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Cover Page Footnote
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VARIABILITY OF MARS' SEASONAL NORTH POLAR CAP

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ABSTRACT

Mars' seasonal north polar cap (hereafter sNPC) underwent year-to-year changes between 2008 and 2015 or Mars years 29–33. The writer monitored changes in the sNPC using images made with the MARCI camera onboard the Mars Reconnaissance Orbiter (MRO). Nine isolated bright spots corresponding to Korolev, Lomonosov, and Louth Craters, the albedo features Ierne, Olympia (or Lemuria), and Cecropia, and three unnamed features were examined. The following was concluded: 1) the sNPC underwent small year-to-year changes between 2008 and 2015 [MY = 29–33], 2) there are no years where all temporary frost features lasted longer than their mean lifespan, and 3) local clouds, dust storms, and winds may affect the location of the sNPC edge.

Keywords: Mars, temporary north polar cap

INTRODUCTION

Mars's north polar cap (hearafter NPC) consists of two parts: a seasonal cap and a permanent cap. The seasonal cap grows and shrinks with the seasons but the permanent cap remains throughout the year (Carr 2006). This paper focuses on the seasonal north polar cap (sNPC).

Dollfus (1973) reviewed early micrometer work done on the sNPC and reported his 1946-1950 measurements. During this time, he used the double image micrometer at Pic-du-Midi observatory to carry out his work. Capen and Capen (1970) analyzed dozens of red and orange light photographs made during 1962–1967 (Mars years 5–7). With these they reported mean sNPC diameters for different L_S values. Clancy et al. (2000) introduced the Mars year. Essentially, each Mars year, hereafter MY, begins at the first day of spring in the northern hemisphere or $L_S = 0°$. For example, MY 33 started on June 18, 2015. Throughout the present paper, L_S refers to the areocentric longitude of the Sun measured from Mars; values of $L_S = 0°$, 90°, 180°, and 270° refer to the beginning of spring, summer, fall, and winter in the northern hemisphere; all values of the areocentric longitude in this paper are taken from the Astronomical Almanac for the years 2008, 2010–2015. Fischbacher et al. (1969) reported mean polar cap boundaries for 1905–1965. Iwasaki et al. (1986) reanalyzed this data and found the sNPC underwent a steady shrinkage for $L_S = 40°–80°$ which was inconsistent with the aphelic chill. [The aphelic chill was a term used to describe the recondensation of the NPC in 1984 when Mars was near aphelion (Beish 2012).] Iwasaki et al. (1979, 1982, 1984) analyzed photographs of the sNPC in 1975–1978, 1979–80, and 1981–82. Their 1981–82 results show that the permanent NPC (hereafter pNPC) had a radius of ~8°. James et al. (1987) analyzed Earth-based photographs (1975–1980) using the Planetary Image Projector at Lowell Observatory. They measured the cap latitude at several longitudes. James (1979, 1982) also used Viking Orbiter images to measure the size of the sNPC in 1977–78 and 1979–80. James (1982) concluded the mean sNPC latitude (θ) followed the equation $\theta = 57.7° + 0.216°\, L_S$ for 1979–80. James et al. (1994) analyzed

Hubble Space Telescope (HST) images of the sNPC during 1990–1991. They concluded that the recession of the sNPC is consistent with what was observed in the late 1970s. Parker et al. (1999) reviewed both micrometer and photographic measurements made of the sNPC between 1962 and 1997. They concluded that the seasonal cap did not always shrink at the same rate each year. They also pointed out five localized dust storms in 1984 that may have affected the regression rate. James et al. (1996) reported that the sNPC in 1972 and the 1990s was similar. Cantor et al. (1998) reported the latitude of the sNPC at a longitude of 270°–280° W for the four apparitions between 1990 and 1997. More recently James and Cantor (2001) used images from the Mars Global Surveyor to measure the size of the sNPC. They considered the cap size at all longitudes and reported mean latitudes as a function of L_s. One of their findings was that the mean latitude of this cap changed at a constant rate from L_s = 345° to 70°—this also contradicts the aphelic chill. They also reported the cap retains a nearly circular shape until midspring. Benson and James (2005) reported that this feature underwent small variations in size, 1°–2° in latitude, during regression in 2000 and 2002 (MY 25 and 26). They base their analysis on Mars Global Surveyor images. Schmude (2013) carried out measurements of the sNPC using Earth-based images along with the software package WinJUPOS (Hahn and Mettig, jupos.privat.t-online.de). He concluded that the sNPC shrinks at a nearly linear rate with L_s which confirms the findings of Benson and James (2005). More recently Schmude (2014a) reported that the sNPC in 2000–2014 had small year-to-year differences before L_s = 70°; this is consistent with the findings of Benson and James (2005). He also concluded that the pNPC had a mean latitude of 81.9° ± 0.3° for 82° < L_s < 134° during 2013–2014. The results of Benson and James (2005) and Schmude (2013, 2014a) are, therefore, inconsistent with the aphelic chill taking place in 2000 and 2009–2014. Kieffer and Titus (2001) analyzed data from the thermal emission spectrometer data on the Mars Global Surveyor recorded in 1999 and 2000. They reported that the temperatures were too high for carbon dioxide ice to remain on the surface after L_s = 78° which is late northern spring. Therefore, although the sNPC is carbon dioxide ice (Carr 2006), ices in the NPC outliers remaining after L_s = 78° are probably mostly water ice (Kieffer and Titus 2001).

The purpose of this study is to look for changes in the seasonal sNPC between MY 29 and 33. One goal is to monitor the sNPC at different longitudes at a resolution of ~11 km/pixel. A second goal is to examine the day-to-day changes that take place near Korolev, Lomonosov, and Louth Craters as they separate from the sNPC. These may yield insights into the factors that control the shrinkage of the sNPC.

The pNPC and several isolated bright areas including the three craters just mentioned are illustrated in Figure 1. This map was constructed from HST images recorded on March 30, 1997 (James et al. 2015) along with WinJUPOS software. The pNPC was drawn mostly from measurements made during 2013–2014 from Earth-based images (Schmude 2014a).

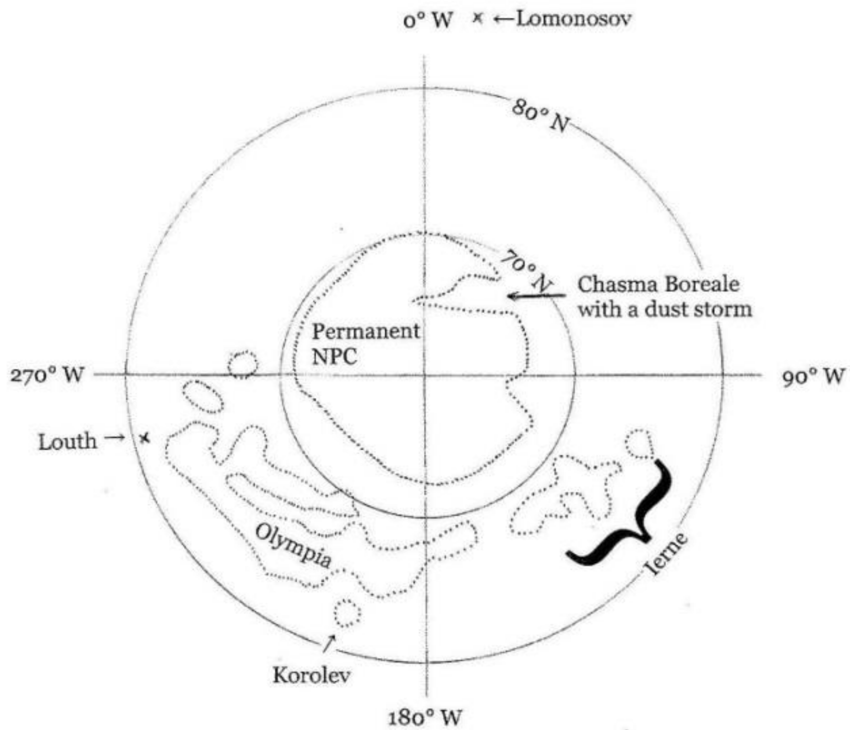

Figure 1. A map of the north polar region based on HST images recorded on March 30, 1997, and measurements made of the 2013–2014 pNPC.

