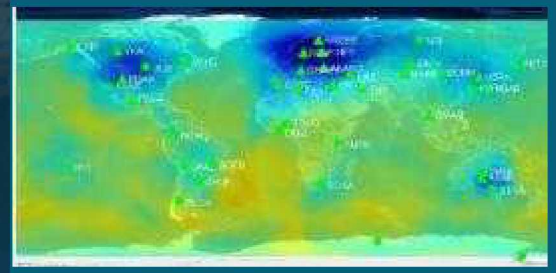
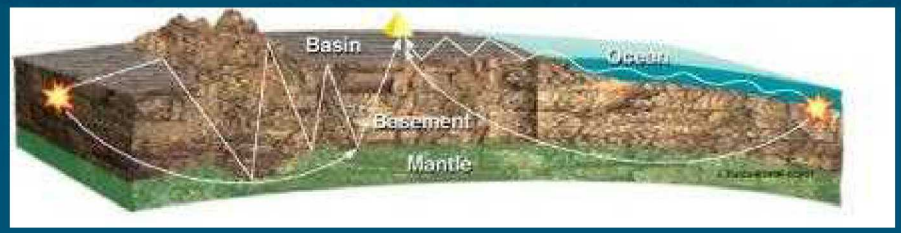
SAND2019-1574PE

GNDD Signal Analysis: Network Performance Modelling





PRESENTED BY

Jessica Bobeck

February 19, 2019

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Motivation & Objective

Motivation:

US nuclear monitoring community has a need to gauge the effectiveness of its network and determine the impact of possible changes to the network, such as a station that is added or unavailable.

Objective:

The objective of this work is to provide a tool based upon relevant research we are able to identify, apply, and potentially improve upon.

Why Assess Sensor Network Performance?

1. Gauge effectiveness of an existing sensor network: what can we see and where do we need to improve?
   - Best approach is just to show actual monitoring results: how well has the network performed?

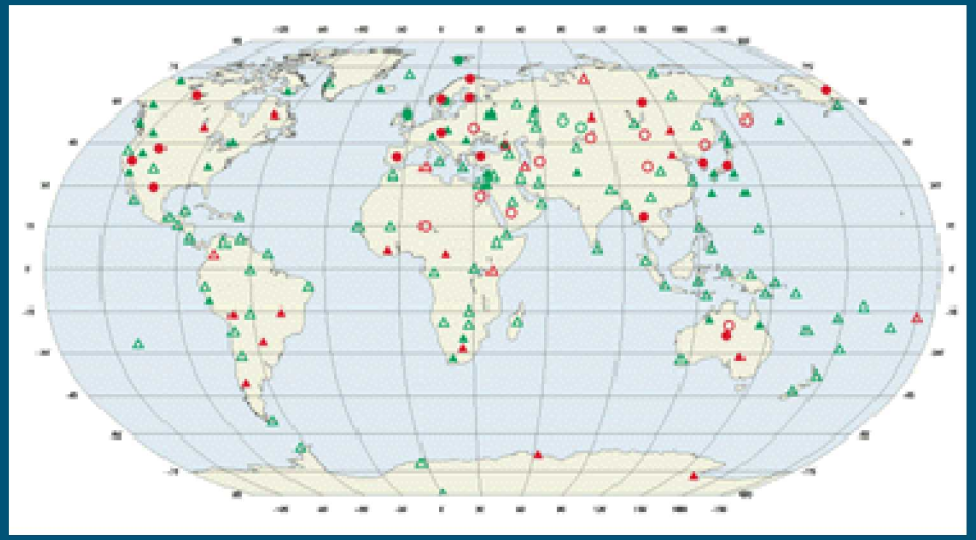
   <u>Problem:</u> limited source sampling
   (plate boundaries + nuclear test sites)

2. Plan a new/augmented sensor network (new stations) and/or new processing

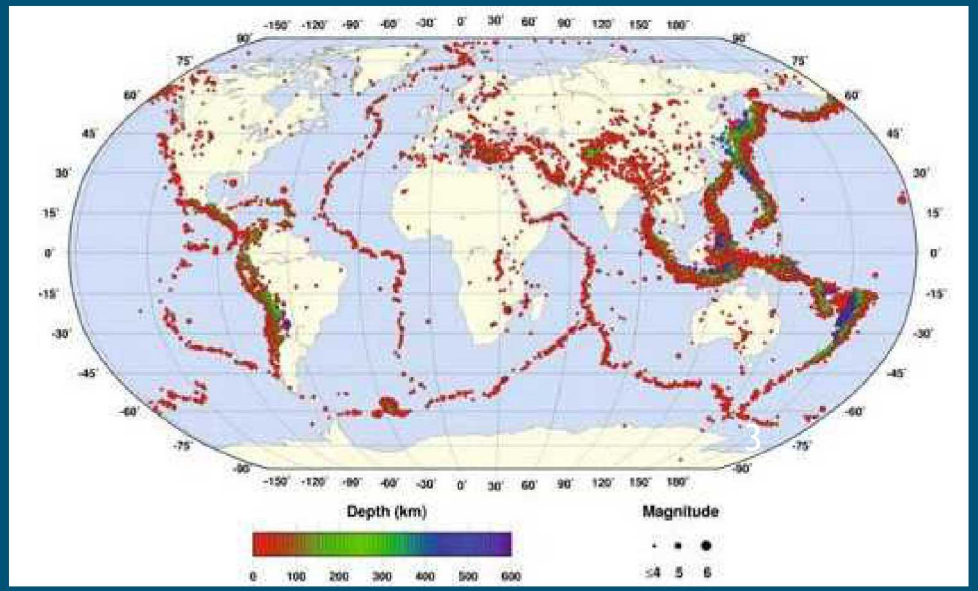
   <u>Problem:</u> no actual data from new sites or new algorithms

In both cases, we must make *assumptions* about what is expected, i.e. we must *model* expected behavior

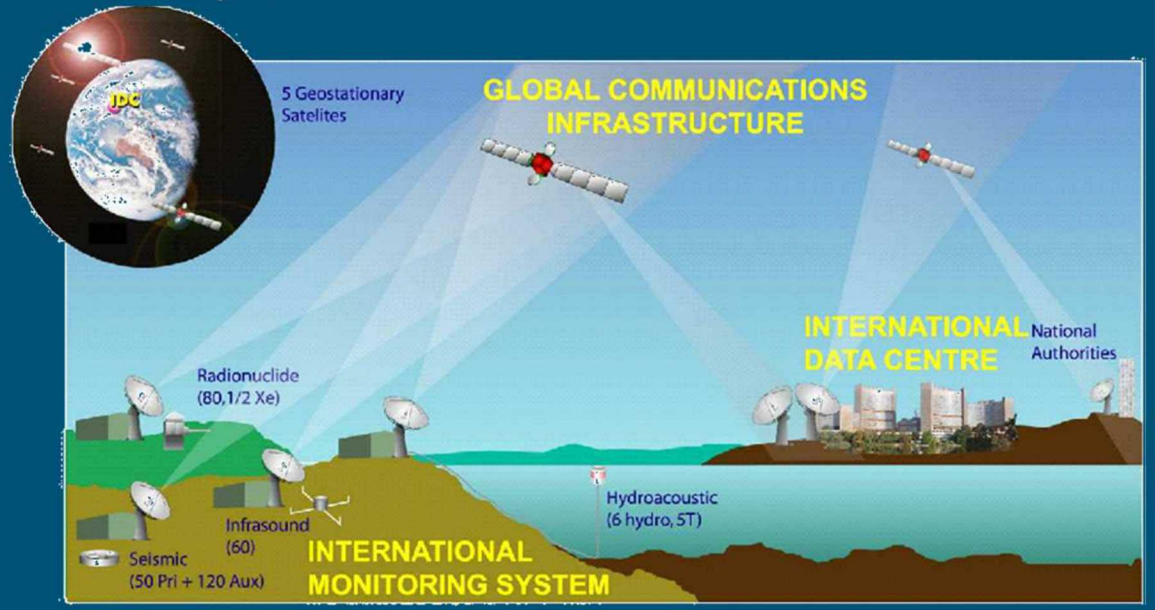
CTBTO Seismic Sensor Network



CTBTO Seismic Event Catalog



What must be included in the modelling?



Earth Physics

- Source
- Signal Propagation

Sensor Network

- Seismic
- Hydroacoustic
- Infrasound
- Radionuclide

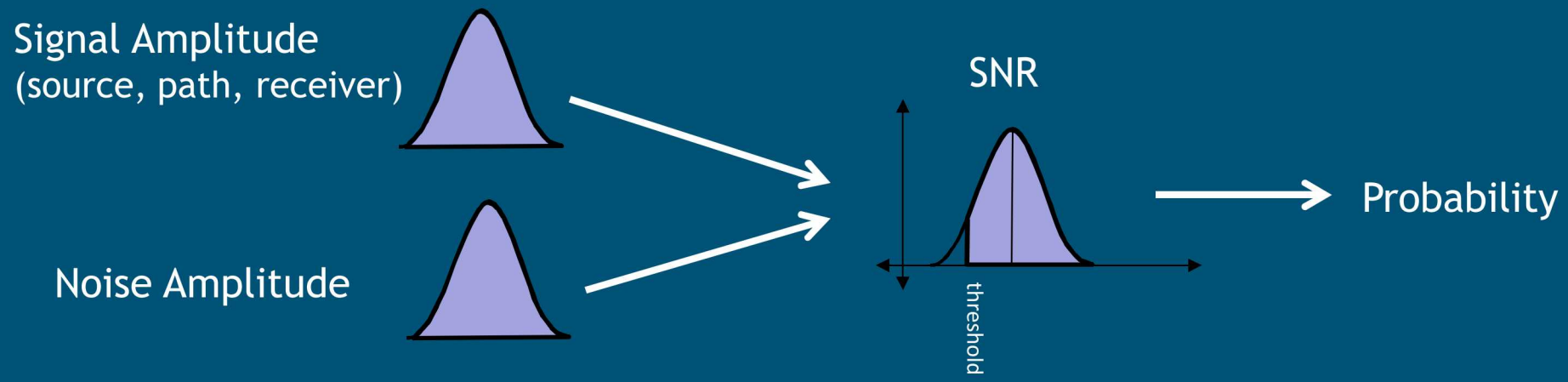
Data Reliability

Data processing

Our Goal: *simulate all of this to assess overall performance*

Research Basis

Primarily solving for the probability of detection by simulating the observed signal and noise amplitudes (Sereno, 1990).

