Global Electric Circuit and Climate

Colin Price[1]

[1] *Department of Geophysical, Atmospheric and Planetary Science*
Tel Aviv University, Israel (cprice@flash.tau.ac.il)

The global atmospheric electric circuit (GEC) is a simplified description of the global electrical properties of the lower atmosphere (below 100km). The currents and fields we measure in the atmosphere are regulated and modulated by global thunderstorm activity, where thunderstorms are regarded as the batteries of the GEC. There is both a direct current (DC) and alternating current (AC) part of the GEC, and both of these are influenced by changes in the Earth's climate. While the overall driving force of thunderstorms and the GEC is solar heating at the surface, today changes in greenhouse gases may also be impacting the GEC. One interesting aspect of this interaction is whether the GEC feeds back on the climate system itself. We will discuss some of these issues in the talk.

1. DC Global Circuit

For more than 200 years it has been known that in fair weather regions of the globe there exists a surface electric field with a value around -130 V/m. This electric field pointed downward toward the Earth implies the Earth is negatively charged with a charge of ~500,000 Coulombs. This DC electric field is more or less constant in time, with small variations with the hour of the day, and day of the year. But the field never disappears.

Due to ions that exist in the atmosphere, this electric field drives a fair weather conduction current (Jz) or approximately 2 pA/m^2 towards the Earth. Given the resistance of the atmosphere (~300 ohms), the current should neutralise the Earth's negative charge within a few minutes! But this never happens.

To explain this, we need to provide a "generator" of current in the system that is constantly charging the GEC. In the 1920s it was suggested that the "batteries" in the circuit were global thunderstorms, that number 1000-2000 at any moment, discharging 50-100 lightning flashes every second. These storms produce rising currents above them of ~1 Ampere per storm, or 1000 Amperes in total, with the return flow of this current in fair weather regions far from the thunderstorms.

2. AC Global Circuit

In addition to the DC components of the circuit described above, lightning itself generates electromagnetic (EM) radio waves that are trapped between the ionosphere and the Earth's surface, allowing the radio waves to travel a number of times around the globe before decaying into the background noise. This happens only for radio waves in the extremely low frequency (ELF) range, producing constructive interference on each trip around the globe, or resonances, at specific frequencies (8, 14, 20….Hz). We call these the Schumann resonances, and they represent the AC part of the GEC since we can detect them anywhere on the planet. The intensity of these radio waves varies also according to time of day, and day of year.

3. GEC and climate

While thunderstorms drive the GEC, the climate of the Earth drives the thunderstorms, primarily as a result of solar radiation heating the surface. Global thunderstorms track the Sun during the day (with maximum tropical thunderstorms in the late afternoon) and the season (most thunderstorms in the summer season). Today we are changing our climate due to increases in greenhouse gases, and hence we may see impacts on the GEC. Can we therefore use the GEC to monitor future changes in the Earth's climate, for whatever reason?

However, perhaps more intriguing is if changes in the GEC impact the climate in return? We know global lightning impacts atmospheric chemistry through NOx production, but maybe the currents also impact clouds, that impact the Earth's albedo?

3. References

Markson, R., *Bull. Amer. Met. Soc.*, Feb. 2007, 1-19.

Williams, E.R., and E. Mareev, *Atmos. Res.*, 2014, 135, 208-227.