JunoCam at PJ46: What the images show

John Rogers (BAA) (2022 Nov.23)

Juno's perijove-46 (PJ46) was on 2022 Nov.6. Perijove was at 38.3°N, over the NNTZ. Minimum altitude of about 3240 km was over the NNTB, slightly after perijove because of Jupiter's oblateness. Equator crossing came 15 mins after perijove, at L1=37, L2=60, L3=1. The highest latitude was 83.7°N. (As usual, all latitudes are planetocentric.)

Abbreviations and acknowledgements are as in our previous perijove reports (e.g. PJ43).

Imaging and processing

The inbound coverage is improving with each perijove, as the orbital orientation evolves; JunoCam can now view the planet for ~10h before north pole crossing. At PJ46 the inbound images started shortly before it crossed the equator heading north, and covered quite a lot of the southern hemisphere (including the GRS: Figure 12), and virtually the whole planet north of the equator. But they did not cover the highest northern latitudes until about an hour before north pole crossing, so coverage of the North Polar Region is still incomplete.

In the hi-res images at low latitudes, compression artefacts ('ponding') are becoming more problematic as the sub-spacecraft track nears the terminator. They are now evident in low-contrast areas from the N4 domain to the STropZ. On the other hand, for PJ46, the team were able to produce several images without lossy compression, and these are excellent, showing subtle cloud textures across the low latitudes. (Figures 9 and 10 show examples, with and without lossy compression.)

Gerald Eichstädt has succeeded in making high-quality automated composite maps from all the inbound and outbound images, both in RGB and in CH4 ('cleaned'). These are used here for the global cylindrical map and the south polar map. Checks using manual assembly of some maps as usual show that full detail is preserved, even in the southern CPCs at the polar terminator. The hi-res images, from the north pole to the mid-southern latitudes, are more resistant to automated assembly because of their complex brightness gradients and edges, so I have still used manual assembly for the north polar maps (Figures 1-4) and for the perijove swathe in the global cylindrical map.

As the inbound and outbound maps overlap, as at PJ45, they can be blinked over parts of the SEB and STB, clearly revealing the wind jets. To produce a blink suitable for measurement, I reproduced this with Gerald's single-image maps in Animation-1.

North Polar Region

Composite north polar projection maps are shown as follows (all manually assembled, with L3=0 to the right):
Figure 1: RGB map down to 75°N at edges, showing the circumpolar cyclones (CPCs).
Figure 2: RGB map down to 45°N at edges.
Figure 3: Ditto but favouring the terminator regions to show haze patterns.
Figure 4: CH4 maps down to 45°N at edges.

In Figure 1, six of the 8 long-lived CPCs are visible, as well as the central NPC, with their usual asymmetric arrangement. The pattern is very similar to the PJ43 map which covered

the same longitudes. There are also smaller cyclones at two corners of the octagon (unlabelled yellow arrows in Figure 1). Blinking of the original maps [not shown] clearly shows the rotation of the CPCs and NPC. It looks especially fast around the white-lobed perimeter of the filled part of CPC-5, whereas counter-rotation can be seen in the centre of that CPC. Both CPC-5 and CPC-7 show counter-spiral structure towards the centre, and elaborate structures including cyclonic eddies further out. Figure 5 shows full resolution on CPC-7 and curious circulations nearby that occupy a comparatively bland strip around the distorted octagon, which has the same texture as the Bland Zone further south (Figure 6).

Haze structures are shown in Figures 3 & 4. The edge of the main methane-bright North Polar Hood (NPH) is clearly visible in the CH4 map, at ~61-64°N. Near the morning and evening terminators (Figure 3) this edge lies along the dark linear bands in the Bland Zone, which are methane-dark (Figure 4). The bands on the dawn (right-hand) side – bright as well as dark -- have particularly high contrast, and are shown hi-res in Figure 6 (as at PJ45). Further south there are large arcs of haze, including a bright rainbow band (at left of Figure 3) that projects beyond the terminator.

Northern domains

Figure 7 is our global cylindrical map from PJ46. Figure 8 is a ground-based map for comparison, which provides a key to features.

Figure 9 shows an orange cyclonic oval in the N3 domain.
(Although it is not visible in Figure 8, it was tracked as a bright spot from ground-based images by the JUPOS team. So was another such oval ~20° following it, adjacent to NN-WS-6, shown in JunoCam's lo-res inbound images and the ground-based map (Figures 7 & 8). The latter oval was a dark spot up to mid-Oct., then turned bright, but still appears reddish in the JunoCam image – typical behaviour for cyclonic spots.)

NEB & EZ

The closeup images did not cover any large distinct features in the NEB or EZ, but the high-quality images (105-108) reveal a plethora of subtle cloud textures. In the almost-featureless NEB, they confirm our frequent impression from lower-quality images, that the clouds are genuinely rather diffuse. The NEBs is also diffuse, with white clouds, and long streaks constituting a festoon in the EZ(N). A small cluster of tiny white clouds in EZ(N) confirms that the images can record fine detail.

