OBSERVATIONS OF POLAR NIGHT CLOUDS WITH THE MARS ORBITER LASER ALTIMETER (MOLA).

Anton B. Ivanov and Duane O. Muhleman, California Institute Of Technology, MS 150-21, 1205 E. California blvd., Pasadena, CA, 91125, anton@gps.caltech.edu

Condensation of CO_2 is an important process for the formation of the perennial ice caps on Mars. CO_2 ice may form on cold surface when temperatures are low enough (~146K) or condense in the atmosphere and fall down on the surface as snow. This paper will focus on observations of CO_2 clouds during the polar night by the Mars Orbiter Laser Altimeter (MOLA). We will interpret MOLA measured height, reflected energy and returned pulse width in terms of microphysical cloud properties.

MOLA is an instrument onboard of the Mars Global Surveyor (MGS) spacecraft, which has been orbiting Mars since September, 1997. Primary goal of MOLA is to measure the topography of Mars. In addition to the range, it can also return reflected energy of every pulse and returned signal pulse width. In case of a ground return, the former is a measure of albedo of the surface and the latter is a measure of the surface roughness within the MOLA footprint. Up to this date, MOLA was able to perform observations during both north (L_s=300-7) and south (L_s=103-136) polar nights. Numerous cloud reflections were detected, which provided first direct observational evidence of clouds during the Martian polar night. MOLA can not distinguish composition of the clouds, whether they are made of water or CO_2 ice. However, it has been suggested (e.g. [1],[4]) that CO_2 clouds may exist at this period. Figures 1 and 2 display spatial distribution of the clouds returns over the North and South poles, respectively. The most extensive cloud formations at both poles are confined to the region over the residual ice caps. A small number of clouds can be associated with topographic features (such as craters) off the ice caps. In addition, in the South there is a type of clouds that was not seen in the North. These clouds are confined in the 68S-78S latitude band and appear episodically over almost all of the longitude range. They do not exhibit as distinct cloud tops like the clouds over the residual caps, but spread out from the ground up to about 7km elevations over the ground. These lower latitude clouds also appear to be correlated with the low emission zones reported by the IRTM instrument on board the Viking Orbiter spacecraft [3], later interpreted as condensing CO_2 snow fall [2].

Cloud echoes are detected when the backscattered energy integrated over a receiver range window exceeds a set threshold. This primarily occurs in clouds with sharp tops on scales of a few meters to the order of about 100 meters. The maximum pulse width MOLA is able to measure is about 160m (two-way). In other words, MOLA can only probe ~80m into the cloud. Since the range gate is closed after the first detection, we do not have any information about the underlying surface or atmosphere under the layer of detection. Based on the observations, we can distinguish two cloud types. Type 1 clouds are illustrated at fig. 3a. We encounter them over both northern and southern ice caps. They are usually confined over the residual ice caps. On fig. 3a blue crosses show returns in channel #4. This channel responds to returned pulse width of about 160 m. This is the maximum pulse width MOLA can detect. Type 2 clouds are illustrated on fig. 3b. This type of clouds was only seen in the south, confined to 68S-78S latitude range. Note that horizontal scale on fig. 3b is larger than on fig. 3a. Most of the returns for this type are in channel 1. This channel responses to the shortest pulse width and designed for detecting reflections off the surface. Response from a cloud in channel 1 indicates a very sharp top, especially compared to clouds of type 1. The width of pulse necessary to trigger detection for type 2 clouds is only 5m, where as type 1 is 160m meters. This indicates high values of particle number density gradients right at the top of the clouds. Moreover, type 2 cloud returns do not form lines, like type 1 clouds the ice caps, but they spread from the surface up to 5-7 km elevations.

MOLA observations of cloud elevations and properties of the cloud tops unable to provide information about the mechanism of cloud formation. Adiabatic and radiative cooling are the most important processes, but we are uncertain about their relative contributions. Topography plays a role here and excites atmospheric waves. Pettengill and Ford suggested ([5]) gravity waves as a mechanism for formation of the clouds over the North Pole (type 1). GCM model runs with precise MOLA topography may provide more information about these processes and especially in formation of type 2 clouds.

MOLA cloud height observations present first direct observational evidence for existence of polar night clouds. Extensive coverage during Science Phasing Orbit and mapping orbits is an excellent dataset, which allows analysis of spatial and temporal variations of cloud heights. Some information about cloud tops can be extracted from returned energy and pulse width measurement. At this point we can identify two types of clouds, possibly due different mechanisms of their formation. Temperature maps from the TES instrument team and future Radio Science temperature-pressure profiles will provide us with more insight into radiative properties of the clouds and cloud forming conditions.

References.

[1] Gierasch P. J. and Goody R. A study of the thermal and dynamical state of the mars atmosphere. *Planetary Space Science*, 16:615--646, 1968.

[2] Forget et al. (1998), CO2 Snowfall on Mars: Simulation with a General Circulation Model, *Icarus*, 131, 302-316

[3] Kieffer et al. (1976), Infrared thermal mapping of the martian surface and atmosphere: First results. *Science*, 193, 780-786

[4] Paige, D. A. (1985). The Annual Heat Budget of the Martian Polar Ice Caps from Viking Observations. Ph.D. thesis, Caltech.

[5] Pettengill G. H. and Ford P. G. (1998) Atmospheric Gravity Waves in the Martian North Polar Cap Winter, *EOS suppl.*, v79, 45.

