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Assimilating martian atmospheric constituents using a global circulation model

Stephen R. Lewis, Liam J. Steele, James A. Horne, and Manish R. Patel
Department of Physical Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK (stephen.lewis@open.ac.uk)

Data Assimilation
Data assimilation is the combination of observations and models, which provide physical constraints and propagate the observational information that is introduced. This offers some significant potential advantages for the analysis of atmospheric data from other planets [4]. Thermal and dust opacity observations have been successfully assimilated over a period of about eight Mars Years (MY), including data from the Thermal Emission Spectrometer (TES) aboard NASA Mars Global Surveyor [5, 6] in MY24–27 and Mars Climate Sounder (MCS) data from NASA Mars Reconnaissance Orbiter (MRO) in MY28–31.

Water Vapour Assimilation
The MGS data can include a full water cycle, coupled to the model radiation scheme. Retrievals of water vapour columns data from TES [6] were assimilated into the model [9], including the global water vapour column error in the MGCM to around 2–4 μm depending on season.

Ozone Assimilation
The Mars Color Imager (MARC) [1] aboard MRO provides near-decadal global mapping of ozone column concentration. These data were used alongside MGS temperature and dust opacity observations, which help to ensure a realistic atmospheric dynamical state. Ozone has been successfully assimilated into the MGCM and can be shown to improve the model’s predictive capability, although the system generally retains information from observations over only a short time interval [10].

Water Ice Assimilation
Water ice assimilation is a new way to assimilate information from spacecraft or in situ missions. In the MGCM, the water ice is assumed to be present in the atmosphere and can be shown to improve the model’s ability to integrate over a longer period of time compared to the control model run.

Water Ice Ice Assimilation
We have assimilated MGS data, which includes vertical profile information [10]. This can be challenging since the MGCM rapidly converts between water vapour and ice.

Right: zonal-mean water ice specific field from the assimilation procedure around northern hemisphere summer solstice and autumnal equinoxes of MY30.

Below: zonal-mean longwave heating rates around northern (a,c) summer, (b,d) autumn, and (e,f) winter, and for local times of 3 am (a,c,e) and 3 pm (b,d,f). Black contours show the zonally averaged heating rates. Tropical climatologies result in additional local heating during the day and cooling at night. Heating is due to boreal winter and tropical storm systems, and cooling is due to boreal summer. These results suggest that the assimilation procedure improves the model’s ability to integrate over a longer period of time compared to the control model run.