A Preliminary Assessment of Proposed Upgrades for the Advanced National Seismic System (ANSS) and Global Seismograph Network (GSN)

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OBJECTIVE:

In this report we assess two potential ANSS and GSN upgrade scenarios using three different capability measures to demonstrate overall network improvement.

The two potential station upgrade scenarios are:

1. Convert 15 media based GSN stations to real-time satellite telemetry systems.
2. Install 9 new stations surrounding the Caribbean Basin region.

The three capability measures analyzed for each upgrade scenario are:

1. Minimum moment magnitude (Mw) earthquake detection threshold.
2. P-wave propagation time to the minimum number of stations required for a solution.
3. Theoretical earthquake location error.

METHODS and ASSUMPTIONS:

Detection Threshold Modeling

The detection analysis method used in this report is unique in that it compares modeled earthquake amplitudes (Brune 1970, 1971) to the real ambient noise conditions at every station in the network to determine a global grid of minimum detectable Mw (Kanimori, 1977). As a part of routine operations at the ANSS NOC we continuously monitor the background noise conditions at every station in the ANSS and GSN network (McNamara and Buland 2004). For an earthquake to be detected in our model, its amplitude must exceed the background noise levels by a factor of two after path corrections have been made for attenuation (Wesson et al., 2003). Each cell in the detection model represents the smallest earthquake that can be detected by the stations used in the simulation. The nine stations included in the earthquake solution are chosen by the signal/noise level and not necessarily due to proximity to the earthquake source to the recording station.

For simulations that include stations that do not yet exist, we can assume the noise conditions of existing stations in similar environments or interpolate between nearby existing stations. This enables us to evaluate the effect of adding new stations to the network and test the changes in earthquake detection levels.

Propagation Time Modeling

The propagation time modeling method is an extension of the detection modeling discussed in the previous section. It computes the travel-time of the first arriving P-wave, using the Tau-P method and the IASPI91 earth model, to first nine stations that detected the minimum Mw earthquake determined in the global detection grid. If larger earthquakes are considered, propagation times could be smaller however, this approach gives us a worse case scenario. P-wave propagation time should not considered an absolute measure of NEIC response time but instead is the delay time required before the NEIC can begin computing a solution. Additional time would be required for automated systems to compute the earthquake location and magnitude.

Theoretical Earthquake Location Error

For this measure of capability we compute a global grid of theoretical earthquake location error for a combined ANSS/GSN Network. We map the length (km) of the major axis of the earthquake epicenter error ellipse. For this preliminary analysis we make three essential assumptions: 1) a standard uniform phase pick error for each station in the network is made, 2) a surface earthquake source is used and, 3) we model only the P-wave first arrival at each real-time station. No secondary phases are currently considered.

RESULTS:

ANSS and GSN Upgrade Scenarios

1. Convert 15 media based GSN stations to real-time satellite telemetry systems.

Detection Threshold Modeling Results (Figures 1, 2 and 3)

In figure 1 we map the minimum moment magnitude (Mw) earthquake for an existing network configuration of 130 existing real-time telemetered ANSS and GSN stations (small white triangles). The detection threshold for the existing networks is mapped in a 2 degree global grid (Figure 1). Figure 2 shows the Mw detection threshold if 15 media-based stations were upgraded to real-time telemetry (large red triangles). Figure 3 is a map of the difference between the existing network and upgrade scenarios 1 and 2. Results vary due to the uneven distribution of stations however, Mw detection capability is improved by up to 0.7 magnitude units in a broad region with the proposed GSN upgrades. Regions with the most improvement due to upgrading 15 GSN statons to real-time telemetry include Europe, northern Africa, Asia and the Pacific Ocean.

Propagation Time Modeling Results (Figures 4, 5 and 6)

In figure 4 we map the P-wave propagation time of an earthquake for an existing network configuration of 130 existing real-time telemetered ANSS and GSN stations (small white triangles). The propagation time for the existing networks is mapped in a

2 degree global grid (Figure 4). Figure 5 shows the propagation time if 15 media-based stations were upgraded to real-time telemetry (large red triangles). Figure 6 is a map of the difference between the existing network and upgrade scenarios 1 and 2. Propagation time reductions of 1-5 minutes are achieved in specific geographic regions with significantly increased station coverage. The time required to compute an earthquake solution is significantly reduced in a broad region including Europe, northern Africa, Asia and the Pacific Ocean. Specific regions in Africa and the Pacific are improved by as much as 5 minutes. In the tsunamigenic region of Sumatra, response time is reduced by approximately 3 minutes.

