JunoCam at Perijove-28: What the pictures show

John Rogers (BAA) (2020 August)

PJ28 was on 2020 July 25, with equator crossing at L1=277, L2=186, L3=266. This was another Gravity orbit so views of low latitudes were again oblique. Abbreviations and acknowledgements from previous perijove reports apply also in this one.

North polar region

Circumpolar cyclones (CPCs) (Figure 1):

The images give a good view of CPCs 4 to 7, and of almost half the North Polar Cyclone (NPC), and of the AWO on the poleward side of CPC-7. The four CPCs all have their usual morphologies. CPC-5, always the largest 'filled' CPC, has a hint of a counter-spiral and definite counter-rotation in its inner parts – both on the edge of the central dark annulus (a clear zone?) and in the trio of white clouds within it, as shown by blinking maps. CPC-7 has a counter-spiral in its inner part but does not show counter-rotation.

CPC-7 is once again at lower latitude than the other filled CPCs, being centred at 82.0ºN, i.e. it has moved away from the pole since PJ27.

Although recent orbits have not strictly followed the pattern of quartets with 90º intervals, the last four orbits have been close to it (just one interval was 67º), so we can make a montage of the north polar polygon from PJ25-PJ28 (Figure 2). The octagon looks beautifully symmetrical (as CPC-7 is shown at PJ27 when it was temporarily at a normal latitude). The NPC is clearly visualised, and appears to be centred exactly on the pole. The AWO poleward of CPC-7 has been present throughout the mission – but here it appears 'balanced' by a reddish AWO poleward of CPC-3, though this was only seen at PJ25.

The North Polar Hood (NPH), haze bands, and Bland Zone:

Figure 3 presents polar projection maps of the high northern latitudes, (A) in normal colour, (B) in the methane band, and (C) in colour favouring near-terminator regions so as to highlight haze bands. The Bland Zone is obvious in map A except for a short chaotic sector. Map C shows three of the usual linear bands on the Bland Zone and its S edge (one of them being a bundle of several bands), which are typical in length and orientation. All three are clearly visible in methane in map B. Two of them, near the morning terminator and the limb, form conspicuous boundaries between methane-bright NPH to the N and methane-dark zone to the S. But away from the limb, the NPH is not recognisable, in keeping with images at other recent perijoves.

Map C also shows a rich tangle of curved and oblique haze bands near the dusk terminator at lower latitudes, all the way down to the NNTZ. The methane map (B) also shows some bands in these latitudes, diffusely near the terminator or limb.

High northern domains

As usual, a wealth of spectacular detail is visible. Figures 4-6 show some of the highlights. The images in these figures are shown with south up, which aligns better with the polar map (Figure 3) and retains the perspective of these oblique views. (Conversely, the cylindrical maps in Figures 7-9 have north up.)

Figure 4 shows the N edge of the Bland Zone. FFRs (folded filamentary regions) are the very bright tangles (partly appearing pink as an artefact of image enhancement) . They may be topped with popup clouds, and some may be pushing outwards with 'bow waves', just like FFRs at lower latitudes. There are many small vortices, cyclonic (blue arrows) and anticyclonic (magenta arrows).

Figure 5 shows the intensely chaotic regions of the N4 and N5 domains. With perijove shifting northwards, the resolution is now sufficient to show that the bright white strips in FFRs here are densely topped with popup clouds, just like FFRs at lower latitudes. Another notable feature is the high density of anticyclonic vortices. They include clusters of many AWOs of different sizes in the N4 domain (boxed in red in panel A), but also many smaller vortices in the N5 domain, which are grey (as also in Figure 4). Conversely, cyclonic vortices are commonly orange, e.g. numerous small eddies in the N4 domain between the AWO clusters, or larger, well-formed spirals seen in Figures 4 & 6A (blue arrows). Similar orange cyclonic vortices in the northern domains are familiar from previous perijoves.
The N3 domain contains a pair of interacting AWOs (green arrows in Figures 5 & 6A).

Figure 6 shows highlights from images 20 to 23, particularly features where there is clear evidence for vertical structure. (Note: As always, all colour descriptions below are only relative.)

In panel A (image 20) the lower part (foreground) is a closeup view of some of the cyclonic and anticyclonic vortices in the N4 domain. At several places (white arrowheads), bands of grey clouds appear to be over-riding lighter, more reddish clouds.

Panel B includes a closeup of NN-WS-7, a bright white AWO that has been tracked throughout this year. It has well-marked anticyclonic structure with bands of popup clouds on the white cloud ridges, but also a reddish annulus near the periphery. It thus resembles other such NNTZ ovals that JunoCam has imaged closely (PJ1,3,7,12,14,21,25).

SE and SW from NN-WS-7 are turbulent portions of the cyclonic NNTB, again with evidence for different coloured clouds which sometimes overlie one another. The area to SW is a FFR, and part of it is shown close-up in panel C. Here, a bright white lobe from the FFR appears to be expanding vigorously to the SE (overlying the N2 jet), over-riding the surrounding orange cloud layer, with a raft of dense popup clouds near its (presumed) leading edge, and a series of concentric arcs ahead of it (red arrows) – possibly some kind of wave ahead of the storm? A smaller lobe on the right is expanding similarly to the S. (Compare views of NEB rifts, described below.)

Panel D shows a v-hi-res image of the NTB (highly contrast-enhanced), showing strange narrow cloud lanes overlying some of the turbulent features.

Equatorial Belts & Zone

Figure 7 is our JunoCam cylindrical map of the whole planet. Figure 8 is a similar map of the NEB & EZ at higher resolution, by Brian Swift. Figure 9 shows ground-based imagery for comparison, within 24 hours of PJ28. [More extensive ground-based maps are in our 2020 Report no.5.]

The images show several major structures in the NEB (Figures 8 & 9), although only obliquely. In the northern NEB (Figure 10), we see the former AWO labelled WS-n (now dull grey with a broad orange surround), and a mini-barge (orange with a dark grey surround). WS-n does show concentric streaks but, like most features in the NEB, it is all quite diffuse and low-contrast. Following it, and only imaged near the limb in receding views, is one of the large cyclonic ovals that are an unusual feature of the expanded NEB at present; its interior seems to contain irregular cloud streaks.

In the southern NEB there are two bright white plumes (Figure 11A: red asterisks), seen from Earth as brilliant white points, within longer bright 'rifts'. These may be the freshest eruptions in NEB rifts that JunoCam has viewed. But here too the clouds appear somewhat diffuse, with no evident popup clouds. SE of the closest one there are arcuate bands of white haze like waves, suggesting that the rift may be expanding towards the EZ (red arrows in Figure 11A), as one did at PJ27. A similar fresh white plume was imaged at hi-res at PJ4, though very obliquely [spot V in Fig.5 of our PJ4 report, image 102] , and it showed somewhat similar waves SE of it, which were interpreted as lee waves (Figure 11D, an enhanced map projection, from Fig.12 of Ref.1).

Large areas of mesoscale waves are visible, even in locations where they have not been seen before [see Ref.1]. They could include the arcs noted above ahead of the southward erupting plumes from the NNTB FFR (Figure 6C) and the NEB rifts (Figure 11A), perhaps reminiscent of bow waves; and there are also numerous wave-like streaks orthogonal to the latter case. Adjacent to it, there are also trains of longer-wavelength mesoscale waves in orange haze lying roughly along the NEBs jet and transverse to it (Figure 11A&B: black polygons enclose the areas where waves are present).

And the EZ itself is mostly covered with mesoscale waves (Figure 11C: image 30). There are conspicuous wave-trains made of bright clouds over a dark blue-grey festoon in EZ(N) and over smallscale blue-grey streaks in EZ(S); and there are large expanses of more subtle ones on the ochre and grey cloudscape in between, although in many areas they appear more like ripples or flocculent clouds with poorly defined periodicity. Image 32 (Figure 12, left) shows that these wave-trains continue to the west, now viewed side-on. Many of these waves can be located in Brian Swift's map (Figure 8).

Finally, there are trains of mesoscale waves along the SEB(S), in image 34 (Figure 12, right), probably just N of the SEBs jet. Also in this image, there are several narrow red bands running parallel to the edges of the SEB(S) (yellow arrow-pairs), similar to haze bands that we have noted at PJ26 and PJ27, and one appears to be bulged southward around a cloud system protruding from the SEB(S) (red arrow), reminiscent of the NEBs at PJ27. (These features are all confirmed in adjacent images.)

Ref.1. G.S. Orton et al. (2020) 'A Survey of Small-Scale Waves and Wave-Like Phenomena in Jupiter's Atmosphere Detected by JunoCam.' JGR-Planets, Vol. 125, no. 7, e2019JE006369.

