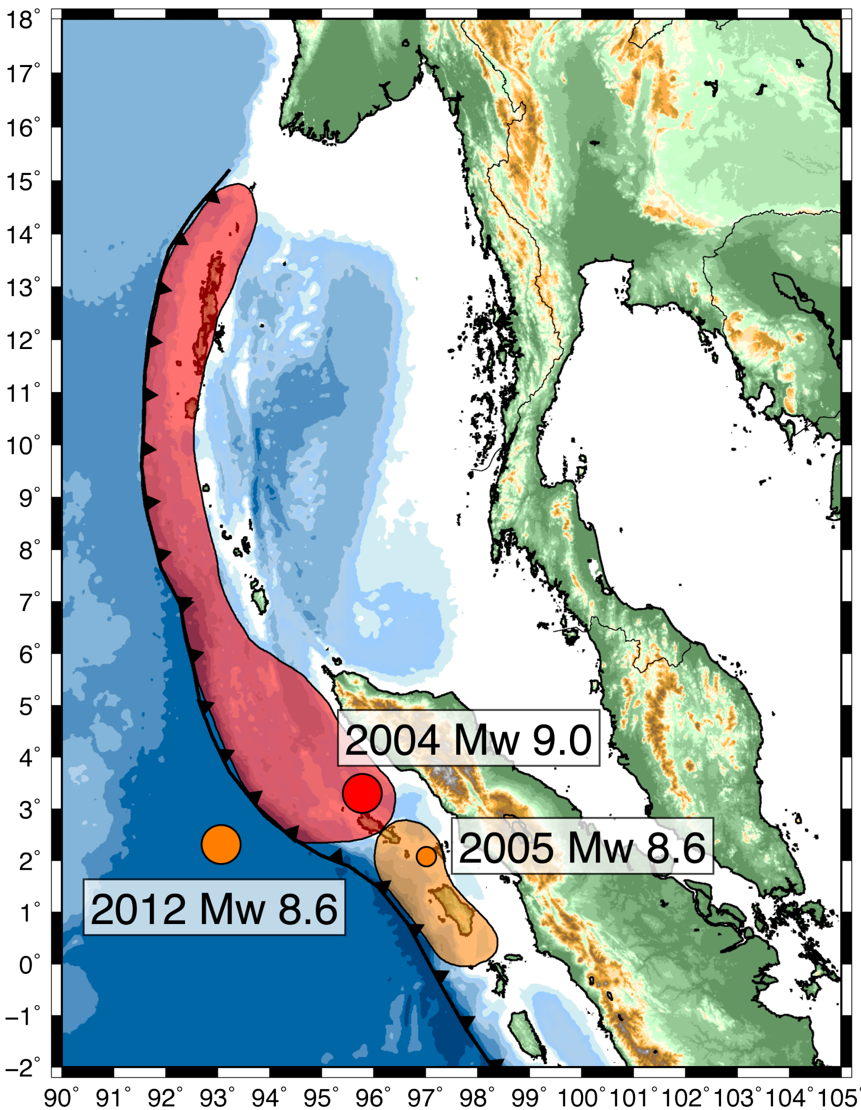
Introduction to Finite Fault Models

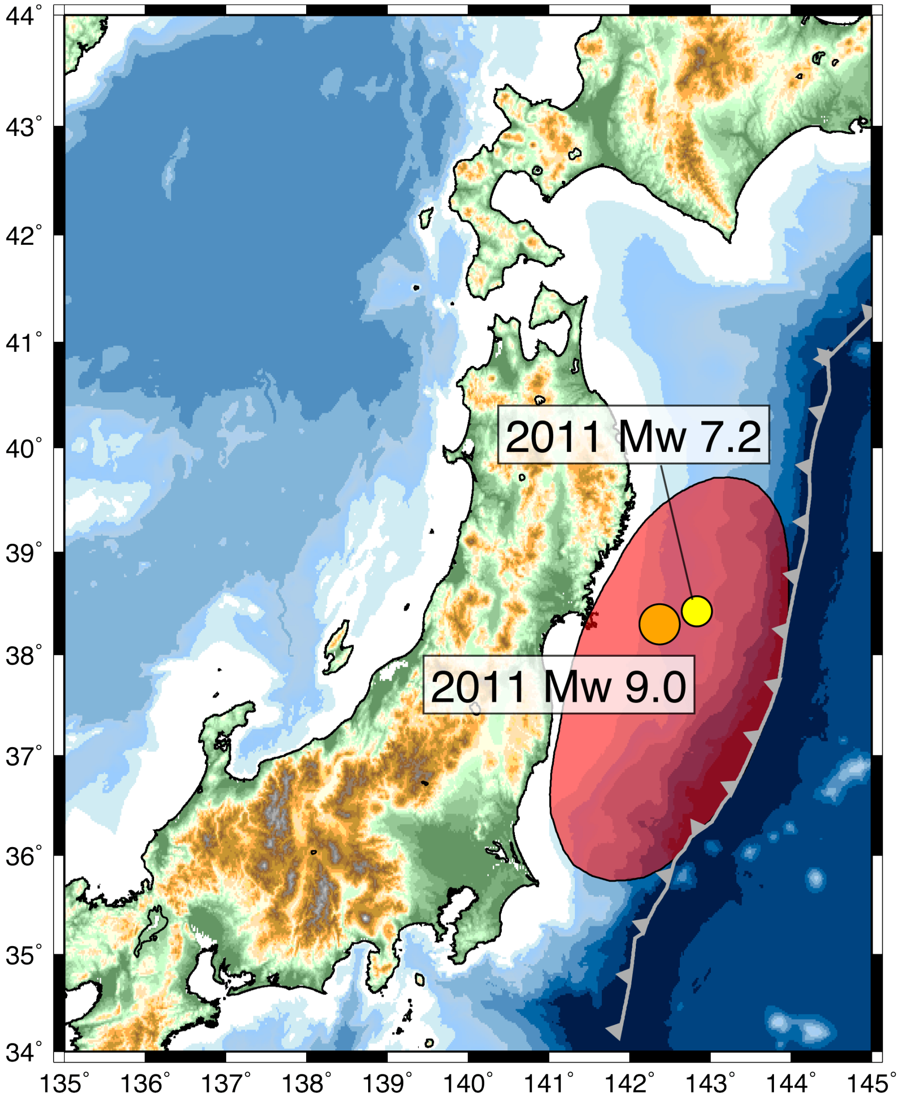
Introduction to FFMs



- 2004 Mw 9.0 Sumatra-Andaman earthquake
- 2005 Mw 8.6 earthquake to south
- Rupture areas are shaded

