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Winter and springtime water vapour distribution in the Arctic stratosphere

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Introduction

Lower stratospheric water vapour is radiatively important (e.g. Solomon et al., 2010). However, the observational data is relatively sparse. There is a very steep gradient in the water vapour profile over the tropopause and the stratosphere is very dry, which makes accurate observations difficult to obtain.

Modelling of the extratropical stratospheric water vapour is also challenging, e.g. due to temperature dependent processes (dehydration) in the tropical tropopause. The main sources of stratospheric water vapour are intrusion through the tropical tropopause and production from oxidation of methane.

The observed winter/spring time water vapour distribution was analyzed together with modelled stratospheric water vapour profiles for the Arctic region.

Modelling and data

Accurate soundings of stratospheric water vapour have been made above Sodankylä (67.7N, 26.6E) since early 2000s. Two major water vapour measurement campaigns have been organized in Sodankylä, i.e. the LAPBIAT Upper Troposphere Lower Stratosphere Water Vapour Validation Project (LAUTLOS-WAVVAP) in 2004 and the LAPBIAT atmospheric sounding campaign in 2010.

The stratospheric water vapour distribution was simulated using the FinROSE chemistry-transport model driven by reanalysis data from the European Centre for Medium-Range Weather Forecasts (ECMWF). In this work the ERA-Interim (1989-2011) winds and temperatures were used. The model was run with a horizontal resolution of 3 by 6 degrees at 35 hybrid levels, from the surface up to 0.1 hPa (ca. 65 km) (Thölix et al., 2010).

The FinROSE-ctm (Damski et al., 2007) is a global model of the stratosphere and mesosphere. The model produces the distribution of around 35 species. The chemistry describes around 110 gas phase reactions and 37 photodissociation processes. The model chemistry includes heterogeneous processing and PSC sedimentation. The tropospheric abundances are given as boundary conditions.

Results

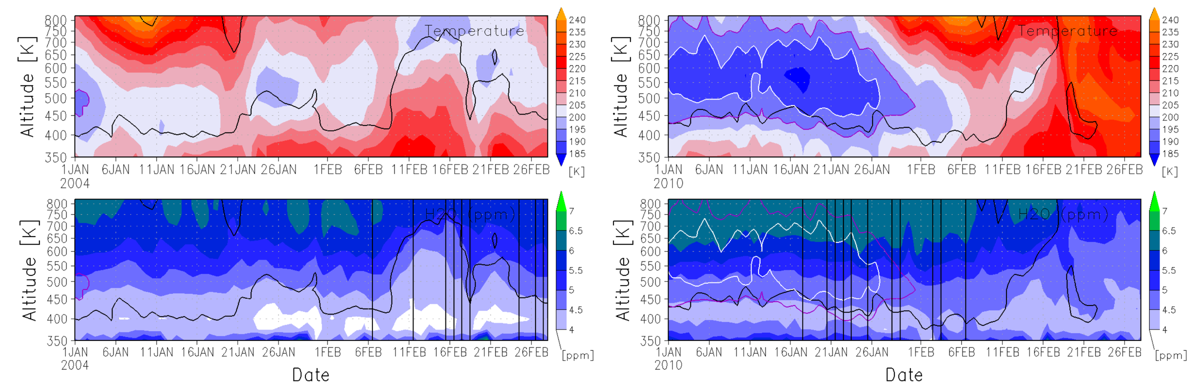

Figure 1. The vertical distribution of temperature (upper panels) and water vapour (lower panels) above Sodankylä during two major sounding campaigns. The left panels show the conditions during January and February 2004 and the right panels for early 2010. The contours show approximate PSC threshold temperatures 190 K (white), 195 K (purple) and polar vortex edge (black). The vortex edge is determined according to Nash et al., 1996. Vertical lines indicate the dates of water vapour soundings.

