A drop in UT humidity in Autumn 2001, as derived from radiosonde measurements at Uccle, Belgium

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1 Aims

- study the time variation of upper-tropospheric humidity (UTH) based on radiosonde measurements at Uccle (Belgium, 50°48' N, 4°21' E, 100 m asl)
- link this UTH time behaviour with climate change and other (upper) tropospheric parameters at Uccle and at other stations

2 Observed data

We make use of the **homogeneous** database of vertical profiles measured at Uccle at 12h00 UT with Vaisala RS80-A radiosondes (1990-mid 2007). The measured relative humidity (RH) profiles are known to exhibit a dry bias. Therefore, we applied the correction algorithm developed by Leiterer et al. [2005] for RS80-A sondes to the RH profiles.

3 Results

The UTH field above Uccle increased from 1990 till Autumn 2001, in Autumn 2001 there is a sudden drop in UTH. This is illustrated in Fig. 1.

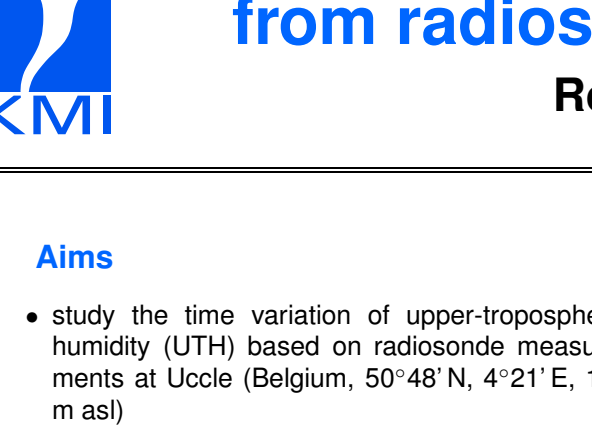

Figure 1: Time series of monthly means of the integrated specific humidity for UTH layers of $10°$C thickness and with top temperature equal to the tropopause temperature $- n * 10°$C (with n = 0, 1, 2, 3 going from the upper to the lower plots). Each time series has a statistically significant change point in Autumn 2001, and the linear regression lines before and after these change points are shown. Full lines denote statistically significant trends, dashed lines are statistically insignificant trends.

3.1 Origin of the Autumn 2001 UTH drop?

INSTRUMENTAL?

No, because

- no instrumental changes in production batches launched before/after Autumn 2001
- the humidity drop is present at different UT layers (see Fig. 1), also these with higher temperatures (and hence enhanced reliability and data quality of the humidity measurements with regard to the lowest temperatures)
- the Autumn 2001 change is also present in the time series of tropospheric temperatures, tropopause properties and the thickness of the free troposphere

PHYSICAL?

Yes, because

- this UTH drop in Autumn 2001 is related with both a sudden lifting and cooling of the tropopause (see upper plot in Fig. 3) and a stretching of the (free) troposphere (see Fig. 2).
- more general, the UTH time series of monthly anomalies is strongly correlated with the tropopause temperature ($R^2 = +0.68$) or tropopause height ($R^2 = -0.72$), and with the thickness of the free troposphere ($R^2 = -0.52$).

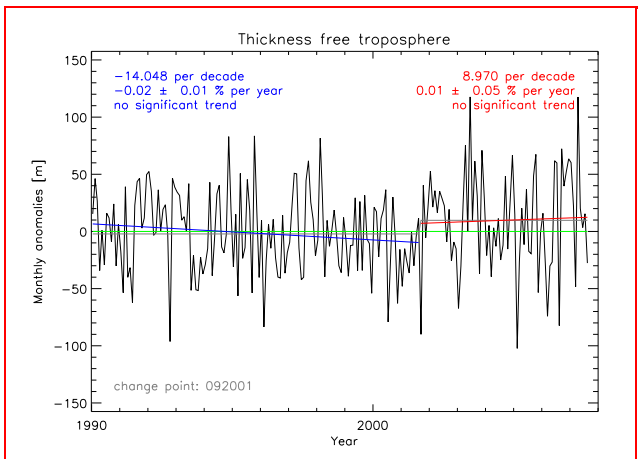

Figure 2: Time series of monthly anomalies of the thickness of the free troposphere, defined as the difference of the geopotential heights at 300 hPa and 700 hPa.

In order to explain the Autumn 2001 change, the following scenario arises: due to the surface warming, the lower troposphere heats up, the troposphere stretches out, and consequently the upper troposphere is lifted up, cools and freeze-dries.

