Earthquake scaling relationships estimated from a 20 year catalogue of source models derived from InSAR data

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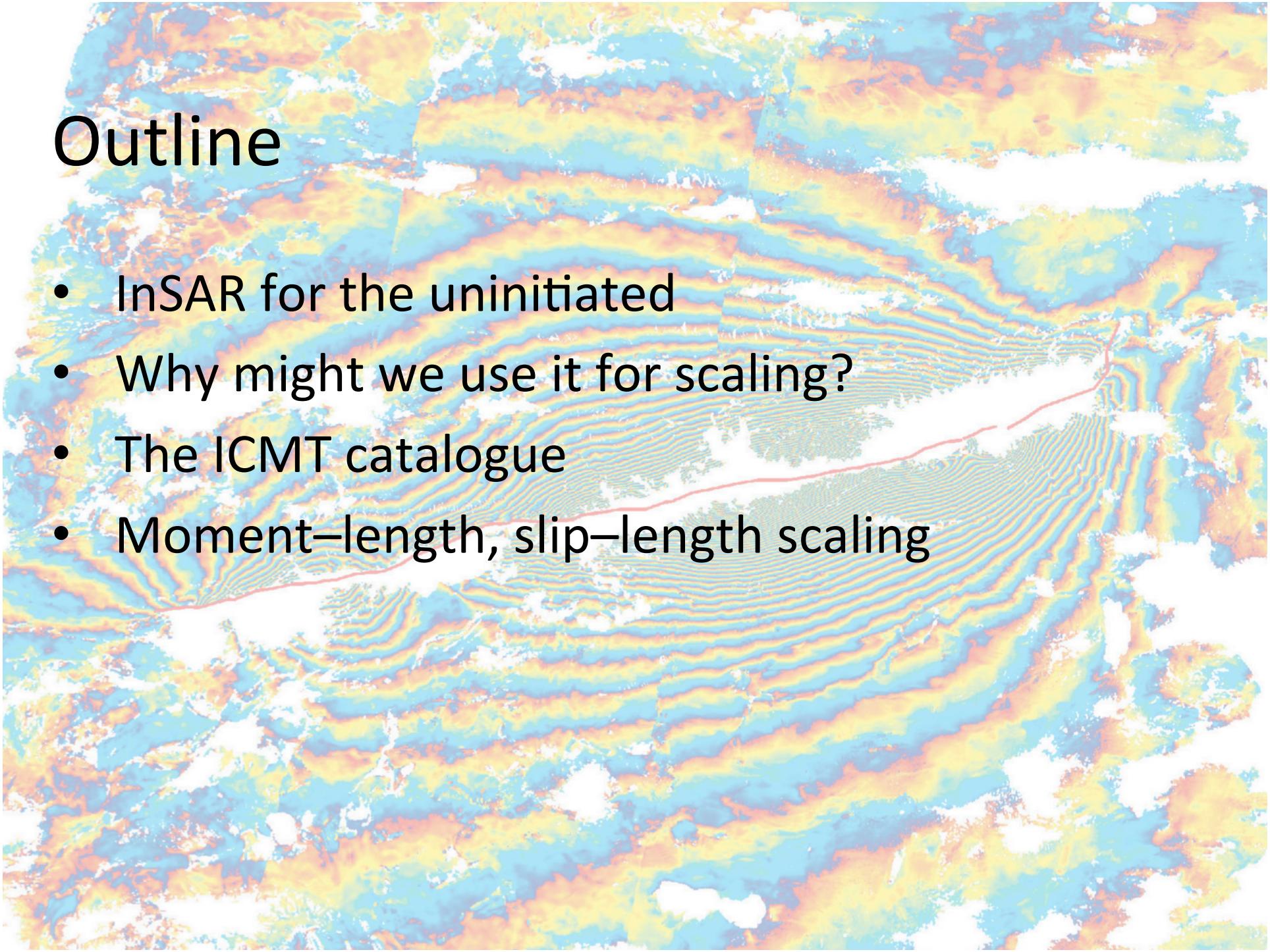
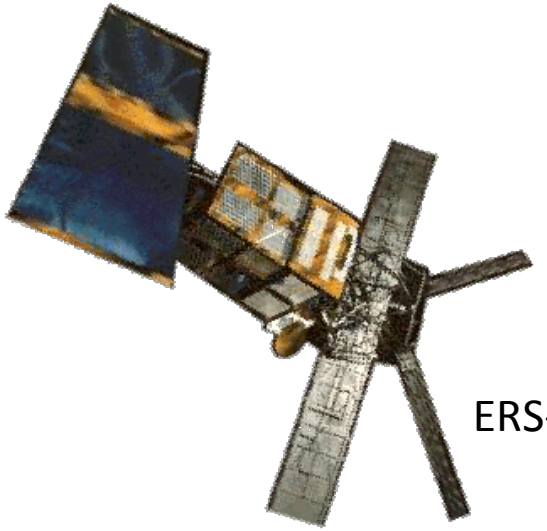


Outline

- InSAR for the uninitiated
- Why might we use it for scaling?
- The ICMT catalogue
- Moment–length, slip–length scaling

Interferometric **S**ynthetic **A**perture **R**adar

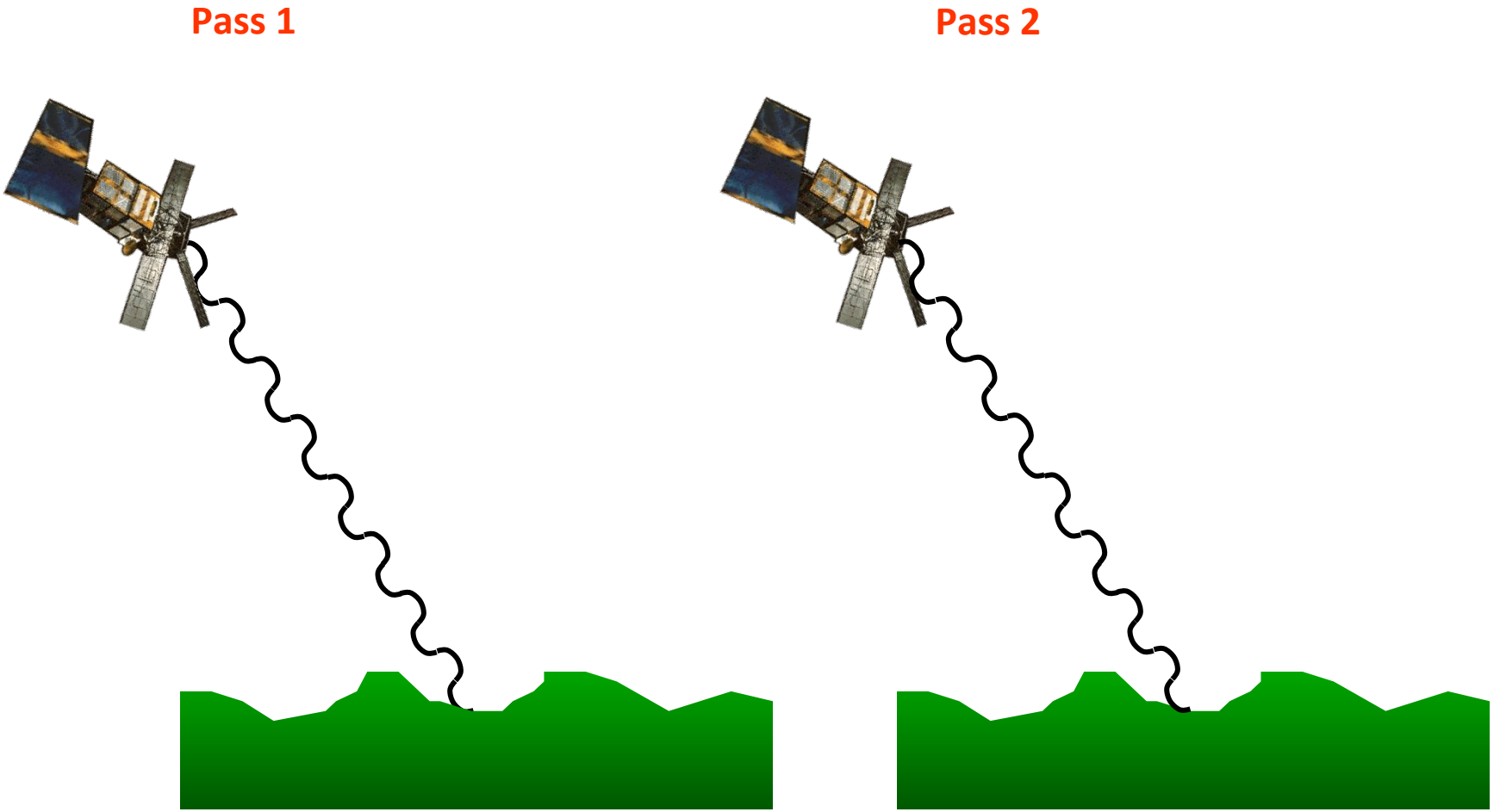


ERS-2 (1995–2011)

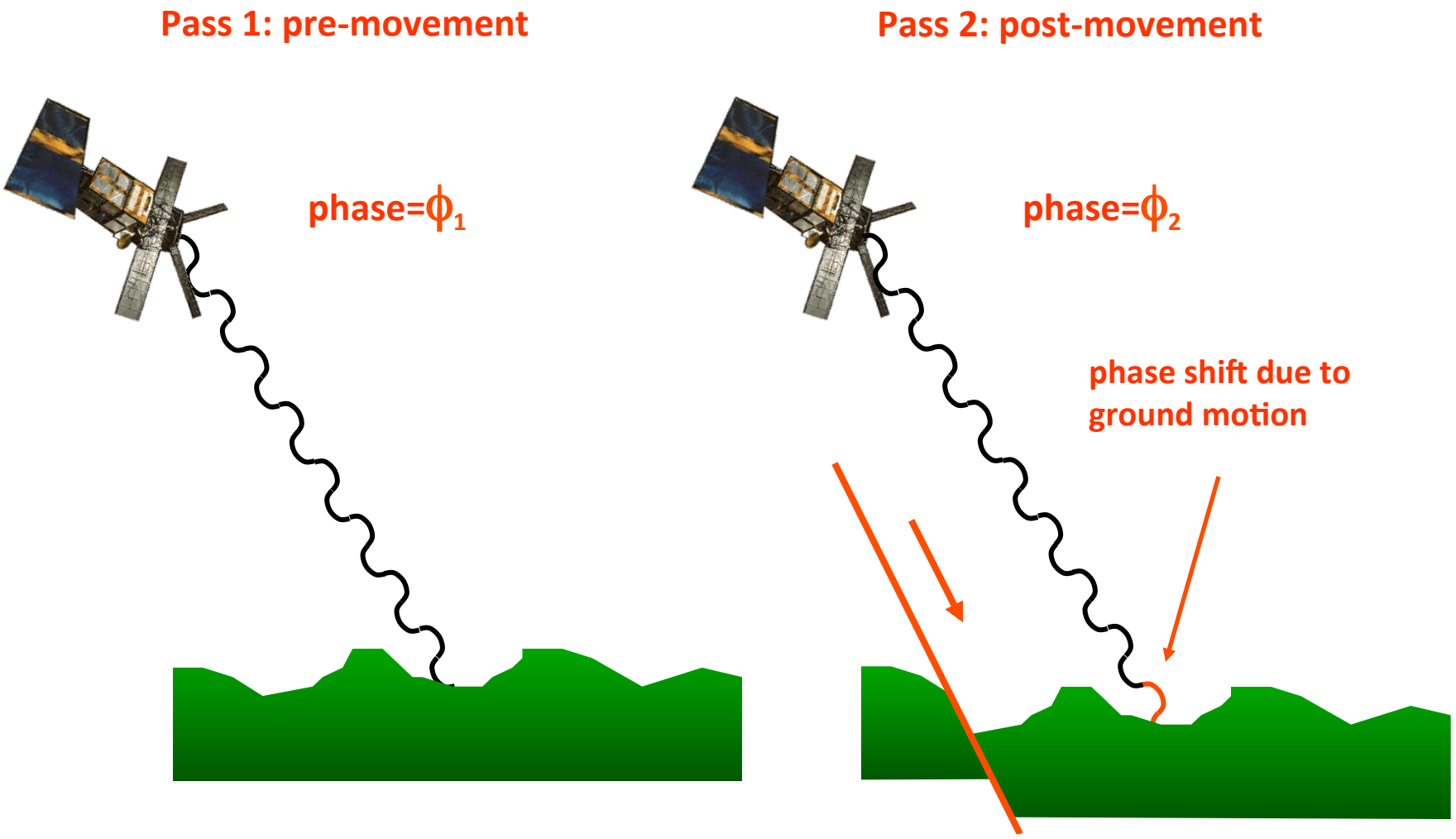
An unusual seismometer

- not coupled to the ground
- measures displacement directly
- it samples every 3000000 s (if you're lucky)
- smallest detected event: $M_w 4.7$

