Jupiter in 2018: Report no.6

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This will be the most substantial interim report of the 2017/18 apparition, and can serve as a draft of the final report. The apparition is nearing its end, and the JUPOS data reported herein (up to the end of July) probably covers most of the phenomena. Previous interim reports will not be repeated here: no.1 (2018 Jan.), no.2 (March), & no.5 (June) contained detailed descriptions, maps, and illustrations of some phenomena, and nos. 3 & 4 presented more maps and images. Annotated JUPOS charts were posted with 2018 Report no.2 (Appendix 2). For the previous apparition, we have yet not done a final report, but 2016/17 Report no.14 (2017 August) https://britastro.org/node/10891 was based on a full set of annotated JUPOS charts which have just now been posted as a supplement to that report.

I am very grateful for the assiduous work of all the amateur observers around the world, and of the JUPOS team who measure the images and prepare maps from them. This report is entirely due to their work, except for explicit references to spacecraft data. For some high-latitude regions, data are included from our maps of JunoCam images (as posted in the 'Results from Juno' pages on this web site); these nicely complement the ground-based data.

As usual, the report mostly uses System II longitude (L2), although L3 scales are given on some maps, and L1 is used for the equatorial region. Drift rates in L1 or L2 (DL1, DL2) are given in degrees per 30 days (deg/mth). DL3 = DL2 + 8.0 deg/mth. Latitudes are planetographic, as estimated from Marco Vedovato's maps. North is up in illustrations in the main report.

The **Appendix** contains annotated copies of the JUPOS charts, plus aligned maps, which have south up. On the JUPOS charts, unless otherwise stated, black points indicate dark features, green points white features, and red points red features. On some of these charts I have added new measurements of extended features such as FFRs (cyclonic folded filamentary regions) and the STB Ghost and Spectre, and also some measurements from our JunoCam maps.

High northern domains

N5 domain

Nothing was clearly tracked here, except a white spot at L2 = 312 in Feb.; this was also seen in Juno's PJ11 images, near the terminator. Other white spots might be trackable if more hi-res images were examined thoroughly. For example a large N5-AWO (anticyclonic white oval) was seen in JunoCam maps at PJ12, PJ13 & PJ14, probably the same oval.

N4 domain

(For background on this domain, see our long-term report [Ref.1]. A distinctive feature is that AWOs can be present at any latitude within it.)
The JUPOS maps and charts show few distinct features in this domain. Only two N4-AWOs were well tracked, dubbed a and d, while b and c were a pair picked up near AWO-a in Juno images at PJ11 (Figure 5).

(a) This was a low-latitude AWO, and around Feb.19, it shifted south into the N3 domain! We recorded another N4-AWO doing the same thing in 2011/12 [see our 2011/12 final report, & Ref.1]. During the transition, AWO-a accelerated from DL2 = 0 (Jan-Feb.) to -33 deg/mth (March), then gradually decelerated to -17 (June) – speeds spanning the N3TC range. Quantitative data from the JUPOS analysis are shown in Figure 6.

Figure 5 shows AWO-a as a big bright oval in southern N4, with a tiny N3-AWO prograding past it to the south without interaction. On Feb.17-22, AWO-a is elongated to the S as it extends across the N4 jet (though not definitely split as in 2011/12). From Feb.25 onwards it is again a white oval, though by that time it has only reached 47.5ºN, i.e. the latitude of the N4 prograde jet, though it did not acquire jet speed. But later data show it gradually descending to 45.5ºN by March 20, well within the N3 domain, and it was still a bright white oval.

(b,c) (Figure 5) These two N4-AWOs were almost in contact in the PJ11 map. The AWO-b is just visible as an unresolved light dot in the best amateur images. It very slowly swings N and p. towards the N edge of AWO-c, but is not seen after Feb.10. We cannot tell whether it merged or disappeared.

(d) (Figure 7) This was a high-latitude AWO with irregular track; viewed by Juno at PJ10 (L2=185) but not subsequently. It was very obscure in March, but a conspicuous AWO on April 18-20 (when it moved south and reversed its drift). On April 1, a track of another light spot appeared at the same longitude but with a different drift; this was probably a cyclonic light area further south:

Figure 7: AWO-d is a small AWO in a complex region with many other light ovals nearby, mainly on its S side (probably in the cyclonic half of the N4 domain). On March 29, one of these on its Sp. side (L2=135) is a large light area; on April 3-6, with the light area fixed at L2 = 135, a very dark blue-grey patch develops just p. it and AWO-d progrades rapidly alongside this very dark patch.

