Passive Tomography of the Caribbean Plate using Surface Waves extracted from Ambient Noise

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Tectonic Setting

- The Caribbean plate geology and tectonics are regarded as being complex and challenging. Limited land exposure along island arcs are among the only locations where to place seismic stations.

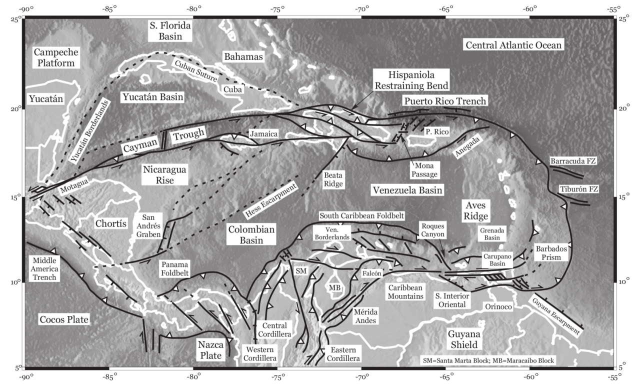


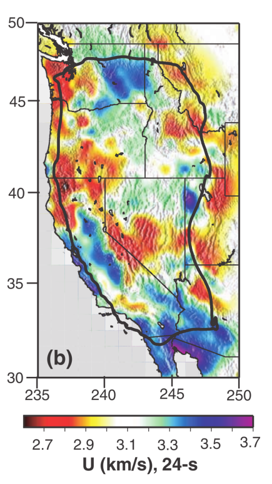
Plate-boundary map and bathymetry of the Caribbean region J. Pindell, 2005

Objective

- Study objective is to create a lithosphere and upper crust velocity model of the Caribbean Plate using ambient noise tomography.
- Recent studies have shown that ambient noise tomography provide accurate velocity structure of the lithospheric plate:
  - M. P. Moschetti, et. al., in the Western US.
  - Nicholas Harmon, et. al., in Costa Rica and Nicaragua.
  - A.L. Levshin, et. al., in Central and Southern Asia.
  - Fan-Chi Lin, et. al., in New Zealand.
  - Yingjie Yang, et. al., in Europe

What is a tomography

- Tomographic Images show the differences in seismic velocities in the interior of the earth.
- These images show abnormalities that may reveal underground structures or changes in geology.
- They help in creating 3-dimensional velocity models to better locate earthquakes.



Wave group velocity map of the Western US (M. P. Moschetti et al., 2007)

Ambient Noise Processing

- Ambient Noise refers to a field that is generated in the earth, this noise field is random and chaotic.
- Several factors influence ambient noise such as:
    - Local noise: Trucks, people, animals.
    - Regional noise: local earthquakes, microseismicity, wave action.
    - Global noise: Tides, “Earth hum”.
- This method allows us to use the patterns within this noise in order to be able to correlate the waveforms from different stations. This is called seismic interferometry.

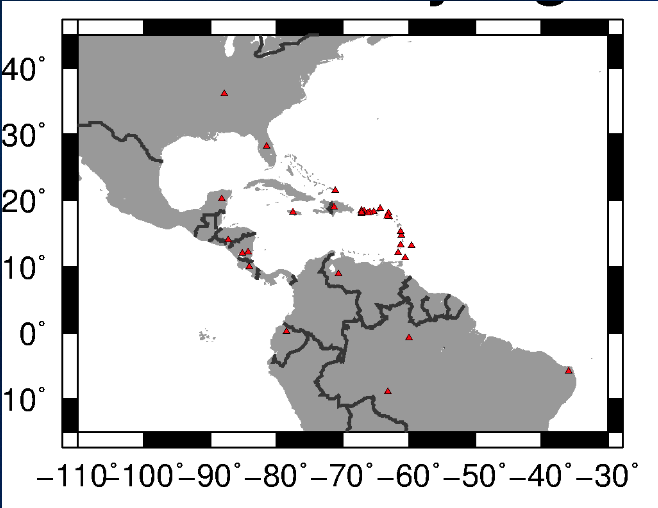
Data

- At least 2 years of data has been gathered for various stations from around the Caribbean.
- These stations have been strategically chosen in order to be able to cover areas that have not been studied before, in particular the eastern Caribbean: Lesser Antilles, Venezuela and Colombian basins.
- Data consist of 24 hours of continuous seismic data records obtained from Incorporated Research Institutions for Seismology (IRIS) Data Management Center (DMC)

Why create a tomography of the Caribbean Plate?

- Recently the installation of more seismic stations around the Caribbean has given us the opportunity to use this ambient noise method.
- This method has been validated successfully in regions like the Western US, Alaska, New Zealand, and others.
- Mapping the Caribbean would ultimately increase our knowledge of the subduction margins around the Caribbean plate as well as the lateral changes the velocity structure.
- Future work can include creating a 3-D velocity model of the Caribbean plate, which can help us to better locate earthquakes.