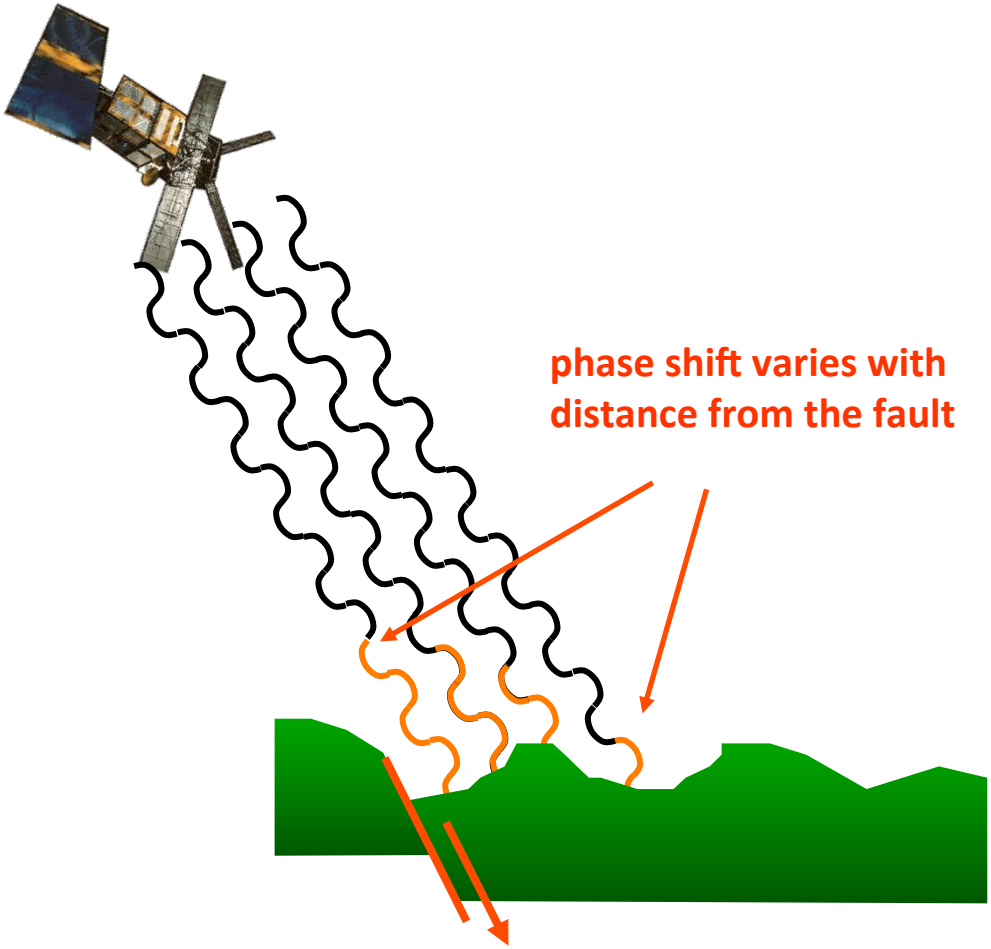
InSAR: how it works

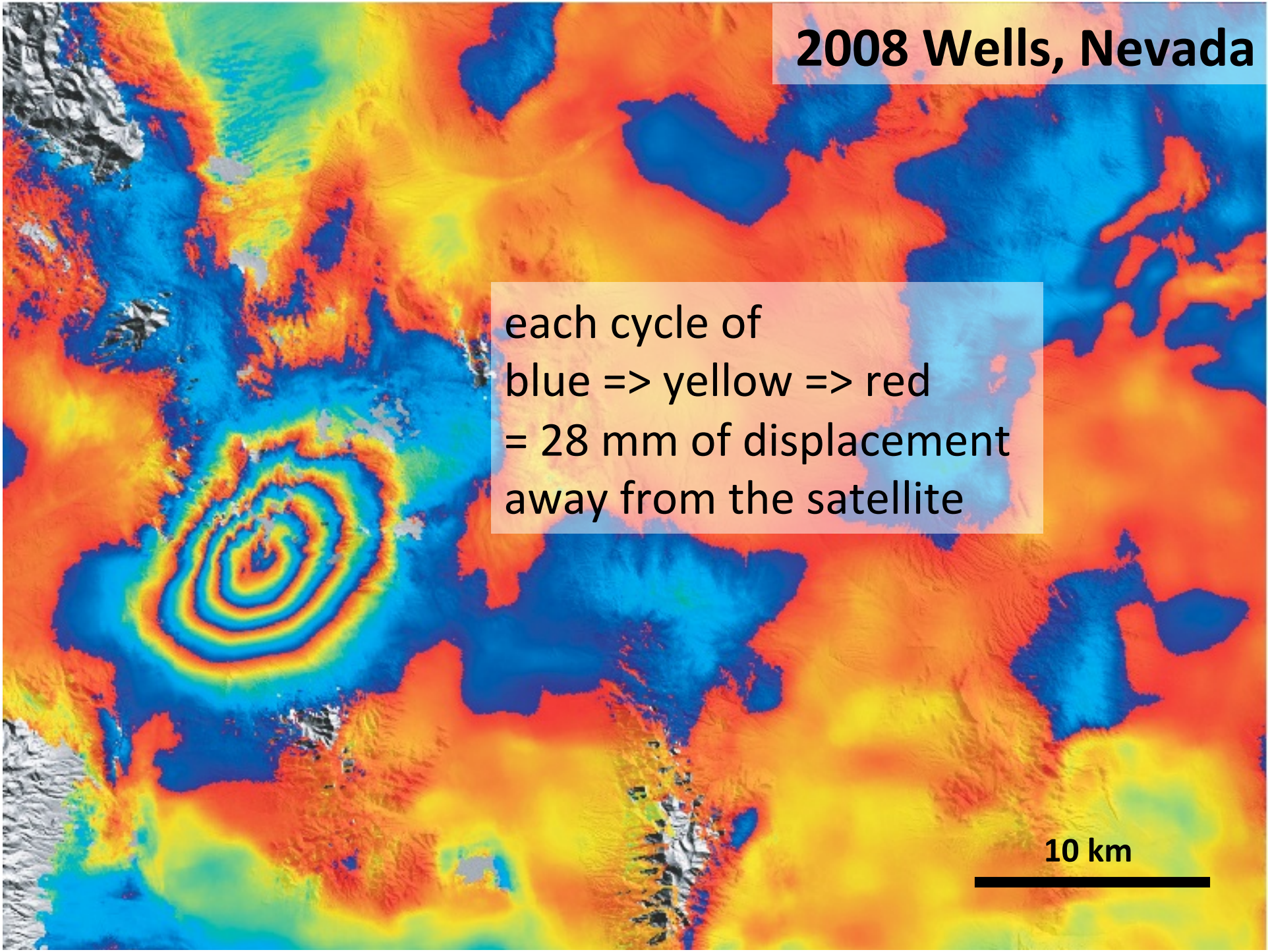


InSAR: how it works

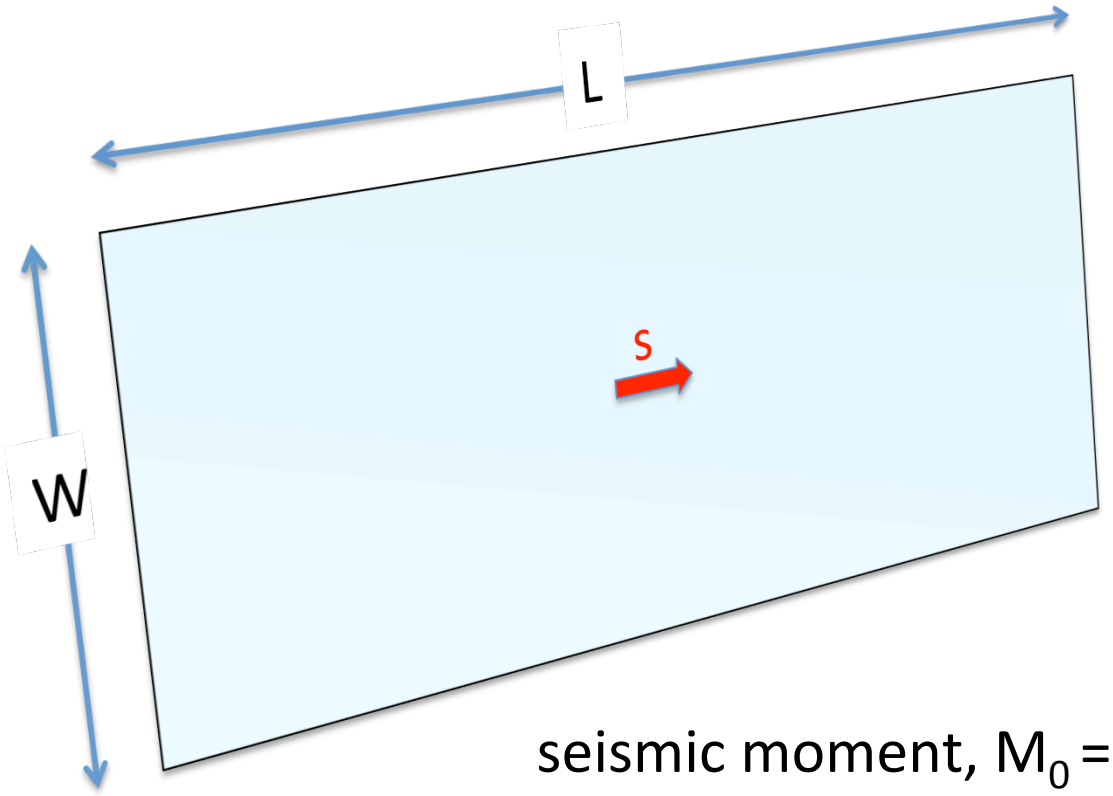


InSAR: how it works




2008 Wells, Nevada
each cycle of
blue => yellow => red
= 28 mm of displacement
away from the satellite
10 km

What controls earthquake size?



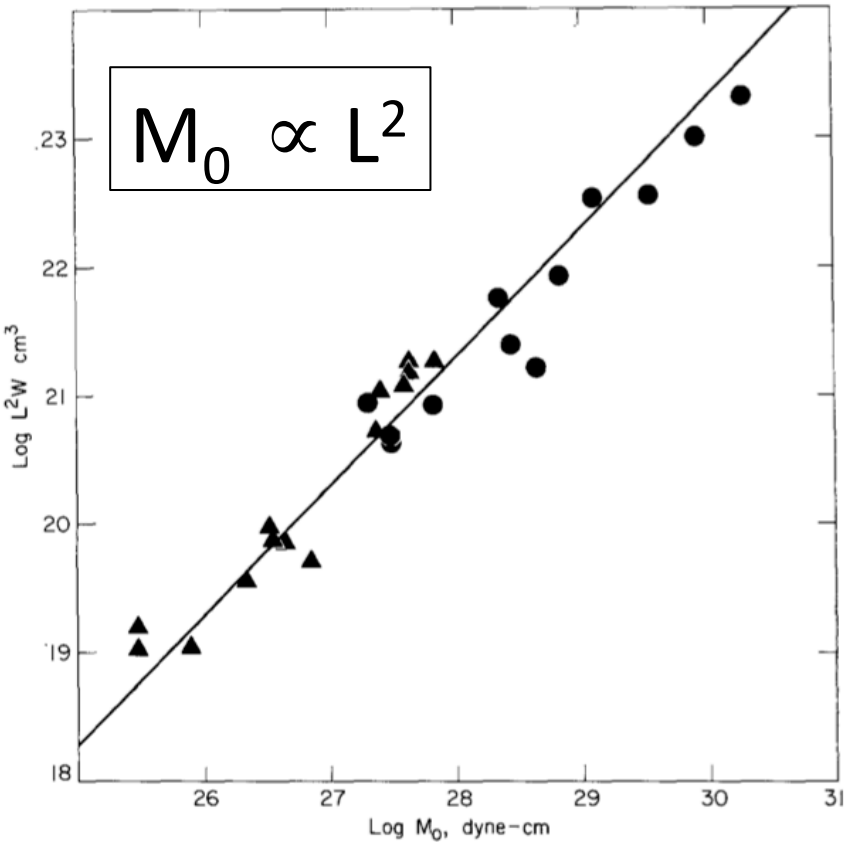
rigidity: μ

seismic moment, $M_0 = \mu L W s$

$M_0 \propto L$? $M_0 \propto L^2$?

