JunoCam at PJ20 (2019 May 29): What the pictures show

John Rogers (BAA) (2019 June 19)

At PJ20, Juno was tilted 30° away from the direct line to Earth and Sun and was at twice its usual altitude. So the camera's views covered a broader region of low latitudes than at most recent perijoves, but otherwise they were similar: a brief, narrow view of the north pole; broad hi-res views of northern latitudes; oblique panoramas of the equatorial region; and extended broad coverage of the southern hemisphere. The orbital inclination is now 79.8° (retrograde). Equator crossing (close to local mid-day) was at L1=155, L2=51, L3=18.

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 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. This report shows mainly Gerald's products, with gradients and contrast adjustments applied. This is Part I; Part II, covering the polar regions, will follow. Abbreviations and conventions are as in previous reports. Latitudes are planetocentric.

Excellent ground-based images of the track were taken shortly before and after the flyby (Figures 1 & 2).

Northern domains

A large N5-AWO had been tracked in amateur images during 2019 by the JUPOS team, retrograding in L2 and L3 at a fairly steady rate. It was captured near the limb, on the edge of the Bland Zone (Figure 5).

The N5 and N4 domains always display spectacularly intricate disturbances, but the latitudinal extent of the chaos appears to be less than usual, as the southern part of the N4 domain instead contains calmer areas dotted with discrete well-formed vortices, mostly cyclones.

The most notable of these are cyclones with very dark circular cores. There is a row of small ones at 43-46°N (see Figure 3), and an eye-catching larger one at ~47.5°N (Figure 6). (This dark-cored cyclone was nicknamed 'the abyss', as the dark core suggests that it maybe free of clouds; but see Fig.6C for its true colour.) Between these is another one whose core is lighter brown, crossed with cream-coloured streaks. (I nickname this one 'the hot cross bun', which British readers will recognise. A closeup [Figure 7A] reveals lines of popup clouds in its white collar, and a curious crossing of white cloud lanes that connect it with a smaller cyclonic eddy.) Interspersed among them (Figure 6) are some much smaller cyclonic vortices; at least one of these, despite the high sun angle, gives the familiar impression of being a depression amid higher cloud banks. There is also an anticyclonic vortex whose clouds are grey, though with lines of white popup clouds on its lighter central disk. All these vortices in the southern N4 domain are just f. (west of) a large FFR, and I wonder whether they have been recently spawned from it. Just north of them is a white dumbell shape containing lines of bright white popup clouds; it is attached to a FFR but its circulation is anticyclonic, and its white cloud deck overlies pale brown cloud streaks at one end. As the pair straddle the N5 jet, I speculate that this is an AWO either being born from the FFR, or advected by it from the N5 domain, crossing the prograde jet.

NNTB:
The PJ20 images 27 & 28 show a long FFR (rifted region), with the now-familiar features of orange cyclonic eddies, cloud layers at multiple altitudes overlying one another, lines of popup clouds, and a brilliant white outbreak within it formed of masses of popup clouds (Figure 7B).

West of it (images 28 & 29; Figures 3 & 8) is a curious sector that looks like a dark NNTB segment being invaded by white clouds, both diffuse and sharp-edged; these include a brilliant white outbreak like in the FFR. Indeed, ground-based maps (Figure 9) show that this was a dark sector of NNTB that began to 'break up' within days of the PJ20 fly-over, going on to form a row of dark spots. The PJ20 map (Figure 3) shows that the disrupted dark sector still had a well-defined f. end at L3=28, but also (very near the limb) diffuse grey patches further f.(W), matching some of the small dark spots seen in the ground-based images.

Diffuse grey patches are a common feature of these northern domains, esp. near FFRs or rifts, and often appear to be actual grey haze rather than cloud-free spots. They remind one of Kevin Baines' hypothesis that such dark patches on Saturn are composed of soot generated by lightning discharges in the methane-rich atmosphere. We need comparison with hi-res 5-micron images to determine if these regions are cloud-depleted or not.

N. Temperate Domain:
For the first time, JunoCam captured an image of the *North Temperate Disturbance (NTD)*, a darkened sector of NTZ that appears f. (west of) a rifted sector of the NTB. There has been such a rifted sector with a NTD since early 2018, but the NTD had faded recently so I had not predicted the opportunity for PJ20. Nevertheless, the NTD has revived (Figure 9) and was imaged (Figure 8), along with some bright rifts emanating from the f. end of the rifted region. The NTZ does appear more thoroughly disturbed, on a small scale, than at many previous perijoves, but a proper comparison remains to be done. The NTD darkening appears to be due to diffuse streaks or patches of dark grey and reddish material – again, quite possibly grey aerosols rather than cloud clearing.

Limb hazes:
The patterns of haze bands will be shown in Part II (Polar regions). Figure 10 shows the limb in images 28-31, the last one being at closest approach. A thickened haze layer is evident in limited sectors: one over the NNTZ/N3 domain, in all 4 images, and one much further north in two images. Haze layers over the NNTB or NNTZ have been seen at some earlier perijoves. I suspect that these limb hazes correspond to the bands of haze that have been repeatedly seen in these latitudes in terminator images.

North Equatorial Belt

The NEB is now fairly quiet and normal (Figure 2), and the images showed what may be the most 'typical' sector yet imaged (Figure 3). In the northern half, there is a short wave-like series of dark streaks with spacing ~1.2° longitude (image 30), and several reddish cyclonic vortices. In the southern half, there is a small rift containing a very brilliant white spot (plume) at 10°N; its structure is indistinct and largely overexposed. These short-lived small outbreaks have been quite common this year (e.g. a line of them in Clyde Foster's image on May 28: Figure 1).

Equatorial Zone

The images of the EZ were taken with higher frequency and quality than usual, and so produced one of the best records from any orbit; and they captured a large range of impressive features

both large and small, all embedded in the persistent ochre shading that fills most of the EZ.

