JunoCam at PJ24 images: What the pictures show

John Rogers (2020 Feb.2)

Perijove-24 was on 2019 Dec.26, just one day before Jupiter passed directly behind the Sun as viewed from Earth. JunoCam images therefore provided the only view of the planet at solar conjunction. The orbital parameters and viewing angles were similar to PJ23.

As usual this report shows results from the whole JunoCam team, and is illustrated both with the 'version 01' images initially posted by the team, and with higher-quality images and maps produced by Gerald Eichstädt. Fig.7 is a global cylindrical map produced from Gerald's single-image maps. In addition, Kevin Gill and Björn Jónsson are now producing high-quality map products which seamlessly merge the individual images. Kevin's include fish-eye views of the globe from points on Juno's trajectory (e.g. Fig.8), and Björn's include hi-res regional maps (e.g. Fig.10).

Satellites

Inbound, JunoCam obtained north polar views of Io and Ganymede. In the Io images (e.g. Fig.1), no plumes were recorded. Processed versions of the best Ganymede image have been posted on the JunoCam web site by several people, and examples are shown in Fig.2.

North polar region

Circumpolar cyclones (CPCs):
Fig.3 is our north polar projection map showing the CPCs. (A similar map was produced by Björn Jónsson.) The reddish cloud ridges of the central North Polar Cyclone (NPC) are seen again; they are not quite centred on the pole but this may be due to their spiral form. We have an excellent view of CPCs-1,2,3, and can just see the outer edges of CPC-4 & 8 on the terminator. There is a weak counter-spiral in the centre of CPC-3.

Fig.4 is a composite map from PJ20-PJ24 to show the whole octagon (compare with Fig.N1 of our PJ23 report). To optimise the fit, the PJ24 map was shifted to the left by several pixels (0.25° latitude), which might indicate that the octagon drifts slightly relative to the pole, conistent with the JIRAM map at PJ4 that showed the NPC centred ~0.5° latitude from the pole.

N. Polar Hood (NPH), haze bands, & Bland Zone:
Fig.5 shows polar projection maps of the northern hemisphere, in RGB and in the methane band. (The latter shows considerable detail because the JunoCam team obtained three closely-spaced methane images that could be blended to reduce noise.) The Bland Zone is clearly seen, though the sector viewed at highest resolution (images 17-22) is partially disrupted by two strings of vortices across it, one mostly cyclonic and one mostly anticyclonic (Fig.6). The polar maps show the usual long linear haze bands in the Bland Zone, away from this disrupted sector.

In methane images, the NPH is usually brightest north of the Bland Zone, though this was apparently not the case at some recent perijoves. The PJ24 raw methane images show this polar region comparatively dark, but in the polar map, corrected for illumination, it appears comparatively bright – though on the side that was viewed most obliquely (lower left quadrant of the polar map), we see very bright hazes both north and south of the Bland Zone, presumably because of the viewing angle. As usual, visibly bright strips in FFRs are methane-bright, in the polar region and also the N5 and N4 domains.

There are also some quite dense haze bands and arcs over the N3 to N5 domains, seen in RGB images near the terminator, with brown shadowing (e.g. Figs.5A & 6); some of them are also visible in the methane map (Fig.5B).

Northern domains

N3 and N2 domains:

These domains are mostly bland, pale fawn or orange, apart from a few distinct spots (Figs. 8&9). One feature is a beautiful spiral cyclone in the N3 domain, shown near the centre of the globe in Fig.8. NN-LRS-1 is seen near the limb (Fig.9A), and is quite strongly reddish now.

Image 26 (Fig.9B) is perhaps the best methane-band image that JunoCam has achieved at such low latitude. The N3 domain is darker than the N2 domain and NTZ, with no obvious sign of NPH or other methane-bright haze bands in this sector in the preliminary mapped version (Fig.9B-D), but it does show plenty of variegation, which may help to understand the relative altitudes of the different visible cloud textures. There are various methane-dark spots, both cyclonic circulations (including the spiral cyclone and a pale orange oval in N3, and a dark brown oval in N2) and anticyclonic dark spots (ADSs) in both domains, in agreement with previous observations. The pale orange NNTB(S) sector, entirely smooth visually, is methane-bright, whereas the darker orange NTB(N) (see below), near the limb, appears methane-dark.

NTB:

There is a strikingly red (orange) band in the NTB(N) latitude, with translucent tendrils of red haze extending from it (Fig.10). Its position matches that predicted for the f. part of a long dark segment of NTB(N) that was recorded in the last ground-based map on Oct.22. So this is an example of a dark belt segment turning red as it fades – probably the most detailed image ever taken of this phenomenon. The image appears consistent with the idea that this is a red haze that appears over the dark segment as it disappears, although it is not methane-bright (Fig.9).

Dark bluish-grey spots just south of it, in mid-NTB, are presumably prograding in the North Temperate Current B, arising from the NTB rifted region which is expected to be tens of degrees west of here. Remarkably, these bluish-grey spots appear anticyclonic, despite being in the middle of the cyclonic belt! This is evident from the spiral forms of the spots themselves, and from the red tendrils that extend around some of them from the red band (Fig.10). Could the anticyclonic vorticity be due to enhanced cyclonic winds around the red NTB(N) segment, producing a distortion of the zonal wind profile in this sector? (We noted another example of an anticyclonic spot in a cyclonic belt at PJ23; that was a white spot in the SEB.)

NEB:

As at PJ23, the latitudes from the NEB to the SEB were imaged only near the horizon, looking forward before equator crossing and backward after (Fig.11). Thus a sector of NEB was fully mapped (Figs.7 & 13), albeit from very oblique images. It shows a ragged NEBn edge (we have no identified circulations in this sector); a calm, reddish strip of northern NEB; a conspicuous, vigorous-looking white rift system; and two NEBs dark formations ('hot spots') with dark blue-grey festoons in the EZ, one of them being particularly large.

The rift system is notable because it was only in late Nov. that ground-based observers recorded the first substantial rift of 2019 [see our recently posted 2019 report no.9], probably the largest since the NEB expansion event in 2017. So this confirms that such activity has now resumed. (See PJ4 for a vertical view of a similar rift system.) The swirls in the rift system appear particularly bright white, possibly because they were viewed so obliquely, enhancing high hazes (Fig.11). White hazes from the rifts can be seen spreading south into the EZ (Fig.13).

EZ:

As the EZ images are so oblique (Figs.11 & 12), they cannot be easily compared with earlier views, and are too distant to record mesoscale waves consistently, but three arrays of such waves can be seen in bands of whitish clouds in the EZ in image 33 (Figs.12 & 13), confirmed in images 34-38.