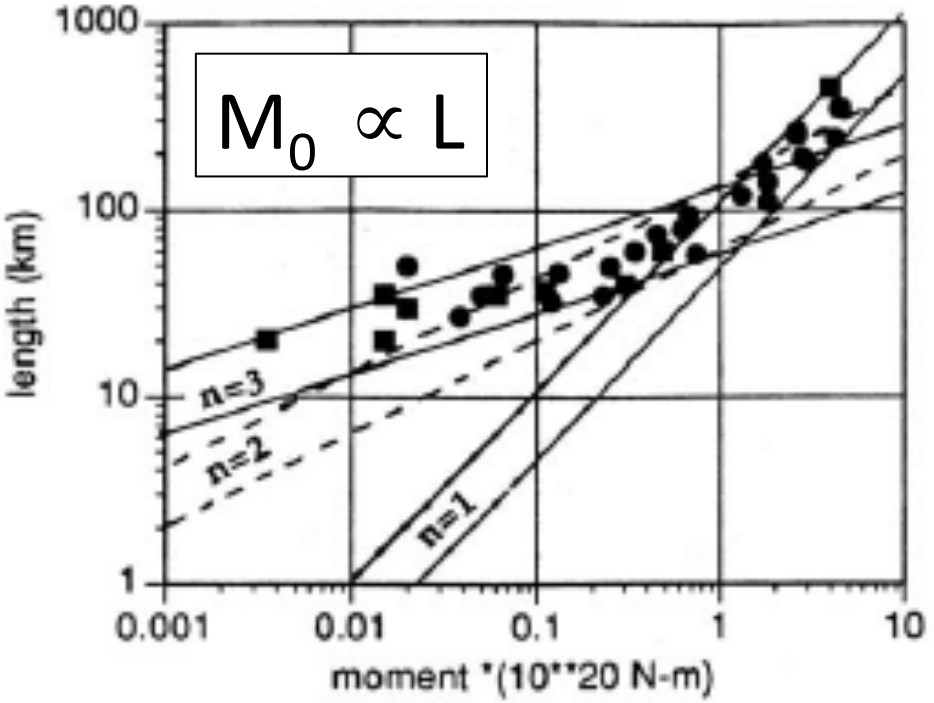
compare log M_0 with log L

‘L model’



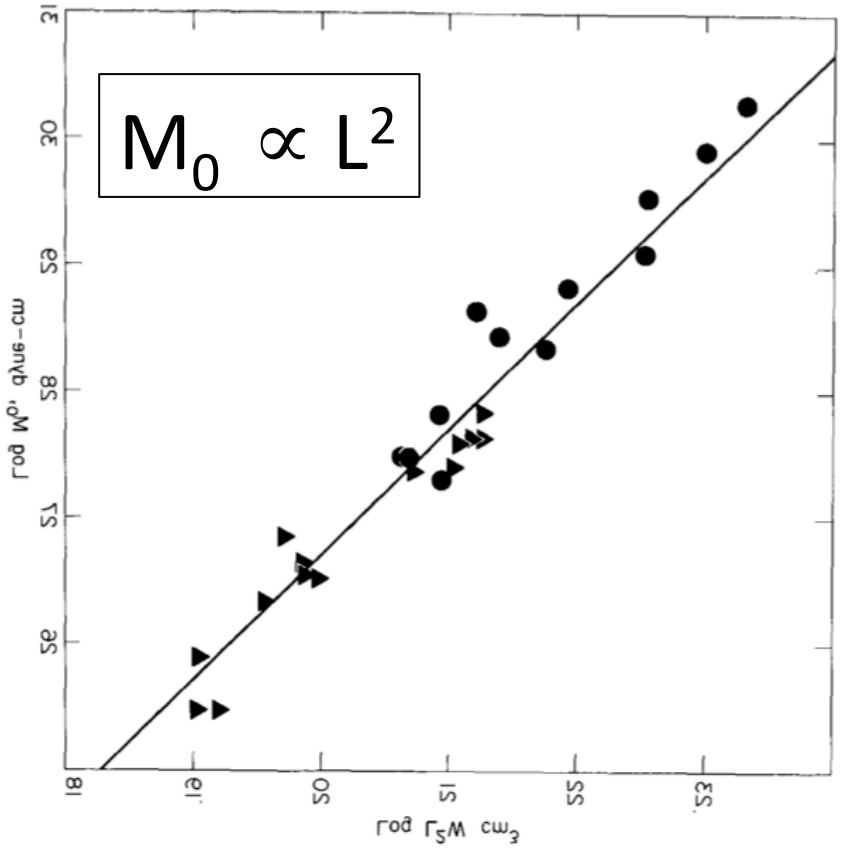
Scholz (1982)

‘W model’



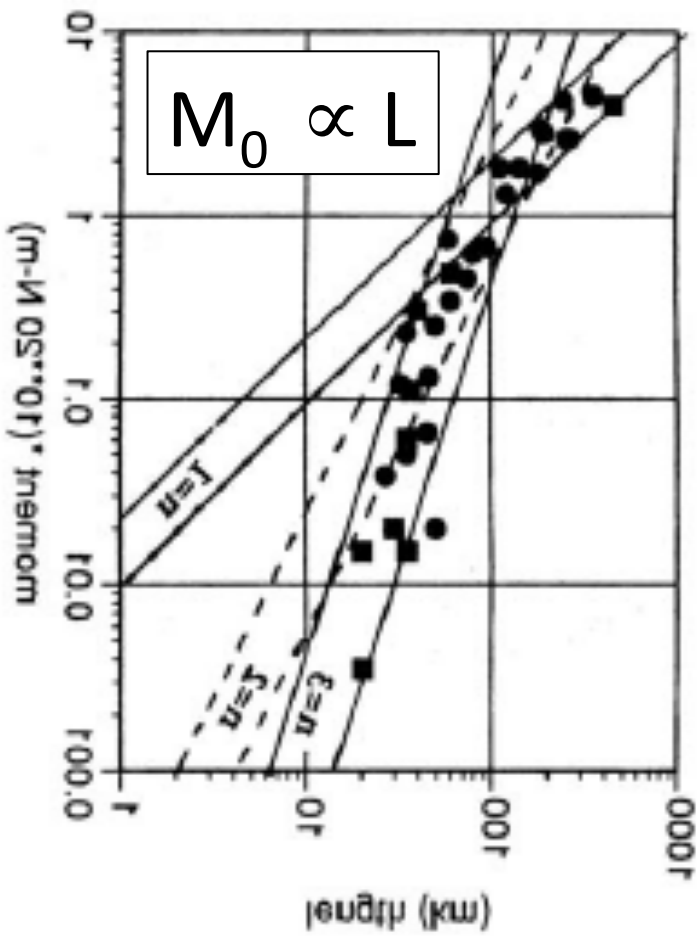
Romanowicz (1992)

‘L model’



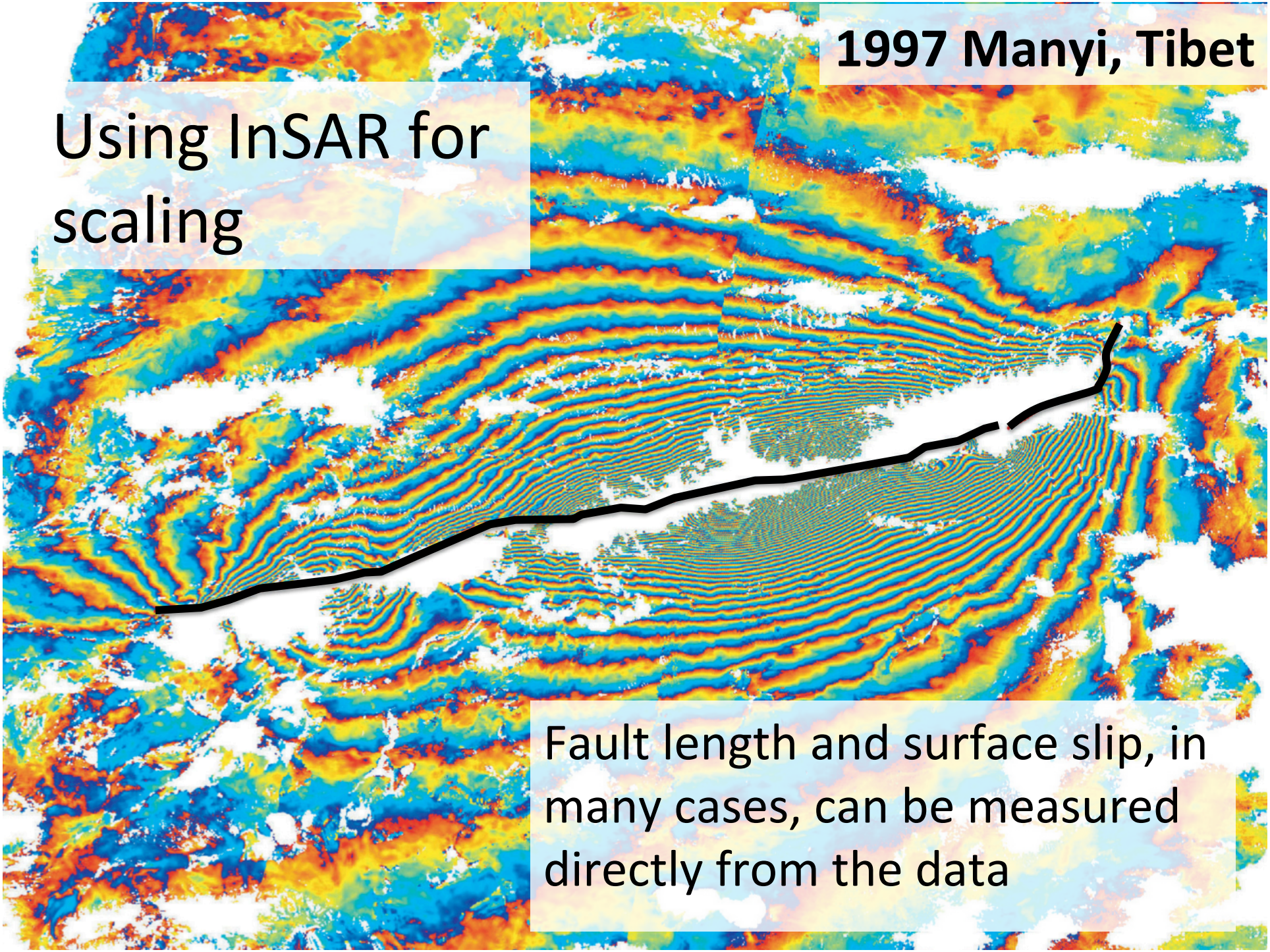
Scholz (1982)

