JUPITER IN 2007: FINAL NUMERICAL REPORT

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Part 5: North Tropical & Temperate Regions

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The NEB was highly disturbed with extensive 'rifted' regions and reddish colour throughout the apparition. However, the major event was the NTBs jet-stream outbreak, part of the global upheaval, which initiated massive disturbances across the whole region from NEBn to NNTBs.

Mid-NEB Rifts

While other belts underwent more obvious outbreaks, the NEB was also exceptionally disturbed, with extensive activity of 'rifts' (bright oblique turbulent cyclonic areas). There was one large rifted region throughout the 2007 apparition, and usually 2-3 other shorter rifts at other longitudes. All rifts had the usual oblique form, often with white spot(s) in the middle. These rifts all obeyed the usual gradient of speed with latitude across the belt, so more southerly rifts always drifted faster **(Fig.1)**. As a result, there was extensive overlapping and entanglement of the different rift systems **(Fig.25)**. The separate rifts were revealed by the JUPOS charts in restricted latitude bands, which showed broad tracks moving at different speeds (e.g. **Fig.26**).

There had been extensive rifted regions since a new outbreak in early 2004, and some of them persisted from year to year, although they had various speeds so their history was complicated. A rifted region ~70º long in spring, 2006, seems to have evolved into the main rifted region of 2007. While the activity in 2007 was not different in kind from that in previous years, it was particularly extensive throughout the apparition.

From 2007 Feb. to April the main rifted region (A) was ~80º long, and there were two other rifts following it with similar speed (B and C), and another further f. travelling faster (F). Thereafter the activity became more extensive and complicated, as further rifts proliferated p. A (comprising region A1), and f. A (with slower drifts: D,E,J). So in the map of July 19-21, the overall rifted region was 115º long (A1-D-E-J). Meanwhile other faster-moving rifts appeared like F: G and H (both emerging p. A). These tended to be initiated with a bright white spot in southern NEB which then expanded into a longer rift (e.g. G in **Fig.25**). An even faster rift, K, was a compact white streak in NEB(S).

The main rifted region was affecting the entire width of the belt by July-August. In the NEB(S), several dark spots appeared alongside it with DL1 = +22, lat. 8.5ºN. In the NEB(N), barge no.7 disappeared as the rifted region passed it in late July; then at the f. end of the rifted region, a new white spot appeared dimly on July 29, and brightened dramatically as it passed barge no.6 on Aug.2-3.

The large number of rifts gave the opportunity to plot the gradient of speed with latitude across the NEB, as we had done for 2003/04 [previously posted on web site; copy on request]. Again we used a simplified procedure for quickly estimating numerous latitudes: for each track, we scored its visibility on a series of JUPOS charts differing by intervals of 1 deg. latitude. Thus speeds and latitudes (+/- 0.5º) were obtained for 21 tracks, summarised in **Table 5** and plotted in **Fig.1**. Many of the features were extensive rifted regions, rather than single rifts, and this incurs the risk that the speed of such a region may represent a source in a different latitude from where the majority of bright features are measured. Nevertheless, the results give a well-defined profile of the gradient across the NEB, which agrees closely with the Cassini profile (**Fig.1**).

The NEB was notably red during 2007, which was surprising as this colour normally follows an expansion event. Perhaps it was a consequence of the high level of rift activity instead.

NEBn/NTropZ

In the NEBn, most of the barges and AWOs from previous apparitions (which were very distinct in 2005 and 2006) disappeared **(Figs.27 & 28).** Some were eliminated by white spot Z, (WSZ), some by mergers, and some by rifts. Even WSZ decelerated (suddenly in April) and faded to near-invisibility as a grey patch. So, with very extensive rifting in the NEB, and turbulence in the NTropZ from the NTBs outbreak, few barges or AWOs remained. But some new barges appeared in July, and WSZ revived somewhat in August.

There were three ongoing climatic processes, any of which might have explained the disappearance of the barges and AWOs:
1) the stage of the NEB expansion cycle: the barges and AWOs had proliferated after the last NEB expansion event in 2004, and would be expected to reduce in number after a few years.
2) the NEB rifting activity, which commonly destroys barges.
3) the NTBs outbreak, which generated intense turbulence in the NTropZ.

White spot Z (WSZ) **(Fig.29)** has existed since 1997. In early 2007 it was a rapidly prograding white oval with very bright core, as usual. But then in late April it suddenly lost both its rapid drift, and its brilliance, and its powerful regional influence. This happened just after the leading white plume in the NTBs outbreak passed it. At this time WSZ had just come up f. barge no.2 (with AWO no.1 ahead of it), and WSZ suddenly halted in L2: they formed a stable triplet thereafter. (This would not have happened in previous years: WSZ always pushed or destroyed other spots which it encountered.) AWO no.1 became small and dim at this time, but always remained as a white oval. WSZ also became much dimmer than before. Then during May, WSZ lost its white cloud cover altogether, and it would have been lost but for the modern hi-res colour images. With turbulent NTB reviving alongside, it was progressively disrupted by grey streaks until by late May it was entirely grey **(Fig.29)**. It remained thus until Aug.7 when a bright white spot erupted in it [lat. 18.6 (+/-0.4)ºN]. This mostly dissipated within a couple of days, but left WSZ as a distinct grey ring with a tiny white core, until late August. (This event adds to my suspicion that WSZ was not a simple anticyclonic oval, but had some characteristics of the equatorial plumes: theoretical modelling would be of interest.)

