Magnetotelluric Measurements at Geomagnetic Observatories

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Space weather interacts with the geomagnetic field to induce geoelectric fields within the Earth. These geoelectric fields have the potential to adversely affect electric power grids. The U.S. Geological Survey (USGS) is currently deploying magnetotelluric (MT) systems at ground-based USGS geomagnetic observatories, which simultaneously measure both the geoelectric and magnetic fields. The geoelectric field varies as a result of the regional geology and the magnitude of the magnetic field. MT measurements will provide geoelectric field data in a broad region around each magnetic observatory. Data from these measurements will be used to calculate realistic regional geoelectric fields using three-dimensional (3D) impedance functions to produce potential hazard maps useful for assessing risk to electric power grids.

Geomagnetic storms induce geoelectric fields within the interior of the Earth that lead to geomagnetically induced currents (GICs) within power grids. GICs can lead to anomalies and faults within power transmission systems and were the cause of the Hydro-Québec power system collapse [Bolduc, 2002]. This has led to increasing interest in the relationship of geoelectric fields with electrical systems in recent years.

Real-time monitoring of geoelectric fields is currently undertaken at only a few geomagnetic observatories throughout the world, including the United States Geological Survey's (USGS) Boulder geomagnetic observatory [Blum et al. 2017]. These installations require permanent infrastructure and support staff to calibrate and monitor the facilities, which can be prohibitively expensive to install at every geomagnetic facility that an institute operates. Rather than installing permanent monitoring stations at all of the observatories, the USGS is beginning to conduct temporary magnetotelluric field deployments at all of their observatories.

The magnetotelluric method simultaneously measures the magnetic and electric fields, which can then be analysed to determine the conductivity structure at each observatory arising from the underlying geology. The impedance, derived from the conductivity structure, will only change over geologic time-scales, meaning that it doesn't need to be continually monitored. Once the impedance near a geomagnetic observatory is determined, it can be used to estimate geoelectric fields that would have been realized in that location.

This year we have deployed magnetotelluric stations to the Fresno (FRN), Tucson (TUC), and Newport (NEW) geomagnetic observatories and calculated the local impedance of the Earth at each site. These impedances can then be convolved with the long historic record of geomagnetic field data at each site to produce estimated geoelectric fields. Figure 1 shows the predicted geoelectric field at the Fresno (FRN) geomagnetic observatory during the 2003 Halloween Storm.

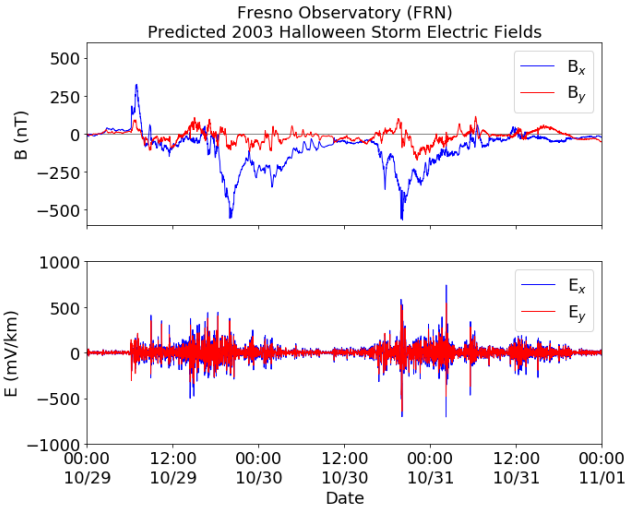

Figure 1: The measured magnetic field at geomagnetic observatories can be combined with local magnetotelluric measurements to make predictions of the local electric field during historic geomagnetic storms.

These temporary magnetotelluric deployments to geomagnetic observatories with long-duration high-quality magnetic field measurements provides a method to generate estimates of local geoelectric fields that would have been realized during historic geomagnetic storms. It also provides a method to predict the real-time geoelectric fields local to the observatories that can be used by utility companies to make informed decisions about operating their transmission network.

References:

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