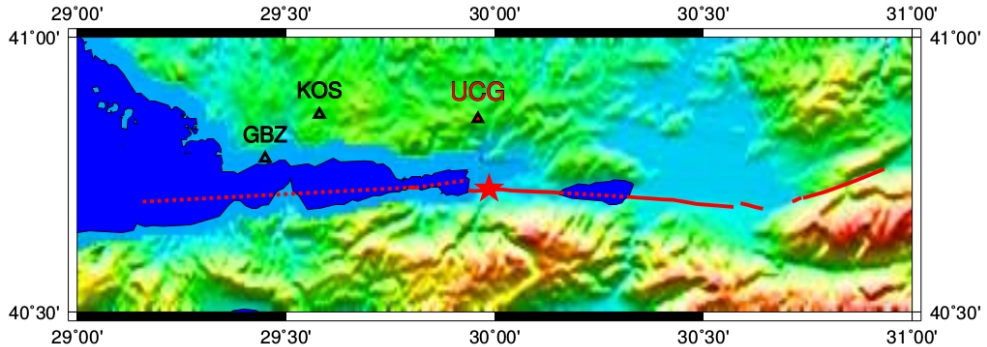
Articles: Bouchon et al. (2011) and Ellsworth et al. (2018)

Pre-slip or cascading earthquakes model for M_w7.6 1999 Izmit earthquake?

Hugo S. Sánchez-Reyes

ISTerre, Université Grenoble Alpes



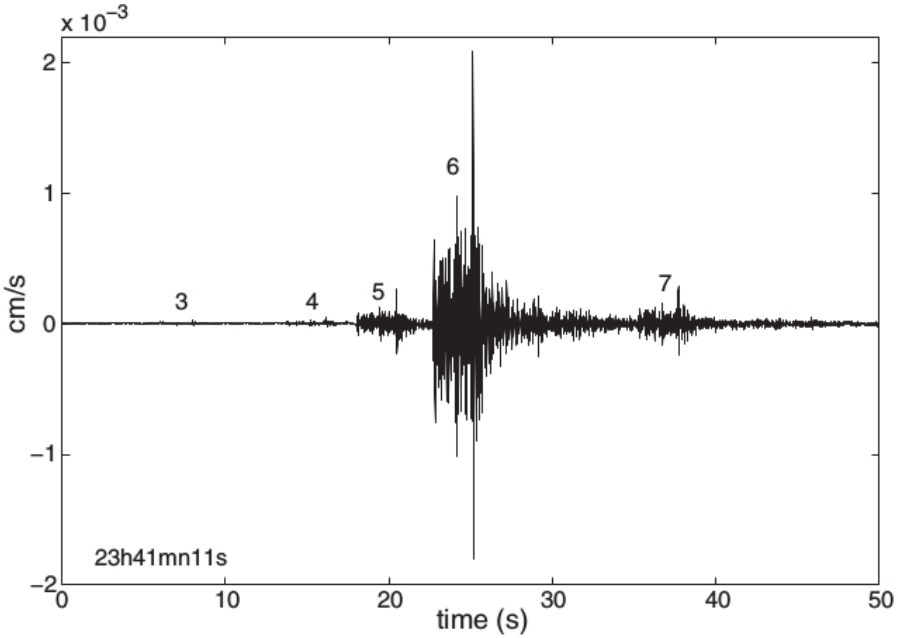
Outline

Bouchon et al. (2011): Pre-slip observations before the M_w7.6 1999 Izmit earthquake.

Waveform similirity: coincidence or same source?

All of the well-distinguished events share nearly the same waveforms:

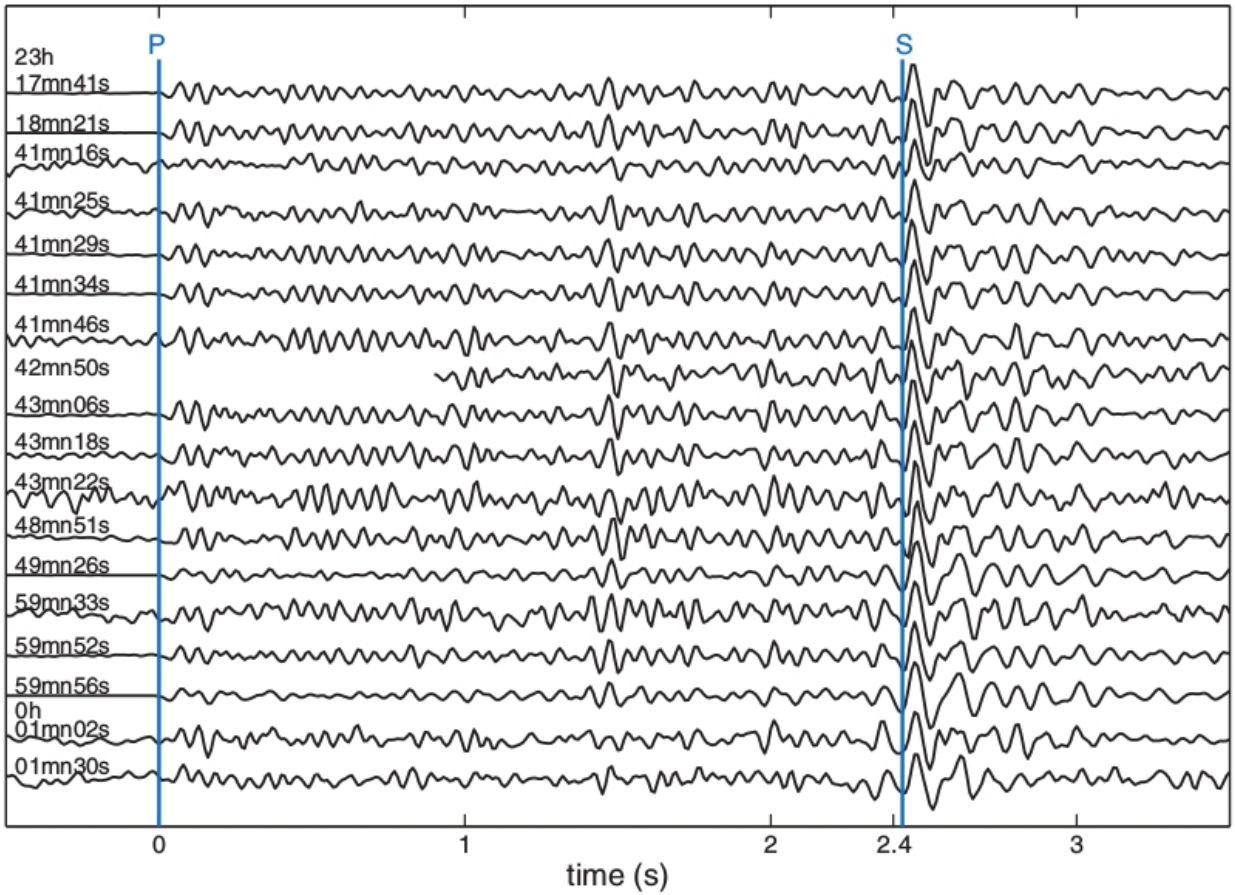
- 7 foreshocks well identified with a receiver $<$14 km epicenter offset.
- $\approx$ 40 events were found using cross-correlation with a template.



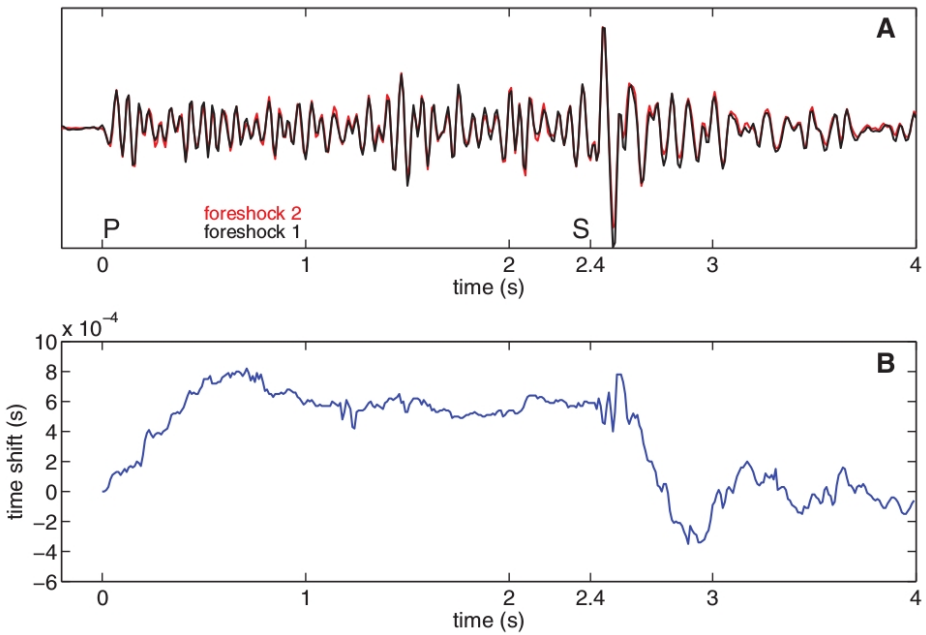
18 foreshocks visually identified

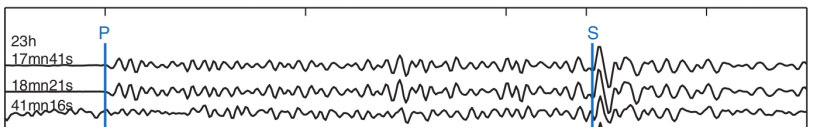
Surprising features:

- S-minus-P traveltime of 2.4 (s).
- Some of them separated by 5 (s) between them.
- Magnitudes ranging from $[0.3, 2.7]$.
- Very similar waveforms.



Other similarities?





Cross-correlating the 1st and 2nd foreshocks:

- S-minus-P travel times differ $\approx$ 0.0006 s.
- $\approx$ 5 m distance from one each other.

The distance of $\approx$ 5 m is not between the sources but the projection of the source distance projected to the ray path.

Why they are so similar?

Applying the same cross-correlation analysis for all the possible P and S couples:

Any of the events differs in S-minus-P travel time by less than 0.0024 s from the majority of the other events

This implies that any one shock is located within 20 m or less from the majority of the other events.

40 m

$\longrightarrow$ **All of the events originate from an area of the fault that is no larger than the size of the largest events.**

Activity accelerated

How?

- 4^{th} largest event occurred 43 min before the mainshock
- 3^{th} largest event occurred 20 min before the mainshock
- 2^{nd} largest event occurred 12 min before the mainshock
- 1^{st} largest event occurred 1 min 45 s before the mainshock

Acceleration increase again 1 min before the earthquake:

- One shock occurred 0.14 s before the mainshock (magnitude $\approx$2.0).
- Another shocked 0.07 s later (P-pulse bigger than previous ones).

Questions related to the acceleration

Magnitude is not increasing in that critical one minute before??
but in the others yes??

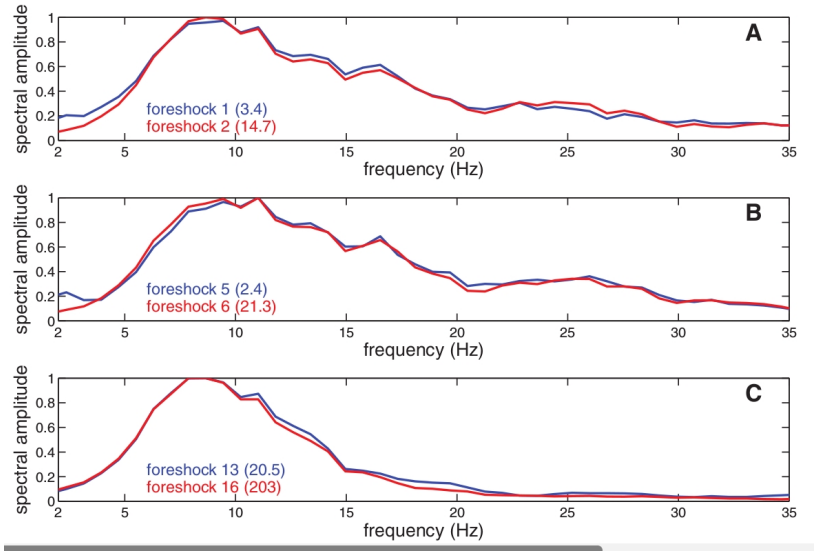
why we can not see this phenomena for other earthquakes??
there are receivers closer than 14 km nowadays!

Why do they look so similar:

Their spectral corner frequencies is higher than the maximum frequency displayed (35 Hz):
(seen as false point sources)

Or, the two events may have nearly the same corner frequencies, because spectral amplitude drops off rapidly beyond an event corner frequency.

Same patch, same length ($\approx$ 300 m) but different slip:
1st a little less than 1 cm (0.8 cm)
2nd a little less than 1 mm (0.8 mm)
1st stress drop of 2.6 MPa
2nd stress drop of 0.3 MPa



(A to C) Comparison of the S-wave ground-velocity spectra of some events. The peak recorded amplitude of each event is given in parenthesis and is expressed in micrometers per second.

Creep loading surrounding areas?

Repetive earthquake due to creep:

They usually have recurrent times of months or years and similar magnitudes.

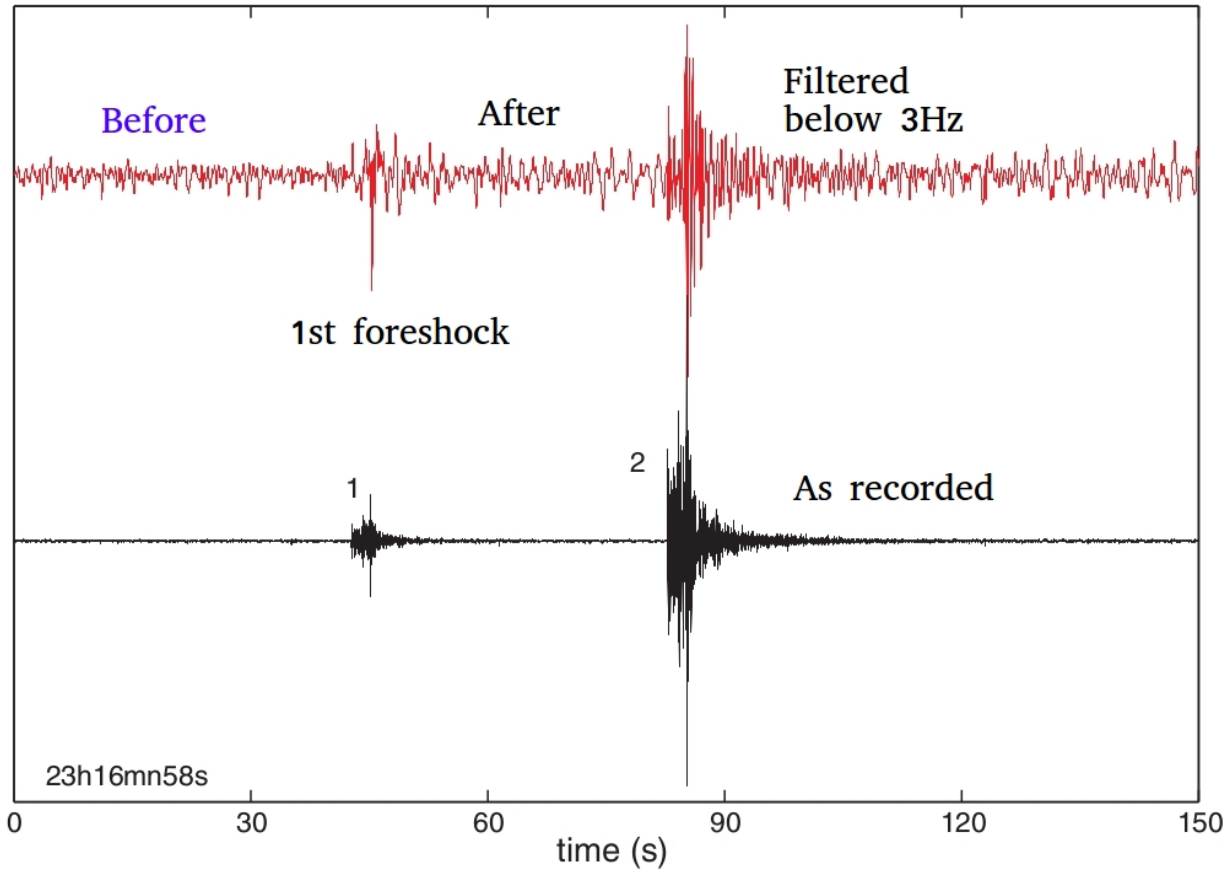
In this case, separated by minutes!

A possible reason for the magnitude difference observed here is that the interevent time of the pre-Izmit shocks is extremely short, possibly forcing the response of the patch.

patch responds not only to the loading but also to the loading rate, which may be highly irregular.

Creep signature in the background noise?

After first the foreshock, the seismic gound motion content at low-frequencies increased significantly. **Its energy is at least below 2Hz.**



No location can be provided for this increase in the low-frequency content.

Hypothesis: Maybe it is the signature of the creep happening around the hypocentral area.

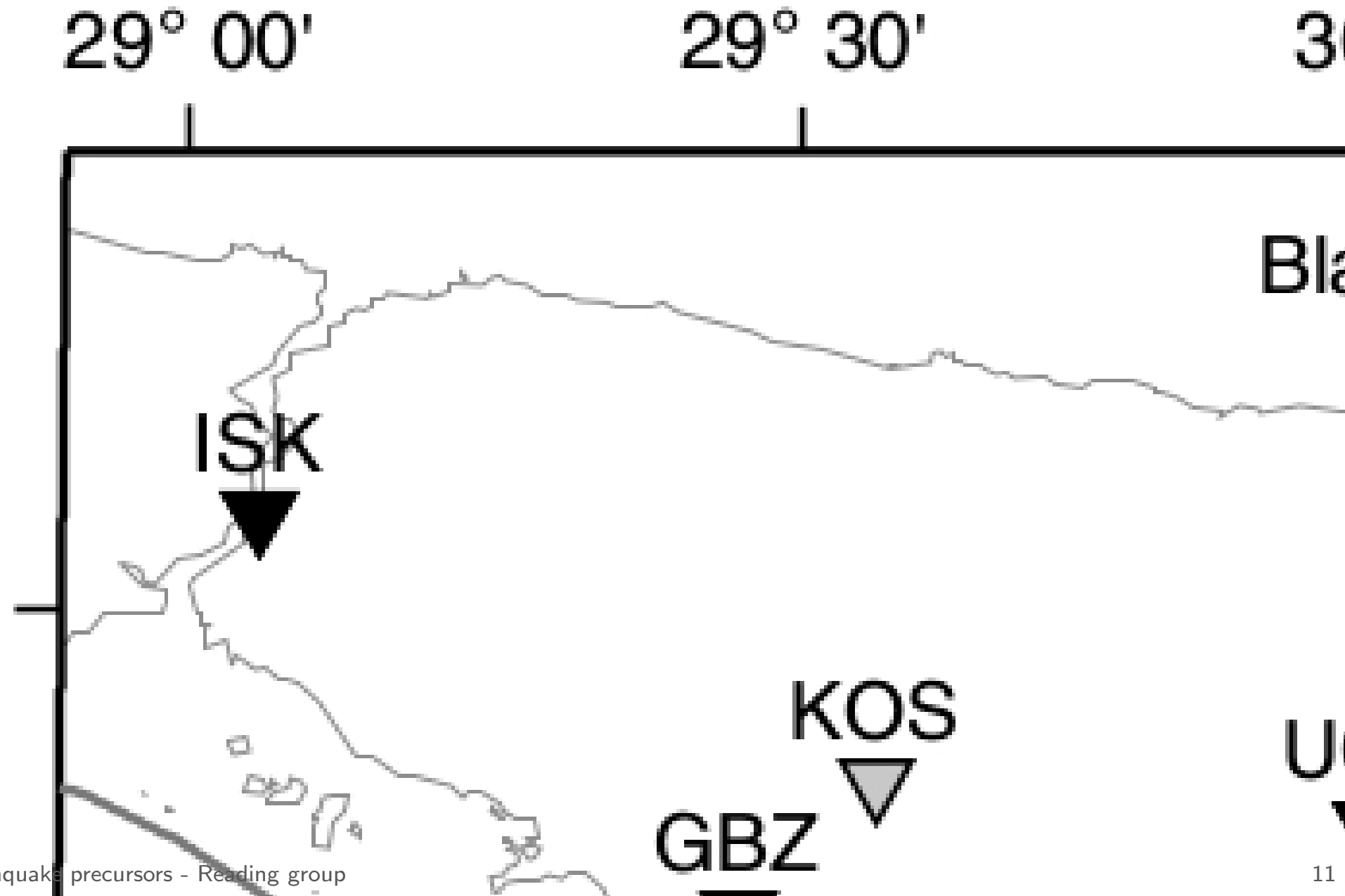
Summary

These observations show that this particular earthquake was preceded by a phase of slow slip occurring at the base of the brittle crust.

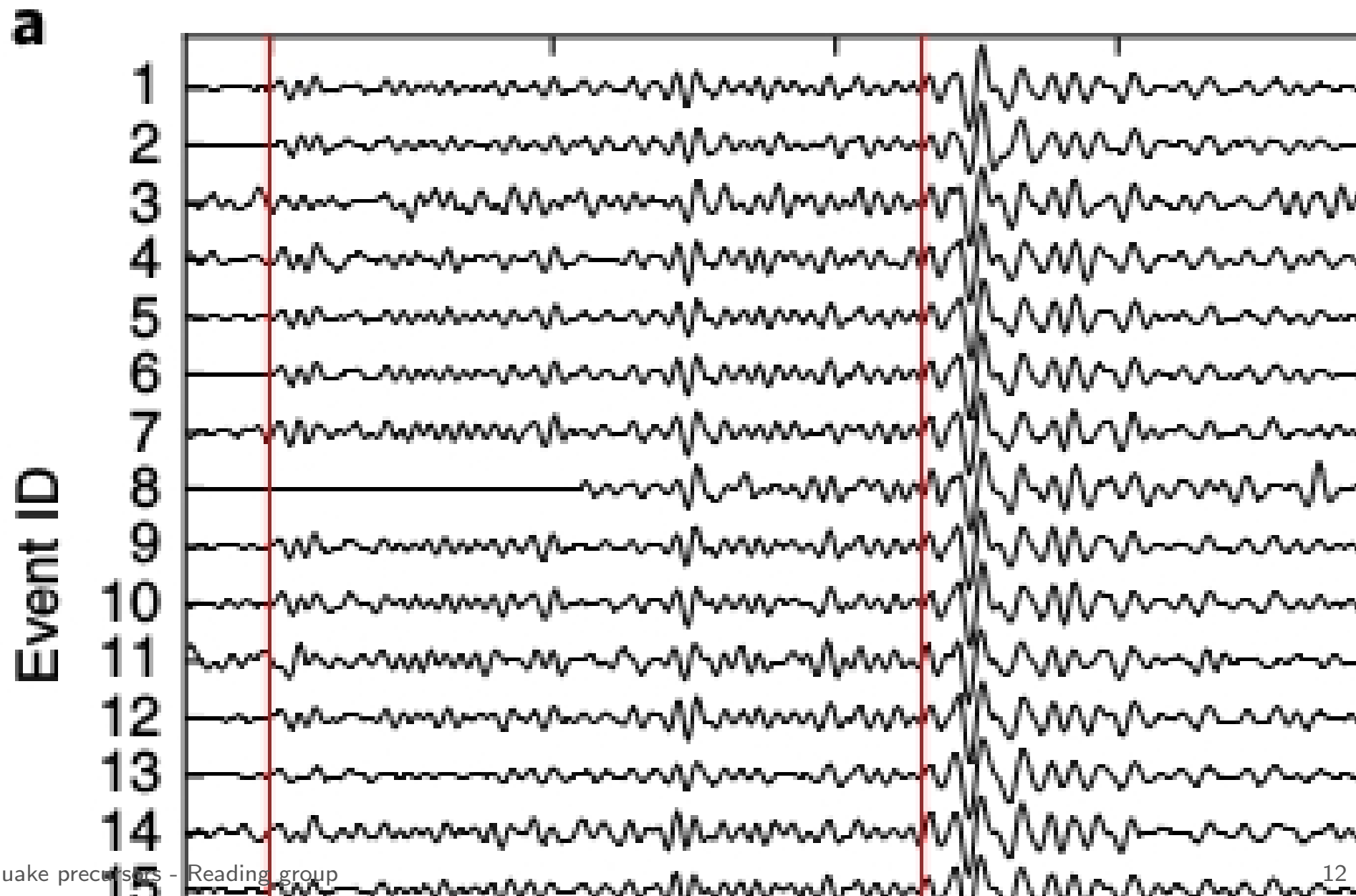
This observations (long duration nucleation phase) and similarity between foreshocks and mainshock are encouraging for early-warning systems...