The barges and AWOs displayed a very clear gradient of speed with latitude (**Fig.30 & Table 5**), but it only matched the Cassini profile for the southernmost (newest) barges and the northernmost AWO (white spot Z) (Fig.1). Those in between confirmed the long-established rule that stable circulations like these move more slowly than the zonal winds.

NTBs jet: Outbreak & NTB Revival

The great outbreak on the NTB was desceribd and illustrated in our interim reports, and much of the amateur data was also included in an analysis of it in *Nature* by A. Sanchez-Lavega et al. [Nature 451, 437; 2008]. The outbreak began with the appearance of two very bright spots or plumes travelling with the super-fast current of the NTBs jet-stream (WS1, WS2). Both were first seen in our images on March 27, though Sanchez-Lavega et al. reported that they were already visible as tiny bright points in HST images on March 25. [They did not exist as of March 22, although Mike Salway's image then did show the NTB(S) already slightly darkened f. L1 = 61 (passing WSZ).] They are shown in **Fig.25**, and the JUPOS chart for the whole outbreak is **Fig.31.** Massive disturbance ensued in the wake of each plume, travelling more slowly. This consisted mostly of dark spots and streaks, but also included a bright white spot (WS4) which split off the Nf. side of WS1 in its first days.

There was actually a third super-fast white plume (WS3), discovered by close scrutiny of the JUPOS charts. It appeared on April 15 at the f. end of the expanding disturbance, and only lasted for 49 hrs, but images on 4 separate rotations **(Fig.32)** showed it had the same super-fast motion. The chart (Fig.31) suggests that several more short-lived white spots like WS3 popped up briefly at the f. end of the expanding disturbance over the following weeks.

Each of the three plumes disappeared suddenly as it caught up with the chaotic dark disturbance following the other plumes. This disturbance expanded slowly to increasing L1, so WS2 disappeared on April 10-11 as it impacted the dark disturbance f. WS1. WS1 likewise disappeared on May 10 (the day before the targetted HST imaging!). It was last seen in Miyazaki's image on May 9. But on May 11, there was a much smaller white spot at its extrapolated position in Salway's image (a methane-bright mini-plume in the HST images), which could be the remains of WS1. And later, the track of the slower-moving, less conspicuous WS5 appeared to extend from this point where WS1 was lost, so it may be that an inconspicuous remnant (detached cloud cap?) of WS1 drifted south into the NTropZ and persisted as WS5.

Massive dark 'cold grey' streaks formed within the expanding disturbance. They were quite variable, but could be tracked well enough to give a range of speeds from DL1 = -11 to -31 in most cases, with two later ones moving exceptionally faster (DL1 = -58) **(Table 5)**. These speeds correspond to the N. Temperate Current C, but the dark streaks were not jet-stream vortices: none of them were consistently oval or ring-shaped. There were also signs of drifts with DL1 ~ 0, but only for short-lived segments of belt (and WS4).

By mid-May, the p. end of streak DS6 had become the p. end of a massive dark belt that was imperceptibly turning red (see maps in **Fig.25**): it was grey on May 11, grey-brown on May 15-17, brown from May 27 to June 9, and red-brown (but the p. end now being gradually tapered) from June 16 onwards. This single p. end locus was tracked with DL1 = -31 (May 11 to July 4) but segments of it had DL1 ~ 0 over some weeks. (While this sector of NTB had become dark red-brown, the other sector was broader and paler and pinkish-grey at this time.) By early July the dark streaks had all merged into a revived red-brown NTB, but the same p. end locus reappeared as a distinct p. end of darker belt, with well-defined DL1 = -28 from July 4 to Aug.28.

However, from its latitude this 'revived NTB' was really only the south component.

In August, surprisingly, two tiny dark projections from NTBs were tracked with positive DL1. The speed suggested the North Temperate Current B (as listed in the Table), but the latitude was anomalous. One of them moved with a small dark spot in the NTB at 24.5^{o}N, so possibly the projections arose from features at this latitude.

However, Fig.1 shows that the dark and bright spots throughout this outbreak showed little adherence to a consistent jet profile. This may be because the disturbance comprised the break-down of the vertical profile of the jet, as the super-fast NTC-D was replaced by the more usual NTC-C current at cloud-top level (as also noted by S-L et al., 2008).

In the following year, more features would be tracked on NTBs, giving further insight into the whole of the NTBs outbreak and global upheaval: see: http://www.britastro.org/jupiter/2008report03.htm

N. Temperate Zone

The NTZ and NTropZ were both filled with intricate turbulence from the outbreak. At low resolution this appeared as dark shading, initially grey but later pinkish-grey, as the red colour of the revived belt spread widely in latitude.

From June onwards at least 6 grey streaks emerged out of the murky turbulence in the NTZ, moving with the North Temperate Current A: mean DL2 = +27 at latitude 32ºN. So these were features of the NTB(N) which was otherwise still absent.

