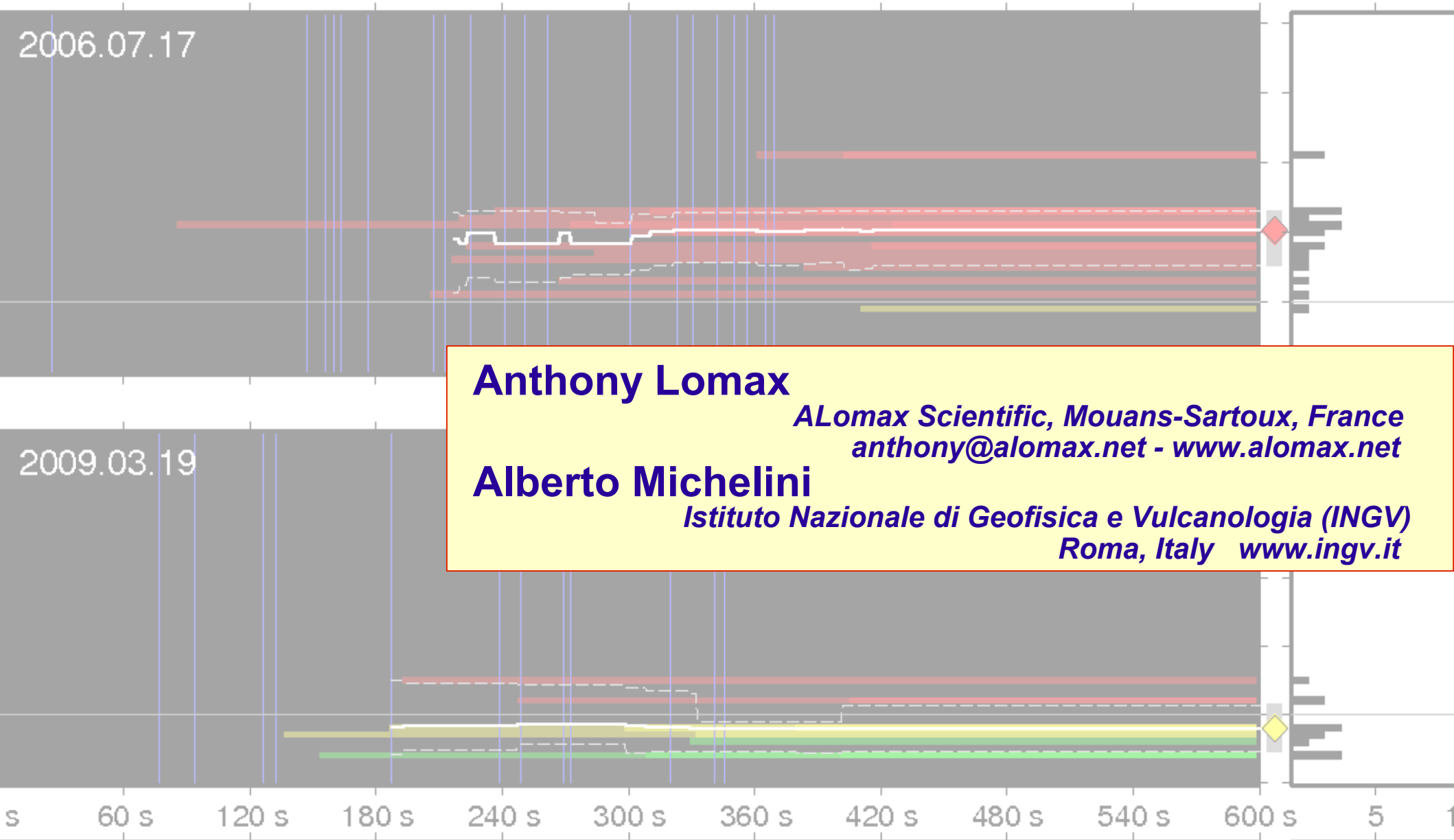
Tsunami early warning using earthquake rupture duration



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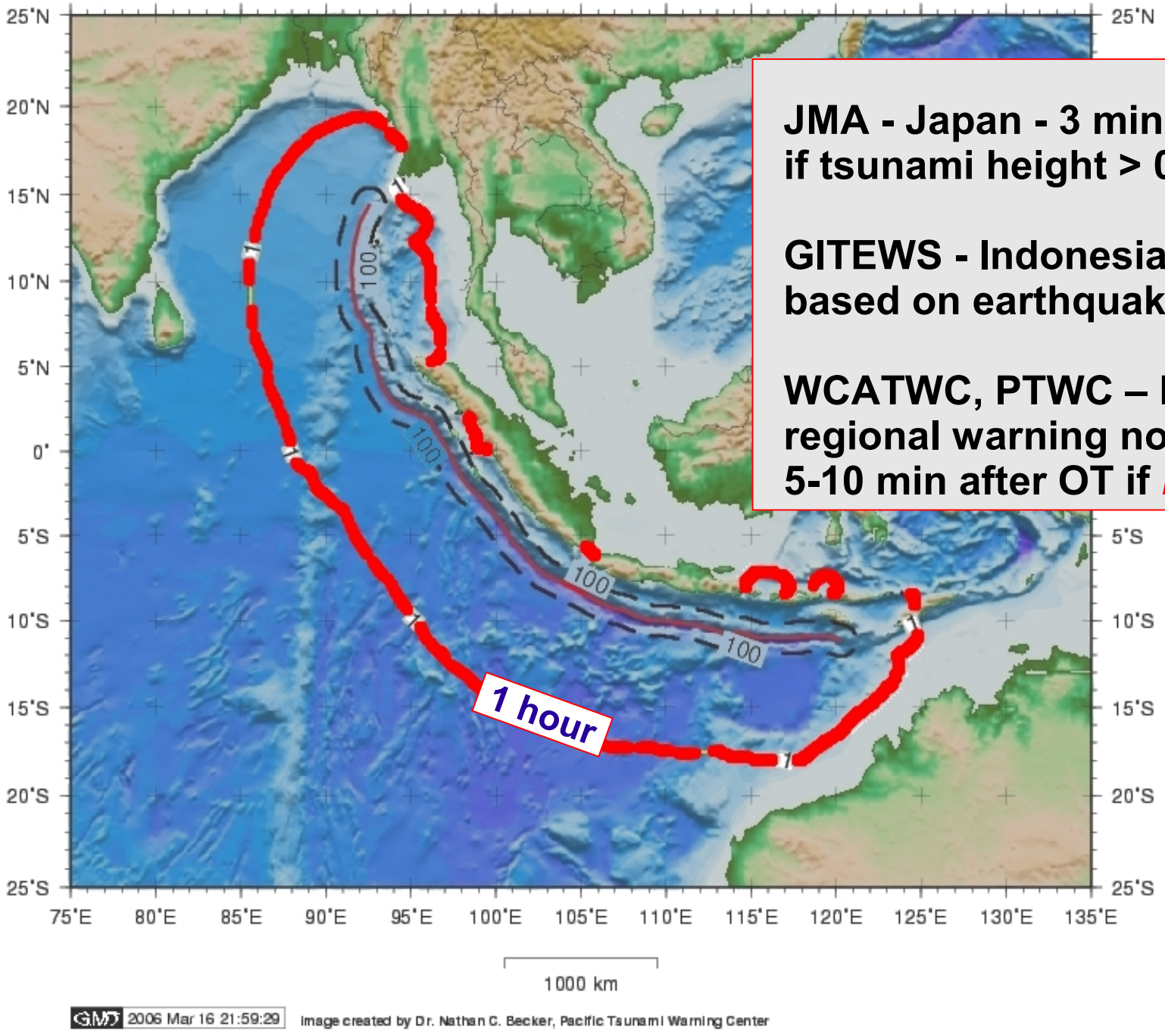
Tsunami early warning → within 5-15min after OT



JMA - Japan - 3 min after OT
if tsunami height > 0.5 m expected

GITEWS - Indonesia - 5 min after OT
based on earthquake parameters

WCATWC, PTWC – Pacific and regional warning notifications
5-10 min after OT if *Mwp*≥7.5

I_t - an approximate measure of Tsunami importance

National Geophysical Data Center (NGDC)
NOAA Satellite and Information Service

Search NGDC Search NOAA Go

Date						Tsunami Cause				Addl Tsu Info	Tsunami Source Location				Tsu	
Year	Mo	Dy	Hr	Mn	Sec	Val	Code	Earth-quake Mag	Vol-cano		Country	Name	Latitude	Longitude	Max Water Height	Nu o Run
1992	1	5	6	30	17.0	4	1	3.7		*	CHINA	SOUTH CHINA SEA	18.000	108.000	.80	1
1992	4	25	18	6	4.2	4	1	7.2		*	USA	CAPE MENDOCINO, CA	40.368	-124.316	1.80	1
1992	5	17	10	15	31.3	4	1									
1992	5	27	5	13	38.8	1	1									
1992	7	3				-1	9									
1992	7	18	8	36	58.7	4	1									
1992	9	2	0	16	1.6	4	1									
1992	12	12	5	29	26.3	4	1									
1993	2	7	13	27	42.0	4	1									
1993	6	8	13	3	36.4	4	1									
1993	7	12	13	17	11.9	4	1									
1993	8	7	19	42	41.9	4	1									
1993	8	8	8	34	24.9	4	1									
1993	11	13	1	18	4.1	4	1									
1994	1	17	12	30	55.3	3	1									
1994	1	21	2	24	29.9	4	1									
1994	2	15	17	7	43.8	4	1									
1994	4	8	1	10	40.8	4	1									
1994	4	28	11	30		4	14									
1994	6	2	18	17	34.0	4	1									
1994	6	3	21	6	59.8	4	1									
1994	6	4	0	57	50.6	4	1									
1994	9	1	15	15	53.0	4	1									
1994	9	19				4	6									
1994	10	4	13	22	55.8	4	1									
1994	10	8	21	44	7.2	4	1	6.8		*	INDONESIA	HALMAHERA	-1.258	127.980	3.00	1
1994	10	9	7	55	39.5	4	1	7.3		*	RUSSIA	S. KURIL ISLANDS	43.905	147.916	.20	2
1994	11	4	4	12		4	8			*	USA	SKAGWAY, AK	59.500	-135.300	11.00	1
1994	11	14	19	15	30.6	4	1	7.1		*	PHILIPPINES	PHILIPPINE ISLANDS	13.525	121.067	7.30	2
1994	12	28	12	19	23.0	4	1	7.8		*	JAPAN	TOHUKU, JAPAN	40.525	143.419	.53	1
1995	1	16	20	46	52.1	4	1	6.9		*	JAPAN	KOBE, JAPAN	34.583	135.018	.20	2

Use NOAA/NGDC Historical Tsunami Database:

$$I_t \equiv i_{height} + i_{deaths} + i_{injuries} + i_{damage} + i_{houses\text{-}destroyed}$$

(where i_{height}=4,3,2,1,0 for h≥10, 3, 0.5m, h>0m, h=0m)

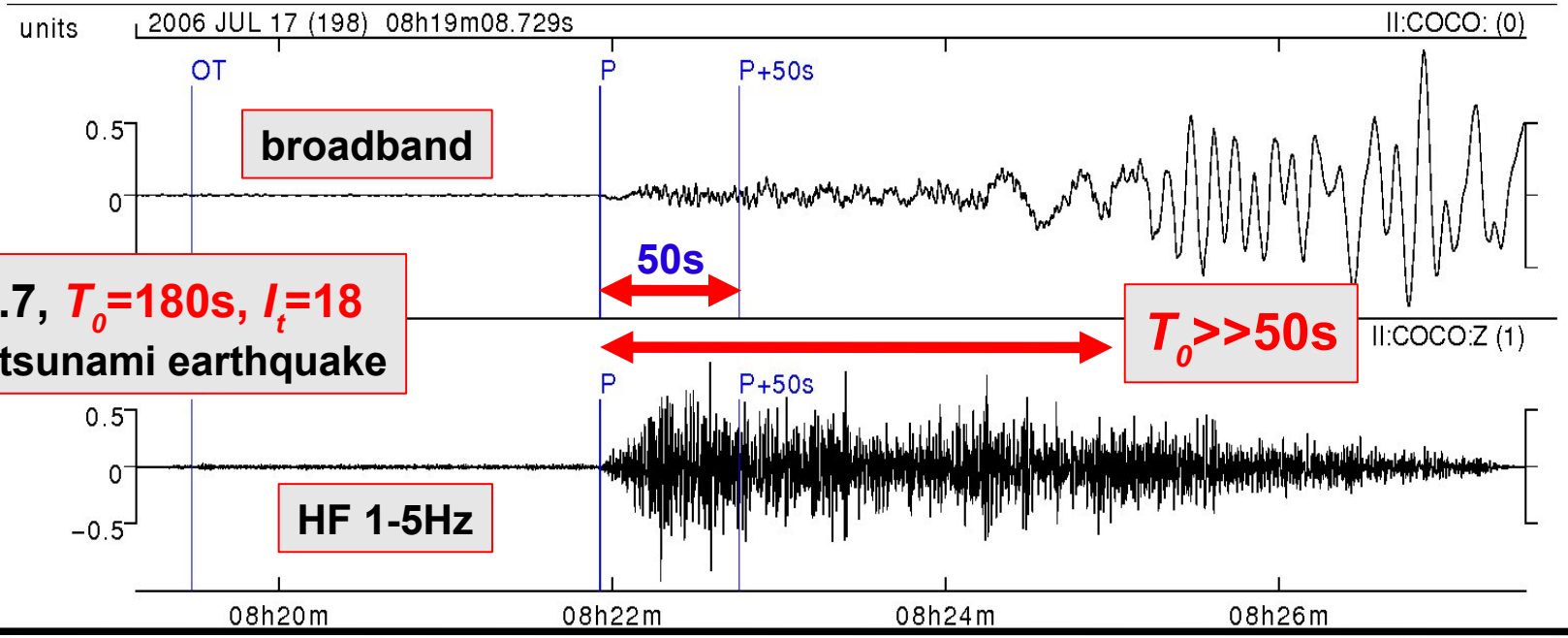
$I_t = 0$ - no tsunami detected

$I_t \geq 2$ ~ JMA "Tsunami Warning"

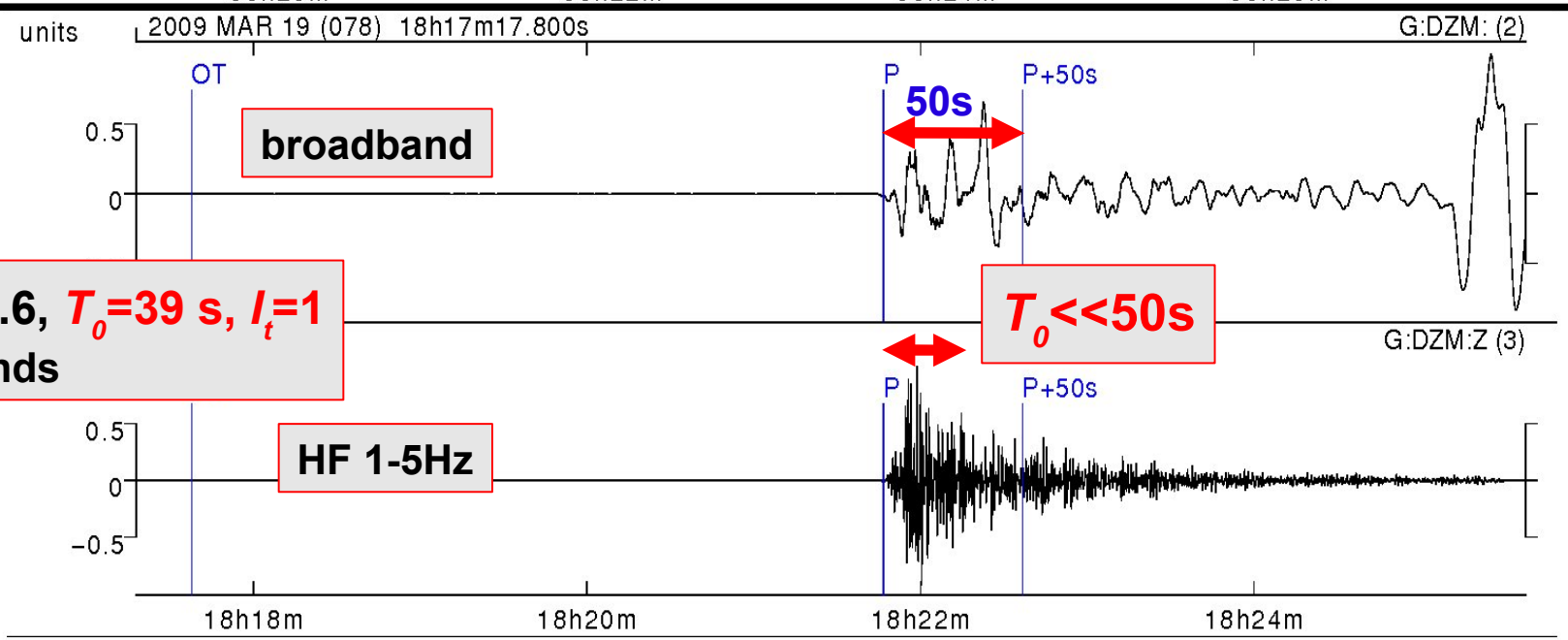
$I_t \geq 10$ - largest or most devastating tsunamis

But: I_t is highly approximate and unstable; a better tsunami catalog is needed

Tsunamigenic earthquakes: rupture duration *To* > 50s

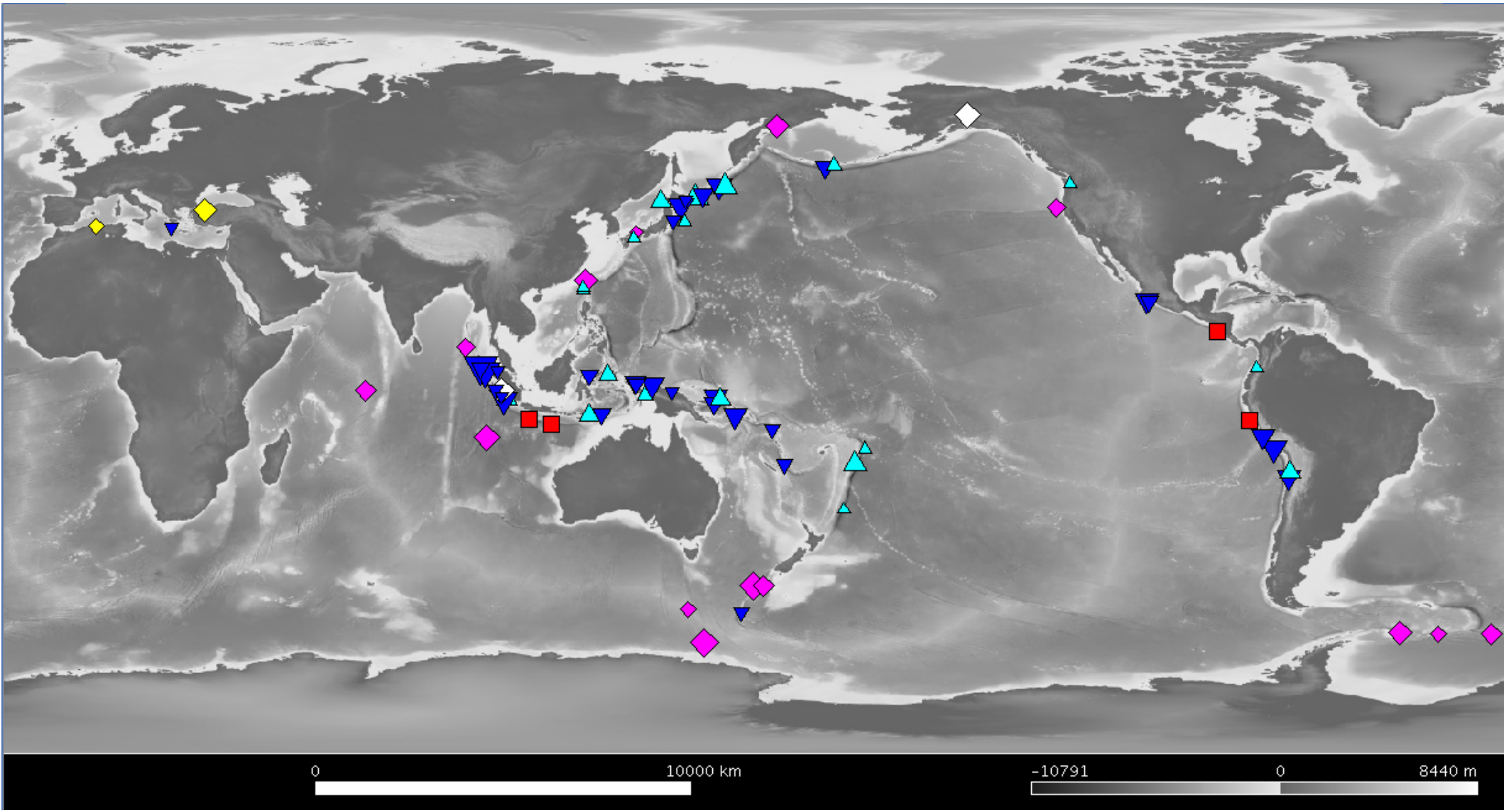


2006, M_w7.7, T_0=180s, I_t=18
Indonesia tsunami earthquake



2009, M_w7.6, T_0=39 s, I_t=1
Tonga Islands

77 underwater earthquakes, 1992-present



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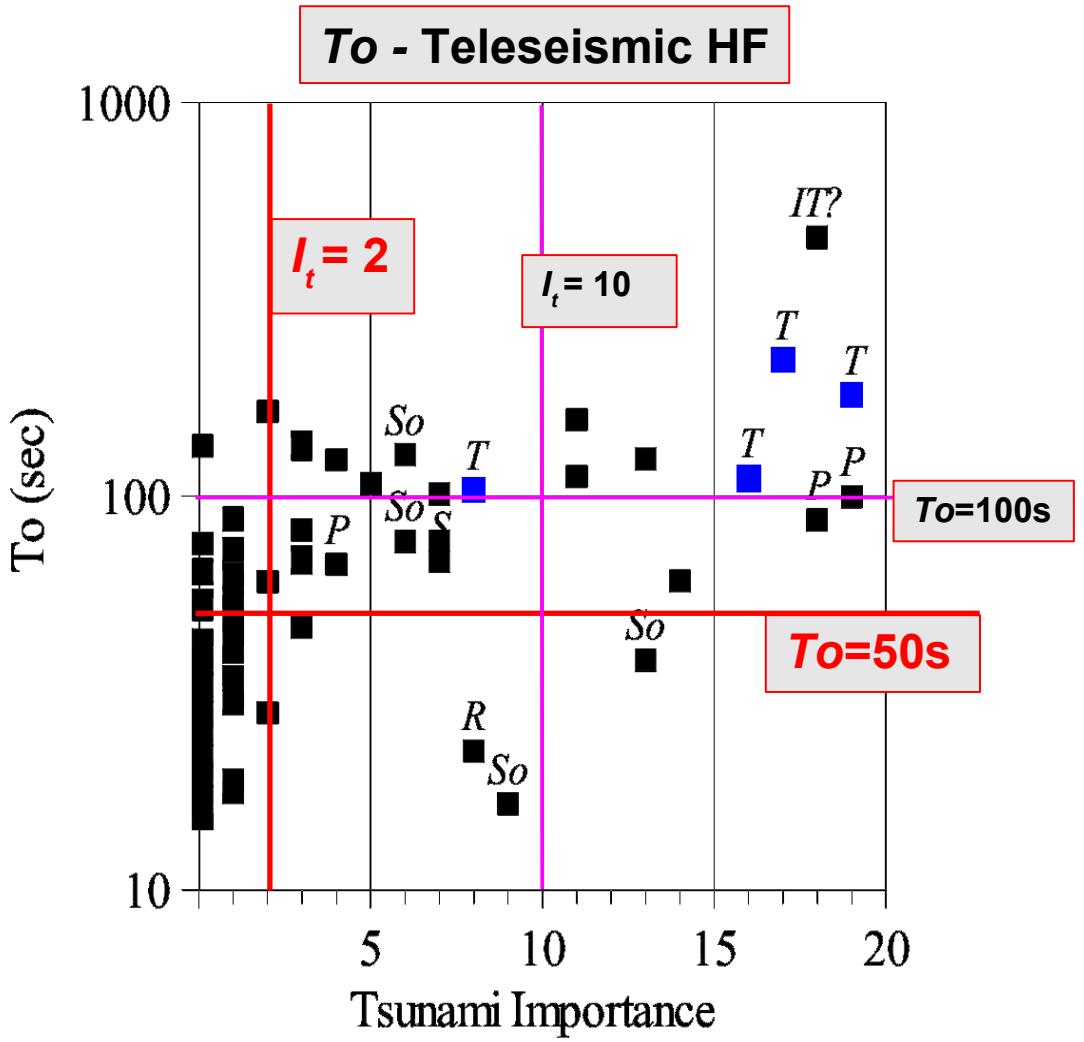
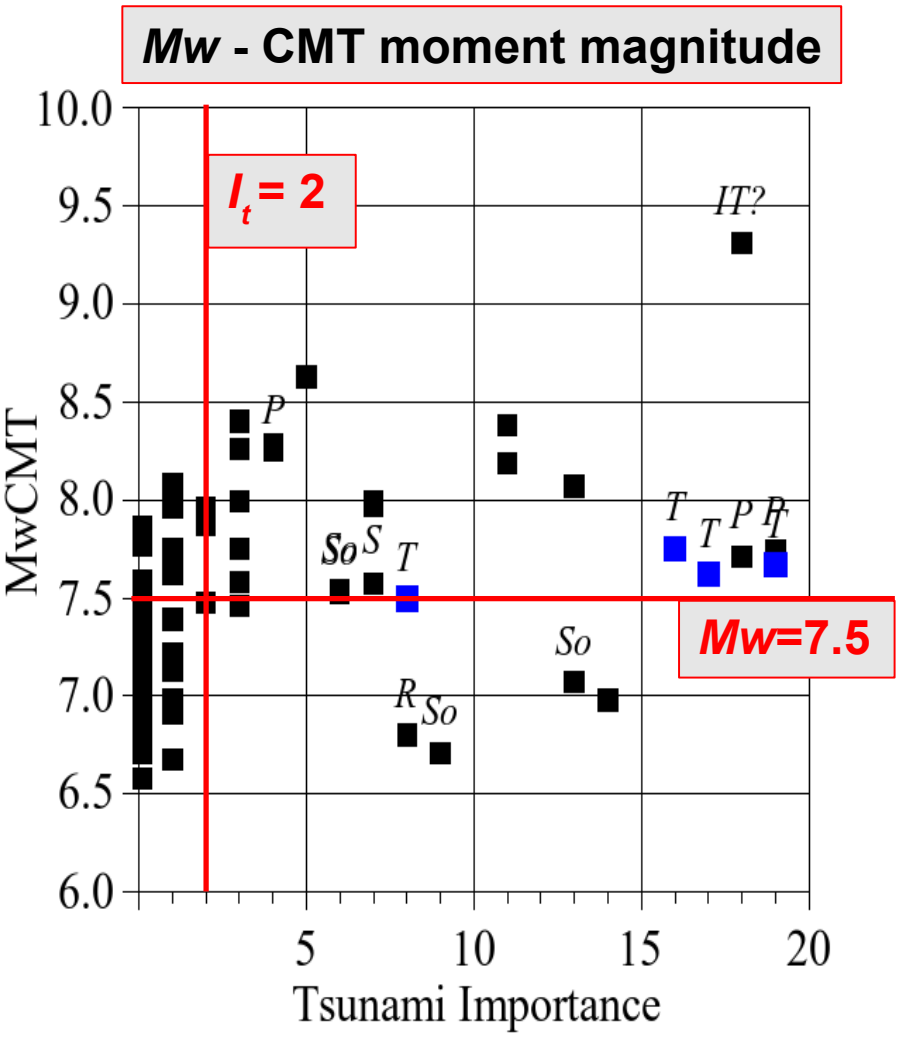
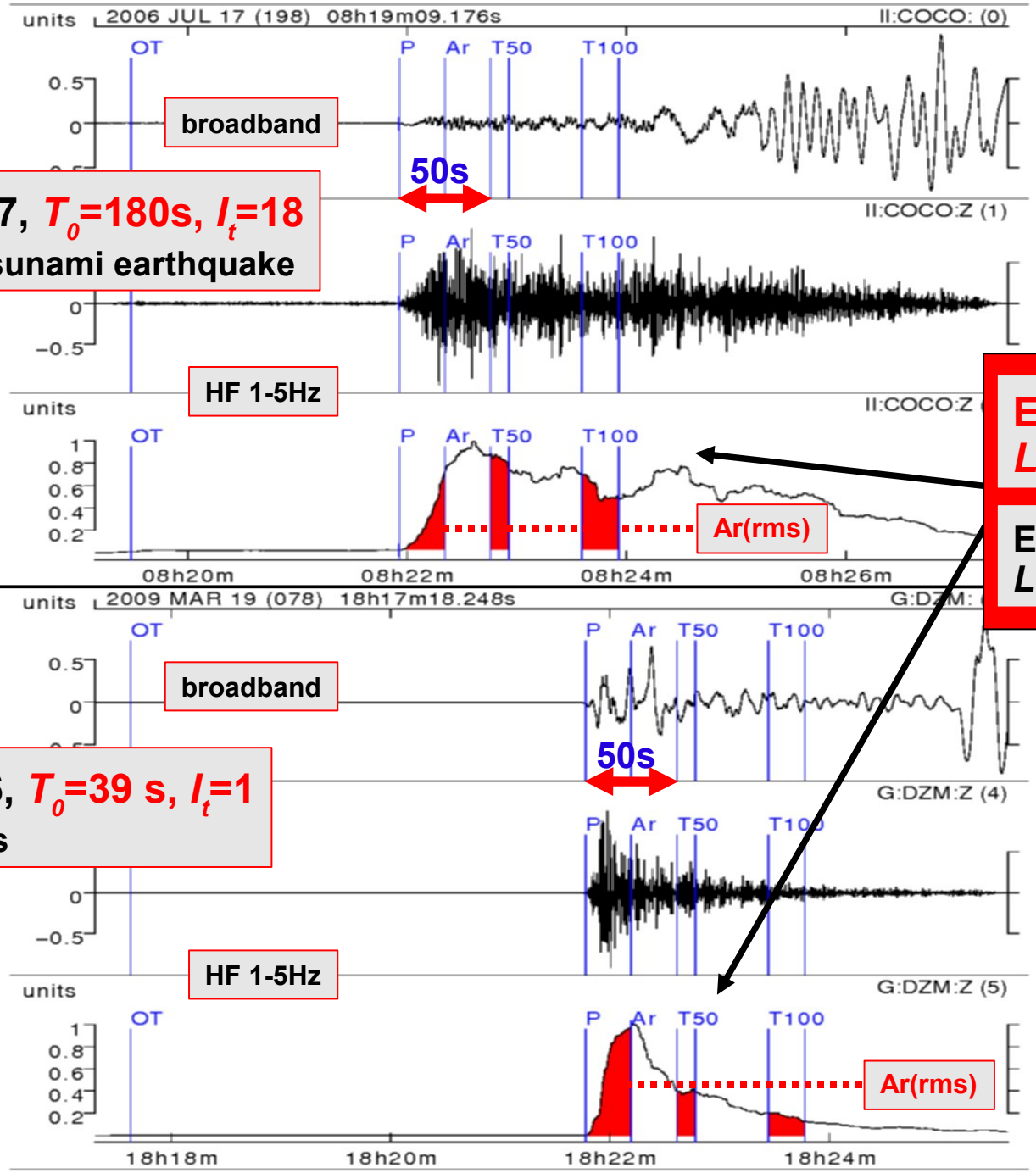




T **– "slow" tsunami earthquake**
P **– intraplate**
So **– strike-slip oceanic**
S **– strike-slip continental**
R **– reverse-faulting**
no sym - interplate thrust or I_t < 2

Methodology for rapid rupture duration determination



2006, M_w7.7, T_0=180s, I_t=18
Indonesia tsunami earthquake

2009, M_w7.6, T_0=39 s, I_t=1
Tonga Islands

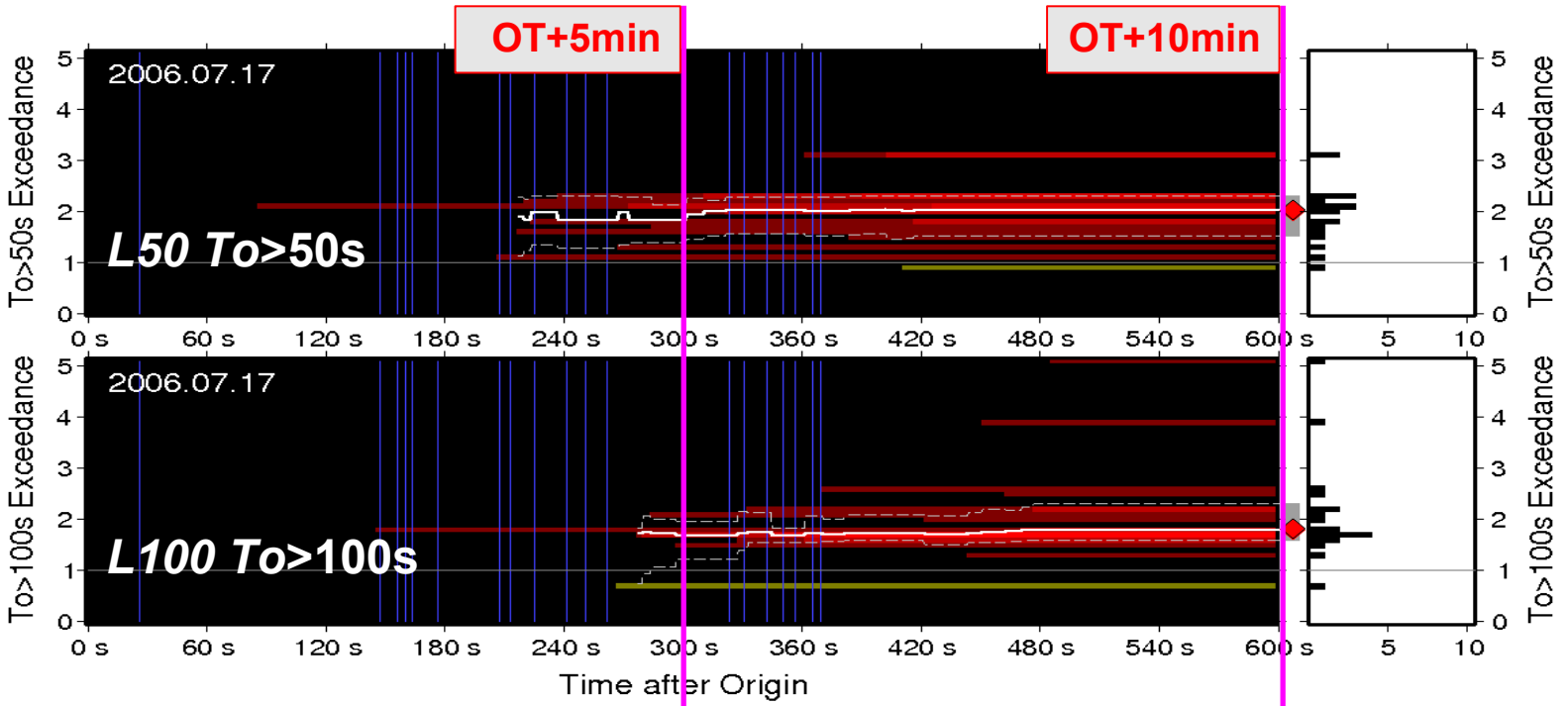
Exceedance level *To*>50s
***L50* ≡ T50/Ar (rms)**

Exceedance level *To*>100s
***L100* ≡ T100/Ar (rms)**

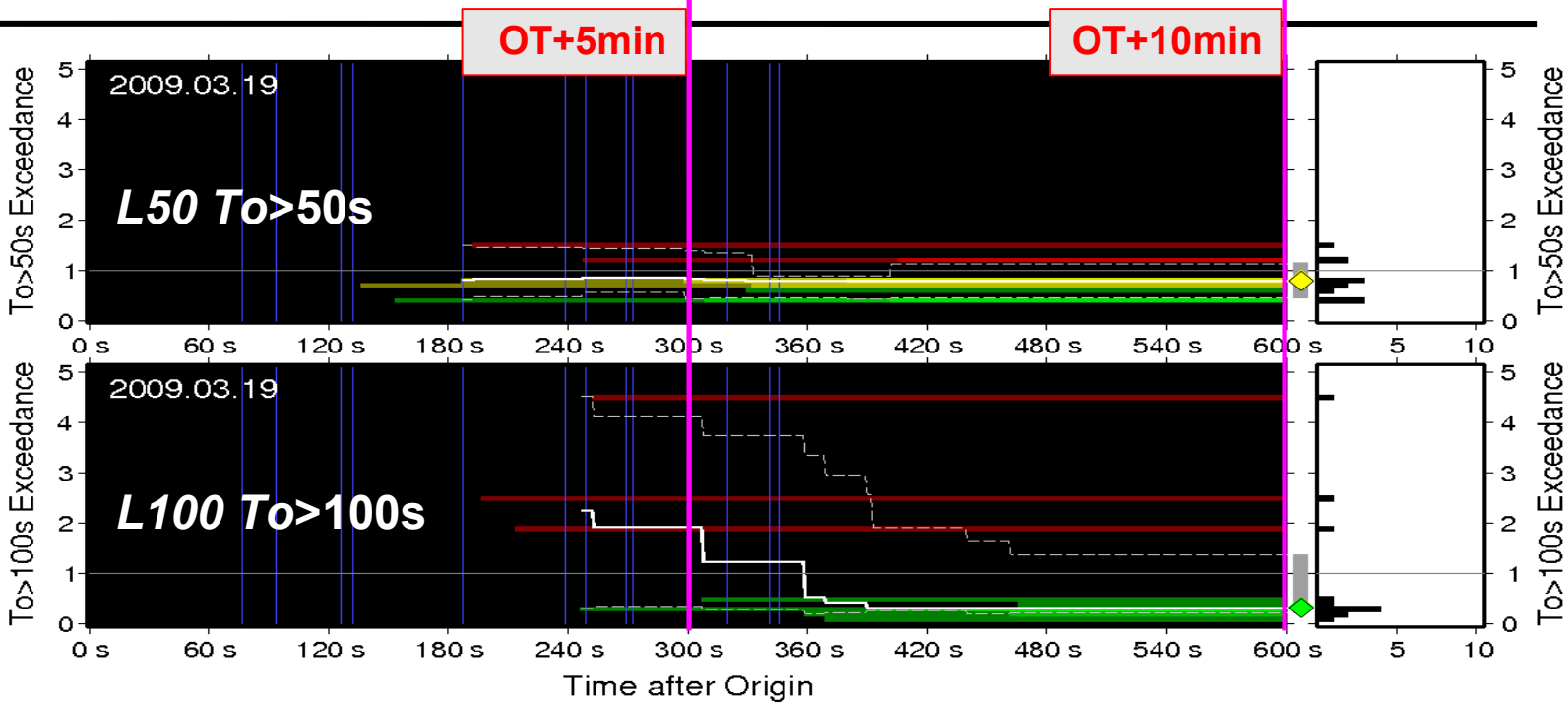
Set of single station calculations
Does not require:
location
magnitude

Duration-Exceedance Warning results

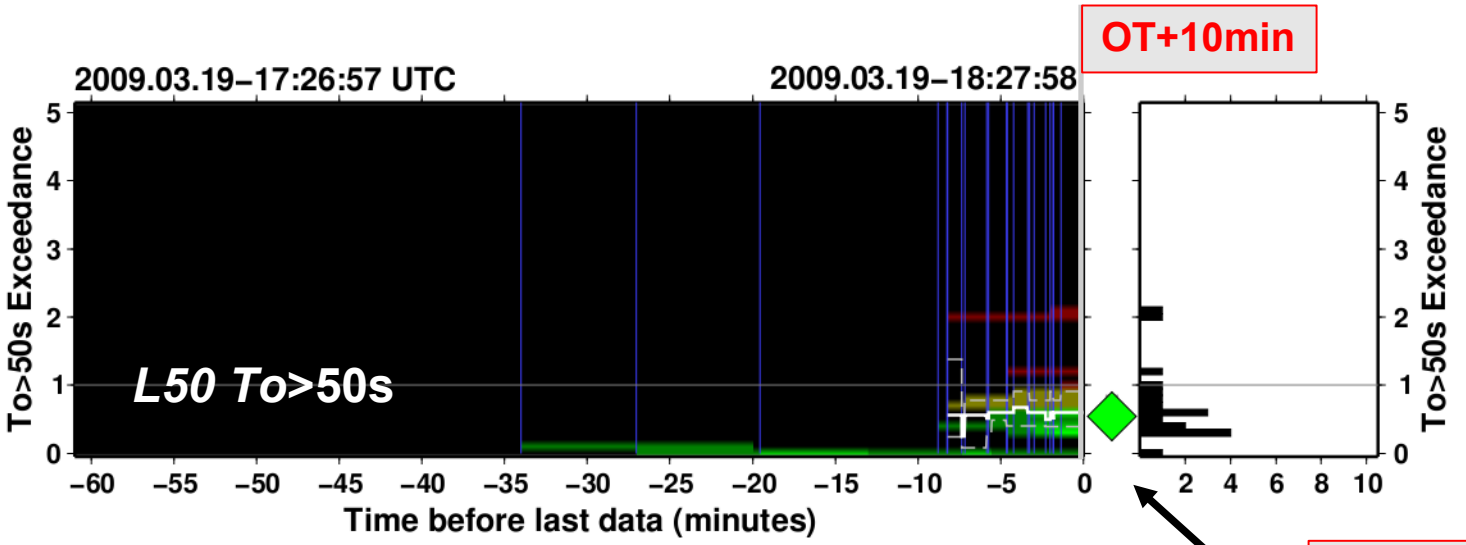
2006, M_w7.7,
T_0=180s, I_t=18
Indonesia tsunami earthquake



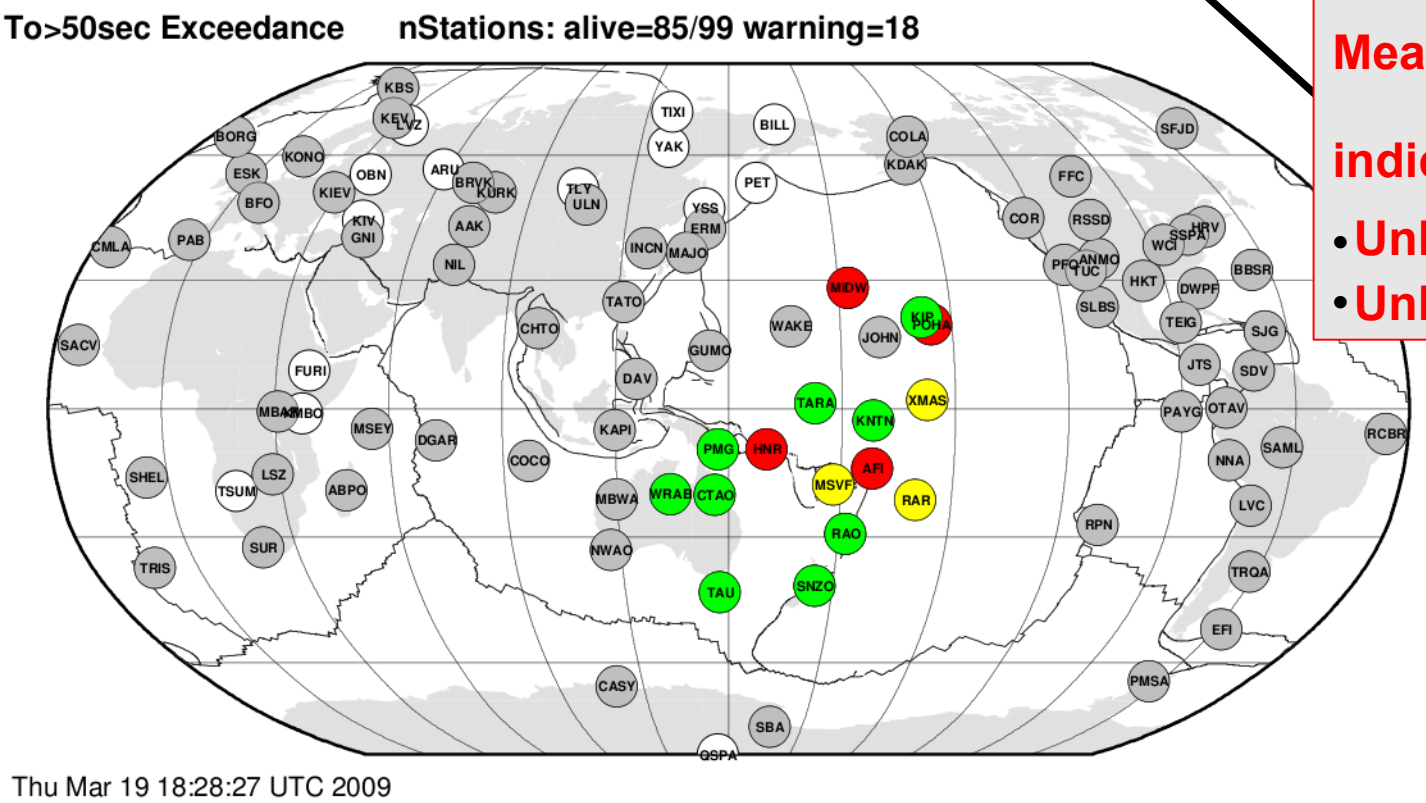
2009, M_w7.6,
T_0=39 s, I_t=1
Tonga Islands



Duration-Exceedance Warning results at OT+10min



2009, M_w7.6,
T_0=39 s, I_t=0
Tonga Islands

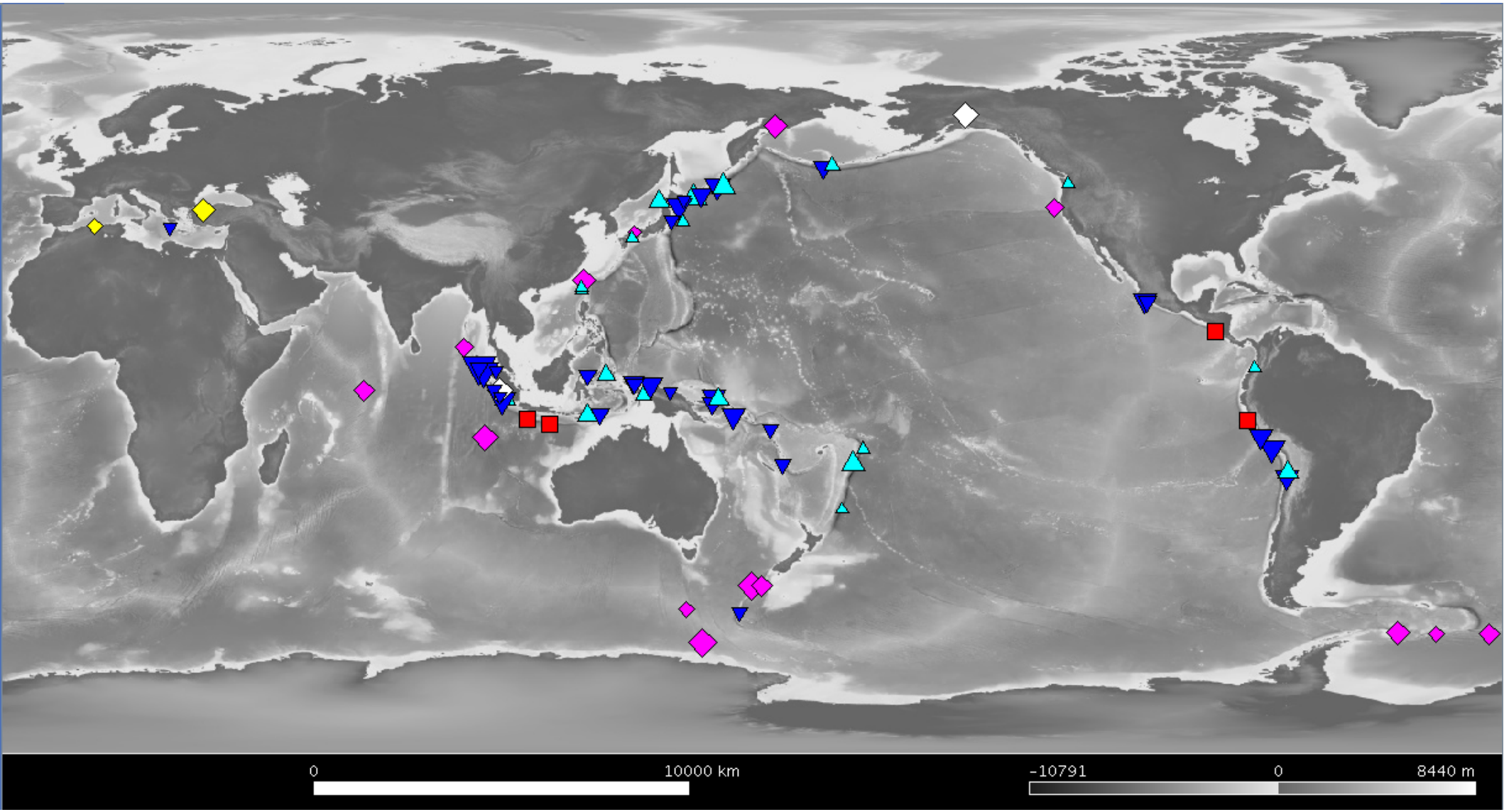


Mean *To*>50s exceedance value *L50* < 1.0 indicates:

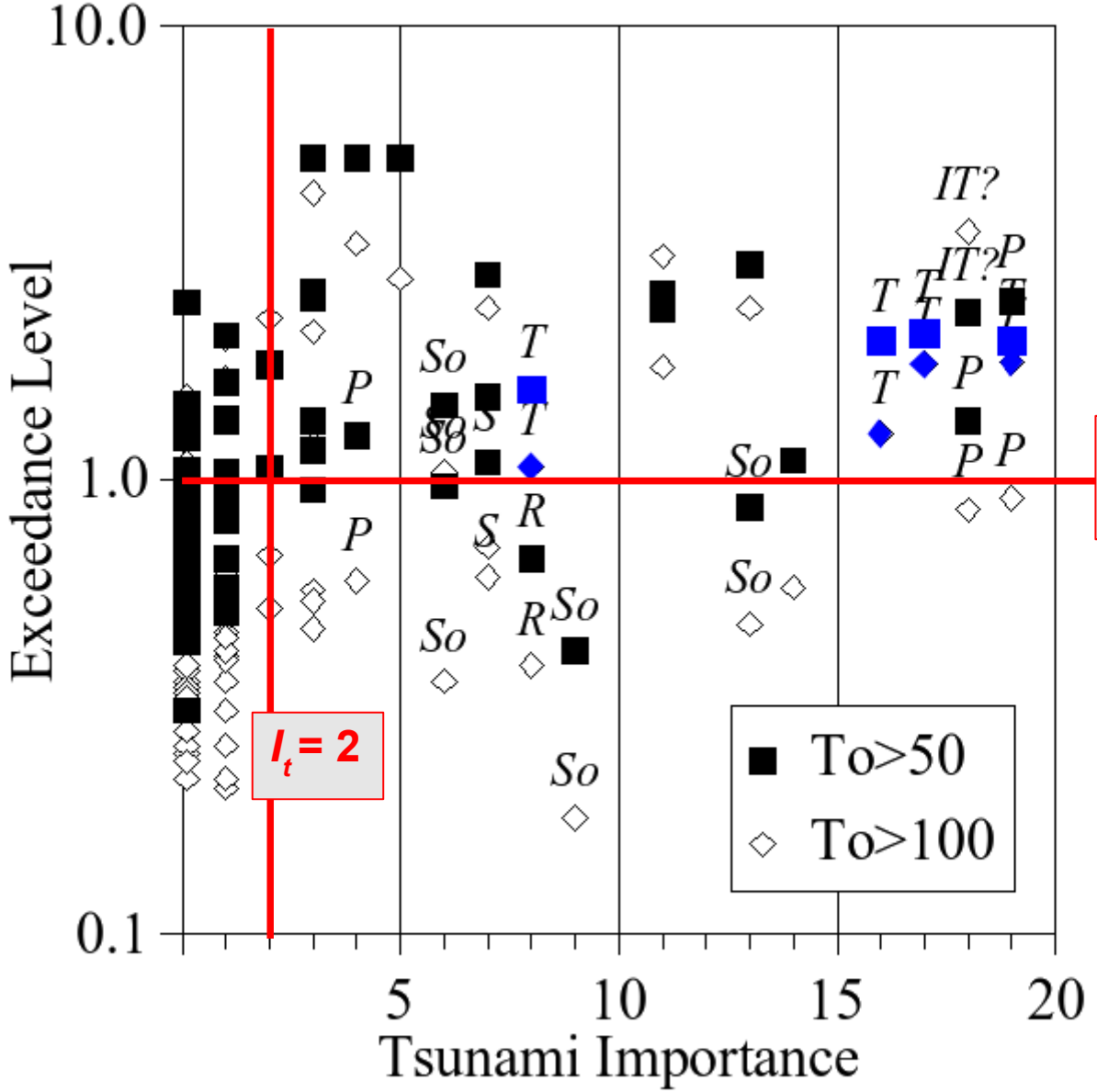
- **Unlikely $I_t \geq 2$**
- **Unlikely tsunamigenic**

Play Movie

Application to 77 underwater earthquakes



Application to 77 underwater earthquakes



To>50s Exceedance
L50= 1.0

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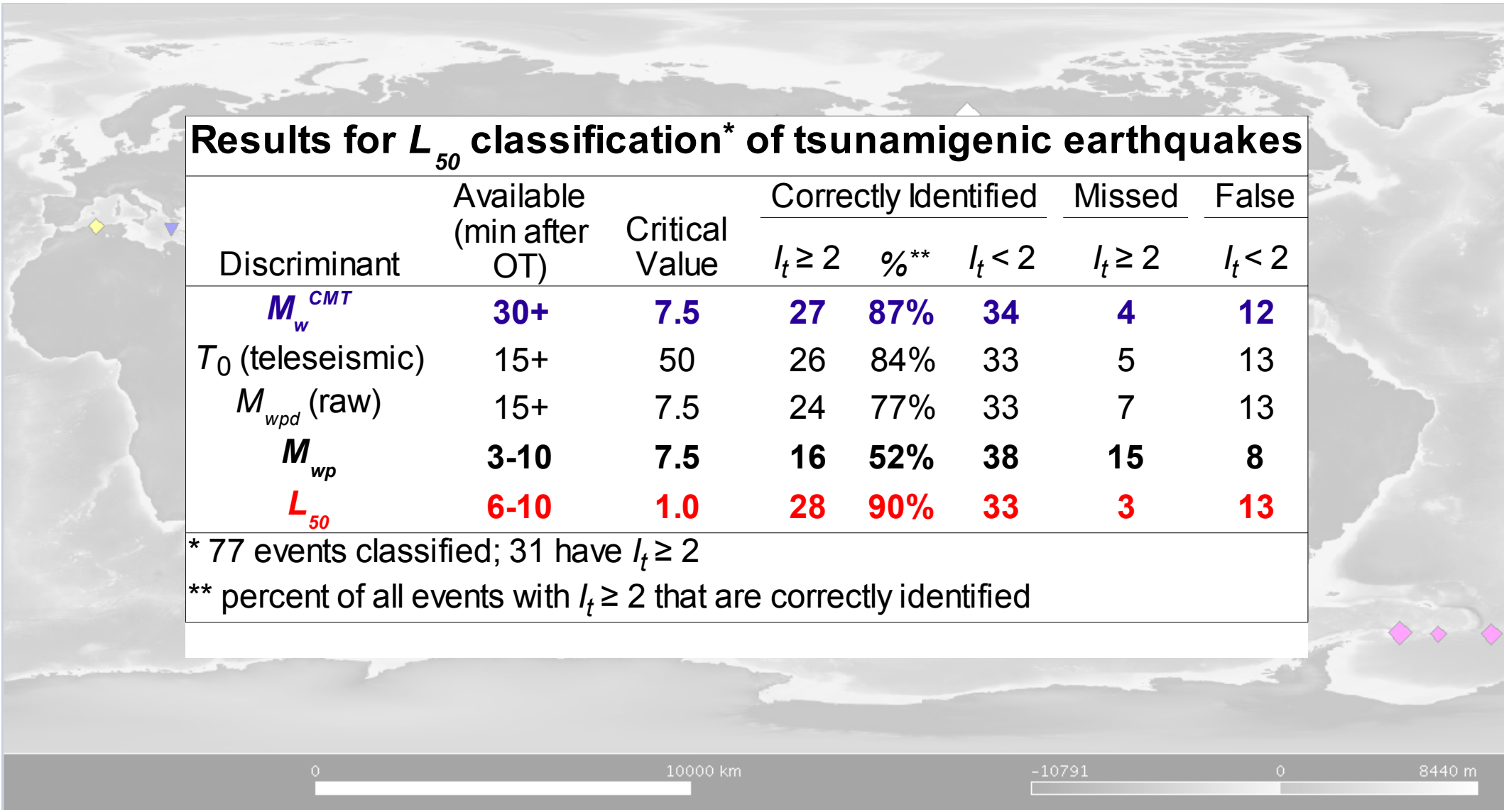
Application to 77 underwater earthquakes

Results for L_{50} classification* of tsunamigenic earthquakes

Discriminant	Available (min after OT)	Critical Value	Correctly Identified			Missed	False
			$I_t \geq 2$	%**	$I_t < 2$	$I_t \geq 2$	$I_t < 2$
M_w^{CMT}	**30+**	**7.5**	**27**	**87%**	**34**	**4**	**12**
T_0 (teleseismic)	15+	50	26	84%	33	5	13
M_{wpd} (raw)	15+	7.5	24	77%	33	7	13
M_{wp}	**3-10**	**7.5**	**16**	**52%**	**38**	**15**	**8**
L_{50}	**6-10**	**1.0**	**28**	**90%**	**33**	**3**	**13**

* 77 events classified; 31 have $I_t \geq 2$

** percent of all events with $I_t \geq 2$ that are correctly identified



Conclusions

- Apparent rupture duration, *To*, provides more information on tsunami importance than *Mw*
  - large “tsunami” earthquakes are associated with *To* likely to exceed 100s
- Earthquakes with high tsunami importance can be rapidly identified by determining if *To* is likely to exceed 50s
  - this identification can be performed within about 10 min after OT for most regions
  - this identification complements initial estimates of location, depth and magnitude to improve tsunami early warning

More information: http://alomax.net/science.html

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Tsunamigenic earthquakes: rupture duration *To* > 50s

Tsunami Importance

Tsunami Magnitude

T – "slow" tsunami earthquake
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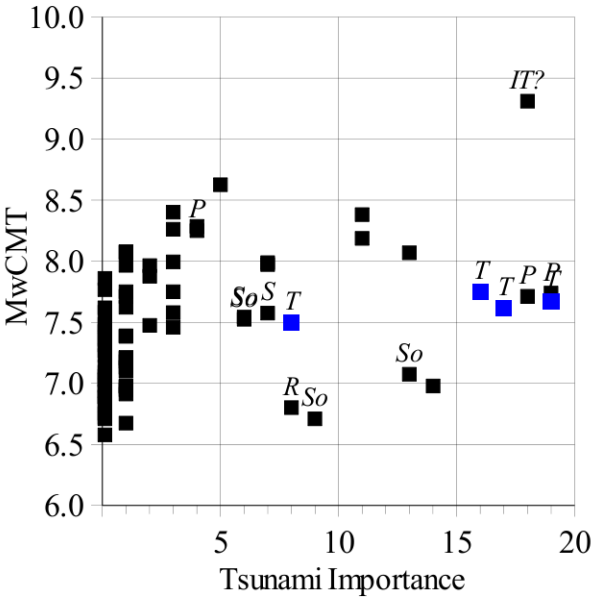
Mw - CMT moment magnitude



To - Teleseismic HF