The cyclic expansions of Jupiter's North Equatorial Belt in 2015-2017

John H. Rogers (1), C.J. Hansen (2), G. S. Orton (3), T.W. Momary (3) , M.A. Caplinger (4), M.A. Ravine (4), G. Eichstädt (5), M. Vedovato (6), G. Adamoli (1,6), M. Jacquesson (6) , R. Bullen (1,6), H-J. Mettig (1,6), C. Go (7), P. Miles (8). [jrogers11@btinternet.com]

(1) British Astronomical Association, London, UK; (2) Planetary Science Institute, Tucson, Arizona, USA; (3) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA; (4) Malin Space Science Systems, San Diego, California, USA; (5) Independent scholar, Stuttgart, Germany; (6) JUPOS team; (7) University of San Carlos, Philippines; (8) Independent observer.

Introduction & Summary

Jupiter's North Equatorial Belt (NEB) undergoes semi-periodic climatic cycles that involve broadening of the visibly dark belt to the north; hence we refer to them as NEB Expansion Events (NEEs) [1-3]. They affect phenomena across the whole width of the NEB. New convective outbreaks ('rifts') are commonly involved in the initiation of NEEs, and it was recently found that these rifts are more northerly and slow-moving than those seen at other times [2]. NEEs occurred every 3-5 years from 1988 to 2012.

The NEB underwent a new expansion event in 2015-16, but the expanded sector covered less than half the circumference; then it completely regressed. But northerly rifts reappeared in 2016 Oct. and led to a second NEE that developed rapidly and completely in early 2017. Here we describe these two NEEs as observed by amateur observers in visible light and in the methane absorption band, and we show how JunoCam images have recorded changing cloud patterns within the NEB during the NEE in 2016-18. Full details of these observations are given at: https://www.britastro.org/section_front/15.

1. The first NEE

A new outbreak of northerly rifts began in autumn 2014, and a sector of NEBn showed some disturbance from then on. However, it was not until solar conjunction in late 2015 that this same sector broadened fully. The expanded sector was ~95º long in 2015 Nov. and ~143º long in 2016 Jan-Feb.; however, this was its maximum extent. In Feb. it began to fade from both ends and by mid-June it had completely regressed, so the NEBn edge appeared disturbed but otherwise fairly normal.

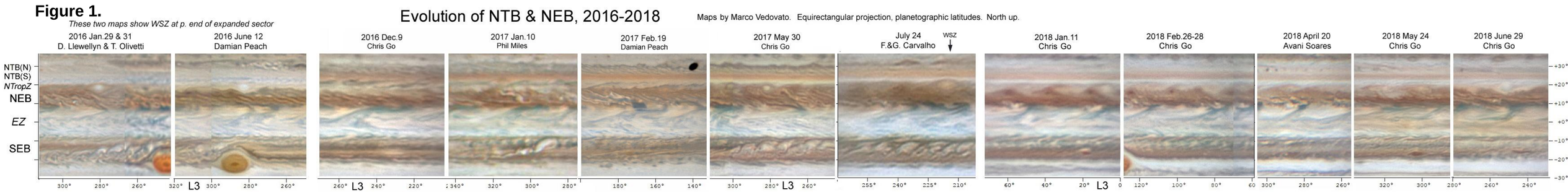
2. The second NEE

During solar conjunction in 2016 Sep-Oct., a major upheaval began at 23°N on the NTBs jet, leading to turbulent revival of the North Temperate Belt (NTB) and massive disturbance of the N. Tropical Zone in the ensuing months. It is possible, though unproven, that this disturbance triggered the subsequent NEE.

In 2016 Oct., a new northerly rift appeared in the NEB, typical of rifts associated with NEEs. This and subsequent rifts appeared close to the locations of compact circulations, although always outside them. These rift systems progressed until by 2017 April they encompassed the whole circumference of the NEB, and in some sectors its whole width.

Between the highly disturbed NTropZ and NEB, the NEB expanded northwards to 20-21ºN around most of the belt from Feb. to April. By June it was clear that a rapid and complete NEE had occurred. Also, anticyclonic white ovals (AWOs) and cyclonic dark 'barges' were forming, as is typical after a NEE. NEB rift activity declined greatly after May.

