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Clouds in the night side of Mars: an analysis using Mars Express VMC

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Abstract

We present a study of high altitude clouds detected in the night side of Mars close to its terminator using images taken by the Visual Monitoring Camera (VMC) onboard Mars Express. With the aid of a cloud-search algorithm, we have detected 200 events of high-clouds, which are analyzed in solar longitude, location and altitude.

1. Introduction

The camera VMC, a simple webcam initially designed to confirm the separation of the Beagle-2 probe, started taking routine images of Mars, initially intended for outreach, in 2007, and has been recently promoted to a scientific instrument [1,2]. When Mars Express is at apoapsis, it provides context images of Mars, with the whole planet visible and in which large and middle scale atmospheric features are often visible. At present, VMC image database covers over five Martian years, and therefore allows the study of the seasonal evolution of different atmospheric phenomena, which can be easily traced in VMC context images. In this work, we describe the appearance of illuminated clouds in the night side of the planet close to the terminator. An analysis of the database will provide information on possible correlations of the height and extension of clouds with location and season, and of the recurrence of the phenomena in different Martian years, thus giving clues on the state of the Martian atmosphere at different regions and seasons.

2. Navigation of images

VMC images are navigated automatically using python software based on SPICE kernels. Initial navigation is corrected via an automatic fitting of the limb of the planet, used to find the precise position of the center of the planet in the image (Figure 1). This corrects initial uncertainties in the navigation, probably related to errors in the bore-sight of the camera as given by SPICE. Together with the navigation of the image, the software calculates different geometrical parameters, such as subsolar and sub-spacecraft latitude and longitude.

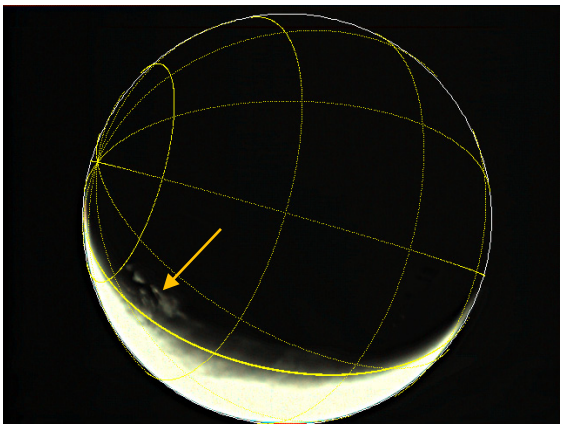

Figure 1: Illuminated clouds in the night side of Mars. Captured by VMC on February 20 2018 over Terra Sirenum.

3. Cloud-search algorithm

The ~20000 images of the database are distributed in series of images taken with different exposure times. We have analyzed 958 such series, of around 10 images each. Out of each series, we chose images with the longest exposure times.

We determine the altitude of the Sun as seen from all points in the visible surface of Mars, and the position of the terminator. Then, all pixels in the night side of the terminator are analyzed, looking for clusters of

bright points that signal the presence of high clouds (Figure 1). The algorithm analyzes the context of any possible cloud and discards false candidates. Clouds connected to the terminator are also discarded, since these clouds are probably illuminated by light dispersed from the dayside, instead of by direct light from the sun.

4. Image analysis

Once a cloud detection is accepted by the software, the algorithm searches for the pixel that lies farthest from terminator, and uses it to estimate the minimum height of the cloud, that is, how high the clouds tops must be located to allow for direct illumination from the Sun (Figure 2).

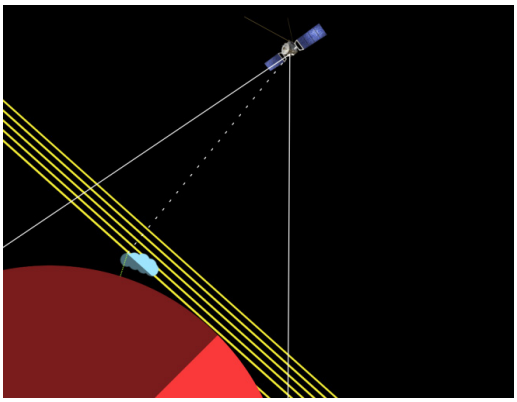

Figure 2: Geometry of the observation and scheme of the analysis for height determination. White lines determine the VMC-MEx field of view and yellow lines the sunlight illumination.

In order to perform a statistical analysis of the results, we determine the sample space of parameters: aerographic longitude and latitude, area coverage, cloud top height, orbital longitude L_s and Martian Year (MY). With this aim, every night pixel closer than 30º from the terminator has been registered and the minimum height that would allow direct sunlight to reach a cloud at that position, and consequently make the corresponding pixel brighter in the Martian night.

5. Results

The algorithm has retrieved so far about 200 clear cases of bright clouds in the night side of Mars. We present a statistical study of their distribution in terms of their aerographic location and Martian epoch of the year looking for their recurrence or singularity. We also classify the events in terms of their top altitude, looking for their possible origin (condensate water-ice and CO_2-ice clouds, and dust) when compared with a reference GCM model [3] and using complementary images from other instruments (e. g. MARCI onboard Mars Reconnaissance Orbiter) [4]. Finally, we will compare the result of this analysis with a previous work on high altitude features [1].

6. Conclusions

The VMC Mars Express camera has become a scientific instrument that can provide by itself new research of the Martian weather and at the same time complement studies performed with other instruments. In particular, it has proven very useful in the detection of high altitude structures in the atmosphere ([1] and this work). Ongoing investigations will profit from the new scientific status of the camera, which will allow planned observations of select targets and the radiometric calibration of the images.

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