Tropical Stratospheric Water Vapour Observed by Ground-Based Microwave Spectrometry

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Introduction

Water vapour plays a key role in middle atmospheric processes. Because of its large infrared resonance, it contributes to radiative cooling. It is a source gas for the highly reactive hydroxyl radical, and exerts further indirect effects on ozone destruction in the formation of polar stratospheric clouds. It also serves as a dynamical tracer. The processes governing water vapour distribution, variability, and trends are still not sufficiently understood [1]. Continuous long-term monitoring of stratospheric water vapour is of particular importance in the separation of trend signals from the large seasonal and annual variations in water vapour entering the stratosphere. This happens mainly through the tropical transition layer.

Instrumentation

The authors observe tropical stratospheric water vapour with the ground-based microwave spectrometer WaRAM2 at Mérida Atmospheric Research Station, Pico Espejo, Venezuela (8°32' N, 71°03' W, 4765 m above sea level). WaRAM2 is the only such sensor to operate at tropical latitudes. It records thermal emission from the rotational transition of water wapour at 22.235 GHz. The incident power is calibrated against two reference loads, and the signal is spectrally resolved at 1.1 MHz resolution. Volume mixing ratio (VMR) profiles are retrieved using the optimal estimation method [2], implemented by the ARTS/Qpack environment [3, 4]. Figure 1 displays some typical averaging kernels (AVK) for the retrieval. Altitude resolution, in terms of AVK full-width at half-maximum, ranges from 8 to 12 km. Profile retrievals are reliable between 30 and 50 km at the moment. The observational error for a 4 h measurement amounts to 20% (0.6–1.0 ppmv). [2]

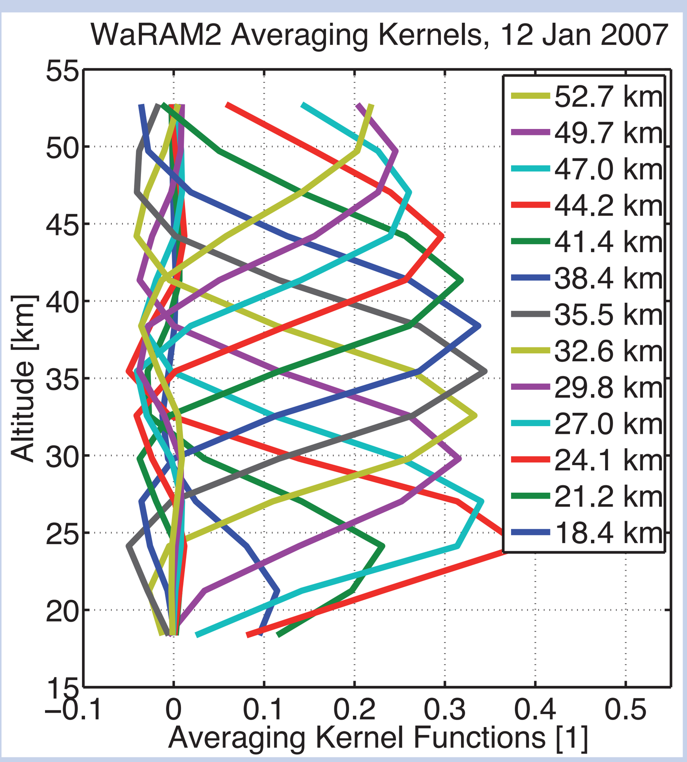

Figure 1: Selected averaging kernels (AVK) of the WaRAM2 retrieval on 12 Jan 2007. The legend indicates centre altitudes of the individual retrieval grid layers. Altitude resolution ranges from 8 to 12 km.

Instrument Sensitivity

To explore the sensitivity limit of the WaRAM2 instrument, the retrieval set-up has been tested against artificial spectra. These have been calculated from UARS/HALOE H_2O results for 1993/94, zonal averages over the latitude band 12°N–12°S, which provides the magnitude of the seasonal signal that WaRAM2 is intended to detect. The artificial spectra are superposed with white Gaussian noise, corresponding to 24 h of WaRAM2 atmospheric observations, and are then used as input to the retrieval. Figure 2 takes a look at the results. At ~24 km, which is the bottom limit of sensitivity (*cf.* figure 1), they match most of the original HALOE data well within error bars, and reproduce the seasonal signal found in them. This gives a first indication of WaRAM2 capabilities in the analysis of seasonal H_2O signals. Note that measured spectra exhibit more effects than just noise, e.g. systematic errors – these must be adequately considered in the sensor model.

