30.10.2018 Precursory earthquake reading group

Propagation of Slow Slip Leading Up to the 2011 M_W 9.0 Tohoku-Oki Earthquake

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Propose：Understanding earthquake nucleation processes

Tools：Foreshock sequence

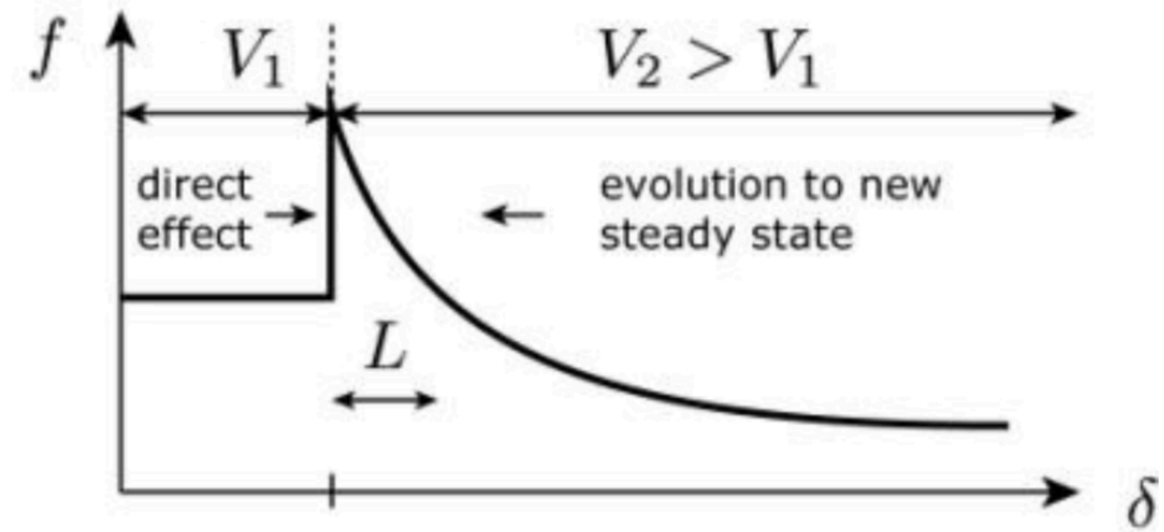
Methods：Matched-filter technique

Results：Two distinct foreshock sequences are identified. One starts 24 days before Mw7.3 foreshock, another one is the Mw7.3 foreshock sequence.

Wei Peng

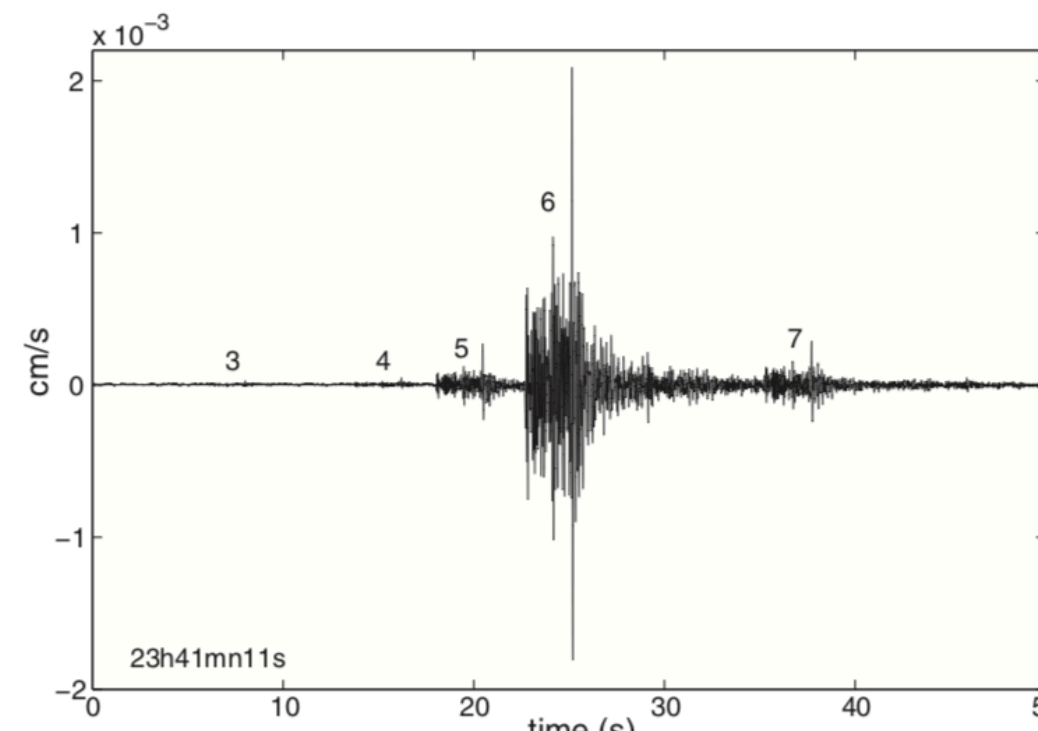
Background knowledge (assumption) of earthquake nucleation in this paper

Rate/state friction law. Earthquakes are preceded by a nucleation process where stable, slow rupture growth develops into unstable, high-speed rupture within a confined zone on a fault.



