

Measurements of mesospheric O₃ and H₂O using ground-based millimeterwave radiometry in the high Arctic

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Abstract

The mesosphere is of major interest for modelling and measuring in the SCOSTEP project. The work presented here deals with measuring mesospheric O₃ and H₂O above the Arctic (78.3°N latitude) using ground-based millimetre wave radiometry. Data from one out of three measuring periods since 2006 are presented and first results are shown.

The method yields O₃ and H₂O profiles up to 65 km with moderate altitude resolution (about 15 km FWHM). Information is sensed up to the mesopause region (ca 85 km altitude).

The presented O₃ data remarkably well match our in-house chemical transport model (CTM), especially in light of the mesospheric chemistry being described in terms of families of species. Yet the data also indicate how this approach breaks down in the mesosphere.

The WaRAM measurements hint a diurnal cycle of in mesospheric H₂O which is not supported by current modelling. However, the data are limited, hence final conclusions can not be drawn from them so far.

1. Introduction

The mesosphere can be considered an interface between space and Earth's atmosphere, but also between "outer" and "inner" atmosphere. The latter formulation highlights that many properties of the atmosphere which are taken for granted in the layer below 50 km altitude start to change in the mesosphere (e.g. Brasseur and Solomon, 2005). The mesosphere exhibits phenomena that are unknown in the regions below the mesosphere, e.g. chemical heating and Joule heating. Grouping of chemical species into families, as commonly exercised in modelling below the stratopause, loses validity. A full new class of reactions evolves, the ion chemistry. Calculations in this scheme are time consuming, because reaction time scales decrease to well below one second (Winkler et al., 2008).

Mesospheric O₃ plays an important role with regard to measuring and modelling. First of all, it is relatively easy to measure because of its strong thermal emission, which is readily detectable by millimetre wave radiometry. This technique allows deriving information up to the mesosphere by ground-based instruments. O₃ plays a central role in mesospheric chemistry, hence many effects can be studied via their influence on O₃ abundance.

2. Instrumentation

The IUP at Universität Bremen operates millimetre wave radiometers from the AWIPEV research base at Ny Ålesund (78.9°N 11.9°E) on the Spitsbergen archipelago.

This work comprises data of two instruments: OzoRAM, tuned to the 142 GHz rotational transition (10_{1,9} → 10_{0,10}) of O₃, and WaRAM, tuned to the 22.2 GHz rotational transition (6_{1,6} → 5_{2,3}) of H₂O. The viewing path is tilted to 20° elevation angle and an azimuth angle of 113.15°. The geolocation of the mesospheric measurement, at 60 km altitude, is 78.3°N, 17°E.

The data are analysed using the well established software package ARTS/Qpack (Bühler et al., 2005; Eriksson et al., 2005).

