Hazes and clouds in Saturn's atmosphere from HST

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Brief abstract

We present the investigations by the Planetary Sciences Group (UPV / EHU) on the haze and clouds of Saturn's polar atmosphere with HST images. We have analysed these situations:

a) A planetary-scale disturbance related to a triple vortex between latitudes 50º-65º N.

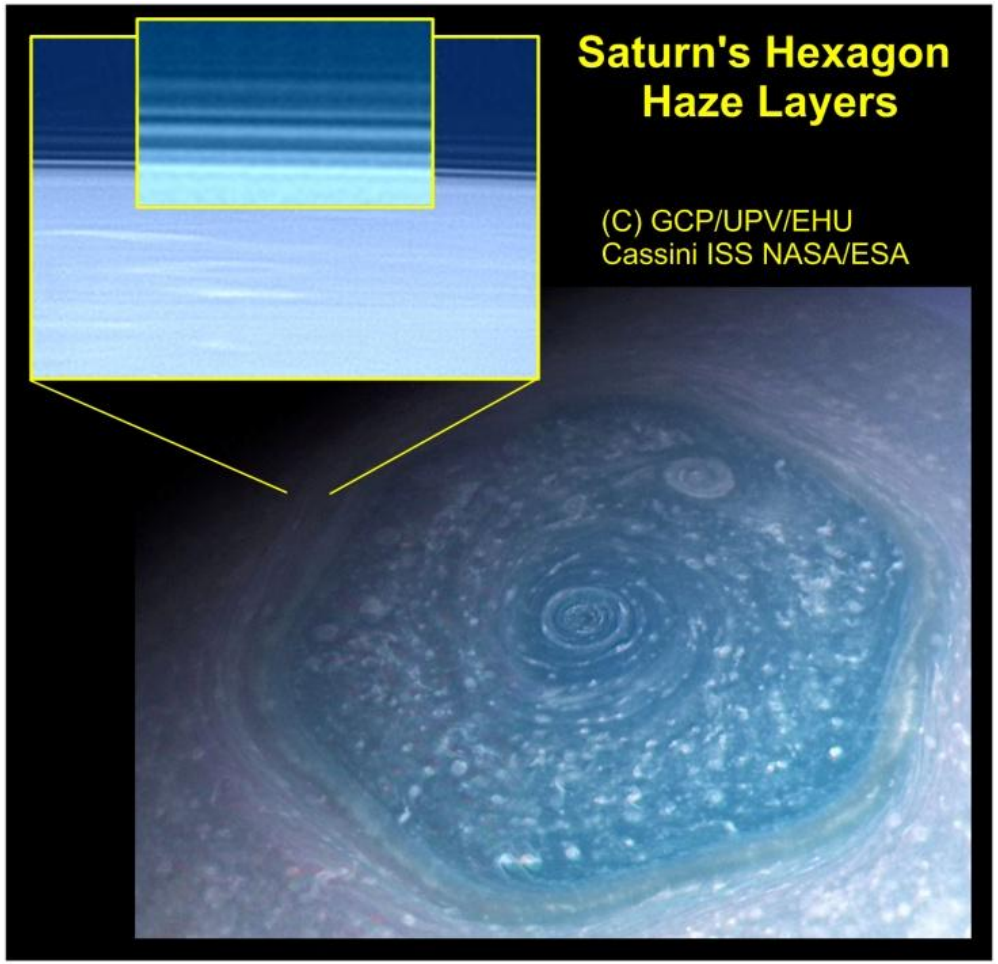
b) A complex storm system in Saturn's north polar atmosphere in 2018

c) Observation of multiple layers of haze on the Hexagon wave of Saturn.

Context of the research

The North Pole of Saturn is a region where we find unique atmospheric features as we move from the Equator to higher latitudes. Examples of these are the Hexagon Wave, a fast eastward jet, cyclonic and anticyclonic vortices or the polar vortex. In order to understand such lively atmospheric dynamics it is essential to know the vertical distribution of haze and clouds, which are used as its tracers. This also requires the knowledge of the physical and optical properties of the cloud and haze particles in the stratosphere and upper troposphere of Saturn.