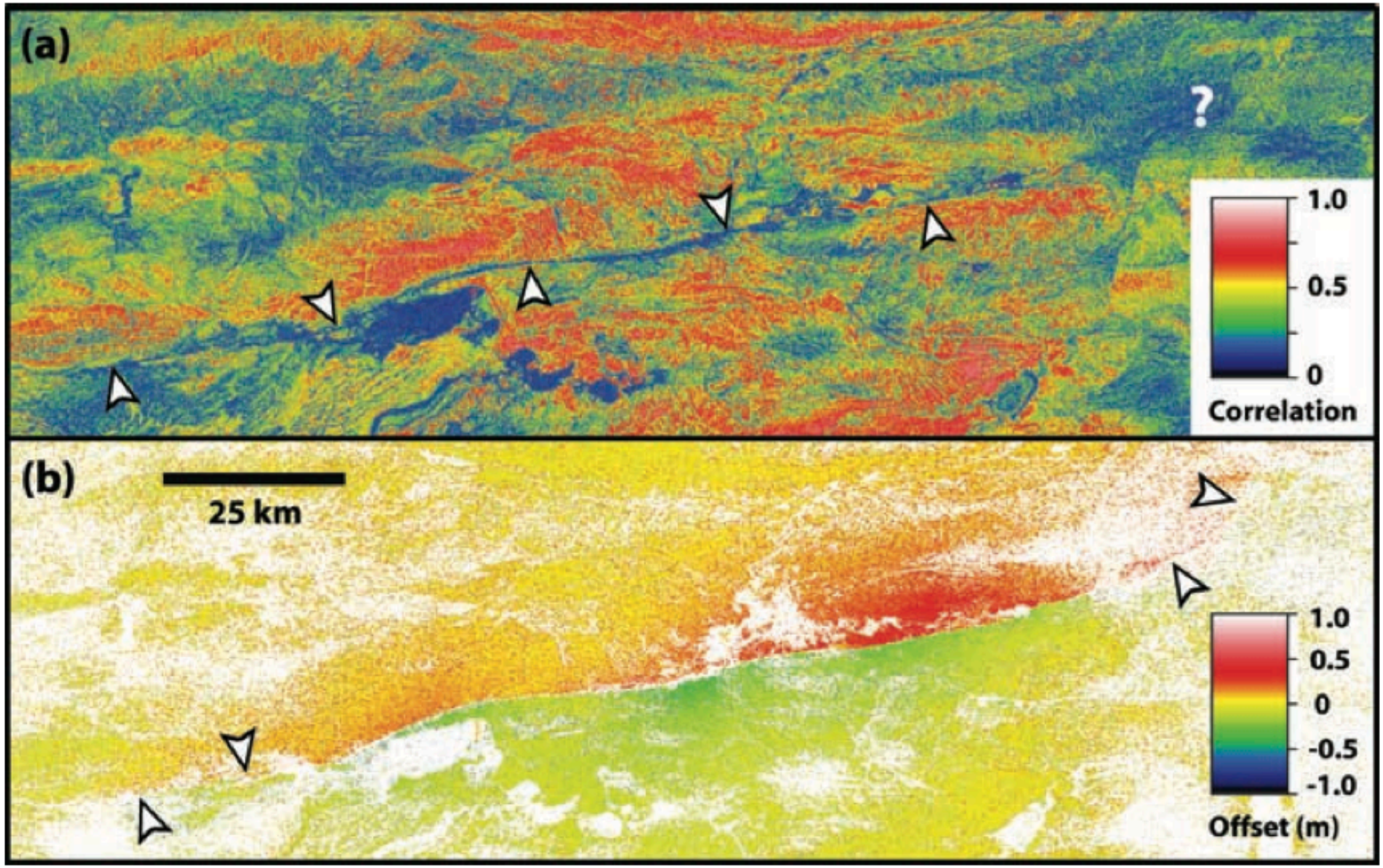
‘W model’



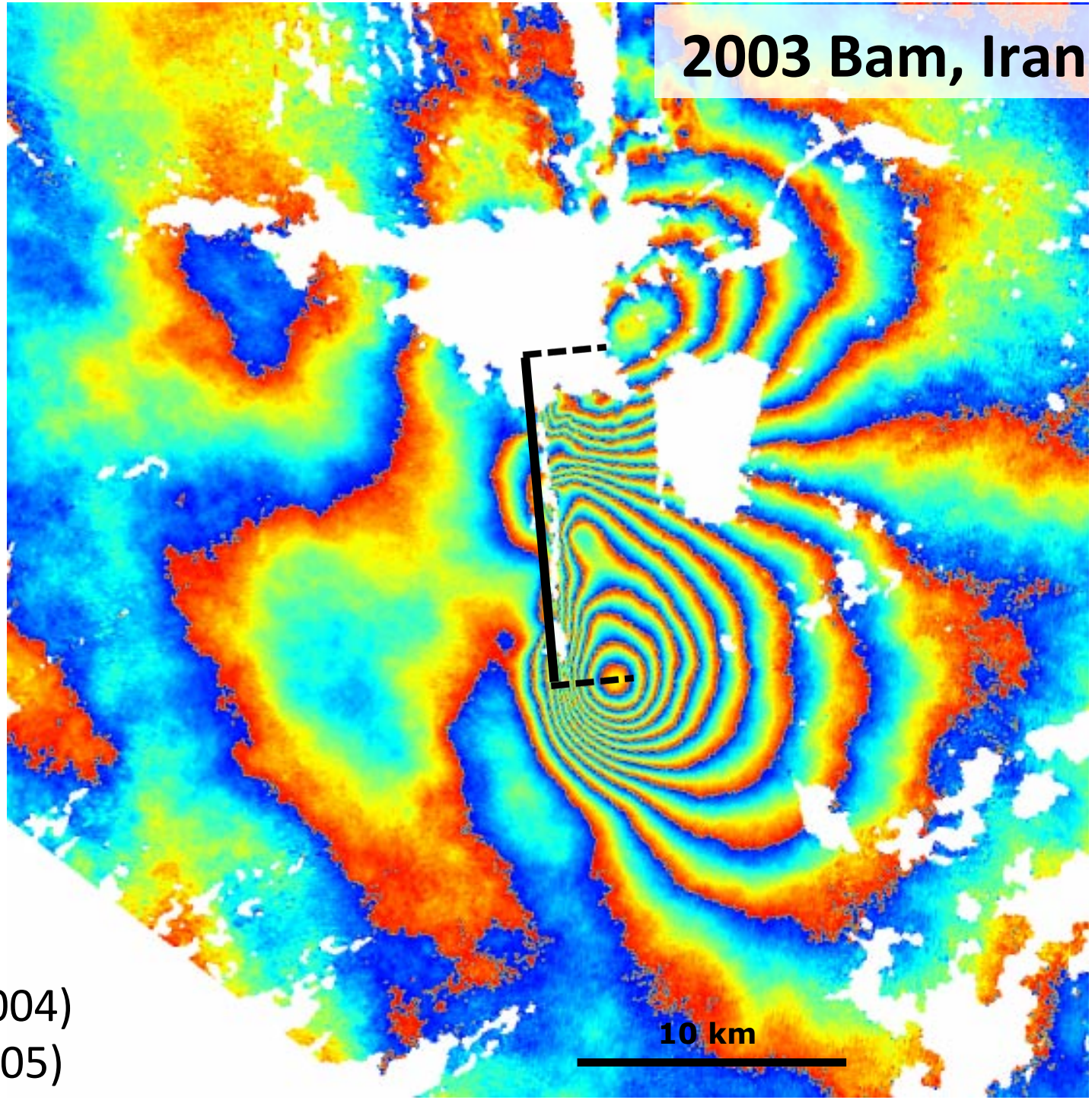
Romanowicz (1992)

same plots with length as the independent variable (horizontal axis)

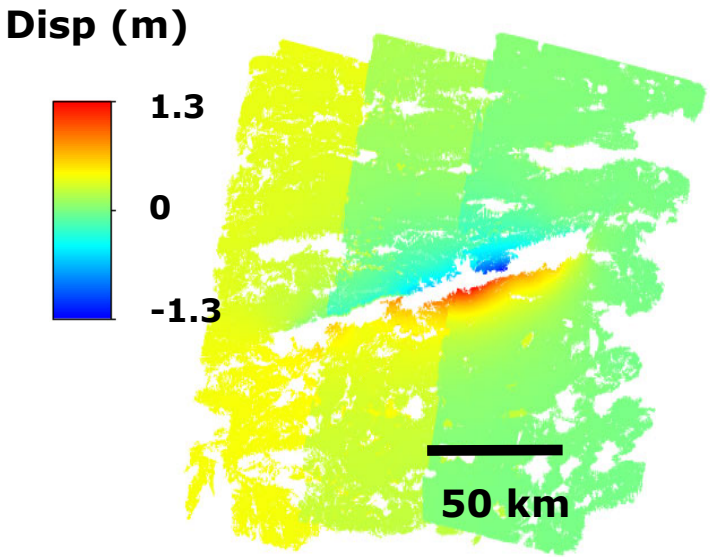

1997 Manyi, Tibet
Using InSAR for scaling
Fault length and surface slip, in many cases, can be measured directly from the data



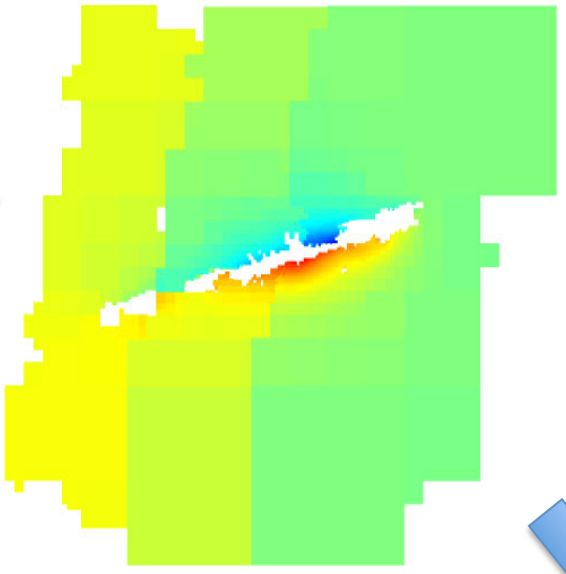
Funning et al. (2007)



Talebian et al. (2004)
Funning et al. (2005)

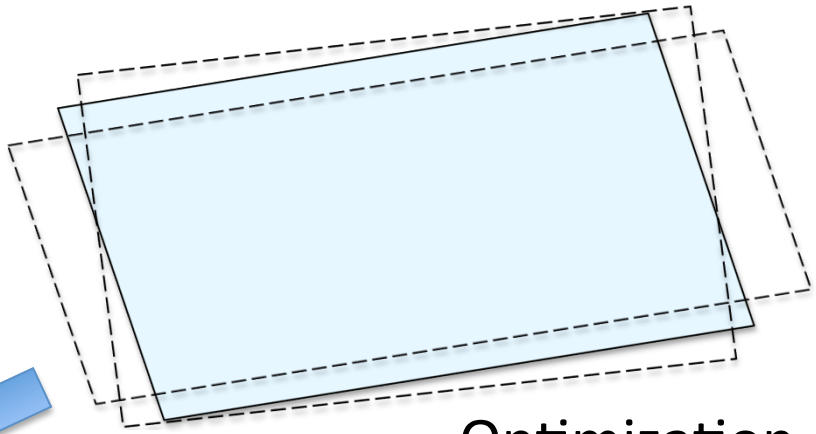


Unwrapped data

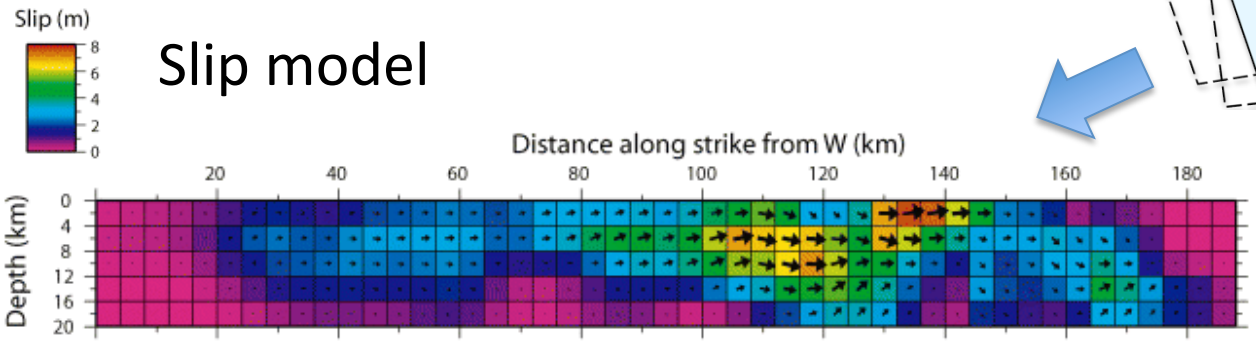


Downsampling

Moment, width, average slip are model-derived



Optimization



Slip model

InSAR Centroid Moment Tensor

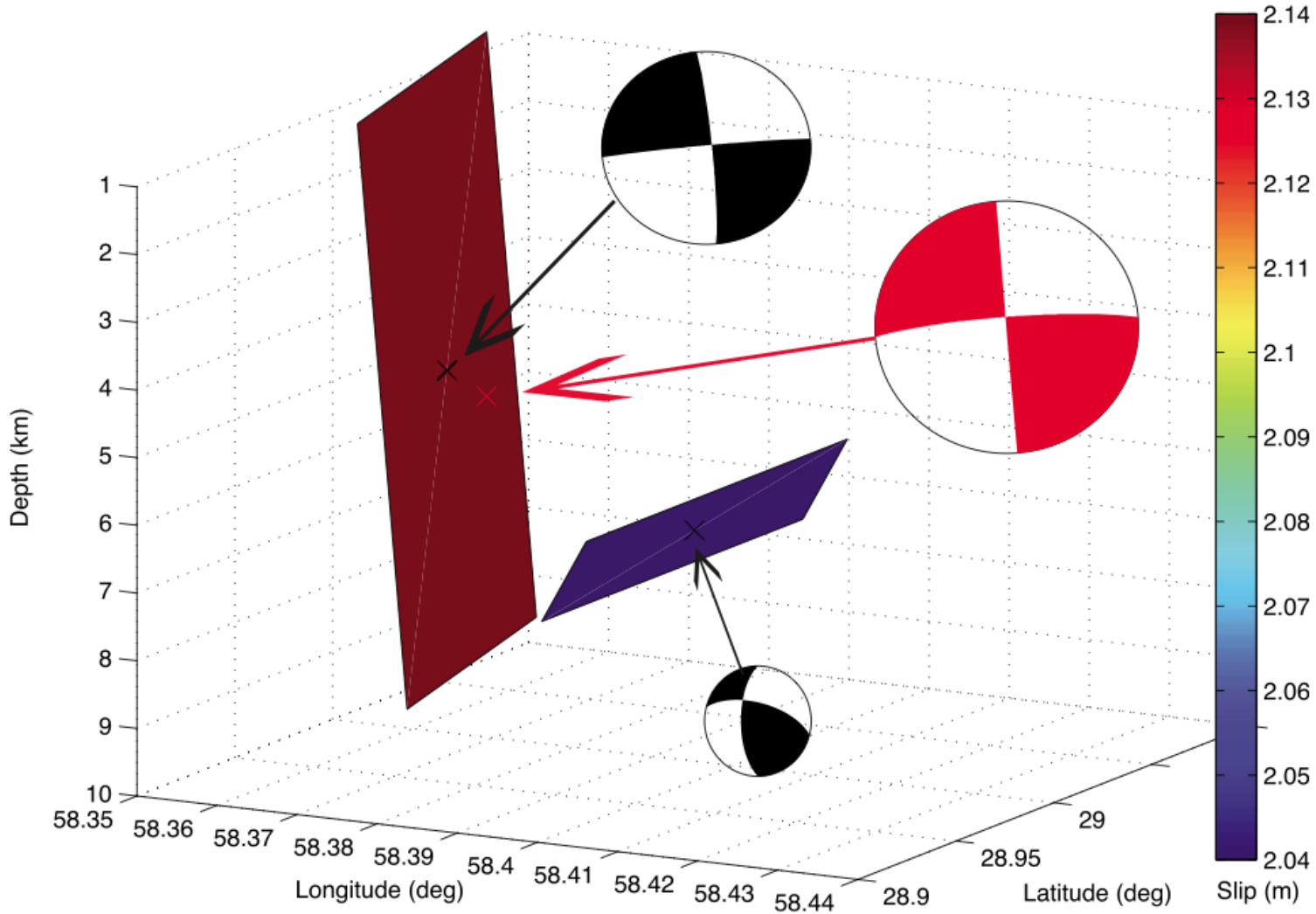
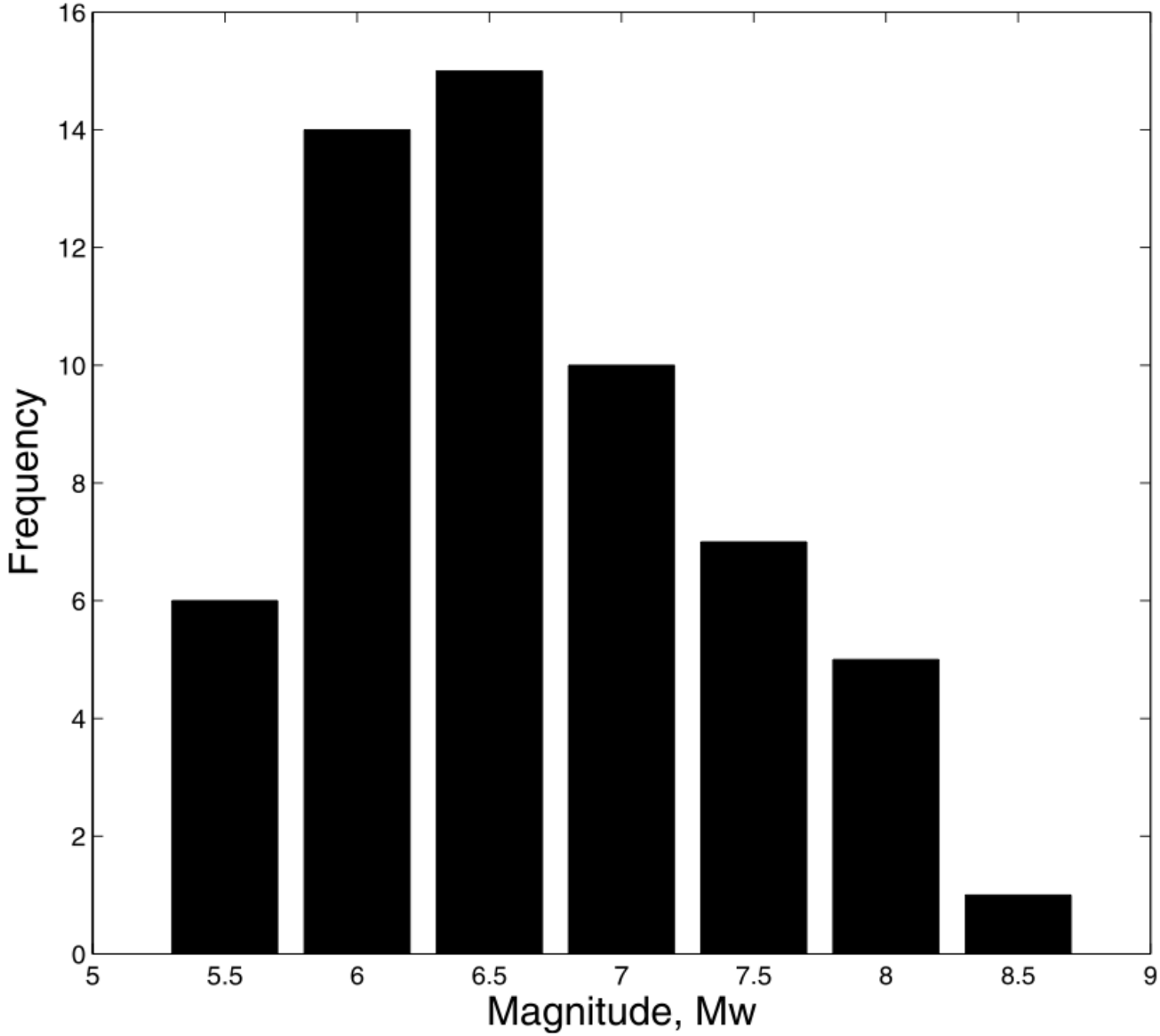


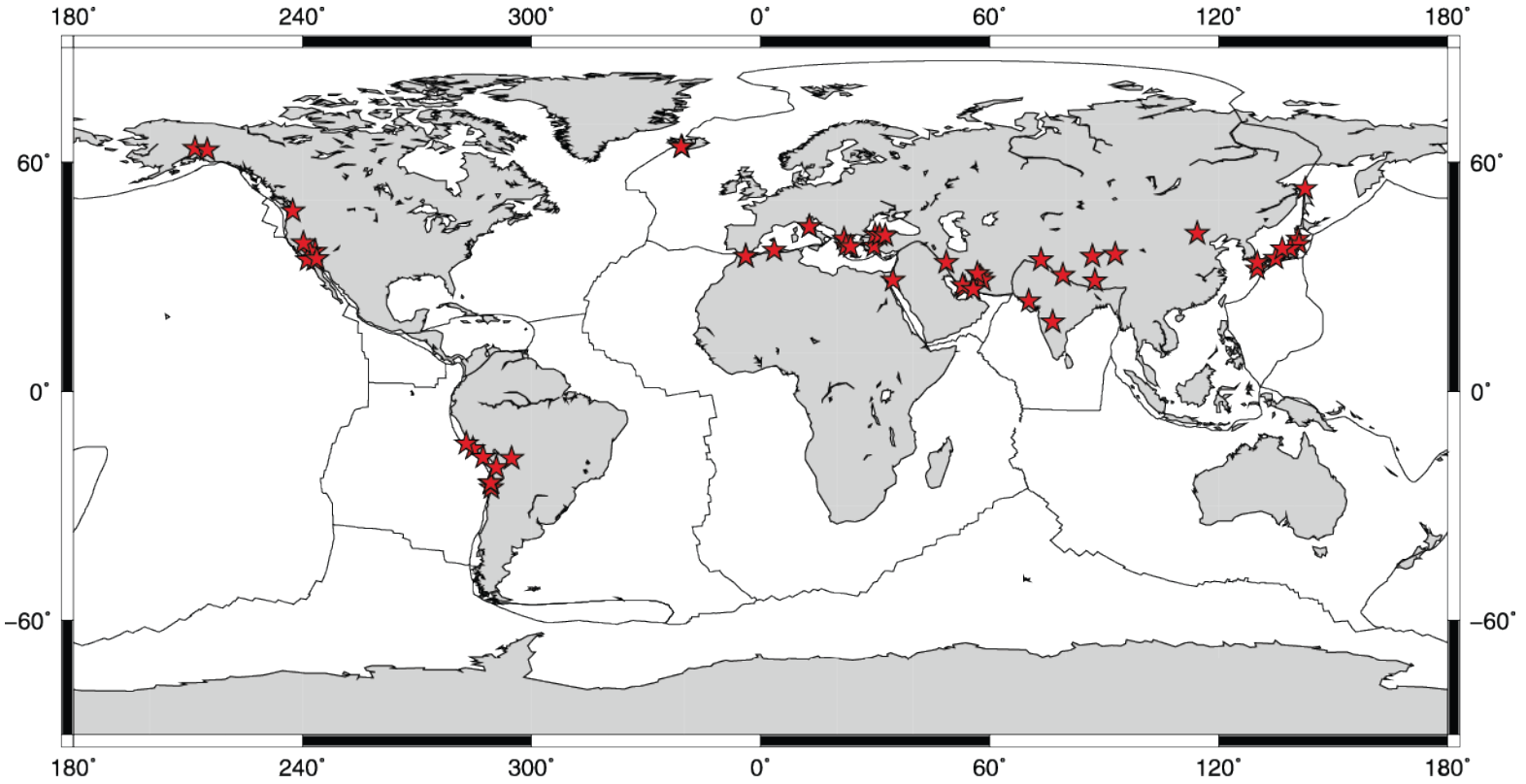
Table 3. Same as Table 1 but for Earthquakes Occurring Between 2004 and 2007

