Seasonal Variations of Orographic Clouds on Mars with MRO/MARCI observations and the LMD Mars Global Climate Model

*Anton M. Fernando[a,b], Michael J. Wolff[c,a] and François Forget[d]
[a]Laboratory for Atmospheric and Space Physics, Boulder, CO 80303, USA
[b]Space and Planetary Science Center, Khalifa University, Abu Dhabi, UAE
[c]Space Science Institution, Boulder, CO 80301, USA
[d]Laboratoire de Météorologie Dynamique/IPSL, Sorbonne Université, ENS, PSL Research University, Ecole Polytechnique, CNRS, Paris, France

Abstract

The formation of water ice clouds can significantly influence the Martian climate, although the Martian atmosphere contains low water vapor concentrations compared to terrestrial levels. The lower Martian atmosphere exhibits three types of global water ice cloud systems: Aphelion cloud belt (ACB), polar hoods (PHs) and orographic clouds. These clouds are associated with topography, solar heating, global atmospheric circulation, wave activity and local convection. Although an appreciable amount of research has been conducted on the first two regimes (ACB and PHs) and very little attention has been given to the third regime (orographic clouds). In general, orographic clouds are observed in northern spring and summer since they are associated with the major Martian volcanoes. Water ice optical depths provided by Mars Color Imager (MARCI) of Mars Reconnaissance Orbiter (MRO) will be used to investigate seasonal variations of such clouds in four volcanic regions: Alba Patera, Olympus Mons, Tharsis region and Elysium Mons. The observed seasonal variations of water ice clouds over volcanic regions are not well understood, and thus context will be provided using the meteorological fields from LMD-MGCM (Mars Global Climate Model led by Laboratoire de Météorologie Dynamique Paris, France).

Keywords: Mars, water ice clouds, MRO/MARCI, LMD-MGCM.

1 General Information

The MARCI is one of the instruments on NASA Mars Reconnaissance Orbiter (MRO) and a wide-angle, low resolution (1 - 10 km) imaging system which operates in five visible and two ultraviolet (UV) bands. The MARCI water ice cloud optical depth retrievals are obtained by the longer wavelength channel of the two MARCI UV bands (Band 7 $\sim$ 320 nm) [5, 1]. The MARCI provides daily global coverage from 13 to 14 south-to-north mapping swaths from a sun-synchronous orbit. The center line of these swaths are separated by $\sim 27^\circ$ in longitude and at local time near 15h00 true solar time (LTST). The data were discarded for emergence angles greater than 70° and the downlinked pixel field-of-view provides 8 km at nadir [5].

The LMD-MGCM takes dust loading of the atmosphere into consideration, which is the main driver of the Martian climate, and provides a series of dust scenarios: standard year (climatology), cold (low dust), warm (dusty atmosphere) and dust storm [3, 4, 2]. Additionally, the LMD-MGCM provides “add-on" scenarios that represent individual Martian years 24 to 34. The LMD-MGCM does not provide water ice optical depths and only offers water ice columns for Martian year scenarios. In this study, water ice columns provided by the LMD-MGCM using the “standard year" dust scenario (combining all “non-global dust storm” years MY 24 - 31) were converted into water ice optical depths using 1.6 µm as the average particle size to directly compare with MARCI water ice optical depths.

2 MARCI water ice clouds

Figure 1 shows MARCI annual average water ice optical depths versus L_s of the major Martian volcanic regions for Martian years 28 - 33. In general, MARCI water ice optical depths over Olympus Mons, Parvonis Mons and Ascraeus Mons show similar features (one peak around L_s = 100°) in contrast to that of Alba Patera and Arsia Mons. Arsia Mons exhibits clouds throughout the year and clouds in Alba Patera show two peaks around L_s = 70° and L_s = 140°. Water ice clouds over Elysium Mons also show two peaks, but the peak at L_s

= 70° is less prominent than the peak at L_s = 110°.

3 Method

Although, the MARCI/MRO has been operating since the Martian year 28 and provides data for 7 continuous Martian years, it only samples one local time (15h00 true solar time). Therefore, MARCI data are only suitable to study seasonal and inter-annual variations of evening water ice clouds.

The boundaries of the volcanoes should be determined in order to investigate seasonal variations of MARCI water ice optical depths. Once the boundaries are established, an average water ice optical depth will be calculated for each major volcanic region (Figure 1) to identify the main seasonal features. Finally, these water ice optical depths will be compared with the meteorological outputs of the LMD Mars global climate model and this comparison will reveal how local topography and meteorological variables are correlated with the seasonal variations of water ice clouds in each volcanic region.