SEB:

In this sector, there is still a narrow SEB(N), broad white SEBZ, and substantial dark SEB(S), all without major disturbances. The texture of the SEBZ is notable for the three-dimensional impression of its northen part (possibly an illusion) and for the absence of diagonal streaking across it (possibly suggesting an abnormal zonal wind profile (ZWP)).

The SEB(S) is disrupted at the eastern end of the sector imaged; this is probably the f. (W) end of the usual disturbance emanating from the GRS region. On the SEBs edge, three anticyclonic vortices are prominent (Fig.13); these no doubt represent turbulence from that same post-GRS disturbance developing into retrograding rings, some of which are seen at lower resolution further west in the global map (Figs.7 & 14).

S. Temperate (S1) domain:

At PJ24, Juno's track came closer to oval BA than ever before; BA had evaded Juno's track until now. The images (Figs.14&15) clearly show the anticyclonic structure and amorphous central cloud texture in BA, and it has no residual red colour. However, because of the increasing altitude of Juno's orbit over the southern hemisphere, the resolution and quality of the PJ24 images is actually similar to those from PJ17 (2018 Dec.21), when BA was nearer the limb. The two image sets make an excellent comparison, and the state of the structures p. and f. BA is quite similar one year apart.

The sector p. BA is particularly interesting, for two reasons [see our 3 long-term reports on the S.Temp. domain, 2000-2012-2015-2018]:

(i) The STB(N) is darkened by disturbance prograding from BA due to the turbulent STB sector f. BA (Figs.13&14). At PJ17 the disturbance was small-scale but at PJ24 it consists largely of dark spots, which show weak anticyclonic structure. This is surprising as such spots generally fall on a weakly cyclonic gradient [see our 2 long-term reports on the S.Temp. domain, 2000-2012-2015]. Similar spots were viewed by Voyager 2 (1979) and by Hubble (2014 April 21), and did not show anticyclonic vorticity, so this seems to be a variable aspect, in keeping with the variable ZWP across this complex jet.

(ii) New major cyclonic circulations tend to arise tens of degrees p. BA; indeed I have been expecting one for the past year or so, but so far it has failed to appear. The PJ24 images show a nice little cyclonic vortex in the whitened STB here, but it is not conspicuous (Figs.13&14). (The PJ17 images showed a triplet of them.) Perhaps of relevance, the SSTBn edge tends to be deformed in this sector, and indeed there is grey material in the SSTZ between BA and the little vortex(es) in both PJ17 and PJ24 images, though the texture indicates that the SSTBn jet is in its regular latitude. So, while the images do not provide a 'smoking gun' to show how BA influences the dynamics for tens of degrees to the east, they do suggest that little cyclonic vortices tend to arise repeatedly there, and I suggest that random interactions will eventually lead to one of these growing (perhaps by mergers) to become the clearly visible circulation from which a new structured segment will grow.

The turbulent STB segment f. BA is also well shown. It is 16° long, so it has resumed shrinking since Sep., in contrast to its constant length earlier [see our 2019 report no.9].

S.S. Temperate (S2) domain:

[See our long-term report on the high southern domains in 2000-2012, & our recently posted 2019 report no.9 for the history of the S2 domain during 2019 including a full set of JunoCam maps.]

There is also a remarkable feature just south of oval BA: two S2-AWOs are merging! (Figs.14 & 15) They are A5a and A7. A5a was a small AWO which appeared in 2015; many mini-AWOs merged with it as it grew, one such merger being imaged at PJ1 [see our 2016/17 reports nos.8,10,14]. A7 was a full-size AWO which had been tracked for many years. A6 merged with A7 in 2018 May, and I wondered whether A5a would grow to replace it, but instead it is following the same fate. It is fortunate that JunoCam captured the merger, which takes only a few days. And it is unexpected, as the two ovals converged closely in Sep., but rebounded. This merger is occurring adjacent to oval BA – like some previous mergers of S2-AWOs. However, as the AWOs had not actually passed BA, I am not sure if this is an adequate explanation. Perhaps a better explanation is renewal of the large FFR p. A5a, which had been present (variably) for several years, then absent from mid-July to Sep., 2019, but is large and turbulent in the PJ24 images. Possibly this revived FFR pushed A5a towards A7, leading to the merger.

Another change is in the interval between A7 and A8: this sector of SSTB has turned into a whitish cyclonic circulation during solar conjunction.

S4 domain:
The images give a good view of S4-LRS-1 (e.g. Fig.15).

Methane-band map of southern hemisphere (Fig.16B)

This map made from outbound images shows all the AWOs and red ovals from the S. Tropical to the S4 domain as methane-bright, including the merging pair of S2-AWOs, and the small AWO in the STZ f. BA. The GRS is followed by a large methane-bright flake (also red in the RGB map, though only caught in the last, lo-res outbound images); this must have been recently emitted from the GRS f. end. The STB Spectre can be traced as a methane-dark band from L3 = 174-309, i.e. 135° long, even longer than before.
The hazes in the South Polar Region are discussed below.

South Polar Region

Juno's view of the SPR is gradually deteriorating as the mission proceeds due to its higher altitude over this region, its more oblique view (orbital inclination is now 74.4°), and decreasing sun angle. The resolution at PJ24 is obviously poorer than a year ago, but still enables us to study the major features. Fig.16 shows maps of the SPR in visible colour, in the methane band, and with low sun angle to highlight haze bands.

60-75°S (Fig.16A):
The usual belt of large FFRs is present around much of this band. In the sector at top of the map (L3 ~ 230-270) there is an unusually large, fine-textured expanse of FFR, with tendrils extending south. The bright strips in it show up near the terminator so are classified as haze bands (Fig.16C&D). Animations of the maps (see below) do not show any exceptional motions here; in particular, there are no meridional motions except *northward* displacement of a haze band.

Two large AWOs are still present at 73°S and 72°S; since PJ23 they have retrograded by 47° and 42° respectively, the latter being typical for an AWO at 72°S.

South Polar Hood (SPH) and haze bands:
The methane map (Fig.16B), as usual, shows the methane-bright SPH with its wavy edge at ~63-65°S and embedded bright FFRs (and the largest AWO). As at PJ23, the SPH has a secondary edge at ~67°S at many longitudes (in the 'upper' half of the map). Sometimes this is aligned with the edge of a FFR, but not always. Both main and secondary edges cut across the large expanse of fine-textured FFR mentioned above.

Maps of near-terminator regions (Fig.16C&D) show a variety of haze bands, including arrays of narrow, tenuous ones and broader, higher-contrast ones. As is typical, most of them are slanted in accordance with the ZWP, with reversals of orientation around 64°S (at the S6 prograde jet) and 72°S (at the retrograde flow). The Long Band of 2017-18 is absent, but a rather similar band is present elsewhere (on the left of the maps), probably running close to CPC-3. There seem to be more dark bands near dawn and more bright bands near dusk, as we have sometimes (but not always) observed at previous perijoves.

