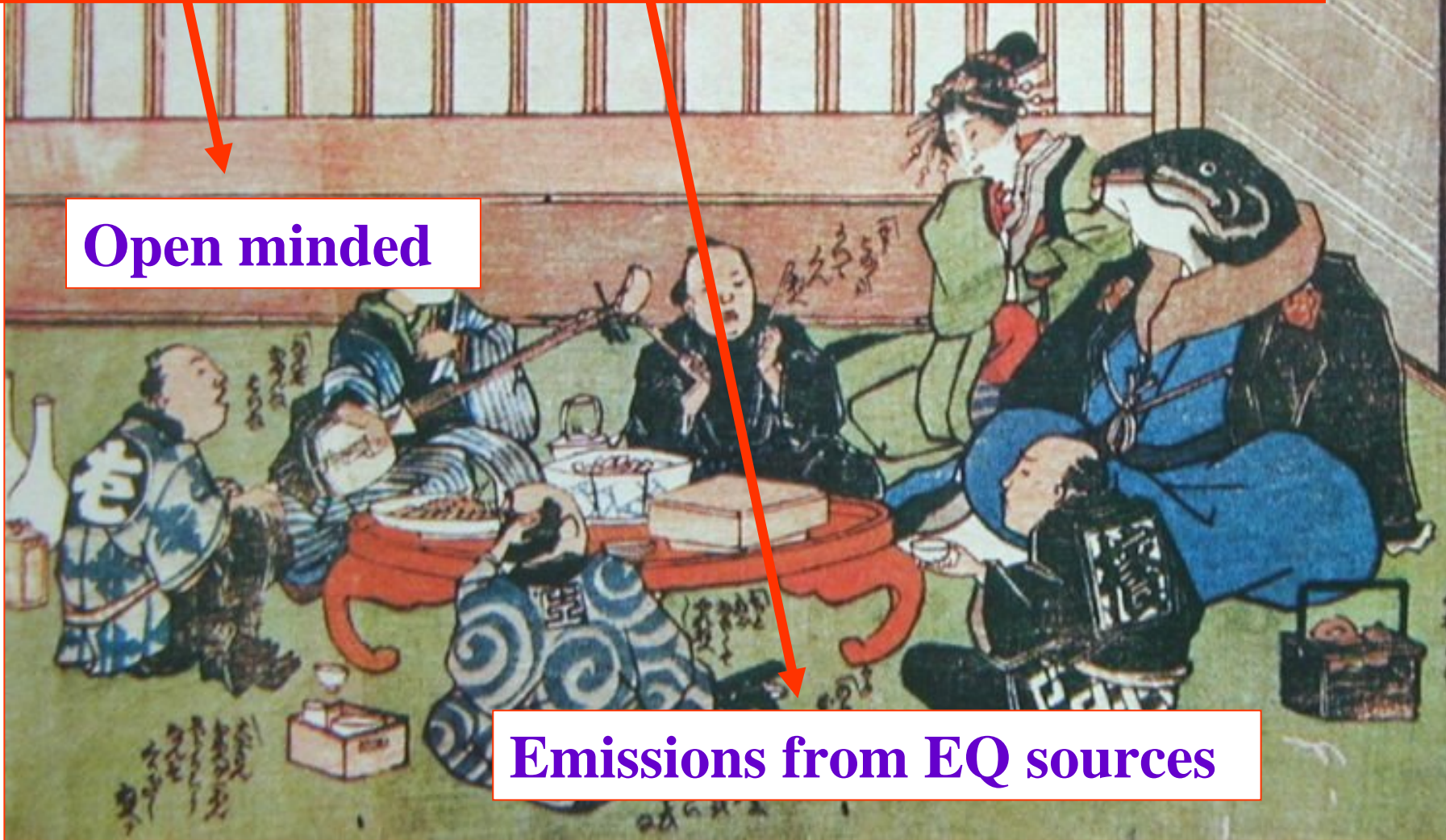


TOWARDS GENERATION MECHANISMS OF SEISMO-EM SIGNALS CONSISTENT WITH OBSERVATIONS

Seiya Uyeda and Masashi Kamogawa

Open minded



Emissions from EQ sources

Major Observations:

1. Any **undoubtedly** EQ related pre-seismic EM signals?

Yes, Pulses in Greece, etc

2. Any precursors?

SES in Greece, Japan, Mexico, India, China ?

Not in USA?, Turkey?

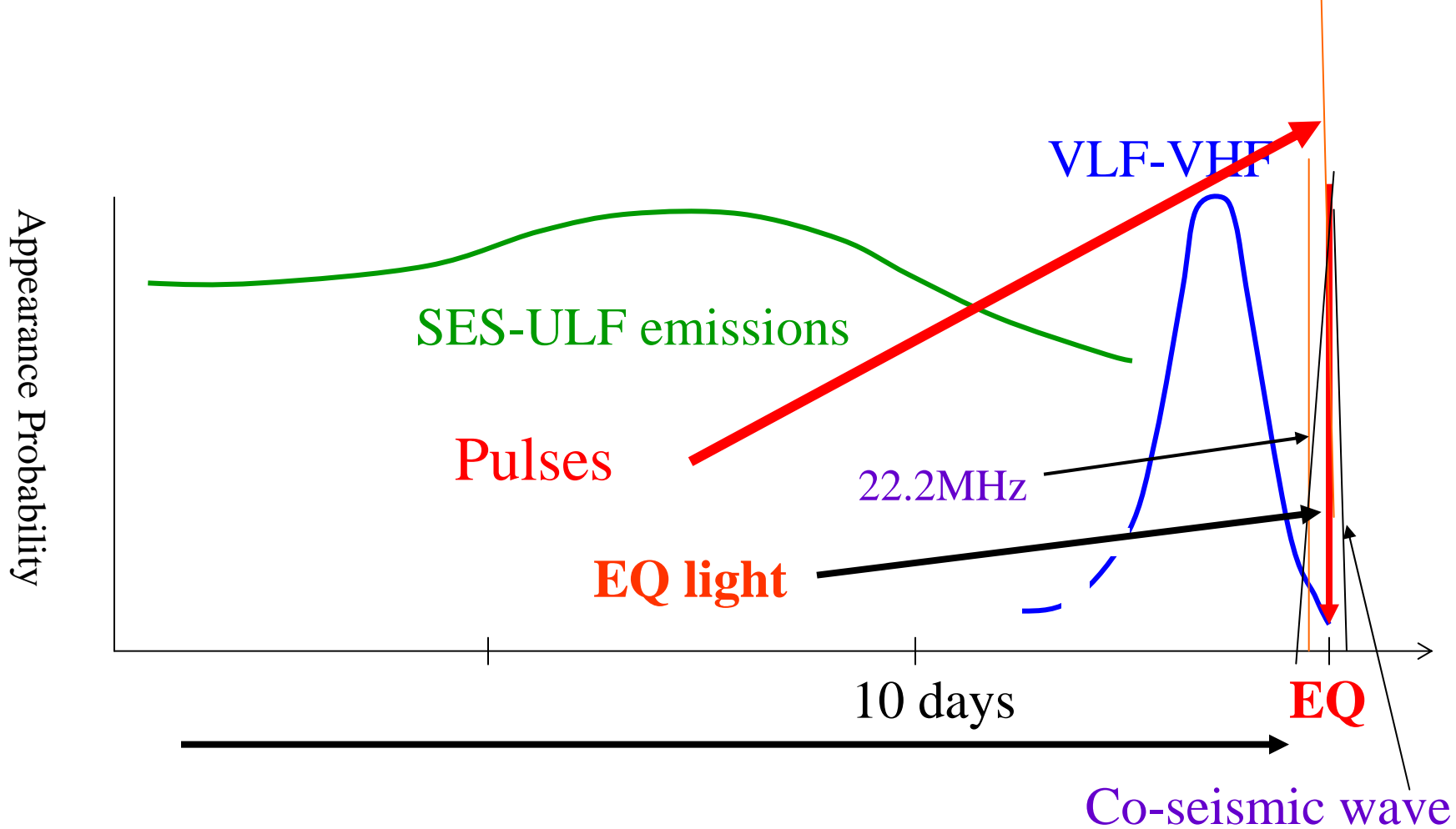
3. Any **true** co-seismic signals?

None observed, so far, except Japan ?

4. Any other simultaneous phenomena?

None, except “NT Coincidence”

5. Others **may be** secondary at this stage



Conceptual view on Seismo-EM phenomena

1. Are there undoubtedly EQ related pre-seismic EM signals?

Difficult to correlate EM signals with EQs when long separated in time.

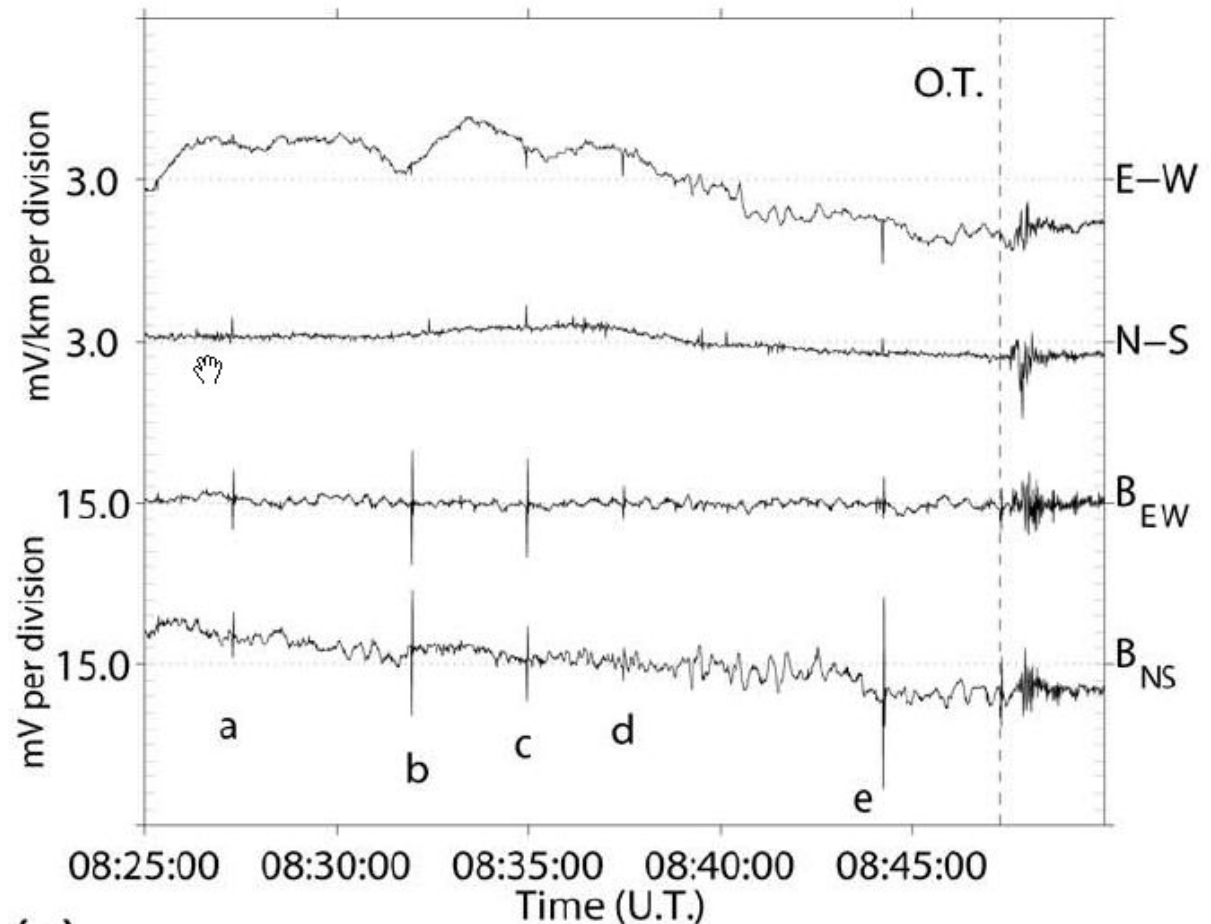
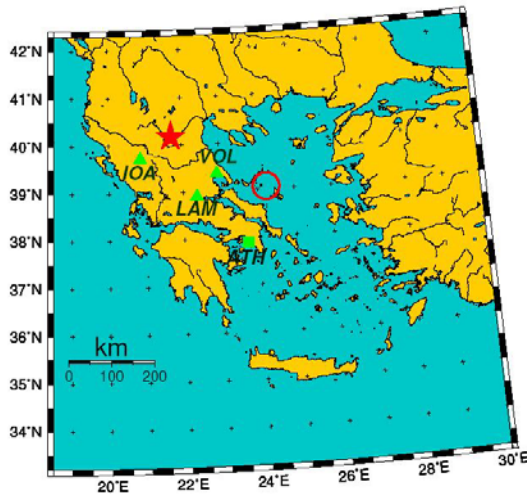
Easier when Short pulses etc occur within short time (<minutes).

So far disregarded for too short lead times for practical prediction.

May be useful when combined with SES and real time warning.

Pulse: ~msec, min before EQ (Varotsos et al., 2007)
Orders stronger than SES

Grevena-Kozani EQ, M6.8, 1995

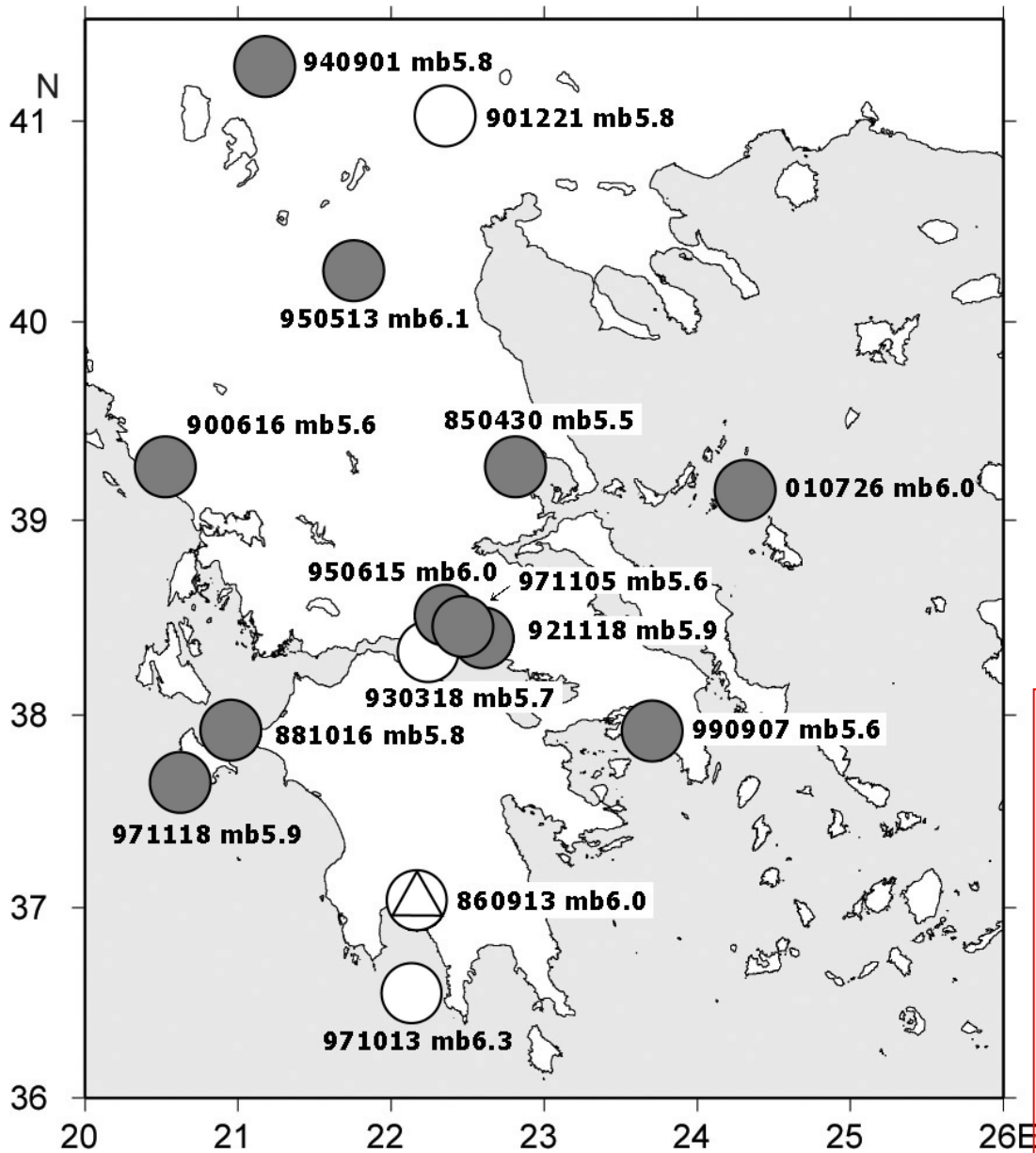


2. Any precursors:

SES in Greece, Japan,
Mexico, India,
China ?

Not in USA?

Turkey?



SES

Despite debate, best established, both experimentally and theoretically

All $M > 5.5$ EQs for 1985-2003.

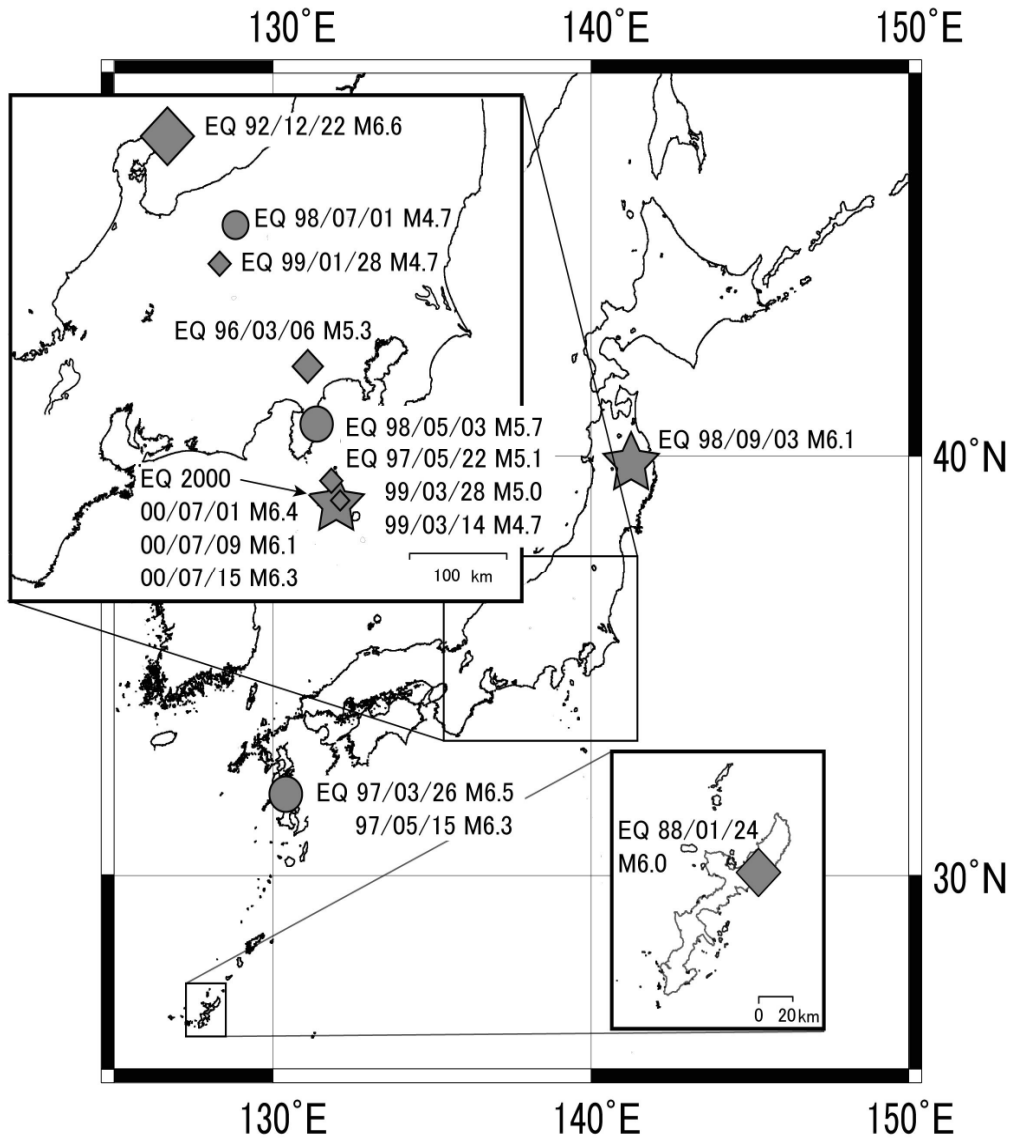
Shaded circles :

“successful”

Circle with triangle :

“unsuccessfully predicted”

Plain white circles :
“missed”.

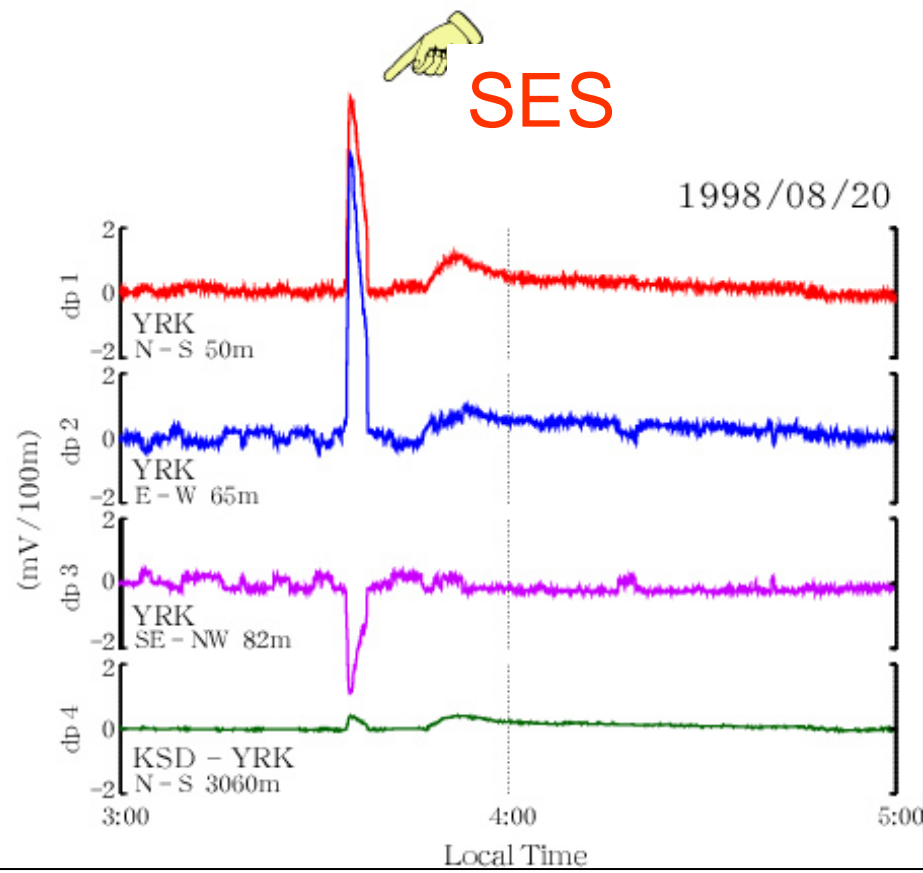
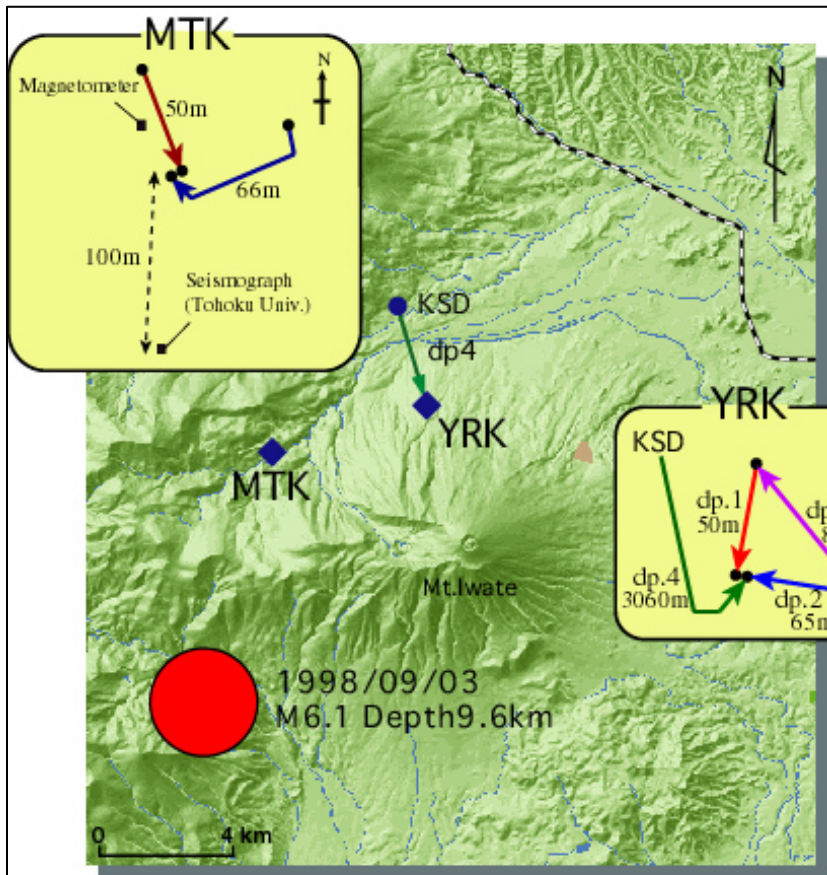


$M \geq 5$ EQs

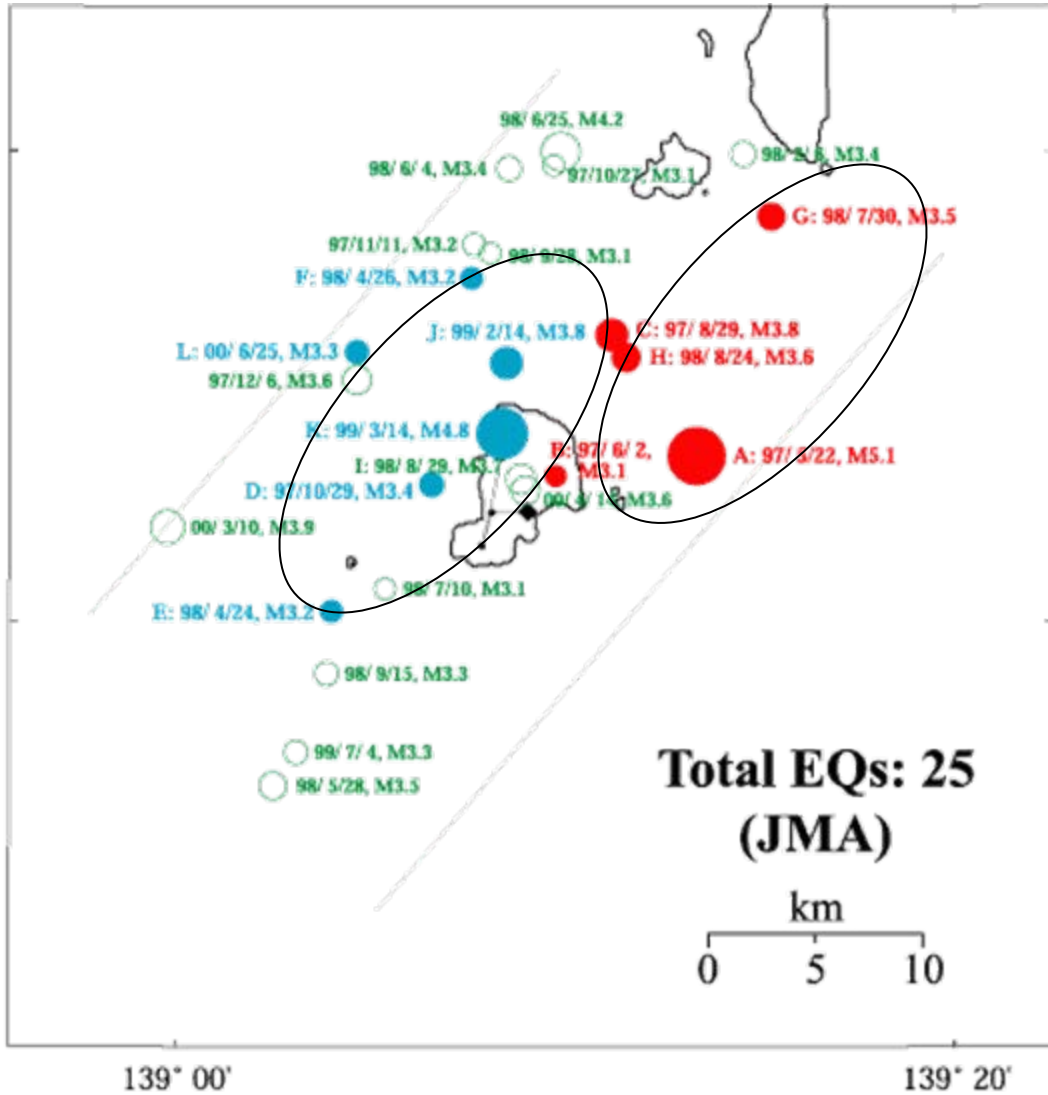
Diamonds: electric signals

Circles: ULF magnetic signals.

Stars: both electric and magnetic signatures.



Selectivity



May 14, 1997 - Jun 25, 2000
Magnitude > 3.0
r < 20 [km]

- : AC with positive polarity
- : AC with negative polarity
- : No AC

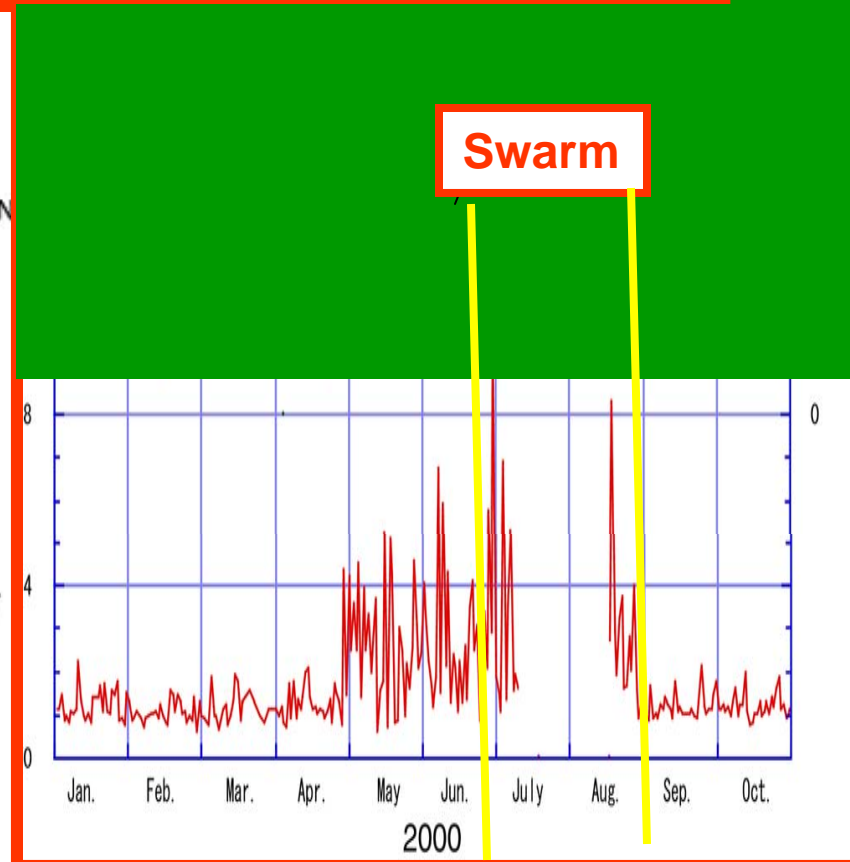
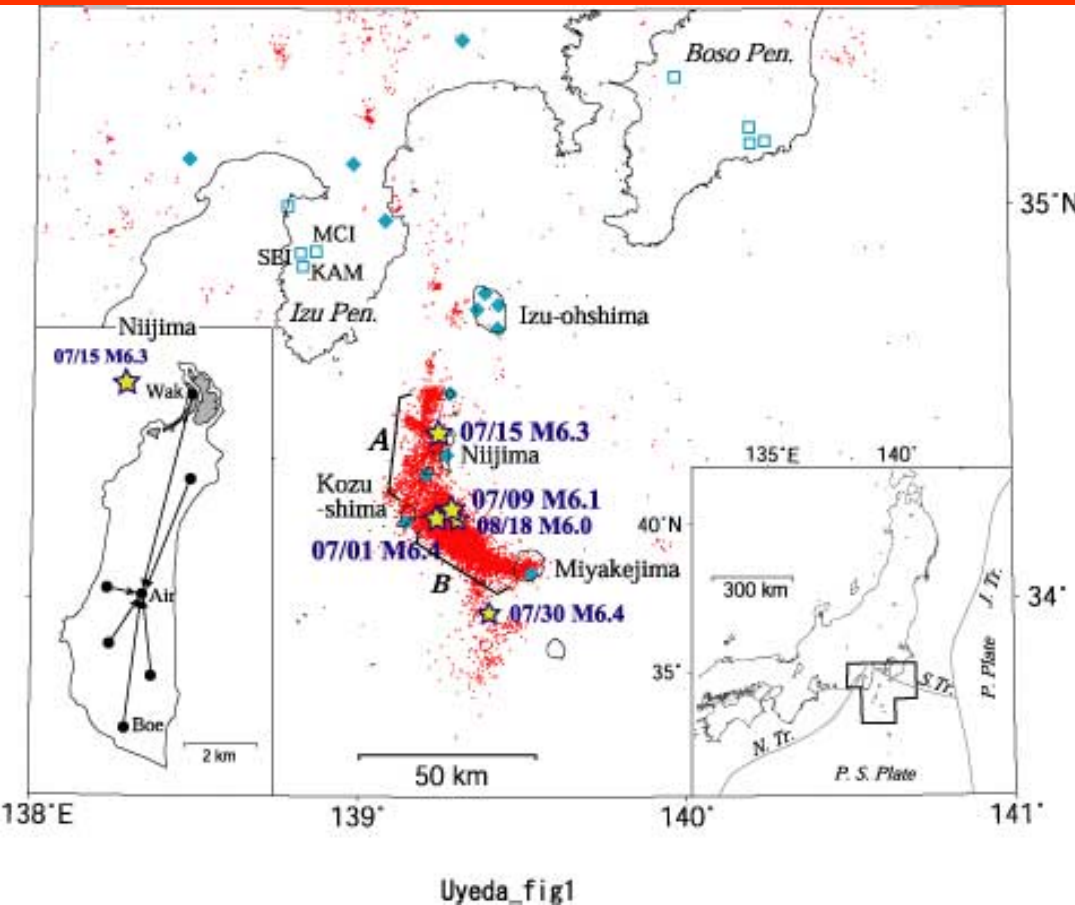
Magnitude Scale

- 5 ○
- 4 ○
- 3 ○

Seismic Swarm Activity in 2000 in Izu Island Region, Japan

June 26 – Early September, 2000

Electrical activity started 2 months before Swarm.



Some reports on SES

from China, Mexico, India

But not from USA?

The absence of E and M field precursors for this, and other EQs with M5-7.3 elsewhere in San Andreas fault system, indicates useful prediction seems unlikely using these EM data.

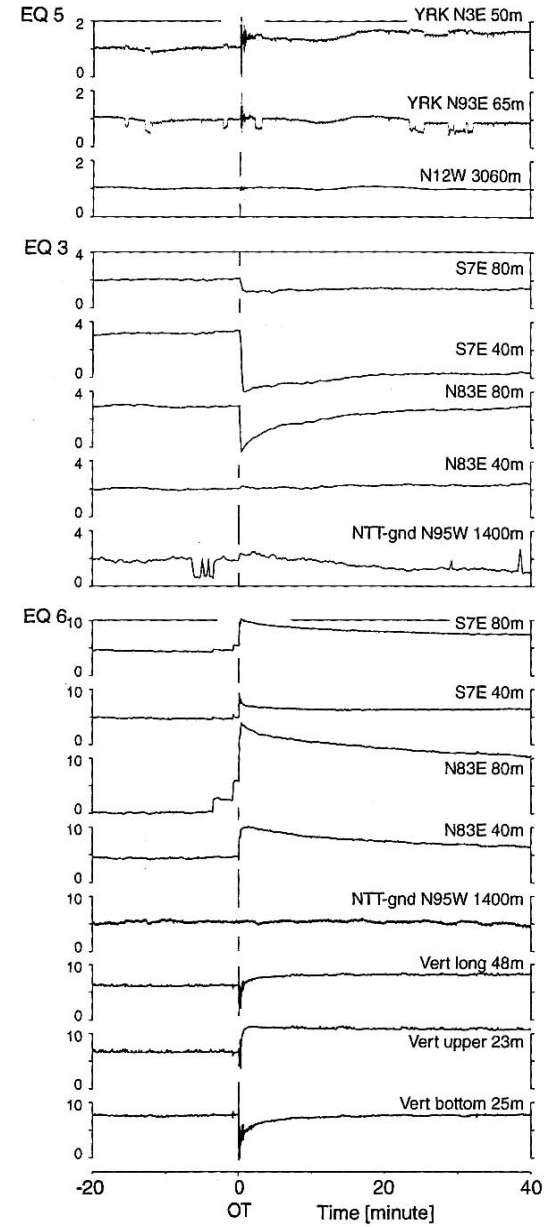
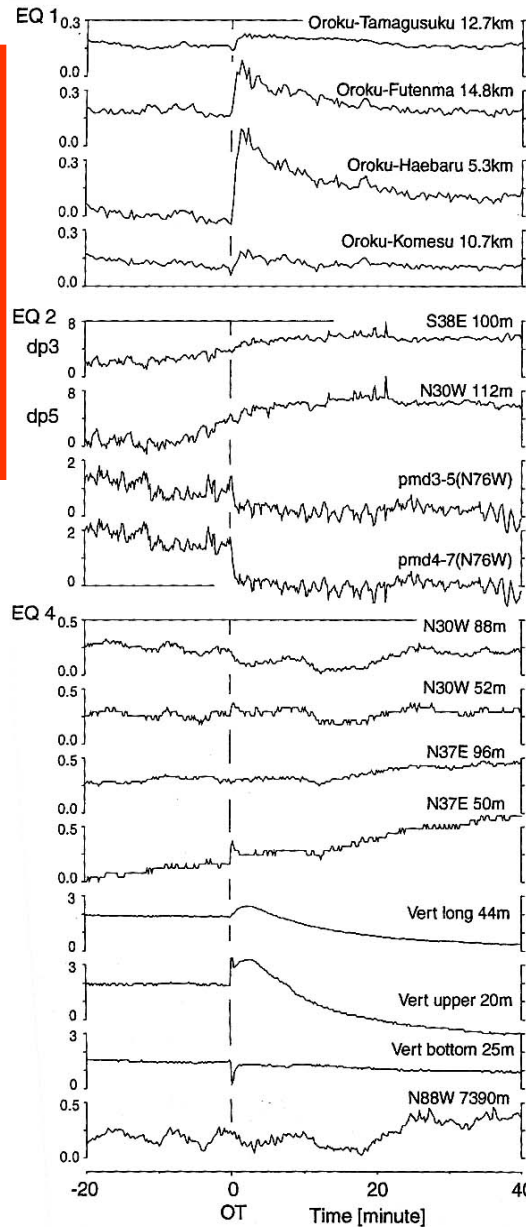
Johnston et al., 2006

3. Are there true co-seismic signals?

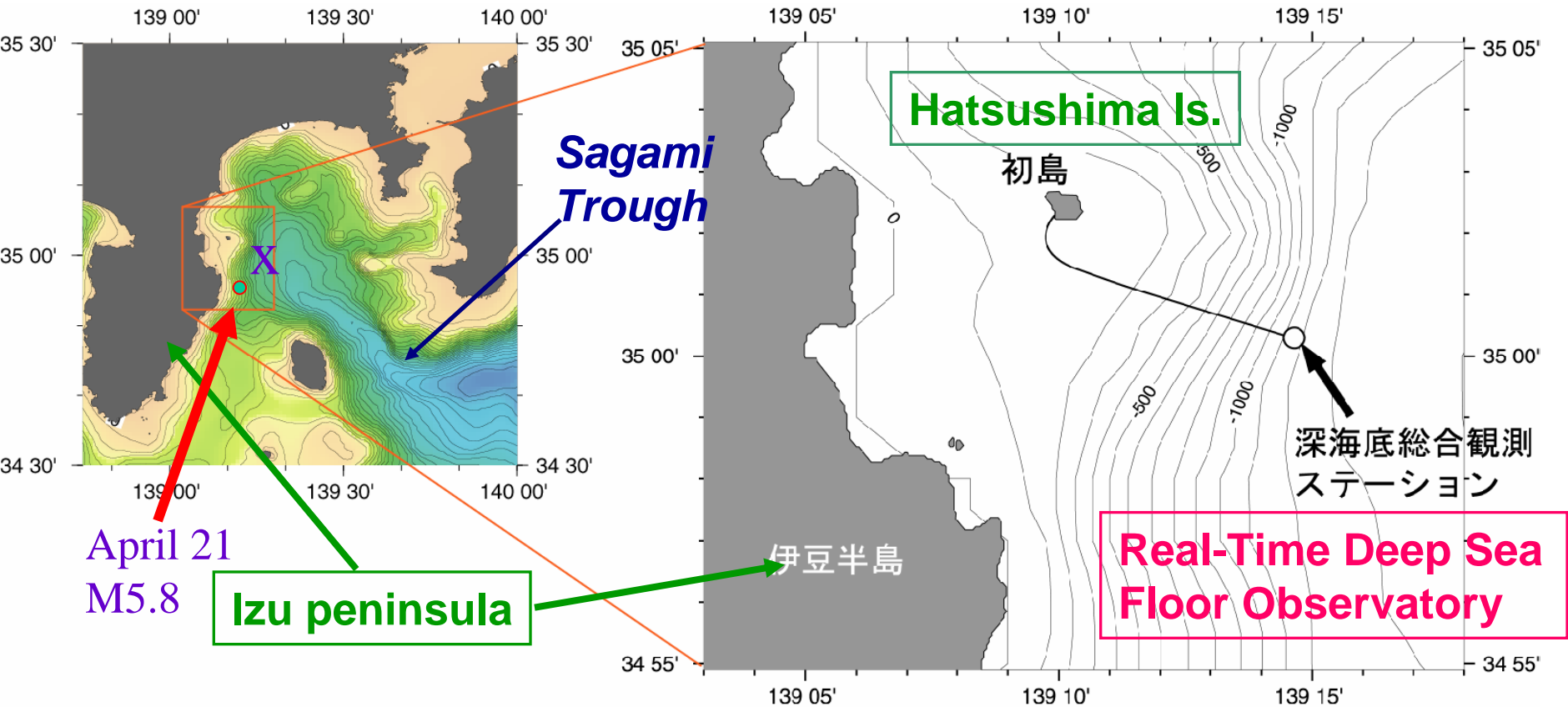
None observed, so far,
except Japan
(Tsutsui, Takano) ?

All “co-seismic”
=> co-seismic
wave.

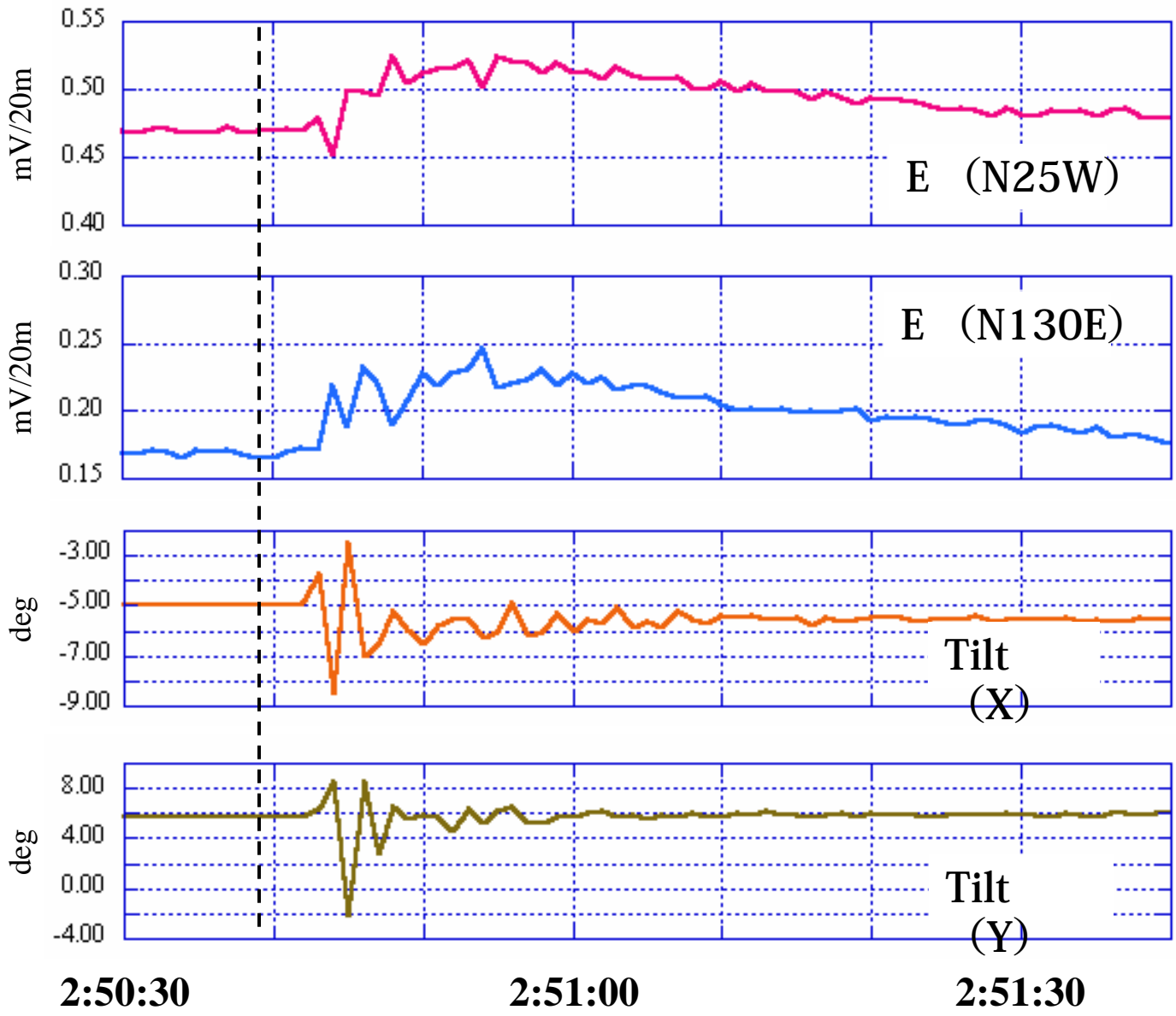
Not “True co-
seismic”.



Seafloor Observatory



EQ



EQ at :
2006/4/21
2:50:39

Epicenter :
34.9N
139.2E

M_{JMA} :
M5.8

depth :
7 km

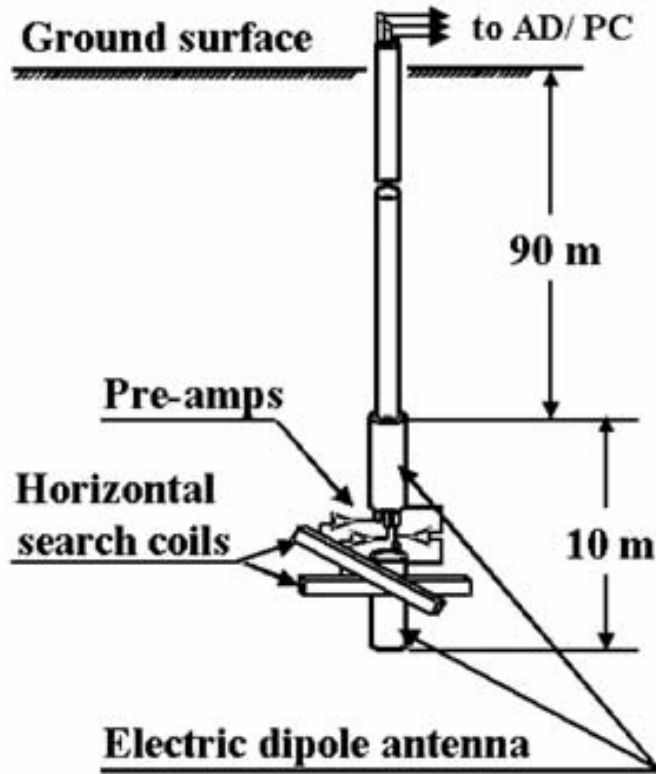
Why no co-seismic?

One of major objections to SES.

 δ

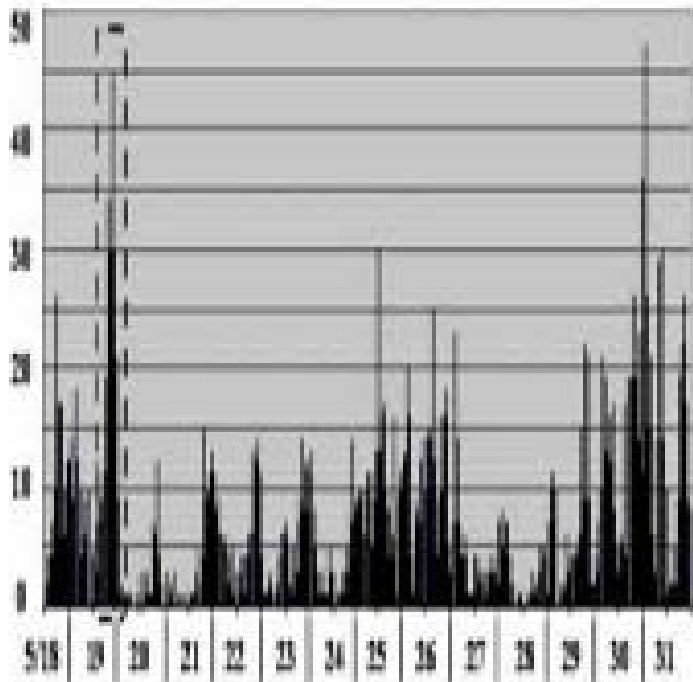
There are ^{δ} no similar coseismic signals observed when the primary EQ energy is released....

Johnston et al., 2006



Frequency-dependent arrival directions form a sector. Frequencies and their intensities are defined by color code. The propagation distance ($d = 130$ km)

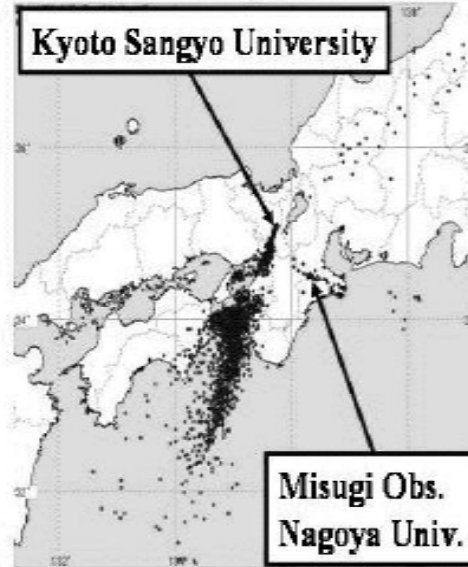
was measured along the direction line on the blue edge of the sector. The source location of the EM pulse is marked by a red dot, which is just on the earthquake epicenter. Tsutsui, 2005



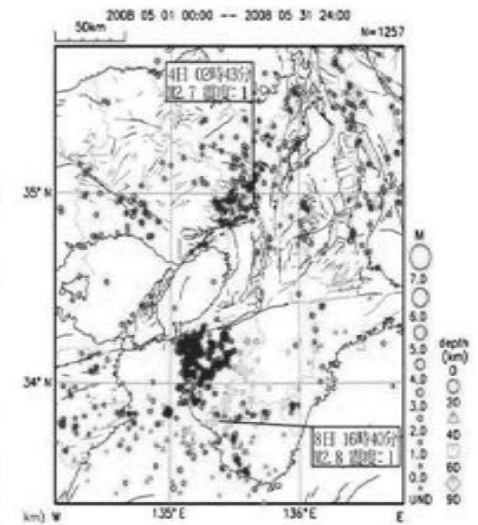
May, 2008

Tsutsui, 2008

Earth-origin EM pulses
18 -31 May, 2008



Earthquakes > M1
1 -31 May, 2008



4. Any other simultaneous phenomena?

**None, except “NT
Coincidence”**

**“No correlation” of SES with other
geophysical events.**

**No independent data (strain,
seismic, pore pressure, etc) exists
that supports the proposed EQ/SES
relationship**

Johnston et al., 2006



1. Some pre-seismic signals (pulse etc) are related EQ. No doubt.

2. SES exists. But not at San Andreas F.

3. True co-seismic SES-type signals are not observed.

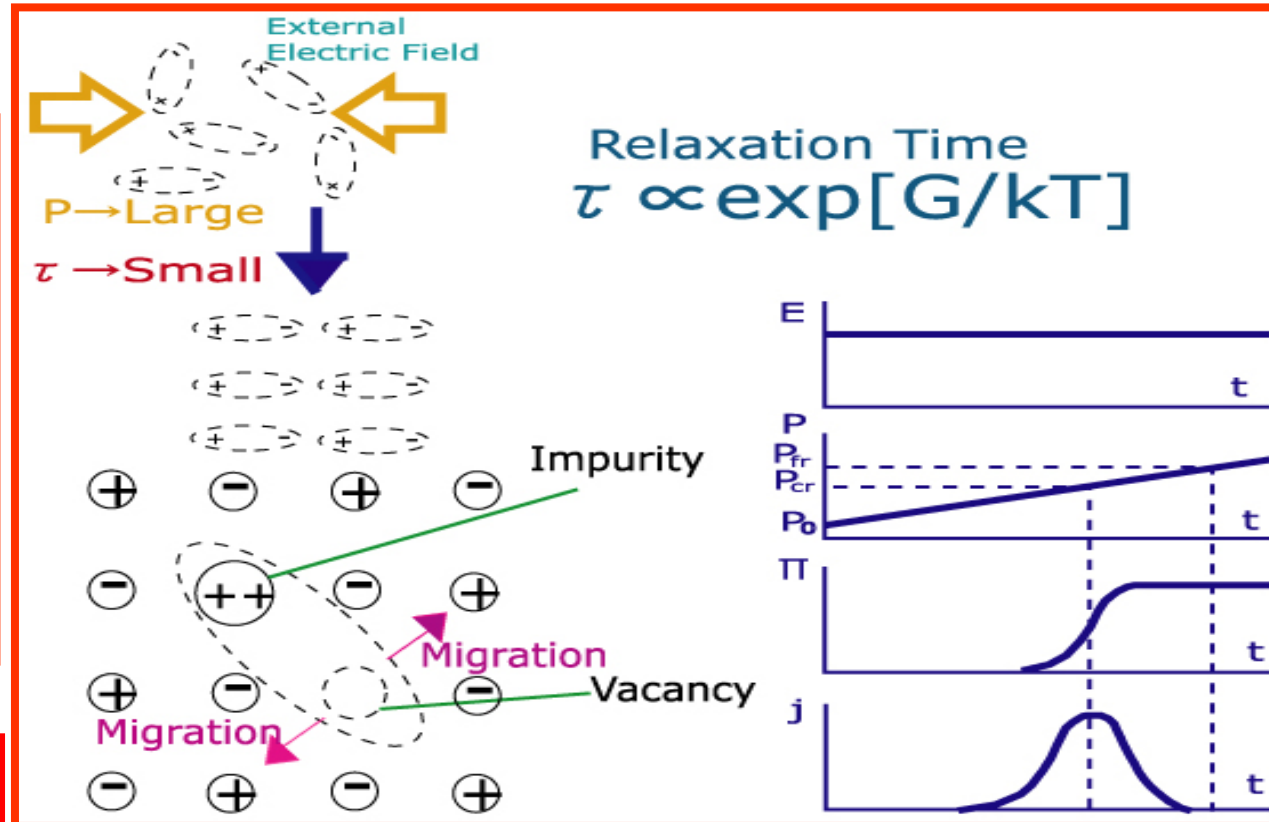
4. No other simultaneous phenomena, except “NT coincidence””

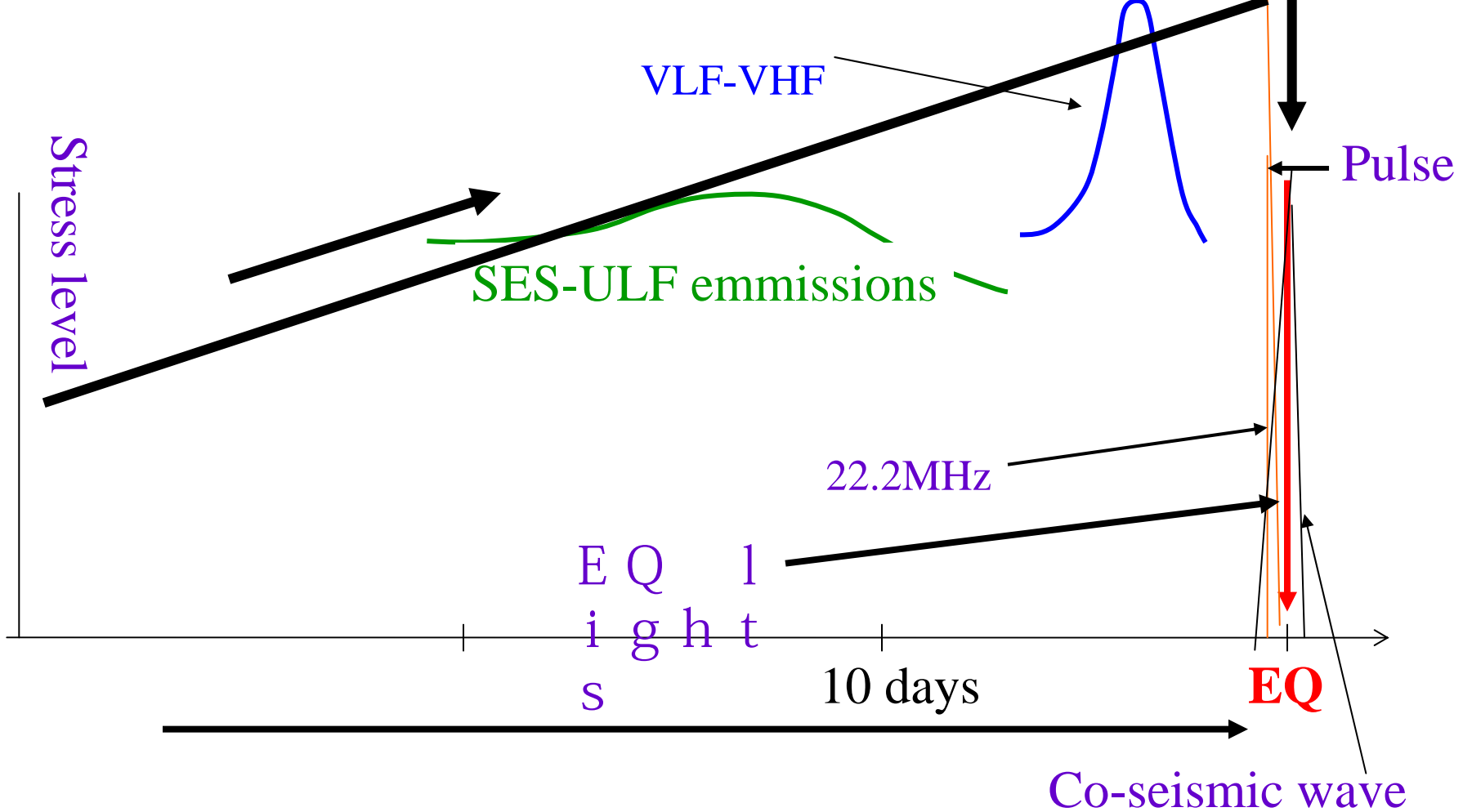
Solution?

Possible solution: SES as critical phenomenon

One example: Pressure Stimulated Polarization Current (Varotsos & Alexopoulos, 1986)

Experimental proof needed!!





SES is generated when stress level reaches critical value, which is slightly less than mechanical failure level. Critical value for pulse etc may be very close to failure level.

San Andreas event shows no EM

No EM at Parkfield M6.0 EQ, 2004 !

Therefore, EM unlikely useful for EQ prediction.

(Johnston et al., 2007; 2008)

Problems with their methodology (Varotsos and Uyeda, 2008)

How about another possibility?

San Andreas

story

Parkfield: 22 recurrence since 1906

M6 expected in 5 yrs,

1985

Alert: M6 in 72 hours . 1992/11/16

EQ after 12 yrs

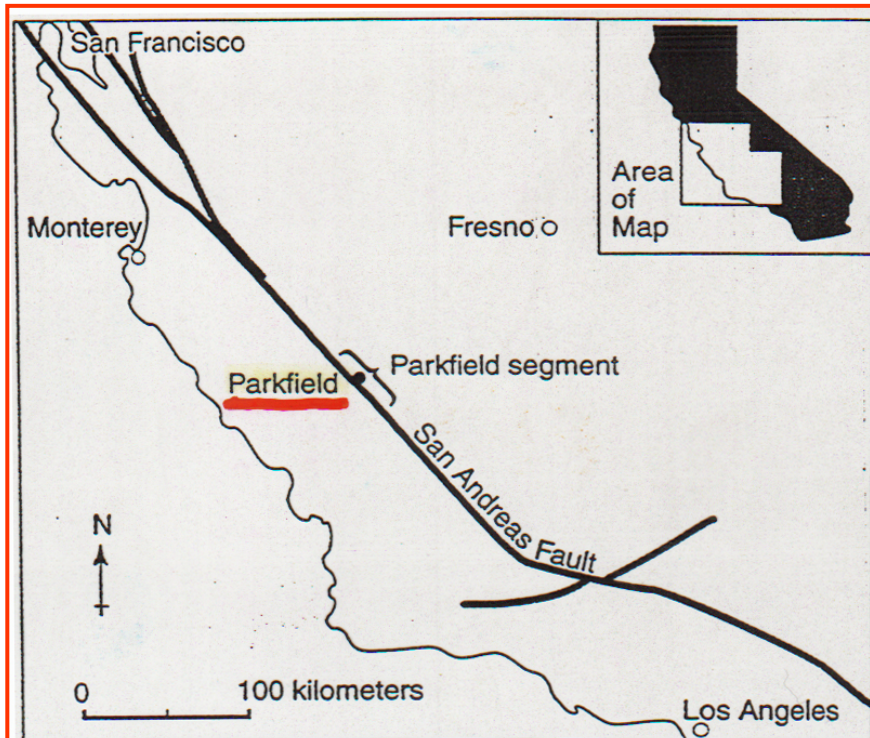
2004 / 09 / 28,

Mw 6.0

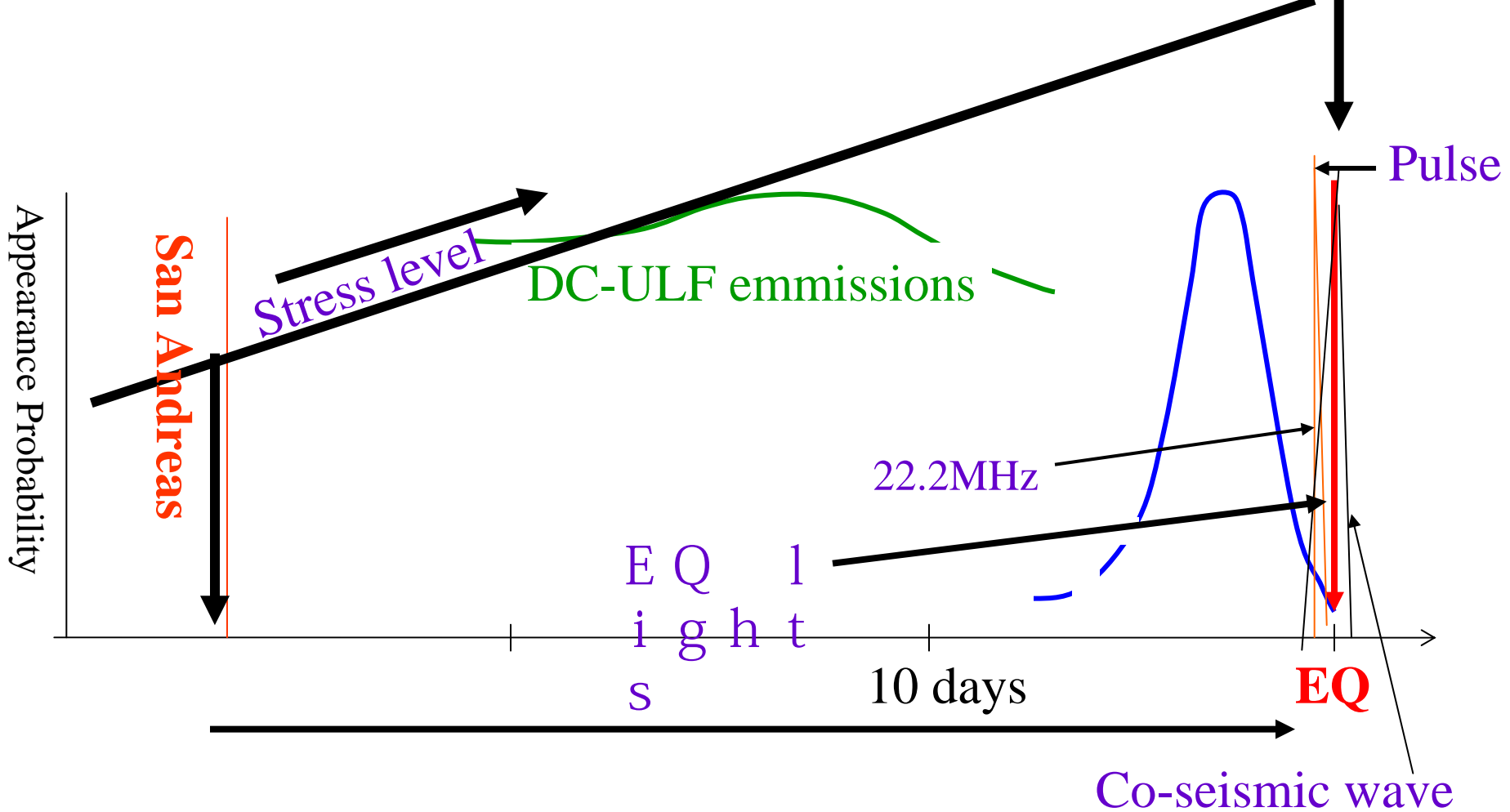
No EM signal

Stress at San Andreas is notoriously low.

(HF Paradox, etc)



Central California's turn? Attention has turned to the Parkfield segment of the San Andreas.



San Andreas is weak, and EQ occurs before stress level reaches critical for SES. How soocial is SAF?

Possible reason for weak fault:

Many proposed mechanisms

Simplest;

Existence of water: Movement of Mendocino Triple Junction?

Although electro-kinetic potential may arise, but it will be small under low stress gradient:

$$\nabla E = \frac{-\varepsilon \zeta}{\eta \sigma} \nabla P$$

3. Why no co-seismic ?

Pre-seismic process for SES is a slow increase of stress.

Co-seismic process (EQ) is instantaneous stress release.

They are different physical processes.

No reason to expect same thing happens (Problem 3).

Then, what are really happening at EQ?

Observations;

In field, no true co-seismic SES type signals, only high freq. (Tsutsui, Takano type measurements needed)

In lab. fracture experiments show, high Freq. EM pulse

 δ

Two possibilities:

1. At EQ only high freq signals by some mechanism (Piezo with pre-slip?) Skin depth problem
2. Since EQ is a sliding, no signal?

Even if only high Freq. pulses at EQ, they should be recorded with low-pass systems, because they should contain low Freq. components as fault motion at large EQ takes seconds of time.

Non observation of true co-seismic suggests EQ faulting does not generate even high Freq. signals.

Why not?

Because EQ faulting is sliding?

If so, how to explain Tsutsui-Takano results?

4. No other phenomena?

Since SES is generated spontaneously, there is no need for other agents or events. It needs only slow rise of stress level.

All problems are solved?

Not really.

Experimental verification of Pressure Stimulated Polarization Current !

What happens at EQ? Skin depth?

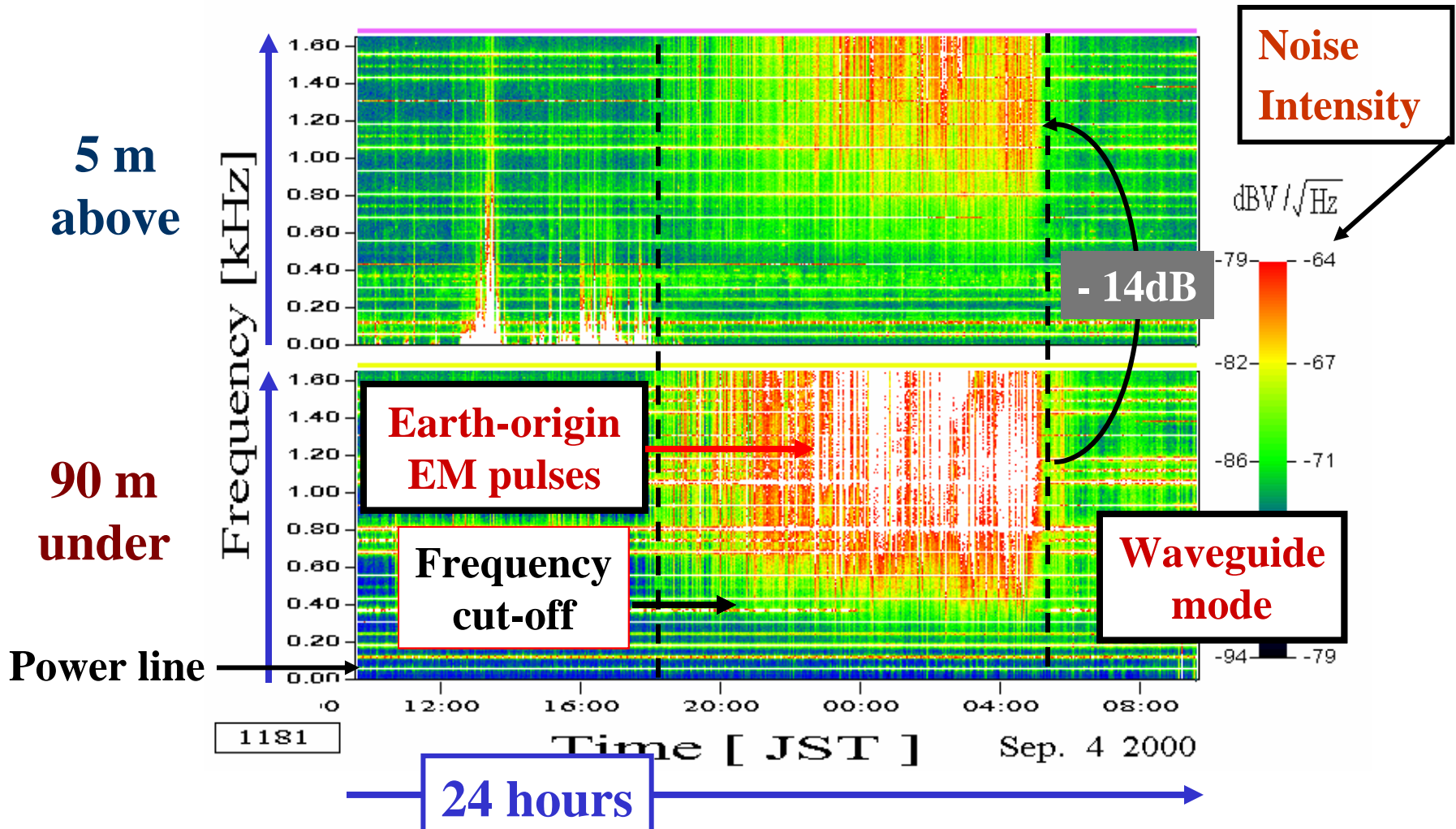
Different mechanisms for different Freq. signals.

END

Discovery of Earth-origin EM pulses

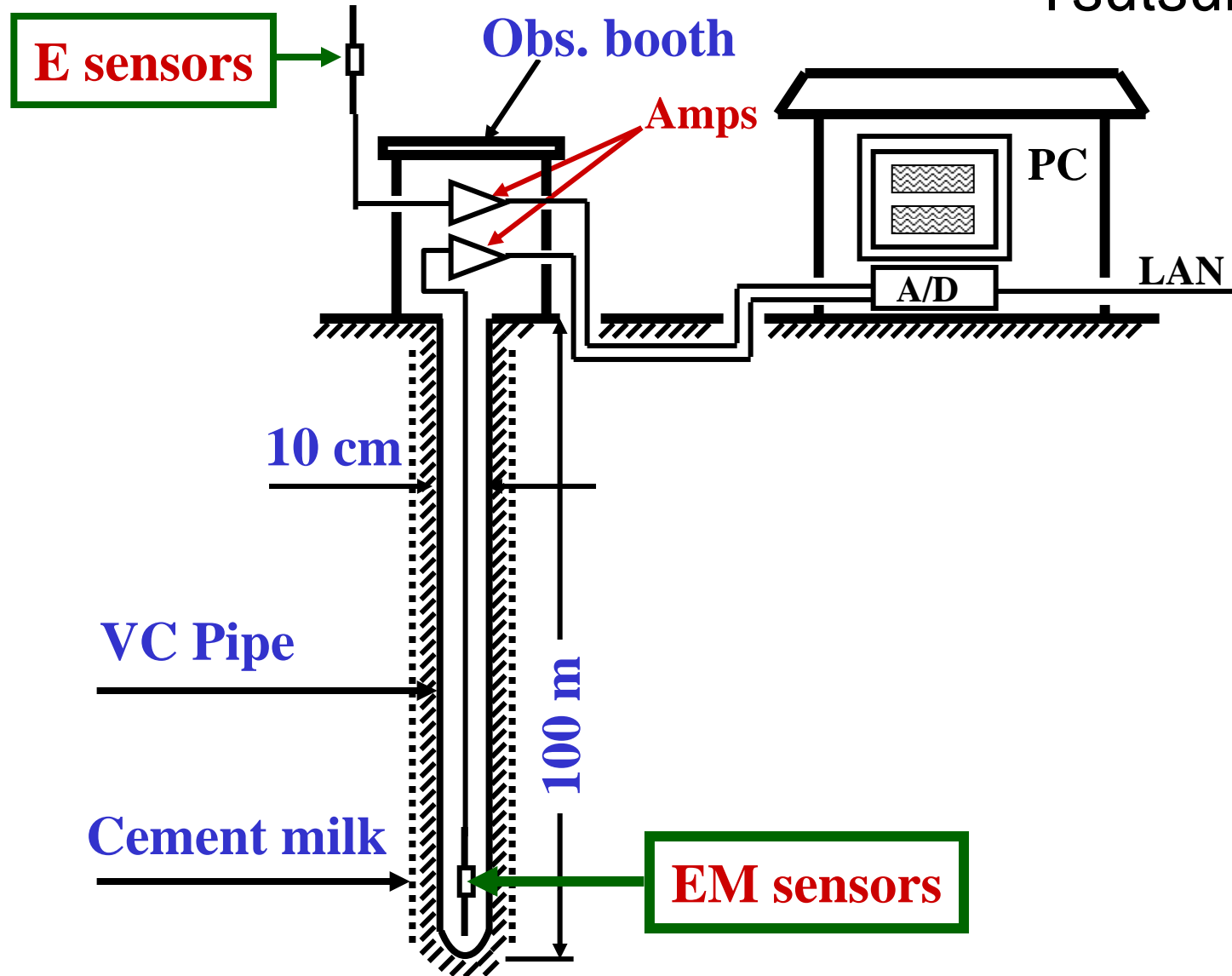
Tsutsui, 2002

Electric Field (Above/Under)



Possibly co-seismic ?

Tsutsui, 2002



Very interesting, but presents another problem.

Can EM wave signals travel through conducting earth ?

Skin depth ~ 100m for 1 kHz wave

Wave guide?

PulseはSESより一桁以上強い。

SESとは異なるメカニズムだろう。

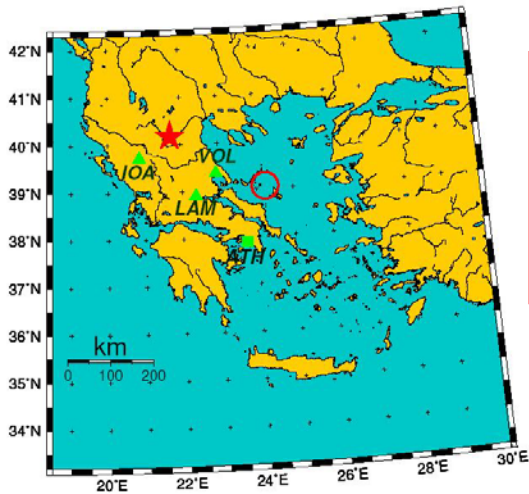
静止摩擦から、動的摩擦への転移過程

(前兆すべり?)

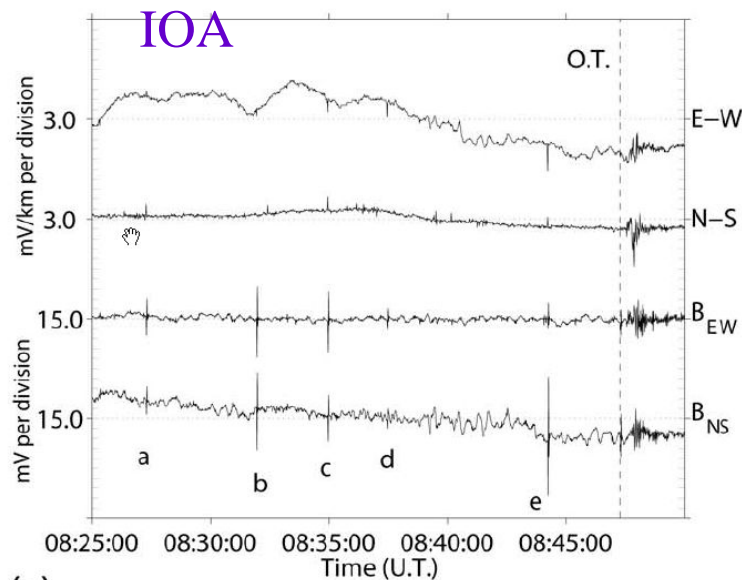
本震は、破壊でなく、**low friction slide**

だからpulseはでない。

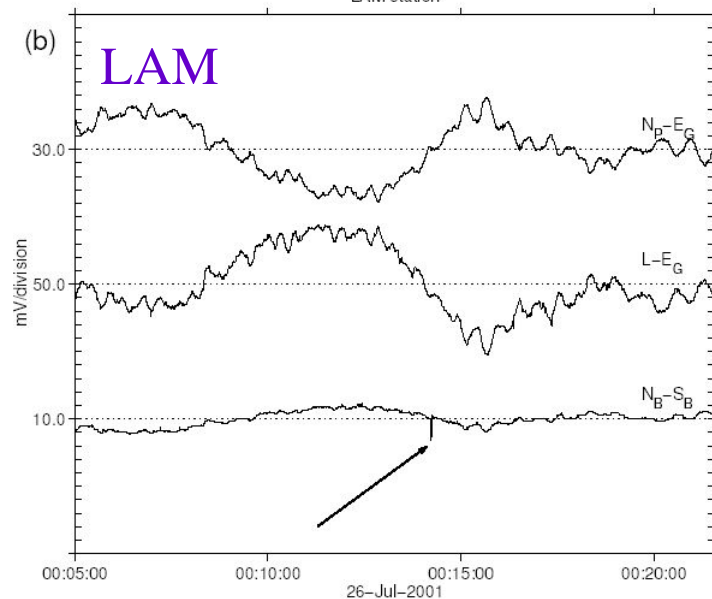
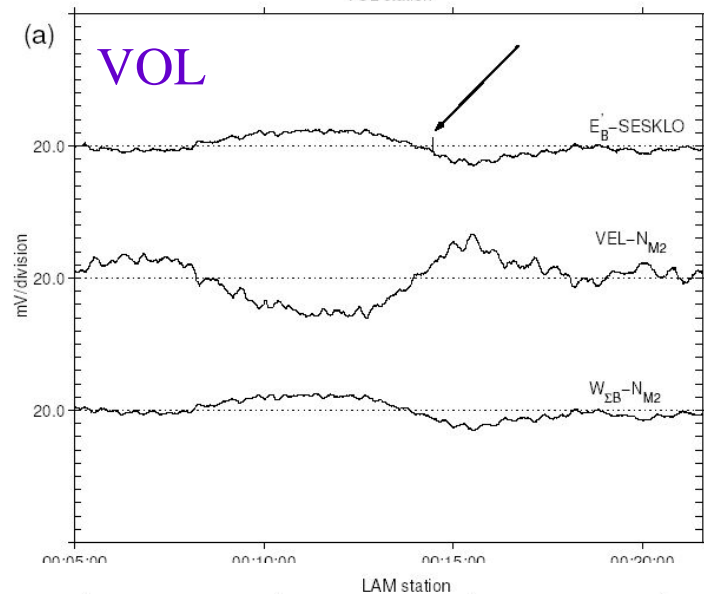
pulse: ~msec, min before EQ (Varotsos et al., 2007)



Orders
stronger
than SES



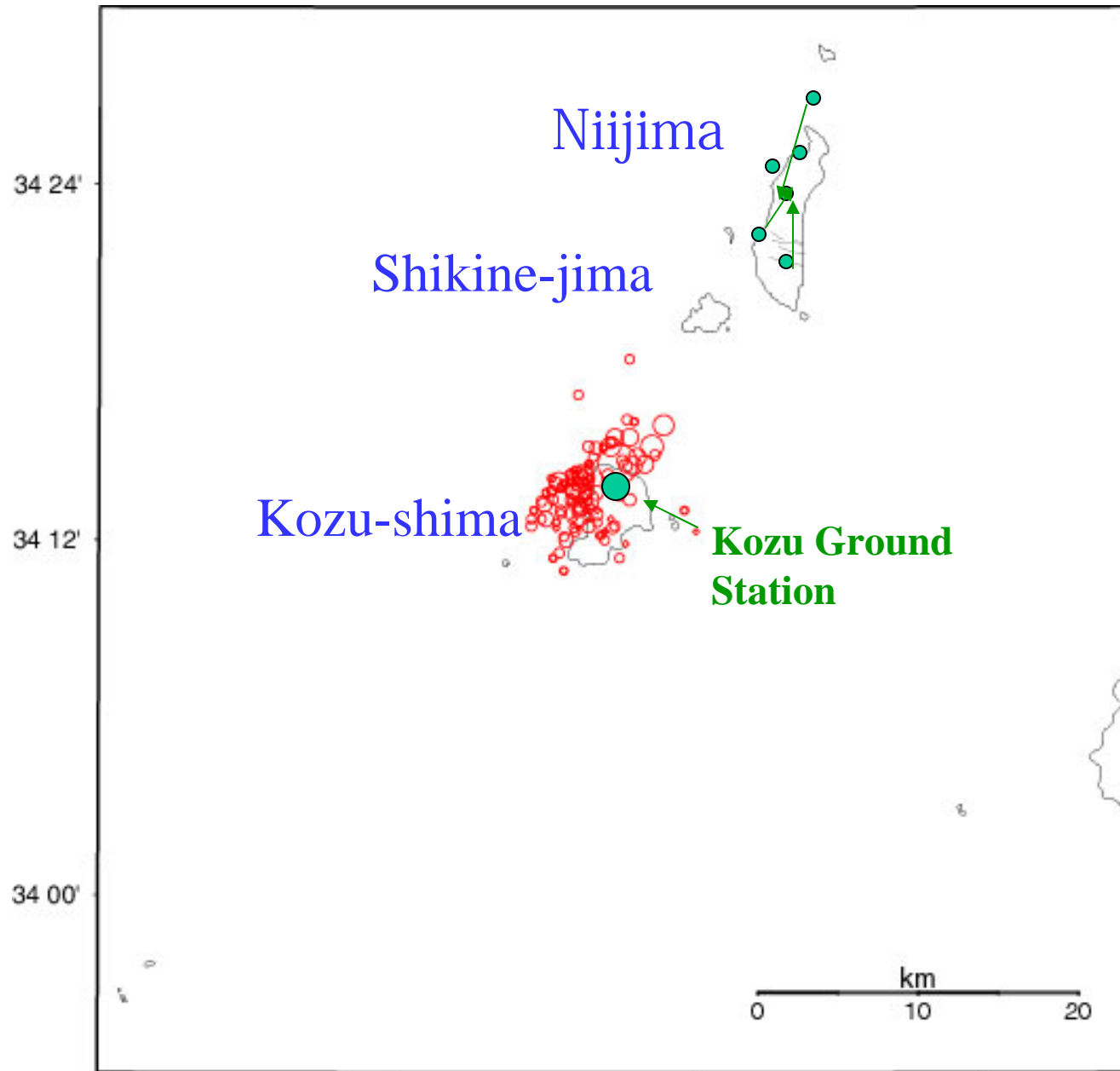
(a) Grevena-Kozani EQ, M6.8, 1995



Aegean Sea EQ, M6.6, 2001

Source File: kz_eq990314.dat

Total EQs: 116



Magnitude Scale

5 ○

4 ○

3 ○

2 ◦

EQ990314
Directly under
Kozu-shima

SES: Feb. 23

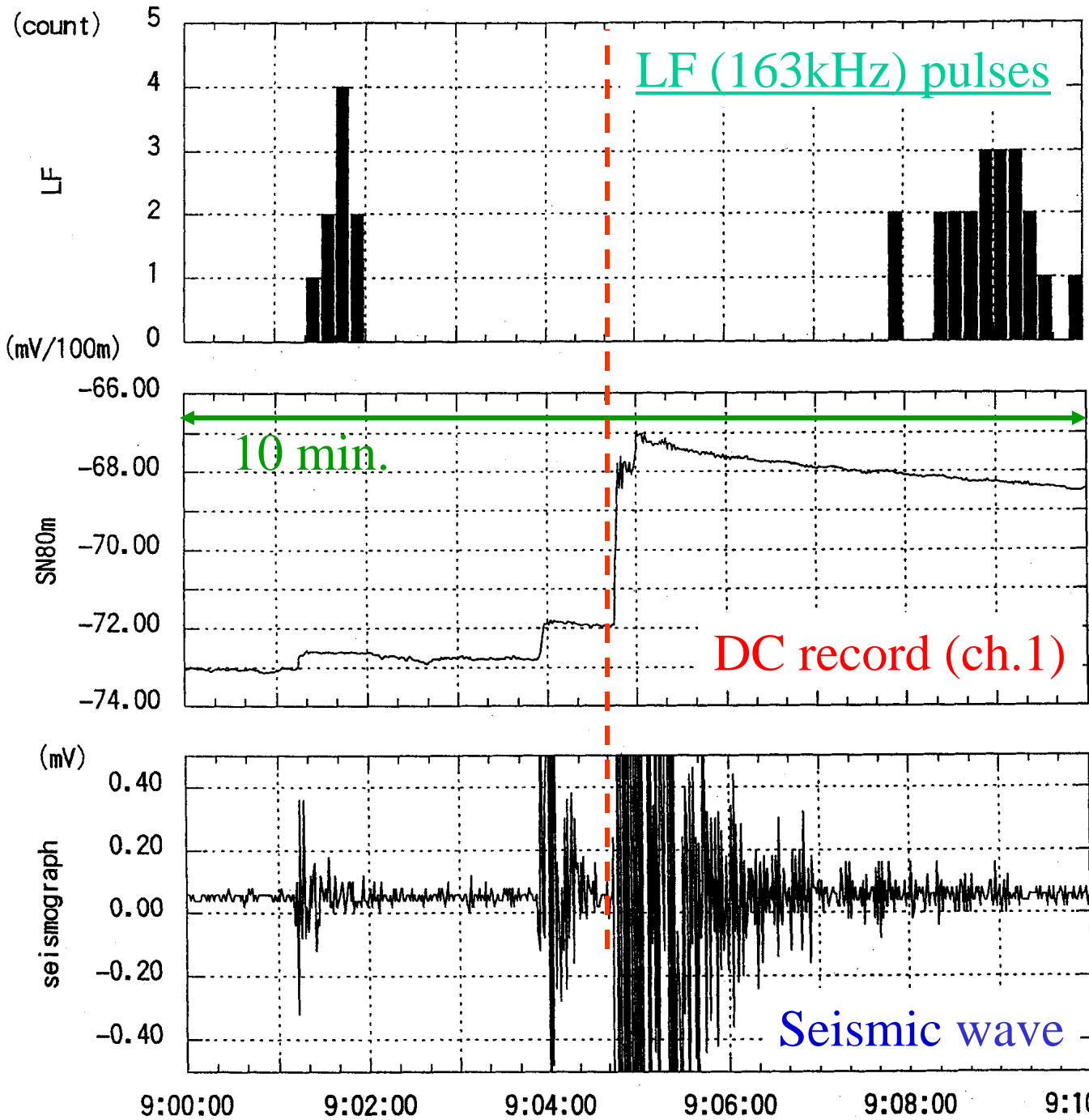
138 48'

139 00'

139 12'

139 24'