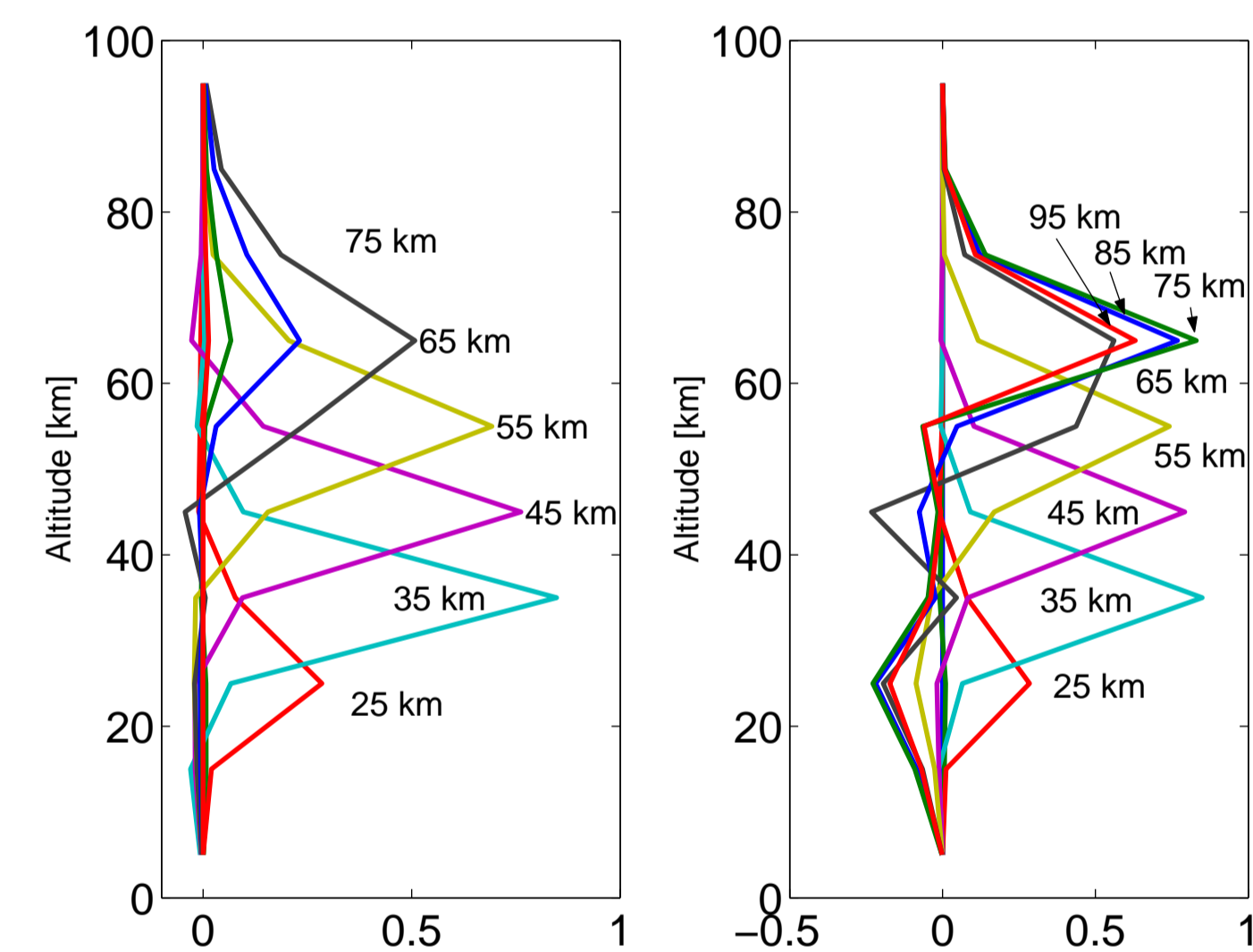


Figure 1: Averaging kernels (AVKs) for OzoRAM measurements in favourable meteorological conditions. The left panel shows the AVKs with respect to the volume mixing ratio (VMR) profile, whereas the right panel displays the AVKs for the profile being normalised to a priori VMR levels.

The instrument function In order to compare model data with the results from measurements, the instrument specific restrictions have to be considered. The instrument and retrieval specific features are summarised in the instrumental function (Rodgers and Connor, 2003; Palm et al., 2005):

$$\hat{x} = x_a + A(x_T - x_a) \quad (1)$$

where x_T denotes the true (but unknown) profile, x_a the a priori profile, and $A = \frac{\partial \hat{x}}{\partial x_T}$ (e.g. Fig. 1) the averaging kernel matrix.

When retrieved data are compared to a model output, the model output takes the place of x_T , hence the instrument would see \hat{x} if the model output were the true atmosphere.

3. Selected results of O₃-measurements

OzoRAM has been measuring mesospheric data during winter in 2006/07 and 2007/08 (cf. fig. 2), and since September 2008. The intermediate times have been used to eliminate problems in the instrumental set-up.

