Trend analysis of the radiosonde relative humidity measurements at Uccle, Belgium

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1 Introduction

Climate models predict that the concentration of water vapour in the upper troposphere could double by the end of the century as a result of increases in greenhouse gases (Soden et al. [2005]). Observations indicate that the height of the tropopause has increased by several hundred meters since 1979 (Santer et al. [2003]). In this study, we try to reconcile these two trends.

2 Aims

- study the time variation of the humidity field around the tropopause based on radiosonde measurements.
- link this time behaviour with climate change and other (upper) tropospheric parameters

3 Observed data

We make use of two subsets of the database of radiosonde vertical profiles measured at Uccle (Belgium, 50°48' N, 4°21' E, 100 m asl):

- the **homogeneous** database of vertical profiles measured with Vaisala RS80-A radiosondes (1990-mid 2007). The measured relative humidity (RH) profiles are known to exhibit a dry bias (see e.g. poster by Clemer et al.). Therefore, we applied the correction algorithm developed by Leiterer et al. [2005] for RS80-A sondes to the RH profiles. If required, we only consider daytime observations (at 12h00 UT).
  ⟶ tropopause height/pressure/temperature/humidity, and temperatures at standard levels (surface, 500 hPa, 100 hPa)
- the 1969-2008 database of ozonesondes, including different types of radiosondes (and hence different temperature and humidity sensors).
  ⟶ same as above, but without humidity field parameters

4 Methodology

- We calculate **monthly anomalies** for the considered parameters.
- We look for linear trends in the time series and test their significance with **Spearman**'s test.
- The **Pettitt-Mann-Whitney** test is used to detect change points.
- Is this change point also a trend turning point?
- We check the **correlation** between/within months for the tropospheric variables.

5 Results

Based on the homogeneous radiosonde database, we find for the humidity field around the tropopause (see Fig. 1a) that

- globally, the tropopause layer is drying since 1990.
- this drying is primarily due to a strong drying since September 2001. Randel et al. [2006] also mentioned decreases in stratospheric water vapour after 2001 in both satellite (HALOE) and balloon (Boulder) measurements.
- before September 2001, a moistening of the upper troposphere occurred.

The time behaviour of the humidity field around the tropopause seems to be driven by the tropopause dynamics:

- as can be seen in Fig. 1b, the monthly means of the tropopause specific humidity (q) are strongly correlated with those of the tropopause temperature: the higher the monthly tropopause temperature, the higher its monthly specific humidity.
- the September 2001 change/trend point is also present in the time series of the tropopause temperature/pressure/height

- the trend analysis of the **tropopause** can be summarized as:
  - 1990 → Sept. 2001: p $\nearrow$, h $\searrow$, T $\nearrow$ $\Longrightarrow$ RH $\nearrow$, q $\nearrow$
  - Sept. 2001 → 2007: p $\searrow$, h $\nearrow$, T $\searrow$ $\Longrightarrow$ RH $\searrow$, q $\searrow$

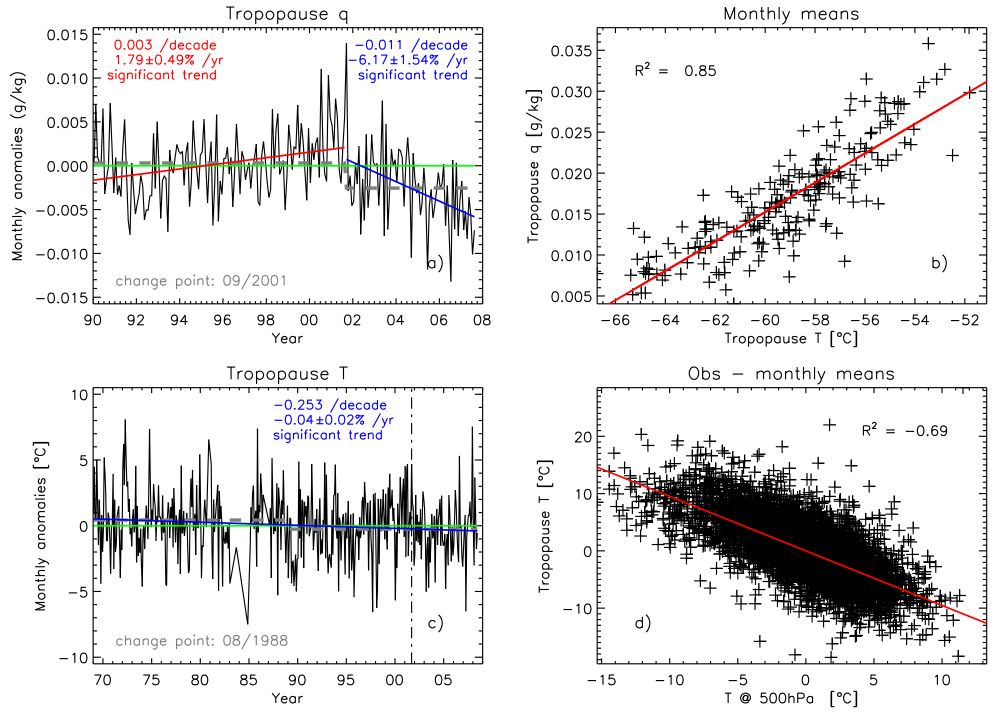

Figure 1: a) Time series of the monthly anomalies of the specific humidity at the tropopause for the 1990-2007 period. b) Scatter plot of the variations between months for the tropopause temperature and specific humidity for the 1990-2007 Vaisala radiosonde database. c) Time series of the monthly anomalies of the tropopause temperature for the 1969-2008 period. d) Scatter plot of the variations within months for the tropopause temperature and the temperature at 500 hPa.

In order to find a cause for this movement of the tropopause layer and to examine the particularity of the September 2001 change/trend point, we repeat our trend analysis for the database of ozonesondes, which started in 1969 in Uccle. The most important conclusions are:

- since 1969, generally, the tropopause temperature (see Fig. 1c) and pressure $\searrow$ (so its height $\nearrow$).
- the surface temperature and the tropospheric temperature at 500 hPa $\nearrow$, but the stratospheric temperature at 100 hPa $\searrow$
- all these mentioned atmospheric variables exhibit a change point ($\neq$ trend turning point) around the year 1988 (see Fig. 1c for the tropopause temperature). The same change point was found in the time series of the surface temperature measured at Uccle by the weather station.
- the Sept. 2001 change point is hence degraded in the longer time series, but can nevertheless still be spotted (see Fig. 1c, marked by the vertical dash-dotted line).
- as can be seen in Fig. 1d, the temperature of the tropopause (at $\pm$225 hPa in Uccle) is anticorrelated (within months) with the temperature at 500 hPa; the latter is correlated with the surface temperature.

6 Conclusions

As the surface heats up, also the lower tropospheric layers heat up and convection lifts up the upper tropospheric layers, so that these layers, including the tropopause, will cool down. The lifting of the tropopause is amplified by the cooling of the lower stratosphere. This is the general picture revealed by the 1969 – 2008 (ozone) radiosonde database at Uccle.

The cooling/lifting of the upper tropospheric layers is responsible for a drying of these layers, as observed after September 2001. To explain the observed decreases in stratospheric water vapour after 2001, Randel et al. [2006] painted the same picture for the tropics: enhanced tropical upwelling after 2001 results in lower temperatures, lower water vapour and lower ozone near the tropical tropopause.

From 1990 to September 2001, the opposite scenario takes place. In this period, the surface temperature is only increasing after the end of 1998!

References

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