JunoCam at Perijove-31: What the pictures show

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Juno's Perijove-31 (PJ31) was on Weds. Dec.30, with equator crossing at L1=231, L2=9, L3=131 (a little way following the GRS). The imaging perspectives were similar to PJ30.

Acknowledgements, abbreviations and conventions are as in our previous perijove reports.

North Polar Region

Lightning flash:

As Juno reached its highest latitude near the north pole, JunoCam apparently recorded a bright flash of lightning in one of the circumpolar cyclones.

This was in image 10, as discovered by Gerald Eichstädt (Figure 1, inset; also see blink animation). The bright spot is believed to be lightning, as it is green and extended, unlike points due to radiation hits and hot pixels. Moreover, it is in the brightest patch of cloud on the rim of the central cloud deck of this CPC, which is dimly lit near the terminator.

Lightning is known to be frequent in other cyclonic storms in mid-to-high northern latitudes, particularly FFRs. Images from Voyager and Galileo showed several flashes per minute in the most active thunderstorms in FFRs [Little et al., 1999: Icarus 142, 306], and a recent paper from Juno's Stellar Reference Unit (a little-publicised high-sensitivity camera on Juno) reported several smaller flashes per second in one storm [Becker et al., 2020: Nature 584, 55]. Juno's Microwave Radiometer also detects lightning, including ~6 bursts/minute within its field of view between ~73-86°N [Brown et al., 2018: Nature 558, 87]; many of these are probably in the CPCs, which span ~80-85°N. So the appearance of a flash in JunoCam's image is not unlikely. There could be more such detections in future as JunoCam gets longer views of the terminator and the dark side during the extended mission.

Circumpolar cyclones (CPCs) (Figures 1 & 2):

PJ31 provided our best view yet of the central North Polar Cyclone (NPC). This was partly because of the gradually rising sun, but mostly because the NPC was displaced from the pole by ~1.2° latitude at this flyby, even greater than the ~0.8° displacement at PJ30.

The 'filled' CPC-3 shows counter-spiral structure near its centre, with a hint of counter-rotation in an animation by Gerald, suggesting that CPC-5 is not the only one to show this.

The Bland Zone and haze bands:

The north polar images (Fig.1) and projection map (Fig.3A) show the usual pattern of the Bland Zone roughly coinciding with the N6 domain, and large FFRs to north and south of it. As usual, long linear haze bands lie obliquely across the Bland Zone and its south edge; some are bright and some dark. Other haze structures, in the N5 domain, include a bright patch near the terminator and limb which is also very bright in the methane band (Fig.3B). Fig.4 shows a closeup of this region, including a medium-sized AWO and many small cyclonic vortices in the N5 domain. Fig.5 is a closeup view of the N4 domain including a large FFR on the left-hand side, which shows intricate turbulence with overlapping cloud structures at different altitudes.

Global maps

Figure 6 presents ground-based maps around the date of PJ31 including Clyde Foster's best image of the track three days before. Figure 7 is our JunoCam global map.

Images 21 & 22 (not reproduced here) show part of a NNTB dark segment, which contains nice examples of diffusely orange-capped vortices. In two or more places, white streaks of haze appear to cross over the orange patches.

North Temperate & Tropical domains

The NTB and NEB are both now quiescent after their great upheavals in 2020. In ground-based images the NTB is generally dark with a pale reddish southern fringe, while the NEB is broad and moderately dark brown. Ground-based observations suggest that turbulence in such upheavals evolves from large to small scale, and the JunoCam images over the last four years – which have provided snapshots of both the NTB and NEB during two cycles of upheaval in each – could be a resource for testing this principle. The PJ31 images show intricate but smallscale turbulence in both belts, nothing spectacular.

Although there is some pale reddish colour along the NTBs edge, in ground-based images it is much less conspicuous than it was after most previous NTBs jet outbreaks. Also the 2020 outbreak did not suppress the NNTBs jet spot activity as previous outbreaks did. Both of these phenomena have occurred after all super-fast NTBs outbreaks since 1970, except that of 1990 – which was the final one in a quinquennial series [Rogers & Adamoli, 2019, JBAA 129, 158]. This raises the possibility that 2020 will be the last in the present series. We should get a firmer expectation in the next two years or so. If the jet speed recovers to an intermediate level, another super-fast outbreak will be expected; but if a set of anticyclonic vortices develops with lesser speed, as in 1991, we could expect that state to be stable for some years.

Figure 8 is a hi-res cylindrical map of the NEB & EZ by Björn Jónsson, shown here at half scale. The broadened, reddish NEB is filled with small-scale turbulence, but no convective white plumes. Along the NEBs edge there is a bluish-grey strip but it is much paler than the usual NEBs dark formations ('hot spots').

