GLOBAL SAND TRANSPORT AND DISTRIBUTION ON MARS

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Summary: The presence of dunes on Mars [1-7] shows that saltating sand plays an important role in the evolution of the planet's surface. Although previous work focused on dust transport [8], numerous studies [9-10] demonstrate that sand is substantially easier to transport by wind. Indirect evidence [11] suggests that saltation may be currently active; however, definitive evidence is lacking. An improved iterative sand transport algorithm was developed based on an earlier model [12] and use of an improved Mars General Circulation Model [13]. The geometry of sand erosion and deposition are dependent on many factors, including the stress threshold required to move sand, sand sources, and potential sand trapping. The new sand transport model takes these factors into account and can be used to predict areas of sand erosion or accumulation. Results are then compared to observed surface features, such as dune fields, sites of dust storm locations, and properties of the surface derived from Viking IRTM data. Runs indicate: 1) net sand transport is from the northern hemisphere to the southern hemisphere, 2) northern plains erosion is prevalent, and 3) sand accumulates in the north polar region.

Technique: The sand transport model is based an earlier algorithm [12] which calculated the flux of sand as a vector mass for each General Circulation Model (GCM) cell and time step. The previous GCM results provided wind shear stress vectors at 7.5° lat. by 9° long. cells every 1.5 hours for 20 days. The new model uses much improved GCM results that are continuous for an entire Martian year, and based on corrected temperatures, pressures, and grid locations. The GCM shear stress values are converted into mass fluxes [12] for each cell and the sand distributed to the surrounding cells. The process is repeated for each 1.5 hour time step of the Martian year. After one year the final mass distributions are used as a starting condition, and the wind stresses are assumed to repeat. The 25 latitudinal by 40 longitudinal cells have two important options: 1) a percentage of sand trapped due to topography, and 2) heterogeneous initial starting thickness and location. Previous models assumed that topography such as craters or Valles Marineris did not impede the flux of sand, and that initially the sand was uniformly distributed. Sand trapping as well as the source location of sand exhibit a strong influence on the final geometry of saltating particles. The percentage of sand trapped at any given cell was *estimated* from topographic features capable of halting flux. Sand that is trapped is prevented from moving for the rest of the simulation, although it does contribute to the final thickness of sand in each cell. A second improvement to the previous model allows for sand to be placed only at the mouths of outflow channels, or other likely sources of sand. A final improvement, still in the experimental stage, is the reversal of GCM time, such that sand could be run backwards from the current positions of sand dunes, to infer the sources that formed them.

Discussion: Eleven cases were run, five with "sand trapping", five with no trapping, and one with sand sources at the mouths of outflow channels [14]. Each set of five corresponds to the increasing stress thresholds of .004N/m^2, .024N/m^2, .032N/m^2, .040N/m^2, .048N/m^2. All runs except the point source model were executed with an initial thickness of 4mm. The channel source run had a threshold of .004N/m^2 and an initial sand thickness of 5m. Lower thresholds result in larger amounts of sand flux, while trapping prevents flux in topographically rough terrain. All models resulted in the net transport of sand from the north to the south, generally resulting in a correlation with dunes and dust storms, which excepting the northern polar dunes, are concentrated in the southern hemisphere. Observed plains regions are commonly associated with areas of erosion. The development of substantial northern deposits and eroded northern plains correlating to Viking IRTM block model results [15] requires low thresholds (< .024N/m^2) in all models (Fig. 1). The no trapping runs generally resulted in a weaker correlation between southern hemisphere erosion and dunes and IRTM data (Fig. 2). Sand trapping prevents sand motion in the rough topography of the southern hemisphere, causing the association of northern plains with erosion and the southern highlands with deposition. Regions of deposition are located on broad

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topographic uplifts that have concentrated small scale topography from craters and troughs. Except for the north polar field, deposition does not correspond strongly to currently known dune fields (Fig. 3). Regions that border the transition from erosion to deposition or of little change are associated with the occurrence of dust storms. As threshold stress increases, very little material moves in the southern hemisphere, and the broad erosional plains of the north become interspersed with broad regions of little change (Fig. 4). In summary, results indicate the equilibrium geometry of sand deposits is a function of threshold stress, topographic trapping, and initial distribution. The best correlation between the predicted erosional geometry and observed dunes requires low threshold stresses (<.024N/m^2) and significant topographic trapping in the southern hemisphere.

