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Zonal wind profiles from ground-based and Hubble images, 2014 February and April

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Summary

We have generated zonal wind profiles (ZWPs) from amateur images of Jupiter taken in 2014 Feb., and from Hubble images taken in 2014 April. The main aim was to record the ZWP for a sector of the S. Temperate domain with an outbreak of STBn jet spots. The STBn jet sub-peak at 29.5ºS is found to be faster alongside the STB dark sector (in agreement with previous results), but is weaker or absent in the STBn outbreak sector, where the ZWP agrees with the drift profile of the visible dark spots. In other latitudes, we find that a cyclonic cell in the NTB has very rapid circulation, whereas the adjacent N.Temperate Disturbance has a normal ZWP.

Introduction

The zonal wind profile (ZWP) on a planet is the relationship between east-west wind speed and latitude. It is commonly obtained by making maps of the same longitude sector separated by ~10 or 20 hours (1 or 2 jovian rotations), and using an automatic algorithm to determine, for every narrow latitude band, the mean east-west movement between the two maps. Until recently this was only possible using spacecraft images. But with modern ground-based imaging of Jupiter, using WinJUPOS, it is now possible to generate ZWPs from the best amateur images when separated by just 10 or 20 hours [*ref.1*]. Given the known variability of Jupiter's winds [*ref.2*], there is much value in obtaining ZWPs both from spacecraft images, for greater precision, and from ground-based images, for checking that results are consistent across a range of dates.

This report focusses on the ZWP for a sector of the S. Temperate domain with an outbreak of STBn jet spots, as the STBn prograding jet has two sub-peaks (at ~29.5 and ~27ºS) which we have shown to vary with time and longitude. In particular, the 29.5ºS sub-peak is faster alongside STB structured sectors, such as the dark segment following oval BA, than in undisturbed sectors [*ref. 3*]. A ZWP has never been determined in a sector with a vigorous outbreak of STBn jet spots, such as was occurring in 2013/14. Given the many v-hi-res amateur images available, we were able to do this from five pairs of images taken in 2014 Feb. (some of these were shown in *ref.4*) (see Fig.1 for map). We also obtained ZWPs from Hubble Space Telescope (HST) images obtained on 2014 April 21 by a collaborative team (A. Simon, I. de Pater, G. Orton, M. Wong, J. Rogers; *ref.5*). (One colour image is Fig.2; see Fig.6B for a concurrent map.)

Methods

Ground-based images:
G. Hahn generated ZWPs from 5 sets of images in 2014 Feb. using WinJUPOS, in 3 longitude sectors, as follows (see map in Fig.1):
Sector A (Feb.16), covering the dark STB segment and its Sf. tail;
Sector B (Feb.15 and Feb.25), covering the STBn jet spot outbreak running from oval BA to the GRS;

Sector C (Feb.2, 10-hour and 20-hour comparisons between 3 sets of images), covering undisturbed sectors but including the STB Ghost.

In obtaining ZWPs from ground-based images, there are often uncertainties in the limb outline, the timing, and the alignment (which requires manual optimisation), leading to possible systematic error in the wind speeds; so the zero-point of the ZWP is adjusted so as to optimise the fit with prior ZWPs from spacecraft, or with tracked spots. In this case:

Sector A was adjusted for best fit with a ZWP from HST in 2012; offsets up to to 8 m/s more negative would also fit.

Sector B was adjusted to the measured speed of the STBn jet spots (+37 m/s) f. the GRS.

Sector C was adjusted to the measured speed of the STB Ghost (+3 m/s) and nearby small spots.

Wind speeds were obtained independently from maps generated from red, green, and integrated-light images, at intervals of 0.3º latitude; they were then averaged within a 0.9º window at 0.3º intervals to generate mean ZWPs, which were optimised for the S. Temperate domain.

