Very Long Period Source Characteristics and Radiated Energy of Large Earthquakes

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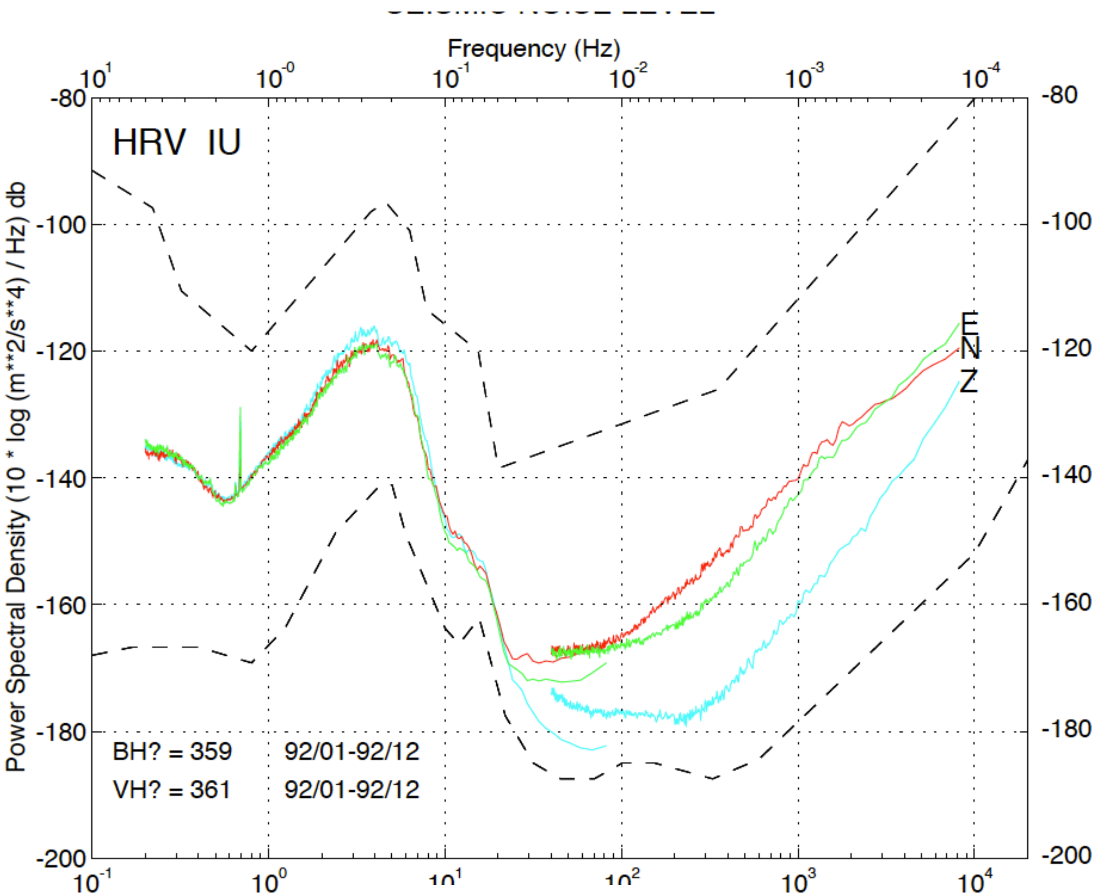
Outline

- Seismic moment estimation at increasingly long period: technique, examples, results.
- Radiated energy estimates:
technique, examples, results.
- Energy partitioning
- Conclusions

Seismic moment estimation at increasingly long period

Strategy at VLP: use high S/N vertical component

Noise level



Period (sec)

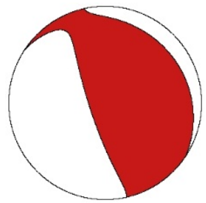
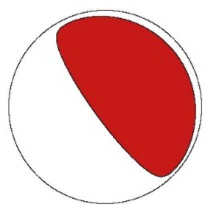
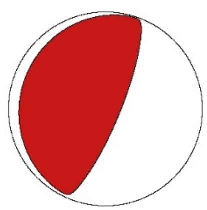
Moment estimation at increasingly long period

- S1: 3 comp. unconstrained inversion (.001 - .005) Hz
  -> focal mechanism

- S2: Only vertical (.001 - .005) Hz
  Focal mechanism – constrained inversion
  → Reference seismic moment: Mo

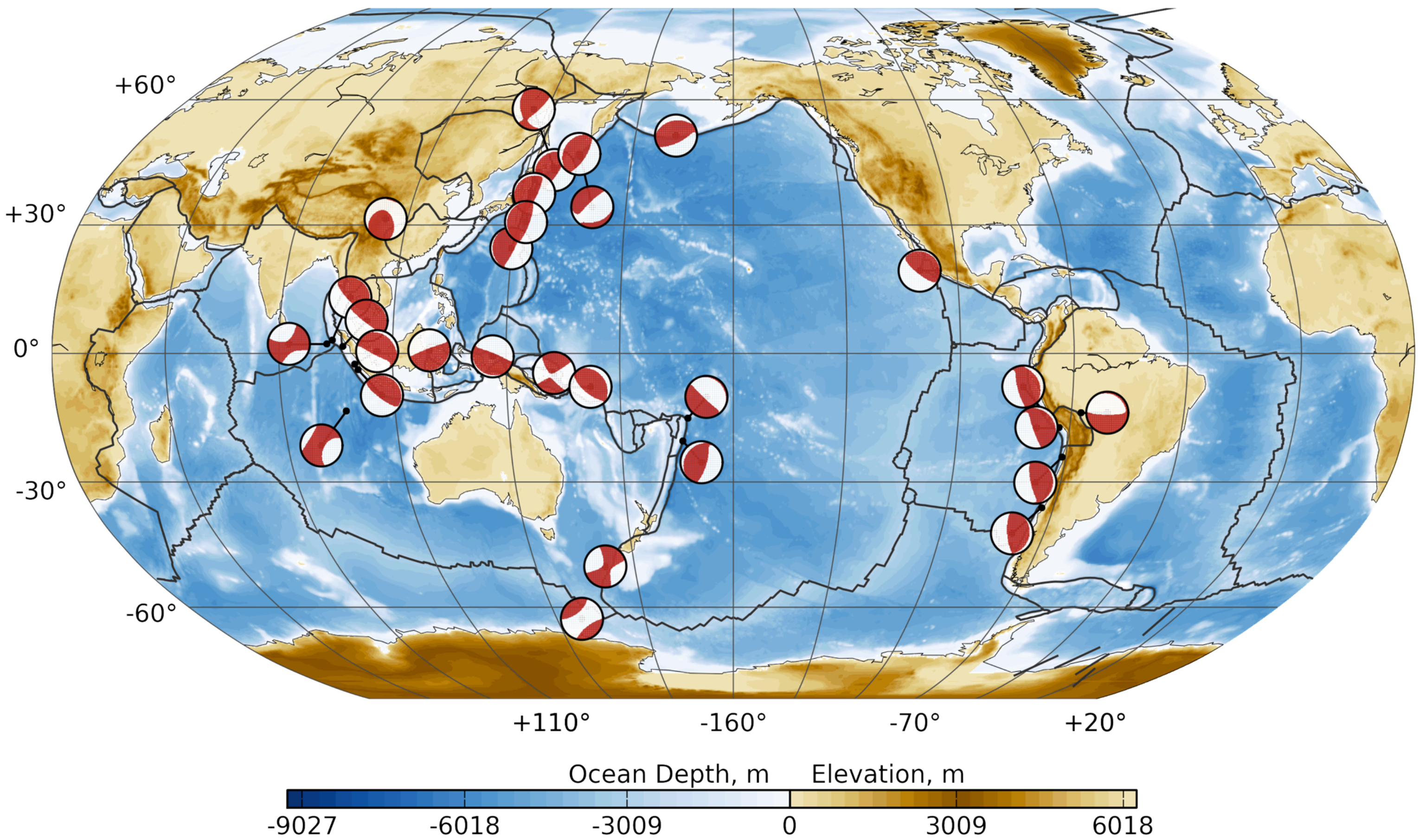
- S3: Only vertical
  Focal mechanism – constrained inversion
  (.0010 - .00250) Hz → Mo’ → ΔM_w
  (.0010 - .00125) Hz → Mo’ → ΔM_w
  (.0008 - .00100) Hz → Mo’ → ΔM_w
  (.0005 - .00100) Hz → Mo’ → ΔM_w

Some examples

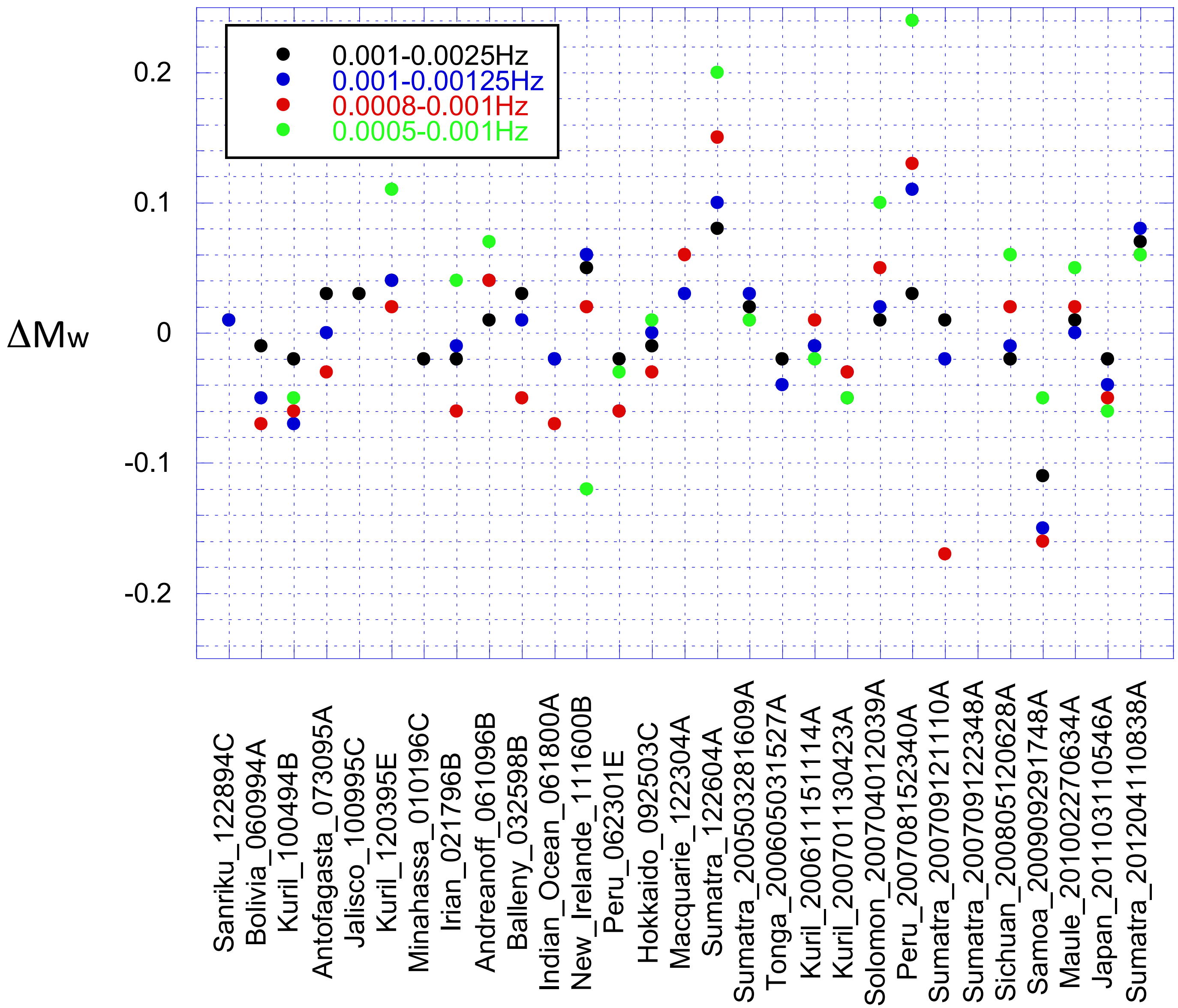
	S1	S2 Mw	S3 ΔMw
Peru 2001		8.37	- 0.02/ - 0.06/ - 0.06/ - 0.03
Sumatra 2004		8.98	+0.08/ +0.10/ +0.15/ +0.20
Tohoku-Oki 2011		9.05	-0.02/ -0.04/ - 0.05/ -0.06

T ~ 500 s → ~1000 s

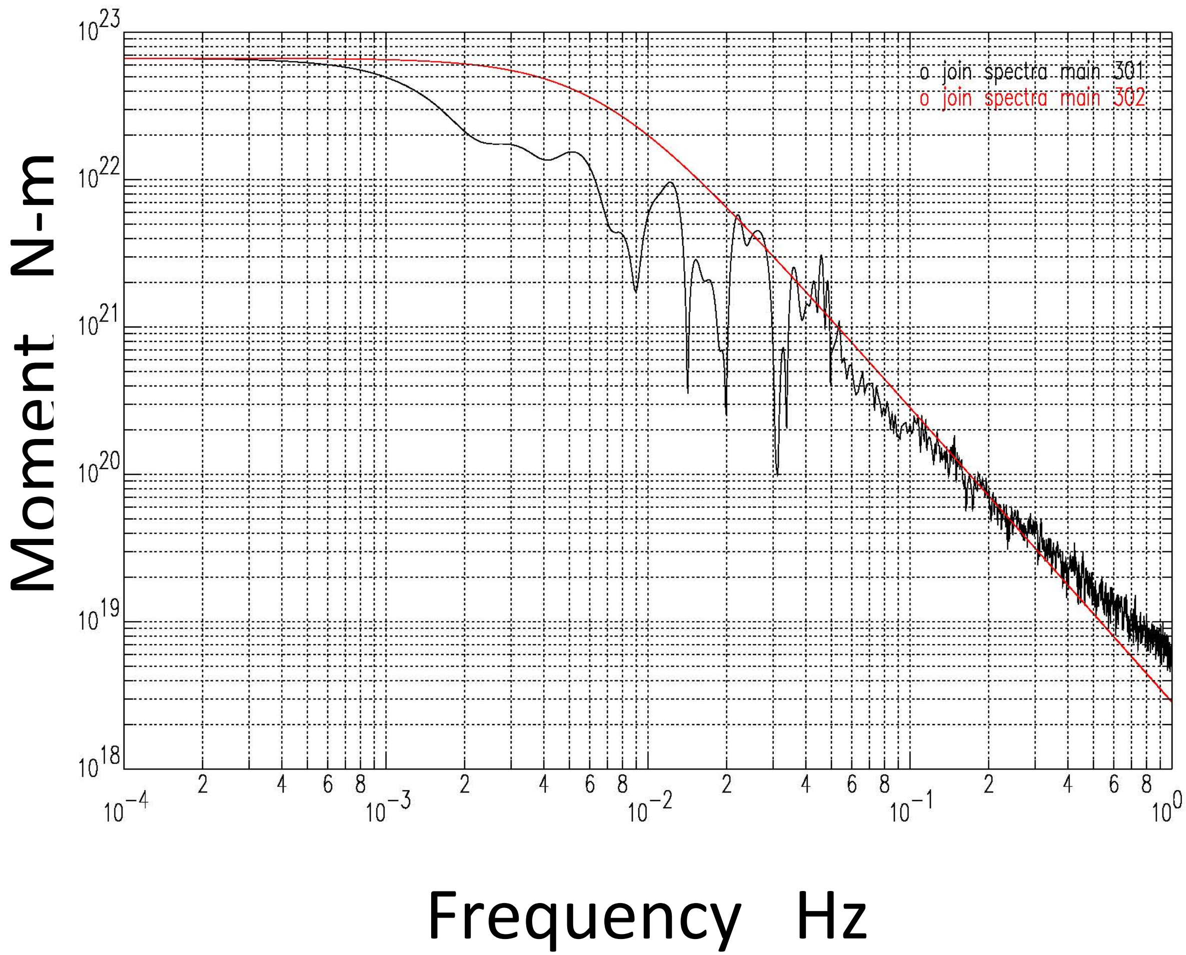
Wphase focal mechanisms (s1)
Mw ≥7.9 1990-2012 28 (+1) events

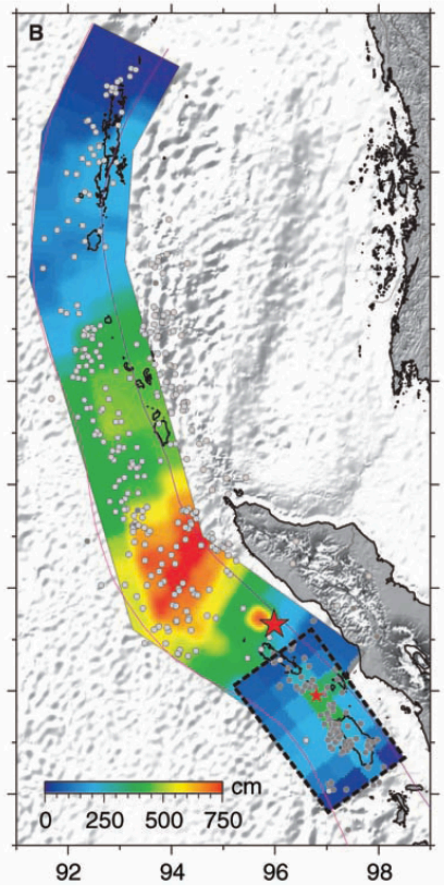


Moment estimation at increasingly long period
Summary of results



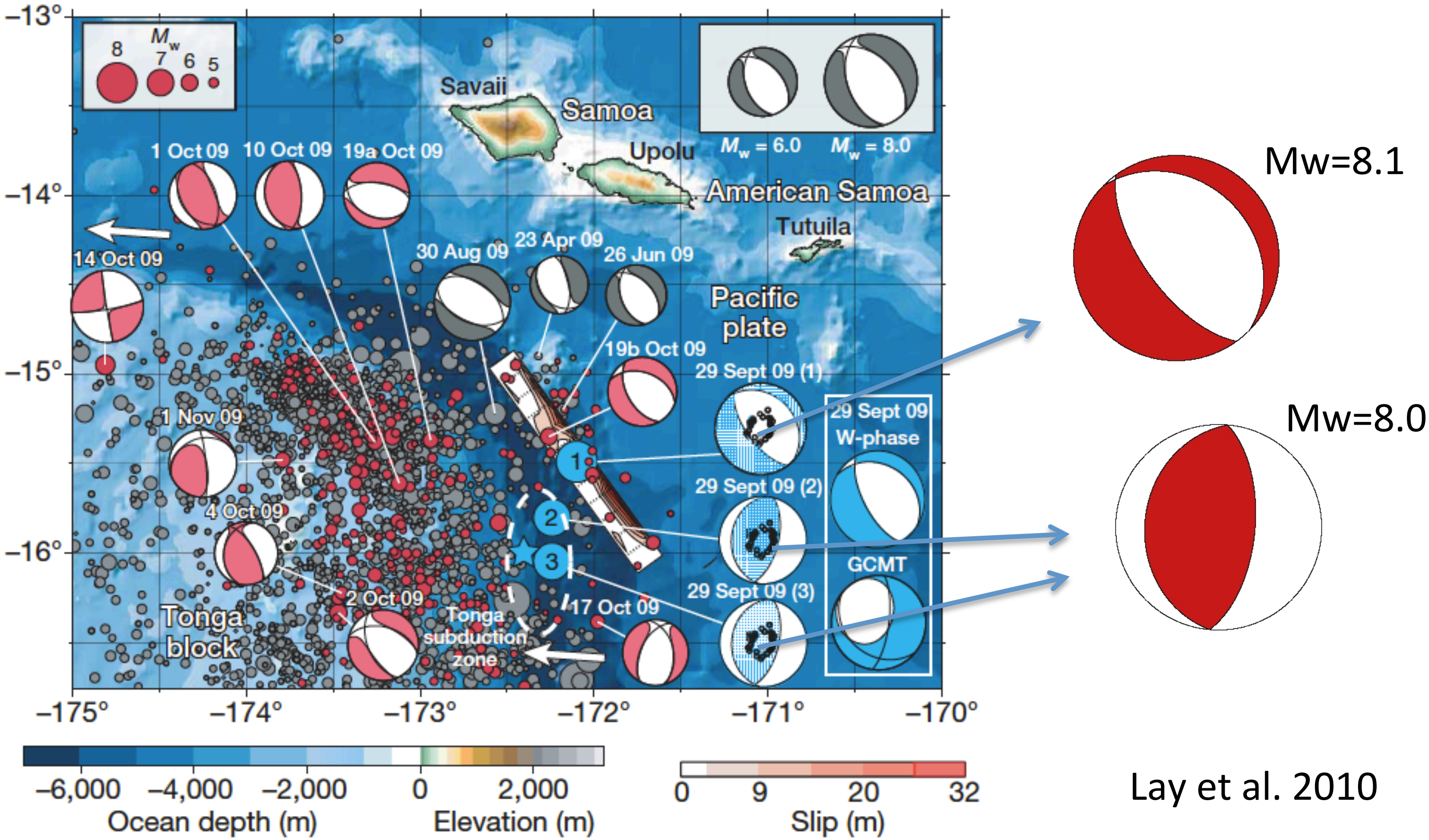
Sumatra 2004 Moment rate spectrum





Amon et al., 2005

The 2009 Samoa doublet earthquake

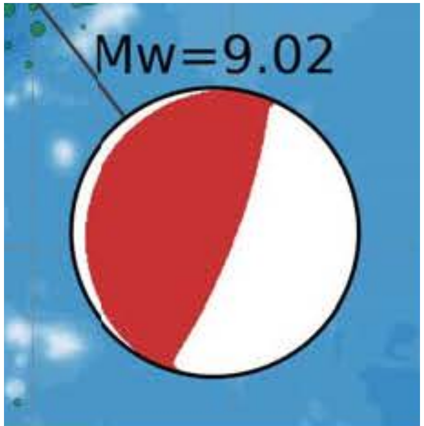


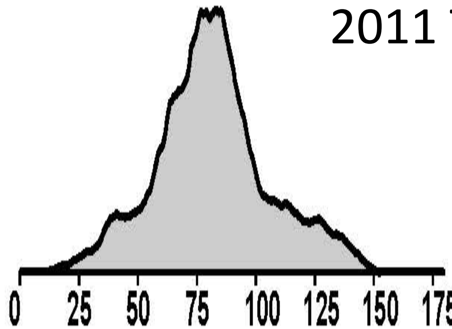
Lay et al. 2010

Moment-rate spectrum
and
radiated Energy estimates

Determination of moment-rate spectrum

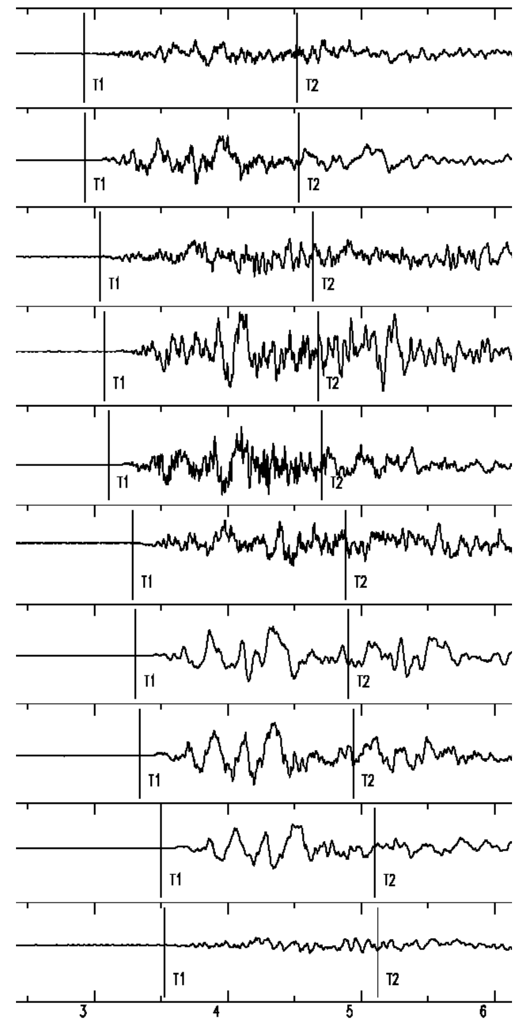
2011 Tohoku-Oki Earthquake

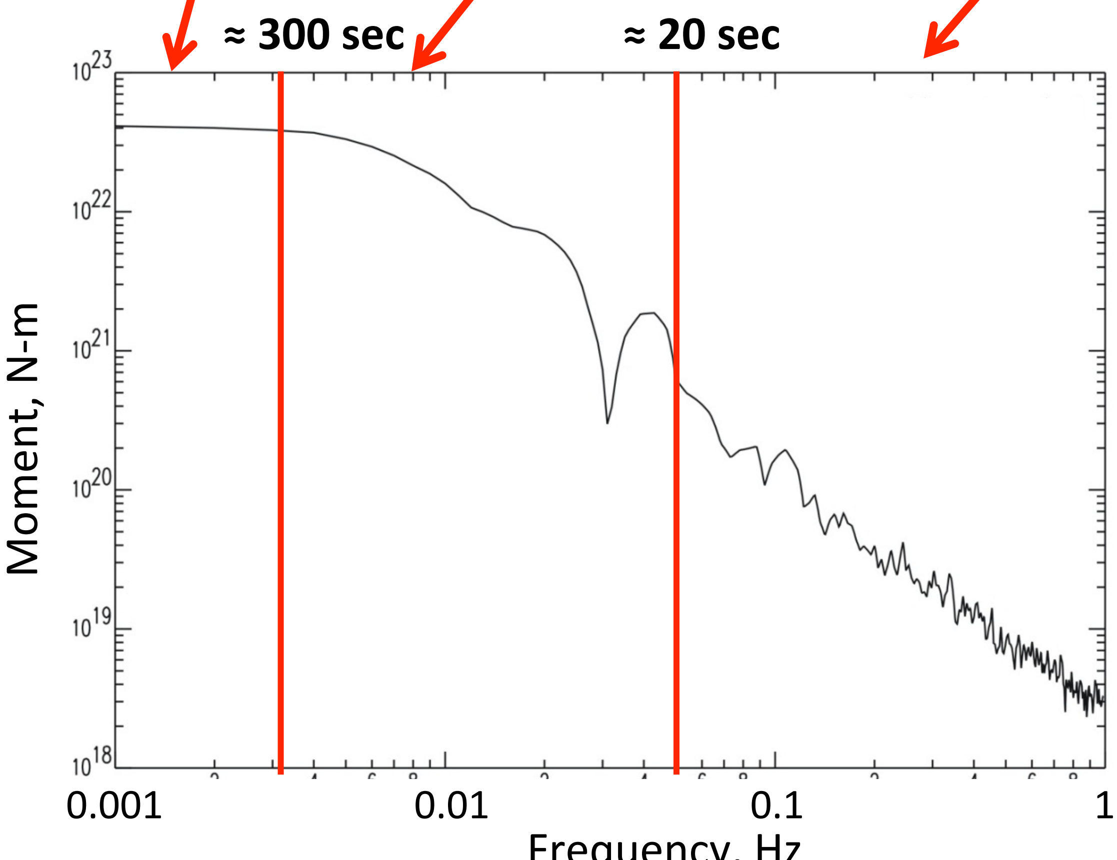




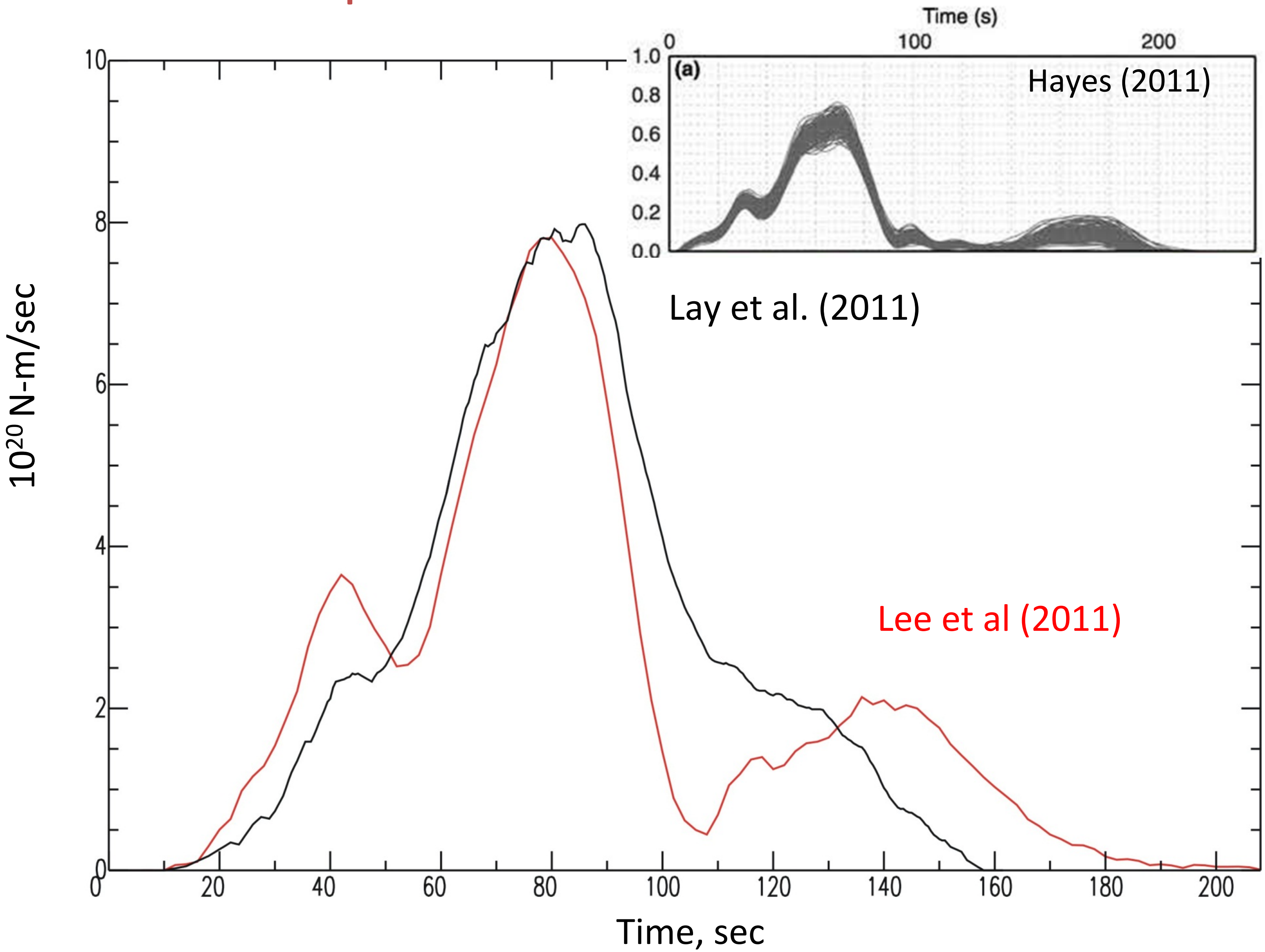
Moment-rate function

$\hat{v}(f)$

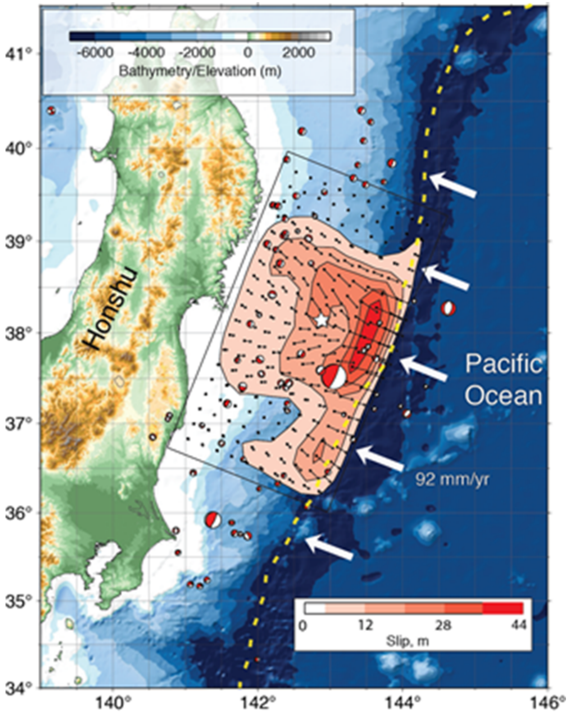


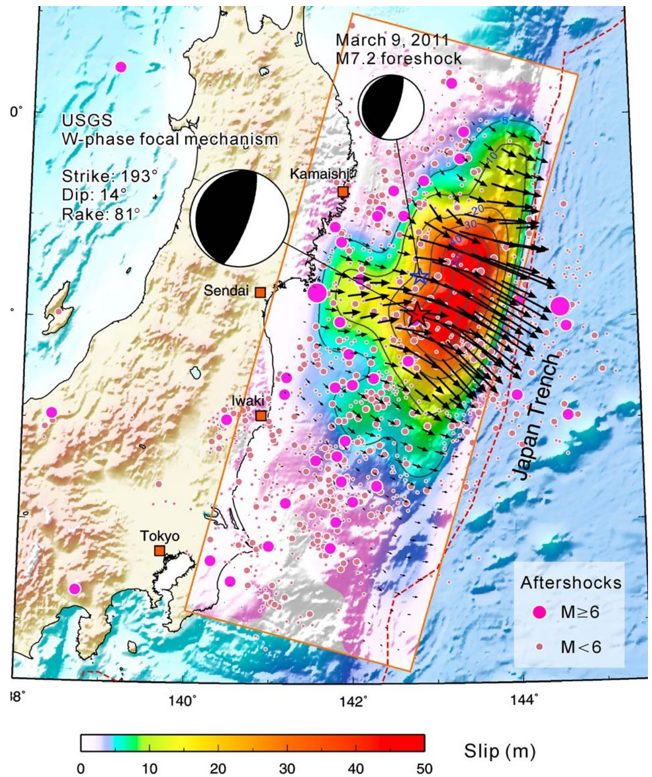


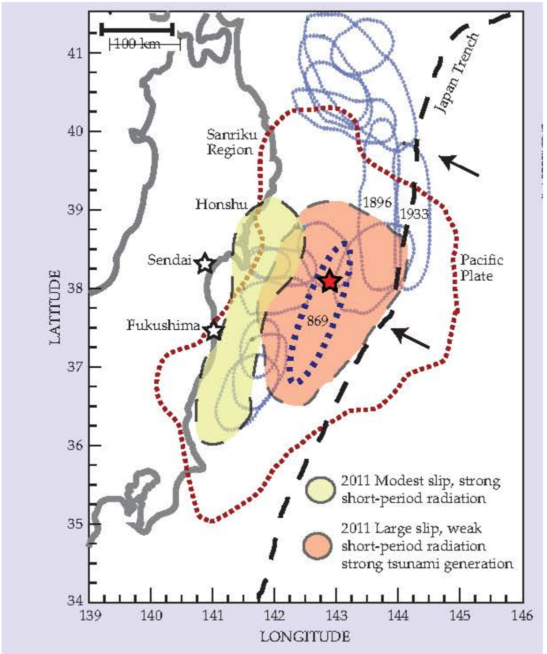
Tohoku-oki 2011
Comparison of moment-rate functions



Tohoku-oki 2011, slip distribution







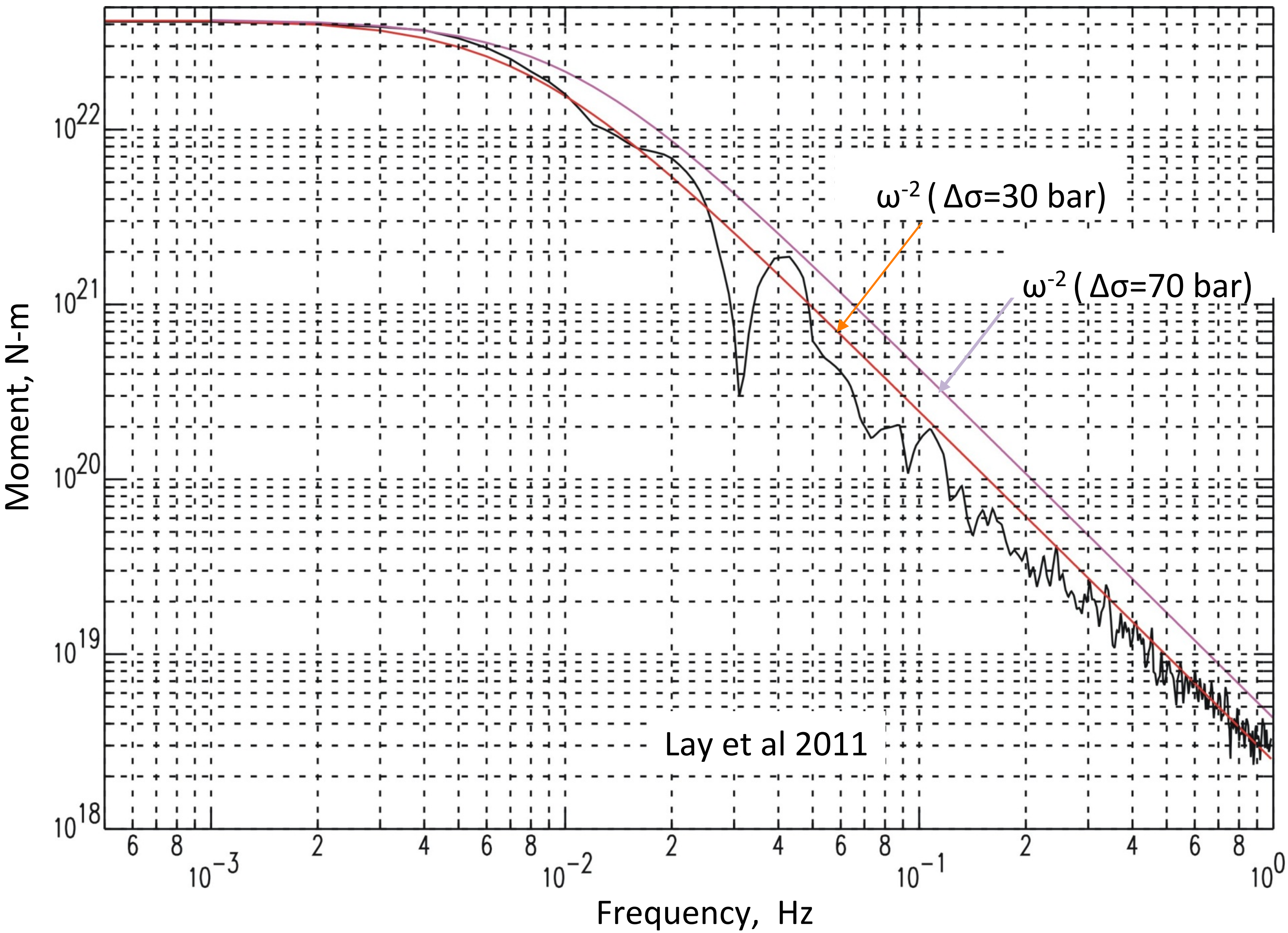
- Large (>50m) slip from a compact area near trench radiating weak high frequency

Lay et al. (2011), Lee et al. (2011)

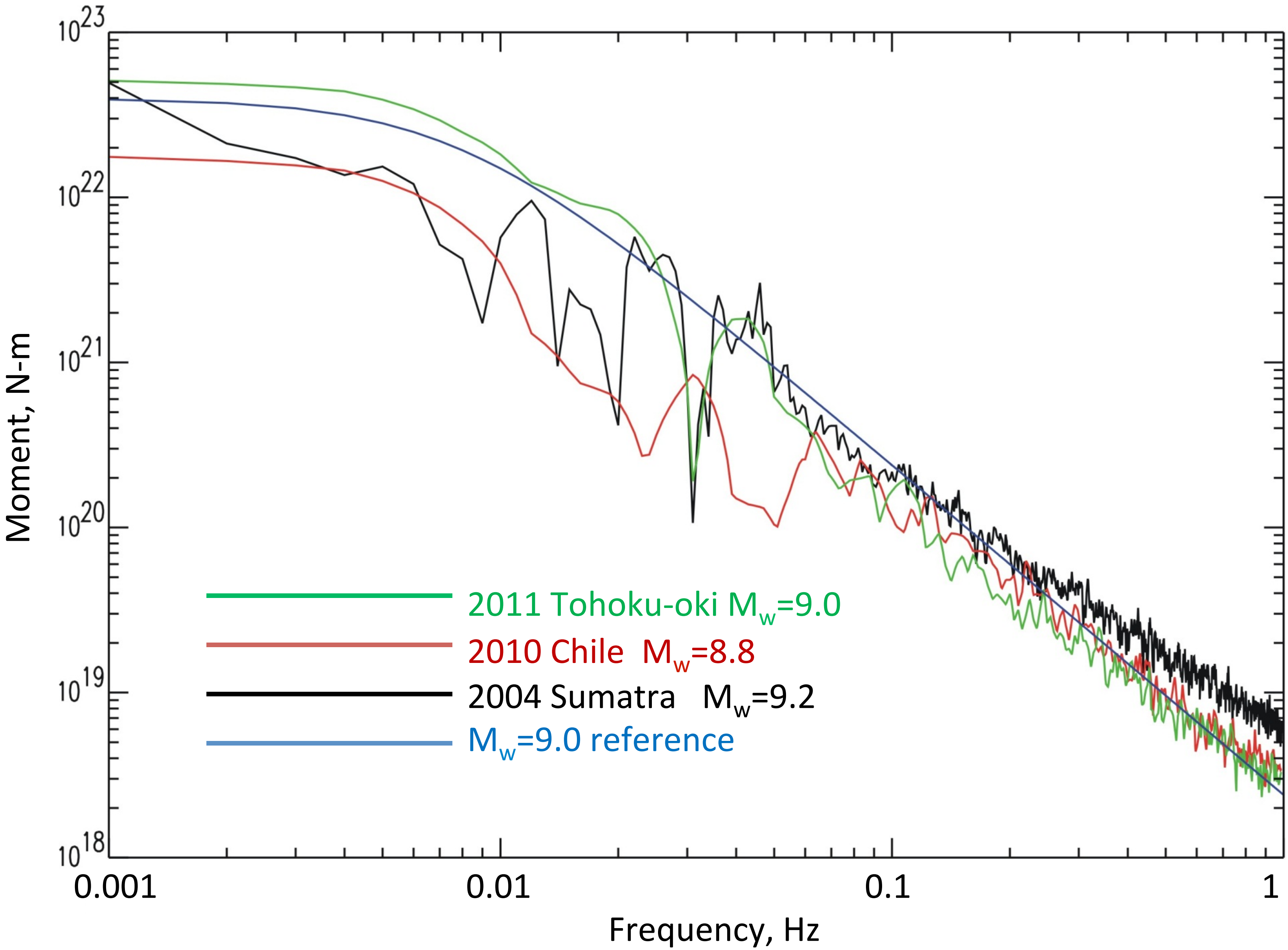
- Strong HF radiation from the down-dip portion

High stress drop
$\Delta\sigma$=70 bar

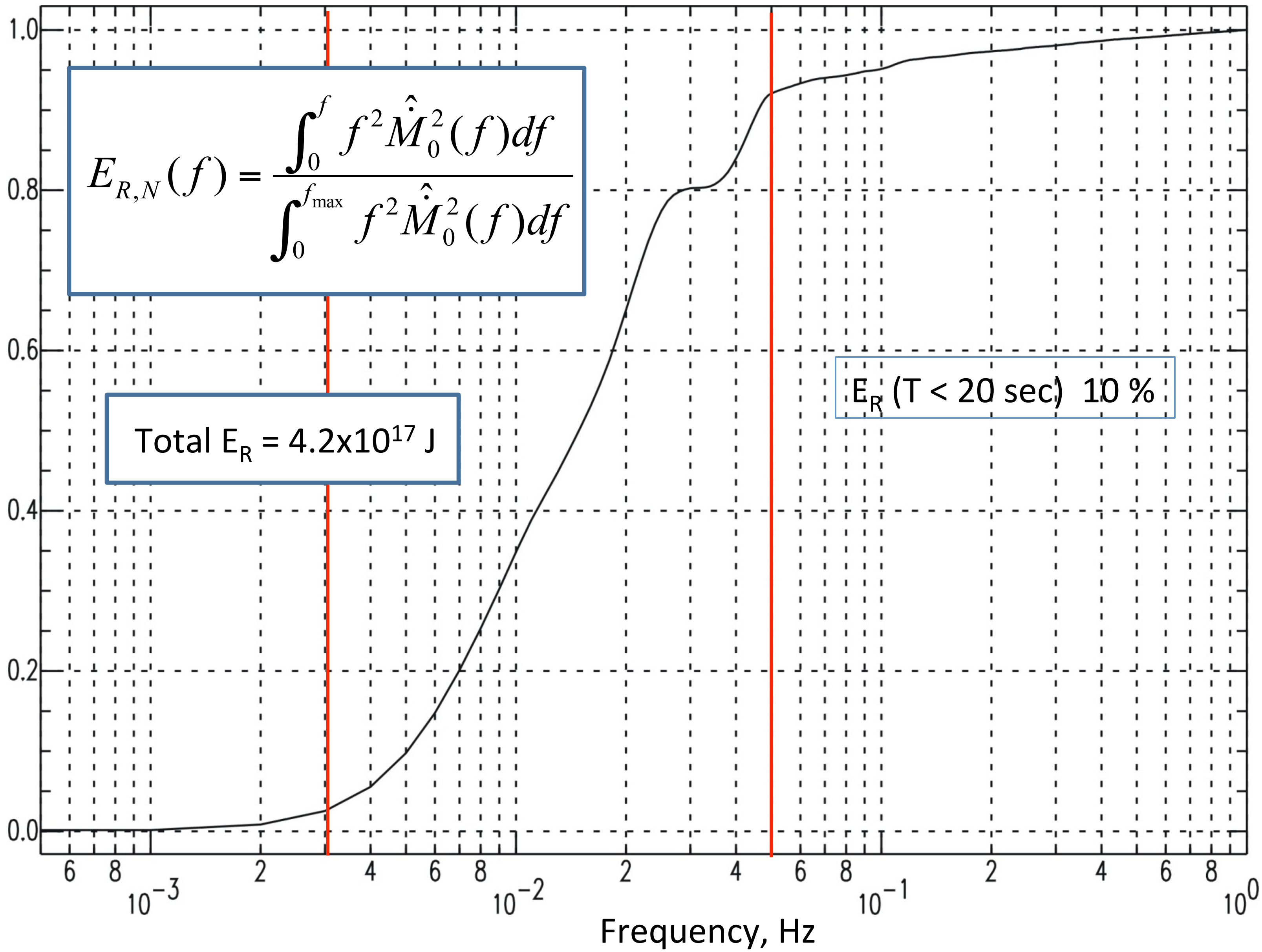
2011 Tohoku –Oki   Moment-rate Spectrum



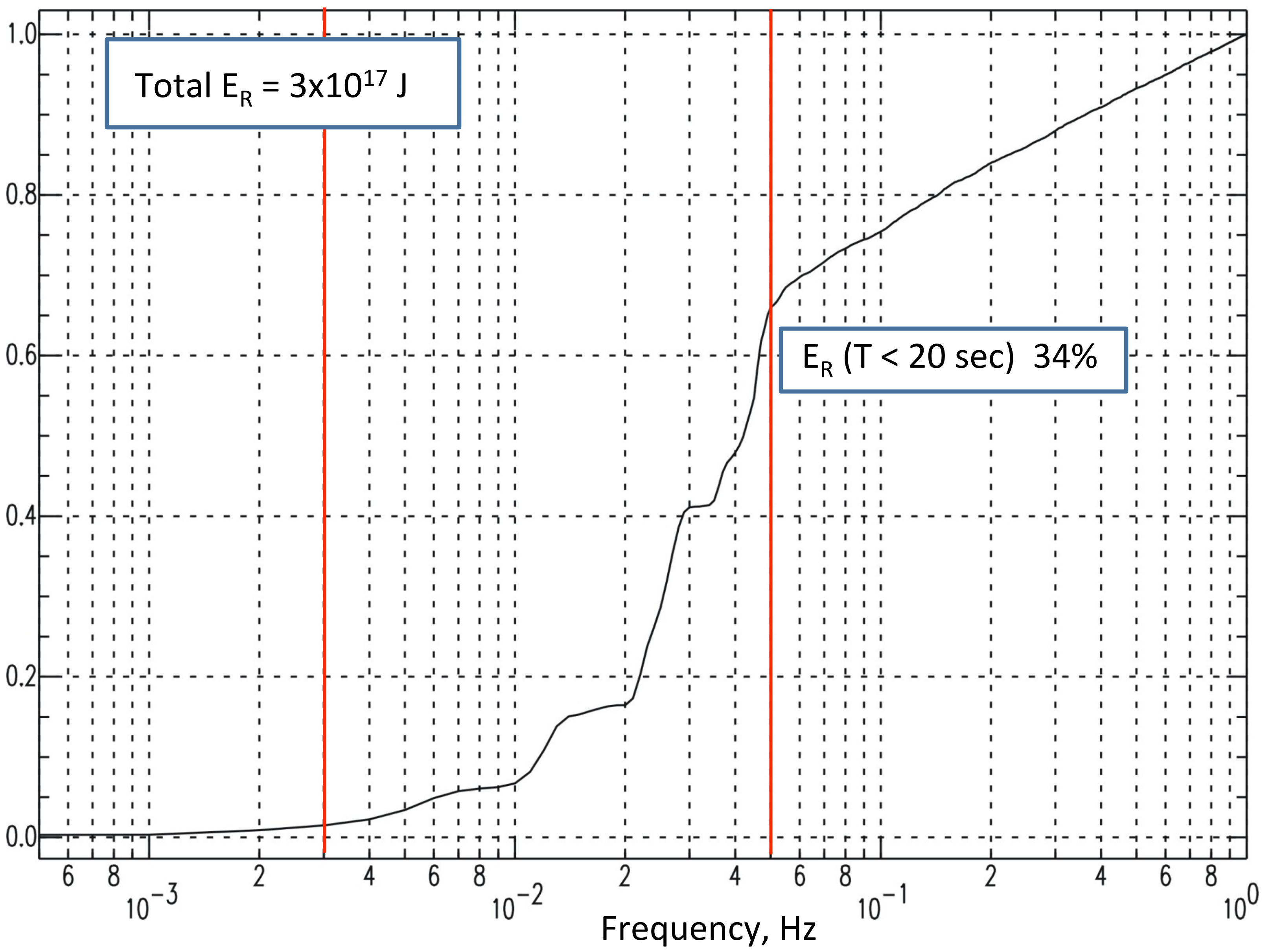
Moment rate spectrum of great earthquakes



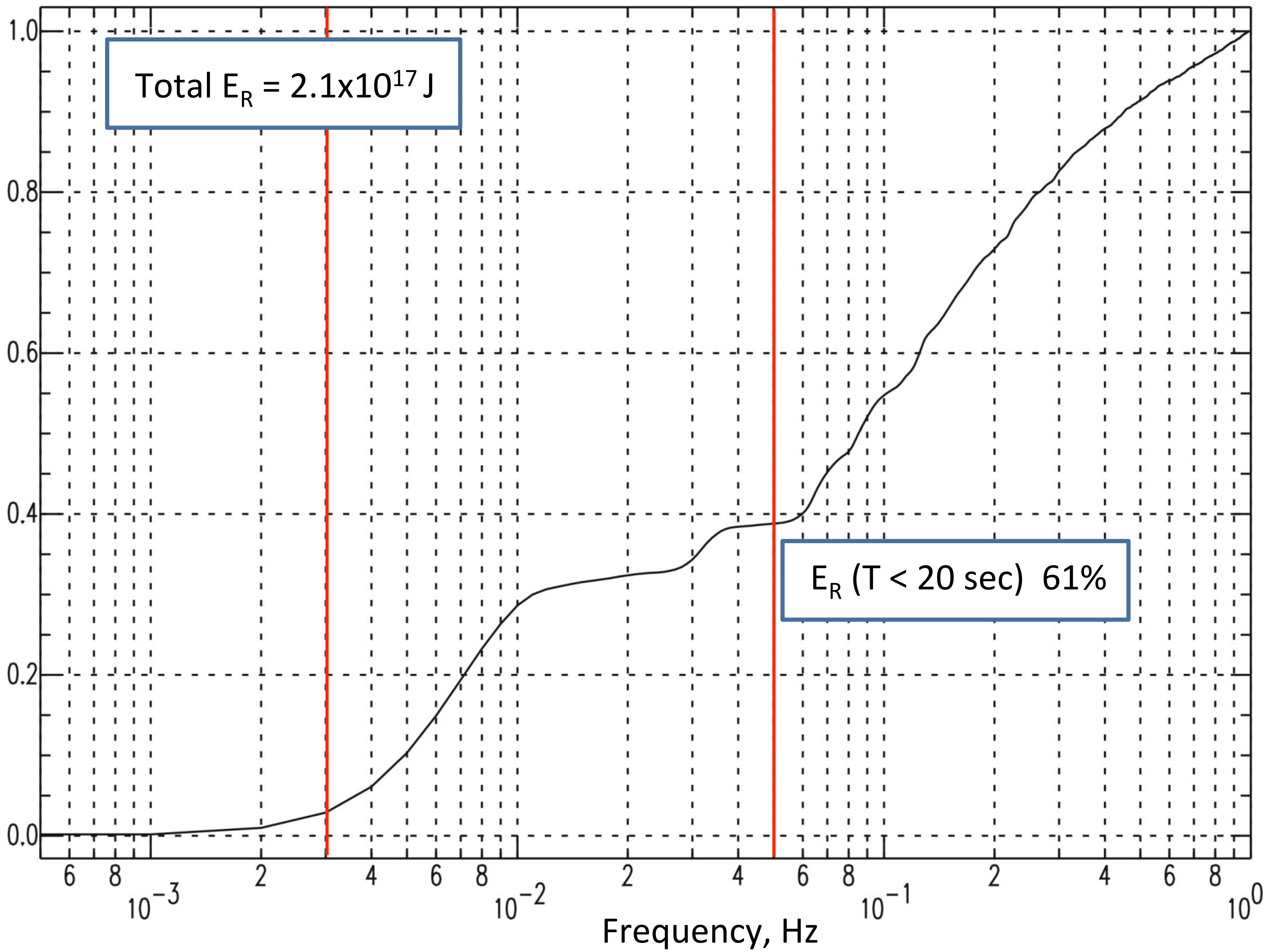
2011 Tohoku-Oki Cumulative energy (normalized)



2004 Sumatra Cumulative energy (normalized)

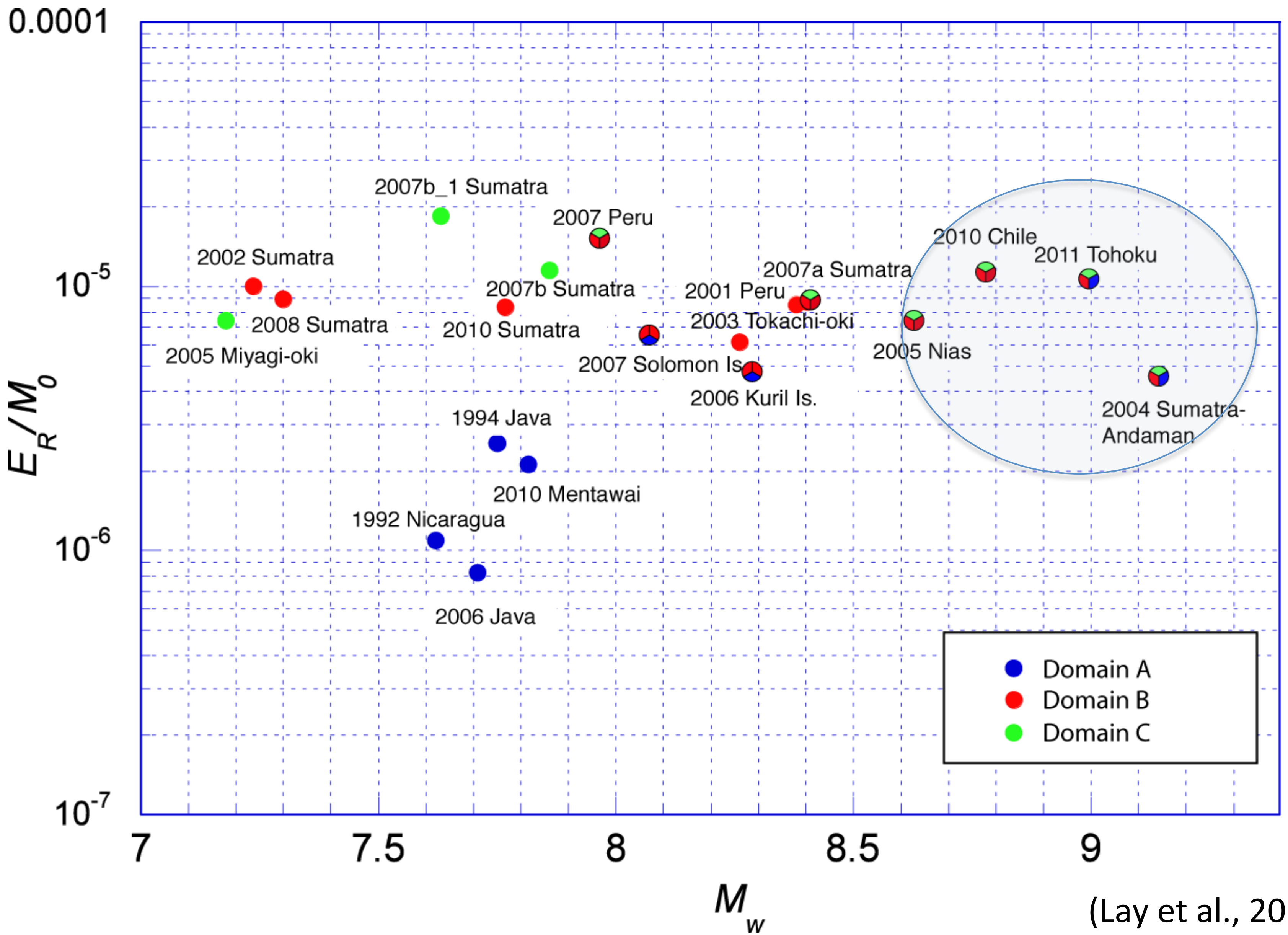


2010 Chile Cumulative energy (normalized)



Energy partitioning
and
Radiation efficiency

Scaled energy, (E_R/M_o), of subduction thrust earthquakes



(Lay et al., 2012)

Radiation efficiency

$$\frac{E_R}{M_0} \longrightarrow \eta_R = \frac{2\mu}{\Delta\sigma_E}\left(\frac{E_R}{M_0}\right)$$

Two ingredients:

- $\Delta\sigma_E = \dfrac{\int_\Sigma \Delta u \Delta\sigma dS}{\int_\Sigma \Delta u dS}$ (Noda and Lapusta, 2012)

– μ is the rigidity "appropriate" for the entire rupture plane.

Both of which cannot be estimated accurately.

$$\Delta\sigma_E \approx C\mu \frac{\Delta u}{\Sigma_{th}^{1/2}}$$

Examples of radiation efficiency

With some assumptions, we obtain the following preliminary values, but the uncertainties are inevitably very large.

Examples

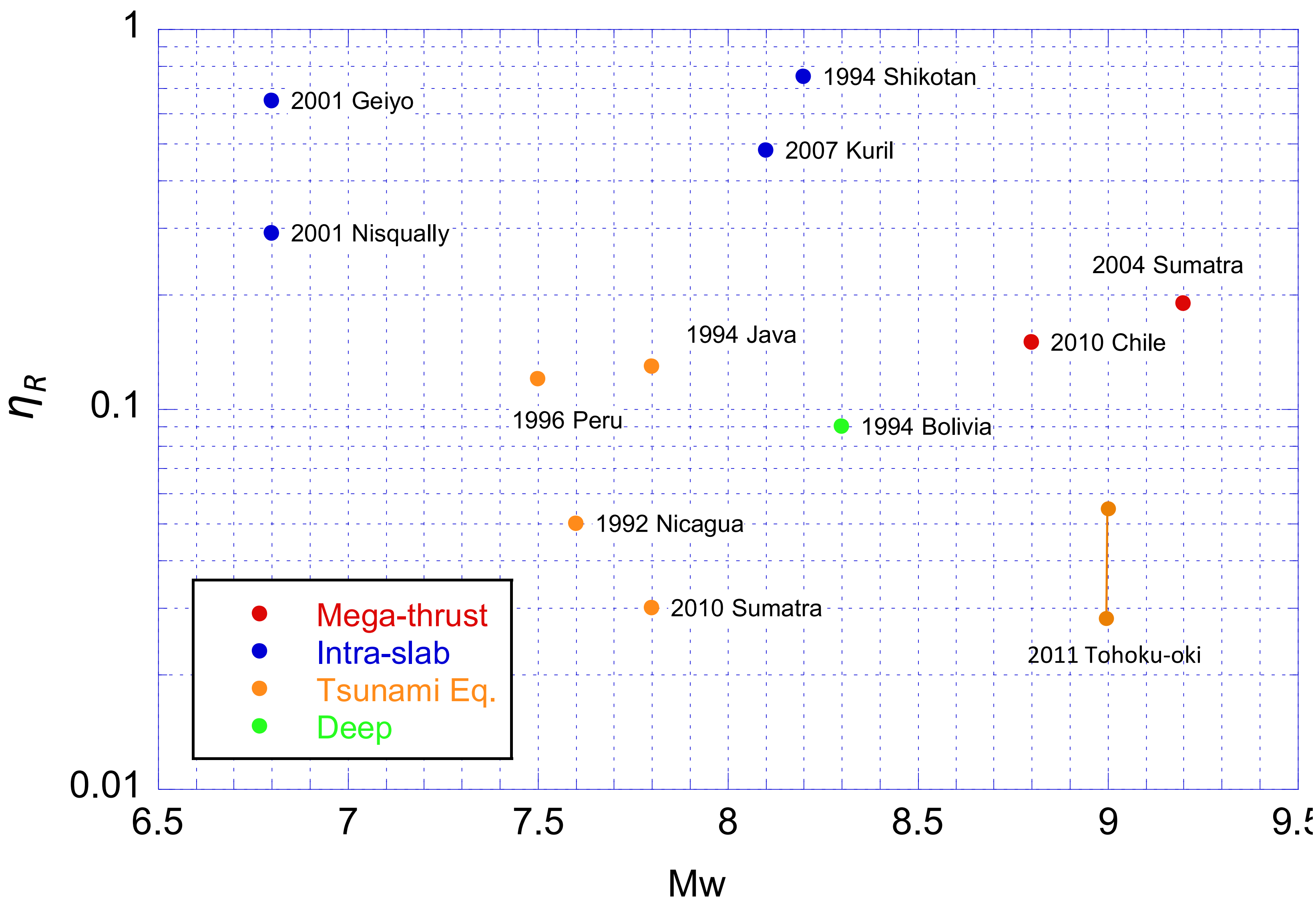
2010 Chile (M_w=8.8) mega-thrust η_R=0.30

2007 Kuril (M_w=8.1) outer-rise η_R=0.48

2010 Sumatra (M_w=7.8) tsunami earthquake η_R=0.03

2011 Tohoku (M_w=9.0) (tsunami E. thrust, HF event combined.)
η_R=0.057

Radiation Efficiency



Conclusion

1. Overall stability of seismic moments at long period
with a few significant exeptions revealing source complexity.

2. Energy estimates:
- At LP strong dependency on the source model and
the structure at the source.
- At HF strong dependency on the attenuation model
(e.g. 2012 off-Sumatra).

3. Radiated energy estimates are more model-dependent and a scatter of a factor of 2 is still an optimistic value.

4. 2011 Tohoku-oki earthquake:
High stress–drop /deficient in HF/low efficiency
Very large smooth slip on a compact region near the trench.

Thanks for your attention