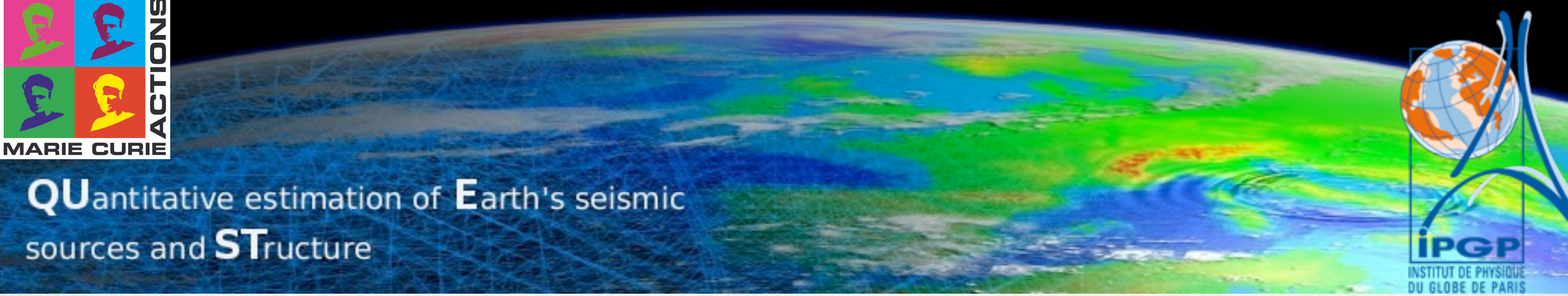


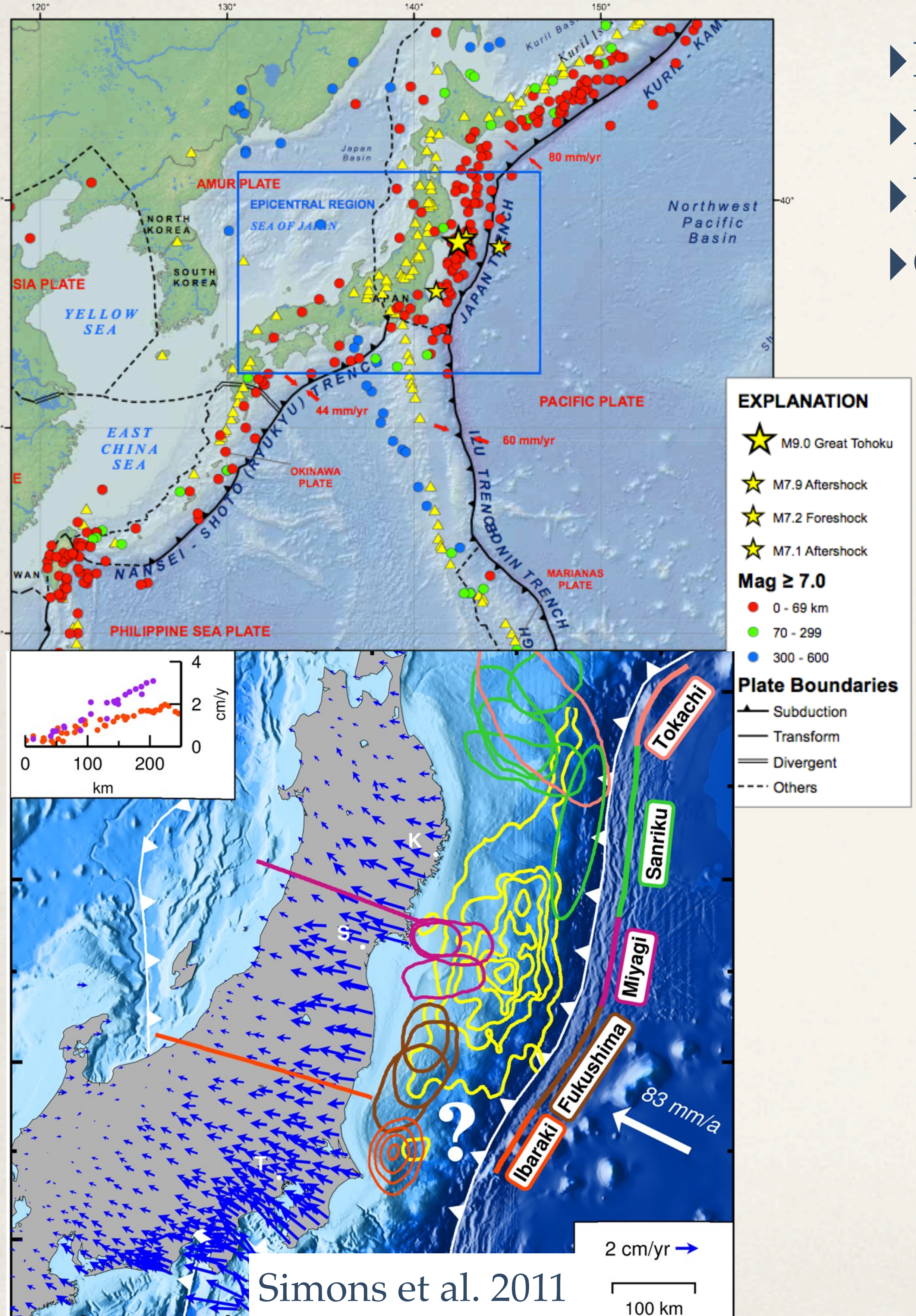
Multi-scale imaging of the large subduction earthquakes combining back projection and kinematic modelling

V. Dionicio, C. Satriano, E. Kiraly, J.-P. Vilotte, and P. Bernard

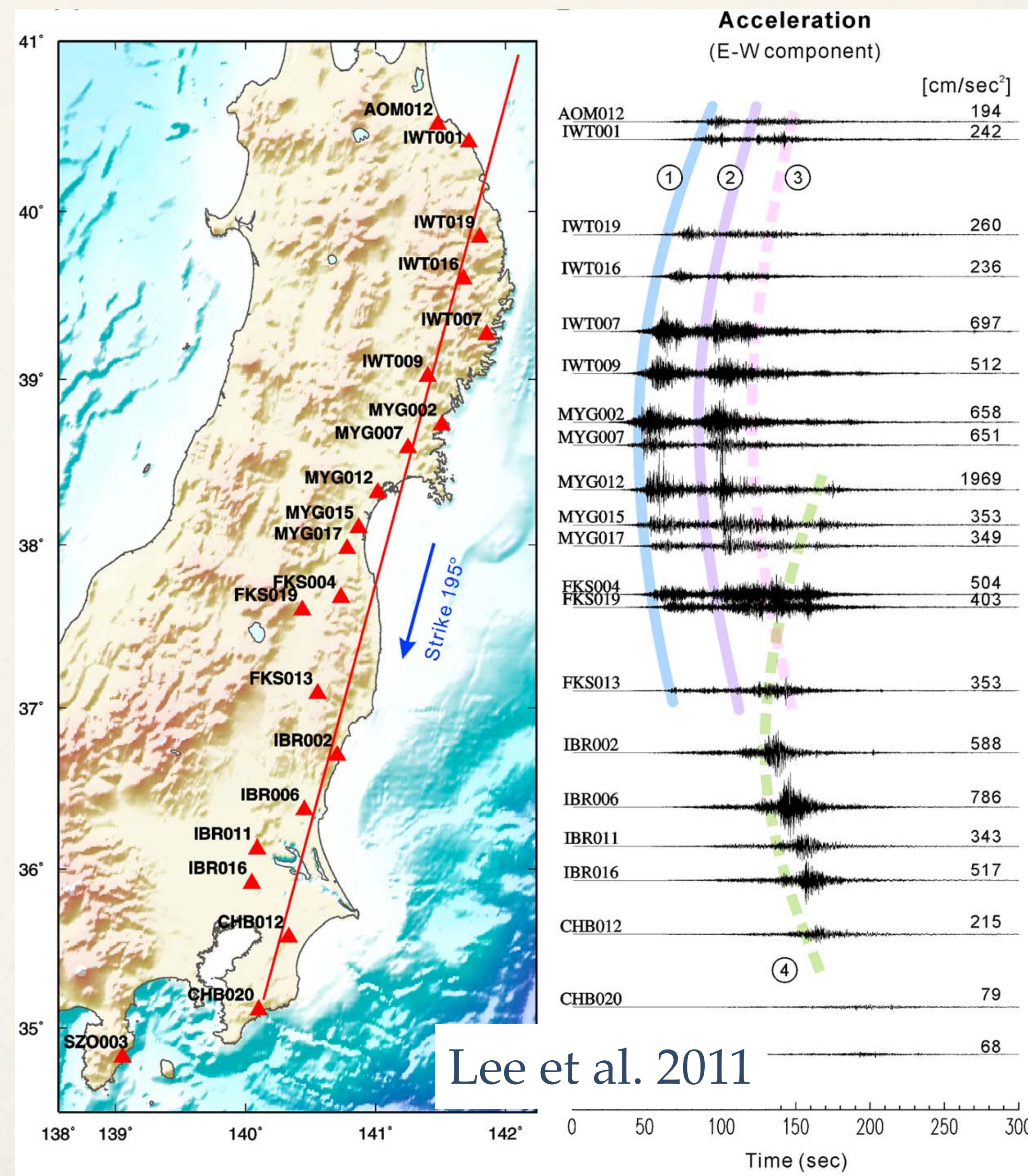
Introduction

- The rupture process of extended earthquakes is actually quite complex involving broadband processes: need to integrate different frequency bands and spatial scales resolution.
- Increasing density of modern global and regional seismology and geodesy networks open up new methodologies to image the earthquake source dynamics (e.g. antenna and coherent interferometry methods).
- Kinematic and dynamic inversion methodologies rely on a-priori source parametrization.
- Combining parametrized inversion methods with iterative deconvolution methods provides new perspectives for extended source imaging.