N3 domain

The JUPOS chart tracked four white spots for >3 months each, including AWO-a from the N4 domain (which is surprisingly bright in methane-band images in Figure 4 [July 25, Aug.1]). Several dark spots were also tracked for a month or more. All had N3TC speeds ranging from DL2 = 0 to -33 deg/mth.

N2 domain

The JUPOS chart tracks four conspicuous AWOs, and one cyclonic oval.
Of the four AWOs, the oldest and largest is LRS-1, which is dull whitish (at least to mid-July). WS-4 and WS-6 are both long-lived and white. WS-x was a new one, which may have arisen

from a FFR during solar conjunction; it was small and very bright white. It drifted irregularly then merged with WS-4 on May 25-29 (see Report no.5).

The drift rates of the long-lived ovals have been unusually steady since Jan., with only minor fluctuations: LRS-1, DL2 = -12 deg/mth; WS-4, ~-10 (the most variable); WS-6, +1. Are the drift rates of the AWOs affected by interactions with FFRs? WS-6 decelerated in Jan., possibly because it then arrived at the f. edge of a FFR. But LRS-1 continued smoothly prograding across a FFR without interruption.

The cyclonic oval was a red-brown spot in the NNTB during March, which then developed into a pale reddish oval. It was tracked from the end of March (L2 = 287; DL2 = +1.7; due N of the GRS). It was first seen as a red-brown patch in the NNTB, adjacent to the small AWO WS-x, e.g. on Feb.26 (C. Go: Fig.2 in our 2018 Report no.2) and March 4-8 (images by D. Peach, C. Foster & C. Go). Then it can be seen as a small red oval with dark rim in images from March 28 to April 8 (Fig.C2 in my report on PJ12), and later.

The NNTB is moderately dark, of variable width, with much small-scale structure, mainly FFRs. On the JUPOS chart, I have plotted the (approximate and variable) limits of FFRs, measured from selected v-hi-res images either directly or via Marco's maps. (Measurements are also plotted from our Juno maps at PJ9 and PJ14. Juno also imaged one of these FFRs at PJ11 and PJ13: Figure 8.) A pair of large FFRs, approximately fixed in L2, has probably persisted since last apparition and indeed since 2016 Jan. A new, third FFR has been partly alongside the N. Temperate Disturbance (see below), so this sector has looked very complicated.

N2 jet (NNTBs jetstream)

Continuing last year's major outbreak, there was a conspicuous series of NNTBs jet spots approaching the N. Temperate Disturbance (NTD) in Feb. & March (esp. on map of March 29-31). Others are shown in Figure 5. Since April, these little dark spots are no longer conspicuous but some are visible. Their speed (DL2 = -61 to -84 deg/mth) is slower than last apparition (DL2 = -92 for many in 2017).

The JUPOS chart shows them at most longitudes up to April. Most of them were not tracked through the NTD, being lost before they reached it or during their transit through it; probably the really vanished, as they did not reappear on the far (p.) side. However a long series of such spots did appear on the p. side of the NTD in Feb.-March – possibly arising from the NNTB-FFR that was alongside the NTD at this time. Some of them may have been destroyed as they passed other NNTB-FFRs, but five did make it round the planet to reach the f. side of the NTD in June.

N1 (N. Temperate) domain

This domain has changed considerably since last apparition and indeed, since the Juno PJ9 map (2017 Oct.24). The dark grey NTB(N) has almost completely faded away during 2018, and the featureless orange NTB(S) has faded somewhat. One remaining feature is a small-scale 'rifted' sector of NTB(N) which generates the dark NTD in the adjacent NTZ. The rifted region and NTD have a typical drift rate, DL2 ~ -14 deg/mth.

