Fast Computation of CO2 Cooling Rates for a Mars GCM.

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We present and discuss a new parameterization of the radiative cooling rates by CO2 at 15-micron in the Martian atmosphere. The new scheme, which is under development, is specially designed to be implemented in Mars' global circulation models. It builds and improves upon a previous parameterization, currently in use in most GCMs. We will discuss briefly the needs for the present update and the improvements expected.

Importance of precise 15-micron cooling rates

The radiative cooling rates by CO2 at 15-micron are a key term of the energy budget of the upper atmospheres of the terrestrial planets [1]. Their precise computation requires a full radiative transfer model with accurate treatment of exchange terms, and able to handle the breakdown of local thermodynamic equilibrium (LTE), the usual situation at high altitudes [2]. In addition to the difficulties inherent to such modeling, the numerical task associated is normally too expensive for operational applications like GCMs. Therefore, a fast scheme or parameterization of the cooling rate is needed [3].

In the case of Mars, an approximate fast scheme was developed some years ago ([4], [5]; or "LVLP" hereonafter) in order to support the extension in altitude of the Martian GCMs developed at LMD and Oxford, and the derived Mars Climate Database, in the framework of an on-going project funded by ESA and CNES (see [6] for more details). At that time, the goal was to extend those models from 80 to about 120 km. That added region is very important for missions using aerobraking or aerocapture. At 80 km the non-LTE effects at 15-micron were expected to be small [3], and this was therefore considered as an upper limit for global models of the lower Martian atmosphere [4].

The situation has changed in the last years, since a whole new set of data on the upper atmosphere of Mars is now available. In-situ density measurements during aerobraking by Mars Global Surveyor, Mars Odyssey and Mars Reconossence Orbiter [5], as well as infrared emissions and absorptions in remote observations by PFS, OMEGA and SPICAM, on board Mars Express [6,7], represent for the first time, a benchmark of new data to test radiative, chemical and dynamical models of the Mars upper atmosphere.

The large scientific interest of exploiting these data rely on the accuracy of the existing models, and for this reason, an extended and improved radiative balance, containing a new and more accurate parameterization, is now needed. Some recent data [8,9] also suggest that the previous scheme may be too simplistic in extreme conditions, far from the nominal assumptions used at that time.

This talk presents the on-going efforts devoted to develop a more accurate approach to the problem, describing the areas where we expect improvements, and the possible impact it may have on the modeling of the Martian upper atmosphere.

Improvements foreseen

At least three major improvements are being investigated.

First, and surely the most serious limitation of the previous non-LTE scheme is,the single profile of atomic oxygen used, constant for all solar and local time conditions. The molecular collisions between CO2 and atomic oxygen are very efficient in transferring thermal and vibrational energy between both colliders, and between different CO2 vibrational states. But atomic oxygen presents a large variability but was completely unknown in the previous version of the GCM. The recent extension of the GCM photochemical module to the thermosphere (Gonzalez-Galindo et al, 2005) allows us to handle a much more realistic and variable atomic oxygen abundance than before.

Secondly, the LVLP approach also used a simplified two-level scheme. A strong band and a weak band were designed in order to simulate efficiently the emission by optically thick and thin bands. During recent numerical experimentation we found that a less simplistic situation does not increase a lot the CPU needed, and at present we are considering a larger number of levels and bands for the next scheme. Some results will be shown for a case with 6 vibrational states of CO2.

And finally, the radiative transfer was treated by LVLP in a very approximate manner, using an cool-to-space approximation with tabulated transmission functions. Such tabulation was largely required due to the simplified 2-level scheme, which required combined transition bands. The foreseen 6-level scheme does not combine bands and is therefor suitable for on-line computation of transmittances. This should also be a large improvement in precision compared to the LPLV scheme. However, our numerical method employs a Curtis Matrix algorithm, and therefore, efficient atmospheric grids and matrix inversion techniques are required for a fast computation of the flux divergences, and we are studying a number of options.

We will describe in this presentation the status of the work, and compare the preliminary results with the previous LVLP scheme.

References

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