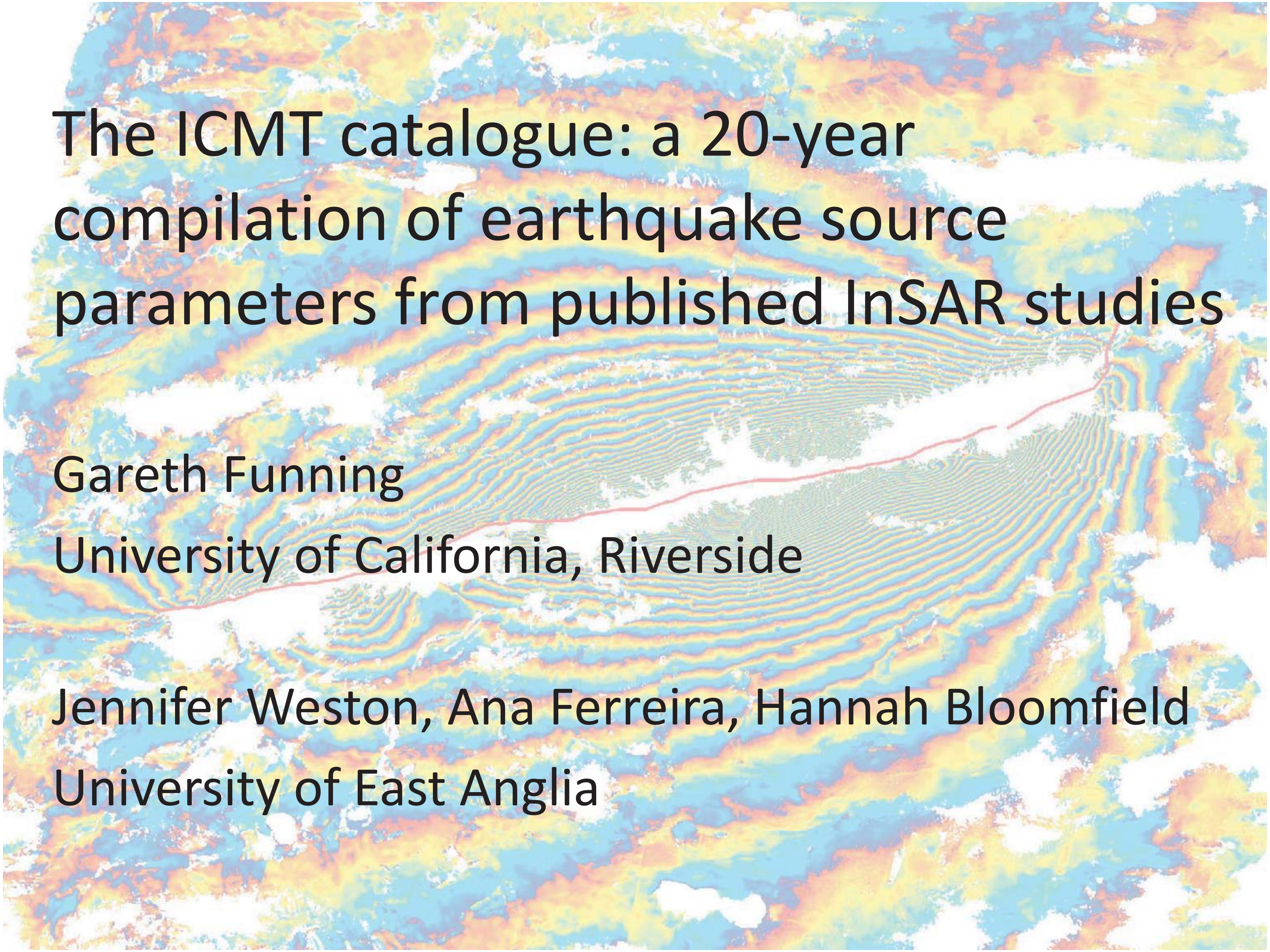


The ICMT catalogue: a 20-year compilation of earthquake source parameters from published InSAR studies

Gareth Funning

University of California, Riverside

Jennifer Weston, Ana Ferreira, Hannah Bloomfield

University of East Anglia

Outline

- The GCMT and ‘ICMT’ catalogues
- Comparisons of earthquake source parameters
  - Are InSAR and seismic solutions compatible?
- Differences in earthquake locations
  - Implications for global Earth models
- Earthquake scaling relationships
  - Implications for earthquake source physics and earthquake hazards

Centroid **M**oment **T**ensor

- Centroid = best point source for an earthquake
- Moment tensor = six numbers that describe an earthquake mechanism

```
Here is the solution for the recent event.

March 11, 2011, NEAR EAST COAST OF HONSHU, JAPAN, MW=9.1

Meredith Nettles
Goran Ekstrom

CENTROID-MOMENT-TENSOR  SOLUTION
GCMT EVENT:     M201103110546A
DATA: II DK IU CU G  GE MN LD
MANTLE WAVES:  100S, 271C, T=300
TIMESTAMP:      Q-20110311234057
CENTROID LOCATION:
ORIGIN TIME:      05:47:32.8 0.2
LAT:37.52N 0.01;LON:143.05E 0.02
DEP: 20.0  FIX;TRIANG HDUR: 70.0
MOMENT TENSOR: SCALE 10**29 D-CM
RR= 1.730 0.006; TT=-0.281 0.005
PP=-1.450 0.005; RT= 2.120 0.068
RP= 4.550 0.065; TP=-0.657 0.004
PRINCIPAL AXES:
1.(T) VAL=  5.305;PLG=55;AZM=295
2.(N)       0.014;     0;    205
3.(P)      -5.319;    35;    115
BEST DBLE.COUPLE:M0= 5.31*10**29
NP1: STRIKE=203;DIP=10;SLIP=  88
NP2: STRIKE= 25;DIP=80;SLIP=  90

           ---#######-
       ---#############---
     --################-----
   --#################--------
  --##################---------
 --##################-----------
 -#######   #########-----------
--####### T ########-------------
-########   #######--------------
-#################---------------
-################--------   -----
 -##############--------- P ----
 -#############----------   ----
  -###########-----------------
   -#########-----------------
     -######----------------
       -###---------------
           -----------
```

time
location

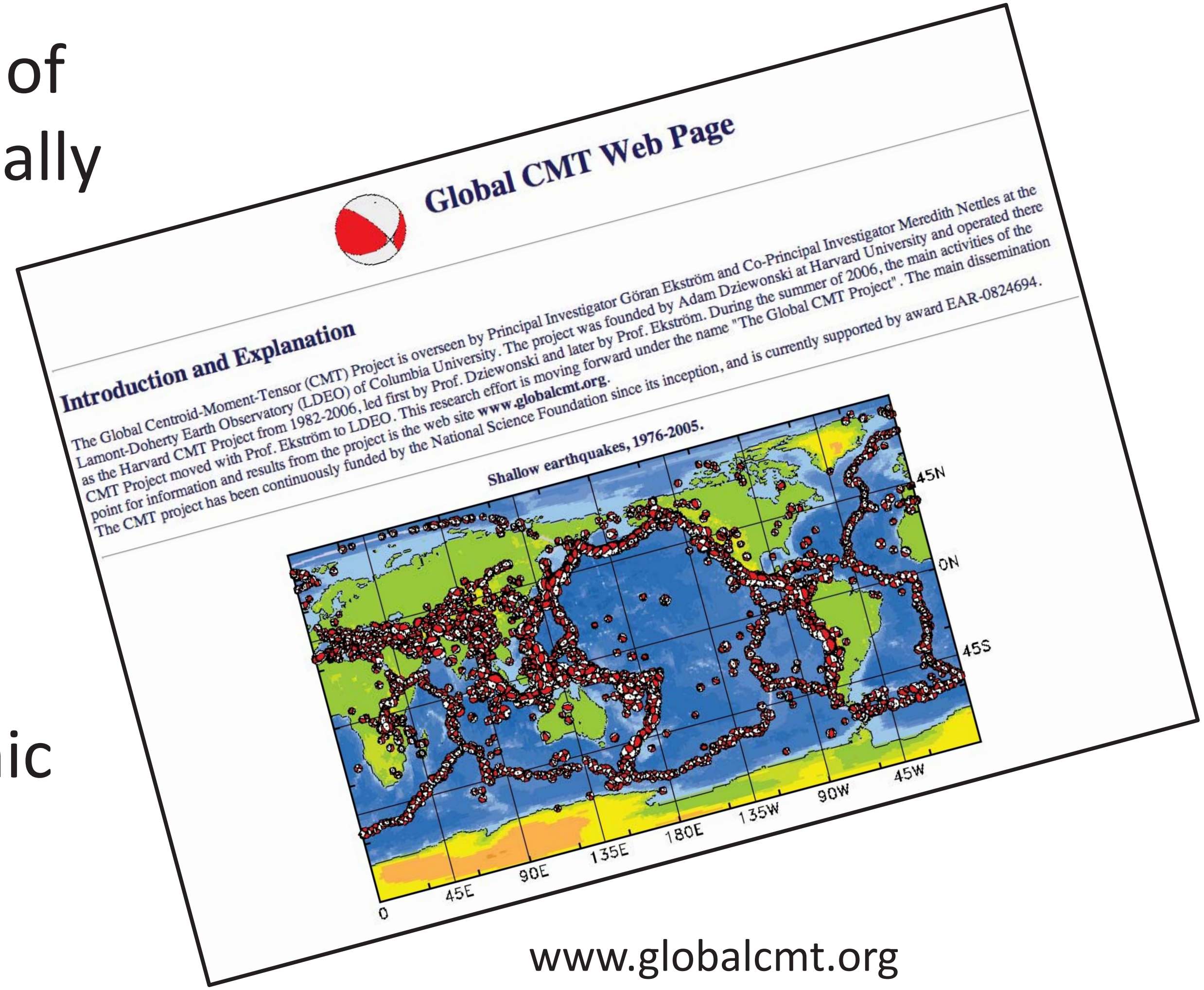
moment
tensor values

moment
fault planes

The Global CMT project

(GCMT)

- Routine analyses of earthquakes globally
- Uses long-period body waves and surface waves
- Earth model spherical harmonic degree 8

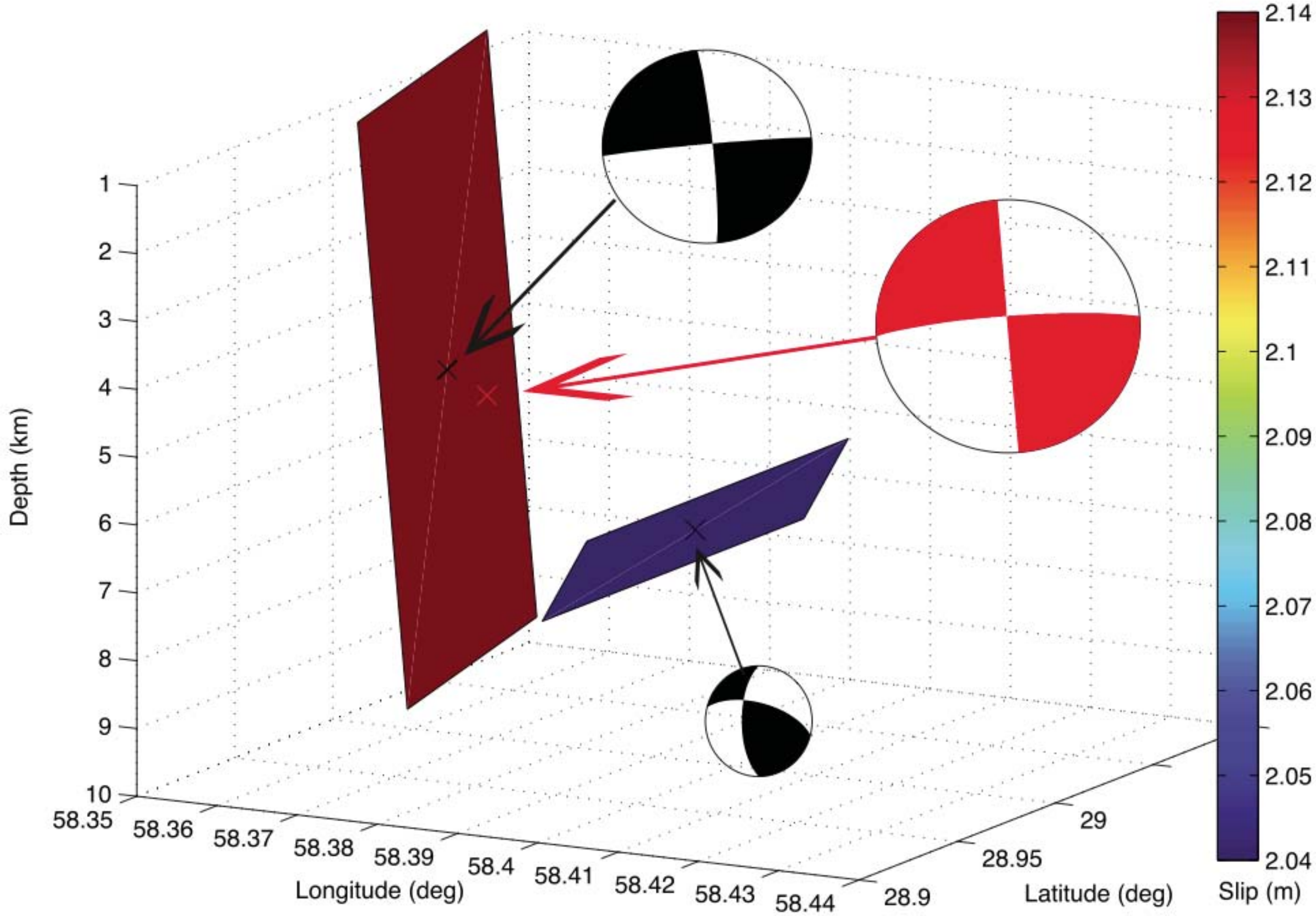


www.globalcmt.org

InSAR Centroid Moment Tensor

- Compilation of earthquake source parameters from published InSAR studies of earthquakes (or the authors)
- Produce CMT-like solutions (centroids, moment tensors, focal mechanisms) that can be compared directly with those from seismology
- Publications: Weston et al. (2011), JGR
  Ferreira et al. (2011), JGR
  Weston et al. (2012), Tectonophysics

