Juno at Perijove-16 (2018 Oct.29): What the images show

--John Rogers

This report is in the same style as our previous ones, which contain explanations of the image sources and the abbreviations.

At PJ16, the spacecraft was tilted so the scanning instruments got hi-res views of the underlying clouds rather than the horizon. However, as the data had to be recorded and the data volume was limited by the approaching solar conjunction, it was not possible to take inbound and outbound images on this orbit, apart from one image after south pole crossing.

With the planet disappearing into evening twilight, ground-based observers were only able to obtain comparatively lo-res images of Juno's track. The best one, by Clyde Foster, is posted with a set of images covering the planet during October in our 2018 Report no. 9 [https://britastro.org/node/16417].

Occultation of Io

Io was captured in image 1, and then fortuitously in three of the closeup images, just before it was occulted by Jupiter (images 10 & 11) and after reappearance (image 23). These views were spotted by Gerald Eichstädt and Justin Cowart. Image 11 actually captured Io as it was being occulted, and its lower part can be seen dimmed and reddened by Jupiter's high-level haze (Figure 1).

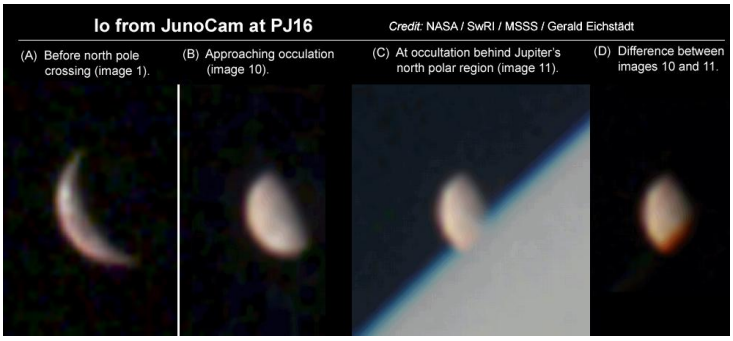

Figure 1

North polar region

Now Juno comes in over the night side before passing quite low over the north pole. With this geometry, and the tilt of the north pole away from the sun, there is little opportunity for extended longitude coverage of the northern hemisphere.

Circumpolar cyclones (CPCs):
Juno now sees less than half of the north polar octagon of cyclones at each perijove, but this is enough to see that the 8 cyclones have not been moving much, with one exception. At PJ15 [unpublished results], we found that one of the prominent filled cyclones, CPC-7*, had drifted from the typical latitude of 82.7ºN down to 81.0ºN, so it was no longer in the neat symmetrical arrangement. At PJ16, fortunately, CPC-7 was well presented and the JunoCam team took several long-exposure images to see as much as possible at the terminator. The new images (Figure 2) show that CPC-7 has moved significantly back towards the pole (to 81.6ºN now), but

is still south of the expected latitude, and they give a satisfyingly simple explanation. The images show an anticyclonic oval north of it: CPCs 6,7,8 & the NPC [the central north polar cyclone, unseen in winter darkness but imaged earlier by JIRAM, presumed to be permanent] form a nearly-square rhomboid of cyclones surrounding this anticyclonic oval. So I suspect that the octagon is still intact, but with one corner distorted as this growing oval has pushed CPC-7 outwards. The oval could be the same one that JIRAM identified at PJ4 and PJ5 [Aguayo et al., 2018, *Nature*], which has remained in this corner and grown larger. JunoCam did see it at PJ5 and PJ9, dimly on the terminator. Figure 2C shows the proposed arrangement.
*(Here I still use our in our provisional numbering, which differs from that in Aguayo et al., 2018.)

