In situ measurements by the ELHYSA balloon-borne frost-point hygrometer:

Contribution to the estimation of the stratospheric water vapor trend

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Abstract

We present here the ELHYSA stratospheric balloon-borne frost-point (FP) hygrometer developed at the LMD/Ecole Polytechnique and now managed at the LPCE/CNRS. We also present an analysis of these *in situ* observations obtained between 1989 and 2005 in mid-latitude conditions with the aim to participate to the evaluation of the stratospheric water vapor trend using independent measurements. Since the ELHYSA measurements are very sparse a careful examination of the vertical profiles combined to potential vorticity analysis is conducted to remove contributions of tropical and possibly-dehydrated polar air masses in the estimation of the water vapor trend. Also, comparisons to monthly-averaged HALOE data enclosing the various ELHYSA observation dates over the 1991-2005 period for mid-latitude conditions (extra-tropical and extra-vortex air in the 40-70°N latitude range) are made to validate the method. Between 80 and 30 hPa, a strong increase is observed in the 1989 – 1993 period. After 1993, a slight decrease of about 0.3% can be pointed out with very nice agreement with HALOE data. In fact, this estimation is not very sensitive to the presence of tropical and polar intrusions. It is proposed that this result could be in favor of the hypothesis of a volcanic origin in addition to El Niño effects for the past changes in the water vapor trend. Even though the analyzed measurements of the ELHYSA hygrometer are sparse the recently reported decrease in the stratospheric water vapor content from 2001 could explain the calculated negative trend.

The ELHYSA frost-point hygrometer

ELHYSA

- For description of the instrument see *Ovarlez* (1991) and *Ovarlez and Ovarlez* (1994).
- Optical detection of the onset of dew or white frost on a cooled mirror. Control of the mirror condensation temperature by means of a control loop for the cooling and heating of the mirror.
- Peltier device from 1989 to 1993 and cryogenic cooling system since 1994. Better accuracy with this new system in the coolest stratospheric regions and better sensitivity to vertical local gradients of water vapor.
- Thermistor embedded in the mirror to measure the temperature of the dew-point or frost-point of the air in contact with the mirror to obtain direct measurements.
- Regular checking procedures of the instrument calibration and quality tests.
- Water vapor mixing ratio obtained using temperature and pressure sensors. Uncertainty of 5% on the absolute mixing ratios in the stratosphere.
- Operation during the slow descent to avoid contamination by the balloon.

ELHYSA gondola before launch

Problem

- Long-term frost-point balloon observations (NOAA) suggested a quite continuous increase of stratospheric water vapor over the past few decades (1963-1977 and 1980-2000 over Washington D.C. and Boulder) corresponding to about a doubling of stratospheric water vapor since the 1960s (*Oltmans and Hofmann*, 1995; *Oltmans et al*., 2000; *Rosenlof et al*., 2001).

BUT:

- ERA-40 temperatures near the tropical tropopause do not suggest a positive trend accounting for the water vapor trend inferred from the long-term balloon observations (*Fueglistaler and Haynes* 2005).

- Recent extensive comparisons has revealed significant differences between HALOE and balloon observations of stratospheric water vapor (*Randel et al.,* 2004; *Fueglistaler and Haynes* 2005).

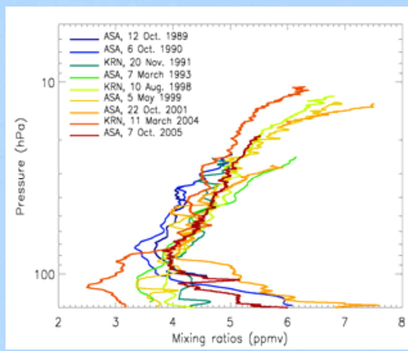
- Recent revision of the NOAA frost-point balloon observations over 1981-2006 period by *Scherer et al*., 2008: high bias after 1991 and low bias before 1987 giving a 40% reduction of the previously estimated trend and leading to a newly-estimated positive trend ranging from 0.3±0.3 to 0.7±0.1% /year depending on altitude (14-25 km range).
However significant differences with HALOE data still remain over the 1992-2005 period: -0.2±0.3 to +1.0%±0.3% /year for the NOAA FP instrument and -1.1±0.2 to -0.1±0.1% /year.

