CLOUD CHARACTERIZATION WITH THE PHOENIX FIELD LIDAR

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ABSTRACT

The Phoenix Field Lidar was developed at York University, Toronto (Canada), for in field measurements for the characterisation of the on the Phoenix Mars Lander Lidar. The lidar was recently involved in the Tropical Warm Pool International Cloud Experiment (TWP-ICE) in Darwin, Australia. Preliminary analysis of cloud properties retrieved from these measurements are in good agreement with in-situ measurements of cloud microphysical properties.

1. INTRODUCTION

In June 2008, the Phoenix spacecraft will land on the northern plains of Mars. The primary goals of the mission are to investigate the history of water on Mars in all its phases, to search for evidence of a habitable zone, and to assess the biological potential of the ice-soil boundary [1].
The Phoenix lidar will measure the height distribution of both dust and clouds within the Martian atmosphere.
For the characterization of the Phoenix flight model lidar, a new lidar has been constructed at York University for use in field measurements. This has the same essential characteristics as the Phoenix flight model lidar, and will be further referred to as Phoenix field lidar. It will be involved in several earth-based field campaigns in order to provide a basis for interpreting observations on Mars. Such a basis will be obtained by combining lidar remote sensing with in situ sampling in conditions that are similar to what is expected in the Martian atmosphere. An opportunity was offered in January/February 2006 during The Tropical Warm Pool International Cloud Experiment (TWP-ICE) in Darwin, Australia. The lidar was operated from a Twin Otter aircraft along side a cloud radar, while two other aircraft (the Egrett and Proteus) flew directly above to acquire in situ measurements of the cloud microphysical characteristics. In this work, we present a brief description of the Phoenix field lidar, and show results of preliminary analysis relating the derived lidar data products (backscatter and extinction coefficients, color ratio) to the in-situ measurements of cloud properties (Ice water content, number concentration).

2. THE PHOENIX FIELD LIDAR

The basic properties of the Phoenix field lidar are summarized in table 1. It uses the first and second harmonic of a Nd-YAG laser (Big Sky Ultra), delivering a pulse energy of 20mJ (at 1064 nm) and 30 mJ (532 nm) at 20Hz.

Table 1. Basic characteristics of the Phoenix Field Lidar

Transmitter		
Laser	Nd: YAG (BigSky ULTRA)	Nd: YAG (Big Sky ULTRA)
Wavelengths	1064 nm	532 nm
repetition rate	20 Hz	20 Hz
Pulse energy	Variable: < 20 mJ	Variable: < 30 mJ
Divergence	0.3 mrad	0.3 mrad
line width	0.25 nm	0.25 nm
Receiver		
Telescope	Cassegrain 9cm Ø	Cassegrain 9 cm Ø
Field of View	0.5 – 10 mrad	0.5 – 10 mrad
Spectral width	1 nm	0.5 nm
Detector	Silicon APD (Perkin Elmer)	PMT (Hammamatsu R7400P)
Acquisition (Licel TR-20)	Analog: 12 bit ADC	Analog: 12 bit ADC + Photon Counting
Sampling frequency	20 MHz (7.5 m)	20 MHz (7.5 m)

3. MEASUREMENTS AND DATA ANALYSIS

One of the most complete data sets of tropical convection was collected during the recent TWP-ICE campaign. The Phoenix field lidar was flying on a Twin Otter aircraft at about 10000 feet, pointing upward, mapping the cloud structure above the aircraft. Data have been acquired for more than 40 flight hours. In situ measurements were acquired simultaneously by the Egrett and Proteus, flying within the cloud being mapped by the lidar.
Several algorithms have been developed that successfully retrieve cloud boundaries, cloud optical depth and effective Lidar Ratio [2], color ratio as well as profiles of backscatter and extinction coefficients.
Fig. 1 shows an example of a measurement section selected for analysis, using the lidar signal obtained with the photon counting channel at 532 nm between 10:29 and 10:31 UTC on February 8, 2006. The top and the base of the cloud are determined by comparing the measured lidar profile with a reference lidar profile (in this case, the lidar signal from the molecular

