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DYNAMICS OF SATURNIAN THUNDERSTORMS

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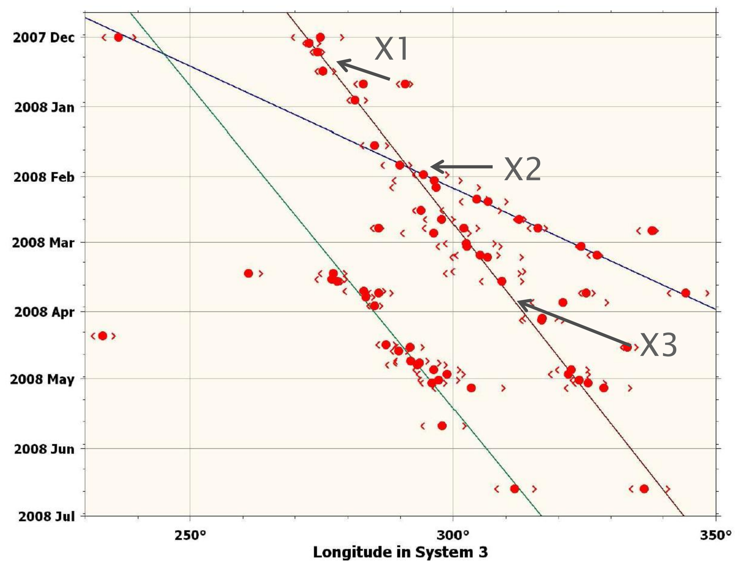
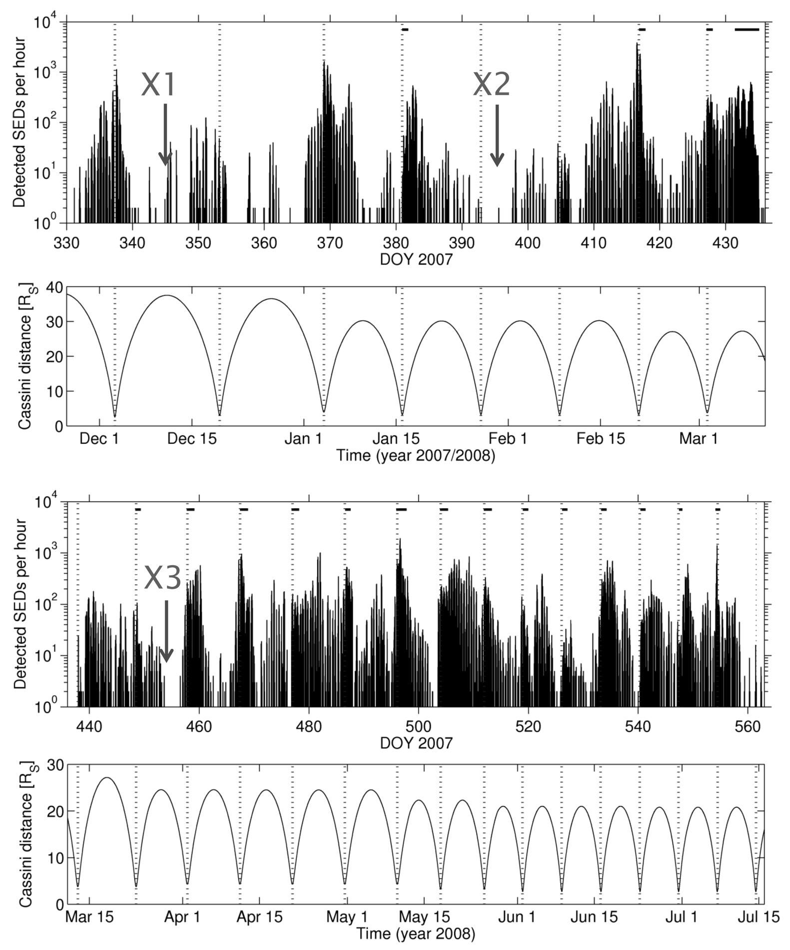
- Thunderstorms on Saturn usually last much longer than their terrestrial counterparts. The Cassini spacecraft has observed Saturnian lightning storms with durations of a few days up to several months. During these long storms the lightning flash rate measured by the Cassini RPWS (Radio and Plasma Wave Science) instrument is waxing and waning or sometimes even going down to zero for a few days before rising up again.
- To gain more insight into the dynamics of the thunderstorms we compare the flash rate with contemporaneous images from the Cassini camera and from amateur astronomers taken on Earth. Thereby we found that the splitting of storm cells might be an important factor in the dynamics of thunderstorms on Saturn. A comparison with the splitting process of terrestrial thunderstorms led to the development of a new conceptual model of the zonal wind speeds at the cloud base for the storm alley at 35°S latitude that is consistent with the observations.

