Numerical Study of the Effect of the Phoenix Mars Lander on the Temperature Sensors.

J.A. Davis[1], C.F. Lange[1], and P.A. Taylor[2], [1]Department of Mechanical Engineering, University of Alberta, Edmonton, Alberta, Canada, [2]Centre for Research in Earth and Space Science, York University, Toronto, Ontario, Canada.

Introduction

The Mars Phoenix lander [1] successfully landed in the northern region of Mars on May 25, 2008 beginning its mission. One of the payloads on the lander was the Canadian meteorological station which consists of a Lidar [2], a pressure sensor, three temperature sensors mounted at different elevations along a mast and a velocity sensor mounted on top of the mast [3]. The purpose of these sensors are to measure representative values of the nearby environment. The temperature, velocity, and pressure sensors used are intrusive instruments subject to measurement uncertainties. It is expected that, under certain conditions, the lander and instruments will affect the readings near the sensors. Experimental quantification of these effects is difficult, due to the extreme Martian environmental conditions (CO_2 gas at a temperature of 200 K and a pressure of 800 Pa in a gravitational field of 3.7 m/s^2) [4, 5]. For this reason, CFD is the only viable tool for analysis.

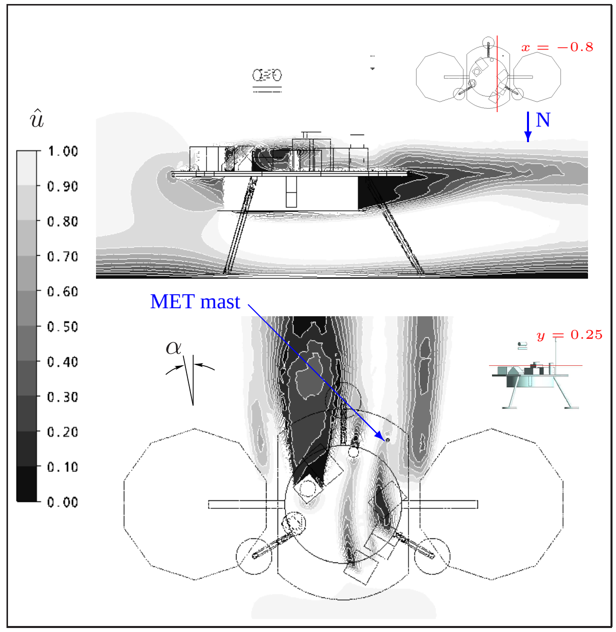

Figure 1: Contour plots of the non-dimensional velocity magnitude in various planes for $\alpha = 0°$.

Momentum Transfer

Two main factors affect the momentum transfer around the lander: the magnitude of the freestream velocity at top mast height, U_∞, and its direction angle α. In the current series of simulations, these variables were varied in the range $0.1 \leq U_\infty \leq 25.0$ m/s and $0° \leq \alpha \leq 360°$. Figures 1 and 2 show sample results from the study where the lander's geometry plays a crucial role. Data here is shown in non-dimensional terms where $\hat{u} \equiv u/U_\infty$ and $\hat{y} \equiv y/y_{TC1} = 4y$ with y counting from the deck surface.

The major sources of momentum deficit (shown in Figure 1), which could influenced the temperature sensors through reduced convection, were found to be caused from the individual instruments on deck. Other minor sources, include the solar panel supports and to some extent the wake produced from the body of the lander itself. The deficit on the temperature sensors themselves is shown in Figure 2 as a function of the wind's direction. Here, two groups of angles near $\alpha = 55°$ and $\alpha = 340°$ are found to cause a significant decrease in the momentum at the lower thermocouple. The two grouping are caused by the alignment of mast with the instruments on each side of the lander. At the highest thermocouple one source of momentum deficit is found

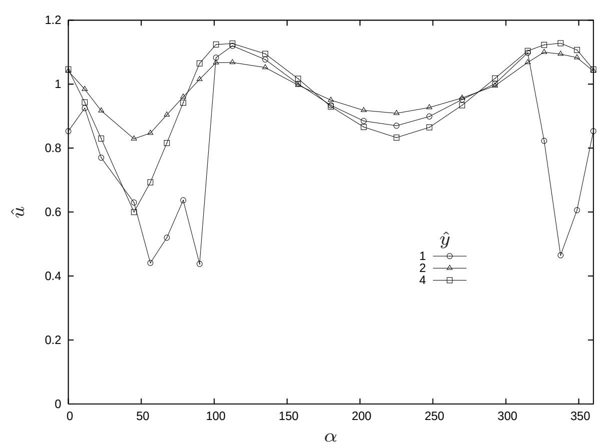

Figure 2: Graph showing the effect α on $\hat{u}$ at the three temperature sensors for $U_\infty =$ m/s.

at $\alpha = 50°$ when the wake of the SSI camera is aligned with the mast.

Heat Transfer

For the simulations involving deck and instrument heating, the wind direction was kept in the range $-15° \leq \alpha \leq 0°$, i.e. coming from North, in which the temperature sensors are in the wake of the TEGA instrument grouping. A range of deck heating and wind magnitudes were then simulated with sample results shown in Figures 3 and 4 where the results are presented in terms of a non-dimensional temperature difference, Θ, defined as $\Theta \equiv (T - T_\infty)/(T_{hot} - T_\infty)$. The effect of varying the wind's magnitude plays an important role, as exemplified in Figure 3, where, for simplicity, only the TEGA instrument was heated.

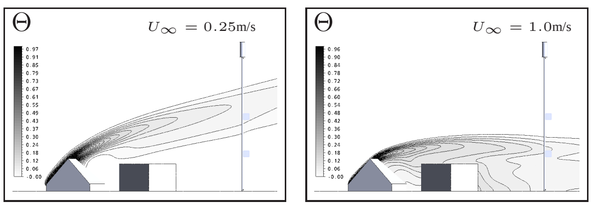

Figure 3: Contour plots of the non-dimensional temperature difference, Θ, showing the effect of varying the freestream velocity for a temperature difference between the TEGA instrument and environment of $T_{hot} - T_\infty = 100$ K.

Here, the thermal plume was found to bend towards the deck as the wind's magnitude was increased. Even in the event that U_∞ is large in average, low velocities can be found in a real case scenario as winds shift direction or atmospheric vortices pass above the lander.

These simulations were able to demonstrate how a recurring evening disturbance, in which the lower temperature sensor measured approximately 2 K higher than the other two, was caused by lander effects. A simulation using environmental conditions obtained from the Phoenix surface operations, corresponding approximately to conditions on sol 19 at 6PM LMST, is shown in Figure 4. Here deck and instrument are kept at 254 K, while the wind comes from the North at 2.5 m/s and 238 K. Results show an approximate temperature difference of 2 K between the lower temperature sensor and the environment, whereas the two upper sensors were found not to be affected by the lander. Note that the heat from the deck is not lifted by simple buoyant convection is this case, but by the wake of the instruments.

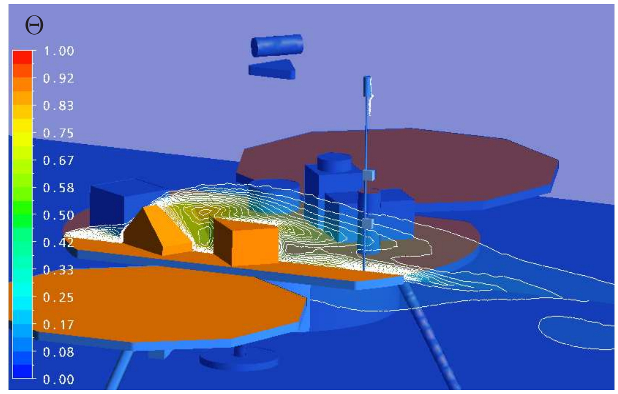

Figure 4: Non-dimensional temperature contours showing how the heated deck surface affects the lowest thermocouple for $U_\infty = 2.5$ m/s and $T_{hot} - T_\infty = 18$ K.

Results

Results from simulations show that, under certain conditions, the heat produced by lander can influence the temperature sensors by approximately 10% of the temperature difference between the deck and the environment, $T_{hot} - T_\infty$. The results also underline the need for continuous velocity measurements during missions, so that these potential errors can be detected and corrected.

Acknowledgments

Funding from the Canadian Space Agency is gratefully acknowledged.

References

[1] P. H. Smith et al. Introduction to special section on the phoenix mission: Landing site characterization experiments, mission overviews, and expected science. *J. Geophys. Res.*, 113, 2008. E00A18 doi:10.1029/2008JE00308.

[2] J. Whiteway, M. Daly, A. Carswell, C. Dickinson, T. Duck, L. Komguem, and C. Cook. Lidar on the phoenix mars mission. *J. Geophys. Res.*, 113, 2008. E00A08 doi:10.1029/2007JE003002.

[3] P.A. Taylor, D.C. Catling, M. Daly, C.S. Dickinson, H.P. Gunnlaugsson, A. Harri, and C.F. Lange. Temperature, pressure, and wind instrumentation on phoenix met. *J. Geophys. Res.*, 113, 2008. E00A10 doi:10.1029/2007JE003015.

[4] F. Hourdin, P. LeVan, F. Forget, and O. Talagrand. Meteorological variability and the annual surface pressure cycle on mars. *J. Atmos. Sci.*, 50:3625–3640, 1993.

[5] J. Mihalov, R. Haberle, J. Murphy, A. Seiff, and G. Wilson. Morning martian atmospheric temperature gradients and fluctuations observed by mars pathfinder. NASA TM-1999-208788, 1999.