atmosphere) within a given threshold. The effective cloud transmittance is calculated from the ratio of the lidar calibration factors obtained above and below the cloud. Results of the analysis are presented in Table 2 for 3 different cases, together with a summary of some of the cloud properties presently being retrieved from the measurements. Of particular importance is the color ratio [3], which will be used to discriminate between dust and clouds. Values of cloud color ratio [1064 nm]/[532 nm] will be directly related to the other cloud properties.

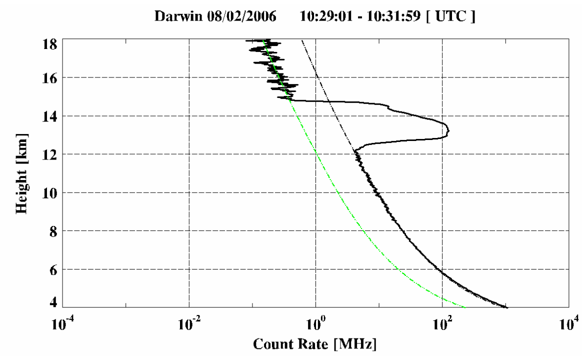

Fig. 1. Signal from cirrus cloud between 12 and 15 km. Reference signal from the molecular atmosphere above and below the cloud is also shown (dotted line)

Table 2. cloud properties retrieved from Phoenix field lidar (□= Extinction Coefficient; □= Optical depth; IWC = Ice Water Content).

Cloud Parameter	**23/01/2006 05:25-05:30**	**08/02/2006 10:29-10:31**	**10/02/2006 09:32-09:39**
Top [km]	7.8	14.8	12.5
Base [km]	5.3	12.3	9.5
□(at 532 nm)	0.69	0.54	0.87
□ [1/km]	0.27	0.22	0.3
IWC [g/m^3]	0.0053	0.004	0.005
Lidar Ratio	14.7	18.5	15
Color Ratio [1064]/[532]	0.6	0.7	0.75

Another important objective of the analysis is to relate lidar measurement to ice water content [4]. Fig. 2 shows a reasonable agreement between the profile of ice water content derived from lidar using the method of Heymsfield et al [4], and that measured in-situ by the CAS/CAPS instrument aboard the Egrett on February 8, 2006. The same instrument measured a particle concentration of 5.5 crystals per cubic cm.

A future field campaign for desert dust will take place in Arizona during June 2006, and will provide similar data for desert dust.

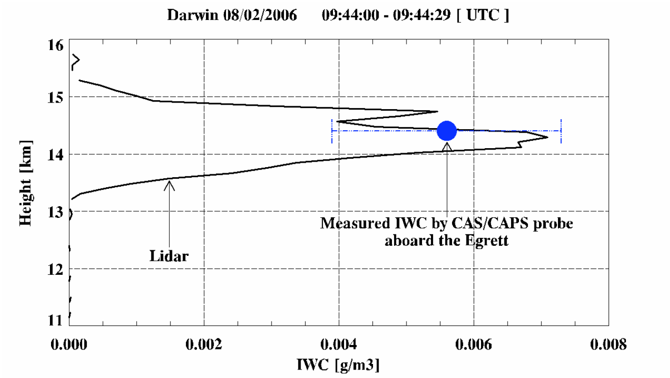

Fig. 2. Ice Water Content (IWC) derived from Phoenix field lidar measurement. In-situ measurement by CAS/CAPS is also shown.

4. CONCLUSION

In this work we have presented preliminary analysis of some measurements acquired using the Phoenix field lidar. A database is being created, which will relate color ratio and extinction retrieved from lidar measurements with the concentration and shape of the scattering particles. This will then provide a basis for differentiating between ice clouds and dust in the lidar measurements conducted during the Phoenix mission.

5. REFERENCES

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