3D chemistry on Mars using the Global Multiscale Model

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There are a limited number of studies of chemistry on Mars using 3D models (eg *Lefevre et al.* (2004)). The work presented here describes the incorporation of a water cycle and a photochemical model into the Global Mars Multiscale Model (GM3) (*Moudden and McConnell* , 2005). We also present some comparisons of chemical species aimed at evaluating the chemistry. Currently GM3 has a water cycle that represents the transport of water in both vapor and ice phases, together with the sedimentation of ice particle and the evaporation of deposited ice back to the atmosphere when the temperatures near the surface exceed the freezing point of water. The chemistry currently includes 30 reactions and 12 photochemical reactions that represent 12 carbon and hydrogen compounds. We are also in the process of including nitrogen compounds and ions. The presentation will detail the properties of the dynamical and chemical models with an evaluation of the model's performance in light of some observations.

The water cycle includes the evaporation of surface deposited water ice, the transfer of water molecules between the vapor and ice phases in the atmosphere depending on the saturation vapor pressure controlled by ambient temperatures, and the sedimentation of water ice particles to the surface, the sedimentation velocity is calculated assuming a constant radius of 2μm. Figure 1(a) shows a 1 year simulation of the water column. The initial ice caps are prescribed such that the values obtained during the summer solstices are comparable with the TES values. It apears that the temperatures can be high enough to allow larger amounts of water to be evaporated from the caps thus the limiting factors are the water available for evaporation at the surface and the evaporation rate.

The Ozone depletion by odd hydrogen compounds is visible in both the column figures (1 (a) and (b)) and in the instantanious zonal averages (2 and 3). Figures 2(a) and 3(a) show two meridional-vertical snap-shots of water mixing ratios. The water is evaporated near the pole and transported in a cross equatorial circulation where the ice clouds play an important role to the winter hemisphere. Due to orbital excentricity the circulation in the northern summer is relatively stronger during the northern summer and the transport of water across the equator is large enough to produce a secondary peak in the water column (see figure 1(a)). The photolysis of water produces odd hydrogen molecules (H, OH, HO_2, see 2 and 3, (c), (d) and (e)) which in turn contribute to the conversion of O_3 back to molecular oxygen.

Panels (d) and (e) of Figure 2 show the HO2 and OH mixing ratios for the Northern summer solstice. As may be expected with high/low values of water vapour at northern/southern polar latitudes, HOx (= OH + HO2) values are relatively high/low produced by photolysis of H2O and reaction of O1D with H2O (more important in winter latitudes). As can be seen there is a layer of HO2 at about 20 km over the northern pole extending to about 30 degrees south. The OH distribution is relatively more uniform but with a layer of global extent at about 60 km. Neither OH nor HO2 peak at the ground in spite of the high values of water vapour. This is because the photolysis of H2O is optically thick at the long wavelength tail near 180 nm.

Panel (f) of Figure 2 shows the O mixing ratio: the main layer of O lies above the surface and in fact mixing ratios increase towards the thermosphere. It is clear that there is more O over the wind pole transported by the global-wide Hadley circulation.

The pattern of consiitents shown in Figure 3 for the southern summer solstice is similar (but reversed) in many respects as the picture shown in Figure 2. But they are not the same. Although there is less water available there is also more O3 at northern latitudes. This refects two important differences. First the pressures are higher at northern latitudes so the same mixinf ratio translates to higher densities. In addition, as can be inferred from

panel (f) there is a downward flux of O (the source of O3) from higher altitudes than is the case for the northern summer.

References

Moudden, Y., and J. C. McConnell, A New Model for Multiscale Modeling of the Martian Atmosphere, GM3, *J. Geophys. Res., 110* doi:10.1029/2004JE002354, 2005.

Lefevre, F., S. Lebonnois, F. Montmessin, F. Forget, Three-dimensional modelling of ozone on Mars, *J. Geophys. Res., 110* doi:10.1029/2004JE002268, 2004.

