Earthquake and Tsunami Monitoring Capabilities of a Caribbean Region International Warning System

Daniel McNamara (USGS)

UNESCO - United Nations Education, Science and Cultural Organization

ICG-C - Intergovernmental Coordinating Group for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions

Working Group I: Monitoring and Detection Systems, Warning Guidance

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Caribbean Waves, Dec. 2008 Guadeloupe

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

UNESCO ICG-C WG I
Monitoring and Detection Systems

The purpose of WG1 is to make recommendations to the ICG for full establishment of a coordinated regional tsunami warning system in the Caribbean region (CTWS).

- Sea level monitoring
- Earthquake monitoring and detection
- Tsunami warning guidance priorities

Earthquake Monitoring Recommendations from WG1

- Define the core of seismic stations
- Data quality, format and transmission
- Maintenance and training programs
- Specific Instrumentation requirements
- Network wide capability requirements

WG1 Minimum Performance Criteria for Initial Earthquake Locations in the Caribbean

- Earthquake detection within 1 minute
- Minimum magnitude threshold = M4.5
- initial hypocenter error of <30 km.

Adjacent regions:

- Earthquake detection within 1 minute
- Minimum magnitude threshold = M6.0
- initial hypocenter error of <30 km.

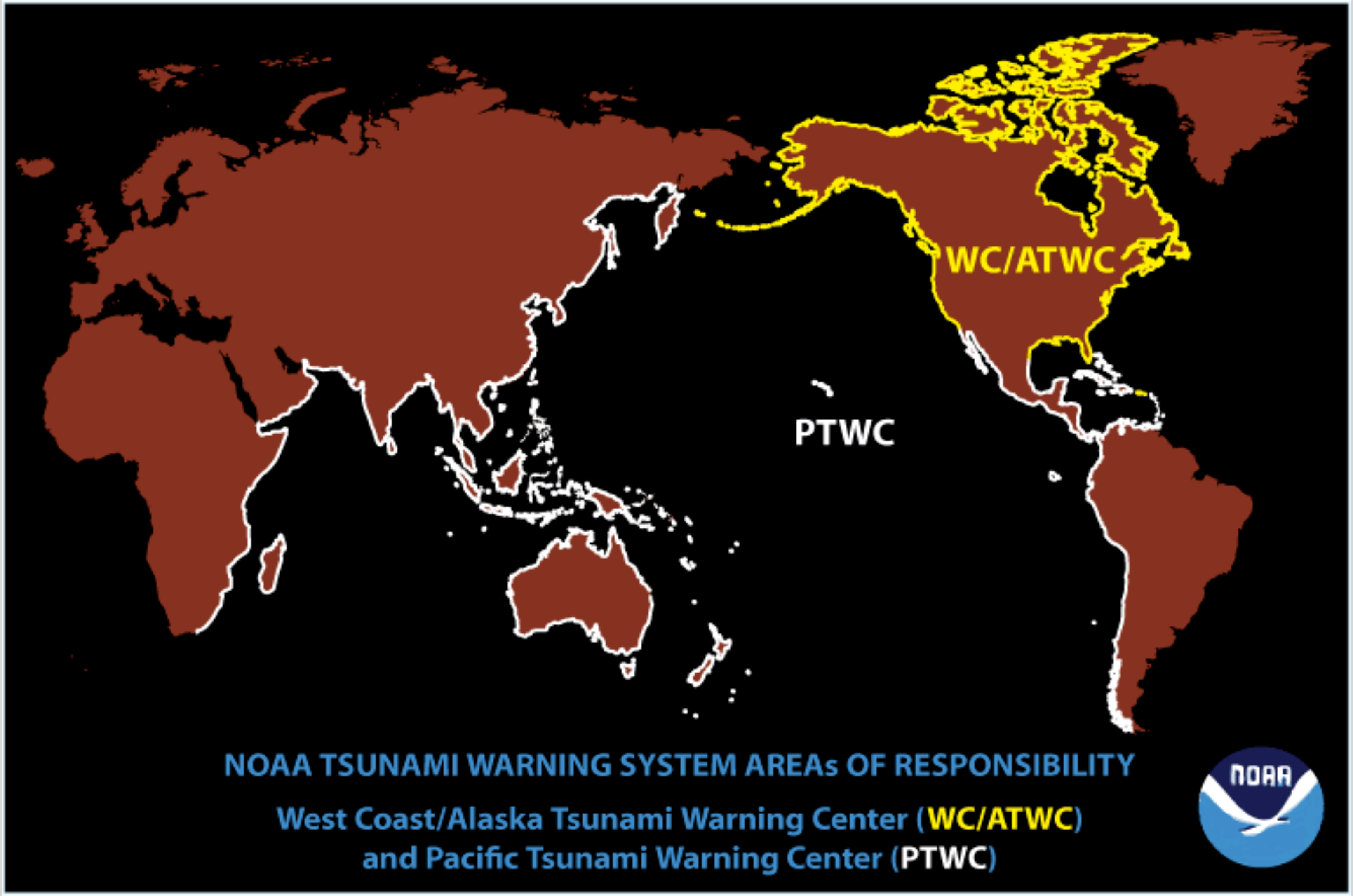
Talk Focus:

Status of current earthquake and tsunami monitoring in Caribbean region

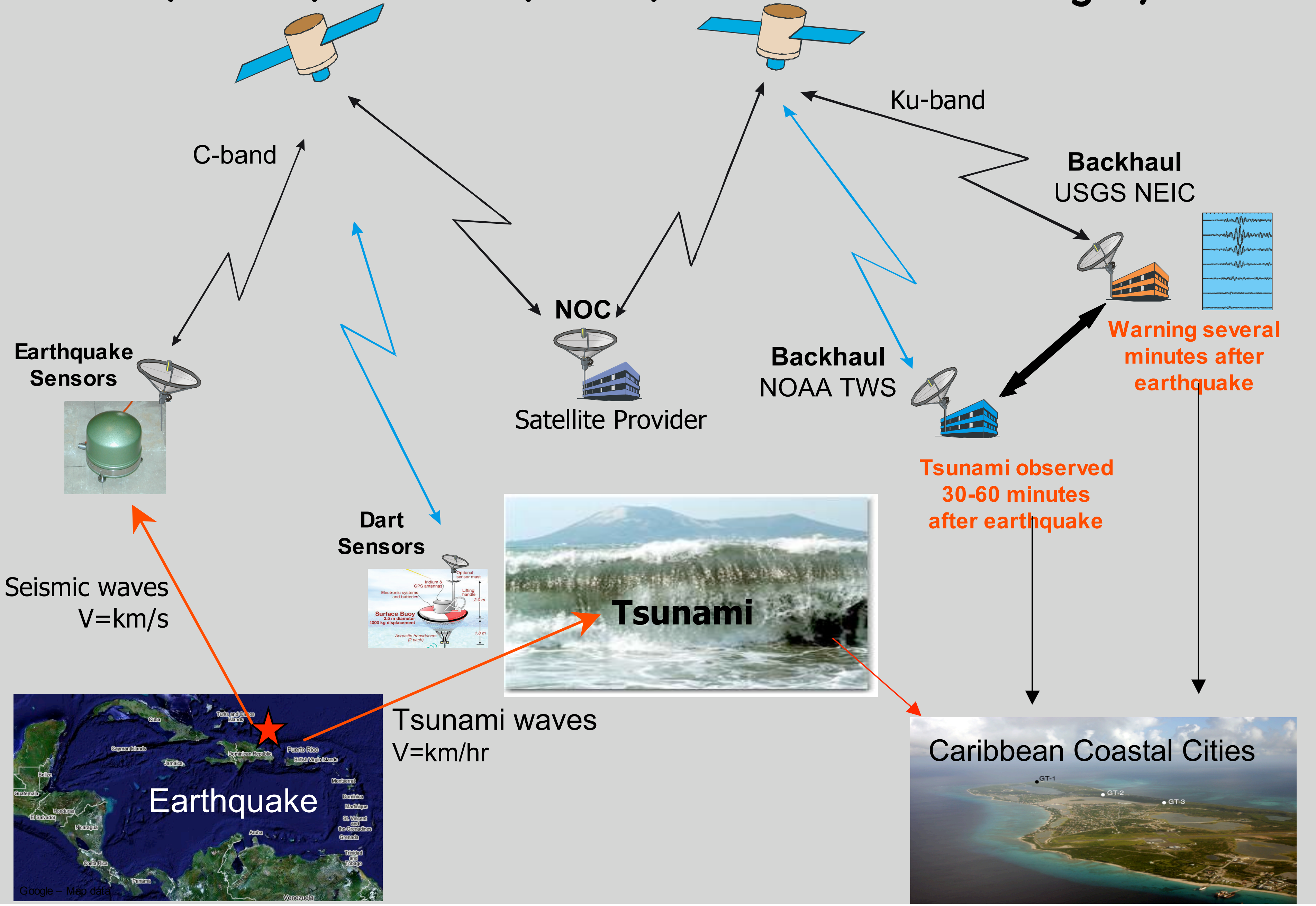
Capability modeling of a combined international seismic network

