Modelling the chemical and electrical impact of lightning in the upper atmospheric plasma of planetary atmospheres

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The electromagnetic field created by terrestrial lightning discharges has a chemical and an electrical impact in the plasma existent in the upper atmosphere, producing Transient Luminous Events (TLEs). We extend previous models of the impact of quasi-electrostatic field (QE) in the terrestrial mesosphere produced by cloud-to-ground (CG) lightning discharges, providing the community with new tools to interpret observations from spacecraft. In addition, we use a Finite Difference Time-Domain (FDTD) model to investigate possible TLEs existence in the atmosphere of giant planets caused by lightning-emitted electromagnetic pulses (EMP). Finally, we apply these models to the case of Venus to investigate the mesospheric optical signature produced by hypothetical Venusian intra-cloud (IC) lightning, proposing an indirect method to determine the existence of lightning discharges in Venus from the Japanese spacecraft Akatsuki, orbiting Venus since December 2015.

1. Impact of quasi-electrostatic field

The QE field produced by lightning induces glow discharges in the upper atmosphere. We have developed a 2D model to investigate the detailed chemical impact and transient optical emissions produced by lightning discharges in the upper atmospheres of the Earth and Venus.

On Earth, we extend the vibrational model proposed in [1]. We study the temporal density evolution of 136 species interacting through 1090 kinetic reactions under the influence of a QE field created by CG discharges. We predict the geometry of the resultant mesospheric optical emissions, and extract physical information from brigthness measurements of the Lyman-Birge-Hopfield (LBH) band, second positive and first negative systems of nitrogen.

On Venus, we define a chemical scheme composed by 27 species interacting through 79 kinetic reactions [3]. We calculate the expected mesospheric optical signature of hypothetical Venusian lightning, obtaining a transient increase in the OI (557 nm) green airglow emissions, observable from Akatsuki spacecraft.

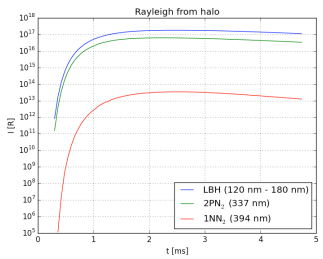

Figure 1: Emission brightness caused by a terrestrial CG lightning with a Change-Moment-Change of 350 C km.

2. Impact of EMP pulses

Terrestrial lightning discharges originate EMPs that can excite the plasma of the upper atmosphere, producing fast (< 1 ms) optical emissions known as elves. The discovery of these emissions could provide new useful information about extraterrestrial atmospheres.

We have developed a 3D FDTD model to solve the Maxwell equations in the atmospheres of giant planets and Venus, using an Intra-Cloud (IC) lightning discharge as a source. This solver is coupled with Langevin's equation for electrons and with a chemical scheme for each planet (Jupiter, Saturn [2] and Venus [3]). We study the influence of lightning channel inclination, background magnetic field and atmospheric composition.

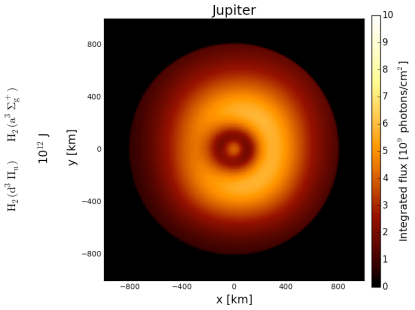

Figure 2: Predicted optical emissions in the upper atmosphere of Jupiter as seen from a spacecraft caused by EMP originated by a vertical lightning discharge.

3. References

[1] Gordillo-Vázquez, F. J. (2010). JGR. 115(A5).

[2] Luque, A., Dubrovin, D., Gordillo-Vázquez, F. J., Ebert, U., Parra-Rojas, F. C., Yair, Y., & Price, C. (2014). *JGR*, *119*(10), 8705-8720.

[3] Pérez-Invernón, F. J., Luque, A., & Gordillo-Vázquez, F. J. (2016). *JGR*, *121*(7), 7026-7048.