NNTBs jet

The NNTBs jet-stream had carried numerous spots in 2006, but only 9 small spots were tracked in 2007, and they all disappeared after the NTBs outbreak.

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TABLE 5 & FIGURES ARE ON FOLLOWING PAGES.....

TABLE 5A.   2007: Positions and drift rates: N. Tropical region

Current/ Spot no.	*Description*	*DL2 range (approx.)*	*Lat. (from charts)*	*Dates*	*No. of tracks*
N. Intermediate Current					
A-E (& J)	Main NEB rifted region:	~-55 to -85	12-13.5	Feb-Sep.	10
	(& faster tracks emerging p.):	-99	12	June-Sep.	2
F1,G,H	Separate rifted regions	~-114 to -137	11.5-12	Feb-Sep.	4
	(& faster tracks within, inc.):				
F2,G,K	Well-defined short-lived rifts	-141 to -183	10-11	May-Aug.	5

N. Tropical Current

Spot no.	*Description*	*L2(O)*	*DL2*	*Lat.*	*(SD)*	*Dates*	*Notes*
1	AWO	40	-2	18.4	0.61	March-May	
			-5.5	18.6	0.5	May-Sep.	
2	Dk. barge	50	-3.4	15.6	0.4	April-Sep.	Accel.; Lat. decreasing?
3 (WSZ)	w. oval	60	-11	19.2	0.59	Jan.-April	
	grey patch		-1.5 -> -6	18.1	0.63	April-Sep.	
	w. core			18.4	0.43	Aug.	
5	Dk. barge	(94)	0	16.3	0.63	June-Aug.	New. Lat. decreasing
6	Dk. barge	146	-3	15.7	0.43	Jan.-Aug.	Lat. decreasing. Destroyed by rifts in late July.
7	Dk. barge	182	-16	14.8	0.47	May-July	New. DL2 varying.
8	AWO	(296)	0	18.2	0.3	March-April	Poss. product of merger
9	Dk. barge	291	-6	15.2	0.54	April-May	
	(v.small)		1	15.8	0.39	May-Aug.	
10	Dk. barge	321	3	16.4	0.47	June-July	Small w.s. on S edge in July
11	AWO (new)	(326)	3	17.9	0.46	July-Aug.	New
		Mean (barges):		15.8	0.5		(N=6)
		Mean (AWOs):		18.4	0.4		(N=4)

NTBs jet:

Spot no.	*Notes*	*L1*	*DL1*	*Lat.*	*(SD)*	*Dates*	*No.of spots*
NTC-D:							
WS1	V. bright	48 -> 0 -> 177	-162	23.0	0.32	Mar.27-May 9	
WS2	V. bright	103 -> 40	-154	23.0	0.35	Mar.27-Apr.10	
WS3		96 -> 86	(-158)	23.1	0.34	Apr.15-17	
	MEAN:		-158	23.0	0.06		(N=3)
NTC-C:							
WS4	Split off WS1	47	(0)	24.7	0.32	Mar.29-Apr.3	
WS5	Remains of WS1?	140 -> 121	-27	21.9	0.52	May 31-June 23	
			[WS1,2,5: Speeds +/- 2 deg/mth. WS3 and WS4: short duration, speeds less precise; no. of obs'ns = 4 (WS3), 6 (WS4).]				
Dark streaks (numbered as on charts, in order of appearance):							
	DS1, DS2 (etc.)	(15-75)	(-30)	24.3	0.75	April	
	DS4: p.end	360 -> 320	(-25)	24.4	0.37	Apr.18-May 30	
	DS5	354 -> 345	-30	23.6	0.4	April 9-22	
	DSX: p.end	322 -> 301	(-25)	23.8	0.39	Apr.13-May 9 (-> July 28?)	
	DS6: p. end	236 -> 177	overall: -31	24.2	0.49	May 11 - July 4	
			segments: (0)			(cont. below)	
	DS7: p.end	191 -> 188	(-14)	24.3	0.37	May 24-June 2	
	DS7	)	-15				
	DS8	) (178-220)	-11	24.1	0.47	May	
	DS9 & 10	)	-23				
	DS11	333 -> 319	-30	24.1	0.45	May 26-June 8	
	P. end main NTB	177 -> 124	-28	24.1	0.37	July 4 - Aug.28	
	MEAN:	(all exc. 'segments')	-23.8	24.1	0.25		(N=11)
Later dark spots (fast):							
	DS12	327 -> 303	-58	24.8	0.48	June 30- July 12	
	DS13	360 -> 332	(-53)	25.2	0.38	June 22 - July 10	
NTC-B?							
Later, v.small dark NTBs projections:							
1	Small dk. proj.	251 -> 317	+37 -> +74	23.5	0.56	July 26 - Sep.3	
	with d.s. in NTB:			24.5	0.61		
2	Small dk. proj.	1 -> 49	+90	23.2	0.49	Aug.5-23	

Table 5B: 2007: Positions and drift rates: N. Temperate region

	DL2	Lat.	(SD)	Dates	No.of spots
N. Temperate Current A					
Dark grey streaks in NTZ (N=6):	mean +27.0 range +22 to +31	32.2	0.49	June-Aug.	N=6
NNTBs jet					
Small dark spots (N=9)	mean -84 range -80 to -87	34.7	0.54	Feb-May.	N=9

