The opposition of Mars, 2005: Part I

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

This report analyses nearly 14,000 observations by 188 contributors during 2004 November to 2006 July. Compared with its appearance at opposition in 2003, *Pandorae Fretum* was dark and complete, as a result of Regional dust activity late in the previous apparition, whilst E. *Deucalionis Regio* and *Mare Serpentis* had returned to normal. Dust activity was observed around the south polar cap (SPC) periphery in 2005 July–August, especially in association with the decay of the SPC outliers *Thyles Mons* and *Novus Mons*. A Regional storm affecting the *Hellas–Margaritifer Sinus–Argyre* area began about 2005 June 5 (Ls= 225°), and a more significant one began in eastern *Valles Marineris* on October 17 (Ls= 308°) with independent bursts of activity over *Solis Lacus* and *Aram*. This major event caused only small-scale albedo changes: it also deposited dust over the SPC summer remnant. Local post-opposition dust storms were observed in *Chryse–Xanthe*, *Aetheria,* NE *Arabia* and NE *Tempe–Mare Acidalium*. As in 2003, but in contrast to 2001 and 2007, there was no planet-encircling storm during 2005. An 'opposition brightening' was observed upon the slopes of *Olympus Mons*, the *Tharsis Montes* and *Elysium Mons*. Part II will discuss white clouds and polar region phenomena.

Introduction

This perihelic opposition occurred on 2005 Nov 7 (Ls= 320°), with Mars in Aries at declination +15.9° (D= 19.9", mag. –2.1): two Interim Reports have already appeared.[1,2] The planet was closest to Earth on Oct 30, 69.4 million km distant (D= 20.2"). The opposition was seasonally similar to 1990 (Ls= 340°),[3] 1973 (307°),[4] 1958 (329°),[5] and – in particular – 1926 (317°).[6] Circumstances favoured observation of the final recession phase of the S. polar cap, the dispersion of the N. polar hood, the start of the N. polar cap recession and the seasonal commencement of the Equatorial Cloud Band (ECB). However, the early fragmentation of the S. polar cap could not be studied in such fine detail as in 2003. Although slightly further from the Earth than at opposition in 2003, the planet's high N. declination made 2005 the most favourable in the current series of perihelic approaches.

Since 2003 there had been improvements in image-processing software: moreover, the Lumenera LU 075 camera (adopted by several of the best observers) offers a much higher frame rate than the popular ToUcam webcam. These improvements, coupled with high N. declination and fine seeing near opposition, meant that 2005 would yield this country's finest crop of images to date. The weather was also reasonably cooperative. Major contributions came from Arditti, Mobberley, Peach (who worked on over 100 nights and made two highly successful trips to Barbados[7] with other UK observers) and Tyler in England, and from Fattinnanzi, Flanagan, Grafton, Ikemura, Kowollik, Lomeli, Maxson, Melillo, Melka, Moore, Morita, Owens, D. C. Parker, Pellier, Sherrod, the Unione Astrofili Italiani (UAI), Vandebergh, Warren and Yunoki abroad. Contributions from Australia were important during the first months of coverage when Mars was in extreme S. declination. The Director made 149 drawings and a few dozen webcam images (2005 Jun 4–2006 Jun 9), whilst Adachi, Biver, Hancock, the late Harold Hill,[2] Macsymowicz, Niechoy and Siegel obtained many drawings. Several observers used the Lick refractor, Fletcher made one sketch at Mount Wilson, and Hancock two at Flagstaff.

In total, 188 contributors (Table 1) sent 13,949 observations (12,504 images, 1,456 drawings and 2 photographs)

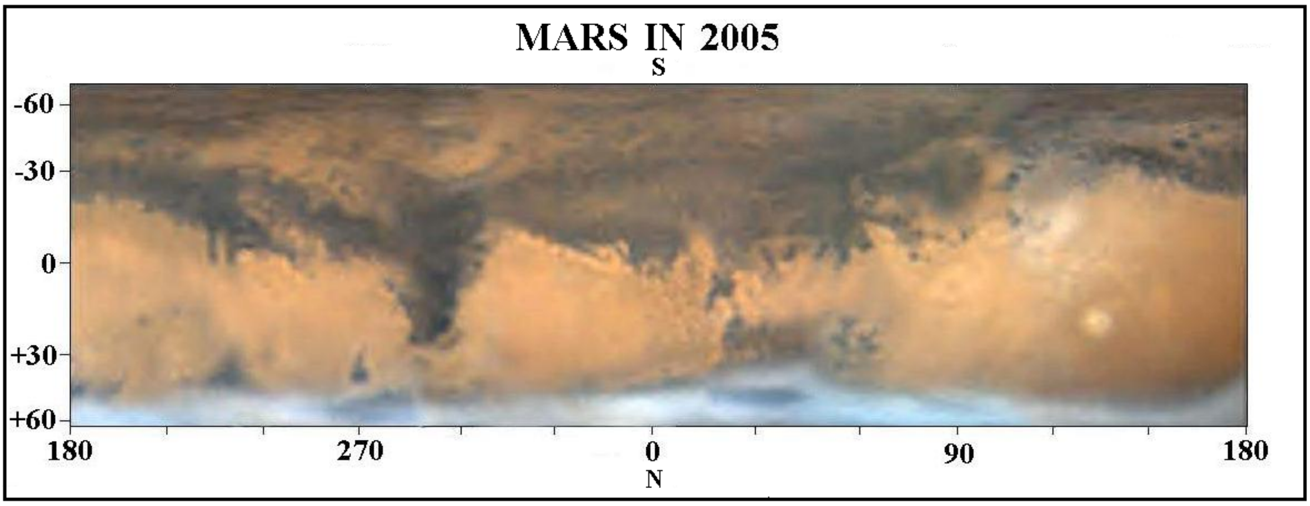

Figure 1. 2005 apparition chart made from his best personal images in 2005 Oct–Nov; 355mm SCT & Lumenera LU 075M camera. *D. A. Peach.*

made between 2004 Nov 9 (image by Akutsu, Ls= 112°) and 2006 Jul 27 (sketch by Adamoli, Ls= 85°). Monthly coverage was excellent (totals of days observed/possible): 2004 Nov 3/30, Dec 4/31, 2005 Jan 6/31, Feb 4/28, Mar 11/31, Apr 18/30, May 27/31, Jun 29/30, Jul 31/31, Aug 31/31, Sep 30/30, Oct 31/31, Nov 30/30, Dec 31/31, 2006 Jan 31/31, Feb 27/28, Mar 31/31, Apr 29/30, May 21/31, Jun 13/30, Jul 6/31.

Physical details of the 2005 apparition

Solar conjunction	2004 Sep 15	Ls= 87°
S. Winter solstice/ N. Summer solstice	2004 Sep 20	Ls= 90°
S. Spring equinox/ N. Autumnal equinox	2005 Mar 22	Ls= 180°
Perihelion	2005 Jul 17	Ls= 250°
S. Summer solstice/ N. Winter solstice	2005 Aug 16	Ls= 270°
Opposition	2005 Nov 7	Ls= 320°
S. Autumnal equinox/ N. Spring equinox	2006 Jan 21	Ls= 0°
Aphelion	2006 Jun 24	Ls= 70°
S. Winter solstice/ N. Summer solstice	2006 Aug 8	Ls= 90°
Solar conjunction	2006 Oct 23	Ls= 124°

The latitude of the sub-Earth point (D_e) was +22° in 2004 early Nov, decreasing to 0° in 2005 late Jan, rising to –25° by late May, falling to –11° in Sep, increasing to –15° at opposition, rising to –20° in Dec and falling to 0° in 2006 Apr, after which D_e again became increasingly positive.

This report continues from that of 2003.[8] The Director described BAA 2003–2005 results in Patrick Moore's *Yearbook*[9] and on the 2005 Nov *Sky At Night* television programme.[10] An opposition report has been published by the Société Astronomique de France (SAF),[11] and the OAA continued its CMO bulletin and online image galleries.[12] Online images may also be seen at the International Marswatch website,[13] and the Japan Association of Lunar & Planetary Observers (JALPON) website.[14] Tanga and Bardelli published detailed 2003–2005 SPC maps.[15] No report of the American ALPO appeared, but a detailed presentation was made by Don Parker at their 2006 Convention.[16] Limited observational details appeared in *Sky & Telescope*.[17] The Hubble Space Telescope (HST)[18] was permitted few imaging opportunities, but by chance caught the 2005 October Regional dust storm. The planet was imaged comprehensively by NASA's *Mars Global Surveyor (MGS)*,[19] *Mars Odyssey*[20] and ESA's *Mars Express*[21] from Mars orbit, and by the surface rovers.[22] *MGS* would fall silent on 2006 November 2, making it the most enduring Mars mission to date (1997–2006).

In this report we again use Ebisawa's telescopic nomenclature.[23] 'Hill' is the late H. Hill and 'Parker' is D. C. Parker.

