**LIDAR OBSERVATIONS OF DUST, CLOUDS, AND PRECIPITATION ON MARS AND EARTH.**

J. Whiteway[1], C. Dickinson[2], L. Komguem[1], F. Daerden[3], [1]York University, Toronto, Ontario, M6J 1P3 (Whiteway@yorku.ca). [2]MDA Space Missions, Brampton, Ontario. [3]Belgian Institute for Space Aeronomy, Brussels.

**Introduction:** The Phoenix mission [1,2] landed on the northern plains of Mars on 25 May 2008 and obtained measurements from the surface for five months through midsummer. A unique instrument on the Phoenix mission was a LIDAR [3] that detected the backscatter of pulsed laser light emitted upward into the atmosphere. It measured the vertical distribution of atmospheric dust and water ice clouds [4,5,6].

Characterization of the Phoenix LIDAR involved field measurements on Earth with a combination of lidar remote sensing and in situ sampling. Field campaigns were carried out in the deserts of Arizona and Australia to characterize the lidar for measurements of desert dust aerosol. Field campaigns were also conducted with aircraft in situ measurements in the tropopause region to obtain measurements of water ice crystal clouds at temperatures similar to the atmosphere of Mars.

The presentation will compare measurements with the Phoenix LIDAR on Mars with similar measurements that were acquired on Earth. The in situ measurements on Earth are used for estimating microphysical properties from the LIDAR measurements on Mars.

**Dust in the Planetary Boundary Layer:** The height profile of the optical extinction coefficient was derived from the LIDAR measurements. This is the fractional reduction in the laser pulse energy per unit length due to scattering. It can also be considered as the effective cross sectional area of scattering material per unit volume, so it is proportional to the mass of scattering material.

It was found that the dust was evenly distributed with height up to about 4 km due to the vertical mixing by convection and turbulence during daytime within the Planetary Boundary Layer (PBL). The height of the PBL was variable between 3 km and 6 km. The atmospheric dust loading reached a peak around summer solstice and then generally decreased.

Measurements in the Australian Desert with a prototype of the LIDAR instrument on Phoenix provided a context for interpreting the measurements on Mars. The optical extinction coefficient on Mars for relatively moderate dust loading was similar to what was found in the Australia Desert during conditions with high wind and blowing dust. Figure 1 shows a comparison of measurements of atmospheric dust above the deserts of Australia and Mars. There is a striking similarity in the distribution of dust within the planetary boundary layer up to height 4 km.

The ratio of the lidar backscatter coefficients at wavelengths of 532 nm and 1064 nm was used to estimate that the dust particle effective radius in the atmosphere above the Phoenix site on Mars was in the range of 1.2 μm to 1.5 μm.

**Clouds and Precipitation:** During the period around summer solstice, clouds were observed sporadically and mainly above heights of 10 km. Moving into late summer, 50 sols after solstice ($L_s$ = 117°) the lidar detected a regular pattern of cloud formation each night within the planetary boundary layer (PBL). A shallow surface based cloud formed at around midnight (Mars local solar time) and a second cloud layer formed after 1 am at heights between 3 km and 6 km. The observed clouds formed at an estimated temperature of -63° C, which is similar to cirrus clouds on Earth. For each sol in late summer the water ice clouds remained throughout the night and then dissipated when the atmosphere warmed sufficiently during daytime. As the summer progressed toward autumn, the clouds persisted longer into the morning hours and extended further toward the ground. Clouds were not detected in the afternoon or evening.

An essential capability of the LIDAR was that it could resolve the internal structure of water ice clouds that drifted past the landing site. The most striking features were vertical steaks at the base of some clouds that were similar to fall streaks under cirrus clouds that are commonly observed on Earth. This pattern is consistent with ice crystals precipitating from the clouds on Mars. The length of the fall streaks in the Mars clouds is consistent with ice crystals that are similar in size to those found in cirrus clouds on Earth. Figure 2 shows a comparison of the LIDAR measurements of clouds on Mars with LIDAR measurements of cirrus clouds on Earth above northern Alberta.

The optical extinction coefficient derived from the LIDAR measurements was used to estimate the ice water content in the clouds observed on Mars. Based on the similarity to cirrus clouds, an empirical relationship that was obtained from airborne in situ measurements was applied to the LIDAR measurements from Mars. The cloud ice water content was on the order of 1 mg/m$^3$ for the boundary layer clouds on Mars.