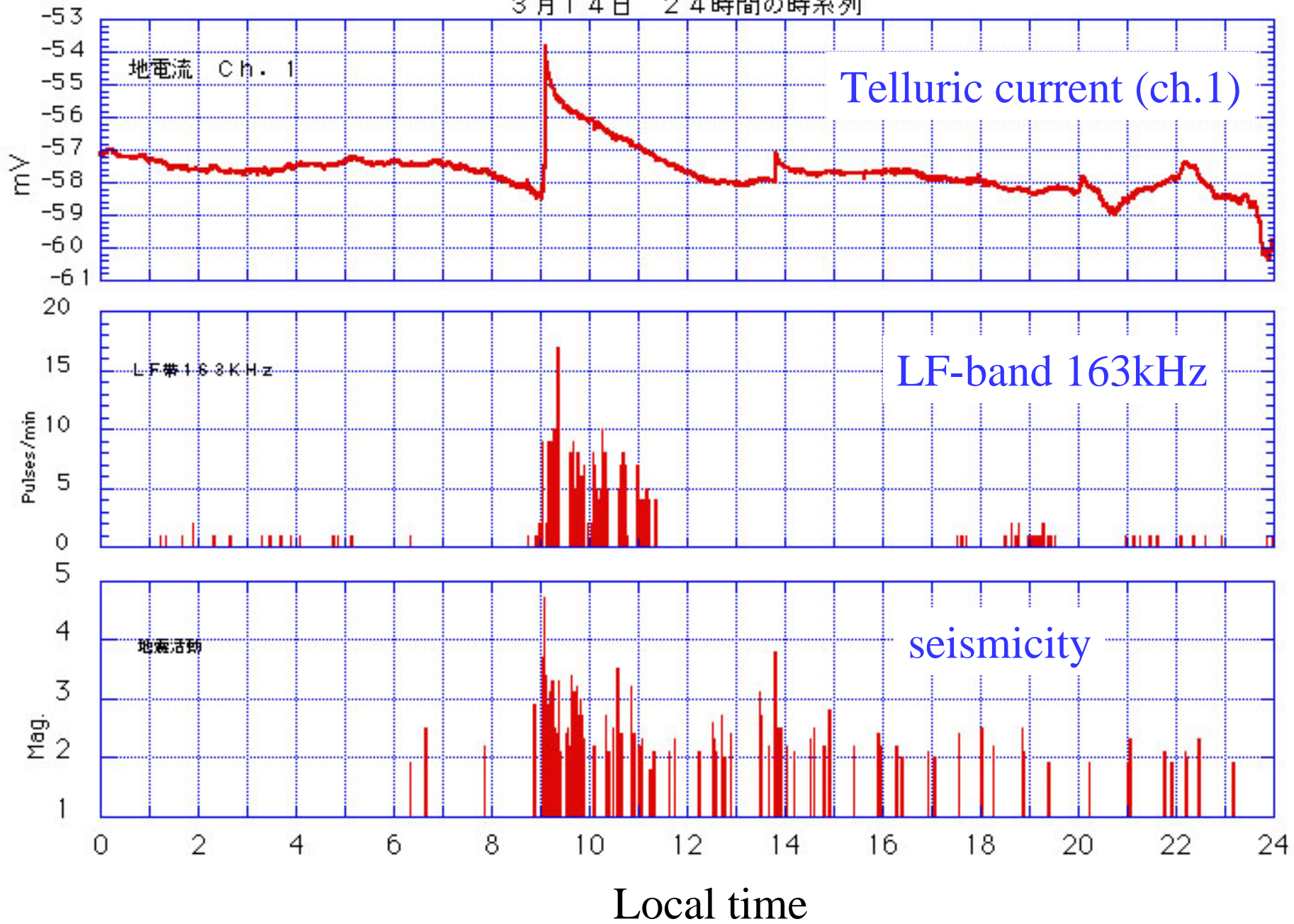
KZ990314EQ



**No signals
at main shock!**

Kozu-shima
March 14, 1999

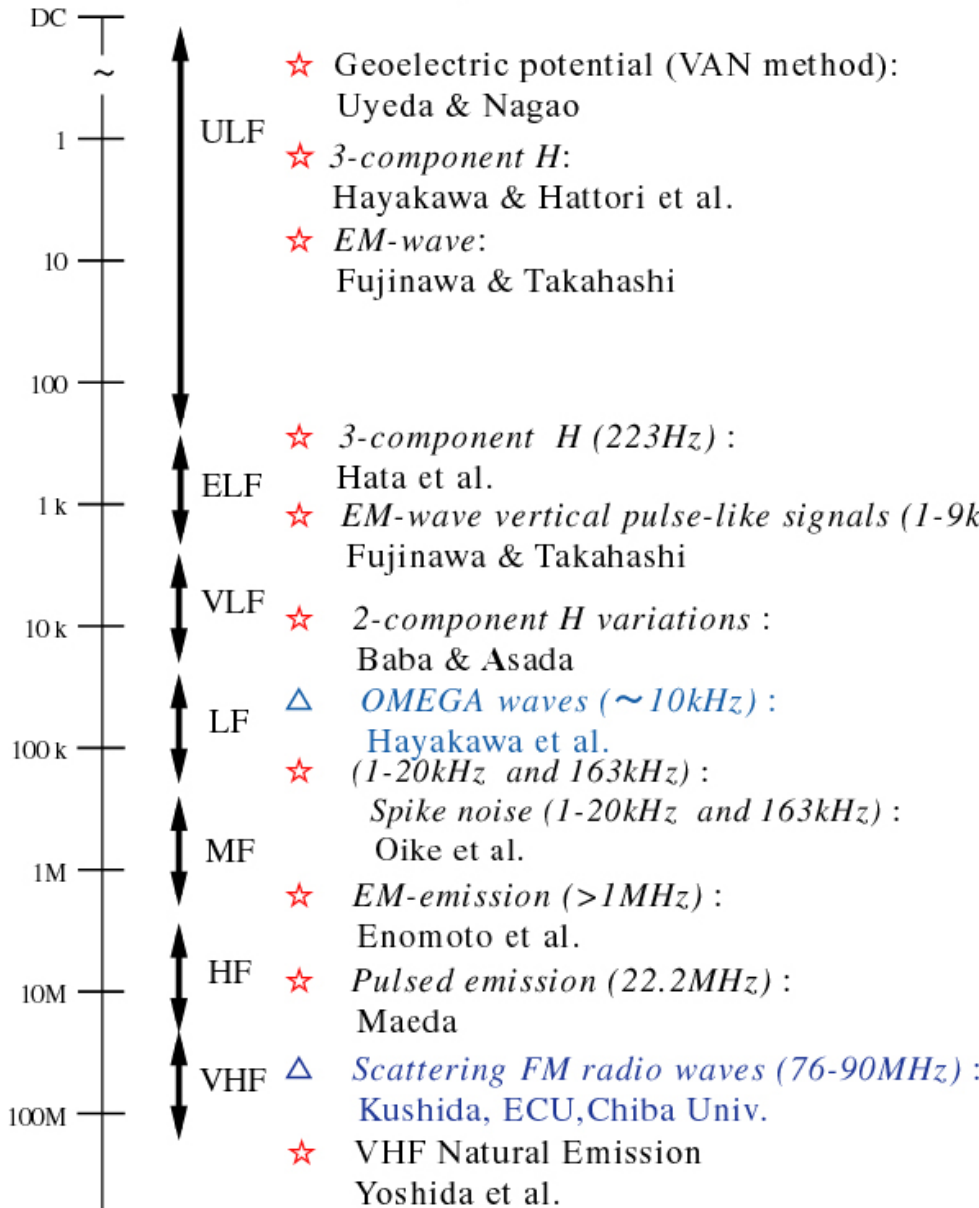
3月14日 24時間の時系列



Local time

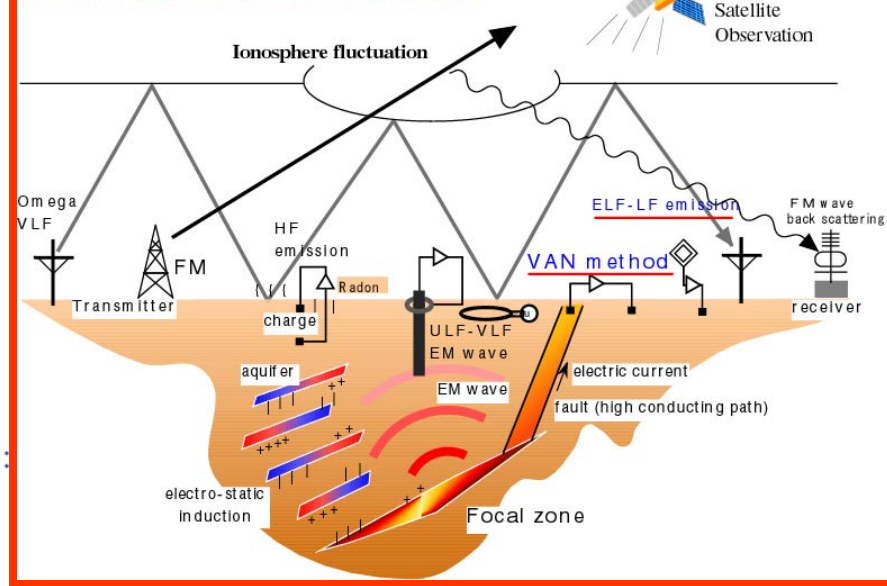
frequency (Hz)

★ : : *signal emission*
 △ : : *transmission anomaly*



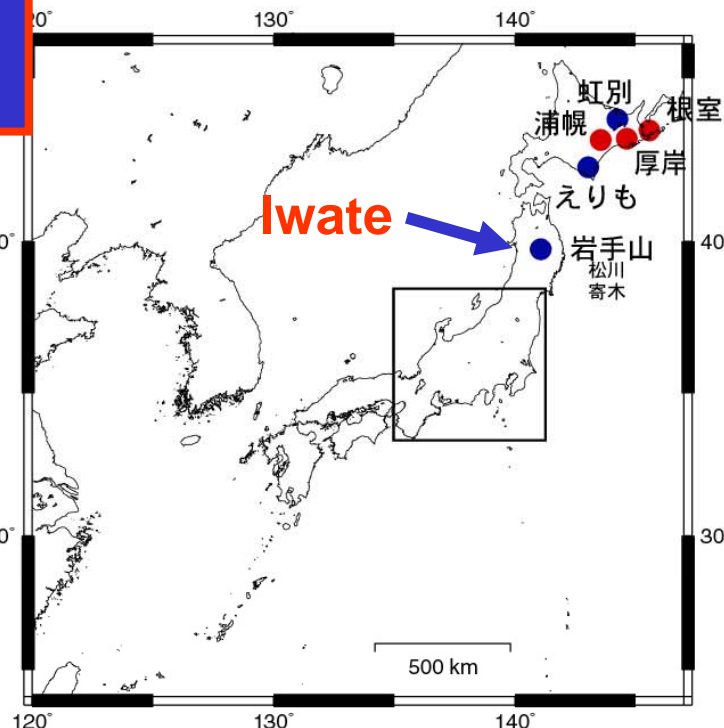
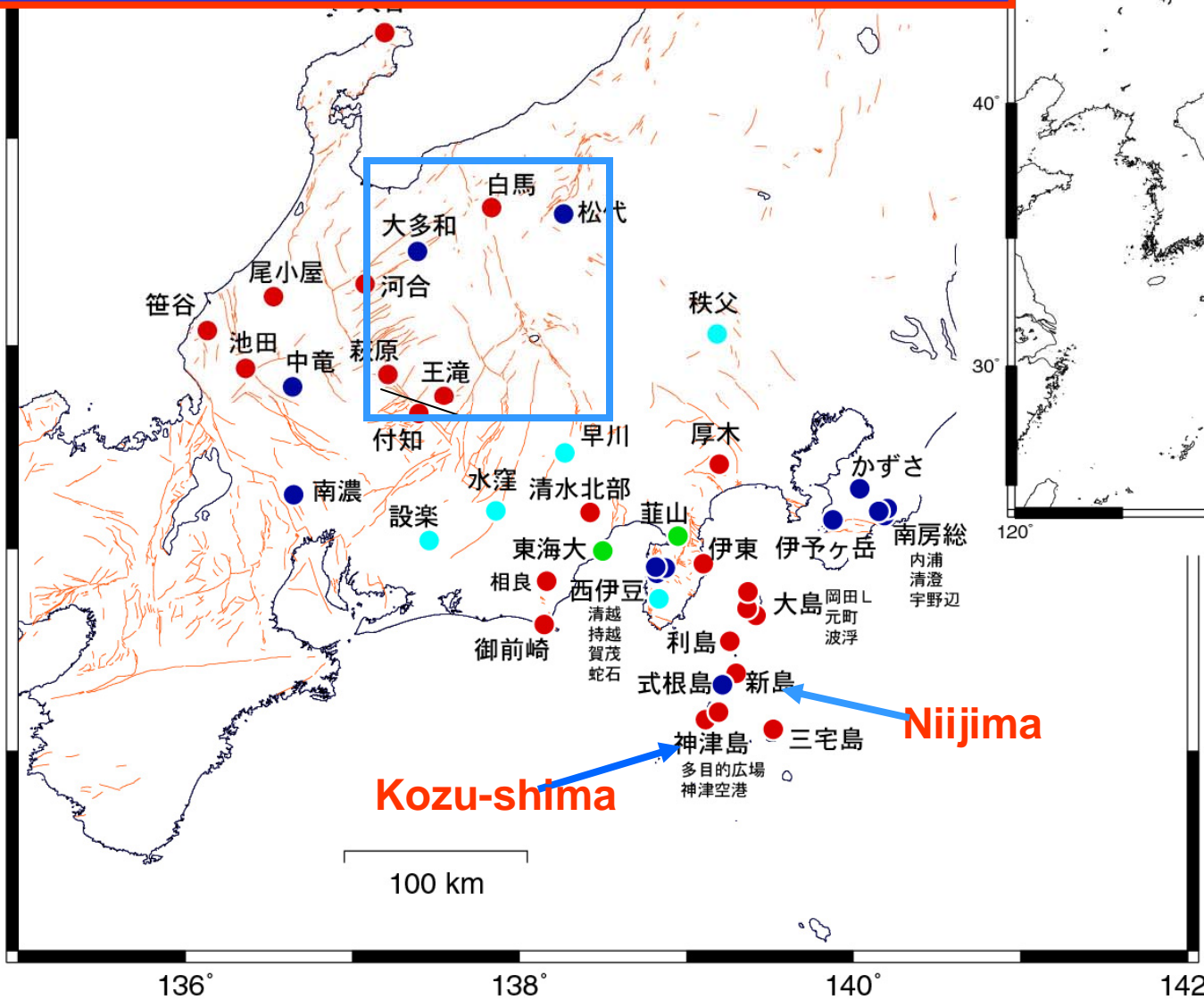
DC to M H z

Current EQ related EM studies in Japan



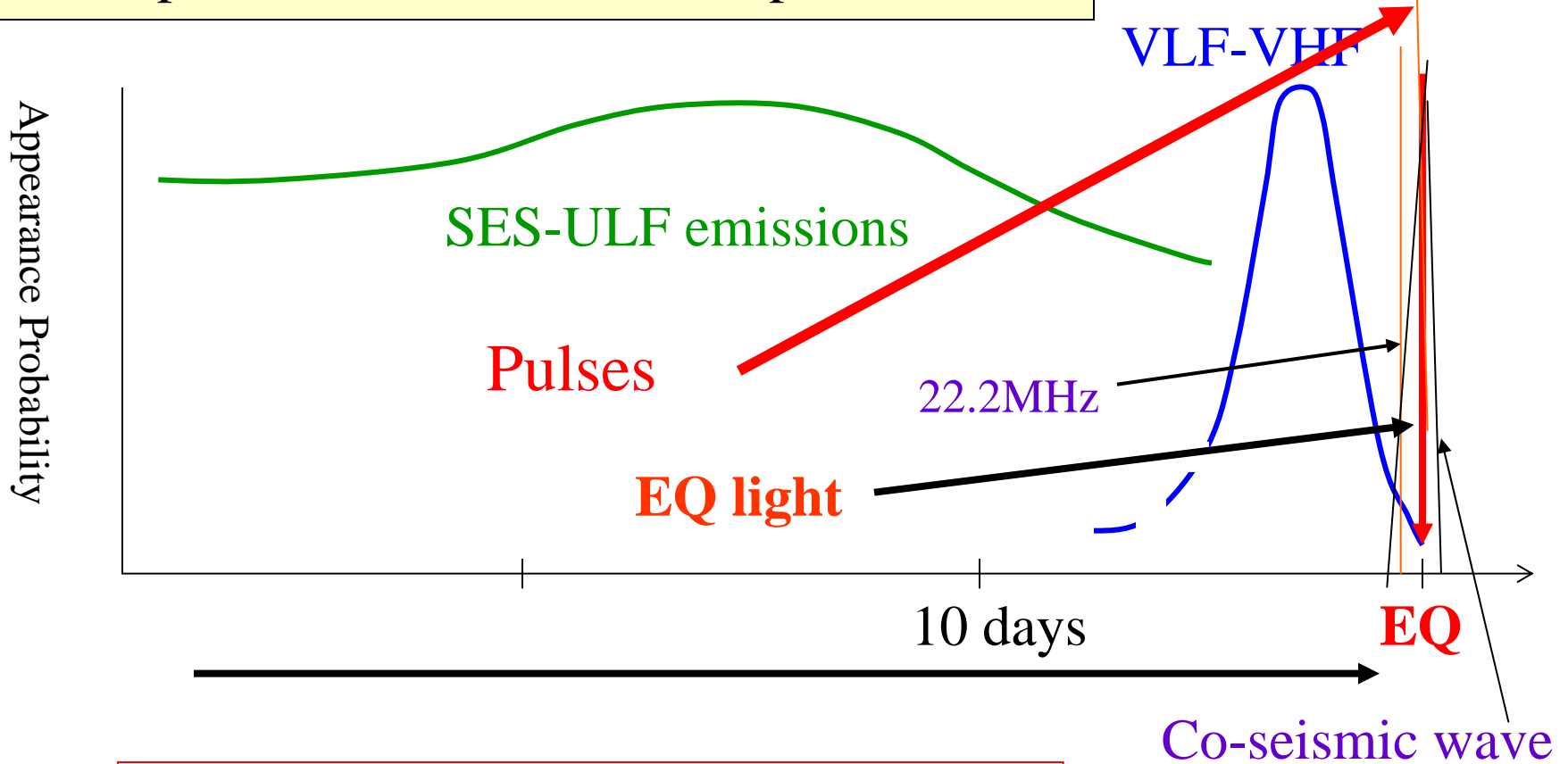
DC-ULF stations in Japan

as of May 2001



- Van type
- 3 comp. magnetic
- Combined
- Other types

Conceptual view on Seismo-EM phenomena



- SES:** Critical point process during slow stress growth
- Pulses:** Pre-slip during Static to Dynamic friction transition
- (Main shock: Low friction without fracture)**

FAQ 1

Why pre-seismic only?

Why not co-seismic?

Field Observations (DC-VLF range)

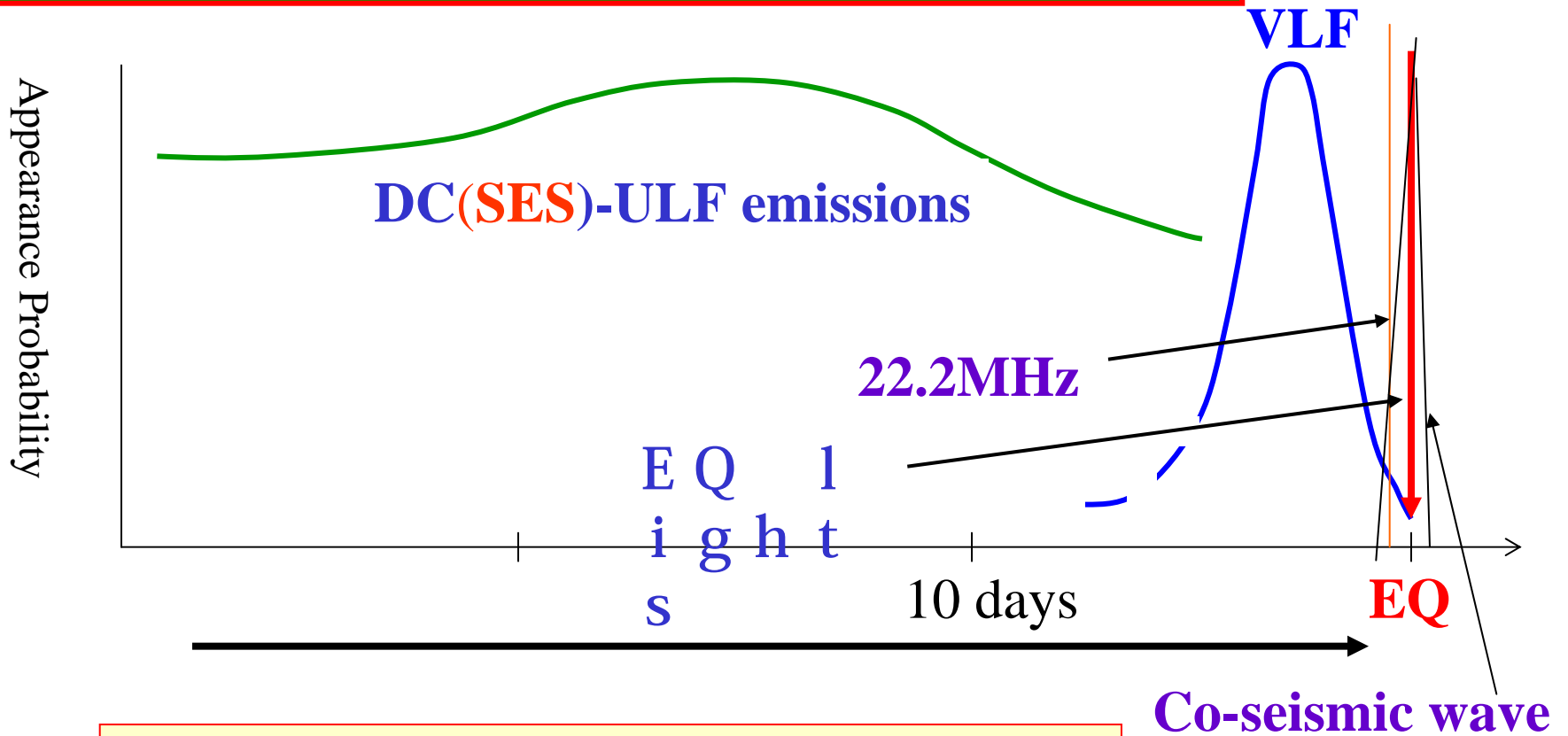
All observed “co-seismic” signals are **co-seismic wave**. Not true **co-seismic** signals.

Lab. Fracture Experiments

High freq. EM waves at fracture. **True co-fracture** signals! They **should still be observed** because fracture of large EQ lasts long (~10 sec).

Only possibility: EQ is not fracture, but sliding of faults which may not generate even high freq. EM waves.

Conceptual view on Seismo-EM Emissions



**Deformation/micro cracking →
Ground water/gas/electrokinetic events**

VLF emission

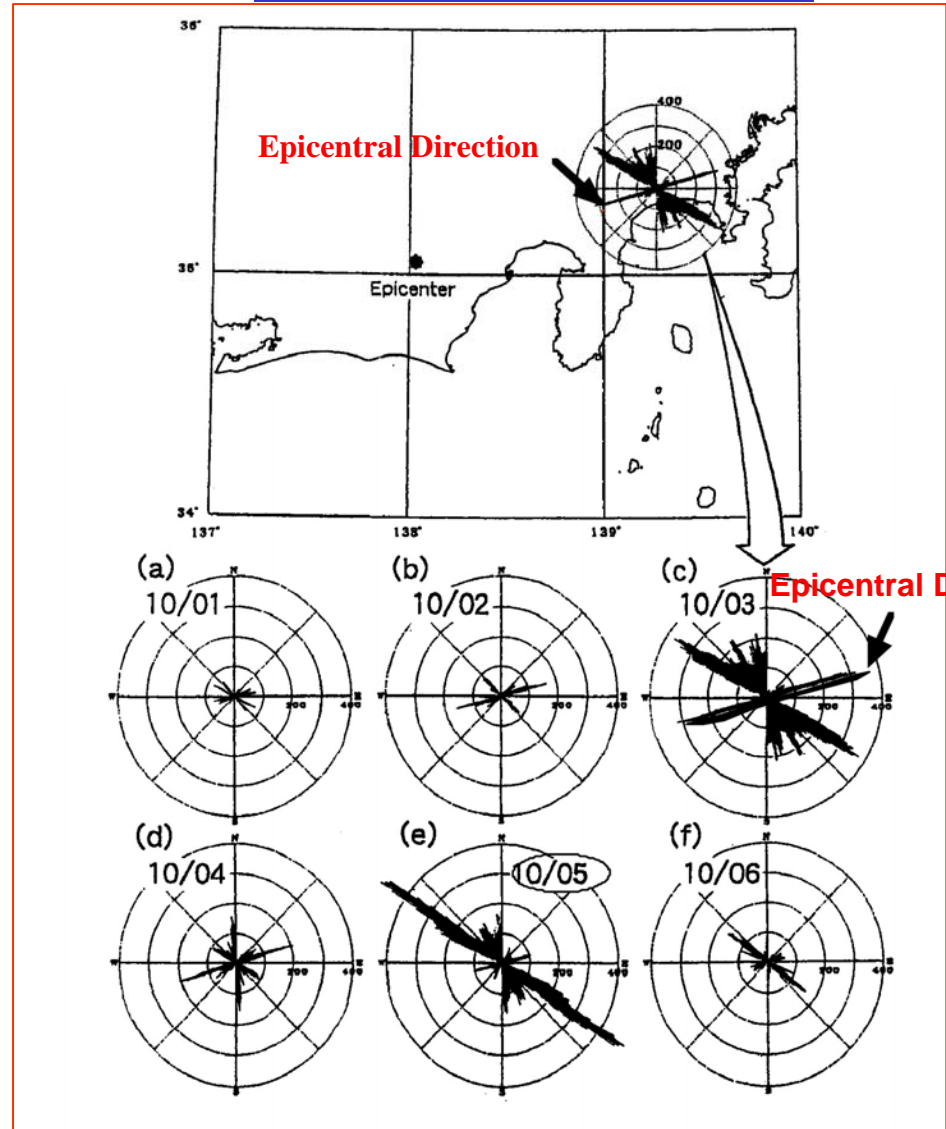
VLF direction finding
(Asada & Baba)

Appear from several days before nearby (<100 km) on land EQ(M>4.5).

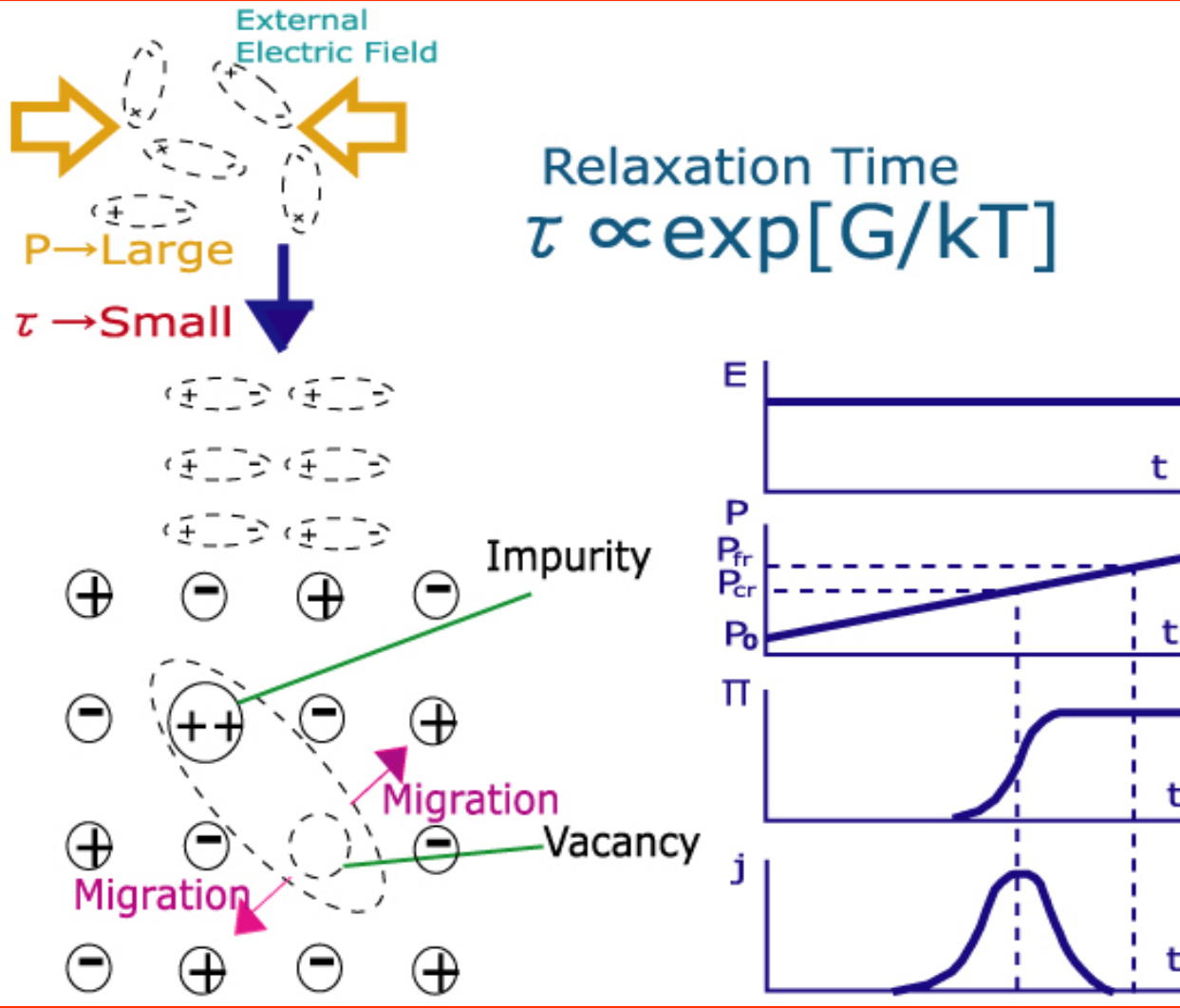
Lightning source moves, while Signal stays.

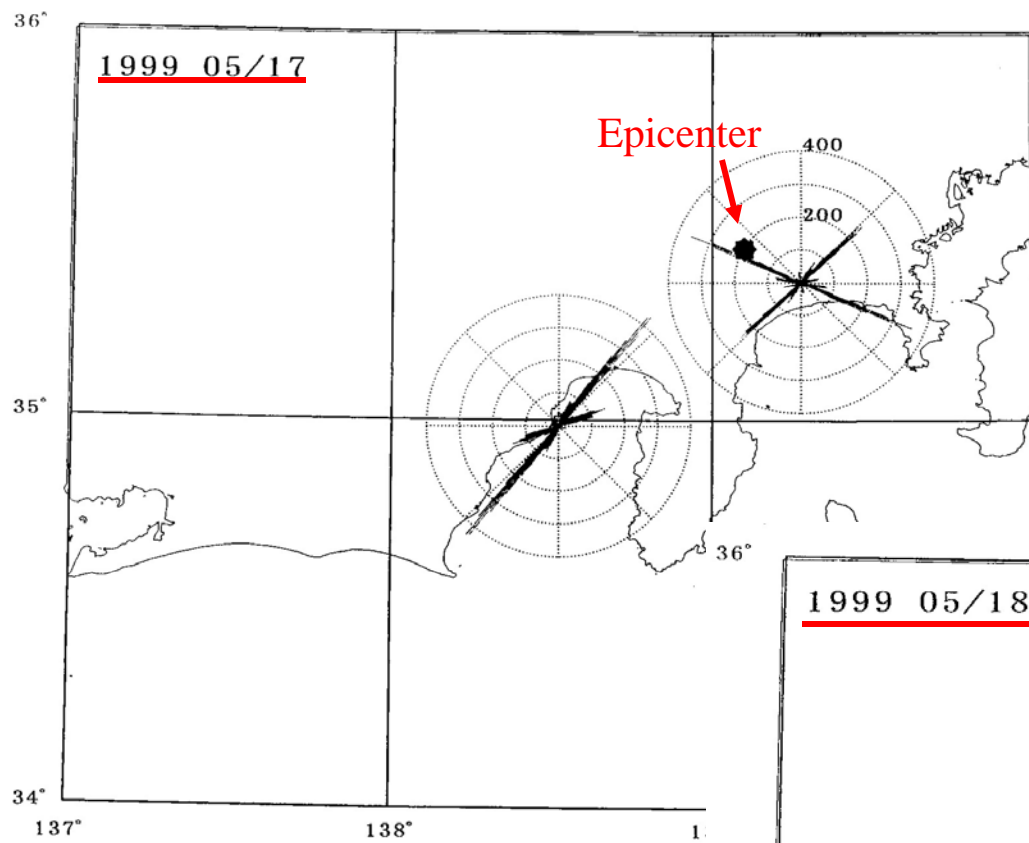
All LF -> lightning (Oike & Izutsu)

EQ961005, M4.4



Pressure Stimulated Polarization Current (Varotsos)



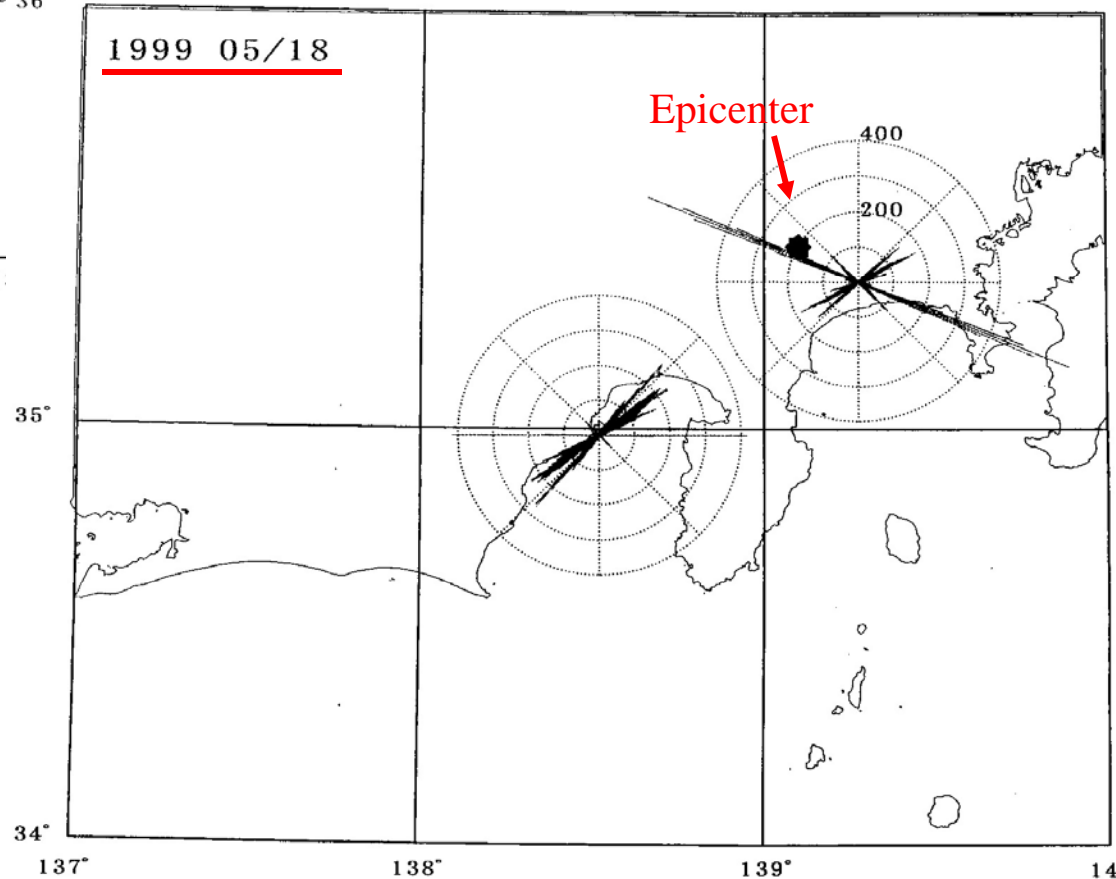


EQ990522

M4.4, D=20km

No-coseismic !!

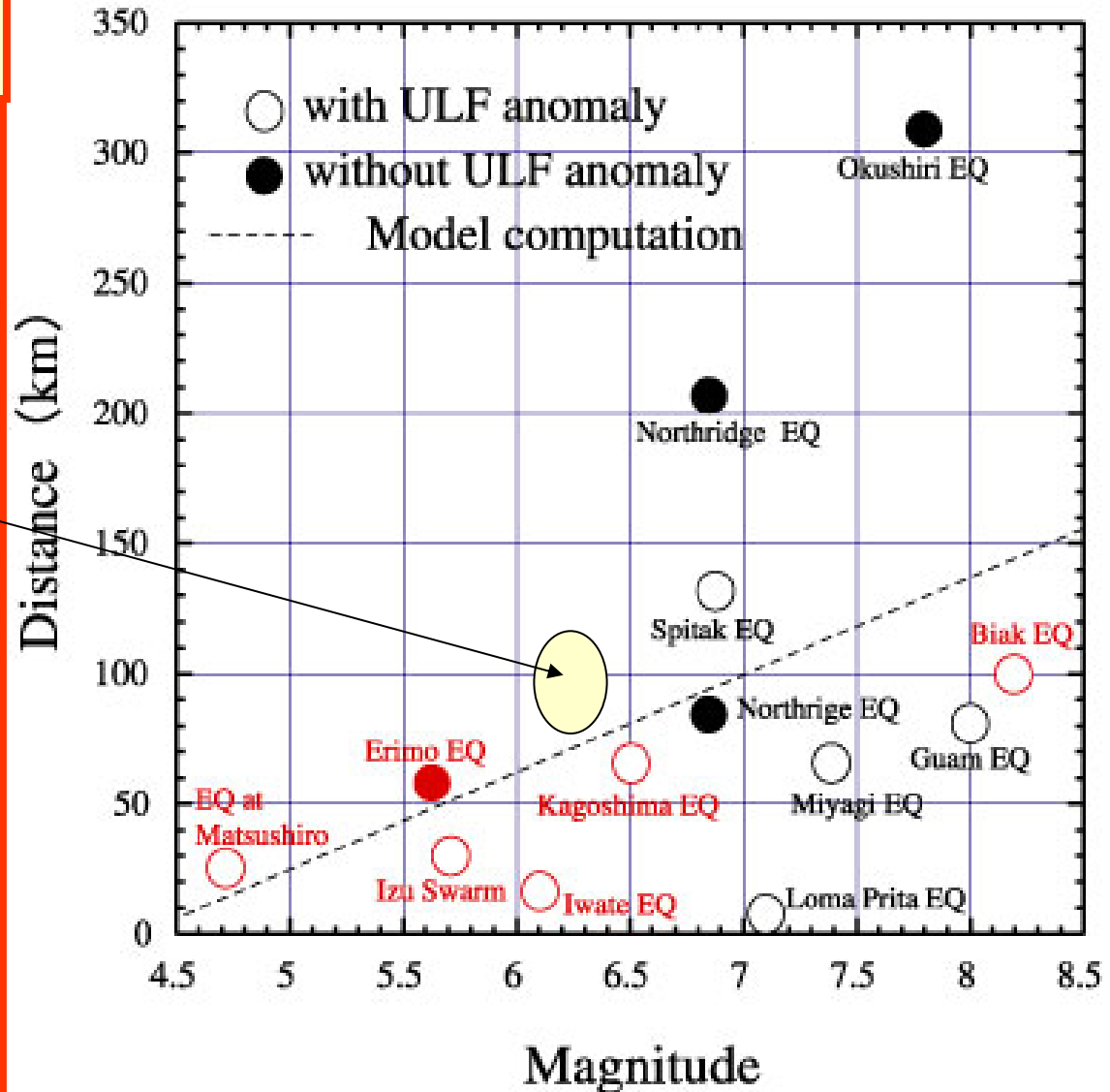
Baba, Asada et al.



ULF
summary
H a t t o r i

Izu 2000

ULF activity relationship between distance and magnitude



Physical mechanism of Seismo-EM

Generation

Transmission

DC ULF

Solid state,
Electro-kinetic

Conductive channel

EM wave

Piezo-E., Exo-E.

