AEOLIAN GEOMORPHOLOGY FROM THE GLOBAL PERSPECTIVE

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Any planet or satellite having a dynamic atmosphere and a solid surface has the potential for experiencing aeolian (wind) processes. A survey of the Solar System shows at least four planetary objects which potentially meet these criteria: Earth, Mars, Venus, and possibly Titan, the largest satellite of Saturn. While the basic process is the same among these four objects--the movement of particles by the atmosphere--the aeolian environment is drastically different (Table 1). It ranges from the hot (730 K), dense atmosphere of Venus to the extremely cold desert (218 K) environment of Mars where the atmospheric surface pressure is only ~7.5 mb.

On Earth most aeolian processes occur in deserts, coastal areas, and periglacial regions. Deserts occupy more than 30% of Earth's land surface. In recent years, considerable attention has been given to desertification--the conversion of useful land to desert terrains. The process has been particularly acute in Africa where the consequences of desertification are having a severe impact on food production. Dust storms figure prominently in desertification, not only by removal of agricultural soils, but also by the burial of useful land. It is estimated that agricultural land damaged by wind erosion in the United States alone varies from 400 to 6,000 km^2 per year.

On Mars, telescopic observations for the last 100 years have shown that dust storms are frequent and can be global in extent. The Mariner 9 spacecraft, put into orbit around Mars in 1971, revealed a wide variety of features directly attributable to aeolian processes, including dunes, yardangs, active dust storms, and the formation of "variable" features. "Variable" features are albedo patterns on the surface which change their size, shape, and position as a function of time and in response to near-surface winds. Most variable features act as "wind vanes" and maps showing their orientation have been used to model the patterns of near-surface winds. Spacecraft observations of the martian surface also show widespread sedimentary mantles which may be of aeolian origin. Understanding the timing and distribution of these deposits is critical in understanding the evolution of the martian surface.

Prior to spacecraft observations, speculation for cloud-shrouded Venus included environments ranging from humid swamps to hot, dry deserts. Results from the Venera and Pioneer Venus missions showed the latter to be true and revealed both the existence of small particles on the surface and near-surface wind velocities well above saltation threshold for sand. Experiments simulating the venusian environment show that small-scale aeolian-bedforms are in some ways analogous to features formed by water on Earth, a result that might be expected, given the high fluid density of the venusian atmosphere. However, questions remain about the efficacy of aeolian processes on Venus, especially in regard to widespread aeolian erosion and deposition. Some of these questions may be addressed with the return of high resolution radar images from Venera and the Venus Radar Mapper missions.

In considering aeolian processes in the planetary perspective, all three terrestrial planets share some common areas of attention for research, especially in regard to wind erosion and dust storms. Although rates of wind erosion have been estimated for small-scale features such as ventifacts, there are few valid methods for determining rates of wind erosion regionally or for large landforms such as hills. This is particularly critical for understanding the evolution of the surfaces of Mars and Venus. Similarly, knowledge of the processes and rates of soil erosion on Earth have a direct social and economic impact. In addition to wind erosion, the generation of dust storms figures prominently in global aeolian processes on Earth, Mars, and perhaps Venus, yet the general processes involved in dust-raising by wind are very poorly understood.

Space technology may provide the opportunity to address some aspects of the problems outlined above. The martian experience has shown that the global inventory of aeolian features and their relationship to current processes can provide direct information on atmospheric circulation. On Earth, remote sensing instruments placed on orbiting spacecraft may provide new data for the investigation of local and regional dust storms. The combination of multi-spectral imaging, infrared sensors, and radar systems may provide an unparalleled opportunity to study the initiation and growth of dust storms in remote regions and provide information on particle sizes, rates of transport, and local environmental factors involved in the formation of dust storms. Such monitoring would enable a much better assessment of the global effects of dust storms and the development of predictive models.

Since the pioneering work of Bagnold, laboratory experiments dealing with various aspects of aeolian processes have shed light on the movement of windblown particles. The ability to conduct similar experiments in Earth-orbital environments may provide unique opportunities (hitherto unavailable on Earth) for assessing aspects of aeolian processes. Threshold curves relating wind speeds required to move particles of different sizes show that dust is as difficult to move as coarse sand. The reasons for this have been attributed to a combination of aerodynamic effects and to interparticle forces which become more important with decreasing particle size. Unfortunately, in experiments conducted on Earth, interparticle force terms are intimately linked with gravity terms. If threshold experiments were conducted in a gravity-free environment, it would be possible to remove the gravity term and thus allow assessment of various interparticle forces. This would enable a much better understanding of the factors involved in raising dust on Earth and other planets as well.

