THE ANNUAL CYCLE OF CO$_2$ SNOW DEPTH AT MARTIAN POLAR CAPS FROM MOLA DATA  J. J. Jian$^1$ and W. H. Ip$^1$, $^1$ Institute of Astronomy, National Central University, Taiwan (d909003@astro.ncu.edu.tw, wingip@astro.ncu.edu.tw)

**Introduction:** The Martian polar caps of CO$_2$ ice play a unique role in the atmospheric structure and meteorology of this planet. As a result of the seasonal variation of the solar radiation on the polar regions, CO$_2$ will alternatively condense during the winter time and sublimate during the summer time. These changes of the seasonal cap margins are almost repeatable from year to year [5]. Such process, on the one hand, controls the sizes of the CO$_2$ year to year [5]. Such process, on the one hand, controls the sizes of the CO$_2$ frost layers and, on the other hand, enforces the exchange of CO$_2$ content between the polar caps and the atmosphere. On the north pole, the residue cap is of H$_2$O composition [4,12] while in the south the residue cap is partly covered in CO$_2$ and partly in water ice [2,11,17]. The study of the time evolution of the Martian polar caps could therefore have important implication on the evolution and inventory of water and carbon dioxide reservoirs on Mars.

North and south polar regions of Mars are affected by the CO$_2$ that stored in the atmosphere. In a seasonal cycle, 25% of the mass of the atmosphere has been estimated to exchange with the surface [10]. A seasonal pressure change was observed at the Pathfinder landing site over a small fraction (12%) of one Martian year [20]. Through the radiative balance calculations [16,18,19] and general circulation model [7] and pressure data of Viking estimate the maximum condensed height was about 1m [1].

The Mars Orbiter Laser Altimeter (MOLA) on the Mars Global Surveyor (MGS) spacecraft provided unprecedented accurate measurements of the topography of Mars [28]. Smith et al. (2001) used the MOLA data collected over one Martian year (1999-2001) to examine the seasonal variations of the CO$_2$ snow depth by analyzing the elevation profiles within two latitudinal annuli between 60$^\circ$-87$^\circ$N and between 60$^\circ$-87$^\circ$S. They found that on the north the CO$_2$ frost was reduced to the minimum level at L$_s$ ~ 90$^\circ$ – 150$^\circ$ and reached to the maximum thickness $\Delta h_{\text{max}}$ at L$_s$ ~ 320$^\circ$-390$^\circ$. The $\Delta h_{\text{max}}$ value varies from 0.4 m at 77.5$^\circ$N to 1.2 m at 86.5$^\circ$N. In contrast, $\Delta h_{\text{max}}$ between 0.5-1.0 m takes place at L$_s$ ~ 150$^\circ$ and an apparent minimum at L$_s$ ~ 240$^\circ$ on the south pole. This sublimation and condensation cycle clearly follows the pattern of solar radiation variations. More recently, Mitrofanov et al. (2003) and Litvak et al. (2003) reported the measurements of the time variations of the global CO$_2$ deposit from the High Energy Neutron Detector (HEND) experiment on the Mars Odyssey spacecraft. From the seasonal variations of the energetic neutron flux from 1 MeV up to 10 MeV, the HEND experiment could be used to probe the presence of CO$_2$ frost up to a thickness of about 20 cm. From the time sequence of maps these authors found that the behaviors of CO$_2$ caps on south and north are very different from each other. At the same time, they also showed that the thickness of CO$_2$ coverage on the north with a value of $\Delta h_{\text{max}}$ is substantially larger than the corresponding value on the south pole.

**Data analysis:** The data analyzed in the study were from Mars Orbiter Laser Altimeter (MOLA) on the Mars Global Survey (MGS) to measure the seasonal cycle of CO$_2$ which between the atmosphere and surface of polar latitude region of Mars. In the accurate determination of the CO$_2$ frost thickness, the most important thing is to compute the crossover residuals resulting from subtracting the altitude (h) of a certain location at some value of L$_s$ to the reference altitude ($h_{\text{ref}}$) at this location at a fixed value of L$_s$(0). (In this work, L$_s$(0) = 120$^\circ$ for the north and 300$^\circ$ for the south). This task would require the extraction of as many points as possible where the trajectories of the MGS spacecraft intersected. Because the CO$_2$ deposit is quite little equatorially ward of 70$^\circ$N and 70$^\circ$S, we have limited our consideration to a latitudinal band between 71$^\circ$ and 85$^\circ$ in both poles. The upper limit is set by the small number of crossover points beyond 85$^\circ$ latitude. At a particular L$_s$, we select data which are 5$^\circ$ behind and after this L$_s$. And we chose several small and smooth area(< 1$^\circ$) in each bin. The small area is about 0.1$^\circ$ ~ 0.2$^\circ$ in longitude and 0.05$^\circ$ in latitude. We then calculated residuals of elevations of different L$_s$ in small area by average all of the residuals in each 1$^\circ$ x 15$^\circ$0 bin. The average of the $\Delta h$ values from these subbins will be used as the representative value of the corresponding 1$^\circ$x15$^\circ$ bin at a particular L$_s$.

**Result:** For each spatial bin, we use the Fourier transform to calculate the elevation changes of different L$_s$. Fig 1 (a) ~ (j) show the result of elevation changes in north polar area from L$_s$=30$^\circ$ to 330$^\circ$. The latitudes of these figures range between 71$^\circ$ and 85$^\circ$ in the north polar area. The interval between these two figures is 30$^\circ$. It is obviously that the elevation change increases with latitude. The maximum elevation change happens at L$_s$=330$^\circ$. At that time the elevation changes northern than 80$^\circ$ are between 0.6 ~ 1.15m. The minimum height change happens at L$_s$=150$^\circ$. After L$_s$=150$^\circ$ the condensation of ice increases slowly until the winter solstice after which the CO$_2$ ice
condensation increases significantly. The results of the south polar area are shown in Fig 2 (a) ~ (j). The latitudes of these figures range between 71° and 85° in the south polar area. The interval between these two figures is 30°. The maximum elevation change happens at Ls=150° and the elevation change is about 0.96m. There is an inverse relationship between the elevation changes of northern polar cap and southern polar cap. The variations of height are lower on the south polar cap than the north one.

![Fig. 1](Lunar and Planetary Science XXXVII (2006) 1777.pdf)

Fig. 1 The elevation changes at different Ls on the north pole. (a) Ls=30° (b) Ls=60° (c) Ls=90° (d) Ls=150° (e) Ls=180° (f) Ls=210° (g) Ls=240° (h) Ls=270° (i) Ls=300° (j) Ls=330°. Coordinates are areocentric with an east positive longitude convention. Latitude is between 71° and 85° N. Height change is shown as color-coded elevation.

**Conclusion:** Our results demonstrate that most of the surface elevation changes at late winter and the lowest elevation changes were observed at late summer in both hemispheres. In the same Ls, most of the accumulation was greater in the high latitude than in the low latitude at both pole. The maximum thickness of CO₂ ice on the north is 1.15 m which is more than at south pole.