HST images:

Wind speeds were obtained independently from maps generated from red, green, and violet images, 10 hours apart. These maps covered only Sector B (excluding the GRS and Oval BA). The global ZWP is in Fig.5.

Results: S. Temperate domain

The results are summarised in the attached charts: Fig.3 shows our ZWPs across the S. Temperate domain; Fig.4 shows transects of wind speed with longitude at the typical latitudes of the three jet peaks (26.9, 29.4, 31.9 ºS), averaged over a 60º window of longitude.

The STBn jet component at 26-27ºS is present as a similar peak in the ZWPs at all longitudes, with a fairly constant mean speed of ~37 m/s, in both ground-based and HST data.

The STBn jet component at 29ºS is much more longitude-dependent:

Sector A (ground-based only): This sector, with the STB dark segment, is the only one with a sharp, fast 29ºS sub-peak, at 44 m/s in the ZWP, consistent with our previous reports which showed a mean of 44 m/s in structured sectors. The speed is ~48 m/s along the dark sector itself, and falls off sharply at its f. end, so in the 'Sf. tail' sector it is only ~30 m/s (uncertain because there are no distinct features to track here). (Depending on the zero-point adjustment applied, these speeds could be as much as 8 m/s lower.)

Sector B: In this sector, the dark STBn jet spots are running from oval BA to the GRS, with a shallow cyclonic gradient of speed versus latitude centred on mean speed 37 m/s at 28ºS, many of them drifting northwards without change of speed, according to thorough JUPOS analysis *[ref.6]*. Accordingly, just f. the GRS, on both dates measured in Feb., the speed at 27ºS is 37 m/s, whereas the speed at 29.4ºS is rather slow (~20 m/s), so this sub-peak is weak or absent after the spots have drifted north. (However, the results on the two dates in Feb. diverge further f., where the spots are arising p.BA; whether this represents inaccuracy or real variability is unclear.) The HST data in April shows a speed of 32 m/s p. BA, decelerating to ~23 m/s towards the GRS, confirming that this sub-peak declines as the spots drift northwards while running towards the GRS.

Sector C (ground-based only): This is largely an undisturbed sector, but includes the STB Ghost in the middle. The 29ºS sub-peak is not detected here, possibly because of lack of features. Instead, the ZWP records the speed of the STB Ghost itself (+3 m/s).

The STBs retrograde jet at 32 deg.S: Most of the ZWPs show a peak speed of -9 to -16 m/s (Fig.3). The HST ZWP in sector B shows a peak of -15 to -18 m/s, typical of previous spacecraft values, with slight decline from the GRS to BA. In the ground-based longitude profiles at 31.9ºS (Fig.4A), the mean speed is lower and there is large scatter, which may be partly due to lack of features, and partly due to the jet peak being slightly south of the transect. Nevertheless, one result shown in both ground-based and HST profiles (Fig.4B) is the decline of this jet going from the GRS to oval BA. This is consistent with our evidence for recirculation of occasional spots from the STBs jet to the SSTBn prograde jet in this sector in recent years [*ref.7*], and is supported by a subtle change in cloud texture in the STZ in the HST images (Fig.2).

Results: other latitudes

There is generally good agreement between the ground-based and HST global ZWPs, although the latter is clearly more consistent. The following data are from the HST ZWP (Fig.5).

SEBn jet (~7.5ºS): u_3 = +152 m/s, DL1 = -97.5 deg/mth.
This high speed is fairly typical of the jet when no large disturbance is present.

NEBs jet (5-9ºN): The ZWP is irregular, and is not faster than the usual NEBs dark formations. It is especially slow in the violet profile, presumably because the dark (bluish) formations are not detected in violet light.

NTBs jet (~24ºN) : u_3 = +156 m/s, DL1 = -130 deg/mth.
This high speed suggests that there will be another NTBs jet outbreak soon, possibly in 2017 as expected from the historical 5-year periodicity.