2011 Mw 9.0 Tohoku Earthquake



- Regular number of large earthquakes
- No great earthquakes in the last 1000 years
- Large rupture size was not expected
- Complexity of the Tohoku rupture

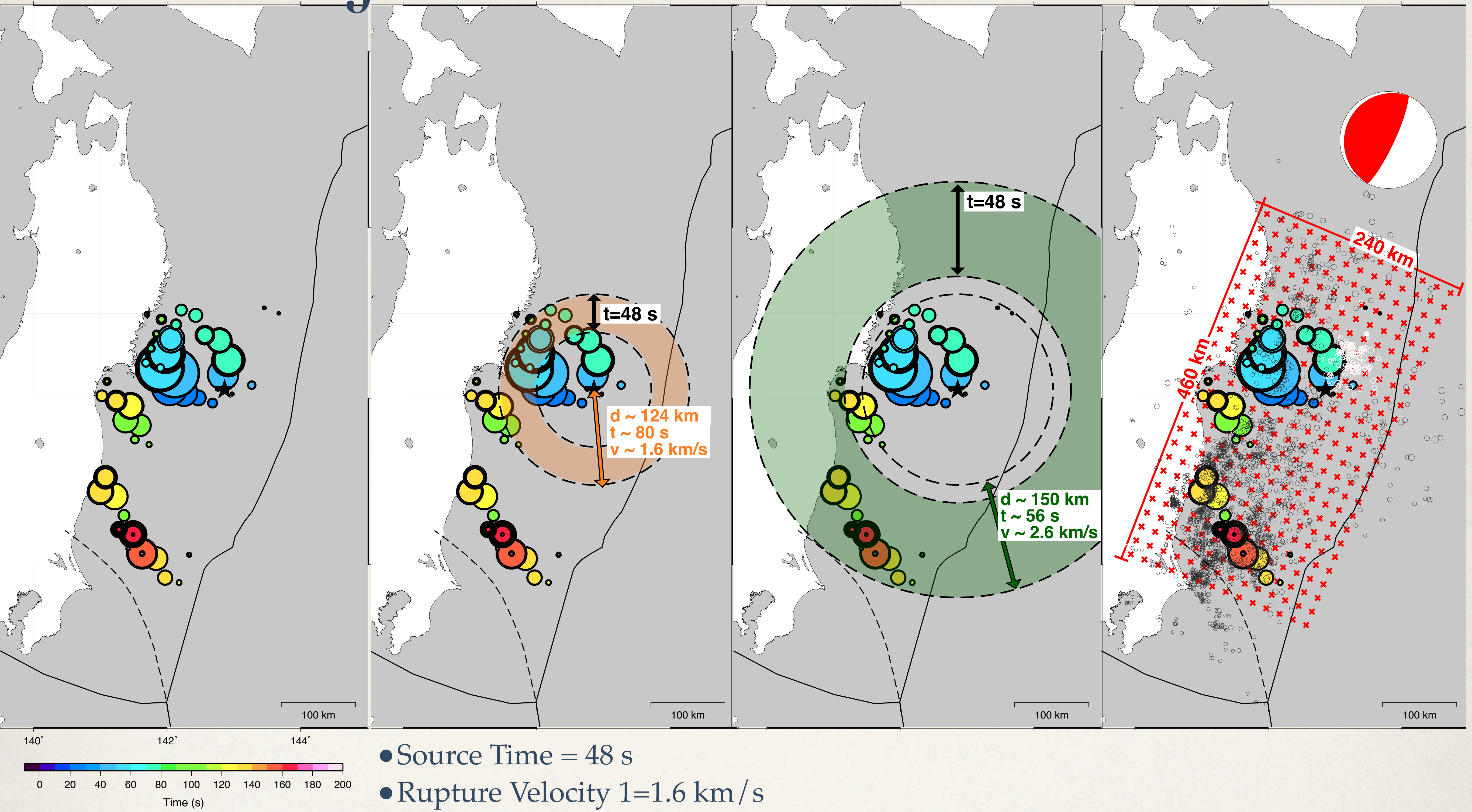


Regional acceleration recordings:

A complex rupture, at least 4 sub-events, closer to the coast.

Back Projection Results

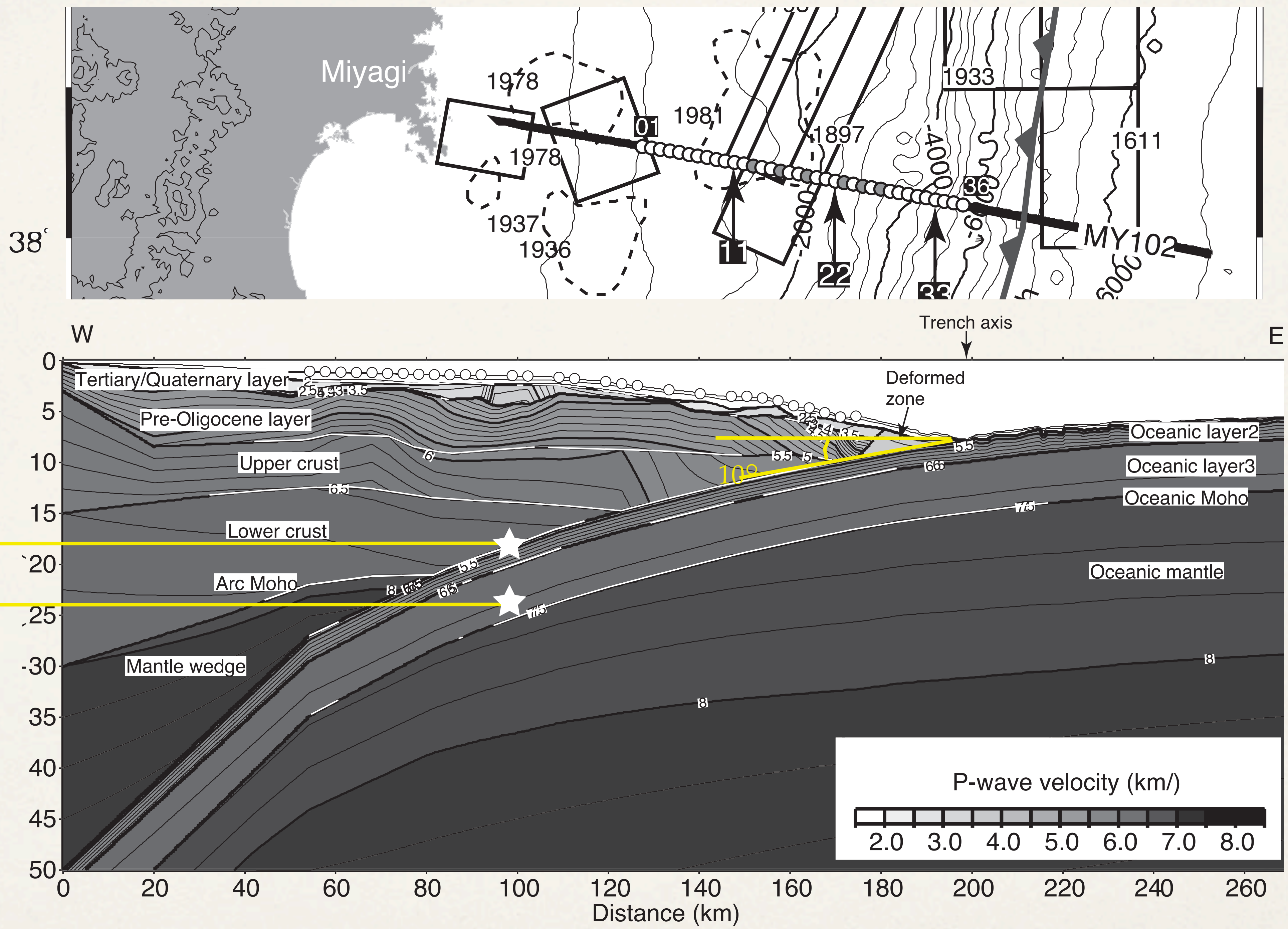
European Array 0.20-0.50 Hz



- Source Time = 48 s
- Rupture Velocity 1=1.6 km/s
- Rupture Velocity 2=2.6 km/s
- Area 460 x 240 km2,
- strike=203°, dip=10°, slip=88°
- 20x20 km2 subfaults

Satriano et al. 2011

Structural Model



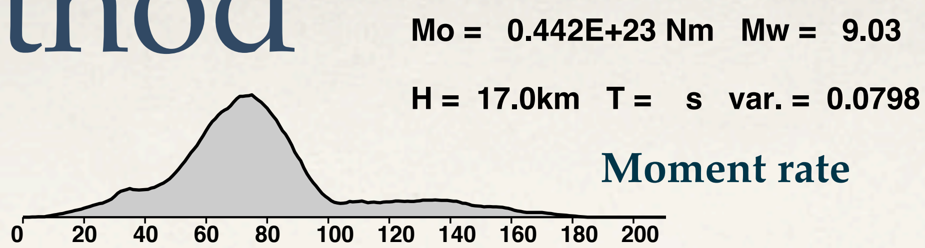
17.0

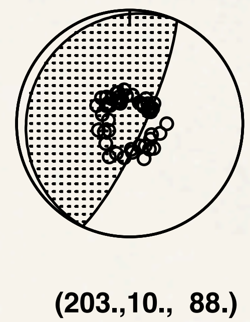
JMA: 23.7

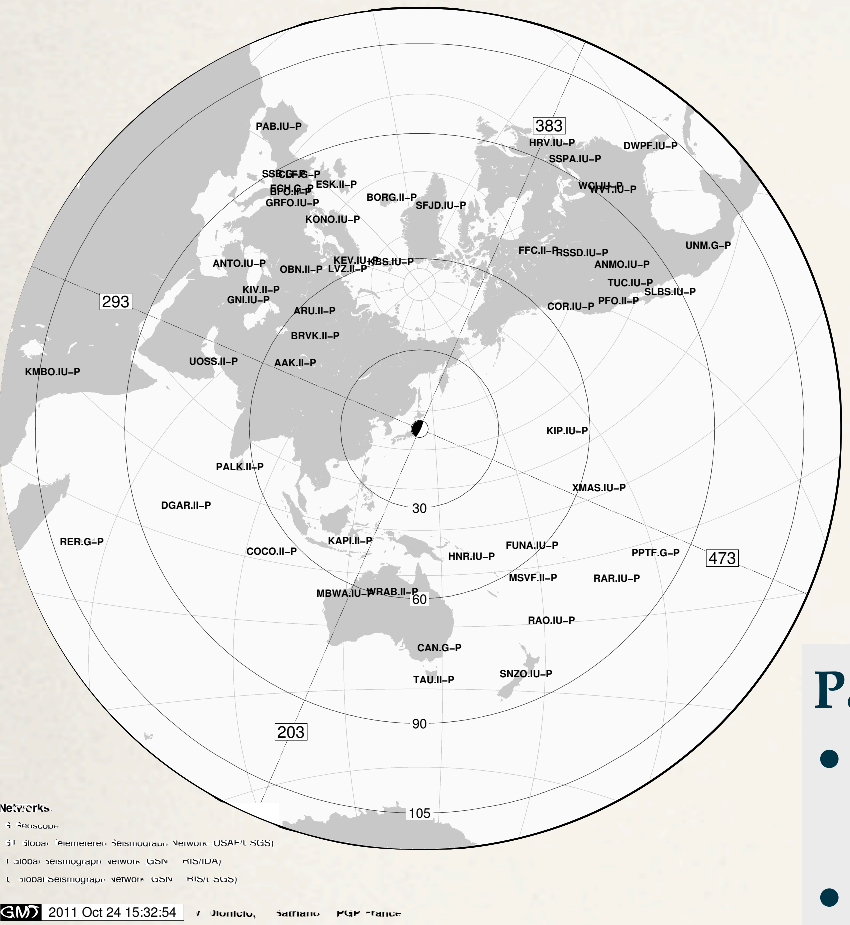
Vertical exaggeration: 2.3

Miura et al. 2005

Data and Method







GPS (not used for inversion)

GPS data: GSI (processed by Caltech)

Seafloor GPS data: Sato et al. (2011)

