### Temporal Variability of Infrasound Propagation and Detectability in the European Arctic

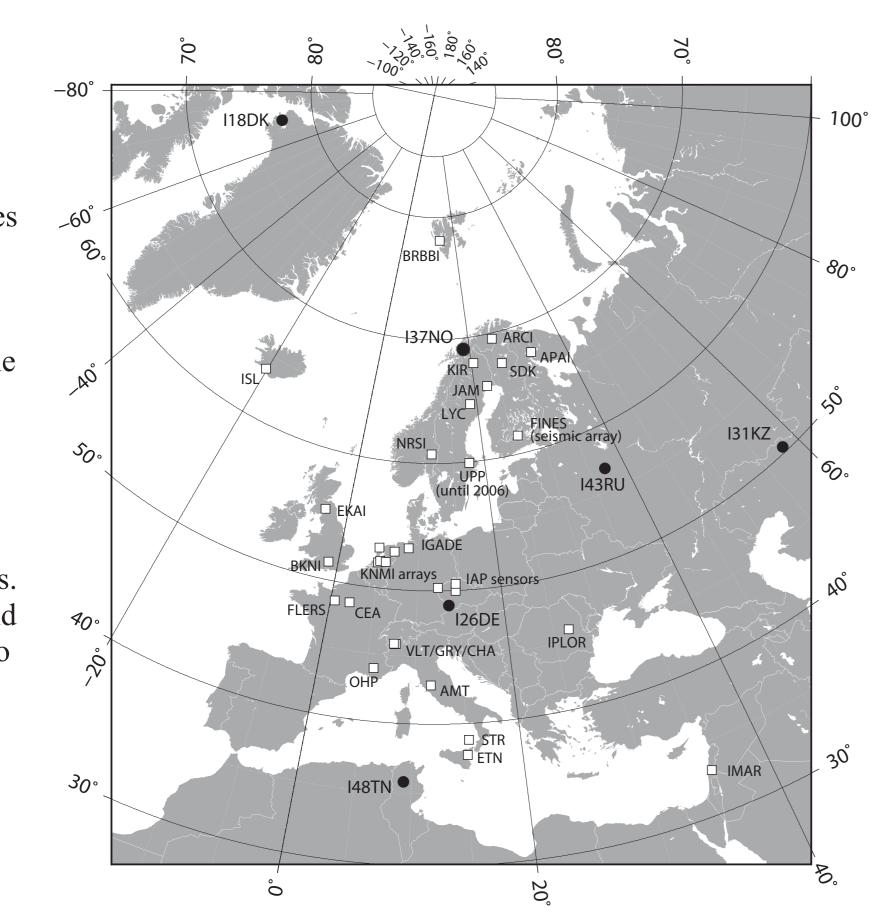
# A SAR

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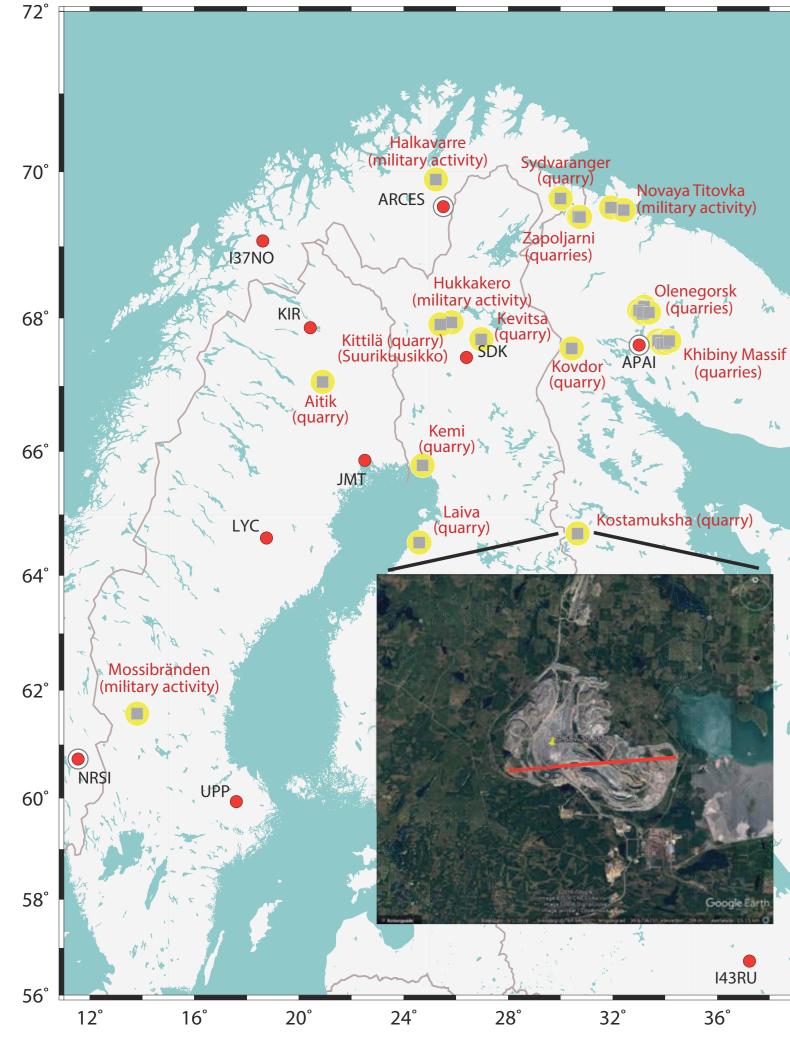


#### **Seismoacoustic Sources and Stations in Fennoscandia**

Infrasound is one of the technologies employed for detecting potential violations of the Comprehensive Nuclear-Test-Ban Treaty. Infrasound signals propagate through the atmosphere: a highly anisotropic, heterogeneous, and time-varying medium. To fully exploit infrasound, we need to understand how signal propagation changes over different spatial and temporal scales. For an explosion at a given time and a given place, what do we expect to see - at which stations and when?



The IMS infrasound network covers the globe. In Europe, a far denser network - including national (non-IMS) facilities - allows us to explore infrasound propagation in great detail. We can then apply these observations to signals on the global network.

