Calculation of Hydroacoustic Propagation and Conversion to Seismic Phases at T-Stations

CTBTO Science and Technology Meeting

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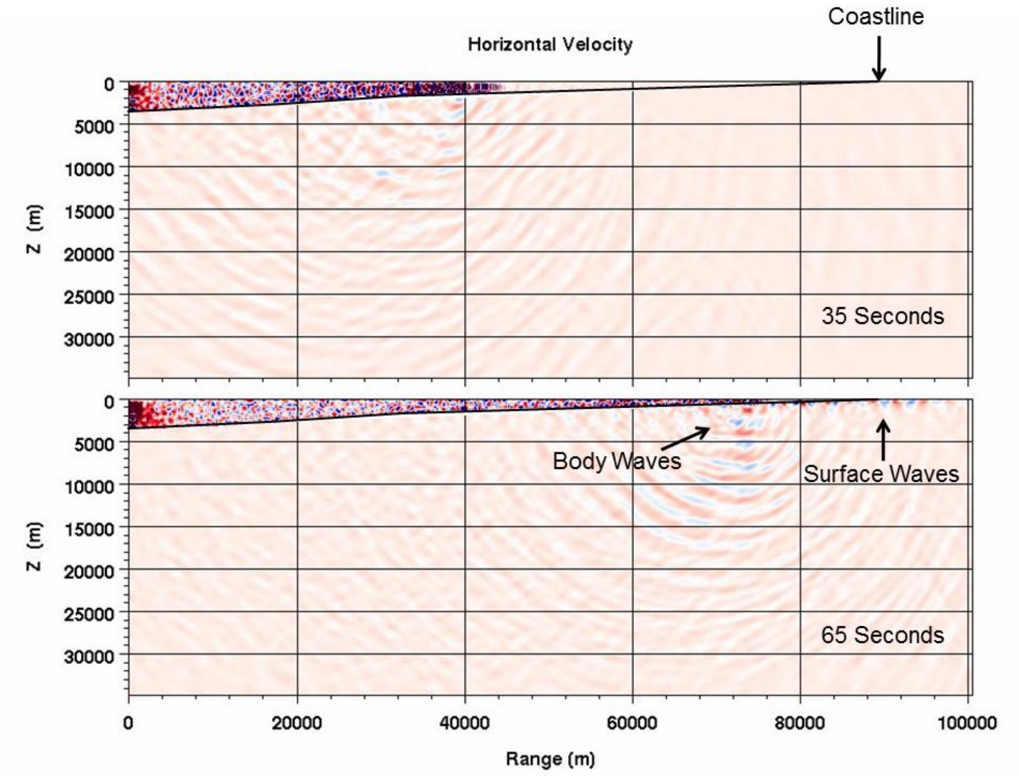
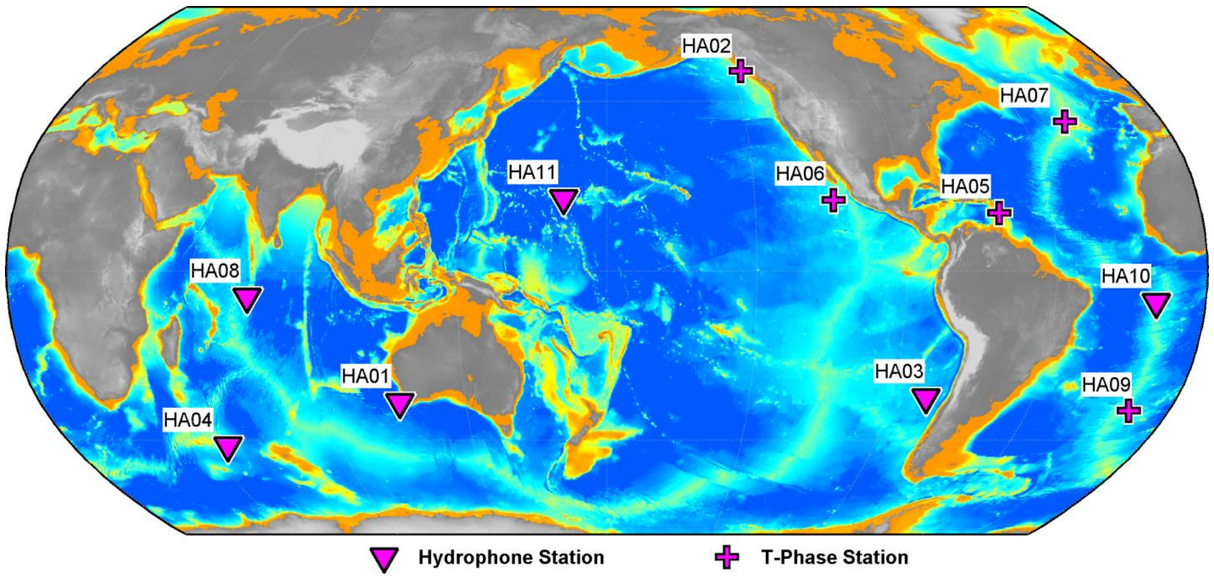
Presentation T1.3-O2

Conversion of Hydroacoustic to Seismic Phases at T-Stations

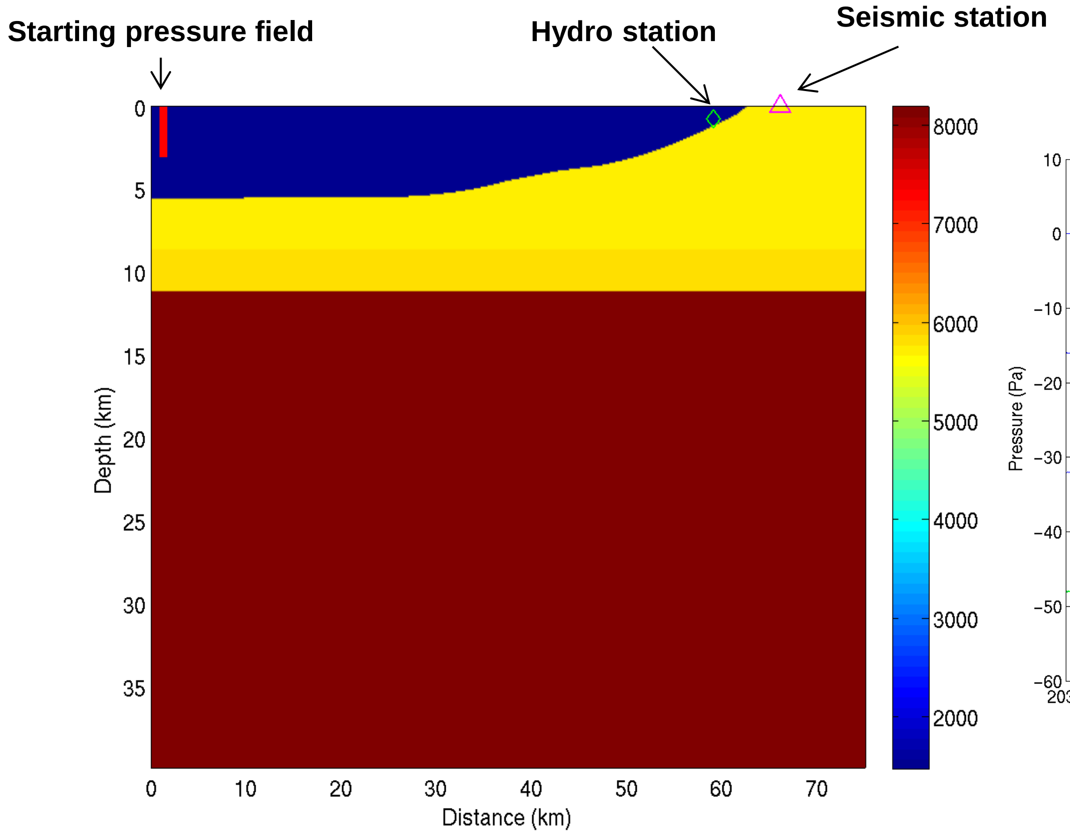


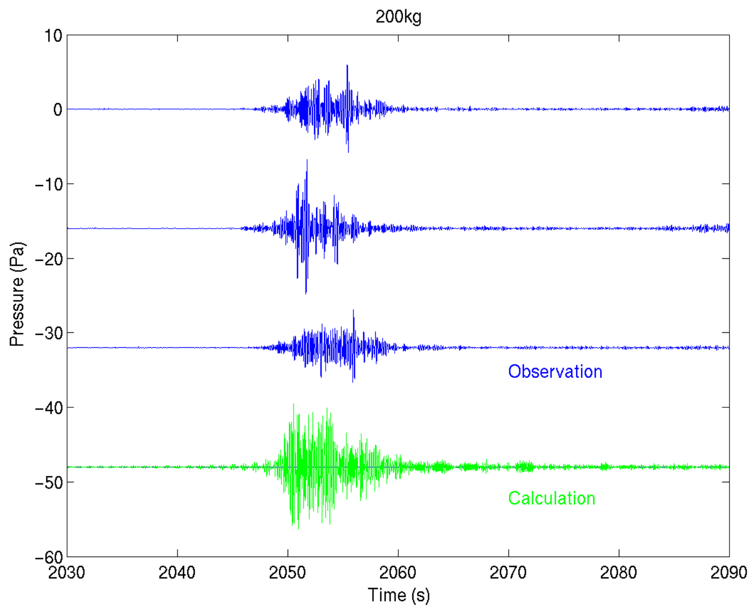


The IMS hydroacoustic network

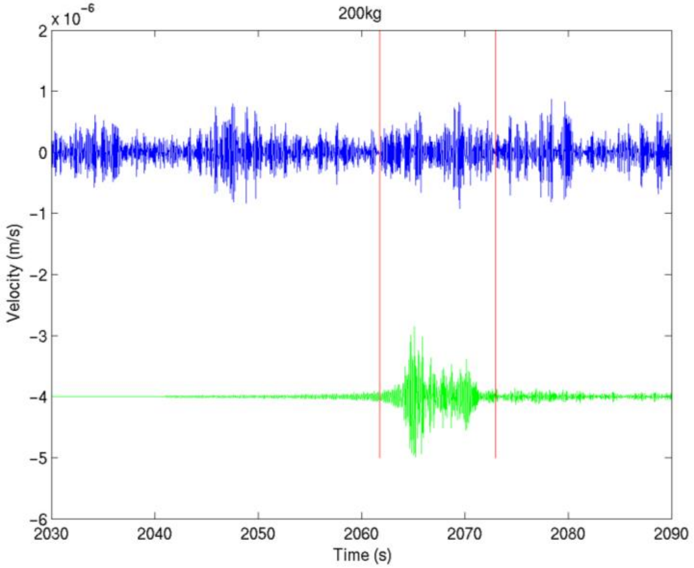
The IMS hydroacoustic network contains five T-stations, coastal stations intended to detect signals from explosions in the ocean. Conversion of hydroacoustic to seismic signals can be complicated and T-station data from in-water explosions is very limited.

