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
- link this UTH time behaviour with climate change and other (upper) tropospheric and stratospheric parameters at Uccle and at other stations

2 Observed data

- **uniform** database of vertical profiles of temperature, relative humidity (RH) and pressure measured at Uccle at 12h00 UTC with Vaisala RS80-A radiosondes (1990-mid 2007)
- these relative humidity profiles are known to exhibit a dry bias. Therefore, we applied the best correction algorithm currently available.

3 Time series analysis

3.1 UTH definition

- because of the high vertical resolution obtained with radiosonde measurements, we can identify the tropopause and hence define an UTH **relative to the tropopause**. Satellite measurements can provide only an "**absolute**" UTH.
- these different UTH definitions give rise to differences in their time behaviour (compare the two panels in Fig. 1):
  - similar variability before $\sim$ 2000: response to and recovery from the Pinatubo volcanic eruption in June 1991
  - after 2000: leveling off of absolute UTH vs. significant drop in UTH defined relative to the tropopause in autumn 2001

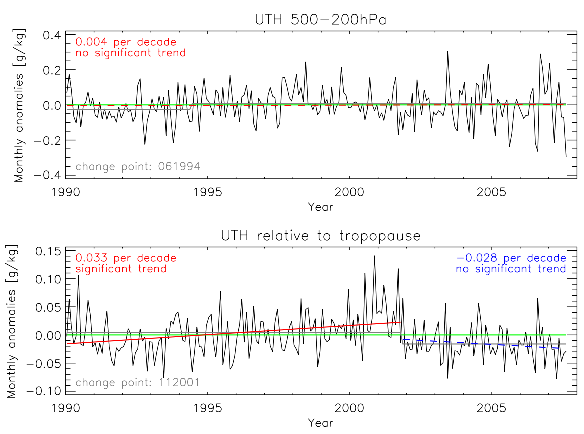

Figure 1: Uccle time series of monthly anomalies of the integrated specific humidity for *(upper)* the upper tropospheric layers between 500 and 200 hPa and *(lower)* a layer that extends from the tropopause to 3 kilometers below the tropopause. The mean before and after the detected change point is shown in grey. The linear regression lines for *(upper)* the entire time period and *(lower)* the time periods before and after the detected change point are also drawn. Red lines are used for positive trends, blue lines for negative trends. A full line denotes a statistically significant trend, a dashed line a statistically insignificant trend. The statistical significance of the trends is investigated by Spearman's test. Green lines denote the zero anomaly lines.

3.2 Origin of the autumn 2001 UTH drop?

- we do not find any instrumental or environmental cause in our dataset for the autumn 2001 change.
- as it is only prominently present in the relative UTH time series, the time behaviour of the **tropopause** itself is at least partly responsible. As a matter of fact, the UTH drop in autumn 2001 is related with both a sudden lifting and cooling of the tropopause (see upper plot in Fig. 3).
- in general, the long-term variability of the tropopause can be of tropospheric and/or stratospheric origin:
  - the autumn 2001 change is also present in the time series of **tropospheric** temperatures from 850 to 350 hPa and of the thickness of the free troposphere (see upper plot in Fig. 2). Before this change point, the troposphere has a tendency to cool down, afterwards, it has the tendency to warm up. Additionally, the tropospheric shrinking trend of the 90s is interrupted by a stretching of the troposphere in 2001.
  - no change around autumn 2001 in the time series of lower-**stratospheric** temperatures (see e.g. lower plot in Fig. 2), thickness of geopotential height and ozone amounts

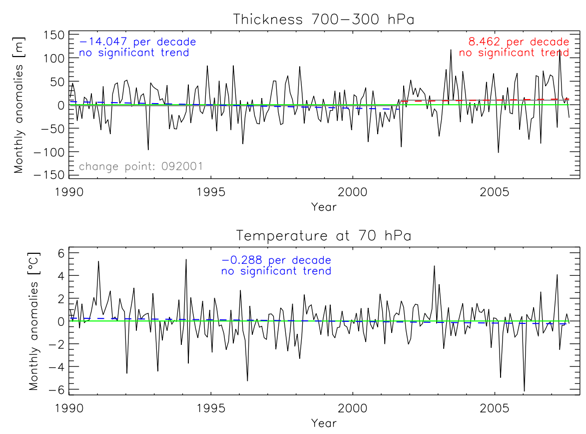

Figure 2: Time series of monthly anomalies of *(upper)* the thickness of the free troposphere, defined as the difference of the geopotential heights at 300 hPa and 700 hPa, and *(lower)* the temperature at 70 hPa. Line and colour codes as in Fig. 1.

The tropospheric dynamics contributing to the change around autumn 2001 can then be summarized as follows:

tropospheric temperatures $\nearrow$
$\Downarrow$
stretching out of the free troposphere
$\Downarrow$
lifting and cooling of the tropopause
$\Downarrow$
freeze-drying of UT

4 Relevance of the autumn 2001 change

4.1 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).

We could not establish a direct link between the UTH/tropopause temperature drop at European stations and the enhanced tropical upwelling (Brewer-Dobson) circulation after 2001, to which these tropical and lower stratospheric changes were ascribed.

4.2 Extended study

In the **total** 1969$-$2009 database of radiosonde observations at Uccle, the autumn 2001 change point is less pronounced in the tropospheric/tropopause temperature/height time series.

5 Conclusions

In the 1990$-$2000 period, the UTH time behaviour above Uccle is dominated by a response to and recovery from the Pinatubo volcanic eruption.

The autumn 2001 changes in UTH and tropopause properties, also present at other European radiosonde stations, are certainly associated with the dynamical behaviour of the troposphere, triggered by the surface warming.

References

- Randel, W. J., F. Wu, H. Vömel, G. E. Nedoluha and P. Forster (2006), "Decreases in stratospheric water vapor after 2001: Links to changes in the tropical tropopause and the Brewer-Dobson circulation", *J. Geophys. Res.*, **111**, D12312, doi:10.1029/2005JD006744
- Rosenlof, K. H. and G. C. Reid (2008), "Trends in the temperature and water vapor content of the tropical lower stratosphere: Sea surface connection", *J. Geophys. Res.*, **113**, D06107, doi:10.1029/2007JD009109
- Van Malderen, R., and H. De Backer (2010), "A drop in upper tropospheric humidity in autumn 2001, as derived from radiosonde measurements at Uccle, Belgium", *J. Geophys. Res.*,**115** D20114, doi:10.1029/2009JD013587

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