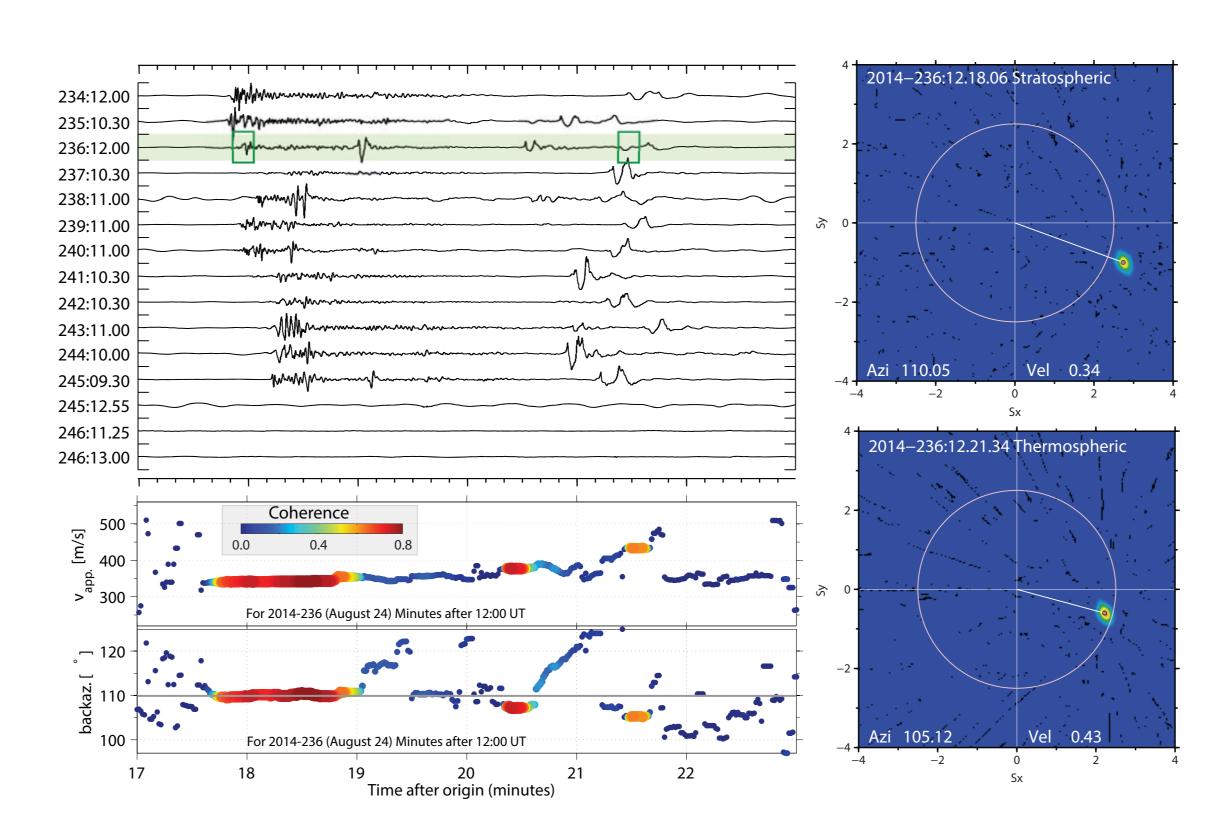


In Fennoscandia, we have not only many infrasound stations but also many repeating sources of infrasound mainly open-cast quarries and military explosions. Repeating explosions are very useful as they allow us to sample "many different atmospheres" over time-scales ranging from days, to seasons, and many years.

The spatial distributions of sources and stations mean that we sample many different distances - with qualitatively different expected infrasonic wavefields - and different directions. The explosions generate seismic signals from which we can often determine the exact time and location.

Many of the sources take place allyear-round allowing us to see seasonal changes.

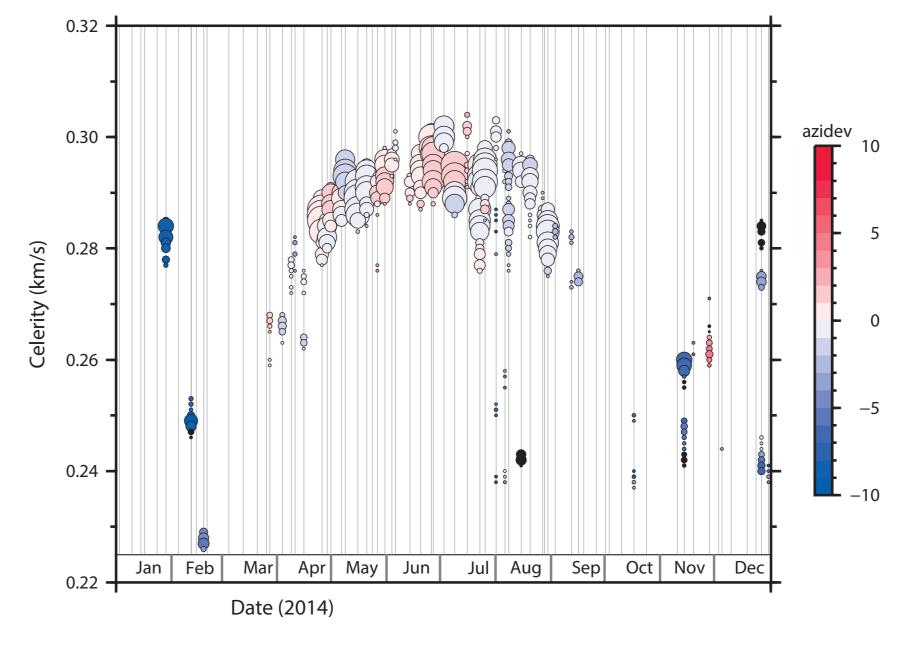
#### The Infrasonic Wavefield over Different Temporal Scales

