Jupiter in 2011/12: Final report up to 2012 February

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John H. Rogers & Gianluigi Adamoli,
using results from the JUPOS team (Hans-Joerg Mettig, Gianluigi Adamoli, Michel Jacquesson, Marco Vedovato, Grischa Hahn)

[EXTENDED SUMMARY: See separate file]

Introduction

Opposition was on 2011 Oct.29 at declination 12ºN in Aries – still close to perihelion with a large disk diameter, and at a decent declination for northern hemisphere observers. After solar conjunction on 2011 April 6, the first images were taken by Tomio Akutsu only three weeks later. Many good images were taken from 2011 June to early March, 2012, and some at lower resolution into 2012 April.

This report only covers the period up to 2012 Feb. or early March. The planet was generally quiet during this period, with the SEB reverting to normal behaviour after the SEB Revival in 2010, and the NEB becoming increasingly (exceptionally) quiescent. Sets of images and maps from this period were posted in our reports nos. 2 and 3. (In this text, our interim reports for 2011/12 are cited as 'report no....'; they are all listed in Ref.box A in the reference list.) After 2012 Feb., dramatic new outbreaks erupted in the NEB (March) and NTB (April), as described in reports nos.5 & 6, and summarised at the end of this report. These would spread all around each belt during solar conjunction, in an unprecedented upheaval covering most of the northern hemisphere, leading to vigorous revivals of both the NEB and the NTB.

When we set out to produce this report, in 2012, we expected it to be quite short and simple. But with thorough JUPOS analysis, and collation of information from previous years, we have found many interesting phenomena of long-term significance which are described more fully in seven 'spin-off' reports, as follows:
--S2 to S5 domains: long-term report [posted as Ref.1]
--S1 (S. Temperate) domain, inc. oval BA and STBn jet: long-term report [posted as Ref.2]
--SEBs jet wave pattern: Appendix 1, to be expanded as a paper.
--NEBs jet acceleration: Appendix 2, to be expanded as a paper for JBAA; & [Ref.3]
--White spot Z: long-term report [posted as Ref.4]
--N1 (N. Temperate) domain: multi-year summary covering the 5-year cycle, esp. the NTD [posted herewith as Ref.5]
--N2 domain, NNTZ ovals: multi-year report [posted as Ref.6]

This report is entirely derived from amateur images. The list of observers has already been posted as report no.7. We are very grateful to all who contributed, whether or not their images are shown in this report. Most of the figures herein use images of the highest resolution available, but many other images have been useful in confirming these phenomena, and tracking features, and providing general overviews.

Imagers continued to use the webcam image stacking technique. During this apparition, some observers attained even higher resolution than before, thanks to a new function in WinJUPOS for 'derotating' either raw or stacked images, to correct for the planet's rotation over time spans of up to 20 mins, thus allowing more stringent criteria for image selection and stacking.

The measurements of atmospheric features ('spots') were done by the JUPOS team as usual: see <http://jupos.org>. The drift rates and latitudes were derived from these data, in WinJUPOS or in Excel; this analysis was mostly done by G. Adamoli. The typical scatter of measurements is ~0.3 to 0.6º (standard deviation). As there are numerous measurements for most spots, the standard errors of the mean are <0.1 deg (much less than the sizes of the spots). Therefore the uncertainties in drift rates are ~1 deg/mth (~0.5 m/s) for features tracked for one month, and less for those tracked for longer.

Our standard conventions are used throughout this report. South is up in all figures. Latitudes are zenographic. Drift rates are given in degrees per 30 days (deg/mth) in longitude System I (DL1) or System II (DL2).

We do not use System III, because the IAU repeatedly redefines its rotation period. Having last redefined it in 2000, they now say: "The rotation rate of Jupiter .... is changed back to the previous (1976) value.... We recommend that a community consensus on a new value be achieved before a new value is adopted." [ref.7]. We cannot use a reference system which has multiple possible values.

Overview of the planet

Maps of the planet: A complete v-hi-res map is presented in **Fig.1**. A large set of maps, from 2011 July to 2012 Jan., has already been posted (report no.3).
Most of the belts and zones were more-or-less normal, apart from the faintness of the NTB.

Multispectral images: Images covering the infrared and ultraviolet, especially the methane absorption band at 889 nm, were taken by several observers, most regularly by Tomio Akutsu. Sets of these images are shown in **Figs.2-4**, with a set of maps in **Fig.5**.
The belt-zone pattern in methane images was similar to the visible pattern but with interesting differences. The NTB(S) was very methane-dark, in spite of its visible faintness, whereas the NTB(N) and STB had low contrast in methane – except for the cyclonically disturbed sectors which were as methane-dark as any other belt. The SEB f. the GRS was anomalously light in methane in summer 2011. The EZ, unusually, was only methane-bright in a northerly strip which extended over the visibly-dark NEB(S). There were also methane-bright polar hoods, as always. The principal methane-bright localised features, as usual, were most of the anticyclonic ovals, as well as new plumes in the SEB f. the GRS (Figs.3-5).

Zonal drift profile:

Given the very detailed coverage now, we can track large numbers of 'spots', and plot their zonal drift profile **(**ZDP; speed versus latitude) at high resolution. This can be compared with the zonal wind profile (ZWP; speed versus latitude for fine-scale cloud textures as derived from spacecraft). In **Figs.6 & 7**, all the JUPOS measurements of speed and latitude are plotted for the whole planet, from 60ºS to 68ºN, and compared with the ZWP from Cassini [ref.8]. Special features of the ZDPs will be noted below. The general features can be summarised as follows.

The charts show excellent agreement with the Cassini ZWP apart from some of the retrograde jets. The JUPOS data record the peaks of most prograde jets: S3, S2, S1 (STBn) and SEBn; NEBs, N2, and close to the peak for N3 and N4. Some are slightly slower than in the Cassini ZWP, some are slightly faster, and for all the temperate jets, the spots display an anticyclonic gradient on the low-latitude flank of the jet. The data also record the SEBs retrograde jet. For the NEBn and mid-latitude retrograde jets (in the S2, S1, N1, N2, N3 domains), the full wind speeds are seldom detectable in the JUPOS data; instead, the visible spots have more moderate speeds (approximating to the slow current for each domain) so the profiles appear blunted. But in addition to these blunted profiles, we do detect the peak retrograde jet speed for several small spots in the NEBn, N2, N3, and S1 domains. For the higher-latitude domains, where the retrograde jets appear blunted anyway in spacecraft ZWPs, there are no distinct slow currents, and all spots follow the ZWP; we record plenty of spots with the same speed as the retrograde jet in the S4, N4 and N5 domains.

The largest anticyclonic ovals are systematically at lower latitudes than the mean profile [ref. 9]: this applies to the GRS, oval BA, and possibly even to the AWOs at 40.5ºS as compared to the profile for small dark spots.

We have already posted similarly detailed global ZDPs for 2005 and 2006 [ref.10] and 2007 [ref. 11], which are reprinted as **Fig.8** for comparison. They are almost identical, even down to the small deviations from the spacecraft profile for some jets. The only significant differences are the variations in the fastest jets that were associated with the activity cycles of the SEB and NTB [ref. 11] and of the NEB (as reported below).

Southern Hemisphere

Table 1 lists the major spots, and averages for recognised jets and currents, in similar format to previous BAA reports. It does not list all spots tracked; they are all plotted on the ZDPs (**Fig.6,** and enlarged ZDPs for selected regions in subsequent figures). The JUPOS charts themselves are provided as supplementary charts ('JUPOS....tif'), or in our long-term reports [refs.1 & 2].

South Polar Region: S4 and S3 domains

The S4, S3 and S2 domains have been thoroughly reviewed in our recent long-term report [ref.1], which can be consulted for further details and context, and for the JUPOS charts.

