2016 Nov.9

Jupiter in 2015/16: Final report

John Rogers (British Astronomical Association) & Gianluigi Adamoli (JUPOS team),
with data from the JUPOS team (GA, Michel Jacquesson, Marco Vedovato, Hans-Joerg Mettig, & Grischa Hahn)

Figures (mini-copies) & Tables 1 & 2 (at end)

North is up in all maps and images.

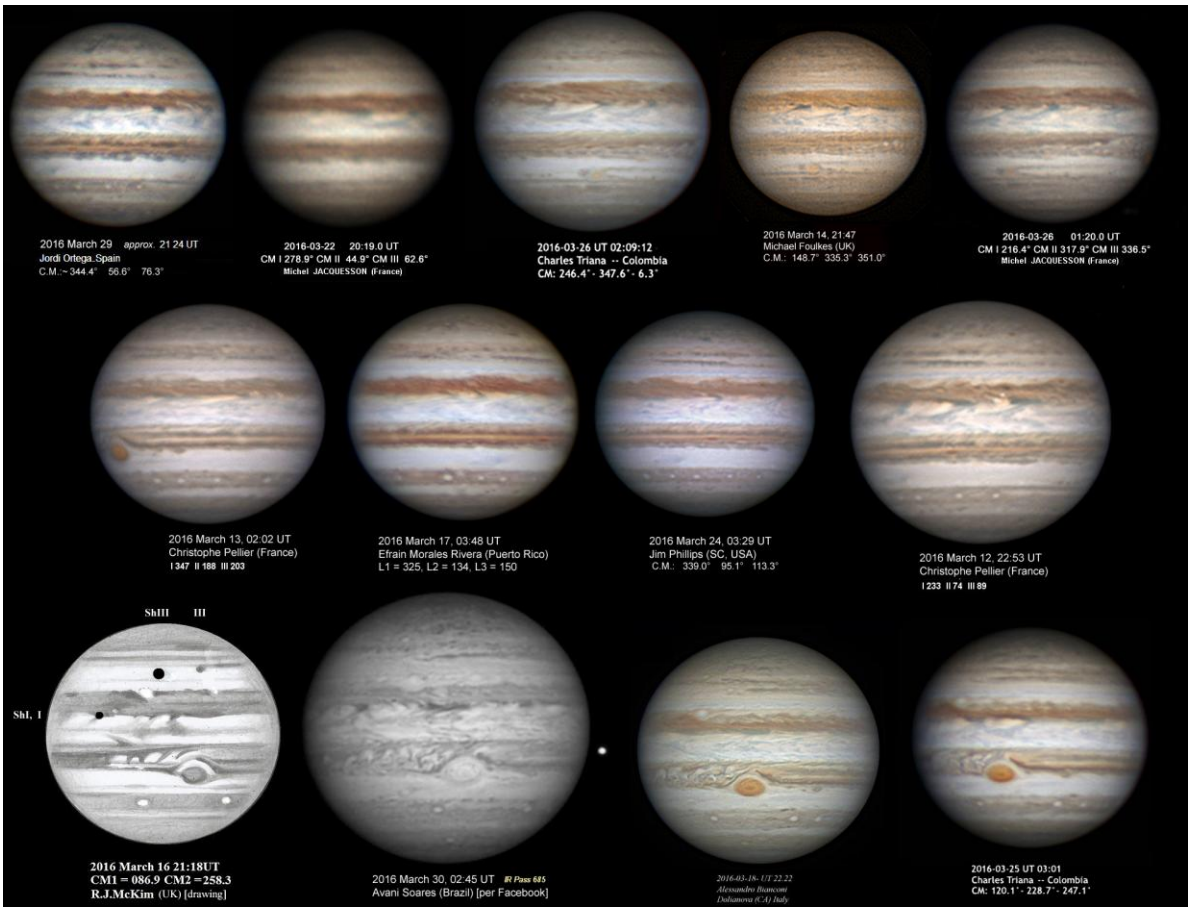

Figure 1. Gallery of images in 2016 March and April, all around the planet.

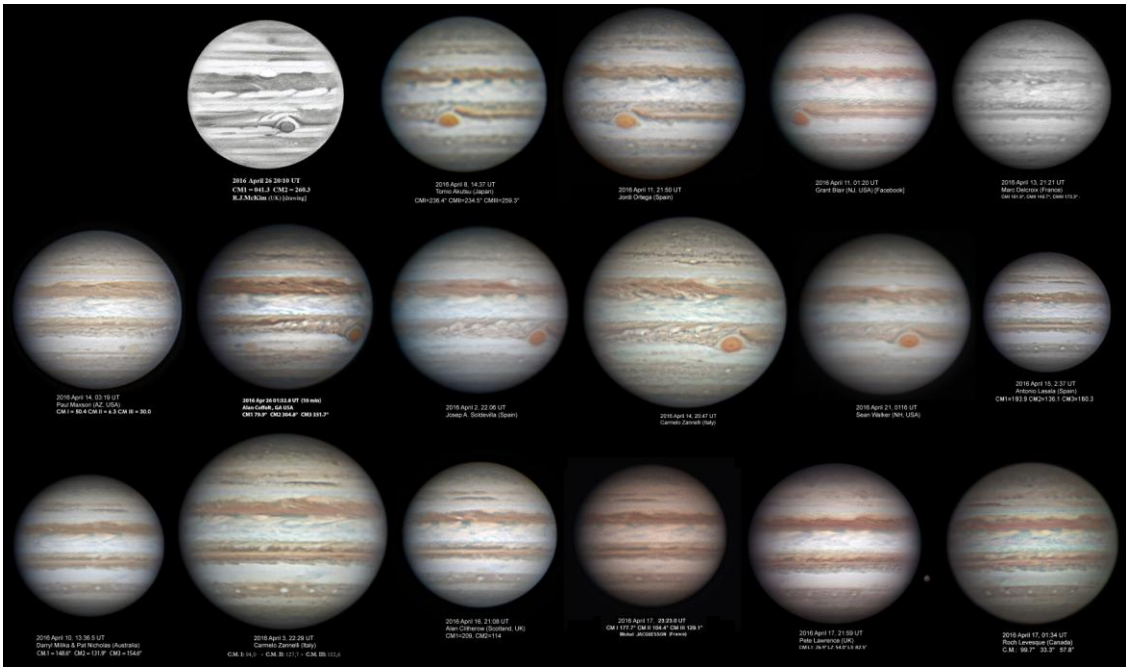

Figure 2. Gallery of images in 2016 April, all around the planet.

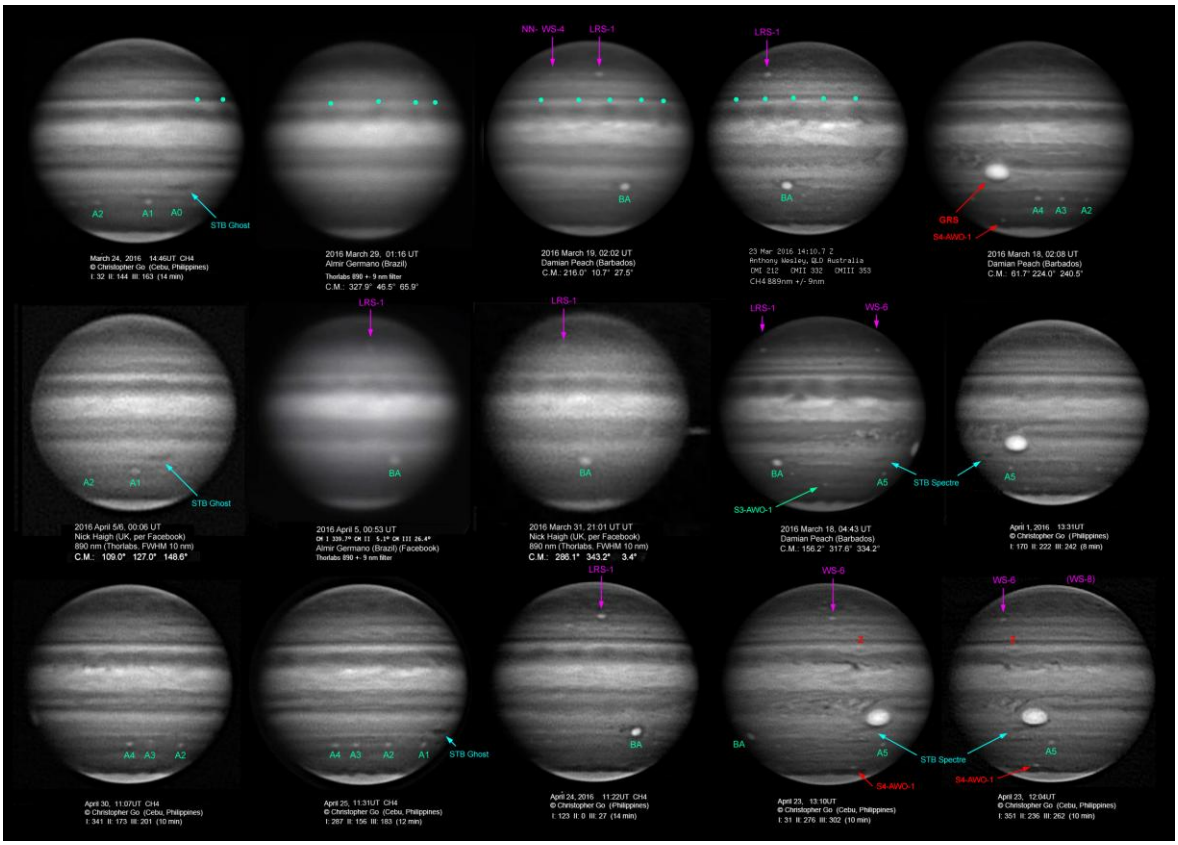

Figure 3. Methane-band images from March and April. Similar sets have already been shown for Nov-Feb.(Reports no.2&3) and May-June (Report no.9). This is a selection of images from observers with more selective filters which clearly showed the methane-dark waves on the NEB (indicated by cyan dots in the top row). Other observers also took good images on which features such as the methane-bright ovals can be tracked but not the NEB waves. Other features labelled are anticyclonic ovals in the NNTZ, NEBn (white spot Z; exceptionally, it is methane-dark), and all southern domains. The STB Ghost and Spectre are cyclonic features and are methane-dark. The polar hoods are clearly visible and some images show waves along the edge of the south polar hood.