- minimum detection threshold
- detection time
- earthquake location error

TWC Areas of Responsibility

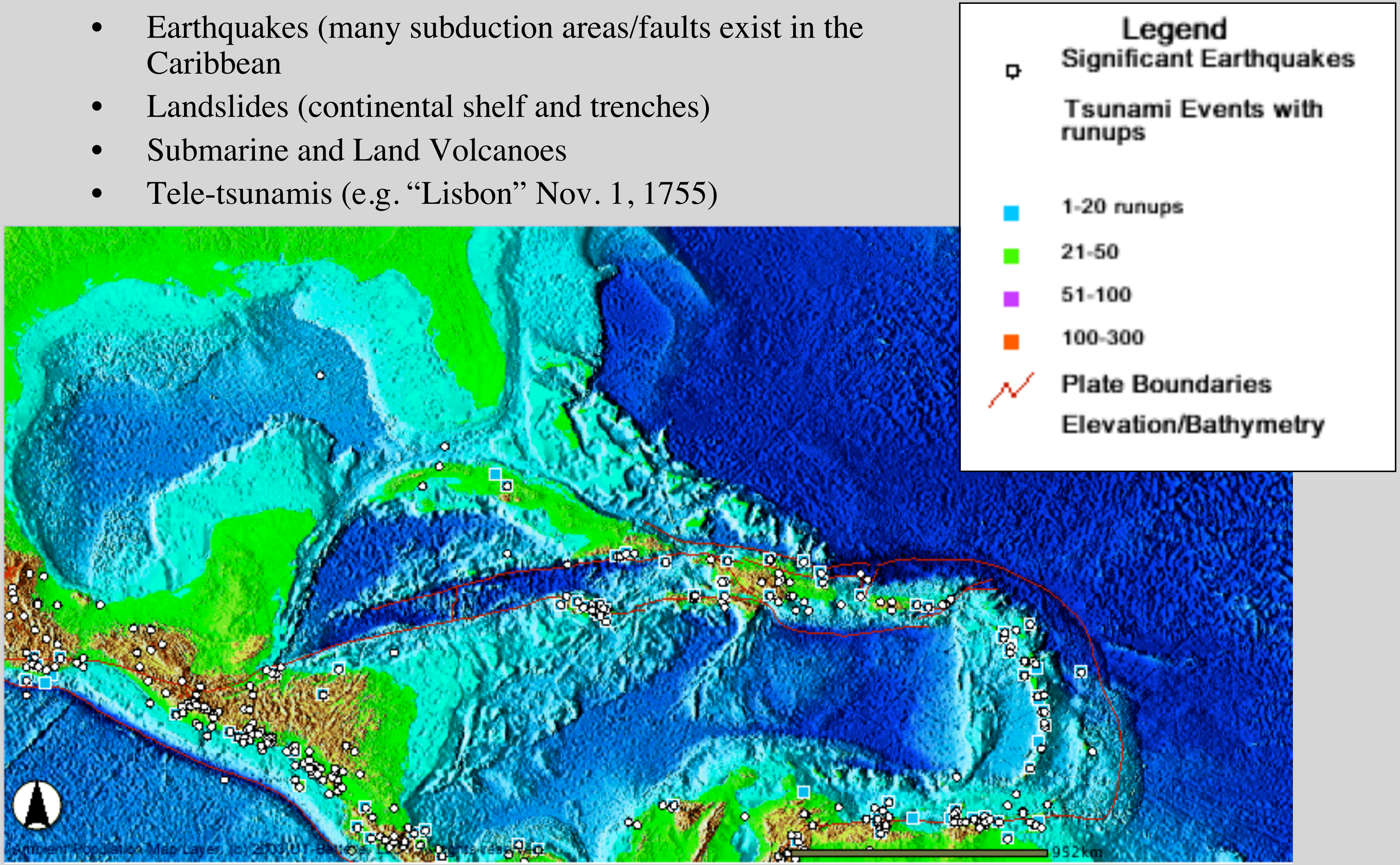


Land (USGSS) and Sea (NOAA) Combined Monitoring System

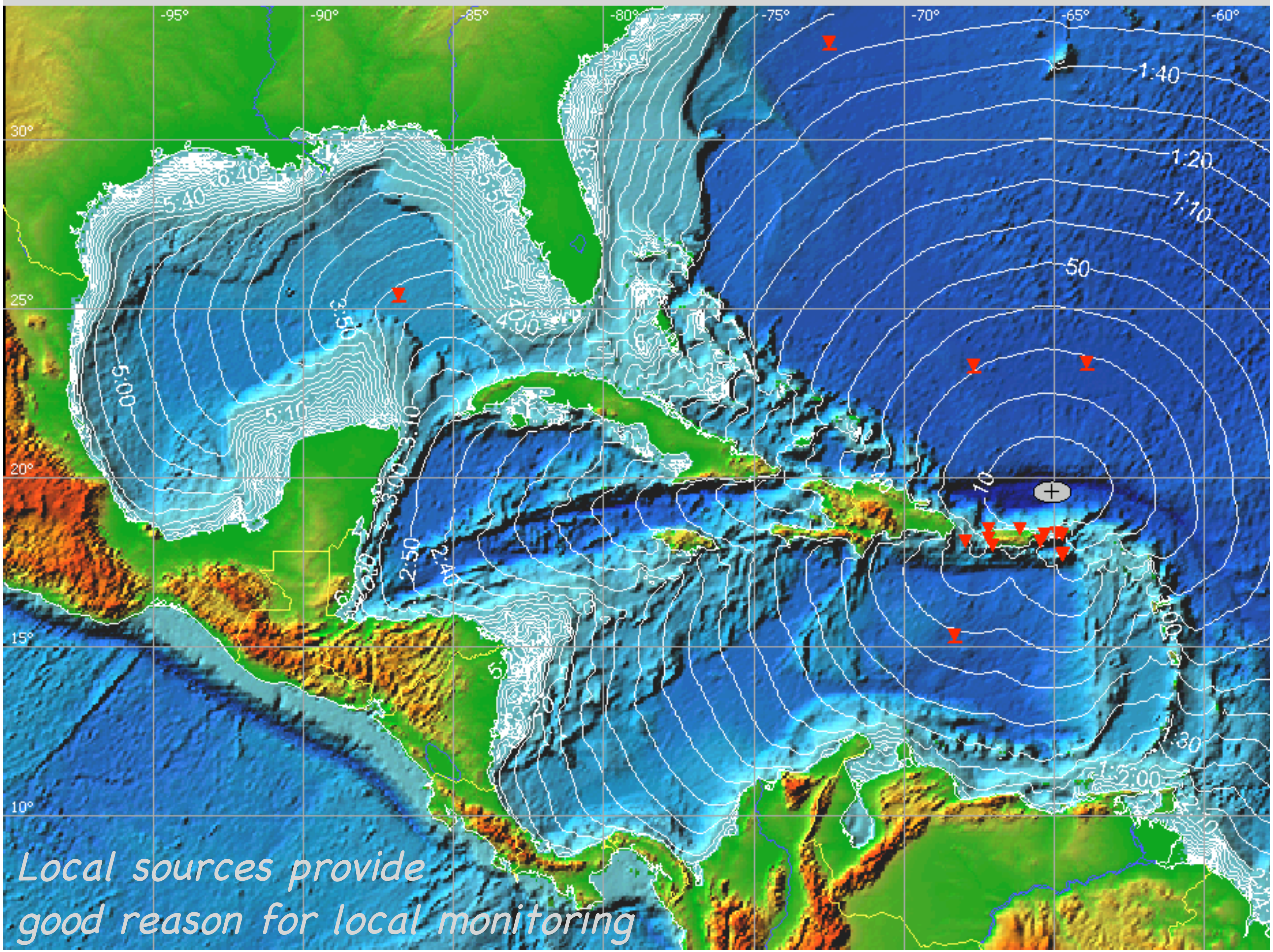


Natural Hazards

- Earthquakes (many subduction areas/faults exist in the Caribbean
- Landslides (continental shelf and trenches)
- Submarine and Land Volcanoes
- Tele-tsunamis (e.g. “Lisbon” Nov. 1, 1755)



Source: National Geophysical Data Center (NGDC)
http://map.ngdc.noaa.gov/website/seg/hazards/viewer.htm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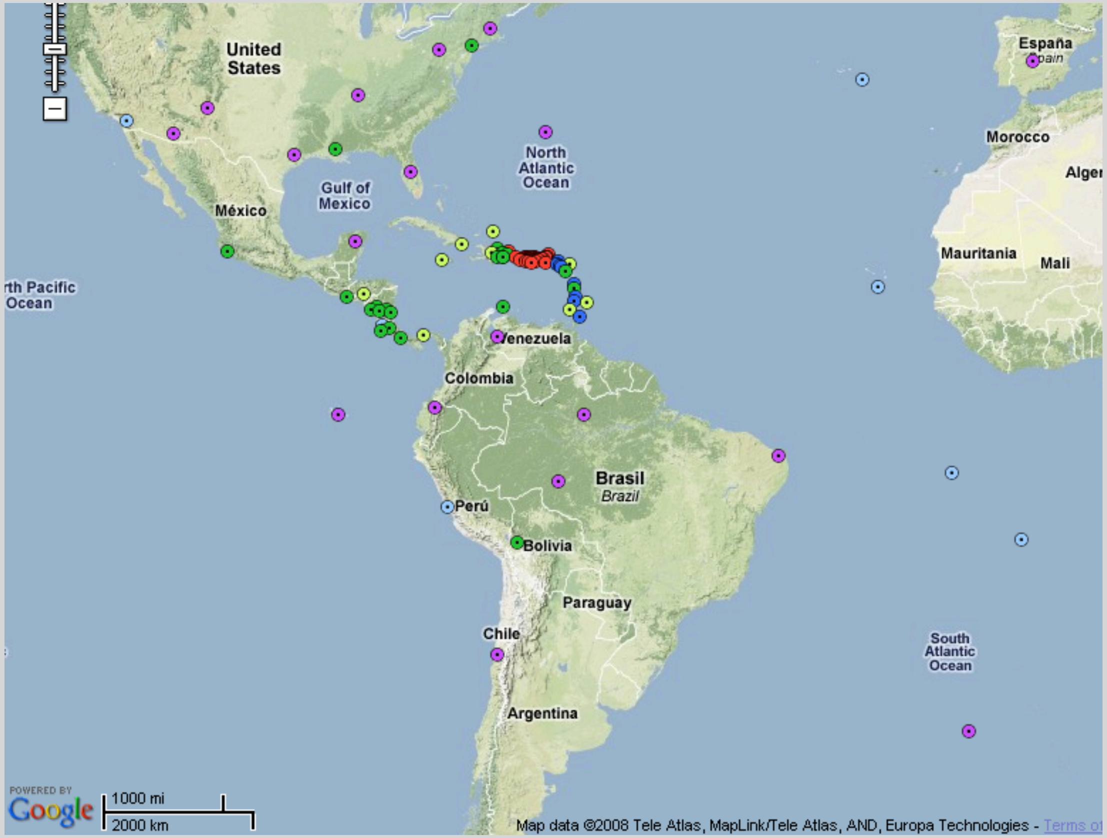
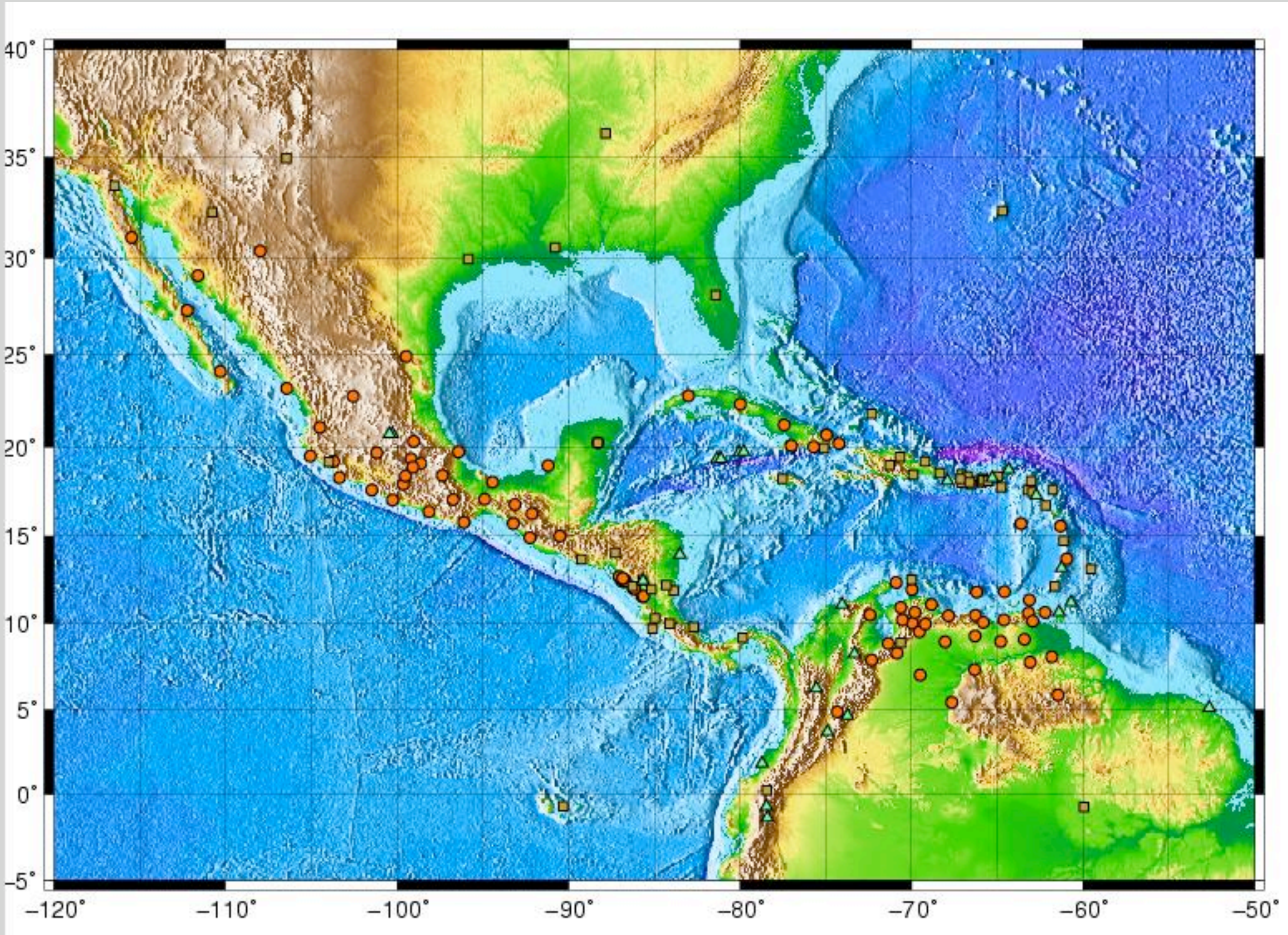
Local sources provide
good reason for local monitoring

