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Variations in VLT/UVES-based OH rotational temperatures for time scales from hours to 15 years

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Hydroxyl (OH) emission is an important tracer of the climate, chemistry, and dynamics of the Earth's mesopause region. However, the relation of intensity variations in different OH lines is not well understood yet. This is critical for the most popular use of OH lines: the estimate of ambient temperatures based on transitions at low rotational levels of the same band. It is possible that the measured variability of the derived rotational temperature does not coincide with changes in the ambient temperature. Such differences can be caused by varying deviations from the local thermodynamic equilibrium (LTE) for the population distribution over the considered rotational levels. The non-LTE effects depend on the ratio of the thermalising collisions (mostly related to molecular oxygen) and competing radiative transitions or collisions without thermalisation of the rotational level distribution. Therefore, significant changes in the vertical structure of excited OH and its main quenchers can affect the temperature measurements.

We have investigated the variability of OH rotational temperatures and the corresponding contributions of non-LTE effects for different OH bands and time scales up to 15 years based on data of the high-resolution echelle spectrograph UVES at the Very Large Telescope at Cerro Paranal in Chile. In order to link the measured rotational temperatures with the structure of the OH emission layer, we have also studied OH emission and kinetic temperature profiles from the multi-channel radiometer SABER on the TIMED satellite taken between 2002 and 2015.

The results show that non-LTE contributions can significantly affect the OH rotational temperatures. Their variations can be especially strong during the night and for high upper vibrational levels of the transitions, where amplitudes of several Kelvins can be measured. They appear to be weak if long-term variations such as those caused by the solar cycle are investigated. These differences in the response correlate with changes in the effective height of the OH emission layer and the effective air density in the layer. The latter confirms the expected important role of molecular oxygen for the thermalisation of the OH rotational level populations.