Potential Impact of Specularly Reflected Whistlers on the Radiation Belt Dynamics

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It is well established that lightning-generated whistlers play an important role in the physics of the inner magnetosphere and impact the radiation belt dynamics via wave-particle interactions that lead to particle precipitation. Whistlers contribute to the generation of slot region and plasmaspheric hiss. Recently, we identified a new kind of whistler, specularly reflected (SR) whistler, in which the lightning energy injected at low latitudes first undergoes a specular reflection in the conjugate hemisphere and then propagates to the magnetosphere (Sonwalkar and Reddy, Science Advances, 2024, in Press). The existence of SR whistlers in the magnetosphere contradicts previous understanding that lightning energy injected at low latitudes cannot escape the ionosphere (Thorne and Horne, JGR, Vol. 99, A9, 1994; Bortnik et al., JGR, Vol. 108, A5, 2003). A survey of data from Van Allen Probes shows that SR whistler is a common phenomenon. To assess the impact of SR whistlers on the radiation belt physics, we calculated the lightning energy reaching the magnetosphere in the form of SR whistlers relative to that reaching as magnetospherically reflected (MR) and ducted whistlers. Using ray tracing simulations and taking into account various propagation losses and the global distribution of lightning flashes, we performed a comparative study of SR, MR, and ducted whistlers. Our research shows: (1) SR whistlers occupy the same region of the magnetosphere as the MR whistlers and have similar wave normal angles and intensity. (2) SR and MR whistlers carry most of the lightning energy reaching the magnetosphere. (3) Ducted whistlers represent ~1-4% of the lightning energy reaching the magnetosphere. (4) When SR whistlers are considered, the global lightning energy contribution to the magnetosphere doubles, implying that the previous estimates of the impact of lightning energy on radiation belts and its role in the physics of the inner magnetosphere may need substantial revisions.

Publication:	AGU Fall Meeting 2024, held in Washington, D.C., 9-13 December 2024, Session: SPA-Magnetospheric Physics / Asynchronous Online Poster Presentations: Space Physics and Aeronomy—Magnetospheric Physics, id. SM01-15.
Pub Date:	December 2024
Bibcode:	2024AGUFMSM01...15S