# Analysis of strong ground motions and high-rate GPS recordings from the Tohoku earthquake: 0 to 10 Hz

Art Frankel
USGS Seattle

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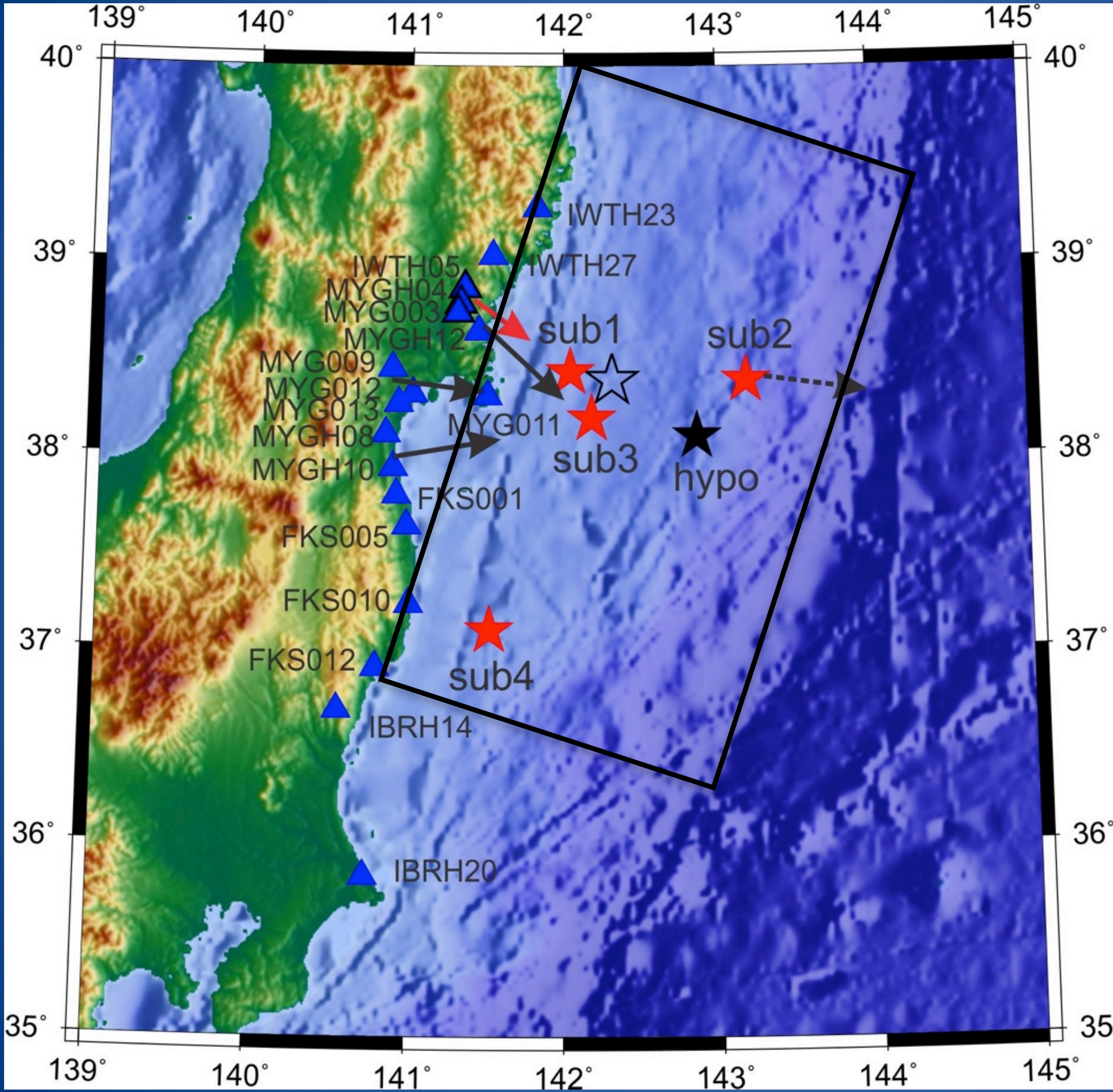
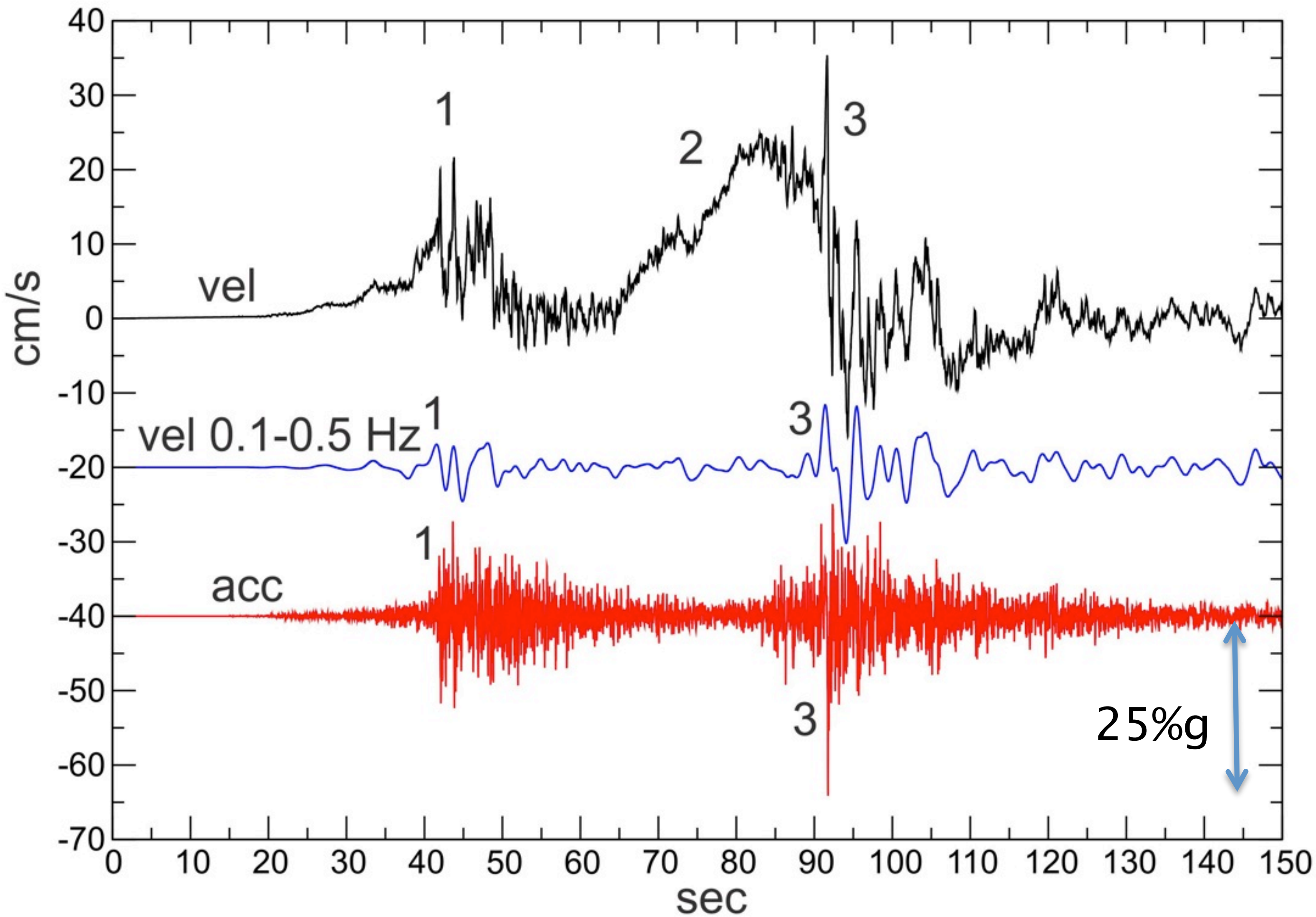



