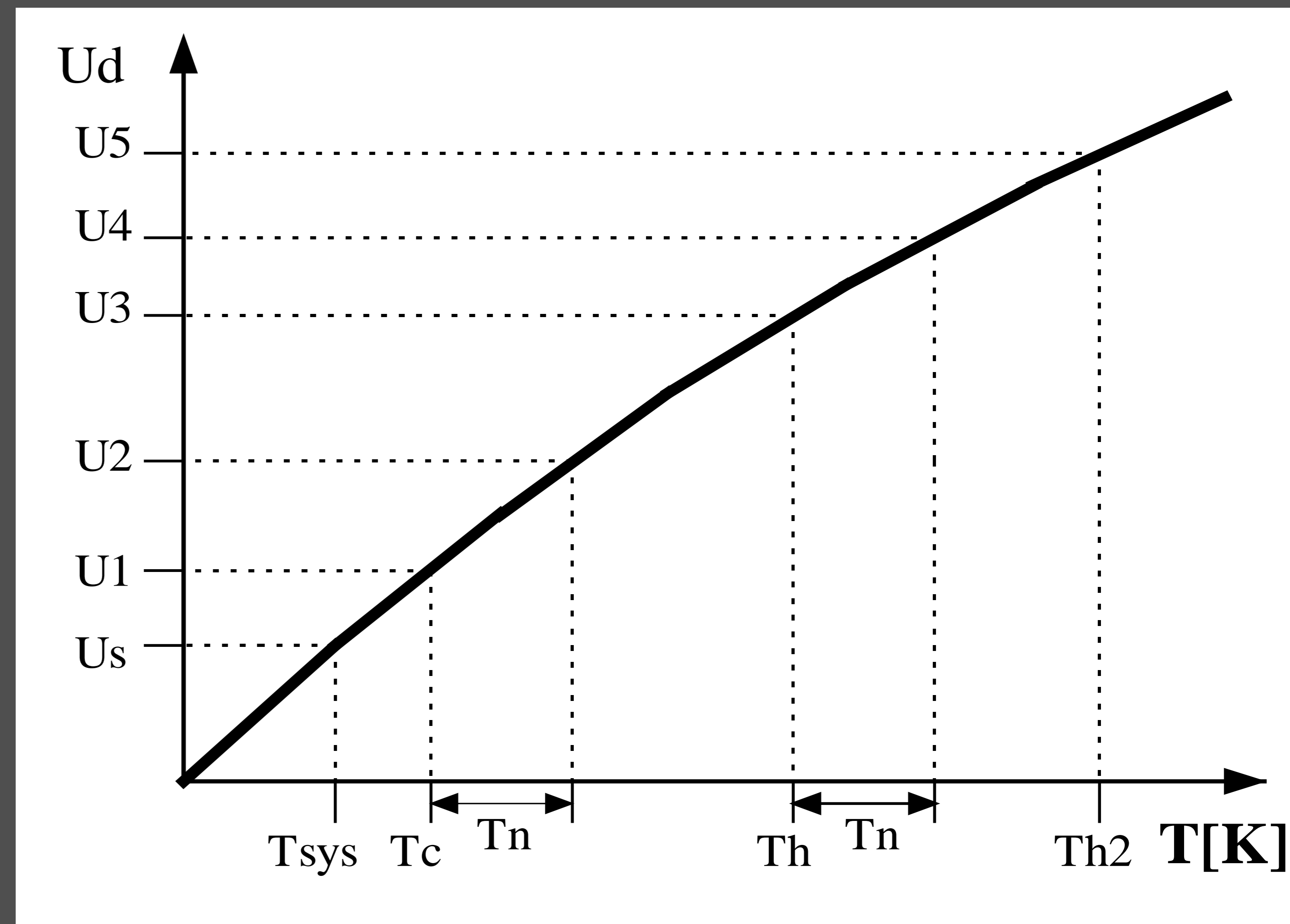
Initial 4-point Calibration:

- 1) Cold load
- 2) Cold load + noise diode
- 3) Ambient load
- 4) Ambient load + noise diode

→ 4 Equations result in: G , T_{sys} , T_N , α
Automatic calibration during operation:

- 1) Dicke switch (ambient load)
- 2) Dicke switch + noise diode

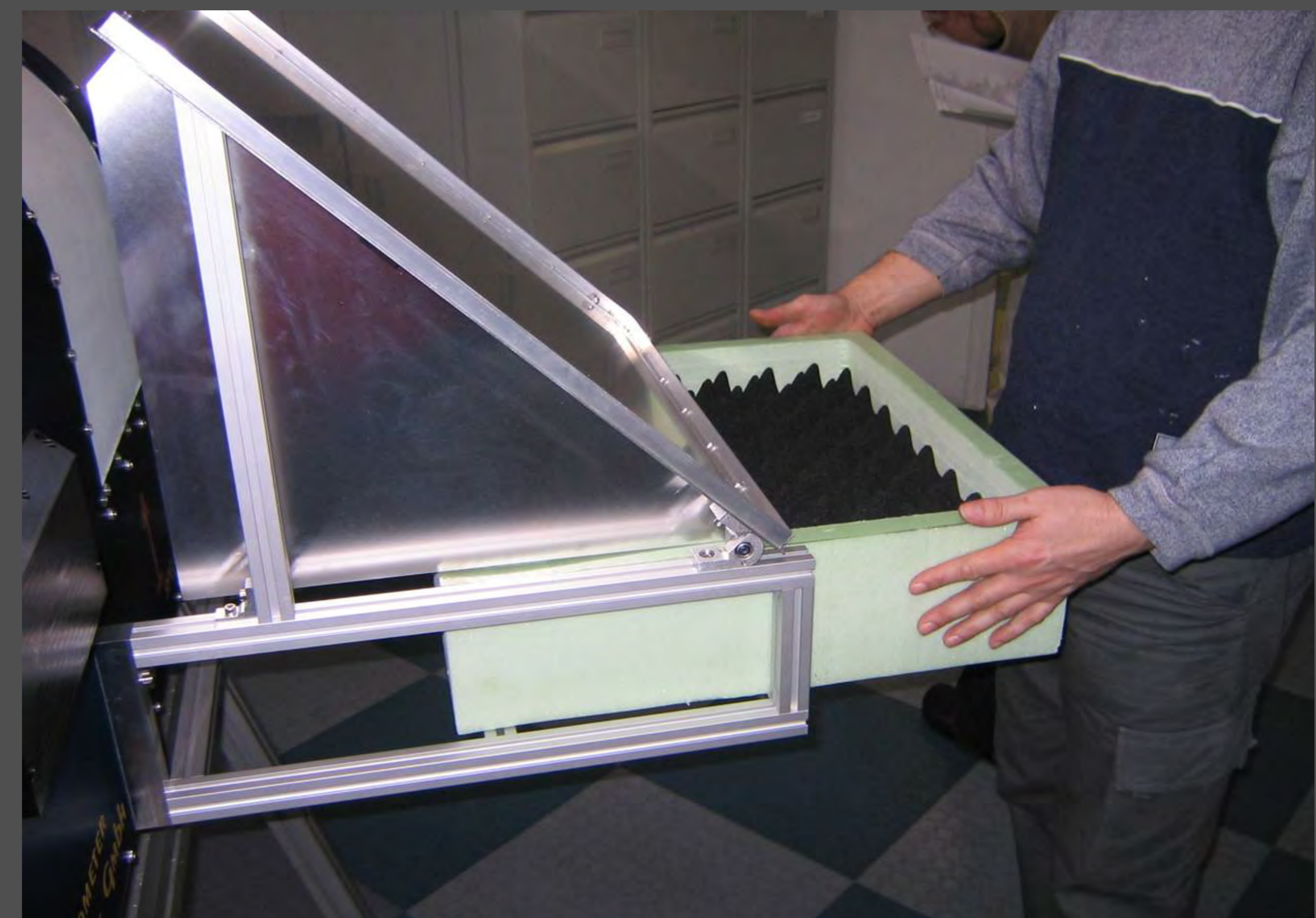
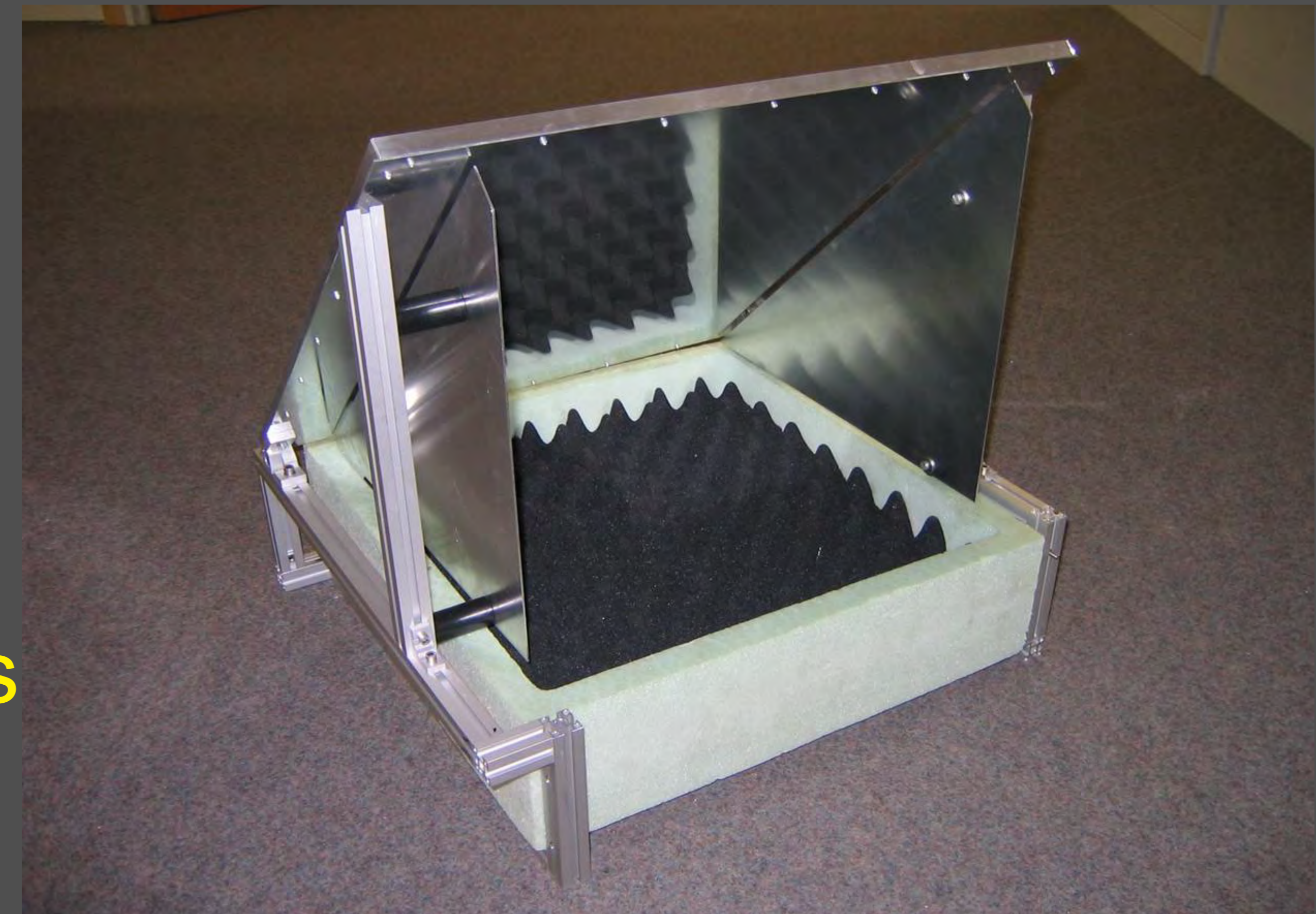
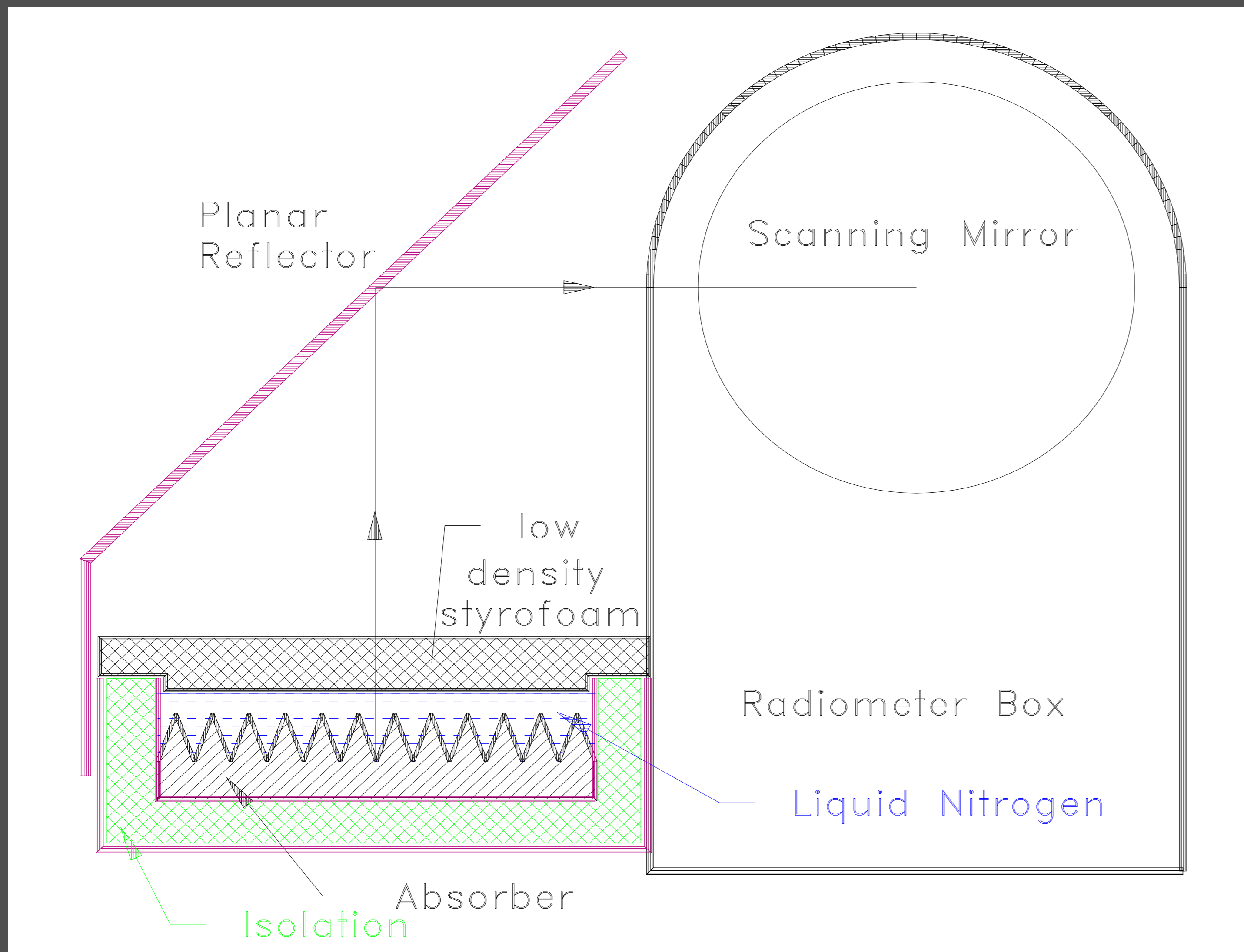
$$U_D = G(T_{sys} + T_{sig})^\alpha, \quad \alpha \leq 1$$



