Long-term monitoring of Jupiter's South Temperate domain: I. Oval BA and the cyclic development of structured sectors

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Abstract

The pattern of atmospheric phenomena in Jupiter's South Temperate domain, covering the years 2001-2012, is here deduced from amateur images. We summarise the long-term history of the major features, viz. a succession of structured cyclonic sectors of the South Temperate Belt (STB), one of which is coupled to the single large anticyclonic oval (oval BA). The other structured segments begin as small dark spots or streaks remote from oval BA, then expand, and eventually catch up and merge with the dark segment at BA, inducing intense disturbance in and around it. This cycle has been completed three times in 15 years, maintaining at least 2 structured sectors at all times. The major changes in drift rate of oval BA appear to be due to the impacts and subsequent shrinkage of the structured segments. From 2008 onwards, oval BA has been shrinking and shifting southwards.

1. Methods

This report is based on measurements by the JUPOS team on the innumerable images taken by amateur observers around the world, whose names are posted on the JUPOS web site (http://jupos.org).

Figure 1. Map of the southern hemisphere, 2011 Sep.24-30 (images & map by Damian Peach). South is up, east to left. Key features of the S. Temperate domain are marked. Asterisks, tiny anticyclonic ovals temporarily marking west ends of structured sectors A and D. DS4, small dark spot which may become new structured sector E.

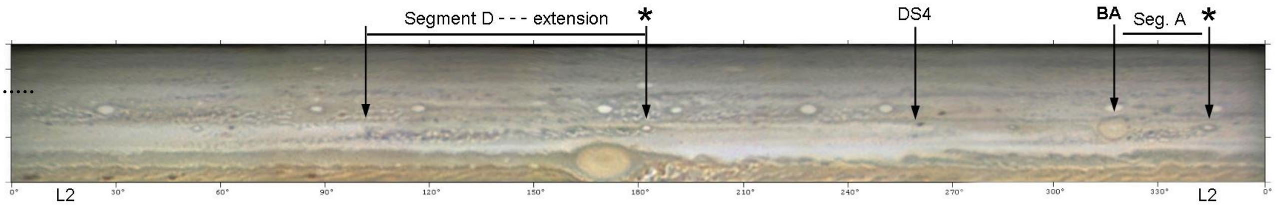
2. Background

Jupiter's South Temperate domain, between the jets at 36ºS and 26-29ºS, has always contained notable features, which usually constitute 2 or 3 distinctive sectors widely separated in longitude, suggestive of control by a planetary-scale wave. The nature of these sectors has changed over the decades. Since 2000, there has been just one large anticyclonic oval (called BA), and one or more dark segments of South Temperate Belt (STB), but their development and variations over multiannual timescales have not previously been analysed.

Here we present a long-term overview of the domain covering the years 2001-2012, from amateur images, with a novel synthesis of the behaviour of the major features.

3. STB structured sectors

There are always 2 or 3 structured sectors (e.g. Fig.1). One of them is headed by oval BA at its east end, followed typically by a dark STB segment (segment A), which sometimes contracts to form a small dark cyclonic oval ('barge'). The other structured sectors are organised only in the cyclonic latitudes: some are dark STB segments, whereas one had very low contrast (the 'STB Remnant' in 2005-2010). Dark STB segments show small-scale turbulence, and emit small dark spots eastwards into the prograding STBn jet, and irregular dark streaks in a westwards extension along the retrograding STBs jet. (This activity was most graphically shown in the Cassini movies.)



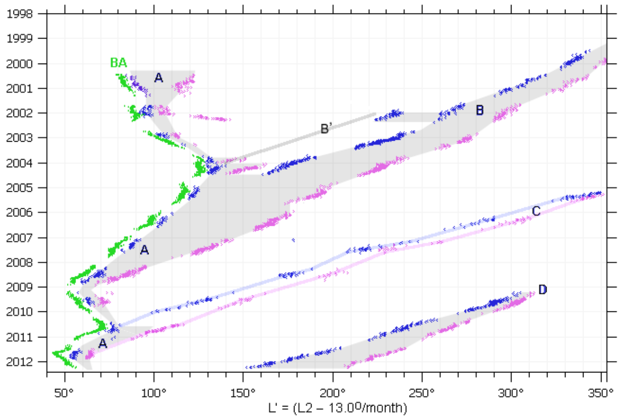


Figure 2. Longitude vs time for STB structured sectors (labelled A to D), 2000-2012. Grey shadings indicate dark STB segments. Green, oval BA; blue, east end of structured sector; purple, west end; B', small feature preceding main part of sector B..