Date	Location	M_0 ($\times 10^{18}$ N m)	Lat (deg)	Long (deg)	Depth (km)	Strike (deg)	Dip (deg)	Rake (deg)	Type	Data	Reference
24.02.04	Al Hoceima, Morocco	6.20	35.14	356.01	**10.05**	295.4 ± 1.1	87.4 ± 1.5	−179.2	ss	I	*Biggs et al.* [2006]
24.02.04	Al Hoceima, Morocco (DS)	7.40	35.14	356.00	8.80	**295.0**	**88.0**	**−179.0**	ss	I	*Biggs et al.* [2006]
24.02.04	Al Hoceima, Morocco	5.88	35.17	355.98	6.90	339.5	88.0	178.0	ss	OI	*Tahayt et al.* [2009]
24.02.04	Al Hoceima, Morocco (DS)	6.60							ss	I	*Akoglu et al.* [2006]
24.02.04	Al Hoceima, Morocco (DS)	6.80					88.0		ss	I	*Cakir et al.* [2006]
24.10.04	Niigata, Japan	13.99	37.30	138.83	4.70	200.0	45.0	72.0	th	I	*Ozawa et al.* [2005]
22.02.05	Zarand Iran	6.70 ±0.2	31.50	56.80	4.65 ±0.3	266.0 ±1.0	67.0 ±2.0	105.0 ±2.0	th	I	*Talebian et al.* [2006]
20.03.05	Fukuoka-ken Seiho-oki, Japan	7.10				298.0	79.0	−18.0	ss	GI	*Nishimura et al.* [2006]
20.03.05	Fukuoka-ken (DS) Seiho-oki, Japan	8.70							ss	GI	*Nishimura et al.* [2006]
13.06.05	Tarapaca, Chile	580.00				189.0	24.0	−74.0	n	OI	*Peyrat et al.* [2006]
08.10.05	Kashmir (DS)	336.00	34.29	73.77		**321.5**	**31.5**		th	I	*Pathier et al.* [2006]
27.11.05	Qeshm Island, Iran	1.27 ± 0.07	26.77	55.92	6.00	267.0 ± 2.0	49.0 ± 4.0	105.0 ± 5.0	th	I	*Nissen et al.* [2007]
31.03.06	Chalan-Chulan, Iran	1.70	33.67	48.88	4.80	**320.0**	60.0	**180.0**	ss	I	*Peyret et al.* [2008]
31.03.06	Chalan-Chulan, Iran (DS)	1.58				**320.0**	60.0	**180.0**	ss	I	*Peyret et al.* [2008]
25.03.07	Noto Hanto	14.52	37.22	136.66	6.00	**50.7**	53.5	150.0	th	GI	*Ozawa et al.* [2008]
25.03.07	Noto Hanto (DS)	11.09				**50.7**	48.0	115.0	th	GI	*Fukushima et al.* [2008]
15.08.07	Pisco, Peru	1900.00	−13.89	283.48	30.00	**316.0**	11–25	71.0	th	SI	*Pritchard and Fielding* [2008]

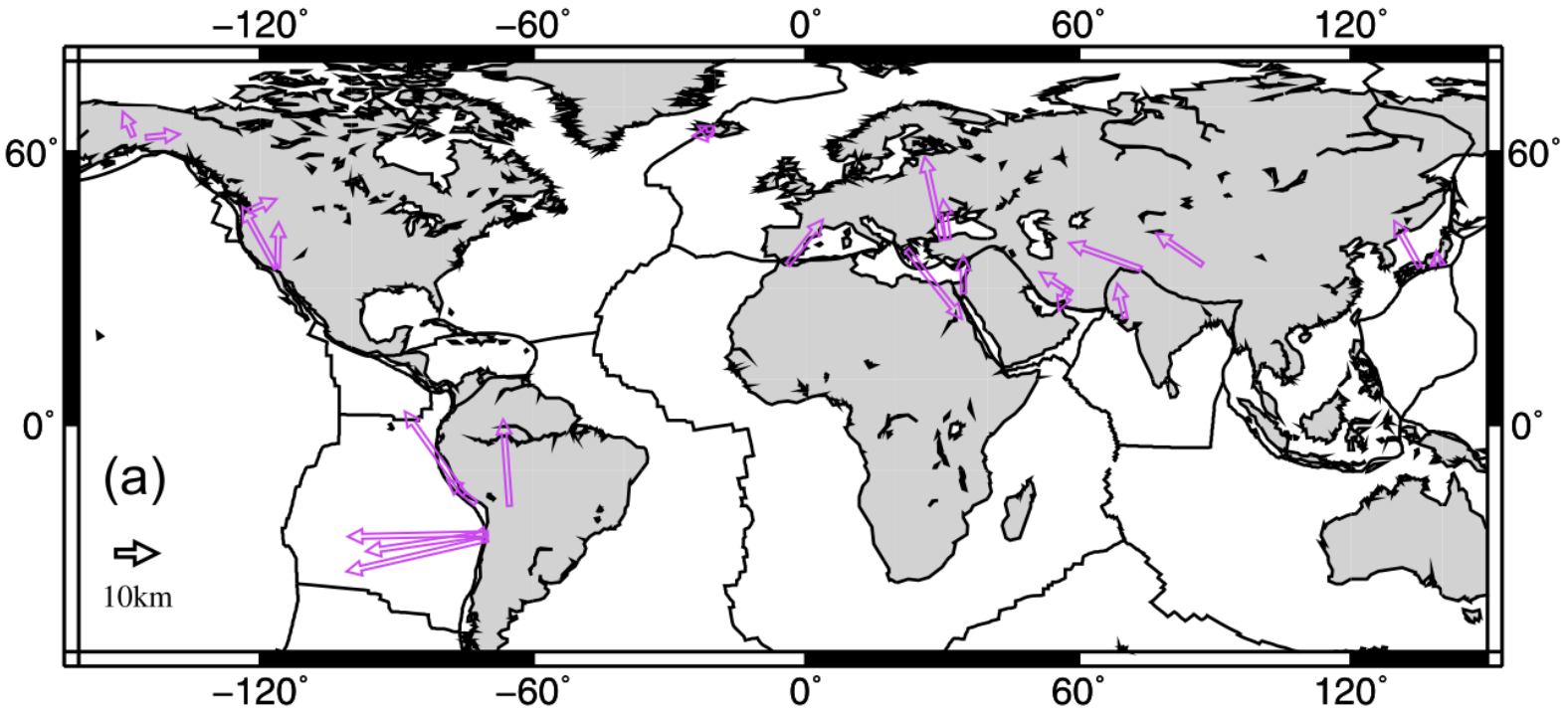
70+ events studied



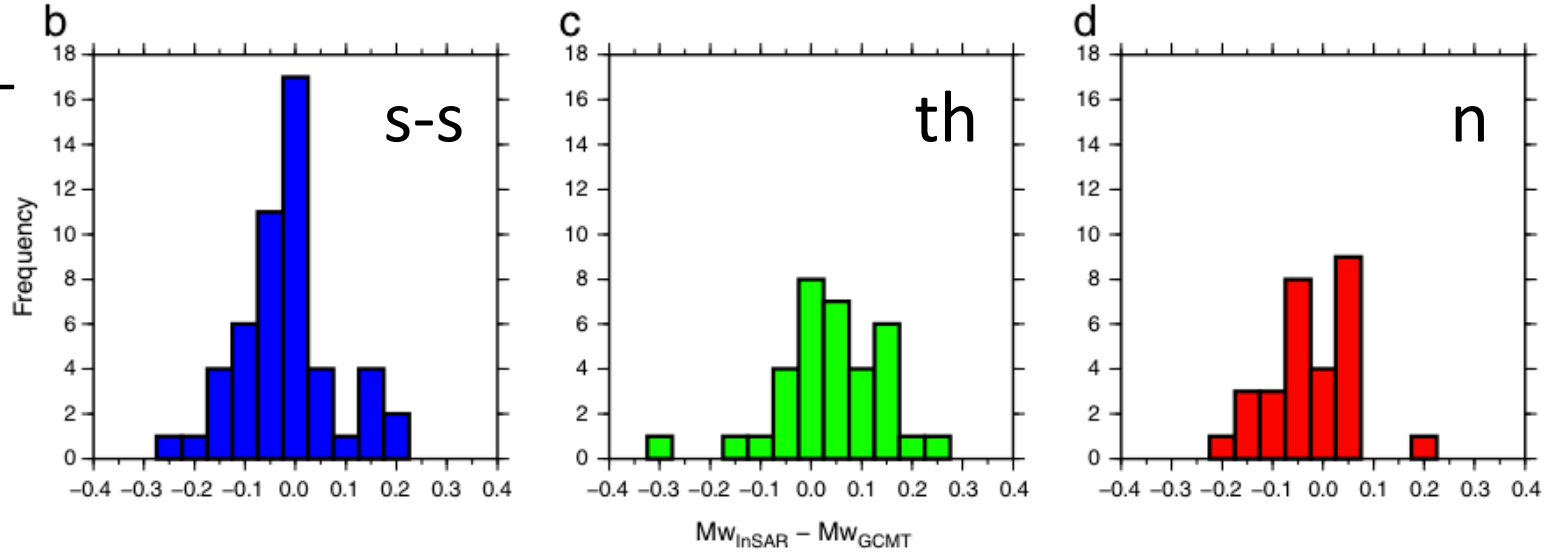
70+ events studied



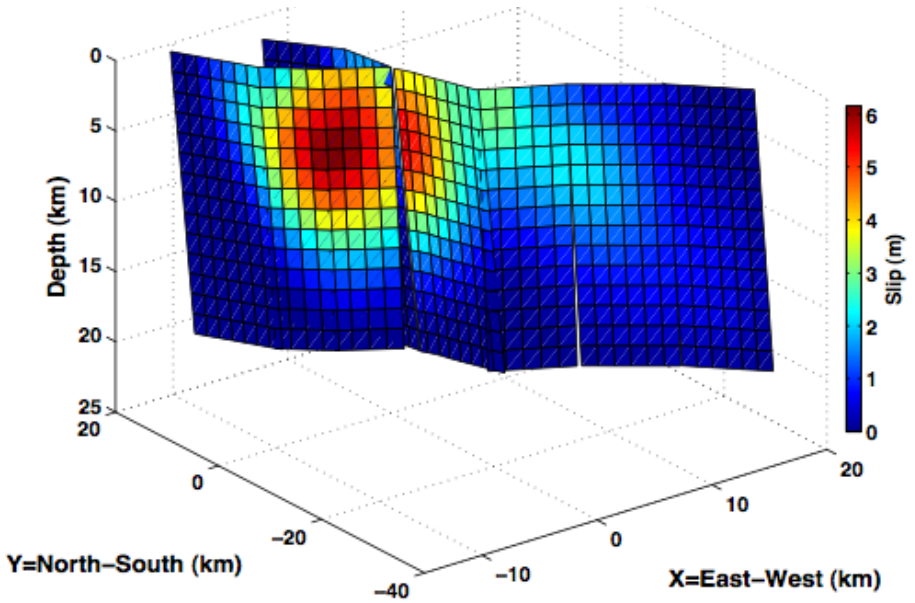
ICMT =>
GCMT



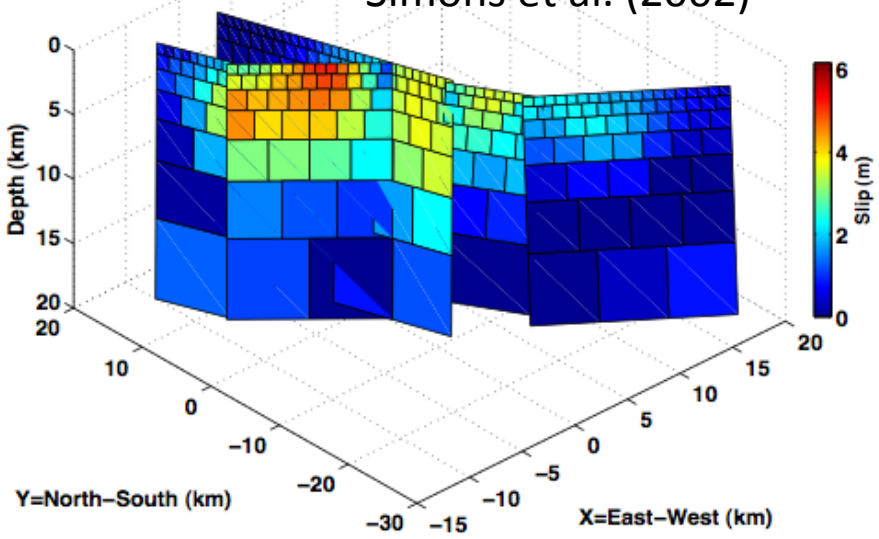
M_w (ICMT) –
M_w (GCMT)



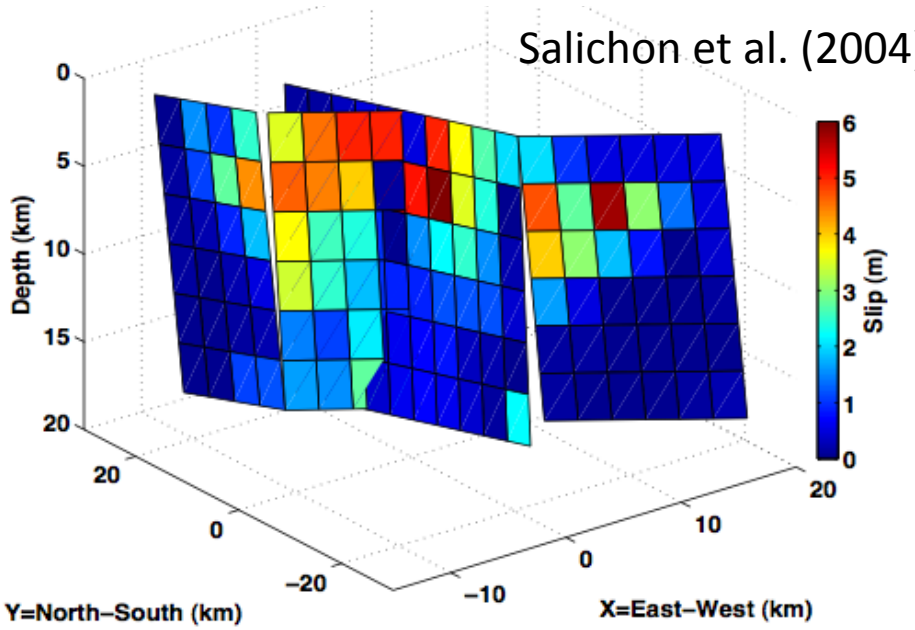
Jonsson et al. (2002)

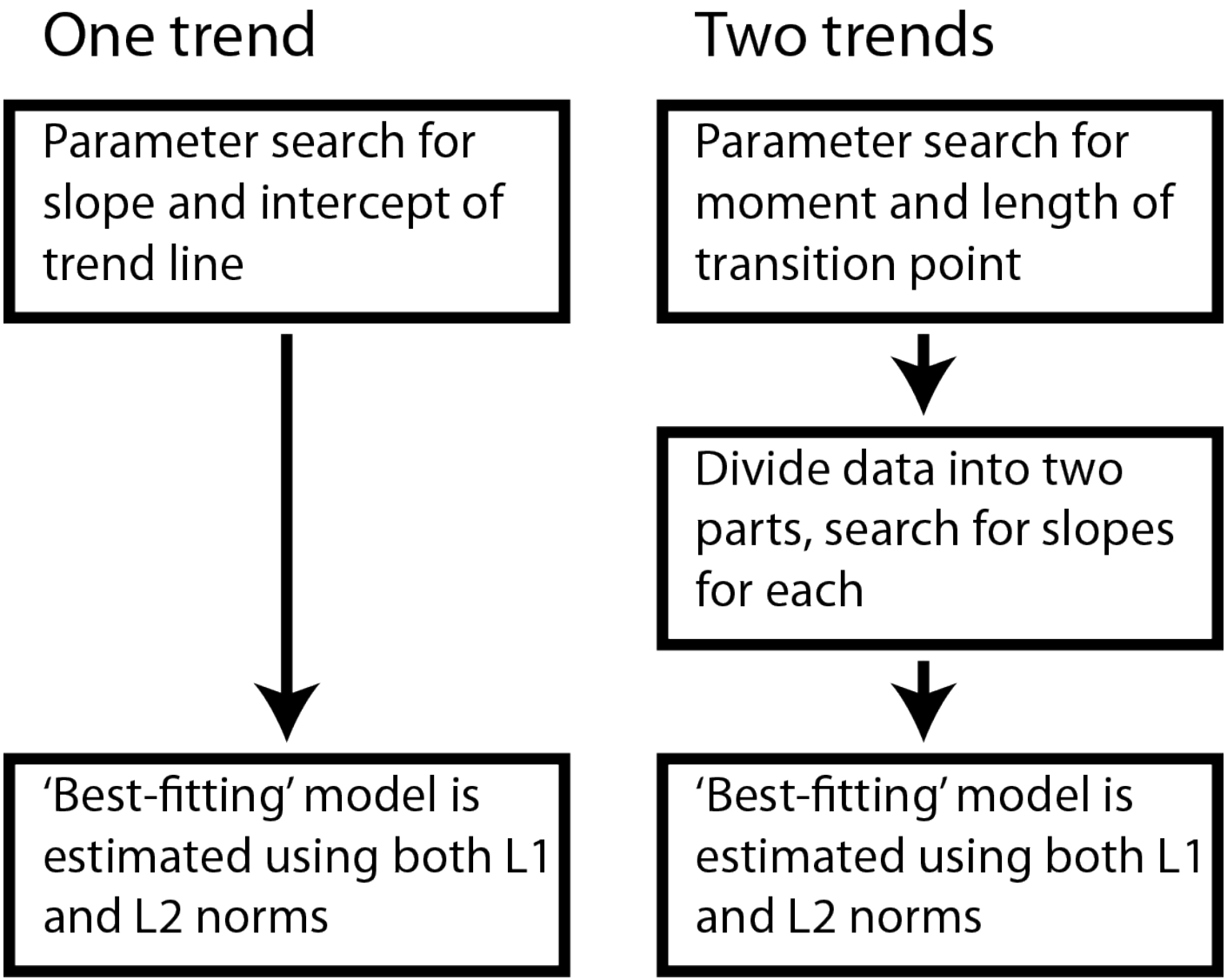


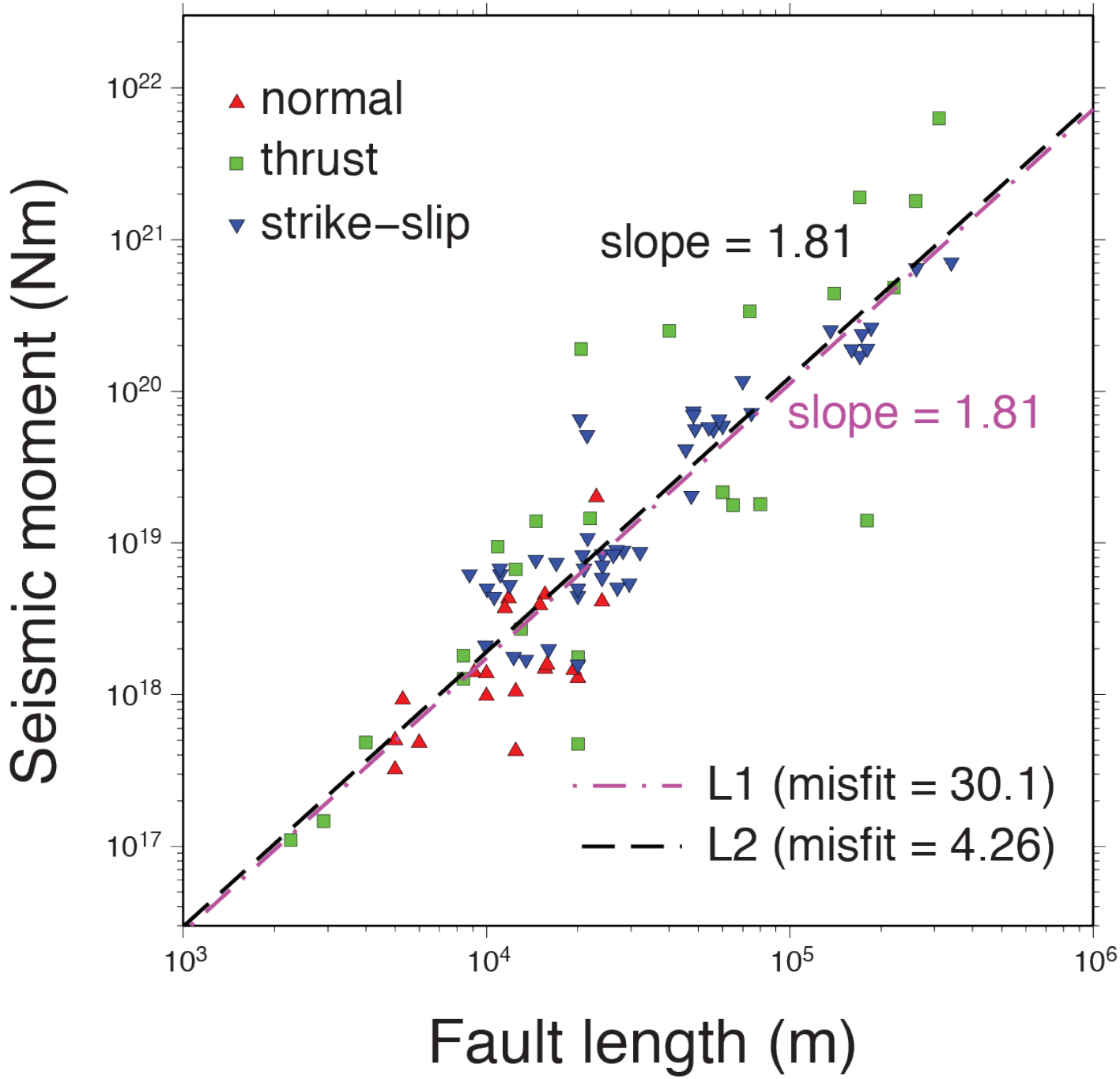
Simons et al. (2002)