Rupture areas: *USGS Seismicity of the Earth 1900-2012: Sumatra and Vicinity*

Introduction to FFMs



- 2011 Mw 9.0 Tohoku-oki earthquake
- Rupture area is shaded

Rupture area: *Ozawa et al. (2011)*

Introduction to FFMs

- Large earthquakes (Mw 7.0+) occur over a finite area, and cannot be treated as a point source or a single rectangular fault

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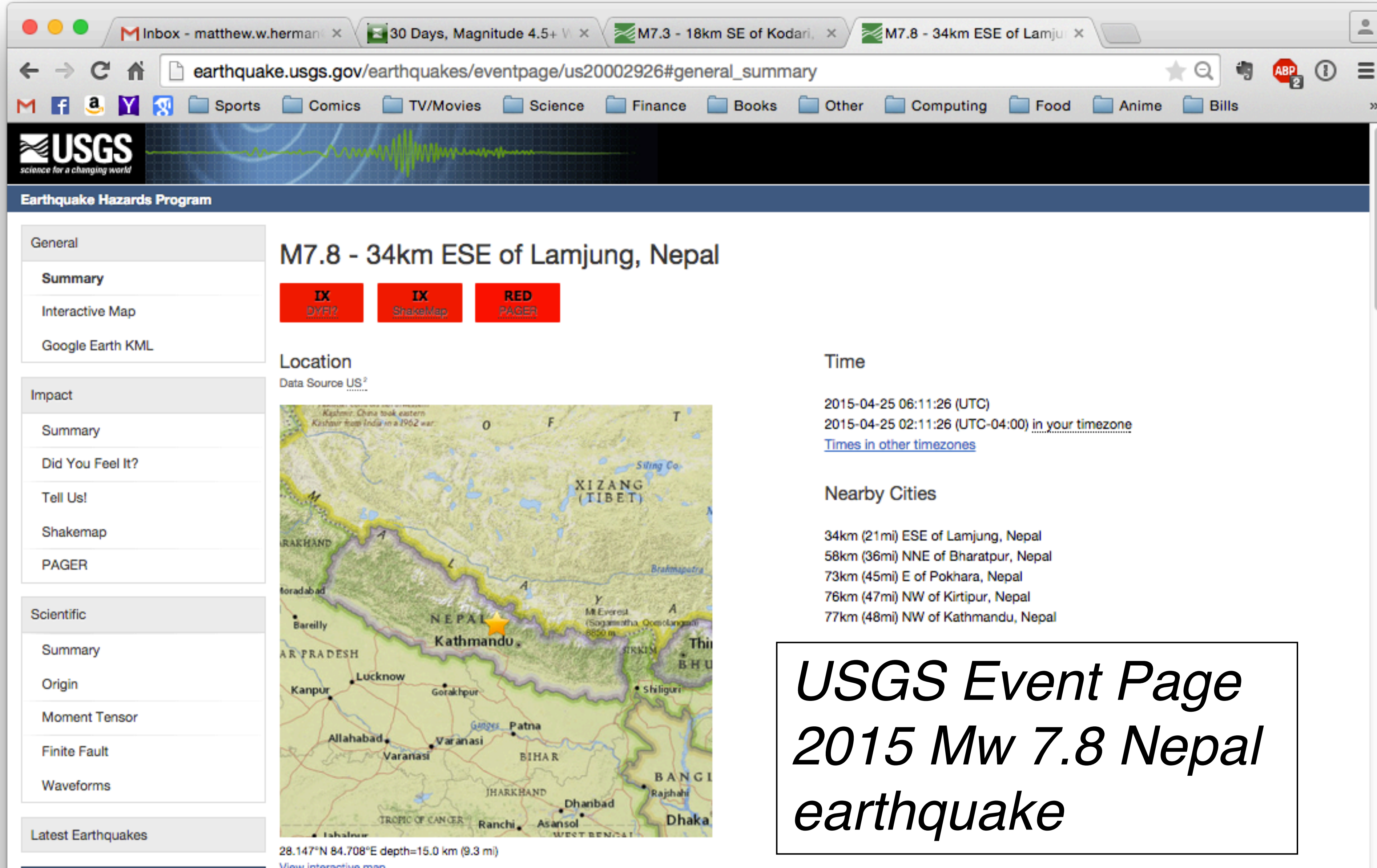
- In general, these large events have complex slip distributions and timing
- Constraining distribution of large slip is important for strong shaking predictions, tsunami generation, and stress change