MATERIALS & METHOD

Movies at http://www.msss.com/msss_images/subject/weather_reports.html (Malin 2009) were examined. Malin et al. (2015p) report images made with the Mars Color Imager (MARCI) on the Mars Reconnaissance Orbiter (MRO) that were map projected and mosaiced together to produce seven false-color daily global maps which are displayed as movies. Each global map was constructed from images made in three color filters at wavelengths of 420, 550, and 600 nm. Quicktime was used as the software to view the movie. I usually exported single images (or portions of a single image) from the movies using Microsoft Paint. A typical image has a resolution of about 11 km/pixel. One advantage of these movies is they cover eight Earth years or five Martian years. A second advantage is their high and consistent resolution.

MRO MARCI images have shortcomings. One is that images were taken from different locations. This may lead to albedo changes caused when the angle between the spacecraft, target, and Sun changes. This does not arise in Earth-based images since the sub-Earth latitude changes slowly from one night to the next. A second problem is that it is difficult to distinguish between condensate clouds, ice fogs, windblown ice particles, and ground frost. A third limitation is that portions of images were not available. In spite of these, it is believed that new insights may be obtained from these movies.

The software package WinJUPOS was used in constructing the map in Figure 1 and some of the information in Table I.

In a few cases, sizes of various ice features were measured from images with a ruler. Since Mars has a diameter of 6800 km it was a simple matter to determine the scale. In all cases, brightness estimates were made visually from images.

Table I. Isolated bright patches near the retreating sNPC

Name	Location[a]	Permanent (P) or temporary (T)	Diameter (km)	Area (km^2)	Source
Ierne	77° N, 127° W[a]	P	---	70,000[b]	Current work
Olympia	76° N, 220° W[a]	P	---	300,000[b]	Current work
Cecropia	74° N, 310° W[a]	T	---	---	Current work
Permanent NPC	89° N, 320° W	P	~960[b]	700,000[b]	Current work & Schmude (2014a)
Korolev	73° N, 197° W	P	79	---	Head et al. (2002)
Louth	70.5° N, 256.8° W	P	36	---	Brown et al. (2008)
Lomonosov	65° N, 8° W	T	135	---	Batson et al. (1979)
Unnamed	~70° N, ~310° W	T	~60[c]	3,000[c]	Current work
Unnamed	~65° N, ~110° W	T	~50[c]	2,000[c]	Current work
Unnamed	~68° N, ~90° W	T	~70[c]	4,000[c]	Current work

[a]The coordinates of Ierne and Olympia were measured from an HST image recorded on March 30, 1997. The latitude of Cecropia was measured from an HST image recorded on February 24, 1995 in the F673N filter and the mean longitude was estimated from a MARCI image recorded on December 12 and 13, 2015.

[b]Areas were estimated from the map. Essentially, I counted the number of 10° by 2° blocks each feature covered and used the appropriate equation (CRC Standard Mathematical Tables, 1955).

[c]Estimated areas are from an October 15, 2015 movie taken at $L_s = 55°$.

RESULTS

As the sNPC shrinks, isolated bright patches remain behind. The three largest are Ierne, Lemuria or Olympia, and Cecropia. Astronomers have noted these for several decades (Beish 2012). Schmude (2014b) reports that Cecropia is a temporary feature and dissipates almost completely by early summer. The other two features (Ierne and Olympia) remained until at least the late summer in MY 29–32 when the north polar hood (NPH) started forming. Additional isolated frost patches remain as the sNPC retreats. These are summarized in Table 1.

The NPH is a group of clouds that forms in the north polar region. They are composed of water ice and can be thick enough to obscure the north polar cap during late winter (Christensen and Zurek 1984; McKim 2011). The NPH becomes thinner during spring but still lingers (Christensen and Zurek 1984).

One goal of this study is to look for year-to-year changes in the sNPC. Figure 2 shows Ierne (top row), Olympia (middle row), and Cecropia (bottom row) at specific seasonal dates. Figure 3 illustrates the sNPC and five smaller isolated bright spots at specific seasonal dates. Figure 4 illustrates images of Lomonosov, Korolev, and Louth Craters. Differences are apparent. In order to better understand these, I examined images covering the 30-day period preceding the images in Figures 2 and 3 (Malin et al. 2008a-p; 2010b-p; 2011b-e; 2012a-k; 2013b-k; 2014a-e; 2015b-p). In the following paragraphs I will describe these and give possible explanations for the differences.

Figure 2. Images of the sNPC and the isolated bright spots Ierne–top row; Olympia–middle row, and Cecropia–bottom row. In all cases north is at the top and east (on Mars) is to the right. All images were taken with the MARCI camera onboard the Mars Reconnaissance Orbiter (Malin et al. 2008l,p; 2010l,p; 2012h,k; 2014b,e; 2015m,p), Image credit: NASA/JPL-Caltech/Malin Space Science Systems.

Ierne. Isolated bright patches between 104° and 151° W make up this area. These become detached from the sNPC at L_s ~70°. According to Ivanov and Muhleman (2000) the western portion of Ierne rises several hundred meters above the surrounding terrain. Either a thick, towering slab of ice rests at this location or a thinner layer covers a small mountain. Most of the rest of Ierne rises less than 100 m above the surrounding surface. On a few occasions, the western portion was brighter (May 26–30, 2008 and March 1, 2012) than the rest of Ierne. They may be the result of low-lying dust clouds or some other factor. Some caution should be exercised when relative brightness is mentioned in this report since visual perception may be biased by contrast or other effects. These would obscure lower lying areas but the mountain would poke through. A more thorough analysis of images using pixel by pixel brightness measurements will yield more accurate brightness measurements.