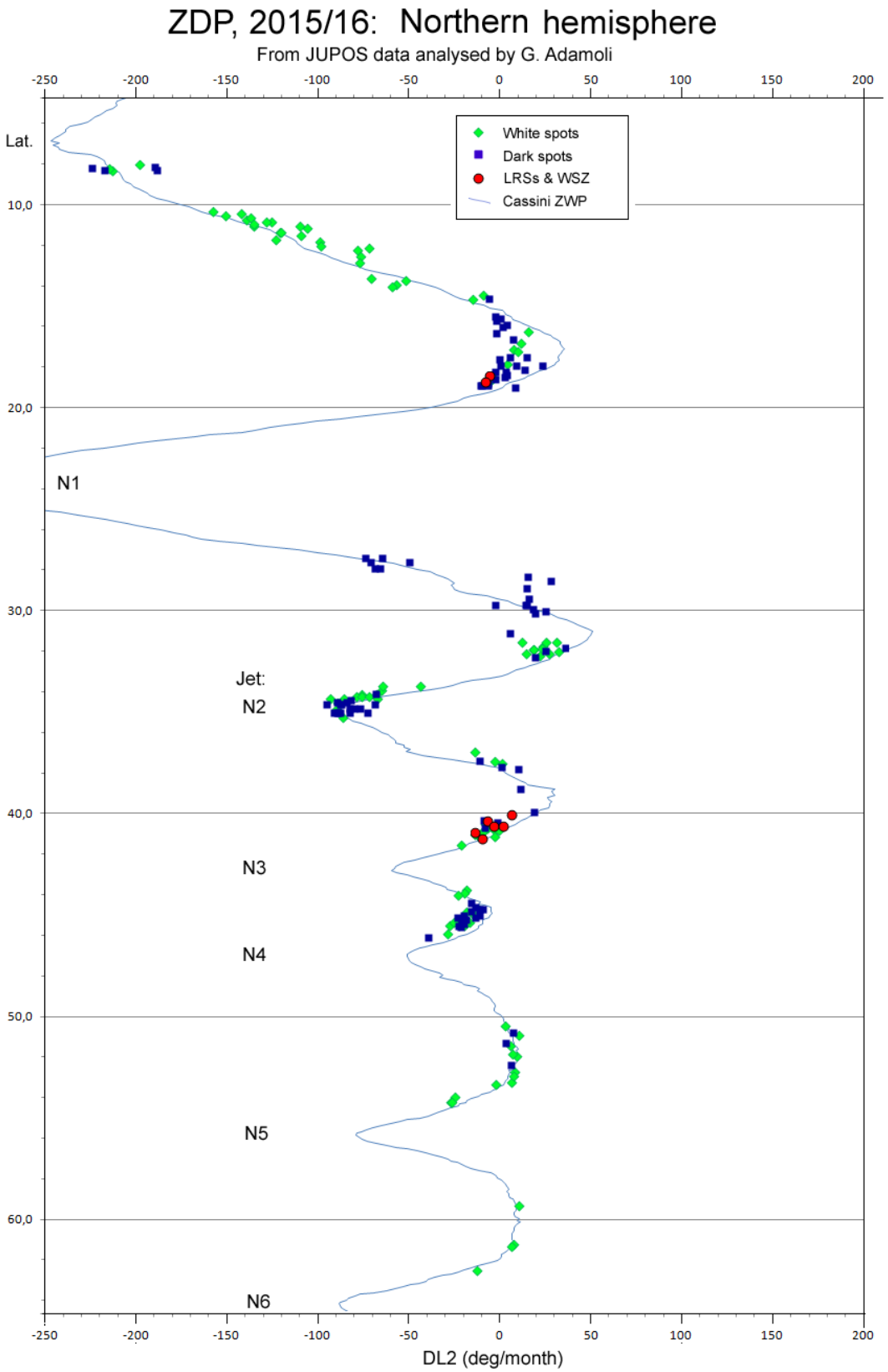

Figure 4. Complete zonal drift profile (ZDP) for N hemisphere. The continuous pale blue line is the zonal wind profile (ZWP) as derived from Cassini spacecraft data [Porco et al., 2003]. All reliable track segments are plotted; for many spots we measured multiple track segments as the drift rate varied.

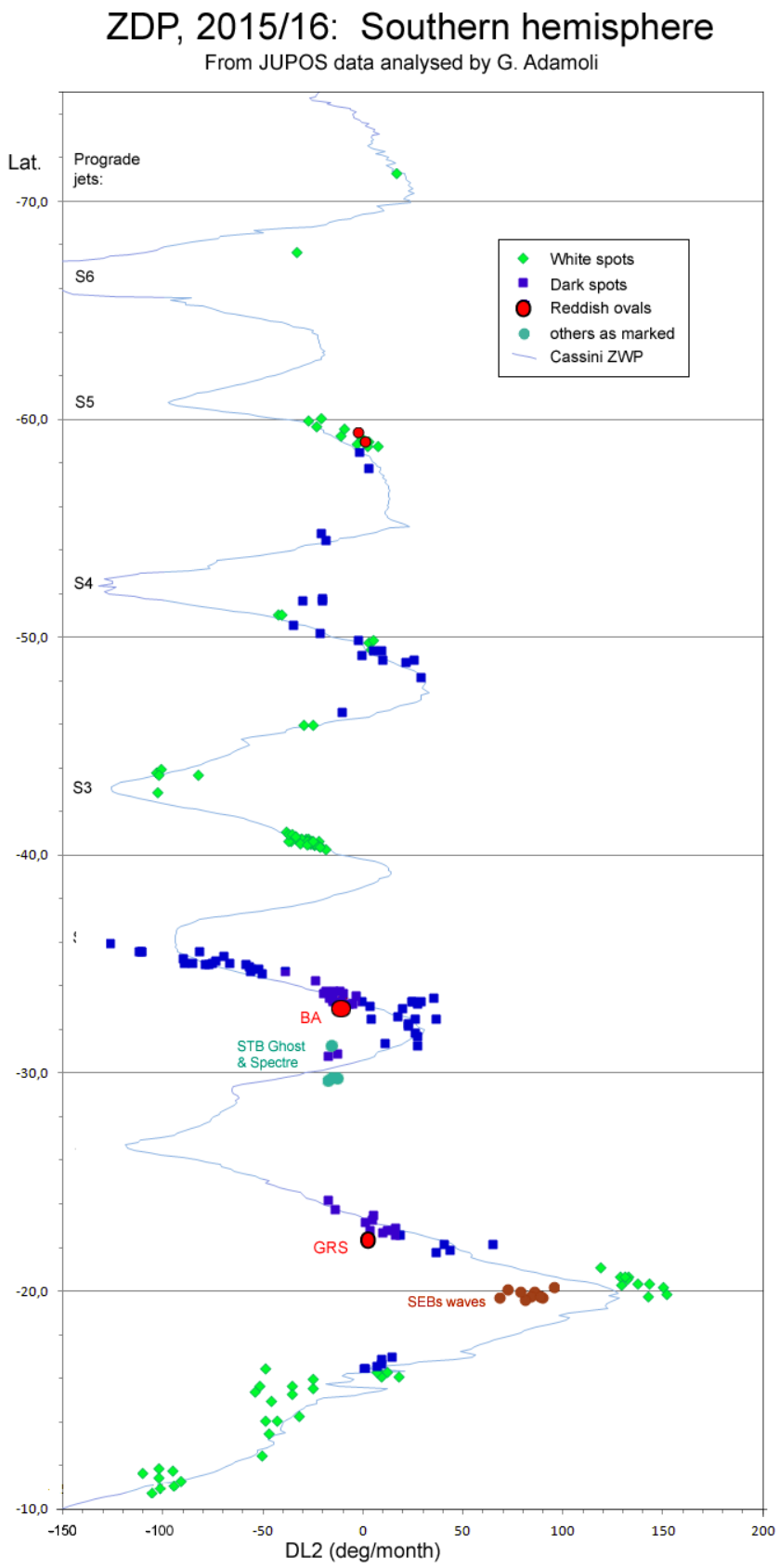

Figure 5. Complete zonal drift profile (ZDP) for S hemisphere. The continuous pale blue line is the zonal wind profile (ZWP) as derived from Cassini spacecraft data [Porco et al., 2003]. All reliable track segments are plotted; for many spots we measured multiple track segments as the drift rate varied.

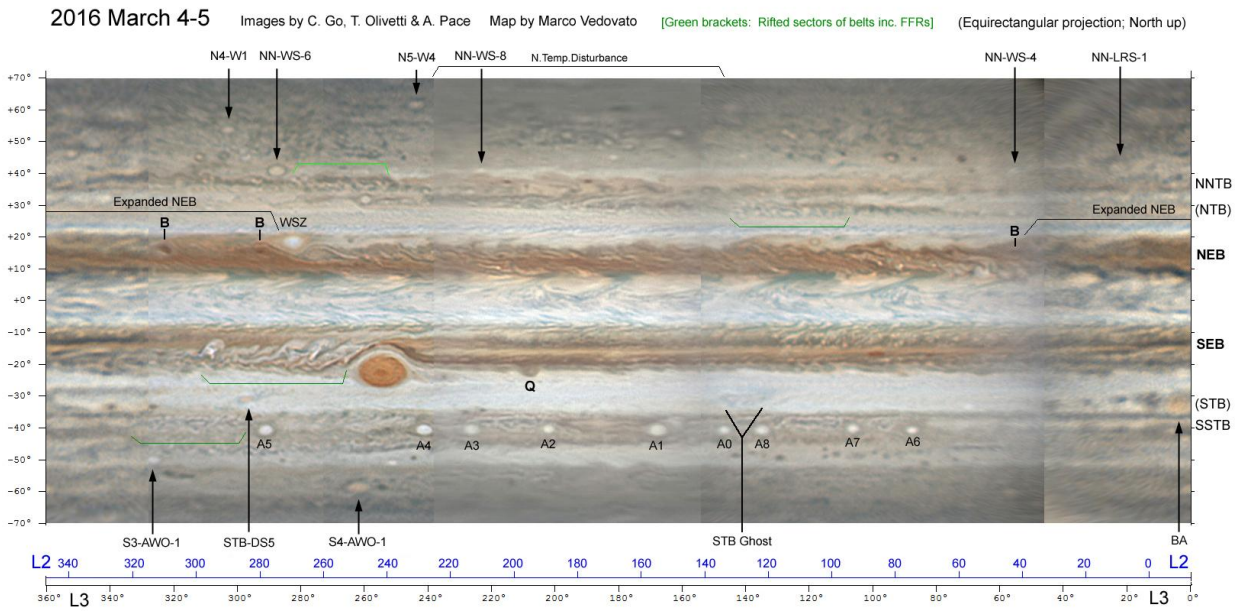

Figure 6. Map on 2016 March 4-5, near opposition. North is up in all maps and images. A copy with south up is **S-Fig.06.**

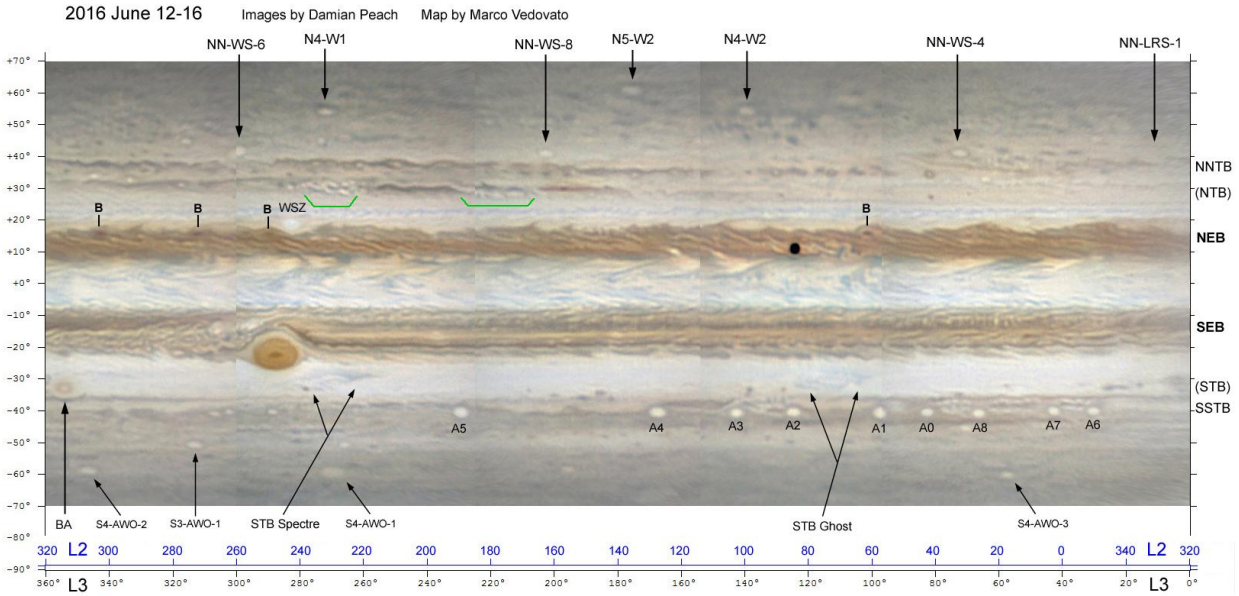

Figure 7. Map on June 12-16, made from images taken by Damian Peach on Barbados. For N and S polar maps, see **Figs.8 & 23**. A copy with south up is **S-Fig.07.**