Circumpolar cyclones (CPCs):
With the reduced resolution at PJ24, we can confidently identify CPCs 1 & 5 and the central south polar cyclone (SPC) (Fig.17A), but we see little or nothing of CPCs 2, 3 & 4.

The SPC is centred at almost the same place as at PJ23 and PJ18 (Fig.17B). It has not moved significantly in latitude since PJ18, but has continued its oscillation in longitude with a period of 11-12 months ever since 2016.

Of most interest was the former gap in the pentagon, which was fortunately well presented. At PJ23 it was occupied by a compact dark cyclone, apparently turning the cluster into a hexagon, but this was smaller than the five long-established CPCs and might have drifted in randomly. At PJ24, this cyclone is absent, but instead the former gap is filled by a larger, irregular cyclonic structure (a FFR) (Fig.17A). We cannot tell whether this has developed from the compact cyclone or has drifted in to replace it, nor whether the configuration will stabilise. Further monitoring is needed.

There are also several compact white ovals (probably AWOs) in the vicinity, including one between CPC-2 and the SPC. (We likewise saw a small AWO inside the pentagon at PJ14.)

An animation can be made between images 53 and 61. Cyclonic circulation is obvious in CPCs 1 & 5 & the SPC and in several FFRs, as usual; and also in the FFR in the gap, but this does not seem as rapid as some. Anticyclonic circulation is just perceptible in the large bright AWO. The motion of the S6 jet is also obvious and measurable. A bluish haze band (in the top right part of the maps) appears to move rapidly northward!

FIGURES

(North is up in all of Figures 7-15. As usual, intensity adjustments, gradients and labelling have been applied by JHR to all figures.)

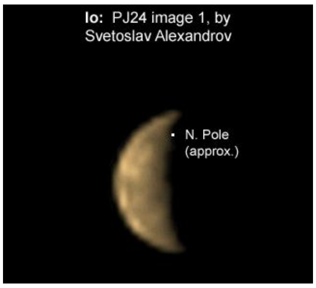

Figure 1. Io.

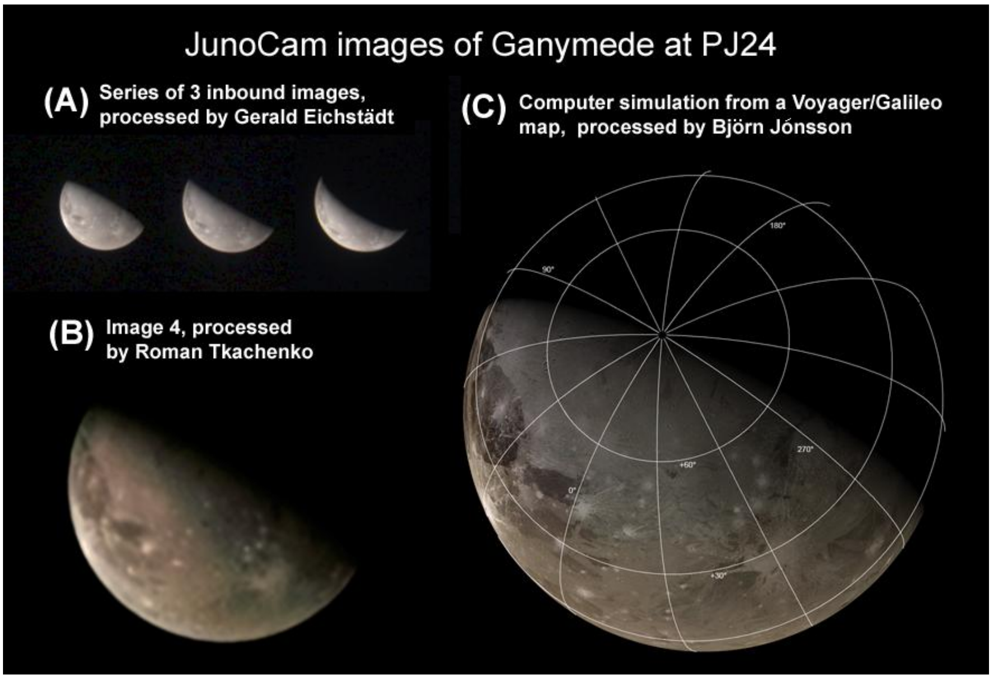

Figure 2. Ganymede.

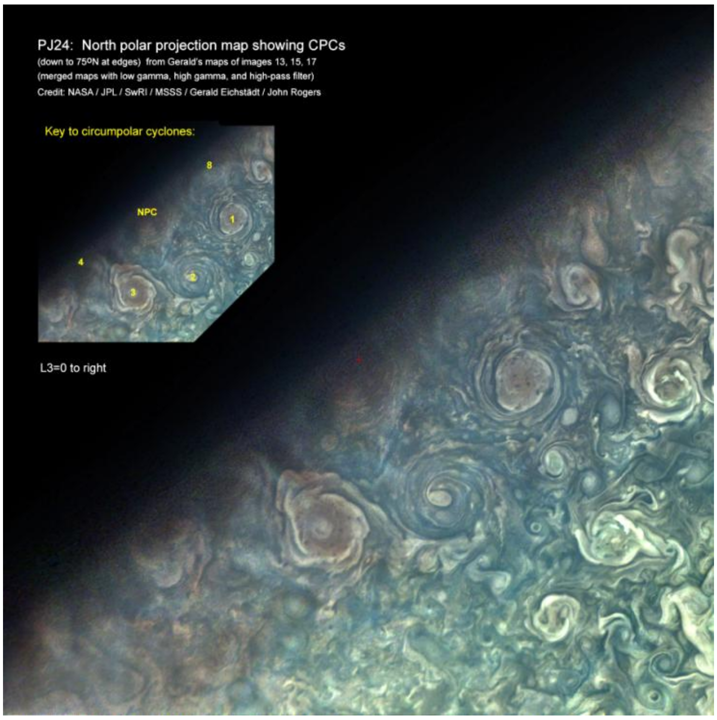

Figure 3. Composite north polar projection map showing the circumpolar cyclones (CPCs) and part of the central North Polar Cyclone (NPC). CPCs are numbered as in Adriani et al.(2018). L3=0 to right.

