Jupiter in 2022/23: Report no.2

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Report no.1 for this apparition was combined with our report on JunoCam's images at Perijove-41 (PJ41). Here we comment on the more interesting developments since then, particularly around PJ42 which was on May 23. During this period, the planet has risen high enough to enable observers to take hi-res images; we show maps in May & June (Figures 1 & 2), and a selection of the highest-resolution images in June (Figure 3). To give context for PJ42, we include a set of maps around that date (Figure 4) and images of the track shortly afterwards (Figure 5). (The PJ42 report is being posted separately.)

N2 domain

Four anticyclonic ovals in the NNTZ were tracked from 2021 (Figure 6):

LRS-1 (near L3~90) has been a rimless, strongly red spot at least since April 22 (Figures 1 & 2). It is very methane-bright, as usual. It was imaged by JunoCam at PJ39.

WS-4 (near L3~180) is moderately-to-weakly methane-bright, and is obscure in RGB images, close to a grey cusp on NNTBs [e.g. Foster, May 19 (see map in Fig.1) & Go, June 8 (see image in Fig.3)].
The first inbound image at PJ42 showed it as a weakly reddish oval, with white collar, surrounded by a broad grey rim. Go's image on June 25 (Figure 3) resolved the oval as a small grey annulus.

N3-w1 was an AWO in the N3 domain that translocated into the N2 domain in 2021 Sep. (at L2~186, L3~19). In 2022 it was difficult to trace until May 11, when it was at L3=16 and converging on WS-6. Niall MacNeill alerted us to their imminent merger, which took place in late May (Figure 7). They were in contact on May 23; N3-w1, shrunken, was moving around the N edge of WS-6 up to May 28; thereafter there was a single large AWO (Figure 5). NN-WS-6 has merged 3 times before (2019 Feb., 2019 Nov., 2020 Oct.) and this is the 4th time.

WS-6 (L3 ~ 10-->30) was bright white but only became strongly methane-bright on May 25 as the merger began; thereafter it was moderately methane-bright.

The NNTB is only visible in restricted sectors and even there it is very disturbed, with FFRs or otherwise. One notable sector is f. WS-6, where the NNTB is broadened and rifted (Figures 1,2,5,7). This happens to be the sector past which N3-w1 prograded, between its translocation from the N3 to the N2 domain and its merger with NN-WS-6. Its f. end showed remarkable cloud patterns in v-hi-res JunoCam images at PJ41 and PJ42 [ref. our PJ42 report]. More recently, this sector appears to be a FFR (Figure 2).

There is an extensive outbreak of dark spots along the NNTBs jet.

North Equatorial Belt (NEB) and Equatorial Zone (EZ)

The NEB faded and narrowed drastically in 2021, leaving only a narrow dark NEB(S). But since late 2021 there have been multiple convective outbreaks within a sector of NEB(S), which have gradually spread brown tint northwards into the faded mid-NEB, and produced disturbances all around the NEBs edge (ref. our PJ41 report = 2022 report no.1). Meanwhile, barges in the northern NEB became very dark in 2021 but have faded a lot during solar conjunction in 2022. In May & June, the NEB continued to revive but only partially. Dark brown material has spread far enough north to be drawn into loops around the fading barges, so the central latitudes of the belt have extensive moderately brown shading, but there is still no sign of convective ('rift') activity north of the NEB(S) (Figures 1, 2, 8). So, if this does deserve to be called a NEB revival, it is different from any SEB revivals, NTB revivals, or NEB expansion events, that have been observed in modern times, as they all crucially

involved energetic convective activity. On the other hand, it may give insights into some apparently calm belt revivals in the historical visual record. One possibility is that this calm partial revival will not progress further, and will be followed by an energetic NEB expansion event on schedule in 2023 as initially predicted (or up to two years thereafter). The process is not developing rapidly and may even have stalled in June.

There are still seven barges and six AWOs, as in late 2022 (Figures 3 & 8). All but one of the barges have become very pale, but each is surrounded by a brown loop. The AWOs mostly have a light grey rim, and are (unusually) methane-bright, esp. White Spot Z (WSZ) (Figures 3 & 4). WSZ is also particularly large. (WSZ, like the GRS, was passing L2=15 and L3=260 in April.) Their motions have stabilised: WSZ has DL3 = -2 deg/30d (DL2 = -10). Another AWO ~180 deg away has a similar rapid drift; otherwise, all barges and AWOs have drifts ranging from DL3 ~ +1.5 to +6.5 (DL2 = -6.5 to -1.5). Several of them were imaged (obliquely or distantly) at PJ41 and PJ42 (Figure 8).

Up to 2022 Feb., before solar conjunction, the narrow dark NEB(S) had increasingly frequent outbreaks of small bright white plumes, all in a limited sector and all behaving similarly, as we described previously [ref. our 2021 reports nos.6&7]. They produced two intensely methane-dark patches (MDPs) which were strongly retrograding in L1, and survived thru solar conjunction, corresponding to dark bluish spots on NEBs. Since solar conjunction, the sector containing these MDPs has become more extended and disturbed, with a third conspicuous MDP joining it in April and May (dp3 on the chart, with DL1 ≈ +1.9 deg/30d); this could have arisen from another plume outbreak unseen during solar conjunction. Figure 9 shows the tracks of all the bright and dark features in the NEB(S) & NEBs edge; details are in the caption. The complete maps and an animation of them are posted by S.M. on the ALPO-Japan web site [http://alpo-j.sakura.ne.jp/Latest/j_Cylindrical_Maps/j_Cylindrical_Maps.htm].

Since solar conjunction, the small plume outbreaks have become more numerous and difficult to distinguish apart, and there is disturbance all round the NEBs including MDPs, small NEBs projections, and bright spots. All the 2021 outbreaks from no.3 to no.8 (numbered in Figure 9) appeared on a single track with DL1 ~ +8 deg/30d, and in 2022 May, a pair of new outbreaks (nos.14 & 15) appeared on the same track and behaved similarly. But starting with no.9 in Jan., outbreaks have also occurred near the faster-retrograding MDPs. This is now the most disturbed sector of the NEBs (L1 ~ 260-360 around June 1). The frequency of outbreaks has increased from 5 in 6 months (2021 May-Oct.) to 4 in 3 months (2021 Nov.—2022 Jan.) and now 7 in 2 months (2022 May & June).

There is a wide range of drift rates on the NEBs relative to System 1, ranging from retrograding MDPs with DL1 ≈ +50 to +60 deg/30d to super-fast plumes and small projections with DL1 ≈ -28 to -50 deg/30d. The latter speeds match the ‘super-fast’ range that dominated the NEBs in late 2021. However, it seems that most features as of late June have drift rates closer to System 1, including a few recently-developed features that appear to be typical NEBs dark formations (NEDFs).

In the EZ, the ochre colour of the central band remains but is obviously weaker than in 2021.

South Temperate Domain

The earliest complete well-resolved map was JunoCam’s at PJ42 (May 23), but we could piece together a composite map from amateur images shortly before (Figure 1), and hi-res ground-based maps are now possible (Figure 2); v-hi-res images of important features are in Figure 3. These reveal the evolution of all the features that attracted attention in 2021.

There is still a substantial outbreak of dark spots prograding on the STBn jet (e.g. Figure 5). They are emerging p. STB segment G, at ≤~27.2°S [planetographic], but then mostly travelling at 25.3°S, which is an unusually low latitude, north of the canonical STBn jet [Ref.: Rogers J & Adamoli G (2015) 'Jupiter's South Temperate Domain, 2012-2015': http://www.britastro.org/jupiter/2014_15report08.htm]. Instead, this is typical of spots in the STropZ in the Circulating Current. Perhaps this could be an effect of the persisting F-Spectre?

There is now some kind of dark STB around half the planet. In order of increasing longitude:

The p. end of the darkened sector is a small white oval of uncertain nature, either the small anticyclonic oval that developed at the F-Spectre, or the cyclonic circulation derived from the F-Spectre itself. It is close to the p. end of STB segment G (the descendent of Clyde's Spot/DS7): this is now a well-defined turbulent sector 30-35° long (e.g. Figure 3). F. it, cyclonic oval WS6 is embedded in dark STB that extends to oval BA. Oval BA has slight 'warm' tint due to a dusky annulus within it. F. oval BA, STB segment A has continued to lengthen and is now 80-85° long, up to the small STZ AWO.

Around the remaining longitudes, the main STB is still faint, but the STBn jet spots and the 'Sf. tail' of segment A provide plenty of dark material along its edges. Spot 8 is confirmed as a dark brown oval (e.g. Figure 5); as a stable dark spot, it could be called DS8.

S2 domain

There are still 7 large AWOs, numbered A1-A5, A7 & A8; and now two cyclonic white oblongs, p. A5 and p. A2. In the latter position, a small light spot had developed in Dec, and was still dull in JunoCam images at PJ39 & PJ40, but became a distinct white oblong by the time of PJ41 (April 9).

Figures

(All figures have north up.)

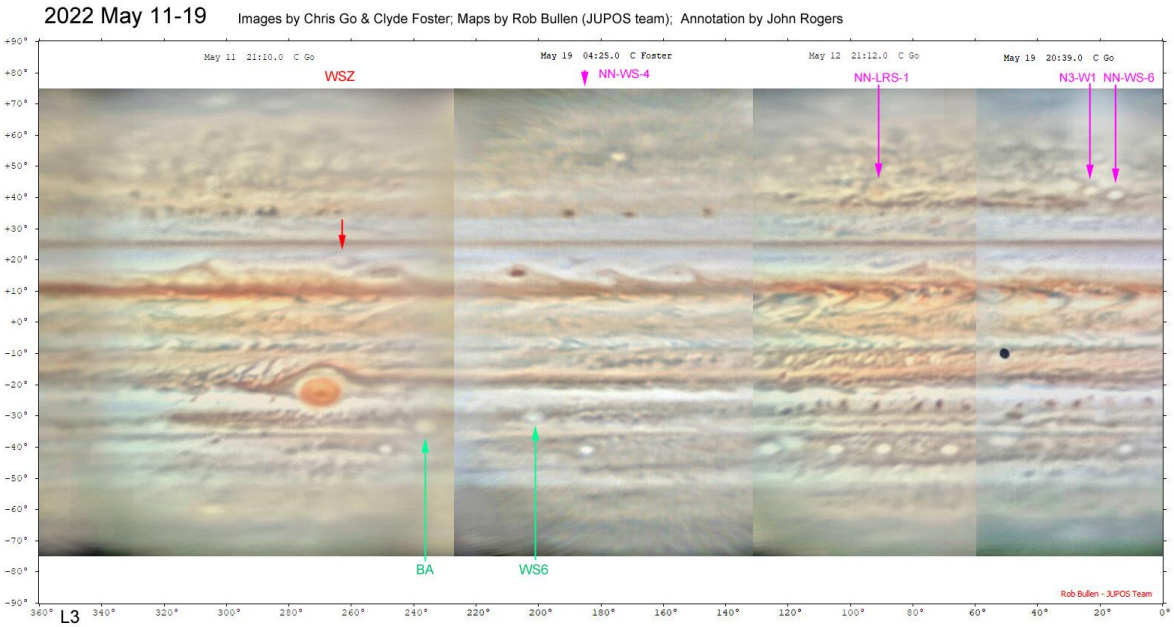


Figure 1. Map of the planet on 2022 May 11-19 (composite from various dates).