Seismic Stations Available in Real Time for the CTWS



Contributing Networks

- USGS Caribbean Seismic Network
- USGS-ANSS
- USGS-GSN
- UWI-SRC
- U. Colima, Mexico
- RS El Salvador
- INETER, Nicaragua
- OVSICORI, Costa Rica
- Baru Network, Panama
- Montserrat Volcano Observatory
- Martinique Volcano Observatory
- KNMI, Dutch Antilles
- Puerto Rico Seismic Network
- Seismological Institute, DR
- GEOSCOPE-France



Other Networks

- FUNVISI
- Cuba NN
- Mexico NN
- Colombia

Existing CEWS   Existing Stations   Planned

Seismic Network Capability Modeling

The following figures show modeled measures of network capability

1) Minimum magnitude threshold
2) Network detection time
3) Earthquake location error

For many station configurations:

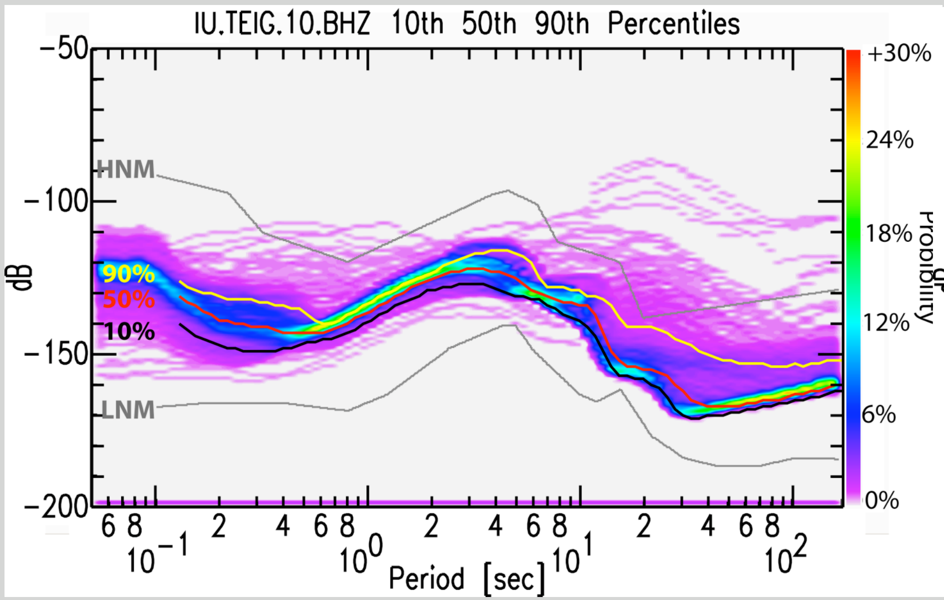
1. USGS Networks
2. Other regional and national networks
3. Combined Network of CTWS

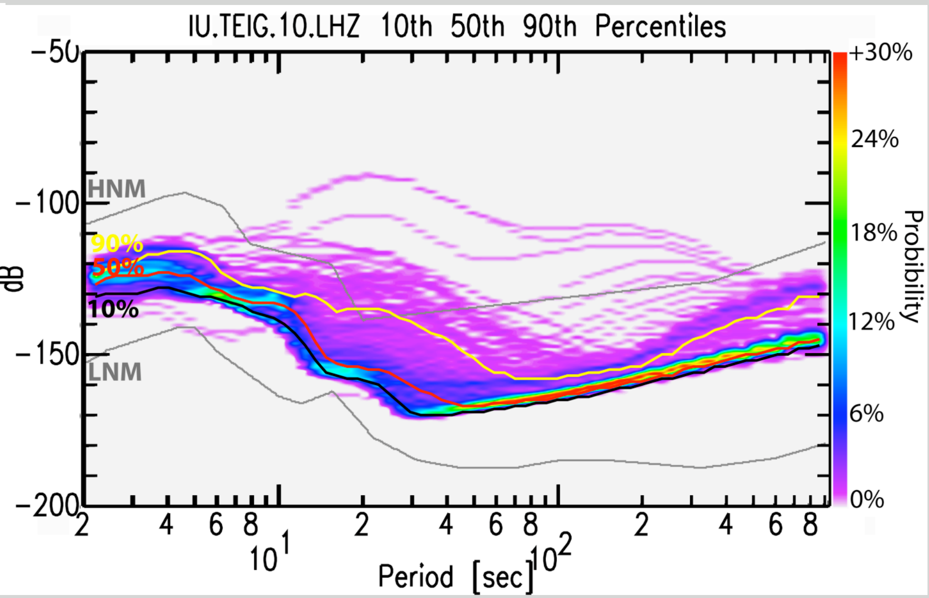
Requires:

1. Calculation of Background Noise Levels
2. Approximate noise levels for stations with no measurements

Station Noise Levels

1. Compute PSDs in 1 hour intervals for several years
2. Fit PDF surface to PSDs
3. Compute 10th 50th and 90th percentiles of PDF distribution





Detection Threshold Method

The minimum Mw level for each grid cell is modeled by computing

the minimum Brune earthquake amplitude that exceeds ambient noise levels at 9 stations.

Mw = 0.667 log(Mo) – 10.7 (*Kanimori,* 1977).

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

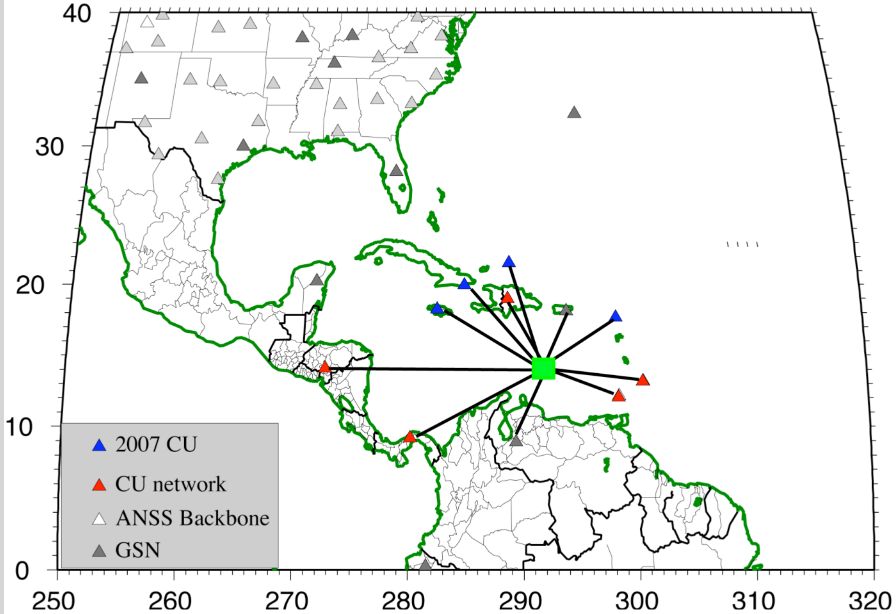
r=fault length

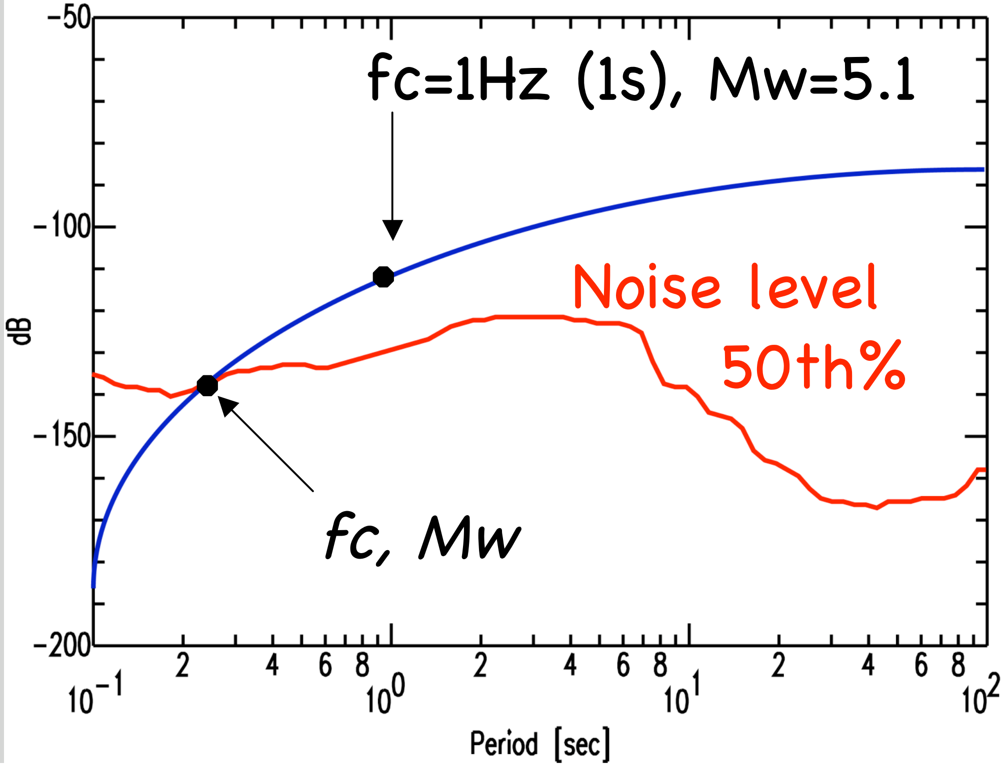
σ=stress drop

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

$$dB = 10\log(As^2)$$

For each path determine min Mw exceeding station noise level.



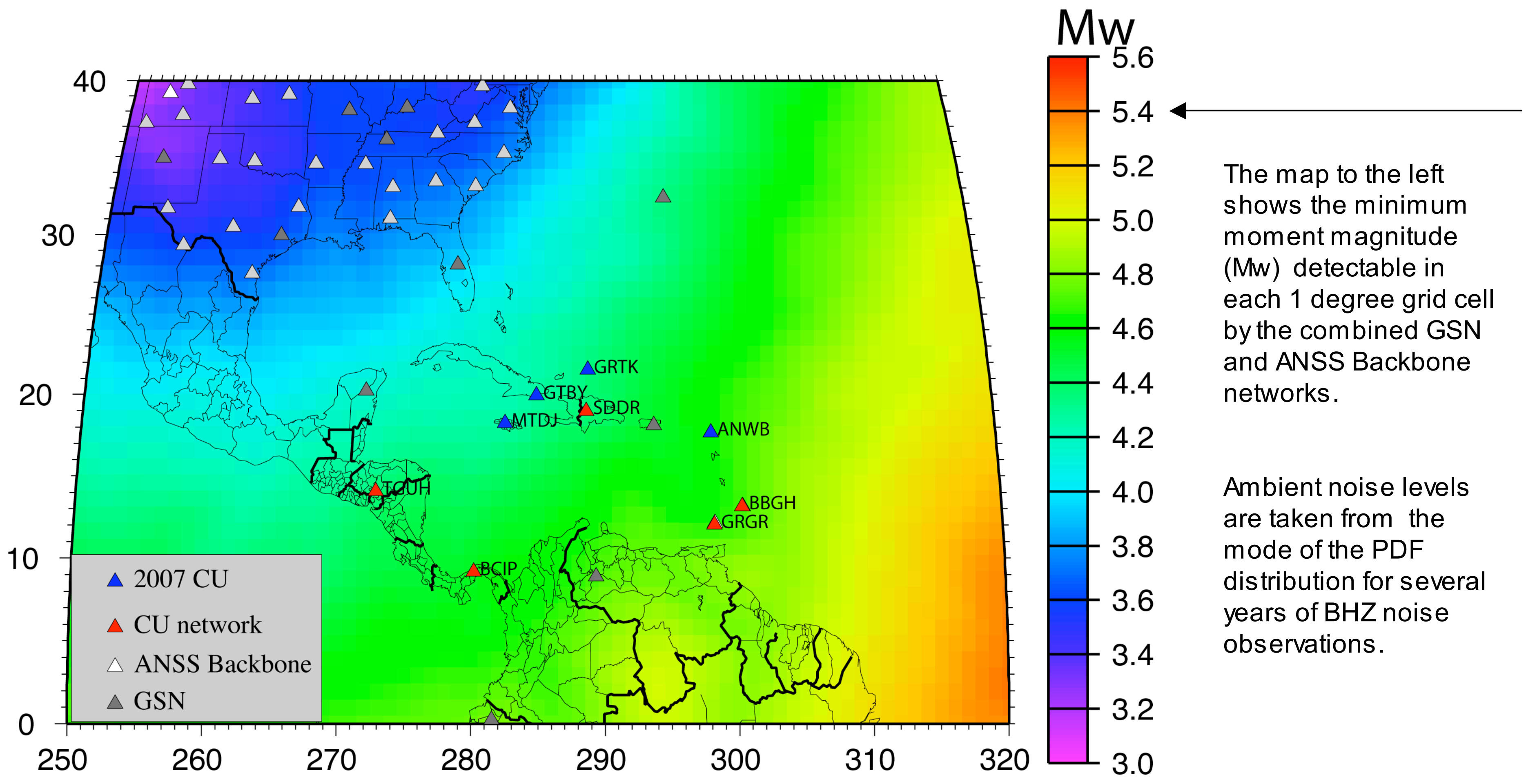


References:

McNamara, D.E., and R. Buland, ANSS Detection threshold, *15th Annual IRIS Workshop*, 19-21 June, Yosemite, CA, 2003.

