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# THE EFFECT OF MODEL RESOLUTION ON WIND-STRESS DUST LIFTING WITHIN THE LMD/UK MARS GLOBAL CIRCULATION MODEL

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## Introduction:

We have investigated how the representation of surface dust lifting by near-surface wind stress within a global circulation model varies across a range of modelling resolutions.

Our aim was to study two aspects of this dust lifting through increasing horizontal resolution: the locations at which dust was lifted from the surface and the total amount of dust lifted.

## Modelling Martian surface dust lifting:

This work uses the UK version of the LMD Mars Global Circulation Model (“the MGCM”). The MGCM is a global, multi-level spectral model of the lower and middle regions of the Martian atmosphere. The UK version of the model uses a truncated series of spherical harmonics to represent horizontal variations in atmospheric fields, with the field values stored as coefficients of the spherical harmonic functions (Hoskins and Simmons, 1975; Read and Lewis, 2004). These field values are transformed onto a three-dimensional grid in order to complete calculations involving parameterisations of physical processes.

The horizontal resolution of the model is defined by the total wavenumber of the spherical harmonic series: for example, a spectral resolution with a series of wavenumber 31 corresponds roughly to a computational grid of 36 latitude by 72 longitude points. This “T31” spectral resolution results in a physical horizontal resolution of 5° latitude by 5° longitude.

T31 is a resolution typically used within Mars global circulation model climate experiments. The highest resolution experiment reported in this work uses a spectral resolution of T85, corresponding to a physical horizontal resolution of 1.88° latitude by 1.88° longitude. All simulations use 25 vertical levels. Higher resolution experiments are underway.

Calculations involving surface dust lifting processes are completed within the MGCM’s physical space. Dust lifting by near-surface wind stress occurs when the horizontal frictional drag force of the wind on the surface dust particles is large enough to overcome the forces keeping the particles on the surface.

This dust lifting is modelled by calculating the friction velocity of the wind,  $u^*$ , and the threshold friction velocity required to lift particulate matter,  $u_t^*$  (e.g. Iversen *et al.*, 1976). Dust particles are lifted from the surface when  $u^* > u_t^*$ .

The threshold friction velocity implemented within the MGCM dust lifting subroutine is derived

from the fluid threshold,  $u_t$ , which is calculated following Shao and Lu (2000):

$$u_t = \sqrt{\frac{0.0246(\gamma\rho_p g)^{0.5}}{\rho_1}}$$

where  $\rho_p$  is the material density of the dust particles,  $g$  is the acceleration due to gravity,  $\rho_1$  is the near-surface atmospheric density, and  $\gamma$  is an experimentally determined constant.  $u_t$  varies across Mars with near-surface atmospheric pressure. The MGCM threshold  $u_t^*$  is a fraction of the calculated  $u_t$ , a measure that allows for the presence of saltating sand particles.

## Results:

*Dust lifting locations.* Results from simulations completed at higher resolutions display regions of near-surface wind stress dust lifting that are not present in the results of lower resolution simulations.

This is particularly evident at certain times of the year, such as the early period in the Northern Hemisphere spring,  $L_S = 0-30^\circ$ , shown in Figure 1. During this period of the year there is almost no dust lifted at the T31 resolution. The area over which dust is lifted increases with increasing resolution.

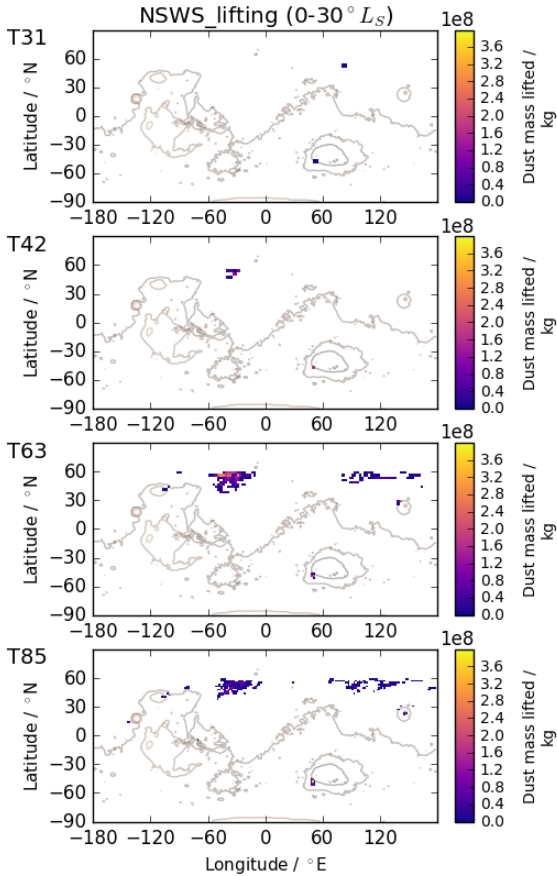
A period during the Southern Hemisphere summer,  $L_S = 210-240^\circ$ , is shown in Figure 2. This also displays variation in the locations of dust lifting regions, although at this time of year even the lowest resolution simulation does resolve some dust lifting.

*Total dust mass lifted.* In simulations completed at higher resolutions more dust is lifted by near-surface wind stress than in simulations completed at lower resolutions. The trend in total dust mass lifted annually, across the entire Martian surface, is shown in Figure 3.

