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Jupiter's NTBs jet outbreak 2025: Convective plumes and plumelets

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Outbreaks of activity on the eastward jet stream on the south edge of the North Temperate Belt (NTBs jet) are spectacular, infrequent phenomena, which include the brightest and fastest-moving spots that Jupiter ever displays. These are believed to be tall plumes driven by moist convection in the water cloud layer below the visible clouds, where the jet is faster than at the cloud tops ('super-fast') [refs.1&2]. Currently they occur every 4 to 5 years [ref.3]. The latest outbreak began on 2025 Jan.10, and has been one of the best observed ever. Here we describe the great plumes and smaller 'wake-induced plumelets' as recorded by amateur observers and by JunoCam. A companion abstract 51 (ODAA4 session) describes the zonal wind profiles and feature drifts as they changed during the cycle.

Because of the high speed of the NTBs jet, maps and charts are plotted in System 1 longitude (L1) unless otherwise stated. Drift rates (DL1) are given in degrees per day; DL3 = DL1 - 7.364 deg/day. Latitudes are planetographic.

The three primary plumes: Plume 1 is shown in Figure 1. It was extremely bright at all wavelengths, especially the methane absorption band (889 nm). In Fig.1A, the brightest cloud in the methane band (the head of the plume) was not the brightest in RGB and near-IR continuum, showing that different parts were at different levels. The second primary plume (only 20º preceding plume 1) appeared on Jan.27, and the third (dubbed Plume 5) on Feb.9.

Early acceleration and latitude shift: All three plumes first appeared at 24.0-24.6ºN, then drifted south and accelerated within a few days (Fig.2), to remain at 23.3 (±0.3)ºN with sustained speeds of DL1 = -5.0, -5.1, and -4.6 deg/day (u = 160-167 m/s). The early acceleration could be due to the change in latitude, following a fixed zonal wind profile (see companion abstract 51). This behaviour supports the theoretical model [ref.2], in which the plumes were convective storms rising from the super-fast jet in the water-cloud layer, initiated with an arbitrary heat pulse; but modelling required this initial source to be at about 24.5ºN, not at the mature plume latitude. This is just what we have observed for all three plumes in 2025. However in 2020, while the three plumes showed a similar early acceleration, we did not find any significant shift in latitude, despite high-quality observations [ref.3].

Plume 1 with lightning: It is well known that many convective eruptions on Jupiter are thunderstorms, but until now there was no direct proof for these greatest of all plumes. On Jan.28/29, Juno flew past Jupiter at perijove-69 (PJ69). The outbreak was not in JunoCam's field of view during the sunlit inbound phase; but a dark-side image revealed two lightning flashes or clusters at 23.2ºN (20.6ºN planetocentric), near the edge of the frame. The brighter of these was on the edge of the head of plume 1 (Fig.4), confirming that the plume is a thunderstorm.

Demise of the plumes: The plumes always disintegrate within a few days when they catch up with the slower-moving wake of the next plume to the east, and this happened to plume 1 on/about Feb.2 (Fig.3). Thereafter, plumes 2 and 5 persisted at full strength until Feb.25, when they each caught up with the expanding wake of the other and started to fade. By March 1 only small remnants were left. This suggests that the convection can no longer be sustained where these storms have disrupted the pre-existing vertical atmospheric layering. Both also decelerated after Feb.25, and moved slightly south, to ~22.7ºN. This may mean that the surface current was still less than the super-fast speed of the plumes, so as soon as their deep convection was cut off, they began to be advected with the higher-level winds, like small northerly bright spots trailing behind the plumes earlier.
Juno's PJ70 occurred on March 2, and JunoCam would have had a fine view of plume 5, but it had just disappeared. So JunoCam obtained an excellent view of the turbulent wake just afterwards (Fig.5).

Wake-induced plumelets:
Bright spots were repeatedly observed near the following (west) end of the wake, which seemed to be weaker versions of the main plumes, therefore designated as plumes 3,4,6,7,8 (e.g. Fig.3). They were also methane-bright, and accelerated to speeds almost as fast as the main plumes, but only lasted for 3-10 days. Mean drifts were ~-3.9 to -4.6 deg/day ($u \approx$ 150-160 m/s), at 23.2 to 24.1ºN. We suggest that the intense disturbance along the wake of the outbreak, while suppressing the jet speed at cloud-top level, is sensed in the super-fast water layer just beyond the end of the wake and thus triggers short-lived plumes, but these are themselves disrupted as they advance into the wake. These wake-induced plumelets have also been observed in some previous outbreaks and are a newly-recognised feature of these events. Fig.6 is a sketch of our present model of the outbreak.

