



# Earthquake Magnitudes in the CEUS

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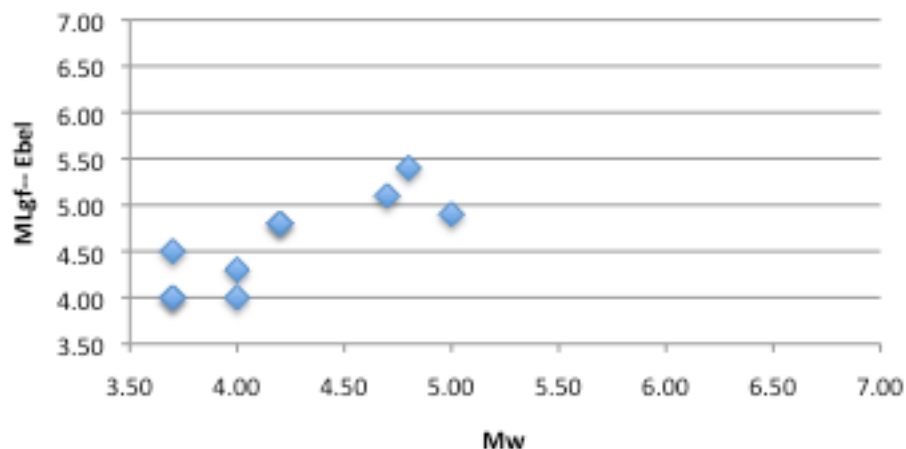
# Issues Regarding CEUS Magnitudes

- Calibration of local magnitude calibrations to  $M_w$
- Accuracy of calibration as a function of event size below  $M_4$  (above  $M_4$ , regional moment tensors or teleseismic moments can be computed)
- Accuracy of calibration with respect to epicentral distance and wave period
- How region-specific should magnitude formulas be for small earthquakes?

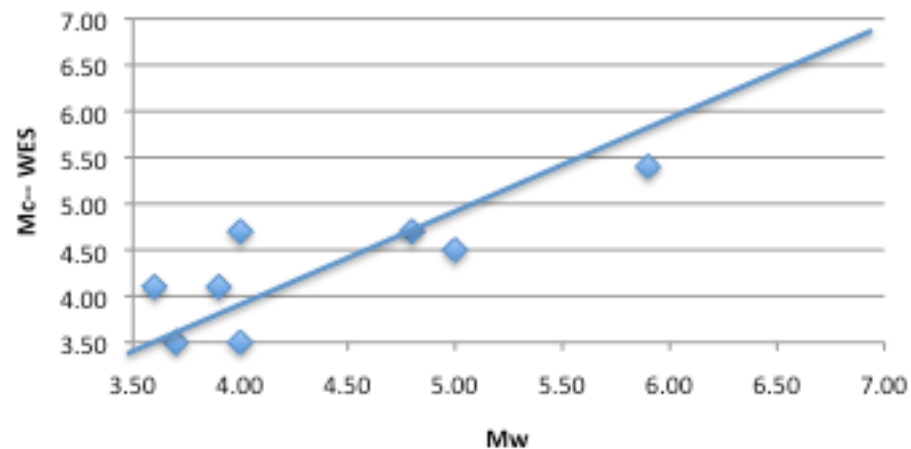


# Weston Observatory Magnitudes

WES MLg(f) vs Mw 1995-2011



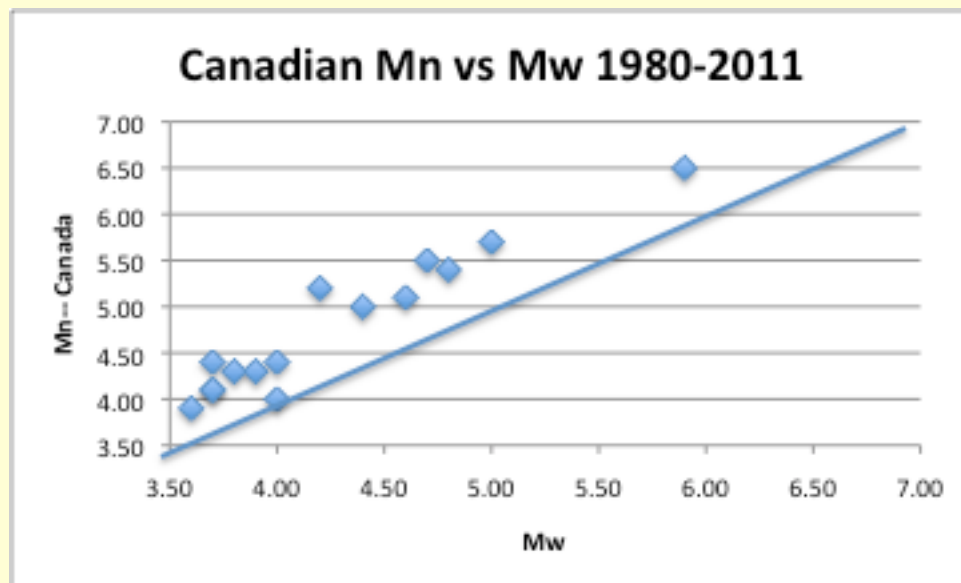
WES Mc vs Mw 1980-2011



- The WES MLg(f) magnitudes overestimate Mw by about .42 magnitude units. The WES Mc magnitudes tend to overestimate Mw between Mw3.5 and Mw4.0, but they seem to underestimate Mw above about Mw 4.8.



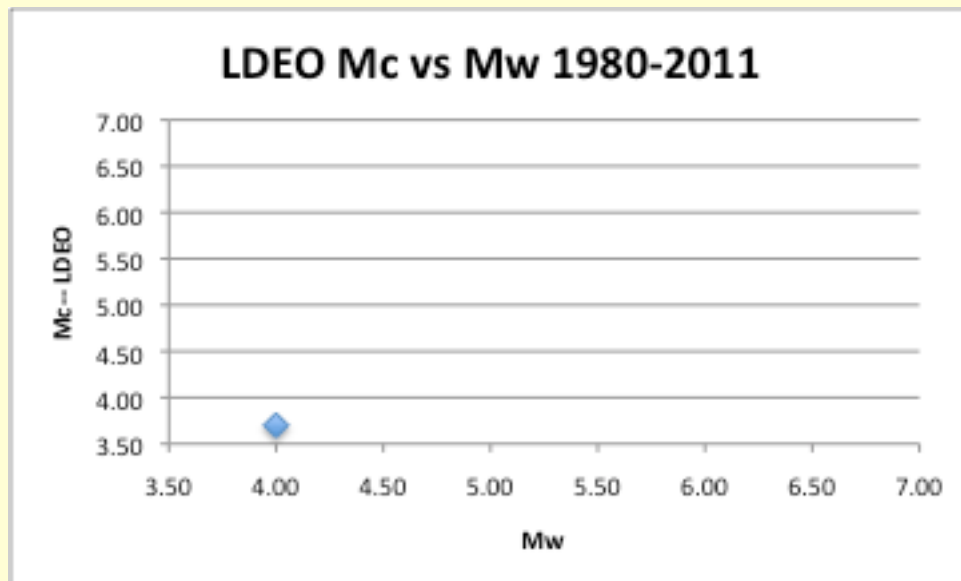
# Canadian Geological Survey Magnitudes



- The CGS Mn magnitudes tend to overestimate Mw by about .56 magnitude units.



# Lamont-Doherty Magnitudes



- There are not enough LDEO Mc reports for events with known Mw to draw any conclusions.

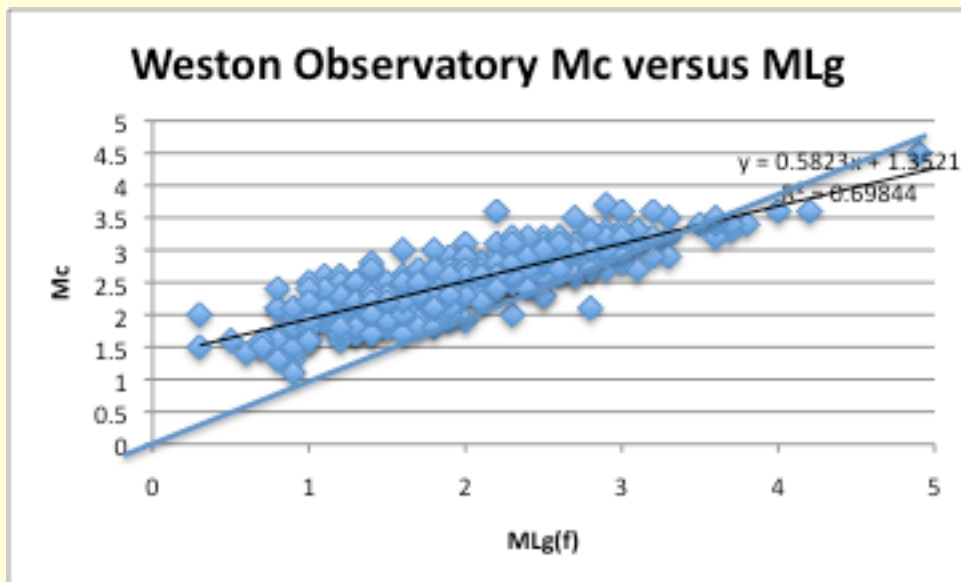


# Magnitude Comparisons

- In the following slides different magnitude scales used in Northeastern North America are correlated with each other for small earthquakes to see how well they scale with each other.



# Weston Observatory Magnitudes

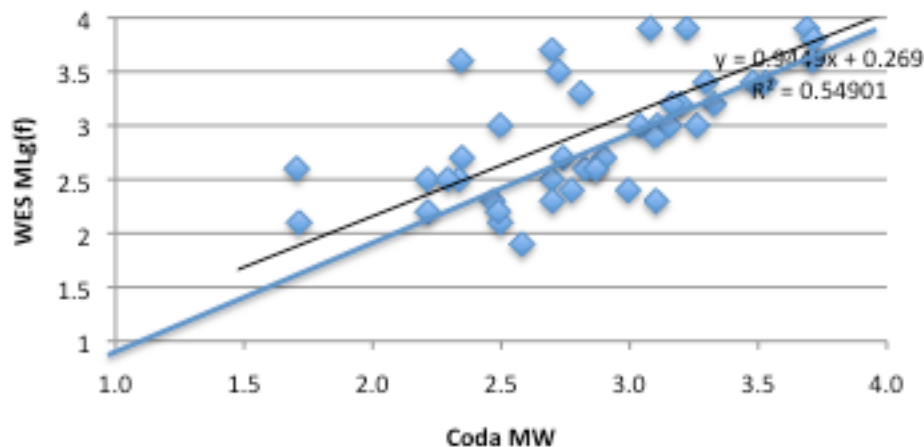


- The WES Mc magnitudes tend to overestimate the MLg(f) magnitudes at smaller magnitudes and tend to underestimate them at larger magnitudes. This effect explains the WES Mc-Mw trend seen in an earlier slide.

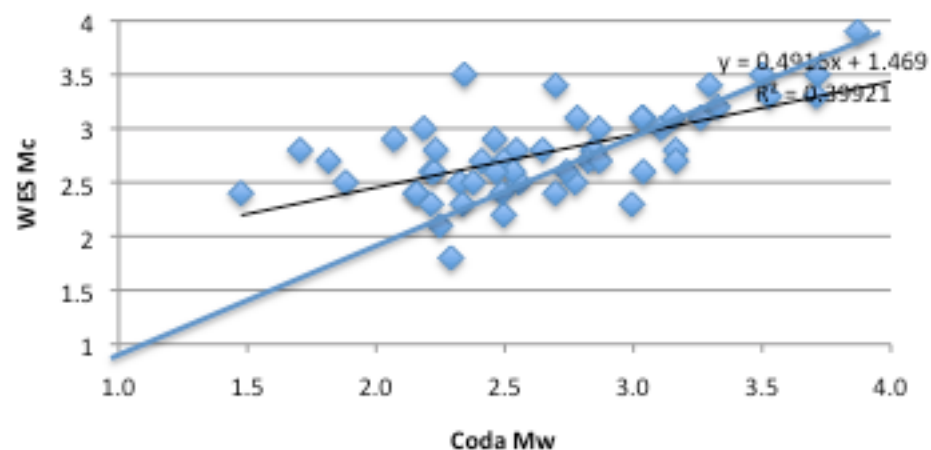


# Weston Observatory Magnitudes

### WES MLg(f) versus Coda Mw



### WES Mc versus Coda Mw

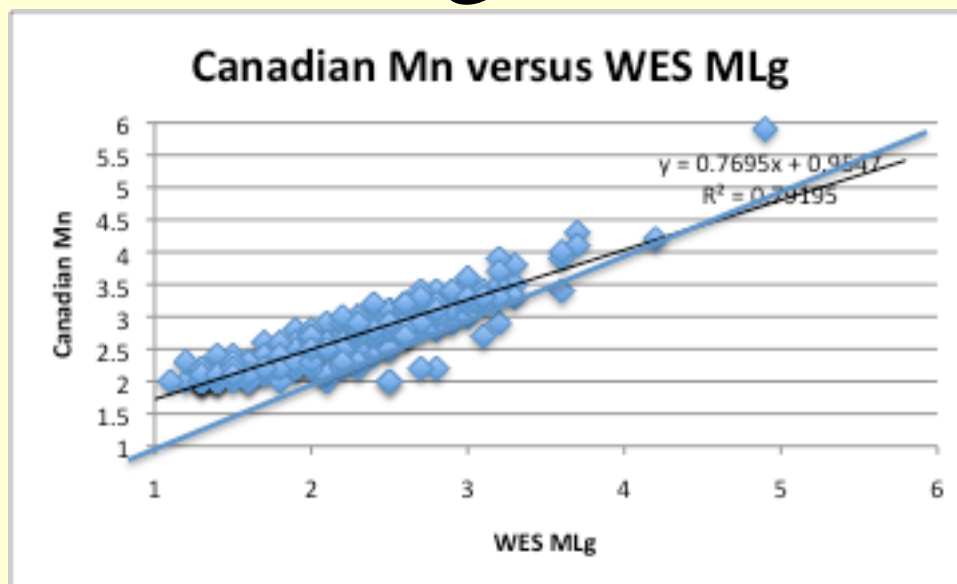


- The WES coda Mw magnitudes tend to slightly overestimate the MLg(f) magnitudes. The WES Mc magnitudes tend to overestimate the coda Mw magnitudes at smaller magnitudes and tend to underestimate them at larger magnitudes.





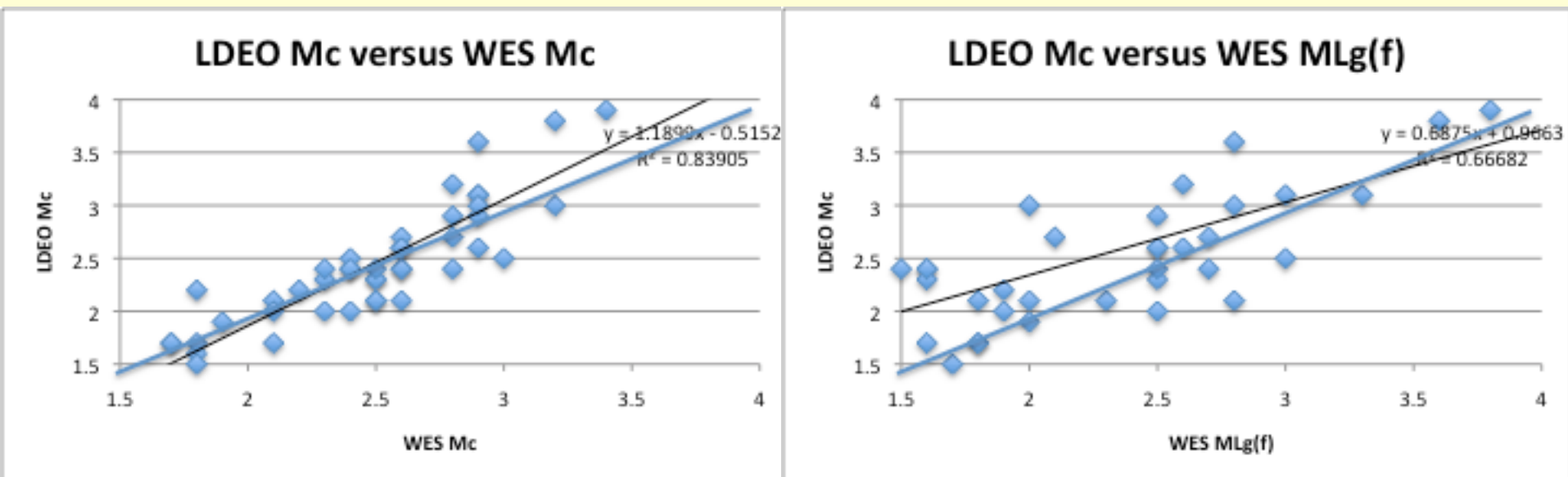
# Canadian Geological Survey Magnitudes



- The CGS Mn magnitudes tend to overestimate the WES MLg(f) magnitudes at lower magnitude and may underestimate them on average at larger magnitudes.



# Lamont-Doherty Magnitudes



- On average, the LDEO Mc scale closely to the WES Mc determination, and the LDEO Mc tend to overestimate the WES MLg(f) magnitudes at smaller magnitudes and tend to underestimate them at larger magnitudes.



# Issue Regarding Magnitudes of Large Historic Earthquakes

- Some historic earthquakes may have larger magnitudes than previously estimated (1663 Charlevoix— $M_w$  about 7.5, Ebel, BSSA 2011)
- Some historic earthquakes may have smaller magnitudes than previously estimated (1870 Charlevoix –  $M_w$  about 5.9, Ebel, unpublished)
- More research on the magnitudes of many historic earthquakes is needed (starting from historic data but also using modern seismicity and attenuation relations)



# Other/Future Issues

- How will local magnitudes change as AQMS rolls out across the country? How to calibrate AQMS magnitudes against existing magnitude scales?
- How do NEIC magnitudes calibrate to local magnitudes computed by RSNs? Has anyone systematically checked this? Should NEIC use same formulas and magnitudes as local RSNs?
- What research is needed to assure that magnitudes for all CEUS earthquakes are better calibrated to  $M_w$ ?



# Discussion

- On average, both WES  $ML_g(f)$  and CGS  $M_n$  magnitudes seems to scale with  $M_w$  at all magnitudes but with different DC offsets. If these offsets are taken into account, these magnitudes scales can be used to estimate  $M_w$  for small events in NENA.
- Since the WES coda  $M_w$  scales with WES  $ML_g(f)$ , it can be used to estimate  $M_w$  for small events in NENA if the DC offset is accounted for.
- Neither the WES and LDEO coda magnitude formulas not scales correctly with magnitude to  $M_w$ . Therefore, they should not be used to estimate  $M_w$  for small events.



# Recommendations

- WES, CGS, LDEO and NEIC should form a working group to develop and jointly implement magnitude relations that can be used by all three networks to compute magnitudes that scale closely to  $M_w$  at all magnitude levels. This working group should also examine the work by A. Bent (SSA meeting, 2011) which suggests that there may be a systematic difference in magnitude determinations between the Appalachian region and the shield.
- There should be new research to develop methods to routinely compute  $M_w$  directly for small earthquakes (below about  $M$  4.0).



**FORECAST: SUNNY AND CLEAR  
WITH A CHANCE OF AN EARTHQUAKE.**



- For seismic hazard analyses, the preferred magnitude measure is **moment magnitude**. For larger events ( $M \geq 4$ ), regional waveform moment-tensor inversions, regional surface-wave inversions, or teleseismic waveform inversions can be used to find the moment and therefore the moment magnitude. Currently, none of these methods can be used to find moment magnitudes for smaller events in northeastern North America.





# Possible Methods for Moment Magnitude Determinations of Small Earthquakes

- *Extend regional moment tensor determinations to smaller magnitudes* (The problem: synthetic waveforms cannot be matched to the high frequency observed waveforms of small earthquakes.)
- *Do spectral analysis of small earthquakes* (The problem: wave propagation effects must be correctly accounted for.)
- *Compute seismic moment from coda waves* (The problem: does the method work?)
- *Compute conversions from other magnitude types to moment magnitude* (The problem: can these other magnitude types scale with moment magnitude?)



- In this study, I will examine how well other earthquake magnitude scales used in northeastern North America correlate with moment magnitude and with each other. I will also examine the scaling of a coda-wave moment magnitude scale developed at Weston Observatory.

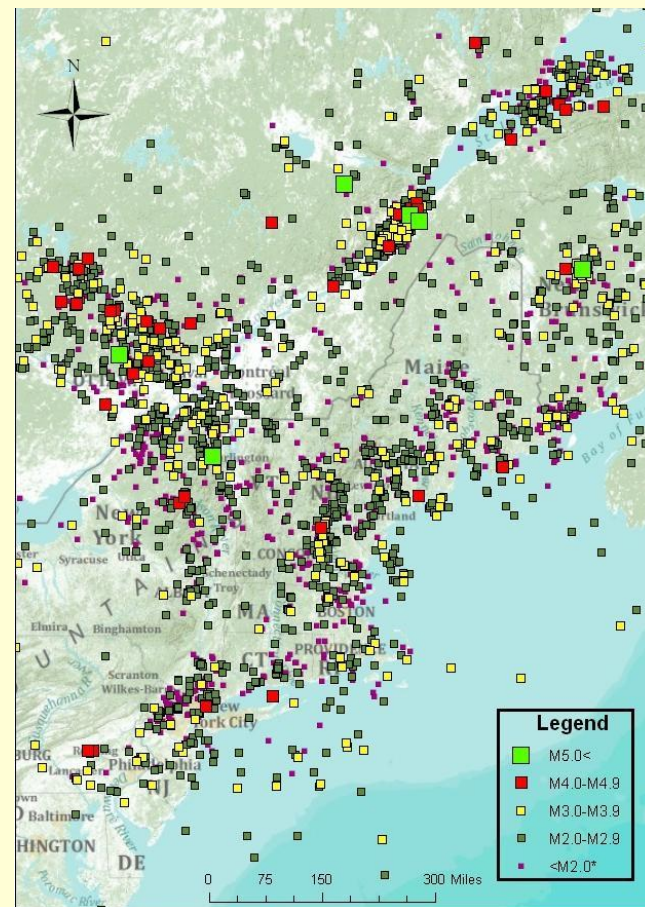
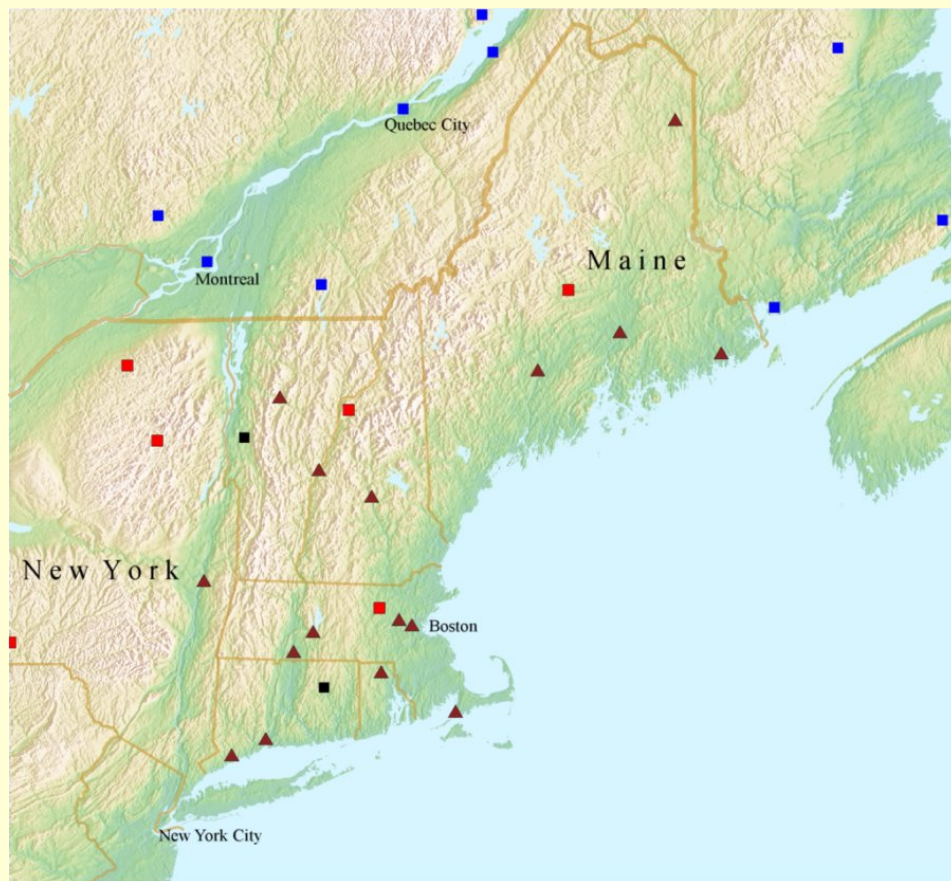


# Magnitude Scales used in Northeastern North America

- **Weston Observatory**
  - MLg(f) – Ebel (SRL, 1994)
  - Mc – Rosario (MS Thesis, Boston College, 1979)
  - Mw – Macherides (MS Thesis, Boston College, 2003 based on Biswas and Aki (BSSA, 1984))
  - ML – Ebel (1982)
- **Lamont-Doherty**
  - ML – Kim (BSSA, 1998)
  - Mc – Peseckis (?)
  - Mw – Regional moment tensor (Dreger method)
- **Canadian Geological Survey**
  - MN – Nuttli (JGR, 1973)



# Seismic Networks and Seismicity in Northeastern North America



Most of the seismic stations now operating in northeastern North America have broadband sensors and 24-bit digitizers.



# Magnitude Comparisons

- In the following slides different magnitude scales used in Northeastern North America are correlated with moment magnitudes for those events with independent moment-magnitude determinations