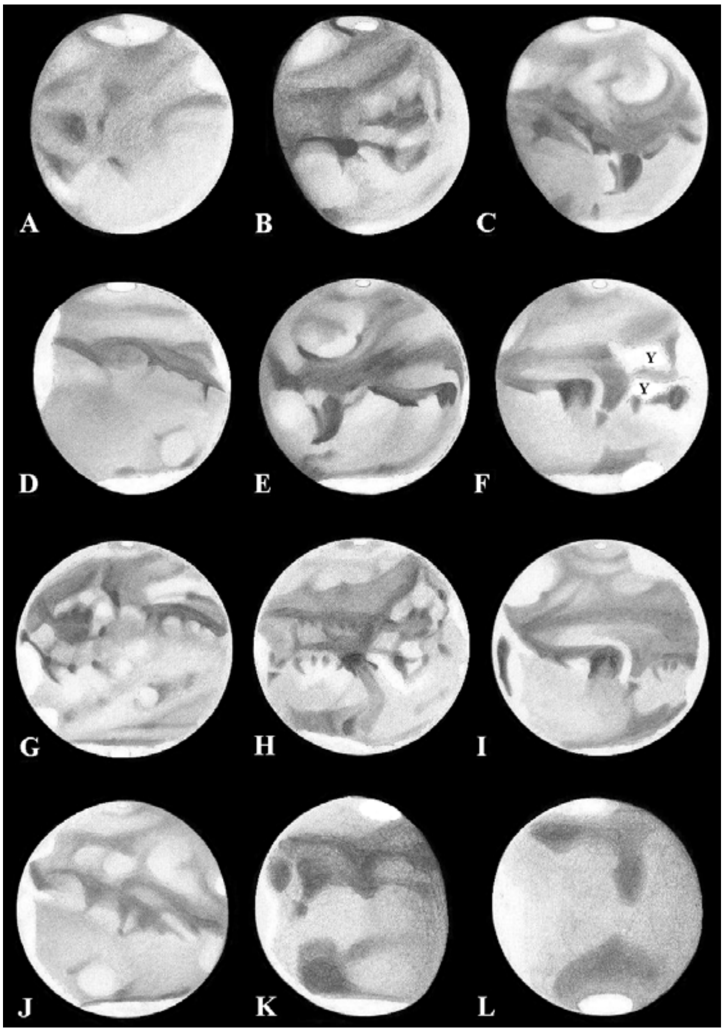

Figure 2 *(left).* Drawings by the Director with 410mm DK Cass., ×265, ×410, INT + W21 orange filter.

A. 2005 Jun 18d 04h 00m, CML= 104°. Large, irregularly bright SPC. (D= 9")

B. 2005 Jul 30d 04h 50m, CML= 066°. Rapid shrinkage of SPC; fine details within *Solis Lacus*.

C. 2005 Sep 14d 23h 30m, CML= 262°. *Mare Tyrrhenum* details, and *Nodus Alcyonius*. Light region N. of SPC.

D. 2005 Sep 22d 22h 30m, CML= 172°. *Propontis* borders the NPH. Extensive bright p.m. cloud includes *Arsia Mons, etc*.

E. 2005 Oct 17d 22h 25m, CML= 304°. Many fine details including dark spots at *Huygens* and *Nerei Depressio*.

F. 2005 Oct 20d 04h 27m, CML= 015°. A regional dust storm (marked 'Y') spreads east along *Valles Marineris*.

G. 2005 Nov 6d 21h 20m, CML= 112°. *Solis Lacus*, *Mare Sirenum* and *Phasis* fine details; *Olympus Mons* brightened by the opposition effect following the CM. (D= 20")

H. 2005 Nov 13d 21h 30m, CML= 053°. Fine details N. of *Mare Erythraeum*; *Juventae Fons*.

I. 2005 Nov 16d 19h 40m, CML= 360°. *Indus* has darkened since October; significant a.m. and p.m. clouds.

J. 2005 Dec 3d 21h 12m, CML= 230°. *Mare Cimmerium*; *Elysium*; tiny SPC; large NPH.

K. 2006 Mar 5d 19h 04m, CML= 050°. New NPC; bright SPH irradiating at terminator; phase near minimum (0.89). (D= 7").

L. 2006 Jun 3d 21h 10m, CML= 293°. NPC recessed; phase has increased again (to 0.95); scant details on tiny disk. (D= 4")

Surface features

Maps

Maps were made by Adelaar, Dickinson and Peach. Adelaar's 2005 and 2007 maps have previously been published.[24] Peach's map (Figure 1)[25] is remarkable for its minute details: compare 2003.[8] A selection of the Director's drawings forms Figure 2. On a number of good nights near opposition he could see the dark markings to be finely mottled in a manner that could never be drawn. Figures 3–5 deal specifically with Regions I, II and III respectively.

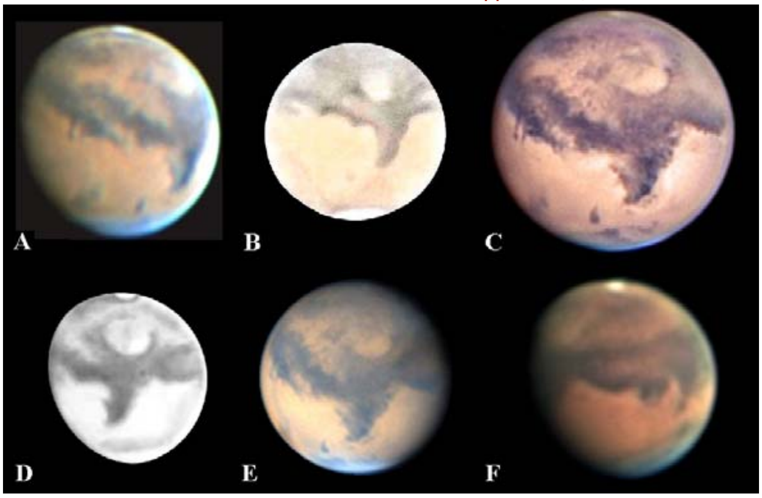

Figure 3. ***Region I: CML=250–010°***
A. 2005 Sep 21d 02h 56m, CML= 256°, 245mm refl., Lumenera LU 075M camera, RGB image, *Mobberley*. SE *Mare Tyrrhenum* remains serrated, as in 2003, due to dust deposition.
B. 2005 Nov 26d 19h 55m, CML= 274°, 102mm SCT, ×222, W23A, *Longshaw*.
C. 2005 Oct 31d 04h 18m, CML= 275°, 356mm SCT, Sony monochrome ICX098BL camera, RRGB image, *Owens*. Very high resolution; *Syrtis Major* at the CM; dark spot within *Huygens*; many tiny dark spots.
D. 2005 Sep 18d 03h 00m, CML= 284°, 415mm DK Cass., ×365, *Gray*. *Huygens*.
E. 2005 Nov 29d 22h 34m, CML= 286°, 279mm SCT, ATK camera, R(G)B image, *Tyler*. Very high resolution, but contrasts lower following Regional dust storm.
F. 2005 Sep 13d 03h 17m, CML= 335°, 300mm SCT, ATK-1HS II camera, RGB image, *Garbett*. Note *Pandorae Fretum*.

Martian colours

Near opposition, McKim saw a blue-grey tone in most of the dark areas, more distinctly than in 2003. Such colour was first apparent in *Syrtis Major* and the equatorial maria under CML= 252–262° on Sep 14, and on Oct 17 (as far S. to include *Pandorae Fretum*) under CML≈ 301°. On Sep 14 and Nov 24–Dec 3 *Mare Chronium* was reddish, as were markings around *Depressiones Hellesponticae* on Oct 9 and Nov 16, and S. of *Thaumasia* or *Mare Sirenum* on Nov 6. In Nov–Dec McKim had several views of deep blue tints in the darker, near-equatorial features, especially in *Solis Lacus*, *Mare Sirenum*, *Mare Cimmerium*, *Mare Tyrrhenum*, *Iapigia*, *Sinus Sabaeus/Meridiani Sinus*, *Mare Erythraeum*, *Aurorae Sinus* and *Solis Lacus*, and *Mare Serpentis* /E. *Pandorae Fretum*, though *Margaritifer Sinus* and W. *Pandorae Fretum* (both areas recently covered by fallout from a Regional dust storm) merely looked grey on Nov 16. As usual the deserts appeared a pale or brick-dust orange to McKim (with *Thaumasia* strongly reddish), as they are also represented in drawings by Hernandez, though Hill found them pale salmon-tinted. Hernandez showed the maria neutral grey. Biver also showed a bluish tone in many of the darkest southern maria from 2005 Aug. Hancock (Sep–Dec) tended to see the S. maria as slightly greenish, and Hill (Jul–Oct) represented them as grey-green,[2] but *Margaritifer Sinus* was bluish on Oct 14. On Sep 14 Hancock (600mm OG) found *Mare Acidalium* greenish compared with the dark grey-green *Margaritifer Sinus*. As usual we recognise subjective contrast, dust and white cloud in modifying the apparent colours.

Region I: longitude 250–010°

Refer to Figures 1, 2 and (especially) 3. *Mare Tyrrhenum* and *Mare Hadriacum* were fractionally darker than in 2003, whilst the deformation of N. *Ausonia* (*Trinacria*) continued. The NE part of *Syrtis Major* (W. of *Moeris Lacus*) was a trifle lighter in 2005, giving it the impression of being slightly more tapering to the north. On 2006 Mar 15 images by Peach and Tyler faintly but freshly revealed the presence of *Nilosyrtis*, further enhancing the tapering (and rather 'antiquarian') aspect. In Figure 11 we illustrate how *Nilosyrtis* possibly darkened as a result of earlier, nearby dust activity: see later for details. *Nodus Alcyonius* remained an isolated dark spot: there was no sign of *Nepenthes*.