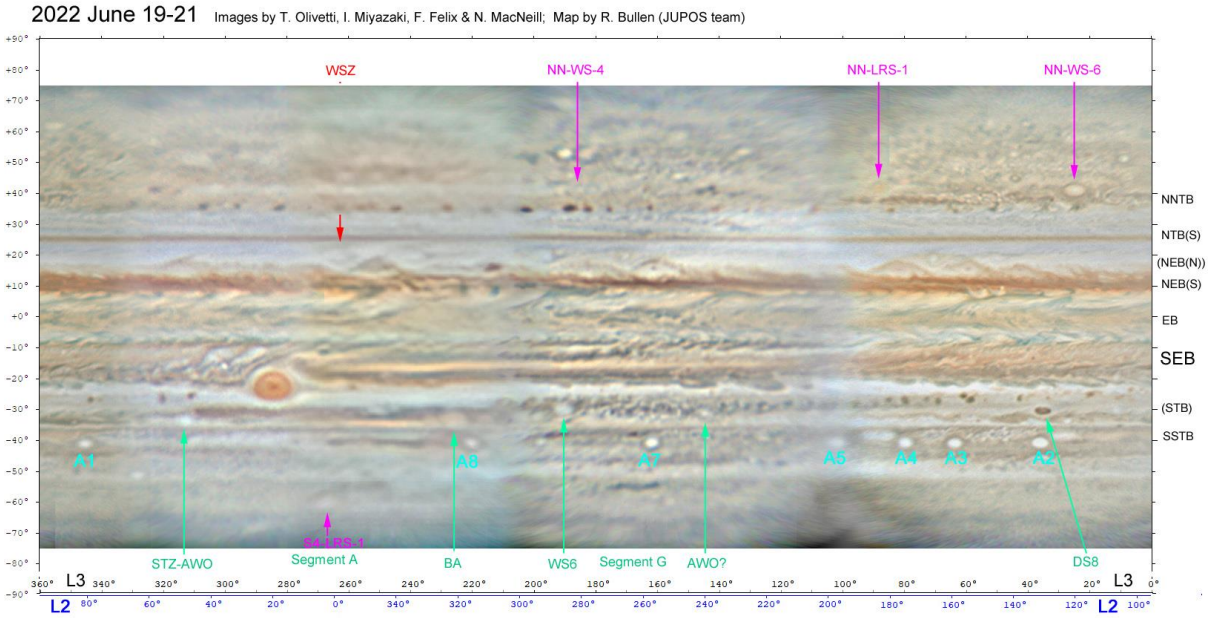


Figure 2. Map of the planet on 2022 June 19-21.

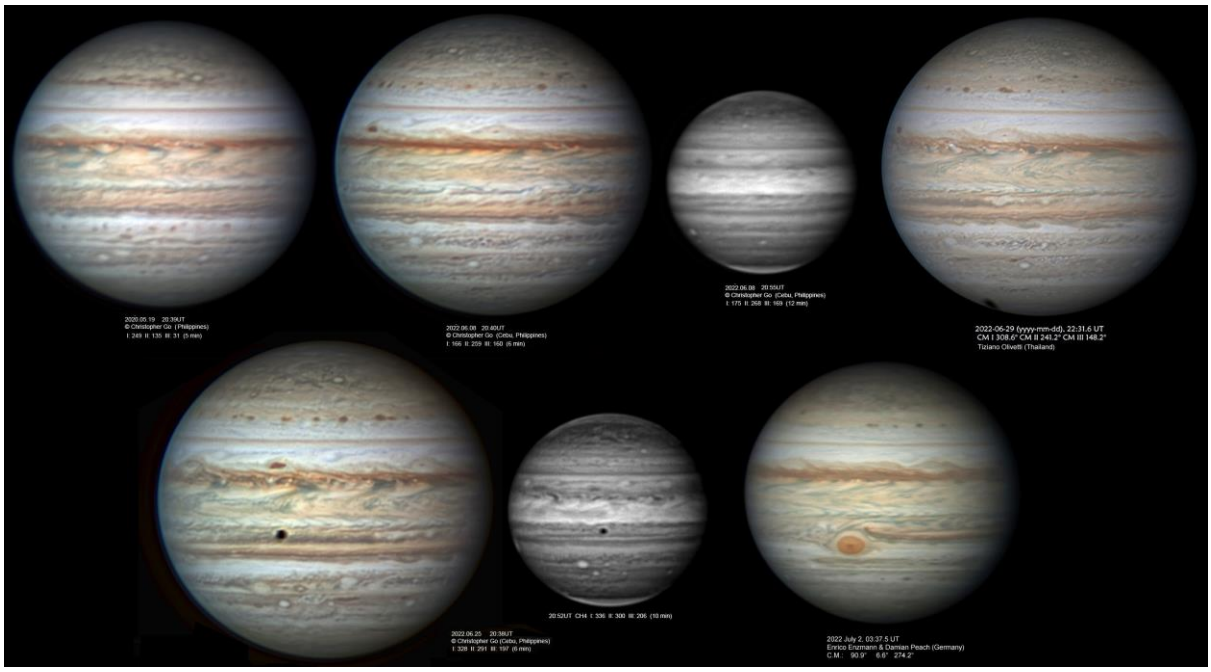


Figure 3. Some of the best hi-res images.

