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Jupiter's NTBs jet outbreak 2025: Zonal winds at cloud-tops and below

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The jet stream on the south edge of the North Temperate Belt (NTBs jet) is liable to spectacular disturbances that emerge from deep below the visible cloud-tops. Between 1970-1990, and since 2007, these have occurred in 4-5-year cycles in which whitening of the belt is followed by outbreaks of brilliant white spots (plumes) travelling at -4.8 to -5.5 deg/day in L1 (u_3 = 163-173 m/s), generating dark turbulent wakes behind them and leading to revival of the belt. The white spots are considered to be convective plumes rising from the water-cloud layer below the visible clouds [e.g. refs.1&2]. The observed cloud-top peak speed of the NTBs jet varies through this upheaval cycle. Just after an outbreak it is lowest, then it accelerates over the years before the next one (although perhaps not steadily); then the plumes appear with speeds even faster than winds recorded otherwise (Figure 1).

The latest outbreak in this series began on 2025 Jan.10. It was very well observed by amateur astronomers, and reveals new details of the changes of the winds before and during the upheaval. The plumes in 2025 are described in a companion abstract (session OPS8). Here we consider what the amateur observations have revealed of the overall structure of the jet during the cycle, at the deep layer from which the plumes arise, and at the cloud-top layer which we observe.

System 1 longitude (L1) is used unless otherwise stated. Drift rates (DL1) are given in degrees per day; DL3 = DL1 - 7.364 deg/day. Equivalence to u_3 (m/s) is shown in Fig.1.

The three primary plumes:

All three primary plumes first appeared at 24.0-24.6ºN, then drifted south and accelerated eastward within a few days (see companion abstract), to remain at 23.3 (±0.3)ºN with sustained speeds of DL1 = -5.0, -5.1, and -4.8 deg/day. Typical images are in Figs.2&3; tracks are in Fig.4. As usual, they all broke up within a few days when they caught up with the wake of the next plume ahead.

The wake and wake-induced plumelets:

As usual, a complex wake grew rapidly (~5 deg/day) following each primary plume, consisting of the following elements (Fig.3). These had a wide range of speeds, all slower than the plumes.

- i) Large dark patches which formed every few days, at ~23.5-24ºN, with a wave-like appearance. Their slow speeds were ill-defined but consistent with mean speeds in previous outbreaks ranging from DL1 = -0.8 to -1.6 deg/day (u_3 = 108-120 m/s), supporting their wave nature.
- ii) White clouds on the northern and southern sides of the wake, apparently streaming behind the plumes.

- iii) 'Wake-induced plumelets': small bright, methane-bright spots arising at the following end of the growing wake, accelerating to speeds similar to the main plume but short-lived. We tracked at least five of them (Fig.4). We suggest that they are similar plumes triggered by the approach of the following end of the wake, but in this situation they are less intense and are short-lived (see companion abstract).

Zonal drift profile & zonal wind profiles:

The drift rates and latitudes of tracked spots are plotted as a zonal drift profile (included in Fig.5B). All the bright spots – plumes, plumelets, and smaller white spots on the N edge of the wake – fit onto a consistent curve. The northern part of this, representing the wake-induced plumelets and the first few days of the main plumes, matches the typical spacecraft-measured zonal wind profile (ZWP) in quiescent states, so it cannot determine whether the speed at deeper levels is different from that at the cloud-tops. However, the main plumes then extend the profile to faster speeds and lower latitudes. All fit a profile which peaks at 23.3ºN, DL1 = -5.1 deg/day (u_3 = +166.6 m/s).

As the plumes are believed to be driven from a deep layer, this may represent the ZWP down at that level. But how are the observed cloud-top winds affected by the deeper winds, either before or during the outbreak? Does the deep ZWP take over the cloud-top winds, or is it only manifested by the plumes themselves? To investigate these issues, we have established the ZWP using hi-res amateur images taken two months before the initial outbreak and several weeks after it, and we compare the results with those published for previous outbreaks (Fig.5).

Previously published pre-outbreak ZWPs all had peaks at 160-163 m/s (1979-2009) or 156-159 m/s (2015-16) at 23.6-23.9ºN, with no systematic change during the year before the outbreak. Our pre-outbreak profile, in 2024 Nov., had a sharp peak at 150 m/s at 23.5ºN. This slightly slower speed could be connected to the reduced interval between outbreaks since 2012. The plume speeds in 2020 and 2025 were likewise somewhat slower than before. Otherwise, all these results are highly consistent.