The last very dark streak in NTB(N) turned red-brown then faded away in Feb.; a shorter dark streak just f. it followed suit in April (see maps with the JUPOS chart). These were at the p. edge of the rifted sector. The rifted sector (defined by small-scale convective turbulence, but resolved only in v-hi-res images) is the one that persisted through the great NTBs jet outbreak in autumn 2016 [see JUPOS charts now posted with 2016/17 Report no.14]. As is often the case [Ref.2], it has generated a NTD (a darkened sector of NTZ) f. it. This was not present at PJ9 (2017 Oct.24) but developed from Dec. to Feb., with a well-defined f. end ('step' to NNTBs) from mid-Feb. onwards. Figure 7 shows this region. The rifted sector and NTD were still well developed in June-July (Figure 1).

JunoCam fly-overs in 2016/17 had yielded closeup snapshots of the reviving NTB, which was longitudinally uniform, except for a view of the rifted sector at PJ6. But from PJ9 at solar conjunction onwards, fortuitously, 4 of the 6 perijoves have covered the rifted sector (Figure 8); only PJ11 and PJ12 covered remote, undisturbed sectors. (None have covered the NTD.) The PJ13 (2018 May 24) view was especially impressive, showing the vigorous rifts sprawling from the NTB(N) into the NTZ; the origin of the NTC-B dark spots (see below); and the adjacent NNTB-FFR and several passing NNTBs jet spots.

We proposed that a NTD depends on a combination of a NTB rifted sector and recirculation from the NTBn into the NTZ [Ref.2]. Recent observations of a NTD, including these in 2018, thoroughly confirm its dependence on the rifted sector, but do not reveal recirculation. Even an animation of Hubble maps (two maps made on 2018 April 17 by the OPAL programme, e.g. Figure 8) does not show any recirculation in the NTZ. So it is still unclear why the rifted sector generates a NTD at some times but not always.

N. Temperate Current B (NTC-B) outbreak:
There is a notable series of tiny dark spots in mid-NTB at 28ºN (e.g. Figures 5 & 7). They appear 10-20º p. the rifted sector, presumably generated by it, and prograde for ~50-100º (two have persisted even further). They have DL2 ranging from -52 to -69, clustering around -64 deg/mth. This is a typical outbreak of the NTC-B following a NTBs jet outbreak.

N. Tropical domain

The NTropZ is narrow and white. The NEB still has a large-scale wave pattern, and an array of cyclonic and anticyclonic circulations which grew within the waves (Report no.2). All of this has shown little change since March (Report no.2) and June (Report no.5), just a gradual lightening of 'bays' in the expanded northern part of the NEB. Juno has obtained closeups of the NEB/NTropZ at each perijove, including several covering AWOs and barges (see reports under 'Results from Juno').

The JUPOS chart shows that drift rates are also unchanged since our earlier reports. The whole array from L2 150-300 has been stationary since March (DL2 range from -0.5 to +1 deg/mth). Barges have DL2 from -0.5 to +1 (mean +0.5). Of the AWOs, WS-a,b,d & x have DL2 from 0 to +1. Only WSZ, as usual, moves faster, with DL2 = -4. Features in the sector f. WSZ have DL2 = +6, representing the residual wave pattern there.

The count of prominent circulations remains as in June (Report no.5), viz. four AWOs and two barges. Other barges faded away, though less distinct circulations could still be present within the other bays and humps of the wave pattern. Of two other anticyclonic ovals:
--The 'Little Red Spot' disappeared in April, i.e. it took on the same fawn colour as its surroundings.
--WS-b was hard to spot because it had a pale reddish-brown core, like the LRS but usually fainter, also having the same fawn colour as its surroundings, from Jan. to May.

WSZ, throughout the apparition, has been mostly shaded except for a small white spot in its northern part at 20ºN. (It has had this aspect in some previous years.) Juno obtained only one, partial closeup of it as PJ9 (2017 Oct.24), but it was generally diffuse and did not show the present aspect. However a closeup of WS-d at PJ13 (2018 May 24) showed a possibly similar aspect: it was a well-formed, dull-white anticyclonic oval, with a diffuse nexus of bright white cloud bands overlying part of its northern half.

NEB waves in methane images:
A set of methane-band images from April was posted in Report no.5. Some others are shown in Figure 12. Figure 4 presents two image sets from late July. Note that NEB methane-dark waves are still prominent in the sector L2 ~ 10-140 (L3 255-25), i.e. the sector between WSZ and WS-d, which lacks substantial circulations but retains the visible wave pattern; but they are no longer evident elsewhere.

