Jupiter in 2020, Report no.9, Supplement A:
Final numerical report: Northern hemisphere *[Full version]*

John Rogers & Gianluigi Adamoli (British Astronomical Association) (2021 June 6)

Figures (small copies)

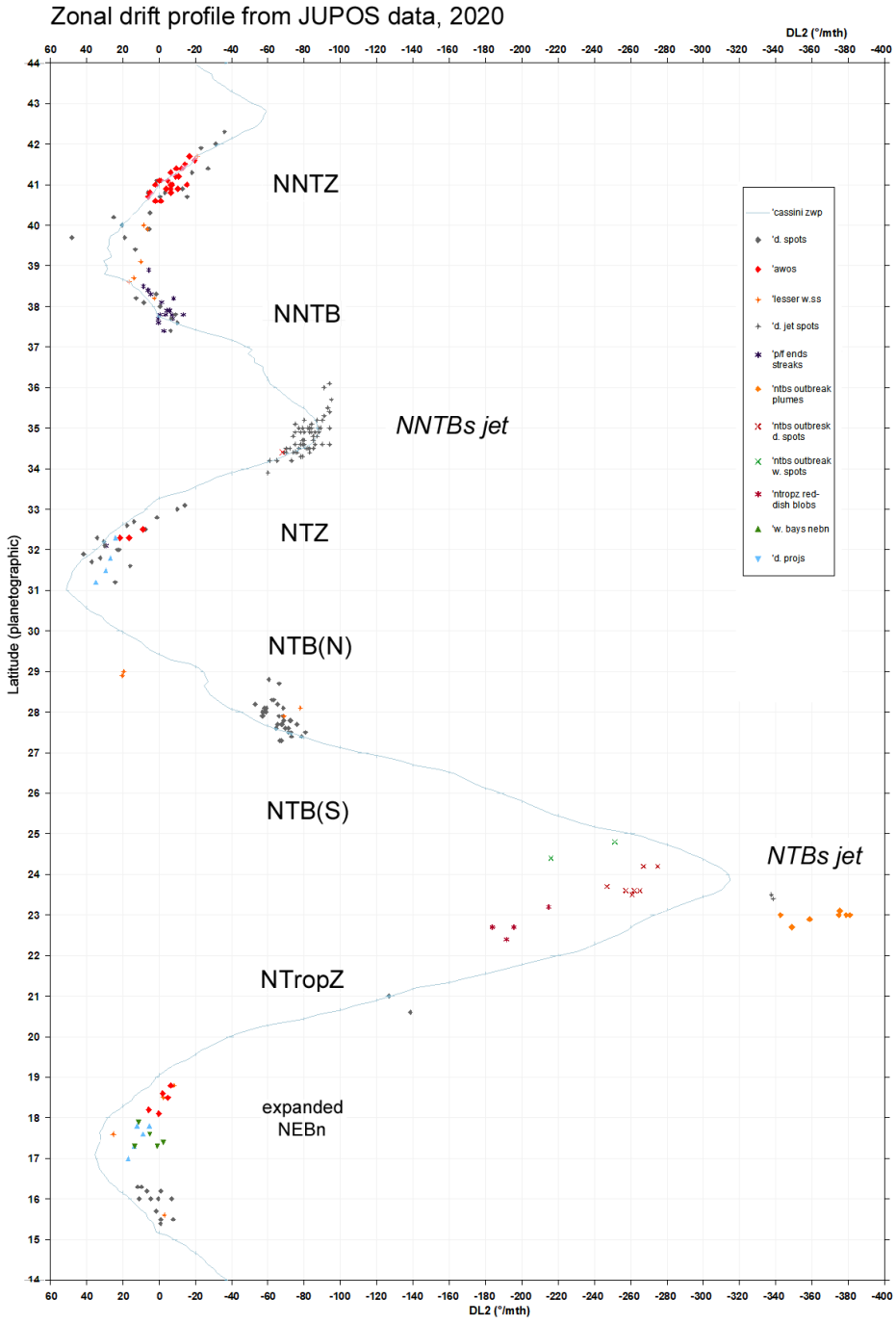


Figure 1. ZDP from JUPOS data from the NNTZ to the mid-NEB, compared with the ZWP from Cassini [Porco et al., 2003; *Science* 299, 1541].

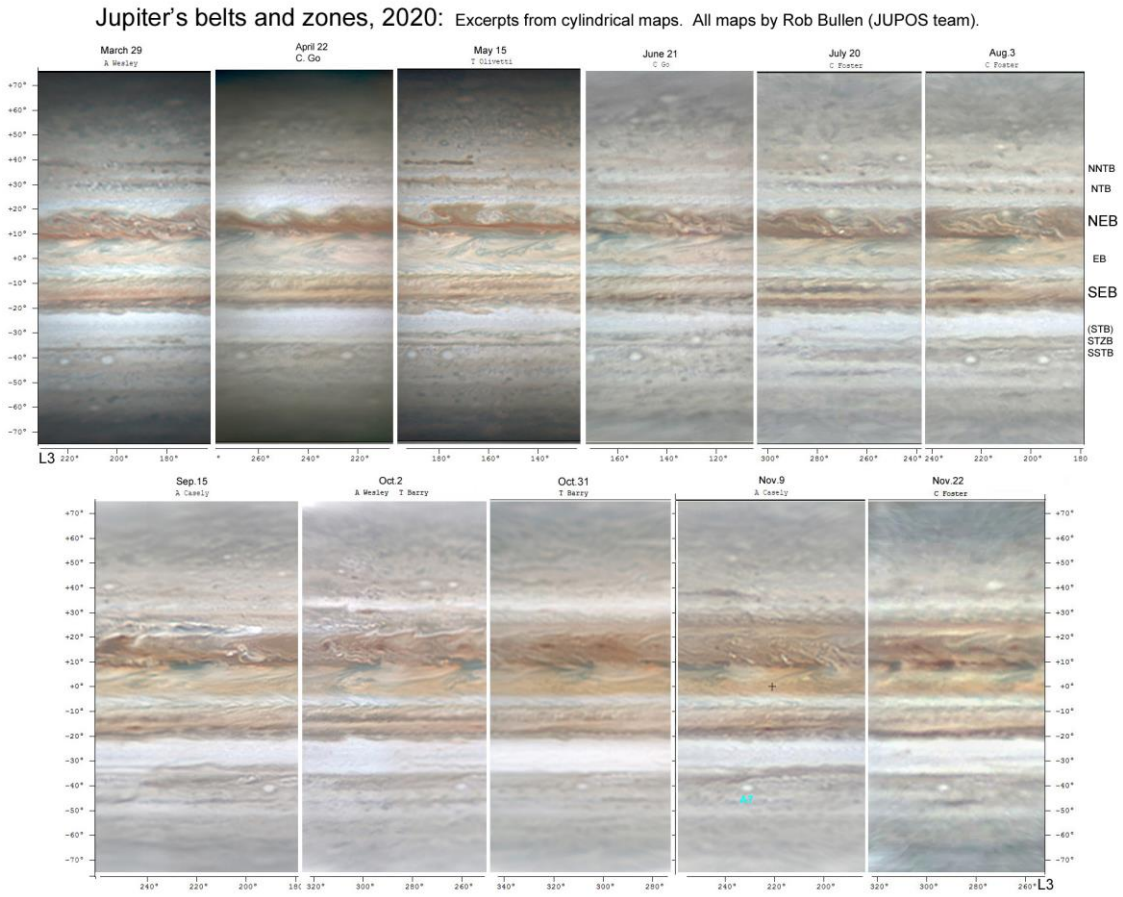


Figure 2. Slices from maps throughout 2020 to show changes in major belts and zones, notably the NTB upheaval, the NEB expansion event, and the EZ coloration. This follows on from a series presented in our 2019 report no.9. Colours and intensities are uncalibrated and in some maps have been adjusted to give more consistent overall balance. (Polar darkening was removed after May.)

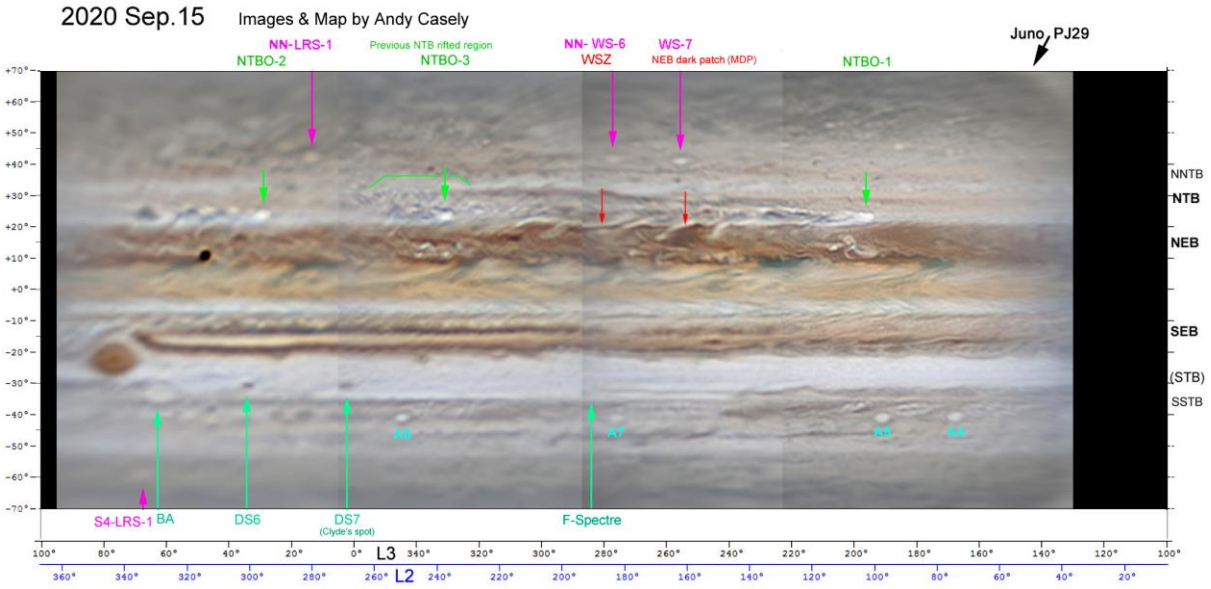


Figure 3. Map from Sep.15; images & map by Andy Casely, giving the best overview of the NTBs outbreak. (Another map from various images on the same date, by Rob Bullen, was posted in our Juno PJ29 report & is in a forthcoming issue of the *Journal of the BAA*.)

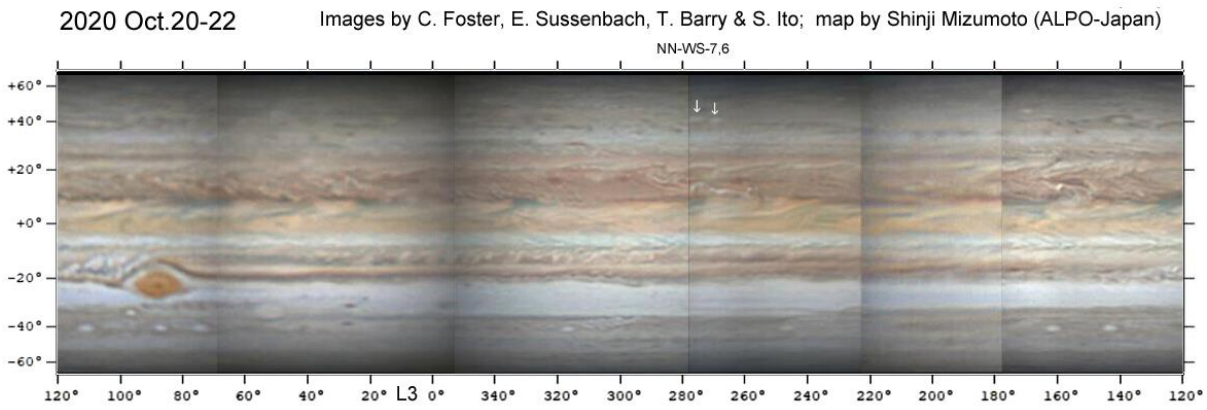


Figure 4. Map from Oct.20-22 (by Shinji Mizumoto).