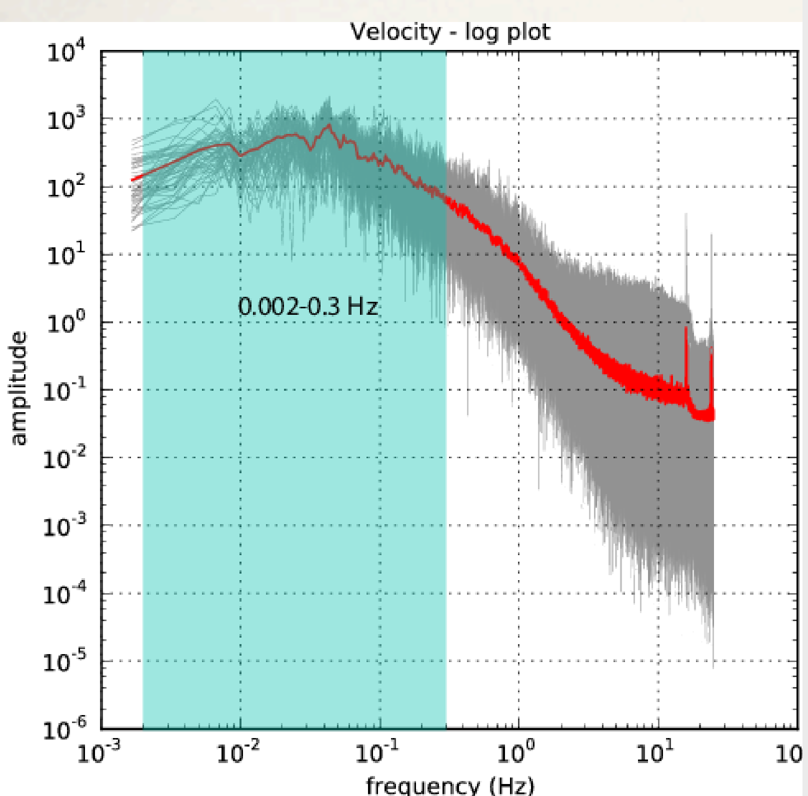
Parameters (driven by back-projection):

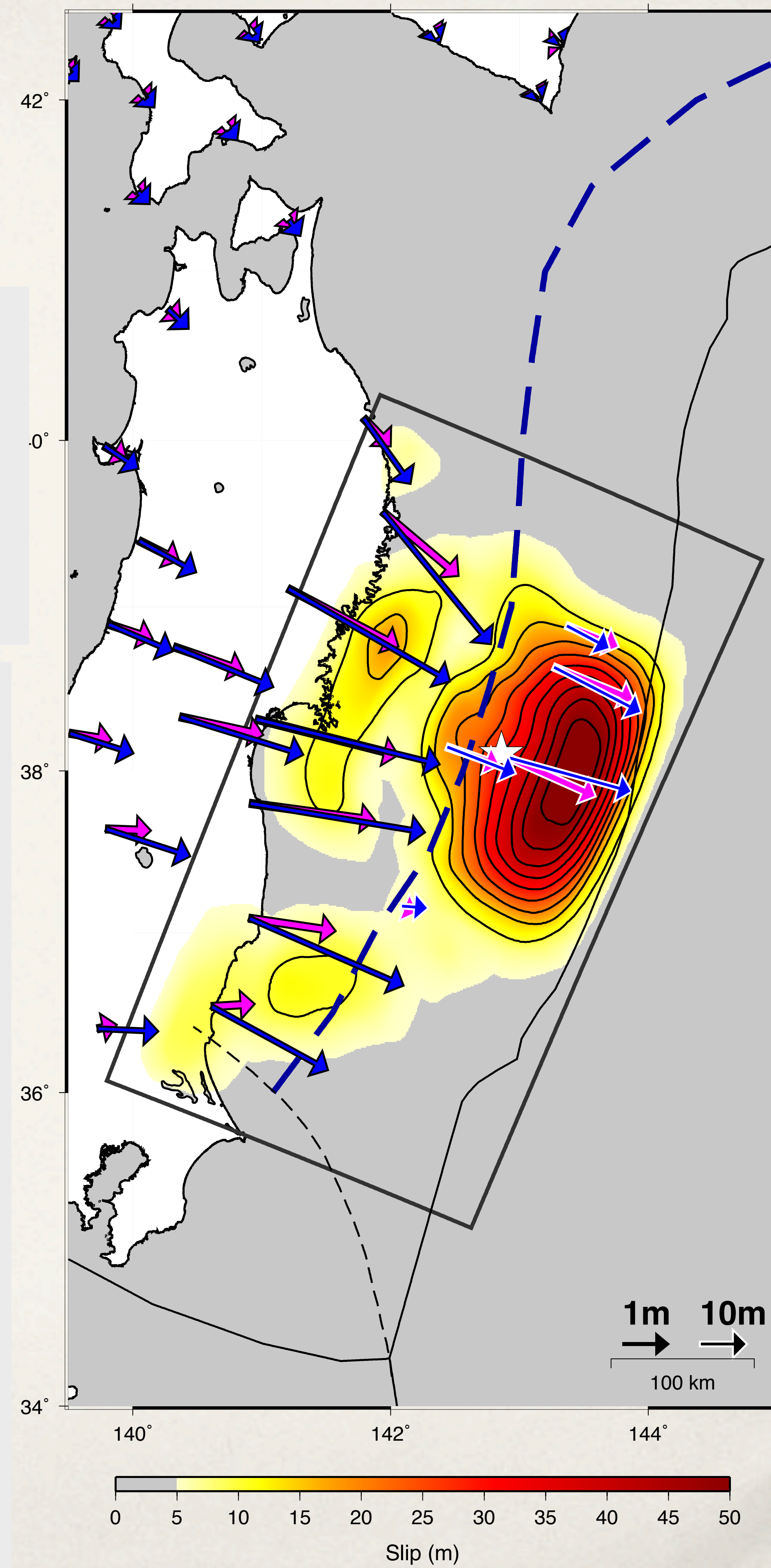
- Rupture velocity 1 = 1.5 km/s (for t<=80s)
- Rupture velocity 2 = 2.5 km/s (for t>80s)
- Source time function = 45 s
- Fault surface 460x240 km^2

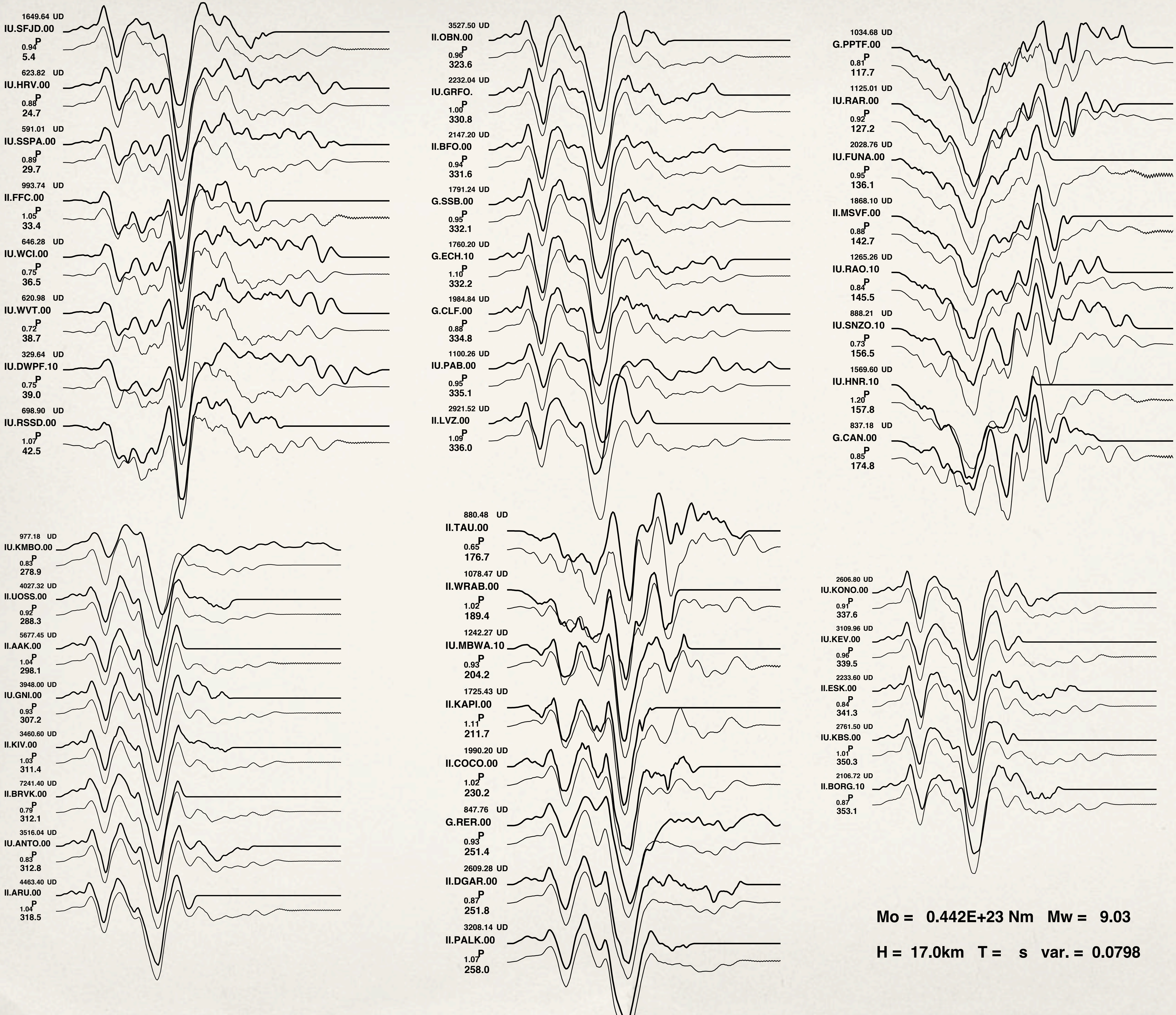
Other parameters:

- Hypocenter location: JMA (depth 23.7 km)
- Fault plane (GCMT): dip 10°, strike 203°