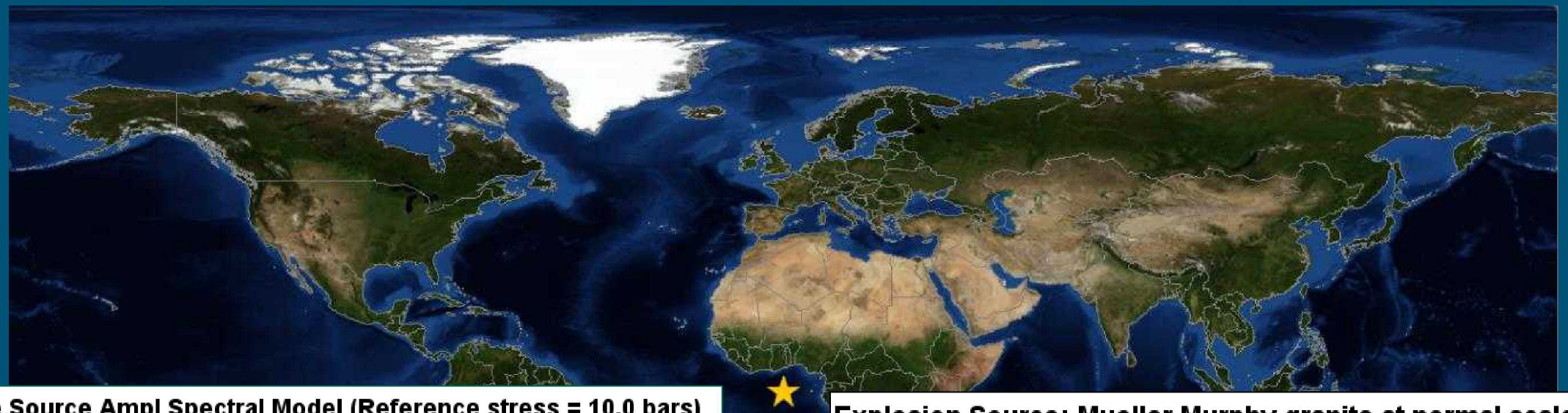


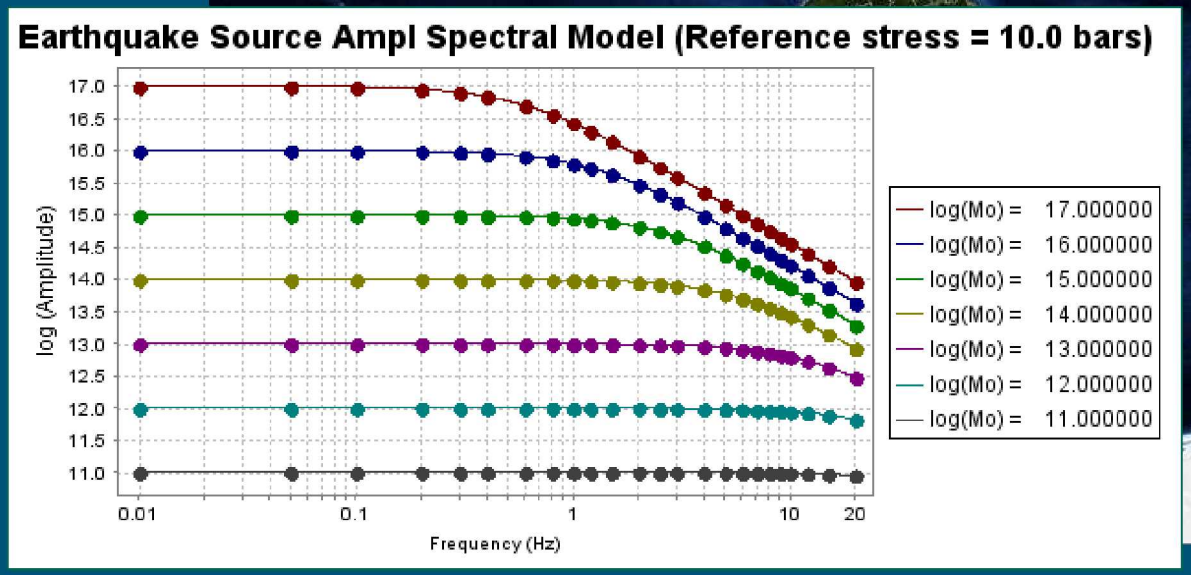
Research Basis

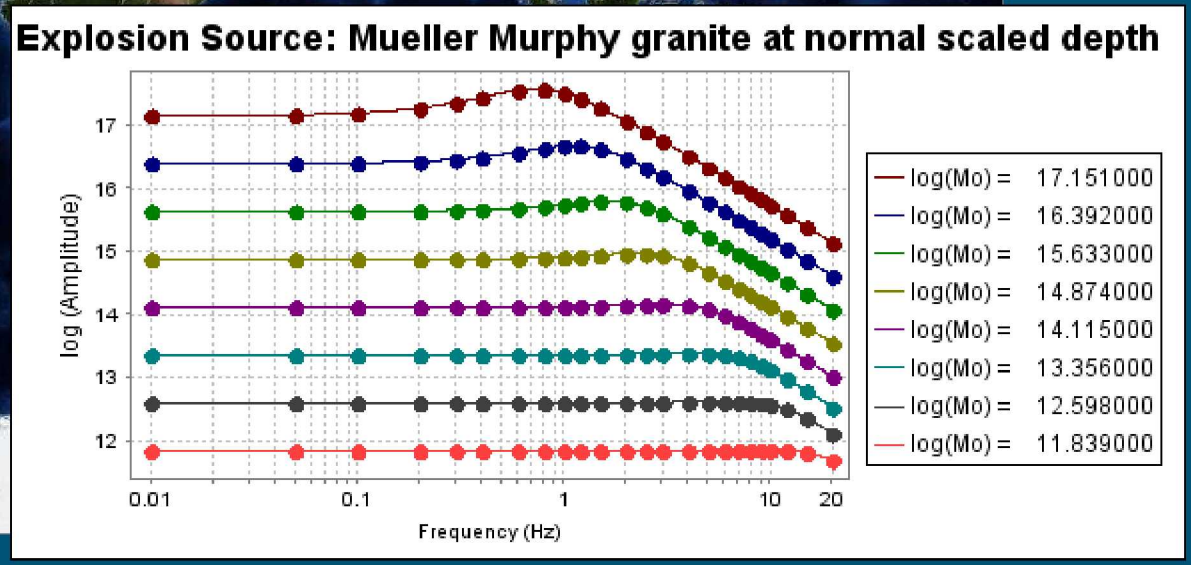
Hypothesize an event location on the earth

Research Basis

Source Model, based on type (earthquake, explosion), coupling, and geographic region

