JunoCam at PJ21 (2019 July 21): What the pictures show

John Rogers (BAA) (2019 July 31)

PJ21 was Juno's second pass directly over the Great Red Spot (GRS); and just as with the first pass at PJ7, by good fortune the spacecraft also flew over an anticyclonic white oval (AWO) in the N.Tropical Zone, and close to another AWO in the NNTZ. At PJ21, these were White Spot Z (WSZ) in the NTropZ, and NN-WS-6 in the NNTZ (Figure 1).
(Equator crossing was at L1=94, L2=307, L3=288.)

The geometry was much less favourable than at PJ7, for two reasons. First, the altitude of this perijove was higher than usual. Second, PJ21 was a 'Gravity' orbit with the spacecraft pointed to Earth and Sun, and perijove now occurs close to local mid-day, so at low latitudes the camera was not looking down at the sub-spacecraft track, but obliquely towards the horizon. However, as it scans across a 57-deg arc, it was still able to image the whole of the sub-spacecraft track, looking forwards before closest approach and backwards after – and so the higher altitude was helpful in expanding the field of view. Figure 2 is a cylindrical map from the JunoCam images. Thus, good images were obtained of NN-WS-6, WSZ, and the GRS.

This report, like all in this series, is due to the work of the NASA JunoCam team: Drs Candy Hansen (Principal Investigator), Glenn Orton, Tom Momary, and Mike Caplinger (Malin Space Science Systems); and Gerald Eichstädt, who produces the high-quality processed images and the map projections. As usual, the JunoCam images have been presented (i) as initial versions ('v01') posted by the JunoCam team (each projected as if from a point above Juno's track, but with reduced resolution); (ii) as full-scale, high-quality versions by Gerald Eichstädt (strips closer to Juno's actual perspective); and (iii) both cylindrical and polar map projections by Gerald. Details were given in our PJ6 report.

Abbreviations and conventions are as in previous reports. P. = east, f. = west. Latitudes are planetocentric.

Excellent ground-based images of the track were taken shortly before and after the flyby, and are presented in our new 2019 Report no.7 (https://britastro.org/node/18917) Figure 3 shows one example, 10 hours before perijove.

North Polar Region

Circumpolar cyclones (CPCs):
Figure 4 shows the hi-res map of the CPCs that form the ditetragon around the north pole. It includes CPC-7, which for most of the mission has been obviously displaced away from the pole by an AWO north of it, so that this corner of the ditetragon is distorted. At PJ21, the distortion has increased further: the angle between CPCs-6, 7, 8 is now acute, only 71°. This is not because CPC-7 has moved further from the pole – it is at 81.2°N, similar to PJ15 and PJ20 – but because CPCs-6 & 8 have closed in to the AWO. Will CPC-7 be expelled from the ditetragon, or will everything return to its original symmetry?

The immediate surroundings of the ditetragon are also unusual. Instead of the usual chaos, a bland zone surrounds the ditetragon down to 76-77°N, and contains a comparatively large AWO adjacent to CPC-7. (There was a small AWO here at PJ20.) Moving further south (Figure 5), there is a scattering of small grey anticyclonic ovals, then a belt of large FFRs which borders on the N7 jet and the usual Bland Zone. Such a semi-organised pattern has not been

evident at earlier perijoves but further comparison with earlier maps could be worthwhile, to see whether it indicates a real change or just a random fluctuation.

Haze bands:
Figure 5 shows composite N. polar hemispheric maps down to ~30-50°N, in both RGB and methane band. The RGB map shows typical aligned dark and bright bands in Bland Zone (some are better seen on Gerald's original image 8 map than this composite), and an elaborate tangle of bright bands and mottlings immediately to the south, in the N5 and N4 domains, towards the terminator. The denser bright bands appear to cast brown shadows. The methane-band map also shows intricate haze structures in the N5 and N4 domains, including the bright strips in FFRs, and the bands that are very bright in RGB. Notably, the latter are even more methane-bright than the main part of the North Polar Hood to the north, whose boundary (at or near the linear bands in the Bland Zone) is unclear over much of this map.

Northern domains

N3-N5 domains: Figure 5 gives a lo-res map of this region. As usual there are spectacular vistas all across it; Figure 6 shows some details. The N5 and N4 domains are completely filled with large chaotic FFRs with a scattering of ovals. The N3 domain, in contrast, contains several beautiful isolated cyclones & anticyclones, with brown central disks (Figure 6).

N2 domain: NN-WS-6 was viewed, though obliquely (Figures 6 & 7).
[Better closeups of two other long-lived AWOs in this zone have already been obtained at several perijoves: NN-WS-4 (PJ1, PJ12) and NN-LRS-1 (PJ3, PJ7, PJ14).] Also, the hemispheric maps (Figures 2 & 4) reveal a new anticyclonic 'Little Red Spot' in the NNTZ. This has been tracked as an AWO by JUPOS since March, but here it is distinctly reddish and methane-bright.

Most of the sector viewed consists of a rather turbulent brown segment of NNTB whose f. end is overridden by a spectacular FFR, showing many of the beautiful features described in earlier perijove reports. This in turn abuts NN-WS-6 (Figure 7).
[The JunoCam map is consistent with our ground-based maps, which suggest that this whole sector has been unstable for the last several months, with varying proportions of FFR and dark NNTB, although the details were difficult to resolve. In April, when there was apparently no FFR there, JUPOS charts showed that WS-6 was prograding rapidly in L2, but thereafter it decelerated, consistent with our hypothesis that interaction with FFRs sometimes prevents these ovals from prograding.]

NTB: Some small cyclonic barges and paler circulations are developing along the NTBn edge, and a closeup of one of the latter (Figure 7) shows a very well-marked circulation.

White Spot Z (WSZ)

A highlight of this perijove was that Juno flew directly over WSZ, and although the spacecraft orientation prevented the oval from being imaged at that moment, it was captured obliquely in slightly earlier images, providing by far the best view ever obtained of this oval (Figure 8; see Figures 3 & 9 for context). In ground-based maps, this AWO has a variable aspect, and has recently appeared as a fairly well-defined oval (Figure 3, & Report no.7 [URL above]); it is still more bluish-grey in the south and white in the north, although this difference is not as obvious as it was earlier in the year. JunoCam's image (Figure 8) shows a well defined anticyclonic pattern of yellowish cloud bands in its outer parts, densely packed with popup clouds on the northern side of the oval, surrounding a central oval region with irregular patches of white clouds on a blue-grey background. The white clouds form more continuous bands in the

northern part, which probably explains the bright white appearance of this part in ground-based images. All in all, WSZ shows well-defined large-scale structure and small-scale texture, unlike most other features in the NEB which tend to be diffuse at highest resolution.

