Crustal structure, seasonal and directional variations of ambient noise in SE Canada and the NE USA

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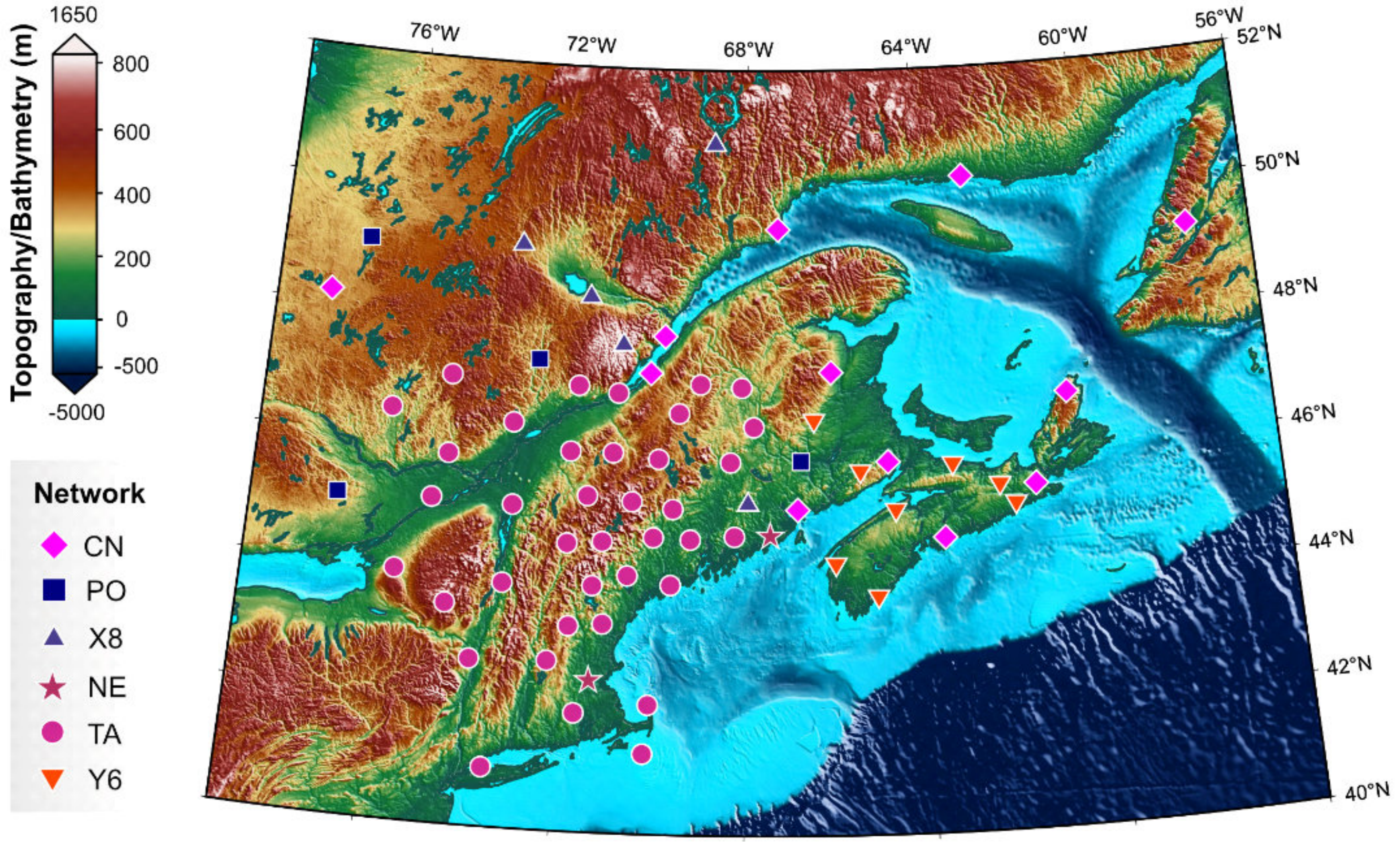
Datasets