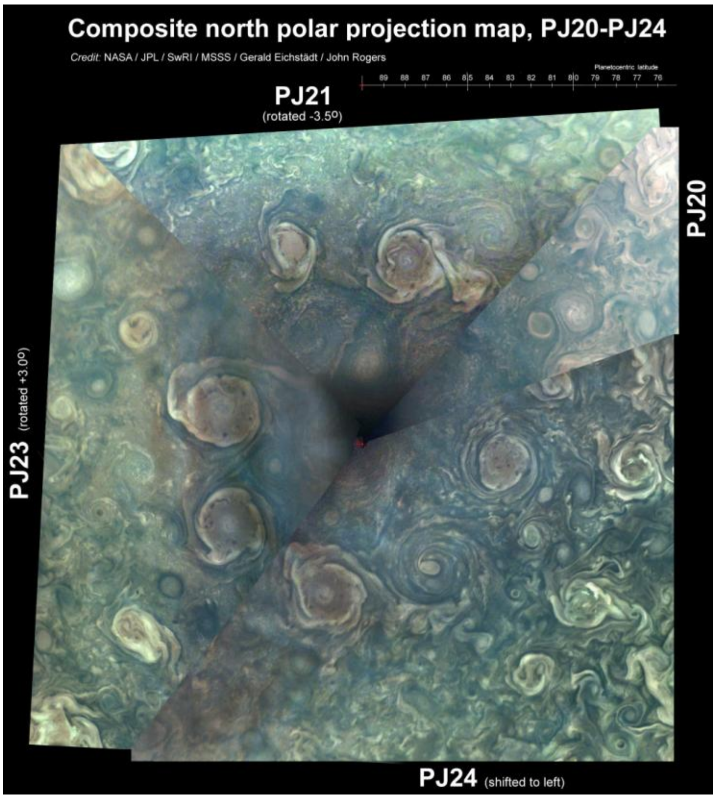

Figure 4. Composite north polar projection map from PJ20-PJ24 to show the whole octagon of CPCs (compare with Fig.N1 of our PJ23 report). Small shifts or rotations have been applied to optimise registration of the CPCs, compensating for small movements between perijoves.

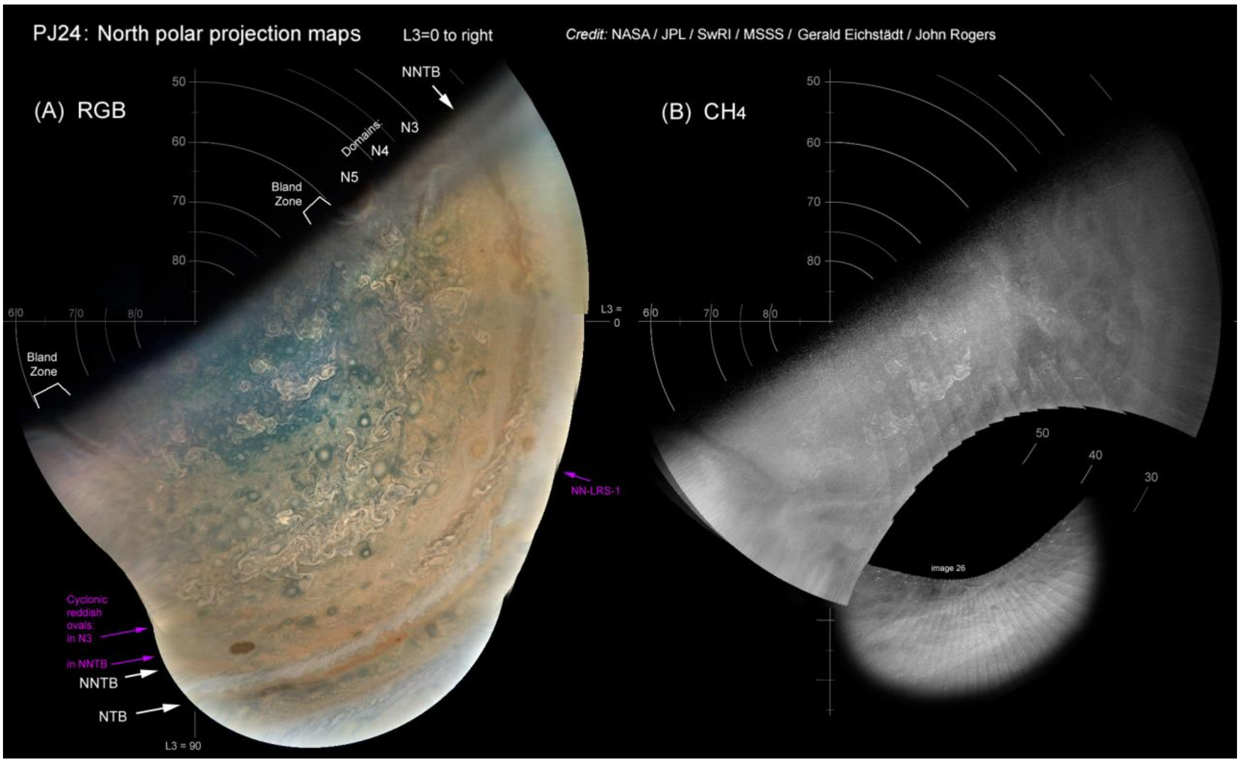

Figure 5. Composite north polar projection maps of the northern hemisphere, (A) in visible colour, (B) in the methane band. L3=0 to right.