S4 domain:
Most unusually, the JUPOS chart tracked 4 white spots at ~60ºS. These are presumably anticyclonic white ovals (AWOs). Since 2008, the long-lived bright oval here [refs.1 & 7] has been joined by one or more others, and with their frequent wild variations in drift rate, it has

not been possible to keep track of them reliably through solar conjunctions. The largest this year [Table 1] were those at L2 ~ 90 (WS-1) and 210 (WS-3) in 2011 Sep., and the latter was most likely to be long-lived; it was reddish and methane-bright (Figs.4, 9, 10) & [ref. 1].

There were oscillations in some of these tracks and sudden changes of speed in others. WS-1 was followed through 2.5 oscillations with period ~ 2.3 months. WS-3 underwent sudden changes of speed; one of these, from DL2 = -35 to +5 deg/mth around Oct.11, was apparently due to a much smaller oval, retrograding with DL2 = +10 deg/mth, passing on its N side on Oct.11 (**Fig.10).** It is remarkable that the smaller oval did not change its speed but the bigger long-lived one did; also that the change was parallel to that of the S3 AWO (see below).

All these speed changes were linked to changes of latitude, as usual, and the resulting ZDP chart **(Fig. 11)** agrees closely with the chart which we obtained for these ovals in other years [ref.1 Fig.17A].

S3 domain:

At ~50ºS there was a single prominent AWO (oval 1), which we have definitely tracked since 2006, and probably since 1998. [ref. 1]

Within just a few days around 2011 Oct.3, oval 1 suddenly changed its drift rate from DL2 ~ -33 (throughout Sep.) to +3 (throughout Oct.); at the same time the latitude changed from 50.5 to 49.5ºS. This change has been studied in detail by Schmude [ref.12], whose measurements are close to ours. The shift occurred just as oval 1 was about to collide with a retrograding dark spot at 49.2ºS with DL2 = +7; they were just 8º apart when oval 1 changed course, then the dark spot disappeared (Fig.10). It seems surprising that such a small spot would so powerfully affect the long-lived AWO, but it is possible that this dark spot was just the leading element in a sector of retrograding features, perhaps with altered ZWP.

S3 jet:

The S3 prograde jet at ~43ºS was very active, with about 12 white spots tracked on it, with mean DL2 = -93.6 (±4.1) deg/mth, at 43.8ºS. The latitude and the ZDP [Fig.6; for hi-res ZDP see ref.1 Fig.11] showed that these spots were on the cyclonic side of this prograding jet peak – unlike spots tracked on all other prograde jets, which are usually anticyclonic dark spots. Some of these are well shown in Fig.10. They were emerging from a dark sector of S^3TB, due S of the GRS (as dark jet spots do on the STBn, NNTBs, etc.).

At other longitudes (south of oval BA), there were several small dark spots at 43ºS which did mark the jet peak. Two of these started further north and shifted south to 43ºS, suddenly accelerating to the full jet speed as they did so.

S2 domain (S.S.Temperate region)

There were 9 long-lived AWOs at ~40-41ºS, with fairly constant drift throughout the apparition. (chart JUPOS-S2, & Fig.1). They were labelled on the maps posted [report no.3].

However, as noted in [ref.1], there was a discrepancy with the provisional nomenclature of 3 of the ovals. We had thought that oval A2 disappeared before 2011; however we now find that it persisted, so the ovals labeled A9,A0,A1 in the interim maps and charts [report no.3] were in fact ovals A0,A1,A2 [as shown in ref.1, and Figs.1, 10, 12].

Otherwise the only notable features – minor, but characteristic of this latitude band -- were two sectors between ovals A2 and A3; these sectors were passing oval BA (see Figures of oval BA, esp. Fig.12). Following A2 there were slower-moving small dark spots, particularly in Aug-Sep., when this sector was also notably reddish brown; while the sector p. A3 was a persistent greyish-white cyclonic lozenge.

S2 jet (SSTBn jetstream):
The S2 jet carried numerous small dark spots, with a wide range of speeds from DL2 ~ -59 to -114 deg/mth. The ZDP chart [Fig.6; for hi-res ZDP , see ref.1 Fig.5] shows that these speeds were tightly related to latitude with most of the spots being on the anticyclonic side of the jet peak, as usual. Some apparently defined the jet peak itself at DL2 = -111 (±4) deg/mth, lat. 36.0 (±0.2) ºS – about the same latitude as in Cassini data but significantly faster.
These jetstream spots were mostly arising in just two sectors. The first sector, between ovals A7-A8, was alongside the chaotic Sf. extension from the long dark STB segment (below), and it is possible that this dark disturbance in the STZ gave rise to the SSTBn jetstream spots, though no direct connection was seen. The other sector, between ovals A2-A3, gradually pulling ahead of oval BA, was odd in several respects, as noted above, and included a bulge from SSTBn into STZ, which in Sep. developed the appearance of a recirculation across the STZ, ~60º p. oval BA (Fig.12, & see below); a pair of jetstream spots arose at this point. There seems to have been a significant dynamical feature spanning the SSTB-STZ at this location but its nature was unresolved.

S1 domain (S. Temperate region)

This domain was thoroughly reviewed in our recent long-term report [ref.2], which can be consulted for further details and context. JUPOS Chart S1 tracks the features in 2011/12.

Oval BA:
Oval BA has shown remarkable changes in drift rate (Fig.14). In 2010 Sep. it had accelerated to DL2 = -16.6 deg/mth as it passed the GRS, in response to the formation of the long dark turbulent STB sector f. it a few months earlier. It then moved more moderately (-14 deg/mth) during solar conjunction, until late July when it suddenly accelerated again (-19 deg/mth) for just one month; then suddenly decelerated to -11.2 deg/mth at the end of August. The change in July occurred in less than a week, and the change in August occurred over only ~10 days.

As explained in our long-term report [ref.2], it appears that the reason for the large deceleration was the shrinkage and quiescence of the dark STB segment f. BA, which became very small during the apparition. We can enquire whether there is any tighter correlation of the appearance of this dark segment with the short-term variations in speed of BA. The chart (Chart JUPOS-S1) shows that this segment was <10º long in July, located between oval BA and a tiny AWO Sf. it, which moved away from BA from July to Sep., during which time the dark segment expanded to 10º long, before shrinking again in Nov. A series of v-hi-res images (e.g. Figs.12 & 13) shows variations in the apparent disturbance of the dark segment as well as its size during the apparition, which are not obviously correlated with each other nor with the short-term changes in speed of BA. But it may be significant that the dark segment was expanding and sometimes turbulent (albeit small) during August, when BA was travelling fast. Despite these fluctuations, by November the transition was complete: the dark segment was rapidly shrinking, and BA was travelling slowly and had lost its dark rim.

BA's latitude changed at the same time as the drift (Table 1), but whereas the smaller dark and bright spots in the STZ closely followed the ZWP (Fig.6), oval BA was always at lower latitude, as is normal for these large reddish ovals [refs.2 & 9].

Throughout the apparition oval BA had weak reddish colour, a light ochre similar to the high north temperate domains although lighter. Initial impressions that the colour varied during the apparition were not borne out by inspecting more hi-res images (Fig.13). The colour occupied almost the whole oval, but a small central white spot was visible in the best images.

From June to Sep., it had a dark grey rim. In Oct. the dark rim faded, and by 2012 Jan. only a very faint grey rim remained, but the internal light ochre annulus was much the same (Fig.13).

On the other side of the planet was the only long sector of dark STB. The main part, ~40-45º long, was passing the GRS in June-July, and it was followed by a slightly southerly extension consisting of many tiny dark spots, which thickened and extended to remain alongside the GRS up to Oct., finally moving on in Nov.

A very dark, very small cyclonic spot (DS1) became distinctly redder in Aug. and then faded during Sep. (**Fig.15**; & see Fig.1), until only the reddish tint was left. In Nov. it was a pink bright spot. Several observers remarked on this spot, and Christophe Pellier summarised its behaviour in Nov.:

> "This spot was dark a few months ago, and looks to follow a typical evolution of those cyclonic ovals. But what looks interesting to me here as well is its brightness in near infrared. The brightness is not correlated with a high altitude, however; it is not bright in methane images. I find a striking similarity between this aspect, and this evolution, and that of the SEB barge of last year before the revival. It was also slightly pink in RGB and bright in IR but not in methane."