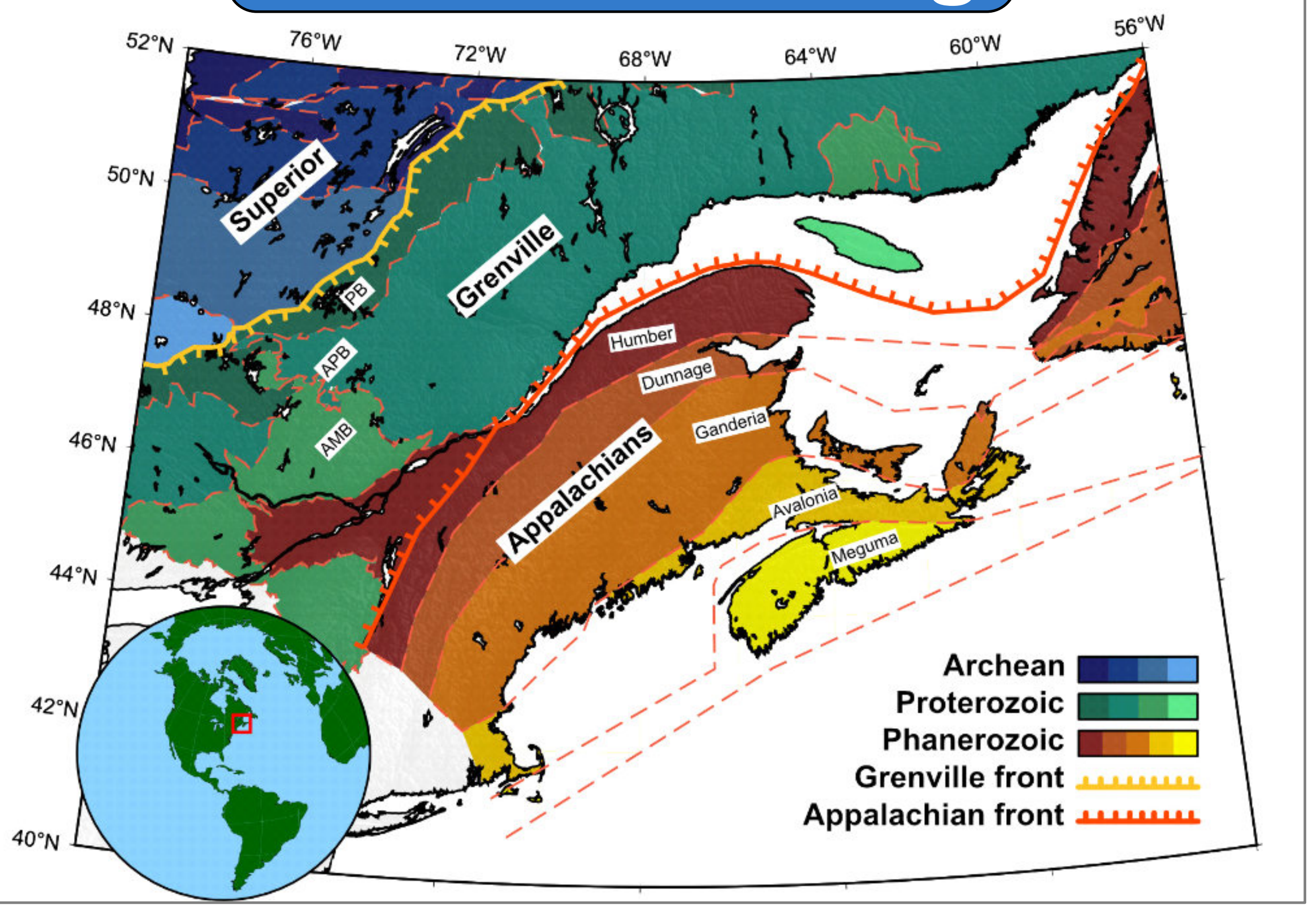
Seismic noise data: 2013-2015

#Networks: 6

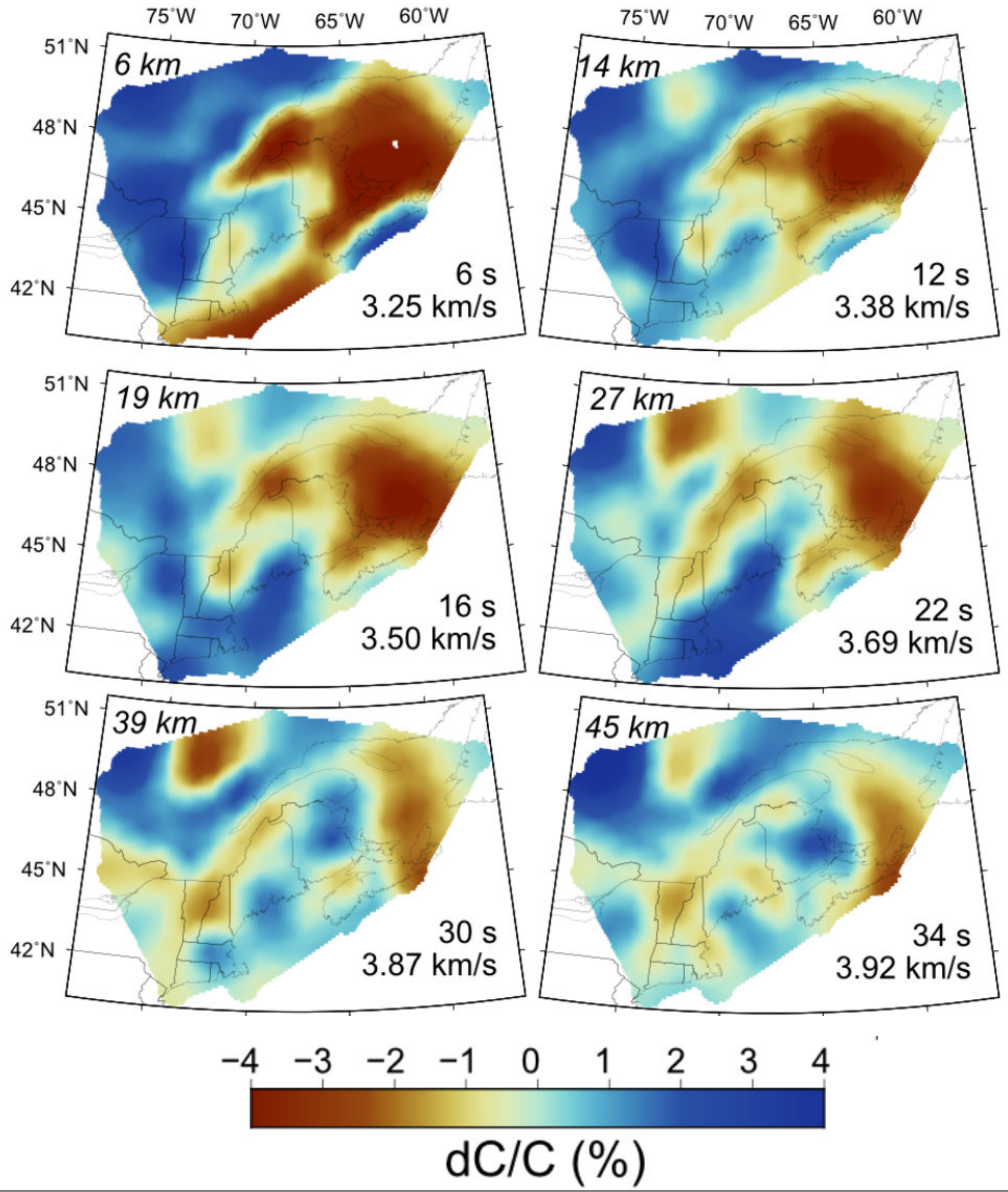
#Stations: 69



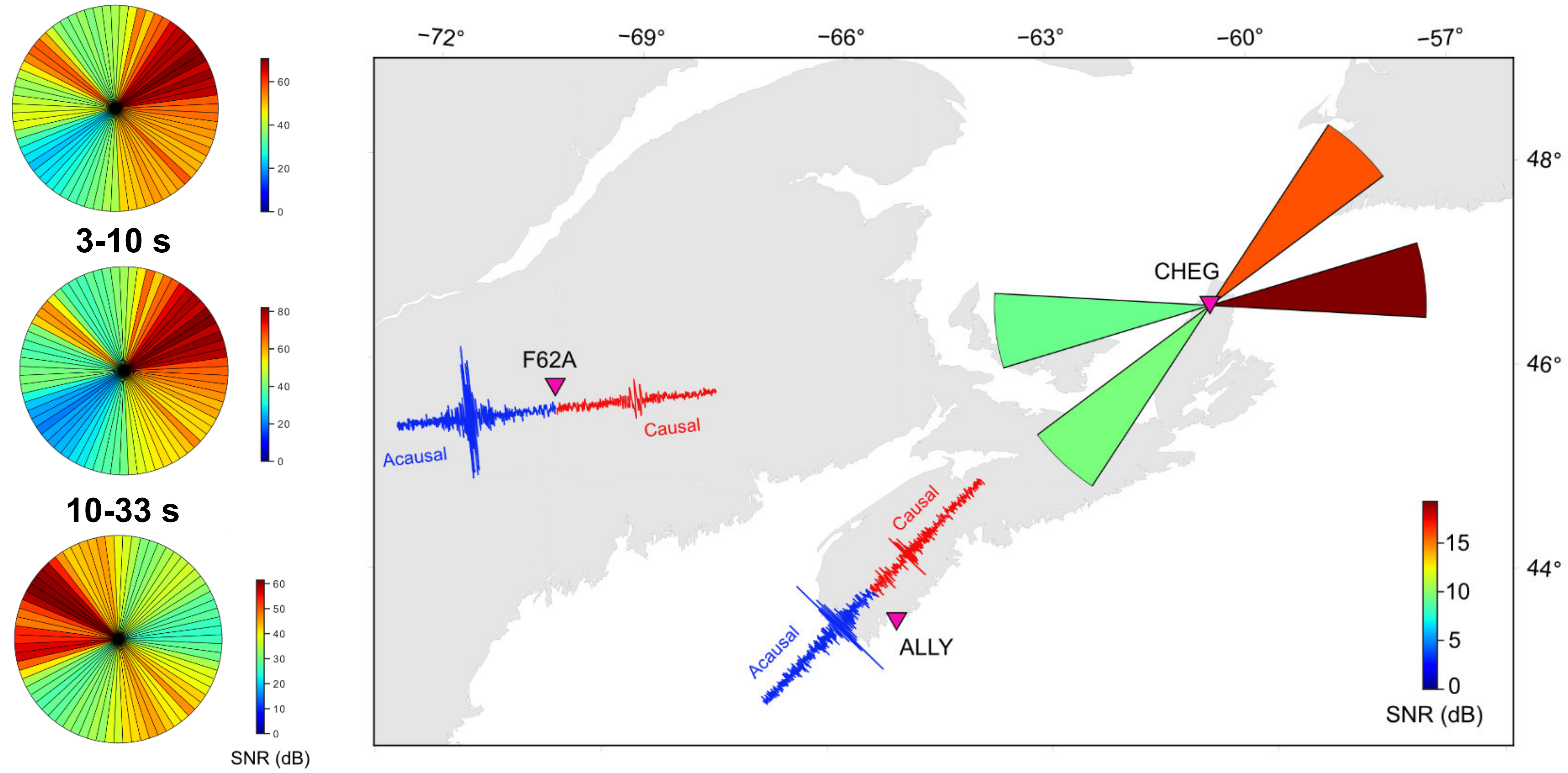
Tectonic Setting



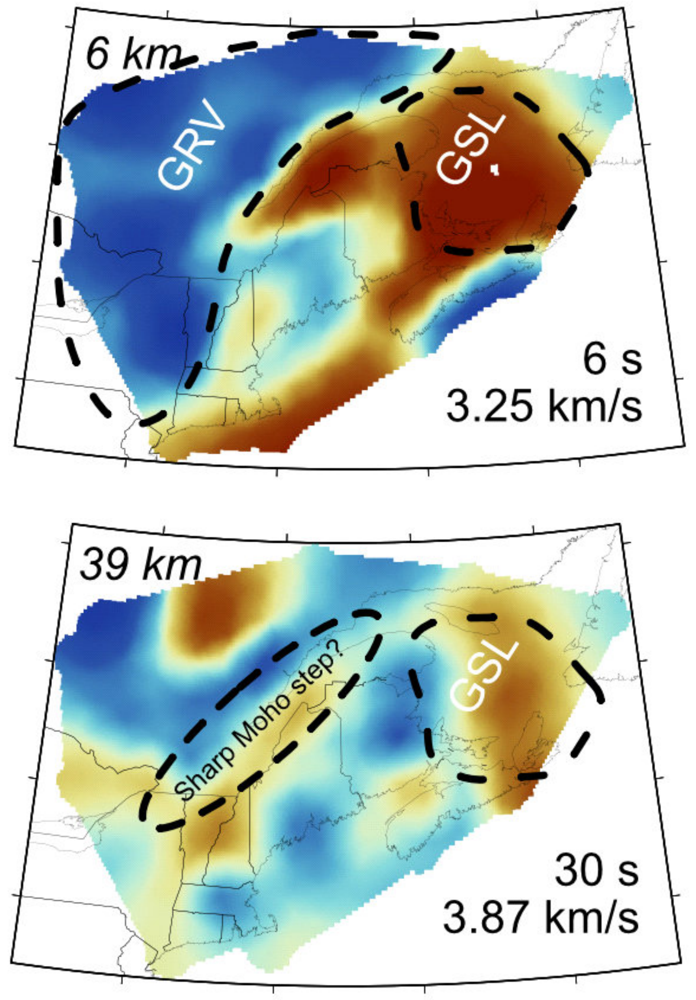
Phase velocities



Directionality analysis



Discussion



GRV: Grenville
GSL: Gulf of Saint Lawrence

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Datasets

Data: With the aim of recovering seismic structure of the crust beneath SE Canada and the NE USA, we analysed more than two years of ambient seismic noise data recorded by 69 broadband seismic stations belonging to 6 different seismograph networks.