NTB:
The elaboration of the N. Temperate domain was described in detail in our reports *[2013/14 reports no.4 & no.6, and 2014/15 report no.3]*. In the HST images, the complex region north of the GRS is the N. Temperate Disturbance (NTD), with rifting of the NTB and darkening of the NTZ; the turbulence and eddying are strikingly shown in the HST images (Fig. 2).
Nevertheless, the ZWP in this sector is normal (Fig.6: L2 190-230):

- (29.1°N) u_3 = -10 m/s, DL2 = +15 deg/mth (equal to NTC-A).
- (31.5°N) u_3 = -26 m/s, DL2 = +54 deg/mth (normal NTBn retro. jet)

Following the NTD is a pale oblong. This was formerly a very dark bar which reddened and faded in 2013 Oct-Dec. ('sector no.4'), then it appeared as a bright cream-coloured or whitish oblong up to 2014 April (Figs.1 & 2), which we believe to be a cyclonic circulating cell. The ZWP here is greatly altered (Fig.6: L2 230-260), showing exceptionally fast winds around the circulating cell, thus:

- S branch (29.1°N) u_3 = +31 m/s, DL2 = -80 deg/mth (exceptional prograde current)
- N branch (31.5°N) u_3 = -40 m/s, DL2 = +88 deg/mth (NTBn retro jet, unusually fast).

Further f., where the NTB(N) and NTZ appear more normal, the ZWP is again normal (Fig.6: L2 260-290).

The NTBn jet speed in the circulating cell is notably faster than in previous ZWPs. The peak speed in spacecraft data from 1979 to 2007 ranged from -15 to -36 m/s, with a mean of -27 m/s (at 31.1 ºN) *[ref. 8]*. (An even faster speed of ~-49 m/s was found in HST images in 2008 May [*ref.2*], but the authors dismissed this as a possible artefact of the high-amplitude waves that were present on the NTBn at that time.) In conclusion, we find that a cyclonic cell in the NTB has very rapid circulation, whereas the adjacent NTD has a normal ZWP.

References:

1. Hahn G (tr: Jacquesson M), 'Jupiter : Longitudinal drifts computation from image pairs':
   http://www.grischa-hahn.homepage.t-online.de/ "Zonal wind profiles"
   or direct to:
   http://www.grischa-hahn.homepage.t-online.de/astro/winjupos/LongDrifts/Jupiter_LongDriftDetermination_English.pdf

2. Asay-Davis XS, Marcus PS, Wong MH & de Pater I (2011) 'Changes in Jupiter's zonal velocity between 1979 and 2008.' *Icarus* 211, 1215-1232.

3. Rogers J, Adamoli G, Hahn G, Jacquesson M, Vedovato M & Mettig H-J (2013), 'Jupiter's South Temperate domain: Behaviour of long-lived features and jets, 2001-2012'.
   http://www.britastro.org/jupiter/stemp2013.htm

4. Rogers JH (2014 March) 'Jupiter in 2013/14: Interim report no.6'
   http://alpo-j.asahikawa-med.ac.jp/kk14/j140406r.htm

5. Simon AA, Wong MH, Rogers JH, Orton GS, de Pater I, Asay-Davis X, Carlson RW & Marcus PS. 'Dramatic Change In Jupiter's Great Red Spot From Spacecraft Observations' *Astrophysical Journal Letters*, 797:L31-L34 (2014 Dec.20) doi:10.1088/2041-8205/797/2/L31.

