Impacts of the 2018 Global Dust Storm on Martian Polar Dynamics

Conference or Workshop Item

IMPACTS OF THE 2018 GLOBAL DUST STORM ON MARTIAN POLAR VORTEX DYNAMICS.

P. M. Streeter[1], S. R. Lewis[1], M. R. Patel[1,2], J. A. Holmes[1], [1]School of Physical Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, U.K. (paul.streeter@open.ac.uk), [2]Space Science and Technology Department, Science and Technology Facilities Council, Rutherford Appleton Laboratory, Harwell Campus, Didcot, Oxfordshire OX11 0QX, U.K.

Introduction: Mars' winter atmosphere is characterized by a polar vortex of low temperatures around the winter pole, circumscribed by a strong westerly jet [e.g. 1]. These vortices are a key part of the atmospheric circulation and impact heavily on dust and volatile transport. In particular, they have a complex and asymmetrical (north/south) relationship with atmospheric dust loading [1]. Regional and global dust events have been shown to cause rapid vortex displacement [2,3] in the northern vortex, while the southern vortex appears more robust.

Suspended atmospheric dust aerosol is a crucial active component of Mars' atmosphere, with significant radiative-dynamical effects through its scattering and absorption of radiation [5]. The exact nature of these effects depends on a variety of factors: aerosol optical depth is important, as are the specific radiative properties of the aerosol particles [6,7], and the vertical distribution of the dust itself [8].

Mars Global Dust Storms (GDS) are spectacular, planet-spanning events which dramatically increase atmospheric dust loading. The 2018 GDS was observed through its lifecycle by the Mars Climate Sounder (MCS) instrument aboard the Mars Reconnaissance Orbiter [9]; using data assimilation [10] to integrate MCS retrievals [11] with the LMD-UK Mars Global Circulation Model (MGCM) [12] therefore offers an opportunity to examine the effects of the GDS on the polar vortices, and the interplay between the factors described above. The reanalysis contains the MGCM's best possible representation of the GDS geographical, temporal, and in particular vertical structure.

Model and assimilation scheme: We use the LMD-UK Mars Global Circulation Model (MGCM), which solves the meteorological primitive equations of fluid dynamics, radiative and other parameterised physics to calculate the state of the martian atmosphere [3,8]. The UK version of the MGCM possesses a spectral dynamical core and semi-Lagrangian advection scheme [13], and is a collaboration between the Laboratoire de Météorologie Dynamique, The Open University, the University of Oxford, and the Instituto de Astrofisica de Andalucia. The model was run at spectral spatial resolution T42 and a vertical resolution of 50 levels, the latter spaced non-linearly. The assimilation scheme used was a modified version of the Analysis Correction scheme developed at the Met Office, adapted for use on Mars [6].

Retrievals used: The retrievals used in this study are from the Mars Climate Sounder (MCS) instrument aboard the Mars Reconnaissance Orbiter (MRO) [4], which now has amassed over five full martian years' worth of data. For this study, the assimilated MCS variables were temperatures, derived column dust optical depth

(CDOD), and dust profiles. Temperature profiles extend from the surface to approximately 100 km, and dust profiles from as low as 10 km above the surface up to a maximum height of approximately 50 km. The retrieval version used is 5.2, a re-processing using updated 2D geometry [7]. This results in improved retrievals, especially in the polar regions.

Results: The 2018 GDS had large and asymmetric impacts on dynamics at both poles. This will be presented via changes in zonal winds and polar vorticity at both poles relative to a clear martian year, MY 30. The GDS provided a natural laboratory for testing the effects of equinoctial high dust loading on polar dynamics, allowing investigation of both how the polar atmosphere behaves in a clear year and under the case of extreme dust loading at this time of year. We present results on the effects of the GDS on both southern and northern polar dynamics, with implications for tracer transport.

Discussion: The 2018 GDS dataset allows the opportunity for investigation of the polar dynamical effects of that specific event, the first fully observed by MCS. The polar vortices and associated zonal jets act as a barrier for cross-vortex tracer transport; their weakening can therefore allow dust to be transported onto the seasonal CO_2 ice caps. Understanding how these barriers work is therefore important for understanding the evolution of Mars' past climate: the Mars' ice caps contain a record of past dust deposition [e.g. 8].

Upcoming retrievals from the ExoMars 2016 Trace Gas Orbiter and its NOMAD spectrometer suite [9] will allow for further investigation of tracer transport and an opportunity to both cross-validate and jointly assimilate NOMAD and MCS data, including over a range of martian local times, which will enable investigation of the diurnal cycles of tracer transport and atmospheric dynamics at the poles.

Acknowledgements: PMS acknowledges support from the UK Science and Technology Facilities Council under STFC grant ST/N50421X/1 and The Open University in the form of a PhD studentship. SRL, MRP and JAH also acknowledge the support of the UK Space Agency and STFC under grants ST/R001405/1, ST/S00145X/1 and ST/P001262/1 and STFC under ST/P000657/1. The authors are particularly grateful for ongoing collaborations with Dan McCleese, David Kass and the MCS team (NASA-JPL) and with Peter Read (Oxford) and François Forget and colleagues (LMD/CNRS Paris).

References: [1] Waugh, D. W. et al (2016) *J. Geophys. Res. Planets, 121,* 1770-1785. [2] Guzewich, S. D. et al (2016) *Icarus, 278,* 100-118. [3] Mitchell, D. M. et al (2015) *Q.J.R. Meteorol. Soc., 141,* 550-562. [4] McCleese D. J. et al (2010) *J. Geophys. Res., 115*(E12016). [5] Gierasch P. J. and Goody R. M. (1972) *J. Atmos. Sci., 29*(2), 400-402. [6] Turco R. P. et al (1984) *Scientific American, 251*(2), 33-43. [7] Madeleine J.-B. et al (2011) *JGR (Planets), 116* (E11010). [8] Tanaka, K. L. (2000), *Icarus, 144*(2), 254-266. [9] Patel, M. R. et al (2017), *Appl. Opt., 56*(10), 2771-2782.