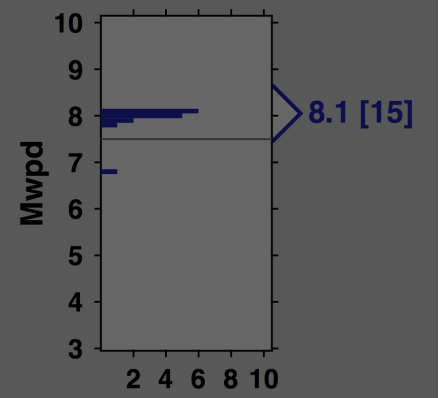
Real-time, real-life performance of Mwpd for rapid, accurate determination of large earthquake magnitudes



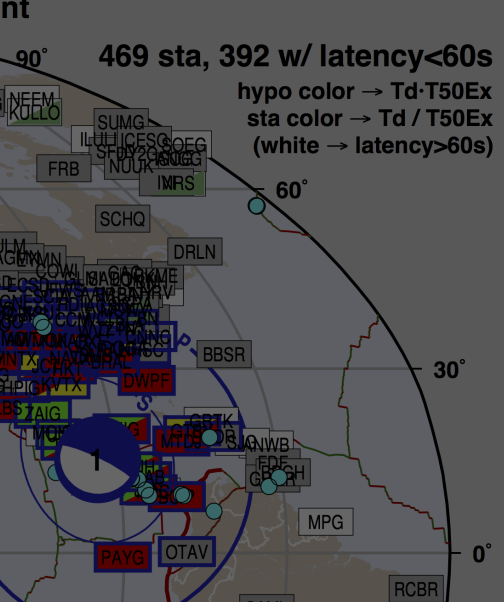
early-est EArthquake Rapid Location sYstem with EStimation of Tsunamigenesis

Currently displayed events: (Automatic solutions – may be incorrect!)

n	seq	pha	Δmin°	σot	origin–time–UTC	lat°	lon°	errH	depth	errZ	Q	T50Ex [n]	Td [n]	TdT50	--	mb [n]	Mwp [n]	To [n]	Mwpd [n]
1	2	43	5.2	1.0	2017.09.08–04:49:20	15.2	–93.7	7	68	8	A	2.4 25	9.1 25	21.8	☐	6.2 22	8.0 21	89 13	8.1 1

Anthony Lomax
ALomax Scientific, Mouans-Sartoux, France

Alberto Michelini, Fabrizio Bernardi, Valentino Lauciani
Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy



Part of Early-est, in operation at the INGV tsunami alert center (CAT, "Centro di Allerta Tsunami")

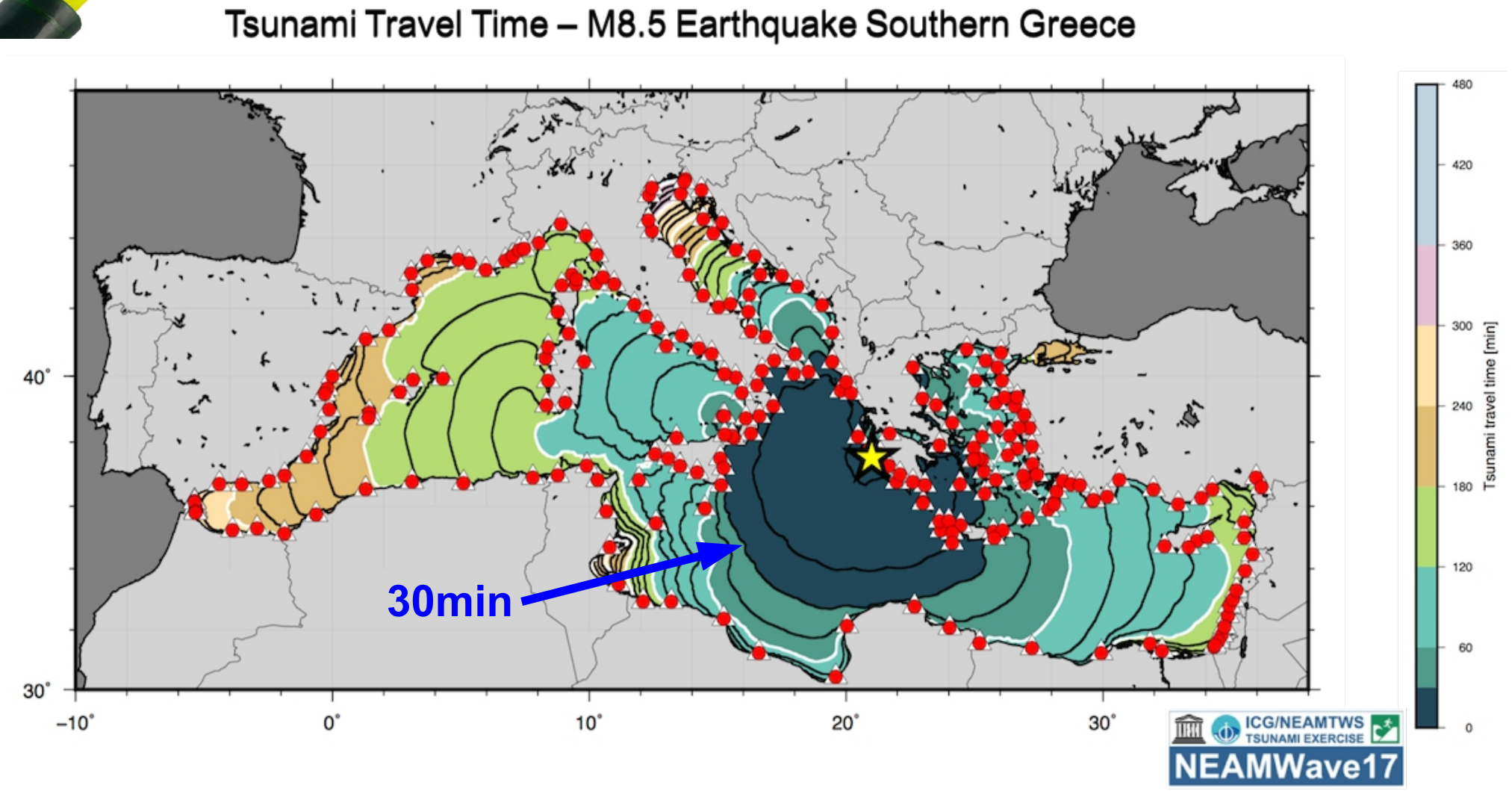
Photos of this presentation are welcome

Tsunami Early Warning: Very little time

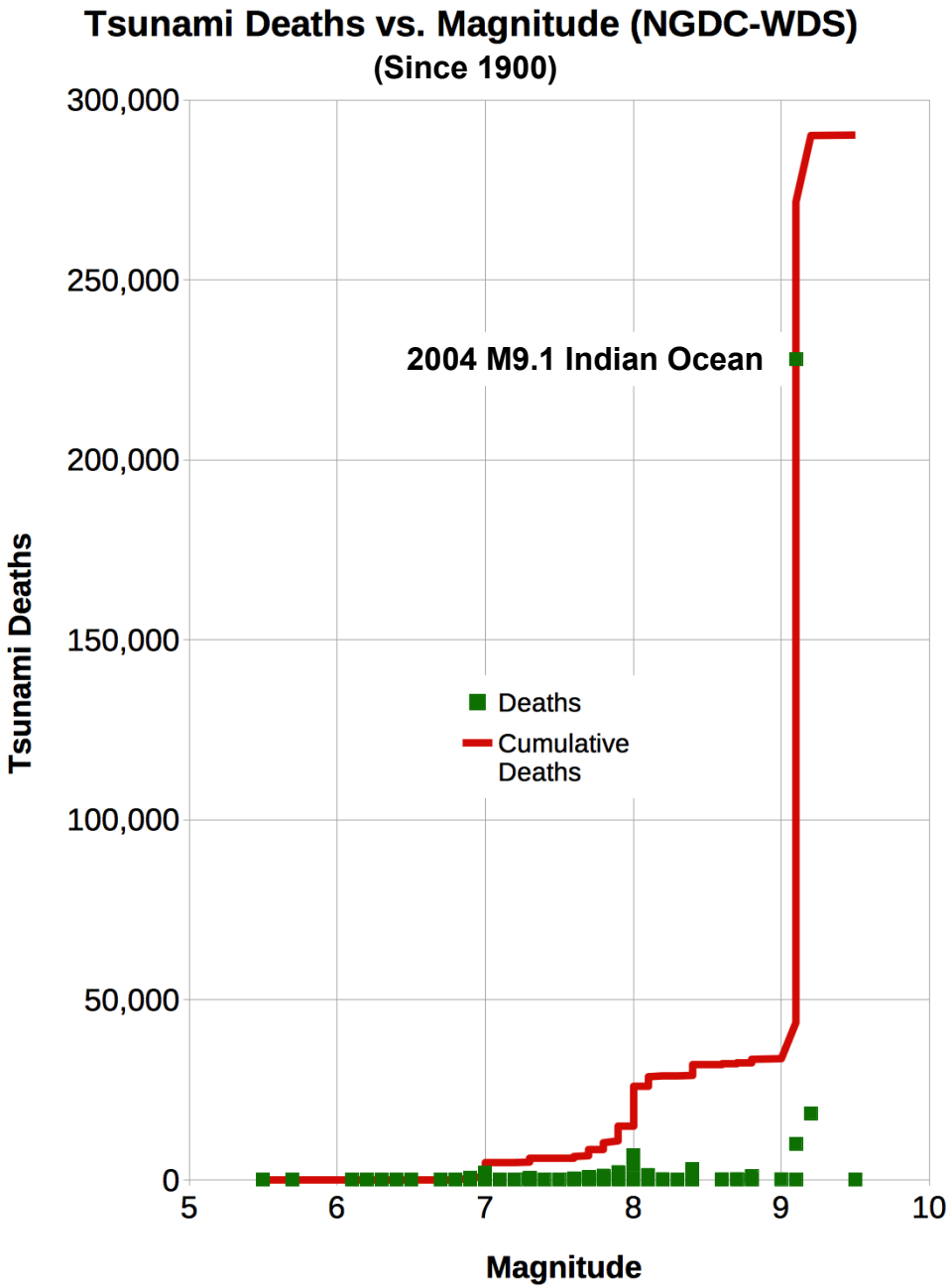
Mediterranean (INGV-CAT) and many other parts of the world:

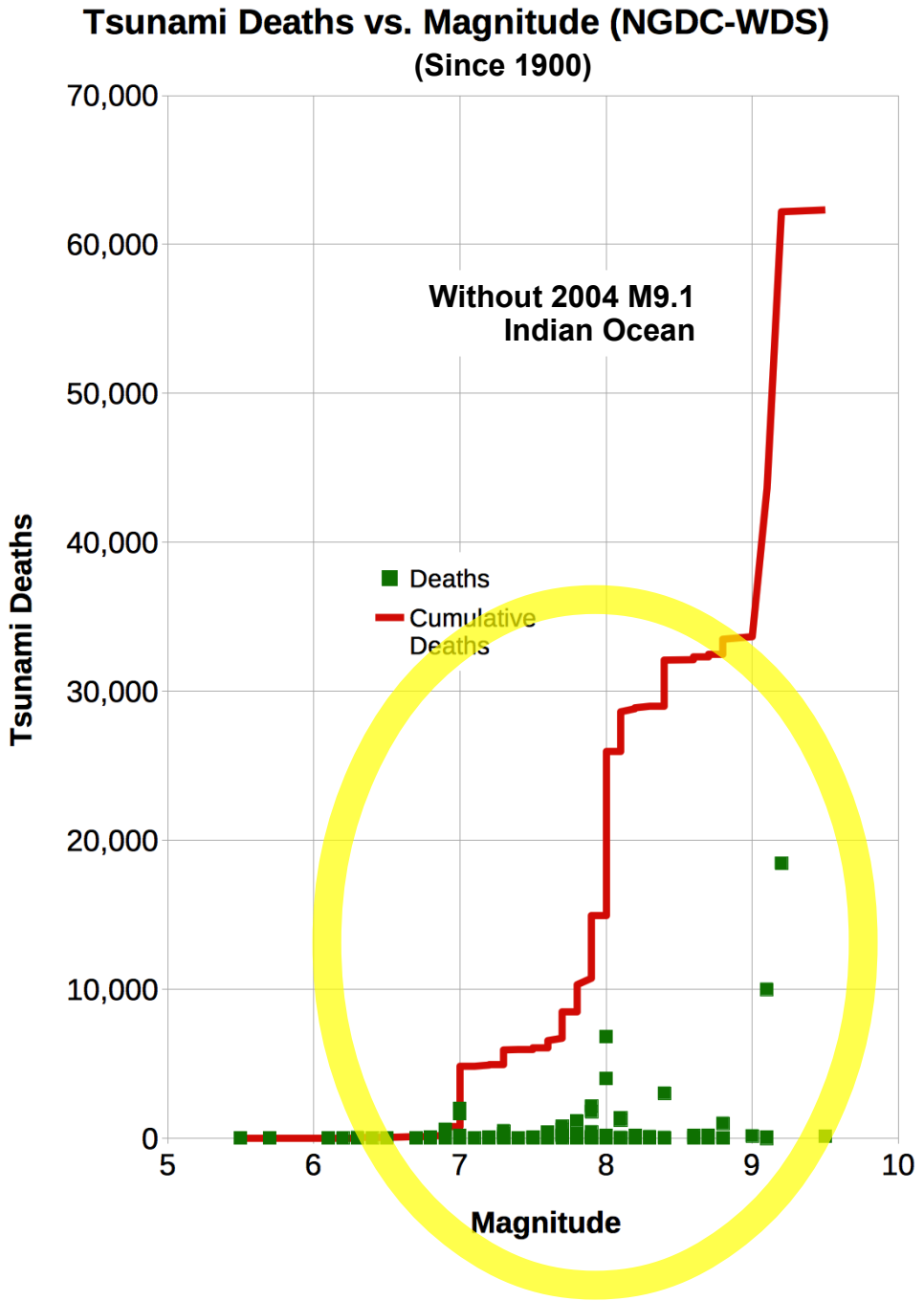
- **Local to near regional distances**
- **Tsunami arrives a few minutes to 10's of minutes after an earthquake**

⟶ Earthquake characterization and warning needed within 10min

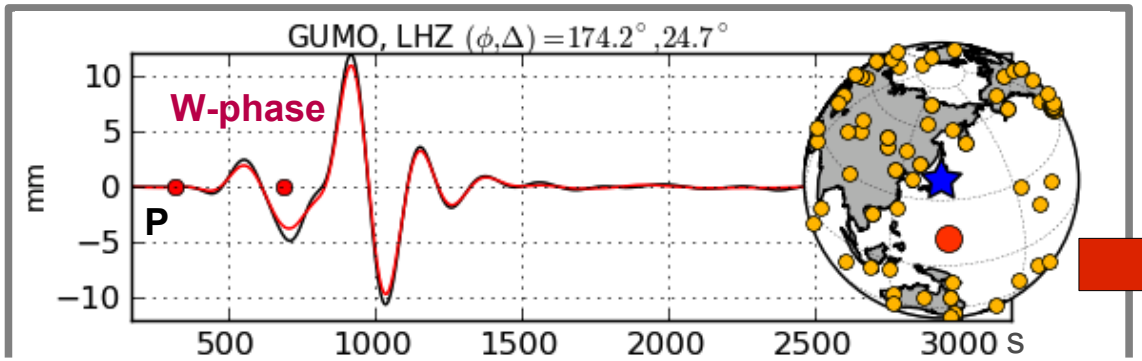


Many tsunami deaths for earthquakes M7.5+

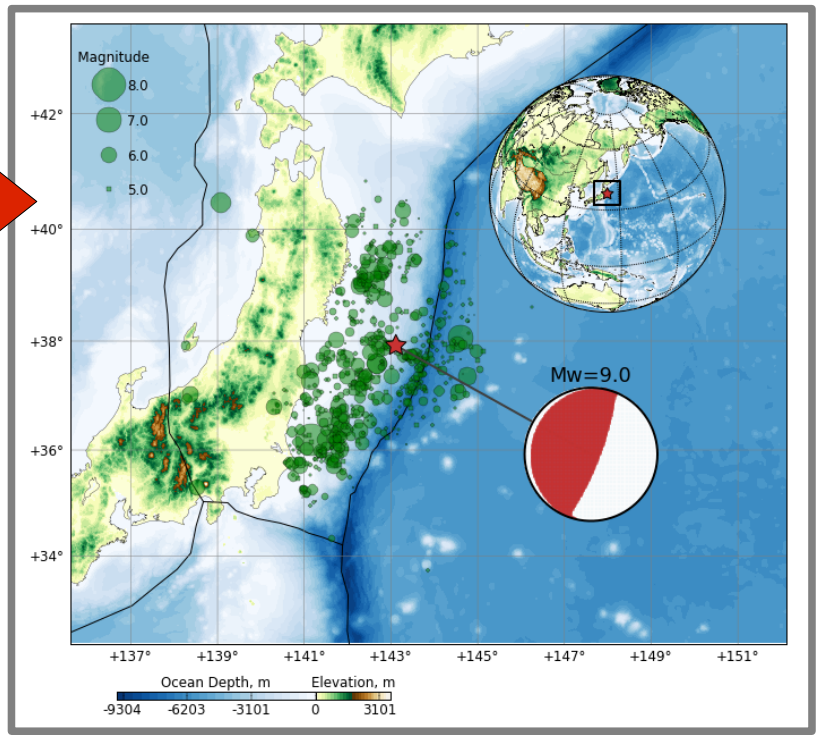




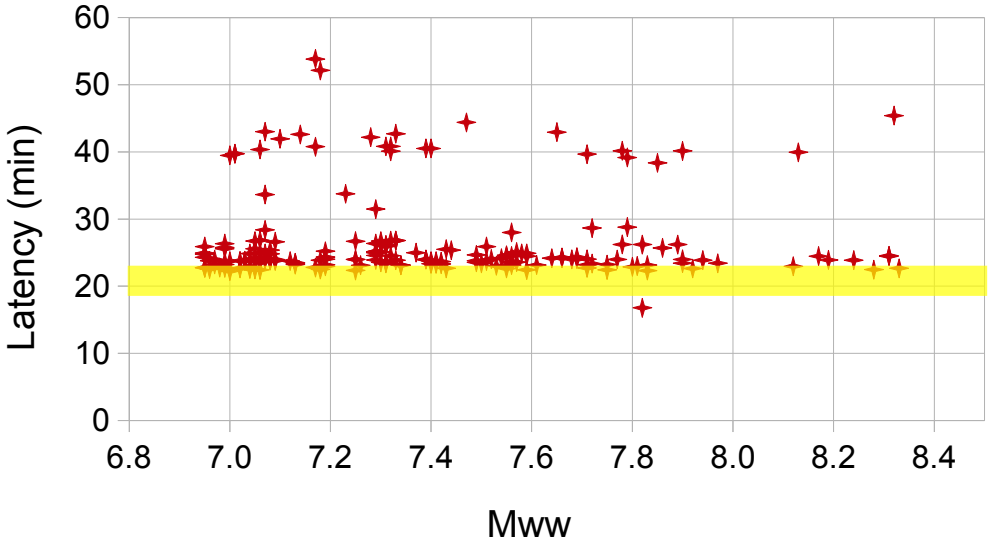
Rapid Mw + rupture model: W-Phase CMT (OT+20min)



Duputel et al., 2011



3/11/2011 (Mw 9.0), Tohoku-oki, Japan

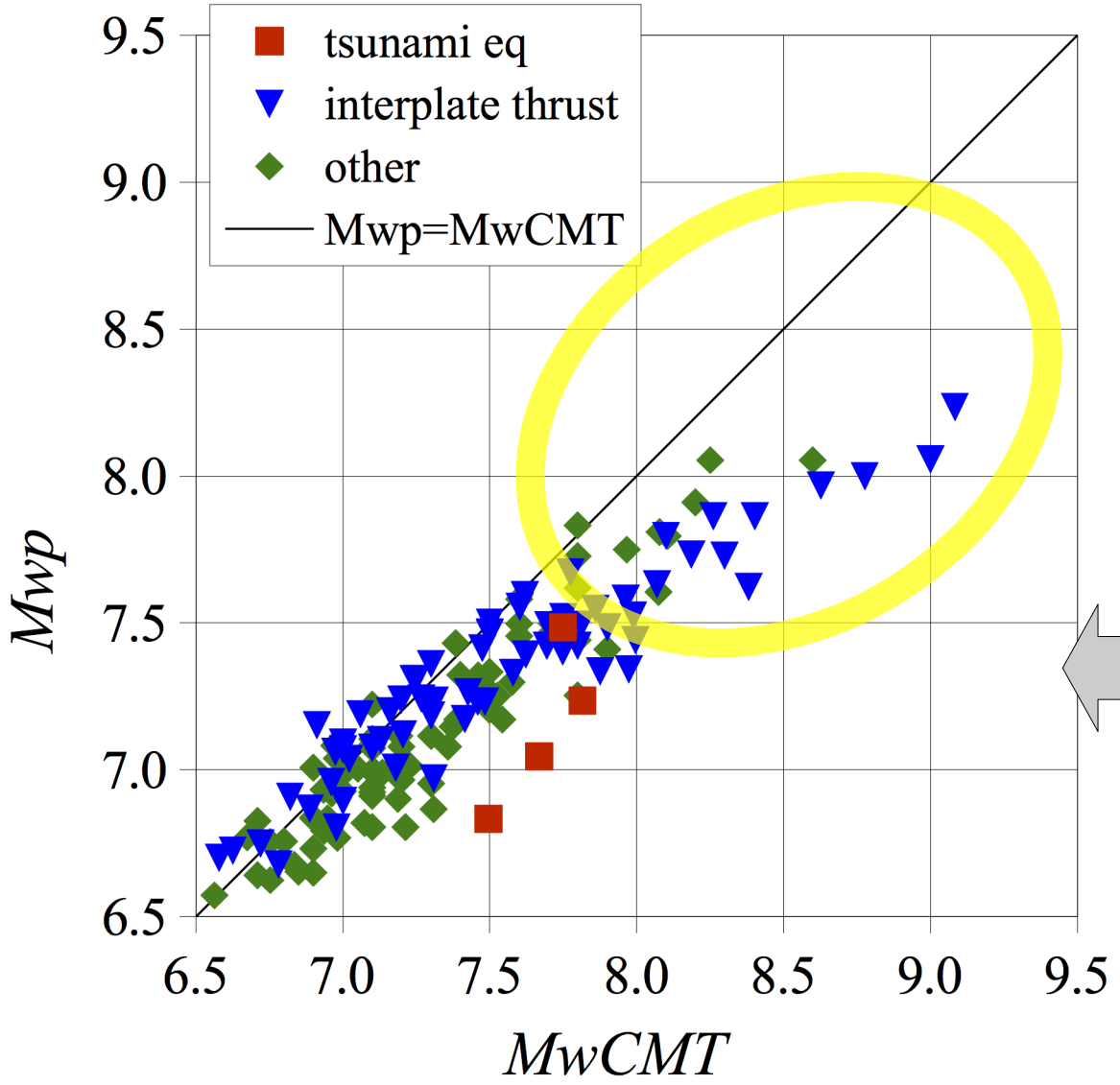


Future:

- **GFZ? Regional CMT? < 10min ?**
- **Local/regional GPS? < M8+ ?**

M_{wp}: fast, but underestimates size of large earthquakes

M_{wp} → OT+3min

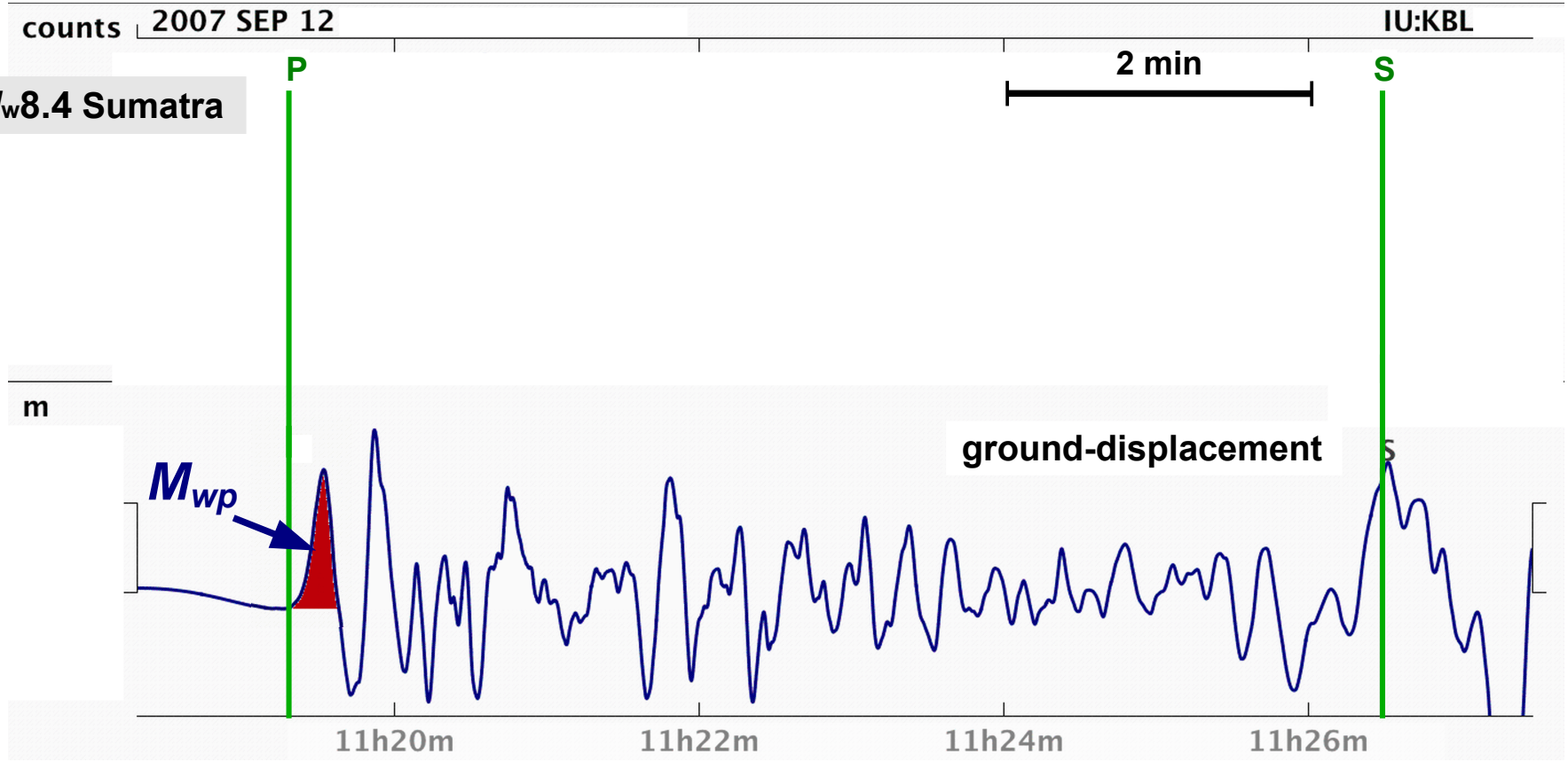


Mwp vs final gCMT magnitude M_w^{CMT} for large earthquakes 1992-2018

gCMT: http://www.globalcmt.org

M_{wp}: fast, but underestimates size of large earthquakes

2007, M_w8.4 Sumatra

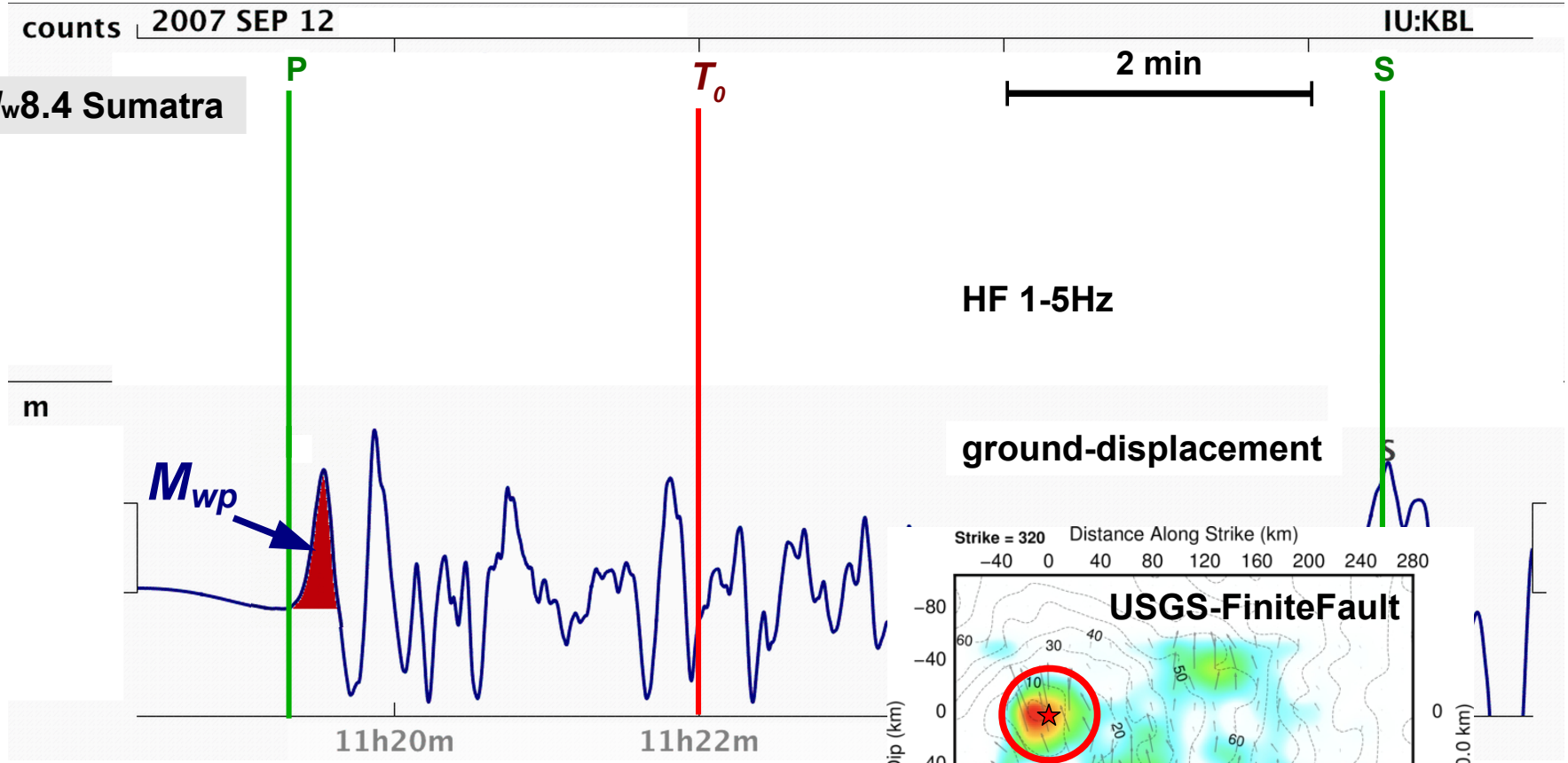


M_0 estimate: integral of displacement over P pulse

M_{wp} OT+3min

M_{wp} – not capturing full rupture duration

2007, M_w8.4 Sumatra



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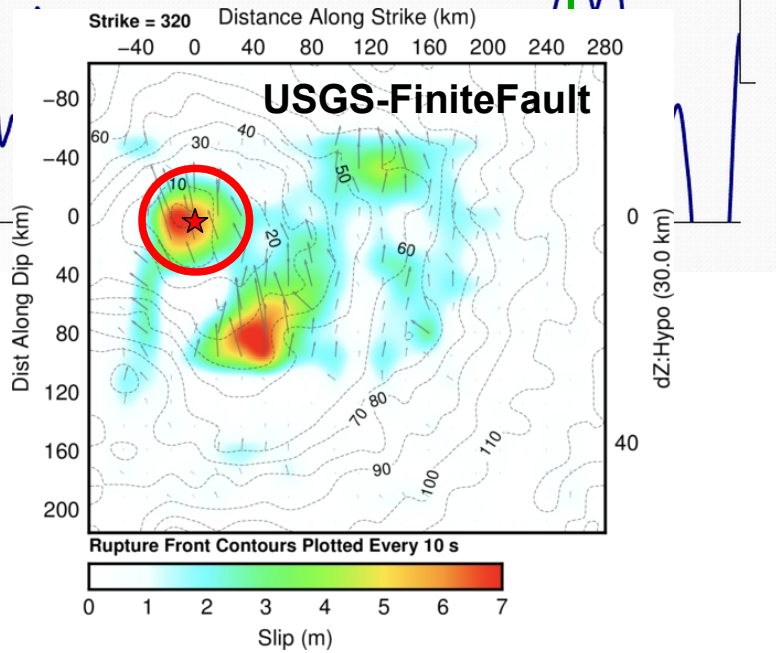
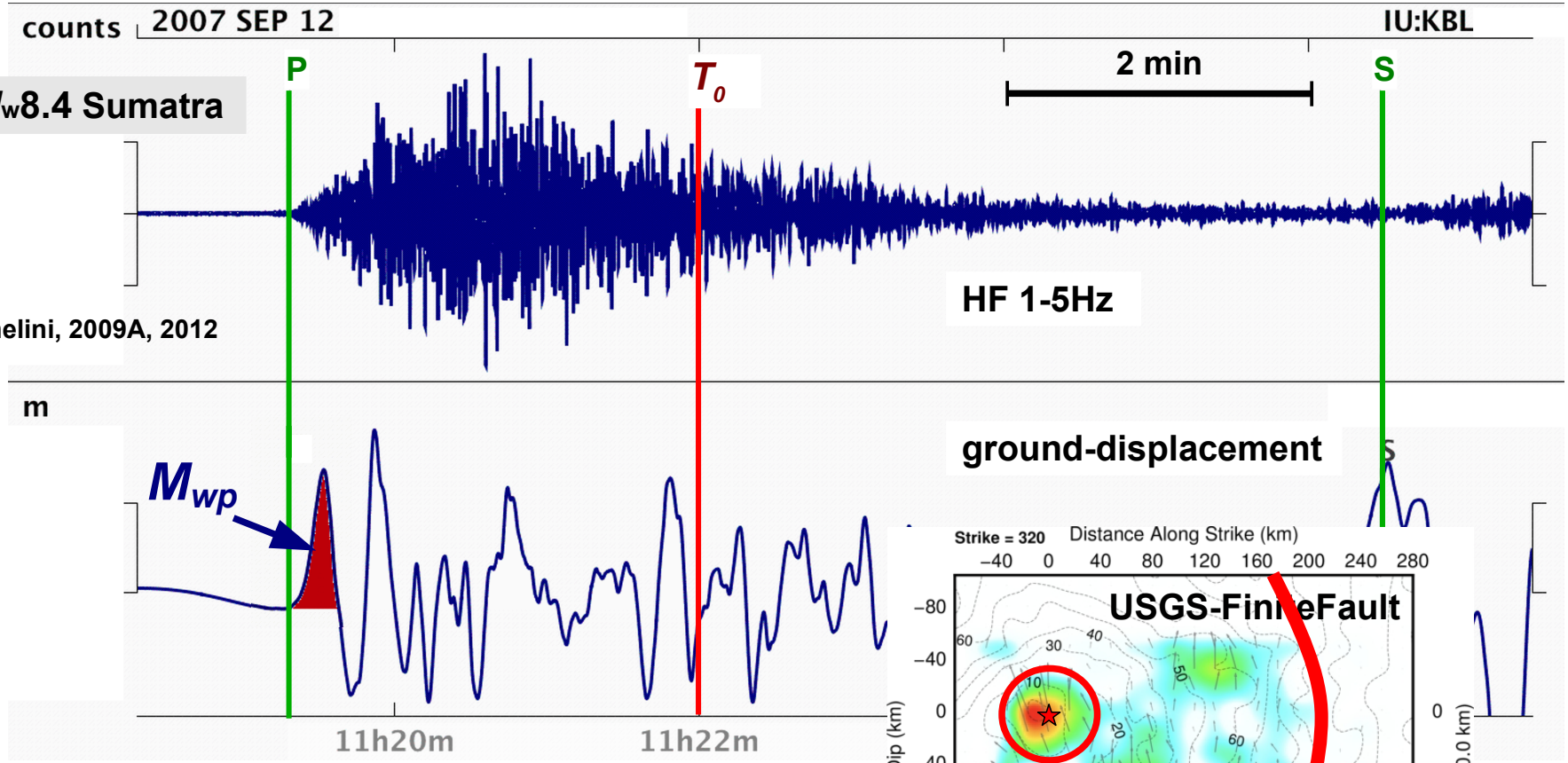


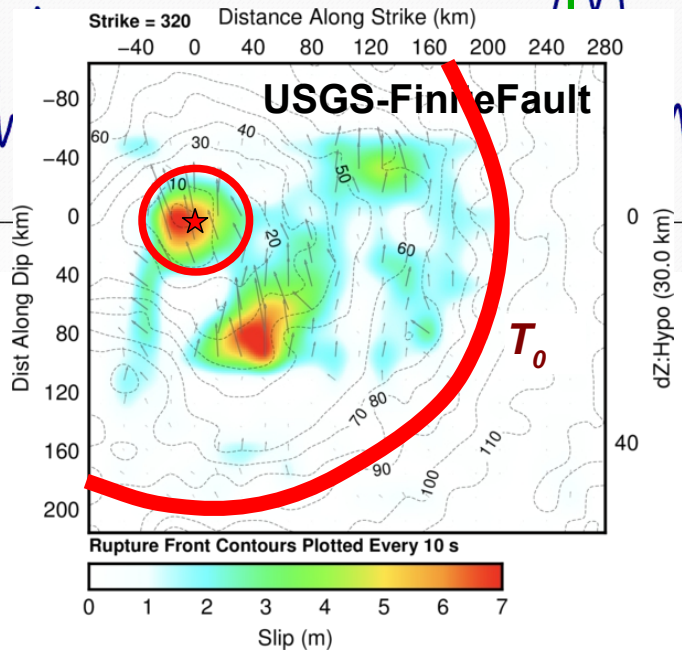
M_{wp} – but we have more information from HF duration

2007, M_w8.4 Sumatra

Lomax & Michelini, 2009A, 2012



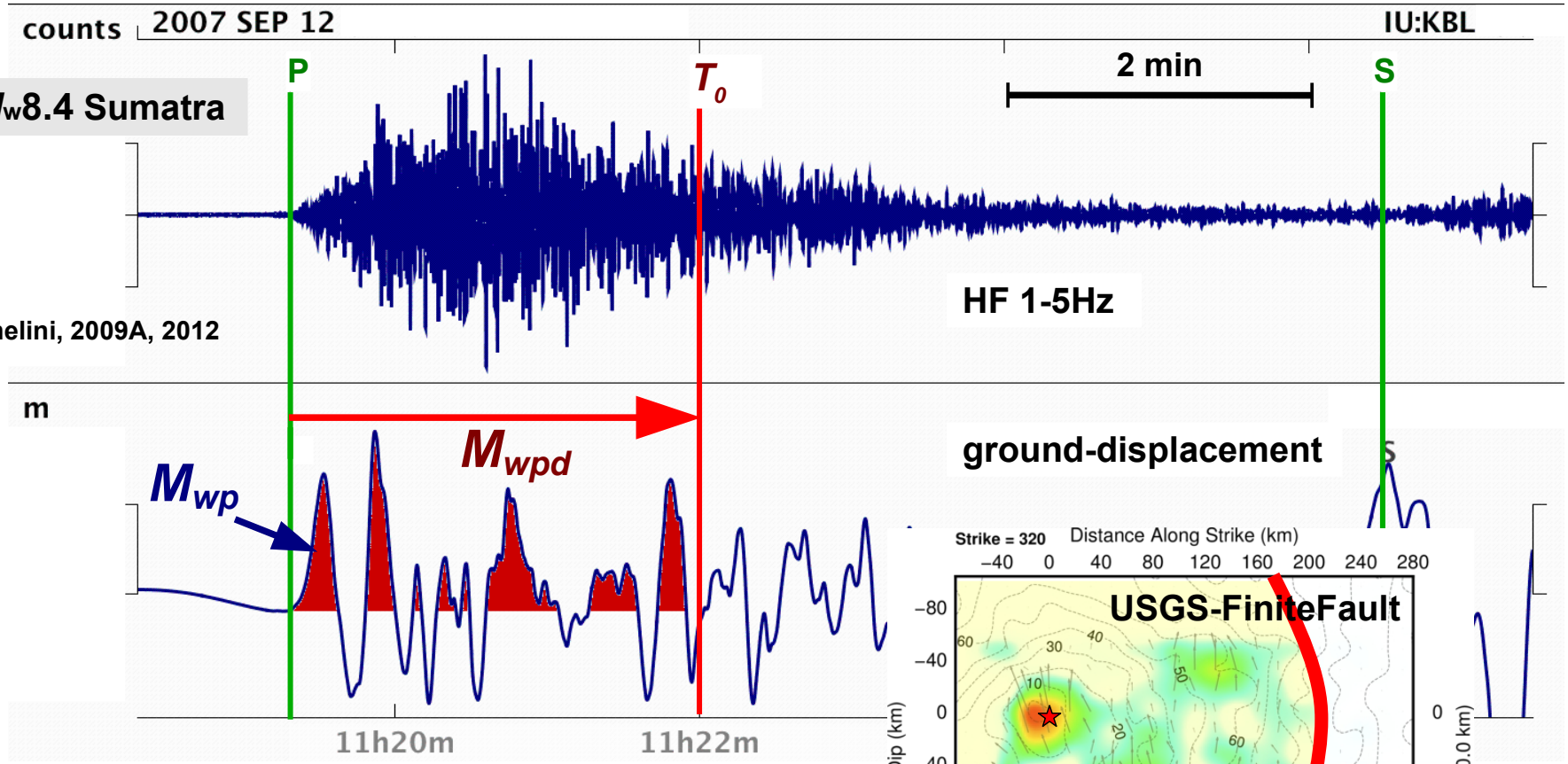
M_0 estimate: integral of displacement over P pulse



M_{wpd} – rapidly gives true size of large earthquakes

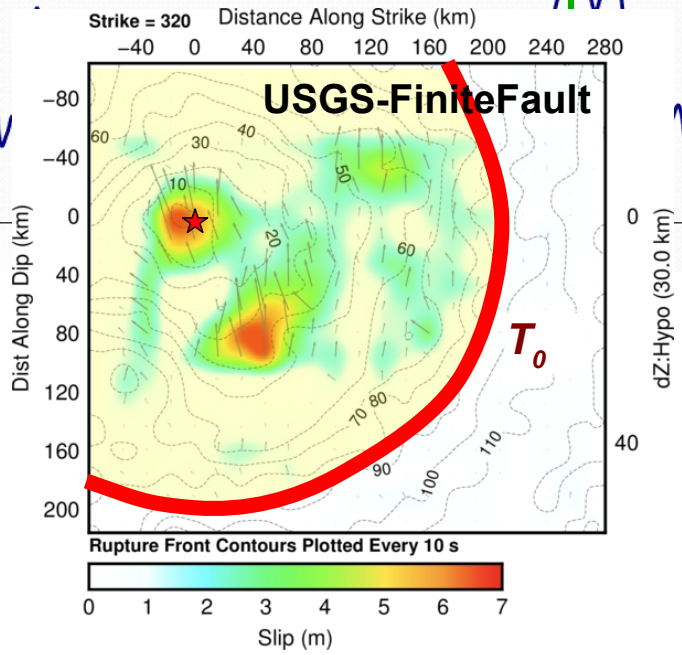
2007, M_w8.4 Sumatra

Lomax & Michelini, 2009A, 2012

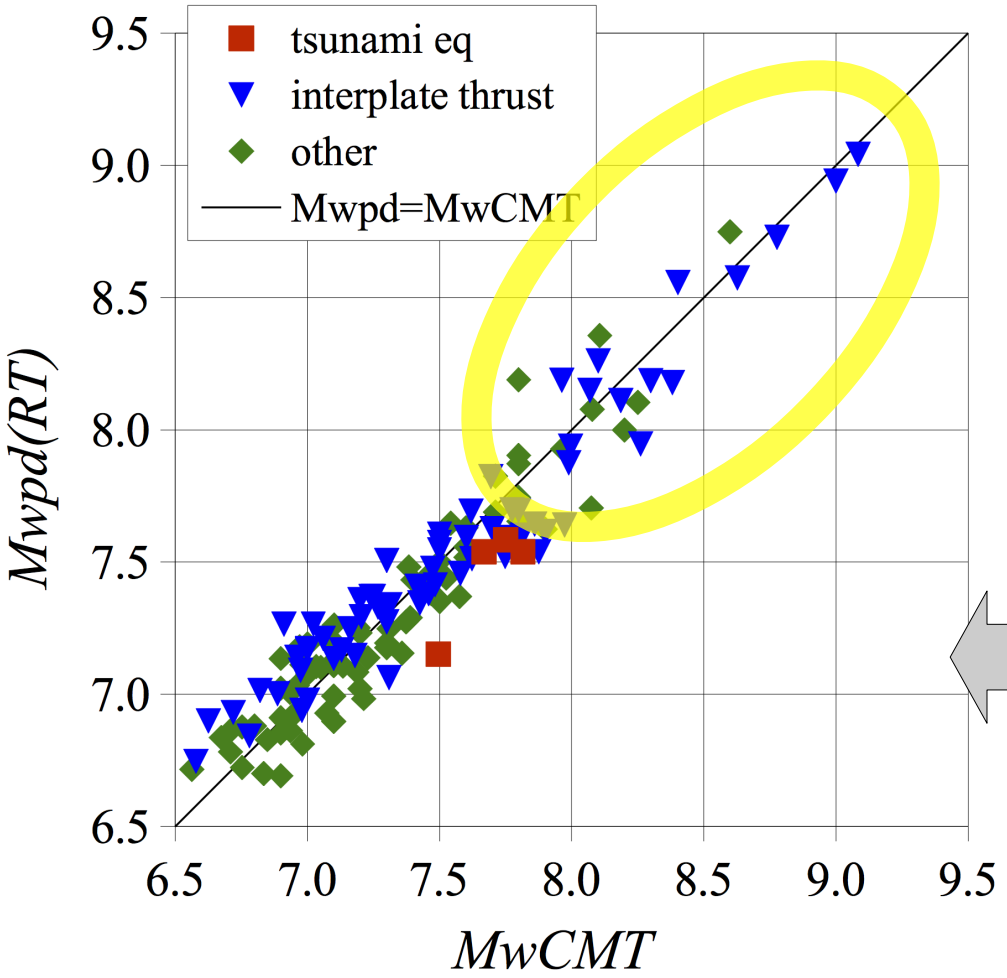


M_0 estimate: integral of P displacement over duration T_0

M_{wpd} OT+5-10min



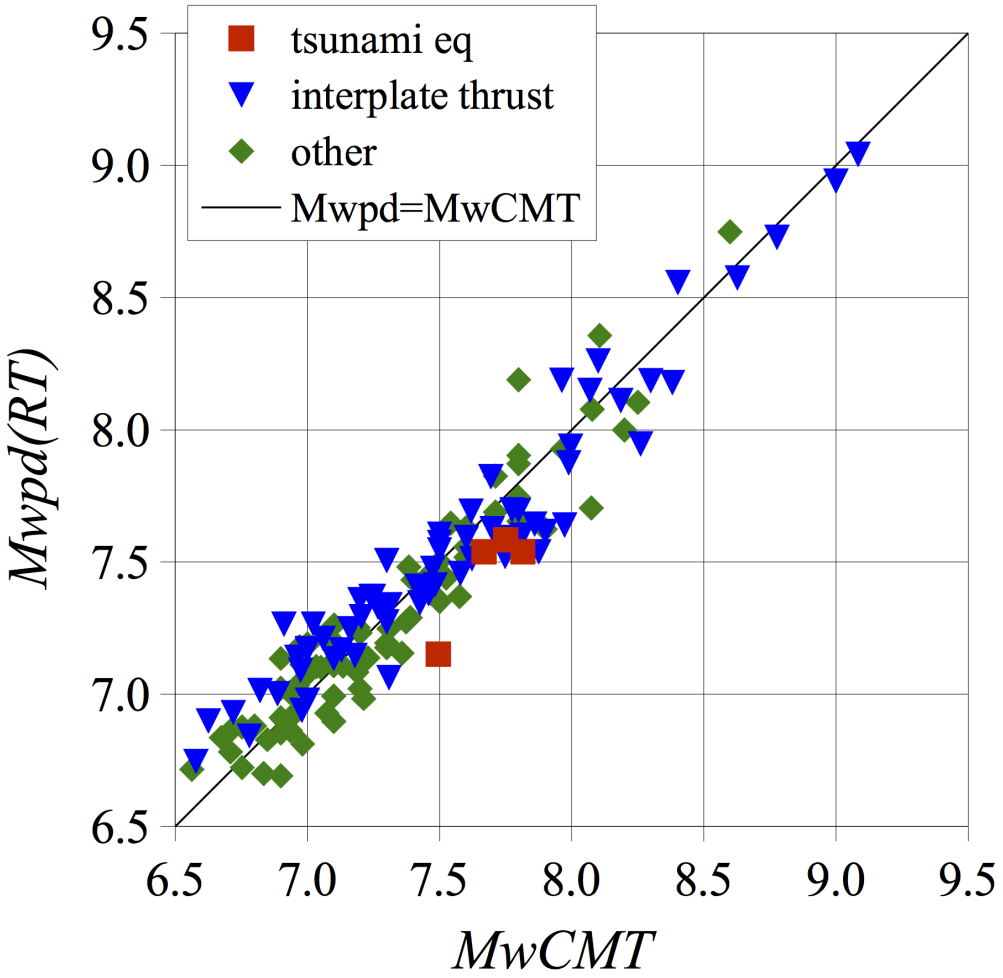
M_{wpd} – rapidly gives true size of large earthquakes



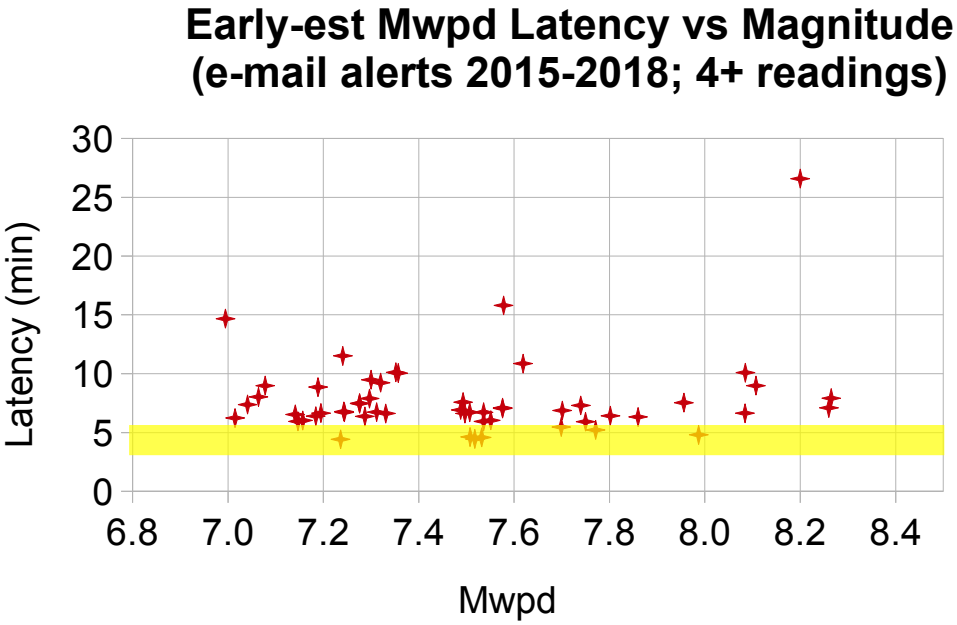
M_{wpd} vs final gCMT magnitude M_w^{CMT} for large earthquakes 1992-2018

Lomax & Michelini, 2009A, 2012

M_{wpd} – rapidly gives true size of large earthquakes

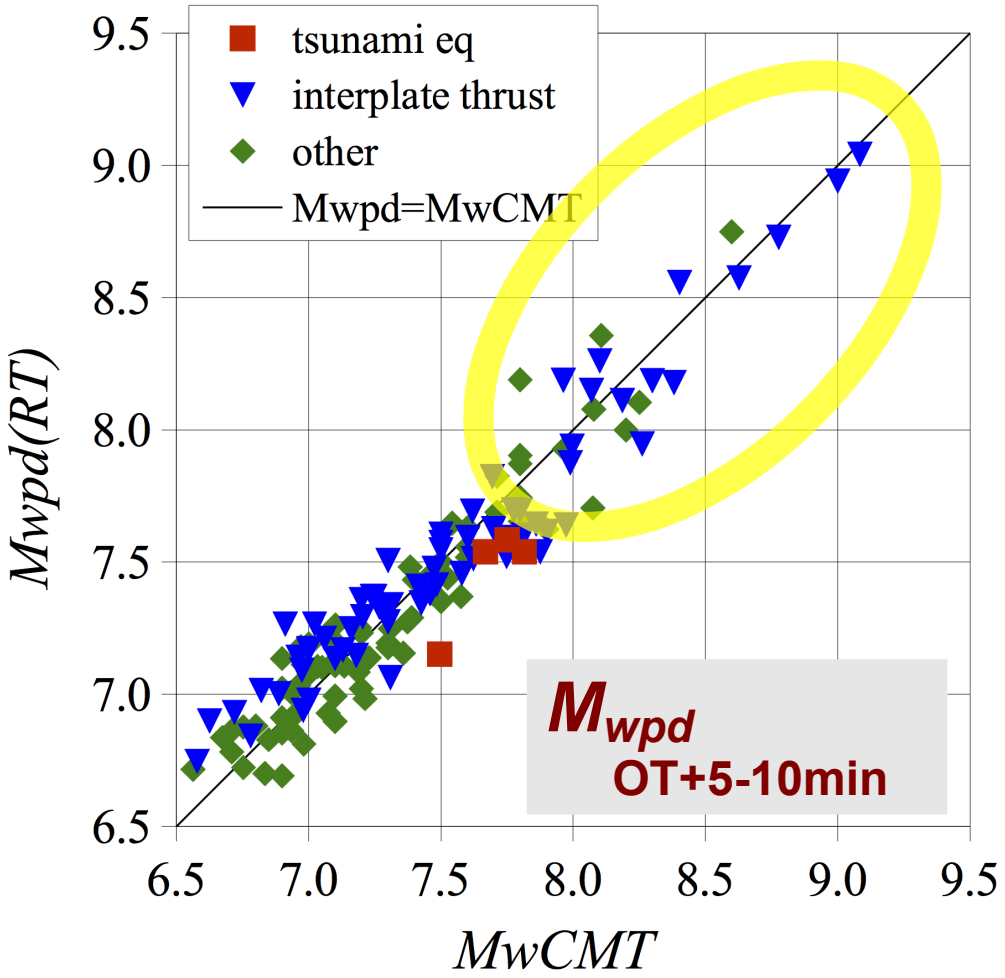


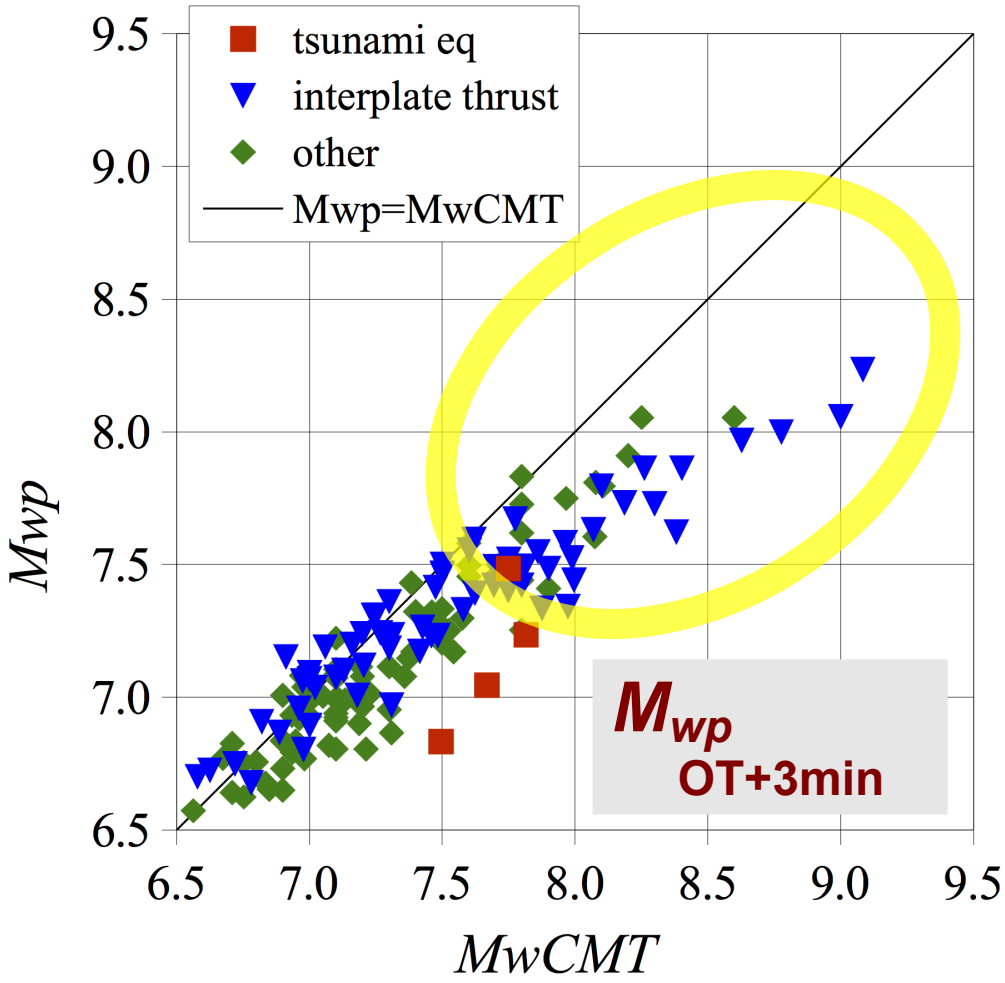
M_{wpd} OT+5-10min



Lomax & Michelini, 2009A, 2012

M_{wpd} vs M_{wp} for large earthquakes



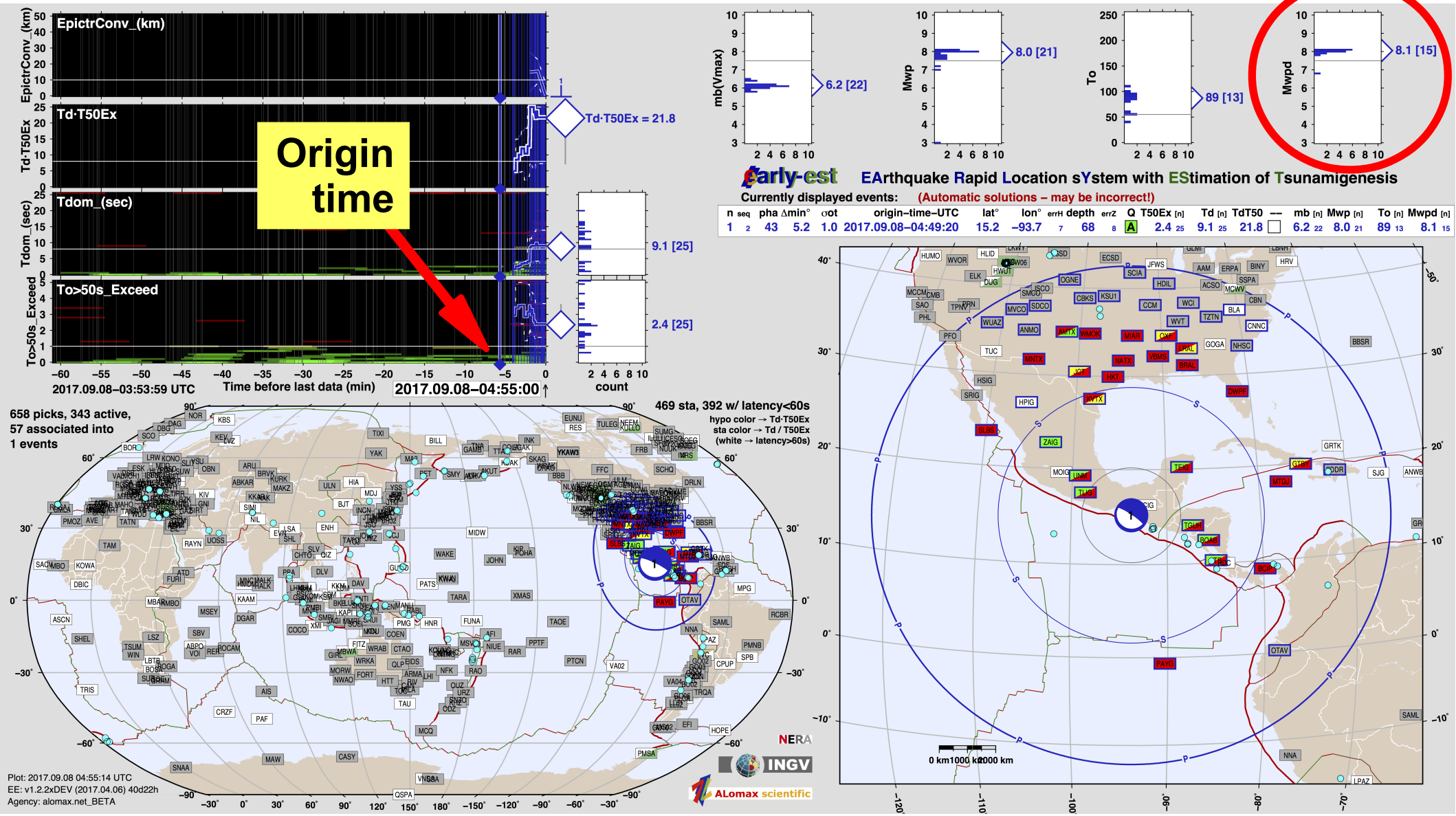


Lomax & Michelini, 2009A, 2012

gCMT: http://www.globalcmt.org

Early-est rapid earthquake detection and analysis

In operation at the INGV tsunami alert center (CAT, “Centro di Allerta Tsunami”)

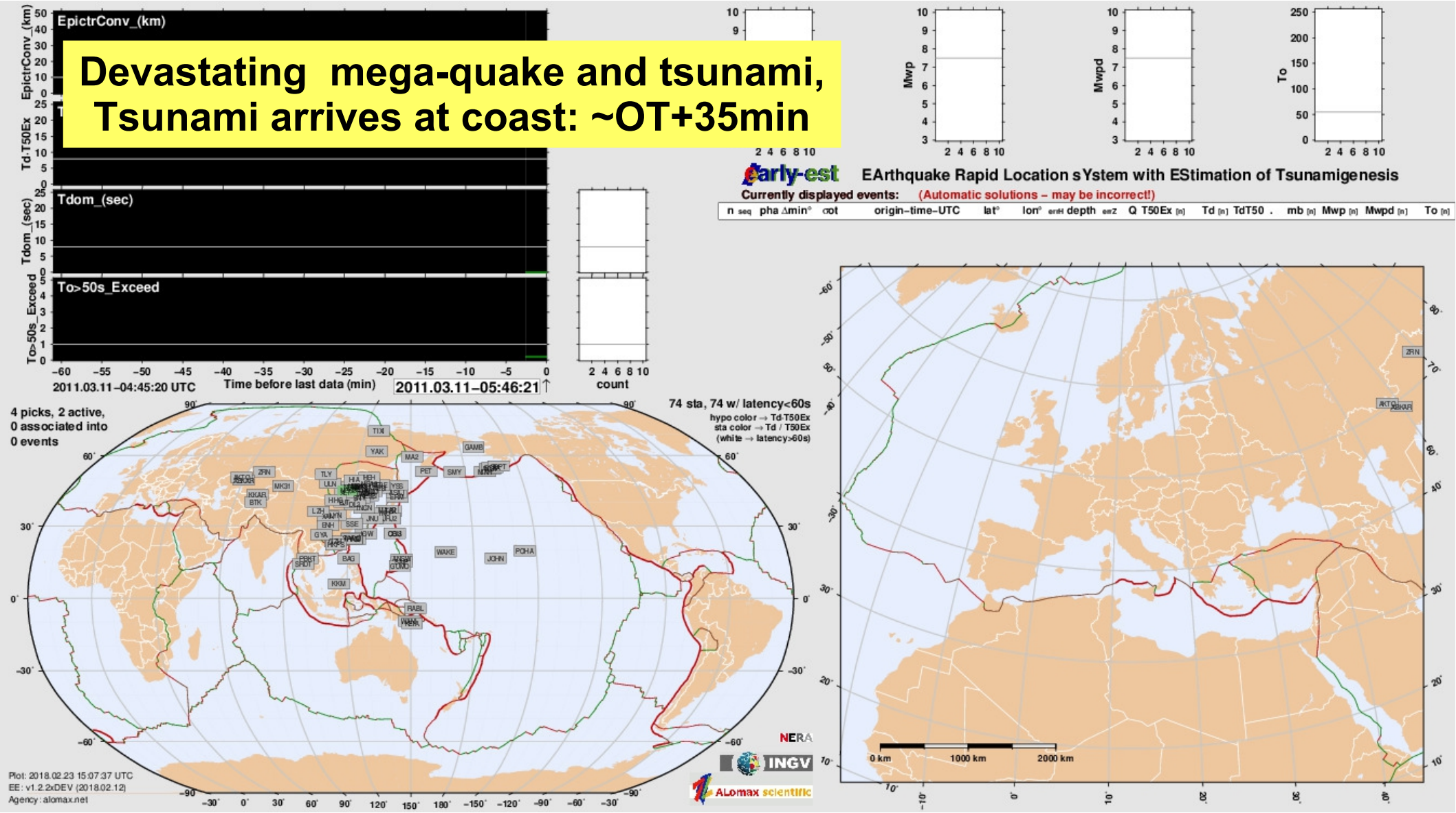


CAT-INGV has been accredited by ICG/NEAMTWS as Tsunami Service Provider)

http://early-est.alomax.net, http://early-est.rm.ingv.it, http://alomax.free.fr/posters/early-est

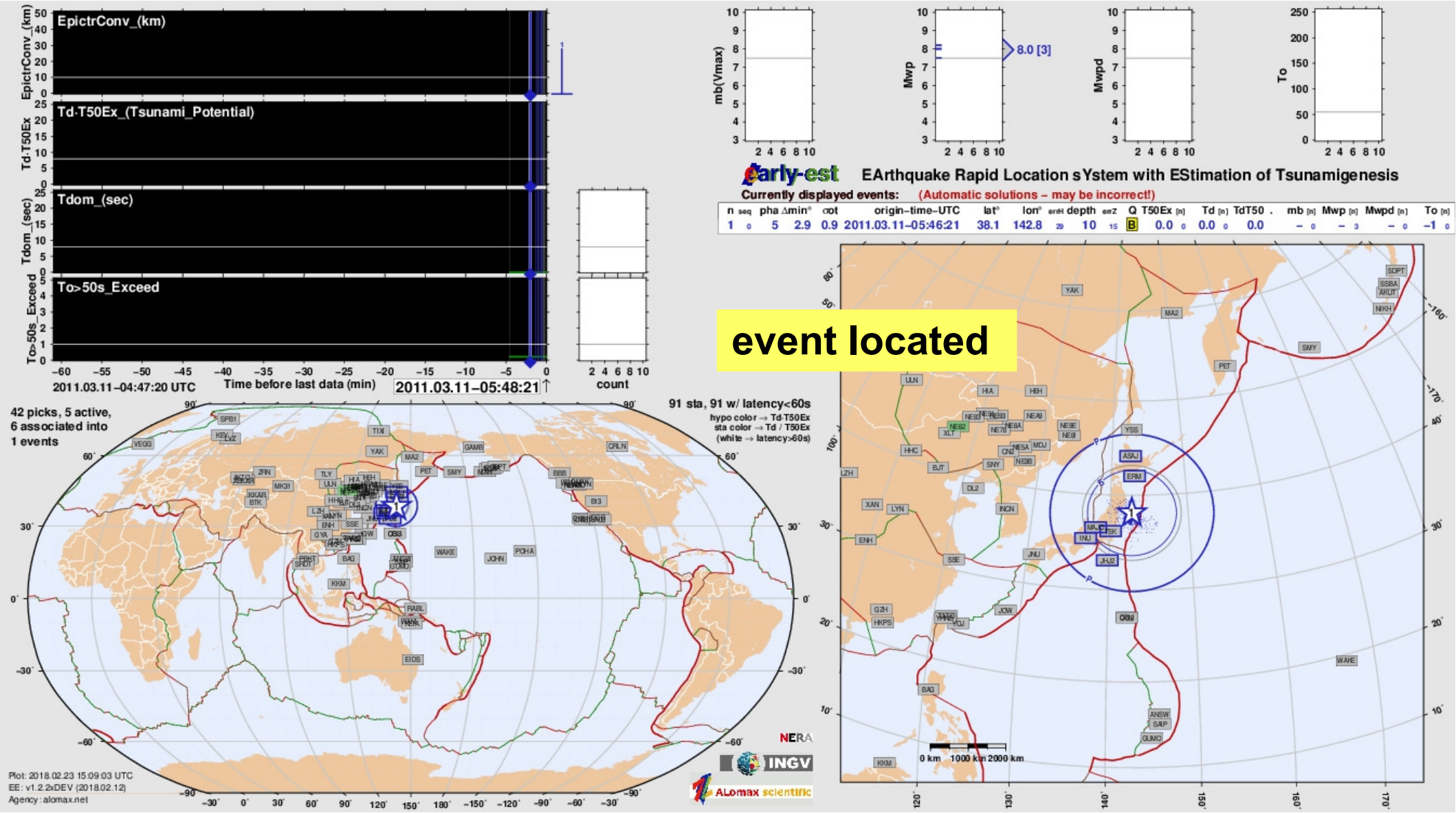
Real-time simulation: *M*w9.1, Tohoku, Japan 2011 OT+0min

Devastating mega-quake and tsunami,
Tsunami arrives at coast: ~OT+35min



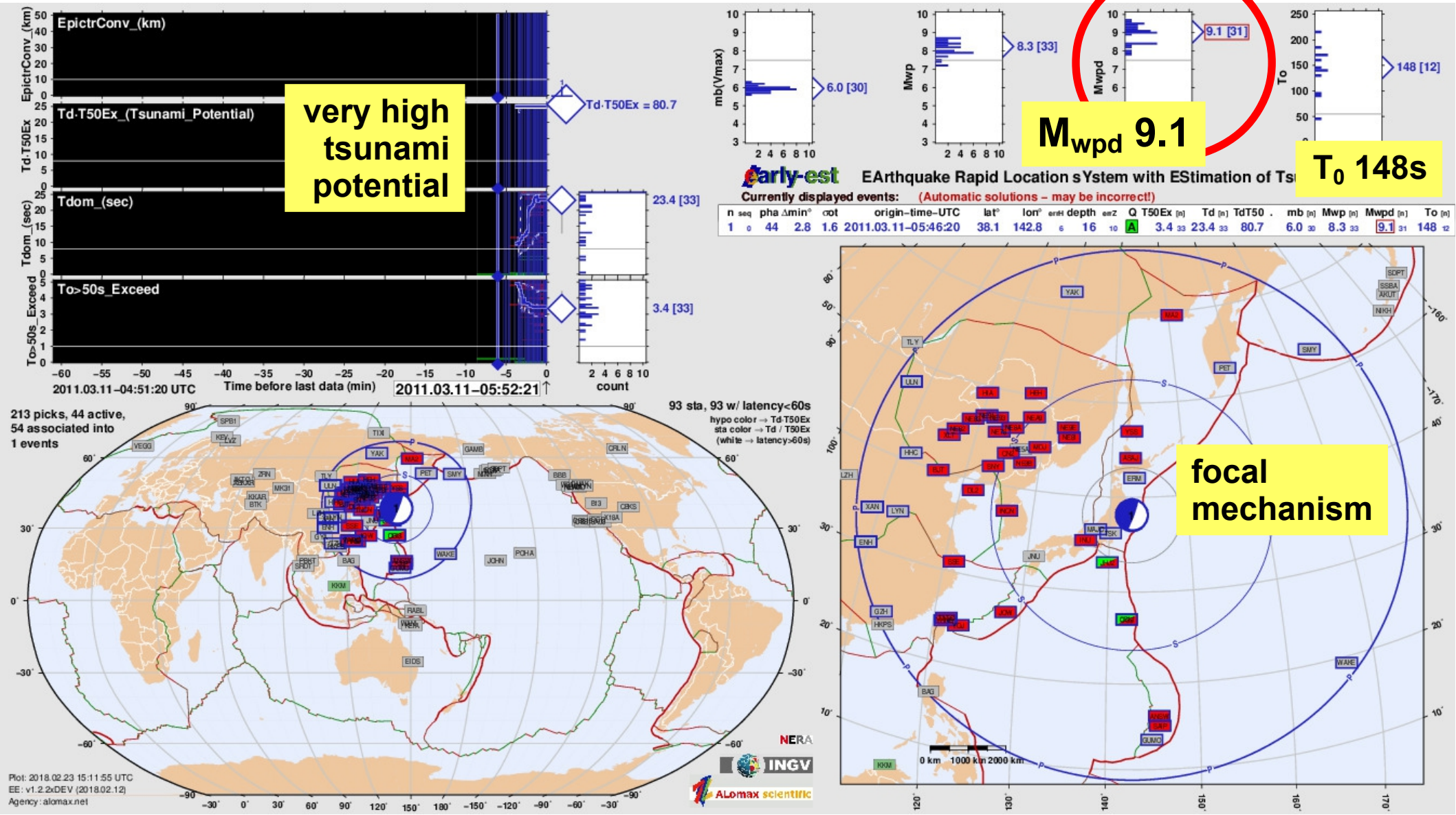
off-line simulation of Early-est realtime monitor - early-est.rm.ingv.it

Real-time simulation: *M*w9.1, Tohoku, Japan 2011 OT+2min



off-line simulation of Early-est realtime monitor - early-est.rm.ingv.it

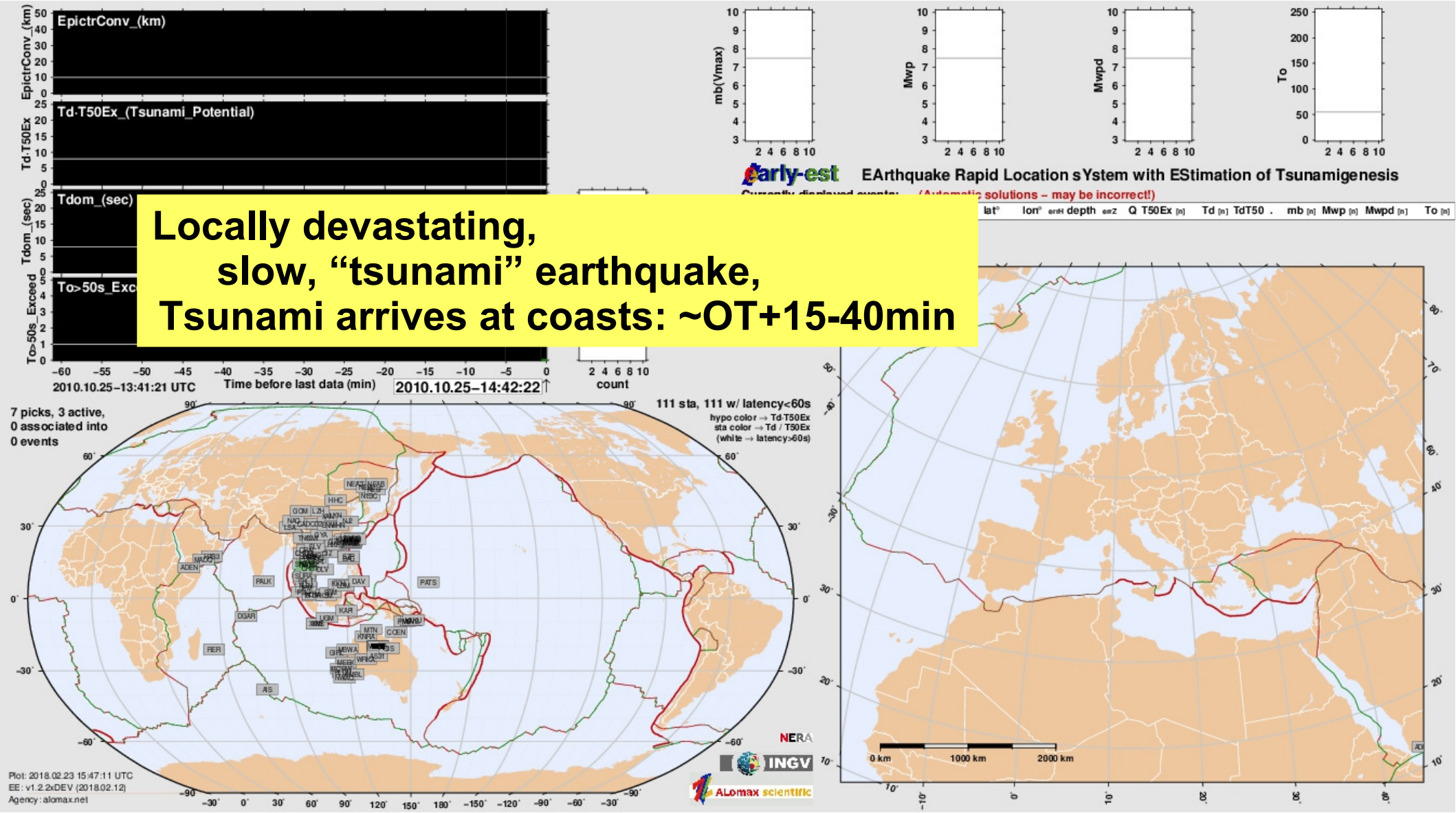
Real-time simulation: *M*w9.1, Tohoku, Japan 2011 OT+6min



off-line simulation of Early-est realtime monitor - early-est.rm.ingv.it

Real-time simulation: *M*w7.8, Mentawai 2010

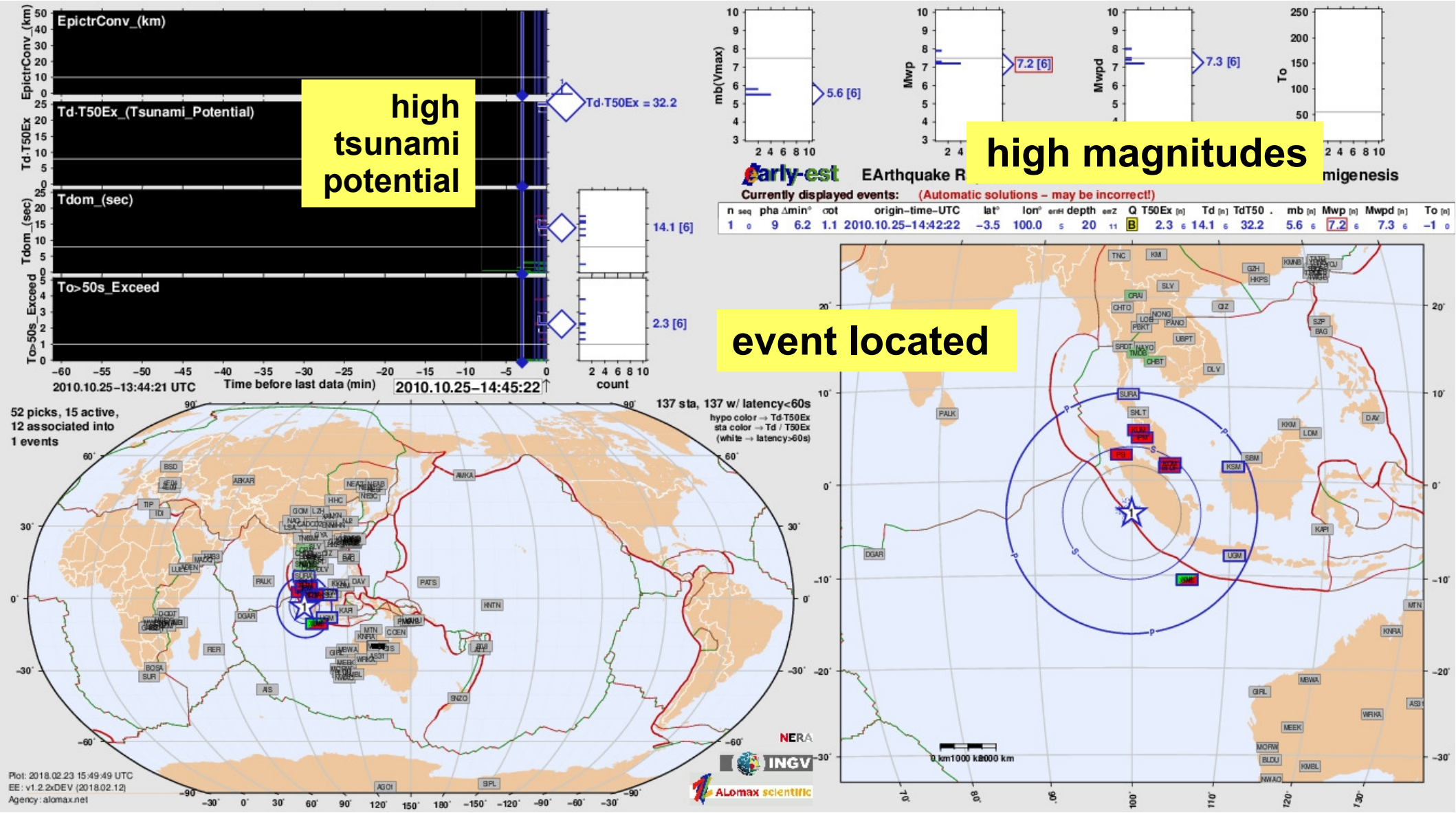
OT+0min



off-line simulation of Early-est realtime monitor - early-est.rm.ingv.it

Real-time simulation: *M*w7.8, Mentawai 2010

OT+3min



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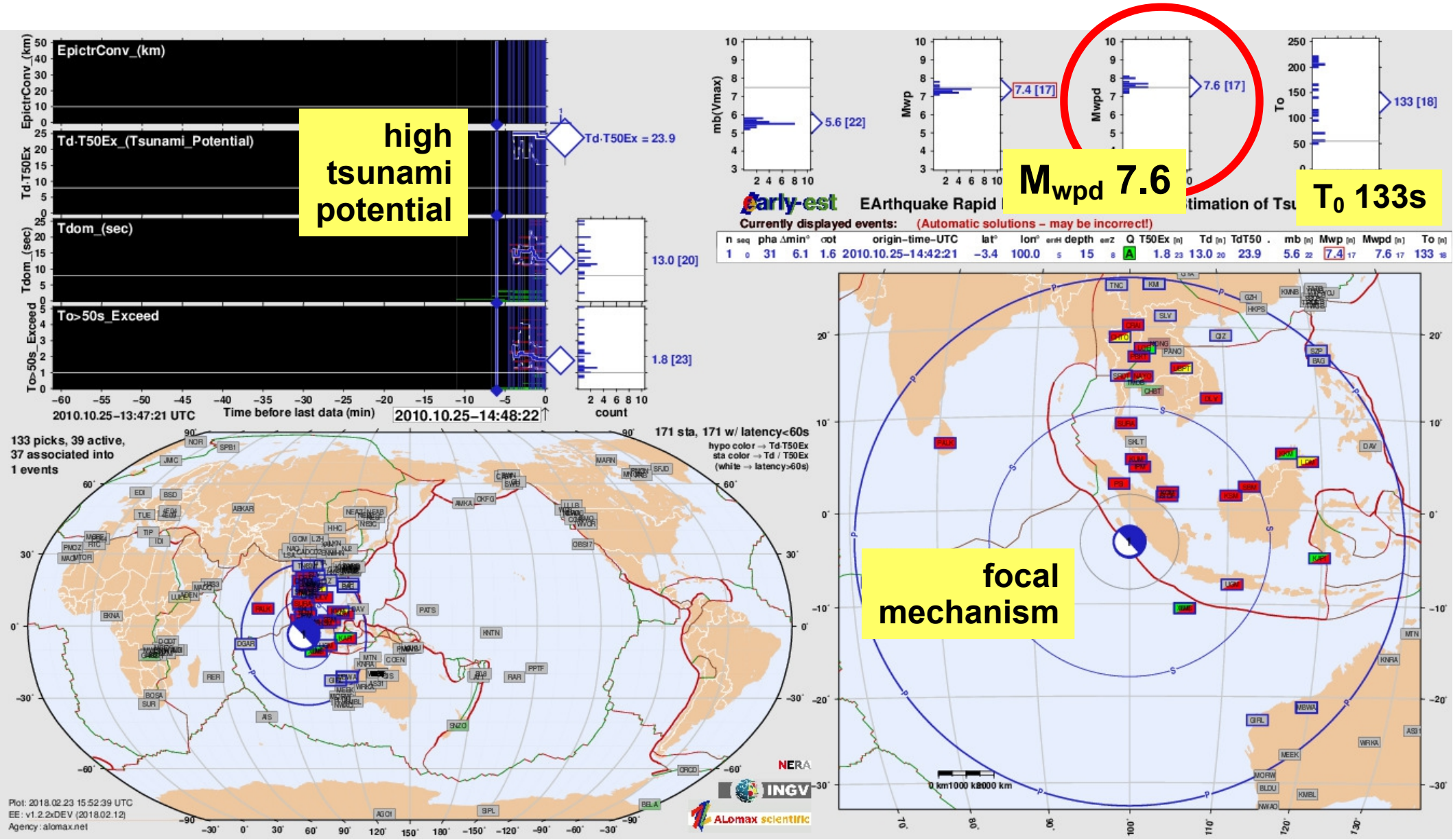
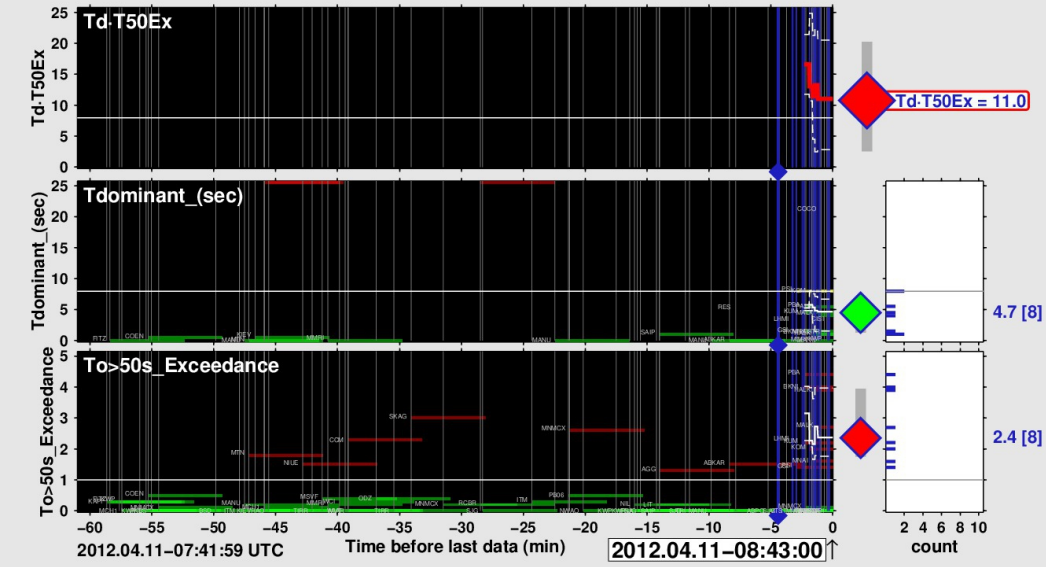
OT+6min

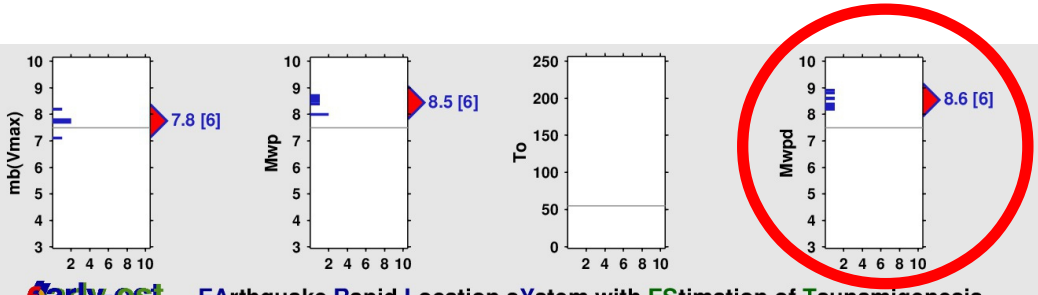


off-line simulation of Early-est realtime monitor - early-est.rm.ingv.it

Real-time: *M*w8.6, Sumatra 2012

OT+5min

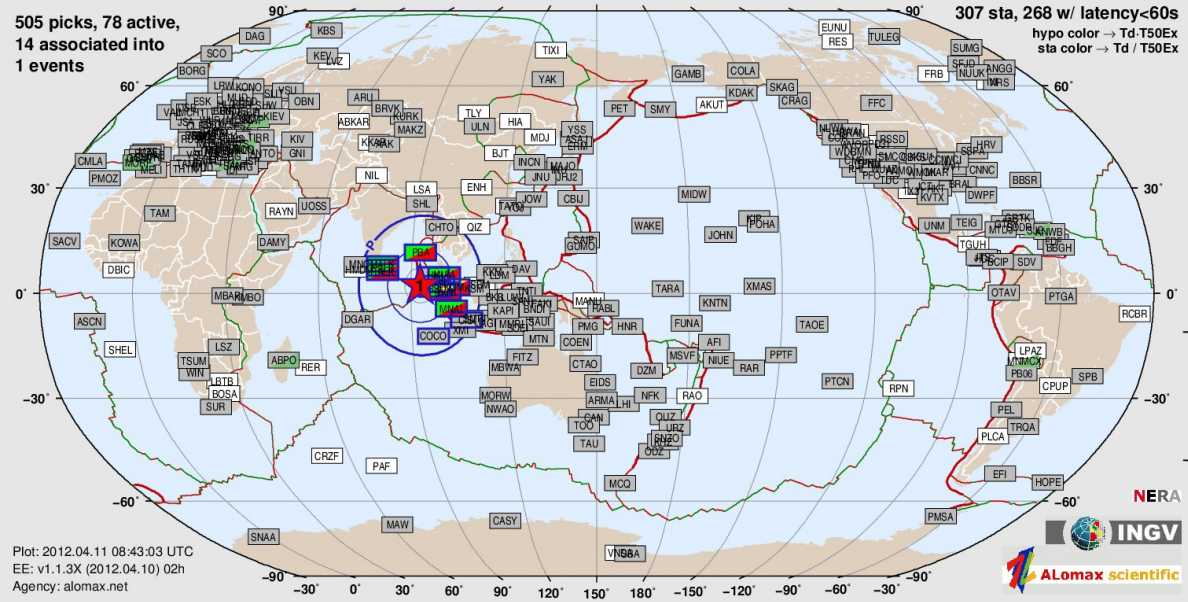


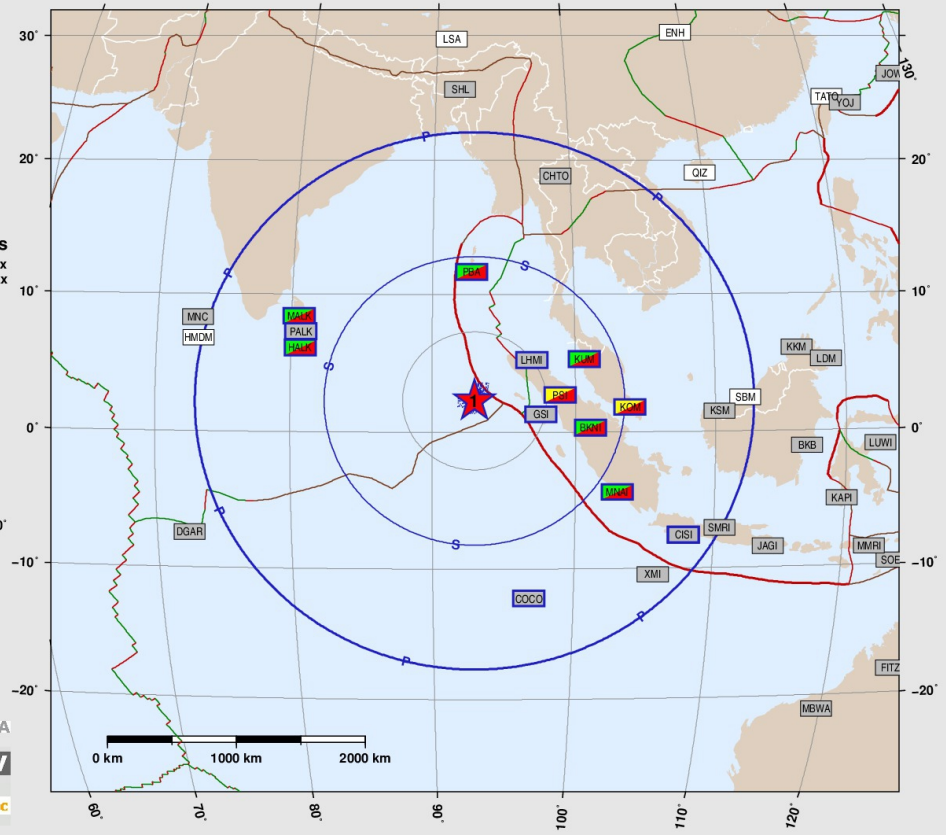


Early-est EArthquake Rapid Location sYstem with EStimation of Tsunamigenesis

Earthquake details (automatic solutions):

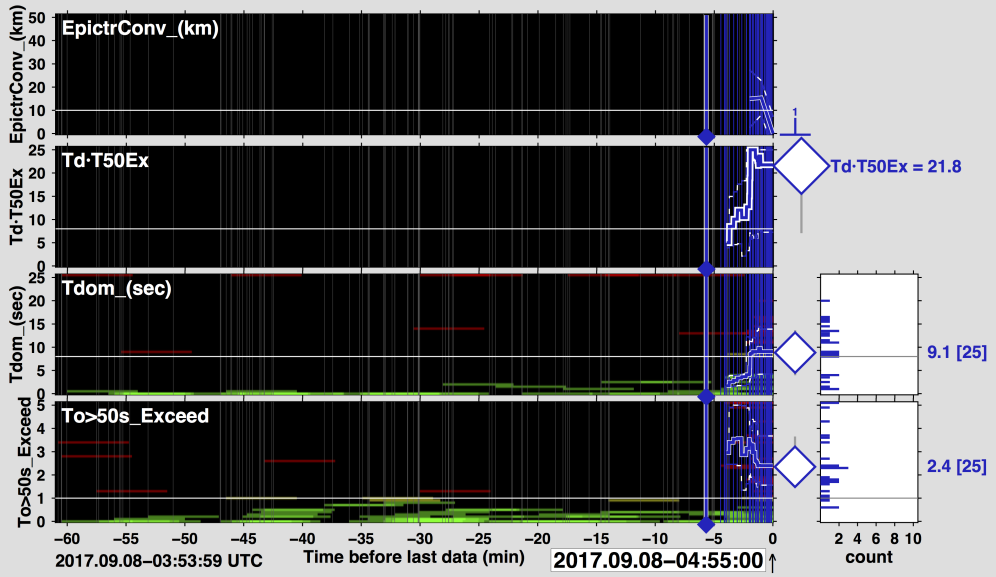
n	pha	Δmin°	σot	origin–time–UTC	lat°	lon°	errH	depth	errZ	T50Ex [n]	Td [n]	TdT50	WL	mb [n]	Mwp [n]	To [n]	Mwpd [n]
1	13	4.7	1.5	2012.04.11–08:38:35	2.3	93.0	8	81	53	2.4 8	4.7 8	11.0		7.8 6	8.5 6	– 0	8.6 6

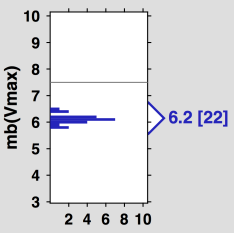


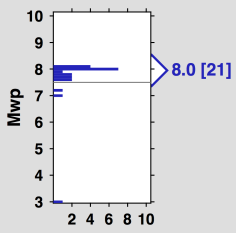


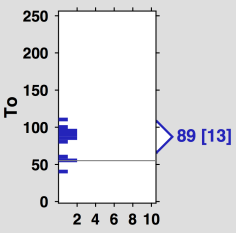
Real-time: *M*w8.2, Mexico 2017

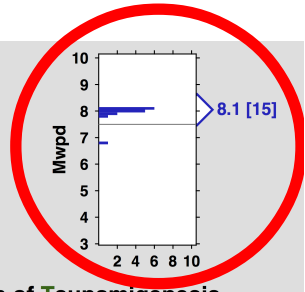
OT+6min











early-est EArthquake Rapid Location sYstem with EStimation of Tsunamigenesis

Currently displayed events: (Automatic solutions – may be incorrect!)

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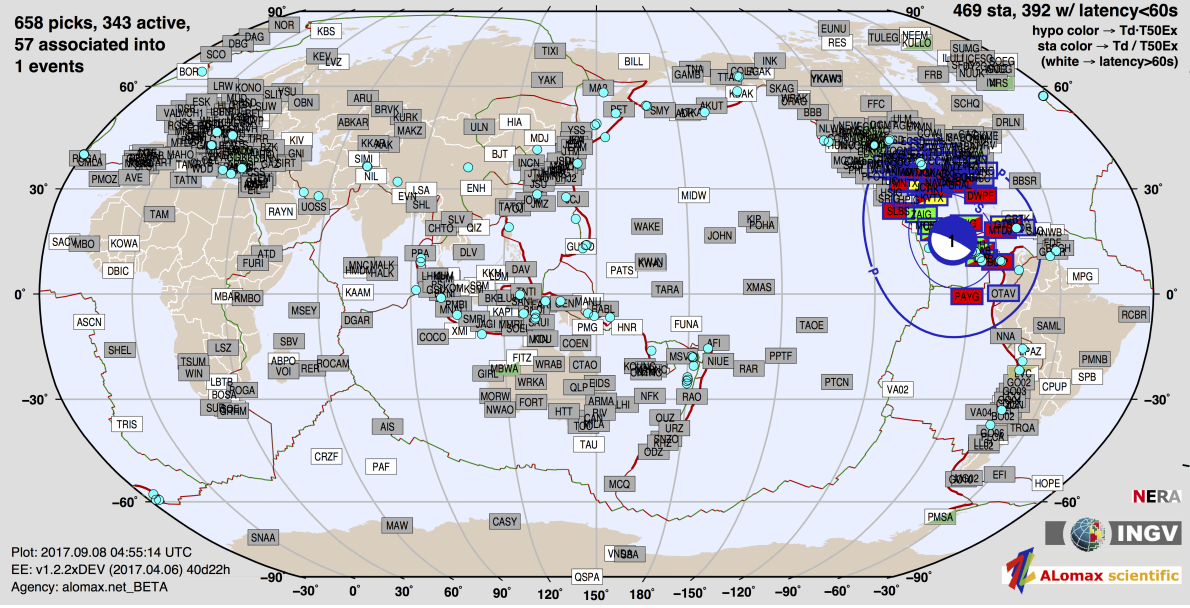
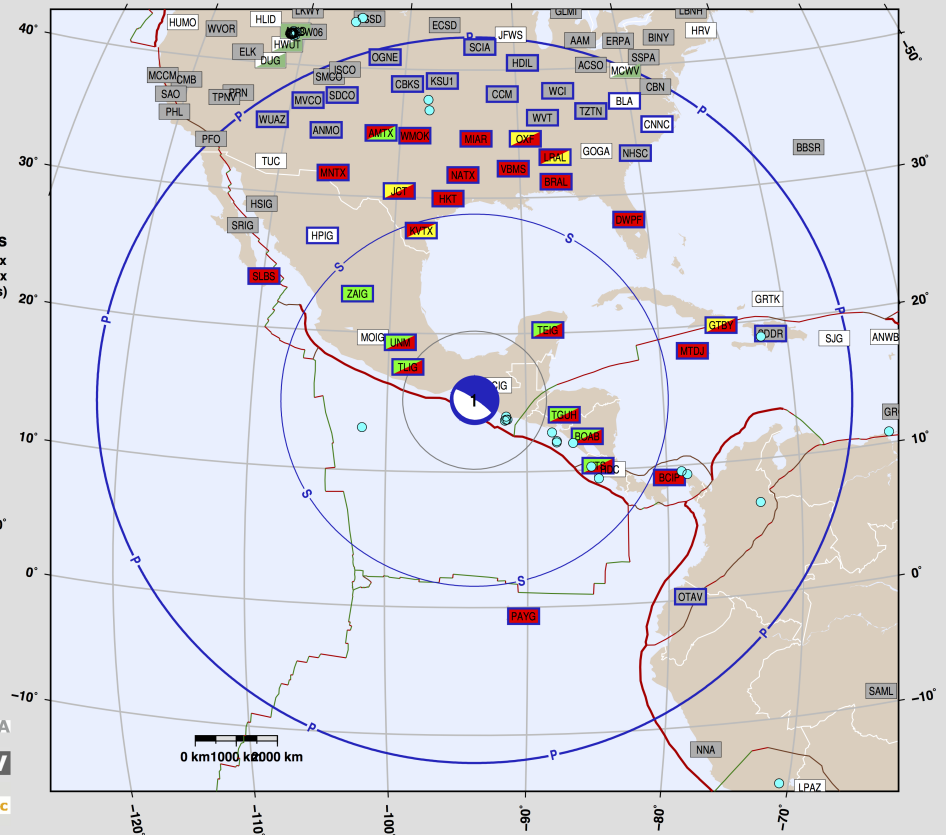




Real-time, real-life Mwpd - Conclusions

We present procedures using real-time seismogram data currently available for most parts of the world to:

1) Determine within 5-10 min an accurate magnitude, M_{wpd}, for very large earthquakes

Extension of M_{wp} to full rupture duration T_0.

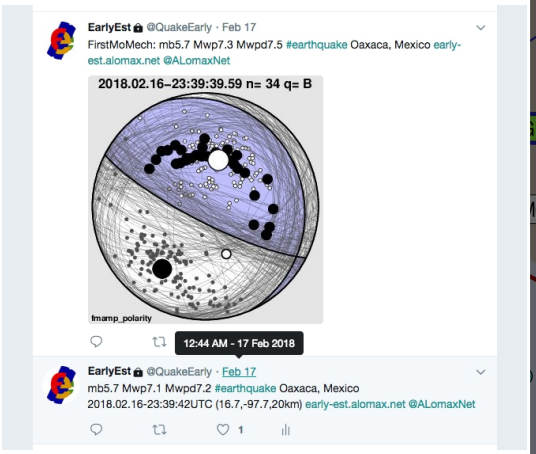
2) Provides basic faulting parameters to aid in early tsunami forecast modeling

Probabilistic, first-motion mechanisms

Resources: Early-est in real-time:
early-est.alomax.net early-est.rm.ingv.it

Real-time Twitter alerts from Early-est development version:

@QuakeEarly



Further information:

early-est.rm.ingv.it early-est.alomax.net

Bernardi, F., A. Lomax, A. Michelini, V. Lauciani, A. Piatanesi, and S. Lorito (2015), Appraising the Early-est earthquake monitoring system for tsunami alerting at the Italian candidate Tsunami Service Provider, Nat. Hazards Earth Syst. Sci., 15 .

Lomax, A. and A. Michelini, 2012. Tsunami early warning within 5 minutes, Pure and Applied Geophysics, 170.

Lomax, A. and A. Michelini, 2011. Tsunami early warning using earthquake rupture duration and *P*-wave dominant-period: the importance of length and depth of faulting, *Geophys. J. Int.*, 185

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

Lomax, A. and A. Michelini, 2009A. *M*wpd: A duration-amplitude procedure for rapid determination of earthquake magnitude and tsunamigenic potential from P waveforms

This project has been funded by the "Dipartimento per la Protezione Civile through the 2017 B2 INGV-DPC Agreement"

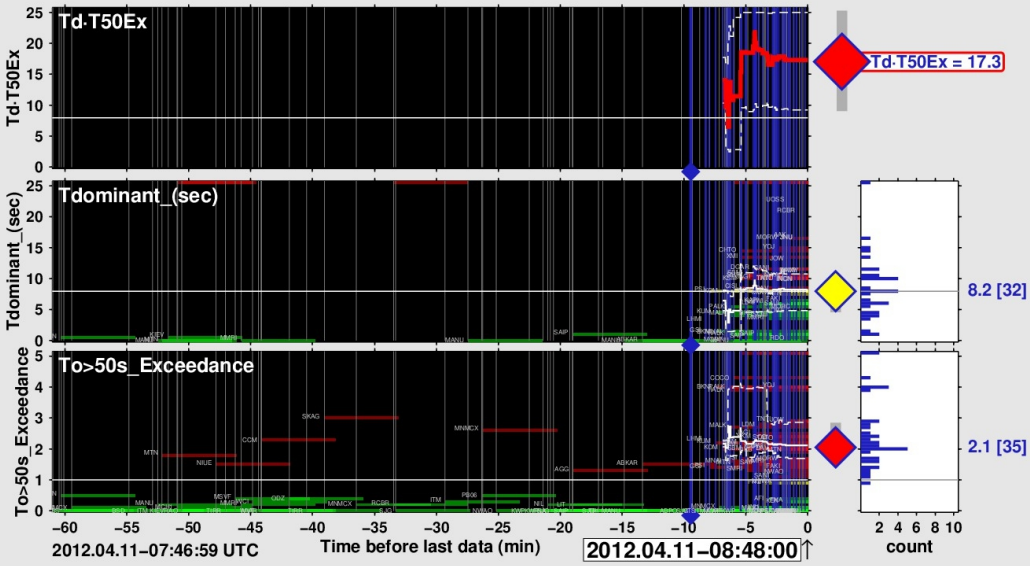
The IRIS DMC and GFZ provided access to waveforms used in this study.

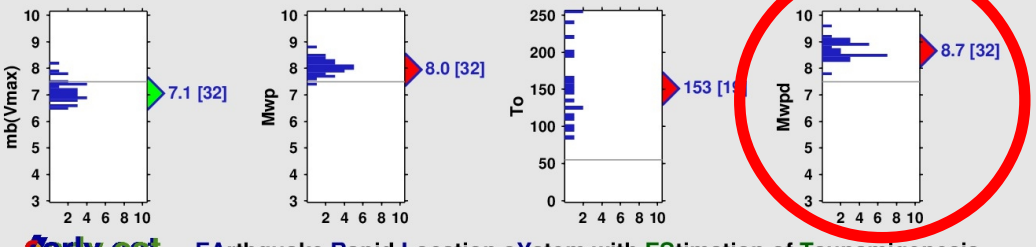
Anthony Lomax
ALomax Scientific, Mouans-Sartoux, France anthony@alomax.net

Alberto Michelini, Fabrizio Bernardi, Valentino Lauciani
Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy alberto.michelini@ingv.it

Real-time: *M*w8.6, Sumatra 2012

OT+10min





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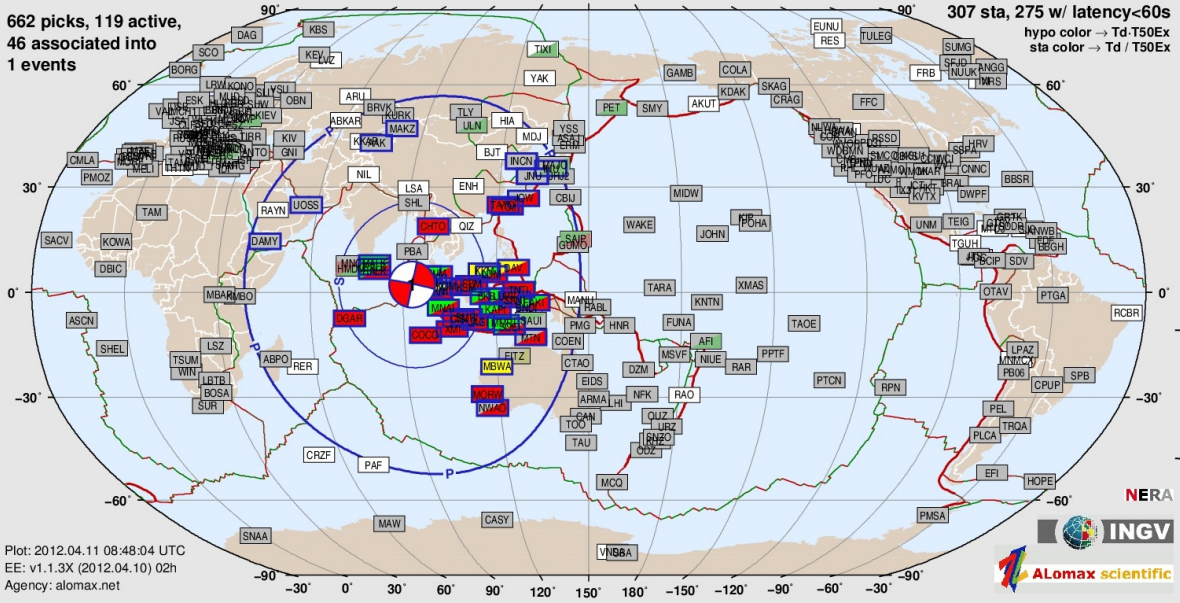
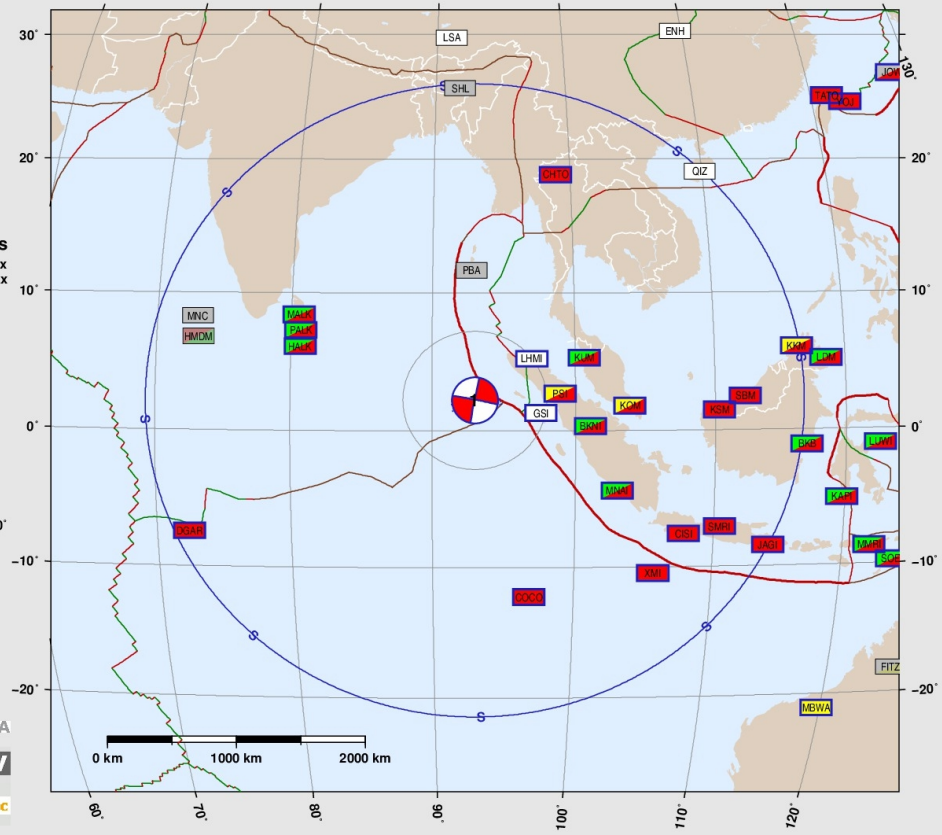
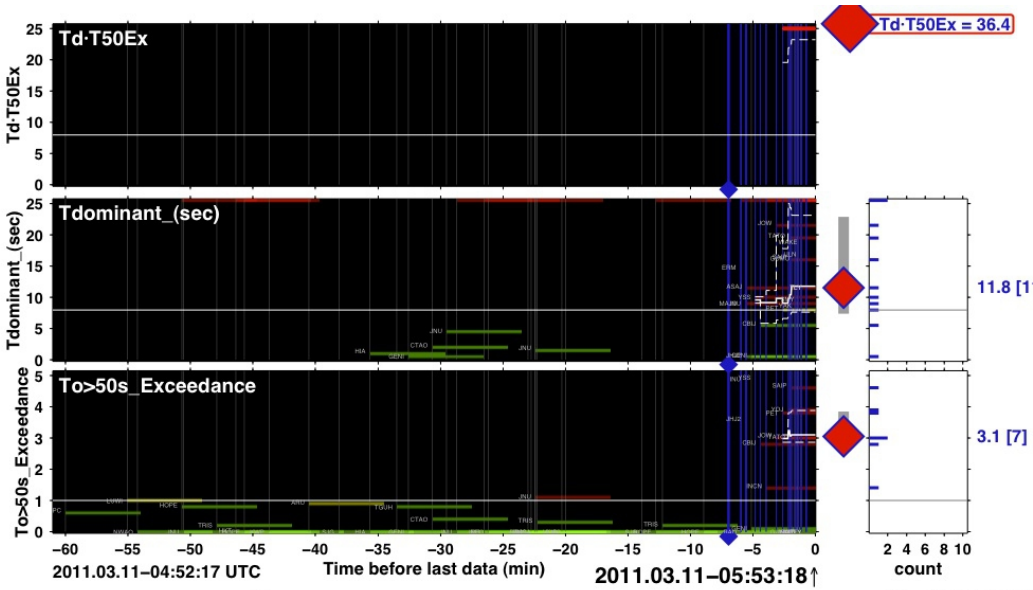
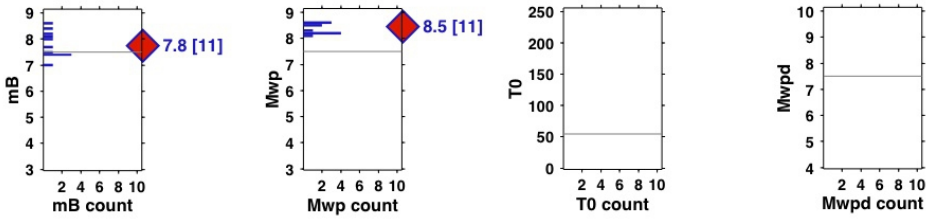




Real-time: *M*w9.1, Tohoku, Japan 2011 OT+7min

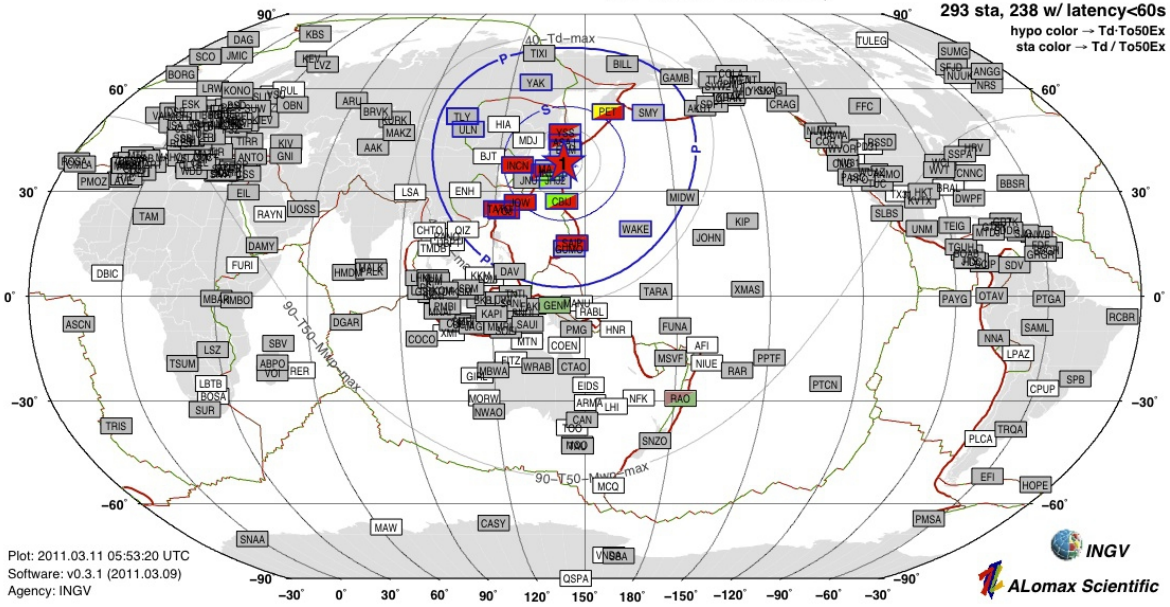


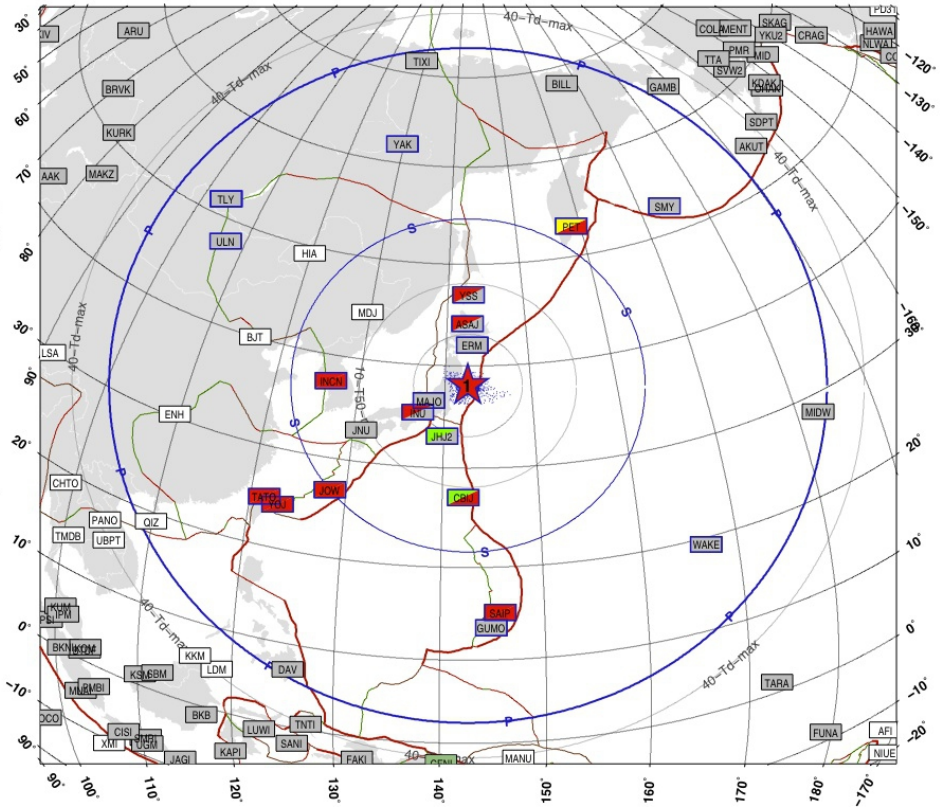


Earthquake Location · Td·T50Ex Level · mB · Mwp · T0 · Mwpd Monitor

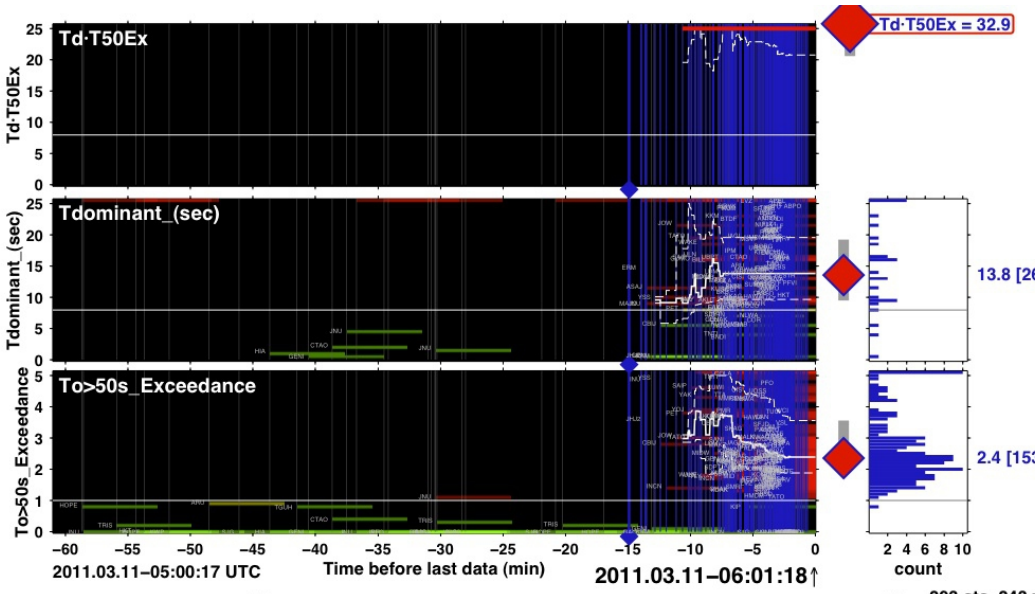
Earthquake details (automatic solutions):

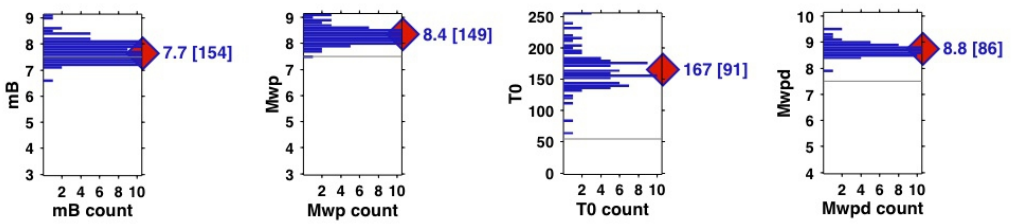
n	pha	Δmin°	σot	origin–time–UTC	lat°	lon°	errH	depth	errZ	T50Ex [n]	Td [n]	TdT50	WL	mB [n]	Mwp [n]	T0 [n]	Mwpd [n]
1	19	3.9	2.1	2011.03.11–05:46:21	38.1	142.7	24	14	15	3.1 7	11.8 11	36.4		7.8 11	8.5 11	n/a 0	n/a 0





Real-time: *M*w9.1, Tohoku, Japan 2011 OT+15min





Earthquake Location · Td·T50Ex Level · mB · Mwp · T0 · Mwpd Monitor

Earthquake details (automatic solutions):

n	pha	Δmin°	σot	origin–time–UTC	lat°	lon°	errH	depth	errZ	T50Ex [n]	Td [n]	TdT50	WL	mB [n]	Mwp [n]	T0 [n]	Mwpd [n]
1	165	3.7	1.9	2011.03.11–05:46:22	38.0	142.5	24	14	14	2.4153	13.8 26	32.9		7.7154	8.4149	167 91	8.8 86