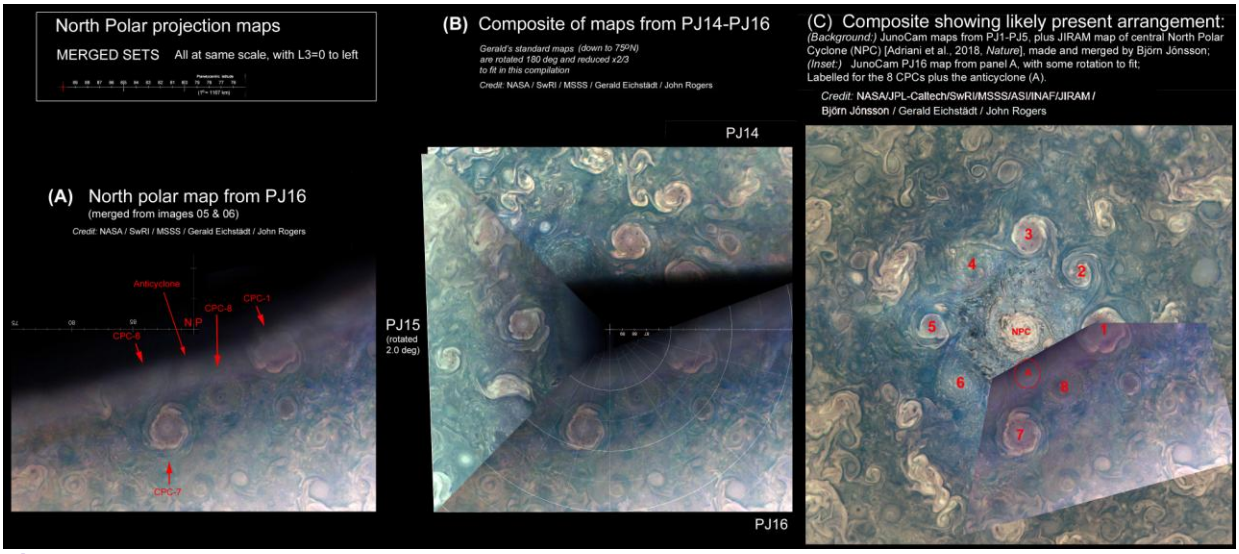

Figure 2

Haze bands:
Despite the limited coverage, a north polar map (Figure 3) shows extensive haze bands near the terminator. There is even a series of oblique bright haze bands at ~67-77ºN, rarely seen before, which presumably represent structure within the North Polar Hood, more evident now that it is being seen at a higher phase angle.

The usual long linear bands are seen in the Bland Zone (~60-65ºN). South of it, there are striking haze patterns. Near the dawn terminator, a bright 'rainbow band' is continuous with a typical linear band in the Bland Zone. Near the dusk terminator, there is an array of ⊃–shaped bands; one of them is a pair of strikingly bright (rainbow) and dark bands, and encloses a large brown 'shadow'. The methane-band map (Figure 3, top) complements the colour map by showing widepsread complex haze structures on the sunlit face, including FFRs and broader haze bands.

