The great perihelic opposition of Mars, 2003: Part I

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

The 2003 great perihelic opposition – marginally the closest for tens of thousands of years – fortuitously coincided with revolutionary new techniques of imaging and image processing. In Part I we show how several albedo changes resulting from the 2001 global storm persisted, notably the fading of *Mare Tyrrhenum* north of *Trinacria*, and the darkening of *Phasis*, whilst *Solis Lacus* returned to its pre-storm shape. Significant dust storms commenced in *Isidis Regio/Hellas*, *Chryse Planitia* and *Chryse/Valles Marineris*, the last attaining large Regional status, commencing seasonally very late. Several small dust events were seen upon and adjacent to the recessing S. polar cap. In Part II of this report we analyse white clouds and polar regions. Over 14,000 observations from 248 contributors covered the period 2002 October to 2004 June.

Introduction

This report continues from that of 2001.[1] Mars was under surveillance from NASA's *Mars Global Surveyor*,[2] which was joined by NASA's *Mars Odyssey*[3] in 2001, and spectacular images were taken by the Hubble Space Telescope.[4] ESA's *Mars Express*[5] reached Mars orbit on 2003 Dec 24 and deployed the UK-manufactured lander *Beagle 2*,[6] which was to have landed in *Isidis Planitia* (telescopic *Isidis Regio*) next day. *Beagle 2* crashed, but the orbiter was highly successful. NASA's twin *Mars Exploration Rovers* (MER)[7] proved a spectacular success: in 2009, both still function, years beyond their 90-day primary mission. Both gathered definitive evidence about layered sediments and the long-term presence of standing water. MER-A, known as *Spirit*, landed on 2004 Jan 4 in *Gusev* crater, north of the *Ma'adim Vallis* channel system (on the *Memnonia/Zephyria* border, at –14.6°, 175.4°) and MER-B, or *Opportunity*, landed on 2004 Jan 25, at *Meridiani Planum* (telescopic *Meridiani Sinus*, at –2.0°, 354.5°).

Mars was in opposition in Aquarius at mag –2.9 on Aug 28 at 18h UT. It was closest to Earth on Aug 27 (10h UT), 0.3727AU (55.76 million km) distant, exhibiting a 25".11 diameter disk. The disk diameter (D) was 25" or greater from Aug 22–Sep 1. Almost precisely at perihelion, the planet exhibited the theoretical maximum disk, the most favourable for some 60,000 years.[8] (Only once during the 20th century did D reach 25".[8])

At opposition the planet's declination was –15.7°, giving a more reasonable altitude than in 2001, culminating at 23° over London. Heath and others countered atmospheric dispersion visually with a small-angle prism, likewise favoured by Ikemura, Kumamori and others for imaging. The Director preferred a red or orange filter.

The opposition was comparable with others such as 1988 (Ls= 280°),[9] 1971 (Ls= 232°),[10] 1956 (Ls= 263°)[11] and 1924 (Ls= 246°),[8] the latter marking the closest approach of the 20th century.

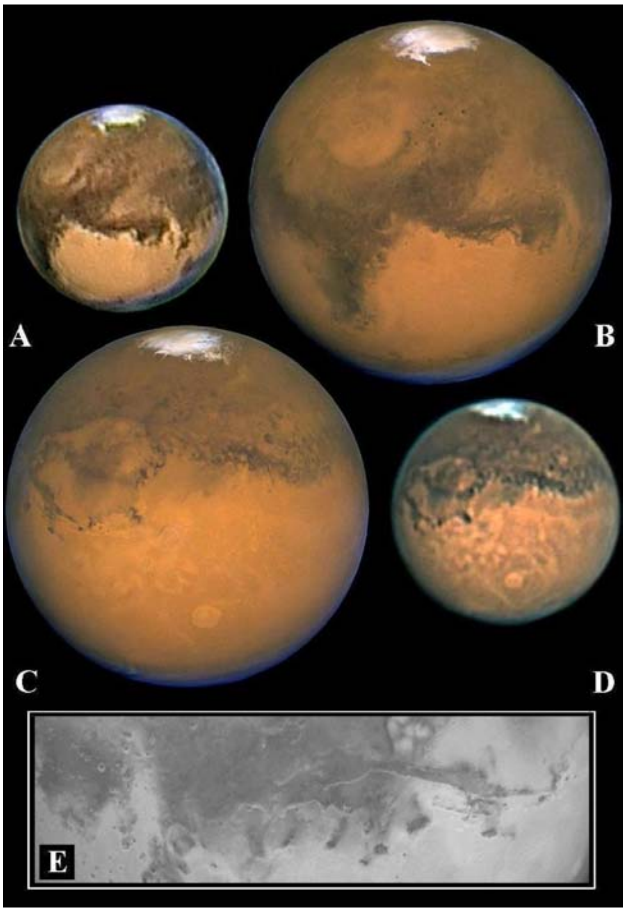

Figure 1. Images of Mars near closest approach, comparing HST and ground-based images.

A 2003 Aug 27d 00h 23–32m, CML= 344°, 450mm refl., ToUcam Pro, combined IR and colour image, *F. Zanotti*.
B HST colour composite image for 2003 Aug 26d 23h 00m, CML= 324°, to compare with A. Note the orange streaks over the SPC in B and C, indicating dust activity/settled dust.
C HST colour composite image for 2003 Aug 27d 10h 00m, CML= 124°, to compare with D. (Taken within minutes of closest approach.)
D 2003 Aug 21d 06h 33m, CML= 126°, 356mm SCT, ST5 CCD, RGB composite image, *E. Grafton*.
E A small part of the HST close-encounter red filter image, 2003 Aug 24: 1 pixel= 6km. (All HST images credit *NASA, J. Bell (Cornell University) & M. Wolff (SSI).*)

Physical details of the 2003 apparition

Solar conjunction	2002 Aug 10	Ls= 53°
Aphelion	2002 Sep 18	Ls= 70°
S. Winter solstice/ N. Summer solstice	2002 Nov 3	Ls= 90°
S. Spring equinox/ N. Autumnal equinox	2003 May 5	Ls= 180°
Opposition	2003 Aug 28	Ls= 250°
Perihelion	2003 Aug 29	Ls= 250°
S. Summer solstice/ N. Winter solstice	2003 Sep 29	Ls= 270°
S. Autumnal equinox/ N. Spring equinox	2004 Mar 5	Ls= 0°
Aphelion	2004 Aug 5	Ls= 70°
Solar conjunction	2004 Sep 15	Ls= 88°

At opposition, D_e was –18.4°. It varied from +25° (2002 Sep) to 0° (2003 Feb) to –26° (2003 Nov), decreasing to 0° (2004 Apr), reaching +26° by conjunction. D exceeded 6" for the terrestrial year, 2003 Feb – 2004 Feb. BAA observations ran from 2002 Oct 7 (Frassati and Niechoy (visual), Ls= 78°) until 2004 Jul 6 (Yunoki (imaging), Ls= 57°): nearly an entire martian year. Peach made the first image on 2002 Nov 13 (Ls= 94°), and McKim the last drawing on 2004 May 13 (Ls= 32°). All totals were record-breaking: 248 observers (Table 1) made 14,343 observations, comprising 12,190 webcam/CCD images, 2,125 drawings and 28 photographs (film/digital). The numbers of days observed per month (actual/possible) were: 2002 Oct, 7/31; Nov, 11/30; Dec, 15/31; 2003 Jan, 13/31; Feb, 17/28; Mar, 19/31; Apr, 25/30; May, 29/31; Jun, 30/30, Jul, 31/31; Aug, 31/31; Sep, 30/30; Oct, 31/31; Nov, 30/30; Dec, 31/31; 2004 Jan, 29/31; Feb, 29/29; Mar, 21/31; Apr, 23/30; May, 14/31; Jun, 7/30; Jul, 1/31.

The year 2002 saw observers abandoning traditional CCD cameras for cheaper 'webcams',[12] whilst software like *Registax* also became available. (Appendix 1.) Many images came from Akutsu, Fattinanzi, Grafton, Hatton, Ikemura, Kumamori, Lazzarotti, Maxson, D. M. Moore, Morita, Ng, D. C. Parker, Peach, Pellier, Sherrod, UAI, Valimberti, Warell, Yunoki and Zanotti. There were more imagers then visual observers. The Director produced 177 drawings, and Adachi, Adamoli, Beish, Biver, Devadas, Haas, Heath, Hill, Minami, Niechoy, Siegel and Teichert each secured good series.

Several persons travelled south and/or used large instruments. After imaging for a year on Tenerife until 2003 Jan, Peach spent a fortnight on La Palma about opposition. Sheehan and co-workers enjoyed high resolution at Lick.[13] Dave Klassen (former Section webmaster) and professional colleagues uploaded to *Marswatch*[14] 1.56–4.10μm infrared NASA IRTF images. Many amateurs uploaded to *Marswatch* (or to a new *Yahoo!* Mars Observers Group), but BAA records are more extensive.

Mars was also monitored by the Mars Sections of the Oriental Astronomical Association (OAA),[15] the Japanese Association of Lunar and Planetary Observers (JALPON),[16–18] the Unione Astrofili Italiani (UAI),[19,20] the Association of Lunar and Planetary Observers (ALPO)[21] and the Société Astronomique de France.[22,23] The Director issued observing tips,[24] a BAA *Circular*,[25] BAA *e-Circulars*,[26–28] and six interim reports,[29–34] all now available online.[35] The Director also published popular material.[36–37] Illustrations have already appeared in the *Journal*,[29–34,38] and on the BBC's website.[39]

Several professional studies cover 2003, including HST studies of winds and mineralogy,[40] dust storms,[41–43] and not least intriguing was the confirmation (by *Mars Express*) of the presence of atmospheric methane.[44]

Unless otherwise stated, in the following report 'Hill' will mean H. Hill, 'Moore' is D. M. Moore, and 'Parker' is D. C. Parker. Since 2003 we have lost by death Neil Bone (author of a popular guide[45]), Edward Ellis, Harold Hill (Section member since 1945), Dr Rowland Topping and a fine planetary imager, Erwin van der Velden.

Part I will relate surface feature changes to dust activity. Part II will deal with white clouds and polar regions. We use Ebisawa's nomenclature.[46]

Surface features

Resolution

Extremely high resolution was routinely reached by Akutsu, Buda, Camaiti, Cidadao, Fattinanzi, Grafton, Hall, Ikemura, Kumamori, Lau, Lazzarotti, Ng, Parker, Peach, Pellier, Tan, Valimberti and Zanotti. For example, in Figures 1A–B we compare Zanotti's Aug 27 image with the HST 'close encounter' image.[4] Similar comparison is made in Figures 1C–D between HST and Grafton's Aug 21 image. We infer that most (but not quite all) of the tiniest dark spots on Figures 1A and D are real, and that many are dark spots within craters, even if crater rims remain elusive. *Huygens* is obvious; even the much smaller *Kaiser* (–46°, 340°) is recognisable.

Reproducing amateur and HST images together is misleading because the latter must be greatly reduced to fit the page. In reality they have exceptional resolution: see Figure 1E.

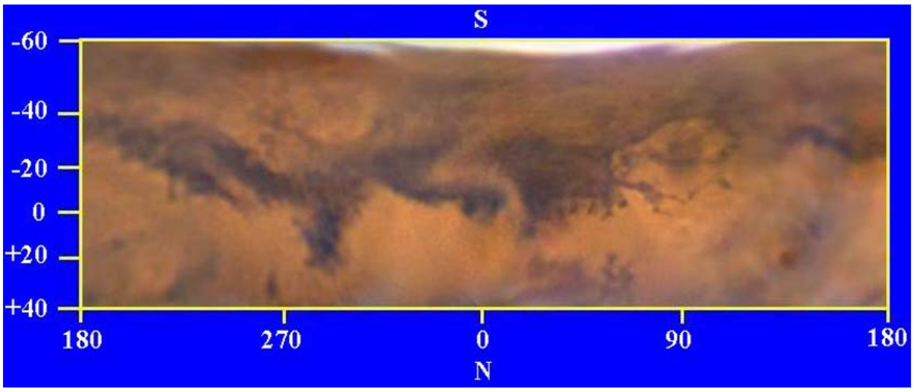

Figure 2. General chart, 2003 Aug 21–Oct 8, 200mm DK Cass. and 600mm Cass., prepared from personal images, *T. Kumamori*. The *Tharsis Montes* and *Olympus Mons* were captured on the morning side, post-opposition, and so appear as dark patches.

