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Saturn's visible lightning and the structure of the 2009-2011 lightning storms.

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Abstract

Visible lightning on Saturn was first detected by the Cassini camera during the August 2009 equinox at ~35° South latitude. We report more lightning observations at ~35° South later in November 2009, and lightning in the 2010-2011 giant lightning storm at ~35° North. The 2009 lightning flashes are detected on the night side of Saturn in a broadband clear filter. The 2011 flashes are detected on the day side in blue wavelengths only. In other wavelengths the images lacked sensitivity to detect lightning, which leaves the lightning spectrum unknown.

The prominent clouds at the west edge, or the "head" of the 2010-2011 storm periodically spawn large anticyclones, which drift off to the east with a longitude spacing of 10-15° (~10,000 km). The wavy boundary of the storm's envelope drifts with the anticyclones. It is not a standing Rossby wave propagating with the head, and the train of anticyclones is not a classic vortex street. The relative vorticity of the anticyclones ranges up to -$f/3$, where f is the planetary vorticity. This is 1/3 of the theoretical maximum value of -f for an anticyclone in gradient wind balance. The lightning occurs in the diagonal gaps between the large anticyclones. The vorticity of the gaps is cyclonic, and the atmosphere there is clear down to level of the deep clouds. In these respects, the diagonal gaps resemble the jovian belts, which are the principal sites of jovian lightning.

The size of the flash-illuminated cloud tops is similar to the previous detections, with diameter ~200 km, suggesting that all lightning flashes on Saturn are generated at similar depths, which are about 125-250 km below the cloud tops, probably in water clouds. Optical energies of individual flashes for both southern storms and the giant storm range up to 8×10^9 Joules, which is larger than the published 2009 equinox estimate of 1.7×10^9 Joules. Cassini radio measurements suggest that the spectral source powers of Saturn Electrostatic Discharges (SEDs) sampled at 35 ms relate to the optical power as a factor of 8×10^{-9}W Hz^{-1} per Joule of optical energy. This, arguably, suggests that radio energies emitted by the lightning are 3 × the optical energies. Southern storms flash at a rate ~1-2 per minute. The 2011 storm flashes hundreds of times more often, ~5 times per second, and produces ~ 10^{10} Watts of optical power.

Saturn's storm's total convective power is of the order 10^{17} Watts, which is similar to Saturn's global energy output to space. This estimate is uncertain by at least an order of magnitude, and probably is underestimated. It suggests that storms like the 2010-2011 giant storm must be important players in Saturn's cooling, and need to be accounted for in the models of Saturn's thermal evolution.

This study is submitted to Icarus [1]

Acknowledgements

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References

[1] Dyudina, U. A. *et al.* Saturn's visible lightning and the structure of the 2009-2011 lightning storms. *Icarus* (2013). Submitted.