Geomagnetic Monitoring in the Mid-Atlantic United States

Near historic battlegrounds of the American Civil War, southeast of Fredericksburg, Virginia, on a secluded grassy glade surrounded by forest, a specially designed observatory records the Earth's changing magnetic field. This facility, the Fredericksburg Magnetic Observatory, is 1 of 14 observatories the U.S. Geological Survey (USGS) Geomagnetism Program operates at various locations across the United States and its Territories as a service to the Nation and in support of a diversity of governmental, academic, and commercial scientific projects (for example, Love and Finn, 2011).

History of Geomagnetic Monitoring

Continuous geomagnetic monitoring in the mid-Atlantic United States commenced in 1887 at the U.S. Naval Observatory in Washington, D.C., using an automatic photographic system. These operations were discontinued in 1898 due to interference from a nearby electrified tram (Skinner, 1899). The next year, in support of a systematic geomagnetic survey of the United States, Congress appropriated funds for the Coast and Geodetic Survey (CGS) to establish magnetic observatories. Among these, the Cheltenham Observatory (CLH) was built in Maryland in 1900. Routine data-acquisition operations began in April 1901 using automatic systems like those used at the Naval Observatory (Hazard, 1909). The Cheltenham Observatory served as the headquarters of the CGS Geomagnetism Program and operated reliably for more than half a century, until physical limitations at the site prevented needed modernizations (Coast and Geodetic Survey, 1960). A photograph of the Cheltenham Observatory is shown in figure 1.

In 1952, Congress appropriated funds for the construction of a new observatory, deeming it, "of inestimable value and importance to the United States in many essential civilian and military fields." The Fredericksburg (FRD) Magnetic Observatory, located in Corbin, Va., was built and began regular operations on December 31, 1955, in time to support projects for the International Geophysical Year (1957–1958). The Cheltenham Observatory operated until October 5, 1956 (Coast and Geodetic Survey, 1960). For many years, not only did the Fredericksburg Observatory support long-term geomagnetic monitoring and serve as the Geomagnetism Program's headquarters, the site was also used to train domestic and foreign geomagneticians, calibrate magnetometers (including for satellites), make geodetic measurements and support seismic, meteorological, and cosmic-ray monitoring. A photograph of the Fredericksburg Observatory is shown in the banner of this fact sheet.

In 1965, services of the CGS, including the Geomagnetism Program, were transitioned into the Environmental Science Service Administration. In 1970, many of these services were transitioned to the National Oceanic and Atmospheric Administration (NOAA), and in 1973, the Geomagnetism and Earthquake Programs were transitioned to the USGS. Still, the NOAA National Geodetic Survey continued to share the Fredericksburg site until 2006, when the observatory site was divided into two parts to better facilitate the independent work and administrations of the NOAA and the USGS.

In the late 1970s, Geomagnetism Program staff began to deploy digital-electronic systems at the various USGS observatories so that 1-minute resolution data could be acquired. The first 1-minute digital data from the Fredericksburg Observatory were reported in November 1982. In 2012, 1-second resolution data began to be routinely reported from Fredericksburg and other USGS magnetic observatories. Today, 1-minute and 1-second data are available for use from all USGS magnetic observatories in near real-time.

Since 1991, all USGS observatories, including Fredericksburg, have operated as part of INTERMAGNET, an international consortium of agencies dedicated to promoting the operation of modern magnetic observatories and the dissemination of their data (Love and Chulliat, 2013). Today, the USGS magnetic observatory network is an integral part of nationally coordinated projects concerned with monitoring and assessing hazardous magnetic storms (National Science and Technology Council, 2019) and electromagnetic pulses (Executive Office of the President, 2019).

Figure 1. The Cheltenham Magnetic Observatory in 1926. Photograph from USGS archive.

Geomagnetic Signals

Data from the USGS observatories record geomagnetic signals that originate within the Earth and in the Earth's surrounding space environment. In figure 2, we show hourly and annual-mean time series of the horizontal intensity of the field from 1901 to 2018 at Cheltenham and Fredericksburg. For more than a century, the horizontal intensity in the mid-Atlantic United States decreased and then increased due to dynamic processes in the Earth's core. The offset at 1956 between the Cheltenham and the Fredericksburg data is due to a localized difference in permanent crustal

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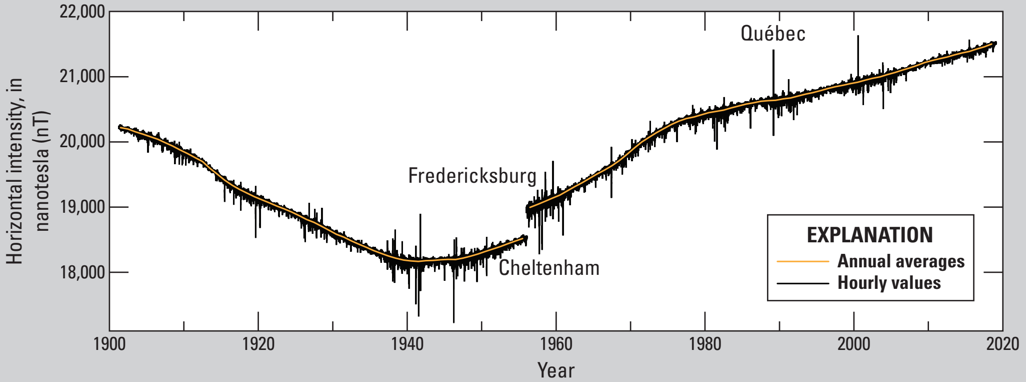

Figure 2. Time series of horizontal intensity measured at the Cheltenham (CLH) and Fredericksburg (FRD) Magnetic Observatories, 1901–2018. Observatory relocation, in 1956, introduced a discontinuity. Intense magnetic storms are seen as transient perturbations in the time series, including the great Québec storm (March 1989).

magnetization. Transient periods of rapid disturbance are magnetic storms. These are temporary disturbances of the Earth's surrounding outer-space environment caused by bursts and concentrated streams of solar wind plasma emitted by the Sun.

The great magnetic storm of March 1989 is labeled in figure 2. During this storm, geoelectric fields induced in the Earth's conducting crust caused the collapse of electricity transmission in the high-voltage grid of Québec, Canada—plunging the province into a blackout (Allen and others, 1989). The same storm caused numerous operational anomalies in northeastern U.S. power-grid systems, including damaging a high-voltage transformer at a nuclear-power plant in Salem, New Jersey (North American Electric Reliability Corporation, 1990; Barnes and others, 1991).

Fredericksburg data are being used by USGS Geomagnetism Program research staff to estimate and map geoelectric hazards across the mid-Atlantic United States, including, in particular, those acquired during the March 1989 storm (Love and others, 2018; Lucas and others, 2018). These projects, and the observatory data, in general, inform utility companies and regulators in their projects for evaluating the vulnerability and improving the resilience of power-grid systems to magnetic storm disturbance.

Fredericksburg is one of several observatories around the world supplying data for calculating standard indices of geomagnetic space-weather disturbance (for example, Mayaud, 1980). Fredericksburg data are used by the NOAA Space Weather Prediction Center (SWPC), the United States Air Force (USAF), and the National Aeronautics and Space Administration (NASA). Fredericksburg data (1) contribute to the construction of the International Geomagnetic Reference Field that is used for navigation, orientation, and scientific research (Chambodut, 2020); (2) are used for academic research into the nature of the Earth's interior (for example, Kelbert and others, 2009); and (3) are used by the commercial sector.

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By Jeffrey J. Love and Kristen A. Lewis

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