Observing the ‘Spheres with the EarthScope Transportable Array

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Abstract

The motivation and objective of the EarthScope Transportable Array (TA) is to record earthquake signals and image the structure of the North American plate, however the observations collected by this National Science Foundation funded project have enabled unanticipated discoveries, innovative data analysis techniques, and ongoing investigations across many disciplines in the Earth and space sciences. The Transportable Array utilized a survey approach to collect data in which high-quality stations were systematically installed in a dense geospatial grid. From the very beginning of the deployment, this strategy allowed for data-driven discovery, such as using seismic data to map out extensive travel time curves for acoustic waves in the atmosphere (Hedlin et al., 2010). While the emplacement of the seismic sensors was kept uniform along with the core components for power and communications, the Transportable Array station design evolved over time to include additional barometric pressure and infrasound sensors and, eventually, meteorological sensors measuring external temperature, wind, and precipitation. As the array rolled across the Lower 48 and the TA became more recognized outside of seismology, collaborations were forged and strengthened with researchers in the infrasound and meteorological communities. Along with standard approaches using direct measurements, inventive techniques were used to apply environmental data for observing tectonic phenomena as well as applying seismic data for observing environmental phenomena. The value of integrated scientific infrastructure became even more apparent with the Transportable Array deployment in Alaska and western Canada, with autonomous and telemetered stations occupying sites within large swaths of previously unmonitored and inaccessible terrain. The majority of Alaska TA stations collect weather data and a subset also include a detached soil temperature probe. As a result, data collected by the Alaska Transportable Array have been used to observe throughout the ‘spheres: the lithosphere (earthquakes, volcanoes, landslides), the cryosphere (sea ice), the hydrosphere (precipitation, fire preparation), the atmosphere and biosphere (weather forecasting, storm systems, bolides), and even into the magnetosphere (space weather).