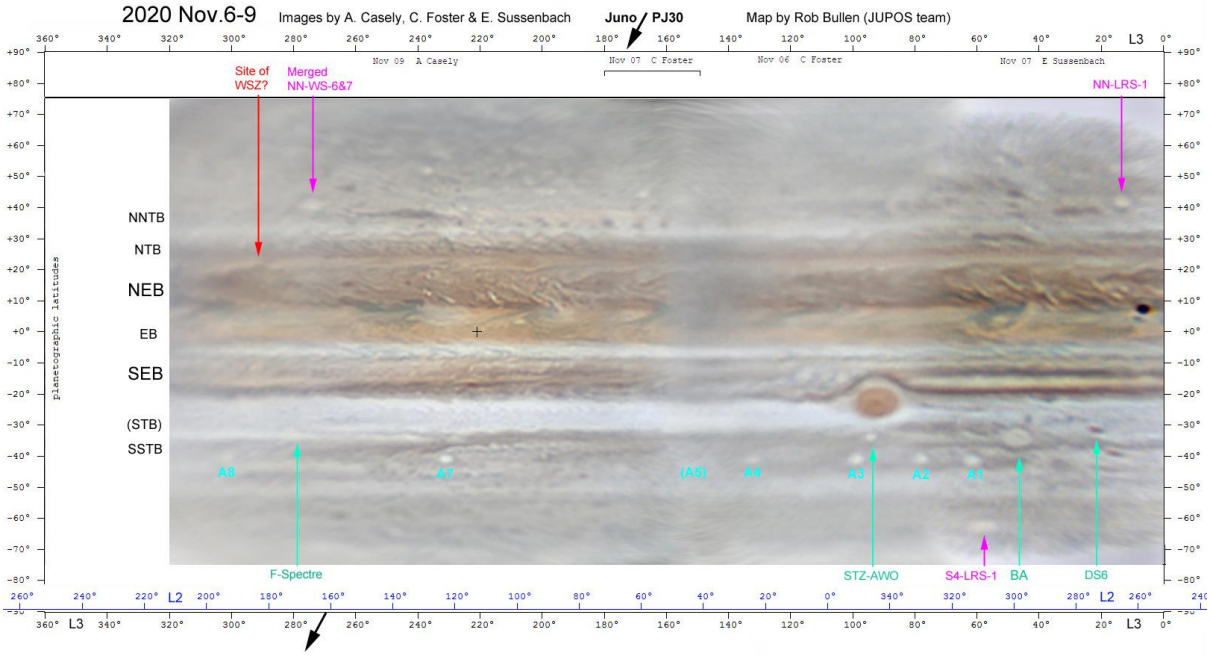


Figure 5. Map from Nov.6-9 (by Rob Bullen; previously posted in our PJ30 report).

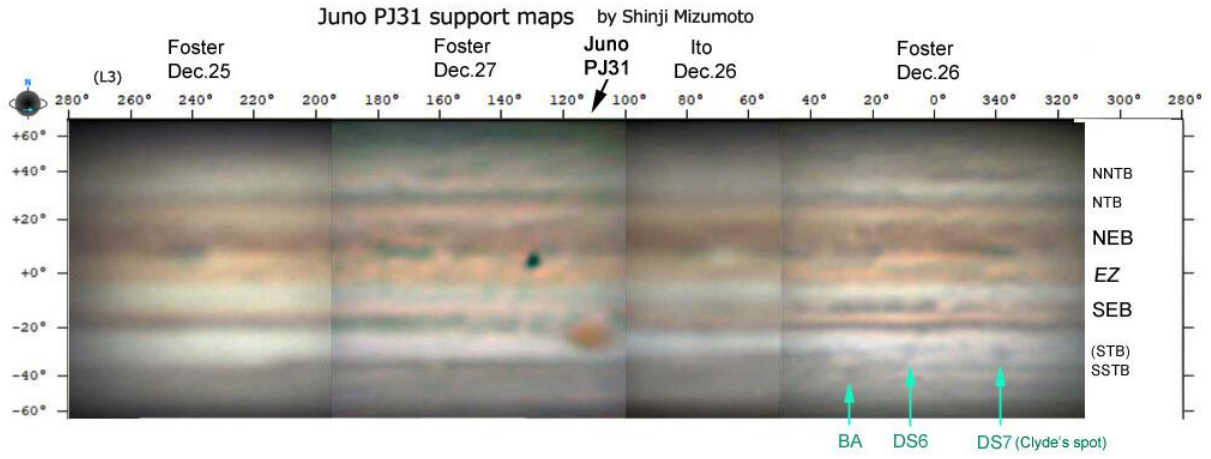
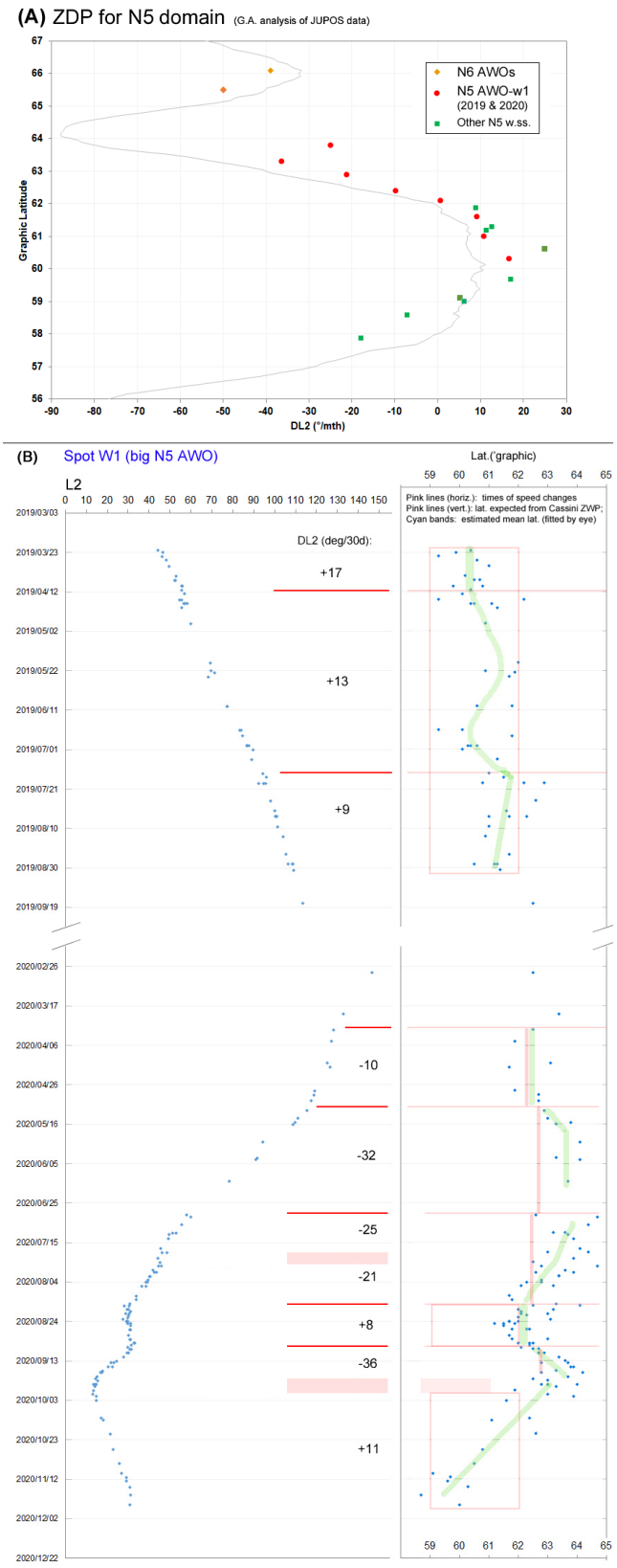


Figure 6. Map from Dec.25-27 (Shinji Mizumoto; previously posted in our PJ31 report).



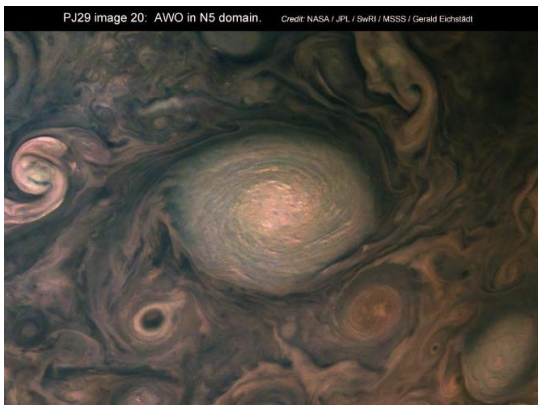


Figure 7. (A) Zonal drift profile for the N5 domain, including some data from 2019 for the large AWO, compared with the ZWP from Cassini. (B) Drift of the large N5 AWO in L2 and in latitude.

Figure 8 (R). Closeup view of the large N5 AWO from JunoCam at PJ29 (from our PJ29 report).

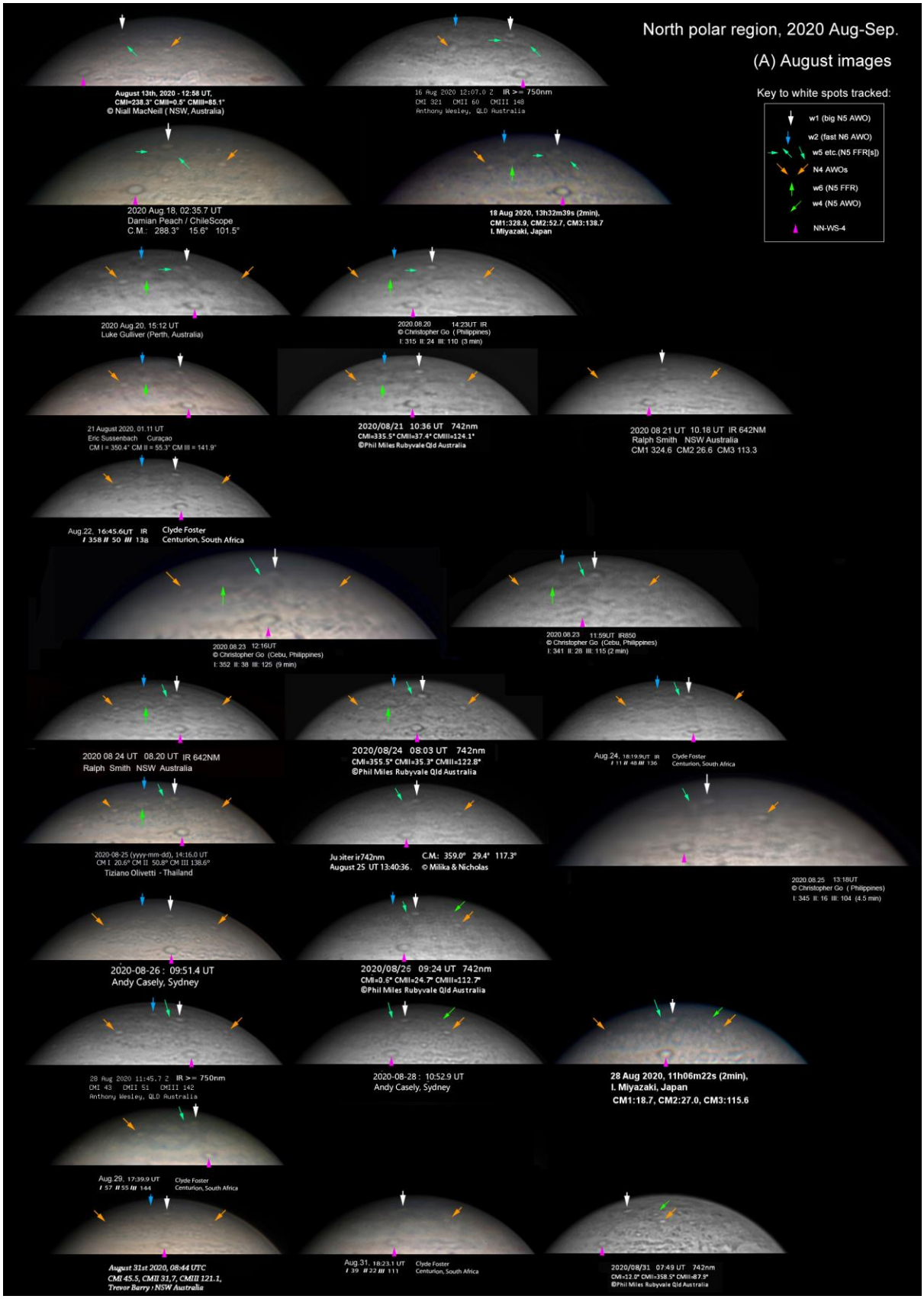
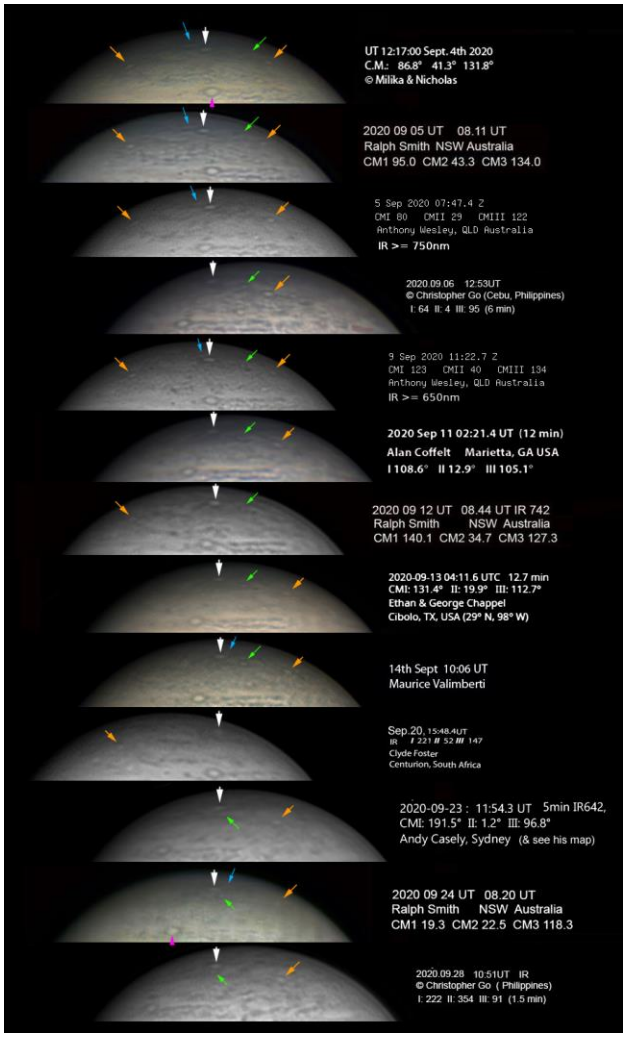