Lapusta and Barbo 2012

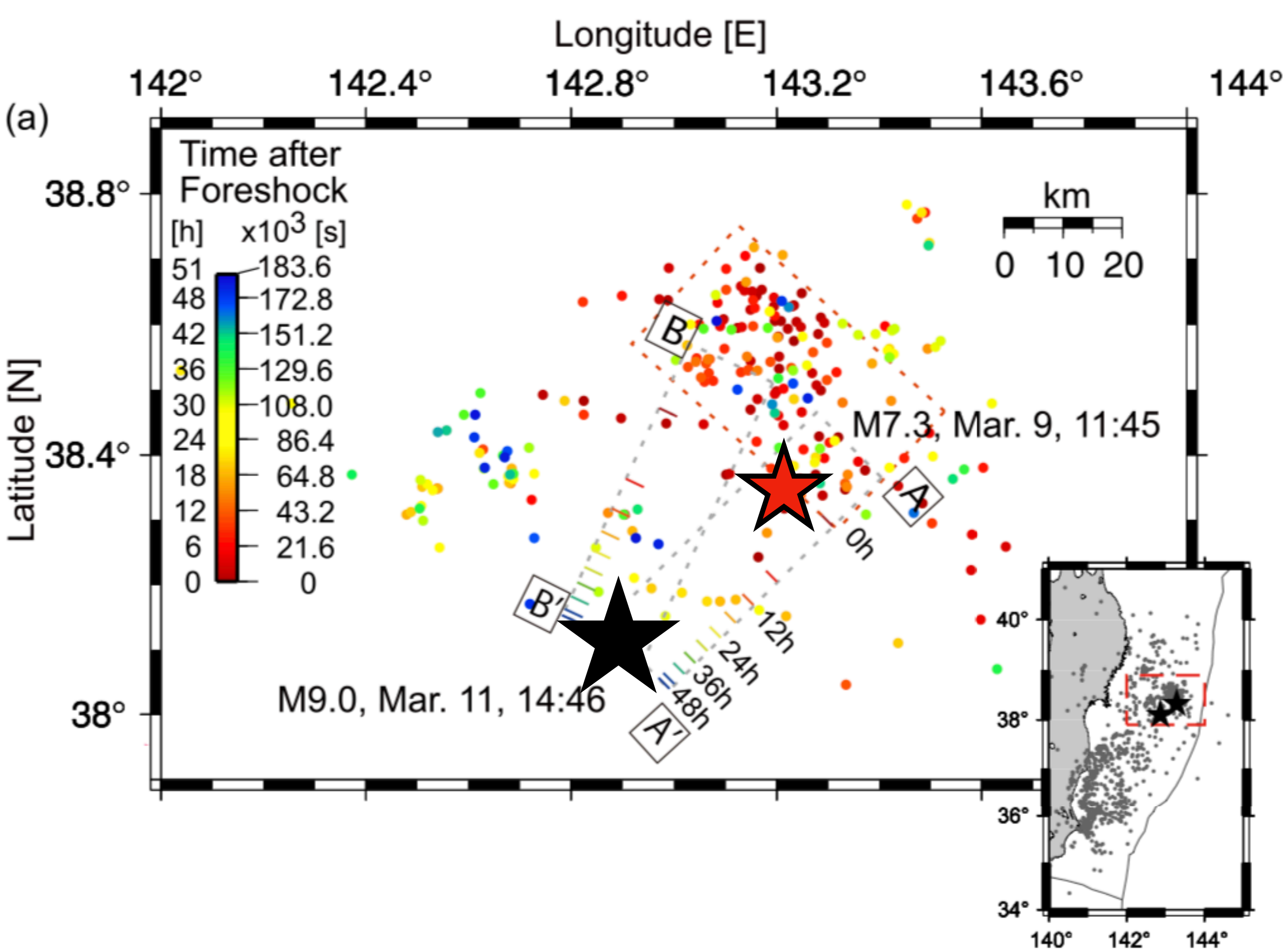
How dose the nucleation process observed on the seismicity ?
association with the occurrence of fore-shocks near the mainshock hypocenters and the presence of short-duration initial phases records of some earthquake events .