On the large scale, the highlight is a major NEBs dark formation (NEDF or 'hot spot') with a large dark bluish festoon; the composite map (Figure 3) also reveals the anticyclonic gyre that is often associated with major NEDFs, and another NEDF further f.(W).

On the small scale, there is a fascinating variety of clouds and streaks and waves, including previously unobserved phenomena, as indicated in Figure 11 (from image 34). Flocculent white clouds are present in parts of the northern EZ, esp. in an area bounded by 'Line 1', a bundle of narrow cloud streaks running obliquely across the NEBs edge. 'Line 2' is an even more remarkable narrow line, dark, and double or triple in places, bounding the S edge of the long, broad festoon. Within the festoon are large expanses of mesoscale waves composed of small whitish cloud streaks, lying approximately transverse to the streaks that make up the festoon itself. Some of these small whitish clouds are broader with crisp edges, lying approximately E-W. Further south there are more large areas occupied by mesoscale waves, both longer-wavelength ones composed of whitish clouds, and shorter-wavelength subtle striations. There are also more crisp-edged clouds, and this is the best view we have had of them (see reports on PJ15 & PJ16). The most remarkable set, at ~1-2°S, is reminiscent of a fleet of ships voyaging across the orange and grey waves! It seems to be part of a swathe of features with C-shaped alignments centred on a long blue-grey streak at ~2.5°S – which is strange as this is not the latitude of the C-shaped ZWP. Moreover, the 'fleet of ships' is oriented orthogonally to a superimposed pattern of faint striations, both lying at a large angle to the line of latitude and the more diffuse streaks in the main cloud deck; so it is not evident which of these patterns represents mesoscale waves, and which is something else. All these curious cloud textures are still unexplained.

South Equatorial Belt

The images covered a quiet sector of the SEB, but even so, many small eddies are visible. The SEBs (e.g. image 38) is in places overlaid with intriguing red streaks including a loop.

The GRS was captured in the outbound images (Figures 3 & 4), in RGB and CH4, showing the complexity of the red, methane-bright streaks that resulted from the latest detachment of 'flakes' from the GRS.

Southern domains

STropZ & STB:
The closeup images covered a quiet, whitened sector of this belt and zone, showing only smallscale texture, apart from one small cyclonic vortex in the STB (Figure 12). Two other small cyclonic vortices, seen at PJ19, were glimpsed near the limb (Figure 3); all are methane-dark (Figure 4). (So are cyclonic vortices in the northern domain; see Part II.) The long, methane-dark STB Spectre can be recognised alongside the GRS.

SSTB:
Juno had a fine view of 3 AWOs , and of the white cyclonic oblong between them (e.g. Figure 12). The border of the white oblong has the wavy or braided texture that is also characteristic of these structures in the S. Temperate domain, e.g. the STB Ghost and Spectre at previous perijoves. Likewise, it is also methane-dark (Figure 4).

S3 domain:
Figure 12 shows typical features of this domain: a substantial AWO, and a FFR, with a line of small dark spots f. it. Once again, it's plausible that these dark spots were generated by the FFR, and they have a diffuse grey shading, and are not methane-dark (consistent with the comments above under 'Northern domains').

The S3 domain does contain several small methane-dark spots (Figure 4), but surprisingly, these are not all cyclonic; some are anticyclonic or amorphous (green arrowheads in Figure 12).

S4 domain:
The images include some of our best views of S4-LRS-1 (e.g. Figure 12); they will enable its rotation to be measured.

FIGURES (small copies)

[Full-size versions are in a separate ZIP file]