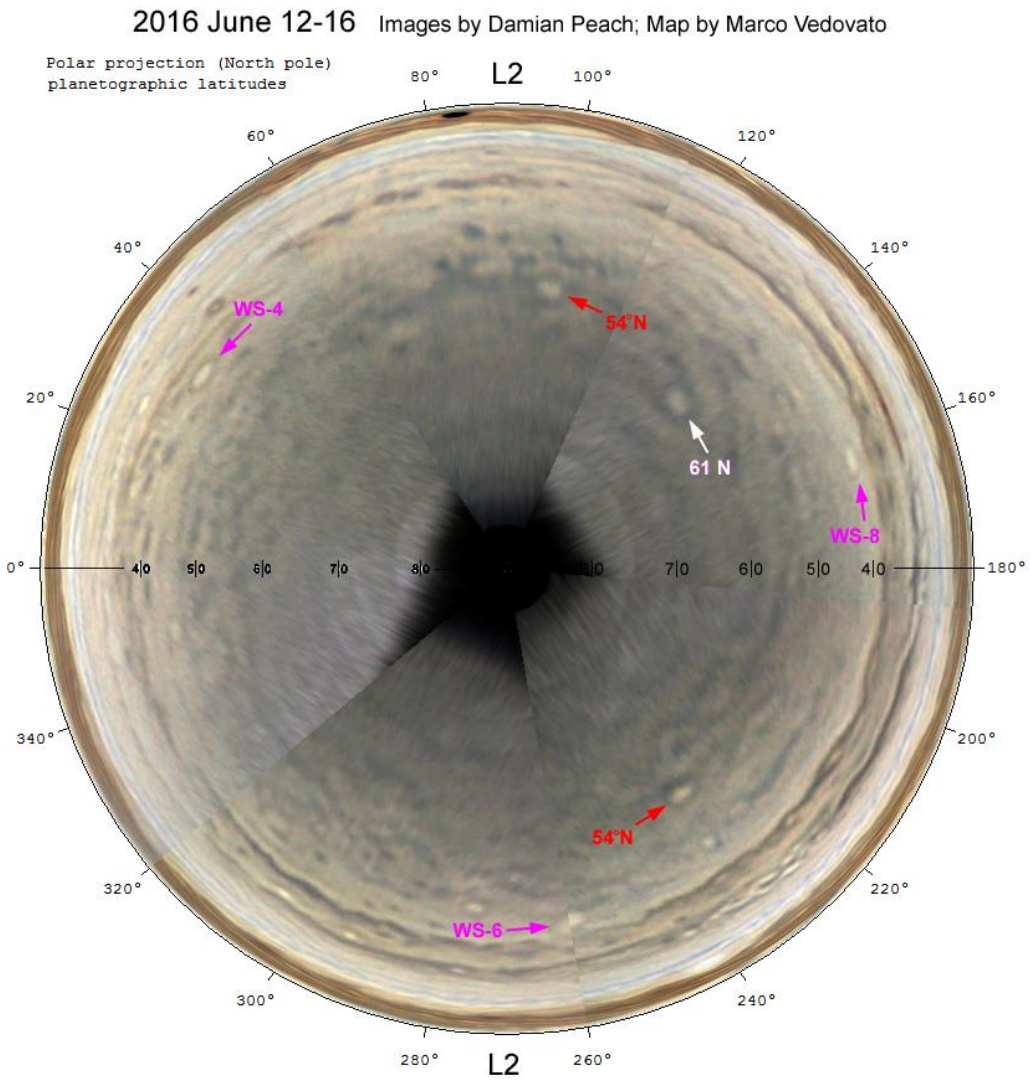

Figure 8. North polar projection map on June 12-16, from the same data as Fig.7. (Compare with map on April 28-29 in Report no.9.)

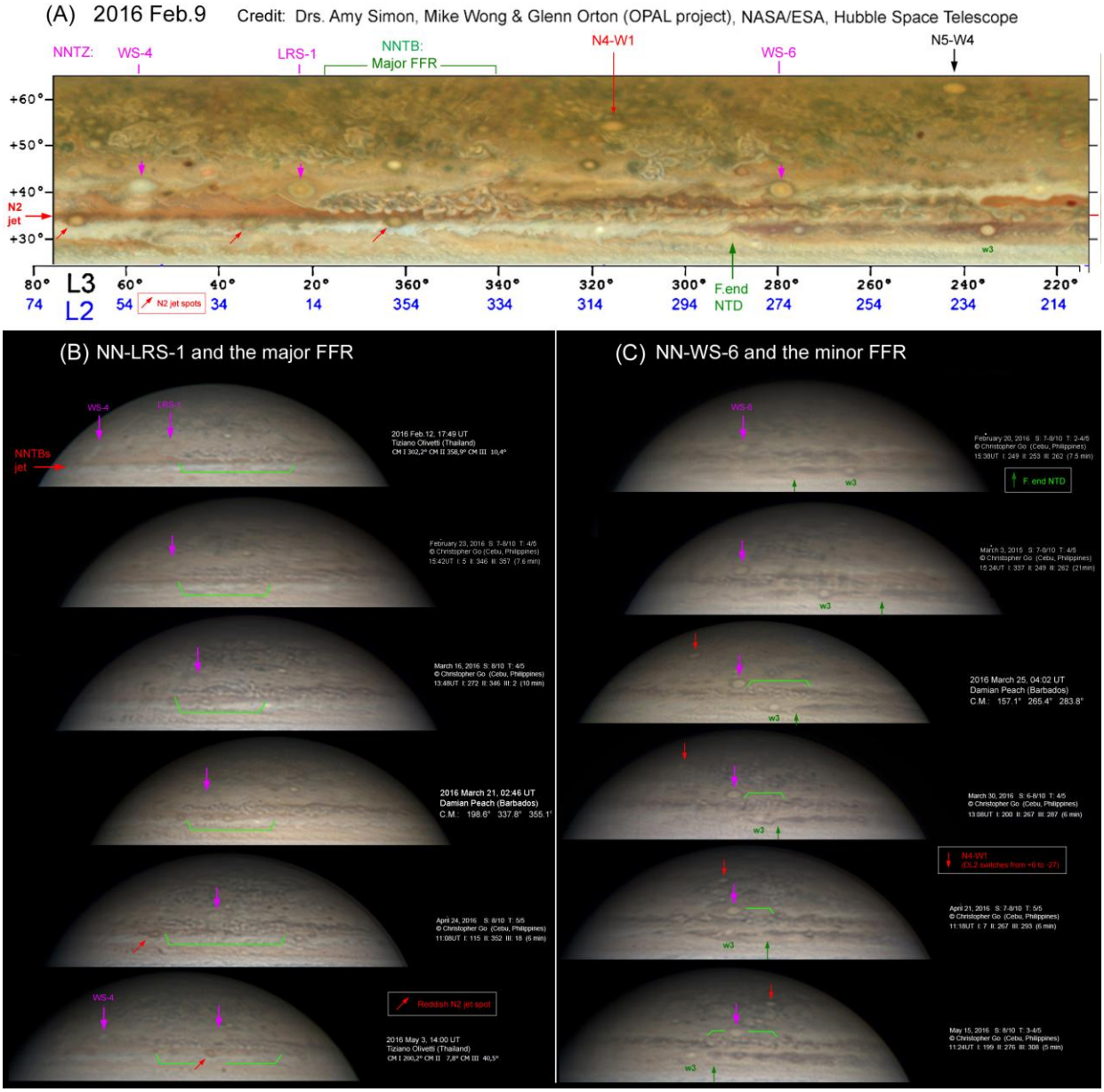

Figure 9. V-hi-res images of the north polar region, especially showing the major anticyclonic ovals (purple arrows) and FFRs (green brackets) in the N2 domain. At top is an excerpt from a Hubble map [ref.5] (with exaggerated colour) showing these features in more detail. (Also indicated on the images are an N4 AWO, N2 jet spots, and features of the NTD.)

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Figure 10. Maps of the northern hemisphere from latitudes 0 to +50, labelled for major features, especially in the N2, N1 (N.Temperate), and N0 (N.Tropical) domains. All except the final map are in equirectangular projection, aligned in L3, plus L2 scales in some cases. All maps were made by Marco Vedovato except the final map and the Feb.9 Hubble map [ref.5]. Similar maps up to Jan.31 were shown in Report no.3. The same maps plotted in L2, with south up, unlabelled, are shown as **S-Fig.10.**

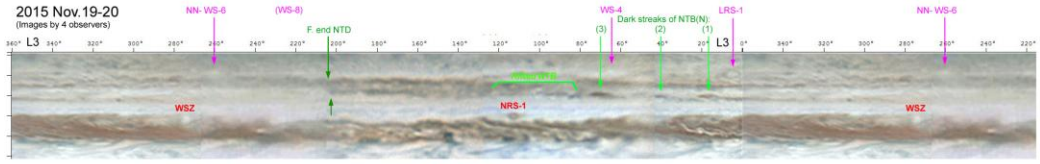
Maps of Northern Hemisphere

All maps by Marco Vedovato except Feb.9 & July 27-30.