Fig.2 shows how 3 structured sectors have successively arisen and expanded, then, drifting faster than segment A, they have caught up and collided with it. Segment B began as a small dark spot in 1998 and became an expanding dark STB segment which collided with segment A in 2003/04.

Segment C began as a small dark spot in 2002-2004, but developed into the low-contrast 'STB Remnant', probably a cyclonic circulation cell, which collided with segment A in 2010. Both these collisions produced large effects:

--Rapid changes in the region, until the long merged STB segment stabilised again;

--Large and sustained acceleration of oval BA;

--A substantial outbreak of small dark spots prograding on the STBn jetstream p. oval BA;

--Dark spots or streaks spreading in the opposite direction southwest from the merging STB complex.

Segment D began as a small faint streak in 2008, and became an expanding dark STB segment which is colliding with segment A in early 2013. Meanwhile another small dark spot appeared on the opposite side of the planet in 2011, and has become a faint cyclonic streak which seems likely to be the next structured segment. Thus a small cyclonic feature can develop into a new structured sector when there are no other major features over a wide range of longitude, and thus initiate the next cycle.

4. Oval BA

Oval BA sometimes undergoes large changes of drift rate, which appear to be caused by two factors: the cyclic impacts and shrinkages of structured STB segments impinging on its west side, and the periodic passages past the Great Red Spot. Since it formed in 2000, its two major accelerations approximately coincided with the impacts of STB structured segments onto segment A, while its major decelerations approximately coincided with shrinkage of segment A (or part of it) into a small closed 'barge' (Fig.2).

From 2008 onwards, oval BA has been shrinking in length and probably in width, which accounts for a progressive southwards shift in its speed-vs-latitude relationship.

5. Discussion: The future of the domain

Since the three long-lived ovals of 1940-2000 have merged to leave just one anticyclonic oval, BA, and oval BA is shrinking in turn, will a new set of large anticyclonic ovals soon arise?

We suggest the following scenario. At present, oval BA is large enough to block the faster drift of the other structured STB segments, and therefore they only last for a few years, not long enough for anticyclonic circulation to develop between them. In the next few years, oval BA will shrink so much that it no longer controls the dynamics of the region, and the other structured STB segments will be free to develop a long-lived pattern of 2 or 3 of them spaced around the domain. Then, within a decade or so, the spaces between them will develop into anticyclonic circulations that will become the next generation of large ovals.

Long-term monitoring of Jupiter's South Temperate domain: II. Variations of the STBs and STBn jets with longitude and time

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Abstract

The precision of recent amateur data allows us to study temporal and longitudinal variations of the wind patterns. We show that the zonal drift profile in the STZ, and the retrograde STBs jet, and the prograde STBn jet all vary with longitude and with time. Most notably, STB structured sectors are distinguished by faster speeds both in the STBs jet (usually) and in one of the two sub-peaks of the STBn jet.

Methods

Wind patterns are analysed as speed-versus-latitude relations both for small-scale cloud textures (Zonal Wind Profile, ZWP), and for individual spots (Zonal Drift Profile, ZDP). ZDPs are obtained from JUPOS data, for the dark spots in the STB(S)/ STZ in all years (2000-2012), and for the dark spots in the STBn jetstream in 2010 and 2011. ZWPs are obtained from both amateur and spacecraft data in different longitudinal sectors of the STB, using 3 data sets: from New Horizons, 2007; from the Hubble Space Telescope, 2012; and from amateur images, 2012.

