Mw 7.1 Duzce Earthquake: Multiple datasets and implications about rupture kinematics

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1. Introduction

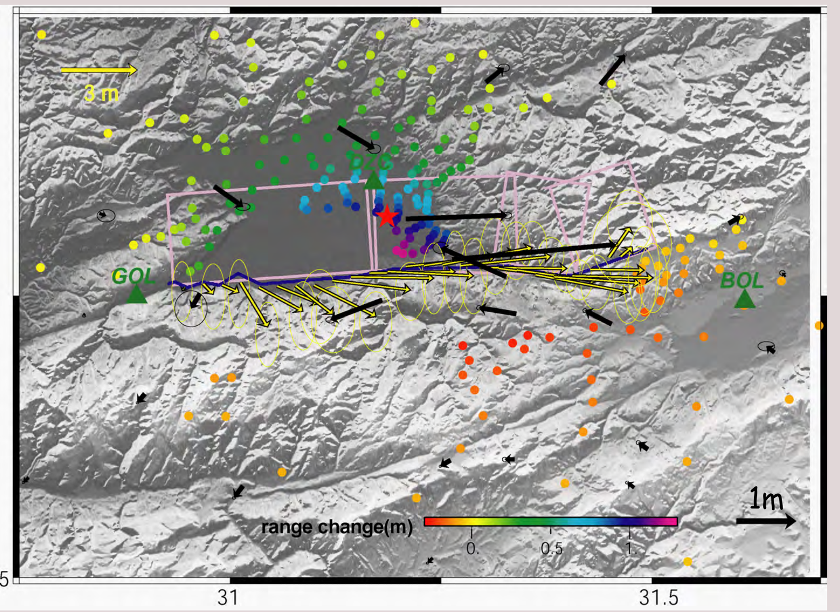


Figure 1a: The Mw7.4 Duzce earthquake data . The black arrows show the GPS offsets, the colored circles show the range change, the green triangles show the strong-motion station locations, the blue curve shows the SPOT obtained fault trace and the yellow vectors show the offset.

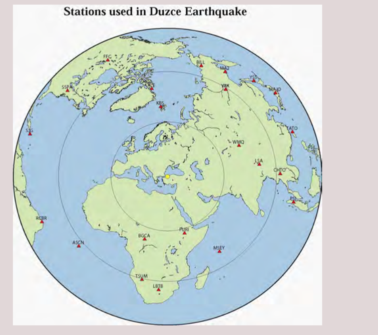


Figure 1b: Location of teleseismic stations for the Duzce earthquake

Datasets used:
1. Campaign GPS data
2. InSAR data
3. SPOT fault map and
4. Surface offset data
5. Strong-motion data
6. Teleseismic data

TARGET

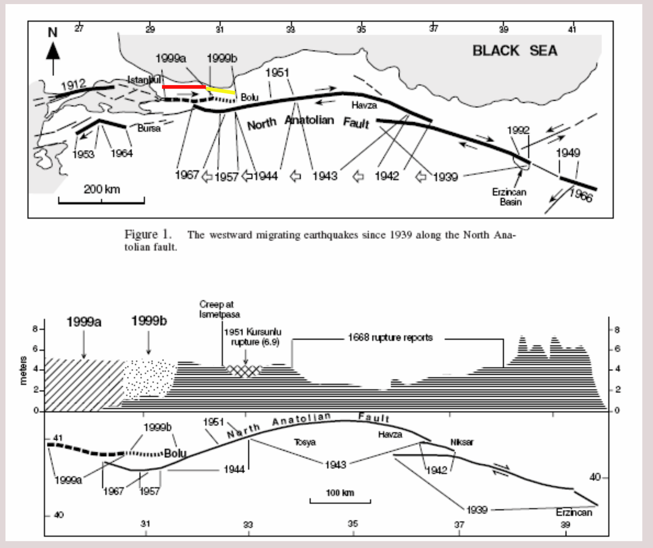
By modeling all available data together, can we learn more about the source of the Duzce event?