NEB rifts:
There are still few rifts (Feb.-June), just occasional small bright spots or streak in the south part of the belt. These southerly rifts seem to be becoming more common and elaborate in June-July.

In the JUPOS chart (latitudes +10/+14), one rift can be tracked as an ensemble of white spots. This was the one mentioned in report no.2, evidently the only substantial rift up to June, and it showed the typical development of a small southerly rift. It was first recorded near L2 = 357 on Feb.3, and accelerated from DL2 ~ -63 deg/mth to -95 deg/mth in Feb., then ran at DL2 ~ -100 during March-April. Later, several faster-moving (presumably more southerly) white spots arose near its extrapolated track, in May-June. The JUPOS chart also shows several shorter tracks for single white spots with DL2 ~ -96 to -146.

Equatorial Region

The Equatorial Zone (EZ) contains many prominent festoons connected with dark formations on the NEBs edge. Even between the festoons, EZ(N) is mostly shaded with a mixture of tints from light ochre to grey, apart from bright, yellowish patches near the bases of some festoons. Most notably, the central part of the EZ has gradually become a broad orange or ochre band, mingled with grey streaks on its edges. The ochre EB has got darker from March to June, and is now conspicuous. This is the first such coloration episode since a short-lived one in 2012. Only a narrow strip of EZ(S) remains white.

NEBs

The NEBs is dominated by a regular array of 12 NEBs dark formations (NEDFs) – typical prominent blue-grey projections with festoons curving across the EZ(N). From April to June, they had DL1 in the range -4 to +10 deg/mth, mostly +4 to +7 deg/mth. There were no definite records of more rapid motions, except for one white spot with DL1 ~ -30, and several dark features within one remarkable NEDF.

One large NEDF, at L1 ~ 260-290 (Feb.) --> 285-315 (July), was remarkable: it consisted of one or two dark ‘arches’ in EZ(N), which almost always enclosed one or more bright white spots (especially brilliant and elaborate from late May through June) (see maps with the JUPOS chart). The white spots were at 9-10ºN, like typical plume cores but enclosed within this complex NEDF. While it had an overall steady drift of DL1 = +5.5, the JUPOS chart shows multiple dark features within it (the bases of the arches). At first these had similar DL1 to the whole NEDF, but in April, a pair of them were prograding with DL1 = -16 and -24, and there are hints of similar rapid drifts within it subsequently.

SEBn

Throught the apparition, a large sector of the SEBn has had many typical small dark projections ('chevrons'), spaced 5.3º – 7º apart. Many of them were tracked by JUPOS in Feb.-April, with mean DL1 = -34.8 (±4.3, SD) deg/mth, i.e. u_3 = 134 m/s. This speed is slow for the undisturbed SEBn, more typical of the speeds when the S. Equatorial Disturbance (SED) was present in the 2000s. Indeed, all these tracked chevrons were in a limited sector, p. a slow-moving gap in the pattern. However, there does not appear to be a SED at present.

S. Tropical domain

Great Red Spot (GRS):

The GRS is still small and dark red, and fully detached from the SEB.

The GRS accelerated in April-May, a few months after the STropD arrived. Given the 90-day oscillation, it's not clear whether it has yet decelerated again, but I'm expecting it to do so now that the STropD is no longer there. In Report no.5 we posted a JUPOS chart extrapolated to estimate the possible range of GRS longitude at PJ18 (2019 Feb.12), and the latest chart does not lead to any change in this prediction.

Outcome of the South Tropical Disturbance (STropD):

The STropD seems to have been determined to defy my predictions. When the p. end (p-STropD) passed the GRS, it produced intense turbulence p. the GRS across the southern STropZ and in the S. Temperate latitudes, but it failed to re-form a p-STropD as expected. When the f. end (f-STropD) arrived at the GRS, on May 30, it did not immediately reappear p. the GRS. But just as I was writing in Report no.5 that it did not re-form, images from June 12 onwards showed a rather inconspicuous feature developing which did resemble a f-STropD [Figure 9]. By June 28 it apparently spanned the STropZ; it was pointed out by Johnny Hsieh and Andy Casely. I nick-named it 'Son of f-STropD', though this is not suggested as a permanent name. Marco Vedovato's extended animation of his maps [Figure 10] suggests that this was simply the f-STropD that did survive passage round the GRS. It was shown near the limb in Juno PJ14 images, and had a form just like a f-STropD; but the turbulence that had earlier streamed into the sector p. it from the STropD had almost entirely subsided [see report on PJ14 under 'Results from Juno']. This seems to have been an example of turbulence evolving from large to small scales.