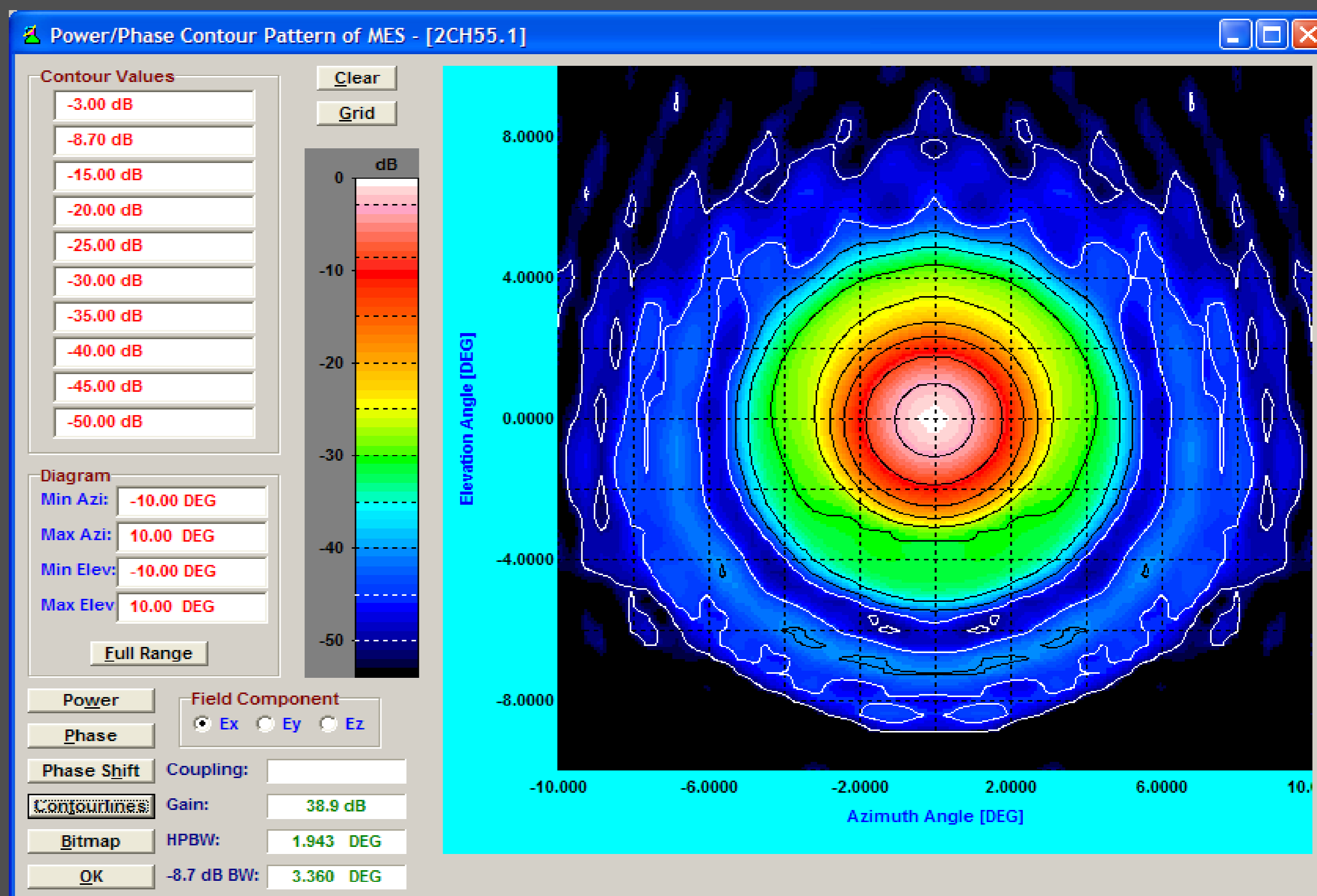
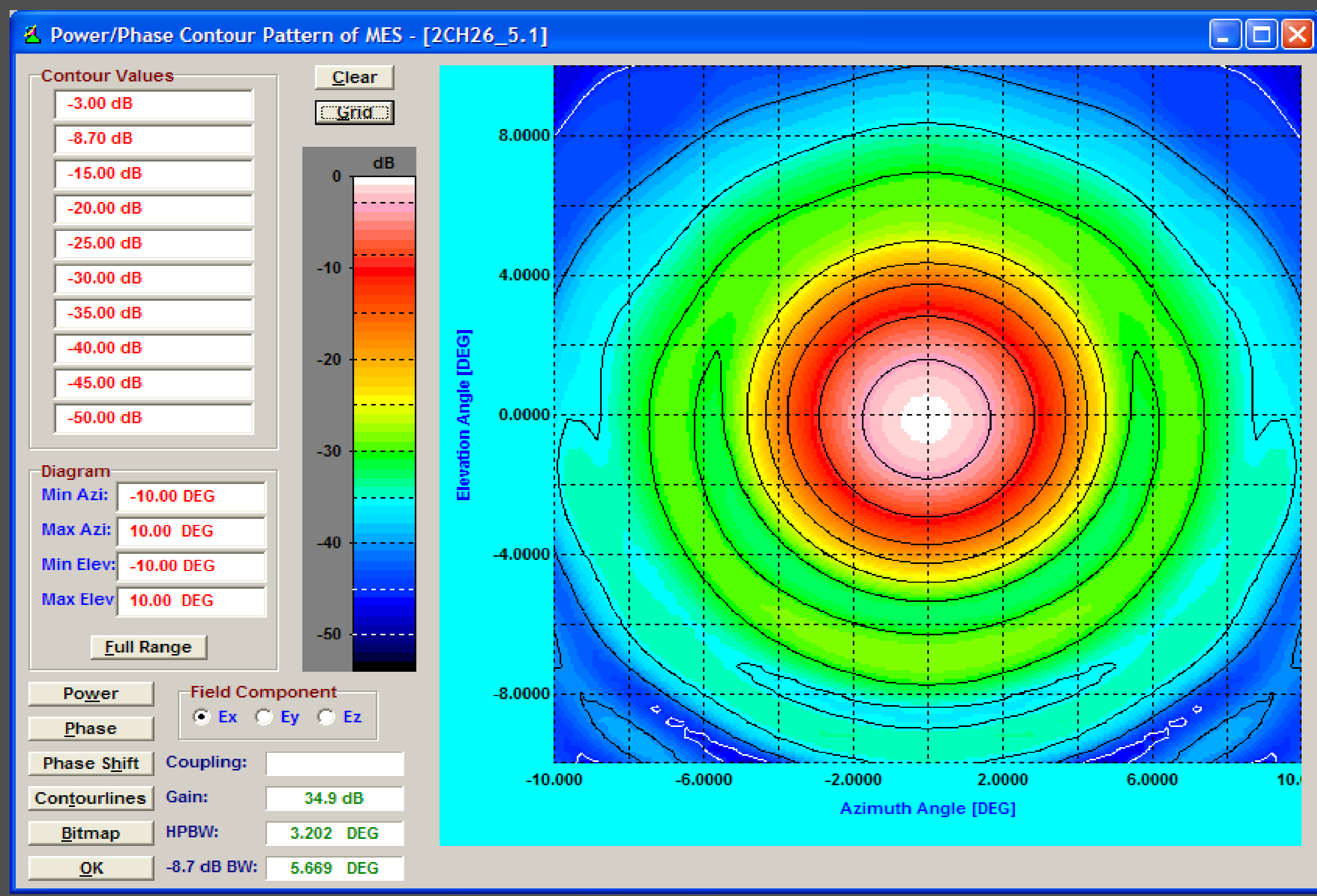
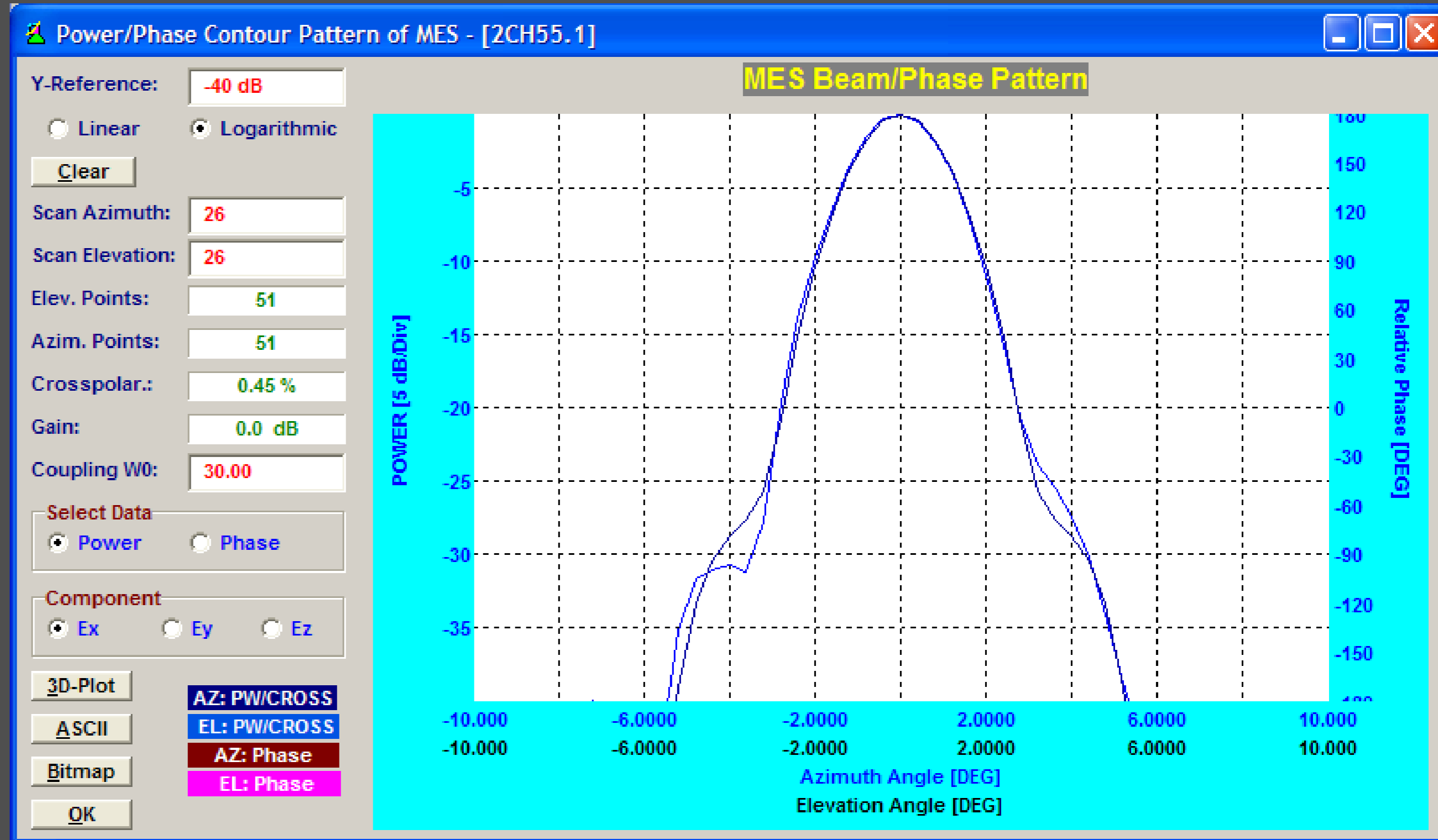
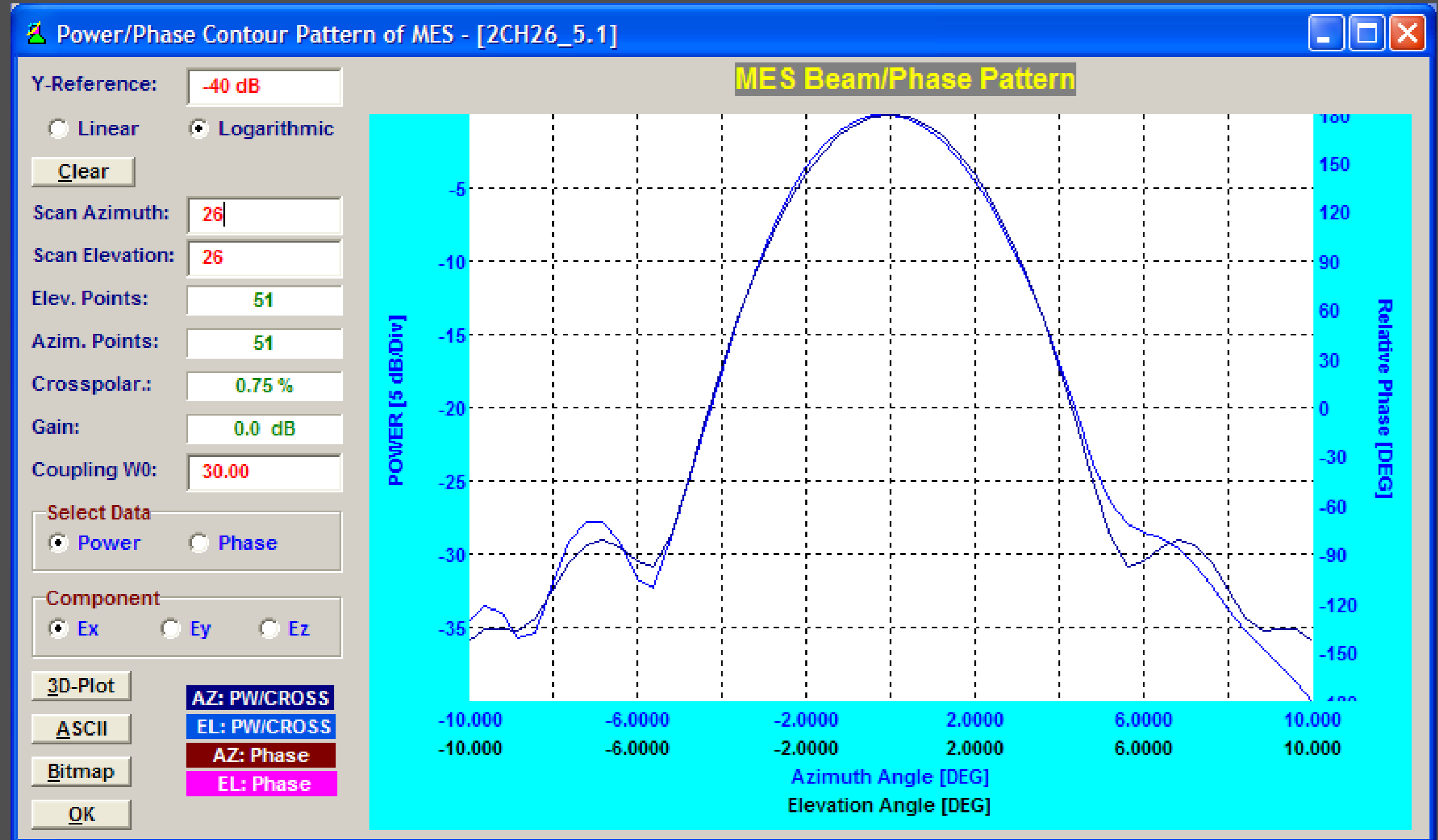
4 Point Calibration – Liquid Nitrogen als cold point