Especially, resolve the details about rupture velocity by modeling the near-field seismic data , but also making sure that

1. the fault geometry and surface offsets are consistent with SPOT data
2. slip model fits the geodetic data

2. Background and former studies

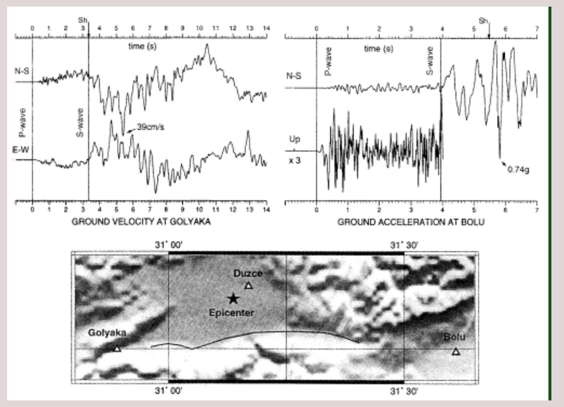
2a. NAF and Izmit and Duzce earthquakes



Barka et al., 2002

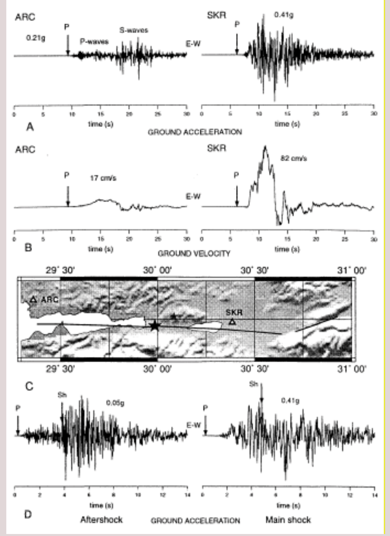
Figure 2: The North Anatolian fault and the western migration of events in 20th century. The Mw7.4 Izmit earthquake occured on August 17, 1999 (1999a) and Mw7.4 Duzce earthquake occured on Nov 12, 1999 (1999b). Both earhtquakes created significant surface offset and were mapped by field geologists

2b. Supershear rupture Speeds



Bouchon et al., 2001

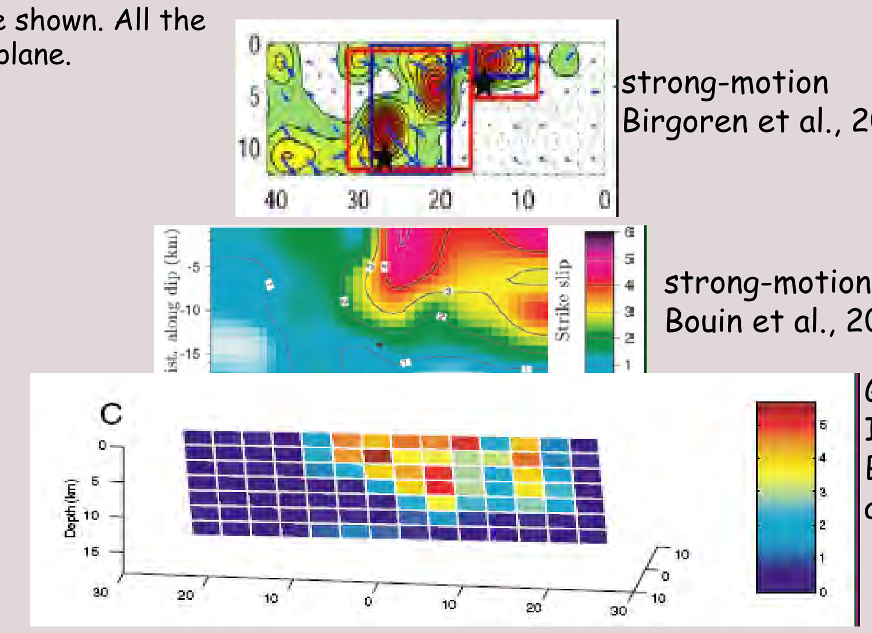
Figure 3: P-S differential timing from strong-motion seismograms of the Duzce earthquake



Supershear rupture velocity was first suggested by Bouchon et al.,2001 for the Duzce Eq. Idea is based on P-S

2c.Slip Models from Various Datasets

Figure 4: Various models from various datasets are shown. All the models use a single plane.



strong-motion Birgoren et al., 2004

strong-motion and GPS Bouin et al., 2004

GPS and InSAR Burgman et al., 2002

3. Fault map from SPOT subpixel correlation

Figure 5: Cross-correlation of SPOT images from 3 images. (a) June 1999, December 2000 (b) September 1999, December 2000. Insets show the offsets at A-A' and B-B'

