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DUST IN THE MARS ATMOSPHERE

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The amount of dust suspended in the Martian atmosphere is highly variable with location and with time. The opacity of the sky is best known at the two Viking Lander sites, where the visual, vertical-column optical depth never fell below a value of a few tenths during the 1 and 1/4 Mars years of observations and yet exceeded 2-3 during two great dust storms in 1977. Elsewhere on the planet, optical depths have been estimated from orbiter visible imaging of surface contrasts and from mapping of infrared emission from the surface and the overlying (dusty) atmosphere. In many cases these opacities (and thus dust amounts) may be uncertain by as much as a factor of two.

Spacecraft and Earth-based observations have revealed local, regional and planet-encircling dust storms. Local storms occur most frequently, are relatively short-lived, and may occur in any season. The larger dust storms are relatively infrequent, are longer-lived, and tend to originate during southern spring and summer. By no means do they occur in every Mars year, and when they do occur, there are vast differences in their longevity and areal coverage. The greatest dust storm observed on Mars began in 1971 before the arrival of Mariner 9, obscured nearly all of the planet's surface for several months, and raised dust up above 50 km in altitude.

Such storms have been observed to alter substantially the global fields of atmospheric temperature, density and wind. General circulation modeling indicates that the rapid development and the variability of these storms are due to a radiative-dynamic feedback in which suspended dust absorbs solar radiation, heats the atmosphere and thereby alters pressure gradients. This,in turn, modifies the winds raising dust into the atmosphere and redistributing it across the planet.

Viking Lander observations of twilight indicate that the background dust haze is more or less uniformly mixed with altitude in the lower atmosphere. Observations from spacecraft indicate that there may be some seasonal variation to the height of these dust hazes, which sometimes extend above 30 km. (Ice haze layers may occur as high as 80 km.) During local dust storms, most of the suspended dust comprising the storm is confined below 20 km. During larger dust storms, however, micron-sized dust particles may be mixed to higher altitudes.

The existing observations do not constrain the composition or the size distribution of the suspended dust particles very well. Remote sensing observations depend principally upon the product of the number of particles, the geometric cross-sections (and so particle size and shape), and the extinction efficiency of the particles (and so the particle composition), as integrated over the particle size distribution and along the line of sight. While the observed variation of dust opacity with wavelength constrains these quantities, it does not often permit the unique determination of the individual properties of the suspended dust.

A size distribution having a cross-section weighted mean particle radius of 2.5 μm was deduced from a synthesis of the IR thermal emission spectra observed in the southern hemisphere by Mariner 9 during the 1971 global dust storm. Although the IR thermal emission is relatively insensitive to the sub-micron sized particles which tend to dominate visible opacity, this same size distribution was consistent with modeling of the sky brightness variation near the sun, as seen through the background haze above the Viking Lander sites, in the northern hemisphere.

However, the ratio of infrared opacity inferred from the Viking Orbiter data to the visible opacity derived by direct imaging of the sun from the Viking Landers differs by a factor of two from that predicted using the canonical (Mariner 9) size distribution. Model fits using smaller particles or particle aggregates have been proposed to resolve this discrepancy, but remain to be tested fully. Furthermore, model simulations of the evolution of the size distribution of dust particles suspended during a great dust storm indicate that considerable spatial and temporal variability in that size distribution should occur.

Observed thermal IR spectra indicate that dust suspended in the atmosphere is a mixture dominated by igneous silicates containing mainly SiO_2 (> 60%), or by weathering products such as clay minerals, perhaps with some basalt also present. At visible wavelengths, the optical depth of the suspended dust tends to be dominated by trace materials; analysis of the Viking Lander images of sky brightness were consistent spectrally with particles having a trace ($\approx$1% by volume) of magnetite.

Future missions to Mars can greatly augment the global, seasonal and interannual observational coverage of dust suspended in the Martian atmosphere. Starting near the end of 1993, instruments onboard the Mar Observer spacecraft, orbiting Mars in a low, circular and nearly polar orbit, will map the distribution of atmospheric dust, including its vertical distribution, globally each day for one and perhaps two Mars years. A combination of IR thermal emission and broadband visual observations, taken in both limb and on-planet viewing modes, will be used. Constraints on particle size and bulk composition similar to those derived from the Mariner 9 and Viking data will be provided, but with systematic global coverage and higher spatial resolution. The MARS 94 mission will also provide visual and thermal emission data and, in addition, is likely to acquire solar and stellar occultation data which can be used to further constrain dust particle properties. Present plans also include direct collection and optical characterization of suspended dust using the other platforms (i.e., balloons, penetrators, mini-rovers) to be deployed as part of the MARS 94 mission.

Monitoring of the sky brightness by surface instruments deployed as part of the proposed MESUR mission could provide multi-year time series of precise overhead opacity measurements and of general constraints on the microphysical properties of suspended dust particles at several locations distributed over the globe, including southern hemisphere, polar, and high altitude sites, all of which are likely to differ from the two low-lying Viking Lander sites. Sampling of suspended dust during the entry of the MESUR landers could also provide more definitive characterizations of the dust particle properties.

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