Equirectangular projection; North up (except the last)

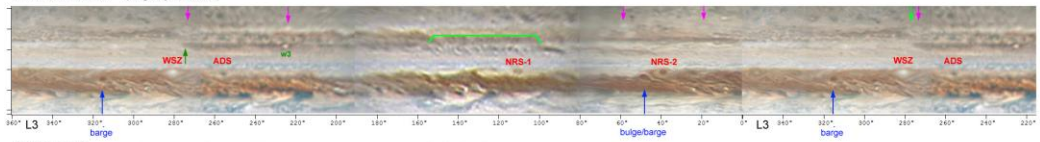
2015 Nov.19-20

(Images by 4 observers)



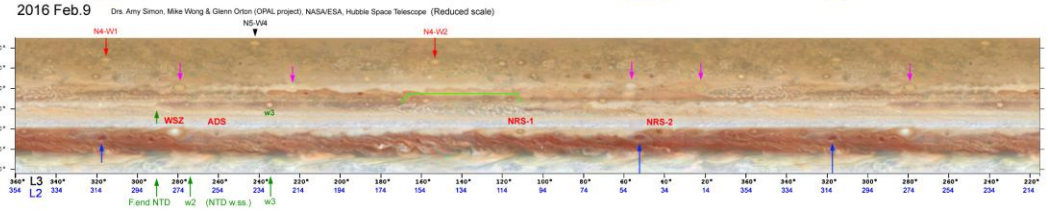
2016 Jan.29-31

(Images by 4 observers)



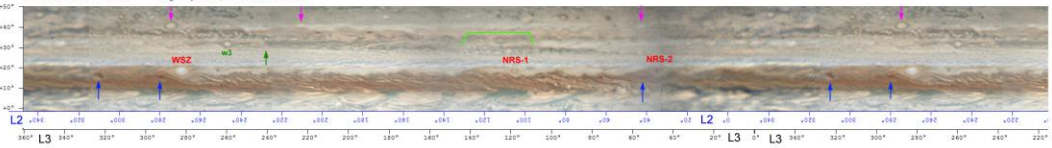
2016 Feb.9

Drs. Amy Simon, Mike Wong & Glenn Orton (OPAL project), NASA/ESA, Hubble Space Telescope (Reduced scale)



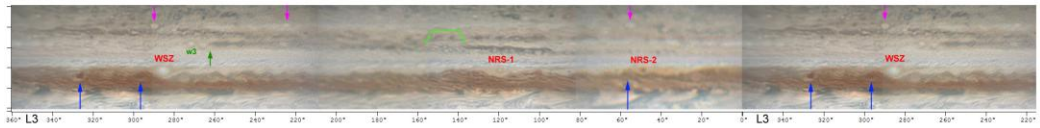
2016 March 4-5

Images by C. Go, T. Olivetti & A. Pace



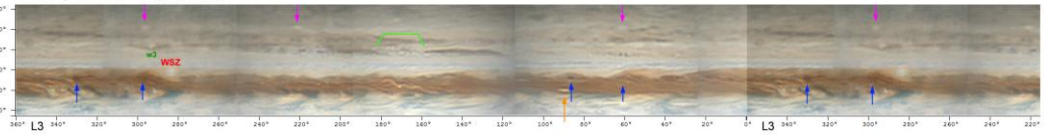
2016 March 17-19

(4 observers)



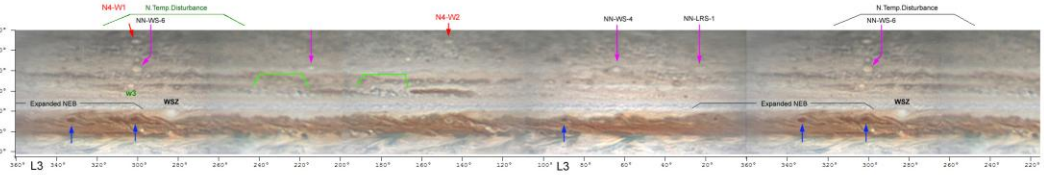
2016 April 14-15

Images by Kevin Quin



2016 April 28-29

Images by C. Go & T. Olivetti;

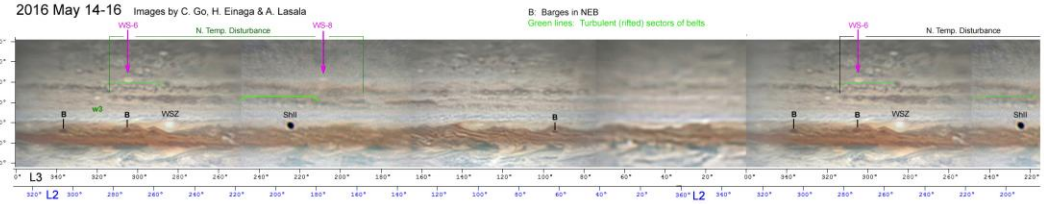


2016 May 14-16

Images by C. Go, H. Einaga & A. Lasala

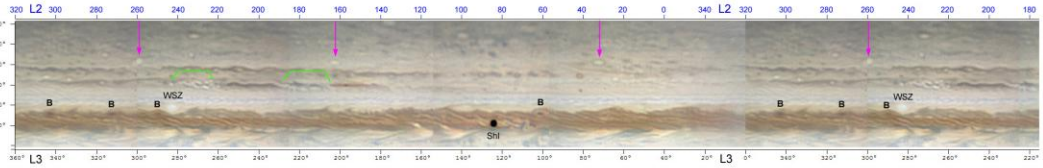
B: Barges in NEB

Green lines: Turbulent (rifted) sectors of belts



2016 June 12-16

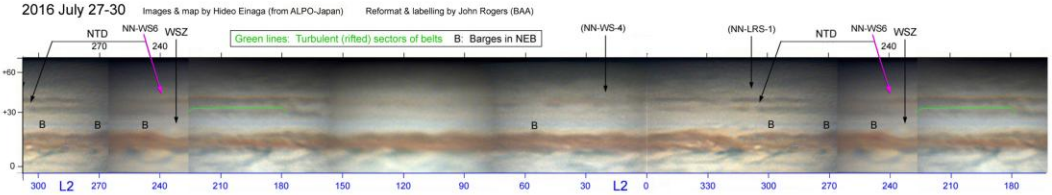
Images by Damian Peach



2016 July 27-30

Images & map by Hideo Einaga (from ALPO-Japan)

Reformat & labelling by John Rogers (BAA)



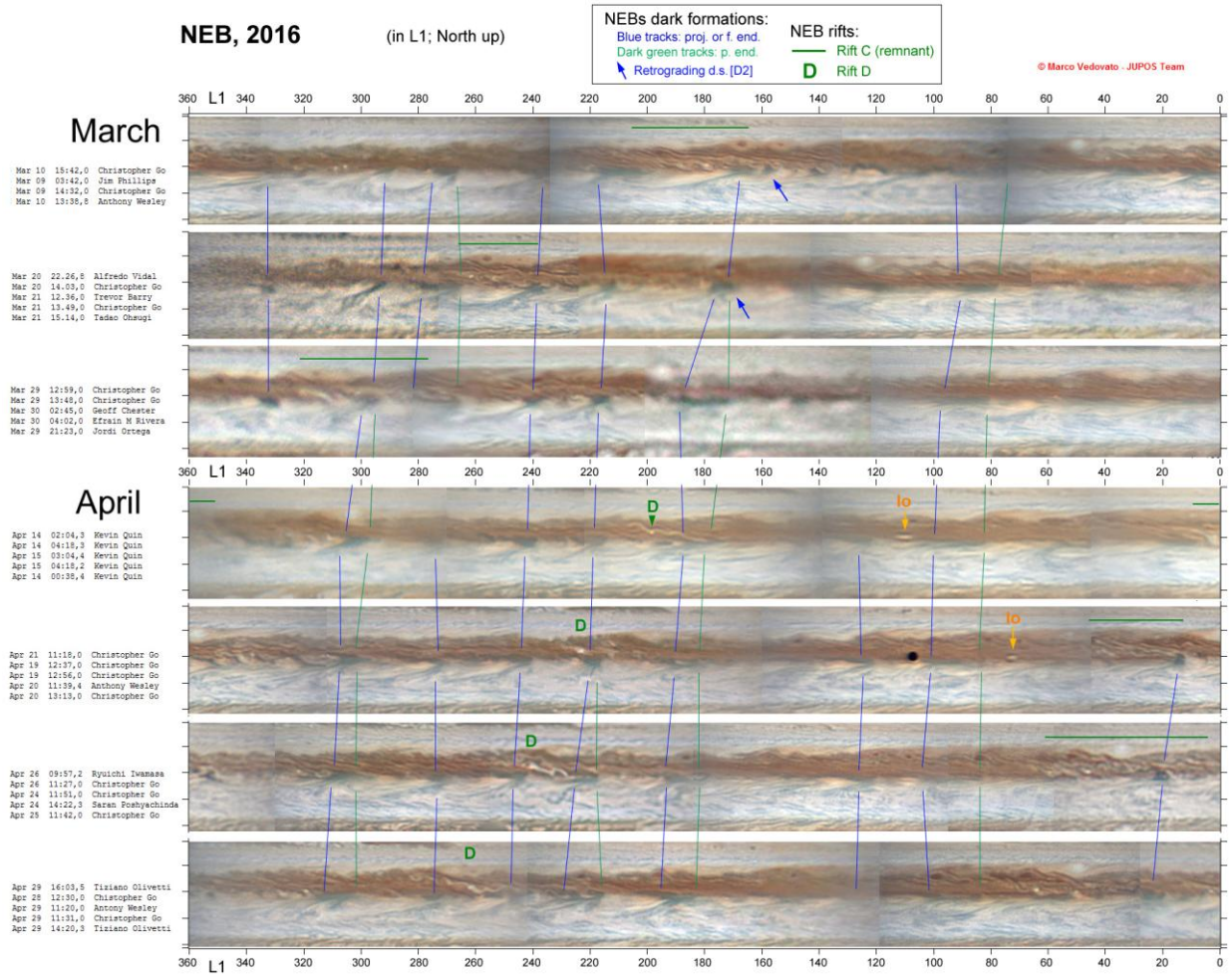


Figure 11. Maps of the NEB showing changes in the rifts and NEB dark formations during March and April, aligned in L1, with north up. All maps were made by Marco Vedovato. These are just examples from a complete series covering Feb. to June, with south up, shown as **S-Fig.11.**

