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Atmospheric Chemistry and Physics Discussions

Interactive comment on “Middle atmospheric water vapour and dynamics in the vicinity of the polar vortex during the Hygrosonde-2 campaign” *by* S. Lossow et al.

S. Lossow et al.

Received and published: 20 May 2009

Anonymous Referee #2 Received and published: 8 August 2008

The paper presents results from the Hygrosonde-2 campaign. The main goal consisted in the investigation of small scale distributions of water vapour at the border of the Arctic polar vortex and the exchange of air between inside and outside of the polar vortex using the water vapour mixing ratio as tracer for dynamical processes. Some accompany measurements complete the campaign. It is true, high resolution water vapour measurements in the middle atmosphere and particularly in the mesosphere are rather rare. Accurate measurements are a precondition to infer assertions about small scale processes. Although the possible error, particularly of the water vapour measurements, is not quantified the results are worth to be published. I recommend the paper for publication in ACP after some minor changes listed below.

The paper discusses the hygrosonde and possible errors of the measurements by contamination of rocket out-gassing and desorption from the payload but it do not estimate an error so that it is difficult to decide between real small scale variations and errors.

Quenching of excited OH is the main loss process and depends on density and temperature. How is this influence considered?

Reply: The actual water vapour concentration [H2O] can be derived from the intensity I of the OH fluorescence emission spectrum according to the following equation:

I = Q*K*[H2O]

In this equation is K a hygrometer specific constant comprising various aspects, such as the photon flux of the light source, the geometry and spectral response of the detection system, as well as the quantum yield and water absorption cross section. This constant has to be determined by calibration efforts. The decay of the excited OH*(A2Σ+) state is not only determined by fluorescence, but also by pressure-depending quenching. In the Earth's atmosphere this process becomes important below about 60 km in this particular case. This is taken into account in equation above by Q, the quenching factor, which actually describes the relative contribution of emission and quenching as competing processes responsible for the decay of OH*(A2Σ+). Q contains the temperature and density dependence mentioned above. These values are taken from the balloon, lidar and falling sphere measurements. For the Hygrosonde instruments this factor has been obtained by means of calibration measurements and model efforts.

Sonnemann et al. 2008 (Sonnemann, G. R., P. Hartogh, M. Grygalashvyly, Song Li, and U. Berger, The quasi 5-day signal in the mesospheric water vapor concentration in high latitudes in 2003 - a comparison between observations in ALOMAR and calcula-

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tions, J. Geophys. Res., 113, D04101, doi: 10.1029/2007JD008875, 2008.) also used the water vapour mixing ratio as tracer for planetary wave activity in ALOMAR. They discussed in this context the role of meridional advection along a certain gradient of the water vapour mixing ratio.

In the paper by Lossow et al. the role of gravity waves to explain the origin of different air masses was pointed out. But which influences have tidal or planetary waves on the exchange of air masses between the vortex and extra-vortex?

Reply: Exchange is maybe a wrong word here. The polar vortex edge separates two air masses of different water vapour characteristics and efficiently prevent any exchange between those. The role of waves is to modulate the location of the vortex edge so that the rocket trajectory can cross it many times. Gravity waves cause this modulation of the polar vortex edge on the small scale, planetary waves on the planetary scale. Tidal waves are likely to have an influence as well, but just in the uppermost part of the polar vortex, where the amplitudes of these waves have grown to a significant size.

The geographic coordinates should be supplied for the Esrange/Sweden.

Reply: We added those to the abstract.

In introduction:

The seasonal variation of water vapour is not only governed by the temperature of the tropopause but also by the velocity of the upward flow in the tropical tropopause. The Brewer-Dobson circulation decreased since 2001 reducing the (lower) stratospheric humidity (see e.g. Randel et al., 2006, Decrease in stratospheric water vapour after 2001: Links to changes..., JGR, 111, D12312 or Scherer et al., 2008, Trends and variability of midlatitude stratospheric water vapour..., ACP, 8, 1391-1402.).

