

Jupiter's North Equatorial Belt and Jet: I. Cyclic expansions and planetary waves

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A report of the Jupiter Section, using data from the JUPOS team

Figures (mini-copies)

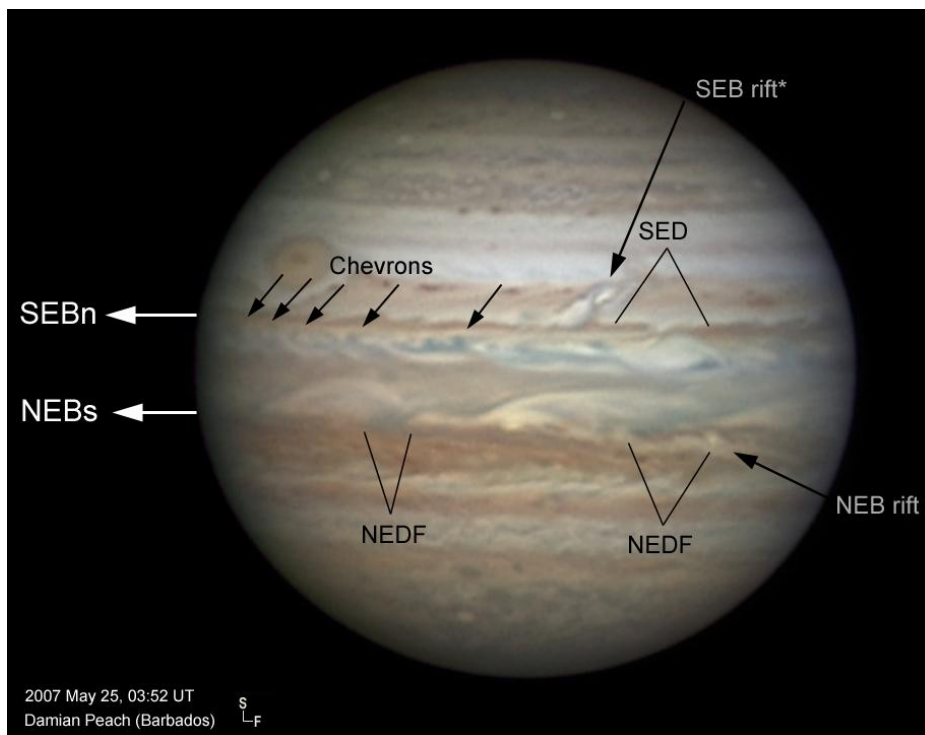


Figure 1. Hi-res image of the planet showing typical NEDFs, and a comparable large-scale wave structure in the southern Equatorial Zone called the South Equatorial Disturbance (SED), as well as small super-fast spots on the SEBn jet called chevrons, and rifts in both NEB and SEB. (Image taken on 2007 May 25 by Damian Peach.) *South is up in all figures.*

[Next page:]

Figure 2. Alignments of map sectors from 1995-2010, showing NEEs. These all include the GRS. A similar set showing white spot Z (WSZ) is in our long-term report on it [Ref.28]; it is also marked in a few panels here, as is oval BA. Scale marks at bottom of some panels are at intervals of 30° longitude. Sources are as follows: for 1995-1999, images by I. Miyazaki, maps by H-J. Mettig (mostly published in our reports in the Journal). For 2000-2002, images by A. Cidadao and T. Akutsu, maps by H-J. Mettig. For 2004, images by D.C. Parker, map by D. Peach. For 2003, 2005, 2006, 2007, and 2010, images and map by D. Peach. For 2008, images by A. Wesley and M. Salway, map by M. Vedovato. For 2009, images by T. Barry, C. Go & T. Akutsu, map by M. Vedovato. Intensities and colours have been arbitrarily adjusted so should not be used for comparisons. *South is up in all figures.*