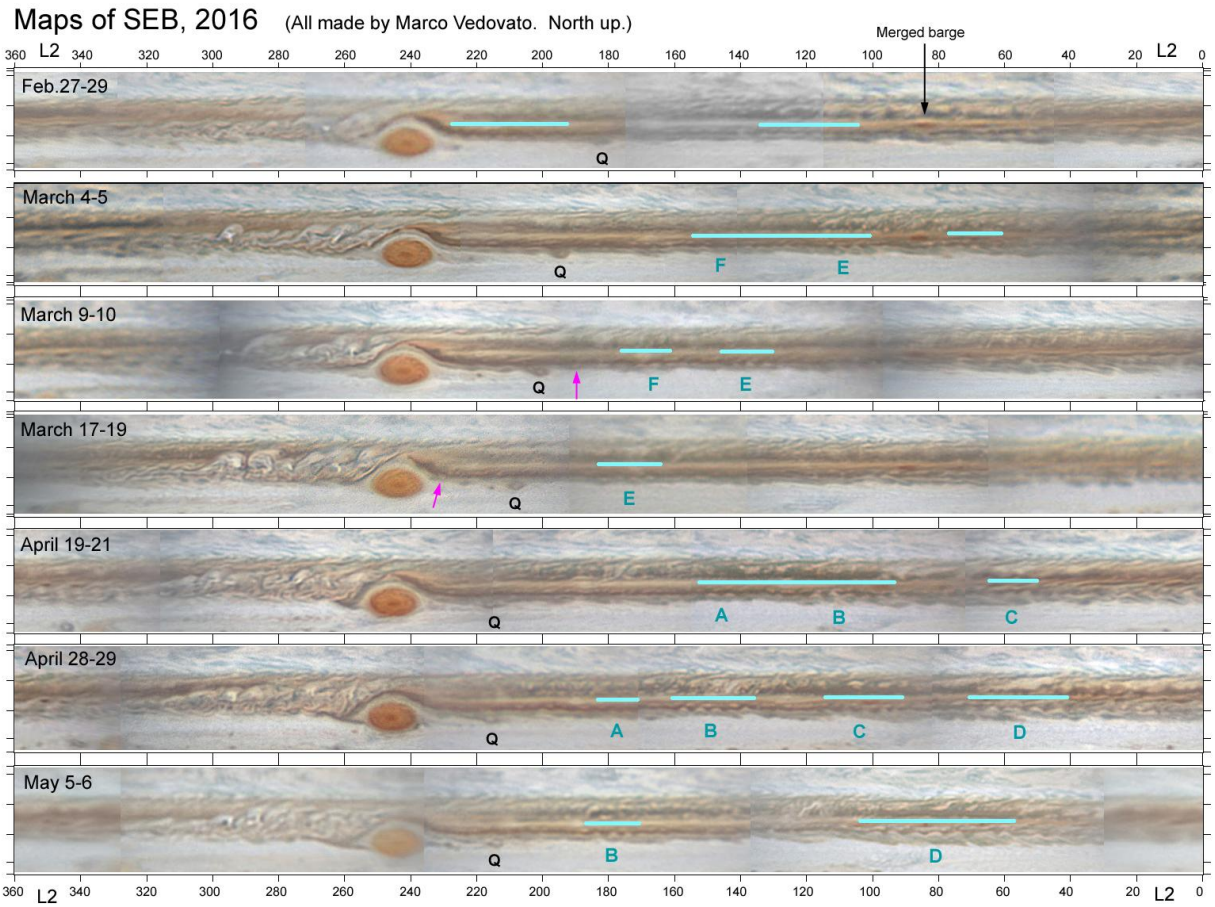
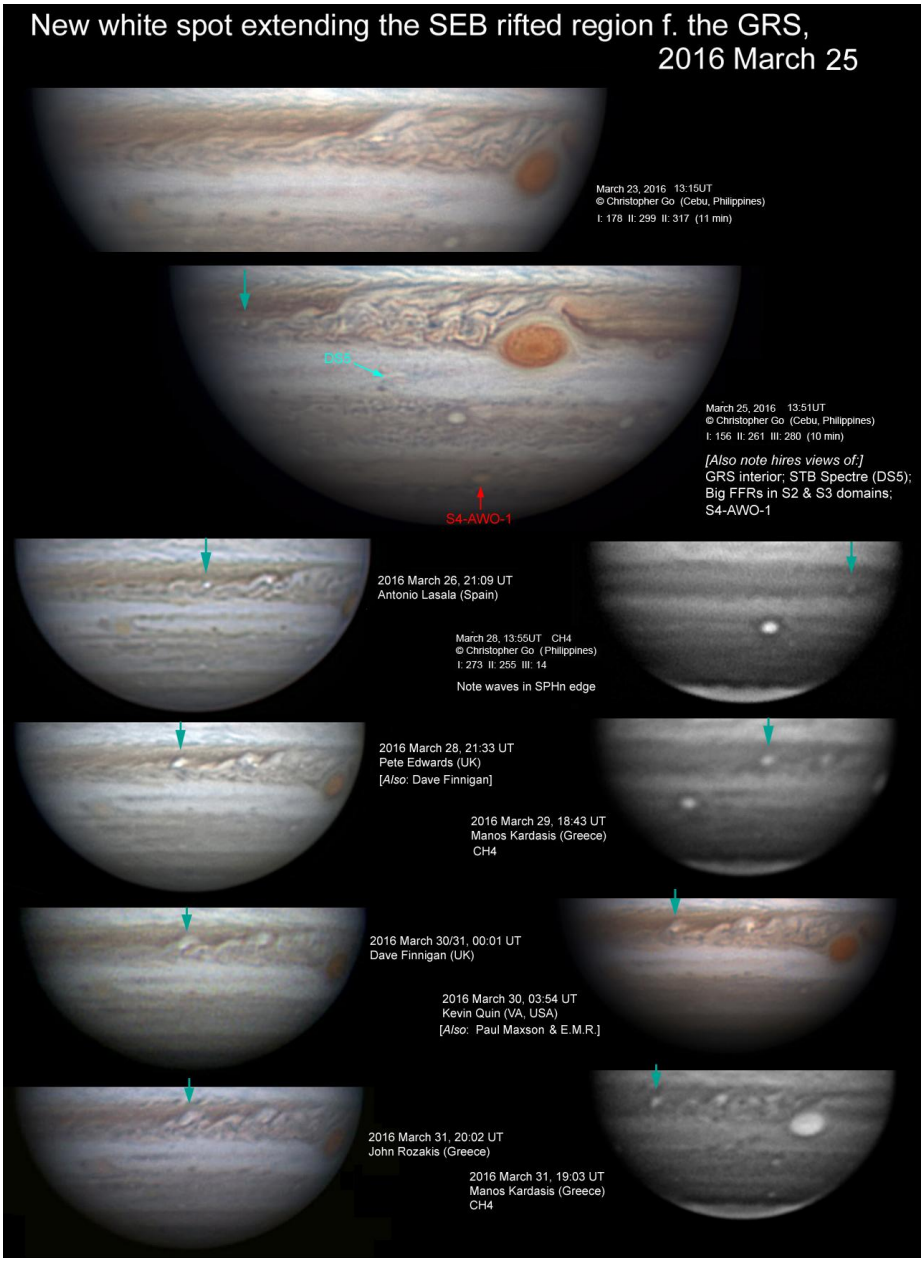


Figure 12. Maps of the SEB, Feb. to May. (Also see main map in June.) Note the expansion and later quiescence of the SEB rifted region f. the GRS. The merged barge is marked, as is oval Q in the STropZ. Wave-trains on SEBs are marked by a cyan bar immediately above them; letters correspond to individual wave-trains described in the Appendix. Magenta arrows indicate a very rapidly retrograding tiny white spot [g] on SEBs. The same maps plotted in L2, with south up, unlabelled, are shown as **S-Fig.12.**

[Next page]:
Figure 13. Extension of the SEB rifted region f. the GRS by a new white spot on March 25 (blue-grey arrow). It was visible as tiny spot in the image by C. Go on March 25, though it was first noticed in the image by A. Lasala on March 26. It was methane-bright on March 28 (C. Go) and 29 & 31 (M. Kardasis). In Go's March 25 image, also note hi-res views of the GRS interior, DS5/STB Spectre, big FFRs in the S2 and S3 domains, and S4-AWO-1.



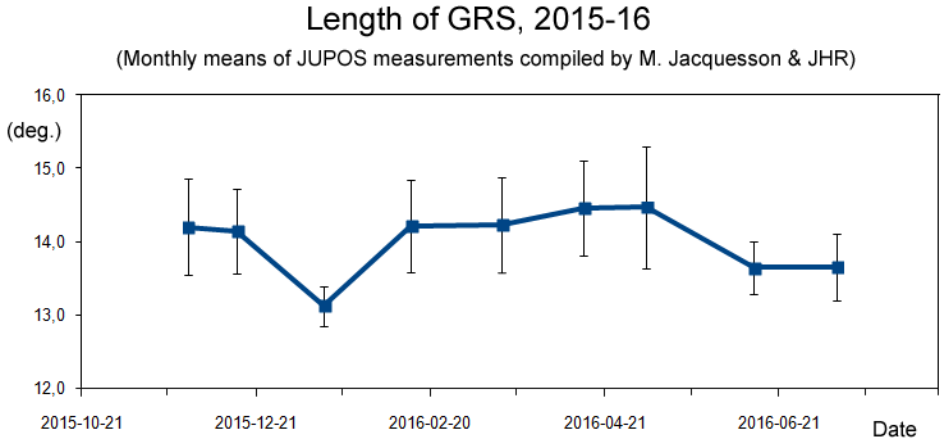


Figure 14. Length of the GRS during 2015/16 (monthly means from hi-res images, with standard deviations).

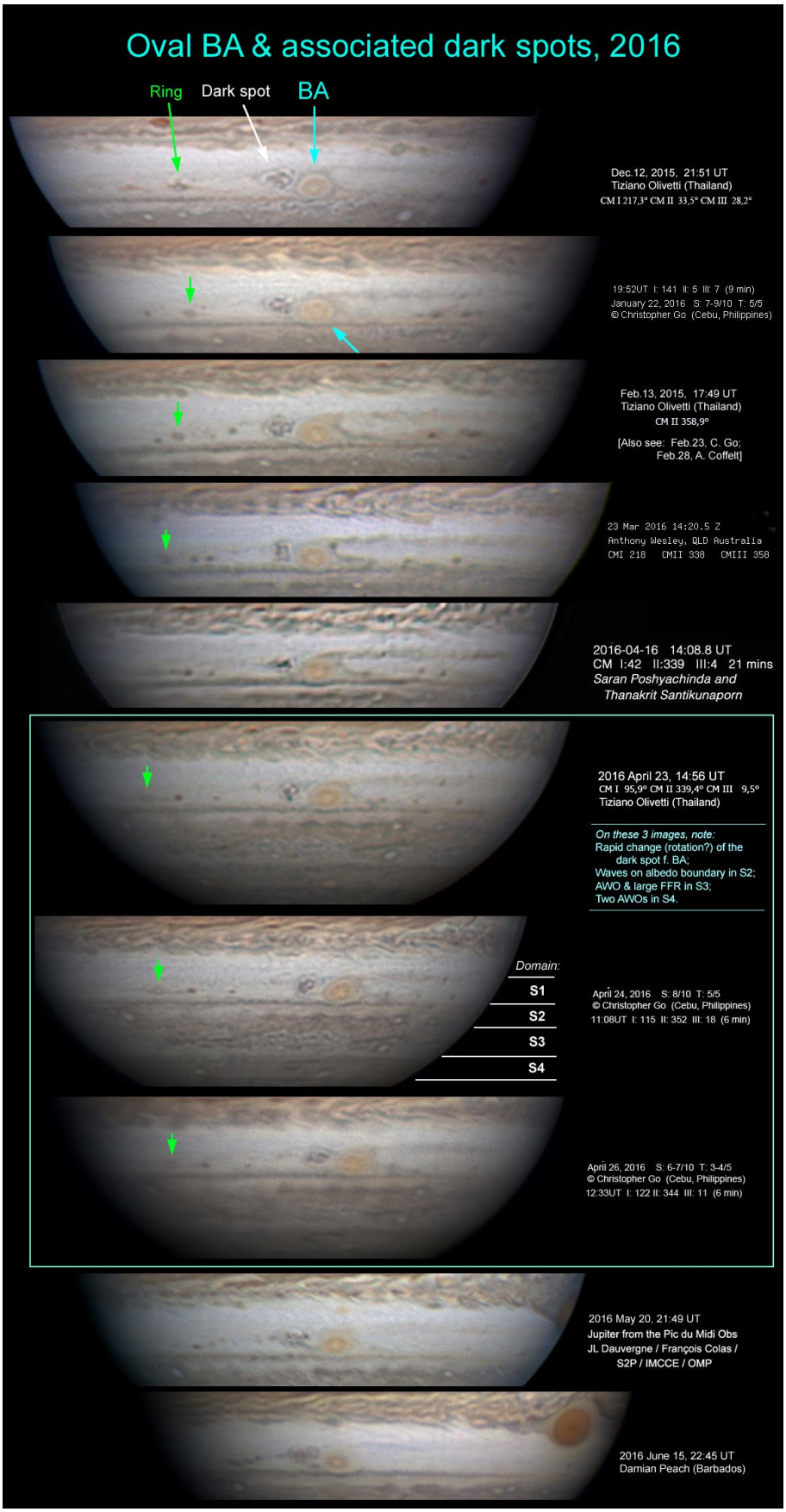


Figure 15. Oval BA and associated dark spots, 2015 Dec. to 2016 June.