Locations determined from timing of arrivals

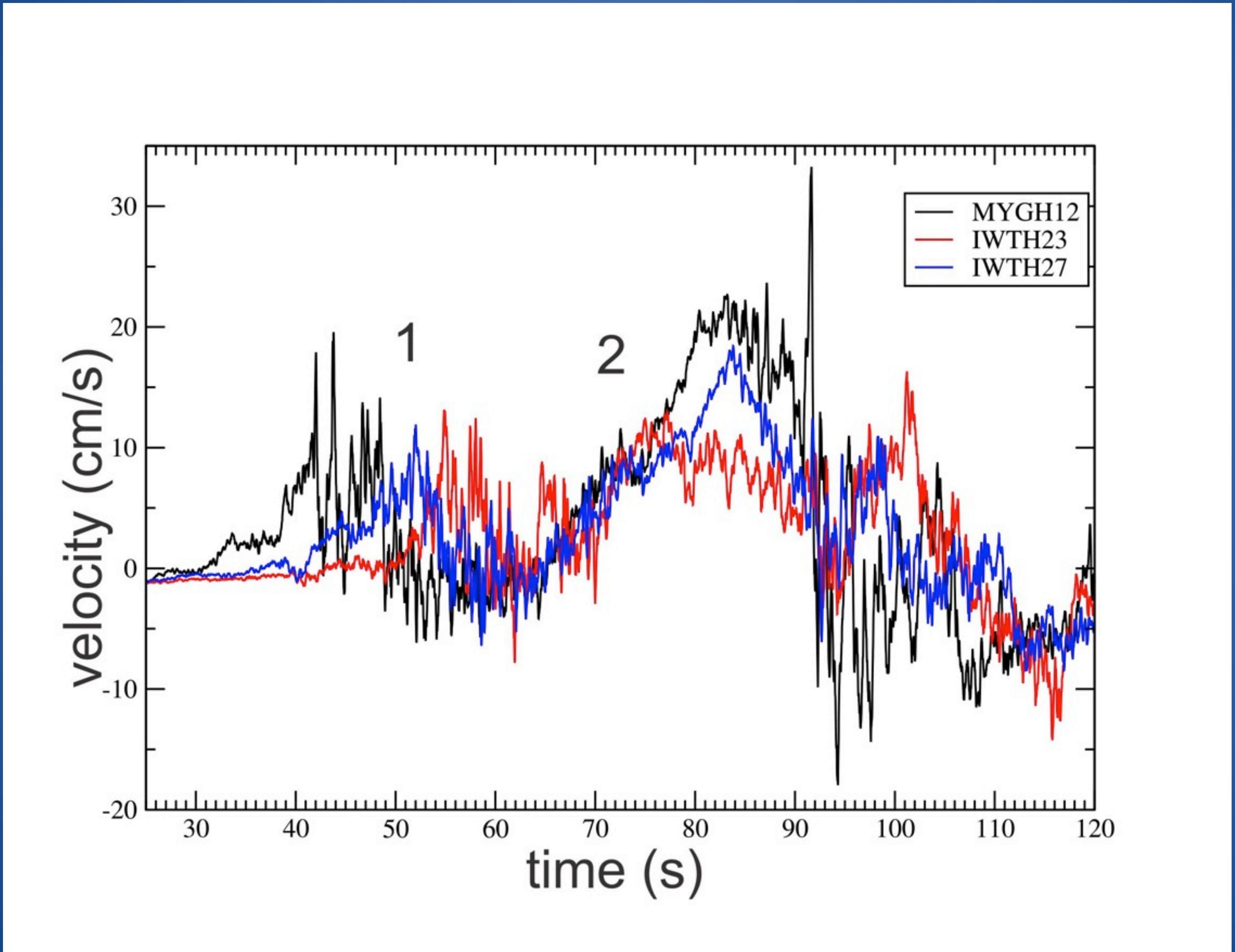
MYGH12 EW

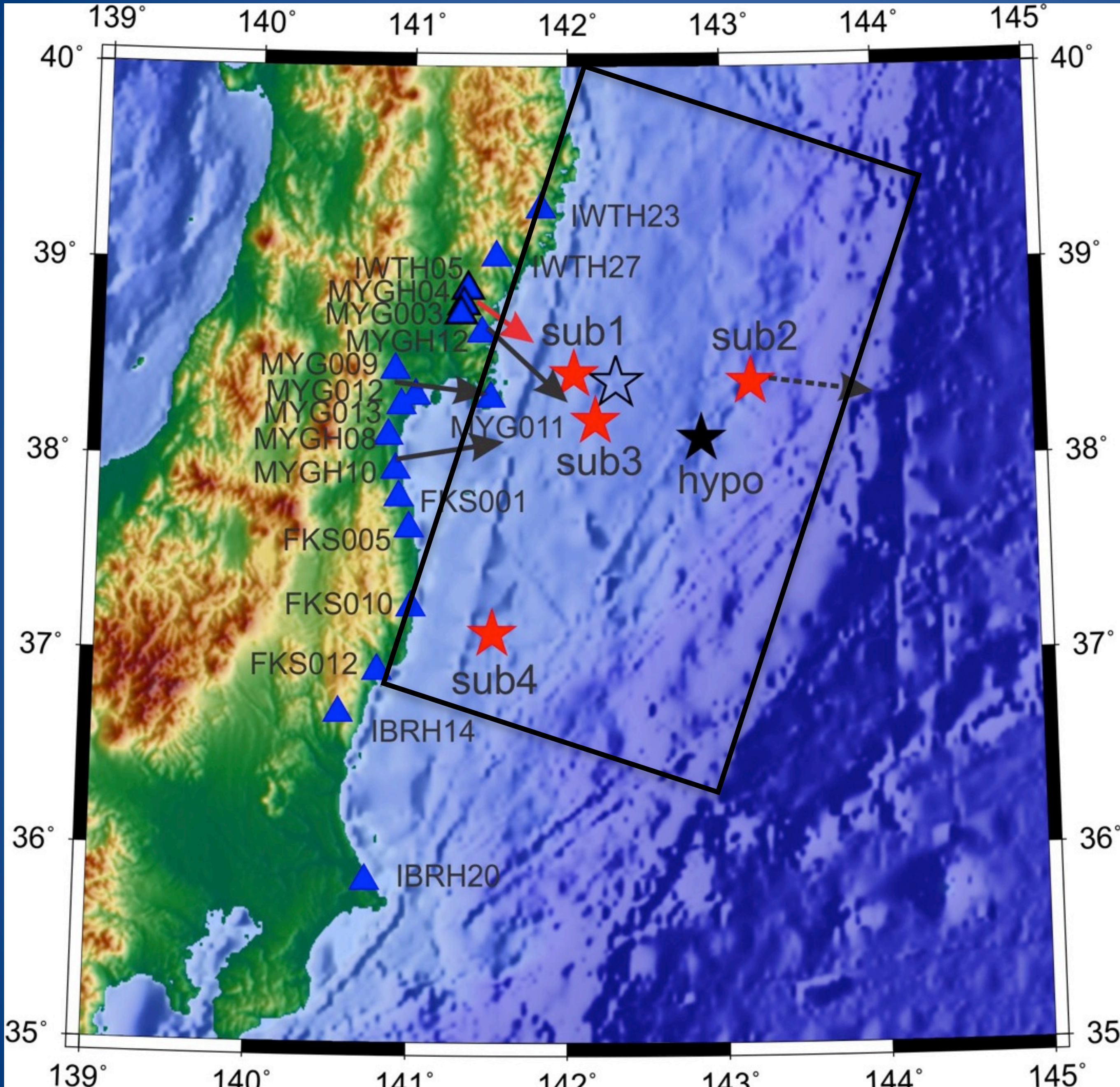
From borehole accel.recording



Timing of sub-event 1 arrivals differs from sub-event 2, indicating different l

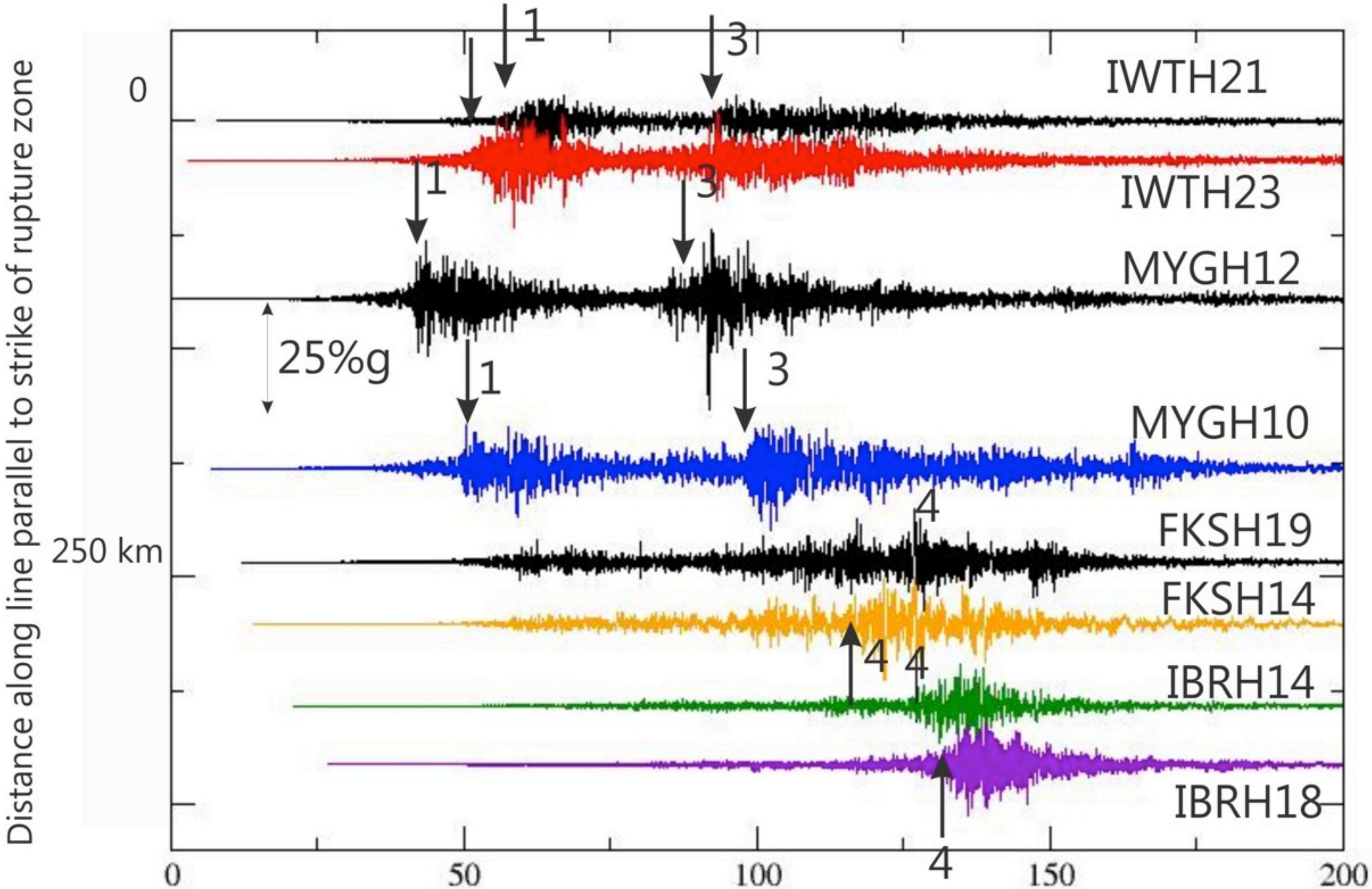
Station IWTH27 is north of MYGH12; IWTH23 is north of IWTH 27