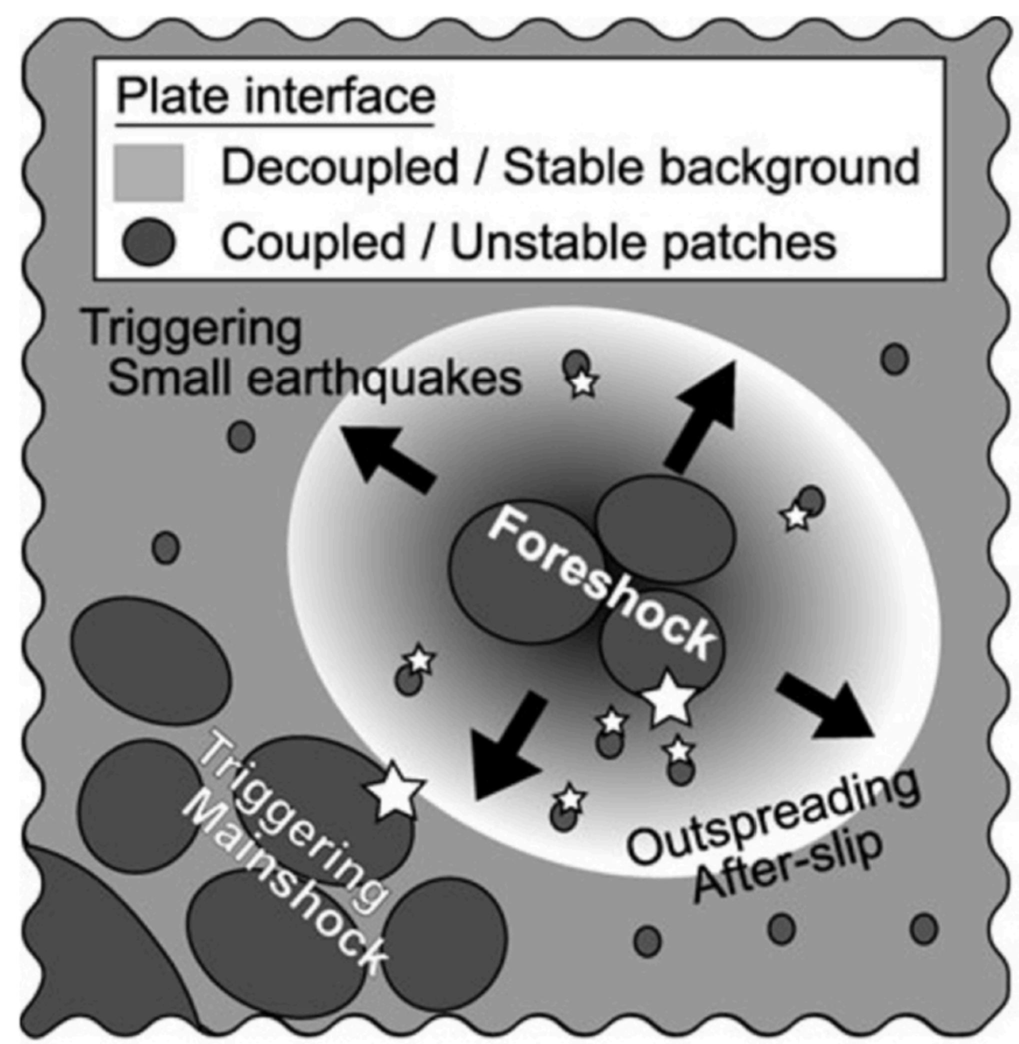


Bouchon et al., 2011

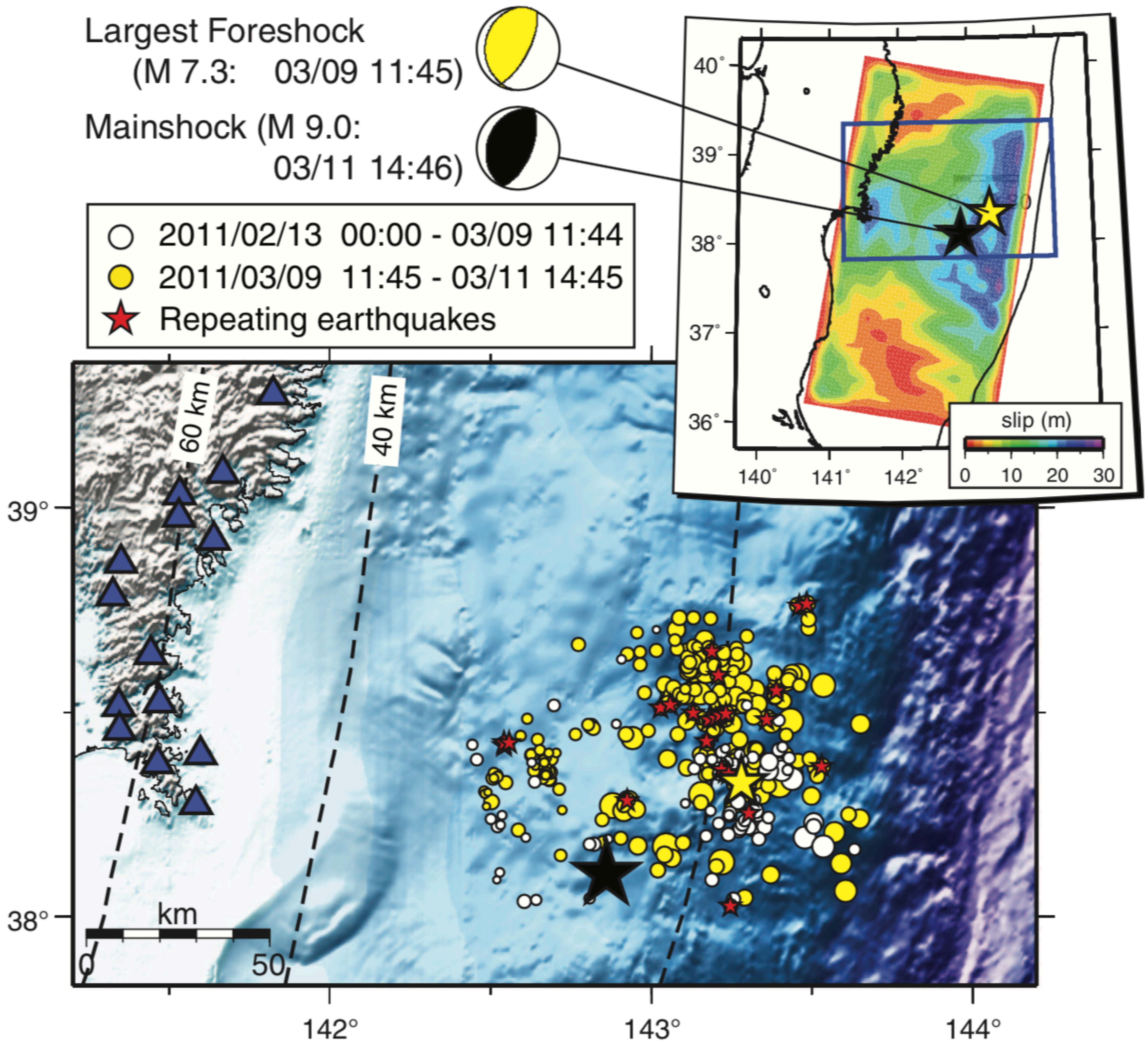
Tohoku M9 earthquake

1. First recorded M9 event by a dense network of continuous and broad–frequency- range seismic stations.
2. Followed by M7.3 foreshock occurred 2 days before. The foreshock sequences occurred in proximity to the initiation point of the mainshock rupture and were located near the deepest end of the area of the largest cumulative coseismic slip.
3. After the Mw 7.3 foreshock, the seismicity from the JMA catalog appeared to migrate toward the mainshock epicenter, which was interpreted as a propagation of afterslip.





