Water vapour in the UT/LS from balloon and aircraft observations with FLASH lyman-alpha hygrometer.

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Abstract

We present a summary of in-situ water vapour measurements using FLASH Lyman-alpha hygrometer flown on board both balloon and M55-Geophysica aircraft during SCOUT-O3 project implementation. The high quality and performance of the FLASH instrument has been confirmed by a number of field and laboratory intercomparison campaigns (LAUTLOS-WAVVAP, AQUAVIT).

The series of water vapour profiles obtained using balloon FLASH-B sensor at the two Arctic stations (Ny-Alesund, 79 N and Sodankyla, 67.4 N) during 2004/05, 2005/06 and 2007/2008 winters allows case studies and detailed characterization of stratospheric water vapour vertical distribution within different conditions in the Arctic Polar stratosphere.

Vertical profiles of water vapour obtained with FLASH-B above Western Africa in August 2006 during SCOUT-AMMA balloon campaign show evidence of the presence of local accumulations of water vapour enhanced layers between the tropopause at 370 K and the 450 K level. Most of them are shown connected with overshooting events upwind identified from MSG satellite IR images, flown over by the air mass probed by the sondes along three days backward trajectories. In the case of a local overshoot identified by echo tops turrets up to 18.5 km in the C-band radar, tight coincidence was found between enhanced water vapour, ice crystal and ozone dip layers indicative of fast uplift of tropospheric air across the tropopause. The water vapour mixing ratio in the enriched layers, higher than that of condensation at the tropopause, and the coincidence with the presence of ice crystals strongly suggest hydration of the lower stratosphere by geyser-like injection of ice particles over overshooting turrets..

Instruments and data sets

FLASH-B and FLASH-M55 Lyman-alpha hygrometer [Yushkov et al., 1998].

FLASH-B is a balloon-borne compact lightweight fluorescence hygrometer with an open cell optical layout. Total measurement uncertainty amounts to 10% in the stratosphere. Only balloon descent measurements were used for analysis.

FLASH-M55 is an airborne version of FLASH with closed cell, operating on board M55-Geopysica aircraft.

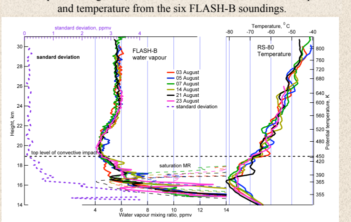
Measurement sites and campaigns

- **SCOUT-AMMA balloon campaign, Niamey, Western Africa, 13.6^0 N, August 2006**
- **SCOUT-O3 aircraft campaign, Darwin, Australia, 12^0 S, November 2005**
- **Regular wintetime soundings at Ny-Alesund (79^0 N) and Sodankyla (67.4^0 N), 2004-2008**
- **Monthly soundings from Payerne (44^0 N) since Feb 2008**
- **Long-duration balloon flight at Esrange (67 N) in March 2007**

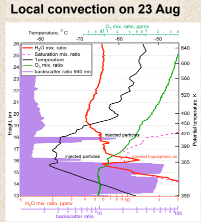
Tropics

SCOUT-AMMA balloon campaign, Niger, 13.6^0 N, August 2006 (sonde programme): H_2O (FLASH-B), particles (BKS sonde) and O_3 (ECC sonde)

Water vapour mixing ratio, standard deviation from the mean WV profile and temperature from the six FLASH-B soundings.



Local convection on 23 Aug



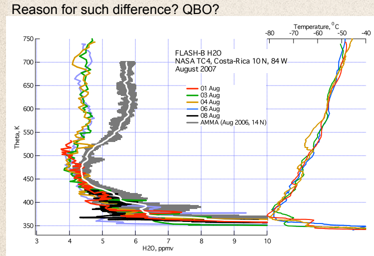
Frequent humid layers above the cold point tropopause observed in the profiles suggest that deep overshooting convection could detrain humid tropospheric air directly into the lower stratosphere up to 450 K potential temperature level and enhance its water vapour content.

Coincident H_2O, particles and ozone features and the indication of the presence of high convective turrets (reported by MIT radar, not shown) suggest fresh injections from the troposphere

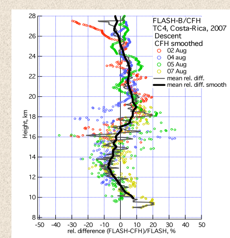
➡ **Hydration of LS by ice geysers (convective overshooting)**

NASA TC4 campaign, Costa-Rica, 10^0 N, August 2007 (sonde programme): simulataneous measurements of water vapour by FLASH-B and CFH hygrosondes

H_2O profiles obtained during TC4 compared to SCOUT-AMMA H_2O profiles taken at the same season and latitude
Reason for such difference? QBO?



