

1 Introduction

Water vapour is a key climate variable. It is the most important gaseous source of infrared opacity in the atmosphere, accounting for about 60 % of the natural greenhouse effect for clear skies, and provides the largest positive feedback in model projections of climate change.

Time series analyses indicate (i) increases in moisture in the atmosphere near the surface, (ii) an upward trend in the lower-tropospheric water vapour over the global oceans and some northern hemisphere land areas, (iii) no detectable trend in upper-tropospheric relative humidity, and (iv) an apparent upward trend in the water vapour in the stratosphere over the last half of the 20th century, but with no further increases since 1996 (IPCC2007).

2 Observed data

At Uccle, the KMI-IRM disposes of a homogeneous database of vertical relative humidity profiles measured by radiosondes since 1990. During this period, two different Vaisala humidity sensors have been used (RS80-A and RS9x-H, with x=0 or x=2). The humidity profiles are known to exhibit a dry bias, due to the following error sources:

- **temperature-dependence error** (RS80-A): inaccurate calibration model for the temperature dependence of the sensor response at low temperatures,
- **(chemical) contamination error** (RS80-A): non-water molecules (e.g. from packaging material) occupy binding sites in the sensor polymer,
- **icing** (RS80-A): a thin ice layer forms around the humidity sensor, so that it behaves more like a (bad) thermometer,
- **time-lag error** (RS80-A, RS9x-H): (too) slow sensor response at low temperatures,
- **solar radiation** (RS9x-H): daytime observations suffer from a solar radiation dry bias.

In order to retrieve unbiased and improved relative humidity data, correction algorithms have been developed by Leiterer et al. [2005] for the RS80-A humidity sensors and by Miloshevich et al. [2004] for both the RS80-A and RS9x-H sondes. These correct for the temperature-dependence error, the contamination error, and the time-lag error.

3 Correction of the humidity profiles

Both correction methods were applied to the humidity profiles measured by RS80-A sondes, the RS9x-H humidity profiles were corrected by the method of Miloshevich et al. [2004]. In June, 2007, an intercomparison campaign was set up in Uccle by launching simultaneously two sondes of different types at the same balloon and retrieving their data independently. A typical example of such an intercomparison is given in Fig. 1.

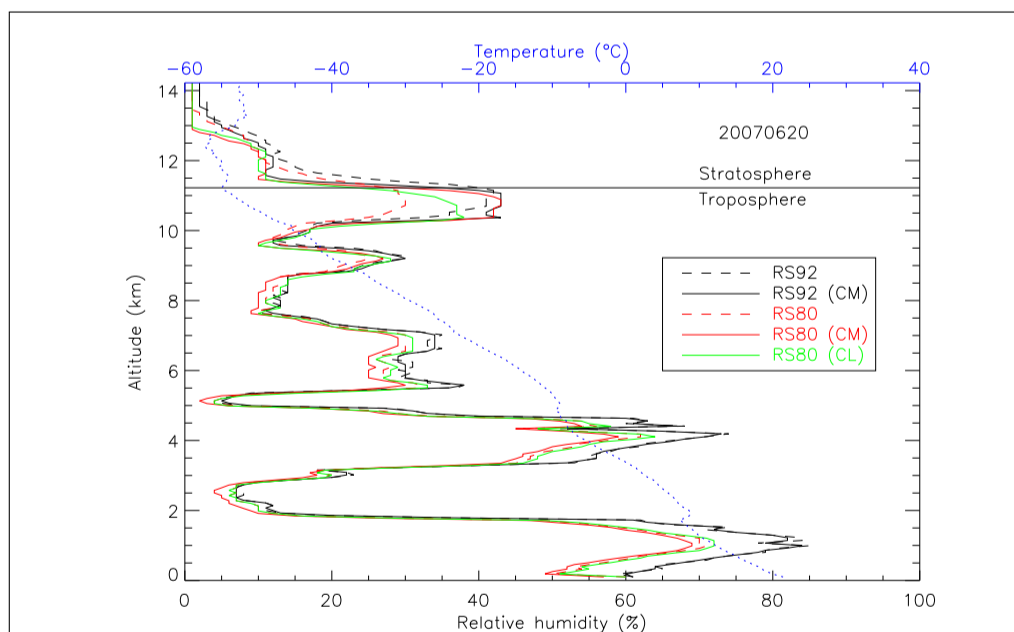


Figure 1. Typical comparison of two simultaneous vertical relative humidity profiles during our intercomparison campaign. Uncorrected data are presented by dashed lines, corrected profiles by full lines. CM = correction of Miloshevich, CL = correction of Leiterer. The blue dotted line is the temperature profile. The transition between the troposphere and the stratosphere, the tropopause, is also indicated.

Acknowledgments

This research was conducted under contract SD/AT/01A of the Belgian Science policy office.