McNamara, D. E. and R.P. Buland, Ambient noise levels in the continental US, Bull. Seism. Soc. Am., 94, 4, 1517-1527, 2004.

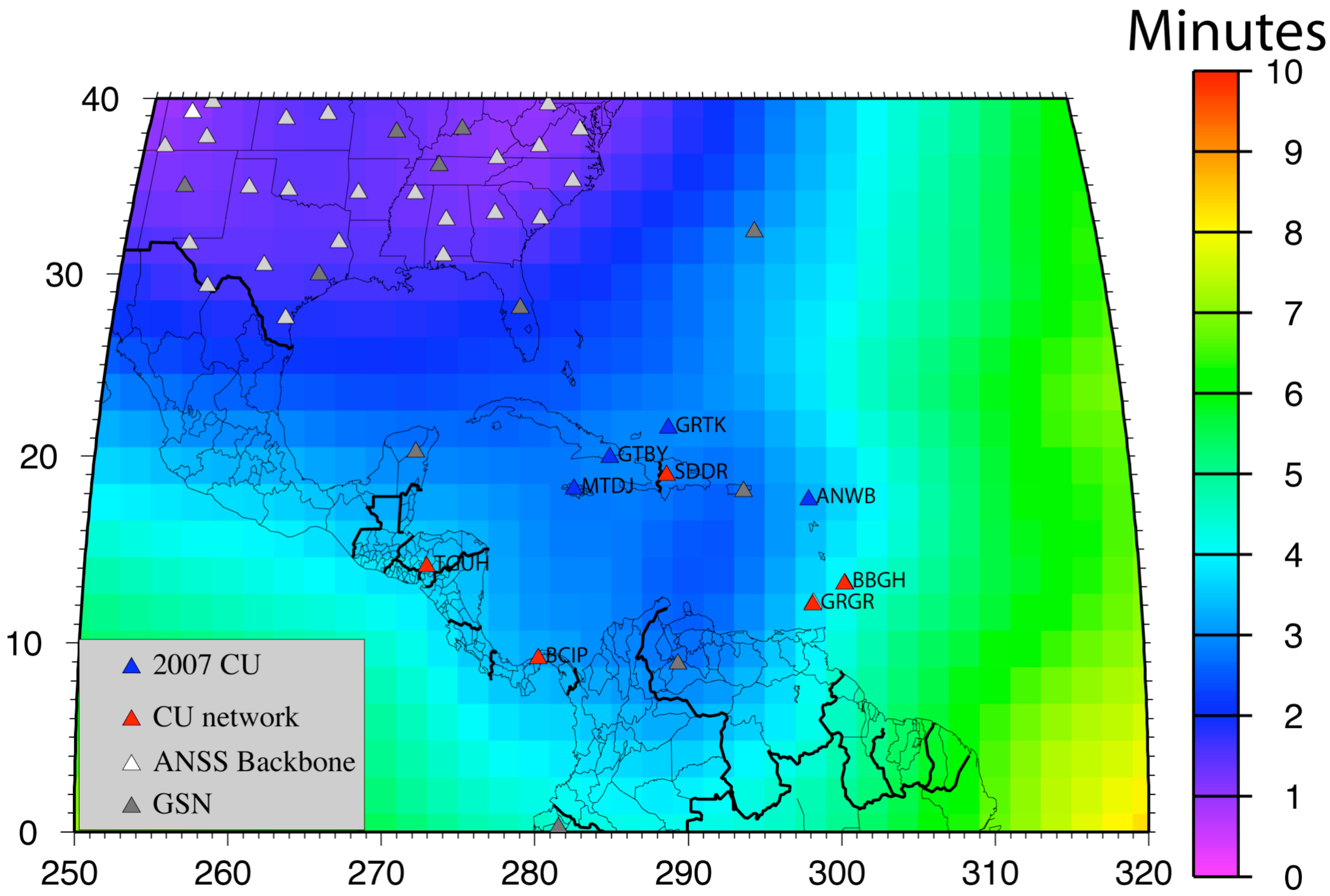
Magnitude Threshold: USGS Networks



The map to the left shows the minimum moment magnitude (Mw) detectable in each 1 degree grid cell by the combined GSN and ANSS Backbone networks.

Ambient noise levels are taken from the mode of the PDF distribution for several years of BHZ noise observations.

Detection Time: USGS Networks



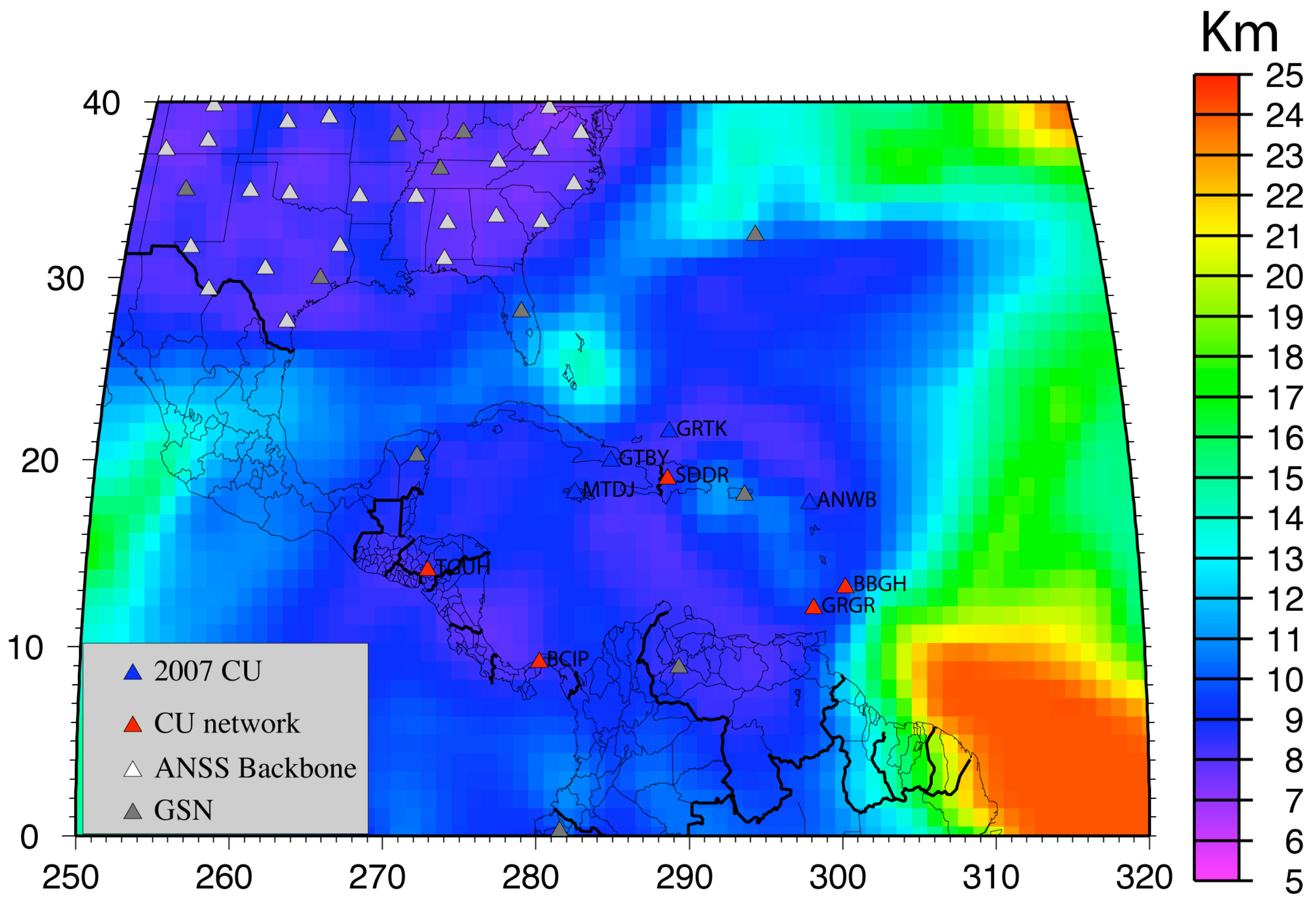
The map to the left shows the time in minutes for a P-wave from an earthquake in each 1 degree grid cell to be detected by the first 9 stations in the GSN and ANSS Backbone Networks.

The P-wave travel time for an earthquake in each grid cell is modeled with the Tau-P method using the IASPEI91 Earth model.

Detecting station distribution is determined from the minimum Mw detection results from the previous slides.

McNamara, D., R. Buland and H. Benz, Capabilities of the Advanced National Seismic Network, Seismo. Res. Lett.,76, 2005.