We now recognise that this is a common phenomenon – a cyclonic dark spot reddening just before it fades, sometimes becoming 'luminous pink', but never methane-bright – and examples were also seen in the NTB(N) and NNTB during this apparition (see below).

Another change happened ~60º p. oval BA, just as oval BA decelerated and STBn jetstream activity ceased (below), so we have investigated it in detail, but why any of these phenomena happened is still not clear. It is shown in maps (interim report no.3 & chart JUPOS-S1). A faint small blue patch here in Aug. was probably a small cyclonic circulation (Fig.12), and it gradually condensed to become a tiny dark grey spot (DS4) by mid-Sep, presumably cyclonic from its latitude. The pattern south of it looked transiently like anticyclonic hemi-circulation from STBs to SSTBn (see maps: report no.3), and indeed in early Sep. a second tiny dark spot appeared here, at lat.~34.5ºS, which accelerated and moved S anticyclonically until it was moving in the SSTBn jet at ~35.5ºS, one of a small volley of SSTBn jetstream spots that appeared at this point (see above).
Meanwhile the first tiny dark spot (DS4) persisted and became remarkably dark in Nov.; there was intense turbulence surrounding it in Peach's v-hi-res map (Fig.1). This turned out to be the origin of new STB segment E ('STB Ghost') which was followed in subsequent years.

S1 jet (STBn jetstream):
From June to August, small dark spots in the STBn jetstream were arising ~40º p. oval BA and prograding with DL2 = -85 to -104, to disappear at the GRS (alongside the f. extension of the long STB dark segment). After the last week of August, when oval BA changed its drift and the new disturbance developed ~60º p. it, the production of jetstream spots ceased. Several of these spots became reddish shortly before disappearing.
Their latitudes ranged from 28.6 to 26.8ºS, within the broad or double peak that is usually recorded for this jet, showing a weakly cyclonic ZDP, although there was no other evidence for cyclonic behaviour of these spots. Several of them drifted north during their lifetimes without change of speed. All these characteristics have also been recorded for STBn jet spots in previous outbreaks, and are illustrated and discussed in our long-term report [ref.2: Section 7 and Fig.17 thereof, which includes the ZDP in 2011].
In **Table 1**, an average is given for the apparent jet peak. It consists of the 9 spots with mean latitude below 27.8ºS; these had the fastest speeds, and include all 5 spots which drifted northwards (from ~28.0 to 26.8ºS). They gave mean DL2 = -98.6 (±2.8) deg/mth, lat.27.5 (±0.2) ºS, for the apparent jet peak.

South Tropical domain

STropZ/STropB/SEBs:
A massive, very dark grey S. Tropical Band was present all round the zone at the start of the apparition. Its origins could be seen in the last images from the previous apparition [ref.13]: Very dark streaks were moving anticlockwise around the rim of the GRS, initially in 2011 Jan but the dark material had increased in Feb. From March 2 onwards, dark brown material was seen streaming p. the GRS. This was probably the origin of the S. Tropical Band which was first imaged by Tomio Akutsu just 3 weeks after solar conjunction, in 2011 April-May.

The main p. end was at L2 ~ 72 on May 29, and by July this had prograded to L2 ~ 288, so this massive dark band occupied the northern two-thirds of the zone at all longitudes except for ~100º f. the GRS. From then on, successive p. ends prograded to L2 ~ 260-290 but halted there, opposed by narrower retrograding streaks f. the GRS (chart JUPOS-S0). The Band persisted throughout the apparition although it was gradually fading (Figs.16 & 17).

This was one of those diverse dark formations which sometimes develop in the STropZ, prograding from the p. end of the GRS, often at the end of an SEB Revival as in this case

The S.Tropical Band consisted partly of dark grey streaks or contained dark condensa-tions, and along its interface with the reddish-brown SEB(S) there were various dark humps and small white spots, some of which appeared to form wave patterns. They showed a great range of speeds, which we have grouped into 7 sets; details for June to Sep. are given in **Appendix 1**.

The speeds fitted closely with the normal ZWP at latitudes >21ºS, but showed a remarkable dual speed pattern on the peak of the SEBs retrograding jet at 19-21ºS (**Figs.18 & 19C)**. On this jet, sets 6 and 7 both consisted of small white spots on SEBs, and yet set 6 ('waves' spaced 10º apart) were modestly retrograding with DL2 = +39 deg/mth, while set 7 (white spots spaced ~12º apart) were retrograding with full jet speed, DL2 ~ +132; and during August, the two sets overlapped and crossed each other within longitudes ~15-75º p. the p. edge of the GRS.

Thus for the third time in one year – as in the SEB Fade and in the SEB Revival **(Fig.19)** – we have discovered a modestly-retrograding 'wave-train' of small bright spots on SEBs, coinciding with other features that have the full jet speed! This wave-like phenomonon will be discussed in a separate paper.

After mid-Sep., some of these diverse speeds were no longer seen, but sets 3, 5, and 7 continued until the end of Nov. or beyond (see **Appendix 1**).

Great Red Spot:
The GRS was a uniform pale orange oval, completely enclosed by a substantial dark grey rim, thoughout the apparition **(Figs.20 & 21)**. It was at L2 = 171 at opposition with DL2 = +1.1 deg/mth: back to its normal drift after the SEB Revival, and still showing the 90-day oscillation.

SEB:
The SEB was fully revived from the start of the apparition, although white spots (convective storms) were still arising close to the position of the source of the Revival and prograding in the northern half of the belt. Meanwhile, in June-July, the southern half, for ~60º f. the GRS, was unusually featureless and reddish, a pale orange-brown colour (see Fig.17, & maps in Appendix 1, and maps in our report no.3). This was probably the end result of the reddish colour seen in a narrow southerly strip during the 2010 SEB Revival, and it may well have been the 'orange flush' that was often recorded visually after previous SEB Revivals [ref.14]; however in 2011 it was limited to the sector f. the GRS. Most remarkably, this sector was very light in methane images. This is shown in a pair of reports posted by Christophe Pellier [ref.15], and is discussed below.

White spots were still arising close to the position of the source of the Revival: at up to L2 ~ 260 in June, and up to L2 ~ 250 in July (Fig.17, & maps in Appendix 1). In August they were more subdued and continued prograding towards the GRS without new outbreaks, though they were still present in the northern half of the belt f. the GRS. Very little disturbance was left by Sep.

In mid-Sep., the complete quiescence of the SEB (and GRS) suggested that the belt might be about to start fading again. Moreover, four dark 'mini-barges' were becoming more conspicuous in the pale ochre SEB at L2 ~ 0-90; the ochre colour (which perhaps also represented the 'orange flush') was becoming lighter. However, this state soon ended (see below).

Meanwhile, in late July an unusual light (cream-coloured) spot arose within the SEB at L2 = 124, prograding at DL2 = -11 deg/mth, later at -4 deg/mth. It was at 14ºS, without any obvious form of a circulation. (The drift was anomalous for this latitude; an explanation would become apparent in the following apparition.) Two of the minibarges drifted up to it and disappeared. The first of these encounters, in Nov., was followed in detail; the barge faded somewhat as it came alongside the light spot, and remained on its S edge for some weeks, but there was no evident interaction. The light spot was still present in 2012 Feb. at L2 ~ 90.

The next transition occurred in the SEB immediately f. the GRS, on 2011 Sep.21, when the first convective white spot appeared there since the SEB Revival, initiating the normal convective activity which has continued since then. (By Sep. the orange, methane-bright haze on this sector of SEB had largely disappeared.) There had been smaller, more northerly whitish spots earlier, but the new spot on Sep.21 seemed to be the first proper convective plume. This outbreak gradually developed until it was large and conspicuous in early Oct. (**Figs.20 & 10**), and it continued to grow more and more elaborate **(Figs.21 & 4).**

In methane images, these new plumes were just visible on Sep.23 and 27-28 (Figs.5 & 20) and in Nov-Dec. they were clearly methane-bright (Fig.4) [& see ref.15].

