AUTOMATIC EXTRACTION AND TEMPORAL MONITORING OF AREA UNDER SNOW/ICE IN NORTH POLAR CAPS OF MARS USING MARS COLOR CAMERA ONBOARD MARS ORBITER MISSION. Rohit Nagori, Aditya Dagar, A. S. Arya, Space Applications Centre, Indian Space Research Organization, India (rohitnagori@sac.isro.gov.in)

Introduction: Mars has two permanent ice caps. The northern ''permanent (residual) cap'' consists of H_2O ice [1] [2] which covers nearly the entire polar layered deposit surface. As 95 percent of the Martian atmosphere by volume is made up of CO_2, approximately 25 percent of the atmosphere condenses and sublimates annually at poles making this cycle a major driver in the current global climate [3] [4] [5]. In this study, an attempt has been made to extract the areal extent of snow/ice of North Polar cap from MCC images.

Data: Mars Orbiter Mission (MOM), the first inter-planetary mission of Indian Space Research Organization (ISRO) is maiden Indian mission and the first one to orbit Mars in its very first attempt. The mission has a unique and highly elliptical Martian orbit of about 261 km (Periareion) and 78,000 km (Apoareion). Mars Colour Camera (MCC), a Bayer Array RGB camera operating in the visible range (0.4-0.7 µm) [6], is a medium resolution camera flown onboard MOM. It captures images of Martian surface and helps in furthering our understanding of events like dust storms, dust devils etc. Its spatial resolution varies from about 15 m to 4 km per pixel. Eight MCC's images have been utilized in our study taken from varying altitude of 54,742 km to 71,217 km during the time range of 24 December 2015 (Ls ~ 85) to 22 January 2016 (Ls ~ 98). All these images are of Martian disc showing partial N-Polar Caps to varying extent and for different viewing geometry.

Methodology: MCC images along with the grid file of latitude and longitude were used for this study. Latitude and longitude are provided in form of data values against the lines_samples and lines corresponding to each pixel, sometimes after regular skipping of intermediate pixels. In order to geo-reference, we need to prepare geographic lookup table (GLT) where we need to have latitude and longitude data at each pixel which are assigned to these intermediary pixels using sine function (as image is the 2D representation of 3D object) as the interpolating function. Radiance images have been utilized in our study in which the region near to N-Polar Caps is extracted and projected using Polar Stereographic projection with Mars' datum having semi-major and semi-minor axis's values as 33,96,190.0 m and 33,76,200.0 m respectively (IAU 2000 Ellipsoid for Mars). The images are normalized such that the brightest snow/ice pixel has the value 1. Five out of eight images have been used for the development of region of interests (ROI). Seven classes are defined as class 1: Bright snow/ice on Polar cap; class 2: Snow/ice on the boundary of polar cap contaminated with dust; class 3: Black soil in nearby areas; class 4: Red soil in nearby areas; class 5: Snow/ice on the edge of MCC's image; class 6: Areas having black soil contaminated with dust; and, class 7: Areas on edge of MCC's image. Using statistics from ROI's, means along with standard deviations are plotted in feature spaces (formed by combinations of different bands) and linearly separable conditions are determined in order to formulate decision boundaries. A program is developed in Interactive Data Language (IDL) to automatically extract the area on the basis of the conditions imposed on the images. While running the program on left out 3 images, decision boundaries are refined by visual inspection.

Results and Discussion: Using the above developed algorithm, aggregate area under Snow/Ice in the North Polar region of Mars was found to be 10,87,230 square km during 24 to 26 December 2015. Area under Snow/Ice compared for common region of Mars' North Polar Cap (Figure 3) during 24 to 26 Dec 2015 and 22 January 2016 showed decrease of 33.47 percent in area from 9,52,700 square km to 6,33,825 square km due to sublimation of ice.

Conclusions: A drastic change is seen in the extent of snow/ice cover due to sublimation of ice which in turn affects a number of weather related phenomena. Thus, monitoring the temporal changes in snow/ice extent is essential for understanding the Martian weather. In future, the yearly/decadal variations in the spatial extension of snow/ice cover for the different seasons will be studied with the help of MCC data and Mars Orbiter Camera data (onboard Mars Global Surveyor).

References: [1] Kieffer H. et al. (1976) Science, 194, 1341– 1344. [2] Bibring J. P. et al. (2004) Nature, 428, 627–630. [3] Tillman J. E. et al. (1993) J. Geophys. Res., 98, 10,963–10,971. [4] Forget F. and J. B. Pollack (1996) J. Geophys. Res., 101, 16,865–16,879. [5] Kelly N. J. et al. (2006) J. Geophys. Res., 111, E03S07. [6] Arya A.S. et.al (2014), *LPS XXXXV*, Abstract# 2449.