Introduction to FFMs

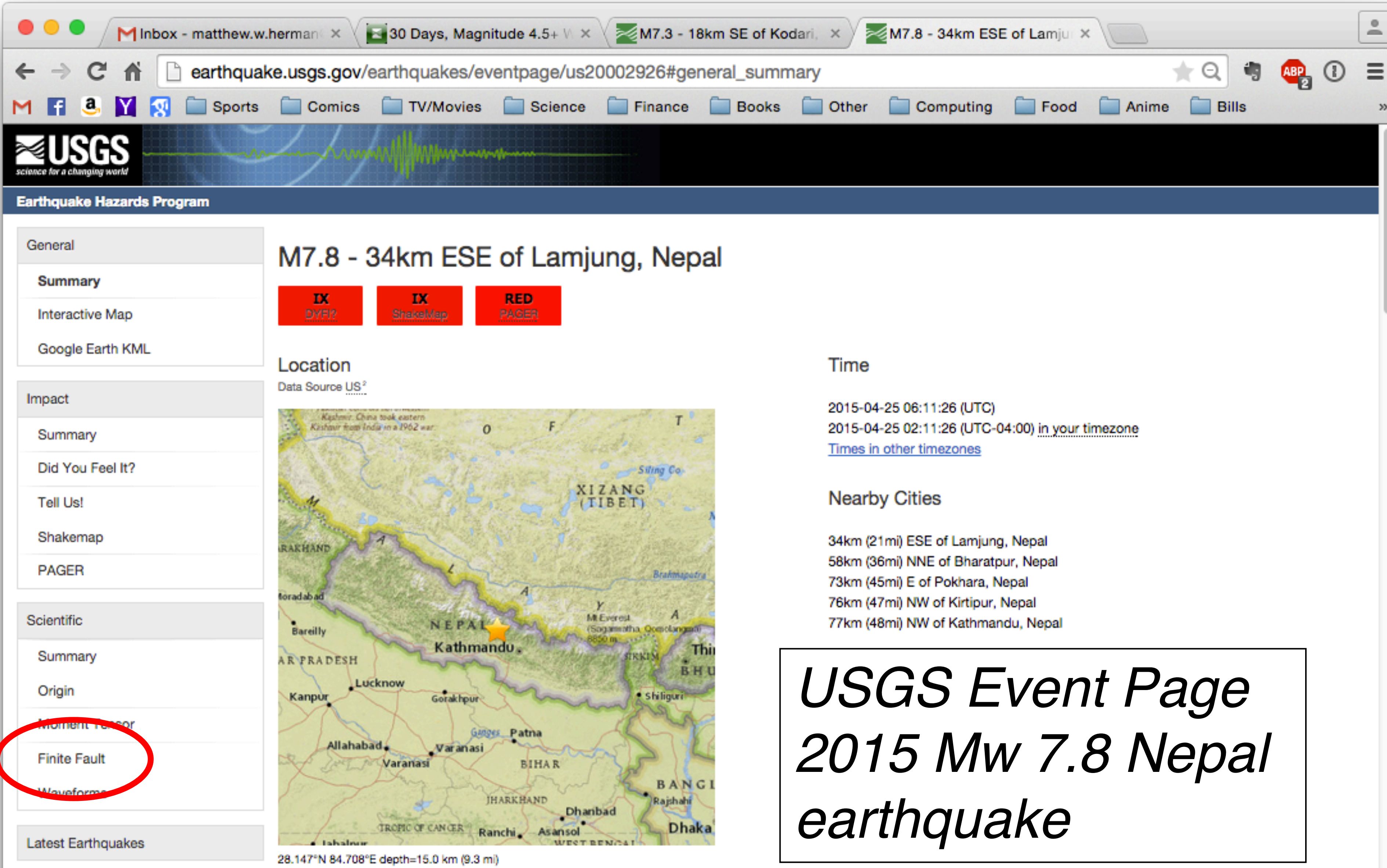
- Using teleseismic and regional seismic data (sometimes in conjunction with geodetic observations), can constrain earthquake slip distribution
- Finite Fault Model (FFM)