SEB: Discussion:

The bland, pale orange-brown colour of the SEB f. the GRS was presumably the 'orange flush' that had often been recorded visually after previous SEB Revivals [ref.14], although this year it was not extensive. The fact that this sector was very light in methane images was consistent with the 'flush' being a high-altitude orange haze overlying the belt. Pellier [ref.15] noted that the same aspect was shown f. the GRS after the SEB Revivals of 1990 and 1993, as seen in HST colour and methane-band images in 1991 and 1994.

The subsequent quiescence of this sector, with no rifts and with ambiguity about the onset of a new SEB Fade, has also been recorded before, and seems to be an under-appreciated aspect of this phase of the SEB cycle. After each of the SEB Revivals of 1971, 1975, 1990, and 1993, the SEB became quiet, showing the orange flush in all except the 1975 cycle (see HST images in 1991 and 1994). After 1971 and 1990, the SEB then began to fade again, beginning the next cycle. In 1975 Dec., likewise, the SEB(S) began a fading which progressed all around the planet by 1976 March; but within a few months, it recovered and rifts were appearing f. the GRS as usual. Likewise in 1994 May-July the SEB, quiet and pale orange in its southern half, had no rifts (except one small rift in HST images, 55º f. the GRS) and could have been starting a Fade; but a bright rift was present just f. the GRS on 1994 Aug.25-26 (HST and Miyazaki; also methane-bright), which presumably marked the resumption of normal rifting activity, as was evident in the next apparition. In conclusion, the SEB usually goes through this phase just as the Revival is completed, when the appearance does not indicate whether it will start a new Fade or start a new period of normal convective activity.

The observations in 2011 Sep-Oct. were probably the first in which the renewal of normal convective activity has been thoroughly monitored.

SEBn

Chevrons or other minor irregularities were present all round the SEBn, but there were no large-scale structures. Apart from one slower group, the chevron speeds ranged from DL1 ~ -57 to -78 deg/mth, mean DL1 = -67 (±6) deg/mth, mean u_3 = 137.5 (±3) m/s [Chart: JUPOS-SEBn]. This was unusually slow for an apparently undisturbed SEBn; we wonder whether this could be an after-effect of the SEB Revival.
There were three 'gaps', i.e. bands on the JUPOS chart with low densities of recorded spots, moving with DL1 = +23 (±3) deg/mth throughout the apparition. Although this is a typical speed for a S. Equatorial Disturbance, there was no visible sign of one and the gaps were not distinct structures on maps. From ~Sep.20—Oct.25, there was a group of dark and bright spots around L1 ~ 280, just p. one of the gaps, with DL1 = -33 to -43 deg/mth; but although this arrangement would also be characteristic of a SED, there were no other features to indicate that one was present. Possibly the gaps represented wave features of a similar nature to the SED but much weaker.

Northern Hemisphere

Table 2 lists the major spots, and averages for recognised jets and currents, in similar format to previous BAA reports. It does not list all spots tracked; they are all plotted on the ZDPs (**Fig.7**, and enlarged ZDPs for selected regions in subsequent figures). The JUPOS charts themselves are provided as supplementary charts ('JUPOS....tif').

North Equatorial region: NEBs

Throughout the 2011 apparition, the EZ was white and featureless apart from an intricate network of faint blue-grey streaks. The NEBs still had a few typical dark 'plateaux' up to 2011 July, but thereafter there were no large features on it, just many miniature projections with small faint festoons. The NEBs edge was at ~8.5ºN, further north than usual (and even this was overlain by methane-bright haze). This visual blandness accompanied an extraordinary dynamical change: the NEBs was completely taken over by super-fast speeds, until all features were moving faster than ever before recorded **(Fig.22 & chart JUPOS_NEBs).**

From 2011 June to Oct., there were only 2 or 3 slow-moving features at any one time, which were small blue-grey NEBs projections with DL1 = +26 deg/mth, accelerating to DL1 ~ +15 to +11 in their final stages. All other tracks were super-fast: 113 tracks gave a mean DL1 = -70.6 (±14.4, SD) deg/mth. These features had the typical appearance of small dark blue-grey NEBs projections with festoons; only their speed was exceptional **(Figs.22 & Fig.23)**.
The speeds were gradually accelerating during 2011, and they were modulated by the few remaining slow projections, although these were very small. New super-fast projections generally appeared on the p. (east) side of these slow projections, usually with DL1 ~ -49 (±5) deg/mth, then they accelerated or were replaced by faster-moving projections, with DL1 ~ -76 (±10) deg/mth. After all the slow projections had disappeared, the super-fast projections continued to accelerate, and in 2012 Jan-Feb., had a mean DL1 = -83 deg/mth, and maximum of -95 deg/mth (**Fig. 24).** The latitudes for all these dark spots were the same as for normal dark formations, thus: slow spots, 7.7ºN (±0.2º, SD); super-fast spots: 7.5ºN (±<0.1º, SEM) .

This remarkable change has profound implications for understanding the dynamics of the region: the existence of symmetrical super-fast jets underlying the SEBn and NEBs; the modulation of cloud-top jet speed by slow-moving wave-like formations; and the association of this change with the cyclic behaviour of the whole NEB, which appears to be recapitulating what was happening a century earlier. The observations and implications are presented more fully in **Appendix 2**, and will be submitted as a full paper for the JBAA; a summary is given in our EPSC abstract [Ref.3] .

North Tropical domain

The whole NEB was very quiet, and its north edge was gradually receding after the last expansion event in 2009. Exceptionally, no rifts were present inside it at all after 2011 July (when there was just one small southerly rift). There were however 6 remarkably dark barges, 3 of which were also very large and conspicuous. These were visually the most prominent features on the planet, and observers commented that they had never seen barges so dark.

Spots in the NEB and NTropZ:
In the absence of rifts, the JUPOS records showed several tracks for small dark spots, with DL2 ranging from -32 to -76 deg/mth. These were narrow condensations in a brown 'NEB(C)' band at 12-13ºN, or just N of it. They fitted a well-defined ZDP **(Fig.25)**, which was up to 1º S of the Cassini ZWP, whereas our ZDPs for the mid-NEB in previous years fitted the ZWP exactly (Fig.8); this may be a change associated with the exceptional quiescence of the NEB.

The JUPOS chart **(JUPOS_N0)** also showed numerous tracks of dark spots retrograding at 16-18ºN, mostly with DL2 ~+9 deg/mth, but with DL2 = +17 to +43 deg/mth between L2 = 280-330. These features were tiny projections on NEBn, moving with the retrograding NEBn jet. Unusually, the maximum speed (+43 deg/mth) was similar to the maximum speed observed by spacecraft **(Fig.25)**, perhaps made visible now by the absence of confounding disturbance around it.

The six dark barges had all persisted since 2010. In 2011 June-Aug. there were also a few other small ones, obscure as the belt had not yet faded; the most distinct ones had arisen just f. WSZ, as we have recorded in other apparitions, with near-stationary or retrograding DL2 in contrast to the prograding DL2 of the six stable barges. These minor dark spots merged with the the stable barges, especially B1 (see chart JUPOS_N0). The six stable ones were extremely dark brown from Aug. to Dec. Thereafter they were not quite so dark, but they all persisted until March without further fading.

There were also five white ovals in the NTropZ, although hard to see because of the whiteness around them. Three of these had been prominent white ovals in the previous apparition, including long-lived white spot Z (WSZ). The other two had been reddish anticyclonic dark spots labelled ADS-2 and -3 [ref.16] -- but by 2011 July they had both become bright white ovals, each poised mid-way between two dark barges, and they persisted for several months (see chart JUPOS_N0, & Fig.27).

