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Simulations of $O_2(a^1\Delta_g)$ with GEM-Mars

L. Neary, F. Daerden and S. Viscardy
Belgian Institute for Space Aeronomy, Brussels, Belgium (lori.neary@aeronomie.be)

1. Introduction

The composition of the Martian atmosphere is driven by a complex system of photochemistry, transport and small scale processes. Constituents that are key to the understanding of these processes are water vapour and ozone, and related to these is the observable oxygen airglow. There have been terrestrial based observations of the O_2 airglow in the Martian atmosphere (e.g. Novak et al., 2002) as well as those from orbit such as the SPICAM (Fedorova et al. 2006) and OMEGA (Altieri et al., 2009) instruments.

During daytime, the O_2 airglow is formed by the photodissociation of O_3 in the lower atmosphere. At night, the formation of $O_2(a^1\Delta_g)$ comes from the three body reaction of atomic oxygen atoms and CO_2. The emission observed at 1.27 μm is a result of the deactivation of the excited molecule. At lower altitudes, it can be quenched by collision with CO_2.

Modelling the photochemistry of the Martian atmosphere with a Global Circulation Model (GCM) helps to understand the interplay between dynamics and chemistry.

2. Gas-phase chemistry in the GEM-Mars model

The chemical package included online in GEM-Mars uses reactions and rate coefficients based on the work of Garcìa-Muñoz et al. (2005). There are 15 photolysis and 31 chemical reactions (solved implicitly using Gaussian elimination method) and include the following 13 species: O_3, O_2, $O(^1D)$, O, CO, H, H_2, OH, HO_2, H_2O, H_2O_2, $O_2(a^1\Delta_g)$ and CO_2.

The chemical species are transported and mixed by the resolved circulation, eddy diffusion and in the upper atmosphere, molecular diffusion. The model includes interactive dust lifting by saltation and dust devils (Daerden et al., 2013) utilizing a detailed map for aerodynamic roughness length (Hébrard et al. 2012).

Other physical parameterisations included in the model are a 14 layer soil model with sub-surface ice, CO_2 condensation/sublimation and a water cycle with simple bulk condensation. The simulations presented are made with horizontal resolution 4°x4°, 103 staggered vertical levels up to approximately 160 km, and a 30 minute timestep.

3. Simulations of $O_2(a^1\Delta_g)$ airglow

Figure 1 shows the modelled zonal average $O_2(a^1\Delta_g)$ volume emission rate for one Martian year (day and night glow combined). The largest emissions are around in the polar regions, between the autumnal and spring equinoxes. This can be shown to be a result of the transport of air rich in atomic oxygen from lower latitudes. These results are consistent with other modelling results and observations (e.g. Fedorova et al., 2006). Further analysis of the interaction between dynamics and chemistry is ongoing.

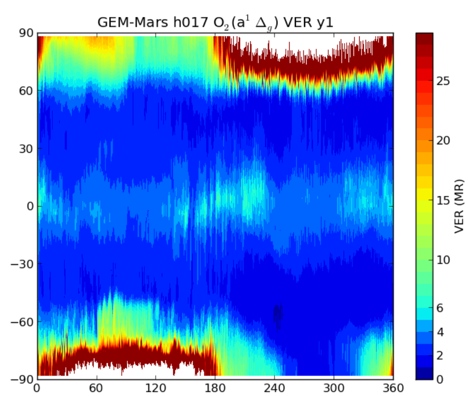

Figure 1: GEM-Mars zonal average $O_2(a^1\Delta_g)$ volume emission rate in MR (1 R = 10^6/photons $cm^{-2}s^{-1}(4\pi$ ster$)^{-1}$).

4. Summary and Conclusions

The GEM-Mars model is a three-dimensional GCM for the Mars atmosphere with active dust lifting, CO_2

condensation/sublimation and water cycles and gas-phase chemistry. The model is able to reproduce the basic distribution of O_2 airglow, an observable phenomenon which provides information about the composition of the Mars atmosphere. The model can be used to complement the observations and make the link between airglow, ozone and water vapour.

References

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