Introduction to FFMs



USGS Event Page 2015 Mw 7.8 Nepal earthquake

Introduction to FFMs



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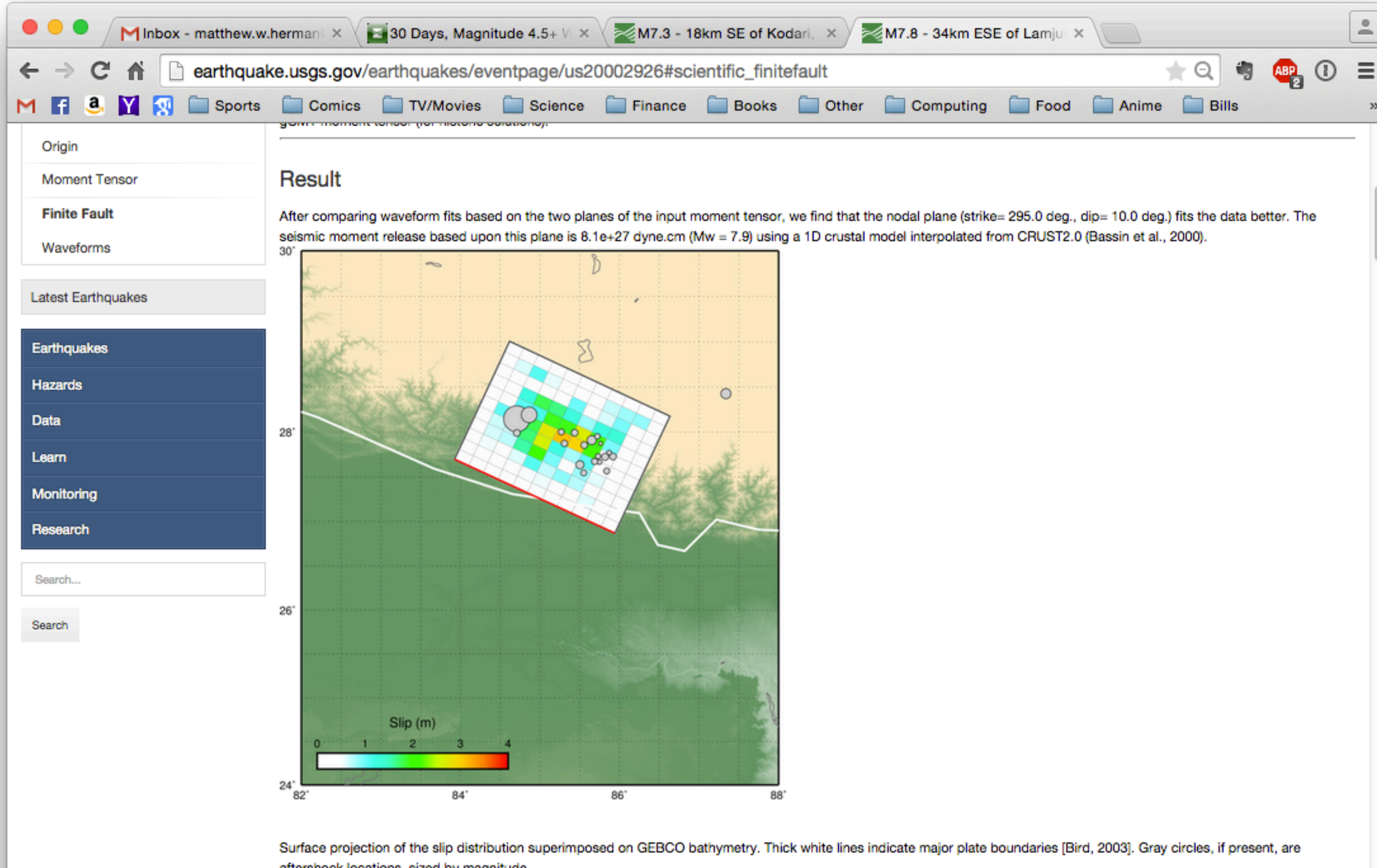
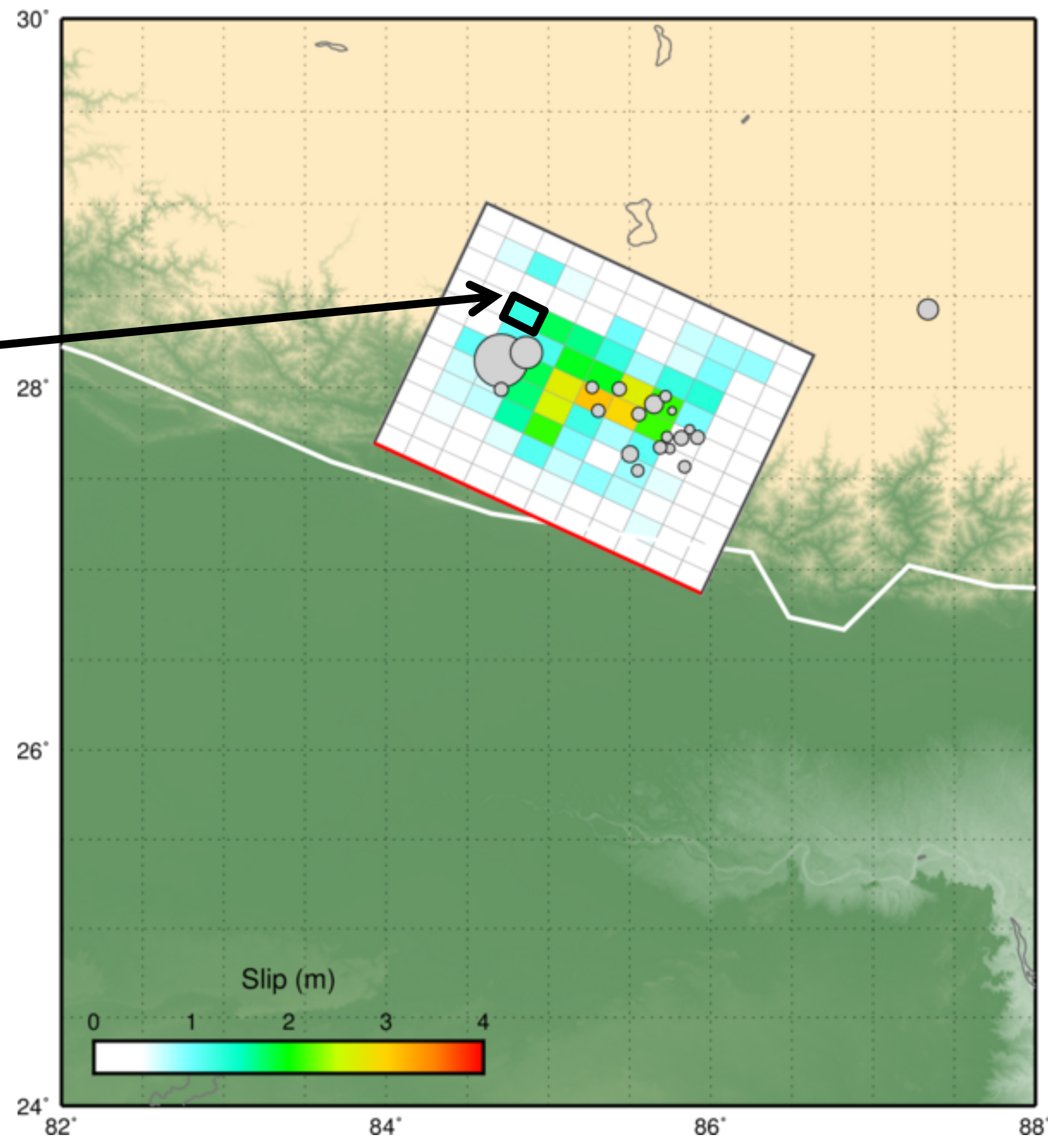


