



Radiometer Physics GmbH

RPG-HATPRO Dual Tropospheric Profiler



APPLICATIONS

- Tropospheric profiling of temperature, humidity and liquid water
- Input for weather and climate models (assimilation)
- Satellite tracking (GPS, Galileo,...) wet/dry delay and humidity profiles along line of sight
- Nowcasting of atmospheric stability (severe weather detection)
- Temperature inversion detection, fog, air pollution
- Absolute calibration of cloud radars
- Wet and dry delay corrections in VLBI applications

FEATURES

- Temperature, Humidity and Liquid Water Profiler (0-10 km)
- Fast data acquisition due to direct detection filterbank receivers (100% duty cycle)
- All 14 microwave channels measured in parallel
- High temporal resolution (1 second), high spatial resolution (2° HPBW)
- IWV (integrated water vapour) and LWP (integrated cloud liquid) full sky maps (350 points) within 6 minutes (only with azimuth positioner option). Determination of cloud coverage and monitoring of abrupt changes in the 3d humidity field
- Satellite tracking mode to determine the wet / dry delay and atmospheric attenuation in the line of sight for all visible satellites like GPS, Galileo, etc. (only with azimuth positioner option), system also measures humidity profile along line of sight
- Immune to RF interference below 18 GHz (e.g. radio transmitters, mobile phones etc.), direct detection receiver layout
- Purely passive operation, no internal oscillators or other RF sources
- Extremely short calibration cycles (absolute calibration takes only 4 minutes)
- Fully automatic internal calibrations (manual calibration required only every 6 month)
- Very high vertical resolution of temperature profiles (50 m) in the planetary boundary layer, important for the detection of low level temperature inversions
- Internal data file backup system
- Stability indices retrievals included
- Rain and fog mitigation system, strong blower and hydrophobic coating, efficient heater module to prevent formation of dew under fog conditions
- All levels of product data available (Level 0 = detector voltages, Level 1 = calibrated brightness temperatures, Level 2 = retrieved atmospheric data)
- Instrument can be upgraded by another radiometer to increase its capabilities and accuracy (Master / Slave configuration), e.g. with a RPG-LWP-150-90 radiometer

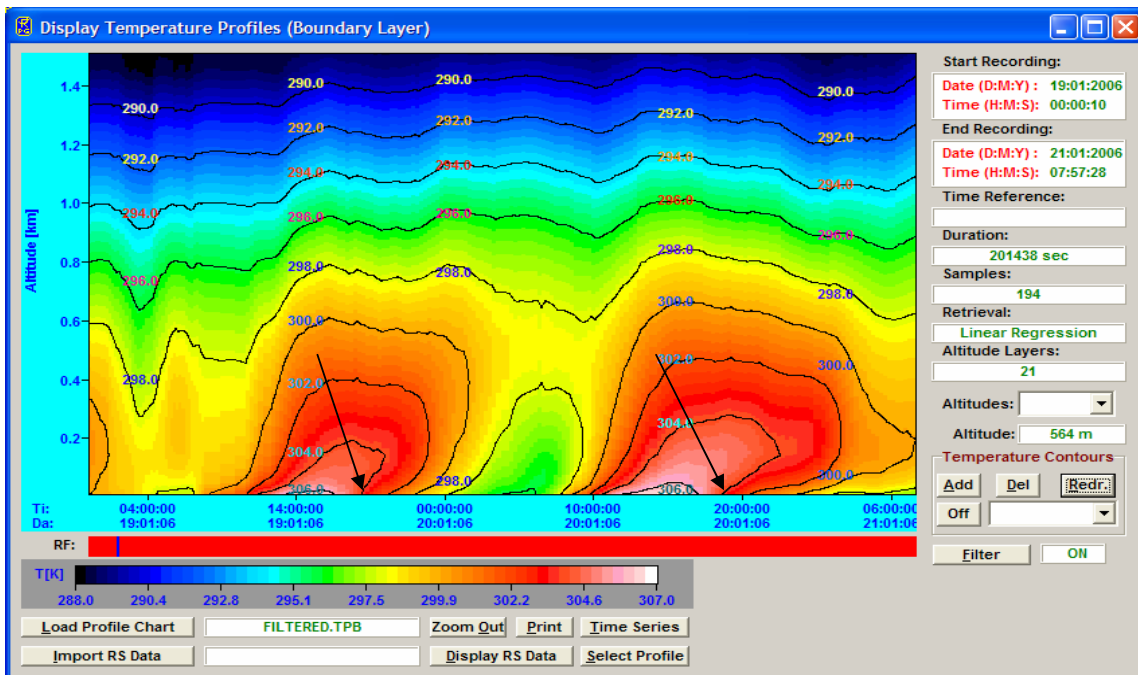
INTRODUCTION

The RPG-HATPRO humidity and temperature profiling passive microwave radiometer measures a variety of atmospheric quantities with high temporal and spatial resolution. Due to its two 7 channel filterbank receivers it offers a high speed parallel detection of all 14 channels. In contrast to other systems that utilize a sequential channel scanning e.g. with a synthesizer (the classical spectrum analyzer concept) the RPG-HATPRO is capable of performing fast LWP (Liquid Water Path) sampling with 1 second time resolution and outstanding noise performance of $< 2 \text{ g/m}^2$ RMS while simultaneously measuring full troposphere (up to 10 km altitude) profiles of temperature and humidity.