Corrections applied:

- Pressure dependent boiling temperature
- Reflection on air-LN2 interface
- Mirror losses
- Spill-over at primary reflector
- (isolator-leakage for auto-calibration receivers)



RPG-HATPRO Optical Performance



26.5 GHz, HPBW = 3.2°, Sidelobes: <-30 dB

55.0 GHz, HPBW = 1.9°, Sidelobes: <-30 dB

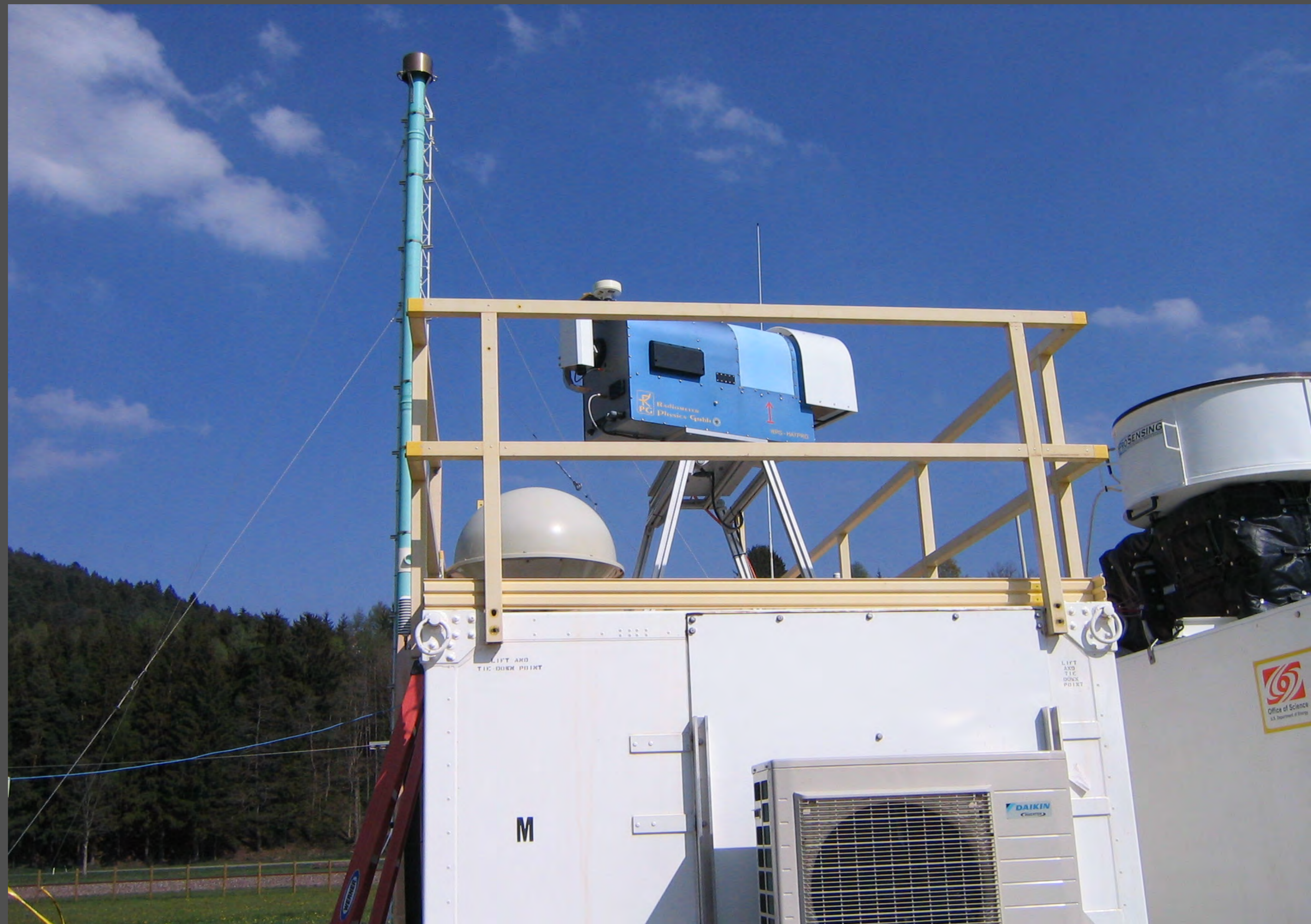
Scanning the full sky

COPS campaign
HATPRO (University
Cologne) at ARM
Mobile Facility
(Heselbach, Germany)

Sampling rate: 0.4 s

Products:

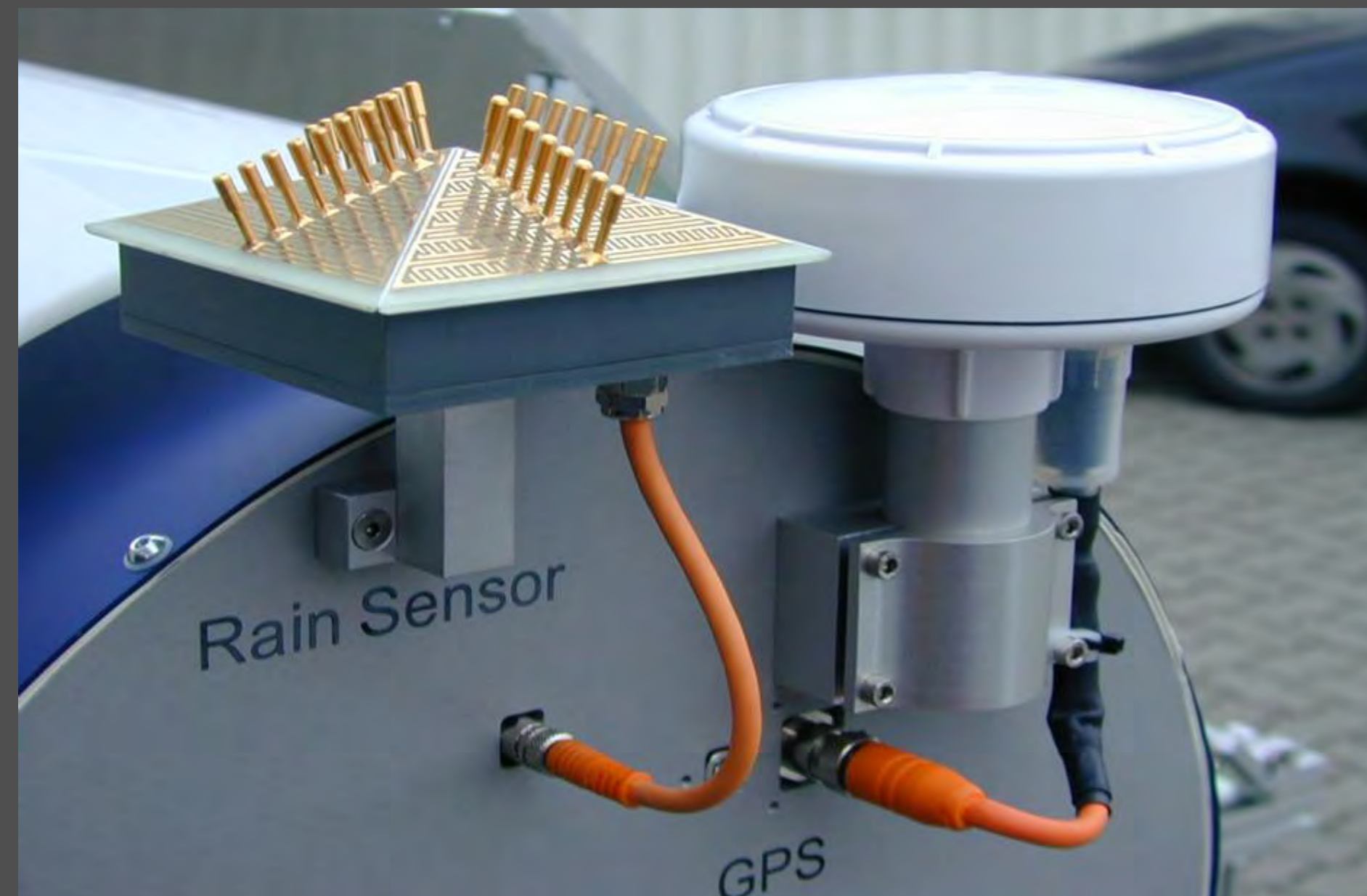
- Cloud cover
- directional (2D) distribution of LWP
- Water vapour inhomogeneities



360° Azimuth Scans: 30° Elev., 5° pitch, every 10 min, 45 sec. duration

Full Sky Scans: 9° pitch, every 15 min, 5 min. duration, 360 samples

Additional Meteorological Sensors



Rain Sensor: Provides rain flag for measurement documentation, control of super blower system, field replaceable

GPS-Clock: Provides time reference standard for synchronization, field replaceable

Humidity Sensor: Provides control of super blower system, documentation, field replaceable

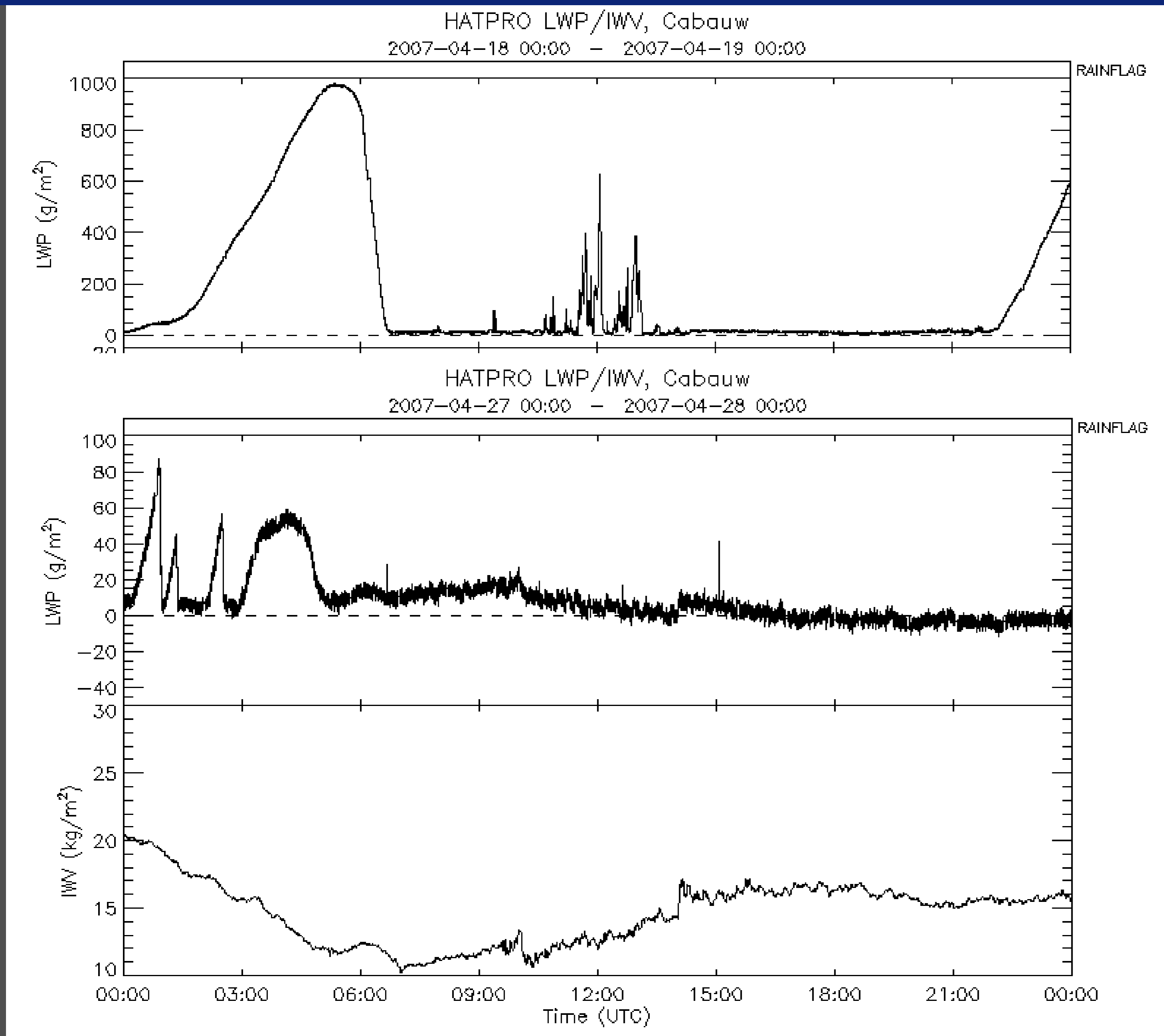


Temperature Sensor: Documentation of surface temperature, field replaceable

Pressure Sensor: Documentation of barometric pressure, LN-target calibration

Optional IR-Radiometer: Cloud base height detection, ceilometer function, observation direction adjustable

Necessity of Heated Blower System



Strong blower + hydrophobic coating are not sufficient to prevent fog condensation on microwave window

Switching heater module on / off demonstrates the effect on removing liquid from the window



