A DUST TRANSPORT MODEL FOR MARS: FROM INJECTION TO DEPOSITION. C. E. Newman, S. R. Lewis, P. L. Read, *Atmospheric, Oceanic and Planetary Physics, Department of Physics, Oxford University, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK (newmanc@atm.ox.ac.uk)*.

Introduction: For many years now it has been recognized that the correct simulation of the atmosphere of Mars requires the inclusion of radiative effects due to dust in the atmosphere. The dust distribution, however, is highly variable in space and time, so it is insufficient for a model which claims to simulate the atmosphere completely to ignore this variation. Currently, the Mars General Circulation Model (MGCM), which has been developed jointly at Oxford and at Laboratoire de Météorologie Dynamique du CNRS in Paris [1], attempts to capture some of this variability by using a dust distribution which may be varied with areocentric longitude (Ls), with latitude, and in total optical depth. An improvement on this method is to try to simulate the dust distribution, and this requires a dust transport scheme. The scheme discussed here consists of a tracer advection model, which uses winds from the MGCM to advect dust mixing ratios, as well as several parameterizations of small-scale dust processes.

The model: The advection model used is a three-dimensional semi-Lagrangian scheme, which has the advantage that it may be run at low temporal resolution without compromising its stability. It has been tested using winds and tracer distributions which have known exact solutions in two dimensions on the sphere, and using idealized tracer distributions (e.g., constant latitudinal or vertical tracer gradients) in three dimensions, and has been found to be accurate and to conserve mass very well utilizing a local mass conservation scheme [2,3].

The parameterizations of dust processes fall into three basic categories: dust lifting, dust mixing once it has been suspended, and dust deposition. The ongoing work concerning this portion of the transport scheme is used in its own right to investigate some of the theories, and to attempt to simulate some of the observations, regarding dust on Mars.

The dust transport model has been interfaced with the MGCM, enabling dust transport to be coupled to the rest of the physics scheme. Changes to the dust distribution in one timestep affect radiative processes and hence temperature profiles, thereby altering the winds which will be used to advect the dust in the next timestep. In this way, by allowing the radiation scheme to react to changes in the dust distribution, a feedback is enabled, and experiments have been designed to study this.

A major source of uncertainty, in the modelling of dust on Mars, concerns the mechanisms by which dust is injected into the atmosphere. Observations indicate that the sizes of aerosol particles are of order a few micrometres, yet theoretical arguments and wind tunnel data using simulated Mars conditions [4,5] *appear* to show that wind speeds are generally not high enough to surmount the large thresholds required for dust to be lifted from the surface simply by the near-surface wind stress. There are many suggestions as to how this problem may be overcome, however. One is that dust devils may be the source of much of the dust found in the atmosphere, as these vortices which grow from convective plumes are far less sensitive to the size of dust particle raised. Another suggestion is that winds may be high enough to raise larger particles (which have smaller cohesive forces binding them together and therefore are more easily lifted). These particles, too heavy to be suspended, would instead saltate back to the surface, thus increasing the total surface stress, perhaps by enough to allow smaller particles to be lifted. Other possibilities include lifting of smaller, aggregate particles, which may then break up in the stronger winds above the surface, becoming small enough to be suspended and forming the smaller size distribution observed.

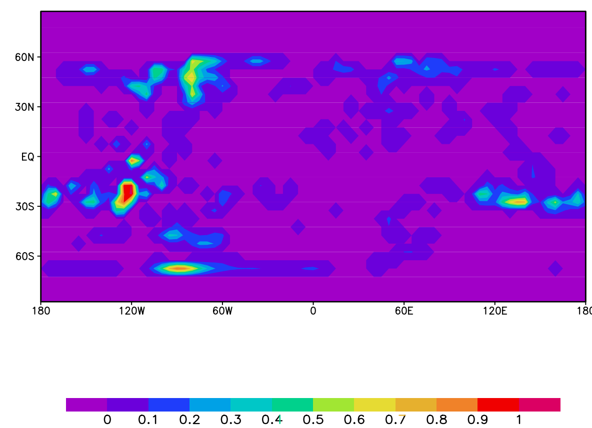

Figure 1: This plot shows the dust mixing ratios lifted from the surface into the lowest level. Dust was lifted if the wind stress at the surface was greater than a threshold, which was calculated assuming a particle diameter of 1 μm and a greatly reduced inter-particle cohesion parameter.