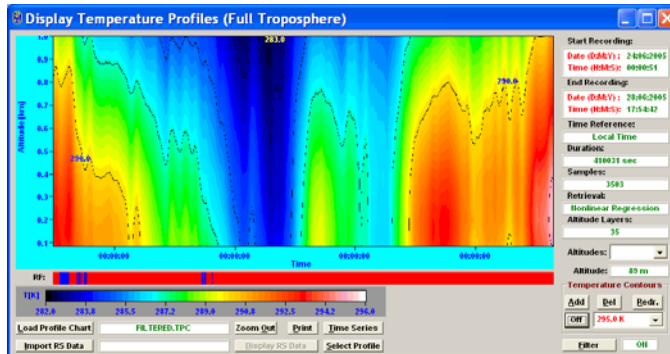
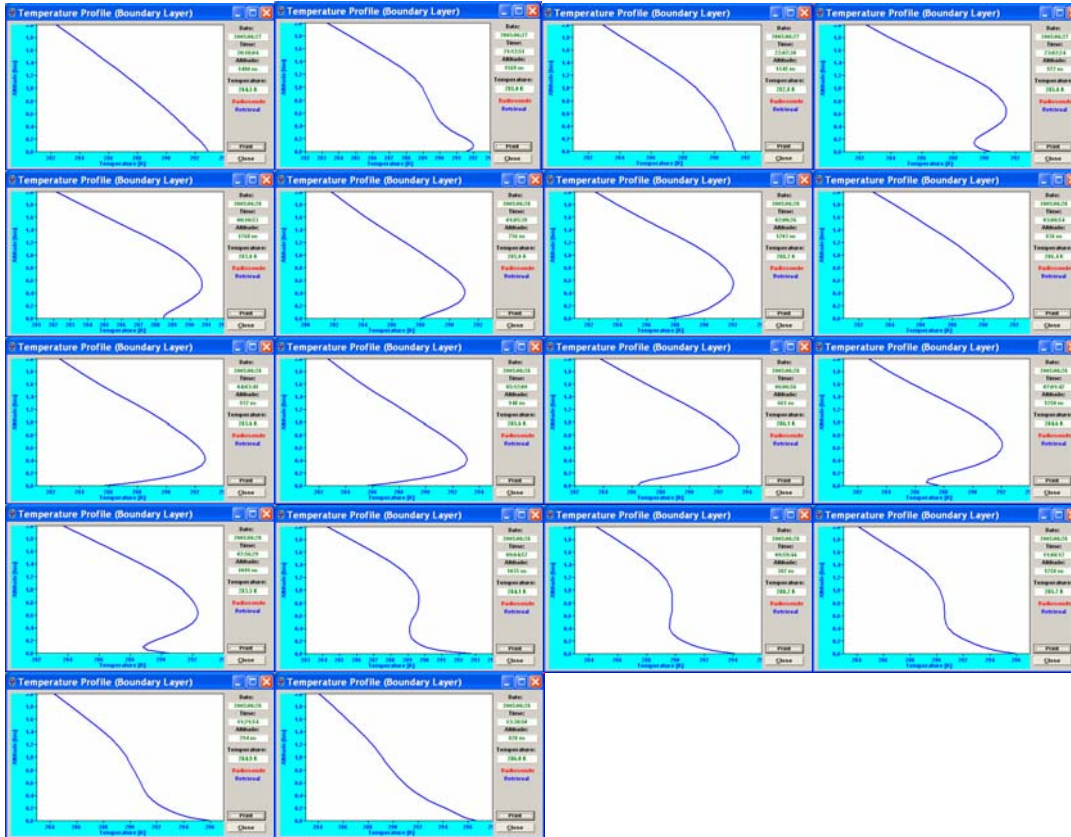
In addition the instrument supports two different scanning modes to achieve a maximum accuracy and vertical resolution for temperature profiling in the full troposphere ($< 10000 \text{ m}$, vertical resolution $150 - 250 \text{ m}$) and boundary layer ($< 1000 \text{ m}$, vertical resolution 50 m). These two modes are referred to as zenith mode (observation only in zenith direction for full troposphere temperature and humidity profiling, LWP, IWV) and boundary layer mode (observation in 6 different elevation angles for boundary layer temperature profiling). In boundary layer mode the system scans the sky in elevation to increase the amount of acquired information by sampling all channels in different directions (down to 5° elevation angle). It has been shown that this method increases the vertical resolution and accuracy of temperature profiles in the atmospheric boundary layer while the zenith mode is best for profiling the whole troposphere with lower vertical resolution. A high vertical resolution in the boundary layer is essential in order to resolve temperature inversions which mainly occur in that layer.