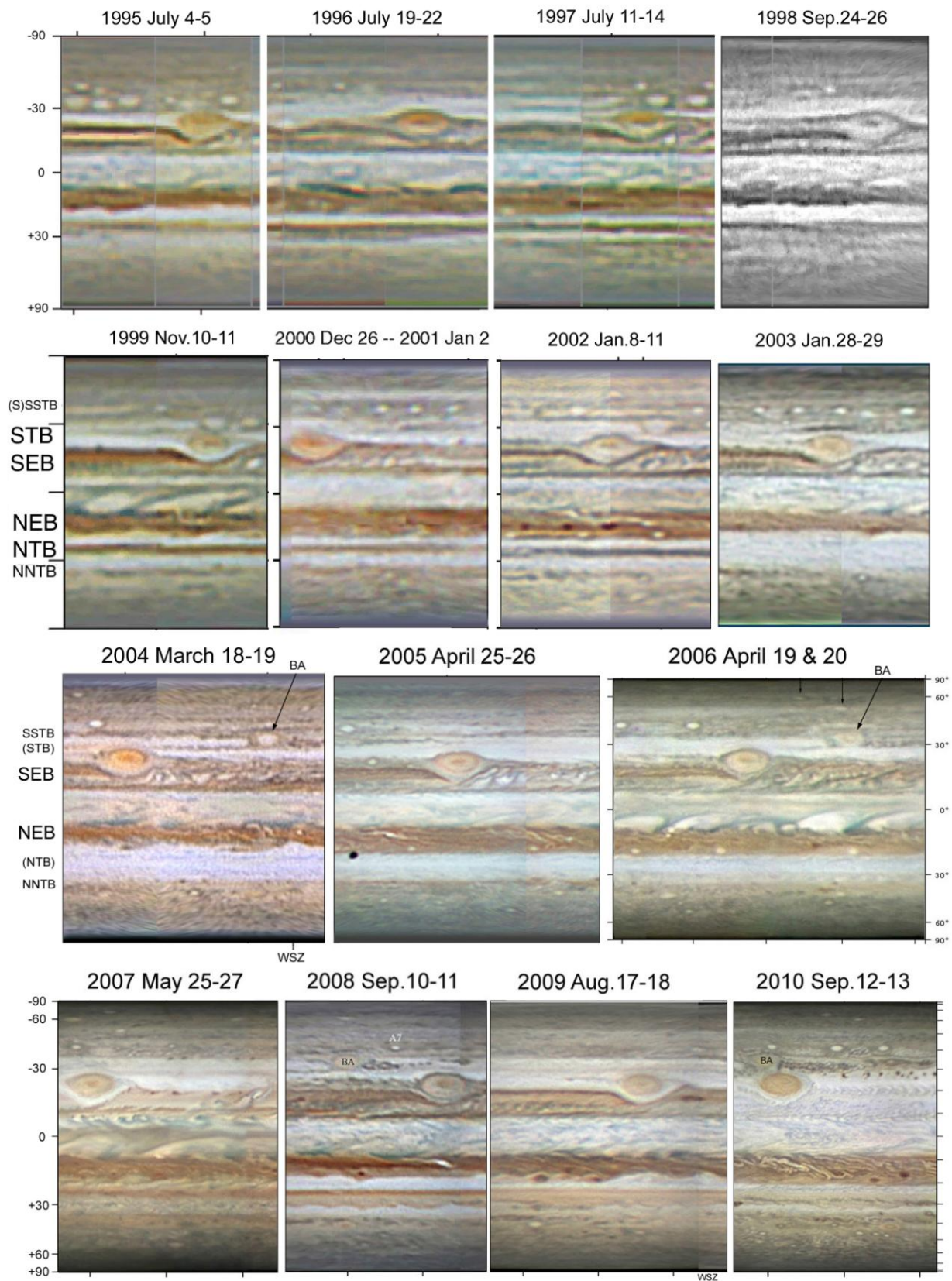


Figure 2.

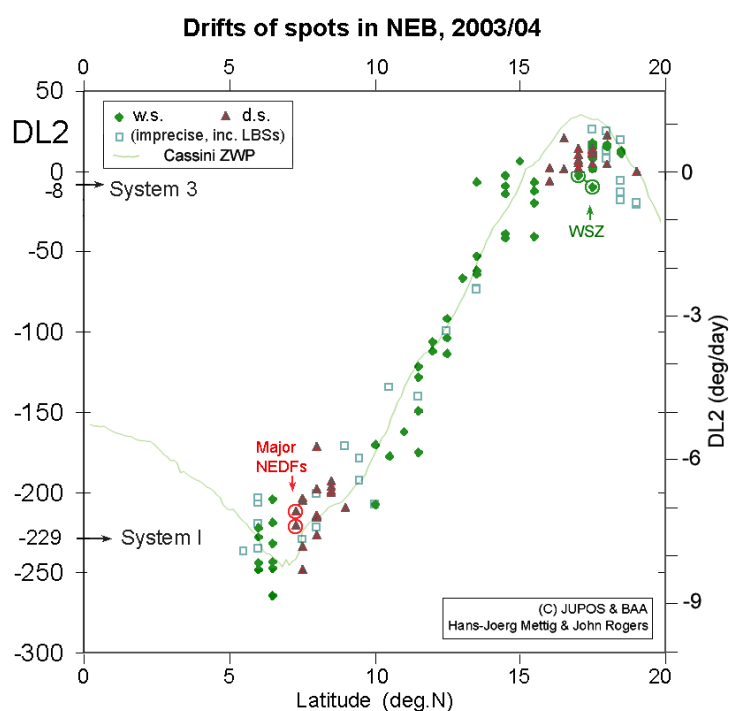


Figure 3(A). Chart of speed vs. latitude across NEB in 2003/04: [Ref.30, report no.5]. Latitudes of white spots (w.s.) and dark spots (d.s.) were assigned to the nearest half-degree by comparison of the visibility of tracks on JUPOS charts at one-degree latitude increments, prepared by H-J. Mettig. Most drift rates are accurate to ± 4 deg/month, but open squares indicates less precise drift rates (due to spots with shorter lifetimes or more variable drifts), accurate to perhaps ± 10 deg/month. In the range 17-19°N, these open squares are sequential values for Little Brown Spots which were oscillating with periods ~ 20 days. Symbols are circled for large spots which would have been tracked visually: white spot Z on NEBn, and averages for two groups of dark projections on NEBs. The larger scatter of drift rates at low latitudes may be because some spots are associated with the NEDFs, while others have faster speeds following the overall gradient.