Location Error: USGS Networks

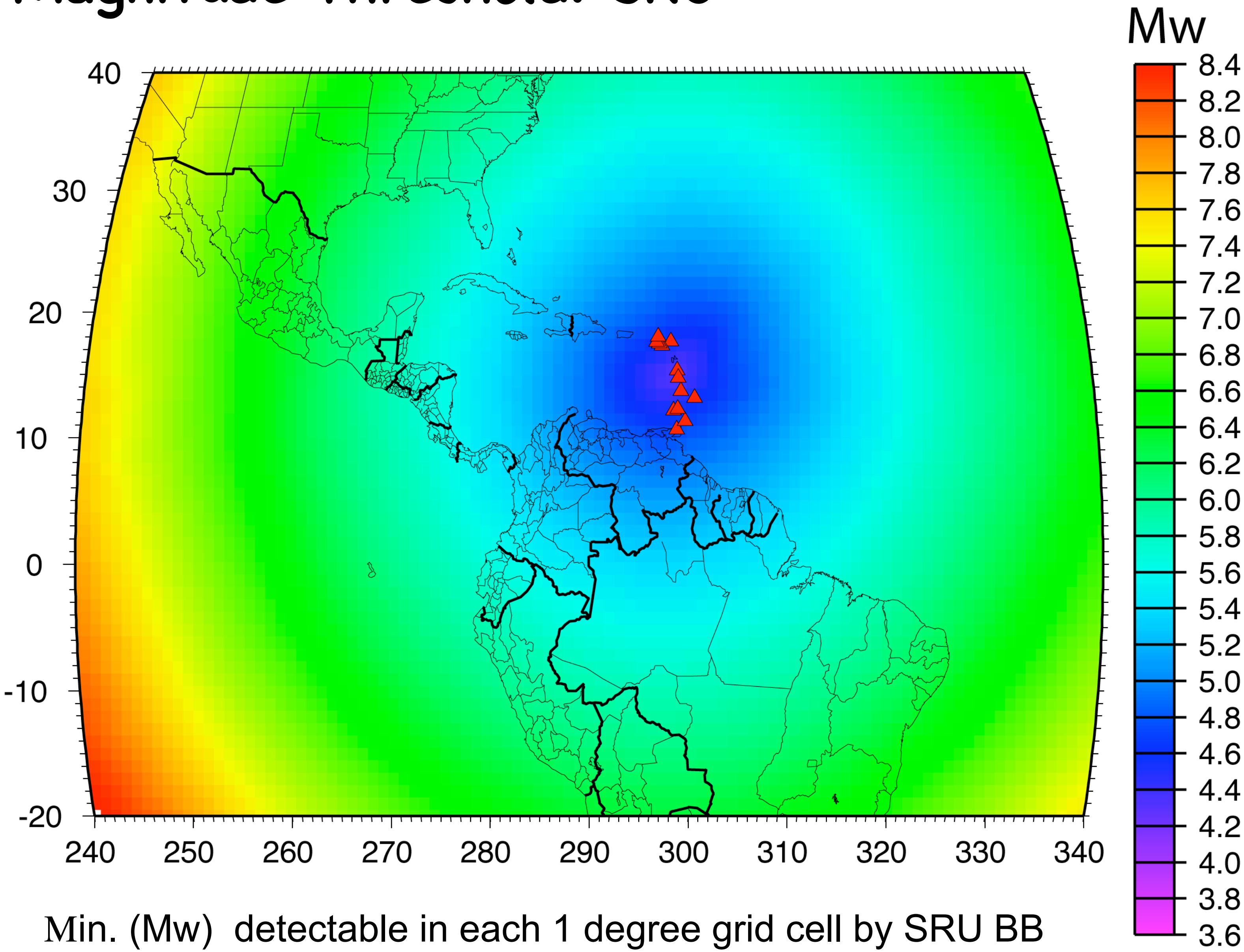


The map to the left shows the theoretical earthquake location error in each 1 degree grid cell for the combined GSN and ANSS Backbone networks.

We map the length of the major axis of the error ellipse in km. For this analysis we assume Surface source and use a P-wave fist arrival at each real-time station.

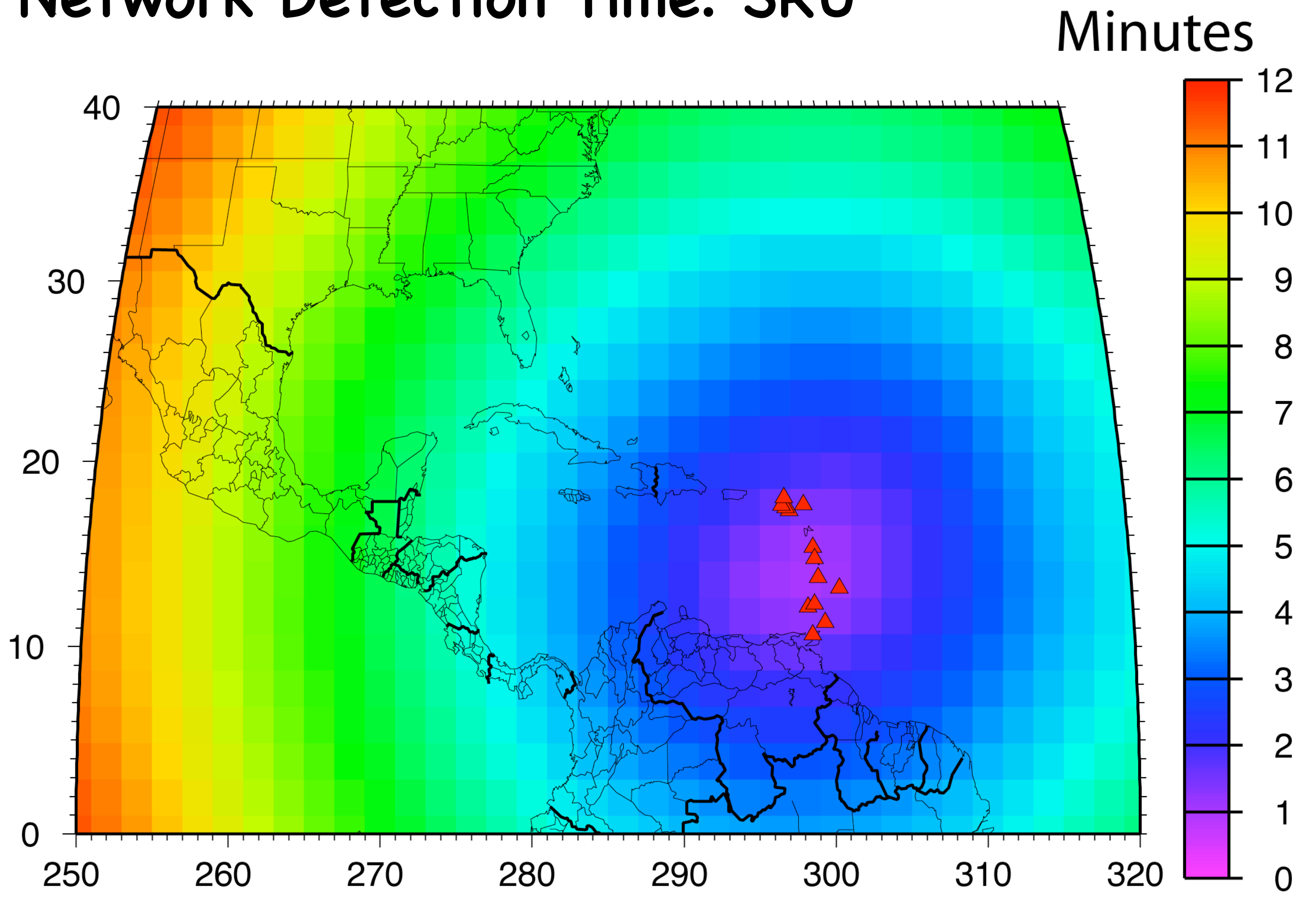
McNamara, D. E. , P. Earle, R.P. Buland and H. M. Benz, An Assessment of Proposed Upgrades to the ANSS Backbone and GSN, *17th Annual IRIS Workshop*, 16-20 June, WA, 2005.

Magnitude Threshold: SRC

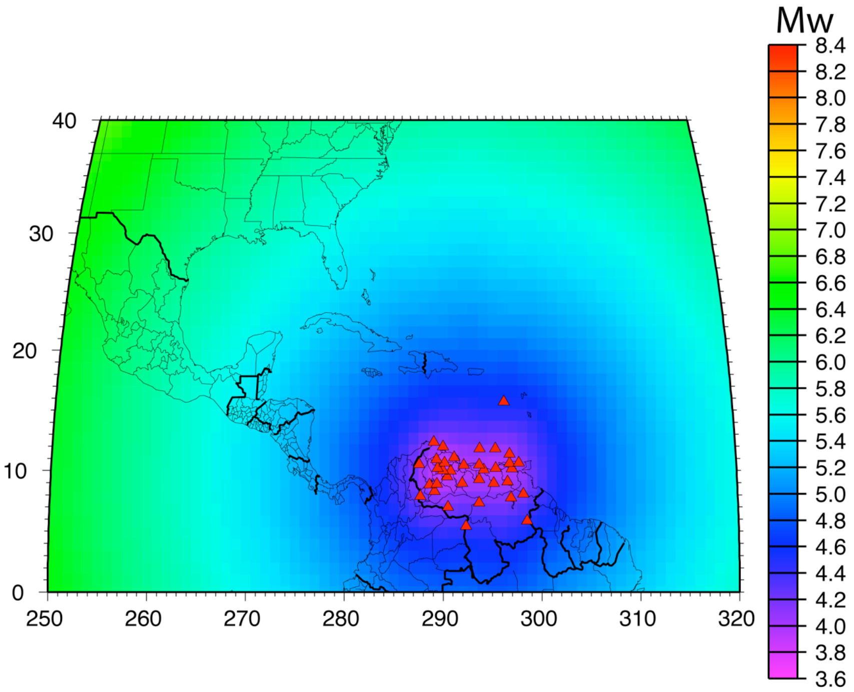


Min. (Mw) detectable in each 1 degree grid cell by SRU BB network. Assume 50th % noise levels for BBGH for stations without measurement.

