Odin/SMR Observations of Water Vapour in the Middle Atmosphere

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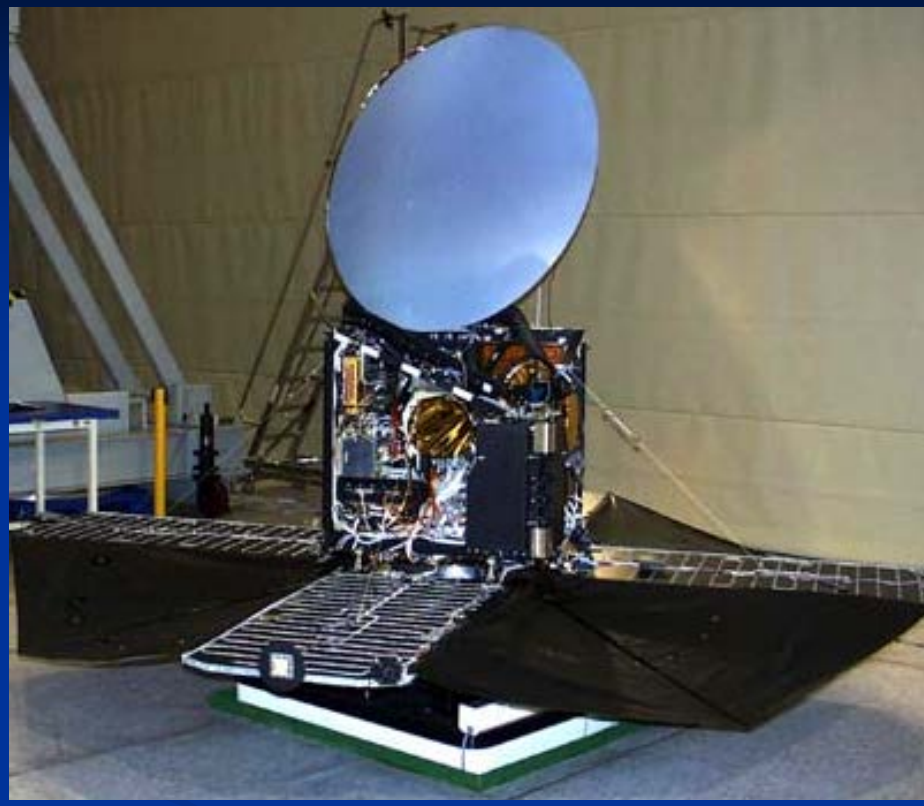
… and the Odin/SMR team

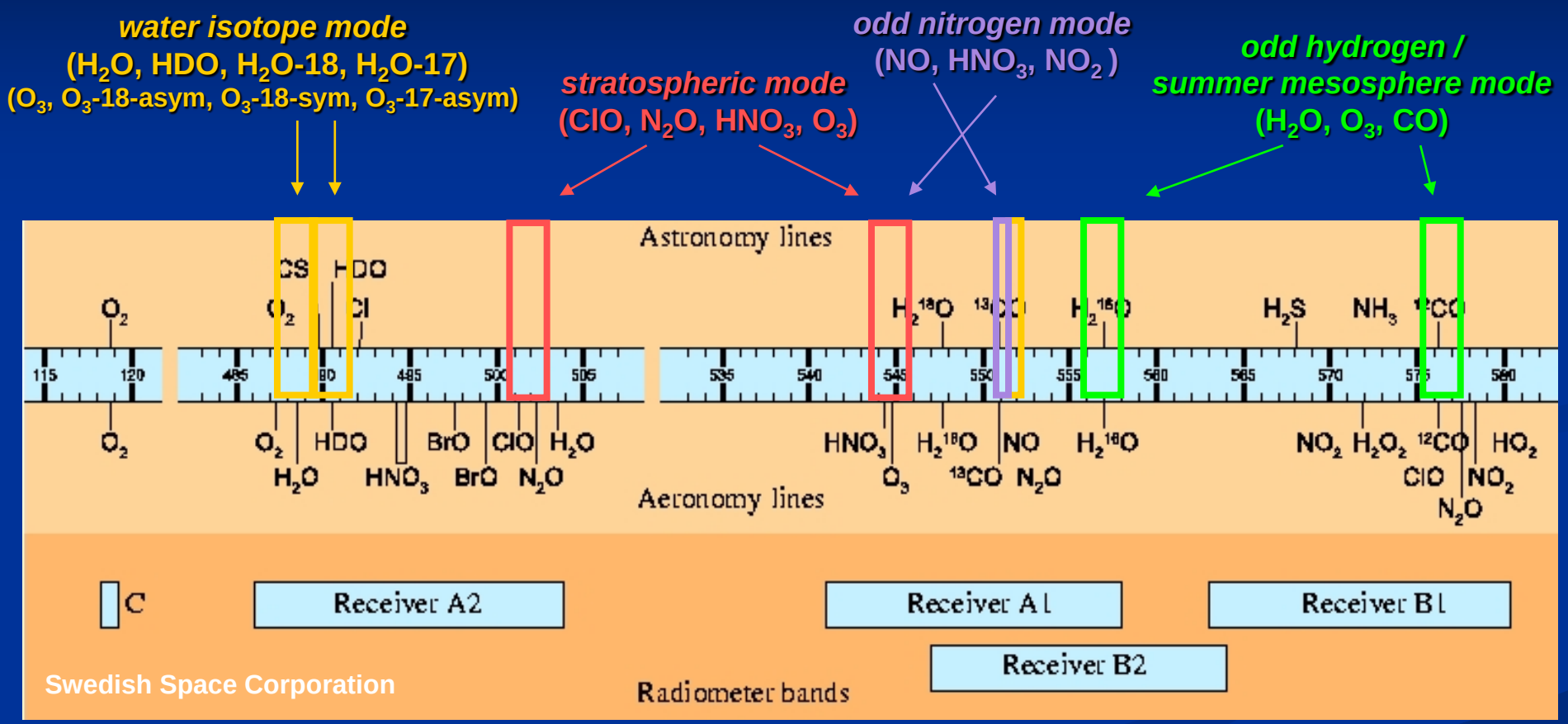
The Odin satellite



- Swedish led **mini-satellite**.
  Cooperation with Canada, Finland, France.
- **Launched in February 2001**.
  Design lifetime: 2 years.
- **Circular quasi-polar sun-synchronous orbit**:
  625km altitude, 96min/orbit,
  6h/18h equator crossing.
- Time sharing: **50% astronomy, 50% aeronomy**.
- **Limb-sounding** in aeronomy mode:
  ~45-65 scans/orbit, ~15 orbits per day.
- 2 instruments:
  SMR (*Sub-Millimetre Radiometer*),
  OSIRIS (Optical Spectrograph and InfraRed Imaging System)
- Aeronomy science objectives**: stratosphere + mesosphere**.

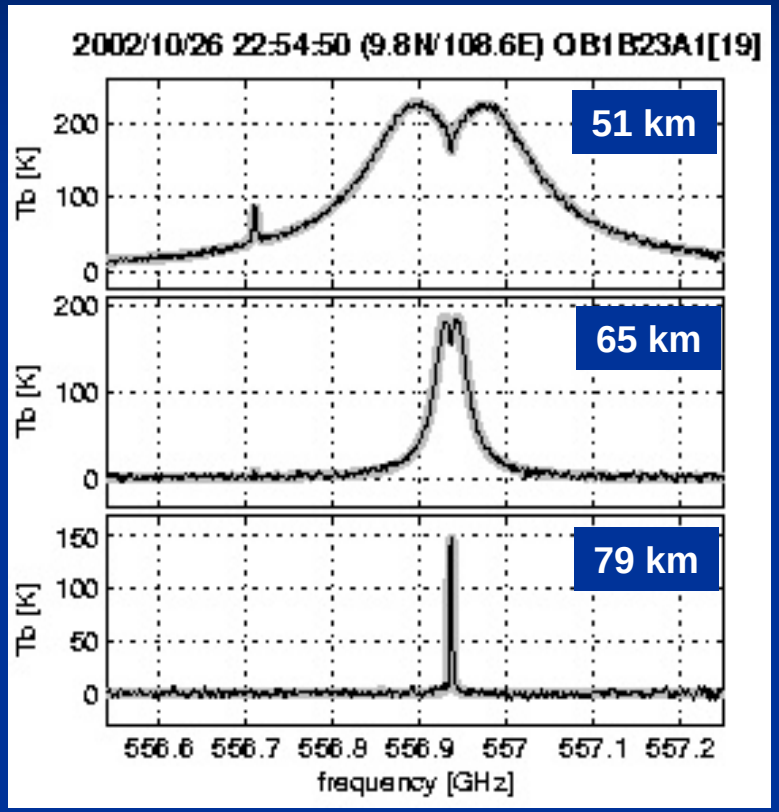
stratospheric mode **(ClO, N_2O, HNO_3, O_3),** ***water isotope mode*** **(H_2O, HDO, H_2O-18, H_2O-17),**
odd hydrogen / summer mesosphere mode **(H_2O, O_3, CO),** ***odd nitrogen mode*** **(NO, HNO_3, NO_2)**

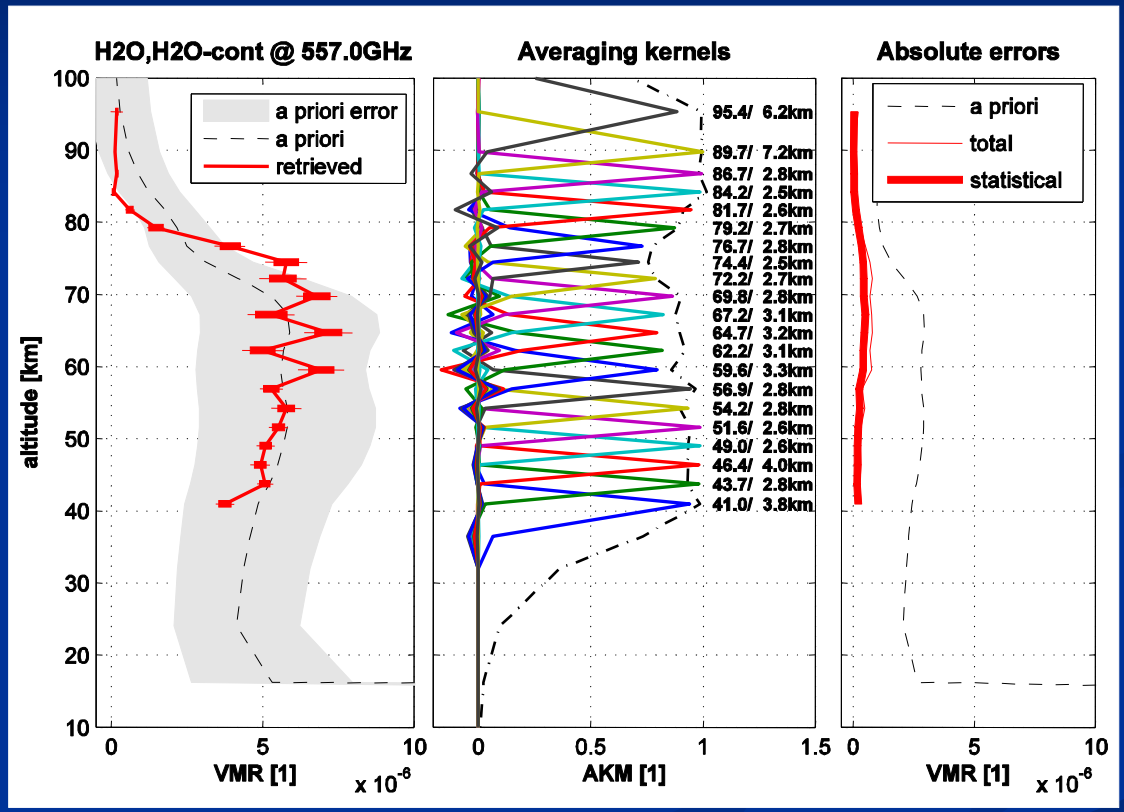
Odin/SMR frequency coverage



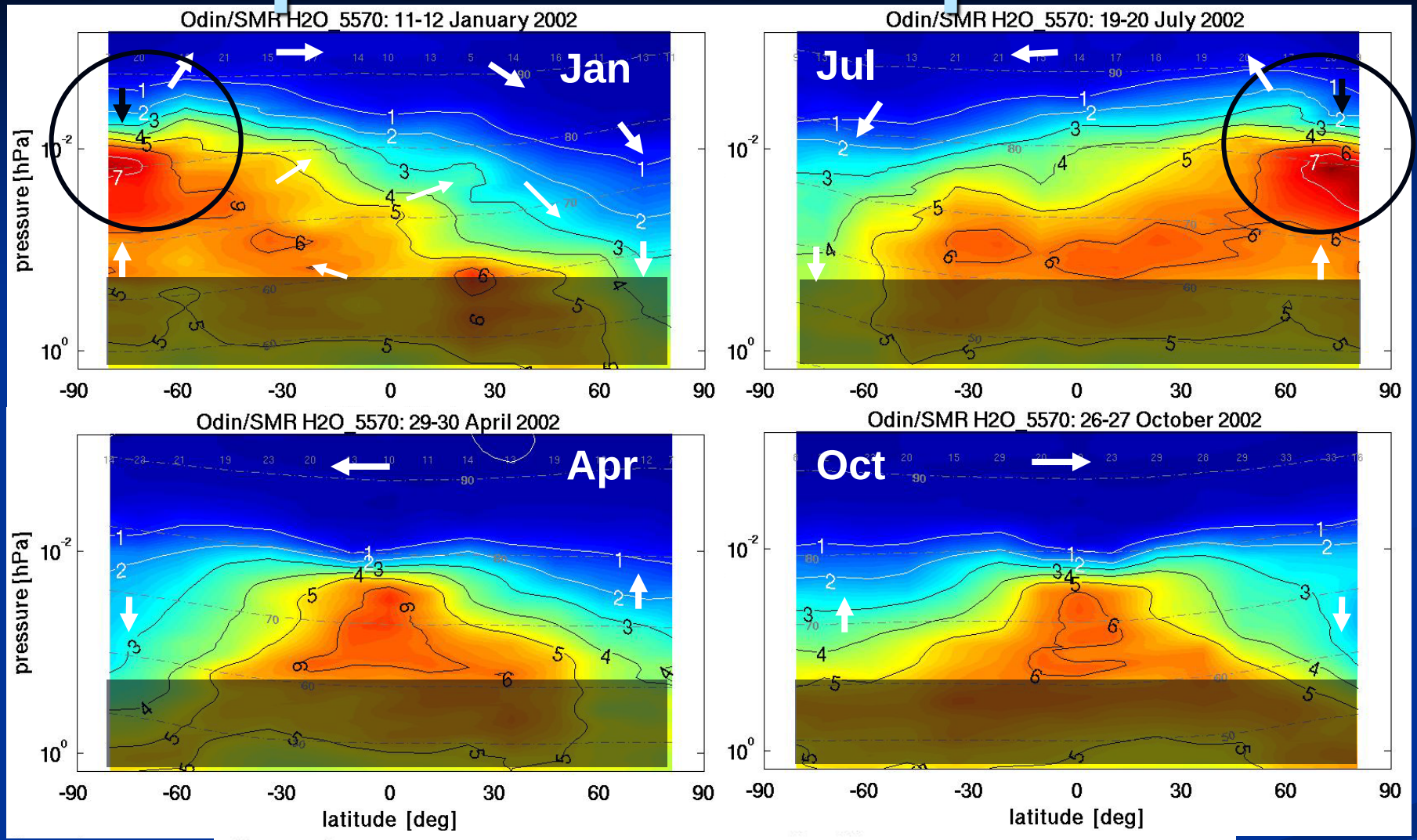
Mesospheric water vapour

Mesospheric water vapour @ 556.9 GHz





Mesospheric water vapour / 2002



Chalmers-v2.0
H_2O @ 557.0 GHz

3-d model: mesospheric H_2O

[Körner & Sonnemann, JGR, 106, 2001]

