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Dust Assimilation in a Martian Global Climate Model

Tao Ruan (1), Luca Montabone (1,3), Peter Read (1), and Stephen Lewis (2)

(1) Atmospheric, Oceanic & Planetary Physics, University of Oxford, Oxford, OX1 3PU, United Kingdom (ruan@atm.ox.ac.uk), (2) Department of Physics Science, The Open University, Milton Keynes, MK7 6AA, United Kingdom, (3) Université Pierre et Marie Curie, Laboratoire de Météorologie Dynamique, Paris, France

With spacecraft, including Mars Global Surveyor (MGS), Odyssey and Mars Reconnaissance Orbiter (MRO), in orbit about Mars in sequence since 1997, there are now measurements of atmospheric temperature and dust extending over nearly 7 Martian years with unprecedented spatial coverage. Although those observations have greatly developed our understanding of the evolution, structure and climate of the Red Planet, the intermittent nature of the measurements still limits our ability to study the full details of the circulation, especially relating to dust activity. A numerical model, on the other hand, can provide continuous simulated data with high temporal and spatial resolutions, but typically fails to produce some significant features of dust storms, as well as their interannual variability. In this context, we make use of data assimilation into a Martian Global Climate Model (MGCM). This approach is able to provide a complete, four-dimensional solution consistent with both observations and with physical constraints and balances represented by the numerical model. The MGCM we use combines a spectral dynamical solver, a tracer transport scheme and dust lifting routines developed in the UK and the Laboratoire de Météorologie Dynamique (LMD; Paris, France) Mars GCM physics package, developed in collaboration with Oxford, The Open University and Instituto de Astrofisica de Andalucia (Granada, Spain).

Previous attempts at data assimilation for Mars have been conducted without explicitly advecting a dust tracer field, mainly because the Mars Global Surveyor/Thermal Emission Spectrometer (MGS/TES) did not provide information on the dust distribution in the vertical direction. The newly-available Mars Climate Sounder (MCS) data, however, provides relatively detailed information in the vertical direction, and accordingly here we describe a new data assimilation scheme with full assimilation of both temperature and dust measurements. The resulting assimilated reanalysis is able to represent many aspects of the evolution of atmospheric structure and dust loading in the atmosphere, including the altitude of the top of the dust layer at different seasons and latitudes as observed on Mars. However, a lack of measurements of dust profiles in the lower atmosphere may lead to an under-constrained dust simulation near the surface. These kinds of study may point to ways of improving numerical modeling and guide the new implementation of measurements that might help the further understanding of the Martian atmospheric circulation and climate.