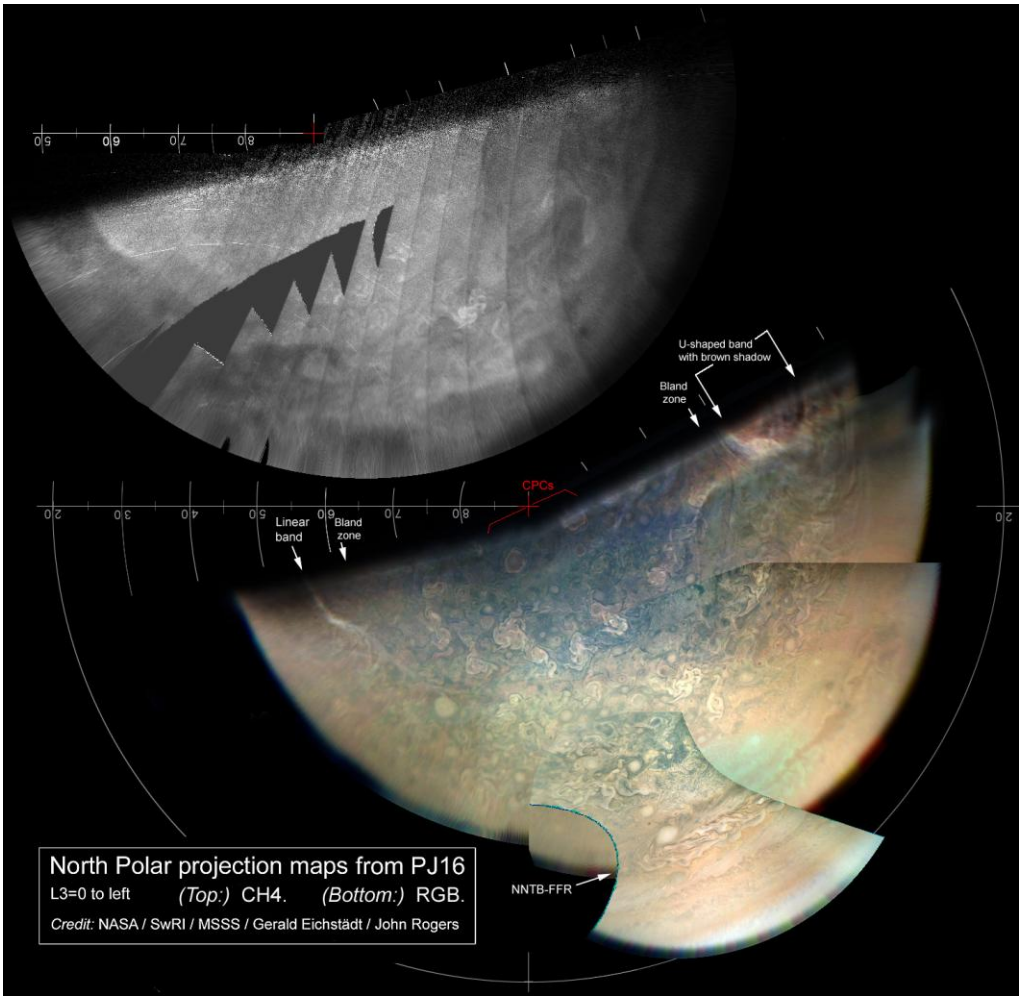

Figure 3

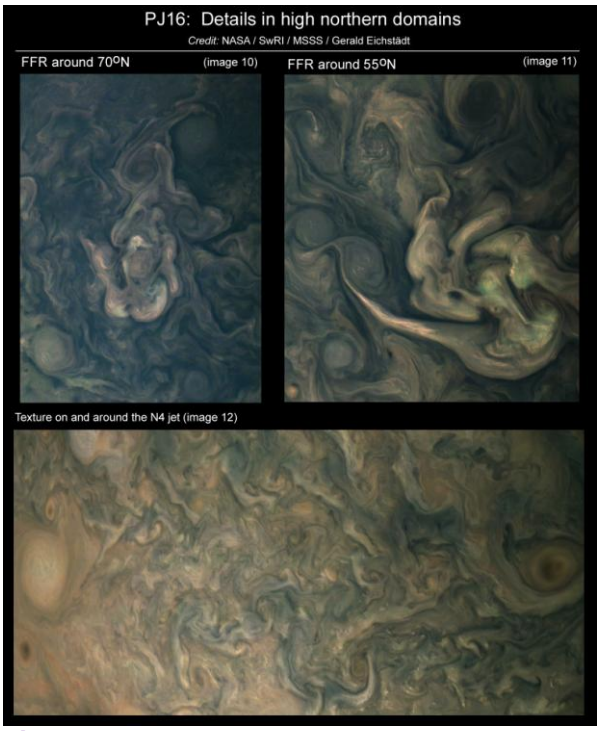

Figure 4

Figure 5

Northern domains

A sample of eye-catching views is presented in Figures 4 & 5.

The view of the N2 domain (image 13; Figure 5) is especially striking, showing a NNTZ-AWO (A), NNTB-FFR (C), and NNTBs jet spot (D). They show several interesting features that we have seen in such views before:
i) Plenty of popup clouds, in the AWO and the FFR. (I have largely retained Gerald's dark tone for these images so as best to show the lines of popup clouds on the bright strips in FFRs.)
ii) In places, the FFR appears to project over underlying cloud patterns. (However, the very dark borders around the FFR are not shadows – they are too broad and the sun is too high. They must be either deep cloud-free strips, or dark grey haze. These dark borders often give a 3D illusion.)
iii) There is evidence for a diffuse patch of *dark* haze, which spreads around a very dark 'channel' (B) between oppositely-directed eddies with diffuse red clouds and popup white clouds respectively.
Moreover, the features p. and f. it are blurred* [region in brackets] as though seen through a translucent but light-scattering haze. Gerald suggests that this may be a layer of thin cirrus streaming across the FFR in a local jet, similar to this striking video of storms over North Dakota: https://climate.nasa.gov/news/2782/severe-storms-show-off-their-plume-age/
*(This is not due to the image processing as it is seen in independently processed versions by Gerald Eichstädt (here) and Björn Jónsson, and is partially visible in more distant oblique views in images 12 & 14.)