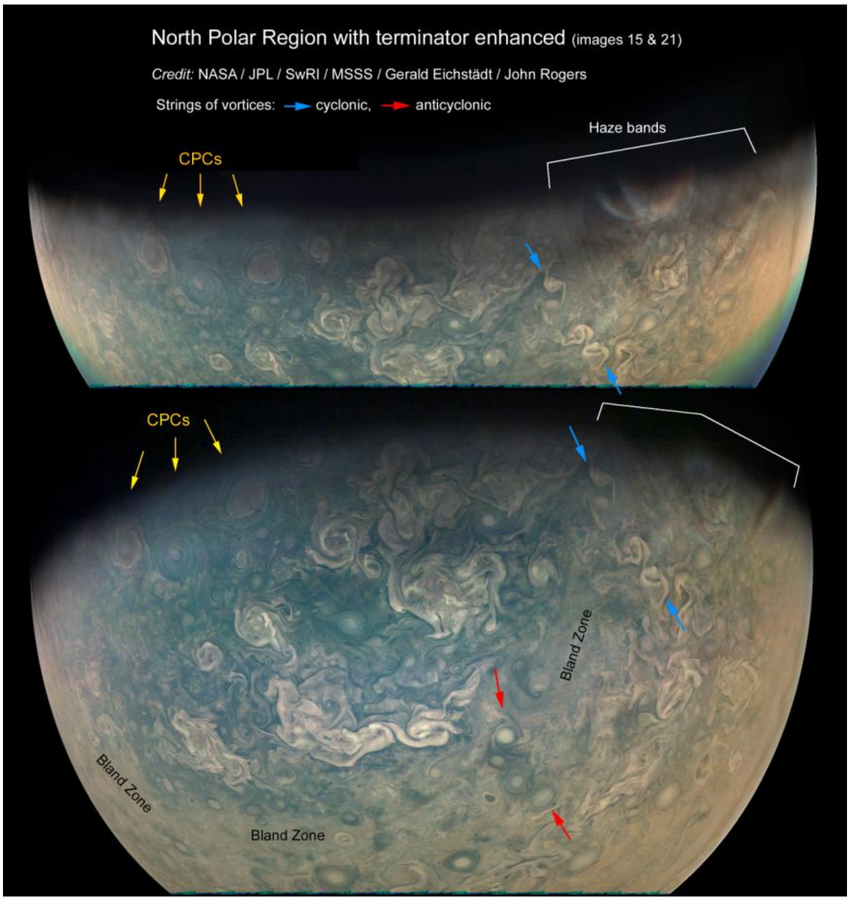

Figure 6. Images 15 & 21 showing the north polar region with terminator brightened to show the CPCs and haze bands. Red and blue arrows indicate strings of vortices spanning the Bland Zone.

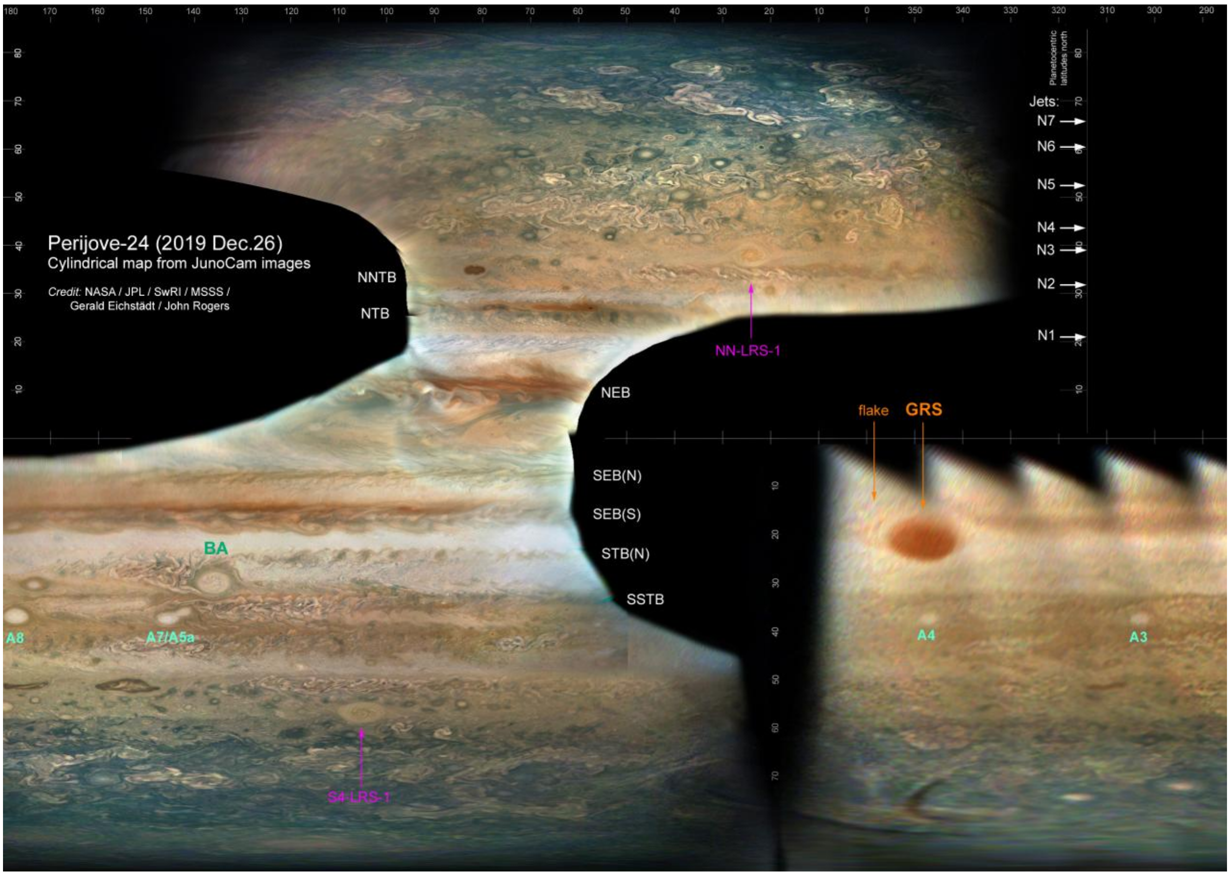

Figure 7. Global cylindrical map produced from Gerald's single-image maps. *[This copy cropped]*

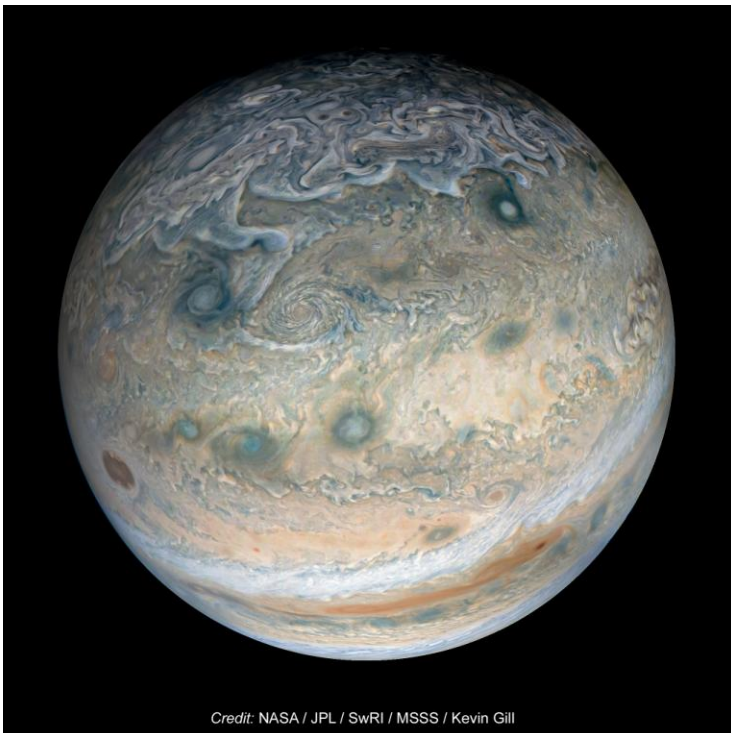

Figure 8. 'Fish-eye' view of the globe from one point on Juno's trajectory, produced by Kevin Gill from his projections of several consecutive images.

