PARTICLE SPEED AND CONCENTRATION IN THE SALTATION CLOUD: FULL SALTATION DEVELOPMENT AND CHOKING;

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Wind transport of surficial material is recognized as an important planetary surface process (1, 2). On Earth, aeolian activity strongly affects land utilization and habitability and can be the dominant agent of geomorphic change in environments where liquid water is absent. Hence, wind erosion and transport has been studied extensively. Several expressions for the quantity of material moved in saltation and the vertical distribution of material in transport have been derived (2). Saltation consists of particles bouncing along the surface; frequent impacts make saltation much more capable of performing geologic work than the suspension mode of transport. The family of particles in saltation transport above the surface is referred to as the saltation cloud.

Although saltation flux is fairly well understood, previous studies do not distinguish between the contribution of the primary flux components: particle concentration and particle speed. This study assessed the relative contribution to flux of particle concentration and velocity for a variety of environmental conditions. This is possible by measuring the average horizontal particle speed at different points in the saltation cloud (3). If particle flux and speed are known, then particle concentration, mean-free-path (MFP) and other characteristics of the saltation cloud can be determined (4).

Expressions for flux are reasonably successful at predicting flux for a variety of planetary conditions (2). However, these expressions are based on two critical assumptions that may not be valid for extra-terrestrial cases or even for all terrestrial conditions. The assumptions are that saltation is "fully developed" and that no mid-air collisions occur between particles in the saltation cloud. "Full" saltation has never been rigorously defined; it is used here to describe a saltation cloud sufficiently "mature" so that any particle on the surface on the verge of initiating a saltation hop due to aerodynamic foces alone has additional kinetic energy available to it from nearby impacts of landing particles that motion is initiated. Impairment of saltation due to poor development is not significant on Earth or Venus but may be quite important on Mars, where large saltation trajectories "dilute" the flux, requiring winds to be ~10% stronger than those expected to cause "full" saltation (4). The second assumption, no mid-air collisions, is neccessary for the orderly transfer of momentum from wind to surface via the saltating particle. The no-collision condition is violated when particle concentration becomes large; subsequently the flux increases more slowly with increasing wind speed than expected, a condition termed "choking" (4). Choking will not occur on Mars but it can on Earth, and probably occurs often on Venus.

Four lines of evidence indicate the existence and importance of choking on reducing saltation flux. 1) Flux is roughly proportional to the cube of the wind speed. At some high wind speed, tghere is insufficient volume through which the material can pass, hence choking must occur. 2) Figure 1 shows saltation flux as a function of freestream wind speed in the ASU wind tunnel (see 5 for description). Note the break in slope at a freestream wind speed of ~18 m/s for smaller particles, presumably the onset of choking. Fine particles choke more readily than coarse particles because their mass scales with r^3 while their collisional cross-section scales with r^2. 3) There is a decrease in particles speed at a given height under increasing wind speed (4). Mid-air collisions would tend to slow the faster particles, diverting their horizontal speed into other directions upon impact, reducing the average horizontal speed at that height for the cloud as a whole. 4) The most compelling evidence for choking comes from combining the flux and particle speed measurements to determine the particle concentration and mean-free-path (MFP) in the cloud (Table 1). The MFP is reduced with increasing wind speed until it is on the order of the saltation pathlength at wind speeds inferred to be those at the onset of choking. While no single line of evidence for choking is compelling on its own, together it should be clear that choking occurs. Once choking conditions are established, additional increase in wind speed only slightly increases particle concentration and speed; the increase in flux is due to an increase in the thickness of the saltation cloud. Choking may be significant on Venus because of the "compression" of the saltation cloud due to very small saltation trajectories.

Saltation behavior can be summarized as follows. On Earth, saltation attains full development at wind speeds near saltation threshold and chokes only during rare, "sand-driving" (1) conditions. On Mars, choking does not occur but "full" saltation development is not common. Dilution of the saltation cloud due to large particle rebound from surface rocks makes full development even less likely, hence, less material is transported in saltation than would be expected from an extrapolation of terrestrial results to martian conditions. On Venus, full saltation would occur immediately at saltation threshold, but choking may occur at higher speeds, reducing saltation flux. The terrestrial environment supports fully-developed, non-choked saltation over a wide range of reasonable wind speeds.

REFERENCES

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Table 1. Listed are total flux, Q *(g/cm sec); flux at 2cm height,* q *(g/cm^{2}sec); particle speed,* u_p *(cm/sec); particle concentration,* n_0 *(particles/cm^3) and mean-free-path,* MFP *(cm), for different wind speeds,* u_∞ *(m/sec). Choking is inferred to occur when the MFP at the base of the saltation cloud (all values are for 2 cm height) is similar to the average saltation pathlength, which is several centimeters in the terrestrial environment.*

	u_∞	Q	q	u_p	n_0	MFP
Quartz	9.8	0.25	0.11	290	83	17
125-175 μm	16.0	2.44	0.86	450	410	3.4
	21.0	4.55	1.27	460	600	2.4
Quartz	10.6	0.49	0.20	360	33	18
210-250 μm	13.3	1.76	0.64	430	89	6.8
	21.3	6.00	1.40	440	190	3.2

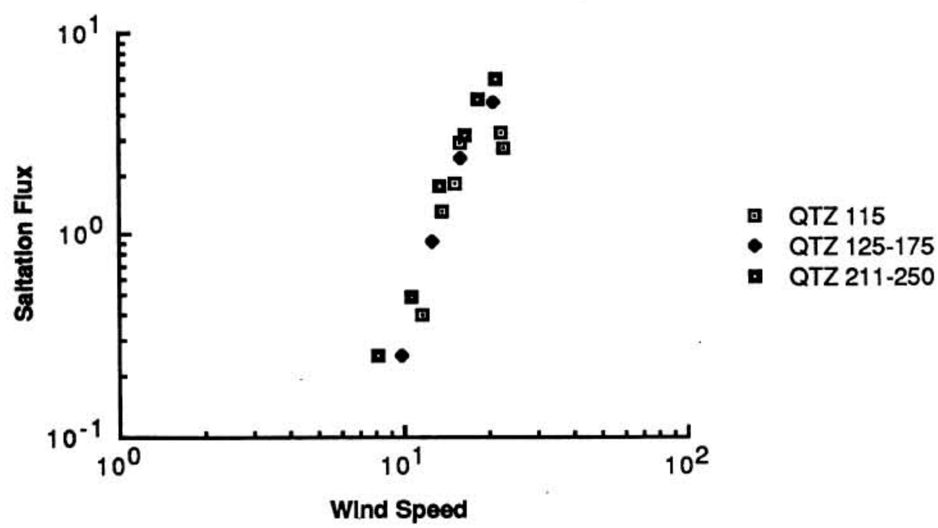

Figure 1. Total saltation flux, Q *(g/cm sec), as a function of freestream wind speed (m/sec) for quartz in three size ranges (μm) under terrestrial conditions. The breaks in slope indicate the onset of choking.*