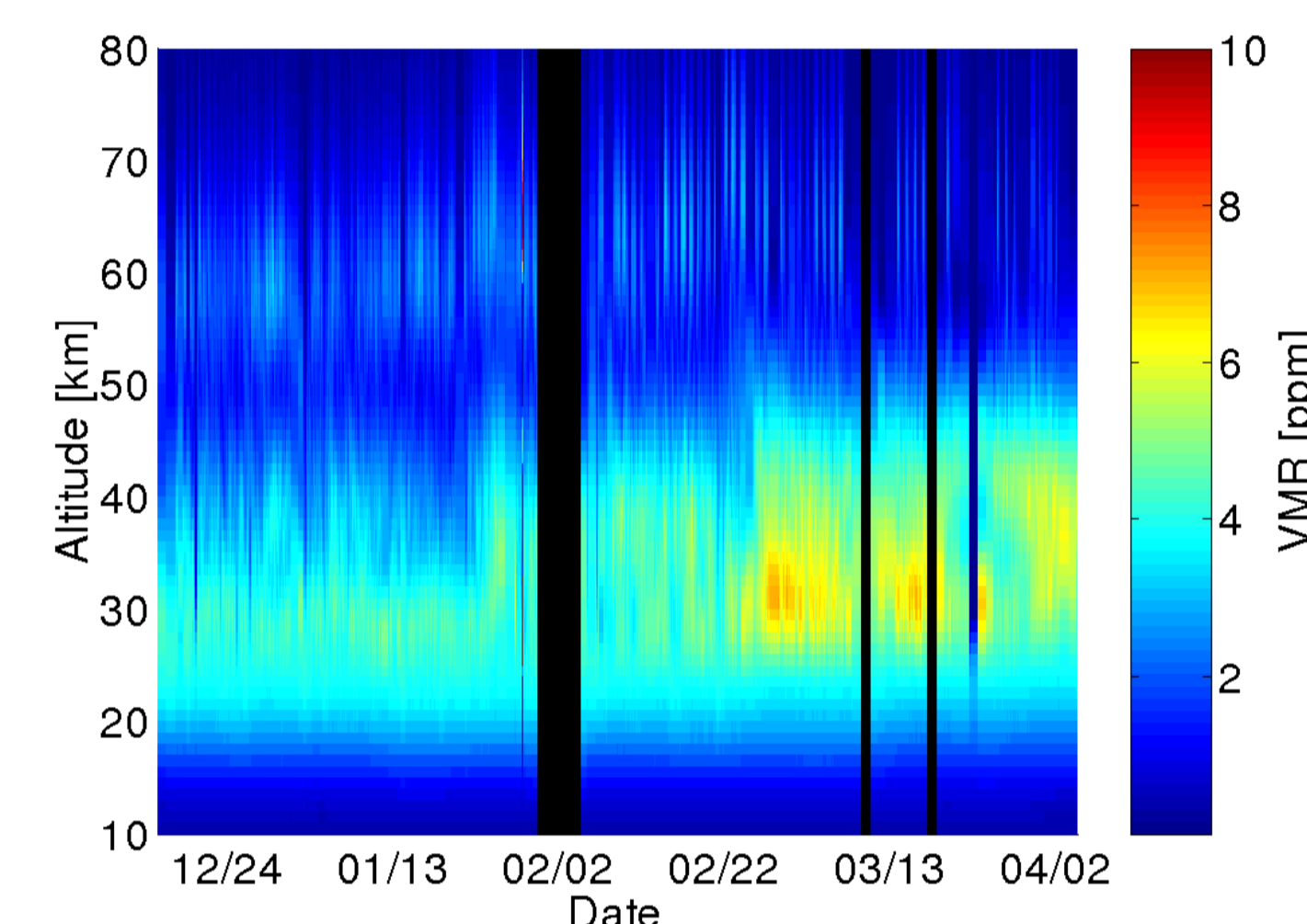


Figure 2: Time series of O₃ during the winter 2007/08.