Equatorial Region

The images only covered the equatorial region near the horizon, but one can see two large NEBs dark formations ('hot spots'), and complex patterns of streaks in the EZ (Figure 2). Even at this large slant range, image 26 shows evidence for widespread small-scale wave and cloud features in the EZ, possibly similar to some of those that were seen much better at PJ20.

Great Red Spot (GRS)

A report on the situation of the GRS at PJ21, from amateur images, has been posted as our 2019 Report no.7 (https://britastro.org/node/18917). The centre longitude was L3 = 295 (±0.8, SD), while Juno flew over at L3 = 298. On July 21, the GRS was notably less disturbed than it was earlier in the year, with a regular oval outline, although still only 12 deg long.

For the past 6 months, the GRS has repeatedly shed red 'flakes' or 'blades', originally induced at its east end by rings (vortices) that had come into the Red Spot Hollow (RSH) from the SEBs jet, but also in recent months at its west end, probably due to persistent perturbation that continued to travel round the periphery of the GRS. However, the last two SEBs rings recirculated southwards before entering the RSH, leaving the GRS to settle down. There were just two, comparatively minor, visible remnants of these phenomena as of July 21: a reddish flake that had emerged from the east end of the GRS on July 19-20, and a small white spot in the RSH representing a fragment of the last of the SEBs rings.

Figure 10 shows some of the views that JunoCam obtained before and after passing over the GRS (see Figure 3 for context); Figure 11 shows a map made by Kevin Gill from the best images; and Suppl. Figure D shows individual images at best resolution. As the view was oblique and backward-looking, the resolution is nowhere near that attained at PJ7, but this is still a valuable view. The two remnant features mentioned above can be seen; the reddish flake is still attached to the GRS by a narrow reddish streak that extends all around the north half of the GRS. Two or three small 'blades' are visible at the west end of the GRS, consistent with the hypothesis that such disturbances are travelling around the periphery of the GRS, but similar small streaks can be seen in earlier HST images so they may be normal features.

Southern domains

The STB Spectre: This much-elongated cyclonic circulation lies alongside the GRS at present, and is well shown in the images (Figure 10). Its west (f.) end is still well defined, and a small AWO (anticyclonic white oval) has formed adjacent to it. The Spectre is clearly compressed alongside the GRS. The east (p.) end, unfortunately, was outside the field of view.

S2 domain: AWOs A8 and A1 are shown, separated by a very long whitened sector of SSTB that is similar to the STB Spectre.

S3 domain: There is a very long FFR, with a lot of small dark rings f. it in the S3 Temperate Zone, consistent with our view that these rings are generated from the FFR (Figure 10).

South Polar Region

As usual, Gerald has produced south polar projection maps from all the individual images, and I have compiled them into merged maps highlighting different aspects (Figure 12). The maps nicely confirm the results from previous perijoves. Blinking them reveals the familiar flow patterns in the CPCs, the FFRs, the wavy S6 jet, and part of the S5 jet. They will be suitable for animations and wind speed measurements. The composite south polar projection maps are shown in Figure 12.

At 71-73°S there are currently 5 AWOs (red arrows in Figure 12B), and they can all be identified from PJ20 to PJ21 with typical displacements of +30 to +48 deg longitude in System III (L3). Two of these, at 73°S, are large, and are also visible in Andy Casely's ground-based maps on June 26-27 (Figure 13).

Haze patterns (Figure 12C&D; component maps are in Suppl. Fig.C):

The methane map (Figure 12D) shows the methane-bright South Polar Hood (SPH) as usual. The pattern of waves around its edge is particular regular this time, with wavelength 22-31 deg. long., mean 26.6 deg.long. This wave pattern was also shown in Andy Casely's map the previous month (Figure 13).

The maps of near-terminator regions (Figure 12C & Suppl. Fig.C) show that haze bands are widespread, though generally faint. As usual, they tend to align with the ZWP on the north and south sides of the S6 jet, although in this map they tend to continue in the same orientation further north and south respectively, thus diverging from the ZWP.

As at all perijoves since PJ13 (except PJ16), there is a long band or bundle of bands overlapping the longitude sector where the prominent Long Band existed from PJ5 to PJ12, but not in such consistent positions nor latitudes, usually being further north. At PJ21 this bundle includes dark, bright, and rainbow-coloured bands, and some are still visible under full sunlight as well as near dawn, esp. a long dark band, whereas bright and rainbow bands are more prominent near dusk (Suppl. Fig.C).

The present long band forms a boundary between brighter and darker sectors of the South Polar Hood in the methane maps, which also show the FFRs beneath the Hood as bright patches (Figure 12D).

Circumpolar cyclones (CPCs):
Given the longitude at which Juno flew over at PJ21, the central cyclone (SPC) was on the far side of the pole towards the terminator, so the images of the pentagon are noisier than usual and do not cover the gap. Nevertheless, the positions of all the cyclones are well defined (Figure 12B). Image 45, the first to show the CPCs, shows that a single well-planned image can be crucial: it is the only one that resolves CPC-2, and most clearly resolves CPC-3 and the SPC (Figure 14A,B). The SPC has a bright reddish core.. It is centred 2.0° from the pole, at 88.0°S, in virtually the same position as at PJ20 (Figure 14C).

ON FOLLOWING PAGES:

Figures (miniature copies)

Full-size versions, & the Supplementary Figures, are available in the attached ZIP file.

