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Some Recent Studies of Mars: the North Polar Cap, Cecropia and Hellas

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SOME RECENT STUDIES OF MARS: THE NORTH POLAR CAP, CECROPIA AND HELLAS

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ABSTRACT

This paper summarizes changes on Mars which occurred in 2014. Images recorded by the Mars Reconnaissance Orbiter's MARCI camera (hereafter MRO) and those made from the Earth are examined. It is concluded a spiral-shaped cloud of water ice crystals developed and moved eastward at an average speed of 1.7 m/s, a temporary isolated bright patch in Cecropia developed and one or more dust storms developed at the NPC edge near 83° N, 320° W. Measurements of the boundary of a white area in Hellas are consistent with it not changing as the year, season or time of day progressed. This white area is probably a dry ice frost coating.

Key Words: Cecropia, Hellas, Spiral shaped cloud of water ice crystals

INTRODUCTION

As the North Polar Cap (NPC) on Mars shrinks, changes occur. For example, spiral-shaped clouds of water ice crystals may develop. Pellier (1) describes two examples. Malin and co-workers (2) also show an image of a spiral-shaped dust cloud near the NPC in their Figure 6. They state that Martian polar low-pressure systems may cause these storms. It is important to remember that these sub-polar clouds usually have an overall circular or elliptical shape and do not appear as actual spirals. See Figure 1. In addition to the development of spiral-shaped clouds of water ice clouds, isolated frost patches become detached from the NPC as it shrinks. Two well-known patches are Ierne near 130° W and Olympia (or Lemuria) near 210° W (3, 4). A third frost patch in northern Cecropia, near 290° W, is a mystery. Cecropia is a light brownish area during the summer but in winter the seasonal NPC covers it. Some astronomers have mapped it as a white area which separates from the retreating NPC in late spring (4, 5), but others do not draw an isolated white area in Cecropia (6, 7). Antoniadi (8) described Cecropia as a "continental region". He reported that Schiaparelli and Molesworth observed a bright patch covering part of this area in 1888 and 1903, respectively. In his plates 2 and 5, Antoniadi drew Cecropia as a light gray area at 70° N, 305° W (8). In these drawings it is not white like Olympia or the NPC. A third change which occurs near the edge of the shrinking NPC is the development of dust storms near 83° N, 320° W. Dust over the NPC appears dark and, hence, may be confused with a rift. One possibility is that small dust storms preferentially form at some longitudes. Therefore, MOR images of this area in 2014 will be examined. A final change which occurs before or as the NPC shrinks is the brightening of Hellas. Hellas has a light brown color in southern summer. In winter it is white, but dark features often show through. This seasonal brightening is examined.

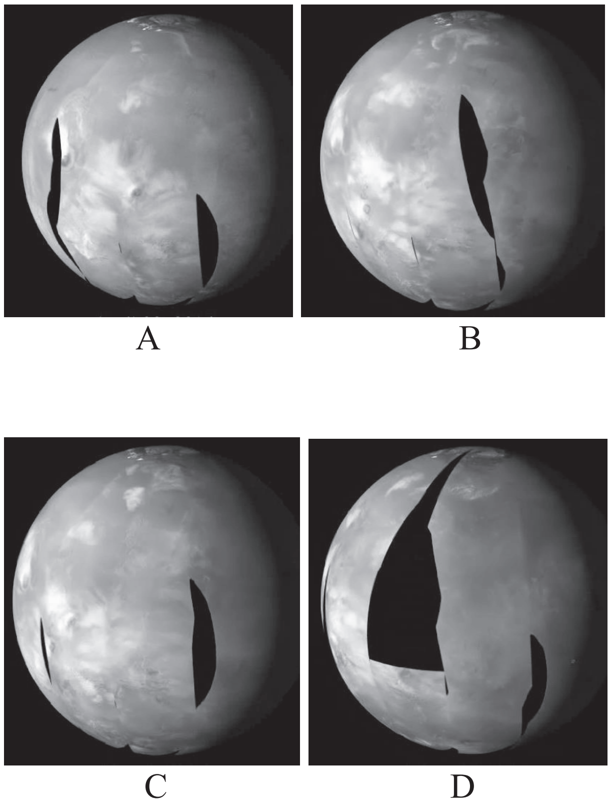


Figure 1. Images showing a spiral-shaped cloud of water ice crystals taken by MRO in 2014; images A – D were recorded on April 30, May 3, May 4 and May 7, respectively. All images are from http://www.msss.com/mass_images /subject/weather_reports.html. Credit: NASA/JPL-Caltech/Malin Space Science Systems (10-11).