InSAR Centroid Moment Tensor



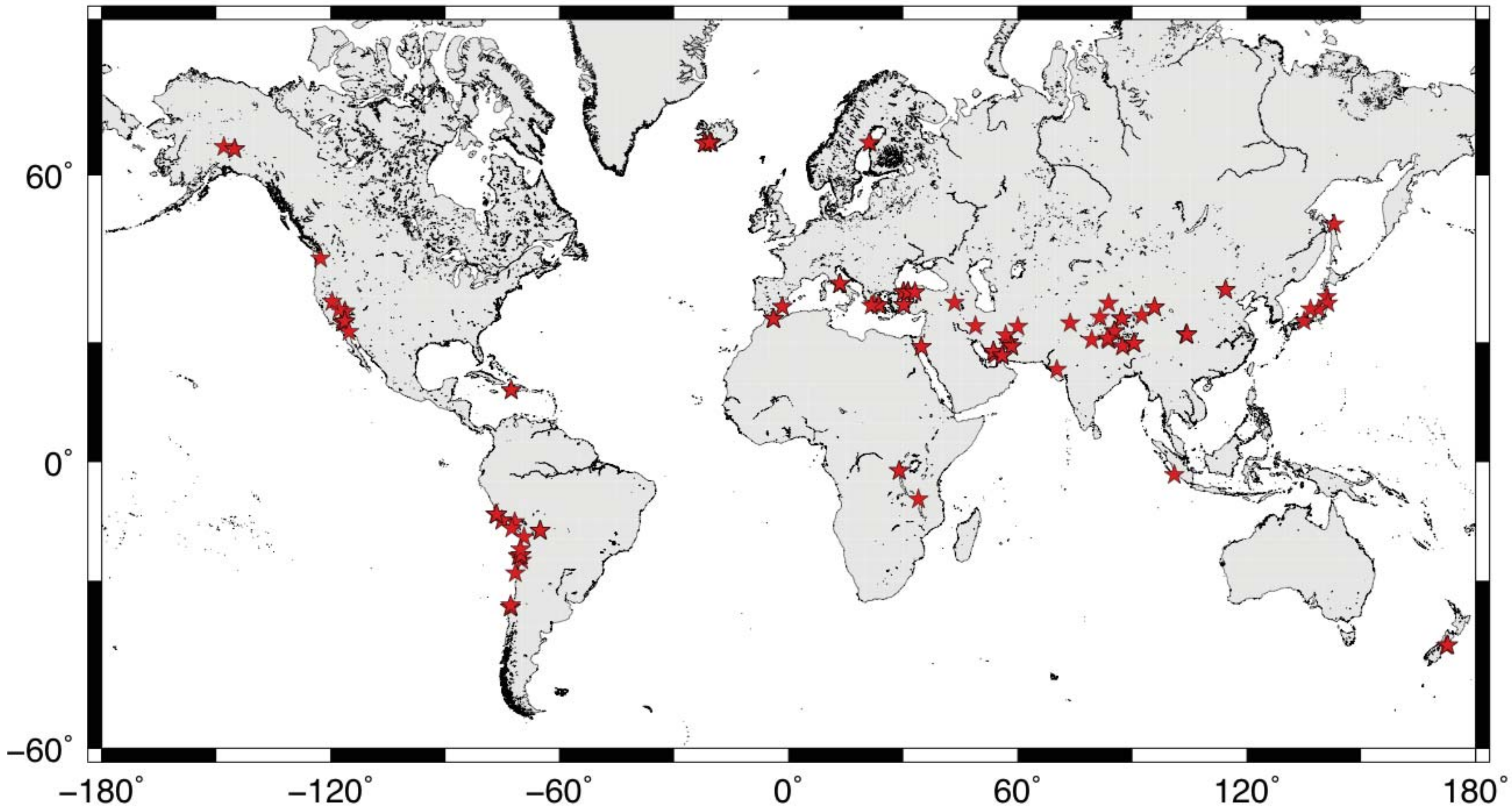
Model from Funning et al. (2005)
Weston, Ferreira, Funning (2011)

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

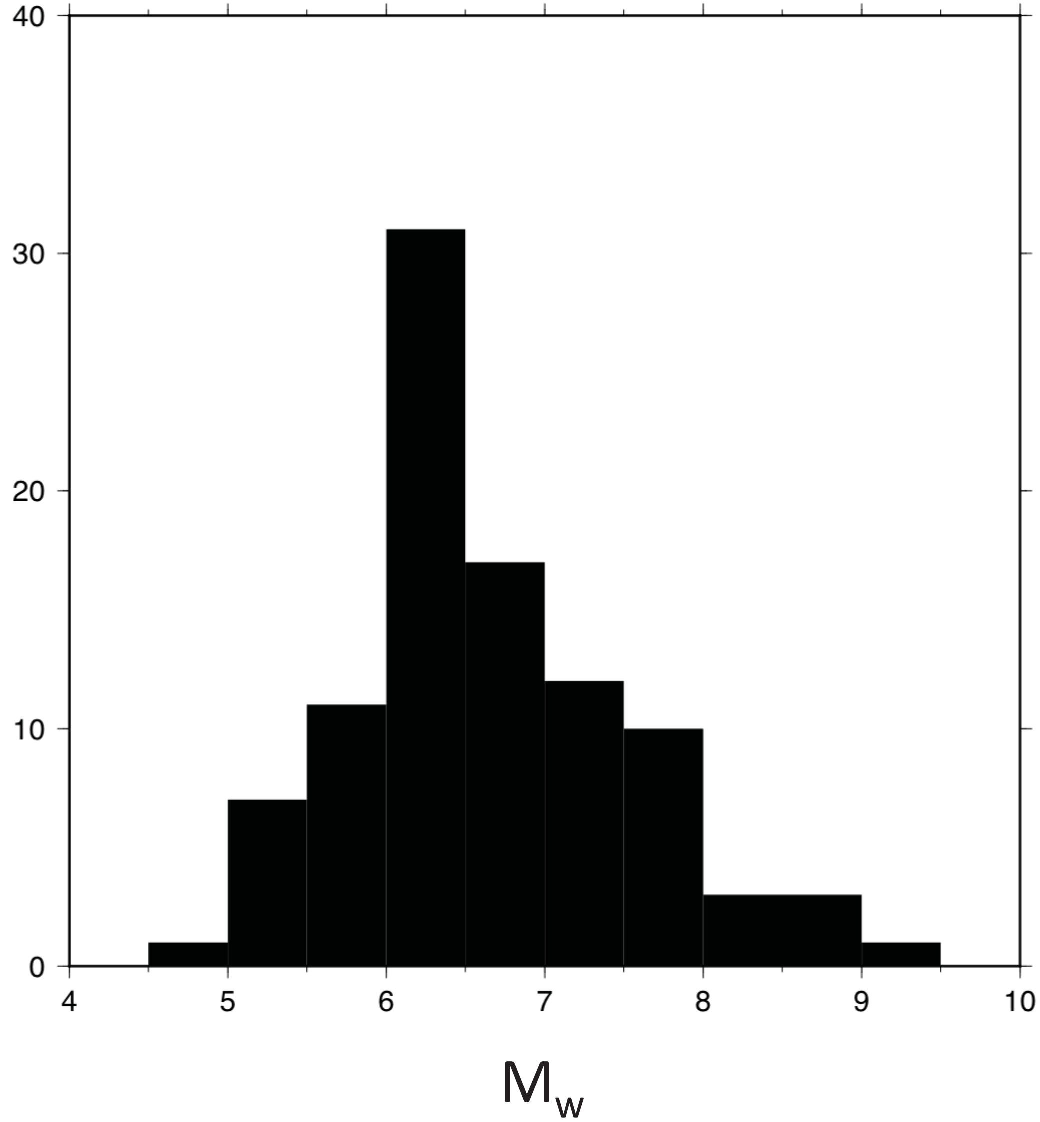
Date	Location	M_0 ($\times 10^{18}$ N m)	Lat (deg)	Long (deg)	Depth (km)	Strike (deg)	Dip (deg)	Rake (deg)	Type	Data	Reference
24.02.04	Al Hoceima, Morocco	6.20	35.14	356.01	**10.05**	295.4 ± 1.1	87.4 ± 1.5	−179.2	ss	I	*Biggs et al.* [2006]
24.02.04	Al Hoceima, Morocco (DS)	7.40	35.14	356.00	8.80	**295.0**	**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]

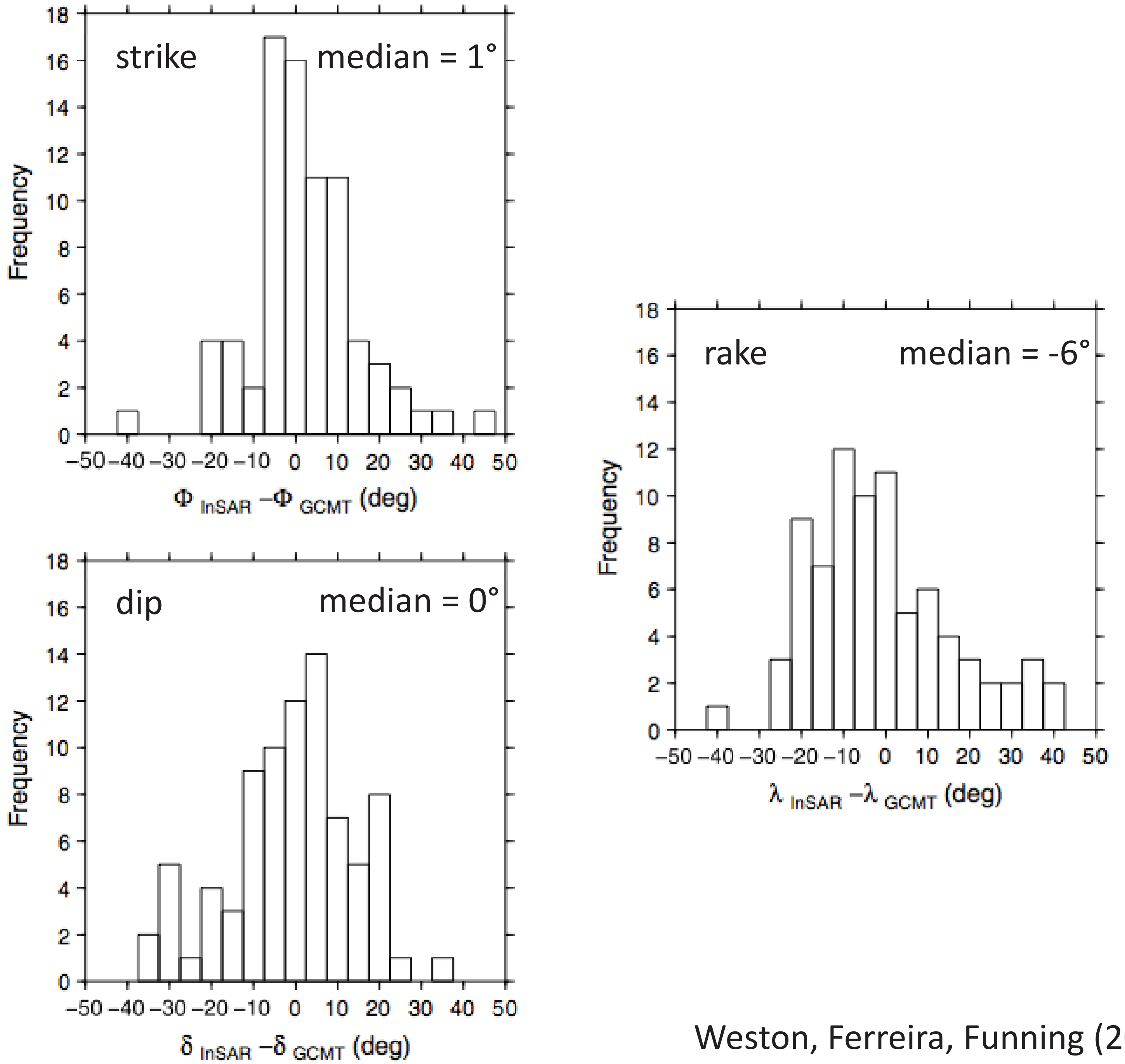
Weston, Ferreira, Funning (2011)

101 events, 206 models



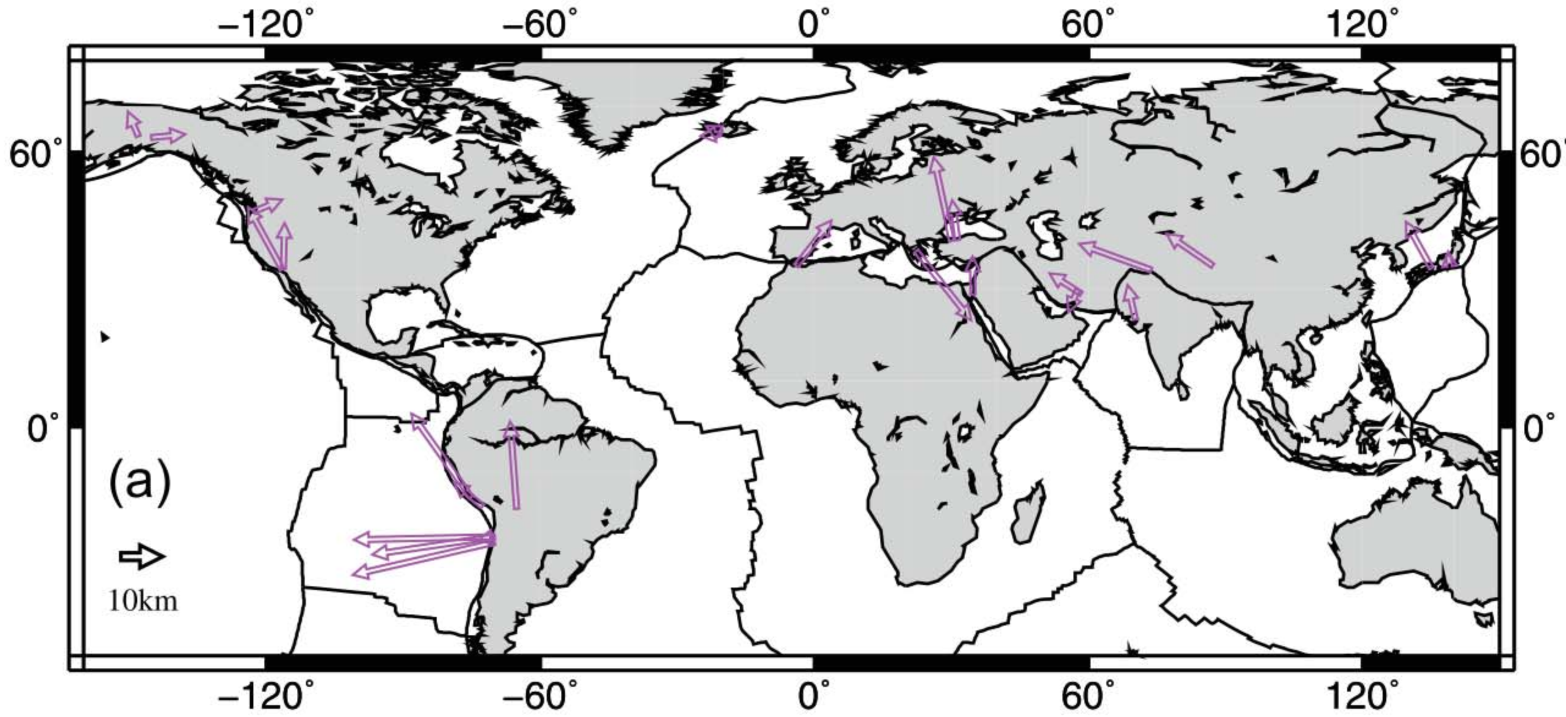
101 events, 206 models



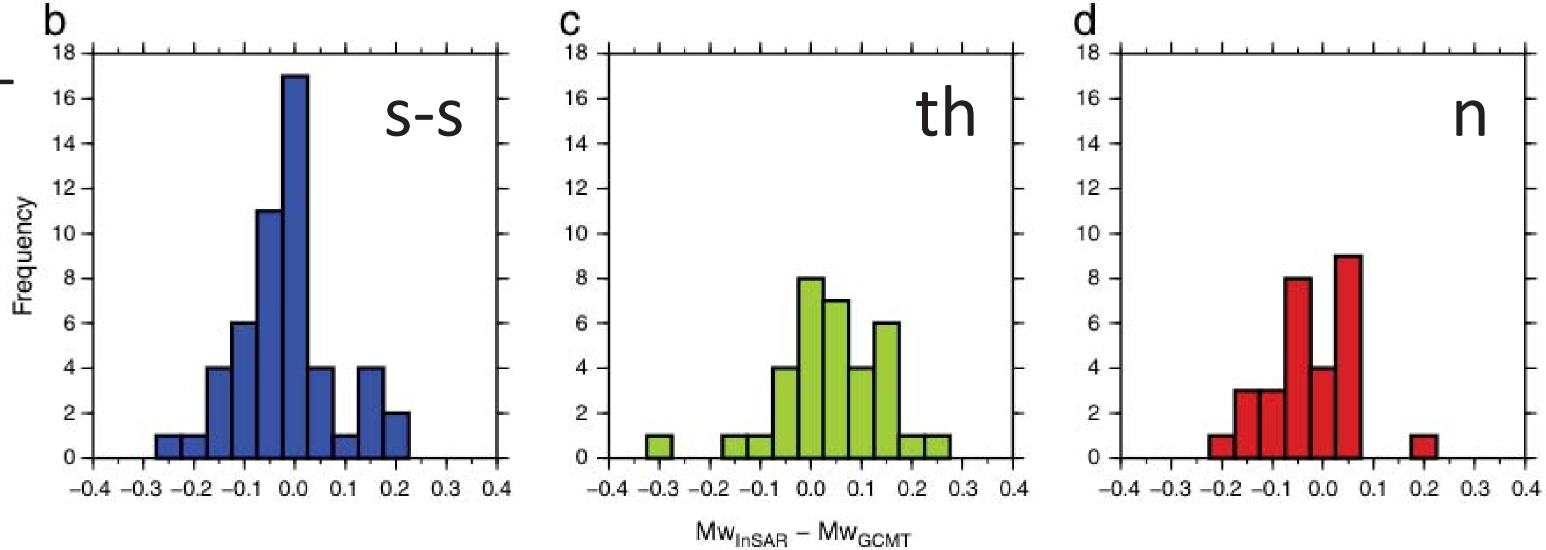


Weston, Ferreira, Funning (2012)

ICMT => GCMT

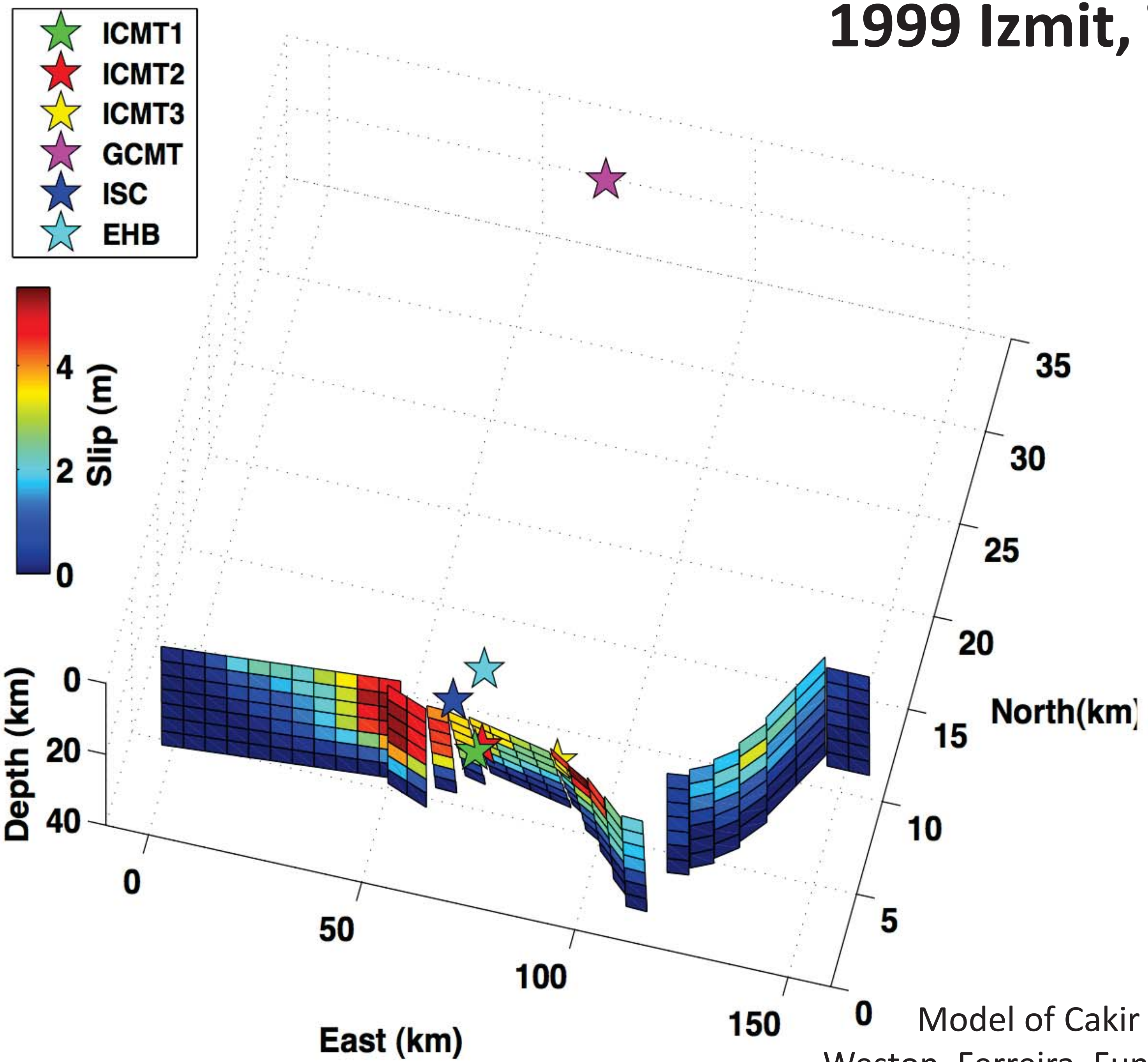


M_w (ICMT) – M_w (GCMT)



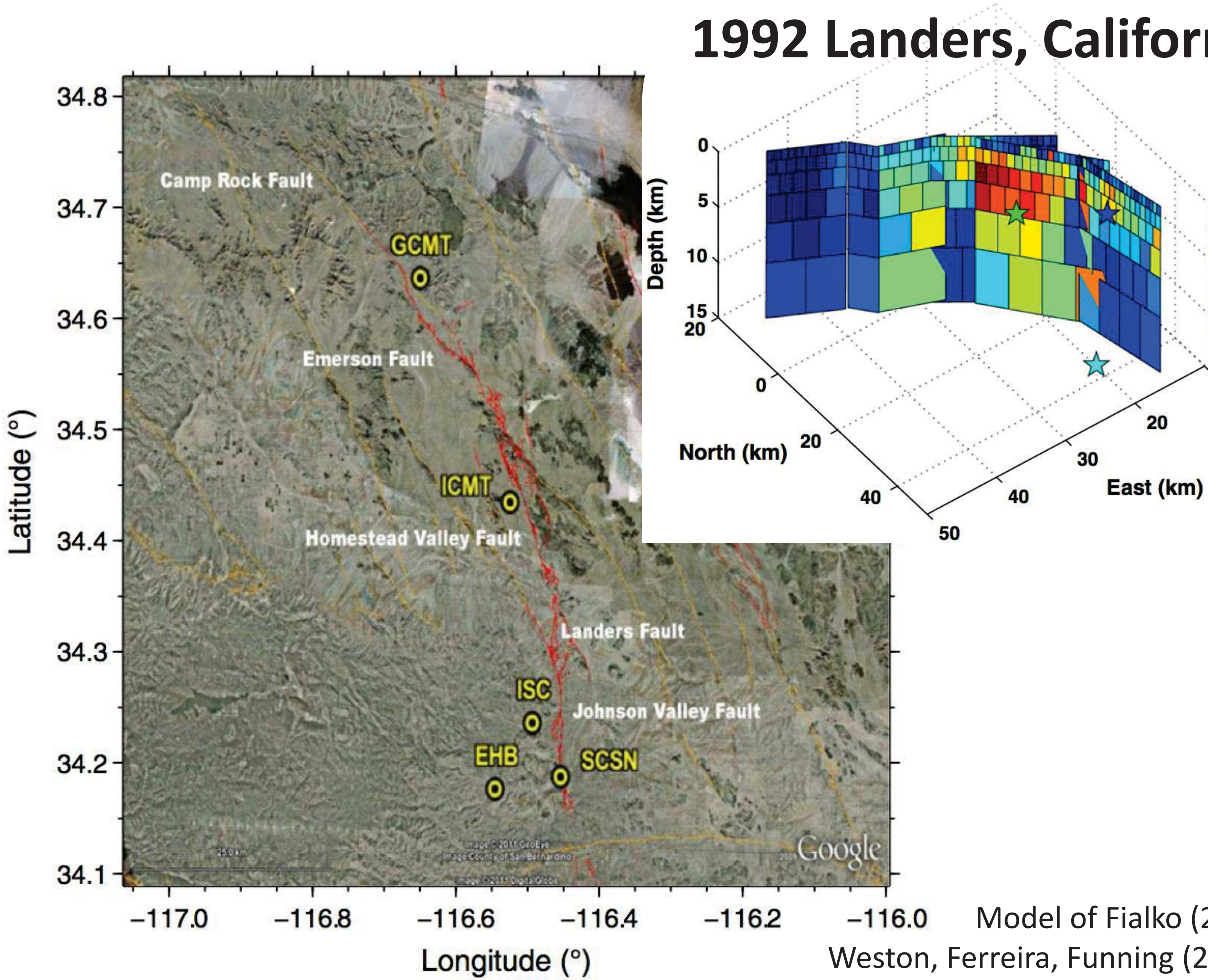
Weston, Ferreira, Funning (2012)

1999 Izmit, Turkey



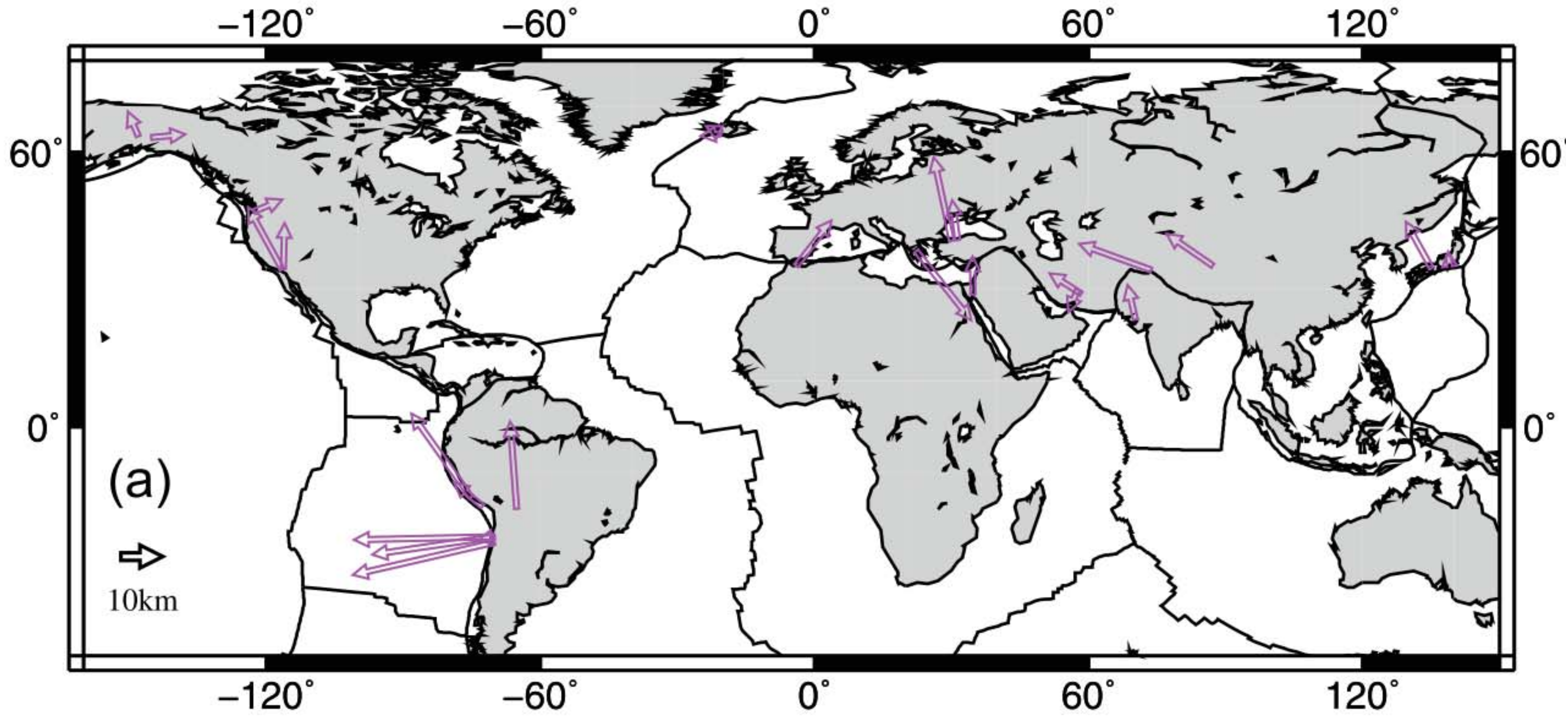
Model of Cakir et al. (2003)
Weston, Ferreira, Funning (2012)

1992 Landers, California

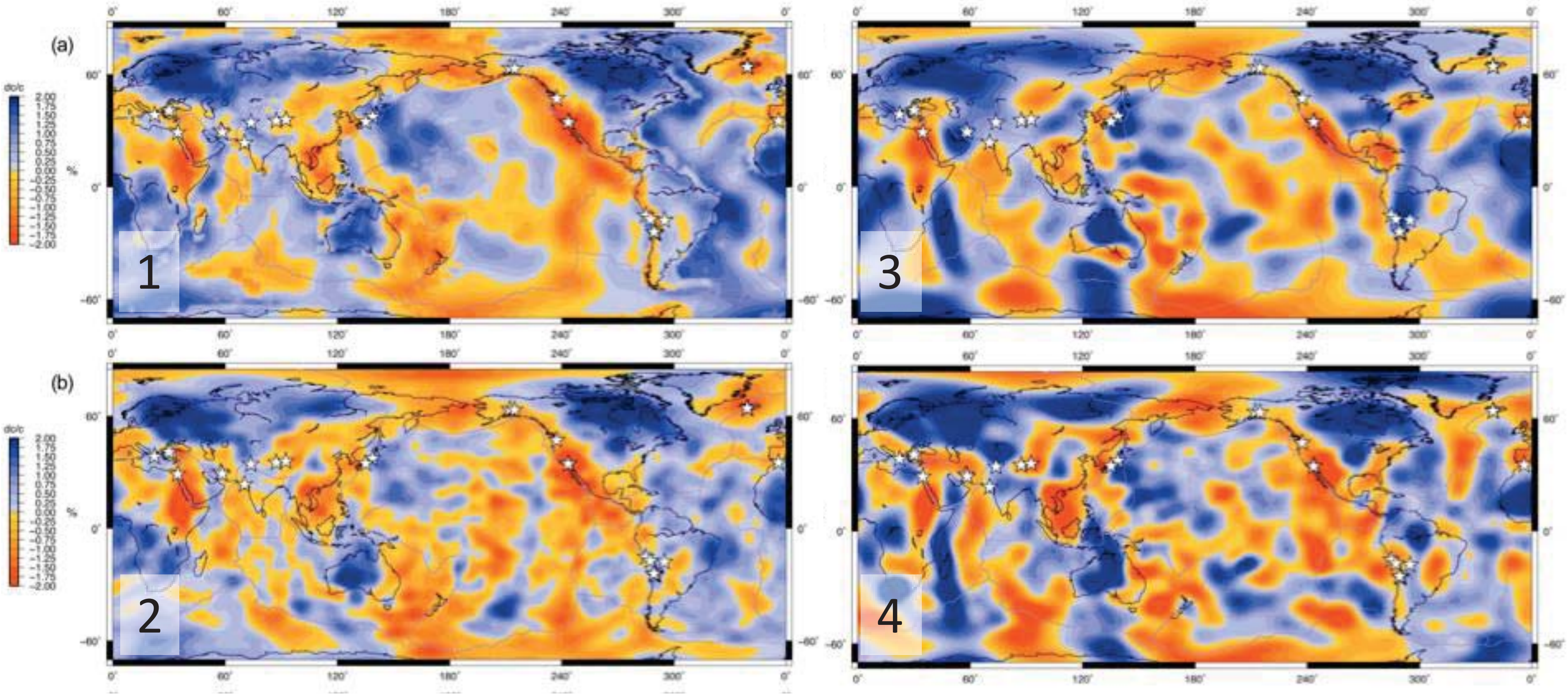


Model of Fialko (2004)
Weston, Ferreira, Funning (2012)

GCMT
=> ICMT

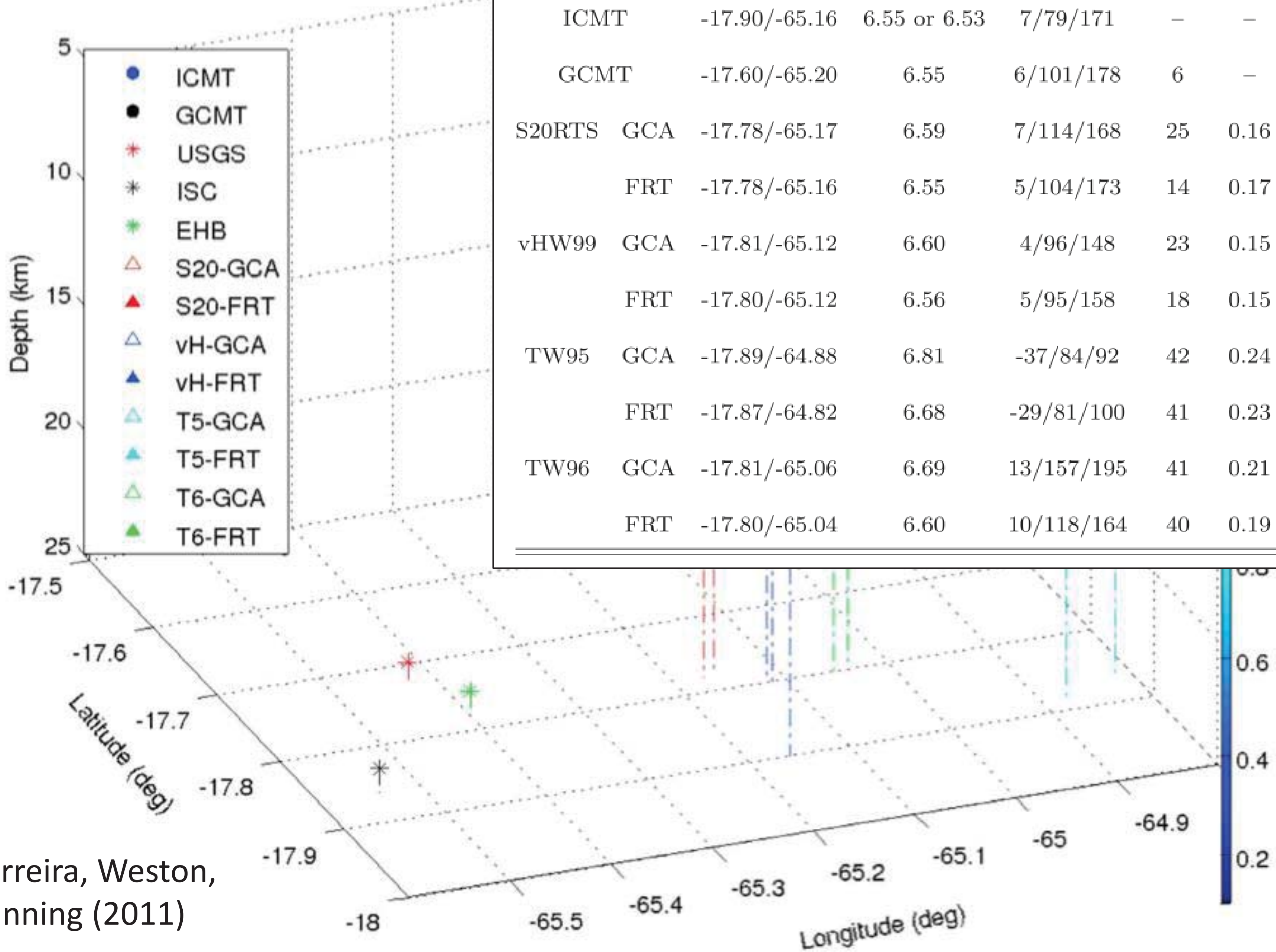


Long-period surface wave velocity anomalies



Models: 1. S20RTS – Ritsema et al. (1999)
2. van Heijst and Woodhouse (1999)
3. Trampert and Woodhouse (1995)
4. Trampert and Woodhouse (1996)

Anomalies with respect to PREM

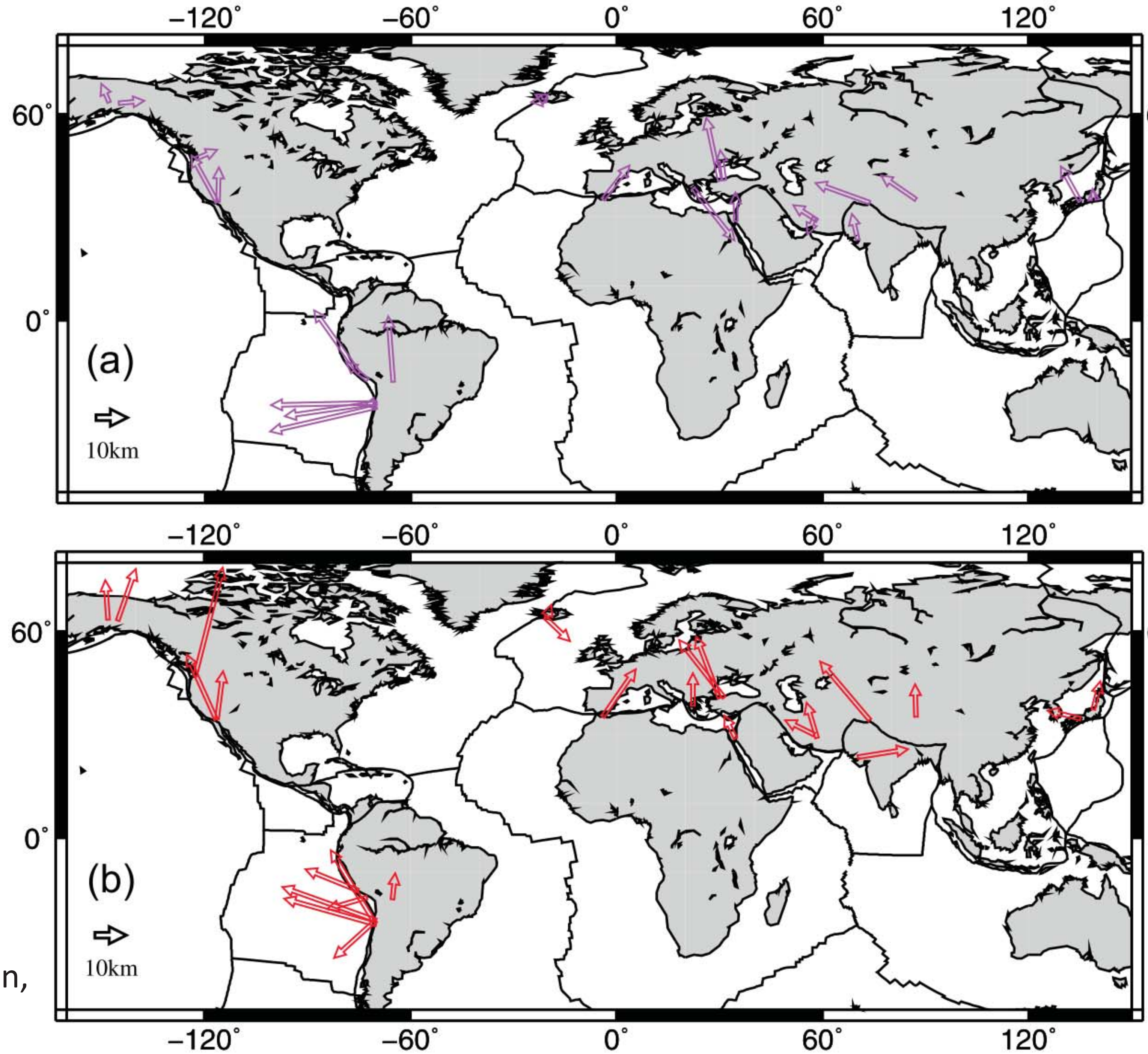


Model	Th.	Lat/Lon (°)	M_w	$\psi/\delta/\lambda$	ϵ (%)	m^2	BB
ICMT		-17.90/-65.16	6.55 or 6.53	7/79/171	–	–	
GCMT		-17.60/-65.20	6.55	6/101/178	6	–	
S20RTS	GCA	-17.78/-65.17	6.59	7/114/168	25	0.16	
	FRT	-17.78/-65.16	6.55	5/104/173	14	0.17	
vHW99	GCA	-17.81/-65.12	6.60	4/96/148	23	0.15	
	FRT	-17.80/-65.12	6.56	5/95/158	18	0.15	
TW95	GCA	-17.89/-64.88	6.81	-37/84/92	42	0.24	
	FRT	-17.87/-64.82	6.68	-29/81/100	41	0.23	
TW96	GCA	-17.81/-65.06	6.69	13/157/195	41	0.21	
	FRT	-17.80/-65.04	6.60	10/118/164	40	0.19	

Ferreira, Weston, Funning (2011)

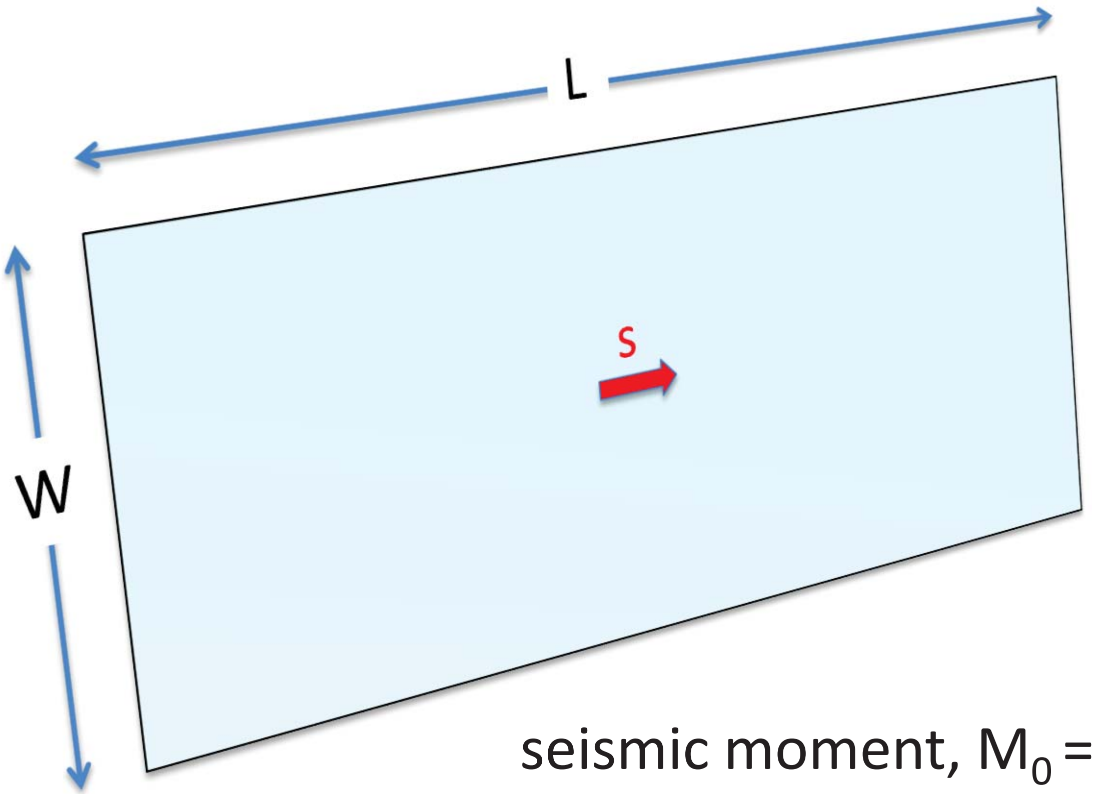
GCMT
=> ICMT

S20RTS +
CRUST2.0
=> ICMT



Ferreira, Weston,
Funning (2011)

What controls earthquake size?



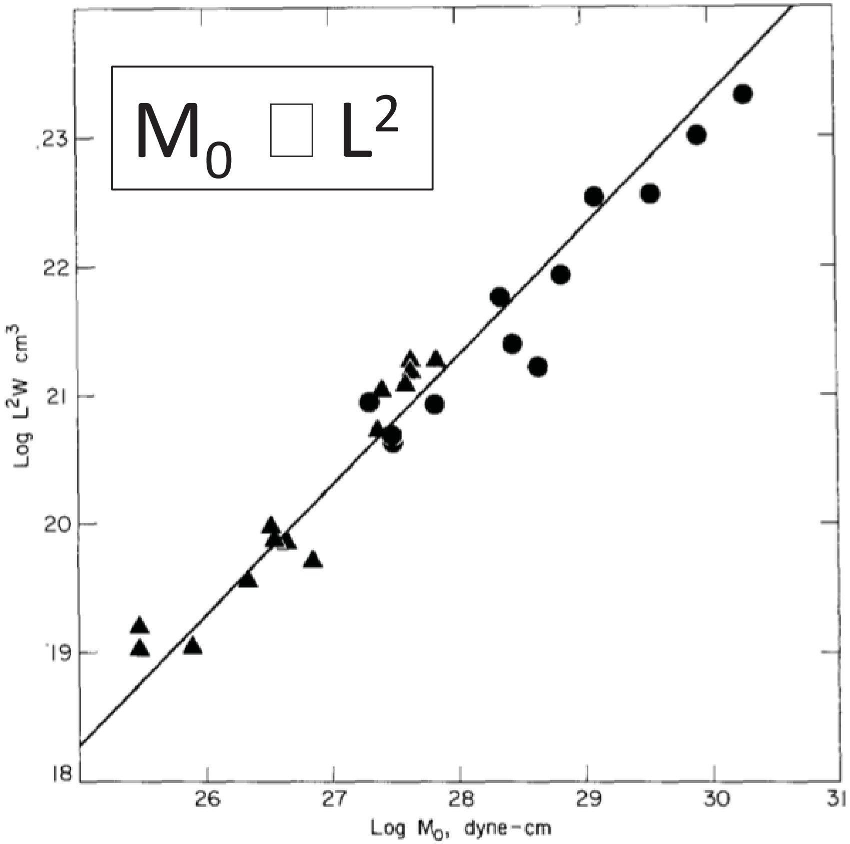
rigidity: μ

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

M_0 □ L ? M_0 □ L^2 ?

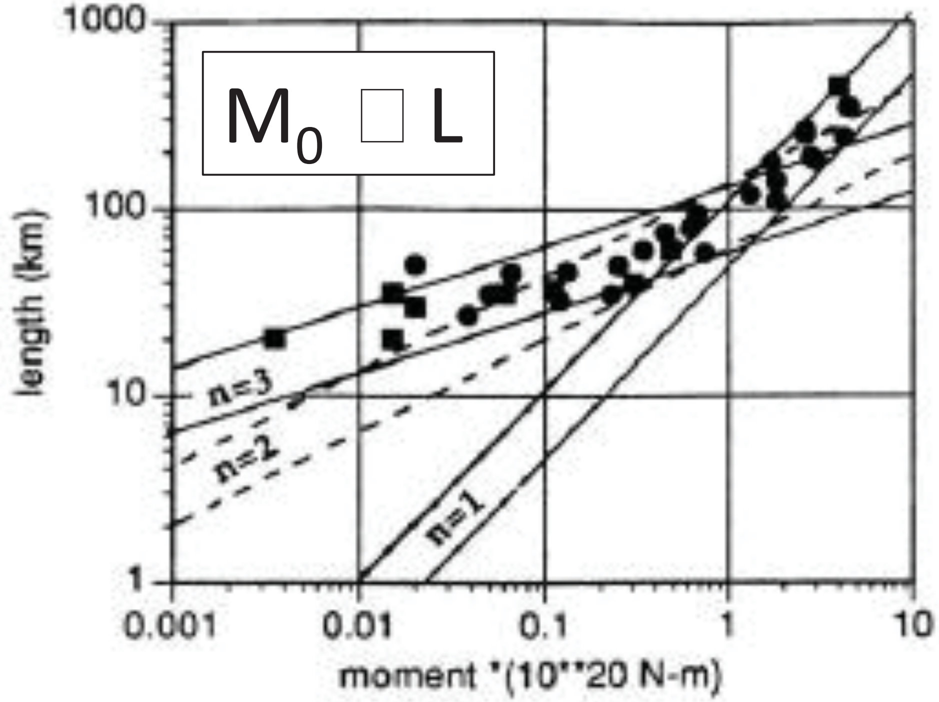
compare $\log M_0$ with $\log L$

‘L model’



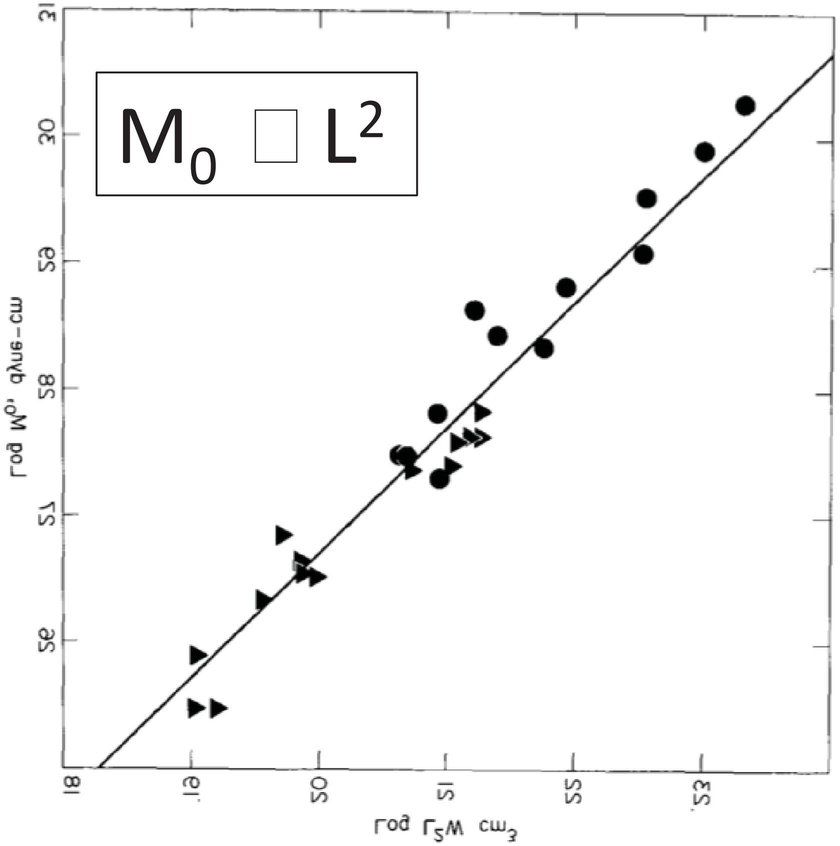
Scholz (1982)

‘W model’



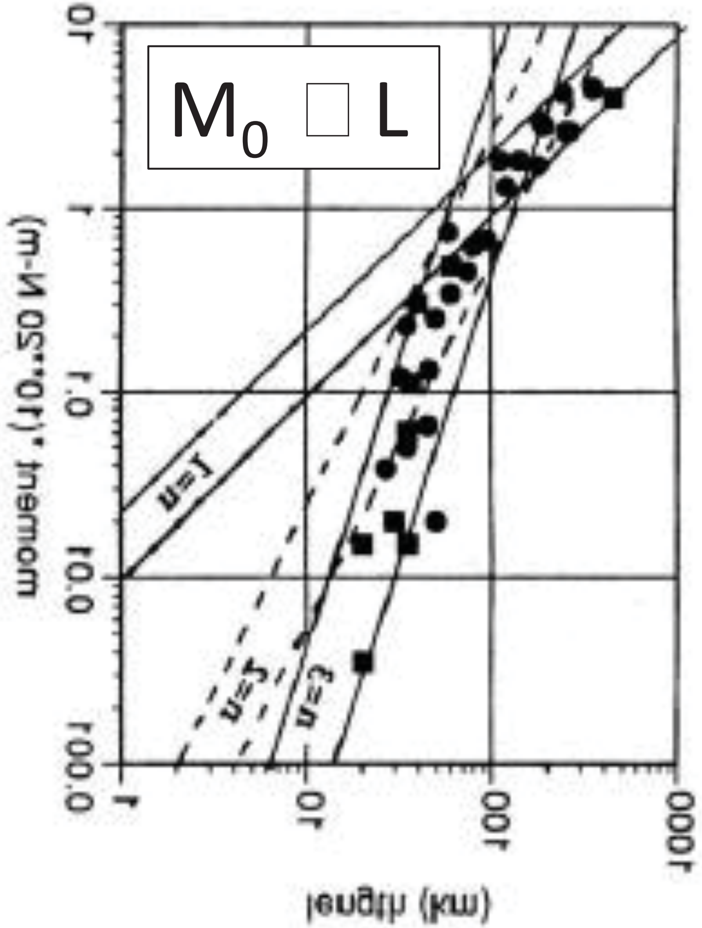
Romanowicz (1992)

‘L model’

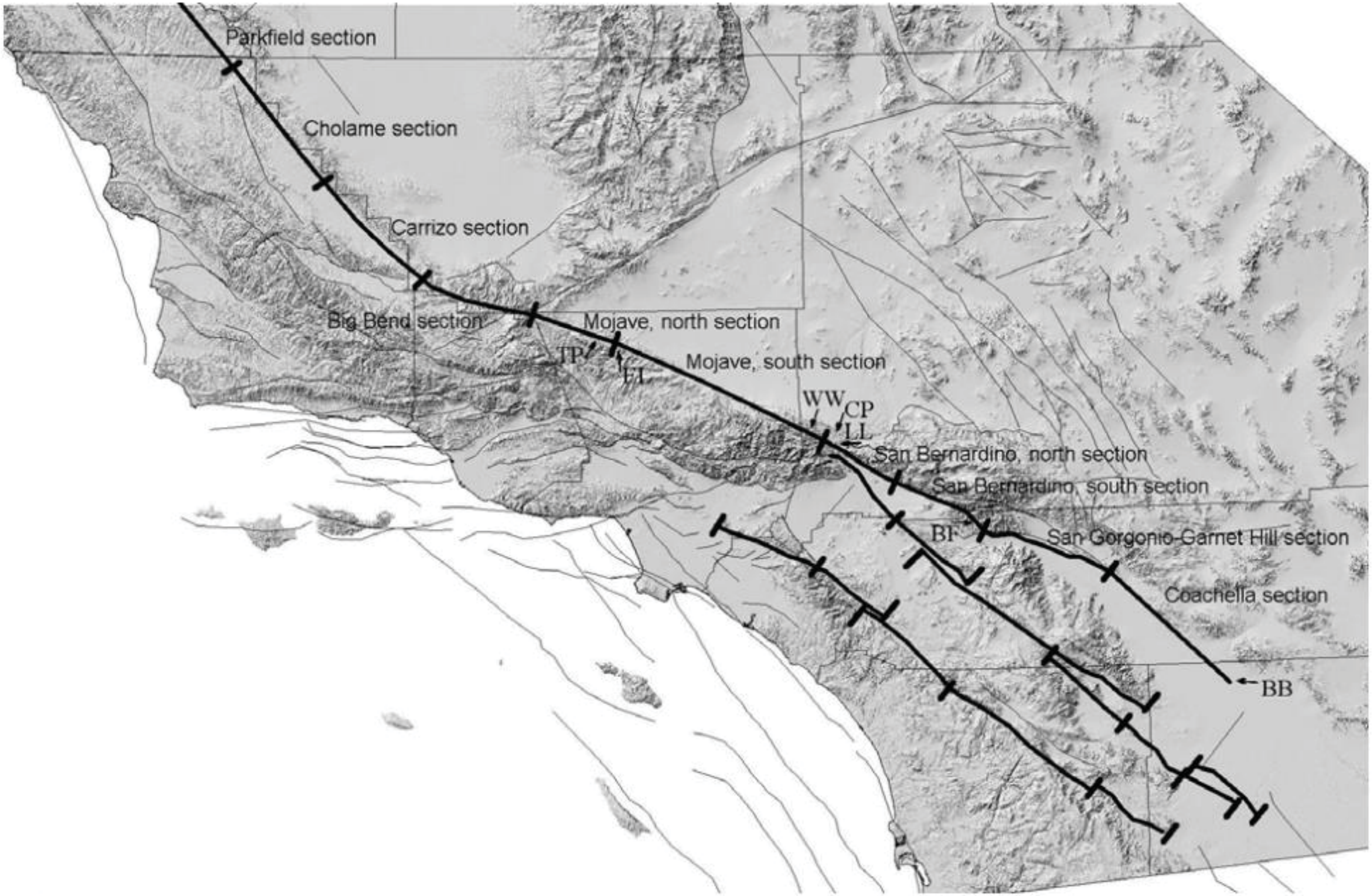


Scholz (1982)

