A Seismic Detection Network Modeling Tool for the Comprehensive Nuclear-Test-Ban Treaty Organization

B. John Merchant, Eric P. Chael, Christopher J. Young

Sandia National Laboratories

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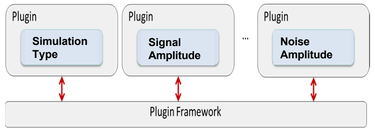
Introduction

Network simulations have long been used to assess the performance of monitoring networks to detect events for such purposes as studying network resilience to outages and planning network upgrades. The standard tool has been the NetSim package, developed in the early 1990s. With correct parameters, NetSim can produce high-quality simulations; however, the package uses an older language (Fortran), has an emphasis on seismic monitoring with limited support for other technologies, limited documentation, and a limited parameter set. Thus, we are developing NetMOD (Network Monitoring for Optimal Detection), a Java-based tool designed to assess the detection performance of seismic ground-based networks. NetMOD's advantages include: utilizes a modern language (Java) that is multi-platform, utilizes modern computing architecture (e.g. multi-core processors), and includes a well-validated default parameter set for the International Monitoring System (IMS) stations.

Design and Implementation

NetMOD is highly configurable by utilizing a plugin-based modular architecture. Plugins are independent components that provide a set of functionality. In the context of NetMOD, plugins will represent different monitoring tasks such as the type of simulation being formed, the method of estimating signal and noise amplitudes, and the data formats for obtaining the geophysical properties.



This software design pattern provides flexibility by allowing the addition or removal of software features via plugins without affecting other functionality.

Configuration File Format

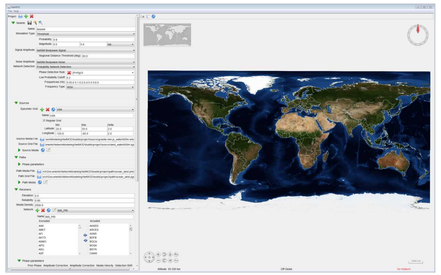
NetMOD uses the libpar file format developed by Robert Clayton of Caltech and widely used by the seismological research community. This format can accommodate comments, as well as the inclusion of the names of the parameters that are being set, making the files much easier to understand and modify. The control parameter, geophysical model, and output file formats used by NetMOD are consistent with the CTBTO libpar simulation configuration files.

```
par=$(NS_CONFIG)/BaselineDesc.par
# Model Declarations
conf=0.95                                   # Default: 0.90
# Three mode parameters
Run-Type=detection                          # Default: detection
Sub-Type=threshold                          # Default: threshold
# Output-Dir=
Verbose-Level=0
Apply-Time-Dependent-Features=0
#!BeginTable EventSizeDesc
        type    | size    | Min-Simul | Max-Simul | Min-GUI | Max-GUI |
units
@mb     mb      4.0     0.5     9.0     -1.0    9.0     MU
@Ms     Ms      3.0     -2.0    6.0     -4.0    7.0
MU#!EndTable
Low-Prob-Cutoff=0.3                         # Default: 0.2
```

User Interface

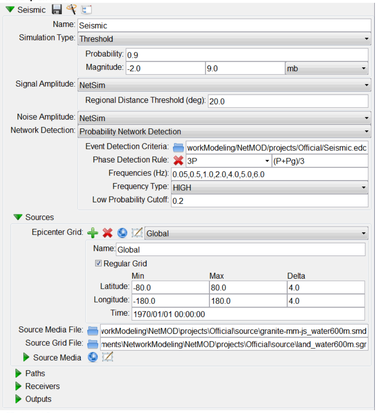
The NetMOD User Interface is designed to give users the ability to easily set up simulations, navigate results and answer many "what-if" questions with minimal effort. Notable features include:

- The ability to create and modify the simulation configuration.
- An integrated map for displaying configuration and results.
- A comparison tool for quickly assessing the differences between two simulations
- An introspection ability to examine the specific details at all levels of the simulation calculations.
- A command-line mode to support the batch execution of simulations from saved configuration files.



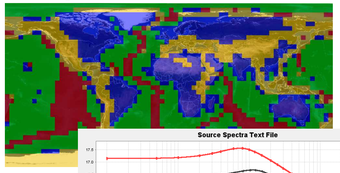
Project Overview

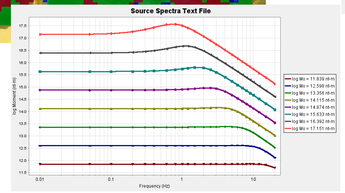
The project configuration panel shows the parameters controlling the overall simulation. The user may interactively visualize, configure, or execute the simulation directly from this panel.

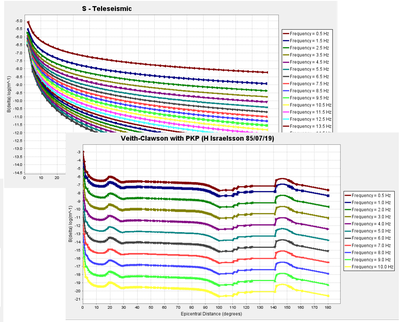


Source and Path Models

The geophysical models for the source and path effects are represented within NetMOD. The source and path regions may be displayed and assigned on the map.