Conductive earth

Skin depth

(kHz-MHz)

LAI coupling

Ionospheric

(Wave anomaly,
Ion density)

Electric, Dynamic, Chemical

FAQ 1

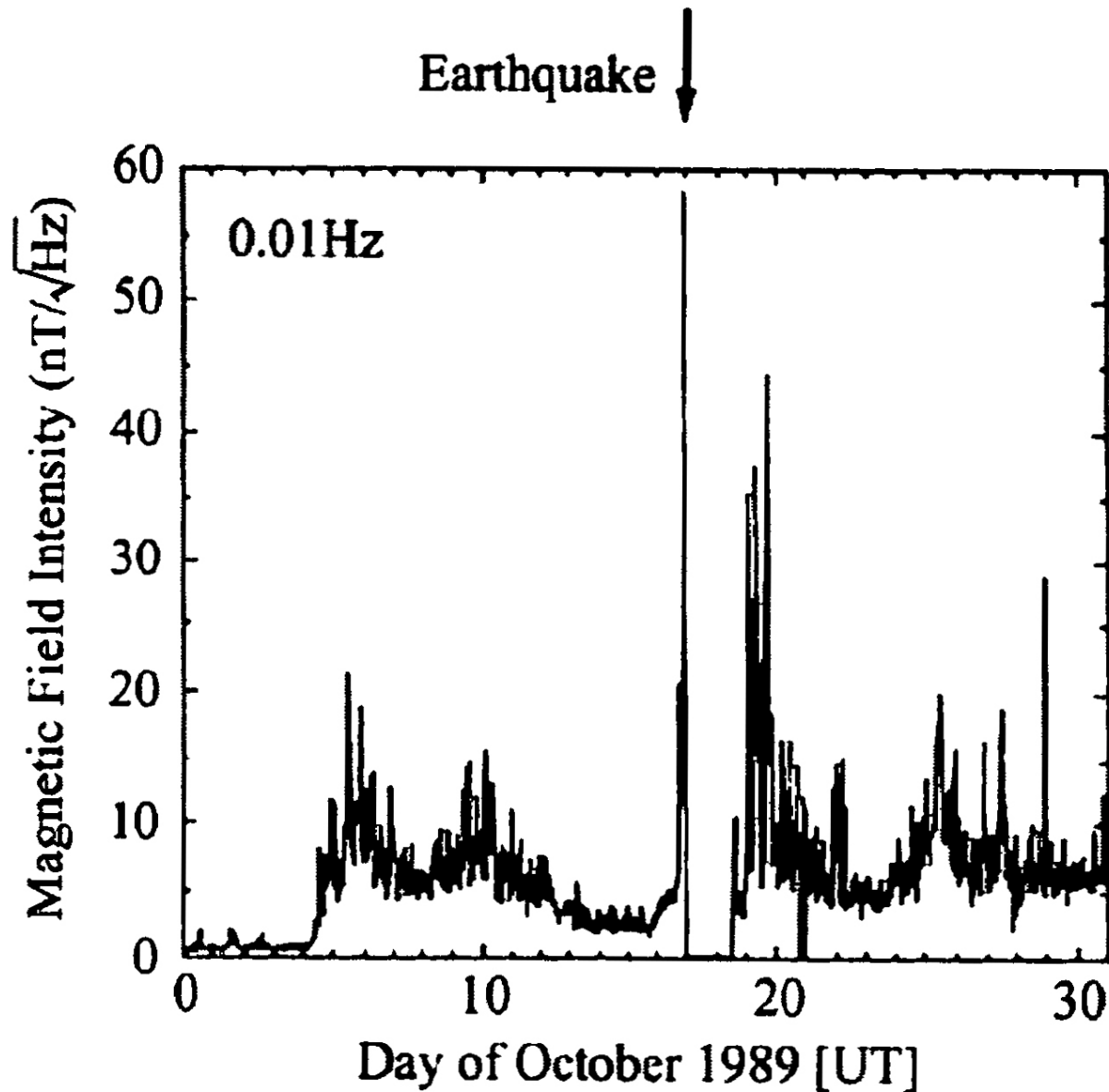
**Why pre-seismic only?
Why not co-seismic?**

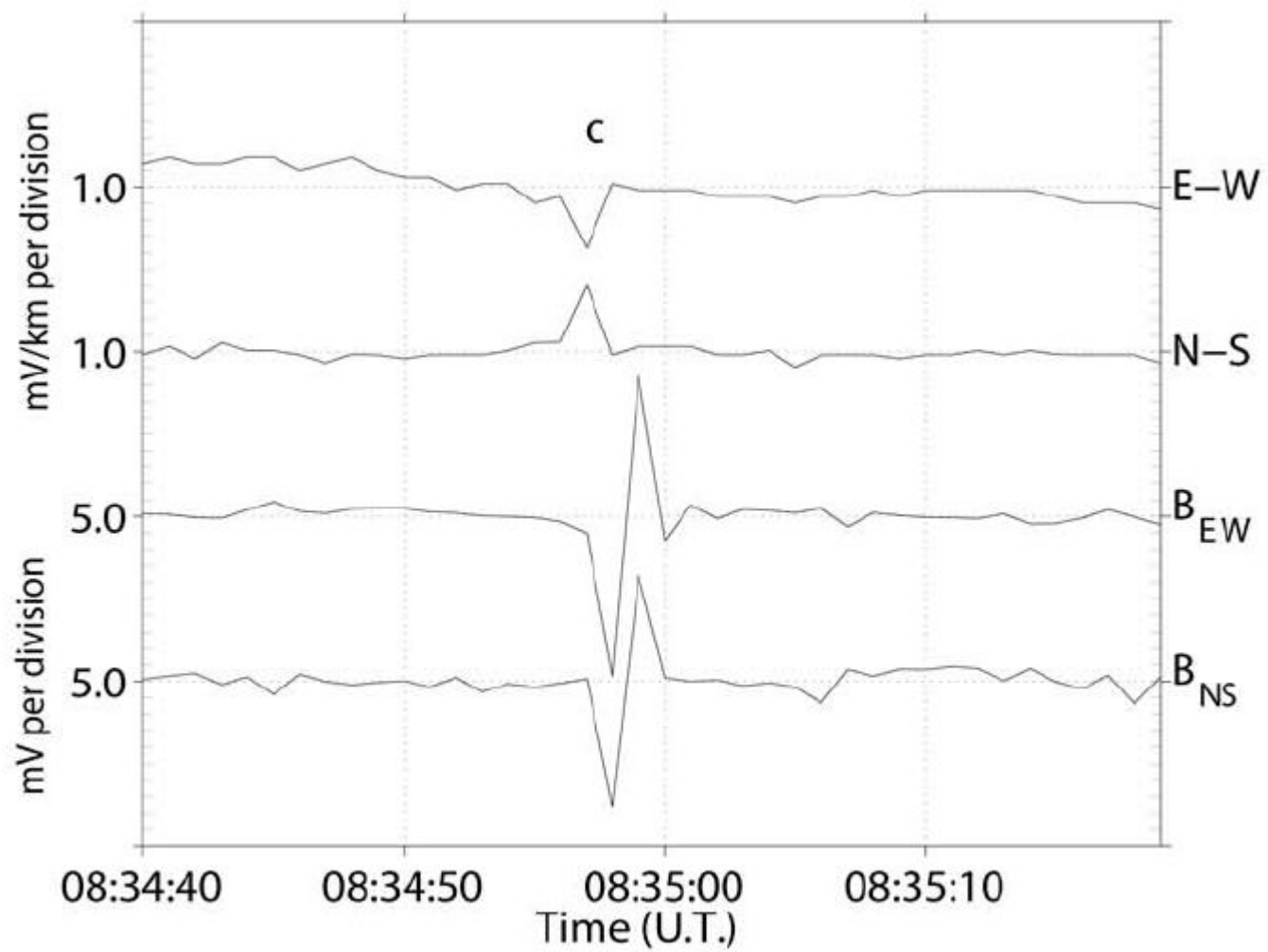
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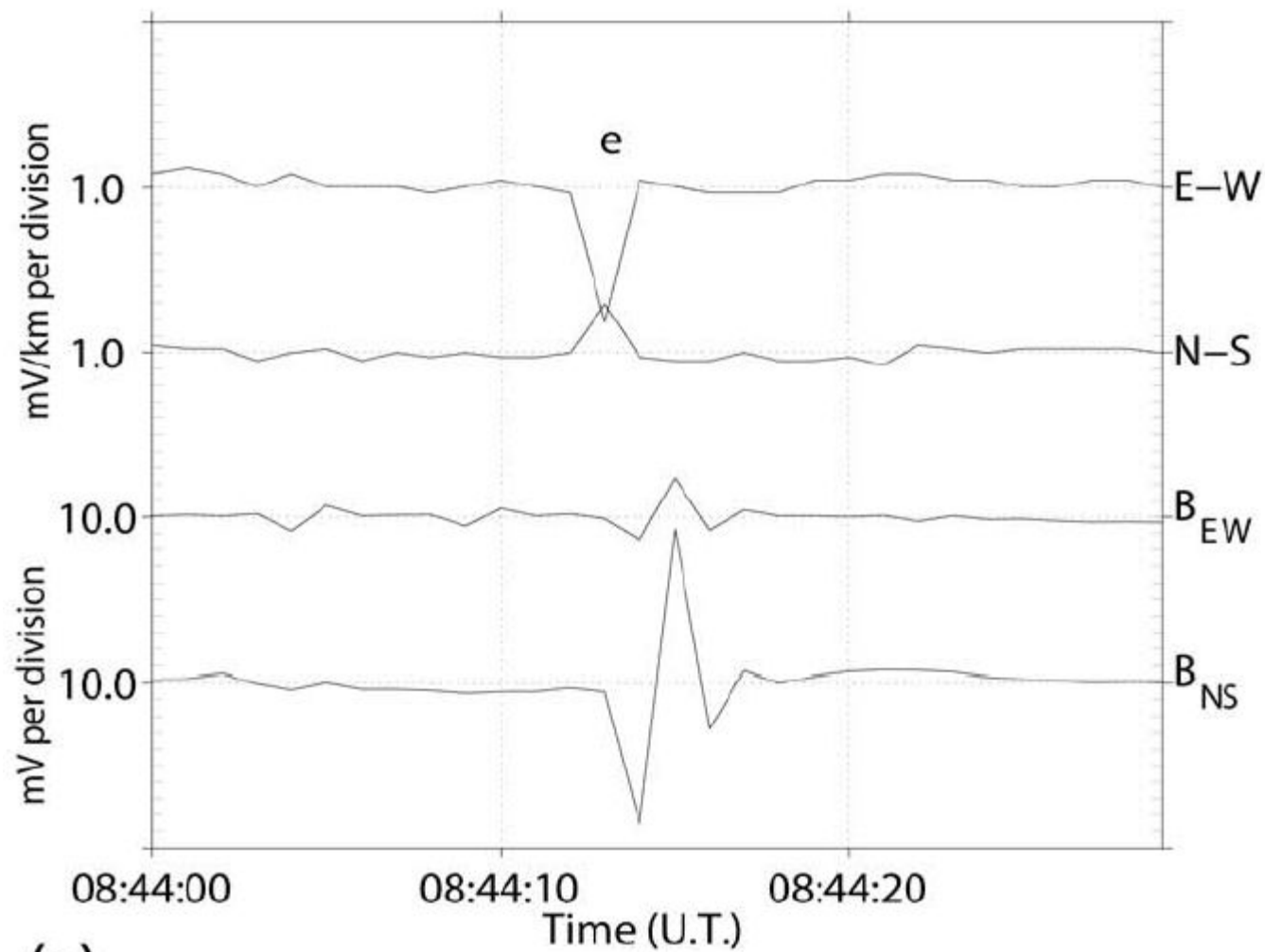
Only possibility: EQ is not fracture, but sliding of faults which may not generate even high freq. EM waves.

U L F 帯における前駆的地磁気変動 ロマプリータ地震の場合

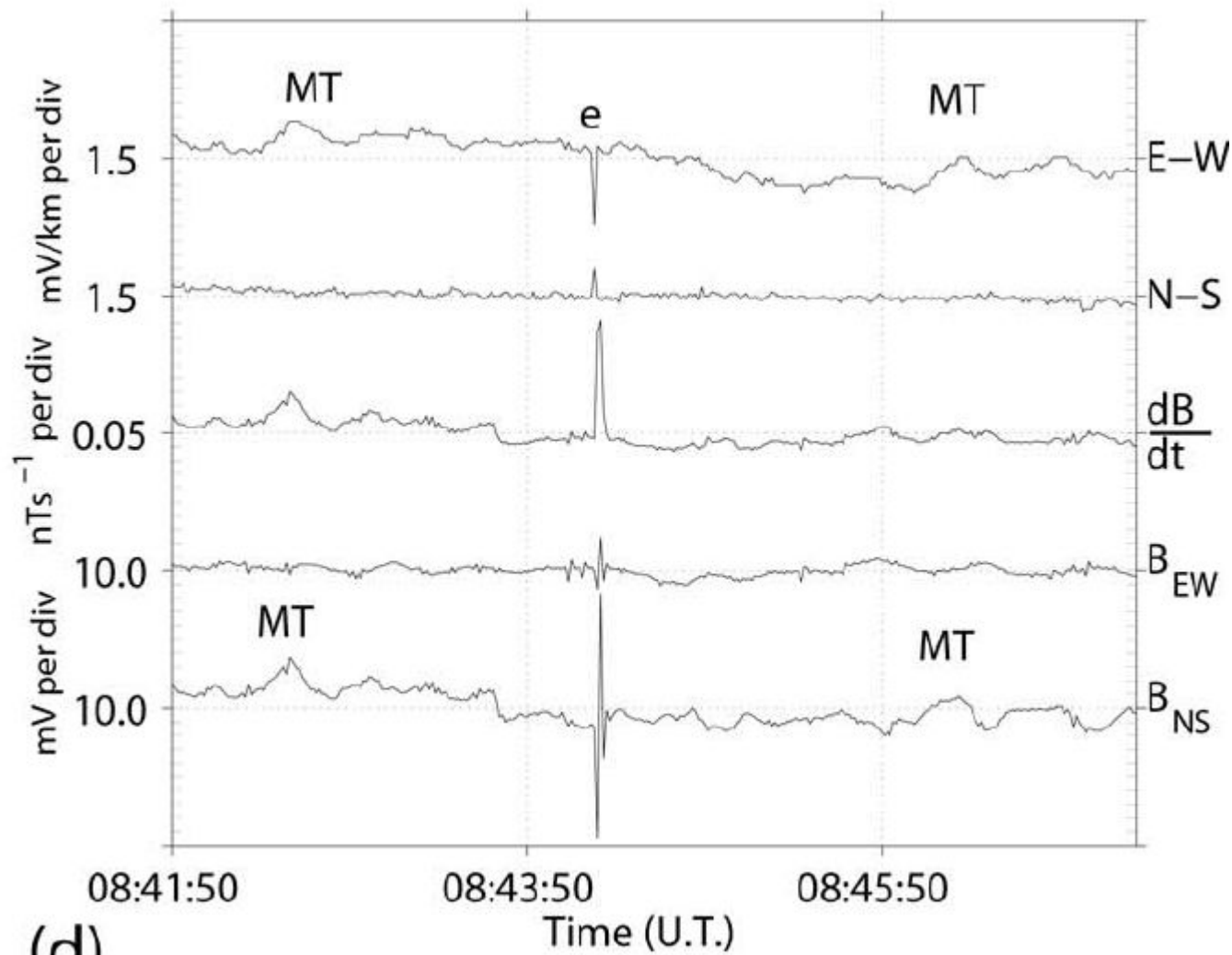


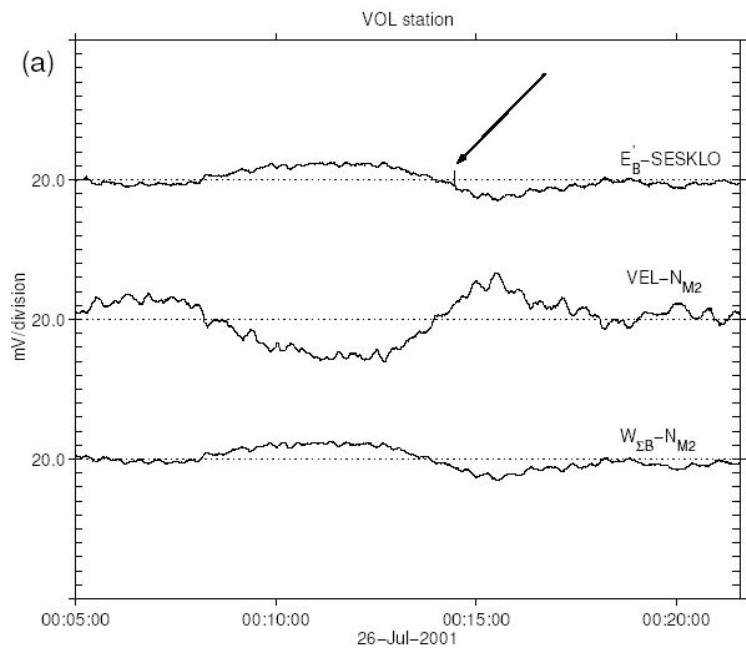


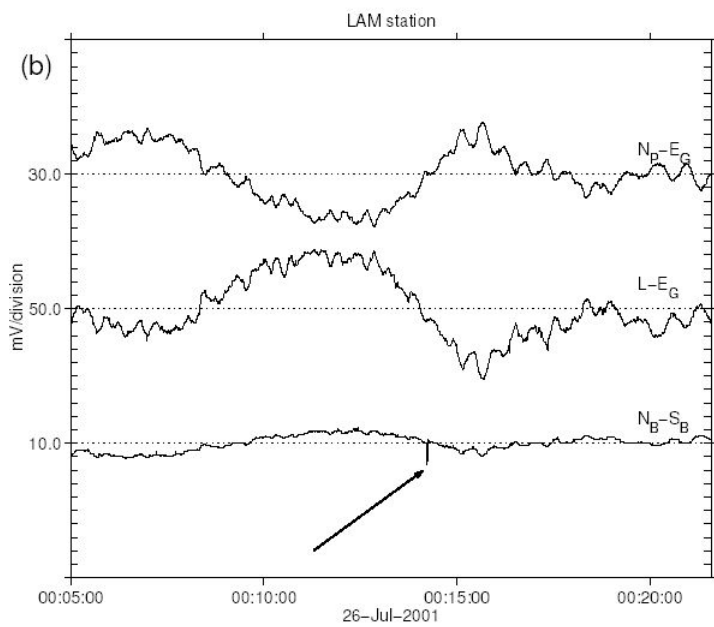
(b)

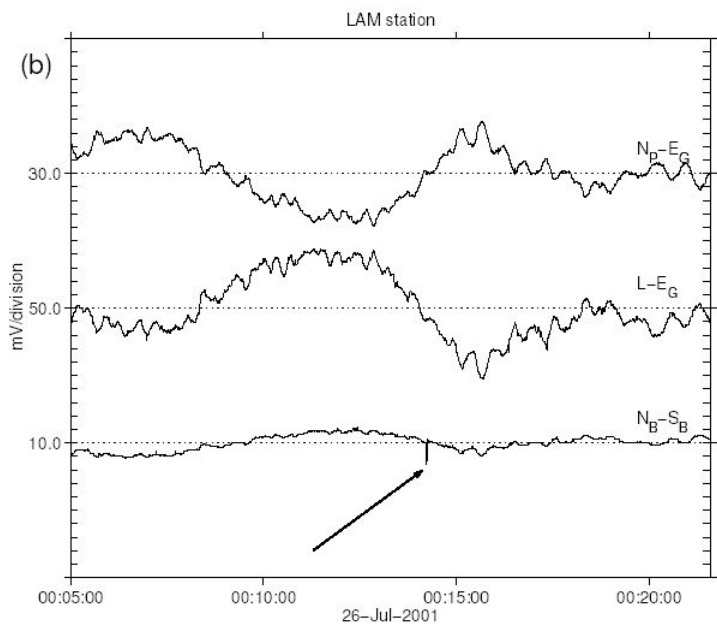


(c)









In summary

- 1) Short-term EQ prediction needs **non-seismic precursors**.
- 2) Despite progress in non-seismic precursor research in the last ~20 years, it is still far from general recognition. **Why?**

A) Walls of prejudice, disinterest, and vested interests.
Lack of “home-run” observations, which are difficult.

B) **Fundamental problems unresolved.**

Pre-seismic signals only?

Transmission in conducting earth

LAI-coupling etc

未解決の根本的問題

- 本当に**地下から**到来する電磁シグナルが存在するか？
- なぜ本震発生時にシグナルが観測されないのか？
最大の応力降下は本震発生時
なぜ電磁気シグナルは**前駆的**なのか？
 - コサイスミックは高周波の現象だから ×
- なぜ（V L F 帯より高い）**高周波の電磁波**が観測されるのか？
 - スキンデプスの問題
- 地震電磁現象発現メカニズムは？
仮説は多数提案されているが、現実的なパラメータを当てはめると．．．