Introduction to Finite Fault Models



- 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

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

Rupture area: Ozawa et al. (2011)

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

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

Inbox - matthew.w	v.hermant × V 🔄 30 Days, Magnitude 4.5+ VI × V 🜌 M7.3 - 18km SE of K	Kodari, × M7.8 - 34km ESE of Lamjur ×
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Science for a changing world		
Earthquake Hazards Program		
General	M7.8 - 34km ESE of Lamiung, Nepal	
Summary	Min.o - 54km ESE of Earljung, Nepar	
Interactive Map	DYRY ShakaMap PAGER	
Google Earth KML	Location	Time
Impact	Data Source US ²	2015-04-25 08-11-26 (LTC)
Summary	Kaptener them lindle on a 1962 war 0 F T	2015-04-25 02:11:26 (UTC-04:00) in your timezone
Did You Feel It?	Sling Co.	Times in other timezones
Tell Us!	XIZANG (TIBET)	Nearby Cities
Shakemap	RAEHAND	34km (21mi) ESE of Lamjung, Nepal
PAGER	Bratmaputy	58km (36mi) NNE of Bharatpur, Nepal 73km (45mi) E of Pokhara, Nepal
Scientific	Bareilly NEPAL	76km (47mi) NW of Kirtipur, Nepal 77km (48mi) NW of Kathmandu, Nepal
Summary	AR PRADESH Kathmandu. STRAM	
Origin	Kanpur Gorakhpur Shiliguri	USGS Event Page
Moment Tensor	patra	
Finite Fault	Allahabad Varanasi Varanasi BIHA R	2015 N/w 7.8 Nepal
Waveforms	HARKHAND Dharibad Rajdahi	
Latest Earthquakes	TROPIC OF CANGER Ranchi, As ansol 28.147*N 84.708*E depth=15.0 km (9.3 ml)	eannquake

Inbox - matthew.w	x.herman∜ × V 🛃 30 Days, Magnitude 4.5+ ₩ × V 🌌 M7.3 - 18km SE of H	Kodari, × ZMT.8 - 34km ESE of Lamju ×
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Science for a changing world		
Earthquake Hazards Program		
General	M7.8 - 34km ESE of Lamiung Nepal	
Summary	W7.8 - 34km ESE of Lamjung, Nepai	
Interactive Map	DYFIY ShakaMap PAGER	
Google Earth KML	Location	Time
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Origin		
Moment Tensor	Result	
Finite Fault	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	l
Waveforms	30° Constant release based upon this plane is 8.1e+27 dyne.cm (ww = 7.9) using a 1D crustal model interpolated from CHOS12.0 (bassin et al., 2000).	l
Latest Earthquakes		
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	Slip (m) 0 1 2 3 4 24' _{82'} 84' 86' 88'	

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

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

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

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Origin		
Moment Tensor	Result	
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•	•		Minbo	ox - matthew.w	.herman ×	30 Days, Magn	itude 4.5+ \/ ×	M7.3 - 1	8km SE of Ko	dari, x	M7.8 - 34km ES	E of Lamjur >				
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Slip Distribution:

The plots above and a variety of data files for the finite fault solution in different formats can be obtained by clicking on the Downloads tab below.

References

Ji, C., D.J. Wald, and D.V. Helmberger, Source description of the 1999 Hector Mine, California earthquake; Part I: Wavelet domain inversion theory and resolution analysis, Bull. Seism. Soc. Am., Vol 92, No. 4. pp. 1192-1207, 2002.

Bassin, C., Laske, G. and Masters, G., The Current Limits of Resolution for Surface Wave Tomography in North America, EOS Trans AGU, 81, F897, 2000.

Acknowledgement and Contact Information

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► <u>Downloads</u>

Contributors

- 1. Lamont-Doherty Earth Observatory Global CMT project, New York, USA (GCMT)
- 2. USGS National Earthquake Information Center, PDE (US)

Additional Information

- About ANSS Comprehensive Catalog (ComCat)
- · Technical Terms used on Event Pages

Questions or comments?

