FAST PARAMETERIZATIONS OF UV HEATING AND PHOTOCHEMISTRY FOR GCM MODELS OF THE MARTIAN ATMOSPHERE.

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Introduction

A 1-D model of the energetics, transport and chemical processes in the Martian atmosphere is being developed at the Instituto de Astrofíisica de Andalucía, as part of a joint project with the Laboratoire of Meteorologie Dinamique-CNRS and the Oxford University, and sponsored by ESA and CNES, in order to extend existing general circulation models to the Martian upper atmosphere. As part of this 1-D model, a study of the UV solar absorption has been performed and employed to simulate the heating and the photochemistry of the atmosphere, and has led to parameterizations of these processes suitable to be implemented in a generic Martian GCM. These UV modeling and parameterizations are briefly described here.

UV absorption and heating

The UV heating model extends from the surface up to 200km and computes the absorption by CO_2, O_2, O, H_2, H_2O and H_2O_2 in the 0.1-210nm spectral range. Optical depths and transmittances are computed with spectral resolution of 1 nm allowing for overlapping between absorbers. The temperature dependence of the CO2 cross section in the spectral interval 118.7-175.5nm is included according to Yoshino et al, 1996, and Anbar et al, 1993. Radiative fluxes at the top of the atmosphere for varying solar activities were taken from SOLAR2000, Kent Toshiba et al, 2000. Photoabsorption rates are computed for each constituent at layers of 1-km thickness, and the total heating rate is evaluated as a given fraction of the total initial absorption.

In agreement with previous results, the CO2 heating in the spectral interval 5.0-100.0nm dominates the UV heating above about 90 km, and in the 118.2-210.0nm interval below 90 km.

A fast parameterization has been developed based on a study of the variation of the cross sections with height in 23 subintervals of the full spectral range. In each subinterval the photoabsorption rate for each compound has been precomputed, using the detailed model, as a function of the slant column amounts of CO_2, O_2 and O. The photoabsorption rates can then be calculated just by interpolating to the slant column amount at the layers where the photoabsorption rate is wanted.

To illustrate the quality of this approach, we include in Figure 1 the photoabsorption profiles for a couple of CO2 and O2 bands computed with the detailed model and with the parameterization.

Photochemistry

A time-marching photochemical model has been developed in the frame of the 1D model mentioned above. This photochemistry model solves the continuity equation for 11 compounds: CO_2, O_2, $O(^3P)$, CO, H, OH, HO_2, H_2, H_2O, H_2O_2 and $O(^1D)$. 21 reactions among them (including photodissociations) are considered. The photodissociation rates needed in the calculation are given by the UV full model or its parameterization described above. The lifetimes and the productions and losses of each compound in each reaction can be obtained, as well as the composition changes for any given time. The internal time step for the calculation is adjusted as a function of the shortest lifetime at each layer.

Strong day-night variations are found for some compounds in the mesosphere and below, in particular $O(^3P)$, HO_2, H, OH, $O(^1D)$ and H_2O_2, although a stationary daily cicle is reached after one day of evolution.

A parameterization for the photochemistry has also been developed using the idea of photochemical equilibrium for the shortest-lived compounds: $O(^1D)$, OH and HO_2. This increases the internal time step and allows for a fast calculation of the abundances of all compounds.

The results obtained with this fast scheme have been compared to those of the full photochemical scheme. We show a couple of them in Figure 2. The time evolution is very similar in all cases, except for some species during a short time interval before the stationary state is reached (for OH in figure 2).

References

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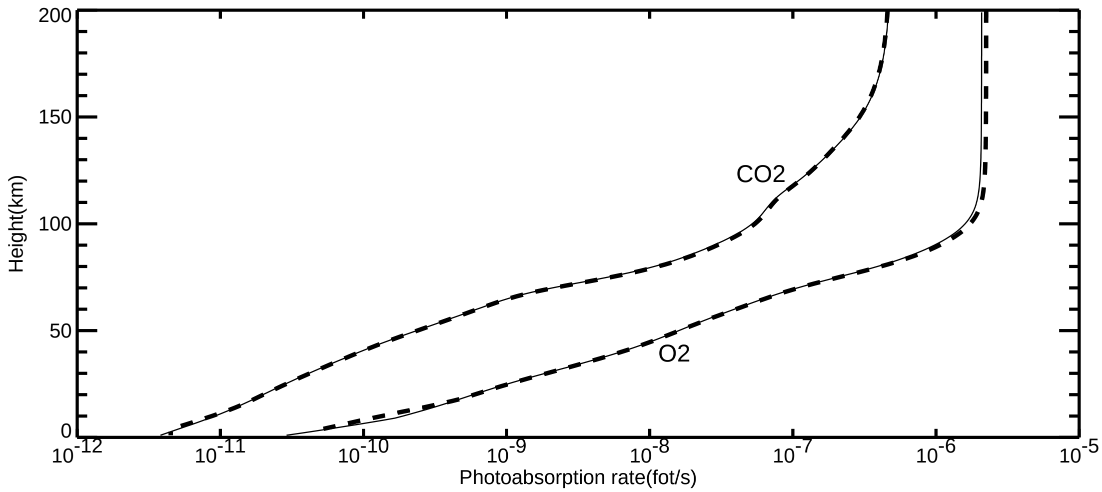