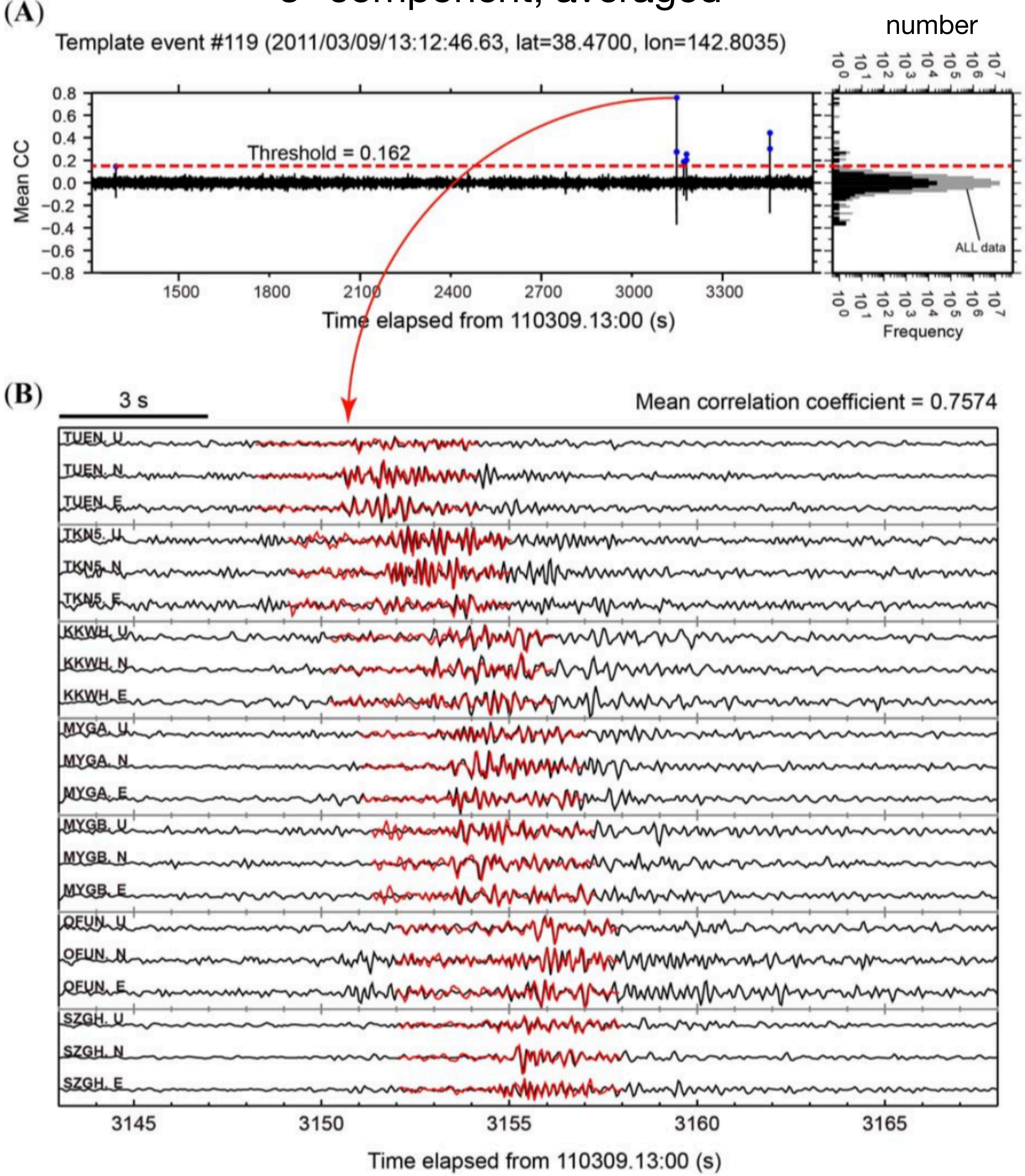
Ando and Imanishi 2011



Seismic data

1. 14 stations used.
2. Period : 13/02/2011 - 11/03/2011
3. Template events : 333 earthquakes occurred during the period in the JMA catalog

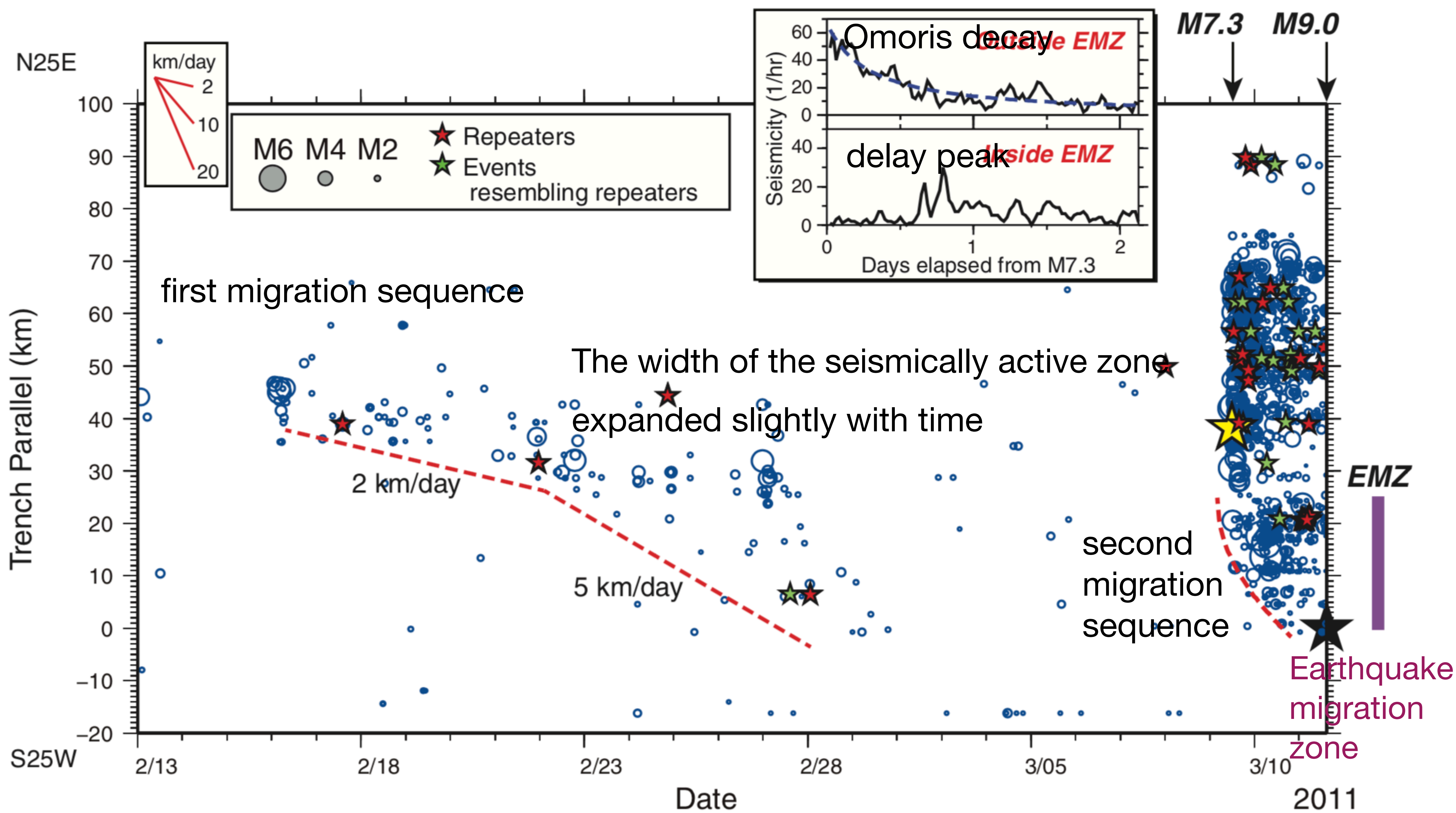
3- component, averaged



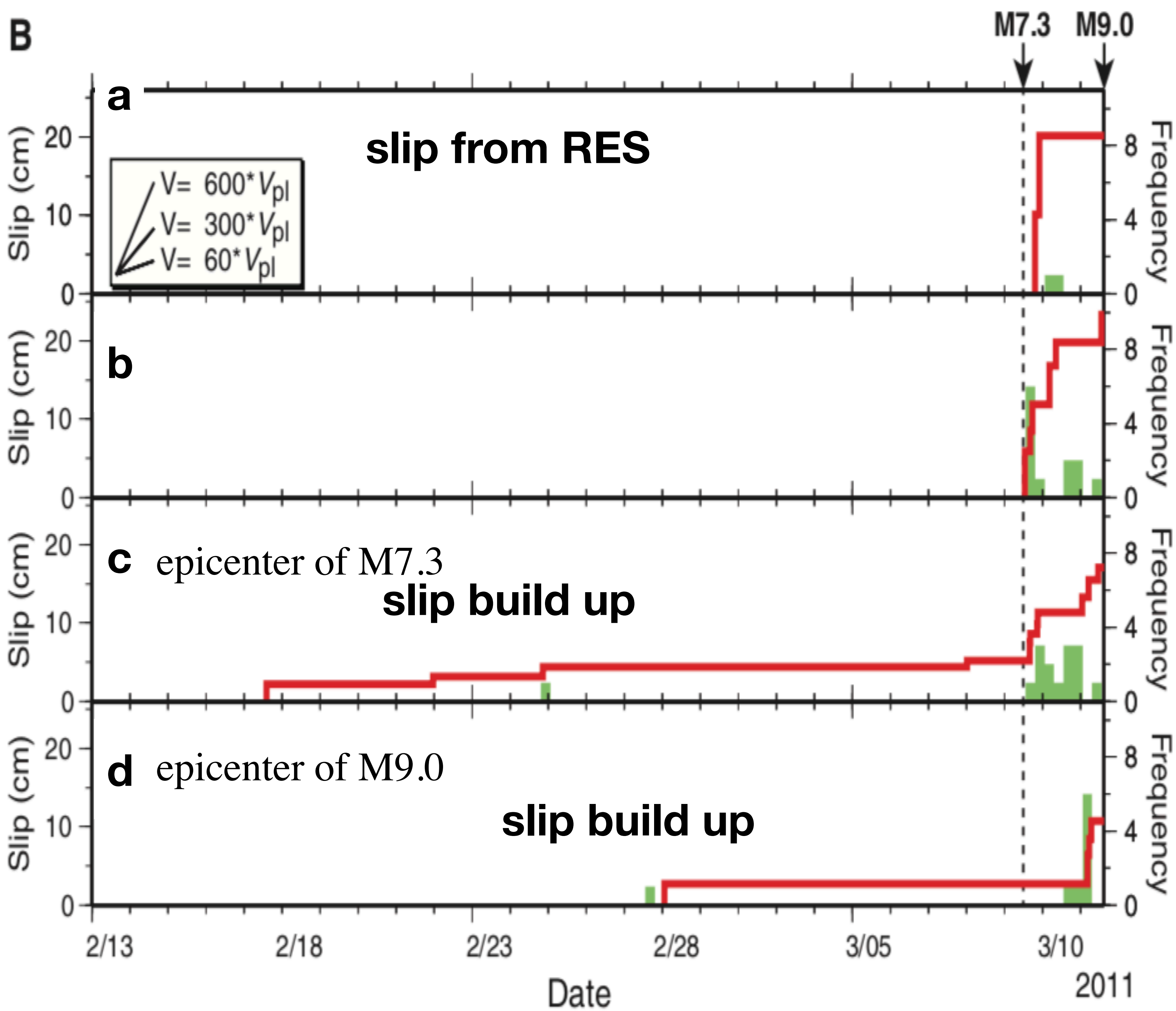
Methodology

1. 6 seconds of the waveform, starting 3 second before the S-wave arrival time computed using 1-D velocity model proposed by the JMA.
2. Calculated the correlation coefficient as a function of time, shifting the window in increments of 0.05 seconds through the continuous waveforms.
3. Threshold = 8 x mean CC value.
4. 1416 events was identified.

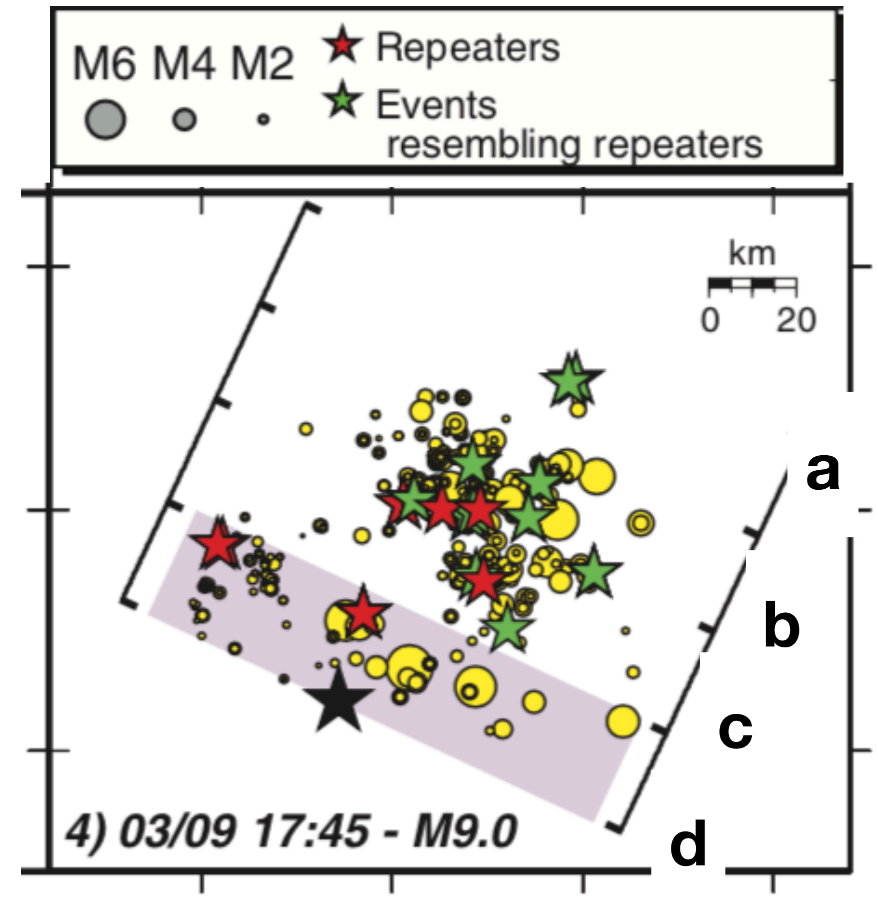
Results


M7.3
M9.0
N25E
S25W
km/day
2
10
20
M6 M4 M2
Repeaters
Events
resembling repeaters
Omoris decay
Outside EMZ
delay peak
Inside EMZ
Seismicity (1/hr)
Days elapsed from M7.3
first migration sequence
The width of the seismically active zone
expanded slightly with time
2 km/day
5 km/day
second
migration
sequence
EMZ
Earthquake
migration
zone
Trench Parallel (km)
Date
2/13
2/18
2/23
2/28
3/05
3/10
2011

Slip history base on Repeating earthquakes



Mainshock is followed by aseismic slip.