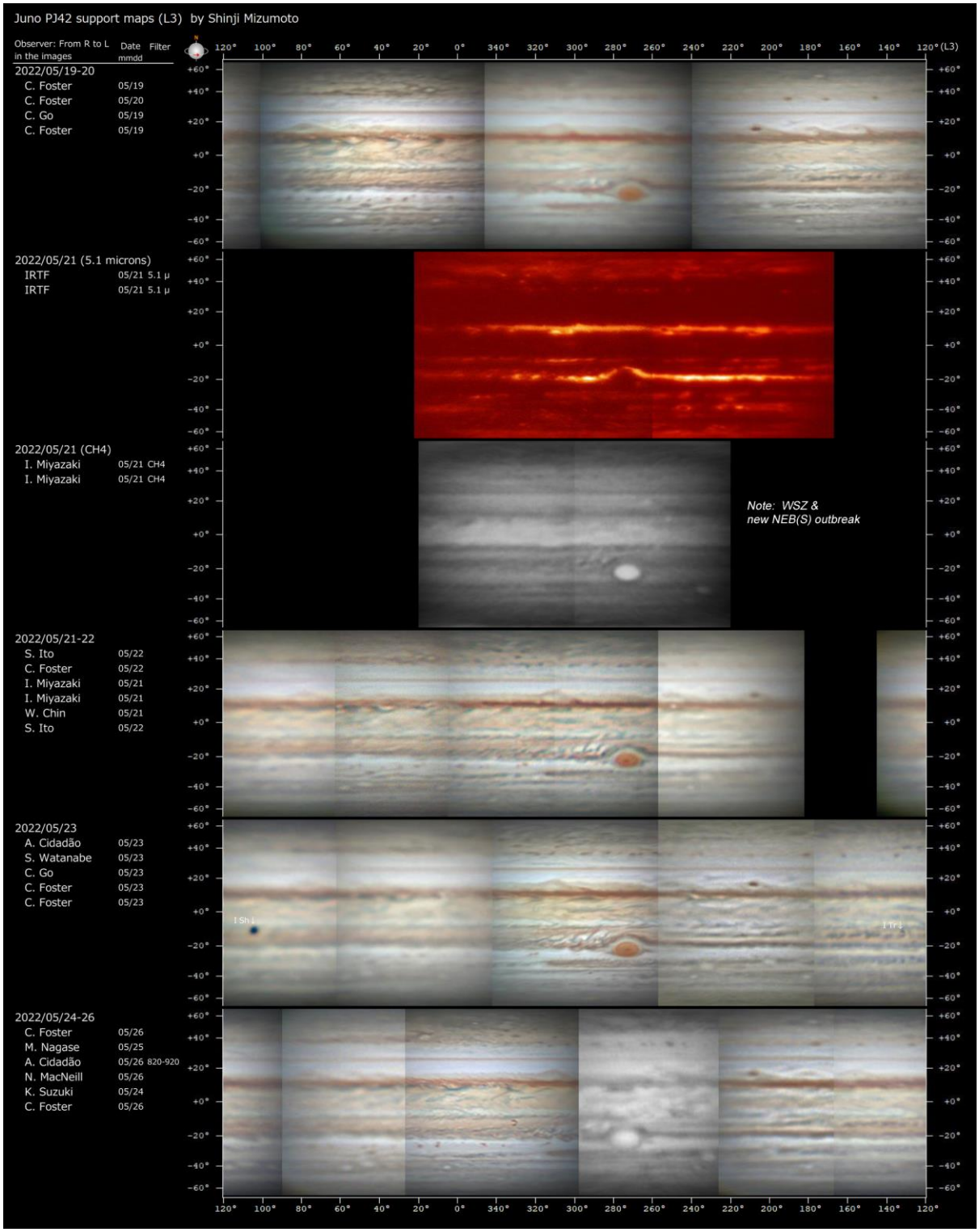


Figure 4. Maps of the planet around the time of PJ42.