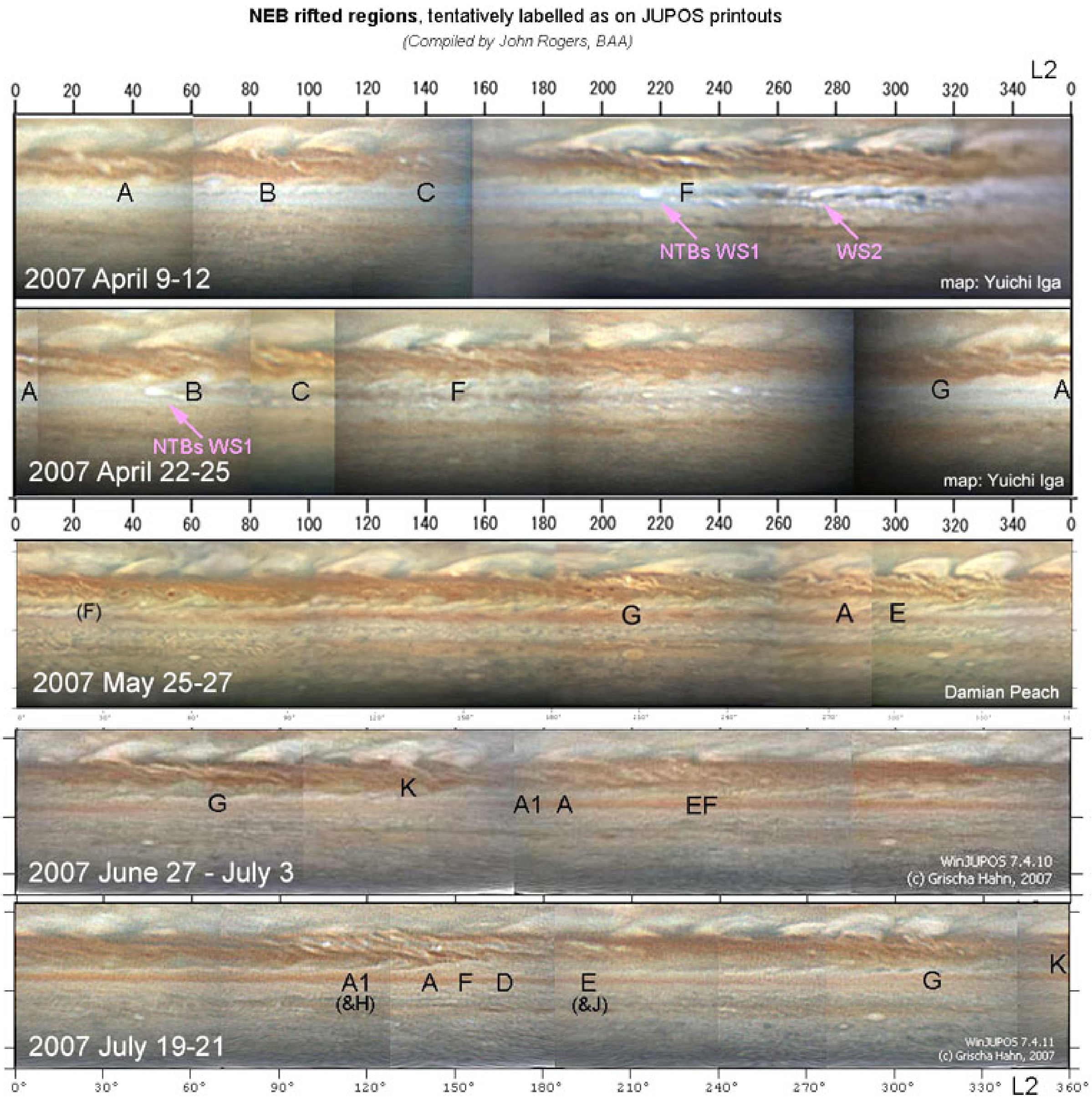

Fig.25. Five maps of the NEB, adapted from the global maps in Fig.2, aligned in L2. Letters below the NEB indicate approximate locations of rifted regions identified from the JUPOS charts such as Fig.26. Although they were fairly distinct in April, in the later maps some of the different rifted regions were extended and overlapping.

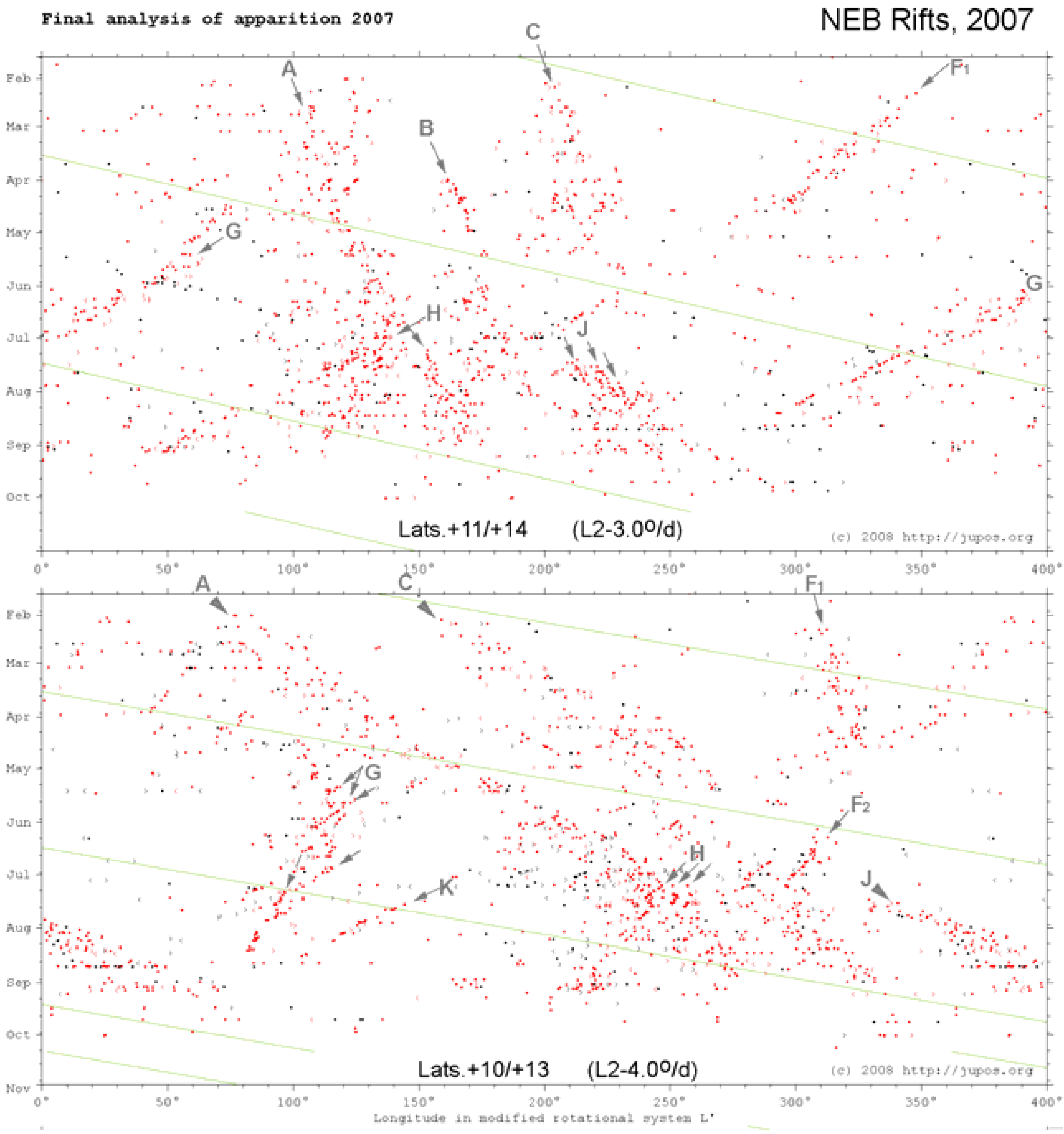

Fig.26. JUPOS charts of white spots and rifts in the NEB. These are just two examples of those used to track the rifts. Similar charts were generated for all 3-deg. latitude bands across the NEB and with longitude systems moving at speeds ranging from 0 to -4.0 deg/day in System 2. Diagonal green lines represent L2 = 0.

