MARTIAN POLAR VORTEX DYNAMICS AND THE 2018 GLOBAL DUST STORM. 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. This has implications for tracer transport through the zonal jets associated with the vortices, including the intra-vortex transport of dust itself [4]; a more coherent and low-latitude zonal jet should provide a more effective barrier against tracers entering the polar regions.

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]. This method has the advantage of being computationally inexpensive, and its use of repeated insertion, weighted over a time window of about six hours, helps counter the issue of relaxation of the atmospheric state – an especially significant problem given the low thermal inertia of Mars' atmosphere.

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. Retrieval of dust profiles allows MCS to observe the complex vertical dust structure in the atmosphere. 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 a large impact on dynamics at both poles. Figure 1 shows the impact of the storm in its growth stage (L_S=180-210°) on the southern zonal jet, "impact" here being relative to the relatively quiet year MY 30. The most notable effect of the GDS here was to significantly reduce the strength of the high-altitude westerly zonal jet, effectively accelerating the progression of the circulation from an equinoctial to a solsticial mode through diabatic dust-related heating of the southern hemisphere. This diminished the high-low latitude temperature contrast which drives the polar westerly zonal jet. We present further results on the effects of the GDS on both southern and northern polar dynamics, and how this relates to transport of tracers (specifically dust).

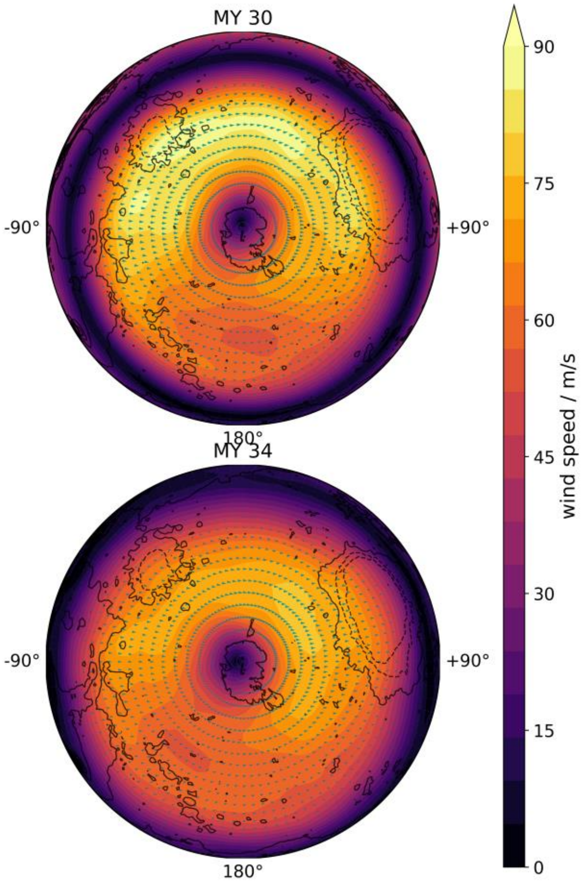

Figure 1: Wind speeds over the southern hemisphere at 50 km above the surface averaged over the period L_S=180-210° for MYs 30 and 34. Arrows show the direction of the westerly jet.

Discussion: Previous reanalysis studies of the polar vortices have used TES data [9,11]; MCS contains temperature profiles for higher in the atmosphere as well as dust vertical profiles, allowing for investigation of higher-altitude phenomena plus the impact of the dust vertical distribution on polar dynamics (and vice versa). Additionally, MCS dust profile retrievals are not restricted to areas with relatively warm surface temperatures (>220 K) as TES CDOD retrievals are [14], which excludes CDOD over the seasonal caps for the latter.

In particular for this work, the 2018 GDS dataset allows the opportunity for investigation of the polar dynamical effects of that specific event, the first fully observed by MCS. We present results from our reanalysis, and compare to free-running MGCMs, reanalyses of previous GDS events, and reanalyses of the older MCS retrieval set. We focus on the dynamics of the vortices themselves, zonal jet structure, and cross-vortex dust transport. 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, among other things, understanding the evolution of Mars' past climate: the Mars' ice caps contain a record of past dust deposition [e.g. 15].

Upcoming retrievals from the ExoMars 2016 Trace Gas Orbiter and its NOMAD spectrometer suite [16] will allow for further investigation of tracer transport and an opportunity to both cross-validate and jointly assimilate NOMAD and MCS data. NOMAD will also provide the crucial feature of observing over a range of martian local times, which will enable investigation of the diurnal cycles of tracer transport and atmospheric dynamics at the poles.

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