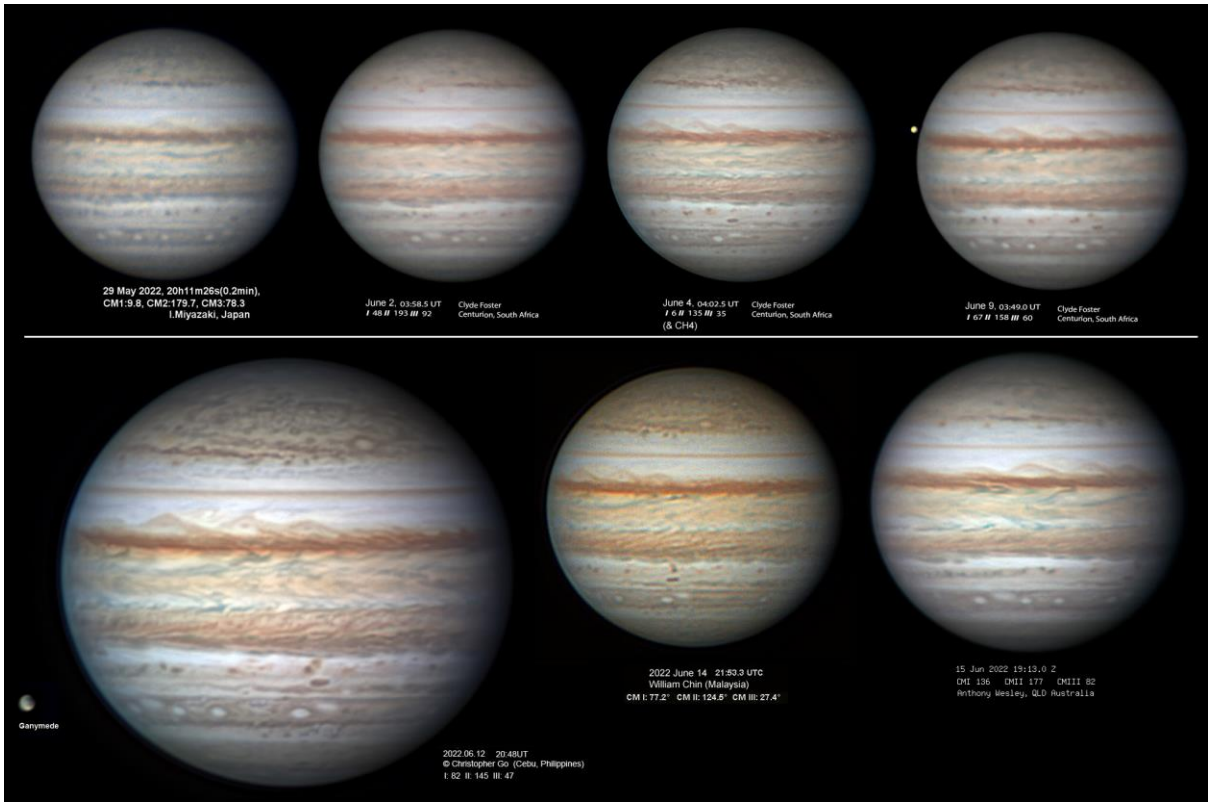


Figure 5. Set of images in the days after PJ42, showing the sub-spacecraft track.

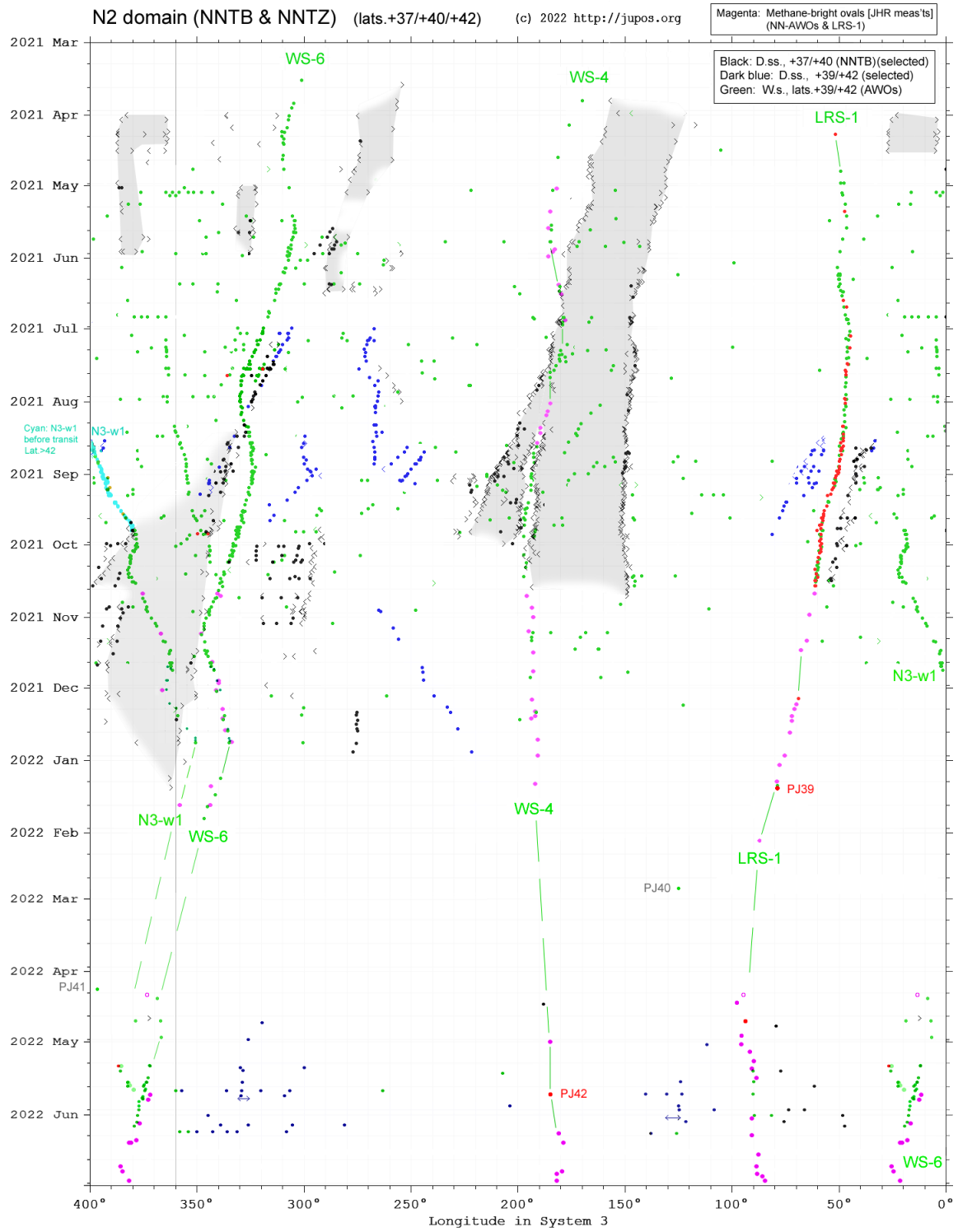


Figure 6. Chart of longitude vs time for the N2 domain, 2021-22, from the JUPOS team, showing the long-lived NNTZ ovals. (Plotted in L3, increasing from right to left to align with north-up maps).

