Body wave constraints on lithospheric thickness: An introduction to web-based tools for assessing seismic data quality and visualizing seismic velocity models

Background

The EarthScope (https://www.earthscope.org/) Data Management Center provides a range of seismic data types, from time series data to station metadata and even a variety of derived data products, including but not limited to, an earth model repository, automatically generated receiver functions, moment tensors and more. The DMC also monitors data quality and provides tools for interested students and researchers to view data quality metrics for data stored at the DMC.

Purpose

Many of you will have probably downloaded seismic data from EarthScope or another similar data center. Today you will be provided a basic introduction to several additional features of the EarthScope DMC that you may have not used before but may prove useful in the future. Because the tools we will be exploring are web based, no software requirements beyond the use of a basic browser are required.

Tasks

This exercise will be broken up into three separate tasks. You will:

1) Learn how to assess data quality using tools available through EarthScope
2) Become acquainted with the EarthScope Earth Model Collaboration (EMC), understand the data types and how to access to quickly generate plots using web-based visualization tools in order to determine which model is right for you.
3) If time allows, discuss how velocity models can be used in order to better constrain lithospheric thicknesses when using methods such as Sp receiver function analysis.

Materials and Software Requirements

- This handout
- A computer with internet access and updated web browser
- Paper by Berkey et al. (2021, JGR)

Task 1: Assessing data quality prior to analysis

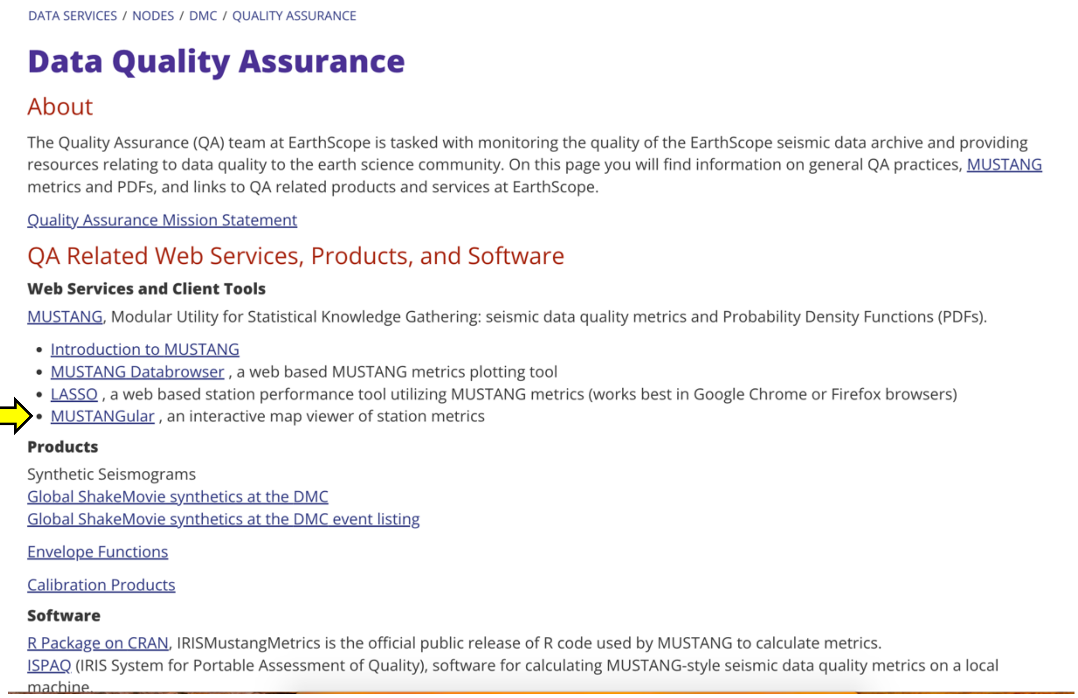
Purpose: In an increasingly data-rich world, it can be difficult to visually inspect all of the seismic records to be used in your analysis. In many cases, researchers are turning to sophisticated and automated methods to complete their analysis. However, not all data is created equal and an important first step is to better understand the quality of the data being used in your analysis. The EarthScope DMC provides a number of tools to allow researchers to visualize data quality quickly and efficiently. In this task, we will use EarthScope's MUSTANG (Modular Utility for STAtistical kNowledge Gathering) tool in order to quickly ascertain data quality for a preselected data set. The instructions are included below.

Goal: Identify which stations are noisy, the frequencies where noise is the greatest, and determine if the noise is restricted to certain time periods or is pervasive throughout the history of the station.

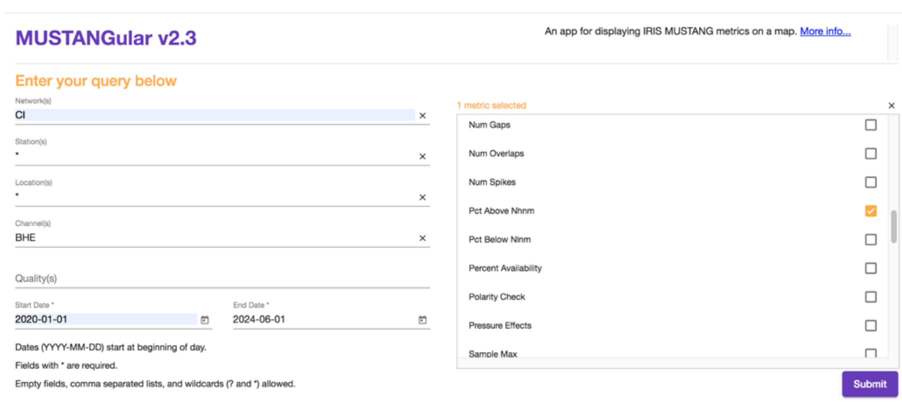
Step 1: Direct your web browser to the following address

https://ds.iris.edu/ds/nodes/dmc/quality-assurance/

Step 2: We will begin by visualizing data quality across an entire network using the **MUSTANGular**. Select "**MUSTANGular**" under "**Web Services and Client Tools**"



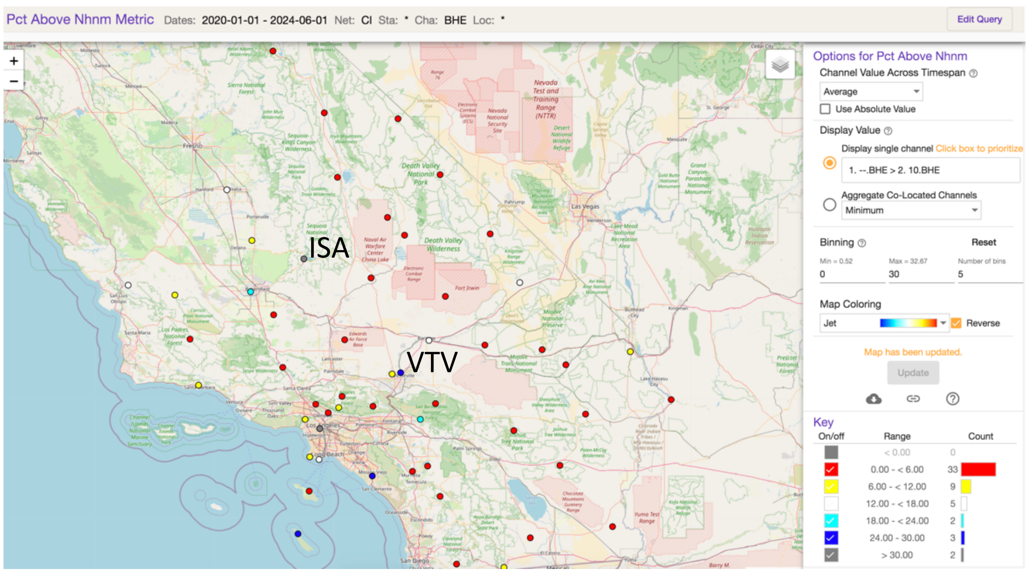
Step 3: We will be requesting data quality metrics for the Southern California Seismic Network (Network Code: CI) between the years 2020 and 2024. To begin, we will search for all stations with a channel that includes "BHE". The metric we will be using to assess quality is the "percent above the New High Noise Model (NHNM)". See below for an example of how your query should look after it is filled out. When the query is submitted it may take several minutes for the results to load given the extensiveness of the network. If speed becomes an issue, try reducing the number of stations to ISA, VTV and FUR.



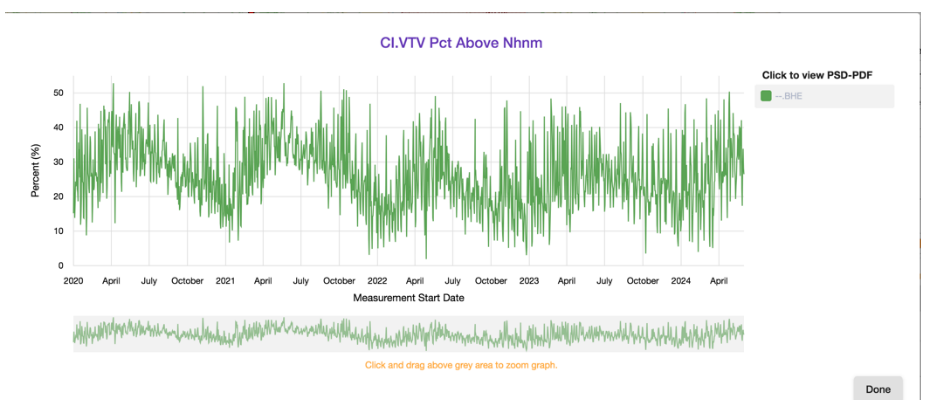
Note 1: For a primer on channel codes and what they mean, check out Appendix A: Channel Naming, included as supplemental file.

Note 2: For an introduction to the New High Noise Model, check out the paper by McNamera and Buland (2004).

Step 4: Once the results have loaded, you can modify the bin size, color bar and more in order to help distinguish stations with higher noise from lower. In the example below, I have reversed the color bar (jet) and divided the data into 5 bins.



Step 5: Hovering your mouse over a station will give a name and the average value across the time span. Clicking on the station will provide a time series plot. You can then click and drag on the time series to zoom in on a specified time interval.



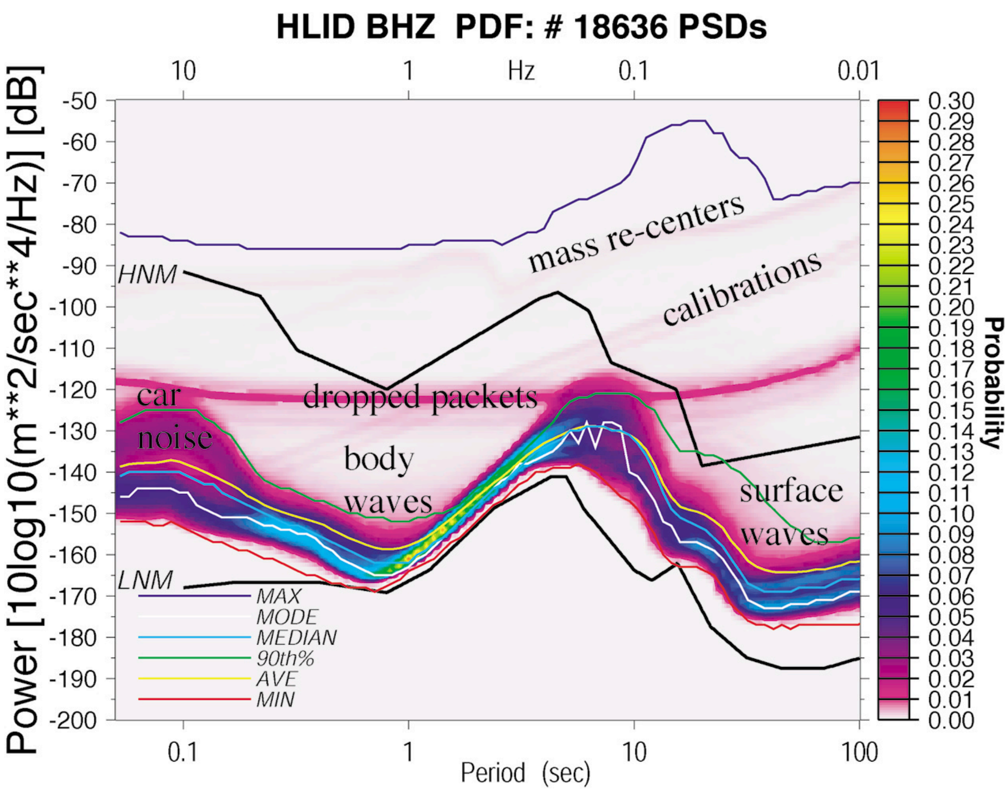
Step 6: Explore the map and associated time series. Can you find an example of station with a data gap (no values plotted)? What do you think is happening at station ISA (grey circle highlighted in step 4)? What about station VTV (blue circle highlighted in step 4)? How do these compare to stations with lower noise? Discuss with a partner.

