INITIAL RESULTS OF THE IMAGER FOR MARS PATHFINDER WINDSOCK EXPERIMENT. R. Sullivan[1] R. Greeley[2], M. Kraft[2], J. Murphy[3], G. Wilson[3], M Golombek[4], K. Herkenhoff[4], and P. Smith[5], [1]308 Space Sciences, Cornell University, Ithaca, NY 14853 sullivan@cuspif.tn.cornell.edu, [2]Department of Geology, Box 871404, Arizona State University, Tempe, AZ 85287-1404, [3]NASA-Ames Research Center, Moffett Field, CA 94035, [4]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, [5]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, 85721.

The Imager for Mars Pathfinder (IMP) windsock experiment measured wind speed as a function of height to evaluate how wind energy is transferred to potentially mobile materials around the Pathfinder landing site. Here we report preliminary results from windsock data analysis pertaining to wind characteristics of the lower boundary layer during mission operations and the potential of wind to alter the configuration of fine particle deposits at the landing site. Winds during daylight hours were very light, seldom reaching 8 m/sec. Wind speeds were higher during the middle of the day, while the lower boundary layer was most unstable, than in the morning or later in the afternoon. Profile data indicate preliminary values of aerodynamic roughness, z_0, of 2-9 cm, but associated values of wind friction speed, u_*, were <1 m/sec, well below experimentally predicted particle saltation thresholds for Martian conditions[1]. These results are consistent with the observed stability of fine-particle deposits at the landing site all during mision operations: wind produced no perceived changes to fine particle deposits or artificially disturbed surface materials. Despite abundant evidence for the effects of aeolian processes, including wind tails behind rocks, drifts, and barchanoid duneforms, the Pathfinder landing site was an extremely quiet aeolian environment during mission operations.

BACKGROUND. Dune fields, time-variable bright and dark streaks associated with topographic obstructions, and other wind-related surface features were revealed by Mariner 9 and Viking Orbiter data [2,3,4,5,6]. Barchan, star, transverse, and longitudinal dunes have been observed and their morphologies and orientations used to interpret regional wind patterns[7,8,9,10], but it is not clear whether any of these dune forms are currently active. Wind tunnel investigations indicate unrealistically strong winds would be required for direct entrainment of dust-sized particles under Martian conditions[1], so the mechanism for raising massive quantities of dust during regional and global dust storms is not well understood. Accumulations of fine particles deposited and shaped by wind were observed at both Viking Lander sites[11,12,13], and the orientations of drifts correlate reasonably well with highest wind speed directions inferred from wind streaks seen from orbit [14]. Changes to the Viking Lander 1 site (Mutch Memorial Station) during the mission were minor, including trenches and small artificial piles of soil affected by winds perhaps as high as 50 m/sec. Previously undisturbed materials were not perceptibly eroded. No wind-related morphological changes were observed at the Lander 2 site [15,16]. Dust deposition and subsequent removal of dust by light winds occurred at both landing sites[17,15]. The Viking Meteorology Experiment measured temperatures and wind speeds from a single location 1.6 m above the surface. Modeling of heat and momentum fluxes within the near-surface boundary-layer was complicated by lack of knowledge of aerodynamic roughness, z_0. The Pathfinder IMP windsock experiment, with three anemometers, has the potential to address this ambiguity, providing an independent determination of u_* directly from the wind speed profile and allowing more constrained modeling of the atmospheric boundary layer than previously.

APPARATUS Three IMP windsock units are mounted on the ASI/Met mast at heights of 33.1, 62.4, and 91.6 cm above the solar panel. The IMP windsocks function like conventional terrestrial windsocks in that deflection from vertical is related to wind speed, and azimuth of deflection relates to wind direction. Each windsock consists of a hollow aluminum cone rigidly joined to an aluminum-sheathed steel counterweight spike, which pivot together on a small, low-friction gimbal mount. The windsocks are counter-balanced for sensitivity to wind at typical Martian surface pressures. Field testing and wind tunnel tests showed the units to be aerodynamically stable at all deflection angles. Each windsock unit is constructed of electrically conductive materials and is grounded to prevent accumulation of static charge from affecting windsock deflection.

