On modeling boundary-layer depths, dust and cloud at the Phoenix lander site.

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Introduction: Dust suspended in the Martian atmosphere is crucial in determining the thermal and dynamical conditions. Diurnal variation of dust, water-ice and boundary-layer characteristics at the NASA Phoenix lander site are investigated using a one-dimensional Atmospheric Boundary Layer (ABL) model and a Mars Microphysical Model (MMM).

The diurnal cycle of temperature measured by the Phoenix lander [1] (used as input for the MMM and a test of the ABL model) has been very consistent for the first 60 sols of the mission. The optical depth, as measured by the SSI camera [2], has generally decreased.

Coupled dust model: The diurnal evolution of dust distribution and boundary-layer characteristics at the Phoenix lander site has been investigated using a one-dimensional coupled Atmospheric Boundary Layer (ABL) model of dust interaction in the Martian atmosphere. This model uses feedback from atmospheric dust through radiative processes (scattering, absorption and emission) to investigate the boundary-layer depth and distribution of suspended dust. The model is initialized using surface pressure [1] and a constant mixing ratio of dust, with particle density specified from the optical depth measured by the SSI camera. Estimates of the upper level winds are extracted from zenith movies of dust and cloud features passing over the lander, which suggest the winds are light. The geostrophic wind, a constant in the ABL model, is assumed to be 5 ms^{-1}. Since the model does not include surface lifting of dust under these conditions we focus on periods with little or no increase in atmospheric dust.

Model output is compared with measurements of dust opacity, LIDAR backscatter and near-surface temperature. As dust settles out it is mixed within the convective boundary layer (CBL). This mixing results in a near-constant concentration of dust within the CBL which, because of the low settling velocity of suspended particles, does not decay significantly during periods without convective mixing. This is seen in the model backscatter profile which shows a sharp drop in backscatter at the top of the afternoon boundary-layer height. Preliminary samples of Phoenix LIDAR backscatter (Figure 1) show the sharp cut-off in backscatter we would expect from model results, regardless of whether there is dust above the boundary-layer (Figure 2).

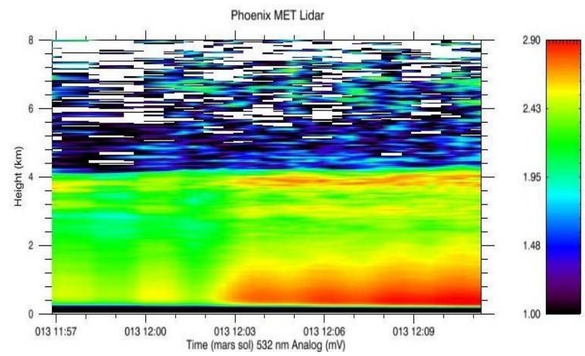

Figure 1: Preliminary Phoenix LIDAR backscatter.

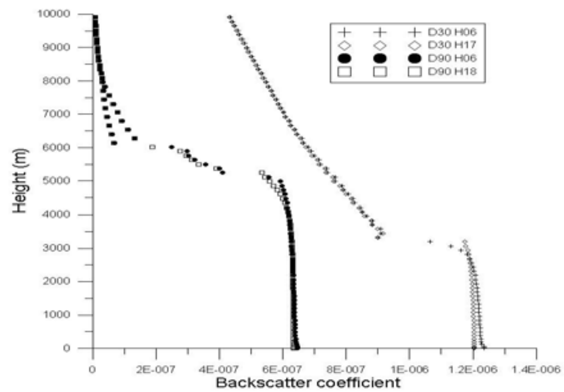

Figure 2: LIDAR backscatter determined from ABL model at two times on sols with and without the presence of dust above the boundary-layer.

Surface temperature is implicit in the ABL model and is derived from a 5-level thermal diffusion soil model [3] which specifies a constant deep-soil temperature. Model results for the diurnal cycle of temperature at the Phoenix thermocouple heights (Figure 3) with an optical depth of 0.3 compare favorably with a typical example from the lander thermocouples (Figure 4) for a similar optical depth.