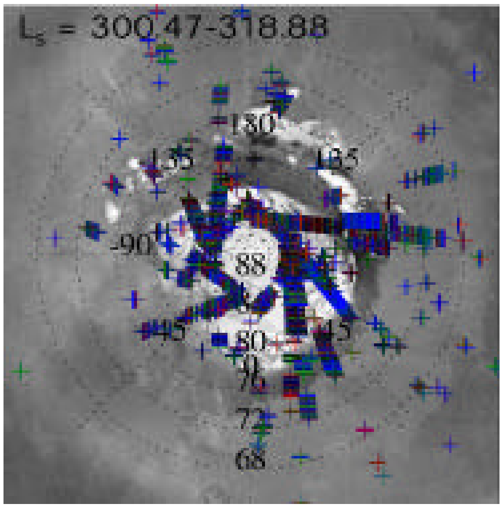

Figure 1. Distribution of cloud returns over the Northern Ice Cap. Observational period used to construct this figure is L_s=300-7. Most of the returns are in channel #4 (blue crosses). Other colors: channel #1 - black, channel #2 - green, channel #3 - red. Note, that most of the returns are concentrated over the permanent ice cap

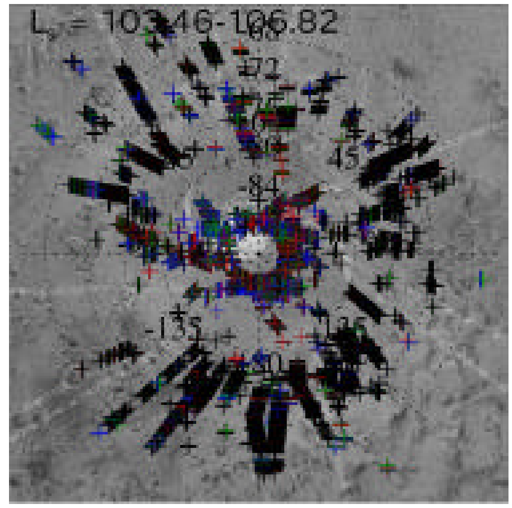

Figure 2. Distribution of cloud returns over the Southern Ice Cap (L_s=105-107). Channel #4 returns are concentrated over the ice cap, like in fig. 1. Note cloud formations in the 68S - 75S latitude band, which were not observed at the North Pole (fig 1). The latter clouds are mostly returns in channel #1 (sharp tops)

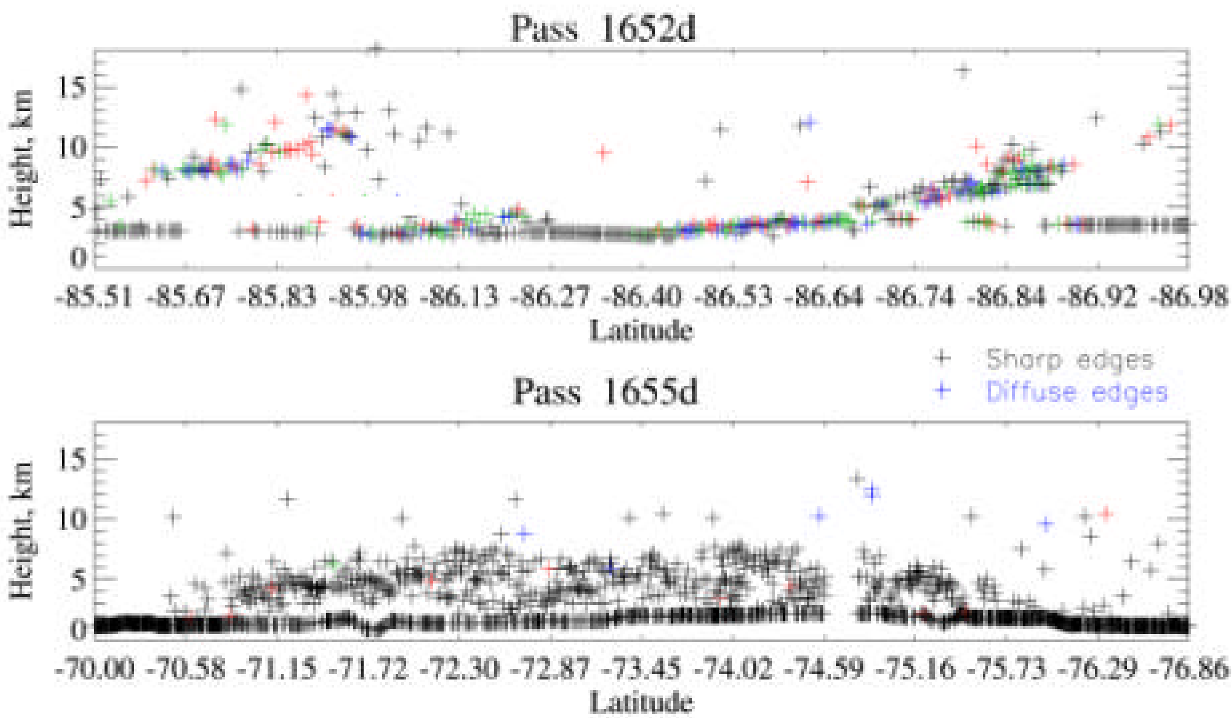

Figure 3. a) (upper panel) Example of a cloud structure over the permanent southern ice cap. Note that most of the returns correspond to a diffuse (gaussian) cloud top. These clouds are called type 1 in text and can be seen over the North Pole as well as over the South Pole. VE ~ 3:1. Due to range gate settings on MOLA, observations are biased towards detection of clouds about 15 km above the surface. b) (lower panel) Example of a cloud structure near southern permanent ice cap. Note that most of the returns correspond to a very sharp (delta function) cloud top. These clouds are called type 2 in text. They resemble a ground fog. VE ~ 6:1