Equatorial Zone (Figure 8)

The EZ again shows a spectacular and intricate multicoloured cloudscape, this time with extensive areas of subtle mesoscale waves from ~1°N to 4°S, mainly over the ochre Eq. Band (see inset in Figure 8), as well as the more obvious semi-periodic patterns of white cloud patterns that have been evident at recent perijoves.

South Tropical domain

Figure 9 is a hi-res cylindrical map of the SEB and surroundings by Björn Jónsson, shown here at half scale. Figure 10 is one of several images used to make it. The GRS was repeatedly imaged but was close to the limb; nevertheless its internal structure can be seen in Figure 9 and it seems to be undisturbed. There was excellent coverage of the 'rifted region' of SEB following the GRS; it is a giant version of a FFR, and showed the usual intense activity including two very bright convective plumes. At this resolution they appear quite extended and complex. The following one (top left in Fig.9) has long lines of white cloud which may be popup clouds extending from its very dense plume head. The rest of the rifted region is largely overlaid with faint swirls and bands of translucent white hazes (Fig.10), as also seen at PJ4. These haze streaks can be seen crossing other cloud features (yellow asterisks in Fig.10) and crossing a long reddish band in the northern SEB (which resembles bands that we have seen in the southern SEB at recent perijoves).

South Temperate domain (Fig.7)

In the best-imaged sector, the STB is entirely white and featureless, but the STZ is filled with a very dark belt called the STZB, which expanded westwards during 2020. The outbound images gave lo-res coverage of other longitudes but only the last two, images 78 & 80, showed features: the final sliver of planet visible in image 80 (and methane image 81) happened to contain oval BA, as well as S2-AWO A1 on its south edge, and S4-LRS-1 further south. Image 78 showed the dark spot DS6, but DS7 (Clyde's spot) was not detected. Whether this was due to an unusual change in visibility near the limb, or due to rapid variab-ility, is unclear; DS7 was still prominent three days earlier in Clyde's own image (Fig.6).

South Polar region

Figure 11 presents our usual composite south polar projection maps, showing the familiar features of the SPR in RGB and in low-sun RGB and in the methane band.

Haze bands:
Figure 11C is a pair of maps, one showing the terminator regions at dawn and the other at dusk. These show the high-altitude haze bands, both bright and dark. There is some overlap at lower left, thanks again to the high-quality final image 80. Here, over the S5 domain, is a conspicuous ⊃-shaped dark band at dawn but a bright one at dusk.

Circumpolar cyclones (CPCs) (Figures 11B & 12):

The pentagon of CPCs is shown in Fig.11B. All five CPCs are visible, although CPC-4 only partially. (As CPC-4 is always large and oval, I believe the cloud arcs seen dimly in the first and last images represent its two ends.) Two features of the pentagon are notable:

i) The central South Polar Cyclone (SPC) has returned to where it was at PJ25, completing a large loop (Fig.12), and confirming the long-term pattern that was postulated in our report on PJ28.

ii) The gap in the pentagon is once again between CPCs 1 & 2, and is particularly wide. From PJ28 to PJ30, when the SPC was at unusually high longitude, the gap was between CPCs 2 & 3 instead, but now both the gap position and the longitude have reverted towards the earlier state. This supports our view [T-V et al., 2020, Icarus] that the gap is on the side displaced furthest from the pole.

Figures:

Animation: Lightning flash in northern CPC-1: Blink of two maps (images 9 & 10), made by Gerald.

Figure 1. Image 10 [Gerald's version, with the lightning restored from his draft; enlarged in inset].

Figure 2. North polar projection map, down to 75°N, showing CPCs (see title on figure).

Figure 3. North polar projection maps, down to low latitudes: (A) RGB, (B) CH4.

Figure 4. Image 15; north up. (a) Most of the image (Gerald's version, reduced), showing the Bland Zone with a brown haze band within it, a very bright FFR north of it, and a N5-AWO south of it. (b) Excerpt, enhanced, showing a cluster of small cyclonic vortices. (c) The same region in an artistic 3D representation by Ryan Cornell (from the JunoCam web site).

Figure 5. Image 19. The left half includes a large FFR, with beautiful multi-level cloud features among its writhing filaments. (A beautiful rendition of the same image was also posted by Kevin Gill.)

Figure 6 presents ground-based maps around the date of PJ31 including Clyde Foster's best image of the track three days before.

Figure 7 is our JunoCam global cylindrical map.

Figure 8 is a hi-res cylindrical map of the NEB & EZ by Björn Jónsson, shown here at half scale. The inset shows part of the field of subtle mesoscale waves, at full scale.

Figure 9 is a hi-res cylindrical map of the SEB and surroundings by Björn Jónsson, shown here at half scale. The panels at top are full-scale excerpts showing the two bright plumes in the SEB.

Figure 10 is one of several images used to make it.

Figure 11 presents our usual composite south polar projection maps covering the SPR; see titles on the figure.

Figure 12. Motion of the SPC throughout the Juno mission.