S. Temperate domain

An expected highlight of PJ28 was the view of the f. end of the STB Spectre (F-Spectre for short) [see our 2020 reports nos.2 & 4]. The images (e.g. Figure 13) did not disappoint. It still has a sharply defined structure implying that it is still a site of cyclonic recirculation, as in previous years when the Spectre was a short segment [see PJ-5,13,15,21&22]. Adjacent to it is a well-defined anticyclonic ring, which I suspect is now a persistent component of the complex. In methane images (Figure 14), the Spectre itself is still darker than its surroundings, while the anticyclonic ring is strikingly methane-bright.

We have made an animation from hi-res maps of these images; Figure 15 is a diagram of the motions observed. The cyclonic recirculation is confirmed. There is no anticyclonic recirculation (which has previously been observed for discrete spots rather than general winds); instead, the STBs retrograding jet emerges on a southward slope f. the F-Spectre, which we have also observed in ground-based images (the motion of spot (d) in Figure 18 of Report no.4). The F-Spectre appears to be a well-established structure, of an isolated type not previously studied by spacecraft, so its future development will be of interest.

Another novel feature of this animation (Figure 15) is the impression that the northern division of the STBn jet does not run straight, but deviates along the waves that are always faintly visible in JunoCam images of it. But we need to check that this is not an artefact of map projection.

In outbound images (incorporated into the global map, Figure 7), Clyde's spot rotates into view at image 51; it is still irregular and has disturbance flanking it, and is still weakly methane-bright (Figure 14). Then the other dark spot (DS6) comes into view, followed by the GRS.

High southern domains

In the S2, S3 and S4 domains, there are well-defined belts (SSTB, S3TB, S4TB) consisting largely of FFRs and/or darker turbulent sectors, with diffuse reddish spots over the cyclonic eddies.

South polar region

Figure 16 presents our usual composite south polar projection maps.

An animation shows the usual currents including the S5 and S6 jets and circulations in the FFRs and CPCs. The S6 jet can be seen to follow the pronounced waves that are visible in the edge of the methane-bright South Polar Hood (SPH), and turbulence appears to be streaming into the jet from several FFRs on its poleward side. There is also a local jet segment further S, prograding in a straight line from L3 ~ 330 --> 260 between 74 and 77ºS; it partly consists of edges of FFRs but also seems to flow between them. It is partially aligned with a bundle of haze bands on its N side. The animation also shows a short flow poleward into the left-hand side of the gap between CPCs-2 & 3.

Haze bands:

The PJ28 images show more conspicuous haze bands near the terminator than PJ27, and Figure 16C is a mosaic map of them. But there are still no very long, high-contrast bands. (Some bands are more completely seen under high sun in the albedo map, Figure 16A.) The methane map (Figure16D) shows not only the methane-bright SPH, but also weaker methane-bright wisps extending to lower latitudes near the dawn and dusk terminators, as at PJ27.

Circumpolar cyclones (CPCs):

With the S. Polar Cyclone (SPC) being on the sunlit side of the pole, it and the five CPCs can all be made out in the composite map (Figure 16A&B), although some of them are indistinct. In Figure 17, the maps from PJ25 to PJ28 are compared; the CPCs are outlined (approximately) in yellow, to aid recognition now that the resolution and contrast of the images are diminishing.

The pentagon of CPCs is still present, but the gap is now between CPCs-2 & 3, not CPCs-1 & 2 as hitherto. This is also the direction in which the SPC is now displaced from the pole (see below), which supports our geometric explanation for the pentagon and its asymmetries [Ref.2].

Figure 18 continues our tracking of the centre of the SPC. It has moved closer to the pole, but has strayed outside its previous range of longitude; its centre is now at L3=273, 88.0ºS. This implies that its tentative identification at PJ27 (at the same longitude as at PJ28, and the same latitude as at PJ26) was correct. Its motion since PJ21 (Figure 18A) describes a long loop, indicating that the SPC continues to oscillate in the same sense as hitherto, though towards higher longitudes.

Looking at the motion over the past four years, since PJ1 (Figure 18B), the seemingly imperfect cyclicity may fit into a longer larger pattern. The SPC continues to oscillate with a period of 11.5 (±1) months, but the centre of each cycle has gradually shifted. Like a soaring bird of prey, the SPC has been performing slow loops which gradually drift in one direction.

Ref.2. F. Tabataba-Vakili, J.H. Rogers, G. Eichstädt, G.S. Orton, C.J. Hansen, T.W. Momary, J.A. Sinclair, R.S. Giles, M.A. Caplinger, M.A. Ravine, S.J. Bolton (2019/20). 'Long-term tracking of circumpolar cyclones on Jupiter from polar observations with JunoCam.' Icarus 335, paper 113405.

Figures

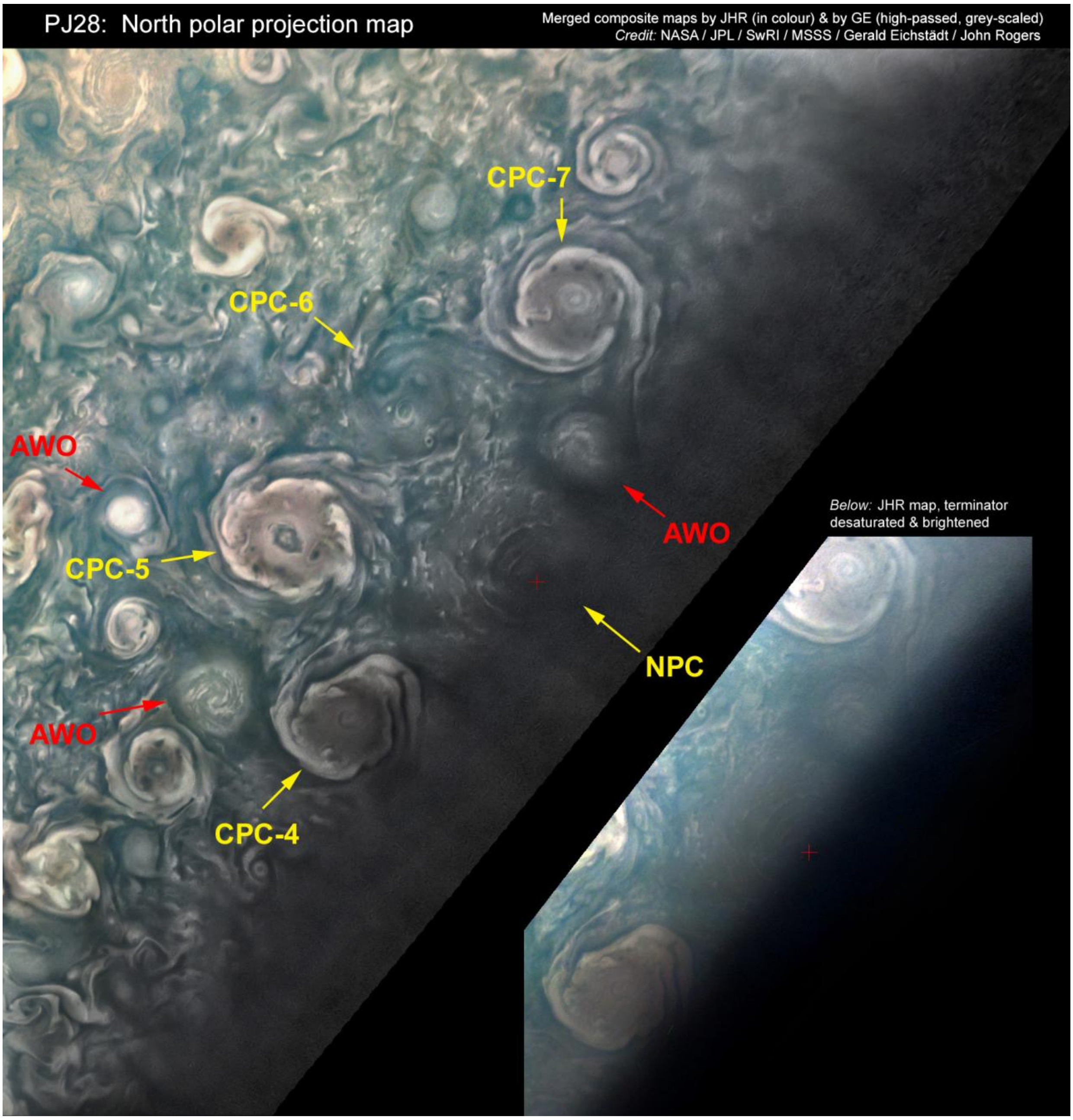


Figure 1.