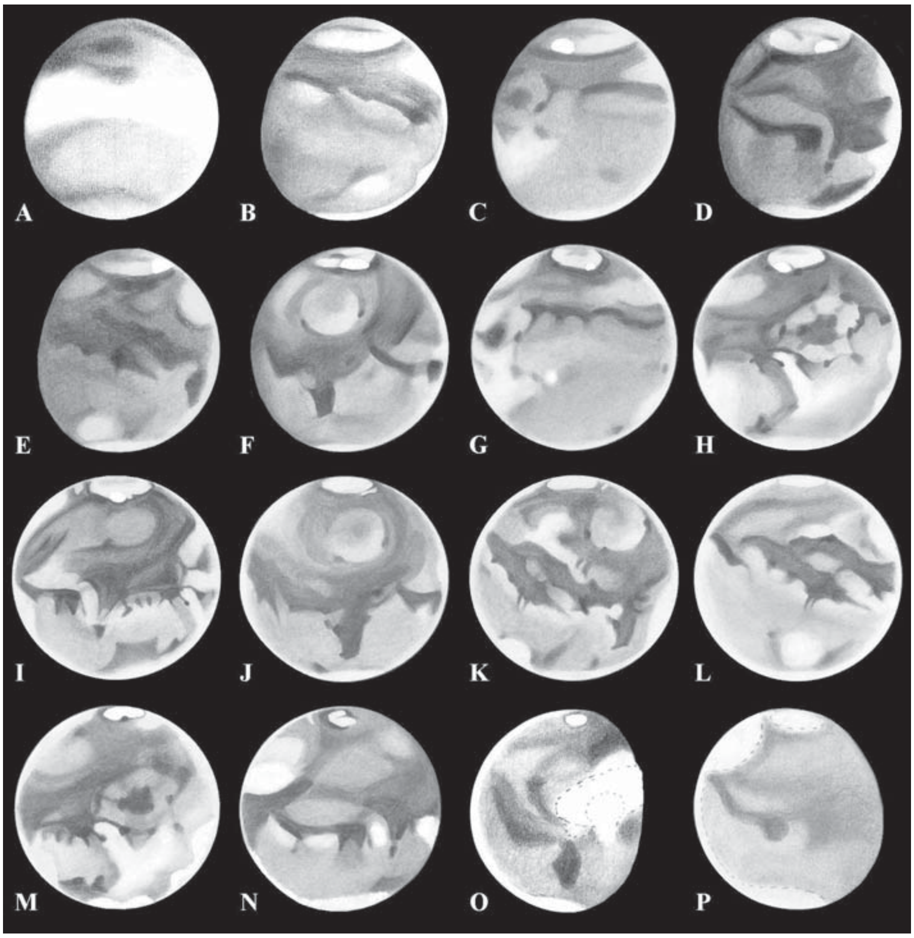

Figure 3. Drawings by the Director using a 410mm DK Cass., ×256, ×410, white light, with (mostly) W15, 21, 25 and 80A filters, *R. J. McKim*.
First row:
A 2003 Jan 11d 06h 50m, CM= 088°. Note the Equatorial Cloud Band. [D= 4.7"]
B 2003 May 26d 03h 45m, CM= 178°. *Elysium* lightish; *Rima Australis* rift in SPC.
C 2003 Jun 2d 03h 50m, CM= 112°. *Phasis*; part of 'W' cloud at terminator; *Dia* as SPC bright patch; *Olympus Mons* dusky.
D 2003 Jun 13d 03h 05m, CM= 354°. *Rima Angusta* and *Rima Australis* rifts; *Argenteus Mons* bright.
Second row:
E 2003 Jun 24d 02h 15m, CM= 237°. *Aetheria* darkening; *Novissima Thyle* bright in SPC (a.m. limb).
F 2003 Jul 28d 03h 30m, CM= 299°. *Depressio Magna* and *Novissima Thyle* in SPC; great darkening of E. *Deucalionis Regio/Noachis*.
G 2003 Aug 10d 00h 10m, CM= 131°. *Thyles Mons* bright in SPC; orographics.
H 2003 Aug 15d 23h 25m, CM= 069°. *Rima Angusta* and *Argenteus Mons* in SPC; *Solis Lacus* fine details.
Third row:
I 2003 Aug 20d 23h 25m, CM= 023°. Fine structures in *Margaritifer Sinus* and in S. *Chryse/Xanthe*, N. of *Valles Marineris*; *Novus Mons* hazy at Sp. limb. *Pandorae Fretum* not visible.
J 2003 Aug 29d 22h 05m, CM= 284°. Note *Novus Mons*; *Moeris Lacus*; *Nodus Alcyonius*; *Huygens*.
K 2003 Sep 3d 23h 05m, CM= 254°. *Novus Mons*.
L 2003 Sep 6d 21h 35m, CM= 206°. Fine details around *Mare Cimmerium*, *Ausonia*.
Fourth row:
M 2003 Sep 21d 21h 57m, CM= 077°. NPR and a.m. clouds.
N 2003 Sep 29d 21h 30m, CM= 358°. Last trace of *Novus Mons*; SPC rift extends further across cap; *Deucalionis Regio/Noachis* development faded; NPH larger.
O 2003 Dec 17d CM= 297°. Dust storm over *Hellas/Noachis* with terminator projection, and anomalous darkening to the SW of *Hellas*.
P 2004 Feb 19d CM= 013°. SPH and NPH. Reappearance of *Pandorae Fretum*; *Noachis–Deucalionis Regio* darkening faded. [D= 6.0"]

Maps

Kumamori's chart (Figure 2) shows small differences from previous perihelic approaches. Fattinanzi,[32] and Seip and coworkers also produced excellent maps. Compare these charts with 1988:[9] little variation in the fine detail in *Mare Cimmerium* or *Casius–Utopia* or *Syrtis Major* is evident, but there are large changes elsewhere, for instance in *Mare Tyrrhenum–Ausonia*, *Mare Erythraeum* and *Claritas–Thaumasia*.

Martian colours

Adachi, Biver, Ebdon, Hernandez, Hill, Lord and McKim made tinted drawings; others made notes. Subjective contrast effects are also inherent in examining colour images. The following remarks relate mostly to 2003 Jul–Sep. We showed in 1999[47] how an intrinsically brown feature could appear blue due to diurnal or equatorial white cloud. Colour on Mars is complex; here we simply report data.

Hill found most dark areas slatey blue-grey; the tone tended towards green in *Aurorae Sinus* and *Margaritifer Sinus*, whilst *Mare Sirenum* was brown. Equatorial deserts were red or pink. McKim also found most of the maria blue-grey, *Syrtis Major* especially so (blue-grey to blue-black). To him, *Aurorae Sinus* and *Margaritifer Sinus* were also blue-grey, but the tint tended towards greenish-grey towards *Mare Erythraeum* and *Bosporus Gemmatus*. *Mare Chronium* and the shading around the SPC edge (including *Depressiones Hellesponticae*) seemed more reddish-brown. Devadas, 2003 Oct–Nov, also found the markings north of the SPC – including *Mare Chronium* – to be brown, as did Minami in September (also see below). McKim saw the deserts either a brick-dust red or a peach tone. Minami's notes in connection with dust activity are given later; he found *Solis Lacus* brownish and *Aurorae Sinus* dark blue (Sep). Lord agreed upon the general tint of the maria, calling them greyish blue-green, whilst the deserts appeared pinkish-orange to yellow ochre. Sheehan's impressions with the Lick refractor form Appendix 2.

In 2003, dust added further complexity. Thin dust tinged the morning *Syrtis Major* green to Minami, late Aug: yellowish dust overlaid the bluish-tinted *Syrtis* (a tint due to morning cloud) to produce the greenish tone. Likewise the evening *Mare Cimmerium* was dark greenish to him, but the *Aetheria* dark patch, unaffected by dust or white cloud, appeared brown. Mentally comparing post- with pre-opposition estimates,

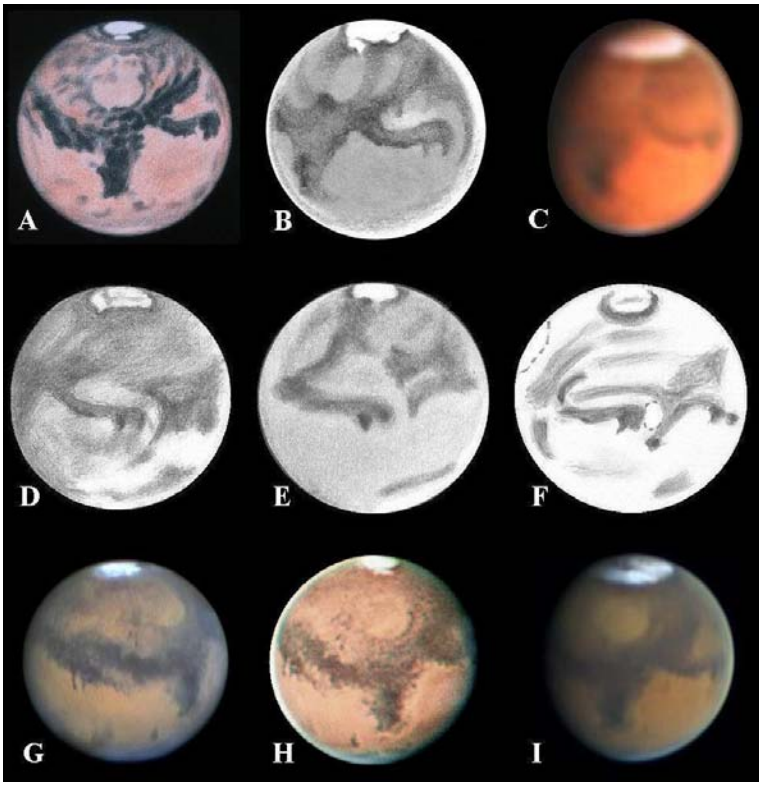

Figure 4. ***Region I, λ= 250–010°.***
Rows 1–2: Drawings and images
A 2003 Aug 27d 22h 10m, CML= 302°, 256mm refl., ×507, *N. D. Biver*.
B 2003 Aug 26d 23h 10m, CML= 325°, 203mm SCT, ×400, W23A+INT, *M. Frassati*.
C 2003 May 24d, CML approx. 310°, 508mm Ritchey–Chrétien, RGB image with ST10XME CCD camera, *A. Block*.
D 2003 Aug 12d 16h 20m, CML= 350°, 310mm refl., ×400, *M. Adachi*.
E 2003 Aug 22d 23h 10m, CML= 001°, 152mm OG, ×152, *P. W. Parish*.
F 2003 Sep 4d 06h 43m, CML= 005°, 320mm refl., ×321, *W. H. Haas*.
Row 3: High resolution images
G 2003 Aug 24d 17h 03m, CML= 254°, 400mm Cass., RGB image with ToUcam Pro camera, *W–L. Tan*.
H 2003 Sep 10d 04h 48m, CML= 284°, 410mm refl., RRGB image with ST9XE CCD camera, *D. C. Parker*.
I 2003 Jul 15d 19h 59m, CML= 298°, 250mm DK Cass., RGB image with ToUcam Pro camera, *W–L. Tan*.

McKim on 2003 Nov 12 remarked how 'washed-out' the desert colours (then appearing a pale peach tone) still looked in comparison with the rich orange-red tones of May and June.

Region I: long. 250–010°

Refer in particular to Figures 2–4. The *Syrtis Major* following the 2001 global storm had been thinned by dust deposition at its NW corner, but had returned more to its pre-storm aspect by 2002 Nov. Using *MGS* imaging, Cantor[43] discussed the recovery of the *Syrtis*. At high resolution one could see a light gap between the NW corner and *Astusapis* S., and this separation had been absent pre-storm in 2001 (and indeed for much earlier, giving the *Syrtis* its blunt N. end). The observed post-storm fading and thinning of *Mare Tyrrhenum* north of *Trinacria* (N. *Ausonia*) persisted into 2003, when the area could be inspected at high resolution. The thinning of *Tyrrhenum* involved an indentation in its S. edge: Figures 3K, 4A, G, H, 6F, H, I. The feature may have been further affected by the Jun–Jul regional storm which partly covered *Mare Tyrrhenum*. By opposition it was clear at highest resolution that dust deposition in the area had been patchy, with bright and dark spots visible.[48] *Mare Hadriacum* was patchy and faint compared with past perihelic oppositions, and two short, narrow streaks ran roughly north from its southern portion towards the indent on the S. edge of *Tyrrhenum*.

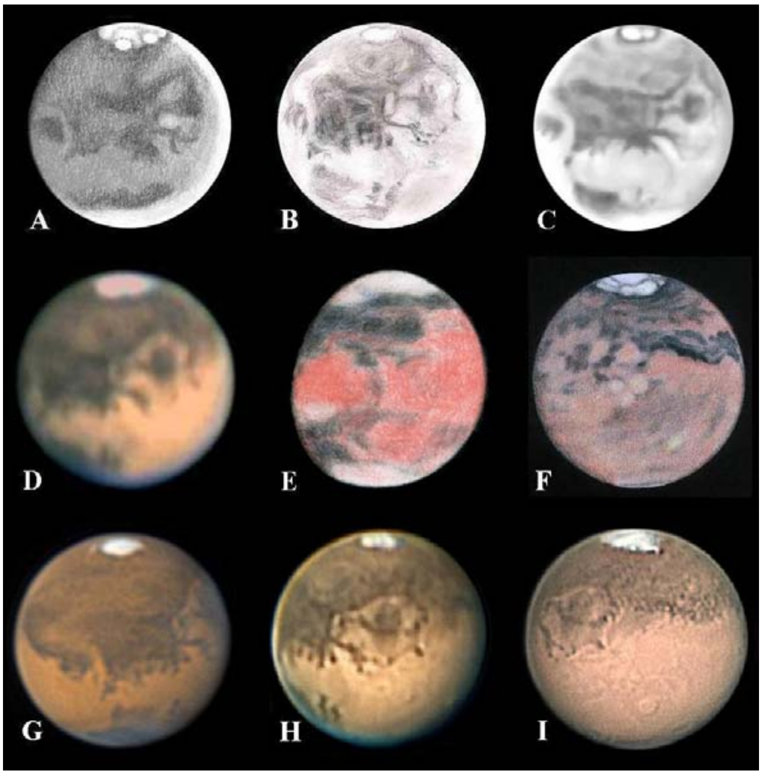

Figure 5. ***Region II, λ= 010–130°***
Rows 1–2: Drawings and images
A 2003 Aug 19d 00h 05m, CML= 050°, 203mm SCT, ×400, W23A+INT, *M. Frassati*.
B 2003 Sep 2d 08h 45m–09h 15m (a composite of several drawings), CML= 053–060°, 91cm (36-in) OG (Lick Observatory), ×735, *W. P. Sheehan*.
C 2003 Sep 23d 21h 45m, CML= 056°, 415mm DK Cass., ×415, INT+W25, *D. Gray*.
D 2003 Aug 20d 01h 42m, CML= 065°, 300mm SCT, LRGB image with ToUcam Pro camera, *M. P. Mobberley*.
E 2003 Mar 25d 05h 12m, CML= 078°, 256mm refl., ×507, *N. D. Biver*. Note SPH.
F 2003 Aug 12d 01h 05m, CML= 127°, 256mm refl., ×507, *N. D. Biver*.
Row 3: High resolution images
G 2003 Sep 12d 12h 59m, CML= 026°, 250mm DK Cass., R(G)B image with TC211 chip CCD camera, *S. Buda*.
H 2003 Sep 20d 22h 00m, CML= 086°, 250mm refl., R/IR-RGB image with Philips Vesta Pro webcam, *C. Fattinnanzi*.
I 2003 Aug 19d 05h 18m, CML= 126°, 410mm refl., RGB image with ST9XE CCD camera, D. C. Parker. Exceptionally fine details, even within *Phasis* and upon *Olympus Mons*.