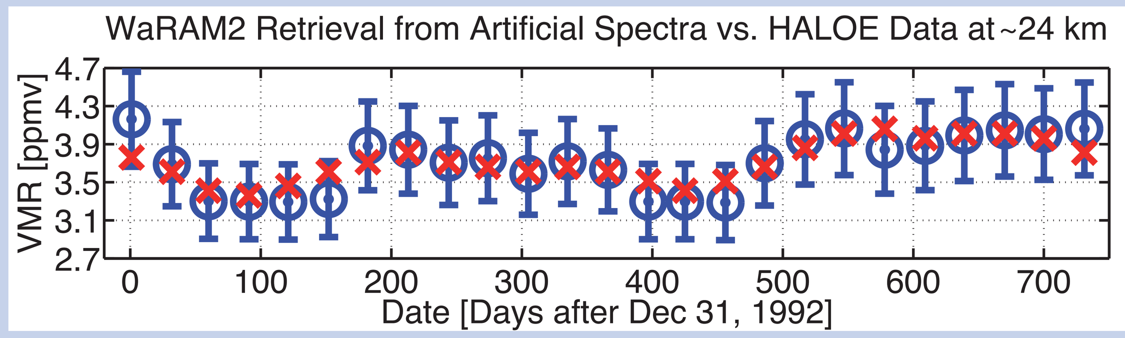

Figure 2: UARS/HALOE water vapour data (red crosses) are used to calculate artificial spectra (see text). Blue circles, with error bars, indicate results of WaRAM2 retrieval from these artificial spectra.

Acknowledgements

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Results

WaRAM2 operation depends on liquid nitrogen being available for calibration, which could only be provided at irregular intervals. Results for 20 days of observations in 2007 are given in figure 3. Individual retrievals are based on daily mean spectra, covering 1.5 – 5.5 h of atmospheric observations (the duration mostly depends on meteorological conditions).