Wake Island FD Calculation (2010)





Hydroacoustic



Seismic

Calculation was initiated with an input pressure field calculated from an explosion at 60 meters depth at a distance of ~3000 km. The input pressure field was placed 66 km from the coast off of Wake Island and propagated to the hydroacoustic and seismic stations. Data is from a 200 kg explosion detonated off Japan in January 2010

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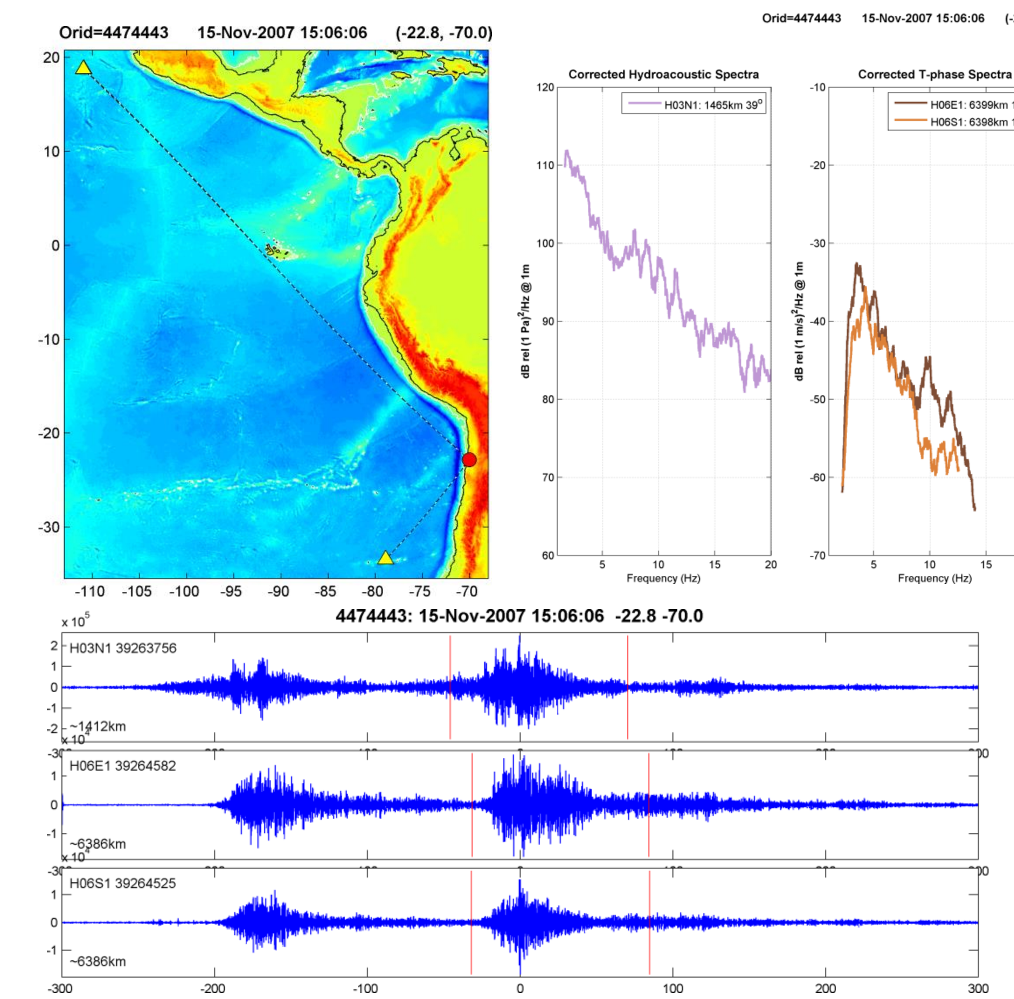
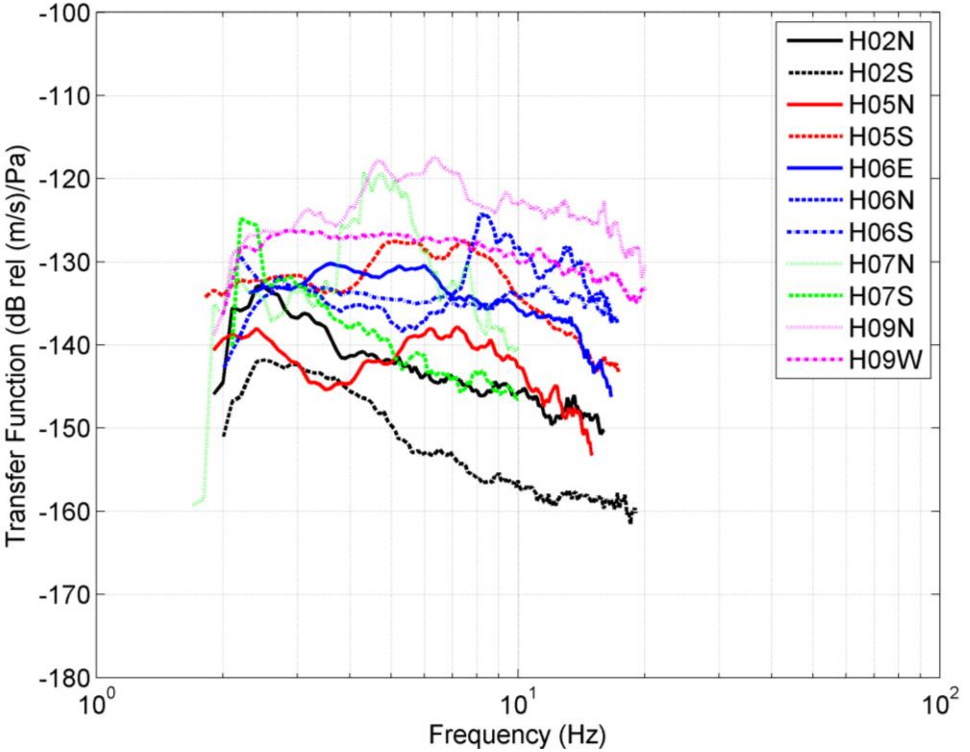
Empirical Transfer Functions (2013)



Event recorded at hydro station H03N1 and T-stations H06E1 and H06S1



Earthquakes observed on both T-stations and hydroacoustic stations allowed calculation of empirical transfer functions.

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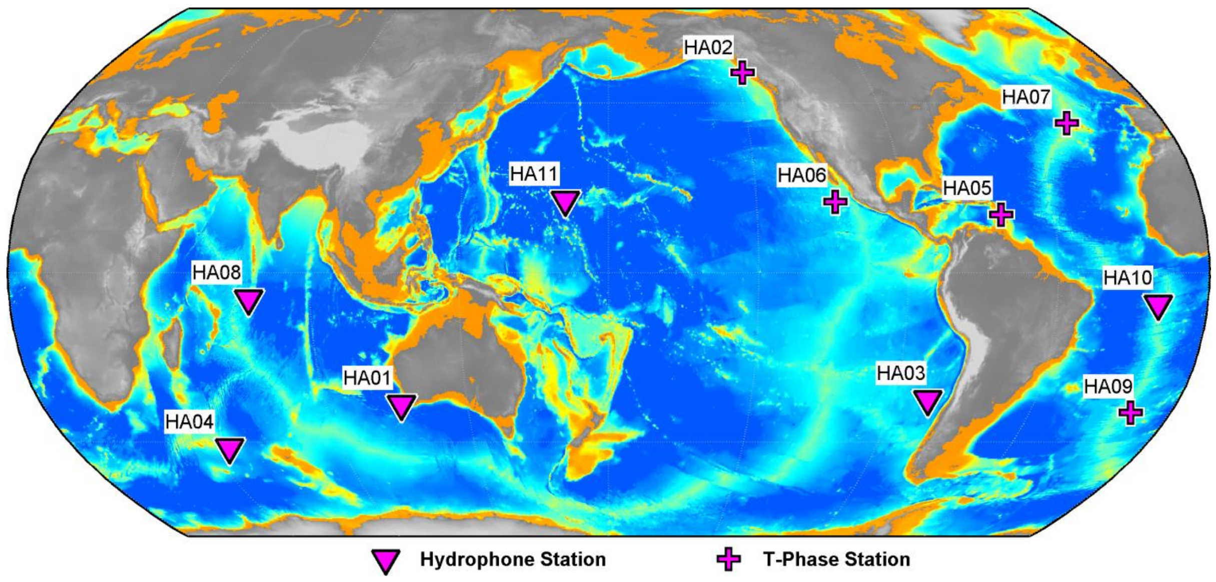
CTBTO Seismo-Acoustic Propagation Project

- Identify canonical environments representative of conditions at the 5 T-stations.
- Collect environmental descriptors for hydroacoustic propagation and T-station conversion for each T-station.
- Calculate waveforms at hydroacoustic, ocean bottom and T-station seismometers .
- Validate results.

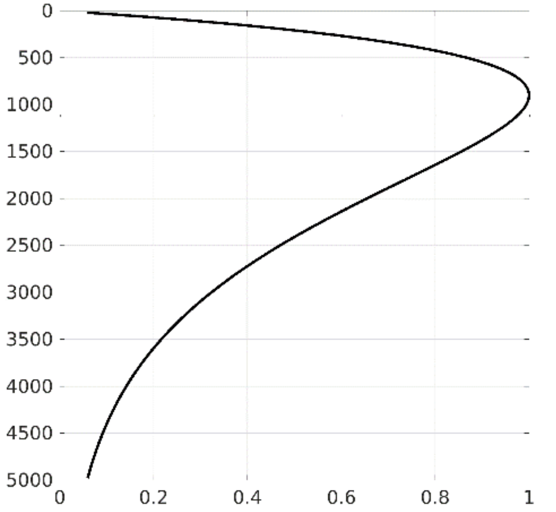


The IMS hydroacoustic network

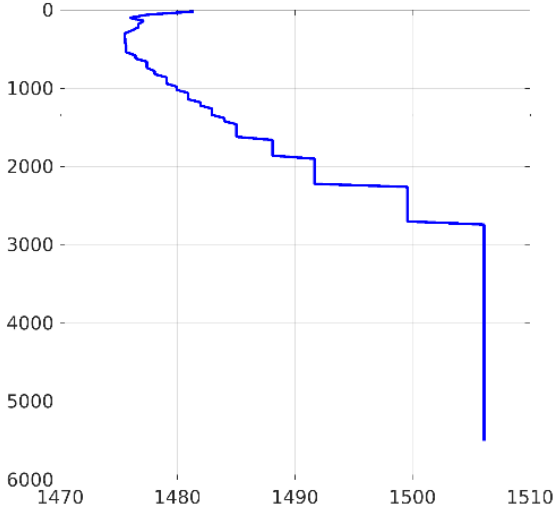
Sloping Bathymetry

- To assess the effect of ocean bottom slope on converted T-phases, we did a series of SPECFEM2D[1] calculations with slopes from 5 to 30 degrees
- All used the same water and land properties.
- The source was a line of Ricker wavelets with a maximum at 900 m depth. Dominant frequency 10 Hz.

20 degree slope



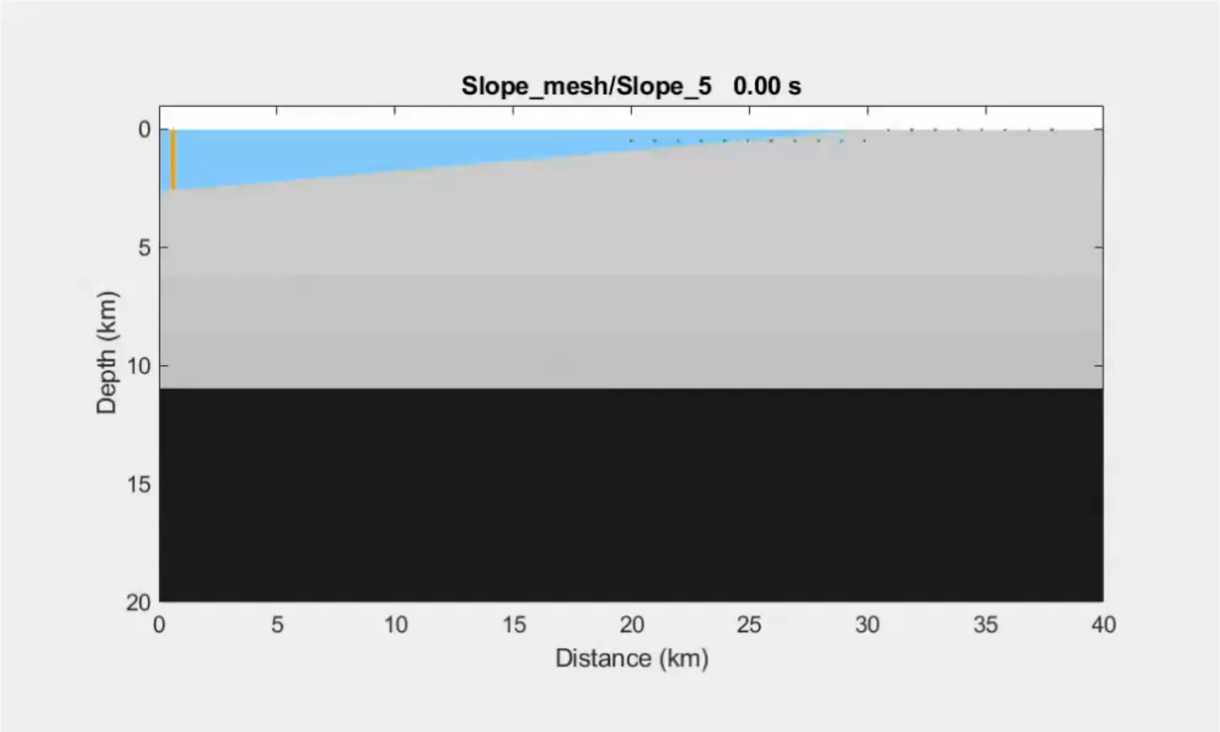
Source Amplitude



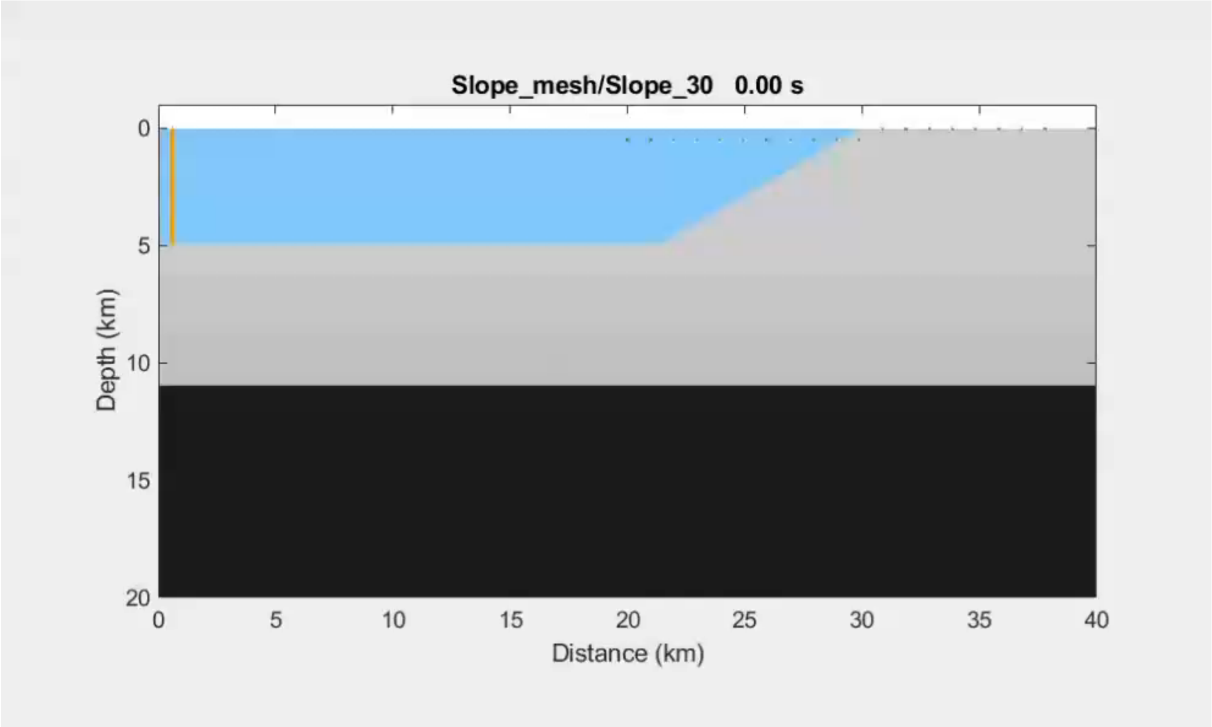
Water velocity profile

[1]https://geodynamics.org/cig/software/specfem2d/

Seismic Conversion Process



5 Degree Slope



30 Degree Slope

Movies show the propagating wave from the start of the calculations through 30 seconds

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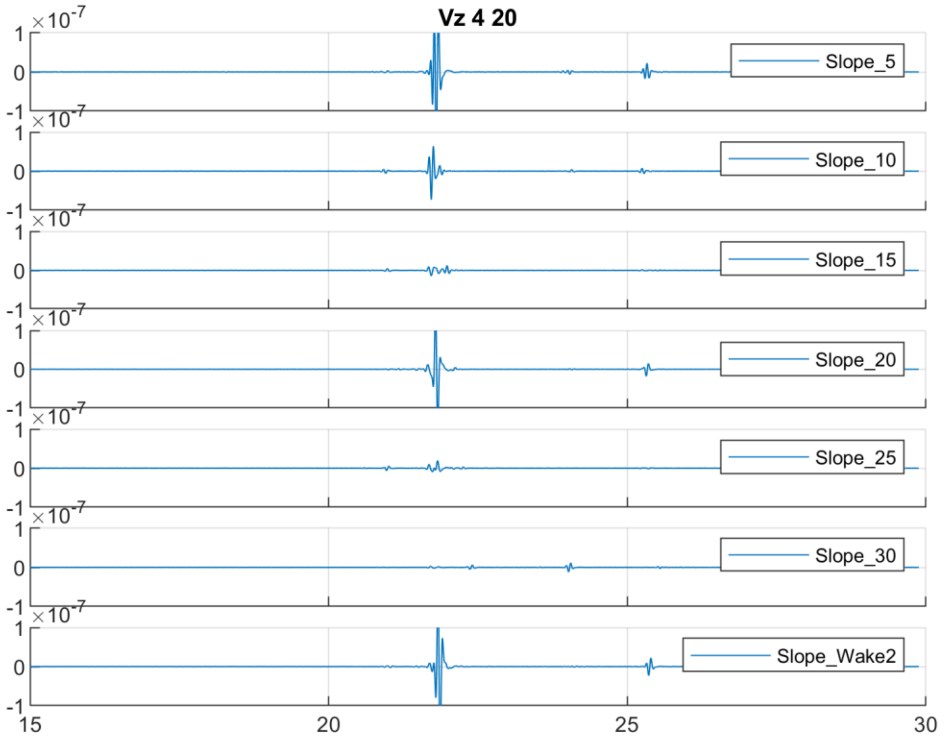
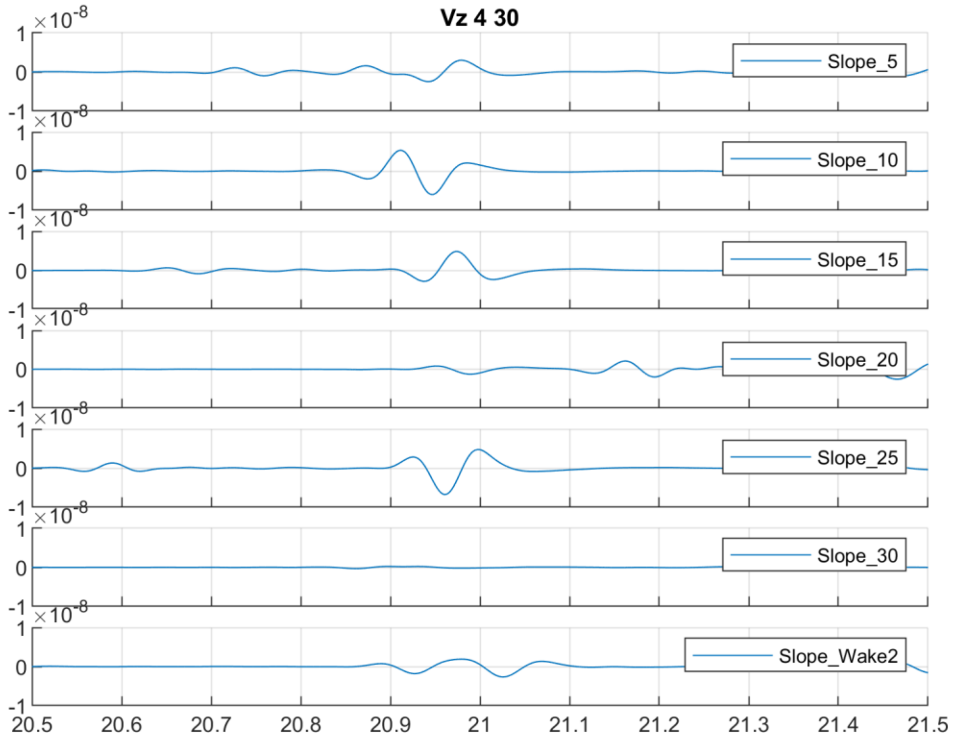
Slope Calculations – Waveforms at T-Station



Full time series



P wave segment

Dependence on slope is complicated. The most important factor is the efficiency of surface wave generation.

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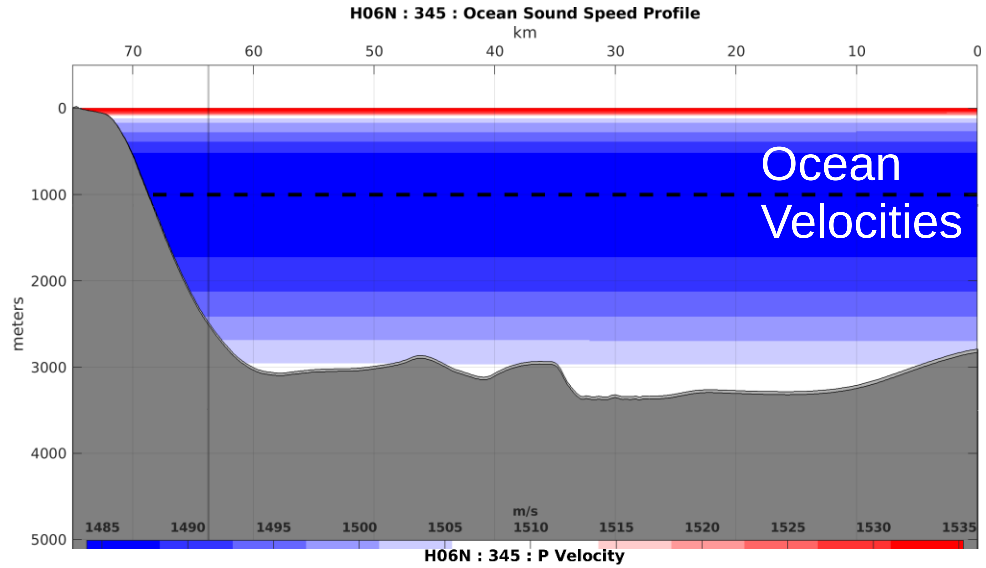
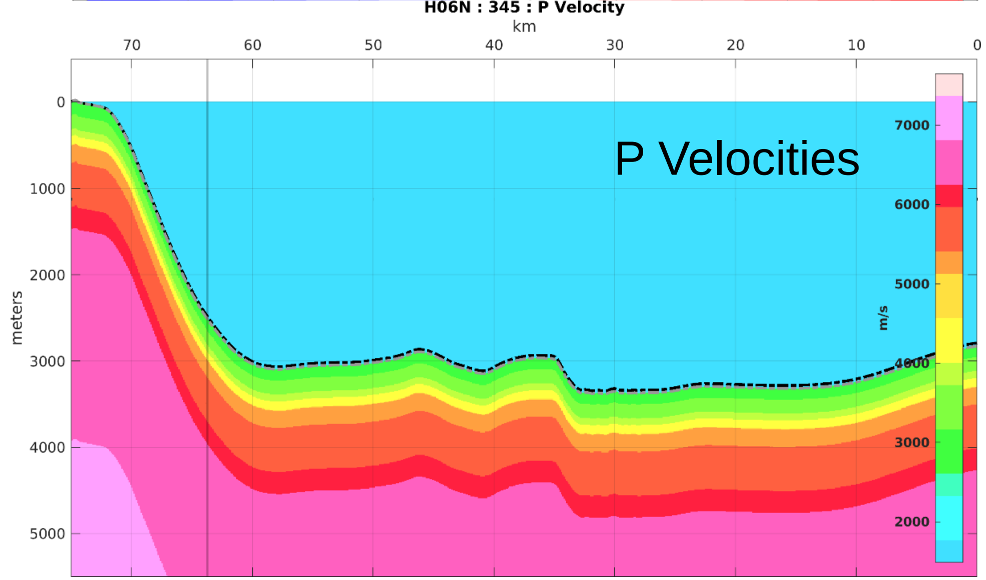
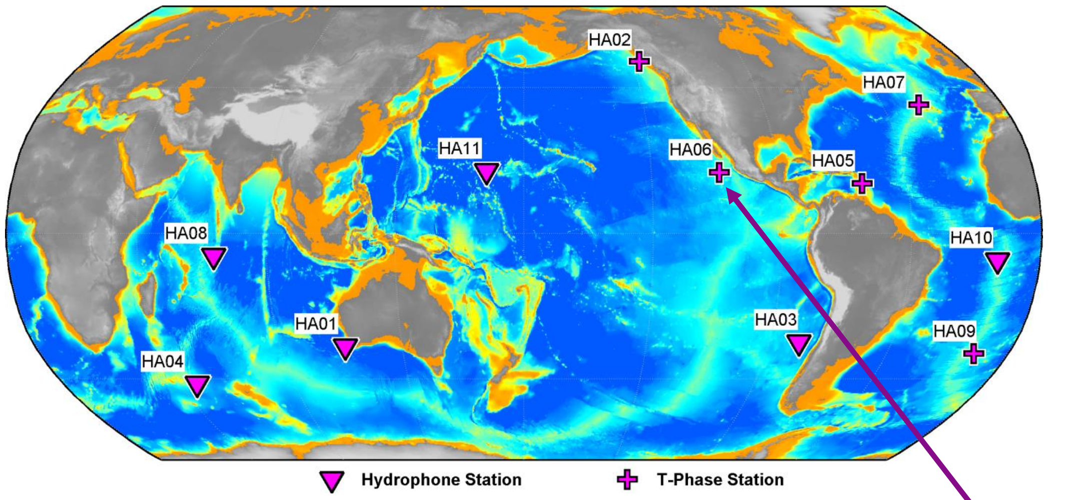
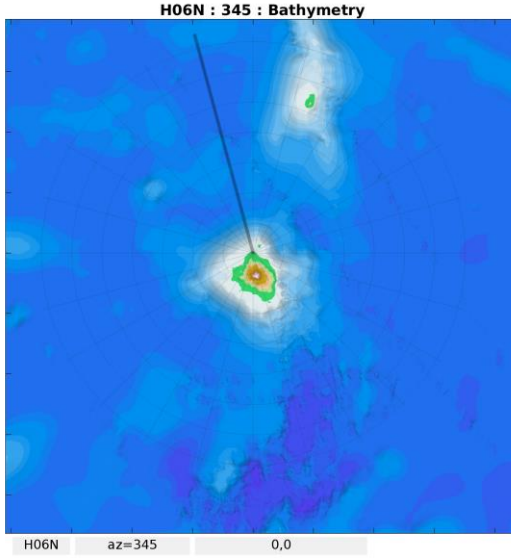
Environmental Descriptors for HA06, Socorro Island, Mexico









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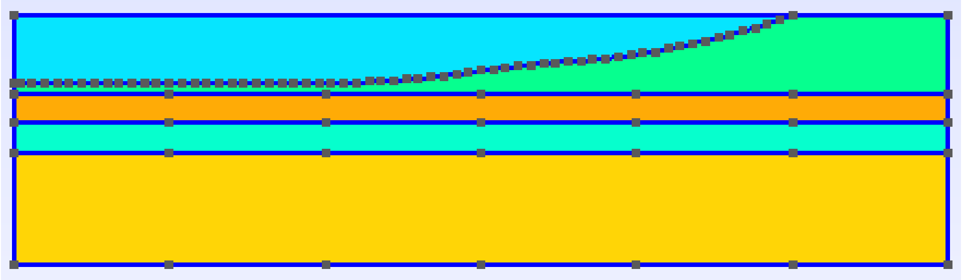
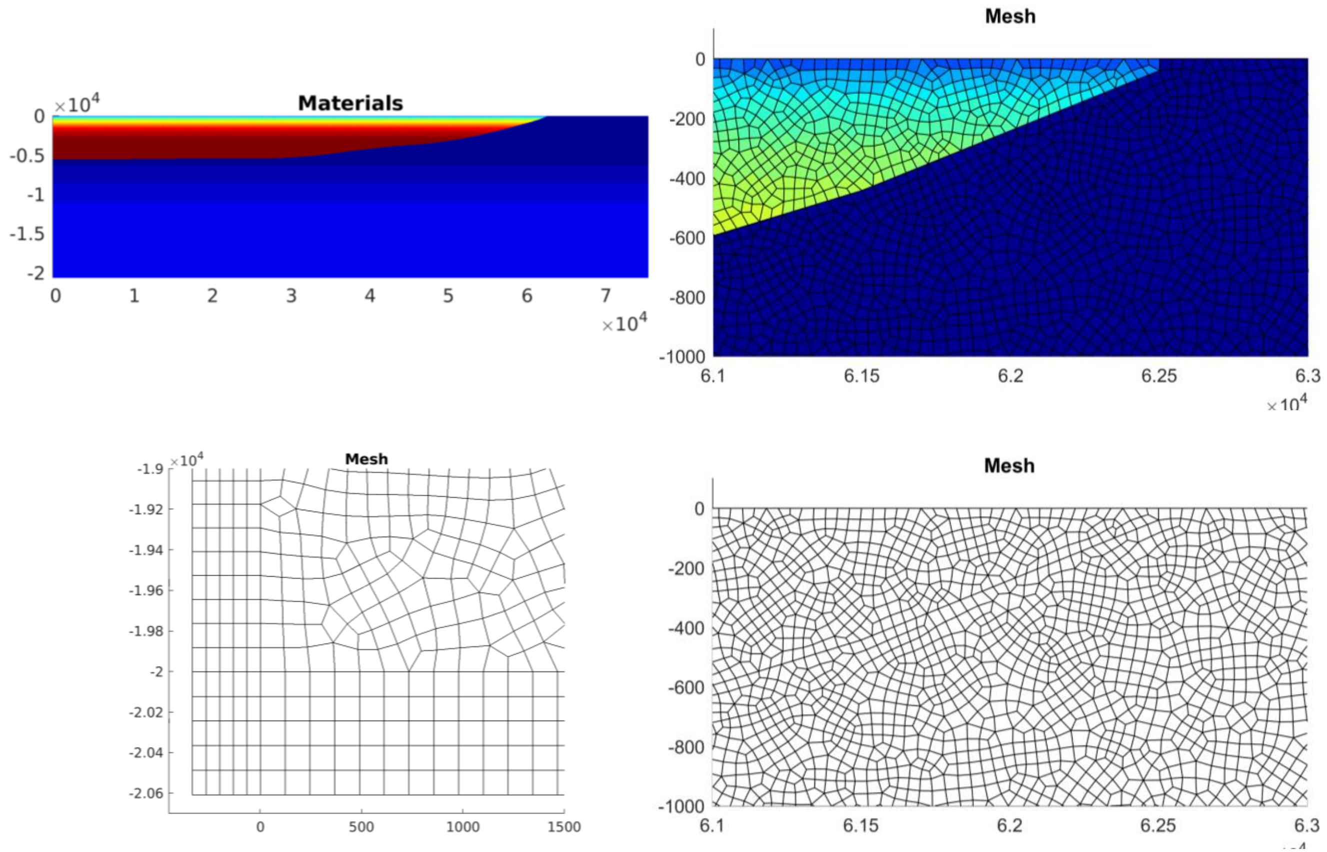
Mesh Generation

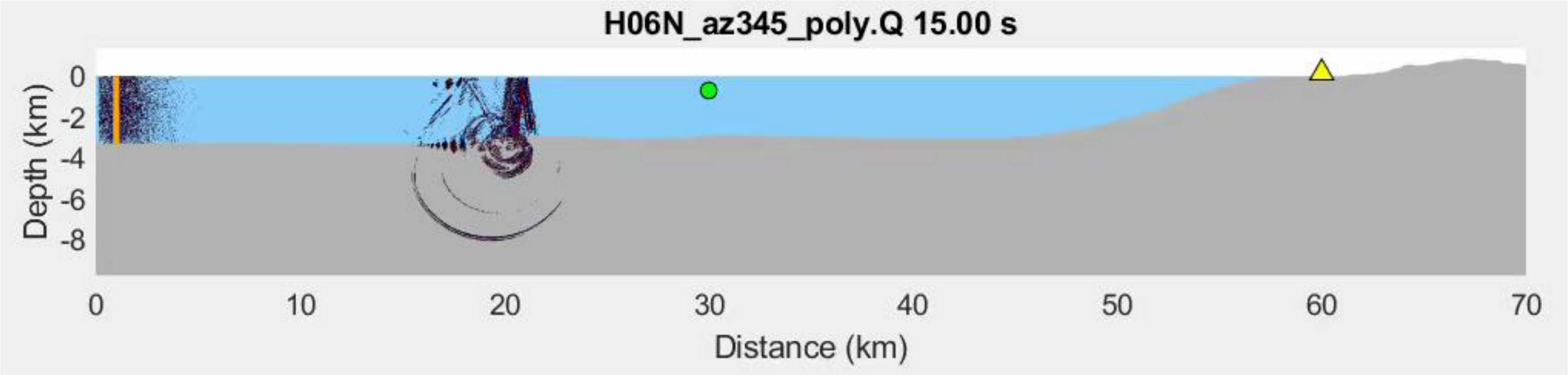
- In previous calculations we have always used a rectangular mesh, which leads to a stair-step shape on the ocean bottom.
- Since the stair-steps cause some reflected and scattered energy, we have used a mesh generator, gmsh, which can generate a much smoother bottom.
- This example shows the Wake Island mesh grid.