On the W. side of the *Syrtis*, *Deltoton Sinus* was darker in 2005 though still small and incomplete. A few degrees west, a small spot was imaged in SE *Aeria* (also caught in 2003), which was much better seen at high phase angle (for example in Figure 11). *Hellas* was white at the CM (and hence frosted) in 2005 Jan (Minami, Jan 23), but dull by early 2005 Mar (Minami and Pujic, Mar 4–6) and later. *Hellas* very often showed diurnal cloud. As usual the basin was often a little lighter in the NW. Details of its interior were as in 2003. *Hellespontus* was obvious, but its S. part became dimmed by dust fallout from the 2005 October Regional storm. Before the 2005 June Regional dust storm (see later) *Hellas* showed floor details; these were effaced by the storm, but returned to visibility in August, though somewhat modified. In particular from 2005 early Aug a small light oval within *Hellas* S. of *Zea Lacus* was enclosed by a dusky fringe in hi-res images, remaining visible into 2006 (unaffected by the 2005 Oct–Nov Regional event). (Figures 1, 3C, E, 8 [bottom row])

Pandorae Fretum was dusky and complete in 2005, as it had been in late 2003, though it had been incomplete prior to the 2003 Nov southern Regional dust storm. *Mare Serpentis* also continued to be darker than normal during the present opposition, though it had weakened somewhat after 2003 Nov. *Mare Serpentis* had greatly invaded E. *Noachis* in 2003; this aspect was reduced on the W. side in 2005, and the feature remained dark, but it faded somewhat after October. Following major changes in 2003, *Deucalionis Regio* – particularly to the east – was more shaded than usual. There was a progressive lightening in 2005 Oct–Dec, so that *Pandorae Fretum* became more prominent by contrast. We shall see later that this change was primarily due to dust settled out from the 2005 Oct Regional storm where a burst of secondary activity over *Aram* moved into *Deucalionis Regio*. According to Peach's images, *Deucalionis Regio* lightened further between 2006 Mar 13 and Apr 22.

Region II: longitude 010–130°

Refer to Figures 1, 2 and (especially) 4. The extreme N. part of *Mare Acidalium* could not be observed for most of the apparition. The variability of the N. polar hood over *Acidalium* was again a constant source of interest. For example, on Sep 16 Parker's green image showed a gap in the NPH over *Acidalium*, and Minami visually noticed the same on Sep 28, Oct 22 and other dates: modern manifestations of the 'Dawes slit', as witnessed by that observer on 1864 Nov 14 at similar seasonal date (see Figures 1, 2, 7 and Part II, Figure 15). Other sightings continued in 2005 Oct–Nov, and – for instance – Hernandez could still see it well on Nov 27.

In 2003 we noted the variability of *Hydaspes* in response to *Chryse* dust activity, and it also looked somewhat variable in 2005 (see under 'dust storms'). More obviously, the little 'canal' *Indus* which joins *Oxia Palus* to NE *Niliacus Lacus* was darkened by the 2005 Oct Regional dust storm, and was noted as complete and dark from early Nov. (Figures 2I, 4A, C, 10)

Detailed images of the large *Solis Lacus* reveal small tonal differences from 2003 but no changes in form: *Nectar* had partially darkened, as did the shading in N. *Thaumasia* between *Solis Lacus* and *Tithonius Lacus* that includes the 'canal', *Calydon*, and also *Phoenicus Lacus*. Due to dust fallout (including that from events in 2005 June and Oct–Nov), *Argyre* and *Noachis* seemed a little lighter and therefore better defined in 2005, and *Aonius Sinus* and the S. part of *Phasis* were a little fainter. *Phasis* remained conspicuous, and (as in 2003) the desert area *Daedalia* was a little darker than *Claritas*. In response to the 2005 Oct dust storm there were small changes in relative intensity of the components of *Solis Lacus* (upon the E. part of which a secondary yellow cloud had originated on Oct 21).

The *Tharsis* and *Olympus Mons* orographic clouds are detailed in Part II. An 'opposition effect'[26] was very clearly noticed for *Olympus Mons*, which was then cloud-free, but appearing bright at all wavelengths, especially in red. Recently settled dust would explain the still higher albedo in red and the visually yellowish-orange tint at opposition. Minami has noted that it was surely through the opposition effect and not by orographic cloud – the season being wrong – that G. V. Schiaparelli was enabled to recognise the feature for the first time in 1879.

Some observers again considered that their images were highly suggestive of these volcanoes casting a shadow when seen before opposition on the evening side. In such instances the volcanoes appeared as dusky spots, darkening on the evening side, an effect which can be traced back to Barnard in 1894.[28] Careful calculation[27] reveals that the centre of the dusky spot, which at first sight appears to be a shadow, is in fact the centre of the caldera. Under excellent conditions the volcanoes appeared as reddish patches in the 2005 Aug–Oct pre-opposition images, especially *Olympus Mons* and *Ascraeus Mons*. Commenting upon these to some observers by email, Maurizio Di Sciullo reasonably suggested that the reddish colour arises 'because they are actually protruding from the atmosphere; I sent an image out back in '99 that showed *Alba Patera's* oval shield clearly punching out of the dense, morning limb haze. In your case, though the haze is far lighter, it is, none the less, present, and the soil's reddish hue is nicely enhanced wherever the atmospheric haze is missing – such as the slopes of the huge volcanoes.' We do not believe any bulk shadows of the volcanoes were seen from Earth in 2005, but it is clear that their E. slopes will darken by oblique illumination towards the evening terminator, when surface roughness will reduce the albedo further.

The reddish-brown tone of the ground seen in white light (or RGB composite images) in conjunction with the atmospheric 'violet holes' (see Part II) must arise from the same cause, namely an absence of overlying white cloud. The apparent darkness of the calderas of the volcanoes is further increased when they are protruding through a bank of white morning cloud, as observed in 1995, 1997 and 1999 by the Section.[29–31]

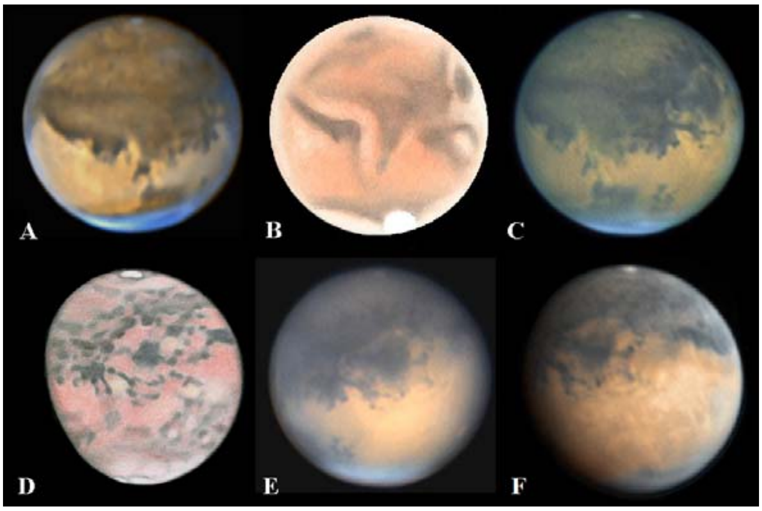

Figure 4. ***Region II: CML= 010–130°***
A. 2005 Nov 19d 22h 25m, CML= 013°, 355mm SCT, Lumenera LU 075M camera, *Mobberley*. As a result of dust activity, *Indus* now connects *Oxia Palus* to SE *Niliacus Lacus* (see also (C)). 'Dawes' slit in the NPH over *Mare Acidalium*.
B. 2005 Nov 17d 22h 00m, CML= 025°, 150mm Mak–Cass., ×200, *Graham*. Brilliant patch W. of NPH.
C. 2005 Nov 5d 15h 38m, CML= 037°, 355mm SCT, ToUcam Pro webcam, RGB image, *Lau*. Very high resolution; bluish NPH; *Margaritifer Sinus* partly recovered after Regional dust storm; contrast generally reduced.
D. 2005 Sep 2d 03h 00m, CML= 074°, 407mm refl., ×700, *Biver*. Many fine details in and around *Aurorae Sinus–Solis Lacus*.
E. 2005 Nov 13d 23h25m, CML= 081°, 355mm SCT, ToUcam Pro webcam, RGB image, *Cooper*. Fine details, but contrast muted after the Regional dust storm.
F. 2005 Oct 5d 01h 27m, CML= 106°, 355mm SCT, Lumenera LU 075M camera, RGB image, *Peach*. Very high resolution; weak *Arsia Mons* orographic cloud. Compare these high contrast levels with (E).