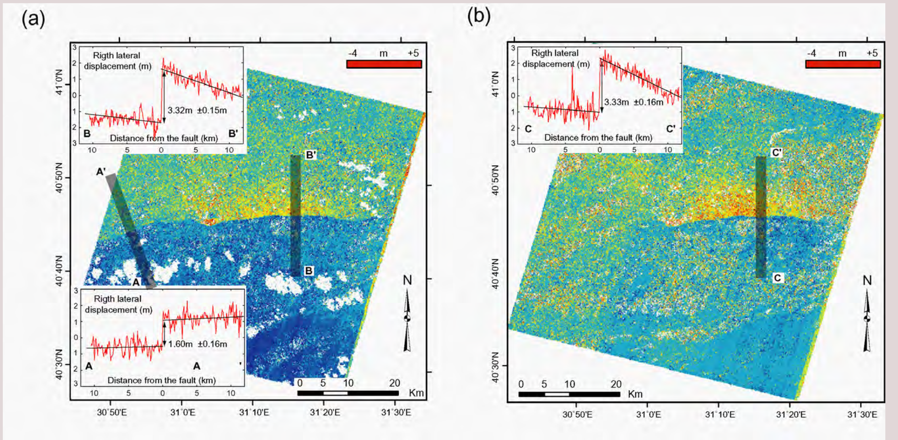
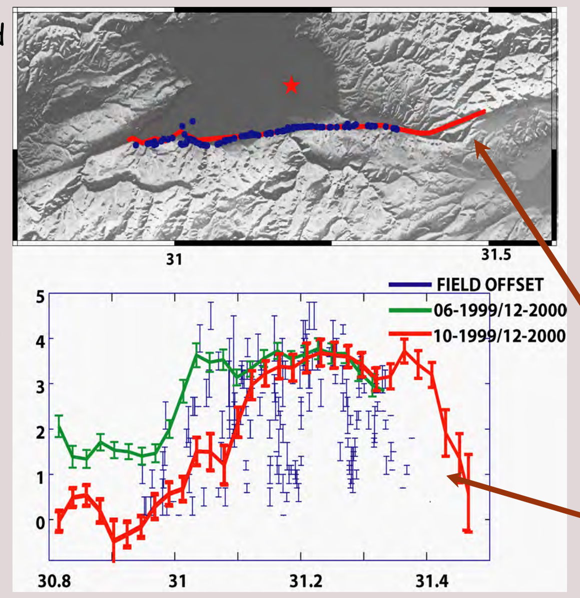


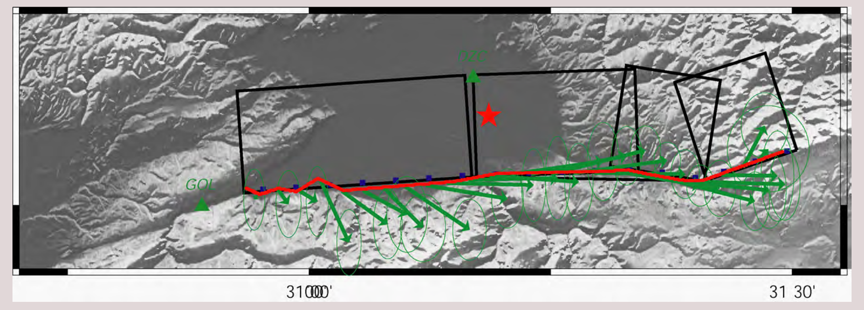
Figure 6: Comparison of fault map and surface offset from field studies by Stefano Pucci (blue line) with the offset map from SPOT image cross-correlation. The satellite image shows a 15 km segment rupturing at the eastern end.

The offsets are similar except around 31 degree latitude. We believe that the field offsets might be reflecting the cumulative offsets from co-seismic and post-seismic motion from the Izmit earthquake as well as the Duzce offsets.



15 km longer fault to the east

Figure 7: 4 segment fault model based on the SPOT obtained fault map with surface offsets constrained. All models shown later have this fault geometry and dip of 65 degrees.



4. Modeling of strong-motion, GPS and InSAR

We have searched for the best fit rupture velocity, to confirm whether supeshear rupture velocities occured to the east. The slip models with different fixed rupture velocities and varying rupture velocities show a very consistent slip pattern due to constraints coming from geodesy.

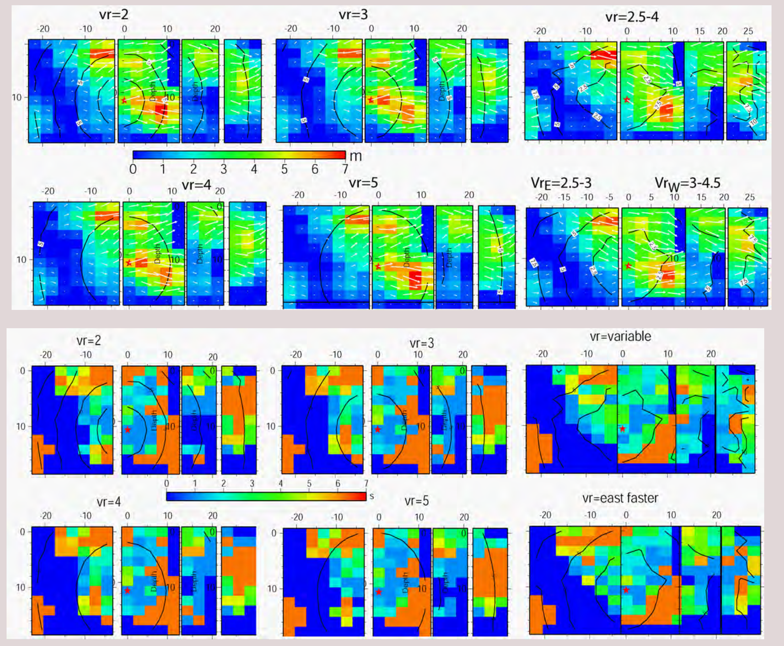


Figure 8: The slip map (top) and rise times (bottome) forjoint models with different rupture velocity constrains.

5. Fits to the strong-motion data

When we look at the fits to the seismograms, it is clear from the station BOL (east of the rupture) that the frequency content of the seismograms can only be obtained by varying rupture velocity runs. None of the single rupture velocity models fit the BOL data, especially in high frequencies as shown by velocity and accelerations.

Why does BOL have more Sensitivity?

We are pinning down slip very well so it cannot trade off with rupture velocity. However stations on the fault record very local time history. There are enough parameters to account for fitting the data with different rupture velocities. Since BOL is off the fault and it records more global behavior of the fault

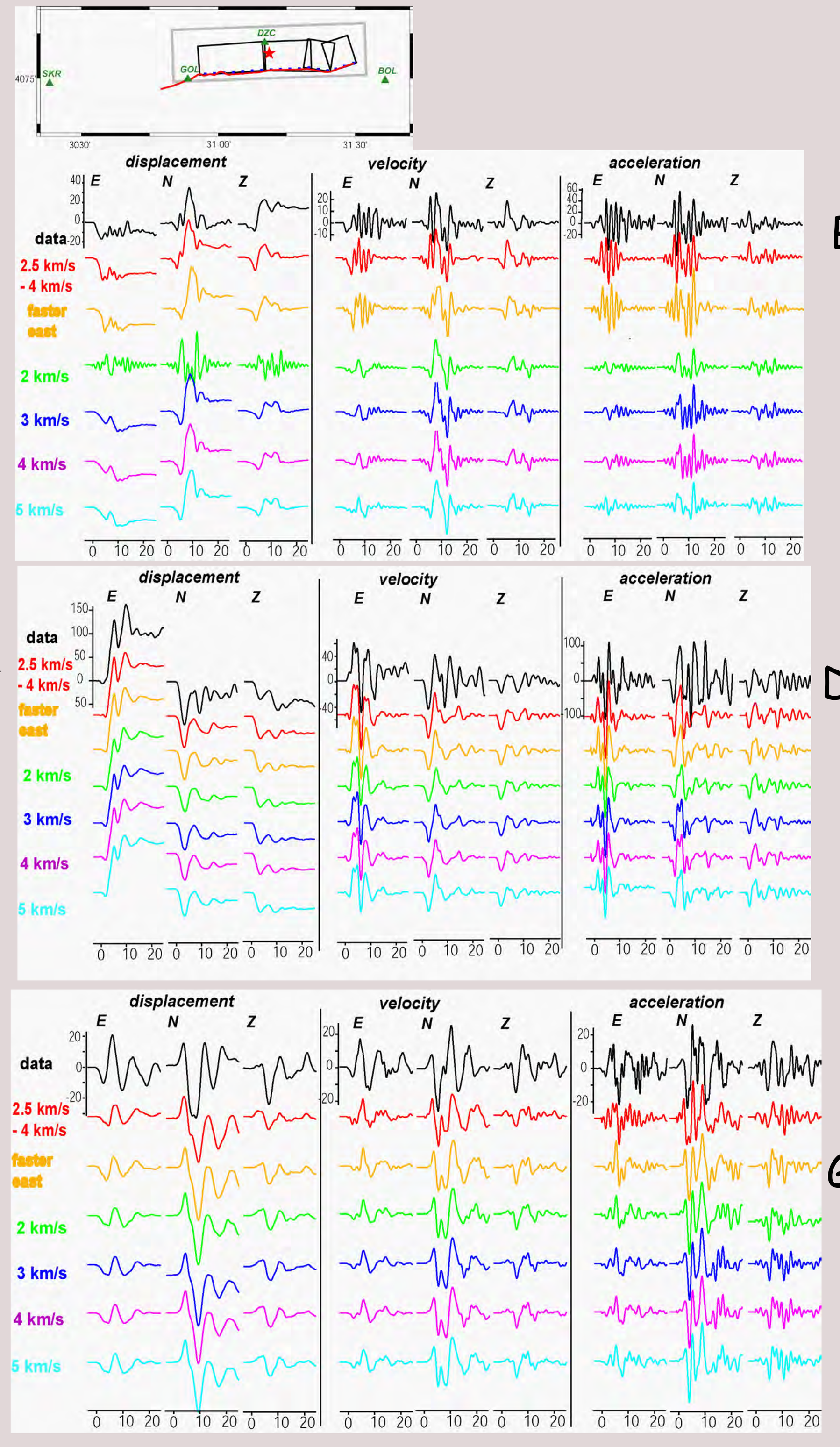


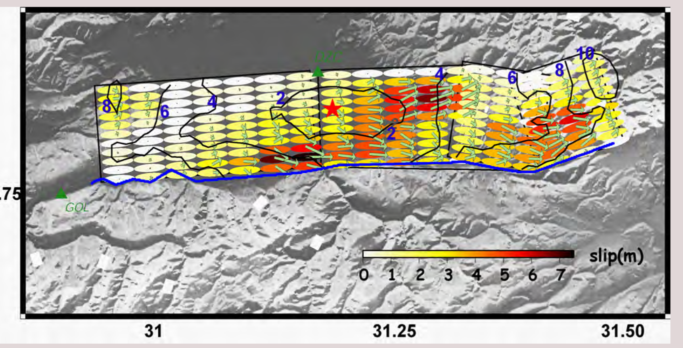
Figure 9:The fits to the strong-motion data, BOL, DZC and GOL from top to bottom. "Faster east" model has 2-3km/s rupture velocity constrain to the west and 2-4.5km/s to the west

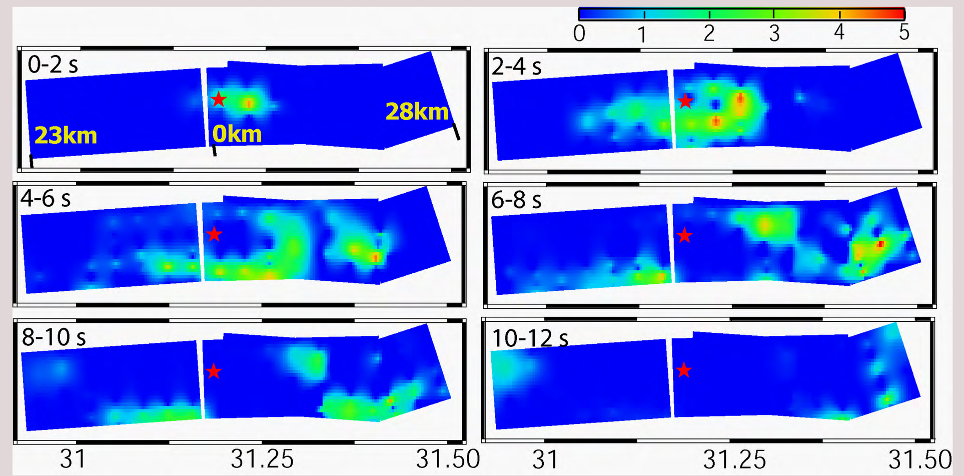
6.Map view of slip and snapshots of rupture

Supershear rupture is only significant in east direction.

The rupture starts subshear, accelerates to supershear speeds and slows down eventually.