In these research works we have used images obtained with the WFC3 camera of the Hubble Space Telescope, that cover from ultraviolet to near infrared, including methane absorption bands that probe different heights in the upper atmosphere



Methodologies

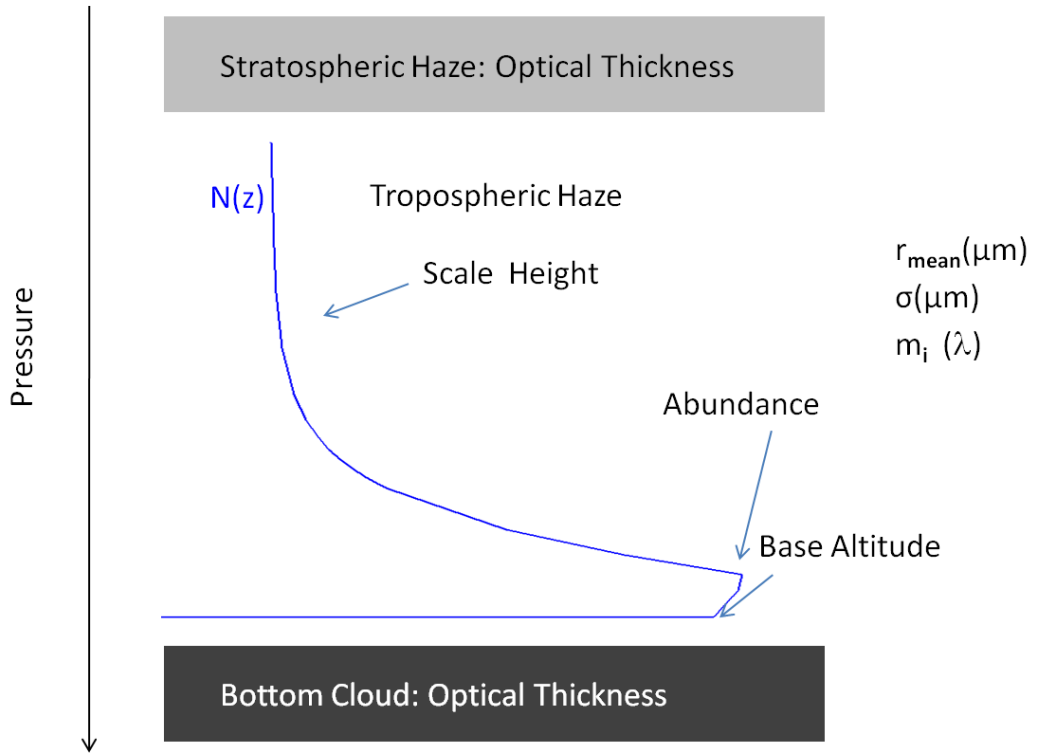
Radiative transfer code

•The goal of our modeling is to reproduce the observed **dependence of absolute reflectivity with geometry** (location on the disk and solar phase angle) **for all wavelengths** at the same time**.**

•In these works we have used the **radiative transfer code** and retrieval suite **NEMESIS** (Non-Linear Optimal Estimator for MultivariatE Spectral AnalySIS)

•We include Rayleigh scattering due to the mixture of H_2 and He as well as the absorption due to CH_4

• The properties of each layer observed at the limb was aimed to reproduce the measured spectral reflectivity we uses a model that solves the radiative transfer problem under **spherical geometry**



Vertical cloud structure model

A vertical structure consisting of three distinct layers of particles is good enough to reproduce the spectral and geometric variations of the absolute reflectivity at visible wavelengths

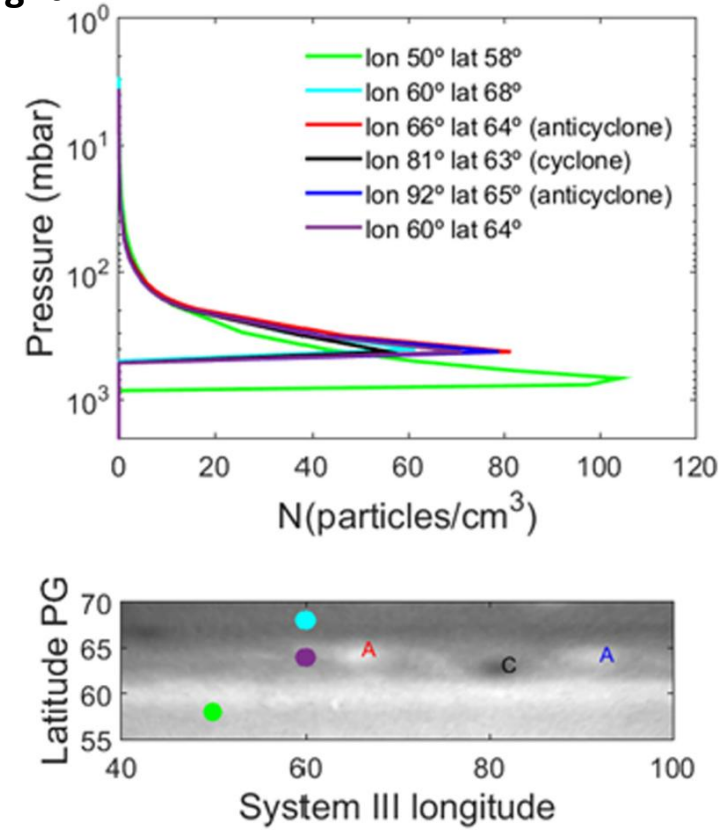
a) A planetary-scale disturbance related to a triple vortex between latitudes 50º-65º N.

