Ground-based Monitoring of Lightning-generated Whistler Mode Radiation in the Plasmasphere

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The lightning-generated whistlers play an important role in the physics of the radiation belts. Magnetospherically reflected (MR) and recently identified specularly reflected (SR) whistlers are the principal contributors to the lightning energy reaching the plasmasphere (Sonwalkar and Reddy, Science Advances, 2024 in press; Sonwalkar and Reddy, AGU 2024). Using plasma wave data from Van Allen Probes and lightning data from the World Wide Lightning Location Network (WWLLN), we performed a correlative study of 22 cases of SR whistlers accompanied by MR whistlers observed in the plasmasphere and the associated causative lightning flashes observed on the ground. Our results can be summarized as follows: (1) The whistlers were observed for $2 < L < 2.5$ and $10°S < \lambda_m < 15°N$. (2) Causative lightning flash locations were between 500 and 5000 km of the satellite geomagnetic footprint. (3) Ray tracing analysis in a typical magnetosphere showed that in most cases, the causative lightning was located within 1500 km of ionospheric lightning energy injection points that generated SR and MR whistlers, though lightning energy injected into the ionosphere as far as 3000-4000 km from the lightning location led to detectable SR and MR whistlers. (4) Most of the lightning flashes were located at $10° < \lambda_m < 30°$, consistent with the observed latitudinal distribution of lightning that shows the majority of lightning flashes occur at low latitudes (<30°) (Orville and Spencer, Monthly Weather Review, 1979). (5) The typical lightning flash energy that generated SR and MR whistlers ranged between 250 J and 6000 J. A whistler propagation model that takes into account lightning location and intensity and various propagation losses could explain the observed intensities of SR and MR whistlers. Our results imply that combining ground-based observations of global lightning activity with the whistler propagation model should provide the levels of lightning-generated whistler mode waves in the plasmasphere, leading to a powerful new space weather technique to monitor lightning-generated plasmaspheric whistler mode waves from the ground.

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