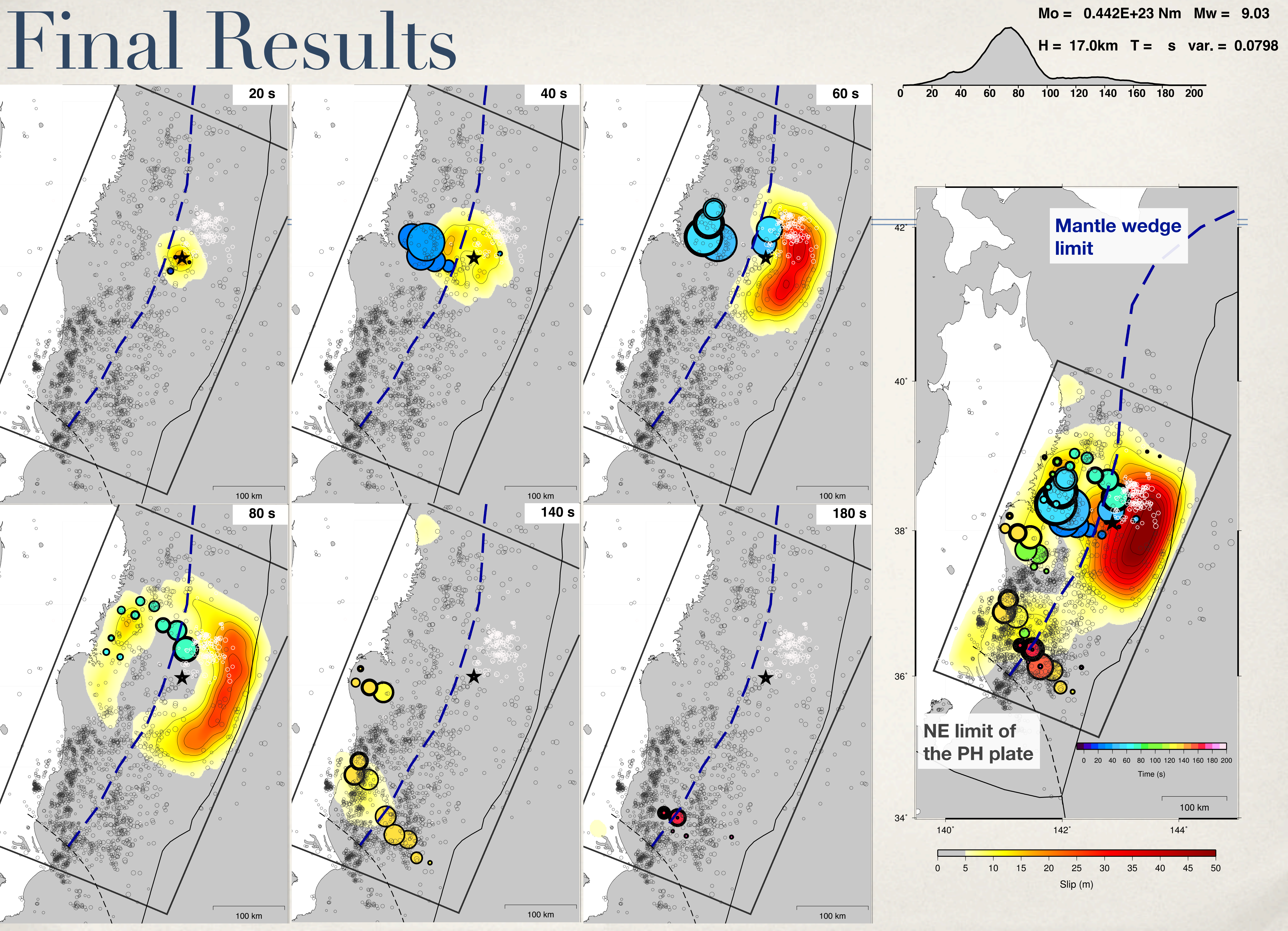
Method by Kikuchi and Kanamori (1991)





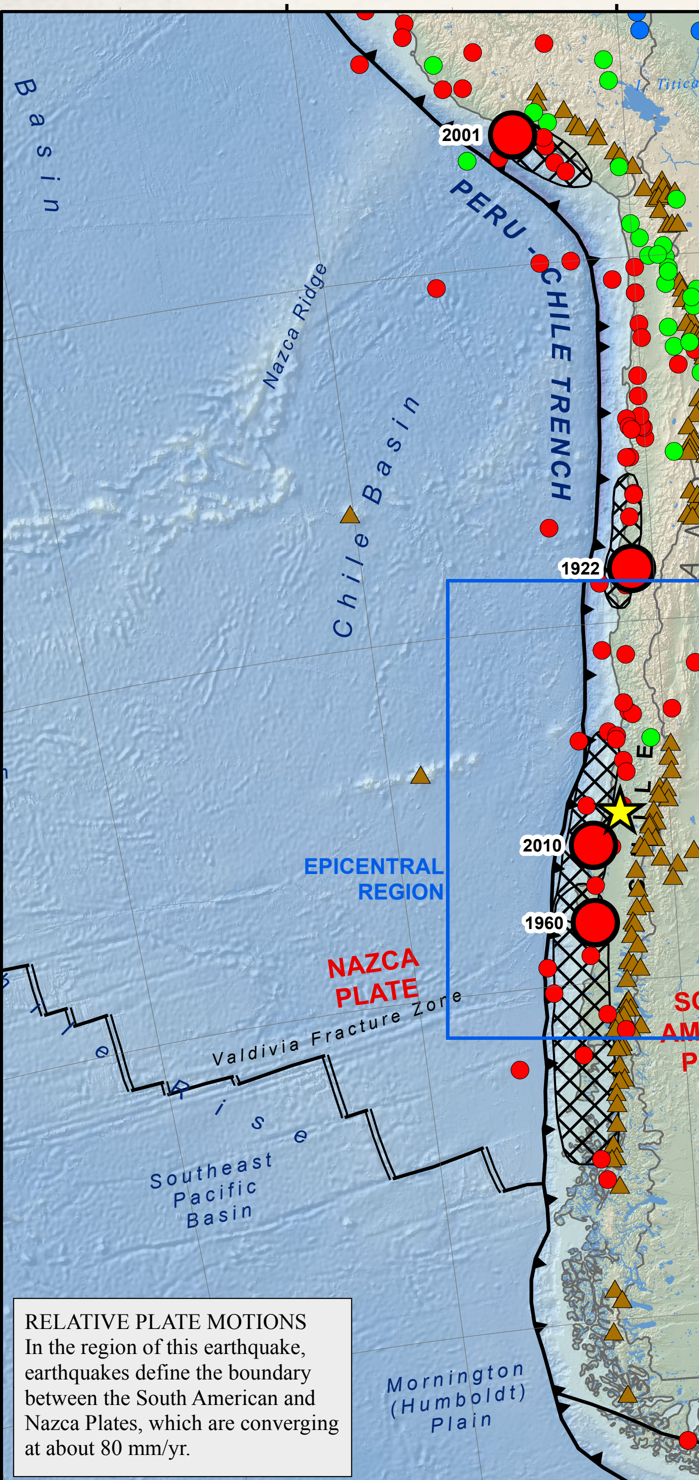

1649.64 UD
IU.SFJD.00
0.94 P
5.4
623.82 UD
IU.HRV.00
0.88 P
24.7
591.01 UD
IU.SSPA.00
0.89 P
29.7
993.74 UD
II.FFC.00
1.05 P
33.4
646.28 UD
IU.WCI.00
0.75 P
36.5
620.98 UD
IU.WVT.00
0.72 P
38.7
329.64 UD
IU.DWPF.10
0.75 P
39.0
698.90 UD
IU.RSSD.00
1.07 P
42.5
3527.50 UD
II.OBN.00
0.96 P
323.6
2232.04 UD
IU.GRFO.
1.00 P
330.8
2147.20 UD
II.BFO.00
0.94 P
331.6
1791.24 UD
G.SSB.00
0.95 P
332.1
1760.20 UD
G.ECH.10
1.10 P
332.2
1984.84 UD
G.CLF.00
0.88 P
334.8
1100.26 UD
IU.PAB.00
0.95 P
335.1
2921.52 UD
II.LVZ.00
1.09 P
336.0
1034.68 UD
G.PPTF.00
0.81 P
117.7
1125.01 UD
IU.RAR.00
0.92 P
127.2
2028.76 UD
IU.FUNA.00
0.95 P
136.1
1868.10 UD
II.MSVF.00
0.88 P
142.7
1265.26 UD
IU.RAO.10
0.84 P
145.5
888.21 UD
IU.SNZO.10
0.73 P
156.5
1569.60 UD
IU.HNR.10
1.20 P
157.8
837.18 UD
G.CAN.00
0.85 P
174.8
977.18 UD
IU.KMBO.00
0.83 P
278.9
4027.32 UD
II.UOSS.00
0.92 P
288.3
5677.45 UD
II.AAK.00
1.04 P
298.1
3948.00 UD
IU.GNI.00
0.93 P
307.2
3460.60 UD
II.KIV.00
1.03 P
311.4
7241.40 UD
II.BRVK.00
0.79 P
312.1
3516.04 UD
IU.ANTO.00
0.83 P
312.8
4463.40 UD
II.ARU.00
1.04 P
318.5
880.48 UD
II.TAU.00
0.65 P
176.7
1078.47 UD
II.WRAB.00
1.02 P
189.4
1242.27 UD
IU.MBWA.10
0.93 P
204.2
1725.43 UD
II.KAPI.00
1.11 P
211.7
1990.20 UD
II.COCO.00
1.02 P
230.2
847.76 UD
G.RER.00
0.93 P
251.4
2609.28 UD
II.DGAR.00
0.87 P
251.8
3208.14 UD
II.PALK.00
1.07 P
258.0
2606.80 UD
IU.KONO.00
0.91 P
337.6
3109.96 UD
IU.KEV.00
0.96 P
339.5
2233.60 UD
II.ESK.00
0.84 P
341.3
2761.50 UD
IU.KBS.00
1.01 P
350.3
2106.72 UD
II.BORG.10
0.87 P
353.1
Mo = 0.442E+23 Nm Mw = 9.03
H = 17.0km T = s var. = 0.0798