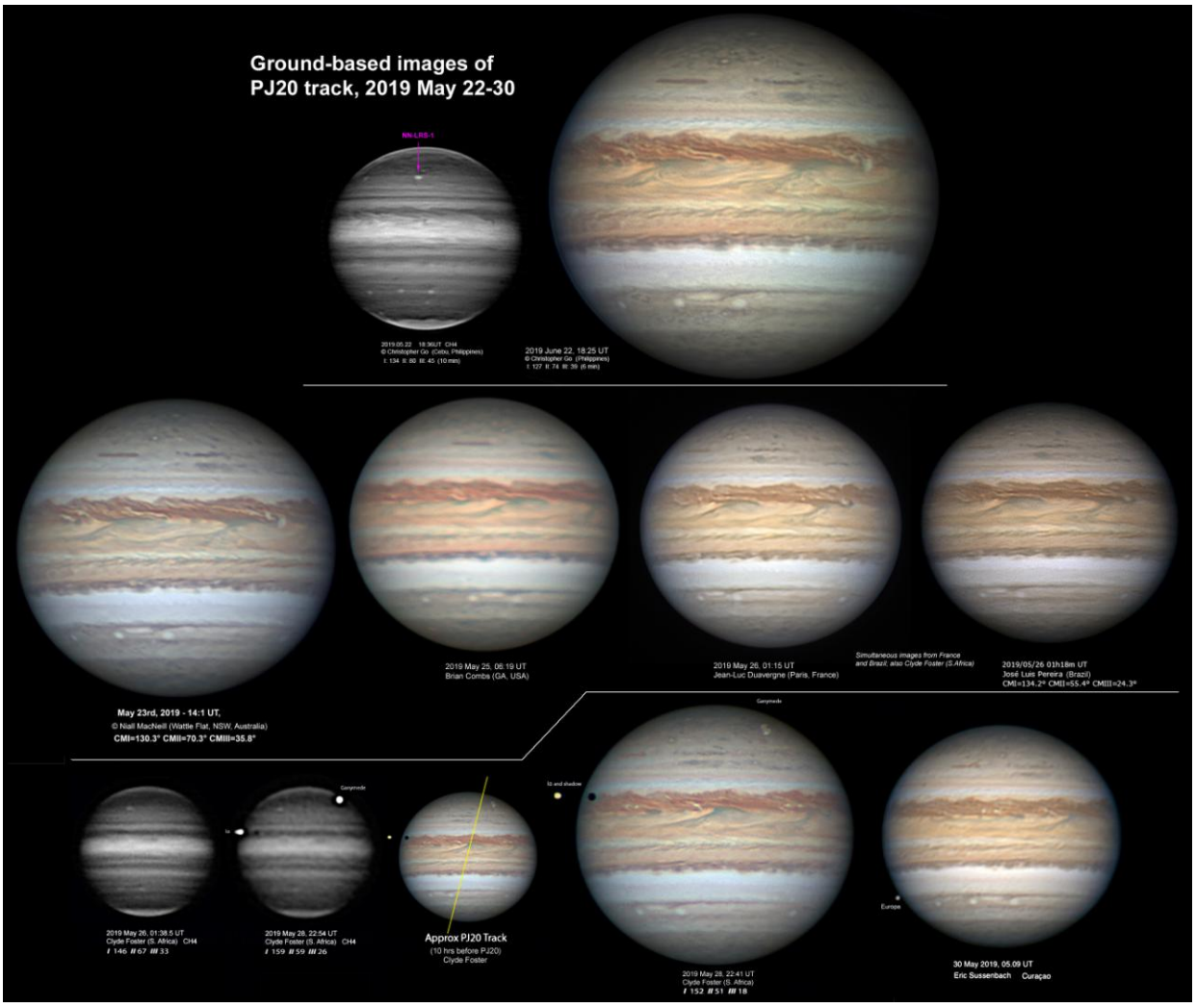


Figure 1. Set of ground-based images for a week around the flyby, including Clyde Foster's best image one rotation before perijove.

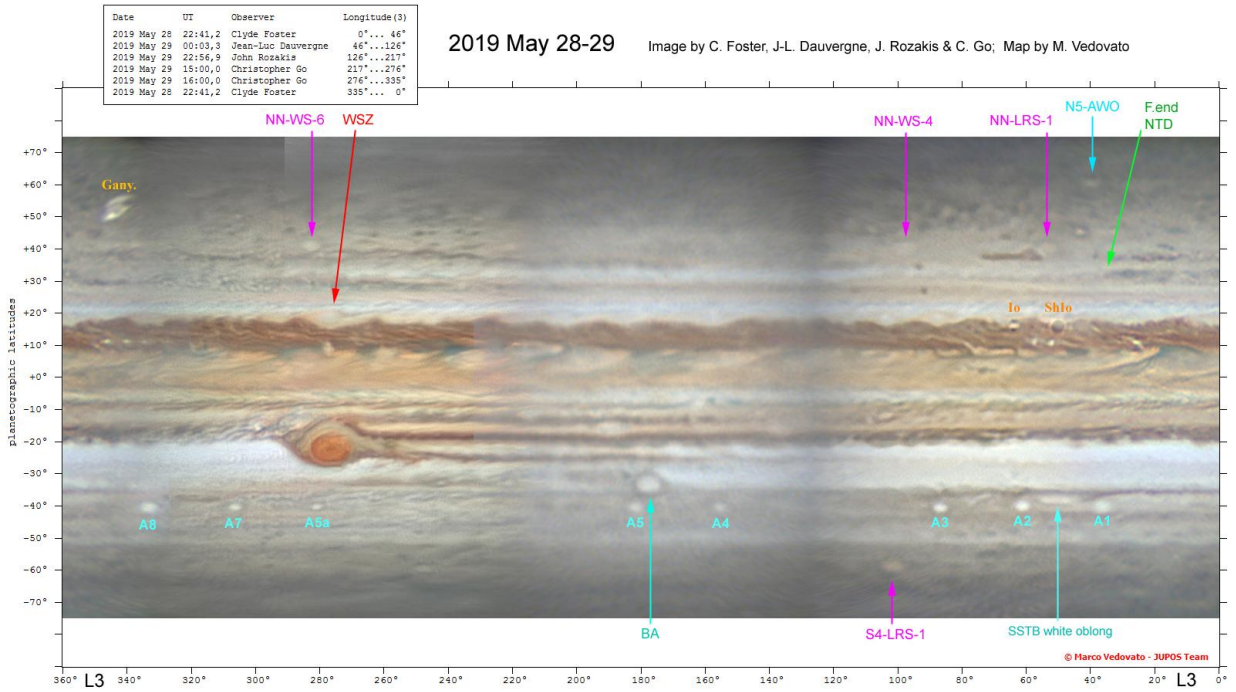


Figure 2. Cylindrical map on May 28-29. Juno's track was close to the right-hand edge. (Orange labels indicate traces of transiting satellites; Ganymede and the shadow of Io were distorted in making the map.)