Throughout this report the areocentric longitude (L_s) is used to report the seasonal date. The areocentric longitude, L_s, defines seasons on Mars where L_s = 0°, 90°, 180° and 270° are the beginning of northern spring, summer, fall and winter, respectively (9).

The purpose of this paper is to describe the 2014 development of the North Polar spiral-shaped cloud of water ice crystals, the ice patch in Cecropia, north polar dust storms near the NPC edge at 320° W and the seasonal brightening of Hellas.

METHOD AND MATERIALS

The results of this study are based on an analysis of MRO (10-17) HST (18-19) and Earth-based images (20) made in visible and near-infrared light. Some of them were submitted to the writer but most were posted elsewhere (10-20).

The software package WinJupos was used in measuring longitudes and latitudes (21). Essentially, to use WinJupos a Mars image is given a name in the following format: YYYY-MM-DD-TTTT.T. The YYYY is the four-digit year (Gregorian Calendar), the MM is the two-digit month, DD is the two-digit date and TTTT.T is the Universal time in Hours, Minutes and fraction of a minute. For example, an image made on January 1, 2014 at 6:00:00 UT would have the name 2014-01-01-0600.0. The software then uses this number sequence to compute the date and time the image was taken and the orientation of Mars as seen from Earth. WinJupos has a circular and adjustable grid. The grid should be adjusted properly before correct readings are possible. I used the locations of about 20 dark areas on Mars as reference points in adjusting the grid. Once the grid is properly adjusted, the software computes the longitude and latitude of any point on the image. One advantage of WinJupos is it allows one to measure images of different sizes. WinJupos may be used for HST images. Extensive calibration must be used before WinJupos is used for spacecraft images.

MRO images at http://www.msss.com/msss_images/subject/weather_reports.html were examined. The images are shown as seven-day movies. I usually exported single images from the movie using Microsoft Paint. No other processing was done to these images.

A preference was given to images made in red and near infrared light. This is because these wavelengths penetrate Martian hazes better. All Hellas measurements were made from red filter images. HST images were also measured. Many HST images used were made with the F673N filter. This filter transmits light with wavelengths near 673 nm and has a full-width-at-half-maximum value of ~8 nm (22).

RESULTS

Spiral-Shaped Cloud. A spiral-shaped cloud of water ice crystals developed on April 29-30 and remained for a week. See Figure 1. It was always brighter in blue than in red and near-infrared light in Earth-based images. This is consistent with it being a cloud of water ice crystals. In location, appearance and color, it was like the feature which HST imaged in 1999 (18). The 2014 cloud developed when several white spots approached each other on April 29 at 65° N, 120° W. See Figure 1A. Over the next few days it evolved and drifted eastwards. See Figures 1B and 1C. Position measurements are consistent with an average speed of 1.7 meters/second (or 3.8 miles/hour). This is close to what is expected for a system near the NPC (23). By May 6 (14:00 UT) it was at 61° N, 82° W. A day or two later, this system broke apart at L_s = 127°. See Figure 1D.

The positions of a suspected spiral-shaped storm in late May 2012 at L_s = 116° – 118° (1) were also measured. WinJupos was used. The resulting mean positions are: May 27: 61° N, 129° W; May 28: 61° N, 123° W; May 30: 60° N, 126° W. The positions are consistent with a mean velocity of 0.6 m/s in the east southeast direction. The 2014 spiral-shaped cloud was at 63° N, 103° W (L_s = 125°) on May 3 and, hence, it developed at a similar location and seasonal date as the 2012 cloud. MRO images are consistent with this cloud being a group of about six smaller clouds (24). Hubble Space Telescope observations show that spiral-shaped clouds of water ice clouds normally develop in mid-summer and, hence, the two features reported here are normal events.

