

# Stratospheric Water Vapour (KOP 69)

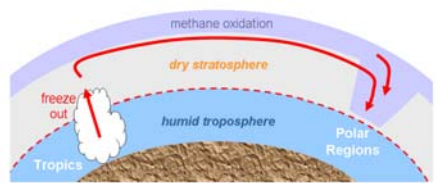
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## Introduction

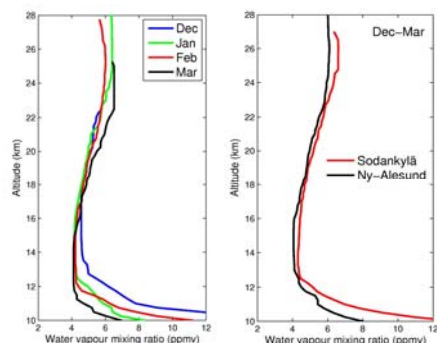
The important role of stratospheric water vapour in the climate system has become evident during the recent years. Radiatively, it is the **most important greenhouse gas** and the observed increase of stratospheric water vapour contributes to increased stratospheric cooling. The increase of stratospheric water vapour is also expected to enhance the occurrence of polar stratospheric clouds (PSCs), thus contributing to heterogeneous reactions that initiate the catalytic loss of stratospheric ozone. Overall, the distribution of stratospheric water vapour is determined by the interaction of radiation, chemistry, and dynamics.

Water vapour enters the stratosphere through vertical transport in the tropical tropopause region and is photochemically produced in the upper stratosphere through the oxidation of methane. The only sink of water vapour in the upper atmosphere is through photolysis by Lyman- $\alpha$ , with its efficiency increasing with altitude in the mesosphere. A minor loss process in the stratosphere is due to gravitational sedimentation of ice particles from PSCs type II inside the polar vortex. This process leading to dehydration and rehydration is linked to very cold stratospheric temperatures and is observed regularly in the Antarctic and to a lesser extent in the Arctic.

Without dehydration, the water vapour concentration inside the polar vortex is generally higher than in the surrounding mid-latitudes due to the descent of air from higher altitudes where water vapour is produced by methane oxidation.



## Climatological Aspects

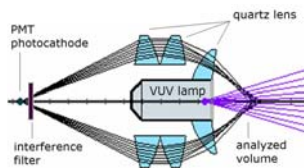


Within the frame of the EU-project SCOUT-O3, similar water vapour soundings have been operated from Ny-Ålesund and Sodankylä (Finland, 67°N). Here, averages refer to the period 2003/2004 to 2007/2008.

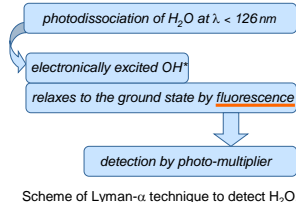
Figure 7 (left): monthly averaged data from both stations.

Figure 8 (right): winter mean profile (December-March) for Sodankylä and Ny-Ålesund.

## The Instrument: FLASH-B



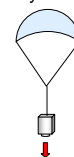
Optical layout of the FLASH-B hygrometer.



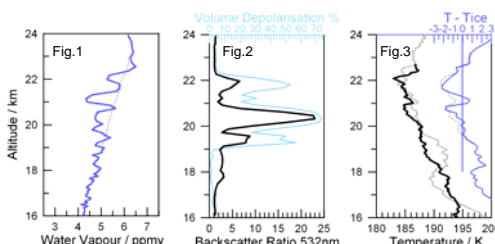
Scheme of Lyman- $\alpha$  technique to detect  $H_2O$ .

The Fluorescent Advanced Stratospheric Hygrometer for Balloon (FLASH-B) is a Lyman- $\alpha$  hygrometer developed at the Central Aerological Observatory in Moscow, Russia. Measurements are taken during descent to avoid contamination by outgassing.

- balloon-borne stratospheric  $H_2O$  measurements at AWIPEV since winter 2002/2003
- generally 1 profile per winter month
- part of the EU projects SCOUT-O3 and GEOmon



## Dehydration due to Polar Stratospheric Clouds ?



Measurements on 26 January 2005. Figure 1: Water vapor mixing ratio  $q_{H_2O}$  as measured by FLASH-B hygrometer at 20 UTC (blue line), and anticipated mean increase of  $q_{H_2O}$  under undisturbed conditions (dashed line). Figure 2: Lidar aerosol backscatter ratio (black line, lower axis) and volume depolarisation (blue line, upper axis) at 532 nm, integrated between 18:55 and 19:34 UTC. Figure 3: Temperature from Ny-Ålesund radiosondes at 11 and 23 UTC (gray and black line, respectively), plus temperature difference  $T - T_{ice}$  ( $T_{ice}$  calculated after Murphy and Koop, 2005) for the 23 UTC radiosonde and the  $H_2O$  profiles shown in Figure 1.

- The ice PSC observed on 26 January 2005 above Spitsbergen was an exceptional event, generated by a combination of 3 closely linked processes: [1] passing cold front with flow inducing mountain waves, [2] location and orientation of the tropopause jet, and [3] presence of the vortex cold pool.
- short time period of potential ice particle formation
- water vapour reduction probably caused by local and temporary freezing of  $H_2O$  out of the gas phase

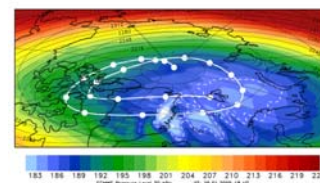


Figure 4 : 30 hPa temperature (color shaded),  $T_{ice}$  for  $q_{H_2O} = 5$  ppmv (dashed white contour line), and geopotential height (solid lines) on 26 January 2005 at 18 UTC, with 10-day backward trajectory for 21 UTC (white line + dot every 12 h).

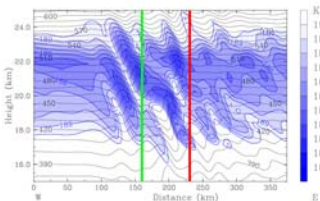
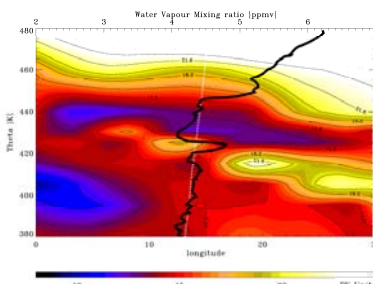


Figure 5: Temperature distribution (17UTC) simulated by MM5, with the location of the measured profiles by lidar and hygrometer (green and red line, respectively).

Maturilli and Dörnbrack (2006): Polar stratospheric ice cloud above Spitsbergen. J. Geophys. Res., Vol. 111, D18210, doi: 10.1029/2005JD006967

## Stratospheric $H_2O$ as a Tracer



In this example on 11 February 2003, the local reduction in the stratospheric water vapour profile was linked to filamentary structures of mid-latitude air at the vortex edge, proving water vapour a valuable tracer for dynamical processes in the polar stratosphere.

Figure 6: MIMOSA (semi-lagrangian advection model) fine scale structures of Lait-modified potential vorticity (colour coded) on 11 February, 2003, 06UTC, in a longitudinal cross-section at 78°N revealing filaments of mid-latitude air (blue colours). Superimposed is the water vapour mixing ratio (black line, upper axis) and the flight trajectory (white dotted line, lower axis) of the frost point hygrometer launched on 11 February, 2003, at 07 UTC.

Müller et al. (2003): Stratospheric Water Vapor as tracer for Vortex Filamentation in Winter 2002/2003. Atmospheric Chemistry and Physics, Vol.3, 1991-1997.