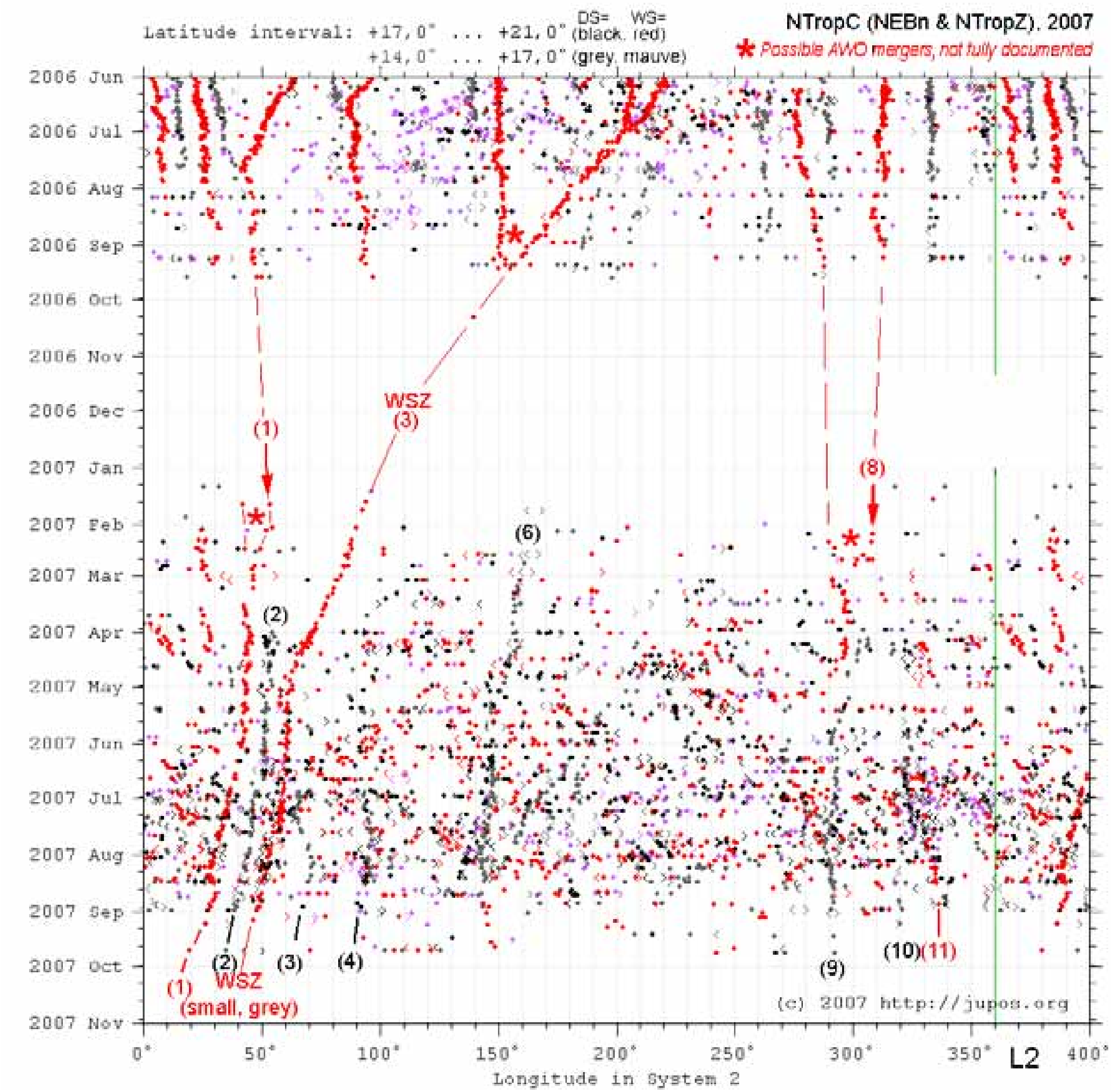

Fig.27. JUPOS chart of barges and ovals in the NEBn, 2006-2007. Tracks of grey points represent barges, tracks of red points represent white ovals.

[Figs. 28 & 29 are on the following page.]

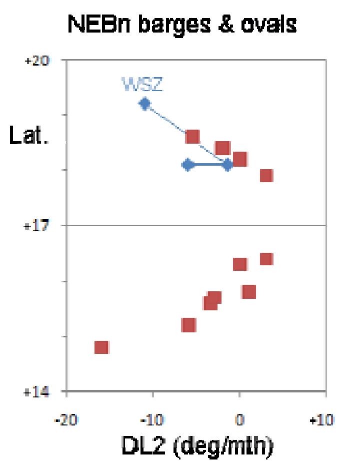

Fig.30. Chart of speed vs. latitude for the NEBn barges and ovals (data from Table 5). Blue diamonds represent white spot Z.

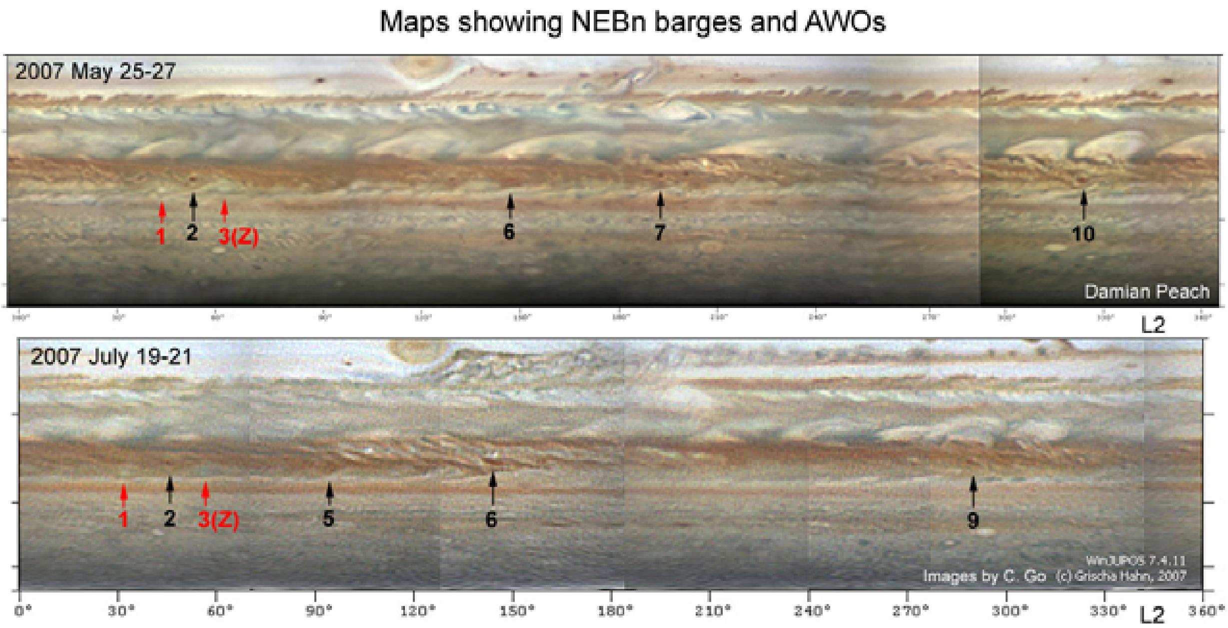

Fig.28. Two maps of the NEB, adapted from the global maps in Fig.2, aligned in L2. Barges and ovals are indicated as in Table 5.