References:
[1] Cutts, J.A., et al, *Science, 194*, 1329-1337, 1976. [2] Cutts, J.A., and R.S.U. Smith, *JGR, 78*, 4139-4154, 1973. [3] Breed, C.S., et al, *JGR, 84*, 8183-8204, 1979. [4] Thomas, P., *Icarus, 48*, 76-90, 1981. [5] Thomas, P., *JGR, 87*, 9,999-10,008, 1982. [6] Thomas, P., *Icarus, 57*, 205-227, 1984. [7] Peterfreund, R.A., *Icarus, 45*, 447-467, 1981. [8] Zurek, R.W., *Icarus, 50*, 280-310, 1982. [9] Greeley, R., et al, *GRL, 7*, 121-124, 1980. [10] Iversen, J.D., and B.R. White, *Sedimentology, 29*, 111-119, 1982. [11] Tsoar, H.R., et al, *JGR, 84*, 8167-8180, 1979. [12] Greeley, R., et al, LPSC XXIV abstract, 563-564, 1993. [13] Polack, J.B. et al, *JGR, 95*, 1447-1473, 1990. [14] Baker, V., The Channels of Mars, 1982. [15] Christensen, P.R., *Icarus, 68*, 217-238, 1986.

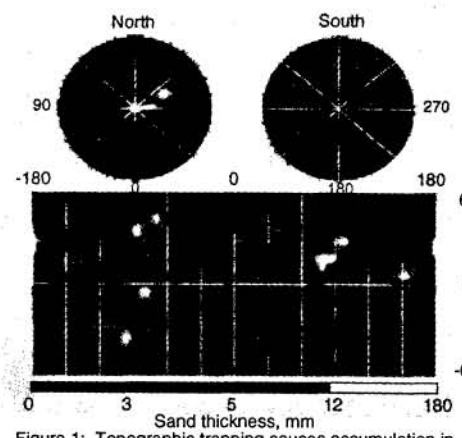

Figure 1: Topographic trapping causes accumulation in the southern hemisphere correlating with dunes (Fig. 3). Note also north polar dune correlation.
Threshold = .004N/m^2, initial thickness = 4mm

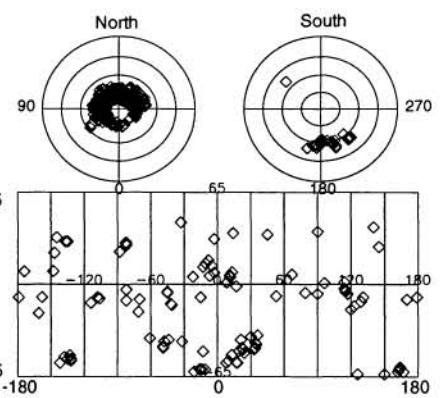

Figure 3: Locations of observed dunes.

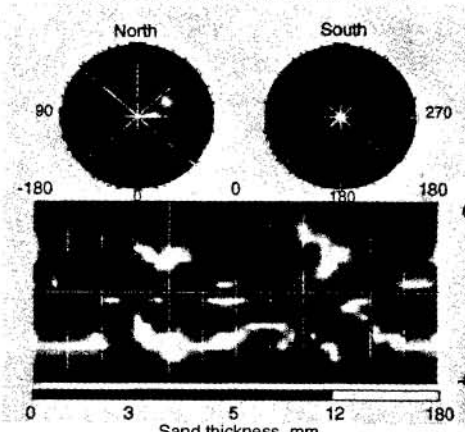

Figure 2: Lack of topographic trapping causes anti-correlation with dunes in the southern hemisphere (Fig. 3).
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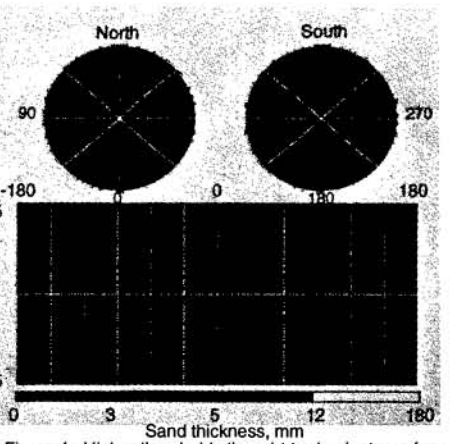

Figure 4: Higher thresholds thought to dominate surface of Mars results in little sand transport.
Threshold = .040N/m^2, initial thicknes = 4mm