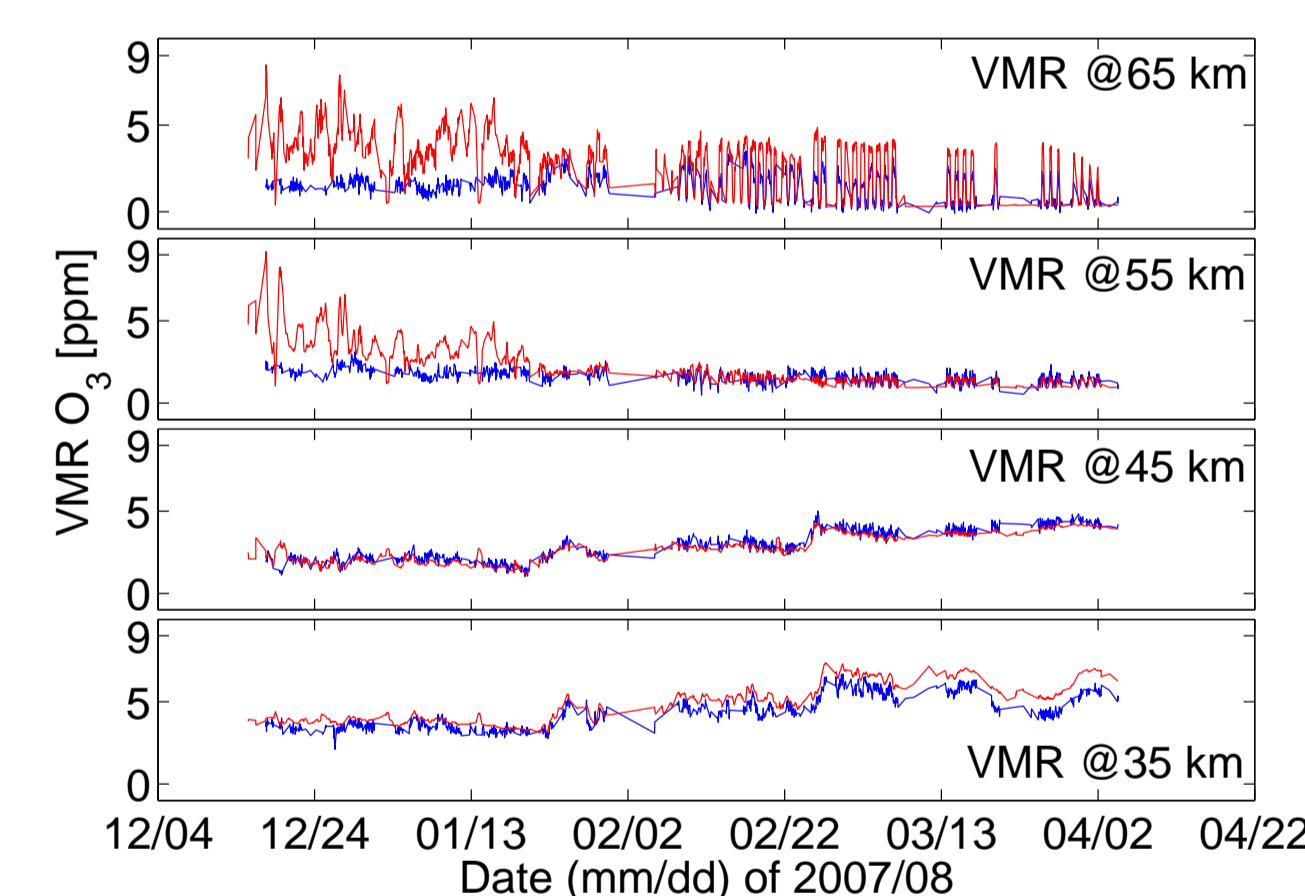


Figure 3: Comparison of several layers of retrieved and modelled O₃. The model output has been convolved using the OzoRAM instrument function.

In fig. 3, comparisons of the Bremen 3D CTM are compared with the observed O₃. For altitudes above the stratopause, the breakdown of the family model of chemistry is obvious. It overestimates O₃ abundance at the beginning of polar night, but settles down to reasonable values at the end of the dark season (end of January).

This feature is to be expected because the photochemical equilibrium is biased to the O₃-side in darkness, yet O and O₃ reactions are considered interchangeable. To individually consider their reactions, both species must be handled on their own, which increases the computational load of model runs because of the smaller time step needed.