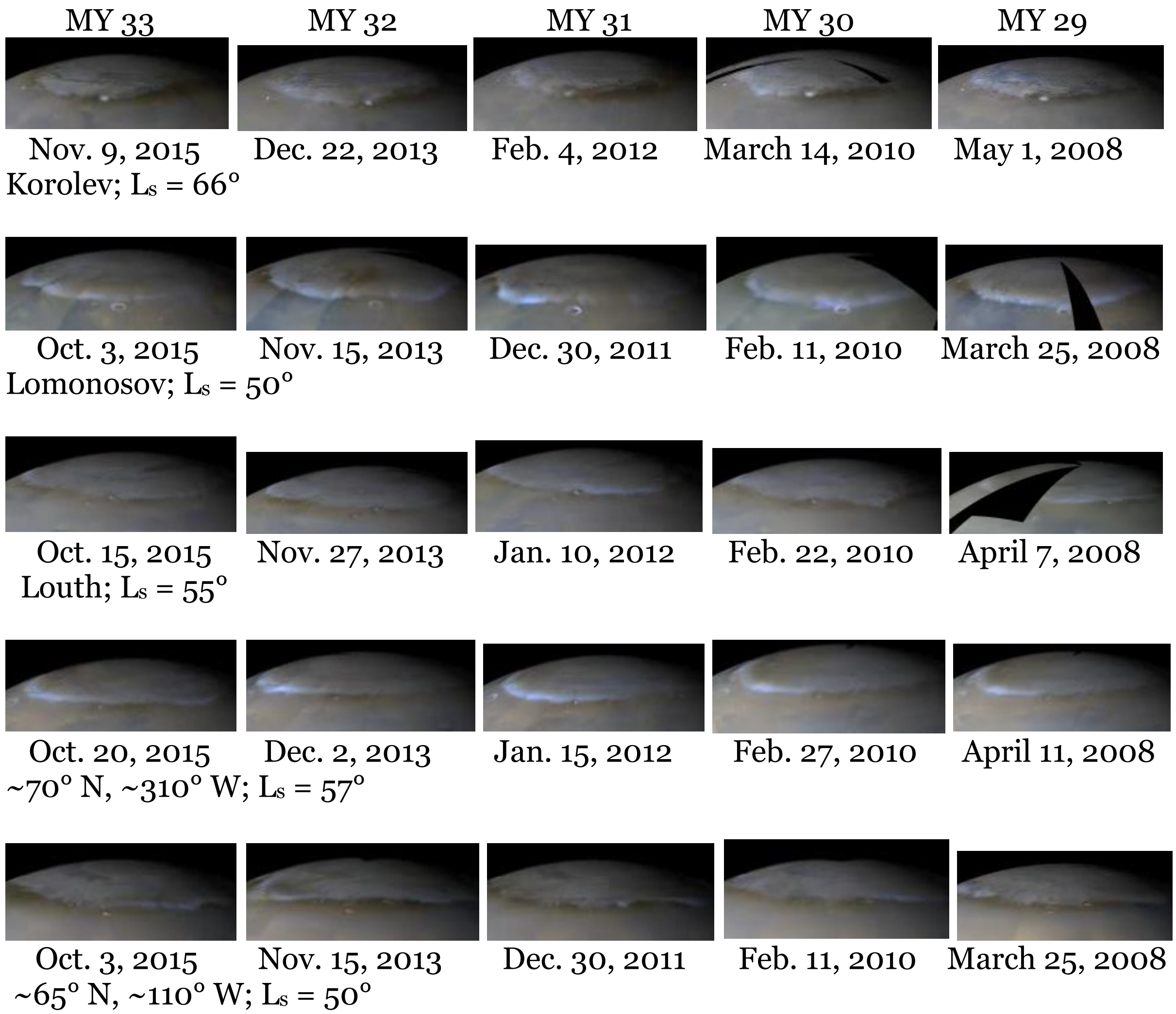

Figure 3. Images of the sNPC and the isolated bright spots Korolev Crater–top row, Lomonosov Crater–second row, Louth Crater–third row, and two unnamed bright spots—fourth and fifth rows. In all cases north is to the top and east (on Mars) is to the right. All images were taken with the MARCI camera onboard the Mars Reconnaissance Orbiter (Malin et al. 2008f,h,k; 2010f,h,j; 2012a,c,f; 2013f,h,i,k; 2015f,h,i,l). Image Credit: NASA/JPL-Caltech/Malin Space Science Systems.

Ierne was smaller in MY 32 than in the previous years. For example, note how much smaller it is on the right in MY 32. Furthermore, note the larger white area on the left is thinner than in MY 33. Dust storms in January 2014 (MY 32) may be the cause of this. It is believed dust activity may have led to stronger winds which in turn led to enhanced sublimation rates. Chittenden et al. (2008) have shown the sublimation rate of water ice increases as the wind speed increases for low relative humidity values.

The changes in Ierne in Figure 2 are after L_s = 78° and, hence, may be the result of changes in the water ice covering. Ivanov and Muhleman (2000) estimate 0.012 g/cm^2 of water sublime from the north polar regions at 80° N per year. This corresponds to a layer of ice which is 0.12 mm thick or a layer of loose snow ~1 mm thick. Therefore, the areas that change in Ierne at L_s = 80° may be thin layers of water ice.

Olympia. This is the largest frost patch to separate from the NPC. It consists of two large parts. See Figure 1. According to Ivanov and Muhleman (2000) most of Olympia rises less than 100 m above the surrounding terrain. Kieffer and Titus (2001) report that a portion of Olympia reaches a peak albedo of 0.37 at L_s = 132° which is near midsummer. Afterwards, the albedo drops.

Olympia had nearly the same size and shape in each of the five Martian years. One difference though is that it appears brighter in MY 32 at L_s = 80° than in the previous three years. See Figure 2. Dust may be the cause. Essentially at least one dust storm was imaged during L_s = 70°–80° near Olympia in MY 29–31 but no storm was imaged in MY 32. The storms in MY 29–31 may have caused dust to be deposited on Olympia or a thin dust cloud may have hung over this area. The large northern section, which is nearly separated from the larger southern section, darkened on May 29, 2008, but grew brighter three days later. Nearby dust activity may be responsible.

Cecropia. Unlike Ierne and Olympia, Cecropia is temporary. At L_s ~69°, this area separates from the sNPC but, by L_s = 80°, no large areas of frost are visible.

Cecropia was thinner in MY 29 than in the following years at L_s = 70°. See Figure 2. Two possible causes of this are winds and low albedo. Firstly a dust storm developed to the west near 80° N on April 24–27, 2008 (MY 29). This may have increased the wind speed. Furthermore it may have led to the deposition of dust a few days later. Cecropia darkened between April 30 and May 2. This will lead to a higher ice temperature and an enhanced sublimation rate. It is not clear whether the dust storm was responsible for the darkening. In MY 30–33, Cecropia would often appear dull one day but brighten a few days later. For example, it was dull on November 12–13, 2015, but was bright on November 14–15, 2015. The cause of this is not clear.

The layer of frost in Cecropia is probably carbon dioxide since it is essentially gone by L_s = 80°. Most of Ierne and Olympia, on the other hand, contain water ice which is at least 0.1 mm thick since they survive during the summer.

Lomonosov Crater. This crater is named after the Russian chemist Mikhail Lomonosov. Frost accumulates on the rim during the winter (NASA photojournal image PIA02394 at photojournal.jpl.nasa.gov/targetFamily/Mars). The floor has dust and slow-cooling material. See Figure 5A. In the top row in Figure 4, a white south-pointing cloud developed to the west (September 3) and moved eastward covering this crater one day later. By September 8, the cloud had cleared revealing Lomonosov Crater. Five days later, the eastern (right) portion of the NPC/NPH had expanded ~2°. It is not clear whether this is the result of clouds, surface frost, or both. At least two clouds types moved passed this crater as illustrated in the second row of Figure 4. One had a white color (probably water ice) and the others had a brownish (darker) color (probably dust). The clouds usually moved from west to east. In one unusual case, a spiral-shaped brown cloud developed on March 2, 2008, near 70° N, 30° W. It eventually covered Lomonosov. White clouds, at the edge of the NPC, would also move east and cover this crater. Unlike the brownish clouds, these did not generally change the appearance of the NPC/NPH. Table II lists the dates when these clouds developed and their approximate velocities. One white cloud with nearby brownish clouds developed on October 26, 2013. Over the next five days, it approached Lomonosov from the west at ~6 m/s and caused little growth or shrinkage of the NPC/NPH.