Ice patch in Cecropia. The goal of this section is to summarize the frost patch in northern Cecropia. Cecropia is a light "continental" area but during the winter, much of it is covered with carbon dioxide ice. Earth-based images in 2012 (March 1 by Peach and March 10 by Buda) show some frost over northern Cecropia. Images taken later did not have sufficient resolution to show frost in northern Cecropia. Images recorded by the MRO show the development of the frost patch in northern Cecropia. See Figures 2A – 2D. This patch starts off as a nearly continuous band extending from Olympia to about 0° W. See Figure 2A. Over the next week or so it grows thinner as shown in Figure 2B. A few days later this frost patch breaks up into several smaller frosted areas. See Figure 2C. Finally, after another ten days, only the eastern portion near 73° N, 254° W retains its frost cover. See Figure 2D. Hence, the frost patch in northern Cecropia is like the Mountains of Mitchell in the South Polar Region which also separates and disappears.

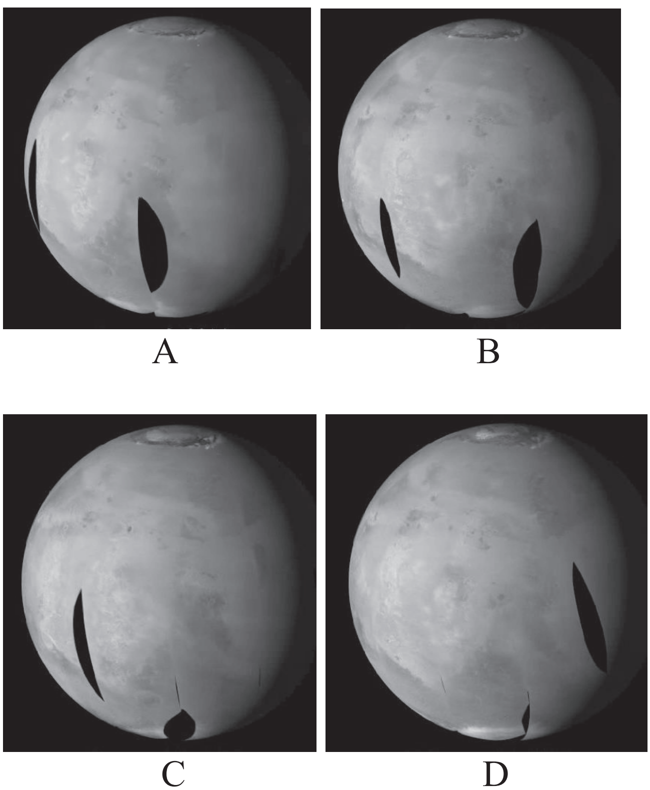
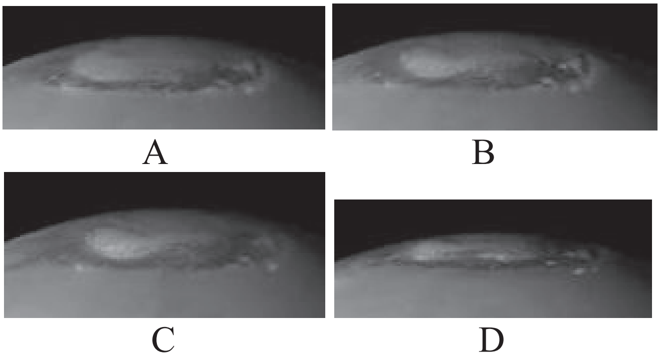