NH summer solstice

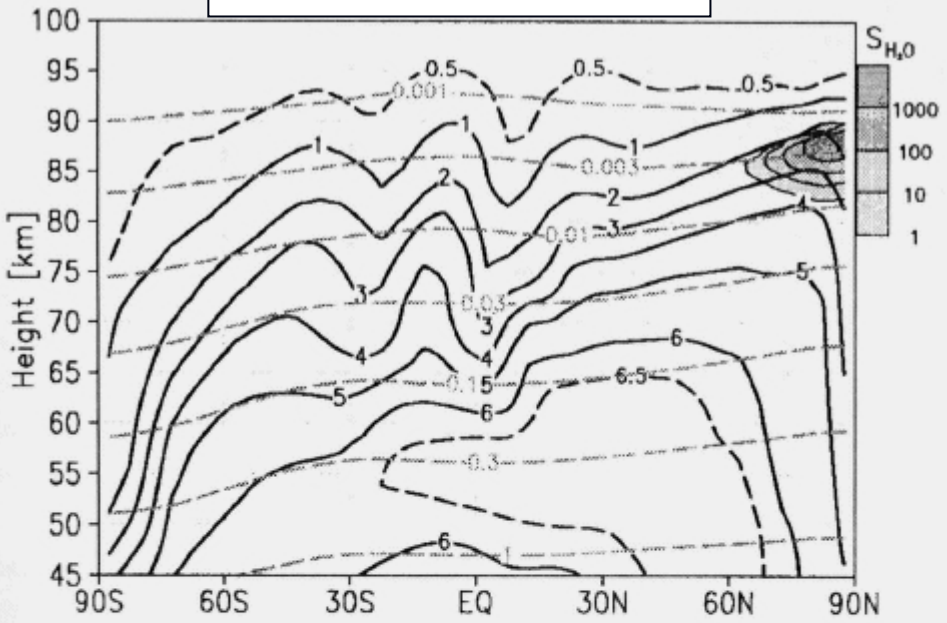


Figure 2. Latitudinal cross section of the water vapor mixing ratio (ppm) between 45 and 100 km altitude for northern summer solstice. The most marked features are the latitudinal decrease of the water vapor mixing ratio from the summer to the winter hemisphere and the equatorial variations due to distinct circulation cells indicated by upward and downward moving air. The figure displays the levels of constant pressure by the grey dashed lines, which demonstrate that the decline of the water vapor mixing ratio in winter partly results from the decrease of the pressure levels.

seasonal variation

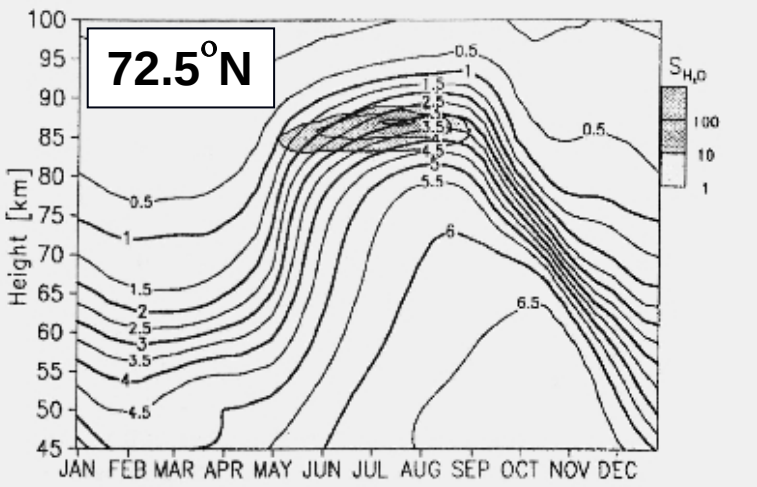


Figure 1. Seasonal section of the water vapor mixing ratio (ppm) for a latitude of 72.5°N between 45 and 100 km altitude. The figure additionally displays contours of the degree of supersaturation of H_2O in the summer mesopause indicated by shaded areas. A high factor is the condition for the formation of ice particles.

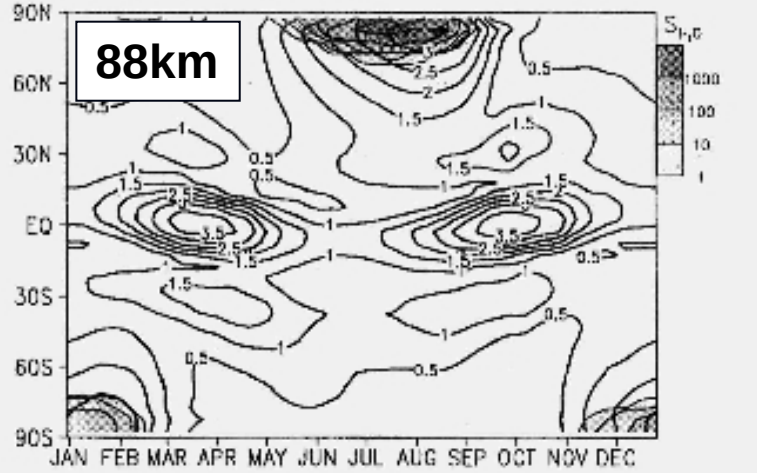
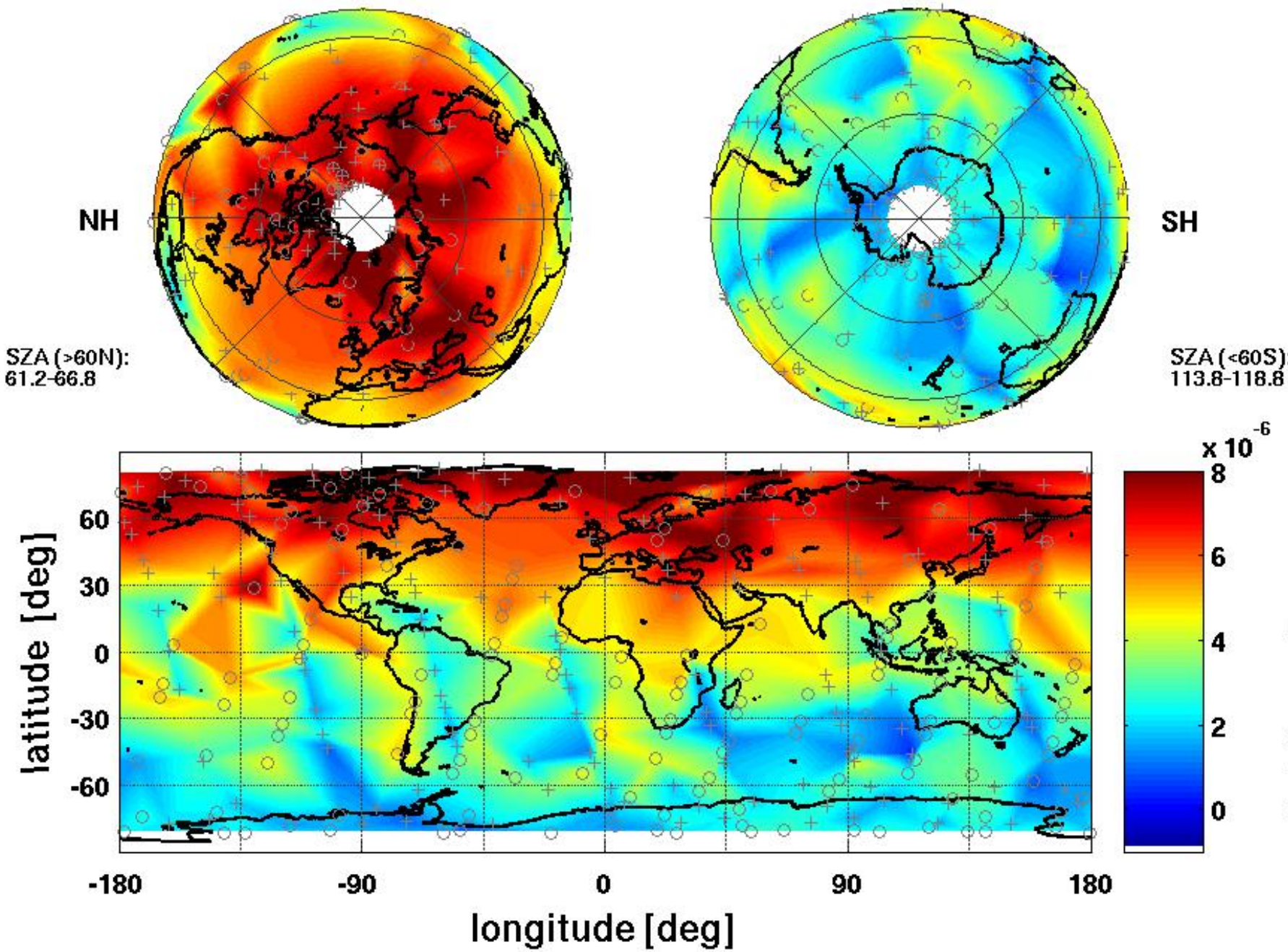
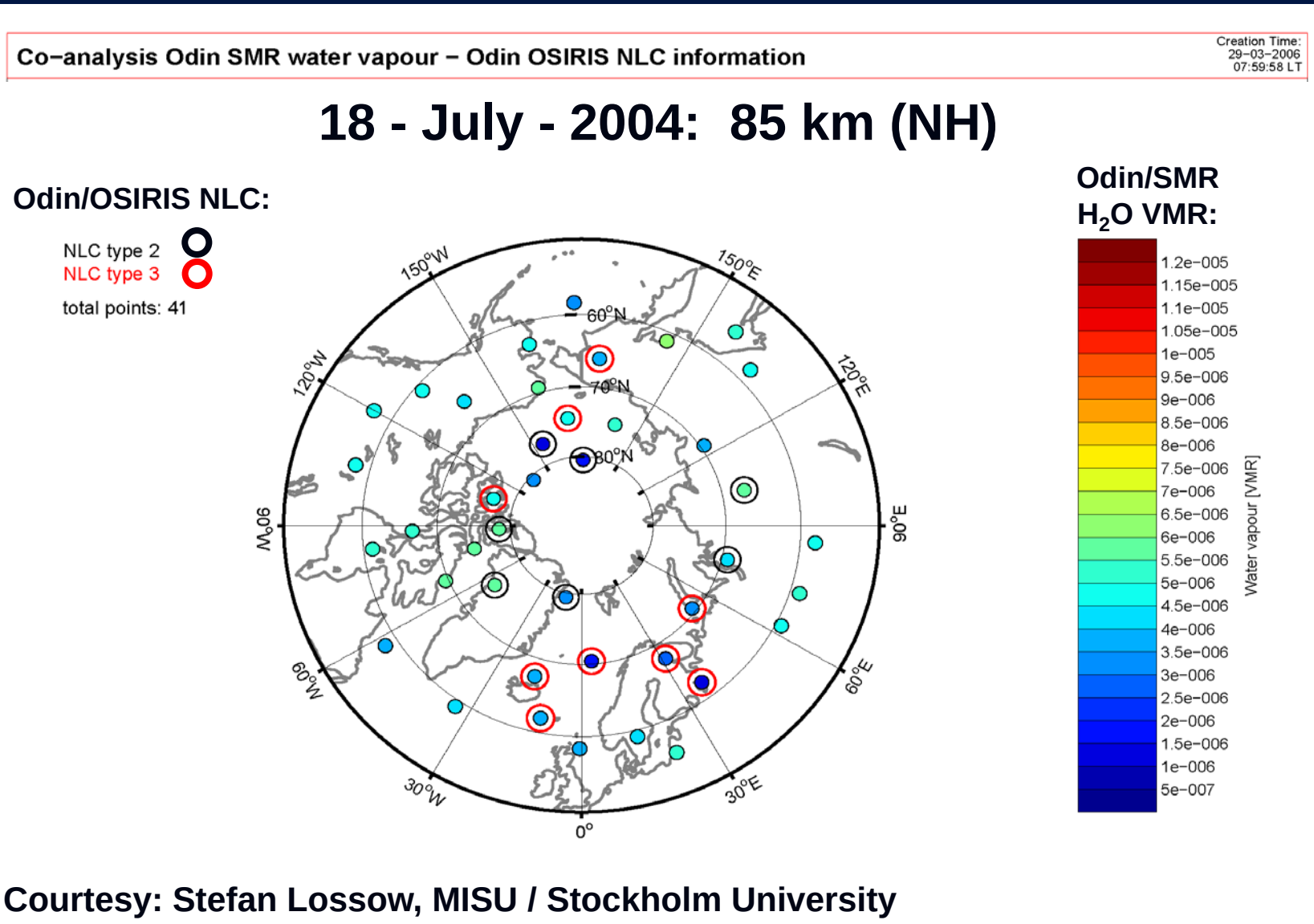


Figure 5. Latitudinal-seasonal cross section of the water vapor mixing ratio (ppm) at 88 km altitude. The figure additionally exhibits the area of supersaturation at summer high latitude. It makes clear the change of the semiannual variation for low latitudes when using different latitudinal sections.