But south of the festoon, the EZ shows many streaks, many forms of whitish clouds, and some more-or-less periodic mesoscale waves (image 107: Figure 10). Most remarkably, there is a long wandering pair of parallel dark lines across the clouds, reminiscent of tyre-tracks! All these features are confirmed, at lower resolution, in images 106 and 108.

SEB

The PJ46 track crossed the very disturbed ('rifted') region of SEB following the GRS, so there were plenty of complex features. Some small-scale cloud patterns within them are shown in Figure 11. In the upper half (mid-SEB) there is a patch of white crisp-edged cloud rafts within an irregular swirl. In the lower half are the vigorous swirls on the SEBs jet (all confirmed to be retrograding in Animation-1); to left are dense streaky white cloud rafts, and to right is an extensive area of mesoscale waves. We have often seen mesoscale waves in

quieter sectors of the SEBs jet, but it is a surprise to see this much larger expanse of them overlying a much more turbulent sector. (No such waves were seen over this sector at PJ43.)

GRS: The GRS was usefully imaged in the approach phase (Figure 12), revealing two slender methane-bright flakes at the p. and f. sides. (One of these could also be seen on Nov.4 in images by Trevor Barry and Chris Go.)

S. & S.S. Temperate domains

STBn: This sector of the STBn has changed recently, so instead of a stream of distinct dark STBn jet spots, there appears to be a dusky, spotty STB(N) (Figure 8). This is confirmed in the JunoCam images (Figures 7 & 13); the STB(N) contains spots much like the previous jet spots, but now embedded in a more dusky, streaky band.

Cyclonic ovals: The best-known feature seen in closeup is STB Spot 8, now called Dark Spot 8 (DS8). Figure 13 shows its very distinct form, the brown oval being surrounded by a bluish collar of tightly wound cyclonic spiral streaks. It can be compared with the cyclonic white oblong (CWO) in the SSTB just south of it (Figure 13), which has a similarly amorphous interior but white, and similar cyclonic collar but less tightly wound, as well as a braided border typical of these whitened cyclonic circulations. It would not be surprising if DS8 were eventually to redden and then whiten, to form a structure similar to this CWO.

Cyclonic circulations are normally dark in methane images, and that as the case for both of these (Figure 12), as well as for a small white cyclone in the STB latitude that is just starting to pass the GRS.

South Polar Region

South Polar Hood and haze bands:
Now that the phase angle is higher for the images, the methane-bright South Polar Hood (SPH) is also visible as a whitish or bluish haze in the RGB images. Also, images 116-131 (Figure 14) show striking oblique haze bands, very bright near the morning terminator; some of them, esp. the brightest (no.1, described below), appear to cast shadows. Those in the S4/S5 domains are part of the systematic array of oblique bands that we have described in previous perijove reports. Others are south of the S6 jet, within the SPH, as described below. Some of these bands, esp. in the S4/S5 domains and band no.1, project beyond the terminator.

Composite south polar projection maps are shown as follows (all down to 45°S at edges except Figure 16):
Figure 15: RGB map down to 45°S.
Figure 16: RGB map down to 60°S (Gerald's auto-assembly from long-exposure images, to look for CPCs: 2 or 3 are visible).
Figure 17: RGB map favouring the terminator regions to show haze patterns.
Figure 18: CH4 map.

Three quite long bands are indicated by dark blue arrows on the maps. All are within the methane-bright SPH and visible as methane-brighter bands within it (Figure 18). They are:
(1) A very bright band, close to the CPCs, well positioned to catch the low sunlight, and seeming to cast a shadow; dark at dusk.
(2) An indistinct bundle of dark bands, tangential to a CPC, best seen under direct sunlight (Figure 16); not bright near the terminator. This seems to be a remnant of the long-lived Long Band, shorter and weaker than before, but its Nf. end (at L3 ~ 80) continues into a

typical ⊃–shaped arc that connects with band (3). A similar complex was present at PJ43 (which had a similar track).
(3) A long rainbow band at 65-->74°S, continuing into the ⊃–shaped arc; both are bright at the dusk terminator (Figure 17).

Circumpolar cyclones (CPCs):
As at PJ43, we see two CPCs on the left in the map (Figure 16); and possibly also a large one below; but with no detail visible.

Figures 1-4: Composite north polar projection maps. All have L3=0 to the right.

Figure 1: RGB map down to 75°N at edges. Yellow arrows mark cyclones including the CPCs (numbered); red arrows mark AWOs.

Figure 2: RGB map down to 45°N at edges.