Theoretical Earthquake Location Error Results (Figures 7, 8 and 9)

In figure 7 we map the theoretical location error of an earthquake for an existing network configuration of 130 existing real-time telemetered ANSS and GSN stations (small white triangles). The location error for the existing networks is mapped in a 2 degree global grid (Figure 8). Figure 9 shows the location error if 15 media-based stations were upgraded to real-time telemetry (large red triangles). Figure 9 is a map of the difference between the existing network and upgrade scenarios 1 and 2. Location error is reduced by as much as 2.0-3.0 km in a broad region with the proposed GSN upgrades. The most notable improvements due to upgrade scenario 1 occur in Africa, India and Indonesia.

2. Install 9 new stations surrounding the Caribbean Basin region.

Detection Threshold Modeling Results (Figures 1, 2 and 3)

The detection threshold for the existing networks is mapped in a 2 degree global grid (Figure 1). Figure 2 shows the Mw detection threshold if 9 stations are deployed surrounding the Caribbean Basin (large yellow triangles). Figure 3 is a map of the difference between the existing network and upgrade scenarios 1 and 2. With upgrade scenario 2, reductions of 0.5-0.6 Mw units are achieved in the Caribbean basin.

Propagation Time Modeling Results (Figures 4, 5 and 6)

The propagation time for the existing networks is mapped in a 2 degree global grid (Figure 4). Figure 5 shows the propagation time if 9 stations are deployed surrounding the Caribbean Basin (large yellow triangles). Figure 6 is a map of the difference between the existing network and upgrade scenarios 1 and 2. Propagation time reductions of up to 3 minutes are achieved in the tsunamigenic regions of the Caribbean with the addition of the 9 proposed stations.

Theoretical Earthquake Location Error Results (Figures 7, 8 and 9)

The location error for the existing networks is mapped in a 2 degree global grid (Figure 8). Figure 9 shows the location error if 9 stations are deployed surrounding the Caribbean Basin (large yellow triangles). Figure 9 is a map of the difference between the existing network and upgrade scenarios 1 and 2. Location error is reduced by as much as 2.0-3.0 km for much of central America and the Caribbean basin.

DISCUSSION

These results are preliminary and may change slightly as additional work is completed on the theory and methods behind the calculations. More results validation is required as well as additional error analysis. However, when completed this work can be converted into a useful tool for network monitoring, design, and planning. It should be possible to compute the three capability measures for any configuration of planned or existing stations given the necessary system inputs (i.e. noise levels and station locations). For example, when locations of planned AFTAC and IMS stations are provided to the NEIC, we will be able to assess the impact they will have on our operations. Future improvements will include real, rather than assumed, station phase pick errors, mapping noise level probability into the detection model, and a fourth measure of network capability, calculation of theoretical magnitude error.

REFERENCES

Brune, J., Tectonic stress and the spectra of seismic shear waves from earthquakes, J. Geophys. Res., 75, 4997-5009, 1970.

Brune, J., Correction, J. Geophys. Res., 76, 5002,1971.

Kanimori, H., 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., 94, 1517-1527, 2004.

Wesson, R., D. McNamara, H. Benz, A. Frankel, A tomographic method to calculate Lg Q across the continental US, EOS Trans. AGU, 84, 2003.