The Mars Geoscience/Climatological Observer mission planned for early 1990's will provide global surveys of surface compositions and may have the ability to monitor dust storms and other aeolian events on a daily basis. The forthcoming Venus Radar Mapping mission may provide a global inventory of aeolian features. Like Mars, the detection and mapping of variable features such as wind streaks could provide the opportunity to map near-surface atmospheric circulation. The detection of wind streaks on Earth via shuttle imaging radar (SIR-A) demonstrates the ability of radar to detect these features.

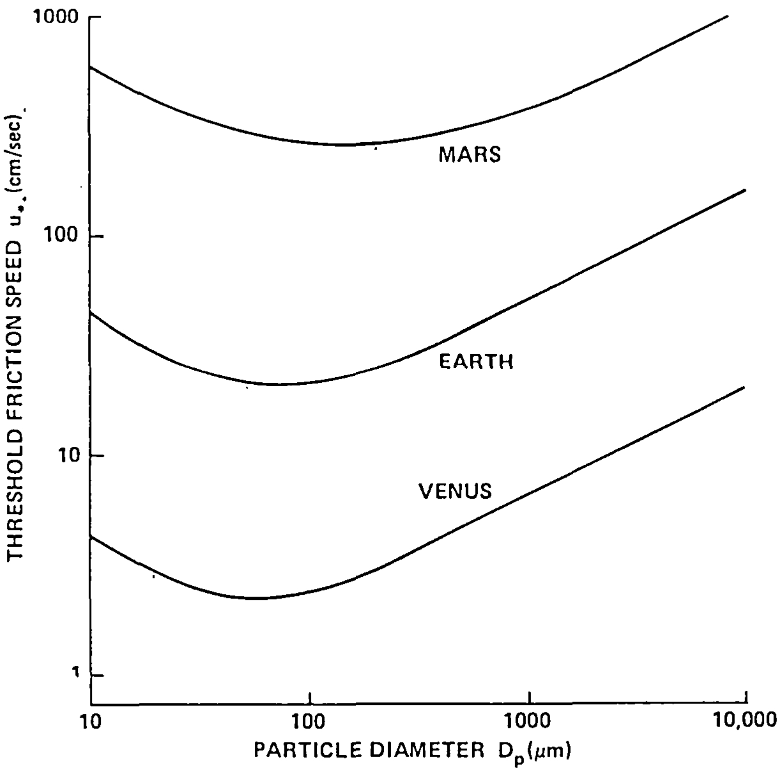
In summary, exploration of the Solar System has shown that aeolian processes are important on planets other than the Earth. By necessity, planetary exploration began with global perspectives and then focused on local processes and features. It is this global perspective that has been largely lacking in studies of aeolian processes on Earth and which may provide potential for future research.

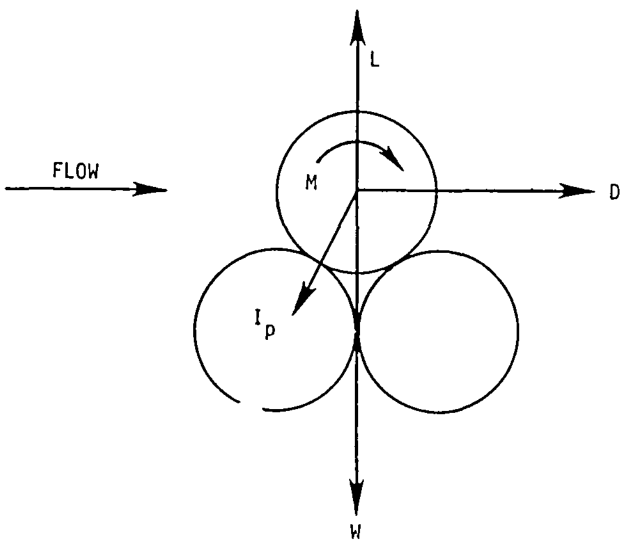
Table 1. Relevant properties of planetary objects potentially subject to aeolian processes

	VENUS	EARTH	MARS	TITAN
Mass (Earth = 1)	0.815	1	0.108	0.02
Density (water = 1)	5.2	5.5	3.9	1.4
Surface gravity (Earth = 1)	0.88	1	0.38	.11
Surface gravity (cm/s^2)	888	981	373	136
Atmosphere (main components)	CO_2	N,O	CO_2	N
Atmospheric pressure at surface (millibars)	9×10^4	10^3	7.5	1.6×10^3
Mean temperature at surface (°C)	480°	22°	-23°	-200°
Minimum U_{*t} (cm/s)	2.5	20	200	3.5
Optimum particle size (μm)	75	75	115	180

REFERENCE

Greeley, R. and J.D. Iversen, 1984, Wind as a Geological Process: Earth, Mars, Venus and Titan, Cambridge University Press, Cambridge, 264 p.





Lift + Drag + Moment = Weight + Interparticle Force