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Saturn's cloud structure inferred from Cassini ISS data

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Abstract

A study of the vertical structure of Saturn's upper atmospheric clouds and hazes is presented using images acquired during Cassini's 2004 approach. High-resolution Cassini Image Sciences Subsystem (ISS) images in eight different bandpasses were analyzed. Individual atmospheric features were examined at both nadir and limb views. Radiative transfer analysis employing an adding and doubling technique was used to model cloud reflectivity. In order to better constrain the vertical structure, a technique based upon the Galileo SSI Jupiter analysis [1] was employed, which examines the extent of correlation in local variations between different filters. Preliminary results suggest most regions of low contrast can be modeled with two simple haze layers. Other locations indicate small-scale variations in optical depth occurring beneath the hazes, interpreted as discrete cloud features located deeper than ~2.5 bars.

1. Introduction

The vertical structure of cloud and hazes provides insight into the dynamics and chemistry that characterize the Saturn atmosphere. The goal was to build the simplest atmospheric models whose radiative transfer solutions concurrently satisfy the observations at multiple wavelengths and viewing angles; by exploiting the wavelength and geometric dependences in the equations of transfer, constraints were placed on models, and properties such as vertical distribution, optical depth, single scattering albedo and size of aerosols were inferred.

Traditional methods for inferring the vertical distribution of aerosols often look at constructing simple atmospheric models whose reflectivities match center to limb variations in observations; however, such methods are subject to ambiguous solutions and assume a zonal homogeneity. In order to improve upon this method and better constrain cloud heights, we employ a technique similar to that used in the Galileo SSI study of Jupiter [1].

1.1 Analysis Technique

The technique employed attempts to utilize small-scale (on order of 100km) features of strongly contrasting I/F as seen in filters penetrating different depths. The degree of observed correlation between varying filters reveals the amount attenuation that occurs in one relative to another and thus helps to constrain the depth of the observed feature in the context of the overlying aerosols. We modeled these features as variations in the optical depth of a localized condensate cloud (as opposed to changes in the presumably more homogenous overlying hazes). As models were iteratively constructed, these parameters placed further constraint on the optical depth of aerosols above the varying layering and thus provide a better estimate of the vertical structure than I/Fs alone could provide.

Model atmospheres consisting of hazes and optically thick clouds were iteratively constructed by a process of least squares minimization with respect to model parameters and observed I/Fs. Fitted parameters included a 619 nm optical depth, singles scattering albedo for particle expressed at 343 nm and 451 nm, particle radius, and a base pressure for each layer. Calculations were performed using an adding and doubling multiple scattering code.

2. Conclusions

Preliminary results suggest that most regions of low contrast can adequately reproduce the observations with just two layers of hazes. This is consistent with other recent studies [2]. In regions with features of small-scale contrast, additional, deeper layers of varying optical depth are required. In at least one instance, the depth of these features must be greater than ~2.5 bars to account for the observed correlations between filters. This depth suggests a deep condensate cloud most likely composed of ammonium hydrosulfide.

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