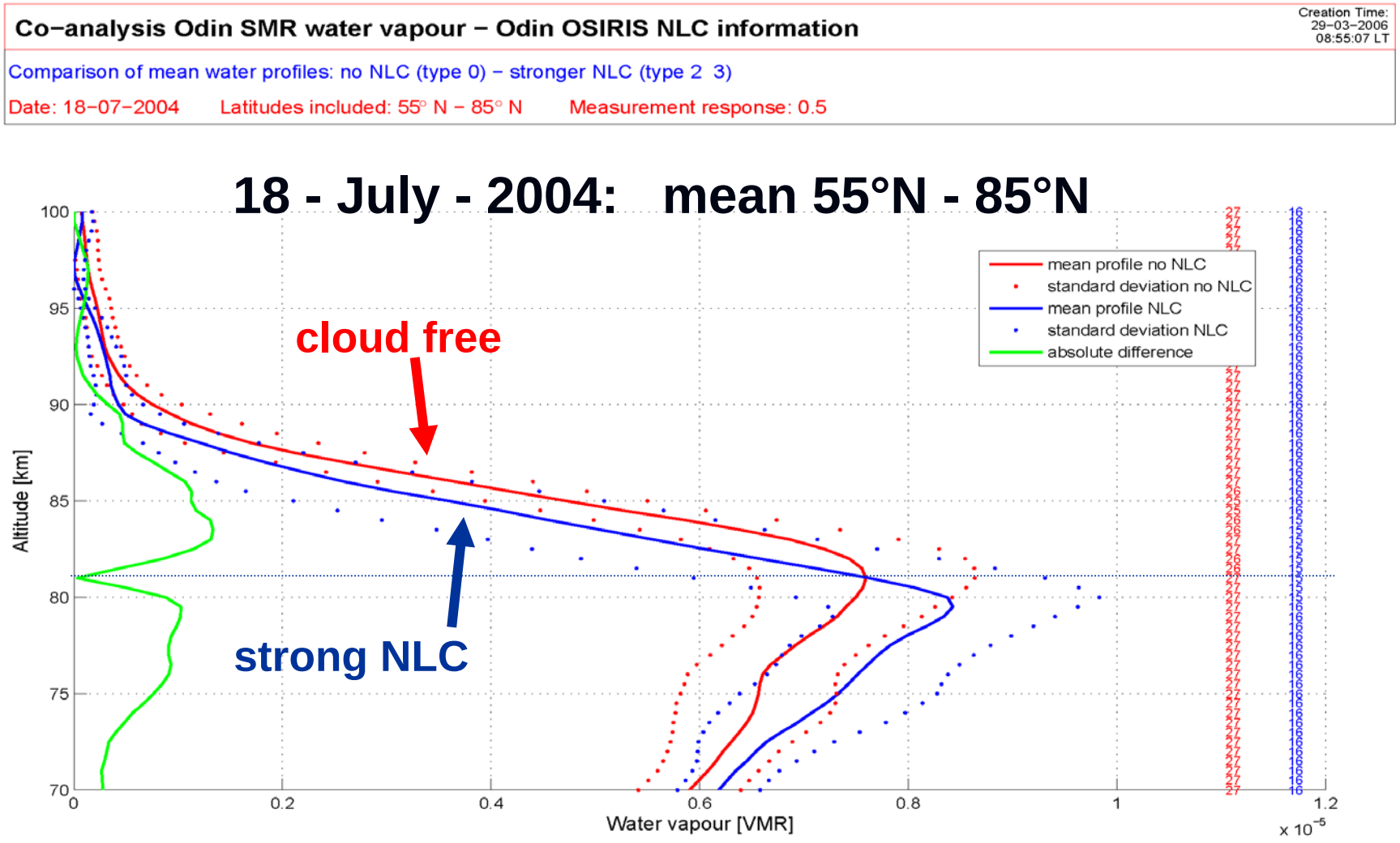

Odin/SMR: H2O_5570 2004-07-18 - altitude 80km
NH
SH
SZA (>60N):
61.2-66.8
SZA (<60S):
113.8-118.8
x 10^-6
8
6
4
2
0
H2O_5570 [ppv]
60
30
0
-30
-60
latitude [deg]
-180
-90
0
90
180
longitude [deg]

Odin: NLC's + H_2O in summer mesosphere



Courtesy: Stefan Lossow, MISU / Stockholm University

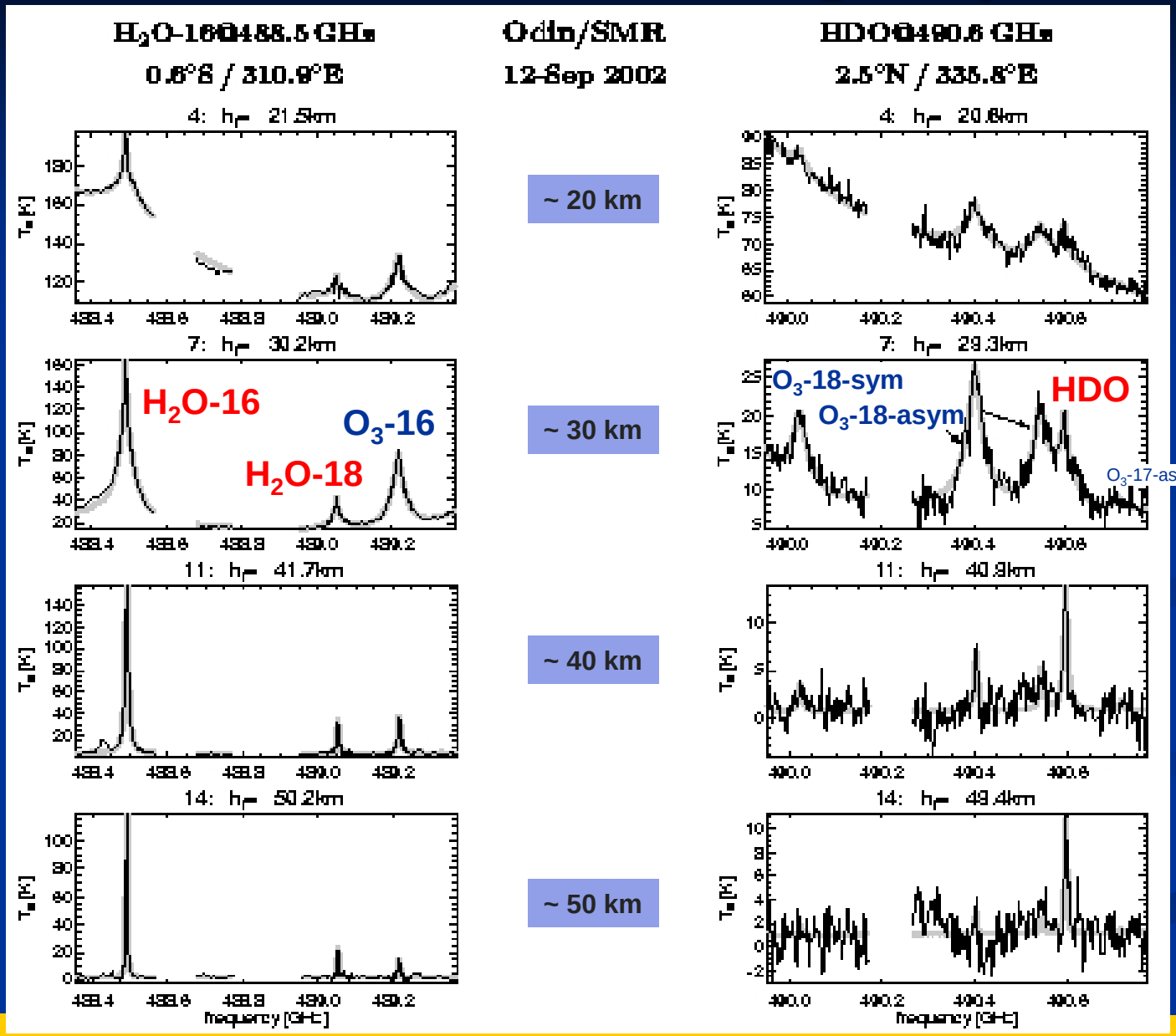
Odin/SMR H_2O @ 557 GHz: summer mesosphere



Courtesy: Stefan Lossow, MISU / Stockholm University

Odin/SMR water isotope mode

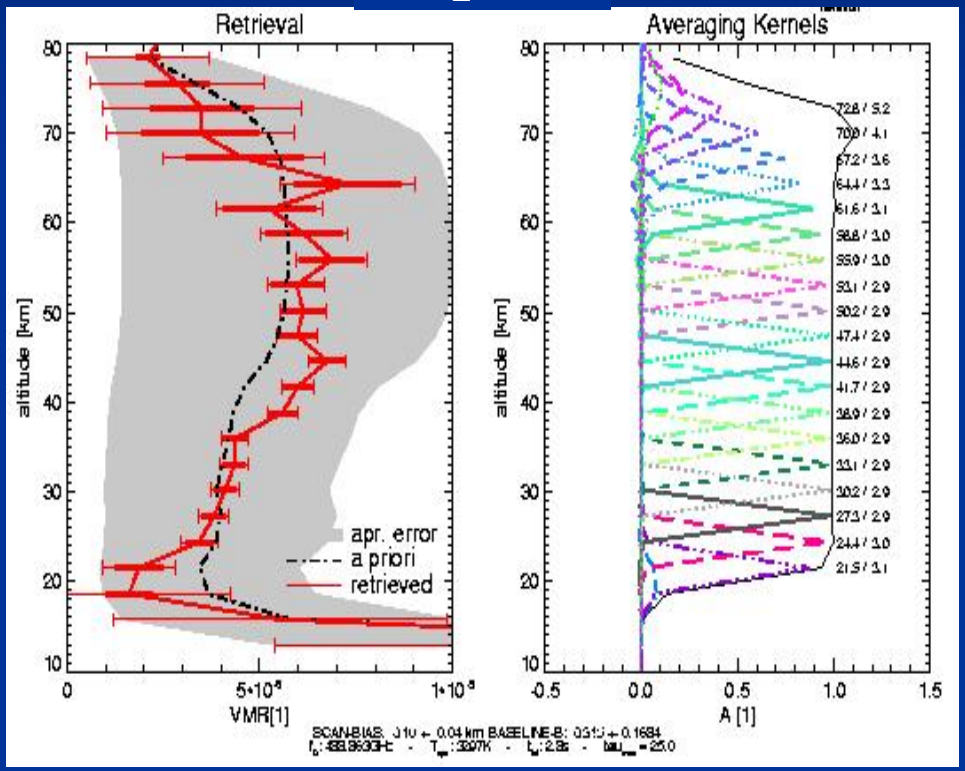
Odin/SMR Water Isotope Mode: H_2O, O_3 + isotopes



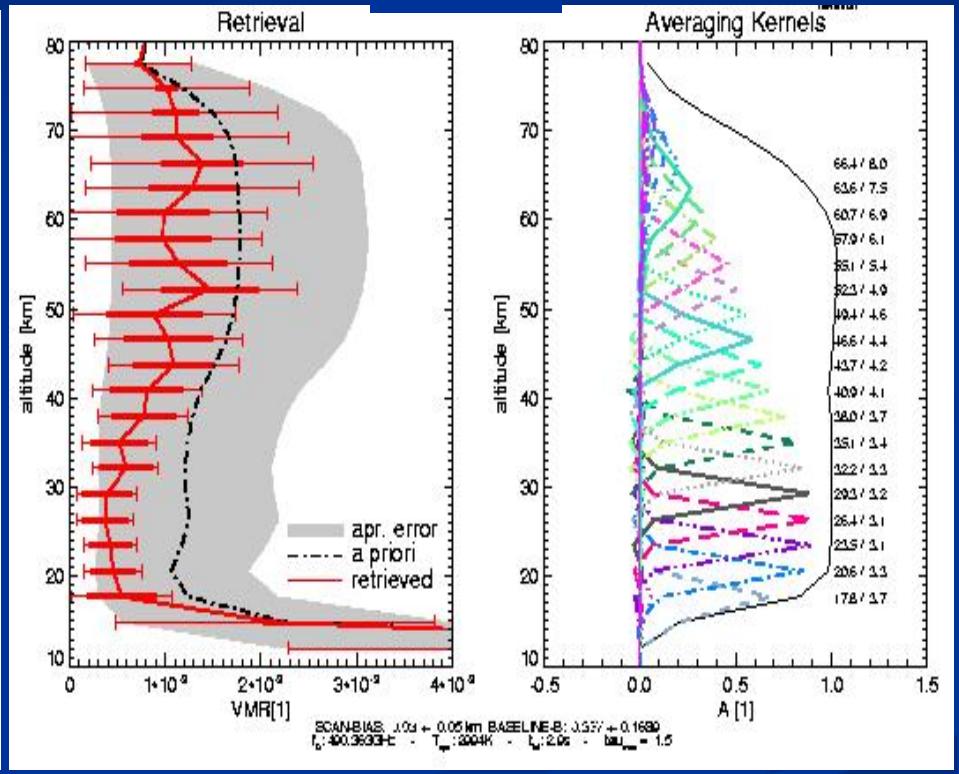
Odin/SMR water isotope mode

Retrieved profiles of **$H_2{}^{16}O$ @ 488.9 GHz and HDO @ 490.4 GHz**

$H_2{}^{16}O$



HDO



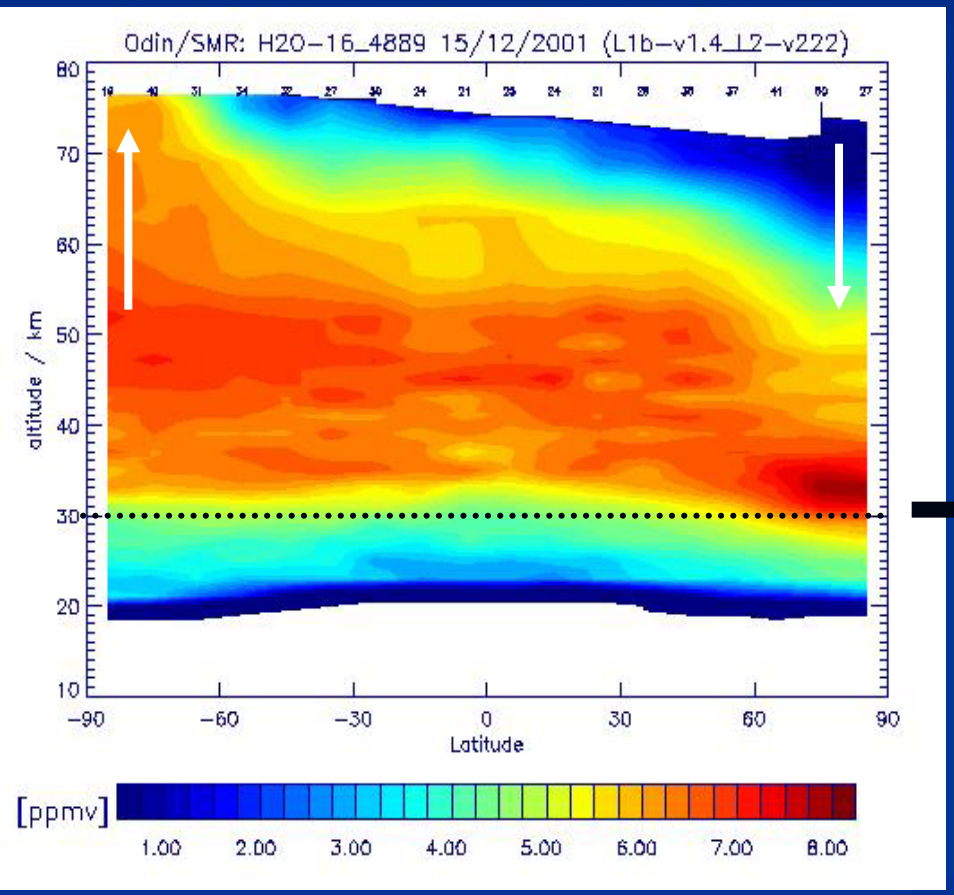
- **Simultaneous retrieval of $H_2{}^{16}O$, O_3, $H_2{}^{18}O$ / HDO, $^{18}O_3$-asym, $^{18}O_3$-sym, scan-bias, linear baseline (offset), temperature, and continuum**