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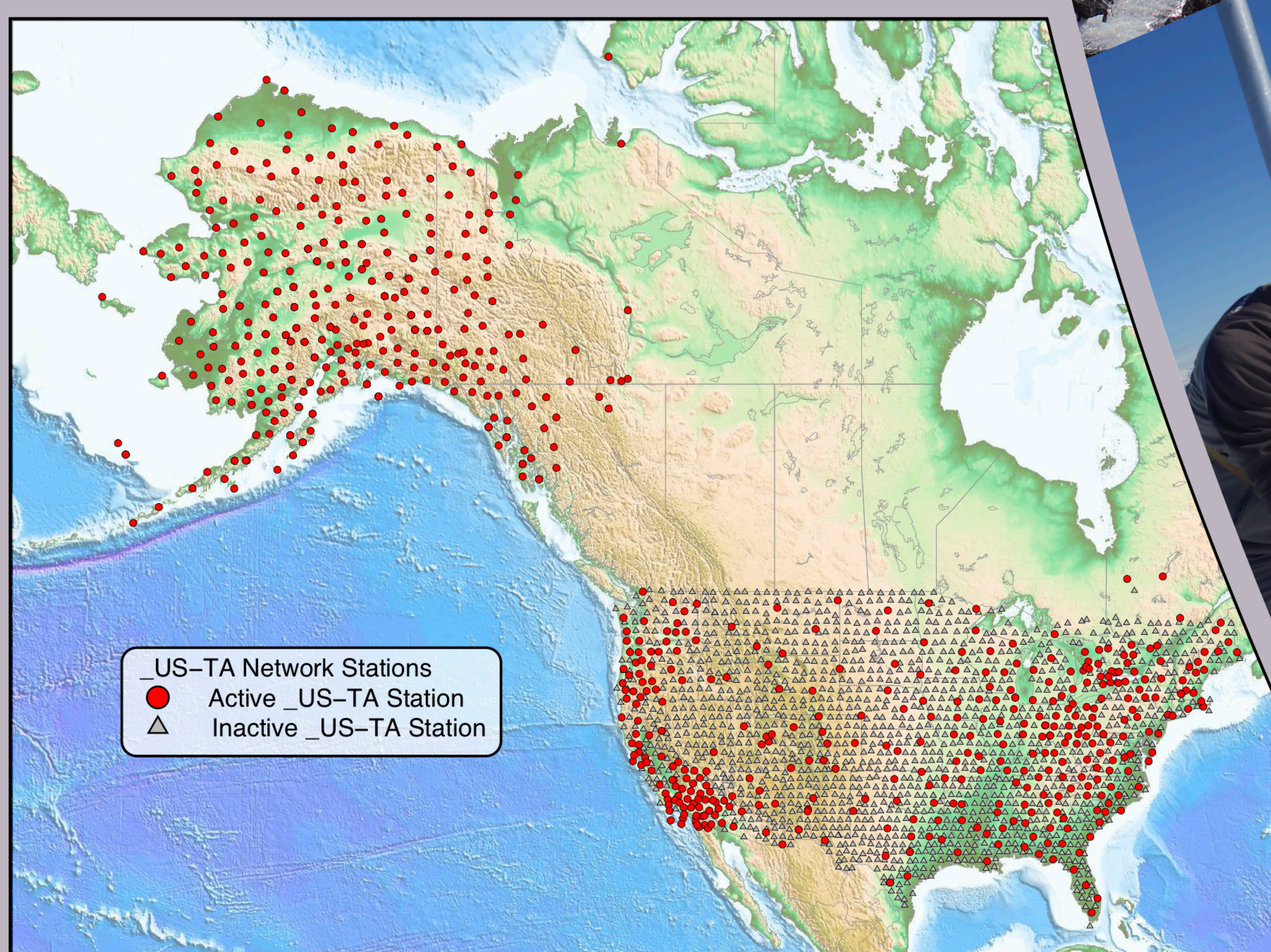
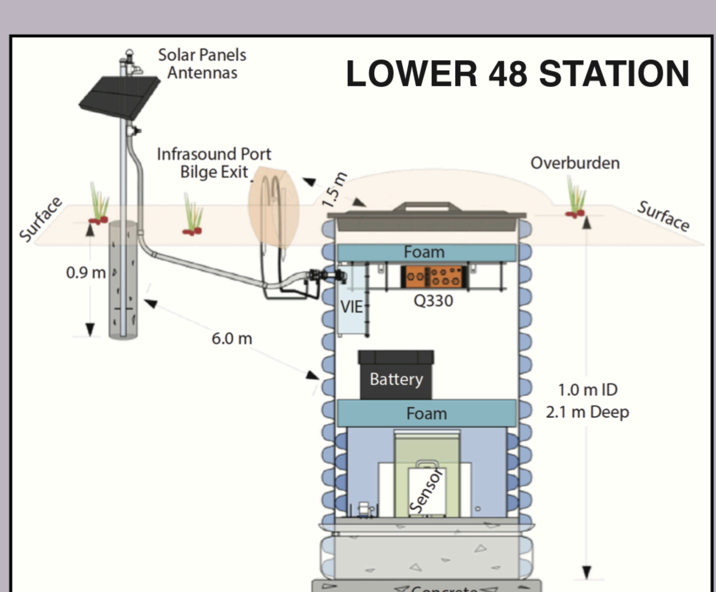
INTRODUCTION: The EarthScope Transportable Array recorded earthquake signals to image the structure of the North American plate. It also enabled unanticipated discoveries and innovative data analysis techniques to observe throughout the 'spheres:

Lithosphere, Cryosphere, Hydrosphere Atmosphere and Biosphere, and the Magnetosphere.

