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Parameter Space for an O_3 Layer in Mars' Past

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Abstract

It has been suggested that an O_3 layer might have formed on Mars under past atmospheric conditions, with consequences for photochemistry and climate. This work attempts to identify past conditions capable of supporting a significant O_3 layer in a humid CO_2 Martian atmosphere. Parameter space explored includes surface pressure, humidity, and insolation. Under conditions which do support a significant O_3 layer, effects on atmospheric structure, loss to space, and habitability are investigated.

1. Introduction

The possibility of a significant O_3 layer existing in a thicker past Martian atmosphere has been raised, with some preliminary support from modeling [12,7]. This would have implications for climate, long-term atmospheric evolution, and surface habitability. However, it has also been pointed out that the conditions most likely to produce a substantial O_3 layer are very dry and cold [11]. The purpose of this study is to quantify under what conditions an O_3 layer might have been supported in Mars' past and what its extent and effects would be.

2. Methods

2.1 Radiative-Convective Model

We use a 1D line-by-line LTE radiative-convective model using the plane-parallel approximation to solve for globally averaged thermal equilibrium. The model extends from the surface up to a pressure ~0.1 Pa, where the assumption of LTE begins to fail for the 15μm CO_2 cooling line [8]. Radiative calculations are based on the HITRAN 2008 spectral database [9] with a Voigt lineshape near the line center, the Van Vleck-Weisskopf lineshape in the wings, and a χ-factor for CO_2 wings [5]. Collision induced absorption (CIA) by CO_2 follows the treatment of Wordsworth et al. [14,2,4]. In the IR/visible from 0-25000 cm^{-1} (400 nm), calculations are carried out on a precomputed non-regular wavenumber grid optimized to resolve radiative lines at < 1 halfwidth. Calculations in the UV are performed from 191-400 nm on a 1 nm regular grid. For absorption cross-sections of photochemical species we use the MT_CKD continuum model [1], MPI-Mainz-UV-VIS Spectral Atlas of Gaseous Molecules [16], and JPL evaluated data [10]. Solar radiation transfer is treated according to the δ-two-stream method of Toon et al. [13].

2.2 Photochemical Model

A photochemical model for humid CO_2 atmospheres is coupled to the radiative-convective model in order solve for chemical equilibrium as well as thermal equilibrium. Background concentrations of CO_2 and H_2O are adopted and their photochemical products are then generated (O_2, CO, H_2, H, OH, HO_2, H_2O_2). Photochemical equilibrium is found using the Kinetic Pre-Processor (KPP) [3] using a set of reactions similar to those used in other studies of current and ancient Martian photochemistry [6,12,15]. Kinetic rates are taken from Krasnopolsky [6] and the JPL evaluated data [10]. Loss of H_2 to space is treated as diffusion limited, and mechanisms of O_2 loss to either space or the surface are considered [7,15].

3. Summary and Conclusions

This study identifies what conditions in Mars' past would have been conducive to forming a substantial O_3 layer by varying the parameters of atmospheric pressure, humidity, and insolation in the described model. We also explore the resulting effects, such as inhibition of CO_2 condensation, increased stratospheric humidity, H_2 loss to space, and the reduction of UV at the surface. These have consequences for the long-term climate evolution and habitability of Mars.

Acknowledgements

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