Table 1. Observers of Mars, 2003

Name	*Location(s)*	*Instrument(s)*
M. Adachi V	Otsu, Japan	310mm refl.
	Hayashi Obs., Kyoto, Japan	350mm SCT
	Kwasan Obs., Kyoto, Japan	450mm OG
G. Adamoli V	Verona, Italy	108mm OG & 120mm MkC
B. Adcock	Melbourne, Australia	360mm refl.
L. Aerts	Heist-op-den-Berg, Belgium	250mm SCT
T. Akutsu	Tochigi, Japan	320mm refl.
D. R. Bates	Houston, Texas, USA	254mm refl.
R. M. Baum V	Chester	150mm MkC
J. D. Beish V	Lake Placid, Florida, USA	410mm refl.
N. Biver V	Versailles, Paris; Ablis; & Col de la Bonette, France	256mm & 407mm refls.
A. Block	Kitt Peak Obs., AZ, USA	508mm RC
J. Blockley	Wakefield, W. Yorks.	127mm OG
G. Boerjan	Assenede, Belgium	300mm refl.
N. M. Bone V	Chichester, West Sussex	102mm OG
K. Bovill & S. Keenor	Cardiff	200mm Mak–Newtonian
R. D. Bowen V	Wakefield, W. Yorks.	300mm refl.
A. G. Bowyer V	Epsom Downs, Surrey	300mm refl.
J. N. Brown V	Warmington, Northants.	254mm refl.
P. Bruce	West Croydon, Surrey	254mm SCT
S. Buda & B. Curcic	Melbourne, Australia	250mm & 400mm DKC
P. Camaiti	Murisengo, Italy	279mm SCT
P. Campbell	Austin, Texas, USA	152mm refl.
D. Chilard & C. Thomson	Worthing Astron. Society	200mm SCT
A. Cidadão	Oeiras, Portugal	254mm SCT
J. A. Clark	Gravesend, Kent	203mm SCT
P. Coelho	Montijo, Portugal	203mm SCT
E. Colombo V	Gambarana, Italy	150mm refl.
B. A. Colville	Cambray, Ontario, Canada	200mm MkC & 300mm SCT
J. Cooper	Wootton, Northants.	178mm Mak–Newtonian
E. Y. Crandall	Winston-Salem, NC, USA	254mm refl.
D. Crussaire	Meudon Obs., Paris, France	254mm & 1m Cassegrain
	Champigny-sur-Marne, FR	102mm OG
D. G. Daniels V	Hampstead	150mm OG & 419mm Cass.
D. H. DeKarske V	Colorado Springs, CO, USA	254mm refl.
P. Devadas V	Madras, India	360mm refl.
D. Dierick	Ghent, Belgium	235mm SCT
J. Dijon	Champagnier, France	500mm refl.
T. Dobbins	Coshocton, Ohio, USA	355mm SCT
C. Ebdon V	Colchester, Essex	254mm refl.
E. L. Ellis V	St. Albans	90mm OG
C. Fattinnanzi	Macerata, Italy	250mm refl.
D. J. Fisher V	Sittingbourne, Kent	215mm refl.
M. Foulkes & P. Carter	Hatfield, Herts.	203mm SCT & 254mm refl.
M. Frassati V	Crescentino, Italy	203mm SCT
A. Friedman	Buffalo, NY, USA	254mm MkC
G. Galli	Pogliano Milanese, Italy	235mm SCT
C. M. Gaskell V	Lincoln, Nebraska, USA	410mm SCT
M. V. Gavin	Worcester Park, Surrey	300mm SCT
P. Georgopoulos	Athens, Greece	279mm SCT
C. Go	Cebu, Philippines	203mm SCT
E. Grafton	Houston, Texas, USA	355mm SCT
D. L. Graham V	Ripon, North Yorks.	102mm OG & 152mm MkC
D. Gray V	Kirk Merrington, Co.Durham	415mm DKC
M. Green V	Trelogan, Flintshire	203mm refl.
W. H. Haas V	Las Cruces, NM, USA	203mm & 320mm refls.
G. D. Hall	Dallas, Texas, USA	310mm SCT
D. Hatch	Brampton, Cambs., & Horncastle, Lincs.	152mm OG
J. P. Hatton (with R. Habermann)	Mill Valley, CA, USA	235mm & 250mm SCT
A. W. Heath V	Long Eaton, Notts.	203mm MkC & 254mm refl.
M. J. Hendrie V	Colchester, Essex	152mm OG
C. Henshaw V	Tabuk, Saudi Arabia	naked eye
C. E. Hernandez V	Miami, Florida, USA	235mm MkC
H. Hill V	Wigan, Lancs.	140mm MkC
R. Hill	Tucson, Arizona, USA	355mm SCT
T. Ikemura	Nagoya, Japan	310mm refl.
G. F. Johnstone V	Birdingbury, Warwicks.	200mm SCT
D. Klassen (with D. Blaney, W. Golisch, D. Griep, S. Noonan, T. J. Wark)	Mauna Kea, Hawaii	3m NASA IRTF
T. Kumamori	Sakai City, Osaka, Japan	200mm DKC & 600mm Cass.
C. Lau	Hong Kong, China	355mm SCT
P. R. Lazarotti (with F. Canapine & N. Guidoni)	Massa, Italy & Mt. Giogo, Italy	178mm MkC
C. J. R. Lord V	Little Eversden, Cambs., & Corfu, Greece	140mm OG
P. Lyon V	Birmingham	203mm SCT
L. T. Macdonald V	Newbury, Berks.	222mm refl.
R. J. McKim V (with M. McKim)	Upper Benefield, Northants.	75mm OG, 216mm refl. & 410mm DKC
S. Massey	Sydney, Australia	200mm refl.
	Siding Spring, Australia	1m SCT
P. W. Maxson	Surprise, Arizona, USA	203mm SCT
F. J. Melillo	Holtsville, New York, USA	203mm SCT
J. Melka	St. Louis, Minnesota, USA	320mm refl.
C. Meredith	Prestwich, Manchester	215mm refl.
M. Minami V	Fukui City Obs., Japan	200mm OG
	Naha, Okinawa, Japan	various
I. Miyazaki	Naha, Okinawa, Japan	400mm refl.
M. P. Mobberley	Cockfield, Bury St. Edmunds	300mm SCT
D. M. Moore (& J. Cordiale)	Phoenix, Arizona,USA	250mm refl. & 362mm Cass.
S. L. Moore V	Thorpe-le-Soken, Essex	222mm & 355mm refls.
P. Morel	Haute Provence, France	406mm Newt–Cass.
Y. Morita	Hiroshima, Japan	250mm refl.
E. Ng (& S. K. Chuen)	Hong Kong, China	250mm refl.
D. Niechoy V	Göttingen, Germany	203mm SCT
D. Novakovic	Yardley Gobion, Northants.	203mm refl.
G. Okša V	Nitra, Slovak Republic	80mm OG
L. T. Owens	Alpharetta, Georgia, USA	355mm SCT
B. Pace	Darwin, Australia	152mm MkC
R. Panther V	Walgrave, Northants.	152mm OG
P. W. Parish V	Rainham, Kent	152mm OG
D. C. Parker (with T. D'Auria, A. Chaikin & S. Faworski)	Miami, Florida, USA Florida Keys, USA	410mm refl. & 250mm DKC
T. J. Parker	Los Angeles, CA, USA	152mm OG
K. C. Pau	Hong Kong, China	212mm Newt–Cass.
D. A. Peach (& J. Mills [La Palma])	Rochester, Kent; High Wycombe, Bucks. Costa del Silencio, Tenerife La Palma, Spain	203mm refl., 254mm & 279mm SCTs
C. Pellier (& S. Marchand)	Bruz, France	180mm refl.
I. S. Phelps V	Warrington, Cheshire	215mm refl.
J. H. Phillips	Charleston, SC, USA	203mm & 254mm OGs
T. C. Platt	Binfield, Berks.	279mm SCT
C. J. Proctor	Torquay, Devon	500mm refl.
G. Quarra	Valmontone, Italy	130mm OG
T. J. Richards	Melbourne, Australia	180mm OG
J. H. Rogers V	Cambridge University Obs.	310mm OG
	Linton, Cambs.	254mm refl.
J. R. Sánchez	Córdoba, Spain	280mm SCT
R. W. Schmude V	Barnesville, Georgia, USA	100mm OG
	Villa Rica, Georgia, USA	250mm & 510mm refls.
S. Seip (with W. Mahl & E. Schulz [Chile])	Stuttgart, Germany Vicuna, Chile	254mm MkC

Table 1. Observers of Mars, 2003 *(continued)*

Name	*Location(s)*	*Instrument(s)*
B. Shaw	Oakley, Hants.	127mm OG
W. P. Sheehan V (with L. Hatch & A. Misch [Lick])	Wellington, New Zealand Lick Obs., CA, USA	152mm OG 36-in (0.91m) OG
P. C. Sherrod	Petit Jean Mtn., AK, USA	410mm SCT
E. Siegel V	Malling, Denmark	203mm SCT
D. Storey V	Douglas, Isle of Man Foxdale, Isle of Man	152mm OG 410mm SCT
D. Strange	Worth Matravers, Dorset	500mm refl.
E. Stryk V	Knoxville, Tennessee, USA	254mm refl.
J. Sussenbach	Houten, Holland	279mm SCT
W–L. Tan	Singapore	250mm & 400mm Cass.
P. Tanga	St.André de la Roche, Nice, France	178mm Mak–Newt.
M. M. Taylor	Leicester	355mm SCT
G. Teichert V	Hattstatt, France	280mm SCT
R. Topping V	Tredegar, Gwent	203mm refl.
D. M. Troiani V	Schaumberg, Illinois, USA	152mm refl.
M. Valimberti	Melbourne, Australia	356mm SCT
A.van der Jeugt V & R.Martens	Gent, Belgium Ghent Univ. Obs., Belgium	200mm SCT 230mm OG
E.van der Velden	Brisbane, Australia	203mm SCT
A. G. Vargas V	Cochambamba, Bolivia	203mm refl.
F. A.Violat Bordonau	Caceres, Spain	203mm SCT
J. Warell	Tucson, Arizona, USA	254mm SCT
A. Wesley	Canberra, Australia	254mm refl.
S. Whitby V	Hopewell, Virginia, USA	152mm refl.
A. Wilson	Paddock Wood, Kent	203mm SCT
W. J. Wilson V	Grange over Sands, Cumbria	203mm SCT
C. & A. Wöhler	Heroldstadt, Germany	200mm refl.
C. K. Yan	Hong Kong, China	254mm MkC
K. Yunoki	Sakai City, Japan	200mm refl.
F. Zanotti (with M. Bonadiman)	Ostellato (Ferrara), Italy	450mm refl.

Abbreviations: SCT= Schmidt–Cassegrain; DKC= Dall–Kirkham Cassegrain; MkC= Maksutov–Cassegrain; RC= Ritchey–Chrétien; OG= Refractor ('Object Glass'); refl.= Reflector. V= visual observations.

In addition to the above, Paolo Tanga, Mars coordinator for the Unione Astrofili Italiani, sent data from these additional Italian observers: F. Acquarone & F. Agliuzza, A. Aletti, V. Amadori, P. Baldoni, L. Bardelli, R. Barzacchi, P. Beltrame, R. Brugo, A. Capiluppi, M. Caponera, A. Carbognani, M. Cardin, M. Cartisano, A. Catapano, P. Catellino, M. Chiarini, M. Cicognani, A. L. Cocco, L. Comolli & A. Zanazzo, F. Corrao, M. Cristofanelli, D. Crudeli, C. Cuman, I. Dal Prete, G. De Falco, N. De Gioia & F. Scarafiotti, M. Di Biase, M. Fabrizio, F. Ferri, V. Fosso, A. Galardo, G. Galli, E. Gandini, G. Gargano, G. Gaudenzio, V. Gavric–Tanga, M. Genovese, M. Giuntoli, Gruppo Astrofili Catanese (E. Lo Savio G. Marino, F. Salvaggio & S. Spampinato), D. Licchelli, M. Locatelli, M. Lorenzi, , R. Mancini, E. Maramonte, E. Mariani, A. Marino, D. Mauro, A. Milone, G. Mittiga, L. Monzo, P. Moroni, D. Nava, F. Padulosi, S. Palmeri, M. Perego, A. Petrone, R. Pipitone, C. Placenti, G. Puglia, A. Ravagnin, L. Ribaudo, N. Rizzi, C. Rossi, N. Ruocco, S. Saltamonti, M. Santinello & L. Zaggia, G. Sbarufatti, M. Sellini, L. Siciliano, P. Siliprandi, D. Sivo, G. Uri, M. Vedovato, M. Verga, S. Vinco, A. Zampedri, C. Zannelli, S. Zazzera & D. Zompatori.

All observers sent images except those marked V. Crandall, Foulkes, Meredith, D. C. Parker, Peach, Phillips and Warell also sent visual work, and Beish and McKim experimented with webcam and video respectively.