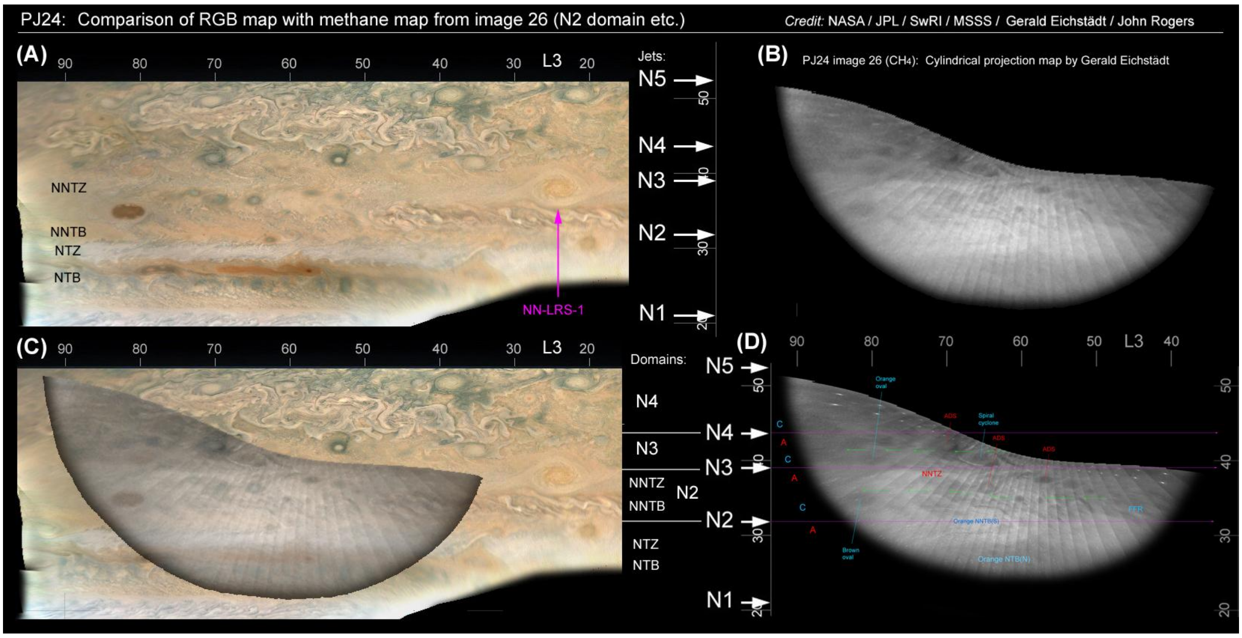

Figure 9. Cylindrical projection maps, especially showing the N3 and N2 domains.
(A) Excerpt from the RGB global map in Fig.7; (B-D) Preliminary map of methane image 26 by Gerald Eichstädt, and composite of this with the RGB map.

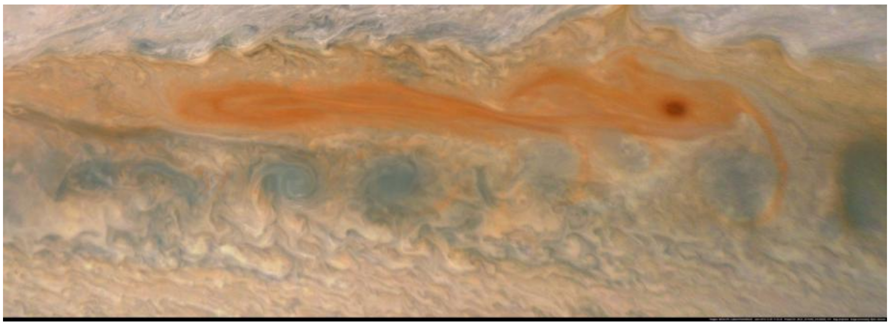

Figure 10. Cylindrical projection map of the NTB, by Björn Jónsson.

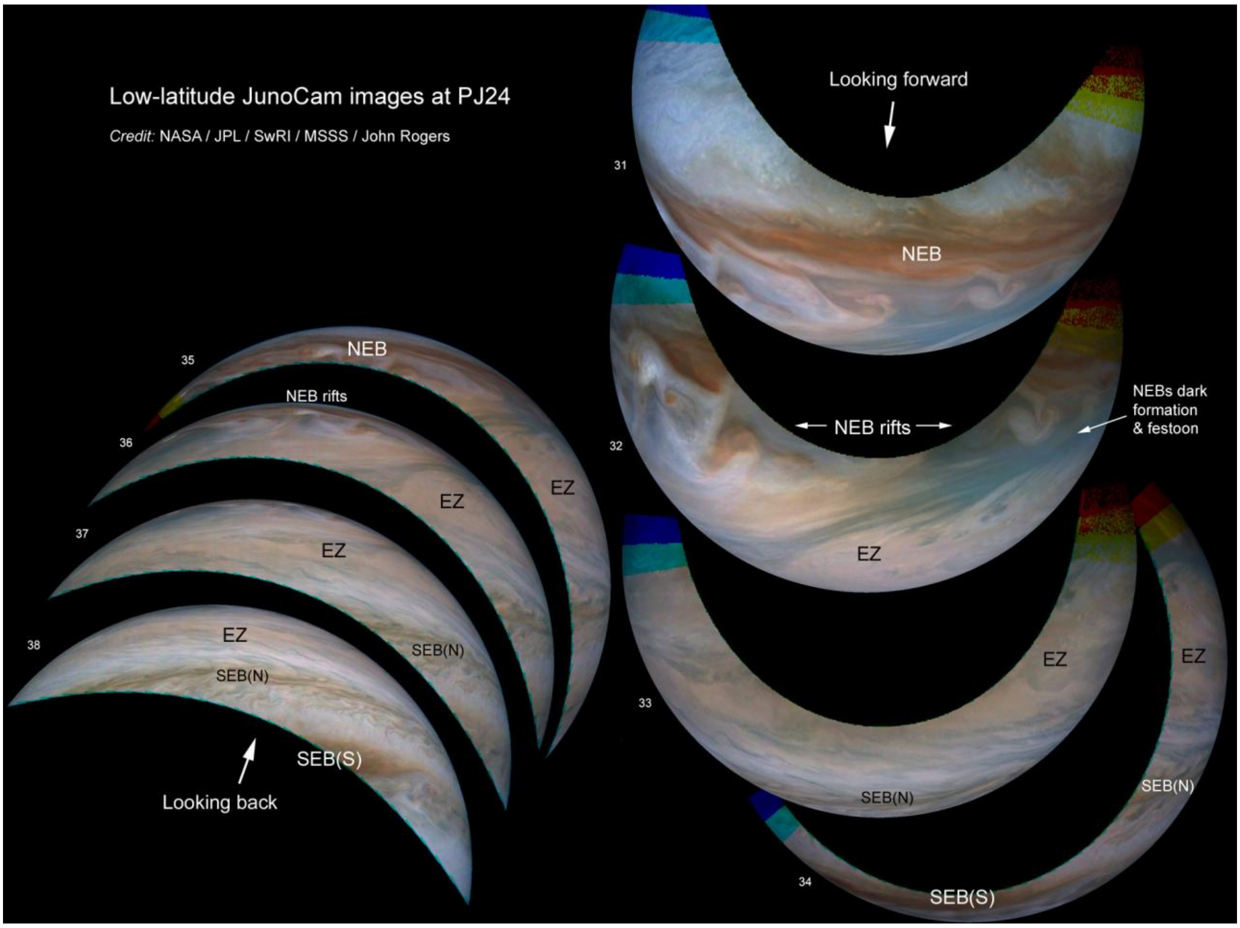

Figure 11. Images 31-38, showing the NEB, EZ, and SEB(N), adapted from the 'versions 01' posted by the JunoCam team.