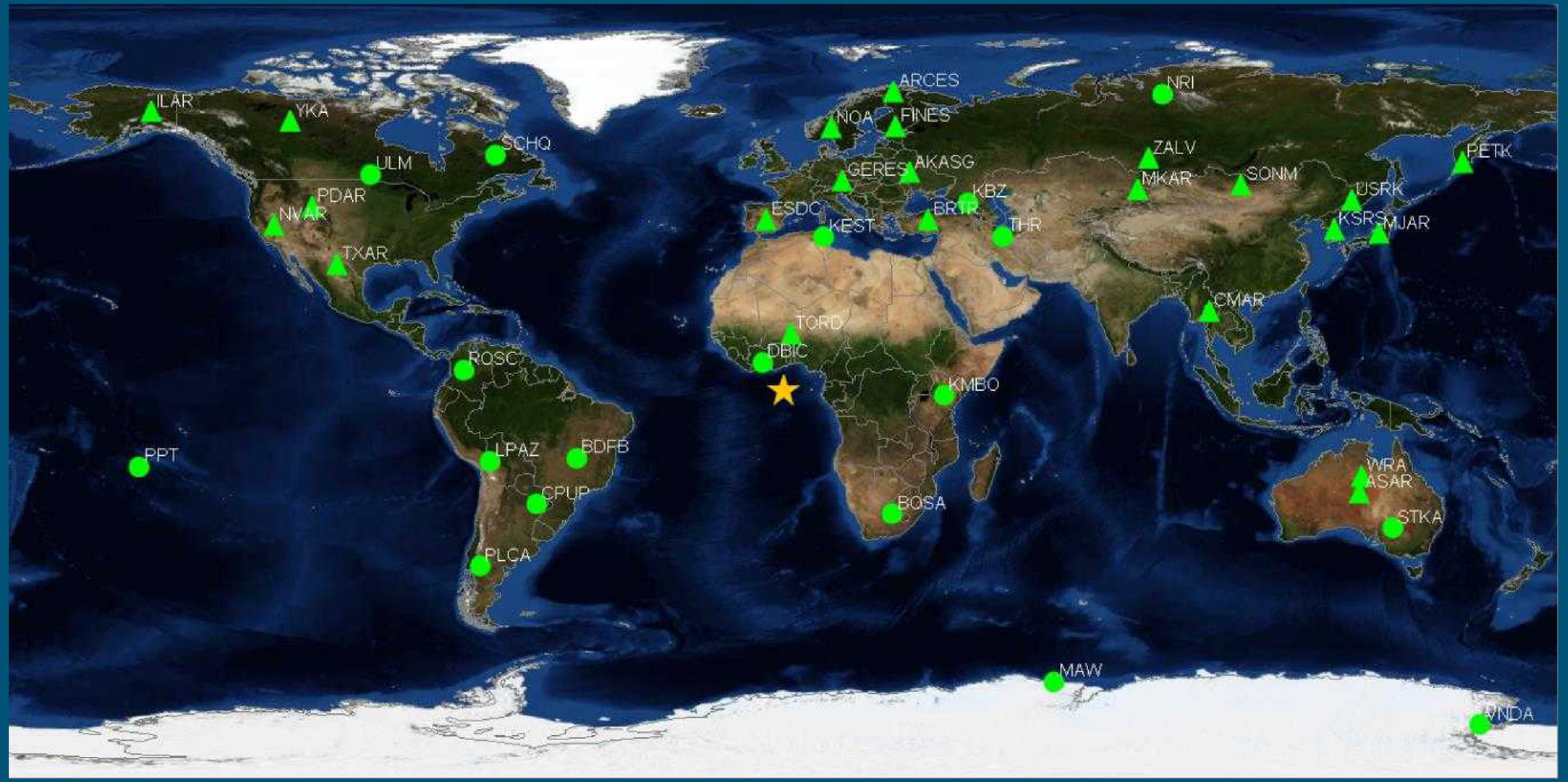






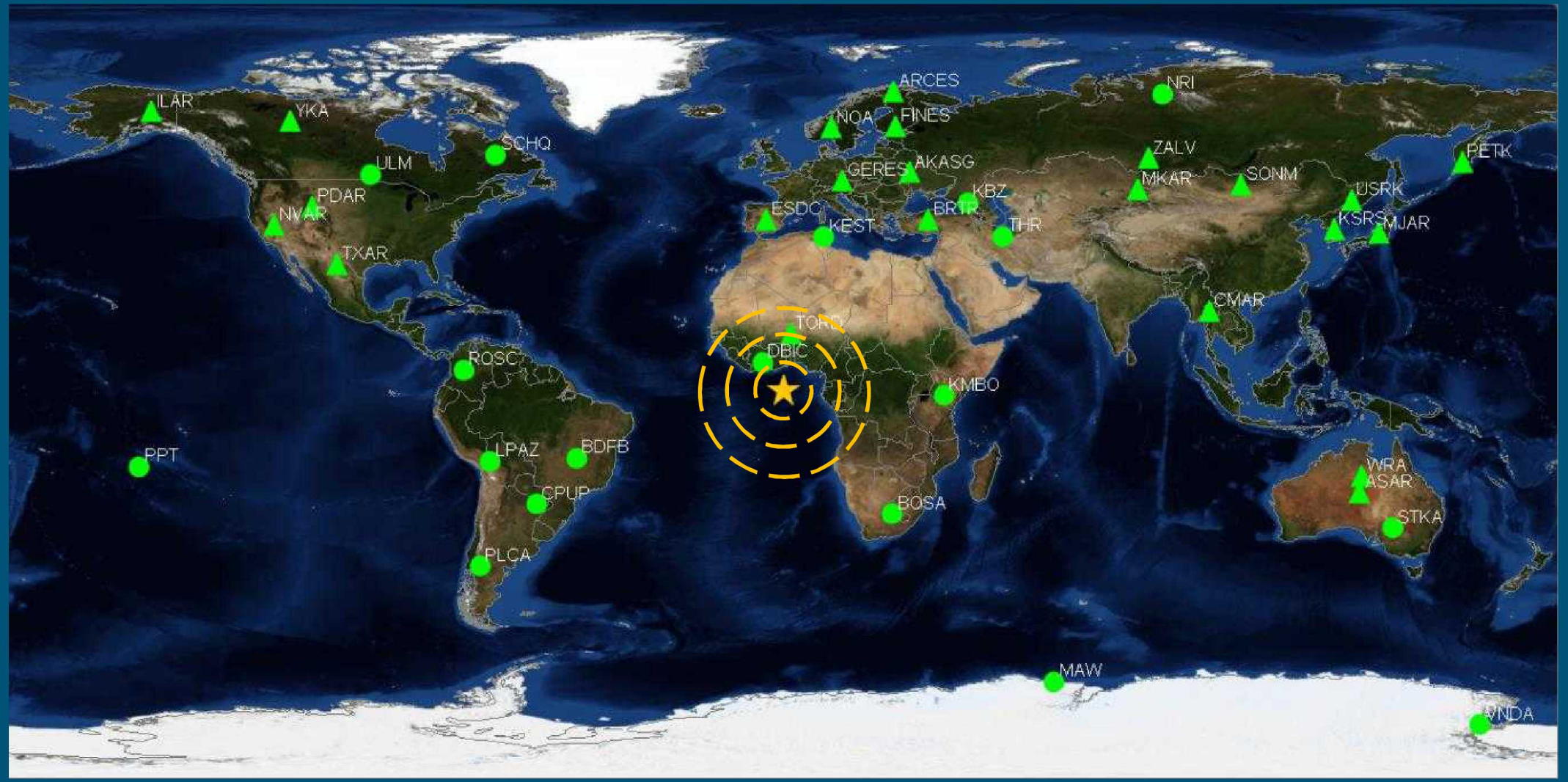
Research Basis

Define a network configuration to simulate, shown here is the IMS Primary Seismic Network