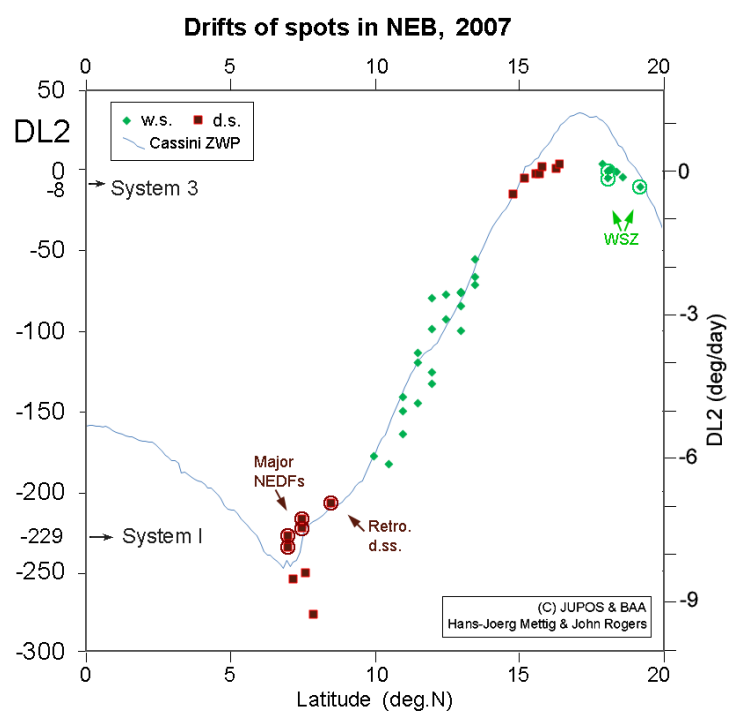


Figure 3(B). Chart of speed vs. latitude across NEB in 2007, produced as in (A); enlargement of data in our 2007 report [Ref.20].

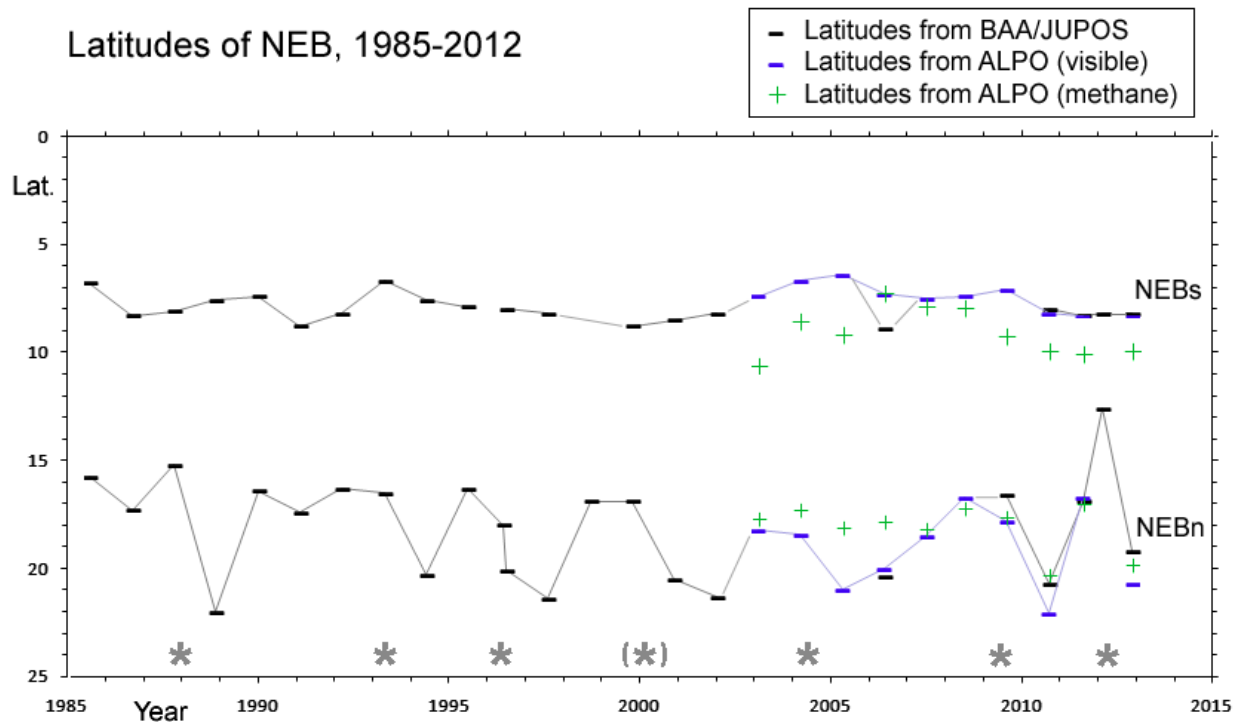


Figure 4. Chart of latitudes of the N and S edges of the NEB over the years 1985-2012. Asterisks indicate times of onset of NEEs. Data are from the following sources: 1985-2002 (black), BAA/JUPOS apparition reports published in the Journal of the BAA (except 1993 and 1994 which are still unpublished); 2002-2012 (blue and green), ALPO apparition reports published by R. W. Schmude in the Journal of the ALPO; 2009-2012 (black), estimates from hi-res maps produced by Marco Vedovato of the JUPOS team. Green crosses are measurements from methane-band images ($0.89\ \mu\text{m}$), in which the NEBs was often at much higher latitude than in visible images, and the NEBn sometimes did not change during visible-light NEEs.

