# Technical Report
# University Of Wisconsin-Madison

**Project Title: Investigating Saturn's Cloud Structure and Composition with CASSINI/VIMS**

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**For the Period of: 07/15/2012 – 07/14/2013**


**Principal Investigator: Lawrence A. Sromovsky**

**Location:** **University of Wisconsin – Madison**
**Space Science and Engineering Center**
**1225 West Dayton Street**
**Madison, WI 53707**


**Reports will be sent to:**
Grants Officer
NASA Shared Services Center
Procurement Office, Bldg 1111
Stennis Space Center, MS 39529
NSSC-ContactCenter@nasa.gov

Technical Officer
Attn: Terry A. Hurford
NASA Headquarters
300 E Street SW, Suite: 693.0
Washington, DC 20546
terry.a.hurford@nasa.gov

New Technology Office
Attn : New Technology Representative
NASA Goddard Space Flight Center
Greenbelt, MD 20771
Melissa.S.Jackson@nasa.gov

*(To be completed by the Principal Investigator)*

**Inventions Report:**
No inventions resulted from this grant.

**Inventory Report:**
No federally owned equipment is in the custody of the PI.

**Publications:** (List)

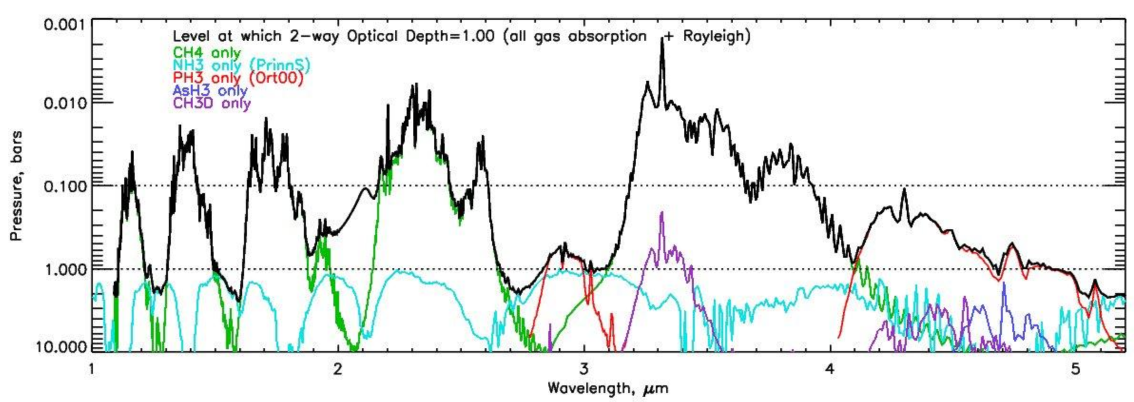
Sromovsky, L. A., K. H. Baines, and P. M. Fry. 2013. Saturn's Great Storm of 2010-2011: Evidence for ammonia and water ices from analysis of VIMS spectra. Submitted to Icarus.

**Summary of Technical Effort:** (Usually several paragraphs. Please feel free to attach additional pages if you wish.)

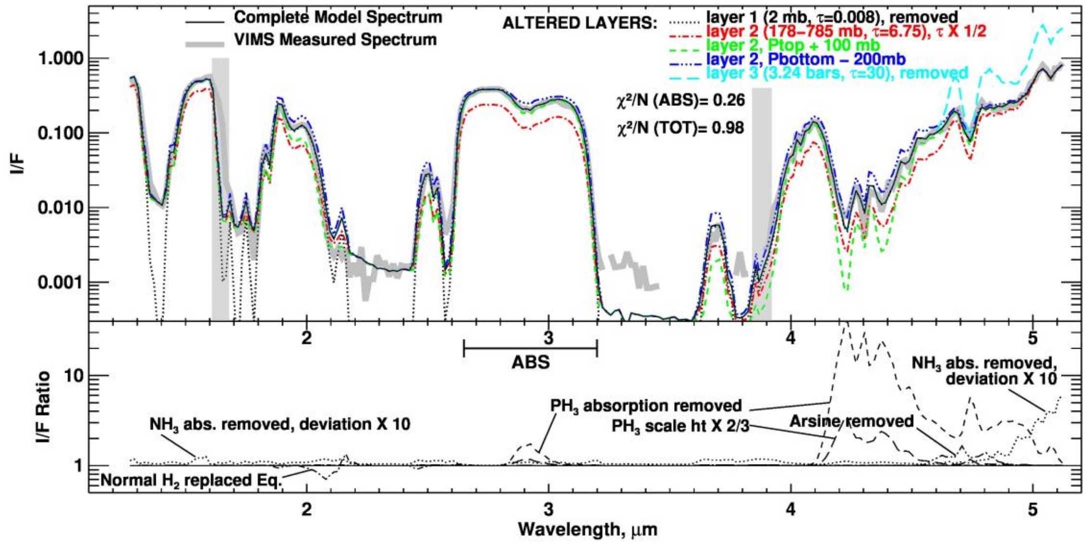
**Objectives:** We proposed to use a combination of imaging and spectral observations by VIMS to constrain the structure and composition of Saturn's cloud particles, with a special focus on (1) possible evidence for ammonia ice in the tropospheric haze on Saturn, and (2) the dynamical discrete features with unusual spectral properties, including bright and dark cloud features associated with thunderstorms and discrete clouds associated with Saturn's southern polar vortex.