Fig. 1: Examples of photoabsorption coefficients. CO2: Band [106.4,210.0]nm. O2: Band [106.4-202.5]
Solid: Detailed model. Dashed: Parameterization. See text for details.

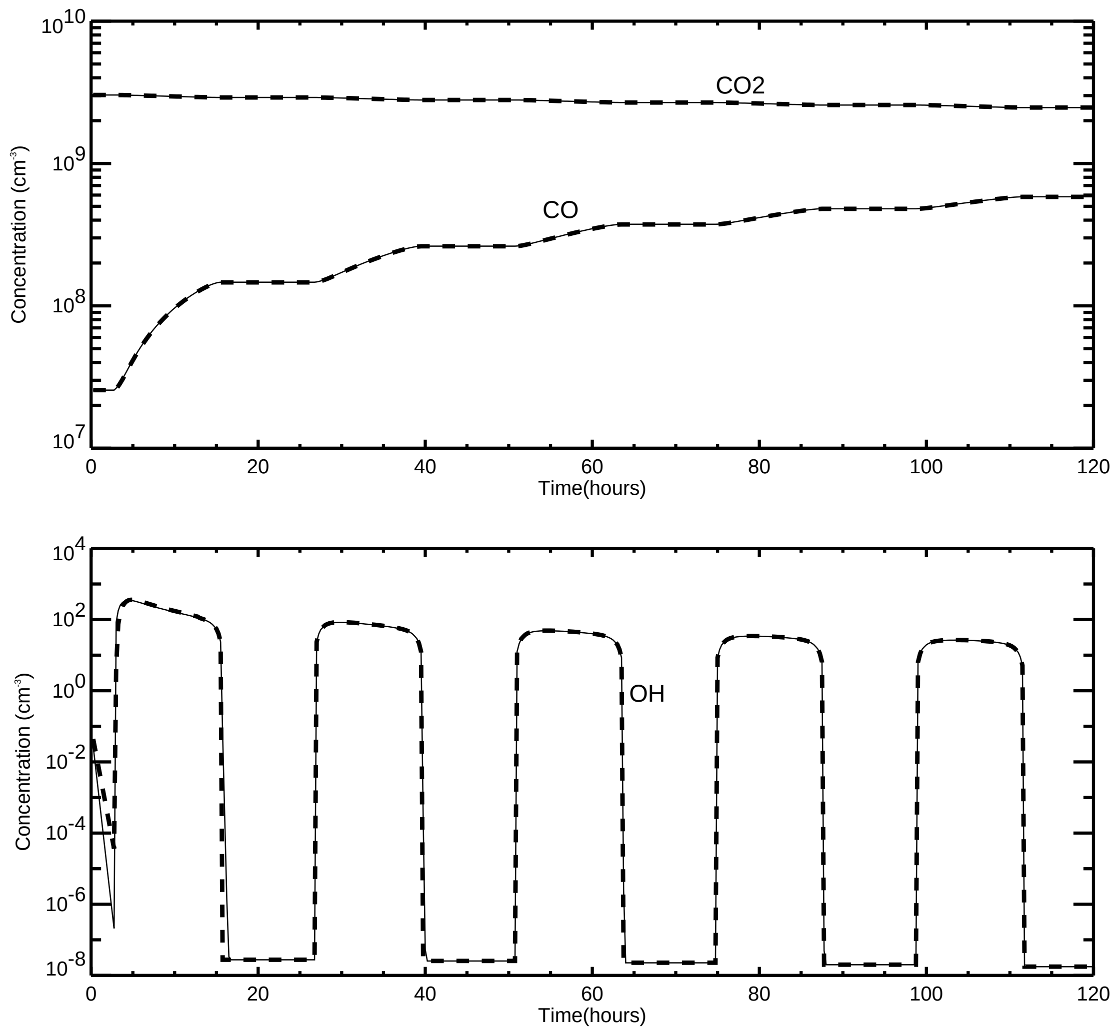

Fig. 2: Examples of daily changes in concentrations for CO2, CO and OH at 150km.
Solid: Detailed model. Dashed: Parameterization. See text for details.