In our companion abstract 51 (ODAA4 session), we show that the cloud-top winds never achieved the full speed of the deeper super-fast jet as shown by the plumes and plumelets. Full details of these studies are in our 2024/25 Report no.5 [ref.4]. Details of the observations are posted in our regular reports on the JunoCam and BAA websites:
https://www.missionjuno.swri.edu/junocam; https://britastro.org/sections/jupiter

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References:
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3. Rogers J & Adamoli G (2021): ‘Jupiter in 2020, Report no.9: Final report on northern hemisphere.’ https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2020/jupiter-in-2020-report-no-9-final-report-on-northern-hemisphere
4. Rogers J et al.(2025). ‘Jupiter in 2024/25, Report no.5: The NTBs outbreak.’ https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2024-25/report-no-5-ntbs-outbreak

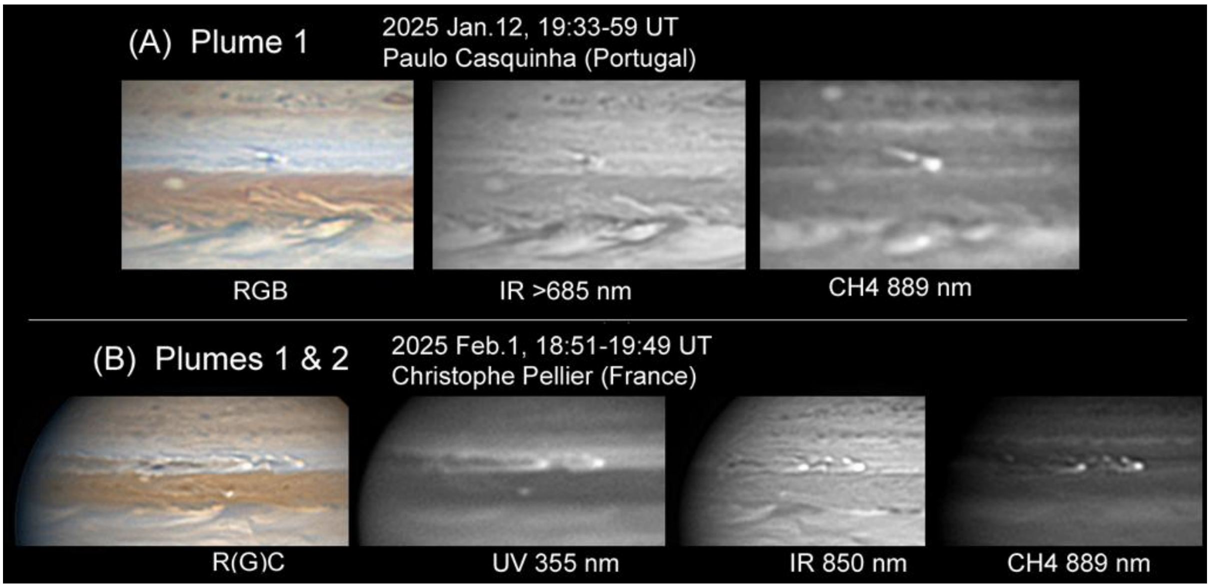

Figure 1. Multispectral image sets showing the plumes.

