

A kinetic model for non-LTE contributions to OH($v = 9$) rotational temperatures

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Rotational temperatures derived from simultaneous spectroscopic observations of various OH emission bands indicate excesses with respect to the effective kinetic temperatures for the corresponding emission layers. Since OH rotational temperatures are an important tool to study the state and variability of the Earth's mesopause region, we investigated the deviations of the rotational level population distribution from the local thermodynamic equilibrium (LTE) in detail by means of a kinetic model. We focused on the vibrational level $v = 9$ since it can only be populated by the OH-producing hydrogen-ozone reaction and therefore is easier to handle than lower v . We assumed an equilibrium between the production of ozone and its losses due to reactions with hydrogen and atomic oxygen. Input profiles for the kinetic temperature, air density, and concentrations of various species were either based on data from the satellite-borne SABER radiometer or the empirical NRLMSISE-00 model. We also considered two different sets of Einstein A-coefficients and two very different rate coefficients for v -changing/destructive collisions of OH with atomic oxygen as these parameters are not well known. Moreover, the crucial rate coefficients for the rotational relaxation at $v = 9$ are highly uncertain. We could estimate them by the comparison of a grid of models differing in the values of an exponential-gap parametrisation with observed populations from measurements of OH(9-3) and OH(9-4) in archival spectra of the high-resolution UVES spectrograph of the ESO Very Large Telescope at Cerro Paranal in Chile. The resulting best-fit models were then used to investigate the amount and variations of the non-LTE contributions to the $v = 9$ rotational temperatures. The analysis also included a comparison to non-LTE excesses that were empirically derived from UVES rotational temperatures and SABER kinetic temperature and OH emission profiles. The results indicate significant effects of several kelvins for the lowest rotational levels that mainly vary due to changes in the height and width of the OH layer. The latter processes are especially efficient if there is a strong vertical gradient in the non-LTE contributions.