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	static_out.nep	al.2015.update1								
1	#Total number of	fault_segments=	1							
2	#Fault_segment =	1 nx(Along-str	rike)= 11 Dx= 2	0.00km ny(down	dip)= 11 Dy= 15	5.00km				
3	#Boundary of Faul	t_segment 1.	EQ in cell 9,6	. Lon: 84.7251	Lat: 28.1654					
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11	26,869000	85,941600	0.860100	18,149680	75,149300	295,000000	10,000000	107,600000	9,600000	6,40000
12	26,945100	85,756600	0.860100	13,718530	78,238790	295,000000	10.000000	98,400000	11,200000	12.80000
13	27.021200	85.571600	0.860100	14.087420	109.260400	295.000000	10.000000	87.200000	11.200000	12.80000
14	27.097200	85.386500	0.860100	0.118570	105.441600	295.000000	10.000000	74.400000	1.600000	6.40000
15	27.173300	85.201500	0.860100	2.159150	125.126600	295.000000	10.000000	60.400000	1.600000	11.20000
16	27.249300	85.016500	0.860100	19.058970	146.691190	295.000000	10.000000	48.800000	1.600000	1.60000
17	27.325400	84.831400	0.860100	2.772390	132.130200	295.000000	10.000000	41.600000	11.200000	12.80000
18	27.401500	84.646400	0.860100	5.095730	140.933000	295.000000	10.000000	38.800000	6.400000	1.60000
19	27.477500	84.461400	0.860100	0.134520	147.097400	295.000000	10.000000	35.200000	4.800000	9.60000
20	27.553600	84.276300	0.860100	3.704150	138.128800	295.000000	10.000000	35.600000	9.600000	3.20000
21	27.629700	84.091300	0.860100	3.665460	128.019700	295.000000	10.000000	38.000000	8.000000	8.00000
22	26,989500	86.005400	3.464800	14.342160	101.244000	295.000000	10.000000	107.200000	11.200000	8.00000
23	27.065600	85.820300	3.464800	41.260720	94.360370	295.000000	10.000000	96.800000	12.800000	12.80000
24	27.141600	85.635300	3.464800	59.689550	147.520710	295.000000	10.000000	82.800000	1.600000	1.60000
25	27.217700	85.450300	3.464800	49.867240	130.532700	295.000000	10.000000	69.200000	4.800000	1.60000
26	27.293800	85.265200	3.464800	44.360320	85.155300	295.000000	10.000000	54.400000	12.800000	3.20000
27	27.369800	85.080200	3.464800	54.424960	147.222700	295.000000	10.000000	45.600000	9.600000	1.60000
28	27.445900	84.895200	3.464800	51.677140	70.438360	295.000000	10.000000	34.400000	1.600000	1.60000
29	27.522000	84.710100	3.464800	7.704420	75.428050	295.000000	10.000000	29.600000	9.600000	1.60000
30	27.598000	84.525100	3.464800	3.529650	131.382900	295.000000	10.000000	28.800000	9.600000	3.20000
31	27.674100	84.340100	3.464800	29.914410	99.737140	295.000000	10.000000	30.400000	4.800000	1.60000
32	27.750200	84.155000	3.464800	13.402270	107.353600	295.000000	10.000000	33.600000	1.600000	1.60000
33	27.110000	86.069100	6.069500	12.263720	85.909080	295.000000	10.000000	105.000000	1.600000	11.20000
34	27.186100	85.884100	6.069500	15.084040	108.554600	295.000000	10.000000	95.200000	9.600000	3.20000
35	27.262100	85.699000	6.069500	50.726420	148.907700	295.000000	10.000000	80.400000	1.600000	8.00000
36	27.338200	85.514000	6.069500	/3.696030	75.950460	295.000000	10.000000	64.400000	4.800000	3.20000
37	27.414200	85.329000	6.069500	88.593870	70.608/10	295.000000	10.000000	46.800000	6.400000	1.60000
38	27.490300	85.143900	6.069500	69.690230	71.039640	295.000000	10.000000	32.800000	1.600000	1.60000

static_out.nepal.2015.update1 ~

static_out.nepal.2015.update1

1	#Total number of	fault_segments=	1							1
2	#Fault segment =	1 nx(Along-str	ike)= 11 Dx= 20	0.00km nv(downo	dip)= 11 Dv= 1	5.00km				
3	#Boundary of Faul	t seament 1.	EO in cell 9.6	Lon: 84,7251	Lat: 28,1654					
4	#Lon, Lat, Dept	h								
5	85,94160	26.86900	0.86010							
6	83,92680	27,69730	0.86010							
7	84.61880	29.00540	29.13990							
8	86.63350	28.17710	29.13990							
9	85.94160	26.86900	0.86010							
10	#Lat. Lon. depth	slip rake strike	dip t_rup t_ris	s t_fal mo						
11	26.869000	85.941600	0.860100	18.149680	75.149300	295.000000	10.000000	107.600000	9.600000	6.40000
12	26.945100	85.756600	0.860100	13.718530	78.238790	295.000000	10.000000	98.400000	11.200000	12.80000
13	27.021200	85.571600	0.860100	14.087420	109.260400	295.000000	10.000000	87.200000	11.200000	12.80000
14	27.097200	85.386500	0.860100	0.118570	105.441600	295.000000	10.000000	74.400000	1.600000	6.40000
15	27.173300	85.201500	0.860100	2.159150	125.126600	295.000000	10.000000	60.400000	1.600000	11.20000
16	27.249300	85.016500	0.860100	19.058970	146.691190	295.000000	10.000000	48.800000	1.600000	1.60000
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18	27.401500	84.646400	0.860100	5.095730	140.933000	295.000000	10.000000	38.800000	6.400000	1.60000
19	27.477500	84.461400	0.860100	0.134520	147.097400	295.000000	10.000000	35.200000	4.800000	9.60000
20	27.553600	84.276300	0.860100	3.704150	138.128800	295.000000	10.000000	35.600000	9.600000	3.20000
21	27.629700	84.091300	0.860100	3.665460	128.019700	295.000000	10.000000	38.000000	8.000000	8.00000
22	26,989500	86.005400	3.464800	14.342160	101.244000	295.000000	10.000000	107.200000	11.200000	8.00000
23	27.065600	85.820300	3.464800	41.260720	94.360370	295.000000	10.000000	96.800000	12.800000	12.80000
24	27.141600	85.635300	3.464800	59.689550	147.520710	295.000000	10.000000	82.800000	1.600000	1.60000
25	27.217700	85.450300	3.464800	49.867240	130.532700	295.000000	10.000000	69.200000	4.800000	1.60000
26	27.293800	85.265200	3.464800	44.360320	85.155300	295.000000	10.000000	54.400000	12.800000	3.20000
27	27.369800	85.080200	3.464800	54.424960	147.222700	295.000000	10.000000	45.600000	9.600000	1.60000
28	27.445900	84.895200	3.464800	51.677140	70.438360	295.000000	10.000000	34.400000	1.600000	1.60000
29	27.522000	84.710100	3.464800	7.704420	75.428050	295.000000	10.000000	29.600000	9.600000	1.60000
30	27.598000	84.525100	3.464800	3.529650	131.382900	295.000000	10.000000	28.800000	9.600000	3.20000
31	27.674100	84.340100	3.464800	29.914410	99.737140	295.000000	10.000000	30.400000	4.800000	1.60000
32	27.750200	84.155000	3.464800	13.402270	107.353600	295.000000	10.000000	33.600000	1.600000	1.60000
33	27.110000	86.069100	6.069500	12.263/20	85.909080	295.000000	10.000000	106.000000	1.600000	11.20000
34	27.186100	85.884100	6.069500	15.084040	108.554600	295.000000	10.000000	95.200000	9.600000	3.20000
35	27.262100	85.699000	6.069500	50.726420	148.907700	295.000000	10.000000	80.400000	1.600000	8.00000
36	27.338200	85.514000	6.069500	73.696030	75.950460	295.000000	10.000000	64.400000	4.800000	3.20000
37	27.414200	85.329000	6.069500	88.593870	70.608/10	295.000000	10.000000	46.800000	6.400000	1.60000
38	27.490300	85.143900	6.069500	69.690230	71.039640	295.000000	10.000000	32.800000	1.600000	1.60000