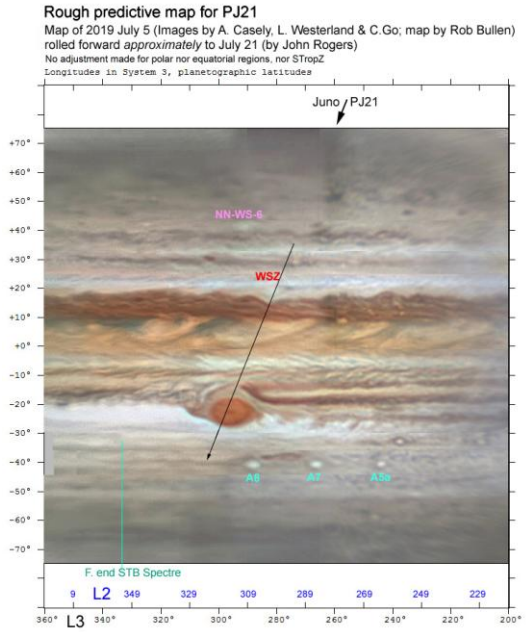
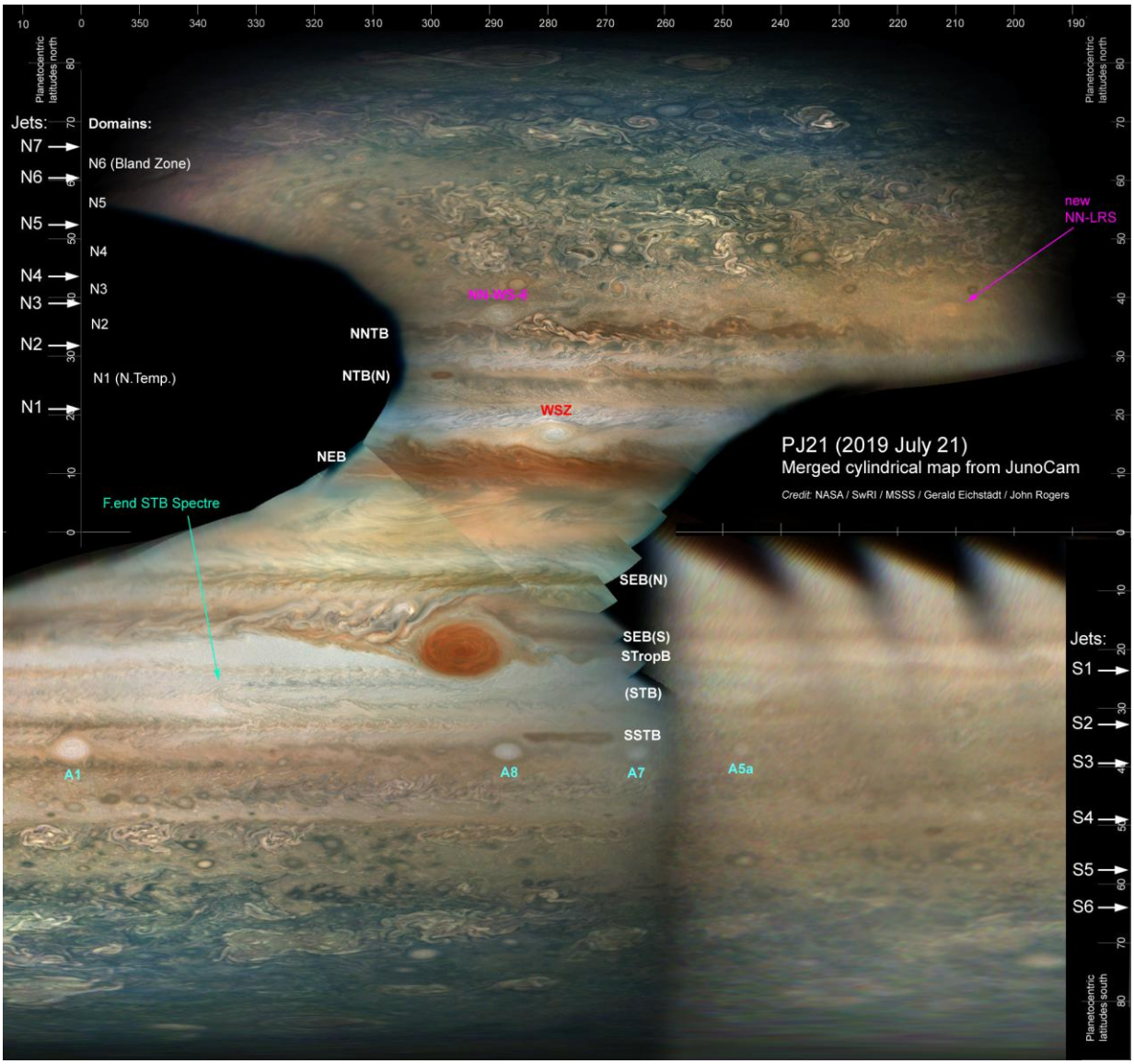


Figure 1 *(left).* Predictive map produced before PJ21, with the sub-spacecraft track aproximately marked.

Figure 2 *(below).* Composite cylindrical map of the planet from Juno's closeup images.

Suppl. Figure A *(in ZIP file)* is an unlabelled version of this map and includes outbound imaging to show all longitudes in the southern hemisphere.



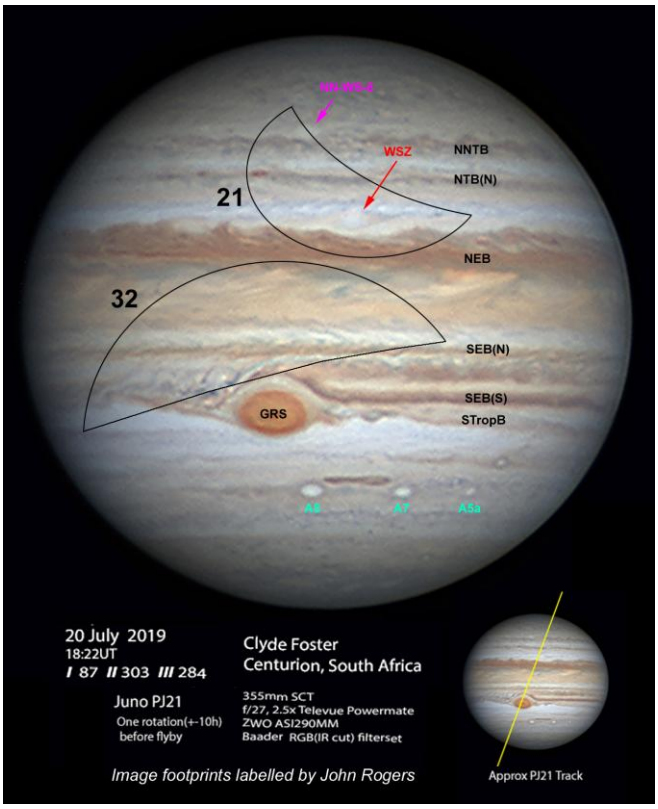


Figure 3. Image by Clyde Foster, ~10 hours before PJ21, on which are marked the 'footprints' of JunoCam's images 21 (before perijove) and 32 (after perijove) (see Figures 9 & 10).

