Temperature and wind data from the Phoenix MET station and their use in estimating turbulent heat fluxes.

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Introduction: There has been near-continuous measurement of temperature [1] on the Phoenix lander mast and wind measurement by the telltale [2]. The wind data is intermitent as it requires the use of the SSI camera [3] to image the telltale instrument. The diurnal cycle of temperature has been consistent throughout the first 60 sols of the Phoenix mission with strong, order of 10 K, fluctuations during the highly convective period (0800-1600).

Using wind data we estimate the friction velocity u_* and we infer T_* from the temperature data, which gives us an estimate of the surface heat flux.

Spectral analysis: Samples of the temperature data during periods of convective (unstable) and stable/neutral (stable) stratification were used to analyse the power spectrum and obtain estimates of the turbulence parameters u_* and T_* and the heat flux. To avoid lander influences on temperature data we used data from the upper level (L1, Figure 1) thermocouple at a height of 1 m above the lander deck, approximately 2 m above the surface. The mean wind speed and temperature over our sampling periods were computed.

Figure 1 illustrates the diurnal temperature cycle for a typical sol and the sampling period used to obtain unstable power spectra. The power spectrum for the unstable temperature data matches well with the theoretical cascade at high frequency (Figure 2).

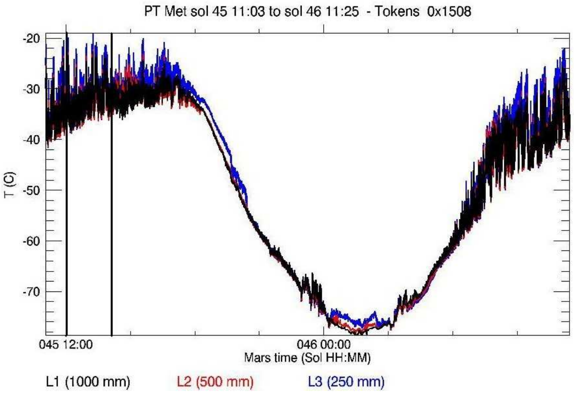

Figure 1: Preliminary thermocouple temperature data for sols 45-46 indicating sample used for unstable temperature spectra.

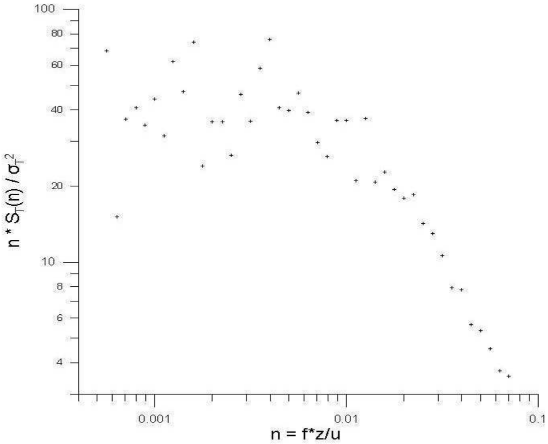

Figure 2: The unstable temperature spectra for sol 44 normalised by $\sigma_T^{\,2}$ as a function of normalized frequency.

Heat flux: By making use of Monin-Obukhov similarity theory we can use relations between the standard deviation in temperature and the turbulent parameter T_* to determine u_*, T_* and the heat flux. For the unstable temperature data we use the relation [4]:

$$\sigma_T \big/ T_* = 0.95\left(-\left(\frac{z}{L}\right)^{-1/3}\right)$$

and for the stable temperature data we use [5]:

$$\sigma_T \big/ T_* = 0.05\left(\frac{z}{L}\right)^{-1} + 3$$

where L is the Obukhov length. By making use of these relations, and by using the relevant log relation for the wind profile to get the friction velocity, we can get an estimate of the heat flux from:

$$H \big/ \rho c_p = -u_* T_*$$

The wind speed has been consistent with mean values of 3-6 ms^{-1} and corresponding u_* of 0.2-0.4 ms^{-1}. Typical mid-day (1200-1430) mean values of the heat flux are 7 W m^{-2} with variation from 4 – 10 W m^{-2} over the 11 sols investigated. The nocturnal (1800-1830) values have a mean of -0.3 W m^{-2} for the three sols investigated.

Lander effects: Although the MET mast that supports the temperature and wind sensors is built at the edge of the lander deck and the sensors are located between 0.25 and 1 m above the deck, there are conditions under which the presence of the lander and its instruments interfere with the temperature and wind measurements. In order to estimate this intereference, an approximation of the Phoenix lander (Figure 3) was discretized, using approximately 10^6 nodes, and calculated with prescribed winds and deck temperatures in the ANSYS/CFX flow solver.

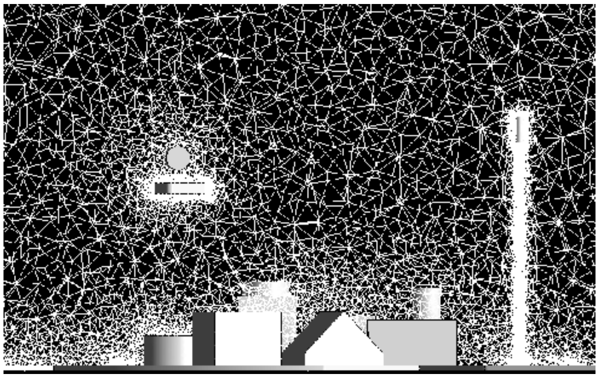

Figure 3: Detail of computational grid used to calculate the effect os the lander on wind and temperature measurements.

The potential effect of the lander has a very strong directional nature, related intrinsically to the position of the other instruments onboard. For example, the 3 temperature sensors experience slightly different wind speeds, which affects their response time, when they are in the wake of one of these flow obstructions. Figure 4 shows estimated changes of a normalized wind speed $u^*=u/U_\infty$ with the direction.

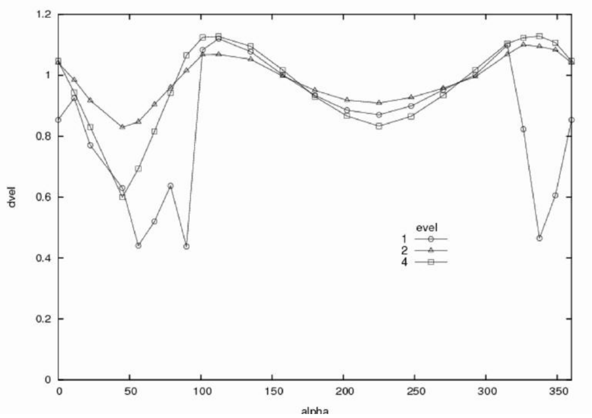

Figure 4: Graph showing the effect of angle α on the wind speed experienced by the temperature sensors at 0.25m (1), 0.5 m (2) and 1 m (4) above the deck.

Although the top thermocouple (and on a smaller magnitude the telltale wind sensor slightly above it) would feel little effect apart from the wake of the camera at approx. 50 degrees angle, the lowest thermocouple suffers from strong influence from deck instruments on a large range of directions. More specifically, the model has allowed us to demonstrate how the elevated temperatures of the lander deck surface and of its instruments are carried by the perturbed flow above the lander and systematically affect the temperature measurement of the lowest sensor (notice blue curve in Fig. 1 between 18:00 and 22:00), when the MET mast is downstream from the lander, i.e. for winds coming mainly from N and E. Figure 5 illustrates this case with a plot of temperature contours above the lander.

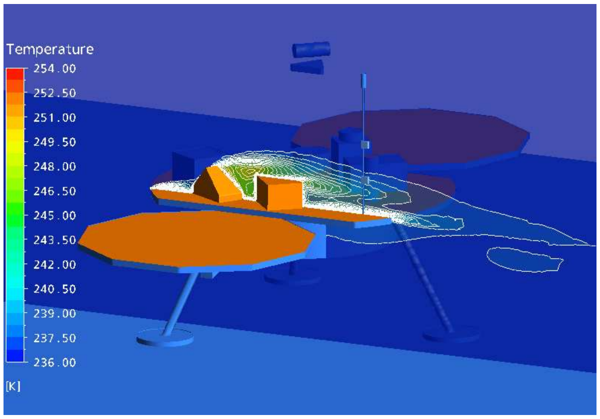

Figure 5: Temperature contours showing how the heated deck surface affects the lowest temperature sensor when wind comes from the N.

These results help us determine the cases when the atmospheric measurement data may not be a reliable representation of the undisturbed patterns.

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