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Comparison of radiative transfer schemes for the calculation of heating rates in the atmosphere of Mars

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The ubiquitous dust aerosol particles in the atmosphere of Mars play a main role on the behaviour and evolution of its climate. By absorbing and scattering the incoming solar radiation, they modify the atmospheric thermal structure and dynamics. Dust radiative forcing calculations are of high relevance to understand Mars' overall atmospheric dynamics. The accuracy in determining internal radiation fields and the resulting atmospheric heating/cooling rates contribute to the uncertainties in these calculations.

Radiative transfer schemes using 2-stream approximations are widely implemented in multiple Mars' dynamical models and Global Circulation Models (GCMs). The uncertainties associated to this approximation are related to neglecting details of dust particles' scattering phase function: the higher the number of streams considered, the better the accuracy of the scheme, although there is a persistent trade-off between accuracy and computational cost. The objective of this work is to evaluate the accuracy of dust aerosol radiative forcing estimations in the Martian atmosphere by multiple-stream schemes.

Several scenarios covering the different atmospheric conditions during the Martian Year were simulated with different radiative transfer models, as well as other high-opacity dust storm scenarios. The atmosphere was discretised into 50 levels from 0 to 100 km, with atmospheric variables loaded from LMD's Mars Climate Database (MCD). The visible and infrared spectral regions were divided into 12 bands, covering from 0.24 to 1,000 μm. Gaseous opacities were calculated with the correlated-k method, with absorption data retrieved from HITRAN. Dust aerosol radiative properties were derived using the wavelength-dependent properties reported by Wolff et al. (2006, 2009), with vertical distributions following a Conrath profile, and assuming a well-mixed dust scenario. Particle size (effective radius) and column dust opacity were given values to characterise every scenario. Finally, the calculated internal radiation fields and heating/cooling rates with the two-stream approximation code were compared with 4, 8, 16 and 32-stream solutions using the discrete ordinates method (DISORT).

The comparison of the results with respect to the 32-stream model shows heating rate underestimations with average differences of about 2.7, 0.3, 0.1, and 0.1 K/sol for the 2-, 4-, 8-, and 16-stream models, respectively. Such differences tend to be larger when there is more dust is loaded into the atmosphere. On the other hand, the average computational times for 1 sol using the 4-, 8-, 16-, and 32-stream schemes are about 15, 25, 40 and 135 times longer than the 2-stream scheme, respectively.

Future research prospects include the implementation of multiple-stream DISORT codes in Mars' mesoscale dynamical models to investigate the accuracy of simulations of the atmospheric effects generated by local and regional dust storms.