**References:**

[1] Smith, P., et al. (2008), *JGR, 113,* E00A18.
[2] Smith, P., et al, (2009), *Science,* 325, 3 July 09.
[3] Whiteway, J., et al. (2008), *JGR,* 113, E00A08.
[4] Whiteway, J., et al. (2009), *Science,* 325, 3 July 09.
[5] Dickinson, C., et al., (2010), *GRL, L18203.*
[6] Dickinson, C., et al., (2011), *PSS,* doi: 10.1016/j.pss.2010.03.004

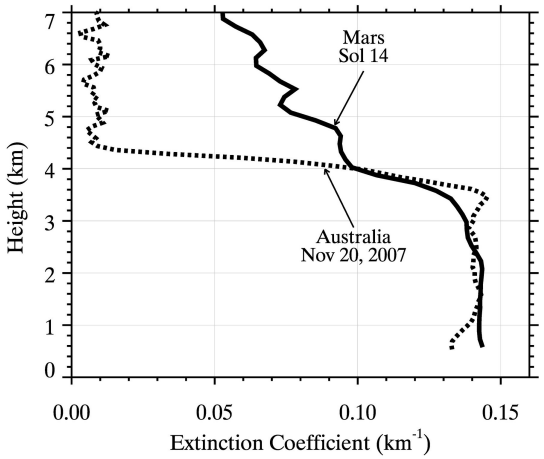


**Figure 1.** Comparison of LIDAR measurements of dust optical extinction coefficient in the atmospheres of Mars and Earth. The greatest dust loading during the Phoenix mission (mission sol 14) is compared with moderate dust storm condions above the Australian desert.

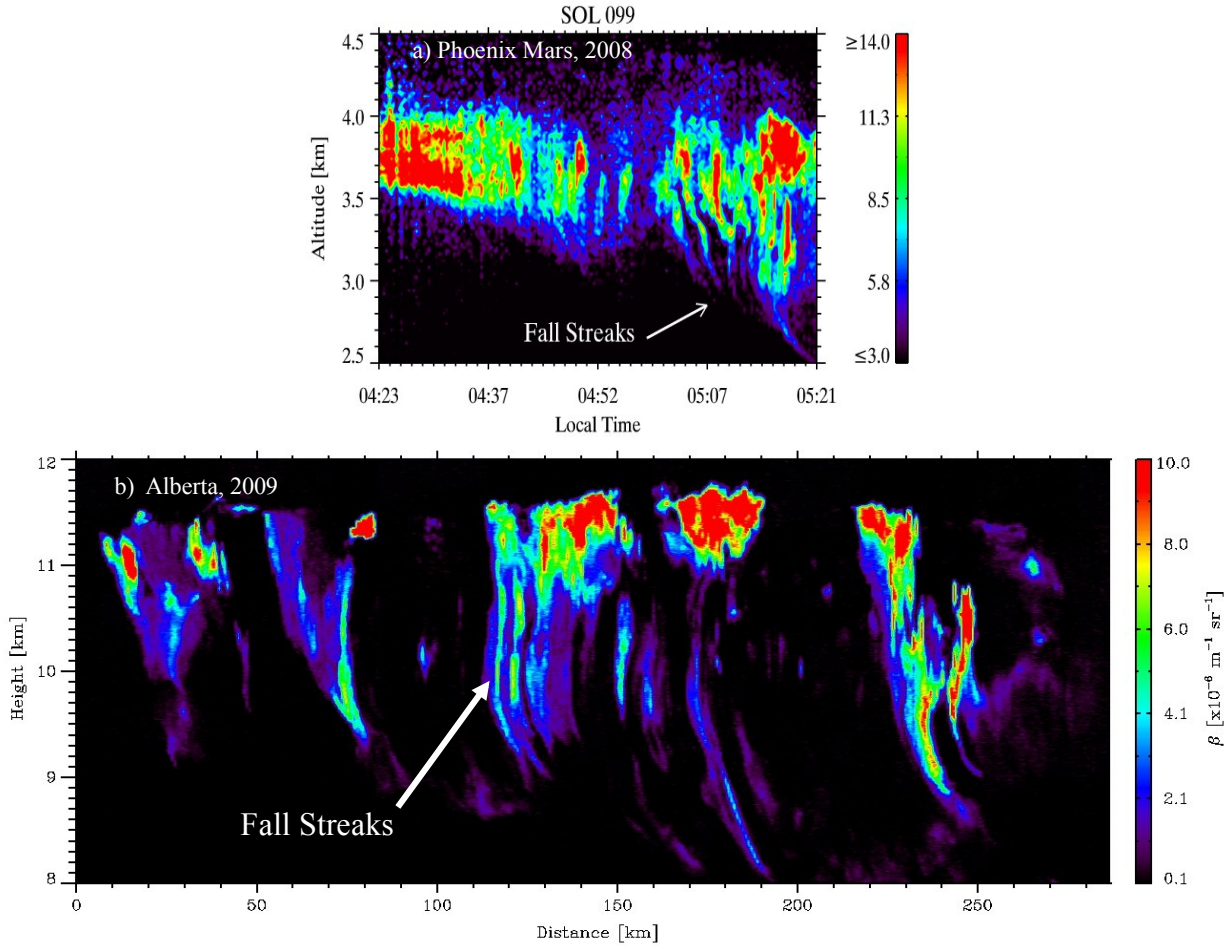


**Figure 2.** Comparison of LIDAR cloud measurements on Mars and Earth. (a) Measurements of backscatter coefficient ($\times 10^{-6}$ $m^{-1}$ $sr^{-1}$) on Mars with the Phoenix LIDAR instrument showing the outline of a water ice cloud with precipitation fall streaks. (b) LIDAR measurements of the backscatter coefficient in cirrus clouds with precipitation fall streaks above northern Alberta.