# The opposition of Mars, 2007: Part I

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*A report of the Mars Section. Director: R. J. McKim*

Part I of this report (covering 2007 Jan to 2008 Aug) describes the first global martian dust storm since 2001. It began on 2007 Jun 23 at Ls= 263° in E. *Noachis* and lasted for around 107 days, continuing into early October: considerably shorter in duration than the 2001 event. The storm led to significant albedo changes in *Aethiopis*, *Daedalia*, *Mare Sirenum*, *Margaritifer Sinus–Mare Erythraeum*, *Noachis*, *Solis Lacus*, *Syrtis Major* and *Trinacria*. All such changes were of a type previously seen. A dark band crossed *Noachis* diagonally, somewhat as in 1928–'29, whilst *Pandorae Fretum* disappeared; *Solis Lacus* became elongated SE to NW, as in 1926–'29 and after the 2001 global storm. Other small dust storms included a local one in *Chryse Planitia* in 2007 Nov, and a rare northern event in *Casius–Utopia* in 2008 Jan, which were both linked to fronts moving off the N. polar region. Part II will describe the white crystal clouds and polar regions.

## Introduction

At opposition on 2007 Dec 24 (88.6 million km, D [disk diameter] = 15".8, Ls= 007°), Mars lay in Gemini at declination +26.7°. This was the first in a new series of aphelic encounters (those occurring within 90° of aphelion (Ls= 70°)). Preliminary results were communicated in *Circulars*,[1] an emailed dust storm alert, a Council Report[2] and two Interim Reports.[3,4] Observing advice was given in popular magazines.[5] The apparition was seasonally similar to 1993 (Ls= 022° at opposition),[6] 1975 (357°),[7] 1960 (014°),[8] and – in particular – 1928 (005°).[9]

The latitude of the sub-Earth point ($D_e$) at opposition was +1.5°. $D_e$ and $D_s$ (the latitude of the subsolar point) coincided exactly on 2007 Dec 20 (+2.2°). Closest approach was on Dec 19. Between 2007 Jun 14 and 2008 Apr 24, D exceeded 6".0.

Many images were available: the Lumenera LU-075M and Skynyx 2-0M cameras proved the most popular. Peach, Morita and Yunoki obtained the longest series. The Director made 116 drawings and Hancock sent 134 originals; Abel, Adachi, Adamoli, Biver, Macsymowicz and Niechoy each contributed a good number. Henshaw made visual magnitude estimates. There were 11,181 observations (10,111 images and 1,070 drawings) from 136 observers (Table 2). Data cover 88% of a martian year between 2007 Jan 4 (Heffner (image), Ls= 161°) and 2008 Aug 24 (Adamoli (visual), Ls= 117°). Days

**Table 1. Physical details of the 2007 apparition**

| | | |
|---|---|---|
| Solar conjunction | 2006 Oct 23 | Ls= 124° |
| S. Spring equinox/ N. Autumnal equinox | 2007 Feb 7 | Ls= 180° |
| Perihelion | 2007 Jun 2 | Ls= 250° |
| S. Summer solstice/ N. Winter solstice | 2007 Jul 4 | Ls= 270° |
| S. Autumnal equinox/ N. Spring equinox | 2007 Dec 9 | Ls= 0° |
| Opposition | 2007 Dec 24 | Ls= 7° |
| Aphelion | 2008 May 10 | Ls= 70° |
| S. Winter solstice/ N. Summer solstice | 2008 Jun 25 | Ls= 90° |
| Solar conjunction | 2008 Dec 5 | Ls= 169° |

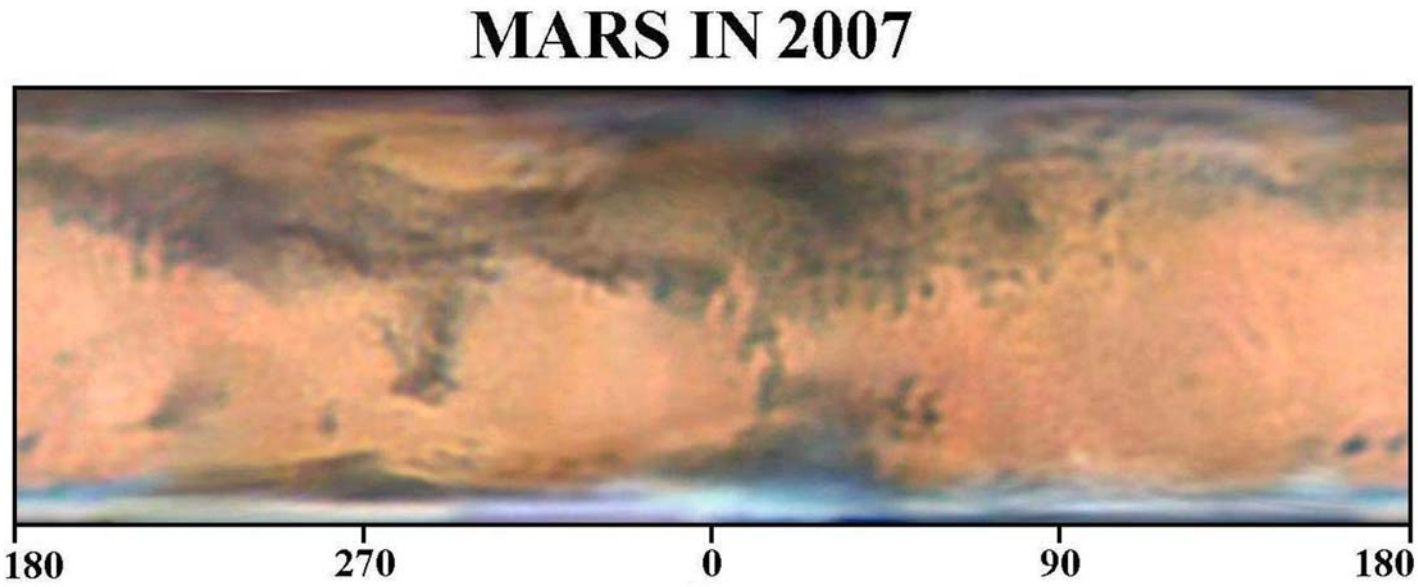



**Figure 1.** Map based upon his personal best near-opposition images (2007 Oct 5–Dec 31), with 320mm refl. and DMK 21AF04.AS camera. South is uppermost. *Sean Walker*.

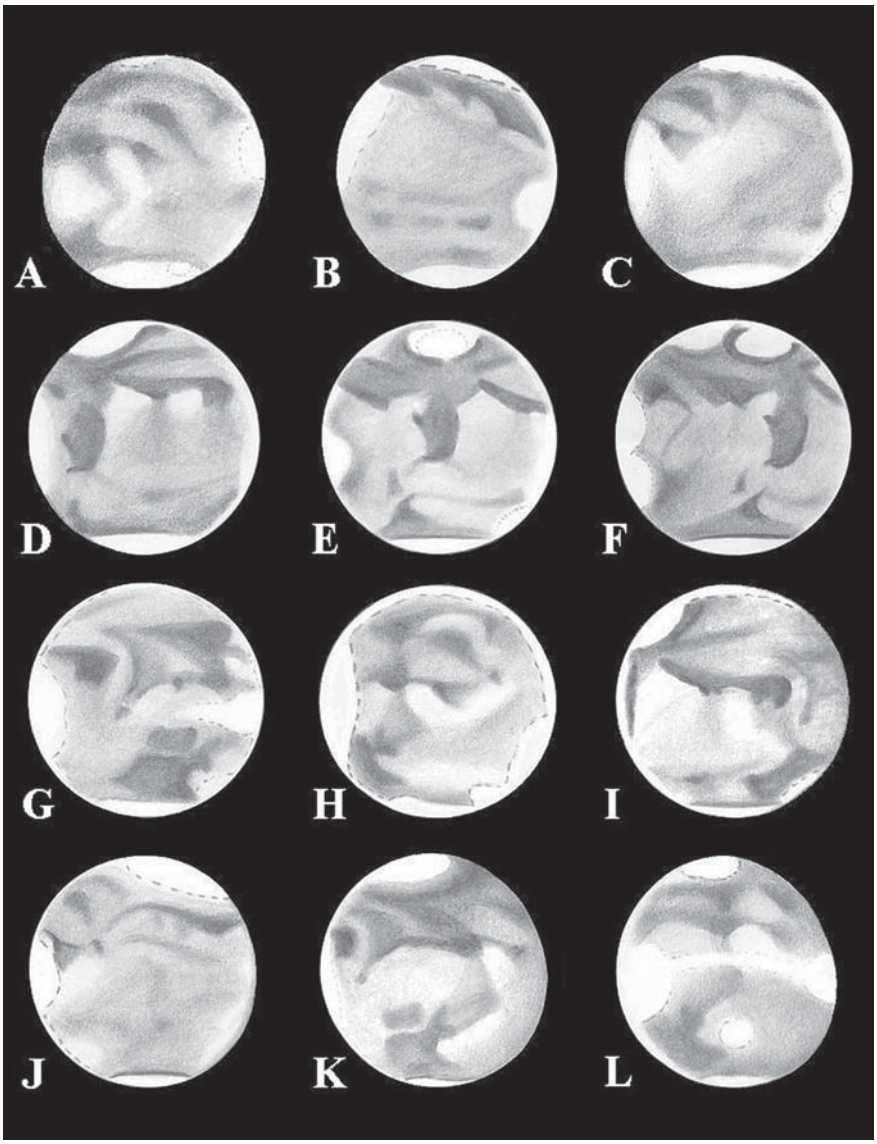



**Figure 2.** Drawings by the Director using a 410mm DK Cass., ×256, ×410, white light, with W21 (orange), 25 (red) and 80A (blue) filters.

***First row*: (a)** 2007 Oct 29d 05h 45m, CML= 96°. *Solis Lacus* extended NW. NPH with bright spot.
**(b)** 2007 Nov 16d 23h 00m, CML= 183°. *Elysium* and *Tharsis* slightly white.
**(c)** 2007 Nov 23d 22h 15m, CML= 108°. *Tharsis Montes* seen. *Phasis*/*Sirenum* extension. Sharp-edged NPC.