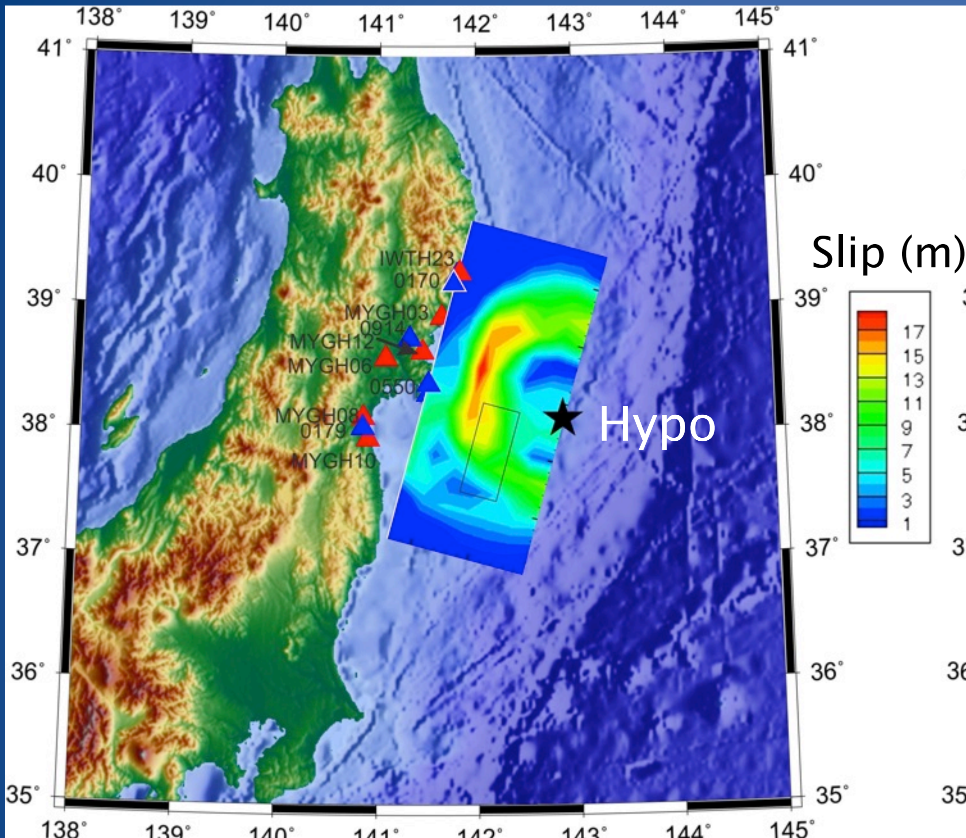

Locations determined from timing of arrivals

# EW Acceleration waveforms (borehole) from north to south

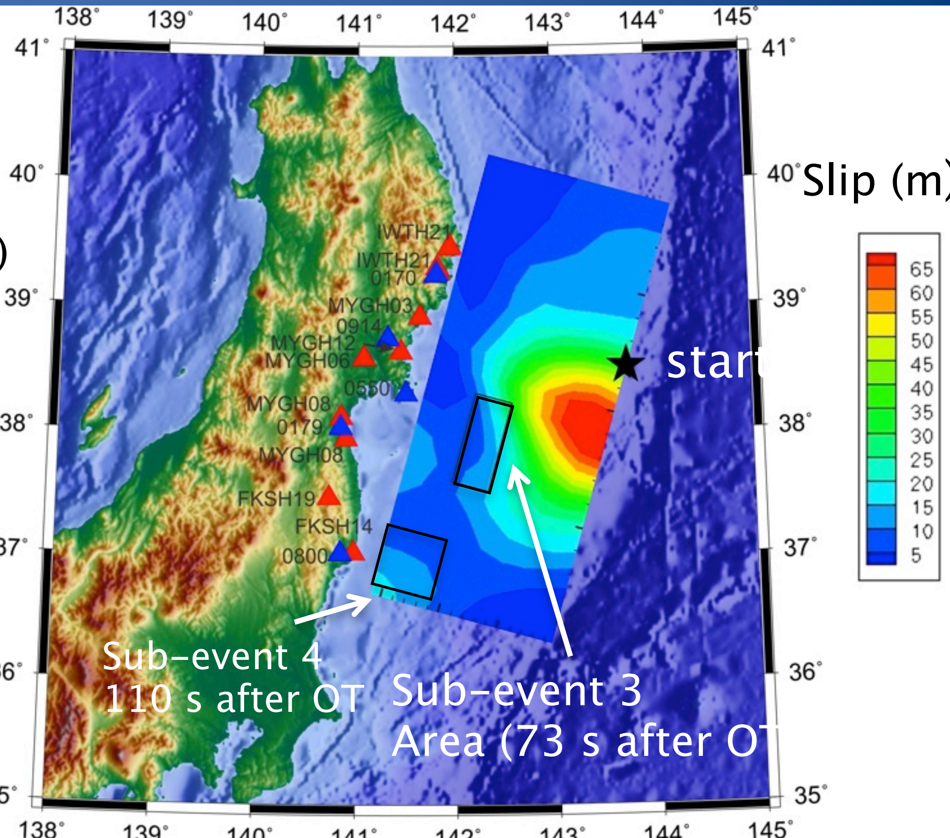


# Results of inversions of velocity waveforms from strong-motion records (0-0.2 Hz) and 1 sps GPS displacement waveforms

Sub-event 1; Mw 8.5



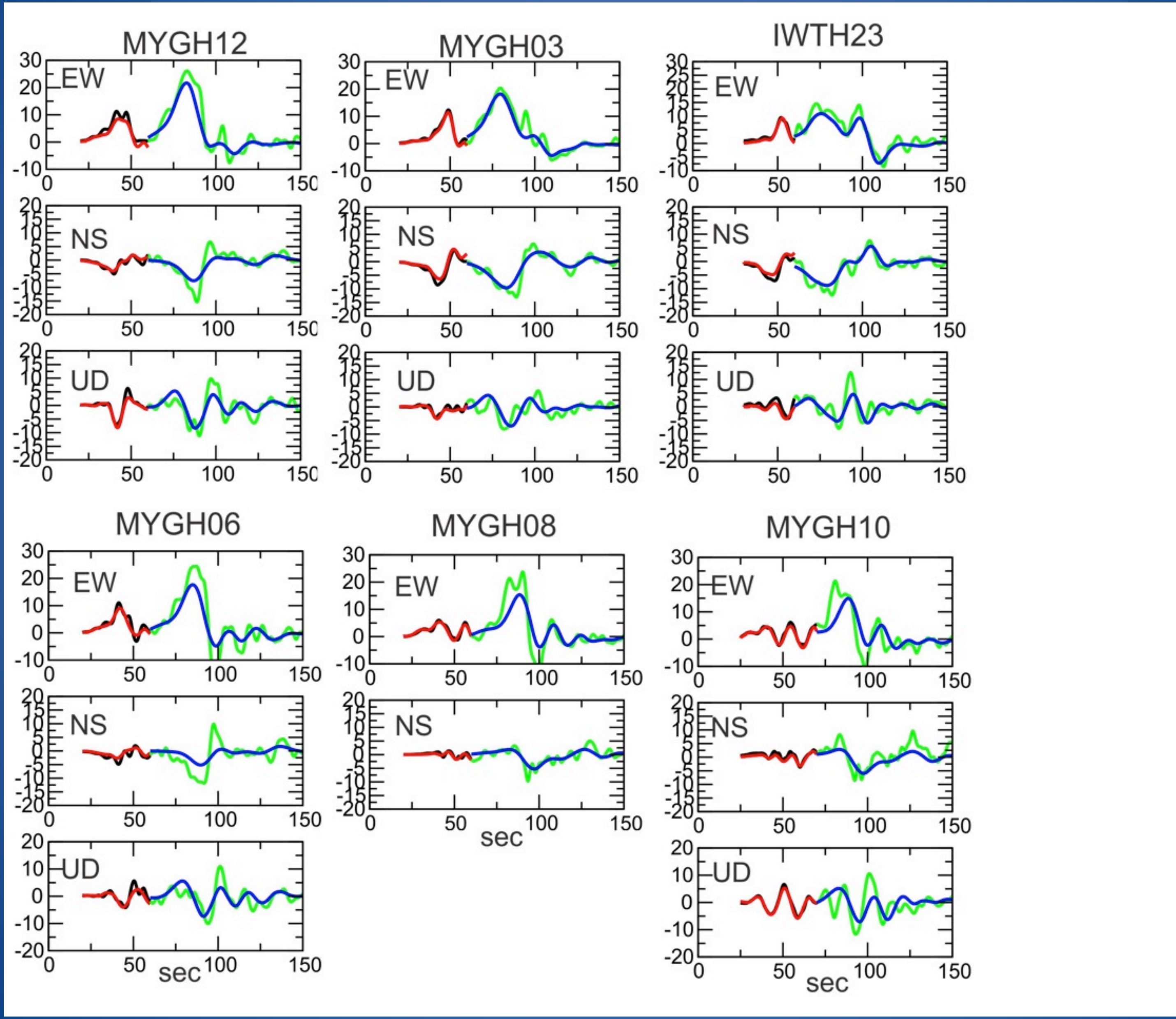

Sub-event 2; Mw 9.05, starts 35 s la




Sub-event 1 ruptures downdip and to north; generates low (< 0.2 Hz) and high frequency ground motions

As sub-event 2 ruptures down dip and to south, high-frequency sub-events 3 and 4 occur (d=40 km). Sub-event 2 only generates low frequencies (< 0.2 Hz) at shallow depths ( < 30 km), has rise time of slip of about 40 sec.