HIGHLIGHTS

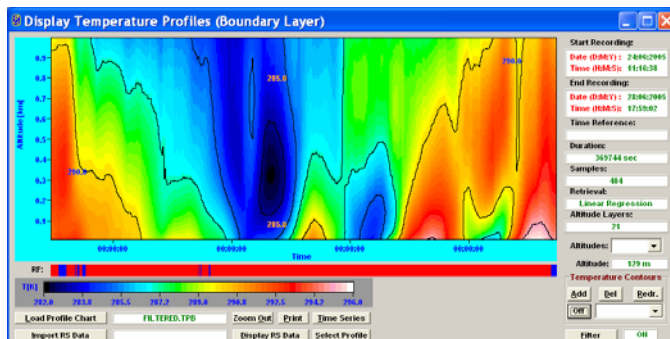
Fast and accurate boundary layer profiling allows for the monitoring of the formation and decay of temperature inversions:



Monitoring formation and decay of temperature inversions:

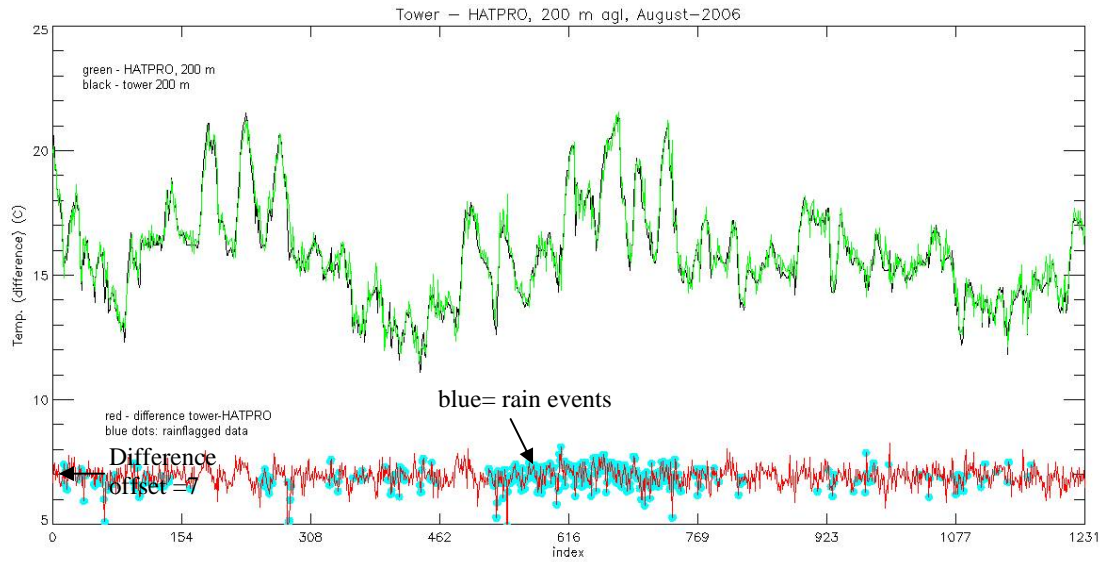


Zenith observation mode: In the lower 500 m layer the vertical structure is poorly resolved.

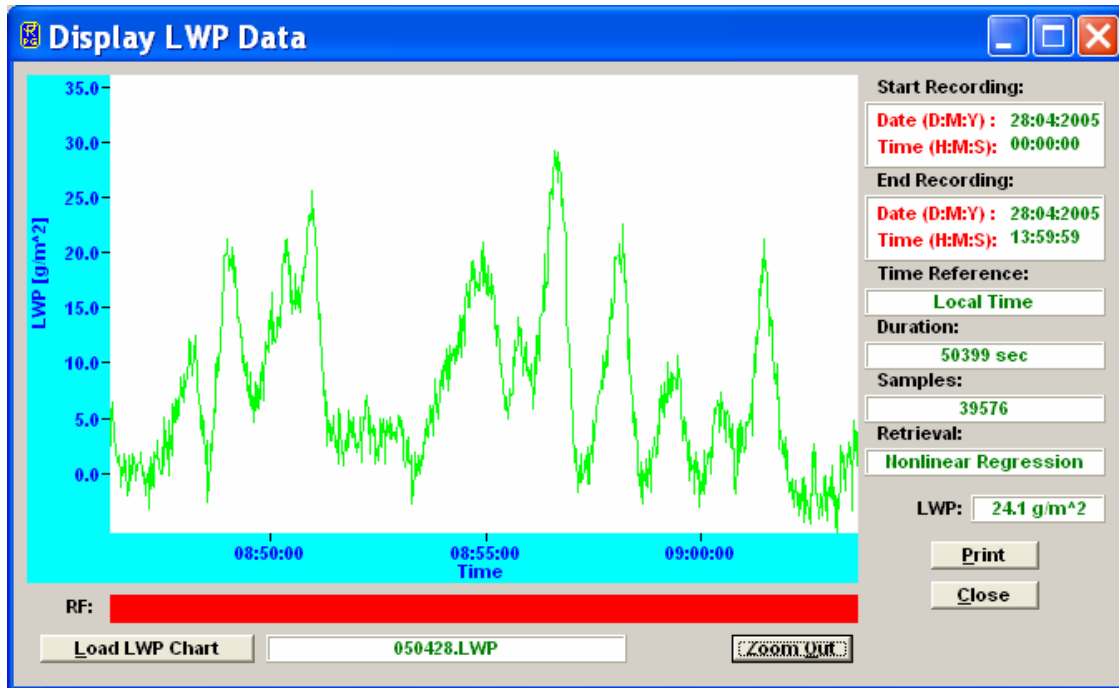


BL observation mode: The vertical structure (inversions) is resolved much better.