In the remainder of the first task, we will investigate the behavior of noise at a few example stations, starting with VTV.

Step 7: Open a new browser window and return to the DMC homepage (https://ds.iris.edu/ds/nodes/dmc/quality-assurance/). This time select the "**MUSTANG**" link.

Step 8: The **MUSTANG** web tool is primarily designed to build URLs that will then provide the user with desired quality measures. For now, we will focus on the **noise-pdf-browser** tool. The documentation on this page provides a full list of service parameters and associated usage. There are a lot of options that I encourage you to explore later! For now, scroll down until you arrive at **Sample Queries** and then further down to *Breakout View* and click on the first link. Replace the station, location and channel so that the link now reads **.../breakout?target=CI.VTV..BHE.M**.

You should now see a series of panels, marked by year, with a cumulative panel on top. The figures plotted are referred to as "PDFs" or "probability density functions", which help us to visualize ambient noise levels at a given station over a given time interval (McNamera and Buland, 2004). Below is an annotated example of a PDF from the paper by McNamera and Buland (2004).

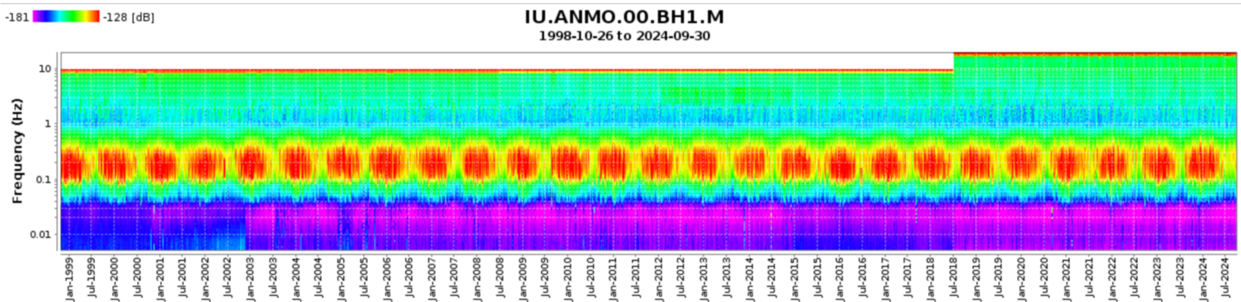


Feel free to try looking at all three components (BHE, BHN and BHZ) of VTV by changing the web address. Note, the higher the noise levels at both high and low frequencies where the majority of the energy appears to be located at or near (above and below) the new high noise model. Why do you think the noise levels at VTV are so high?

