THE IMPACT OF SURFACE DUST SOURCE EXHAUSTION ON THE MARTIAN DUST CYCLE IN THE MARSWRF GENERAL CIRCULATION MODEL. C. E. Newman[1] and M. I. Richardson[2], [1]Ashima Research, 600 S. Lake Ave., Suite 104, Pasadena, CA 91001, claire@ashimaresearch.com, [2]mir@ashimaresearch.com.

Introduction: Observations of Mars show changes in the surface dust distribution during and after major storm events [1], suggesting that availability of surface dust must affect – and may be an important factor in – the Martian dust cycle. We study the evolution of the dust cycle in the case of finite surface dust availability using the MarsWRF [2] General Circulation Model (GCM) with parameterized wind stress and dust devil lifting and tracked budgets of surface lifting, deposition and total surface dust inventory. The dust lifting scheme involves three globally-uniform free parameters: (i) a threshold wind stress below which wind stress lifting does not occur, and (ii) a wind stress and (iii) a dust devil lifting rate parameter, which are used to scale the predicted spatio-temporal distribution of (respectively) wind stress and dust devil lifting rates.

Goals of this work: We seek a self-consistent, long-term 'steady state' dust cycle for present day Mars, consisting of (a) a finite surface dust distribution that varies from year to year but is constant in a long-term sense and is in balance with current dust redistribution processes, and (b) a fixed set of dust lifting parameters that continue to produce major dust storms for this distribution of surface dust. In such a steady state, by definition, the remaining source regions must receive as much dust via deposition as they lose via lifting, on timescales of ~1 to 10 Mars years.

The dust cycles in all interactive dust Mars GCMs are 'tuned' in some manner, meaning that their free parameters are adjusted until the simulated dust cycle shows the best match to that observed. If only a fraction of the initial surface area has dust available, however, the lifting rate parameters will need to increase and/or the threshold decrease to produce the same amount of dust lifting globally. In other words, the best fit dust lifting parameters by some point in a finite surface dust simulation – after several source regions have dropped out completely, or only have dust available in certain seasons – should be very different to the best fit parameters when dust is available everywhere.

For this reason, we relax the GCM's surface dust inventory toward steady state by increasing the dust lifting rate parameters as progressively more surface sites are exhausted of dust, with the goal of eventually reaching a long-term steady state in which dust storms continue with the dust lifting parameters held fixed.

Results: In one simulation, using a threshold of 0.02 Pa, the wind stress lifting rate was increased a total of 17 times over 374 years, as surface dust rearranged and source regions were exhausted and dropped out. We were unable to find a true, long-term steady state as described above; however, near the end of the simulation, it exhibits quasi steady state behavior in which very few new surface grid points are exhausted during a period with constant dust lifting parameters lasting over 60 years, with complex regional-scale dust redistribution behaviors on time-scales from less than seasonal to decadal. When we examine a 10 year portion of this period, we find that the GCM generates a range of regional to global dust storms showing many commonalities with observations (see Figure 1).

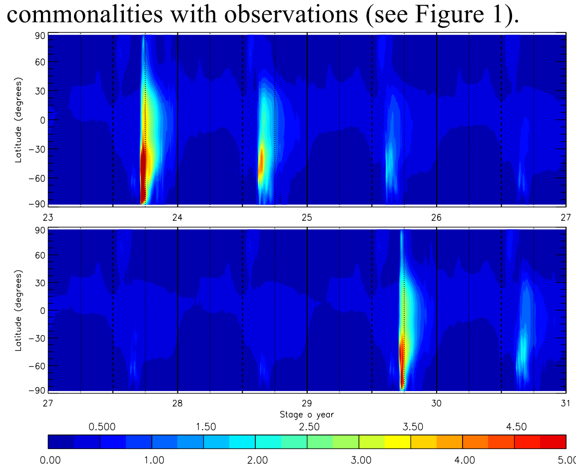

Figure 1: Zonal mean dust visible opacities over 8 years of a simulation with finite surface dust, with 3 global (post-perihelion in years 23 and 29, pre-perihelion in year 24) and 2 large regional storms (pre-perihelion in years 25 and 30).

The same 10-year period contains seven distinct regional storm types, merging regional storms, cross-equatorial storms, and major storms that begin soon after southern spring equinox and decay prior to the end of southern summer, in addition to major storms beginning later in the storm season. Figure 2 shows two regional storm types (two Noachis/Hellas storms and one northern frontal storm), as well as onset of the year 24 pre-perihelion global storm, which appears to develop following the combination of the 2nd Noachis / Hellas storm and an Acidalia-Chryse frontal storm.

We find evidence that our pre-perihelion major storms may require replenishment of dust in certain source regions (often via fallout of dust associated with a previous year's major storm) in order to occur, whereas the occurrence of our simulated post-perihelion major storms appears to be primarily dependent on atmospheric variability. The difference in major storm source regions is shown in Figure 3.