From late 2011, WSZ was again the fastest-moving stable spot in the domain, along with barge B6 pushed along p. it. WSZ is reviewed in our long-term report, which includes hi-res images from 2011/12 [ref.4, Appendix Figs.6&7]. It was very bright in 2011 May (Fig.16) but then blue-grey shading developed in its S part until it appeared as a faint blue-grey 'eye' with a small but brilliant northerly white spot (N.w.s.) within it (Fig.27). Only the N.w.s. was visibly bright (which explains its anomalous latitude in the ZDP : Fig.25), and it was also methane-bright [ref.4, Appendix Fig.7]. The N.w.s. was interacting with tiny irregularities prograding on the N. Tropical Band, and this interaction was generating tiny white spots among them [ref.4,

Appendix Fig. 6&7], which were especially prominent in an image on 2012 March 8 (shortly before the NTBs jet outbreak arose near this latitude).

NEB recession:
The recession of the NEBn edge is shown in Fig.26. Up until August, the NEB spanned 8.5º to 17ºN. In Sep., sectors of the northern half began to fade (brighten), until in Nov. all of the northern half was lighter. So far, this appeared to be normal for this stage of the NEB cycle; but what happened next was remarkable. The northern half continued to fade rapidly until by late Jan. it was just a very pale fawn colour, almost white, leaving just a narrow southerly NEB between 9 and 12.5ºN, which had also become somewhat fainter than usual.

Discussion:
The NEB had not been so narrow nor faint since the 1920s [ref.14]. From 1893 to 1912, it regularly shrank to this narrow state or even narrower, prior to a vigorous outbreak of spots leading to revival every 3 years, which were grander versions of the familiar NEBn broadening events, usually being vigorous affairs much like an SEB Revival [ref.14 chapter 8.5]. We therefore suspected that the exceptional narrowing of the NEB was setting the scene for a NEB Revival. Indeed, a NEB Revival began suddenly in 2012 March (see section below) and proceeded vigorously during solar conjunction. So in 2011/12 we have observed the first major NEB fading event in modern times.

Three accompanying phenomena were notable: the absence of large NEBs projections, the acceleration of the NEBs jetstream to unprecedented speeds [see above and Appendix 2], and the complete absence of NEB rifts (convective white spots or streaks). These phenomena were probably connected, and comparable to the fading of the SEB, which likewise begins with the complete disappearance of rifting in the SEB [see our reports for 2007 and 2009]. At other times, the SEB and probably the NEB always show at least one rift; for example, in 2008-09 during the previous narrowing of the NEB, small mid-NEB rifts had appeared repeatedly. Other records of previous NEB narrowings still need to be reviewed. But it seems likely that the process began in summer 2011 with the cessation of NEB rift activity, which led to the loss of NEBs projections, the acceleration of the NEBs jet at cloud-top level, and the enhanced narrowing of the NEB, comparable to fading of the SEB.

At ~22.5ºN there was a narrow blue-grey line, but this was not the NTB(S); from its latitude and colour, it was a typical N.Tropical Band, which often appears when the true NTB(S) is faint.

North Temperate Region (N1 domain)

In 2011/12, most of the NTB was pale, and the only conspicuous features were a pair of very dark brown streaks on NTB(N). (As usual in these circumstances, the NTB(S) was still a prominent very dark belt in methane images: **Figs.2-5.**) However, hi-res imaging revealed much interesting structure.

After the great NTBs jet outbreak led to the revival of the NTB in 2007, complex structures arose all around the domain, including rifted sectors which generated a N. Temperate Disturbance (NTD), as we have documented since 2008 [ref.5 & refs. therein]. All this appears to be a reproducible prolonged sequel to a typical NTBs jet outbreak. Our last report on it was in 2010 Sep. [ref.17]. Here, we show the chart (JUPOS_N1) which follows directly on from the JUPOS chart in that report, in the same format; plus a set of maps from this apparition (**Fig.27**). A summary of the whole life-time of the NTD is posted herewith [ref.5].

The same major sectors have persisted throughout most of these years, viz:
1) An oblique sector of small-scale turbulent bright spots in the NTB (rifted region);
2) Preceding it, a string of tiny dark streaks or spots rapidly prograding (NTC-B sector);
3) Alongside and/or f. the rifted sector, several very dark streaks or longer segments of NTB(N) (which do not last individually for more than a year, but the sector has persisted overall);
4) Also alongside or f. the rifted sector, a darkened sector of NTZ which we call the NTD.
5) The remaining longitudes (about half way round the planet) are quiet with a faint NTB and clear white NTZ.

The boundaries of the NTD have varied over months and years, and we have shown that it arises because the rifted sector perturbes the retrograding NTBn jet, and these disturbances recirculate into the NTZ at various points, tracking dark material into the NTZ [see ref.5 & refs. therein]. The extent of the NTD varies according to the extent and activity of the rifted sector, and perhaps randomness of recirculation.

The rifted sector seems to have been quite short and quiescent in 2011 July-August (Figs.27 & 29A), with no remaining NTD; but it was much more extensive from Sep. to Jan.(at least), and a NTD reappeared near its f. end in Nov.

The most conspicuous features of the NTB were a pair of very dark brown streaks on NTB(N), which became redder in August and faded in Sep. They were replaced by a light pale orange strip, flanked by darker grey segments on the p. and f. sides (Fig.29B). The grey segment on the p. side was the f. end of the rifted sector, and from Nov. to Feb. it became darker and broader within the NTZ, comprising the renewed NTD.

The small dark spots in NTB p. the rifted sector were all rapidly prograding with DL2 = -56 (±6) deg/mth, representing the classical N. Temperate Current B (Fig.30). These appeared to be disturbance generated from the rift activity.

All the other features were moving with the N. Temperate Current A (NTC-A), except for a few small dark spots prograding further N in the NTZ. Fig.28 shows the ZDP, which is typical in agreeing with the ZWP on the prograding side but being blunter on the retrograding side of the NTC-A. A pair of spots recirculating in the NTZ followed the same ZDP, as did a similar recirculating spot in 2010 Nov. (Fig.28).

Two dark blue-grey spots recirculated from the NTC-A to prograde in the NTZ at the p. end of the dark brown streaks in 2011 Sep. ('D8', marked on Fig.27; 'D9', marked on the chart JUPOS_N1; both marked on Fig.29). They formed near the boundary between the rifted sector and the dark brown streaks, from tenuous blue streaks which rounded up to form small anticyclonic rings in the NTZ; and NNTBs jet spots interacted with them and disappeared (see examples in Fig.29B). This was the process that initiated the new mini-NTD in Oct. Although these events are uncommon, their repeated occurrence -- just downstream of a NTB rifted region in both 2010 and 2011 – supports our hypothesis that such recirculations lead to the appearance of a NTD, reinforcing the vortices in NTZ and sometimes destroying NNTBs jet spots [ref.5].

NNTBs jetstream (N2 jet)

Many jet spots were present (chart: JUPOS_N2-jet). In Aug-Sep., they were appearing at L2 ~40-60, alongside a long dark segment of NNTB (Fig.29A). Why they appeared here is unclear; but v-hi-res images by Chris Go (Fig.29A) showed two possible sources of disturbance, both 'folded filamentary regions' (FFRs) which are regions of cyclonic turbulence in the adjacent belts. One was a small FFR ~30° f., on the Sp. edge of NN-LRS-1. The other was the NTB rifted region (small and inconspicuous then, but still present). After Sep., very few new jet spots appeared. Some of the spots disappeared at the point where the NTD revived, interacting with anticyclonic vortices in the NTZ, as mentioned above (Fig.29B).

N.N. Temperate region (N2 domain)

In July and August, there was a well-defined narrow dark NNTB at most longitudes, but broken up into many separate segments which changed from month to month, splitting or merging or fading (Chart JUPOS_N2, & Fig.30). Sometimes the f. end of a dark segment appeared to be trapped alongside anticyclonic ovals LRS-1 or WS-7 for a month or more. Most of the dark segments faded between Sep. and Nov., turning orange as they did so in the now-well-recognised fashion of dark cyclonic segments, until from late Nov. onwards there were just two very dark grey-brown streaks, each ~25° long, and the rest of the NNTB was merely a very pale ochre band, including some distinctly bordered lozenges of the same colour which were the remnants of previously dark streaks, just like similar ones in the NTB.