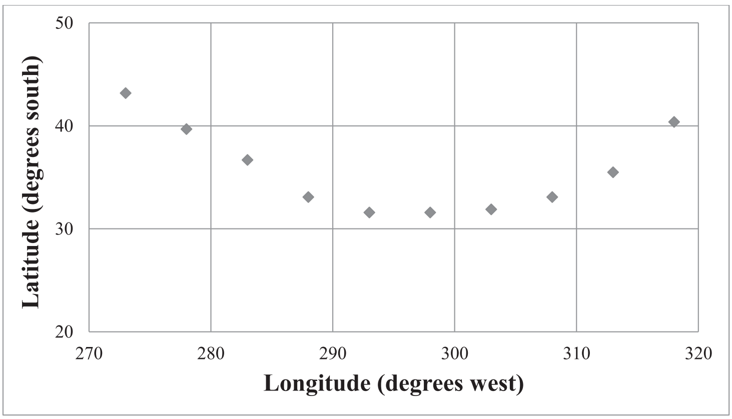
Figure 2. Images showing northern Cecropia during late spring taken by the MRO in 2014; images A – D were taken on January 8 (L_s = 73°); January 15 (L_s = 76°); January 23 (L_s = 80°) and February 11 (L_s = 88°); respectively. All images are from http://www.msss.com/mass_images/subject/weather_reports.html. Credit: NASA/JPL-Caltech/Malin Space Science Systems (12, 14, 13, 15).

The frost patch in Cecropia is different from those in Olympia and Ierne in two other ways. The patches Olympia and Ierne lie on top of the “Late Amazonian Polar Dunes Unit”, but the frost patch in Cecropia lies on top of the “Late Hesperian Lowland Unit” (25). The difference in surface geology may be one reason why frost in Cecropia does not last through the summer whereas it does in Olympia and Ierne. A second difference is the Cecropia patch is not brighter than the surrounding NPC frost in early spring. The ice patches in Olympia and Ierne, on the other hand, are brighter than the surrounding frost in the NPC. Peach’s image taken on January 23, 2012 (23:34 UT) shows Ierne as brighter than the surrounding polar frost and Kumamori’s image taken on January 29, 2010 (13:16 UT) shows Olympia as brighter than the surrounding polar frost (20). McKim (2005) also reports that the region of Olympia was brighter than the surrounding areas almost four months before Olympia separated from the NPC. A thicker layer of ice may be responsible. Lowell (26) and James et al. (27) suggest that this is also the case for the Mountains of Mitchell and Mons Argenteus, two areas in the South Polar Cap, which are white longer than surrounding areas.

Dust near 320° W. MRO images were examined for the presence of dust near 83° N, 320° W. Dust will show up as a dark and brownish spot on the NPC. The NPC near 320° W had regular frosted edge on January 17 (L_s = 77°) with no indentions. See Figure 3A. Eight days later a darkening began developing. See Figure 3B. Essentially, there were brownish spots developing over the cap. Much of the cap outline, however, was still present. See Figure 3B. One week later on February 1 (L_s = 84°) a brown layer covered part of the NPC. See Figure 3C. The brown areas lead me to believe that a local dust storm spread over part of the NPC. Some of the dust may have settled on the cap. Much of the area near 320° W became brighter by May 15 (L_s = 131°). See figure 3D. Even on this date, however, there was still a dark indention into the NPC.

A careful search of similar events near 320° W was made dating back to the 1990s. Longitudes were measured with WinJupos. The results are summarized in Table 1. Several more events are evident in MRO images. It is concluded that dust storms preferentially form at the NPC edge near 83° N, 320° W. In a recent geological map of Mars (25), the area at 83° N, 320° W is near the “Amazonian Polar Undivided Unit” which is up to 1000 m thick. This is a relatively young area on Mars having very few impact craters. It is also close to a 30 km crater at 85.3° N, 0° W (28).





E

Figure 3. A: An MRO image of the NPC taken on January 17, 2014 at L_s = 77°; B: An MRO image of the NPC taken on January 25, 2014 at L_s = 81°; C: An MRO image of the NPC taken on February 1, 2014 at L_s = 84°; D: An MRO image of the NPC taken on May 15, 2014 at L_s = 131°. The longitude of the central meridian for images A – D is near 320° W. All images are from http://www.msss.com/mass_images /subject/weather_reports.html. E: Mean latitudes of the white coating over Hellas measured in early 2014. Credit: NASA/JPL-Caltech/Malin Space Science Systems (14, 13, 16, 17).

Table I. Suspected dust storms developing over the NPC 300° W and 360° W.

