Analysis of Very Long-Period Noise at Flexible-Array Stations in the North-American Midcontinent

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Abstract

The Superior Province Rifting Earthscope Experiment (SPREE) deployed seismic stations in 2011-2013 throughout Wisconsin, Minnesota, and Ontario. To protect equipment from groundwater damage, SPREE stations were buried at unusually shallow depths, increasing the power of long period noise and facilitating an investigation into the regional effects of atmospheric tides and soil properties (Wolin et al., 2015). Here we utilize the SPREE array to study the effects of solid-earth tides and meteorological conditions, on very long-period seismic noise in the U.S. midcontinent. Continuous seismic data was collected from SPREE and Transportable Array (TA) stations located in Wisconsin and Minnesota (WIMN) between July 2011 and September 2013. This data was "cleaned", filtered, and averaged to produce a monthly representation of the very-long period signals recorded by the SPREE stations. The signals showed diurnal (24 hr) and semidiurnal (12 hr) periodicities, whose magnitudes and dominance vary seasonally. Using cross correlations, we compare our very-long period observations with theoretical solid-earth tides (Milbert, 2018) as well as meteorological components in the WIMN region. Meteorological data, specifically temperature and pressure, was obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Center for Environmental Information (NCEI). Solid-earth tides result from the gravitational pull of the moon and sun, and have previously been documented in seismic data (e.g. Pillet et al.,1994; Lambotte et al., 2005). We observe a distinct correlation between theoretical solid-earth tides and very-long period signals in seismic data from SPREE and TA stations in the WIMN region, where one frequency component is correlated while the other appears delayed. In addition, we observe a remarkable seasonal change in SPREE recordings of these signals, but not in TA recordings. We will report our findings from testing the hypothesis that the observed very-long period signals in SPREE data are a combination of both tidal and thermal effects and that these cumulative effects are the result of the unusual burial depth of SPREE stations.

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Background

The Superior Province Rifting Earthscope Experiment (SPREE) deployed seismic stations in 2011-2013 throughout Wisconsin, Minnesota, and Ontario. To protect equipment from groundwater damage, SPREE stations were buried at unusually shallow depths, which increased the power of long period noise, facilitating an investigation into the effects of atmospheric convection and soil properties (Wolin et al., 2015) on the seismic data. We study the effects in SPREE data of solid-earth tides and meteorological conditions, on very long-period Z-component seismic noise in the Wisconsin and Minnesota (WIMN) region between July 2011 and September 2013.

Observations

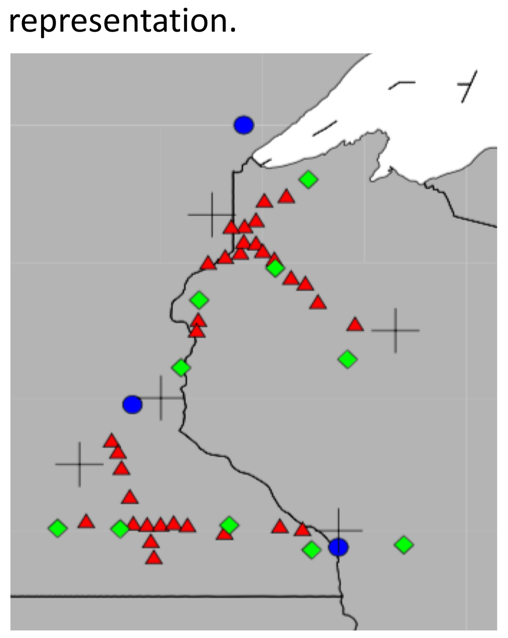
Signals are dominated by a 24-hr signal during the summers and a 12-hr signal during the winters. Seasonal transitions occur during November and either March (2012) or April (2013). ATA signals are not affected seasonally and are dominated by a 12-hour signal. The WMIN signal is much stronger during the warmer months than in the colder months. The trend of these signals follows the trend in atmospheric pressure. We hypothesize that the observed very-long period WIMN signal represents a weak 12-hr tidal signal that is drowned out during warmer months by a strong, thermally-driven 24-hr signal. Because the latter seismic signal dampened slightly after more sand was added to the vaults in the Fall of 2011, we hypothesize the effect stems from thermal expansion and contraction of vault air or heating and cooling of the seismometer itself.

Discussion

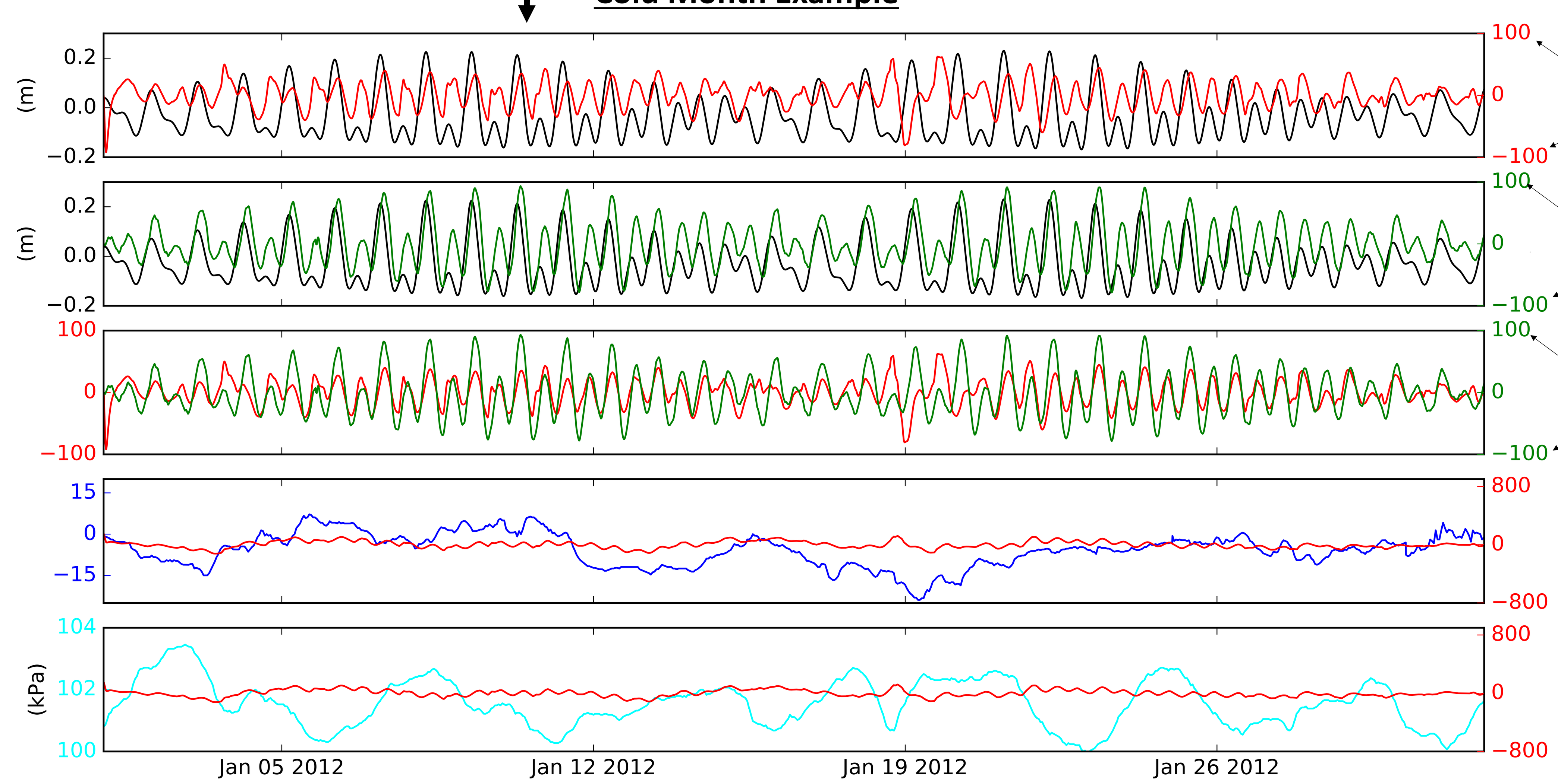
Due to the shallow burial depth, SPREE stations are more sensitive than is typical to surface temperature and pressure changes, while being similarly sensitive to tidal forces. We hypothesize that the diminishing of the 24-hr thermally-driven WIMN seismic signal during winter months is due to either thermal insulation of vault air, vault sand, and seismometer by snow cover. We find that the WIMN tidal signal is noisier than that recorded by ATA stations and that the observed tidal signal correlates very well with the theoretical tidal signal but has an unexplained lag of about 2.5 hours. This research has provided the opportunity to explore the types of atmospheric conditions that can affect a seismometer in order to gain insight on future seismic station installation practices as well as introduces an alternative source that can be used to monitor changes in the Earth's atmosphere.

Data

Red triangles represent a subset of 33 SPREE stations (WIMN). Green diamonds represent 11 Transportable Array stations (ATA). Blue circles represent 3 Local Climatological Data (ALCD) stations. Black X marks the location of theoretical solid-earth tides (Milbert, 2018). Seismic signals are "cleaned" to remove peaks and low-pass filtered to remove oscillations with periods less than 3 hours. Signals are averaged over all stations in their network to get a regional signal representation.