V-hi-res images also resolved two FFRs in the NNTB, features which are usually below the threshold of ground-based resolution. One was on the Sp. edge of NN-LRS-1, only in August, possibly the source of N2 jet spots (see above, & Fig.29A). The other was on the f. edge of WS-7 in Sep-Oct. (Fig.30), and may have been the source of dark streaks f. it in the NNTZ, although these were not tracked.

There were four anticyclonic ovals in the NNTZ. Since our long-term account of these ovals [ref.9], we posted an update to the end of 2012 [ref.6] which included the present apparition. In 2011/12, the longest-lived, LRS-1, was initially weakly reddish but then lost almost all colour, becoming invisible against the light brownish-grey NNTZ except in v-hi-res images which still revealed its oval outline. However, it remained strongly methane-bright as always. WS-6 and -7 were AWOs first recorded in 2010, and were weakly methane-bright. WS-4 had been tracked for many years, but in methane images was still very weak or invisible. (Figs.2-5, esp. Fig.3, & Fig.30).

The JUPOS chart (JUPOS_N2) shows that the NNTB dark segments were mostly near-stationary in L2 (typical of the NNTC), while the 4 anticyclonic ovals were mostly prograding with DL2 ~ -11 deg/mth, which is also common (although WS-7 had much more variable drift). However there was also a wide variety of other drifts in this domain, mostly for very small dark spots, both in the NNTB and in the NNTZ. Almost all the drifts obeyed a ZDP very close to the ZWP (Fig.31), except for the usual blunting on the retrograde side. Most drifts ranged from DL2 = -28 to +17 deg/mth. But there were also a few more retrograde drifts, up to DL2 = +47 (at 39.8°N), which is an extreme value for the peak of the retrograde jet; and a few even faster drifts, up to DL2 = -49 (at 42.1°N), approaching the peak of the prograde N3 jet.

The chart (JUPOS_N2) shows that retrograde drifts in NNTZ were notable from L2 ~ 320-40 (DL2 ~ +14 at 40°N in NNTZs). From L2 ~ 0-20, these retrograde drifts alternated with prograde drifts (DL2 ~ -20 at ~42°N in NNTZn), suggesting that these tiny dark spots may have been recirculating within a sector of NNTZ. Some are marked with blue arrows on Fig.30.

North Polar Region: N3, N4, N5 and N6 domains

North of 43°N (the N3 jet), there was a generally dark and mottled texture with no prominent belts or spots, but hi-res images revealed innumerable spots and more complex structures, as has previously been seen in spacecraft images. **Fig.35** shows five north polar projection maps in 2011 Nov-Dec., which dramatically show the chaotic landscape of the region. Many small dark spots and several bright spots were tracked in these four domains, all having drifts close to the known ZWP, as shown in **charts JUPOS-N3, N4, & N5-N6**, and **Fig.7**. North of the N3 domain, the only features lasting more than 2 months were a few white spots, presumed to be AWOs.

In the N3 domain, many dark spots and several bright spots were tracked. About half the spots had speeds around DL2 = -15.4 (±2.3) deg/mth, at lat. 45.4 (±0.3)ºN (N=13), i.e. the classical N^3TC; these included a row of about 6 anticyclonic rings or dark spots from L2 ~ 210-300 in Sep. (visible on Fig.30). The other spots had more scattered speeds, from DL2 = -3 to -40, mostly on the anticyclonic side. One of these was an AWO which had crossed the N4 prograde jet (see below).

In the N4 domain, there were short-lived dark spots, mostly on the cyclonic side, whereas bright spots were mostly on the anticyclonic side (Fig.7). All had drifts typical of the N^4TC, averaging DL2 = +5 deg/mth. The only persistent and fairly conspicuous features were two AWOs. They, and some smaller white spots, tended to maintain fixed speeds for a while but then undergo sudden, sometimes extreme changes in speed, as we have noted in other apparitions. The larger of them (N4-WS-a, or 'W7') was methane-bright (Fig.5), and so was the smaller (N4-WS-b, or 'W3') during its notable transition on Nov.26 & 29.

An AWO moved from the N4 to the N3 domain!

The smaller AWO (N4-WS-b, or W3) underwent a remarkable transition in late Nov., when Chris Go noticed a pair of white spots here that looked as though they were merging. In fact, what occurred was much more surprising: this AWO shifted from the N4 domain to the N3 domain, splitting and then recombining as it did so! **(Figs.32&33)** Its initial speed and latitude (DL2 = +8 deg/mth, 51.4ºN) placed it on the retrograde jet, then it moved rapidly south in late Nov., crossing the prograde (N4) jet at 47ºN. As it did so, on Nov.26, it split into two white spots which orbited round each other clockwise (anticyclonically) by ~140º in 13 d, until Dec.9-10, when they merged again to form a single AWO prograding at 46ºN in the N3 domain.

What impelled this AWO to undergo such a dramatic shift is not clear. One may suspect the adjacent turbulent FFRs (labelled FFR-a and –b in Fig.32), which were in close contact with it; in particular, the large FFR-b emitted a streamer north of the AWO which could have driven the AWO to the south. The spot(s) adhered closely to the ZWP throughout the transition (Fig.33), splitting just as it crossed the prograde N4 jet, presumably due to the anticyclonic shear on its S flank, and then recombining within the anticyclonic N3 domain.

This is the first instance, to our knowledge, of a spot crossing across a prograde jet. The closest parallel reported, in Cassini images, was when a FFR in the N4 domain generated a small AWO in the adjacent N3 domain [ref.18 Fig.2b]. But such an event may not be exceptional at these high latitudes, which have only recently been resolvable by amateur images. We have seen signs of interactions between high-latitude domains here in other years, and spacecraft have shown large FFRs that spread across the jets. In the Cassini north polar movie [ref.19], the whole region was seen to consist of numerous spots and large turbulent FFRs constantly jostling one another, and the prograde N4 and N5 jets were seen as statistical averages but not as smoothly channelled flows.

In the N5 domain, there were several persistent white spots, again with notable interactions and variations in drift and latitude, though adhering to the ZWP. Two pairs underwent interactions.

W1 and W2 appeared to show a complex interaction on the chart (JUPOS N5-N6), but the images (Fig.34) show that despite close contact on Aug.24, they simply passed each other, producing temporary oscillation in the drift rate of each. W1 started with DL2 = -43, at 63.0 N in the anticyclonic zone, and after the conjunction it underwent two cycles of oscillation to speeds as slow as +2.5, at 62.3ºN, before resuming steady drift of DL2 = -48, at 63.4ºN. W2 started with DL2 = +11, at 60.3ºN on the retrograde jet, then underwent one oscillation after the conjunction, before resuming steady drift of DL2 = +16, at 60.5ºN. The figure shows that just before the conjunction, another white oval appeared just S of the two spots, at ~56ºN, which was probably cyclonic.

W3 (a tiny AWO; DL2 = +14, 61.6ºN) and W4 (a light cyclonic patch; DL2 = -29, 57.0ºN) converged steadily until they were in contact (N-S) on Oct.6, then they disappeared; the interaction may have destroyed both.

The behaviour of these spots may well be typical of these latitudes, although rarely visualised; similar drifts and phenomena were recorded in the Cassini imagery.

Finally, one more white spot was recorded with remarkably fast drift and high latitude, in the N6 domain, on the flank of the **N7 jet** (see chart, JUPOS_N5-N6, & Fig.35). It had DL2 = -91 deg/mth at 67.3ºN! (Although the drift rate sounds extreme, this equates to a quite modest speed, +16.4 m/s, due to the high latitude.) After October, it decelerated to -47 deg/mth at 66.5ºN.

