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Infrared radiation in the mesosphere and lower thermosphere: energetic effects and coupling with lower atmosphere

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The translational degrees of freedom of atmospheric molecular and atomic gaseous compounds represent the heat reservoir. This reservoir obtains or loses energy due to a number of sources and sinks, among them heating and cooling related to various types of mass motions, redistribution of energy released in the course of various photochemical reactions (the translational energy, the chemical energy and the nascent electronic, vibration and rotational energy of the reaction products), and absorption and emission of the infrared (IR) radiation. In the latter case, one deals with interaction between matter and the IR radiative field, which, for the case of the mesosphere/lower thermosphere (MLT), includes the atmospheric radiation formed in these layers, the upwelling radiation from the ground and lower atmosphere, and, during daytime, the IR solar radiation.

In this talk, we address the energetic effects of IR radiation in the MLT and its radiative coupling with lower atmosphere by analyzing the interaction between IR radiation and matter. In the MLT, this interaction is strongly affected by the situation when vibrational (and in its upper part also rotational) excitation of the molecules does not obey Boltzmann's law with the local kinetic temperature. As a result, the IR radiation emitted in these layers does not reflect the thermal state of matter. This situation is referred to as the breakdown of local thermodynamic equilibrium (LTE) for the vibrational (or rotational–vibrational) degrees of freedom. Detailed treatment of non-LTE plays a crucial role for estimating thermal effects of the IR radiation as well as for the diagnostics of space-based IR observations.

We discuss the peculiarities of the non-LTE radiation formation in the IR bands of CO_2, O_3, and H_2O molecules, estimate radiative cooling/heating rates for typical atmospheric scenarios, and analyze sensitivity of the MLT radiative energy balance to various mechanisms of populating/depopulating molecular vibrational levels. We also consider radiative pumping and small-scale gravity wave effects, which couple the MLT with the lower atmosphere.