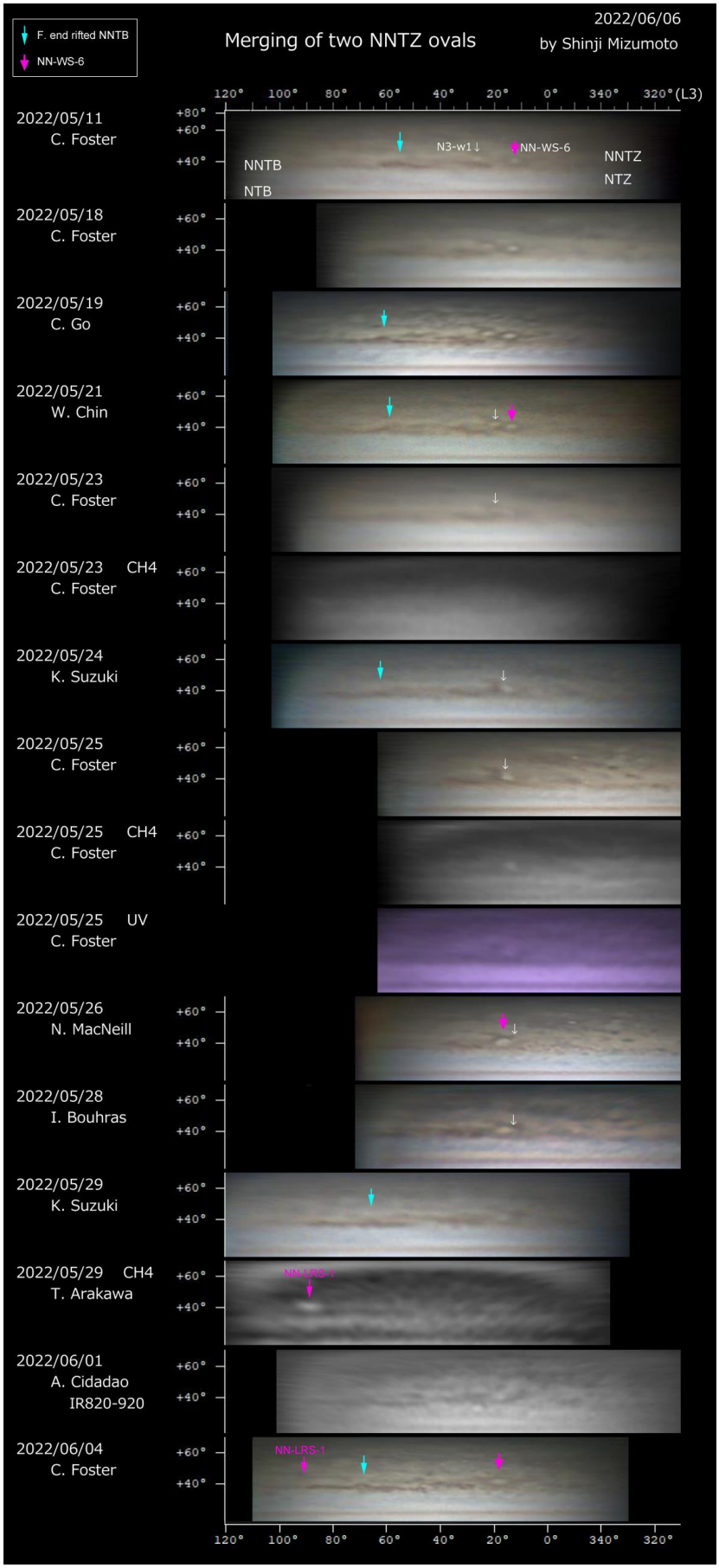


Figure 7. Maps of the N2 domain covering the merger of AWOs N3-w1 and NN-WS-6.