IMS T-Station Calculations

- Calculations initiated using hydroacoustic field in the water column generated by a distant source using KRAKEN or RAM
- 11 Seismometers at 5 T-stations
- Explosion sources at 60m and 3000m depth
- Example is H06N from a 3000m deep explosion source 500 km to the north
- Anelastic attenuation was included in this calculation



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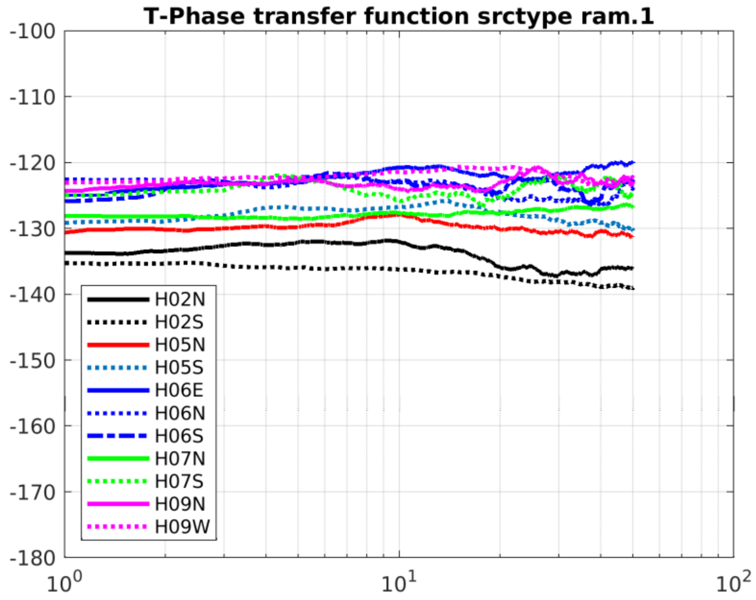
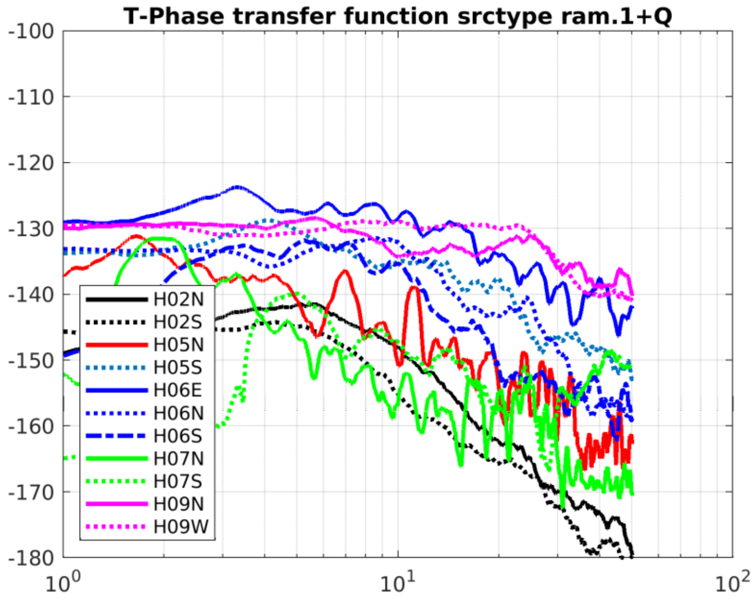
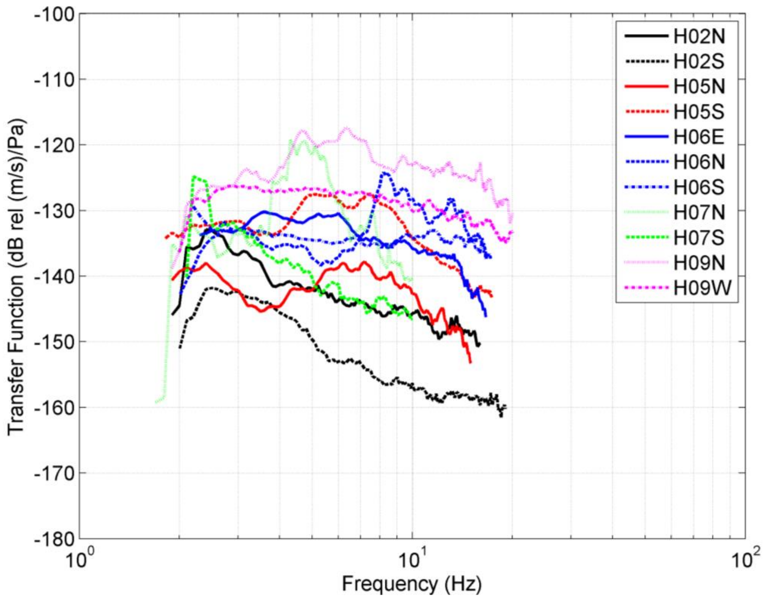
T-Phase Transfer Functions



Calculated without anelastic attenuation 2-50 Hz



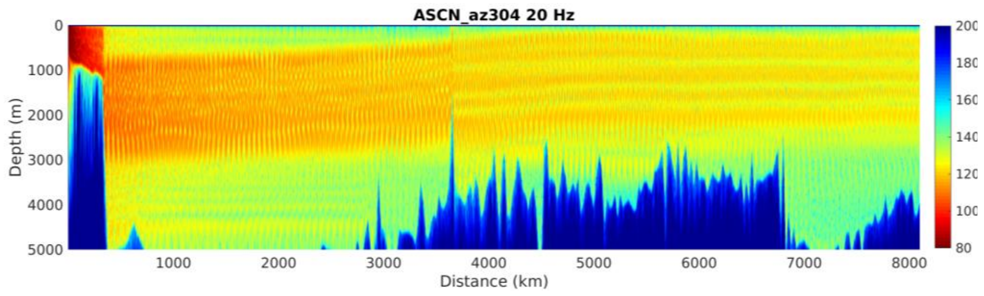
Calculated with anelastic attenuation 2-50 Hz



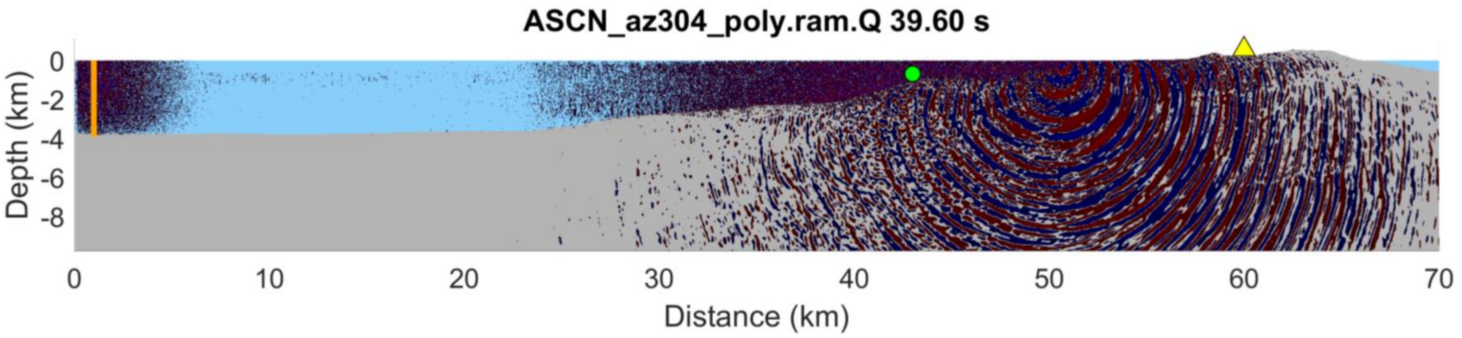
Observed 2-20 Hz

Comparison with Data from Florida Explosions

- Two 5 ton explosions off of Florida generated hydroacoustic and T-phases at Ascension Island.
- Calculations were initiated using the PE code RAM[1], then propagated using SPECFEM2D. Attenuation was included in the calculation.



Transmission loss at 20 Hz calculated with RAM. Explosion source is on the left. SPECFEM2D calculation starts on the right.