4. Selected results of H₂O-measurements

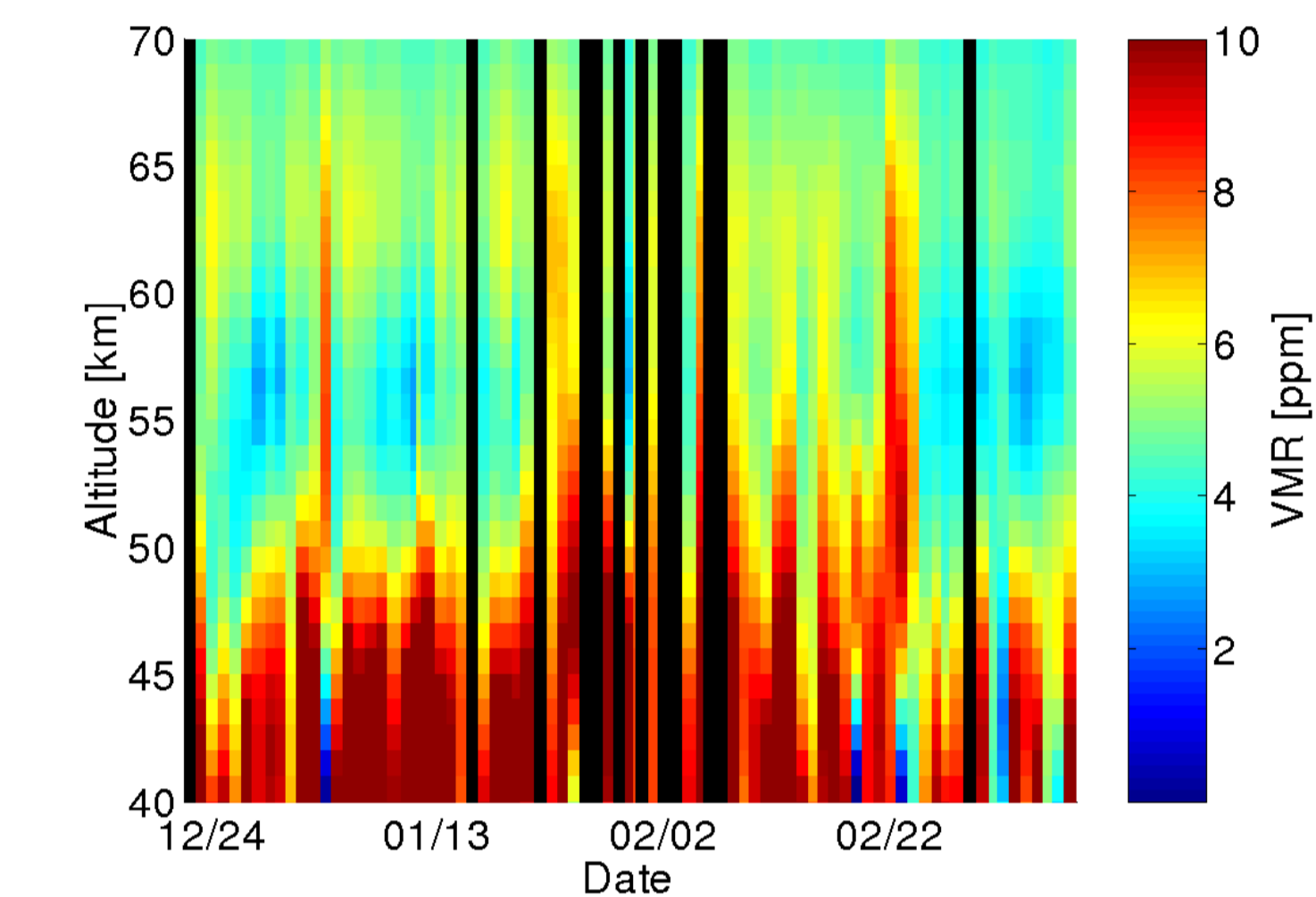


Figure 4: Time series of H₂O during winter 2007/08.

During winter 2007/08 H₂O (cf. fig. 4) was measured in sufficiently good quality to derive daily mean profiles. The profiles are in accordance with the general profile shape reported by Nedoluha et al. (1995).

In order to search for a diurnal variation, the spectra of ca. 20 min integration time each have been re-sorted before they were co-added.