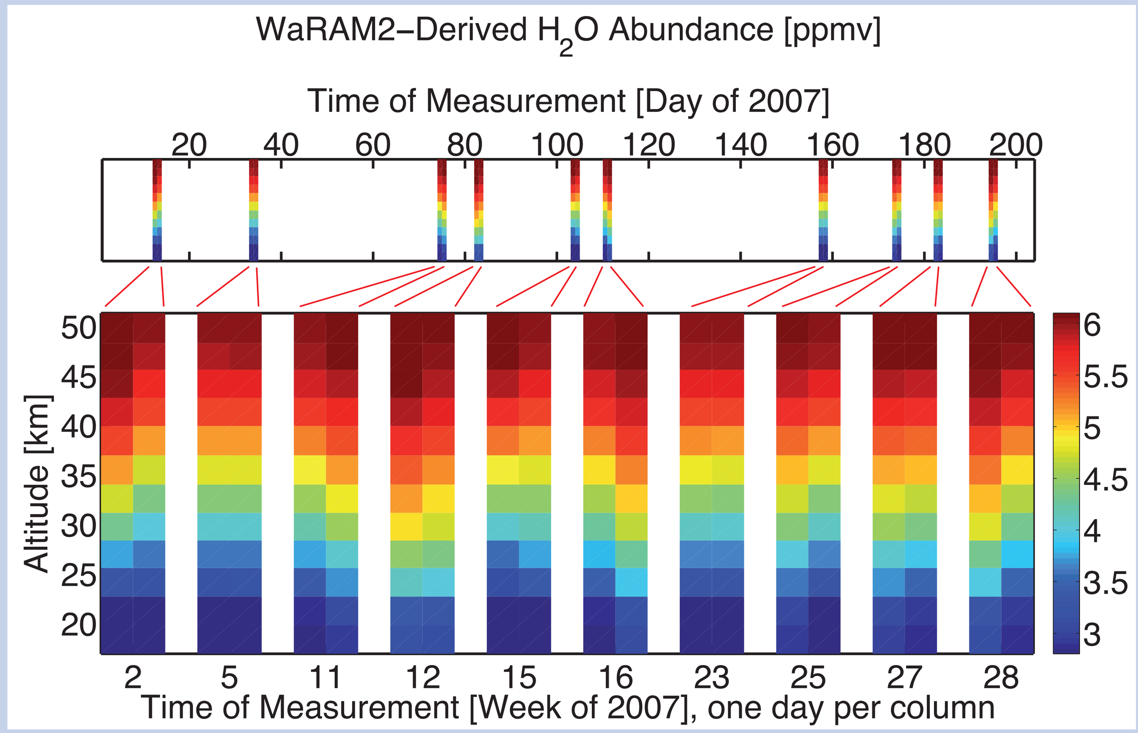

Figure 3: (Upper panel) Time-line of WaRAM2 observations in 2007. (Lower panel) Water vapour VMR retrieved from these observations. Note the broken time-line, one day per column, which has been chosen to get a better view of the results.

The individual profiles reproduce the typical stratospheric gradient in water vapour that is caused by methane oxidation. H_2O abundance at any given altitude varies by ±0.5 ppmv, well to expectation. However, day-to-day variation for weeks 11, 16, and 28 exceeds 0.4 ppmv (10%) at layers below 30 km, which appears unrealistically large. [6] estimates this parameter to be 5% at most. At the present time, the retrieval also suffers from marked variability in sensitivity to the measurement at these layers. Contrary to past experience with WaRAM2, so-called standing waves have been ruled out as a cause for this issue [5]. The variability can instead be attributed to shortcomings of the sensor model and retrieval set-up. These are currently being addressed by better separating tropospheric from stratospheric contributions to the measurement. The matter of day-to-day variation will then be re-investigated.

Initial Comparison

Each day of WaRAM2 data is compared to the closest matching result from Aura/MLS, convolved with WaRAM2 averaging kernels. Distances for individual data pairs range between 100 – 1500 km, without apparent effect on match quality. The data are given in figures 4 and 5.

