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Saturn's Atmospheric Photochemistry: Haze Production in Ring-Shadowed Atmosphere and within the Hexagon

S.G. Edgington (1), S.K. Atreya (2), E.H. Wilson (3), K.H. Baines (1,4), R.A. West (1), G.L. Bjoraker (5), L.N. Fletcher (6), T. Momary (1)
(1) Jet Propulsion Laboratory/California Institute of Technology, USA (scott.g.edgington@jpl.nasa.gov), (2) University of Michigan, USA, (3) Space Environment Technologies, USA, (4) University of Wisconsin, USA , (5) NASA Goddard Space Flight Center, USA, (6) University of Oxford, UK

Abstract

Cassini has been orbiting Saturn for nearly thirteen years. During this epoch, the ring shadow has moved from covering a relatively large portion of the northern hemisphere (Figure 1a) to covering a large swath south of the equator as solstice approaches. At Saturn Orbit Insertion on July 1, 2004, the sub-solar point was ~24º South. At this time, the projection of the optically thick B-ring onto Saturn reached as far as 40ºN along the central meridian (~52ºN at the terminator). At its maximum extent, the ring shadow can reach as far as 48ºN/S (~58ºN/S at the terminator). The net result is that the intensity of both ultraviolet and visible sunlight penetrating into any particular latitude will vary greatly depending on both Saturn's axis relative to the Sun and the optical thickness of each ring system. In essence, the rings act like semi-transparent Venetian blinds (Figure 2) over the atmosphere of Saturn.

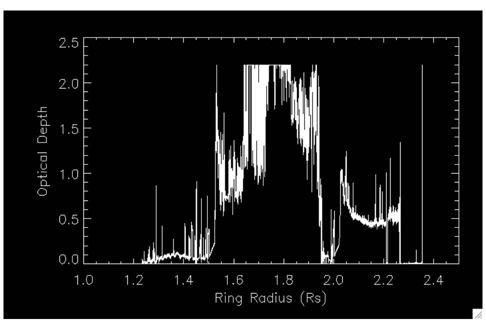

Figure 2. The optical depth of Saturn's rings in the ultraviolet (Josh Colwell, *pers. comm.*) The rings act like a periodic Venetian blind that will shield atmospheric molecules from solar photons.

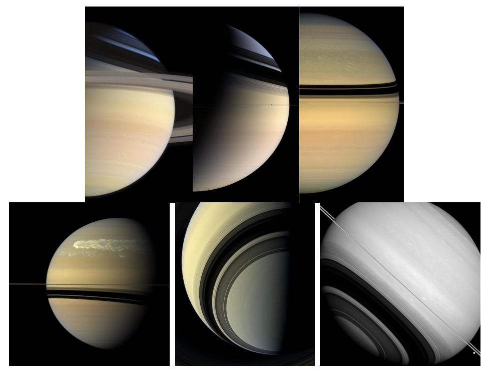

Figure 1. Saturn's atmosphere changes in response to the changing inclination of the ring plane relative to the Sun: (a) December 14, 2004, (b) March 16, 2006, (c) April 23, 2008, (d) July 6, 2011, (e) July 29, 2013, (f) November 24, 2014. Images are courtesy of NASA/JPL/Space Science Institute.

Our previous work [1,2] examined the variation of the solar flux as a function of solar inclination, i.e. ~7.25 year season (Figure 3) at Saturn. Beginning with methane, phosphine and ammonia, we investigate the impact on production and loss rates of the long-lived photochemical products leading to haze formation are examined at several latitudes over a Saturn year. We report on the impact of the oscillating ring shadow on the photolysis and production rates of hydrocarbons in Saturn's stratosphere and upper troposphere, including acetylene, ethane, and propane. Similarly, we assess its impact on phosphine abundance, a disequilibrium species whose presence in the upper troposphere is a tracer of convection processes in the deep atmosphere. Comparison to the corresponding rates for the clear atmosphere and for the case of Jupiter, where the solar insolation is known to be insignificant (~3º inclination), will also be presented. We will present our ongoing analysis of Cassini's CIRS, UVIS, and VIMS datasets that provide abundances of key molecules and an estimate of the evolving haze content of the northern hemisphere and we will begin to assess the implications for dynamical mixing.

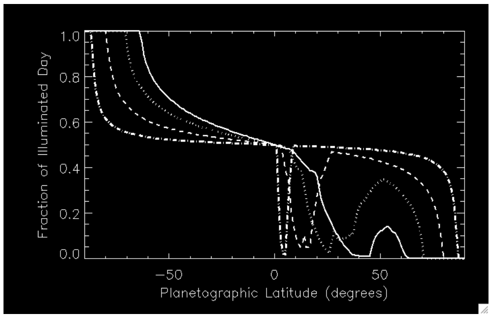

Figure 3. This plot illustrates the fraction of Saturn's day that is illuminated by the Sun as a function of solar declination, i.e. season. The curves correspond to sub-solar points of 26.7ºS (solid), 19.6ºS (dotted), 10.7ºS (dashed), and 3.5ºS (dot-dashed). Ultimately, this will determine the flux of photons allowed to enter the atmosphere relative to those of a clear, un-shaded atmosphere.

In addition, we will examine how the now famous hexagonal jet stream acts like a barrier to transport, isolating Saturn's north polar region from outside transport of photochemically-generated molecules and haze. We explore the role of increasingly intense sunlight in explain the buildup of hydrocarbon hazes in this region, which is relatively unaffected by transport from more southerly latitudes (Figure 4).

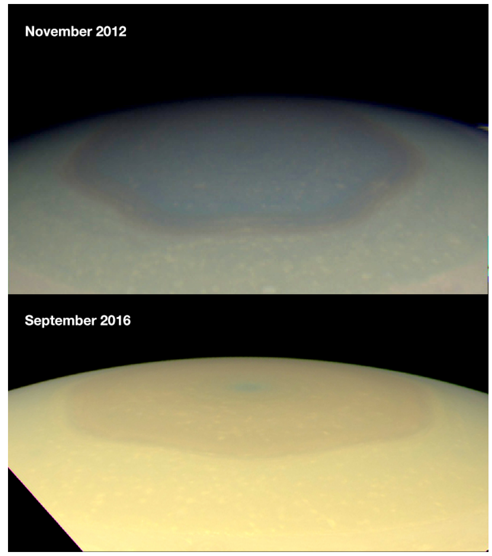

Figure 4. One of the aims of this exercise is to characterize the haze content Saturn's atmosphere. Several Cassini data sets from ISS (above) and VIMS (below) are being used to meet this goal.

Acknowledgements

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References

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[2] Edgington, S.G., R.A. West, K.H. Baines, S.K. Atreya, E.H. Wilson, G.L. Bjoraker, L.N. Fletcher, and T. Momary, 2012. Photochemistry in Saturn's Ring Shadowed Atmosphere: Modeling, Observations, and Preliminary Analysis. *Bull. American. Astron. Soc.*, **38**, 499 (#11.23).