Odin/SMR water vapour – 15 Dec 2001

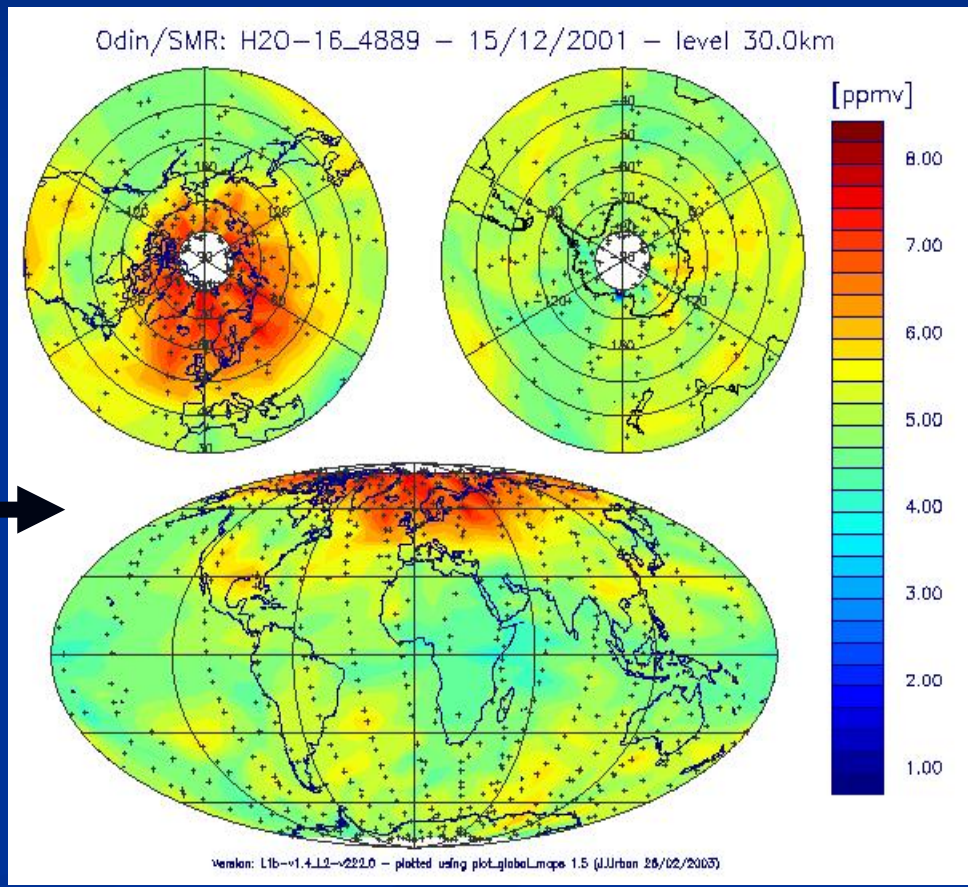
Retrieval of water vapour **$H_2{}^{16}O$** - band **488.35-489.35 GHz**

zonal mean and global distribution

zonal mean $H_2{}^{16}O$



$H_2{}^{16}O$ at 30km



24 hours = 14 orbits x 50 scans / orbit

Water Vapour "Delta-D" : a tool to study the origin of air masses

- **Isotopic depletion/enrichment**: $\delta D = (R_{obs}/R_{ref} - 1) \times 100$ [%]

- **SMOW - Standard Mean Ocean Water**: D/H ratio = $R_{ref} = 1.5576.10^{-4}$

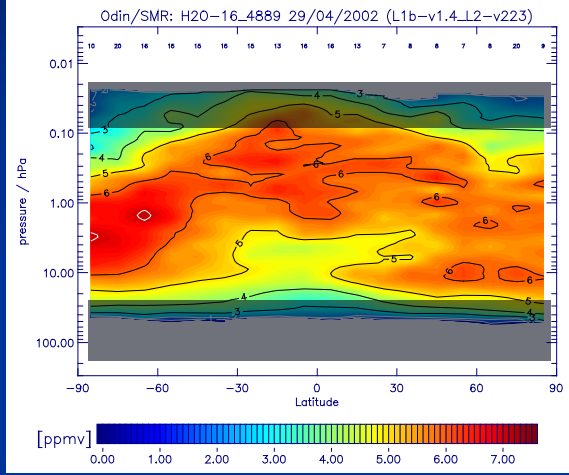
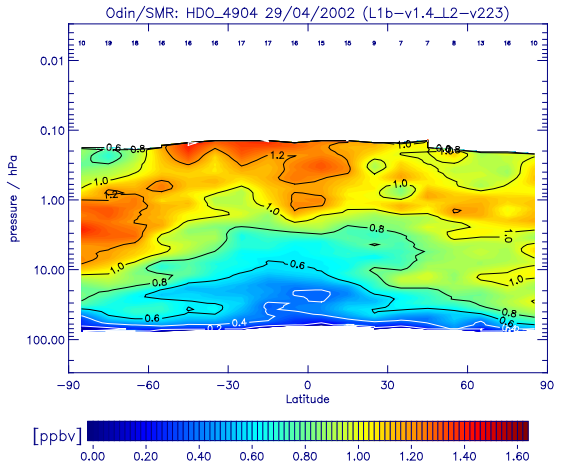
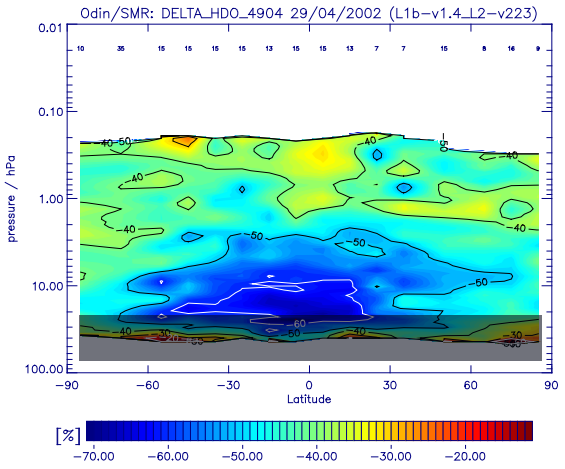
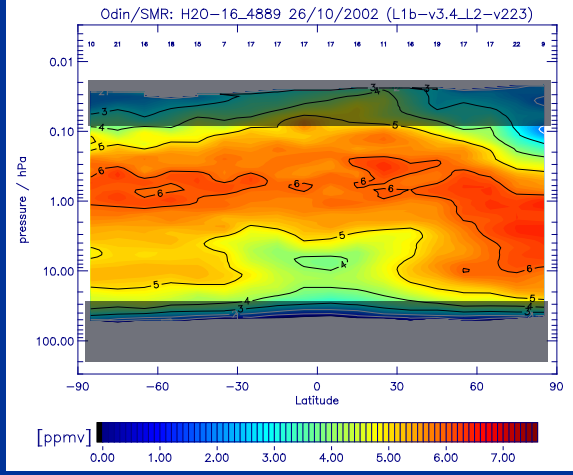
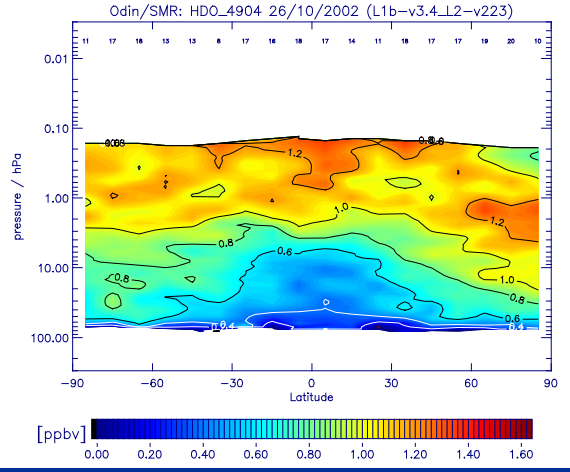
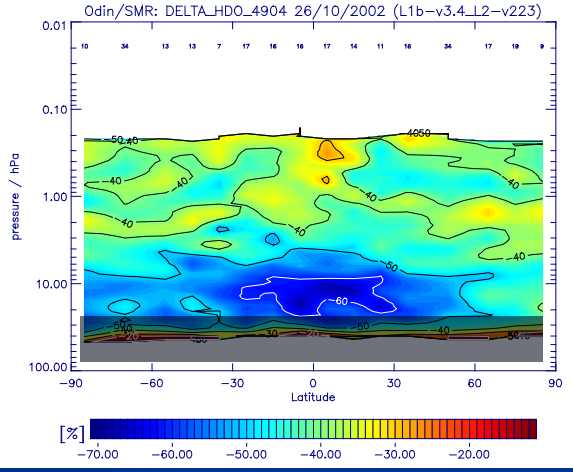
- δD variations caused by **isotopic fractionation** processes (phase changes, chemistry)

- Initial δD (tropical tropopause) = ~ - 65% (due to condensation / phase changes in TTL)

- δD in water vapour increases with altitude in stratosphere due to chemical production from CH_4 and CH_3D oxidation, since stratospheric entry value of δD in methane is larger.

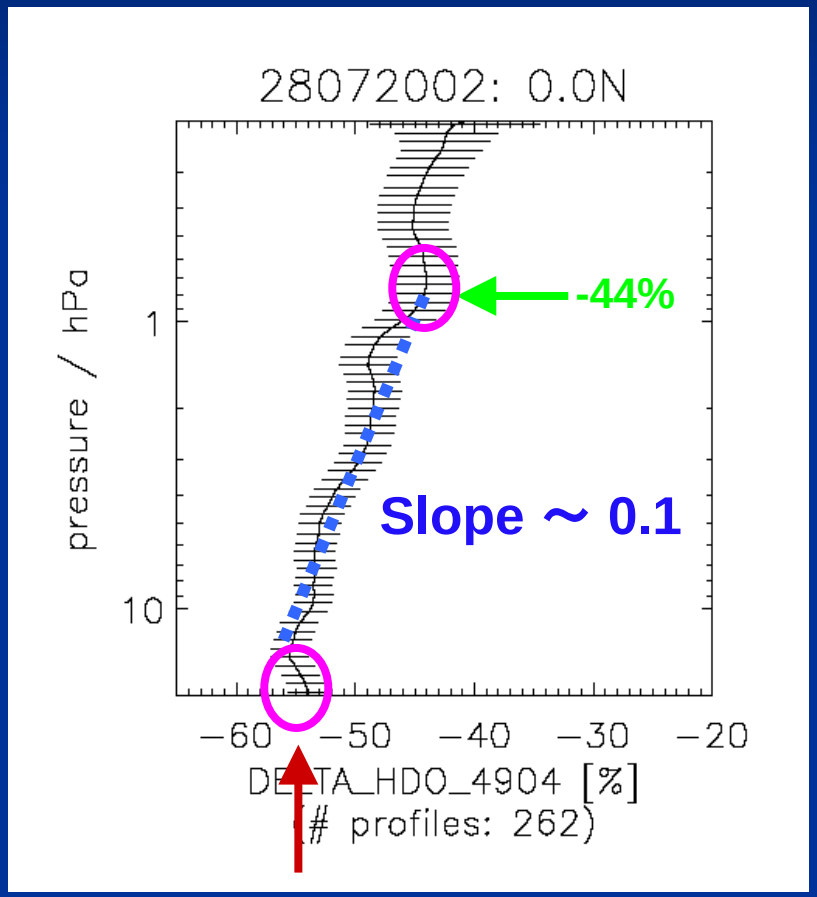
Odin/SMR water isotope mode: H_2O, HDO, δD