Network Detection Time: SRU



Time (mins) for P-wave from an earthquake in each 2 degree grid cell to be detected by the first 9 stations in the SRU Network. P-wave travel time modeled with the Tau-P method using the IASPEI91 Earth model.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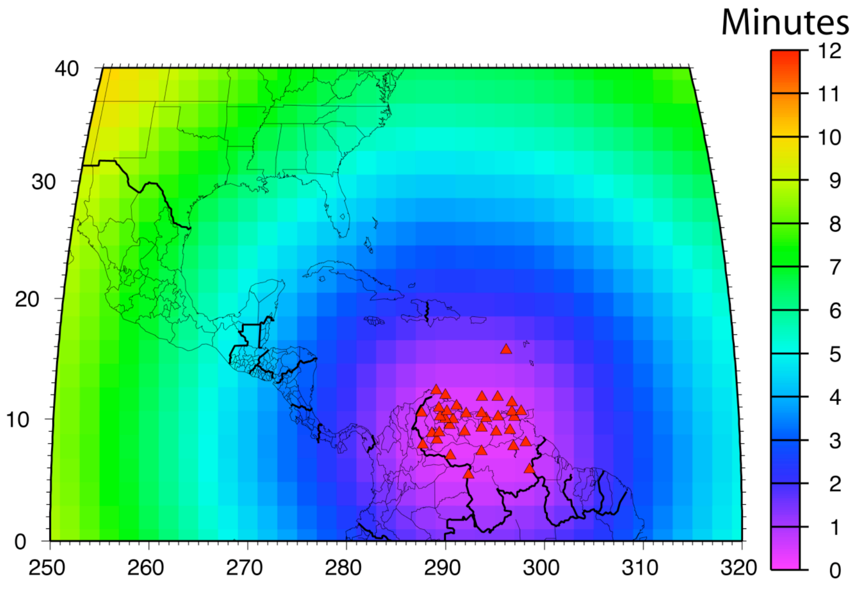
Venezuela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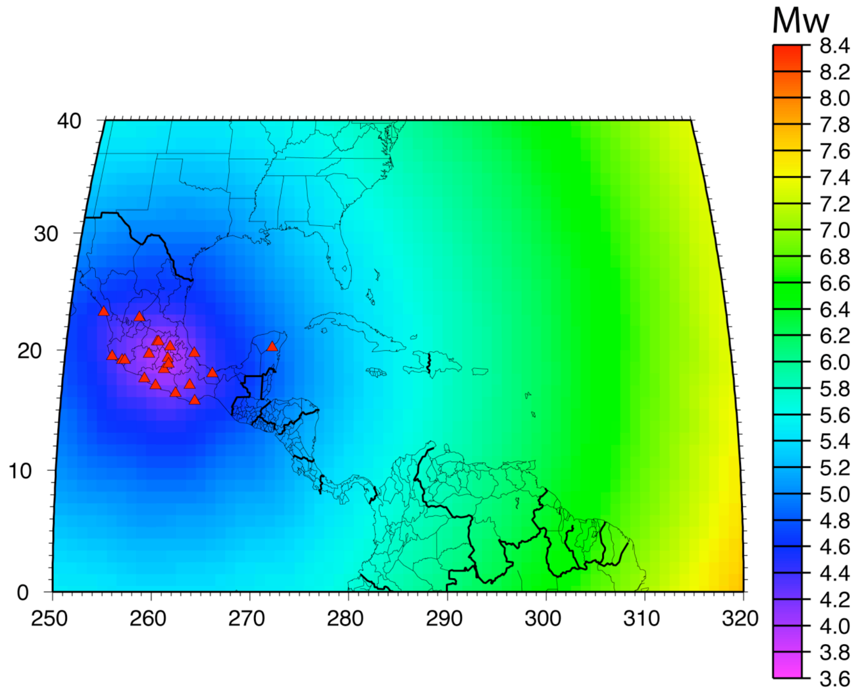
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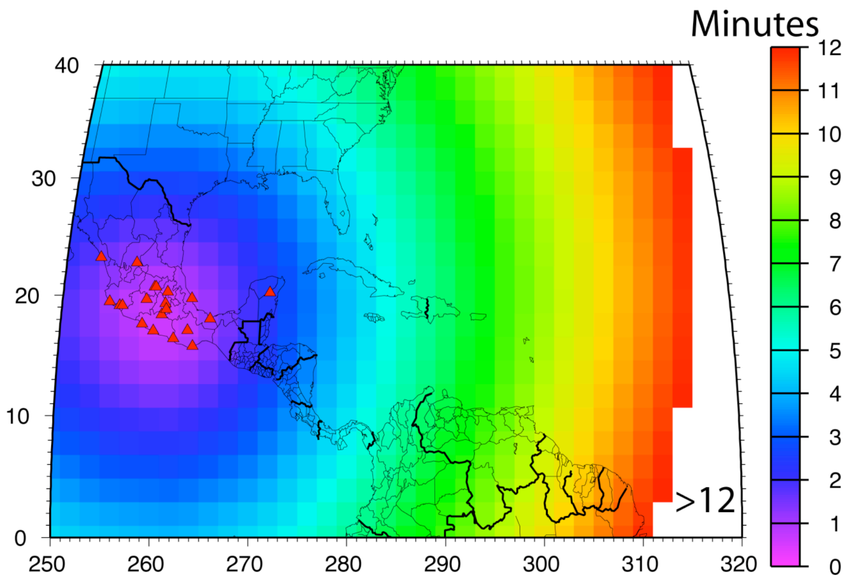
Mexico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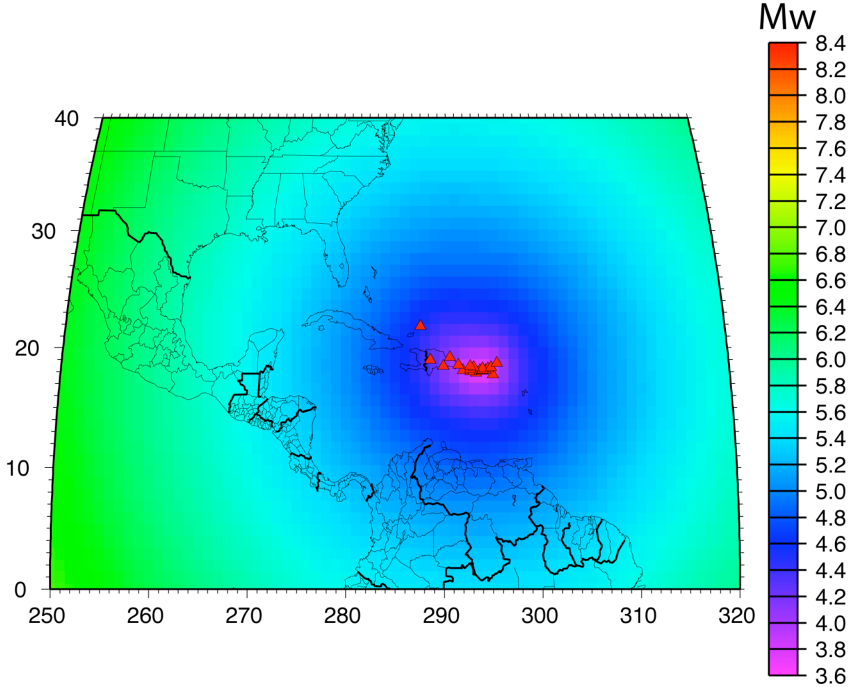
PRSN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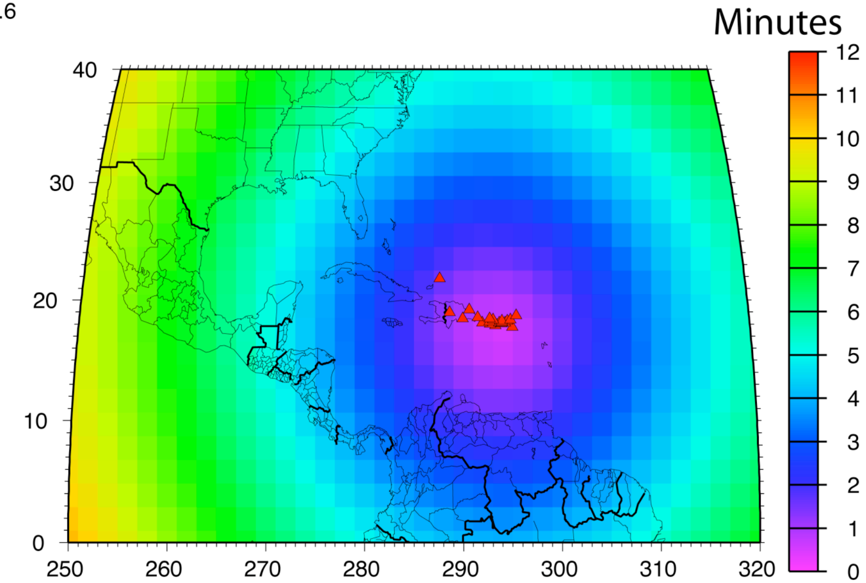
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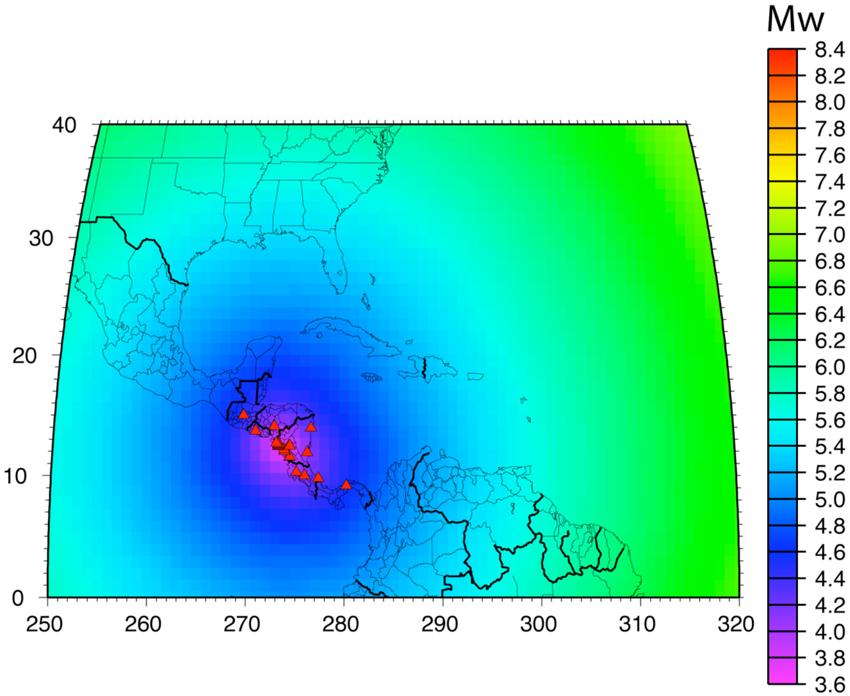
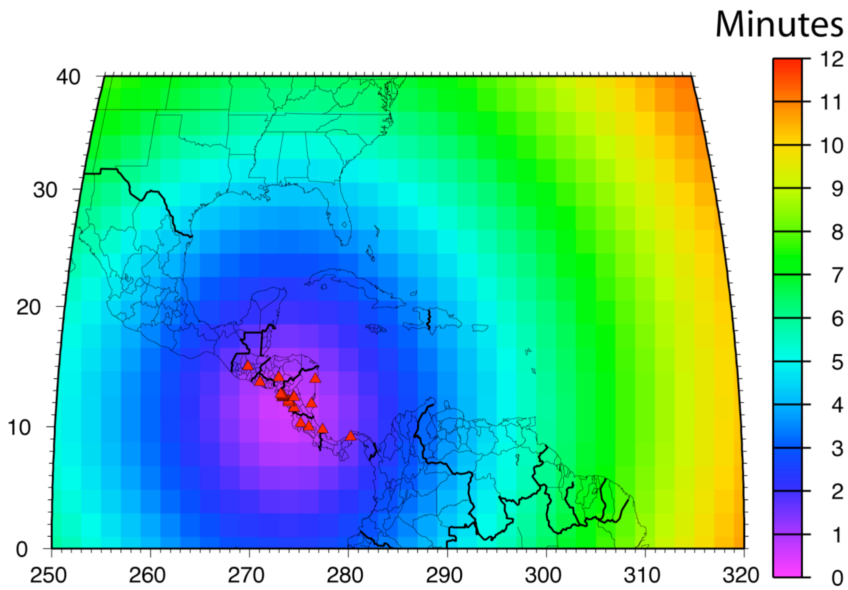
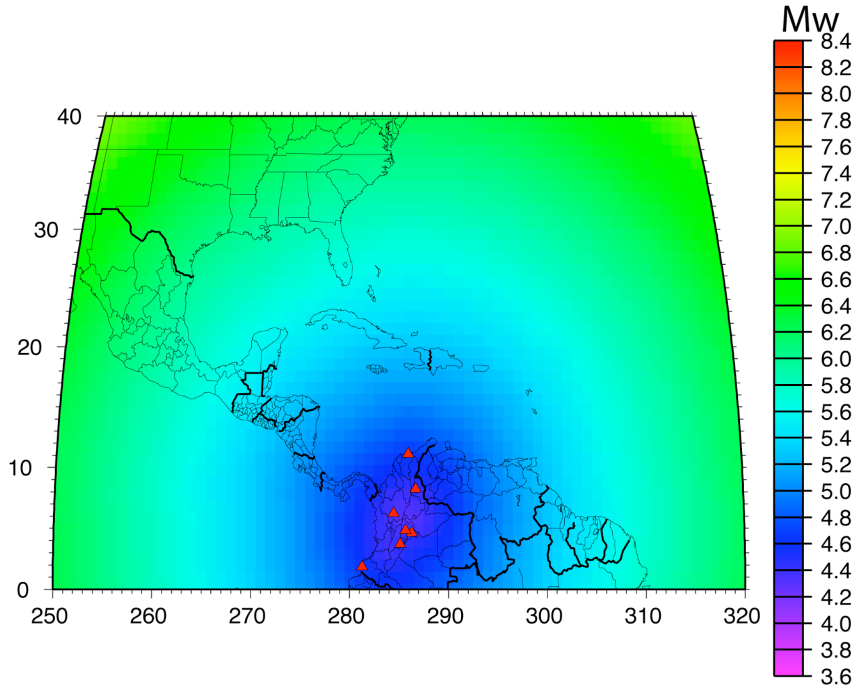