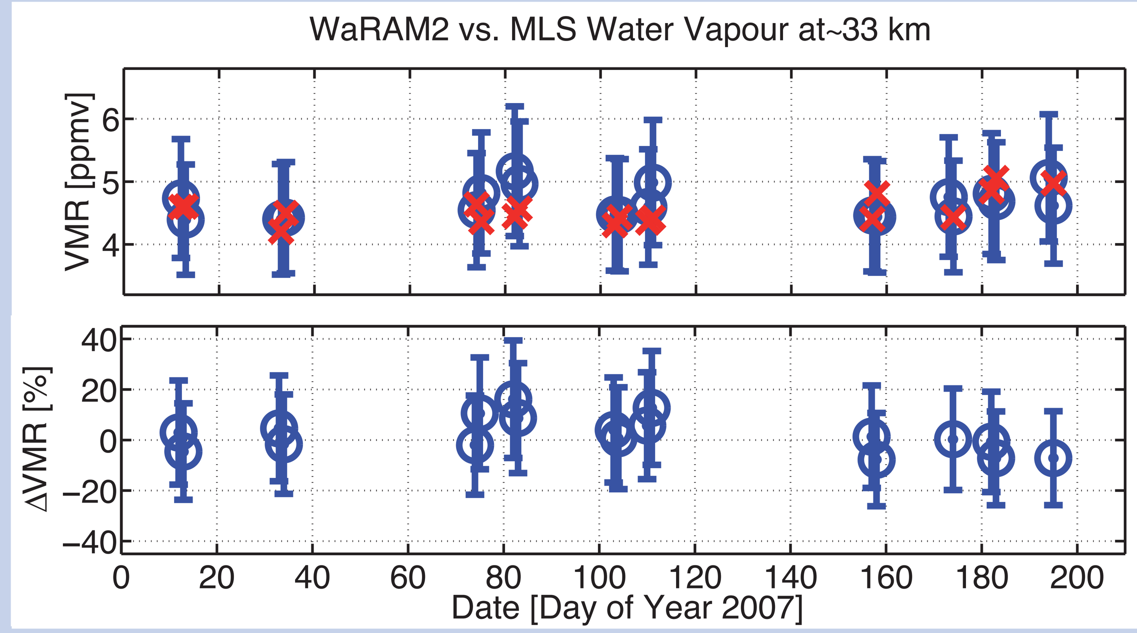

Figure 4: (Upper panel) H_2O VMR from WaRAM2, indicated by blue circles, with error bars, at ~33 km, compared to MLS data, indicated by red crosses (see text). (Lower panel) Same data as above, but given in relative units with respect to MLS.

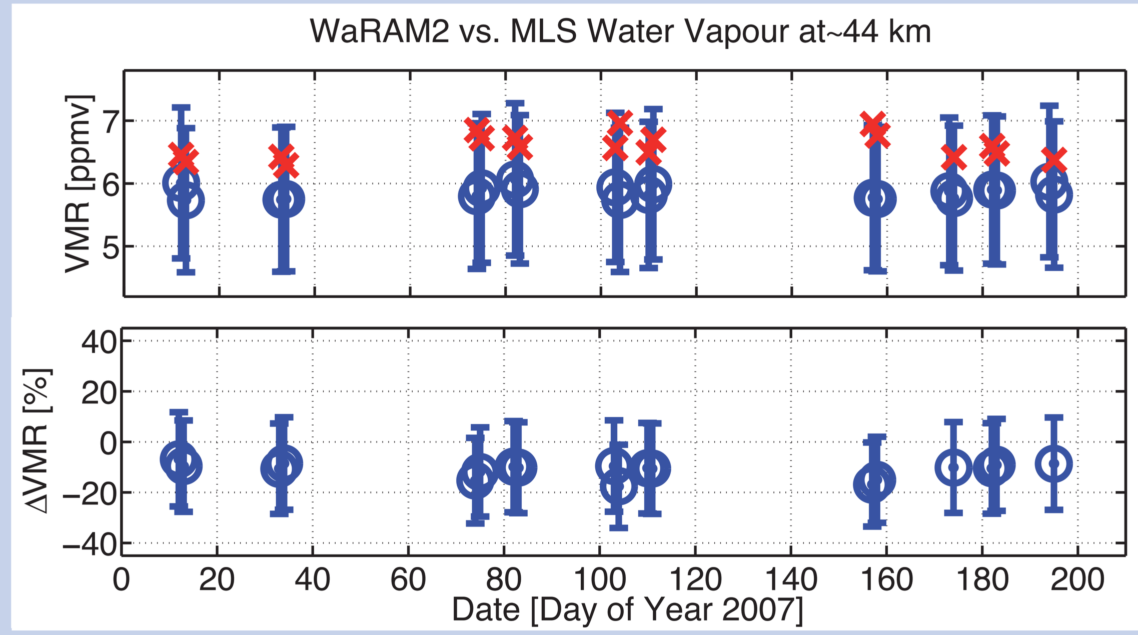

Figure 5: Same as figure 4, but data taken at ~44 km.

At ~33 km, the results match within 10% (0.4 ppmv), except for days 82 (16%) and 112 (13%). At ~44 km, WaRAM2 data appear biased to lower values. The mean difference amounts to 11% (0.7 ppmv). At this level, WaRAM2 data also exhibit less variability (σ = 0.11 ppmv, compared to σ > 0.20 ppmv for the other three time-series). This may be attributed to excess regularisation of the retrieval, which will be considered in future updates of WaRAM2 results.

Conclusions

Observations of stratospheric water vapour at tropical latitudes are of particular concern for the analysis of large-scale diabatic ascent through the tropical transition layer. Initial WaRAM2 results demonstrate the sensor's general suitability to provide long-term data of such kind. A first comparison against Aura/MLS yields good agreement at ~33 km, while WaRAM2 results appear biased low at ~44 km. The retrieval is currently being refined to overcome the indicated issues, and to extend the range of sensitivity into the lower stratosphere.

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