JunoCam at Perijove-40: What the pictures show

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PJ40, on 2022 Feb.25, came just 8 days before geocentric solar conjunction, so these pictures provided the only view of the planet over this period. The detailed views of the polar regions generally confirmed what was found at other recent perijoves, and the views of lower latitudes showed quiescent sectors without major features. On the inbound leg, distant views of Europa's north pole were obtained (Fig.1). Later, a visual highlight was the enormous elongated shadow of Ganymede coming onto the disk on the S. Tropical Zone (Fig.9).

Perijove was at latitude 33.1°N, and Juno crossed the equator at L1=256, L2=60, L3=294. This was on the opposite side of the planet to the longitudes scanned on the last four orbits, but the same side (in L3) as at PJ33-PJ35.

Conventions and acknowledgements in our previous reports apply also in this one.

North Polar Region

Circumpolar cyclones (CPCs):
The PJ40 map of the NPR is shown in Fig.2 (paired with the PJ39 map to show the whole polygon of cyclones) and Fig.3 (compared with maps of the same sector from PJ33-PJ35) and. The polygon is now supplemented by smaller 'filled-type' cyclones that have joined the vortex crystal in the past year, labelled 'IX' and 'X', and we can assess the stability of this arrangement. This assessment for half the polygon was given in our PJ39 report; now we can see the other half at PJ40 (Fig.2). CPC-7 is still displaced away from the pole. Of the extra cyclones, 'cyclone X' has been present since PJ30, and not earlier. 'Cyclone IX' gradually drifted away after PJ36 (see our PJ39 report). A smaller one south of CPC-6, unnumbered, was first seen at PJ39 so may not be stable. Inside the polygon, the AWO north of CPC-3 is prominent, and a small anticyclonic vortex has reappeared north of CPC-7; there is also one north of CPC-1 (see PJ39), but none north of CPC-5.
By blinking maps of images 11 & 14 (not shown here), the large filled CPCs-4 & 5 show clear rotation, except for the centre of each which appears stationary; it has well-resolved counter-spiral structure near the centre. The adjacent AWO and 'cyclone X' also show clear rotation.

Bland Zone & Haze bands:
Fig.4 shows broader north polar projection maps, from RGB and CH4 images.
In the lower part of the Bland Zone there is a disturbed sector near the evening terminator. In the upper (morning) part of the Bland Zone, there are some typical prominent linear bands, bright with a dark band on the S side that is methane-dark. Later images showed one of these bright bands in unprecedented closeup (Fig.5 image 18): it is fully transparent, and under high sun the adjacent dark band is not visible.

Northern domains

Fig.5 shows some hi-res details in the N4 and N2 domains. Image 20 shows multi-layered extensions of a FFR in northern N4 domain (~42-50°N), possibly pushing south to the N4 jet. Image 22 shows a small cyclone within a pale orange segment of the NNTB. Fig.6 is our global cylindrical map.

No large features are covered in the hi-res images of the N. Temperate or Tropical domains, but subtle cloud textures are again seen in great detail.

Equatorial Region

PJ40 gave us an opportunity to look for any sign of the recent NEB(S) outbreaks. The perijove sector was outside the region where outbreaks had occurred before solar conjunction, but it does show some disturbance; this could be merely continuing spread of the pre-existing disturbance to lower longitudes. Part of the previously disturbed sector was imaged very obliquely on the inbound leg, and is aligned with the previous maps in Fig.7; it does not show obvious disturbance. (A previously tracked AWO is dimly visible in the NEBn edge.) So the PJ40 images show no evidence for any more extensive revival of the belt, but they do not preclude outbreaks occurring at other longitudes.

The Equatorial Zone shows only a few faint mesoscale waves, as at PJ39, even though the broad orange Equatorial Band is still present.

Southern domains

The SEB is notably turbulent in its southern half (Fig.8), because this is the sector just downstream of the perennial rifted sector following the GRS (Fig.6).

The STB is also notably turbulent,, because this is STB segment A following oval BA (Figs. 6, 9, 10). It has now grown considerably to a length of to 72°.

I have sometimes commented on chains of vortices, often dark rings, following (west, i.e. to the left of) FFRs in the southern domains, probably emitted from them. There is a nice example in the S3 domain between a FFR and an AWO (Fig.10), as well as scattered rings in the S2 and S4 domains that could have similar origins.

South Polar Region

Fig.11 presents our composite map of the SPR, with parts of the PJ39 and PJ38 maps for comparison.
For this map, individual maps (images 41-69) were shifted by small amounts in order to optimise registration of features surrounding the CPCs. To assess the confidence limits of the south pole position, I plotted the nominal pole positions of all of these maps. All fitted within a circle of radius 0.20°, and almost all were within this distance of the pole on the MEA map, except for a few of the later ones which were up to 0.33° away from it.

At PJ39, we could identify a chain of AWOs and cyclones at ~70°S (red & cyan arrows in Fig.11) which had probably persisted since PJ38, with a common retrograding drift of ~+34° in L3. From west to east, it consists of a small AWO, a large AWO, three cyclones (more circular and brownish than typical FFRs), and one more small AWO. At PJ40, the same chain can be identified again, with similar drift: +31° for the large AWO and ~+35° for the cyclones. So this seems very likely to be a persistent set of features, all sharing the common retrograding drift of this latitude [Rogers et al., 2021/22, Icarus]. However, the larger FFRs in a belt slightly further north are still not recognisable from one perijove to the next.
By blinking pairs of individual maps of the SPR, the motions of the jets and currents can be clearly seen, including the shearing of the FFRs.