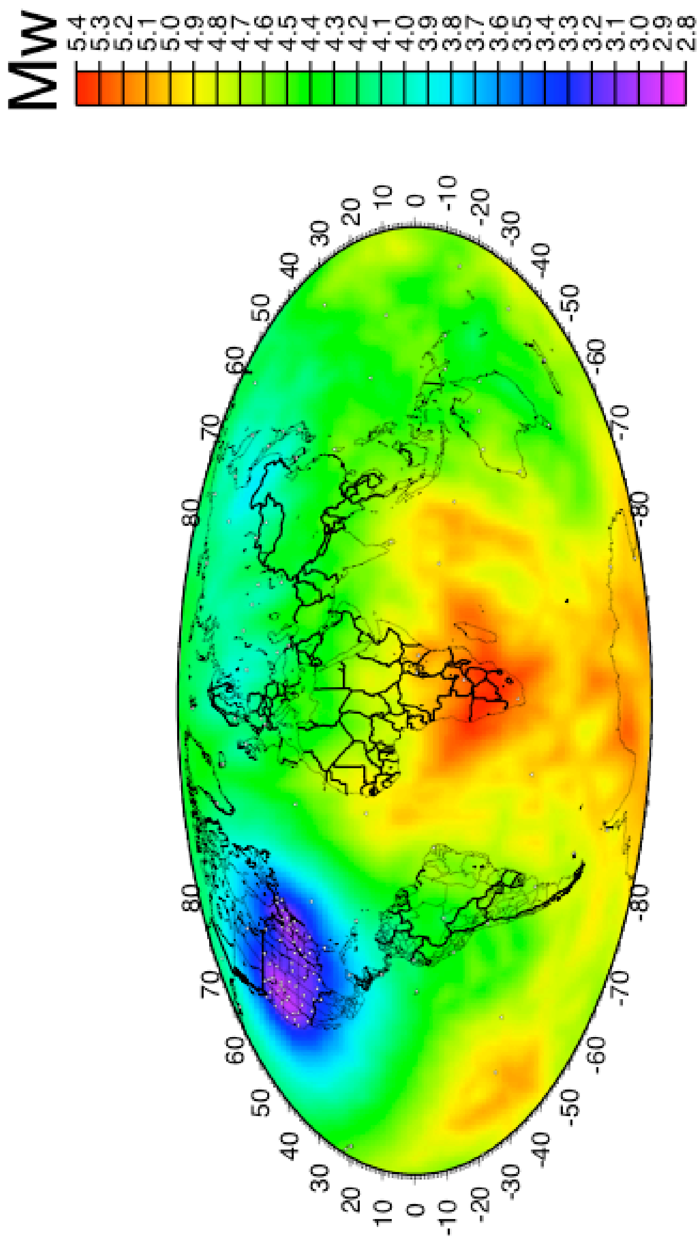

FIGURE 1: ANSS/GSN modeled minimum Mw detection threshold. Existing real-time ANSS and GSN stations are shown as small white triangles.

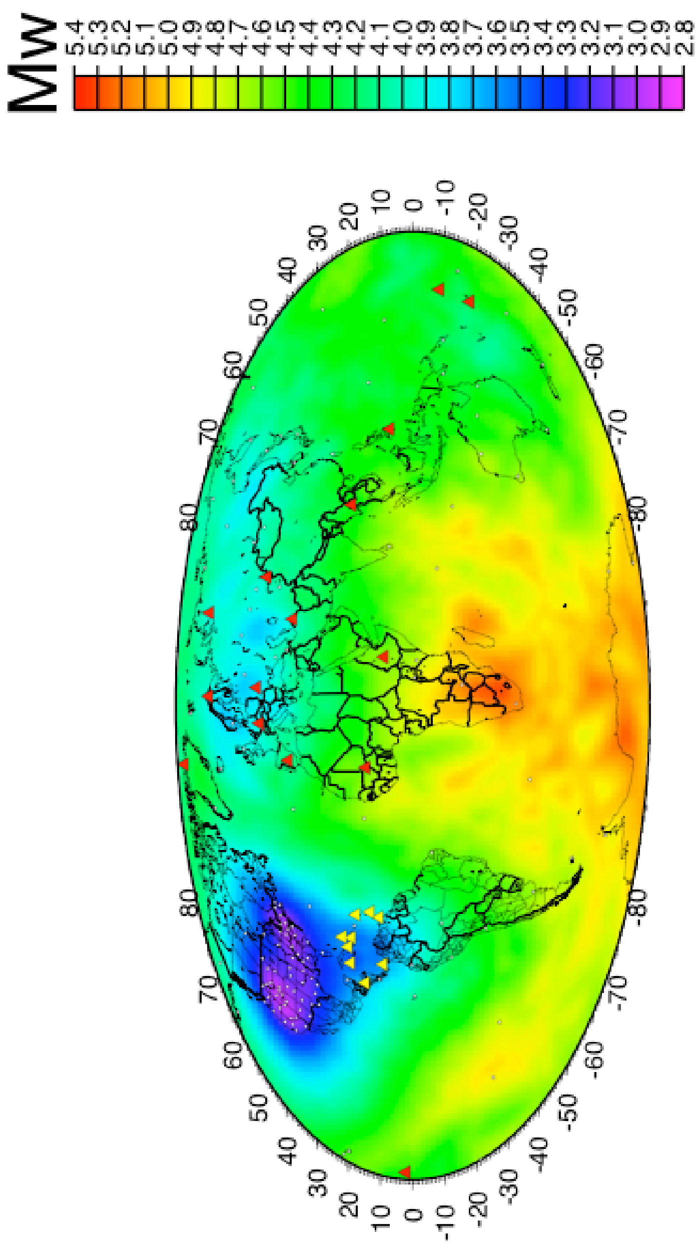

FIGURE 2: ANSS/GSN modeled minimum Mw detection threshold with upgrade scenarios 1 and 2. Red triangles are 15 media based GSN stations, and yellow triangles are the proposed 9 station Caribbean Network. Existing real-time ANSS and GSN stations are shown as small white triangles.