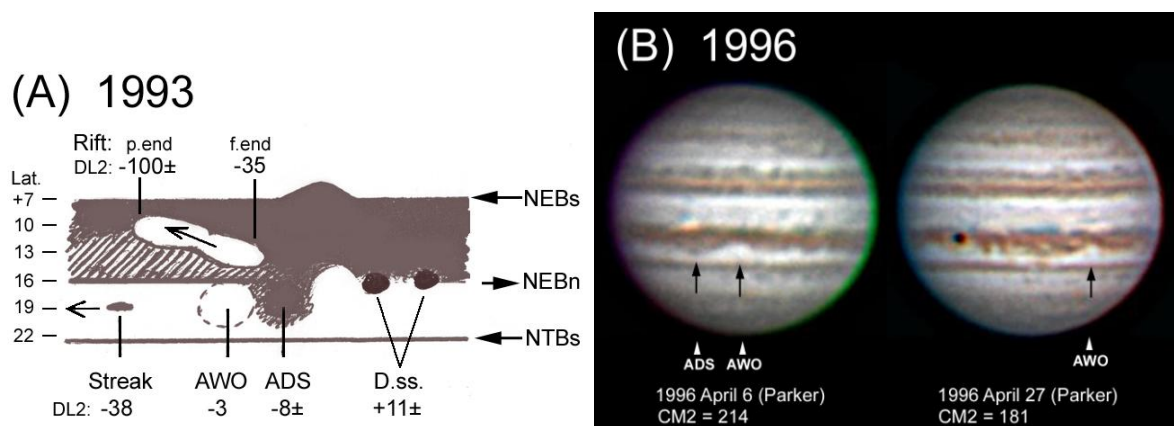
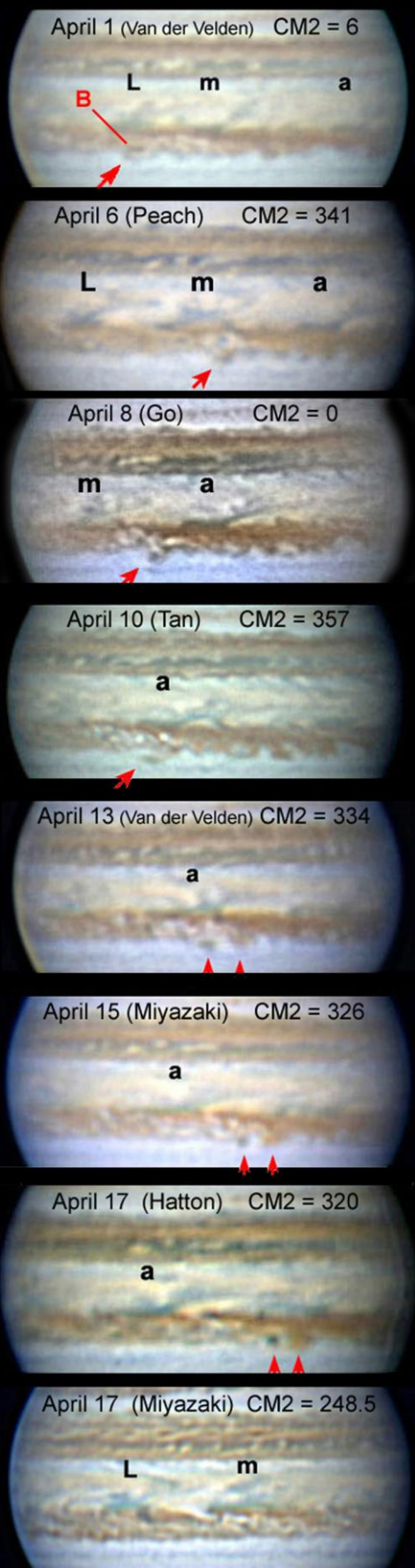


Figure 5. Images of early stages of four NEEs, including NEBOs. (A) 1993; (B) 1996; (C) 2004; (D) 2009. (A) The NEBO at the origin of the NEE in late March, 1993, summarised from drawings and photographs. Numbers are drifts (DL2) in degrees per month. (B) Origin of the NEE in 1996 April. On April 6 (the first image to show it) there is a newly formed ADS and bulge just p. an AWO. By April 27, a spotty expansion of NEBn has spread some way p. this AWO. (Colour fringing of the disk and satellite shadow are due to time intervals between the colour channels.)

