Earthquake Lights: Time-dependent Earth surface-ionosphere coupling model

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Co-seismic luminescence, commonly referred to as Earthquake lights (EQLs), is an atmospheric luminous phenomenon occurring during strong earthquakes and lasting from a fraction of a second to a few minutes [e.g., Derr, J. S., Bull. Seismol. Soc. Am., 63, 2177, 1973; St-Laurent, F., et al., Phys. Chem. Earth, 31, 305, 2006; Herauld and Lira, Nat. Hazards Earth Syst. Sci., 11, 1025, 2011]. Laboratory experiments of Freund, F. T., et al. [JGR, 105, 11001, 2000; JASTP, 71, 1824, 2009, and references therein] demonstrate that rocks subjected to stress force can generate electric currents. During earthquakes these currents can deliver significant amounts of net positive charge to the ground-air interface leading to enhancements in the electric field and corona discharges around ground objects [Freund et al., 2009]. The eyewitness reports [Herauld and Lira, 2011] indicate similarities of the blue glow observed during EQLs to St. Elmos fire observed during thunderstorms around wing tips of airplanes or around the tall masts of sailing ships [e.g., Wescott, E.M., et al., GRL, 23, 3687, 1996]. Recent work indicates that the vertical currents induced in the stressed rock can map to ionospheric altitudes and create 10s of % variations in the total electron content in the Earths ionosphere above the earthquake active region [Kuo, C. L., et al., JGR, 116, A10317, 2011]. The magnitudes of the vertical currents estimated by Kuo et al. [2011] based on work by Freund et al. [2009] range from 0.01 to 10 μA/m^2. In this talk we report results from a new time-dependent model allowing to calculate currents induced in the ambient atmosphere and corona currents under application of vertical stressed rock currents with arbitrary time variation. We will report test results documenting the model performance under conditions: (1) relaxation toward the classic global electric circuit conditions in fair weather regions when ionosphere is maintained at 300 kV with respect to the ground; (2) relaxation toward the steady state conditions when the earth-air surface charge is maintained by balance of the current induced by stressed rock and ambient atmospheric current [Kuo et al., 2011]; and (3) a 2 min duration model episode in which the stressed rock current reaches value of 0.4 μA/m^2 producing electric fields at the ground on the order of 0.5 kV/cm leading to an additional injection of positive corona current. One of the interesting results of this modeling is that the reduced electric field (i.e., field normalized by air density) remains low at the ground-air interface due to the injection of the positive corona charge and at high altitudes due to the naturally high conductivity of the Earths atmosphere. At the intermediate altitudes in clear air above earthquake region the reduced electric field can dynamically reach values exceeding both relativistic ($\sim$2 kV/cm when scaled to the ground level) and conventional ($\sim$30 kV/cm ground value) breakdown thresholds. The exact geometry would depend on the spatial extent of the earthquake active region, ambient atmospheric conductivity and the time dynamics of the driving stress rock current. We suggest that the enhancements of the reduced electric field in clear air at high altitudes in the Earth atmosphere is a likely scenario leading to transient (sub-second duration) flashes some time observed during earthquakes [Herauld and Lira, 2011].