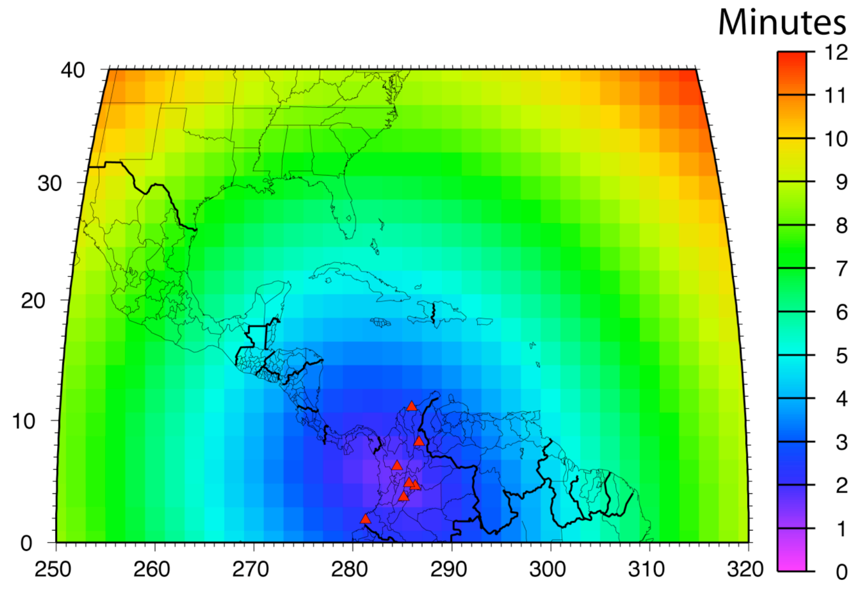
Central America

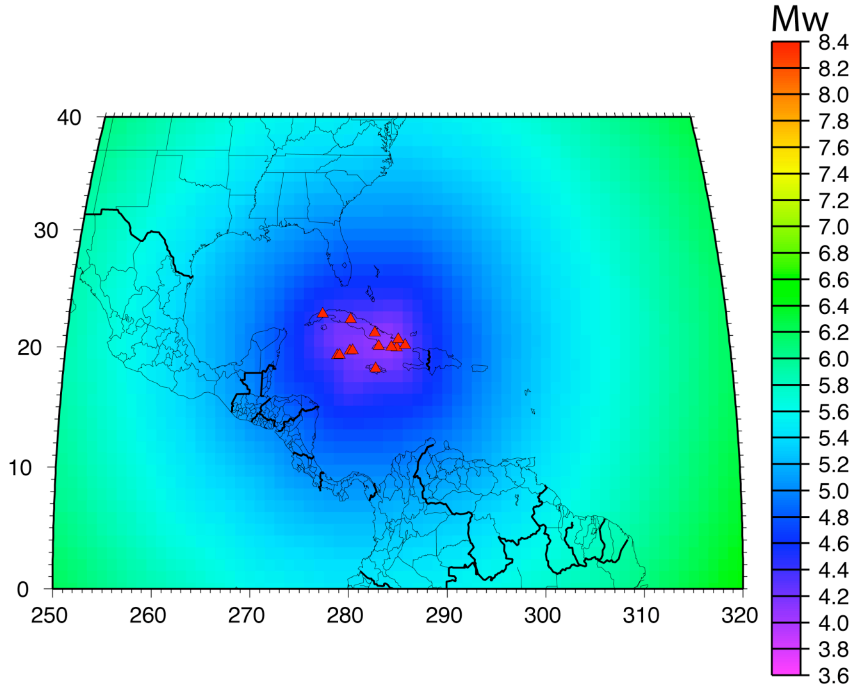


Colombia

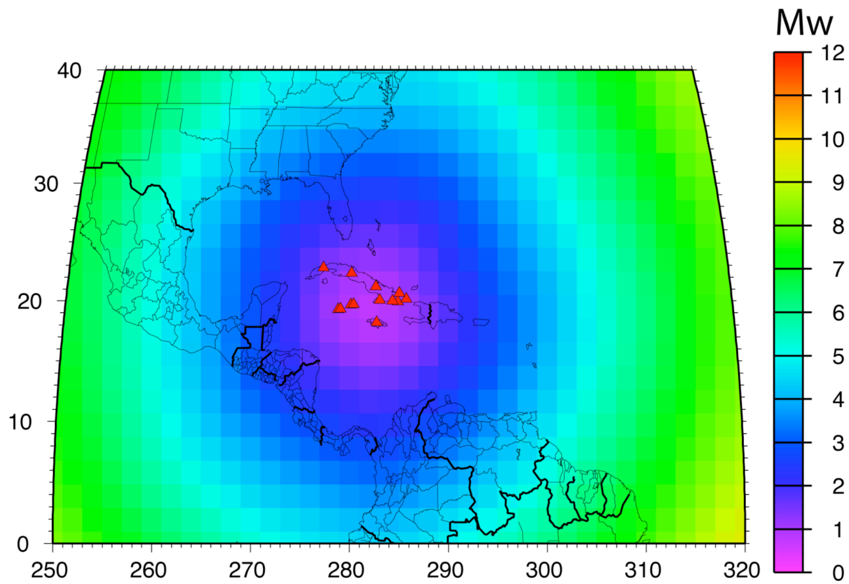
7 station network capability







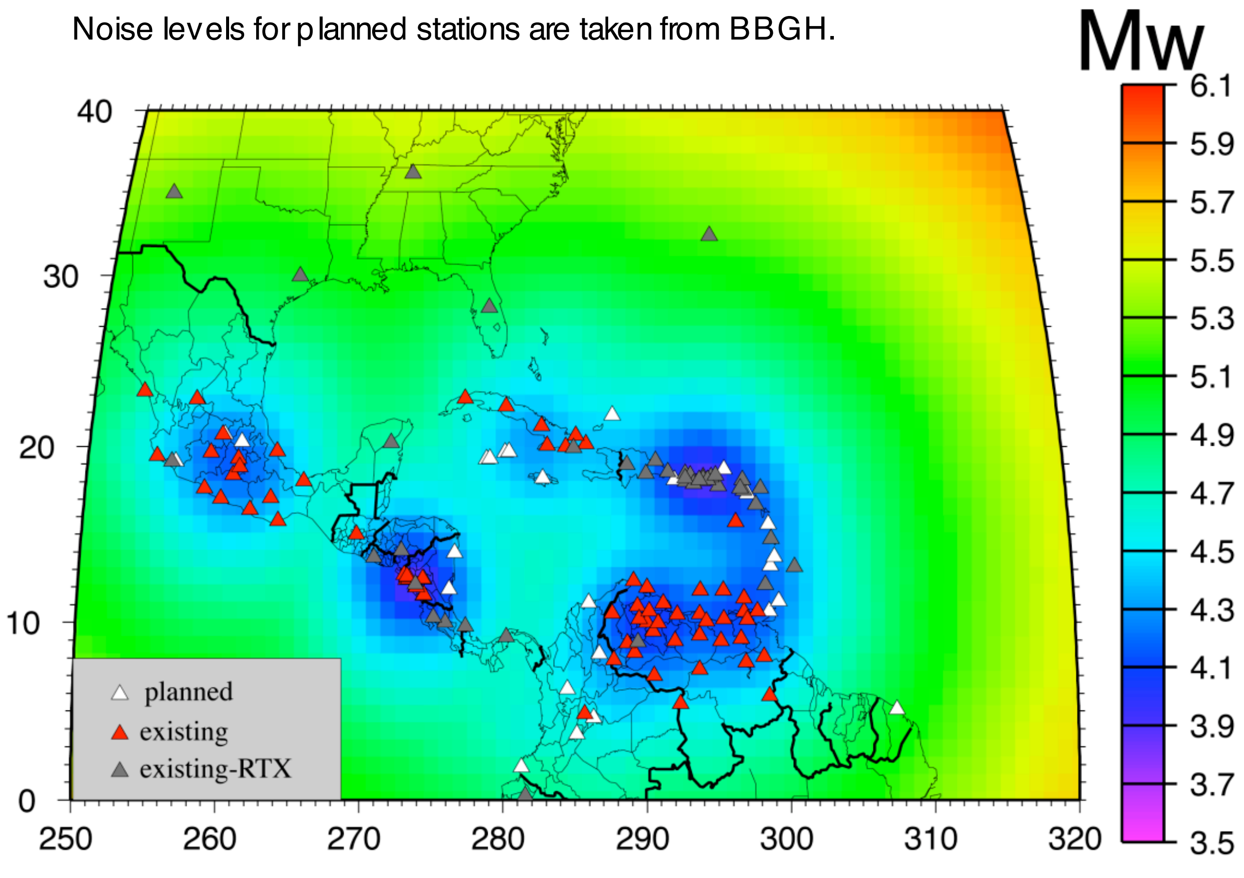
Jamaica, Caymans, Cuba



Combined Network Magnitude Threshold: including Planned

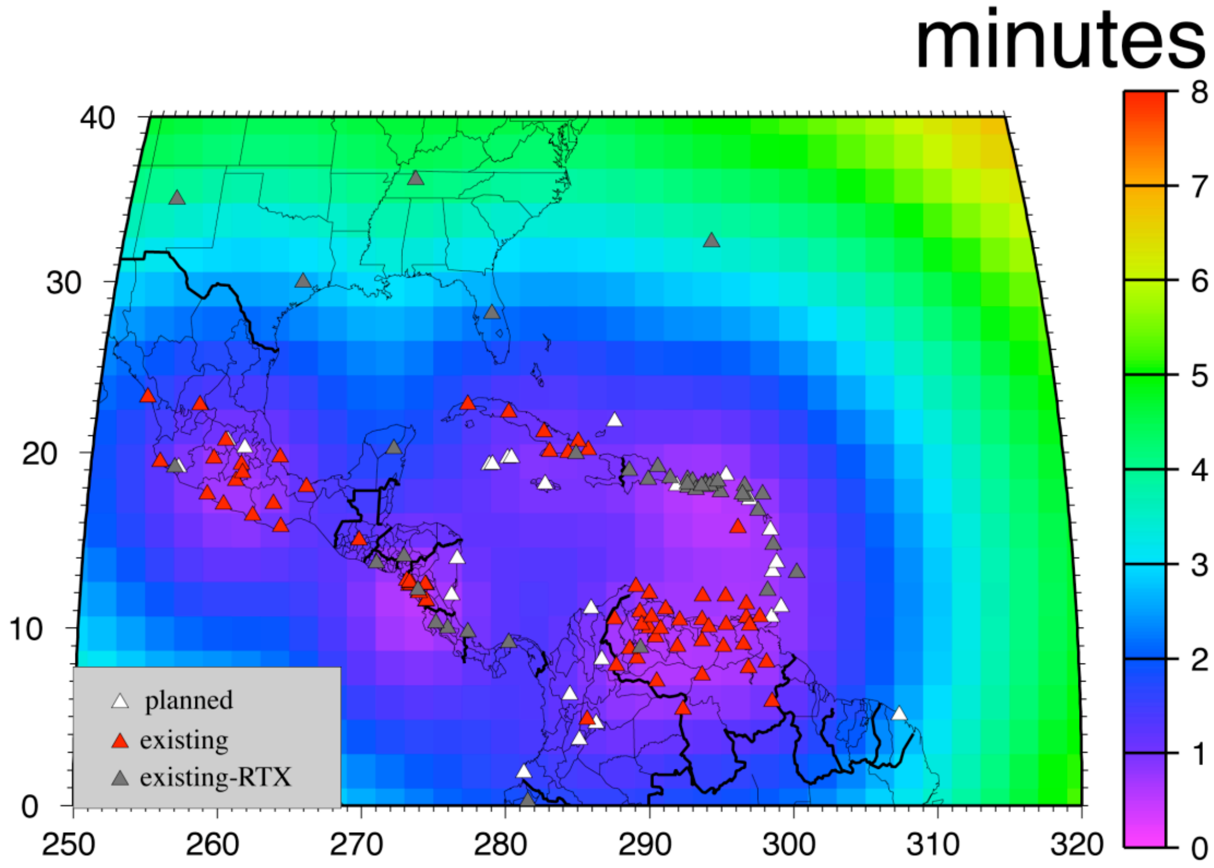
The map to the left shows the minimum moment magnitude (Mw) detectable in each grid cell by the Existing-RTX, other existing Caribbean networks and planned stations.

Noise levels for planned stations are taken from BBGH.



