Auroras and Earthquakes: Strange Companions

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By Earthquake Hazards Program

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Overview

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In 1722 and 1723 a London clockmaker, George Graham, observed daily and consistent variations on one of his instruments, a "Needle upon the Pin" (a compass), for which he had no explanation. Swedish scientists obtained some of Graham's instruments to record what is now known to be the variations in Earth's magnetic field. In 1741, they noticed a significant deflection of the compass needle during an aurora, thus connecting auroral phenomena with the Earth's magnetic field for the first time.

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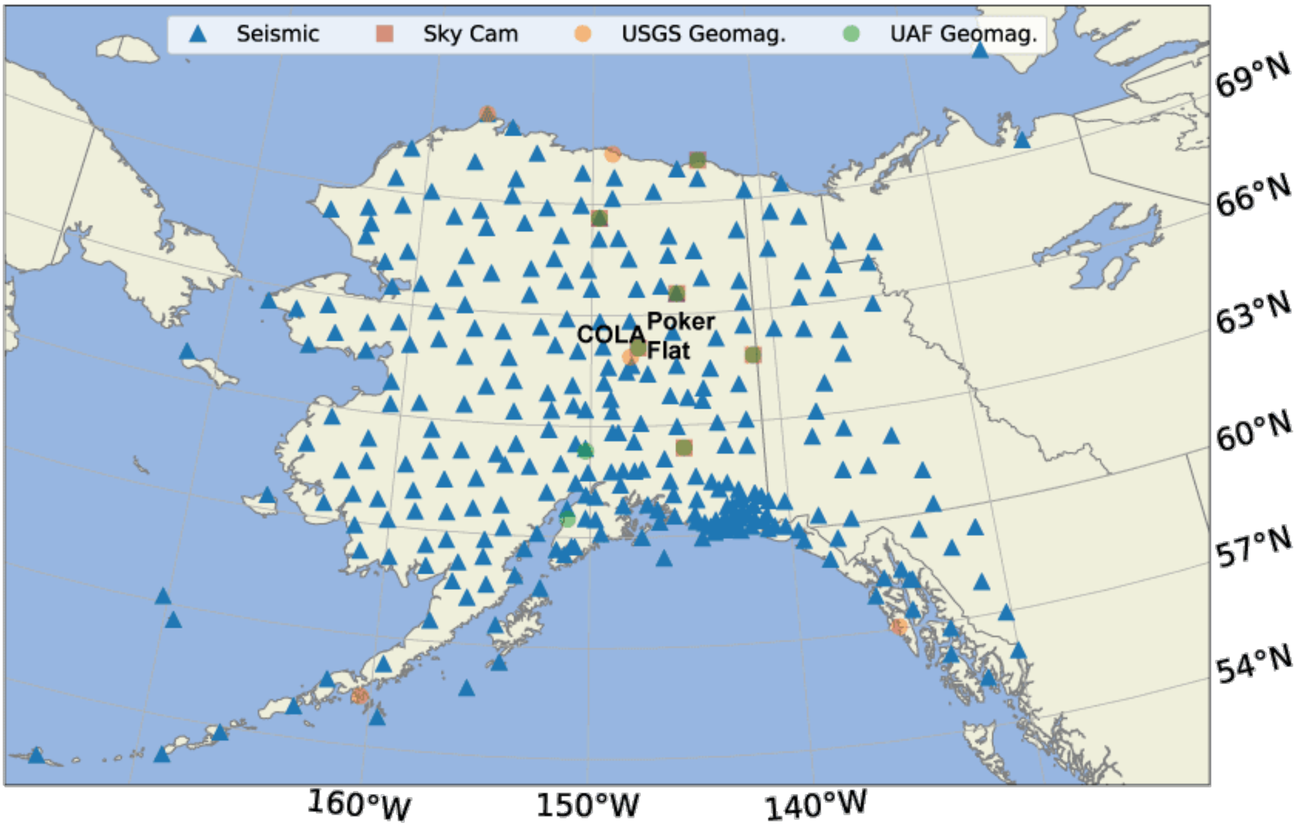
Photo of an aurora in central Alaska taken at 09:11 UTC on February 2, 2019 by Aaron Lojewski near Poker Flat (Credit: Aaron Lojewski. used with permission from Aaron Lojewski and Carl Tape)

Fast-forward 250 years. A new very sensitive seismometer, an instrument used to record earthquakes, was installed in 1991 at the Black Forest Observatory (BFO, Schiltach Germany). This was, and still is, one of the quietest locations in the world, with little outside noise that could contaminate the ground signals recorded by the seismometer. And yet… on February 21, 1994 a strong magnetic storm that was recorded on magnetometers throughout the planet was also recorded on the BFO seismometer. What follows is a story about an unusual marriage between instruments used to measure what's above us (Earth's magnetic field) and instruments used to measure what's below us (earthquakes).

An aurora is a colorful light display in the night sky mostly in the polar regions caused by the interaction between the **solar winds** and particles in the **magnetosphere**. These events in turn, influence the geomagnetic field that exists in the Earth, which in turn influence the electrical currents in the Earth (and in our built electrical systems, see Keeping the Lights On in North America.) The study of geomagnetic storms is driven both by scientific curiosity and also by the need to understand and mitigate the risk they pose to electrical grids.

Aaron Lojewski, a local resident, was driving on a dark road near Fairbanks, Alaska on February 2, 2019 just after midnight when the sky "erupted" with mostly pink colors. He stopped his car and took a photograph that was published in the local newspaper. This auroral event was one of three that were used by U.S. Geological Survey (USGS) and University of Alaska, Fairbanks scientists in one of two studies on the unusual connection between auroras, magnetometers (instruments that measure the Earth's geomagnetic field), and seismometers (instruments that record the ground shaking during earthquakes). The space physicists and the seismologists were brought together by two different goals that turned out to have the same solution: 1) there are very few magnetometers around the world—and especially in remote arctic Alaska—because a geomagnetic observatory is very expensive; but we need more, and 2) there are a large number of seismometers around the world, and some of them record geomagnetic storms that are considered “noise” that needs to be removed.



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Map of instrument locations used in both studies. The triangle symbols depict seismic stations including the Transportable Array (TA) and the Alaska Regional Network (AK). The 6 all-sky cameras are depicted in red squares at Kaktovik, Toolik, Fort Yukon, Poker Flat, Eagle, and Gakona. The magnetic stations are depicted as orange circles (USGS; 5 stations) and green circles (University of Alaska Fairbanks; 8 stations). (modified from original, Adam Ringler) (Public domain.)

Although it is well known that the ferro-magnetic material used in seismometers is sensitive to magnetic fluctuations, the exact influence had not been carefully analyzed. Geomagnetic signals are in the low frequency range, so seismic instruments that record in the low frequency range sometimes have a shield around them to block out the geomagnetic signals. But the shields are expensive, so they were not used on the 193 Transportable Array (TA) seismic stations that are currently in Alaska. The TA provided an excellent opportunity to observe the geomagnetic signal (“noise”) on this dense network in a region where space weather events (auroras) are frequent.

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Top of the 116 m borehole where the Trillium T-360 seismometer is buried at Incorporated Research Institutes for Seismology (SAGE)/USGS station COLA (College, Alaska). (Credit: Kyle Persefield and Kenneth Oliver, USGS. Public domain.)

In one study, analysis of the data from the magnetometer and the seismometer at the permanent Global Seismographic Network (GSN) COLA station near Fairbanks showed that using a relatively inexpensive magnetometer to record the geomagnetic signal and then removing that “noise” from the seismic signal dramatically improved the seismic data. This approach worked for magnetometers up to 100-200km from the