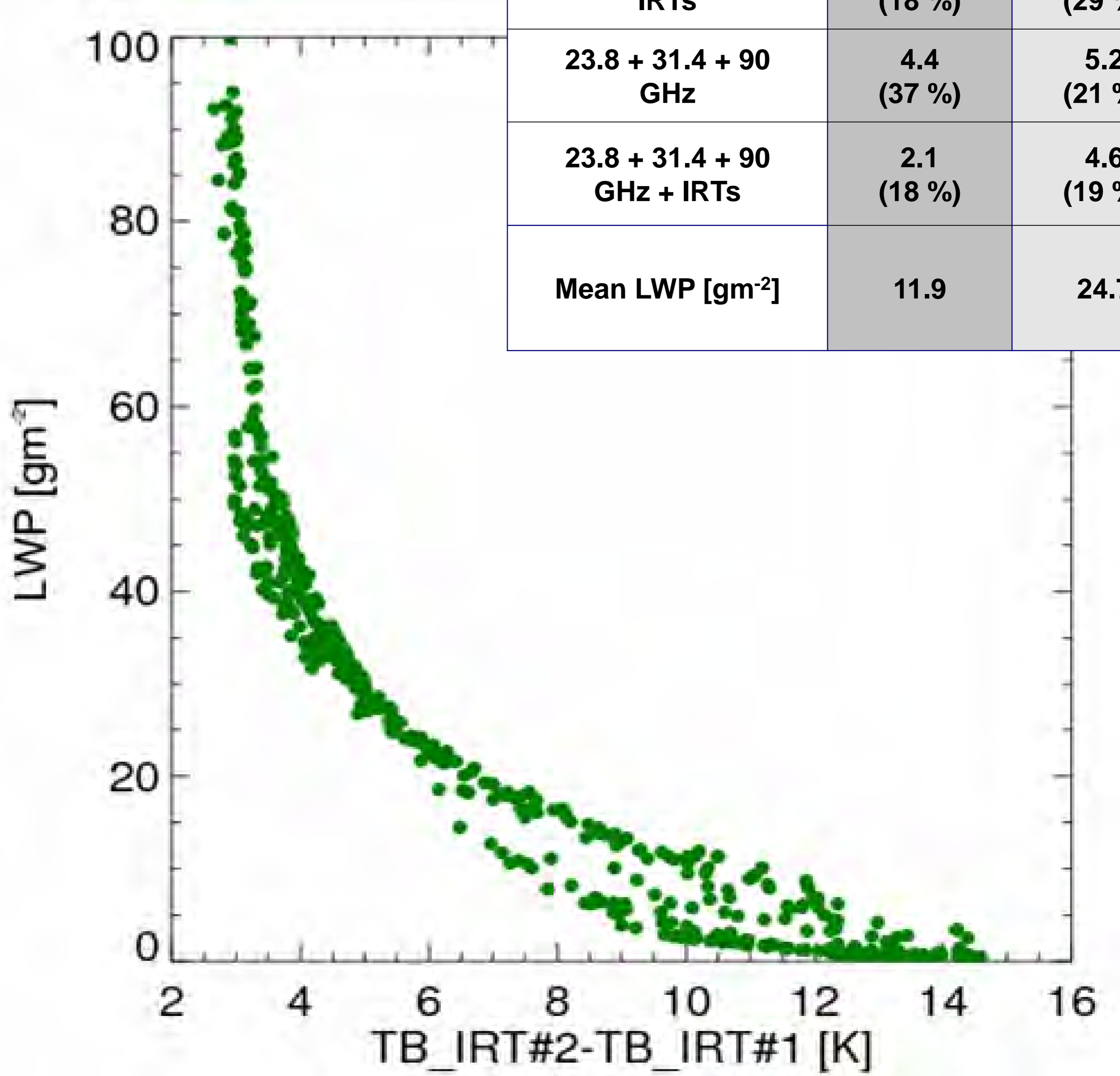
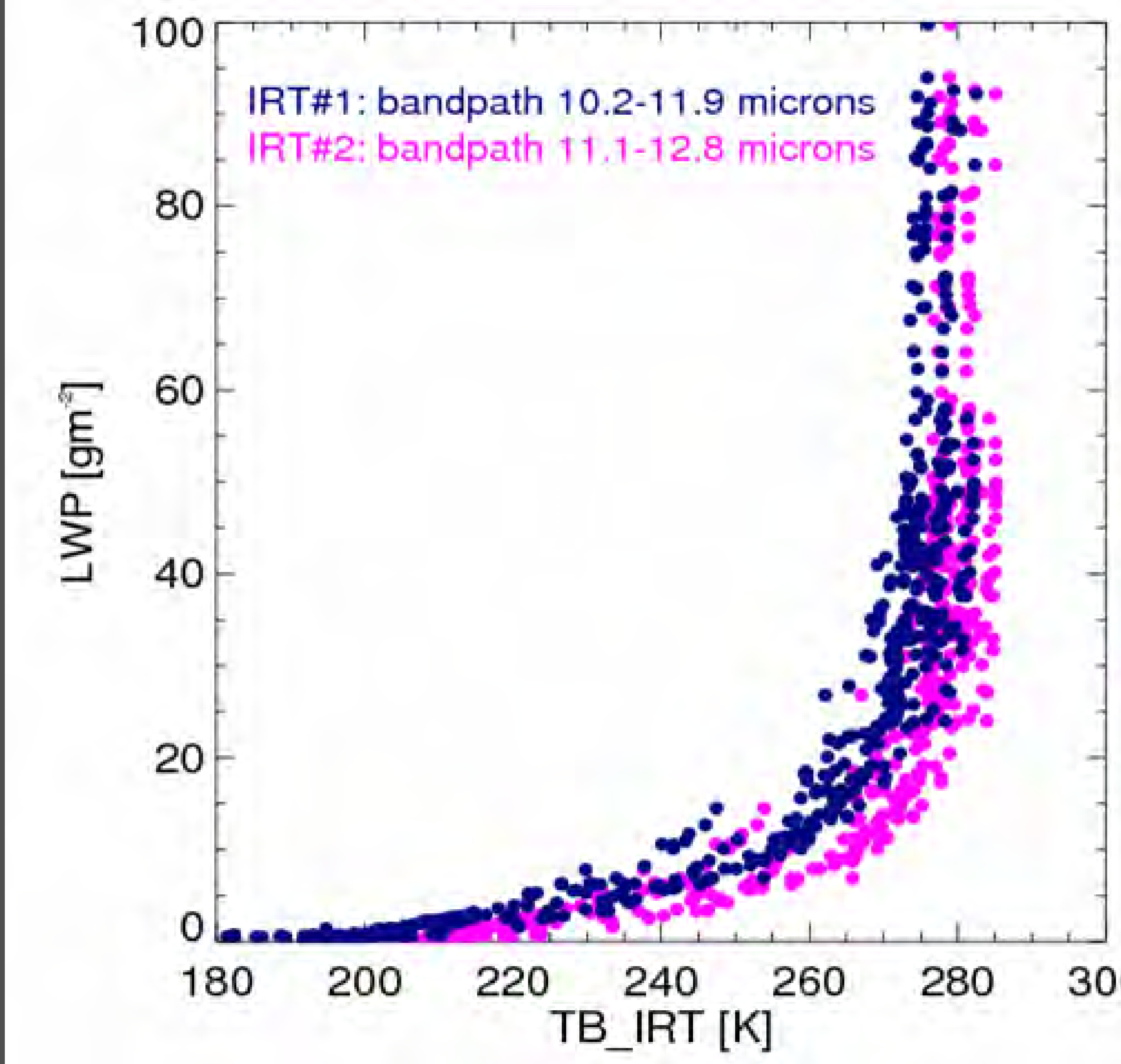
Courtesy of:
Henk Klein-Baltink
KNMI / Netherlands
(Dutch Weather Service)

Dual-Channel Infra-Red Option

Ulrich Löhnert / Dave Turner

Two slightly shifted IR channels are sensitive to LWP (or: effective radius)

Channel combination	RMS LWP < 40 gm ⁻²	RMS LWP < 100 gm ⁻²	RMS all LWP
23.8 + 31.4 GHz	6.2 (52 %)	9.1 (37 %)	12.4 (19 %)
IRTs only	2.5 (21 %)	9.2 (37 %)	42.3 (64 %)
23.8 + 31.4 GHz + IRTs	2.1 (18 %)	7.1 (29 %)	12.9 (20 %)
23.8 + 31.4 + 90 GHz	4.4 (37 %)	5.2 (21 %)	5.8 (9 %)
23.8 + 31.4 + 90 GHz + IRTs	2.1 (18 %)	4.6 (19 %)	5.4 (8 %)
Mean LWP [gm ⁻²]	11.9	24.7	65.7



Detailed description of the software

HATPRO Software – general remarks

- Software supports all models, with all optional hardware
- Software may be copied by customer to a large number of PC
- Software can be used off-line (no radiometer connected) for training or data processing
- Software updates are free, improvement cycles (new features) rapid
- Source code available

A large user community gives feedback to RPG

Product enhancement benefits the whole community

HATPRO Software – Data concept

- Files for all products and relevant data: meteorological sensors, brightness temperatures, temperature profile, internal system data, retrieved water vapour amount, IR signal, ...
- Several file formats available, additional on request:
 - Binary (proprietary, but well documented in Manual)
 - ASCII
 - NetCDF
 - BUFR
- Within data file, every sample is stored with precise GPS time, rain flag, elevation data, and quality flags
- During data acquisition, quick-looks (JPG, WMF, ...) can be generated

Key Question: How to define and control measurements?

Radiometer (autonomous entity):

- Controls all hardware components
- All timing / scheduling performed without outside interference
- Performs all retrievals, all calibrations
- Communication on RS-232 to outside world / network computers
 - Uses internal DOS-PC with low power consumption (intel 486)

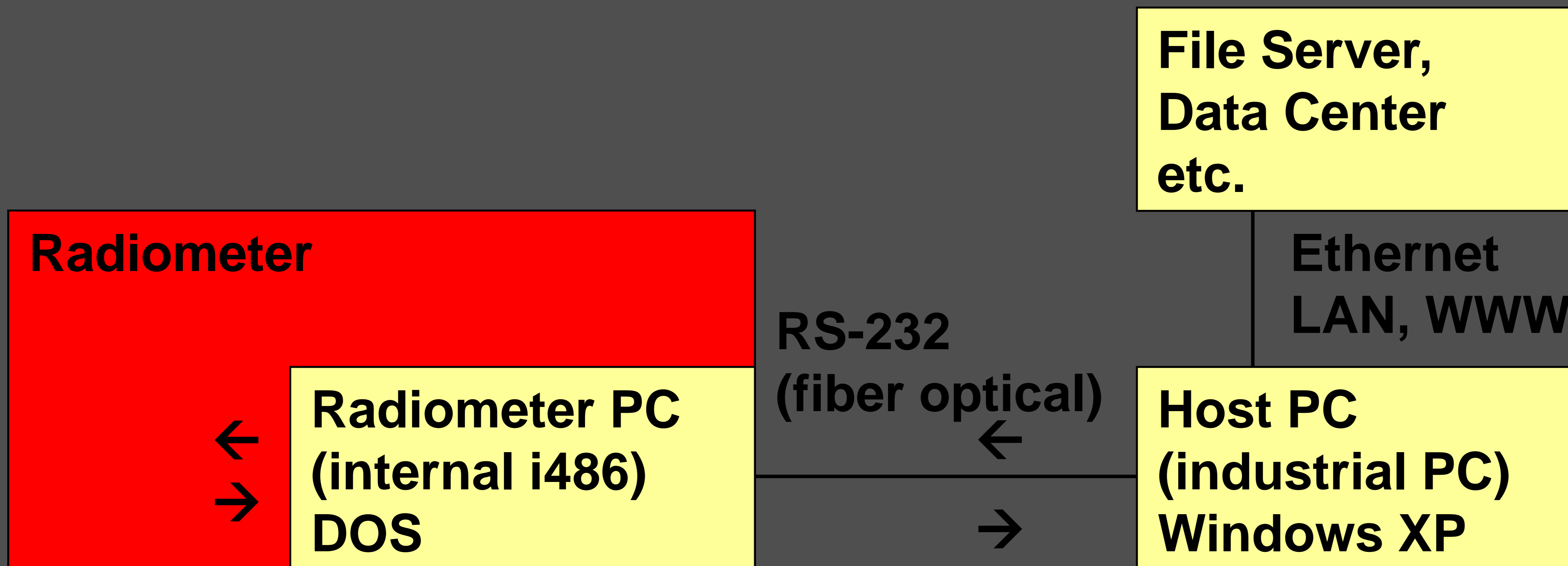
Host PC:

- Used for starting, terminating, or changing a measurement setup
- Usually used for recording the measured data
 - Non-standard industrial PC (running Windows XP) with 4x RS-232 + LAN
 - Significantly enhanced robustness: temperature, humidity, dust

Other PC (Network):

- Used for
 - backing up data archive on Host PC
 - Post-processing of data
 - Monitoring network, quality control, alarm, ...
- Connected via LAN or WWW to Host PC
- Remote-Control of Host PC possible

Radiometer Control Concept



Network:

- Data Backup of host PC
- Off-line post processing

Radiometer PC:

- Booting / initializing the instrument
- Controls all hardware
- Performs all retrievals
- Runs communication with Host PC
- *May be used for data storage*

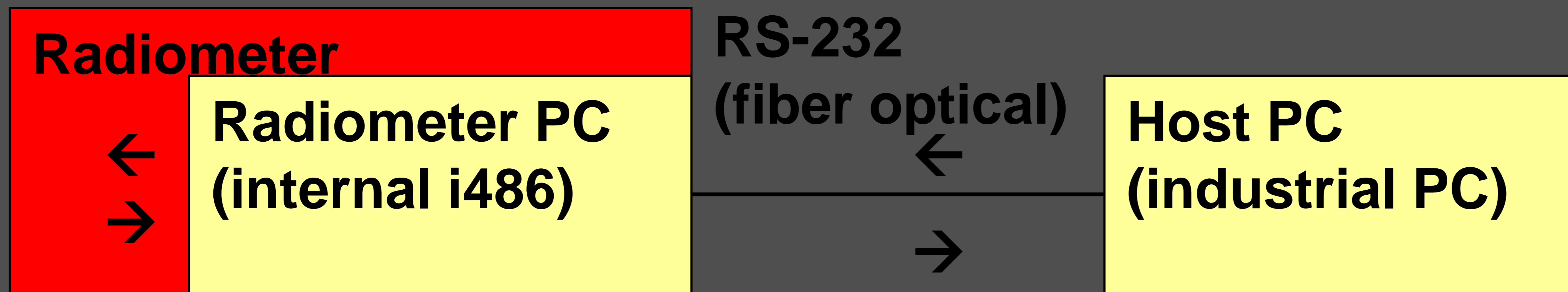
Low power consumption mandatory!

Host PC:

- Connects to running radiometer
- Needed for defining, changing, and starting a measurement cycle
- Recording and storing the measurement data stream
- Post processing possible

Robust Industrial PC (non-standard)

Sequence of communication



Actions on Radiometer PC:

On power-up: Auto-Boot DOS

Autostart of 2CH.EXE (may be configured for auto-boot, auto-start

→ Full control of all hardware

→ Listening for host on RS-232

Actions on Host PC:

Boot PC, Start R2CH.EXE

and cuto-connect to radiometer)

- 1) send commands for connection on RS-232
- 2) Establishes connection, standby-mode
- 3) request instrument status data
- 4) From now on, send data stream
- 5) read status data stream, display status
- 6) Keep listening for commands from host
- 6) send MBF
- 7) Read and check the MBF
- 8) send „start measurement command“
- 9) Execute MBF as M1 file, send data
- 10) Read data stream, display data, etc.

Starting a measurement: The simple case

After Radiometer is powered up and R2CH.EXE has been started on Host PC:

- 1. Start Host PC (skip this if BIOS has auto-boot option set)*
- 2. Start R2CH.EXE software (skip this if R2CH.EXE is in auto-start-folder)*
- 3. Connect to radiometer (skip if auto-connect is configured in R2CH.CFG)*
- 4. Select/load pre-defined MBF (Measurement Batch File) on Host PC**
- 5. Send MBF to radiometer**
- 6. Press „start measurement“ button in software**
- 7. Measurement keeps running until it is**
 - finished (sometime never)
 - interrupted by user (may be resumed later on, just a pause)
 - terminated by user (for re-definition, maintenance, etc.)

In the following, most of the software handling is either

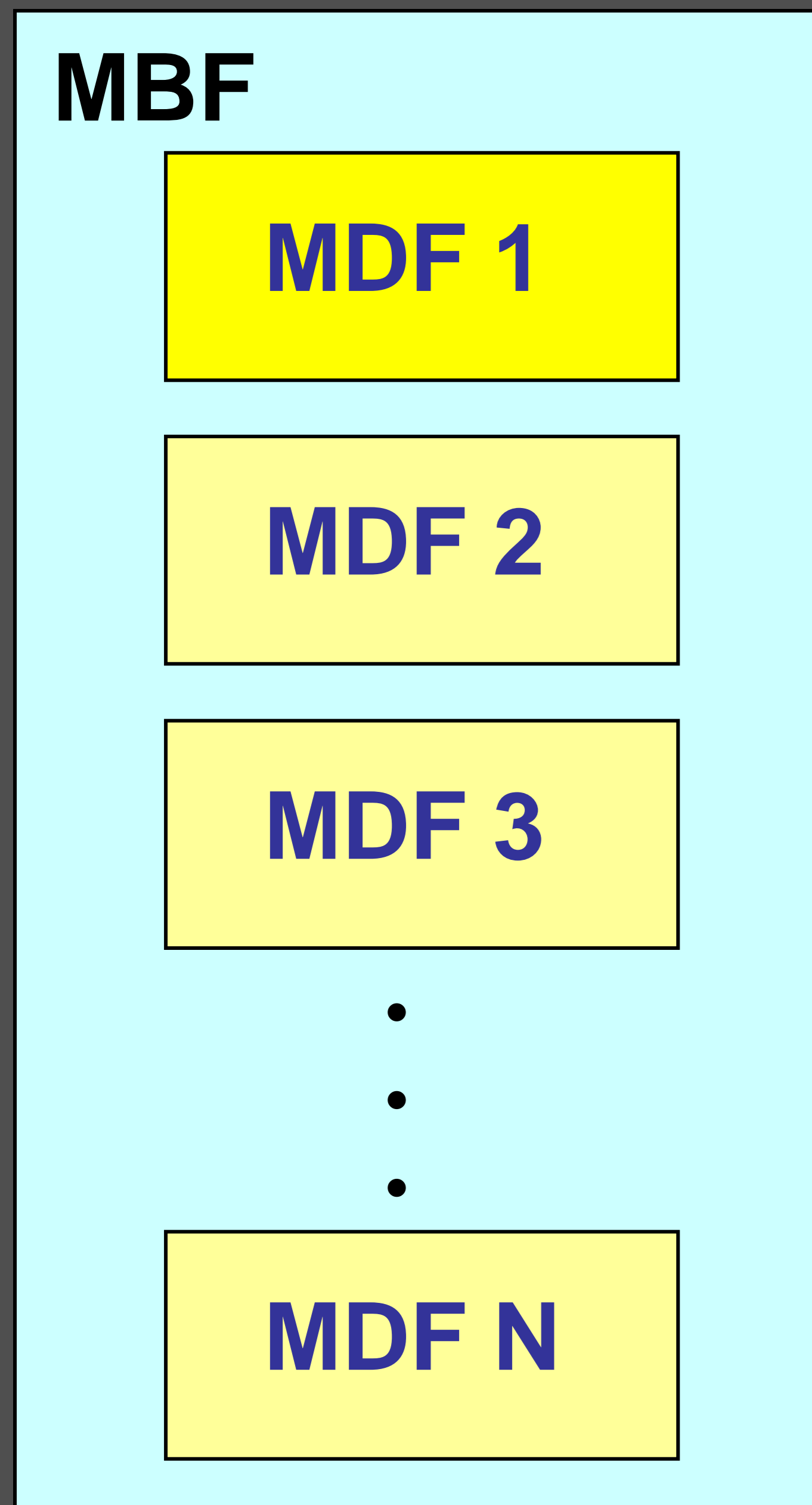
- **Setting up the MBF (including all products, calibrations, timing, scanning etc.)**
- **Data post-processing and inspection**

Data Level Concept

Along the data processing, we have different levels of data:

- Level-0: Uncalibrated raw data
Only the Voltages (as sampled by the data acquisition) and relevant readings of calibration target temperatures, noise-diodes etc. is recorded
→ Re-calibration during post-processing possible **(expert mode)**
- Level-1: Calibrated data
 - Calibrated brightness temperatures (at all observation frequencies)
 - Meteorological sensor readings
 - IR radiometer reading
- Level-2: Retrieved data
Only direct retrievals with custom-designed statistical retrievals
 - LWP, IWV, T-profile, BL-T-profile, Q-profile
- Level-3: Products derived from data processing
 - Composite-T-profile, LWC-profile

Measurement Definition: Basic Concept



**Radiometer Software (R2CH.EXE) needs instructions:
Measurement *Batch* File (MBF) is sent to radiometer**

- The MBF contains at least one and up to N Measurement *Definition* Files (MDF-1 to MDF-N)
- Each MDF defines
 - Type of data to be recorded (H2O, O2, MET-data, etc.)
 - Retrievals to be used for Level-2 products
 - Scan patterns (pointing, scanning) for observation
 - Timing and scheduling for the observations
 - Calibration procedures to be executed during obs.
- Highly variable and complex observations can be build up by sets of simpler MDF within one MBF (several definition files within one batch file)
- MDF can have limited or unlimited execution times (for multiple MDF: Never use unlimited timing!)
- MBF and MDF can have counted repetitions

HATPRO software features

Definition of Measurements:

Full control over integration times, retrieval versions, selected products...