Stations chosen

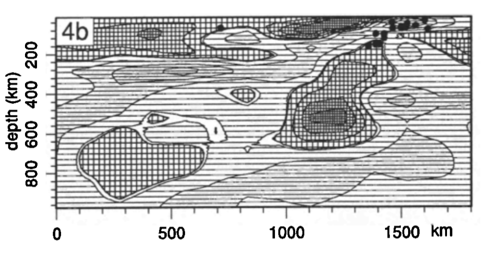


Previous Work

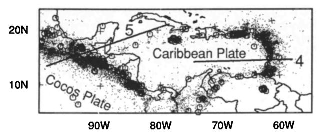
- Several tomographic studies of the Caribbean have been performed in the past: van der Hilst and Spakman (1989), Godey et. al. (2003) and Gonzáles et. al. (2007).
- These studies use active sources such as earthquakes in order to create the tomography. None have used ambient noise.
- Among the reasons that have disallowed the ability to generate a comprehensive Caribbean-wide tomography model are insufficient data to cover the entire Caribbean plate, and poor data quality.

Van der Hilst and Spakman, 1989

- Van Der Hilst and Spakman correlated earthquake P-wave arrival times to create vertical cross-section tomography.

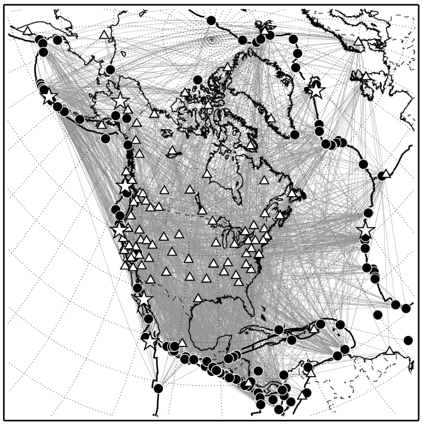


Vertical cross-sections, from Van der Hilst and Spakman, 1989; Map view for cross-sections



Godey, S., et. al., 2003

- Tomography based on earthquake surface waves
- Mostly focused on North America
- 172 events
- 91 stations
- Poor data coverage in the Caribbean region



Ray paths for Godey, S. Tomography, 2005

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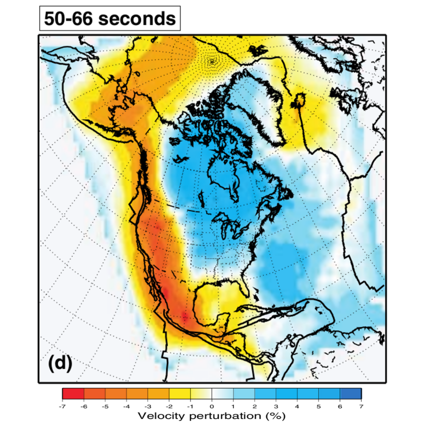
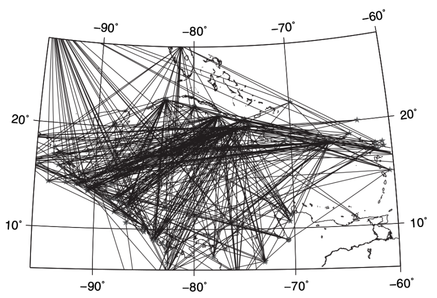


Results of Godey, 2005, estimated phase velocity map in %.

Gonzáles, O., et. al., 2007

- Tomography based on earthquake surface waves
- Mostly focused on the Caribbean
- 200 events
- 13 stations
- Poor data coverage in the Southeastern Caribbean region



Ray paths for González, O., Tomography, 2007

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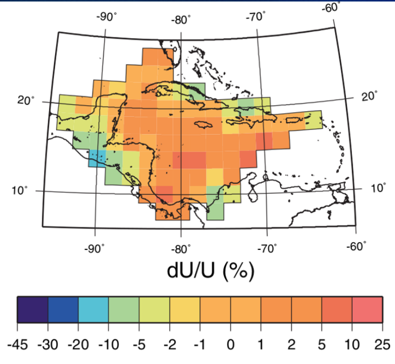
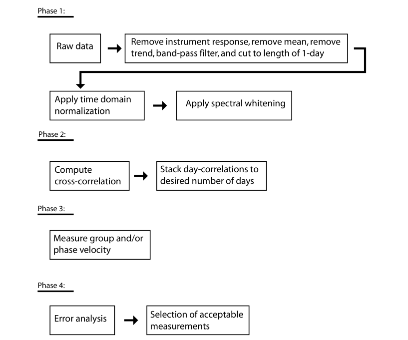