The STZ and the STBs jet

Slow-moving dark spots constitute the Sf. extensions of the dark STB sectors. Most of them are in the anticyclonic latitudes of the STZ, while the remainder are close to the retrograde STBs jet latitude (32ºS) and sometimes cross the jet. In general, their motions (ZDP) agree with the ZWP as established from spacecraft, but not reaching the peak speed of the retrograde jet. However we find two substantial variations:

i) In 2005-2007 only, the spots f. segment A showed the full retrograde jet speed. This may have been a long-lasting effect of the STB collision in 2003/04.

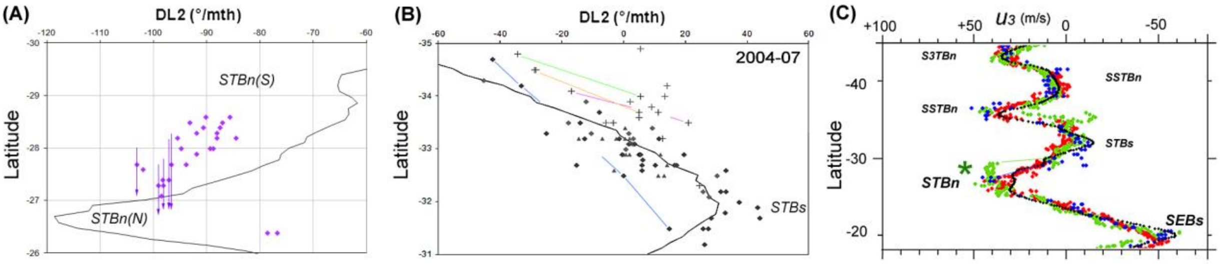
ii) In 2004-2007, the ZDP for spots Sf. the STB Remnant was displaced southwards. Most of these spots had been recirculated from the SSTBn jet at the Sf. end of the STB Remnant, which apparently interrupted the ZDP across the STZ.

Within dark STB segments, the STBs jet is faster than in undisturbed sectors, in 2 out of 3 sets of ZWPs.

The STBn jet

The STBn jet, as observed by spacecraft, is broad and variable with two sub-peaks at 26-27ºS and 29ºS. In all 3 sets of sectoral ZWPs, the 29ºS sub-peak is relatively stronger alongside STB dark segments, and the speeds of these sub-peaks also vary between years. Combinations of these patterns can account for all previously published spacecraft profiles.

The STBn jet often carries small dark spots, emanating from the dark STB segments. Unlike spots on other prograde jets, these span a wide range of speed and latitude. Both the visible narrow STB(N), and the jetstream spots travelling along it, trend northwards with decreasing longitude; but ZWPs imply that this is mostly not due to a variation of jetstream latitude. If the ZWPs obtained in 2007 and 2012 also apply in the presence of dark jetstream spots, many of which drift from ~28-29ºS to ~27ºS, these spots must be drifting between the two sub-peaks of the jet. These results reveal a novel longitudinal and latitudinal structure in a prograde jet.



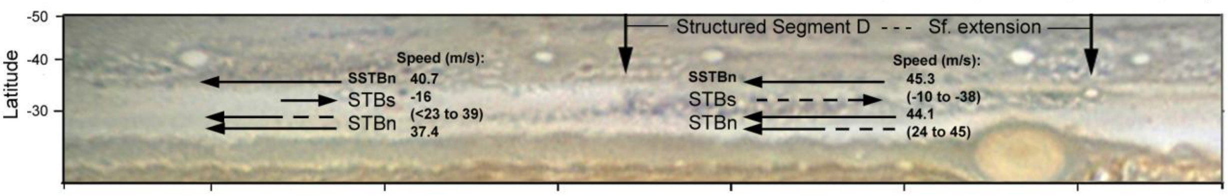


Figure 3 (top): (A, B) ZDPs for dark spots, compared with mean ZWP from Cassini. (A) ZDP for STBn jetstream spots in 2011 (inc. some shifting northward). (B) ZDP for STZ/STB(S) dark spots in 2004-2007 (+, spots f. STB Remnant, mostly recirculated from SSTBn jet). (C) ZWPs from amateur images in 2012 Sep-Dec. in 3 sectors (colours), compared with mean ZWP from New Horizons. (See full report for details.)
Figure 4 (bottom): Mean parameters of the jets in the structured and undisturbed sectors. (Base map as in Fig.1.)