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Temporal Evolution of the Aftermath of Saturn's 2010-2011 Great Storm through Multi-Spectral Analysis of Cassini ISS and VIMS Images

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We present an analysis of the temporal evolution of the aftermath of Saturn's 2010-2011 Great Storm using images captured by the Imaging Science Subsystem (ISS) and Visual and Infrared Mapping Spectrometer (VIMS) cameras onboard the Cassini orbiter. The intense cumulus convection in the storm lifted an enormous amount of mass from the water condensation level, estimated to be at a depth of 20 bar, to the upper tropospheric altitudes above 1 bar. Cassini's remote-sensing instruments detected numerous changes triggered by the storm in the cloud morphology and thermal structure. In particular, we analyzed the vast cloudless latitude band left behind the storm. The formation of this cloudless band is surprising because a cumulus storm transports saturated air upward and forms clouds, while such a clearing is normally associated with subsidence rather than upwelling. Our analysis of the rich Cassini datasets has produced a detailed record of when and where the storm's cumulus convection released the lifted mass and examines the expansion of the post-storm clearing until the entire latitudinal zone becomes cloudless.

Saturn's Great Storm of 2010-2011 started on December 5, 2010 as a small spot that appeared extremely bright in reflected sunlight (Sanchez-Lavega et al. 2012, Sayanagi et al. 2013). White clouds rapidly expanded from the spot to cover a wide swath of area between 30°N and 40°N latitude (latitudes in this proposal are planetocentric). By June 2011, the storm clouds engulfed the full-360° longitude; the intense cumulus convection, indicated by the radio-frequency pulses emitted by lightning discharges in the storm, ceased as the storm completed its circumpropagation around the planet (Sayanagi et al. 2013). The storm also disturbed the cloud morphology between 20°N and 30°N latitudes, which acquired a turbulent, billowing appearance similar to that of Jupiter. A cloudless region emerged in May 2011 near the end of the convective phase of the storm; the cloudless area subsequently grew to cover the entire 360° longitude between 30°N and 40°N latitude by January 2012.

We created a detailed record of the temporal evolution of the clouds left behind the storm by measuring the areal expansion of the storm clouds and their motion. Previous studies such as Sanchez-Lavega et al. (2012) and Sayanagi et al. (2013) focused primarily on the bright clouds between 30°N and 40°N latitudes, which are likely the anvil clouds atop the cumulus storm. On Earth, the anvil cloud covers a wider area than the underlying clouds associated with a storm; the underlying clouds form predominantly through horizontal mixing of air parcels in the cumulus upwelling with the environment (Houze, 1993). However, Sayanagi et al. (2018) found that the latitudes affected by the mass lifted by the storm extended to latitudes between 15°N and 45°N, far wider than the storm clouds analyzed by Sayanagi et al. (2013). We produced 12 fully processed Cassini ISS mosaics in the 750-nm filter, which senses sunlight scattered by tropospheric clouds. This sequence of images records the expansion of the storm clouds as an indicator of the mass detrained from the storm. All Cassini ISS images and mosaics will be archived at the PDS Atmospheres Node

We also employed a 2D Correlation Imaging Velocimetry (CIV) cloud tracking method to measure the wind fields to the north of the storm in latitudes between 30°N and 45°N. To the south of the storm between 20°N and 30°N, we employed a 1D CIV to measure the zonal wind speed. The motivation is to detect changes in the zonal mean wind caused by the mass loading through the thermal wind balance. The end products are the two-dimensional wind vector field of the swirling motion to the north of the storm 30°N and 45°N, and zonal-mean wind speeds to the south of the storm 20°N and 30°N that are compared to past measurements by Sayanagi et al. (2013).

We then established a temporal record of the formation and growth of the cloudless area that formed after the storm. The formation of the cloud-free region started in May 2012 near the end of the convective phase of the storm in June 2012. The clearing started near the farthest point in the storm clouds downwind of the cumulus head of the storm, from where the clearing spread upwind. The latitude band transformed over only 1.5 Earth-years between May 2011 and December 2012 from being fully covered by newly injected cloud particles to being nearly free of clouds in all detectable altitudes. Using 15 fully processed mosaics from Cassini VIMS 5-μm images, we established a temporal record of the formation and evolution of the post-storm cloud-free region. The timescale of the cloud clearing is used to estimate the cloud particle settling rate. The end product is the area occupied by the post-storm cloud-free region as a function of time. All Cassini VIMS images and mosaics will be archived at the PDS Atmospheres Node.