***Second row*: (d)** 2007 Dec10d 21h 35m, CML= 307°. Evening *Hellas* and *Isidis Regio–Libya* very white (v.w.). *Noachis* streak.
**(e)** 2008 Dec 12d 21h 15m, CML= 285°. *Hellas*, *Elysium* and N*f*. limb bright patches.
**(f)** 2008 Dec 13d 20h 35m, CML= 266°. *Aetheria* and *Aethiopis* developments. SPH in *Ausonia* and *Hellas*.

***Third row*: (g)** 2008 Jan 5d 17h 35m, CML= 20°. A.m. and p.m. clouds (the former extending along equator). W. end of *Mare Erythraeum* very dark.
**(h)** 2008 Jan 5d 21h 27m, CML= 77°. A trace of NPH broadens the NPR on the p.m. side.
**(i)** 2008 Jan 16d 22h 05m, CML= 348°. Foreshortened NPC. *Noachis* streak. *Ismenius Lacus* weak.

***Fourth row*: (j)** 2008 Feb 4d 18h 50m, CML= 128°. *Mare Sirenum* E. extension–*Phasis*. Details in N. and equatorial deserts include *Olympus Mons*. SPH.
**(k)** 2008 Feb 11d 18h 00m, CML= 52°. *Argyre* and environs v.w.
**(l)** 2008 Mar 21d 19h 10m, CML= 63°. As (k), plus Equatorial Cloud Band fully formed, crossing *Ganges*.

observed: 2007 Jan 2/31 (*e.g.*, 2 out of 31 possible); Feb 5/28; Mar 2/31; Apr 17/30; May 25/31; Jun 23/30; Jul 30/31; Aug 31/31; Sep 30/30; Oct 31/31; Nov 29/30; Dec 31/31; 2008 Jan 31/31; Feb 29/29; Mar 30/31; Apr 29/30; May 27/31; Jun 14/30; Jul 17/31; Aug 8/31.

Adelaar[10] reported for the VvS (Netherlands). Other groups included the Association of Lunar & Planetary Observers (ALPO, USA),[11] ALPO Japan (JALPON),[12] OAA (Japan),[13] Société Astronomique de France (SAF),[14] and Unione Astrofili Italiani (UAI).[15] Observers continued to upload images to the online databases of the latter groups and to *Marswatch*.[16]

*Mars Global Surveyor* ceased to operate on 2006 Nov 2, but the planet was still followed by ESA's *Mars Express*,[17] was bypassed by *Rosetta* on 2007 Feb 24,[18] continued to be scrutinised on the surface by NASA's twin *Mars Exploration Rovers* (*MER*), *Spirit* and *Opportunity*,[19] and from orbit by *Mars Reconaissance Orbiter* (*MRO*).[20] The Rovers' images of the Sun and sky particularly helped in studying the 2007 global storm; during 2007–'08 they both continued their journeys over the surface, although *Spirit* would become permanently stuck in soft soil on 2009 May 1. The Hubble Space Telescope[21] made near-opposition images. *Mars Odyssey* continued to provide particularly relevant data from its *THEMIS* instrument in martian orbit, as summarised by Smith.[22] NASA's *Phoenix* spacecraft[23] landed safely on 2008 May 25 at +68.2°, 125.7° in E. *Scandia* (within *Vastitas Borealis*); its early work, including the positive detection of surface water ice, was briefly discussed by the writer in an earlier report.[4] Contact was lost on Nov 2 after 150 Sols.

For telescopic nomenclature, see Ebisawa's map.[24] This report is a direct continuation to that for 2005–'06.[25]

## Surface features

### General

Adelaar's 2005 and 2007 whole-planet maps have been previously published.[4] Charts were also made by Abel, Cardin and Comolli (both UAI), Walker (Figure 1) and (at very high resolution) Peach.[26] In early 2007 the markings looked identical to 2006 summer.[25] We concentrate here upon appearances during and after the global dust storm (2007 Jun–Oct). Post-storm images and drawings comprise Figures 2–5. At the end of the apparition, dust movement had not annulled any of the changes arising. Selected intensity estimates[27] are included.

## Limits of resolution

Among the very best near-opposition images received were those of Flanagan (2007 Dec 21) and Peach (Dec 14): see Figure 3 and note the numerous minute dark spots running NNW from *Meridiani Sinus* along the course of telescopic *Gehon*. Comparison with USGS Mars maps reveals them to be dark spots *within* the craters *Marth*, *Radau*, *Becquerel*, *etc*., although these features cannot, of course, be recognised as craters. Ten other observers just resolved these features during Nov–Jan. They had been captured more easily during 2003 and 2005, and have been seen visually with large apertures, but to image them at an aphelic opposition is a real achievement. None of them exceeded 1° in longitude (50km, or 0.12").

## Martian colours

Colours appeared muted straight after the global storm. Near opposition, Abel noted a hint of green in E. *Syrtis Major*. On 2008 Apr 2 Adamoli found *Casius–Utopia* brownish compared with the greenish *Syrtis Major–Mare Tyrrhenum* near the CM, which is seasonally typical. (As in the past, the seasonal Equatorial Cloud Band (see Part II) crossing *Syrtis Major* made the latter especially blue (or greenish blue) near the edge of the disk.) Biver often drew a blue tint to the darkest markings (S. particularly), Dec–Jan. Colombo, Jan 26, saw *Mare Cimmerium* bluish. Hancock in 2007 Oct–2008 Jan found the dark areas (when they showed any colour) bluish or greenish grey.

McKim on Dec 12 found *Syrtis Major–Mare Tyrrhenum–Iapigia* dark bluish grey, but the blue tint was not noticeable to the N. in *Casius–Utopia*. Minami on Nov 16 and Dec 19 found *Mare Acidalium–Nilokeras* brownish compared with the more southerly *Aurorae Sinus*. On 2008 Jan 19 he found *Mare Cimmerium* brownish, but *Mare Chronium* further south was dark blue. Brown tints over both E. *Mare Cimmerium* and *Mare Chronium* are implied by Pellier's images of 2007 Dec 22–23 (see 'violet holes', Part II).

## Region I: long. 250–010°

Refer to Figures 1–5. Dust fallout from the global storm affected the shape and darkness of *Syrtis Major*. Viewed from late 2007 Aug it looked thin, and diminished to the east. After the storm it slowly returned to its normal intensity, and from November onwards patches of dust fallout could be seen to be responsible for irregularly brightening its E. side, the entire marking showing a complex mottling. Gradually some further darkening of the E. side occurred: the lighter E. side made it look narrower than usual (*e.g*., compared with 1980–2006) at low resolution. This narrowing was once thought (by Antoniadi, Capen and others) to be a regular, seasonal change. Dust also obscured the NW tip of the *Syrtis* as well as darkening terrain on the NE side, so that the N. end seemed somewhat more rounded than formerly. By early October it was evident that this was due to the fact that *Astusapis Sinus* had darkened on account of the storm.

NW of *Hellas*, part of *Mare Hadriacum* became fainter. *Mare Tyrrhenum* generally was considerably faded and distorted by dust fallout, the *Syrtis Minor* promontory being almost obliterated. The N. part of *Ausonia* (IAU *Trinacria*) had appeared light since 2003. After the storm subsided it was seen to have darkened to resemble its appearance prior to the 2001 global storm, appearing less contrasty against the faded *Mare Tyrrhenum*. Other small changes are apparent when comparing 2005 images with 2007–'08.

*Hellas* behaved typically. Before the storm in 2007 Apr it was merely ground-lit, and not cloudy, with floor details visible in the centre and south. After the storm, it formed a huge yellow ellipse, with both suspended and settled dust. In 2007 late Oct, evening white cloud activity weakly resumed in the southern half of the basin, gradually penetrating northward and continuing at least until 2008 May. *Hellas* was also affected by thin morning cloud from 2007 late Oct till at least 2008 Apr, commencing seasonally late due to the global dust storm. The first appearance of the cloud was at the W. edge of the basin, and during Nov–Dec it was linked to a belt of white cloud that had become visible near latitude –50° (see later). In 2008 Jan, some floor detail began faintly to reappear. By Mar 4, *Zea Lacus* could be identified (Parker).

*Hellas* was not exceptionally light at the CM until the very end of the apparition: Minami found it so on 2008 Jul 13 (Ls= 98°); undoubtedly frosted. From the 1999 BAA Report[99] we find: '*Hellas* was brighter than the NPC by Feb 1, having brightened during Ls= 85–91°, and was very bright all day, indicating a frosted surface...'

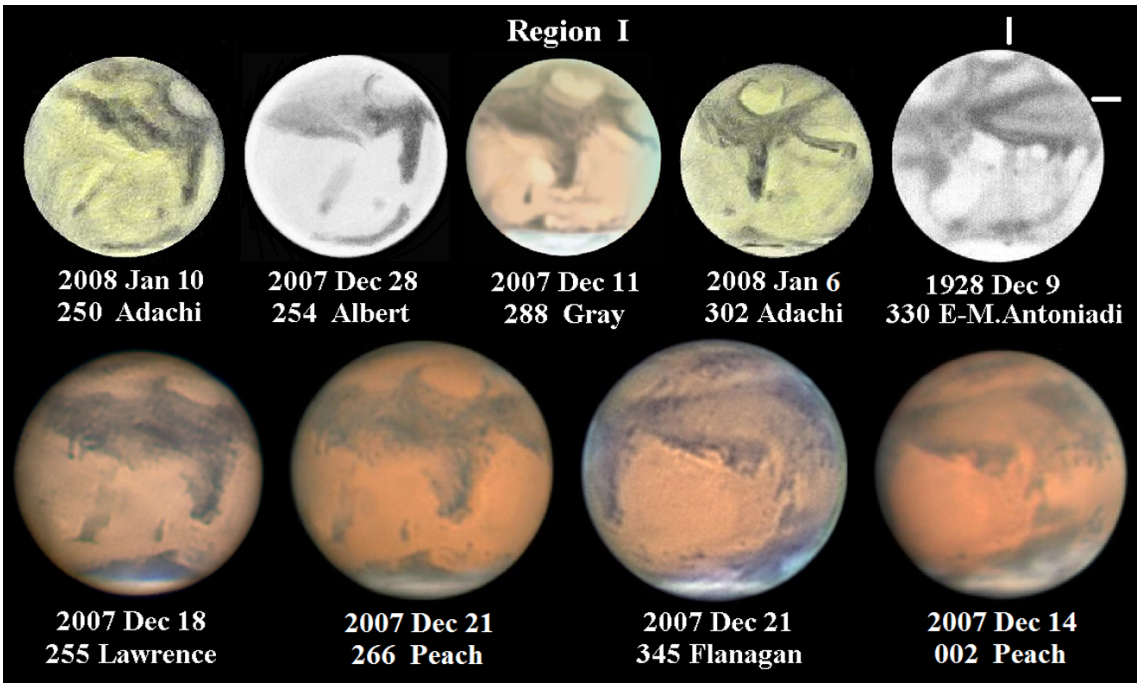



**Figure 3.** ***Region I. Top row*****:** Drawings of the dust-free planet by M. Adachi (450mm OG, ×608, ×675), J. Albert (×400, W23A) and D. Gray (×365). Also a comparison drawing by E.–M. Antoniadi (Meudon 830mm OG, up to ×1100),1928 Dec 9d, CML= 330°; note the weakness of *Pandorae Fretum* and the dark band crossing *Noachis* diagonally indicated (reproduced from *La Planète Mars*.[41]) ***Lower row*****:** Selected near-opposition images by W. D. Flanagan (Lumenera LU-075M), P. Lawrence (Skynyx 2-0M), D. C. Parker and D. A. Peach (Skynyx 2-0M). Date and CML are indicated in this and subsequent figures.