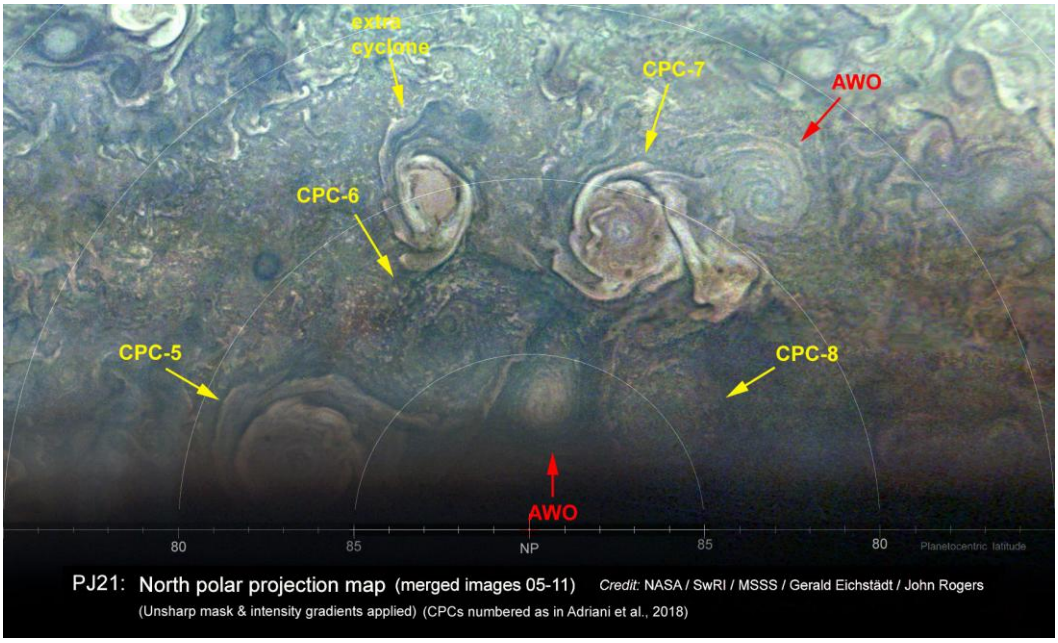


Figure 4. Composite north polar projection map showing the northern circumpolar cyclones. The CPCs are numbered as in Adriani et al.(2018). L3=0 is to the right.

Suppl. Figure B is a compilation of our hi-res north polar maps from PJ17 to PJ21, including Figure 4, with a montage of them, compared with the previous montage of PJ14 to PJ17.

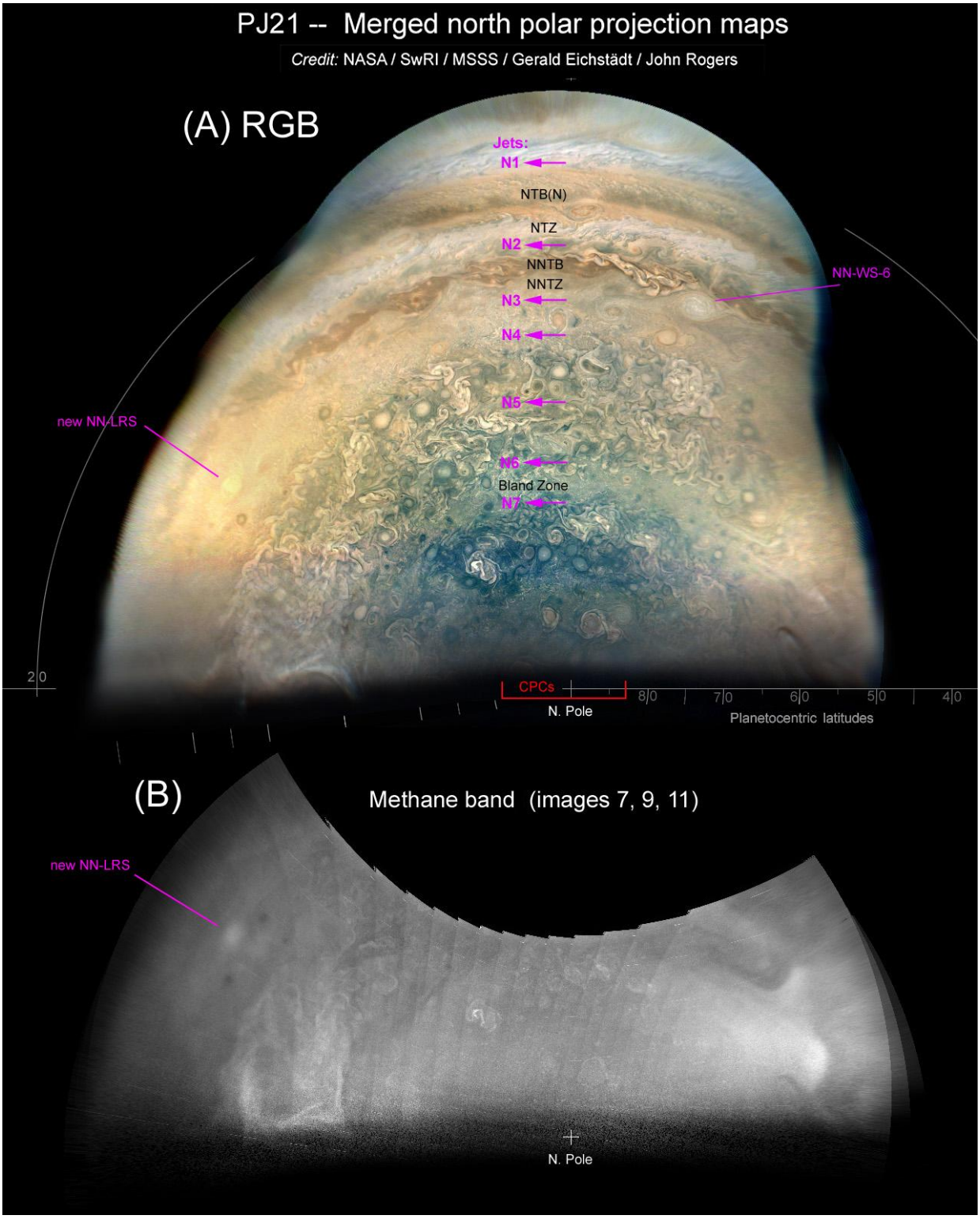


Figure 5. Composite north polar projection maps of the hemisphere: (A) RGB, (B) CH4. L3=0 is to the right.

