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Martian cloud coverage and diurnal cloud life cycle derived from gridded Mars/Express OMEGA data

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Abstract

The ice cloud index (ICI) and the percentage of cloudy pixels (PCP) in a given region are derived from a long series of OMEGA images covering 7 Martian years. The pixels 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 mid-latitude regions closer to the poles, (lat = 40-55° N or S), fewer clouds are present in the afternoon, and more clouds closer to the equinox period (Ls=0-45° and 135-180°).

We also investigated areas partially covered with clouds by determining the percentage of cloudy pixels in the area. During the examined period, partially cloud-covered areas basically overlap with fully cloud-covered areas. Exceptions are the volcanoes (on Tharsis, and Olympus and Elysium Mons), with very few partially cloud-covered areas. Hellas is also a particular case: the basin is covered by a continuous cloud cover surrounded by a thin ring of partially cloud-covered grid-points.

1. Introduction

Water ice clouds have been first observed from space in the 1970-80's (by Mariner and Viking spacecrafts), and more intensively in the 1990's, starting with the MGS mission. But due to their heliosynchronous orbits, most past 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, and therefore cannot provide information about the diurnal cloud life cycle. Recently launched satellites MAVEN and MOM / Mangalaayan) move along non-heliosynchronous orbits, but have only provided images over a short period (~2 years). The OMEGA spectrometer onboard the (non-heliosynchronous) Mars Express 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 normalized 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 pixels are binned into two 4D arrays (cloudy and cloudy+non-cloudy) according to their longitude, latitude, Ls and LT, and counted. The bins have sizes of 1° in latitude and longitude, 5° in Ls and 1 (Martian) hour in LT. ICI values are also binned and averaged on the same 4D grid.

The cloud coverage, i.e. the percentage of cloudy pixels (PCP) of each bin is obtained by dividing the number of cloudy pixels in the first array by the number of all pixels in the corresponding bin in the second array.

In a third step, several 4D bins covering larger spatial areas and longer time periods are assembled (averaged) in order to form 2D subsets showing temporal evolutions of clouds.

Comparisons of the ICI with the integrated water ice column of the Martian Climate Database (derived from the Martian GCM of the LMD) show that both datasets have a good correlation and show the same cloudy areas [2].

3. Cloud cover

Figure 1 shows the average cloud cover of for all values (0-100%) for Ls=[45°-135°] and LT=[7-17h]. The main cloud structures can be identified: the Aphelion Belt, around the Tharsis, Olympus and Elysium volcanoes, Arabia Terra, Syrtis Major, the edges of polar hoods. The areas with partial cloud coverage (fig. 2) are basically the same but less dense. Partial cloud cover is almost absent on Arsia, Olympus, and reduced over most cloudy areas. The Hellas basin is covered by a dense cloud cover, surrounded by a narrow ring with partial cloud coverage.

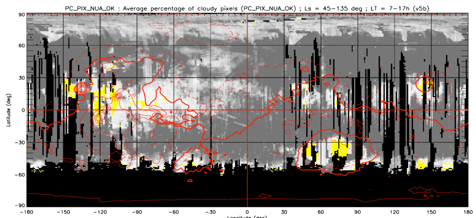

Figure 1: cloud cover (PCP). Highest values in yellow.

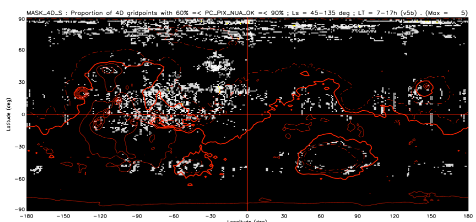

Figure 2: Where are the non-continuous clouds ? Ratio of non-continuously cloud-covered grid-points (60<PCP<90%) to the number of all cloud-covered grid-points (0.01<PCP<100%).

4. Diurnal cloud life cycle

The 4D gridded ICI has been aggregated and averaged over 17 large regions, covering several degrees of longitude and latitude during specific seasons. Although data coverage is sometimes sparse, 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 temperate regions (lat < 40°N). Fig. 3 shows a different cloud life cycle configuration observed in the Tempe Terra region (30-50°N). In the temperate regions closer to the poles, (lat=35-55° N or S), fewer clouds are present in the afternoon, and more clouds closer to the equinox periods (Ls=0-45° and 135-180°). This may be related to the presence or motion of the edge of the polar hoods.

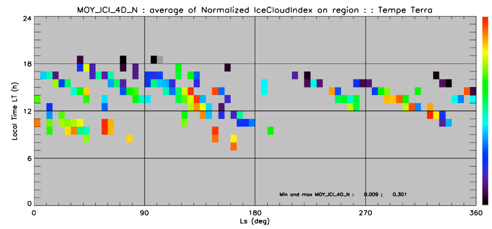

Figure 3: Normalized Ice Cloud Index (ICI) over the Tempe Terra region (30-50°N ; 90°W-55°W). Color scale : black: no cloud ; from purple (low ICI, thin clouds) to red (high ICI, thick clouds) ; gray: no data.

5. Conclusions

Although the spatial and temporal coverage by OMEGA data is sparse (~1-2 % of all 4D grid-points), the derived ICI and PCP are valuable indicators for detecting and characterizing Martian water ice clouds when they are aggregated or averaged over larger regions or longer periods. They may be useful for the validation of results produced by high-resolution Martian GCMs [3].

Acknowledgements

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