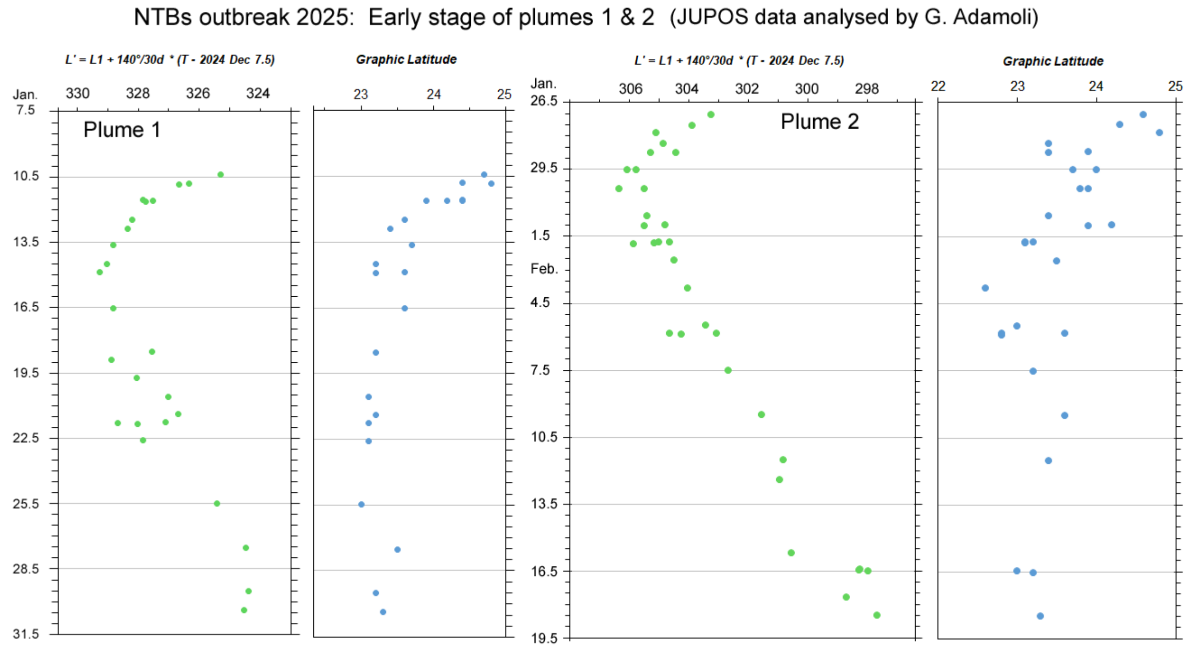

Figure 2. Charts of longitudes and latitudes for the early stages of plumes 1 & 2. Longitudes are plotted in a system moving with L1 – 4.667 deg/d.