6. Rogers J, Adamoli G & Jacquesson M (2015) Jupiter in 2013/14: Report no.9: 'The GRS and adjacent jets: Further analysis of amateur images, 2013/14'
   http://www.britastro.org/jupiter/2013_14report09.htm *[Posted along with this report.]*

7. Rogers JH (2015) 'Jupiter's South Temperate Domain, 2012-2015'.
   http://www.britastro.org/jupiter/2014_15report08.htm *[Posted along with this report.]*

8. Rogers JH (2013), 'Reference list of Jupiter's Jets'.
   http://www.britastro.org/jupiter/reference/jup_jets/ref_jets.htm

Figures

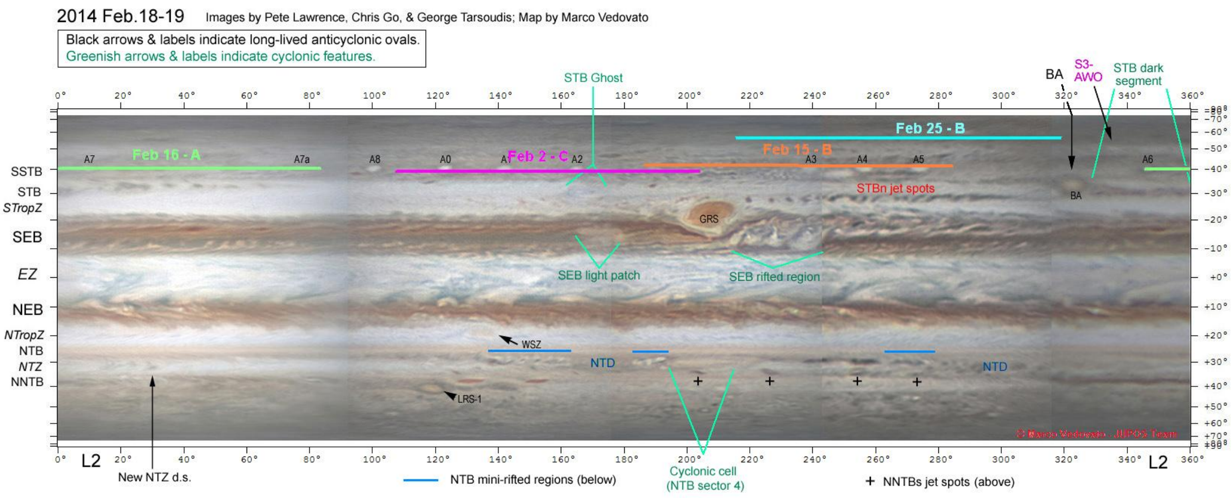

Figure 1. Map of the planet, 2015 Feb., from our 2013/14 Report no.6 *[ref.4]*, with the longitude sectors used for ZWPs (A, B, C) marked. *South is up in all figures.*