In 2003 March *Hellespontus–Mare Serpentis* and *Depressiones Hellesponticae* were broad and dark. In April, *Depressiones Hellesponticae* was partly effaced by the expanded S. polar hood, and by then *Hellespontus* and *Yaonis Fretum* could be resolved. *Hellespontus* and *Yaonis Fretum* formed a double dark streak running to *Depressiones Hellesponticae* at the edge of the SPC before opposition. As dust from the Jun–Jul regional dust storm (Figure 9A) settled by mid-Jul it was apparent that *Hellespontus–Yaonis Fretum* had darkened and broadened to the west, forming a massive dark belt that covered part of E. *Noachis*, *Mare Serpentis* and E. *Deucalionis Regio*. Although E. *Deucalionis Regio* was brightening again in October, the large feature still existed until the 2003 Dec regional storm. Following that event dust settled upon the new development, leaving a more normal aspect to *Hellespontus* and *Mare Serpentis* (Figure 12A).

The *Hellas* basin showed seasonal change. Before 2002 Dec, it was affected by diurnal cloud. Then, through 2003 Feb, it was frosted. The frost-free basin floor in 2003 Apr was bland, but the north–south halftone *Alpheus*, and central *Zea Lacus* gradually became apparent from then through June. All floor details disappeared during the Jun–Jul storm. Later, the still dusty *Hellas* gradually showed different, patchy surface features: albedo markings broken by dust fallout. By August it was possible to glimpse *Peneus* and *Zea Lacus* again as weak halftones; they intensified through Sep–Nov.

Deltoton Sinus was typically small. The dark spot within *Huygens* was well seen (Figures 1A, 3J, K, 4A, G–I). The dark W. perimeter of *Huygens* was more complete than in 2001. *Pandorae Fretum* was not visible prior to the 2003 Jun–Jul regional storm, and that event did not affect its visibility. However, the 2003 Dec–2004 Jan regional storm caused *Pandorae* to darken abruptly.

In the north, *Nodus Alcyonius–Casius–Utopia* resembled 2001, insofar as the value of D_e allowed inspection. Near-opposition images show that *Ismenius Lacus* remained more prominent on its W. side.

Region II: long. 010–130°

Refer to Figures 2, 3 and 5. *Mare Erythraeum* was dark, distinctly separated from *Margaritifer Sinus*. Northern *Mare Acidalium* could not be viewed at opposition.

The boundaries of *Argyre* were hard to define for most of 2003, typical for perihelic oppositions. Was its appearance as a light-coloured 'island' to Schiaparelli in 1877 due to fresh dust fallout? Normally it cannot be differentiated from *Noachis*, except when frost-covered and then an obvious bright patch. For months after the 2001 global storm, *Argyre* had been very bright due to settled dust. A similar circumstance occurred in 2003 Dec as a result of regional activity again affecting *Argyre*; the basin became bright in green and red light, but not in blue: a sign of settled dust (Figure 12A).

The area from *Aonius Sinus* to *Mare Sirenum* was initially very dark: a normal seasonal effect. After 2003 Apr it faded considerably, as the SPH/SPC south edge retreated.

Solis Lacus changed its shape following the 2001 global storm. By 2003 Mar, when it could be satisfactorily imaged, it could be seen to have reverted to its pre-storm form as a large dark patch, more elongated E–W than N–S, but faint at the NW corner, and a bit lighter than in 2001 in the south. The NW part darkened in Jun–Jul following local dust activity in May. The two dark spots/protrusions at the S. edge of *Solis Lacus* were again noticeable (Figures 3H, M, 5B, H, I), diffuse streaks running southwards from them to the edge of *Thaumasia*. At opposition it could be seen that there was a new (but very diffuse) darkening of *Thaumasia*

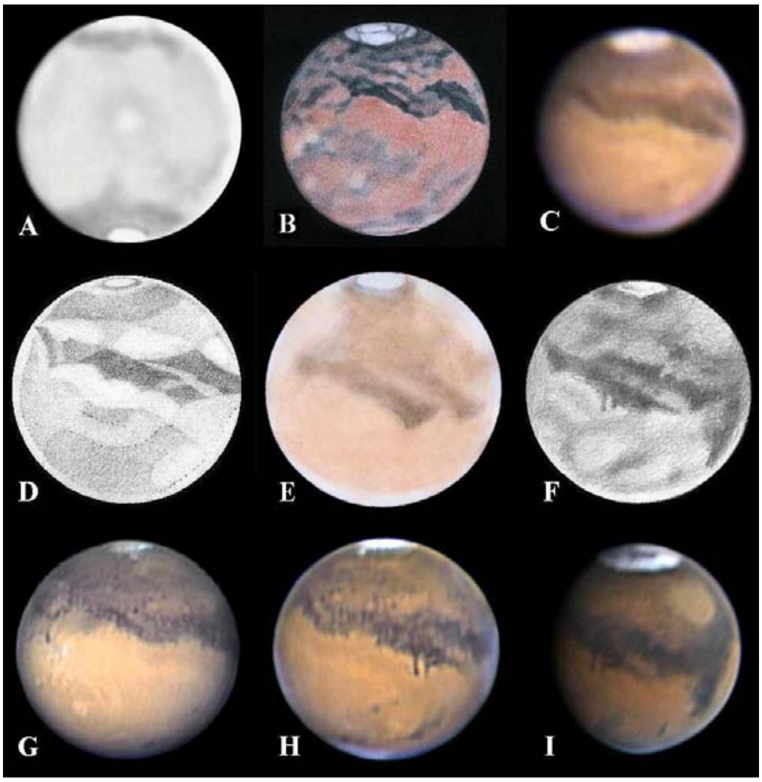

Figure 6. *Region III, λ= 130–250°*
Rows 1–2: Drawings and images
A 2002 Oct 24d 06h 30m, CML= 133°, 415mm DK Cass., ×663, INT+W15, *D. Gray*. NPC. Nix Olympica is light at the CM, despite the tiny disk. [D= 3.7"]
B 2003 Aug 9d 01h 00m, CML= 153°, 256mm refl., ×507, *N. D. Biver*.
C 2003 Aug 08d 02h 34m, CML= 184°, 500mm refl., image with Starlight Xpress MX5c camera, *C. J. Proctor*.
D 2003 Sep 6d 21h 33m, CML= 205°, 150mm refl., ×184, *E. Colombo*.
E 2003 Sep 4d 21h 30m, CML= 222°, 150mm OG, ×200, *D. G. Daniels*.
F 2003 Aug 21d 13h 45m, CML= 233°, 310mm refl., ×400, *M. Adachi*.
Row 3: High resolution images
G 2003 Sep 3d 16h 25m, CML= 157°, 250mm DK Cass., RRGB image with ToUcam Pro camera, *W–L.Tan*. Exceptionally fine details.
H 2003 Aug 27d 15h 38m, CML= 206°, 320mm refl., RGB image with ToUcam Pro, *E. Ng*. Exceptionally fine details, *e.g.*, within *Elysium*, including *Elysium Mons*.
I 2003 Jul 18d 18h 10m, CML= 243°, 320mm refl., RGB image with ToUcam Pro, *E. Ng*.

between *Solis Lacus* and *Tithonius Lacus* (Figures 5H, I). The streak *Geryon*, noticeable in 2001, was much fainter. *Araxes* was darker, especially after the local storm in 2003 May. *Nectar* had disappeared in late 2001 but it was visible again by late 2002. The dark spot *Nectaris Fons* was conspicuous at the E. side of *Nectar*, as were the curved streak *Nia* and the light patch *Aurea Cherso*.

The *Phasis* development (created by the 2001 storm) persisted throughout as a dark, curved streak uniting *Aonius Sinus* and *Gallinaria Silva*. Following adjacent local dust activity in 2003 May it became more extended to the north (compare Figures 3C and 8 with Figures 3G, H, M and 5B, D, H, I), as far as *Phoenicus Lacus*. At hi-res, *Phasis* was seen to be joined to *Solis Lacus* by its short continuation, *Acampsis*. Its southern part contained several small spots (Figures 5F, H, I). J. H. Rogers[49] commented: ‘It seems that the new dark *Phasis* consists of small dark streaks lying in valleys on the SW edge of the Claritas rise… an eroded mountain range that marks the border of the *Sinai/Solis/Thaumasia* ‘continent’… Just as the darkest material in this area tends to be in lowland such as the floors of the chaos regions and *Valles Marineris* and the outflow channels of *Lunae Palus* and the *Solis Lacus* depression, so the new dark streaks are in valleys on the slopes of the continent… you can already see this in the USGS map of Mars, which was made from *Viking* images… after the 1973 planet-encircling dust storms.’ The *Claritas–Daedalia* secular darkening of 1973 was located over *Phasis* and its environs.

The *Tharsis Montes* clouds were well observed, especially *Arsia Mons* (Figures 3, 6). This seasonal activity (see Part II) was interrupted by the 2003 Jun–Jul regional storm, which caused atmospheric warming. During July, as the latter event declined, the volcanoes themselves together with *Olympus Mons* were seen as dusky reddish-brown patches, darker than the dust still swirling dust around them, their calderas darkest in the afternoon (see Part II). In Aug–Sep the relatively huge disk even allowed Buda, Grafton (Figure 1D), Hall, Ikemura, Parker (Figure 5I) and Tan (Figure 6G) to catch fine albedo details upon the slopes of *Olympus Mons*. In late Aug and Sep the volcanoes appeared as smaller and darker spots at the sunrise terminator, surrounded this time by morning white cloud (through which their high summits protruded): this is the aspect shown by Hall on Aug 29 and Ng on Sep 11 (see Part II, Figure 13A), and in the composite map of Figure 2. Pellier[23] considered that (given appropriate lighting) the very best images revealed traces of the shadows of the summits of *Olympus Mons*, *Arsia Mons* and *Ascraeus Mons*.

Region III: long. 130–250°

Refer particularly to Figures 2, 3 and 6. After the 2001 global storm, the western part of *Mare Sirenum* had darkened between longs. 160–180°, resuming its classical pre-1986 shape. Its NW point, *Titanum Sinus*, was still noticeable upon Peach’s 2002 Nov 21 image, but his 2003 Jan 2 image no longer showed it clearly, nor did observations at opposition. South of *Mare Sirenum*, *Caralis Fons* (crater *Newton*) was conspicuous as an isolated spot (Figures 5I, 6G).

Cerberus–Trivium Charontis (Figure 6H) comprised a few small points: these were quite prominent in 2003 May and again some months after opposition, but close to opposition they were less conspicuous. This ‘opposition effect’, noted several times during the 1990s, points to rough terrain. The *Aetheria* dark shading persisted, appearing somewhat more linear (elongated NE to SW with dark condensations at the ends) and paler in places than before the 2001 encircling storm (Figure 6H). On the NE side, *Chaos* continued from this feature to form a dark N. border to *Elysium*. Ng’s image of Aug 27 (Figure 6H) showed a lightish patch over *Elysium Mons* and even tinier patches N. and S., marking the locations of *Hecates Tholus* and (at the limit of perception) *Albor Tholus*, with tiny bright patches indicating the craters *Adams* and *Lockyer*. Similarly excellent images came from Buda (Aug 19–25), Grafton (Aug 11 and 17), Lau (Aug 30), Parker (Aug 12 and 13), Pellier (Aug 6), Tan (Aug 31), and Wesley (Aug 29), all of them showing *Elysium Mons*.

Propontis was easier to see well before opposition. Peach's images of 2002 Dec 30 and 2003 Jan 2 show its normal rod-like character. The best images in 2003 Aug resolved it into two dark spots, the middle part being faint. *Euxinus Lacus* to the east was much fainter.

Dust storms (yellow clouds)

Introduction

In addition to several small events, there were two large regional S. hemisphere storms: first, one that developed from the N. border of *Hellas* in 2003 July, invading mostly *Ausonia* and *Noachis–Argyre*, and another which began in S. *Chryse/Xanthe* in 2003 Dec and which spread over *Ausonia–Hellas*, *Noachis–Argyre* and *Thaumasia*. Pellier[23] points out that both regional storms originated as small dust disturbances moving south from the northern hemisphere: the reverse of the origin of the 2001 encircling storm.[1]

During 2003 it was noticed that green images also showed the dust clouds well, sometimes better even than red images, as discussed elsewhere.[17] Daily maps of the larger telescopic events of 2003 have been constructed by Nakakushi *et al*.[17]

We also cite the most significant events observed between the 2002 and 2004 solar conjunctions, viewed only by spacecraft.

2002 Mar–Aug: Chryse

As mentioned in the last Report,[1] a regional storm originating in *Chryse Planitia* (classical N. *Xanthe*) was imaged by the *MGS* MOC, 2002 Mar 26–Apr 1, prior to solar conjunction.[2] It partly covered *Mare Acidalium* and showed a long crescent-like frontal pattern (Figure 7). Another, rather similar event occurred there in 2002 May.

Afterwards, *MGS* images in 2002 August showed an albedo variation: the classical canal *Indus* had become dark and continuous from *Margaritifer Sinus* to SE *Mare Acidalium*. The strength of this little feature, bearing a striking similarity to the unusual aspect of nearby *Hydaspes* as drawn by Secchi in 1858[50] (Figure 7), implies the aftermath of similar (but unrecorded) dust activity then. *Indus* had faded by 2003 spring (probably earlier): a similar intensification with identical cause was observed in 2005.