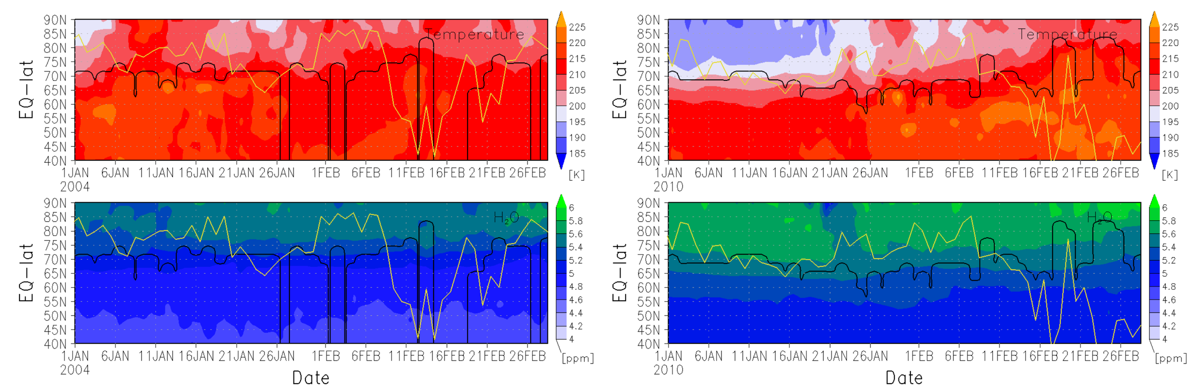

Figure 2. The distribution of temperature and water vapour at the 500 K level on equivalent latitudes. The vortex edge and Sodankylä equivalent latitude are indicated by black and yellow lines, respectively. The vortex was very cold during the 2010 campaign.

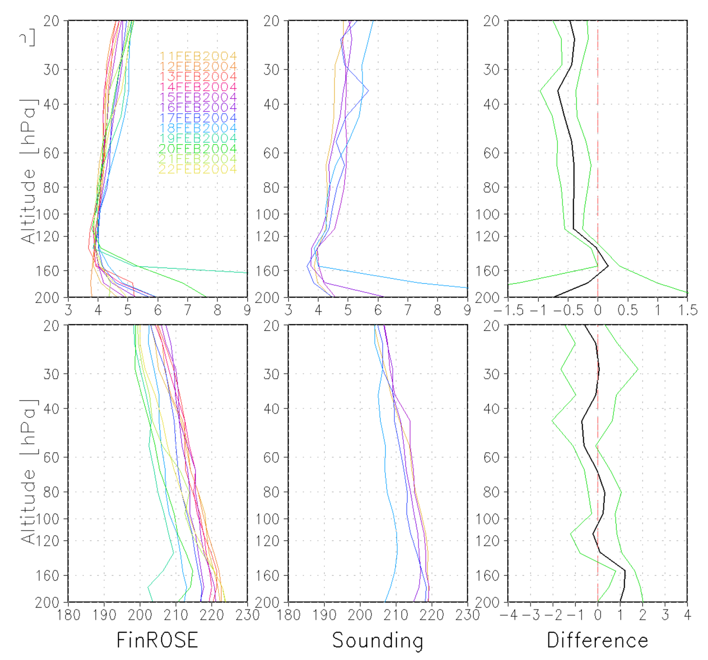

Figure 3. Comparison between Sodankylä water vapour sounding profiles and model data, during the 2004 campaign. Upper panels: water vapour (ppm) from FinROSE, soundings and difference (model-sounding). Lower panels: temperature (K) from ECMWF ERA-Interim reanalysis, soundings and difference (ECMWF-sounding).

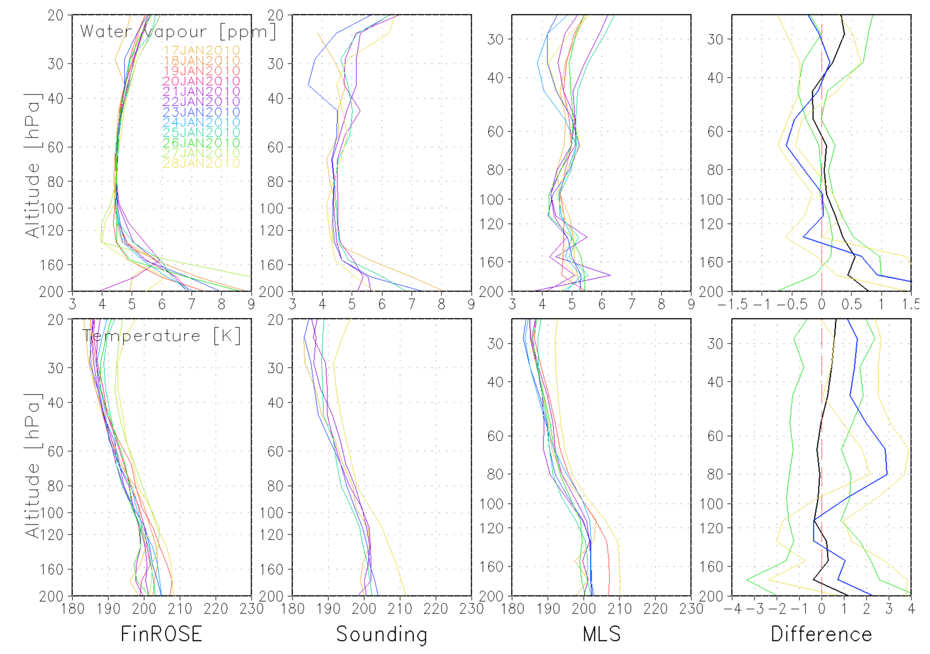

Figure 4. Same as for Figure 3, but now for the 2010 campaign. A fourth set of panels were added showing the comparison to MLS data.