Gerald also points out that some images show a detached haze layer on the northern horizon, and provides the following info. In image 14 it is at ~49ºN. In image 16 it is at ~34-36ºN, i.e. over the NNTB – confirming the detached haze layer seen over the NNTB at PJ14.
Less distinct horizon haze may reach down to about 20ºN in image 18.

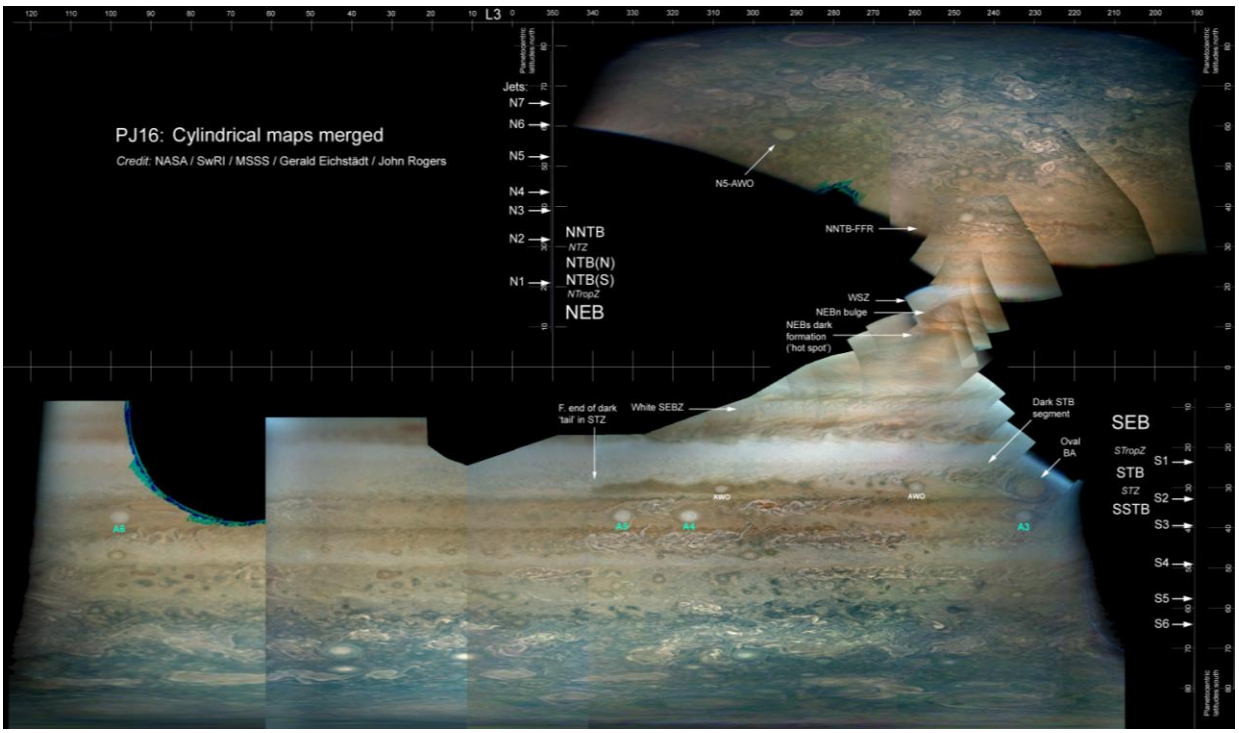

Figure 6

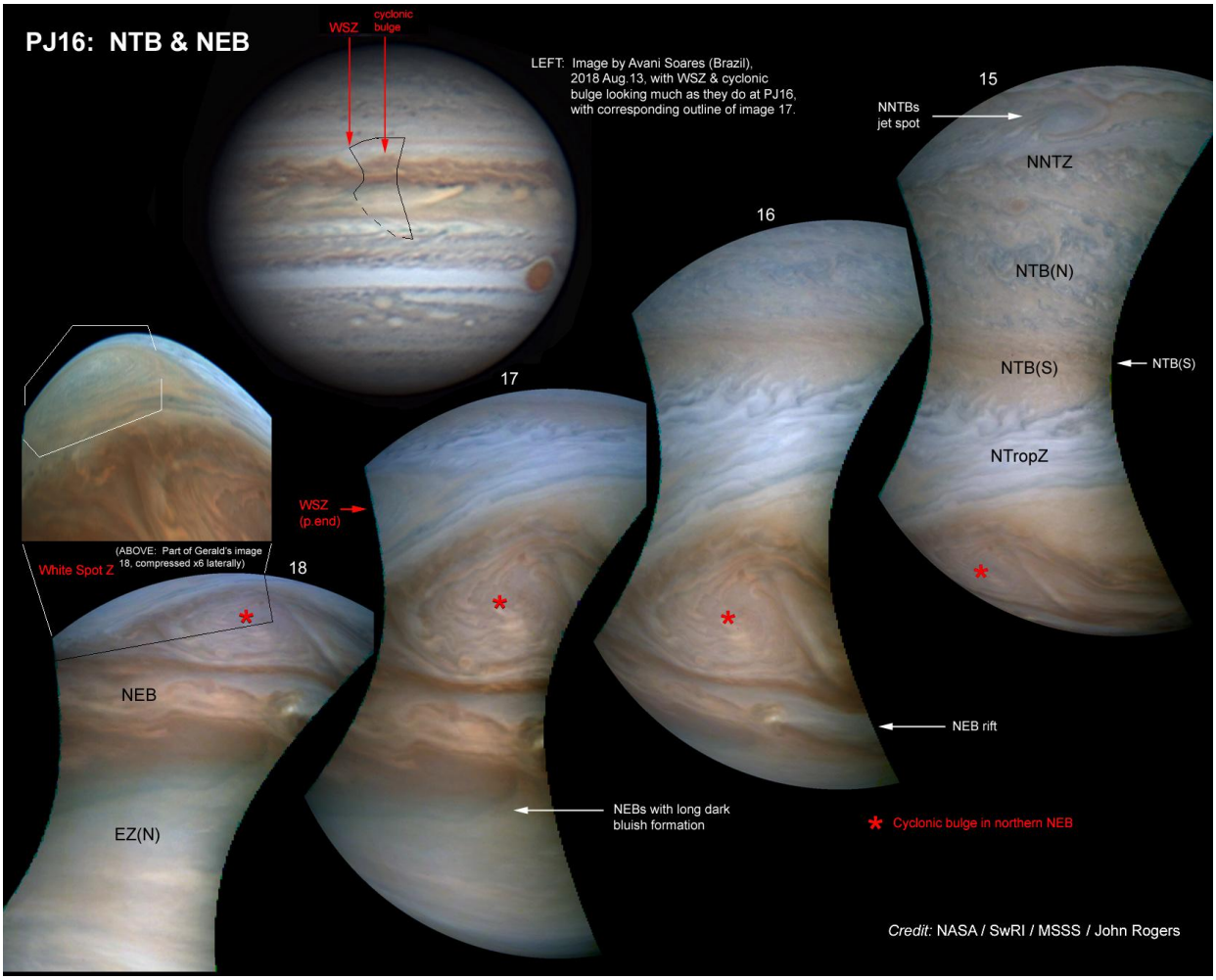

Figure 7

North Tropical Domain

Figure 6 is a global composite map from Gerald's projections of the PJ16 images. Figure 7 is an 'index' set of images over the NTB and NEB.

I hoped that Juno would obtain a closeup image of White Spot Z (WSZ), but unfortunately it was just out of the field of view (though it can be seen distantly, very near the horizon, on image 18, and its p. tip is visible in image 17). As indicated on Figure 7 (inset of an earlier ground-based image), the main feature imaged is a cyclonic bulge just preceding WSZ. It's interesting to see the apparently slack circulation and definitely no barge in the bulge. At high resolution, the cloud patterns in it are diffuse, as is usual in the NEB, although there are some crisp small clouds just north of it in image 17 (not shown here).

