The 2022 Taitung (Guanshan and Chihshang), Taiwan, earthquake Workshop
May 25, 2023, Ohsaki Research Institute, Inc.

Strong Ground Motions during surface-faulting earthquakes

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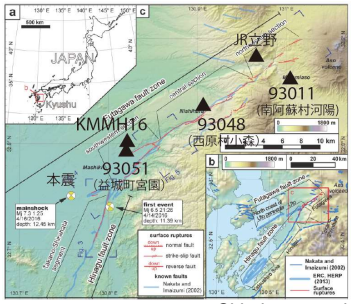
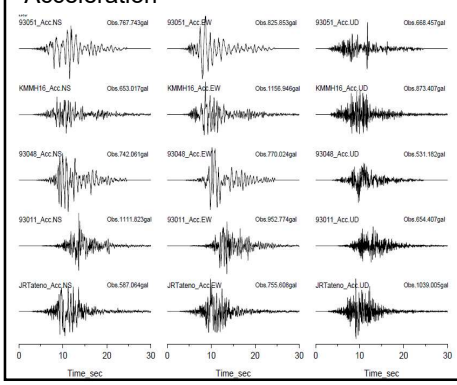
2016 Mw 7.0 Kumamoto earthquake

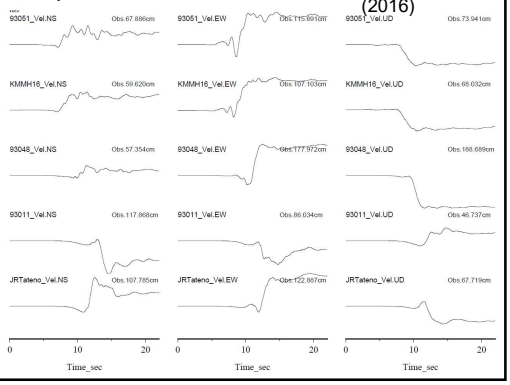
Strong motion records at very-near-fault stations



Acceleration



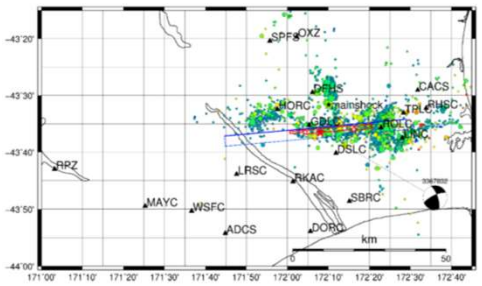
Displacement



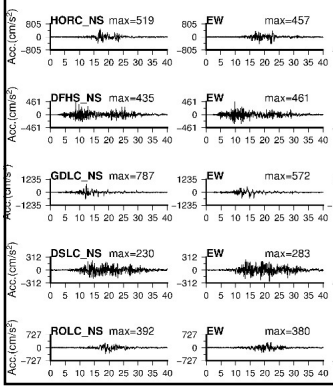
Shirahama et al. (2016)

2016 Mw 7.1 Darfield earthquake In New Zeeland

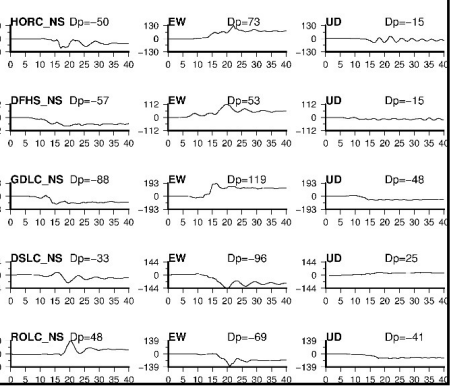
Strong motion records at very-near-fault stations during the



Acceleration



Displacement

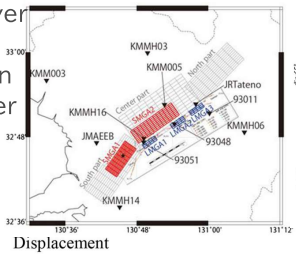


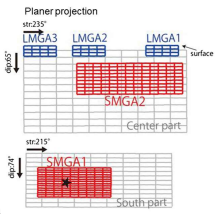
Extended Characterized Source Model (Irikura et al.,2019)

Surface layer above seismogenic layer
- ⇒ Stress drop low
- ⇒ Slip vel.: smoothed ramp function

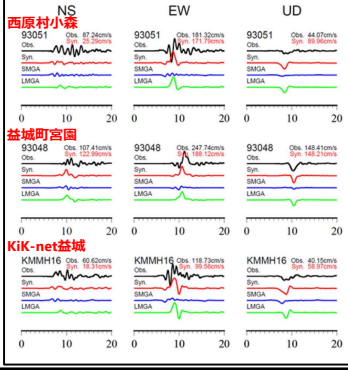
Seismogenic layer beneath surf-layer
- ⇒ stress drop high
- ⇒ Kostrov-type function

Map projection

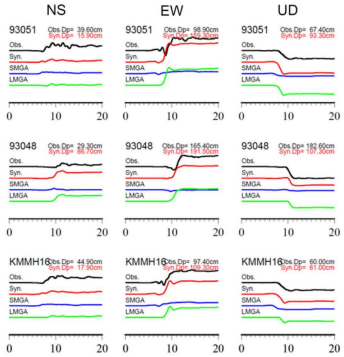


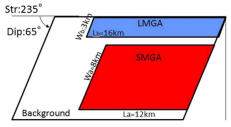


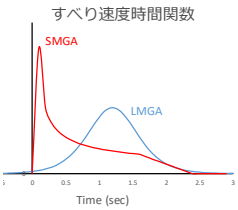
Velocity



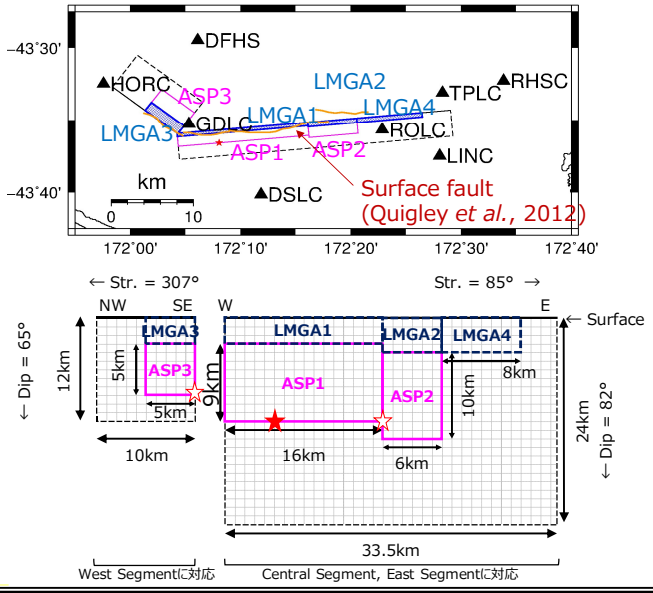
Displacement





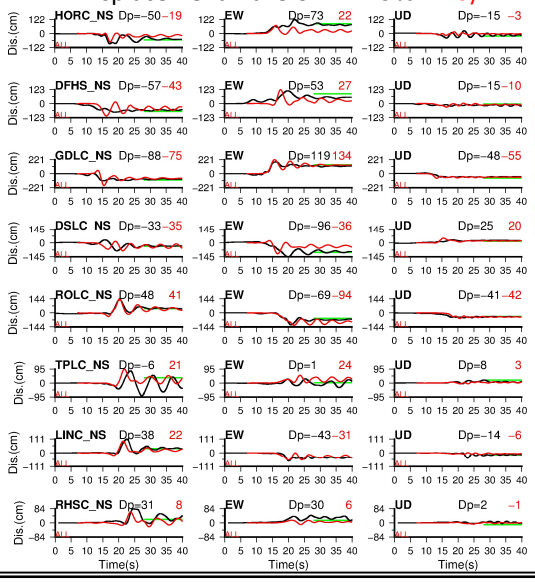


Estended Characterized Source Model for the 2010 Mw 7.0 Darfield earthquake

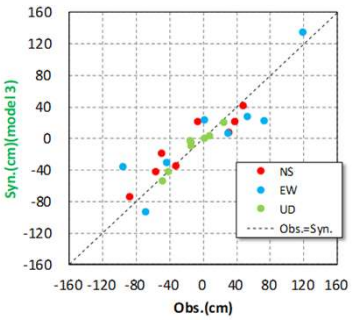


Observed and Synthetic displacements at Near-fault-distance Stations for the 2010 Darfield Earthquake

Displacement waveform ー:Obs. ー:Syn.



Pernament Displacement
Observed vs Synthetic

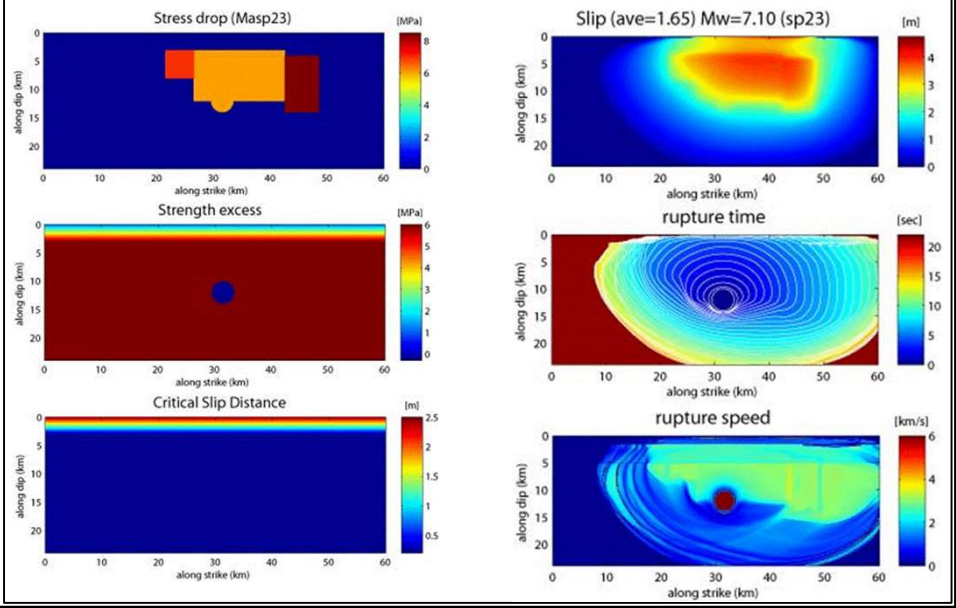


Displacement of LMGA: 2.8 - 3.0 m
Rise time：4.0 s

Central parts of fault:
Right strile-slip with reverse-fault
East and west-edge parts of fault:
Right strile-slip with normal fault。

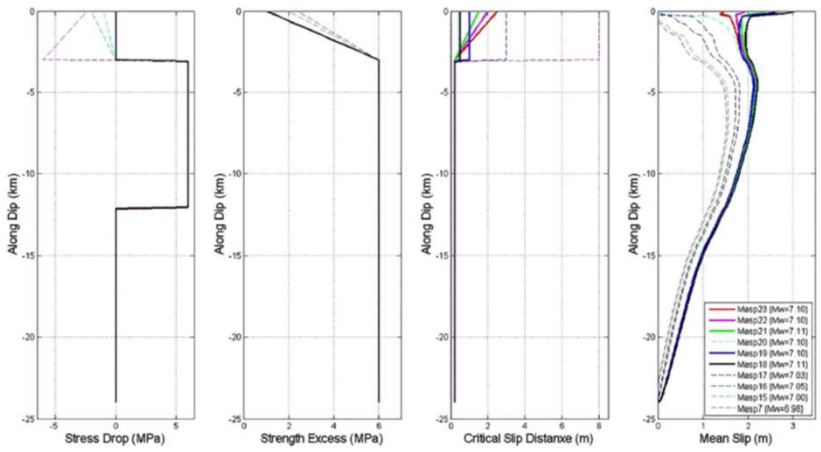
Dynamic Rupture Model based on SMGA model

(Dalguer *et al.*, 2018)

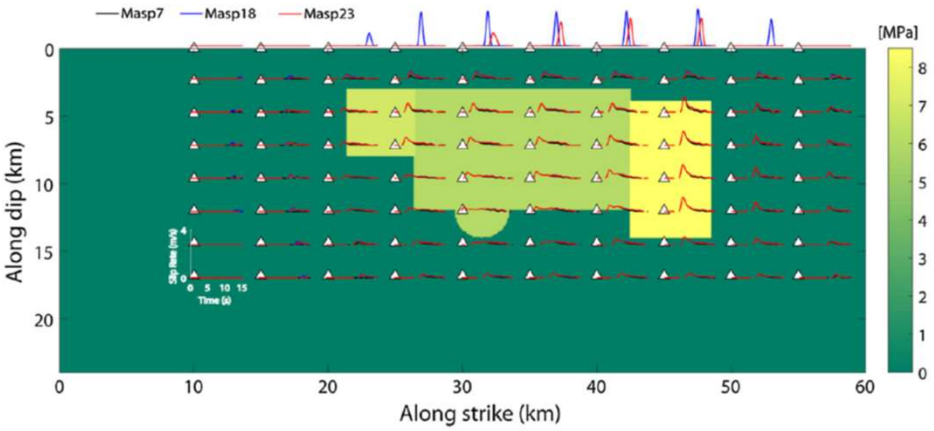


Dynamic parameterization profile along dip crossing the center of Asperity 1

(stress drop, strength excess and critical slip distance)



Slip velocity functions distributed at some points on the fault



Background correspond to the final slip distribution

2008 Wenchuan earthquake

The 12 May 2008 Mw7.9 earthquake occurred at the eastern margin of the Tibetan Plateau

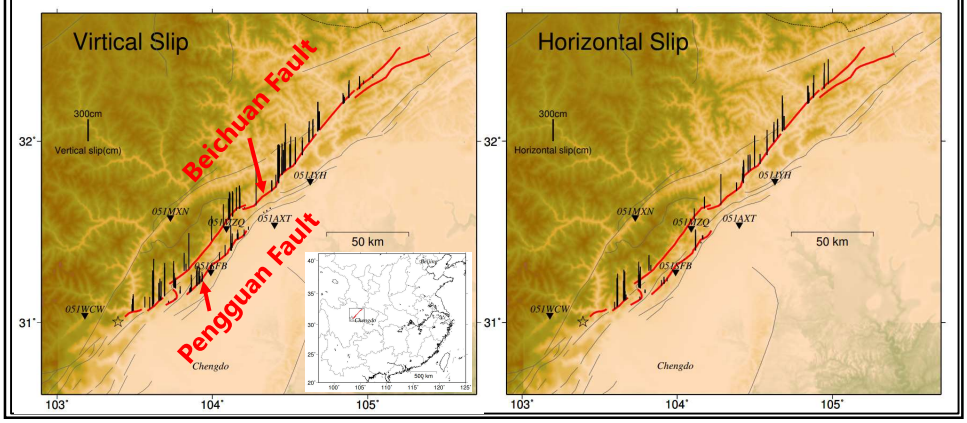
Fault length: about 240km

Max. vertical offset: 6.5 m　Max. horizontal slip: 4.9m（Yu et al., 2010)

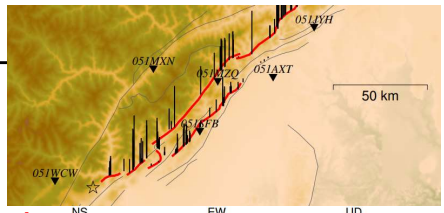
Segments: West-Beichuan Fault, East-Pengguan Fault

Seismic moment1.19×10^{21}Nm（USGS）

Very-near-fault stations: 051MZQ, 051SFB



Strong motion records



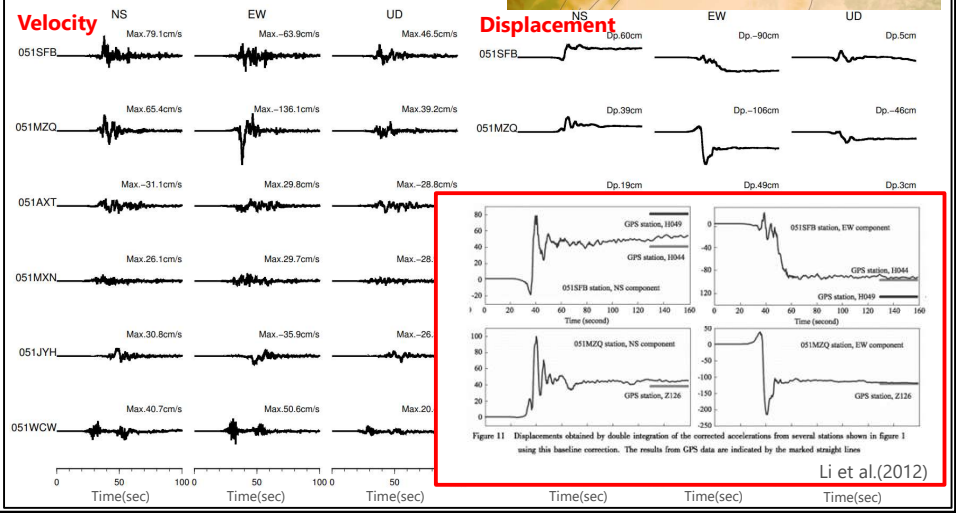


Figure 11 Displacements obtained by double integration of the corrected accelerations from several stations shown in figure 1 using this baseline correction. The results from GPS data are indicated by the marked straight lines

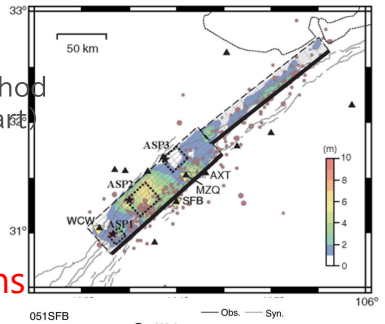
Li et al.(2012)

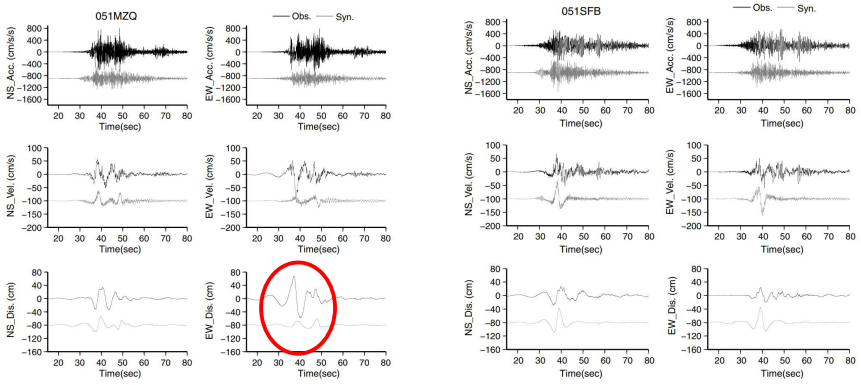
Kurahashi and Irikura(2010)

Characteried source model by hybrid method
・Assume a single segment (south-west part)

・Long-period pulses at MZQ were not reproduced.

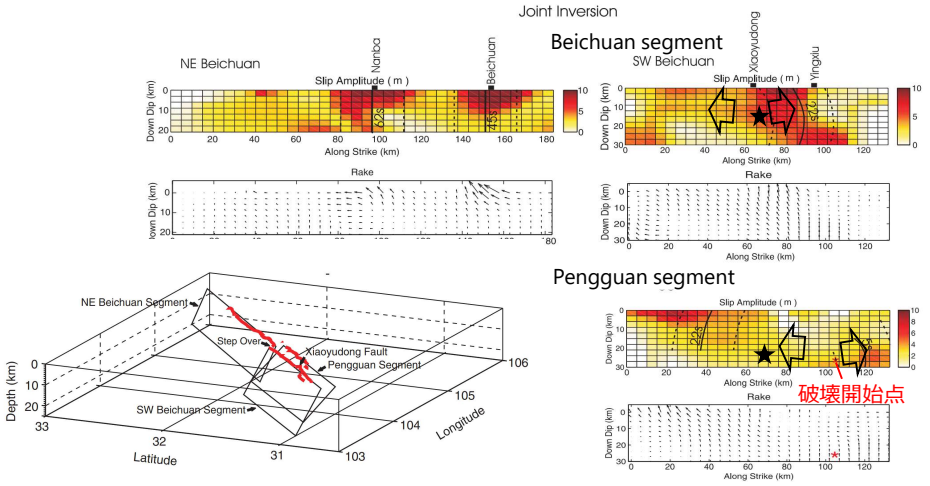
⇒Need to reproduce long-period pulses at very-near-fault stations





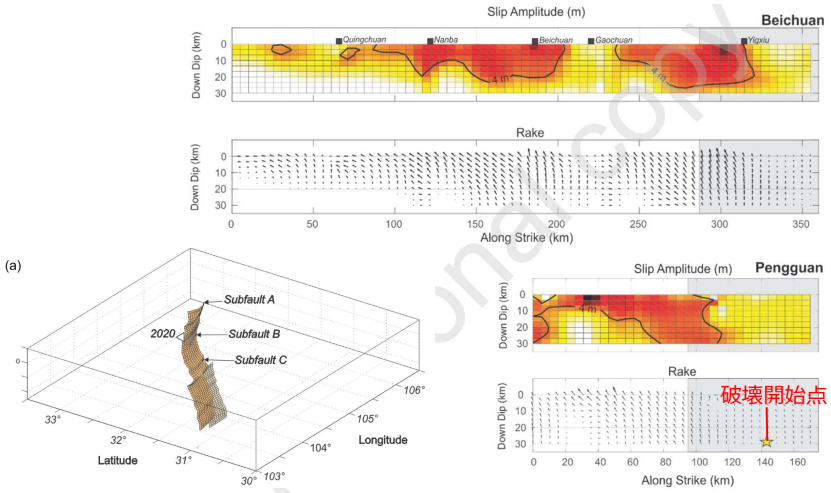
Slip distribution of Wenchuan earthquake (Hartzell et al., 2013)

・Joint inversion of teleseismic, geodetic data and strong motion data
・Rupture initiates on the southern end of the Pengguan fault.
The Beichuan fault starts at the juncture and proceeds bilaterally to the northeast and southwest.



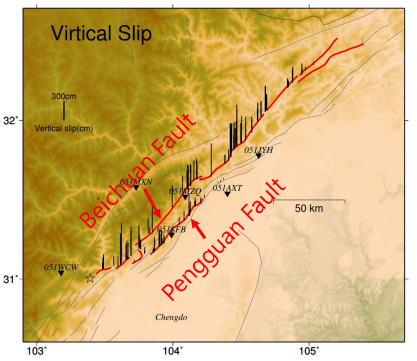
Slip Distribution of Wenchuan e. (Guzman and Hartzell, 2020)

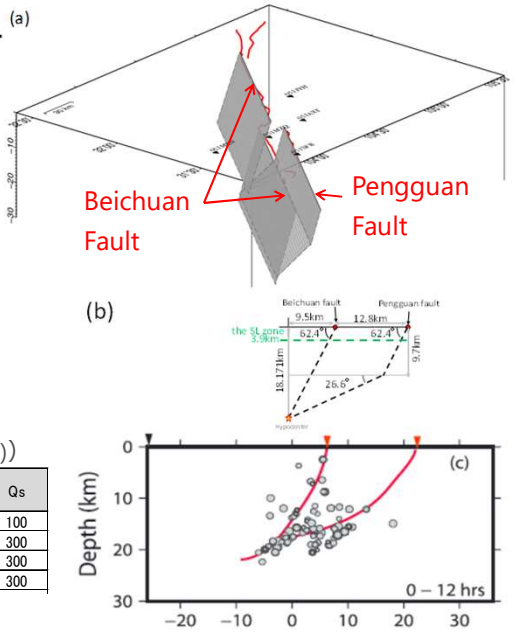
・3-D joint geodetic and strong-motion finite fault inversion
・Rupture initiates at Pengguan segment.
⇒ Refer this model for forward modeling.
Assume SMGA+LMGA model,



Personal copy

Fault model





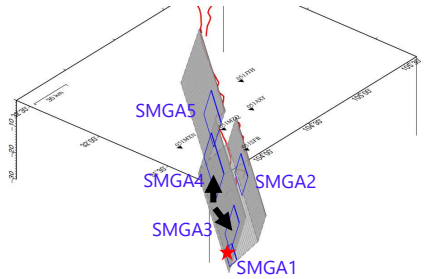
Velocity model（Hartzell et al.(2013)）

	Thickness (km)	Vp (km/s)	Vs (km/s)	Density (g/cm^3)	Qp	Qs
Sichuan	6	4.8	2.7	2.2	200	100
	4	6.0	3.4	2.4	600	300
	15	6.2	3.5	2.6	600	300
	–	6.6	3.8	2.8	600	300

Yin et al.(2018)

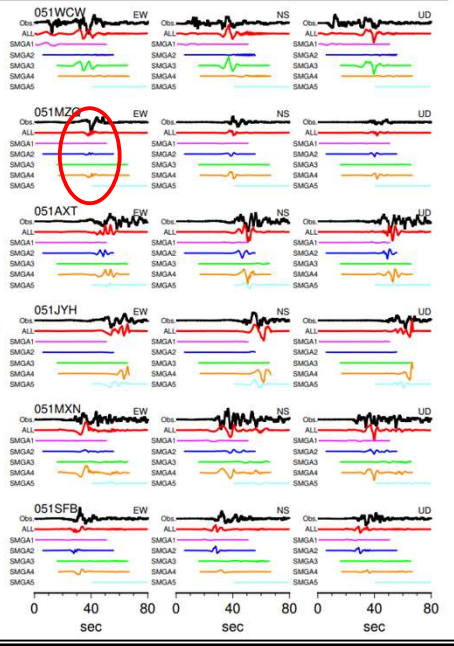
Construction of SMGA model

・少し遠地の観測点の強震動の再現をターゲット
・2×2kmの小断層の小地震波形を算出して，波形合成し，観測に合うSMGAを構築
・解析手法：離散化波数法（Bouchon,1981）



	unit	SMGA1	SMGA2	SMGA3	SMGA4	SMGA5	合計
Dx	km	22.0	30.8	22.0	50.0	40.0	-
Dy	km	13.2	8.8	12	10	16	-
Area	km^2	290.4	271.04	264.0	500.0	640.0	1965.44
剛性率	N/m2	3.12×10^{10}					-
D_{ave}	m	1.3	3.3	4.0	4.0	4.0	-
M0	Nm	1.2×10^{19}	2.8×10^{19}	3.3×10^{19}	6.25×10^{19}	8.0×10^{19}	2.2×10^{20}
Vr	km/s	2.8					-
rise time	sec	2					-

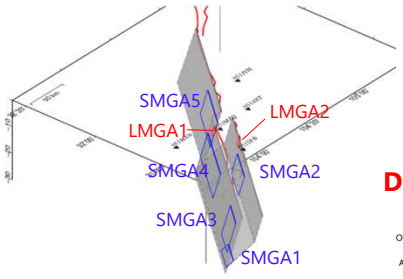
すべり速度関数：中村・宮武関数



Construction of LMGA model

・断層直上の観測点(MZQ,SFB)の再現をターゲットとして構築

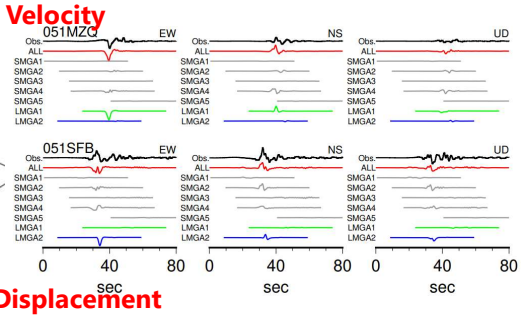
・解析手法:波数積分法(Hisada and Bielak,2003)



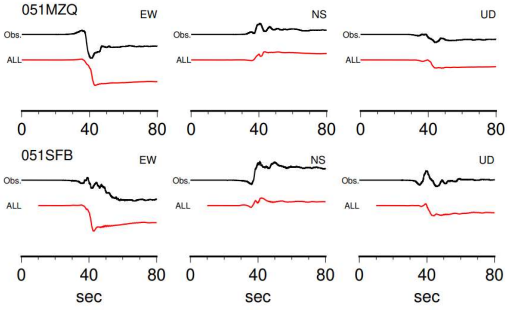
	unit	LMGA1	LMGA2	合計
Dx	km	4.0	4.0	-
Dy	km	5.0	5.0	-
Area	km^2	20.0	20.0	40.0
剛性率	N/m2	1.75×10^{10}		-
D_{ave}	m	5.7	2.0	-
M0	Nm	2.0×10^{18}	7.0×10^{17}	2.7×10^{18}
Vr	km/s	2.5		-
rise time	sec	4.0		-

すべり速度関数：Smoothed ramp 関数

Velocity

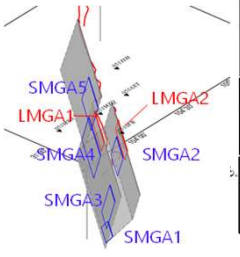


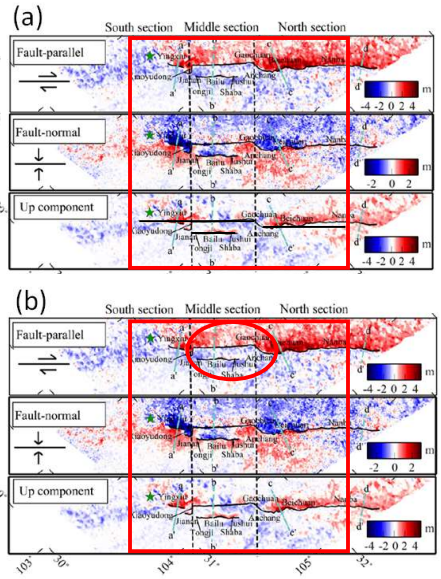
Displacement



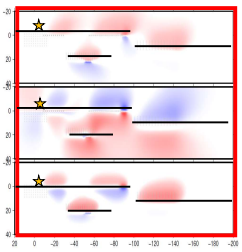
Comparison between 3D displacements by InSAR and those by LMGA model

- **InSAR displacement**

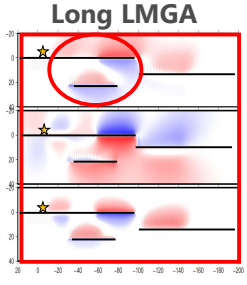




Short LMGA

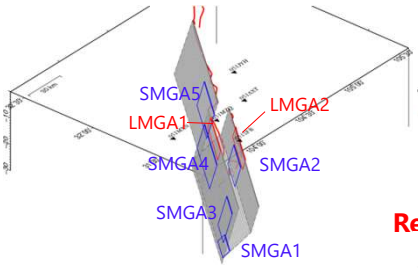


Long LMGA



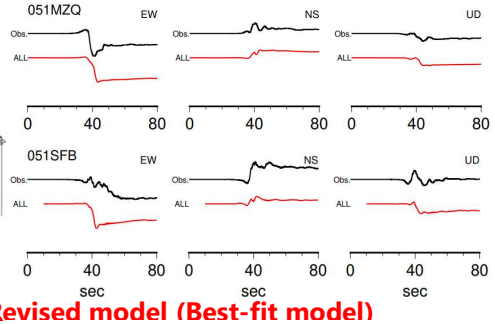
Construction of Best-fit Model

- The InSAR displacements
- are satisfied.

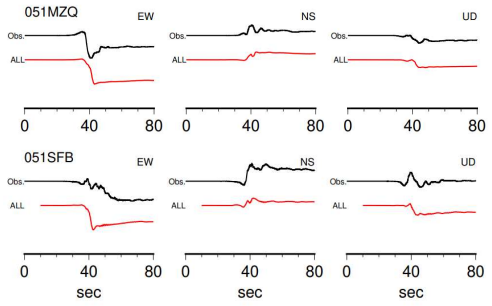


	unit	LMGA1	LMGA2	合計
Dx	km	65.0	65.0	-
Dy	km	5.0	5.0	-
Area	km^2	325.0	325.0	650.0
剛性率	N/m2	1.75×10^{10}		-
D_{ave}	m	5.7	2.0	-
M0	Nm	3.2×10^{19}	1.1×10^{19}	4.4×10^{19}
Vr	km/s	2.5		-
rise time	sec	4.0		-

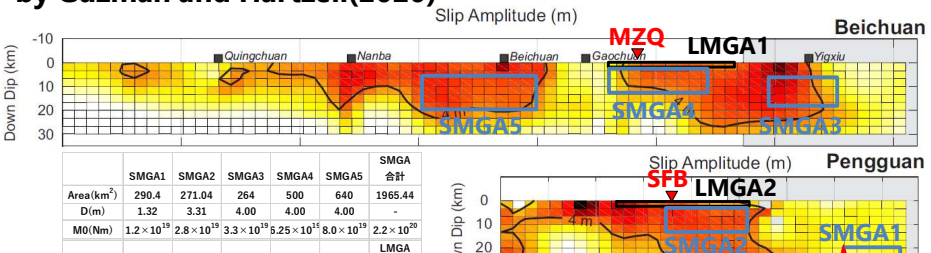
SMGA+LMGA model



Revised model (Best-fit model)



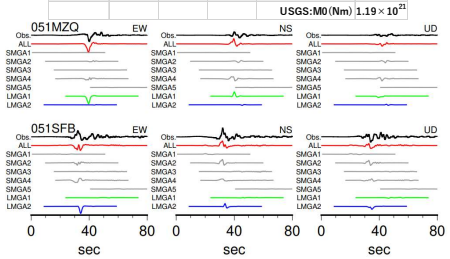
Comaparison between the best-fit model and slip distribution by Guzman and Hartzell(2020)

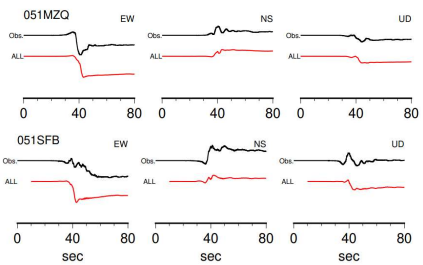


	SMGA1	SMGA2	SMGA3	SMGA4	SMGA5	SMGA 合計
Area(km^2)	290.4	271.04	264	500	640	1965.44
D(m)	1.32	3.31	4.00	4.00	4.00	-
M0(Nm)	1.2×10^{19}	2.8×10^{19}	3.3×10^{19}	5.25×10^{19}	8.0×10^{19}	2.2×10^{20}

	LMGA1	LMGA2	LMGA 合計
Area(km^2)	325	325	650
D(m)	5.72	2.00	-
M0(Nm)	3.2×10^{19}	1.1×10^{19}	4.4×10^{19}

	合計
Area(km^2)	2615.44
M0(Nm)	2.64×10^{20}
USGS:M0(Nm)	1.19×10^{21}





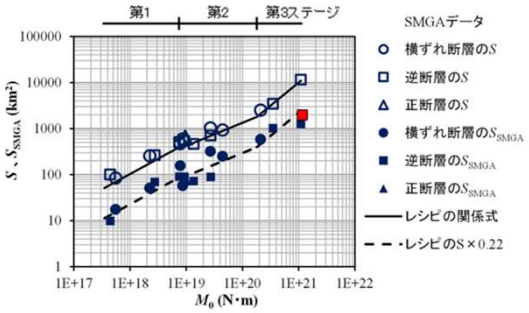
Scaling relations versus parameters of the best-fit model

a) Seismic Moment vs Combined Area of SMGAs
b) Seismic Moment vs Slip of LMGAs (D_{LMGA})

	SMGA1	SMGA2	SMGA3	SMGA4	SMGA5	SMGA 合計
Area(km^2)	290.4	271.04	264	500	640	1965.44
D(m)	1.32	3.31	4.00	4.00	4.00	-
M0(Nm)	1.2×10^{19}	2.8×10^{19}	3.3×10^{19}	6.25×10^{19}	8.0×10^{19}	2.2×10^{20}

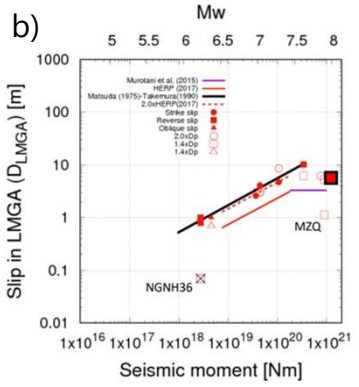
	LMGA1	LMGA2	LMGA 合計
Area(km^2)	325	325	650
D(m)	5.72	2.00	-
M0(Nm)	3.2×10^{19}	1.1×10^{19}	4.4×10^{19}

a)



藤堂他(2022)

b)



Miyakoshi et al.(2020)

Summary 1

1. We have learned that strong ground motions for most of medium- and large-sized earthquakes were reproduced, taking strong-motion-generation areas (SMGAs) with high stress drop and a background area with less stress drop inside faulting areas. We call it the characterized source model.
2. However, we found that near-fault ground motions with sharp pulses and permanent displacements were not possibly simulated using this conventional characterized model.
3. Then, we proposed an extended characterized source model with long-period generation areas (LMGAs) inside the surface layer above the seismogenic zone in addition to the SMGAs inside the seismogenic zone.
4. We successfully simulated the near-fault ground motions for the 2016 Mw 7.0 Kumamoto earthquake and the 2010 Mw 7.0 Darfield earthquake.

Summary 2

5. We attempted to simulate near-fault ground motions for the 2008 Mw 7.9 Wenchuan earthquake applying the extended characterized source model with the SMGAs and LMGAs.
6. Therefore, near-fault ground motions for the Wenchuan earthquake are successfully with significant velocity pulses and permanent displacements at MZQ and SFBfo
7. Miyakoshi et al. (2020) found that D_{LMGA}, i.e slip in LMGA, is about 2 times of average slip D given by the scaling relation D versus Mo, i.e. seismic moment.

   The obtained D_{LMGA} for the Wenchuan earthquake is less than D_{LMGA} is smaller than the expected value from the D_{LMGA} – Mo relation, suggesting saturation of D_{LMGA} for largre-size earthquakes.