The polar projection maps in **Fig.35** give a panorama of the region, which has no well-defined belts, and is packed with chaotic structures. In addition to the white ovals described above, the maps show many large FFRs; their turbulence is partially resolved in some maps, whereas in others they just appear as irregular grey patches. The most well-defined FFRs are outlined on the maps and can be seen to persist over several weeks, though with variable shapes. Most notably, there is a broad band of persistent light patches (possible FFRs) at 70-75ºN, further north than anything we have ever tracked. There are plenty of other features which cannot be confirmed from one map to the next, partly because these features are at the limit of ground-based resolution, but possibly also because they are indeed rapidly variable. Similar NPR maps are in our reports for 2007 [ref.11] and 2010 [ref.17]. The Cassini polar map [reproduced in ref.11] and movie [ref.19] showed a very similar picture at much higher resolution, with many light patches even at 70-80ºN, and revealed how extensive and turbulent these FFRs and other structures were in the north polar region.

<u>The great northern upheaval</u>

The general calm was dramatically broken in 2012 March and April, just before solar conjunction, with violent outbreaks in the NEB and NTB. We quickly alerted observers that these could be the onset of a NEB broadening event or revival, and a NTBs jetstream outbreak with revival, respectively, and indeed observations early in the next apparition proved that this was the case. These outbreaks were described in our reports for 2011/12 (nos. 5 and 6) and 2012/13 (nos.1-3) [Ref.box B]. Here we just give a brief summary.

The NEB outbreak began on 2012 March 8 with a small bright spot in NEBs and small dark blue-grey spot on its S edge; they remained associated, with DL1 = +1.8 deg/day, until March 14. By then the dark blue-grey spot had become a conspicuous, very dark projection, while the bright spot had expanded into a long rift which moved more slowly. On March 12, a second bright spot appeared p. the first (at ~9.5ºN); a dark blue-grey spot appeared on its S edge on March 14 and repeated the behaviour of the first one (DL1 = +2.0 deg/day). The outbreak was first reported by Wayne Jaeschke on March 18, with the two dark spots accompanied by a bright rift. The two dark spots became intensely dark and large, and remained so in the last image on April 6; they were at 7.6 (±0.6) ºN. However by this time there was still no rapid expansion of the disturbance and no revival of the NEBn; we suspected that these might follow.

We had also been expecting a NTBs jet outbreak in 2012, as explained in [ref.16], based on the recent acceleration of the jet back to super-fast speeds at cloud-top level, and the 5-year periodicity of such outbreaks from 1970 to 1990. Indeed the outbreak began in mid-April, as seen in the last few images before solar conjunction. It was discovered by Manos Kardasis in his images on 2012 April 19, as a bright spot on the NTBs with a very dark spot f. it. By comparison with the 2007 outbreak, it had probably started around April 12, although it had not been visible in a lo-res image on that date.   On April 21, Gianluigi Adamoli also recorded these features, consistent with the expected super-fast drifts (DL1 ~ -5 deg/day). The very last images probably showed the f. end of the outbreak on April 26. All the data indicated that a typical super-fast outbreak had begun, but it was impossible to determine accurate speeds or to resolve the features.

Kardasis then made the first image of the next apparition on 2012 June 4, which confirmed that both outbreaks had developed impressively. His and other images soon showed that a NTBs super-fast outbreak had indeed occurred, and that a NEB Revival was under way. In June and July there were many dark formations on the NEBs edge including striking dark spots; the NEB was very broad, though pale and chaotic; and reddish or ochre colour covered much of the NEB, NTropZ, and NTB(S). The whole region was very complex. There was also an ochre band in central EZ, probably associated with the NEB Revival; conversely, the NNTB latitudes were almost white. Thus the unique occurrence of great disturbances on the NEB and NTB could be called a 'great northern upheaval', affecting all latitudes from 0 to ~38ºN. Events proceeded rapidly and by late August the disturbed regions were already settling down, with a very broad NEB and an orange NTB(S); both belts had indeed fully revived.

Images of the satellites

Sets of v-hi-res images of the galilean moons in 2011 were already posted in our report no.2. These include many beautiful images of the moons in transit, and many which detect surface features on Io and Ganymede. Another spectacular set was taken by Tomio Akutsu on 2011 Oct.24, showing a double transit of Io and Ganymede, available on ALPO-Japan at: http://alpo-j.asahikawa-med.ac.jp/kk11/j111024z.htm.

Some more superb examples, from early 2012, are in **Fig.36.**

References

Ref. box A:
Our interim reports for 2011/12 are cited as 'Report no....' in the text; all are at:
http://www.britastro.org/jupiter/2011reports.htm

1. Jupiter well placed for observing this autumn (September 14th, 2011.)

2. Images of Jupiter's Moons (November 28th, 2011.)

3. Maps of Jupiter in 2011/2012 (Jan 25th, 2012.)

4. *Visual observations in 2011/12 [prepared 2012 by Paul Abel, posted herewith]*

5. The NEBs outbreak in 2012 March.

6. Report on the NTB outbreak (June 2012.)

7. List of Observers 2011-2012 (Sep 2012.) *[now replaced with amended version]*.

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[same numbering as in Extended Summary]:

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'Changing characteristics of an anticyclone in Jupiter's S.S.S.Temperate Current'.

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& 'SEB aspect in CH4 after a SEB revival'
http://www.astrosurf.com/planetessaf/jupiter/doc/Jupiter_2011_note1b.html

16. [2010-11 report no.19] 'Some developments in Jupiter's northern hemisphere'
http://www.britastro.org/jupiter/2010report19.htm

17. [2010-11 report no.9], 'Interim report: Northern hemisphere.'
http://www.britastro.org/jupiter/2010report09.htm
[esp. Figs.18-23, inc. JUPOS chart and maps of NTD]

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Our reports on the great northern upheaval in 2012; all are at:
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'Jupiter's northern upheavals coming into focus.'

2012/13 report no.3 (2012 Sep.)
'Progress of Jupiter's great northern upheaval, 2012 July-August.'

Figure legends

South is up in all figures.

Fig.1: Map, 2011 Nov.19-20 (images by Damian Peach, map by Marco Vedovato). (See **Figs.9 & 35** for same data in polar projections.)

Fig.2. Multispectral images in 2011 August, all by Tomio Akutsu unless otherwise stated. CH4, methane absorption band at 889 nm; IR, near-infrared continuum; UV, near-ultraviolet; with false-colour composites.

Fig.3. Methane-band images, all by Tomio Akutsu unless otherwise stated. Anticyclonic ovals are normally methane-bright, including the S2 AWOs (visible but not marked), oval BA, the GRS, and 3 of the 4 ovals in the N2 domain (NNTZ). Of the NNTZ ovals, LRS-1 is strongly methane-bright, WS-6 and -7 weakly methane-bright, and WS-4 very weakly so (not visible at all on some methane images). However, AWOs in the NTropZ are not methane-bright; even White Spot Z is only weakly detectable (marked Z).

Fig.4. True-colour and methane-band images in 2011 Nov-Dec., showing the GRS and the SEB f. it, where new plumes in the rifted sector are often methane-bright for a few days. The best images show that small high-latitude AWOs are also methane-bright, e.g. S2-A8, S3-ws1, and S4-ws3.

Fig.5. Maps made by Silvia Kowollik from her own images taken with a 0.8-metre Cassegrain by courtesy of the Observatory Zollern-Alb, Germany, in visible colour, methane band (Astronomik, 12 nm width), and ultraviolet (Schüler). Methane-bright anticyclonic ovals are marked.

Fig.6. Zonal drift profile (ZDP; speed versus latitude) for the southern hemisphere, from our JUPOS data, compared with a typical spacecraft-derived ZWP, from Cassini [ref.8]. As in all our ZDPs in this report, the large number of points represent many small spots as well as multiple track segments for larger spots, divided up to obtain the most precise values possible.

Fig. 7. Same as Fig.6, for the northern hemisphere.

Fig.8. Global ZDPs from our JUPOS data for 2005 and 2006 [ref. 10] and 2007 [ref. 11].

Fig.9. South polar projection map made from images by Damian Peach on 2011 Nov.19-20 (same data as **Fig.1**).

Fig.10. The GRS and latitudes south in 2011 Oct., with long-lived AWOs in the S2, S3 and S4 domains undergoing interactions as decribed in the text.