Method: We use a relatively recent passive seismic tomography technique named ambient noise tomography (Shapiro et al., 2005) to obtain high resolution phase velocity maps at periods sensitive to crust and sub-Moho structures. The first step is to obtain inter-station Empirical Green's Functions (EGFs) for all possible station pairs. The calculated EGFs can be treated same as if they are surface wavetrains and their frequency content is analysed to obtain phase velocities as a function of period i.e. dispersion curves. The main inputs to the tomography program (method explained in Darbyshire et al., 2009) are the calculated dispersion curves.

Tectonic Setting

Eastern Canada is an excellent region to study tectonic evolution of continental lithosphere from Archean times. Our study area is situated in SE Canada and the NE USA that records more than 1 Ga of tectonic history. There are three main tectonic provinces in eastern Canada and two of those are covered by our datasets. The included tectonic provinces in this study are the Proterozoic eastern Grenville domain and the Phanerozoic northern Appalachians.

The Grenville Province was tectonized after ~100 Ma orogeny at ~1 Ga associated with the formation of supercontinent Rodinia. The younger northern Appalachian orogen consists of terrains with either Laurentian or Gondwanan origin that were accreted to the north America during four orogenic episodes including the Taconic (485-450 Ma), Salinic (450-423 Ma), Acadian (421-400 Ma), and Neo-Acadian (395-350 Ma). The northern Appalachians mostly escaped the deformation, magmatism, and metamorphism related to the Alleghanian orogeny that led to the formation of supercontinent Pangea, because the collision zone was situated far from present-day northern Appalachian domains. Therefore, the Paleozoic terranes are very well preserved.