'Son of f-STropD' is still visible as a 'step' in the STBn, up to Aug.16 [Figure 3] but there is no visible disturbance. Otherwise, the STropZ is clear.

S. Equatorial Belt (SEB):

The rifted sector f. the GRS, which was quite extensive when the STropD was alongside it, revived again with white spots in late May, as described in Report no.5. Similar white spots continued to appear at the same location (L2 = 337.5 ±3.3). As usual, they appeared as tiny brilliant white spots which presumably then expanded and prograded. The new spots were: May 26 (L2=334), June 2 (336), and possibly more, making an elaborate series until: June 7 (343), and possibly more, until: June 14 (340), June 24 (335), June 28 (336), July 1 (341), July 10 (335, the last new one at the source). After July 10, the sector of activity contracted toward the GRS. Small bright spots were still sometimes seen in it – e.g. on July 20 (B. Macdonald), but were short-lived. By August, only remnants of previous spots were present. In mid-August, it seems possible that the activity has switched off and that a SEB Fade may ensue; but we will have to wait to find out.

Outside the rifted sector, i.e. at most longitudes, the SEB has been quiescent all apparition, with several components:
--Narrow dark SEB(N);
--A bluish zone with many tiny white spots and blue-grey streaks prograding;
--Dark grey SEB(C);
--A brown zone which has become lighter during the year;
--Narrow SEB(S) which appears increasingly dark, though perhaps only by contrast.
Several small brown barges at ~16.5ºS lie at the boundary between the light brown zone and the dark SEB(S) (Figure 1).

SEBs jet:
The JUPOS chart shows many white spots retrograding between L2 ~ 60-170, from Dec. to April – especially many in Feb., but few thereafter. Here we update the account of them given in Report no.2. They were tiny white spots within the dark SEB(S) at 18-19ºS, on the north flank of the SEBs jet. Mean DL2 was +45.5 (±12.5; n=6) in Dec-Jan., and +67.2 (±5.9; n=6) in Feb-April. Similar spots were observed in 2014/15 [see 2014/15 Report no.10 and Final Report, SEBs spot group F]: mean latitude 18.3 (±0.2)ºS, DL2 = +89 (±14).

The SEBs jet peak did not carry visible spots this apparition, apart from five recorded in May-June: just one typical vortex at 20ºS with typical jet speed (DL2=+116), and four dark spots or streaks slightly further south with lower retrograding speeds.

STBn jet:
Two sets of spots were recorded on or near this jet:
(1) Small dark spots arising p. the GRS, from the STropD as it passed the GRS, in Feb-May. Of many spots seen, just five were tracked, with DL2 increasing from -40 (one in early April) to ~-47 (±1; three in April-May) to -56 (one in May-June).
(2) Small dark spots arising from the edge of oval BA, embedded in the dark STB(N), tracked in May-July at latitudes 29 --> 28ºN; DL2 = -87 (±1) (n=3) and -74 (n=2). This is the STBn jet outbreak that was predicted with the transformation of the STB Ghost into the new dark turbulent STB segment f. BA.

S. Temperate domain

STB(N) was a very narrow dark belt all around the planet in June, apparently darkened due to turbulence both from the STropD and from the region of oval BA. (See above for STBn jet spots.) While most of the STB(N) was dark grey, the sector that had been disturbed by the STropD, extending for ~60-75º p. 'Son of f-STropD', was further north (down to 25ºN in the STropZ) and orange [Figures 1 & 9]. However, this and other sectors have been fading during July-August, suggesting that the effects of the STropD are finished. In mid-August, the only remaining very dark STB(N) is the sector p. BA, as far as the GRS [Figures 1-3], which is also spotty with STBn jet spots (see above).

