A Super Sub-Event of Mw8.4 Obtained by GPS High Rate Records of GEONET and a Stress Record of TRIES in Japan

Ichiro KAWASAKI[1], Hiroshi ISHI[1], Yasuhiro ASAI[1],
and Takuya NISHIMURA[2]
[1]Tono Research Institute of Earthquake Science, Mizunami, Japan
[2]Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan

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Motivation

(1) Worry about a gap between a predominant period of M9 class earthquake and sensitivity of accelerometers at periods longer than 100 s.

(2) Worry about a priori assumption of model space set on subduction interface.

(3) Check of uniqueness of solution by stress records.

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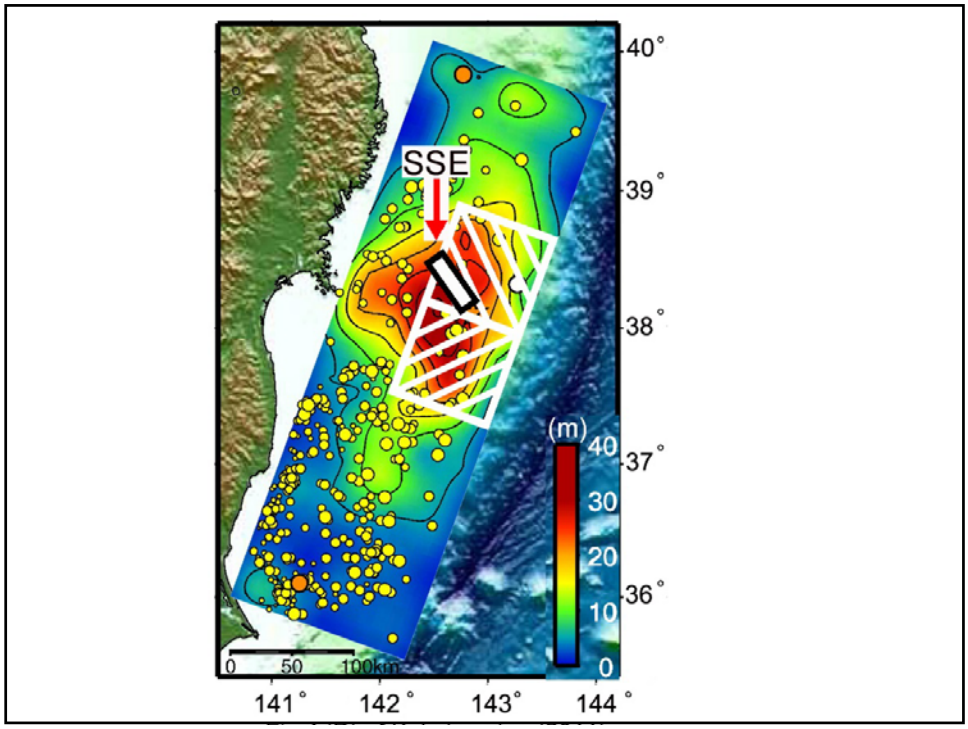

Relative location of the main event (the larger rectangle) and the super sub-event (the narrow rectangle, designated as SSE) with the slip distribution of the 2011 Tohoku earthquake [Fig. 4D of Koketsu *et al*. (2011)]. The super sub-event is an extraordinary event which we suppose to have occurred during the rupture process of the 2011 Tohoku earthquake on the strike slip fault within the rupture area of the Tohoku earthquake. The M_w and slip velocity are estimated to be 8.4 and approximately 10 m/s, respectively. See text for the detail of the super sub-event.

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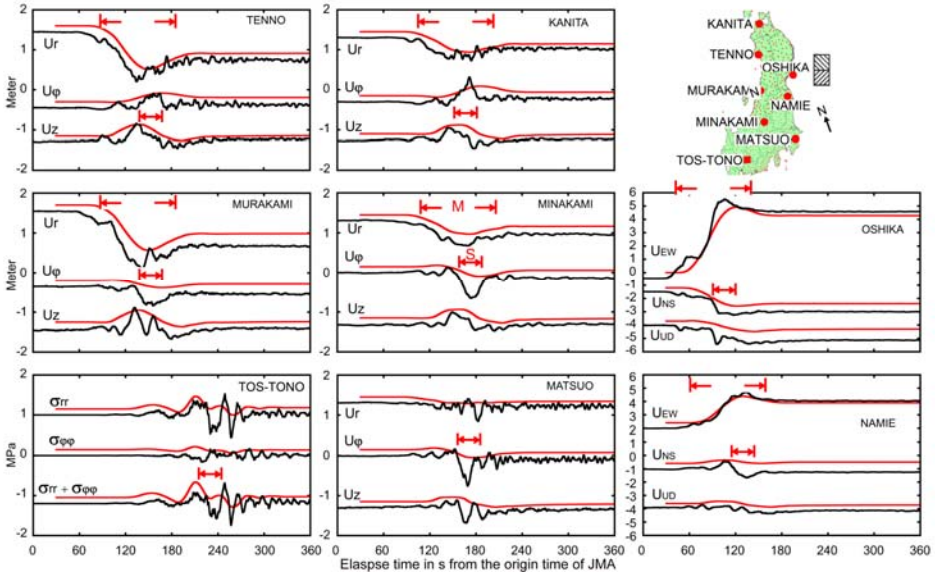

M: main pulse S: sub-pulse

Dark traces are three component GPS displacement records at seven GEONET stations and stress records at TOS-TONO. The red traces are the synthetics of the main event (the large rectangle in Fig. 2). Sampling rates are 1 s. Letters M and S with arrows indicate the main pulse and sub-pulse, definitions of which are provided in the section 2 of the text. The horizontal axis represents the elapsed time from the origin time of the JMA. Data is courtesy of GSI, Japan. Base map of the observation site distribution is from a map of the GEONET website (http://terras.gsi.go.jp/ja/index3.php). Dark and red traces indicate observation and synthetics, respectively, throughout this article.

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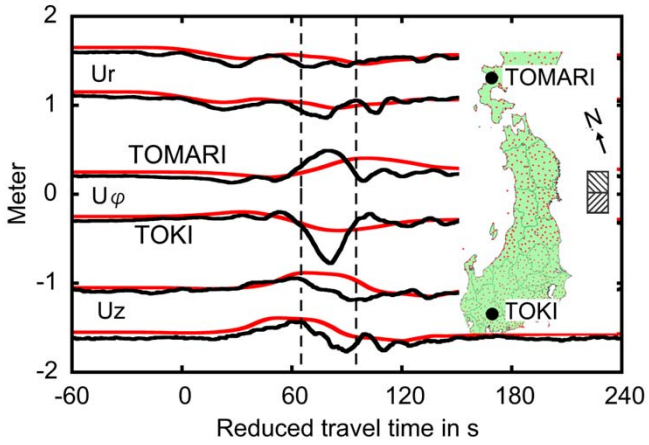

GPS displacement records at TOMARI, Hokkaido, and TOKI, Gifu, observed for the Tohoku earthquake with synthetics for the main event fault model. The horizontal axis is the elapsed time reduced by 3.9 km/s.

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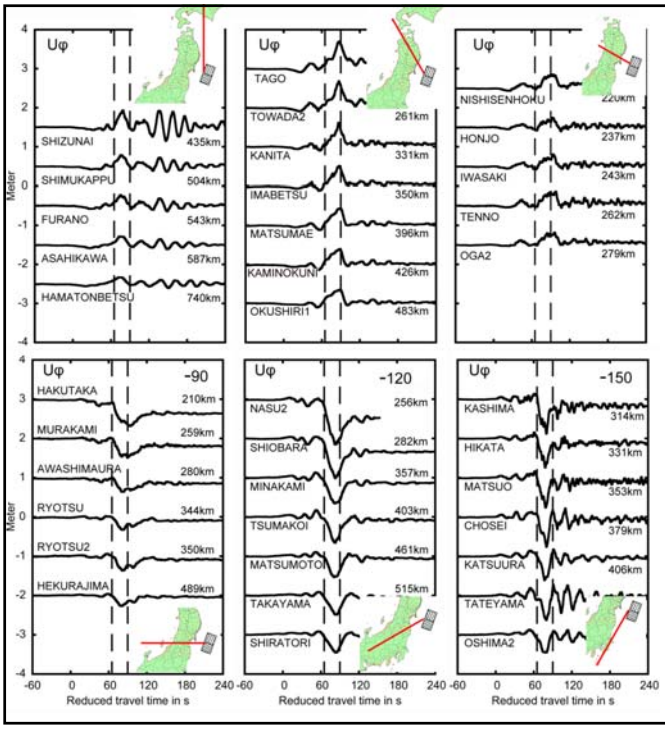
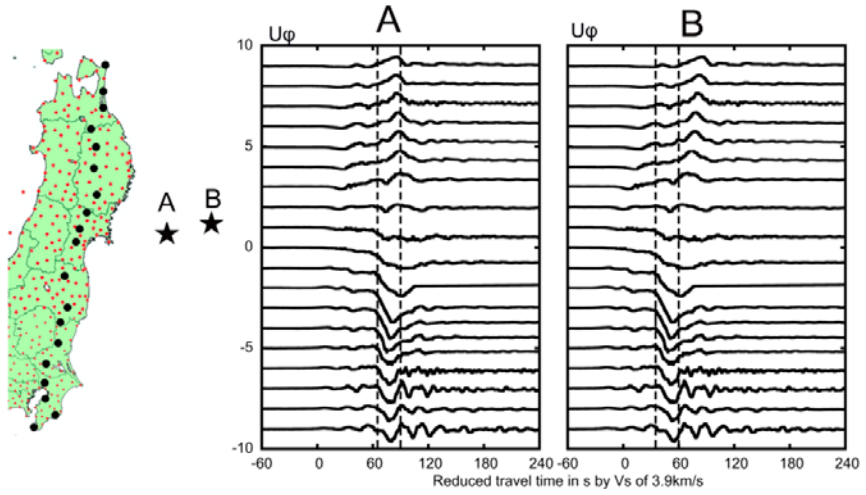


The record sections of the Uφ component of GPS displacements in azimuths of every 30 degrees. They are reduced by S wave velocity of 3.9 km/s with reference to the epicenter (E142.5, N38.5).



The record sections reduced by 3.9 km/s along a profile along a N-S direction with reference to the epicenters off-Miyagi (A) (E142.5, N38.5) and the near-trench (B).

trial and errors to obtain fault model

constraints

node of sub-pulse is N70-80W

total process time is less than 35 s

propagated south

grid search

by 20 degrees in the first step

by 5 degrees in the second step

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After large amount of trial and errors,

Table 2. Fault parameters of the main event and the sub-event

	main event	sub-event	description
	(E142.6,N38.2)*1	(E142.5,N38.5)*2	epicenter
To	35 s	60 s	initial time after JMA origin ti
ϕ	N200° E	N145° E	strike
δ	12°	85°	dip angle
λ	90°	15°	slip direction
D	30 km*3	30 km*4	fault depth
L	160 km	50 km	fault length
W	80 km	40 km	fault width
Do	50 m	50 m	slip
to	50 s	5 s	risetime
Do/to	1 m/s	10 m/s	slip velocity
Vr	2.5 km/s*5	2.5 km/s*6	rupture propagation velocity
Mo	2.8×10^{23} Nm	$(4-5)\times10^{22}$ Nm	seismic moment
M_W	8.9	8.4	moment magnitude

*1 and *2 are locations of the center of the lower margin and the north end of the upper margin of the fault, respectively. *3 and *4 are depths of the lower margin and the upper margin of the fault, respectively. *5 and *6 denote bilateral to north and south, unilateral to upper margins and unilateral from northwest upper to southeast lower corners, respectively.

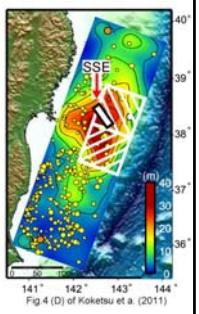
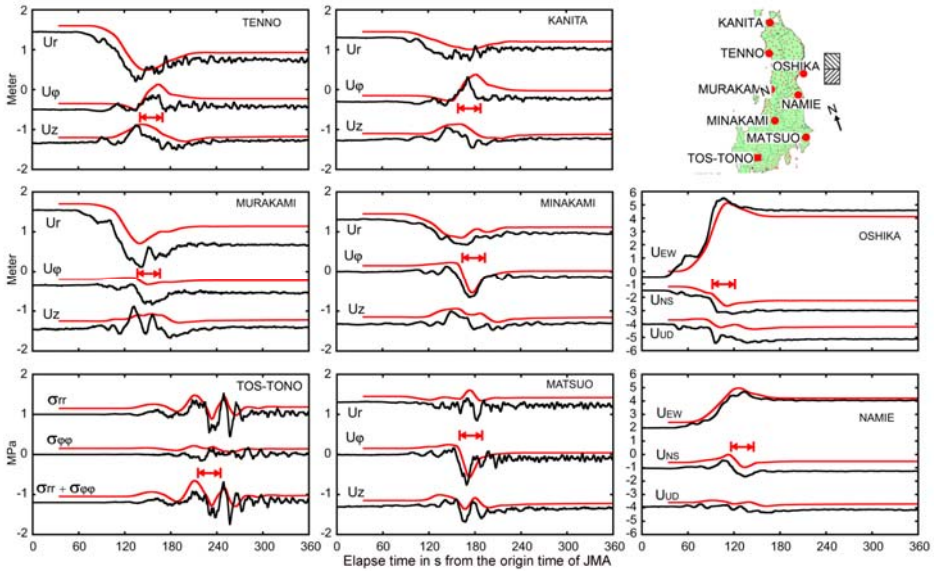


Fig.4 (D) of Koketsu et a. (2011)

left-lateral strike slip faulting on nearly vertical plane



Same as previous figure except that synthetics are superposition of those for the main event and the super sub-event fault models.

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Questions

(1) 'intraslab' below subduction interface or
'crustal' above subduction interface?

(2) a possibility of low-angle thrusting
on subduction interface?

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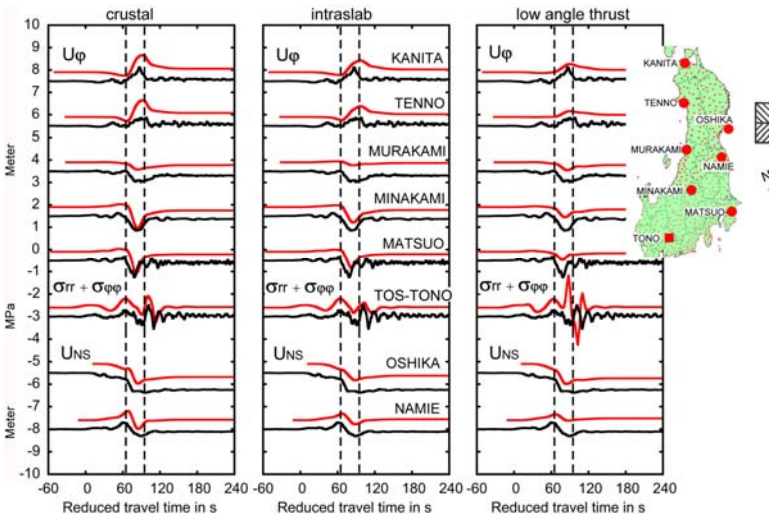
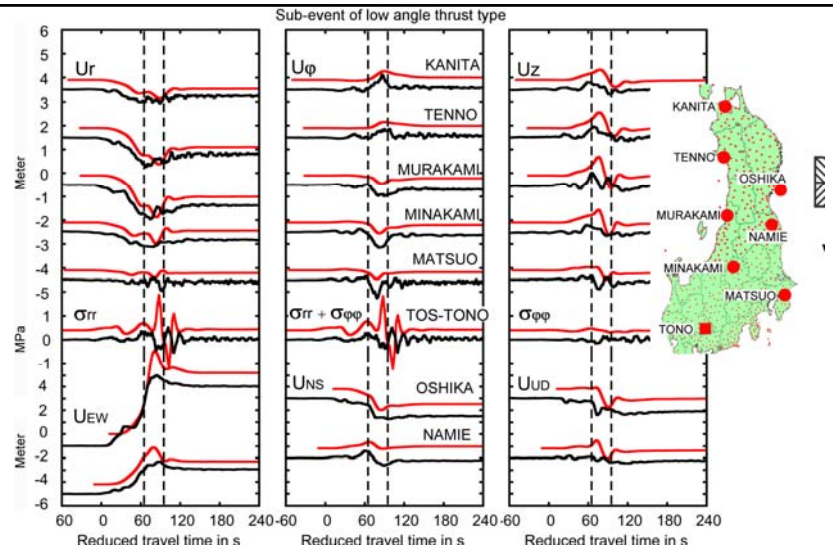
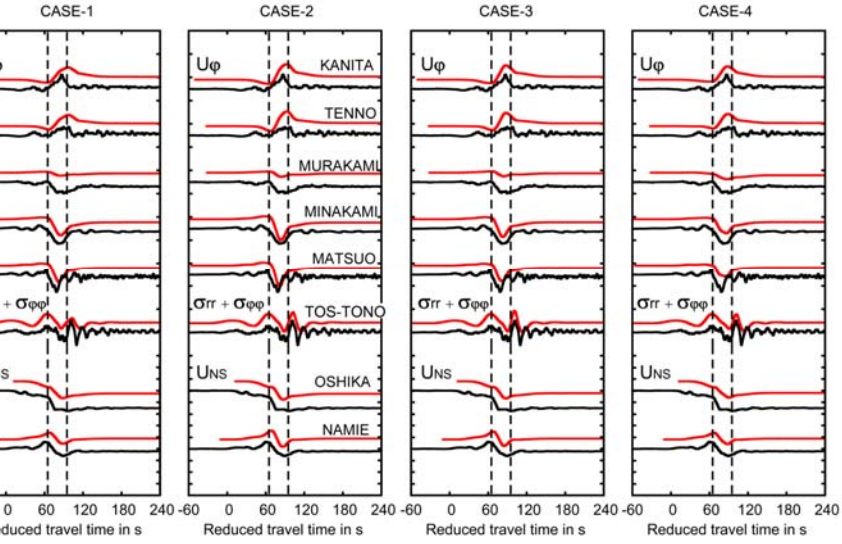


Uφ component GPS displacement records at seven GEONET stations and stress records at TOS-TONO, compared with the synthetics, which are superposition of those for the main event and sub-event fault models of the crustal (left), intraslab (center) and low-angle thrust faulting (right) types.



Three component GPS displacement records at seven GEONET stations and stress records at TOS-TONO, compared with the synthetics which are superposition of those for the main event and sub-event of a low-angle thrust faulting type.



Same as Fig. 8 except that the synthetics are superposition of those for the main event and the super sub-event with fault models of CASE-1 to CASE-4 in Table 3.

Table 3. Focal parameters of the super sub-event

	Case-1	Case-2	Case-3	Case-4	unit	
L	50	40	30	25	km	fault length
W	40	30	20	15	km	fault width
Do	50	100	150	200	m	slip
to	5	10	15	20	s	risetime
Do/to	10	10	10	10	m/s	slip velocity
Ts	22	23	25	28	s	source duration time
Δe	1.2	3.3	7.5	13.3	$\times 10^{-3}$	strain drop
$\Delta\sigma$	35	94	211	375	MPa	stress drop*1
Mo	4.4	5.3	4.0	4.0	10^{22} Nm	seismic moment
M_W	8.4	8.4	8.3	8.3		moment magnitude

*1 is estimated following Knopoff (1958).

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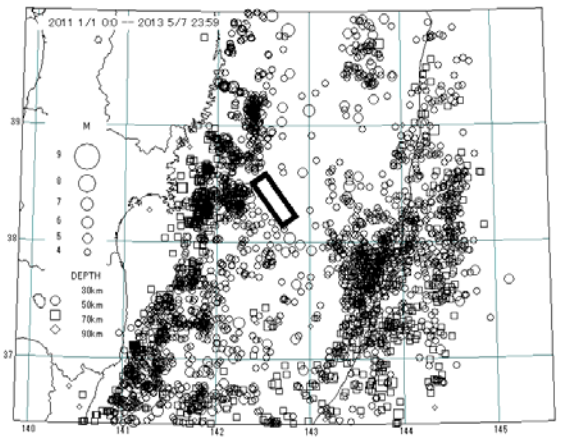

Earthquake activity for the period from January 1, 2011, to May 7, 2013, at depths below 30 km. Data is courtesy of JMA.

Conclusion

(1) Main pulse of pulse width of around 100 seconds. An overall feature can be explained by simple rectangle fault model of Mw 8.9.

(2) Sub-pulse of pulse width of around 30 seconds. SH wave radiated from off the coast of Miyagi prefecture within rupture area of main event.

(3) Extraordinary sub-fault model.
Rupture started 65 s after JMA origin time and 30 s after main event, of left-lateral strike slip faulting on nearly vertical plane stinking NW-SE. Slip velocity is around 10 m/s. Mw is 8.4.

Authors don't think these conclusions are absolutely solid. There could be alternative local minimum. Re-examination of GPS high sampling records is welcome.

Thank you

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We would like to express our sincere thanks
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