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Saturn's cloud structure and particle phase function based on Cassini ISS observations

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Abstract

Cassini ISS observations of Saturn provide images with high spatial resolution that allow dynamical analysis of many Saturnian meteorological phenomena, such as the giant storms [1] or the Hexagon wave [2]. Observations in selected narrow filters in and out the methane absorption bands in the near infrared also provide information on the vertical distribution of clouds and hazes in the lower stratosphere and upper troposphere, in particular regarding micron-sized or smaller populations. In this work, we use Cassini ISS observations to constrain the vertical distribution of particles in the Northern Hemisphere in the 2011-2013 period with particular emphasis in the Equatorial Zone and the Polar Region, where the Hexagon is located. We also focus on the phase function describing the scattering of light by tropospheric particles, which is a substantial piece of information only accessible with observations at high phase angles.

1. Observations

The observations used in this work are all images taken in the methane bands at 727nm and 890nm (MT2 and MT3 filters) and an adjacent continuum at 752 nm (CB2). These filters are sensitive mostly to tropospheric levels [3], moving deeper as the methane absorption decreases from MT3 to CB2. At the same time, these filters have wavelengths similar enough to assume that other characteristics (such as the phase function parameters) are the same for all of them.

The observations were selected based on the following criteria: (1) to cover partially or completely the Northern Hemisphere, (2) to span as much phase angles as possible, (3) to be taken in as short as possible amount of time at a given latitude to avoid temporal variations in the atmosphere. In this way, more than 70 images were selected, navigated and calibrated to retrieve maps of absolute reflectivity as a function of latitude and scattering angles. Phase angles covered from as low as 10º to values as high as 160º for some filters and latitudes.

2. Modelling approach

In order to reproduce the observed maps of absolute reflectivity, the NEMESIS retrieval code [4] and its underlying radiative transfer correlated-k algorithm was used. The multiple-scattering radiative transfer code is based in the doubling/adding scheme and includes gas absorption.

NEMESIS is designed to use fixed spectral parameters and iterate over the possible vertical atmospheric profiles. Since we aimed to retrieve phase function parameters, an initial scanning of the free parameter space using a Nelder-Mead simplex algorithm was performed. Using the best-fitting result for the spectral parameters, NEMESIS provided the optimal solution for the vertical distribution of particles.

In our model, we included three layers of particles: stratospheric and tropospheric hazes (with different properties) and the tropospheric upper cloud, putatively formed by ammonia ice, following common assumptions in similar previous works [3,5].

The particle phase function for the troposphere was assumed to be a double Henyey-Greenstein phase function, in order to compare later with previous works based on Pioneer flyby observations on the late 70s that determined the Saturnian phase function for first and only time [6].

Retrieved free parameters include the particle density as a function of height for the hazes, average particle density for the cloud, particle phase function parameters for the tropospheric haze and particle size distribution for the stratosphere.

3. Particle phase function

The double Henyey-Greenstein phase function (2HG) is described by a forward scattering assymetry (g_1), a backward scattering assymetry (g_2) and the relative contribution of each (f). We show some preliminary results for the latitudinal dependen of these parameters in Figure 1 below.

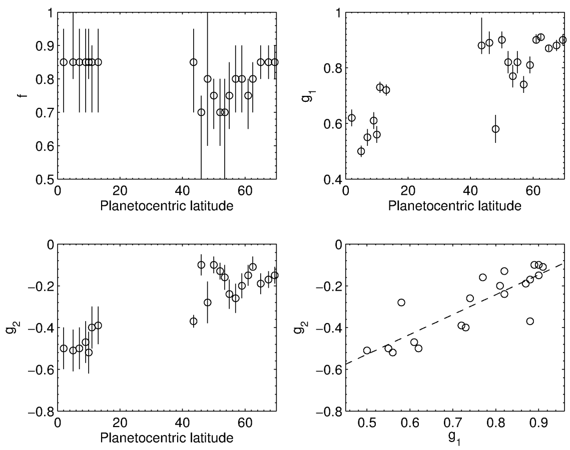

Figure 1: Sample retrievals of the 2HG phase function parameters as a function of latitude for the 2011 observations. Bottom right panel shows the correlation between forward and backward parameters. The gap at mid-latitudes is due to the 2010 GWS, whose rapid evolution makes impossible to work with several phase angles at the same time.

4. Conclusions

In general terms, we find the particles to be more forward scattering at equatorial latitudes than at the mid-latitudes, suggestive of larger sizes. The phase function for the particles at mid-latitudes is more similar to the one retrieved using previous missions [6].

We also find a distinct vertical cloud structure in the equatorial region, with higher and more vertically extended hazes in the low latitudes. This kind of vertical distribution of particles agrees well with the observed differences in the dynamics as seen in methane absorption bands or the adjacent continuum, which could be sounding dynamically decoupled levels in the atmosphere.

We are currently undergoing a detailed analysis of the vertical cloud structure of Saturn's North Polar Region and we will also show the phase function results for the Hexagon and adjacent latitudes.

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