A Novel Ground-based Microwave Radiometer for High Precision Atmospheric Observations Between 10 and 90 GHz ATPROP (ATmosperic Propagation and Profiling System)

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Motivation

Atmospheric constituents like water vapour and clouds show a high spatial and temporal resolution. On one hand it is of high interest for **meteorological applications** to better capture the turbulent structure of the atmosphere. On the other hand atmospheric constituents also control the propagation of electromagnetic waves. For **radio science applications** it is therefore important to accurately describe atmospheric disturbance.

A precise and stable microwave radiometer to observe the relevant atmospheric parameter has been developed in the frame of an ESA-ESTEC project: the *Atmospheric Propagation and Profiling* System (ATPROP)

- A new calibration technique using a fast cycling between target, Dicke Switch and noise diode enables highly precise and continuous measurements
- A turntable combined with internal elevation mirrors allows flexible pointing, for example tracking individual satellites or mapping the spatial variability by volume scanning.

Technical Specifications

Freuquency channels:

HATPRO - Humidity And Temperature PROfiler:

- Water vapour band (WV) 7 frequencies at K-band between 22 and 31 GHz
- Oxygen band (OXY) 7 frequencies at V-band from 51 to 59 GHz for temperature profiling

Additional frequencies:

- 15 GHz with high sensitivity to heavy cloud and light rainfall
- 90 GHz with high sensitivity to cloud liquid water

Two separate radiometer coupled by control software:

Master – Slave system:
Master: HATPRO (top)
Slave: 15 / 90 GHz

Retrieved Quantities:

Atmospheric parameters:

- Temperature profiles
- Humidity profiles
- Integrated Water Vapour – IWV
- Liquid Water Path – LWP

Propagation parameters:

- Excess Path Length (EPL)
- Attenuation for rainy / non-rainy conditions

Evaluation using Radiosondes

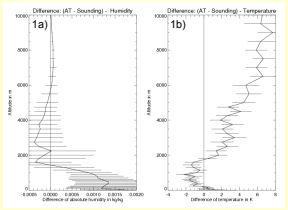


Figure 1: Differences and standard deviation between ATPROP and Radio soundings of a) humidity, b) temperature profiles

- Comparison with radiosondings shows RMS in the order of instrument noise
- Mean difference of humidity profiles less than 10%
- Bias and RMS of +/- 1.5 K in the lower troposphere acceptable compared to other studies

During the intensive observation period of the EUCAARI campaign (European Integrated project on Aerosol Cloud Climate Air Quality Interactions) in May 2008, 3 radio soundings a day were launched next to ATPROP. Different retrieval algorithms have been applied to ATPROP brightness temperature measurements and compared to radio sonde observations.

Best results for this time range were found using a retrieval algorithm including water vapour frequencies + 90 GHz +15 GHz

IWV: respecting only clear sky cases
Attenuation: respecting all cases

Table 1: Comparison of retrieval algorithms using different frequency constellations

Retrieval	Frequency combinations in GHz	RMS	BIAS	Corr coeff	Relative error in %
Attenuation 36.5 GHz	31.4 + 51.26	0.0044 nep	-0.038 nep	0.79	6.18
	27.84, 31.4 , 51.26, 52.28	0.0045 nep	-0.037 nep	0.79	6.30
	WV - Band	0.0042 nep	-0.037 nep	0.81	5.88
	WV - Band + 15.3 + 90	0.0040 nep	-0.036 nep	0.81	5.63
	All ATPROP frequencies	0.0076 nep	0.0065 nep	0.77	13.07
IWV	WV - Band	0.74 kg / m²	1.26 kg / m²	0.98	5.60
	WV - Band + 90	0.76 kg / m²	0.91 kg / m²	0.98	5.72
	WV - Band + 90 + 15	0.74 kg / m²	0.81 kg / m²	0.98	5.59
	All ATPROP frequencies	0.77 kg / m²	0.82 kg / m²	0.98	5.83

Example of ATPROP measurements on 19. June 2008

Weather conditions

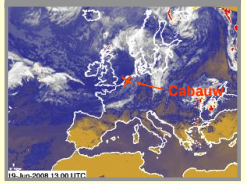


Figure2: Satellite image from the frontal passage on 19.07.2008 13:00 UTC

Cold frontal passage :