Reply: The simple point we want to make here is that the water vapour throughput into the stratosphere is determined by the temperature in the TTL. The coldest temperatures can be observed in boreal winter (December to March) which corresponds to

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the lowest water vapour concentrations. The warmest and moistest conditions can be observed between June and September. Changes in the upwelling, like in the Brewer-Dobson circulation, modulate only the picture.

ECMWF should occur in the reference list.

3.2 Polar vor tex situation:

A major stratospheric warming on 20 December is early but not very early (this would be if it occurred during end of November - beginning of December).

Reply: That is right! Has been corrected!

Page 11: ...Current model results show a wide spread in the water vapour distribution in the polar vortex region... Please provide citations.

Reply: This can be nicely seen in Eyring et al., JGR, 111, D22308, 2006. Reference has been added.

An increase of the water vapour mixing ratio above 70 km shown in Fig. 1 seems to be unrealistic. What is the reason of this increase? Contamination, uncertainty of the hygrosonde measurements at this altitude or can you explain the increase in terms of geophysics? The temperature (Fig. 3) does not show any anomaly there. Unfortunately, Fig. 2 and Fig. 4 have, at least in the version which I received, only cryptographic symbols for the designations of the axes so that I cannot assess whether the meridional wind blew toward the pole conveying more humid air from the extra-vortex.

Reply: When the rocket approaches the apogee and decreases the speed the shock front concept does not hold any longer. For this particular flight the aerodynamical concept applied broke down at about 80 km. Above clear contaminations are visible in the derived water vapour distribution (the derived concentrations can increase by a factor of 5 to 10). The profile showed in the manuscript is cut at 75 km, i.e. several kilometres below the altitude, where the aerodynamical concept we rely on broke down. Definitely,

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the water vapour uncertainty increases quickly in this altitude range. However, there is no apparent reason why we should disregard the data at even lower altitudes. A possible geophysical explanation for the observation could be the wind shear observable around 70 km.

The caption of figures could provide more information (where and when) so that the reader must not read the text before.

Reply: More information has been added.

Fig. 3: It is certainly difficult to define the tropopause (11 km) from the temperature measurements shown in this figure as the absolute minimum occurs around 25 km and in the domain of the normal tropopause the temperature varies around a general decrease with height.

Reply: That the absolute temperature minimum occurs somewhere above 20 km is actually is a common feature in the polar winter atmosphere. The common lapse rate definition fails here often. The troposphere is characterised by weak static stability and turbulent thermal energy transport. The stratosphere, on the other hand, is characterised by strong static stability. Thermal energy transport is rather unimportant here and the thermal balance is essentially determined by radiation. The tropopause describes therefore also the upper boundary of the turbulent energy transport. During winter time the vertical radiative fluxes are small in the polar region, leading to a temperature minimum above the tropopause.

In the extra-tropics a common tropopause definition is based on the potential vorticity. Typically a potential vorticity of 2 PVU is used to determine the location of the tropopause. We have used this criterion.

The dashed line in Fig. 5 for water vapour outside of the polar vortex seems to show too large values (6 ppmv) in the upper domain (at 70 km). How certain are the peaks (particularly the maxima) of the water vapour mixing ratio of the Hygrosonde-1 mea-

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surements which seem to determine the dashed line? The very strong oscillations ($>$3 ppmv variation, meaning more than a doubling of the water vapour mixing ratio) would indicate a long-range transport but not a transport induced by gravity waves.

Reply: Yes, it seems a little bit too high. The analysis of the ACE/FTS measurements shows a water vapour concentration of somewhat more than 4 ppmv. The horizontal resolution of the ACE/FTS measurements, expressed by the path length at the tangent height, is some hundred kilometres. Hence, the water vapour concentration derived describes an integration over this distance. This does not disprove the higher concentrations locally observed by Hygrosonde-1. Confidence in the Hygrosonde-1 measurements arises from the fact that these peak structures were consistently observed both on the ascent and descent of the rocket flight. Please have a look in Khaplanov et al., GRL, 23(13), 1645 - 1648, 1996. We have adapted the water vapour concentration outside the water vapour vortex to about 5 ppmv at 70 km now.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 12227, 2008.