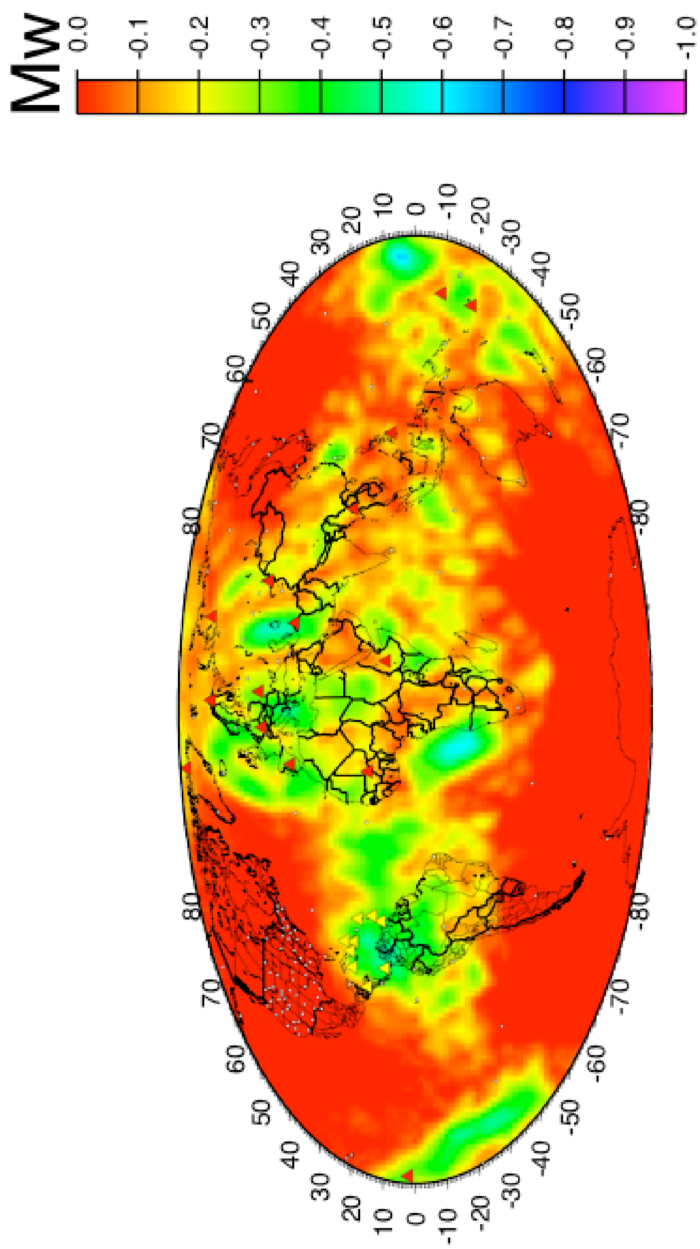

FIGURE 3: Minimum Mw difference map between current network (Figure 1) and upgrade scenarios 1 and 2 (Figure 2). The map demonstrates the reduction in Mw that we could achieve with the two proposed upgrade scenarios.