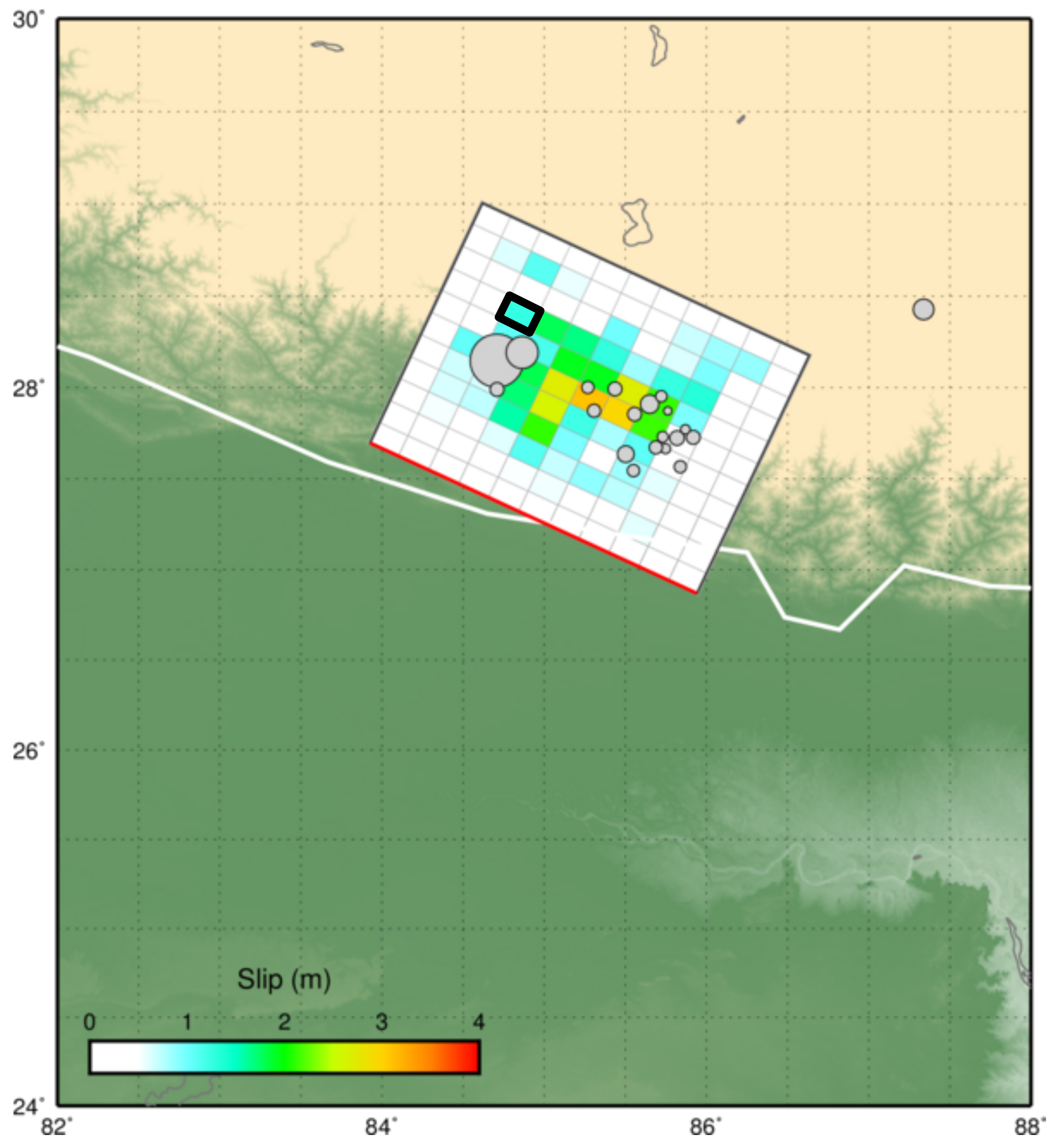
Introduction to FFMs

- Fault divided into small rectangular patches called “subfaults”
- Each subfault can be considered to be an earthquake



Introduction to FFMs

- *The problem: find the origin time and slip of each subfault that generates best fit to observed data*



Introduction to FFMs

Origin
Moment Tensor
Finite Fault
Waveforms

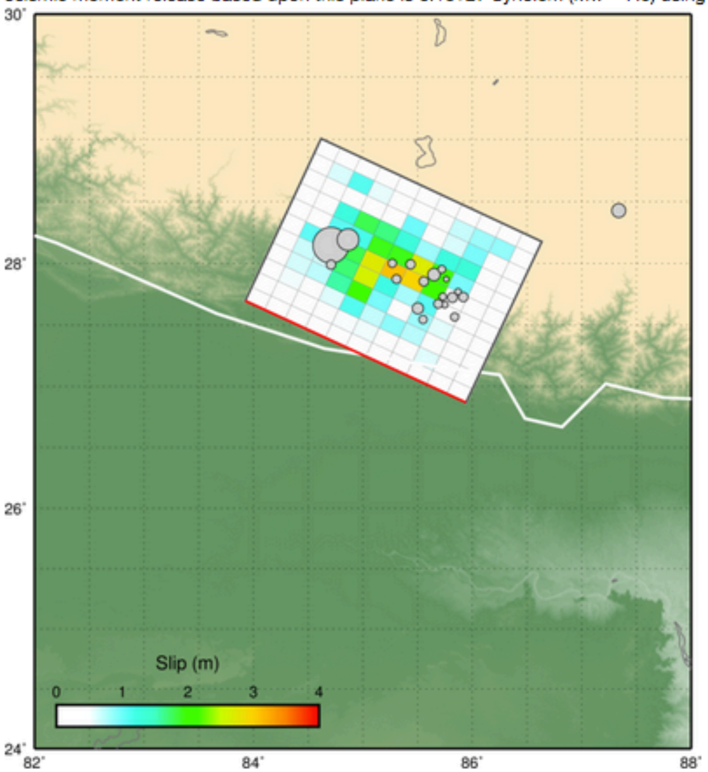
Latest Earthquakes

Earthquakes
Hazards
Data
Learn
Monitoring
Research

Search...
Search

Result

After comparing waveform fits based on the two planes of the input moment tensor, we find that the nodal plane (strike= 295.0 deg., dip= 10.0 deg.) fits the data better. The seismic moment release based upon this plane is 8.1e+27 dyne.cm (Mw = 7.9) using a 1D crustal model interpolated from CRUST2.0 (Bassin et al., 2000).