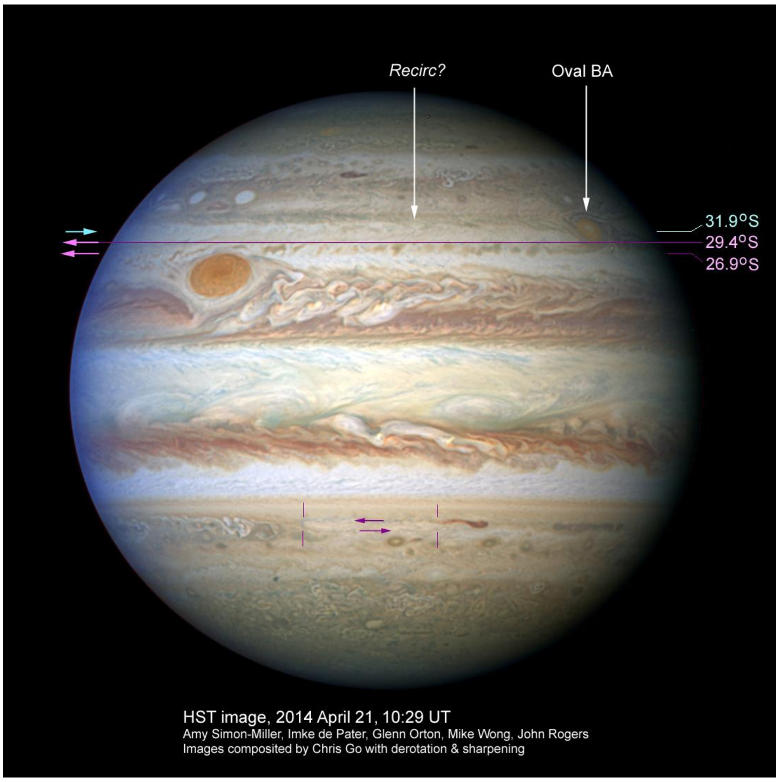

Figure 2. HST image, 2014 April 21. Latitudes used for the transects in Fig.4 are marked. 'Recirc?' indicates a region where a change in the cloud texture of the STZ may be consistent with anticyclonic recirculation, ~45° p. oval BA. In the north, the rapidly-circulating cyclonic cell is outlined.

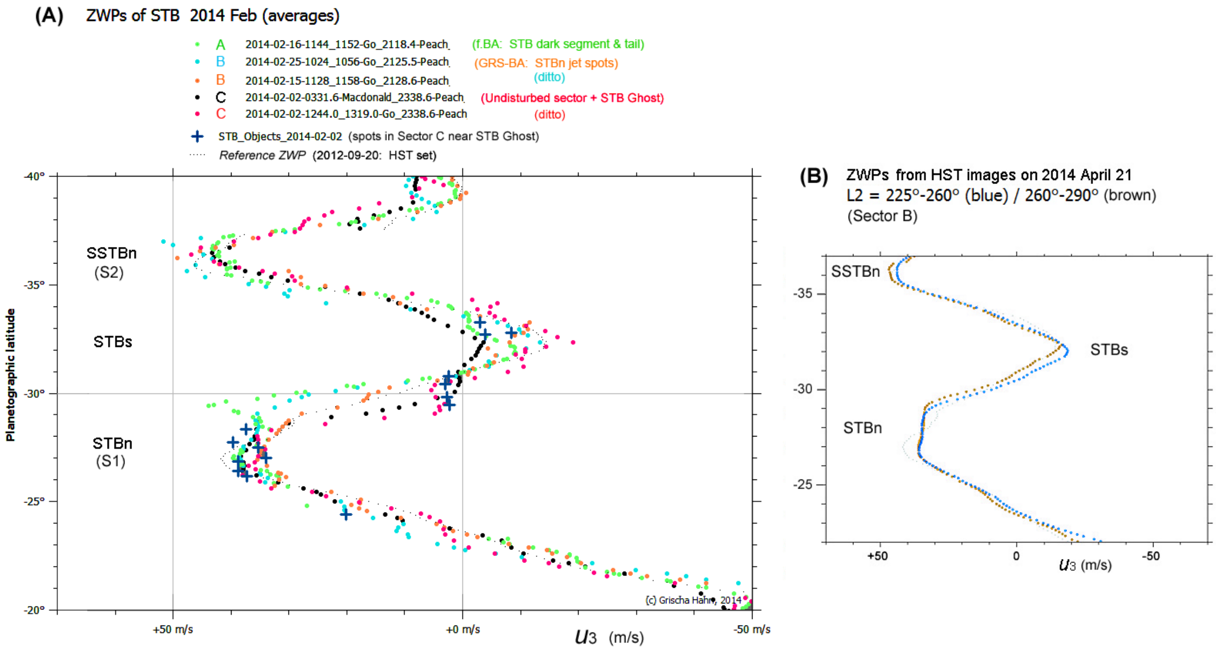

Figure 3: ZWPs across the S. Temperate domain. (A) 2014 Feb. from ground-based images by Christopher Go, Damian Peach, and Bruce MacDonald (per ALPO-Japan), at dates and times as listed on the chart. (B) 2014 April 21, from HST images, in two longitude sectors.