Figure 1.
These two maps show WSZ at p. end of expanded sector



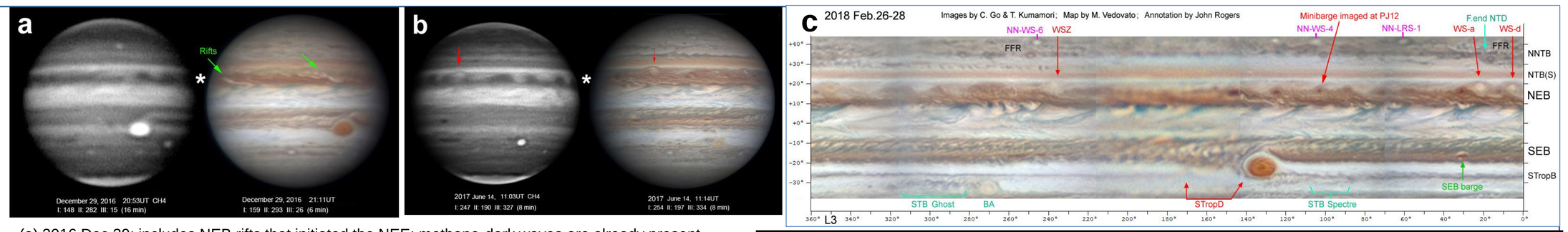
3. Methane-dark waves

A notable feature in 2015-2018 was a wavelike pattern seen in methane absorption band images, both at 889 nm (amateurs) and 2.1—2.3 μm [3]. Such waves were also prominent during the NEE in 2000-01 [4]. They are diffuse methane-dark patches over the NEB with wavelength ~17°-22° longitude, representing clearings in high-altitude haze. They coincide with thermal waves above the main cloud deck, detected at mid-IR wavelengths both in 2000-01 and in 2015-16 [3,4]: the haze is thinner where the atmosphere is warmer.

The methane-dark waves over some sectors persisted even after the first NEE, and were still prominent throughout 2017. In 2015-16, there was no obvious correspondence between the methane-dark waves and the underlying visible circulation patterns, but by late summer 2017 there was a striking pattern of waves that were both methane-dark and visibly dark brown around most of the NEB. In visible light, the NEB returned towards normal width during mid-2018. In methane band, waves diminished during 2018.

These events are consistent with the following model [3,4]. The methane-dark waves coincide with thermal waves, which may be Rossby waves, above the cloud tops. These may be forced by meridional waves in the retrograding jet in the main cloud deck. The intensity amplitude of the methane-dark waves, and later of their visible brown counterparts, which increased from 2015 to 2017-18, perhaps reflected the spatial amplitude of the waves in the jet.

Figure 2. Methane-band images (889 nm) compared with RGB images, all by Christopher Go (& T. Kumamori in (c)), showing methane-dark waves on the NEB (asterisk).



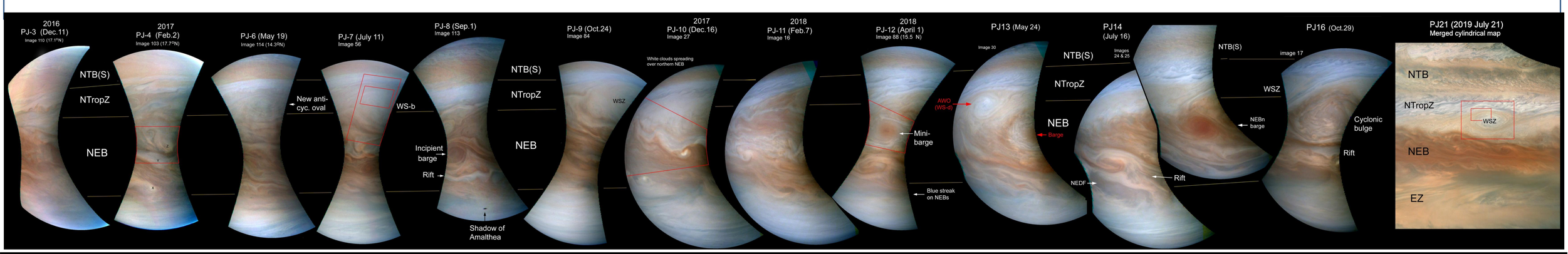
(a) 2016 Dec.29; includes NEB rifts that initiated the NEE; methane-dark waves are already present.
(b) 2017 June 14; red arrow indicates White Spot Z.
(c) 2018 Feb.26-28; Cylindrical map from RGB images. Major features in other latitudes are indicated.
(d) 2018 Feb.25—Mar.5, methane images; there are now high-contrast methane-dark waves around almost the entire circumference, which are also visibly dark brown.