Figure 12. Image 33, showing the EZ and SEB(N) along the horizon: approximately correct perspective projection by Gerald Eichstädt.

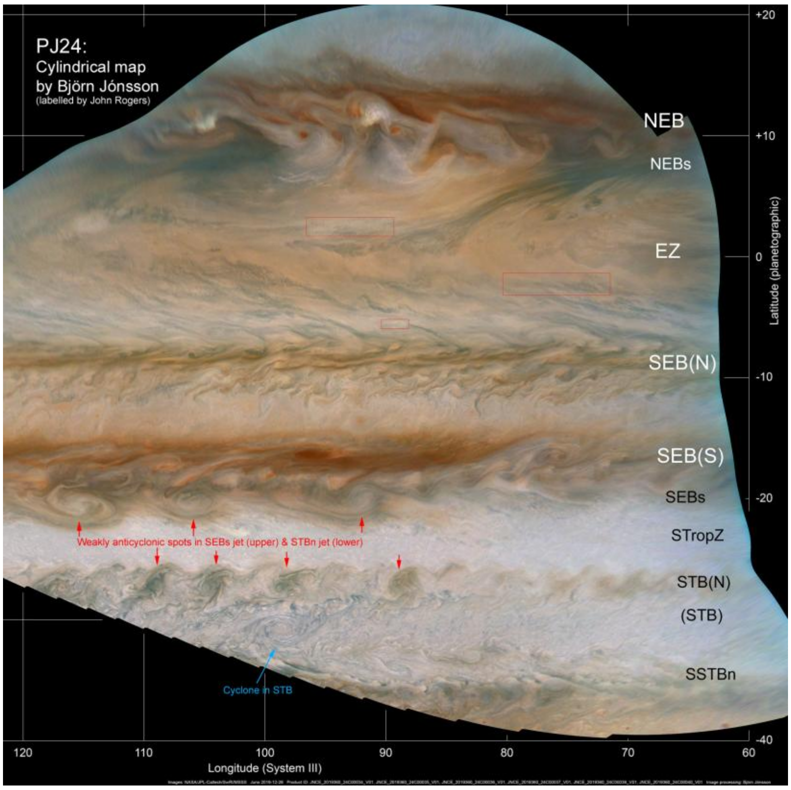

Figure 13. Cylindrical projection map from the NEB to the STB, by Björn Jónsson. This overlaps with Fig.14.

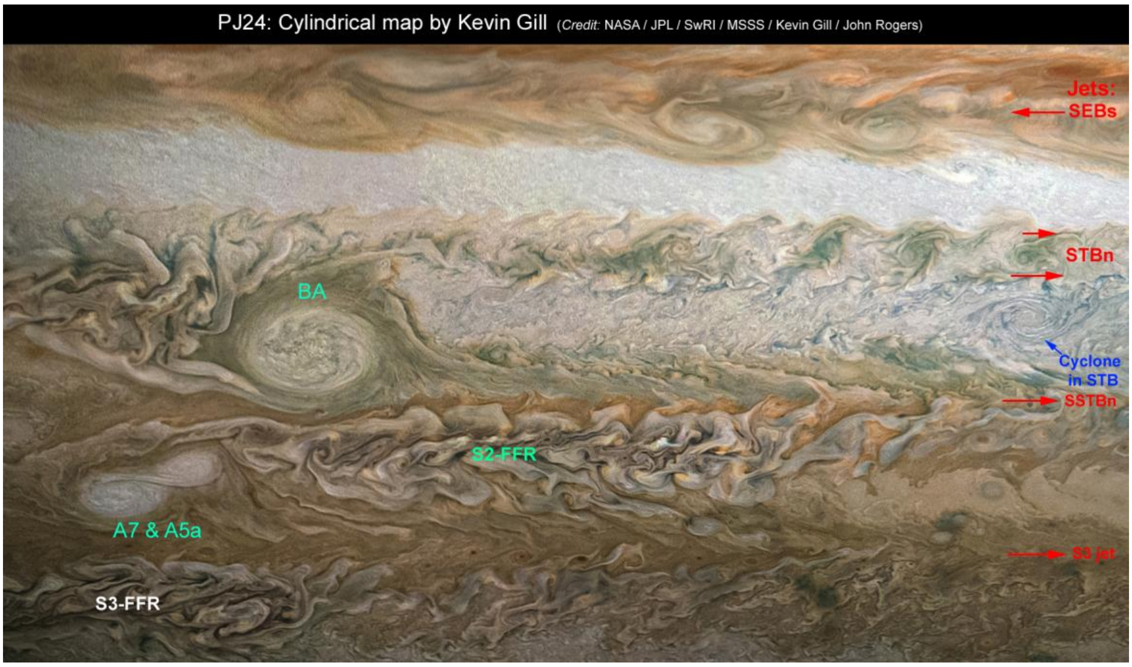

Figure 14. Cylindrical projection map from the STB to the S3 domain, by Kevin Gill. (He also produced a beautiful fish-eye globe view.)

Figure 15. Image 43, covering southern domains and including oval BA (upper left), merging ovals A7 & A5a, and S4-LRS-1 (lower right).