- Before the front a humid air mass with cloudy conditions and some rain dominates the Netherlands
- The warm sector was present over Cabauw between 4:00 and 12:00 UTC
- The frontal passage occurred between 12:00 and 14:00 UTC with varying cloud thickness and some rain events
- Behind the front a much drier air mass occurs over Cabauw - first with convective events later withlonger clear sky periods

Temperature and humidity

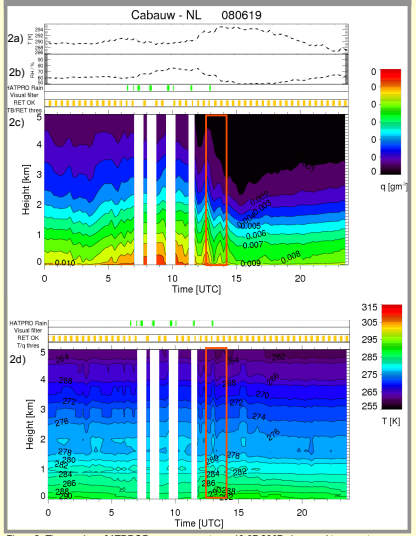


Figure3: Time series of ATPROP measurements on 19.07.2007 a) ground temperature, b) ground humidity, c) humidity profile, d) temperature profile

Since mid April ATROP has been operated at the Cabauw Experimental Site for Atmospheric Research (CESAR) in the Netherlands.

As an example Figures 3 to 5 illustrate a single day, e.g. 19th June 2008 of ATRPOP data. Temperature and humidity profiles (Fig. 3) of the whole day identify the time range of the frontal passage: air mass exchange can be clearly noticed around 13:00 UTC (red box all three plots)

Volume scans (Fig. 5) reveal the strong spatial inhomogeneity in water vapour and liquid at 12:40, 13:08 and 13:36 UTC. The exchange of the air mass from North-West can be identified clearly and strong differences in both quantities can be found particularly at the two first time steps.

Integrated quantities

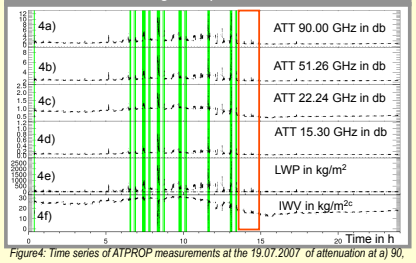
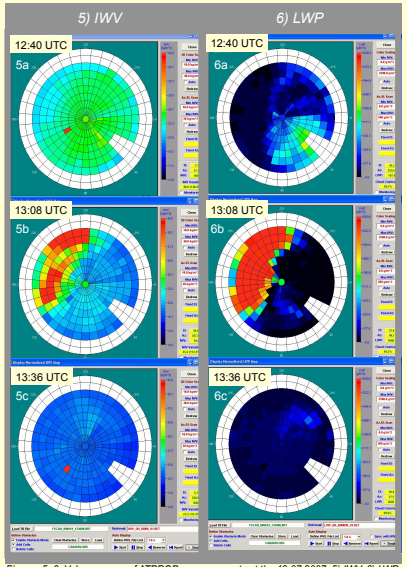


Figure4: Time series of ATPROP measurements at the 19.07.2007 of attenuation at a) 90, b) 51.26, c) 22.24, d) 15.3 GHz; e) LWP, f) IWV , Gaps are due volume scans



Figures 5, 6: Volume scans of ATPROP measurements at the 19.07.2007; 5) IWV, 6) LWP; at a) 12:40, b) 13:08, c) 13:36 UTC

Conclusions

- ATPROP is able to investigate the spatial and temporal variability of different meteorological and propagation parameters
- Comparison of ATPROP measurements with radio soundings are close to the theoretical accuracy
- Comparisons with another microwave radiometer (HATPRO) show a very high level of agreement (not shown)
- The 90 and 15 GHz channels improve IWV and attenuation retrieval even at frequencies which can not be measured directly as seen on the example of the attenuation at 36.5 GHz (Tab. 1)

Outlook

- Further comparisons with auxillary instrumentation (cloud radar, lidar, aircraft) will be performed
- Comparisons will be limited to clear sky conditions using ceilometer or infrared radiometer data
- Automatic sky tipping procedure will be improved and first data will berecalibrated
- Three-dimensional distribution of attenuation at different frequencies will be investigated

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