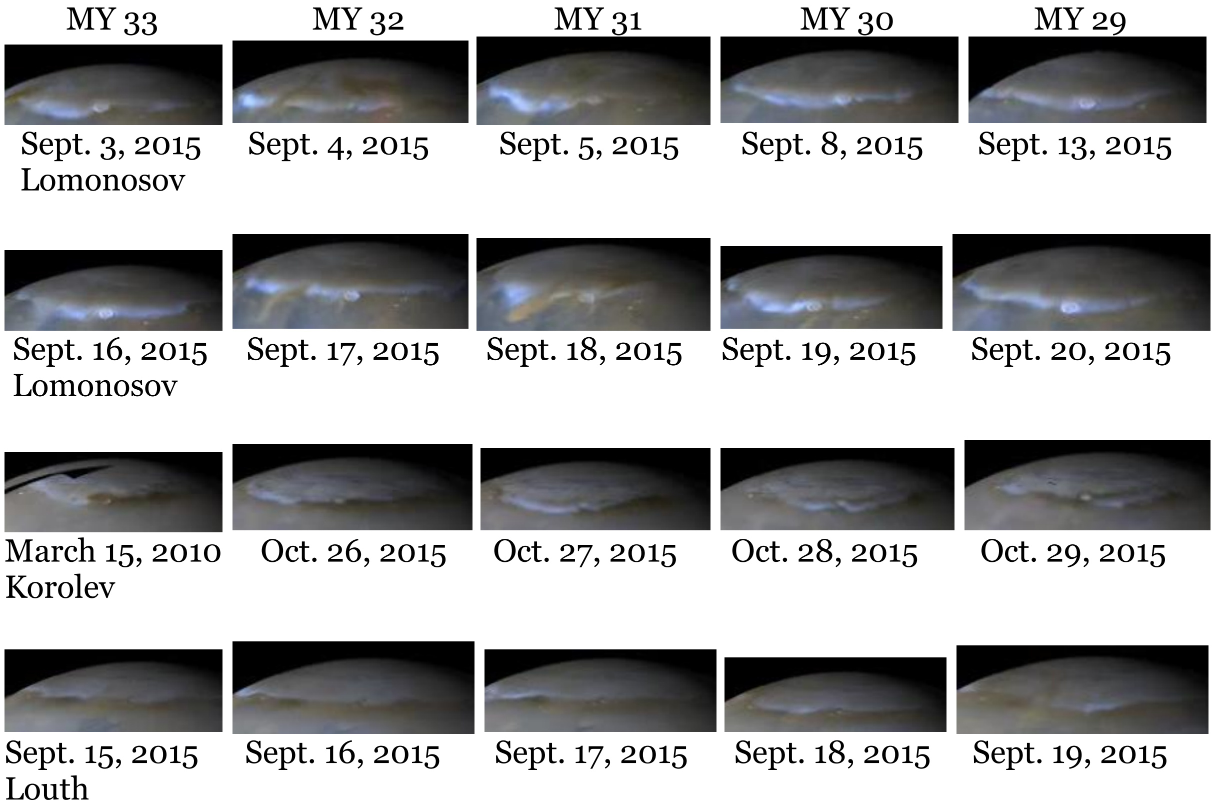

Figure 4. Images of the sNPC and weather systems near Lomonosov Crater–first and second rows; Korolev Crater–third row and Louth Crater–fourth row. In all cases north is to the top and east (on Mars) is to the right. All images were taken with the MARCI camera onboard the Mars Reconnaissance Orbiter (Malin et al. 2010k; 2015b-d,j). Image credit: NASA/JPL-Caltech/Malin Space Science Systems.

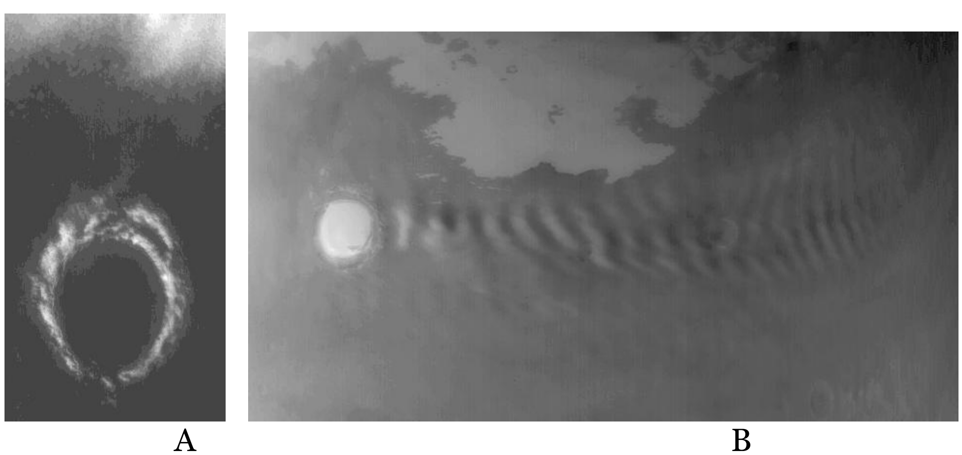

Figure 5. A. A blue filter image of Lomonosov Crater taken by the Mars Global Surveyor. The frost covered rims of this image are evident. Credit: NASA/JPL/Malin Space Science Systems. B. An image of Korolev Crater taken in red light. Note the cloud pattern to the right. Credit: NASA/JPL/Malin Space Science Systems.

Korolev Crater. This crater is named after Sergei Korolev, a Russian rocket designer. Figure 5B shows a wavy cloud pattern near Korolev (NASA photojournal image PIA06896 at photojournal.jpl.nasa.gov/targetFamily/Mars). This crater is mostly filled with ice. The third row in Figure 4 shows images of it which is the central white dot just south of the sNPC. On March 15, 2010, Korolev was darker than normal but it returned to its normal brightness one day later. A similar event happened on March 8, 2012. The sequence of images between October 26 and 29, 2015, shows a cloud approaching from the west. As it passed, a cloud band developed to the east of Korolev. By October 29, only a portion of the cloud band in the east remained. A portion of this crater's rim rises ~1.3 km above the surrounding plains (Head et al. 2002) and this may be the cause of the cloud band on October 29, 2015.

Louth Crater. This crater has a diameter near 36 km and it has the IAU provisional name of Louth (Brown et al. 2008). Part of the interior remains frost covered throughout the year. The last row in Figure 4 illustrates a five-day sequence of images showing changes near this crater. On September 16, a dark notch developed at the edge of the NPC. Louth lies to the southeast of this notch. One day later this feature became detached from the NPC. On September 18, a cloud developed to the west. It moved eastward and covered the crater on September 19. Dust storms often developed to the west of Louth. For example, a regional dust storm developed on January 28, 2010, and covered areas near it for several days. Several south-pointing clouds like the one on September 18, 2015, frame developed and moved over this crater.

Table II. Velocities of south-pointing clouds along the edge of the NPC

Date	Velocity	Longitude
Sept. 1-3, 2015	7 m/s eastward	East of Lomonosov
Sept 4-6, 2015	7 m/s eastward	“ “
Sept. 10-11, 2015	7 m/s eastward	“ “
Oct. 26-31, 2013	6 m/s eastward	“ “
Jan. 21-23, 2010	9 m/s eastward	“ “
Feb. 19-22, 2010	8 m/s eastward	“ “
Oct. 22-24, 2015	7 m/s eastward	East of Korolev
Dec. 23-24, 2013	5 m/s eastward	“ “
Dec. 24-25, 2013	9 m/s eastward	“ “
May 2-3, 2008	1 m/s westward	West of Korolev
Sept. 17-19, 2015	9 m/s eastward	East of Louth
Oct. 29-31, 2013	6 m/s eastward	“ “
Jan. 26-30, 2010	4 m/s eastward	“ “
Mean Velocity	**6 m/s eastward**	---
Standard deviation	**2.7 m/s**	---

Unnamed feature near 65° N, 110° W. This feature appears in the last row in Figure 3 and is near the image center and sNPC. It appeared as an isolated bright spot near the sNPC at L_S ~38°. The seasonal dates when this feature was last seen brighter than the surrounding terrain are summarized in Table III. It remained bright longer in MY 30 than in MY 29 and 31. This is one more example of a small year-to-year change.

