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Analysis of the Martian ozone cycle by assimilation of SPICAM observations

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Abstract

Observations of ozone, a trace gas on Mars, have the potential to constrain atmospheric dynamical and physical processes. Current Mars Global Circulation Models (MGCMs) [1, 2, 3] are able to represent the photochemistry occuring in the atmosphere, with comparisons to observations used to confine particular species. However, a long term comparison using data assimilation provides a more robust constraint on the model. We have assimilated total-ozone observations from SPICAM into an MGCM to study the Martian ozone cycle. Ozone has never before been assimilated for an extraterrestrial planet. Our aim is to use ozone to provide a preliminary 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. Ozone has multiple avenues worthy of study which can improve our understanding of atmospheric processes. The quasi-passive nature of ozone in the polar night can be used to investigate polar dynamical processes. It can also be used as a tracer for hydroxyl which is a key species regarding the stability of the atmosphere. Water vapour has a strong anti-correlation with ozone and so observations can also provide indirect information for this species.

Observations from SPICAM (Figure 1) on Mars Express can be assimilated into an MGCM to provide insight into the aforementioned areas of study, with future observations from MARCI [4] and NOMAD on the ExoMars Trace Gas Orbiter eventually increasing the observational dataset.

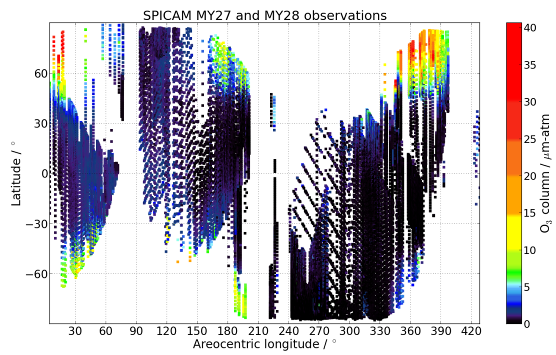

Figure 1: SPICAM total-ozone retrievals from nadir observatons for Martian year 27 and the start of Martian year 28 as a function of latitude and areocentric longitude.

2. Modelling and data assimilation

We use the UK version of the LMD GCM to study the ozone cycle. This model consists of a spectral dynamical core, semi-lagrangian transport scheme [5] and Analysis Correction assimilation scheme [6] (adjusted to Martian conditions by [7]) coupled with physical parameterisations used and developed primarily by Laboratoire de Météorologie Dynamique [8]. An additional photochemical module [9] provides volume mixing ratios of 16 chemical species including argon, water vapour and ozone. To make optimal use of information, observations and model information are combined by the process of data assimilation. 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.

Although data assimilation is now commonplace on Earth [10, 11, 12], it is a fairly new concept for other planetary systems, with Mars the only other current candidate. The satellites currently orbiting Mars, combined with the future planned satellite missions, create a great opportunity for the development of trace gas data assimilation techniques for extraterrestrial planets. The outcome of this process is a robust 4-D map of the Martian atmosphere which has been refined using real data.

3. Total-ozone assimilation

Figure 2 shows a comparison between a control model run and an assimilation of total-ozone. Premature decrease of the northern and southern polar maximum is evident, which could suggest an early excess of water vapour being transported northward/southward respectively. The tropics, where the majority of observations occur, show a general increase around aphelion and a decrease around perihelion. Heterogeneous reactions cannot explain this, but slight adjustments in the vertical profile of water vapour could cause such an effect. In the tropics, ozone has a very short lifetime during the day which means the ideal parameter choice for assimilating the observations will need to be carefully chosen.

Active ozone assimilation can also be used to probe other chemical species which are affected by a reduction/increase in ozone levels. The assimilation technique will be tuned and refined using the SPICAM observations. This will provide valuable information for future instrument observing strategies for measuring trace gases in the Martian atmosphere.

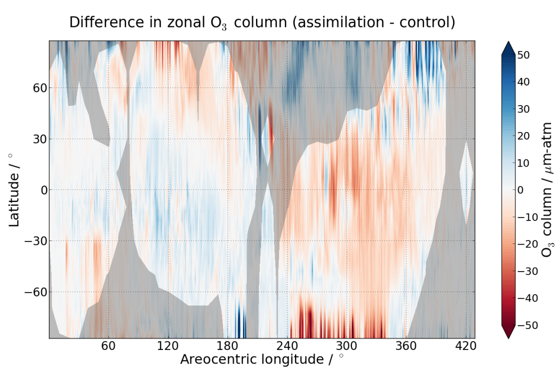

Figure 2: Percentage difference in zonally averaged total-ozone between the assimilation and control run for Martian years 27 and 28. Shading indicates regions where there are no nearby SPICAM observations.

Acknowledgements

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