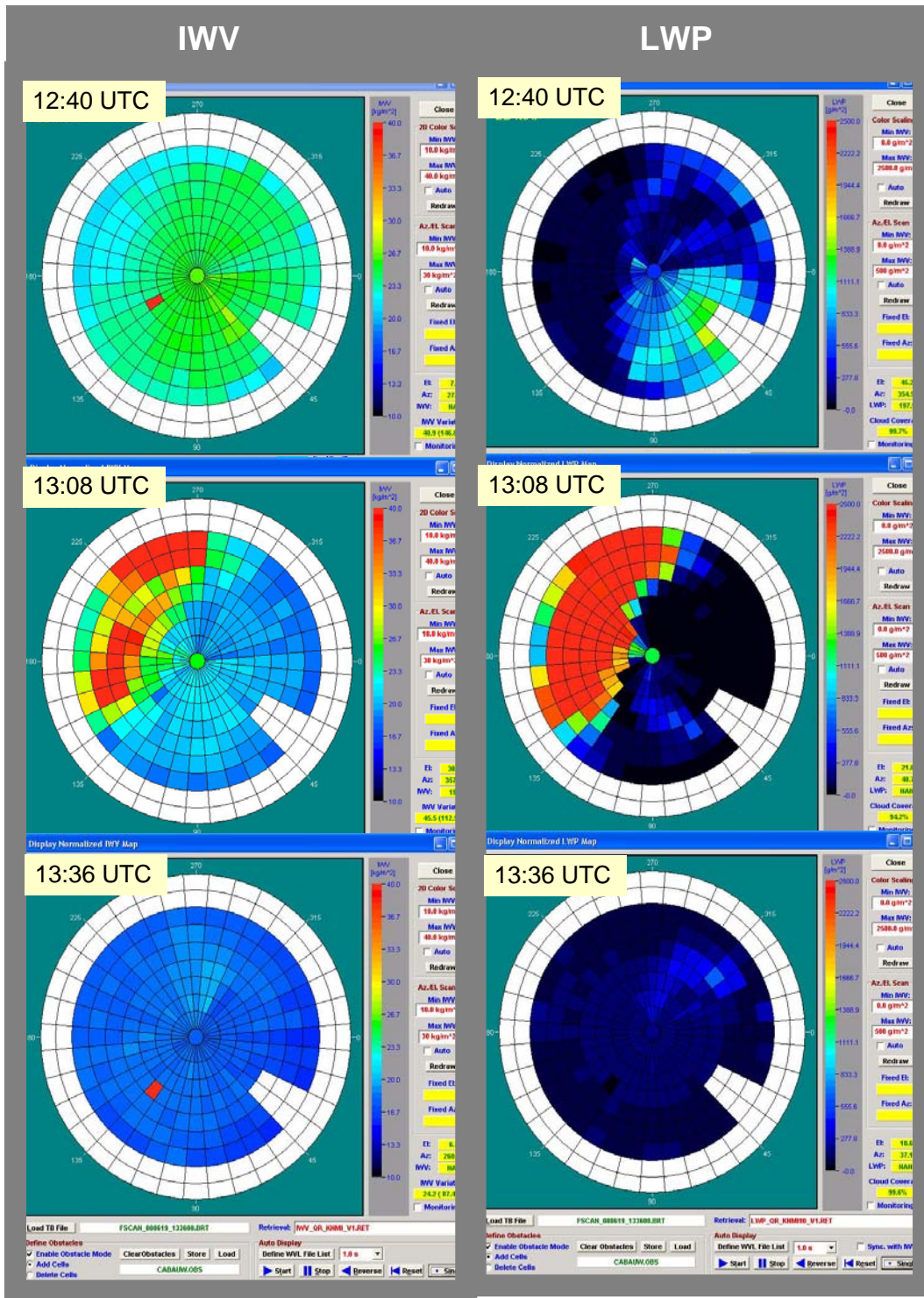
Comparison of HATPRO 200 m temperature measurements (in BL mode) with meteorological tower temperature sensor readings in the same altitude (courtesy of Henk Klein-Baltink, KNMI, Neatherlands):



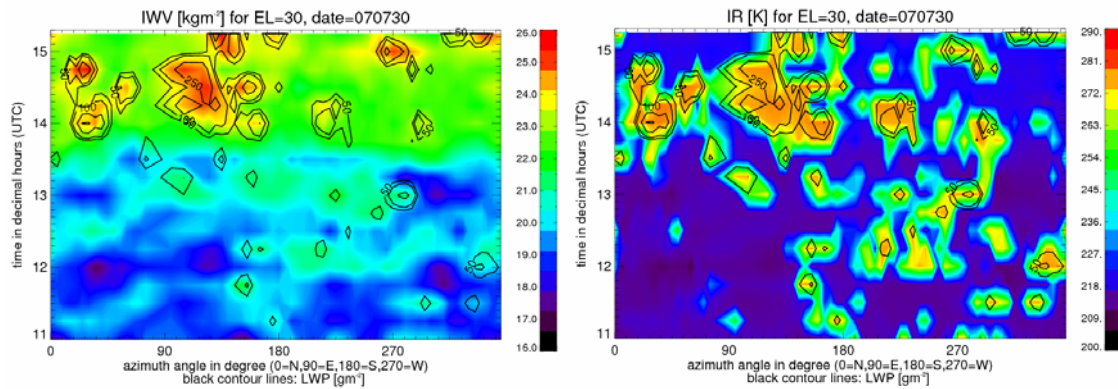
High temporal resolution LWP time series with measurement noise of only 2 g/m² (0.002 mm) RMS:



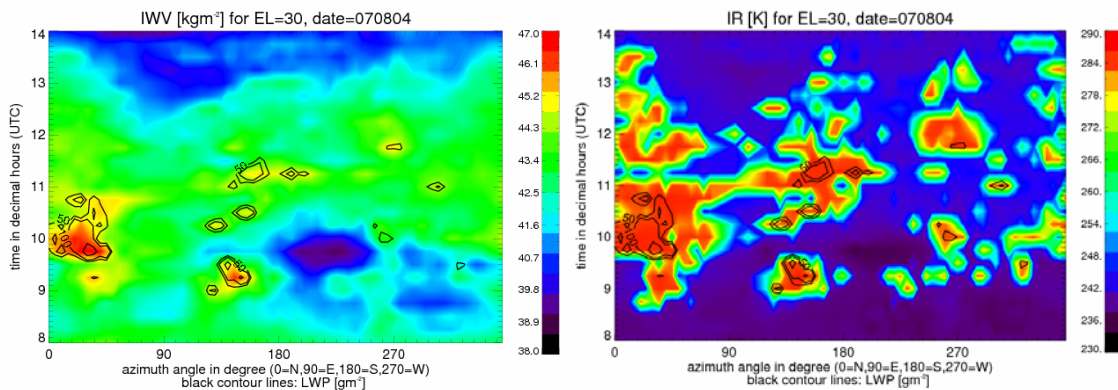
Full sky IWV and LWP maps showing inhomogeneous water vapour distributions and cloud coverage:



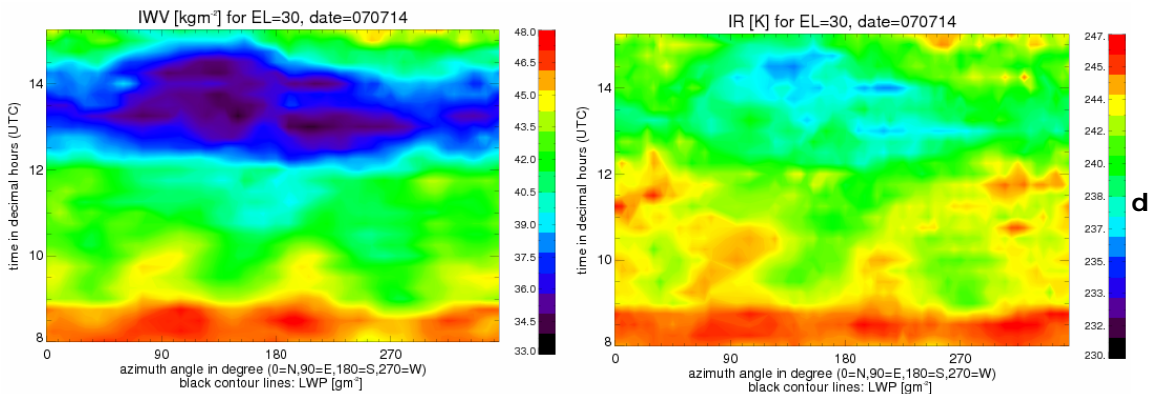
The spatial and temporal evolution of integrated water vapour content (IWW), sky-temperature (IR) and liquid water path (LWP) are visualized by Time-Azimuth-(Hovmöller) Diagrams (courtesy of Stefan Kneifel, University of Cologne).



30 July 2007: Development of Cu-convection after frontal passage; Observed IWW varies up to 20% even in regions with low LWP (<50 g/m²); max. LWP ~500 g/m²