# bserved velocity waveforms (black and green) and synthetics (red and blue) from inversions: 0– 0.2 Hz (borehole records)

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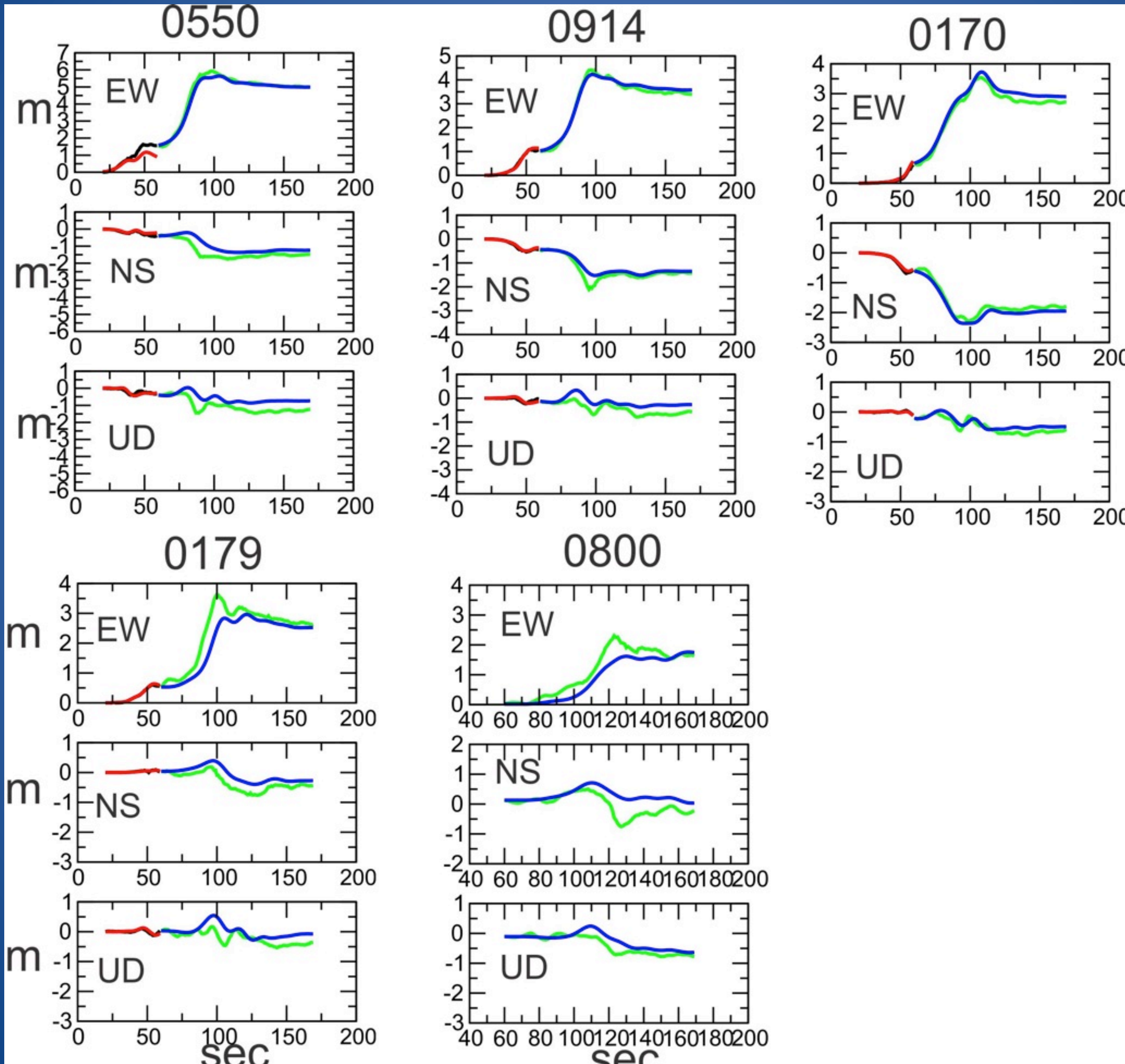
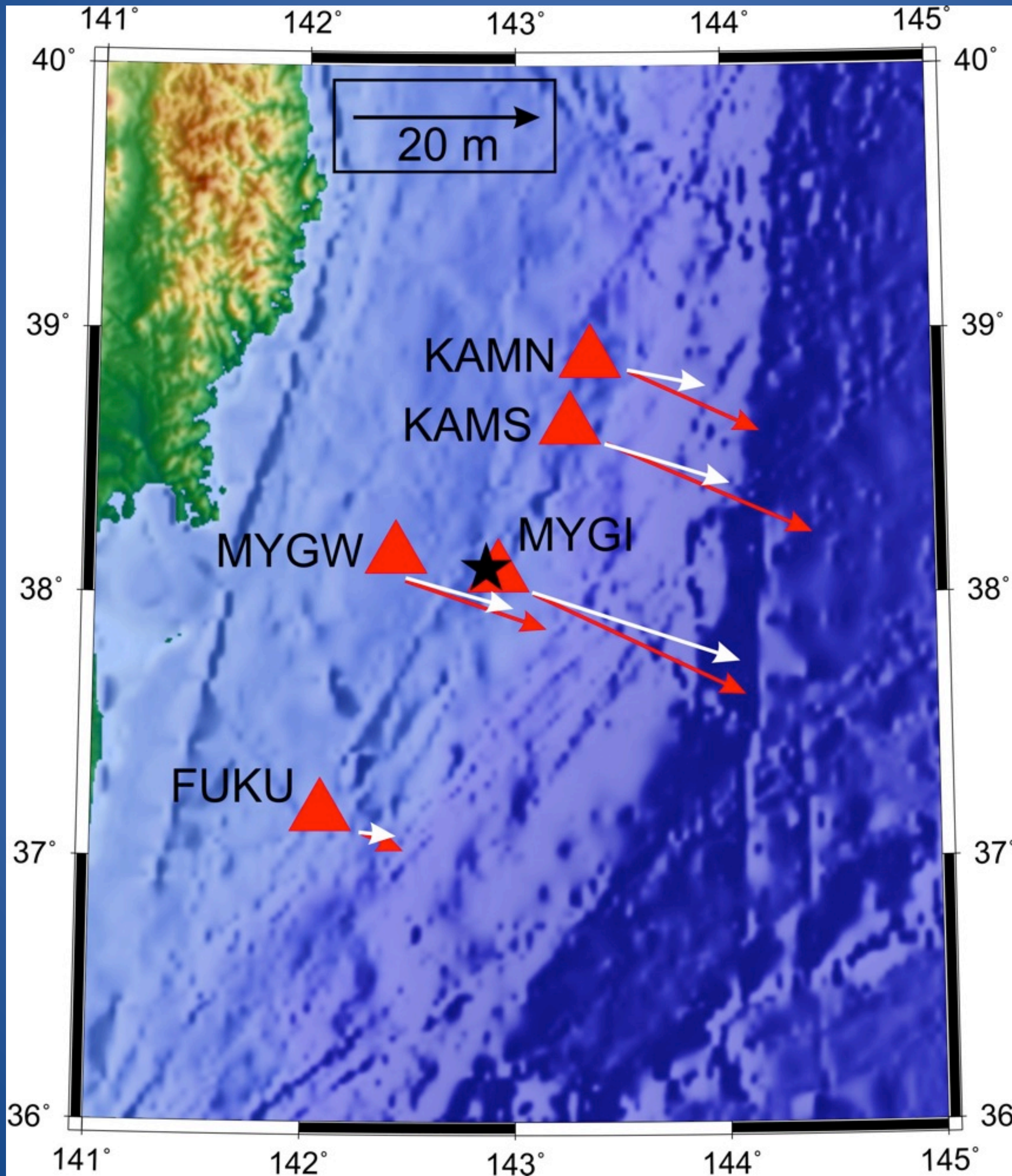
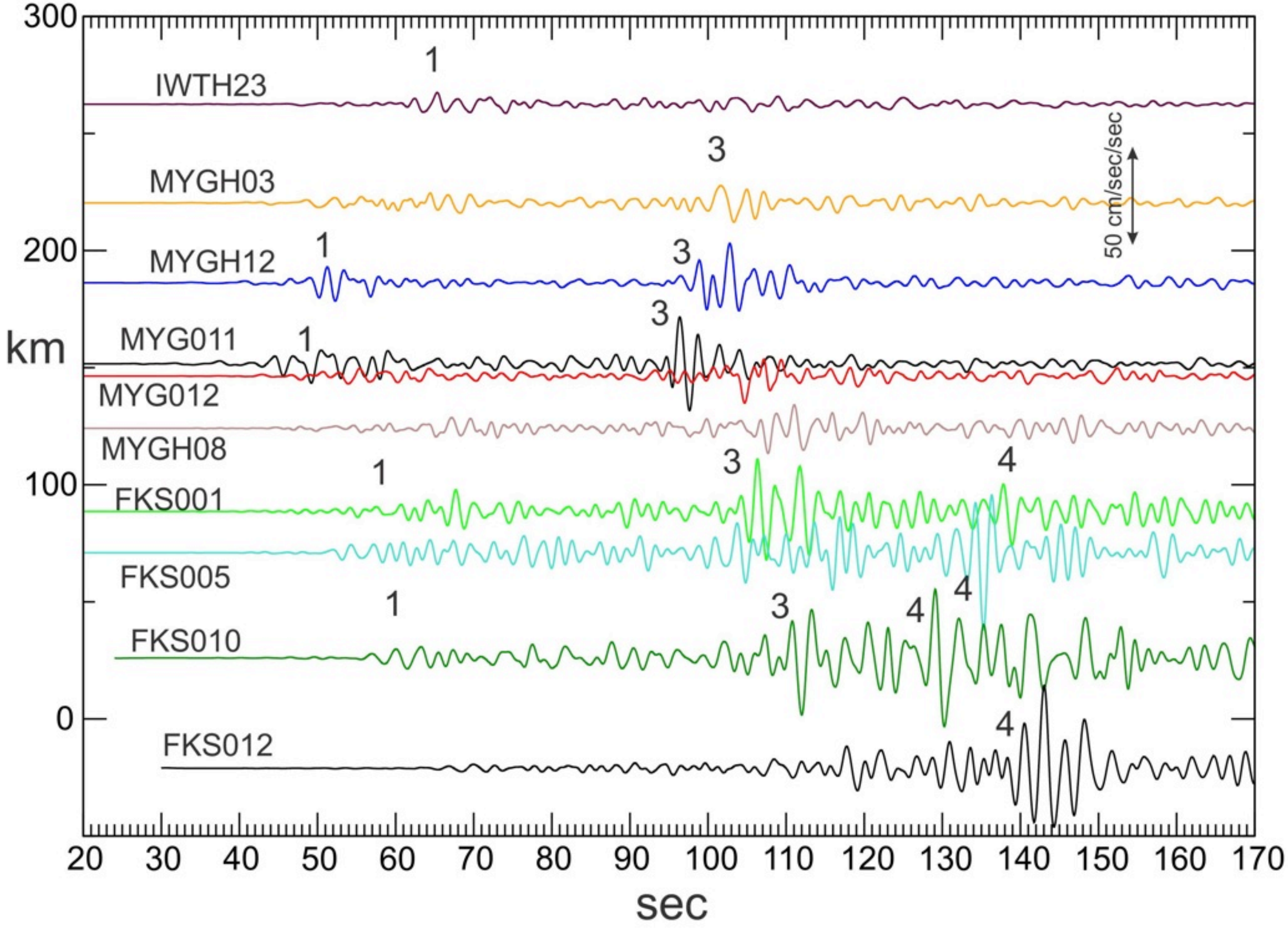
# Observed displacement records from GPS (black and green) and synthetics from inversions (red and blue)



