Bridging Geodesy and Seismology

On joining Near-field and far-field data for robust earthquake source modelling

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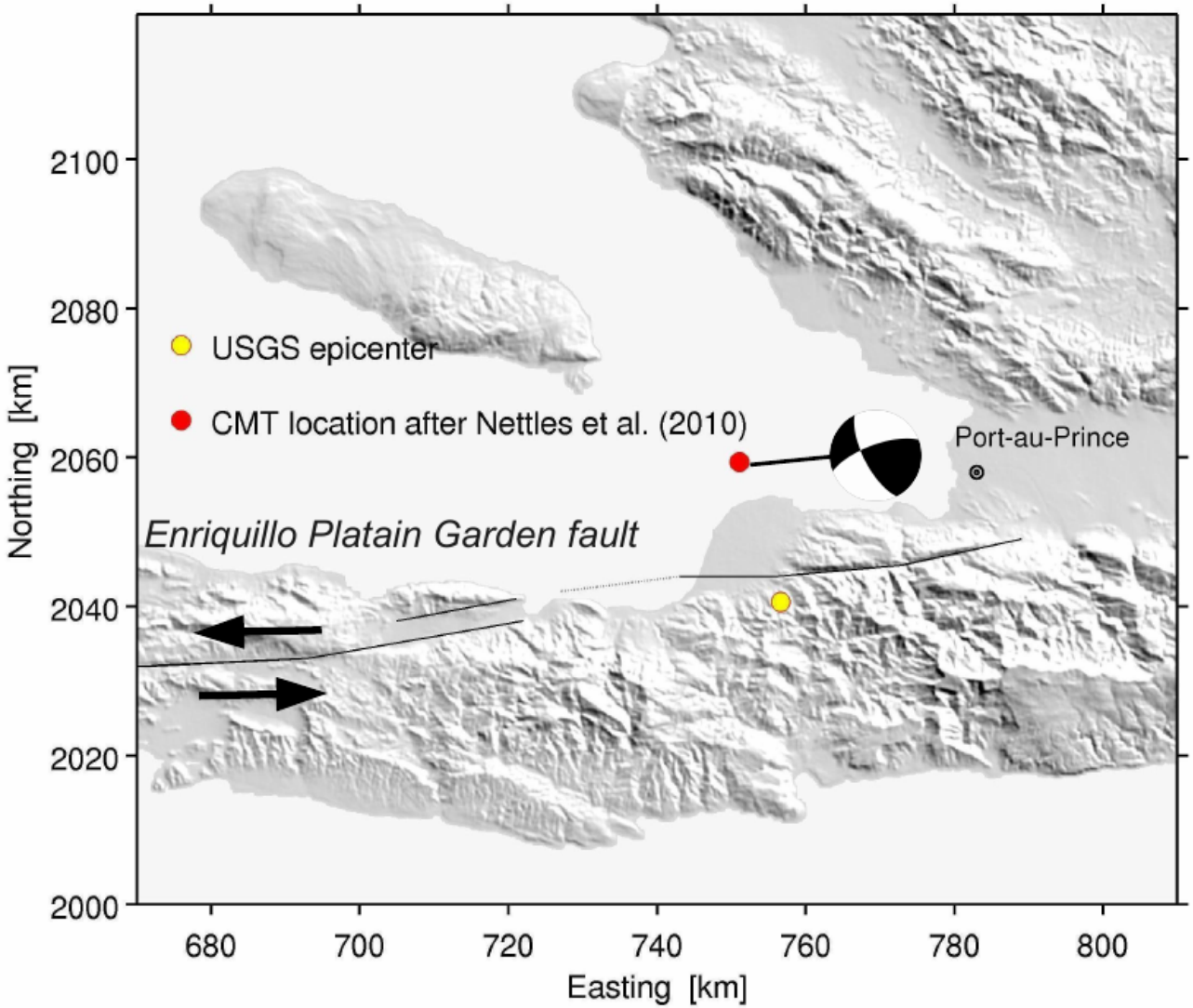
www.pyrocko.org
www.bridges.uni-kiel.de

CAU BridGeS

The Haiti 2010 earthquake (a short catch up)



