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Assimilating martian atmospheric constituents using a global circulation model

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

Introduction
The technique of data assimilation is employed in a novel way for a planetary atmosphere to perform a complete spatial and temporal assimilation of martian atmospheric constituent data over periods of several Mars years. Observations of martian atmospheric constituents, generally made from orbiting spacecraft, are often sparse and incomplete. A global circulation model can be used to predict the transport, phase changes and chemical reactions that these species undergo. If constrained by observations, it can then provide a consistent interpolation to unobserved regions and, in principle, a useful a priori for future retrievals. Furthermore, any consistent mis-fit between the model predictions and new observations can be used to identify potentially important physical processes that are missing from the model, including inferring the presence and location of sources and sinks.

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) from NASA Mars Reconnaissance Orbiter (MRO) in MY28–31.

Previous work has focussed on assimilation of temperature and total column dust opacity into a Mars global circulation model (MGCM), which includes the option of a coupled photochemical model [2, 3]. We now add assimilation of water vapour, water cloud aerosol and chemical species. Results shown in this poster for water vapour are for MY24–25 and for water ice and ozone for MY30.

Below: dust absorption optical depth at 9.3 μm, normalised to 810 Pa and averaged over longitude. This should be multiplied by about 2.6 to get a broadband visible dust total extinction. The data here are from [7]. assimilation gives similar zonally- and diurnally-averaged results.

Water Vapour Assimilation
The MGCM can include a full water cycle, coupled to the model radiation scheme. Retrievals of water vapour column data from TES [6] are assimilated into the model [8], reducing the global water vapour column error in the MGCM to around 2–4 ppv depending on season.

Left: zonal-mean water vapour mass mixing ratios for the equator of the northern hemisphere in spring, summer, autumn, and winter seasons. Black contours show the mean meridional circulation (0°-90°) with solid, dashed lines representing clockwise, anti-clockwise circulation. Dotted white lines show ice mass mixing ratios. Water transport by transient eddies is largest at northern mid-latitudes close to equinoxes, with a net northward transport of water vapour toward the ice cap.

Below: water vapour column field in northern hemisphere summer (left) from (a) an assimilation of TES water vapour; (b) a model with outlying ice deposits around the main ice cap; and (c) a model with the main ice cap represented, revealing the impact of outlying ice deposits around the north pole ice cap (located between 75°–80° N and 120°–210° E).