Interestingly, the eastern portion of Ierne, which is just west, appears to be larger in MY 30 than in MY 29 and 31.

Unnamed feature near 68° N, 90° W. This feature developed just to the east of the spot at 65° N, 110° W. Interestingly, it survived longer in MY 30 than in the other years like the one at 65° N, 110° W.

Unnamed feature near 70° N, 310° W. This is shown in the fourth row in Figure 3 as a small isolated white dot near the center next to the sNPC. Differences at L_s = 57° are evident. It became detached from the cap at around L_s = 55°. The seasonal dates when this feature last appeared brighter than the surrounding terrain are listed in Table III. It retained its frost covering longer in MY 32 than in the other years.

Table III. L_s values when spots were last seen brighter than the surrounding terrain

Mars Year	**Isolated bright spot locations**		
	~65° N, ~110° W	**~70° N, ~310° W**	**~68° N, ~90° W**
33	63°-66°	71°	76°
32	65°	75°-76°	75°-75°
31	62°[a]	71°	74°
30	67°	70°	86°[b]
29	62°	64°	75°
Mean	**64°**	**70°**	**77°**

[a]Dust covered this feature after January 26. It may have survived longer under the dust.
[b]Additional images at Malin et al. (2010q,r) were examined.

The date when each of the features in Table I (excluding the pNPC) first became detached from the sNPC are listed in Table IV. Dates were determined from Malin et al. 2008a-f, k-m; 2010a-g, k-m; 2011a-e; 2012a,f,g; 2013a-g,k; 2014a,b and 2015a-e,k,l. There is some variation in the dates which is caused by a combination of changes in the border of the sNPC and clouds.

Table IV. Dates (L_s values) when frost features first separated from the sNPC

Feature	**Date of first separation (L_s)**					**Mean L_s**
	MY = 29	**MY = 30**	**MY = 31**	**MY = 32**	**MY = 33**	
Ierne	70	69	68	69	67	68
Olympia	70	71	68	68	68	69
Cecropia	67	70	68	70	68	69
Korolev	52	55	49	52	45	50
Louth	37	36	37	37	38	37
Lomonosov	40	42	43	39	38	41
Unnamed ~70° N, ~310° W	36	38	40	39	35	38
Unnamed ~65° N, ~110° W	40	39	39	37	37	38
Unnamed ~68° N, ~90° W	42	44	45	41	41	43

DISCUSSION

Figures 2–4 and Tables III and IV show there are year-to-year changes in the sNPC. It is difficult to distinguish between changes in cloud coverage and changes in the sNPC. Changes in Cecropia in MY = 29 (Figure 2), Ierne in MY = 32 (Figure 2), and the delayed disappearance of the frost spot at ~68° N, ~90° W in MY 30 (Table III) are consistent with changes in the frost areas. Essentially, frost disappears in some years earlier than in others. Therefore, it is concluded that the sNPC underwent small year-to-year changes between 2008 and 2015 (MY = 29–33).

It is also apparent that there are no years in MY = 29–33 where all frost features last longer than their mean lifespan. Essentially, the lifetimes of frost features at one longitude do not correlate with those at other longitudes. For example, in MY = 30, Korolev separated from the sNPC later than the mean date whereas, in that same year, Louth separated a little earlier than the mean date. As a second example, the edge of the sNPC was farther north of Korolev in MY = 29, but was farther south of Lomonosov a few weeks earlier. See Figure 3. Finally, the feature at ~68° N, ~90° W lasted much longer in MY = 30 whereas, in that same year, the feature at ~70° N, ~310° W lasted at nearly the mean time. Therefore, a second conclusion is that there are no years where all temporary frost features lasted longer than the mean date.

A third conclusion is that local clouds, dust storms, and winds probably play a role in the apparent location of the sNPC edge. Local winds may also play a role in the year-to-year thickness of the cap at specific locations. Essentially, a thick portion will disappear later than a thin one with all other factors being equal. Clouds are illustrated in Figures 4 and 5. Table II summarizes cloud movement along the edge of the sNPC; this movement was undoubtedly influenced by wind.

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REFERENCES

Astronomical Almanac, U.S. Govt. Printing Office, Washington D.C.

Batson, R.M., P.M. Bridges, and J.L. Inge. 1979. Atlas of Mars, NASA SP 438, Washington DC.

Beish, J.D. Observing the Planet Mars. 2012. www.alpoastronomy.org/jbeish/Observing_Mars.html, Table 3–3.

Benson, J.L. and P.B. James. 2005. Yearly comparisons of the Martian polar caps: 1999–2003 Mars Orbiter Camera observations. Icarus, 174, 513-523.

Brown, A.J., S. Byrne, L.L. Tornabene, and T. Roush. 2008. Louth Crater: Evolution of a layered water ice mound. Icarus, 196, 433-445.

Cantor, B.A., M.J. Wolff, P.B. James, and E. Higgs. 1998. Regression of Martian North Polar Cap: 1990-1997 Hubble Space Telescope observations. Icarus, 136, 175-191.

Capen, C.F. and V.W. Capen. 1970. Martian north polar cap, 1962-1968. Icarus, 13, 100-108.

Carr, M. 2006. The Surface of Mars, Cambridge University Press, Cambridge, p. 211.

Chittenden, J.D., V. Chevier, L.A. Roe, K. Bryson, R. Pilgrim, and D.W.G. Sears. 2008. Experimental study of the effect of wind on the stability of water ice on Mars. Icarus, 196, 477-487.

Christensen P.R. and R.W. Zurek. 1984. Martian north polar hazes and surface ice: Results from the Viking Survey/Completion mission. J. Geophys. Res. 89, 4587-4596.

Clancy, R.T., B.J.U. Sandor, M.J. Wolff, P.R. Christensen, M.D. Smith, J.C. Pearl, B.J. Conrath, and R.J. Wilson. 2000. An intercomparison of ground-based millimeter MGS TES and Viking atmospheric temperature measurements: Seasonal and interannual variability of temperatures and dust loading in the global Mars atmosphere. J. Geophys. Res., 105, 9553-9571.

CRC Standard Mathematical Tables, Chemical Rubber Publishing Co., Cleveland, OH, p. 340, 1955.

Dollfus, A. 1973. New optical measurements of planetary diameters IV. Size of the north polar cap of Mars. Icarus, 18, 142-155.

Fischbacher, G.E., L.J. Martin, and W.A. Baum. 1969. Martian Polar Cap Boundaries. Final Report, part A under Contract No. 951547, Planetary Research Center, Lowell Observatory.

Hahn, G. and H.J. Mettig. 2016. Please see: jupos.privat.t-online.de

Head, J.W., P. Russell, M. Hecht, and J.B. Garvin. 2002. Korolev Crater Mars: Characteristics and origin of volatile-rich deposits in the crater interior. Microsymposium, 36, MS031.

Ivanov, A.B. and D.O. Muhleman. 2000. The role of sublimation for the formation of the northern ice cap: Results from the Mars Orbiter laser altimeter. Icarus, 144, 436-448.

Iwasaki, K., Y. Saito, and T. Akabane. 1979. Behavior of the Martian north polar cap, 1975-1978. J. Geophys. Res., 84, 8,311-8,316.

Iwasaki, K., Y. Saito, and T. Akabane. 1982. Martian north polar cap, 1979-1980. J. Geophys. Res., 87(B12), 10265-10269.