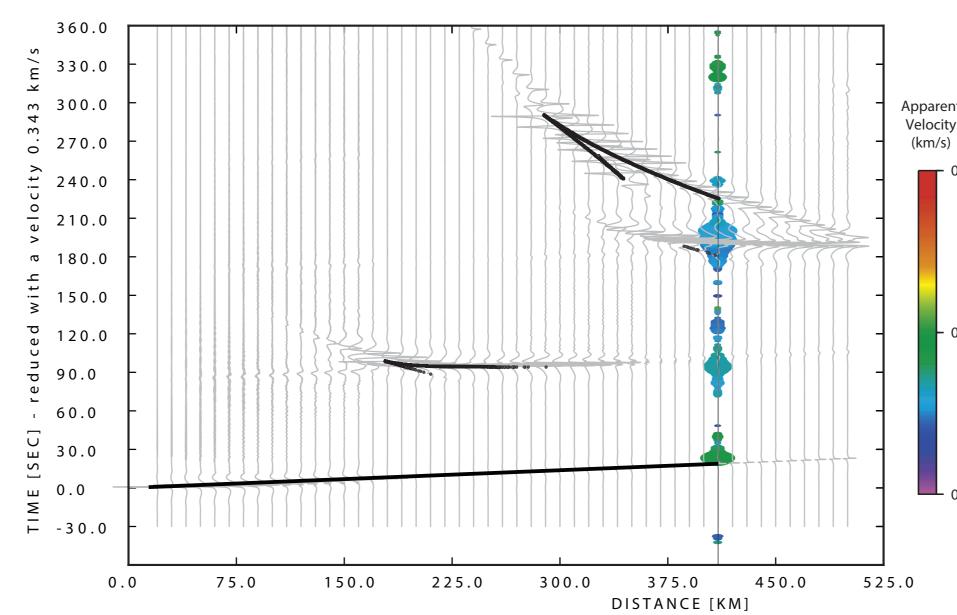


The infrasonic wavefield from a single repeating source of explosions can change significantly from one day to the next. Here we see infrasound signals at station IS37 (Norway) for 15 military explosions at Hukkakero in northern Finland on consecutive days. We see both stratospheric phases (higher frequency, 18-20 minutes after each explosion) and thermospheric phases (very low frequency, 20-22 minutes after each explosion). We examine how the backazimuth, the apparent velocity, and the celerity (distance over ground traveled divided by time taken) vary for each arrival and each explosion.

The infrasonic wavefield from a given site changes significantly with the season. Here we see how one year of mining explosions at Aitik are recorded at IS37, 245 km to the North West. In the wintertime, infrasound is rarely observed (consistent with the stratospheric winds) and, in the summertime, the traveltime is a minimum in June/July (for the most efficient wave guide).

We see both changes to the traveltime (or celerity) and to the deviation in backazimuth.