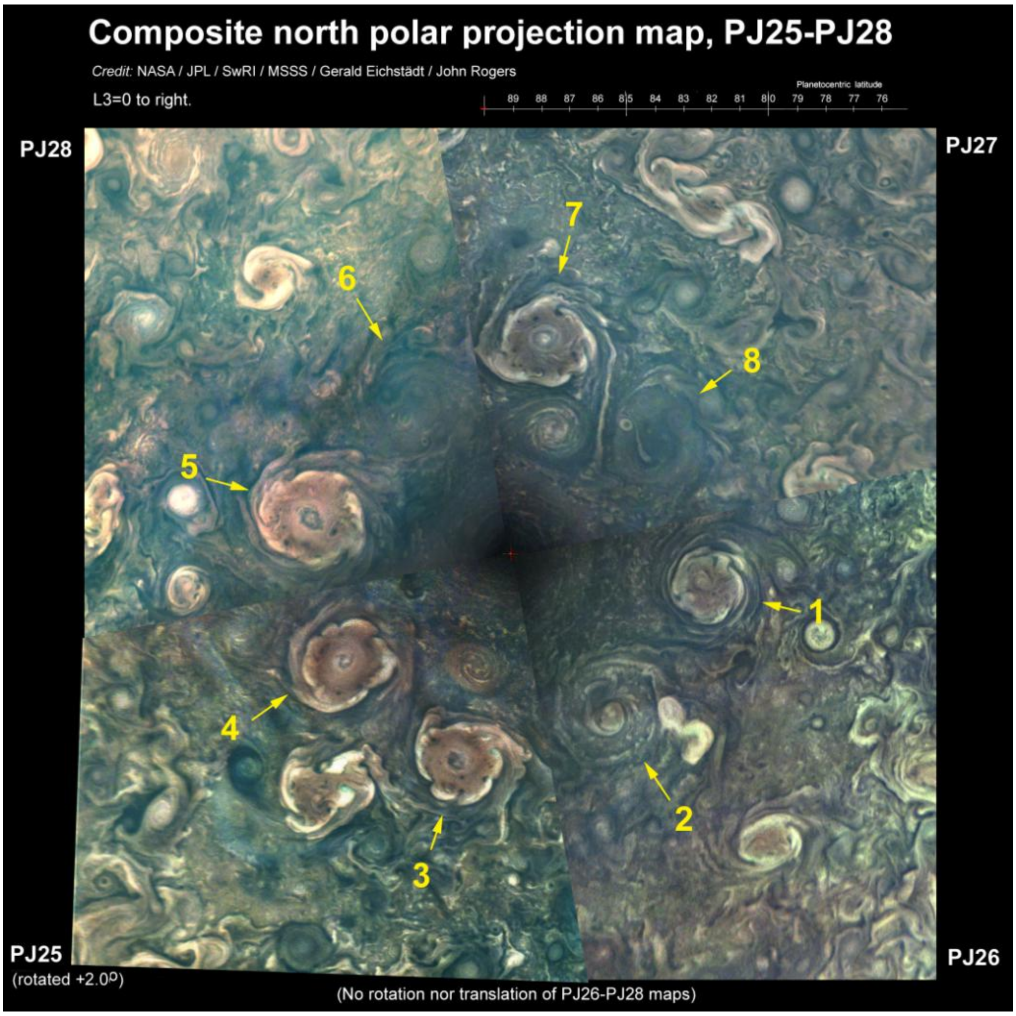


Figure 2. Montage of the north polar ditetragon from four perijoves; CPCs labelled.

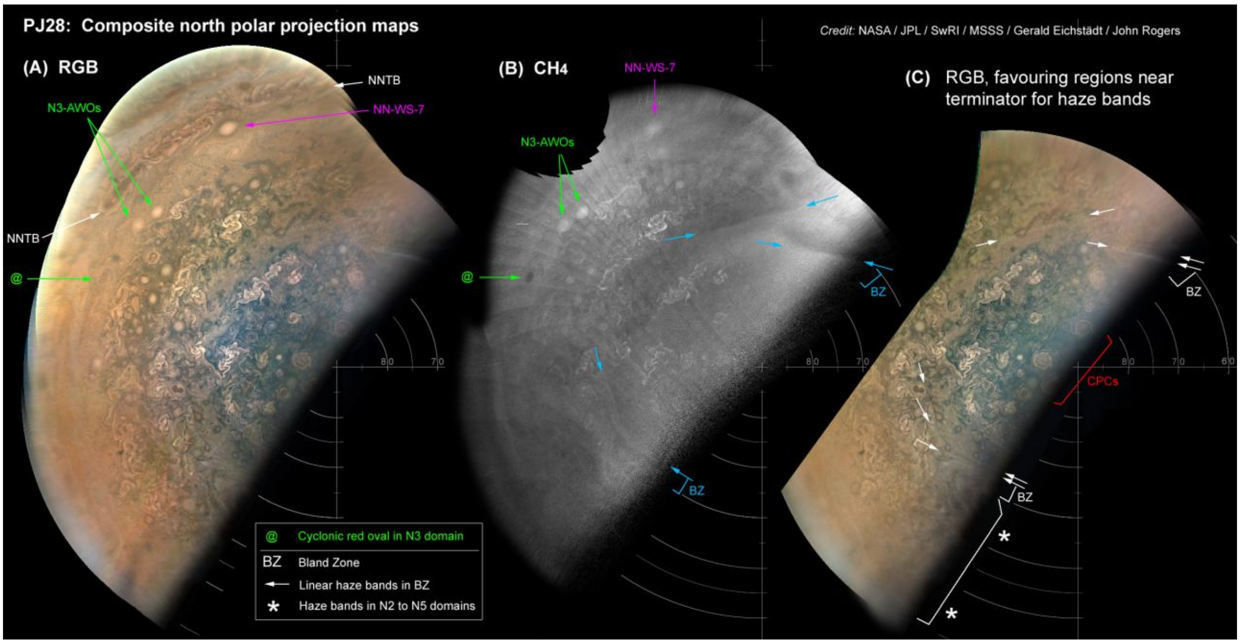


Figure 3. Composite north polar projection maps at PJ28.

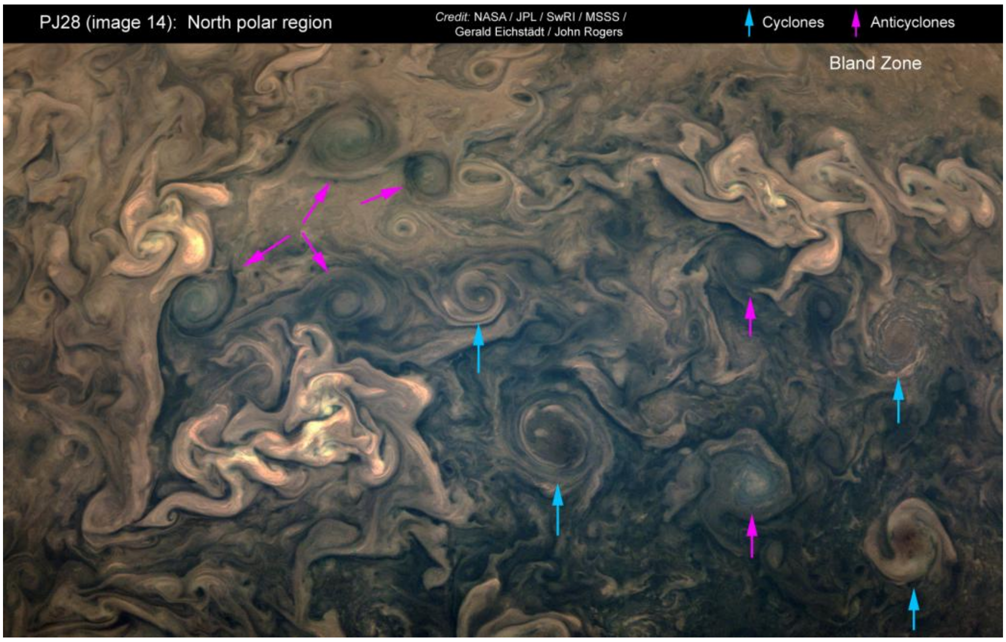


Figure 4.

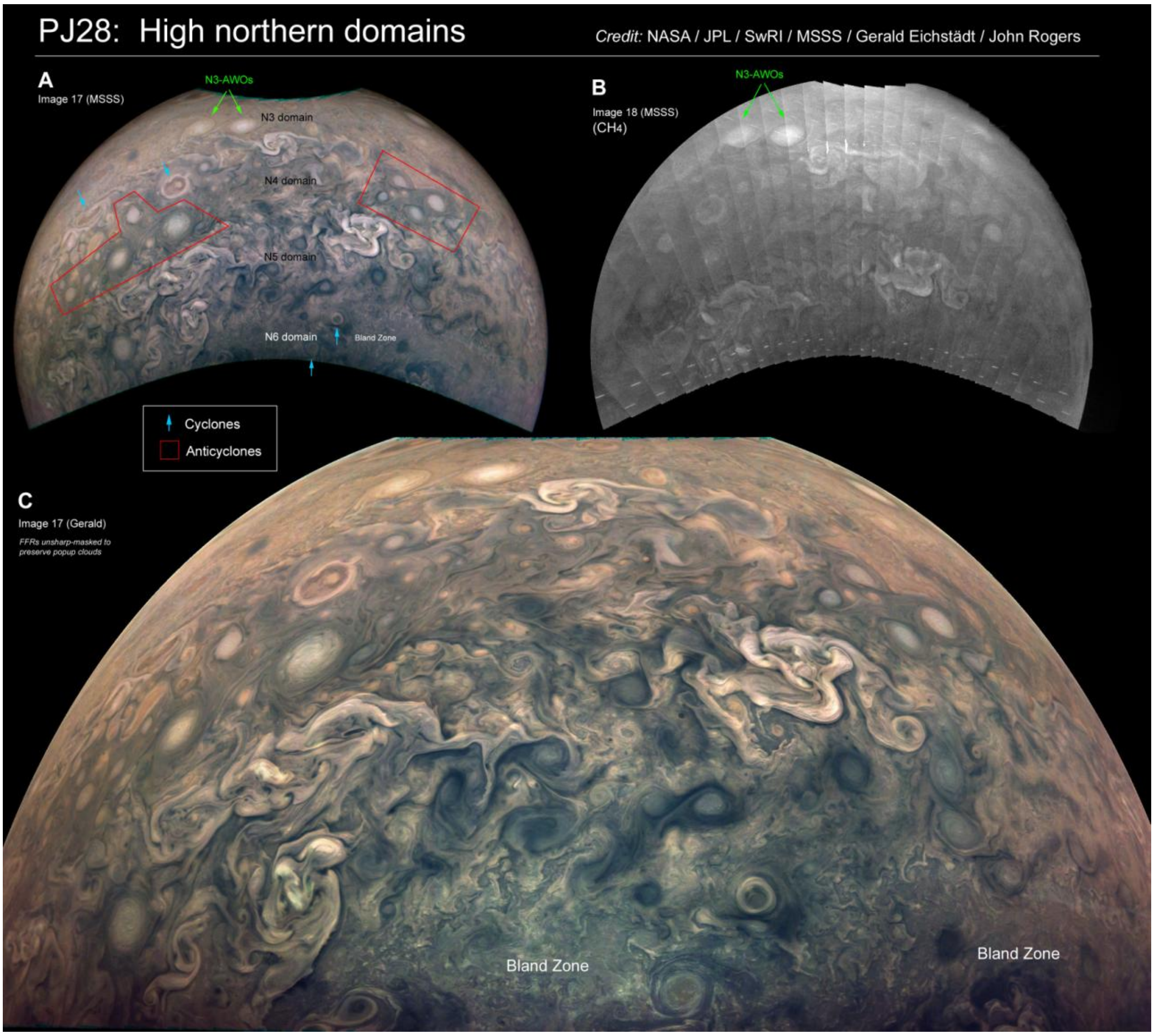
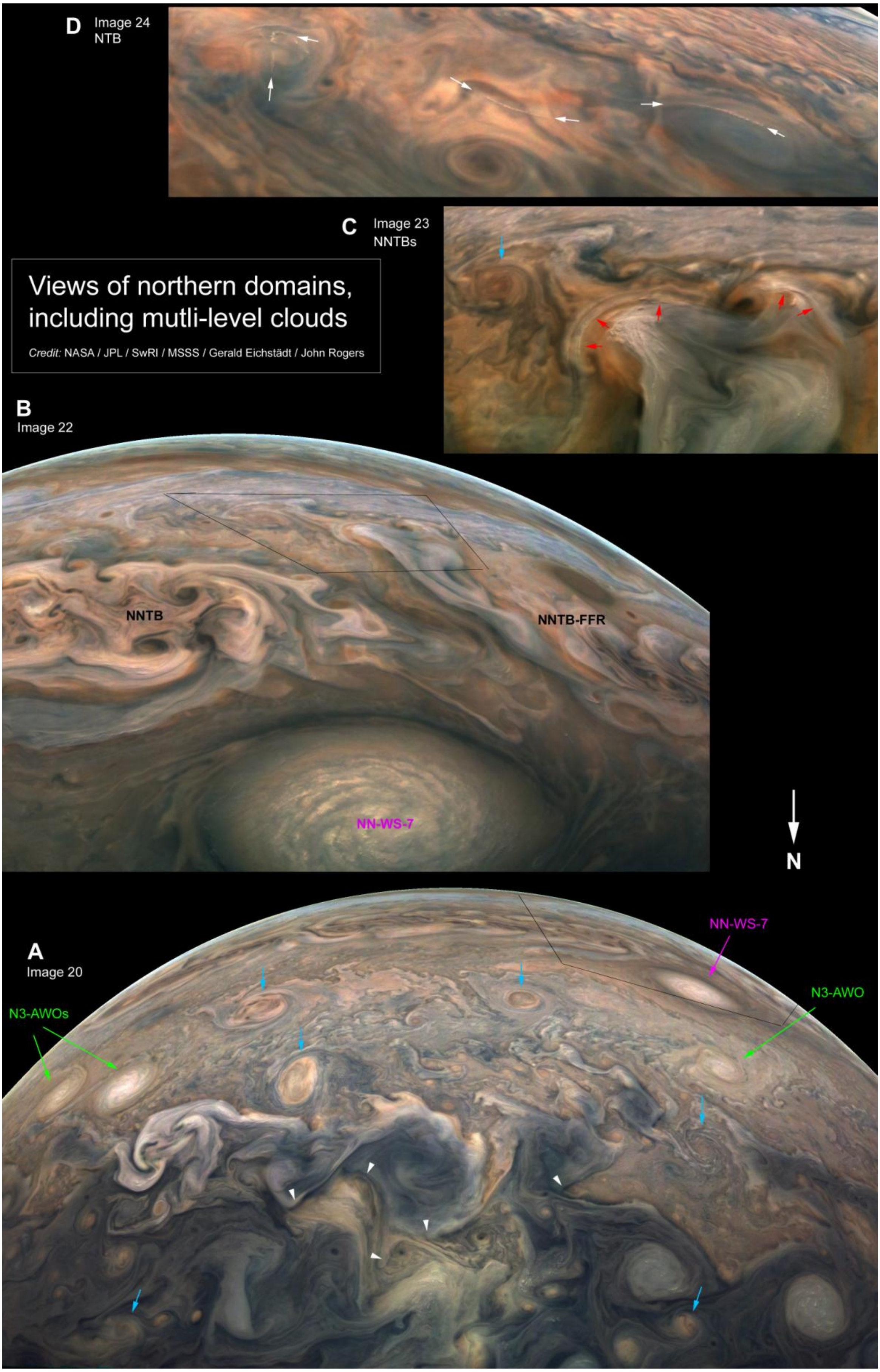


Figure 5.



D
Image 24
NTB
C
Image 23
NNTBs
Views of northern domains, including mutli-level clouds
Credit: NASA / JPL / SwRI / MSSS / Gerald Eichstädt / John Rogers
B
Image 22
NNTB
NNTB-FFR
NN-WS-7
N
A
Image 20
NN-WS-7
N3-AWO
N3-AWOs

Figure 6.

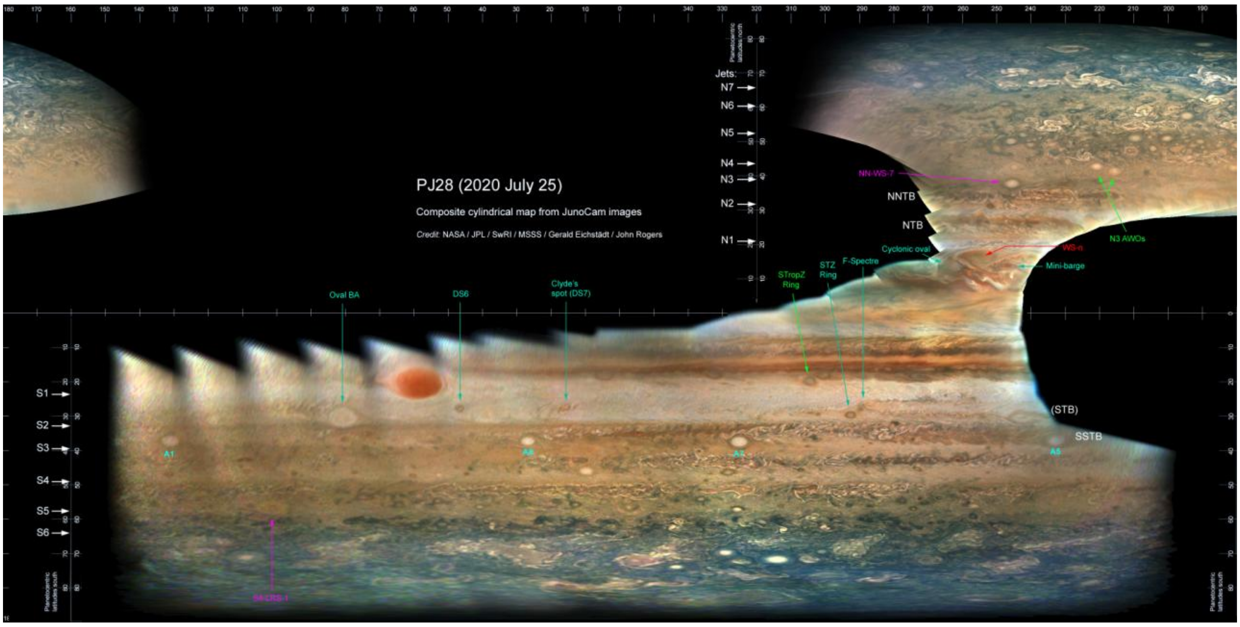


Figure 7. Composite cylindrical map of the planet (from Gerald's maps).

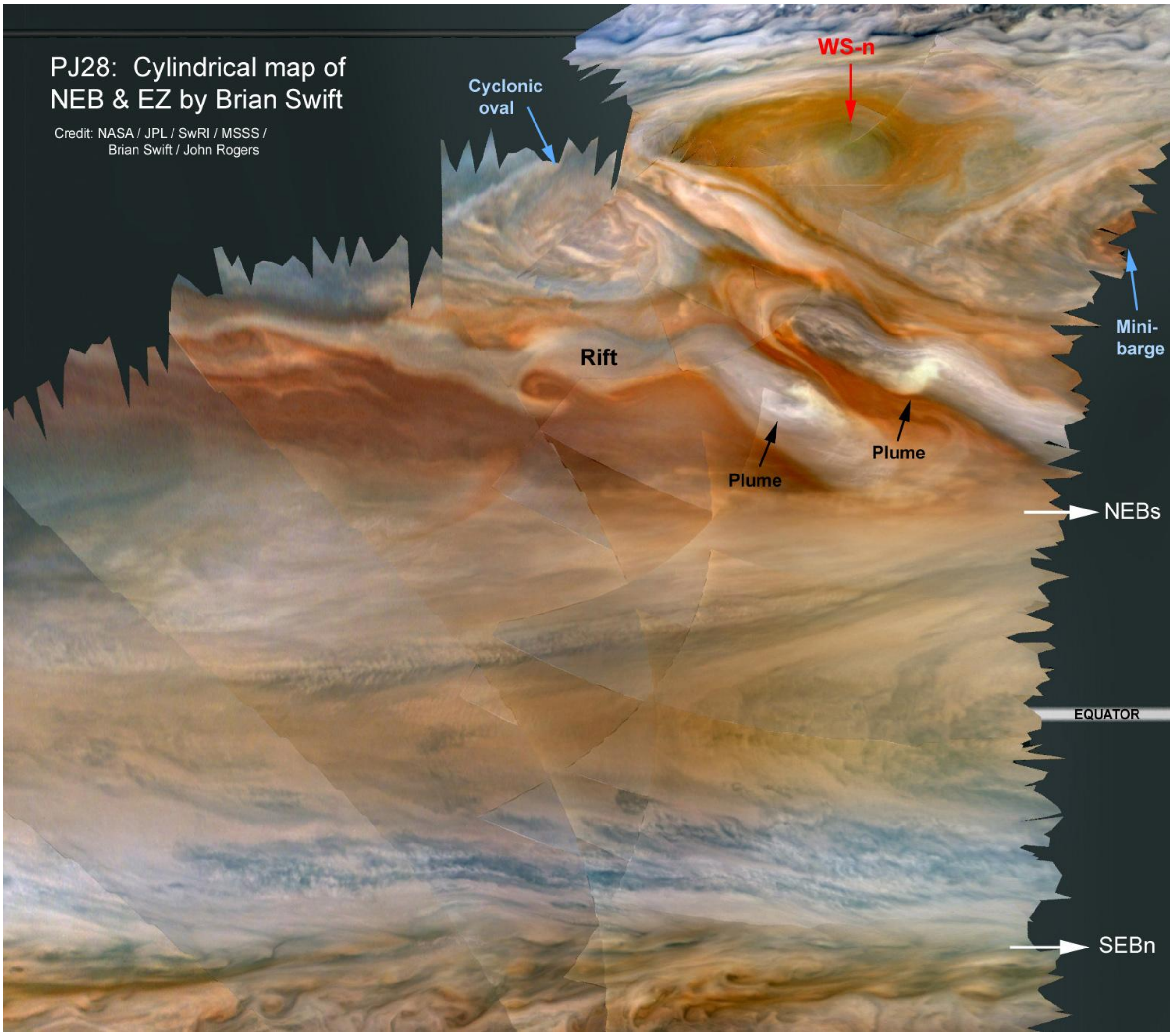


Figure 8. Composite cylindrical map of the NEB & EZ, by Brian Swift (intensities adjusted).

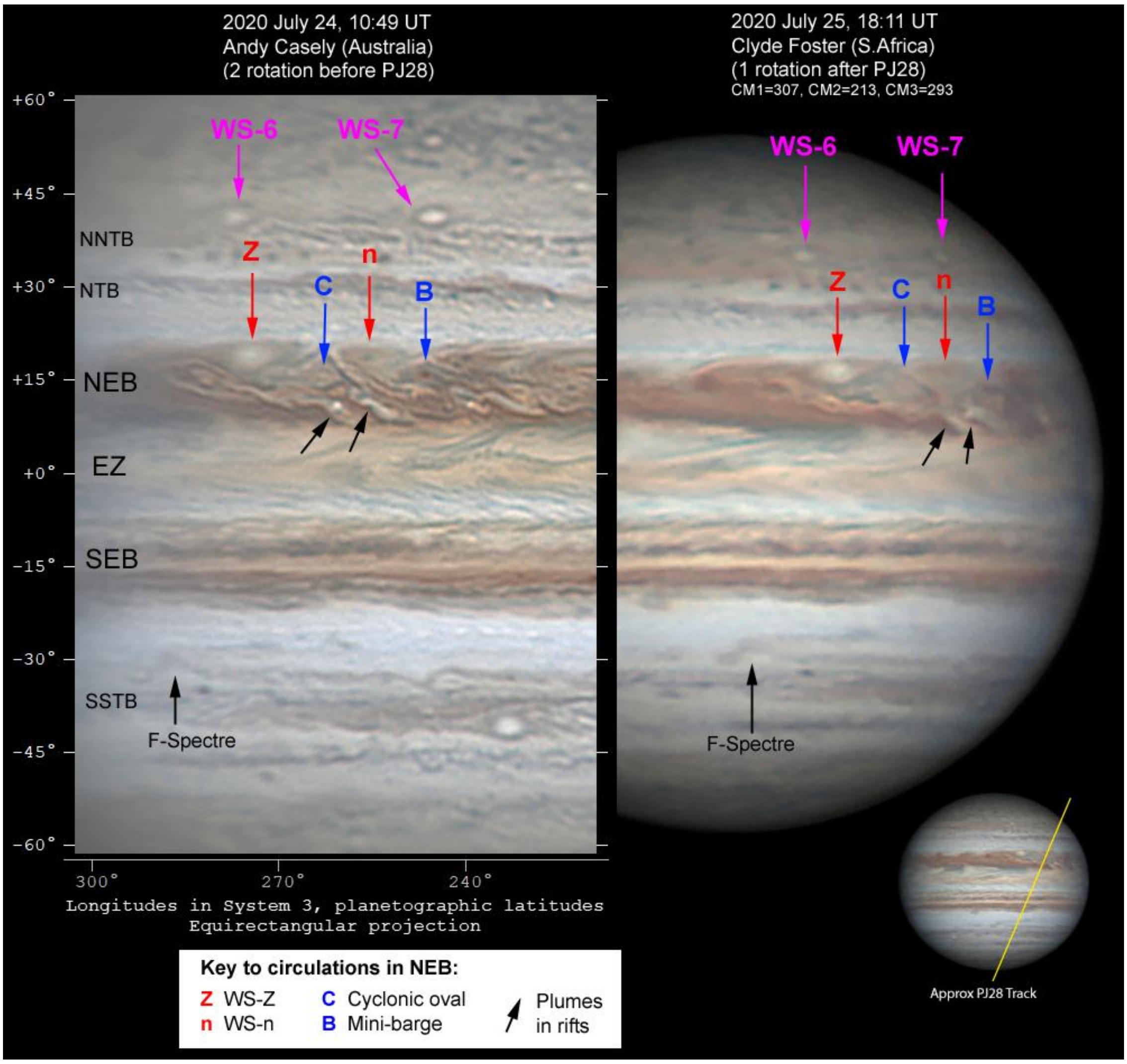


Figure 9. Ground-based imagery from Andy Casely (July 24) & Clyde Foster (July 25).

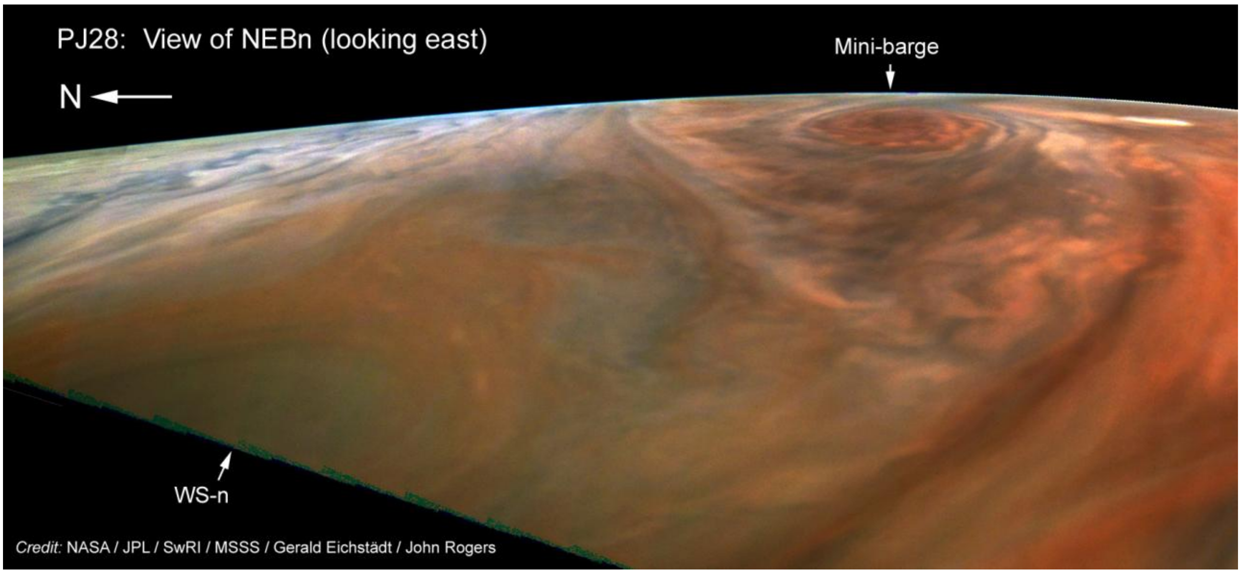


Figure 10. Oblique close-up view of NEBn ovals: WS-n (now dull grey with an orange border) and a mini-barge (orange with a dark grey border).

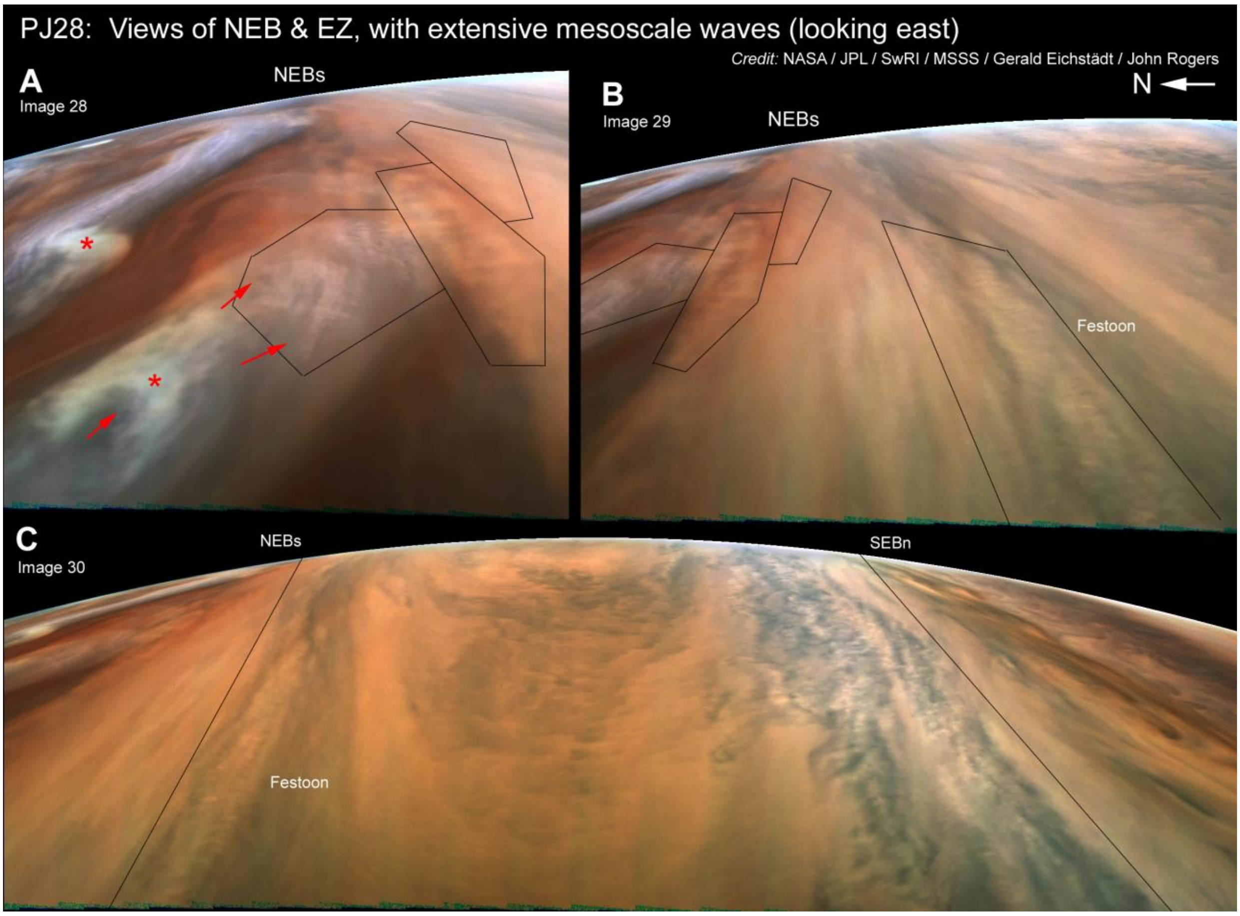
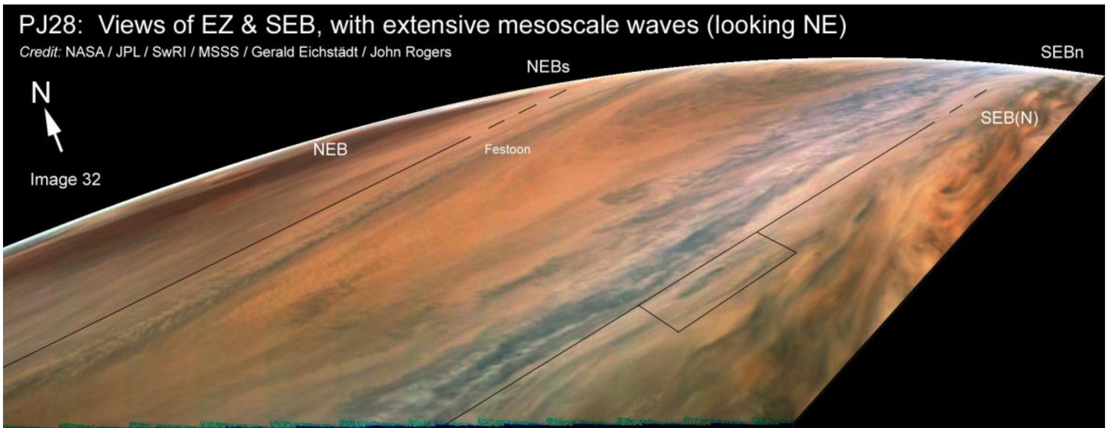
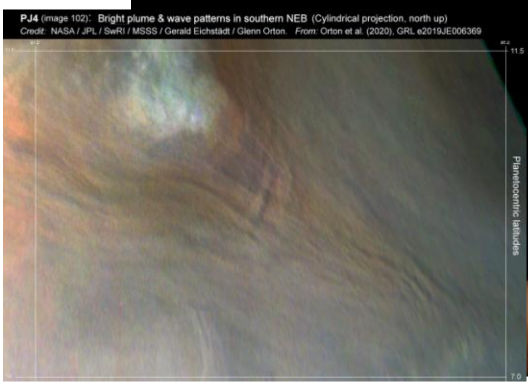


Figure 11. Areas with mesoscale waves are boxed.





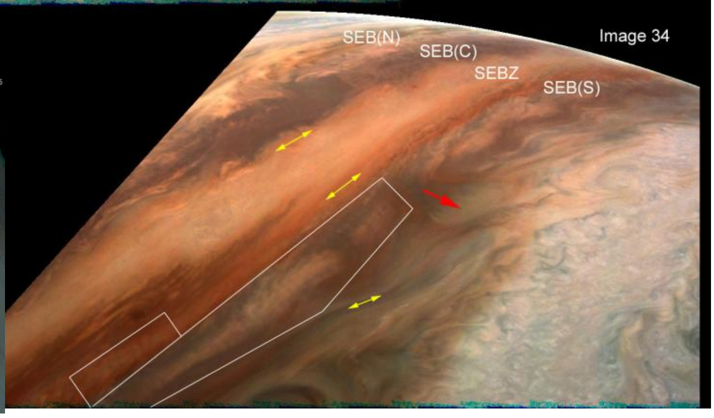


Figure 11D *(above L):* from PJ4, N up.

Figure 12. Areas with mesoscale waves are boxed.

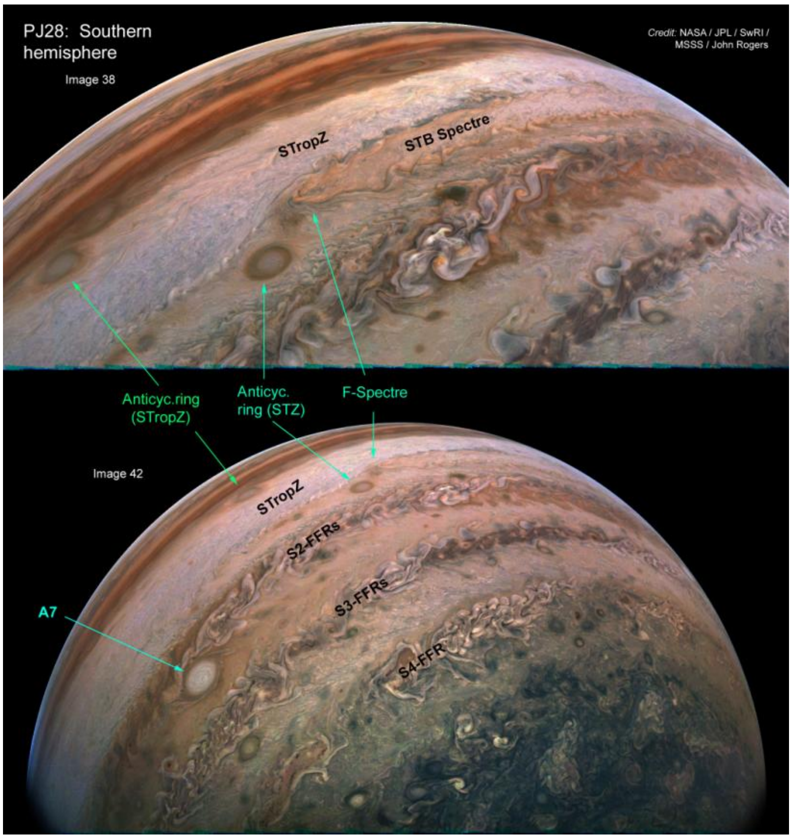


Figure 13.

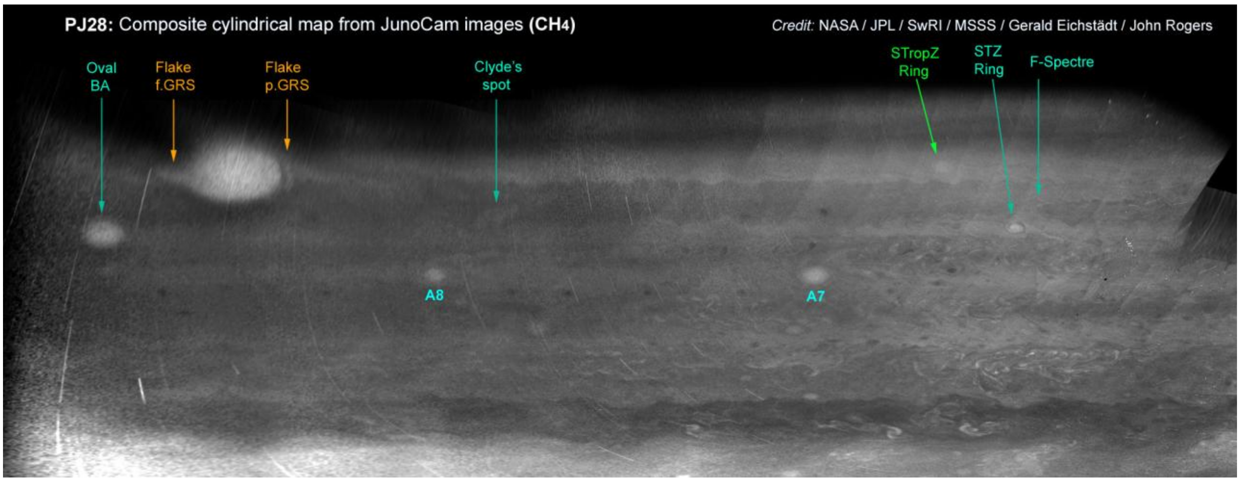


Figure 14.

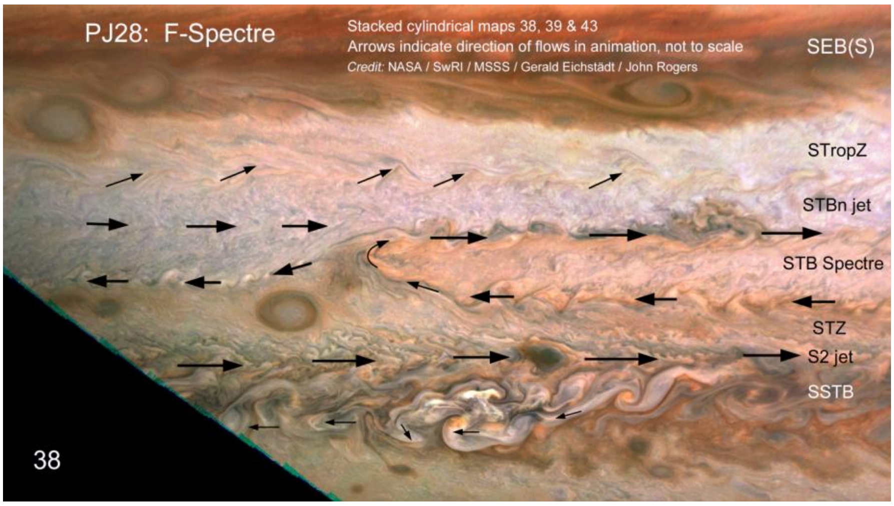


Figure 15

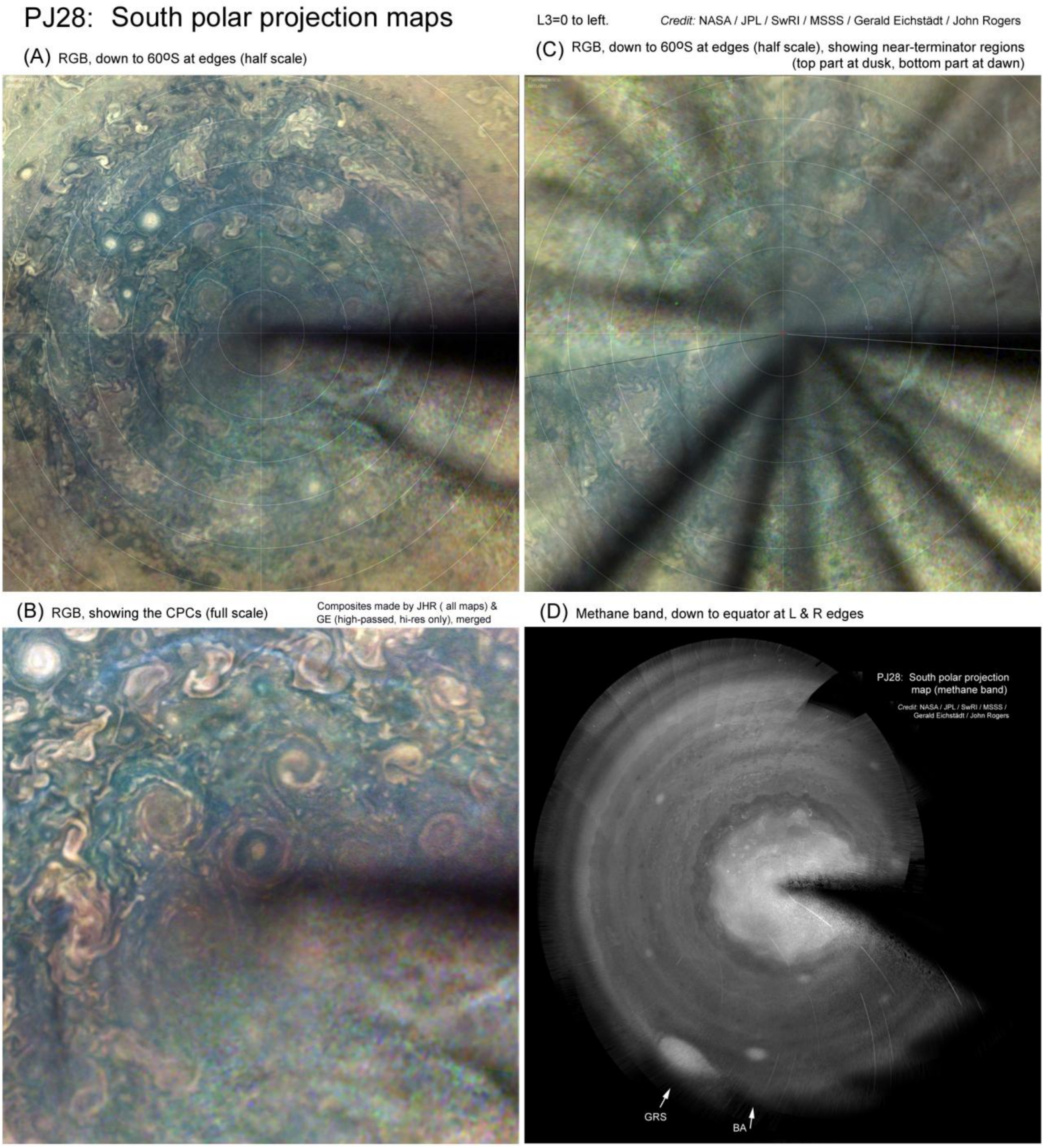

PJ28: South polar projection maps
L3=0 to left.
Credit: NASA / JPL / SwRI / MSSS / Gerald Eichstädt / John Rogers
(A) RGB, down to 60ºS at edges (half scale)
(C) RGB, down to 60ºS at edges (half scale), showing near-terminator regions
(top part at dusk, bottom part at dawn)
(B) RGB, showing the CPCs (full scale)
Composites made by JHR (all maps) &
GE (high-passed, hi-res only), merged
(D) Methane band, down to equator at L & R edges
PJ28: South polar projection
map (methane band)
Credit: NASA / JPL / SwRI / MSSS /
Gerald Eichstädt / John Rogers
GRS
BA

Figure 16.

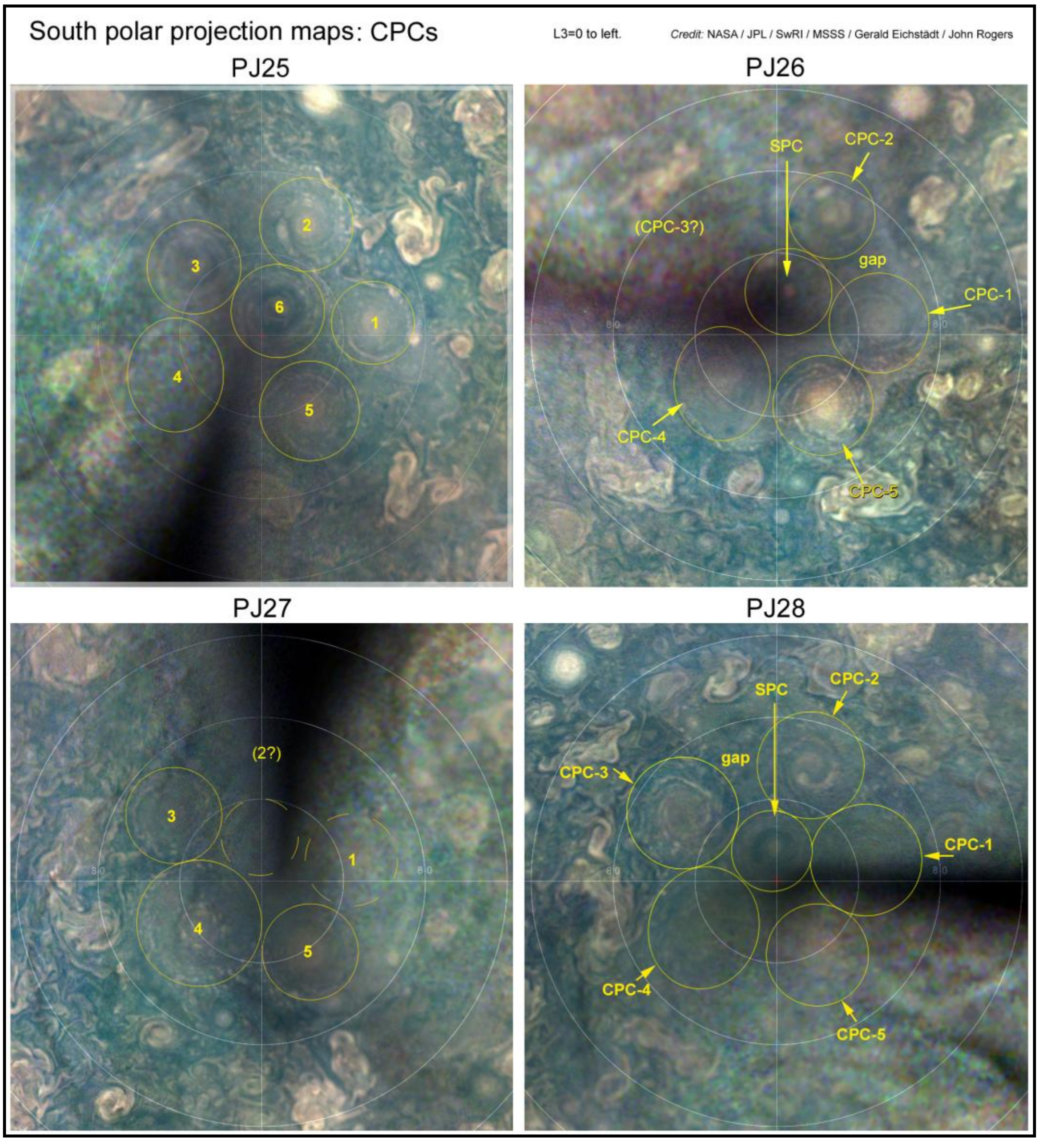


Figure 17.

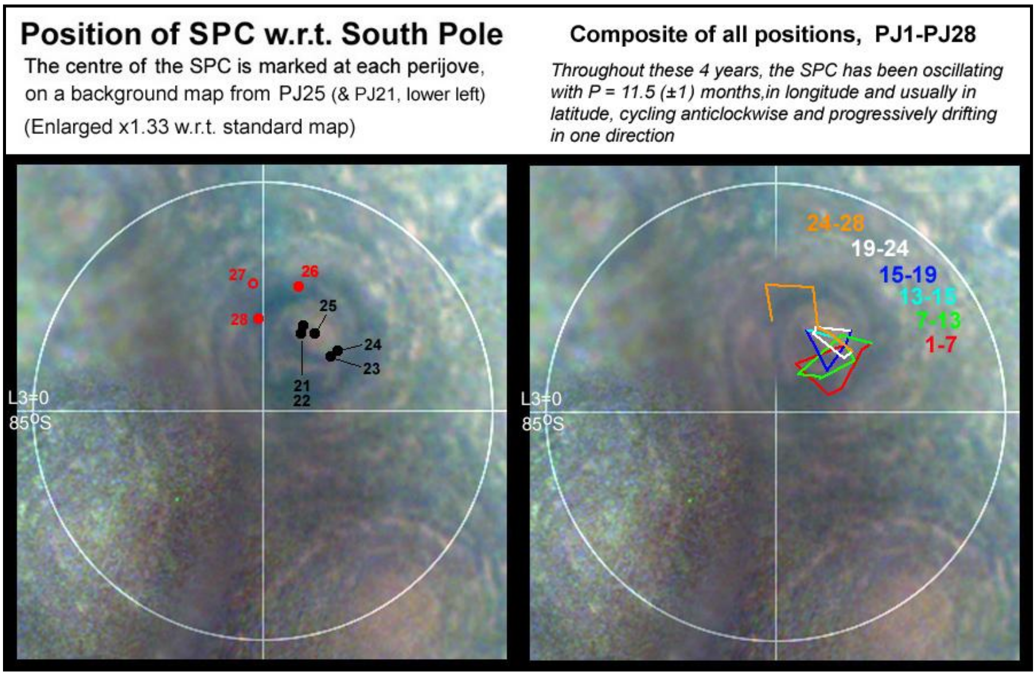


Figure 18.