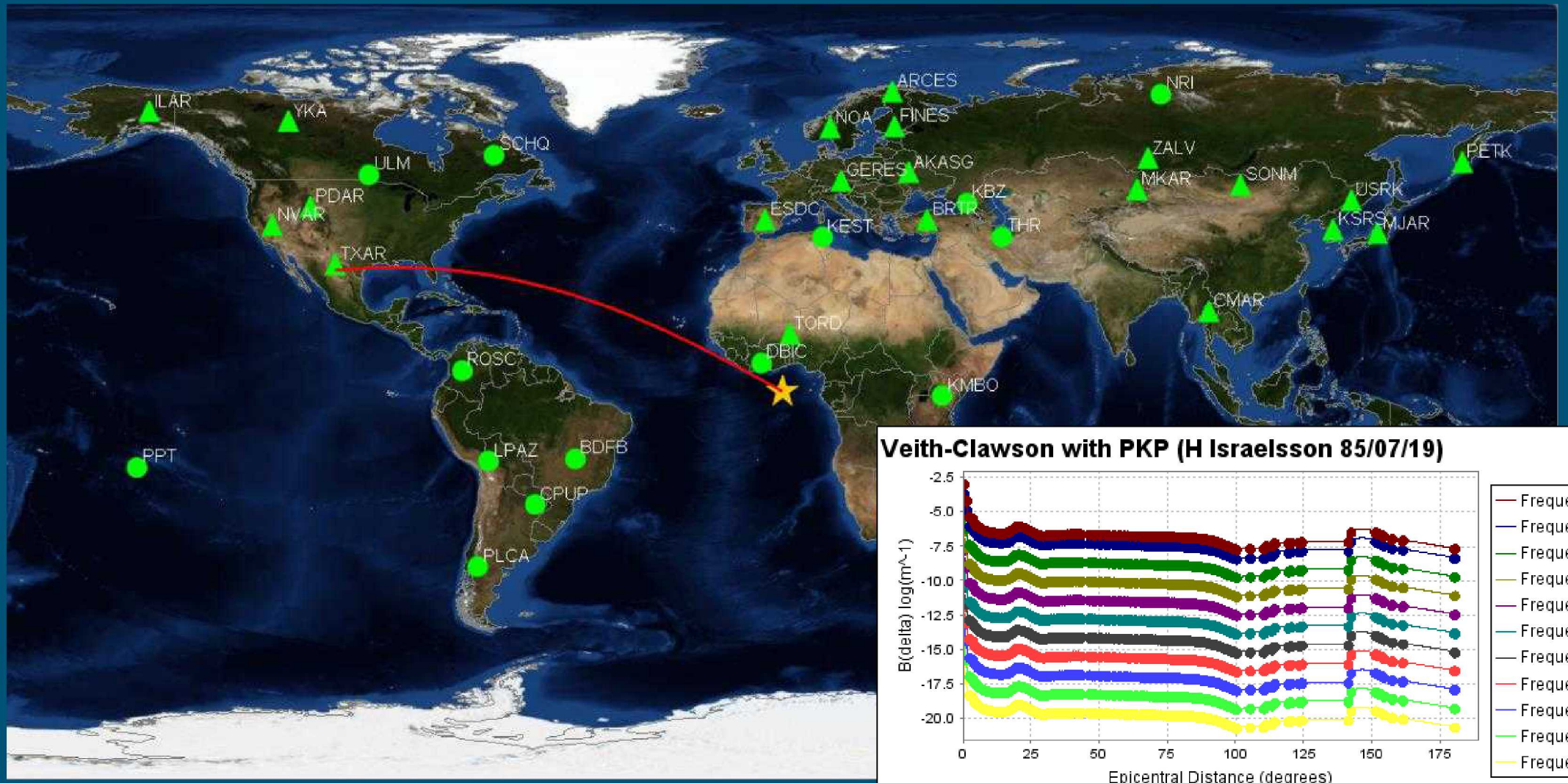
Research Basis

Simulate path attenuation as the signal propagates from the source to a station



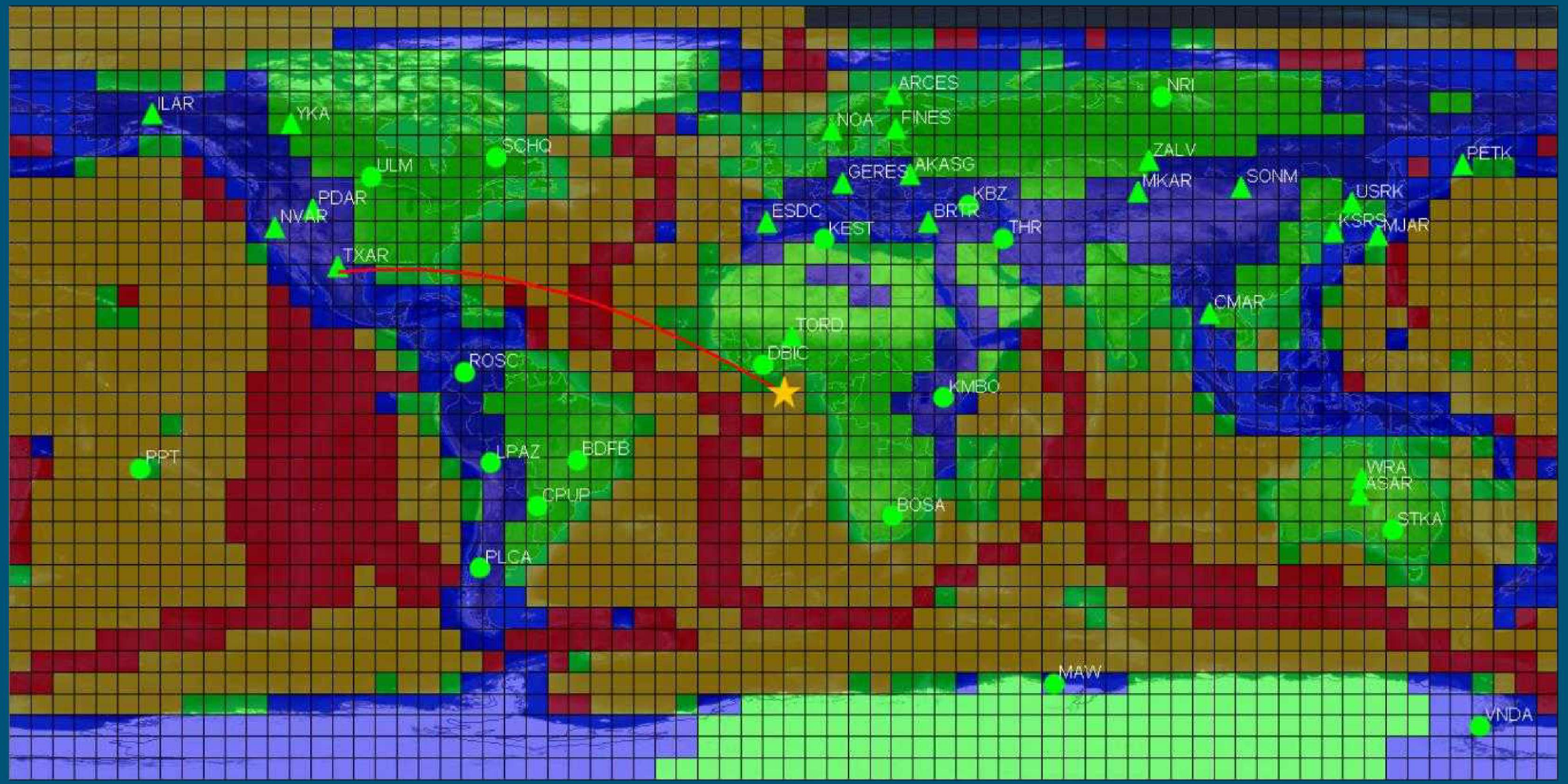
Research Basis

Teleseismic attenuation uses a reference model with a simple lookup table – homogenous earth