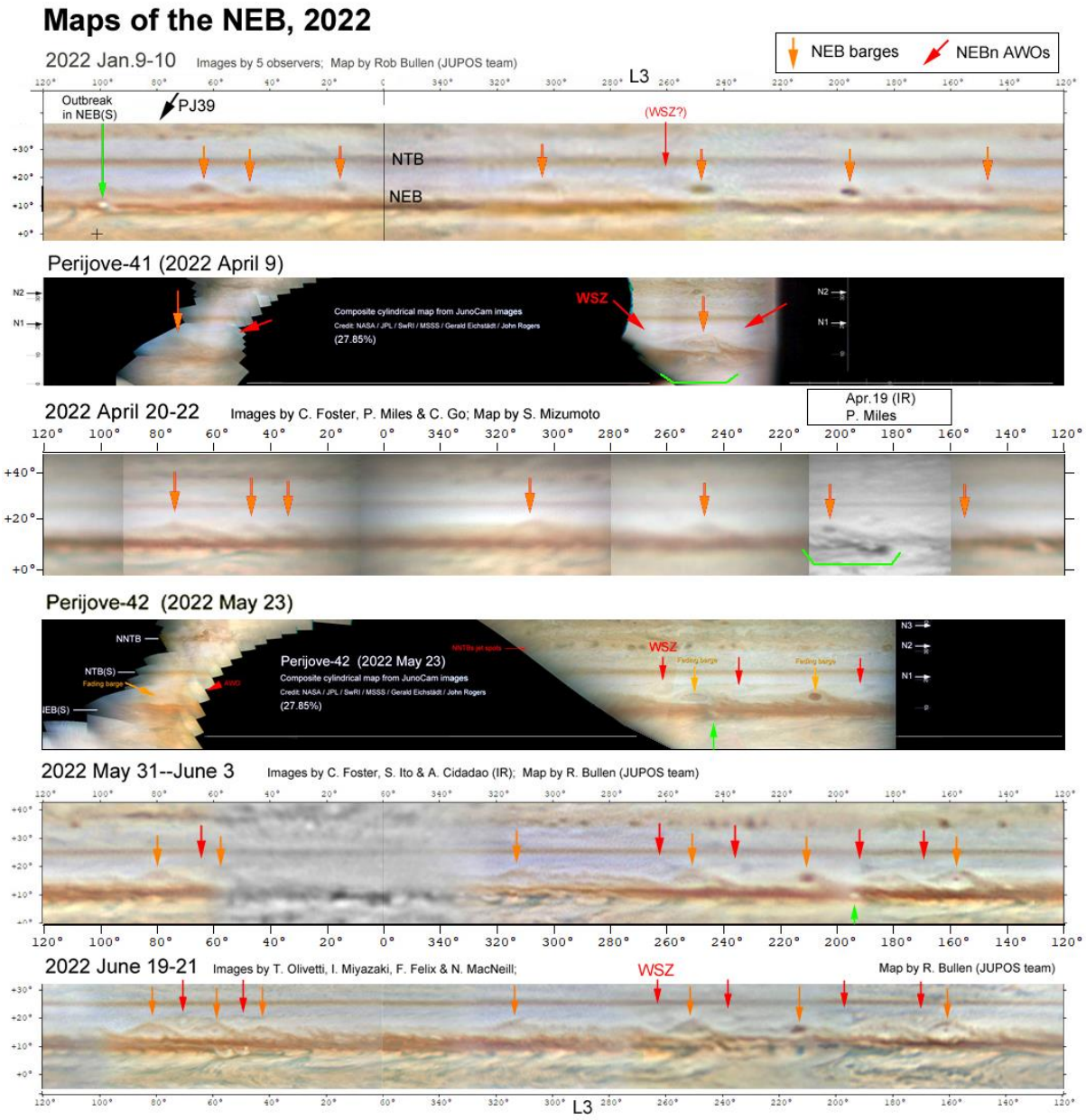
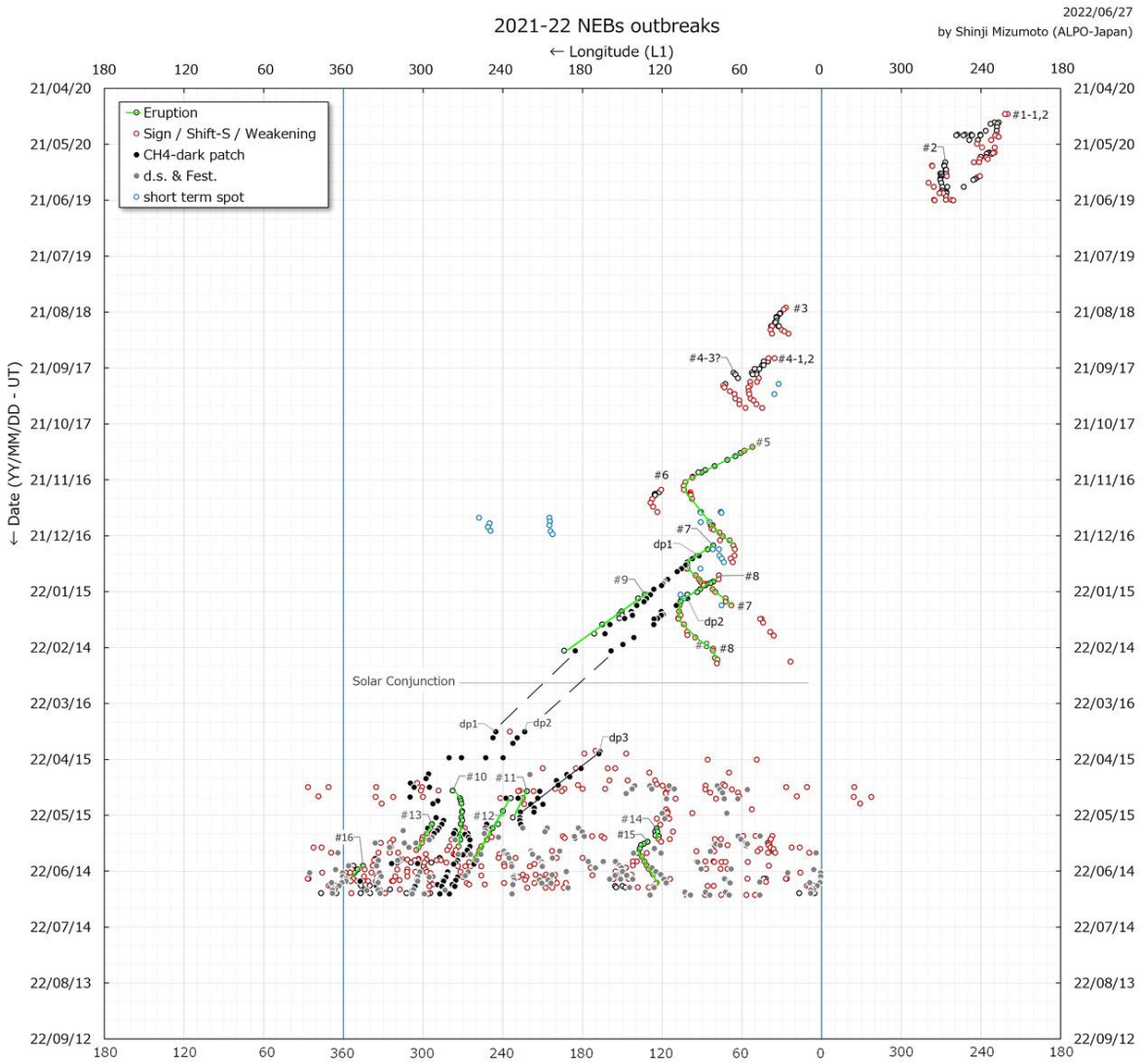