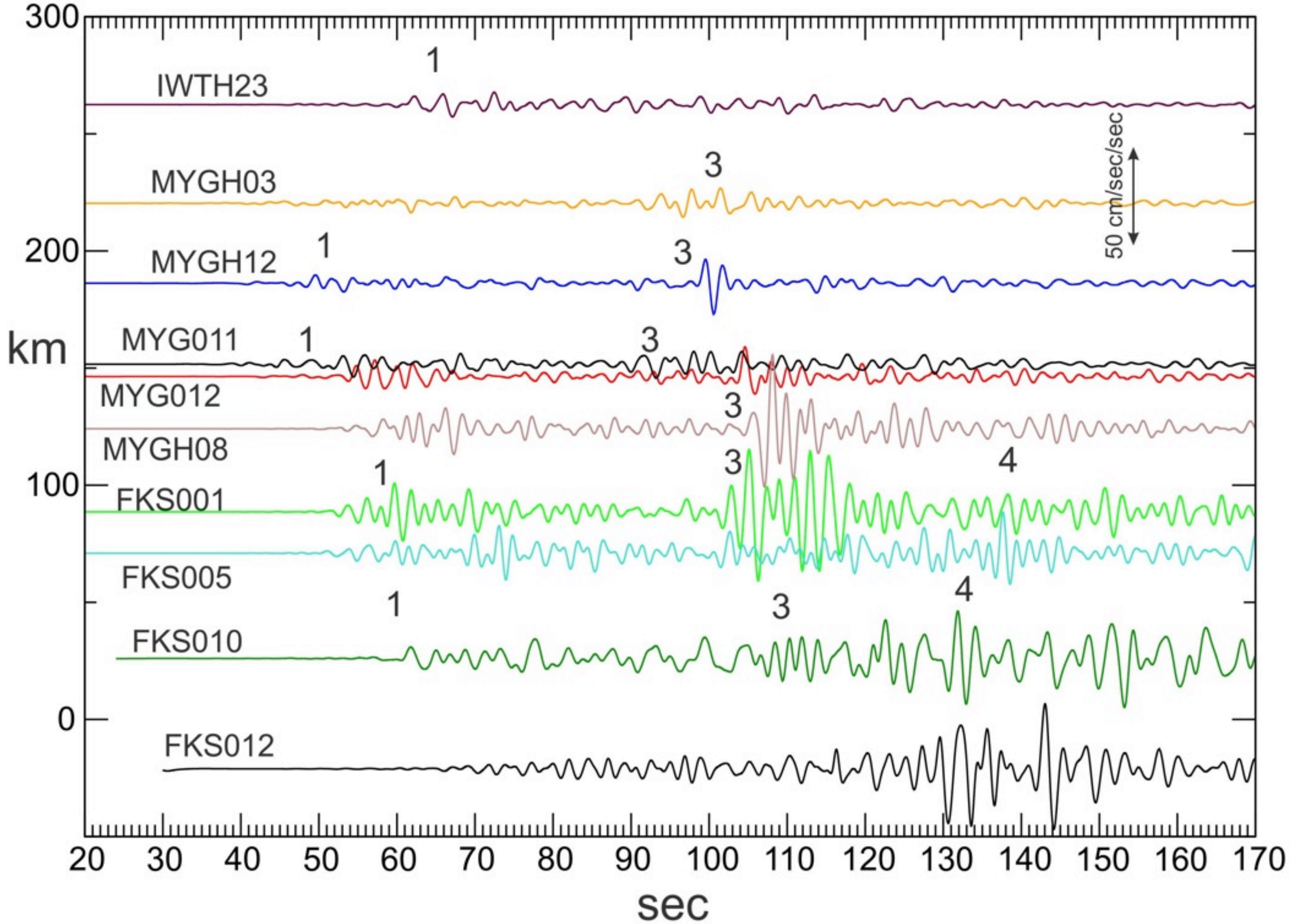
Observed (red arrows) displacements of seafloor transducers (Sato al. 2011) and predicted displacements from inversion results (white arrows); these observations not used in inversion

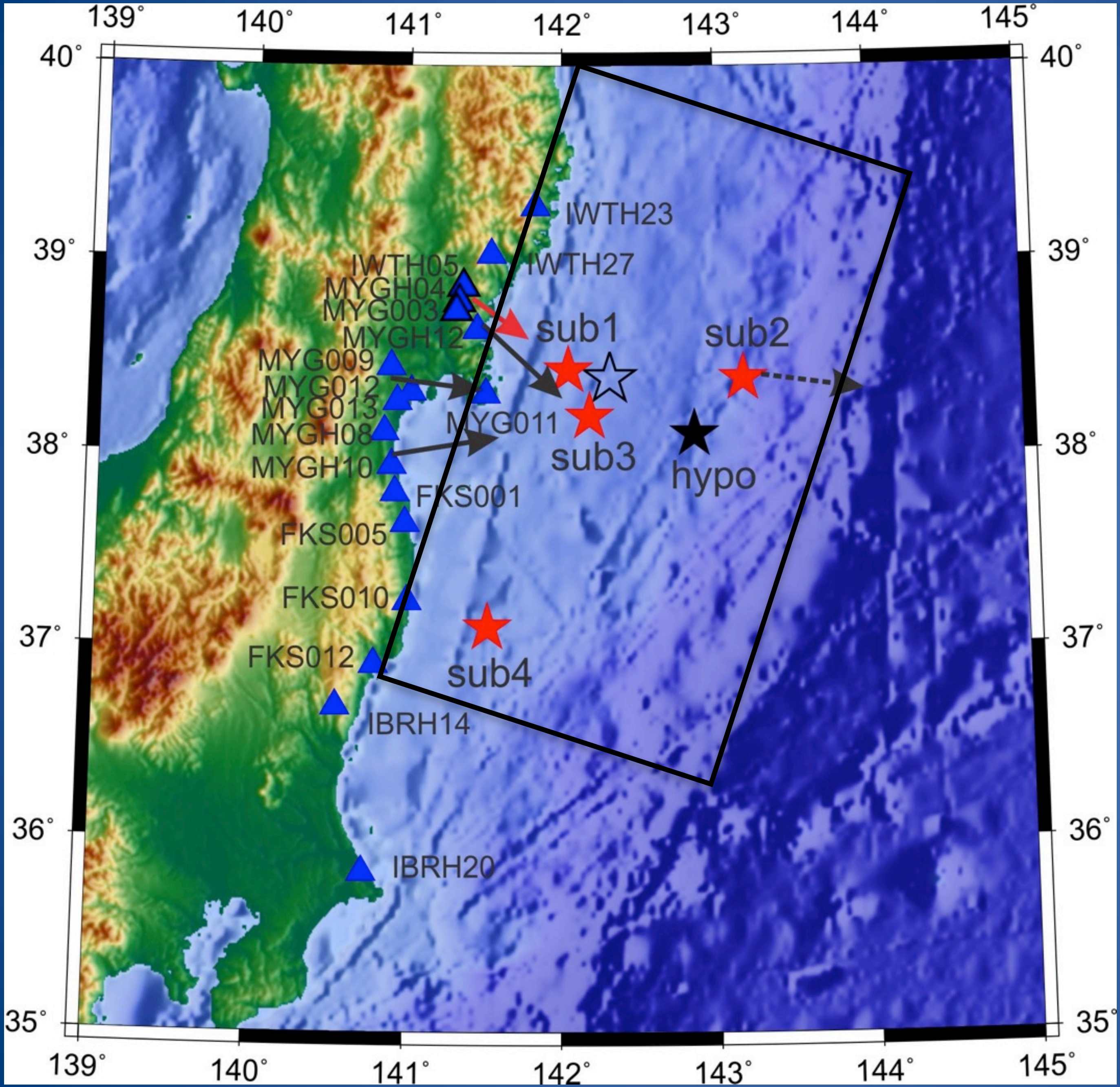


EW acceleration 0.1 – 0.5 Hz



NS acceleration 0.1-0.5 Hz (surface records)






