Global Estimate of Lightning Energy Injected into Earth's Plasmasphere

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Across the globe, lightning flashes on average between 40 and 50 times every second. The electromagnetic radiation emitted by lightning is primarily concentrated in the Very Low Frequency (VLF, 3-30 kHz) band and can propagate very efficiently over long distances through the Earth-ionosphere waveguide. However, a small fraction of the wave energy escapes the waveguide and travels in the whistler mode enabled by Earth's magnetic field through the ionosphere and into the Earth's plasmasphere. There, the waves, called whistlers, can resonate with electrons in the Van Allen radiation belts, causing the electrons' pitch angles to scatter, which in turn can cause the electrons to precipitate into the ionosphere and thereby be removed from the Van Allen radiation belts.

Previous studies quantifying the impact of lightning on electrons in the Van Allen radiation belts have estimated the total energy input into the plasmasphere from lightning using a set of Helliwell's sub-ionospheric absorption curves that have recently been called into question for general use because of the number of simplifying assumptions that were made to generate the curves. Since then, we have compared estimates of VLF trans-ionospheric propagation calculated by full electromagnetic wave method (FWM) finite element numerical simulations with measurements from the low-Earth orbiting DEMETER satellite and showed that our model accurately predicts the energy injected into the plasmasphere by anthropogenic VLF transmitters to within a few dB. For VLF waves emitted by lightning, our model has shown a slight underestimate of the total energy measured by DEMETER, but the underestimate is still smaller than the >10 dB overestimate given by the Helliwell absorption curves for VLF transmitters.

Combining data from the global lightning detection network GLD360 with a global sample of FWM simulations, we present here a global estimate of the amount of lightning energy that propagates through the ionosphere and is injected into the Earth's plasmasphere. Results from our study will provide a great step towards determining the true impact of lightning on the Van Allen radiation belts.