Zonal mean of water vapour **$H_2{}^{16}O$** and its isotope **HDO**

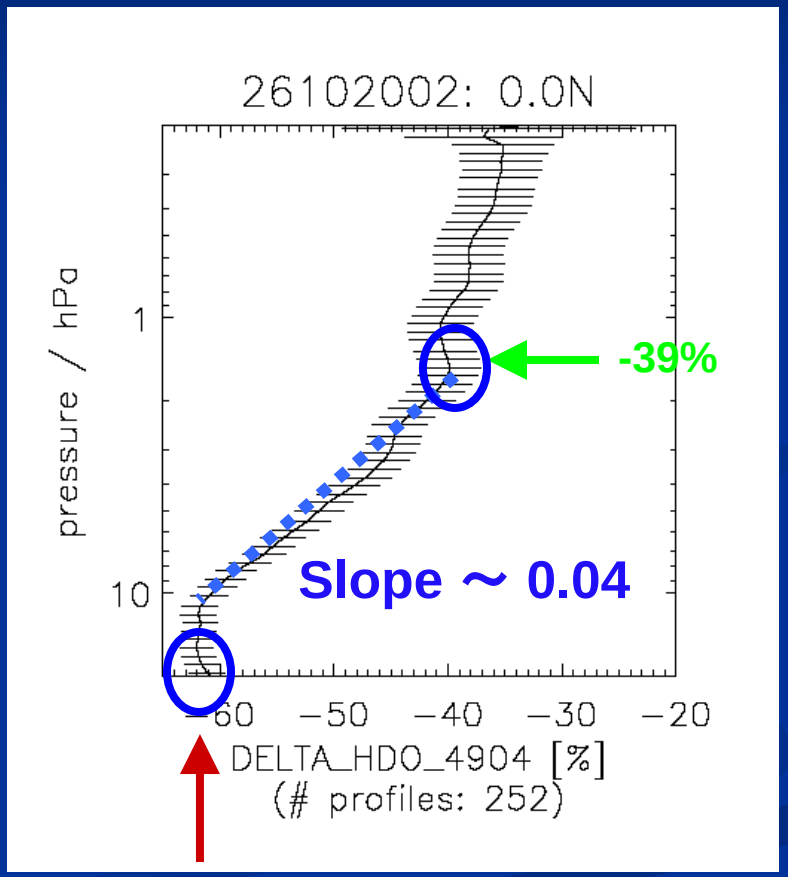
	H_2O @ 488.9 GHz	**HDO @ 490.4 GHz**	**δD (HDO)**
29-30 April 2002			
26-27 October 2002			

δD - 20S-20N mean

3 month mean
July-Aug-Sep 2002

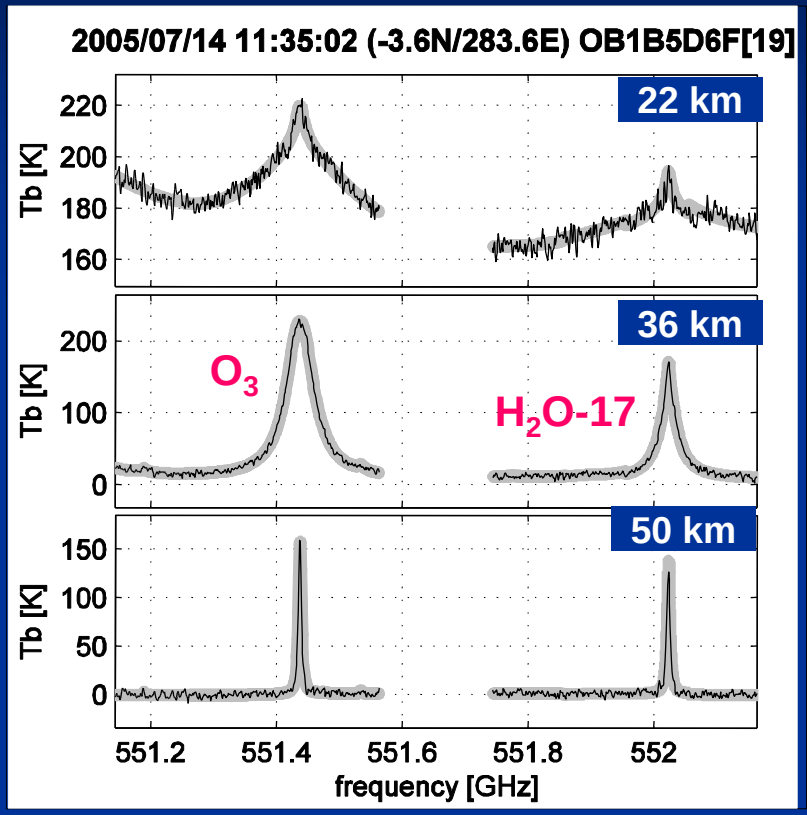


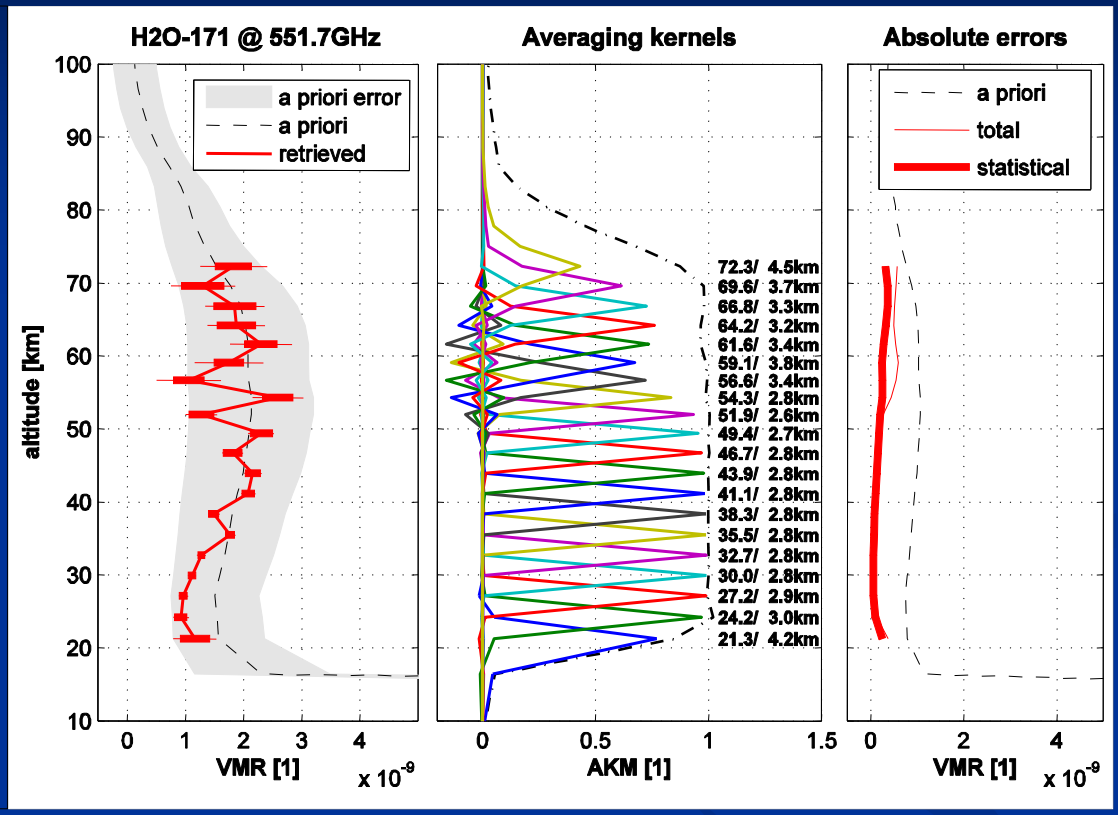
3 month mean
Oct-Nov-Dec 2002



Courtesy: Y. Kasai / NICT Tokyo

Odin/SMR: H_2O-17 @ 552 GHz





H_2O-17, NO, O_3: 1 observation day per month since Nov 2003

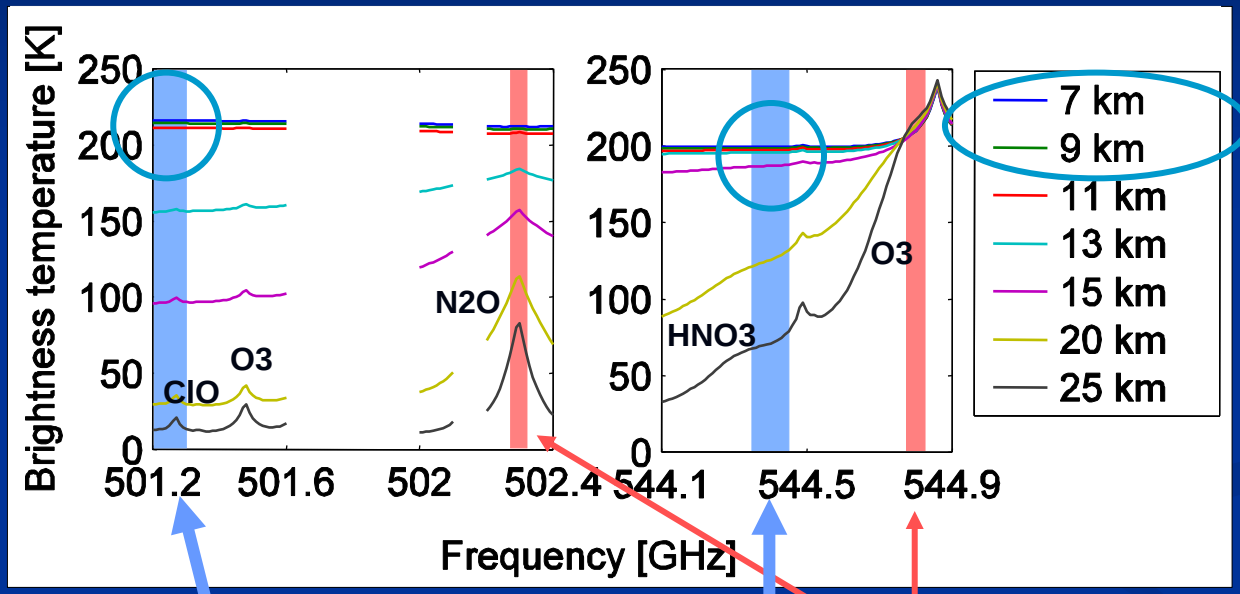
Relative humidity in tropical upper troposphere