(a)

Water column in precipitable μm

(b)
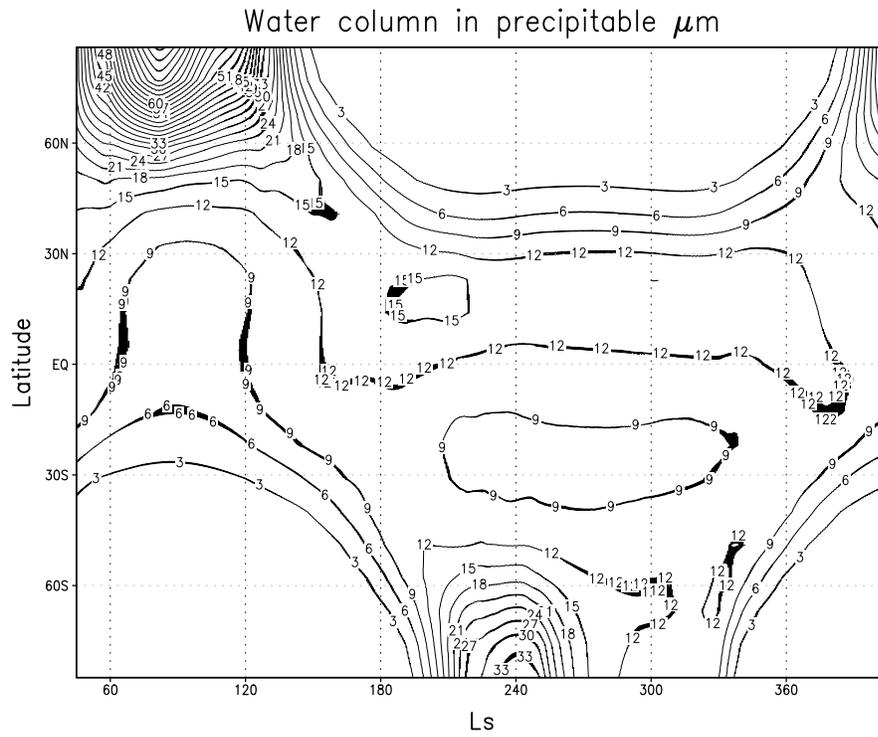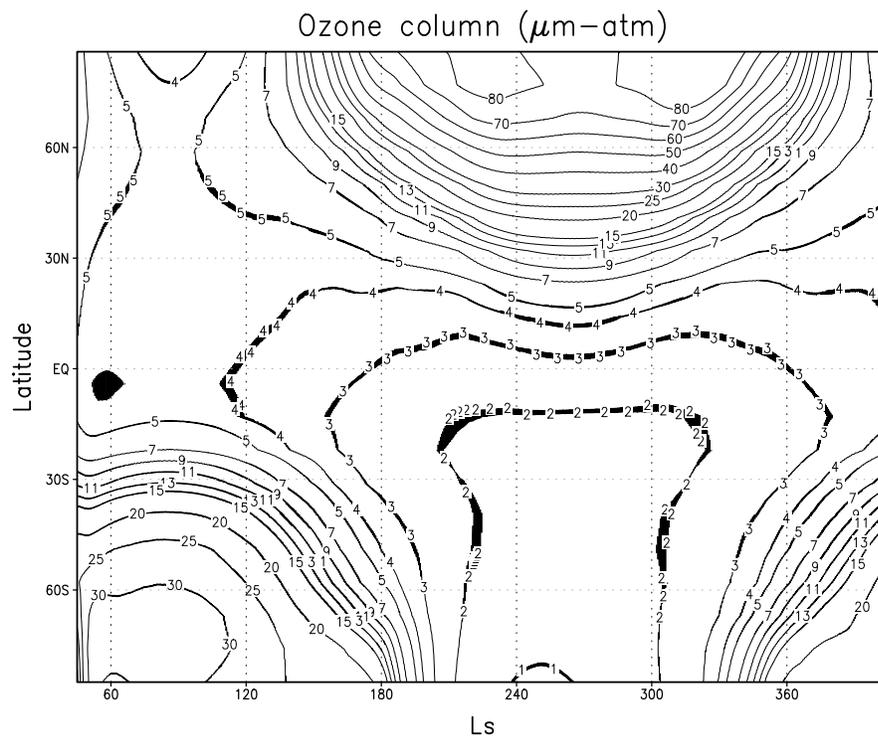
Ozone column (μm$-$atm)