Date	Individual or instrument	Longitude (°W)	Reference	Comments
April 17, 1997	HST	337	18	Brownish area
May 17, 1997	HST	308	18	Dark notch
May 1, 1999	HST	312	18	Thin dark notch
Dec. 17, 2007	HST	340	19	Thin orange dust clouds over NPC
April 16, 2010	D. Peach	324	20	Shallow dark notch; not visible the next day in a low resolution image
March 14, 2012	C. Go	322	20	Dark notch in NPC; low resolution
March 28, 2012	D. Peach	313	20	Shallow dark notch in NPC; not visible the next day in a low resolution image
April 7, 2012	E. Morales Rivera	315	20	Dark notch in NPC; less distinct or gone three days later
May 12-13, 2012	D. Peach	310	20	NPC nearly split into two pieces
March 9, 2014	C. Pellier	324	20	IR image shows dark notch
April 1 to June 13, 2014	Several	322	20	Dark area in NPC; bisects NPC in late April

Hellas. Hellas is a large depression in the southern hemisphere which undergoes seasonal changes. Because of its location, its seasons are opposite of those for the NPC. During the summer, Hellas has a light brown color. During the southern fall (or northern spring) it becomes white. Images in 2009-2010 show that the color changes gradually between L_s = 35° and 80°. By late fall, Hellas is nearly as bright as the NPC in visible light. Images in 2011-2012 and 2013-2014 are consistent with this trend. Hellas was bright on Walker's June 4 image (L_s = 140°) but was no longer white in Einaga's July 29, 2014 image (L_s = 169°). McKim (29) reports that it was very bright until May, 1984 (L_s ~ 150°) (30) when it was "less conspicuous than in late March/early April." This is consistent with Hellas undergoing a gradual change in brightness. It is concluded that this area gradually brightens during the southern autumn near L_s = 45°

and it remains bright until at least mid-winter. It probably returns to its summer appearance in late winter near $L_s = 160°$.

Two relevant questions are: (1) Does the white area spread to more northern latitudes from mid-autumn to early winter? and (2) Does the white area in Hellas change throughout the day or from year to year? To answer these questions, I measured the latitude of the northern edge of the Hellas white area for each five degree interval of longitude between 270° and 320° W. HST images in the late 1990s along with red-filter Earth based images made between 2009 and 2014 were examined. The mean latitudes for early 2014 are plotted in Figure 3E. Based on a Wilcoxon Signed Rank Test at the 90% confidence level there was no difference in the latitudes to within 100 km when the central meridian was east of 283° W or west of 300° W. This is consistent with the white area not growing or shrinking as the local time changed. Based on a second Wilcoxon Signed Rank Test, there was statistically no difference in the latitudes in 2012 and 2014. This result is consistent with the northern boundary of the Hellas white area being the same in the two years. A third Wilcoxon Signed Rank Test was carried out to determine whether the Hellas white area expands during late autumn. Again there was no difference between its boundary in mid-autumn in 1995 and early winter in 2014. MRO images recorded in January through April 2014 (12, 15, 31-33) were examined. During this time no large irregularities were observed. A smaller one on April 8 was suspected. Therefore, a more careful analysis of MRO images using the appropriate software may yield small variations.

Is the white material covering Hellas frost, clouds or both? A Viking Orbiter image shows a white Hellas with dark albedo features showing through. Some Earth-based images also show similar dark areas. Putzig and Mellon (34) report that the northern portion of Hellas along with the North Polar Region have very high thermal inertias at $100° < L_s < 150°$. They suggest this may be the result of a partial CO_2 frost coverage (34). Therefore, the most likely explanation of the Hellas white area is a thin frost coating. This is consistent with the fact that the northern border of the white area did not change as the longitude of the central meridian moved westward. I believe that frost preferentially forms in Hellas because of its low elevation. The atmospheric pressure on Mars, and, hence, the carbon dioxide partial pressure rises about 10% for each kilometer of depth (35). Therefore, if the carbon dioxide pressure is 5.8 millibars at an elevation of 0 km, it would be 8.7 mbar at an elevation of – 4.0 km and 13.2 mbar at an elevation of -8.2 km. Consequently, carbon dioxide will condense at a higher temperature in Hellas than in areas with a higher altitude (36). The northern border of the Hellas white area matches the topography (35). Essentially, the areas at a higher elevation do not turn white.

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