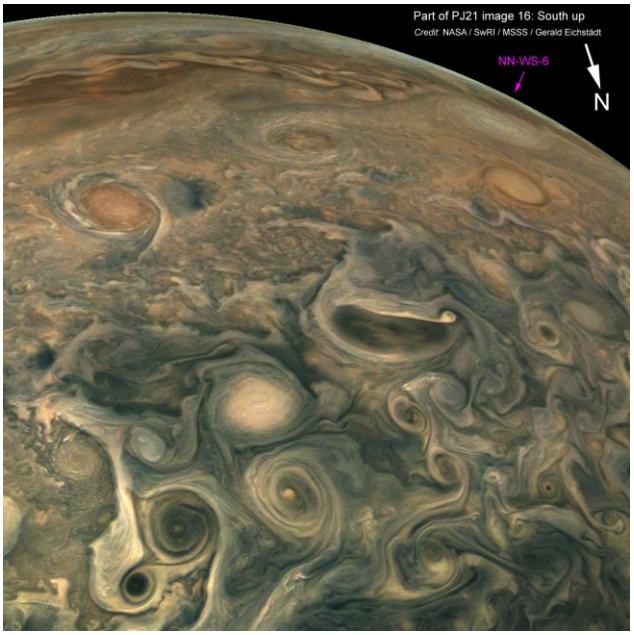


Figure 6. Full-resolution image showing cyclones & anticyclones in the N3 & N4 domains, with NN-WS-6 near the horizon.

Figures 6-8 have south up, to preserve the perspective, and to align with the polar map in Figure 5.

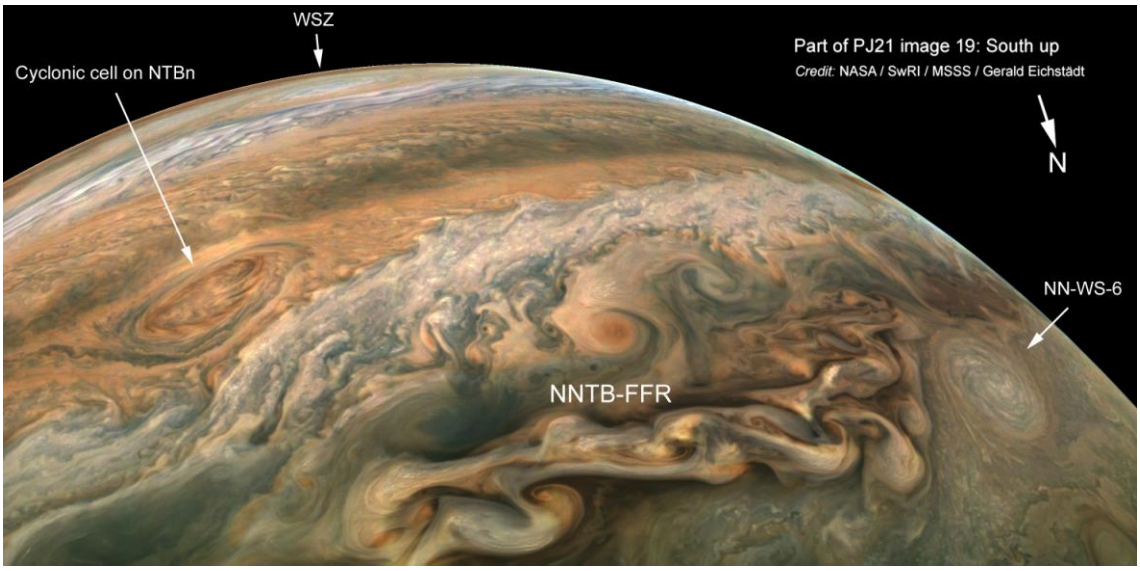


Figure 7. Full-resolution image showing features in the N3 & N4 domains. (South is up.)

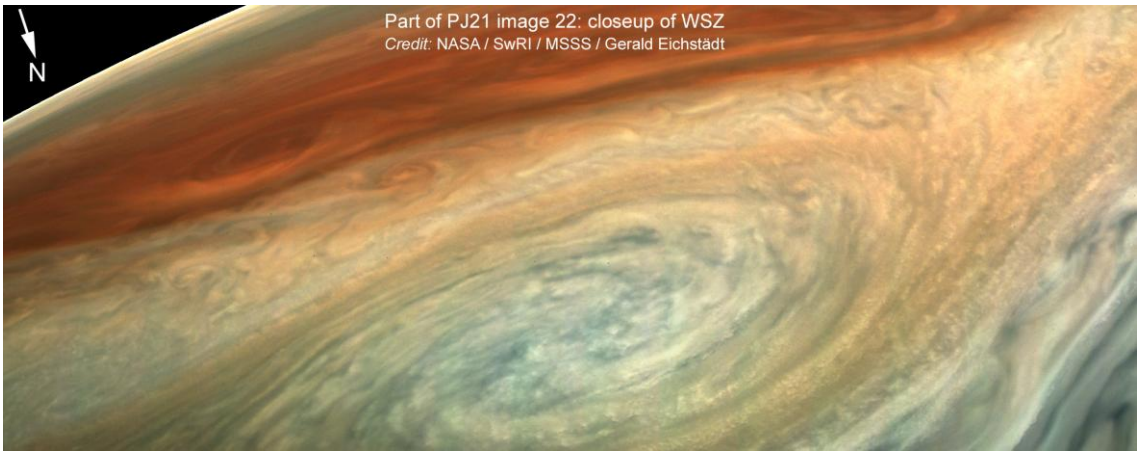


Figure 8. Full-resolution image showing White Spot Z. (South is up.)