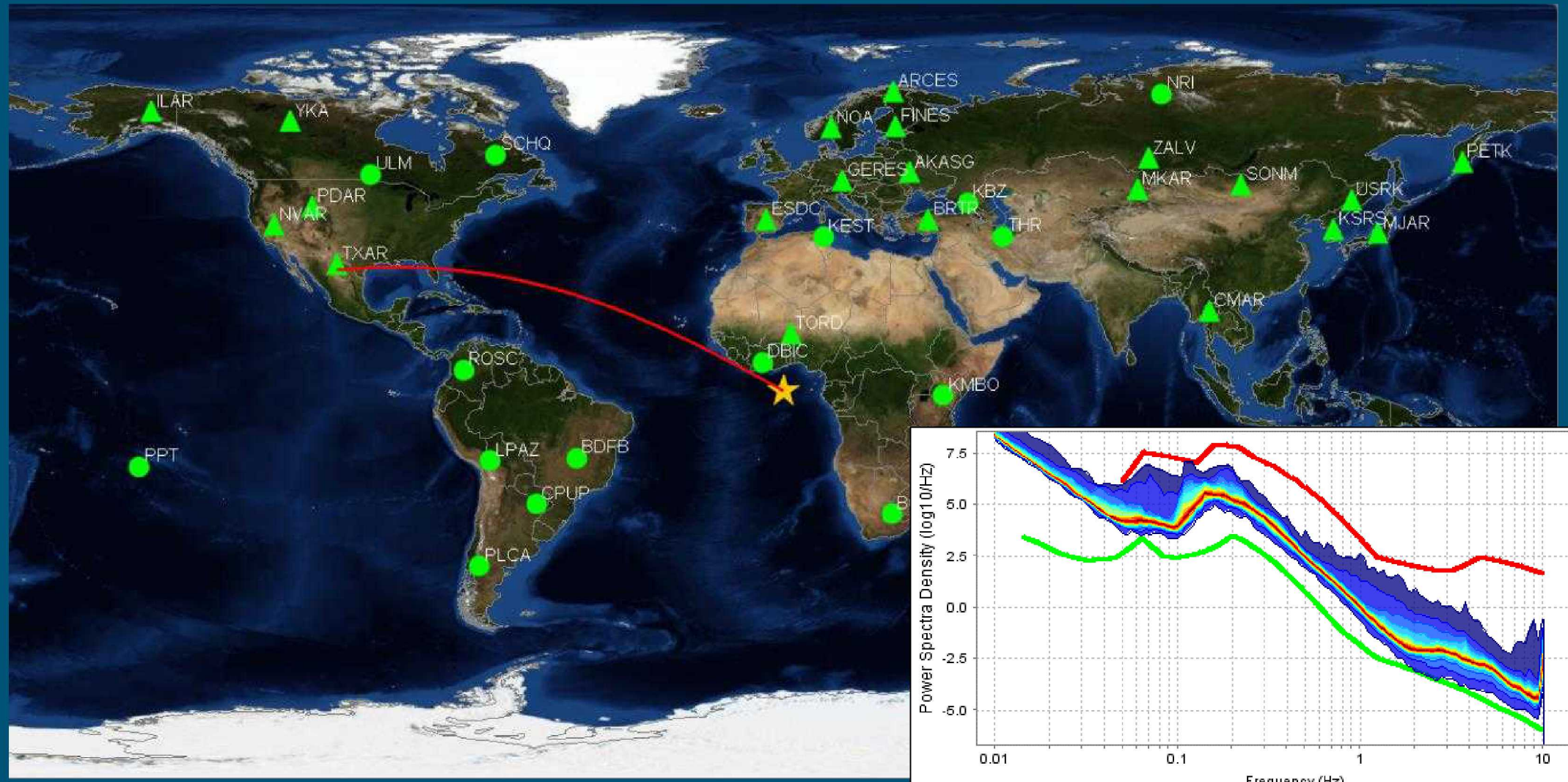
Research Basis

Regional attenuation modeled based on path-weighted geographic regions



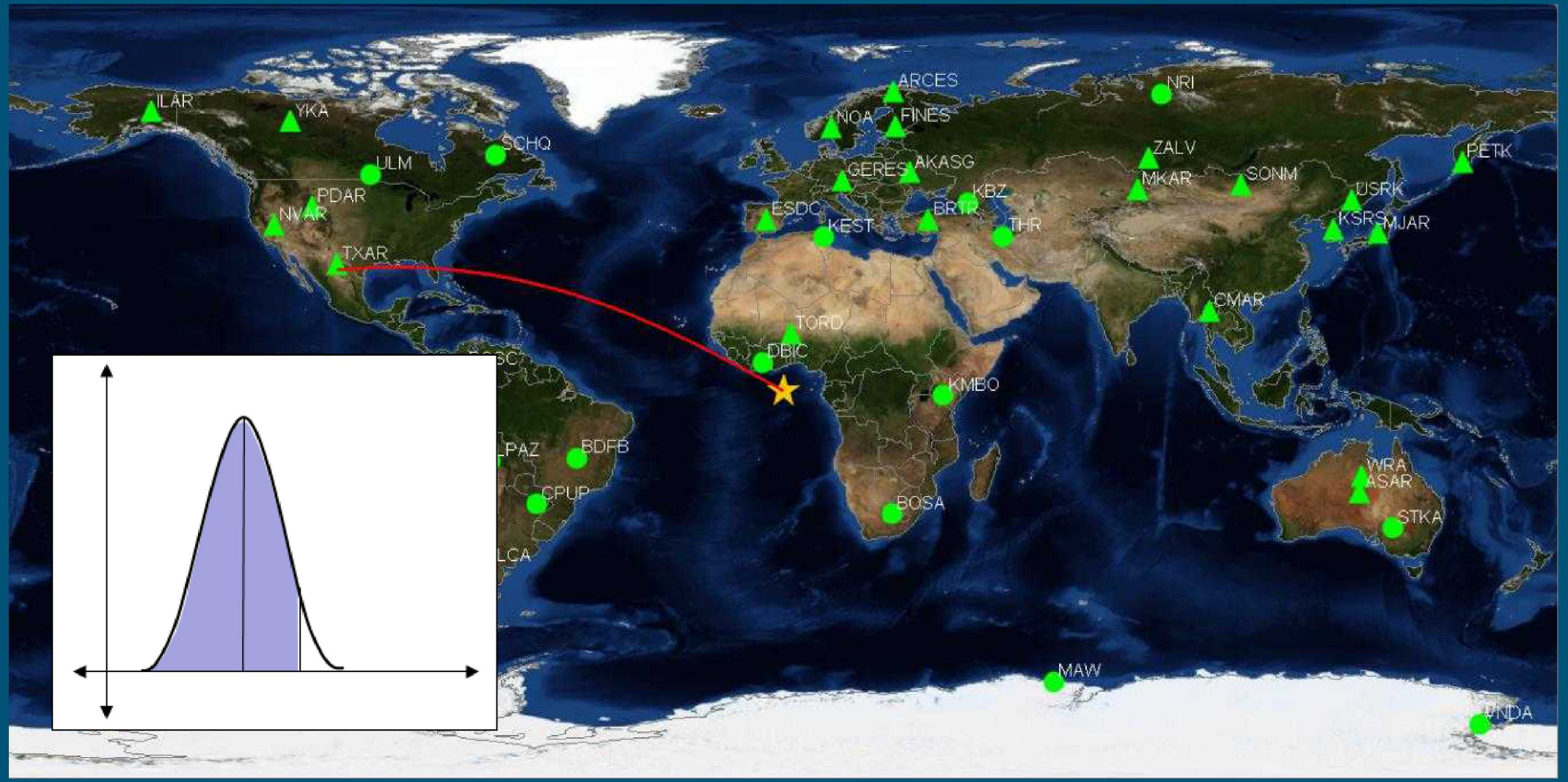
Research Basis

Noise includes empirical site noise and coda from earlier phases



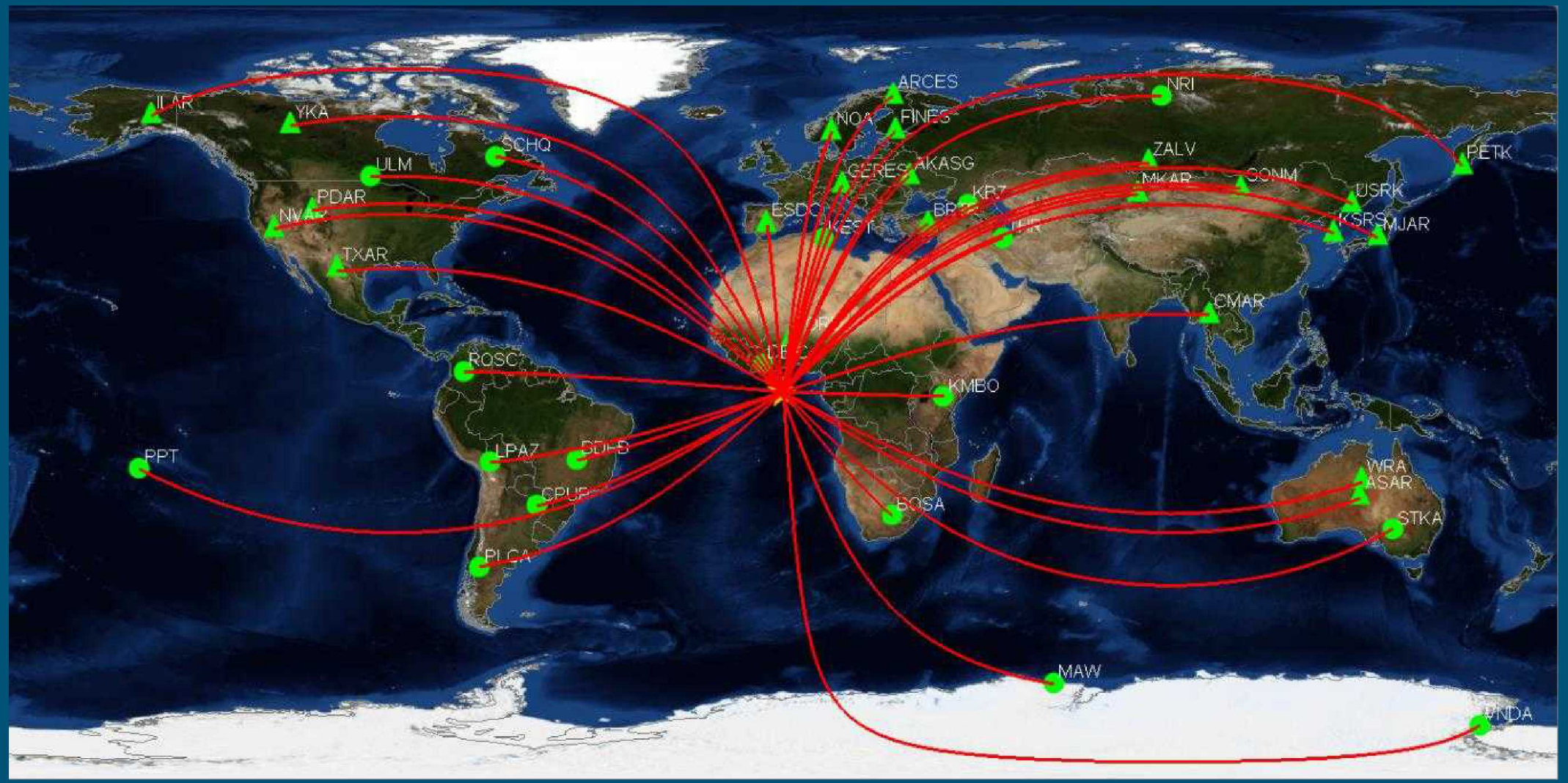
Research Basis

Compute station probability, integrating SNR above detection threshold



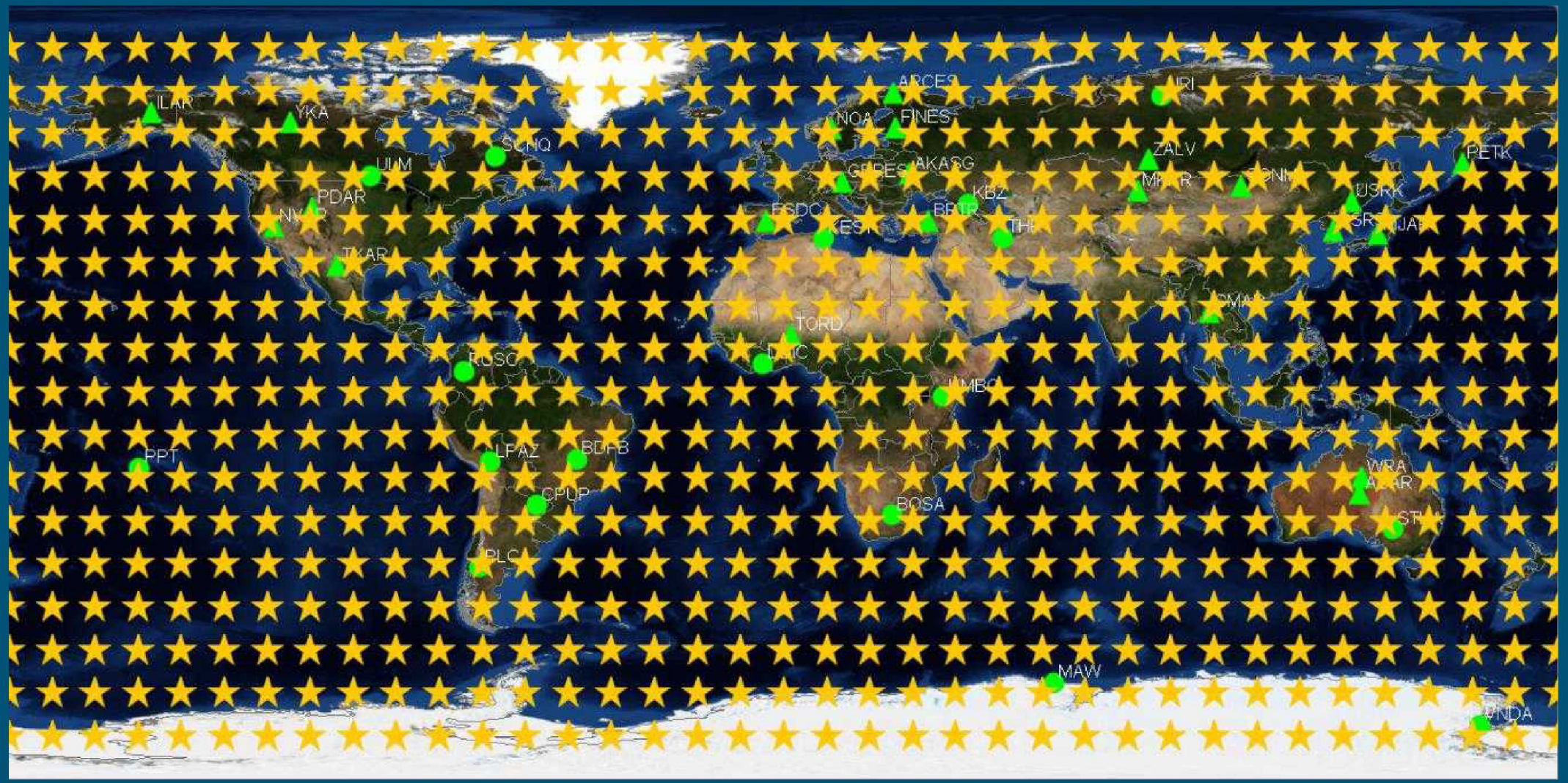
Research Basis

Compute probabilities at every station in the network, combinations to get a network probability



Research Basis

Simulation repeats for any number of source locations



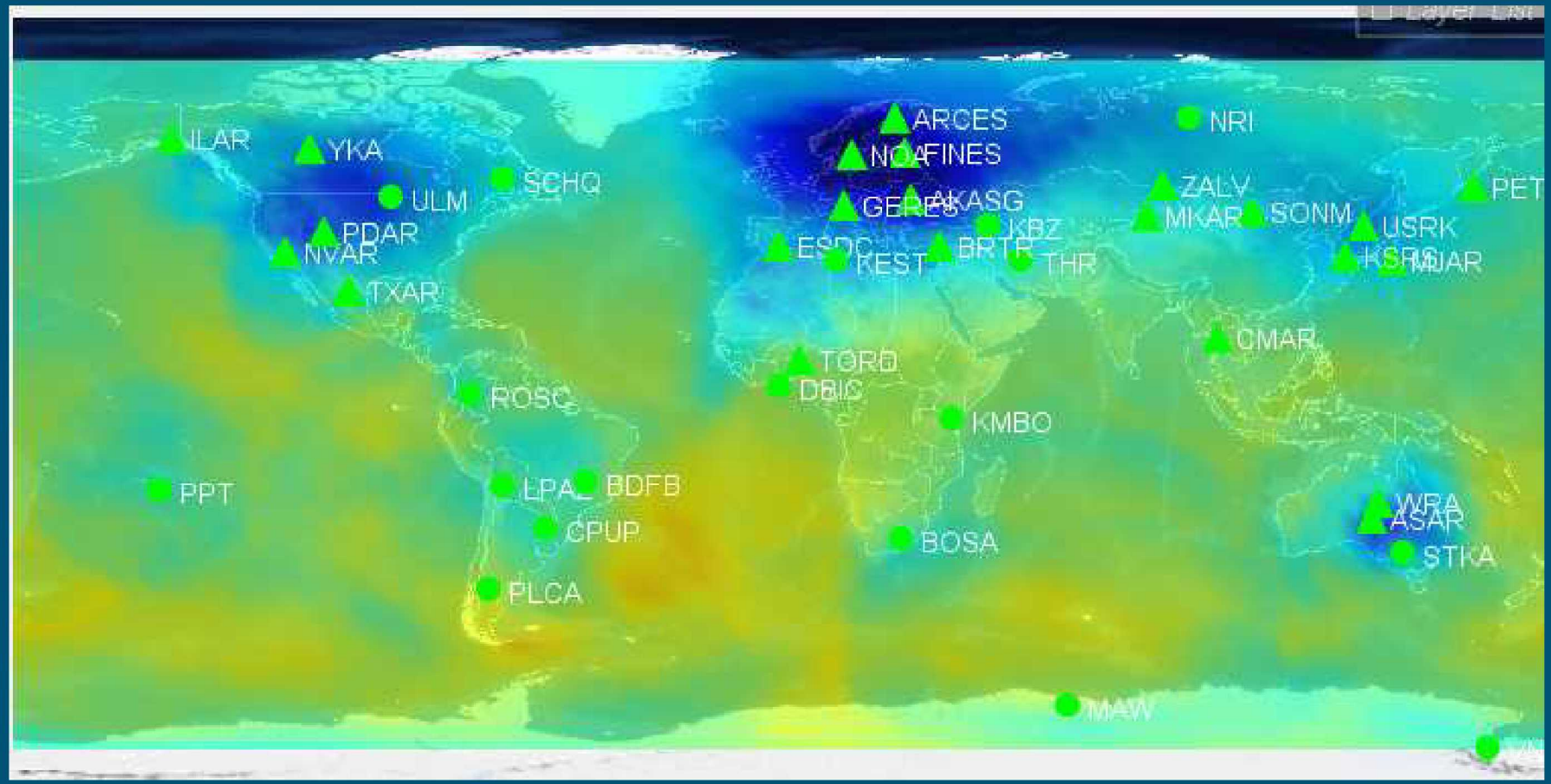
Seismic - Example

Detection:

- Probability of detecting a given magnitude
- Magnitude that may be detected with a given probability

Minimum detectible size with 90% probability

Current IMS Primary Seismic Network, 3-station detection



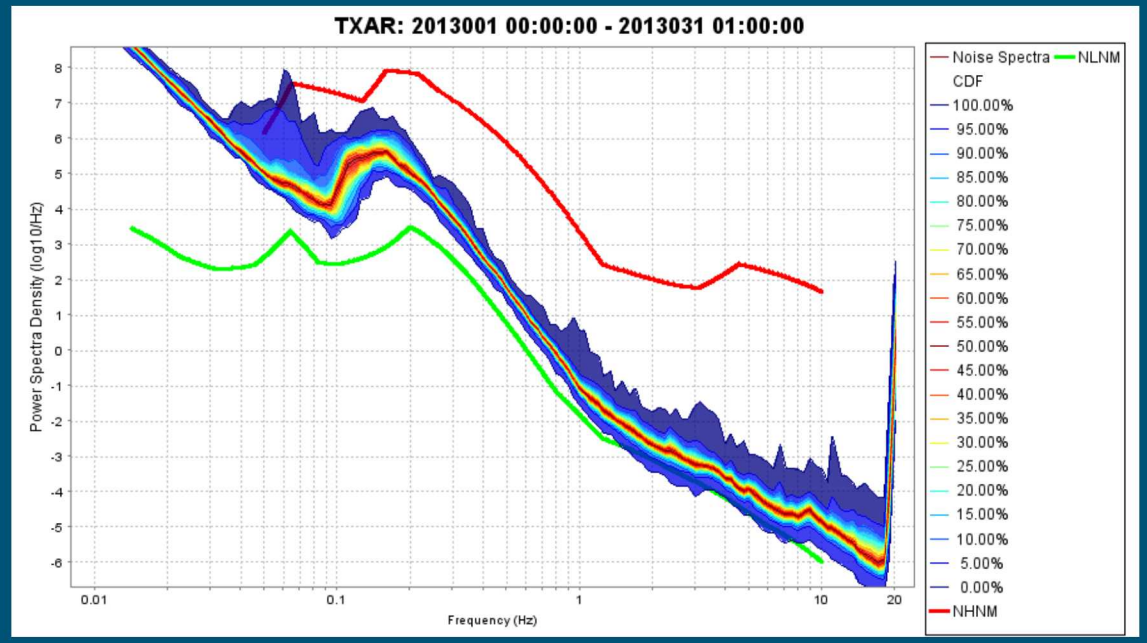
Seismic - Improvements upon earlier research

Monte Carlo simulations

- Bypass assumption of normal distributions

Enhanced empirical site noise models:

- Worked with IDC to obtain empirical site noise data
- Models that vary with time of day and time of year
- Cumulative Distribution Function, no assumption of a normal distribution



Seismic – Depth of Burial / Height of Burst

All the seismic source models assume a scaled depth of burial, so that energy is fully contained within the ground media.

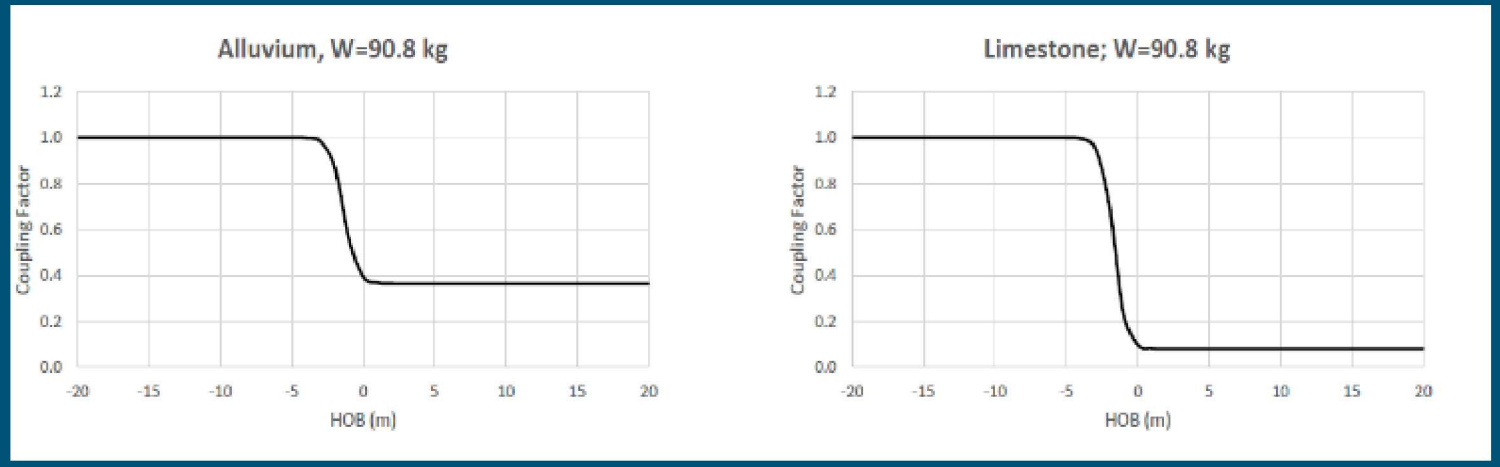
How to account for a shallow or above surface source?

Correction factor for height of burst (Pasyanos & Ford, 2015)

- Based on field experiments

$$\mathrm{Log}A_{s(\mathrm{w})} = \log A_{s'}(\mathrm{w}) + \mathrm{beta3}[\tanh(\mathrm{beta4} * h_s + \mathrm{beta5}) + 1]$$

h_s: scaled height of burst, has units of $(\mathrm{m/kg}^{(1/3)})$

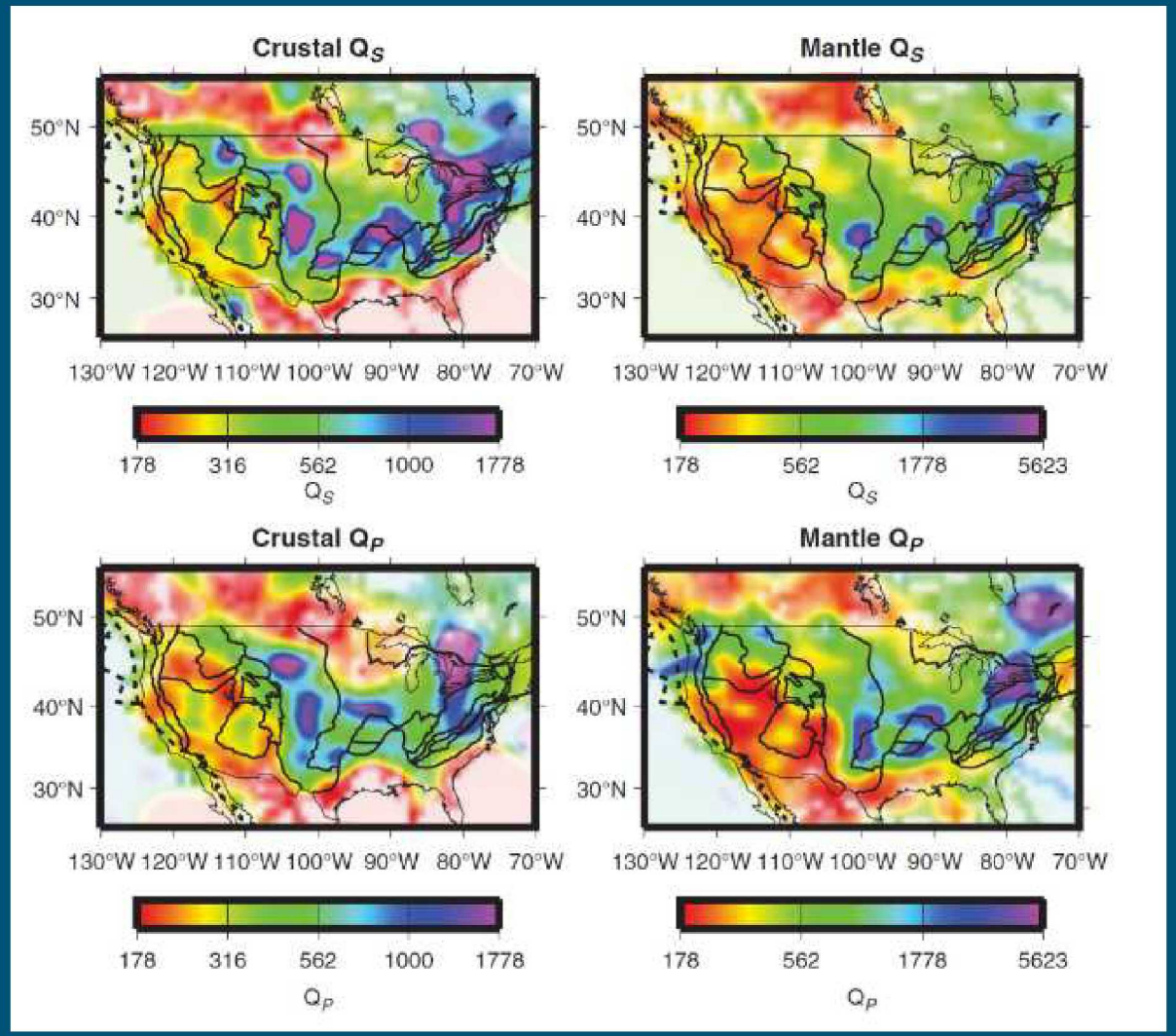


Coefficient	Source Media	
	Alluvium	Limestone
β_1	-3.39	-3.73
β_2	-1.74	-1.74
β_3	-0.22	-0.55
β_4	4.84	4.84
β_5	1.23	1.23