The segment of STB f. BA, created by the turbulent transformation of the STB Ghost in Feb., is still dark and disturbed [Figure 11]. The sector of STZ f. it ('the Sf. tail') has been extremely dark grey since April. There is still a tiny AWO embedded in it. The origin of the dark Sf. tail and of the embedded AWO (which was then reddish and methane-bright) is shown in Figures 11 & 12.

All the predicted effects of the STB Ghost collision have now occurred: its dramatic transformation into a turbulent dark STB segment; emission of dark spots p. it on the STBn jet and f. it in the STZ; a dark rim around oval BA; and acceleration of oval BA, which occurred decisively in May. Oval BA itself has only weak orange tint in July and August, probably paler than it was early in the year.

The STB Spectre is now very pale again, barely discernible in recent images, though still a very coherent circulation according to Juno images at PJ13.

Drift rates from the JUPOS charts are as follows, from April or May to July:

	Mean DL2 (± estimated uncertainty)
Oval BA (accel. decisively in May):	-13.8 (±0.2)
F. edge of turbulent STB	(-13.8) (±1.3)
Small AWO in Sf. tail	-9.6 (oscillating)
STB Spectre: P.end	-21.6 (±0.6)
-- F.end	-20.4 (±1.3)
Dark spot	-12.5 (±0.8)

Structured segments such as the STB Ghost and Spectre usually retain steady drifts, but this is not the case now. After the transformation of the Ghost f. BA, the drift of its f. end has varied and is now about the same as BA's, so it is not shortening. Conversely the STB Spectre accelerated and lengthened as it passed the GRS in Dec-Jan. (perhaps influenced by turbulence already streaming past it from the STropD on the STB(N), but before it was directly impacted by further turbulence from the STropD in March). So as of July, the Spectre was converging on the dark STB segment at up to 8 deg/mth – but they may yet revert to more typical speeds.

Oval BA is now approaching the GRS. The central conjunction is expected to occur in 2018 Dec., with a possible range of Dec.2-19, and the passage will last about a month altogether. I do not expect any change in BA, but the surrounding cyclonic structures could be affected.

One other anticipated event would be the appearance of a new STB structured sector, somewhere in the long undisturbed sector between the Spectre and oval BA. In the past, such structures have arisen as small cyclonic spots tens of degrees p. oval BA, so it is interesting that dynamical events have recently started occurring in that region (see below).

STZ and SSTBn (S2) jet:
The following features have all appeared tens of degrees p. oval BA, which could be further consequences of the transformation of the STB Ghost.
(1) The only spots recorded in the SSTBn (S2) jet this year were a pair of dark spots that were tracked from late March until mid-May, with DL2 increasing from (-66,-69) to -89 deg/mth.
(2) A dark spot in southern STZ (34ºS) appeared in late May (33 --> 40 p. BA; DL2 ~ -19), followed by a dark streak alongside the SSTBn from mid-June to early July (DL2 ~ -23) [Figure 11].

High southern domains

S2 domain [Figure 11]

AWOs:
Since the merger of AWOs A6 and A7 in May (see Report no.5), the count is seven large AWOs plus the younger, smaller AWO A5a.

As described in Report no.2, A5a has stopped growing as it approached the long FFR p. it. They came into contact in April, and A5a remained at the f. end of the FFR in May-June. This may be why A5a changed its drift suddenly in late May, from DL2 -31.5 to -21.0.

Drift rates of AWOs from Feb. onwards: A8 and A1 to A5 had steady mean DL2 values ranging from -26.8 to

-28.3 (though with a few faster track segments up to -31). A6 and A7 accelerated suddenly in March, from ~-27 to ~-38 (A6) and from ~-32.5 to -40 (A7), as a new FFR appeared and expanded alongside them, possibly pushing them p. away from A8. They passed BA in April, then merged in late May (Report no.5). (A7 attained DL2 = -48 before the merger.)

Cyclonic features:
There were no whitened sectors of SSTB until April, when a pale fawn-coloured cyclonic circulation between A8 and A1 gradually brightened [Figures 11 & 12]. It was brilliant white by late May, and expanding, and surprisingly methane-bright (even up to Aug.16 [Casely]). A cyclonic dark spot f. A5a shrank and turned reddish in March, then light fawn-coloured in May.