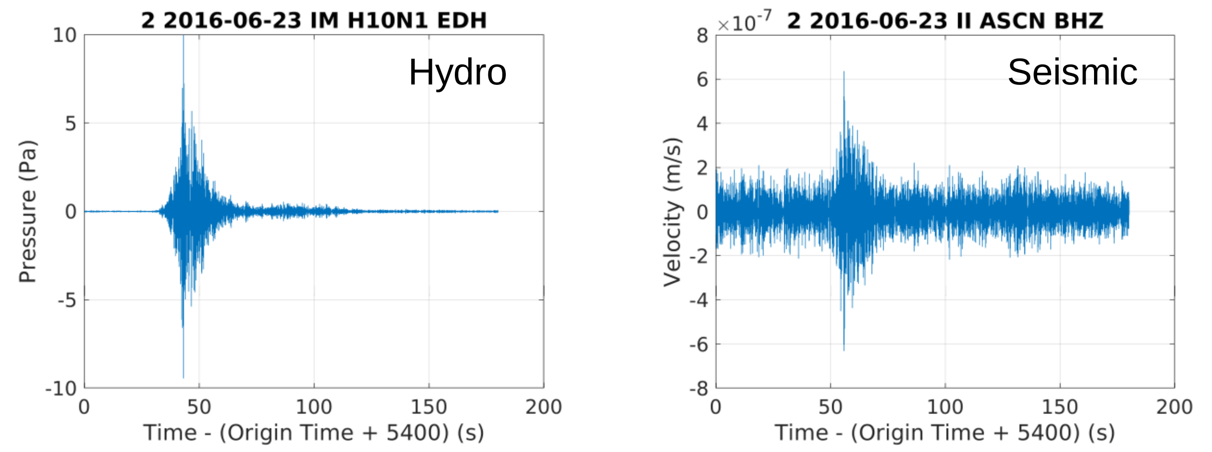


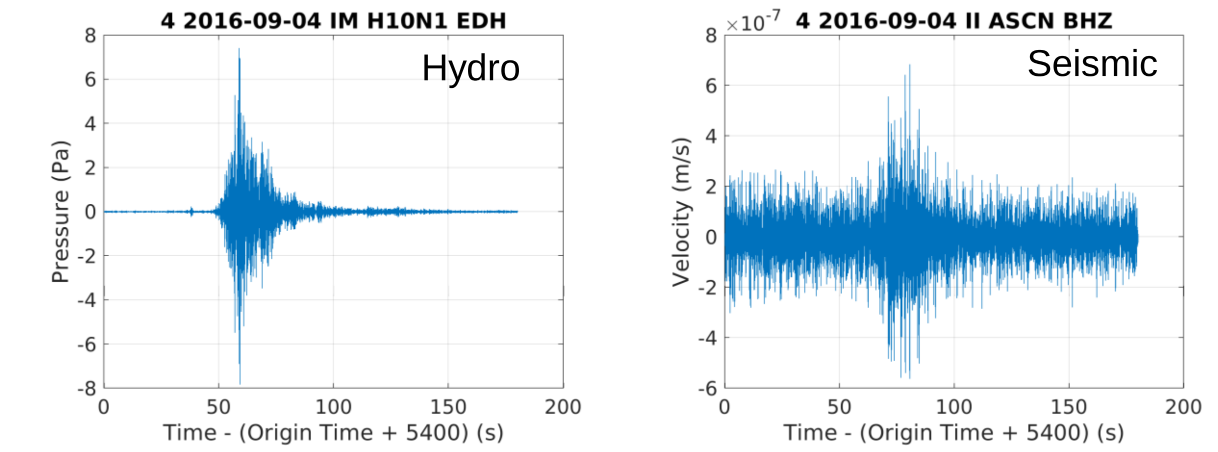
Conversion from hydroacoustic to seismic calculated with SPECFEM2D

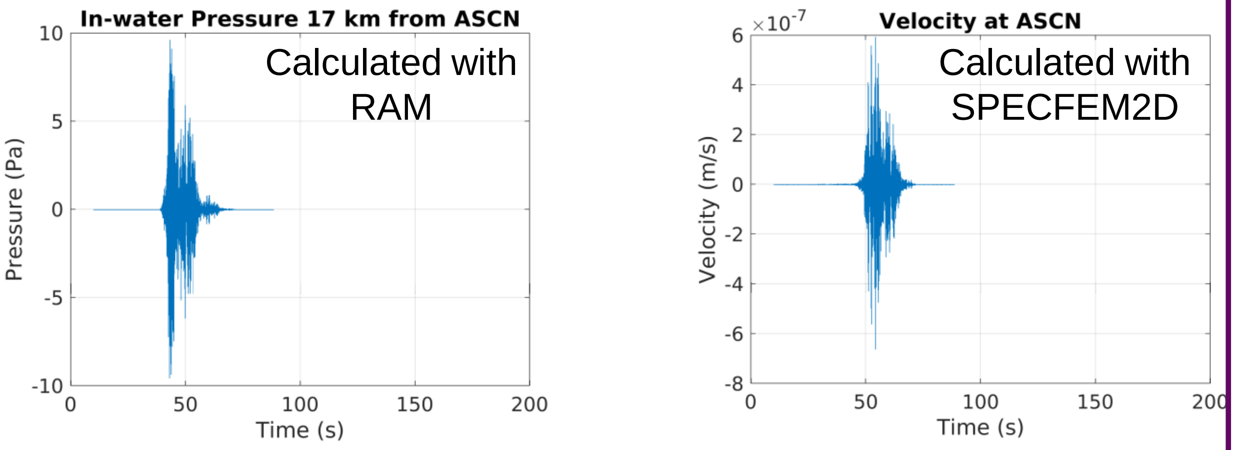
[1]http://oalib.hlsresearch.com/

Comparison with Data from Florida Explosions

- Two 5 ton explosions off of Florida generated hydroacoustic and T-phases at Ascension Island.







Calculations were initiated using the PE code RAM, then propagated using SPECFEM2D. Attenuation was included in the SPECFEM2D calculation. All waveforms filtered 6-10 Hz.

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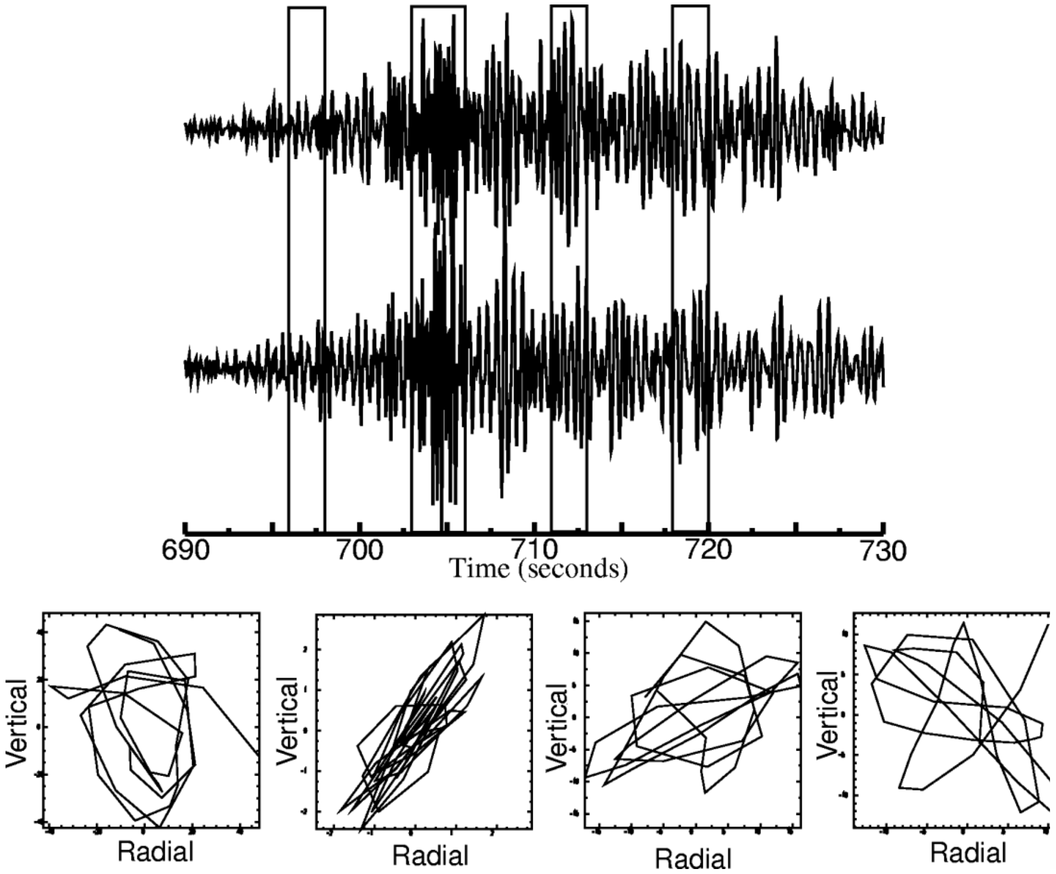
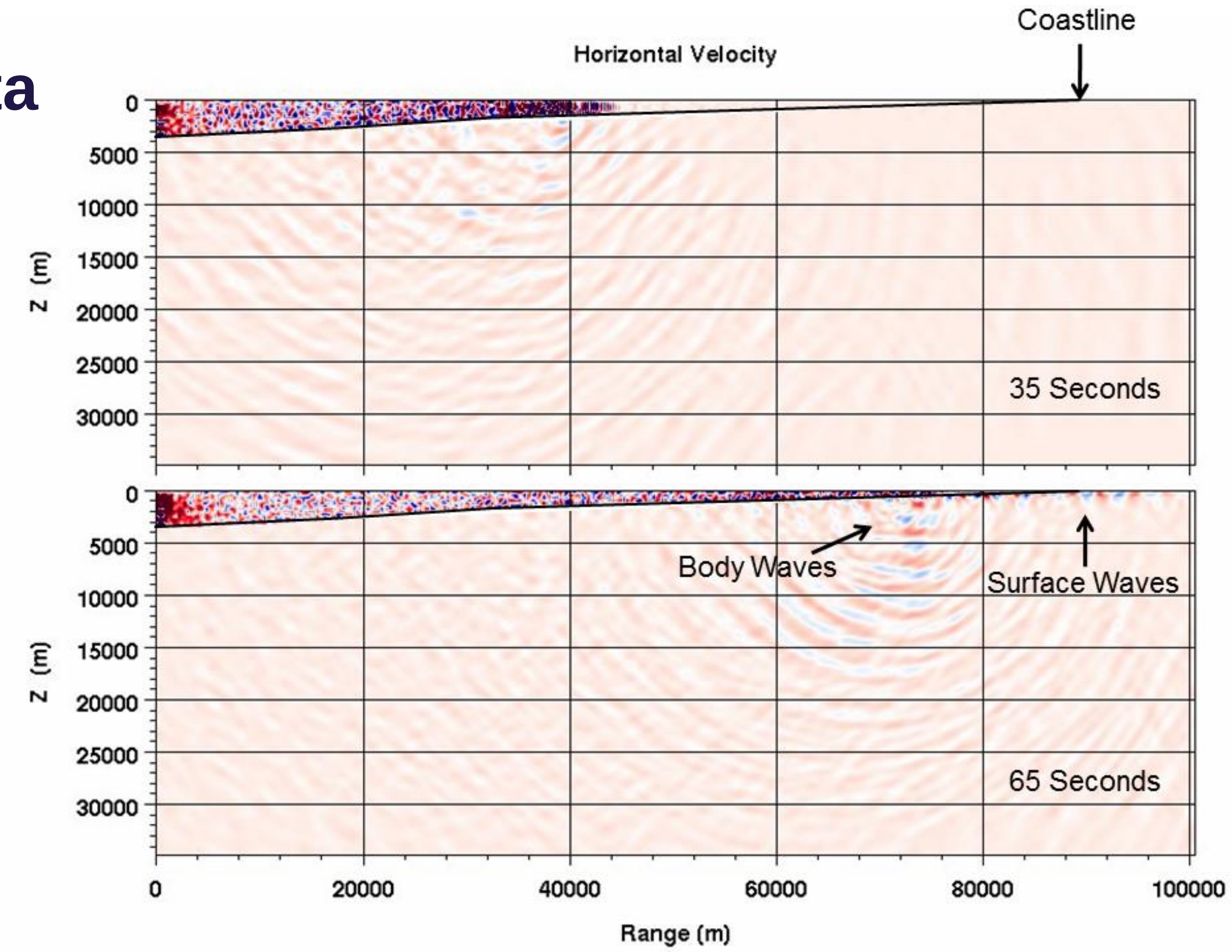
Backup

