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Shallow Water simulations of Saturn's 1990 and 2010 Great White Spots

E. García-Melendo (1,2), A. Sánchez-Lavega (1,3)
(1) Departamento de Física Aplicada I, E.T.S. Ingeniería, Universidad del País Vasco, 9 Alameda Urquijo s/n, 48013 Bilbao. Spain.
(2) Fundació Observatori Esteve Duran, Montseny 46, 08553, Seva. Spain.
(3) Unidad Asociada Grupo Ciencias Planetarias UPV/EHU- IAA (CSIC). Spain.

Abstract

The last two, and best observed, planetary scale storms in Saturn have been the 1990 and 2010 Great White Spots (GWS.) These two giant convective events gave us information about Saturn's atmosphere dynamics below the cloud top level at deeper levels of the troposphere [1, 2] for two different regions: Equator dominated by strong Eastward winds (GWS 1990) and mid-latitudes within the peak of a Westward jet (GWS 2010). After these events, the observable zonal wind profile at the storm region has been observed to change, especially at Saturn's equatorial region [3, 4]. These changes may be due to massive mass injection which alters momentum balances. Here we present shallow water (SW) simulation results, which show the interaction of the storms with zonal winds.

1. Introduction

The 1990 GWS was the first storm to be thoroughly observed by ground-based and Hubble Space Telescope [5, 6]. It appeared on September 25, 1990 on the north side of the planet's equatorial region, at about +12º, lasted for months and changed its morphology for years [7], and probably its dynamics with a substantial alteration of the strength of the equatorial jet. The impact at a planetary scale of the 2010 giant storm was not a minor one. It appeared on December 5, 2010 at +40º, lasted for nearly seven months and it locally altered Saturn's zonal winds, created a temperature anomaly in the planet's high stratosphere [8], and also altered the morphology of the regions for years. Previous numerical simulations showed that continuous mass and energy injection by the convective event could explain the dynamics of the 2010 storm's head [1, 9]. Numerical models of the 1990 GWS storm suggest that mass injection could not significantly change the equatorial jet strength [10]. Here we revisit the 1990 GWS effects on zonal winds with SW models.

2. The computer model

Our numerical model consists in a one layer SW model whose fundamental parameters are the SW layer thickness *H*, the zonal wind profile, the latitude where the storm is injected, and the strength of the storm itself. The storm is parameterized as a mass pulse whose amplitude, extension, shape, drift velocity with respect System III, and time duration are also free parameters. SW models are far more simple than most of 3D models, but in many situations they capture the essential physics with a much lower computational cost allowing to test a wider range of parameters at higher spatial resolution. Currently we have developed a two-layer shallow water model. Results on the GWS with the new code will be presented at the meeting.

3. Results

For the 1990 GWS case, we tested storms injected from 0º to +15º in latitude, and several real zonal wind profiles such as Voyager [11], and Cassini [12]. For the 2010 event similar test were done in the latitude range of +36° to +45°. We put these results in the context of the 2010 GWS previously published baroclinic simulations that also served to test the vertical thermal and wind shear structure, as well as the storm dynamics at cloud top level [1, 9].

4. Conclusions

Our first results indicate that it is possible to reproduce the main morphological aspects of the cloud tops in the 1990 and 2010 giant storms, the instabilities and waves produced by the real phenomena, and alterations of the zonal wind system

consistent with the observations. SW simulations allow to discriminate very well the pre-shape of the zonal wind profile at the 1990 storm, the latitude location of the outburst, the magnitude of mass injection and its effects on the zonal wind profile. Simulations also stress the importance of the shape of the local zonal wind U(y) in both storm developments. For example, storm dynamics and morphology during the initial development is totally different between the 1990 and 2010 GWS due to different local U(y) as shown by Figure 1.

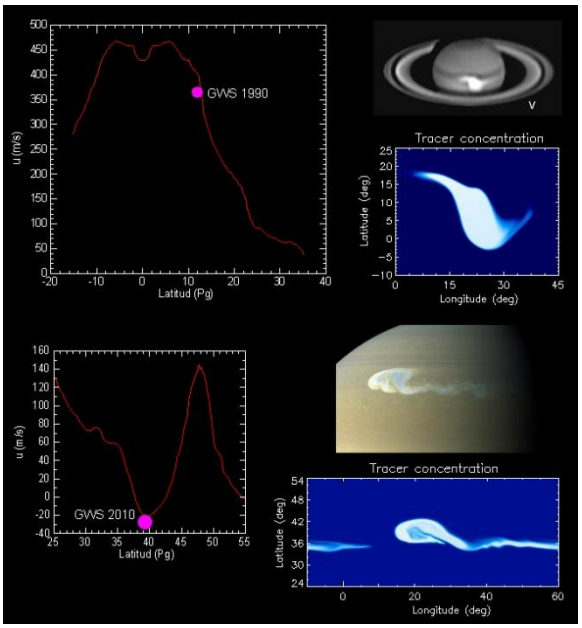

Figure 1: Comparison between the initial stages of the 1990 GWS (up) and the 2010 GWS (down) according and SW simulations as they sit at totally different points of the zonal wind system. GWS 1990 image taken by the 1m planetary telescope at Pic du Midi. 2010 GWS image taken by Cassini-ISS.

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