(C) 2004



(D) 2009

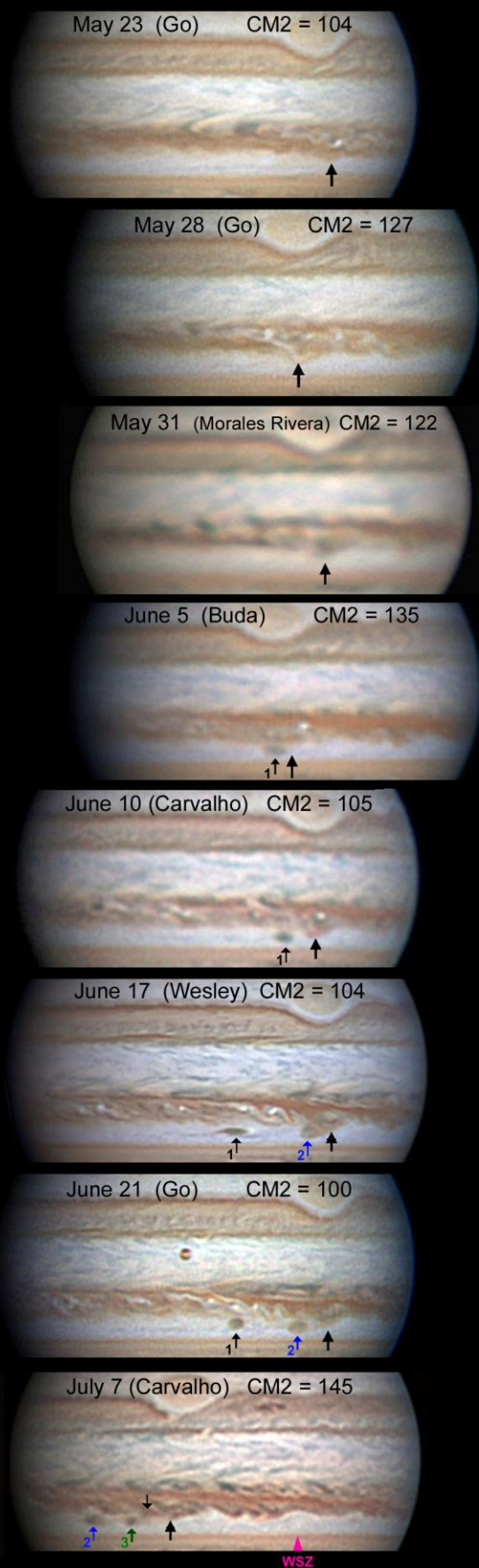


Figure 5 [cont.]. (C) Origin of the NEE in 2004 April. On April 1, a NEBO begins as an ADS (red arrow) appears adjacent to a pre-existing barge (B), while a large NEB rift system is passing it. New bright rifts then proliferate around this longitude. While the first ADS changes from grey to brown, a second, very dark grey ADS appears 10° p. it on April 13. Meanwhile, NEBs dark formations labelled L, m, and a drift past; m and a are disturbed as they pass the outbreak. The final panel shows the sector p. the NEBO, filled with the large pre-existing rift system.

(D) Origin of the NEE in 2009 May-June. On May 23 a brilliant white spot appears in a pre-existing rift system (arrow). By May 28, this develops into rift pushing northwards into the NTropZ, which generates a very dark grey ADS (May 31). This is the first of three ADSs which are formed at this site and prograde (numbered arrows).