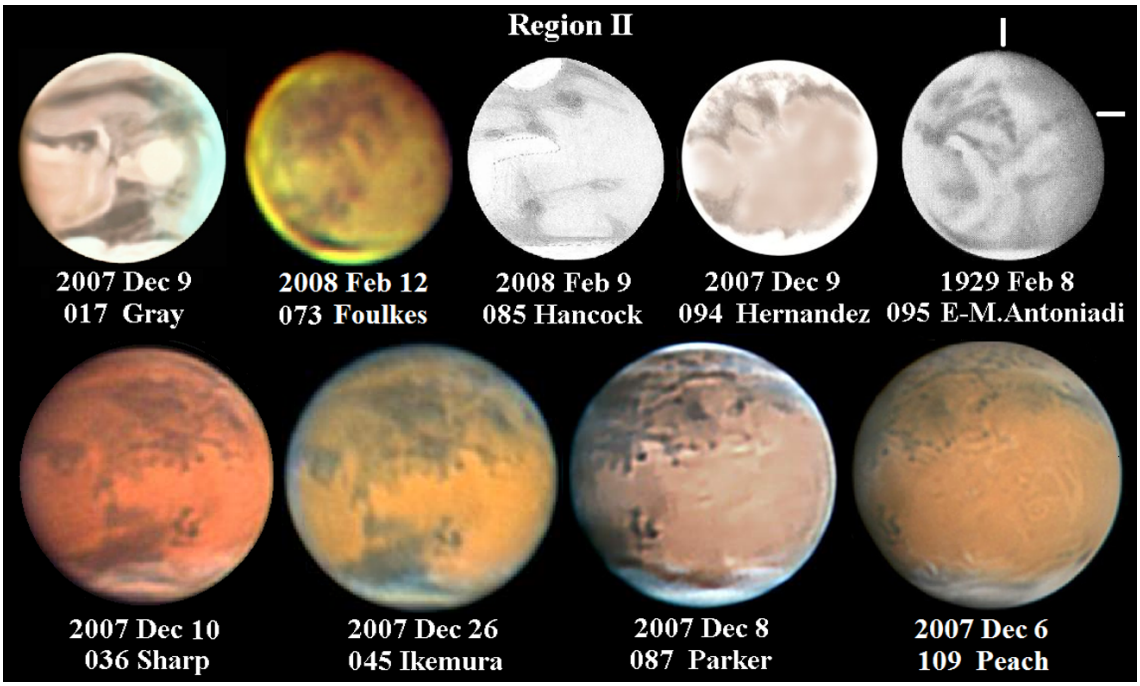



**Figure 4.** ***Region II. Top row*****:** Drawings of the dust-free planet by D. Gray (×365), I. R. Hancock (×278) and C. Hernandez (×359), and webcam image by M. Foulkes (ToUcam Pro). Also a comparison drawing by E.–M. Antoniadi (Meudon 830mm OG, up to ×1100), 1929 Feb 8d, CML= 095°; *Solis Lacus* is extended to the NW, as indicated (from *La Planète Mars*.[41]). ***Lower row*****:** Selected near-opposition images by T. Ikemura (ToUcam Pro), D. C. Parker (Skynyx 2-0M), D. A. Peach and I. D. Sharp (Skynyx 2-0M).

*Mare Serpentis* was broad and dark prior to the storm, and *Hellespontus* was complete. The *Sinus Sabaeus* to *Meridiani Sinus* area showed its usual form; to the north, *Sirbonis Palus* was seen as a tiny, sharp dark spot in 2007 Oct–Nov, and from 2008 Jan onwards: a phase-dependent feature.

The *Pandorae Fretum–Noachis* area was once again considerably changed by dust fallout. In place of the canonical *Pandorae Fretum* there emerged a tapering, dark, rather narrow band which ran diagonally ENE to WSW across *Noachis* and continued south to reach *Depressiones Hellesponticae*. This dark streak exhibited bright dust fallout along its S. edge, which was still light at least until 2008 Mar. In location, the dark belt across *Noachis* somewhat resembled the feature observed in 1928–'29, which the Director[28] tentatively linked to a poorly-observed Regional storm: see also Figure 3. The 1928–'29 development had been broader and darker.

A somewhat similar bright fallout belt was spotted at the north edge of the halftone feature *Deuteronilus*, being continuous with the tilted 'mouth' of the light streak *Achillis Pons* which divides *Mare Acidalium* from *Niliacus Lacus*. This aspect also continued at least until 2008 Mar.

Markings surrounding the NPC were better seen than in 2005. The *Casius–Utopia* area looked similar to its appearance throughout the 1990s aphelic oppositions. *Ismenius Lacus* remained inconspicuous.

## Region II: long. 010–130°

Refer to Figures 1–5. The far E. part of *Mare Erythraeum* was also lightened by dust fallout, together with all of *Margaritifer Sinus* (especially the S. part) leading to a rather diagonal (SE–NW) division of bright and dark albedo: see Figures 1–4. Dust was deposited to brighten *Bosporos Gemmatus*, leaving the SE border of *Thaumasia* as an unusually thin dark line.

Even during the global storm, from the end of 2007 Jul onwards, it was possible to see that *Solis Lacus* had become smaller and that the orientation of its long axis had changed from E–W to SE–NW, as it had in 1926–'29 and after the 2001 global storm, due largely to the fading of the SW part, but also to an extension to the NW towards *Phoenicus Lacus*. We reproduce a drawing from 1929[29] for comparison (Figure 4). *Nectar* (except in its S. part) was deformed by dust deposition. After the storm, *Nectar* was no longer dark, except for a thin, slanting spine running NE to SW. *Solis Lacus* remained tilted at least till the end of the apparition: Peach's images of 2008 Jun 4 show the basic aspect unaltered, and Yunoki's image on Aug 1 (D= 4") remarkably confirms the more N–S orientation remaining. The best images showed several nuclei, and at high resolution the marking was complex.

In the early post-storm phase the 'canal pattern' around *Solis Lacus* was rather marked, and in particular the streaks *Acampsis* and *Eosphoros* were very clearly defined and apparently linear even at high resolution. Abel noted the bicycle wheel-like nature of the area. The Director had a similar canaliform view of this area in 1988,[30] and it is easy in retrospect to see how temporary linearity might arise by local dust removal in a preferred direction. However, the sharpness of these linear features slowly faded (see the Director's views on Oct 29, Jan 5 and Feb 4 (Figures 2A, H and J) and Figure 7), as did the bright yellow spots of dust fallout nearby, redistributed by martian winds. At high resolution at and just after opposition the small spots and streaks around *Solis Lacus* appeared very complex.

Since 2003 a faint halftone existed in *Daedalia*. This too was altered by fallout from the dust storm. First, in July, there was a considerable darkening of the adjacent *Claritas*, much resembling the large dark shading in *Claritas–Daedalia* that appeared after dust activity in 1973. However, this faded out again as the dust settled, but it left *Sirenum Sinus* thin and dark, appearing to extend the E. end of *Mare Sirenum* a long way to the northeast as far as *Gallinaria Silva*. This change was referred to as the '*Sirenum* extension' by a number of observers. Peach's best images of December (*e.g.*, Dec 6, Figure 4) show it patchy and slightly faded on the W. side. The little dark feature *Phasis*, which runs NW from *Aonius Sinus* to *Gallinaria Silva*, was observed again after the storm, slightly altered in form. The more noticeable '*Sirenum* extension' intercepted it.

The *Tharsis Montes* and *Olympus Mons* were well observed. Their calderas were caught in incredibly fine detail in the images of Flanagan, Parker, Peach and others. In particular Peach on Dec 6 (Figure 4) and Parker on Dec 1 (Figure 5) show the charac-

teristic doughnut-shaped lighter ring surrounding the caldera, whilst the summit was a light spot. These volcanoes all appeared as reddish-brown patches during the global storm, until October. Slowly their orographic clouds began to appear: these are discussed in Part II. After opposition, as the morning terminator became well placed to observe, in 2008 Feb, the *Tharsis Montes* again appeared as dark reddish patches poking through a sea of morning white cloud (see Part II). The volcanoes also showed an opposition brightening, as in 2005.

In the south, *Argyre* become noticeable when filled with white cloud (pre-polar hood) for some months after opposition. Like *Hellas*, *Argyre* interacted with the white cloud belt near latitude 50°. Part II gives details.

To the north, *Mare Acidalium–Niliacus Lacus* showed no large change from 2005. *Hydaspis Sinus*, to the W. of *Margaritifer Sinus*, was well developed, and, as was the case in 2005, *Indus* formed an obvious curved 'canal' uniting *Oxia Palus* with the NE end of *Niliacus Lacus*.