Figure 9(a). Images of the high northern latitudes in Aug.& Sep., showing motions around the large N5 AWO (indicated by a white arrowhead). Other persistent, tracked white spots are indicated with colour-coded arrows. *[Figure 9(b & c) are on following pages]*


UT 12:17:00 Sept. 4th 2020
C.M.: 86.8° 41.3° 131.8°
© Milika & Nicholas
2020 09 05 UT 08.11 UT
Ralph Smith NSW Australia
CM1 95.0 CM2 43.3 CM3 134.0
5 Sep 2020 07:47.4 Z
CMI 80 CMII 29 CMIII 122
Anthony Wesley, QLD Australia
IR >= 750nm
2020.09.06 12:53UT
© Christopher Go (Cebu, Philippines)
I: 64 II: 4 III: 95 (6 min)
9 Sep 2020 11:22.7 Z
CMI 123 CMII 40 CMIII 134
Anthony Wesley, QLD Australia
IR >= 650nm
2020 Sep 11 02:21.4 UT (12 min)
Alan Coffelt Marietta, GA USA
I 108.6° II 12.9° III 105.1°
2020 09 12 UT 08.44 UT IR 742
Ralph Smith NSW Australia
CM1 140.1 CM2 34.7 CM3 127.3
2020-09-13 04:11.6 UTC 12.7 min
CMI: 131.4° II: 19.9° III: 112.7°
Ethan & George Chappel
Cibolo, TX, USA (29° N, 98° W)
14th Sept 10:06 UT
Maurice Valimberti
Sep.20, 15:48.4UT
IR I 221 II 52 III 147
Clyde Foster
Centurion, South Africa
2020-09-23 : 11:54.3 UT 5min IR642,
CMI: 191.5° II: 1.2° III: 96.8°
Andy Casely, Sydney (& see his map)
2020 09 24 UT 08.20 UT
Ralph Smith NSW Australia
CM1 19.3 CM2 22.5 CM3 118.3
2020.09.28 10:51UT IR
© Christopher Go (Philippines)
I: 222 II: 354 III: 91 (1.5 min)

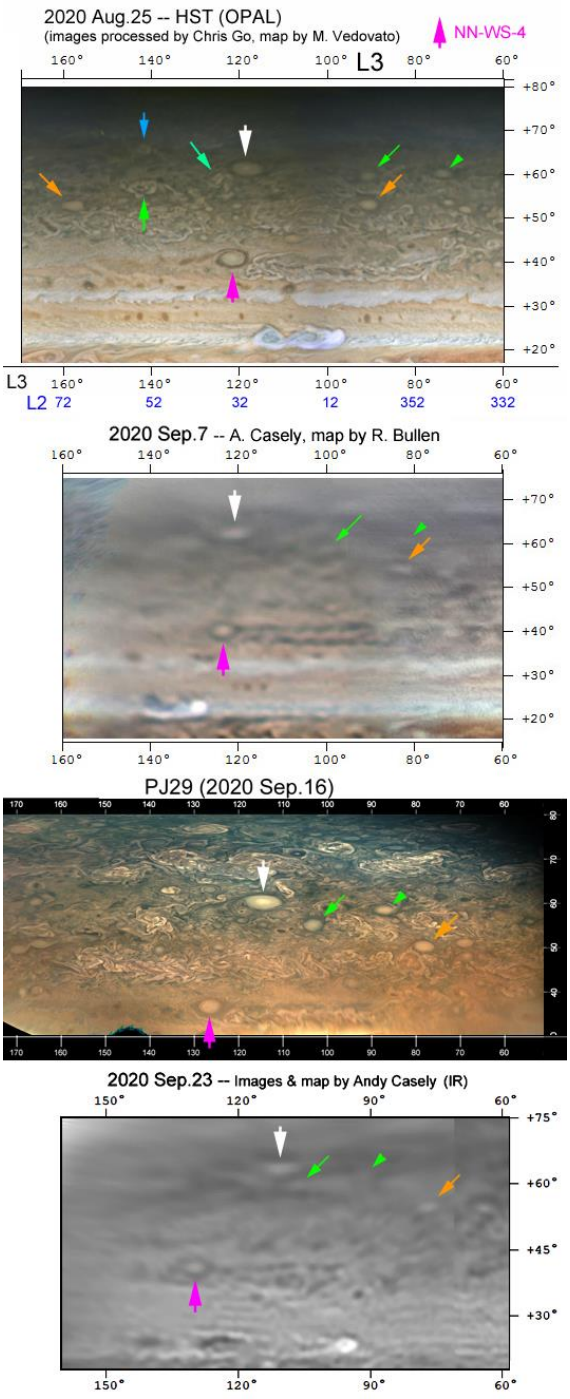

2020 Aug.25 -- HST (OPAL)
(images processed by Chris Go, map by M. Vedovato)
NN-WS-4
L3
L2 72 52 32 12 352 332
2020 Sep.7 -- A. Casely, map by R. Bullen
PJ29 (2020 Sep.16)
2020 Sep.23 -- Images & map by Andy Casely (IR)

Figure 9(b & c).

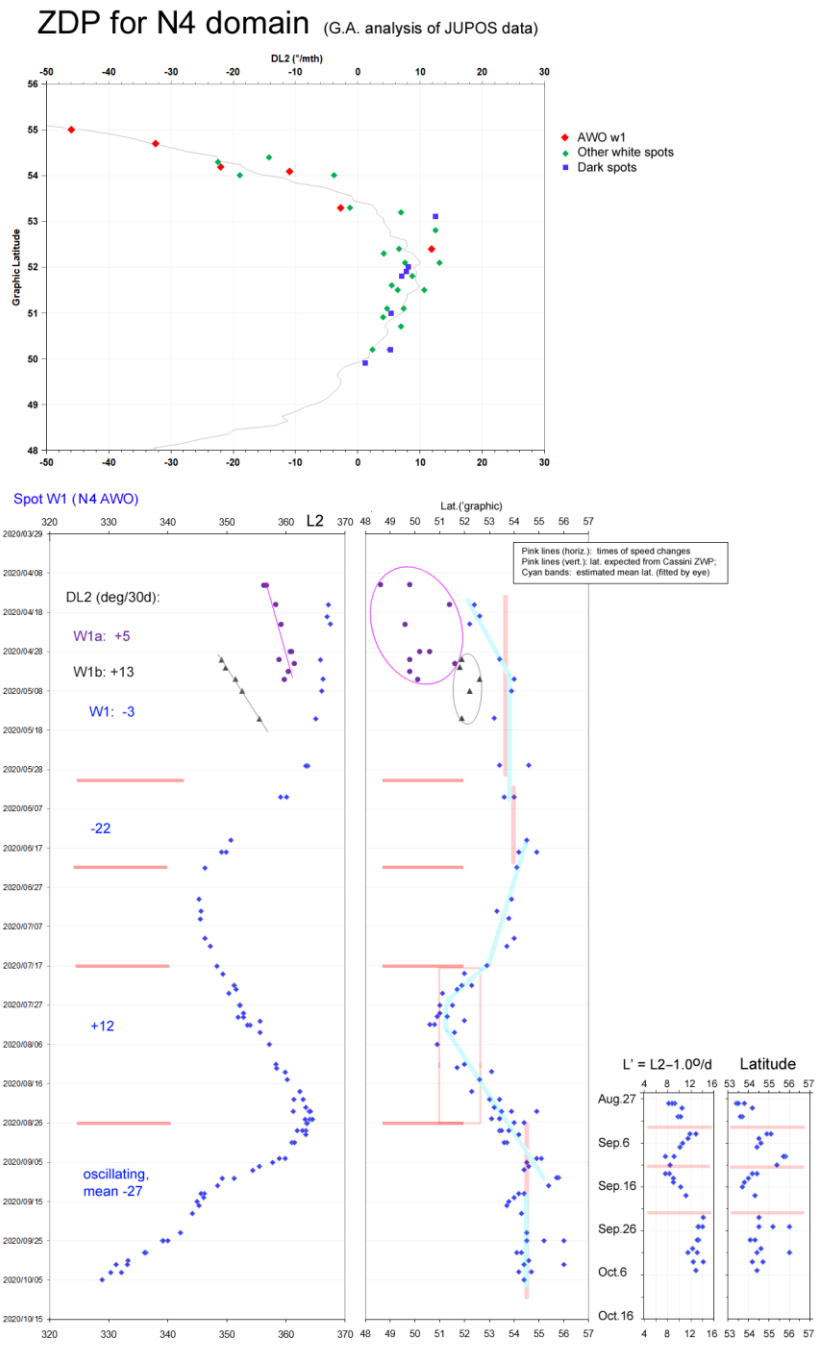


Figure 10. (A) Zonal drift profile for the N4 domain, compared with the ZWP from Cassini. (B) Drift of an N4 AWO in L2 and in latitude.

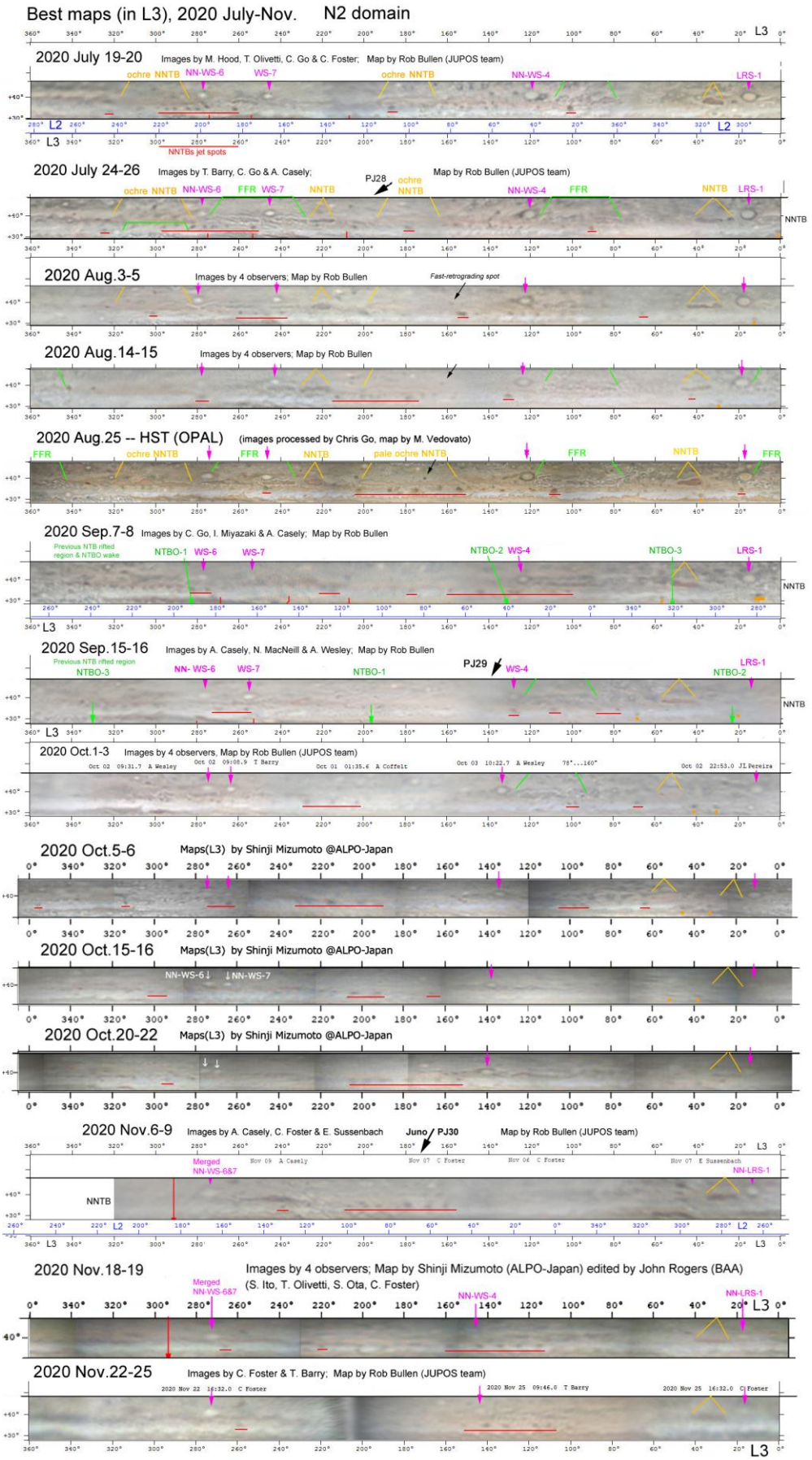
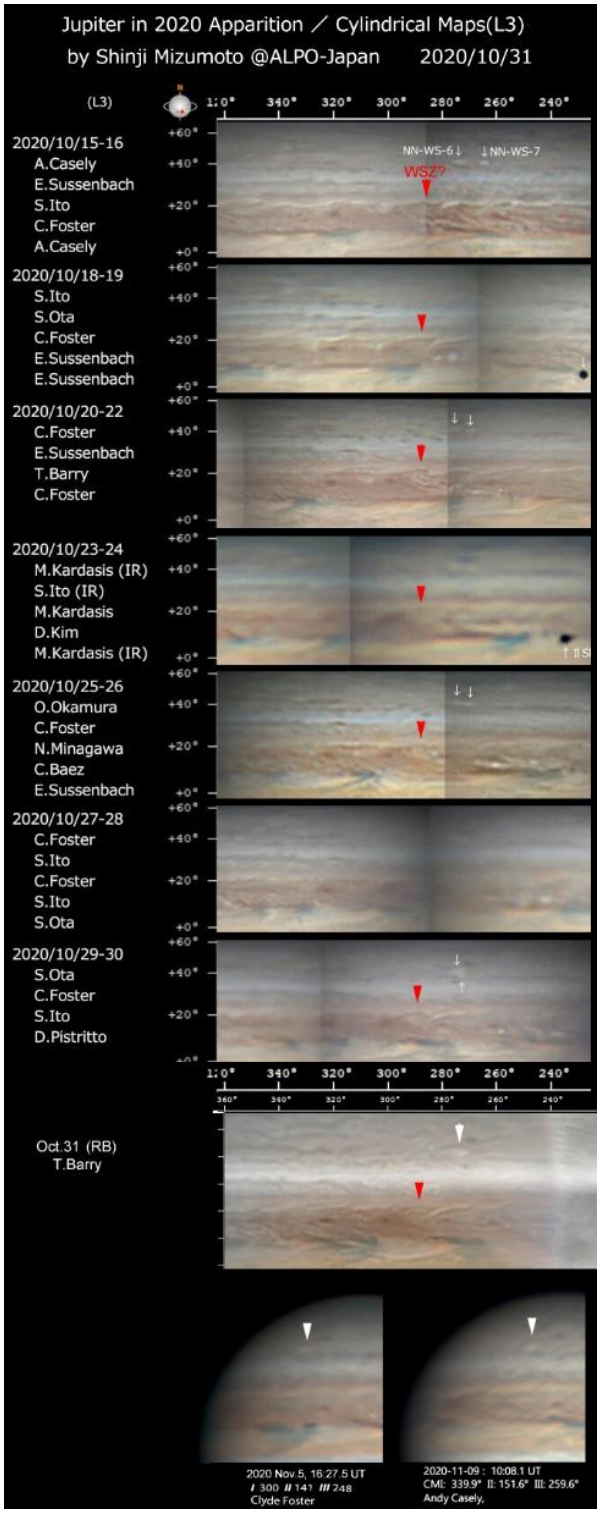