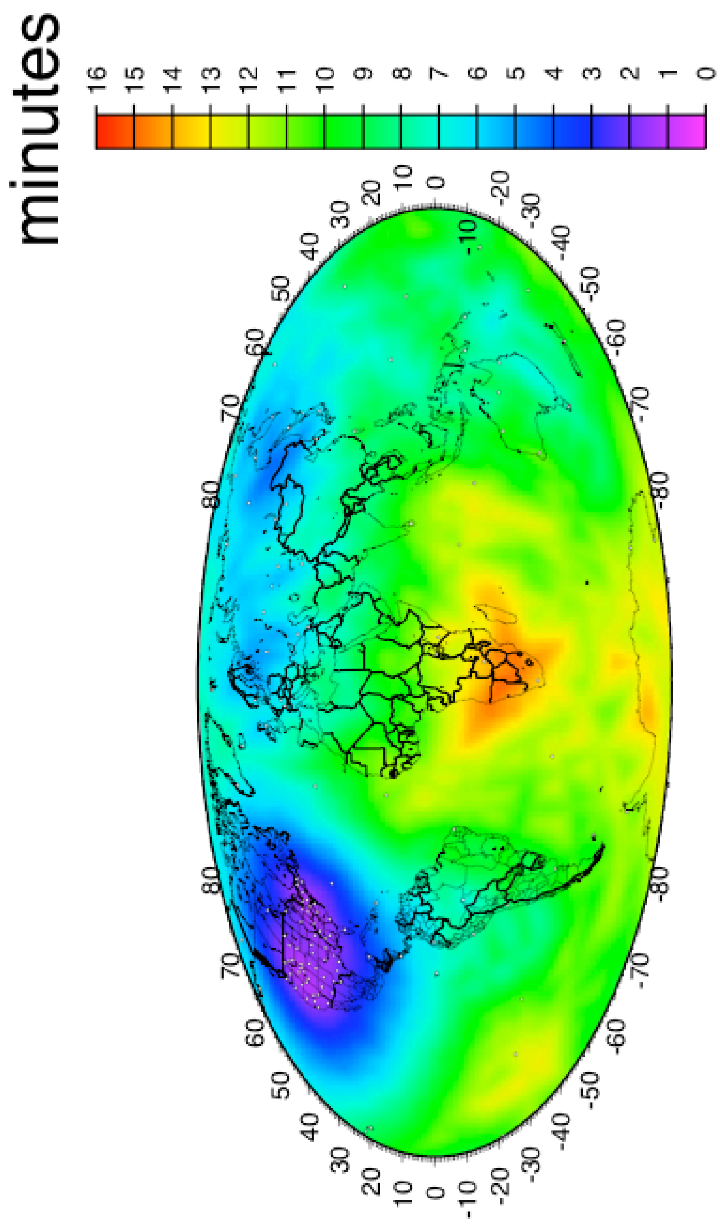

FIGURE 4: ANSS/GSN modeled P-wave propagation time to the first 9 detecting stations. Existing real-time ANSS and GSN stations are shown as small white triangles.