Table 1. Observers of Mars, 2005

Name	Location(s)	Instrument(s)
J. E. Abbott V	Rivenhall, Essex	254mm & 300mm refls.
M. Adachi V	Otsu, Japan	310mm refl.
	Hayashi Obs., Kyoto, Japan	350mm SCT
G. Adamoli V	Verona, Italy	235mm SCT
B. Adcock	Melbourne, Australia	360mm refl.
J. Adelaar	Arnhem, Holland	235mm SCT
L. Aerts	Heist-op-den-Berg, Belgium	250mm SCT
T. Akutsu	Tochigi, Japan	203mm & 279mm SCT
	Cebu City, Philippines	
J. Albert V	Lake Worth, FL, USA	279mm SCT
D. L. Arditti	Edgware, Middlesex	254mm DK Cass.
D. R. Bates	Houston, Texas, USA	254mm refl.
J. D. Beish V	Lake Placid, FL, USA	410mm refl.
N. Biver V	Paris, France	407mm refl.
N. M. Bone V	Chichester, W. Sussex	102mm OG
D. Boon	Bures, Suffolk	350mm refl.
R. Bosman	Enschede, Netherlands	279mm SCT
R. D. Bowen V	Wakefield, W. Yorks.	300mm refl.
A. G. Bowyer V	Epsom Downs, Surrey	300mm refl.
N. D. Bryant	Glasgow	305mm SCT
S. Buda	Melbourne, Australia	400mm DK Cass.
P. Campbell	Austin, Texas, USA	152mm refl.
P. Casquinha	Palmela, Portugal	250mm refl.
R. Chavez	Powder Springs, GA, USA	254mm MK Cass.
M. Cole	Keighley, Yorks.	279mm SCT
E. Colombo V	Gambarana, Italy	150mm refl.
B. A. Colville	Cambray, Ont., Canada	300mm SCT
A. E. Coombs & J. Robinson	Melbourne, Australia	250mm refl.
J. Cooper	Wootton, Northants.	355mm SCT
E. Y. Crandall V	Winston-Salem, NC, USA	110mm OG & 254mm refl.
D. G. Daniels V	Hampstead, London	150mm OG & 419mm Cass.
K. De Groff	Scottsdale, AZ, USA	254mm refl.
D. H. DeKarske V	Colorado Springs, CO, USA	300mm refl.
M. Delcroix	Tournefeuille, France	254mm SCT
W. H. Dickinson	Glen Allen, VA, USA	203mm SCT
D. Dierick	Ghent, Belgium	235mm SCT
A. Ellis	Newcastle-upon-Tyne	180mm refl.
G. Elston	Chesham, Bucks.	203mm SCT
C. Fattinnanzi	Macerata, Italy	250mm refl.
D. Fisher V	Sittingbourne, Kent	215mm refl.
W. D. Flanagan	Houston, Texas, USA	355mm SCT
J. R. Fletcher V	Lick Obs., California, USA	36in (0.91m) OG
	Mount Wilson Obs., CA	60in (1.52m) refl.
M. Foulkes	Hatfield, Herts.	203mm SCT
M. Frassati V	Crescentino, Italy	203mm SCT
A. Friedman	Buffalo, NY, USA	254mm MK Cass.
H. Fukui	Fujieda, Japan	250mm DK Cass.
P. J. Garbett	Bedford	300mm SCT
C. M. Gaskell V	Lincoln, NE, USA	200mm refl. & 410mm SCT
G. Gilligan	Liverpool	355mm refl.
M. Giuntoli V	Montecatini Terme, Italy	203mm SCT
C. Go	Cebu, Philippines	203mm & 279mm SCT
E. Grafton	Houston, Texas, USA	355mm SCT
D. L. Graham V	Ripon, N. Yorks.	102mm OG; 150mm & 230mm MK Cass.
D. Gray V	Kirk Merrington, Co. Durham	415mm DK Cass.
I. R. Hancock V	Canterbury, Kent	222mm refl.
	Lowell Obs., AZ, USA	610mm OG
A. W. Heath V	Long Eaton, Notts.	254mm refl.
C. E. Hernandez V	Miami, Florida, USA	229mm MK Cass.
E. Hidalgo	Jaen, Spain	300mm DK Cass.
H. Hill V	Wigan, Lancs.	140mm & 203mm MK Cass.
R. Hill	Tucson, AZ, USA	355mm SCT
D. A. Holt V	Chipping, Herts.	355mm refl.
C. J. Hooker	Didcot, Oxon.	200mm MK Cass.
K. C. Howlett V	Cwmbran, Gwent	250mm refl.
	Wroughton, Wilts.	150mm MK Cass.
D. Hunter	York	239mm refl.
N. D. Huskisson	Middleton, Warwicks.	200mm refl.
T. Ikemura	Nagoya, Japan	310mm refl.
J. Jefferson	Ruislip, Middlesex	127mm SCT
K. Johnson	Selsey, W. Sussex	140mm MK Cass.
M. Justice	Melbourne, Australia	250mm DK Cass.
K. Kennedy	Dundee, Scotland	203mm SCT
	Mills Obs., Dundee	254mm OG
A. S. Kidd	Welwyn, Herts.	254mm refl.
B. A. Kingsley	Maidenhead, Berks.	235mm SCT
N. Koiza V	Histon, Cambs.	410mm refl.
	Cambridge Univ. Obs.	310mm OG
S. Kowollik	Ludwigsburg, Germany	152mm refl.
T. Kumamori	Osaka, Japan	200mm DK Cass & 600mm Cass.
J. Lancashire V	Cambridge Univ. Obs.	310mm OG
C. Lau	Hong Kong, China	355mm SCT
P. Lawrence	Selsey, W. Sussex	254mm SCT
P. R. Lazzarotti (with P. Baldoni)	S. Romualdo & Mt.Giogo, Italy	252mm refl. & 315mm DK Cass.
E. Lomeli	Sacramento, CA, USA	235mm SCT
N. Longshaw V	Oldham, Lancs.	78mm OG, 102mm SCT
	Godlee Obs., Manchester	203mm OG
P. Lyon V	Birmingham	203mm SCT
R. J. McKim	Upper Benefield, Northants.	410mm DK Cass.
	Selsey, W. Sussex	381mm refl.
S. Macsymowicz V	Ecquevilly, France	150mm OG
S. Massey	Sydney, Australia	254mm refl.
P. W. Maxson	Surprise, AZ, USA	203mm & 250mm SCT
F. J. Melillo	Holtsville, NY, USA	203mm SCT
J. Melka	St Louis, MO, USA	300mm refl.
C. Meredith	Prestwich, Manchester	215mm refl.
M. Minami V	Fukui City Obs., Japan	200mm OG
	Lick Obs., CA, USA	36in (0.91m) OG
I. Miyazaki	Okinawa, Japan	400mm refl.
M. P. Mobberley	Bury St Edmunds, Suffolk	245mm refl. & 355mm SCT
D. M. Moore	Phoenix, AZ, USA	250mm refl.
Y. Morita	Hiroshima, Japan	250mm refl.
D. D. Mottershead	Manchester	254mm SCT
E. Ng	Hong Kong, China	320mm refl.
D. Niechoy V	Göttingen, Germany	203mm SCT
T. Olivetti	Bangkok, Thailand	180mm MK Cass.
L. T. Owens	Alpharetta, GA, USA	355mm SCT
P. W. Parish V	Rainham, Kent	152mm OG
D. C. Parker	Miami, FL, USA	410mm refl.
T. J. Parker	Los Angeles, CA, USA	203mm SCT
D. A. Peach	High Wycombe, Bucks.	355mm SCT
	Barbados, W. Indies	235mm SCT
	Selsey, W. Sussex	381mm refl.
C. Pellier	Bruz, France	210mm DK Cass.
I. S. Phelps V	Warrington, Cheshire	215mm refl.
J. H. Phillips	Charleston, SC, USA	254mm OG
M. Porter	Petts Wood, Kent	178mm MK Newt.
J.–J. Poupeau	Pecqueuse, France	350mm Newt–Cass.
Z. Pujic	Brisbane, Australia	310mm refl.
A. Robertson V	Broome, Norfolk	300mm DK Cass.
M. Salway	NSW, Australia	254mm refl.
E. Sampson	Worthing, W. Sussex	203mm SCT
J. R. Sánchez	Córdoba, Spain	180mm MK Cass.
	Tenerife, Spain	203mm & 279mm SCT
R. S. Scagell	Flackwell Heath, Bucks.	254mm SCT
R. W. Schmude V	Barnesville, GA, USA	120mm OG
R. Schulz	Vienna, Austria	320mm refl.
S. Seip	Stuttgart, Germany	254mm MK Cass.
I. D. Sharp	Chichester, W. Sussex	200mm refl.
	Selsey, W. Sussex	381mm refl.
W. P. Sheehan V	Willmar, MN, USA	279mm SCT
	Lick Obs., CA, USA	36in (0.91m) OG
P. C. Sherrod	Petit Jean Mtn, AR, USA	400mm Ritchey–Chrétein
D. Storey	Isle of Man	203mm & 410mm SCT

Table 1. (continued)

Name	*Location(s)*	*Instrument(s)*
E. Siegel V	Malling, Denmark	203mm SCT
J. Sussenbach	Houten, Netherlands	279mm SCT
I. Takimoto	Kagawa, Japan	310mm refl.
M. M. Taylor	Leicester	355mm & 203mm SCT
G. Teichert V	Hattstatt, France	279mm SCT
D. B. V. Tyler	Flackwell Heath, Bucks.	279mm & 355mm SCT
M. Valimberti	Melbourne, Australia	80mm OG & 356mm SCT
R. Vandebergh	Wittem, Netherlands	254mm refl.
E. Van der Velden	Brisbane, Australia	203mm SCT
D. Vidican V	Bucharest, Romania	100mm refl.
S. Walker	Methuen, MA, USA	178mm MK–Newt.
J. Warell	Uppsala Univ. Obs., Sweden	254mm SCT, 300mm Cass. & 360mm OG
J. Warren	Amarillo, Texas, USA	203mm SCT
M. E. Wasiuta	Spotsylvania, VA, USA	203mm SCT
A. Wesley	Canberra, Australia	254mm refl.
W. J. Wilson V	Grange-over-Sands, Cumbria	203mm SCT
C. Wöhler	Heroldstatt, Germany	200mm refl.
K. Yunoki	Sakai City, Japan	200mm refl.
F. Zanotti	Ferrara, Italy	450mm refl.

Abbreviations: SCT= Schmidt–Cassegrain; DK= Dall–Kirkham; MK= Maksutov; OG= Refractor (Object Glass).

In addition to the above, Paolo Tanga, UAI Mars coordinator, kindly provided data from many Italian observers: V. Amadori, F. Aquarone, G. Bartolini, D. Barucco, P. Beltrame, A. Bernasconi, A. Bertoglio, D. Botallo, S. Calafiore, M. Cardin, C. Ciceri, A. L. Cocco, L. Comolli, S. Simonelli & A. Zanazzo, F. Corrao, M. Costantinis, S. Di Mauro, A. Di Stazio, M. Fabrizio, F. Ferri, P. Galianni, E. Gandini, D. Gasparri, A. Grassi, D. Licchelli, R. Mancini, G. L. Marchetti, D. Mauro, C. & F. Mazzotti, I. Melandri, L. Monzo, P. Morelli, F. Padulosi, G. Pompeo, A. C. Ravangin, N. Ruocco, S. Saltamonti, G. Sbarufatti, M. Sellini, D. Sivo, E. Sordini, A. Tonon, G. Uri & C. Tamburini, M. Vedovato, C. Zannelli and D. Zompotari.