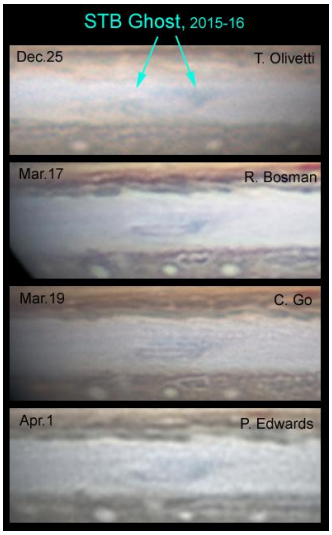


Figure 16. The STB Ghost, 2015 Dec.25 to 2016 April 1.

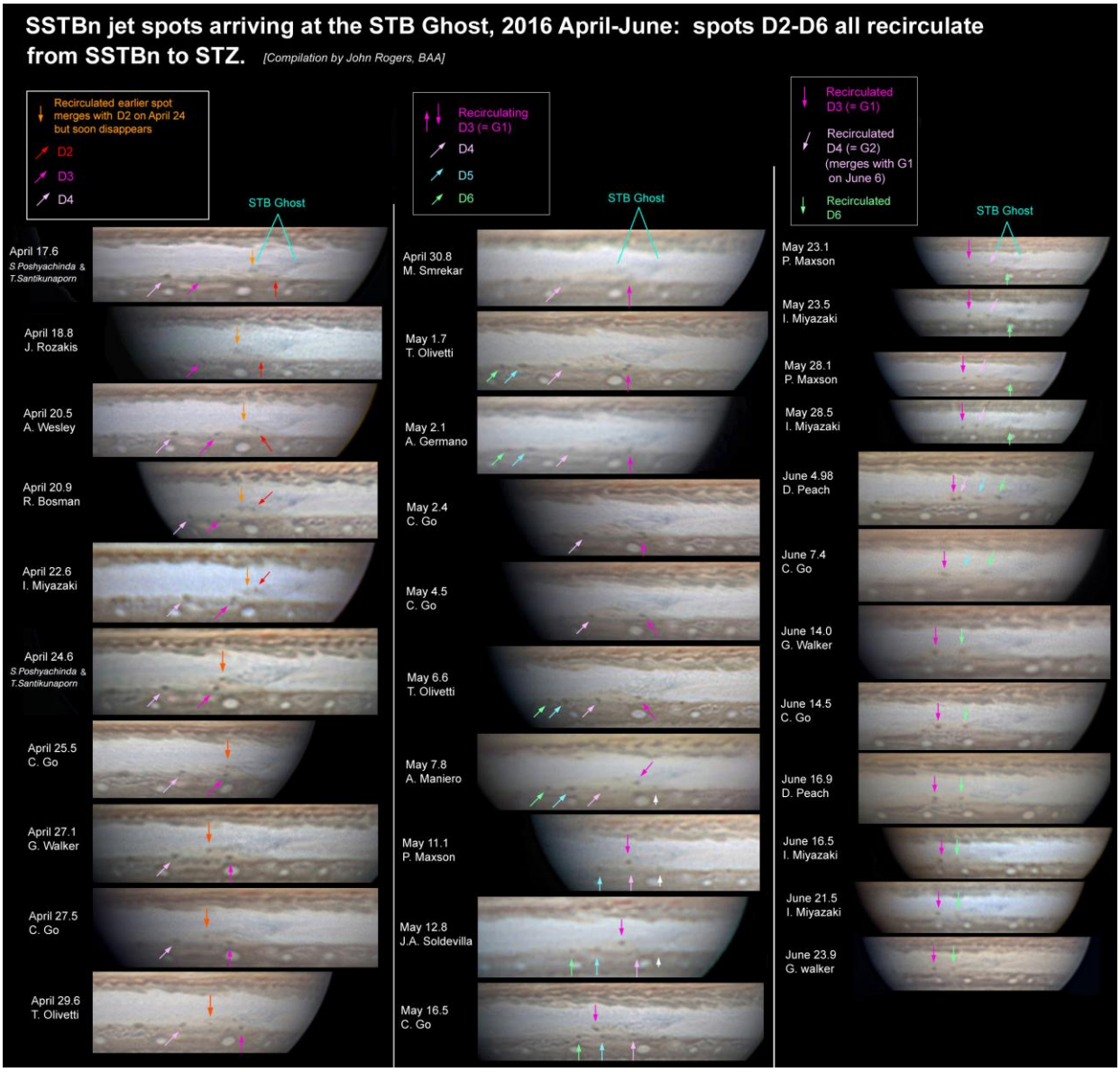


Figure 17. The STB Ghost, 2016 April-June, showing SSTBn jet spots D2 to D6 arriving and recirculating back into the STZ. (D5 was not seen as it recirculated, but it then reappeared in the STZ.) These images also show SEBs wave-trains, as indicated in Appendix 1.

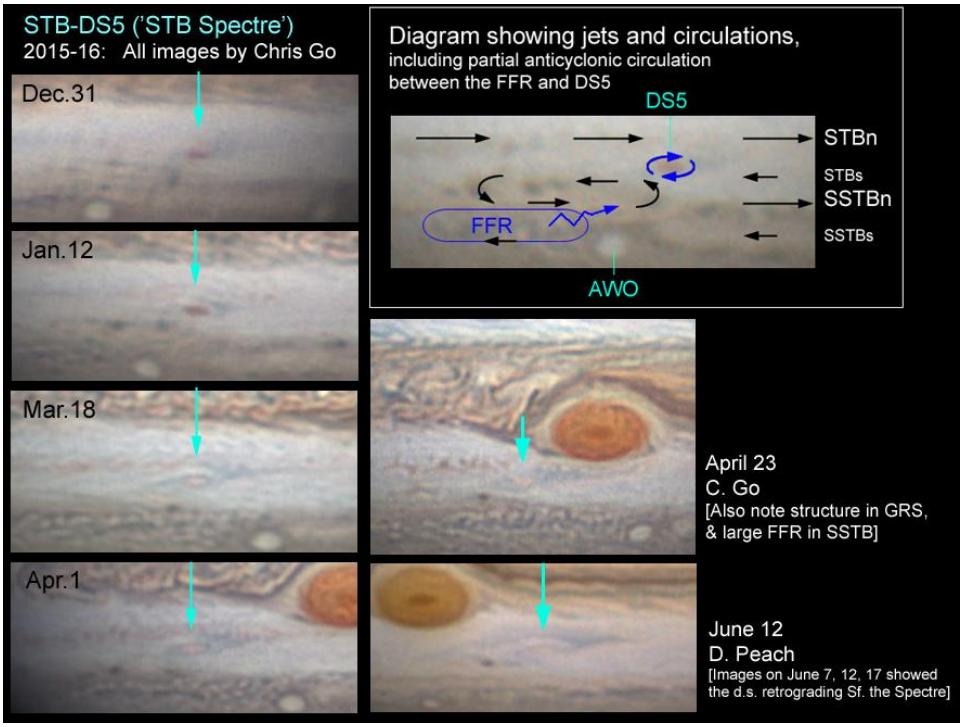


Figure 18. STB spot DS5, reddening and fading, passing the GRS, and evolving into the STB Spectre. [Figure 19 does not exist.]

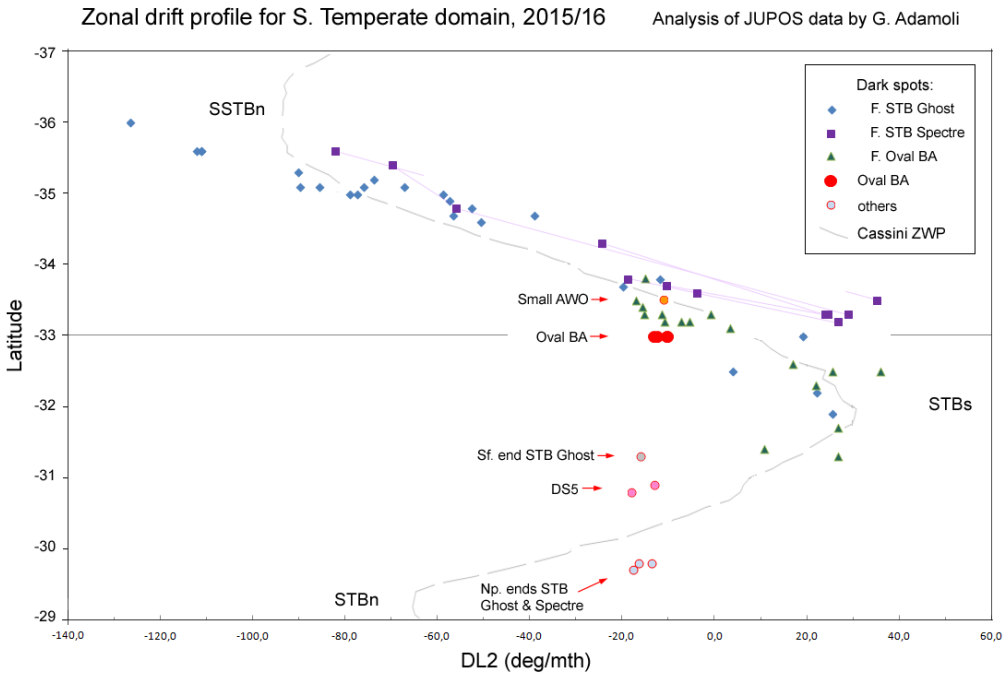


Figure 20. Zonal drift profile (ZDP) for the S. Temperate domain including SSTBn jet, 2015/16. The dashed grey curve is the Cassini ZWP from Cassini. Note that SSTBn jet spots (blue diamonds) have a much faster jet peak, although they adhere closely to the ZWP on the north side of the peak. Pale mauve lines connect points for individual spots circulating at and f. the STB Spectre; note that they lie systematically above the Cassini ZWP. (Curiously, this is less so for the spots which had reverted from retrograding to prograding (STC), i.e. DL2 ~ 0 to -25 – although each spot did change latitude when it recirculated in the appropriate sense.) Points for the ends of the STB Ghost naturally have a mean speed matching the centre of the Ghost despite their different latitudes.

