The two global electrical circuits: Challenges with continuous monitoring and intercomparison

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The earth's lower atmosphere is sandwiched between two conductors: the earth's surface is a good conductor (and an isopotential) by virtue of the ubiquity of water and the upper atmosphere is a good conductor (and an isopotential) by virtue of the continuous impingement of ionizing radiation (galactic cosmic rays and solar uv light). This geometry sets the framework for the two global electrical circuits: the DC global circuit in the form of a giant spherical capacitor, and the AC global circuit, in the form of a giant electromagnetic waveguide containing quasi-standing waves known as Schumann resonances, whose fundamental resonance mode (8 Hz in the ELF frequency band) has a wavelength equal to the Earth's circumference. The DC global circuit is sourced by vertical currents from thunderstorms and electrified shower clouds, whereas the AC global circuit is powered by thunderstorms alone.

The value of the global circuits as natural frameworks for monitoring global weather and climate is highlighted by the responsiveness of global lightning to surface air temperature on many natural time scales from the diurnal to El Niño. The continuous monitoring of the DC global circuit with local electric field measurement has long been plagued by noise in the form of local conductivity and space charge variations that compete with and often overwhelm the global signal, and simultaneous measurements at separate sites rarely agree. Globally representative measurements are traditionally difficult to achieve. As a possible remedy, the fair-weather measurement of air-earth current to a long decommissioned power line near Milano has been proposed in a scientific collaboration among MIT, Federico II and TERNA, the Italian Transmission System Operator. A weak test of global representativeness will be achieved by the attempted simultaneous measurement of air-earth current to separate segments of this transmission line. The effective area for current collection on this line is $>10^5 m^2$ which may help considerably in the suppression of local noise.

For the AC global circuit, the mismatched Schumann resonance intensities at different ELF stations cannot be attributed to medium variations, because permittivity and permeability are independent of aerosol variations and are much more stable than conductivity for the DC global circuit. But the intensity contribution of different continental lightning sources ("chimneys") depends nonlinearly on source-receiver distances on the basis of theory. These variations linked with multiple sources can be strongly suppressed by finding ELF receivers which are roughly equidistant from the chimney sources. High latitude receivers, like Hornsund in the Arctic and Maitri in the Antarctic, broadly satisfy this condition, and these station intensity records at 8 Hz are highly correlated (r=0.93), in support of global representativeness.

If the TERNA measurements of air-earth current are successful, this record can be compared with the simultaneous Hornsund and Maitri records for continuous comparison of the DC and AC global circuits for the first time.