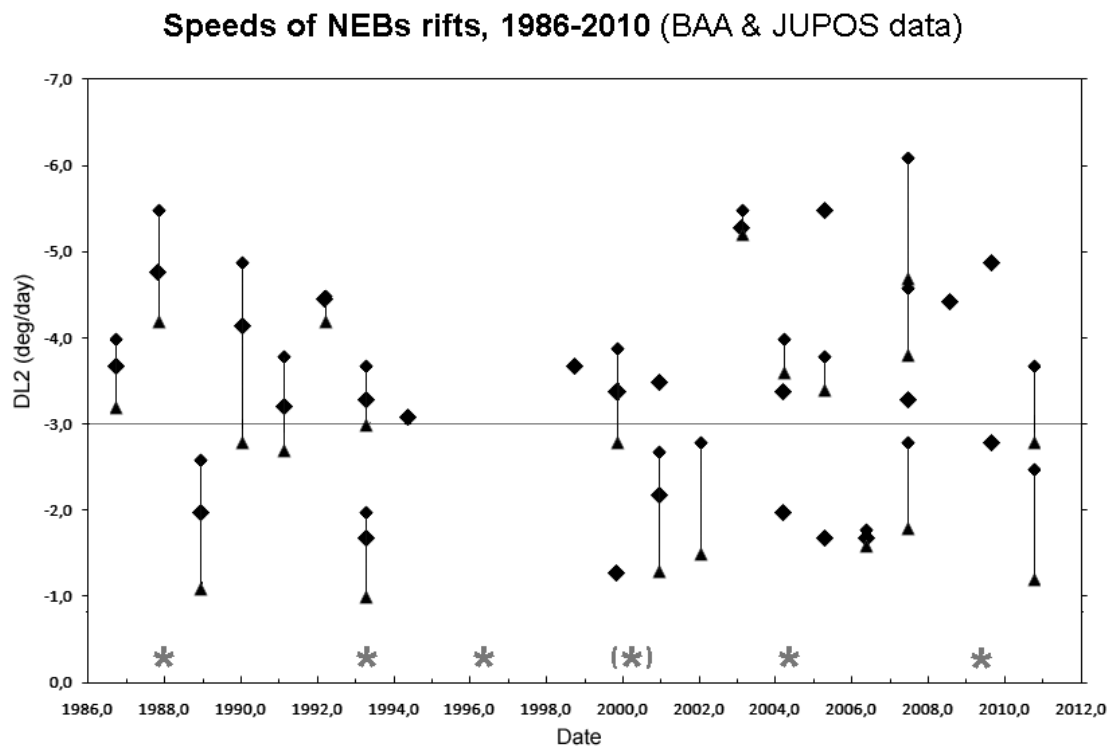


Figure 6. Chart of speeds measured for NEB rifts, 1986-2010 [Ref.29]. Large diamonds, averages or single points; small diamonds and triangles, range of observed speeds; asterisks, dates of onset of NEB expansion events. Note that speeds are largely segregated into ranges above or below -2.8 deg/day.

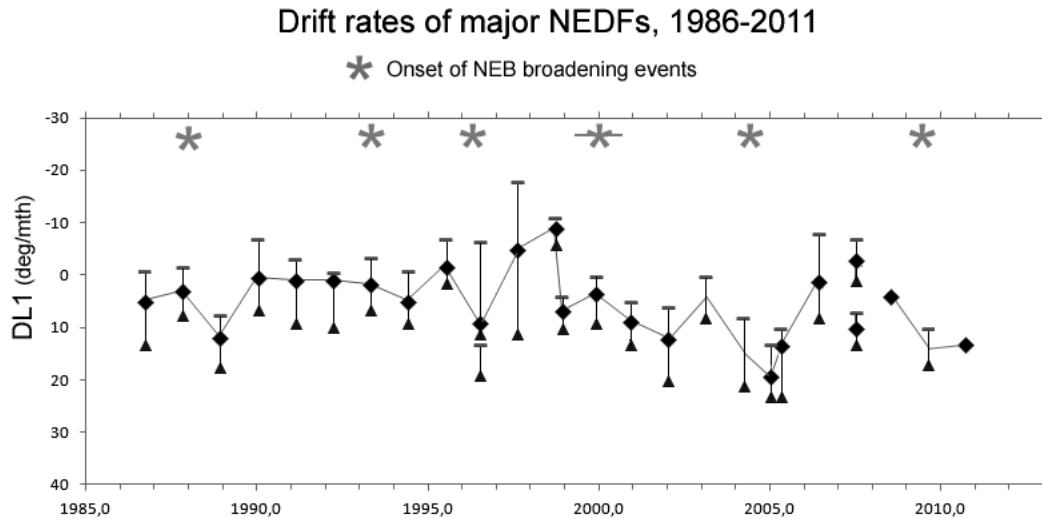


Figure 7. Chart of NEDF speeds in each apparition. 1986-2010. Bars show the range of speeds observed. Only the major NEDFs are included, so the list is comparable with the historical record and does not include small features which might have different characteristics. Asterisks indicate times of onset of NEEs.