Figure 1: Water and Ozone columns in a 1 year simulation.
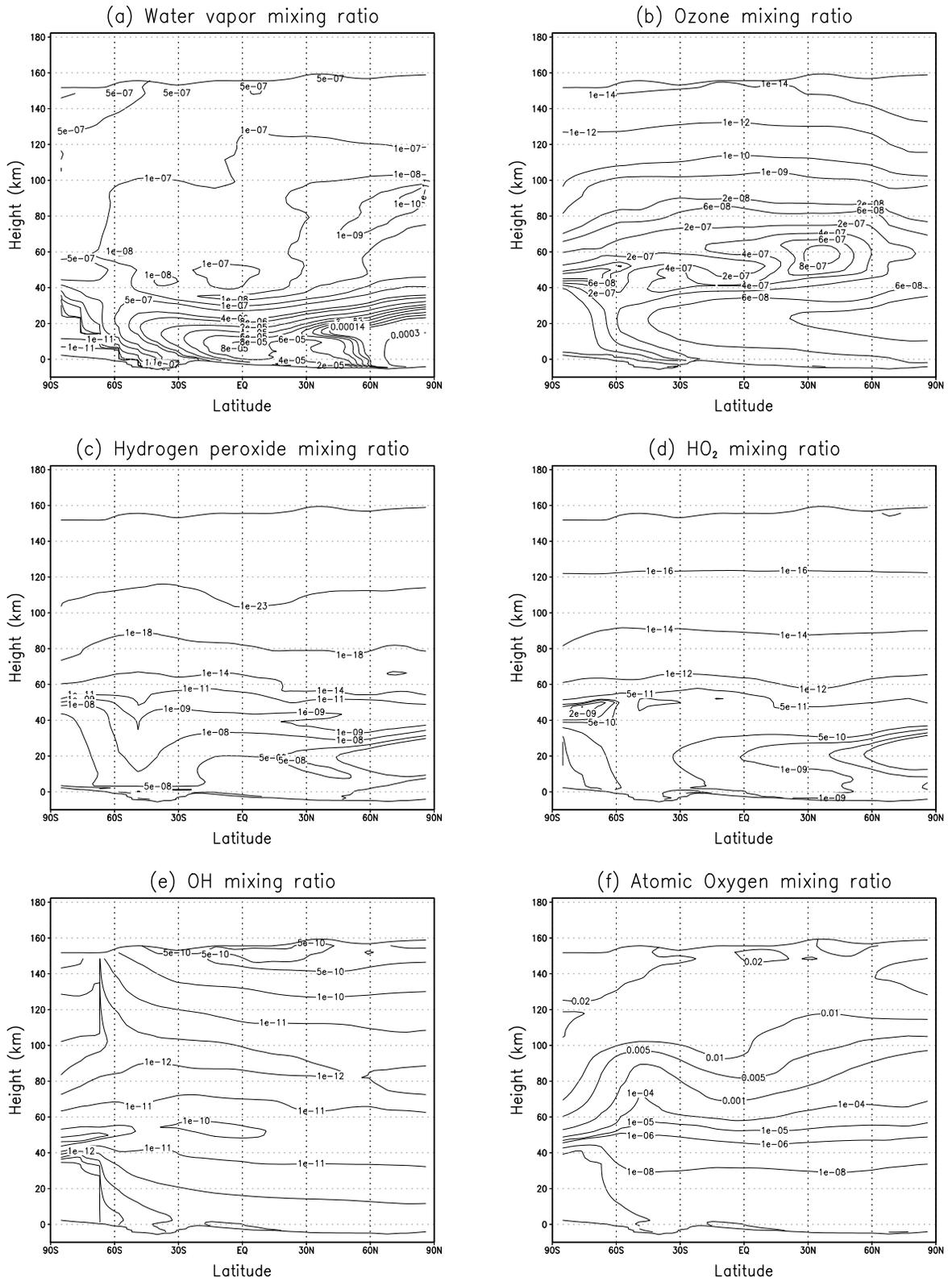
Figure 2: Mixing ratios of H_2O, O3, H_2O2, HO_2, OH and O in the northern summer solstice.