Definition of Measurement and Calibration Parameters

Sky Tipping | Standard Calibrations | **Products + Integration** | Scanning | Timing + ... | MDF + MBF Storage

Instruments: RPG-HATPRO

List of Products	Corresponding Retrievals	Total Integr. Time
Level 0:	Retrieval File Editor	
<input type="checkbox"/> Detector Voltages + Cal. Par. + ...		
Level 1:		
<input checked="" type="checkbox"/> Brightness Temperatures	no retrieval required	1 sec
<input checked="" type="checkbox"/> Brightness Temperatures (BL)	no retrieval required	100 sec
<input type="checkbox"/> Infrared Radiometer Data	no retrieval required	1 sec
Level 2:	(press <return> for retrieval display)	
<input checked="" type="checkbox"/> LWP (Liquid Water Path) +	LWP_QR_MA_Kolkata_v2.ret	1 sec
<input checked="" type="checkbox"/> IWV (Integrated Water Vapour) +	IWV_QR_MA_Kolkata_v2.ret	1 sec
<input type="checkbox"/> Atm. Attenuation +		1 sec
<input checked="" type="checkbox"/> Via Tmr		
<input checked="" type="checkbox"/> Humidity Profile (full trop.) +	HPT_QR_Kolkata_v2.ret	60 sec
<input checked="" type="checkbox"/> Temperature Profile (full trop.) +	TPT_QR_Kolkata_v2.ret	60 sec
<input checked="" type="checkbox"/> Temperature Profile (BL) +	TPB_LR_Kolkata_v2.ret	100 sec
TP-BL Repetition: 1200 sec		
Others:		
<input type="checkbox"/> Tmr Retrieval Overwrite +	TMR_LR_SFH_V1.RET	
<input checked="" type="checkbox"/> Meteorological Sensors	no retrieval required	1 sec
<input checked="" type="checkbox"/> Housekeeping Data Specify	no retrieval required	1 sec

Boundary Layer Scan Mode
 Main Quadrant 2nd Quadrant
 Bilateral Average
 Bilateral (Two Scans)

Quit

Measurement Definition: Angles and Scanning

Frame #1

Scan-1

Scan-2

Scan-5

•
•
•

Scan-X

Complex angular scan patterns:

Definition similar to MDF/MBF concept

- One larger container for – possibly repeated – patterns of simple azimuth/elevation movements
- The smallest mirror movement definition is a scan:
 - Start and stop azimuth and elevation
 - Number of steps from start to stop position
 - Either 1D or 2D movement
- The scans are grouped into a „frame“
- At least one scan in one frame
- 200 frames possible within one MDF

Software – Housekeeping data (HKD)

RPG-HATPRO Humidity- and Temperature-Profiler (Version 8.10)

Files Communication Measurement Control Calibration Background Processes Configuration

Gain: [] Noise: [] Sky Tip: [] BL-S: []
Elev.: 89.70
Azi.: 232.00
AutoViewer: Halted...
Rep.: 1 / 1
File: 09040401
RF: []
R1: [] R2: [] RH: 69%
P: 997 mbar Target T: 29.4 / 29.5°C
Enviro. T: 13.8°C
LTime: 23:56:56
Date: 26-03-2010

Status and Config.
Brightness Temps
24 Hour Atmospheric Data
Current Time Series
Current Trop. Profiles
Tephigram + Stability
Attenuation
Satellite Tracking
Housekeeping

Temperatures

Ambient 1: 302.6 K
 Ambient 2: 302.7 K
 Receiver 1: 310.0 K
 Receiver 2: 311.2 K

Receiver Stability / Flash Disk Capacity

Stab. Rec.1: 0.001 K
 Stab. Rec.2: 0.001 K
 Flash Disk: []

Digital Flags

Receiver 1 Channels: [Green bars]

Receiver 2 Channels: [Green bars]

Rain Flag: [Green bar]

Dew Blower Status: [Green bar]

BL-Mode: [Green bar]

Sky-Tipping Cal.: [Green bar]

Gain Cal.: [Green bar]

Noise Cal.: [Green bar]

Noise Diode Rec.1: [Green bar]

Noise Diode Rec.2: [Green bar]

Rec.1 Temp. Stability: [Green bar]

Rec.2 Temp. Stability: [Green bar]

Power Failure: [Green bar]

Ambient Target Stab.: [Green bar]

Quality Flags

LWP: []

IWV: []

Atmos. Attenuation: []

Humidity Profile: []

Temperature Profile: []

Temp. Profile BL: []

Rel. Hum. Profile: []

Liquid Water Profile: []

Quality Management: OM

Remove Interferences: IIO

Time / Date: 04/04/2009 -- 01:30:09 (U) #: 1148 2000 s

Color Legend
GPS Position
Long: [] Lat: []
Alarm

Master Message: Master Mode: MEASUREMENT RUNNING Master COM: Posi. Port: NONE

Software – Brightness temperatures

RPG-HATPRO Humidity- and Temperature-Profiler (Version 8.10)

Files Communication Measurement Control Calibration Background Processes Configuration

Gain: [] Noise: [] Sky Tip: []
Elev.: 89.70
Azi.: 232.00
AutoViewer: Halted...
Rep.: 1 / 1
File: 09040401
RF: []
P: 997 mbar Target T: 29.4 / 29.5°C
RH: 69%
Enviro. T: 13.8°C

Status and Config.
Brightness Temps
24 Hour Atmospheric Data
Current Time Series
Current Trop. Profiles
Tephigram + Stability
Attenuation
Satellite Tracking
Housekeeping

Brightness Temperatures

K

45.00	22.24 [K]
39.98	23.04 [K]
39.05	23.84 [K]
35.05	25.44 [K]
26.70	26.24 [K]
24.08	27.84 [K]
21.89	27.84 [K]
20.98	31.40 [K]

Time: 01:10:00 01:20:00 01:30:00

K

130.0	51.26 [K]
111.49	52.28 [K]
150.41	53.86 [K]
248.65	54.94 [K]
278.92	56.66 [K]
284.80	57.30 [K]
285.26	58.00 [K]
285.65	58.00 [K]

Time: 01:10:00 01:20:00 01:30:00

RF: []

Current Parameters

#: 1036 T/D: 04|04|2009 01:30:09 (U) El.: 90.0° Azi.: 232.0° 2000 s ND Elevation Angles: ALL

Boundary Layer Scans

Time / Date: 01|20|46 (L) 04|04|2009 # 1

Frequency: 58.00 GHz

Brightn. T.: []

El.: []

Azi.: 232.0°

Rain: []

Brightness Temp. [K] vs Elevation [°]

Infrared Radiometer(s)

Time / Date: 01|30|09 (U) 04|04|2009 # 1149

12.0 um -3.0°C

11.1 um -10.4°C

2000 s

Infrared Temp. [°C] vs Time

RF: []

Line Profiles

TB Window 1

Brightness Temp. [K] vs Frequency [GHz]

Lower Limit: 22 GHz Upper Limit: 32 GHz

TB Window 2

Brightness Temp. [K] vs Frequency [GHz]

Lower Limit: 51 GHz Upper Limit: 59 GHz

TB Window 3

Brightness Temp. [K] vs Frequency [GHz]

Lower Limit: 20 GHz Upper Limit: 60 GHz

Master Message: Master Mode: MEASUREMENT RUNNING Master COM: Posi. Port: NONE

Azi.: 232.0° 2000 s ND Elevation Angles: ALL

Infrared Radiometer(s)

Time / Date: 23|59|59 (U) 04|04|2009 # 2148

03|59|12 -50.3°C

12.0 um 3.0°C

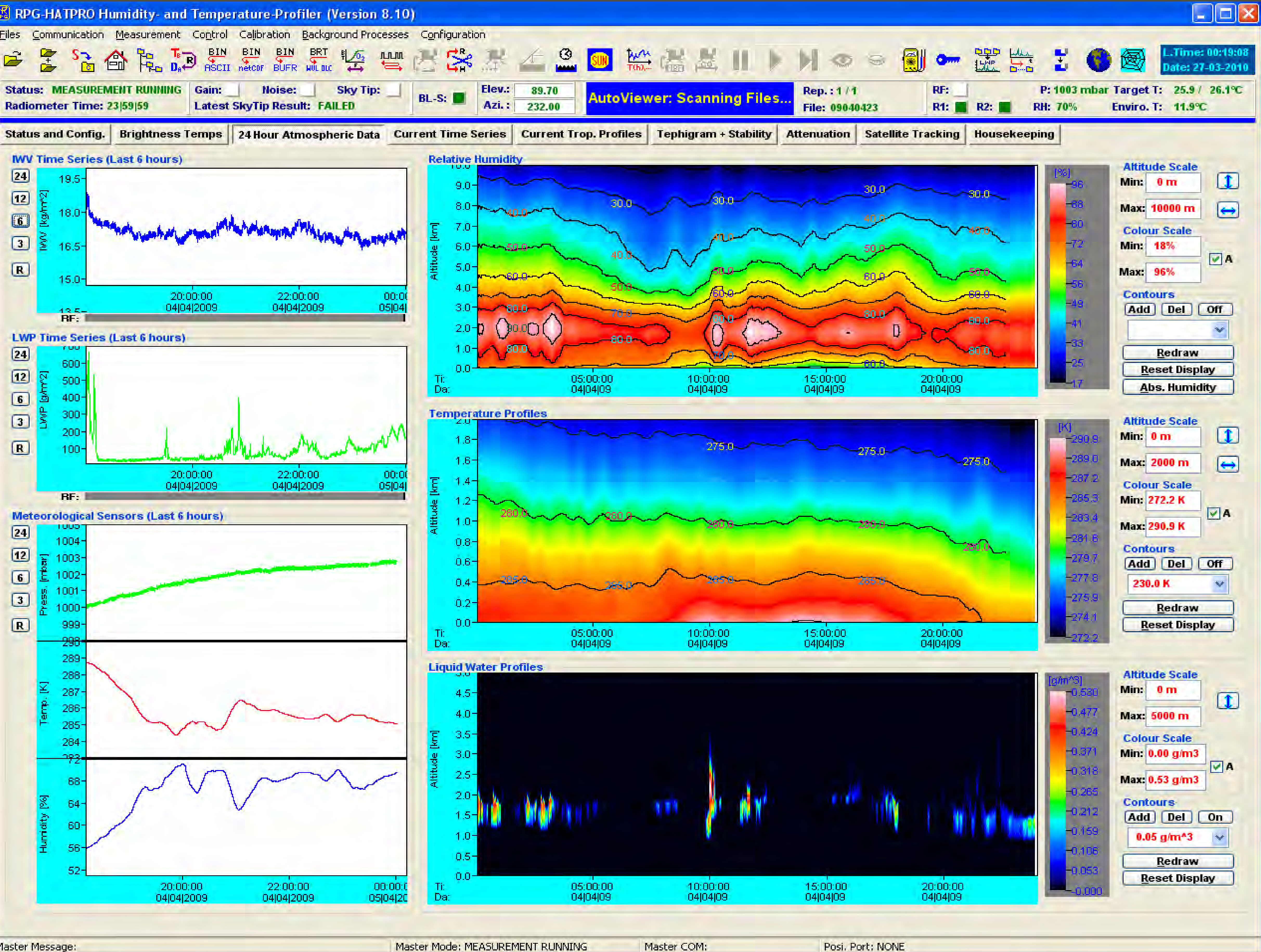
11.1 um 3.2°C

2000 s

Infrared Temp. [°C] vs Time

RF: []