Some images by Takimoto and Fukui (ALPO Japan) were contributed by Ikemura; those by Hidalgo came via Sanchez.

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

Region III: longitude 130–250°

Refer to Figures 1, 2 and (especially) 5. *Elysium* continued to be bordered by the much faded *Cerberus* and the persistent *Aetheria* secular darkening, precisely as in 2003. Close to opposition the best images captured the 'opposition effect'[26] atop the cloud-free *Elysium Mons*. Thus Grafton's image of Nov 7 is an outstanding example of the effect: see Figure 5F. On Nov 10 Grafton even captured a tiny bright spot on the top of *Hecates Tholus*. The *Elysium Mons* opposition brightening could be traced, less noticeably, a couple of days on either side of the date of opposition (*ca*. Nov 5–13), and with the Lick 36-inch Sheehan recognised its location easily as early as Oct 7. *Propontis* was not easy to observe for much of the apparition: Peach's July 18 image caught it at the N. limb, foreshortened and not obvious. In later months it edged the fringe of the NPH around opposition: it seemed unchanged from 2003, still somewhat faded in the middle (Figures 1, 2D, 5D,E).

In our Reports and charts since 1988 we described the near-linear halftone marking, patchy at high resolution (especially so in the 2005 images), running parallel with and to the N. of *Mare Sirenum* and *Mare Cimmerium*, and hence traversing *Memnonia*, *Zephyria* and *Aeolis*. (ALPO's name – *Valhalla* – has not been adopted by the Section because the patches comprising it were already named on Ebisawa's chart.)[23] In 2005 the Lick observers clearly noticed that it consisted of many small patches. It was, as noticed in the past, more intense at months away from opposition (*e.g.*, 2005 Jul–Oct and Dec–2006 Jan). The explanation[11] is of rough terrain where albedo is lowered by oblique lighting, particularly near quadrature. (Figure 4F) On Parker's images of 2006 Jan 24 a still darker condensation was visible upon the aforementioned streak, near λ= 180°, N. of the W. end of *Mare Sirenum*. Darkening towards quadrature has also been shown by *Cerberus*.

South of *Mare Sirenum* observers could catch many fine high latitude details, amongst which *Caralis Fons* (*aka* crater *Newton*) was particularly dark and easy to see. *Mare Sirenum* continued to be truncated to the NW.

Dust storms (yellow clouds)

Introduction

On the martian surface small-scale sediment movement was directly observed at the *Spirit* rover site in 2005 March (for example) after several small dust storms passed by, together with small scale albedo changes in *Gusev* crater due to removal or deposition of a few microns' depth of dust.[32] Concerning spacecraft data for the early part of the apparition, Smith[33] has written of an unusually intense low-latitude storm at Ls= 135° (late 2004 Dec) and then Regional activity commencing at Ls= 225° (early 2005 June). Only the latter was a telescopic event.

From a telescopic viewpoint, there were a number of small dust events during the apparition, but only one significant storm (2005 Oct–Nov).

SPR dust, 2005 May

MGS images from mid-May reveal a strong orange tint near the SPC centre, as witnessed at the same season in 2003. The planet was then too distant for detailed ground-based imaging, but Adachi thought the SPC yellowish on May 28. In our previous Report[8] we cited a model in which gas, dust and sand are vented onto the cap as a possible explanation.[34]

Hellas Regional storm, 2005 June

Despite the small disk diameter, on June 11 Bates imaged dust running from the W. *Hellas–Ausonia* border north across *Mare Hadriacum*, which Maxson's image of Jun 13 tends to confirm. Melillo's images of Jun 8 already showed bright dust in *Hellas* extending beyond its canonical boundaries, with *Depressiones Hellesponticae* darkened and *Hellespontus* constricted in the middle suggesting westward dust propagation. The area E. of *Hellas* had appeared normal to McKim on Jun 4, and *Hellas* and points west to Lazzarotti on Jun 3. Until the storm, *Hellas* had shown floor details such as *Zea Lacus*, and these were obliterated during the event.

A shortage of high resolution observations at the critical date and CML range precludes detailed analysis, but from Jun 11 (and on Jun 13 in particular) several observers imaged bright yellow dust over *Argyre* (particularly light in R and IR), demonstrating that a Regional storm of the *Hellas–Noachis–Argyre* type was in progress. *Argyre* was still clearly yellow, and bright in R and IR to Morita on Jun 18–19. It was still quite light on Jun 23–27 to Cardin, Gasparri and Mobberley, but the lack of further change by then suggests settled dust. Further confirmation comes from Jun 9–16 data by Adachi (visual), Kumamori, Morita, Valimberti and Yunoki that show the *Margaritifer Sinus* area considerably masked by light yellow haze. Biver shows a small yellowish patch over *Chryse* on his Jun 22 sketch. *Hellas* and surroundings were quite normal once more by Jun 17, though with a loss of some contrast, but *Mare Hadriacum* remained faint even on Jun 24 (Morita). *Hellas* floor details returned weakly to visibility by 2005 late Jun.

Analysis of *MGS* daily red image swathes gives support to the phenomenon, with dust confined to the *Hellas* basin in early Jun, apparently spilling from it from Jun 5 (Ls= 225°) onwards, and the event decaying after mid-Jun.[19] Smith[33] refers to this event as the first indication of Regional activity observed by *MGS* in 2005. Possibly the suspended dust migrated towards the S. pole – and/or was augmented by further local activity at the cap edge to account for the veiled nature of the high southern latitudes to be recounted below. Similar events have been seen many times in the past.[40]

We have not illustrated this event, which occurred five months prior to opposition.

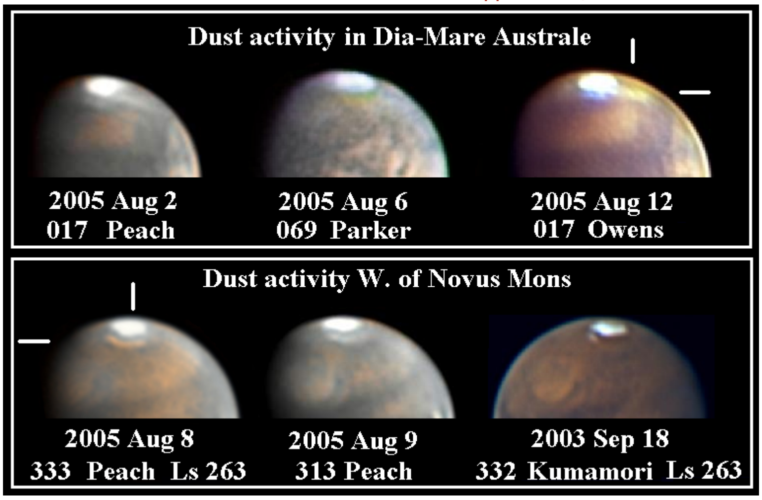

Figure 6. South polar region dust activity. CM longitude is indicated. *Top row*: Dust over *Dia–Mare Australe*, 2005 Aug. *Bottom row*: Dust W. of *Novus Mons*, 2005 Aug. For comparison with the normal appearance an image from 2003 Sep (at the same Ls) is given.

High latitude dust, 2005 July–August

At the last opposition[8] high latitude dusts had been detected during 2003 Aug 19–28 and Sep 2–13 (Ls= 244–260°), whilst *Novus Mons* had rapidly sublimed. Although observations at the same season this opposition (*e.g.*, 2005 Jul 6–Aug 1) were impeded by the small disk size, there was much polar dust activity apparent. From 2005 mid-July till late August there were numerous observations of a faint dusty yellowish haze down to about latitude –60°, within which certain more specific, better defined events could sometimes be followed, without the SPC ever being affected.

For instance, on Aug 3 Minami found the cap's surroundings dusty at CML= 195–224°, but clear by CML= 253°, whilst Hill on Aug 17–21 found a faint dusty patch encompassing those longitudes, but only on the evening side, under CML= 155–244°. Pellier[11] illustrates similar results to these. On 2005 July 13–22 Adelaar, Peach, Sussenbach and Tyler captured a patch of dust N*f*. the decaying *Thyles Mons* (λ= 150°). Nothing atmospheric was recorded there later. Other dust activity just north of the cap was detected during July 30–Aug 13 over *Dia–Mare Australe*, according to Chavez, Owens, Parker, Peach, Tyler and Walker: in Figure 6 (top row) we show images from Aug 2–12.