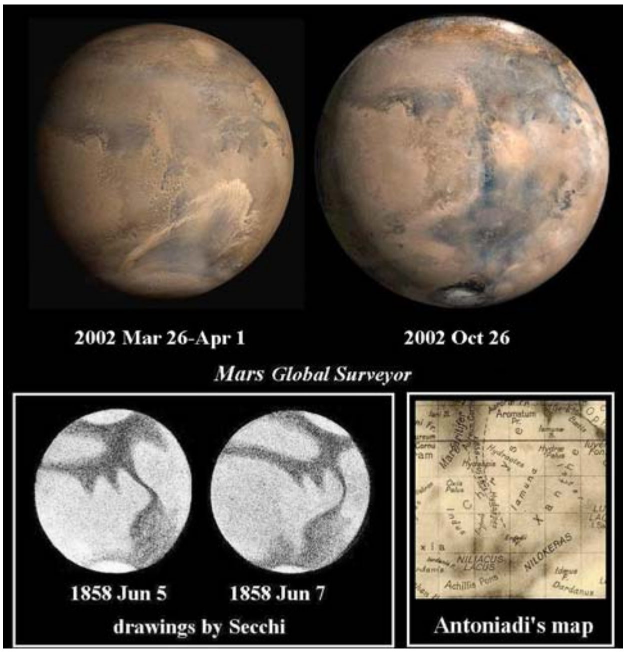

Figure 7. Regional dust storm activity witnessed by *Mars Global Surveyor*, with historical comparisons.
Top row: MGS images *(left)* of the 2002 Mar 26–Apr 1 storm over S. *Mare Acidalium* and *Chryse*, and *(right)* of the intensified *Indus* 'canal' after activity abated, 2002 Oct 26.
Bottom row: (left) Drawings of the strongly-marked *Hydaspes*, 1858, *A. Secchi*.[50] (Reproduced from Camille Flammarion, *La Planète Mars*, 1, Paris, 1892), and *(right)* E. M. Antoniadi's chart of the area.[60]

2003 May: Phoenicus Lacus and Eos

Adachi and Minami saw a discrete yellow cloud NW of *Solis Lacus* and E. of *Phoenicus Lacus* on May 21. *MGS* had caught it from May 20.[2] See Figure 8. We imaged the cloud on May 22 when it was already weakened. It was more diffuse next day, but with further faint patches of yellow dust in SE and SW *Thaumasia*: all activity stopped on May 24. Consequentially, by mid-June, *Phasis* had become extended further north to meet *Phoenicus Lacus*, and there arose the albedo streak *Acampsis* connecting the dark spot on *Phasis* (*Gallinaria Silva*) to the NW (N*f*.) corner of *Solis Lacus*; also, the NW side of *Solis Lacus* darkened. This brief event recalls the nearby telescopic storm of 1986 Aug 3.[51]

A one-day local event occurred on May 29 when Ng and Valimberti imaged a very small dusty streak over *Eos* (*Eos Chasma*), in eastern *Valles Marineris*.

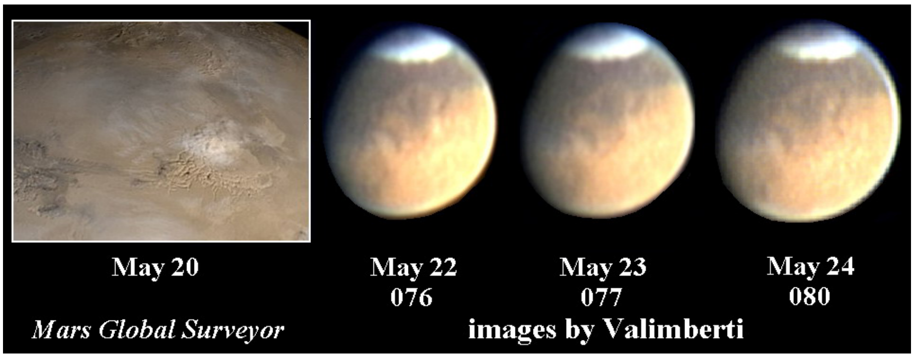

Figure 8. Images of the 2003 May local dust storm NW of *Solis Lacus*. Here and in Figures 9–12, CM longitudes are given beneath the dates.

2003 June–July: a southern hemisphere Regional storm

For the first time since 1963,[52] *Isidis Regio–Libya* produced a dust event large enough to be witnessed telescopically. A small yellowish-white cloud over the extreme W. of *Isidis Regio* (at *Osiridis Promontorium*) was caught by Fattinanzi on Jun 20 (Ls= 206°), then by Georgopoulos, Licchelli and Seip on Jun 22. See Figure 9A. It was observed by Crudeli, Fattinnanzi, Lazzaroti, Pellier, Teichert and others until Jun 25, but hardly changed form.

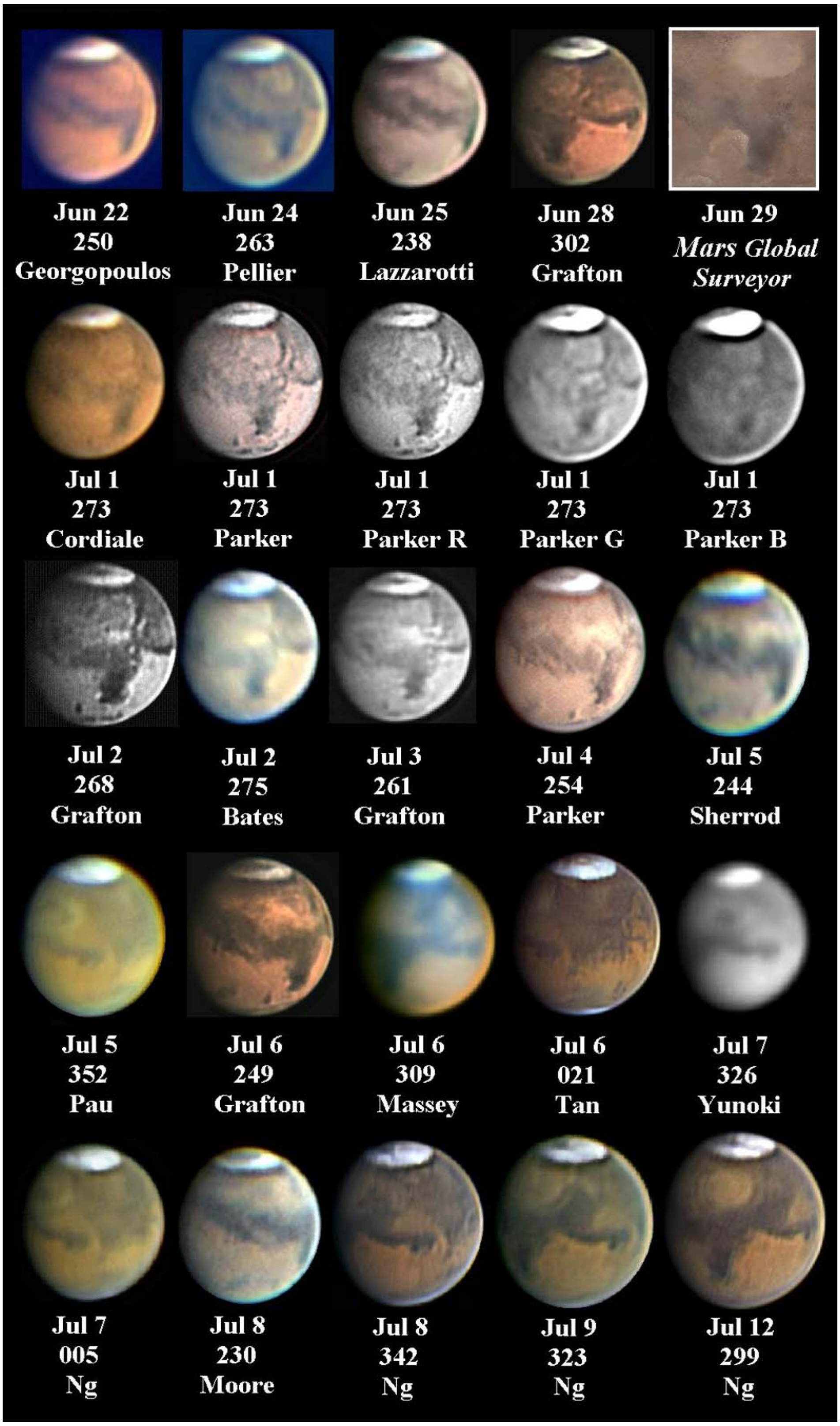

Figure 9A. Images (RGB composites or R filter images, unless stated otherwise) of the 2003 Jun–Jul dust events. Commencing with local activity over *Isidis Regio*, activity developed into a large Regional storm stretching from *Ausonia–Hellas–Noachis*.

According to Cantor's analysis[43] of spacecraft images, it was a local storm over NW *Elysium* sweeping southwest that initiated the subsequent regional storm. This event, not definitely caught in any of our observations, began on Jun 28 at Ls= 211°, and soon reached and veiled *Mare Tyrrhenum*, as shown on the Jun 29 *MGS* image[2] in Figure 9A. During Jun 24–28 *Hellas* appeared creamy to McKim at the a.m. limb, but there was no specific dust storm there yet, and indeed diurnal cloud still affected *Libya–Isidis Regio* and *Syrtis Major* on Jun 26. Then there was a sudden development. Whitby found clear evidence of a light area over *Iapigia* on mid-disk on Jun 30. On Jul 1, Beish, Parker and others reported several small dusty patches at the rim of *Hellas*, especially at its N. edge, and over *Iapigia* (including *Huygens* and *Crocea–Oenotria*) and *Deltoton Sinus*. Parker's filter images show that there was also a water-ice component to the cloud.

This dust activity, obvious by Jul 1, was quickly announced.[25,27,39,53] As it expanded (Figures 9A–9B), its development into *Ausonia* and across *Hellespontus* into *Noachis* closely paralleled previous events from 1911,[54] 1924, 1971, 1973 and 1988.[8] Dust did not veil the SPC, though spacecraft data[43] showed small storms generated at the cap edge.

Resonant local dust activity was seen upon the S. polar cap during Jun 28–Jul 8 (next section), and in the form of a heart-shaped patch W. of *Achillis Pons* (in *Chryse Planitia*) on Jul 2, but only a vague dustiness obscuring the S. part of *Mare Acidalium* and *Chryse Planitia*

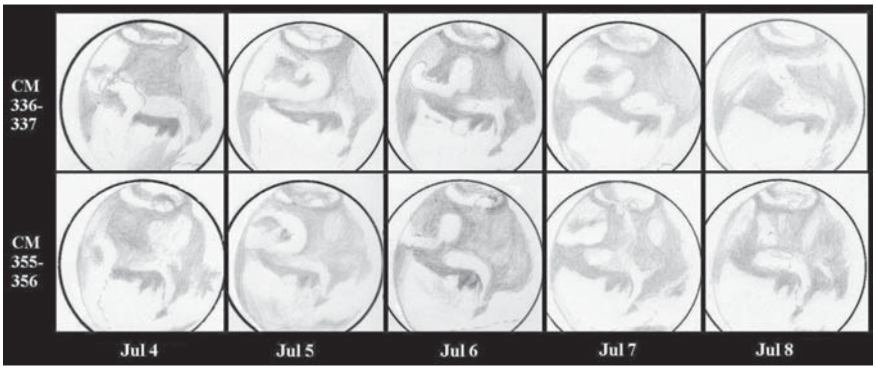

Figure 9B. The 2003 Jun–Jul Regional dust storm; drawings on successive days at comparable CML, 200mm OG, *M. Minami.*

was seen in the following days (Figure 10B (top row)): the last trace of activity was on Jul 8.

Regarding the development of the storm on the E. side, on Jul 2 *Mare Hadriacum* was already covered, as was the N. border of *Hellas*, and dust flowed into *Ausonia*. On Jul 3 a tendril of dust stretched as far east as *Eridania*. During Jul 3–4 dust occupied *Ausonia Borealis* (*Trinacria*), and streaked across *Iapigia*. On Jul 5 a small dust cloud was over central *Mare Cimmerium* south of *Cyclopia*. Activity now seemed to decline. On Moore's Jul 8 image dust had reached *Hesperia* but had not substantially changed the affected area. (Figure 9A)

We now consider the western branch. On Jul 3 there was a new bright dust core over N. *Yaonis Regio* (Figure 9A). The main storm moved further into N. *Hellas* on Jul 4, and a bright dust cloud (with strong water vapour content) lay over *Mare Serpentis*, partly cutting *Hellespontus*, and extending NW to sever *Sinus Sabaeus*, shown in Minami's drawings (Figure 9B) and in various images. Next day, although *Sinus Sabaeus* recovered, *Hellespontus* was visible only in the middle, a band of dust swirling into *Noachis* and curling back upon itself (Figures 9A, B). There were daily changes after this, with *Hellespontus* becoming reduced to a small patch, and small dust clouds appearing over central *Deucalionis Regio*, but the *Noachis* cloud now weakened every day (Figures 9A, B). On Jul 8 the *Noachis* cloud was greatly weakened. At maximum on Jul 5–6 the cloud had extended to long. 340–345° on the W. side

On Jul 8 the new large dark area that extended *Hellespontus* to the west (see also Region I), began to be revealed. Its appearance during Jul 8–12, as remaining dust cleared from the southern part, is well shown in Figure 9A, and it was located over the site of the new cloud core of Jul 3. By this time *Hellas* was dull and featureless, full of slowly settling dust. The whole S. hemisphere strikingly lacks contrast in images by Tan on Jul 15 or Parker on Jul 22. On Jul 15, *Hellas* was still featureless, but *Mare Hadriacum* was weakly reappearing. Over the next week, *Hadriacum* returned to normal. The OAA reported dust over *Argyre* when viewed obliquely, Jul 17–19. This was effectively the last direct record of this event. However, dusty haze tinged the limb yellow throughout Jul–Aug, and Hill found Mars more yellow than red to the naked eye. Only in August did *Hellas* reveal floor detail.

The yellow haze cleared irregularly. Minami: 'On Aug 4 ... the higher latitude region around *Argyre* to *Noachis* showed a ruddy tint ... because the higher-latitude region was ... rather free from the yellow dust except for the morning and evening sides.' A similar tint was seen south of *Hellas* and over south *Noachis* on Aug 15, but the north of *Noachis* remained dirty yellowish. Oblique morning lighting showed a trace of atmospheric dust to haunt *Hellas* till mid-Aug. The morning *Syrtis Major* appeared green to Minami, Aug 20 and 29, when yellowish dust overlaid the bluish *Syrtis*. Minami found *Aeria* ruddy on Aug 17, and likewise the desert north of *Mare Cimmerium* on Aug 21, and *Zephyria* on Aug 23. On the latter date he found *Eridania–Ausonia* more pinkish, still affected by a trace of yellow haze. Thus by late August the yellow haze had mostly cleared.