Software – 24-hour readings of OWV, LWP, Cloud, Met-sensors



Software – thermo-dynamic diagrams

RPG-HATPRO Humidity- and Temperature-Profiler (Version 7.97) (License: UNLIMITED)

Files Communication Measurement Control Calibration Background Processes Configuration

Status: **MEASUREMENT RUNNING** Radiometer Time: 10|15|01

Gain: Noise: Sky Tip: BL-S: Elev.: 30.0° Azi.: 0.0°

P: LWP STANDARD.MDF Rep.: 1/1 P: 1001 mbar Target T: 38.5 / 38.6°C RH: 47% Enviro. T: 24.9°C

Current MDF: STANDARD.MDF

Status and Configuration | Brightness Temperatures | Atmospheric Data (24 Hours) | Atmospheric Data (Time Series) | Current Trop. Profiles | Skew-T & Stability | Attenuation | Satellite Tracking | Housekeeping

Skew-T Diagram

Barometric Pressure [mbar]

Temperature [°C]

Blue : Env. Temperature Green : Dewpoint Red : Pseudo-Potential Temperature Tpp-60°C

Stability Indices

Index [K]

CAPE [J/kg]

Time

RF: [REDACTED]

Time / Date: 10|11|15 (U) 23|08|2009 #: 2 1000 s Info

KI: 6.5 K KOI: 8.7 K TTI: 35.5 K Cursor [K]: 43.3 K

LI: 9.8 K SI: 9.4 K CAPE: 0 J/kg Cursor [J/kg]: 1971 J/kg

LCL: 825 hPa : 1548 m

LFC: [REDACTED]

Diagram Legend

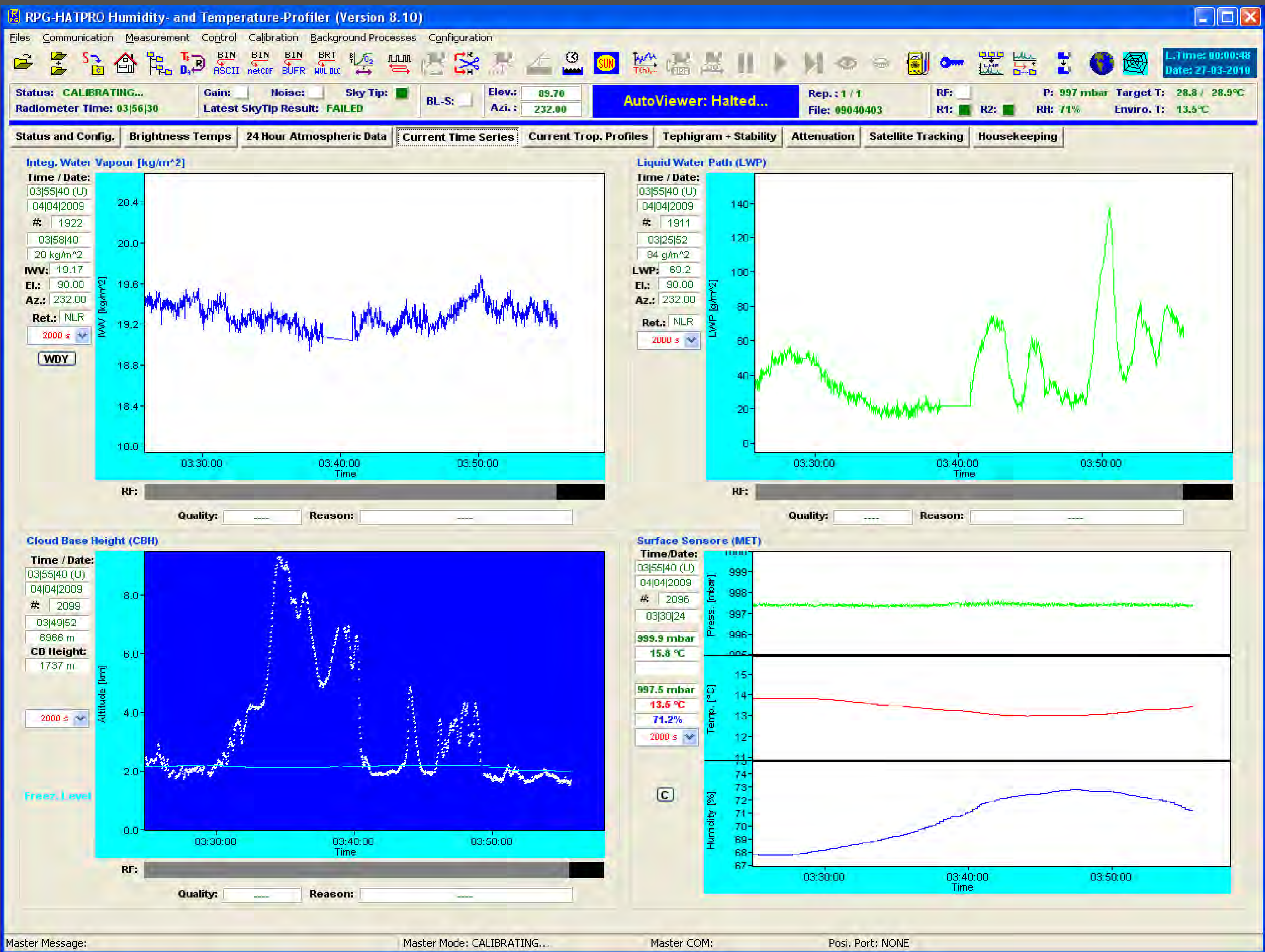
- Solid black : Isobars [mbar]
- Solid red : Isotherms [°C]
- Solid teal : Dry Adiabats [°C]
- Dashed magenta : Saturated Adiabats [°C]
- Dashed green : Saturation mixing ratio [g / kg]

Cursor

Temp: 14.6 °C Press: 384 mbar Alt: 7657 m

Message: Radiometer connected Mode: MEASUREMENT RUNNING Rad. Port: COM1 [115200] Posi. Port: NONE

Software – LWP, IWV details



Network and forecast suitability

- Software checks for instrument status and sanity, generates error flags
- Software checks for radio-frequency interference (RFI)
- Software checks for weather situations, in which retrievals lose their credibility / precision
- Quality flags are stored with data, allow black-listing
- Maintenance and service contracts available
- Warranty extendible to 10 years through year-by-year support contract

Current efforts in Europe

- COST (cooperation on science and technology, funded by EU Science Foundation)
- Action „EG-CLIMET“: European ground-based observations of essential variables for climate and operational meteorology
- Focus for MW-radiometers:
 - Boundary layer temperature profile with high precision in lowest 1.5 km
 - Directional (2D) assessment of LWP, IWV, cloud cover, coarse Hum. Profile
- Website: <http://www.eg-climet.org/>

EG-CLIMET: action within EU funded COST program

cost
European Cooperation in the field of Scientific and Technical Research

EG-CLIMET
EUROPEAN GROUND-BASED OBSERVATIONS OF ESSENTIAL VARIABLES FOR CLIMATE AND OPERATIONAL METEOROLOGY

EU COST
Earth System Science and Environmental Management Domain
Action ES0702

Navigation:
Main Menu
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01 - Brussels
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03 - Oslo
04 - Funchal
05 - Reading
News

News:
09/03/2010 - **Next WG+MC meeting will take place March 24-25, 2010 in Reading (UK)**
14/12/2009 - **Presentations from the last WG+MC meeting in Funchal are available...**

EG-CLIMET - European Ground-Based Observations of Essential Variables for Climate and Operational Meteorology

Specification, development and demonstration of cost-effective ground-based integrated profiling systems suitable for future networks providing essential atmospheric observations for both climate and weather

Duration of the Action: 15 Feb 2008 - 13 Nov 2012

Website:
<http://www.eg-climet.org/>

EG-CLIMET: action within EU funded COST program

The screenshot shows the EG-CLIMET website interface. At the top, the COST logo is on the left, and the EG-CLIMET title and subtitle are on the right. The main content area is divided into a left sidebar and a main panel. The sidebar contains three main sections: 'Main Menu' with links to Home, List of Acronyms, and Working Groups; 'Informations' with links to Fact Sheet, Memorandum of Understanding, Expressions of Commitment, Management Committee, Working Groups, and COST Vademecum; and 'Meetings' with links to 01 - Brussels, 02 - Payerne, 03 - Oslo, 04 - Funchal, and 05 - Reading. The main panel features the title 'EG-CLIMET Working Groups (WG)' and a list of four working groups, each with its chair's name and country. A box on the right side of the main panel contains the website URL.

EG-CLIMET
EUROPEAN GROUND-BASED OBSERVATIONS OF ESSENTIAL VARIABLES
FOR CLIMATE AND OPERATIONAL METEOROLOGY

EG-CLIMET Working Groups (WG)

- 1. Instrumentation**
WG1 Chair: **Volker Lehmann (DE)**
- 2. Assimilation**
WG2 Chair: **Per Uden (SW)**
- 3. Observing Experiments**
WG3 Chair: **Catherine Gaffard (UK)**
- 4. Optimum Observation Strategies**
WG4 Chair: **Herman Russchenberg (NL)**

Website:
<http://www.eg-climet.org/>

Recommendations by the EG-CLIMET group (so far)

- Use MWR networks to diagnose / monitor the forecasting (NWP) systems
- Model evaluation carried out
 - in space of retrieved operators at first
 - At a later stage, compare simulated measurements with instrument data (calculate TB radiances, „forward operator“)
- Data assimilation either with retrieved quantities or radiances (depending on grid of instruments available)
- Using 4D-VAR assimilation, time resolution will likely compensate poorer spatial sampling!

- Current effort (until next meeting in June) focuses on forward-operators for microwave radiometer
- Stimulate the community to run OSSEs (Observing System Simulation Experiments) to assess the optimum observation system grid

International efforts towards MWR data assimilation

- One immediate result from EG-CLIMET: Starting of MWRnet

MWRnet - An International Network of Ground-based Microwave Radiometers

Home

Information

- What is MWRnet?
- News
- More information
- Picture Gallery
- Contacts

Community

- How to join
- Members
- The network
- MWRnet library
- Software

Last update: 22 March 2010

Designed by N.C. - Powered by [HIMET](#)

MWRnet – a central point for expertise and data

- Share expertise, software, publications
- Data archive
- Real-time dissemination of data

MWRnet - An International Network of Ground-based Microwave Radiometers



The screenshot displays the MWRnet website interface. On the left is a navigation menu with sections: Home, Information (What is MWRnet?, News, More information, Picture Gallery, Contacts), Community (How to join, Members, The network, MWRnet library, Software), and a footer with 'Last update: 22 March 2010'. The main content area features a world map with red location pins indicating radiometer sites across North America, Europe, Asia, South America, Africa, Australia, and Antarctica. A scale bar at the bottom left shows 5000 Meilen and 5000 km. A text box in the center of the map contains the website URL: <http://cetemps.aquila.infn.it/mwrnet/>. The map includes a 'Karte' tab and a 'Gelände' (terrain) view option. A small diagram in the top left shows a 3D coordinate system with x, y, and z axes and a sine wave labeled 'net'.