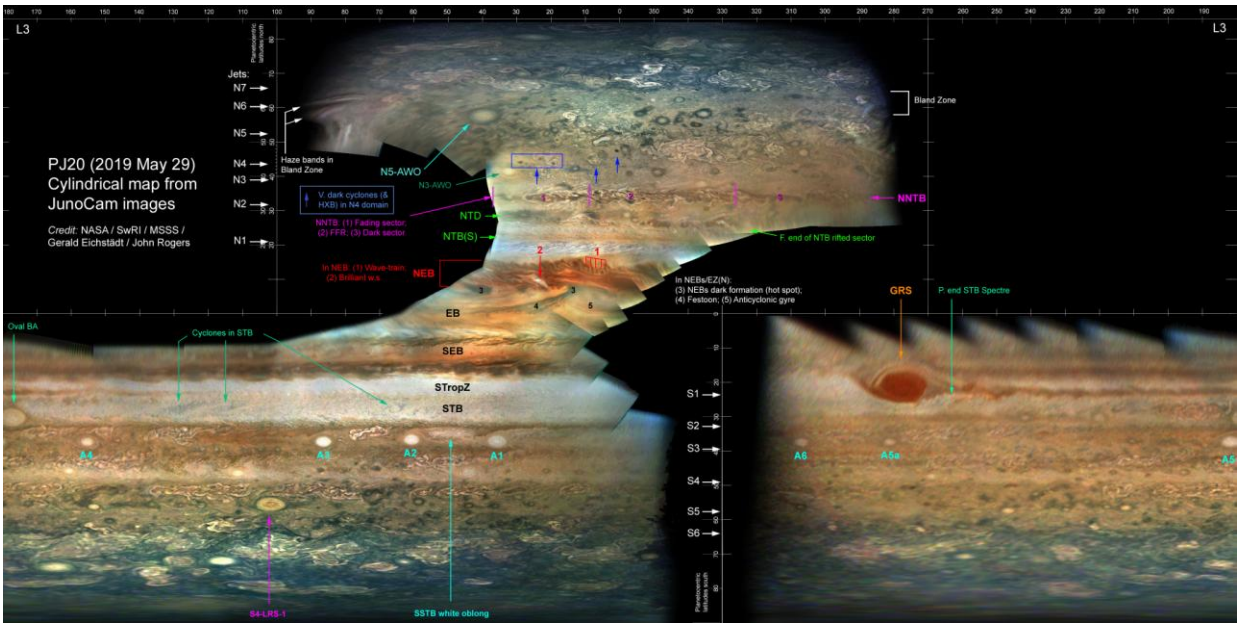


Figure 3. JunoCam global cylindrical map at PJ20 (RGB).

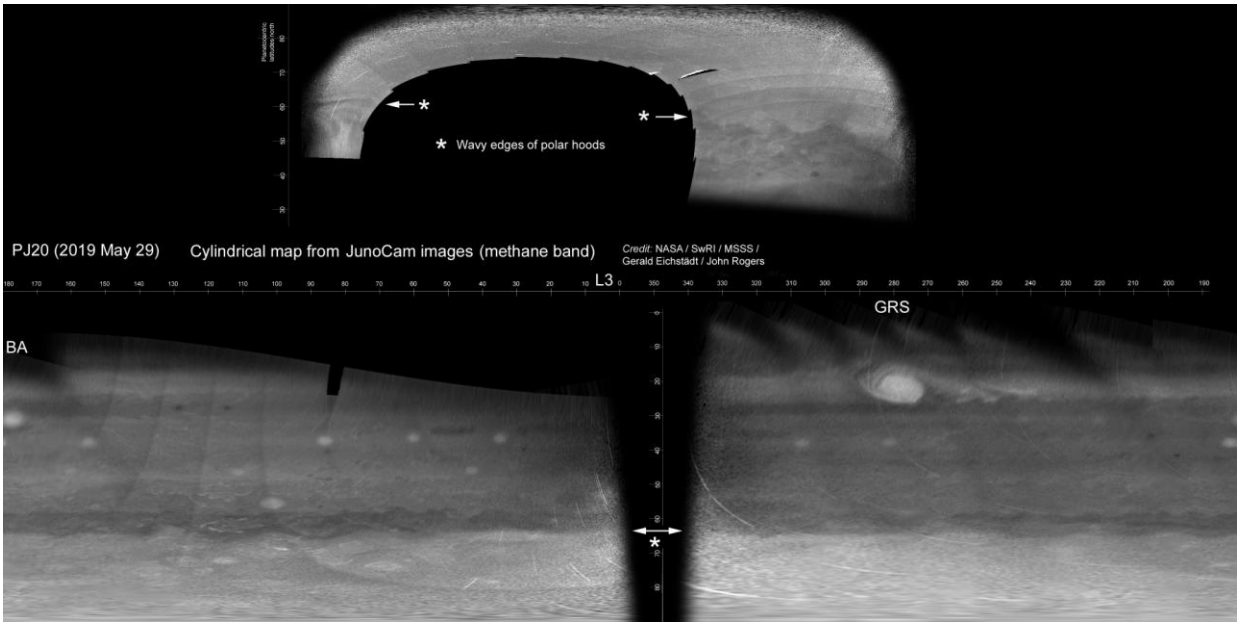


Figure 4. JunoCam global cylindrical map at PJ20 (methane band).

