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The December 2010 outbreak of a major storm in Saturn's atmosphere: Observations and models

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Abstract

On December 5, 2010, a major storm erupted in Saturn's northern hemisphere at a planetographic latitude of 37.7 deg [1]. These phenomena are known as "Great White Spots" (GWS) and they have been observed once per Saturn year since the first case confidently reported in 1876. The last event occurred at Saturn's Equator in 1990 [2]. A GWS differs from similar smaller-scale storms in that it generates a planetary-scale disturbance that spreads zonally spanning the whole latitude band. Studies of the 1990 case indicated that the storm produced a long-term substantial change in the cloud and haze structure around the tropopause level, and in the equatorial winds. We report on the evolution and motions of the new GWS and its associated disturbance during the months following the outbreak, based mainly on high quality images obtained in the visual range submitted to the International Outer Planet Watch PVOL database [3], with the 1m telescope at Pic-du-Midi Observatory and 2.2 m telescope at Calar Alto Observatory. The high temporal sampling and coverage allowed us to study the dynamics of the GWS in detail and the multi-wavelength observations provide information on its cloud top structure. We present non-linear simulations using the EPIC code of the evolution of the potential vorticity generated by an impulsive and localized Gaussian heat pulse that compare extraordinary well to the observed cloud field evolution.

1. Dynamical behaviour

As in previous GWS eruptions the spot grew rapidly both in size and brightness, expanding from a length of ~ 3,000 km to 8,000 km in just one week. The head of the storm moved from its initial place and centered onwards at latitude 41.1 ± 1.1° N with a rotation period of 10 hr 41 min 43.6 s, implying a westward zonal wind speed of -28.7 ± 0.2 ms^{-1} in System III reference frame. Two weeks after the outbreak, the GWS consisted of an initial bright compact spot followed eastward by a zonally expanding tail of bright clouds between latitudes 30ºN and 45ºN (Figure 1).

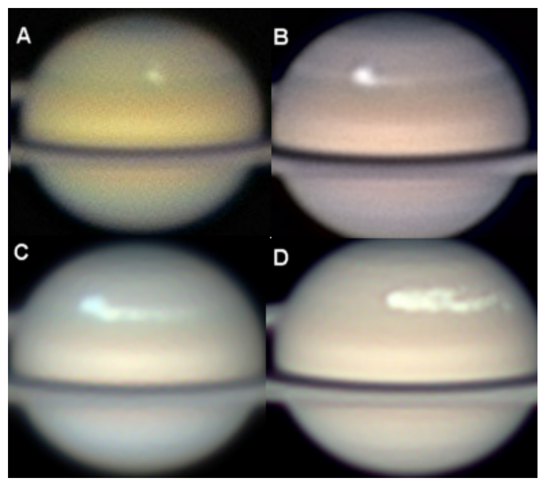

Figure 1 Images of Saturn's 2010 storm. *(A) Dec. 9, 2010 (Kumamori); (2) Dec. 13 (Akutsu); Dec. 21 (Parker); Jan. 2, 2011 (Parker). North up, East right.*

The spreading tail formed a planetary-scale disturbance that encircled the planet after 55 days when it encountered the head. The shape of the head of the storm and its drift rate remained unperturbed. Tracking of individual cloud elements during the observing period (December 5^{th} 2010 – February 19^{th} 2011) showed they moved in the zonal direction with speeds very close to the ambient winds. Therefore winds at the upper cloud level, which have remained essentially unchanged throughout a whole Saturn year were not altered by the disturbance at this early stage. This behavior is consistent with essentially a drag of the disturbance clouds by ambient zonal winds. In the stratosphere however, the structure of the temperature field was strongly modified by the

GWS with related changes in the thermal wind with respect to the undisturbed atmosphere

2. Radiative Transfer Model

Photometric observations obtained with a variety of filters from the ultraviolet (375 nm) to the near infrared (954 nm) showed that the GWS is brighter relative to the adjacent undisturbed area at the same latitude by ~ 10% (375 nm), 19 % (450 nm), 25 % (537 nm), 16 % (580 nm) and 11% (630 nm). Ground-based telescopes did not detect the storm head in the deep methane absorption band at 883 nm. The high brightness can be attributed to fresh ice particles injected into the tropopause by the storm, where they mix with the pre-existing haze. Radiative transfer models indicate that the GWS storm clouds tops were at an altitude level of ~ 150 mbar embedded within a tropospheric haze. This is 20 km below the tropopause that is located at 100 mbar according to thermal infrared measurements.

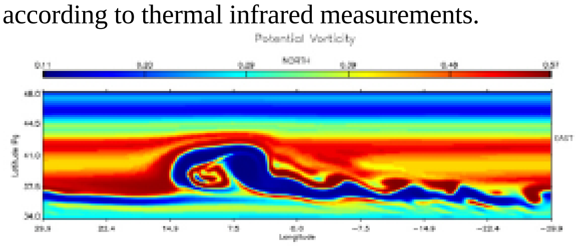

Figure 2 EPIC simulation of the storm clouds. The potential vorticity map is for 12 days after the injection of a columnar Gaussian-shape continuous heat source.

3. Dynamical Models

In order to explain the disturbance structure at cloud level, we ran nonlinear simulations of the response of Saturn's upper troposphere and stratosphere to a steady vertical heat source that tries to mimic the GWS convective storm head using the EPIC code [5]. We tested the structure of the atmosphere varying the zonal wind vertical profile and thermal structure in a forward modeling of the potential vorticity (*PV*) field. Figure 2 shows a result from a simulation of the *PV*-field that highly resembles the cloud disturbance evolution. These successful simulations require a weather layer (0.5 – 10 bar) with a very low static stability close to a neutral profile (except where clouds form), and winds that increase slightly with depth across it.

GWSs have been observed to occur one per Saturn year in the northern hemisphere summertime season. The 2010 event occurred at a much earlier springtime season within the same westward jet as the 1903 event, pointing towards seasonal insolation as their triggering mechanism. This is puzzling since the solar radiation penetration in Saturn's atmosphere and thermal infrared measurements indicate that seasonal temperature changes occur mostly above ~ 1bar altitude, much higher than the 10-12 bar level for the storm source. The observed GWS properties and its modeling suggests that a reservoir of water vapor must exists at the 10-12 bar level in the westward jet with sustained strong convergence to fuel the storm. The huge planetary scale disturbance triggered by the GWS did not modify substantially the westward zonal jet structure indicating that Saturn tropospheric winds are robust and extend well below the sunlight penetration level altogether favoring the hypothesis for their deep origin as also found for Jupiter's winds [7].

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References

[1] Sánchez-Lavega A., et al., *Nature*, in press.

[2] Sánchez-Lavega A., et al., *Nature*, **353**, 397-401 (1991)

[3] Hueso R., et al., *Planet. Space Sci.*, **58**, 1152-1159 (2010).

[4] Fletcher, L.N., et al., *Science*, in press.

[5] Dowling, T. E., et al., *Icarus* **132**, 221-238 (1998).

[6] Pérez-Hoyos S. and A. Sánchez-Lavega, *Icarus*, **180,** 368-378 (2006).

[7] Sánchez-Lavega A., et al., *Nature*, **451**, 437- 440 (2008).