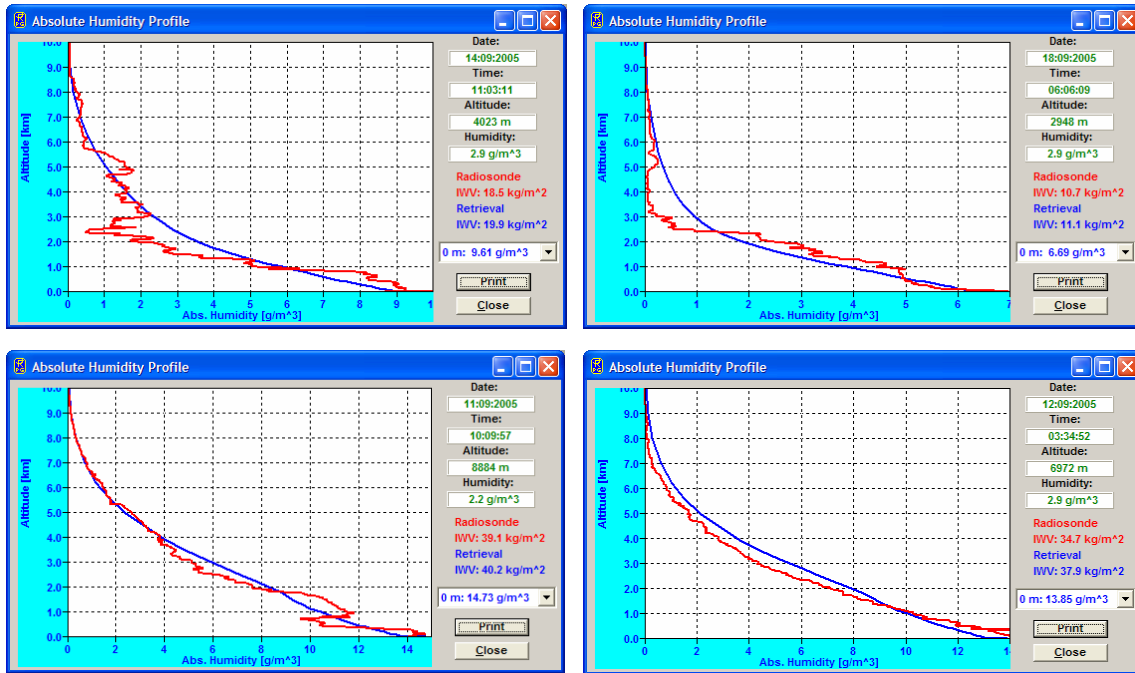


05 August 2007: Cloud development suppressed by strong subsidence; weak winds in the lower troposphere; IWW-differences of ~14% in the NE/SW from 6 to 15 UTC



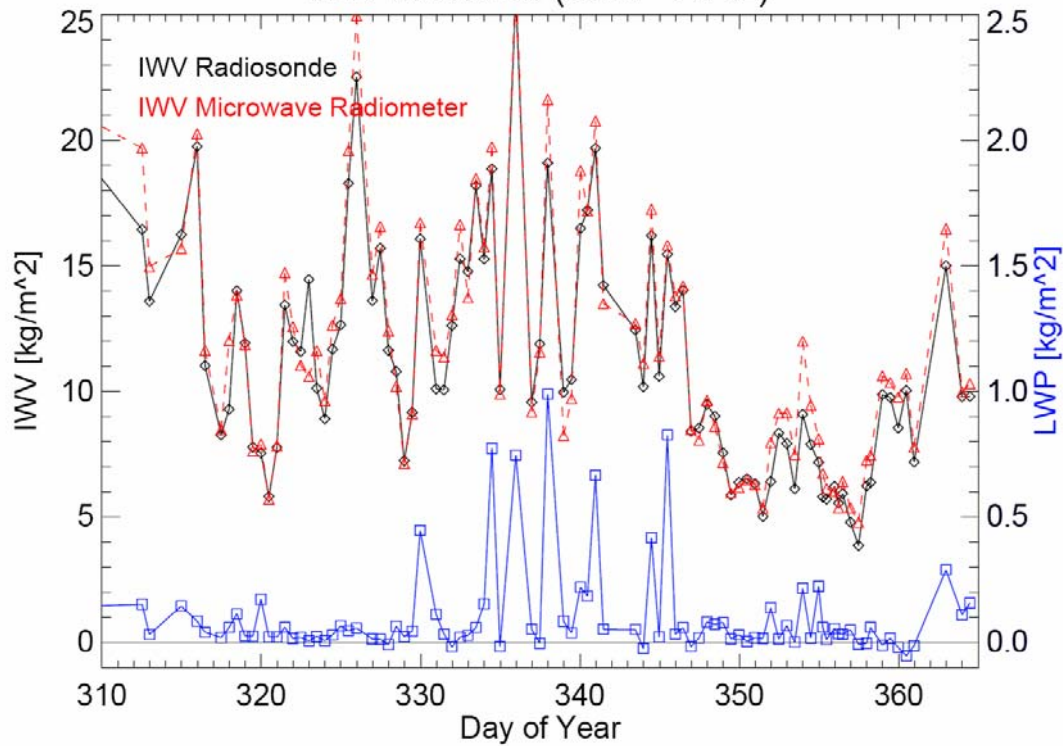
14 July 2007 (IOP 8a): Clear sky conditions (strong subsidence); Spatial and temporal structures appear in the measurements of IWW and IR-temperature.

Accurate humidity profiling:

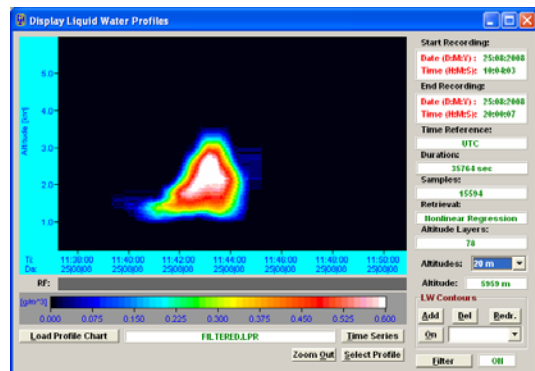
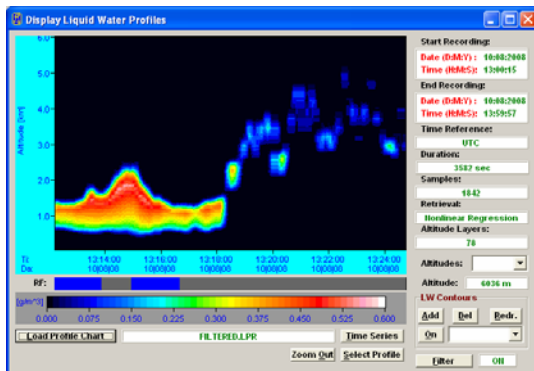
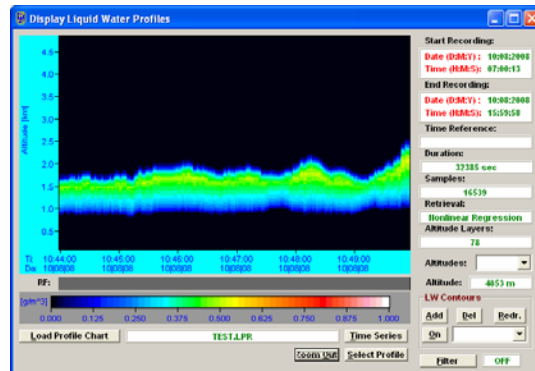
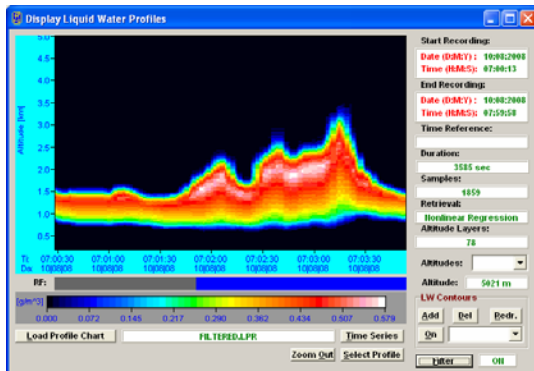
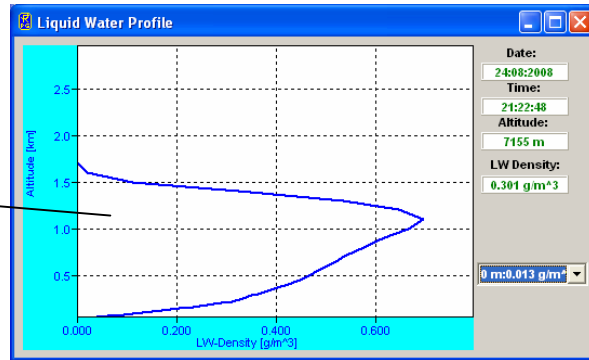
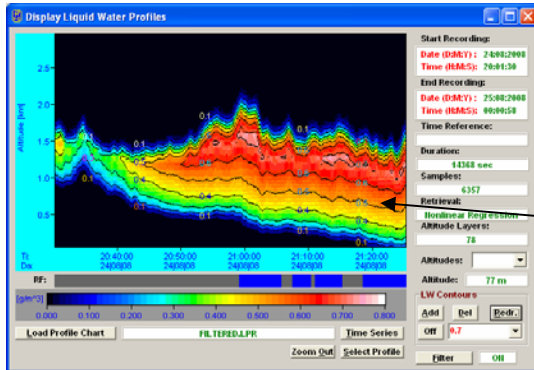
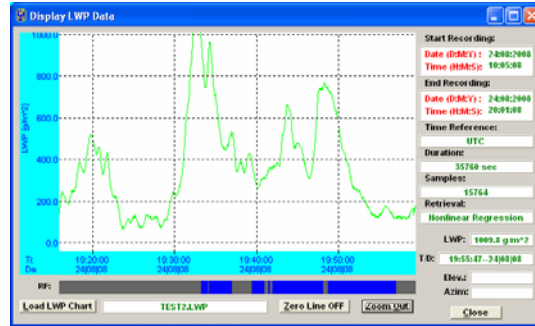
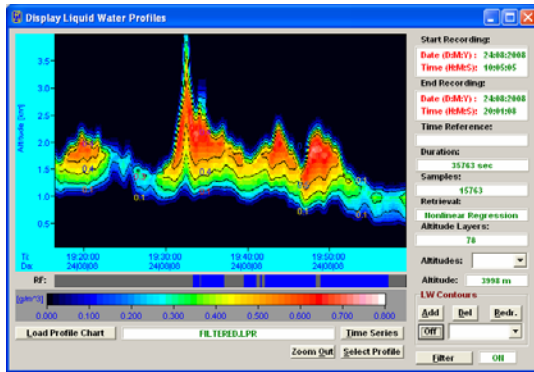


Water Vapour measurements remain accurate even with LWP of 1000 g/m²:

IWV Retrieval (2007-11.12)



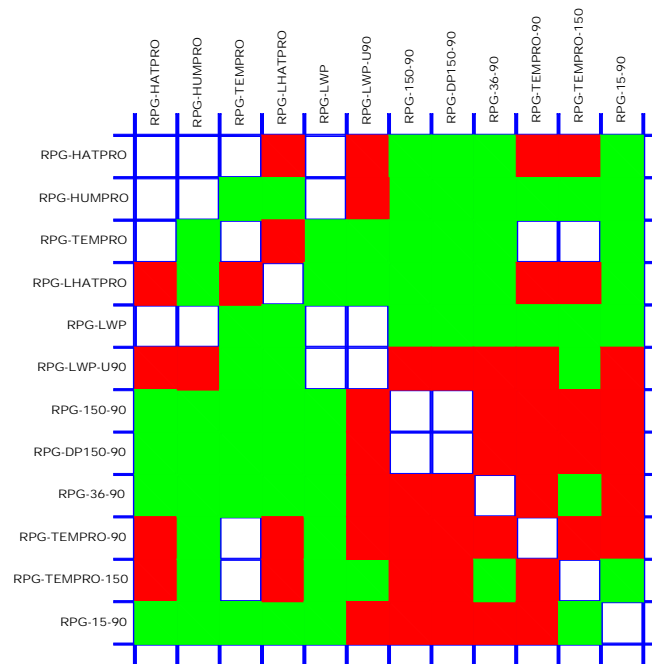
Liquid water profiling of clouds:



Radiometer extensions: The RPG-HATPRO can be combined with other RPG radiometers to a virtually single instrument.