Seismic – 2D Regional Attenuation

Recently added the capability to include regional 2D Q models for computing seismic attenuation:

- Path Averaged Q Calculation
- Frequency dependent



(Pasyanos, 2013)

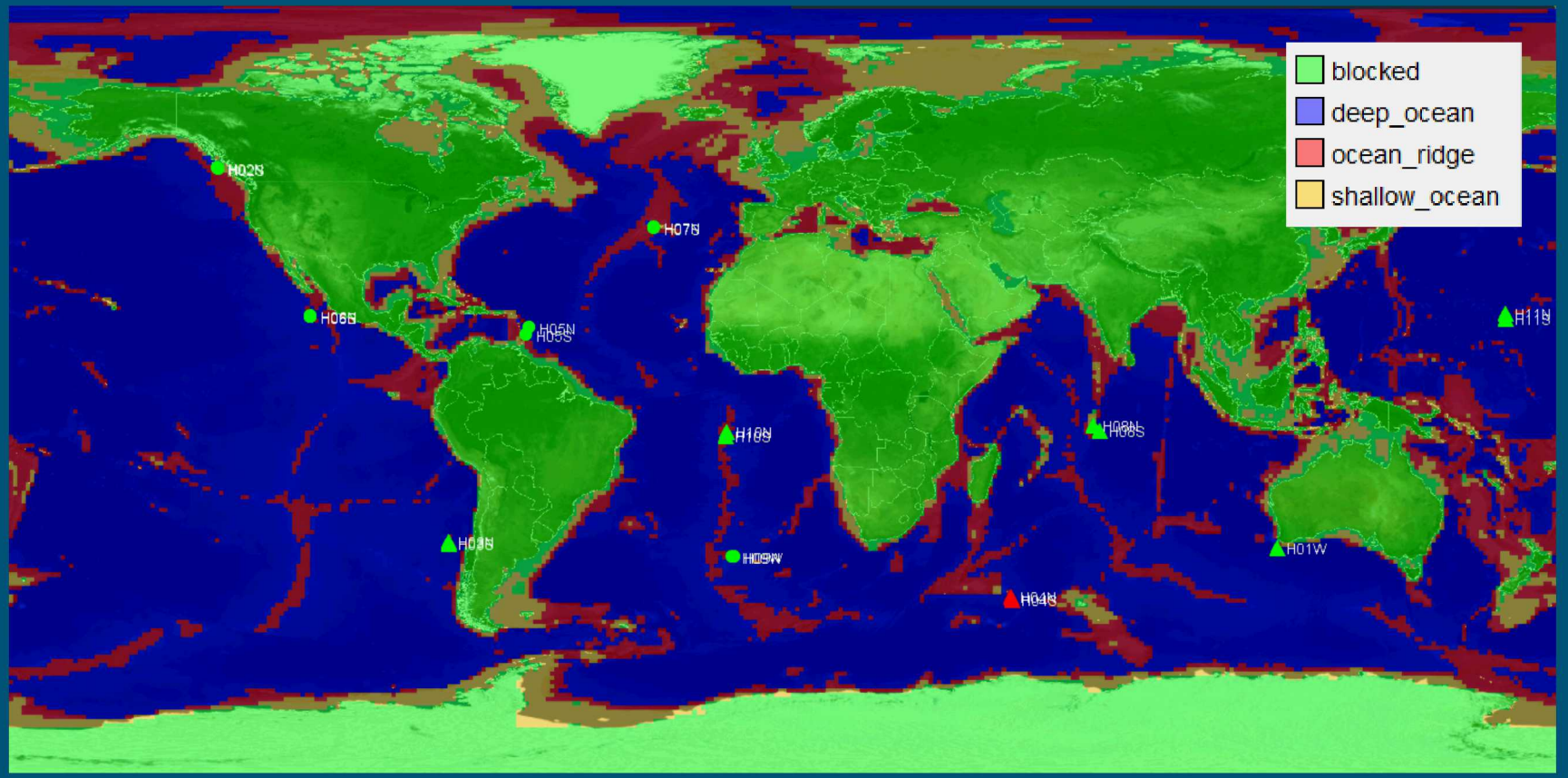
Hydroacoustic

Path attenuation based on bathymetry model

Line-of-sight blockage model.

Does not model reflection / refraction of signal

- Some small localized impact
- large computational increase



Bathymetric derived attenuation model

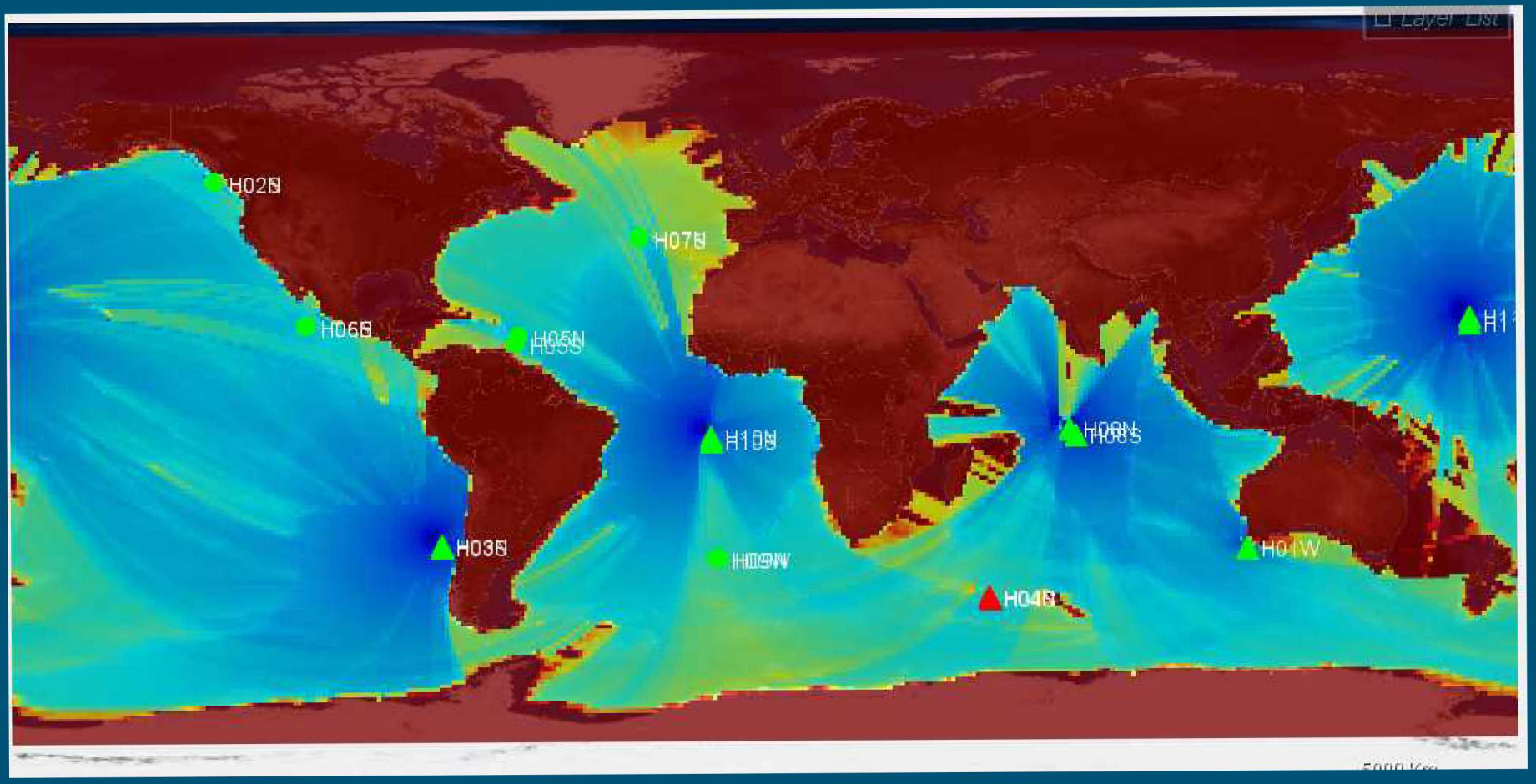
Hydroacoustic - Example

Minimum detectible size with 90% probability

Current 10 station IMS network

- H04 is offline

1-station detection



Infrasound

Presumes that stratospheric signal path dominates detection

Fundamental problems:

- Atmosphere is a dynamic medium
- Research on how to account for those effects is evolving

Utilizes research from:

- Whitaker, et al (2003)
- Green & Bowers (2010)
- Le Pichon, et al (2012)
- Kinney & Graham (1985)

