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Chemical ozone formation- and destruction pathways in Mars' atmosphere

J.W. Stock (1,2), C.S. Boxe (3), R. Lehmann (4), J.L. Grenfell (2,5), A.B.C. Patzer (5), H. Rauer (2,5), and Y.L. Yung (6)
(1) Instituto de Astrofísica de Andalucía, IAA-CSIC, Granada, Spain (jstock@iaa.csic.es), (2) DLR, Institut für Planetenforschung, Berlin, Germany, (3) Medgar Evers-City University, New York, NY, United States of America, (4) Alfred-Wegener-Institut für Polar- und Meeresforschung, Potsdam, Germany, (5) Zentrum für Astronomie und Astrophysik, TU Berlin, Germany, (6) Division of Geological and Planetary Sciences, Caltech, CA, United States of America

Abstract

Ozone is a species of central interest on the Mars, since it has a significant impact on the photochemical stability of the atmosphere and is furthermore a suitably observable species. The abundance of ozone is controlled by chemical pathways. In this contribution we apply a unique algorithm, called the Pathway Analysis Program - PAP to the results of the JPL/Caltech photochemical column model of the Martian atmosphere to investigate the chemical pathways producing and consuming ozone as functions of height.

1. Introduction

On Mars, ozone is a trace gas of major significance. It has been observed not only in the infrared from ground-based telescopes e.g. [1, 2, 3] but also in the ultraviolet by space telescopes e.g. [4] and orbiters e.g. [5, 6, 7]. Additionally there exist also some in situ measurements e.g. [8, 9, 10].

Ozone is related to the photochemical stability of the main atmospheric constituent, CO_2 in two ways. Firstly its abundance is anticorrelated to the abundance of HO_x (see [11, 12]), which catalytically destroys ozone. Note that HO_x is also the family including the major catalyst species acting in chemical CO_2 formation pathways e.g. [13, 14, 16, 17]. Secondly, it can be directly involved in those pathways either by providing atomic oxygen via photolysis or by acting as catalyst species [16, 17, 18].

From both, modeling and observations, it has been shown, that the concentration of ozone varies with altitude. The Martian atmosphere exhibits two ozone layers, one near the surface and the other one around 40 km altitude. It is therefore desirable to identify the chemical pathways acting at different heights and to quantify their efficiency by calculating the rates of different pathways.

2. Method

Finding chemical pathways in complex reaction networks is generally a challenging task. In this study, we use an automated computer algorithm, the Pathway Analysis Program (PAP, [19]) and apply it to the results of the updated JPL/Caltech photochemical column model of the Martian atmosphere which is based on [15] in order to address this problem. Rates of individual ozone production and destruction pathways are computed for different altitudes, by analyzing each vertical layer from the surface up to 80 km of the column model separately with the PAP.

3. Results and Conclusions

In this contribution we identify all dominant pathways responsible for ozone production and consumption. Furthermore, we determine their efficiency by calculating altitude dependent pathway rates. Our results suggest, that in the lower altitudes ozone is mainly produced by a Chapman-like mechanism involving CO_2

$$\begin{array}{rrcl} & CO_2 + h\nu & \longrightarrow & CO + O \\ & O + O_2 + CO_2 & \longrightarrow & O_3 + CO_2 \\ \hline \text{net:} & O_2 + CO_2 & \longrightarrow & O_3 + CO \end{array}$$

In the upper ozone layer ($40\,\mathrm{km} < z < 60\,\mathrm{km}$), downwards-diffusion by atomic oxygen plays the dominant role for ozone production. Ozone is mainly destroyed by photolysis, leading to the conversion of CO to CO_2 and/or O_2 via O_x-HO_x-pathways in all heights in the considered altitude range.

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