Water-ice clouds: Diurnal variation of water-ice cloud formation at the NASA Phoenix site is investigated using a one-dimensional MMM coupled with the results from a one-dimensional ABL Model. The microphysics includes the processes of nucleation, condensation, evaporation, coagulation and sedimentation suitably modified for Martian conditions.

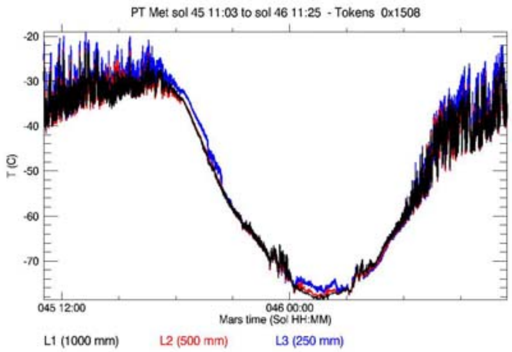

Figure 3: The preliminary diurnal cycle of temperature from the Phoenix thermocouples (sols 45-46) with heights given in meters above the lander deck.

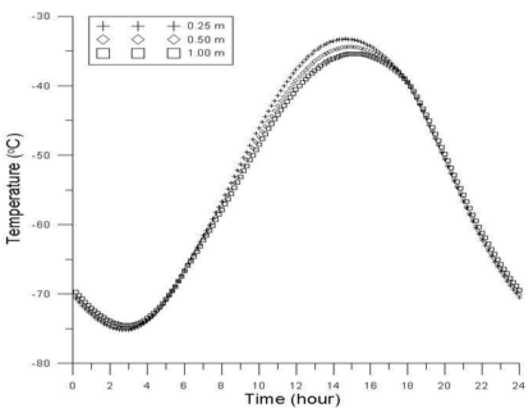

Figure 4: ABL model at 0.25, 0.5 and 1 m above the lander deck for optical depth of 0.3.

Dust particles act as cloud condensation nuclei with heterogeneous nucleation being responsible for water-ice cloud formation on Mars. The model is initialized with surface temperature and pressure as measured by the Phoenix MET component and the temperature profile is constructed from the averaged MGS TES observations of nadir temperature and atmospheric retrieval products for the landing site and season. Initial dust distribution, taking into account the dust opacity from Phoenix, has been constructed using a gamma distribution over particle size [4].

The coupled cloud microphysics model is used to study the formation, evolution and dissipation of water-ice clouds on Mars at the Phoenix lander site. Measurements made by the Phoenix LIDAR on Mars have also been simulated by analyzing the theoretical backscatter, extinction, LIDAR ratio and color ratio of dust and ice clouds over the landing site. It is found that the majority of the water-ice clouds simulated for conditions at the lander site are confined below 12 km with a peak forming between 5 and 7 km (Figure 5). Ground fogs are generated under low temperature conditions in the early mornings (Figure 5) and the diurnal cycle of clouds show varying cloud base heights. The sensitivity of the simulated optical properties was studied by changing some input parameters. Formation and abundance of the ground fogs and clouds is found to be sensitive to changing input water abundance and the temperature profile.

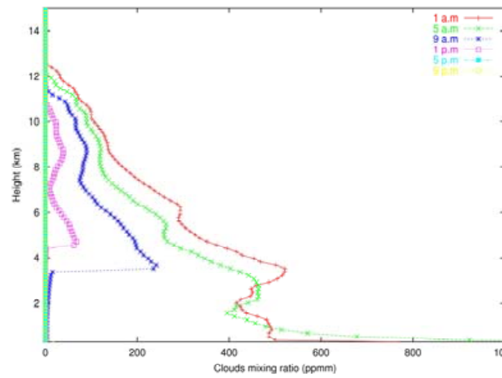

Figure 5: Ice-water mixing ratio as a function of height at various times in a diurnal cycle.

References:

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