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Cassini ISS Observations of Saturn's Great White Spot Storm 2010-2011

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Abstract

We present Cassini ISS observations of a giant cumulus storm on Saturn that started raging in early December of 2010 at 33°N latitude. Since then, the storm has evolved to become one of the fastest-evolving and largest-scale cumulus disturbances observed to date in our Solar System, and substantially altered the northern hemisphere cloud morphology. We believe that the new storm is the latest occurrence of the recurring Great White Spot storms on Saturn, which has an apparent ∼30-year quasi-periodicity and last erupted in 1990. Our measurements indicate that the new storm drifts westward at a rate of ∼2.8° in System III longitude per Julian day. Our observations also reveal that the storm erupted out of a cloud feature called the String of Pearls (SoPs), which was first discovered by Cassini VIMS instrument in 2004, and revealed to be a chain of cyclonic vortices by Muro et al (*1*). We have monitored the SoPs motions and showed that it has drifted westward at a constant rate of 2.28° in longitude per Julian day over a three-year period with less than 1-percent variation in its propagation rate. The drift rates of the new storm and the SoPs are substantially different from the local zonal wind speed; we propose that these drift rates reflect motions deep within Saturn's molecular hydrogen envelope.

1. Introduction

Cumulus storms on Saturn are known for their episodic behaviors, in which large outbursts often last for many months. The largest of them are called the Great White Spots (GWS), which have been recorded in 1876, 1903, 1933, 1960 and 1990, all of which have occurred in the northern hemisphere, alternately erupting in mid-latitude and equatorial regions (*2*). The event in 1990 was an equatorial event and erupted at 12°N latitude. The current event erupted at 33°N, which temporal development has been monitored with unprecedented details by Cassini probe in orbit around Saturn.

2. Cassini ISS View of GWS 2010

On December 5, 2010, the Cassini ISS camera imaged a spot on Saturn centered at 33°N latitude and 116° System III longitude, which covered approximately 1.5×10^6 km^2 and was notably brighter than the surrounding clouds. The next sighting of the spot by ISS occurred on December 24th, by which time the storm has substantially altered the morphology of the latitudinal zone. The storm became large enough to be detectable using Earth-based small telescopes by mid-December. Since the storm's eruption, the storm clouds have expanded from a bright leading edge at the west and billow eastward from the north and south end of the leading edge such that the clouds form an elongated horseshoe shape surrounding a dark interior and diffusely opened eastern boundary. The leading edge of the storm propagated westward at 2.8° longitude per Julian day (26.9 ms^{-1}) on average.

3. Storm Eruption from String of Pearls

The new storm marks the first time that the pre-storm cloud morphology was documented in detail. Our analysis reveals that the storm's initial latitude and longitude coincided those of a pre-existing feature known as the String of Pearls (SoPs), which was first discovered in 2004 using Cassini VIMS instrument at 33°N planetocentric latitude. We tracked the motion of the SoPs between May 2007 and December 2010 and found that SoPs drifts westward at a constant speed of 2.28° per Julian day in System III longitude (22.42 ms^{-1}) with less than 1-percent variation in its propagation speed during that interval. We then extrapolated its propagation back in time to determine that its position indeed agrees with that documented by (*3*) on September 11, 2006, demonstrating that the feature observed by VIMS and ISS are indeed the same (in September 2006, the SoPs region was obscured by ring shadows and not visible to ISS).

4. Discussion

Before the current GWS event, the largest cumulus event observed by Cassini occurred at 35°S and lasted until around the equinox in 2010. Our measurements show that the String of Pearls, the new storm at 33°N, and the previous storms at 35°S have drift rates that deviate substantially from the background zonal wind speed, indicating that the new storm and SoPs are not passively advected in the background wind field; explaining their drift speeds requires other governing mechanisms.

One possibility is that the observed cloud motion reflects the circulation deep within Saturn. System III reference frame has a 10h 39m 24s rotation period established from Saturn Kilometric Radiation (SKR) (*4*). However, Cassini detected two SKR periods, both of which have temporally varied by 1-percent (*5*). As the SKR signals do not indicate a unique state and their variations are too large to be that of the planet's interior, the SKR measurements leave the interior period uncertain. The internal magnetic field is axisymmetric, so it reveals nothing about the rotation period (*6*). The atmosphere has many discrete features that give well-defined rotational periods ranging from 10h 10m to 10h 40m (*7*) such as the hexagon at 75°N which is stationary in System III (*8*), and the storms described above have periods around 10h 41m.

Other studies have proposed faster rotation periods, which would make Saturn's wind profile more like Jupiter. A minimization principle that finds a particular weighted average of the atmospheric periods yields 10h 32m 35±13s (*9*). The method works for Jupiter, which has a tilted magnetic field that independently gives the rotation period, but it does not work for superrotating atmospheres like Venus and Titan. Shear stability analysis based on the cloud-level potential vorticity distribution finds a period of 10h 34m 13±20s, which assumes a teleconnection to the deep interior (*10*).

We propose that the internal period may be closer to the longer SKR, hexagon, and northern storm periods than to the shorter periods based on the average flow in the atmosphere. We do not claim that the longer periods are superior for estimating the interior period, and we freely admit that these ideas are speculative. Our goal is to raise the possibility that Saturn is different from Jupiter and instead has a superrotating atmosphere qualitatively like those of Venus and Titan.

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