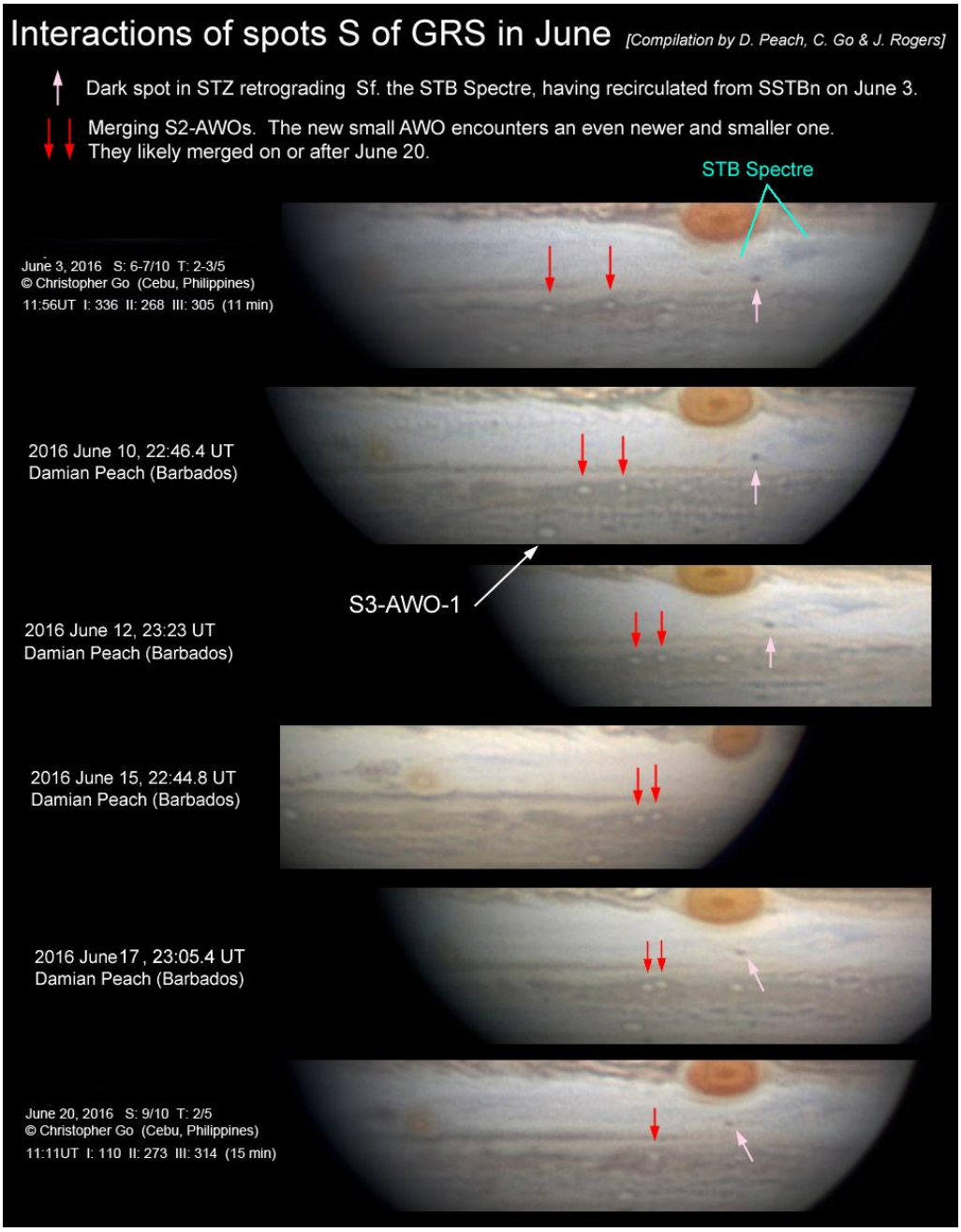


Figure 21. V-hi-res images in June showing interactions of small spots south of the GRS. Red arrows: Merging S2-AWOs. The new small AWO encounters an even newer and smaller one, and they likely merge after June 20. Pink arrow: Dark spot in STZ retrograding f. the STB Spectre, having recirculated from SSTBn on June 3. White arrow: S3-AWO-1.

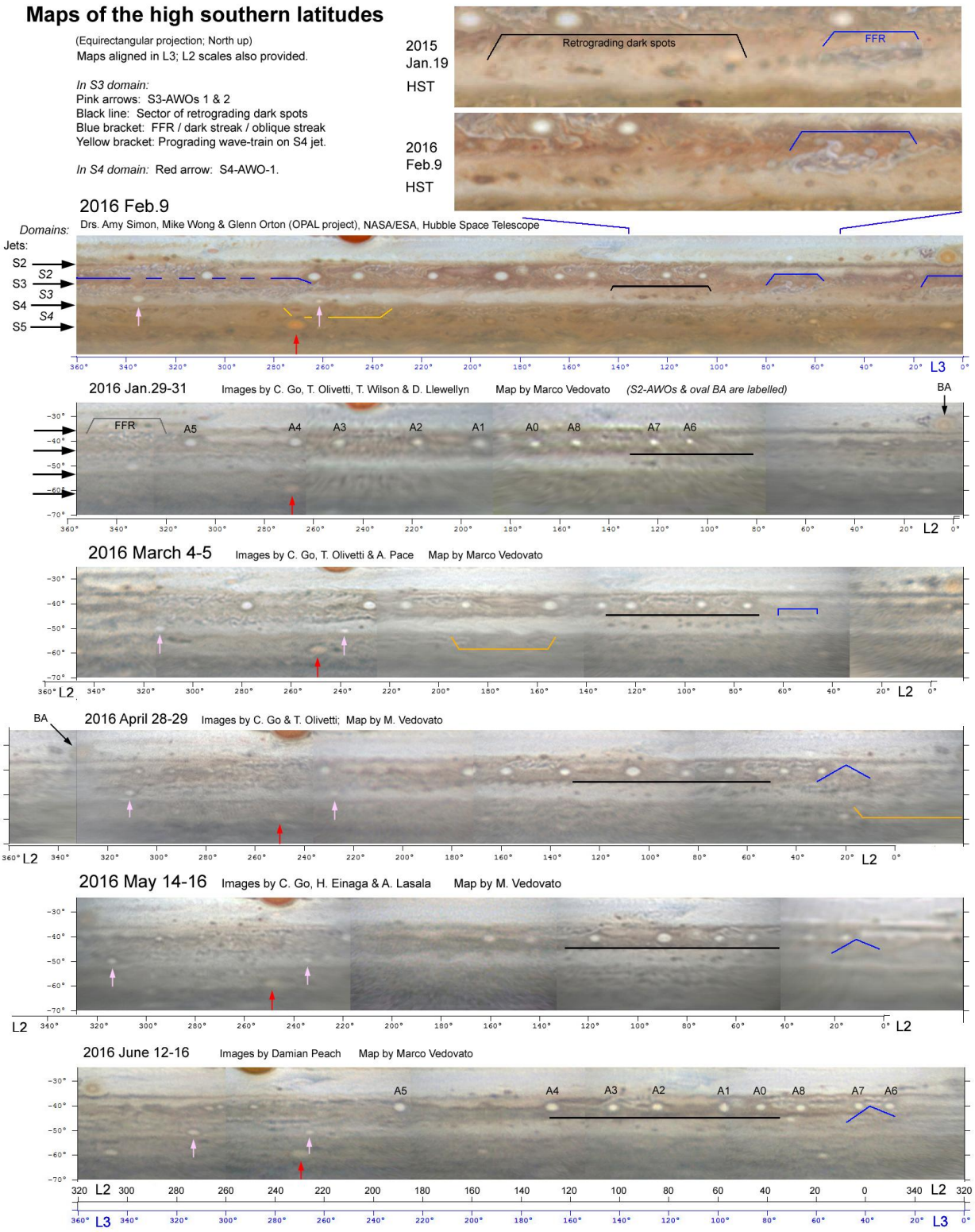


Figure 22. Maps of the high southern latitudes (Equirectangular projection, north up); aligned in L3 with L3 scales at top and bottom and L2 scales also given. At top is a map from Hubble on 2016 Feb.9, shown at the same scale as the ground-based maps, plus a full-size excerpt covering the most interesting region of the S3 domain, and a similar excerpt from a Hubble map on 2015 Jan.9 [refs.5 & 23].
The following features are labelled: In the S2 domain, the nine stable AWOs. In the S3 domain, AWO-1 and 2, and the sector of retrograding dark spots, with the dark streak which may mark a FFR that generates them. In the S4 domain, AWO-1 (reddish oval).

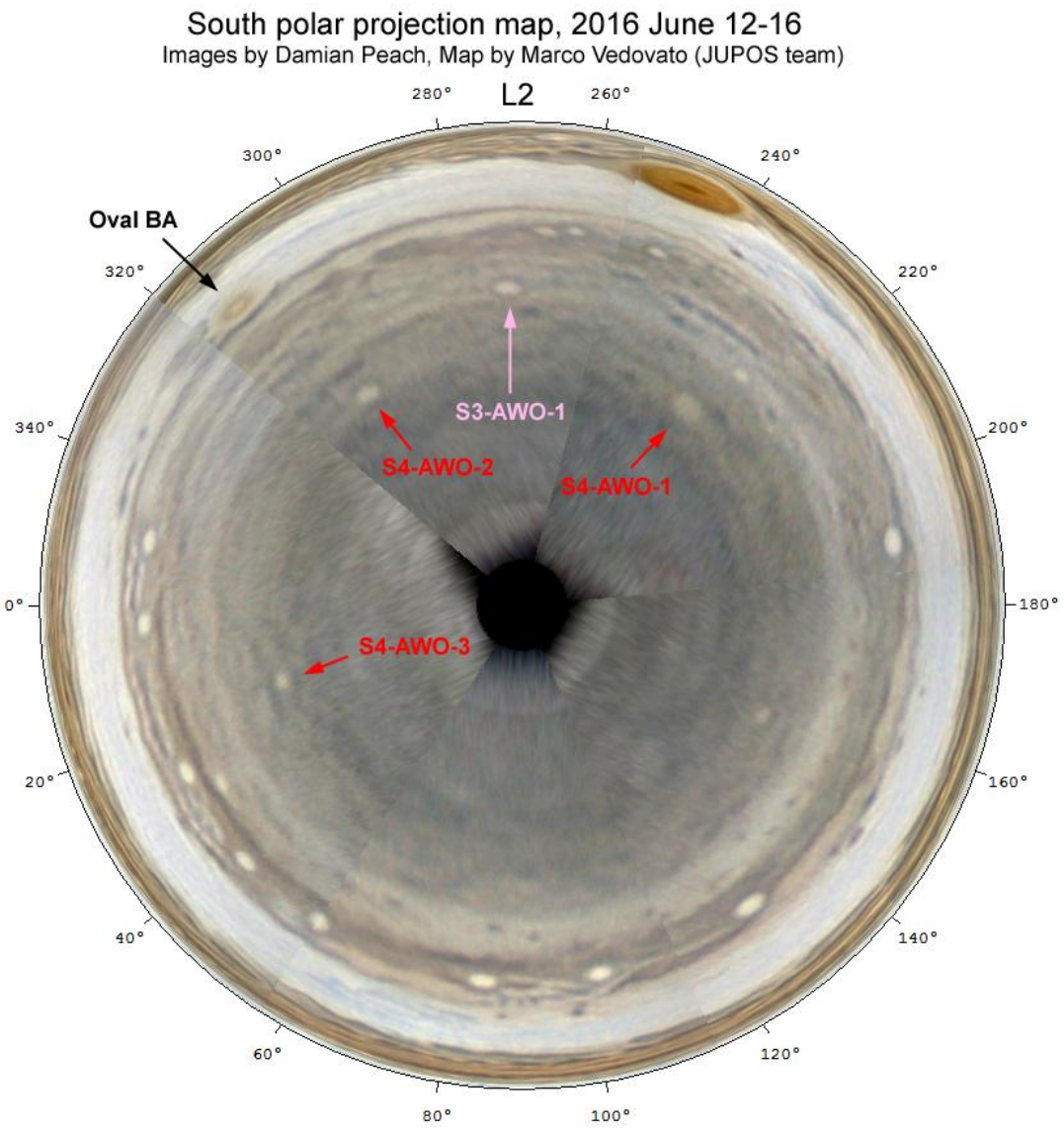


Figure 23. South polar projection map, 2016 June 12-16, from the same data as Fig.7. (A similar map from April 28-29 was posted in Report no.9.)