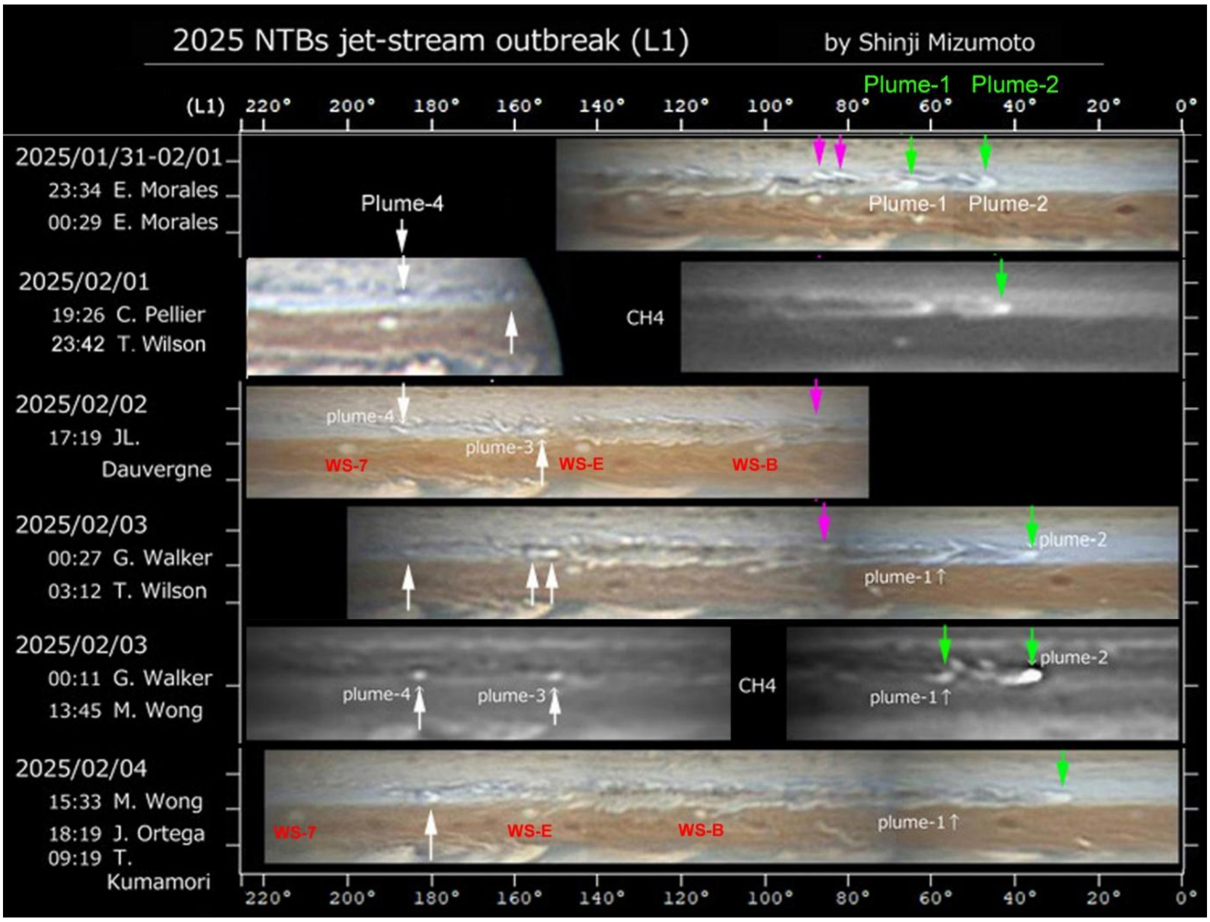

Figure 3. Strip-maps from Feb.1-4. They show plume 1 disappearing (green arrow); miniplumes 3 & 4 (white arrows); and a northerly white spot (magenta arrow).

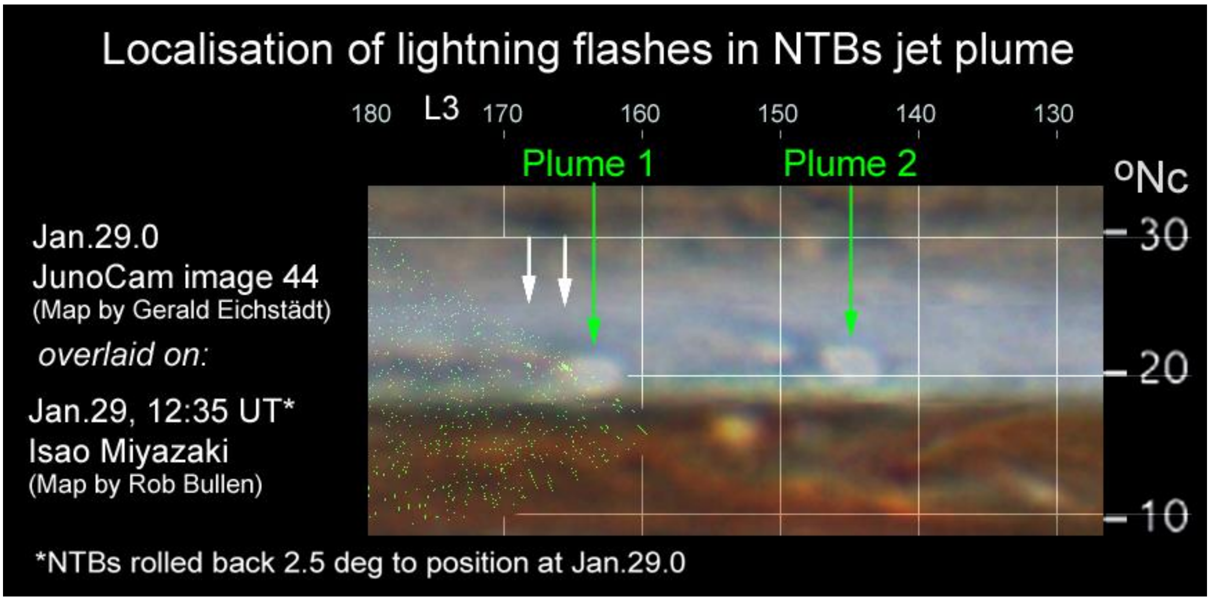

Figure 4. Map of the JunoCam dark-side lightning image merged with day-side ground-based map, showing how the lightning flashes (white arrows) come from the edge of the first plume and just west of it.