Iwasaki, K., S. Yoshikazu, and T. Akabane. 1984. Martian north polar cap and haze 1981–1982. Pub. of the Astron. Soc. Japan, 36, 347-356.

Iwasaki, K., Y. Saito, and T. Akabane. 1986. Interannual differences in the regressions of the polar caps of Mars. MECA Symposium on Mars: Evolution of its Climate and Atmosphere, V. Baker et al., editors, LPI Technical Report Number 87-01.

James, P.B. 1979. Recession of Martian north polar cap: 1977–1978 Viking observations. Journal of Geophysical Research, 84(B14), 8332-8334.

James, P.B. 1982. Recession of Martian north polar cap: 1979–1980 Viking observations. Icarus, 52, 565-569.

James, P.B., M. Pierce, and L.J. Martin. 1987. Martian north polar cap and circumpolar clouds: 1975–1980 telescopic observations. Icarus, 71, 306-312.

James, P.B., R.T. Clancy, S.W. Lee, L. Martin, R. Kahn, R. Zurek, R. Singer, and E. Smith. 1994. Monitoring Mars with the Hubble Space Telescope: 1990–1991 observations. Icarus, 109, 79-101.

James, P.B., J.F Bell III, R.T. Clancy, S.W. Lee, L.J. Martin, and M.J. Wolff. 1996. Global imaging of Mars by Hubble Space Telescope during the 1995 opposition. J. Geophys. Res., 101, 18883-18890.

James, P.B. and B.A. Cantor. 2001. Martian north polar cap recession: 2000 Mars orbiter camera observations. Icarus, 154, 131-144.

James, P., S. Lee, L. Martin, T. Clancy, M. Wolf, and J. Bell. 2015. See http://marswatch.tn.cornell.edu/hst96-97.html.

Kieffer, H.H. and T.N. Titus. 2001. TES mapping of Mars' north seasonal cap. Icarus, 154, 162-180.

Malin Space Science Systems, San Diego, California. 2009. please see: http://www.msss.com/msss_images/subject/weather_reports.html

Malin, M.C., B.A. Cantor, and J.A. Lougen. 2008a. MRO MARCI Weather Report for the Week of 18 February 2008 – 24 February 2008, Malin Space Science Systems Captioned Image Release, MSSS-19, http://www.msss.com/msss_images/2008/02/27/.

Malin, M.C., B.A. Cantor, D.E. Shean, M.R. Kennedy, and J.A. Lougen. 2008b. MRO MARCI Weather Report for the Week of 25 February 2008 – 2 March 2008, Malin Space Science Systems Captioned Image Release, MSSS-20, http://www.msss.com/msss_images/2008/03/05/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, and D.E. Shean. 2008c. MRO MARCI Weather Report for the Week of 3 March 2008 – 9 March 2008, Malin Space Science Systems Captioned Image Release, MSSS-21, http://www.msss.com/msss_images/2008/03/12/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, and D.E. Shean. 2008d. MRO MARCI Weather Report for the Week of 10 March 2008 – 16 March 2008, Malin Space Science Systems Captioned Image Release, MSSS-22, http://www.msss.com/msss_images/2008/03/19/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, and D.E. Shean. 2008e. MRO MARCI Weather Report for the Week of 17 March 2008 – 23 March 2008, Malin Space Science Systems Captioned Image Release, MSSS-23, http://www.msss.com/msss_images/2008/03/26/.

Malin, M.C., B.A. Cantor, D.E. Shean, and M.R. Kennedy. 2008f. MRO MARCI Weather Report for the Week of 24 March 2008 – 30 March 2008, Malin Space Science Systems Captioned Image Release, MSSS-25, http://www.msss.com/msss_images/2008/04/02/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, and D.E. Shean. 2008g. MRO MARCI Weather Report for the Week of 31 March 2008 – 6 April 2008, Malin Space Science Systems Captioned Image Release, MSSS-26, http://www.msss.com/msss_images/2008/04/09/.

Malin, M.C., B.A. Cantor, D.E. Shean, and M.R. Kennedy. 2008h. MRO MARCI Weather Report for the Week of 7 April 2008 – 13 April 2008, Malin Space Science Systems Captioned Image Release, MSSS-27, http://www.msss.com/msss_images/2008/04/16/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, and D.E. Shean. 2008i. MRO MARCI Weather Report for the Week of 14 April 2008 – 20 April 2008, Malin Space Science Systems Captioned Image Release, MSSS-28, http://www.msss.com/msss_images/2008/04/23/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, and D.E. Shean. 2008j. MRO MARCI Weather Report for the Week of 21 April 2008 – 27 April 2008, Malin Space Science Systems Captioned Image Release, MSSS-29, http://www.msss.com/msss_images/2008/04/30/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, and D.E. Shean. 2008k. MRO MARCI Weather Report for the Week of 28 April 2008 – 4 May 2008, Malin Space Science Systems Captioned Image Release, MSSS-31, http://www.msss.com/msss_images/2008/05/07/.

Malin, M.C., B.A. Cantor, D.E. Shean, and M.R. Kennedy. 2008l. MRO MARCI Weather Report for the Week of 5 May 2008 – 11 May 2008, Malin Space Science Systems Captioned Image Release, MSSS-32, http://www.msss.com/msss_images/2008/05/14/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, and D.E. Shean. 2008m. MRO MARCI Weather Report for the Week of 12 May 2008 – 18 May 2008, Malin Space Science Systems Captioned Image Release, MSSS-33, http://www.msss.com/msss_images/2008/05/21/.

Malin, M.C., B.A. Cantor, D.E. Shean, and M.R. Kennedy. 2008n. MRO MARCI Weather Report for the Week of 19 May 2008 – 25 May 2008, Malin Space Science Systems Captioned Image Release, MSSS-34, http://www.msss.com/msss_images/2008/05/28/.

Malin, M.C., B.A. Cantor, D.E. Shean, and M.R. Kennedy. 2008o. MRO MARCI Weather Report for the Week of 26 May 2008 – 1 June 2008, Malin Space Science Systems Captioned Image Release, MSSS-35, http://www.msss.com/msss_images/2008/06/04/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, and D.E. Shean. 2008p. MRO MARCI Weather Report for the Week of 2 June 2008 – 8 June 2008, Malin Space Science Systems Captioned Image Release, MSSS-36, http://www.msss.com/msss_images/2008/06/11/.

Malin, M.C., B.A. Cantor, D.E. Shean, and M.R. Kennedy, T.N. Harrison. 2010a. MRO MARCI Weather Report for the Week of 4 January 2010 – 10 January 2010, Malin Space Science Systems Captioned Image Release, MSSS-104, http://www.msss.com/msss_images/2010/01/13/.

Malin, M.C., B.A. Cantor, T.N. Harrison, and D.E. Shean, M.R. Kennedy. 2010b. MROMARCI Weather Report for the Week of 11 January 2010 – 17 January 2010, Malin Space Science Systems Captioned Image Release, MSSS-105, http://www.msss.com/msss_images/2010/01/20/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2010c. MRO MARCI Weather Report for the Week of 18 January 2010 – 24 January 2010, Malin Space Science Systems Captioned Image Release, MSSS-106, http://www.msss.com/msss_images/2010/01/27/.

Malin, M.C., B.A. Cantor, D.E. Shean, M.R. Kennedy, and T.N. Harrison. 2010d. MRO MARCI Weather Report for the Week of 25 January 2010 – 31 January 2010, Malin Space Science Systems Captioned Image Release, MSSS-107, http://www.msss.com/msss_images/2010/02/03/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2010e. MRO MARCI Weather Report for the Week of 1 February 2010 – 7 February 2010, Malin Space Science Systems Captioned Image Release, MSSS-108, http://www.msss.com/msss_images/2010/02/10/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2010f. MRO MARCI Weather Report for the Week of 8 February 2010 – 14 February 2010, Malin Space Science Systems Captioned Image Release, MSSS-109, http://www.msss.com/msss_images/2010/02/17/.