Step 9: Please repeat the exercise for station ISA (**.../breakout?target=CI.ISA..BHE.M**). How does ISA compare to VTV? Are there any notable features in the PDF? Is there consistency year over year or do the PDFs vary in time?

Step 10: Another useful feature to look at changes in noise over time, is a spectrogram. It utilizes the same data as the PDFs, but displays it as a time series. To begin, return to the page for **noise-pdf-browser**, but this time, scroll down to *Spectrogram View* and click on the first link, once again replacing the station, location and channel information so that the link now reads **...spectrogram?target=CI.VTV.*.BH*.M**.

The plot should look similar to the image below. Note that cooler colors correspond to less energy at a given frequency. Are there any noticeable patterns as a function of time? If so, at what frequencies are these centered? Why do you think they exist?



Step 11: Please repeat the exercise for station ISA **...spectrogram?target=CI.ISA.*.BH*.M**.). How does ISA compare to VTV? Are there any notable features in the spectrogram? If you were to request data for this station, are there any time periods for which you would not request data? Why or why not?

<u>Task 2: Visualizing assorted seismic velocity models</u>

Purpose: As you will learn throughout this workshop, constraining lithospheric structure is not necessarily a straightforward exercise, as different geophysical (as well as geochemical and petrological) constraints have varying levels of sensitivity to the structure. Therefore, some researchers like to compare the results of their analysis to different types of geophysical models. EarthScopes Earth Model Collaboration (EMC) is a repository for Earth models, mainly seismic tomography models, but increasingly including other types of models include receiver functions, resistivity models, and thermal models. In this task, we will use EarthScope's EMC tool in order to quickly visualize various models. We will also note how to download models for further use outside of the web-based tools.

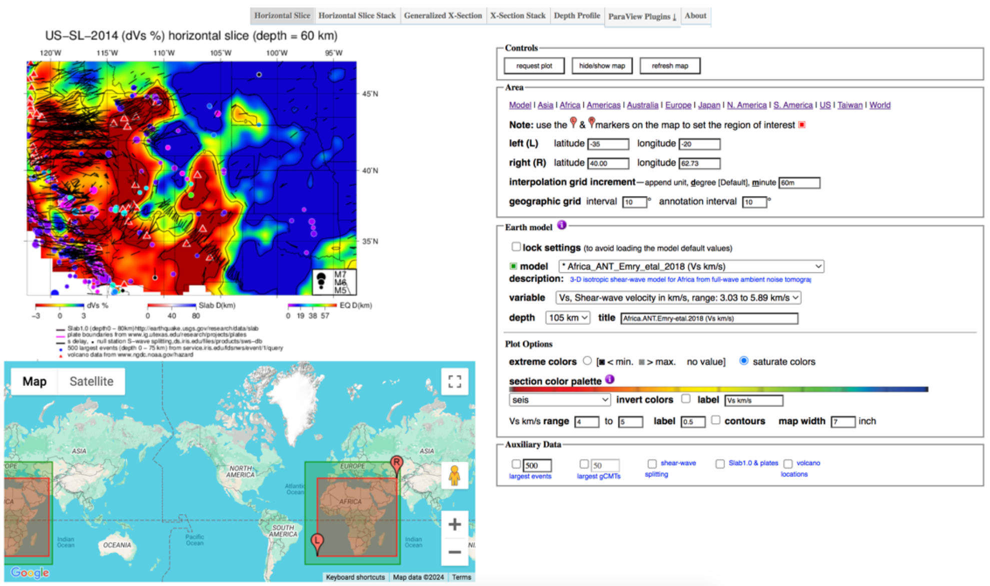
Goal: Generate plots of seismic tomography models. Become acquainted with the visualization tools and their associated features. Learn where to download the models.

Step 1: Direct your web browser to the following address: https://ds.iris.edu/ds/products/emc/

Step 2: Familiarize yourself with the description of the EMC. Once you have done so, please look under the **Quicklinks** menu near the top of the page and select **Earth models**. From there, you can click through to learn more about the any of the EMC-hosted Earth Models. Alternatively, you can scroll further down to a table with the same links, along with a corresponding description of the variables and a brief summary of the model itself.