At other longitudes, from Aug 2 the recently detached *Novus Mons* appeared drawn out into a long, dusty, westward extension (Figure 6, bottom row). The latter streak was most prominent around Aug 8–10, especially in red light (being invisible

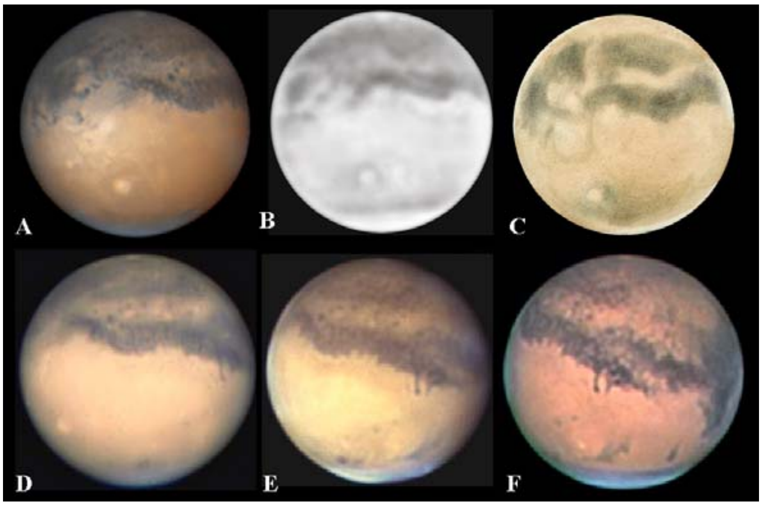

Figure 5. *Region III: CML= 130–250°*
A. 2005 Nov 6d 23h 05m, CML= 138°, 355mm SCT, Lumenera LU 075M camera, RGB image, *Peach*. Very high resolution image; much fine detail in *Solis Lacus–Phasis–Mare Sirenum*; opposition-brightened *Olympus Mons*, *etc*.
B. 2005 Nov 1d 03h 00m, CML= 141°, 415mm DK-Cass., ×365, *Gray*. Light *Olympus Mons*. Faint albedo streak N. of *Mare Sirenum*.
C. 2005 Nov 6d 23h 46m, CML= 145°, 419mm Cass., ×350, *Daniels*. *Acampsis* well seen; light *Olympus Mons*.
D. 2005 Nov 5d 00h 30m, CML= 176°, 279mm SCT, ATK-2HS camera, RGB image, *Bosman*. Finely structured S. maria.
E. 2005 Nov 23d 13h 15m, CML= 203°, 279mm SCT, DMK21BF04 camera, RGB image, *Go*. Fine details around *Elysium*, *Mare Cimmerium*; doubled *Propontis*; bluish, structured NPH.
F. 2005 Nov 7d 05h 44m, CML= 234°, 355mm SCT, ST402 CCD, IRGB image, *Grafton*. Very high resolution. Tiny *Elysium Mons* shines by the opposition effect; *Cerberus* consists of two small spots.

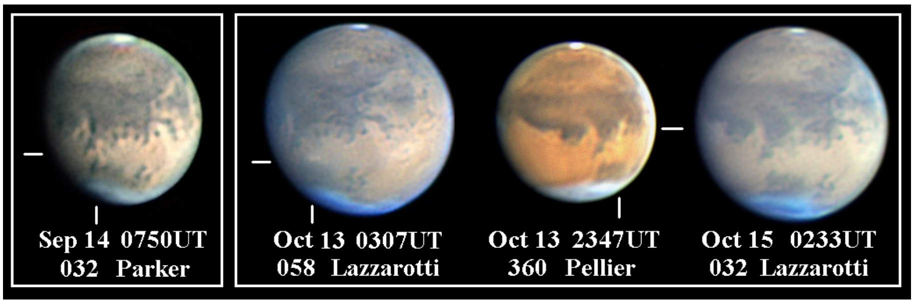

Figure 7. The 2005 Oct Regional dust storm – I: precursor events. CM longitude is indicated for each image.

in blue): compare Peach's 2005 Aug 8 image with a normal one at identical Ls on 2003 Sep 18. On Aug 9 Peach just resolved the latter peripheral from the dust streak (as confirmed by others, Aug 10–13), as *Novus Mons* decayed in longitudinal extent, while to Parker on Aug 17 the streak consisted of three components. *Novus Mons* (which we describe further in Part II) was not identified explicitly later than Aug 20 (Ls= 272°, a near-identical result to 2003)[8]. The dust streak then faded, after which lowered albedo and lack of change implied settlement upon the surface. (It is shown for example in Hill's sketch of Sep 12 (Ref. 2, Figure 3B), for example, whilst McKim on Sep 14 (Figure 2C) found the circumpolar region generally light.)

Some of the circumpolar dust diffused further north, for *Hellas* looked a little dusty under oblique illumination on July 21 (and significantly yellowish in an image by Owens), resulting in at least one dust storm false alert. Furthermore, Mateshvil *et al.*[35] reported *Mars Express* SPICAM data implying dust in *Hellas* on July 9. Our image archive does not reveal any specific outbreak, but traces of diffused dust above the basin were still visible, at the limb only, in Aug–Sep.

In summary, several separate dust events at the SPR periphery were detected during 2005 July–Aug, the most striking having been associated with the decay of *Novus Mons*.

Minor dust activity, 2005 September

On 2005 Sep 16 the Director issued an email alert that Parker and Pellier had both commented upon the presence of small dust outbreaks. On Sep 13 Pellier found a small bright yellowish patch located N. of *Mare Erythraeum* in E. *Pyrrhae Regio*. This was a weak storm, conspicuous only under oblique morning lighting, supported by a similar image of Peach: later images on the same date by Parker and Vandebergh do not show it, but with *Mare Acidalium* central, Parker found the NPH disrupted by a moving 'front'. Parker on Sep 14 (Figure 7) and Parker and Warren on Sep 16 showed small dust disturbances in E. *Chryse*, between SE *Mare Acidalium* and *Oxia Palus*, particularly in red light, and obscuration of *Acidalium* was also apparent. Various observers on Sep 17–30 (*etc.*) showed the region normal at the CM.

On Sep 13–19 an anomalous darkening of the centre of the (previously weak) *Hydaspes* streak some 5° W of *Oxia Palus* (bordering the storm) provided confirmation of the event's dusty nature. This feature weakened within days. Any doubts about the foregoing interpretation of enhanced images were quickly dispelled: a much larger event would arise from precisely the same location one month later.

Major Regional storm, 2005 October–November

This was the largest Regional event of the apparition, illustrated on the cover of the *Journal* and elsewhere[1,9] with a fine sequence by Sherrod. The event was announced by another email alert, and by a BAA *Circular* and an *E-Circular*.[36] Commencement was widely observed in Europe, but the region was soon lost over the morning terminator, when dozens of observers in the USA and Australasia followed it up. Only a few European observers watched the E. end of the mature storm creeping along *Valles Marineris*: The Director (Figure 2F) was able to see dust filling *Valles Marineris* and

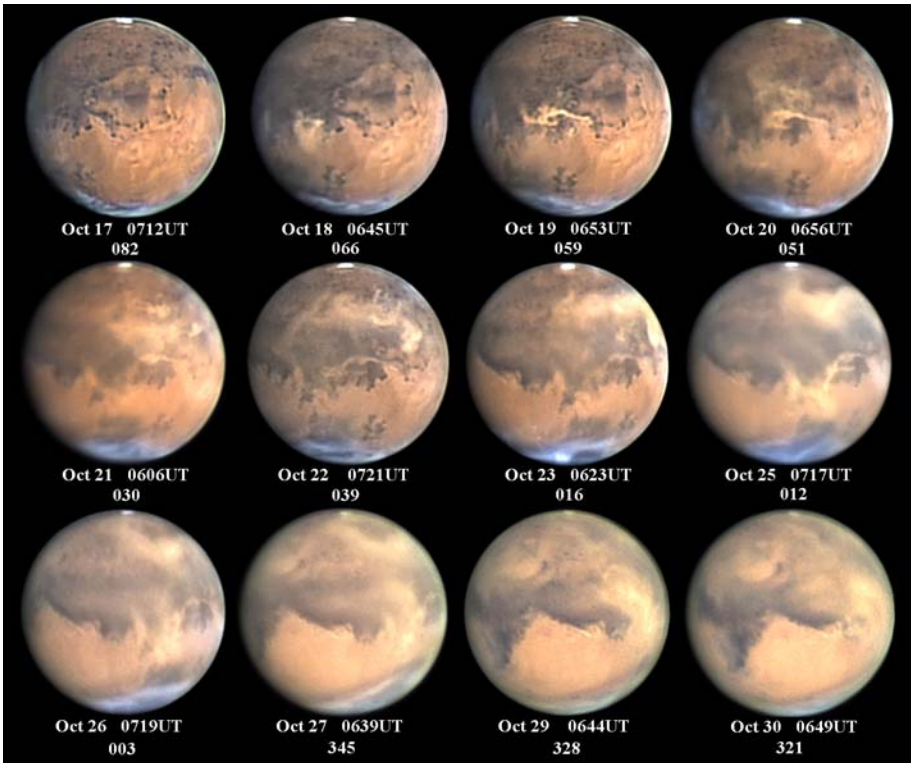

Figure 8. The 2005 Oct Regional dust storm – II: main focus of activity. LRGB images with 355mm SCT, Lumenera LU 075M camera, *Flanagan*.