### Region III: long. 130–250°

Refer to Figures 1–5. *Cerberus* remained virtually non-existent, and *Trivium Charontis* consisted just of two tiny spots. Several months after opposition these albedo features appeared significantly more prominent, as in past years, being somewhat phase-dependent markings. *Elysium* showed the usual meteorological behaviour, and *Elysium Mons* and *Hecates Tholus* again showed an opposition brightening as well as orographic cloud. The brightening of the centre of *Propontis* (noted in our last Report) continued, so that it now consisted of two quite separate – but adjacent – dark spots, as shown for example on the 1937–'41 Mars map of G. de Vaucouleurs.[31] No longer was it the rod-like marking of the 1980s and 1990s. From 2007 Aug onwards, a halftone double streak (and patchy at high resolution) extended to the SW from the end of the long-lived *Aetheria* secular darkening, running across *Aethiopis* towards the NW end of *Mare Cimmerium* to *Tritonis Sinus*. This albedo change recalls a similar one noted in 1931 and 1933,[32,33] also shown in Figure 5, as well as another in 1969.[34] The area has a history of change back to the time of Herschel and Schroeter. The *Aetheria* darkening itself was also slightly modified in contour by the storm, fading towards the NW.

As in recent apparitions, the halftone streak (ALPO's *Valhalla*) running parallel to the N. borders of *Mare Sirenum* and *Mare Cimmerium* was noticeable in the months well before and after opposition, visibility being rather strongly phase-dependent. Thus Peach's early images of 2007 May showed it well, and it was very apparent in October after the global storm, becoming faint near opposition, and finally after opposition it became noticeable from 2008 Feb.

There was little change from previous years in the south of Region III, though a bright E–W strip of dust fallout was visible from mid-October onwards south of *Mare Sirenum*. The fallout also covered the S. part of *Mare Sirenum*, reducing it to a very thin dark line running E–W. The dark patch corresponding to *Herschel* crater could be detected in some near-opposition images against *Mare Cimmerium*. *Caralis Fons* (*aka* crater *Newton*) was obvious to the south of *Mare Sirenum*, just to the W. end of the bright fallout region. *Hesperia* was much distorted by the fallout from the global storm.

## Dust storms

### Introduction

We caught the planet at the start of southern spring, and no major phenomenon was missed prior to the global storm. From *Mars Odyssey THEMIS* data Smith[22] wrote that there was Regional dust activity at Ls= 220° (*e.g.*, 2007 mid-Apr), less intense than in the previous few apparitions. It is possible some BAA April images (see Part II, Figure 14 for some examples) show some southern markings a bit weaker than usual, but the disk (D= 5") was too small to be sure.

### Local dust activity, 2007 May–June

Peach's images of May 31–Jun 4 (Ls= 248–251°, Figure 6) showed a small high latitude dust cloud, just west of the newly decayed S.

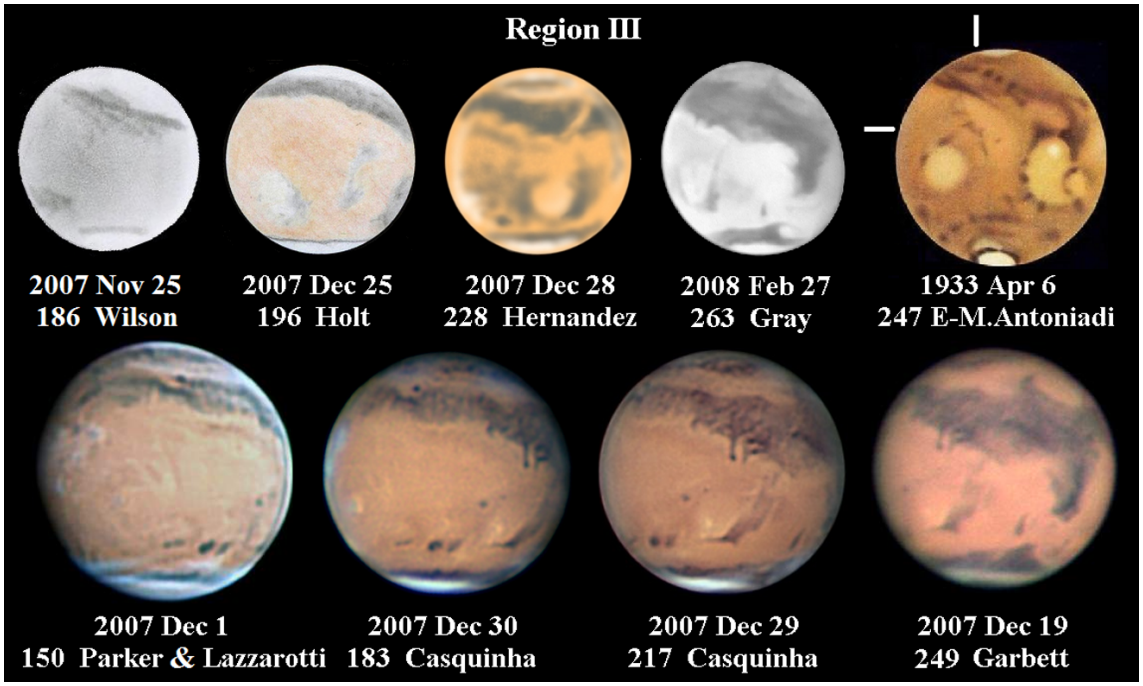



**Figure 5.** ***Region III. Top row*:** Drawings of the dust-free planet by D. Gray (×535, W15, W22), C. Hernandez (×359), D. A. Holt (350mm refl., ×308) and W. J. Wilson (×213, W25). Also a comparison drawing by E.M. Antoniadi (Meudon 830mm OG, up to ×1100), 1933 Apr 6d, CML= 247°; A dark marking appears in *Aethiopis*, as indicated (from Sadil[27]).
***Lower row*:** Selected near-opposition images by P. Casquinha (Skynyx 2-0M), P. J. Garbett (Skynyx 2-0M) and D. C. Parker & P. R. Lazzarotti (410mm refl., Skynyx 2-0M).

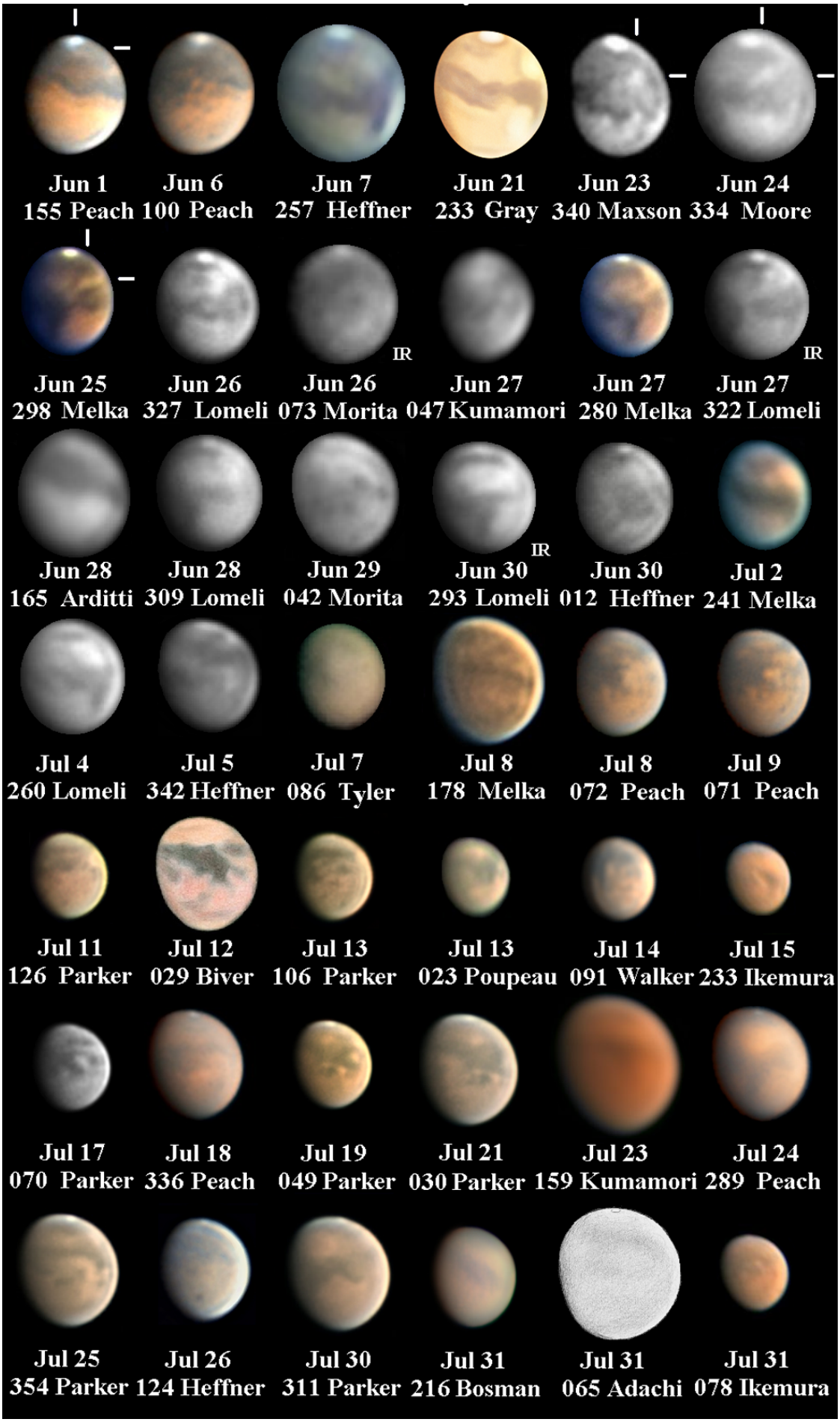



**Figure 6. Dust activity in 2007–'08: I.** This collage shows a small dust storm at the edge of the SPC, 2007 May –Jun, followed by a global storm outbreak on Jun 23, up to its period of maximum opacity in July.

polar cap projection *Thyles Mons*: these phenomena had been linked in 2003[38] and 2005.[25] On Jun 6 a similar bright patch (again in red and green light) was seen near *Dia* west of the location of the decaying *Argenteus Mons*.

## Global dust storm, 2007 June–September

### Origin

Figures 6 and 8 present collages of the global storm and other dust events observed by the Section in 2007–'08. The period of onset to maximum opacity is covered by Figure 6; Figure 8 chronicles the storm's decline. The global storm was originally thought to have commenced on Jun 24[1,3] in the form of a bright yellow, E–W elongated cloud whose E. limit was near –25°, 325° in NE *Noachis*, extending to *approx*. long. 010° upon images by David Moore. However, the cloud is actually shown as a smaller light patch in W. *Noachis–Argyre* in Paul Maxson's images of Jun 23. No images are to hand for Jun 22. Kardasis recorded *Hellas* normal at the morning limb on Jun 23, as did Gray on Jun 21. According to images by *Mars Reconnaissance Orbiter*, small-scale dust activity began at *Eos*, followed by resonant activity in *Argyre*. Hence Jun 23 (Ls= 263°) marked the start of visible telescopic activity, the benchmark by which we compare historical events. *Noachis* was also the origin of the encircling storm of 1956.