Step 3: To start our exploration, please quickly look over the description for seismic velocity model Africa.ANT.Emry-etal.2018. You can do this by finding the link on the page or clicking here (https://ds.iris.edu/ds/products/emc-africaantemry-etal2018/). The model contains absolute Vs determined from full-wave ambient noise tomography. Look for information in the description regarding depth and areal extent. Where is the citation for the paper related to the model located?

Step 4: Now that we have acquainted ourselves with the velocity model, let's try visualizing the model. To begin we will make a horizontal depth slice of the Emry model at 105 km. To do this, first ensure that the tab at the top of the screen is on "**Horizontal Slice**", we will then use the right-hand control panel to select the appropriate location bounds (latitude and longitude), the appropriate model, depth and plot options. Once you have made the appropriate selections, select "request plot" from the Controls subpanel. An image of how the control panel should look prior to generating the plot is shown below. **Hint 1**: The area panel has the option to a select a continent, for our model you should select Africa. You can then adjust the bounds on the map as you see fit. **Hint 2**: When you select **Africa.ANT.Emry-etal.2018**, the bounds of the model will show up on the map.



Once you have figured out how to make a horizontal depth slice, try other depths and consider adding in auxiliary data, like "volcano locations" shown on the bottom. Is there a relationship between volcano locations and wavespeed at 105 km?

Step 5: Now that you have an introduction to the visualization tool, try using some of the functions. For example, you can stack four depths by selecting the "**Horizontal Slice Stack**" at the top of the screen. Note that this allows you to stack the same models at different depths, or you can compare similar depths of two or more models! Be sure to try making cross sections (singular or stacks) as well as 1D profiles. Helpful hint: When switching between plot types I would suggest refreshing the browser window.

Special note: For those of you interested, the figures can be downloaded via a link at the bottom of the image as either a .ps or .png file. Alternatively, the entire package can be downloaded so that you can re-plot the same data slice with **GMT** via a link immediately below the image download link. However, for those of you interested in working with the models beyond the abilities of the visualization tools, return to the description page for the model you are interested and scroll down until you see the heading "**Model Download**". All files are formatted as netCDF files. There is documentation here (https://ds.iris.edu/ds/products/emc/) on the format and links to a github repository with python applications to convert the files. There are also MATLAB commands, such as **ncread**, that can read netCDF files.

Task 3: Paper discussion

Purpose: Sp receiver function analysis has proven to be a useful tool in helping to constrain the thickness of the lithosphere, as well as imaging other intralithospheric structure. However, interpreting Sp receiver function results can be difficult in the absence of other geophysical constraints. In papers such as Fischer and Hopper (2018) and Birkey et al. (2021), other geophysical data sets are used in order to help discriminate between the lithosphere-asthenospere boundary and other structure beneath the United States (Fischer and Hopper, 2018) and Australia (Birkey et al., 2021).

Goal: We will discuss the results of Berkey et al. (2021) and the comparisons made between Sp receiver funtions and the AusREM tomography model (Kennett et al., 2013).

References

Birkey, A., Ford, H. A., Dabney, P., & Goldhagen, G. (2021). The lithospheric architecture of Australia from seismic receiver functions. *Journal of Geophysical Research: Solid Earth*, *126*(4), e2020JB020999.

Hopper, E., & Fischer, K. M. (2018). The changing face of the lithosphere-asthenosphere boundary: Imaging continental scale patterns in upper mantle structure across the contiguous US with Sp converted waves. *Geochemistry, Geophysics, Geosystems*, *19*(8), 2593-2614.

Kennett, B. L., Fichtner, A., Fishwick, S., & Yoshizawa, K. (2013). Australian seismological reference model (AuSREM): mantle component. *Geophysical Journal International*, *192*(2), 871-887.

McNamara, D. E., & Buland, R. P. (2004). Ambient noise levels in the continental United States. *Bulletin of the seismological society of America*, *94*(4), 1517-1527.