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Dynamics of Saturn's Great White Spot observed by Cassini ISS

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Abstract

On December 2010 a giant-size convective storm started to develop in Saturn's North tropical latitudes. This was the first storm in the northern hemisphere in the new season (early spring) and was observed by many amateurs in the ground with an almost daily coverage that showed a rapid development first into a compact bright feature, and later into a compact head followed by a tail that fully encircled the planet in 2 months [1]. Undoubtedly this was a type of Saturn storm coined as "Great White Spot" [2]. The RPWS instrument onboard Cassini detected an unprecedented level of electrical activity in this storm and Cassini ISS was able to obtain images of the storm in certain dates [3], [4]. Here we present a study of some of the highest resolution series of observations of the storm in 26th February 2012 when the tail of the storm had attained a planetary scale.

1. Introduction

Convective storms in Saturn are rare phenomena that seem to be restricted to certain latitudes. The Voyagers observed storms with sizes on the order of 2000-3000 km originating at 35ºN latitude (planetocentric), while Cassini observed similar storms originating at the same latitude in the South hemisphere from 2004 [5]. The Cassini era storms have been linked to electric activity through Saturn Electrostatic Discharges [6] and direct observation of lightning in the night-side in the storms locations [7] provide a definitive proof of this connection. The onset of the 2010-2011 GWS offers a unique opportunity to study these violent phenomena. High-resolution observations obtained by the Cassini ISS instrument on particular dates of the evolution of the GWS allows studying key aspects that characterize a storm system of this magnitude such as the emergence of one or several convective active spots, development of fronts, vortices and interaction with the environment winds.

2. Observations

We analyzed Cassini NAC images obtained with the CB2 filter with a spatial resolution of 14 km per pixel. Images were acquired with the spacecraft looking to the planet while the planet rotated. Each CB2 image is delayed with respect to the previous one by 10 minutes. The combination of the images allows building a cylindrical projection of the large storm and its tail. Images in other filters were acquired at the same time (BL1, MT2, MT3) but most of them were binned and compressed loosing the original high-resolution of the CB2 images. We also used images separated by a planetary rotation. However the large changes in the features morphology didn't allow obtaining precise measurements and we only used BL1 images separated by 10 hrs since they had the clearest view of small scale features in the storm head. The CB2 images, on the contrary, have a better view of the overall storm morphology and its environment. For consistency with previous studies we refer here to the head of the GWS as the initial part of the disturbance and we call tail to the chain of vortices and clouds that developed Eastwards of the head.

3. Wind measurements

We retrieved winds in the storm head and its tail by comparing two consecutive images using an automatic cloud wind correlation technique. Since the images are separated by 10 minutes any small navigation uncertainty or pointing error produces a large uncertainty in the wind measurement. We have used images separated by 20 minutes (with a relatively small common area) and 30 minutes (with a very small common area). The correlation algorithm was used to inspect the winds northwards of the storm in regions not perturbed by the storm. This was checked by measuring the wind in this area (35º-50º) in a pair of WAC image separated by 10 hours which showed that the winds had not changed northwards of the storms compared with previous wind studies of Saturn's North Hemisphere [8]. The information about this area was used to slightly correct the navigation of the images (1-3 pixels) in an iterative manner. This technique was successfully used previously by our team in measurements of motions in Jupiter's Oval BA with high-resolution images from several missions [9]. We run our correlation algorithm proposing correlation boxes of different sizes depending on the contrast and size of the features. In the GWS tail we used correlation boxes of 0.5º x 0.5º and in regions with almost no features we used correlation boxes of 2.0ºx1.0º. Additionally the software visualizes the correlation map for each individual measurement as well as the template in the first image and its match in the second image allowing the user to validate or not the measurements as they are being obtained. We measured winds in 11 CB2 and 6 BL1 image pairs, the later covering only the GWS head. We obtained 14410 wind measurements in a cylindrical map covering 60º x 20º. Statistical analysis of the measurements in bins of 0.5ºx0.5º offered a median standard deviation of the winds of 14 m/s.

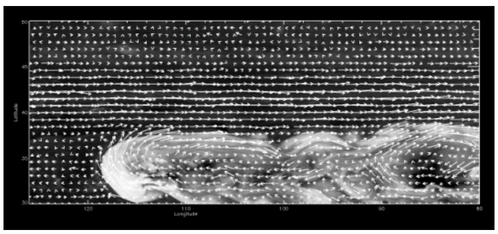

Figure 1: Wind field in the GWS head and tail. Each wind vector represents the mean value over several vectors obtained typically at least in 2 pairs of images. The global behavior of the wind field was validated by independent manual tracking measurements in BL1 images separated by a planetary rotation which indicated the sense of the motions and the magnitude of the winds in agreement with the winds obtained by correlation.

Strong meridional motions were present in the storm head at longitudes 115-118º. The tail of the storm is dominated by small cyclones and large anticyclones with a strong circulation in the northward part of the GWS. Vorticity maps correlate well with preliminary dynamical simulations presented by Sánchez-Lavega et al. [1] and divergence of the storm is concentrated in the southward part of the head and some of the southernmost elongated features appearing in the images.

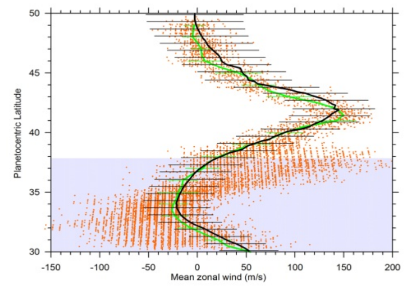

Figure 2: Main zonal winds outside the storm (black line) in a pair of WAC images separated by 10 hours. The wind field in the NAC images on the Westward side of the storm (green line) shows the unperturbed atmosphere in images separated by 20 minutes. Dots represent the ensemble of all measurements. All measurements are given in System III longitudes.

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