Ray paths for González, O., Tomography, 2007

Workflow

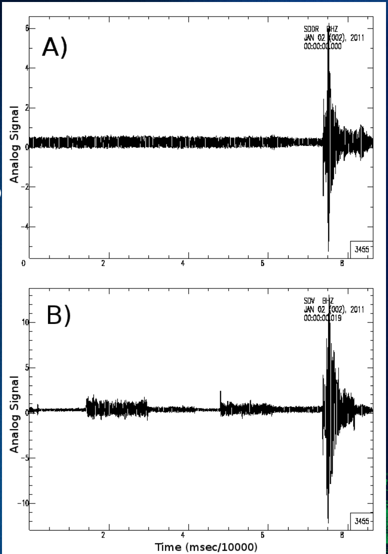
The workflow for ambient noise studies has already been outlined by Benson et. al. (2007) and it consists of the following steps:

1. Remove instrument response
2. De-trend, de-mean, apply a Taper
3. Apply a band-pass filter
4. Normalize the data
5. Compute cross-correlation & Stack
6. Select acceptable measurements
7. Measure group or phase velocity
8. Construct a wave period map (s)



Verify the data

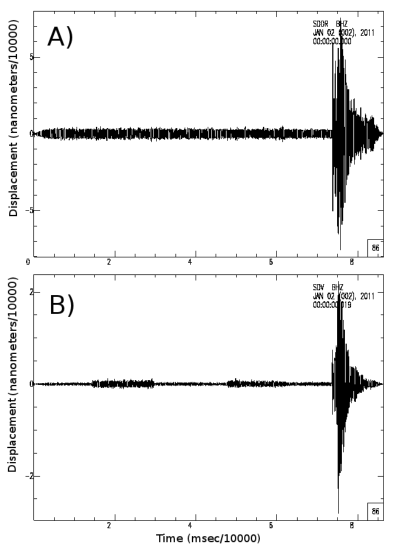
- Data acquisition from the IRIS DMC is in its raw format straight from the instrument. In order to use this data filters must be used to correct for normal errors and noise.
- To perform the data stacking it is necessary to have 24 hours of continuous data.



Waveforms from 2 stations in our study: A) SDDR in the Presa de Sabenta, Dominican Republic, and B) SDV in Santo Domingo, Venezuela. Both are from January 2, 2011

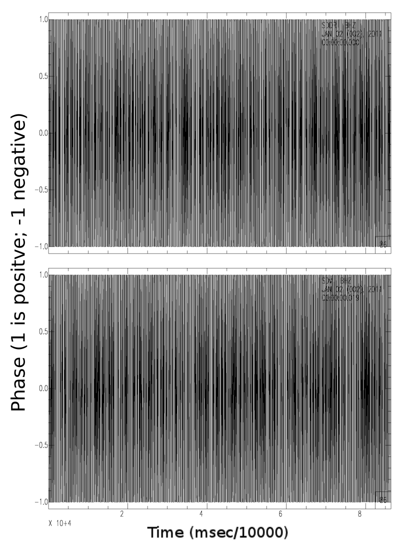
Normal seismic pre-processing

- First we have to remove the instrument response. This translates from raw data in volts into velocity typically $\frac{nm}{sec}$.
- We remove the trend and the mean. Next a taper is applied to correct for errors from factors, such as temperature fluctuation effects.
- Apply a band-pass filter, to obtain the desired frequencies. Typically this consistedin a Butterworth filter between 5 and 16 seconds.



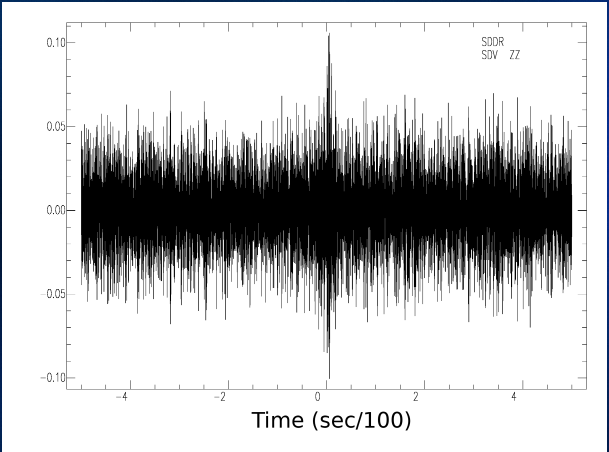
Normalize the data

- We then normalized the data in order to continue to the cross correlation. This step is important to remove the effects of things like local earthquakes and microseismicity, they tend to include errors.
- To do this we simply assign a 1 when it is in a positive phase, and a -1 when it is on the negative phase.