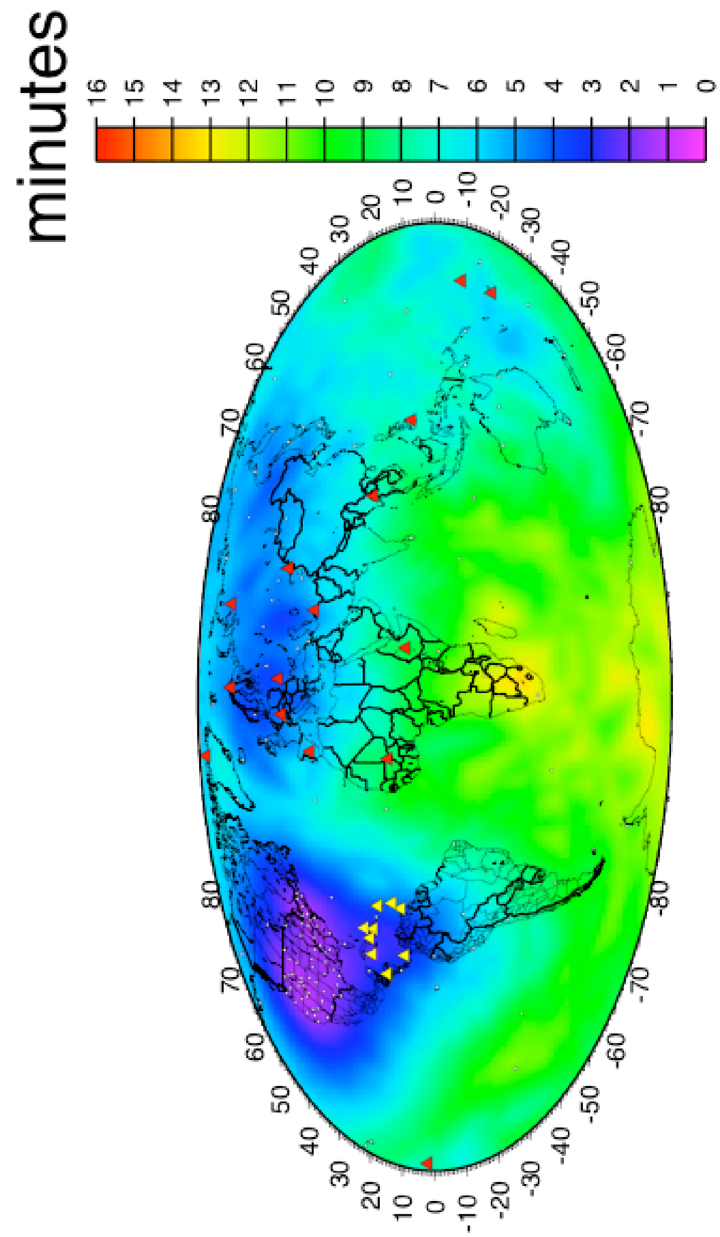

FIGURE 5: ANSS/GSN modeled P-wave propagation time to the first 9 detecting stations with upgrade scenarios 1 and 2. Red triangles are 15 media based GSN stations, and yellow triangles are the proposed 9 station Caribbean Network. Existing real-time ANSS and GSN stations are shown as small white triangles.

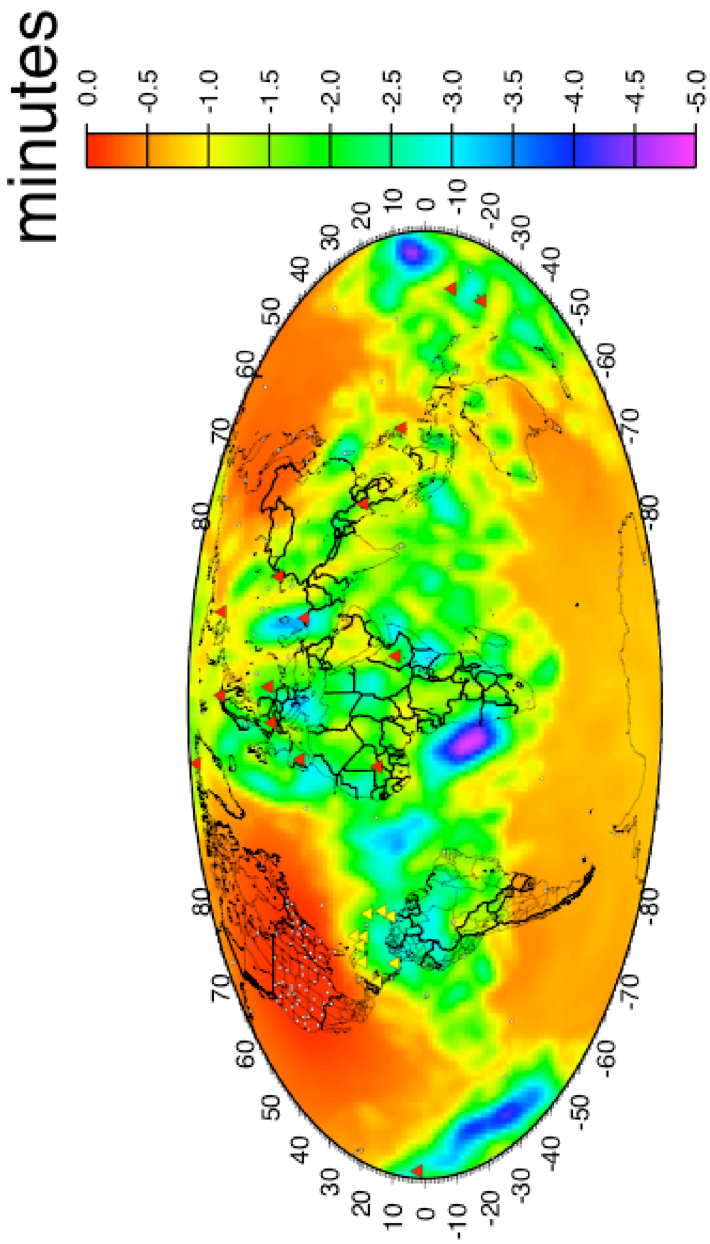

FIGURE 6: Propagation time difference map between current network (Figure 4) and upgrade scenarios 1 and 2 (Figure 5). The map demonstrates the reduction in propagation/response time that we could achieve with the two proposed upgrade scenarios.

