A Martian Cloud Climatology derived from Mars Express / OMEGA Observations and its Use for the Determination of the Cloud Life Cycle. A. Szantai1, J. Audouard2, F. Forget1, K.S. Olsen1,2, B. Gondet3, E. Millour1, J.-B. Madeleine1, A. Pottier1,2, Y. Langevin1, J.-P. Bibring1, 1Laboratoire de Météorologie Dynamique (IPSL, Sorbonne Université, École Normale supérieure / PSL Research University, École polytechnique, CNRS), Paris, France, 2Laboratoire Atmosphères, Milieux, Observations spatiales, (CNRS/UVSQ/IPSL), Guyancourt, France, 3Institut d’Astrophysique Spatiale, (CNRS, Université Paris 11), Orsay, France.

Introduction: The water cycle is an important element of the Martian climate, but has not been completely described yet. In particular, the life cycle of water ice clouds at different scales is not well known. Data from the OMEGA spectror-imager onboard Mars Express gave us a better description of the water ice cloud life cycle, due to two major qualities: (1) the length of the observation period, 7 Martian years (MY 26-32), and (2) its non-heliosynchronous orbit, unlike instruments on long-living heliosynchronous satellites (MGS, Odyssey, MRO), and on recently launched satellites (MAVEN, MOM, ExoMars / TGO). For each valid pixel from this abundant OMEGA data, we derived two indicators, the ICIR (Reversed Ice Cloud Index) and the PCP (Percentage of Cloudy Pixels), which characterize the presence and coverage of water ice clouds. We mapped these indicators on a 4D regular spatio-temporal grid, in order to build an annual and daily cloud climatology.

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 use the slope of an absorption band around 3.4 μm to define the original ice cloud index (ICIo) [2], and the reversed ice cloud index (ICIR = 1 − ICIo). After comparison with a threshold value, this ICIR indicates if the pixel is cloudy or not. The ICIR range is between 0 (no cloud) and 1 (extremely thick cloud and total cloud coverage of the pixel).

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, solar longitude (Ls) and local time (LT), and counted. The bins have a size of 1° in latitude and longitude, 5° in Ls and 1 (Martian) hour in LT. ICIR values are also binned and averaged on the same 4D grid. Data from the MY 28 global dust storm period has been excluded. An error bar is also calculated at each gridpoint.

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, due to the small number of 4D gridpoints containing valid ICIR data (~2% of daytime gridpoints), we integrate and average values from several 4D bins covering larger spatial areas and longer time periods in order to form 2D subsets showing temporal evolutions of clouds.

ICIR error estimation. We have also calculated the error bars of the ICIR, which result from two components: instrumental errors of the OMEGA spectrometer [3] at the two wavelengths used, and the variability of the OMEGA ICIR pixels averaged on the grid. Larger error bars are calculated in general over areas with reduced solar illumination (e.g. around 50°S – where clouds are present, around the southern winter solstice period), or with low surface albedo, where clouds can be present (Syrtis Major) or not. Error bar values are small, less than 10 % for the vast majority of original (ICIo) values.

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 ICIR) 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 confirmed with model data (water ice column) produced by the LMD Martian GCM and extracted from the Martian Climate Database (MCD).

The ICIR has also been compared to variables derived from other satellite data, also showing the seasonal cloud life cycle. The main cloudy areas (aphelion belt and polar hood edges) can also be observed (more or less) on water ice optical thickness derived from TES [4], MARCI[5] and SPICAM[6] data. Note that the OMEGA- and SPICAM-derived indicators (when available) reach higher latitudes than TES and MARCI optical thicknesses during spring. The aphelion belt is detected earlier in northern spring and is observed later in summer on OMEGA and MARCI data than on TES data. Differences can be explained partly by the differ-
Diurnal cloud life cycle: The 4D gridded ICI has been aggregated and averaged over 26 large regions of various size, 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. 2 shows a different cloud life cycle configuration observed in the Chryse Planitia region (20-50°N ; 60-30°W). Clouds can be observed mainly in the morning and beginning of the afternoon during a large part of the year. For the period around the winter solstice (Ls=270°), the LMD Martian GCM suggests that the observed clouds are mainly low-level fogs, which form during the night, are maximal in the morning and dissipate partly during the afternoon when the surface heated by the sun is warm enough to heat the atmosphere at low level.

Physical signification of the ICIR: In a complementary study, Olsen et al. [7] have shown that the ice cloud index is a good proxy for the water ice column. Based on the measure of the water ice column mass from a small number of OMEGA orbits, they derived the following linear relation (after use of the ICIR instead of ICIo) between the ice cloud index and the water ice column (WIC), valid for small particles (reff < 7 μm) : WIC = A + B ICIR (in pr.μm) with A = -0.7197 and B = 7.121

Conclusion: This abstract presents a part of the study detailed in an article “Martian cloud climatology and cloud life cycle extracted from Mars Express OMEGA spectral images”, by the same authors, which has been submitted to Icarus.

The ICI derived from OMEGA is a valuable and practical indicator for detecting and characterizing Martian water ice clouds, especially when it is aggregated and averaged over larger regions or longer periods. The PCP is representative of subgrid cloud properties and presence, and may be useful for the validation of results produced by high-resolution GCMs [8]. Comparisons of the ICI with optical thickness derived from SPICAM – measurements from 2 instruments on the same platform - and with data from other instruments on heliosynchronous satellites, in particular MARCI have also started. They could also help to find better relations between the ICIR and physical properties of clouds, and in the end improve the characterization of the diurnal cycle of clouds.

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References: