Rapid determination of the magnitude and tsunami potential of large earthquakes, and implications for source physics

1. M_{wpd} and high-frequency, apparent rupture duration T_0
2. Tsunamigenic earthquakes: T_0 > 50s
3. P-wave dominant period calculation T_d
4. Tsunamigenic earthquakes: the $T_d \cdot T_0$ discriminant
5. Importance of identifying length and depth of faulting

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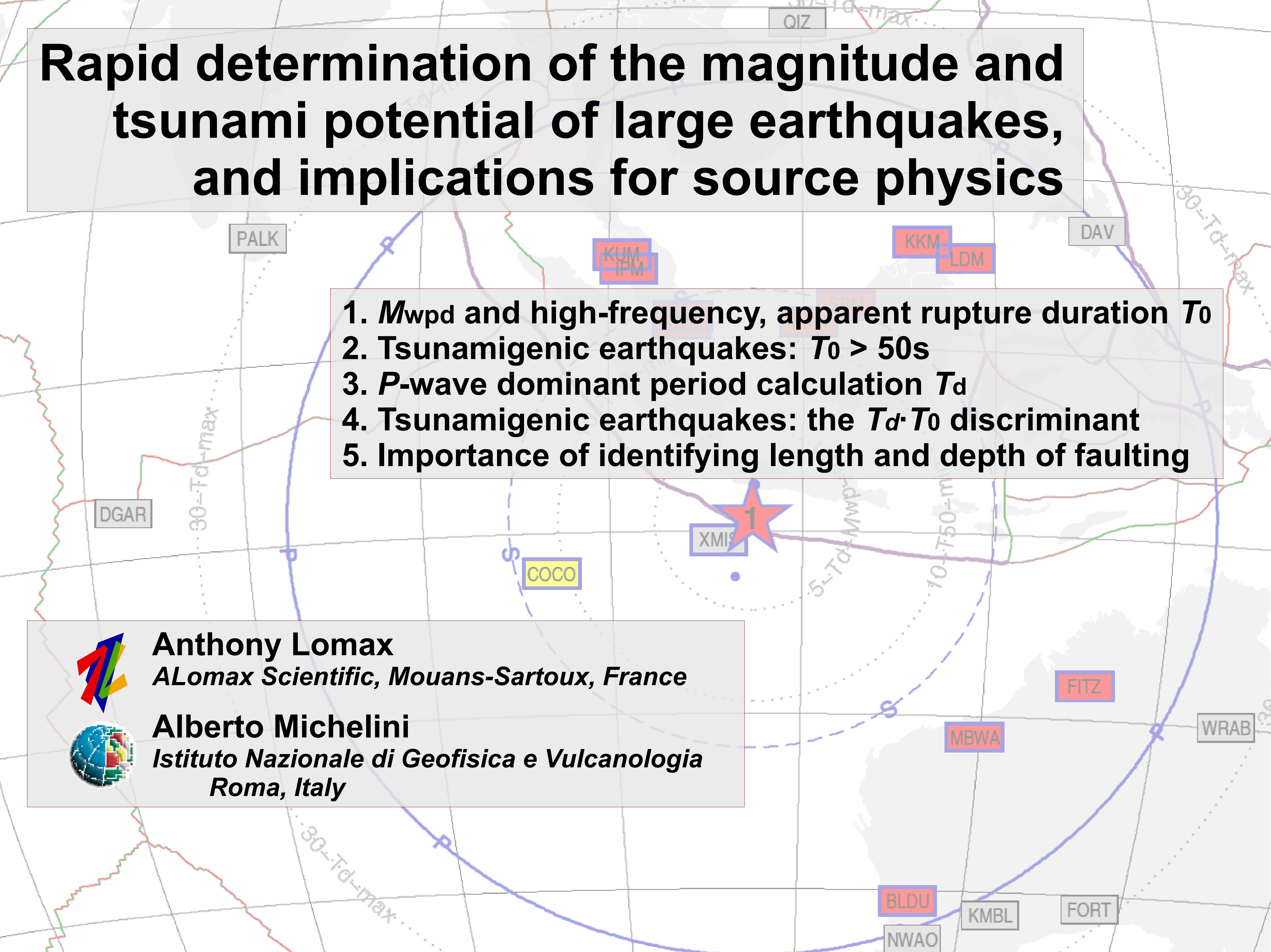
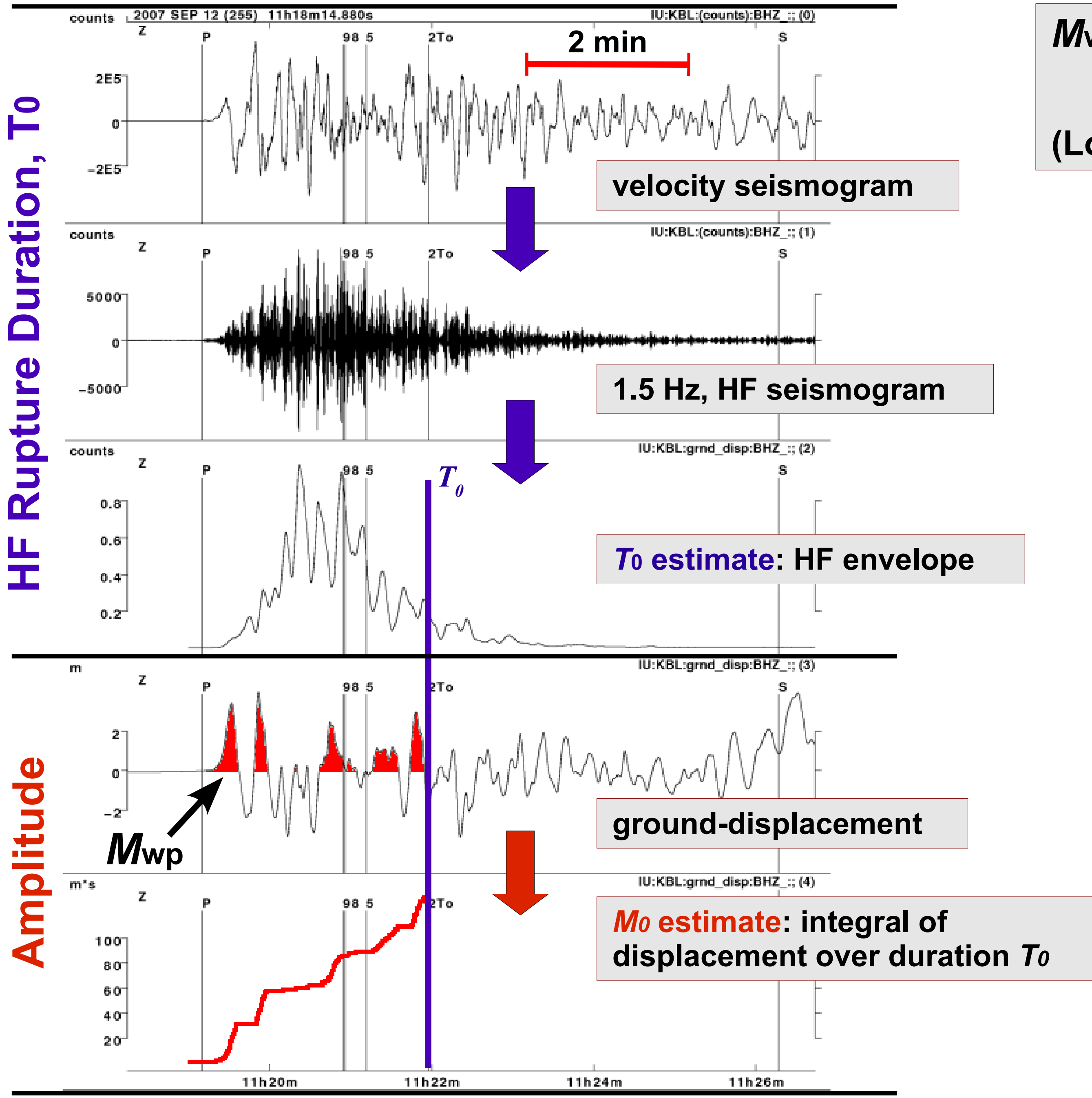


M_{wpd} and high-frequency, apparent rupture duration T_0

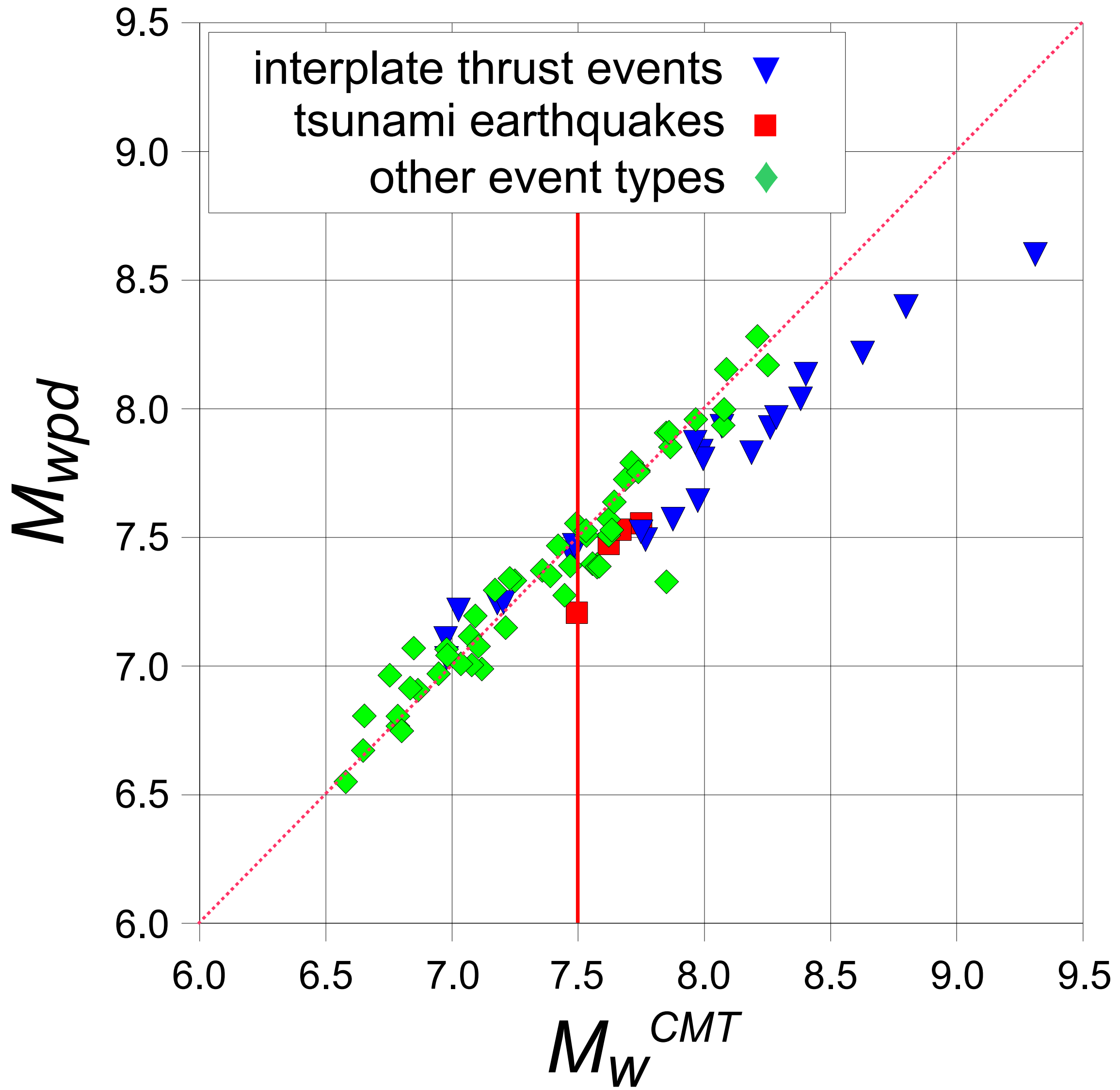
M_{wpd} processing steps:
12 September 2007,
M8.4 Sumatra
(Lomax & Michelini 2009A)



M_{wpd}
OT+8-15min

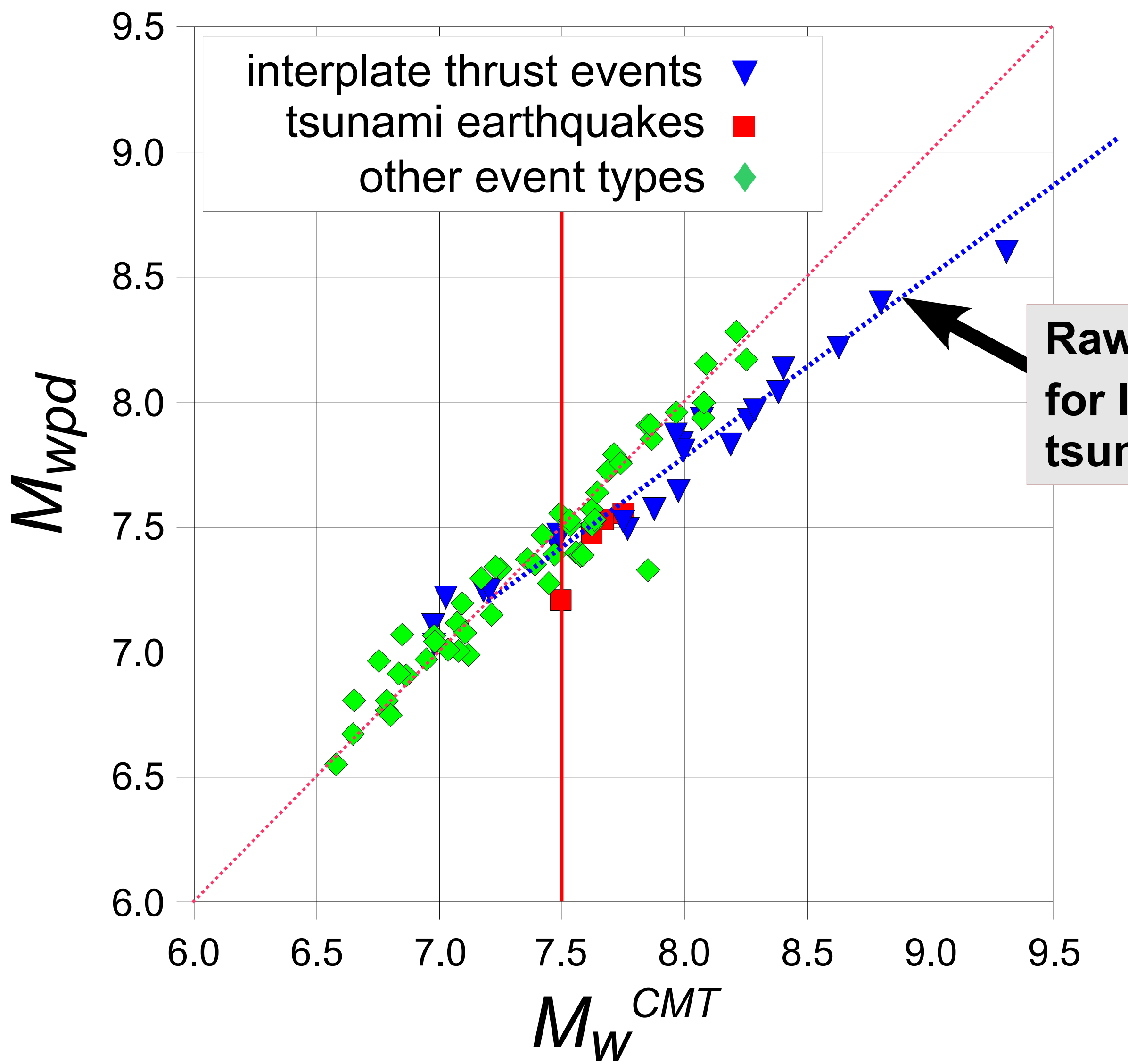
Duration-amplitude magnitude M_{wpd}

Raw M_{wpd} compared to M_w^{CMT} for 79 recent, large earthquakes.



Duration-amplitude magnitude *M*wpd

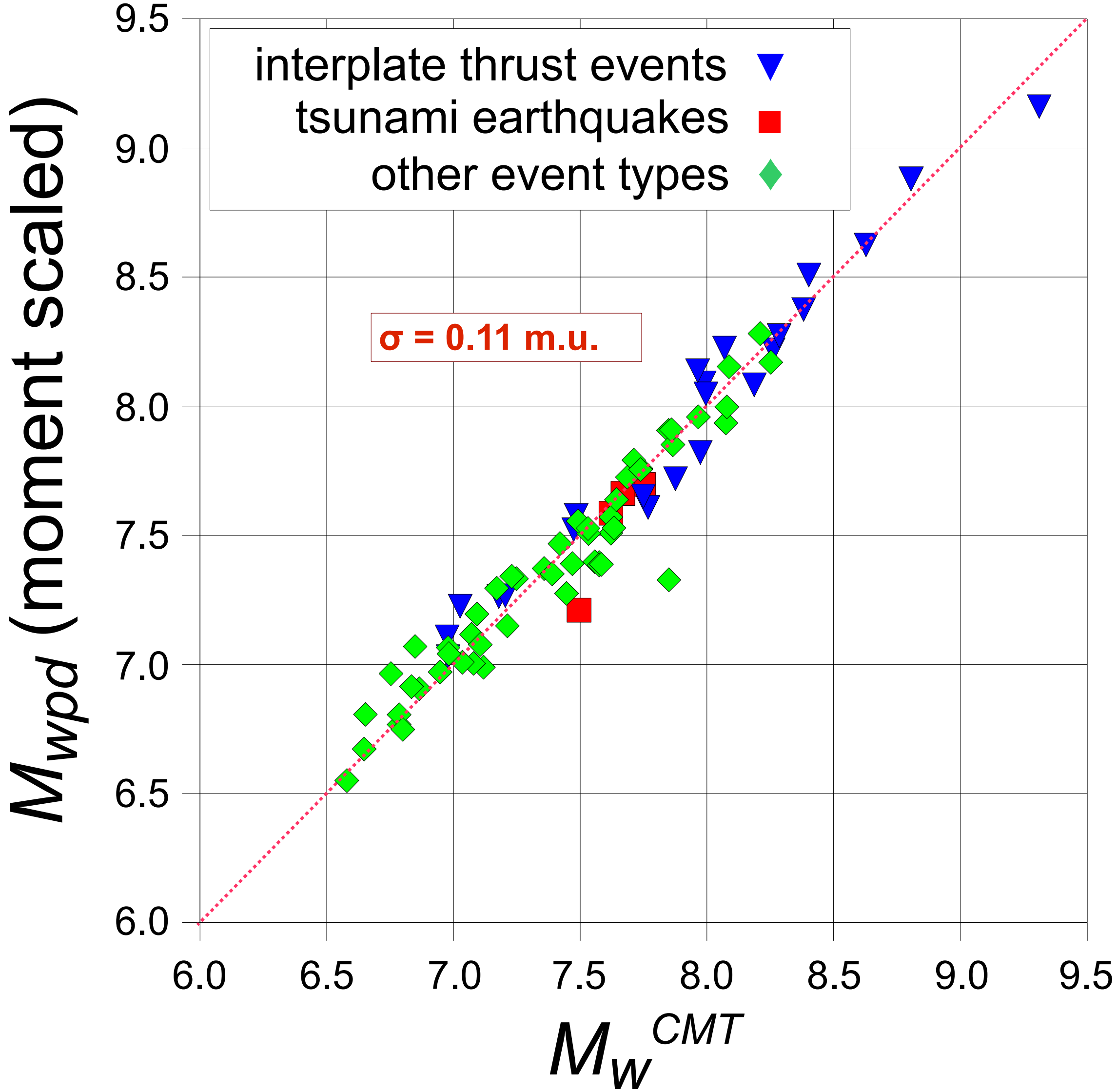
Raw M_{wpd} compared to M_w^{CMT} for 79 recent, large earthquakes.



Raw M_{wpd} underestimates M_w^{CMT} for largest interplate thrust and tsunami earthquakes

Duration-amplitude magnitude *M*wpd with moment scaling

Comparison of M_w^{CMT} with M_{wpd} corrected *with moment scaling* for interplate thrust and tsunami earthquakes.

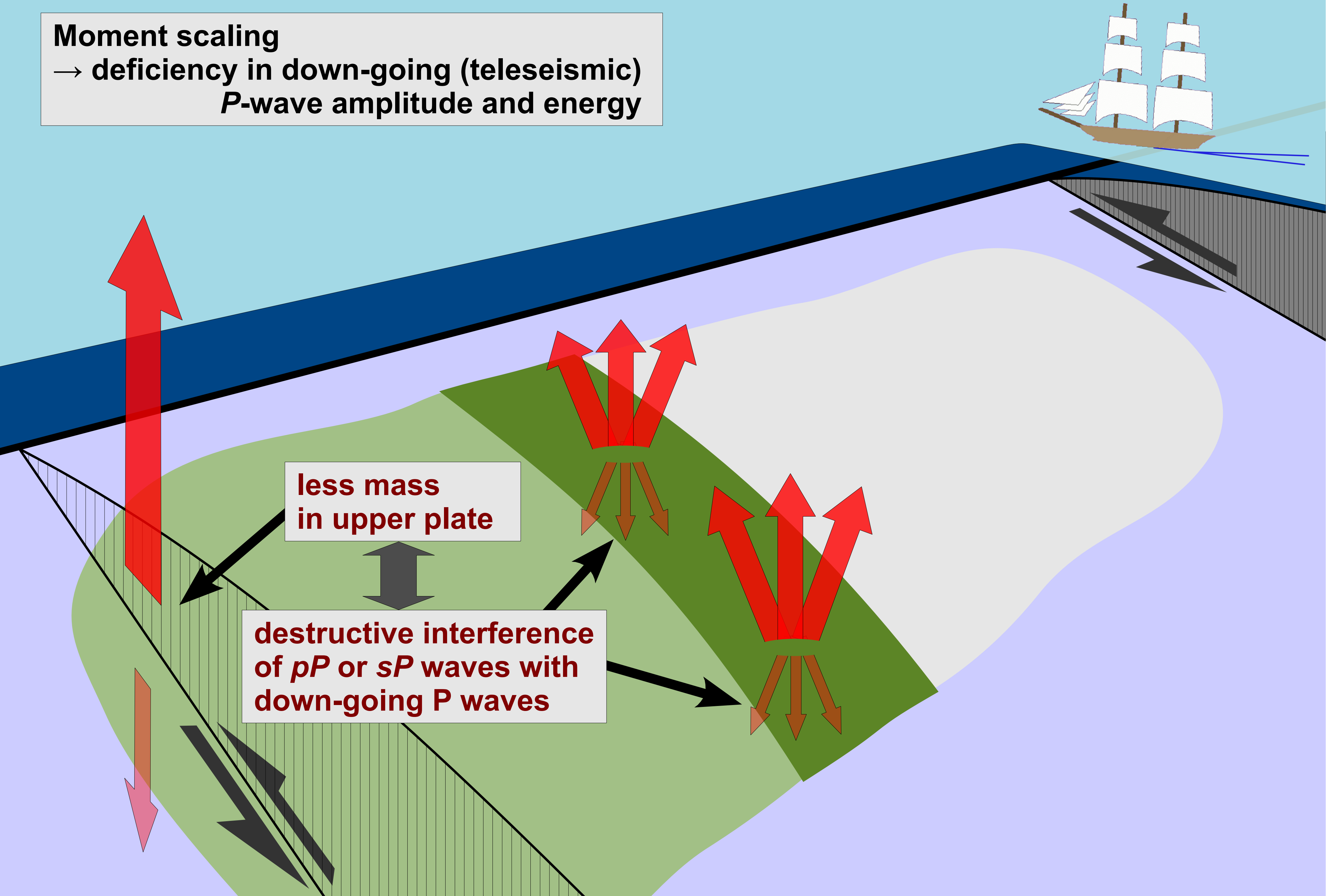


$$M_0^{pd} = \hat{M}_0 \left(\hat{M}_0 / M_0^{cutoff} \right)^{0.4}$$

$M_0^{cutoff} \approx 7.5\text{x}10^{19}$ N-m
(equivalent to $M_w \approx 7.2$)

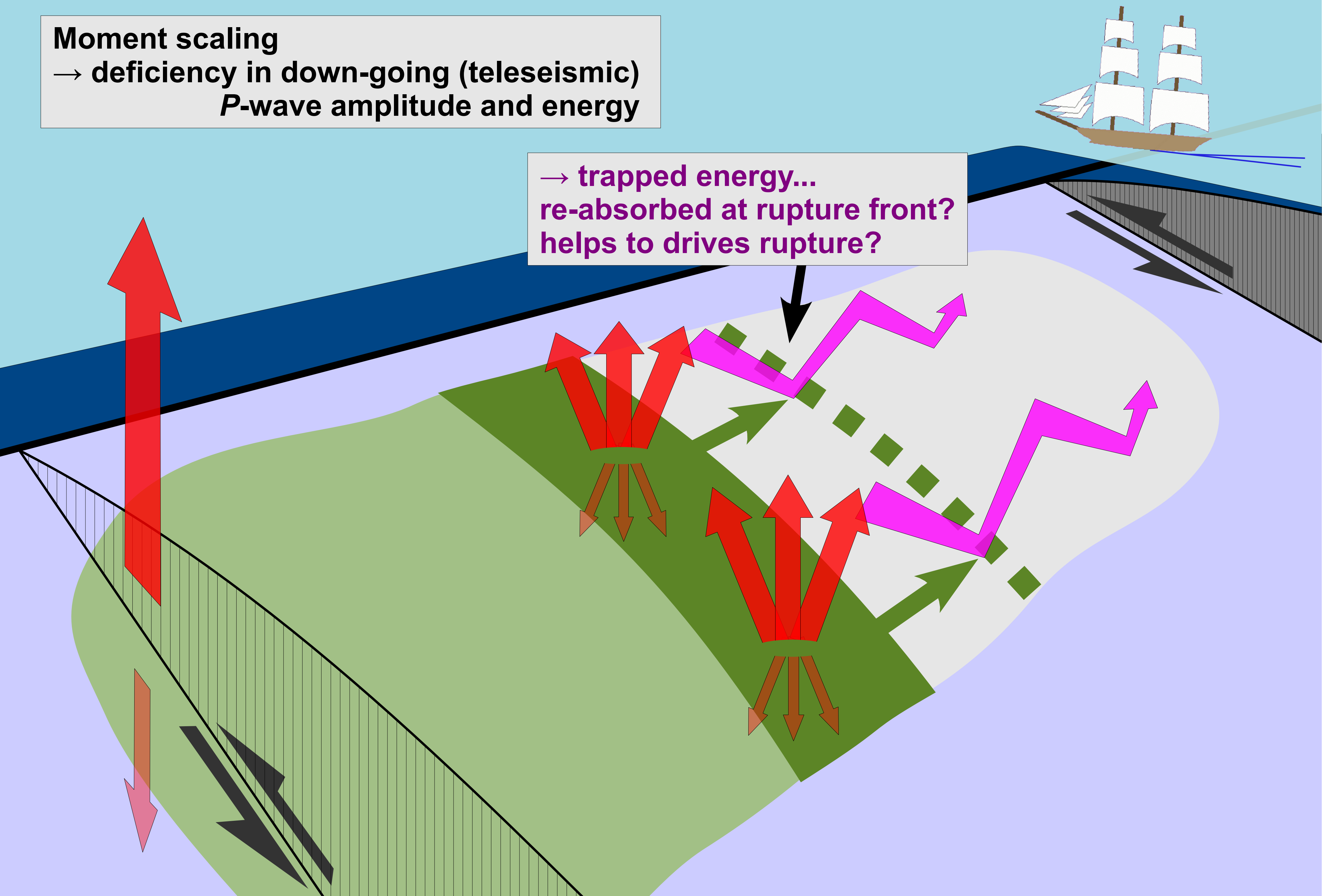
***M*wpd** OT+8-15min
***M*wCMT** OT+30min

Implications of moment scaling: large earthquake rupture

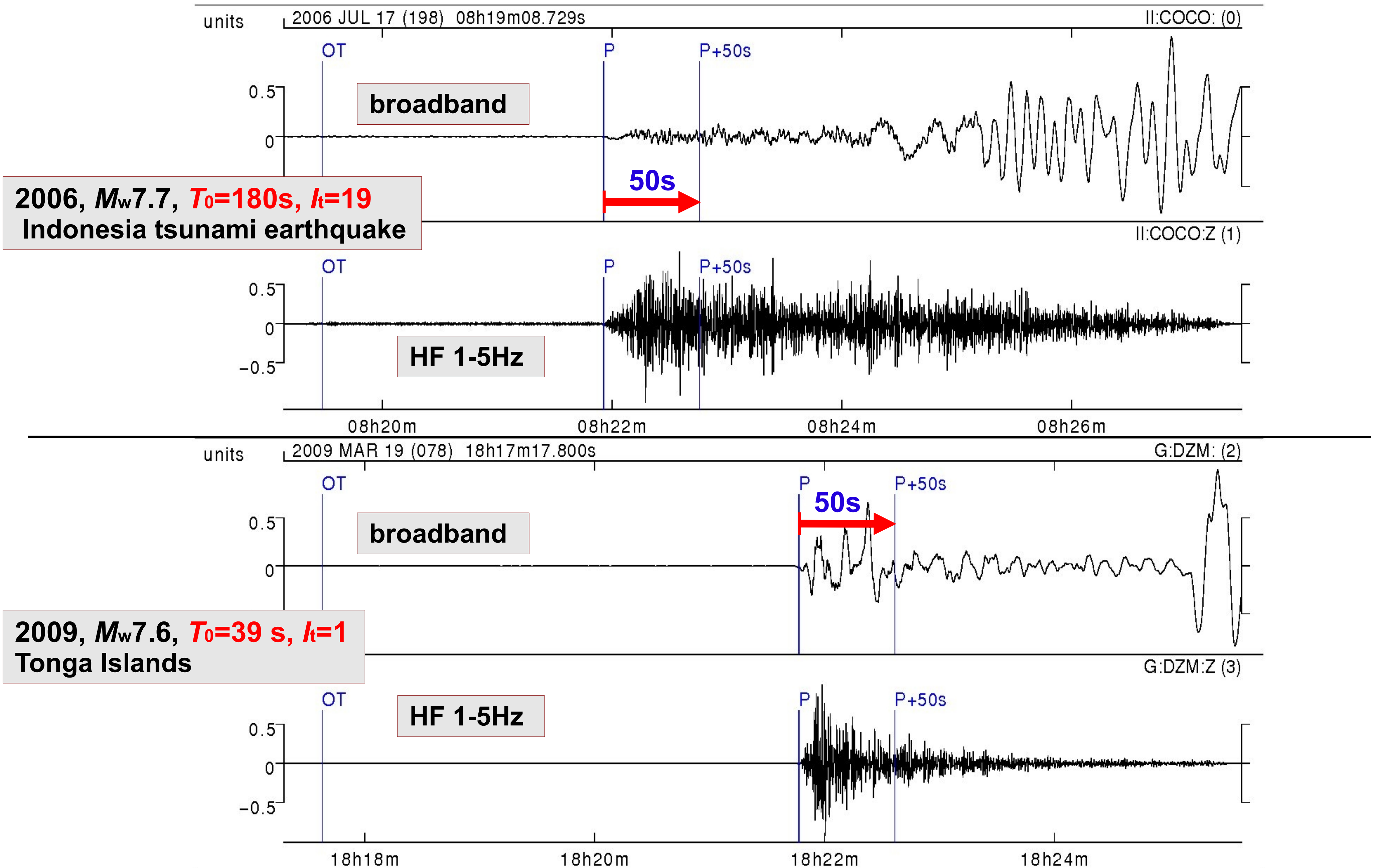


Implications of moment scaling: large earthquake rupture

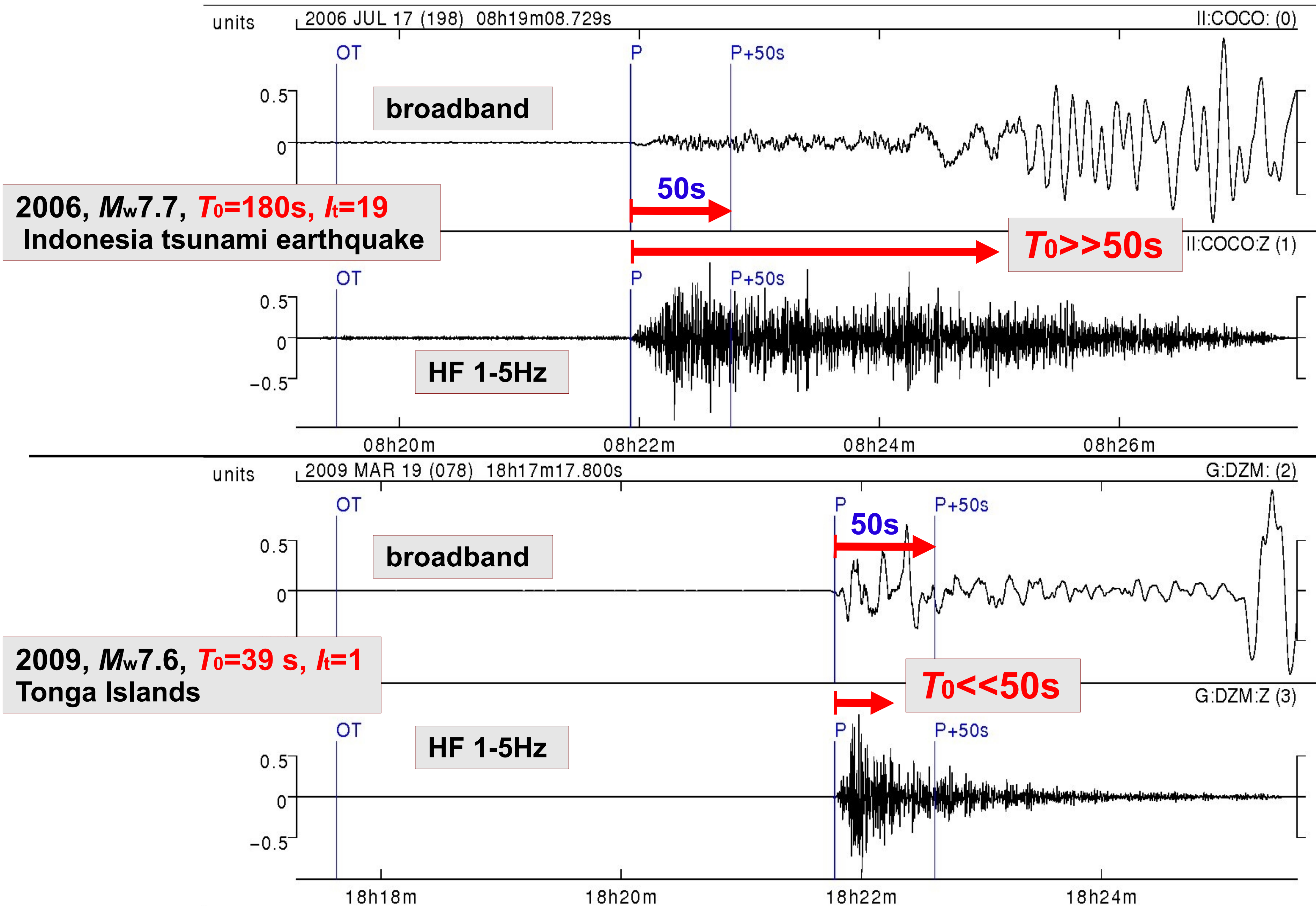
Moment scaling
→ deficiency in down-going (teleseismic)
***P*-wave amplitude and energy**



Discriminating Tsunamigenic earthquakes: T_0 > 50s

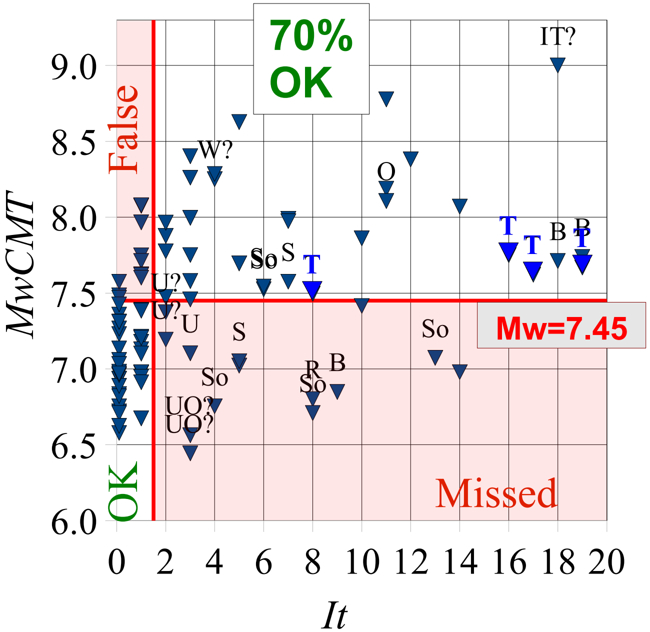


Discriminating Tsunamigenic earthquakes: T_0 > 50s

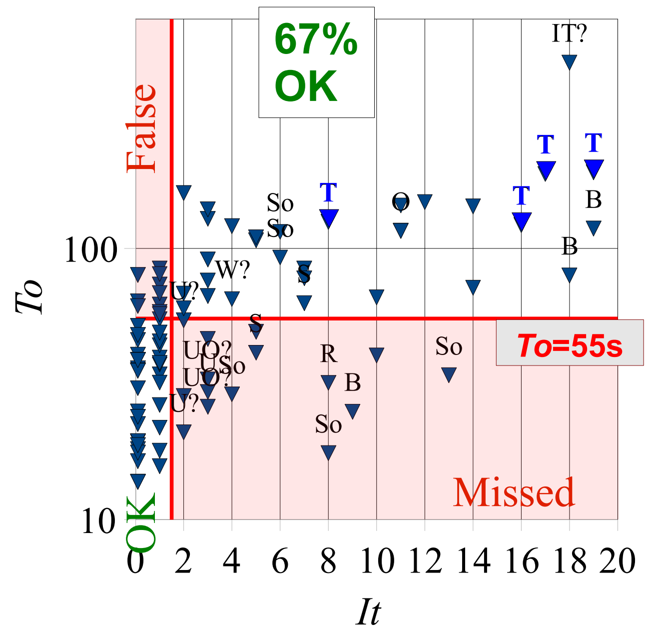


Discriminating Tsunamigenic earthquakes: T_0 > 50s

M_{wCMT} → OT+30m+



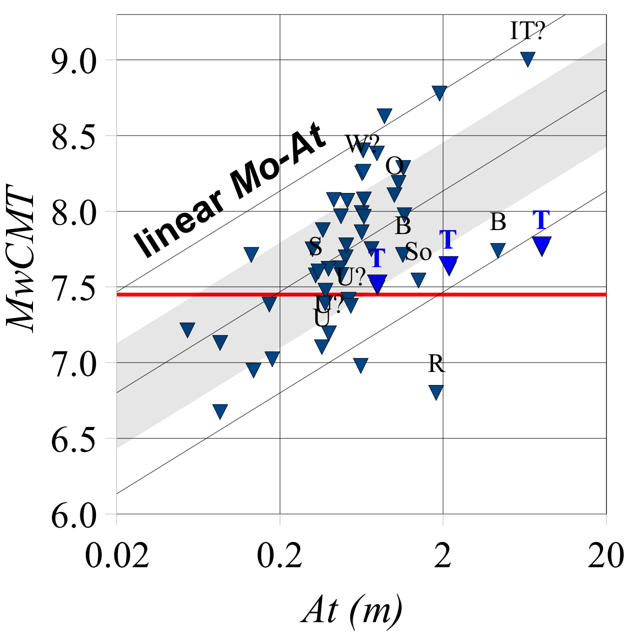
T_0 - teleseismic HF → OT+15m

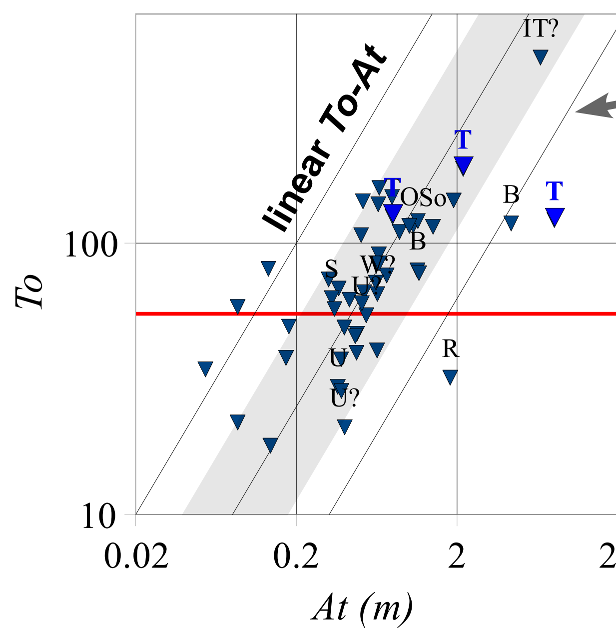


91, recent large earthquakes (M_w≥6.4-9.0)

- **T – "slow" tsunami earthquake**
- **I – interplate-thrust**
- **O – outer-rise intraplate**
- **B – back-arc or upper-plate intraplate**
- **So – strike-slip oceanic**
- **S – strike-slip continental**
- **R – reverse-faulting**
- **no symbol - interplate thrust or I_t < 2**

I_t - approximate measure of "tsunami importance"
(derived from NOAA/NGDC Historical Tsunami Database)



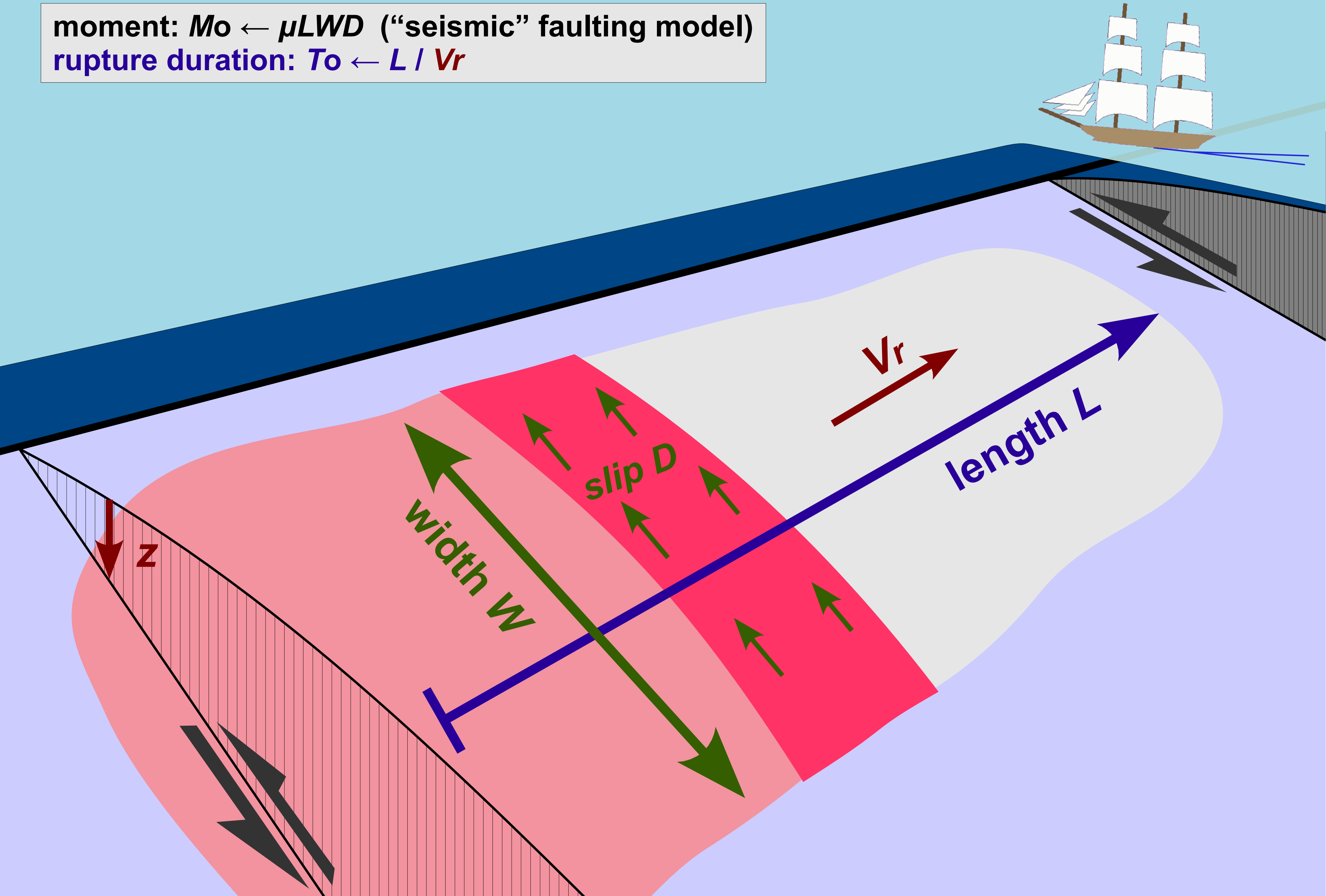


possible linear relationships

A_t - tsunami amplitude at 100km
(NOAA/NGDC data, using energy conservation on a sphere; e.g. Woods and Okal, 1987)

Faulting size, rupture duration and dominant period

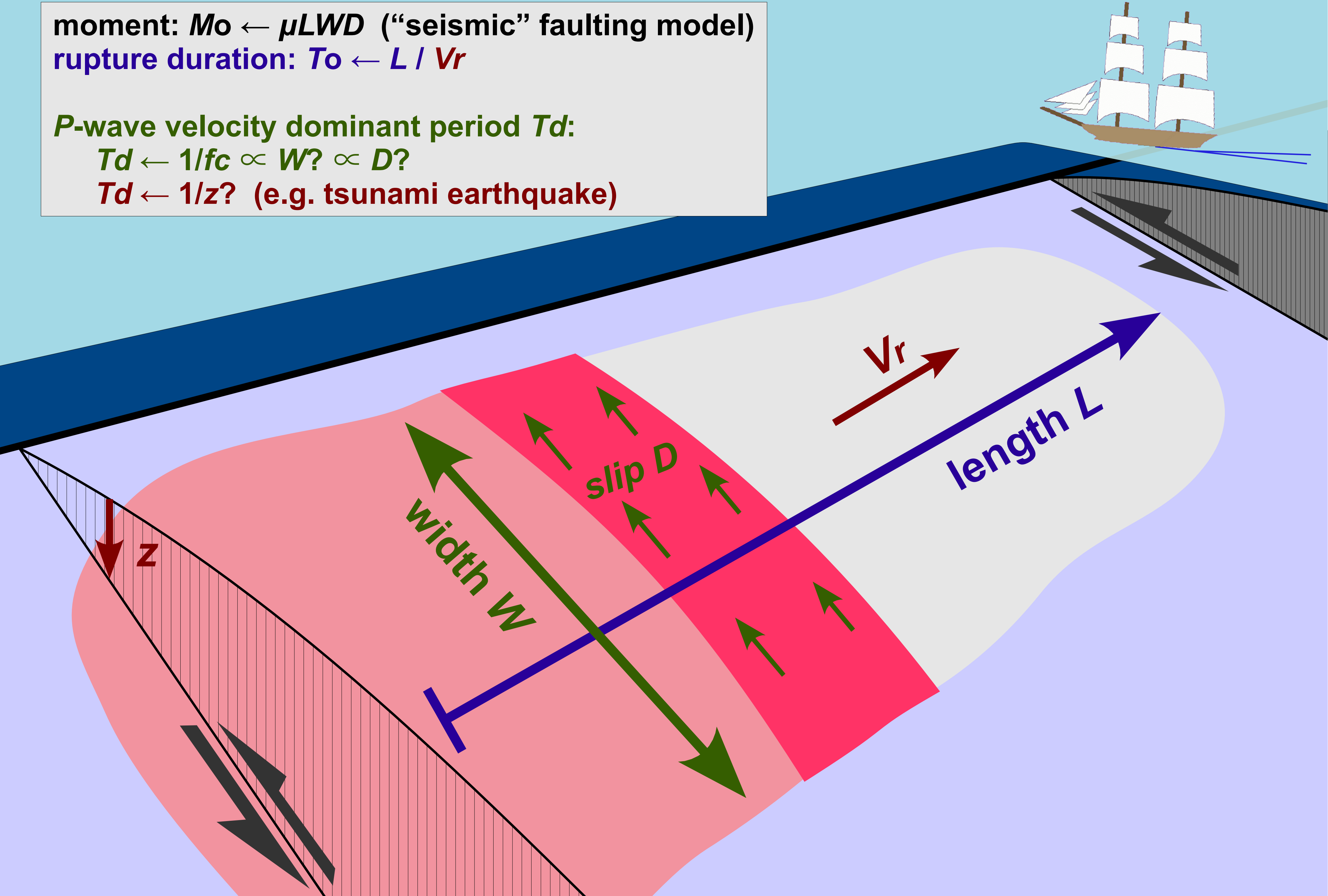
moment: *Mo* ← *μLWD* ("seismic" faulting model)
rupture duration: *To* ← *L* / *Vr*



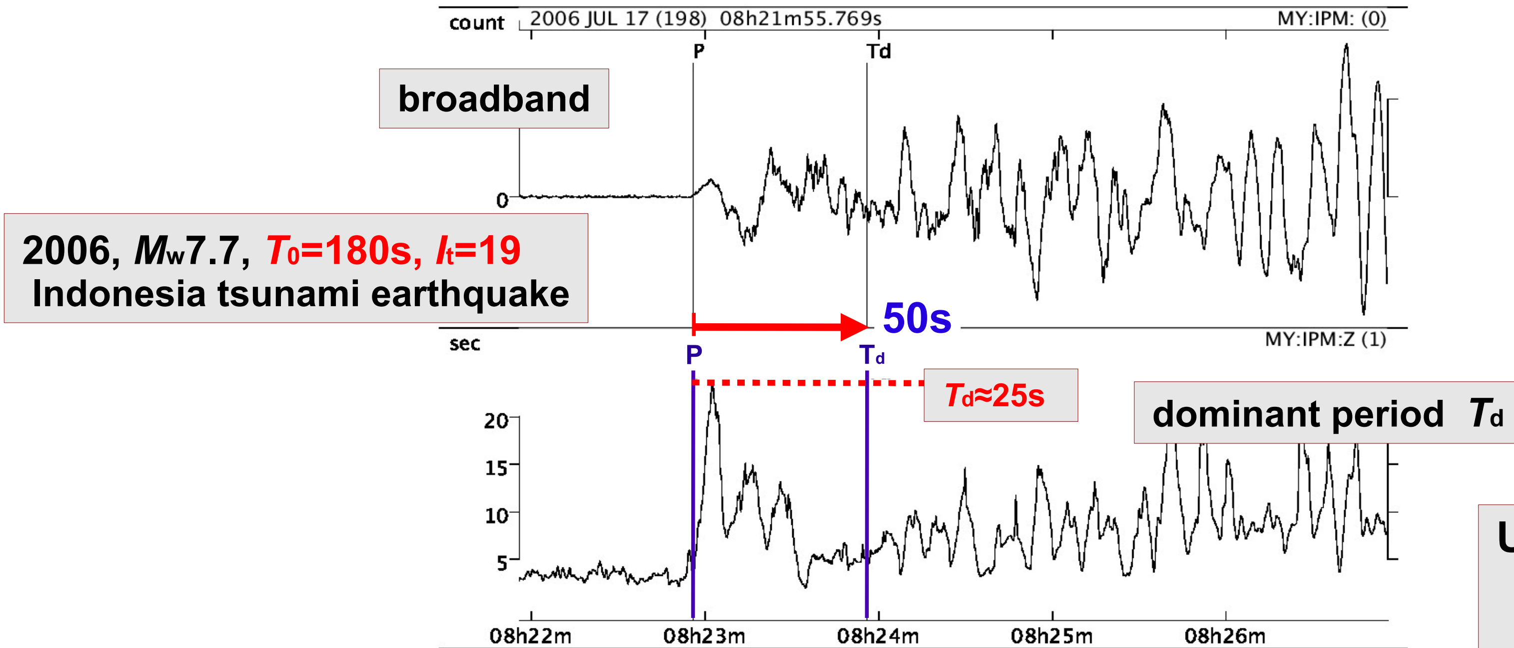
Faulting size, rupture duration and dominant period

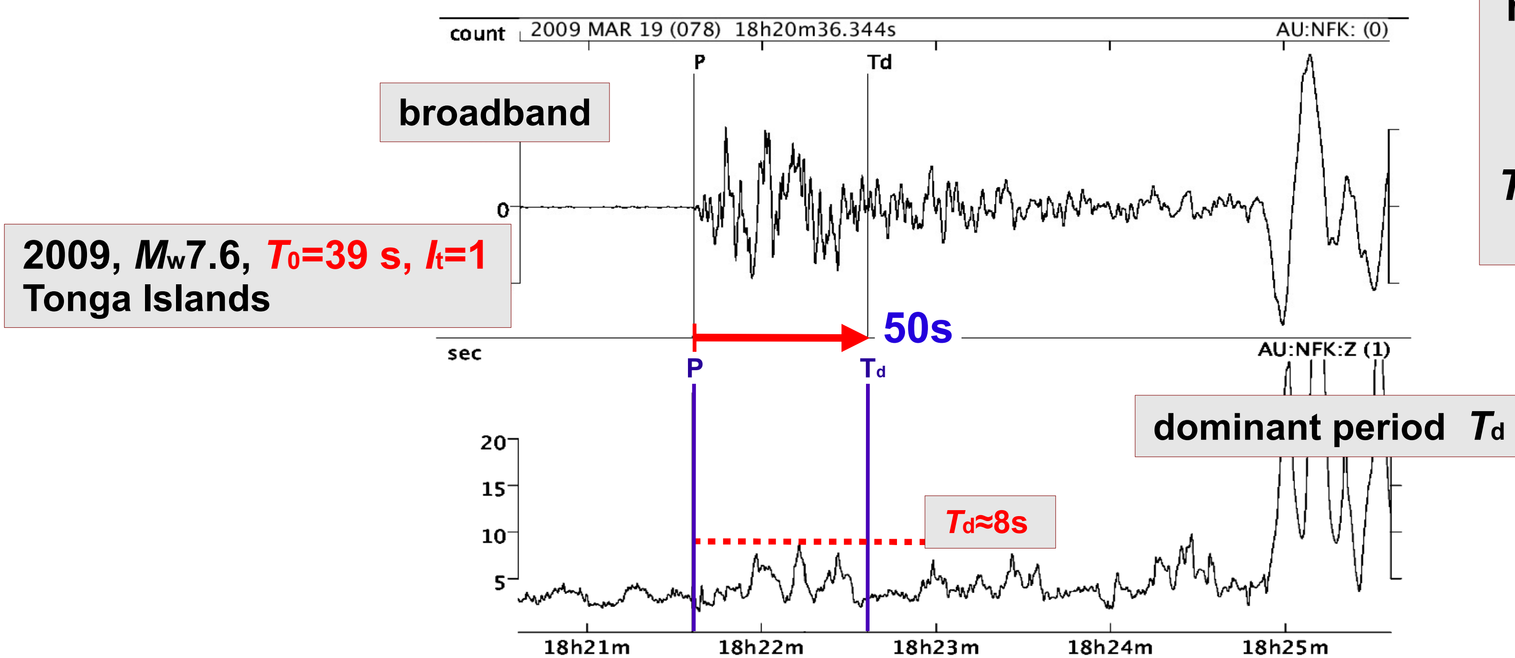
moment: *Mo* ← *μLWD* (“seismic” faulting model)
rupture duration: *To* ← *L* / *Vr*

P-wave velocity dominant period *Td*:
Td ← 1/*fc* ∝ *W*? ∝ *D*?
Td ← 1/*z*? (e.g. tsunami earthquake)



P-wave dominant period calculation



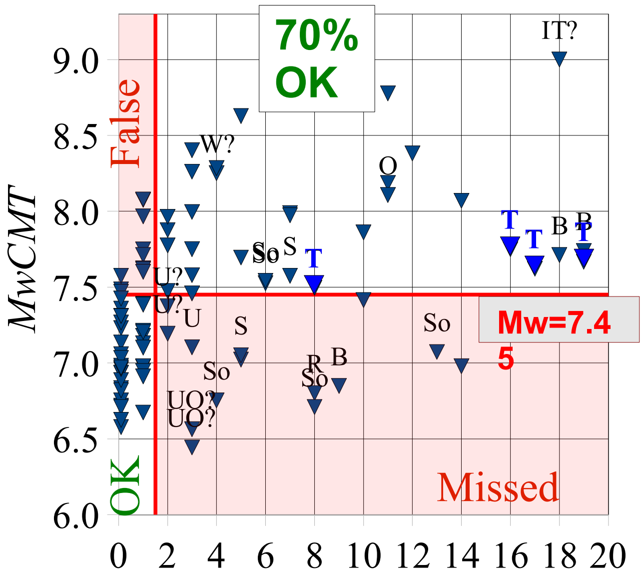


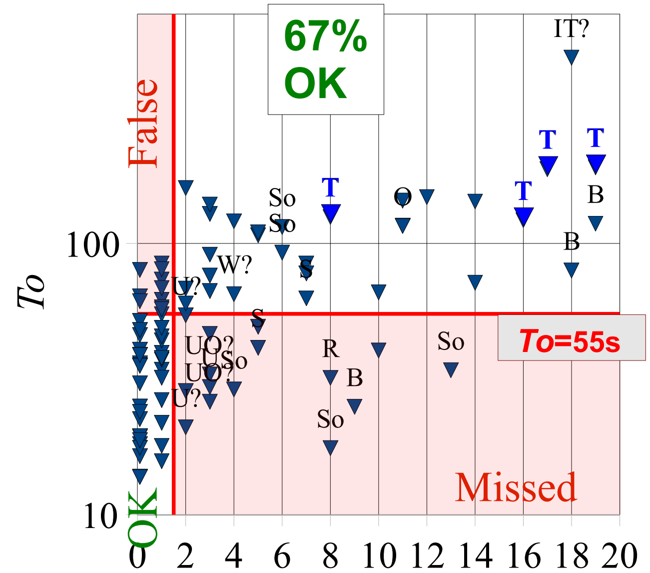
Use TauC:
time-domain, instantaneous-period methodology (Nakamura 1988; Wu and Kanamori 2005)

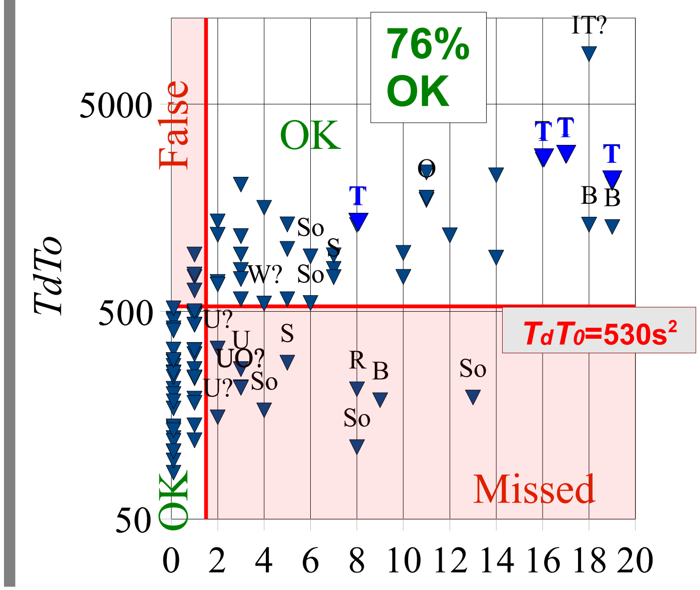
T_d event completed at OT+6-10m

Tsunamigenic earthquakes: the *Td·To* discriminant

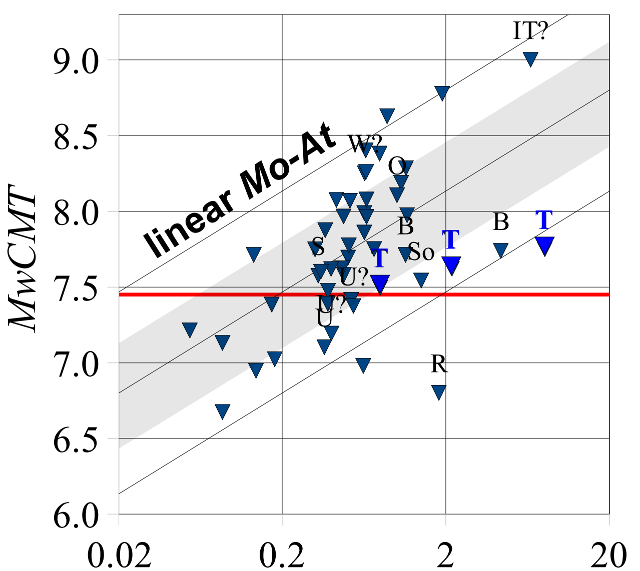
MwCMT → OT+30m+	*To* - teleseismic HF → OT+15m	*Td·To* discriminant → OT+15m

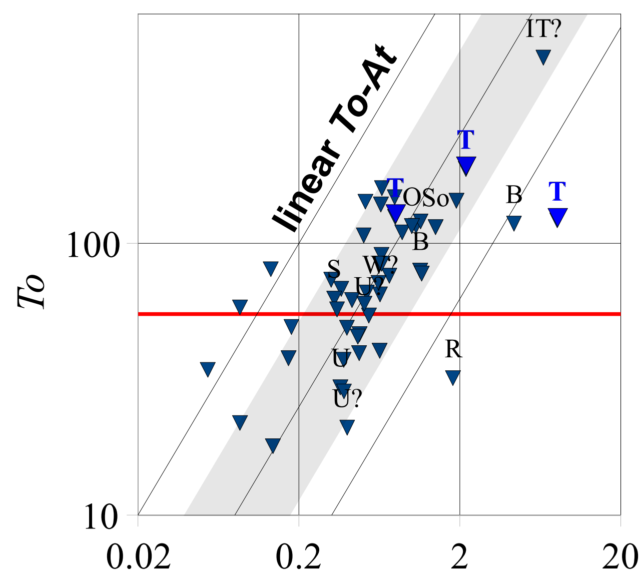


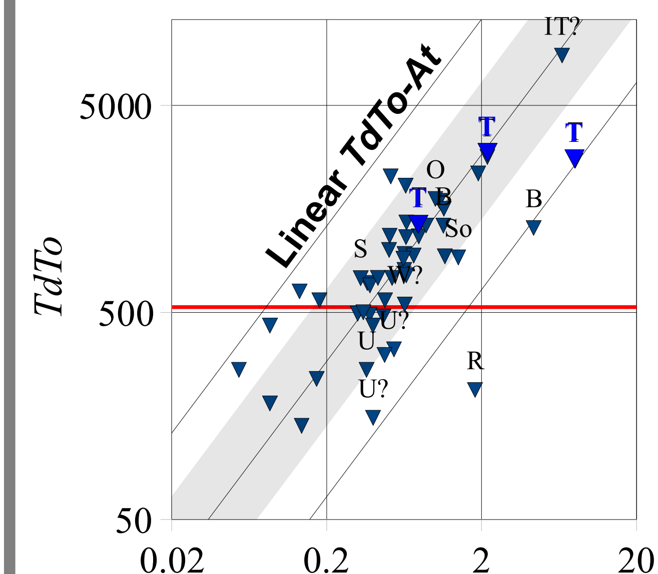




It “tsunami importance” *It* “tsunami importance” *It*



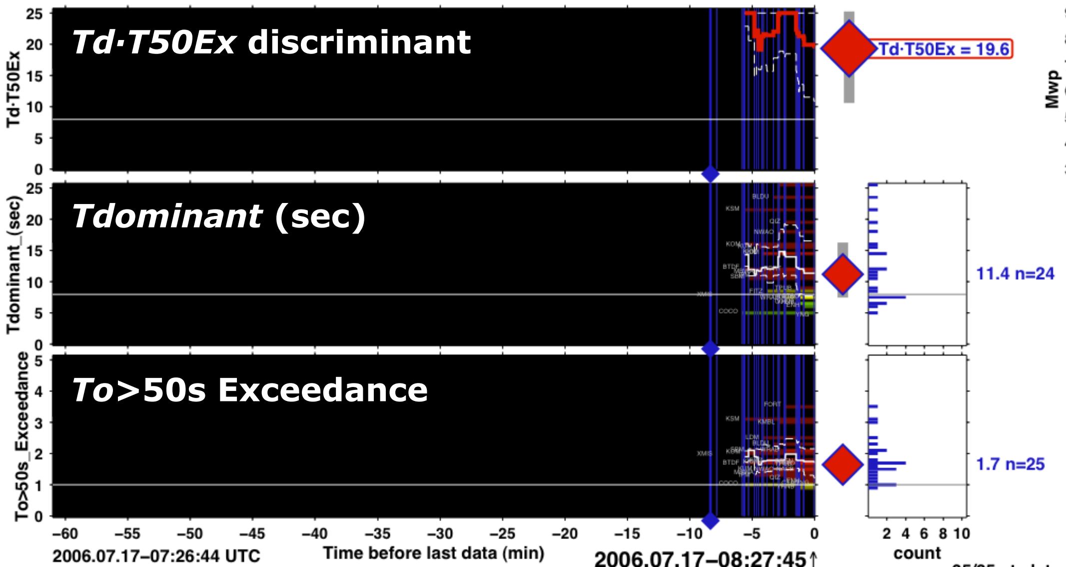


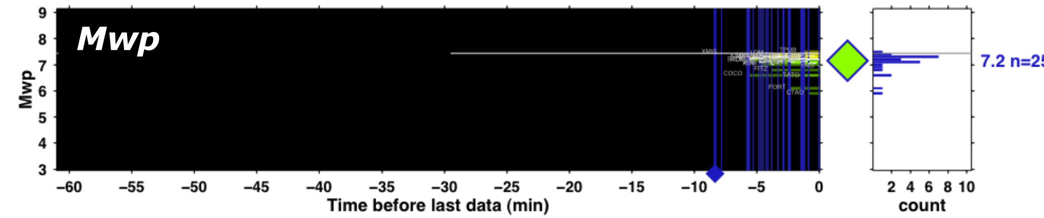


At (m) tsunami amplitude at 100km *At (m)* tsunami amplitude at 100km *At (m)*

Real-time monitor: Indonesia 2006, M_w7.7, T_0=180s, I_t=19

INGV monitor simulation, IRIS realtime data, OT+9min, rapid To>50s exceedance estimate



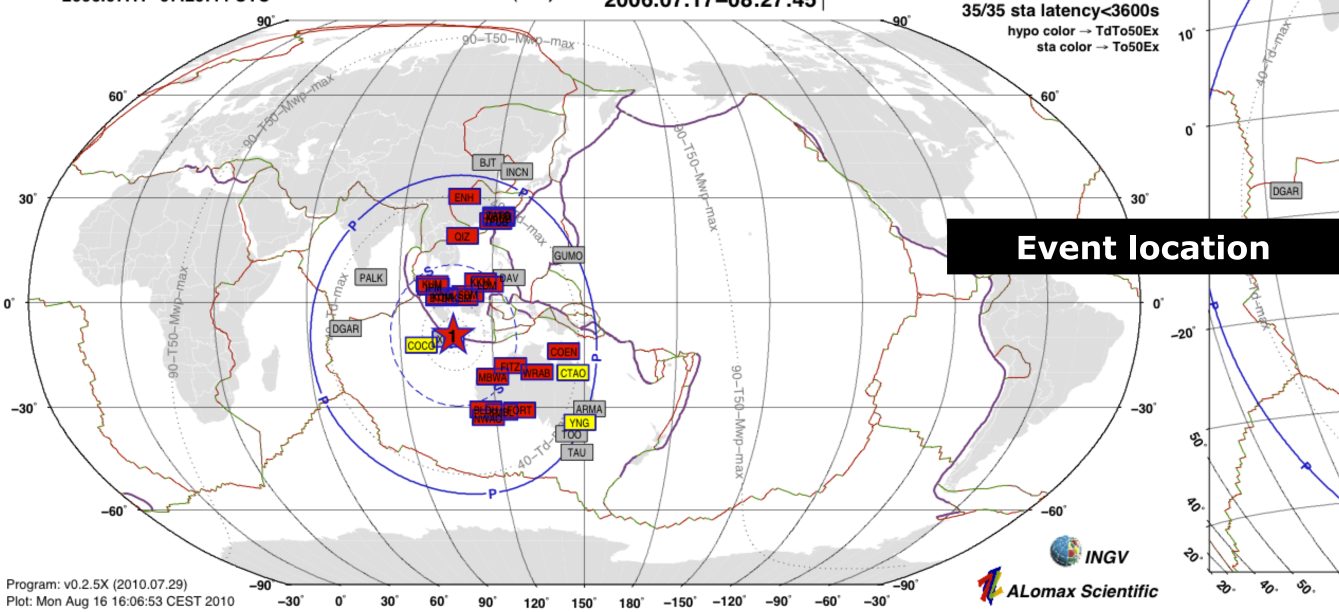


Global Earthquake Location · (Tdominant)·(To>50s_Exceedance) Level · Mwp

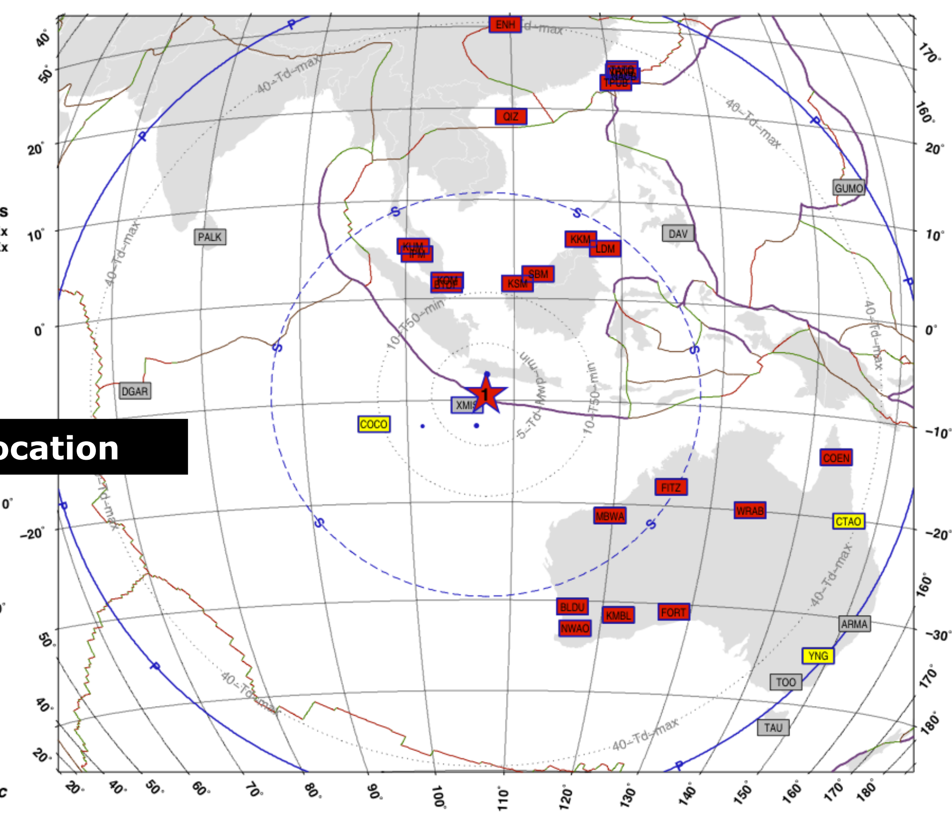
Location Results (Note: automatic solutions):

n	sta	Δmin°	σot	origin–time–UTC	lat°	lon°	depth–km	T50Ex	n	Td	n	TdT50	WL	Mwp	n
1	26	2.0	2.3	2006.07.17–08:19:23	–9.4	107.4	0–20	1.7	25	11.4	24	19.6		7.2	25

35/35 sta latency<3600s
hypo color → TdTo50Ex
sta color → To50Ex



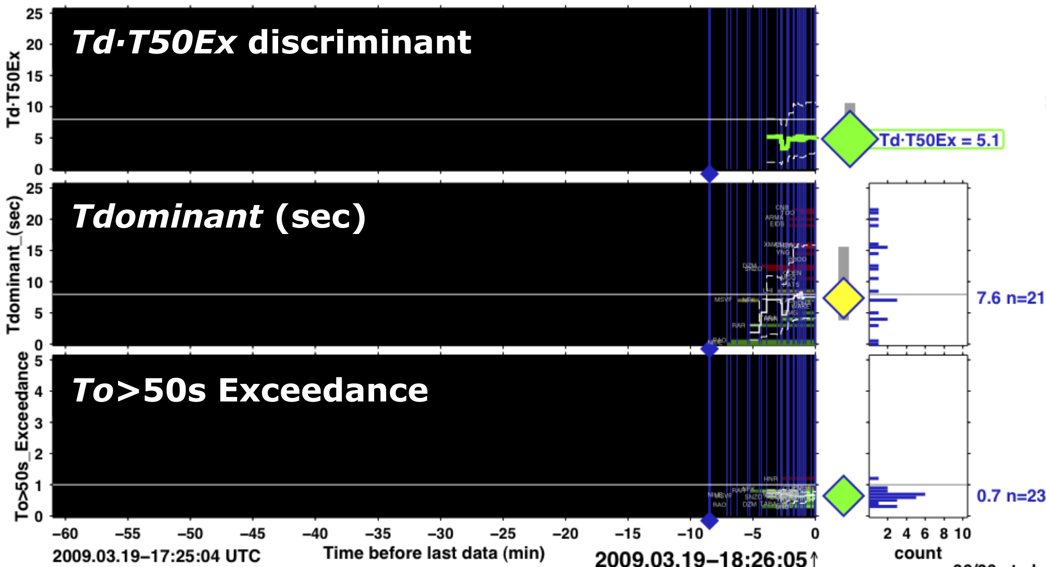
Program: v0.2.5X (2010.07.29)
Plot: Mon Aug 16 16:06:53 CEST 2010

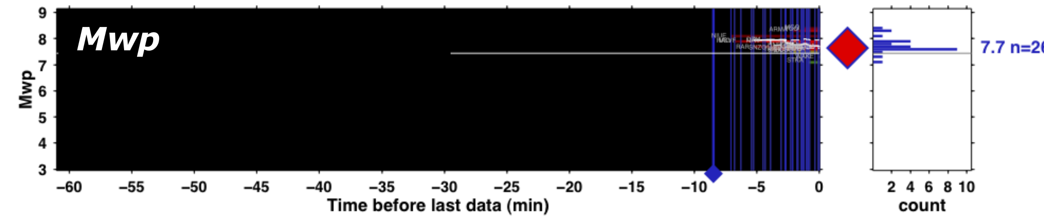


http://s3.rm.ingv.it/

Real-time monitor: Tonga Islands 2009, M_w7.6, T_0=39s, I_t=1

INGV monitor simulation, IRIS realtime data, OT+9min, rapid To>50s exceedance estimate

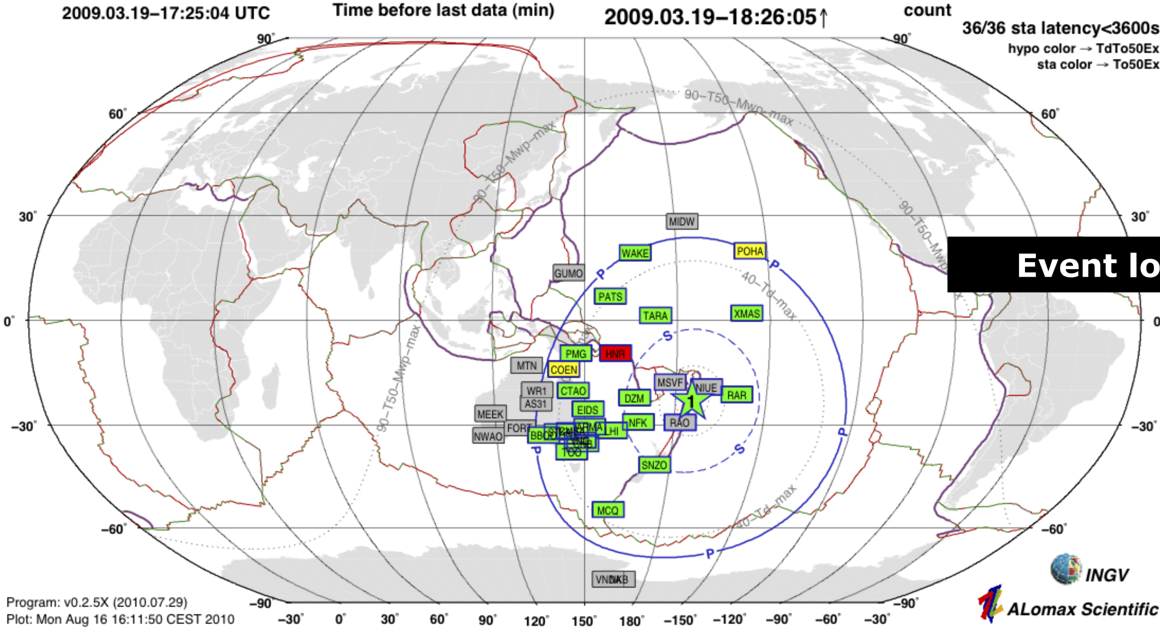


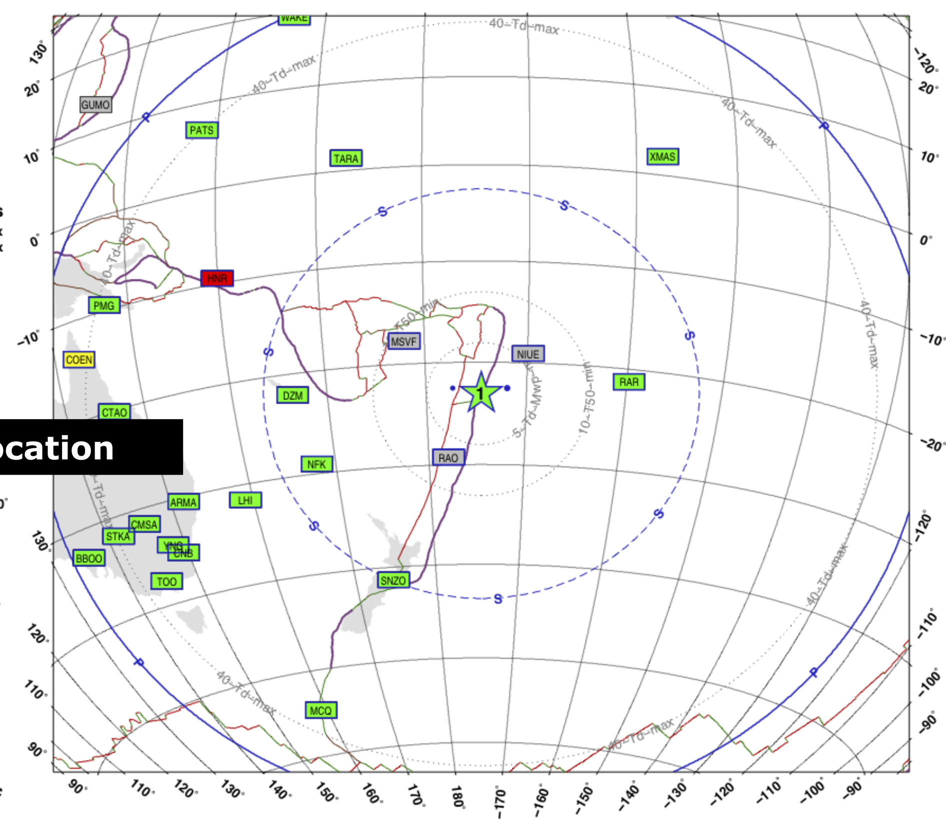


Global Earthquake Location · (Tdominant)·(To>50s_Exceedance) Level · Mwp

Location Results (Note: automatic solutions):

n	sta	Δmin°	σot	origin–time–UTC	lat°	lon°	depth–km	T50Ex	n	Td	n	TdT50	WL	Mwp	n
1	27	5.8	1.9	2009.03.19–18:17:36	–23.1	–174.5	0–20	0.7	23	7.6	21	5.1		7.7	26

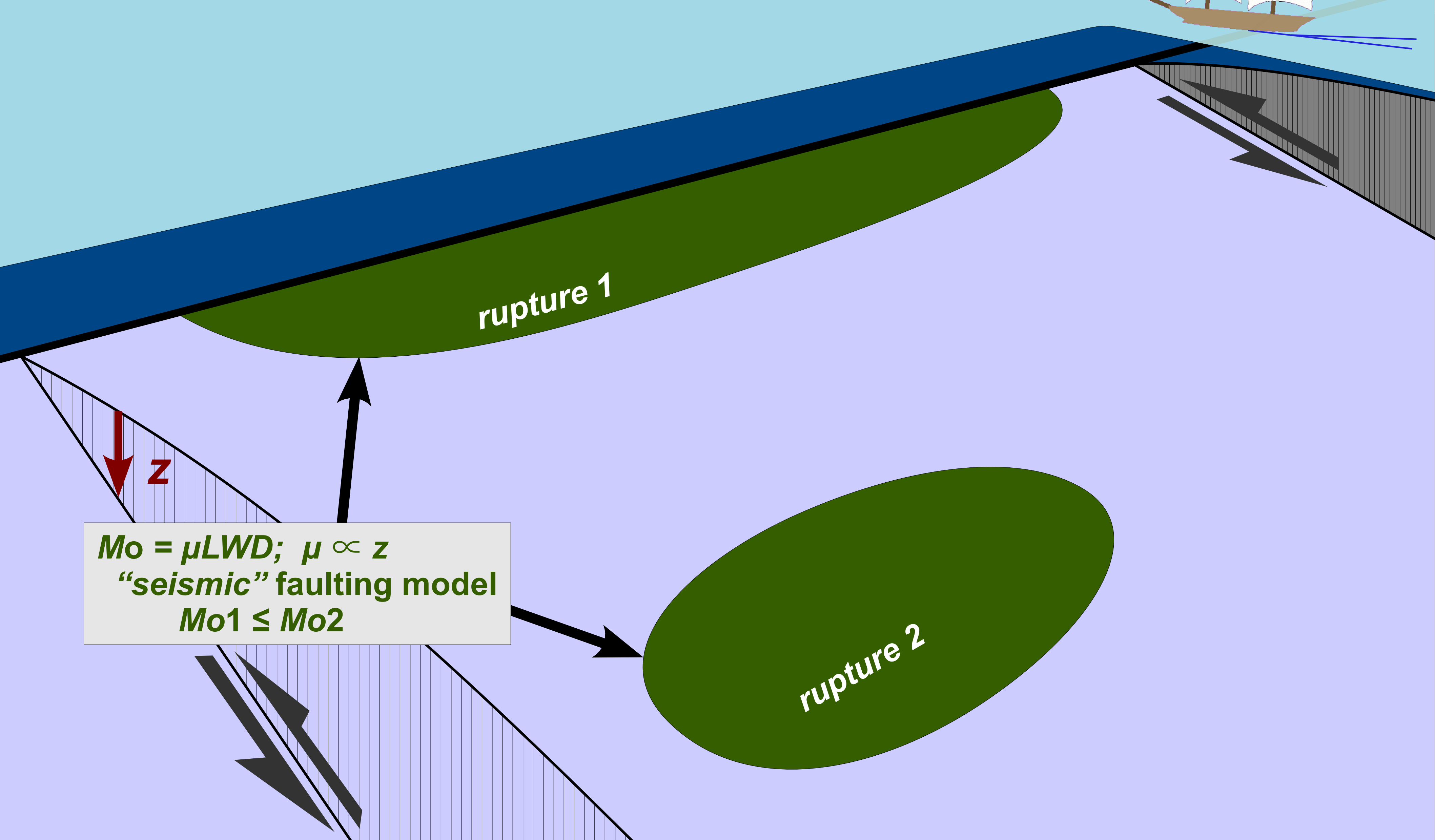




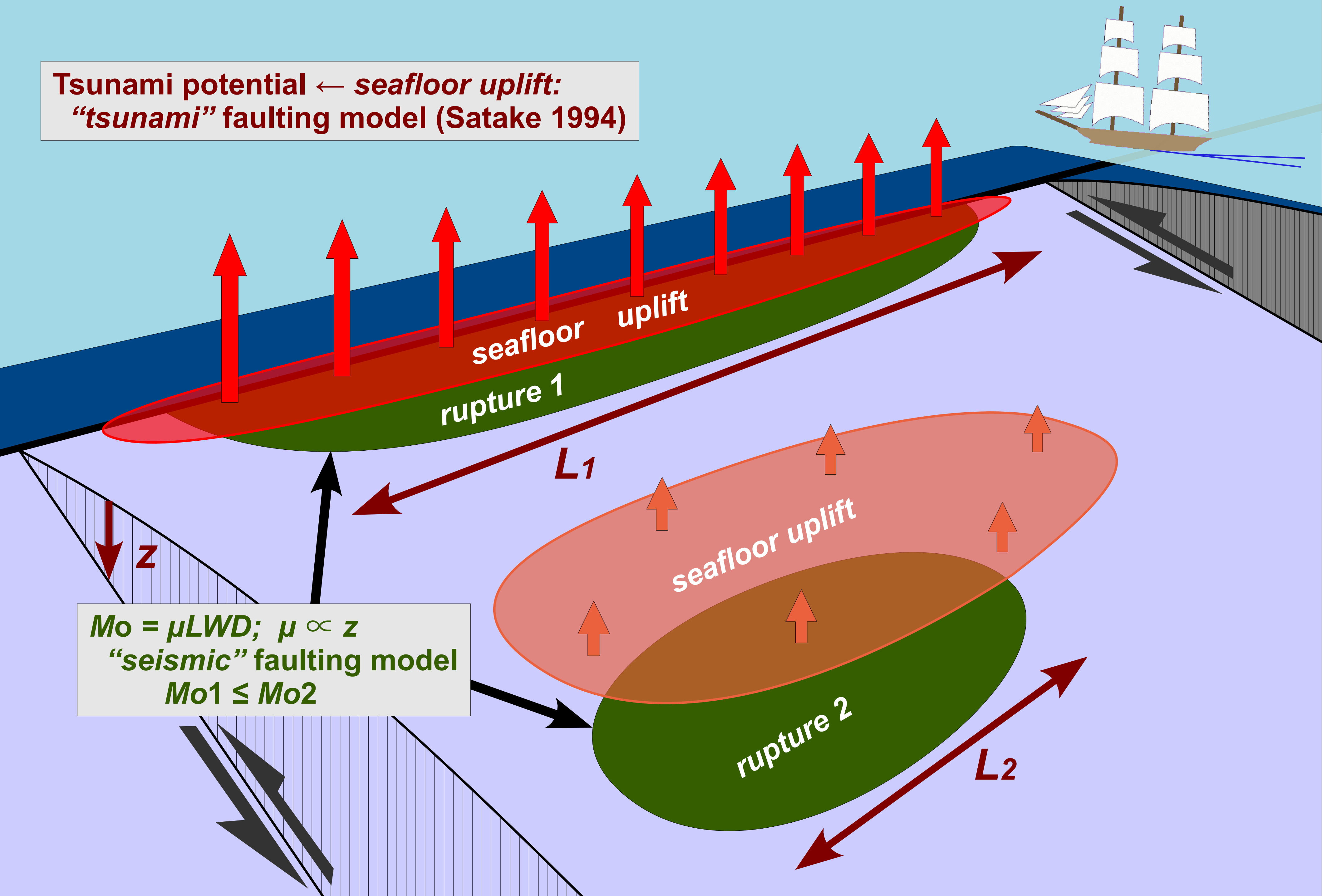
http://s3.rm.ingv.it/

Importance of identifying length and depth of faulting

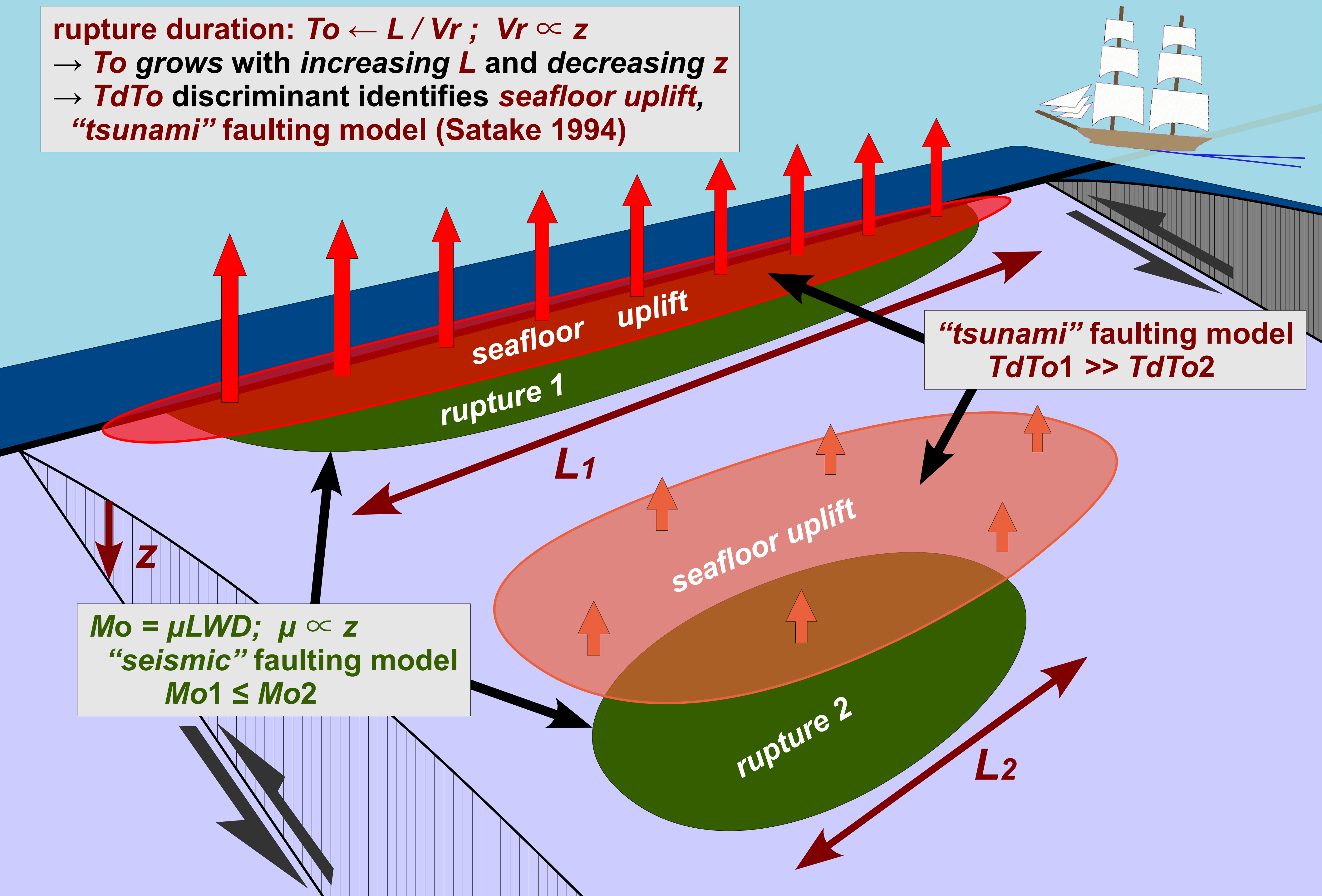
Two ruptures with similar seismic potency *LWD*



Importance of identifying length and depth of faulting



Importance of identifying length and depth of faulting



Rapid determination of the magnitude and tsunami potential of large earthquakes, and implications for source physics

The duration-amplitude magnitude *M*wpd:

- available <15 after OT
- with moment scaling matches well M_{wCMT}
- shows deficiency in down-going energy, which may help to drive rupture for large earthquakes (???)

The *Td*·*To* period-duration discriminant:

- available <10 min after OT
- gives more information on tsunami impact than M_{wCMT} or teleseismic *To*
- possibly identifies directly the “tsunami” faulting potential of an earthquake

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Further information:

http://www.alomax.net/posters/period-duration

http://s3.rm.ingv.it/

Lomax, A. and A. Michelini, 2010. Tsunami early warning using earthquake rupture duration and *P*-wave dominant-period: the importance of length and depth of faulting, *Geophys. J. Int.*, submitted.

Lomax, A. and A. Michelini, 2009B. Tsunami early warning using earthquake rupture duration, *Geophys. Res. Lett.*, 36, L09306, doi:10.1029/2009GL037223

Lomax, A. and A. Michelini, 2009A. *M*wpd: A duration-amplitude procedure for rapid determination of earthquake magnitude and tsunamigenic potential from P waveforms, *Geophys. J. Int.*, 176, 200–214, doi:10.1111/j.1365-246X.2008.03974.x

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