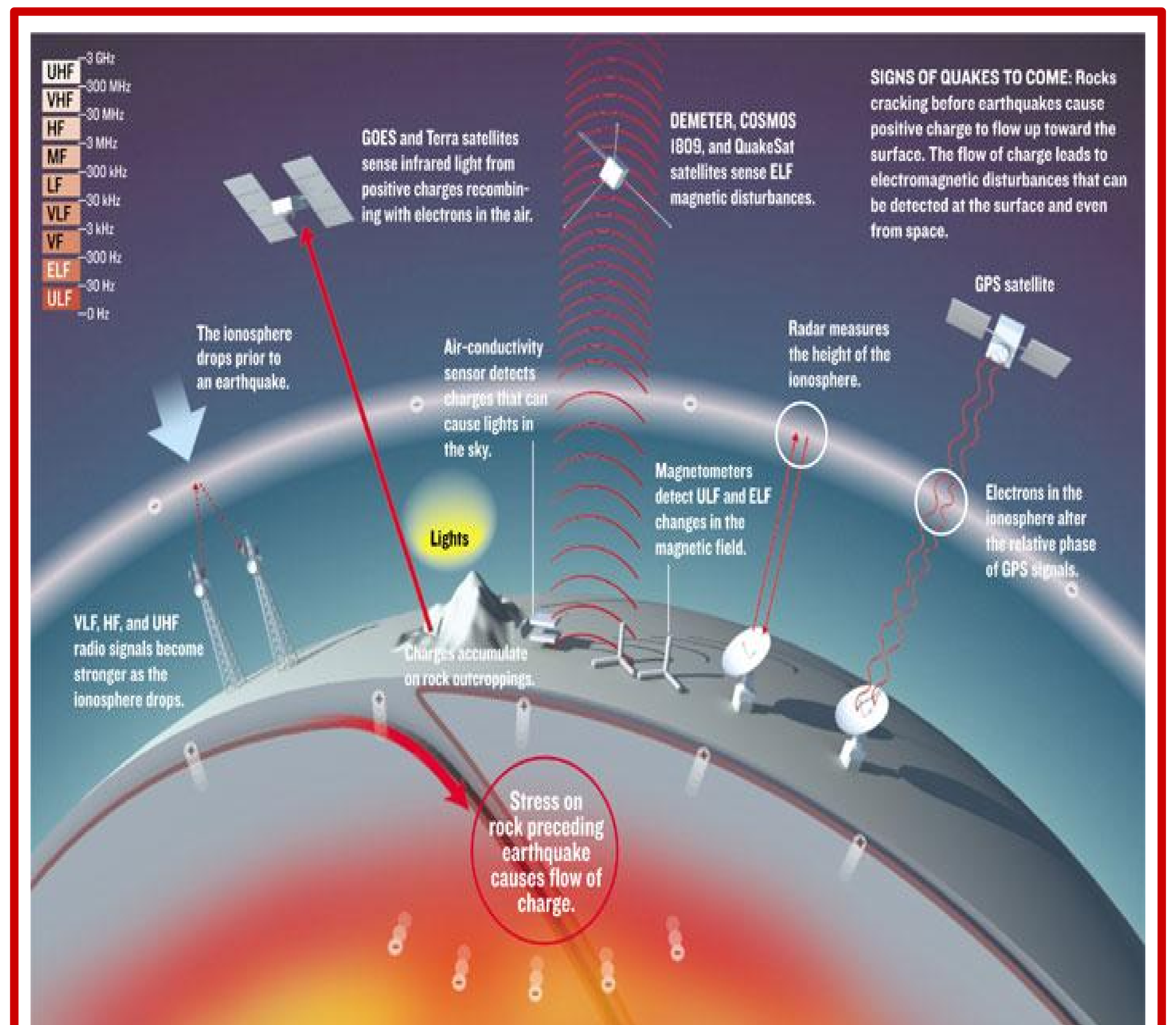
Multi-Sensor Physical Observations at CEESMO to Study Earth's Electromagnetic Geospheres Interaction

Velez A., Ouzounov D., Haztzopoulos N., Calderon I.

Abstract

We aim to study the key processes in the atmosphere that modify the Earth's plasma environment system under various geophysical conditions. These conditions include natural and anthropogenic disasters. We are currently in the process of installing multiple sensors at Chapman University for measuring: (i) Vertical Electrical Field (Boltek EFM-100), (ii) Very High Frequency (VHF) signals, (ii) Very Low Frequency (VLF) signals and (iv) Real-time weather for continuous observation of translational coupling between the atmospheric boundary layer up to the lower ionosphere. Statistical studies performed by recent scientists on similar physical observations have already proven the complex nature of the interconnection between the lithosphere and atmospheric events. These connections have also been made between the Earth and space environments through the Global Electric Circuit. One of the main drivers for such coupling is the change of the boundary layer conductivity. This conductivity can be changed by air pollution, ion nucleation triggered by natural (geodynamics) and anthropogenic activities, and mesoscale atmospheric systems such as tropical hurricanes/typhoons. Combining data from remote sensing and ground-based (in situ) instrumentation could provide the experimental background for the modeling of these coupling effects from the earth's surface up to the ionosphere. These observations are a part of the collaboration between CEESMO and the “Multi-instrument Space Borne Observations and Validation of the Physical model of the LAIC” project at the, International Space Science Institute (Bern, Switzerland).