Malin, M.C., B.A. Cantor, D.E. Shean, M.R. Kennedy, and T.N. Harrison. 2010g. MRO MARCI Weather Report for the Week of 15 February 2010 – 21 February 2010, Malin Space Science Systems Captioned Image Release, MSSS-110, http://www.msss.com/msss_images/2010/02/24/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2010h. MRO MARCI Weather Report for the Week of 22 February 2010 – 28 February 2010, Malin Space Science Systems Captioned Image Release, MSSS-111, http://www.msss.com/msss_images/2010/03/03/.

Malin, M.C., B.A. Cantor, D.E. Shean, M.R. Kennedy, and T.N. Harrion. 2010i. MRO MARCI Weather Report for the Week of 1 March 2010 – 7 March 2010, Malin Space Science Systems Captioned Image Release, MSSS-112, http://www.msss.com/msss_images/2010/03/10/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2010j. MRO MARCI Weather Report for the Week of 8 March 2010 – 14 March 2010, Malin Space Science Systems Captioned Image Release, MSSS-113, http://www.msss.com/msss_images/2010/03/17/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2010k. MRO MARCI Weather Report for the Week of 15 March 2010 – 21 March 2010, Malin Space Science Systems Captioned Image Release, MSSS-114, http://www.msss.com/msss_images/2010/03/24/.

Malin, M.C., B.A. Cantor, D.E. Shean, M.R. Kennedy, and T.N. Harrison. 2010l. MRO MARCI Weather Report for the Week of 22 March 2010 – 28 March 2010, Malin Space Science Systems Captioned Image Release, MSSS-115, http://www.msss.com/msss_images/2010/03/31/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2010m. MRO MARCI Weather Report for the Week of 29 March 2010 – 4 April 2010, Malin Space Science Systems Captioned Image Release, MSSS-116, http://www.msss.com/msss_images/2010/04/07/.

Malin, M.C., B.A. Cantor, D.E. Shean, M.R. Kennedy, and T.N. Harrison. 2010n. MRO MARCI Weather Report for the Week of 5 April 2010 – 11 April 2010, Malin Space Science Systems Captioned Image Release, MSSS-117, http://www.msss.com/msss_images/2010/04/14/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2010o. MRO MARCI Weather Report for the Week of 12 April 2010 – 18 April 2010, Malin Space Science Systems Captioned Image Release, MSSS-118, http://www.msss.com/msss_images/2010/04/21/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2010p. MRO MARCI Weather Report for the Week of 19 April 2010 – 25 April 2010, Malin Space Science Systems Captioned Image Release, MSSS-119, http://www.msss.com/msss_images/2010/04/28/.

Malin, M.C., B. A. Cantor, D.E. Shean, M.R. Kennedy, and T.N. Harrison. 2010q. MRO MARCI Weather Report for the Week of 26 April 2010 – 2 May 2010, Malin Space Science Systems Captioned Image Release, MSSS-120, http://www.msss.com/msss_images/2010/05/05/.

Malin, M.C., B. A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2010r. MRO MARCI Weather Report for the Week of 3 May 2010 – 9 May 2010, Malin Space Science Systems Captioned Image Release, MSSS-121, http://www.msss.com/msss_images/2010/05/12/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2011a. MRO MARCI Weather Report for the Week of 21 November 2011 – 27 November 2011, Malin Space Science Systems Captioned Image Release, MSSS-199, http://www.msss.com/msss_images/2011/11/30/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2011b. MRO MARCI Weather Report for the Week of 28 November 2011 – 4 December 2011, Malin Space Science Systems Captioned Image Release, MSSS-200, http://www.msss.com/msss_images/2011/12/07/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2011c. MRO MARCI Weather Report for the Week of 5 December 2011 – 11 December 2011, Malin Space Science Systems Captioned Image Release, MSSS-201, http://www.msss.com/msss_images/2011/12/14/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2011d. MRO MARCI Weather Report for the Week of 12 December 2011 – 18 December 2011, Malin Space Science Systems Captioned Image Release, MSSS-202, http://www.msss.com/msss_images/2011/12/21/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2011e. MRO MARCI Weather Report for the Week of 19 December 2011 – 25 December 2011, Malin Space Science Systems Captioned Image Release, MSSS-203, http://www.msss.com/msss_images/2011/12/28/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2012a. MRO MARCI Weather Report for the Week of 26 December 2011 – 1 January 2012, Malin Space Science Systems Captioned Image Release, MSSS-204, http://www.msss.com/msss_images/2012/01/04/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2012b. MRO MARCI Weather Report for the Week of 2 January 2012 – 8 January 2012, Malin Space Science Systems Captioned Image Release, MSSS-205, http://www.msss.com/msss_images/2012/01/11/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2012c. MRO MARCI Weather Report for the Week of 9 January 2012 – 15 January 2012, Malin Space Science Systems Captioned Image Release, MSSS-206, http://www.msss.com/msss_images/2012/01/18/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2012d. MRO MARCI Weather Report for the Week of 16 January 2012 – 22 January 2012, Malin Space Science Systems Captioned Image Release, MSSS-207, http://www.msss.com/msss_images/2012/01/25/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2012e. MRO MARCI Weather Report for the Week of 23 January 2012 – 29 January 2012, Malin Space Science Systems Captioned Image Release, MSSS-208, http://www.msss.com/msss_images/2012/02/01/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2012f. MRO MARCI Weather Report for the Week of 30 January 2012 – 5 February 2012, Malin Space Science Systems Captioned Image Release, MSSS-209, http://www.msss.com/msss_images/2012/02/08/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2012g. MRO MARCI Weather Report for the Week of 6 February 2012 – 12 February 2012, Malin Space Science Systems Captioned Image Release, MSSS-211, http://www.msss.com/msss_images/2012/02/15/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2012h. MRO MARCI Weather Report for the Week of 13 February 2012 – 19 February 2012, Malin Space Science Systems Captioned Image Release, MSSS-212, http://www.msss.com/msss_images/2012/02/22/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2012i. MRO MARCI Weather Report for the Week of 20 February 2012 – 26 February 2012, Malin Space Science Systems Captioned Image Release, MSSS-213, http://www.msss.com/msss_images/2012/02/29/.

Malin, M.C., B.A. Cantor, T.N. Harrison, D.E. Shean, and M.R. Kennedy. 2012j. MRO MARCI Weather Report for the Week of 27 February 2012 – 4 March 2012, Malin Space Science Systems Captioned Image Release, MSSS-214, http://www.msss.com/msss_images/2012/03/07/.

Malin, M.C., B.A. Cantor, M.R. Kennedy, D.E. Shean, and T.N. Harrison. 2012k. MRO MARCI Weather Report for the Week of 5 March 2012 – 11 March 2012, Malin Space Science Systems Captioned Image Release, MSSS-215, http://www.msss.com/msss_images/2012/03/14/.

Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013a. MRO MARCI Weather Report for the Week of 7 October 2013 – 13 October 2013, Malin Space Science Systems Captioned Image Release, MSSS-295, http://www.msss.com/msss_images/2013/10/16/.

Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013b. MRO MARCI Weather Report for the Week of 14 October 2013 – 20 October 2013, Malin Space Science Systems Captioned Image Release, MSSS-296, http://www.msss.com/msss_images/2013/10/23/.

Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013c. MRO MARCI Weather Report for the Week of 21 October 2013 – 27 October 2013, Malin Space Science Systems Captioned Image Release, MSSS-297, http://www.msss.com/msss_images/2013/10/30/.

Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013d. MRO MARCI Weather Report for the Week of 28 October 2013 – 3 November 2013, Malin Space Science Systems Captioned Image Release, MSSS-298, http://www.msss.com/msss_images/2013/11/06/.
Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013e. MRO MARCI Weather Report for the Week of 4 November 2013 – 10 November 2013, Malin Space Science Systems Captioned Image Release, MSSS-299, http://www.msss.com/msss_images/2013/11/13/.
Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013f. MRO MARCI Weather Report for the Week of 11 November 2013 – 17 November 2013, Malin Space Science Systems Captioned Image Release, MSSS-300, http://www.msss.com/msss_images/2013/11/20/.
Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013g. MRO MARCI Weather Report for the Week of 18 November 2013 – 24 November 2013, Malin Space Science Systems Captioned Image Release, MSSS-301, http://www.msss.com/msss_images/2013/11/27/.
Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013h. MRO MARCI Weather Report for the Week of 25 November 2013 – 1 December 2013, Malin Space Science Systems Captioned Image Release, MSSS-302, http://www.msss.com/msss_images/2013/12/04/.
Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013i. MRO MARCI Weather Report for the Week of 2 December 2013 – 8 December 2013, Malin Space Science Systems Captioned Image Release, MSSS-303, http://www.msss.com/msss_images/2013/12/11/.
Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013j. MRO MARCI Weather Report for the Week of 9 December 2013 – 15 December 2013, Malin Space Science Systems Captioned Image Release, MSSS-304, http://www.msss.com/msss_images/2013/12/18/.
Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2013k. MRO MARCI Weather Report for the Week of 16 December 2013 – 22 December 2013, Malin Space Science Systems Captioned Image Release, MSSS-305, http://www.msss.com/msss_images/2013/12/25/.
Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2014a. MRO MARCI Weather Report for the Week of 23 December 2013 – 29 December 2013, Malin Space Science Systems Captioned Image Release, MSSS-306, http://www.msss.com/msss_images/2014/01/01/.
Malin, M.C., B.A. Cantor, L.M. Saper, and M.R. Wu. 2014b. MRO MARCI Weather Report for the Week of 30 December 2013 – 7 January 2014, Malin Space Science Systems Captioned Image Release, MSSS-307, http://www.msss.com/msss_images/2014/01/08/.
Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2014c. MRO MARCI Weather Report for the Week of 6 January 2014 – 12 January 2014, Malin Space Science Systems Captioned Image Release, MSSS-308, http://www.msss.com/msss_images/2014/01/14/.

Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2014d. MRO MARCI Weather Report for the Week of 13 January 2014 – 19 January 2014, Malin Space Science Systems Captioned Image Release, MSSS-309, http://www.msss.com/msss_images/2014/01/22/.

Malin, M.C., B.A. Cantor, M.R. Wu, and L.M. Saper. 2014e. MRO MARCI Weather Report for the Week of 20 January 2014 – 26 January 2014, Malin Space Science Systems Captioned Image Release, MSSS-310, http://www.msss.com/msss_images/2014/01/29/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015a. MRO MARCI Weather Report for the Week of 24 August 2015 – 30 August 2015, Malin Space Science Systems Captioned Image Release, MSSS-390, http://www.msss.com/msss_images/2015/09/02/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015b. MRO MARCI Weather Report for the Week of 31 August 2015 – 6 September 2015, Malin Space Science Systems Captioned Image Release, MSSS-391, http://www.msss.com/msss_images/2015/09/09/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015c. MRO MARCI Weather Report for the Week of 7 September 2015 – 13 September 2015, Malin Space Science Systems Captioned Image Release, MSSS-392, http://www.msss.com/msss_images/2015/09/16/.

Malin, M.C., B.A. Cantor, A.W. Britton and, M.R. Wu. 2015d. MRO MARCI Weather Report for the Week of 14 September 2015 – 20 September 2015, Malin Space Science Systems Captioned Image Release, MSSS-393, http://www.msss.com/msss_images/2015/09/23/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015e. MRO MARCI Weather Report for the Week of 21 September 2015 – 27 September 2015, Malin Space Science Systems Captioned Image Release, MSSS-394, http://www.msss.com/msss_images/2015/09/30/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015f. MRO MARCI Weather Report for the Week of 28 September 2015 – 4 October 2015, Malin Space Science Systems Captioned Image Release, MSSS-395, http://www.msss.com/msss_images/2015/10/07/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015g. MRO MARCI Weather Report for the Week of 5 October 2015 – 11 October 2015, Malin Space Science Systems Captioned Image Release, MSSS-396, http://www.msss.com/msss_images/2015/10/14/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015h. MRO MARCI Weather Report for the Week of 12 October 2015 – 18 October 2015, Malin Space Science Systems Captioned Image Release, MSSS-397, http://www.msss.com/msss_images/2015/10/21/.

Malin, M.C., B.A. Cantor, A. W. Britton, and M.R. Wu. 2015i. MRO MARCI Weather Report for the Week of 19 October 2015 – 25 October 2015, Malin Space Science Systems Captioned Image Release, MSSS-398, http://www.msss.com/msss_images/2015/10/28/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015j. MRO MARCI Weather Report for the Week of 26 October 2015 – 1 November 2015, Malin Space Science Systems Captioned Image Release, MSSS-399, http://www.msss.com/msss_images/2015/11/04/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015k. MRO MARCI Weather Report for the Week of 2 November 2015 – 8 November 2015, Malin Space Science Systems Captioned Image Release, MSSS-400, http://www.msss.com/msss_images/2015/11/11/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015l. MRO MARCI Weather Report for the Week of 9 November 2015 – 15 November 2015, Malin Space Science Systems Captioned Image Release, MSSS-401, http://www.msss.com/msss_images/2015/11/18/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015m. MRO MARCI Weather Report for the Week of 16 November 2015 – 22 November 2015, Malin Space Science Systems Captioned Image Release, MSSS-402, http://www.msss.com/msss_images/2015/11/25/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015n. MRO MARCI Weather Report for the Week of 23 November 2015 – 29 November 2015, Malin Space Science Systems Captioned Image Release, MSSS-403, http://www.msss.com/msss_images/2015/12/02/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015o. MRO MARCI Weather Report for the Week of 30 November 2015 – 6 December 2015, Malin Space Science Systems Captioned Image Release, MSSS-404, http://www.msss.com/msss_images/2015/12/09/.

Malin, M.C., B.A. Cantor, A.W. Britton, and M.R. Wu. 2015p. MRO MARCI Weather Report for the Week of 7 December 2015 – 13 December 2015, Malin Space Science Systems Captioned Image Release, MSSS-405, http://www.msss.com/msss_images/2015/12/16/.

McKim, R. 2011. The opposition of Mars, 2005: Part II. J. Brit. Astron. Assoc., 121(4), 215-222.

Parker, D.C., J.D. Beish, D.M. Troiani, D.D. Joyce, and C.E. Hernandez. 1999. Telescopic observations of Mars, 1996-1997: Results of the Marswatch program. Icarus, 138, 3-19.

Schmude, R.W. Jr. 2013. The north polar cap of Mars from 2007 to 2012. Journal of the Royal Astronomical Society of Canada, 107, 233-239.

Schmude, R.W. Jr. 2014a. The north polar cap of Mars. Georgia Journal of Science, 72, 88-93.

Schmude, R.W. Jr. 2014b. Some recent studies of Mars: The north polar cap, Cecropia and Hellas. Georgia Journal of Science, 72, 109-119.