⇒ Interest in analyzing independent in situ balloon data.

Stratospheric water vapor observations by the ELHYSA Frost-Point hygrometer over the 1989-2005 period

- ELHYSA balloon observations: 22 flights obtained since 1989, 9 for mid-latitude conditions at two sites (44°N, Aire sur l'Adour, France and 68°N, Kiruna, Sweden).

- Possibility to use these sparse data for the estimation of the stratospheric water vapor trend over this period ?
  - Water vapor modulated by the QBO periodic effect (*Randel et al*., 2004) but less effect at mid-latitudes than in the tropics.
  - Seasonal variations less marked at mid-latitudes than in the tropics: 4.6-4.8 ppmv at 25 km and 5.0-5.2 ppmv at 30 km from January to October (see Fig. 7 and Fig. 9 of *Randel et al*., 1998 and *Rosenlof et al*., 1997 respectively).
  - Much less variability above 80 hPa than below (seasonally-varying ventilation of the lower stratosphere below 400 K, see Berthet et al., 2007).



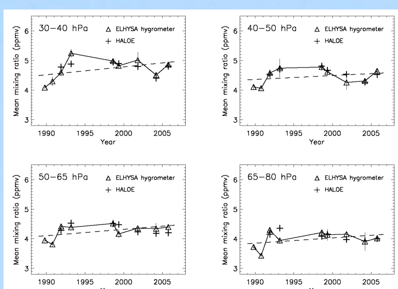
Contribution to the stratospheric water vapor trend estimation

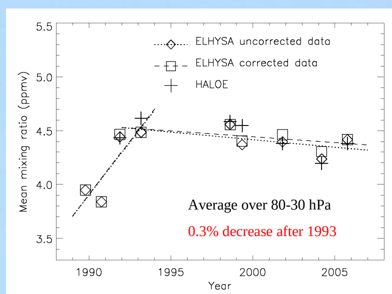
Methodology:

- Water vapor observations by the ELHYSA FP hygrometer sorted by latitudes and altitudes. From PV maps (ECMWF and MIMOSA model, *Hauchecorne et al*., 2002)
→ removal of air masses originating from vortex and tropical latitudes for the trend estimation:
  - -1991 profile:30-34 hPa
  - -1999 profile: 51-59 hPa
  - -2001 profile: 37-42 hPa, 43-50 hPa
  - -2004 profile: 36-50 hPa, 24-35 hPa

⇒ ELHYSA "corrected data"
⇒ "Uncorrected data": Whole profiles

- Comparison to HALOE data (taken at mid-latitudes and monthly-averaged around each observation of the hygrometer) for validation of the consistency of the ELHYSA results.





Conclusions

- Water vapor observations by the ELHYSA FP hygrometer sorted by latitudes and altitudes. Elimination of air masses originating from vortex and tropical latitudes.

- We must keep in mind that the seasonal variability of stratospheric water vapor (even considering in this study mid-latitude conditions and altitude levels above 80 hPa) is likely to scatter the ELHYSA FP hygrometer data and affect the estimation of the trend.

- Excellent agreement with HALOE observations appears which validates our method.

- Very similar trend obtained over 80-30 hPa with the hygrometer when removing parts of the profiles attributed to vortex or tropical air ("corrected data") or using the whole profiles ("uncorrected data").

- Water vapor modulated by QBO (*Randel et al*., 2004), ENSO (*Fueglistaler and Haynes*, 2005) and possibly volcanic eruptions.

- Drop in stratospheric water vapour mixing ratio observed after 2001 by HALOE (*Randel et al*., 2006) and by the NOAA FP hygrometer (*Scherer et al*., 2008) apparently due to a decrease in the tropical tropopause temperatures (approximately -1K).
→ Indication of this event in the ELHYSA observations.

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