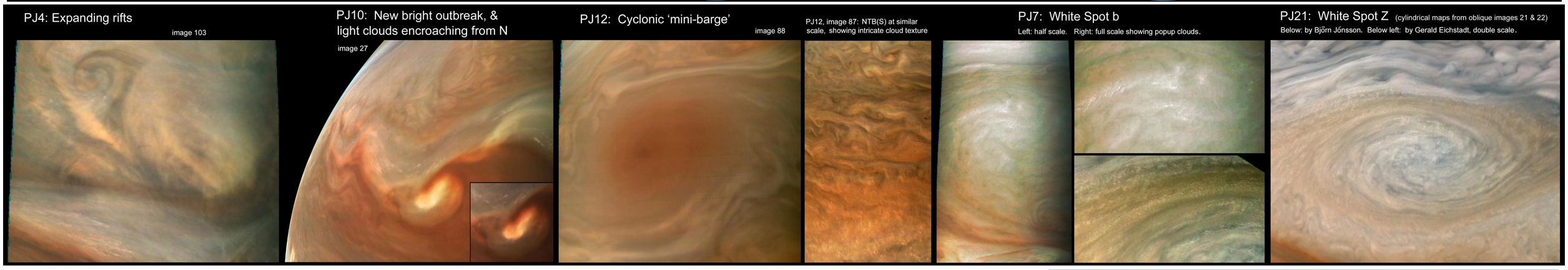
4. Images from JunoCam

Juno's orbital mission coincided with the second NEE, so the camera (JunoCam) has obtained closeup views of the NEB at every perijove from PJ3 onwards. These reveal fine details such as multi-level haze streaks, changing NEB cloud textures, and incipient circulations.

Figure 3 *[upper row below]* shows 'index images' (from MSSS);
Figure 4 *[lower row below]* shows parts at full resolution (by G.E.).

The most distinctive property of the NEB at highest resolution (~3-10 km) is its diffuseness (e.g. the PJ12 image); in contrast to almost all other regions of the planet, there are few crisp clouds. However, a new bright outbreak (PJ10) is a mass of white clouds like convective plumes in other latitudes. More developed 'rifts' are found to consist of multiple layers of whitish clouds and haze streaks (PJ4). Tiny bright elevated clouds ('pop-up clouds') are present on some rifts (PJ4). A long-lived AWO (WSZ) (PJ21) has well-defined spiral structure and, on the north side, dense pop-up clouds like AWOs elsewhere. In contrast, an AWO that formed only a few months earlier after the NEE (PJ7) has more diffuse structure and texture, with only local bands of pop-up clouds.





5. Conclusions

The NEE of 2015-16 only covered a limited longitude sector and then regressed. But then, the NEE of 2017 confirmed the typical features of such events: the initial association with slow-moving northerly rift(s); the broadening to 20-21°N; the subsequent appearance of AWOs and barges. The NEE of 2017 also had special characteristics that raise interesting dynamical questions:

--It occurred shortly after the adjacent NTBs outbreak started, and the two outbreaks together resembled the 'great northern upheaval' of 2012; but any mutual causality remains unclear.

--The methane-dark waves were very prominent, and persisted outside and between the two NEEs. This gave the opportunity to confirm their relationship to thermal waves and visible waves.

--As the second NEE occurred during the Juno mission, it was possible to obtain hi-res images of the changing cloud textures from JunoCam, and deep thermal scans from the Microwave Radiometer which could give unprecedented information on any changes that were occurring below the known clouds.

Acknowledgements

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