Mars analysis correction data assimilation: a multi-annual reanalysis of atmospheric observations for the red planet

Conference or Workshop Item

Mars Analysis Correction Data Assimilation: A Multi-Annual Reanalysis of Atmospheric Observations for the Red Planet

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Ever-increasing numbers of atmospheric observations from orbiting spacecraft, and increasingly sophisticated numerical atmospheric models, have recently permitted data assimilation techniques to be applied to planets beyond the Earth. Mars is the first extra-terrestrial planet for which reanalyses of the atmospheric state are now available.

The Thermal Emission Spectrometer (TES) on board NASA's Mars Global Surveyor (MGS) has produced an extensive atmospheric data set during its scientific mapping phase between 1999 and 2004. Nadir thermal profiles for the atmosphere below about 40 km altitude, and total dust and water ice opacities, have been retrieved from TES spectra, covering almost three complete Martian seasonal cycles (each seasonal cycle on Mars corresponds to 668.6 mean solar days, and the Martian mean solar day is about 24 hours and 40 minutes). Note that dust on Mars plays a key role in the weather and climate, mainly through its strong absorption of short wave radiation with a short radiative relaxation timescale of 1-2 days. Assimilating dust opacities correctly is, therefore, particularly important for atmospheric data assimilation on the Red Planet.

TES retrieved observations have been analysed by assimilation into a Mars general circulation model (MGCM), making use of a sequential procedure known as the Analysis Correction scheme, a form of successive corrections method which has proved simple and robust under Martian conditions, even during the less-than-ideal MGS aerobraking period. The MGCM used at the University of Oxford and at The Open University consists of a spectral dynamical solver and a tracer transport scheme developed in the UK. Its package of state-of-the-art physical parameterization routines is shared with the LMD-MarsGCM, developed by the Laboratoire de Météorologie Dynamique in Paris (France).

One limitation of TES is that relatively few limb profiles are available, compared to nadir soundings. Our MGS/TES reanalysis, therefore, does not include observations of temperature above about 40 km altitude, nor 3D information on dust opacity (the vertical distribution of dust opacity is prescribed assuming a well mixed dust layer with a rapid transition to a clear upper atmosphere at a height which depends on latitude and season.

In September 2006 NASA's Mars Reconnaissance Orbiter (MRO) started its mapping phase. The Mars Climate Sounder (MCS) on board MRO is a radiometer with eight mid- and far-infrared channels and one visible channel, which takes measurements in limb and off-nadir geometries. Retrieved vertical profiles of temperature, dust and water ice opacities from MCS observations can now be assimilated using the same scheme we used for TES, with the advantage of the extension in altitude (thermal profiles can extend to above 80 km altitude, although errors become

larger at greater altitudes), the increased vertical resolution (~ 5km compared to > 10km for TES nadir retrievals), and the direct information on the vertical distribution of dust and water ice.

Overall, the application of our data assimilation scheme to retrieved observations from TES and MCS spans almost six complete Martian seasonal cycles. This represents a multi-annual climatology for Mars, which has the advantage of being a complete, dynamically-balanced, four-dimensional best-fit to observations for all the atmospheric variables, including those for which no direct measurements are available (e.g. wind and surface pressure) and with regions of no observations filled-in in a physically-consistent way.

The reanalysis represents, therefore, a unique opportunity to study the inter-annual variability of the Martian weather and climate with respect to all its components, such as the dust cycle, the water cycle, the CO_2 cycle, the atmospheric tides and other prominent waves, such as high latitude baroclinic waves.

In this contribution we present the first results of a complete assimilation of both datasets, using a consistent model and data assimilation scheme, and highlight the challenges of combining TES and MCS data assimilation to produce a multi-annual climatology. Particular attention will be devoted to the inter-annual variability of the atmospheric thermal field in response to dust storm activity. We will also provide an insight into the dynamics, looking in particular at the high latitude winds, waves and polar vortices.

Our data assimilation products are freely available to the community for both science- and engineering-oriented purposes. The British Atmospheric Data Centre (BADC, http://badc.nerc.ac.uk) hosts our datasets, which, for the time being, are limited to the MGS/TES reanalysis. People may contact the corresponding author in order to register their interest and be updated about the status of the project. New versions of the MGS/TES reanalysis as well as the MRO/MCS reanalysis will be made available through the BADC in future.

Interested people can download the current TES reanalysis dataset by registering at the BADC and searching for the MACDA (“Mars Analysis Correction Data Assimilation”) project. The direct link to the project is provided by the following URL:
http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__DE_095e8da2-cf02-11e0-8b7a-00e081470265