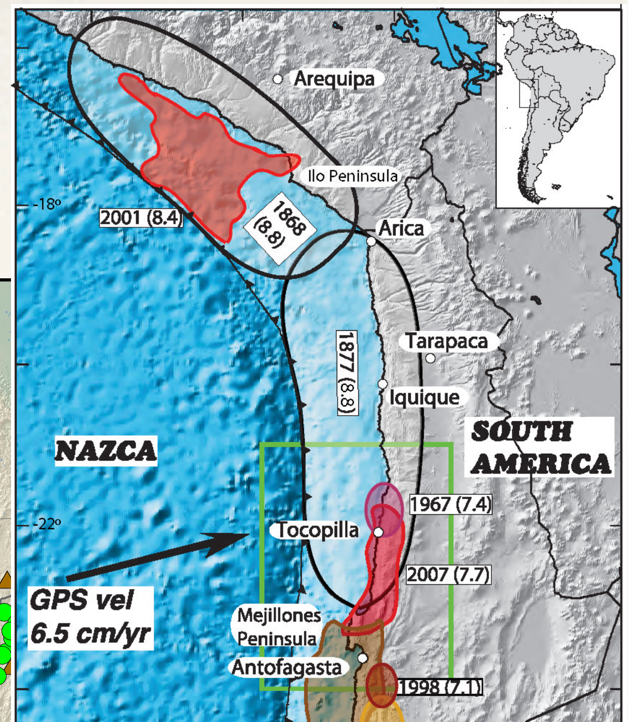
Final Results

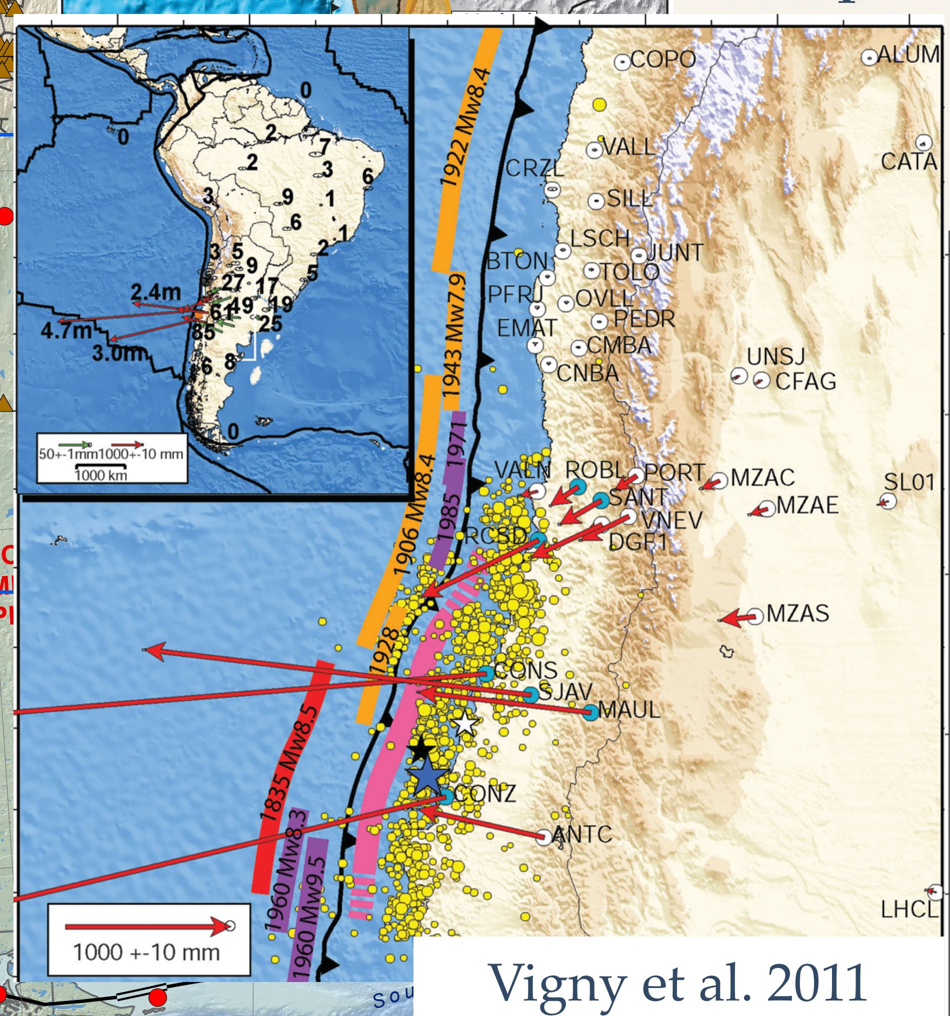


2010 Mw 8.8 Maule Earthquake

- Segments based on the historic seismicity.
- GPS high coupling on Maule rupture zone
- Post seismic activity:
  - Deficit of large aftershocks in the first months.
  - Rupture extended over than expected with partial overlap with previous ruptures.