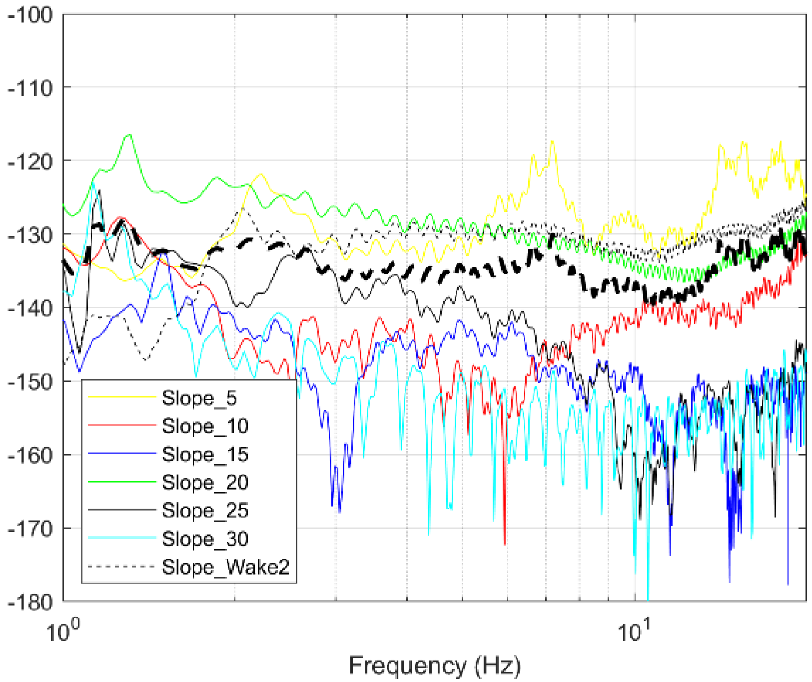
Pt. Sur Calculation and Data



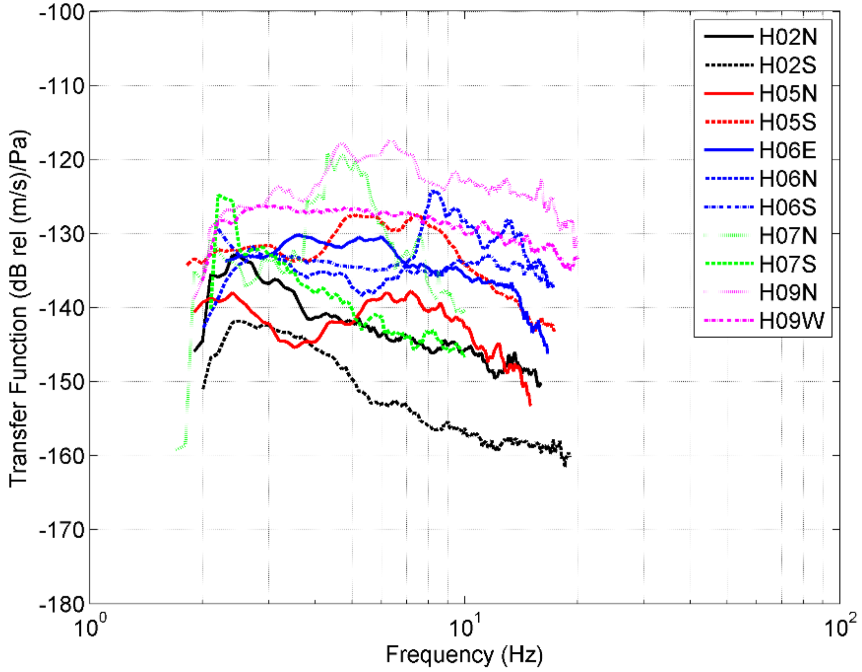


Observed Pt. Sur T-Phases have the Predicted Complexity

Observed and Calculated Transfer Functions

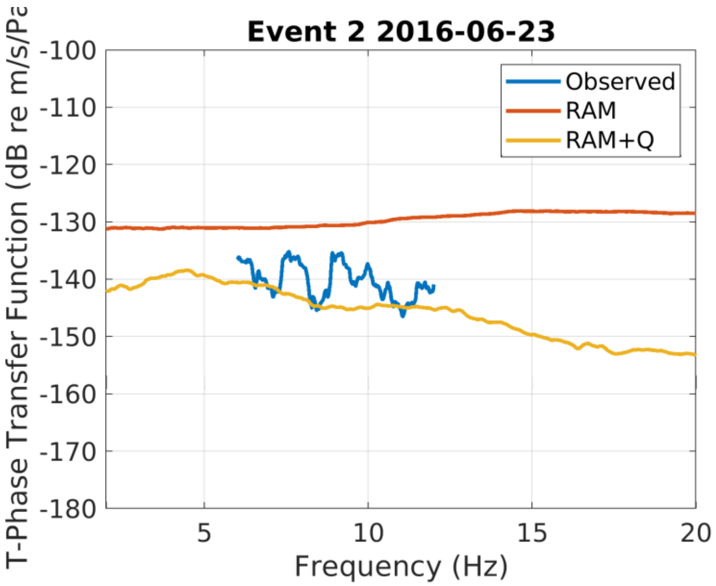


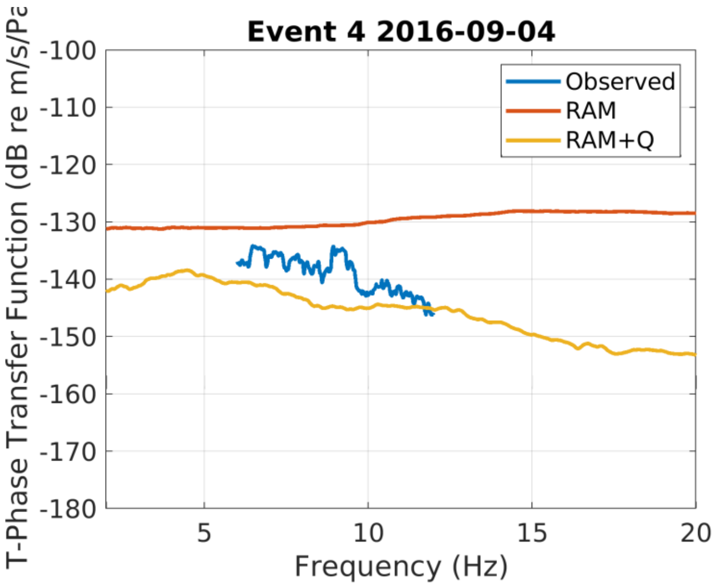
Calculated

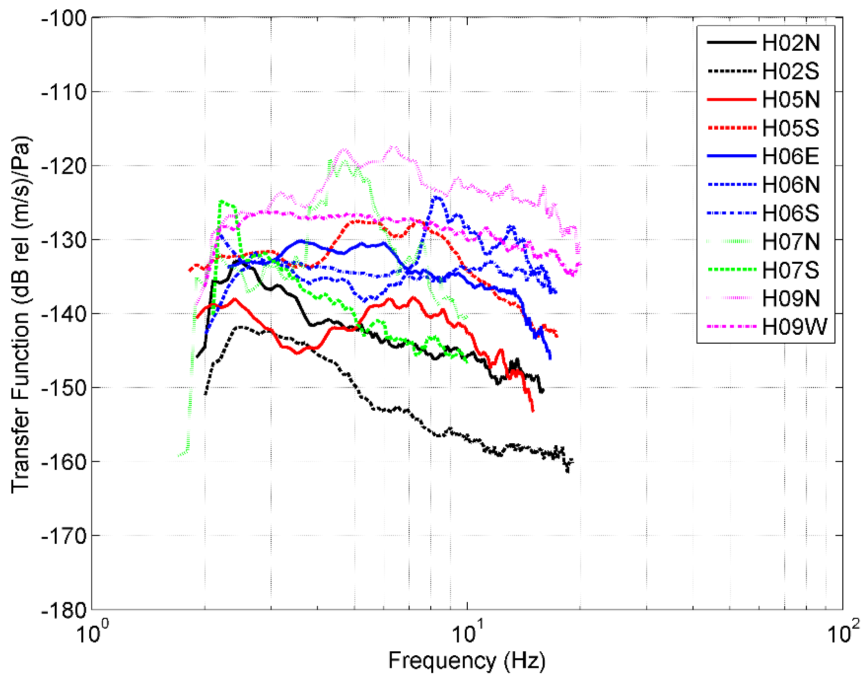


Observed

Florida Explosion Transfer Functions







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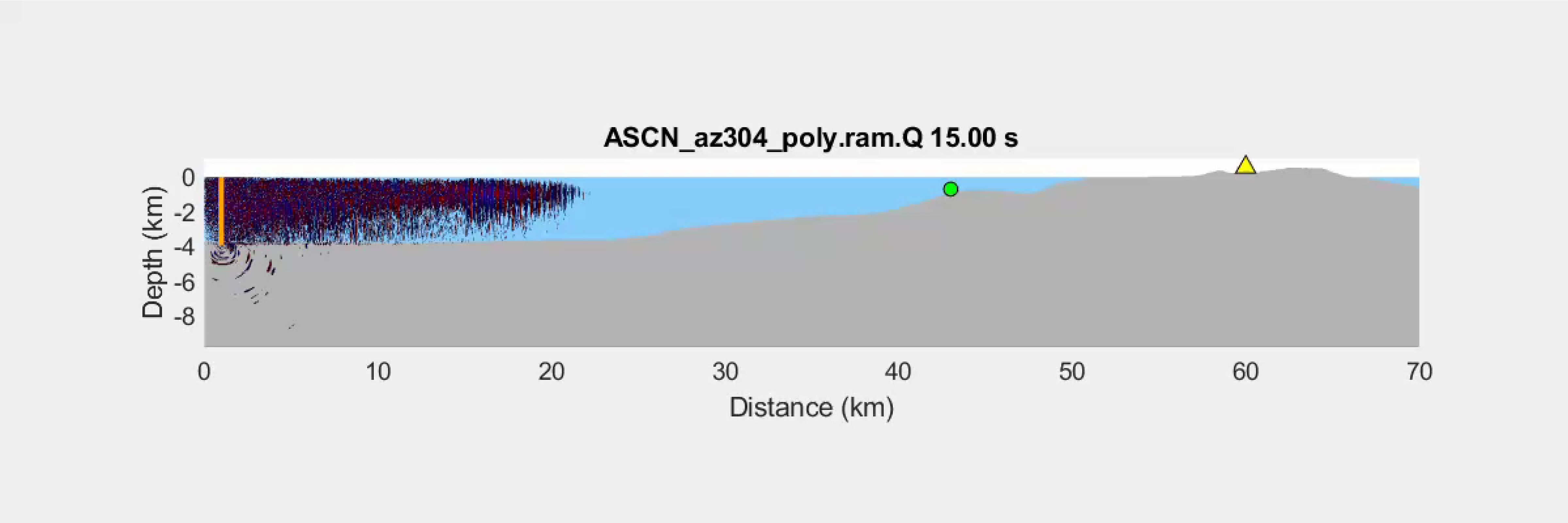
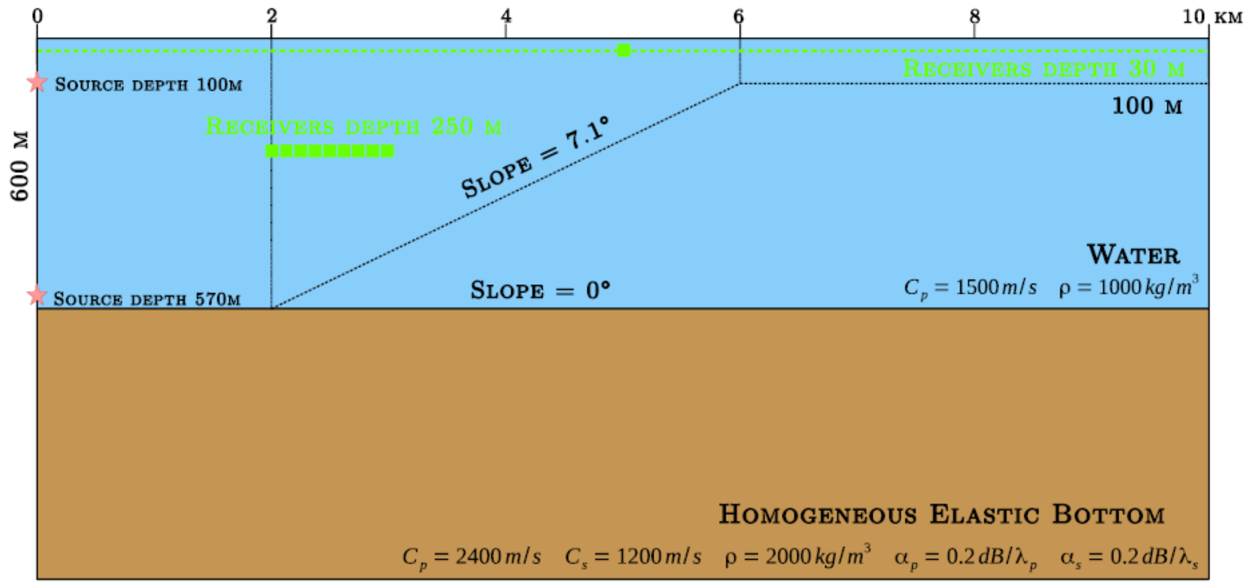
ASCN Calculation

