PHOENIX LIDAR CHARACTERIZATION. J. Whiteway[1], C. Cook[1], L. Komguem[1], M. Ilnicki[1], M. Greene[1], C. Dickinson[2], A. Heymsfield[3], [1]Department of Earth and Space Science & Engineering, York University, 4700 Keele Street, Toronto, Ontario, Canada , [2]Department of Physics and Atmospheric Science, Dalhousie University, Halifax, Nova Scotia, Canada, [3]National Center for Atmospheric Research, Boulder, Colorado, USA.

Abstract: Field measurement campaigns are being carried out with a lidar that is essentially equivalent to the Phoenix Lidar. The measurement campaigns focus on scenarios within the Earth's atmosphere that are similar to what is expected to be observed with the Phoenix lidar from the surface of Mars: ice clouds and airborne desert dust. The first campaign has involved airborne lidar and in situ measurements of very cold ice clouds (cirrus) in the tropical tropopause region above Darwin, Australia. The second campaign involved ground based measurements of airborne desert dust at Eloy, Arizona. The third campaign will combine lidar and airborne in situ measurements of desert dust within the Australian interior. A fourth campaign will involve conducting measurements with the Flight Model of the Phoenix lidar, while the Field Lidar will be operating simultaneously at the same location. The goal is to transfer the characterization of the Field Lidar to the Phoenix Flight Model Lidar in order to aid in interpreting the measurement data from Mars, and also to identify any peculiarities in the characteristics of the Flight Model. This will provide a basis for the development of analysis techniques for the Phoenix mission and for interpreting the results.

The Phoenix Lidar: The Lidar instrument on the Phoenix Lander will observe dust and cloud for investigation of atmospheric processes that determine the climate and the transport of water within the Martian atmosphere. The basic lidar measurement technique is that a laser emits pulses of light vertically into the atmosphere and the backscattered light is collected by a telescope, detected, and recorded as a function of time, or equivalently distance. Vertical profiles of backscatter are recorded sequentially in time and this provides a continuous view of the dust and cloud layers that are drifting past the Phoenix landing sight. (See Figs. 3 and 4 in Michelangeli et al., this volume.)

The fraction of light that gets backscattered in a volume of air depends on the characteristics of the dust particles and ice crystals suspended in the air. Different wavelengths have different scattering efficiencies which depend on the size, shape, composition, and concentration of the particles. The Phoenix lidar emits and detects two wavelengths. The difference in the backscatter at the two wavelengths can provide a basis for interpreting the measurements in terms of the characteristics of the scattering particles; for example discriminating between ice and dust.

The attenuation of the lidar signal can be used to derive the optical extinction coefficient and this is related to atmospheric properties. The extinction due to dust has a first order effect on the climate at the surface of Mars. The measured optical extinction can also be related to the amount of scattering material. For example, for a thin cloud the extinction coefficient measured by a lidar can be used to derive the ice water content within the cloud; a measurement that will be of vital importance to the mission goal to investigate water on Mars.

The Field Lidar: A new lidar has been constructed at York University for use in field measurements for characterization of the Phoenix lidar. This has the same essential characteristics as the *Phoenix Lidar*. For example: the transmitted wavelengths are the same (1064 nm and 532 nm), and the same detectors are applied in the receiver. The data acquisition electronics provide the same function as in the Phoenix lidar: analog detection at 1064 nm; both analog and photon counting at 532 nm.

Field Campaigns: The scientific characterization of the Phoenix Lidar involves establishing a link between the lidar measurements and properties of the Martian atmosphere. This is being achieved with earth based field campaigns in which lidar remote sensing is combined with in situ sampling in conditions that are similar to what is expected in the Martian atmosphere. The culmination of this activity will be an atmospheric measurement campaign in which the *Field Lidar* will be operated simultaneously with the *Flight Model*. The calibration and characterization activity conducted with the *Field Lidar* will then, in a sense, be transferred to the *Flight Model* by directly comparing the backscatter signals from identical atmospheric conditions.

Two aspects of the Martian atmosphere that the lidar will observe are ice clouds and airborne dust. The first critical step in the scientific analysis of the measurements will be to discriminate between dust and ice clouds. An available method for doing this is to utilize the ratio of backscatter coefficients at the two transmitted wavelengths – the *colour ratio*. A basis for interpreting the *colour ratio* will be obtained by conducting measurements in a variety of conditions within the Earth's atmosphere. Ice clouds at temperature and humidity similar to Mars can be found in the Earths atmosphere in the tropics at heights of 15 to 18 km – cirrus clouds at the tropical tropopause. Airborne desert dust can be found in a variety of locations. The *Field Lidar* will be applied in atmospheric field campaigns with simultaneous airborne in situ measurements in tropical cirrus clouds and within desert dust.