but

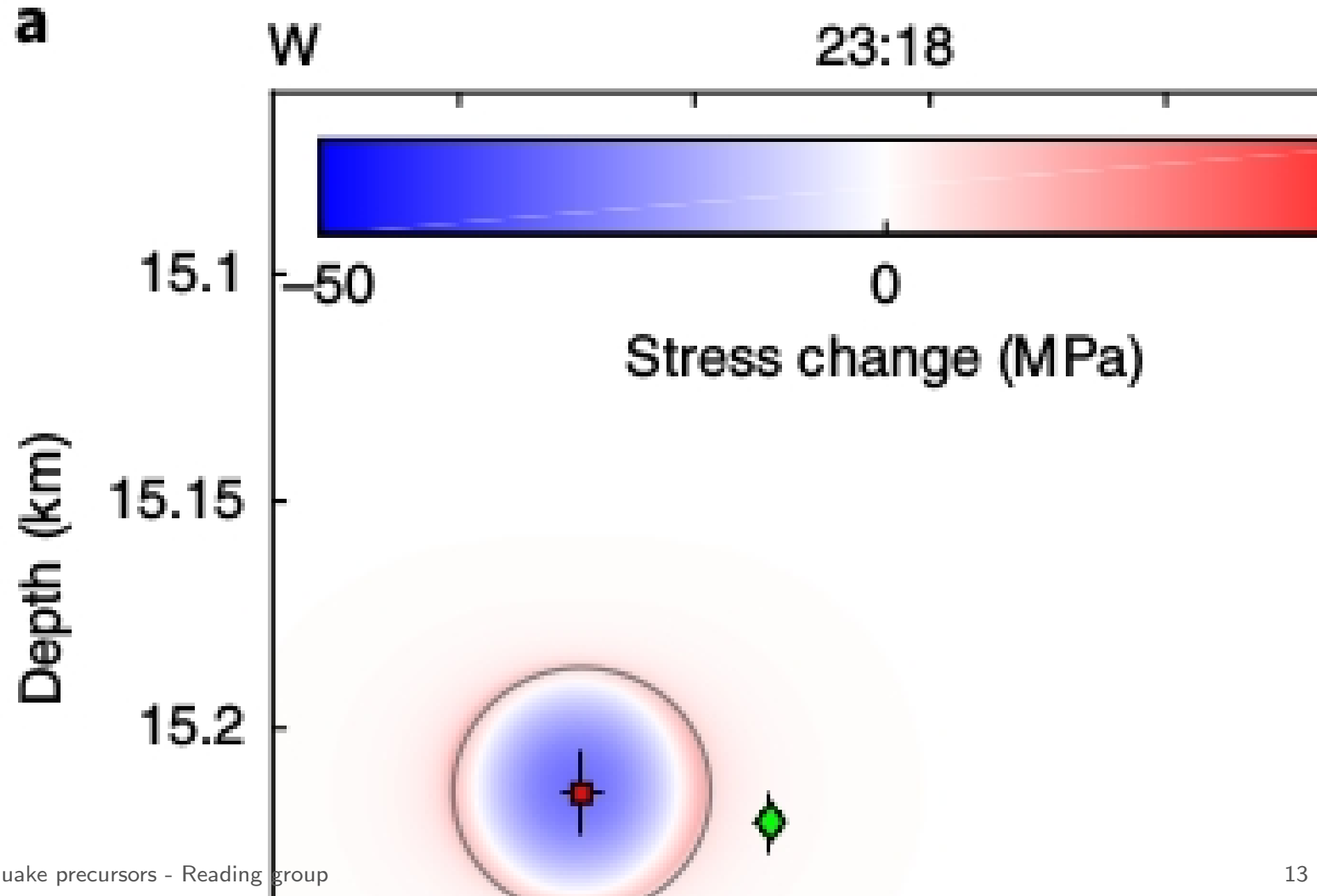
other well-recorded earthquakes, 1999 Chi-Chi (Taiwan) or 2004 Parkfield (California), o not show evidence for similar foreshocks or nucleation events.