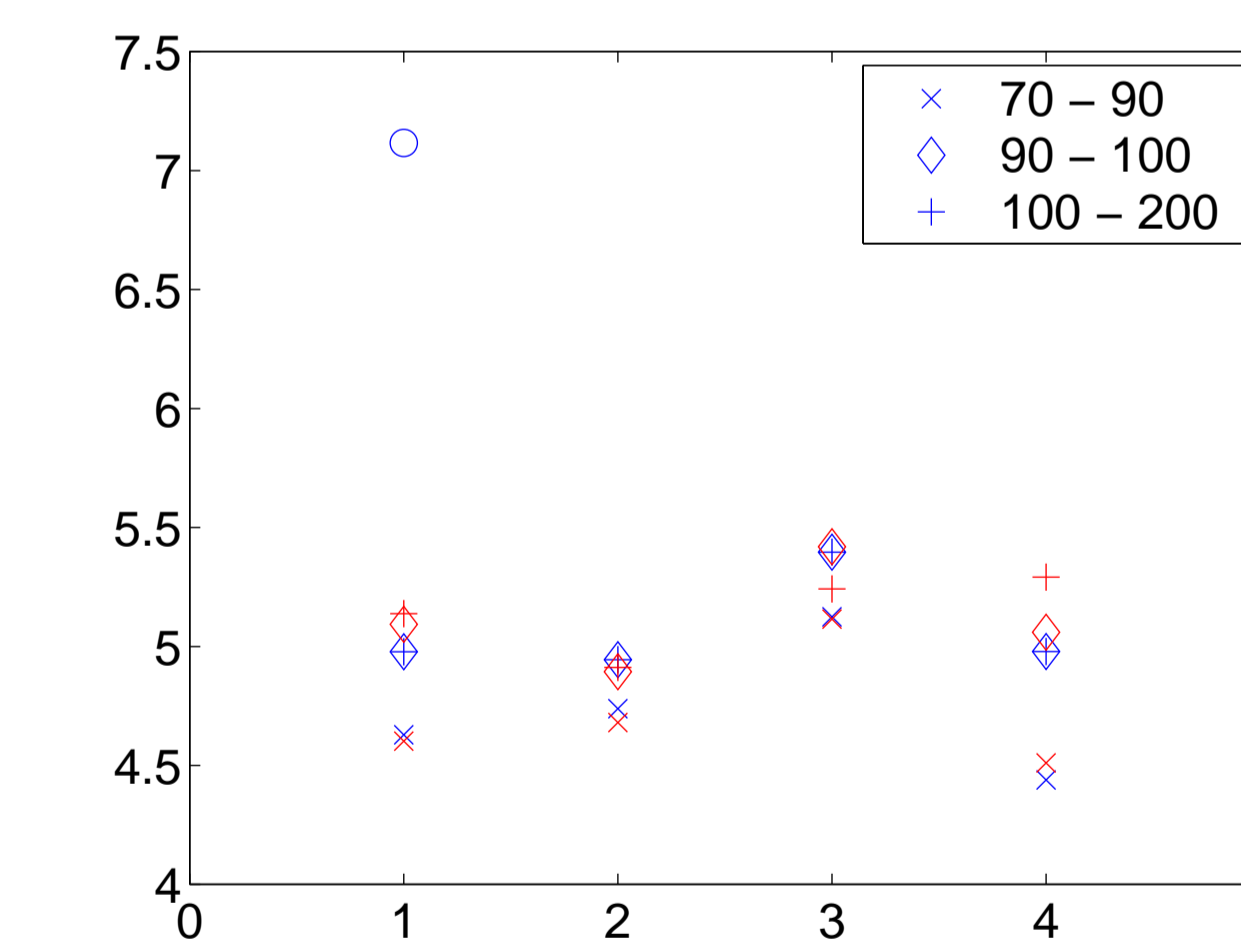


Figure 5: H₂O VMR in the lower mesosphere during day, night and twilight conditions. The marks denote different bins of data during winter 2007/08 in order to examine the influence of the solar zenith angle. For a further description of the data we refer to the text.

The spectra were sorted according to solar zenith angle (SZA) at the time of measurement: smaller than 90° (fully illuminated), larger than 100° (no illumination up to 100 km altitude) and in between. For each type of data, spectra have been averaged over a period of 5 days. In total 30 batches of data have been created. One half comprise the period

from the 27th of February to the 25th of March. The results are documented in fig. 5, blue symbols. The other half correspond to a two-day shift in the period of measurements, from the 29th of February to the 27th of March 2008. They are depicted as red symbols in Fig. 5. No indication of strong dynamic variation is apparent for this period, i.e. the temperatures and the pressure levels determined from ECMWF data remain constant. Also the mean background and the mean SNR are constant for all of the co-added spectra.

While there is some indication for a variation of H₂O depending on solar illumination, the data set is not sufficient to determine such a variation beyond doubt.

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