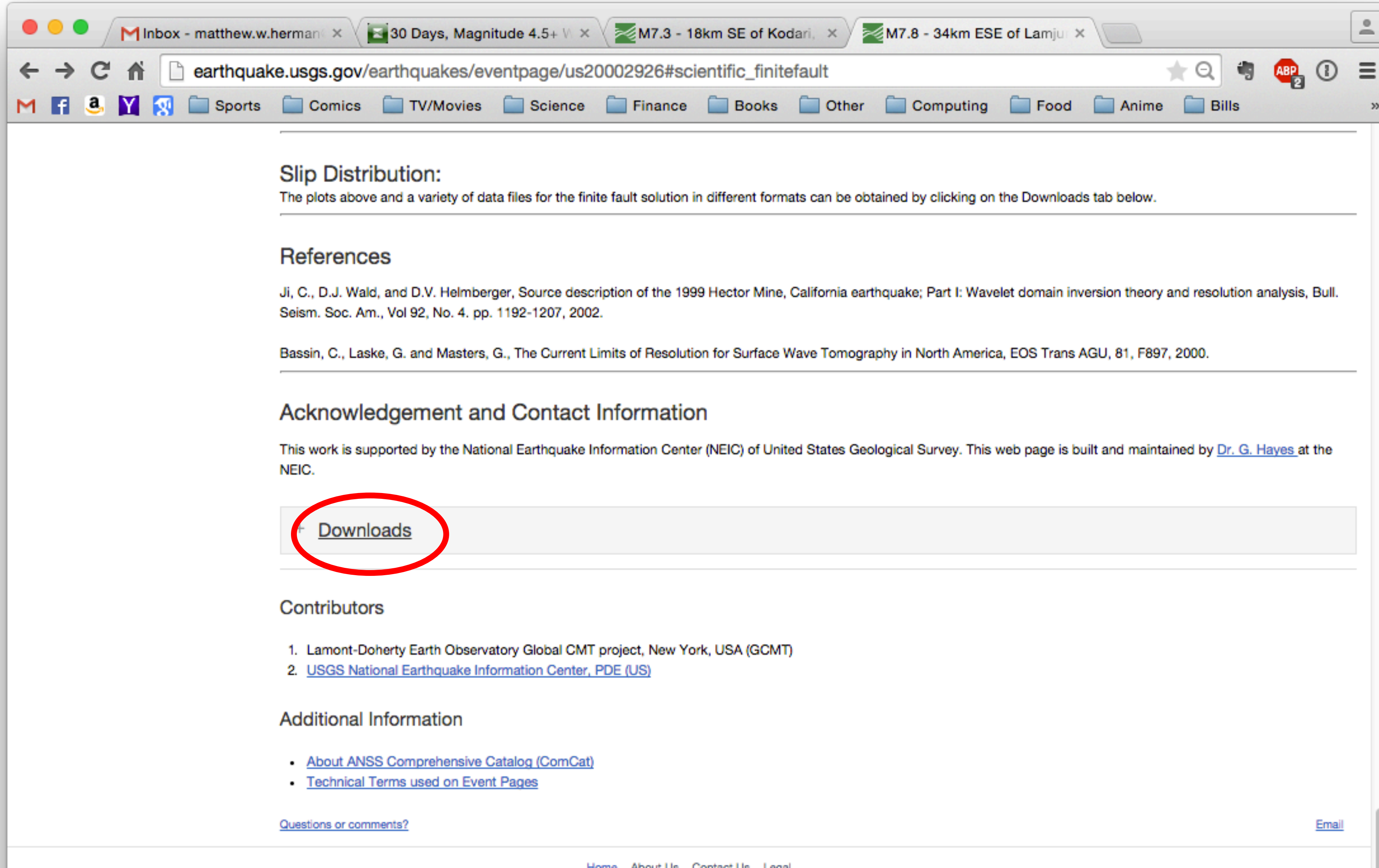


An FFM is produced by the USGS for every event Mw 7.0 and larger.

Other solutions can be found online or in publications.

Surface projection of the slip distribution superimposed on GEBCO bathymetry. Thick white lines indicate major plate boundaries [Bird, 2003]. Gray circles, if present, are aftershock locations, sized by magnitude.

Introduction to FFMs



Introduction to FFMs

- PNG (336.0 KB)

Surface Waves Plot
Multi-panel plot showing body wave data from all contributing stations

- PNG (320.4 KB)

Surface Waves Plot
Multi-panel plot showing body wave data from all contributing stations

- PNG (34.1 KB)

CMT Solution
Full CMT solution for every point in finite fault region

- WEB/CMTSOLUTION (90.7 KB)

Inversion Parameters File 1
Basic inversion parameters for each node in the finite fault

- PARAM (20.1 KB)

Inversion Parameters File 2
Complete inversion parameters for the finite fault, following the SRCMOD FSP format (http://equake-rc.info/)

- FSP (11.9 KB)

Coulomb Input File
Format necessary for compatibility with Coulomb3 (http://earthquake.usgs.gov/research/software/coulomb/)

- INP (15.7 KB)

Moment Rate Function File
Ascii file of time vs. moment rate, used for plotting source time function

- MR (31.0 KB)

Surface Deformation File
Surface displacement resulting from finite fault, calculated using Okada-style deformation codes

- DISP (1004.9 KB)