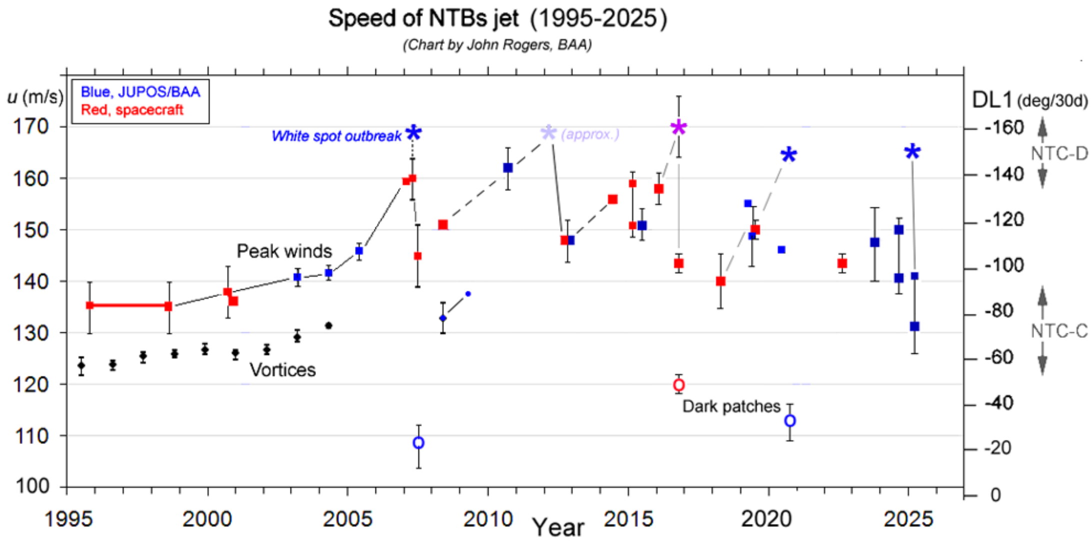
Our profiles in 2025 Feb. – covering the wake – are the earliest yet produced during an outbreak, and range from a narrow peak at ~141 m/s to a broad peak at ~126-136 m/s. When compared with previous ZWPs from spacecraft, these profiles confirm that there is no detectable acceleration of the cloud-top ZWP during the outbreak, apart from broadening on the flanks of the wake; instead, it quickly collapses to a slower but sometimes broader state. Then it recovers gradually over the next two years or so.

These results confirm that the jet is faster at depth than at the cloud-tops, comparable to the NEBs (7ºN) jet as shown by the Galileo Probe. The plumes and plumelets erupt from the deep-level jet, but other features at cloud-tops in that latitude do not achieve this speed.

The plumes in 2025 are described in a companion abstract (session OPS8). Full details of these studies are in our 2024/25 Report no.5 [ref.3]

References:

- Sanchez-Lavega A et 24 al. (2008) Nature 451, 437-440.
- Sanchez-Lavega A, Rogers JH, et al.(2017). GRL 44, 4679–4686. DOI: 10.1002/2017GL073421
- Rogers J et al.(2025). https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2024-25/report-no-5-ntbs-outbreak



Speed of NTBs jet (1995-2025)
(Chart by John Rogers, BAA)
u (m/s)
Blue, JUPOS/BAA
Red, spacecraft
White spot outbreak
(approx.)
Peak winds
Vortices
Dark patches
DL1 (deg/30d)
NTC-D
NTC-C
Year

Figure 1:

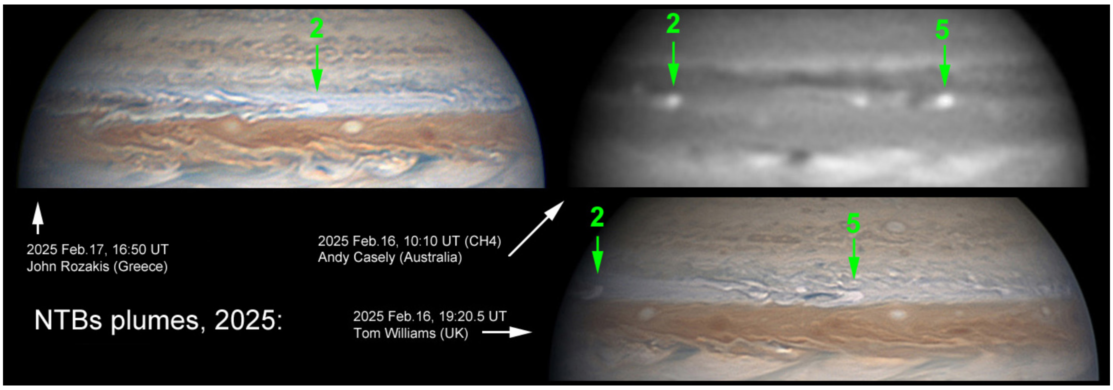


Figure 2:

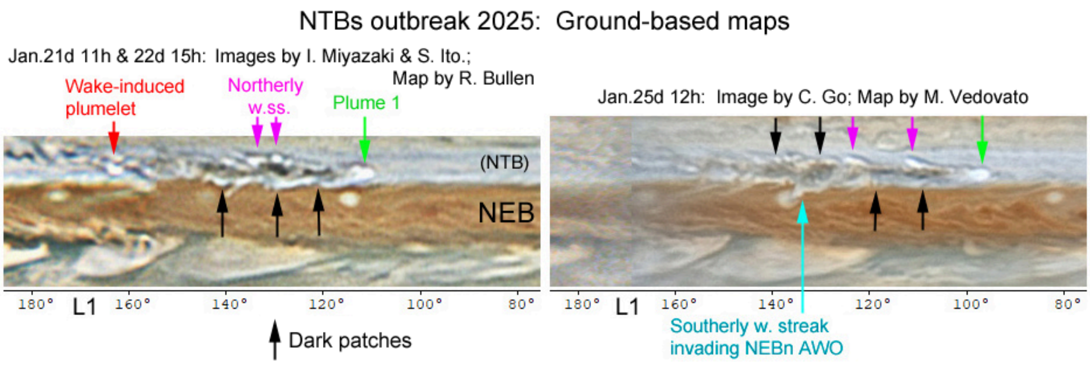
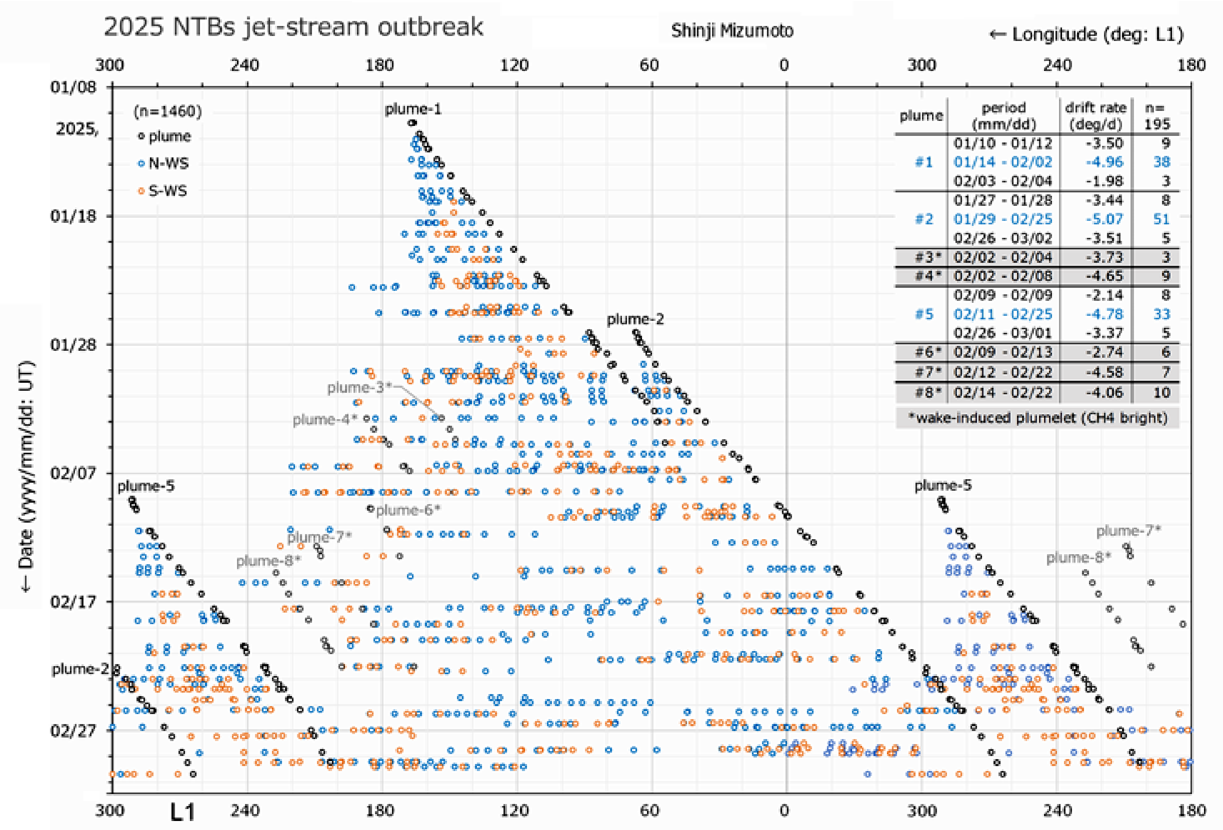
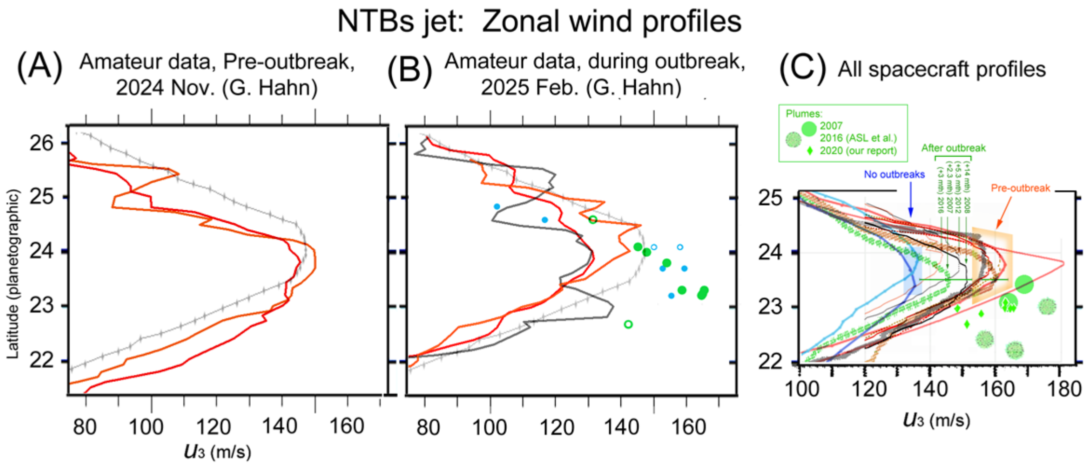


