The major circulations in Jupiter's North Tropical domain

John H. Rogers (1), Gianluigi Adamoli (2), Hans-Jörg Mettig (2), Michel Jacquesson (2), Marco Vedovato (2)

(1) British Astronomical Association, Burlington House, Piccadilly, London, UK; (2) JUPOS team.

1. Introduction

Jupiter's North Tropical domain covers the North Equatorial Belt (NEB: cyclonic) and North Tropical Zone (NTropZ: anticyclonic). Here we analyse ground-based amateur images from 1997 to 2015 with data from the JUPOS project, to describe the nature and behaviour of the major circulations therein, both cyclonic (dark brown ovals, called 'barges') and anticyclonic (white ovals, AWOs). Arrays of these circulations typically appear about a year after a NEB broadening event, which occurs every 3-5 years. Most of the circulations disappear between these cycles. The only one which has persisted through the whole period is a very bright AWO called White Spot Z (WSZ) [1].

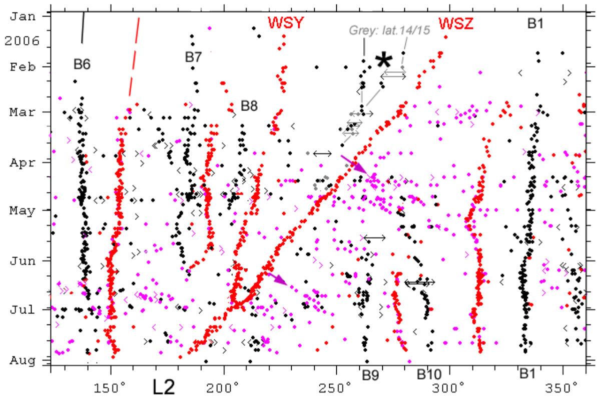

Figure 1. Excerpt from JUPOS chart of longitude vs time for N. Tropical spots. Red, white spots, lats.+18/+21 (AWOs); mauve, white spots, lats.+15/+18 (some on retrograde jet, arrowed); black, dark spots, lats.+15/+18 (barges). Note rapid drift of WSZ, its merger with WSY, merger of two small barges (asterisk), & origin of new barges among retrograding spots following WSZ.

2. White spot Z, the long-lived AWO

WSZ is a great AWO at 19ºN (Fig.2). But when the NEB is narrowed so that WSZ is in the N. Tropical Zone, its oval form is often obscured by a pale grey streak, whereas a tiny, bright white spot appears on its N edge. During the great NTBs jet outbreaks in 2007 and 2012, WSZ became dark grey.

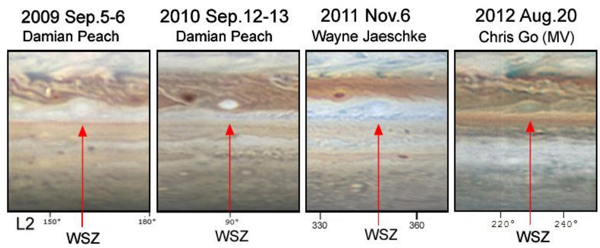

Figure 2. Views of WSZ, 2009-2012, from cylindrical-projection maps. The map labelled (MV) was made by Marco Vedovato. Note the variations in width of the NEB and in the appearance of WSZ. South is up in all figures.

WSZ almost always has a faster drift than other AWOs in the domain, and lies slightly further north. Its dominant nature is evident from its powerful effects on barges and AWOs that it approaches. In its early years, it eliminated other spots preceding it; later it more usually accelerated them to its own speed, 'pushing' them ahead of it and sometimes causing them to merge with other spots further ahead. After the great northern upheaval of 2012, it accel-erated to an exceptionally rapid speed, and collided with an AWO preceding it in early 2013.