Odin/SMR: Upper tropospheric humidity / tropics

stratospheric mode

501.8 GHz

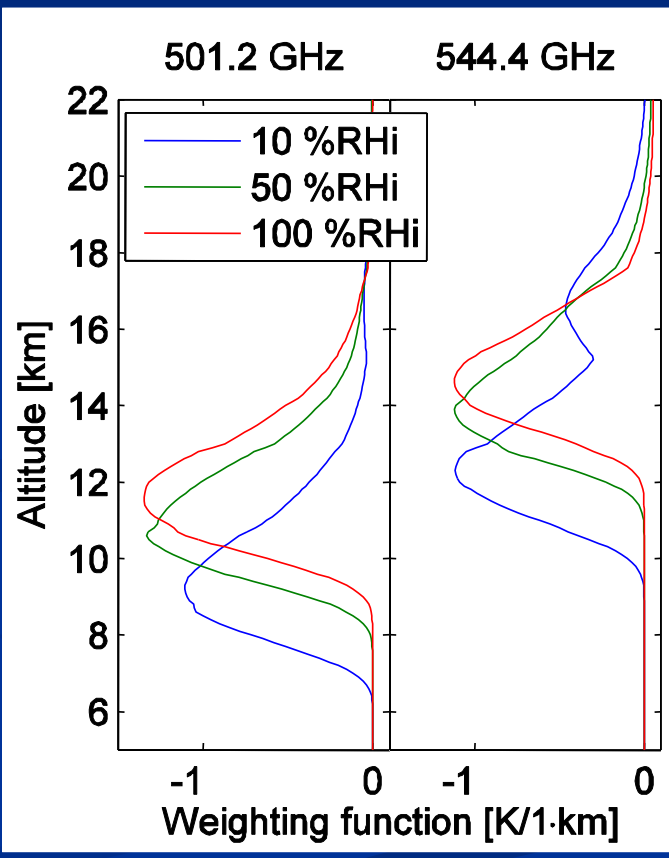
544.6 GHz



sub-bands for RH retrieval

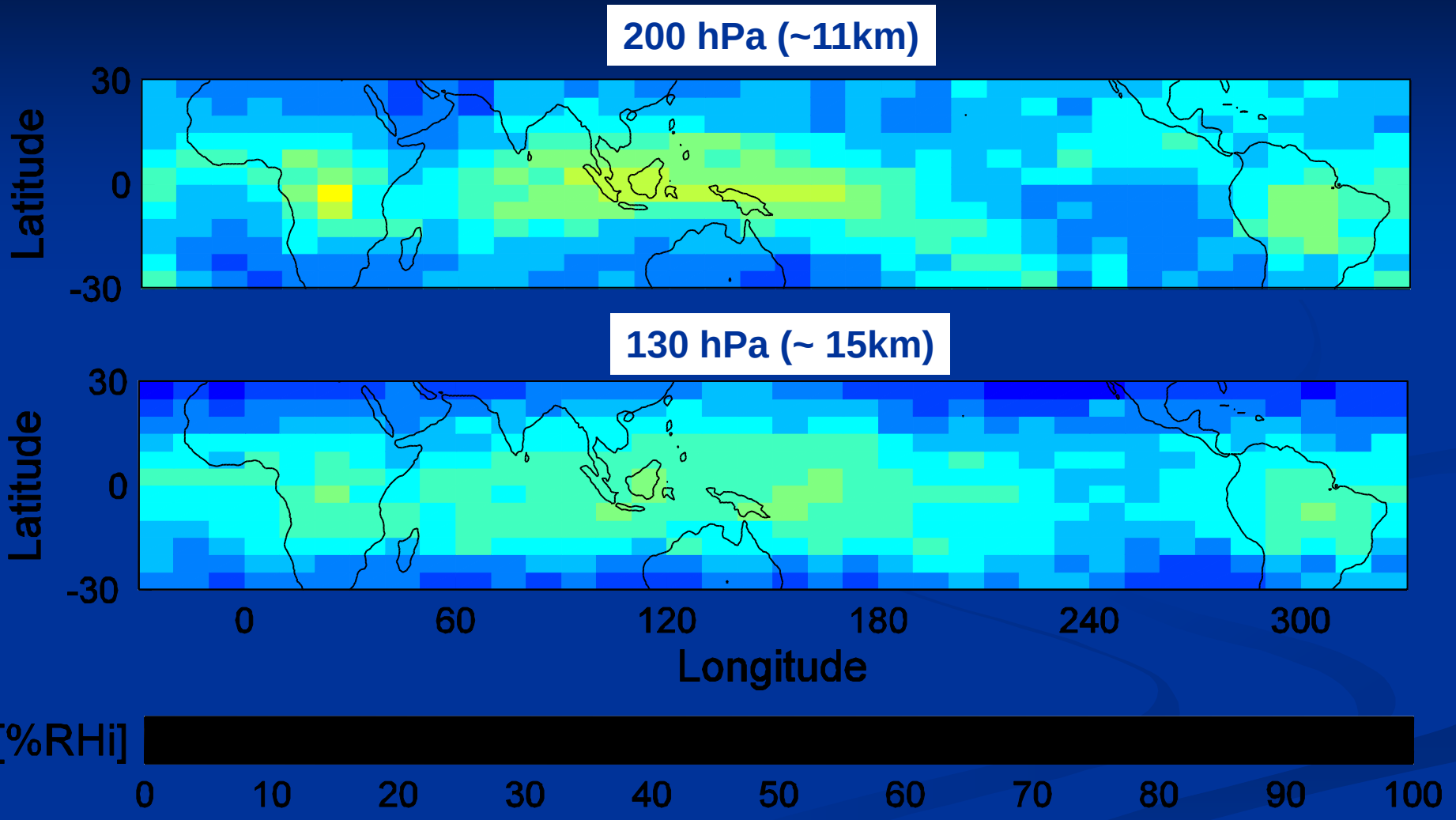
sub-bands for cloud correction

RHi weighting functions



Odin/SMR: Upper tropospheric humidity / tropics

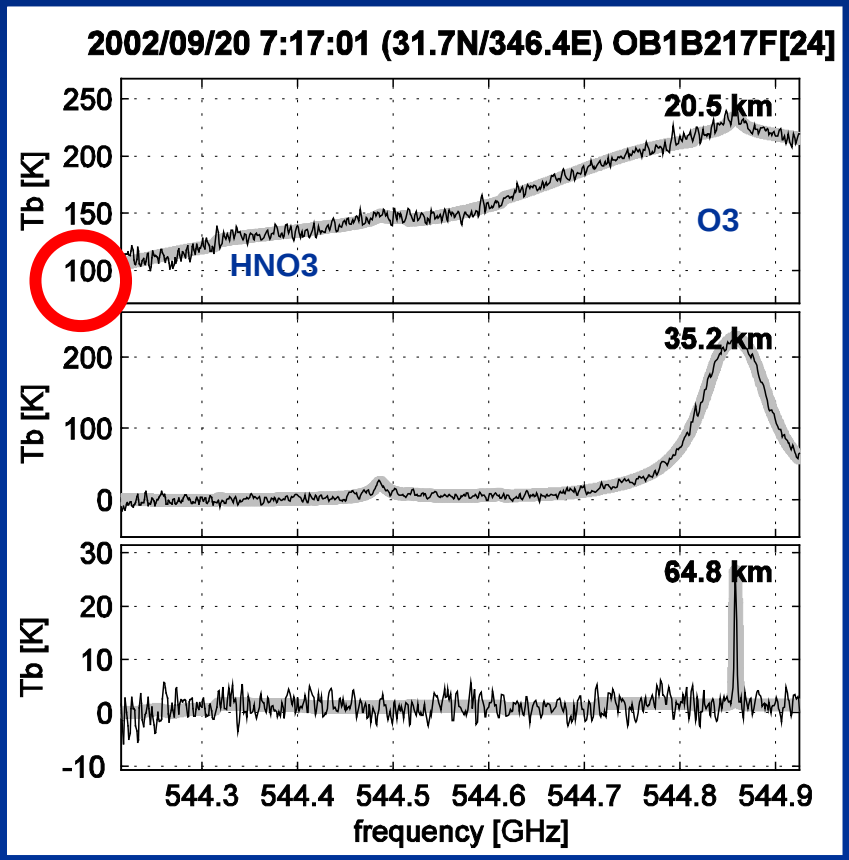
multi-annual mean: December 2001 – August 2004



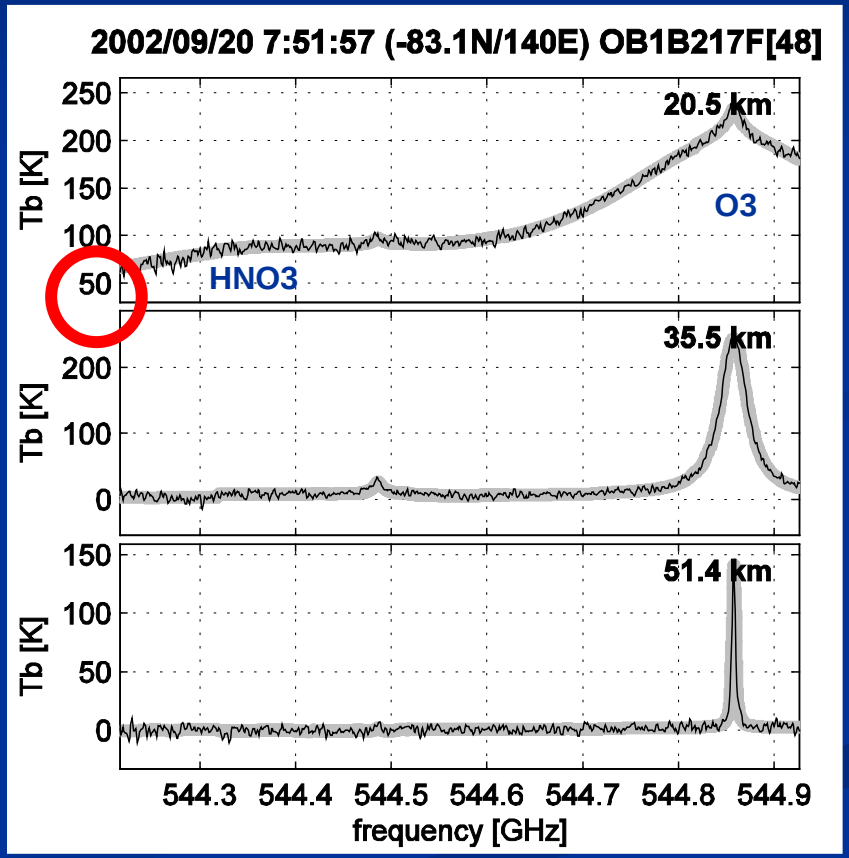
UT/LS water vapour from continuum emissions

544.6 GHz retrieval: H_2O continuum

32 N



83 S



H_2O @ 544.6 GHz: 2003

- **H2O retrieval from continuum emissions** in 544.6 GHz stratospheric mode measurements (O3, HNO3), ~10 observation days per month.

- **Global coverage** (~83S-83N), **good altitude resolution** (~3-4 km), useful **altitude range** ~10-30 km covering UT/LS, noise requires averaging.

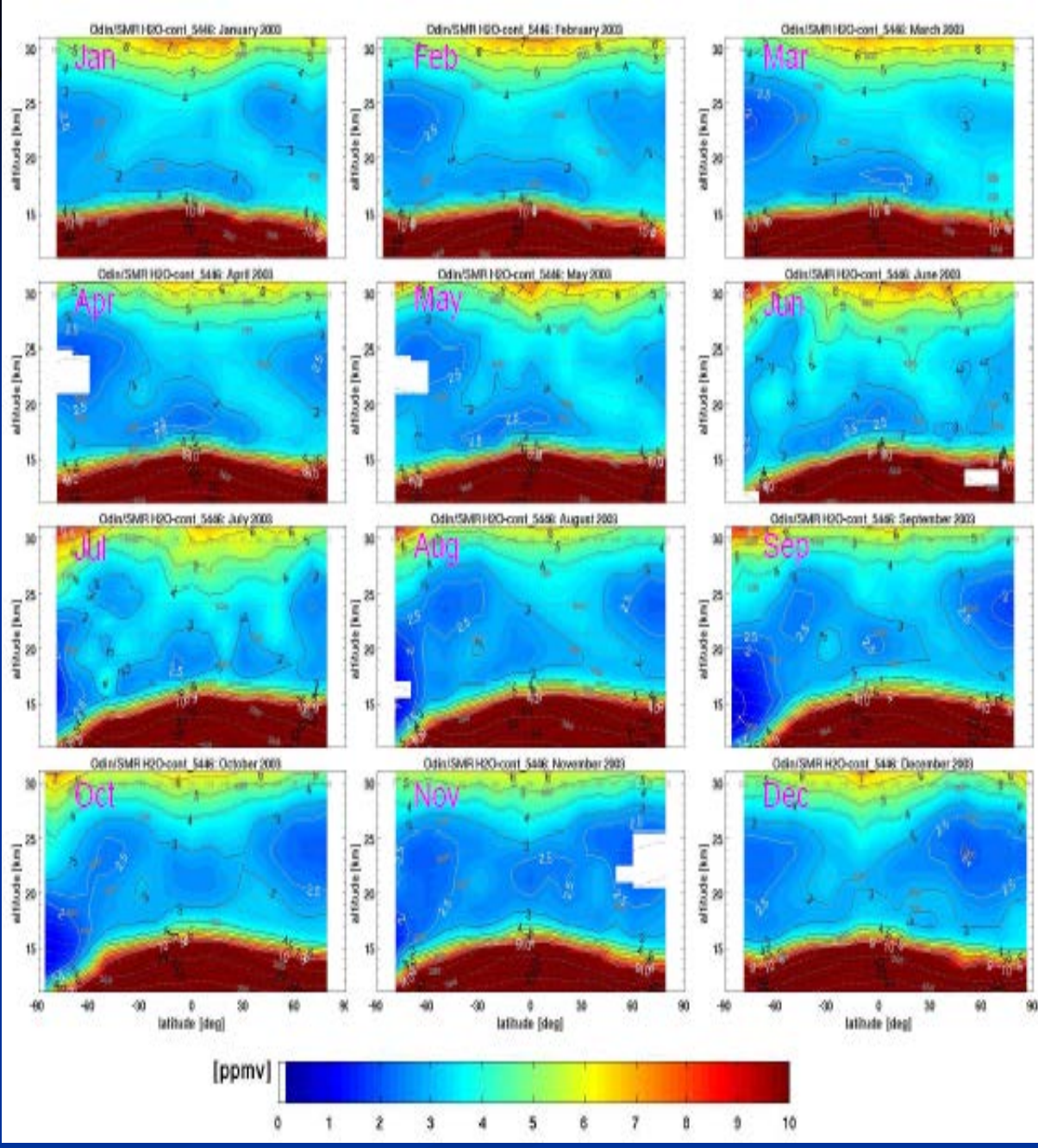
- **Monthly zonal mean fields**:

  - **Large VMR in troposphere**, change of gradient indicates tropopause,

- Typical **VMR in lower stratosphere** (~15-25km) of 2.5-4 ppmv,

- **De-hydrification inside Antarctic polar vortex:** Very low values at 12-20km in southern winter hemisphere (~Jul-Nov),

- **Minima around ~20-25 km at high latitudes** (summer hemisphere and outside vortex during winter). Correlation with HNO3?



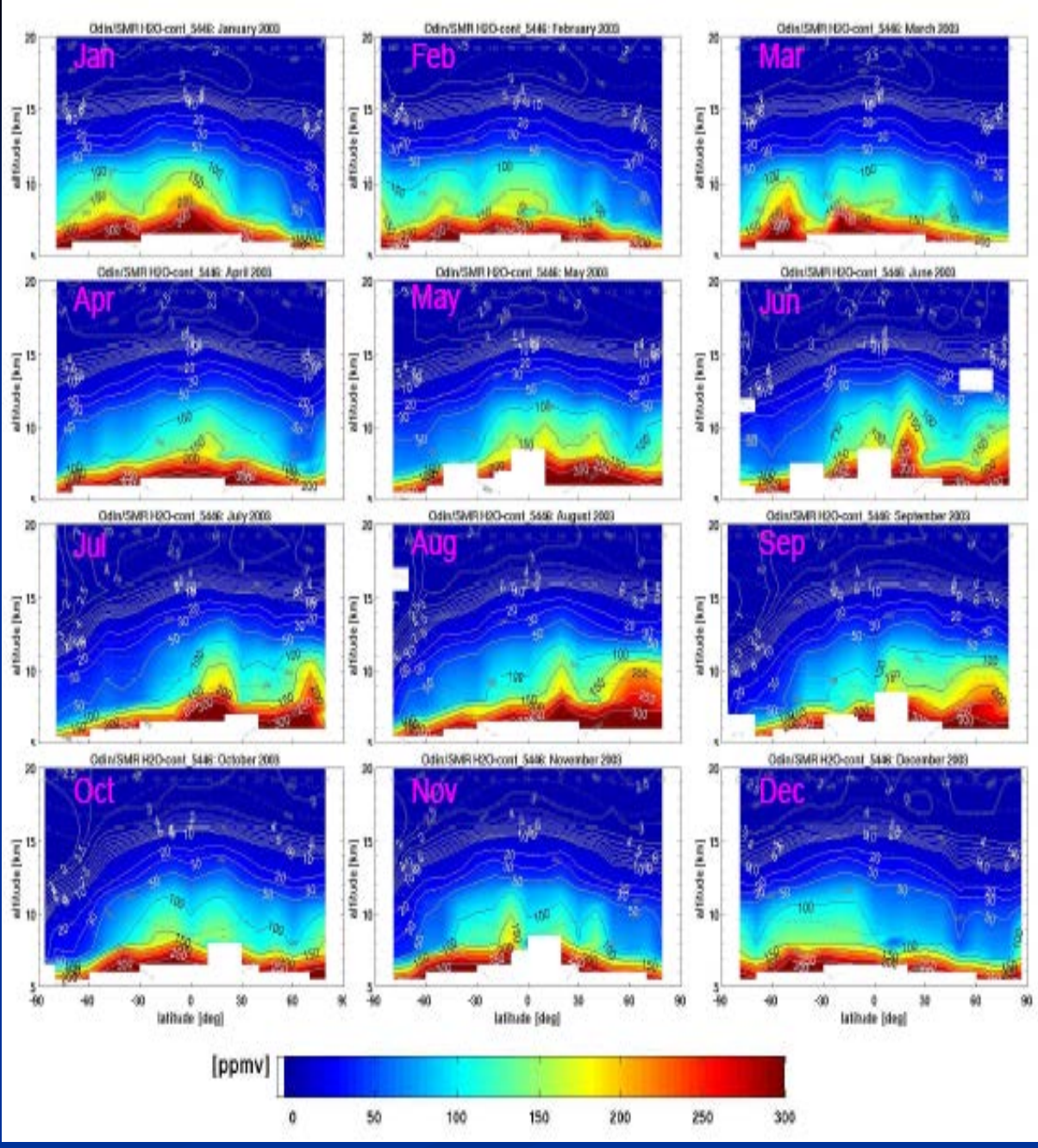
H_2O @ 544.6 GHz: 2003

upper troposphere

- **H2O information in troposphere from continuum emissions** in 544.6 GHz measurements

