WIND AND WATER AT THE SURFACE OF MARS. C. B. Leovy[1] and J. C. Armstrong[2], [1]Dept. of Atmospheric Sciences, Box 351640, University of Washington, Seattle WA 98195 (conway@atmos.washington.edu), [2]Dept. of Astronomy, Box 351580, University of Washington, Seattle WA 98195.

Introduction: It is widely assumed that the surface of Mars has been exposed to massive flows of liquid water. These flows are supposed to have taken place both near the end of the early intense bombardment period under a warm wet climate regime and in massive outburst floods, mainly around the periphery of large low latitude volcanic complexes such as Tharsis. However, these scenarios do not adequately account for several lines of evidence that point toward a smaller role for flowing water and a larger role for wind in surface modification. With the aim of broadening the terms of discussion of martian surface history, these lines of evidence are reviewed and interpreted here.

Thermal Inertia Distribution: Over a wide range of scales, thermal inertia is negatively correlated with elevation. Since very high thermal inertia corresponds to high rock abundances or bedrock, and very low thermal inertia corresponds to fine dust particles, this relationship indicates that fine particles have been systematically transported from low areas to high areas, in marked contrast to the usual direction of fine particle transport on Earth. This up-gradient sediment transport can be accounted for only by wind action.

Atmospheric Circulation Models and Dust Storms: General circulation models predict a distribution of potential erosion and deposition that is remarkably consistent with the distribution of thermal inertia on large scales. The predicted wind erosion pattern also coincides well with the observed pattern of dust storm occurrences. Mesoscale models of atmospheric flows show a strong tendency for channeling of strong winds by topography, in agreement with the observed association of thermal inertia with topography on small scales. General circulation models also show that the spatial distribution of erosion and deposition is stable with respect to orbital parameter variations and surface pressure changes. These models also predict that erosion rate would have been much higher than at present with as little as 2-4 times the present mean surface pressure.

Surface Geomorphology: Very low areas such as the northern plains and the floor of Hellas have unique surface features suggestive of very rapid resurfacing, and of long-term sedimentation and erosion. These include paucity of small craters (diameters < several hundred meters), highly degraded large craters and “ghost” craters with diameters > 100km. These features are widely assumed to be due primarily to sedimentation, but, in view of the evidence cited above, it is likely that erosion is a more important factor than sedimentation for the observed degradation of craters at all scales in the northern plains and Hellas.

Another important piece of evidence is the observation of widespread surface exposures of sedimentary layers. These layers indicate past sub-aqueous or subaerial sedimentation. It is equally significant that many of these layer remnants appear to be undergoing rapid erosion in the present climate regime. Only wind can account for this erosion. The widespread occurrence of partially eroded sedimentary layers also indicates that burial and exhumation of surfaces is a common phenomenon that obscures surface modificaton processes and sequences.

Greenhouse Models: The most recent and complete greenhouse models have not been able to produce enough warming of the surface to account for a warm wet early climate regime with any plausible combination of greenhouse gases.

Surface Minerology: No large deposits of carbonates that could correspond to the residue of an early dense carbon dioxide atmosphere have been identified. It is sometimes assumed that such deposits could be buried beneath the northern plains, but in view of the evidence cited above that these plains are primarily erosional rather than depositional surfaces, this is unlikely. Crystalline hematite indicative of weathering by liquid water has been identified, but only in a few relatively small areas.

Implications: Taken together, these lines of evidence suggest that the surface of Mars has been systematically and massively modified by wind erosion and dust redistribution over geological time. They cast doubt on interpretations of surface geomorphology that fail to take wind modification of the surface into account. These interpretations include deep sedimentary layers in the northern plains, lakebeds in crater floors and basins, and fluvial origins of some channel features that may have been streamlined as well as widened and deepened by wind action.

Wind action, by itself, does not seem capable of accounting for the initial formation as distinct from the subsequent modification of channel features, and it does not seem capable of accounting for the geomorphology of gully features that may be due to the localized release of water from near-surface ice. However, the observational evidence for massive wind modification of the surface and the theoretical and observational evidence against an early warm climate regime implies that Mars may have been cold and dry with only modest amounts of water ice (a few tens of meters) available at the surface since early in the Noachian period.