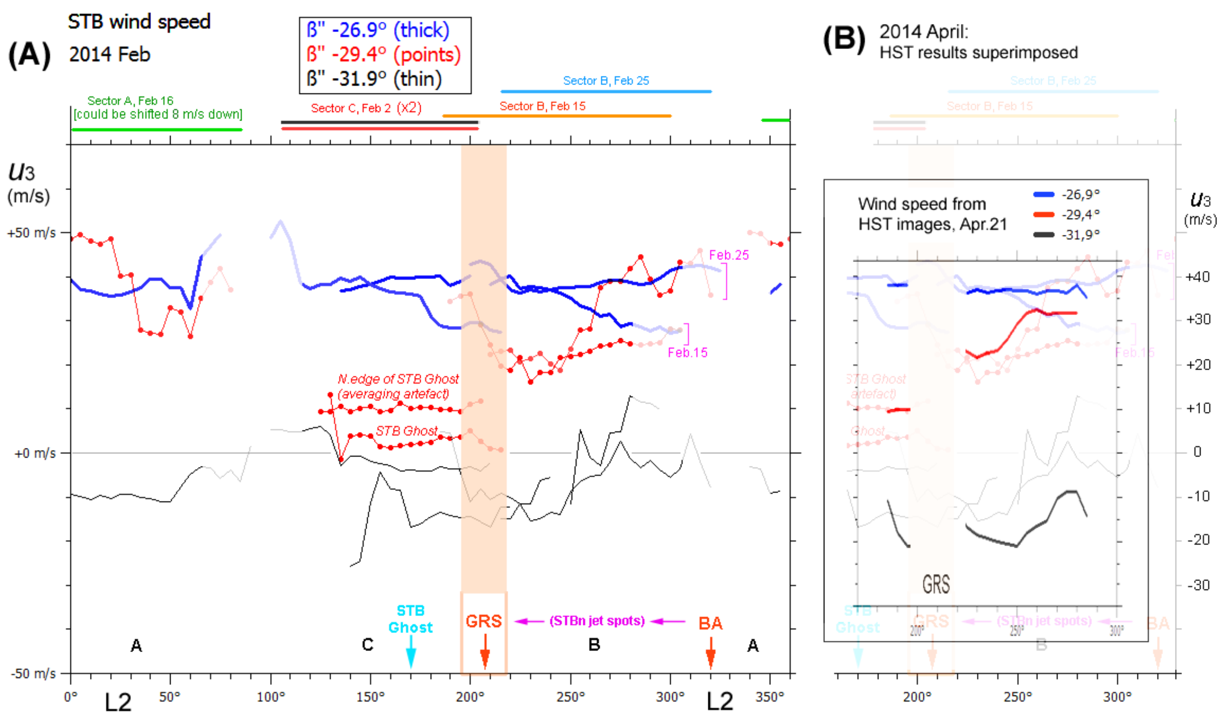

Figure 4: Profiles of wind speed with longitude at the typical latitudes of the three jet peaks (26.9, 29.4, 31.9 °S). Wind speed is averaged over a 60° span (+/-30° from the longitude indicated). The longitudes >40° from the CM are shown paler as the speeds may be imprecise; likewise longitudes alongside the GRS, where speeds may be anomalous.