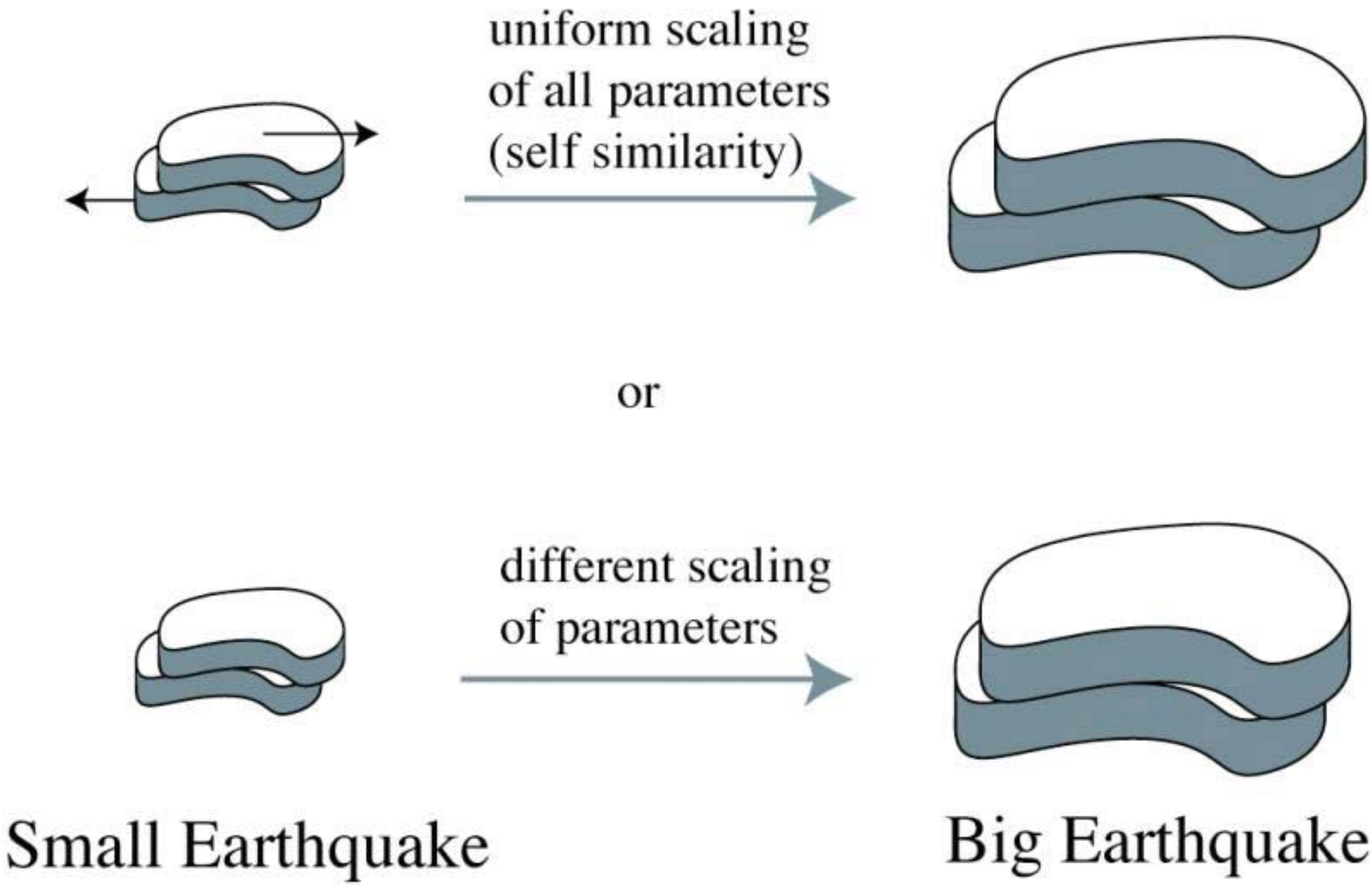
‘W model’



Romanowicz (1992)