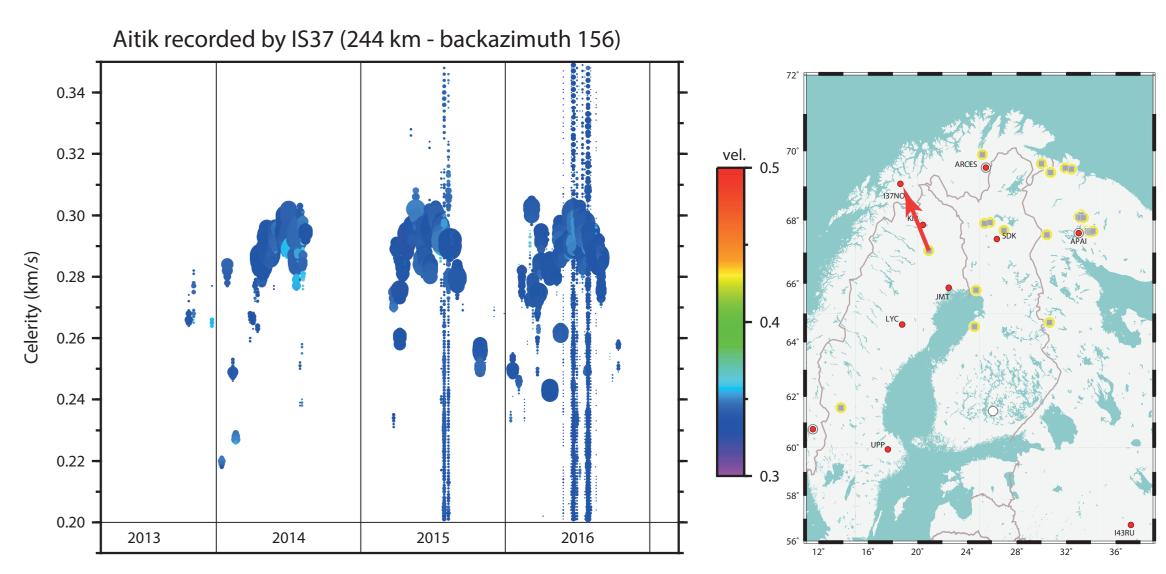




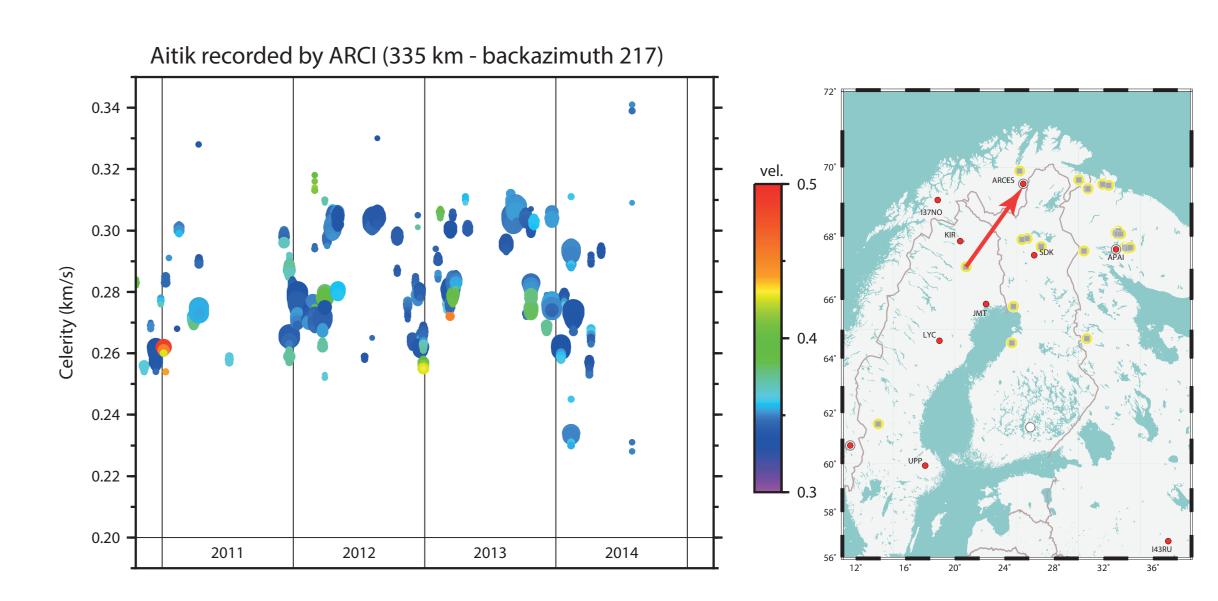
We also need to make sure that we can model the arrivals. For this (accidental) explosion in northern Norway, raytracing (black lines) is only able to predict 3 of the 4 observed arrivals. A full waveform (reflectivity) calculation - grey lines - predicts them all.