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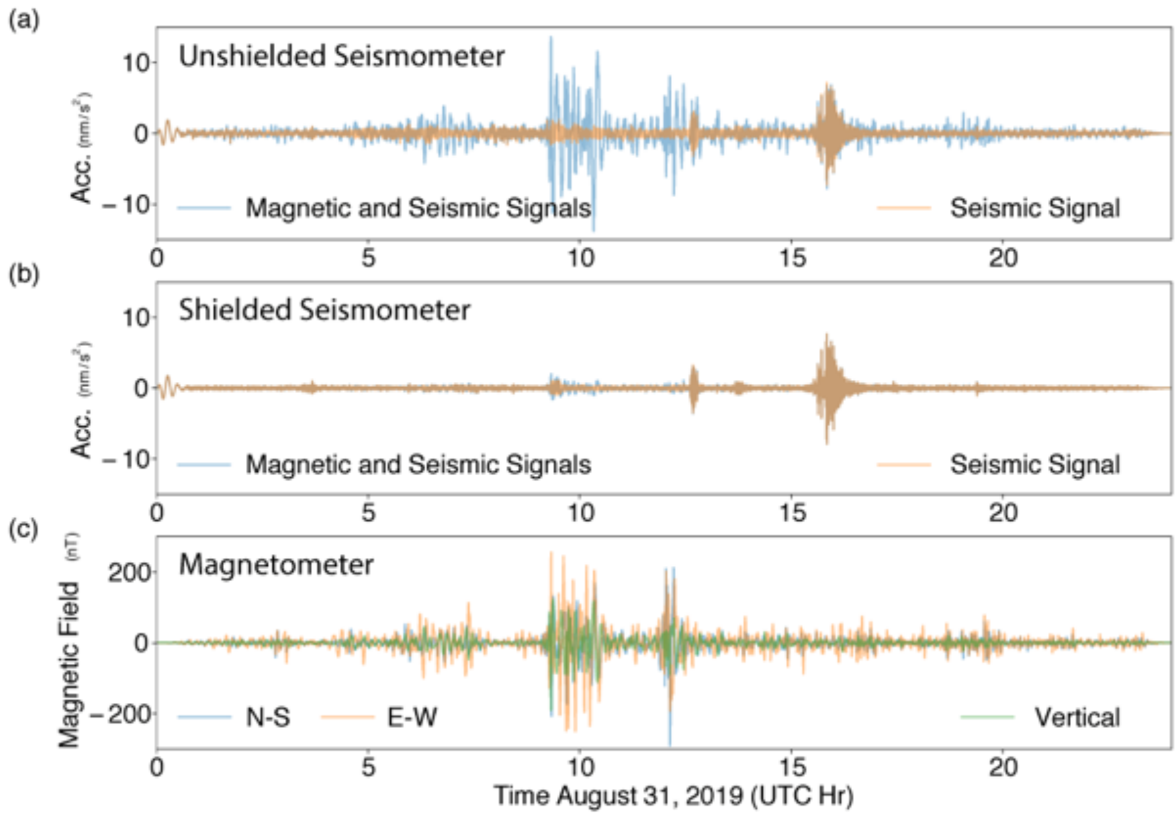
The Trillium T-360 seismometer on a winch at SAGE/USGS station COLA (College, Alaska). (Credit: Kyle Persefield and Kenneth Oliver, USGS. Public domain.)

seismic station; variations of the geomagnetic field were too different from the seismometer location beyond that distance to be usable. During a magnetic storm, the magnetic signal is so strong compared to the background seismic signal that it can be detected on the seismometer. The COLA station is part of a network of 150 permanent seismometers around the world used by the USGS to locate earthquakes.



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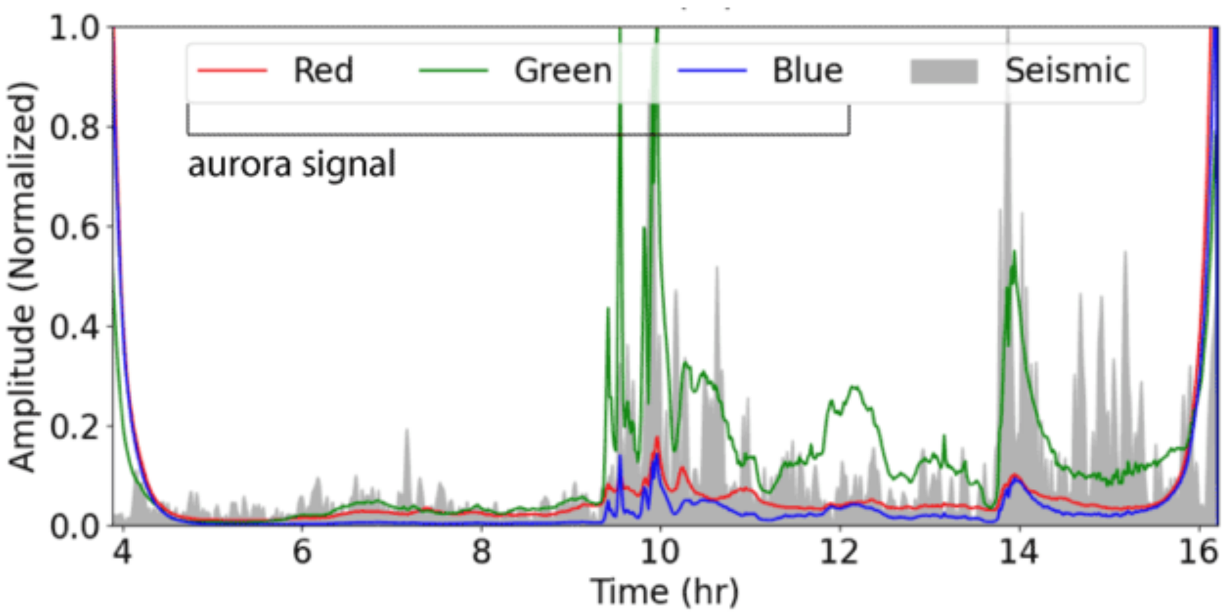
(a) Vertical seismic data beginning at Coordinated Universal Time (UTC) 00:00 on August 31, 2019, from SAGE/USGS station COLA (College, Alaska) from the unshielded sensor before correcting for the magnetic field (blue) and after correcting for the magnetic field (orange). (b) Same as (a), but for the shielded sensor. (c) Magnetic field data from the magnetometer at COLA that was used to remove the magnetic signal from the seismometer data. The August 31, 2019, M5.4 Burma earthquake can be seen on both sensors at approximately 15:20 UTC.