The tiny disk (D= 6") at the start of the global storm proved to be a severe test of observers' ability. Remarkably, Lomeli provided good images on 13 out of 14 mornings, from Jun 26 to Jul 8.

The 2007 event's development was typical of planet-encircling events originating in E. *Noachis* or *Hellas*. Dust expanded across *Noachis* and rapidly reached *Argyre*. Secondary dust cores originated around *Solis Lacus* and spread along *Valles Marineris*. A general yellow haze quickly spread over the planet, making the event not only encircling but global. The *Tharsis Montes* and *Olympus Mons* appeared as dusky spots within an overall yellow veil. Most features became ghostly, completely invisible or unrecognisable, although the *Syrtis Major* and the W. part of *Mare Erythraeum* were always dimly discernable. White cloud activity was absent for months, and the planet's limb was tinged yellow. The S. polar cap's summer remnant was also obscured, though the value of $D_e$ was only marginally south, hindering scrutiny.

### Expansion and secondary activity

We now describe the E and W spreading of activity in more detail during the first week of the event, Jun 24–Jul 1.

**Eastwards:** On Day 2, Jun 25, Melka showed the storm longer, its E. end propagating east (impinging upon NW *Hellas*) and north towards *Hellespontus*, and occupying *Mare Serpentis* and SW *Iapigia*. On Jun 26 Lomeli showed dust breaking through N. *Hellespontus* to fill *Hellas*. Melillo, Melka, Owens and Walker on Jun 27 show yellow cloud filling *Hellas* and spilling across *Mare Hadriacum*, with *Hellespontus* hidden. Bates and Lomeli on Jun 29 found the *Hellas* branch of the storm spread over *Iapigia* and part of *Ausonia*. The images of Maxson on Jul 29 suggest brighter nuclei within *Ausonia-Hellas-Noachis*. On Jun 30-Jul 1 *Ausonia* was full of dust to Warren, who also recorded the fading of *Mare Tyrrhenum* and environs: a more general loss of contrast was beginning, showing widespread general yellow haze. Walker found dust under CML= 210° and westwards on Jun 30, implying coverage of all of *Eridania*. By Jun 30 *Syrtis Major* was fading. On Jun 30-Jul 1 Lomeli found the S. border of *Hellas* darkened, with dust spreading further into *Ausonia*.

**Westwards:** On Jun 26 Lomeli and Maxson showed the *Noachis* cloud's E. end near long. 320°, having expanded primarily north–south, impinging upon *Pandorae Fretum*, and reaching and occupying *Argyre*. *Depressiones Hellesponticae* was darkened at the cloud's S. border. On Jun 27 Lomeli, Maxson and Moore found *Sinus Sabaeus* cut by dust (propagating into *Aeria*) at the E. end, as with the Regional storms of 1971 July, 1986 November and 1988 June,[35] and Minami visually saw dust no further W. than *Argyre*.

On Jun 26 under CML *approx*. 60° Mars looked mostly normal upon images by Morita, but on Jun 27 Kumamori showed dust in W. *Mare Erythraeum* (adjoining the belt of dust from *Argyre* through *Noachis*) and E. *Thaumasia*. The latter dust cloud lay mostly over *Solis Lacus*, whilst to the NW of the latter there was a large anomalous dark patch. On Jun 29, Morita's images near CML= 40° revealed the now fading *Aurorae Sinus* and environs, and anomalously darker patches over *Nectar* and W. of *Tithonius Lacus*. Bright fingers of dust from (or resonant patches independent of) the southern bright dust belt penetrated *Mare Erythraeum*, and covered the previously visible *Bosporos Gemmatus* as well as *Solis Lacus*. Heffner on Jun 30 caught a similar situation under CML= 4–12°, as well as a normal *Margaritifer Sinus* complex, but *Meridiani Sinus* was now covered by a belt of dust coming diagonally from the SE. Minami on June 30 found a lemon yellow tint from pole to pole, with *Niliacus Lacus* faded, and with anomalous northern dark extensions to *Aurorae Sinus* and *Margaritifer Sinus*. However, dust had not quite encircled the planet.

The limb brightening became yellowish and more diffuse according to many images and drawings from around Jun 27 until the end of August.

### Encirclement

By Jul 4–5, Heffner's and Morita's images under CML *approx*. 345° showed all the albedo patterns distorted, with *Mare Erythraeum* however remaining dark. The original expanded core of the storm was conspicuous though diffuse in Heffner's Jul 5 images but no longer bright by Jul 7. All the markings were recognisable, albeit muted, in Lomeli's images at CML≈240–260°. A gradual fading of the southern maria continued whilst dust propagated largely to the east at high southern latitude. By Jul 6 Melka showed that patches of dust had reached east of CML= 190°, surely joining the activity which had reached the environs of *Solis Lacus*. Likewise under CML= 201° on Jul 8, Lomeli showed all albedo features obliterated E. of the CM. By the end of the first week of July the planet was encircled by dust.

## Secondary activity and the mature storm

The first UK images to be obtained since the storm's beginning were taken on Jul 7–8 by Arditti, Kidd, Peach and Tyler. Together with drawings by Hancock, these all showed *Solis Lacus* covered by a bright new dust cloud, and other albedo markings faint. On Jul 8, Arditti, Bosman, Kingsley and Peach found the *Solis Lacus* cloud extending east to end in a new, brighter patch in NE *Thaumasia* (IAU *Sinai*), –10 to 30°, 85–100°. Meanwhile, another bright dust cloud had formed over *Aram–Margaritifer Sinus* (*e.g.*, to the extreme E. of *Valles Marineris*) according to Heffner on Jul 5. This either continued, or more likely was subject to a local resurgence, on Jul 25 (see later).

On Jul 9 Peach found the *Sinai* cloud brighter and more condensed. Images during Jul 13–17 by Moore, Parker, Poupeau and Walker showed it continuing, with *Solis Lacus* largely obscured, and *Tithonius Lacus* anomalously broad and dark. Parker's images of Jul 11 caught the first appearance of a large dark area in *Claritas–Daedalia* whose W. edge was near long. 130°, and whose appearance was very similar to the secular darkening of 1973.[35] *Mare Sirenum* was hardly visible, dust obscuring *Electris–Phaethontis*, while a brighter dust cloud lay over E. *Mare Cimmerium–Eridania* at the morning limb. In the N. hemisphere, *Olympus Mons* was dusky: the first record of its dark appearance during the storm. On Jul 13 Parker caught numerous small dust clouds around *Thaumasia* as well as the new dark area to the west.

On Jul 13–14 only the faintest traces of markings were caught by Lomeli and Maxson (144–162°) and Pellier (long. 7–10°). Another specific bright cloud was found by Japanese observers on Jul 15, filling Hesperia between the absent *Mare Cimmerium* and the still faint *Mare Tyrrhenum*.

## The S. polar cap

The already eccentrically placed SPC began to lose contrast within days of the start of the storm, becoming nearly indistinguishable from the limb brightening by Jun 30. Heffner on Jul 5 saw it again visually as a dull white, blurred patch. On Jul 13 Parker caught a glimmer of the cap. It was more distinct to Bosman, Peach and Tyler on Jul 16–19 (CML≈ 327–358°) at more favourable longitudes, and after then it slowly returned to visibility, being followed until Aug 26, the later sightings being frustrated both by the decrease in the negative value of $D_e$, its eccentricity with respect to the rotational pole, and its seasonal decline.

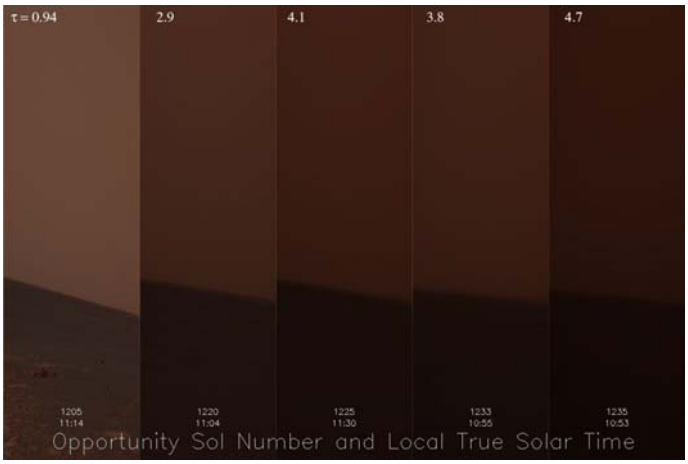



**Figure 7.** The start of the global storm witnessed by *Opportunity* (*MER*), with sky opacity measurements (tau [τ] values) indicated. Images were taken on sol 1205 (2007 Jun 14), 1220 (Jun 30), 1225 (Jul 5), 1233 (Jul 13) and 1235 (Jul 15). After Jul 15, *Opportunity* was forced to halt imaging, and most other operations, in order to conserve battery power *(NASA /JPL /Cornell)*.

## Spirit *and* Opportunity *view the storm*

NASA's *MER* suspended operations due to lack of solar power; solar and general images from the surface by *Opportunity*[36] dramatically illustrated the storm's influence (Figure 7). The Sun began to be obviously dimmed on Jun 25. Sky opacity increased rapidly, and a graph[36] shows how the tau (τ) values ultimately reached maxima of 5.3 above *Opportunity* and 4.7 over *Spirit*. Tau values are a logarithmic measure of opacity, calculated from the incident ($I_{incident}$) and surface ($I_{surface}$) light intensities as defined by:

$$I_{surface} = I_{incident}\, e^{-\tau}$$

These large tau values imply an increase in sky opacity of 200-fold and 110-fold respectively (corresponding to reductions in sky transparency to just 0.5% and 0.9%).

Opacity began to fall after Jul 19: the JPL website[36] gives more details. At *Spirit's* site, at *Gusev* crater, between sol 1283 (Aug 12) and sol 1286 (Aug 16), the atmosphere cleared substantially. These indicators of the storm's decline compare well with groundbased impressions now to be recounted.