Cantor[43] found that dust activity had declined to its seasonal norm by about Ls= 227° (Jul 23). The event had exhibited a propagation rate in early July to the east and west of about 5–15m/s (18–54km/h).[43] During the event the N. polar hood had been slightly weakened, but quickly recovered.

Hellas from August appeared slightly lighter in the north, especially the NW and particularly in red light: a result of settled dust, the same aspect persisting till the December regional storm. *Hellas* again showed conspicuous diurnal white cloud, Sep–Dec.

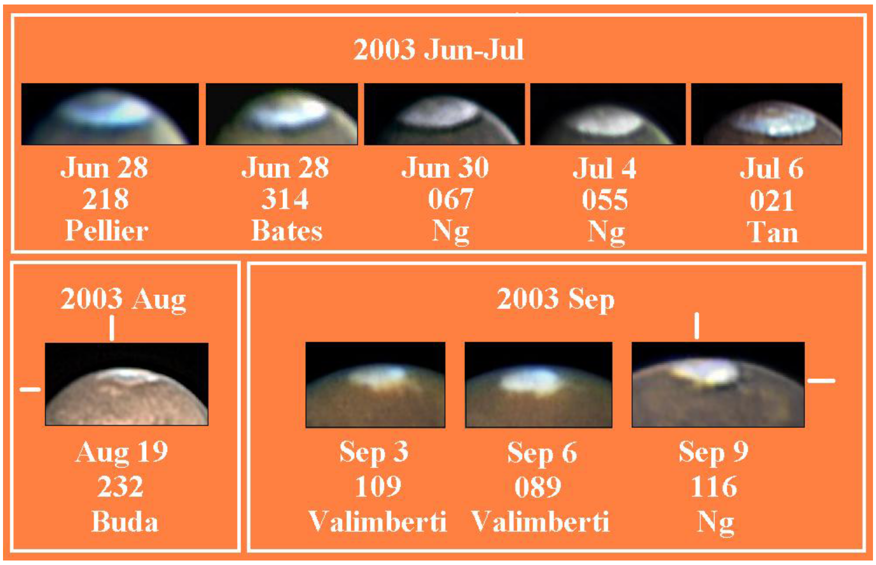

Figure 10A. SPR dust storms.
Top: A very small storm near the S. pole, 2003 Jun–Jul.
Lower left: A storm (marked) at the cap edge, 2003 Aug.
Lower right: Another dust event, 2003 Sep. The storm obscures the cap edge near the CM; the dull patches Nf. the cap on Sep 3 include the remnants of decaying *Thyles Mons*.

2003 Jun–Sep: South polar region

Analysis of *Mars Odyssey* THEMIS data[55] suggests that geyser action by jets of carbon dioxide could spray fine sand and dust onto the cap during southern spring.[55,56] The yellow or orange colouration upon the spring SPC might arise from this cause. There are a number of such reports in the literature, described by the Director (cited within Ref. 52); in 2003 Adachi reported a yellowish tint upon the SPH/SPC from Apr 6–May 21. Given the huge disk at opposition, a few SPR dust events were telescopically resolvable: one over the centre of the cap (Jun–Jul) and others at its periphery (Aug–Sep).

2003 Jun–Jul: SPC

A small, circular dust cloud, orange in tone and close to the rotational pole was observed south of the *Rima Australis* rift between Jun 28 and Jul 10 (Figure 10A), according to the best images of Bates, Kumamori, Lau, Lazzarotti, Ng, Parker, Pellier, Tan and Valimberti. (See also Parker's Jul 1 image, Figure 9A and early Jul images in Figure 10B.) On the sharpest images in Figure 10A, *e.g.*, Jul 6 (when it was about 240km or 4° in diameter), the dust cloud exhibited a dark border, but otherwise showed little change.

Later HST images (Figure 1) show patches of orange dust settled upon the polar snows, resulting either from this or other events.

2003 Aug–Sep, SPR

Buda (Figure 10A, lower left), Grafton, Valimberti and Yunoki on Aug 19 clearly caught a small bright yellowish patch at high S. latitude just S. of *Mare Chronium* near long. 210°. Rapid sublimation of *Thyles Mons* had just occurred to the south. One could use only the sharpest images: recently recessed parts of the cap also appeared as faint, diffuse and off-white patches, though invariable in position. Akutsu, Buda, Ikemura, Minami, Tan and Yunoki saw this dust cloud again on Aug 20–22. Its appearance varied little, but images by Yunoki on Aug 23 and Tan on Aug 24 (Figure 4G) showed expansion and fading. Minami also found it larger on Aug 26. Ng and Tan (Figure 6H) found it smaller and weaker on Aug 27–28, and Tan's fine image of Aug 31 no longer showed it.

Another dust storm was traceable in images between *ca.* Sep 2 and 13, illustrated in Figures 5G and 10A (lower right). It was located over and following the rift indenting the SPC near long. 80–90°. The best images showed that it obscured the edge of the cap. The Sep 6 image in Figure 10A suggests a further tiny dust burst *p.* the CM. Pellier[23] provides confirmation, and Schmude *et al.*[21] also mention these phenomena.

There were also a number of streaky clouds emanating from the more irregular points at the SPC periphery: we assume these were crystal clouds (see 'SPC eruptions' in Part II). Of course, some could also have been associated with dust activity at the cap edge.

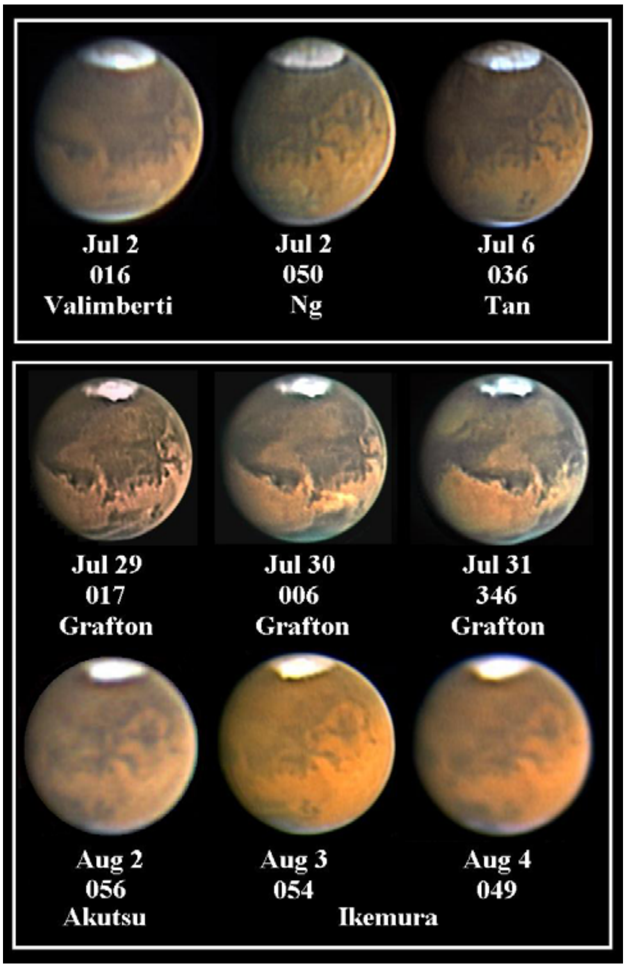

Figure 10B. Two small dust storms, 2003 Jul–Aug. *Top row:* images of a local event at *Chryse Planitia*, 2003 early Jul. *Middle and lower rows:* images of a regional storm from *Chryse* to *Valles Marineris*, 2003 Jul–Aug.

2003 July: Chryse Planitia to Eos

As briefly noted earlier,[31] a significant regional storm began at *Chryse Planitia* (telescopic NW *Xanthe*) on Jul 29, and a narrow filament ran to the NE across *Mare Acidalium*. This was observed by Grafton, Moore, and others. On Jul 30 brilliant tendrils of dust had spread SE to cover telescopic *Chryse*, as the sequence in Figure 10B (lower part) portrays, whilst the *Acidalium* component disappeared. On Jul 31 (Adcock, Grafton, Kumamori, Maxson, Moore, Parker, Sherrod, Valimberti, *etc.*), the storm propagated even further south, as a bright dust core had arisen over *Eos*, at the E. end of *Valles Marineris* (with the core unchanging throughout the whole martian day) while some dust stretched westward along the valley, and the previous activity persisted over *Chryse*.

Sherrod's image of the *Eos* core on Aug 1 showed development to the SE over *Pyrrhae Regio* and SW towards *Aurorae Sinus*, making a V shape; dust showed up clearly on Morita's IR image. This was the maximum, as activity spread along *Valles Marineris* as far as *Aurorae Sinus* (*e.g.*, *Capri Chasma*). Images in Figure 10B show the core persisting in *Eos–Capri Chasma* and spreading a little E. and W. on Aug 2–3, then fading, with the *Chryse* dust already settled or dispersed, and the southern dust dissipating over *Mare Erythraeum*. A trace of airborne dust remained on Aug 4–7,

Figure 11. Terminator projections due to dust, 2003 Nov.

but Valimberti's image of August 9 showed no sign of it. Ikemura caught a minor resurgence of the bright E–W streak at *Achillis Pons–Chryse Planitia* on Aug 3. These small events were apparently also generated by fronts moving south from the NPR.

2003 Oct–Nov: terminator projections

A projection over W. *Noachis* at the a.m. terminator was evident on Parker's Oct 13 RGB and red images, increasing in prominence from CML= 292 to 308°. Dobbins confirmed this, and one assumes dust was responsible. Nothing was seen next day at that CML, but Parker's red images of Oct 19 suggest a further dull projection over N. *Hellespontus*/E. *Noachis*.

During Nov 4–8, Minami, Miyazaki and others observed a dull terminator projection located at the *Ausonia–Hellas* border at 40–50°S. (Figure 11) It did not register on Miyazaki's blue images, implying dust, not white cloud. The feature was soon lost to the Japanese through bad seeing, but Frassati (Figure 11) saw the same or a similar feature on Nov 17 (preceded by bright morning cloud). Polarisation measures by Schmude[21] for Nov 16 demonstrated a lack of airborne dust over longitudes 300–360°, so this dust must have been locally raised.

2003 Dec–2004 Jan: a southern hemisphere Regional storm

Parker on Dec 9 (23h54m UT, Ls= 313°; Figure 12A) showed *Chryse–Xanthe* and *Candor–Ophir* unusually bright in red light. *MGS* data[43] showed these local dust clouds over *Chryse* had appeared the previous day, and that they had crossed the equator, moving south into E. *Valles Marineris* on Dec 9–11. Maxson found a considerable southward expansion on Dec 12, while on Dec 13 Parker (01h35m; Figure 12A) found dust from southern *Xanthe* and E. *Valles Marineris* covering *Eos*, *Candor–Ophir*, *Ganges* and part of *Aurorae Sinus*. Smaller dust cores were seen in N. *Argyre* and *Thymiamata* (*Aram*), with *Solis Lacus* unaffected. The Director correctly predicted that the event would not exceed Regional status.[28,57]

On Dec 14 Parker's 00h19m UT image (Figure 12A), despite poor conditions, showed further expansion, confirmed by Colville and Maxson. Dust cores were seen over *Eos*, *Capri Chasma* and *Argyre*, the dust reaching *Solis Lacus* and *Aonius Sinus*. The dust in *Chryse* looked less active. Some hours later, Akutsu and Kumamori captured the W. end of the storm at the evening limb (Figure 12A), with *Solis Lacus* veiled and a new core to the south over *Dia*. On Dec 15 (00h36m UT) Grafton caught the eastern half of the storm: the area in red light looked larger than in the RGB composite, and *Sinus Sabaeus* had become obscured in its following part, as was all *Meridiani Sinus*. The western part was imaged by Hatton (03h32m UT). By now the event occupied a large crescent in the S. hemisphere from a new bright core south of *Thymiamata* (*Aram*) extending south through *Argyre*, curving north to cover S. *Thaumasia* and *Solis Lacus*, terminating on the west near long. 100°. Cores at *Eos* and *Capri Chasma* remained. Some white a.m. cloud was also present over *Argyre*; water-ice cloud activity was still visible at the terminator at high S. latitudes. According to Cantor[43] three more small storms moved south from *Chryse–Xanthe* and *Tempe* during Ls= 316–321°; some of these were caught in our images and will be described below.

On Dec 15/16 there was a sudden development of a large, bright dust core in E. *Deucalionis Regio*. The NE end was at long. 330° (it would move east over the next few days), and the core was elongated to the SW across *Noachis*. The activity was caught by Parker (Figure 12A shows his 00h43m UT images) and Maxson. It united with existing dust over *Argyre*, *etc*. From Europe on Dec 16, Proctor (19h27m; Figure 12A) and Pellier caught the new core on the terminator at the next rotation. Pellier's image showed condensate cloud over *Iapigia–Mare Serpentis–Aeria* preceding the appearance of the new core. *Hellas* was unaffected, and *Sinus Meridiani* somewhat recovered. The western limit of dust remained near long. 90°, with activity over *Dia* and *Solis Lacus*.