PROGRESS ON SPECIFIC TASKS:

**Radiative Transfer Model Improvements**. Our radiation transfer model has been upgraded to include correlated-k absorption models for all significant gases affecting VIMS spectra of Saturn's atmosphere, including methane, phosphine ($PH_3$), $CH_3D$, arsine ($AsH_3$), and $NH_3$. The spectral regions where these gases are important can be seen from the following penetration depth plot.

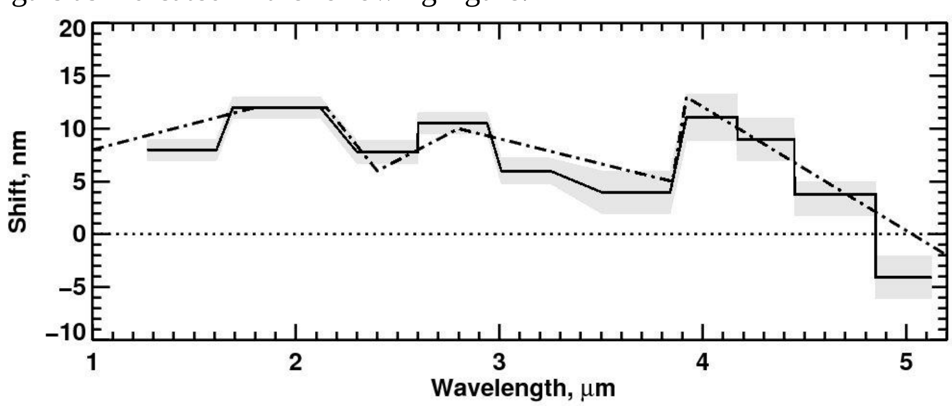



The accuracy of the absorption models is partially validated by the excellent agreement between model spectra and observed VIMS spectra, as shown by the following figure.