EMZ

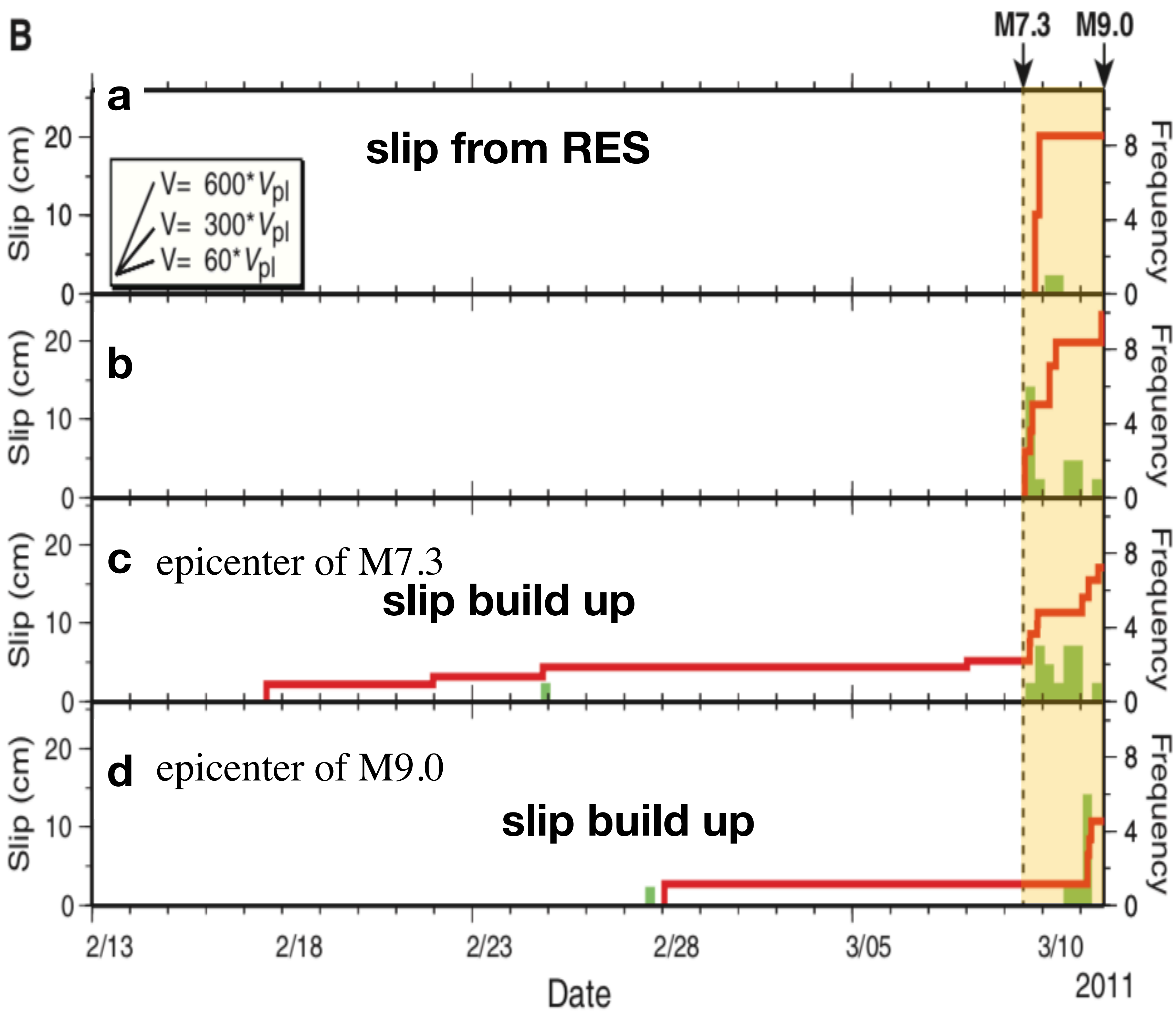
Slip outside the EMZ:

Decay logarithmically with time.

Slip inside the EMZ:

Slip started to build up on the mid-Feb, and accelerated till the occurrence time of M9.0 mainshock.

Slip history base on Repeating earthquakes



Mainshock is followed by aseismic slip.

average slip ~ 20 cm -> Mw 7.1 event with 90 km x 90 km fault patch

EMZ

Slip outside the EMZ:

Decay logarithmically with time.

Slip inside the EMZ:

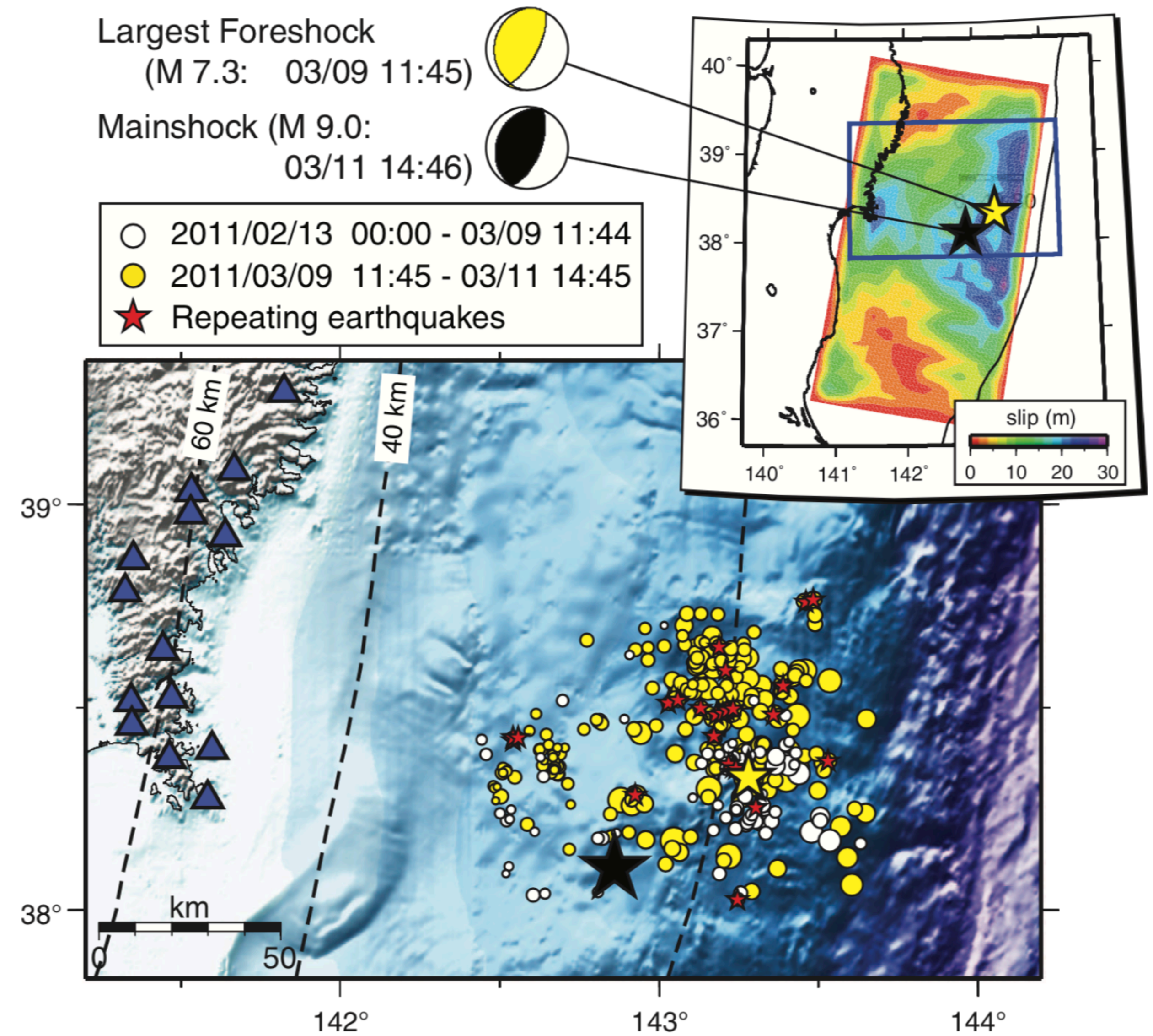
Slip started to build up on the mid-Feb, and accelerated till the occurrence time of M9.0 mainshock.

Summaries of foreshock sequences

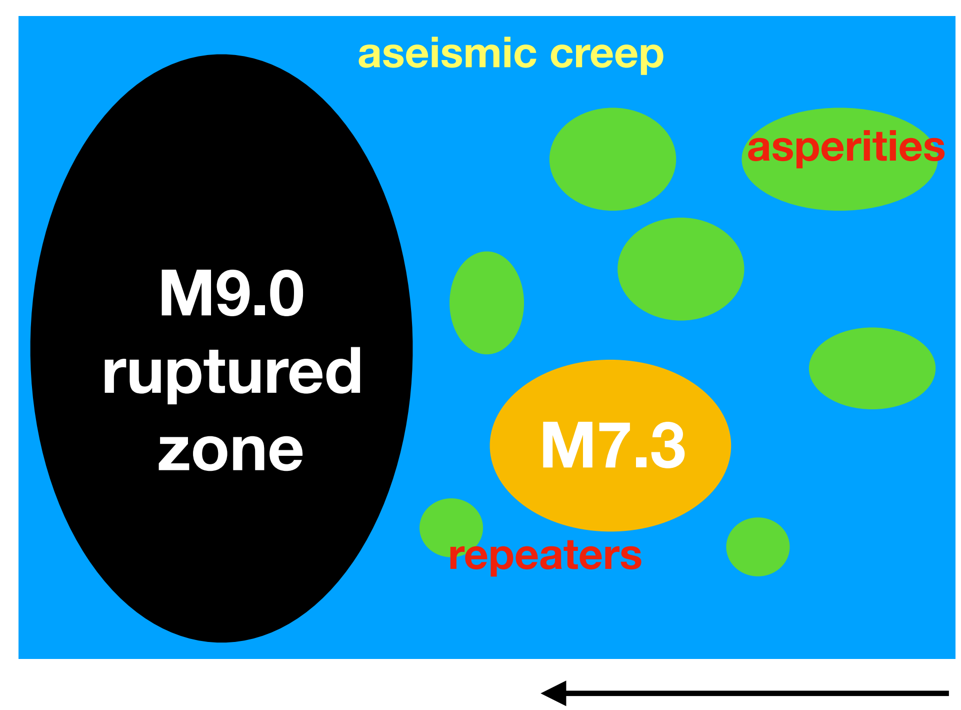
1. 90% migrating foreshocks are moderate-to-large magnitudes located within the EMZ.
2. Focal mechanisms are similar to mainshock.
3. Foreshock sequence including small repeating earthquakes.

Summaries of foreshock migration

1. Migrations before M7.3 and M9.0 are found.
2. Migration speeds of 2 - 5 km/day -> episodic-tremor and slow-slip events found along deeper extensions of warm subduction zones.
3. Migration speeds of 10 km/day -> well approximated by a parabolic curve describing a diffusive process