Six months later, WSZ had become strongly methane-bright, which is unprecedented for these AWOs. Then it gradually acquired a reddish tint, also unprecedented (first reported by C. Go), which persisted as the oval brightened in early 2014, though the colour remained weak. The colour and methane-brightness faded away again by early 2015. We suspect that the partial merger in 2013 intensified the circulation of WSZ, leading to a gradual thickening of its cloud cap, which then became reddish as well. Red colour is seen intermittently in the largest and longest-lived anticyclonic ovals in several domains on Jupiter [2], including oval BA which reddened 6 years after forming by a triple merger, and some seen historical-ly in the same latitude as WSZ, so WSZ could in future become a Little Red Spot.

3. Zonal drift profile and zonal wind profile

The variation of east-west speed with latitude has been plotted for defined spots (Zonal Drift Profile, ZDP, from ground-based observations) and for small-scale cloud textures (Zonal Wind Profile, ZWP, from spacecraft). As in most domains, the ZDP coincides with the ZWP for prograding speeds but is systematically 'blunter' for retrograding speeds, i.e. the barges and AWOs are only partially entrained by the NEBn retrograde jet. The full speed of the NEBn retrograde jet is only occasionally detected (Fig.3). It was detected in 2006, following WSZ and following a rifted region, where it probably comprised a disturbed wake; and in 2011/12 when the NEB was fading, perhaps allowing the jet to be more visible in the absence of confounding disturbance around it.

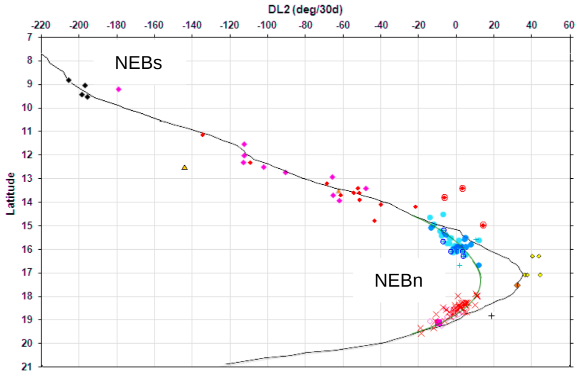

Figure 3. Zonal Drift Profile for NEB, 2005 and 2006, with the Cassini ZWP for comparison. Red symbols: bright spots; blue symbols: dark spots. The ZDP (green curve) diverges from the ZWP at positive (retrograding) drift values.

4. Origins of barges

New barges and AWOs appear circum-globally after a NEB broadening event, and more locally in the sector following WSZ, and sometimes in the wake of a turbulent cyclonic sector ('rift'). It is conjectured that they arise from instability of the NEBn retrograding jet. In 2006, small spots were visible in the NEBn jet up to 30-40º following WSZ, and at that point, new barges and AWOs were appearing. One such barge was observed forming from successive retrograding dark brown streaks. These were probably ripples on the retrograding jet, perhaps forming where the speed or turbulence of the jet dropped below a critical value, and amplifying into an eddy. Eventually, as the incipient circulation drifted beyond the end of the wake, it became a stable barge. More commonly, new barges just appear imperceptibly within the turbulence of the NEB, but the process observed in 2006 could be operating on a smaller scale.

5. Collisions between pairs of ovals

Mergers between barges are quite common. The first three were described in [3]. Others have occurred since [4], and typically followed much the same course, with the two barges in slightly different latitudes sliding together with initial overshoot but without obvious disturbance, although sometimes a small white spot appeared briefly.

Collisions of WSZ with other AWOs have occurred in 2006 (twice) and in 2012/13, always when WSZ was moving exceptionally fast. We have also recorded 5 collisions between other pairs of N. Tropical AWOs [1]. In the well-observed cases, there is only a partial merger. The leading oval ('A') shrinks as it squeezes along the S edge of the following oval ('B'); then they usually can be seen to spiral together, but only partially; in every case, part of oval A continues or re-emerges following the surviving oval B, as a slow-moving small white cloud which only lasts for a few days or weeks before disappearing. The surviving oval sometimes shows signs of instability or methane-brightness in the days during and after the interaction. Although the mergers appear to be incomplete, the observations do not constrain how much of the energy and vorticity of oval A is transferred to the surviving oval B.

Acknowledgements

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