Water Vapour Isotopes in the Stratosphere: Comparison between the CHEM2D model and observations by Odin/SMR

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INTRODUCTION

Water vapour plays a major role in lower stratospheric chemistry, dynamics and radiative transfer.

- The distribution of water in the stratosphere is maintained by transport of water from the troposphere and by local chemical production and destruction.

- The transport of water vapour from the troposphere to the stratosphere depends on temperature and transport processes in the Tropical Tropopause Layer (TTL).

Stratospheric humidity has increased significantly over the past century as methane concentrations have increased in the atmosphere, but there are additional inter-annual variations in the water vapour content of the stratosphere which are not fully understood.

The isotopic composition of water vapour at a given time and location is sensitive to the temperature, condensation and chemical history of the pathway by which the location was reached.

Isotopic compositions are reported in delta notation, representing the deviation of the D/H ratio of water in an airmass from that of the ocean mean standard.

$$\delta D = 1000 \times \left[\frac{([HDO]/[H_2O])_{measurement}}{([HDO]/[H_2O])_{VSMOW}} - 1 \right]$$

Therefore δD provides information on the possible transport mechanisms.

CHEM2D MODEL

CHEM2D is a zonally average 2D model developed at Naval Research Laboratory in Washington, USA (McCormack and Siskind,2002).

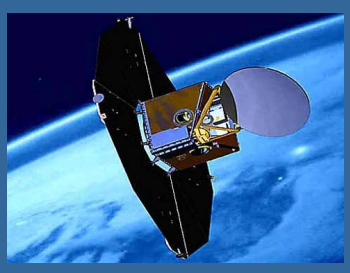
- Fully self-consistent treatment of radiative, photo-chemical and dynamical processes of the middle atmosphere;

- Dynamical framework is based on the Transformed Eulerian Mean Formulation;

- Radiative transfer calculations are performed once per day and model dynamics are updated every 2 hours;

- Model grid points are spaced every 4.8˚ in latitude from pole to pole, 41 levels in the vertical between the model surface (P=1000 hPa) and the model top (P= 2 x 10-4 hPa ~106 km altitude) spaced every 2.6 km.

ODIN SATELLITE

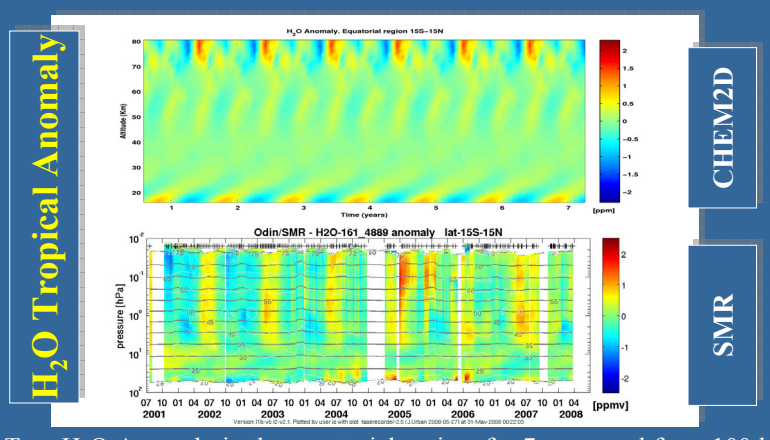


- Launched in February 2001.

- Carries the limb-scanning Sub-Millimetre Radiometer (SMR), which measures thermal emission lines of a large number of middle atmospheric constituents in the 486-581 GHz spectral range (Murtagh et al. 2002).

- Spectral lines of water vapour and HDO are measured by SMR in different spectral bands on about one observation day per week.

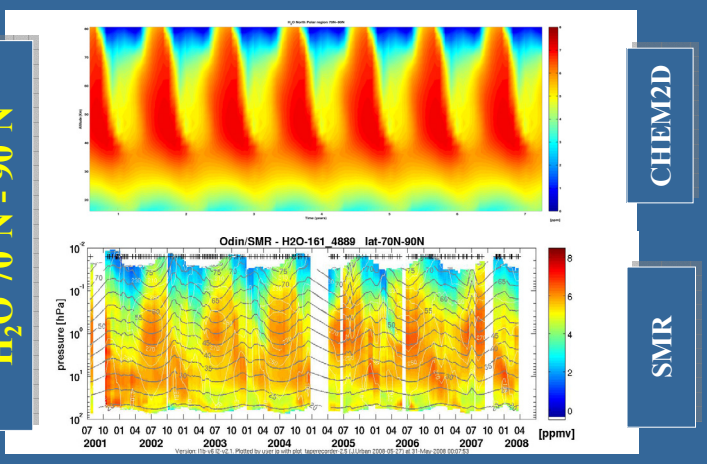
TEMPORAL EVOLUTION



Top: H_2O Anomaly in the equatorial region, for 7 years and from 100 hPa to 0.01 hPa. CHEM2D on top and ODIN/SMR on bottom

- The tape recorder effect appears in the model (prescribed) and in the observations, inside the lower stratosphere;

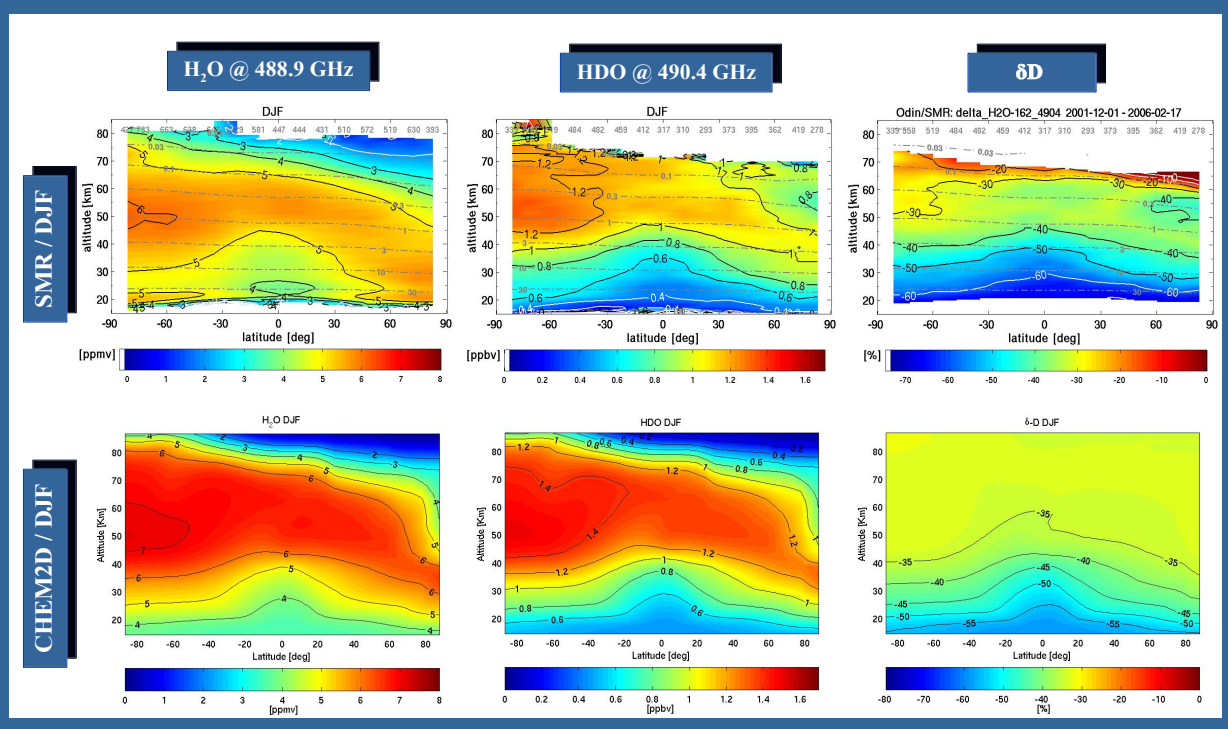
- The model simulates a semi-annual oscillation (SAO) in the middle stratosphere and mesosphere;



Top: As above but for water mixing ratio in the Northern polar region.

- Subsidence of air at high northern latitudes shows a similar pattern in model and Odin data.

COMPARISON ZONAL FIELDS FOR H_2O, HDO and δ-D



Top: Zonal mean fields for H2O (left), HDO (centre), and δ-D (right). Top: Odin/SMR fields; bottom: CHEM2D. Winter (December, January and February) seasonal means.

- Modelled and measured fields show a similar morphology;
- Bias of 1 ppmv between model and observations for water vapour and 0.2 ppbv bias for HDO;
- CHEM2D does not produce the increase of δ-D in the mesosphere observed in the Odin data.

FUTURE WORK

- Implement a parameterization for the quasi-biennial oscillation (QBO);

- Carry out a comprehensive study of the stratospheric transport and chemistry by varying the water vapour input from the troposphere, and the impact this might have on ozone depletion and radiative balance.

- Study the relationship between the age of air and δ-D.

- McCormack, J. P., and D. E. Siskind (2002), Simulations of the quasi-biennial oscillation and its effect on stratospheric H2O, CH4 and age of air with an interactive two-dimensional model, J. Geophys. Res., 107(D22), 4625.
- Murtagh, D., Frisk, U., and Merino, F. et al., 2002: An overview of the ODIN mission, Can. J. Phys. 80, 4, 309–319.

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