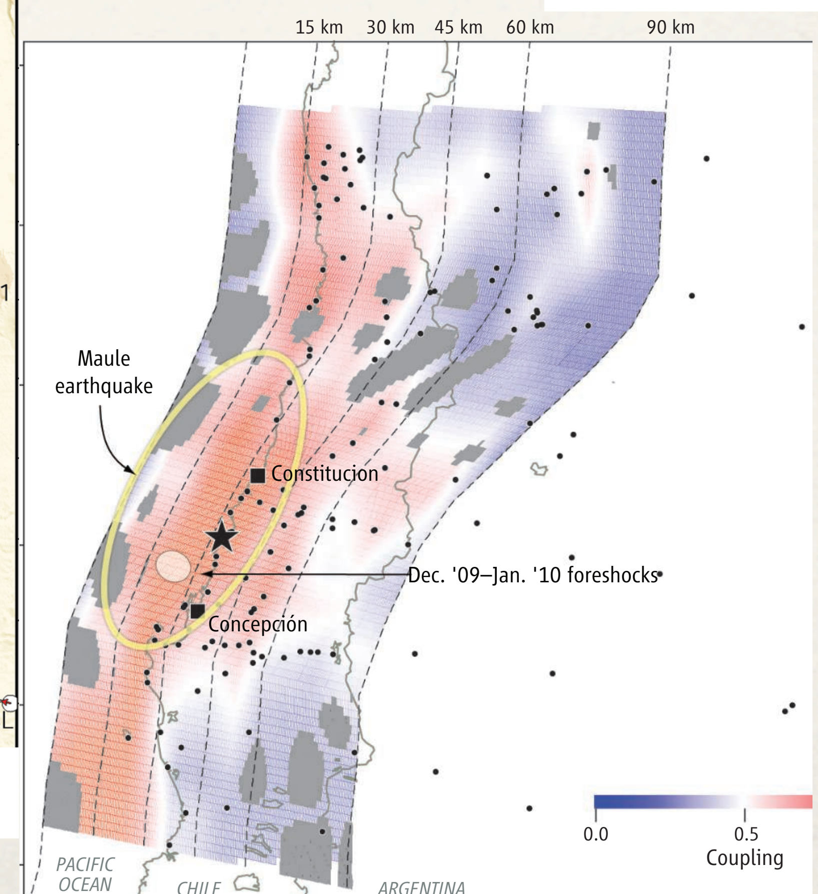






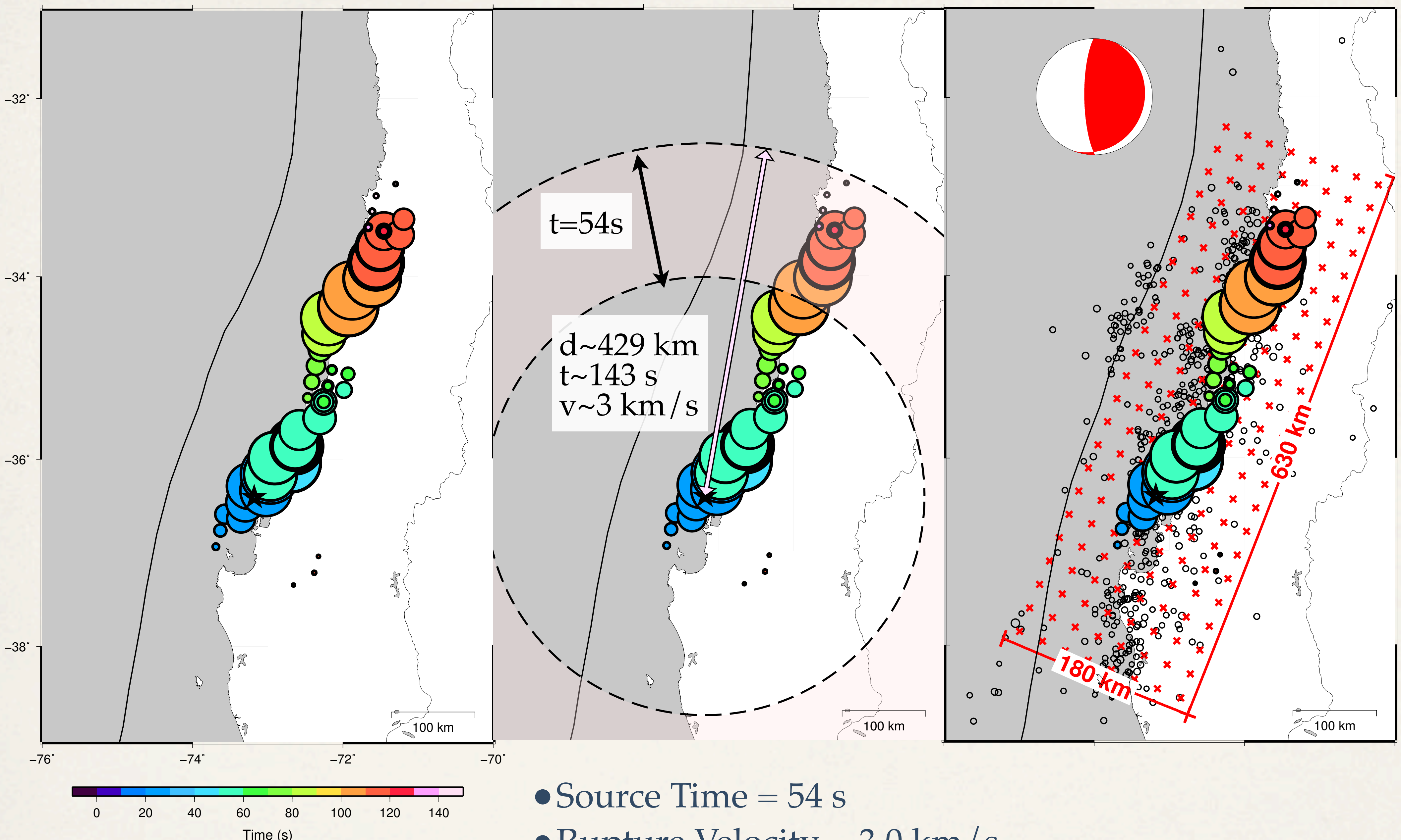
Vigny et al. 2011

Madariaga et al. 2011



Back Projection Results

US Array 0.30-1 Hz

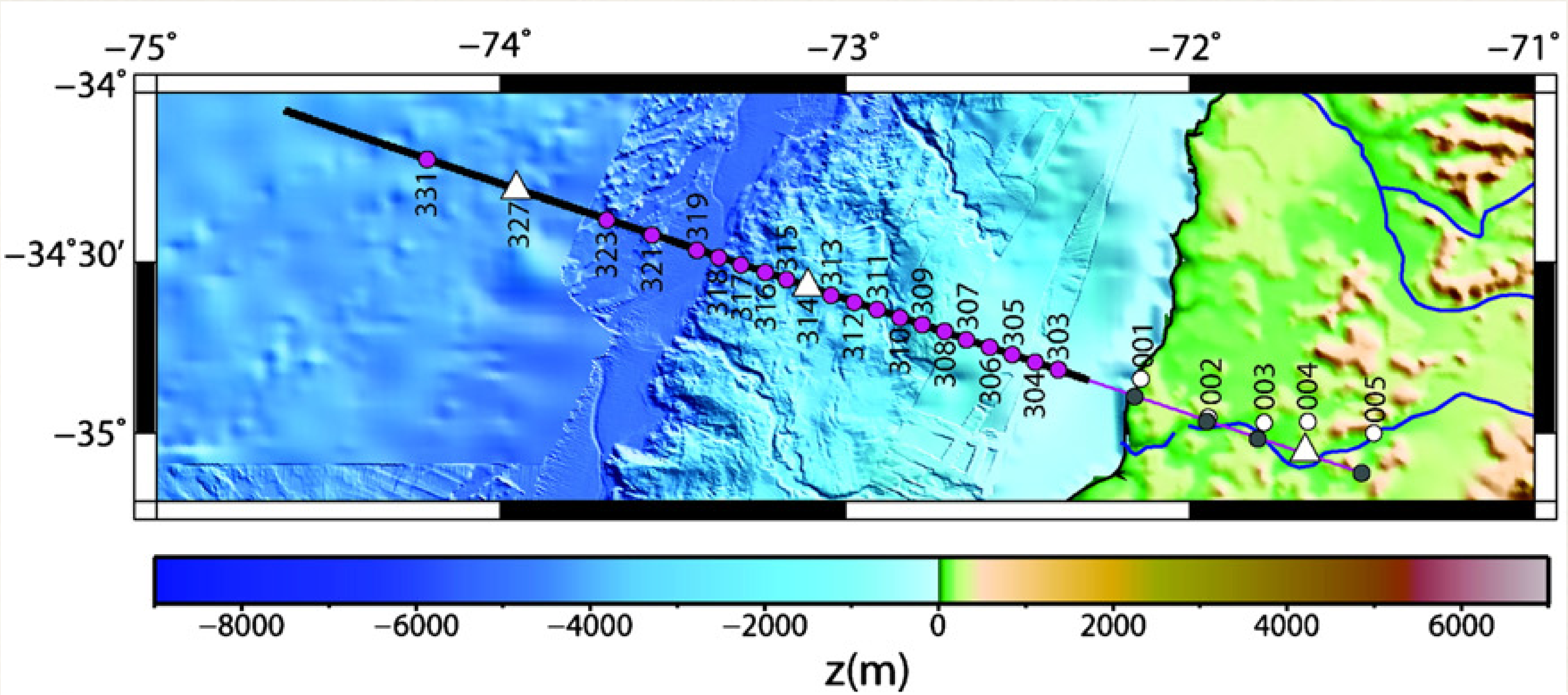


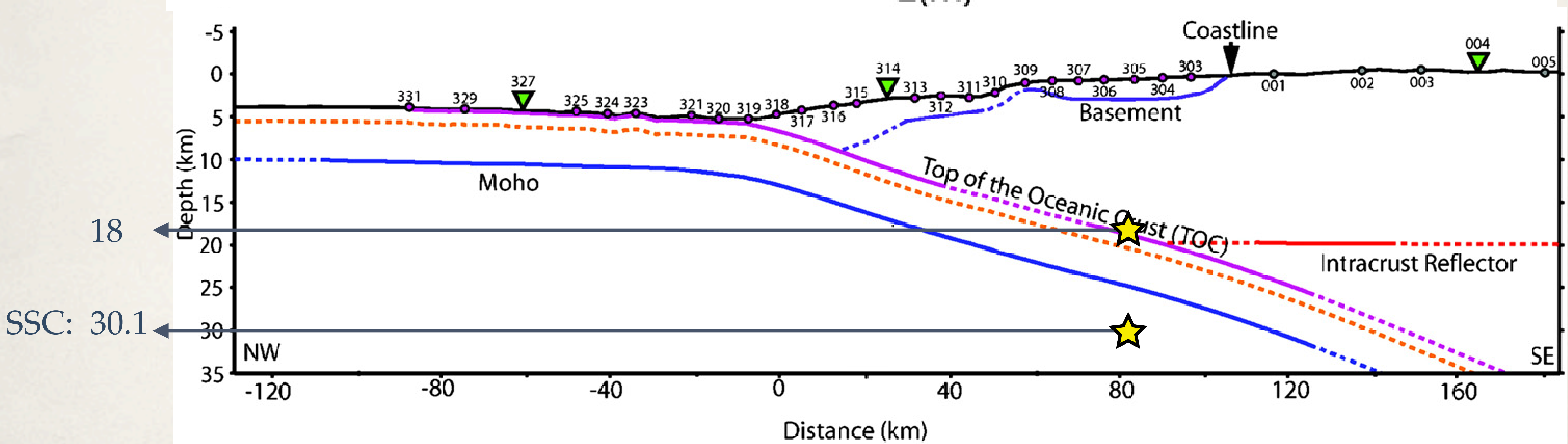
- Source Time = 54 s
- Rupture Velocity = 3.0 km/s

- Area 630 x 180 km2,
- strike=22°, dip=15°, slip=112°
- 30x30 km2 subfaults

Satriano et al. 2012

Structural Model

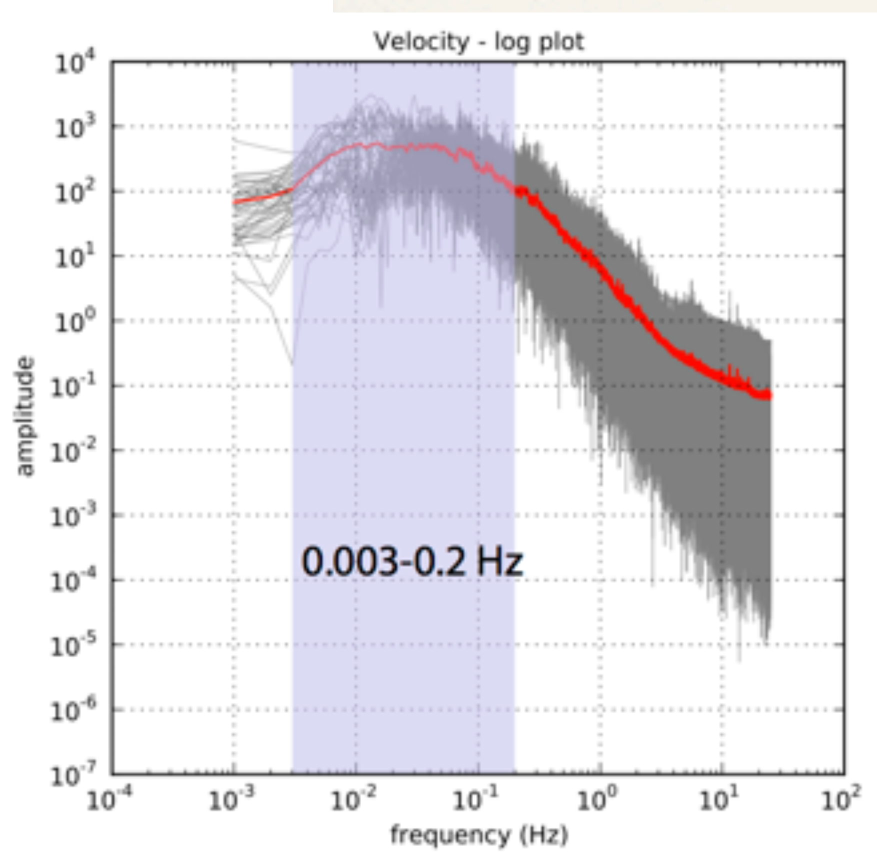


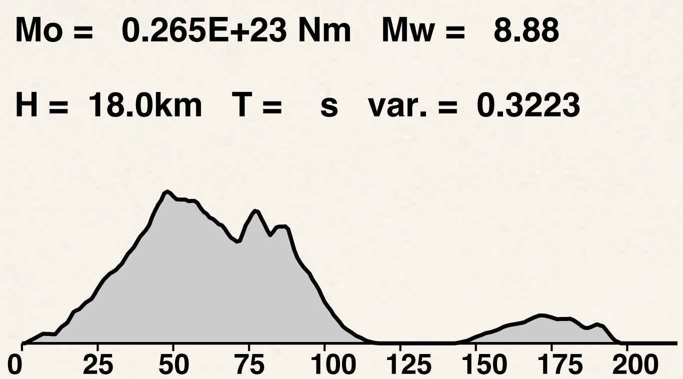


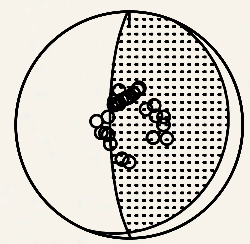
Moscoso et al. 2011

Vertical exaggeration: 2.0

Kinematic slip inversion







(22.,15., 112.)

Moment rate

Parameters (driven by back-projection):

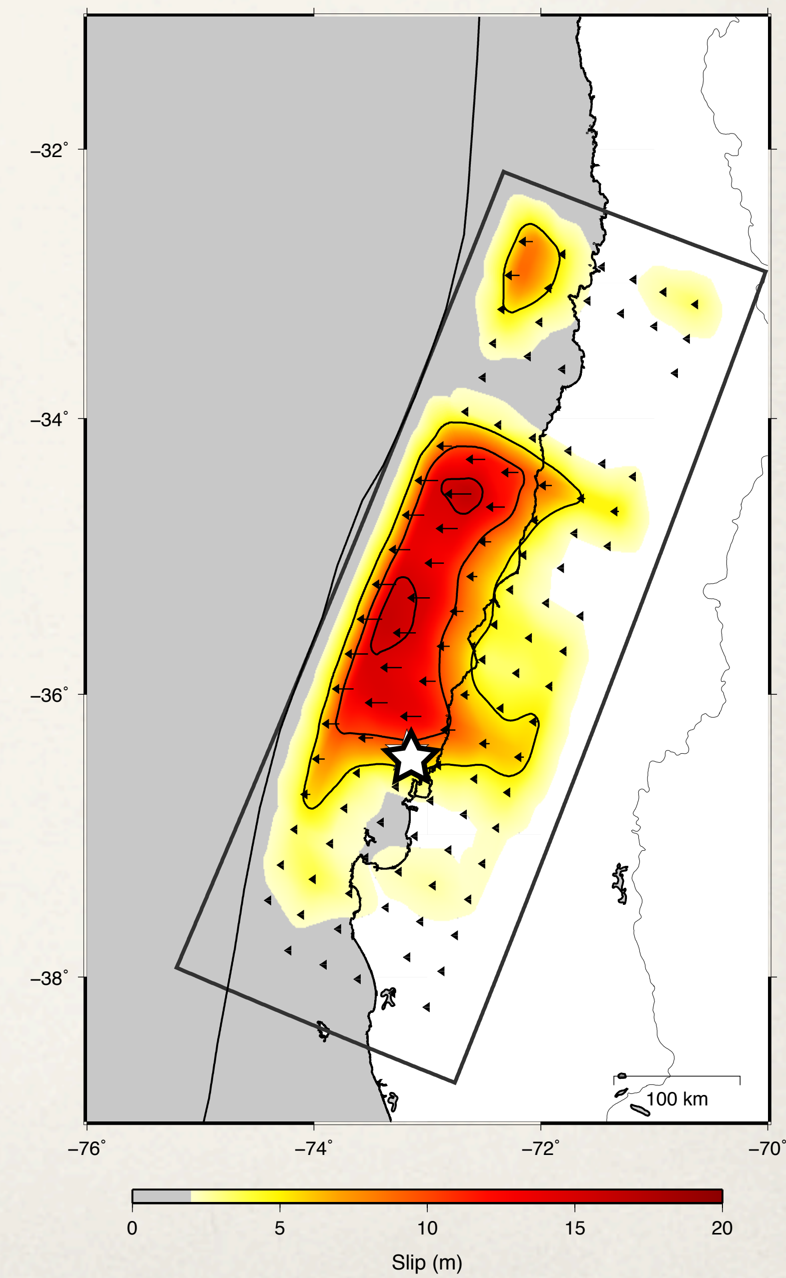
- Rupture velocity = 3.0 km/s
- Source time function = 54 s
- Fault surface 630x180 km^2