3.2 Spatial uniformity?

The Autumn 2001 change does not only occur at Uccle, but also at other European stations. An example for the tropopause temperature is given in Fig. 3.

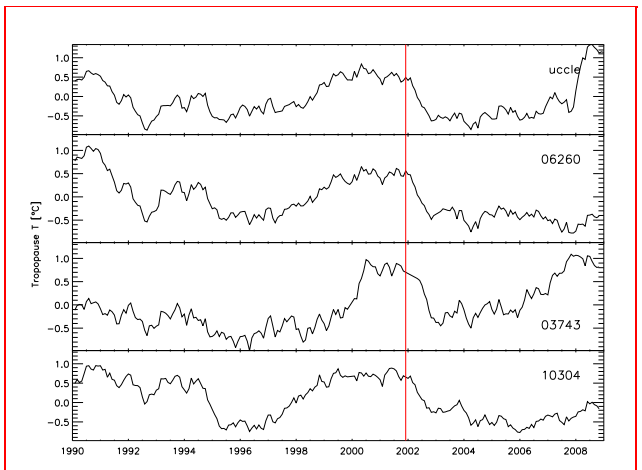

Figure 3: Time series of moving averages of the monthly anomalies of tropopause temperatures for Uccle, De Bilt (= 06260, NL, 52°6' N, 5°11' E), Larkhill (= 03743, UK, 51°12' N, 1°48' W), and Meppen (= 10304, D, 52°44' N, 7°20' E). The data of the latter 3 stations are taken from the IGRA database. Autumn 2001 is marked with a vertical red line.

Rosenlof and Reid [2008] also reported a dramatic decrease in **tropical** tropopause/lower stratosphere temperatures during the 2000-2001 time period.

Randel et al. [2006] found a substantial, persistent decrease in **stratospheric** water vapour since 2001 in both global ($60°$N$-60°$S) satellite observations from HALOE (at 82 hPa) and balloon observations at Boulder ($40°$N).

$\Longrightarrow$ both effects are ascribed to an enhanced tropical upwelling (Brewer-Dobson) circulation after 2001, so there does not seem to be a **direct** link with our study.

3.3 Going back in time

If we consider the 1969-2009 time series of radiosonde observations at Uccle, we find that

- surface temperature ↗, lower-tropospheric temperature ↗, thickness of the free troposphere ↗ (shown in Fig. 4), tropopause height ↗, tropopause temperature ↘, lower-stratospheric temperature ↘
- the Autumn 2001 change point hence marks the return to these longer-term trends
- however, the Autumn 2001 change point is less pronounced in the longer time series (compare Fig. 2 and Fig. 4)
- correlations exist between the tropopause properties and the thickness of the free troposphere or tropospheric temperatures at one hand, and the lower-stratospheric temperature at the other hand
- the tropospheric dynamics, responsible for the Autumn 2001 change, might partly lie at the origin of these trends

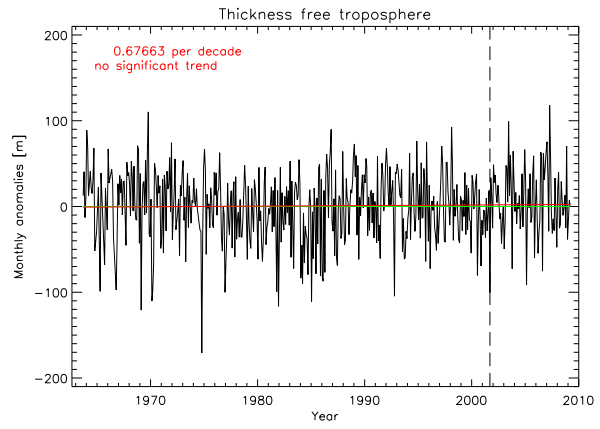

Figure 4: Time series of the monthly anomalies of the thickness of the free troposphere at Uccle (see Fig. 2 for its definition). The Autumn 2001 change point is marked by a vertical dashed line.

4 Conclusions

The drop in UTH in Autumn 2001, present in the homogeneous Uccle radiosonde database, is related to a stretching of the troposphere and tropopause lifting. A link with lower-tropospheric warming is also established.

A similar behaviour around Autumn 2001 in the temperatures and tropopause properties of other European radiosonde stations is found.

This tropospheric dynamics might also at least partly be responsible for the longer-term tropopause trends in the mid-latitutes.

References

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