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)

Observations are sparsely spread across the globe and limited to repeat observations at same local time due to spacecraft’s orbit

Mission to gain a clearer understanding of sources and sinks of trace gases have been proposed such as the Exomars Trace Gas Orbiter

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 Météorologie 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\(_s\) = 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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References