An Assessment of Proposed Upgrades to the ANSS Backbone and GSN

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Introduction

In this work we assess three proposed upgrade scenarios to the Advanced National Seismic System (ANSS) and the Global Seismograph Networks (GSN) using three different measures of network capability.

The three measures of network capability are:

1) minimum Mw detection threshold;
2) response time of the automatic processing system and;
3) theoretical earthquake location errors.

The three proposed upgrades scenarios include:

1) the installation of six additional ANSS backbone stations within the United States;
2) the installation of a nine station network surrounding the Caribbean Sea and;
3) upgrading fifteen GSN tape-based stations to real-time telemetry.

Noise Based Detection Modeling

Methods

For each 1 degree cell from lat=20.0 to 55.0 and lon=-60.0 to –130.0
Calculate distance to each ANSS backbone station, Δ
For each cell-station path
Step through periods from 0.01-120s (100-0.0083Hz) in 0.225 octave intervals.

1. Compute shear-wave moment (Mo) assuming source corner of fc=1.0/period.

   $Mo = 2.29\sigma r^3$ dyne-cm (*Brune* 1970, 1971)

   where $\sigma = 1.0 \times 10^6$ effective stress

   $r = \frac{2.21\beta}{2\pi fc}$ fault dimension in cm (*Brune* 1970, 1971).

   where β = shear wave velocity = 3.5km/s
   fc = source corner frequency

2. Compute Moment Magnitude (Mw).

   $Mw = 0.667 \log(Mo) - 10.7$ (*Kanimori*, 1977).

3. Find angular frequency (*fm*), by bisection, where Brune source spectrum is a maximum given USNSN short-period detection filters (0.5-12Hz) and Q.

4. Calculate Shear-wave amplitude (*As*) due to Brune Source model, delta, and USNSN short-period detection filters.

   $As = \frac{Mo}{4\mu\beta} \cdot \frac{fmfc^2}{fm^2 + fc^2} \cdot \frac{fc^2}{\Delta}$ (*Brune* 1970, 1971).

   where μ = rigidity
   fc = source corner frequency
   fm = effective frequency where amplitude is maximum
   β = shear-wave velocity (3.5km/s)
   Δ = source-receiver distance.

5. Apply attenuation to Shear-wave amplitude (As). Q(f) obtained from source region in Lg Q models. (Q from McNamara and Wesson, 2004)

   $As = \frac{As}{\Delta^\gamma} \cdot e^{\frac{-\pi fm\Delta}{Q\beta}}$ where γ = geometric spreading is a function of distance

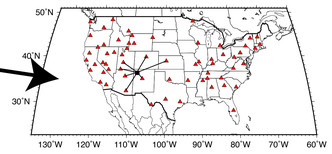
   if $\Delta < 70$ $\gamma = -1.0$
   Δ 70-150 $\gamma = +1.1$
   $\Delta > 150$ $\gamma = -0.5$

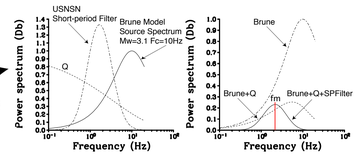
6. Convert and normalize P-wave amplitude (*Ap*) form shear-wave amplitude (*As*). Ratio determined from P and S-wave source spectrum comparisons.
   Ap = As/8.0

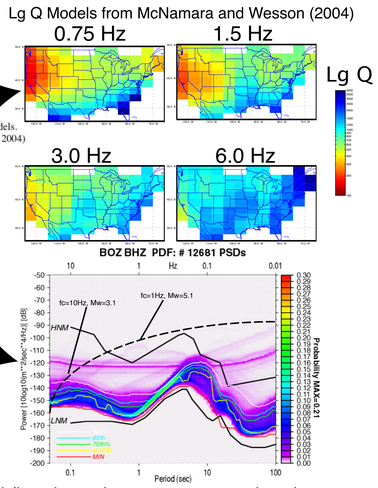
7. Convert P-wave amplitude to power (*P*) in dB.
   $P = 10\log(Ap^2)$

8. Compare power from quake with 80th percentile power for station (dB80).
   If P > dB80 then declare a successful detection.

Declare minimum Mw detection for cell if detected by at least 5 ANSS backbone stations.



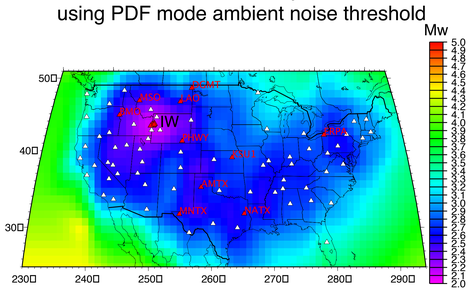




The Dashed line shows the powers generated at the source corner frequency for a range of magnitudes at 1 degree from BOZ.

