Investigation of polar mesospheric dynamics and temperature changes by means of ground-based OH* airglow spectroscopy and model studies above Spitsbergen

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1. Introduction & Motivation

• The OH airglow layer is a prominent feature of the mesopause region at approx. 87 km altitude.
• Vibrationally excited OH* radicals are produced via the reaction of ozone and atomic oxygen:
  \[
  \text{O}_3 + \text{H} \rightarrow \text{OH} \ (v \leq 9) + \text{O}_2 \tag{1}
  \]
• Radiative deexcitation of OH* contributes to the airglow, which we can observe from space and ground-based platforms.
• For low excitation levels (v ≤ 6) it is assumed that the OH* emission is a measure of ambient temperature.
• Vertical air mass displacements affect mesopause temperatures via adiabatic cooling or warming. In particular the polar regions are strongly affected by this process due to the meridional summer-winter pole circulation.
• Tidal as well as gravity wave forcings are crucial to understand the dynamical variability of the mesopause region at time scales ranging from minutes to hours.

These forcings can lead to harmonic modifications in airglow temperatures and intensities with pronounced phase relations. There is a growing consensus among observational and theoretical studies that these phase relations reflect vertical wave properties of associated forcings [4,5].
• The interplay of mesospheric variability at different time scales is still poorly understood. Ground-based measurements will contribute to our general understanding of the mesospheric response to climate change [1].

2. Instrumentation & Retrieval

• A Bruker 120HR Fourier-Transform Spectrometer (FTS) is located at the AWIPEV research base in Ny-Alesund, 78°55′N, 11°56′E and was upgraded to an 125HR in autumn 2012.
• Measurements of OH* airglow are available since autumn 2007. Further improvements to the automatic operation during the polar-night have been implemented in 2010. In addition, changes in the instrumental setup have significantly improved the signal-to-noise ratio by the winter season 2010/11.

Fig. 2.1: OH* spectroscopy: 793.5–794.5 Å measured in Ny-Alesund, 78°55′N, 11°56′E

Fig. 2.2: (OH-3-1) emission spectrum observed by 120HR FTS at 21/12 spectral resolution. The fit corresponds to a temperature of 197 K and a 1 hour spectral averaging time (1).

• The spectral sensitivity of the 120HR FTS covers several OH* emission bands, while the OH(3-1) is one of the most preferable emissions with regard to atmospheric transmission and its low initial vibrational excitation level (fig. 2.1).
• From the relative emission peak intensities we derive OH* rotational temperatures by means of forward modelling as shown in fig. 2.2.

3. OH* Airglow Temperatures and Intensities above Spitsbergen

Fig 3.1: Left panel – Hourly variability in temperatures and relative intensities of the P1 branch from the OH(3-1) emission on January 23rd–24th, 2011. Uncertainties are indicated by dashed lines. Middle and right panel – Temperature and associated uncertainties derived from hourly averaged OH(3-1) spectra (blue squares), daily temperature average (red line), daily averaged temperatures derived from thermal oxygen emissions observed from the MLS instrument on the EOS Aura satellite at two different height levels.
• On Jan 23rd–24th, 2011 we can find that temperature changes are leading OH(3-1) intensity changes (fig. 3.1).
• The large scattering of hourly temperatures compared to their daily averages reflects the strong dynamical variability at shorter time scales.
• Two mesospheric warming events appear in our retrieved temperatures after mid-January in 2011 and 2012.
• By comparison with MLS observations our derived temperatures are generally cooler.

Fig 4.1: Left panel – Normalised vertical distribution of OH(v) populations based on our model approach. Middle panel – Total OH* column based on our model approach. Right panel – Atomic oxygen concentrations weighted with vertical OH* concentration profiles.
• The population of vibrational states according to eq (1) not only depends on the radiative lifetimes, but also on the quenching rates with other species, mainly N2, O2, and O.
• Other studies suggest that O concentrations significantly affect the vertical displacements among vibrational populations [2].

Fig 4.2: Correlation between the vertical displacement at peakpoints (each shifted by +0.5FWHM) of simulated OH(3)/OH(5) layers and O concentrations at same altitudes. Scattering points are constrained to the polar night between 72°N and 60°N.
• Can we link this dependency to studied temporal changes in O concentrations?
• To assess this question, we updated the McDade quenching model [6] with latest rate constants and use chemical profiles from the SD-WACCM4 [2] chemistry transport model to derive vertical OH(v) populations (fig. 4.1).
• Enhancements in mesospheric O concentration (right panel of fig. 4.1) could reflect an enhanced downward transport from the thermospheric region.
• In our model approach we can find a significant correlation between temporal changes in O concentrations and vertical OH(v) displacements (fig 4.2).

4. Modelling the OH* airglow layer

5. Summary & Outlook

• In this work hydroxyl emission measurements were established at an arctic station.
• First results already show interesting dynamical features at different time scales. The implementation of additional OH* emission bands or even different airglow sources, such as the O2 (C-I) emission, would further contribute to our understanding of observed temperature/intensity phase relations with regard to gravity wave activity & tidal forcing.
• We will improve our OH* temperature comparison with spaceborne instruments by weighting temperature profiles with OH* volume-emission-rate profiles observed from the SABER and SCIAMACHY instruments.
• Following up the question in Sect. 4., we will compare SABER measurements of OH* and O with our model results in terms of their diurnal and seasonal variability to improve our understanding on the associated processes.

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