Locations determined from timing of arrivals

From Wu et al. 2008 JGR: 1978 (M7.4) and 2005 (M7.3) Myagi-Oki earthquake



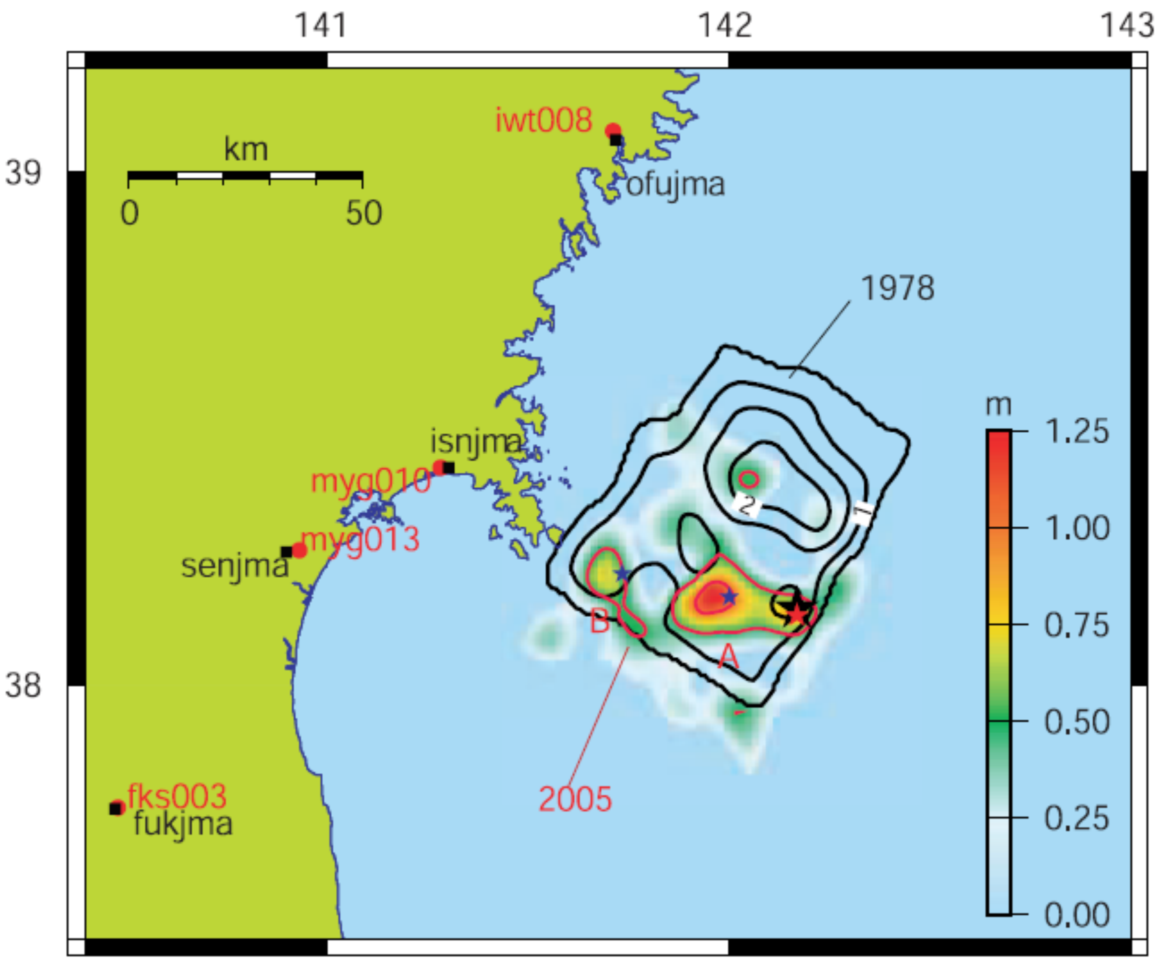
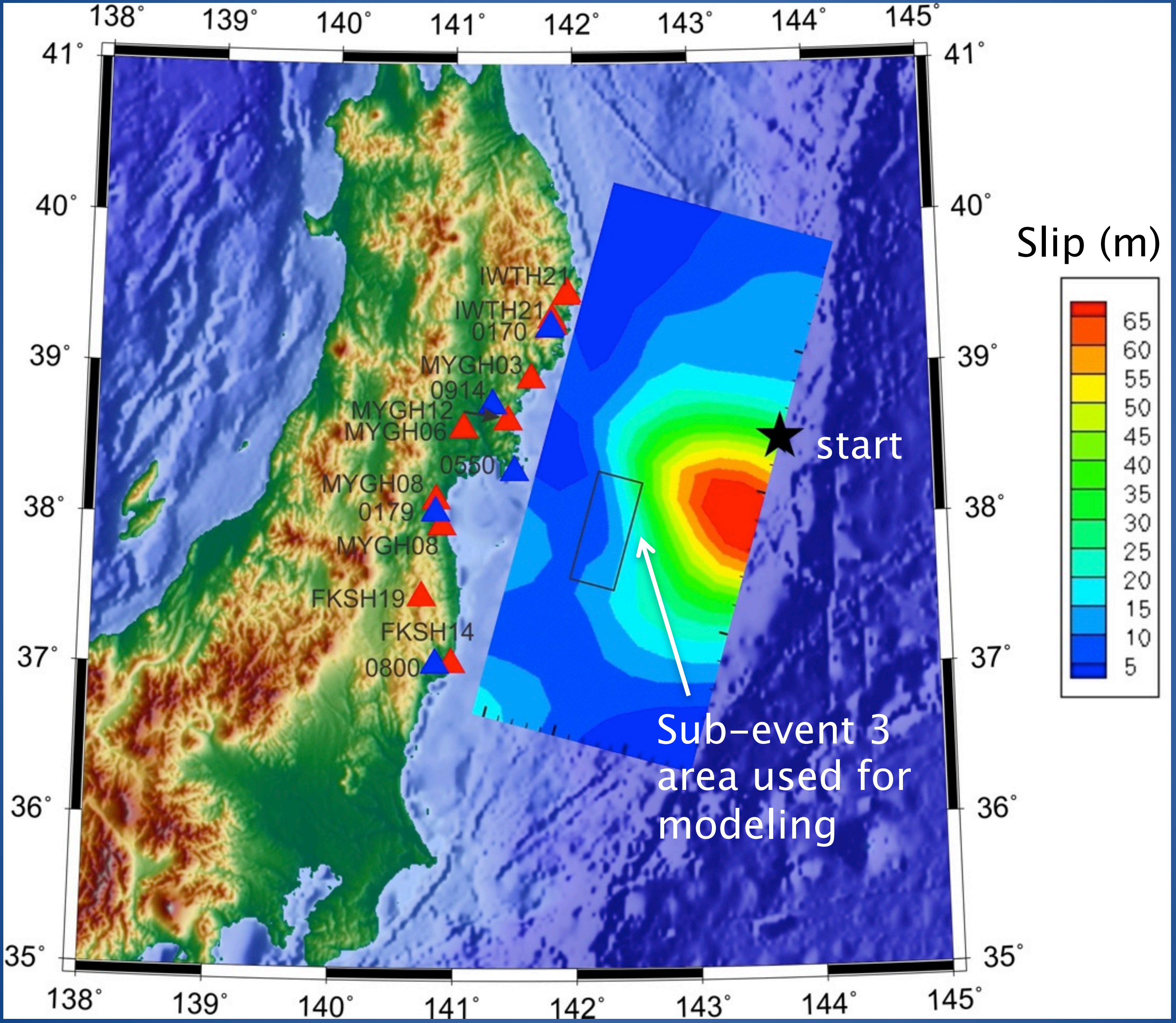



**Figure 5.** Slip distributions of the Miyagi-oki earthquakes. The black contour lines and color contours represent the slip distributions of the 1978 and 2005 events, respectively. The epicenters of the two events are marked by black (1978) and red (2005) stars, respectively; note that because of the similar locations of the two epicenters, the black star is almost completely obscured by the red one. The seismograms in Figure 3 were observed at the four pairs of stations shown on the map (black squares for the 1978 event and red circles for the 2005 event).