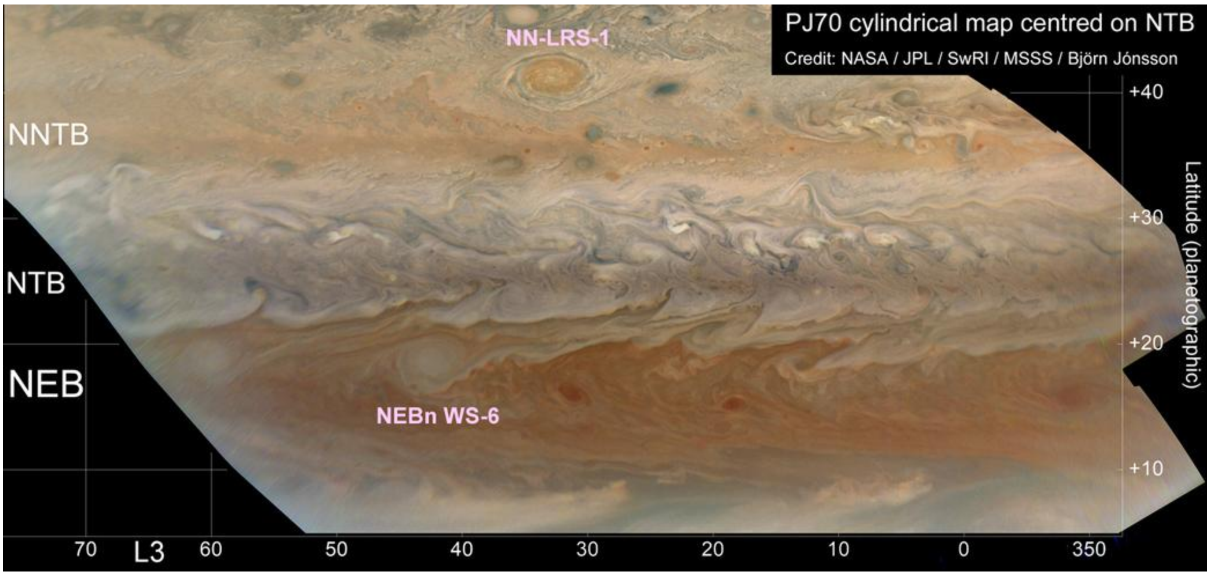

Figure 5. Map projection of JunoCam PJ70 images, showing the turbulent wake comprising the reviving NTB on March 2. Plume 5 would have been just north of NEBn WS-6, had it not just disintegrated.

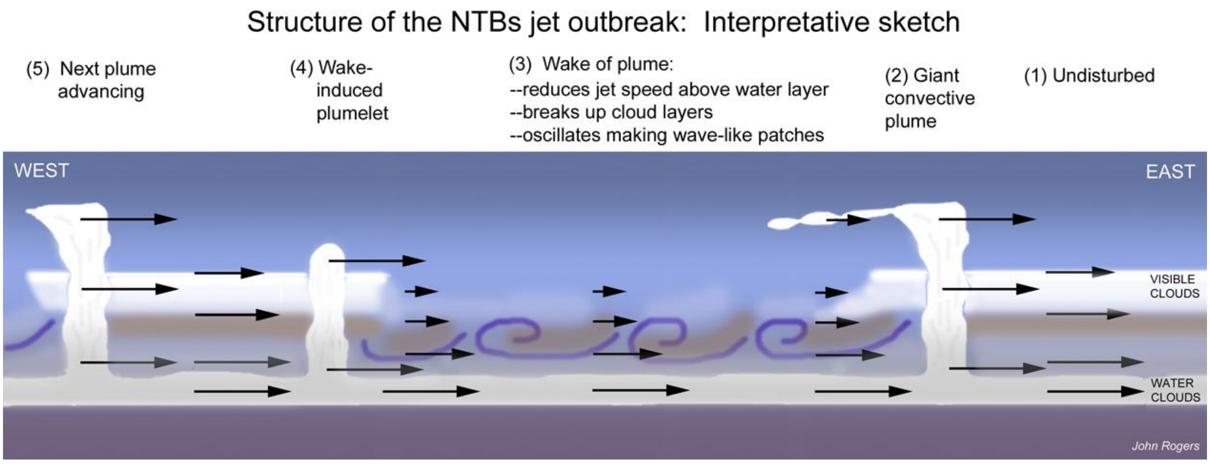

Figure 6. Diagram of the proposed structure of the outbreak, shown as a vertical profile (vertically much exaggerated) along the latitude of the NTBs jet. Arrows indicate the eastward wind strength. This is only a qualitative sketch, and is not intended to suggest any specific dynamical processes in the wake. Read from right (east) to left (west).