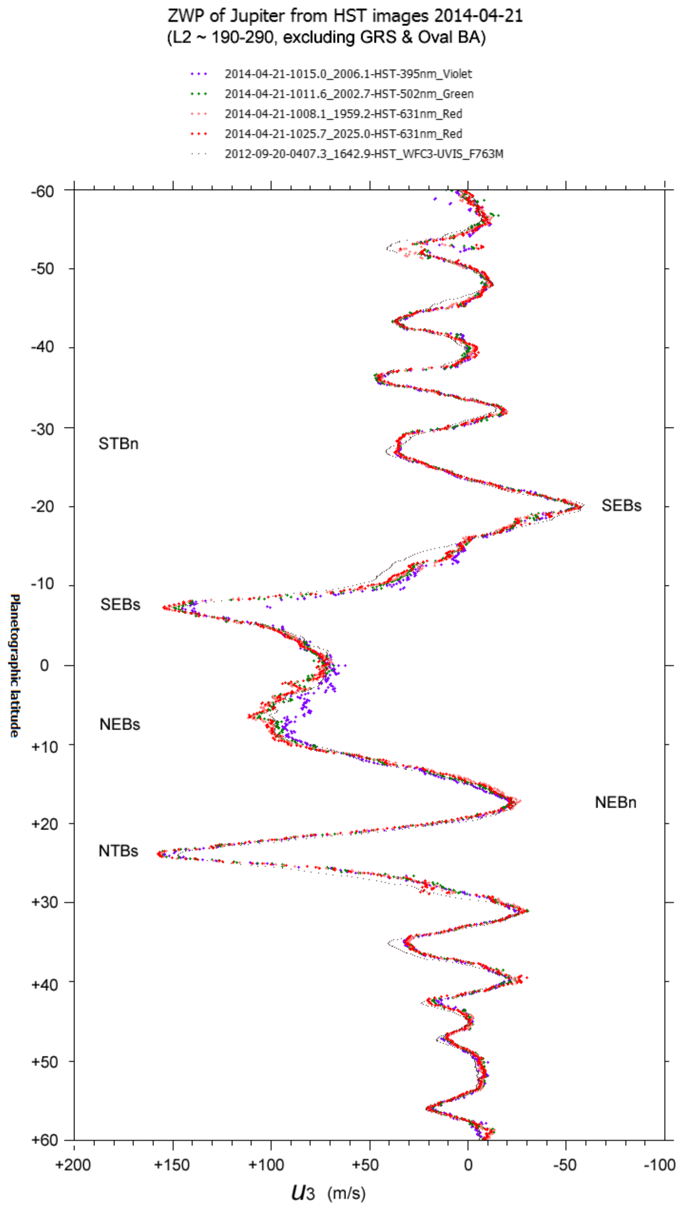

Figure 5. Global ZWP from the HST images on 2014 April 21. Points in 3 colours represent independent ZWPs from images in violet, green, and red. Background small points represent a ZWP obtained from HST images in 2012, for comparison *[ref.1]*.

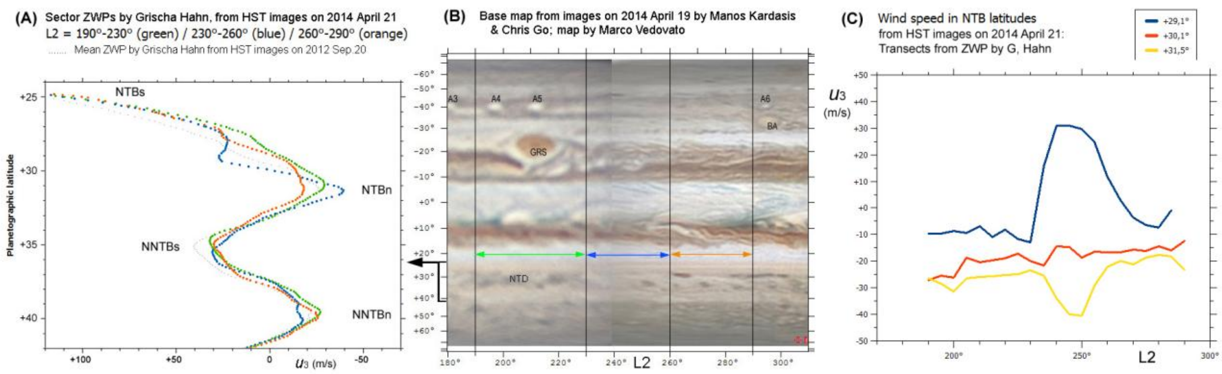

Figure 6. Results for the N. Temperate domain. (Captions on image.)