Ice Cloud Measurements: An ice cloud measurement campaign was conducted at Darwin, Australia during January and February 2006. The Field lidar was operated from a Twin Otter aircraft while the Egrett aircraft flew directly above to acquire in-situ measurements of the cloud microphysical characteristics. The outcome of this activity will be a direct connection between lidar measurements and the microphysical characteristics of ice clouds. Particular values of the lidar colour ratio will be associated with the shapes, size distribution, and concentration of the scattering particles. Another important objective will be to relate the lidar measurements of extinction coefficient to the in situ measurements of cloud ice water content. These two data sets can then be utilized to optimize the method for deriving ice water content from the lidar extinction measurements. A comparison of lidar and in situ measurements of ice water content is shown in Figure 1.

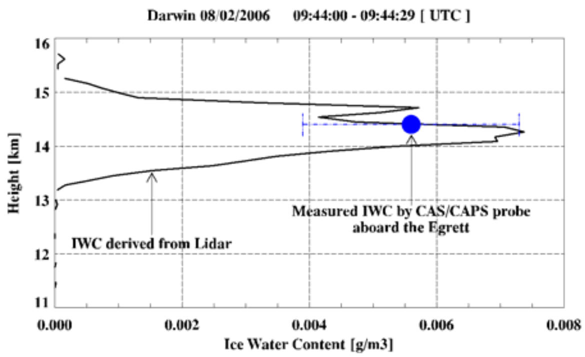

Figure 1. Ice water content in a tropical cirrus cloud derived from lidar measurements and compared with airborne in situ measurements.

Desert Dust Measurements: A field campaign to measure desert dust was carried out in Arizona during June 2006. This will provide a basis for using the lidar colour ratio to discriminate between dust and ice clouds and also a valuable experience for interpreting the Martian observations. An example of lidar measurements in an Arizona dust storm is shown in Figure 2.

Another desert dust field campaign for lidar characterization will be conducted in the Australian Desert. This will involve the application of the *Phoenix Field Lidar* on the ground and simultaneous in situ measurements from an aircraft.

Flight Model Characterization and Validation: The *Phoenix Flight Model Lidar* will be operated for atmospheric measurements simultaneously with the *Field Lidar*. The operational modes of each system will be identical to what has been specified for the lidar operations during the mission. The analysis of the campaign data will mainly involve a direct comparison of the backscatter signals in order to characterize various aspects of the *Flight Model Lidar*. For example: the transmitter-receiver alignment, the overlap range, and the linearity of the detection system. This is vital in order to identify any peculiarities in the Flight Model lidar rather than speculating on such features in the mission data.

By making a direct comparison in simultaneous observations, the measurements with the *Flight Model* during the mission can be related to the measurements in the field campaigns with the *Field lidar*. For example, the values of *colour ratio* measured with the *Flight Model* can be calibrated against what is measured with the *Field lidar* during the comparison campaign. Then the values measured in the Martian atmosphere can be related directly to *Field Lidar* measurements from a variety conditions such as dust and clouds in which there were also in situ measurements available.

The side-by-side comparison campaign will also serve as a test of the function of the *Flight Model.* The separate recorded signals should agree within the statistical variance after taking account for differences between system parameters such as output power and optical bandwidth. This will also provide a valuable rehearsal for the Phoenix Met team interactions during the mission. The side-by-side comparison is currently scheduled for November, 2006.

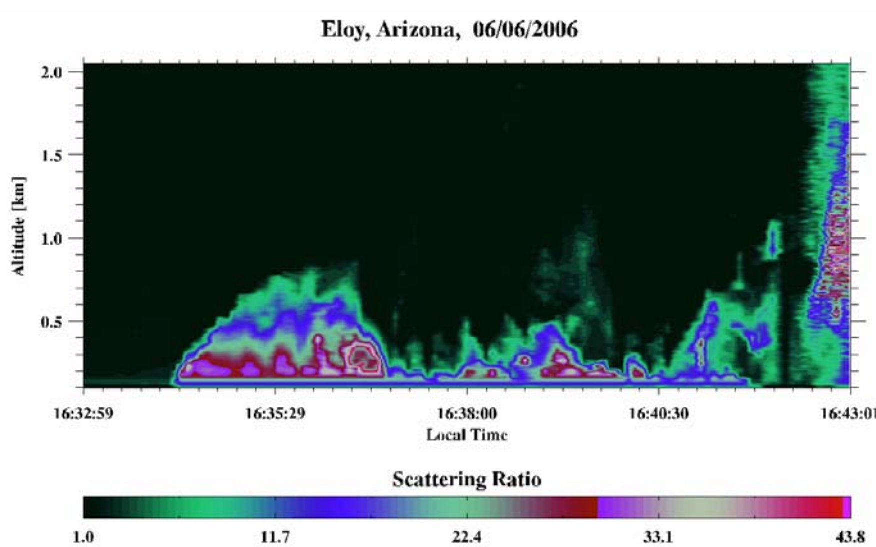

Figure 2. Lidar measurements of a desert dust storm associated with a gust front (16:34:15) from a thunderstorm. The Scattering Ratio is the ratio of the total signal to that expected with no dust; a scattering ratio of unity corresponds to a clear molecular atmosphere with no dust.