Fig.11. ZDP for the AWOs in the S4 domain. As in all our ZDPs in this report, the numerous points represent many small spots as well as multiple track segments for larger spots, divided up to obtain the most precise values possible.

Fig.12. Images showing development of local circulation(s) in the STZ ~60 p. oval BA in 2011 Aug-Sep., including appearance of the small dark spot DS4 in the STB, which in later years became STB structured sector E (the 'STB Ghost').

Fig.13 . V-hi-res images of oval BA, and the dark STB patch and small AWO f. it.

Fig.14. Long-term JUPOS chart of oval BA, 2009-2012, showing its abrupt changes of speed.

Fig.15. Excerpts from maps, showing the very dark spot DS1 in STB latitudes reddening and whitening. (Also see **Fig.1.)**

Fig.16 . Images in 2011 May, early in the apparition, showing the S.Trop.Band developing p. the GRS, and disturbance in the northern SEB f. the GRS persisting from the SEB Revival. In the NTropZ, white spot Z (at L2 ~ 45) is very bright.

Fig.17. Map on 2011 June 8-12, showing the S.Trop.Band developing p. the GRS, and intense disturbance in the northern SEB f. the GRS persisting from the SEB Revival. (The image from June 8 has been inserted without map-projection, and thus does not fit the map scale accurately.)

Fig.18. ZDP chart for the S. Tropical domain. Spots are grouped as defined in Appendix 1.

Fig.19. Images showing the SEB in 3 different epochs, showing how a slowly retrograding spot-chain or wave-train (purple marks below) co-exists with rapidly retrograding features in the same latitude (black arrows above).
(A) 2010 July, during the SEB Fade; gaps in the wave-train had full jet speed.
(B) 2010 Dec., during the SEB Revival; dark spots in the southern branch of the Revival had full jet speed. (C) 2011 Aug., after the SEB Revival; tiny bright spots had full jet speed.

Fig.20. The GRS and the onset of new SEB rifting, 2011 Sep., including some paired ultraviolet and methane-band images.
(There were also v-hi-res images by Peach on Sep.23/24, Sep.27/28, and Oct.3, which have been posted already in our sets of hi-res maps and satellite images: reports nos. 2 & 3.)

Fig.21. The GRS in 2011 Nov.

Fig.22. Maps of the EZ and NEB in 2011, aligned in L1 or (for closely spaced maps in Nov.) in L1 minus 2.0 deg/day to identify individual super-fast projections. The few remaining 'normal-speed' projections are indicated by green arrows, from the JUPOS charts; there is nothing to visibly distinguish them from the super-fast ones.

Fig.23. Hi-res images tracking some super-fast NEBs projections in 2011.

Fig.24. Chart of speed ranges vs time for the super-fast NEBs projections in 2011/12. For Aug-Sep., the projections are divided into those p. the few remaining slow projections (a) and those f. them (b), and a few outliers (individual values very different from most of the group) are shown separately.

Fig.25. ZDP for N. Tropical domain.

Fig.26. Sections of maps showing the shrinkage of the NEB. (Maps labelled 'MV' were constructed by Marco Vedovato.)

Fig. 27. Maps showing the evolution of the NEB and NTB: latitudes 0-50ºN, from the same set of maps as in previous figures. AWOs of the NTropZ and NNTZ are labelled, as well as key features of the N.Temperate domain that led to the reappearance of the NTD.

Fig. 28. ZDP for N1 (N. Temperate) domain. This chart shows points for minor spots and short track segments as well as the major features listed in the Table. As usual, spots on both sides of the retrograde jet move with the slow current (NTC-A, DL2 ~ +20 deg/mth), and the ZDP is blunter than the ZWP on the retrograding side, so the full speed of the retrograde jet is not detected. Conversely the ZDP agrees well with the ZWP on the prograding side, particularly the ZWP from Voyager which in the NTZ is ~0.4º S of the Cassini ZWP shown. Our ZDP is the same as in 2009 [ref. our 2009 report no.8]. The chart also marks the track of two spots which recirculated from the NTBn to prograde in the NTZ: one in 2011 Sep., and one from the previous apparition in 2010 Nov. which did start on the retrograde jet.

Fig.29. Sets of images covering a sector of the N1 and N2 domains, showing the renewal of NTB rifting in 2011 Sep., and developments which led to the reappearance of a NTD in Oct.; also showing activity on the N2 (NNTBs) jetstream.

(A) Images from 2011 August. This set shows:
--WSZ in NTropZ, and NN-LRS-1 in NNTZ (red arrows).
--The NTB rifted region or FFR (marked above in green; small and inconspicuous at this time, but still active), with dark brown streaks f. it, and NTZ dark spot D8 (black arrow) between them.
--A small FFR on the Sp. edge of NN-LRS-1.
--NNTBs jet spots: tiny dark spots numbered 1-7 in order of appearance. Sometimes a new spot is connected to a cusp of dark NTBn by a tenuous wisp (small oblique black arrow).

(B) Images from 2011 Sep.1 to Oct.15. This set shows:
--The rifted sector of NTB, reappearing in Sep., p. the orange streaks.
--The pair of NTBn dark streaks, now orange and fading.
--Two dark blue-grey spots in NTZ, which successively reverse their drift from retrograding (NTC-A) to prograding. V-hi-res images show both become anticyclonic rings. They are:
--D8, at p. end of the orange streaks; it becomes slightly prograding, but becomes more difficult to track as it passes alongside the increasingly turbulent rifted sector.
--D9: forms in late Sep. from a changeable narrow streak f. D8. It forms as two NNTBs jet spots interact with it. (They go on to disappear when interacting with D8. The third NNTBs jet spot disappears when it contacts D9.)
--(D10:) a third such spot can be seen forming as a pair of tiny dark blue spots interact on Oct.9-10.
--NNTBs jet spots: A pair passes through this region smoothly in Sep. Later, a triplet progrades into the region and all three disappear as they interact with one or both NTZ dark spots.
--Very dark streaks of NNTB; AWO (WS-7) in NNTZ; a FFR immediately f. it (beautifully resolved in Peach's v-hi-res images).
--Further f., another very dark streak of NNTB is brownish-grey, and becomes redder in Oct., fading.
--NN-LRS-1, invisible in most images as it has low contrast, but its oval form is evident in v-hi-res images. (It is also very methane-bright; see **Fig.3**).

Fig.30. Maps showing the NTB and NNTB: latitudes 20-50ºN, from the same set of maps as in previous figures, with features of the N1 and N2 domains marked.

Fig.31. ZDP for the N2 domain. See text for details.

Fig.32. An AWO moving from the N4 to N3 domain, as described in the text. .

Fig.33. Charts of the AWO moving from the N4 to N3 domain. The oval (N4-AWO-b) was originally numbered N4-W3, and became N3-W2. (A) JUPOS charts of L2 and latitude vs time. (Grey band marks N4 jet, range of latitude measurements from spacecraft.)
(B) Summary of data, as plotted in (C).
(C) ZDP chart, showing that the spot adhered closely to the ZWP throughout this transition, splitting just as it crossed the prograde N4 jet, presumably due to the anticyclonic shear on its S flank.

Fig.34. Encounter between two white ovals in the N5 domain, 2011 August, as described in the text.

Fig.35. Five north polar projection maps in 2011 Nov-Dec. Some of the northerly AWOs are marked. Some of the irregular light patches likely to be FFRs are marked, where they can be identified from one map to another. They are at ~47-53ºN (green), 57-62ºN (mauve), 70-75ºN (cyan).

Fig.36. Hi-res images showing the galilean moons from 2011 Dec. to 2012 Feb. Surface features are detected on Ganymede (as shown in the two WinJUPOS simulated images), and on Io (the dark polar caps and a dusky band near the central meridian).
From left to right, top row: Ganymede just before transit (similar aspect to the bottom row); Ganymede just before occultation (with simulation); Io in transit near the GRS (x3).
Bottom row: Ganymede in transit. The images detect the bright ray system of Osiris crater; Galileo Regio; an unnamed dark area on the f. side (further darkened by the phase effect); and the white north polar cap, which becomes invisible against the clouds below.