Equatorial Zone

Many mesoscale waves are visible in images 18 and 19 (Figure 8). Image 18 shows a band of low-contrast waves on a streaky orange part of the northern EZ [white box], and image 19 shows more substantial bands, in white clouds on the EB and on its south edge [red box]. (Note that image 18 has green/magenta stripes which are residual traces of the original scan strips, showing up due to the high contrast enhancement.)

There is also a set of odd, sharply outlined whitish clouds on the orange EB (Figure 8 [blue box]), similar to a few seen close to the EZs edge at PJ15 and in a Voyager 1 image [see report on PJ15]. This set is seen close to the horizon in images 18 and 20. These sharp-edged clouds are centred at about 0.8ºS and span about 1º latitude, highly elongated in the N-S direction; they could be controlled be mesoscale waves. It's unfortunate that they fell just outside image 19, as a closeup view of them could have given clues to their nature.

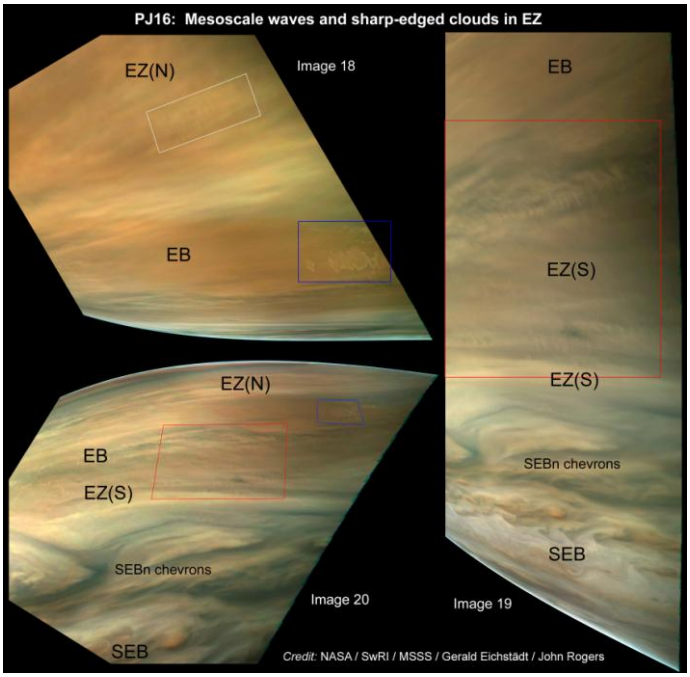

Figure 8

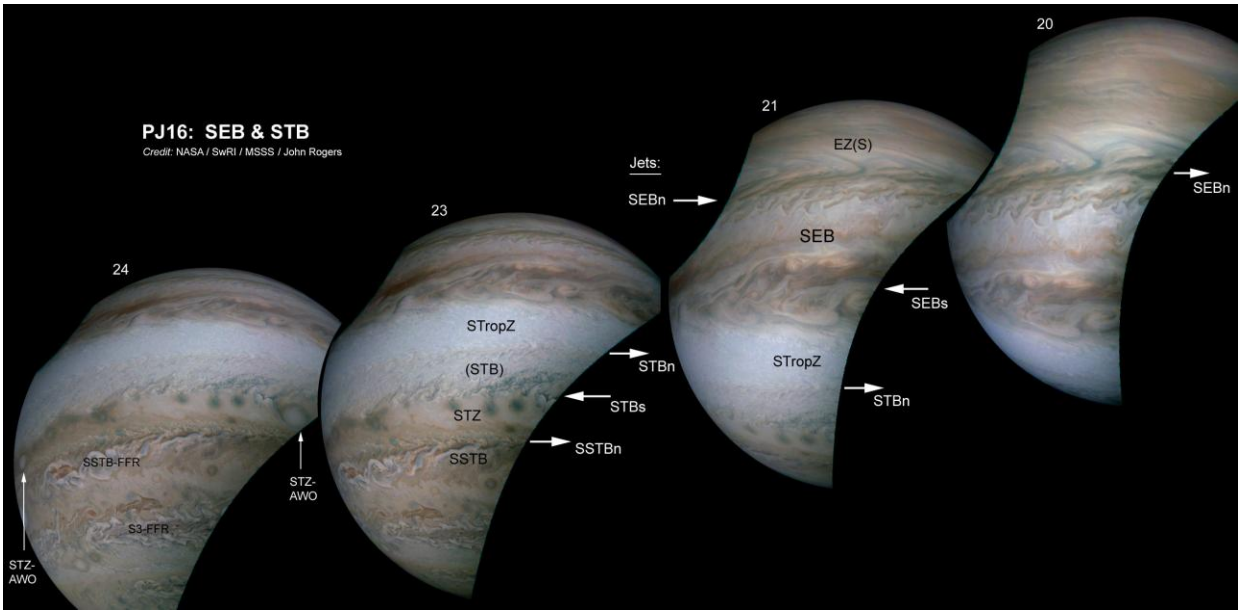

Figure 9

Southern hemisphere

The present pattern of southern-hemisphere belts does not simply reflect the pattern of the jets, so the map (Figure 6) and set of 'index' images (Figure 9) are useful for localisation.

South Equatorial Belt (SEB):
One new feature is obvious: the remarkable white cloud cover within the SEB (images 20 & 21). Is this the onset of a SEB Fade? The compilation of recent ground-based colour images (2018 Report no.9: https://britastro.org/node/16417) shows that there were still bright convective rifts in the SEB following the GRS in early October, so I wasn't expecting a Fade. On the other hand, the rest of the SEB has been quiet for months, and much of it is now pale except for the dark SEB(S). So, it is possible that a Fade is developing; we will find out after solar conjunction.

South Temperate Belt & Zone (STB-STZ):
In 2018 Feb-March, the 'STB Ghost' transformed into a dark turbulent segment of STB f. oval BA, which emitted retrograding dark spots south-following (Sf.) it, and also more extensive dark material to form a long dark grey sector of STZ. Our previous analyses of ground-based observations have shown that such STB segments normally emit such dark spots Sf. them forming an expanding 'Sf. tail'. These spots often drift across the retrograding STBs jet without changing speed, which is puzzling, and they sometimes merge to form one or more small AWOs in the STZ. Although we do not have ground-based drift measurements since June, it is evident that the PJ16 images show this activity close up.