Thus we have in this domain several instances of phenomena that we suspect or know to be general: two where a FFR probably excluded AWO(s) from the same longitude sector; one where a cyclonic white segment expanded; and one where a cyclonic dark spot turned red before fading away.

S3 jet:
Exceptionally, only two spots were tracked in the S3 jet, both white, with DL2 = -96 and -97.

S3 domain

There is a very long FFR in this domain, centred at 47ºS, shown in Figures 11 & 12.
FFRs at such high latitudes were never resolved in amateur images until the last few years, and now can only be resolved in the best images. On the JUPOS chart, I have added measurements of S3-FFRs from Marco's ground-based maps and from our JunoCam maps. These show a long FFR since late Feb.; in L2 it is prograding, in accord with the S3TC, but as this current is almost stationary in L3, we can quote L3 ranges. According to the Juno maps, this FFR apparently formed by merger of two long FFRs after PJ10 (2017 Dec.16), and its f. end was probably delimited by dark streak(s) that we tracked in summer 2017 (see JUPOS chart). From late Feb. to early April, the FFR spanned L3 ~ 280-335. In April and early May its interior was quiescent, dark and not very rifted; but in late May it became more disturbed again, spanning L3 ~ 260-330. It was rarely resolved in ground-based images after May.

Alongside and f. the FFR, the 2018 JUPOS chart shows numerous small dark spots, mostly retrograding with DL2 ~ +9 to +12 deg/mth, at 49ºS. Those f. the FFR very likely belong to the same sector containing dark streaks and retrograding dark spots that was recorded the 2016/17 apparition, drifting then with DL2 ~ -11 deg/mth; it would have drifted at ~-14 deg/mth during solar conjunction. This was very similar to sectors in 2005-2010 [Ref.3] and 2014-2016 [see our final report for 2015/16]; all these sectors had similar drift rates typical of the S3TC.
All this confirms our theory [Ref.3] that such long-lived bands of retrograding dark spots, moving with the S3TC, represent spots produced continuously from a long-lived FFR further p. (east). This theory is also supported by details seen in some JunoCam images (as noted in some of our Juno reports, although a systematic study remains to be done).

There was only one conspicuous AWO in 2016/17, which was the long-lived S3-AWO-1 [Ref.3 & our final report for 2015/16]. In 2018 it was one of three S3-AWOs sporadically tracked (see JUPOS chart); adding Juno measurements shows that it had a mean drift of DL2 ~ -18 (Feb-July). It was barely visible in some Juno global maps, but fortuitously captured close-up at several recent perijoves (PJ10, PJ12, PJ13, PJ14), as it was prograding rapidly to the south of the GRS and past S4-LRS-1. These images show it as a well-formed AWO with no rim and therefore virtually no contrast with the surrounding white zone ('S3TZ').

S4 domain

The JUPOS chart shows three dark barges at 54ºS, prograding with DL2 ~ -11 deg/mth (variable speeds from 0 to -20). All three are shown on Figure 12. The central one elongates to become an extremely dark oblique streak which then splits. (So this was not an impact scar, despite its resemblance to the Bird Strike impact in 2009!)

The main features, as usual, are the anticyclonic ovals. AWOs-2 & 3 converged and possibly merged around the start of 2018 (see Report no.2). The survivor, dubbed AWO-2, had rapid drift (DL2 = -20; lat.59.5ºS) throughout the year, apart from some early oscillations, and acceleration since June. The largest oval, LRS-1 (the 'south polar little red spot') has been a distinct reddish oval S of the GRS region throughout 2018, with slow drift (mean DL2 = +4.5; lat.58.5ºS). LRS-1 and AWO-2 are converging rapidly as of mid-August (as Clyde Foster and Andy Casely have reported) and could merge in the next few weeks.