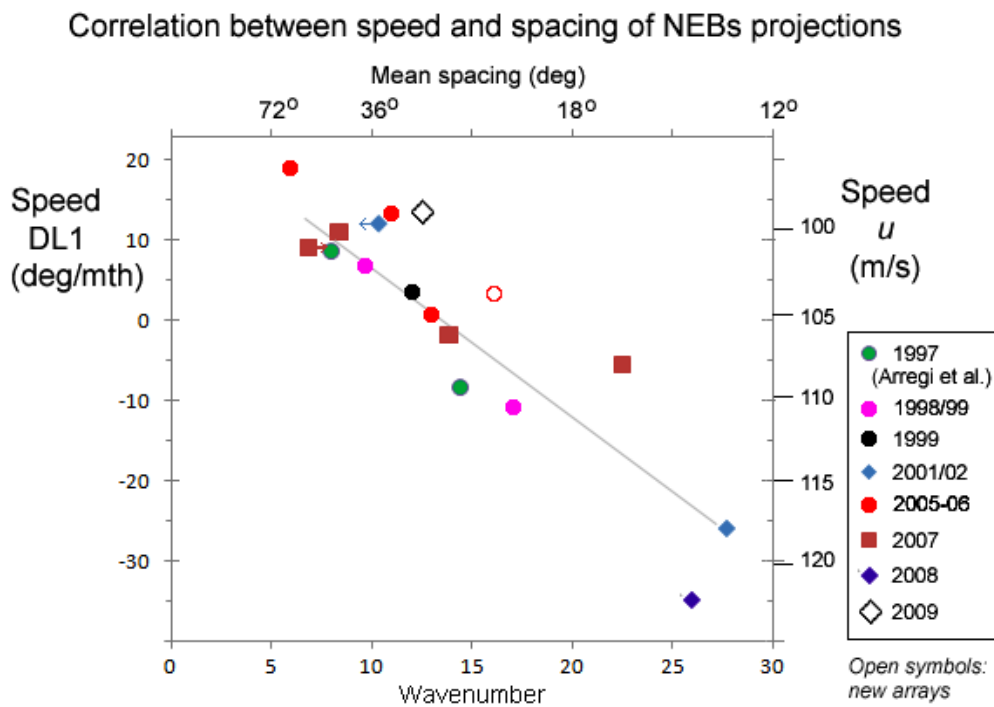
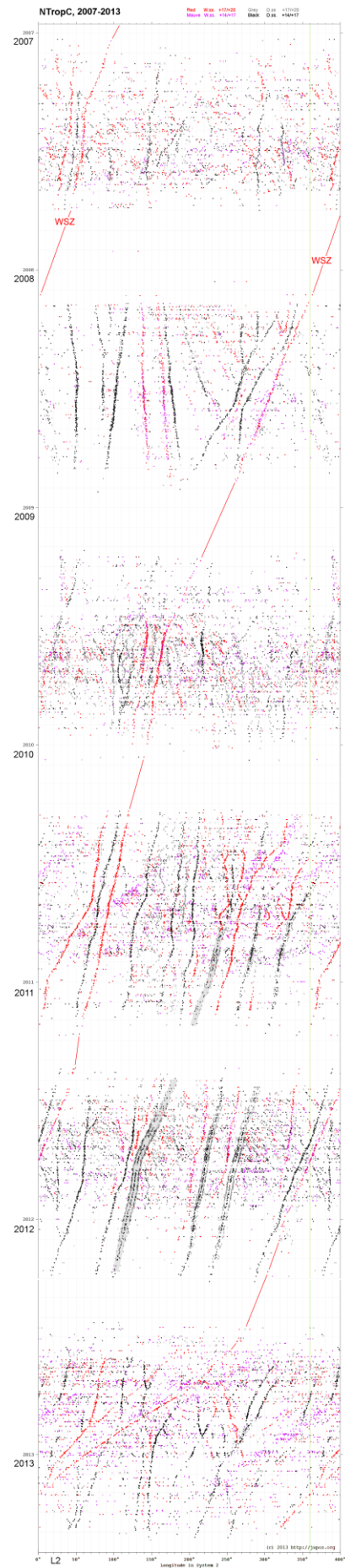
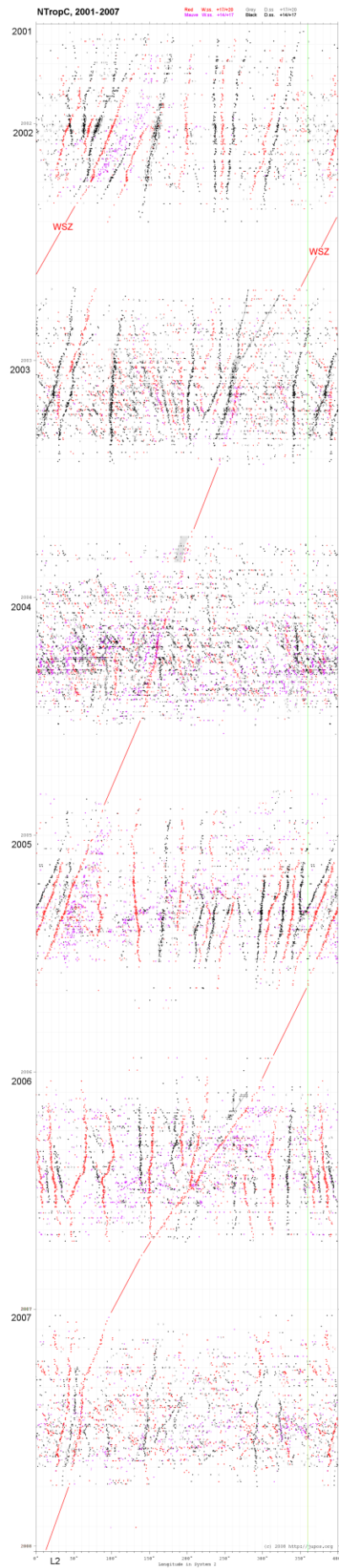


Figure 8. Correlation between speed and spacing for NEDFs, from BAA/JUPOS reports, plus 1997 points from [Ref.18]. Chart updated from [Ref.20]. Points are only plotted for times when there were arrays of NEDFs with reasonably uniform spacing. Open symbols represent poorly-fitting values, which were for newly-created arrays of NEDFs, suggesting that the relationship may be disturbed in times of transition. This chart includes ‘fast’ but not ‘super-fast’ features.

Appendices (Supplementary Online Material)

- I. JUPOS chart of NEBn/ NTropZ from our long-term WSZ report [below, from [Ref.28](#)].*
 - II. Summaries of the observations year-by-year for NEB rifts [already posted, [Ref.29](#)]*
 - III. Ditto for NEDFs [below]*
 - IV. JUPOS/BAA chart of NEBs formations in 1998/99 [below].*
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APPENDIX I:
JUPOS chart for
N.Tropical domain,
2001-2013 (in L2).
Track of WSZ is
marked in red.
(From [Ref.28](#))



APPENDIX III: Chronicle of appearance of the NEDFs, 1986-2010

These notes summarise the appearance and behaviour of the NEDFs (including 'fast' features when present), in each apparition, from the same sources listed in the main text, viz: published BAA reports up to 2002, on-line BAA/JUPOS reports from 2005-2009, and unpublished data as noted below.