Figure 11. Maps covering the N2 domain from July to Nov.



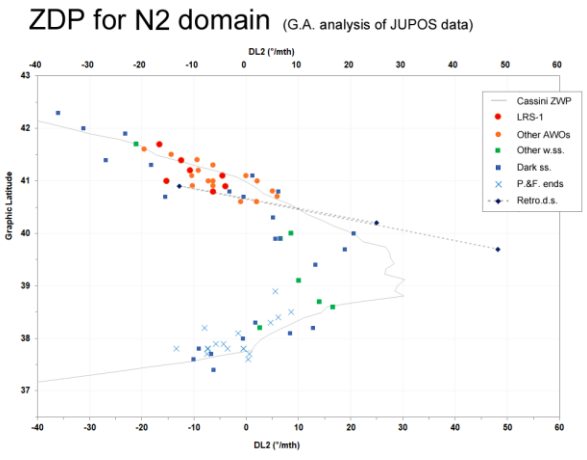


Figure 12. Excerpts from maps of the N hemisphere in October showing the merger of NN-WS-6 & 7, as well as waves along the NEBn after the NTBs outbreak, and the remnant of White Spot Z. (By Shinji Mizumoto). (For original images see Fig.26.)

Figure 13 (R). ZDP for the N2 domain. (Note that the speed axis is reversed relative to Fig.14.)

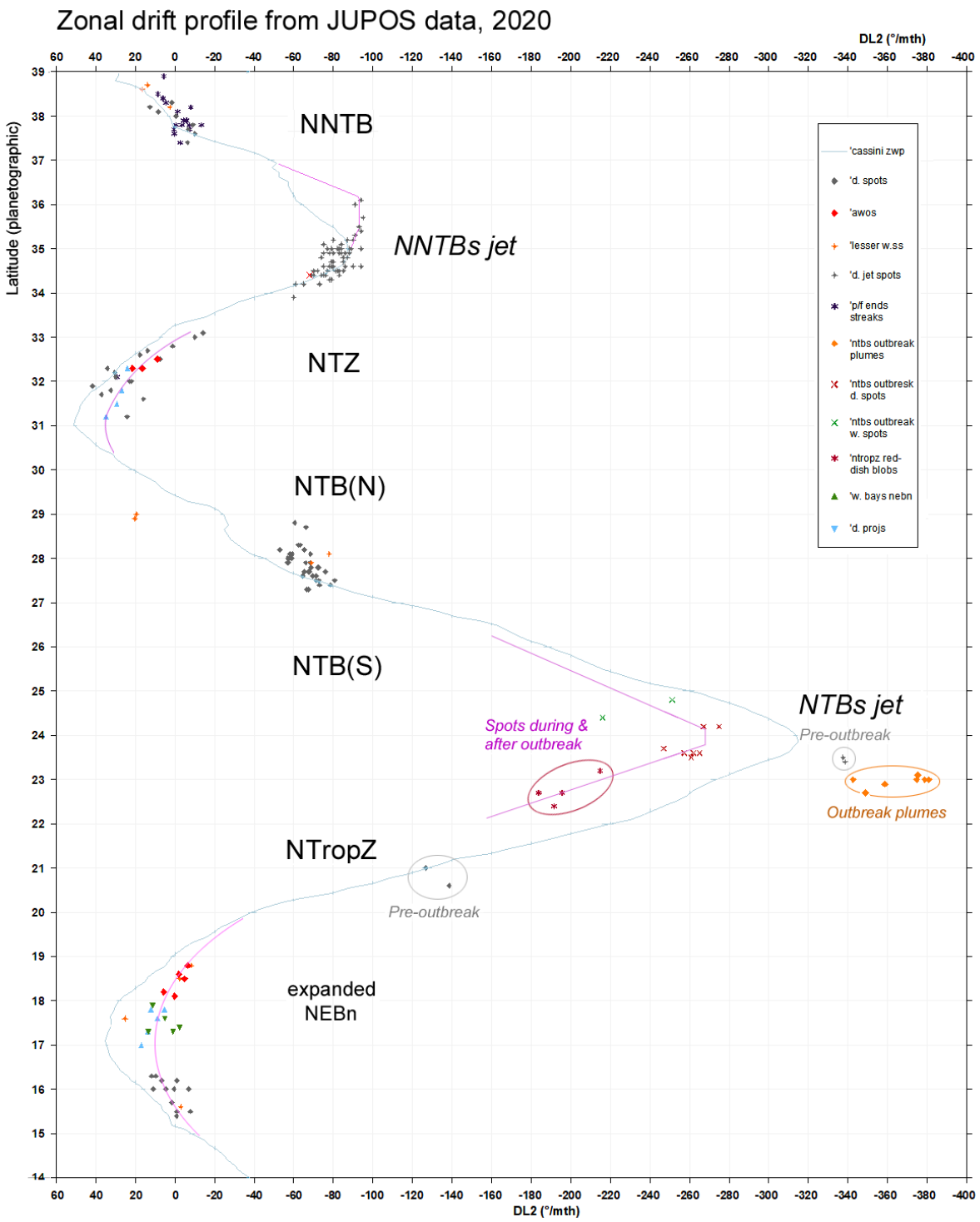


Figure 14. ZDP from JUPOS data from the NNTZ to the mid-NEB, annotated. The pale blue curve is the ZWP from Cassini [Porco et al., 2003]. The pale mauve curves indicate possible ZDPs which diverge from the Cassini ZWP. (Annotated version of Fig.1.)

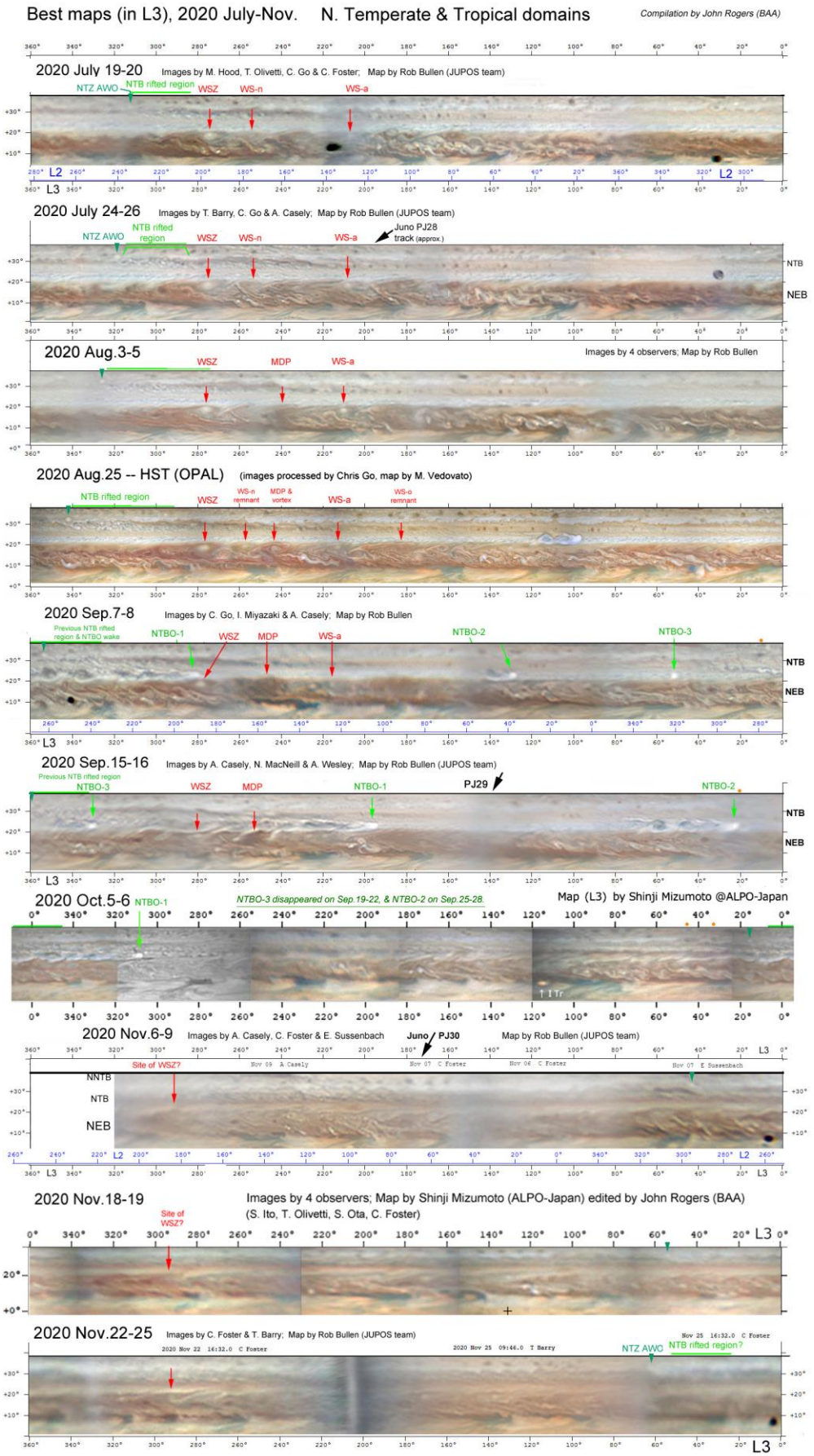


Figure 15. Maps covering the N. Temperate & Tropical domains from July to Nov.

The following figures show large collections of images and maps from Aug. to Oct., covering both the NTBs outbreak in all its aspects, and the effects in the NEBn, and the methane-dark patch (MDP).