## More secondary activity and gradual storm decay

On Jul 18–19 Peach was able to faintly image *Pandorae Fretum* and *Sinus Sabaeus*, though *Meridiani Sinus* was absent. On Jul 21 Parker found a bright dust cloud over *Ogygis Regio–Argyre*, with *Margaritifer Sinus–Meridiani Sinus* still invisible, but features to the west were returning gradually to view. Furthermore the N. polar hood was weakly imaged by Parker on Jul 11, and it was more obvious from Jul 21 onwards (being quite distinct by Jul 25). Arditti, Peach and Poupeau on Jul 21–25 caught the faint *Syrtis Major* and the E. half of *Sinus Sabaeus*, but features further W. were obscure, a sequel typical of a great storm. *Hellas* was lighter and more yellowish than other areas, with dust spilling over its N. edge to enlarge the basin, but resuming its normal contour by Jul 25.

The same longitudes were caught by Parker on Jul 30, now clearer still, but the W. part of *Sinus Sabaeus* remained fainter than the east. Kumamori on Jul 23 faintly caught *Mare Sirenum* at CML= 159°. Images from Japan during Jul 23–28 showed the *Tharsis Montes* and *Olympus Mons* as dark reddish-brown spots, especially towards the evening terminator. At the end of July clearance had begun at many longitudes, but the longitudes from E. *Mare Sirenum* through W. *Mare Cimmerium* remained heavily obscured and very low in contrast.

On Jul 19 and 21 a fresh outbreak of bright yellow dust was caught by Parker over *Candor–Ophir* which continued south of *Aurorae Sinus* via *Valles Marineris* to the east to *Eos*. Bright dust lay over *Sinai*, and *Solis Lacus* remained veiled. *Mare Acidalium* was not visible to the north, having disappeared by Jul 13 or earlier. Repeated activity of the secondary core had been a feature of the 2001 global storm,[37] but the core seemed less persistently active in 2007.

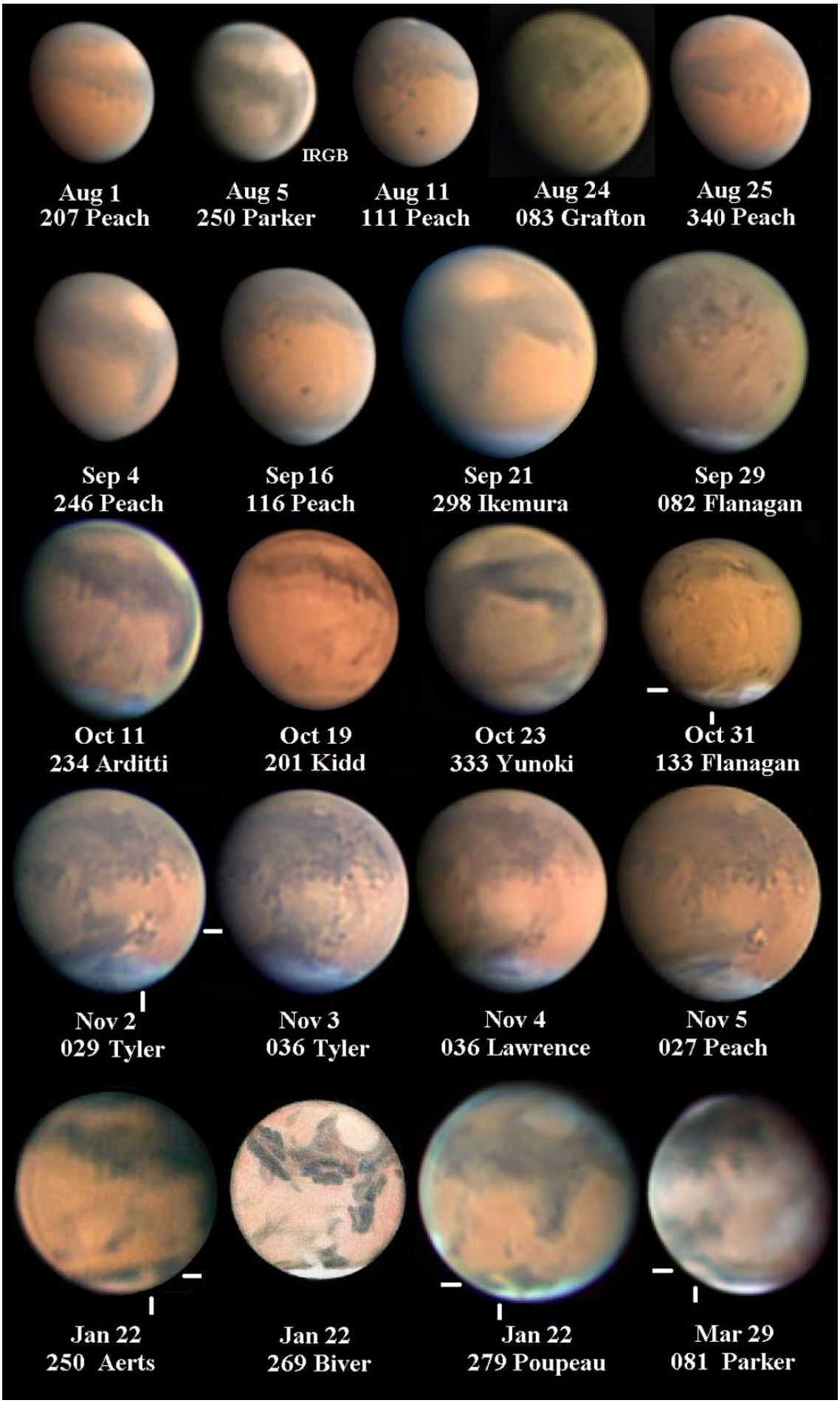



**Figure 8. Dust activity in 2007–'08: II.** Showing the global event's decline, with subsequent small-scale activity in 2007 Oct–Nov and 2008 Jan and Mar.

## Table 2. Observers of Mars, 2007

| *Name* | *Location(s)* | *Instrument(s)* |
|---|---|---|
| P. G. Abel V | Leicester | 203mm refl. & 406mm Cass. |
| | Selsey, W. Sussex | 381mm refl. |
| M. Adachi V | Otsu, Japan | 310mm refl. |
| | Kwasan Obs., Kyoto, Japan | 450mm OG |
| G. Adamoli | Verona, Italy | 125mm MKT & 235mm SCT |
| J. Adelaar | Arnhem, Holland | 235mm SCT |
| L. Aerts | Heist-op-den-Berg, Belgium | 250mm SCT |
| T. Akutsu | Cebu City, Philippines | 355mm SCT |
| J. Albert V | Lake Worth, Florida, USA | 279mm SCT |
| D. L. Arditti | Edgware, Middlesex | 279mm & 355mm SCT |
| D. R. Bates | Houston, Texas, USA | 254mm refl. |
| R. M. Baum V | Chester | 152mm MKT |
| J. D. Beish V | Lake Placid, Florida | 410mm refl. |
| N. D. Biver V | Versailles, Paris, France | 256mm & 407mm refls. |
| N. M. Bone V | Chichester, W. Sussex | 102mm OG |
| D. Boon | Bures, Suffolk | 355mm SCT |
| R. Bosman | Enschede, Netherlands | 279mm SCT |
| C. E. R. Brook V | Plymouth, Devon | 102mm OG |
| S. Buda | Melbourne, Australia | 400mm DK Cass. |
| P. Casquinha | Palmela, Portugal | 355mm SCT |
| R. Chavez | Powder Springs, Georgia, USA | 320mm refl. |
| E. Colombo V | Gambarana, Italy | 150mm refl. |
| M. Delcroix | Tournefeuille, France | 254mm SCT |
| D. Dierick | Ghent, Belgium | 203mm SCT |
| P. Edwards | Horsham, W. Sussex | 279mm SCT |
| C. Fattinnanzi | Macerata, Italy | 250mm refl. |
| D. Fisher V | Sittingbourne, Kent | 215mm refl. |
| W. D. Flanagan | Houston, Texas, USA | 355mm SCT |
| M. Foulkes | Henlow, Beds. | 203mm SCT |
| P. J. Garbett | Sharnbrook, Beds. | 355mm SCT |
| S. Ghomizadeh | Teheran, Iran | 279mm SCT |
| M. Giuntoli V | Montecatini Terme, Italy | 203mm SCT |
| C. Go | Cebu, Philippines | 279mm SCT |
| E. Grafton | Houston, Texas, USA | 355mm SCT |
| D. L. Graham V | Catterick, N. Yorks. | 152mm OG & 230mm MKT |
| D. Gray V | Kirk Merrington, Co. Durham | 415mm DK Cass. |
| M. Green V | Holywell, Flintshire | 203mm refl. |
| P. T. Grego V | Rednal, W. Midlands | 152mm refl. |
| I. R. Hancock | Canterbury, Kent | 254mm SCT |
| A. W. Heath V | Long Eaton, Notts. | 254mm refl. |
| R. Heffner | Nagoya, Japan | 279mm SCT |
| C. Henshaw V | Tabuk, Saudi Arabia | naked eye |
| C. E. Hernandez V | Miami, Florida, USA | 229mm MKT |
| D. A. Holt V | Chippingdale, Herts. | 350mm refl. & 152mm OG |
| C. J. Hooker | Didcot, Oxon. | 200mm MKT |
| K. C. Howlett V | Cwmbran, Gwent | 250mm refl. |
| | Wroughton, Wilts. | 203mm MKT |
| T. Ikemura | Nagoya, Japan | 380mm refl. |
| S. Johnson V | Plymouth, Devon | 203mm SCT |
| M. Kardasis | Athens, Greece | 254mm SCT |
| A. S. Kidd | Welwyn, Herts. | 355mm SCT |
| B. A. Kingsley | Maidenhead, Berks. | |
| | Barbados, West Indies | 279mm SCT |
| S. Kowollik | Ludwigsburg, Germany | 203mm refl. |
| | Zollern-Alb Obs., Germany | 800mm refl. |
| T. Kumamori | Sakai City, Osaka, Japan | 200mm DK Cass. |
| P. Lawrence | Selsey, W. Sussex | 355mm SCT |
| P. R. Lazzarotti (with N. Guidoni) | Massa, Italy | 315mm DK Cass. |
| W.J.Leatherbarrow V | Sheffield | 235mm SCT |
| M. R. Lewis | St Albans, Herts. | 222mm refl. |
| R. N. B. Lewis | Cardiff | 254mm SCT |
| E. Lomeli | Sacramento, CA, USA | 235mm SCT |
| N. Longshaw V | Oldham, Lancs. | 78mm OG |
| P. Lyon | Birmingham | 203mm SCT |
| R.J.McKim V | Upper Benefield, Northants. | 410mm DK Cass. |
| S. Maksymowicz V | Ecquevilly, France | 200mm Cass. |
| P. W. Maxson | Surprise, Arizona, USA | 203mm & 250mm SCT |
| F. J. Melillo | Holtsville, NY, USA | 254mm SCT |
| J. Melka | Chesterfield, Miss., USA | 300mm refl. |
| C. Meredith | Prestwich, Manchester | 215mm refl. |
| M. Minami V | Fukui City Obs., Japan | 200mm OG |
| D. M. Moore | Phoenix, Arizona, USA | 362mm Cass. |
| Y. Morita | Hiroshima, Japan | 250mm refl. |
| D. Niechoy V | Göttingen, Germany | 203mm SCT |
| | Violau, Bavaria, Germany | 102mm OG |
| T. Olivetti | Bangkok, Thailand | 275mm refl. |
| L. T. Owens | Alpharetta, Georgia, USA | 355mm SCT |
| P. W. Parish V | Rainham, Kent | 152mm OG |
| D. C. Parker | Miami, Florida, USA | 410mm refl. |
| D. A. Peach | High Wycombe, Bucks. | 355mm SCT |
| | Barbados, West Indies, & Miami, Florida, USA | 254mm DK Cass. |
| C.Pellier | Bruz, France | 250mm Cass. |
| K. Peters & G. Boots | Worthing, Sussex | 381mm refl. |
| I. S. Phelps V | Warrington, Cheshire | 215mm refl. |
| J. H. Phillips | Charleston, SC, USA | 203mm OG |
| J.–J. Poupeau | Pecqueuse, France | 350mm Newt–Cass. |
| M. J. Porter | Petts Wood, Kent | 178mm Mak–Newt. |
| A. R. Pratt | Leeds | 200mm MKT |
| M. Salway | Central Coast, NSW, Australia | 305mm refl. |
| J. R. Sánchez | Córdoba, Spain | 254mm SCT |
| R. W. Schmude V | Barnesville, Georgia, USA | 130mm OG |
| R. Schulz | Vienna, Austria | 320mm refl. |
| S. Seip | Stuttgart, Germany | 254mm MKT |
| I. D. Sharp | Ham, W.Sussex & Barbados, West Indies | 279mm SCT |
| D. Storey | Isle of Man | 410mm SCT |
| D. Strange | Worth Matravers, Dorset | 235mm SCT |
| J. Sussenbach | Houten, Netherlands | 279mm SCT |
| A. Tasselli | Lincoln | 250mm refl. |
| | Volpiano, Italy | 203mm MKT |
| P. Tanga | Tourrette Levens, France | 180mm MKT |
| M. Morgan–Taylor | Leicester | 355mm SCT |
| G. Teichert V | Hattstatt, France | 279mm SCT |
| D. B. V. Tyler | Flackwell Heath, Bucks. | 355mm SCT |
| | Barbados, West Indies | 279mm SCT |
| M. Valimberti | Melbourne, Australia | 355mm SCT |
| R. Vandebergh | Wittem, Netherlands | 254mm refl. |
| A. G. Vargas V | Cochambamba, Bolivia | 305mm refl. |
| S. Walker | Chester, N. Hampshire, USA | 320mm refl. |
| J. Warell | Uppsala, Sweden | 280mm SCT |
| J. Warren | Amarillo, Texas, USA | 203mm SCT |
| W. J. Wilson V | Grange over Sands, Cumbria | 203mm SCT |
| K. Yunoki | Sakai City, Osaka, Japan | 260mm refl. |