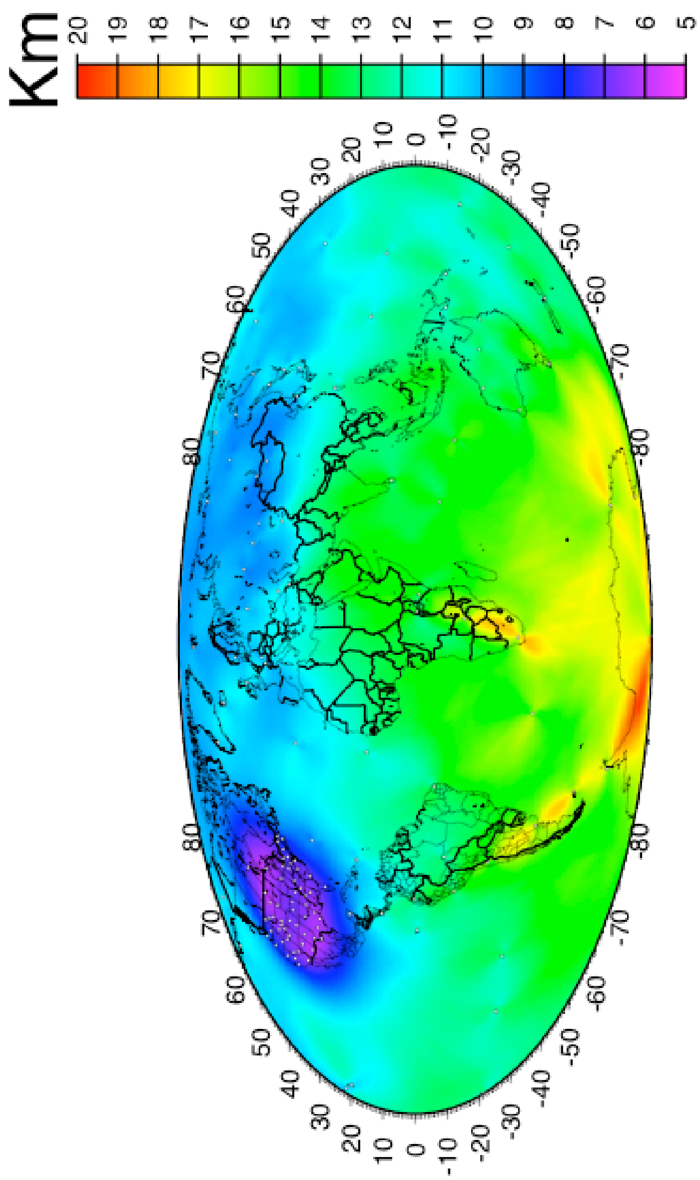

FIGURE 7: ANSS/GSN theoretical earthquake location error. Existing real-time ANSS and GSN stations are shown as small white triangles.