Comparison between FLASH-B and CFH H_2O descent profiles
Differences lay within 10 % range

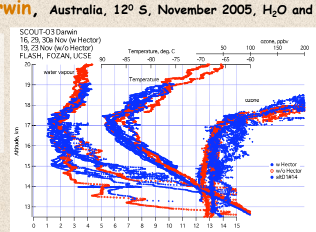


➡ **Local dehydration/ rehydration around CPT.**

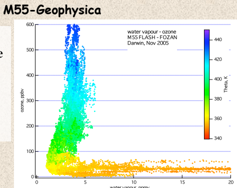
SCOUT-O3 Darwin, Australia, 12^0 S, November 2005, H_2O and O_3 measurements on board M55-Geophysica

H_2O, T and O_3 vertical profiles obtained with and without the presence of Hector.

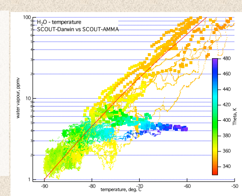
No signs of LS hydration above Hector



H_2O – O_3 relation for all FLASH-M55 flights above Darwin. Markers are cc wrt theta.
No mixing lines observed



H2O - temperature relation for all FLASH-M55 flights above Darwin (small markers) and FLASH-B flights above Niamey (larger markers) cc wrt theta. Different mechanisms controlling H_2O amount in the UT/LS



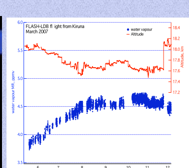
➡ **H_2O is controlled by the temperature**

Arctic

Long-duration balloon flight, Esrange, Sweden, March 2008.

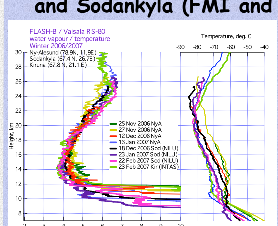
CNES Super pressure 12m^2 balloon (SPB) launched from Esrange with FLASH-B on board operating during the night time. The balloon was launched inside the polar vortex and encircled the pole in 9 days.

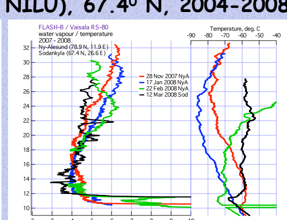
Trajectory of the SPB/FLASH-B flight

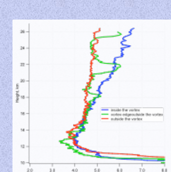


Water vapour along the SPB flight path measured with FLASH-B and flight altitude. Only the contamination free data obtained during balloon descent are shown. In 3 days the effect of contamination becomes negligible

Wintertime water vapour soundings at Ny-Alesund (AWI), 79^0 N and Sodankyla (FMI and NILU), 67.4^0 N, 2004-2008







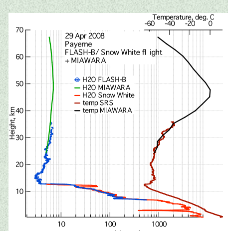
Water vapour profile at the edge of polar vortex (17.02.2004 Sodankyla) superimposed on the mean water vapour profiles inside and outside the vortex (Feb 2004, Sodankyla).

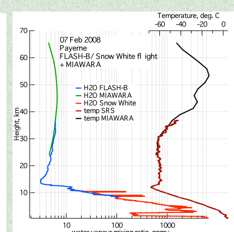
Mid-latitude

H_2O Soundings from Payerne-MeteoSwiss, Switzerland, 44^0 N, 2008.

Combined FLASH-B and Snow White flights supported by microwave measurements using MIAWARA 22 GHz radiometer (IAP Bern).

Combination of different H2O measurement techniques: Snow White - frost point (troposphere), FLASH-B – fluorescence (upper troposphere and stratosphere) and MIAWARA- microwave (upper stratosphere and mesosphere) allows retrieving a water vapour profile from the ground up to the mesosphere





Concluding remarks

- A series of high resolution water vapour measurements have been obtained using both balloon and airborne FLASH hygrometer
- H_2O, O_3 and particles measurements above Africa during monsoon season strongly indicate that convective overshooting above continental region hydrates lower stratosphere
- Observation above Darwin in November and Niamey in August point out different mechanisms controlling H_2O amount in the UT/LS
- Combination of different in situ and remote measurement techniques allows retrieving a water vapour profile from the ground up to the mesosphere
- H_2O soundings in the Arctic allow detailed characterization of the chemical and dynamical processes governing water vapour distribution in the Winter Arctic stratosphere.

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