* The jet **at +60ºPC of the zonal wind profile of Saturn has a singular** structure, with a double peak that is not present in any other jet either in Saturn or in Jupiter.

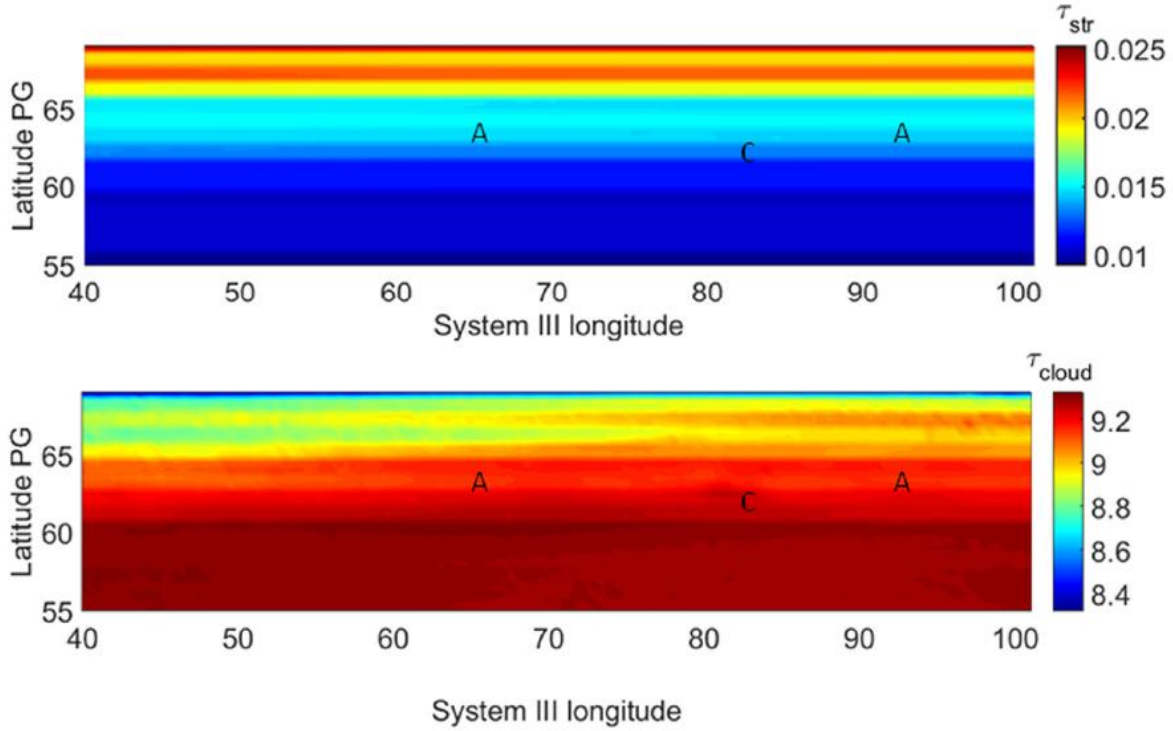
* At the latitude of this double peak, a system of three vortices, a cyclone and two anticyclones. (**triple vortex**)

Results

1.- Variations correspond to characteristic parameters of the tropospheric haze: **particle number density and the base height.**