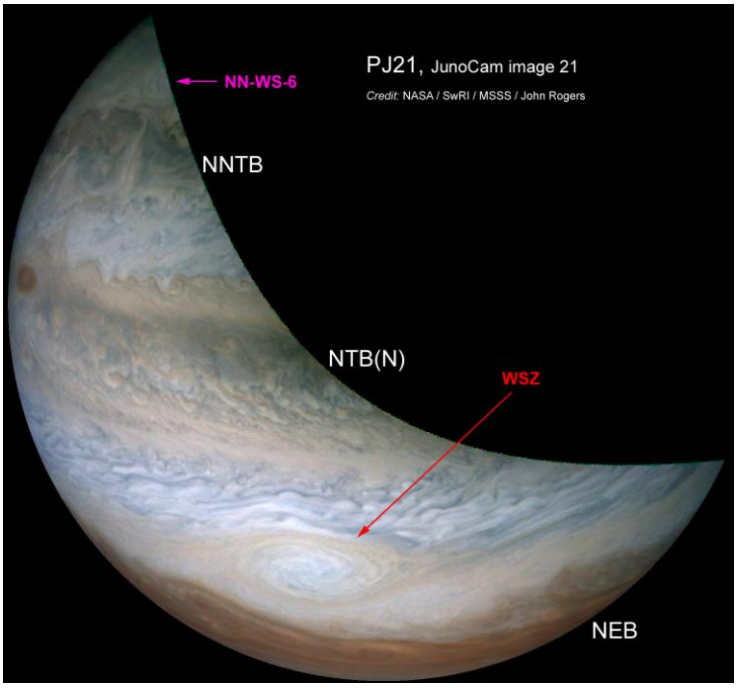


Figure 9. The 'v01' version of image 21 showing White Spot Z and the NTB. (North is up.)

Figure 10: *SEE NEXT PAGE.*

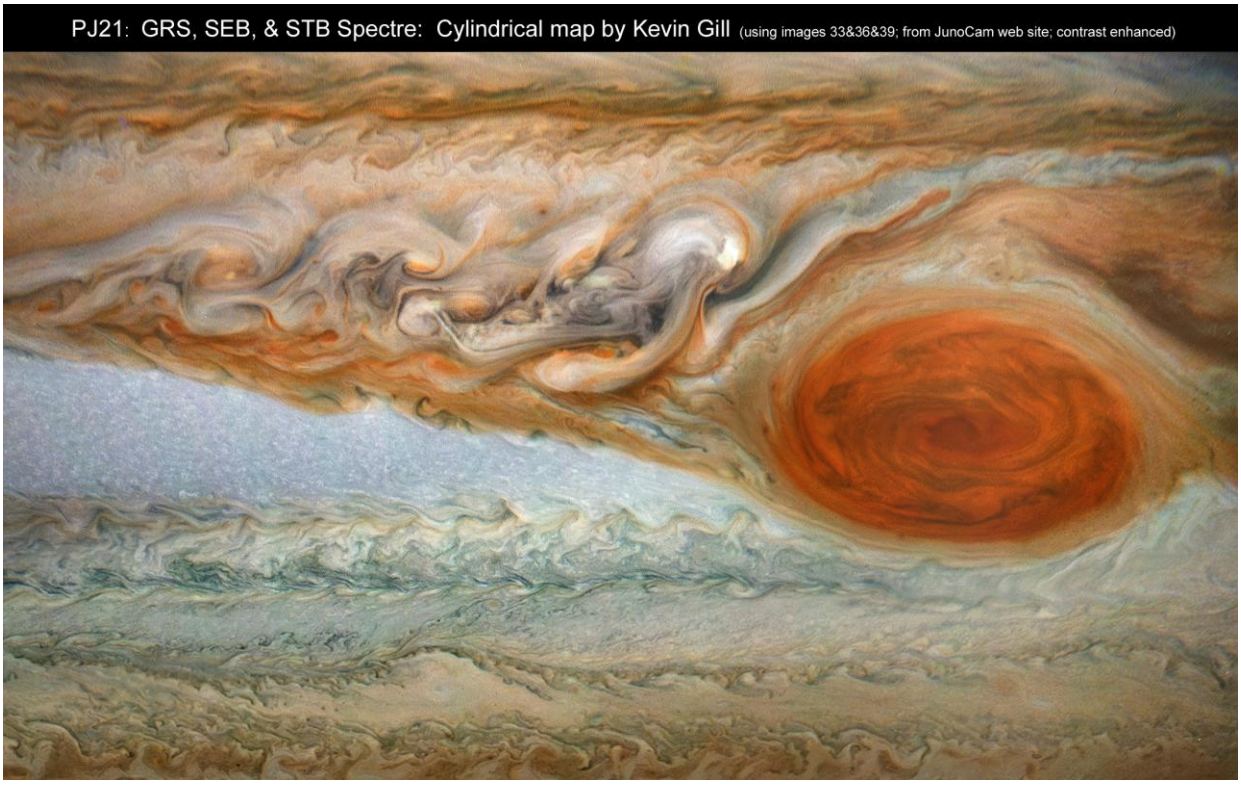


Figure 11. Map of the GRS and adjacent regions made by Kevin Gill from the best images (33, 36, 39).

Suppl. Figure C presents images 33 & 36 at best resolution.