## Seasonal Variability of Infrasound Propagation Along Different Paths

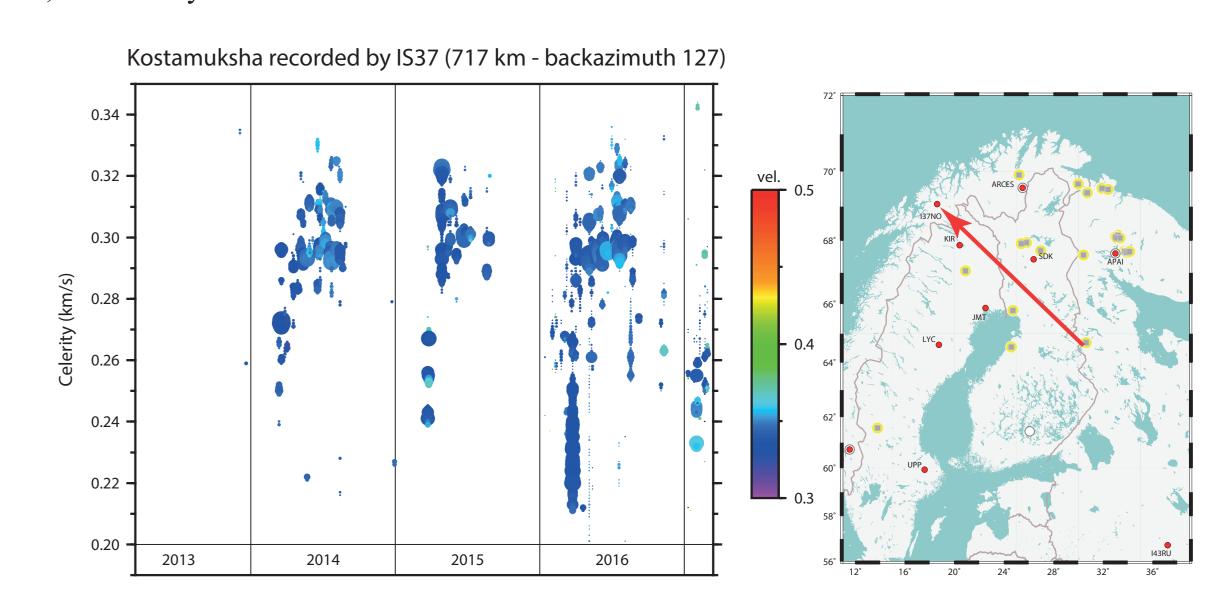
We here examine infrasound recordings from repeating explosions over several seasons.



If we examine the Aitik explosions recorded at IS37 from 2013 (when the station opened) through to the fall of 2016, we see the same characteristics each year. We also see a problem of an unrelated source generating continuous infrasound signals from almost the same direction as Aitik.



Explosions at Aitik are also observed at ARCI to the North East. Signals are not observed at midsummer. However, there appear to be two different types of arrival with different celerities in the colder months. At the peak of winter, arrivals have celerity between 0.26 and 0.28. In spring and fall, the celerity is closer to 0.30. This needs to be accounted for in event location.



Explosions at the Kostamuksha mine in Russia are also recorded infrasonically at IS37. The picture is similar to Aitik with no winter signals and a sinusoidal variation of traveltime in the summer. However, at this far greater distance, we see multiple stratospheric arrivals. This too needs to be accounted for when locating events.