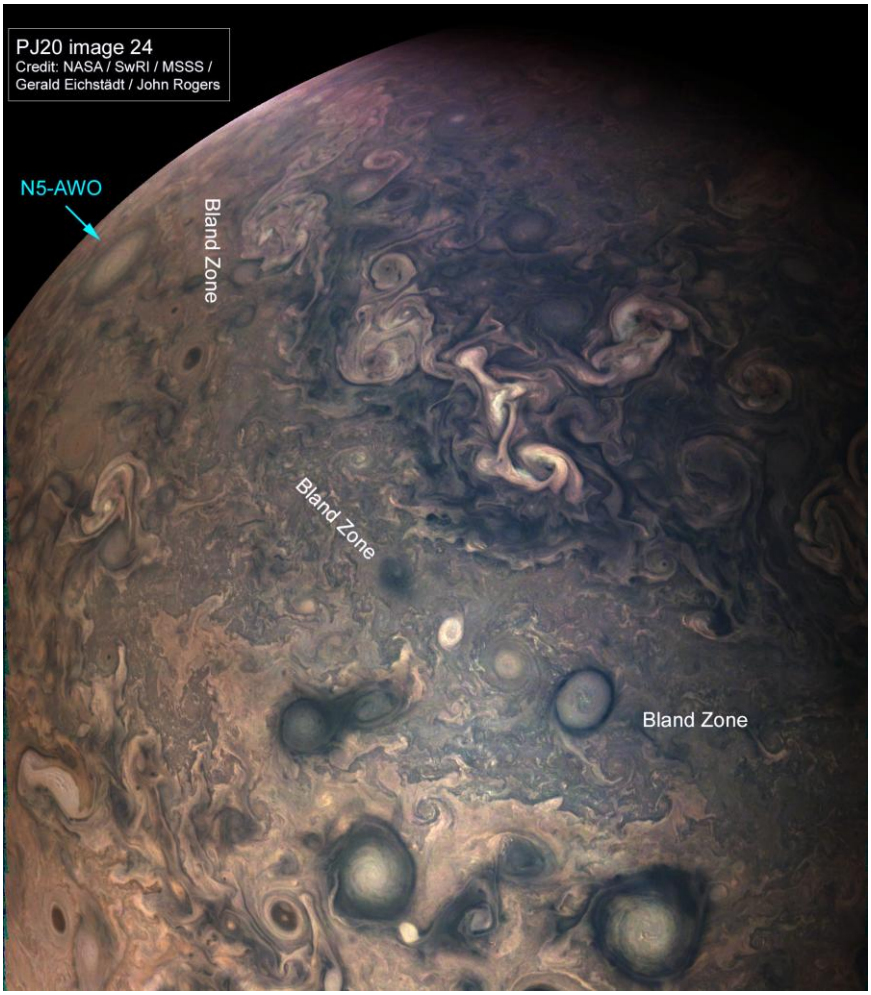


Figure 5. The Bland Zone, with the large N5-AWO near the limb. (Part of image 24.)

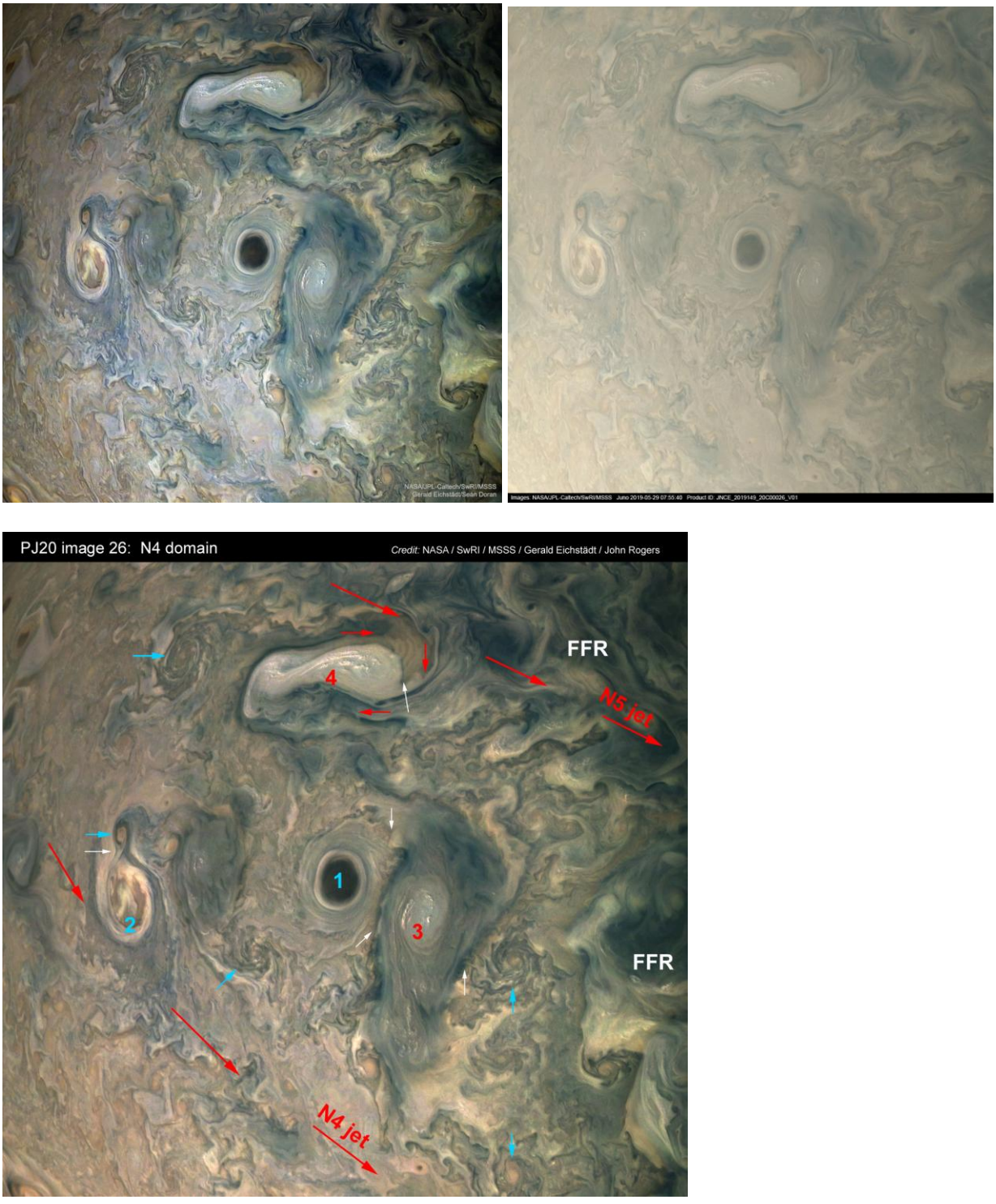


Figure 6. The N4 domain. (Full-resolution versions of part of image 26.) **(A)** By Gerald Eichstädt and Sean Doran, colour-balance and sharpened; this was posted on 'Astronomy Picture of the Day' as 'Jupiter Abyss'. **(B)** By Bjorn Jonsson: 'reality check' in approximately true colours. **(C)** By Gerald Eichstädt & JHR, labelled.
Key to (C): Features in N4 domain: (1) Very dark-cored cyclone. (2) 'Hot cross bun' cyclone. (3) Grey anticyclone with popup clouds. (4) Dumbell-shaped anticyclone with popup clouds. Blue arrows: Smaller cyclones. White arrows: Places where higher clouds (esp. associated with anticyclones) overlie lower clouds. Large red arrows: Approximate courses of prograde jets.
Note: Circulations are inferred from the sense of the spiral streaks, as the images did not cover this region over a long enough time-span to detect wind motions.

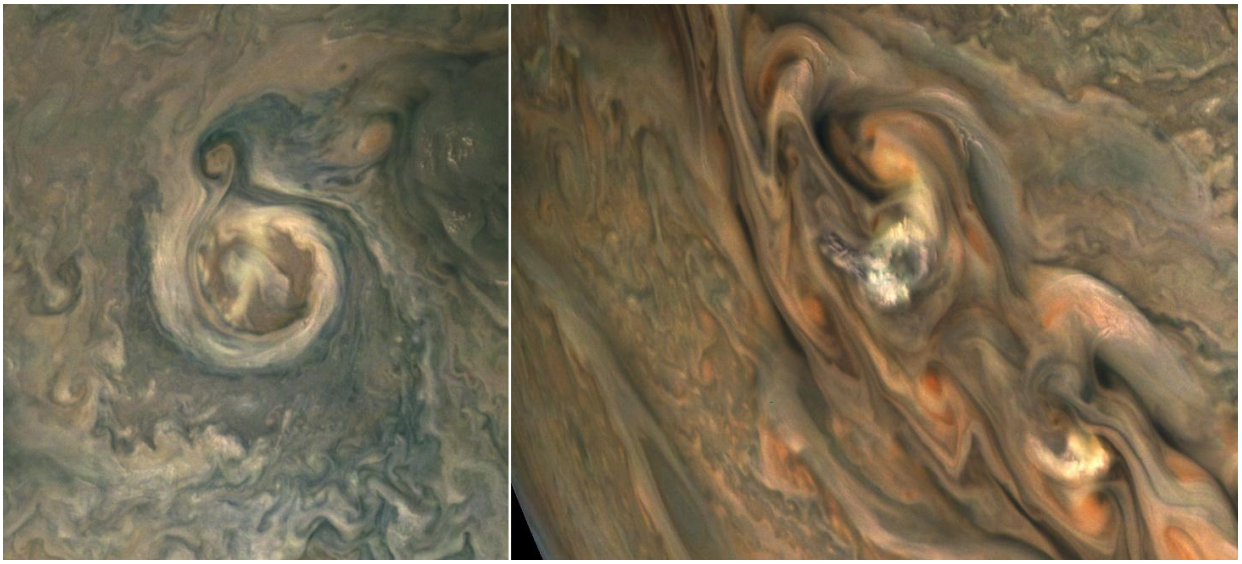


Figure 7. Details from image 27: (A) The‘hot cross bun’ cyclone in N4 domain. (B) Bright convective outbreak in NNTB-FFR (with horizon at