EPSC Abstracts
Vol. 6, EPSC-DPS2011-453, 2011
EPSC-DPS Joint Meeting 2011

Saturn's wind profile from Cassini ISS images and its long term variability

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Abstract

A complete view of Saturn's global circulation from Cassini images between 2004 and 2009 near the tropopause (MT filters) and in the upper troposphere (CB filters,) is presented. A comparison of previously published zonal wind sets obtained by Voyager 1 and 2, Hubble Space Telescope, and ground-based telescopes (1990-2004) with the present Cassini profiles (2004-2009) covering a full Saturn year shows that the shape of the zonal wind profile and intensity of the jets has remained almost unchanged except at the Equator where the intensity of the equatorial jet has slowed down ~ 100 m s^{-1}. Analysis of CIRS data also shows that differences between CB and MT measurements can be explained by the presence of vertical shear due to the thermal wind effect.

1. Introduction

Saturn undergoes a strong thirty-year-long seasonal cycle, probably influenced by the shadow cast by the rings. In addition, planetary scale convective storms called Great White Spots (GWS) develop at the equator and other latitudes injecting important amounts of aerosols and mass, possibly modifying the atmospheric dynamics [1]. Observing the atmosphere of the planet at different wavelengths sensing cloud reflectivity at different altitudes, allows us to study their dynamics and relationship with the temperature field through the thermal wind. High resolution observations of Saturn are difficult and retrieving detailed wind measurements is only possible with data from the space missions Voyager [2], and Cassini [3]. A detailed knowledge of Saturn's zonal wind profile in time is essential to understand its origin and dynamics. Indeed, Voyager and Cassini zonal wind profiles show differences at the equator difficult to reconcile [3]. These differences will not be fully understood until we have observations of Saturnian winds and other important physical variables through additional seasonal cycles. We present measurements of the mean zonal winds in Saturn obtained from Cassini ISS images during the 2004-2009 period and compare the wind profiles with measurements from HST and the Voyagers.

2. Observations and wind retrieval

Data presented in this study were derived from images acquired by the Cassini Imaging Science Subsystem (ISS) instrument onboard the Cassini spacecraft from late 2004 to early 2009. Image resolution ranged between 160 km pix^{-1} and 30 km pix^{-1}. Our analysis includes images obtained in the MT2, MT3, CB2, and CB3 filters. We used the Planetary Laboratory Image Analysis (PLIA) software to navigate Cassini images [4]. Zonal wind profiles were retrieved by using 1D automatic correlation techniques. Wind results were divided in bins and averaged to obtain MT and CB average zonal profiles.

3. Wind results

We obtained two distinct zonal wind patterns, one for the continuum CB filters and another for the methane absorbing band MT filters. In total, over 35000 wind measurements were collected in CB2 and CB3 covering planetocentric latitudes from 90ºS to 85ºN, and over 26000 in MT2 and MT3, spanning a latitude range from 80ºS to 73ºN. Uncertainties yielded average values between 5 m s^{-1} and 9 m s^{-1} for the respective MT and CB profiles. As a general result, (i) the MT profile is ~ 100 m s^{-1} slower than the CB profile at the equatorial jet, except for a very narrow jet centered on the equator [5], (ii) the MT profile is symmetrically faster than the CB profile around latitudes ±15º, and (iii) both profiles are coincident at the rest of latitudes except at the peaks of the prograde jet streams. Integration of the thermal wind equation upwards by using CIRS data [6] and the CB profile between 500mbar and 100 mbar, shows that differences between the CB and MT profiles are consistent wind vertical shear due to the thermal wind effect (Figure 1.)

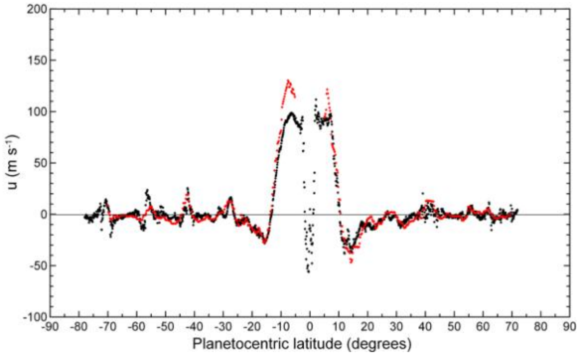

Figure 1: Zonal wind velocity difference between CB and MT tracers (solid dots,) and vertical wind shear computed from CIRS data (red dots).

4. Long-term variability and conclusions

Comparison between Voyager zonal wind measurements and Cassini results spanning almost a Saturn year (~30 terrestrial years) shows the following: (1) outside the equatorial region the zonal wind structure remained essentially unchanged in intensity and jet location, (2) the high temporal variability of the equatorial jet (Figure 2). Cassini ISS images confirm the ~ 40 m s^{-1} H^{-1} vertical wind shear previously detected in HST images during the GWS event in 1990 and from 1994 to 2003, (3) the major temporal difference in the Equatorial jet occurred when comparing the Voyager (1980-81) with the HST and ground-based periods (1990-2003) and Cassini (2004-2009). Differences are probably due to major changes in the equatorial circulation, although it is still unclear if they were introduced by the outburst of the GWS event in 1990. The ~100 m/s difference between Voyager and Cassini cannot be accounted for by only invoking vertical wind shear.

Acknowledgements

We are grateful to Leigh Fletcher for sharing with us CIRS data used in our thermal wind computations. This work has been funded by Spanish MEC AYA2009-10701 with FEDER support and Grupos Gobierno Vasco IT-464-07.

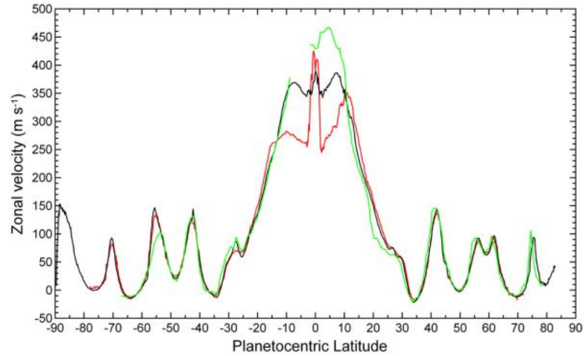

Figure 2: Voyager (light green), Cassini CB (black,) and MT (red) zonal wind profiles. The major difference between the Voyager and Cassini era is the ~100 m s^{-1} slow down of the equatorial jet.

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