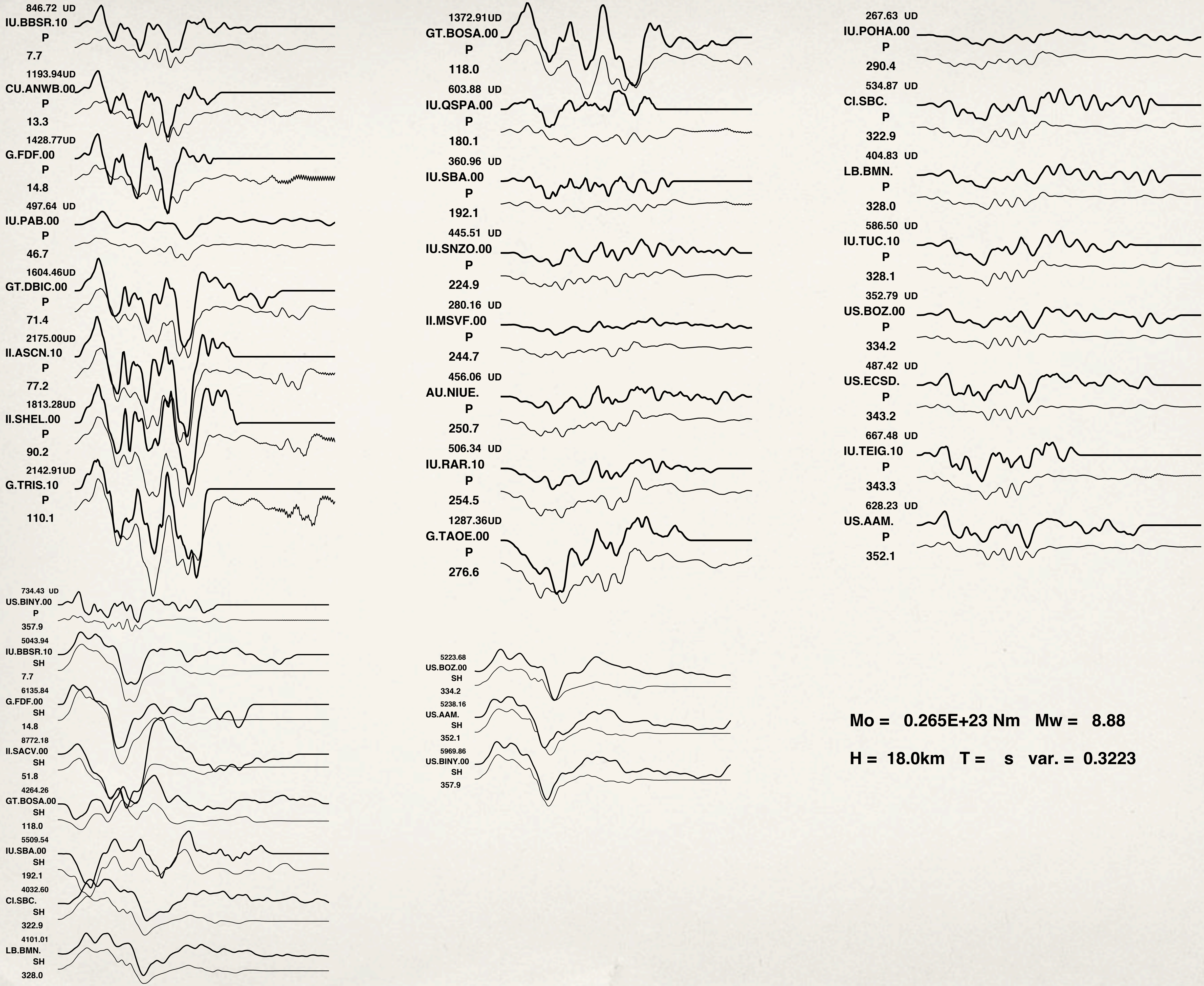
Other parameters:

- Hypocenter location: Vigny et al. 2011 (depth 18 km)
- Fault plane (GCMT): dip 15°, strike 22°

Method by Kikuchi and Kanamori (1991)

- Why no slip in the south part of the rupture if the GPS indicates big displacement?
- Is it a bi-lateral effect?

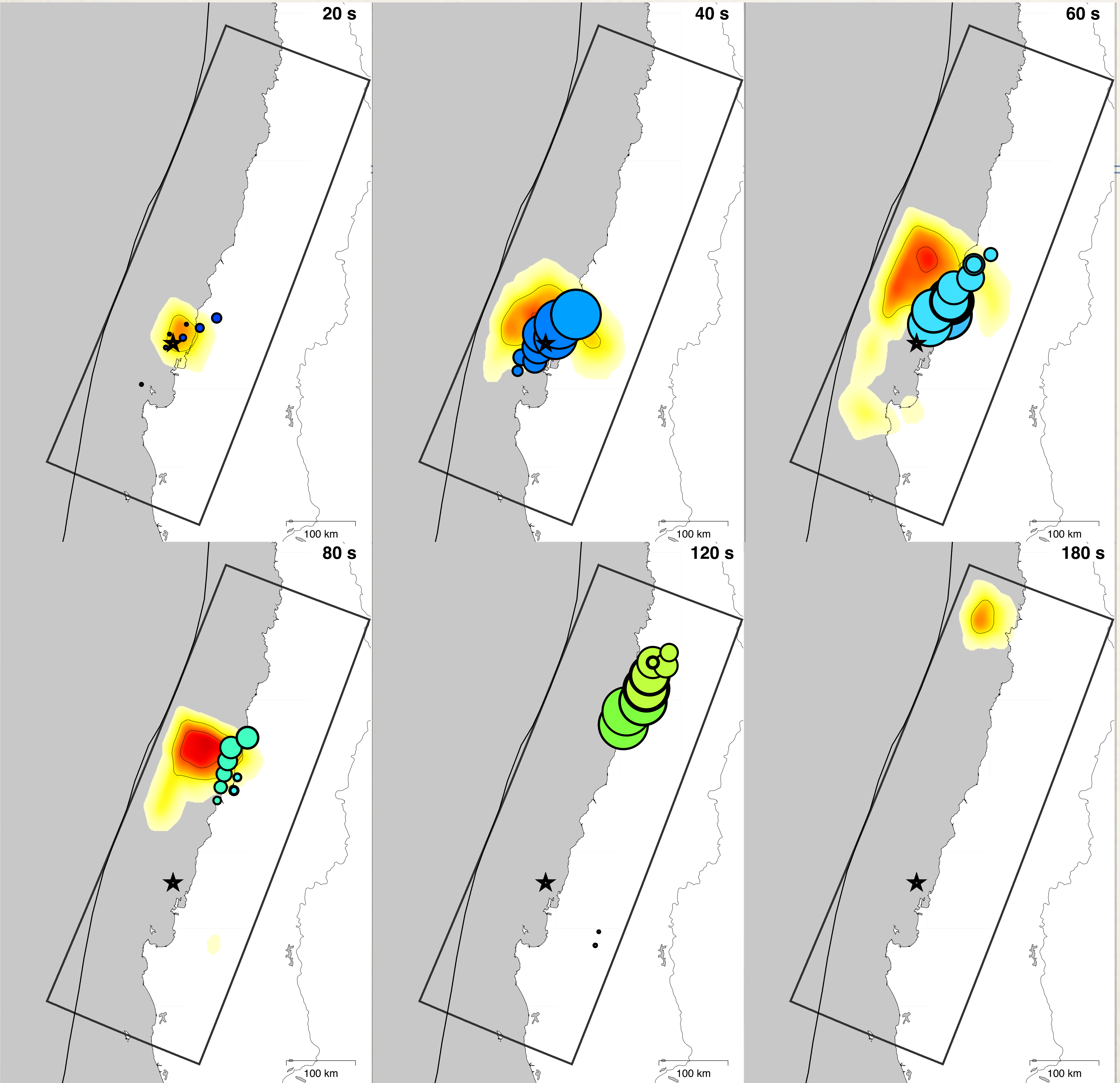


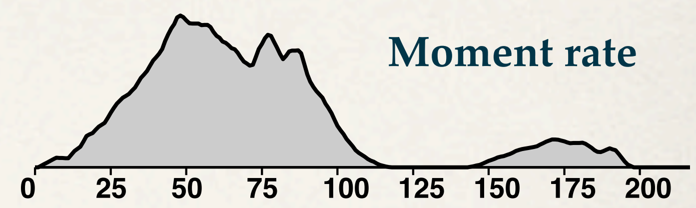

846.72 UD
IU.BBSR.10
P
7.7
1193.94UD
CU.ANWB.00
P
13.3
1428.77UD
G.FDF.00
P
14.8
497.64 UD
IU.PAB.00
P
46.7
1604.46UD
GT.DBIC.00
P
71.4
2175.00UD
II.ASCN.10
P
77.2
1813.28UD
II.SHEL.00
P
90.2
2142.91UD
G.TRIS.10
P
110.1
734.43 UD
US.BINY.00
P
357.9
5043.94
IU.BBSR.10
SH
7.7
6135.84
G.FDF.00
SH
14.8
8772.18
II.SACV.00
SH
51.8
4264.26
GT.BOSA.00
SH
118.0
5509.54
IU.SBA.00
SH
192.1
4032.60
CI.SBC.
SH
322.9
4101.01
LB.BMN.
SH
328.0
1372.91UD
GT.BOSA.00
P
118.0
603.88 UD
IU.QSPA.00
P
180.1
360.96 UD
IU.SBA.00
P
192.1
445.51 UD
IU.SNZO.00
P
224.9
280.16 UD
II.MSVF.00
P
244.7
456.06 UD
AU.NIUE.
P
250.7
506.34 UD
IU.RAR.10
P
254.5
1287.36UD
G.TAOE.00
P
276.6
5223.68
US.BOZ.00
SH
334.2
5238.16
US.AAM.
SH
352.1
5969.86
US.BINY.00
SH
357.9
267.63 UD
IU.POHA.00
P
290.4
534.87 UD
CI.SBC.
P
322.9
404.83 UD
LB.BMN.
P
328.0
586.50 UD
IU.TUC.10
P
328.1
352.79 UD
US.BOZ.00
P
334.2
487.42 UD
US.ECSD.
P
343.2
667.48 UD
IU.TEIG.10
P
343.3
628.23 UD
US.AAM.
P
352.1
Mo = 0.265E+23 Nm Mw = 8.88
H = 18.0km T = s var. = 0.3223

