National Aeronautics and Space Administration

Can a Multi-Wavelength Data Set Lead to a Consistent Model of Giant Planet Clouds and Dynamics?

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Program: Innovative Spontaneous Concepts

Project Objective:

Use Cassini data to explore how a combined near-IR, mid-IR, and radio-wavelength data set can be used to resolve basic questions about giant planet dynamics and cloud formation.

Conclusions:

- Retrievals of atmospheric temperature and composition as a function of altitude have non-unique solutions, even with a combined data set. Specific models can, however, be tested.
- Limitations of the Cassini spacecraft typically put gaps of >12 hours between a location being observed with one instrument and the next, requiring more extensive co-registration efforts than were possible under this award.
- The results are promising enough, however, that follow-up work with Cassini data is planned.

Background

When retrieving atmospheric properties from remote sensing observations of thermal emission, there is a uniqueness problem; there are many vertical profiles of temperature and opacity which can fit the data.
To get around this problem, assumptions (expressed as mathematical models) are typically made that couple various parameters or set limits on their allowed values.
Recent observations, such as from the Juno spacecraft, have found that our models of atmospheric dynamics and cloud formation are wrong.
We set out to explore how a multi-wavelength analysis could reduce our reliance on models or better constrain their validity.

Approach

We first used the Cassini CIRS instrument working at wavelengths from the mid- to far-IR to constrain atmospheric temperature profiles as a function of latitude.

We then used Cassini Radar-Radiometer data at 2.2 cm to retrieve the vertical profile of NH_3 vapor near the 1-bar level.

Finally, we co-registered a Cassini VIMS data set (near-IR wavelengths) to the Radiometer data, and retrieved cloud properties and various vapor abundances including NH_3. NH_3 was used as both a free parameter and set according to the Radiometer results.

Results

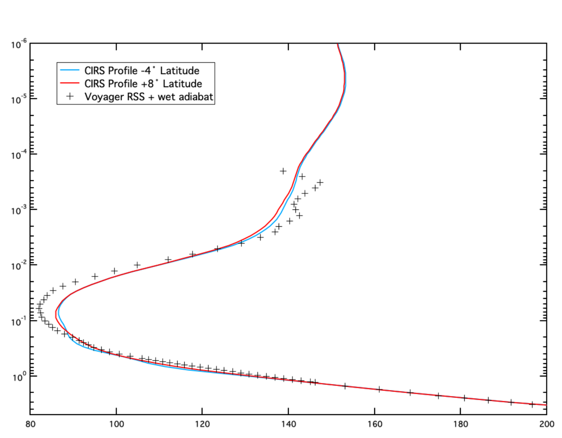

Fig. 1: Retrieved CIRS temperature profiles and Voyager Radio Occultation Results (used as a priori for CIRS retrievals).

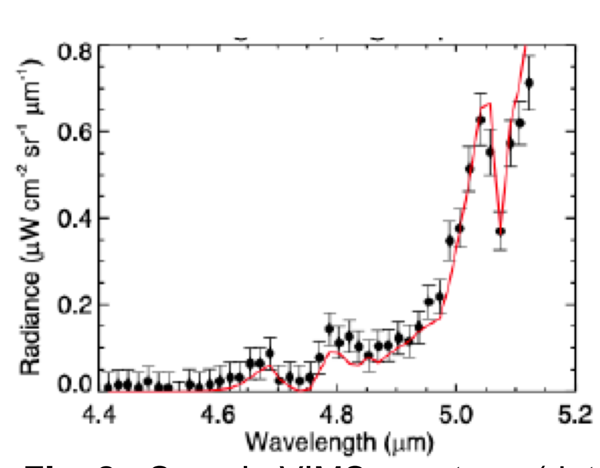

Fig. 2: Sample VIMS spectrum (data points) for the bright test spot in Region 1 (see Fig. 3), and model fit (red curve).

