conditions, will charge positive, due to the dominance of photoelectron emission (Walker, 1973). Negative electric charging can take place in shadow in the terminator region due to the lack of photoelectron emission (Borisov and Mall, 2006; Wang and Robertson, 2009). However, the generation of substantial negative electric fields can also take place in sunlight near the terminator (Berg, 1978; Halekas et al., 2005; Farrell et al., 2007; Wang et al., 2008), such as during low sun angles or plasma conditions with high electron fluxes, leading to either stable levitation or ballistic ejection of negatively charged particles. Ultimately, it is likely that populations of both charge states exist. However, it is also at least plausible that the populations are asymmetric, because of the diversity of processes that produce each one, such that any net accumulation of dust will not be perfectly canceled by movement of oppositely charged dust. Note that charged dust may also accumulate by repulsion from a region, not just attraction.

3.3. Horizontal lunar dust transport

Lofted charged dust that is within or around a positive electrostatic anomaly produced by a crustal magnetic field will be either horizontally repelled or attracted towards to the anomaly. Although the distance traveled may be small during lofting and repulsion (<1–100 cm), repeated loftings may eventually transport a particle over kilometers, Fig. 5. Because the lowest mass material is preferentially lofted, the finest fraction of lunar soil will be preferentially transported. The finest fraction of lunar soil (<45 μm) is known to dominate its spectral properties (Pieters et al., 1993). Because fine-grained material is continually being created and matured in a steady-state equilibrium (McKay et al., 1974), the transport of newly created fine dust into or out of an electric anomaly would also alter the local steady-state equilibrium, and ultimately change the spectral properties of the region.

Firstly, to determine if lofting and repulsion can transport dust on the length scale of swirls, approximately 2–10 km, we calculate the total transportation distance for a dust grain assuming a variety of parameters. The total distance a grain travels, d, can be written:

$$d = N\frac{1}{2}\left(\frac{Eq}{m}\right)t^2$$

where N is the total number of lofting events and subsequent horizontal movements, E is the local electric field, q is the charge on the dust grain, m is the dust grain mass, and t is the time the particle spends horizontally accelerating in each lofting. The equation is for 1-dimensional acceleration of magnitude (Eq/m), multiplied by N. N can be equivalently expressed as the number of years over which the transportation takes place, $N = P \times 2 \times 365t_y/(29.5)$, where t_y is the total exposure time at the surface in years, and P is the probability of lofting during both sunset and sunrise (Berg et al., 1976). We assume $m = (4/3)\pi\rho r^3$, where r is the dust grain radius, and ρ is the effective density, assumed to be 2000 kg/m^3. We explore $r = 1$ μm and $r = 5$ μm, based on the two lofting models put forward by Stubbs et al. (2006) and (Criswell (1972), respectively. Lofted grains with $r \ll 1$ μm, as modeled in Colwell et al. (2009), are easily transported.

To estimate the efficiency of the dust transport process, we will assume that grains are charged positively, as in the case of lofting into sunlight. We do so because the voltages calculated for positive charging are usually smaller than those due to negative charging, and will therefore serve as a lower limit. Following Goertz (1989), Stubbs et al. (2006), Wang et al. (2008), we assume $q = C\phi$, where q is the charge on the grain, C is the capacitance and ϕ is the grain voltage, with $C \approx 4\pi\varepsilon_o r$, where ε_o is the electric constant. The grain potential will change after the grain is ejected from the sunlit surface and transitions into or out of the photoelectron layer (Nitter et al., 1998). However, the equilibrium charge in flight will be close to the lunar surface potential (Walker, 1973). Note that a similar assumption has also been made for negatively charged particles in the past (Farrell et al., 2007; Wang et al., 2008) (a detailed exploration of the time dependent charge is warranted when more information about the lofting process becomes available). Also note that this is entirely different from making the (incorrect) assumption that an individual grain's potential while at rest on the surface is the same as the total surface potential (see discussion in Singer and Walker, 1962a,b).

A range of sunlit lunar surface potentials have been previously calculated (see Halekas et al., 2008), such as +4 V (Willis et al., 1972; Stubbs et al., 2006), +9 V (Manka, 1973), +20 V (Singer and Walker, 1962a,b), <+20 V (Halekas et al., 2008), +200 V in some conditions (Reasoner and Burke, 1972), and higher values in the terminator region (Criswell and de, 1977). We assume the surface is at approximately 10 V, and therefore, assuming that the surface potential is a reasonable approximation for the potential of grains in flight, we assume $\phi = 10$ V, as in Singer and Walker (1962a,b) and Walker (1973). Collective effects of multiple lofted grains

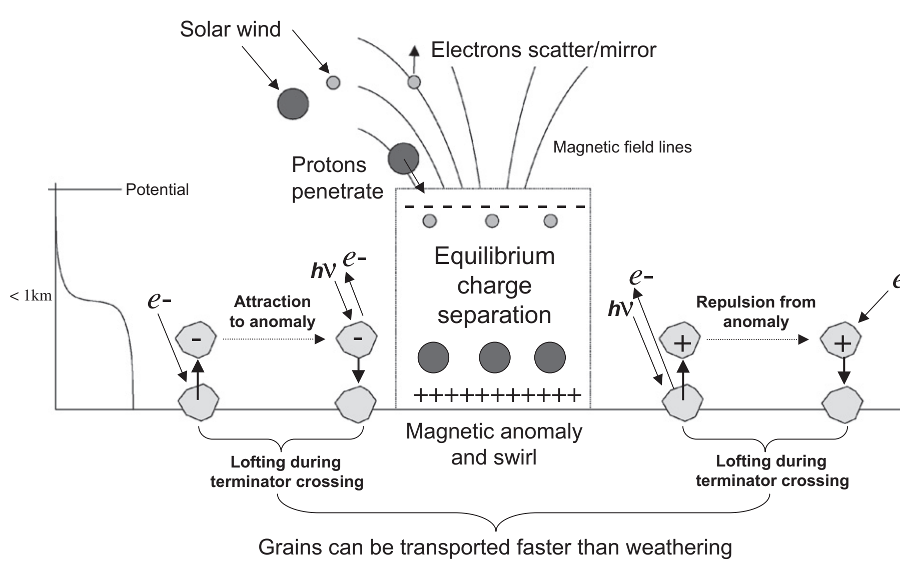

Fig. 5. Charge separation at magnetic anomalies produces an increasing electric potential known as a double layer. The potential increase due solely to the charge separation is sketched at the left, and ignores the photoelectron sheath or other sources of electric potential. Fine dust that is electrostatically lofted each day can be repelled or attracted to the positive potential above the surface.