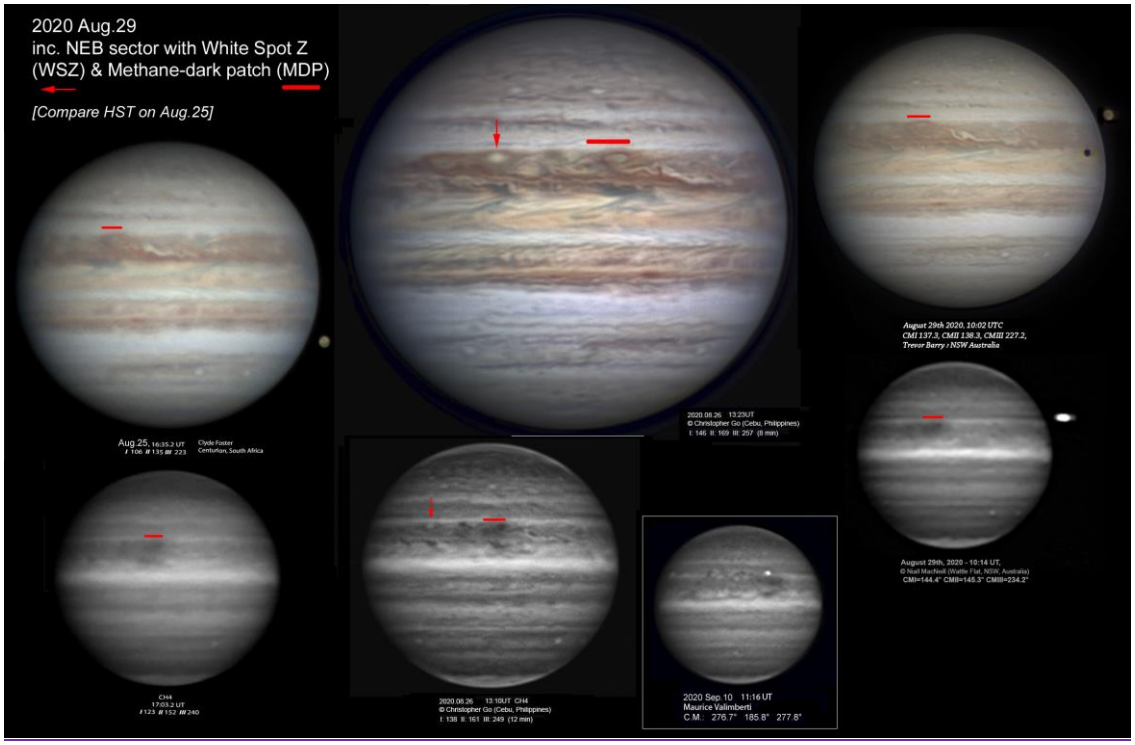


Figure 16. Images from Aug.25-29, in RGB & CH4, including the NEB sector with WSZ and the MDP. Compare the HST map on Aug.25 (**Fig.15**). Plus a CH4 image from Sep.10 showing NTBO-1 passing the NEB methane-dark patch (MDP).

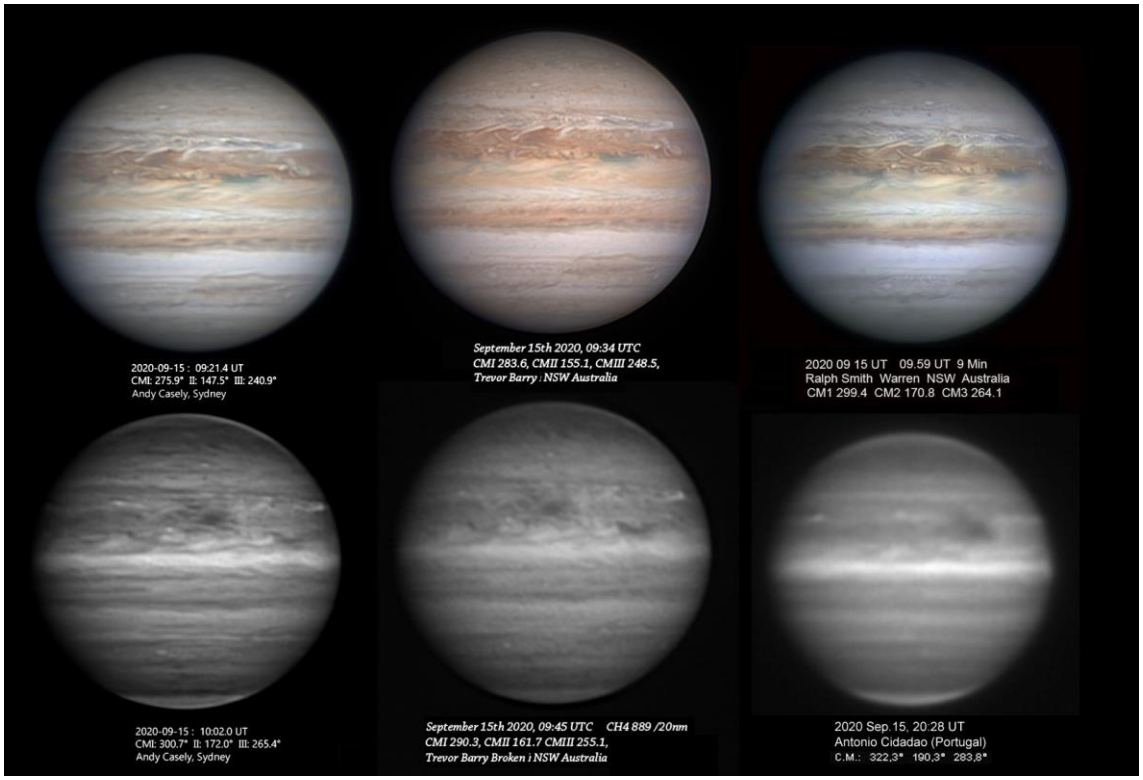


Figure 17. RGB & CH4 images from Sep.15&20, showing the NTBs jet outbreak, and the MDP in the NEB. *Top row:* RGB images on Sep.15, by three observers, showing NTBO-1; its wake spans the disk. *Middle row:* matching CH4 images. *Bottom row:[on next page]*

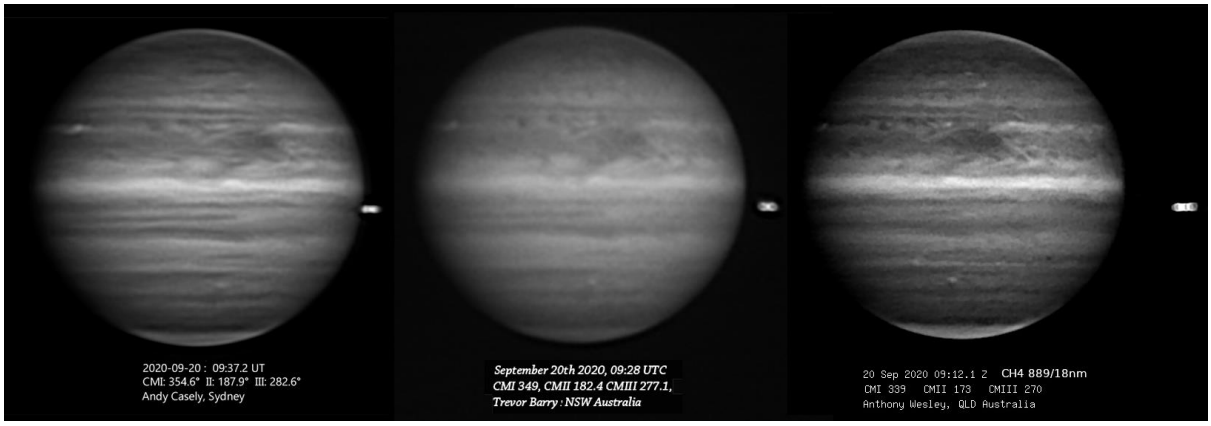


Figure 17 (cont.): *Bottom row:* CH4 images, Sep.20, by 3 observers. Compare RGB images in Fig.20.

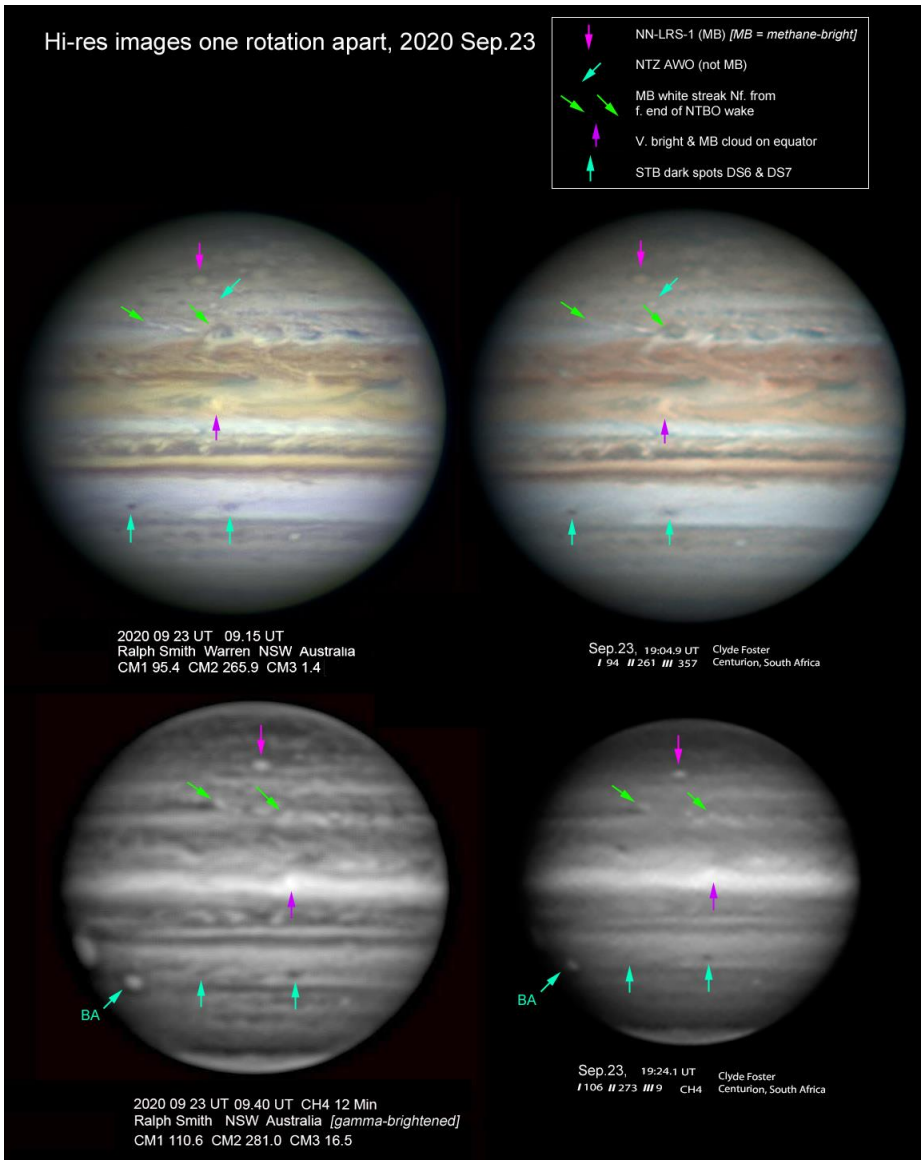


Figure 18. Images on Sep.23, in RGB & CH4; the RGB images are one rotation apart and can be blinked to show the winds. Notable features are indicated, esp. those that are methane-bright (MB).

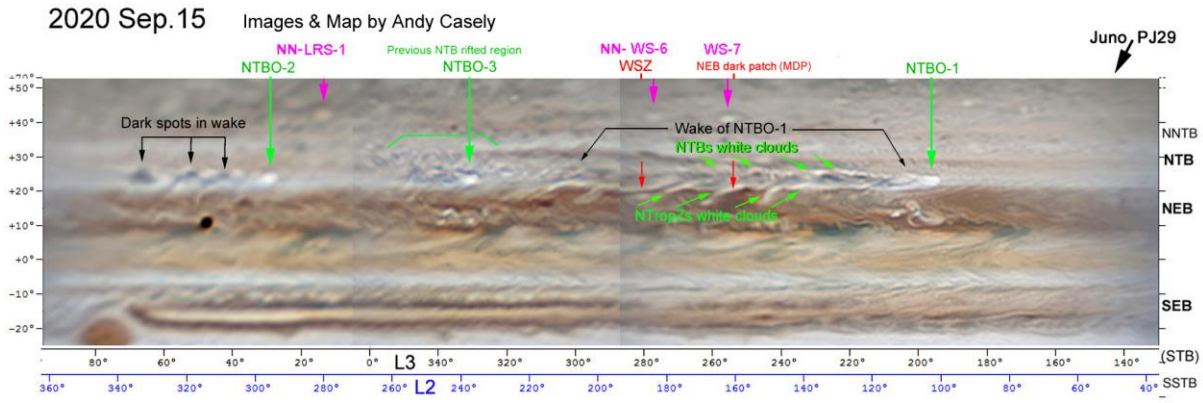


Figure 19. Map from Sep.15 (copied from Fig.3), showing the key features of the NTBs outbreak. The three plumes are labelled NTBO-1,2,3. Each has a 'wake' or 'tail' of length proportional to its age. The wake of NTBO-2 has three dark spots; that of NTBO-1 has more but on this date they are in the irregular phase of their cycle (see text). Note that NTropZs white clouds are invading the NEBn in a wave-like pattern around the anticyclonic features such as WSZ and the MDP.