Combination Matrix:



Possible Master/Slave combinations for current RPG models. Green: Ideal combination (no channel overlaps). Red: Channel overlaps

DETAILED INSTRUMENT SPECIFICATIONS

Parameter	Specification
Humidity profile performance (zenith and along track)	Vertical resolution: 200 m (range 0-2000 m) 400 m (range 2000-5000 m), 800 m (range 5000-10000 m) Accuracy: 0.4 g/m ³ RMS (absolute hum.) 5% RMS (rel. humidity)
Temperature profile performance (zenith and along track)	Vertical resolution: BL-Mode: 50 m (range 0-1200 m) Z-Mode: 200 m (range 1200-5000 m) 400 m (range 5000-10000 m) Accuracy: 0.25 K RMS (range 0-500 m) 0.50 K RMS (range 500-1200 m) 0.75 K RMS (range 1200-4000 m) 1.00 K RMS (range 4000-10000 m)
Liquid water profile performance (only with IR radiometer option)	Vertical resolution: 250 m (range 0-2000 m) 300 m (range 2000-5000 m), 500 m (range 5000-10000 m) Accuracy: cloud base height: 50 m (range 0-300 m) 100 m (range 300-1000 m) 200 m (range 1000-3000 m) 400 m (range 3000-5000 m) 600 m (range 5000-10000 m) density: 0.03 g/m ³ RMS Threshold: 50 g/m ² LWP Only single layer clouds are modelled
IR radiometer option	9.2-10.6 μm band, accuracy 1 K, noise: 0.2 K RMS
LWP	Accuracy: +/- 20 g/m ² Noise: 2 g/m ² RMS
IWV	Accuracy: +/-0.2 kg/m ² RMS Noise: 0.05 kg/m ² RMS
Full sky IWV and LWP maps (only with azimuth positioner option)	350 points in 6 minutes rapid scanning
Satellite tracking mode (only with azimuth positioner option)	Determines wet/dry delay, atmospheric attenuation and humidity profiles along line of sight for all visible GPS / Galileo satellites in a single scan (2 minutes) scanning with RINEX navigation file or direct GPS vector reading from GPS clock
Channel center frequencies	K-Band: 22.24 GHz, 23.04 GHz, 23.84 GHz, 25.44 GHz, 26.24 GHz, 27.84 GHz, 31.4 GHz V-Band: 51.26 GHz, 52.28 GHz, 53.86 GHz, 54.94 GHz, 56.66 GHz, 57.3 GHz, 58.0 GHz
Channel bandwidth	2000 MHz @ 58.0 GHz, 1000 MHz @ 57.3 GHz, 600 MHz @ 56.66 GHz, 230 MHz @ all other frequencies
System noise temperatures	<400 K for 22-31 GHz profiler, <700 K for 51.4-58.0 GHz profiler
Radiometric resolution	K-Band: 0.10 K RMS, V-Band: 0.20 K RMS @ 1.0 sec integration time
Absolute brightness temperature accuracy	0.5 K
Radiometric range	0-800 K
Absolute calibration	with internal ambient & external cold load
Internal calibration	gain: with internal noise standard gain + system noise: amb. temp. target + noise

	standard abs. cal. of humidity profiler: sky tipping calibration
Receiver and antenna thermal stabilization	Stability better than 0.03 K over full operating temp. range
Gain nonlinearity error correction	Automatic, four point method
Brightness calculation	based on exact Planck radiation law
Integration time	≥ 0.4 seconds for each channel, user selectable
Sampling rate for profiles	> 1 sec, user selectable
Rain / fog mitigation system	High efficient blower system (130 Watts), hydrophobic coated microwave transparent window, 1.8 kW heater module preventing formation of dew under fog conditions
Data interface	RS-232, 115 kBaud
Data rate	10 kByte/sec., RS-232
Instrument control (external)	Host: Industrial PC, temp. range -10°C to $+60^{\circ}\text{C}$, 4 x RS232, 2 x LAN, 2 x USB
Instrument control (internal)	Embedded PC, controls all internal calibrations, data acquisition, data file backup on 1 Gbyte flash memory, control of azimuth positioner, communication with host, can run measurements independently from host PC
Housekeeping	all system parameters, calibration history documen- tation
Retrieval algorithms	neural network, lin. / nonlin. regression algorithms
Optical resolution	HPBW: 3.5° for water vapour, 1.8° for temperature profiler
Sidelobe level	$< -30\text{dBc}$
Pointing speed (elevation)	$45^{\circ}/\text{sec}$
Pointing speed (azimuth), optional	$40^{\circ}/\text{sec}$
Operating temperature range	-40°C to 45°C
Power consumption	< 120 Watts average, 350 Watts peak for warming-up (without dew blower heater), blower: 130 Watts max.
Lightning protection	Power line: circuit breakers Data line: Fiber optics data cable (max. length: 1400 m)
Input voltage	90-230 V AC, 50 to 60 Hz
Weight	60 kg (without dew blower)
Dimensions	$63 \times 36 \times 90 \text{cm}^3$