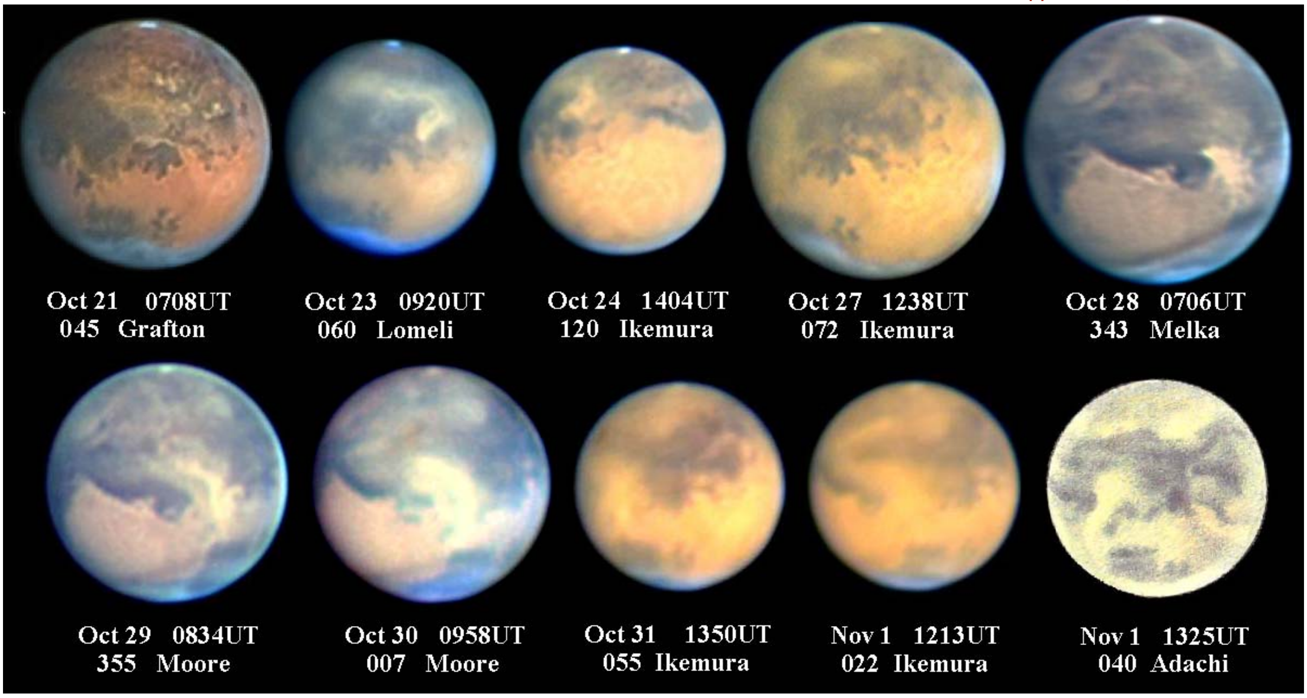

Figure 9. The 2005 Oct Regional dust storm – III: mature phase and western end. CM longitude is indicated for these images (and Adachi's drawing).

beginning to obscure *Mare Erythraeum*. Casquinha, Hidalgo, Kowollik and Sanchez also had good views. Adachi[14] (Figure 9) and Minami[12] made drawings of the dust clouds.

Although the main event began on the night of Oct 17/18, there had been a local precursor: see Figure 7. Towards midnight UT on Oct 13 Pellier had caught a bright dust cloud in *Eos*, which had not been seen at the previous rotation, though small nascent dust clouds had been noted in NE *Chryse*. The *Eos* cloud was confirmed by several observers on Oct 13–14, including Hill (Ref. 2, Figure 3C). On Oct 15 and 16 dust was fading and dispersing in canyons to the SE and SW, and on Oct 16/17 dust remained only in NE *Chryse*. Pellier noted that his Oct 15 image showed a gap in the NPH front at the CM.

A dramatic resurgence of activity began on the night of Oct 17/18. Just before midnight UT on Oct 17 (Ls= 308°) Peach caught a bright nascent cloud system, again located in S. *Chryse*, right on the morning limb; a few hours later Kowollik announced the independent discovery of this feature which would quickly become a Regional event.

Flanagan's image series (Figure 8) beautifully shows – far better than words – the activity from Oct 18 onwards as the bright V-shaped dust storm developed from *Eos*, its brightest part at the SW end laying in *Ganges Chasma*. The event continued: Oct 19, small eastward and large westward expansion along *Valles Marineris*; Oct 20, further dust over *Mare Erythraeum*; Oct 21, two new dust cores were apparent in W. *Argyre* and over SE *Solis Lacus*, with the original core in *Valles Marineris* subsiding; Oct 22, *Noachis–Argyre–Thaumasia–Solis Lacus* dust expansion, a long dust streak running NE to SW cutting *Pandorae Fretum* in the north, and *Mare Acidalium* faded by dust; Oct 23, brilliant dust core at *Solis Lacus* on *f*. limb; Oct 25, storm spills N. from E. end of *Valles Marineris* into S. *Chryse/Xanthe*, and impinges upon the S. polar region via *Noachis–Argyre*; Oct 25–30, widespread loss of contrast, particularly over *Thymiamata* (*Aram*)–*Margaritifer Sinus* where fresh activity developed, as well as *Meridiani Sinus–Deucalionis Regio–Pandorae Fretum*. Though not illustrated, filter images showed the event best in red light, almost as well in green, and faintly but obviously in blue.

Figure 9 collects other records of the mature storm including the extreme W. end which Flanagan could no longer access, as well as a secondary outburst over *Thymiamata* (*Aram*) on Oct 28 which he did not record. Albedo markings in that area began to return to visibility on Nov 2 and later, but *Margaritifer* remained faint, and we can see dustiness in *Noachis–Argyre* as well as the fading of the SPC – due to fallout – in the last days of October. McKim first found the SPC difficult on Oct 27 in poor seeing and definitely faded on Oct 29 in better conditions. Many observers who looked at Mars only close to opposition or just afterwards were surprised by the pallor of the SPC. However, by Nov 13 (McKim) it had partly recovered. By Nov 5 (Figure 4C), further darkening of *Margaritifer* was evident, and we take this date to be the approximate end of the event, but contrast remained muted over a wide area. On Nov 12 McKim still found *Margaritifer* weaker than pre-storm, but observers agreed that it was notably darker by Nov 16. *MGS* TES data[19] show that at high latitude dust had actually encircled the planet by Nov 6; some images show a slight reduction in contrast of the albedo markings that lay beyond the geometric limits of the bright dust, and the characteristic yellow tint at the limb: visual data were most useful as a 'reality check'. Cooper's natural-looking image of Nov 13 (Figure 4E) still shows contrast below normal in the *Solis Lacus* hemisphere. At the E. limit, dust settled upon the *Mare Serpentis–Hellespontus* region, further affecting albedo patterns in this area. Eastern *Mare Erythraeum* was also faded by dust deposition, and there were minor changes in relative intensity within *Solis Lacus* itself, but on the whole

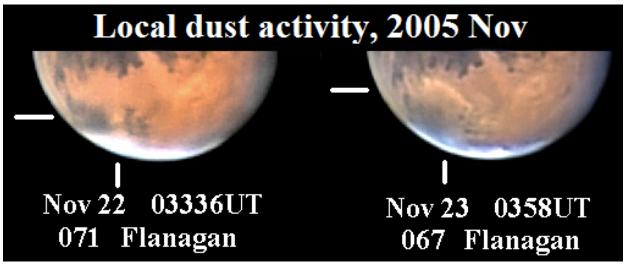

Figure 10. The 2005 Nov local dust storm. LRGB images with 355mm SCT, Lumenera LU 075M camera, *Flanagan*.

such changes were small.

By November dust had also reached the high southern latitudes around and S. of *Mare Oceanidum*. McKim noticed this circumpolar haze as being prominent on Nov 9; on Nov 12 it had greatly declined.

The initial bright core on Oct 17/18 was, according to Parker's images, well seen in red and green light, and weaker but obvious in blue. This was true for the core over *Solis Lacus* on Oct 23, as Lomeli's work showed, and also for the Oct 28 outburst over *Aram*. The diffused dust was considerably weaker in blue but still traceable in images, such as Lomeli's just cited. Each night there were many images submitted from around the globe, and these showed that the exact shape of the dust storm did not vary throughout the martian day.

There was a noticeable warming of the atmosphere: the *Libya–Isidis Regio* evening white cloud, so conspicuous up until the outbreak, disappeared on Oct 22 and did not reappear until 2006 Jan 26 (Akutsu). The *Tharsis Montes* clouds also vanished.

An odd phenomenon was observed in conjunction with the powerful expansion into *Deucalionis Regio* witnessed after Oct 28, attention being drawn to it by Moore and T. J. Parker. A short oblique reddish or wine-coloured streak can be seen near –30° to –40°, 350° (*Noachis*) on the Oct 29–Nov 1 images (Figure 9). It was invisible in the red filter images. But in the blue filter images (and somewhat less in green) it was a particularly dark area, where water vapour clouds had disappeared in response – it is assumed – to atmospheric warming by the dust storm front. This corresponds to the 'violet hole' phenomenon discussed in the 2003 Report,[8] which we shall also discuss in Part II. Figure 9 reveals, especially clearly in Melka's Oct 28 image, a long, slanting red-brownish band in the N. hemisphere just S. of the course of the classical *Protonilus–Deuteronilus* and extending to *Niliacus Lacus*: this was an anomalous feature too, shown too by Chavez, Flanagan (Figure 8), Maxson, Moore and Phillips, Oct 27–30. In blue light it was adjacent to the S. edge of the NPH.

In summary there was a small local event, Oct 13–17, followed by a significant Regional one, Oct 17–(*approx*.) Nov 5. Cantor[37] remarks that the 2005 Regional storm was less extensive in area than the 2003 events, dust lifting being confined mostly to latitude 0–60°S and longitude 320–120°.

The outburst of dust over *Aram* on Oct 28 fell close to the Mars Exploration Rover *Opportunity's* landing site in *Sinus Meridiani*, and the rover was able to measure sky opacity.[22] On Oct 29 *Opportunity's* instruments found that the dust opacity overhead was lower than during the 2001 global storm.

A dust streak in Chryse, 2005 November

On 2005 Nov 22 (Ls= 328°) a small bright dust cloud appeared in the *Chryse Planitia* basin. On Nov 23 and 24 this had moved south, drawn out into a sinuous E–W streak over *Chryse–Xanthe* (Figure 10), and *Nilokeras*/S. *Mare Acidalium* was also affected. Nothing was seen of this local storm (witnessed by Beish, Flanagan, Grafton, Melka, Parker, Vandebergh and Warren) on Nov 21 or 25, the affected albedo features fully recovering on Nov 26.