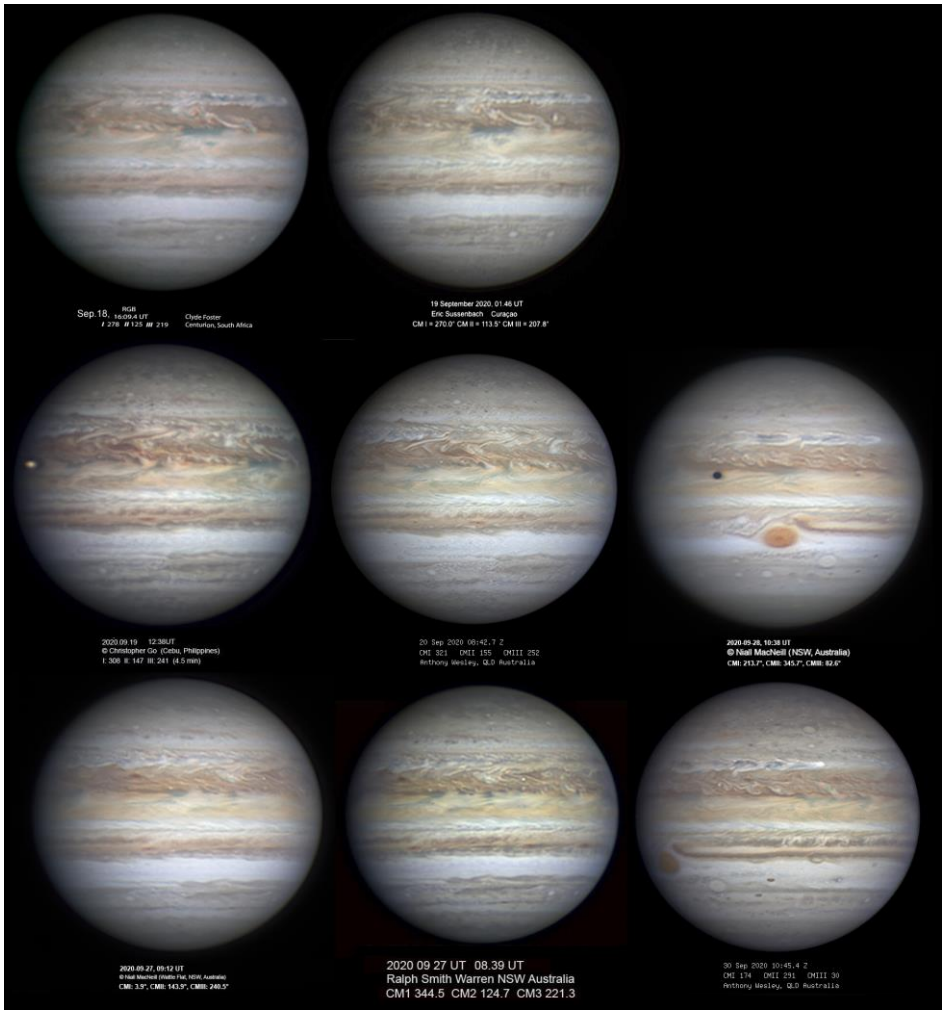


Figure 20. Hi-res images showing details of the NTBs outbreak (Sep.18-30).
Left & middle columns: Pairs of images showing rapid motions; the top two pairs also show the MDP in the NEB (compare Fig.17 for CH4 images & Fig.24 for a map). The bottom two pairs show the demise of NTBO-3. *Right column:* Images showing NTBO-1, & the GRS & oval BA.

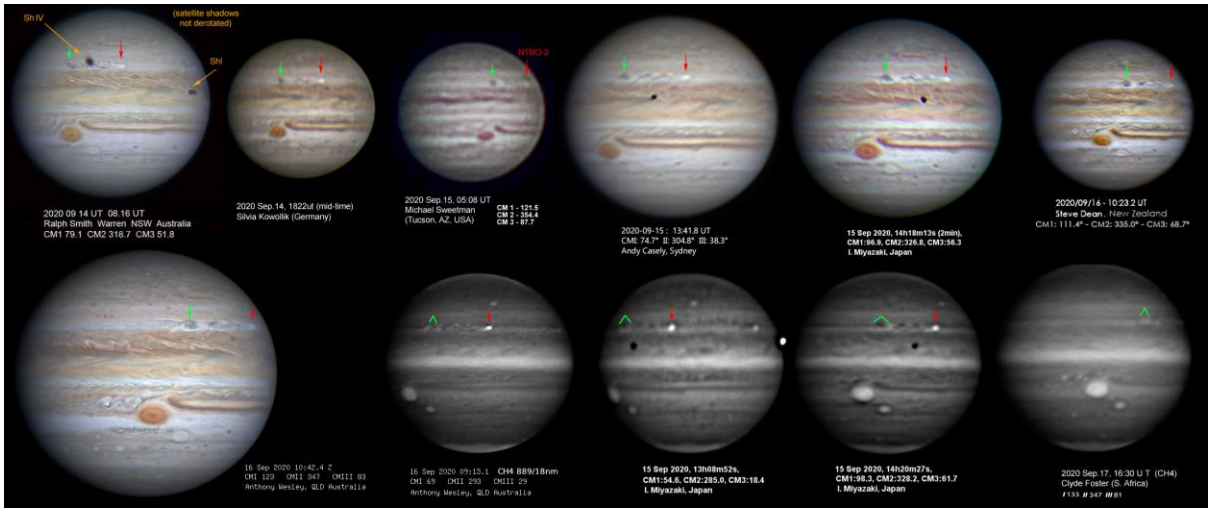


Figure 21. Images on Sep.14, showing NTBO-2, with the very dark spot developing at the f. end of its wake, which is wrapped in methane-bright streaks that dominate it when seen near the limb. (The maps in Fig.22 show the dark spot in the context of the growing NTBO-2 wake, and higher-resolution images are in Fig.18.)

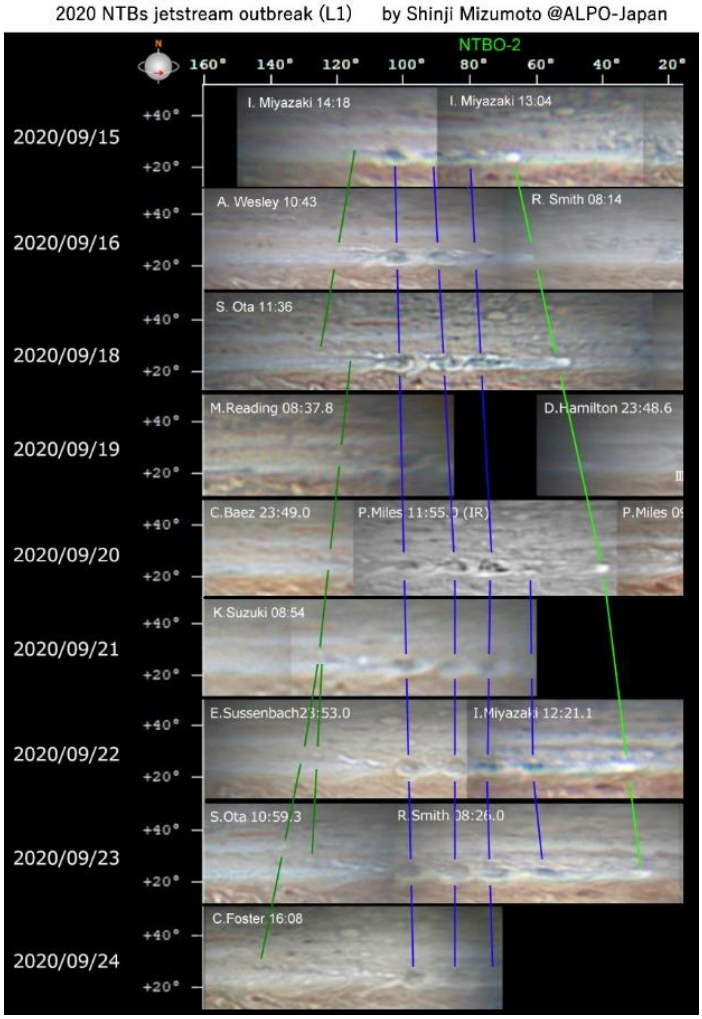


Figure 22. Maps of NTBO-2 and its wake (by Shinji Mizumoto), Sep.15-24, plotted in L1. (Also see Figs. 18 & 21.) They show the wake expanding from 3 to 4 dark spots (dark blue lines), aligned with wave structure on the NEBn; the westernmost dark spot is an anticyclonic ring; bright spots and streaks extend Nf. from it (dark green lines).

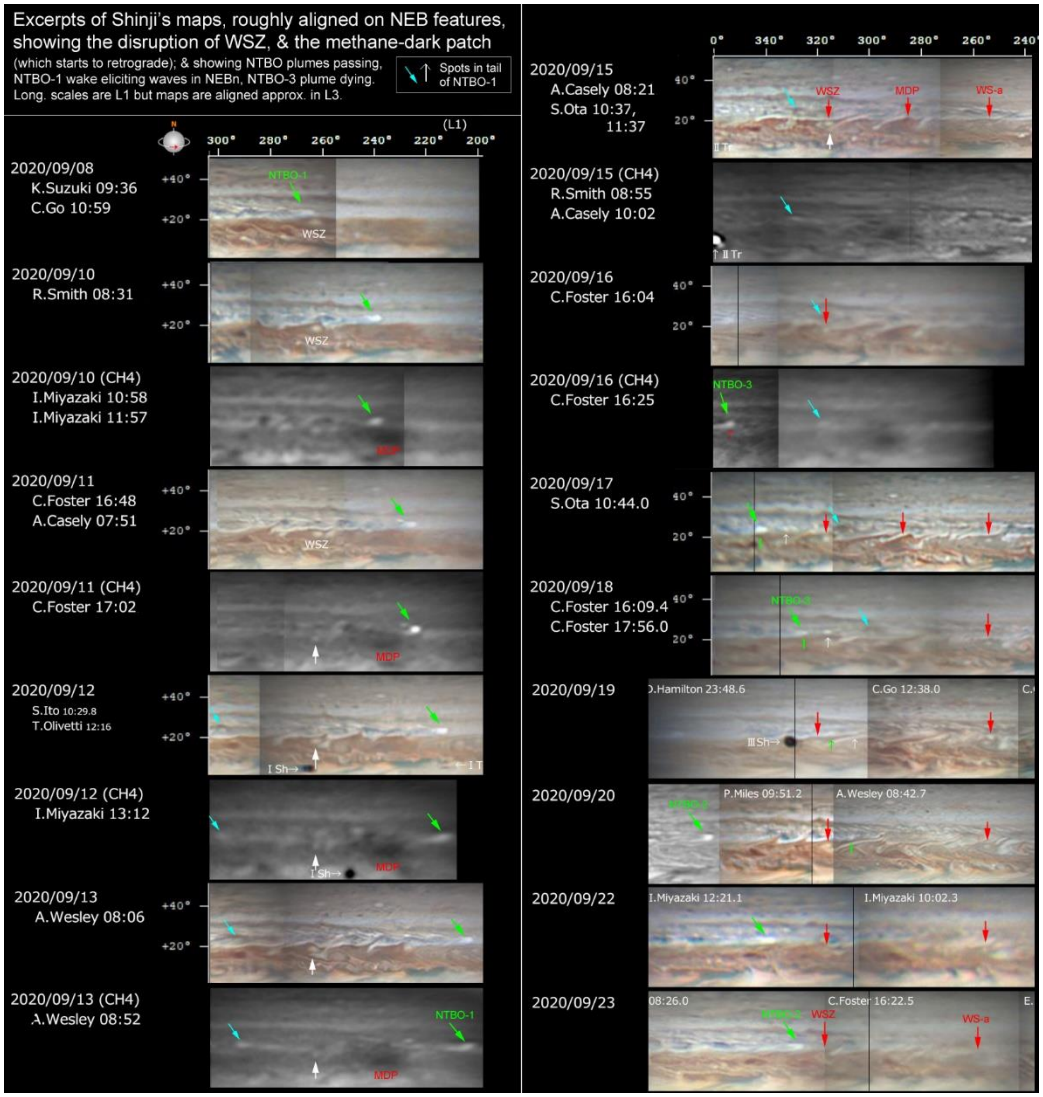


Figure 23. Maps by Mizumoto (with scales at the top in L1) have been realigned on the NEBn features. They show the main series of NEBn circulations including WSZ and the MDP, and NTBO-1 passing them; waves in NEBn induced by the passage of the wake of NTBO-1; and the MDP, including its dissociation from the tropospheric features when it began retrograding. Also shows the demise of NTBO-3.

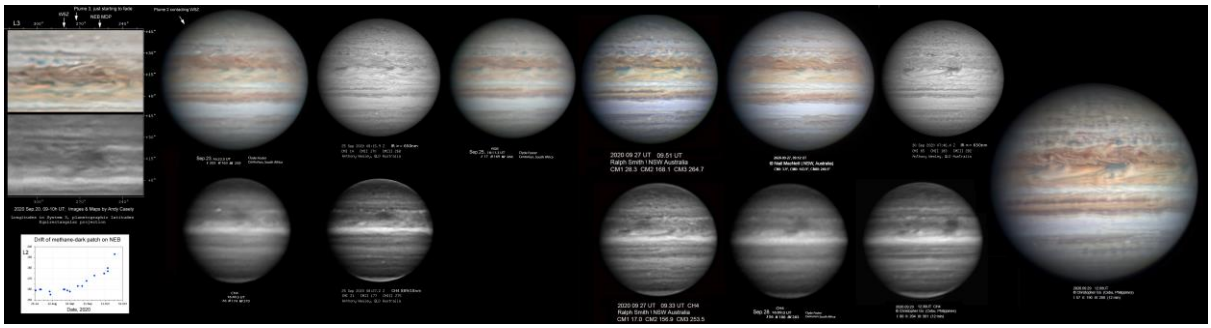


Figure 24. Images from Sep.20-29, including CH4 images, including the demise of NTBO-2, and the MDP. *Top left:* Pair of maps from A. Casely on Sep.20, allowing precise registration of visible & CH4 maps. *Bottom left:* Drift of the MDP in L2.