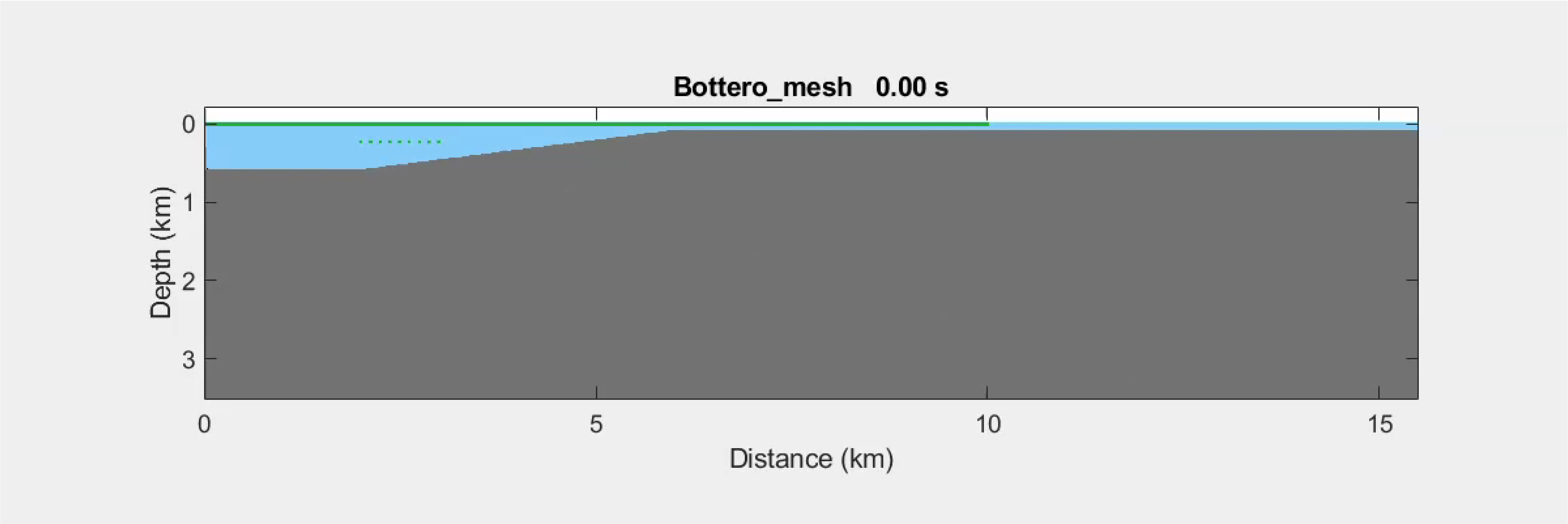


Comparison with Bottero et al[1] Paper



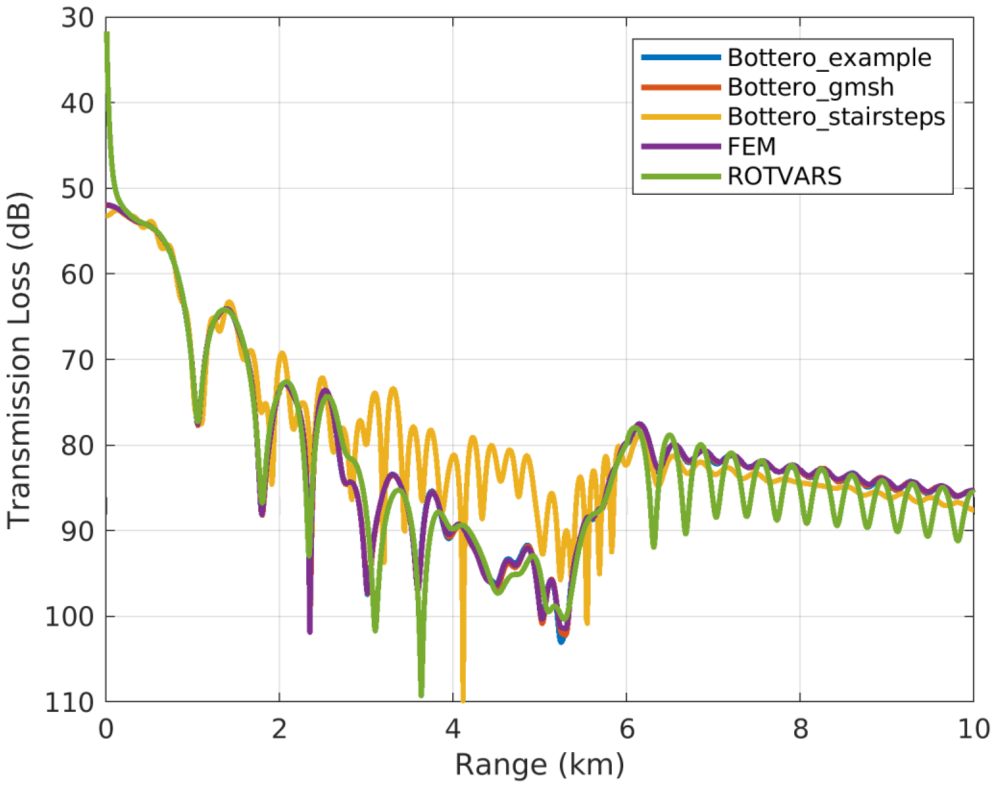
[1]Bottero, A., P. Cristini, D. Komatitsch and M. Asch (2016), "An axisymmetric time-domain spectral-element method for full-wave simulations: Application to ocean acoustics. Journal of the Acoustical Society of America 140, 3520, doi: 10.1121/1.4965964.

Calculation Equivalent to Bottero et al Paper



Comparison with Bottero et al Paper

- With a smooth mesh, the transmission loss calculated with SPECFEM2D is almost identical to the calculated transmission loss shown in the paper.



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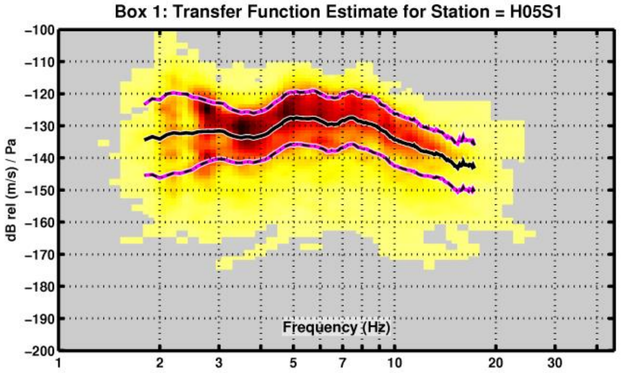
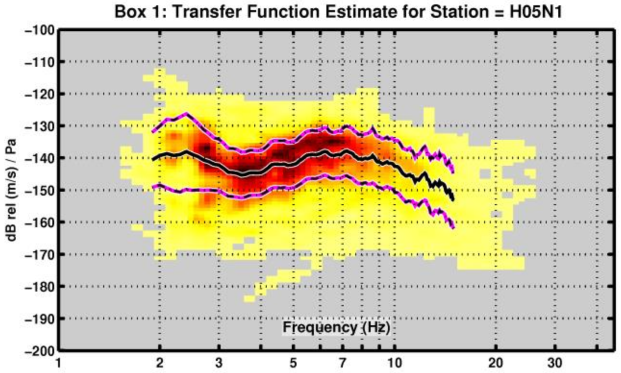
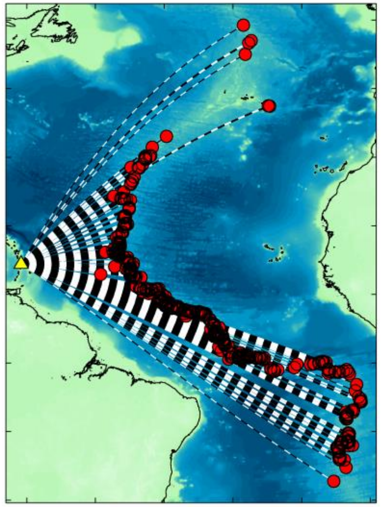
H05

H05N and H05S show no anomalies and have well-defined transfer functions. The transfer functions are relatively flat with a slow decrease with frequency. H05N is ~10 dB lower than H05S.

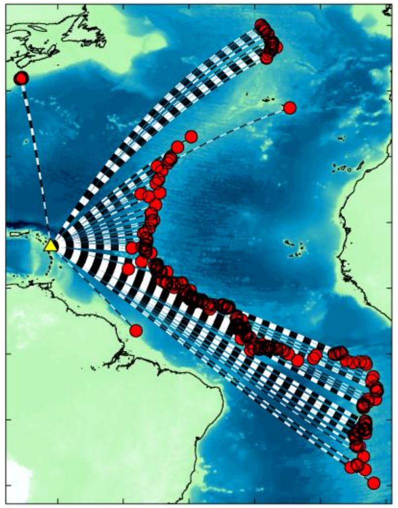




H05S



H05N



H02S

- H02S has a bimodal distribution that can be corrected by removing events with low amplitude signals.