Latitude Longitude Depth (km)

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static_out.nepal.2015.update1

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, a	86,63350	28,17710	29,13990							
9	85,94160	26,86988	0.86010							
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12	26,945100	85,756600	0.860100	13,718530	78,238790	295,000000	10.000000	98,400000	11,200000	12.80000
13	27,021200	85,571600	0.860100	14,087420	109.260400	295,000000	10.000000	87,200000	11,200000	12.80000
14	27,097200	85.386500	0.860100	0.118570	105,441600	295,000000	10.000000	74,400000	1,600000	6.40000
15	27,173300	85,201500	0.860100	2,159150	125,126600	295,000000	10.000000	60,400000	1,600000	11,20000
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25	27.217700	85.450300	3.464800	49.867240	130.532700	295.000000	10.000000	69.200000	4.800000	1.60000
26	27.293800	85.265200	3.464800	44.360320	85.155300	295.000000	10.000000	54.400000	12.800000	3.20000
27	27.369800	85.080200	3.464800	54.424960	147.222700	295.000000	10.000000	45.600000	9.600000	1.60000
28	27.445900	84.895200	3.464800	51.677140	70.438360	295.000000	10.000000	34.400000	1.600000	1.60000
29	27.522000	84.710100	3.464800	7.704420	75.428050	295.000000	10.000000	29.600000	9.600000	1.60000
38	27.598000	84.525100	3.464800	3.529650	131.382900	295.000000	10.000000	28.800000	9.600000	3.20000
31	27.674100	84.340100	3.464800	29.914410	99.737140	295.000000	10.000000	30.400000	4.800000	1.60000
32	27.750200	84.155000	3.464800	13.402270	107.353600	295.000000	10.000000	33.600000	1.600000	1.60000
33	27.110000	86.069100	6.069500	12.263720	85.909080	295.000000	10.000000	106.000000	1.600000	11.20000
34	27.186100	85.884100	6.069500	15.084040	108.554600	295.000000	10.000000	95.200000	9.600000	3.20000
35	27.262100	85.699000	6.069500	50.726420	148.907700	295.000000	10.000000	80.400000	1.600000	8.00000
36	27.338200	85.514000	6.069500	73.696030	75.950460	295.000000	10.000000	64.400000	4.800000	3.20000
37	27.414200	85.329000	6.069500	88.593870	70.608710	295.000000	10.000000	46.800000	6.400000	1.60000
38	27.490300	85.143900	6.069500	69.690230	/1.039640	295.000000	10.000000	32.800000	1.600000	1.60000
			_		7	7				

Slip (cm) Rake Strike

Dip

static_out.nepal.2015.update1 ~

static_out.nepal.2015.update1

1	#Total number of	fault segments=	1							1
2	#Fault segment =	1 nx(Along-str	ike)= 11 Dx= 20	0.00km ny(downo	dip)= 11 Dy= 1	5.00km				
3	#Boundary of Fau	lt seament 1.	E0 in cell 9.6.	Lon: 84.7251	Lat: 28,1654					
4	#Lon, Lat, Dep	th								
5	85.94160	26.86900	0.86010							
6	83.92680	27.69730	0.86010							
7	84.61880	29.00540	29.13990							
8	86.63350	28.17710	29.13990							
9	85.94160	26.86900	0.86010							
10	#Lat. Lon. depth	slip rake strike	e dip t_rup t_ris	s t_fal mo						
11	26.869000	85.941600	0.860100	18.149680	75.149300	295.000000	10.000000	107.600000	9.600000	6.40000
12	26.945100	85.756600	0.860100	13.718530	78.238790	295.000000	10.000000	98.400000	11.200000	12.80000
13	27.021200	85.571600	0.860100	14.087420	109.260400	295.000000	10.000000	87.200000	11.200000	12.80000
14	27.097200	85.386500	0.860100	0.118570	105.441600	295.000000	10.000000	74.400000	1.600000	6.40000
15	27.173300	85.201500	0.860100	2.159150	125.126600	295.000000	10.000000	60.400000	1.600000	11.20000
16	27.249300	85.016500	0.860100	19.058970	146.691190	295.000000	10.000000	48.800000	1.600000	1.60000
17	27.325400	84.831400	0.860100	2.772390	132.130200	295.000000	10.000000	41.600000	11.200000	12.80000
18	27.401500	84.646400	0.860100	5.095730	140.933000	295.000000	10.000000	38.800000	6.400000	1.60000
19	27.477500	84.461400	0.860100	0.134520	147.097400	295.000000	10.000000	35.200000	4.800000	9.60000
20	27.553600	84.276300	0.860100	3.704150	138.128800	295.000000	10.000000	35.600000	9.600000	3.20000
21	27.629700	84.091300	0.860100	3.665460	128.019700	295.000000	10.000000	38.000000	8.000000	8.00000
22	26.989500	86.005400	3.464800	14.342160	101.244000	295.000000	10.000000	107.200000	11.200000	8.00000
23	27.065600	85.820300	3.464800	41.260720	94.360370	295.000000	10.000000	96.800000	12.800000	12.80000
24	27.141600	85.635300	3.464800	59.689550	147.520710	295.000000	10.000000	82.800000	1.600000	1.60000
25	27.217700	85.450300	3.464800	49.867240	130.532700	295.000000	10.000000	69.200000	4.800000	1.60000
26	27.293800	85.265200	3.464800	44.360320	85.155300	295.000000	10.000000	54.400000	12.800000	3.20000
27	27.369800	85.080200	3.464800	54.424960	147.222700	295.000000	10.000000	45.600000	9.600000	1.60000
28	27.445900	84.895200	3.464800	51.677140	70.438360	295.000000	10.000000	34.400000	1.600000	1.60000
29	27.522000	84.710100	3.464800	7.704420	75.428050	295.000000	10.000000	29.600000	9.600000	1.60000
30	27.598000	84.525100	3.464800	3.529650	131.382900	295.000000	10.000000	28.800000	9.600000	3.20000
31	27.674100	84.340100	3.464800	29.914410	99.737140	295.000000	10.000000	30.400000	4.800000	1.60000
32	27.750200	84.155000	3.464800	13.402270	107.353600	295.000000	10.000000	33.600000	1.600000	1.60000
33	27.110000	86.069100	6.069500	12.263720	85.909080	295.000000	10.000000	106.000000	1.600000	11.20000
34	27.186100	85.884100	6.069500	15.084040	108.554600	295.000000	10.000000	95.200000	9.600000	3.20000
35	27.262100	85.699000	6.069500	50.726420	148.907700	295.000000	10.000000	80.400000	1.600000	8.00000
36	27.338200	85.514000	6.069500	73.696030	75.950460	295.000000	10.000000	64.400000	4.800000	3.20000
37	27.414200	85.329000	6.069500	88.593870	70.608710	295.000000	10.000000	46.800000	6.400000	1.60000
38	27.490300	85.143900	6.069500	69.690230	71.039640	295.000000	10.000000	32.800000	1.600000	1.60000

Rupture Time

- 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.

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

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

Introduction to Finite Fault Models Completed