Inversion results for Sub-event 2; Mw 9.05; rise time 40 s; starts 35 s after sub-event 1

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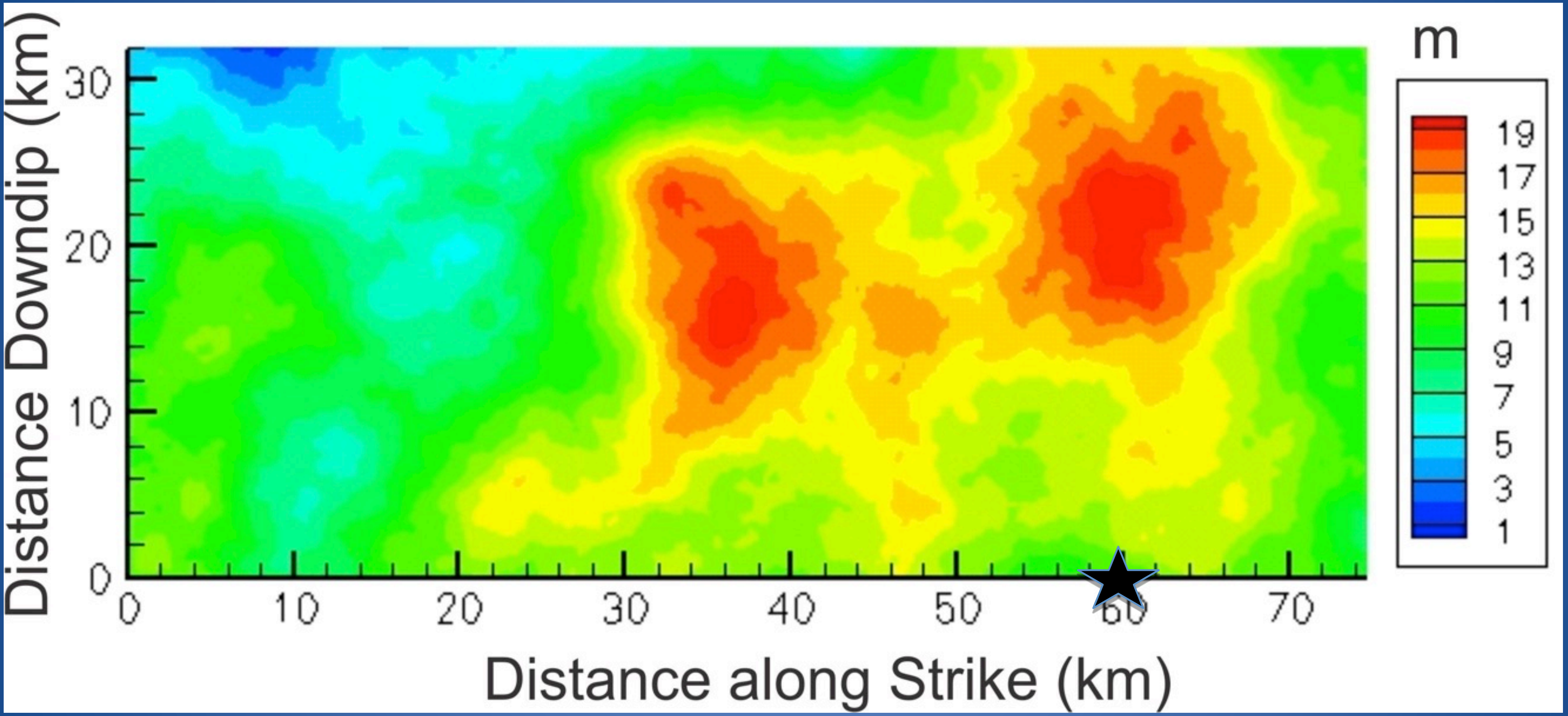
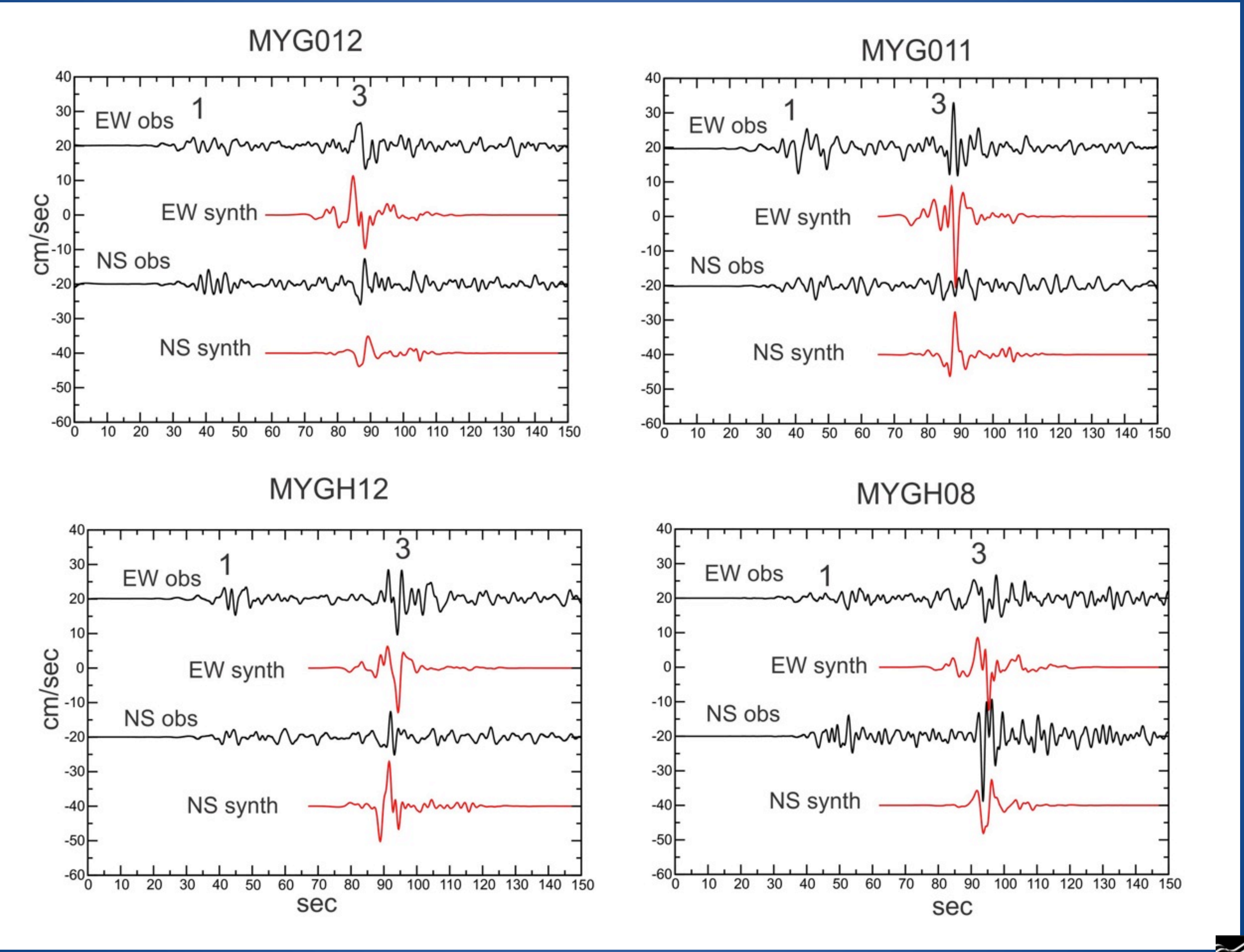
# Slip used to model sub-event 3 using synthetics from a plane-layered velocity model
# Mw 8.0, slip velocity 15 m/s, ave Vr= 3.0 km/s

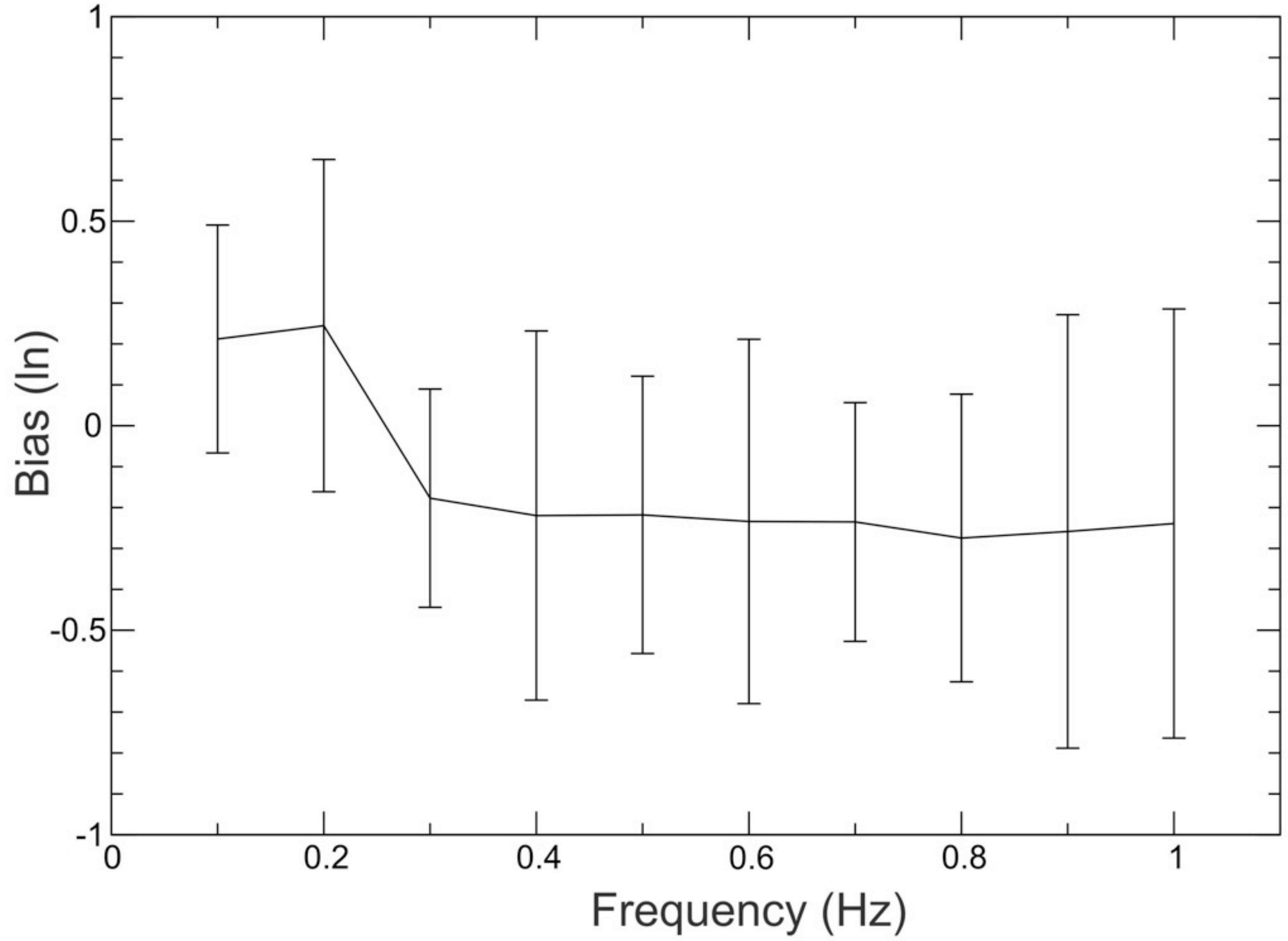



Compare the 15 m/s slip velocity to the 2.7 m/s slip velocity used for modeling crustal earthquakes and NGA (Frankel, 2009; 100 bars). Implies stress drop for sub-event 3 is about 560 bars