References to some of our long-term reports:

1. Rogers J, Adamoli G, Jacquesson M, Vedovato M, & Mettig H-J (2017),
'Jupiter's high northern latitudes: patterns and dynamics of the N3 to N6 domains.'
https://britastro.org/node/11328

2. Reports on the N. Temperate Disturbance via links at:
http://www.britastro.org/jupiter/reference.htm

esp.: Adamoli G & Rogers J (2009) Jupiter in 2009, Report no.8: 'Jupiter's North Temperate Region in 2009: The nature of the North Temperate Disturbance.'
http://www.britastro.org/jupiter/2009report08.htm

3. Rogers J, Adamoli G, Hahn G, Jacquesson M, Vedovato M, & Mettig H-J (2014).
'Jupiter's southern high-latitude domains: long-lived features and dynamics, 2001-2012.'
http://www.britastro.org/jupiter/sstemp2014.htm

Figures:

Figure 1. Recent maps of Jupiter: (a) June 28-30; (b) July 19-20; (c) August 12-16. Longitudes in L3, with N up.
(Maps for May 23-24 & June 9-10 were shown in Report no.5; maps for July 9-10 and July 14-17 (Einaga) were shown in Report on PJ14. In the Appendix is a larger set in L2 with S up, from June to Einaga's in August.)

Figure 2. Set of images, 2018 July 15-17, covering Juno's perijove-14.

Figure 3. Set of images, 2018 Aug.12-16, ordered by longitude.

Figure 4. Methane band images, 2018 July. Here are two sets of methane-band (889 nm) images from late July, by different observers, ordered by longitude. They were not made with

the most selective filters possible, but still show the important features. These include methane-bright anticyclonic ovals, esp. the LRSs (marked), and also the S2-AWOs and (weakly) several others. Methane-dark waves are still prominent in the NEB sector from L2 10-140 (L3 255-25), but not elsewhere.

Figure 5. These images show the behaviour of three AWOs imaged in the N4 domain by JunoCam at PJ11 (see map in centre). AWO-a moves north from the N4 to the N3 domain, crossing the prograde jet. AWO-b , barely visible in the ground-based images, moves clockwise around the edge of AWO-c until it disappears. The images also show many spots on the NNTBs jet, and the NTC-B spots p. the NTB rifted sector.

Figure 6.   Charts tracking the translocation of N4-AWO-a from the N4 to the N3 domain, measured from images in Figure 5. Charts show the longitude (L2), latitude, and speed (DL2) compared with the ZWP from Cassini.

Figure 7. Images showing part of the northern hemisphere from March 16 to April 10, showing (at top) a complex region of the N4 domain containing the small AWO-d, and (at bottom) the NTB with NTD, rifted sector (rather quiescent at this time), fading orange remnant of a dark streak, and spots prograding in NTC-B.

Figure 8. The NTB rifted sector and NTD in from spacecraft in this apparition: a map from Hubble on April 17, with index maps of the closeup images from JunoCam. (They are approximately aligned relative to the rifted sector rather than absolute longitude.) Fortuitously, 4 of the 6 perijoves covered the rifted sector (FFR), while PJ11 and PJ12 covered remote, undisturbed sectors.

Figure 9. Set of images showing what seems to be the f. end of the STropD reappearing after rapidly passing the GRS.

Figure 10 *[separate file]*. *ANIMATION* by Marco Vedovato of his maps, covering the STropD and its entire passage past the GRS. {GRS-STrD-2018anim_MV_FINAL}

Figure 11. Set of maps showing part of the S1 and S2 domains. (All maps by Marco Vedovato, with north up.) In the S1 domain, the maps show oval BA and the new turbulent STB segment f. it formed from the STB Ghost; and in the STZ, the formation of the very dark 'Sf. tail' and the little AWO within it; also see Figure 12. In the S2 domain, the array of AWOs, with A6 and A7 merging on May 28-30, and the pale area between A8 and A1 turning white.

Figure 12. Set of images showing part of the southern hemisphere:
(S1 domain:) In the STZ, the very dark 'Sf. tail' and little AWO within it, both newly forming; the little AWO shows possible anticyclonic motion, and reddish colour (May 24, April 3) and was methane-bright from April 3 onwards – also in the PJ12 (April 1) south polar methane map [in my PJ12 report].
(S2) S2-AWOs A6-A8 & A1-A3, with the pale area between A8 and A1 before it turned white [see Figure 11]; also variation in activity in a cyclonic circulation between A2 and A3, between dark-quiescent and FFR states.
(S3) The long FFR and the sector of retrograding dark spots f. it.
(S4) A very dark streak or barge which elongates and splits, plus other such barges p. and f. it.