Next day, Dec 17, dust began to expand across *Hellespontus* into *Hellas*. *Hellas* had appeared normal to the Director on the evening of Dec 15, but on Dec 17 (18h25m UT onward; see Figure 3O) he observed a slanting creamy-yellow lozenge filling the N. of the basin with a brighter core in the NW. According to Grafton's image of Dec 18 (00h10m UT; Figure 12), the NE limit of the core was now centred at –20°, 315° over N. *Mare Serpentis*. The Director found dust had spilled over the western part of a faded *Sinus Sabaeus* near *Edom*. There was an anomalous darkening at the S. border of *Hellas* that continued west along the S. edge of the storm to include *Depressiones Hellesponticae*. On first observing under CML= 279° (and until 297°, implying terminator longitudes of *ca*. 339–357°, at lat. approx. –47° (S. *Noachis*)), the Director saw the dust cloud projected over the morning terminator, but not at CML= 308°. Hellas dust was confirmed by Pellier's images (18h59m; Figure 12A). According to Grafton (Dec 18, Figure 12A), separate yellow clouds occupied *Noachis* (following the line of *Hellespontus* on the E. side) and *Argyre*. His image also showed S. *Hellespontus* broken by dust (linking *Hellas*), whilst *Depressiones Hellesponticae* was anomalously dark, as it has been in previous events. A similar darkening of a section of *Mare Australe* was captured by van der Velden (Dec 18, 09h01m, Figure 12A; also Dec 19), adjacent to the S. edge of the storm. The latter image also showed dust extending further west from the *Dia* core to long. 140°, south of *Mare Sirenum* in E. *Phaethontis*. Dec 17/18 seems to have been peak activity.

Next day, Dec 18/19, McKim again witnessed the terminator projection, now at lower latitude. It was present at CML= 273°, but not 291°. These data suggest an approximate position –31°, 333°; measurement of drawings (using published formulae[59,60]) suggests a height of up to *ca*. 90km: necessarily an overestimate. Grafton's images (Dec 19, 00h19m; Figure 12A) showed a contraction of the eastern core (–20°, 308°), but dust still linked *Noachis* to *Hellas* via breaks at the N. and S. of *Hellespontus*. Small changes were apparent in the structure of the clouds, whilst van der Velden's image (Dec 19, 09h01m; Figure 12A) showed the event's W. end fairly static. Further contraction of the E. core was apparent in Grafton's Dec 20 images taken at 00h55m (Figure 12A).

On Grafton's Dec 21 image (00h11m UT, Figure 12A) the E. core was narrower east–west but ran further south, located at –22 to –32°, 308° at its NE limit and therefore just impinging on the extreme NW of *Hellas*. Dust still arched southward across *Noachis* into *Argyre*, then northward to S. *Thaumasia*. W. *Sinus Sabaeus/Meridiani Sinus* remained very faint at the CM on Maxson's images. To Kumamori (Dec 21, 09h10m UT; Figure 12A), *Solis Lacus* was recovering, with *Dia* no longer dusty, the W. end of the storm having retreated eastwards. On Dec 22 Akutsu and others showed the weakening W. end, persistent *Argyre* core, and the return to prominence of *Solis Lacus*.

On Dec 23, Kumamori's image (08h00m UT) showed new dust activity over *Chryse–Xanthe* which impinged upon the E. end of *Valles Marineris*. *Aurorae Sinus* was enlarged, the adjacent desert having darkened to the north, this aspect persisting for several days. As on Dec 21, the southern dust belt terminated near extreme western *Argyre*. As on Dec 21, *Bosporos Gemmatus* was faded. Activity in the south would now decline every day.

Figure 12A. Images (RGB composites or R filter) of the S. hemisphere large regional dust storm, 2003 Dec–2004 Jan. Commencing in *Chryse–Valles Marineris*, this large event spread to cover longitudes from *Hellas* to *Claritas*.

By Dec 25 (00h47m UT), Parker imaged dust from S. *Hellas* to *Ausonia*, but with albedo markings evident in central

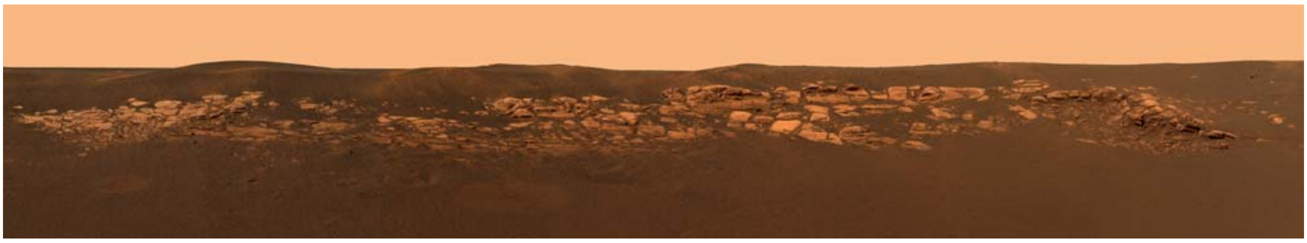

Figure 12B. Panorama from NASA's Mars Exploration Rover *Opportunity* at Eagle crater, *Meridiani Planum* (*Meridiani Sinus*). The layered rock outcrop – of sedimentary origin – lies to the NW. Press release 2004 Jan 28, credit: *NASA/JPL/Cornell*. (*Meridiani Sinus* had then recovered from the large Regional dust storm.)

Hellas, and *Mare Serpentis* somewhat recovered. *Argyre* now showed a constant bright yellowish appearance, persisting into January. On Dec 25–27 Kumamori's and Ikemura's images (Figure 12A) showed that the *Chryse* dust had penetrated W. *Deucalionis Regio*, veiling *Margaritifer Sinus*; however, *Sinus Meridiani* had recovered. Parker's Dec 27 images show the NPH prominently, and the *MGS* images charted by Cantor[43] show considerable diminution in dust between Dec 25 and 27 (Ls= 322–323°). On Dec 29 Adachi drew *Margaritifer Sinus* again, with yellow cloud over *Hellas*. On Dec 29–Jan 1 van der Velden's images (Figure 12A) show *Pandorae Fretum* darkened.

By Jan 1, dust cores had stabilised in *Hellas*, *Noachis* and *Argyre*. To Adachi the limb looked less yellowish and contrast higher; *Mare Serpentis* was very dark. The N. part of *Hellas* was lighter and dusty to Japanese observers, Jan 5–8, though to Adachi it was already less visually yellow by Jan 5. On that date, evening white cloud was caught by Adachi over *Isidis Regio*, and next day *Hellespontus* partly reappeared. To McKim on Jan 4, *Argyre* and *Candor–Ophir* showed up brighter in red, contrasts around *Solis Lacus* were low, and the darkest feature was the anomalous darkening of *Mare Australe* SE of *Thaumasia*. On Jan 8–9, Bowen and McKim found contrast still below normal (CML= 60–70°), bright (surface) dust covering *Argyre* westward. By Jan 12, CML= 5°, contrasts were nearly normal to McKim with *Hellas* whitish at the limb. Parker's Jan 15–17 images (Figure 12A) showed *Aurorae Sinus* detached from the southward halftones by a stable bright strip (more dust fallout) along *Capri Chasma*. At the eastern limit, the pre-storm aspect of *Trinacria* prevailed. In late Jan, *Hellas* was still light and yellowish, settled dust being responsible. Images by Peach, Jan 16, and Parker, Jan 23–26, suggest more typical contrasts in the *Syrtis–Sabaeus–Meridiani* region, with *Hellas* normal in red. Taylor and the Director agreed on Jan 24. Morning cloud over *Argyre* reappeared in Parker's images, Jan 23 (Figure 12A), but on mid-disk throughout January settled dust there left it bright and yellowish. Similar remarks apply to *Edom*, which was very bright in red (*e.g.*, Parker, Jan 23–26), but stable. Schmude's polarimetry showed a return to normal in mid-Jan. We take 2004 Jan 15 as the approximate termination. *MGS* MOC data[43] confirmed the persistence of the dust veil into 2004 Jan, thinly extending well beyond the confines of the event's bright telescopic clouds. The cameras of the *Opportunity* Exploration Rover revealed a typical martian sky upon landing at *Meridiani Sinus* on 2004 Jan 25. (Figure 12B)

After Dec 28, dust from the storm had made the summer SPC remnant impossible to see for a week, but it was visible with difficulty from Jan 5 for a short time, before being covered by the S. polar hood.

This dust event may be taken to have begun on Dec 9 (Ls= 313°). The E–W extent of the storm at maximum was similar to that of the 1988 Nov event (which initiated south of *Solis Lacus*, also at Ls= 313°). In its initial development, the present event more resembled the regional storm of 1990 Nov (Ls= 326° onwards). The Director cannot recall any historical event beginning in the location of the present one (that is, S. *Chryse–Xanthe*/E. *Valles Marineris*) which showed such considerable expansion in longitude, or long duration. The Director supplied regular reports to *Beagle 2* team leader Prof. Colin Pillinger (who used them at Press conferences). On its E. border the bright clouds of the storm approached – but failed to reach – *Beagle*'s landing site in *Isidis Planitia*, so that the craft's failure more likely resulted from landing system malfunction.

There was no certain evidence of later telescopic dust activity, and the *MGS* website[2] contained no later events other than subtelescopic ones.

Acknowledgments

Mr M.Green compiled opposition distance data covering 0–3000 AD, and we thank Mr J. D. Beish[8] for his computations spanning more than 60,000 years. All observers are congratulated for their superb efforts, and it is hoped that this report – inevitably delayed – will be some reward.

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Appendix I

Webcam and CCD imaging with filters

Webcams are inexpensive, and were being widely adopted in 2002. Because of the importance of blue waveband observations for Mars, and the insensitivity of some detectors in this region, the choice of detector (and blue filter) becomes more important than for Jupiter or Saturn. As noted ealier, the W47 filter must be combined with an IR-blocking filter to produce useful images, as the 'red leak' gives anomalous results.

The popular Philips ToUcam (and ToUcam Pro) webcam (used by the Director in 2005) is excellent for good resolution (with a sensitive Sony chip) and for attractive colour rendition, but lacks blue sensitivity. One can hardly see this visually in the tint of the disk, but there is a lack of blueness about the N. polar hood, and white clouds are less pronounced. Obtaining the (filter) B image (with camera in b&w mode) requires a longer exposure time, hampering accurate compositing. Most observers produce R, G and B images and RGB composites. (A short .avi video is made through each filter, and several hundred of the best frames composited.) The G filter image is very useful for Mars work, being sensitive to the presence of dust, so we would generally discourage the R(G)B technique (where synthetic green (G) = R and B averaged) unless observing time is limited. The LRGB composite is useful if the image brightness is reduced, where L= luminance (unfiltered white light image), and one can improve surface feature detail by replacing R by IR, *etc*., at the cost of suppressing the blue end. Pellier[23] gives more details.

Those observers who merely split a single-shot colour image into the R, G and B 'channels' are not generating scientifically filtered images, and in particular the G channel so obtained heavily contaminates the B with albedo detail. The appearance of Mars in blue light depends critically upon wavelength, and only B images through approved filters are useful. (See Part II of this paper.) We cite Parker's experience. With his 41cm reflector in 2003 he used a SBIG ST-9XE cooled camera and a CF W-8A filter wheel with R (612~670nm), G (488~574nm) and B (392~508nm) filters, using a Schott RG610 rejection filter with B. Parker also used a ToUcam with a portable instrument.

As to image-processing, most observers used – and in 2009, are still using – *Registax* (freeware). In 2003, D. M. Moore recommended observers to use K3 CCD (web) tools before applying *Registax*, in order to pre-select images in order of quality. Mobberley recommended Christian Buil's *IRIS* software, after *Registax* treatment. Dobbins recommended using *AVIedit*. Of our UK observers, Mobberley used a capture rate of 5 frames per second, and Peach 5–10 fps. 60–120s was generally enough for a successful .avi, with a gamma setting around 20%.

There was much about webcams in the popular literature in 2003; the contemporary review by Davis & Staup[12] gives useful links to available software.

This was the state of play in 2003; further developments would follow during the next few oppositions.

Appendix 2

W. P. Sheehan's observations at Lick Observatory

In late 2003 August to early September W. P. Sheehan and his co-workers L. Hatch and A. Misch used the Lick 36-inch (0.91 metre) refractor. They were able to repeat the visual experience of such observers as Barnard and Keeler. Their website[13] contains many drawings and notes, but little about perceived colours. At the Director's request Sheehan kindly wrote the following:

'The seeing on Mount Hamilton during this period was remarkably steady... (The extreme dryness of the late summer in Northern California produced a ring of wildfires around the observatory... but only once did we need to shut down for fear that airborne ash from these fires would descend on and damage the great lens.) The view of Mars in the telescope... was unforgettable. My first look at Mars recalled Barnard's impressions in early September 1894, when he reported that the surface of Mars appeared broken with mountain, ridge, and slope... I wrote in my notebook: ... 'What a magnificent world is Mars! ... We enjoyed five hours of steady steel-engraving seeing. There were wild fires burning in the distance, lighting up the night with strange orange glows like those of the pit in which the cylinder landed in *The War of the Worlds*. *Solis Lacus* was in view; the *Valles Marineris* appeared as a thick dark streak, and the whole region broke up into intricate beads and tessellated threads. I could well understand why W. H. Pickering in Peru thought he was seeing forty lakes! ...It was impossible to do more than hint at all the detail in a drawing. (See Figure 5B).

'The perception of colours of Mars by visual observers played a very important role in directing interpretations... The perception of planetary colours is difficult for a number of reasons. For one thing, the perceived colour depends not only on the state of adaptation of the eye but on the visual context in which the stimulus appears. The colours of a planet seen in the eyepiece against a black surround (with no gray content) are not what would be seen when standing beside the planet, with familiar objects available for context. Thus, as seen in the eyepiece the Moon, though it is actually as dark as the average asphalt paving surface, appears bone-white. Mars, whose actual surface materials are dirty yellowish-brown, looks yellowish-orange (or, as often described, ochre). The dark areas of Mars consist of surface materials of similar hue but lower lightness and saturation; if we were actually standing on the surface of the planet, they would appear brown, but in the eyepiece the 'unrelated' colours tend to expand to fill the colour space.[61] Apparently what is happening is that the visual system turns up the gain on the chroma when presented with a scene of very limited colour gamut. This, by the way, plays a part in Edwin Land's well-known demonstration of producing a wide colour gamut from a scene that really just contains various shades of pink – an extreme example of the phenomenon made use of in the old colour movies shot in two rather than three colours, which used to be known as 'Tru-Colour' Westerns! Mars – ever since Percival Lowell compared the colours to those seen in the Painted Desert from Mars Hill or Edgar Rice Burroughs opened the *Princess of Mars* on the deserts of Arizona – has been a kind of 'Tru-Colour' Western for visual observers of the planet.