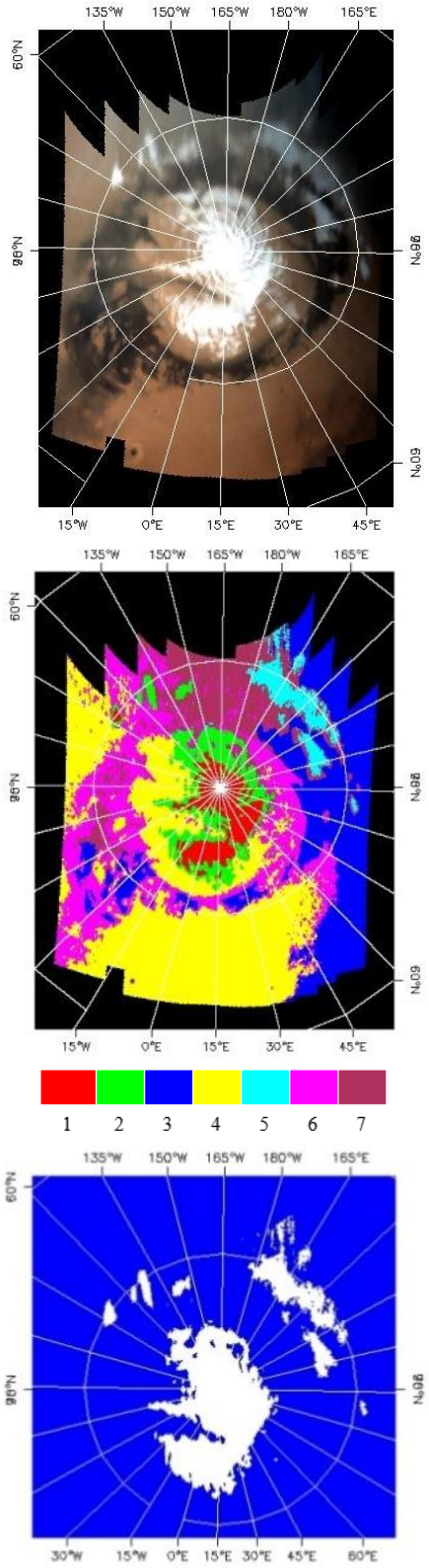

Figure 1: Mars N-Polar projected image of 22-01-2016 (top) and classified image (middle) showing different classes. Bottom figure shows the area under Snow/Ice on 22-01-2016 which is estimated to be 7,06,426 square km.

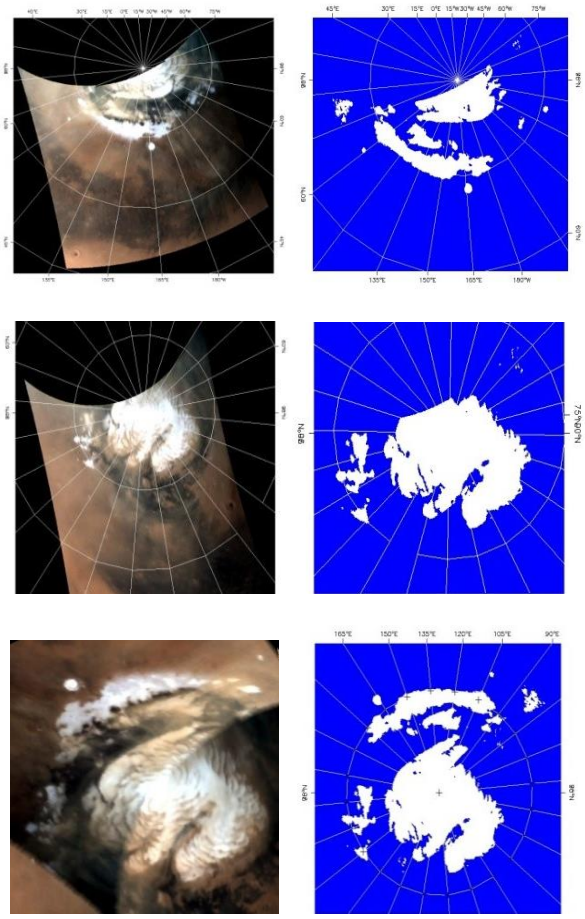

Figure 2: Mars N-polar images of 24 Dec (top row) and 26 Dec, 2015 (middle row) showing the extracted area under Snow/Ice from algorithm. The mosaic (bottom row) shows the total area under snow/ice as 10,87,230 square km during 24 to 26 Dec, 2015.

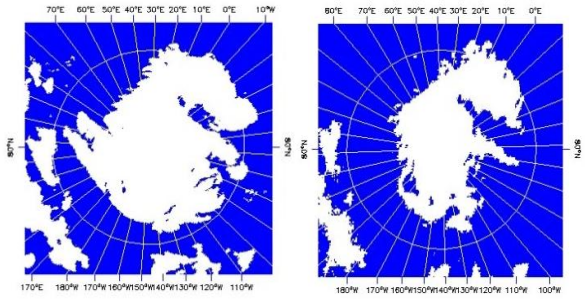

Figure 3: Comparison of area under Snow/Ice for common region of N-polar Caps of Mars during 24-26 Dec 2015 (left) and 22 Jan 2016 (right).