Figure 3: RGB map down to 45°N at edges, favouring the terminator regions to show haze patterns. BZ = Bland Zone (approx. N6 domain).

Figure 4: CH4 maps down to 45°N at edges: Composite map from images 76-88, then the image 88 map singly, showing how the appearance of haze layers varies with viewing angle. In image 88, the NPH directly below the spacecraft is less methane-bright, whereas bright hazes show up near the limb to the left.

Figure 5: Full-resolution close-up of CPC-7 (bottom centre), and smaller features in a broad bland strip around the CPCs. This is a composite of images 89 (left) and 90 (right) (processed by Gerald). South is up, for consistency with Figure 1. At left, note a small AWO paired with a compact dark cyclone. Above right centre, there is a distorted pair of ovals topped with white pop-up clouds; these may be two small AWOs merging. Just right of centre, a small white band runs over a grey vortex. Between all these features, the bland strip has the same texture as the Bland Zone further south (Figure 6), marked by swirling textures and white cloud flecks. The latter resemble pop-up clouds but cast little or no shadow; possibly this is because sunlight is diffused by the NPH that overlies this region.

Figure 6: Full-resolution close-up of the Bland Zone, which is overlaid by a dark brownish linear band flanked by bright bluish bands. From image 92 (Gerald's processed version, with approximate correction of artefactual colour bands parallel to the terminator).

Figure 7: Global composite cylindrical map from PJ46. This is compiled from Gerald's automated inbound and outbound maps (divided along the STropZ, or along the STZ near the GRS), plus a manually assembled strip of perijove maps. North is up in this and subsequent figures. Figure 8 provides a key to features.

Figure 8: Ground-based map on Nov.5-7, spanning PJ46.

Figure 9: An orange cyclonic oval in the N3 domain, and a dull anticyclonic oval ("ADS") in the NNTZ. The latter has very low contrast and so is marred by compression artefacts. Also note a cluster of white crisp-edged cloud rafts ("CR"); these are increasingly seen in JunoCam images as perijove moves northward. This is image 99, taken close to perijove, from an altitude of only 3503 km. It was processed by Gerald then contrast-adjusted.

Figure 10: Details in the EZ, spanning 3.5°N to 1°S (a distance of ~3100 km), with north up. Part of Huffman-encoded image 107; Gerald's version, contrast-enhanced. Various forms of clouds are visible, especially overlying the darker bluish regions where the main cloud layer is presumably incomplete. The black "comb" indicates an array of mesoscale waves. White arrows indicate the "tyre-tracks". All these features are confirmed, at lower resolution, in images 106 and 108.

Figure 11: Details in the SEB. Part of Huffman-encoded image 110; Gerald's version, contrast-enhanced. Insets show more details of cloud rafts from images 109 and 111 (enlarged x1.6). North is up. An array of mesoscale waves is boxed.

Figure 12: Inbound images and maps showing the GRS, in RGB and CH4, taken on Nov.6 around ~15:00 SCET. Methane-bright flakes can be seen extending from the p. and f. sides of the GRS. Also note that cyclonic features are methane-dark: a faded barge in the NEB, DS8 and a small white cyclone in the STB, and a cyclonic white oblong (CWO) in the SSTB.

Figure 13: Close-up of the STB and SSTB, with DS8 and a cyclonic white oblong (CWO), and two of the S2 AWOs (A5 & A4). Image 114, Gerald's processing.

Figure 14: Images 116-131, showing southerly haze bands bright near the morning terminator and into daylight. They are labelled according to the domain in which they lie: S+ denotes the southernmost belt south of the S6 jet; no.1, in the SPH, is described in the text. Some of them, esp. no.1, appear to cast shadows, though there are also brown bands independent of bright bands. South is up.

Figures 15-18: Composite south polar projection maps. All have L3=0 to the left.

Figure 15: South polar RGB map down to 45°S at edges (Gerald's auto-assembly from short-exposure images).

Figure 16: South polar RGB map down to 60°S at edges, with grid (Gerald's auto-assembly from long-exposure images, to look for CPCs: 2 or 3 are visible). Dark blue arrows indicate the main bright haze bands.

Figure 17: South polar RGB map down to 45°S at edges, favouring the terminator regions to show haze patterns: (L) dusk, (R) dawn. (Manual assembly from small copies of maps.)

Figure 18: South polar CH4 map down to 45°S at edges (Gerald's auto-assembly). (A manual assembly was also done for higher-resolution maps of some longitudes: not shown here.) Dark blue arrows indicate the main bright haze bands.

Animation-1. Blink of inbound and outbound maps covering parts of the SEB and STB, revealing the wind jets. This used Gerald Eichstädt's maps of images 37 & 123 (at right: 16:00 & 22:52 SCET: 6h 52m apart) and 43 & 129 (at left: 16:45 & approx. 23:23 SCET: 6h 38m apart).