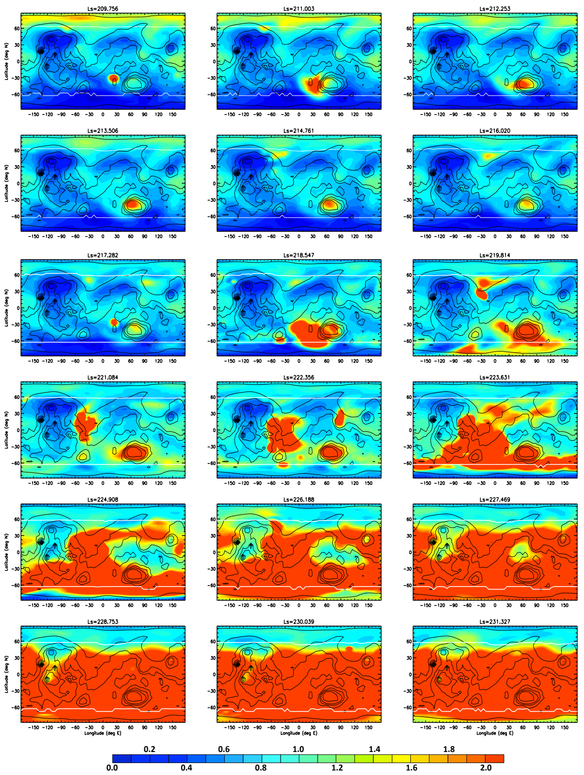

Figure 2: Visible dust opacity every 2 sols for L_s~210 – 231° in year 24, showing two Noachis/Hellas regional storms, the second of which combines with an Acidalia-Chryse regional storm and leads to onset of a pre-perihelion global storm.

Discussion: Within the range of parameter space examined, no MarsWRF simulation continued to produce realistic dust cycles with constant dust lifting parameters for longer than 60 years. Also, the long-term surface dust distribution predicted during the quasi steady state period has significant differences to the observed albedo map, in particular predicting the Tharsis highlands and NE Arabia to be dust-free when they are believed to have a dust cover several meters thick. This may reflect deficiencies in the GCM (such as the absence or incorrect representation of important dust lifting and transport processes), the existence of some ancient, deep dust deposits, or the difficulty of numerically 'retrieving' a putative steady-state surface dust distribution when the dust cycle and surface dust distribution are inextricably linked.

Pankine and Ingersoll [3] propose that changes in surface dust cover might impact the wind stress injection threshold so as to provide a negative feedback on future dust injection. We have tested various parameterizations of this effect, and find it possible to reach a long term steady state surface dust distribution when a higher dust cover results in lower thresholds and vice versa (see Figure 4). However, more work is required to define a physically appropriate parameterization.

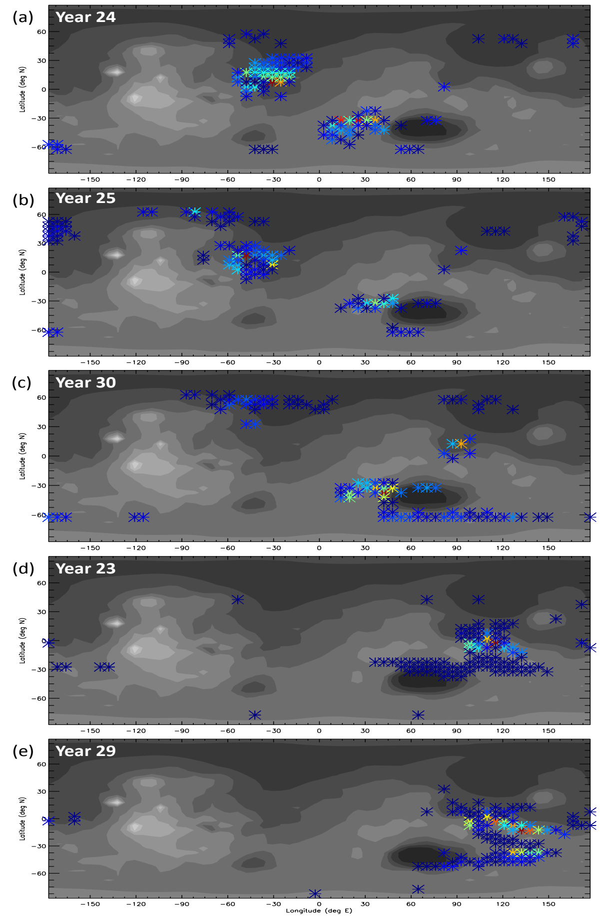

Figure 3: The top 100 source gridpoints for onset of the 3 pre-perihelion (top 3 plots) and 2 post-perihelion (bottom 2 plots) major storms in Figure 1. Deep red = most dust lifted.

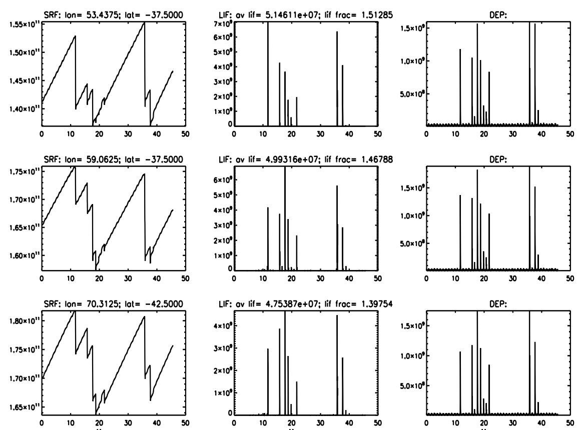

Figure 4: Variation of surface gridpoint dust cover (left), lifting (middle) and deposition (right column) at the 1st (top), 2nd (middle) and 3rd (bottom row) ranked dust contributors, for a simulation in which threshold varies with dust cover.

References: [1] Szwast M.A. et al. (2006), *JGR, 111,* E11008. [2] Richardson M.I. et al. (2007), *JGR, 112*, E09001. [3] Pankine A.A. and Ingersoll A.P. (2004), *Icarus*, *170*, 514–518.