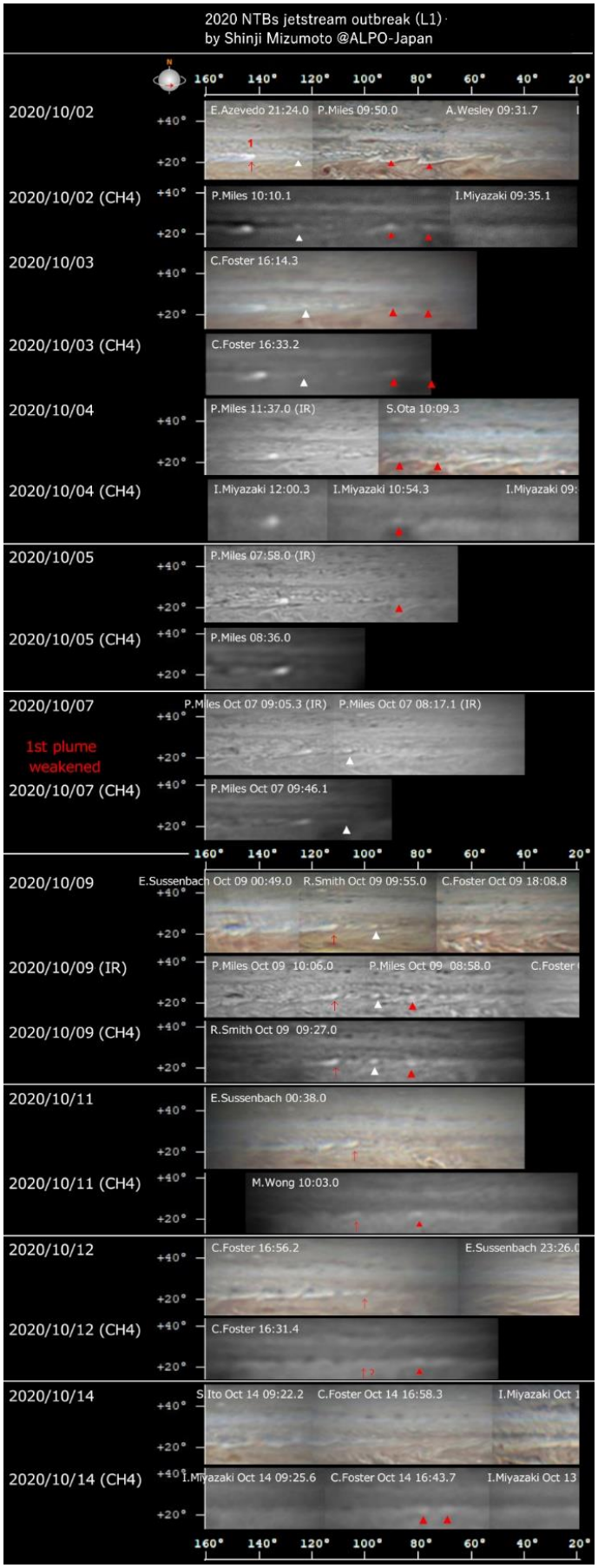


Figure 25. Maps (Oct.2-14, by Shinji Mizumoto) showing the demise of the NTBO-1 plume (small red arrow at left) as it catches up with the wake of NTBO-3. Two dark spots in the wake of NTBO-2 are anticyclonic, methane-bright rings (red arrow-heads). Note a small methane-bright white spot (white arrowhead) f. the NTBO-2 wake on Oct.2&3, ~17° p. the NTBO-1 plume, and the same or another on Oct.7&9 as the plume starts to weaken. Original images are in Fig.26 & the map series is continued in Fig.12.

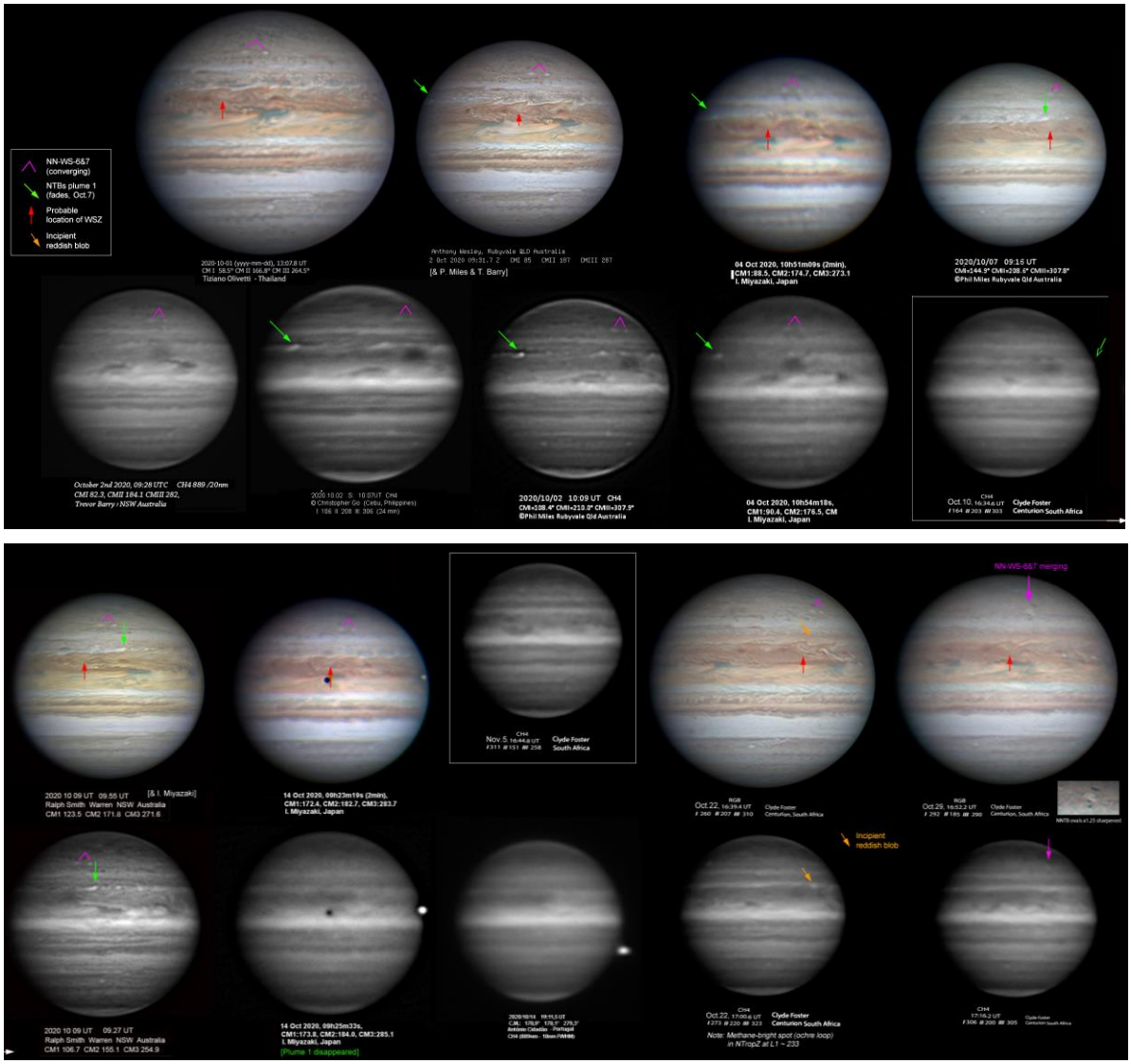


Figure 26. Images in RGB & CH4 (Oct.1-14), showing the MDP & WSZ & demise of NTBO plume 1, which started fading as it passed WSZ & the MDP. (Also see Mizumoto's maps from these & subsequent images: Fig.25 & Fig.12.). Also note methane-bright anticyclonic rings in NTropZ as described above. The MDP is due S of NN-WS-6&7, but gradually retrograding relative to them. The last 2 images, Oct.22 & 29 (by Foster), are spectacular, showing vigorous activity: NN-WS-6&7 merging; bright new rifts in the NEB, another bright intrusion from NTropZs into NEBn, perturbing the remnant of WSZ; & origin of a prograding red blob in NTropZ from an eddy in the NTropZ/NEBn waves.

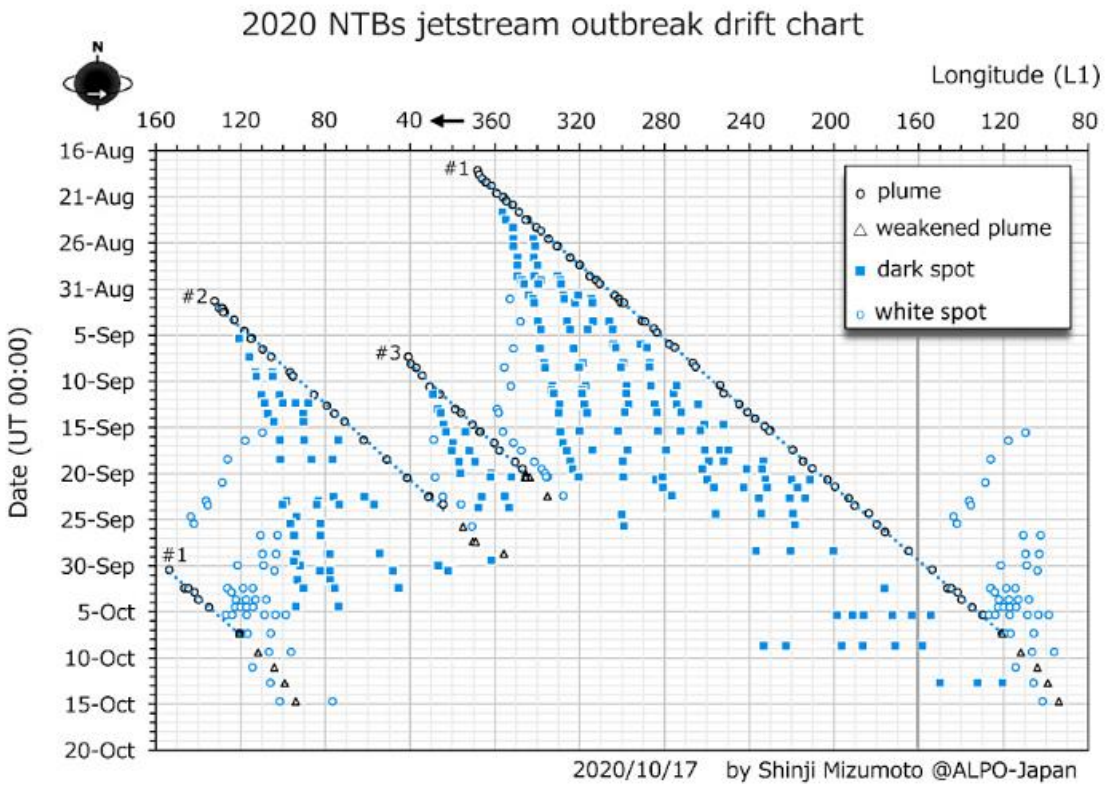


Figure 27. Chart of longitudes vs time for the spots in the NTBs jet outbreak, by Shinji Mizumoto. (The equivalent JUPOS chart is in **Supplement B**.)

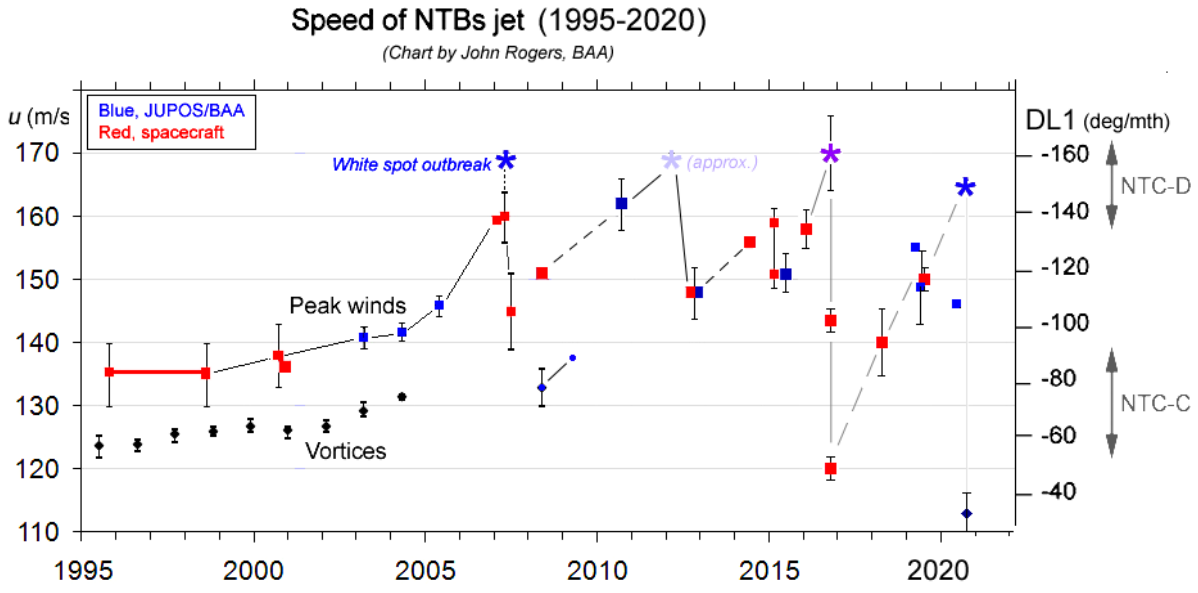


Figure 28. History of the NTBs jet from 1995 to 2020: chart showing its recorded speeds.