In 1986/87, several large dark plateaux on NEBs 'collapsed' as rifts passed, then disappeared, while their p. ends appeared to prograde rapidly.

In summer 1987, there were still some long plateaux but some largely featureless sectors. NEDFs were very variable, some large, some again 'collapsing' in the p. direction, with rift interactions. From 1987 Sep. onwards, more NEDFs were developing. (NEE started at the end of Dec.)

In 1988/89, NEBs features were inconspicuous, not projecting into EZ.

In 1989 Aug-Sep., NEBs remained quiet. In Oct-Nov. a great NEB rift induced an impressive series of NEDFs, but they mostly subsided after ~2 weeks. From 1990 Jan. onwards there were more substantial NEDFs (probably the earlier small ones were revived by a rift).

In 1990/91 there was a complete array of NEDFs, spacing 25-35°, mostly large and well-formed and stable.

In 1991/92 and 1993 there was still an array of major NEDFs, many being stable. In 1994 there were still some typical major NEDFs, though some sectors had only minor features [BAA, unpubl.]. In 1995, NEDFs were still quite conspicuous but variable and not stable for long.

In 1996 (after the NEE started in early April), there were typical dark plateaux all round in late April, but by late May the NEBs was more broken up and variable. Many NEDFs became large and dark and bluish since the NEE. They included 4 large slow-moving plateaux (DL1 = +13 to +19), but also a sector of 6 more variable projections.

In 1997, NEDFs were irregular and very rapidly varying, with diverse drifts.

In summer 1998, the NEBs was exceptionally disturbed, with 3 sectors: (i) NEDFs subdued or chaotic; (ii) 4 NEDFs with DL1 ~ -11, spacing 21°; (iii) 4 NEDFs with DL1 ~ +4 to +9, spacing 38°. In autumn, drifts reversed and some oscillated. By early 1999, all sectors had more coherent DL1 ~ 0 to +10.

In 1999/2000, there was an exceptionally conspicuous array of 12 projections with well-formed dark festoons, leading into a very dark EB; drifts were fairly stable (DL1 = 0 to +9).

In 2000/01, there were still very dark festoons and EB up to 2000 July, but these were broken up in Aug-Sep., and some NEDFs disappeared, leaving only 7. By Dec., the festoons and EB had almost disappeared.

In 2001/02, there were only 4-5 remaining large features (long low plateaux with thin festoon). Meanwhile there were also numerous fast-moving small spots, both bright spots in EZ(N) and dark projections.

In 2002/03, there were plenty of large projections but they were variable and transient; and many short-lived rapidly-moving spots, mostly bright spots in EZ(N) but also some dark projections. [JUPOS, unpubl.]

In 2003/04, there were several examples of NEDFs altered by passing rifts. In early 2004, there was a well-defined array of 11 large dark projections, and again some fast-moving small spots; these cut across the positions of some large features, but were mostly seen at the former locations of two which were broken up by passing rifts. Again these fast features included many bright spots (6 to 6.5°N) and some dark spots (7.5°N). (There were also many spots with exceptional positive DL1, at 8-9°N.) [JUPOS, unpubl.]

In 2004/05 [*updated from final report*]: there were initially 6 long plateaux with extreme positive DL1; disrupted by rifts in 2005 Feb. and replaced by a new array of NEDFs. (All at ~ 8 deg.N.)

In 2006 [*updated from final report*], there was a major change, last seen in 1999: the NEBs was dominated by a very regular array of 12 formations with faster speed (DL1 $\sim +1$), whose festoons were much darker than before, as was the EB; this led up to the global upheaval of 2007. (A pair of very fast white spots, DL1 = -27, at 8.2°N , in plume cores, were atypical. There were also small retrograding features.)

In 2007, The dark projections and festoons were still very prominent, dark blue-grey, linked to the very dark brown Equatorial Band. All these features gradually faded to moderate darkness during the summer. There were about 12 well-defined projections, but they were quite variable in appearance and drifts, with a number of mergers, splittings, and new appearances during the year. There appeared to be two concurrent sets - one set of compact projections with zero or slightly negative DL1, and a set of longer, more widely spaced plateaux with positive DL1 - probably superimposed as wave-trains showing interference. Two of the formations consisted of successive fast-moving dark projs., DL1 from -17 to -37 (at 7.3°N). There was also one white spot (7.9°N) with DL1 = -47 for one week.

In 2008, the typical large projections were subdued and few in number, and the space vacated by them was occupied by small spots and projections with unprecedentedly fast speeds [*see main text*].

In 2009, up to June, there were no large features on NEBs, but there were minor transient festoons with DL1 ~ -18 to -40 (mean 7.0°N). But in July, all was transformed with the appearance of many retrograding dark spots, large and small, probably generated by the adjacent rift system associated with the ongoing NEE. There were 10 of them by Sep-Oct., with a typical spacing of 29° . Only a few fast features were detectable up to early Sep., and none thereafter.

In 2010 and 2011/12: *See Paper II [new analysis for this report]*.

APPENDIX IV. JUPOS/BAA chart of NEBs formations in 1998/99.

JUPOS chart of all visual and photographic measurements (produce by H-J. Mettig, annotated by JHR).