Phase velocities

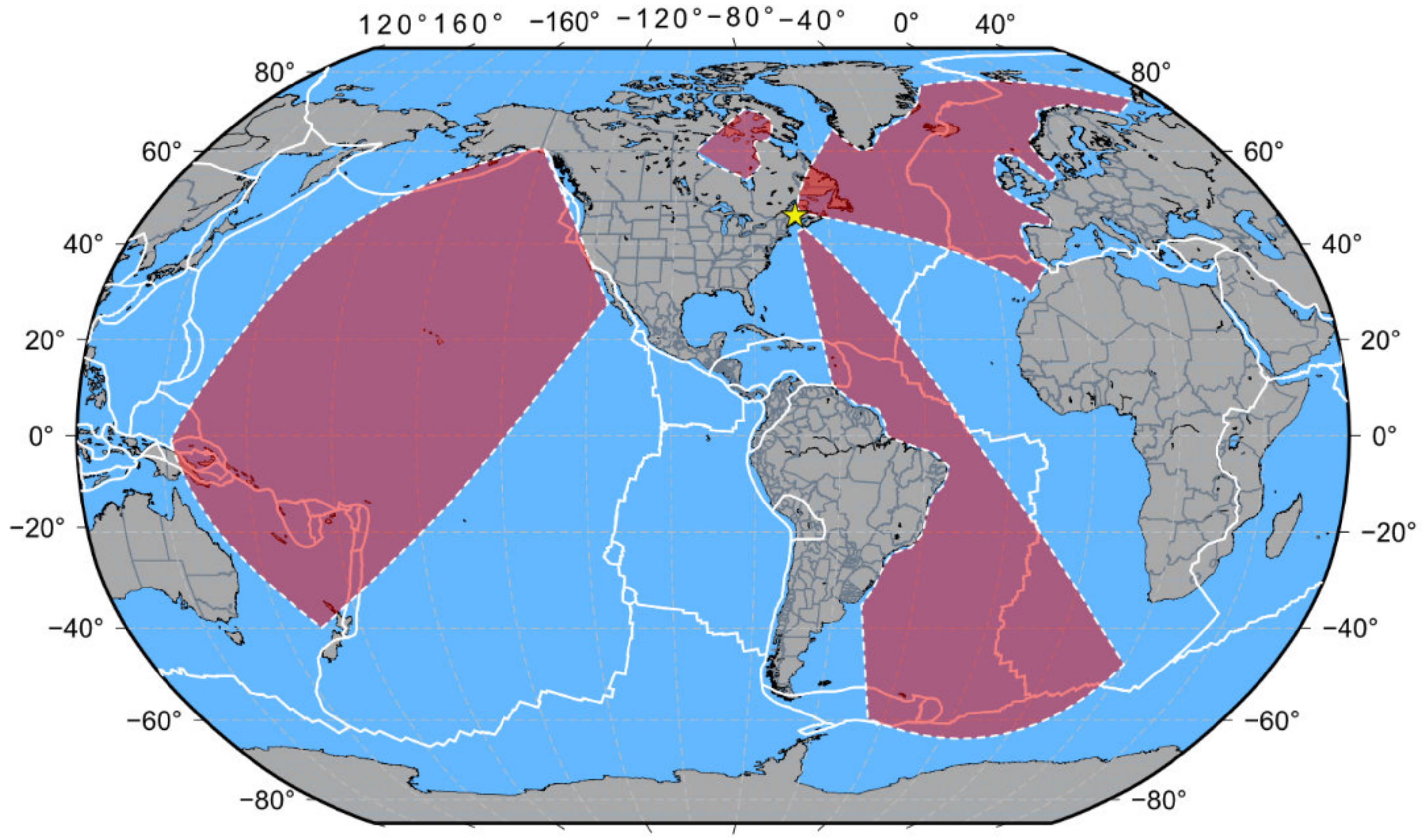
The main outputs of the tomography program are the Rayleigh wave phase velocity maps at different periods. We obtained reliable phase velocity maps at periods from 4 s to 50 s. Our directionality and seasonality analysis suggest that the bias due to inhomogeneous character of noise source in our datasets is minimal at periods from 4 to 40 s. This period range provides adequate sensitivity to study the seismic structure at depths from upper crust to sub-Moho.

Phase velocity maps at periods sensitive to upper crustal depths (<12s) suggest that the Grenville Province is dominated by faster than average velocities. In the Appalachians, however, there are patches of slow anomalies in the Gulf of Saint Lawrence (GSL) and the Gulf of Maine. The slow anomaly beneath the GSL is very strong and continues to exist at longer periods. A slow anomaly is observed in the north of the study area inside the Grenville orogen at periods from 16 to 30 s. The next prominent slow anomaly is observed beneath the Appalachian-Grenville boundary (also known as the Appalachians structural front) at periods sensitive to lower crusatl depths to Moho structure.

Directionality analysis

The reliability of ambient noise tomography method depends on noise distribution of datasets. The inhomogeneous character of noise data causes bias in the array measurements. As a result, a careful investigation of seismic noise directionality and seasonality is a crucial part of a ambient noise tomography study.

To have a better understanding of noise source locations, the signal-to-noise-ratios of the positive lags (causal signal) and negative lags (acausal signal) of the calculated EGFs are compared. We use fan-diagram representation (Tian and Ritzwoller, 2015) to illustrate SNR variations of both causal and acausal signals. In our definition of fan-diagrams, high SNR bars point to the direction of dominant noise source locations. This illustration helps us to locate dominant noise sources in the Atlantic and Pacific oceans (red patches in the right figure).



Discussion

The strong and persistent slow anomaly observed in the GSL suggests a very thick sedimentary basin beneath this area.

The fast anomaly observed beneath the New Brunswick province in the Appalachians (located at -65, 46.5) may be resulting from thinner crust beneath this region. The velocity contrast across the Appalachian front (Grenville-Appalachian boundary) is very sharp and is interpreted as step-like Moho geometry beneath this area with shallower Moho situated under the Grenville side.

The seismic velocities beneath the Grenville domain are less variable than the Appalachians. The Grenville province is dominated by faster than average velocities at upper crustal depths, and a slow anomaly starts to appear beneath the Parautochthonous Belt of the Grenville Province at periods sensitive to mid-crustal depths (16-22 s) to the periods sensitive to lower crust and the Moho interface (25-34 s). This may be resulting from thicker crust beneath this region.