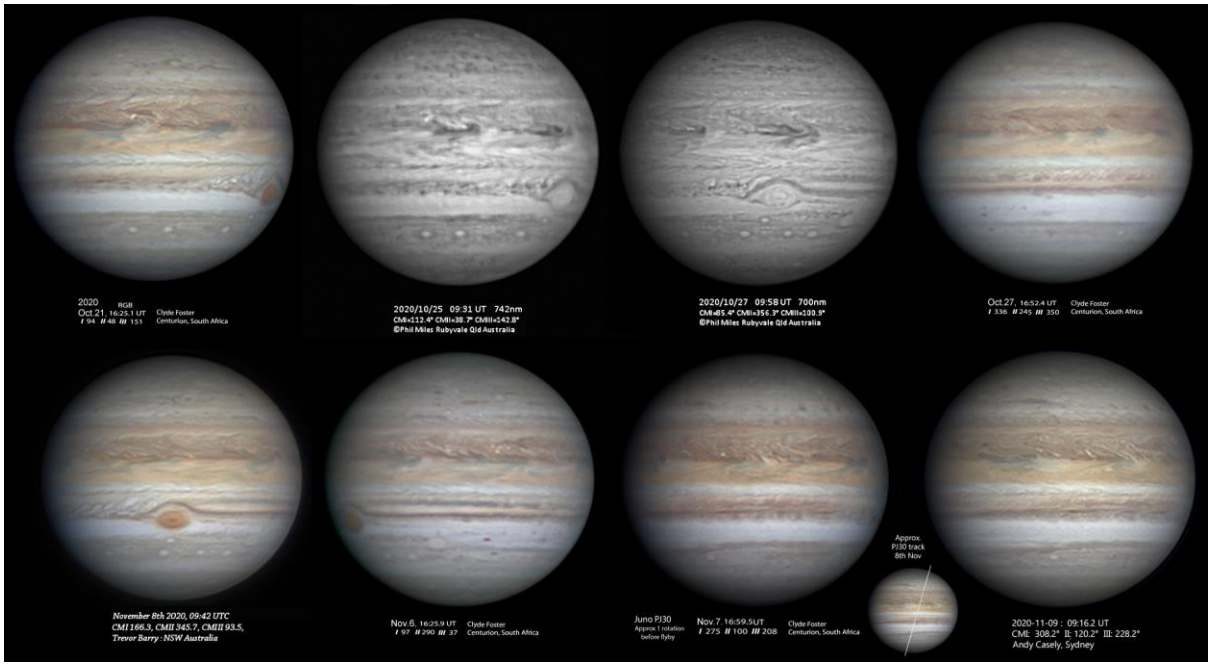


Figure 29. Some v-hi-res images from Oct.21 to Nov.9, when everything from the NTB to the EB was reddish, giving the appearance of a 'great northern disturbance'. The images of Nov.7 & 9 cover the PJ30 track, including the red blob in NTropZ that was imaged by JunoCam.

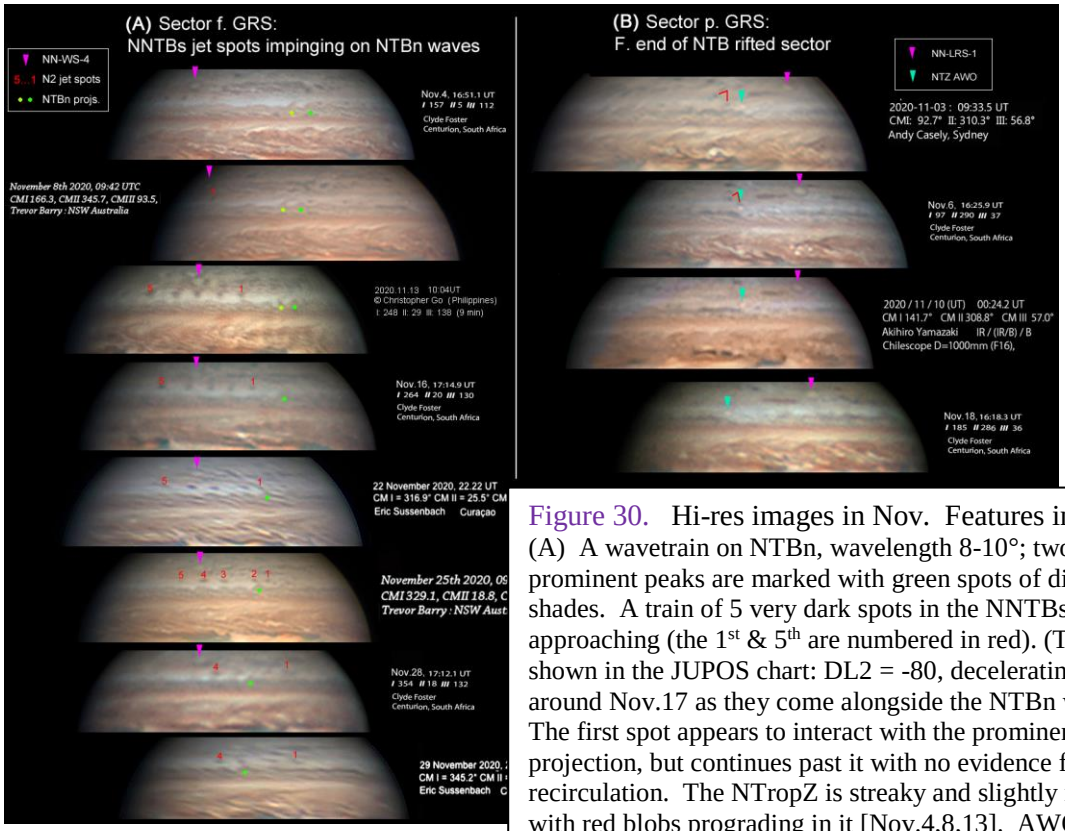


Figure 30. Hi-res images in Nov. Features include:
(A) A wavetrain on NTBn, wavelength 8-10°; two prominent peaks are marked with green spots of different shades. A train of 5 very dark spots in the NNTBs jet is approaching (the 1st & 5th are numbered in red). (They are shown in the JUPOS chart: DL2 = -80, decelerating around Nov.17 as they come alongside the NTBn waves). The first spot appears to interact with the prominent NTBn projection, but continues past it with no evidence for recirculation. The NTropZ is streaky and slightly reddish, with red blobs prograding in it [Nov.4,8,13]. AWOs are reappearing in the NEBn.
(B) The small bright NTZ AWO, at the f. end of the rifted sector of NTB (which is rapidly variable). A very dark streak of NTB(N) developing f. it. No N2 jet spots reach the AWO, but a pair of tiny dark spots in NNTBs & NTZ prograde up to it at DL2 ~ -1 deg/day (Nov.3 & 6).

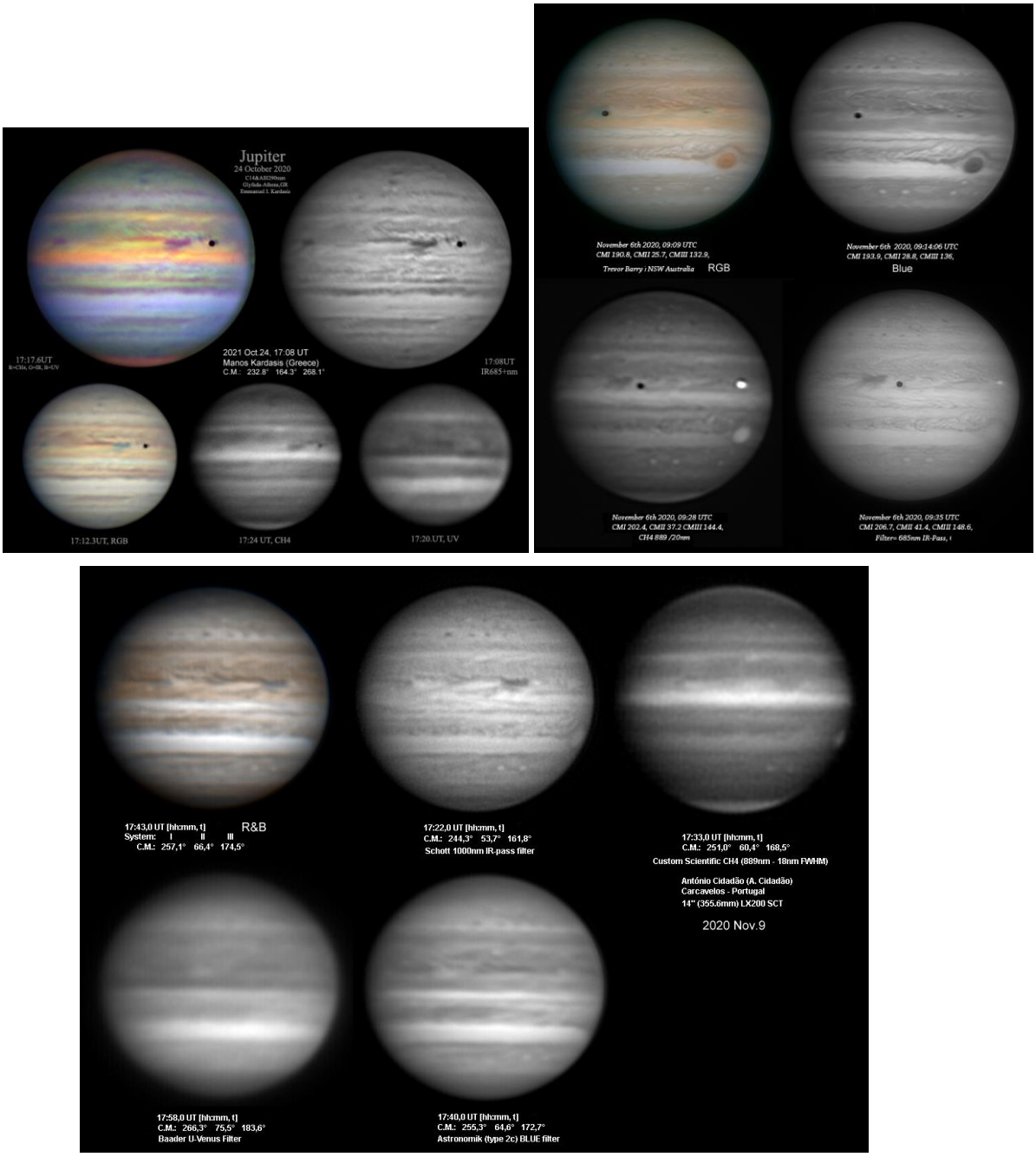


Figure 31. Multispectral image sets: (A) Manos Kardasis (Oct.24); (B) Trevor Barry (Nov.6); (C) Antonio Cidadão (Nov.9).

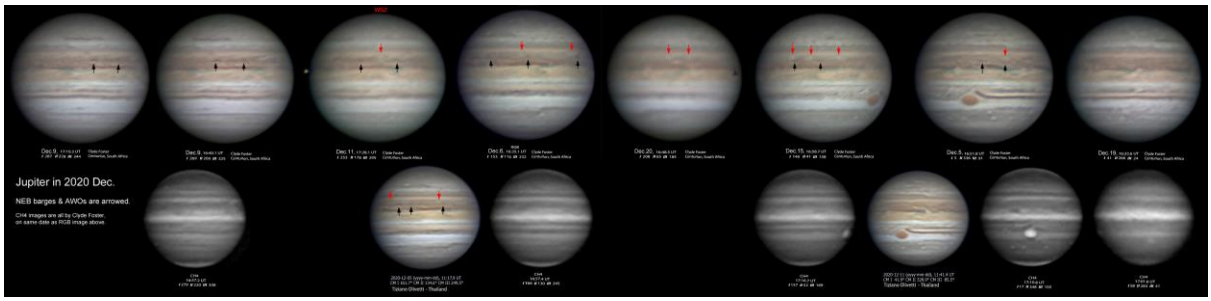


Figure 32. Set of RGB & CH4 images all around the planet in Dec., with arrows indicating NEBn AWOs (red) & barges (black).