Bleier and Freund 2008

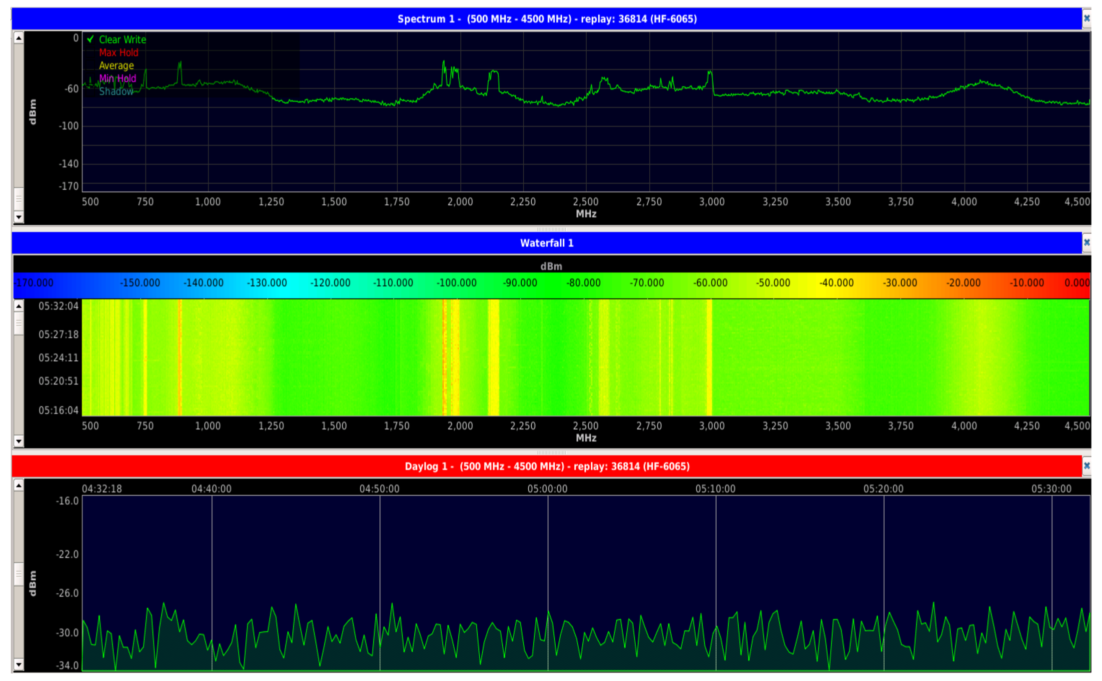
Sensors

Sensor Locations

VHF Antenna

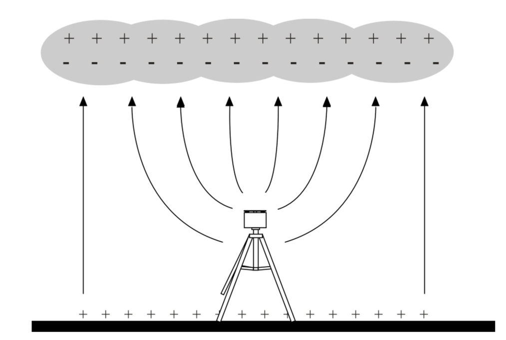
500 MHz - 6 GHz

The propagation characteristics in the VHF range are mainly subject to the solar and geomagnetic situations at the time and to diurnal and seasonal variations. At low-latitude stations, the signal reception quality is further complicated by ionospheric current systems that show large variations in magnitude as well as in their types. Thus, conditions in the ionosphere may develop where the limit (normally about 30 MHz) increases dramatically, leading to an enhancement in travel distance of the signal, termed ‘anomalous’. There may be an increase in path length also by reflection and/or scattering from strong sporadic layers. Such anomalous behavior of radio signals may be expected prior to major earthquake activities. Our VHF studies aims to examine seismic-induced ionospheric factors leading to abnormally long paths (Moryia et al, 2010,2011)



