THE 183-GHZ HAMSTRAD-TROPO RADIOMETER: VALIDATION OVER THE PYRENEES MOUNTAINS (FRANCE) AND FIRST MEASUREMENTS AT DOME C (ANTARCTICA)

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1. INTRODUCTION

Water vapor (H_2O) plays a key role in the Earth climate system since it is the main greenhouse gas emitting and absorbing in the infrared domain. Its variability both in the troposphere and in the stratosphere is still an enigma or, at least, is still under discussion [1]. The HAMSTRAD (H_2O Antarctica Microwave Stratospheric and Tropospheric Radiometers) programme aims to develop two ground-based microwave radiometers to sound tropospheric and stratospheric H_2O above the Dome C (Concordia Station), Antarctica (75°06'S, 123°21'E, 3233 m asml) over a long time period. HAMSTRAD-Tropo is a 183-GHz radiometer for measuring tropospheric H_2O, subject to the present paper. The geographical situation of Dome C (high altitude and dry air) is particularly well adapted to the setting of instruments for monitoring the stratosphere and the troposphere, as for instance the microwave radiometers. The altitude of the Dome C site associated with a weak amount of water vapor in the troposphere and very low temperatures encountered in the lowermost altitude layers (one of the driest and coldest site around the world) favors the setting up of microwave radiometers at high frequency and with a much better sensitivity (weak integration time) with respect to sites located at sea level in order to detect both stratospheric and tropospheric water vapor. The present paper focuses on the description of the HAMSTRAD-Tropo instrument dedicated to sound tropospheric H_2O over Dome C. A validation campaign has been performed at the Pic du Midi (PdM, 42°56'N, 0°08'E, 2877 m asml, France) in the Pyrenees Mountains during the period February-June 2008. We will show comparisons of the HAMSTRAD-Tropo H_2O profiles against radiosondes and against measurements from the nadir-viewing IR space-borne Infrared Atmospheric Sounding Interferometer (IASI) instrument aboard the MetOp platform. We will finally show very preliminary results from the HAMSTRAD-Tropo radiometer after being installed at Dome C in January 2009.

2. THE HAMSTRAD-TROPO RADIOMETER

2.1. Theoretical background

The HAMSTRAD-Tropo radiometer [2] has been developed by the Radiometer Physics GmbH (RPG) German Company. It uses spectral information in the microwave bands 51-59 GHz (lower frequency wing of the oxygen line) and 169-197 GHz (strong water vapor line, centered at 183.3 GHz) to derive accurate tropospheric profiles of temperature and low humidity. For temperature profiling the pressure-broadened oxygen line shape is evaluated while the strong water vapor line allows for the profiling of very low humidity with an IWV amount of < 2 kg·m^{-2} (or < 2 mm in precipitable water units). The frequency and bandwidth of seven channels have been optimally selected to derive the vertical profile of temperature from the oxygen line whilst the humidity profiling from the 183-GHz line uses six optimized channels.
A statistical approach is used to calculate the profiles from the brightness temperatures (TBs) measured by the radiometer. The retrieval algorithms are based on a few thousand radio soundings from the area where the instrument is deployed (namely Pic du Midi and Dome C) which provide a set of temperature and humidity data points as a function of altitude. From radiative transfer calculations, a corresponding set of TBs measured on the surface of the two stations and at the radiometer frequencies is derived. Then statistical fit algorithms are applied using linear or quadratic regressions to solve the inverse problem, namely to estimate humidity and temperature profiles from the TB sets. During radiometer operation, the statistical fit coefficients provide an online determination of the tropospheric profiles from the measured TBs. Consequently, the *a priori* information from the radio soundings is introduced into the retrievals.