Table 1. Positions and drifts, 2015/16: Northern hemisphere

Spot	*Time interval*	*L2(0)*	*DL2*	*SD*	*Lat.*	*SD*	*N; n*	
N5 domain								
White spots								
W1	Oct 26 – Jan 13	162	10,2		59,3		18	
W2	Apr 7 –22	135	7,2		61,2		18	
W3	Apr 12 – May 5		-12,7		62,5		8	
W4	Apr 5-18	232	6,4		61,3		9	
N4 domain								
White spots								
W1	Dec 29 – Feb 9		*-25,0*		*53,9*		*13*	
	Mar 5 – 14	291	5,9		53,2		7	
	Apr 11 – Jun 17		*-27,0*		*54,2*		*33*	
W2	Oct 30 – Feb 19		9,1		51,9		26	
	Feb 26 – Mar 29	149	-2,5		53,3		27	
	Apr 3 – May 6		*-26,6*		*54,2*		*16*	
Mean of fast tracks (W1, W2):			***-26,2***	*1,06*	***54,1***	*0,17*	*3*	
N4TC = Mean of slow tracks (all spots):			**6,4**	2,0	**51,8**	0,96	11	
N3 domain								
N3TC = Mean of all w. & d. spots:			**-18,7**	4,53	**45,1**	0,32	26	
(except two faster ones)					**43,9**	0,15	3	
N2 domain								
NNTZ: Anticyclonic ovals								
LRS-1	Nov 21 - Feb 23		-1,0					
	Mar 4 - Apr 2	10	-12,7					
	Apr 29 - Jul 17		-12,7					
WS-4	Oct - Jul	41	Fluctuating between -1 and -14					
WS-6	Dec 6 - May 11	274	0	(Fluctuating between +6 and -7)				
	May 11 - Aug 2		-12,7					
WS-8	Jan - Jul	210	Fluctuating between -3 and -21,5					
N2 jet (NNTBs jetstream)								
Mean of w. & d. spots:								
(Omitted 3 spots with DL2 <-66)			**-82,2**	8,3	**34,6**	0,34	28	
(Omitted all spots with DL2 <-80)			**-87,6**	4,0	**34,7**	0,27	18	
N1 domain								
NTC-A:								
NTB(N) dark bars/streaks:								
D6	Nov 18 – Dec 26	83	13,8		29,7		14	V. dark bar in Nov., turned red & faded away in Dec
								to a v.pale streak in Jan.(but darkened as D10 in March?).
D7	Nov 10 – Dec 15	111	15,7		29,4		14	Short dark streak.
D7	Dec 10 – Jan 1	120	18,0		29,9		11	
D10 p.end	Feb 26 – Apr 6	67	27,9		28,5		26	V. dark streak, arose from a grey sector encompassing
D10 p.end	May 14 – Jun 19	88	14,4		28,9		12	remnant of D6, expanded to 43 deg long during March;
D10 f.end	Dec 24 – May 28	114	14,4		29,7		56	v.dark grey in March, v.dark brown in May-June.
D11 p.end	Mar 17 - Jun 17	140	+13 --> +19				18	Sector between 2 rifted sectors.
D11 f.end	Mar 7 – Jun 27	155	19,4		30,1		25	Became v.dark in June.
F. ends of NTD:								
D12 f.end	Feb 25 – Mar 26	232	35,7		31,8		39	F.end NTD, Feb-March.
D13 f.end	Nov 22 – Jan 21	292	19,2		32,3		25	F.end NTD, Nov-Jan.
	Jan 29 – Feb 27	305	24,7		32,0		11	
NTZ white spots & rings (AWOs)								
w3	Nov 12 - May 28	248	20,3	*5,7*	31,9	*0,3*	102	Small bright white oval with dark rim, embedded in NTD
			(Fluctuating between +14 and +27)					until Feb. No gradient. Prob. from last appar'n.
w2	Dec 4 – Feb 27	328	20,5		31,9		21	Small bright white oval in NTZ, prob. from last appar'n.
			(Fluctuating between +18 and +23)					
w4	Dec 11 – Feb 12	296	31,1		31,5		16	Tiny dark ring
w5	Apr 12 – May 15	199	32,3		32,0		13	Tiny dark ring
NTC-A means:			***DL2***	*SD*	***Lat.***	*SD*		
(inc. spots above)			**17,1**	*2,7*	**29,4**	*0,67*	10; 9	DL2 is divided between fast and slow ranges (for all lats.).
			29,4	*4,4*	**31,9**	*0,24*	6; 7	Latitude is divided between NTB and NTZ ranges (for all DL2).

Table 1 (continued)

NTC-B:												
Small dark spots in faint NTB:		**Mean:**	**-69,0**	*3,8*	**27,6**	*0,3*	5					
NTropZ & NEBn												
Name	*Time interval*	*L2(0)*	*DL2*		*Lat.*							
Barge-1	Dec 5 - July 25	310	-2		15,7							
Barge-2	Feb 28 – Aug 1	280	-2,3		16,0							
Barge-3	June 1 - July 18	--	3									
Barge-4	Feb 13 – May 20	62	0		15,6							
Barge-4	May 20 - July 28		-3									
Barge-0	Apr 19 – May 10	335	7		16,6			Short-lived				
NTropC mean (from NEBn spots above):			**0,5**	*3,9*	**16,0**	*0,45*	6					
Bulge	Nov - April	46	-2					Large bulge at f. end NEE				
Bulge	Nov 11 - Aug 8	125	-5,2		18,2							
Bulge	Dec 3 – Feb 28	209	-0,3		17,6							
NRS-1	Nov 8 - Dec 23		-5		18,9							
	Jan 13 - Mar 12	105	-1									
NRS-2	Nov - April	34	Var.		18,7							
	DL2: gradual accel. from +8,5 to -7,0											
ADS	Nov 28 - Mar 12	251	Var.									
	Grey ADS, oscillating DL2 between ~+23 and -20; lat. -17,5 to -18,8											
WSZ	Nov 8 – Apr 5	269,3	-6,0		18,4							
	Apr 6 – Jul 21	270,1	-8,2		18,7							
NTropC mean (from NTropZ spots above):			**-5,1**	*3,0*	**18,7**	*0,21*	4					

These tables combine data on single spots and averages for groups.
In black: Single spots that were long-lived or otherwise notable.
In red: Average (with standard deviation) for groups of spots representing the main currents or jets.

Spot: Name or type of feature (in grey if temporary designation for this apparition only).
W. white; d., dark.
Time interval: Dates for drift calculation (the feature may have been observed for longer).
L2(O): L2 at opposition on 2016 March 8.
DL2: Drift in L2 in degrees per 30 days.
Lat.: Zenographic latitude.
n: For single spots, number of latitude measurements.
N: For averages, number of spots or track segments.

Table 2. Positions and drifts, 2015/16: Southern hemisphere

Spot	*Time interval*	*L2(0)*	*DL2*	*SD*	*Lat.*	*SD*	*N; n*	*Notes*
S. Tropical domain								
SEB:								
SEB(N) white spots	Mean:		**-100,8**	6,2	**-11,4**	0,40	8	
White spots f. GRS	Mean:		**-42,3**	10,1	**-14,9**	1,13	13	
White spot in SEB	Nov - June	168	9,0		-16,1		78	
Reddish barge after merger	Dec 1 - May 6	86	9,2		-16,9		>37	
SEBs jet:								
Vortex W1	Dec 30 – Jan 25		118,5		-21,1		12	
White spots (vortices) exc. W1	Mean:		**131,3**	3,0	**-20,6**	0,18	5	
Super-fast white spots	Mean:		**146,3**	4,9	**-20,1**	0,28	4	
Slow wave-trains	Mean:		**82,8**	8,2	**-19,9**	0,19	10	
GRS	Sep 11 – Jul 21	242	1,9		-22,4		182	Evident 90-day oscillation
STropZ:								
Dark spots in SEB(SS)	Mean:		**9,2**	6,4	**-22,9**	0,3	9	
Oval Q	Apr 8 – May 7	214	0,7		-23,2		16	
S. Temp. domain								
Oval BA	Sep 22 – Dec 15		-13,2		-33,0		30	
Oval BA	Feb - July	350	-11,0		-33,0		107	
STB Ghost: p. end	Sep 23 – Jul 3	119	-16,5		-29,8		106	Blue-grey patch
STB Ghost: f. end	Oct 31 – Jun 21	133	-16,2		-31,3		47	Composite of recirculating spots etc.
DS5	Nov 10 – Dec 20		-13,1		-30,9		28	
DS5 (centre of Spectre)	Jan 8 – Mar 3	278	-18,0		-30,8		23	Fading; becomes centre of Spectre
STB Spectre, p. end	Mar 4 – Apr 23	278	-17,8		-29,7		40	Blue veil = Np. end of Spectre
STB Spectre, p. end	Jun 1 – Jul 21		-13,7		-29,8		11	After conjunction with the GRS
SSTBn-STZ recirculating spots:								
Retrograding d.ss. (after recirc. from prograde SSTBn)								
(1) F. oval BA	Mean:		23,5	8,0	-32	0,56	7	
(2) F. the STB Ghost	Mean:		22,2	3,2	-32,4	0,57	3	
(3) F. the STB Spectre	Mean:		27,8	4,5	-33,3	0,11	5	
Prograding spots in STC (after recirc. from retrograde):								
(1) F. oval BA								
D1	Dec 26 – Jan 25	16	-15,3		-33,3		16	
D1	Feb 11 – May 13	30	-5,5		-33,2		67	Now an anticyc. ring
(2) F. the STB Ghost								
G2	Jun 7 – 24	139	-12,0		-33,8		11	
(3) F. the STB Spectre								
S1	Feb 20 – May 20	314	-10,5		-33,7		74	
S2	Jan 29 – Mar 18	327	-3,9		-33,6		41	
S2	Mar 26 – Apr 14	330	-19,0		-33,8		15	
S2 jet: dark spots								
Initial fast speeds	Mean:		**-116,1**	6,6	**-35,7**	0,17	5	All then decelerated ,some recirculated.
S2 domain								
Slow-moving d.ss.	**Mean**		**-13,9**	0,9	**-40,6**	0,1	3	Best 3 tracks
AWOs	**Mean**		**-28,4**	4,6	**-40,7**	0,15	9	
S3 jet: white spots	**Mean**		**102,8**	1,2	**-43,6**	0,48	4	
S3 domain								
Retrograding d.ss.	**Mean**		**16,4**	10,0	**-49,0**	0,44	6	
inc.: DS3	Dec – April	132	9,5		-49,0		55	Best tracked of these d.ss.
White spot	March – July	121	-30 --> -25		-46,0		30	
AWO-1	Nov – Feb.		-19	average-oscillating			6	Continuous oscillation until March
	Mar 4 – May 15	313	3		-49,6		39	Av. of 2 segments
S4 domain								
AWO-1	Nov – Feb.		-17	average-oscillating				Long-enduring Little Red Spot
	Mar 2 – May 8	250	0,5		-59,0		71	
AWO-2	Nov – June		-12	average-oscillating			10	Continuous oscillation