(a) Water vapor mixing ratio

(b) Ozone mixing ratio

(c) Hydrogen peroxide mixing ratio

(d) HO$_2$ mixing ratio

(e) OH mixing ratio

(f) Atomic Oxygen mixing ratio
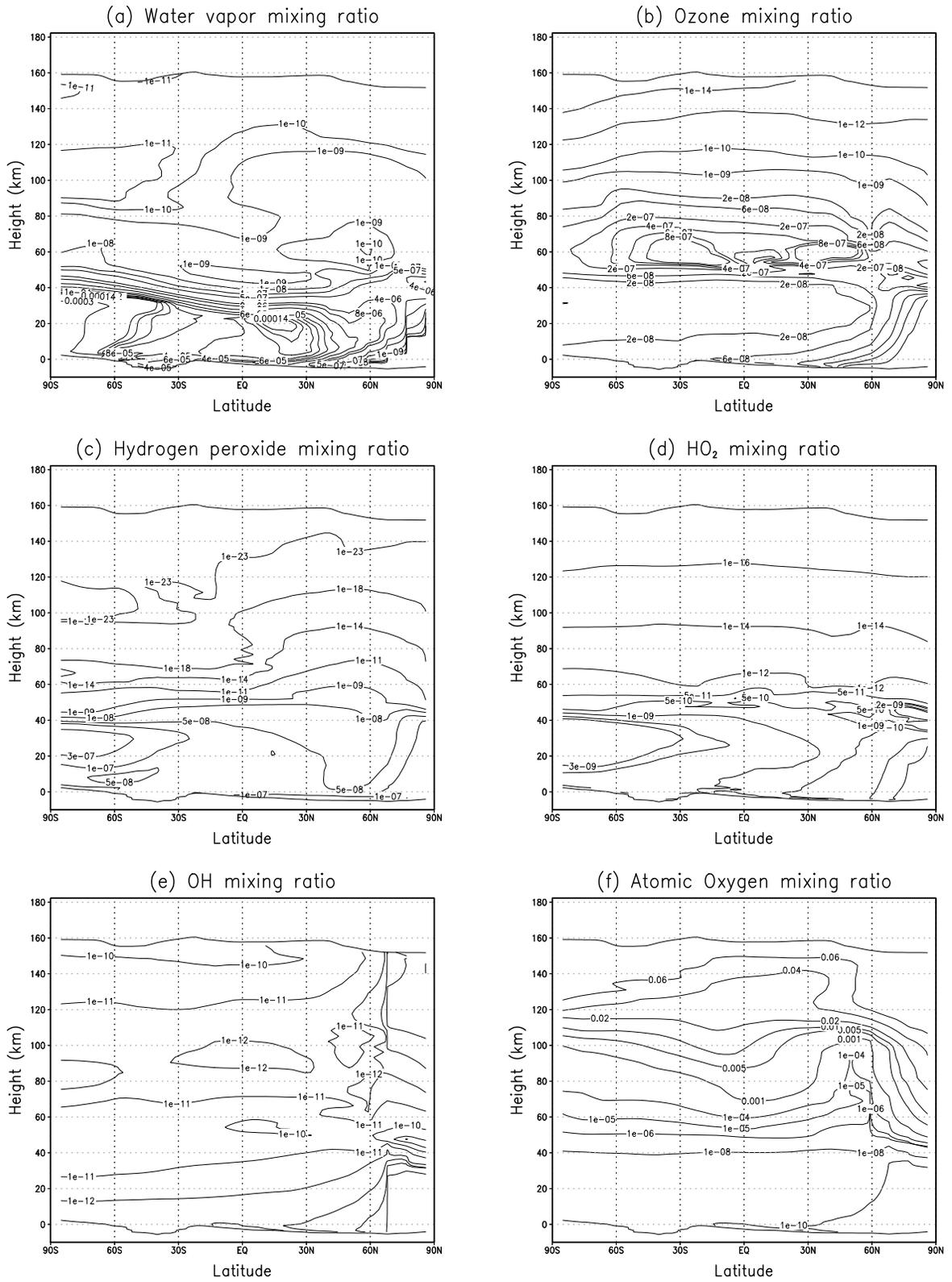
Figure 3: Mixing ratios of H$_2$O, O3, H$_2$O2, HO$_2$, OH and O in the southern summer solstice.