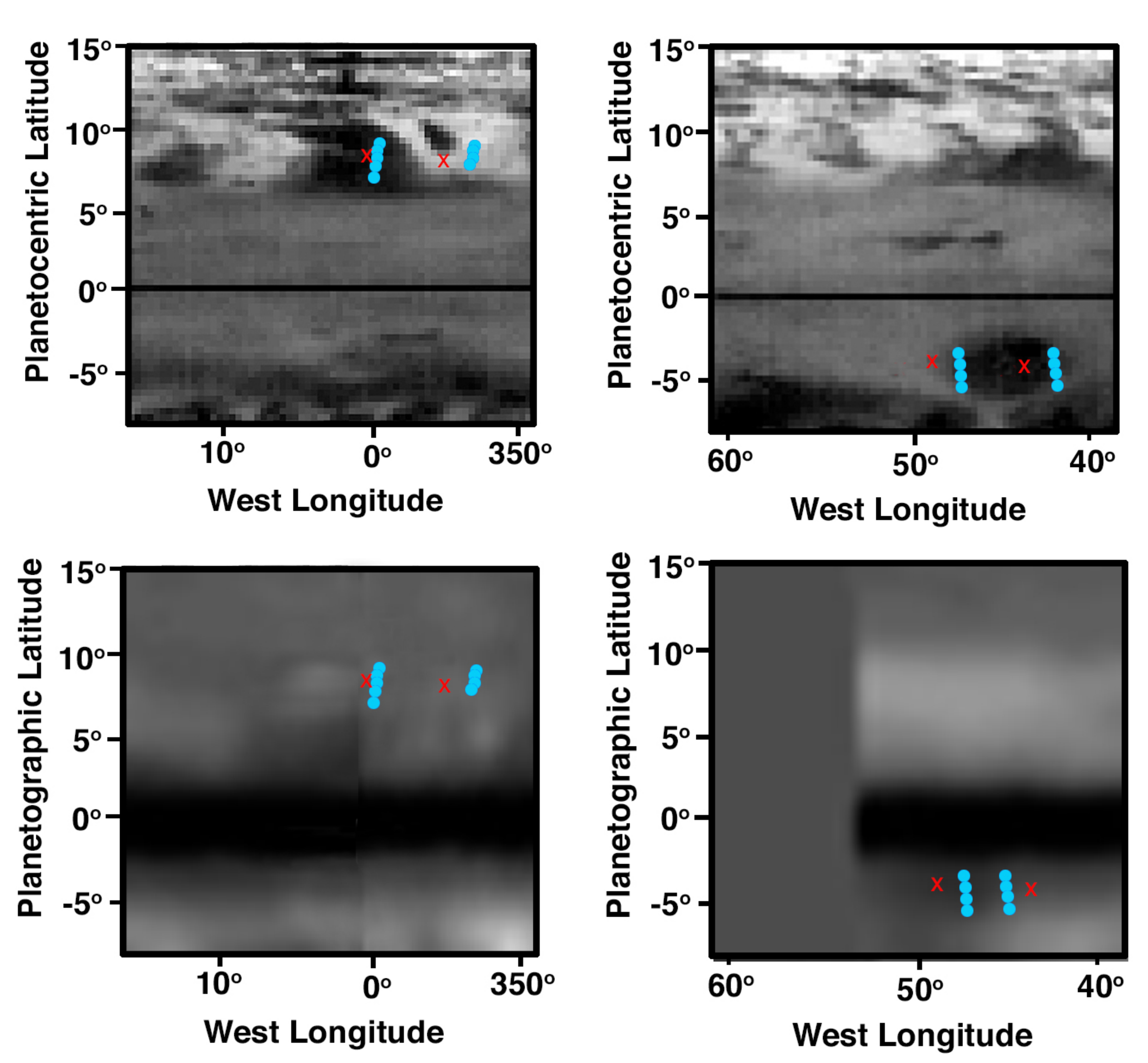

Fig. 3 (right): Top panels are VIMS brightness at 5 μm in two test regions, referred to as Region 1 (left) and Region 2 (right). Lower two panels are Radiometer brightness measurements of the same regions at 2.2 cm. Red X's mark VIMS bright and nearby VIMS dark regions chosen for study. Blue circles indicate the location of nearby Radiometer measurements at 2.2 cm.

Co-registration of VIMS and Radiometer data (26 hours apart) assumed Voyager-derived equatorial wind speeds of 400 m/s. This neglects temporal changes between Voyager and Cassini and the possibility of wind-shear between the altitudes probed at visible, near-IR, and radio wavelengths. (A better approach, which we intend to do in the future, is to use two sequential VIMS maps---which bracket the Radiometer map---to interpolate the location of VIMS features to the time of the Radiometer map.)

Discussion of Retrievals:
The temperature profile is important for interpreting VIMS data, but not Radiometer.

VIMS brightness variations are primarily due to variations in the optical depth of an upper NH_3 cloud. Bright regions have an optically thin cloud, which allows emission to come from warmer (brighter) deeper regions. Optical depth of the cloud is more than 10x lower in bright regions than dark ones. This is consistent with previous analyses [e.g. Fletcher et al., 2011, Icarus 214]. VIMS retrievals are not very sensitive to NH_3 vapor, so results are similar whether or not the Radiometer constraint (see below) is applied.

Bright and dark areas in the radiometer test regions have factors of a few variation in NH_3 abundance. We found both test areas in Region 1 were bright to the Radiometer, while in Region 2 bright/dark areas were correlated with VIMS. The correlations are suspect, however, due to the crude co-registration applied.

These results do allow us to conclude that cloud models could be tested using a properly co-registered data set, with VIMS constraining aerosol properties and Radiometer constraining the vapor.

Benefits/Significance to NASA and JPL:

Scientific Benefits:

- We have developed tools and a collaboration that can be used to explore Saturn's atmosphere at multiple wavelengths.
- This approach can be used to study atmospheric clouds and dynamics at any giant planet.

Programmatic Benefits:

- Our results help inform decisions about the payload to fly on future giant planet missions.
- Our results help inform decision about how to schedule remote sensing observations on future giant planet missions.

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