Figure 3:

Figure 4:


2025 NTBs jet-stream outbreak
Shinji Mizumoto
← Longitude (deg: L1)
← Date (yyyy/mm/dd: UT)
(n=1460)
plume
N-WS
S-WS
plume-1
plume-2
plume-3*
plume-4*
plume-5
plume-6*
plume-7*
plume-8*
L1
plume | period (mm/dd) | drift rate (deg/d) | n= 195
#1 | 01/10 - 01/12 | -3.50 | 9
01/14 - 02/02 | -4.96 | 38
02/03 - 02/04 | -1.98 | 3
#2 | 01/27 - 01/28 | -3.44 | 8
01/29 - 02/25 | -5.07 | 51
02/26 - 03/02 | -3.51 | 5
#3* | 02/02 - 02/04 | -3.73 | 3
#4* | 02/02 - 02/08 | -4.65 | 9
#5 | 02/09 - 02/09 | -2.14 | 8
02/11 - 02/25 | -4.78 | 33
02/26 - 03/01 | -3.37 | 5
#6* | 02/09 - 02/13 | -2.74 | 6
#7* | 02/12 - 02/22 | -4.58 | 7
#8* | 02/14 - 02/22 | -4.06 | 10
*wake-induced plumelet (CH4 bright)



NTBs jet: Zonal wind profiles
(A) Amateur data, Pre-outbreak, 2024 Nov. (G. Hahn)
(B) Amateur data, during outbreak, 2025 Feb. (G. Hahn)
(C) All spacecraft profiles
Latitude (planetographic)
26
25
24
23
22
80
100
120
140
160
180
U3 (m/s)
Plumes:
2007
2016 (ASL et al.)
2020 (our report)
After outbreak
(+14 mth) 2008
(+5.3 mth) 2012
(+2.3 mth) 2007
(+3 mth) 2016
No outbreaks
Pre-outbreak

Figure 5: