Preliminary slip model of M9 Tohoku earthquake from strong-motion stations in Japan - an extreme application of ISOLA code.

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The devastating M9 Tohoku, Japan earthquake of March 11, 2011, is investigated from a methodical point of view as an extreme application of the ISOLA code [Sokos and Zahradnik, 2008]. By the 'extreme' we mean that although using the stations in the epicentral distance range of 200 to 340 km, as in many previous near-regional applications of ISOLA, all routinely chosen parameters had to be carefully reconsidered due to the enormous size of the event.

Six accelerographic stations in Japan providing free on-line data [CESMD] were chosen more or less randomly to sample the latitude range between 36° and 41° N, see Fig. 1. The inversion was performed in a 1D crustal model and the frequency range 0.01-0.10 Hz, using the fixed focal mechanism, characterized by the strike=200°, dip=12° and rake=90°. Multiple point sources were grid searched in time and space, using trial source positions shown in Fig 1. The match between the data (displacements) and synthetics is demonstrated in Fig. 2. The un-fitted NS components at stations IBR013 and IWT009 are due to the instrumental baseline problem. Shown in Fig. 3 is the best fitting model, where the size of circles is proportional to scalar moment, and color indicates the time.

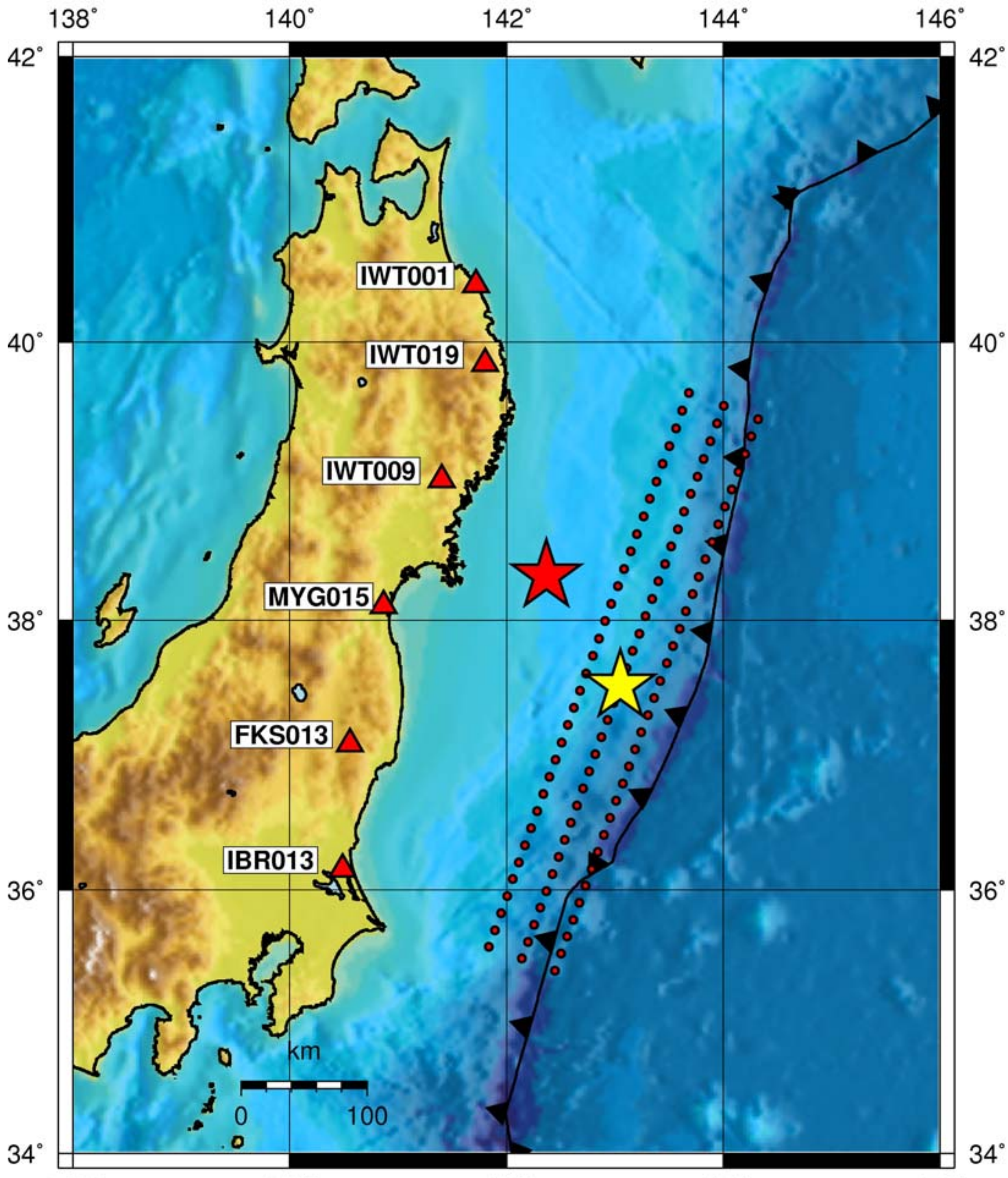

Fig. 1. Strong motion stations of NIED, downloaded from CESMD, and the 2D grid of trial source positions used in this report (strike=200°, dip=12°). The USGS epicenter 38.322°N, 142.369°E and the Global CMT (Harvard) centroid 37.52° N, 143.05° E are shown by the red and yellow stars, respectively. The central trial position (below the yellow star) has the depth of 15 km.

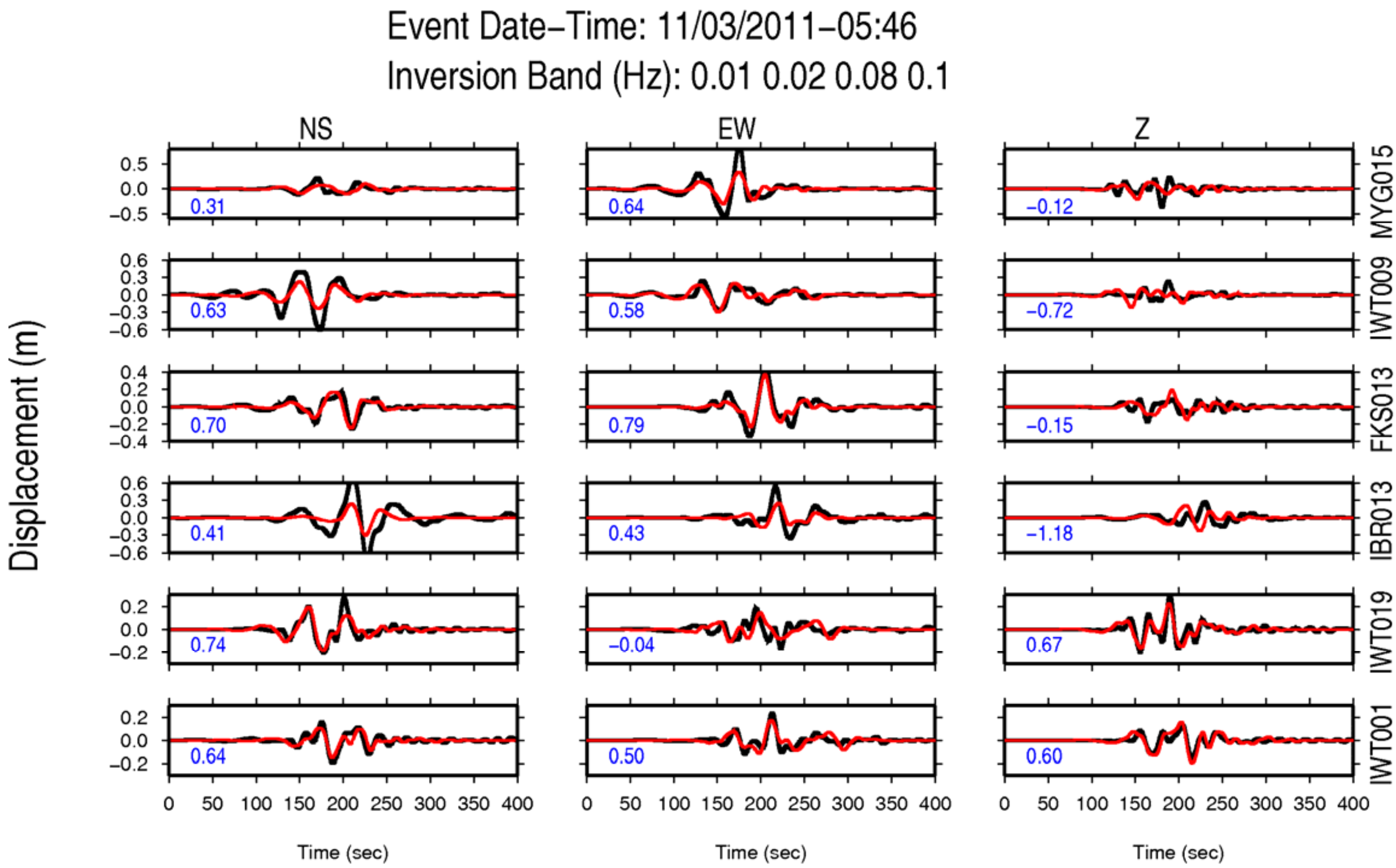

Fig. 2. Observed (black) and synthetic (red) displacements (m), 0.01-0.10 Hz. The variance reduction is 0.48. The zero value of the time axis corresponds to 05:45:10 UTC.

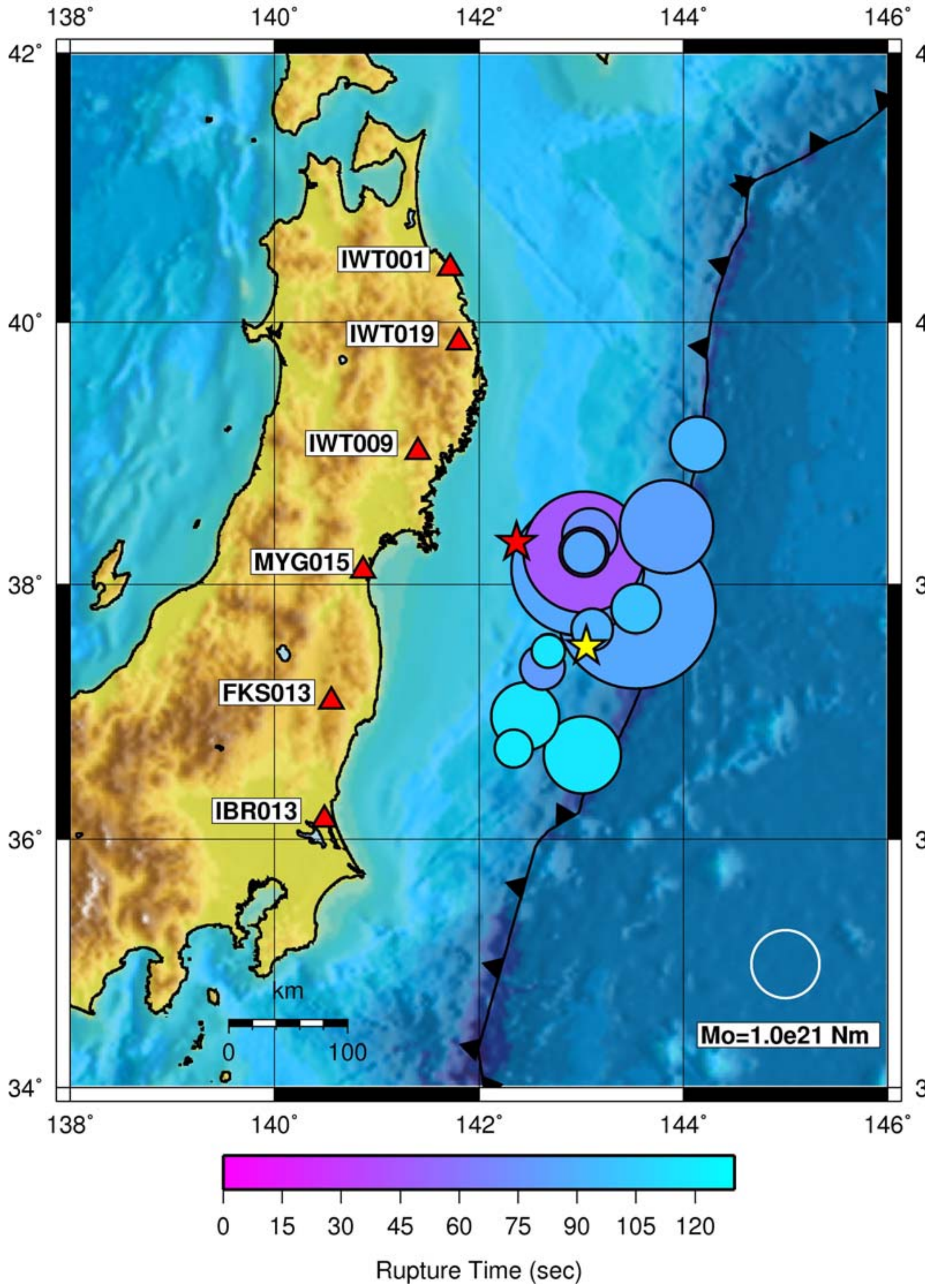

Fig. 3. The preliminary multiple-point source model. Radius of the circles is proportional to scalar moment, and color indicates the time. The USGS epicenter and the Global CMT (Harvard) centroid are shown by the red and yellow stars, respectively.

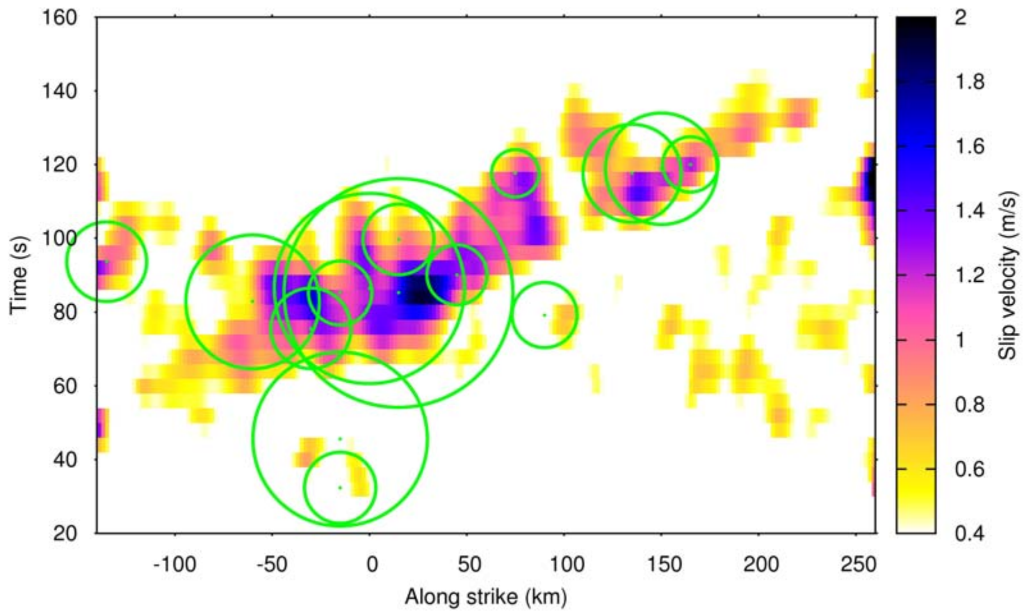

Fig. 4. Comparison of the ISOLA result (green circles) with an independent method (color) shown in form of the *temporal* evolution of the slip along the fault strike. The zero value of the horizontal axis corresponds to projection of the USGS epicenter.

The ISOLA solution is compared to the result from an independent method based on the truncated SVD technique (truncation at 1/100 of the largest singular value), [Gallovic and Zahradnik, 2011]. An equivalent 1D (line) source at the 15 km depth was used, and the variance reduction was 0.51. Fig. 4 compares the latter solution (color scaled with slip rate) with the solution from ISOLA, the variance reduction 0.48 (green circles proportional to moment). The horizontal axis in Fig. 4 is the along-strike distance. The vertical axis in Fig. 4 is time (not dip!), with zero value (not plotted) corresponding to the reference time 05:46:00 UTC. The agreement between the two solutions is satisfactory, except the early subevent near the published hypocenter, strong only in one of the two solutions. It is to emphasize that both methods are completely free of any assumption about the hypocenter position, hypocenter time and rupture velocity. No smoothing is needed in the two methods, thus it was not applied.

The solution can be characterized as predominantly unilateral rupture propagation along the strike, with a velocity around 3.3 km/s. The total moment of our solution needs to be multiplied by a factor of 2.6 to be compatible with Mw 9; the deficit is due to absence of frequencies less than 0.01 Hz in our solution. Numerical output is in Appendix.

Finally, it is also to underline that the present solution is consistent with the regions of the slip deficit on the locked segment of the interplate boundary, detected before the earthquake by geodetic methods (Hashimoto et al., 2009).

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References

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CESMD: http://strongmotioncenter.org/cgi-bin/ncesmd/iqr_dist_DM2.pl?IQRID=Japan_11Mar2011&SFlag=0&Flag=3

Appendix:

Time (sec) *	Moment (Nm) +	Strike	Dip	Rake(^{o})	Lon (^{o}E)	Lat (^{o}E)	Depth (km)
86.4	1.94E+21	200	12	90	142.97	38.1184	21.2
45.6	1.78E+21	200	12	90	143.028	38.2454	21.2
85.2	2.34E+21	200	12	90	143.538	37.8096	8.7
117.6	1.00E+21	200	12	90	142.452	36.9739	21.2
75.6	8.19E+20	200	12	90	143.087	38.3724	21.2
82.8	1.36E+21	200	12	90	143.836	38.4429	8.7
118.8	1.14E+21	200	12	90	143.014	36.6675	8.7
32.4	7.29E+20	200	12	90	143.028	38.2454	21.2
79.2	6.62E+20	200	12	90	142.623	37.3557	21.2
85.2	6.49E+20	200	12	90	143.028	38.2454	21.2
120	5.66E+20	200	12	90	142.339	36.7192	21.2
99.6	7.24E+20	200	12	90	143.538	37.8096	8.7
90	6.14E+20	200	12	90	143.108	37.647	15
117.6	4.84E+20	200	12	90	142.68	37.4829	21.2
93.6	8.16E+20	200	12	90	144.139	39.0754	8.7

* The time is counted after 05:46:00 UTC

\+ Total moment must be multiplied by a factor of 2.6 to approximately fit Mw 9.