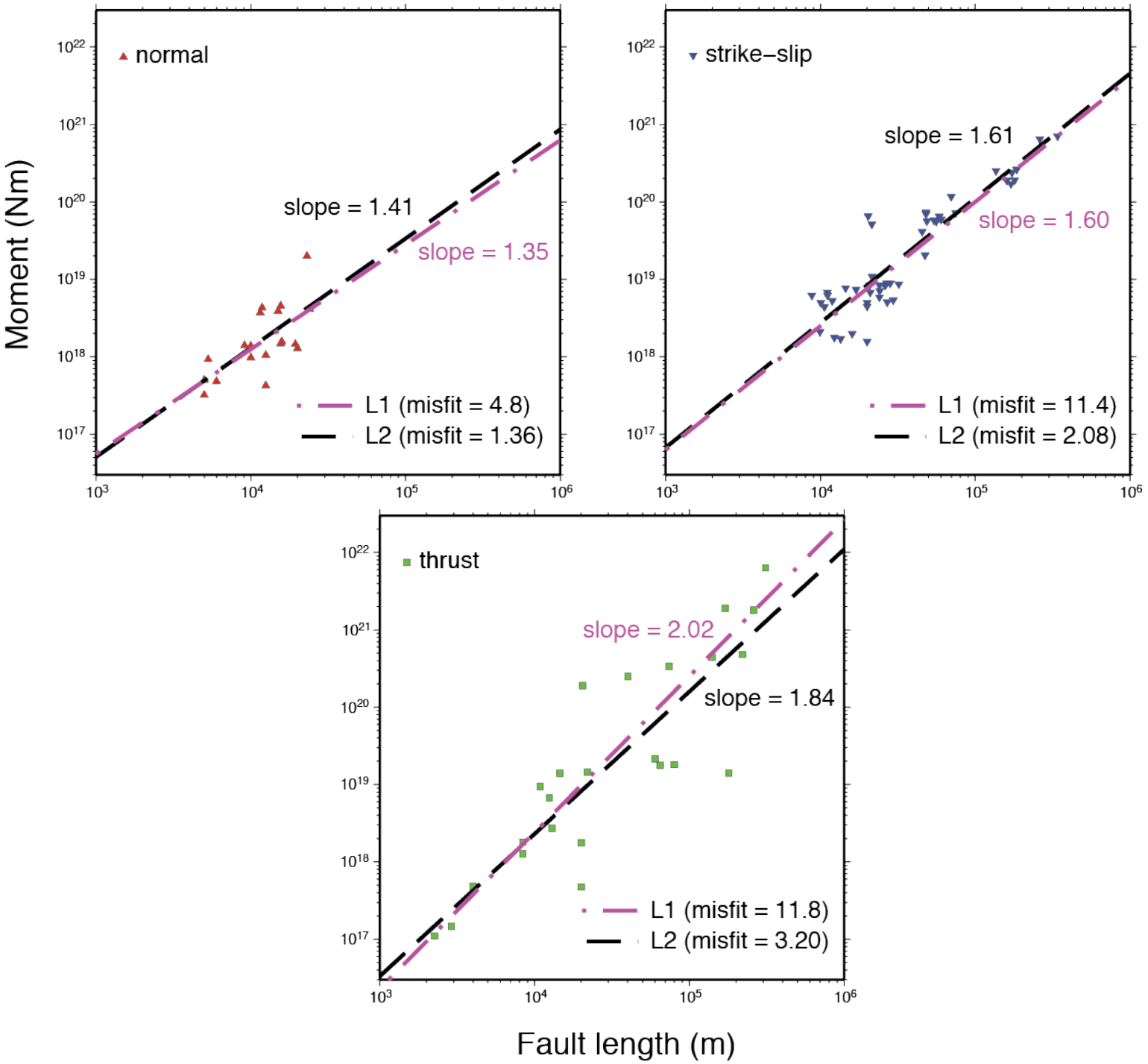


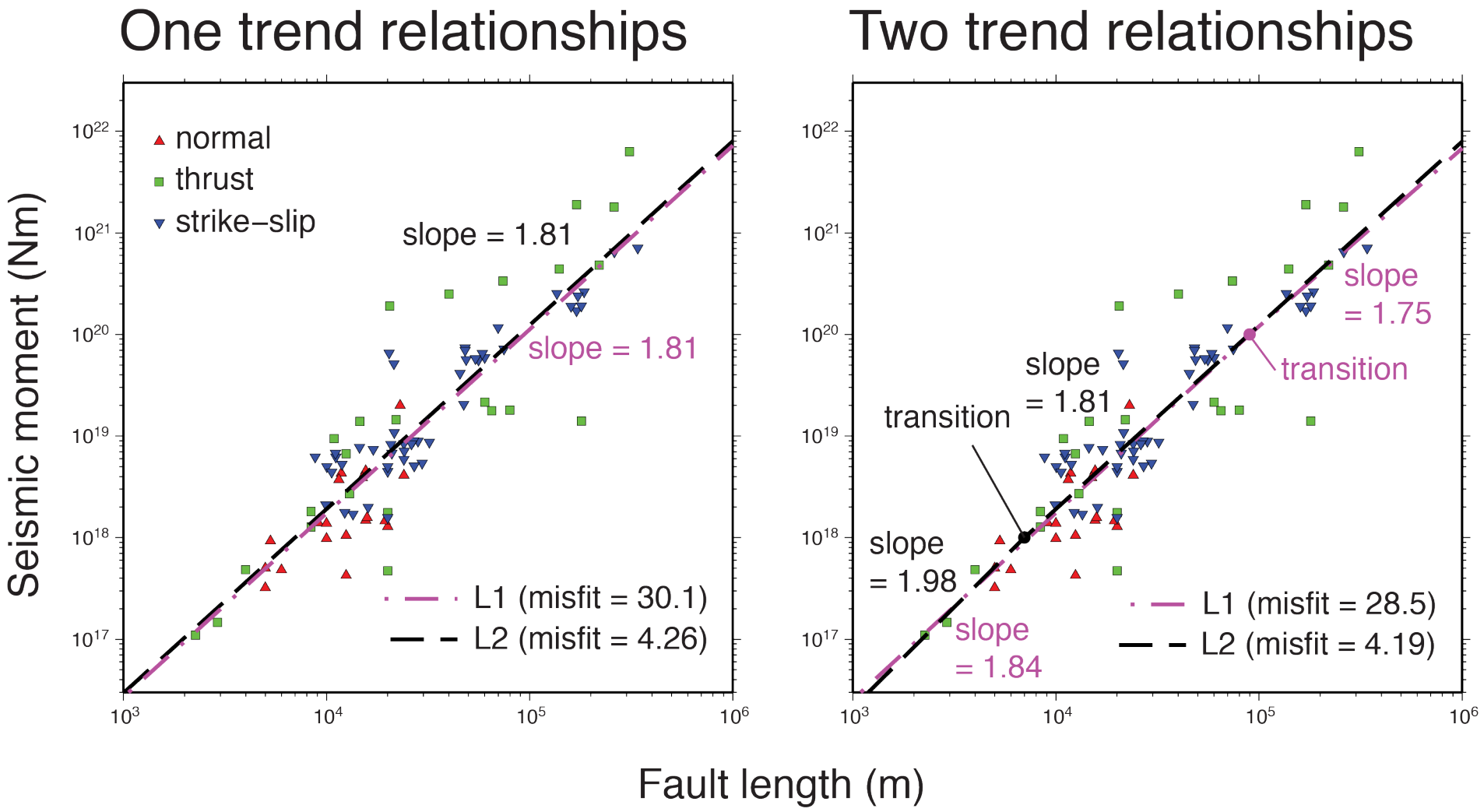
Salichon et al. (2004)

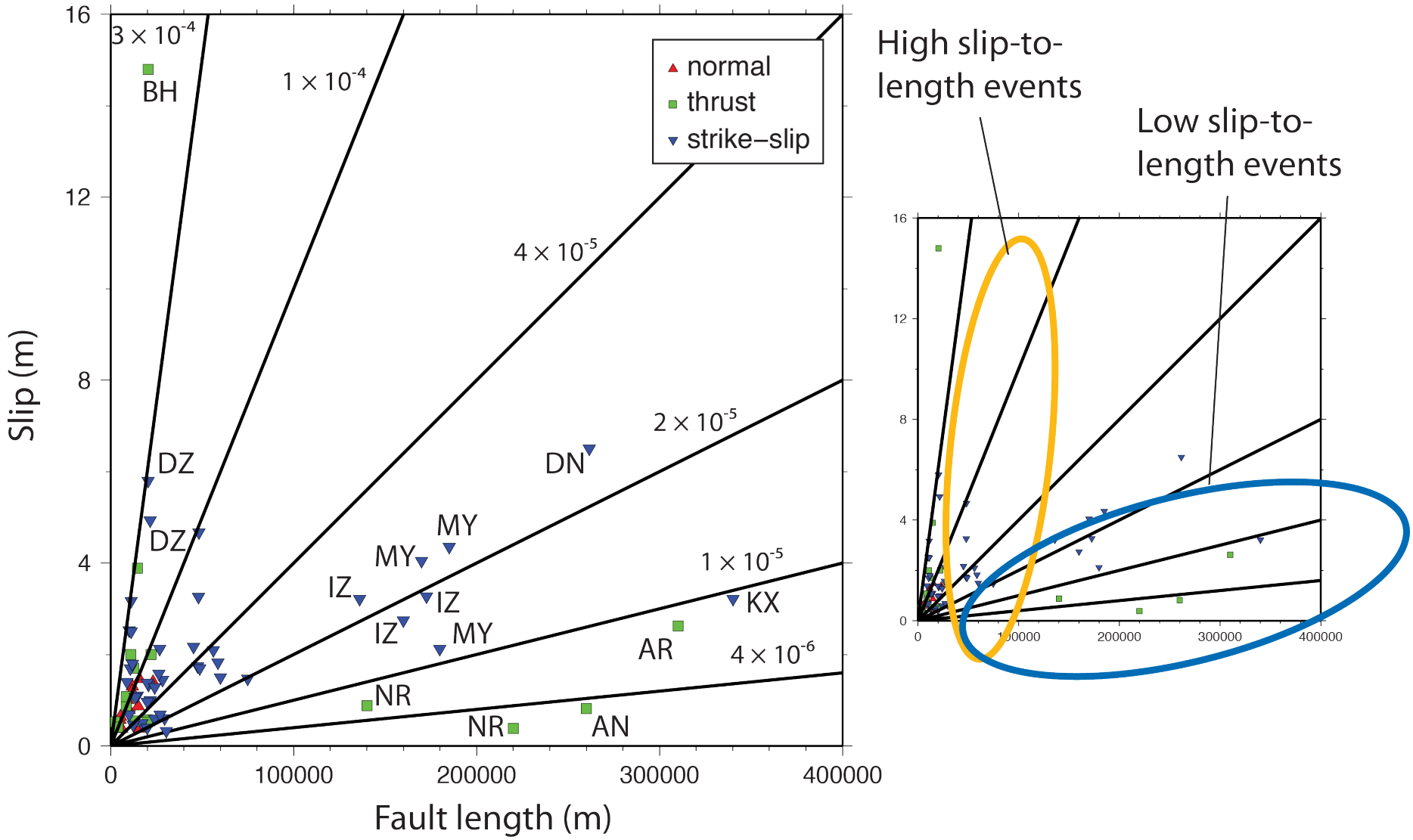



One trend
Parameter search for slope and intercept of trend line
'Best-fitting' model is estimated using both L1 and L2 norms
Two trends
Parameter search for moment and length of transition point
Divide data into two parts, search for slopes for each
'Best-fitting' model is estimated using both L1 and L2 norms


normal
thrust
strike–slip
slope = 1.81
slope = 1.81
L1 (misfit = 30.1)
L2 (misfit = 4.26)
Seismic moment (Nm)
Fault length (m)
10^{22}
10^{21}
10^{20}
10^{19}
10^{18}
10^{17}
10^{3}
10^{4}
10^{5}
10^{6}


normal
slope = 1.41
slope = 1.35
L1 (misfit = 4.8)
L2 (misfit = 1.36)
strike–slip
slope = 1.61
slope = 1.60
L1 (misfit = 11.4)
L2 (misfit = 2.08)
thrust
slope = 2.02
slope = 1.84
L1 (misfit = 11.8)
L2 (misfit = 3.20)
Moment (Nm)
Fault length (m)


One trend relationships
Two trend relationships
Seismic moment (Nm)
Fault length (m)
normal
thrust
strike–slip
slope = 1.81
slope = 1.81
L1 (misfit = 30.1)
L2 (misfit = 4.26)
slope
= 1.81
slope
= 1.75
transition
transition
slope
= 1.98
slope
= 1.84
L1 (misfit = 28.5)
L2 (misfit = 4.19)
10^{22}
10^{21}
10^{20}
10^{19}
10^{18}
10^{17}
10^{3}
10^{4}
10^{5}
10^{6}


Slip (m)
Fault length (m)
0
4
8
12
16
0
100000
200000
300000
400000
normal
thrust
strike–slip
3 × 10-4
1 × 10-4
4 × 10-5
2 × 10-5
1 × 10-5
4 × 10-6
BH
DZ
DZ
DN
MY
MY
IZ
IZ
IZ
MY
KX
AR
NR
NR
AN
High slip-to-length events
Low slip-to-length events

Summary of findings

- For all events, $M_0 \propto L^{1.8}$
- Strike-slip events: $M_0 \propto L^{1.6}$
- Thrust events: $M_0 \propto L^{2}$
- A change in scaling is not required to fit the data
- Slip to length ratios vary by 2 orders of magnitude; relationship with recurrence rate?


SENTINEL-1A and -1B
European Space Agency
Launch Q2 2013, 2015
6 day repeat in same orbit
mean post event wait => 3 days
ascending + descending => mean wait < 3 days
esa