lower left). Image processed by Gerald Eichstädt & JHR.

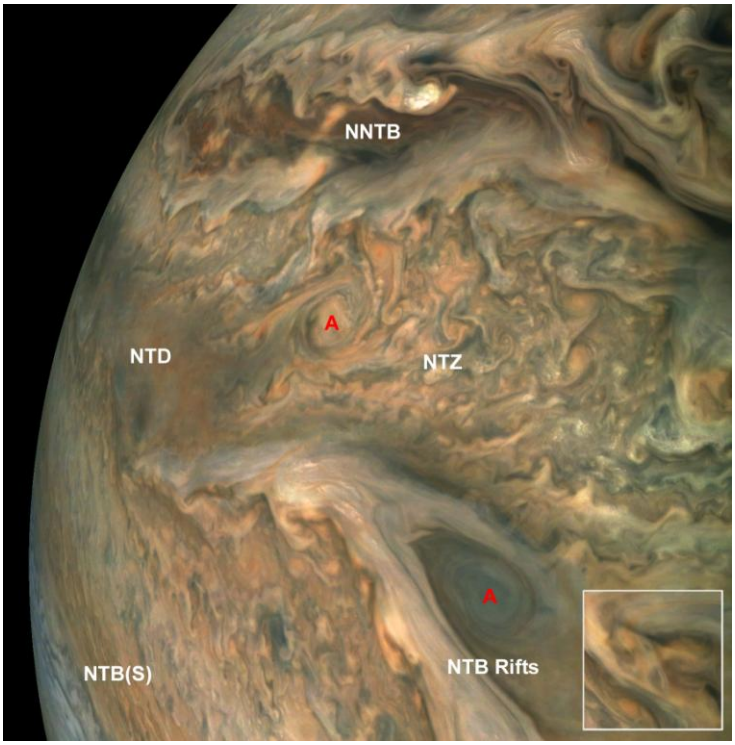
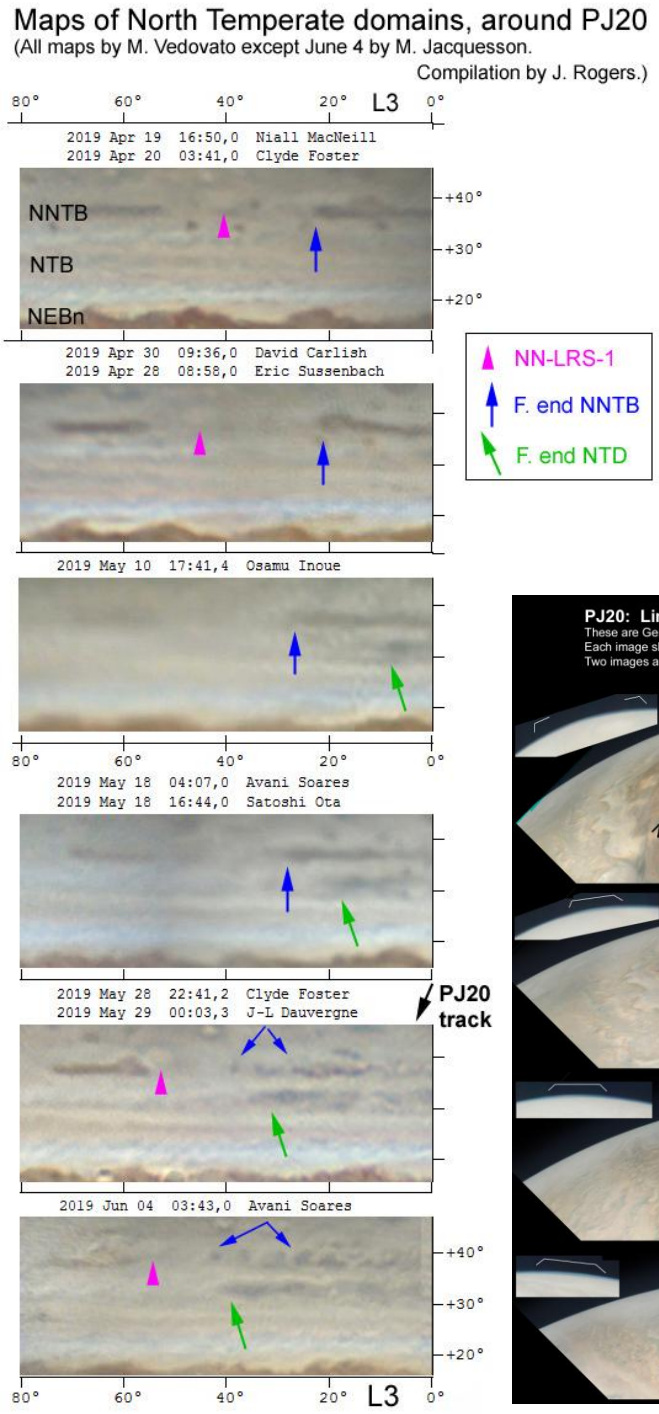
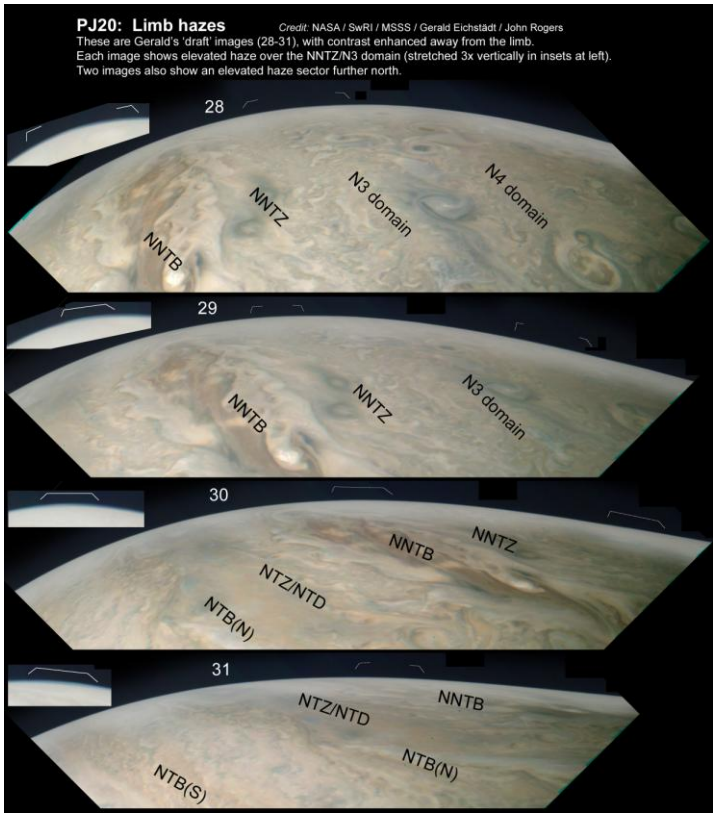