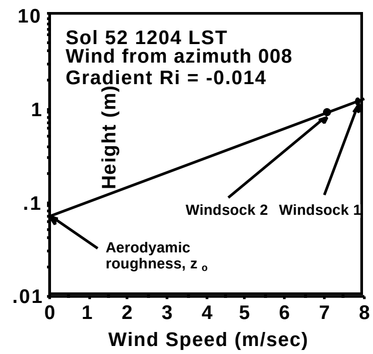
DATA IMP windsock observations were carried out to (1) monitor wind speed and direction (image the top windsock only) during daylight hours, and (2) measure the wind profile for aerodynamic roughness, z_0, and wind friction speed, u_* (image all three windsocks together). Terrestrial experience shows that valid z_0 determinations require accumulation of a statistically significant amount of data (e.g., [18]); a single instantaneous "snapshot" of the wind speed at all anemometer heights can reflect the turbulent nature of the planetary boundary-layer more than its long-term average behavior. Determination of z_0 improves as wind profile data accumulate. Three IMP windsocks were successfully deployed with the ASI/Met mast on sol 1. A regular program of daily windsock imaging was established on sol 13, and occasional monitoring of likely areas for wind-related changes was begun on Sol 19. A dust devil search sequence was activated on Sol 66. Daily windsock observations from Sol 13 typically involved four six-frame observations of the top windsock, and one or more twelve-frame observations of all three windsocks for profile information. This program was cut back later in the mission as overall downlink allocations declined, ending with final profiles returned on Sol 82. All windsock images were tightly sub-framed and compressed 6:1. Six-frame observations of the top windsock generally were carried out at 0850, 0950, 1400, and 1630 local time with some sol-to-sol variations due to scheduling of spacecraft or other camera activities. Wind profile measurements were obtained near noon, a time when ASI/Met and windsock data indicated relatively stronger winds than in morning or afternoon.

ANALYSIS AND PRELIMINARY RESULTS Deflection of the windsocks due to wind represents a balance between aerodynamic forces causing deflection and a gravitational moment acting to return the windsock to vertical. Windsock deflection and azimuth are completely determinable from IMP images by measuring apparent width:length ratio (foreshortening) and clock angle of the windsock in IMP images, with a knowledge of IMP pointing. Stereo imaging was not required. Concurrent ASI/Met temperature and pressure data are used to calculate the atmospheric density which is applied with deflection angle to calculate wind speed.

The windsocks were optimized for measuring moderate-to-strong winds where mechanical turbulence is an important characteristic of the near-surface boundary layer, and the main aerodynamic influence on surface particles. However, winds were generally very light during mission operations. Fortunately, calibrations for Martian wind speeds as low as 5 m/sec were obtained for the flight units, and these calibrations have been applied to the stronger wind data to obtain wind speed and profile information. Daylight winds during mission operations were rarely greater than 8 m/sec at the top windsock position (about 1.3 m above the surface), and commonly were less. Wind conditions around 0850 and 1630 were generally calm, with sustained breezes less than the 5 m/sec measurement threshold for the windsocks. Stronger winds were more common from late morning to early afternoon, generally from the west.

A maximum recorded wind speed of 12 m/sec was measured from azimuth 255 (WSW) at 1218 LST on Sol 32. Stronger measured winds such as these were still relatively light, however, and were not from azimuths that correspond with wind tails of fine particles, duneforms, and other surface features indicative of much stronger winds and aeolian activity. No wind-related changes to surface materials were observed during the mission.

The very light winds complicated efforts to obtain significant amounts of high quality wind profile data for determining z_0 and values of u_*: only a small fraction of the wind profile observations have strong enough winds for detailed profile analysis. A further complication is the state of the partially retracted airbag materials surrounding the solar panel where the ASI/Met mast is mounted. Airbag material protrudes above the solar panel, altering the flow of wind, especially from the south and west. Most winds recorded by the lowest windsock are affected by these obstructions, and can not be included in profile analysis. Wind profiles analyzed so far are characterized by thermal instability rather than fully developed mechanical turbulence typical of strong winds causing particle saltation on Earth. An example profile from 1204 LST, sol 52 is shown in Figure 1. These data are typical of the best profile data: they were compiled from a sequence of 12 images obtained in rapid succession, and show wind speeds no greater than 8 m/sec at the top windsock position. This particular profile is unusual, however, in that it was obtained immediately after the passage of a wind vortex ("dust devil") as revealed by ASI/Met data. This may explain the northerly wind azimuth that contrasts with more typical mid-day winds from the west. After gradient Ri values are calculated and applied to correct for thermal instability, a value for z_0 of 2-9 cm is indicated, with some dependence on assumed height of the solar panel above the ground surface, with u of ~1 m/sec. Similarly values of z_0 were measured from an equally strong westerly profile obtained at 1158 LST on sol 58. Wind friction speeds were well below experimentally prediected particle saltation thresholds (Greeley et al., 1980) in all cases. Despite abundant evidence for aeolian processes, including the presence of drifts, wind tails behind rocks, and barchanoid duneforms, the Pathfinder landing site was an extremely quiet aeolian environment during mission operations, even accounting for lower wind speeds expected during northern summer. A visitor to the landing site shortly after the end of the mission would have found complete stillness in his/her surroundings - except for small movements of the windsocks in response to light breezes.



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