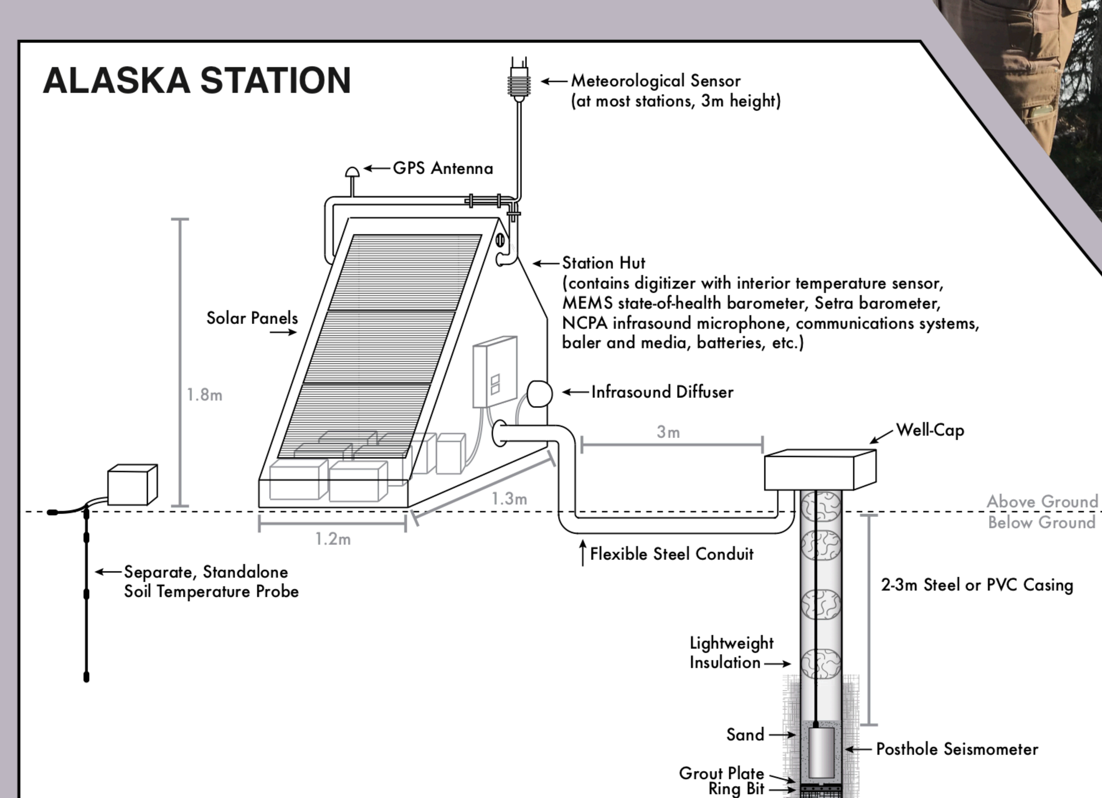


The Transportable Array utilized a survey approach to collect data with high-quality and uniform seismic stations systematically installed in a dense geospatial grid.



The Transportable Array station design evolved over time to include additional barometric pressure, infrasound, meteorological, and soil temperature sensors.

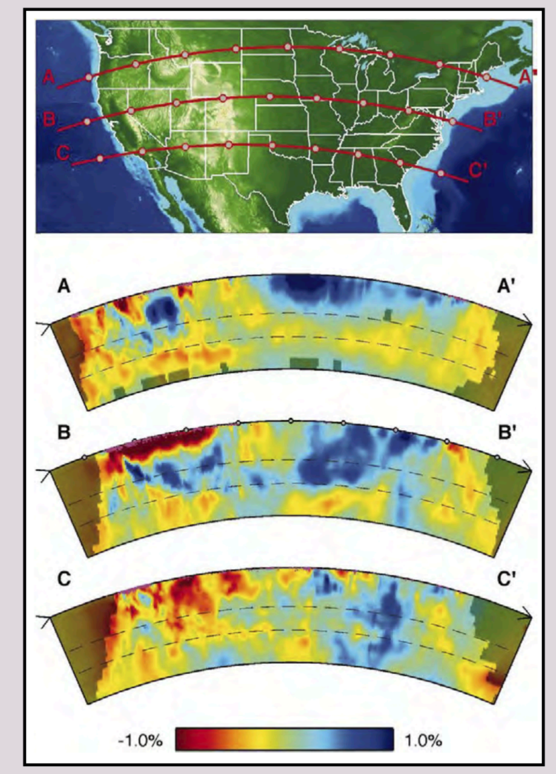
For more information, go to www.usarray.org



LITHOSPHERE

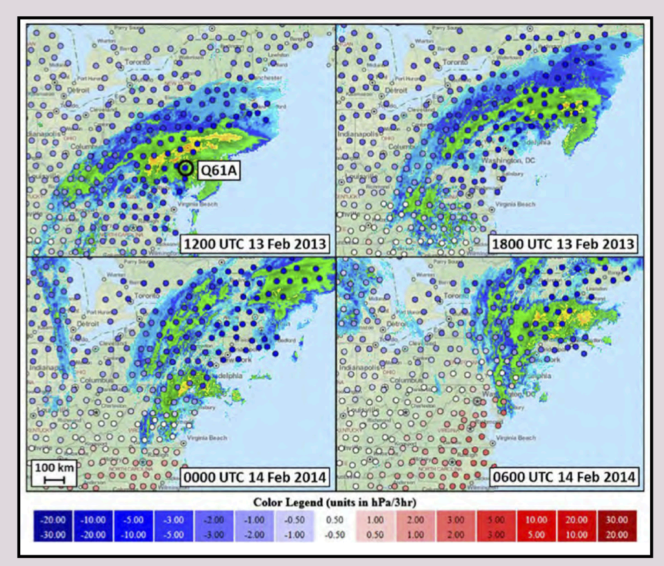
Photos courtesy of the EarthScope Alaska Transportable Array Team

EARTH'S STRUCTURE: The primary goal of the EarthScope Transportable Array was to map Earth's structure beneath the North American continent by collecting high-quality recordings of earthquakes using broadband seismometers installed on a dense grid. Researchers used a number of methods to achieve this goal and continue to analyze the collected data set to improve their models.



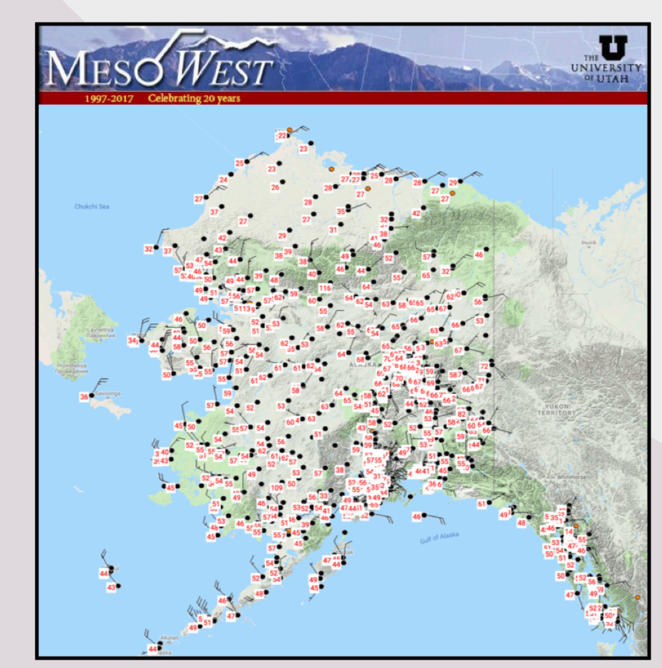
Similar to a CT scan or CAT scan, these cross sections of the mantle down to 1000 km depth show variations in the speed that seismic P waves travel through Earth. Blue indicates faster P-wave speeds, red indicates slower speeds. From Burdick et al., 2017.

ATMOSPHERE AND BIOSPHERE



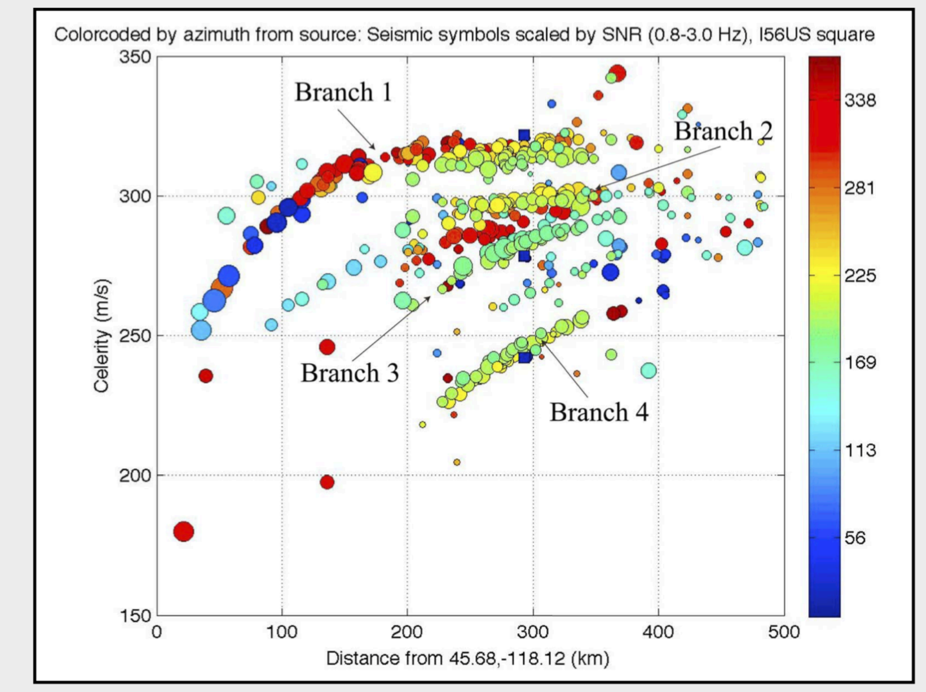
Pressure as recorded by Transportable Array stations (circles) in New England. Red colors indicate higher pressure tendencies and blue colors indicate lower pressure tendencies. Overlaying the stations is radar reflectivity imagery depicting a snowstorm that moved northward over the course of two days in 2014. From Jacques et al., 2015.

WEATHER AND FORECASTING: "[Alaska TA data] is being used directly for situational awareness. The data is also directly being in the RTMA/URMA analysis for Alaska and our local analysis. These analysis are used to verify our forecasts, situational awareness, and for ground truth to post-process modeling systems."
- Gene Petrescu, NWS



Temperature (°F), wind speed, and wind direction from Alaska Transportable Array and additional networks. From MesoWest web interface: mesowest.utah.edu.

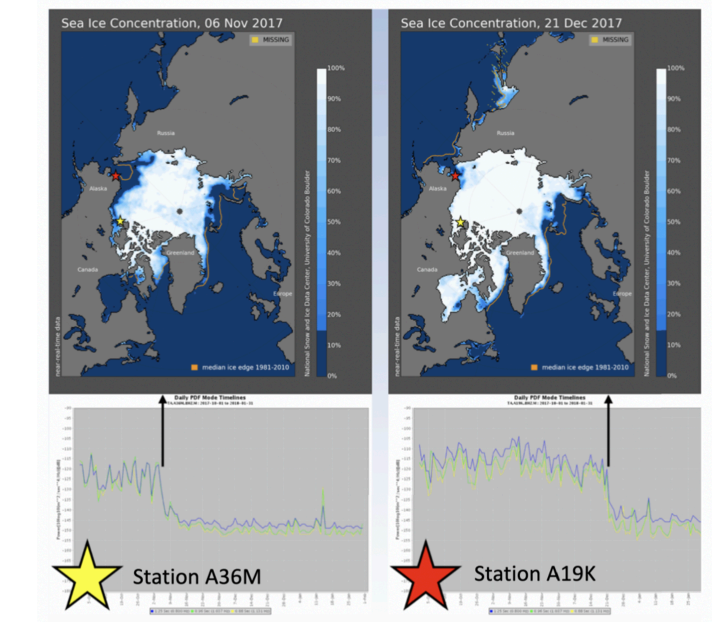
BOLIDES: Seismic data recorded by Transportable Array stations in the Lower 48 U.S. were used to map out extensive travel time curves for acoustic waves in the atmosphere caused by a meteor (Hedlin et al., 2010).



Celerity of all seismic and infrasound signals within 500 km range showing the different traveltime branches of a 2008 meteor above NE Oregon. The symbols are color coded by azimuth from the source and scaled by the maximum signal-to-noise ratio. From Hedlin et al., 2010.

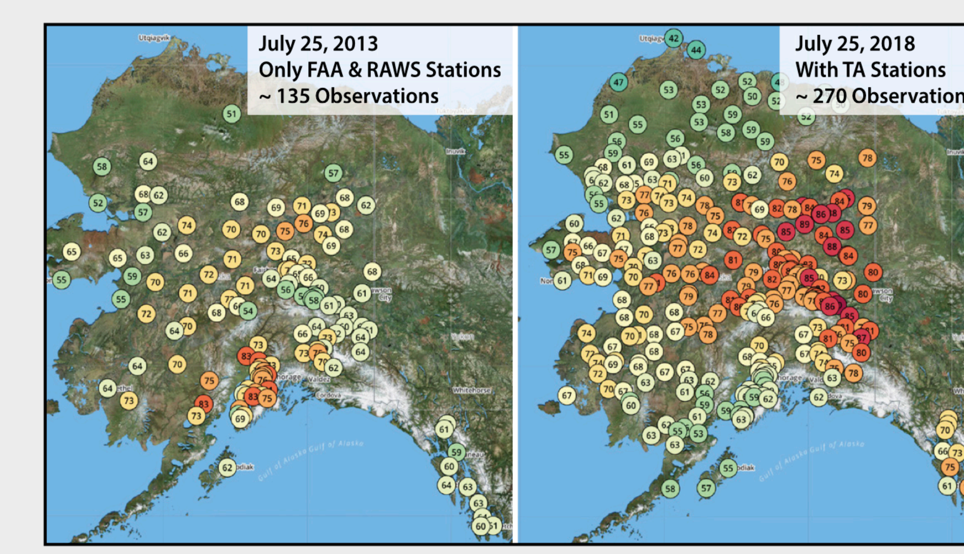
CRYOSPHERE

SEA ICE: Seismic noise levels around 1 Hz at Alaska Transportable Array stations anticorrelate strongly with satellite estimates of sea ice concentration near seismic stations. (See Poster S23D-0660 L. Estrada)



Seismic data and metrics requested from IRIS DMC and MUSTANG. Sea ice concentration estimates from DMSP SSM/Is/SSMIS requested from the NSIDC.

FIRE PREPARATION: The TA is able to provide weather data from many areas in Alaska that were not previously monitored. The sensors record temperature, wind speed and direction, humidity, pressure, and precipitation and are made available in real time so that they can be incorporated into National Weather Service regional weather forecast models. The Alaska Interagency Coordination Center (AICC) uses the precipitation data to make important decisions on positioning resources before the fire season begins.

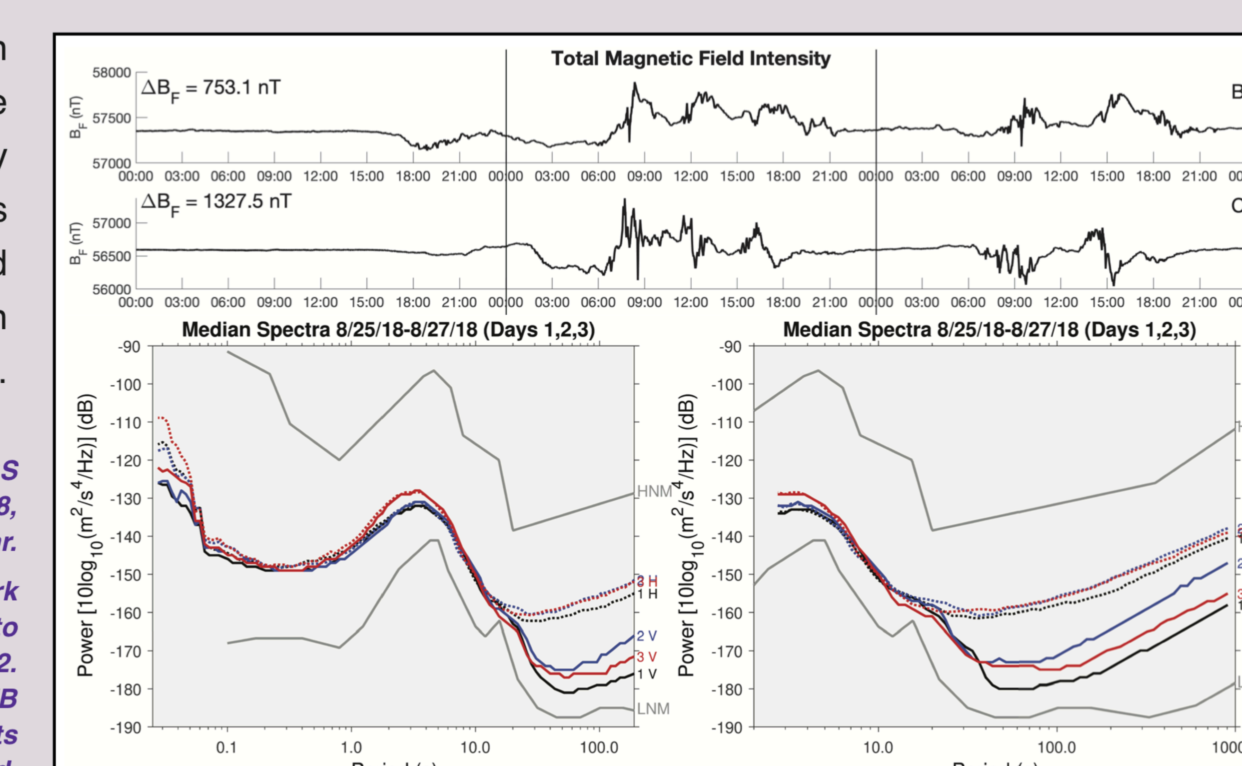


Numbers in the circles show temperature in °F recorded at meteorological stations across Alaska in 2013 compared to 2018 with the addition of USArray TA stations. Note that stations deployed in western Canada are not plotted. From akff.mesowest.net/map.

HYDROSPHERE

MAGNETOSPHERE

MAGNETIC STORMS: Force feedback seismometers contain ferromagnetic metals and magnetic coils and can be susceptible to magnetic interference. Geomagnetic activity caused by space weather has been observed on seismometers (e.g. Forbriger, 2007; Kozlovskaya and Kozlovsky, 2012) and geomagnetic activity does manifest in the ground motion spectra and timeseries of the Alaska TA.



top) Unfiltered total magnetic field intensity at USGS magnetic observatories during August 25-27, 2018, covering the largest geomagnetic storm of the year.

bottom) The median spectra of the full network for days 1-3. Geomagnetic signal begins to emerge at ~30 seconds period on day 2. Vertical components show a 10-15 dB increase, while horizontal components are relatively unchanged.

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