Combined Network Detection Time: including planned

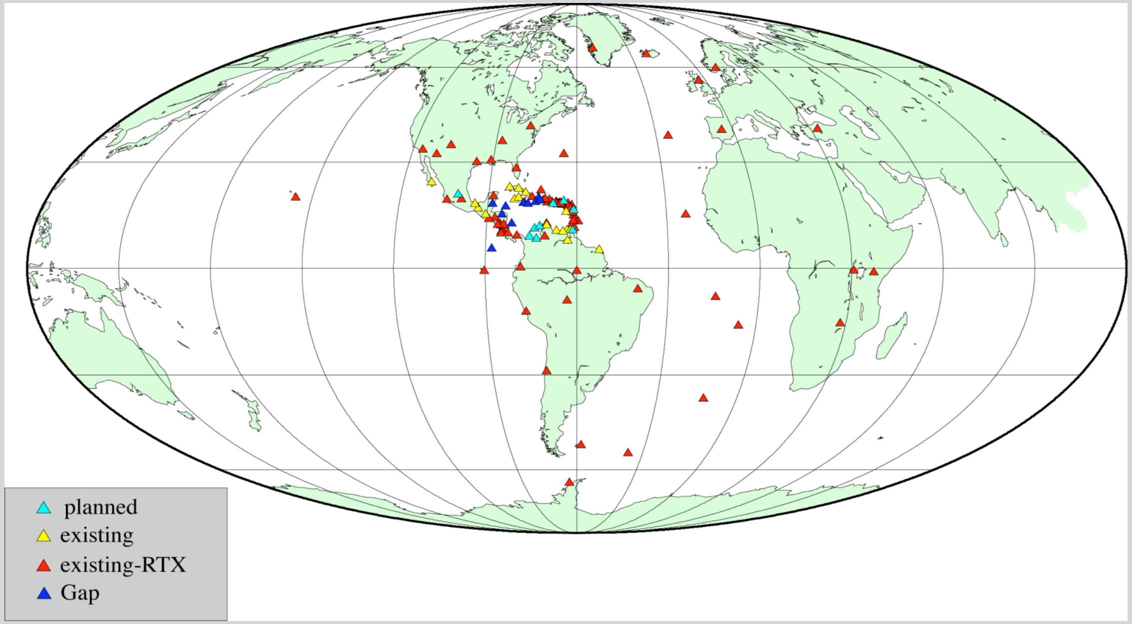
The map to the left shows the time in minutes for the initial P-wave from an earthquake in each cell to be detected by the first 9 stations in the Existing-RTX, other existing Caribbean networks and planned stations.



WG1 earthquake monitoring requirements met with combined network

Modeling Improvements:

- investigate station downtime, jacknife methods
- apply regional attenuation models
- compute noise levels for all stations
- ground-truth with known events



Next Step:

- model core stations by Martinique ICG in March 2009

Earthquake Summary Poster

http://earthquake.usgs.gov/eqcenter/eqarchives/poster/2007/20071129.php

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By Year

- 2007
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- 2005
- 2004
- 2003
- 2002

By Region

- Africa
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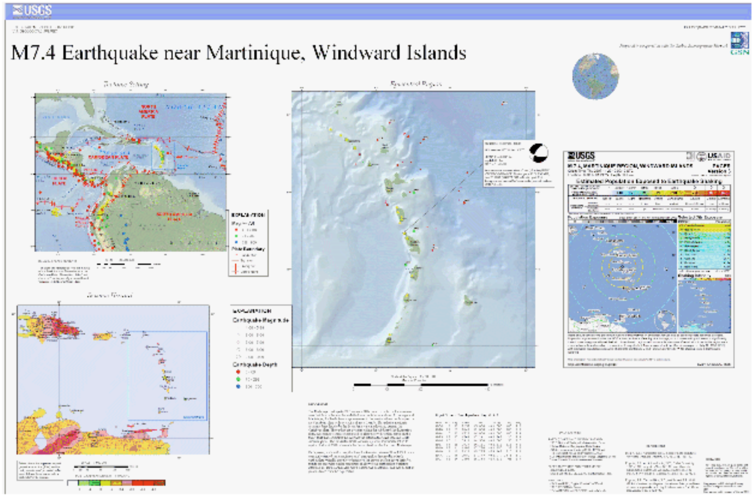
- Caribbean Sea
- Central America
- Indian Ocean
- Indonesia
- Japan
- Mexico
- New Zealand
- Pacific Ocean
- Papua New Guinea
- Philippines
- South America
- United States

Earthquake Summary Poster

Poster of the Martinque, Windward Islands Earthquake of 29 November 2007 - Magnitude 7.4



Larger Image • PDF version

The posters may be downloaded for viewing or for printing on a color plotter. Adobe PDF (.pdf) format files are provided. Adobe Acrobat 6.0 or higher is required for viewing the PDF file on a computer monitor and for printing the PDF map graphic. IMPORTANT: The PDF map graphic was produced using TrueType fonts; change the following setting to:

Page(Print)Setup<Properties<Layout<Advanced<Graphic<TrueTypeFont<DownloadAsSoftFont

Attention MAC users: If you have problems viewing the pdf files, please download the pdf file and view it in the lastest verion of Adobe Acrobat.

DISCUSSION

The Martinique earthquake 29 November 2007 occurred in the inclined seismic zone that dips to the west beneath the Lesser Antilles islands arc. In the region of Martinique, the South America plate moves to the west-northwest with respect to the Caribbean plate with a velocity of about 2 cm/yr. This relative motion is accommodated largely by the South America plate thrusting beneath the Caribbean plate. The earthquake occurred within the subducted South America plate, in response to stresses generated by plate's slow distortion, rather on the thrust fault that constitutes the interface the between the Caribbean and South America plates. The subducted South American plate is seismically active to depths of almost 200 km beneath the Lesser Antilles island arc near Martinique.

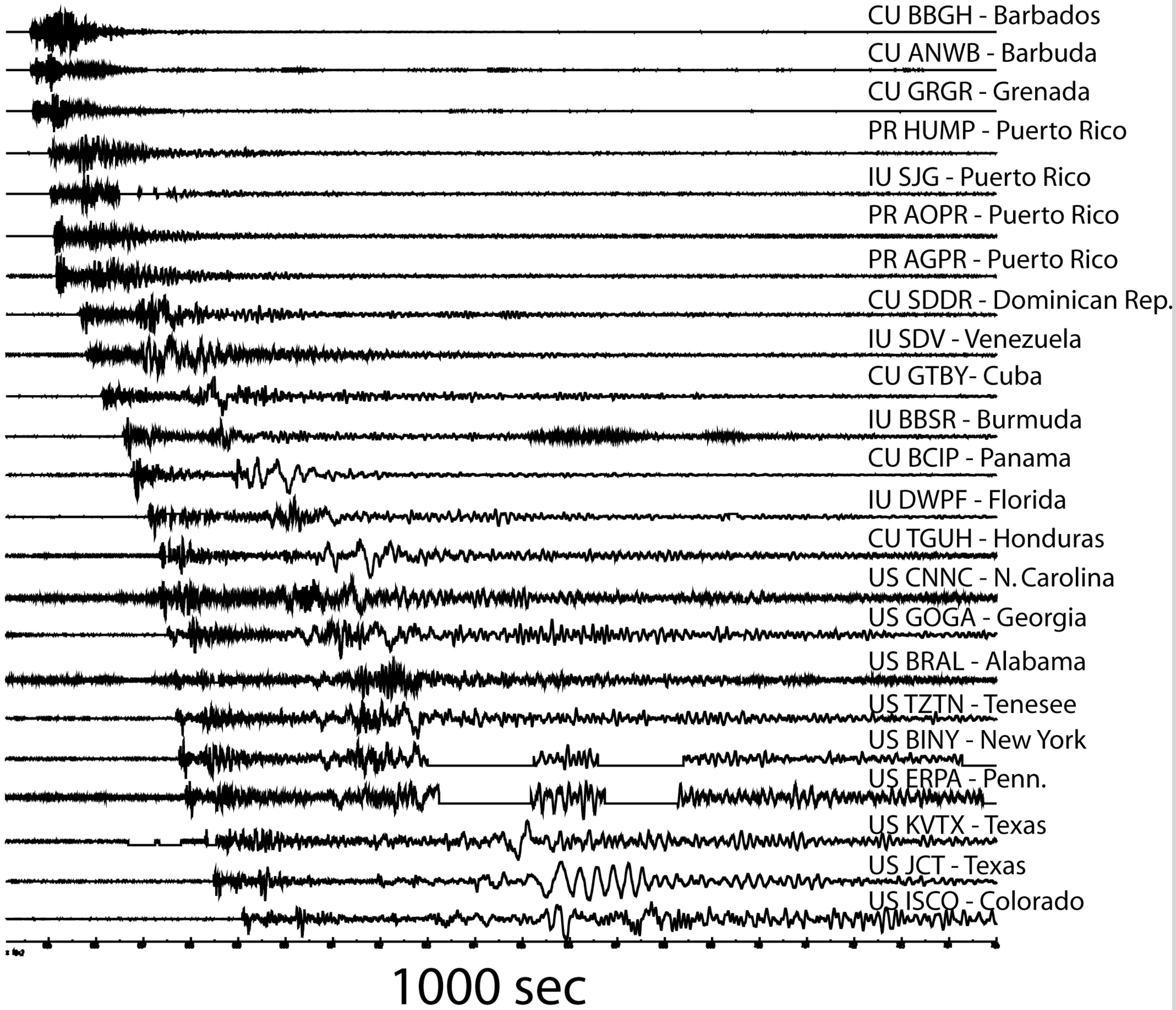
Earthquakes, such as this one, that have focal-depths between 70 and 300 km are commonly termed "intermediate-depth" earthquakes. Intermediate-depth earthquakes typically cause less damage on the ground surface above their foci than is the case with similar magnitude shallow-focus earthquakes, but large intermediate-depth earthquakes may be damaging nonetheless and may be felt at great distance from their epicenters.

http://earthquake.usgs.gov/eqcenter/

Martinique Timeline

Minutes after Origin time:

- 00:00 Event origin
- 00:58 ATWC First seismic alarm (1 station, FDF)
- 01:04 ATWC First automatic location (Ml 6.8, 15.0N 61.3W, 109km depth, 3 stations)
- 01:55 ATWC 4th automatic solution (1st Mwp) (Mwp 7.5, 15.1N 61.1 W, 145km depth)
- 02:44 ATWC Watchstander reviewed solution (Mwp 7.3, 15.1N 61.1W, 151km depth)
- 03:20 NEIC P-wave detection (9 stations)
- 03:21 ATWC WCATWC Observatory message issued (Mwp 7.3, 15.1N 61.2W, 149km depth)
- 05:00 ATWC/PTWC coordination call – collaborate on earthquake parameters & subsequent action
- 05:57 NEIC First automatic location (12 stations) (14.9N 61.3W, 149km depth)
- 06:01 NEIC First automatic magnitude (12 stations) (mb 7.4, 14.9N 61.3W, 149km depth)
- 07:01 NEIC 2nd automatic solution (33 stations) (mb 7.3 Mwp 7.5, 15.0N 61.3W, 131 km depth)
- 07:40 ATWC WEXX22 Tsunami Information Statement/WEXX32 Public Tsunami Information Statement issued
- 08:40 PTWC WEXX32 Public Tsunami Information Statement issued
- 09:40 ATWC announcement on National Warning System
- 10:40 ATWC call down list
- 11:48 NEIC First automatic Body Wave Moment Tensor (Mb 7.4, 14.945N 61.1W, 156 km depth)
- 12:00 NEIC Reviewed solution (Mwp 7.4, 15.0N 61.2W, 143km depth)
- 14:00 NEIC PAGER warnings and call down list – report w/ population exposure & estimated shaking intensity
- 19:31 NEIC First automatic Centroid Moment Tensor (CMT) solution (Mwp 7.4, 14.9N 61.2W, 147km depth)


CU BBGH - Barbados
CU ANWB - Barbuda
CU GRGR - Grenada
PR HUMP - Puerto Rico
IU SJG - Puerto Rico
PR AOPR - Puerto Rico
PR AGPR - Puerto Rico
CU SDDR - Dominican Rep.
IU SDV - Venezuela
CU GTBY- Cuba
IU BBSR - Burmuda
CU BCIP - Panama
IU DWPF - Florida
CU TGUH - Honduras
US CNNC - N. Carolina
US GOGA - Georgia
US BRAL - Alabama
US TZTN - Tenesee
US BINY - New York
US ERPA - Penn.
US KVTX - Texas
US JCT - Texas
US ISCO - Colorado
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