Contributors

Introduction to FFMs

static_out.nepal.2015.update1

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#Boundary of Fault_segment     1. EQ in cell 9,6. Lon: 84.7251   Lat: 28.1654
#Lon.   Lat.   Depth
       85.94160       26.86900        0.86010
       83.92680       27.69730        0.86010
       84.61880       29.00540       29.13990
       86.63350       28.17710       29.13990
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#Lat. Lon. depth slip rake strike dip t_rup t_ris t_fal mo
      26.869000      85.941600      0.860100      18.149680      75.149300     295.000000      10.000000     107.600000      9.600000      6.4000
      26.945100      85.756600      0.860100      13.718530      78.238790     295.000000      10.000000      98.400000     11.200000     12.8000
      27.021200      85.571600      0.860100      14.087420     109.260400     295.000000      10.000000      87.200000     11.200000     12.8000
      27.097200      85.386500      0.860100       0.118570     105.441600     295.000000      10.000000      74.400000      1.600000      6.4000
      27.173300      85.201500      0.860100       2.159150     125.126600     295.000000      10.000000      60.400000      1.600000     11.2000
      27.249300      85.016500      0.860100      19.058970     146.691190     295.000000      10.000000      48.800000      1.600000      1.6000
      27.325400      84.831400      0.860100       2.772390     132.130200     295.000000      10.000000      41.600000     11.200000     12.8000
      27.401500      84.646400      0.860100       5.095730     140.933000     295.000000      10.000000      38.800000      6.400000      1.6000
      27.477500      84.461400      0.860100       0.134520     147.097400     295.000000      10.000000      35.200000      4.800000      9.6000
      27.553600      84.276300      0.860100       3.704150     138.128800     295.000000      10.000000      35.600000      9.600000      3.2000
      27.629700      84.091300      0.860100       3.665460     128.019700     295.000000      10.000000      38.000000      8.000000      8.0000
      26.989500      86.005400      3.464800      14.342160     101.244000     295.000000      10.000000     107.200000     11.200000      8.0000
      27.065600      85.820300      3.464800      41.260720      94.360370     295.000000      10.000000      96.800000     12.800000     12.8000
      27.141600      85.635300      3.464800      59.689550     147.520710     295.000000      10.000000      82.800000      1.600000      1.6000
      27.217700      85.450300      3.464800      49.867240     130.532700     295.000000      10.000000      69.200000      4.800000      1.6000
      27.293800      85.265200      3.464800      44.360320      85.155300     295.000000      10.000000      54.400000     12.800000      3.2000
      27.369800      85.080200      3.464800      54.424960     147.222700     295.000000      10.000000      45.600000      9.600000      1.6000
      27.445900      84.895200      3.464800      51.677140      70.438360     295.000000      10.000000      34.400000      1.600000      1.6000
      27.522000      84.710100      3.464800       7.704420      75.428050     295.000000      10.000000      29.600000      9.600000      1.6000
      27.598000      84.525100      3.464800       3.529650     131.382900     295.000000      10.000000      28.800000      9.600000      3.2000
      27.674100      84.340100      3.464800      29.914410      99.737140     295.000000      10.000000      30.400000      4.800000      1.6000
      27.750200      84.155000      3.464800      13.402270     107.353600     295.000000      10.000000      33.600000      1.600000      1.6000
      27.110000      86.069100      6.069500      12.263720      85.909080     295.000000      10.000000     106.000000      1.600000     11.2000
      27.186100      85.884100      6.069500      15.084040     108.554600     295.000000      10.000000      95.200000      9.600000      3.2000
      27.262100      85.699000      6.069500      50.726420     148.907700     295.000000      10.000000      80.400000      1.600000      8.0000
      27.338200      85.514000      6.069500      73.696030      75.950460     295.000000      10.000000      64.400000      4.800000      3.2000
      27.414200      85.329000      6.069500      88.593870      70.608710     295.000000      10.000000      46.800000      6.400000      1.6000
      27.490300      85.143900      6.069500      69.690230      71.039640     295.000000      10.000000      32.800000      1.600000      1.6000
```

Length (km)

Width (km)

Introduction to FFMs

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      27.262100      85.699000       6.069500      50.726420     148.907700     295.000000      10.000000      80.400000       1.600000       8.0000
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```

Latitude   Longitude   Depth (km)

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      27.490300      85.143900       6.069500      69.690230      71.039640     295.000000      10.000000      32.800000       1.600000       1.6000
```

Slip (cm)   Rake   Strike   Dip

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      27.173300      85.201500       0.860100       2.159150     125.126600     295.000000      10.000000      60.400000       1.600000      11.20000
      27.249300      85.016500       0.860100      19.058970     146.691190     295.000000      10.000000      48.800000       1.600000       1.60000
      27.325400      84.831400       0.860100       2.772390     132.130200     295.000000      10.000000      41.600000      11.200000      12.80000
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      27.369800      85.080200       3.464800      54.424960     147.222700     295.000000      10.000000      45.600000       9.600000       1.60000
      27.445900      84.895200       3.464800      51.677140      70.438360     295.000000      10.000000      34.400000       1.600000       1.60000
      27.522000      84.710100       3.464800       7.704420      75.428050     295.000000      10.000000      29.600000       9.600000       1.60000
      27.598000      84.525100       3.464800       3.529650     131.382900     295.000000      10.000000      28.800000       9.600000       3.20000
      27.674100      84.340100       3.464800      29.914410      99.737140     295.000000      10.000000      30.400000       4.800000       1.60000
      27.750200      84.155000       3.464800      13.402270     107.353600     295.000000      10.000000      33.600000       1.600000       1.60000
      27.110000      86.069100       6.069500      12.263720      85.909080     295.000000      10.000000     106.000000       1.600000      11.20000
      27.186100      85.884100       6.069500      15.084040     108.554600     295.000000      10.000000      95.200000       9.600000       3.20000
      27.262100      85.699000       6.069500      50.726420     148.907700     295.000000      10.000000      80.400000       1.600000       8.00000
      27.338200      85.514000       6.069500      73.696030      75.950460     295.000000      10.000000      64.400000       4.800000       3.20000
      27.414200      85.329000       6.069500      88.593870      70.608710     295.000000      10.000000      46.800000       6.400000       1.60000
      27.490300      85.143900       6.069500      69.690230      71.039640     295.000000      10.000000      32.800000       1.600000       1.60000
```

Rupture Time

Introduction to FFMs

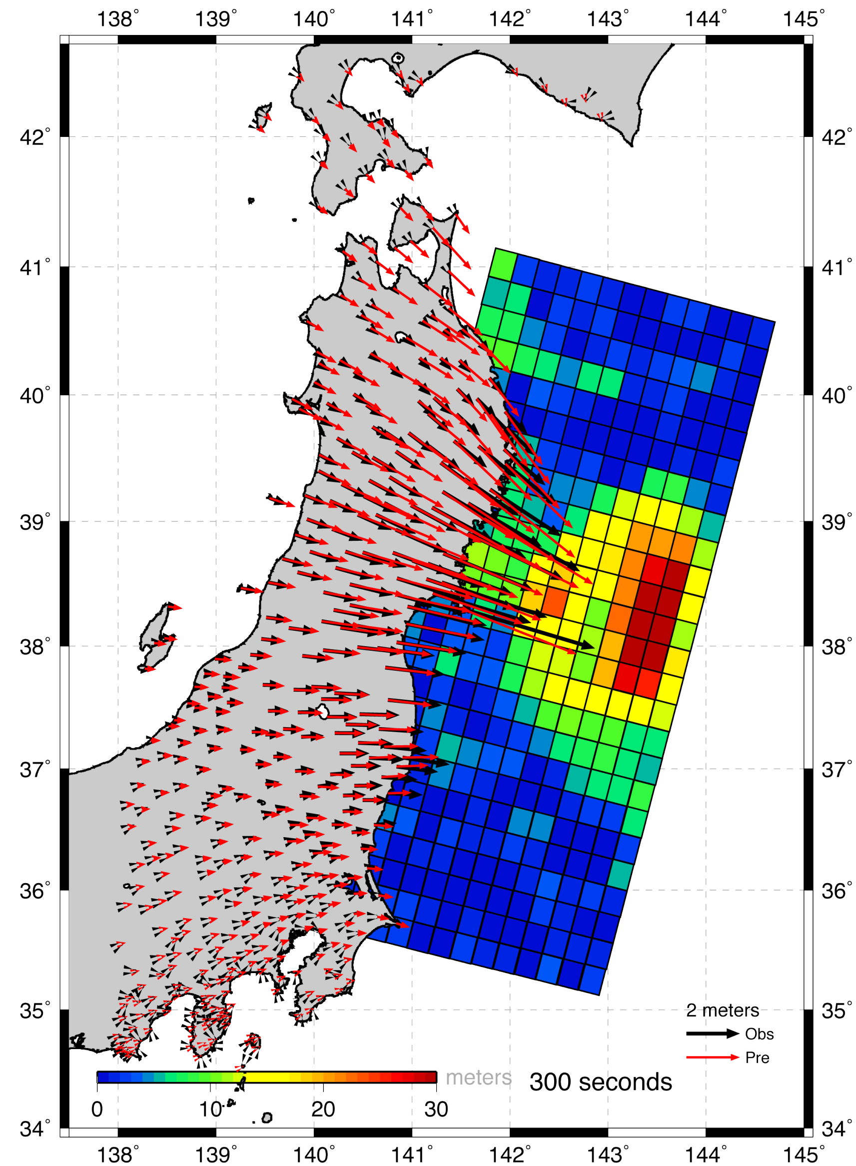
- Each of these subfaults is a rectangular segment that can be used with O92UTIL
- FFMs in the USGS subfault format can be directly input in O92UTIL using the -ffm option