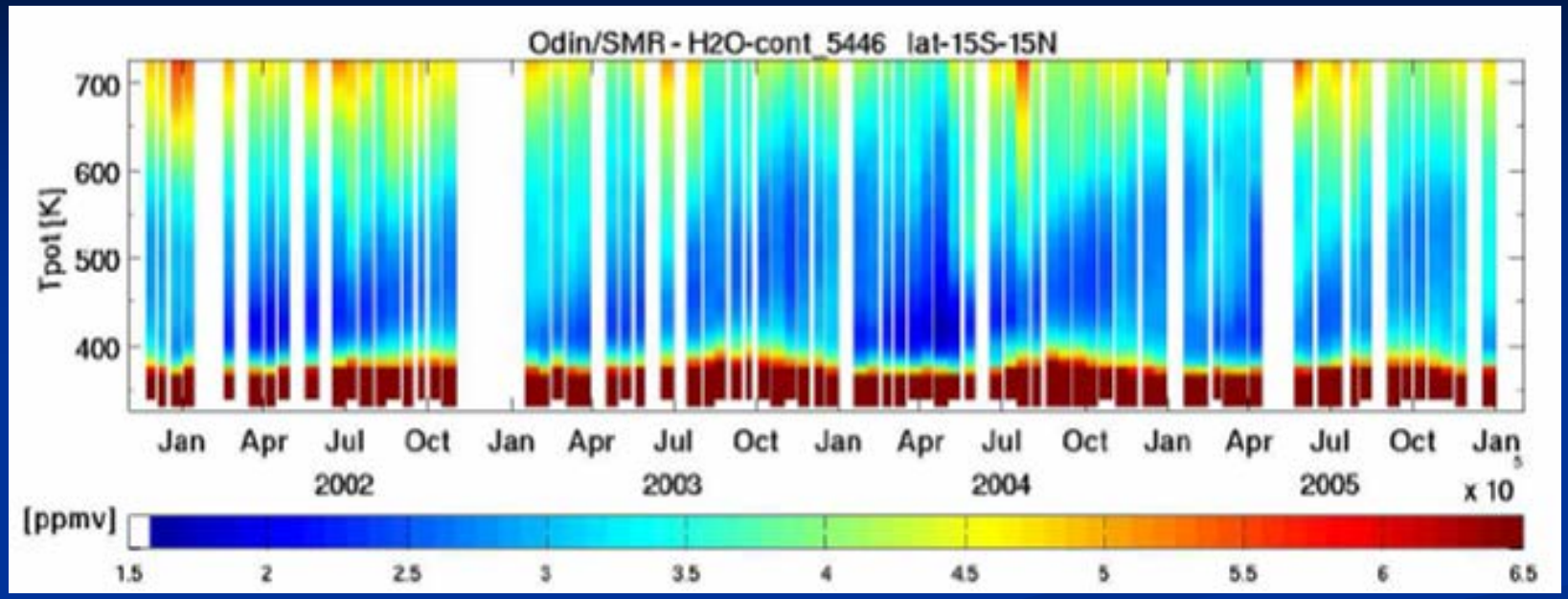
- **Troposphere:**
  - No cloud correction yet applied!!!
  - A priori contamination 10-30% !

- **Large VMR in troposphere**, change of gradient indicates tropopause, large seasonal variation.