ANSS Backbone Expansion in 2003-2004

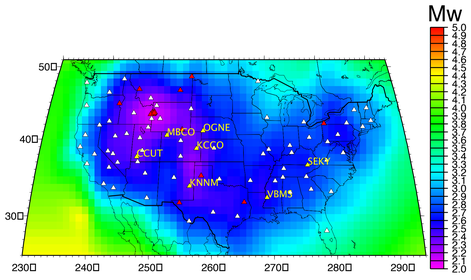
Brune Minimum Mw Detectable by the ANSS Backbone using PDF mode ambient noise threshold



The detection capability of the ANSS backbone has improved with the addition of 18 new broadband digital stations during the 2003-2004 field seasons.

The new 8 station regional Wyoming network (IW) has lowered detection thresholds in that region to Mw~2.1.

Planned ANSS Backbone Expansion in 2005



Using the PDF mode noise levels at existing ANSS stations, we estimate the noise characteristics of 7 planned ANSS backbone stations for 2005.

We then calculate the theoretical Mw detection threshold for the planned network based on the Brune source modeling procedure described to the left.

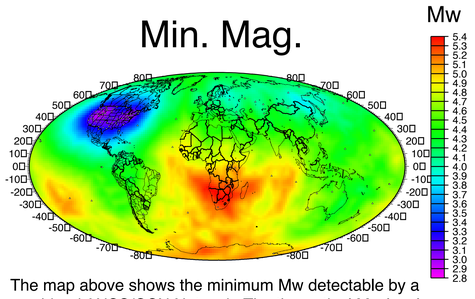
This exercise demonstrates the reduction in Mw detection threshold with the addition of several stations.

ANSS/GSN Combined Capabilities

In this section we examine three separate measures of capability for a combined ANSS backbone and Global Seismograph Network (GSN). These include:

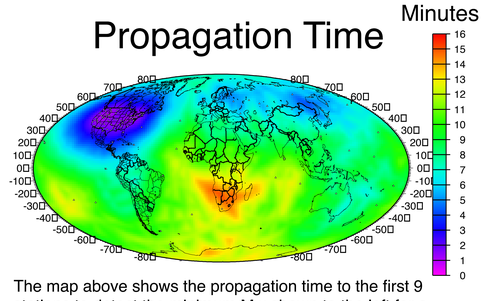
1) Minimum magnitude threshold (using methods discussed to the left).
2) Propagation time to a detection by the real-time system at the ANSS National Operations Center (NOC).
3) Theoretical Location error.

Min. Mag.



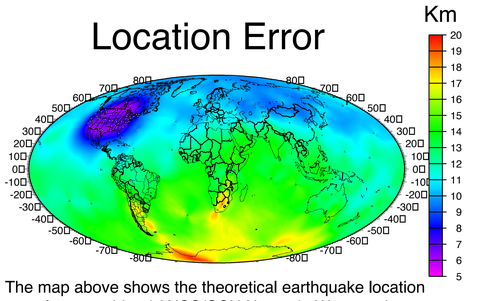
The map above shows the minimum Mw detectable by a combined ANSS/GSN Network. The theoretical Mw levels are determined based on ambient noise conditions at each stations. (see method discussion to the left).

Propagation Time



The map above shows the propagation time to the first 9 stations to detect the minimum Mw shown to the left for a combined ANSS/GSN Network. The theoretical travel times are determined using the Tau-P method.

Location Error



The map above shows the theoretical earthquake location error for a combined ANSS/GSN Network. We map the length of the major axis of the error ellipse in km. For this preliminary analysis we assume Surface source and use a P-wave fist arrival at each real-time station.

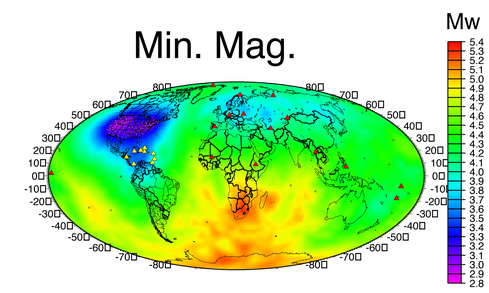
Improved Capabilities with Proposed GSN Upgrades

In this section we examine the capability improvements for two proposed GSN upgrade scenarios.

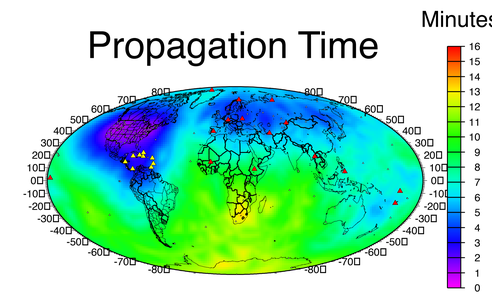
These include:

1) Deployment of a 9 station network in the Caribbean (yellow triangles)
2) Upgrade 15 existing GSN stations to a real-time telemetry system (red triangles).

