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Modeling the non-equilibrium emissions of the Martian atmosphere in the infrared bands of CO$_{2}$ and CO molecules taking account for the extinction of radiation by aerosol

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Heating due to the radiative transfer in the infrared (IR) ro-vibrational bands of CO_2 and CO molecules is an important component in the energy balance throughout the entire atmosphere of Mars. Also, the emissions in some of these bands are used for remote sensing of the Martian atmosphere. So, a development of more sophisticated models for estimating the values of the Martian atmosphere emissions in the IR bands of CO_2 and CO molecules is required. A high rate of absorption of solar radiation in near-infrared (NIR) spectral interval by these molecules and a low density of the Martian atmosphere result in that the non-local thermodynamic equilibrium (NLTE) takes place in wide altitude intervals for populations of the excited vibrational states. On other hand, dust and water ice aerosols permanently exist in the atmosphere of Mars. The aerosol optical depth of the Martian atmosphere varies from less than 0.1 for the condition of transparent atmosphere up to about 5 during global dust storms. Thus, the values of aerosol optical depth are comparable to the ones of some NIR bands of CO_2 and CO. So, one needs to take into account of the extinction of the NIR radiation by the aerosol particles for accurate modeling the radiative transfer in the CO_2 and CO bands in the Martian atmosphere.

In the paper [1], the model used for solving the NLTE problem of radiative transfer in the CO_2 bands in the Martian atmosphere has included the 321 excited vibrational states belonging to 7 isotopologues of CO_2 and 779 radiative vibrational transitions (about 100000 lines). The most upper state is 20^03 of the principal isotopologue with energy of about 9500 cm^{-1}. In the present study, this model has been further improved to solve the above radiative transfer problem in the following directions. 1) The 10 bands rising between 8 vibrational states of 2 isotopologues of the CO molecules have been included. 2) The radiative transfer in all the bands of CO_2 and CO within the 15-1.02 μm spectral interval is taken into account with an exact treatment of overlapping of the spectral lines in frequency. 3) The processes of scattering and absorption of radiation by aerosol particles at the frequencies of the IR bands of CO_2 and CO molecules were taken into account. 4) A reflection of the IR radiation by the Martian surface is also taken into account. 5) The accelerated lambda-iteration technique used for solving the NLTE radiative transfer problem has been modified for the case of the aerosol extinction presence.

Using this model, the dependence of non-equilibrium populations of the high excited CO_2 and CO vibrational states on adopted optical properties of the Martian aerosol particles and on their vertical distribution as well as the effect of reflectance properties of the Martian surface on these vibrational state populations have been investigated. The spectra of the NIR emissions outgoing from the Martian atmosphere with and without taking account for the aerosol extinction are simulated. Using these emissions for the retrieval of aerosol optical properties in the atmosphere of Mars is discussed.

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[1] Ogibalov, V.P., and Shved, G.M. // *Solar System Res.*, Vol. **37**, No. 1, pp. 23-33, 2003.