Trace gas assimilation of Mars orbiter observations

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1. Introduction

- Observations of trace gases are a key reference for chemical processes in the martian atmosphere
- Computer models can be used to explore their global temporal and spatial distribution
- Our project aims to assimilate trace gases into the LMD/UK MGCM to develop the representation of trace gas transport, sources and sinks in the model

2. Observations

Current observations of trace gases come primarily from 2 instruments:
- **TES** (Thermal Emission Spectrometer) providing water vapour column abundances (1999–2006)
- **MCS** (Mars Climate Sounder) and **MARCI** (Mars Color Imager) acquiring water ice optical depth and ozone column abundances respectively (2006–present)

3. Modelling trace gases

To model the spatial and temporal distribution of trace gases we use:
- The **LMD/UK MGCM** (Martian Global Circulation Model) [1] developed by a close collaboration of Laboratoire de Métorologie Dynamique, Instituto de Astrofísica de Andalucía, University of Oxford and the Open University with the LMD physics package
- The **LMD photochemical module** [2] containing 16 chemical species including ozone and methane

Specific to our UK version:
- A spectral dynamical core to solve fundamental laws of physics and fluid motion
- A semi-lagrangian tracer advection scheme [5] to provide realistic 3-D fields of trace gases
- The **Analysis Correction** (AC) scheme [3,4] for assimilation of observations

4. Ozone in our model

- Strong anti-correlation between ozone and water vapour evident in polar regions linked to HO\(_2\) radicals
- Comparisons at L\(_{\text{eq}}\) = 346.4° between a LMD/UK MGCM run and MARCI observations are very good, with clear features such as the Hellas basin and Elysium Mons visible
- Discrepancies do exist though, and these could be larger in other seasons

5. Removing topographical effects

- Spatial distribution is largely characterised by the topography of Mars in northern winter
- Wave-like activity can be seen at the sharp gradients of ozone column abundance in the northern hemisphere
- After normalising ozone column abundance a similar pattern is seen indicating the variations across the globe are not an artefact of the topographical effects
- Models are important to use since they can ‘fill in’ gaps in observations
- However models are likely to have construction errors and include physical parameterisations, so an optimal combination of a model and observations is preferred

6. Assimilation of trace gas species

- Perform data assimilation using AC scheme [3,4], a sequential scheme adjusted to martian conditions
- Temperature and dust optical depth have been successfully assimilated and water vapour is currently in progress [6]
- Currently studying assimilation of artificial passive trace gas in preparation for assimilation of ozone observations
- Ozone is difficult to assimilate since it is a reactive tracer. Therefore ozone destruction and creation due to photochemical reactions need to be taken into account

Why do we want to assimilate trace gases?

- To study how accurately trace gases are modelled and identify sources and sinks
- To compare models against multiple observations over long time periods automatically, which is much less time consuming than manual comparisons

7. Near surface winds

- In northern winter the ozone is concentrated close to the surface
- Advection by near surface winds transports ozone-enriched air masses southward

8. Summary

- Trace gases in the martian atmosphere can be represented using the LMD/UK MGCM which has full transport and photochemical capabilities
- A wealth of ozone column abundance observations over the global domain from MARCI can be inserted into the LMD/UK MGCM using the AC scheme to study the ozone cycle and identify sources and sinks
- Assimilation of ozone can potentially be used to study the dynamics of the atmosphere and the technique would also be useful for other trace gas species such as methane

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