Figure 8. Maps of the N. Tropical domain showing the barges and AWOs and the gradual darkening of the mid-NEB latitudes, with extensive disturbance on the NEBs. (See our Juno PJ41 and PJ42 reports for the original JunoCam maps.)



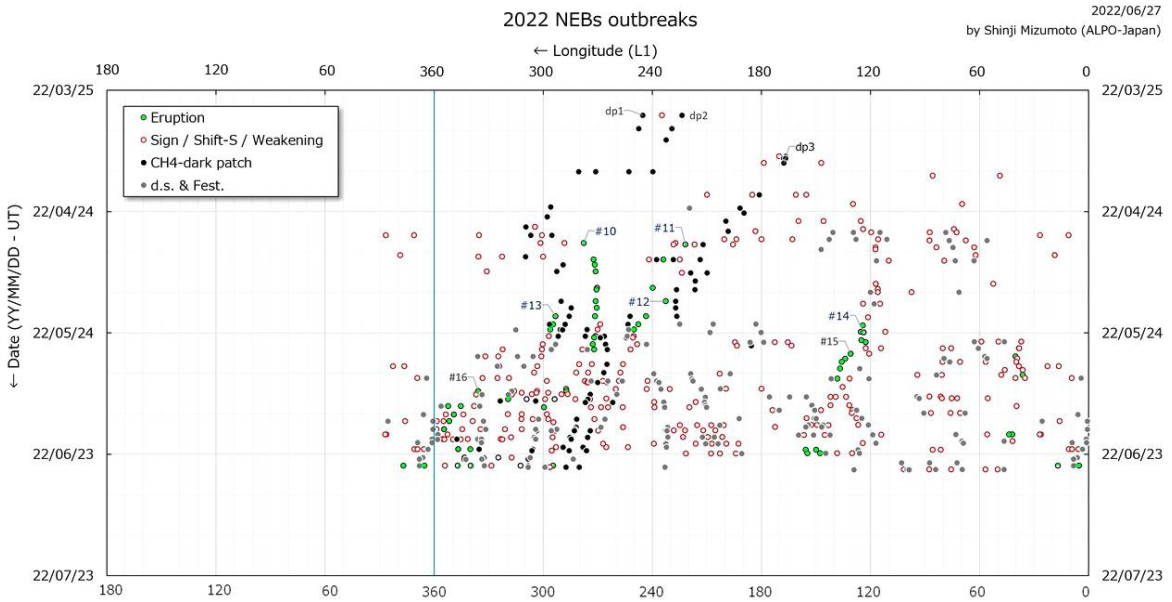


Figure 9. Charts of longitude vs time for the NEB(S), showing the bright plume outbreaks (highlighted in green) and other bright and dark spots. (Plotted in L1, increasing from right to left to align with north-up maps). (A) 2021-22; (B) 2022 apparition only. *[Continued...]*

The maps and charts produced by the ALPO-Japan show the following behaviour in 2022 May & June:

L1 ~ 260-360: The main disturbed sector, which included the three long-lived MDPs (very dark bluish NEDFs), though the first two are no longer traceable. The third (dp3) may have survived as a more modestly retrograding MDP/NEDF with DL1 = +28 deg/30d from late May to mid-June (at L1 265-->285). This sector was chaotic with small-scale disturbances until mid-June, then what look like three large typical NEDFs emerged, one just mentioned plus two with smaller DL1.

L1 ~ 200-250: Here there were three small prograding NEBs projections, initially continuing the super-fast drifts of 2021. In mid/late May, they appeared near L1 = 250 (prograded to L1 ≈ 230 and halted there); 230 (prograded to L1 ≈ 200; DL1 ≈ -35 deg/30d, but -50 deg/30d for an associated white spot); and 210 (prograding but torn apart in early June).

L1 ~ 120-200: Small-scale prograding projections, and occasionally a larger but short-lived feature. In late May at L1 ~ 125 occurred NEB(S) outbreaks nos.14 & 15; like previous ones, they initially retrograded but then broke thru into EZ(N) and prograded (-27 deg/30d for no.15).

L1 ~ 60-120: Small-scale features, probably rapidly prograding but not imaged consistently enough to track if they persisted.