The PJ39 and PJ40 maps can be combined to show the SPR with the best available resolution (Fig.12) – which is quite poor now due to the increasing altitude of the spacecraft and decreasing elevation of the sun, but enables us to identify the five CPCs.

Circumpolar cyclones (CPCs):
At PJ40 alone (Fig.11A), only CPCs-2 & 3 are clearly seen, and CPCs-1 & 5 probably seen; CPC-4 is obscured by the Long Band and the terminator. However, the central South Polar Cyclone can be partly made out, as it is ~1.2° from the pole, displaced towards the longitudes of the closest PJ40 images.
The most interesting finding is that the whole pentagon has rotated by ~+10° (±2°) since PJ39, and by ~+16° (±3°) since PJ38 (Fig.11), amounting to ~66°/year. This is far greater than the mean rate of +8.3 (±0.5)°/year from 2016 to 2021 (PJ1 to PJ33) [Tabataba-Vakili et al., 2019/20, Icarus; Rogers et al., 2021, EPSC].

The Long Band:
This long dark band, partially overlapping CPCs-3 & 4, has been notable from PJ33 onwards, and likewise at PJ40 (Fig.11). It is a conspicuous dark band under full sunlight (although at its highest latitude, 84°S, the sun only rises 5°). It is also dark at dawn and dusk (see below). Its exact position varies somewhat, especially at its f. end which may be waving to and fro.

Haze bands and the South Polar Hood:
The general comments in our PJ38 and PJ39 reports apply also to PJ40. Fig.13(A&B) presents south polar maps of the near-terminator regions, at dawn and dusk. Even though the sub-spacecraft track was on the opposite side from PJ38 and PJ39, the haze patterns are very similar, confirming that the longitudinal asymmetries are real. The main systems of haze bands are as follows (from north to south):
(i) S4 & S5 domains, ~50-62°S: The same pattern is seen as at other perijoves, esp. oblique bands at 54-60°S seen mainly at dawn.
(ii) A long band at ~63-73°S (lower left quadrant of the dusk map only): Also seen at PJ38 & PJ39: it measures >110° longitude and is very broad, with signs of 'rainbow band' colours. It lies largely over an oblique band of FFRs.
(iii) Two conspicuous straight bright bands on the left side of the full-sun map (Figs.11A & 15), one running up to 73°S, the other to 80°S, both at an angle to other bands. Both are partially visible in the dusk and dawn maps, but do not project over the terminator. The higher-latitude one is methane-bright (Fig.14).
(iv) The long-lived Long Band. At dawn, and under high sun (see above), it is only a dark band. At dusk there is a bright band on the north side of the dark band, and multiple bright following ends curving north as usual, very bright on the terminator despite low resolution; they connect with one or more extensions of band (ii) above.

Figures

Figure 1: Europa: images processed by Andrea Luck and Björn Jónsson, from the JunoCam web site.

Figure 2: North polar projection map (down to 70°N at edges) from our PJ39 & PJ40 maps.

Figure 3: North polar projection maps (down to 75°N at edges) from PJ33-PJ35 and PJ40, showing the stability of the 'vortex crystal' of CPCs, including extra cyclones 'IX' and 'X'.

Figure 4: PJ40 north polar projection maps (down to ~45°N at edges): (A) RGB; (B) CH4.

Figure 5: Hi-res details in northern domains, processed by Gerald Eichstädt.
Image 18: A bright linear band crossing the Bland Zone (~60-65°N). Image 20: Multi-layered extensions of a FFR in northern N4 domain (~42-50°N), possibly pushing south to the N4 jet.
Image 22: Small cyclone within a pale orange segment of the NNTB.

Figure 6: Global cylindrical map.

Figure 7: Maps of the NEB from PJ39 and PJ40 aligned with ground-based maps of the disturbed sector of NEB(S) before solar conjunction [copied from our 2021-22 Report no.7 Part II].

Figure 8. Image of the SEB, processed by Gerald Eichstädt.

Figure 9. Two images showing the shadow of Ganymede coming onto the disk. The first has been contrast-enhanced, the second just brightened in order to preserve the shadow's wide penumbra. The images show the southern domains well.

Figure 10. Cylindrical map from two hi-res images covering the STB and southwards. (This shows the patterns of features better than the composite in Fig.6.)

Figure 11. Composite map of the SPR, down to 60°S at edges, with key features labelled, and with parts of the PJ39 and PJ38 maps for comparison. Yellow circles indicate estimated positions of CPCs. Red and cyan arrows indicate the chain of AWOs and FFRs that has probably persisted throughout. [As always, unlabelled copies of maps are available if required.]

Figure 12. Composite map of the SPR, down to 60°S at edges, combining our PJ39 & PJ40 maps to show the whole region at best resolution.

Figure 13. Composite south polar maps of the near-terminator regions, down to 45°S at edges, at dawn (A) & dusk (B).

Figure 14. Composite map in methane band, down to 30°S at edges. Just three of the higher-resolution maps were used, omitting all the later maps.

Figure 15. *Top:* Image 50 (MEA), showing the straight bright bands at discordant angles. *Middle & bottom:* Maps of images 48 & 89, one rotation apart. The maps go down to 45°S at edges, and have been rotated 40° here. These images were taken ~10 hours apart and show essentially the same haze patterns at the terminator. They can also be blinked to show the shearing of the FFRs. All processed by Gerald Eichstädt & JHR.