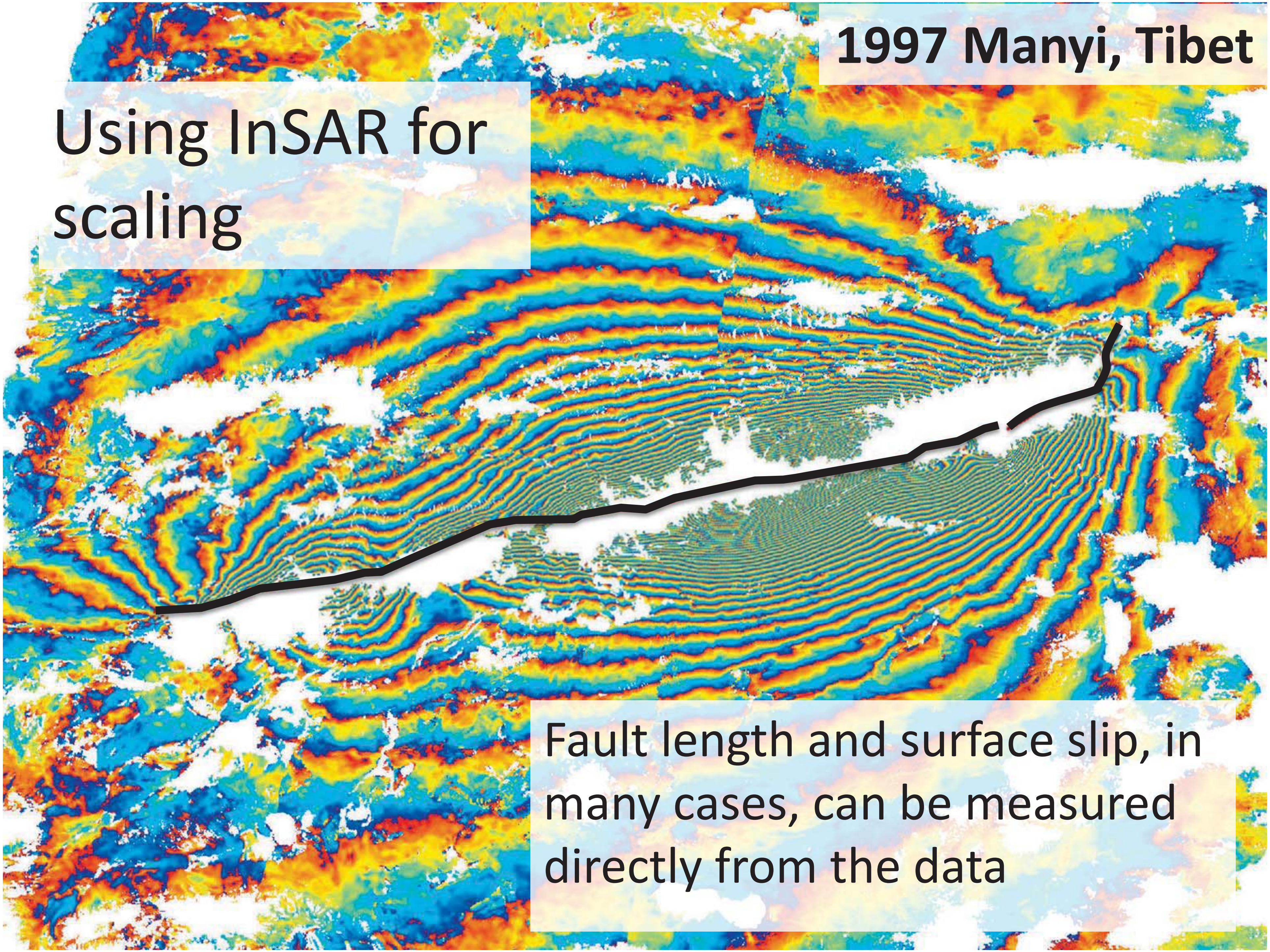


Working Group on California Earthquake Probabilities, 2008

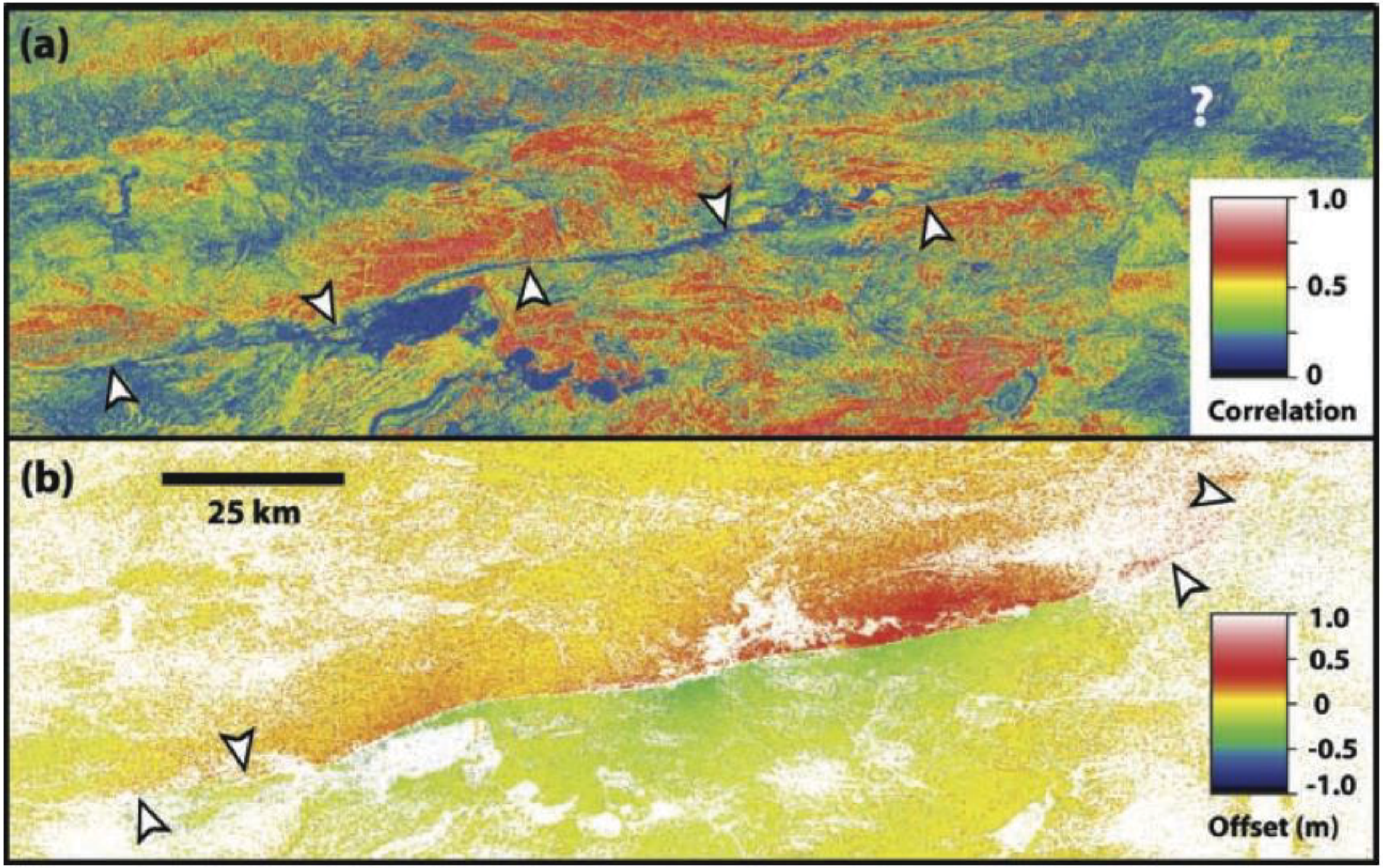


Peter Shearer

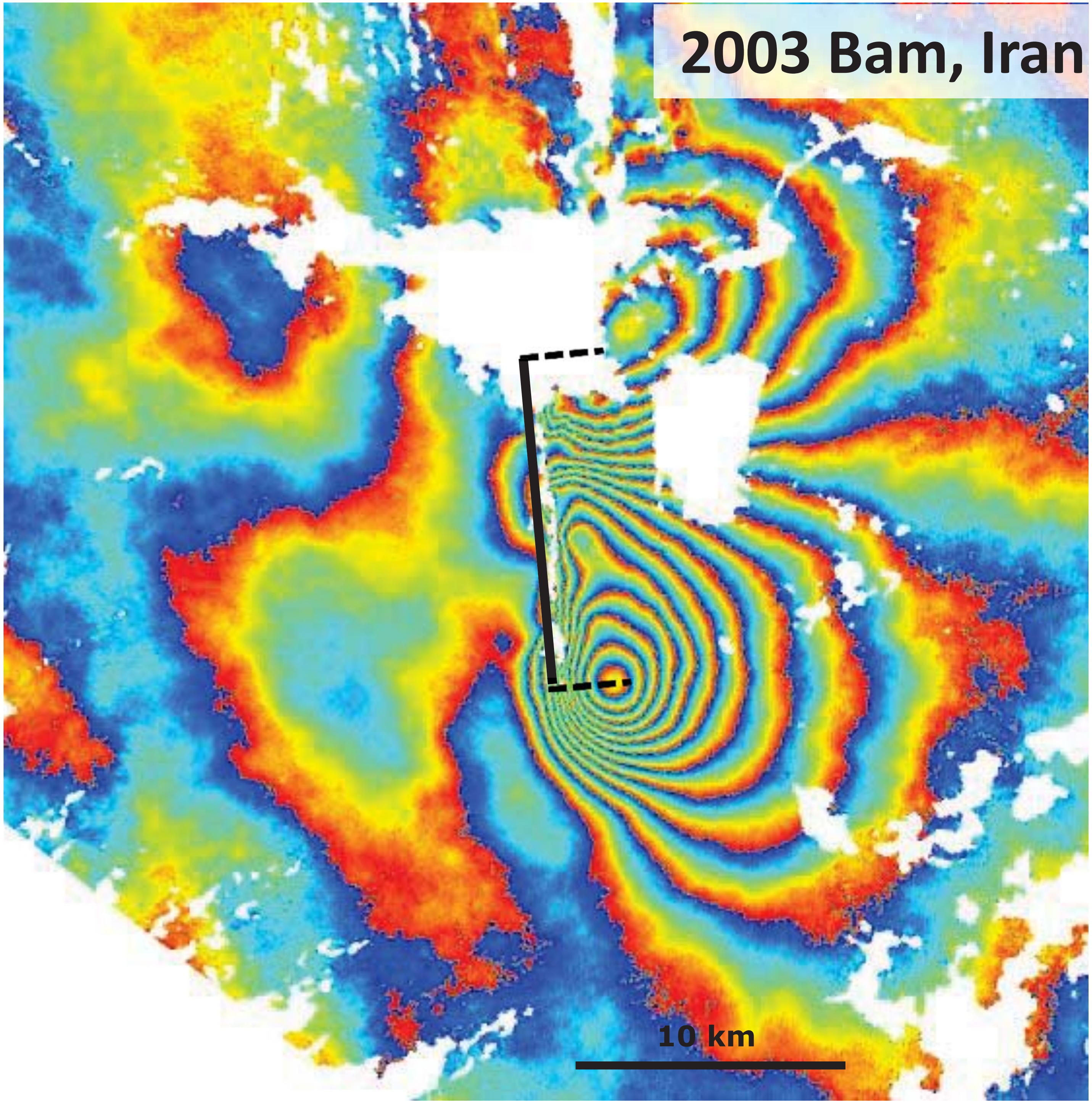
Using InSAR for scaling



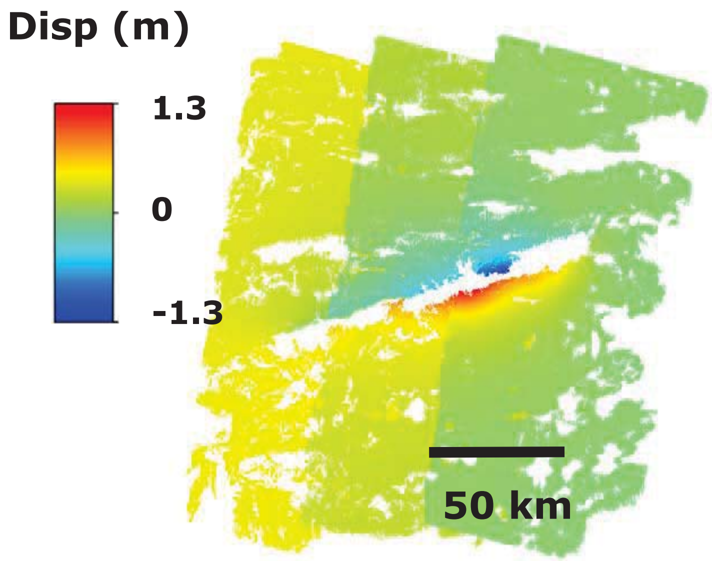
Fault length and surface slip, in many cases, can be measured directly from the data



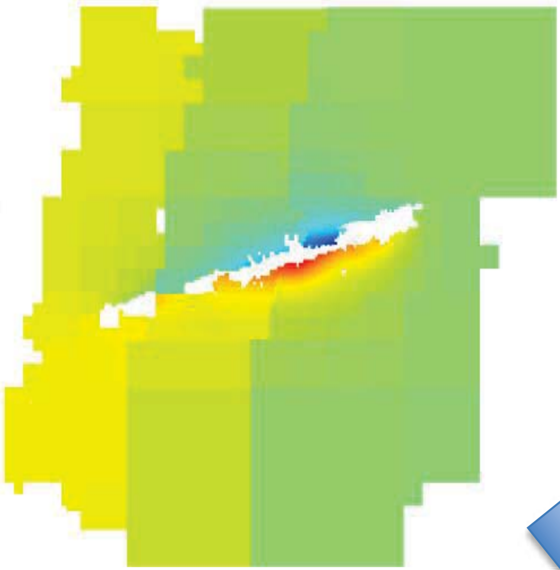
Funning et al. (2007)



Funning et al. (2005)

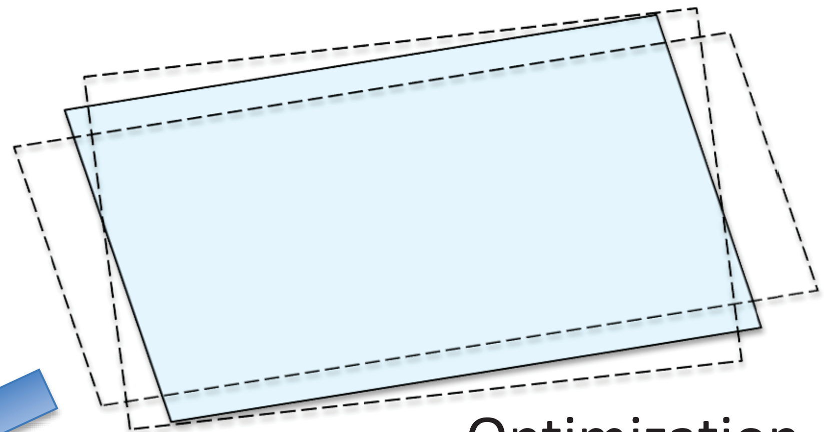


Unwrapped data



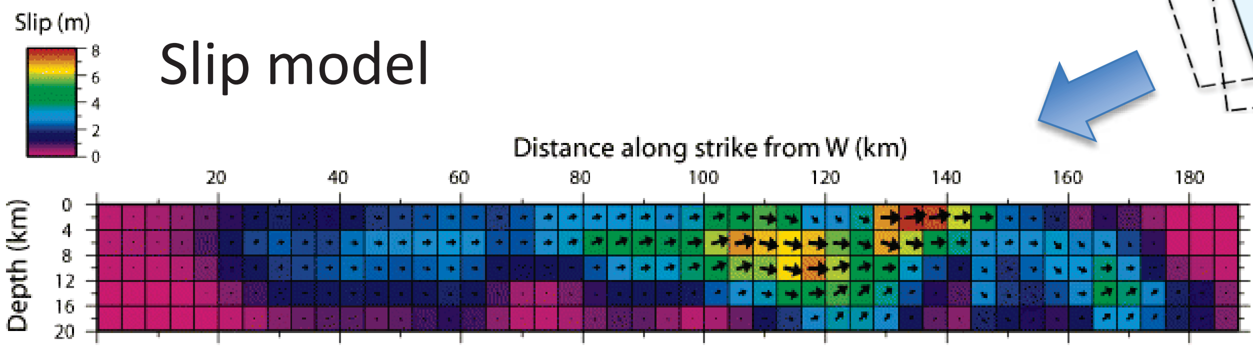
Downsampling

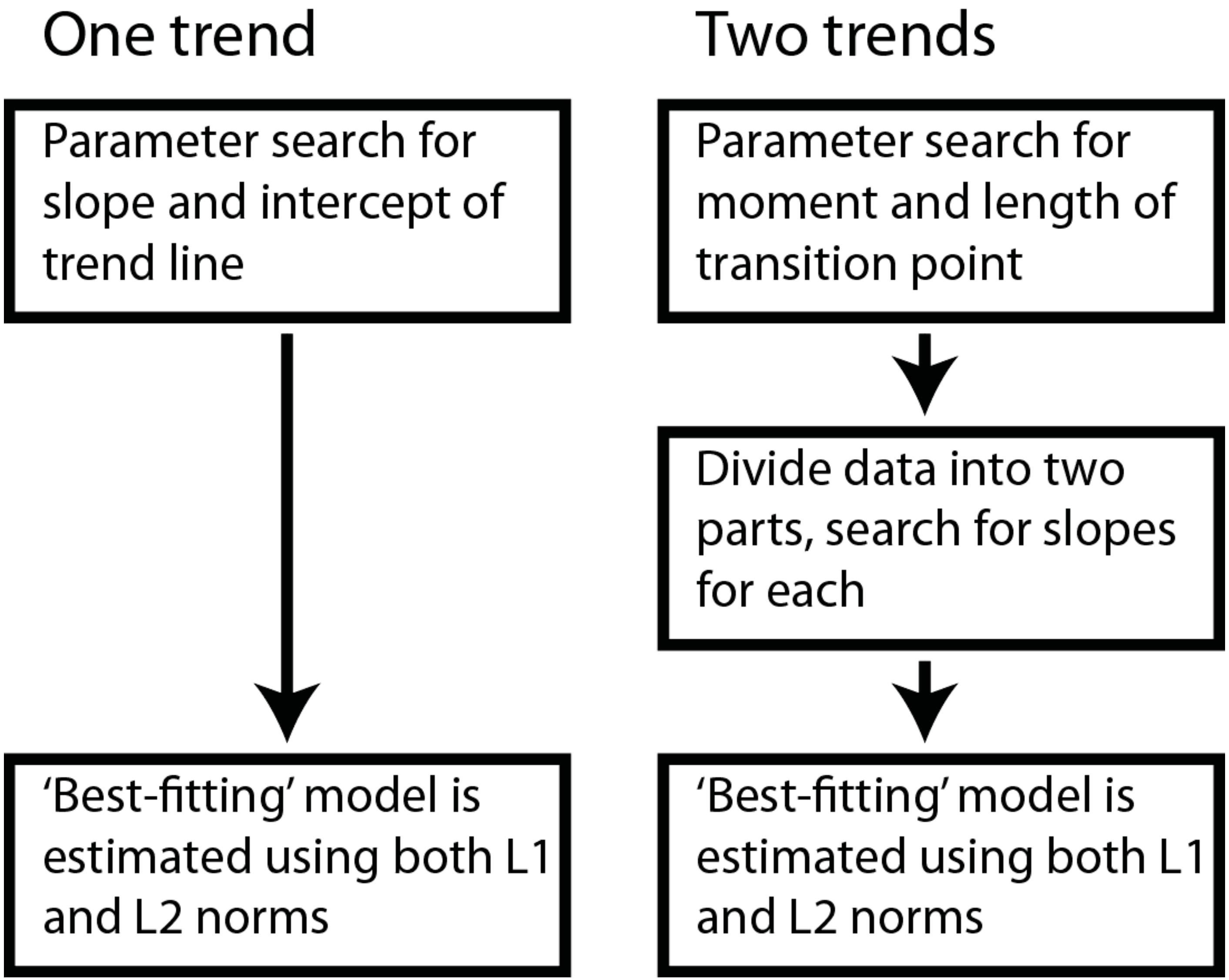
Moment, width, average slip are model-derived

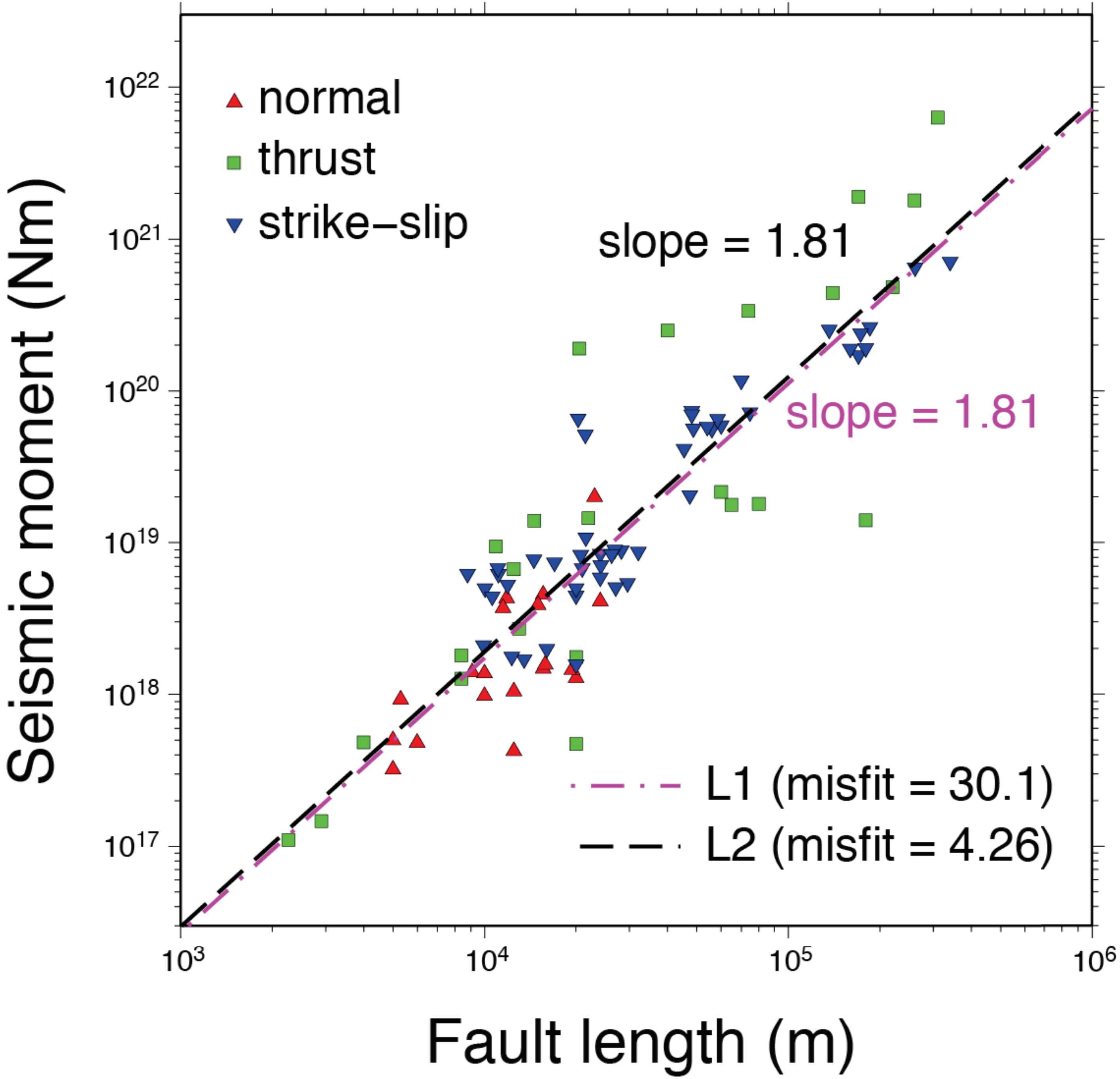


Optimization

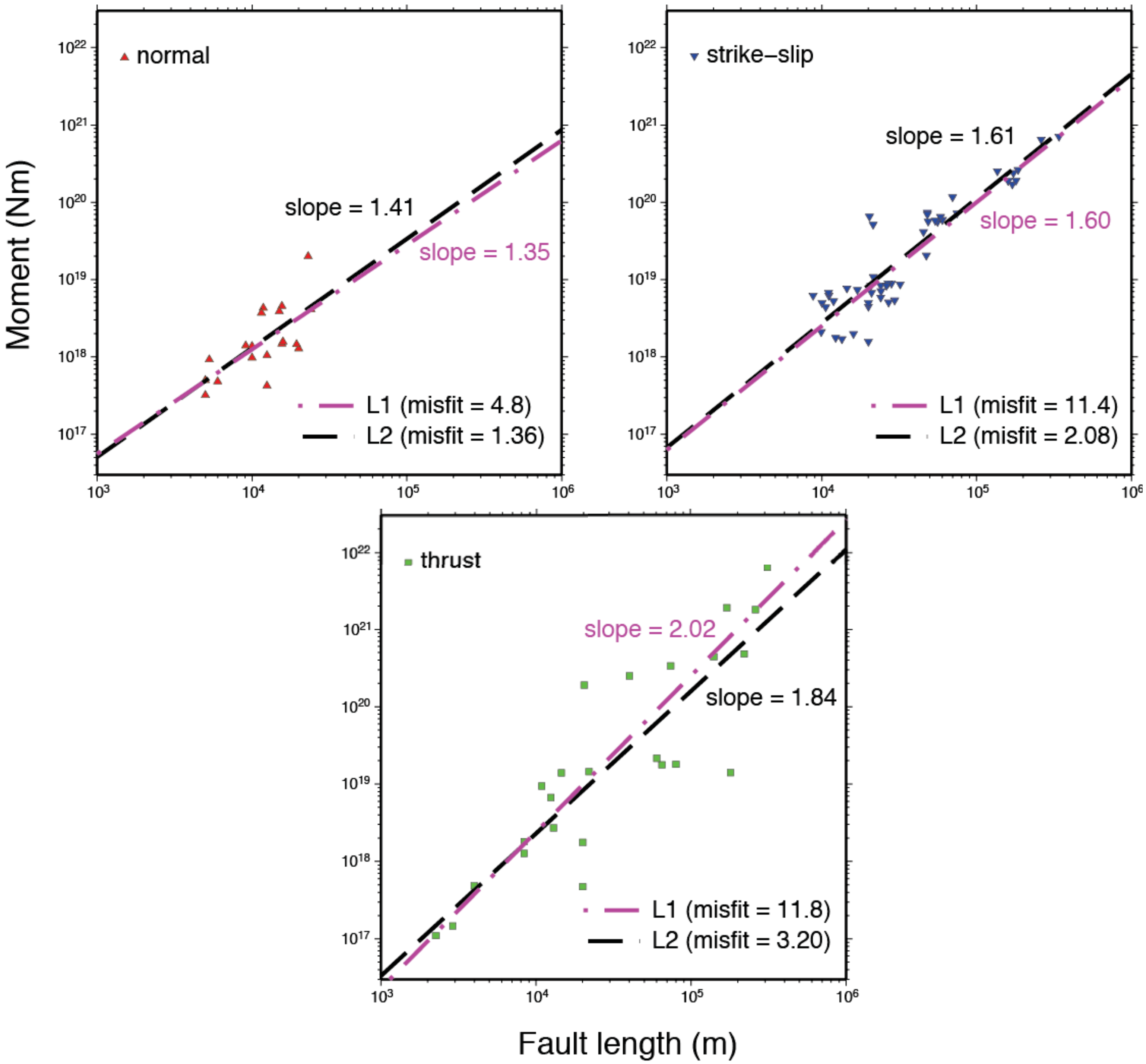
Slip model



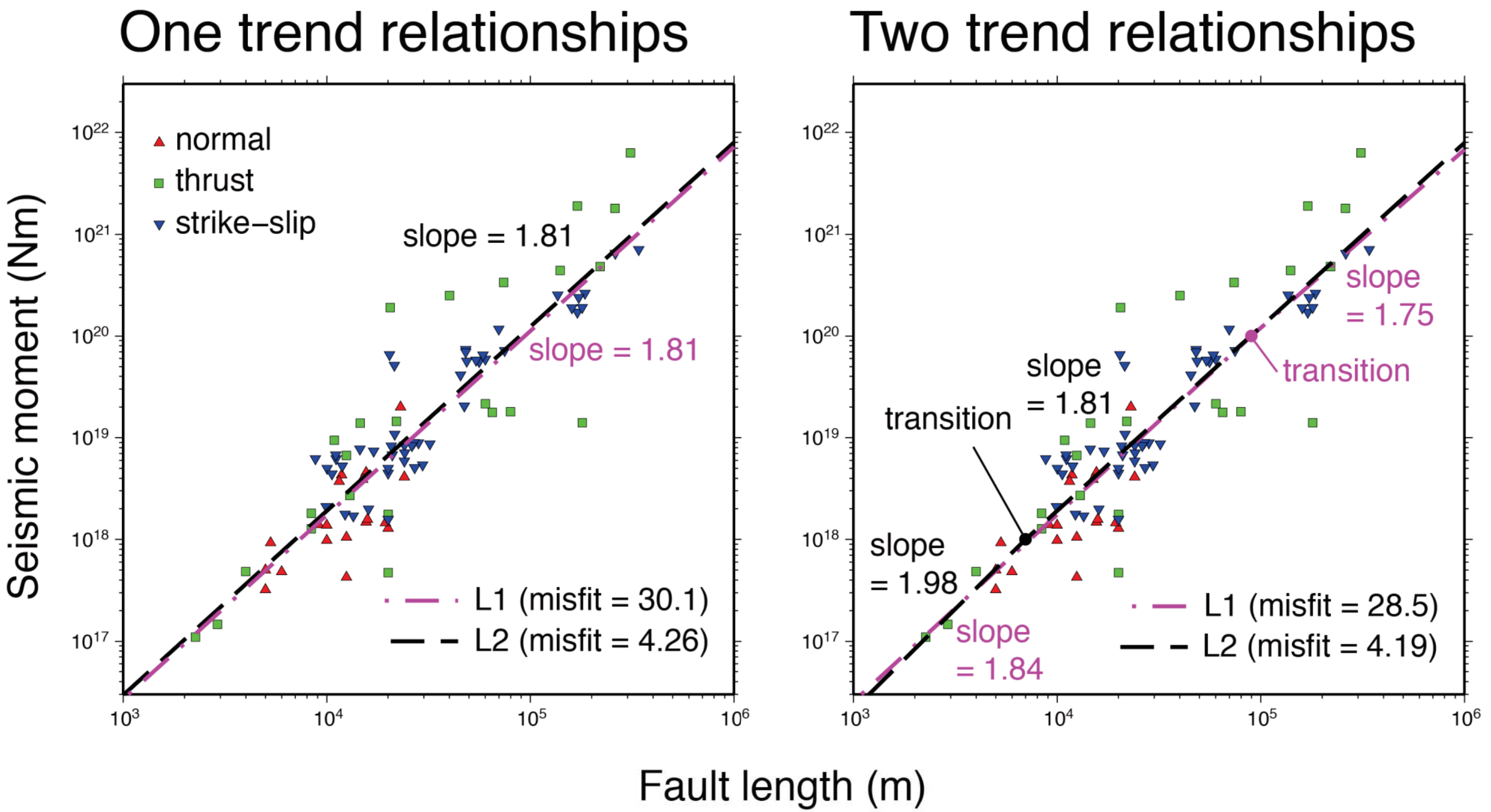

One trend
Two trends
Parameter search for slope and intercept of trend line
Parameter search for moment and length of transition point
Divide data into two parts, search for slopes for each
'Best-fitting' model is estimated using both L1 and L2 norms
'Best-fitting' model is estimated using both L1 and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

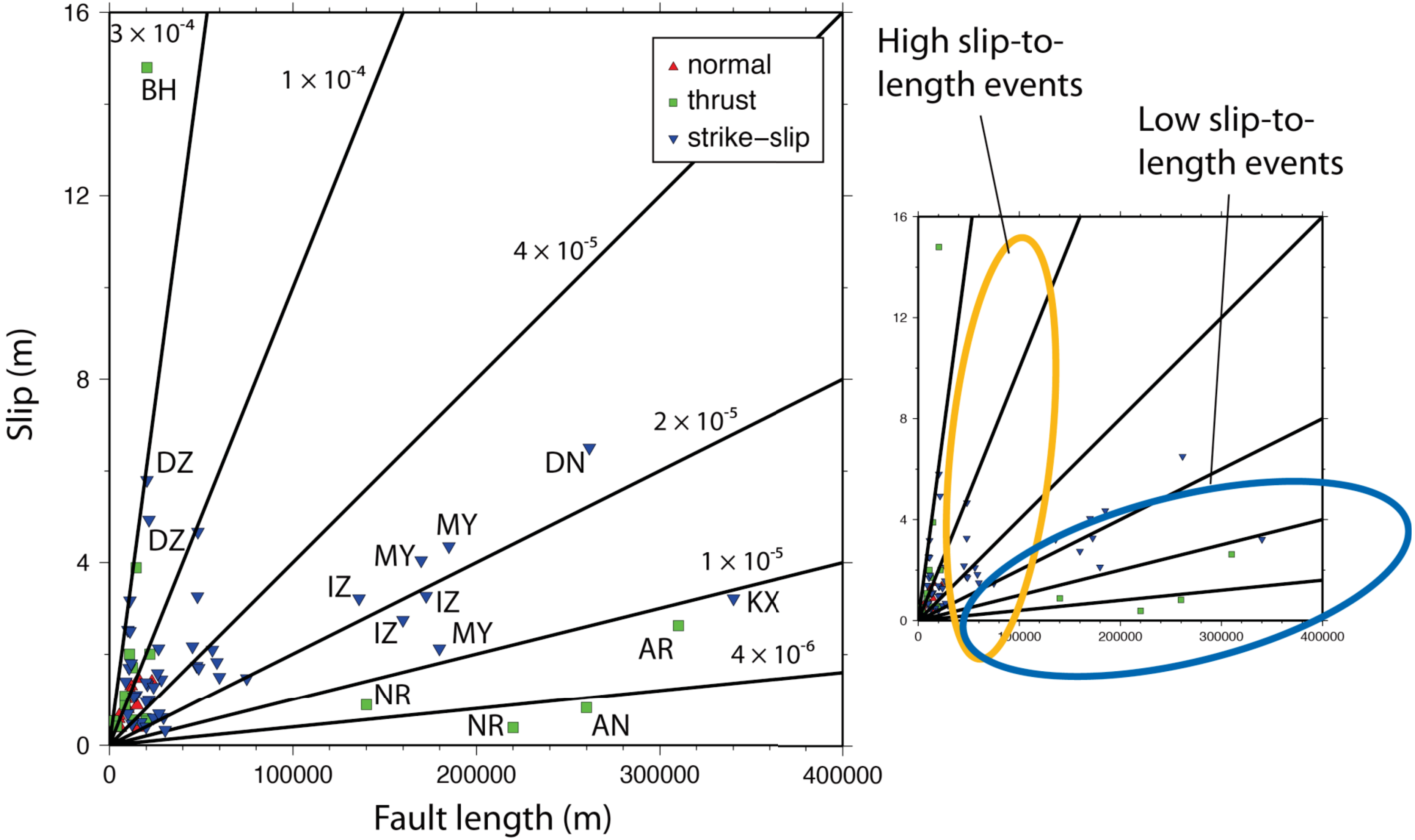


normal
thrust
strike–slip
slope = 1.81
slope = 1.81
L1 (misfit = 30.1)
L2 (misfit = 4.26)
Seismic moment (Nm)
Fault length (m)
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
10^{22}
10^{3}
10^{4}
10^{5}
10^{6}



Moment (Nm)
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)
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
= 1.75
transition
slope
= 1.81
transition
slope
= 1.98
slope
= 1.84
L1 (misfit = 28.5)
L2 (misfit = 4.19)



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

Summary of findings

- Global CMTs are mislocated by 20 km on average compared with InSAR
- We evaluate effectiveness of different Earth models; mislocation problem is not yet solved
- Moment-length scaling: $M_0 \quad L^{1.6} – L^2$
  – this is more consistent with ‘L-model’ scaling
- 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?