Trace gas assimilation of Mars orbiter observations

Conference or Workshop Item

EPSC Abstracts
Vol. 7 EPSC2012-217-2 2012
European Planetary Science Congress 2012

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Abstract

Ozone, water vapour and argon are minor constituents in the Martian atmosphere, observations of which can be of use in constraining atmospheric dynamical and physical processes. This is especially true in the winter season of each hemisphere, when the bulk of the main constituent in the atmosphere (CO_2) condenses in the polar regions shifting the balance of atmospheric composition to a more trace gas rich air mass. Current Mars Global Circulation Models (MGCMs) [5, 7, 9] are able to represent the photochemistry occuring in the atmosphere, with constraints being imposed by comparisons with observations. However, a long term comparison using data assimilation provides a more robust constraint on the model. We aim to provide a technique for trace gas data assimilation for the analysis of observations from current and future satellite missions (such as ExoMars) which observe the spatial and temporal distribution of trace gases on Mars.

1. Introduction

With observations of trace gases, we have the ability to refine parameters in MGCMs which are not fully understood, providing a more realistic global view of the atmosphere. For example argon is a passive species which has been shown to have a large enhancement over the winter pole [10] and due to its unreactive nature can feasibly be used to constrain atmospheric wind components which are observed indirectly by current MGCMs [2]. Water vapour has been heavily studied, most recently to investigate the effect of water ice clouds on the atmosphere [11]. Ozone (O_3) shows a well documented anti-correlation with water vapour (Figure 1) and comparisons of O_3 between MGCM output and Ultraviolet and Infrared Atmospheric Spectrometer observations have been conducted to refine simulations of its seasonal distribution, mainly surrounding the rate of O_3 loss and production [4]. Methane is also of interest due to the role it plays for life on Mars [3].

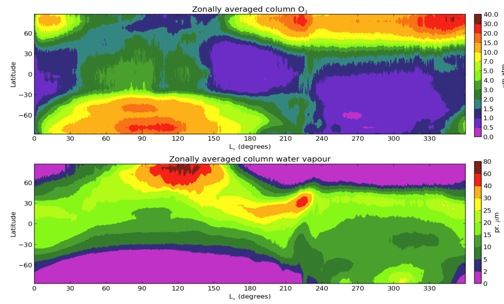

Figure 1: Latitude-Solar longitude plot of ozone column abundance (Top) and total water vapour column (Bottom) from the UK MGCM.

2. The UK MGCM and photochemical model

To study trace gases in the Martian atmosphere, the UK MGCM is used. It is composed of a UK spectral dynamical core coupled to the same physical schemes used by Laboratoire de Météorologie Dynamique [2]. An additional component [5] necessary to examine trace gas species is the photochemical model which provides volume mixing ratios of 16 chemical species including argon, water vapour and O_3. Figure 1 shows how O_3 is in low abundance when water vapour reaches its peak in the summer season at the north or south pole respectively. This is due to the photolysis of water vapour resulting in hydrogen radicals which readily destroy ozone in the Martian atmosphere. When water vapour is present in much lower abundance, due to the majority of it depositing as ice on the surface in the polar regions, O_3 is able to thrive due to the coinciding decrease in production of hydrogen radicals. Observations of the Martian O_3 layers have continued with new satellite missions [4], and vertical profiling of O_3 distribution is currently in operation onboard the Mars Reconnaissance Orbiter [1].

3. Data assimilation

Data assimilation is a reanalysis producing a best estimate of the state of the atmosphere, based on combining model results and observational data corresponding in time allowing for errors in both the model and observations. It is ideal for observational data sparse regions since the increased constraints provided by the assimilation on data rich regions will indirectly improve these less observed regions. The outcome of this process is a robust 4-D map of the Martian atmosphere which has been refined using real data. The assimilation scheme used by the UK MGCM is based on the Analysis Correction scheme by [8] adjusted to Martian conditions by [6]. Figure 2 shows a comparison between standard model temperature and an assimilation of temperature and dust from the Thermal Emission Spectrometer in which an under-prediction by the model in the south-west region is evident. Assimilation of water vapour is ongoing, and we aim to improve the understanding of the Martian O_3 cycle further by assimilation of O_3 from Mars Color Imager and Mars Climate Sounder observations.

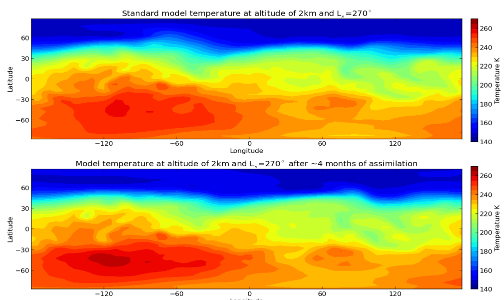

Figure 2: Comparison of standard model temperature (at 0000 UTC) 2 km above the surface at northern winter solstice (top) and the same run ith 4 months of assimilation of temperature and dust optical depth (bottom).

Acknowledgements

The authors gratefully acknowledge the support of the UK Space Agency / STFC.

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