Figure 8. Image 29: Details in the NNTB (dark sector invaded by white clouds), NTZ/NTD, and NTB(N) rifts. Inset, crossing cloud bands further east in the NTB rifts. A, anticyclones. Image processed by Gerald Eichstädt & JHR.





Left: **Figure 9. Ground-based maps of the NNTB & NTB** (in L3).

Right: **Figure 10. Views to the horizon** in four of the closest images, with the horizon relatively brightened and (in the insets) stretched vertically x3 to reveal the thicker haze layer. Images processed by Gerald Eichstädt & JHR.

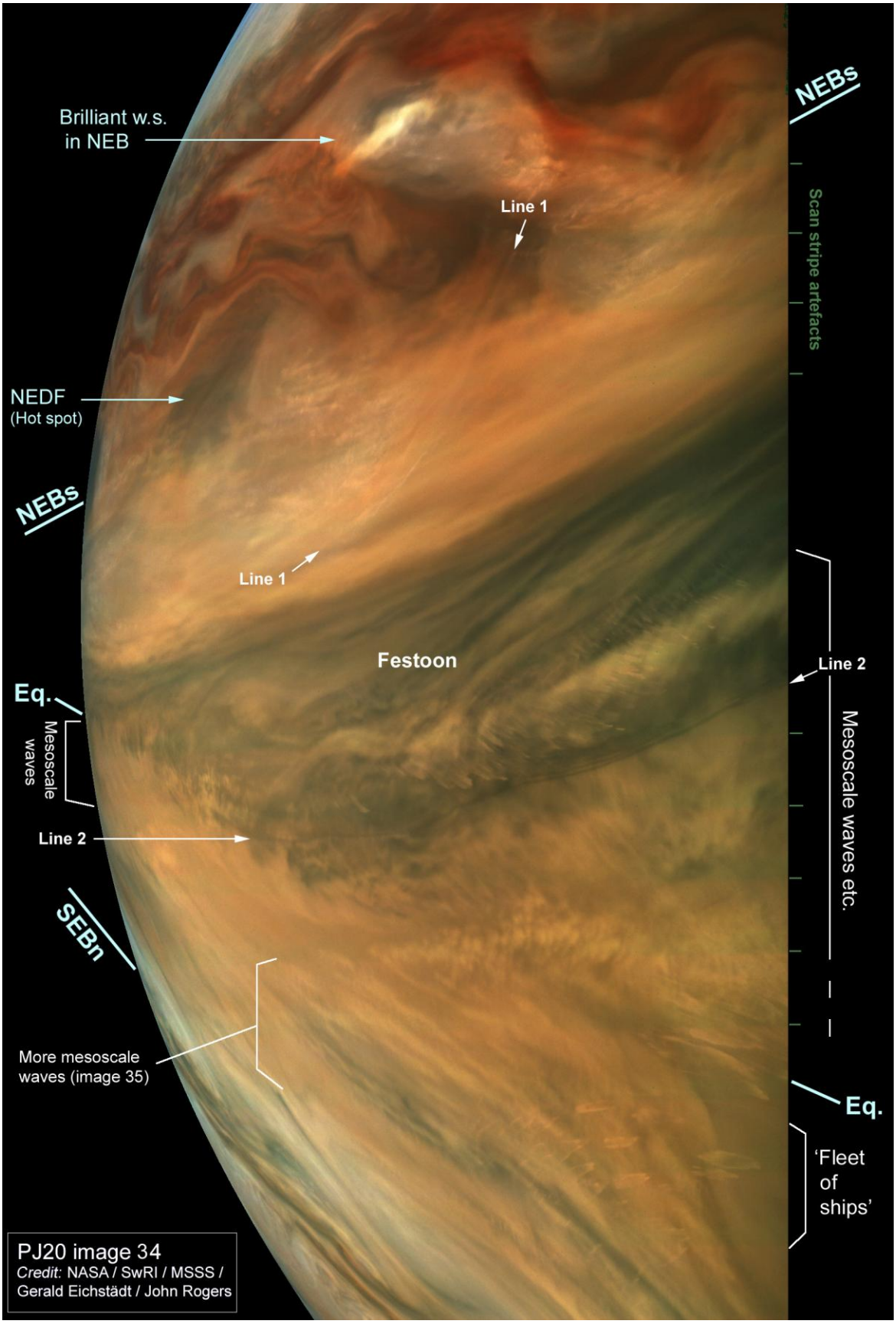


Figure 11. View of the EZ (image 34). Image processed by Gerald Eichstädt & JHR.

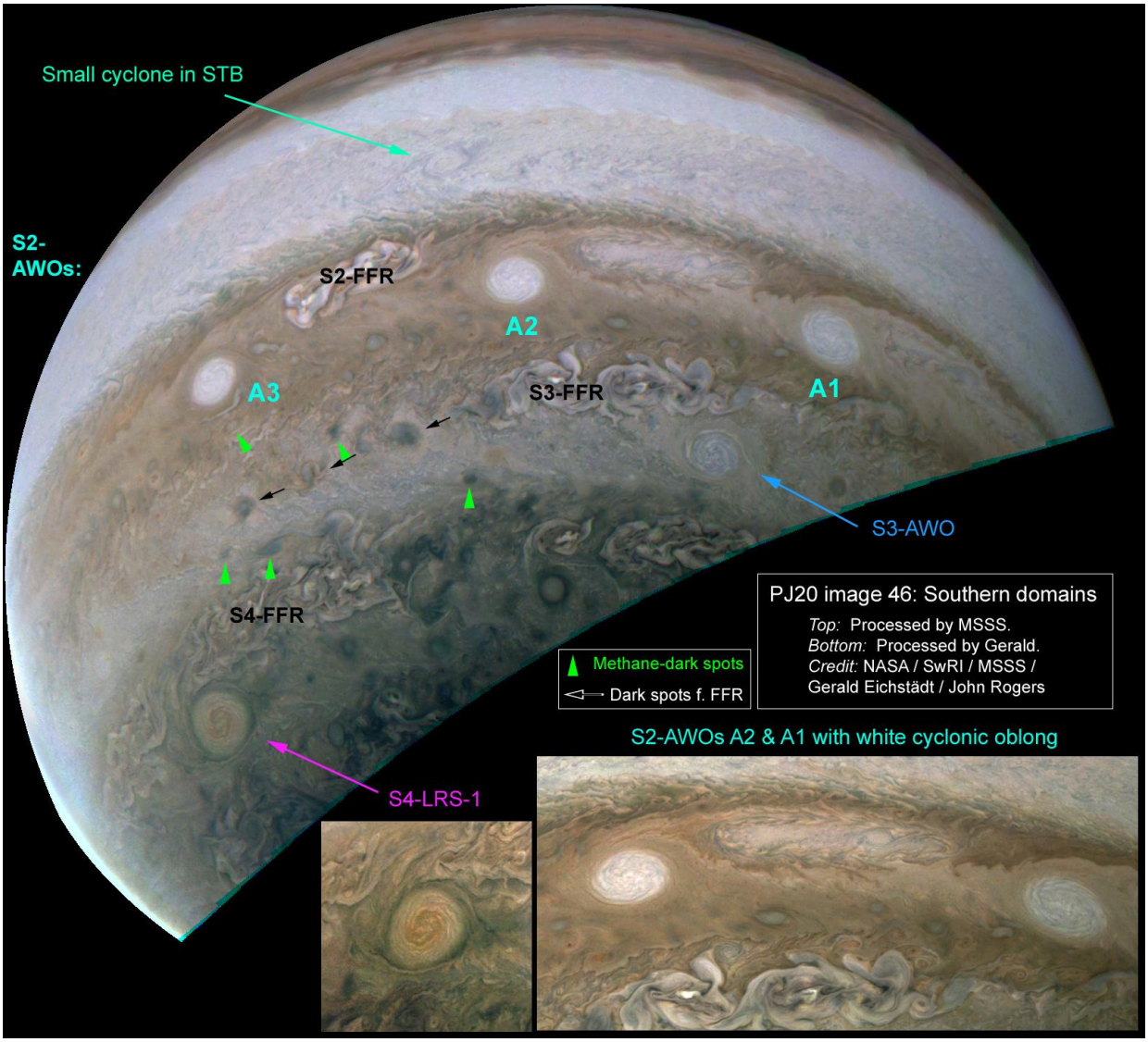


Figure 12. Southern domains (image 46, one of a series).