[**Figure 16:** *Next page*]

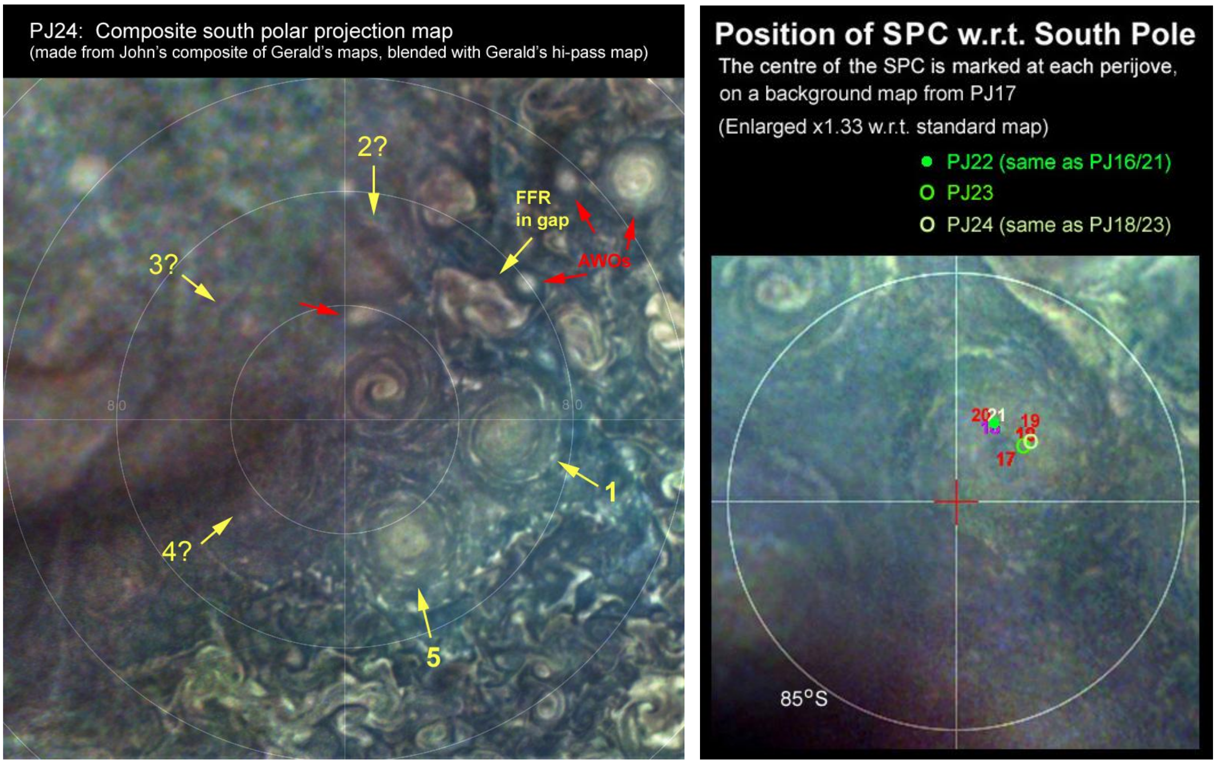

Figure 17. (A) South polar projection map, down to 75°S at the edges, with the CPCs and other features labelled. This is a blend of the RGB map (part of Fig.16A) with a high-pass-filtered version by Gerald. (B) Position of the centre of the SPC at perijoves 16–24.

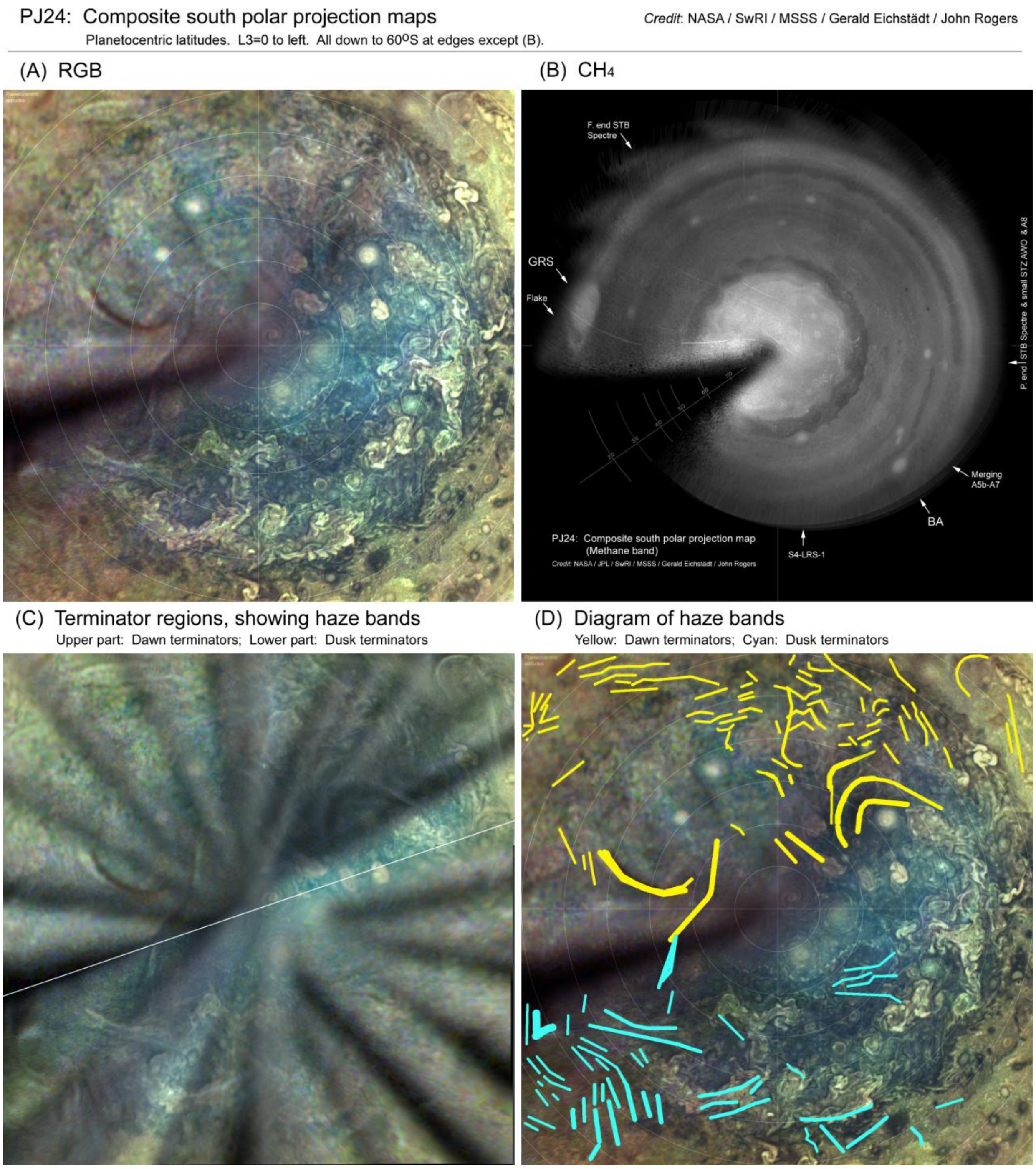

Figure 16. Composite south polar projection maps; all except (B) go down to 60°S at the edges.