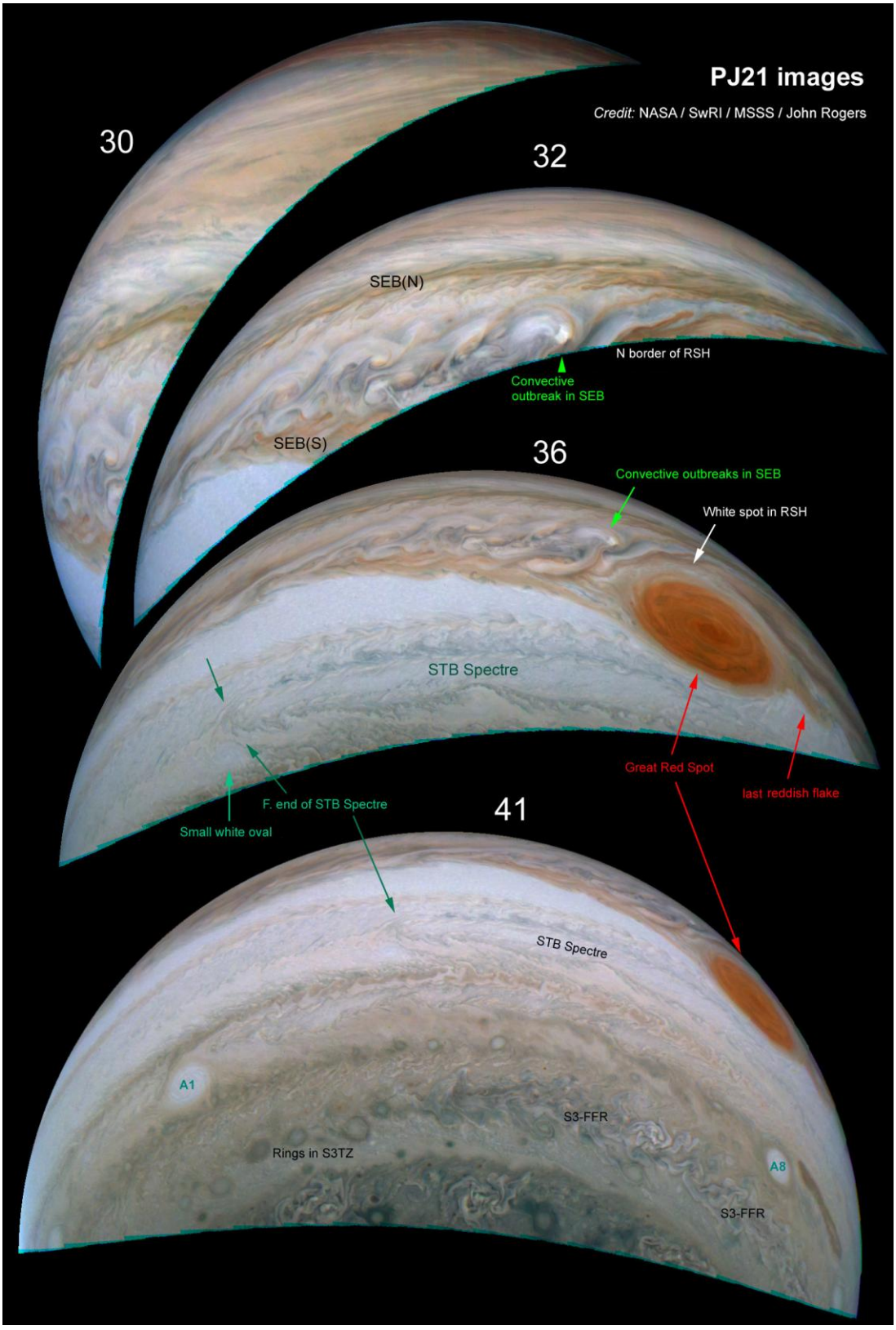


Figure 10. The ‘v01’ versions of several images covering the SEB, GRS, and STB Spectre. showing how the persepctive changed during the fly-over.

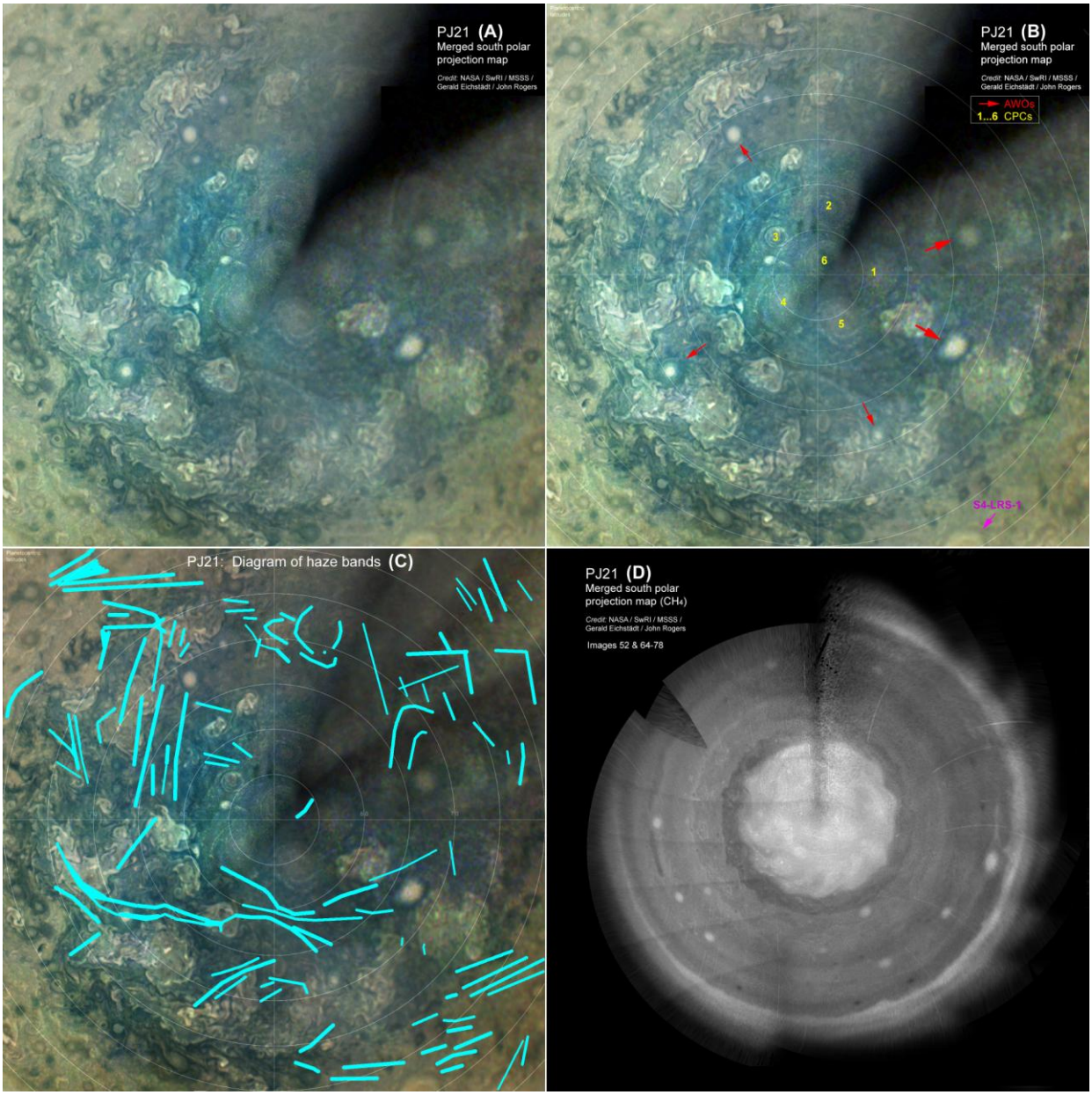


Figure 12. Composite south polar projection maps. L3=0 is to the left.
(A,B,C) RGB map, down to 60°S at the edges. On (C), the positions of all haze bands are drawn schematically, from composite maps shown in Suppl.Figure C.
(D) Methane-band map, down to the equator at the edges.

