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Do the OH Meinel bands provide mesospheric temperatures?

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It is customary to determine local temperatures in the mesosphere and MLT by using Boltzmann plots based on the rotational distributions of the bands of the OH Meinel system, assuming that populations in these levels are in local thermodynamic equilibrium (LTE) with the kinetic temperature [Beig et al., Rev. Geophys., 2003; Turnbull and Lowe, PSS, 1989; von Savigny and Lednyts'kyy, GRL, 2013]. It has long been known that the higher rotational levels are not in LTE [Dodd et al., JGR,1994], so that a conventional Boltzmann plot cannot be used to obtain a temperature – only the lowest rotational levels are used, in the hope that LTE for such levels is appropriate.

Because the atmosphere is dynamically active, it is important that the OH bands be observed simultaneously, particularly if the intent is to compare apparent temperatures from different vibrational levels. Using sky spectra from the Keck II telescope and the ESI echelle spectrograph, it has been shown that the LTE assumption seems to be invalid even for low rotational levels, based on earlier observations that show a reproducible pattern of apparent temperature vs OH vibrational level, with a general upward trend of temperature with increasing vibrational level, averaging 15-20 K [Cosby and Slanger, Can. J. Phys, 2007].

This work has now been repeated with a much larger database. using the X-shooter telescope and echelle spectrograph at the VLT (Very Large Telescope) in Chile [Noll et al., ACPD, 2015]. The results are in close accord with the earlier work, showing the same general pattern, with a marked temperature maximum at OH(v = 8), and an upward "temperature" trend from v = 2 to v = 9.

As the OH layer lies below the mesopause, kinetic temperatures should fall from that layer (87 km) to the mesopause, near 95 km. Typically the modeled temperature in the OH layer is 17 K higher than that in the O_2(b,v=0) layer [NRLMSIS00]. Rocket and satellite experiments indicate that there is a trend in altitude of the OH levels – the higher levels lie above the lower [von Savigny and Lednyts'kyy, GRL, 2013], and thus the higher levels should be colder than the lower. These conclusions are not met by the experimental results.

The two sets of data, taken in different decades, with different investigators, in different hemispheres, and with different instruments, are remarkably similar. The point in common is that broadband echelle spectrographs were used to collect the data. Thus, it is important to realize that there are problems with the standard ground-based mesospheric temperature measurement procedure, most likely due to the details of the relaxation processes of OH(v) involving the most important colliders, O_2 and O(^{3}P).