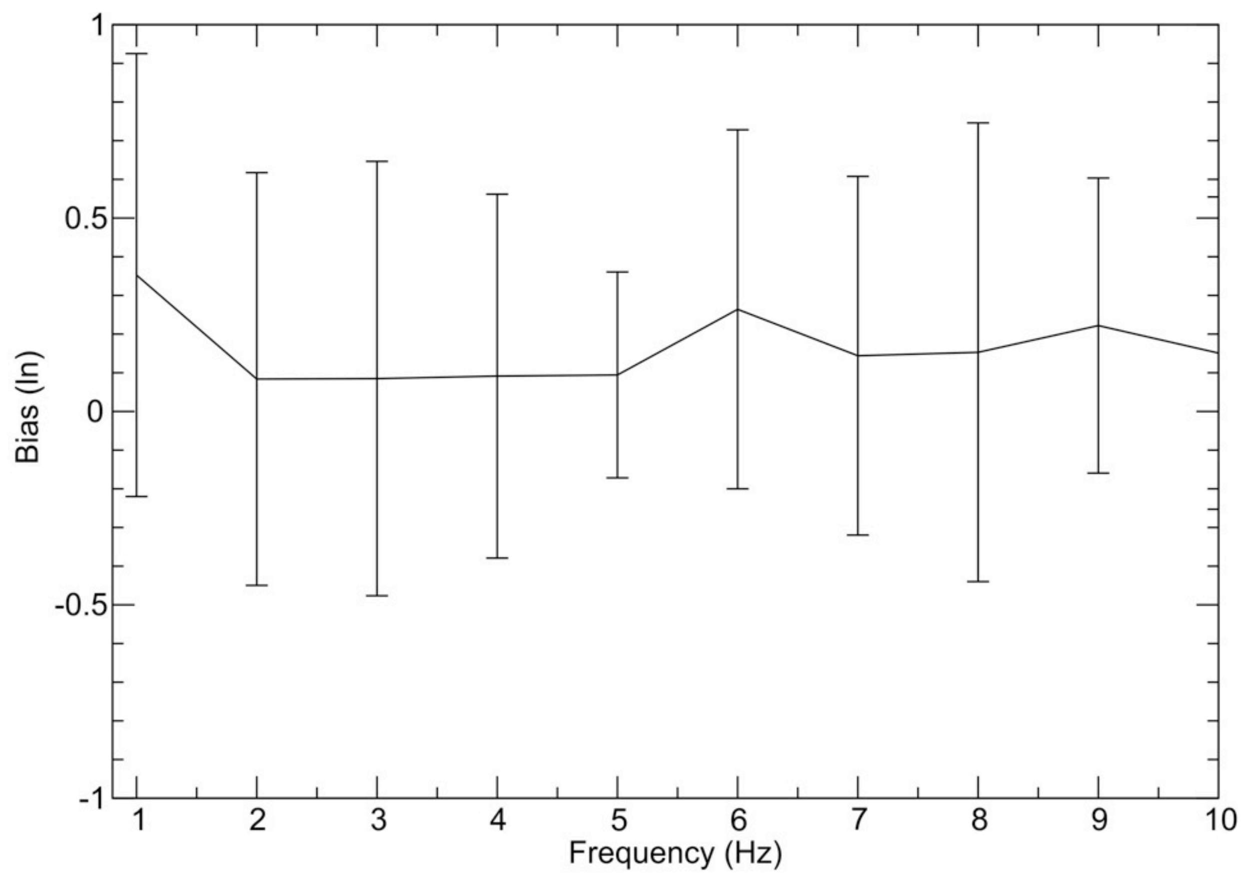
# Observed and synthetic seismograms for sub-event 3 filtered at 0.1-0.5 Hz (surface recordings)



# Bias and stddev of response spectra of synthetics vs. observed at 4 stations (surface recordings)_

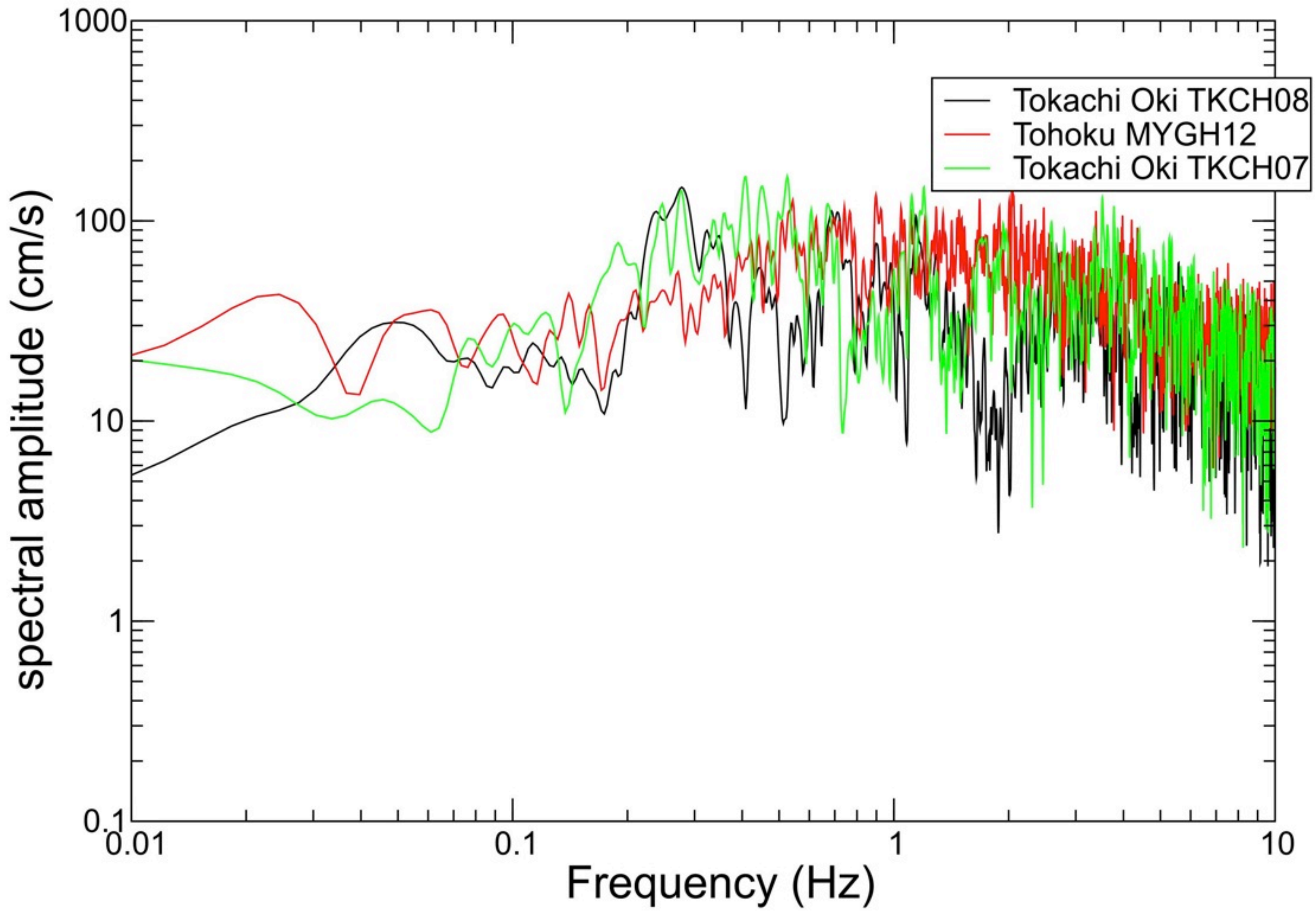


Bias and stddev of response spectra of synthetics vs. observed at 4 stations. Synthetics were made using finite fault stochastic simulation (Frankel, 2009) with 100 by 50 km rupture (expanded sub-event 3), 560 bars stress drop, MYC near-surface velocity model, and kappa= 0.01 ; needed mainshock fc of 0.5 Hz



# Comparison of Fourier acceleration spectra from Tohoku Mw 9.0 and Tokachi-Oki Mw 8.1

Spectra from borehole records



# Conclusions

- Sub-event 1: M8.5 ruptured downdip and to north, rise time of 20 s
- Sub-event 2: M9.05 had 65m peak slip near trench, rise time of 40 s
- For frequencies that tall buildings are affected by (0.1 – 0.5 Hz) earthquake looked like widely spaced M8.0 earthquakes (75 x 30 km). One of these ruptured down dip of area of highest slip: high stress drop of 560 bars, rise time of 1 s. Also explains high PGA's (with site amplification)

# Will Cascadia M9 ground motions look like Tohoku?

- Given that Tokachi-Oki and Tohoku had different distribution of rise times, why should we expect Cascadia to have similar rise times as Tohoku?
- High frequency sub-event for Tohoku was located near where M7 events occurred in 1976 and 2005.
- Very low seismicity on most of CSZ, in contrast to Tohoku; M4 events off of Oregon coast in 2004
- Different age of subducting plate (> 100 my vs. 10 my for CSZ).