## Discussion and future work:

*Dust lifting locations.* The friction velocity,  $u^*$ , is derived within the MGCM from large scale wind speeds. Wind speeds within a given area are affected by a change in model resolution: increasing the resolution improves the modelled representation of local slopes. At higher resolutions there is consequently a more detailed resolution of local slope winds, producing higher near-surface wind speeds within regions of varying terrain height.

The dust lifting regions in the higher resolutions shown in Figure 1 are associated with the latitude of the north polar ice cap edge. The terrain height variations at the cap edge are expected to produce local



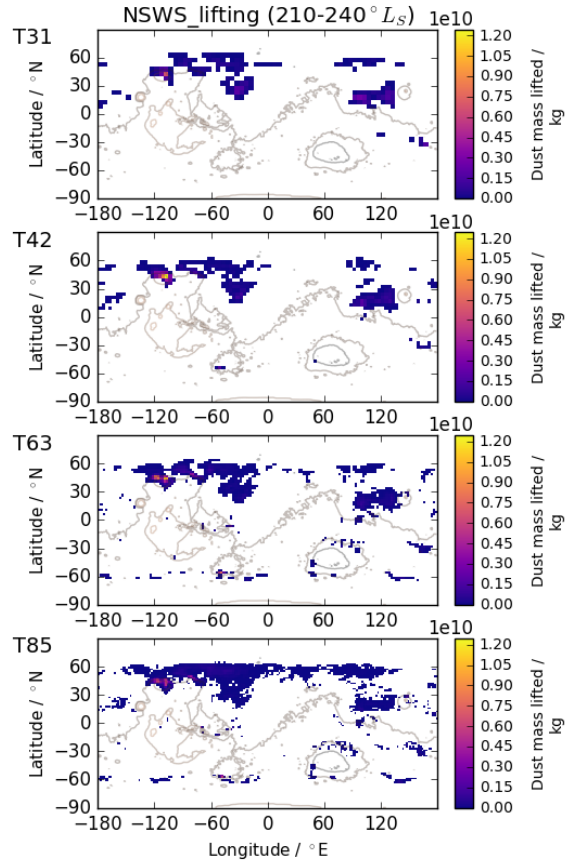
**Figure 1:** Total mass of dust lifted by near-surface wind stress through the period  $L_S = 0-30^\circ$ , across four resolutions (resolution increases from top to bottom). The colour bar denotes the amount of lifted dust; areas where exactly zero dust was lifted are white.

slope winds; these are not well enough represented in the lower resolution simulations to initiate dust lifting by near-surface wind stress.

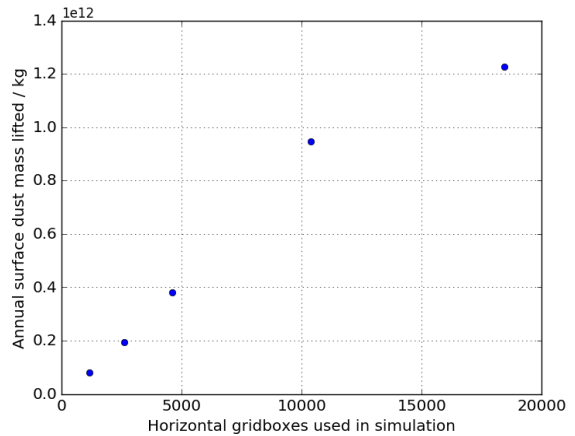
A similar effect can be identified in the results shown in Figure 2. The higher resolution simulations exhibit scattered dust lifting regions around  $-60^\circ$  latitude, the latitude of the edge of the south polar ice cap; these dust lifting regions are not evident in the results from the lower resolution simulations.

Dust lifting by near-surface wind stress is generally considered to be the primary dust lifting process associated with Martian dust storms (e.g. Strausberg *et al.*, 2005; Basu *et al.*, 2006; Wilson, 2011). We can compare dust lifting regions in our results with orbital observations of dust storms as a proxy for identifying dust lifting regions on the surface.

The dust lifting regions shown in Figure 1 correlate with observations of high latitude storms forming at this location during Northern Hemisphere spring (Cantor *et al.*, 2010). Areas of Northern Hemisphere dust lifting shown in Figure 2 correlate with locations that have been observed to generate ‘flushing’ storms during Southern Hemisphere summer (Wang, 2007).



**Figure 2:** As for Figure 1, for the period  $L_S = 210-240^\circ$ .



**Figure 3:** Total dust mass lifted annually across the Martian surface in simulations of different resolutions. Higher resolutions (using more gridboxes) appear to tend towards a ‘plateau’ in dust mass lifted.

To complement the global depictions of dust lifting regions across increasing model resolutions, we are planning to compare in detail a range of local regions that display differing dust lifting rates across resolutions. We will again compare these results with observations of dust storms in those regions.

*Total dust mass lifted.* While the results from the

lowest resolution simulations appear to produce a linear plot, the result from the highest resolution simulation so far completed does not continue this trend. Our results suggest that, within the MGCM, the quantity of dust lifted annually by near-surface wind stress may tend towards a 'plateau' as the resolution increases; the point at which this occurs cannot currently be estimated accurately.

Higher resolution simulations are planned (e.g. T127, corresponding to a physical horizontal resolution of 1.25° latitude by 1.25° longitude, and T170, corresponding to 0.94° latitude by 0.94° longitude) that will extend the data available in assessing the trend of total dust mass lifting with increasing resolution.

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