2.- The **optical thickness** of the **stratospheric** haze and the **cloud.**



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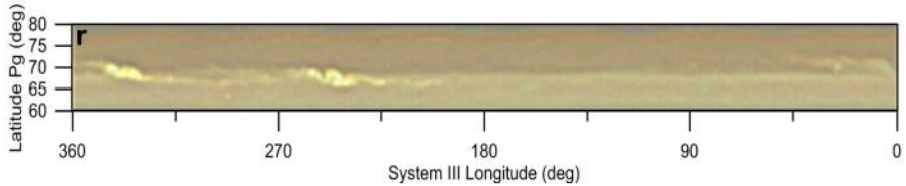
b) A complex storm system in Saturn's north polar atmosphere in 2018

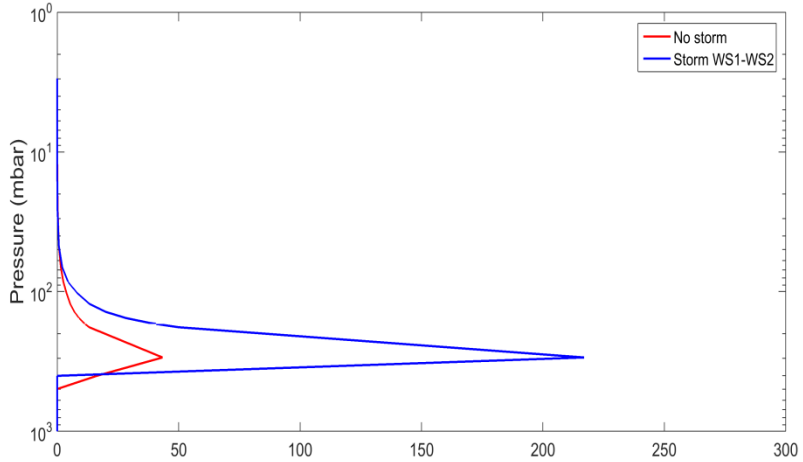
* We report a **new storm type**, observed in 2018 in the North Polar Region

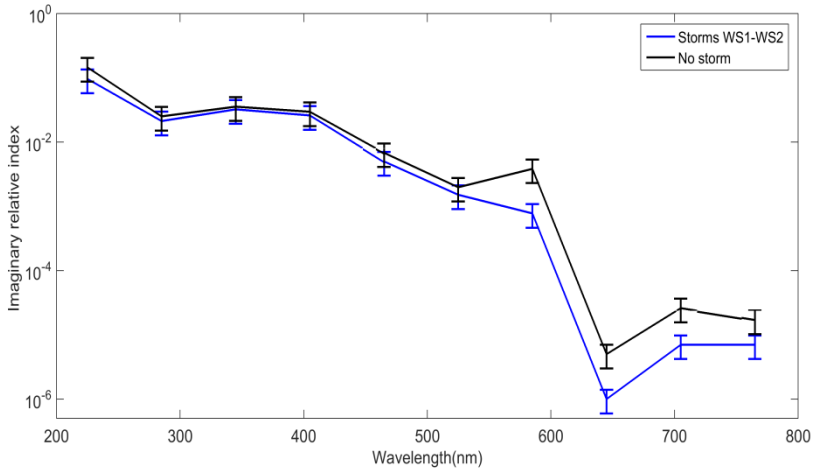
* This event occurred at about the same latitude and season as the GWS in 1960



Cylindrical map projection strips showing the storms WS1 and WS2 on 6 June 2018 using the WFPC camera on Hubble Space Telescope

Results





1.- Comparing the storm cloud structure to the surrounding clouds, the model fit to the observations is improved if **the storm clouds are denser and slightly highe**r.

2.- The storm model requires an increase in the optical depth of the tropospheric cloud , that is, **an increase in the particle density** (~50 to 215 cm^{-3}) together with an **increase in the top altitude of the hazes** (~ 600 to 200 mbar)

3.- The **particles in the storm clouds are marginally brighter** (that is, with lower imaginary refractive index) and slightly larger relative to surrounding clouds.

4.- We propose that the 2018 storms represent **an intermediate case of a convective disturbance** between a classical GWS planetary-scale phenomenon and the smaller-scale convective activity

A.Sánchez-Lavega, E García-Melendo, J Legarreta, R.Hueso, T.del Río-Gaztelurrutia, J. F. Sanz-Requena, S. Pérez-Hoyos, A. A Simon, MH Wong, M Soria, J. M. Gómez-Forrellad, T. Barry, M. Delcroix, KM Sayanagi, JJ Blalock, JL Gunnarson, U. Dyudina, S Ewald, **2020**. *A complex storm system in Saturn's north polar atmosphere in 2018*. **Nature Astronomy** 4 (2), 180-187

c) Observation of multiple layers of haze on the Hexagon wave of Saturn.