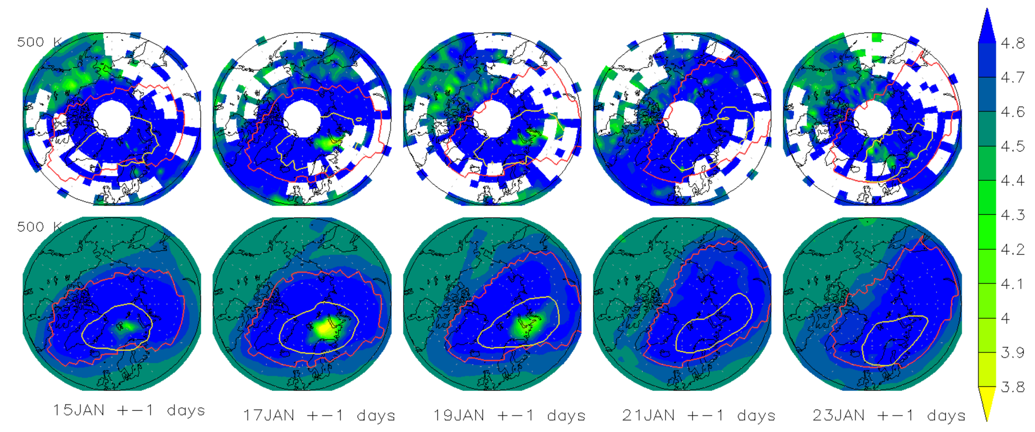

Figure 5. The distribution of water vapour (ppm) at the 500 K potential temperature level during part of the 2010 campaign. The vortex edge is indicated by a red contour (largest PV gradient). The approximate area of ice PSC occurrence is shown by the 190 K isotherm (yellow contour). MLS data is shown in the upper row and FinROSE data in the lower row. The figures show data averaged over three days, 15th to 23rd of January 2010. Large scale dehydration is seen in the coldest part of the vortex.

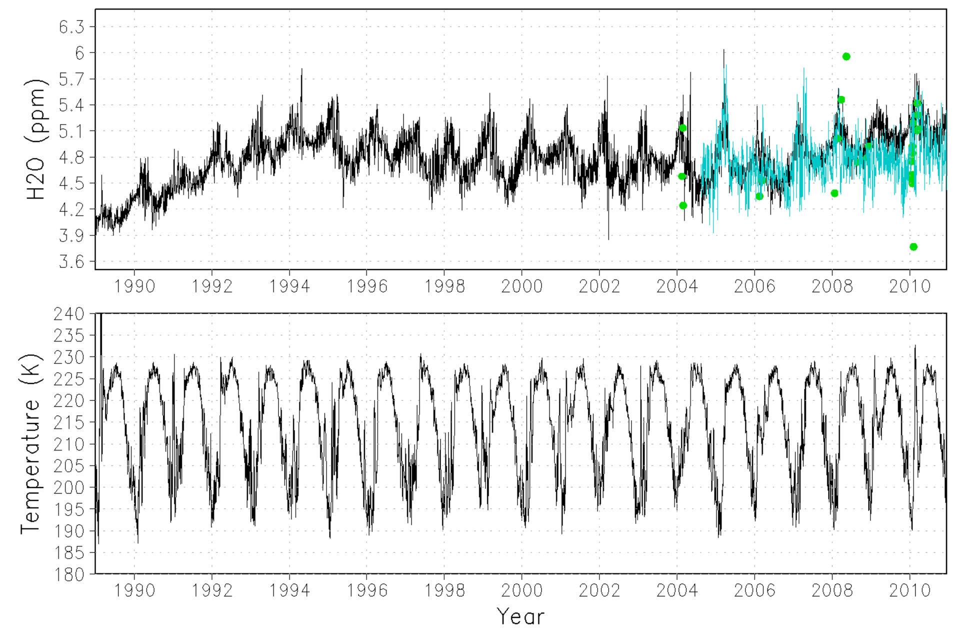

Figure 6. Water vapour and temperature at 54 hPa above Sodankylä. The black line in the upper panel shows the water vapour concentration (ppm) from FinROSE. The cyan line shows MLS data and the green dots represent individual soundings.