'The vivid colours reported by classical observers of the planet (including olive-green and even blue in the dark areas, which, coupled with intensity changes due to the effects of windblown dust, led to fanciful ideas about the presence of seas or tracts of vegetation) are due to this expansion of the range of perceived colours in a scene of limited colour range... I viewed the planet with and without a neutral density filter, with and without the dome lights on, and made comparisons against the standards in the Munsell Colour system (A. H. Munsell, *A Colour Notation*, Munsell Colour Company, New York (1975); *Munsell Book of Colour (Glossy Finish)*, Munsell Colour Company, New York (1980)). The following are my impressions:

Xanthe 5YR8/4; *Mare Erythraeum* 5YR7/4 (no filter and no dome lights);

Arabia 5YR7/8; *Noachis* 5BG 6/4; *Mare Acidalium* 5BG7/8 (neutral-density filter and dome lights);

Syrtis Major 5BG8/6 or 5G8/6; *Arabia* 5YR8/6; *Isidis Regio* 5YR8/2; *Hellas* 5YR 7/2;

'Descriptively, these colours correspond to dull brownish-grey (*Hellas*) to rather intense ochre (*Isidis Regio*) to pale ochre (*Xanthe*) to brownish (*Arabia*), on the yellow-brown side of the palette; from intense blue-green (*Mare Acidalium*) to dull olive-green (*Noachis*) to blue-green to greenish (*Syrtis Major*).

'It was clear that these colours were subjective, and the impression of more or less vivid greens or blue-greens in the dark areas was largely a contrast effect produced by the intensity difference at the boundaries of the adjoining light areas. That being the case, changes in intensity due to the deposition or removal of dust during the martian dust storms would produce dramatic changes in the washes of colour seen by the eye. Percival Lowell, for instance, recorded in his observing book in 1894, witnessed changes in the intensity of the markings from June when the martian air was clear until October when a major dust storm got underway ... 'a whole-scale transformation of the blue-green regions into orange-ochre ones was in progress upon that other world.'

'My study in 2003 adds emphasis to the fact that visual studies of Martian colour are fraught with many perils. We have so long been entranced by the 'blue that is not really blue' on the Red Planet, as Ray Bradbury puts it – entranced by the evocative 'pale blue, the usual sky-colour' or 'robin's-egg blue' of Percival Lowell's chromatic descriptions; but blues are the colours of our world, not of the Martian one. On Mars, these colours are mirages.

'If it is any consolation, the first coloured images of the surface of Mars from the *Viking* spacecraft missions were no less misleading. Tim Mutch wrote two years after the publication of the first images from the surface of Mars which showed a blue sky: 'We had no intimation of the immediate and widespread public interest in the first colour products. Several days after the first release, we distributed a second version, this time with the sky reddish. Predictably, newspaper headlines of 'Martian sky turns from blue to red' were followed by accounts of scientific fallibility. We smiled painfully when reporters asked us if the sky would turn green in a subsequent version.'[62]

'Though mirages – artifacts of the eye-brain system – the colours exhibited by Mars in the great refractor were nevertheless aesthetically pleasing and evocative of a bygone era – the 'amazing dream of reality' (Ray Bradbury, in *The Martian Chronicles*) that still haunts the dreams of those who put eye to eyepiece in wonderment at Mars.'

As Sheehan writes, the blue tones upon mid-disk are largely illusory; however, especially when observed near the limb, they are quite real, when morning or evening clouds over *Syrtis Major* scatter the blue light component in the direction of the observer. We may compare Sheehan's eyepiece impressions with those of BAA member A. P. Lenham who (together with Gerard P. Kuiper) worked with colour comparison cards on the large reflectors at McDonald Observatory in 1958.[63]

Notes and references

1 R. J. McKim, *J. Brit. Astron. Assoc.*, **119**(3), 123–143 and (4), 205–211 (2009). BAA Mars reports are available at: **http://www.britastro.org/mars**

2 *MGS* reached the end of its primary mission in 2002, but continued to operate until 2006 November.
MGS website: **http://mars.jpl.nasa.gov/mgs/index.html**
MGS global views: **http://www.msss.com/msss_images/subject/global.html**

3 *Mars Odyssey* operated till 2006 when a computer system failed; a reboot in 2009 March followed. *Mars Odyssey* website: **http://mars.jpl.nasa.gov/odyssey/**

4 HST website**: http://hubblesite.org**

5 Early results from OMEGA upon ESA's *Mars Express* featured in *Science*, **307** (No. 5715), 1,574–1,597 (2005).

6 We cite the *Beagle 2* website (**http://www.beagle2.com**); *Beagle 2* Bulletins Nos. 1–15 (2002–2004); C. Pillinger, *Beagle: from sailing ship to Mars spacecraft*, XNP Productions, 2003; C. T. Pillinger, M. R. Sims & J. Clement, *The guide to Beagle 2*, C. T. Pillinger, 2003; and C. T. Pillinger, *Space is a Funny Place*, Barnstorm Productions, 2007.

7 For a recent summary of *Mars Exploration Rover* (*MER*) work, see: J. Bell, *Sky & Telesc*., **118**(1), 22–29 (2009). *MER* website: **http://marsrovers.nasa.gov/home/index.html**

8 The following paper discusses the proximity of perihelic oppositions: J. D. Beish, *J. Assoc. Lunar Planet. Obs*., **44**(4), 44–45 (2002). In the 20th century, Mars reached 25" diameter in 1924 (opposition Aug 23); the 1924 literature is cited in: R. J. McKim, 'Telescopic martian dust storms: a narrative and catalogue', *Mem. Brit. Astron. Assoc*., **44** (1999).

9 R. J. McKim, *J. Brit. Astron. Assoc.*, **101**, 264–283 (1991)

10 E. H. Collinson, *J. Brit. Astron. Assoc.*, **83**, 283–290 (1973)

11 E. H. Collinson, *J. Brit. Astron. Assoc.*, **68**, 142–147 (1958)

12 M. Davis & D. Staup, 'Shooting the Planets with Webcams', *Sky & Telesc*., **105**(6), 117–122 (2003)

13 Sheehan's Lick website: **http://mthamilton.ucolick.org/public/TwoWeeksOnMars/.** Also of interest: T. A. Dobbins & W. P. Sheehan, 'The Canals of Mars Revisited', *Sky & Telesc*., **107**(3), 114–117 (2004)

14 The Pro-Am *Marswatch* site: **http://www.elvis.rowan.edu/marswatch**

15 See the OAA's printed *Circular*, *Communications in Mars Observations*, 2002–2004 (an incomplete series, the gap partly filled by web-only *Circulars*). The OAA website: **http://www.mars.dti.ne.jp/~cmo/oaa_mars.html**

16 The JALPON website: **http://alpo-j.asahikawa-med.ac.jp/Latest/index.html**

17 T. Nakakushi, M. Adachi, *et al.*, *Publ. Astron. Soc. Japan*, **56**, 845–860 (2004)

18 T. Nakakushi, M. Adachi, *et al.*, *ibid.*, **57**, 497–506 (2005)

19 M. Frassati, 'Martian Landscapes', *Coelum Astronomia*, **7** (No. 68), 75–78 (2003)

20 P. Tanga & L. Bardelli, 'Marte nel 2003–2005: la regressione della Calotte polare Sud', *Astronomia*, 2008, No. 3, pp 9–18

21 R. W. Schmude, D. Troiani, *et al.*, *J. Assoc. Lunar Planet. Obs.*, **46**(4), 28–46 (2004). D. C. Parker reviewed the results of the 2003 apparition in *Sky & Telesc*., **108**(2), 92–94 (2004). The ALPO website: **http://www.lpl.arizona.edu/alpo**

22 Montages of SAF observations feature in D. Crussaire, *Bull. Soc. Astron. France*, **117**, 431 and 494–495 (2003); see also the SAF Mars Section website: **http://www.astrosurf.com/planetessaf/**

23 C. Pellier, 'L'apparition de Mars en 2003', *Soc. Astron. France, Observations et Travaux*, No. 60, pp 2–20 (2005)

24 R. J. McKim, *J. Brit. Astron. Assoc.*, **113**, 70–71 (2003)

25 R. J. McKim, BAA *Circular* No. 791 (2003)

26 R. J. McKim, BAA *E-Circular* No. 100 (2003)

27 R. J. McKim, BAA *E-Circular* No. 109 (2003)

28 R. J. McKim, BAA *E-Circular* No. 127 (2003)

29 (1st Interim Report) R. J. McKim, *J. Brit. Astron. Assoc.*, **113**(3), 130–131 (2003)

30 (2nd Interim Report) R. J. McKim, *ibid.*, **113**(4), 189–190 & fc (2003)

31 (3rd Interim Report) R. J. McKim, *ibid.*, **113**(5), 249–251 & ifc (2003)

32 (4th Interim Report) R. J. McKim, *ibid.*, **113**(6), 318–319 (2003)

33 (5th Interim Report) R. J. McKim, *ibid.*, **114**(1), 6 (2004)

34 (6th Interim Report) R. J. McKim, *ibid.*, **114**(2), 62–63 (2004)

35 The BAA Mars Section website: **http://www.britastro.org/mars**

36 R. J. McKim, 'Observing Mars in 2003', *Astronomy Now 2003 Yearbook*, Pole star publications, 2002, pp 102–103

37 R. J. McKim, 'Mars at its best', in P. A. Moore *(ed.), 2007 Yearbook of Astronomy*, MacMillan, 2006, pp 159–168

38 N. M. Bone, *J. Brit. Astron. Assoc.*, **115**, 298 (2005)

39 Images and drawings of the 2003 June–July regional storm were sent to the BBC for their website at the request of Dr David Whitehouse: **http://news.bbc.co.uk/1/hi/sci/tech/3051548.stm**

40 V. G. Kaydash, *et al.*, *Icarus*, **185**, 97–101 (2006); E. Noe Dobrea, J. F. Bell, M. J. Wolff, *et al.*, *ibid.*, **193**, 112–124 (2008)

41 H. Wang, 'Dust storms originating in the northern hemisphere during the third mapping year of *Mars Global Surveyor*', *Icarus*, **189**(2), 325–343 (2007). This paper refers to 2003–2005.

42 L. Montabone, S. R. Lewis & P. L. Read, 'Interannual variability of Martian dust storms in assimilation of several years of Mars global surveyor observations', *Adv. in Space Res.*, **36**(11), 2146–2155 (2005). This paper refers to data from 2001 and later.

43 B. A. Cantor, *Icarus*, **186**, 60–96 (2006). This paper about the 2001 global storm also discusses 2003 and 2005 events.

44 The presence of methane, suggested by ground-based data, was confirmed in 2004 by *Mars Express*. See: **http://www.astrobio.net/index.php?option=com_exclusive&task=detail&id=899**

45 N. Bone, *Philip's Mars Observer's Guide*, Philip's, 2003

46 S. Ebisawa, *Contr. Kwasan Obs*., Kyoto, no. 89 (1960)

47 R. J. McKim, *J. Brit. Astron. Assoc.*, **117**, 314–330 (2007)

48 The Director wonders if the post-encircling storm spottiness in the dark markings (described in the text) could have contrived to assist E. M. Antoniadi, in the wake of a planet-encircling storm, to detect maria fine structure with the 83cm OG at Meudon in 1909 September?

49 J. H. Rogers, from an email to the Director dated 2003 Jul 25.

50 A. Secchi, *Mem. dell'Osservatorio del Collegio Romano*, Rome, 1859. Secchi's 1858 work is also reproduced in C. Flammarion, *La Planète Mars*, **1**, Paris, 1892, pp 134–141.

51 R. J. McKim, *J. Brit. Astron. Assoc.*, **99**, 215–232 (1989)

52 See R. J. McKim, *op. cit*., ref. 8 for telescopic dust storms. E. C. Slipher in 1962 (*Mars: The Photographic Story*, Arizona University Press, 1962) wrote that *Isidis Regio* had produced the most telescopic storms. At that time he was correct, but then the site became inactive. Renewed activity supports the writer's idea[8] that upon a timescale of decades, active sites become depleted of dust, remaining inactive till replenished by new deposits. This idea has been discussed recently by Cantor.[43]

53 D. C. Parker, IAU *Circular* No. 8162 (2003)

54 Antoniadi in 1911 was the first to map the progress of a Regional storm that mostly occupied *Hellas–Noachis*: see R. J. McKim, *op. cit*., ref. 8.

55 H. H. Kieffer *et al.*, 'CO_2 jets formed by sublimation beneath translucent slab ice in Mars' seasonal south polar cap', *Nature*, **442**, 793–796, (2006). (THEMIS = Thermal Emission Imaging System.)

56 **http://www.space.com/scienceastronomy/060816_mars_icecaps.html**

57 The seasonally latest planet-encircling storm ever observed began as late as Ls= 311° (1924 Dec).

58 C. Flammarion, *La Planète Mars*, vol. **2**, Paris, 1909, page 85

59 E. M. Antoniadi, *Mem. Brit. Astron. Assoc*., **20**, part 4 (1916)

60 E. M. Antoniadi, *La Planète Mars*, Paris, 1930

61 A. T. Young, 'What colour is the Solar System?', *Sky & Telesc*., **69**, 399–403 (1985)

62 T. A. Mutch, 'The *Viking* lander imaging investigation: an anecdotal account' in *The Martian Landscape* (NASA SP-425), Washington DC, 1978, page 27.

63 A. P. Lenham, *J. Brit. Astron. Assoc.*, **74**, 128–135 (1964)

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