References

[1] J. F. Bell III, M. J. Wolff, M. C. Malin, W. M. Calvin, B. A. Cantor, M. A. Caplinger, R. T. Clancy, K. S. Edgett, L. J. Edwards, J. Fahle, F. Ghaemi, R. M. Haberle, A. Hale, P. B. James, S. W. Lee, T. McConnochie, E. Noe Dobrea, M. A. Ravine, D. Schaeffer, K. D. Supulver, P. C. Thomas, Mars Reconnaissance Orbiter Mars Color Imager (MARCI): Instrument description, calibration, and performance, Journal of Geophysical Research: Planets 114 (E8) (2009) S92.

[2] F. Forget, F. Hourdin, R. Fournier, C. Hourdin, O. Talagrand, M. Collins, S. R. Lewis, P. L. Read, J.-P. Huot, Improved general circulation models of the martian atmosphere from the surface to above 80 km, Journal of Geophysical Research: Planets 104 (E10) (1999) 24155–24175.

[3] L. Montabone, F. Forget, E. Millour, R. Wilson, S. Lewis, B. Cantor, D. Kass, A. Kleinböhl, M. Lemmon, M. Smith, M. Wolff, Eight-year climatology of dust optical depth on mars, Icarus 251 (2015) 65–95.

[4] L. Montabone, A. Spiga, D. M. Kass, A. Kleinböhl, F. Forget, E. Millour, Martian year 34 column dust climatology from mars climate sounder observations: Reconstructed maps and model simulations, Journal of Geophysical Research: Planets 125 (8) (2020) e2019JE006111.

[5] M. J. Wolff, R. T. Clancy, M. A. Kahre, R. M. Haberle, F. Forget, B. A. Cantor, M. C. Malin, Mapping water ice clouds on Mars with MRO/MARCI, Icarus 332 (2019) 24–49.

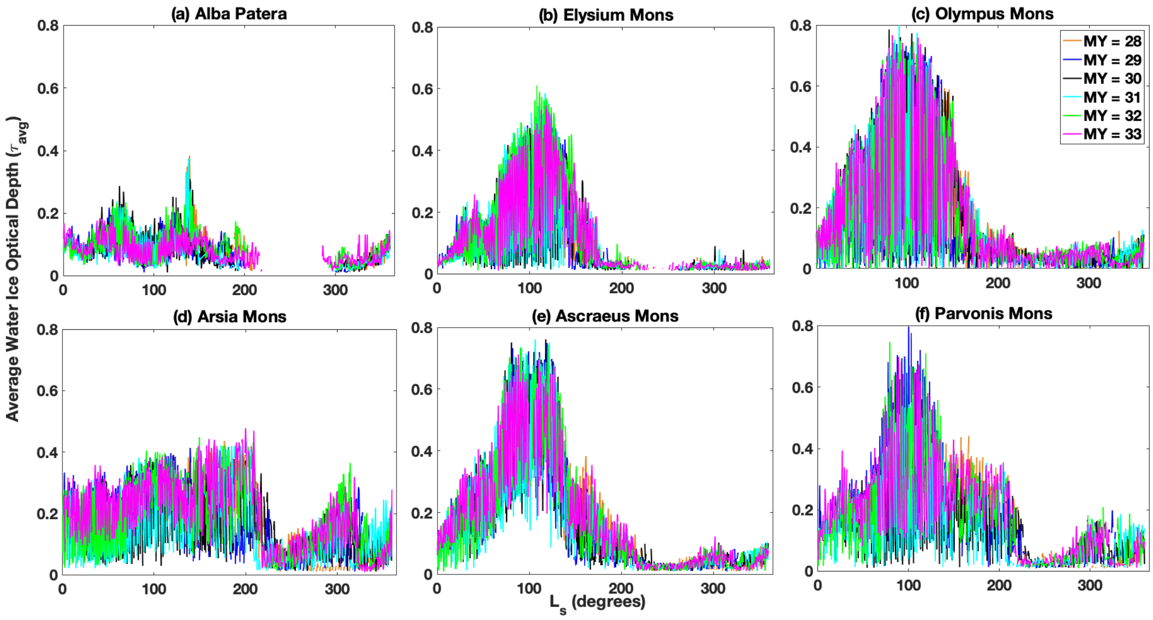

Figure 1: Average water ice optical depths against L_s of the volcanic regions a) Alba Patera, b) Elysium Mons, c) Olympus Mons, d) Arsia Mons, e) Ascraeus Mons and f) Parvonis Mons from MRO/MARCI for Martian years 28-33