```
o92util -ffm ffm_file -sta station.dat
    -haf hafspace.dat -trg target.dat
    -disp disp.out -coul coul.out
```

See also: Hayes, G.P. (2017). The finite, kinematic rupture properties of great-sized earthquakes since 1990. EPSL.

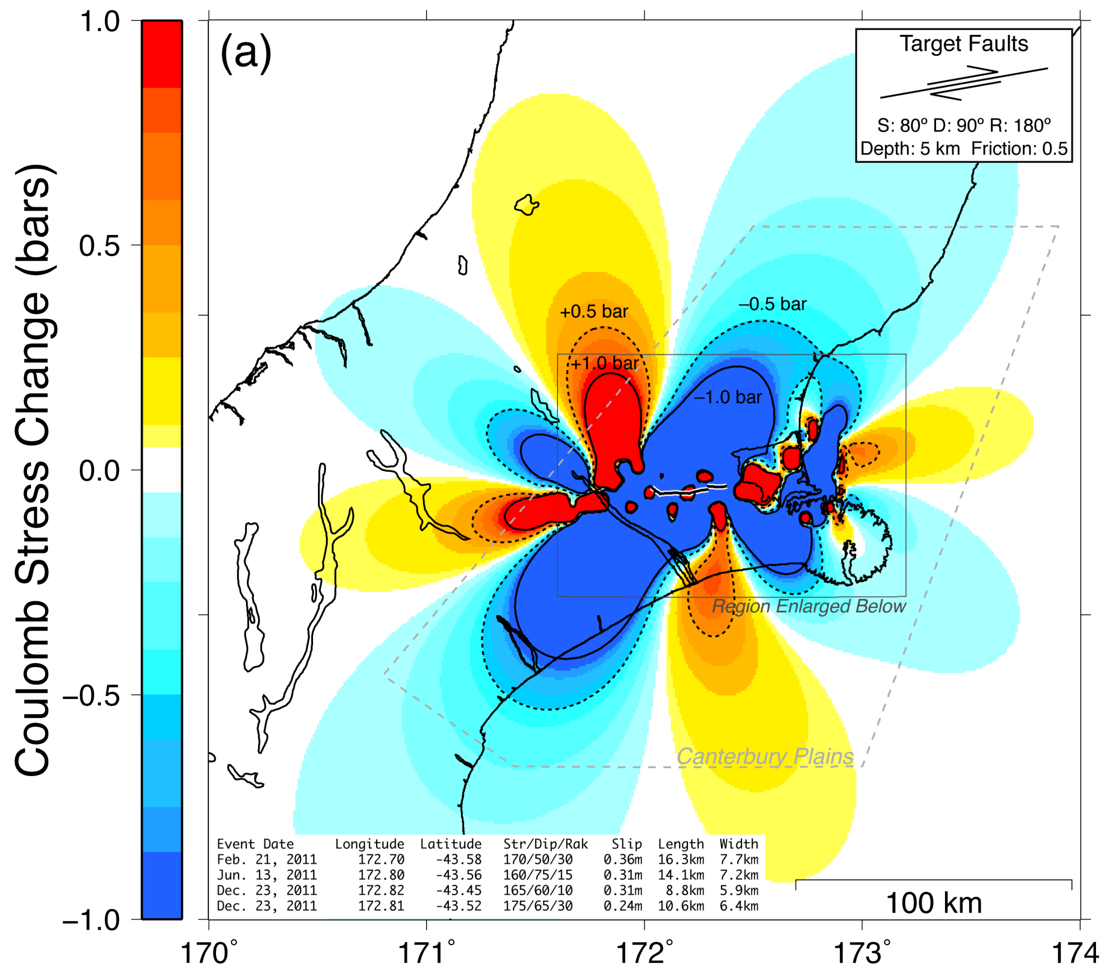
Introduction to FFMs

- Example: 2011 Mw 9.0 Tohoku earthquake
- Observed surface deformation in black, modeled displacements in red



Introduction to FFMs

- Example: 2010 Mw 7.0 Darfield earthquake
- Modeled stress change from the rutpure



Introduction to Finite Fault Models Completed