References

- Leiterer, U., H. Dier, D. Nagel, T. Naebert, D. Althausen, K. Franke, A. Kats and F. Wagner, Correction method for RS80-A Humicap Humidity Profiles and Their Validation by Lidar Backscattering Profiles in Tropical Cirrus Clouds, *J. Atmos. Oceanic. Technol.*, 22, 18-29, 2005.
- Miloshevich, L. M., A. Paukkunen, H. Vömel and S. J. Oltmans, Development and Validation of a Time-Lag Correction for Vaisala Radiosonde Humidity Measurements, *J. Atmos. Oceanic. Technol.*, 21, 1305-1327, 2004.

The main conclusions of the correction of the humidity profiles are:

- about one fifth of the RS80-A humidity sensors are affected by icing, only 3 % of the RS9x-H sensors, the latter being heated.
- both time-lag correction methods are able to recover more vertical structure in the upper-tropospheric humidity field (see Fig. 1).
- the Miloshevich temperature-dependence correction method tends to overcorrect (relatively, see Fig. 1) the RS80-A humidity profiles at low temperatures and high relative humidities (e.g. around the tropopause).
- the RS80-A humidity profiles show, on average, an absolute dry bias of more than 10 % at the surface, which decreases with increasing height, with regard to simultaneous RS9x-H profiles (see again Fig. 1 for a typical example). The corrections only reduce the difference by a few percents. This discrepancy is probably caused by the deterioration of the RS80-A humidity sensors due to their long storage time.

4 Time series analysis

A time series analysis is undertaken by calculating monthly anomalies of (i) tropopause properties and (ii) integrated water vapour (precipitable water) of different atmospheric layers. For reasons of consistency, only corrected humidity profiles, **measured by RS80-A sondes**, were included in this analysis. Moreover, all iced RS80-A humidity profiles were rejected.

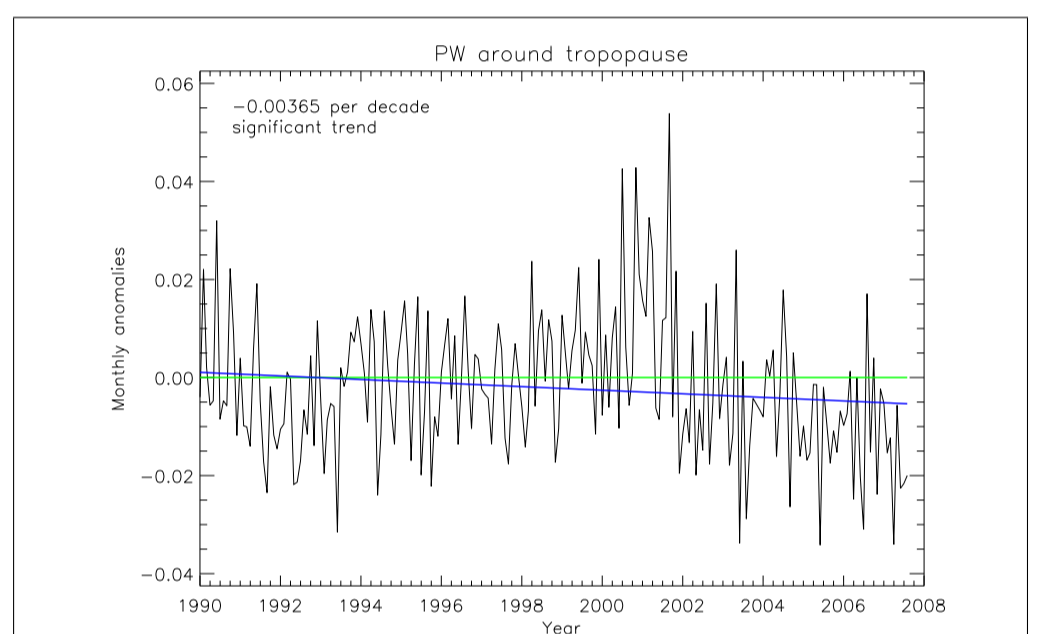


Figure 2. Monthly anomalies of the precipitable water (in mm) in a layer centered around the tropopause with thickness = 4 km.

The following preliminary conclusions on the trend analysis can be drawn:

- no statistically significant trends of the tropopause properties (height, temperature, pressure, density) were found.
- only layers around (see Fig. 2) and just above the tropopause show a significant tendency in their integrated water vapour. Globally, there is a drying of this tropopause region within the 1990-2007 period, which could primarily be attributed to the strong drying starting from November 2001. Before this change point (the result of the Pettitt-Mann-Whitney test), a moistening occurred. The same trend is detected in the time series of the tropopause's relative humidity.

5 Conclusions

The KMI-IRM database of relative humidity profiles is corrected by the state-of-the-art correction methods. Nevertheless, a dry bias - depending on the storage time of the sondes - is still present in the humidity profiles.

Since November 2001, a strong drying of the layers around and just above the tropopause is observed. In the period therefore, a moistening occurred.

This trend seems more or less consistent with the reported lower-stratospheric water vapour trend (see Sect. 1), but its cause is still unclear and needs further investigation.