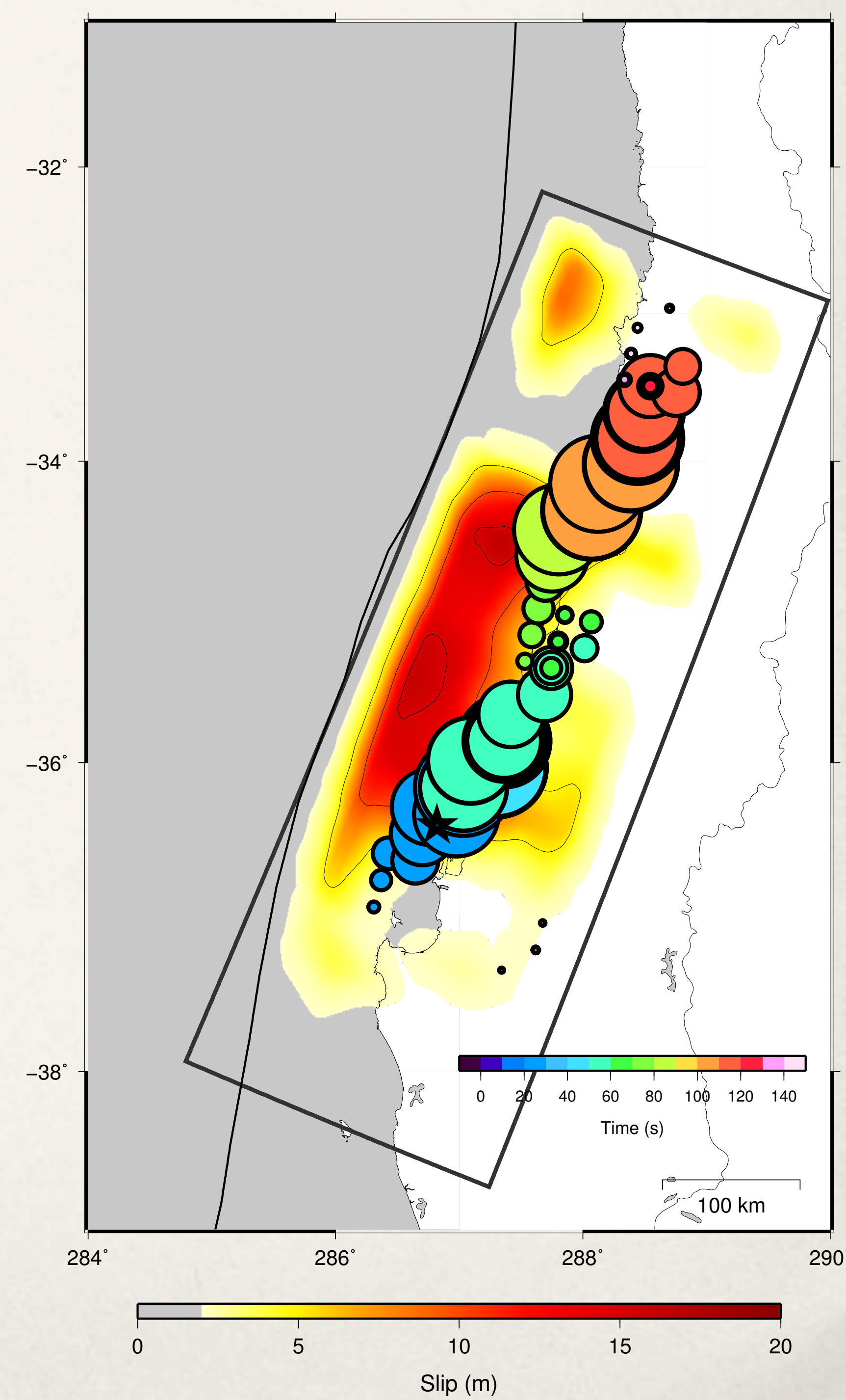
Final Results

Mo = 0.265E+23 Nm Mw = 8.88

H = 18.0km T = s var. = 0.3223







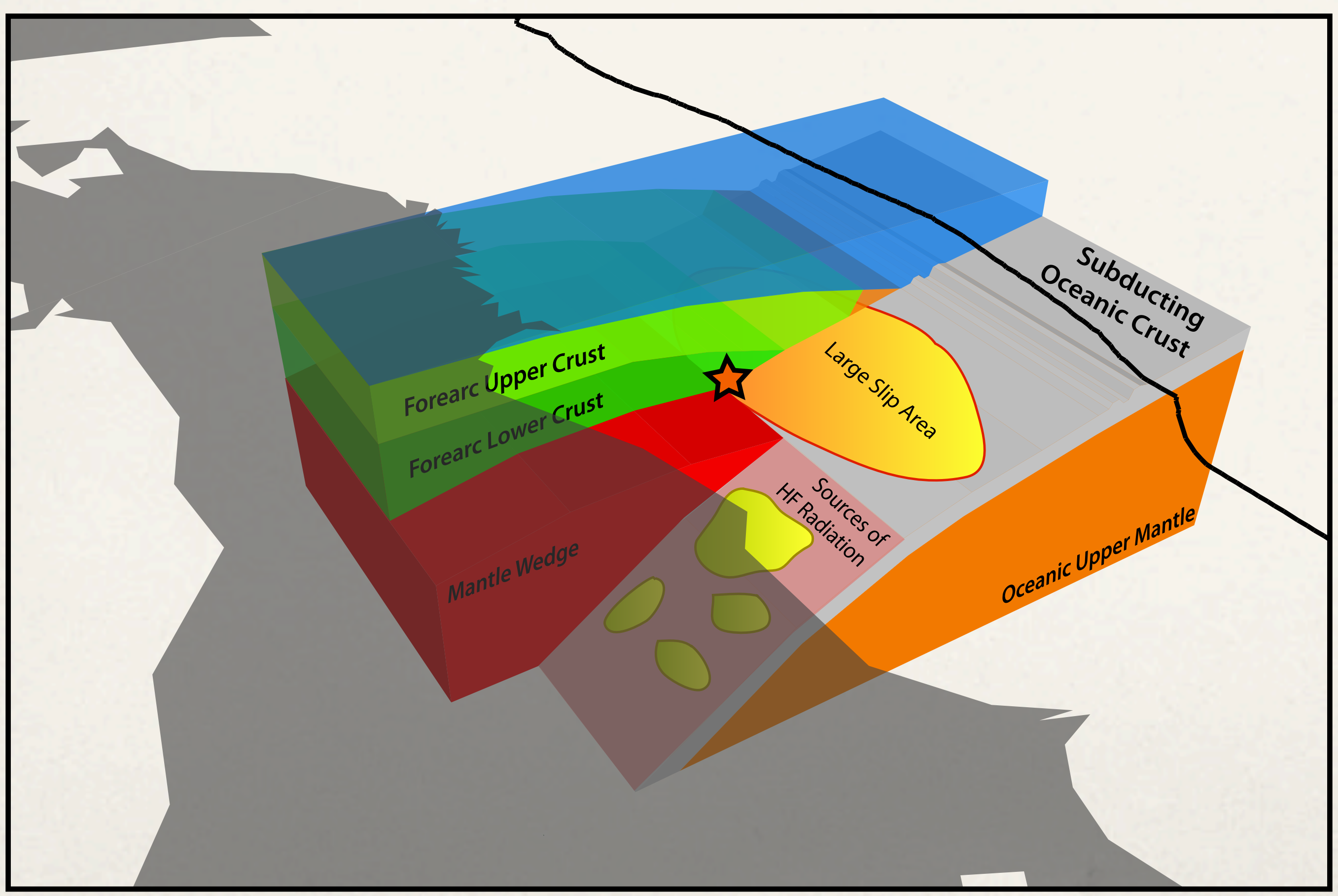
Conclusion and Discussion

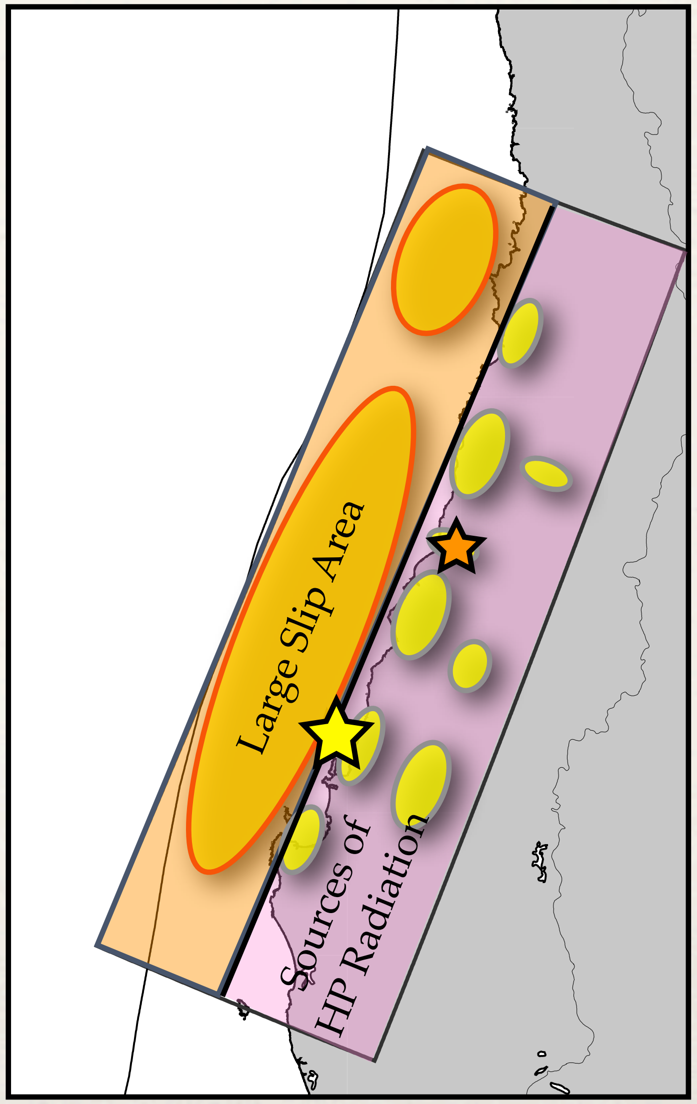
✓The HF coherent radiation is located on the border of the coherent slip.

✓Multi-scale distribution of asperities, it must reflect specific frictional behavior on the asperities and around them, depending on pressure, temperature, rheology composition,...

✓Is this distribution related to the mantle wedge geometry and rheology ?

✓Is the distribution a feature of ALL the subduction zones?





Conclusions and Perspectives

✓Need of structural studies for characterizing the subduction structure.

✓Need of innovative multi-frequency source imaging techniques to understand the rupture complexity of large subduction earthquakes combining both **teleseismic and local monitoring** networks on land and on the ocean bottom.

✓The inverted slip distribution strongly depends on the **kinematic parametrization**: it is necessary to constrain the kinematic parameters by other means (e.g. **back projection**) in order to obtain physically acceptable results.

Thank you