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Construction and use of a 4D cloud database derived from MEx/OMEGA data – Cloud life cycle over polar regions

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Abstract

We have derived a product characterizing water ice clouds from a long series of OMEGA images covering 7 Martian years, the ice cloud index (ICI). Individual ICI pixel values are binned onto a 4D regular grid (longitude, latitude, solar longitude Ls and local time LT). The resulting gridded ICI enables the (partial) climatological reconstruction of the diurnal cloud life cycle by aggregating values from large regions, covering several degrees of longitude and latitude during specific seasons. Clouds are more frequent around summer solstice (Ls=45-135°) early in the morning and in middle and late afternoon than around noon (12 h LT) in the tropics and northern low to mid-latitude regions (lat < 40°N). In the north polar region (lat > 75°N), clouds are present during a large part of the long daytime period during northern spring before disappearing abruptly around Ls=55°. In the south polar region (lat < 75°S), clouds present mainly in the afternoon disappear more progressively and mainly during southern spring around Ls 230-250°, before reappearing more abruptly at the end of southern summer, around Ls=340°.

We also plan to compare the ICI from OMEGA to water ice optical depth derived from MARCI/MRO reflectances and expect to find a qualitative agreement between both datasets on cloudy areas.

1. Introduction

Due to their heliosynchronous orbits, most recent and current Martian satellites have observed the planet only at a specific local time (LT) during the day (typically at 2-3 p.m. and 2-3 a.m. LT) over most regions except around the poles, and therefore cannot provide information about the diurnal cloud life cycle. Recently launched satellites MAVEN, MOM/Mangalaayan and Exomars/TGO) move along non-heliosynchronous orbits, but have only provided images at best over a short period (~2 years). The OMEGA spectrometer onboard the Mars Express (non-heliosynchronous) satellite has been providing spectral images at various times of the day over ~7 Martian years (MY 26-33, i.e. 2003-2016). For each valid pixel from this abundant spectral image data, we derived parameters representative of the presence and abundance of clouds and used them to construct a daily and annual climatology on a regular spatial grid.

2. Methodology

The detection of clouds is based on the measure of the depth of a water ice absorption band, initially applied at 1.5 μm [1]. In practice, we now use the slope of an absorption band around 3.4 μm to define the original ice cloud index (ICIo) and the reversed ice cloud index (ICI = 1 – ICIo) [2]. After comparison with a threshold value, this ICI indicates if the pixel is cloudy or not.

In a second step a cloud climatology is constructed. The ICI values of pixels are binned into a 4D array according to their longitude, latitude, Ls and LT, and then averaged. The bins have sizes of 1° in latitude and longitude, 5° in Ls and 1 (Martian) hour in LT. Due to the small number of 4D gridpoints containing valid ICI data (~2% of daytime gridpoints), we integrate and average several gridpoints covering larger spatial areas and longer time periods in order to form 2D subsets showing the evolution of clouds.

3. Seasonal cloud life cycle

We show the annual cloud life cycle over different periods of the day : morning (6-10 h LT), noon (10-14 h LT) and afternoon (14-18 h LT), on Ls–lat diagrams (fig. 1). During all 3 periods, cloudiness (i.e. high values of ICI) are present and dominant in the same areas wherever data is available, namely at the edge of the polar hoods (or belt) and in the tropics during northern summer (Ls=30-150°, aphelion belt). The main difference is the relative attenuation of cloudiness around noon in the aphelion belt, explained by the presence of a thermal tide.

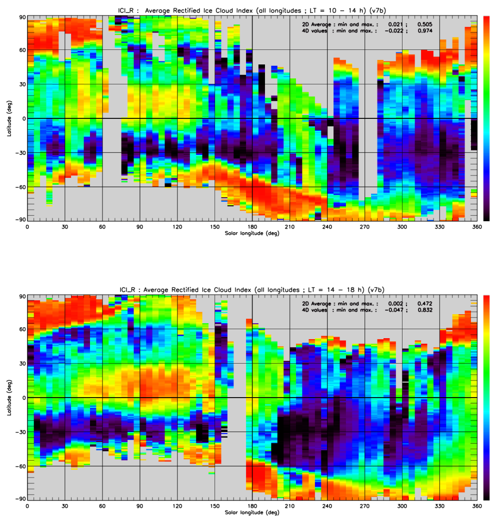

Figure 1 : Ice Cloud Index (ICI) as a function of Ls (solar longitude) and latitude, all longitudes, around noon (10-14 h LT ; top) and in the afternoon (14-18 h LT ; bottom). Color scale : black: no cloud ; from purple (low ICI, thin clouds) to red (high ICI, thick clouds) ; gray: no data.

4. Cloud life cycle at the poles

We have averaged the 4D ICI values around each pole (at latitude > 75°). Figure 2 shows that during the long period of solar illumination in northern spring, clouds are abundant at all times during the day (6-18 h LT) after Ls=30°, but also in the evening (18-24 h LT) after Ls=35°. Clouds are less abundant in the early morning (0-6 h LT). They disappear completely at Ls=70°. Clouds around the south pole evolve with a more progressive pattern : clouds are present and abundant durning early spring (Ls=180-200°), are then present during the late evening and early morning (LT=19-5h LT). The cloud cover decreases progressively until summer solstice. An abrupt increase of cloudiness can be observed at the end of summer, at Ls=330°, at different instants of the day and the night.

4.1. Comparison of MARCI-derived optical depth and ICI

In order to validate the OMEGA-derived ICI, we will compare ICI values with water ice optical depth values derived from MARCI data, and resampled onto the same 4D grid. Whereas the comparison is only possible over a limited temporal range (around 15 -16 h LT) in the tropics and midlatitudes, it will be possible over a larger range of local times accessible high latitudes due to MRO's orbit. This should improve and validate the determination of the diurnal cloud life cycle around the summer solstices in the polar regions.

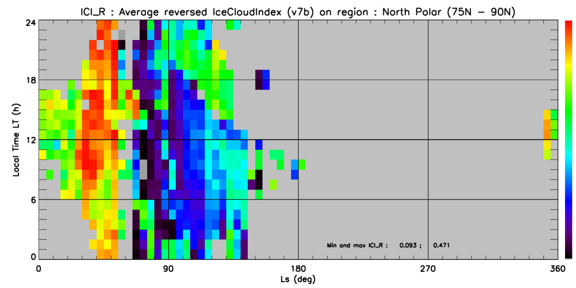

Figure 2: Ice Cloud Index (ICI) , function of Ls and LT, over the North Polar region (75-90°N ; all longitudes). Color scale : black: no cloud ; from purple (low ICI, thin clouds) to red (high ICI, thick clouds) ; gray: no data.

5. Conclusion

The ICI derived from OMEGA is a valuable indicators for detecting and characterizing Martian water ice clouds. By using statistical results, Olsen et al. [3] have already shown that the ICI is strongly related to the water ice column (which in turn depends on the radius of ice particles and on the water ice optical thickness). Comparisons of the ICI with optical thickness derived from SPICAM – measurements from 2 instruments on the same platform – are planned. Comparisons with data from other instroments on heliosynchronous satellites (CRISM, THEMIS...) could also help to determine the diurnal cycle of clouds over polar regions.

Acknowledgements

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References

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