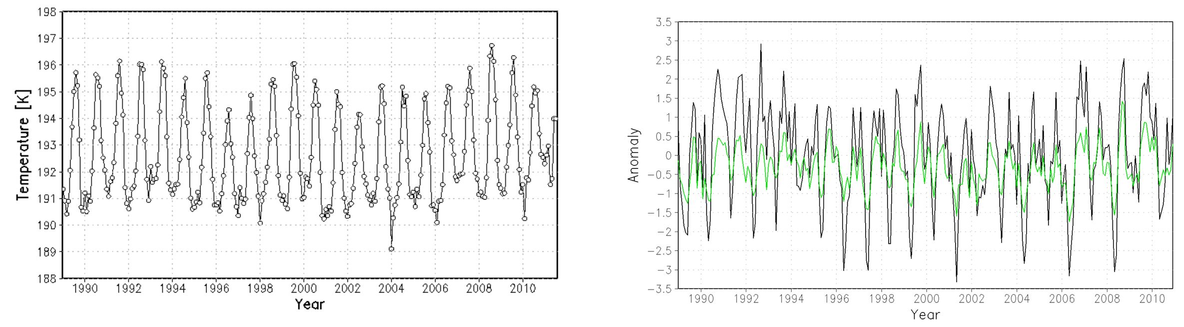

Figure 7. The left panel shows the monthly mean cold point temperature calculated as an area average from 20S to 20N. The right panel shows the tropical monthly mean water vapour and temperature anomaly.

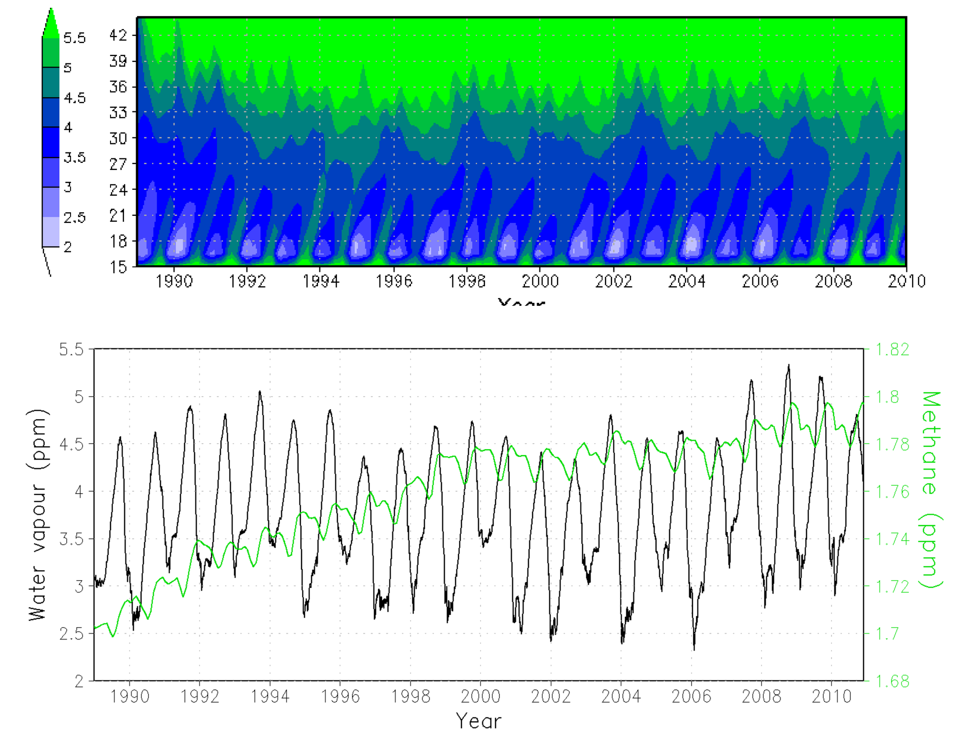

Figure 8. The upper panel shows the so called tape recorder effect in the water vapour timeseries (FinROSE). The lower panel shows the area averaged (20S-20N) tropical water vapour at 85 hPa (black line) and tropospheric methane concentration (green line). The main sources of stratospheric water vapour are intrusion through the tropical tropopause and production from oxidation of methane.

Summary

- Long term variations were seen in the Arctic stratospheric water vapour. Similar features can be seen from observations, but requires further studies.
- The next step will be the attribution of the observed and modelled changes water vapour changes.

Acknowledgements

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