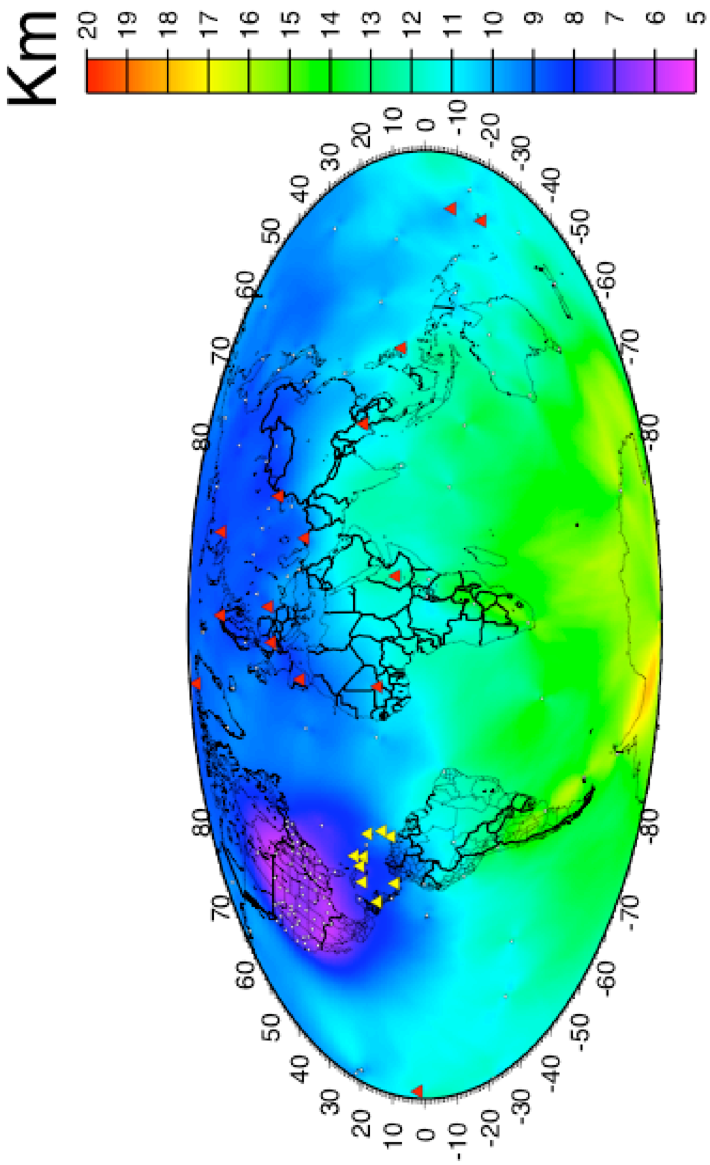

FIGURE 8: ANSS/GSN theoretical earthquake location error with upgrade scenarios 1 and 2. Red triangles are 15 media based GSN stations, and yellow triangles are the proposed 9 station Caribbean Network. Existing real-time ANSS and GSN stations are shown as small white triangles.

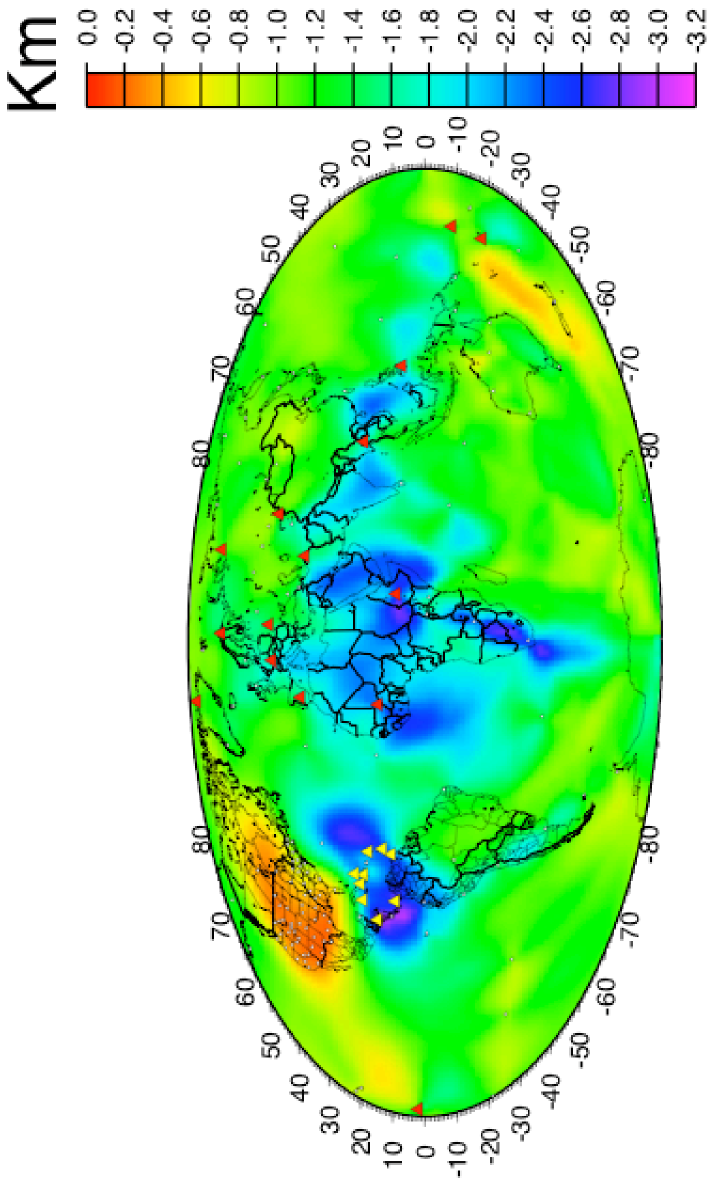

FIGURE 9: Earthquake location error difference map between current network (Figure 7) and upgrade scenarios 1 and 2 (Figure 8). The map demonstrates the reduction in earthquake location error that we could achieve with the two proposed upgrade scenarios.