Suppl. Figure C presents various south polar projection maps showing haze bands.
(A, B) Two single-image maps, optimally showing the long band or bundle, seen under morning light (A) and afternoon/evening light (B). In (A), a large expanse of parallel bands is also visible under afternoon light (upper left).
(C,D) Two composite maps from successive sets of images, preferentially showing the regions near the terminator from each image, to highlight the haze bands seen under low sun.

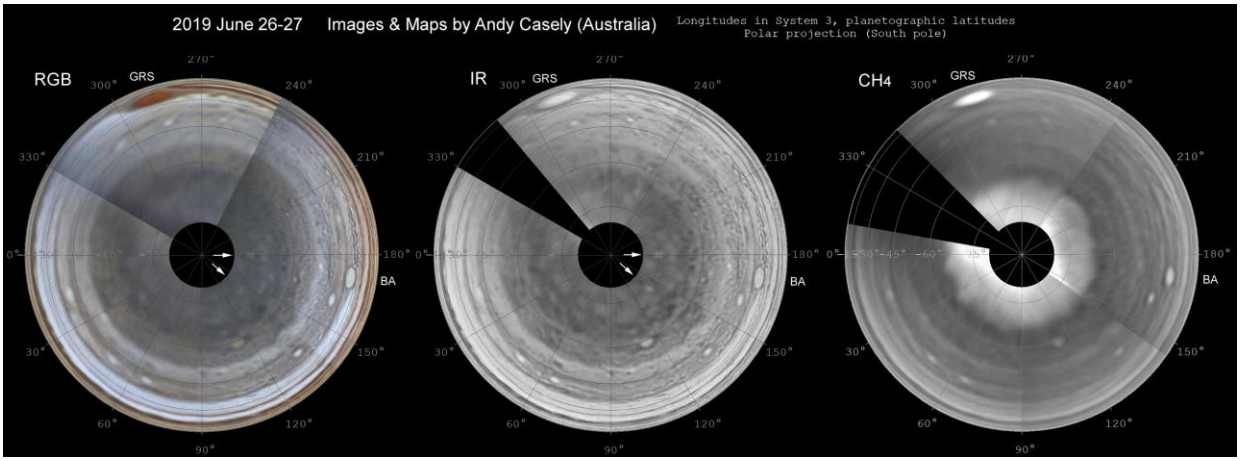


Figure 13. A set of ground-based south polar projection maps on June 26-27, made by Andy Casely from his own images. (These use planetographic latitude and polar stereographic projection, different from Figure 12.) Arrows indicate the two high-latitude AWOs also seen in Figure 12B.

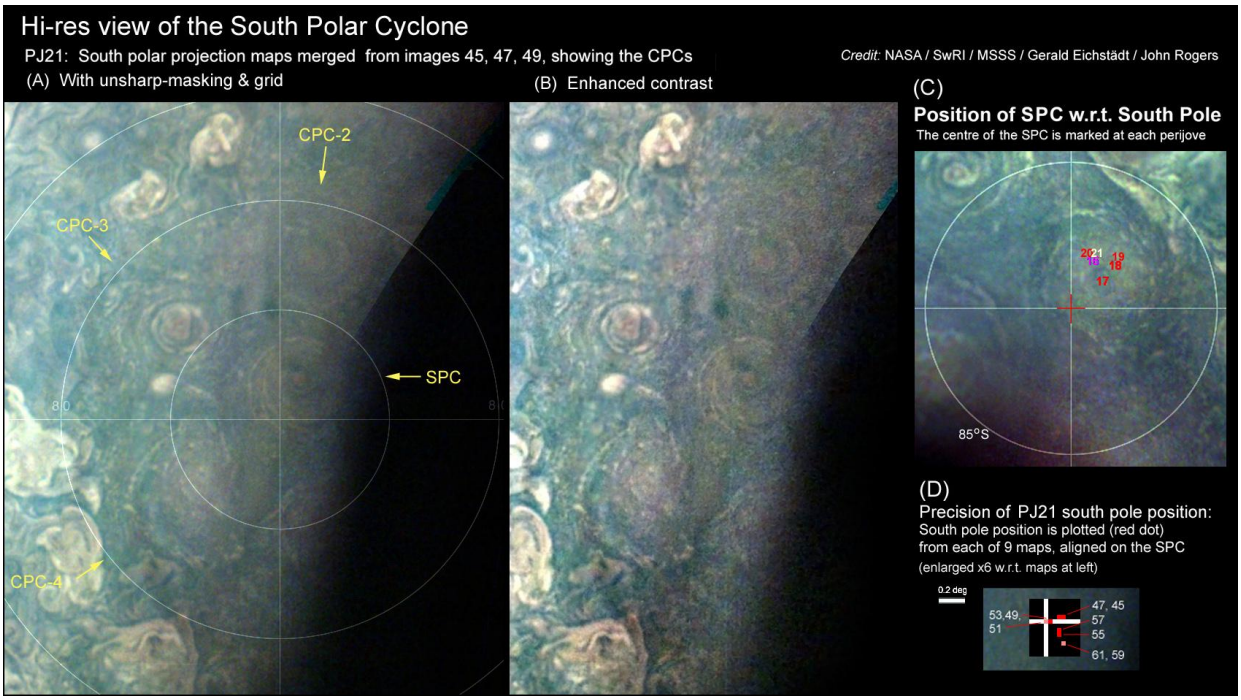


Figure 14. Hi-res view of the southern CPCs, especially the central cyclone (SPC).
(A,B) From Figure 12B, enhanced. (C) Position of the centre of the SPC at each perijove from PJ16 to PJ21, relative to the south pole. (D) Precision of south pole position in the PJ21 maps.