The images show the whole affected sector (map in Figure 6, & some images in Figure 9), although oval BA itself is not visible, except very near the limb in image 26. Since the summer, the turbulent dark STB segment has become separated from the very dark STZ sector. Between them, the images show a small AWO (there is another one embedded in the dark STZ sector), and several small dark grey spots, which lie close to the latitude of the retrograding STBs jet. It is interesting that they are round and dark but show little sign of vorticity, and that they lie within a very bland cloud deck that covers this part of the STZ. It is similar to cloud cover of the SSTZ just to the south, but different from other zones which are much more highly textured with turbulence or popup clouds. These may be clues to the nature of these puzzling dark spots. Perhaps this cloud deck enables the dark spots to drift across the retrograde jet without being influenced by it?

South polar region

Figure 10 shows south polar projection maps down to 60ºS in colour (A,B), and with preference for near-terminator regions (C), and in methane (D). They nicely show the usual features of the SPR.

S5 & S6 jets & the edge of the South Polar Hood (SPH):
An animation of south polar maps (images 34 & 36: Figure 11) clearly shows the powerful S6 jet, and the circulations of the FFRs further south, and of the CPCs, and some local flows within the south polar region. As previously surmised, strong retrograde winds at ~71ºS are restricted to the FFRs. North of the S6 jet, the S5 jet is only weakly detectable. This pair of maps shows the close relationships between the S6 jet, the edge of the methane-bright South Polar Hood (also seen in visible light as a pale bluish haze over the very dark polar region), and the wave pattern along them. Details will be reported elsewhere.

Haze bands:
The map (Figure 10C) has limited longitude coverage of near-terminator regions because there was only one outbound image taken after south pole crossing, but it does show widespread bundles of ⊃–shaped bright and dark bands over the S6 jet and in the S5 domain. One casts a

brown shadow (near lower left corner in map). There are also bands in the S4 domain (not all included in this map). Dark bands are prominent. However, the long band that was draped around the pentagon of cyclones from PJ5 to PJ12 has still not reappeared.