Results: Experiments have been carried out for the peak dust season (Ls$\sim$270) using a prescribed zonal dust collar source at $\sim 30^\circ$ South, i.e., an area where dust activity is high at this time of the year and within which many of the large or global dust storms originate. Other experiments used the same conditions, but with a dust source which was determined by the magnitude of the friction velocity at the surface (thereby relating lifting to surface stress). Dust was lifted according to a standard formula *if* the friction velocity exceeded a threshold which had a simplified density and particle diameter dependence. (The normalized dust mixing ratios lifted into the lowest level are shown in Fig. 1.) The true threshold friction velocity includes a threshold parameter which depends largely on the inter-particle cohesion. By ignoring this, and instead setting the threshold parameter constant the cohesion effects, which prevent smaller particles (those which are small

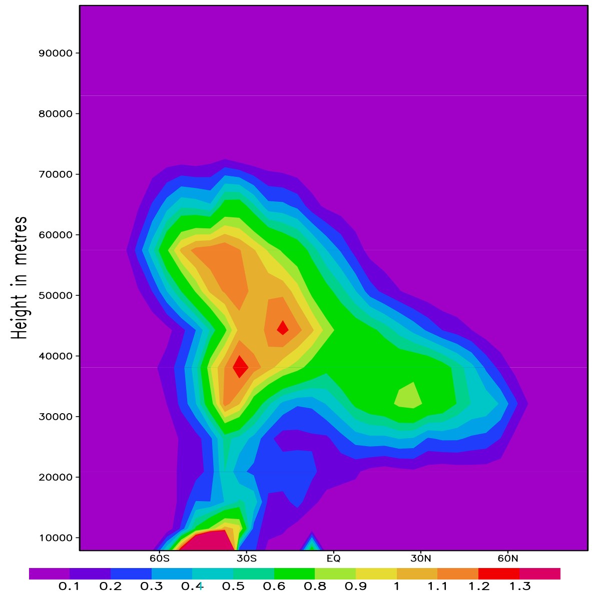

Figure 2: This plot shows the dust mixing ratios (g/kg) 5 days after dust lifting was initiated, as described in Fig. 1. The model run was for Ls=240, (Southern hemisphere summer).

enough to go into suspension) from being raised, were effectively removed. These experiments indicated greatest dust injection at high Northern latitudes, for Ls=240, with strong lifting also at latitudes $\sim 30^\circ$ South. Model runs in which the rest of the MGCM could not respond to changes in the aerosol distribution showed very little dust lifted above a few hundred metres after 10 days. Model runs with feedback between the dust scheme and the rest of the MGCM, however, (see Fig. 2), showed not only dust pluming events at $\sim 40^\circ$ South, lifting dust up to 70 km after a few days, but also that the Northern hemisphere dust, although efficiently lifted into the lowest levels of the atmosphere, did not plume upwards like its Southern hemisphere counterpart - this was partly due to the radiative-dynamic feedbacks but mainly to the shape of the Hadley circulation at this time of year, which has a particularly strong upward branch at the latitudes of Southern dust injection.

Such experiments indicate what might be expected were dust to be lifted by some mechanism which enhances dust lifting in proportion to wind stress at the surface, and so areas of greatest lifting correspond to those of maximum wind stress. Current interests are aimed at investigating the various factors which may enhance lifting due to wind stress – these include the effects of saltation of larger particles, and the modification of the friction velocity in non-neutral conditions. Work is also ongoing, however, in investigating the possibilities of modelling dust devil activity, which has been observed to be a definite feature on Mars [6], using theoretical work [7] which relies partially on careful terrestrial observations.

Dust deposition will also be discussed, including deposition due to scavenging of dust by particles forming ice near the poles, and the effects of the turbulent suspension of dust against gravitational sedimentation, which may have important ramifications for the transport of dust in the atmospheric boundary layer.

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References: [1] Forget F. et al. (1999) *J. Geophys. Res.*, in press. [2] Garcia-Navarro P. and Priestley A. (1993) *Department of Mathematics, University of Reading, Numerical Analysis Report*. [3] Priestley (1993) *Monthly Weather Rev. 121,* 621-629. [4] White B. R. et al. (1997) *J. Geophys. Res. 102,* 25629-25640. [5] Greeley R. et al. (1980) *Geophys. Res. Lett. 7,* 121-124. [6] Thomas P. and Gierasch P. J. (1985) *Science 230,* 175-177. [7] Rennó et al. (1998) *J. Atmos. Sci. 55,* 3244-3252.