Abbreviations: SCT= Schmidt–Cassegrain; DK= Dall–Kirkham Cassegrain; MKT= Maksutov–Cassegrain

In addition to the above, Paolo Tanga, UAI Mars coordinator, kindly provided data from the following 31 Italian observers: V. Amadori, D. Barucco, P. Beltrame, P. Berardi, M. Beretta, A. Bernasconi, M. Cardin, L. Comolli, R. Cosenza, I. Dal Prete, R. Di Nasso, A. Di Stazio, D. Fiacconi, D. Gasparri, M. Genovese, A. Gnudi, M. Guidi, A. Malisani, R. Mancini, E. Mariani, A. Medungo, G. Pompeo, N. Ruocco, S. Saltamonti, G. Sbarufatti, F. Scarpa, M. Sellini, S. Simonelli, D. Sivo, G. Uri and D. Zompatori.

All observers sent images except those marked V (for visual observations *only*).

On Jul 25 Melka and Parker showed the secondary activity had developed further: a bright belt of dust ran from *Chryse* curving to the SE over *Margaritifer Sinus* (the latter with *Oxia Palus* and *Meridiani Sinus* now partly visible again), into W. *Deucalionis Regio*. This event mixed with the existing dust activity running along *Valles Marineris*, recalling the bursts of dust here seen during the Regional events of 2003 Dec[38] and 2005 Oct.[25] Meanwhile, dust remained in *Noachis* with a bright condensation persisting in *Argyre–Ogygis Regio*. Maxson and Moore imaged this activity continuing, Jul 26–28.

Ikemura's and Yunoki's Jul 31 images show the *Margaritifer–S.Chryse* dust activity in decline but the *Sinai* dust cloud persisting, with *Solis Lacus* returning but now orientated with the long axis running SE to NW. After this, the *Sinai* cloud would fade quickly.

We give a collage to represent the later stages of the storm in Figure 8. Images from Arditti, Maxson, Parker, Peach and Walker (and drawings from Hancock) on Aug 1–5, particularly the near-infrared images, show the *Mare Cimmerium–Syrtis Major* longitudes more distinctly, even revealing fine projections from N. *Mare Cimmerium*, but the opposite hemisphere remained more densely veiled. Observing at dawn on Aug 1 Hancock (CML= 203°) wrote: 'disk beautiful against the blue sky, the colour of butterscotch.'

From Aug 5 Peach could image the still dark *Olympus Mons* at the evening terminator, whilst *Mare Sirenum* had faintly reappeared (confirmed by Abel visually). Around Aug 6–12, *Sinus Meridiani–Margaritifer Sinus* remained unrecognisable, but a new dark belt ran diagonally across *Noachis*. On Yunoki's Aug 10 image, *Meridiani* at last began to faintly show up. On Aug 5 *Nodus Alcyonius* was also weakly returning to view on Parker's images. Parker caught some other northerly details (*Trivium Charontis* and *Cerberus*) faintly on Aug 9, whilst at the same time a new halftone streak running north from *Tritonis Sinus* through *Aethiopis* to the *Aetheria* development was evident. Residual bright dust lay over W. *Electris–Eridania–Ausonia*. Arditti, Peach, Pellier, Tasselli and Tyler on Aug 10–11 clearly imaged the tilted *Solis Lacus* and the new darkening in *Claritas*.

In the best images a narrow streak (*Eosphoros*) ran NW from the NW tip of *Solis Lacus* via *Phoenicus Lacus* to the caldera of *Arsia Silva*, a near-Lowellian appearance which the writer had witnessed in 1988. This would be a temporary phenomenon, fading as the dust settled. The *Claritas* development consisted of a new halftone streak running from *Gallinaria Silva* to the E. end of *Mare Sirenum* at *Sirenum Sinus*. *Phasis* was weakly returning to visibility. The area somewhat resembled the *Claritas–Daedalia* development during its 1973–'75 phase, though the N. part was fainter this time. Meanwhile, the dark summits of the *Tharsis Montes* and *Olympus Mons* stayed visible throughout August, but were very faint by Aug 31. Their longitudes, however, remained low in contrast. By mid-month, *Hellas* remained bright, yellowish, featureless and dusty. As of late August, the newly emerged *Syrtis Major* looked thin, dust having settled more on its E. side.

As *Argyre* turned towards Europe it was seen to be still light, and the area north of it around *Mare Erythraeum* remained low in contrast. Peach's Aug 17 images around CML= 50° show recognisable but still faint features: the slightly lighter parts in *Argyre* and *Candor–Ophir* were by now static, and surely settled dust. Poupeau on Aug 18 and Sussenbach on Aug 24 showed the region south of the new *Noachis* dark belt was dusty and light, especially in the infrared. *Meridiani Sinus–Margaritifer Sinus* were very faint, but Vandebergh's high contrast images (Aug 24) showed they had at least recovered their shapes. Next day the regions were distinctly darker to Peach and Tyler, though in Morgan–Taylor's infrared image a bright patch (dust fallout?) in *Edom* nearly cut off *Meridiani* from *Sinus Sabaeus*.

From then on the area recovered rapidly. Parker remarked upon bright patches in his Aug 28 image, over W. *Argyre*, *Candor–Ophir*, *Eos* and *Coprates*. These seem to have been due to surface dust fallout for they are identical in position and form when compared with a good image by Poupeau ten days earlier. It is clear from these and later images that dust had settled more over *Margaritifer* than over *Aurorae Sinus* and *Mare Erythraeum*. With this exception, the Aug 31 images of the area looked essentially normal. Comparing the work of Poupeau (Aug 18) with Parker (Aug 28) shows that *Mare Acidalium* was weakly returning in its S. parts on the first date, and fully visible by the second.

Thus by the end of August features were recognisable at all longitudes, albeit faintly, whilst the bright dust remaining in *Hellas* and the smaller bright patches represented specific fallout. The changes noted under 'Surface features' had all been detected. Settlement continued almost imperceptibly during September: Minami found no improvement in contrast between Aug 25 and Sep 12. By the end of the first week of October there was a return very nearly to normal, though even around opposition the most experienced observers (Baum, Heath, McKim) found contrast still marginally below par.