1. DYNAMICS OF STORM FROM 2007/2008

This Saturn lightning storm lasted from 27 November 2007 until 15 July 2008. It was characterized by a single convective storm region of ~2000 km in size during its first half, but it also developed a second convective cell at the same latitude (35°S) separated by ~30° in longitude during its second half.

We explain the decrease of the flash rates in late January 2008 by a splitting of the thunderstorm cell (X2). This led to two storm cells, a weaker one with probably no SED activity that drifted westward, and a stronger one that kept its drift rate and developed large SED activity again by mid-February. There might have been similar processes in December 2007 (X1) and March/April 2008 (X3).

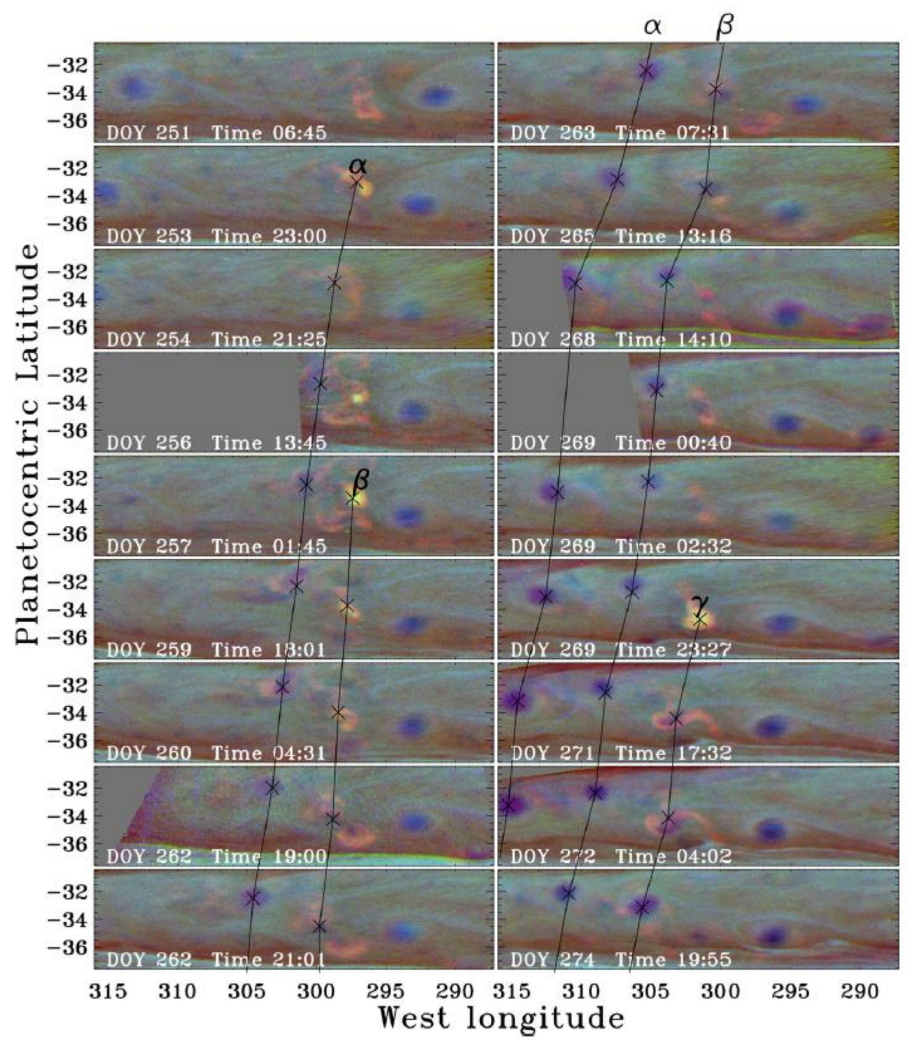


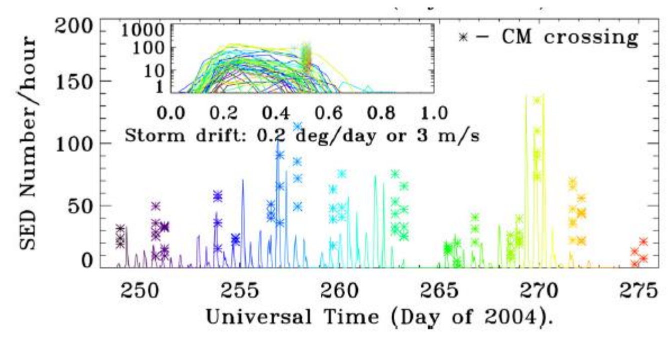


Figures 1+2: Western longitudes of cloud features observed by amateurs during lightning storm (above). Flash rates (Saturn Electrostatic Discharges per h) and Cassini distance as a function of time from the end of November 2007 until mid-July 2008 (right side).

2. DYNAMICS OF 2004 DRAGON STORM

Since the 2007/2008 storm was observed by Cassini only on 6 days (Dec. 6, March 4, April 23, May 19, June 4 and 18) we take a closer look at the potential splitting process during the "dragon storm".





Figures 3+4: False color map showing the variation of the dragon storm (Sept. 2004) with time. Red colors indicate deep clouds, green colors show intermediate clouds , and blue colors sense higher altitudes . The symbols α, β, γ denote individual cloud eruptions turning into blue ovals with westward drift of ~1°/day (left, from Dyudina et al., 2007). Number of SEDs as function of time and stars (*) show excess reflectivity (above, from Dyudina et al., 2007).

Fig. 4 shows that the brightness of cloud spots is correlating with the flash rate (see days 257, 269). A close inspection of Fig. 3 suggests splitting processes on DOY 253/254 (for α) on DOY 263 (for β) and on DOY 272 (for γ) corresponding to low SED rates.

ZONAL WINDS AT SATURN AND A NEW CONCEPTUAL MODEL

Fig. 5 shows that there is a minimum in eastward wind speed around 35°S at the cloud top level (planetocentric; corresponding to 41°S planetographic latitude).
Fig. 6 shows our conceptual model of wind speeds at deeper levels around the cloud base, which is derived from the shape of the "dragon storm". It is consistent with a splitting storm that develops a blue spot (probably an anticyclone) northward of the convective region which should be cyclonic. The two peaks for the number of vortices in Fig. 5 around the storm alley could also be explained by our model.