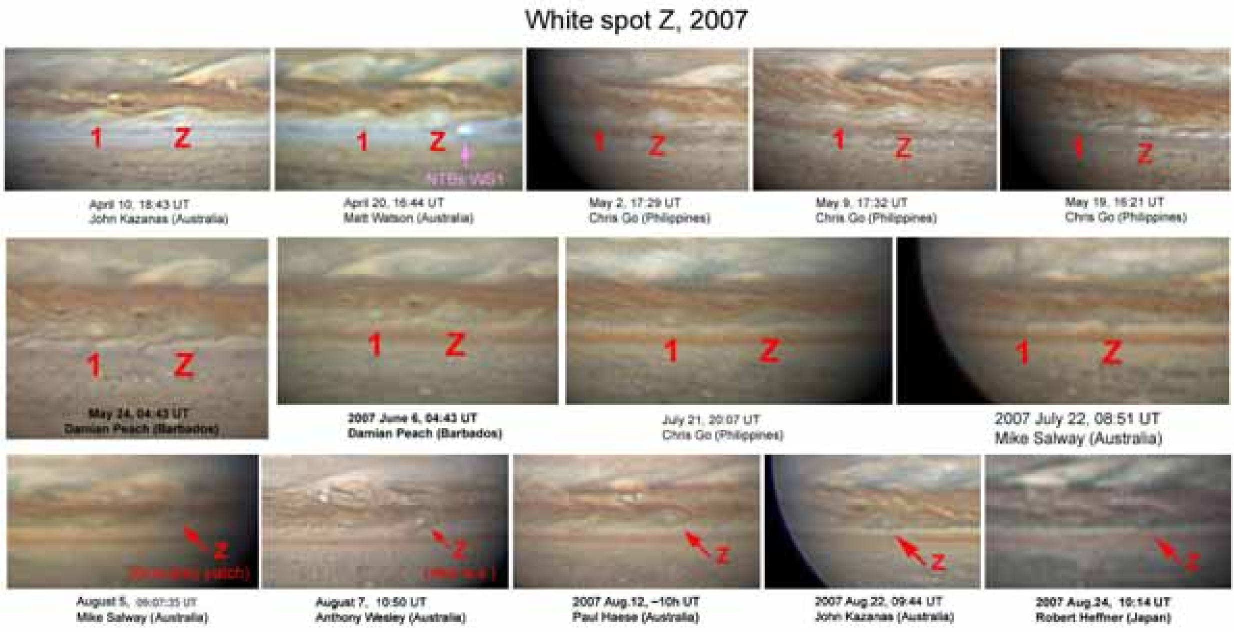

Fig.29. Images of white spot Z, with white oval no.1 p. it, and the small barge no.2 between them. WSZ lost its bright cloud cover after the brilliant WS1 in the NTBs outbreak passed it. A white spot suddenly appeared within it again on August 7.

[Fig.30 is on the previous page.]