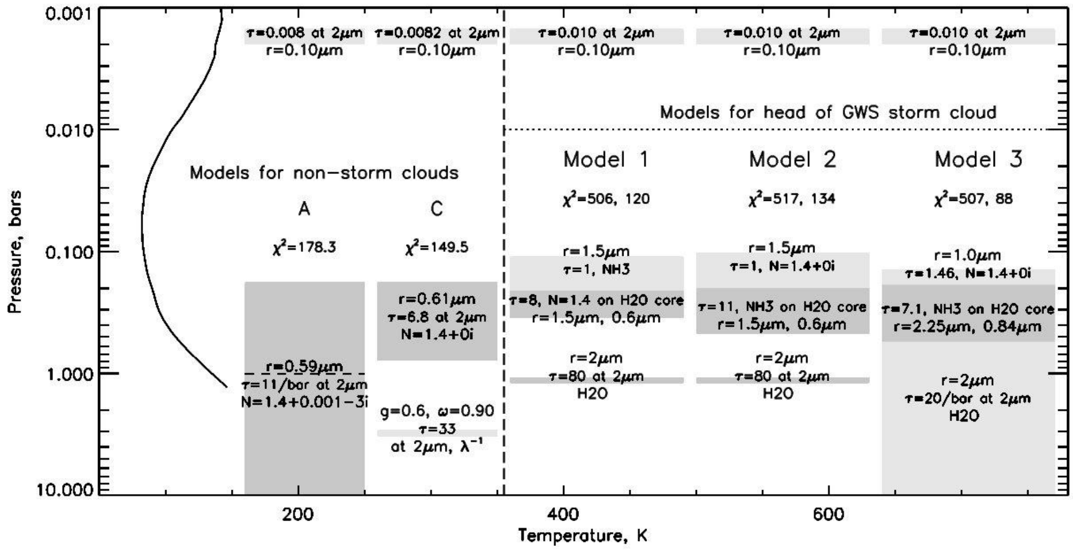



**Analysis of 2.98-micron anomaly.** The above plot displays a spectrum that has been corrected for what we determined to be a responsivity error at a joint between two order sorting filters over the VIMS detector array. The resulting 30% narrow dip in the VIMS spectra near 2.98 microns was also near an ammonia ice absorption feature, but the characteristics of the feature, namely being a constant I/F fraction independent of view angle and location on Saturn, made it clear that the feature was not produced by a real absorption in the atmosphere. It also varied slightly with column position, but not row position. Outside the region of convective storms, where an $NH_3$ absorption could be detected, we measured the fractional dip as a function of column position, then applied that correction to all spectra in the data cube. The result is a very good match between model and measured (after correction) spectra, as shown in the above figure. It also enabled us to obtain a corrected version of the storm spectra where $NH_3$ absorption and the response anomaly overlap.

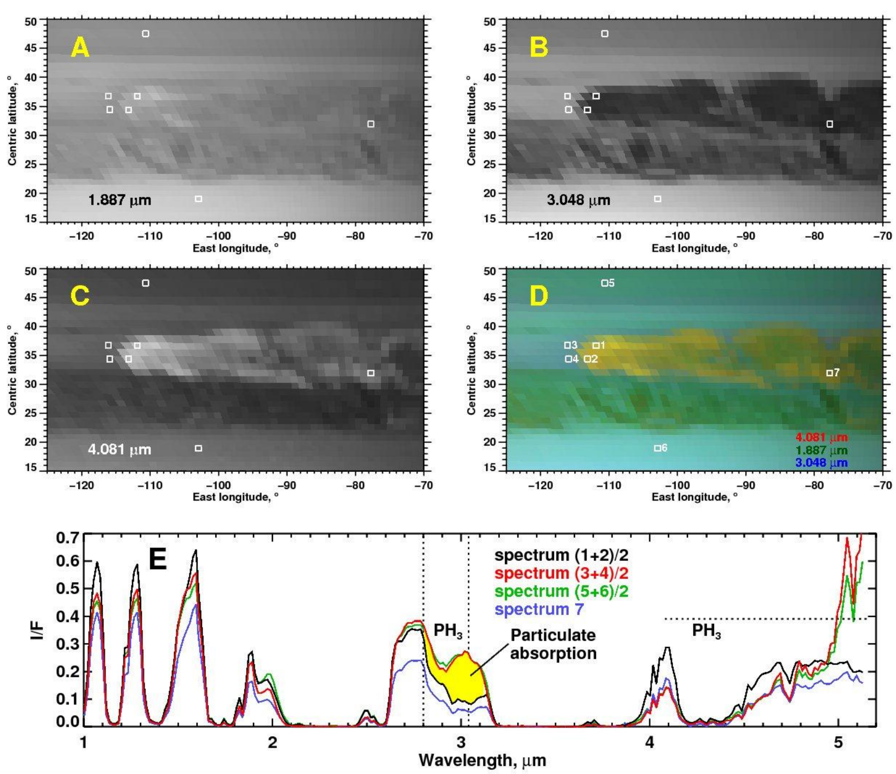
**Correction of wavelength calibration.** After incorporation of additional gas absorbers into our radiative transfer model, we computed a good reference spectrum for comparison of VIMS wavelength scales. To obtain consistency we needed to apply shifts to VIMS wavelengths as indicated in the following figure.