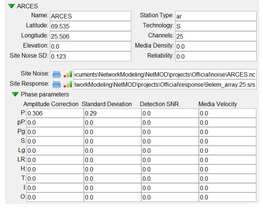


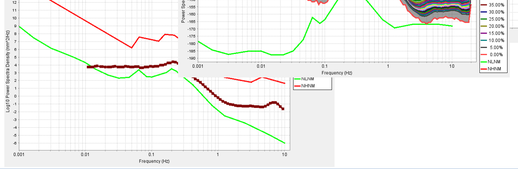


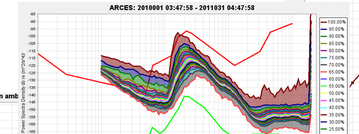


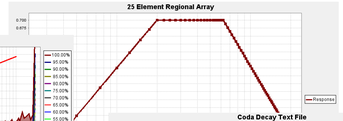
Stations

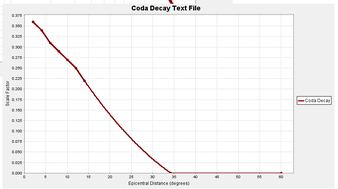
The Stations configuration shows the relevant simulation parameters for each station in the network: ambient noise, secondary phase noise levels, station array gain and amplification corrections, etc.







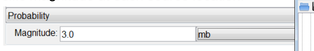




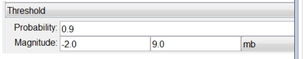
Simulation Type

Presently, NetMOD provides for two types of detection simulations that may be performed:

Probability Simulation computes the probability of the network detecting a seismic event of a specific magnitude at each source location.

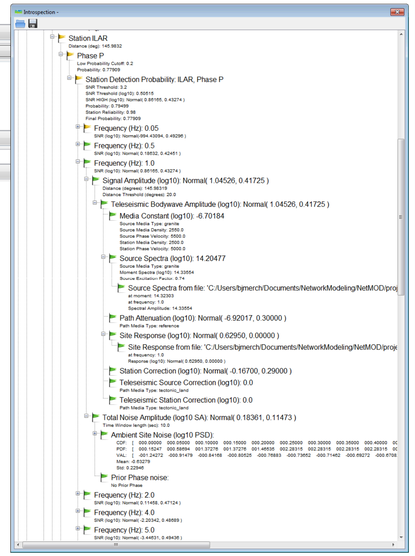


Threshold Simulation computes the magnitude of the event that the network has a specified probability of detecting at each source location.



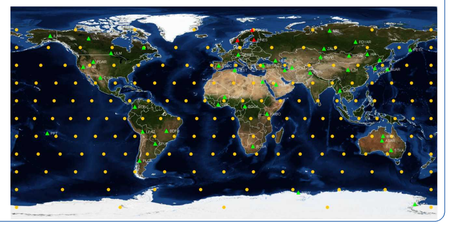
Introspection (Calculation Details)

Trying to determine why a simulation result was calculated requires access to the details of the calculation. NetMOD provides the ability to hierarchically examine the calculation details at each station for a selected source position



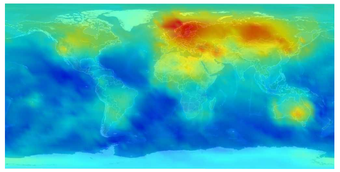
Sensor Networks & Source Locations

The integrated map in NetMOD shows station and source locations. In this figure the stations are represented by green or red triangles, depending on whether they are selected, while event epicenters are represented by orange circles.

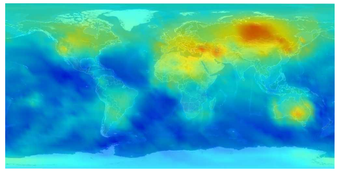


Simulation Results

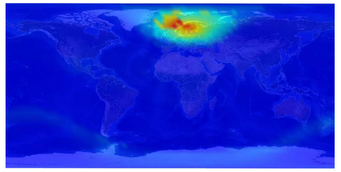
90% Threshold Detection, Full Network



90% Threshold Detection, Less 3 Stations



90% Threshold Detection, Difference



Simulation results are shown as a color overlay on an interactive map (zoom, pan, etc.). The cursor can be used to find the value at a given position. Various types of reference information (station locations, political boundaries, etc.) can also be shown to facilitate the interpretation. The map allows the user to toggle between overlays for multiple simulation. NetMOD also has the ability to difference the simulation results and display those differences.

Development Status

Version 1.0 of NetMOD was delivered to the CTBTO in January, 2014. This version includes the ability to perform seismic detection simulations. The CTBTO is currently making use of NetMOD as their primary means for performing seismic detection simulations.

Additional plugins for NetMOD are currently being developed to support hydroacoustic and infrasound detection simulations. These extensions, when completed, will be included in a version 2.0 of NetMOD that will be made available to the CTBTO.

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