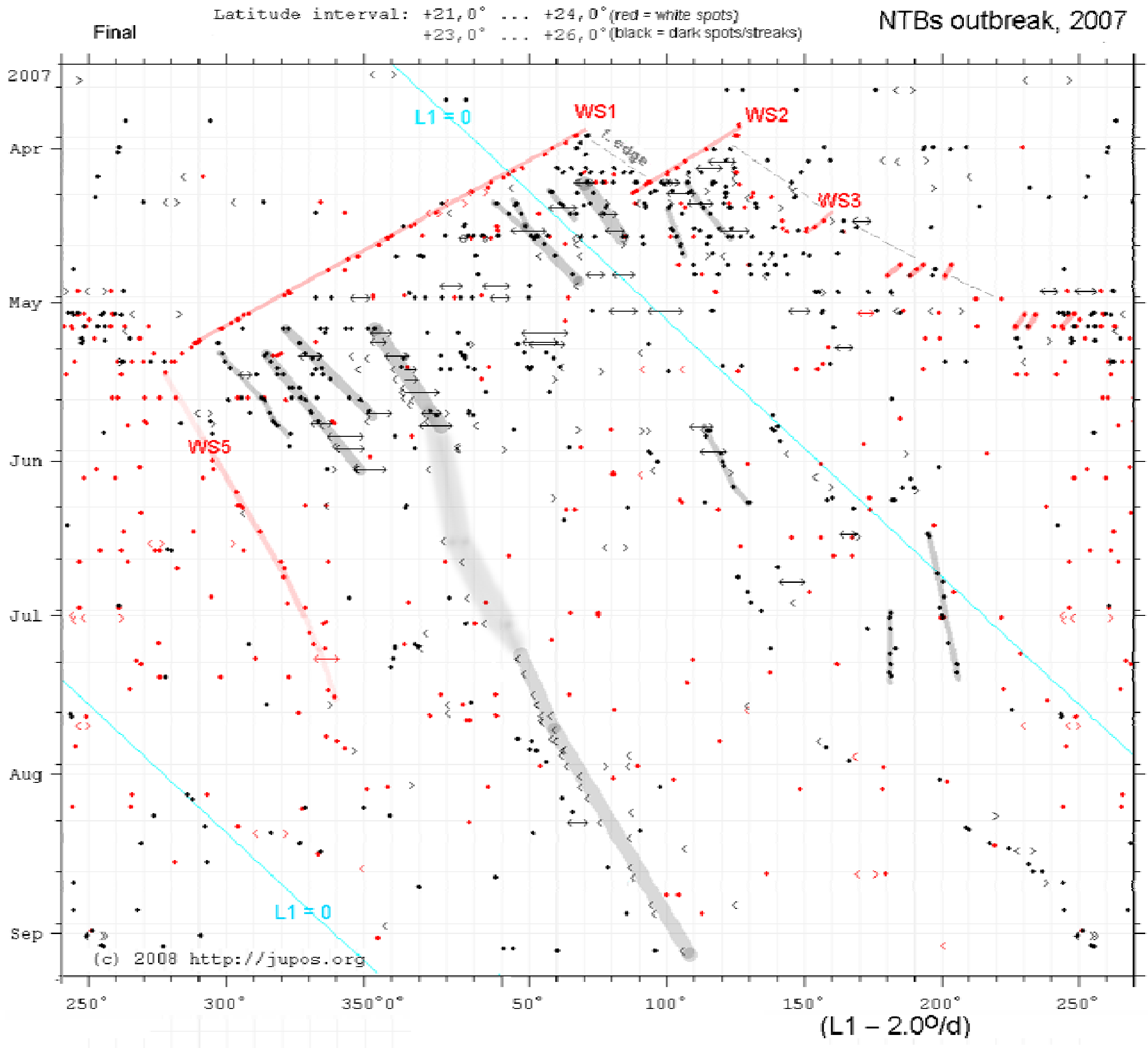

Fig.31. JUPOS chart of the NTB outbreak: white spots in lats. +21 to +24, dark spots in lats. +23 to +26, longitude scale moving –2.0 deg/day in System I. < > denote p. and f. ends of NTB segments. WS4 is not included as it was at lat. +24.7.

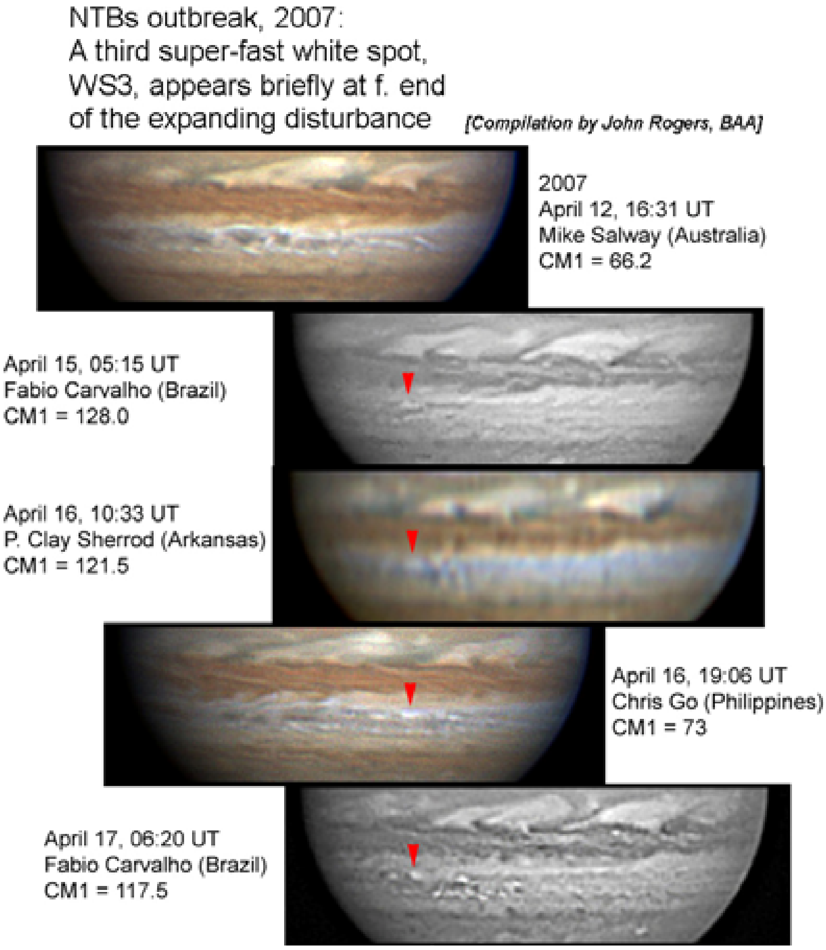

Fig.32. The third super-fast bright plume in the NTBs outbreak: the 49-hour life-span of WS3.