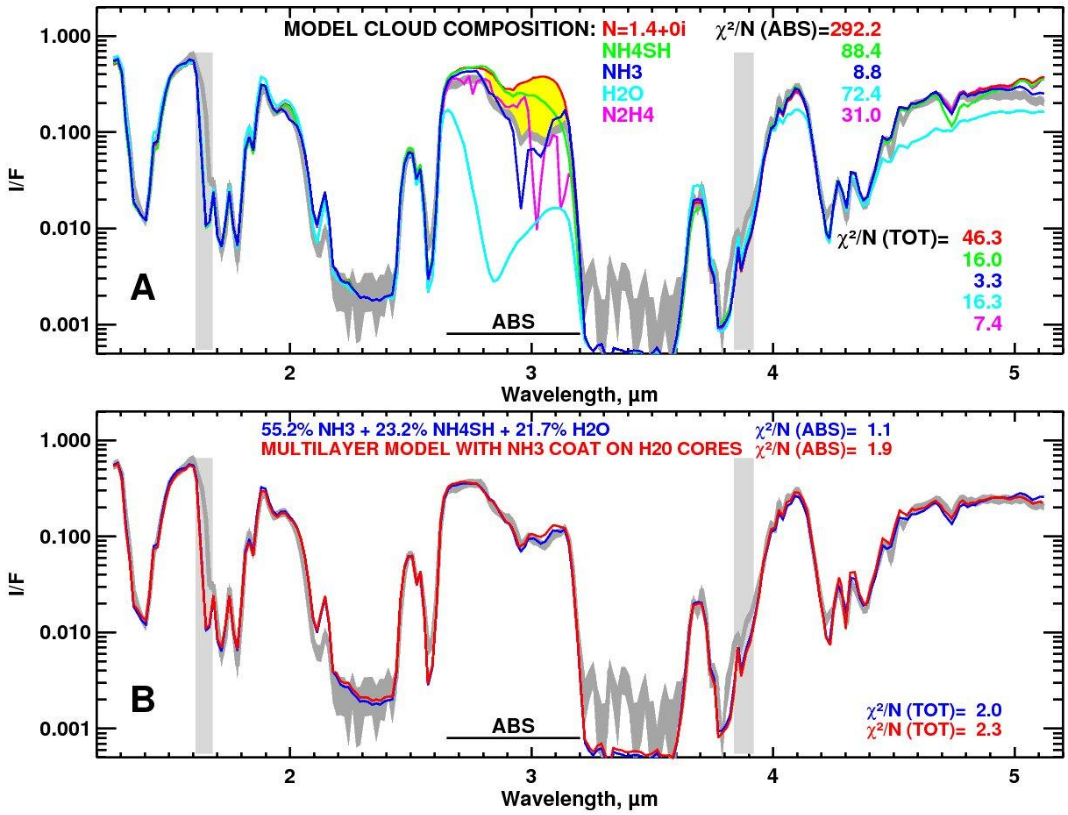

**Cloud structure modeling.** We began the process of fitting cloud structure models to major cloud features, focusing first on the 2010-2011 Great Storm feature, which seems to be another example of a rare (once per Saturn year) Great White Spot. Results will be presented at DPS or AGU meetings based on work already submitted to Icarus. Typical cloud models are shown in the following figure for non-storm regions (left) and for the Great Storm (right).




**Storm Analysis:** Spectra of the head of the Great Storm show strong absorption features near 3 microns that are indicative of $NH_3$ and water ice, and a third component that is either $NH_4SH$ or some relatively conservative material with N≅1.4. Selected spectra and VIMS images of the storm at selected wavelengths are shown in the following figure.



The difference between spectra from locations 1 and 2 (in the storm head) and spectra 3-7 (outside the storm) is shaded in yellow to indicate where particulate absorption is primarily responsible. We tried single-composition models, in which the main upper tropospheric layer is composed of a single material ($NH_4SH$, $NH_3$, $H_2O$ ice, or $N_2H_4$), with results shown in the following figure (panel A). It is clear that ammonia ice




yields the best fit, but still leaves some significant discrepancies, especially near 2.95 microns. In panel B, we show that a linear combination of spectra from three materials provides a much better fit (see blue curve). We also tried horizontally homogeneous models with layers of different compositions and with particles of one material coated with a second material. The best of the composite models (spectrum showed by red curve in panel B) has an optically thin conservative layer of 1-micron particles above an optically thick layer of water ice particles 0.84 microns in radius coated by a 1.4 micron layer of condensed ammonia, as indicated in the top figure on page 4 (Model 3).

PLANNED TASKS FOR YEAR 3

**Publication of Great Storm paper.** We will revised and resubmit our paper on the composition of the Great Storm cloud particles, as needed.

**Additional structure modeling.** We will continue the process of fitting cloud structure models to major cloud features, turning towards the thunderstorm related cloud features, and polar cloud features. The preliminary results will be presented at DSP or AGU meetings and and one or two papers will be prepared for submission to Icarus.