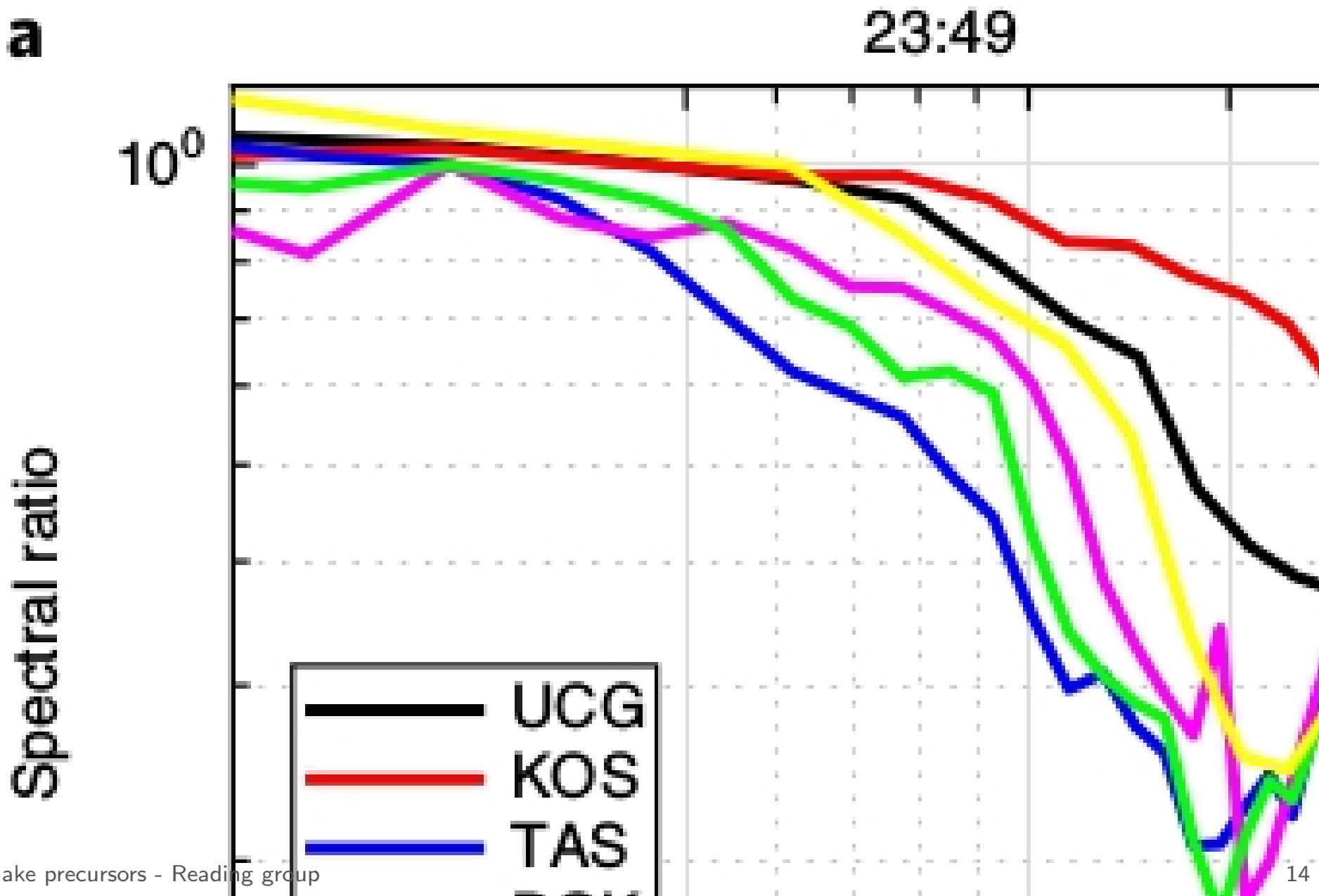

29° 00'
29° 30'
ISK
KOS
GBZ

Summary



Summary




a
23:49
10^0
Spectral ratio
UCG
KOS
TAS