## Indicators for the return to normal

Visual data are essential for historical comparison and for providing a 'reality check'. Minami found the reddish ground tint had reappeared by Aug 14 (Day 52; N. deserts, E. of *Syrtis Major*), earlier than his experience with the 2001 storm (when the coloration had returned on Day 73). Confirmation came on Aug 18 and 25 at CML>160°. Hancock (who also provided numerous detailed colour notes) first mentions redness on Aug 30, under CML= 289–300°, and on Aug 26 Biver wrote: 'The storm looks like finally clearing up: *Sinus Sabaeus* and *Mare Serpentis–Hellespontus* looked dark and relatively well defined. But... *Sinus Meridiani* is still very pale and obscured by dust. *Mare Acidalium* is also probably obscured...'

Minami found the NPH affected by yellow haze till at least Aug 14, but on Aug 25 he called it 'pure white'. Hancock found a notable colour contrast between SPR and NPR on Aug 7 with the former cream and the latter white. Images agree that the NPH became prominent in the last week of August. It became slightly bluish from early September, until the time when the cap displaced it: Tyler first noticed this colour on Sep 13. With $D_e$ becoming positive from Sep 13 too, geometry would soon contribute to the better visibility of the hood.

In early October, the *Tharsis Montes* continued to appear as dark patches. Signs of returning white cloud activity included: thin evening cloud over *Hellas*, Oct 5; thin morning cloud over *Hellas*, Oct 30; *Arsia Mons* orographic cloud and thin evening cloud over *Tharsis*, Oct 18. As the orographics returned, the *Tharsis Montes* no longer appeared as prominent dark patches.

Hancock found the limb still yellowish on Aug 30. His next observation, on Sep 8, showed it white, which Parker's images confirmed. The planet still looked pinkish-yellow to Brook to the

naked eye, Sep 15. Minami caught *Syrtis Major* very close to the morning limb for the first time on Sep 26: another sign of the atmosphere clearing. The global event would seem to have finished by the end of the first week of 2007 Oct. After that, any faintness of the surface markings would be due to dust fallout. One other factor contributed to the pallor of the far southern markings in 2007 Dec–2008 Jan: a bright E–W belt of water-ice cloud visible near latitude –50°: see Part II.

It is likely that suspended dust lingered in *Hellas*, the bright yellow oval remaining larger than its canonical boundaries. Lazzarotti on Oct 16 noticed it was yellowish compared with red *Aetheria*.

### Intensity estimates

Relative intensity estimates for the greater part of *Syrtis Major* during 2007 were made by Abel (Ab), Adamoli (Ad), Hancock (Ha), Heath (He) and Phelps (P): Aug 24 (Ad) 3; Aug 28 (Ad) 4; Sep 27 (P) 4; Sep 30 (Ab) 5; Sep 30 (Ha) 4; Oct 2 (Ad) 4; Nov 11 (P) 7.5; Nov 12 (Ab) 4.5; Nov 12 (Ha) 7; Nov 16 (Ha) 6; Dec 7 (Ha) 6; Dec 10 (He) 6; Dec 12 (Ab) 5; Dec 13 (Ad) 6.5; Dec 13 (He), 6; Dec 13 (P) 7; Dec 23 (P) 6.5. These at least confirm that the return to normality began after early Oct.

### Visual photometry

Henshaw's systematic naked eye magnitude estimates (2007 Jun 21–2008 Jul 3) show very close accord with the BAA *Handbook*, including the period of the dust storm. The same conclusion was reached by Schmude.[11] It seems that atmospheric dust can affect the colour of the planet, but does not appreciably affect its visual magnitude.

## Local dust activity, 2007 October–November

By 2007 early Oct, the N. polar ground cap was clearly imaged in red light, though an overlying hood would often return to mask it. On Oct 31 (Ls= 340°) a fortuitous gap in the polar hood revealed an apparent stream of dust (located near longitude 130°) heading SW away from the dark annulus that would later surround the summer cap remnant. This event was caught by Flanagan (Figure 8), Grafton and Walker. Doubtless ejected by a polar 'front', this stream appeared yellowish, and brighter in red and green than in blue light, probably having a small water component. A large patch of NPH, striking in blue light, was confined to the morning limb. Next day the dust event was hidden by the newly expanded hood, but activity was triggered elsewhere within days.

There were further signs of such activity from the hood reaching up to around *Propontis* on Nov 3 (Chavez, Flanagan), and doubtless a number of frontal systems were active at this time. A third southward surge of the hood surely initiated a more widely-observed local storm which would be monitored mostly from Europe (Figure 8). On 2007 Nov 2 (Ls= 341°), Casquinha, Sánchez (illustrated elsewhere[4]), and Tyler (Figure 8) imaged a small bright dust core over *Chryse Planitia* (telescopic northern *Xanthe*), and two others nearby: one N. of *Nilokeras* and one at its SW end.

On Nov 3 the cores were dull but the small event had expanded over *Nilokeras* and *Niliacus Lacus*–S. *Mare Acidalium*, spreading south into telescopic *Chryse*, and there was a narrow dull belt of dispersed dust crossing *Acidalium* NE to SW to *Chryse*. A thinning of the NPH in the longitudes W. of *Acidalium* could be observed next day, and the dust crossing *Acidalium* may have reached and also interacted with the complex hood/cap system. Small variations in the existing dusts were seen, with Arditti, Flanagan, Lawrence, Parker, Peach and Sharp providing further data, Nov 4–5. On Nov 5 a fresh core was seen between *Achillis Fons–Idaeus Fons*, the same place as one of those from Nov 2, which was static throughout the martian day. The NPH was weak over CML≈ 350–60°. The bright core vanished next day, with all dust dispersing, and *Niliacus Lacus* and environs returning to normal within a couple of days.

## Local dust activity, 2008 January–May

The N. polar hood remained active in 2008 Jan, so a further frontal system leaving the cap is a plausible precursor for at least the first of the events now to be described.

On Jan 20 and 21 *Utopia* was normal, but on Jan 22 (Ls= 21°) Adelaar, Aerts (19:03UT, Figure 8), Biver (20:21UT, Figure 8), Bosman, Ghomizadeh and Poupeau (21:00UT, Figure 8) found a bright dust streak (yellow in the images) over the E. part of *Casius–Utopia*. Jan 23: no BAA observations of this area; *MRO* sequence reveals a very small dusty cloud. Jan 24: nothing shown on drawings by Maksymowicz; dust very weak or absent upon images by Casquinha, Ghomizadeh, Schulz, Tanga and others. Jan 25: no dust evident to Boots & Peters, Delcroix, *etc*.

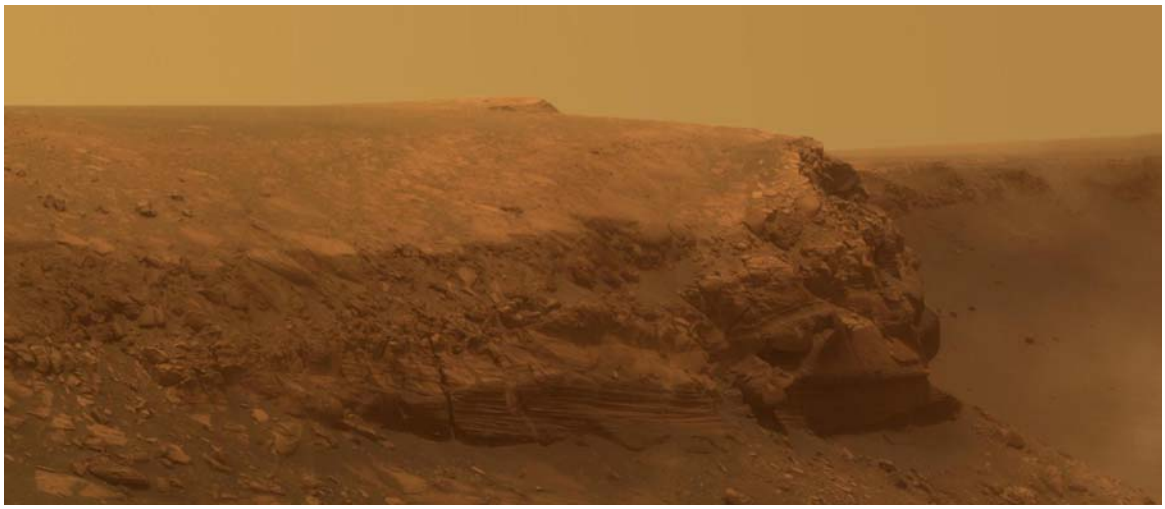
On Mar 29 Parker (00:56UT, Ls= 051°, Figure 8) found a bright patch in red light over the evening *Cydonia*–N. *Mare Acidalium*. This local dust cloud moved southwards: next rotation, Peach (18:36UT) showed *Achillis Pons* irregularly widened and *Niliacus Lacus*–SW *Acidalium* slightly faded, in green and red light. Next day, Kidd's image did not catch any disturbance on the morning side. This event was somewhat like that witnessed at the 2005 opposition[25] at Ls= 41° from *Tempe–Mare Acidalium* to *Cydonia*.

As late as May 8, Parker's images (Part II, Figure 9) revealed a narrow, apparently dusty E–W streak, commencing at the NE of *Mare Acidalium* and running west, from S. *Baltia* into S. *Mare Boreum*.

Telescopic events at these high northern latitudes are rarely detected. Examples from 1886 and 1961 (*Casius–Utopia*, *Neith Regio*) were discussed by the writer.[39]

## General discussion

The seasonal starting date of the global event (Ls= 263°) is typical for such phenomena, and very close to that of 1971 (Ls= 260°).[40] Through its origin in *Noachis*, its evolution and decay, the 2007 storm was typical. Specific secondary dust activity was witnessed over *Hesperia* and *Valles Marineris–Eos*, *Solis Lacus* and S. *Chryse–Margaritifer Sinus*. The year 2007 produced the first encircling storm observable since the start of the 'webcam revolution', enabling its start to be followed in detail despite the tiny disk diameter. The 2007 event was less severe and less enduring compared with 2001;[22] witness BAA data:



'Cape Verde' promontory juts out from the walls of Victoria Crater in this true colour image taken on 2007 October 20 by the *Mars Exploration Rover Opportunity*, taken more than a month after it began its slow descent into the crater. *NASA/JPL-Caltech/Cornell.*

| *Date range* | *Ls (°) at start* | *Duration (days)* |
|---|---|---|
| 2001 Jun 26–Dec 1 (approx.) | 185 | 159 |
| 2007 Jun 23–Oct 7 (approx.) | 263 | 107 |

That there should be such events in 2001 and 2007 agrees with existing statistics that such phenomena are – on average – likely to occur every third martian year.

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