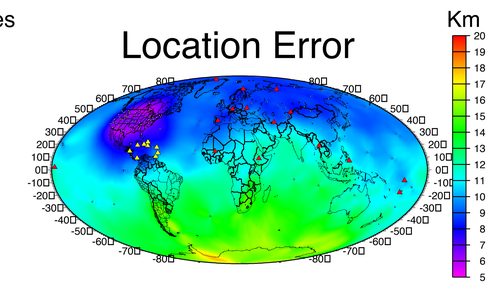
Min. Mag.



Propagation Time

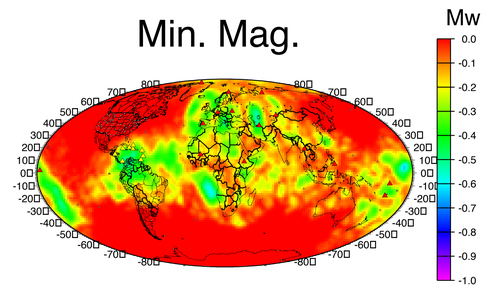


Location Error



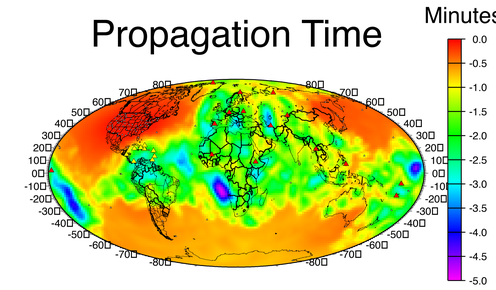
Difference Maps Between Existing GSN and Upgrades

Min. Mag.



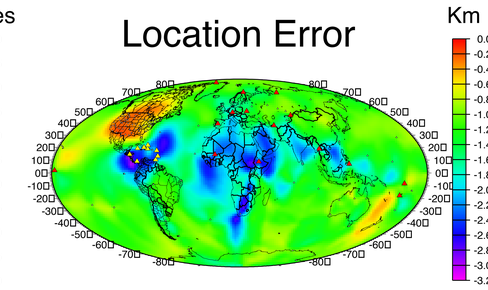
Mw detection capability is improved by up to 0.7 magnitude units in a broad region with the proposed GSN upgrades.

Propagation Time



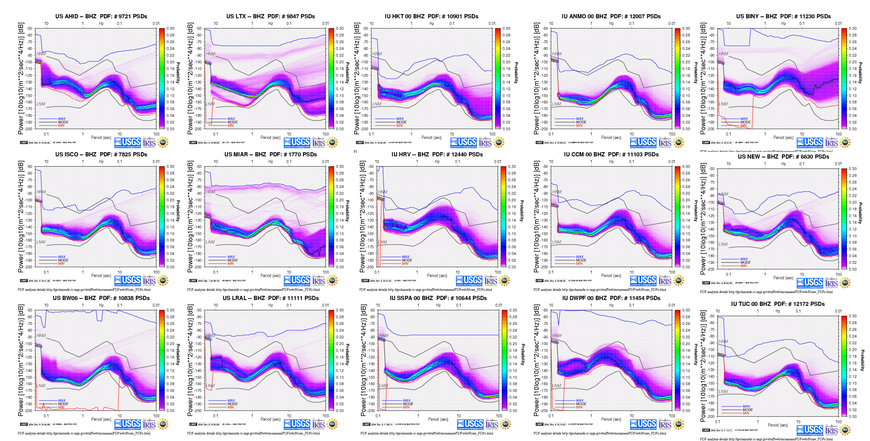
The time required to compute an earthquake solution is significantly reduced in a broad region with the proposed GSN upgrades. In tsunamigenic regions such as the Caribbean, response time is improved by 3 minutes.

Location Error



Location error is reduced by as much as 2.0-3.0 km in a broad region with the proposed GSN upgrades.

Ambient Noise Characterization



Summary and Conclusions

For each upgrade scenario we demonstrate that considerable improvement in network magnitude threshold, response time and earthquake location error can be achieved. We also demonstrate that the technique used in this analysis is valuable for quantifying seismic network capability improvements and a useful tool for network design planning.

References

Brune, J., Tectonic stress and the spectra of seismic shear waves from earthquakes, J. Geophys. Res., 75, 4997-5009, 1970.
Brune, Correction, J. Geophys. Res., 76, 5002,1971.
Kanimori, The energy release in great earthquakes, J. Geophys. Res, 82, 2881-2987, 1977
McNamara, D. and R. Buland, Ambient noise characteristics in the Continental US, Bull. Seis. Soc. Am., in review, 2003.
R. Wesson, D. McNamara, H. Benz, A. Frankel, A tomographic method to calculate Lg Q across the continental US, EOS Trans. AGU, 84, 2003.