Atmospheric Electrical Field Monitor

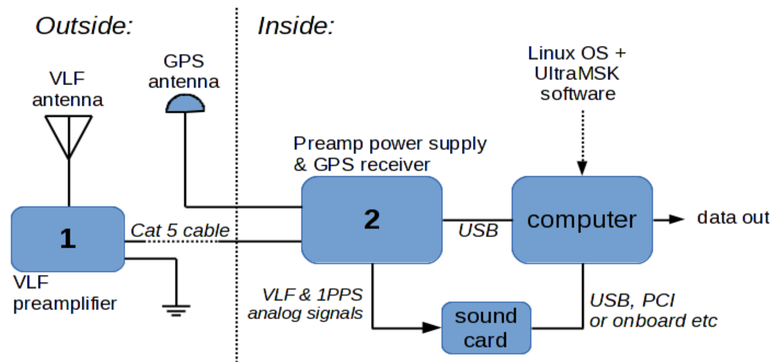
+- 5k V/m



The Global Atmospheric Electric Circuit (GAEC) is generally known as the Carnegie curve. The Carnegie curve was obtained from the averaging of thousands of measurements of the Earth's fair weather electric field. The vertical atmospheric electric field is about E= -130V/m, where the minus sign indicates that the electric field vector is pointing downwards (Tacza et al, 2014). The GAEC has also been studied as a short-term Pre-earthquake phenomena. The main reason is that increased radon emanation and/or electrical charge generated by cracking rocks is associated in time and space with strong seismic events. The radon decay process also dominates the amount of atmospheric ionization in the near-Earth boundary layer and, therefore, changes of radon concentration there will significantly affect the electrical conductivity, which in turn will produce changes on the measured atmospheric electric field (Tacza et al, 2014; Pulinets and Ouzounov, 2011). Because of the great variety of phenomena and perturbations that can affect its value(such as fog, strong winds, precipitation, aerosols, and pollution), the search for earthquake precursor effects in the atmosphere needs to know the behavior of the atmospheric electric field in various meteorological conditions (Tacza et al, 2014).

VLF Antenna

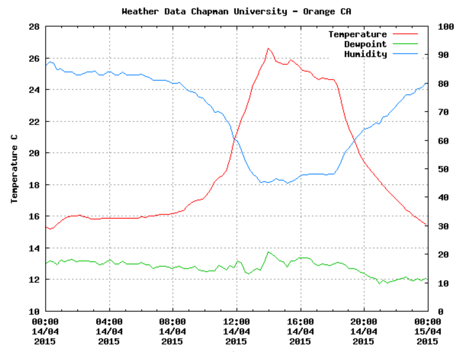
15-60 kHz

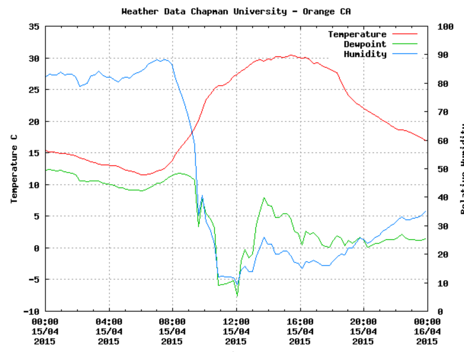


The electromagnetic method for earthquake studies can be designed to detect an indirect effect of earthquakes taking place in the atmosphere and ionosphere by means of the pre-existing radio transmitter signals. As the result of research during the last decade, it has been a consensus that the ionosphere is, unexpectedly, extremely sensitive to the earthquake effects.A number of nations currently operate large VLF/LF transmitters primarily for navigation and communication with military submarines. To radiate electromagnetic waves efficiently, one needs an antenna with dimensions on the order of a wavelength of the radiation, which suggests that VLF/LF transmitter antennas are very large, typically many hundreds of meters high. Most of the energy radiated by such VLF/LF transmitters is trapped between the ground and the lower ionosphere, forming the Earth-ionosphere waveguide (~ 70-90 km). Subionospheric VLF/LF signals reflect from the D-region of the ionosphere, probably the least studied region of the Earth’s atmosphere. Any variations on the ionospheric D/E-region lead to changes in the propagation conditions for VLF waves propagating sub-ionospherically, and hence change in the observed amplitude and phase of VLF/LF transmissions are due to different kinds of perturbation sources. In addition to these solar-terrestrial effects we study the effects of earthquakes onto the lower ionosphere. (Hayakawa et al, 2007)

Weather Station

This weather station collects data on many different weather parameters. We receive data on temperature, humidity, dew point, along with wind and rain measurements. The main purpose for having our own weather station is to have accurate readings for our exact location. The figure to the bottom right shows the start of a period with Santa Ana winds, while the figure to the left shows the day before. On the windy day we saw some anomalies in our other sensors. Without this sensor it would be hard to tell what the source of those anomalies were.





Future Work

We are currently a year into our project and have made great progress towards our end goal. We currently have three out of four of our sensors fully operational and collecting data. We plan to have our VLF antenna mounted and operational by the end of June 2015. Once everything is fully operational we plan to continuously monitor the multiple geophysical parameters that all of our sensors collect. From this data we will create a reference field for all of the sensors so that we will be able to find anomalies in our data. We will combine this analysis with our geospace segment here at Chapman, which includes the integration of our X-Band Antenna and the Gamma sensor. The integration of all these sensors has never been done together. Each instrument brings its own information and together will help us understand how the Earth’s geospheres interact with one another over Southern California. We are applying this geosphere study to the case of pre-earthquake phenomena, but these instruments can be applied to many different geophysical interactions. These can include any severe weather storm, hurricanes, floods, fires and space weather events.

References

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