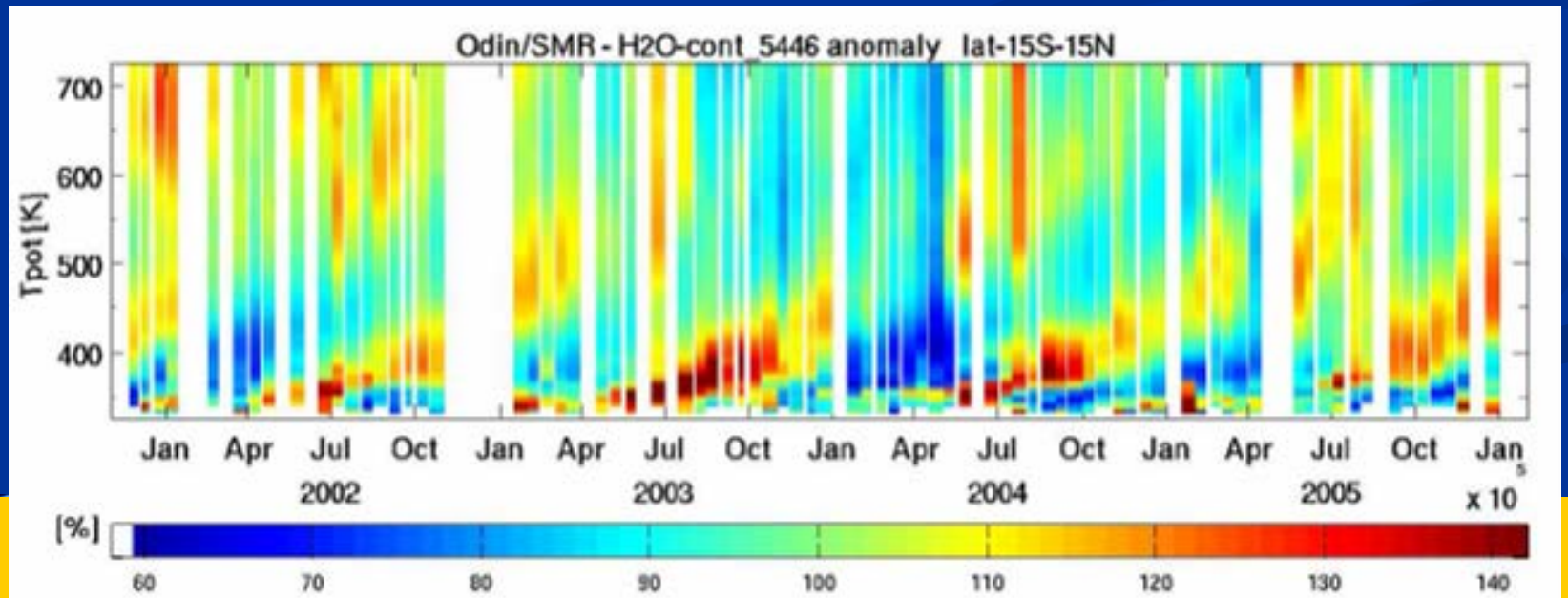


H_2O tape recorder: tropics 15S-15N

VMR

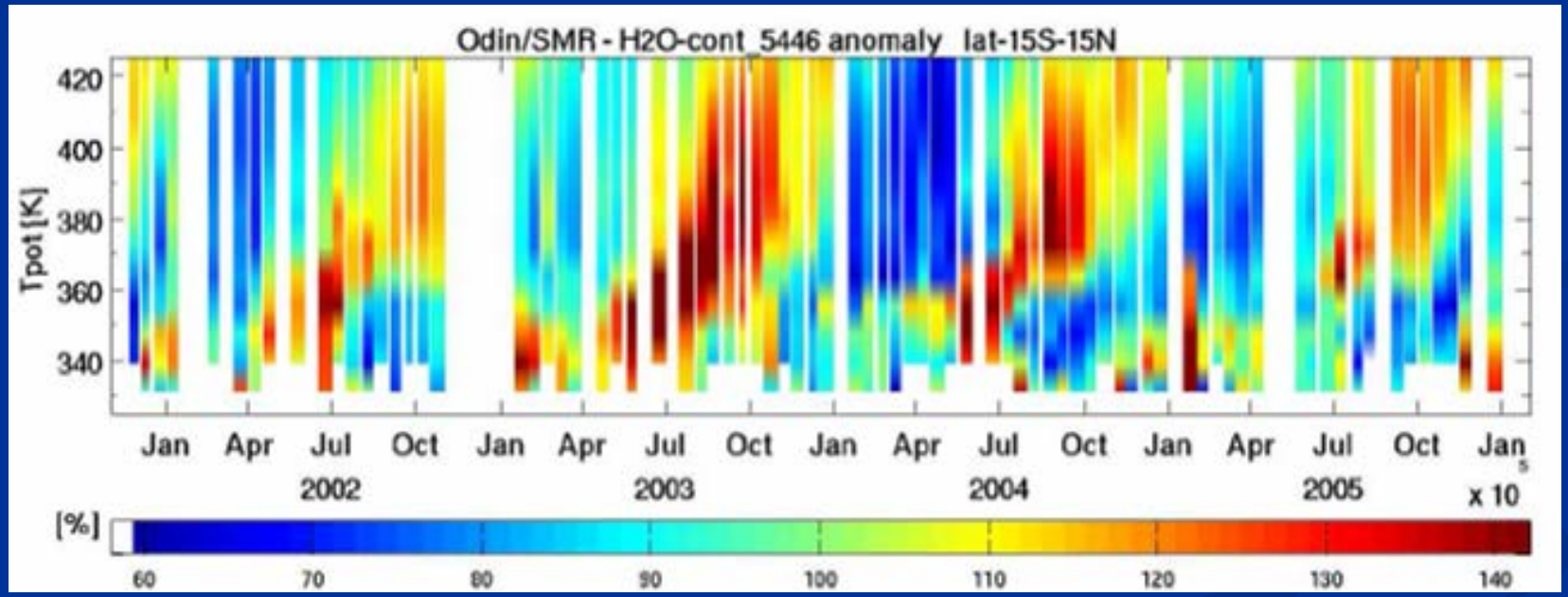


relative to mean



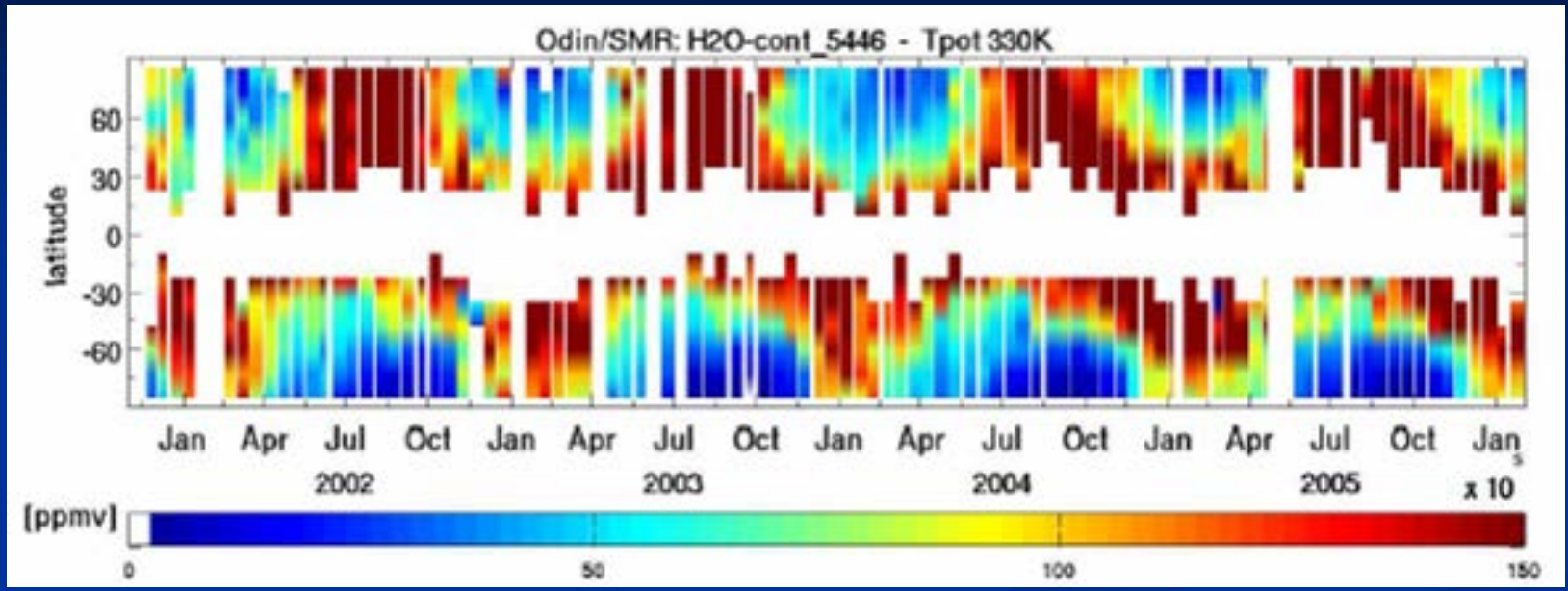
UT/LS tape recorder: tropics 15S-15N

relative to mean

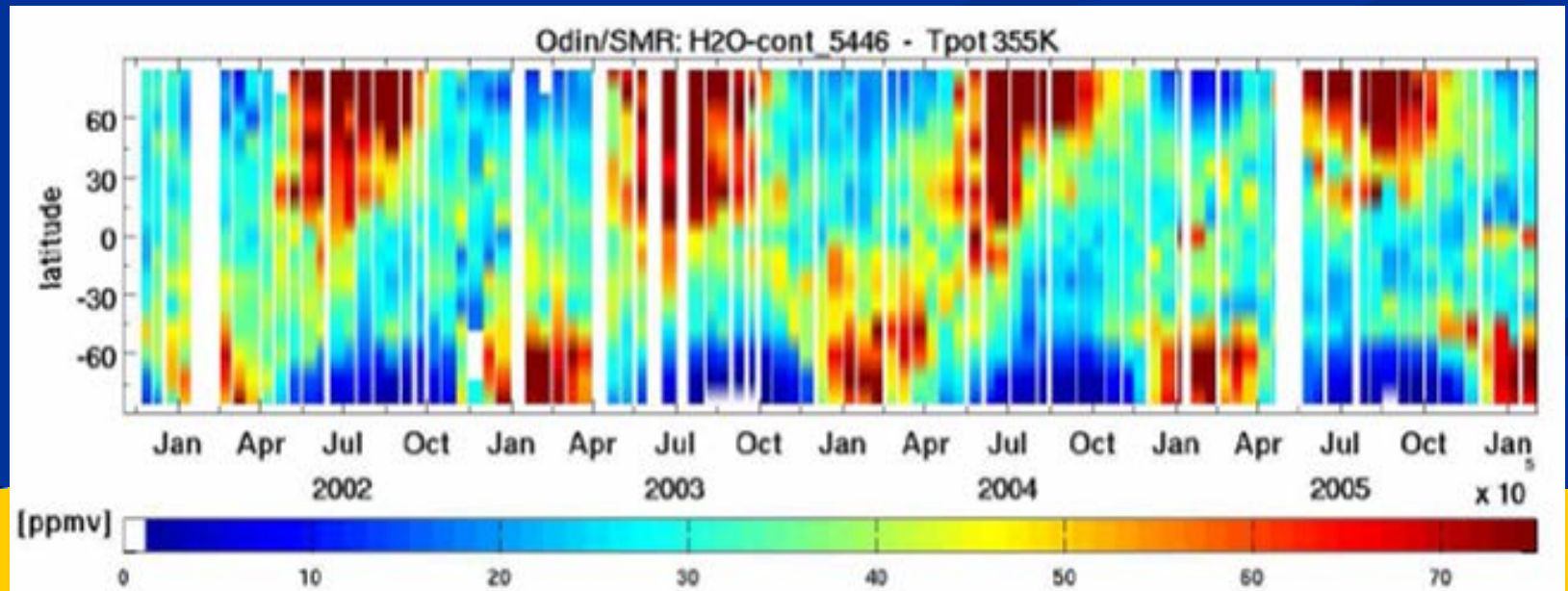


H_2O @ 544.6 GHz: upper troposphere

330 K

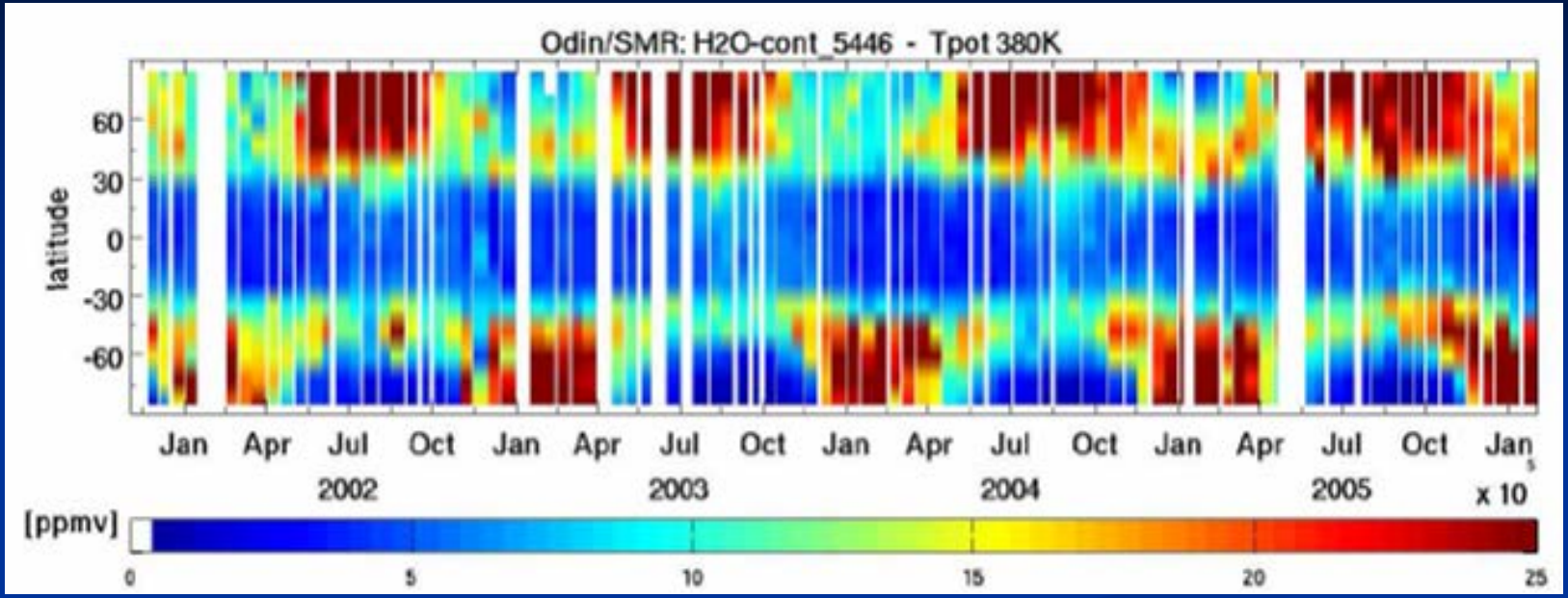


355 K

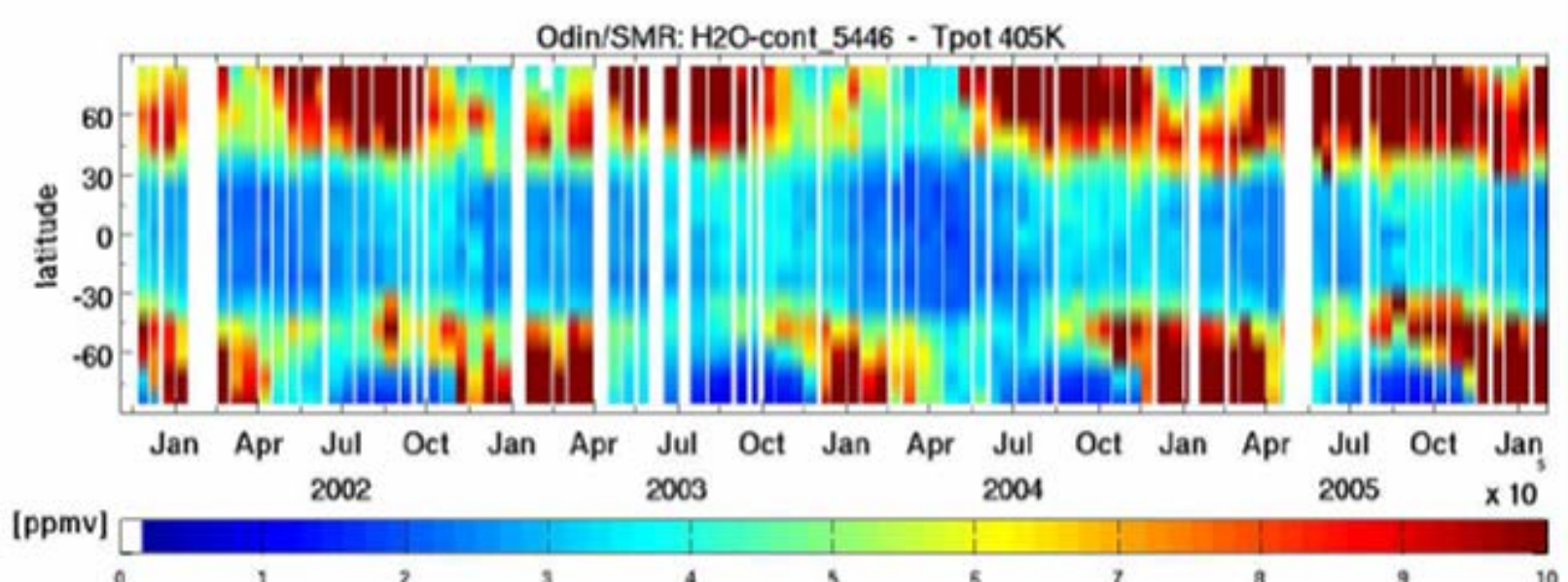


H_2O @ 544.6 GHz: lowermost stratosphere

380 K

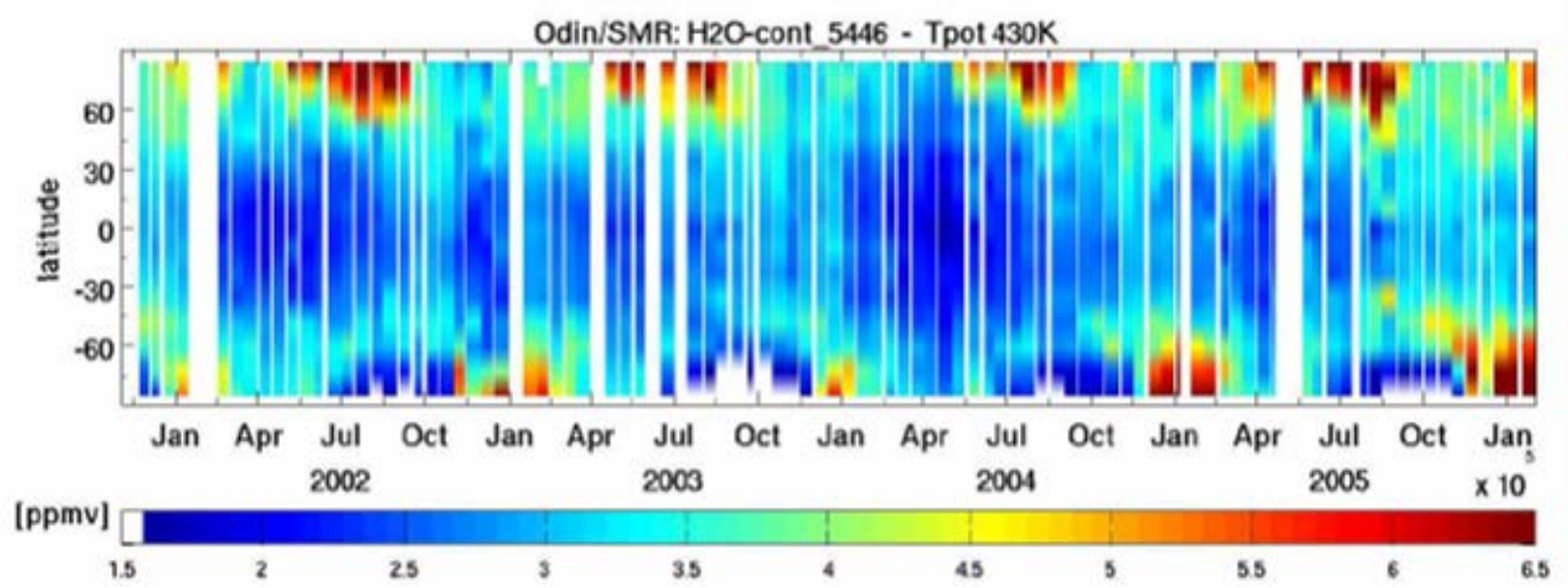


405 K

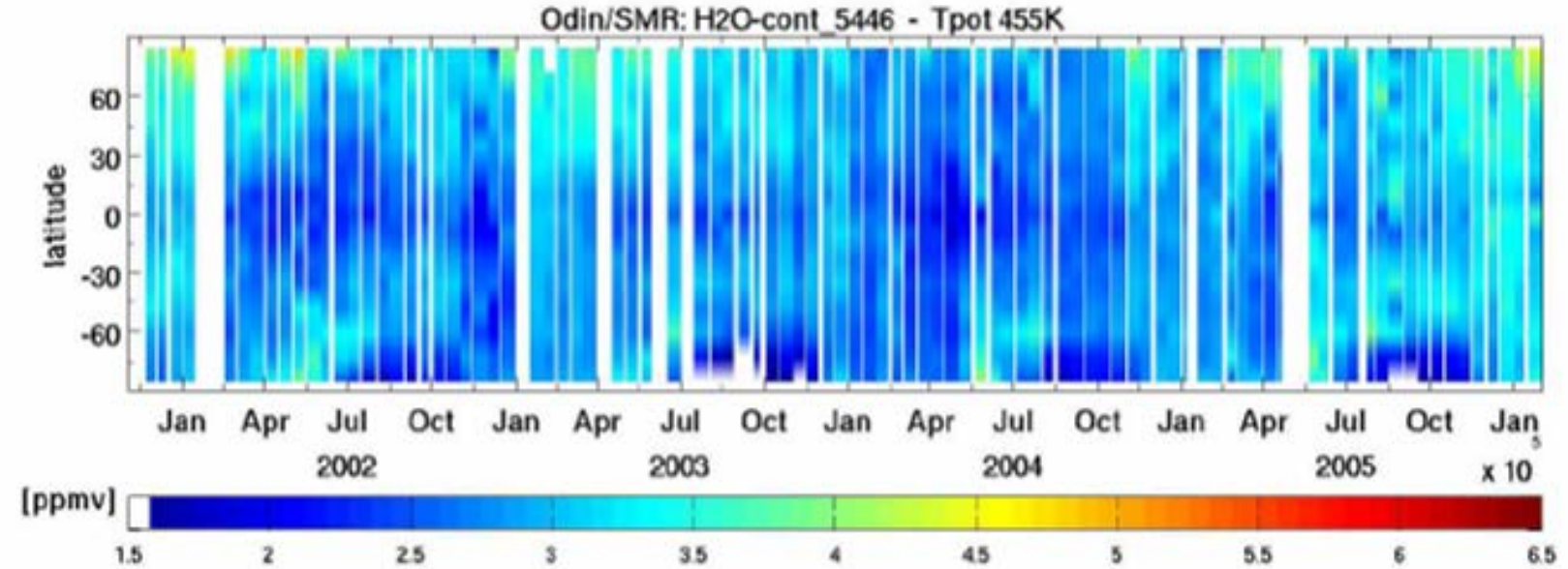


H2O @ 544 GHz: lower stratosphere

430 K



455 K



Summary and Perspectives

- Odin carrying SMR (Sub-Millimetre Radiometer) launched in February 2001.
  - now: ~4.5 years of aeronomy observations starting from Nov 2001 (quasi-global coverage), time-shared with astronomical observations.
- Odin/SMR water vapour measurement modes:
  - Mesospheric water vapour:

    H_2O, O_3, T at 557GHz: ~4 days / month, Nov 2001 - , mesosphere (~40-100km),
  - Strato-mesospheric water vapour and isotopes:
    - H_2O, HDO, H_2O-18, O_3-isotopes around 490GHz:

      ~4 days / month, Nov 2001 - , strato+mesosphere (~20-75km),
    - H_2O-17, NO, O_3, T at 551GHz:

      ~1 day / month, Oct 2003 - , strato+mesosphere (~18-75km),
  - Upper tropospheric humidity (from stratospheric mode):

    N_2O, ClO, O_3, HNO_3,T ~10 days / month, Nov 2001 - , stratosphere (~100hPa-1hPa), also used for UT/LS humidity retrievals.
- Reprocessing of L1b- and L2-data for main stratospheric and water isotope modes ongoing during 2006 (→Ch-v2.0), new version in preparation.
- Validation of water vapour products ongoing.

Thank you!