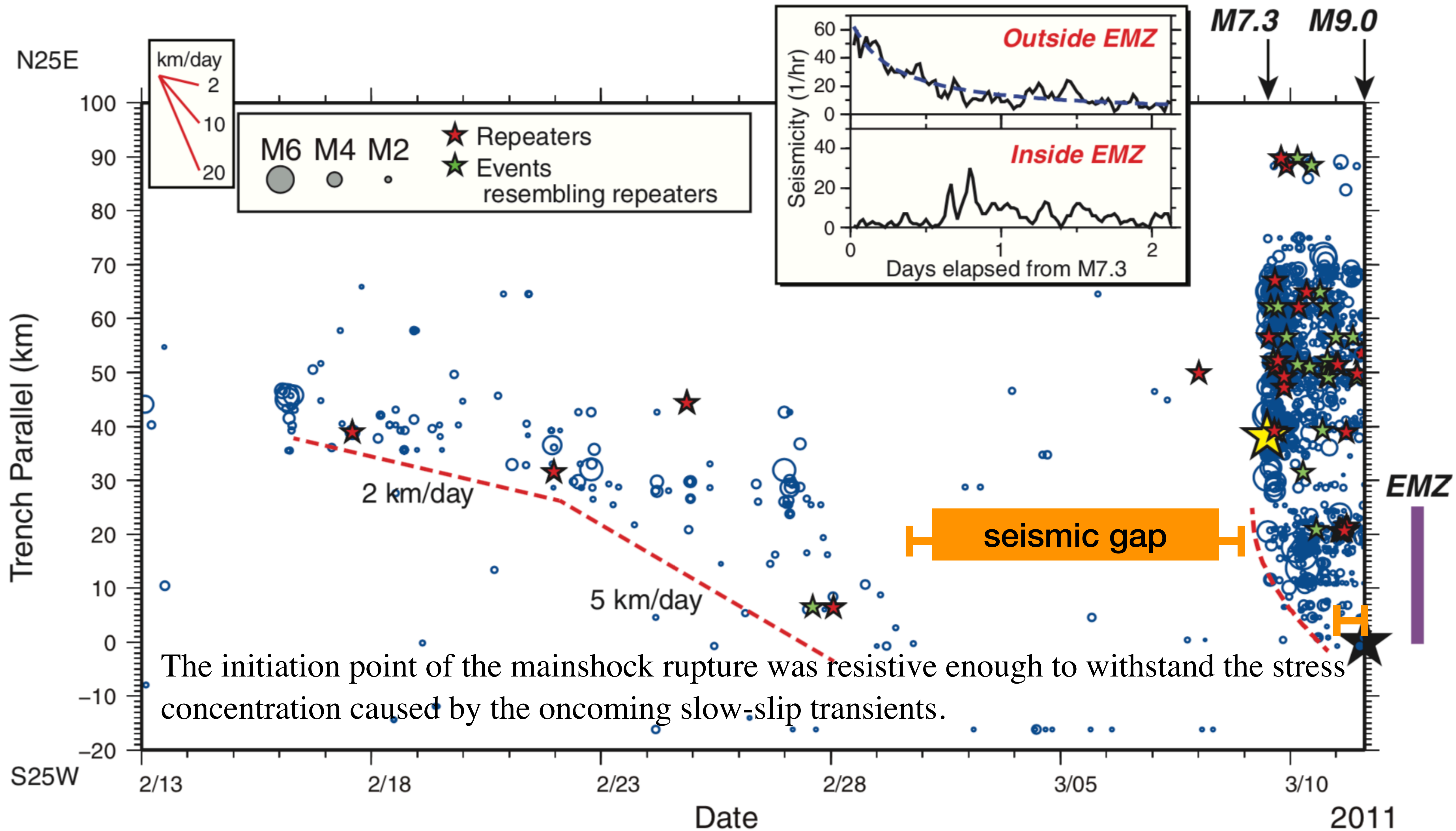
Fault patch



migrating direction

Triggering sinerio

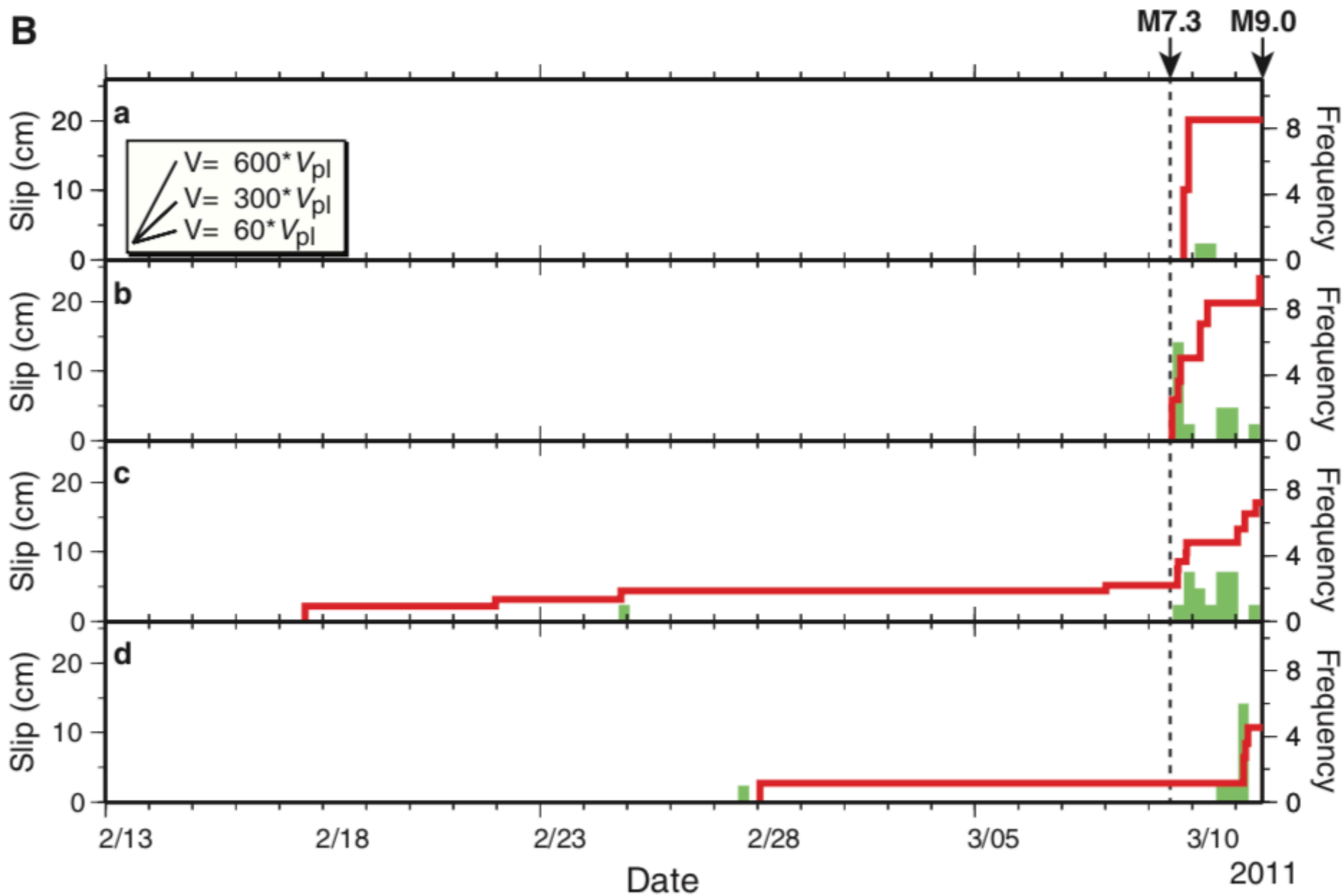
First migration -> seismic gap -> M7.3 shock -> second migration-> seismic gap -> M9.0 shock



The initiation point of the mainshock rupture was resistive enough to withstand the stress concentration caused by the oncoming slow-slip transients.

No power law acceleration in the slip and rupture growth to the mainshock

Mainshock was not preceded by accelerating occurrences of foreshocks close to the mainshock like Izumit event



The second slip released large amount of moment as previous results. (600 times Vpl vs 150 time Vpl)

First sequence ->weakened the plate interface within the EMZ. Second sequence of slow slip -> caused substantial stress loading onto the prospective hypocenter of the Mw 9.0 mainshock and prompted the initiation of unstable dynamic rupture there.