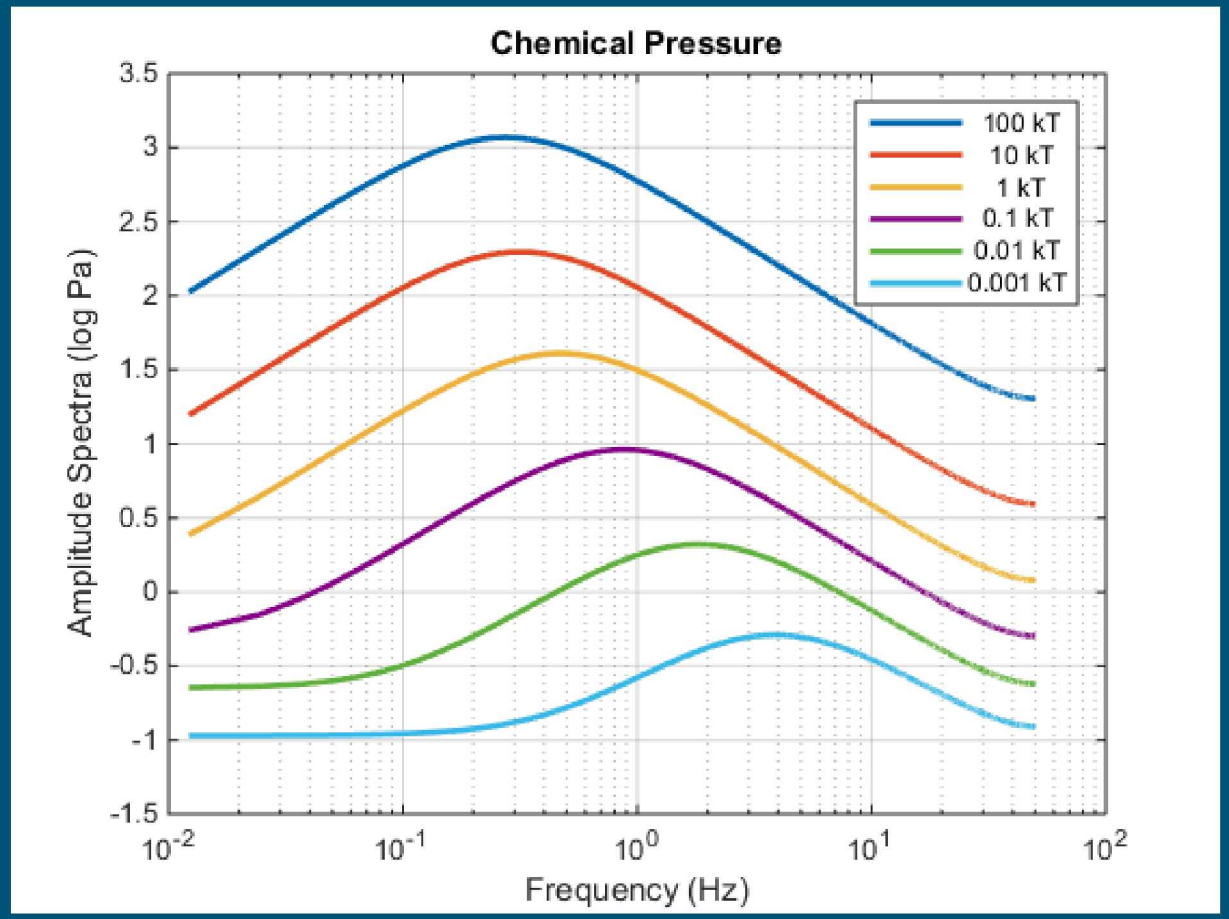
Wind models to support attenuation

- HWM 2007
- HWM 2014

Climatological

- G2S
- ECMWF

Meteorological



Kinney & Graham (1985)

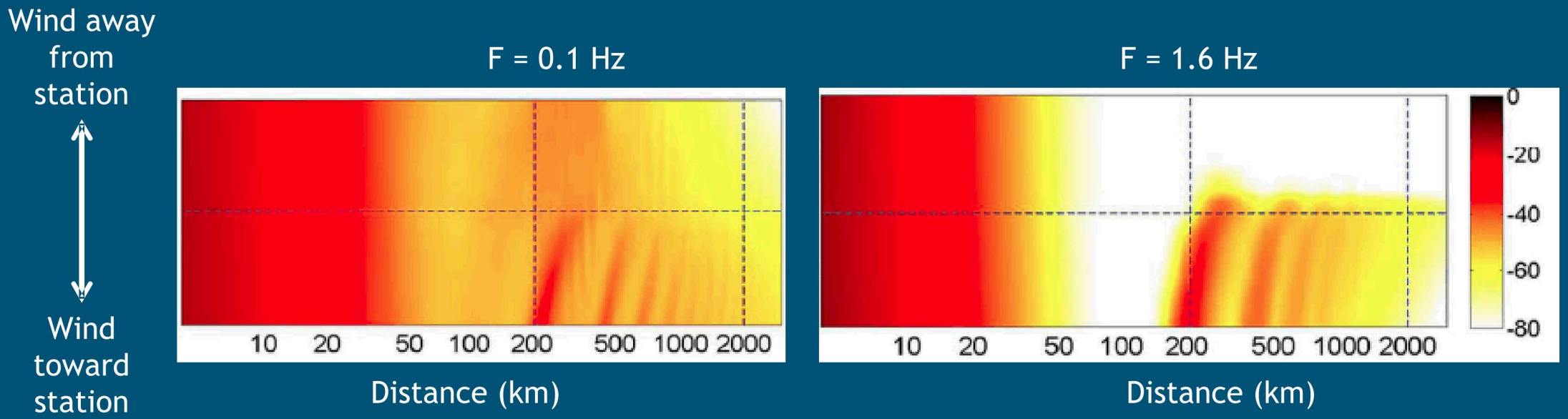
Infrasound – Wind Attenuation

Variable wind conditions affect path attenuation

Earlier attenuation models (Whitaker 2003), only accounted for wind speed and distance:

$$\log atn = 0.018 * v_s - 1.4072 * R$$

More recent attenuation models (LePichon, 2012) incorporate dependence between wind speed, distance, and frequency:



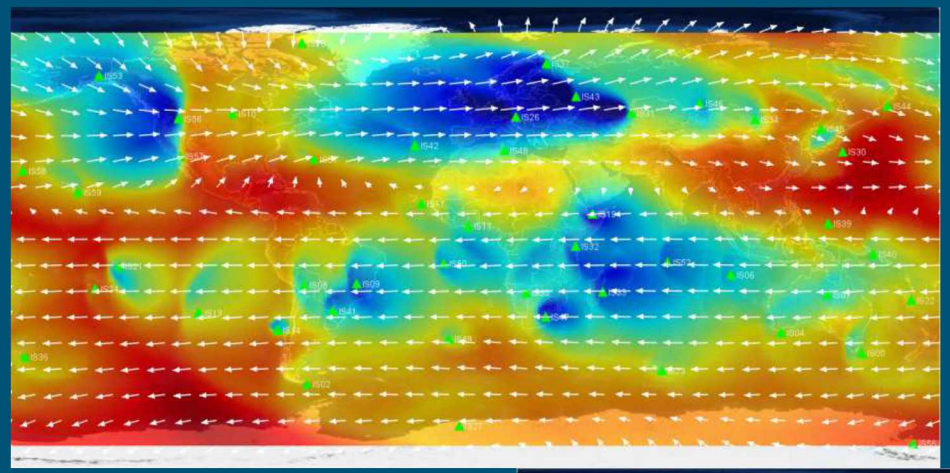
Infrasound – Example

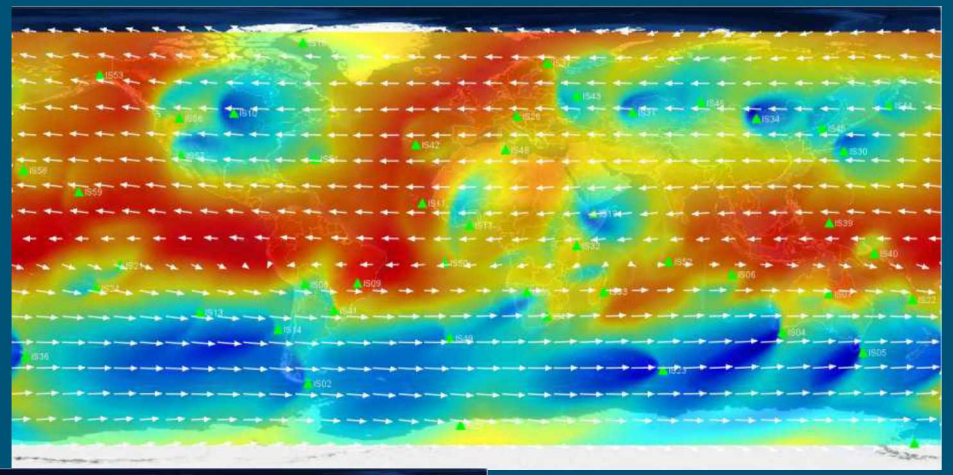
Minimum detectible size with 90% probability

Current 48 station IMS network

2-station detection, HWM 2007 winds, 2013 IDC noise data

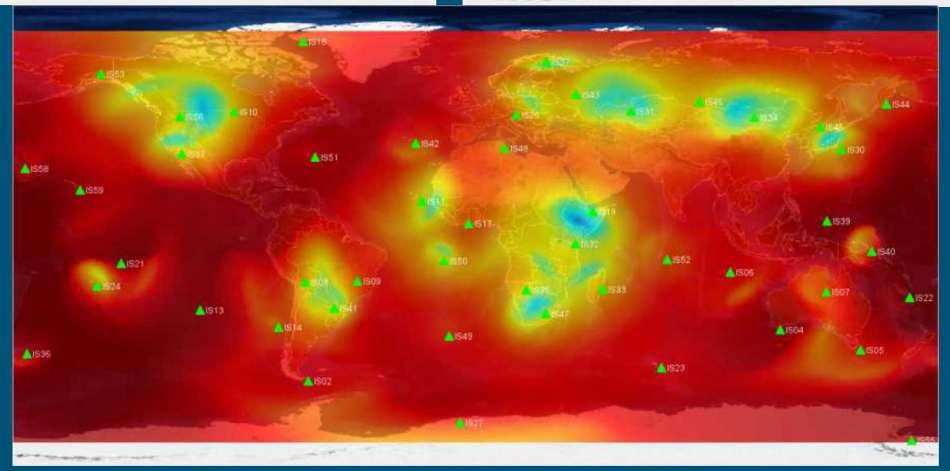
January 1





July 1

No Wind



Summary

Provided an open source tool that applies current modelling research

- https://www.osti.gov/biblio/1337571-netmod
- http://www.sandia.gov/geotess/assets/documents/NetMOD/NetMOD.html

2018 - 19 Enhancements:

- G2S and ECMWF Infrasound Wind Models
- 2D Regional Q Attenuation Models
- Height of Burst (in progress)