2.2. Instrument description

The HAMSTRAD-Tropo radiometer is a compact fully-automated instrument. Its dimensions are: 36x65x115 cm^3. The two profiler receiver modules are oriented orthogonally and the two beams are superimposed by a wire grid beam combiner. An off-axis parabola mirror forms an image on the sky with ~2° HPBW (Half-Power Beam Width). The parabola mirror scans the ambient temperature calibration target underneath the mirror. The receiver modules and their feed horns are encapsulated in thermal insulation and a two-stage stabilization system (regulated cooler and Peltier stages) stabilizes the receivers to better than 30 mK over the full operating temperature range. This high stability is essential to fulfill the radiometric stability requirements in the boundary layer mode (namely 0.1 K RMS). The humidity profiling receiver design is a double sideband heterodyne system with a set of frequencies optimized for the Intermediate Frequency (IF). The water vapor line is symmetrical so that both line wings can be detected in parallel by the double sideband detection. This doubles the receiver sensitivity. A low noise sub-harmonic mixer is used as the front end component with a wide IF-bandwidth of 0.4 to 20 GHz. The mixer noise temperature is close to 500 K. Receiver gain fluctuations are calibrated by a precision noise standard that is periodically (100 Hz) injected into the receiver input. The overall system noise temperature, including noise injection section and IF-chain noise temperature is approximately 1500 K. The local oscillator comprises a dielectric resonant oscillator operating at 30.55 GHz followed by a frequency tripler.

3. VALIDATION AT PIC DU MIDI, FRANCE

The HAMSTRAD-Tropo radiometer has been installed at the Pic du Midi (PdM) on 6 February 2008 and was run almost continuously until 20 June 2008. Measurements from HAMSTRAD-Tropo were systematically compared with meteorological soundings routinely performed at 00:00 and 12:00 UTC (and sometimes 06:00 UTC) in Bordeaux-Mérignac Airport (BOR, 44°49'N, 0°42'W, 50 m asml, France) [~220 km North-West from PdM] and in Zaragoza (ZAR, 41°39’N, 0°53’W, 263 m asml, Spain) [~170 km South-West from PdM], together with some sporadic soundings performed from the site of Lannemezan (43°07′N, 0°23′E, 610 m asml, France), about 50 km North-East from PdM, during the February-March 2008 period around 12:00 UTC. In parallel, we also used the tropospheric H_2O profiles measured by the space-borne IASI instrument on the MetOp platform routinely delivered by EUMETSAT. The comparisons show a great consistency to within 0.2-0.3 $g{\cdot}m^{-3}$ between all absolute humidity data sets in dry conditions (mainly February 2008) from 0 to 6 km above the PdM, and a wet bias of HAMSTRAD-Tropo in standard wetter conditions.

4. FIRST MEASUREMENTS AT DOME C, ANTARCTICA

We will also present the very first measurements of tropospheric H_2O performed by the HAMSTRAD-Tropo instrument after its installation at the Dome C (Concordia station, Antarctica) over the period January-February 2009.

5. CONCLUSIONS

Using state-of-the-art technology, the HAMSTRAD-Tropo radiometer uses spectral information in the domains 51-59 GHz (oxygen line) and 169-197 GHz (water vapor line) to derive accurate tropospheric profiles of temperature (accuracy ranging 0.25-1.0 K) and low absolute humidity (accuracy ranging 0.01-0.03 $g{\cdot}m^{-3}$). Prior to its installation at Dome C in January 2009, the fully-automated radiometer has been deployed at the Pic du Midi (PdM, 42°56'N, 0°08'E, 2877 m asml, France) in February-June 2008. Comparisons with radio soundings and IASI space-borne sensor show a great consistency to within 0.2-0.3 $g{\cdot}m^{-3}$ between all absolute humidity data sets in dry conditions (mainly February 2008). The very first measurements of tropospheric H_2O performed by the HAMSTRAD-Tropo instrument after its installation at the Dome C (Concordia station, Antarctica) in January 2009 will also be presented.

6. REFERENCES

[1] M. Scherer, H. Vömel, S. Fueglistaler, S. J. Oltmans, and J. Staehelin, “Trends and variability of midlatitude stratospheric water vapor deduced from the re-evaluated Boulder balloon series and HALOE,” *Atmos. Chem. Phys*., vol. 8, pp. 1391-1402, 2008.

[2] P. Ricaud, G. Gabard, S. Derrien, O. Drasin, J.-P. Chaboureau, T. Rose, A. Mombauer, and H. Czekala, “HAMSTRAD-Tropo, A 183-GHz Radiometer Dedicated to Sound Tropospheric Water Vapor over Concordia Station, Antarctica,” *IEEE Transactions on Geoscience and Remote Sensing*, Revised, 2009.