* In June 2015 the Cassini spacecraft obtained images of **the planet limb** at a high spatial resolution.

* These images revealed the existence of **a system of at least six stacked haze layers** located above the upper cloud deck, southwards of the hexagon, and not present at any other imaged latitude.

Results

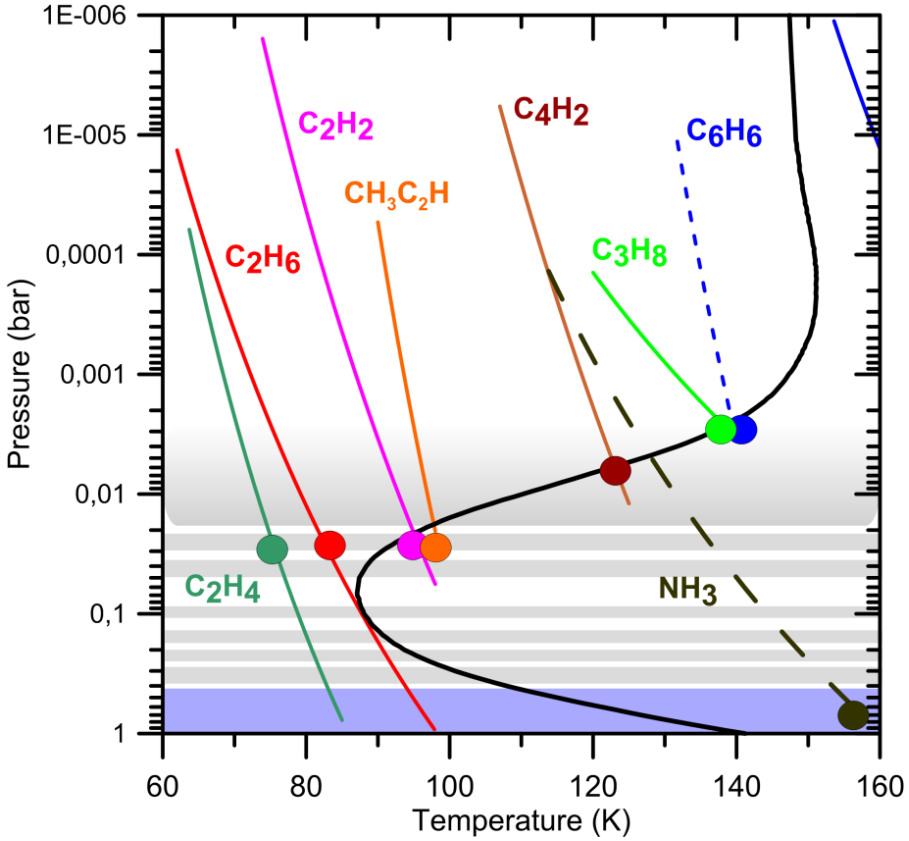
1.- The **vertical thickness** of the layers ranges from ~ 8 to 18 km (or about 0.2-0.3 atmospheric scale-height).

2.- The **stratospheric** layers have **small particles** with effective radius ~ **0.02 µm** and **density** by number in the range ~ **100- 500 cm^{-3}**, and in the **tropospheric** layer has effective radius ~ **1.4 µm** and number density~ **100 cm^{-3}**

3.- The nature of these hazes is compatible with their formation by **condensation of a number of hydrocarbons** detected in Saturn's atmosphere forming high in the atmosphere by photochemical reactions.

4.- We propose that **the vertical distribution** of the stacked system of haze layers could be **produced by the upward propagation of internal gravity waves** excited in the hexagon wave and its eastward jet area, perhaps in a similar way to what it occurs in Earth's jets and fronts

Vertical temperature profile and saturation vapor pressure curves for different hydrocarbons



A. Sanchez-Lavega, A. Garcia-Muñoz, T. del Rio-Gaztelurrutia, S. Pérez-Hoyos, J.F.Sanz-Requena, R Hueso, S Guerlet, J Peralta. **2020**. *Multilayer hazes over Saturn's hexagon from Cassini ISS limb images.* **Nature communications** 11 (1), 1-8

Impact

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