Figure 10: Map view of total slip with time contours and snapshots of for slip every 2 second time windows





7.Fits to the GPS and InSAR data

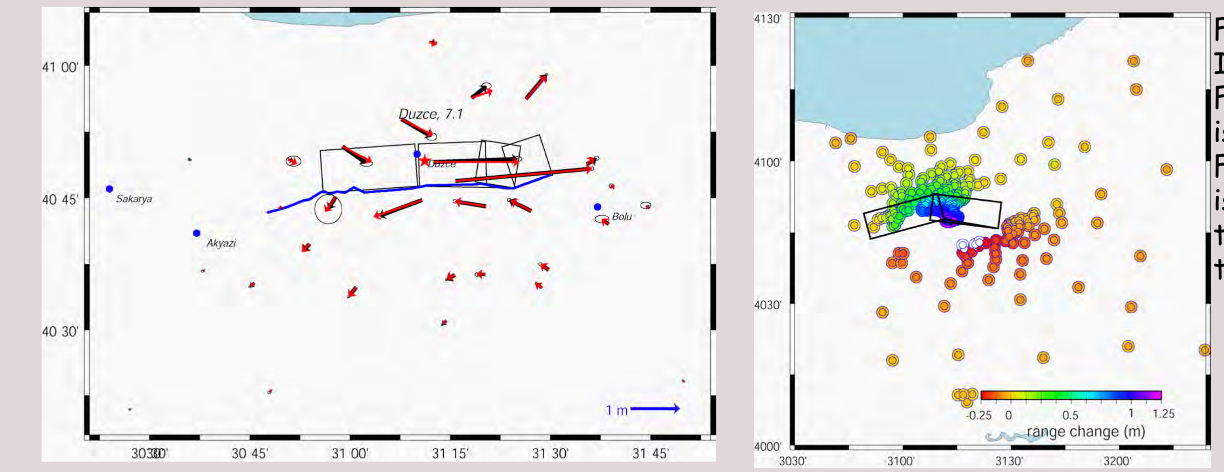


Figure 11: Fits to the GPS and Insar data for the model shown in Figure 10. For the GPS fits, black is data and red are synthetics. For the InSAR data every circle is a data poin. Outer circle shows the data and inner circle shows the synthetic.

8. Reconciling teleseismic and Strong motions

The main finding of this study is that in order to predict the teleseismic waves from joint inversion of strong-motions and geodetic data, we have to shift teleseismic waves by ~2 seconds. The shifts imply that when earthquake starts small, then the teleseismic picks can be later than the actual arrival time, leading to bulging around the hypocenter, while usually more slip happens away from the hypocenter.

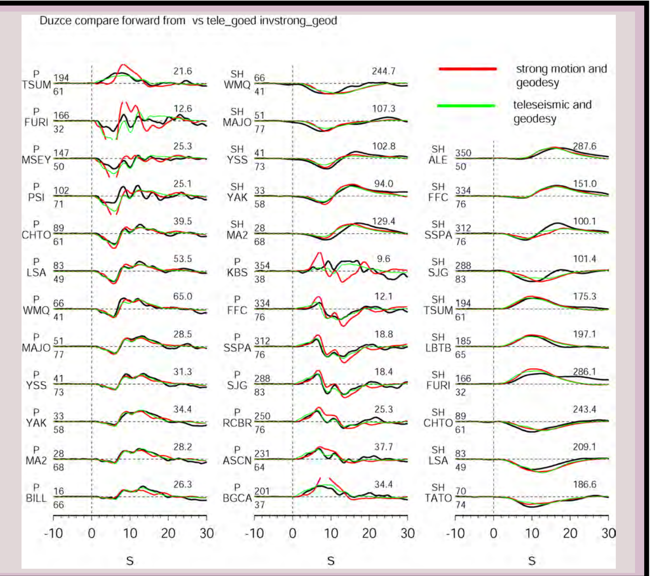


Figure 12: Telesesmic data (black) and forward prediction of the data from the joint strong-motion and geodetic inversion shown in Figure 10 (red). Greens are the fits from a teleseismic and geodetic joint inversion

9. Summary and Conclusions

1. We have modeled the Mw7.1 Duzce earthquake using an accurate 4 segment fault model obtained from SPOT imagery.
2. The Duzce rupture has extended further east than the models based on field observations.
3. We have modeled the earthquake with all available data.
4. In Duzce Earthquake, rapid variations in rupture velocity are required to explain the strong-motion data, along with geodetic data
5. Supershear rupture velocity is local and only to the east of the rupture.
6. The teleseismic data can miss the beginning of the events leading to more compact models with a lot of slip around the hypocenter than the actual sources.