(modified from original, Adam Ringler) (Public domain.)

In the second study, the scientists used 6 all-sky cameras in Alaska that record optical data, in other words, photos of auroras; 8 magnetometer stations (several at the same sites as the cameras) to monitor space weather activity; and more than 200 seismic stations from the temporary TA stations and the permanent regional network in Alaska operated by the University of Alaska, Fairbanks. They focused on data from auroras on 3 different dates. The three different types of instruments all recorded the activity from the auroras, and the use of data from multiple seismometers allowed the seismic signal and the geomagnetic signal to be separated, providing geomagnetic data from locations where there were only seismometers.



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Comparison between optical imagery and seismic data for February 28, 2019 UTC. The seismic data (gray) is from the POKR (Poker Flat Research Range, Alaska) seismometer, and red, blue, and green are all components of the all-sky camera at Poker Flat. The signal on the seismometer correlates with the sky camera signal that recorded the aurora, indicating that the dominant signal is from the magnetic field variations during the aurora. (modified from original, Adam Ringler) (Public domain.)

In addition to the ability to use seismometers and inexpensive magnetometers to increase the density of data collected for geomagnetic activity, the GSN stations have 3 extra unused communication channels that could be used to send the geomagnetic data back to the central processing system immediately, providing additional realtime data to monitor space weather that may be negatively affecting power grids.

The outcome of the two studies results in a win-win situation for both seismologists and space physicists. Adding a relatively cheap magnetometer to each Alaska seismic station would result in better seismic data for earthquakes and also more geomagnetic data in real time for monitoring space weather.

- written by Lisa Wald, USGS, July 6, 2020

For More Information

- Ringler, A. T., R. E. Anthony, D. C. Wilson, A. E. Claycomb, and J. Spritzer (2020). Magnetic Field Variations in Alaska: Recording Space Weather Events on Seismic Stations in Alaska, Bull. Seismol. Soc. Am. XX, 1–11, doi: 10.1785/ 0120200019
- Carl Tape, Adam T. Ringler, Don L. Hampton; Recording the Aurora at Seismometers across Alaska. *Seismological Research Letters* doi: https://doi.org/10.1785/0220200161

- Keeping the Lights On in North America
- Aurora Forecast (Geophysical Institute, University of Alaska, Fairbanks)
- All-Sky Aurora Display from Poker Flat, Alaska, on March 2, 2017
- All-Sky Aurora Display from Poker Flat, Alaska, on February 2, 2019
- All-Sky Aurora Display from Poker Flat, Alaska, on February 28, 2019

Note: The TA project was funded by the National Science Foundation and more information is available at Transportable Array – Alaska.

The Scientists Behind the Science

Adam Ringler is a scientist at the Albuquerque Seismological Laboratory where he has been working since 2008. He obtained his Ph.D. from the University of New Mexico in 2009. He works on seismic instrumentation

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Adam Ringer. (Public domain.)

and data quality. In his free time he enjoys rock climbing, skiing, and running with his wife.

Carl Tape grew up in Fairbanks, Alaska, and found his way back home in 2010. He develops and applies techniques in computational and observational seismology to obtain better images of Earth's internal structure and to obtain a better understanding of earthquakes. Improved seismic images can be used to help assess seismic hazard in earthquake-prone regions. While waiting for the next Alaska earthquake, he likes to explore the Alaskan Outdoors via running, hiking, and boating.

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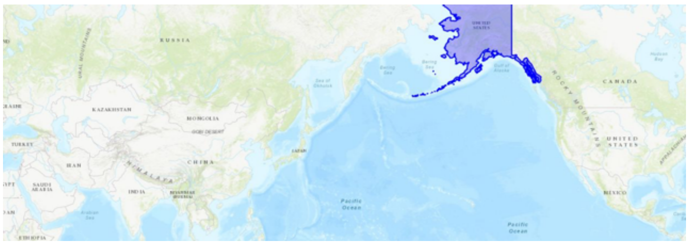
Carl Tape. (Public domain.)

Study Area



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