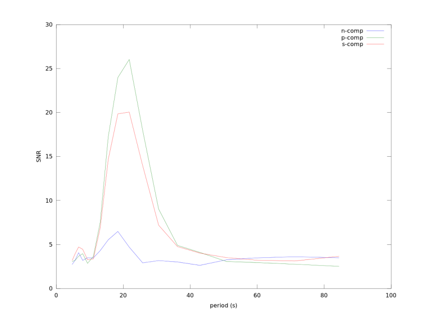


Compute cross-correlation & Stack

- We then proceed to perform the cross correlation using all the data of the study from all the possible station.



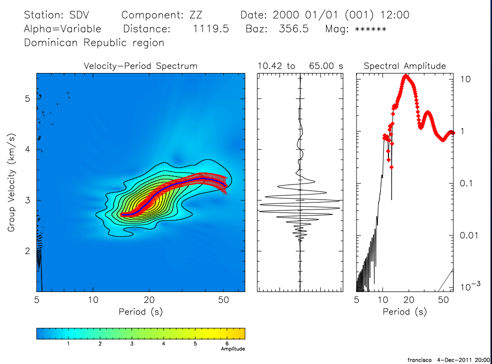
Select acceptable measurements



- Separate among different components; positive, negative and symmetrical components.
- Then I use a program by M. Moschetti to run a tests to verify Signal to Noise Ratio (SNR) for each component
- Only those that exceed a 5 SNR were used in this study

Measure group or phase velocity

- Dispersion curves measure the average velocity of a particular surface wave period.
- The analysis program I am using is called PGplot Surface Wave Multiple Filter Analysis (PGSWMFA) created by C. Ammon (PennState).

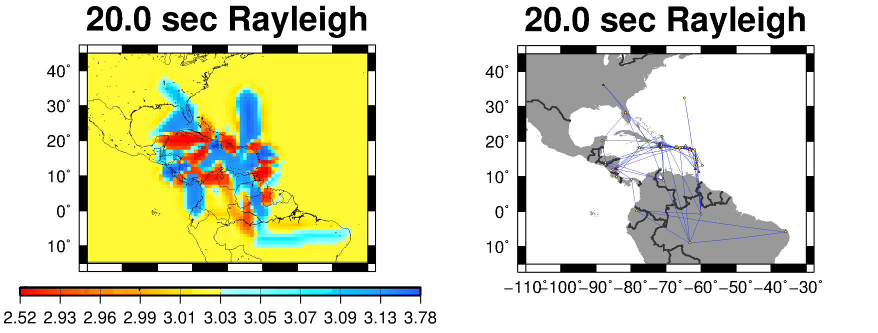


Construct a map

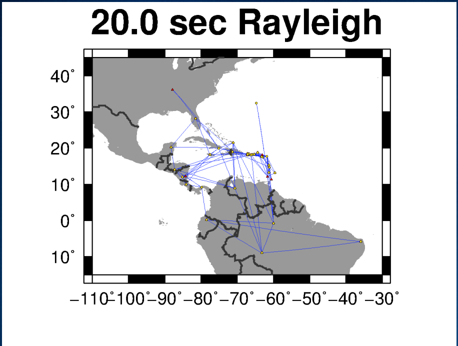
- Then we assemble the measurement from the dispersion and use surf_cg program to calculate the values needed to create the tomography.
- We select the measurements for a particular frequency with a high SNR and create the most ray paths.
- Use GMT to create a surface grid with velocity anomalies that reflect the underground geology and related stratigraphy of the Caribbean plate and beyond.

Preliminary Work

- The work I have done so far is examining the viability of using this methodology in the Caribbean region. The preliminary work presented here consist of 6 months of data.
- Preliminary results are promising, therefore using additional 24 months of data is expected to generate results not seen for the Caribbean before.



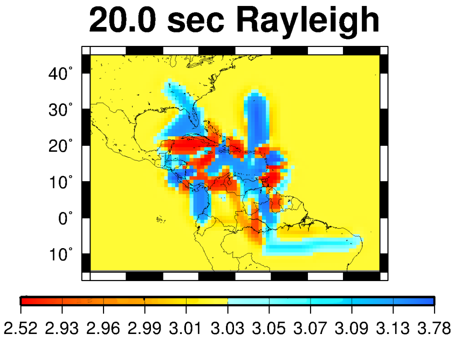
The paths



- From this figure we can see that the stations that correlated the best are often islands that are next to each other.
- We do not see many paths that extends through the entire Caribbean sea.
- Earthquake data should be used to cover the shadow areas where noise correlation is unavailable.

The tomography

- We can see changes in the wave velocity using ambient noise
- These changes can be attributed to several things:
    - Changes in the geological properties of the upper crust
    - More information can be obtained through path proximity.
- More information is needed to make better conclusions.



Acknowledgements

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