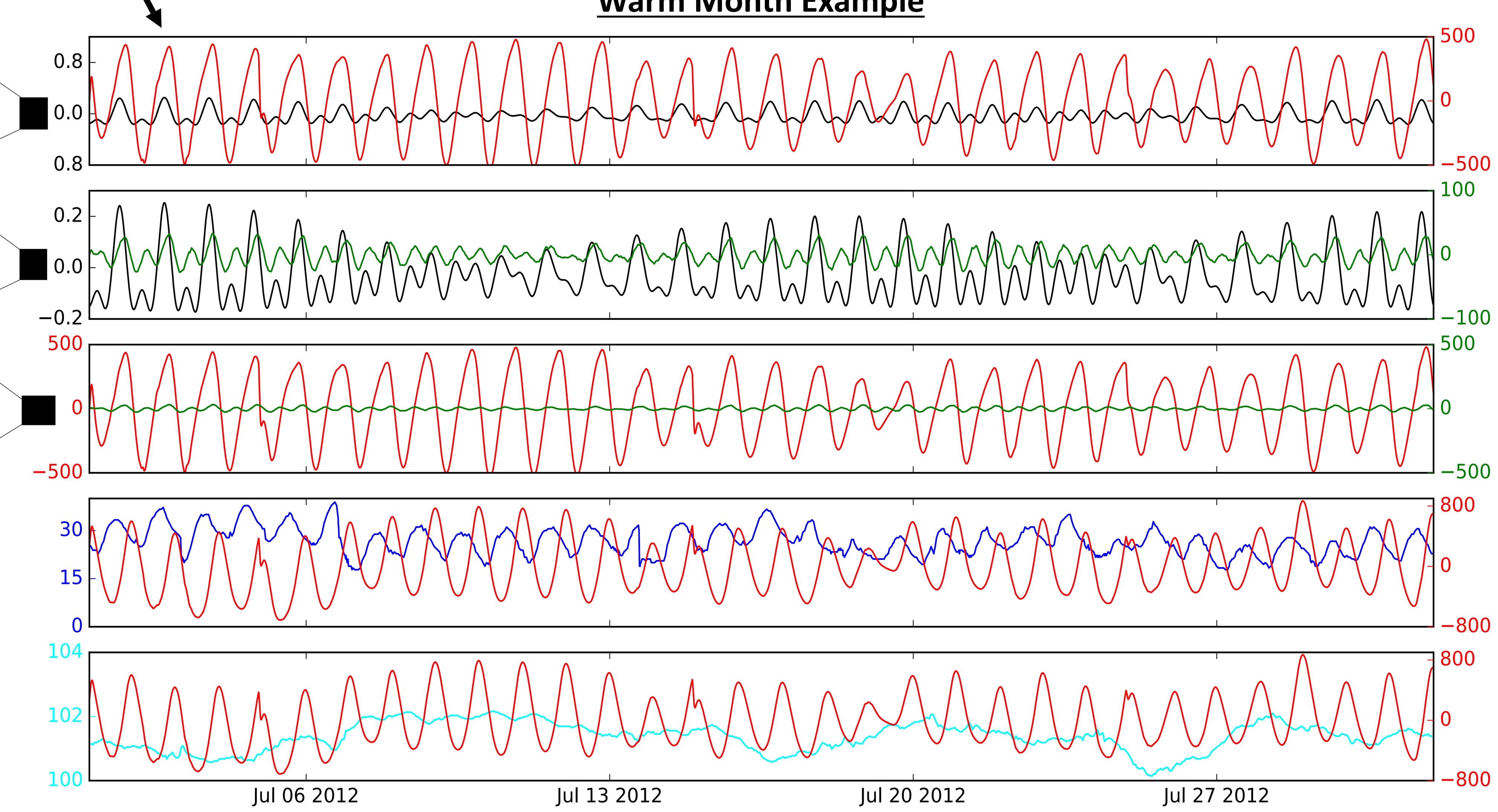


Cold Month Example



Winter signals. Signals in the bottom two frames are described on the left, while signals in the top three frames are band-passed between 7 and 28 hours, and integrated to give displacement. Both WIMN and ATA signals show the presence of tides and correlate well with Theoretical Solid Earth Tide signals, though with a small delay and with the ATA signal being less noisy. Secondary effects such as from temperature and pressure are also observed. Temperature is correlated and pressure is anti-correlated with WIMN signal during the colder months.

Warm Month Example



Summer signals. The WIMN signal anti-correlates strongly with daily temperature variations. Pressure correlates weakly with the mean of the WIMN signal during the warmer months. The WIMN signal has low correlation with the ATA signal during warmer months. ATA signal correlates with the Theoretical Solid Earth Tide.

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