Dust over Aetheria, 2006 January

Flanagan on 2006 Jan 12 (Ls= 355°, Figure 11) imaged a dusty patch W. of the *Aetheria* dark marking, confirmed by Phillips. Dickinson caught it on Jan 13, after which it was not seen. This is a rare but not unique location for telescopic dust storms.[33]

Dust in NE Arabia, 2006 February

Tyler's 2006 Feb 4 image (Ls= 007°, Figure 11) shows a small yellow patch of dust activity at the NPC periphery. Neither confirmation nor contradiction is available, but the patch adjoined the W. edge of *Coloe Palus* (in NE *Arabia*) in three successive image sets from 18h 20m–58m UT and was brighter in red light. It therefore seems possible that this could have been the event responsible for the reappearance of *Nilosyrtis* on 2006 Mar 15–18 according to Peach and Tyler (Figure 11). As we have already seen, a strong phase effect can also account for increased contrast in such halftones, but the effect seems too strong to be explained other than by surface dust removal. In com-

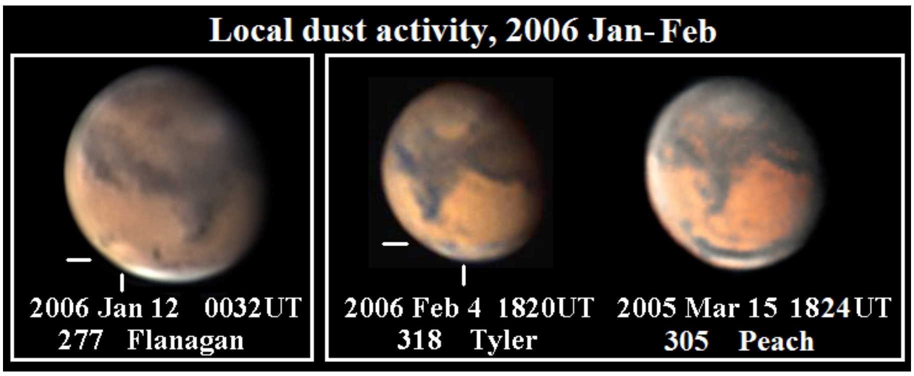

Figure 11. Local dust storm activity over *Aetheria* on 2006 Jan 12, and W. of *Coloe Palus* on 2006 Feb 4 (RGB images) The latter activity probably caused the darkening of *Nilosyrtis*, visible on the 2006 Mar 15 (RGB) image. CM longitude is indicated.

paring *Mariner* and *Viking* imagery for albedo changes, Geissler[35] has described the *Nilosyrtis* area as being literally crisscrossed by filamentary linear streaks diagnostic of dust devil tracks.

Dust in Tempe–Mare Acidalium, 2006 April

On his second Barbados imaging trip, Peach provided data nearly every day for 2006 April 7–24. Data prior to Apr 17 showed the existence of a band of white cloud from N. *Tempe* to N. *Arcadia*. On Apr 17 (Ls= 41°) a very bright patch adjoined the NPC in NE *Tempe*, visible in red, green and blue, and much longer E–W in blue than in red light. (Figure 12) On Apr 18 this had become a bright patch within N. *Mare Acidalium*, brighter in red than in blue, with diurnal cloud in *Tempe*, following; next day it was not visible in blue. On Apr 20 it faded, and on Apr 21 it had diffused east, breaking through *Mare Acidalium* into *Cydonia*, still visible only in red light. After Apr 22 it could not be traced. Maxson's Apr 16–25 work (from much higher CML) shows the pre-storm belt of bright cloud across N. *Tempe–Arcadia*.

The *MGS* TES instrument does not positively indicate dust in these longitudes on Apr 19, but such data relate to the 20–30km altitude band, and do not negate what clearly must have been a local dust storm, probably initiated by a front moving off the NPC. The patch was too far south to be frost: the filter reaction suggests dust plus white cloud on Apr 17, and dust alone later. The historical record[6] shows various events in *Tempe* during Ls= 35–129°. The specific partial obscuration of N. *Mare Acidalium* is, however, unique in the experience of the Director (and Minami).[12]

General discussion

The first Regional event began about Jun 5 (at Ls= 225°), an entirely typical result.[40] Compare Ls= 211° for the start of the similar event in 2003 late June.[8]

For the 2005 Oct large Regional event, Pellier[11] has carefully reviewed the circumstances for the storm generation: latitude measurements showed that during Oct–Nov (but hardly at all for the adjacent months) the NPH periodically expanded southward on a timescale of a few days. The largest southward excursion perfectly corresponded with the initiation of the main event on Oct 17. Thus this Regional storm would be classified as 'cross-equatorial', after the model of Wang *et al*.,[38] in which wind speed is adequate for southward dust propagation only between about Ls= 210–230° and 310–350°, at least in the longitudes around *Mare Acidalium* and *Utopia*. With the main event commencing at Ls= 308° it occurred at one seasonal limit of the theoretical model. Furthermore, the small event of Nov 22–24 coincided with the largest NPH southward oscillation[11] of that month. A detailed examination of the historical records[6] in the light of Wang's mechanism[38] would be of much interest.

Historically, the commencement of the Regional event on Oct 17 (Ls= 308°) was typical. The storm's evolution was somewhat similar to the Regional storms that began in 1990

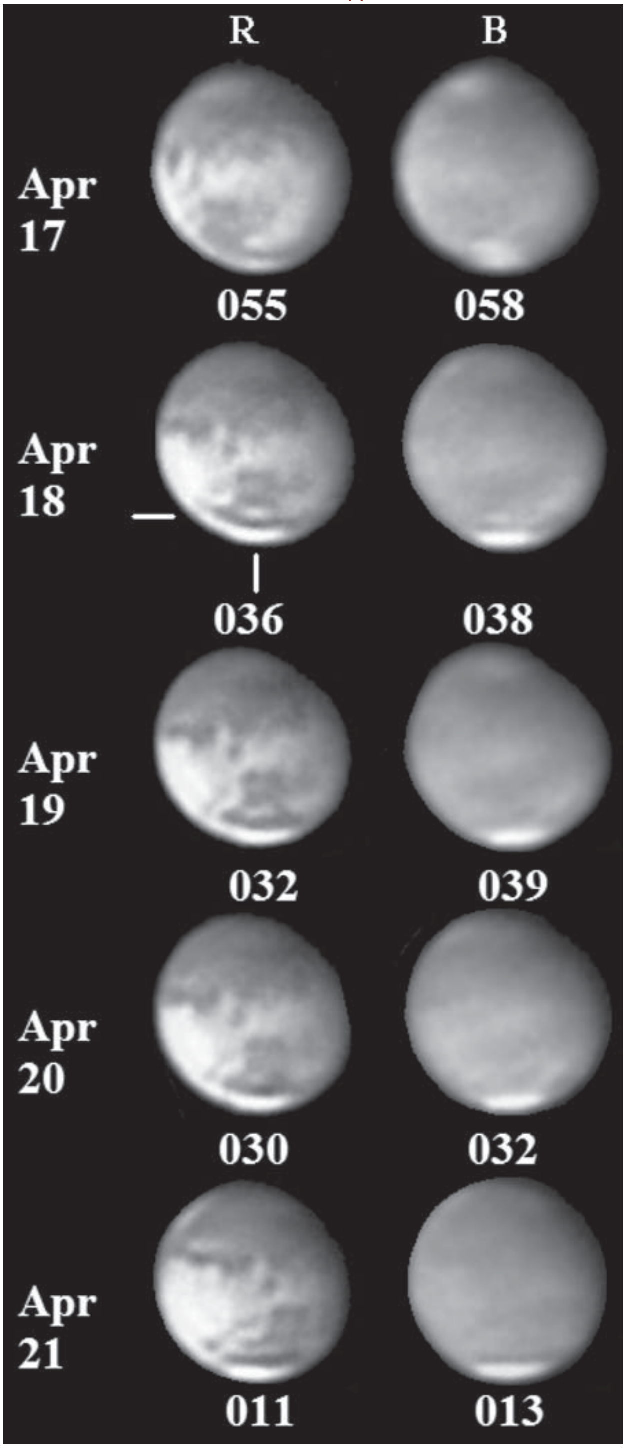

Figure 12. Local dust storm activity in NE *Tempe–Mare Acidalium*, 2006 April. Red and blue images with 355mm SCT, Lumenera LU 075M camera, *Peach*. D= 5". CM longitude is indicated.

Nov (Ls= 326°)[40] and 2003 Dec (Ls= 313°)[8]; in 2003 dust had also shown a secondary burst over *Thymiamata* (*Aram*), but had ultimately spread further east to reach *Hellas*, causing more extensive albedo changes. Records show that the latest-ever planet-encircling event began at Ls= 311° (in 1924 Dec);[6] hence the 2005 October event could potentially have become encircling, but it did not. Only at the next opposition would there be a further planet-encircling event.[39]

The high resolution of the pre-opposition images again allowed us to follow details of the polar dust activity in some detail. Ground-based visual historical data tend to be rather low in resolution, although definite records do exist of dust over the SPC.[40] The dust event adjacent to the NPC in 2006 Feb is of great interest in suggesting a mechanism for the periodic revival of the 'tail' of the *Syrtis Major*, *Nilosyrtis*. The continuing high activity of the *Chryse* initiation site, accompanied by *Thymiamata* (*Aram*)–*Margaritifer Sinus* was a noticeable feature of both 2003 and 2005, whilst *Hellas* was less active. This supports the writer's conclusion[40] that, on a timescale measured in decades, the preferred focus of activity of major storms shifts from one site to another.

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