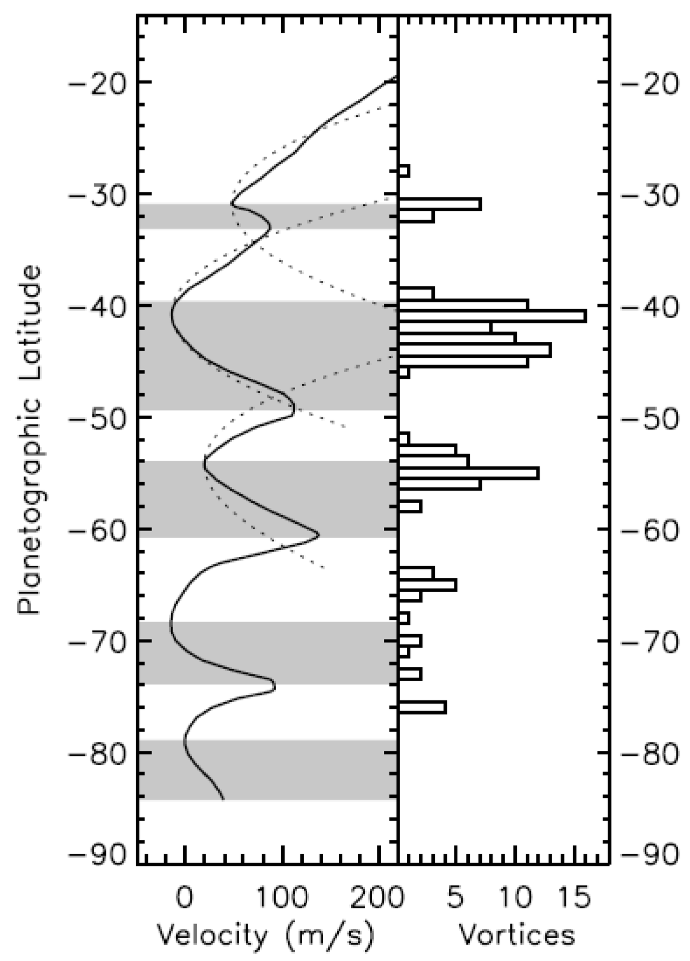


Figure 5: Zonal wind in Saturn's southern hemisphere (eastward velocity) as function of planeto-graphic latitude. Shaded regions have anticyclonic shear. Number of observed vortices at various latitudes (from Vasavada et al., 2006)

3. STORM SPLITTING ON EARTH AND SATURN

On Earth ordinary convective cells can last for just a few hours, but multicell or supercell storms occasionally last for a few days. Since SED storms can last for several months, it might be useful to compare their dynamics to terrestrial supercell storms. The still increased longevity of SED storms might be due to the almost continuous availability of hot and moist gas from below the water condensation level around 10 bar, whereas on Earth the supply of hot and moist air might stop much sooner. Storm splitting is a common process in supercell storms, where *vertical wind shear* strongly influences the form the convection takes. Panel (d) in Fig. 6 shows that vertical wind shear of ~40 m/s between cloud base and cloud tops is present in Saturn's storm alley. This westward shear can cause a split of the thunderstorm into a left-moving cyclone (i.e. southward with respect to the wind shear vector) and a right (northward) moving anti-cyclone, just as observed in Fig. 3. Note that on Earth and in the northern hemisphere it is usually the right-moving storm that is cyclonic and enhanced compared to the left-mover (Klemp & Wilhelmson, 1987), but it is the other way round in the southern hemisphere.

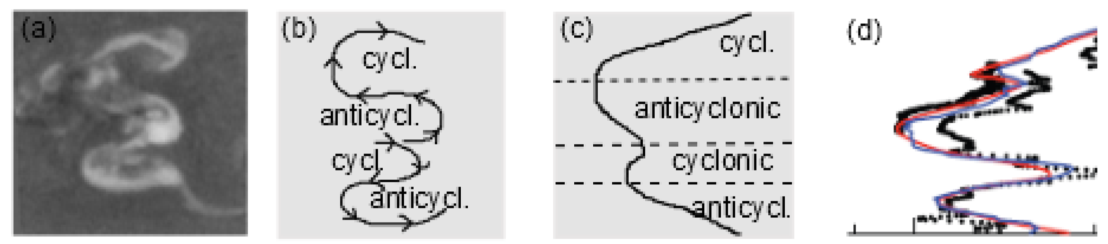


Figure 6: Conceptual model of wind speeds at cloud base level in Saturn's storm alley around 35°S. Image (a) shows the dragon storm on DOY 256, 13:45. Assuming an outflow from the center , sketch (b) shows cyclonic and anticyclonic parts of the „dragon". Note that cyclones rotate clockwise in the southern hemisphere and anti-cyclones rotate counter-clockwise. Sketch (c) shows our conceptual model with the western wind speed as function of latitude (from ~50°S to 30°S) with regions of cyclonic and anti-cylonic shear indicated. Sketch (d) was taken from Choi et al. (2009) showing wind speeds (from -50 m/s to 150 m/s eastward) as function of latitude (from ~60°S to ~20°S) as measured by Cassini ISS (red), Voyager (blue) and Cassini VIMS (black), the latter indicating wind speeds at deeper levels.

SUMMARY

We have shown that a splitting of thunderstorms similar to terrestrial supercells can also take place on Saturn. Using amateur observations of an SED storm from 2007/2008 we identified three instances of reduced flash rates that might be related to splitting. Using Cassini ISS observations of the dragon storm from 2004 we developed a conceptual model for the zonal wind speed at the cloud base level that is consistent with the observations. Cassini VIMS observations suggest a vertical wind shear in the storm alley at 35°S which can lead to left-moving (southward) cyclones and right-moving anticyclones.

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