Circumpolar cyclones (CPCs):
All of the pentagon is well shown except for CPC-3 which is in darkness. The position of the central South Polar Cyclone (CPC-6) is almost the same as at PJ14 and PJ15: so after two full cycles of motion, it has almost halted rather than returning towards the pole as expected.
The SPC no longer has a large dark core or annulus as it always did up to PJ14; the central half is now light and unresolved, except for a small dark 'eye' at the centre. However, it also looked like this at PJ15 (although the images were then of lower quality).

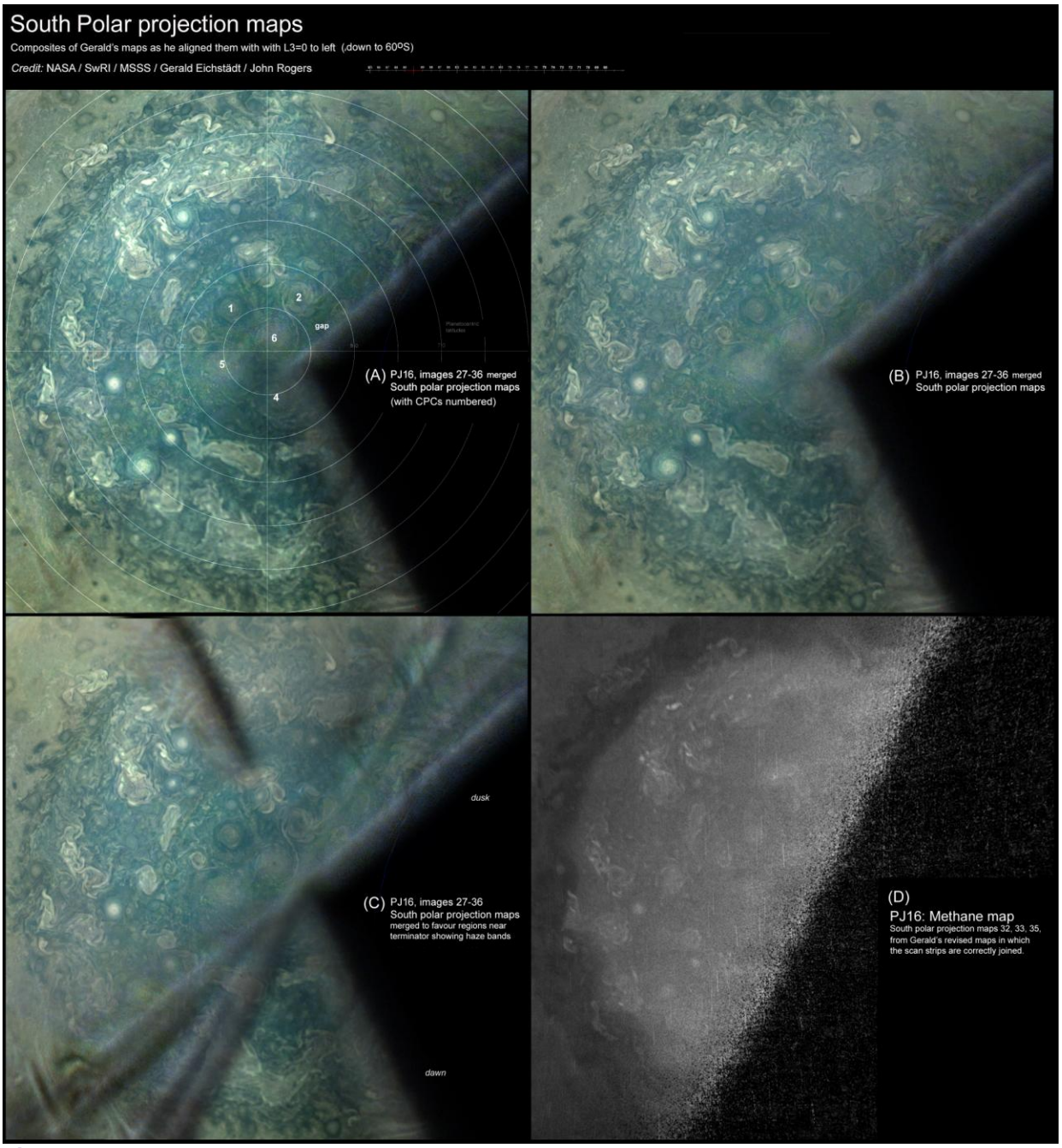

Figure 10