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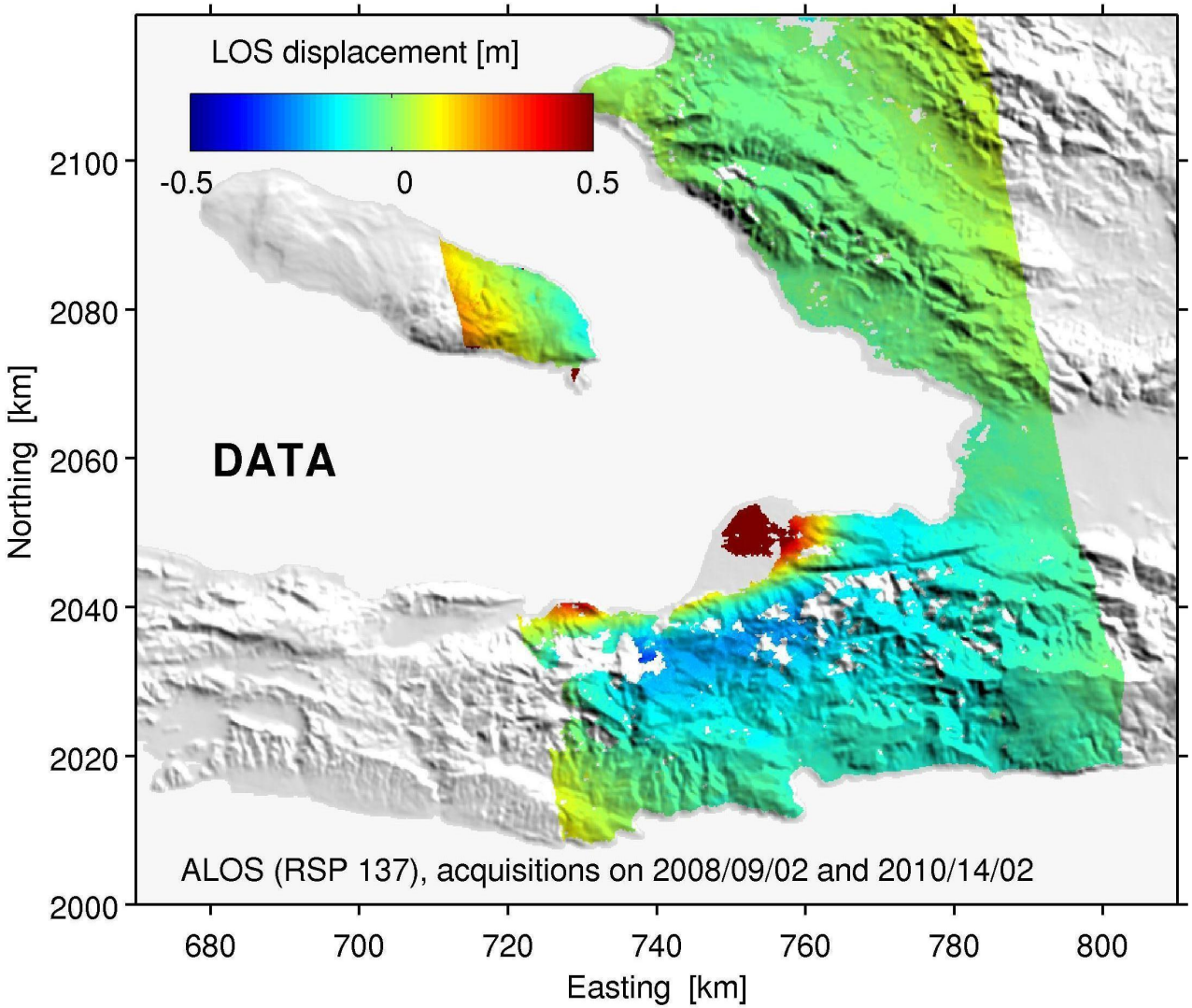
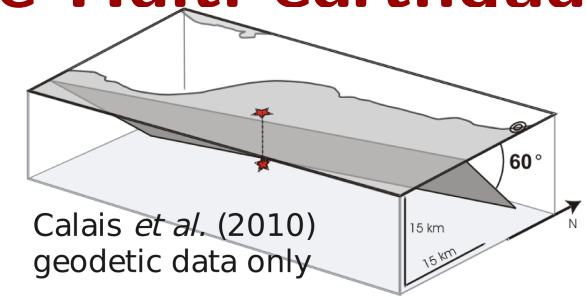
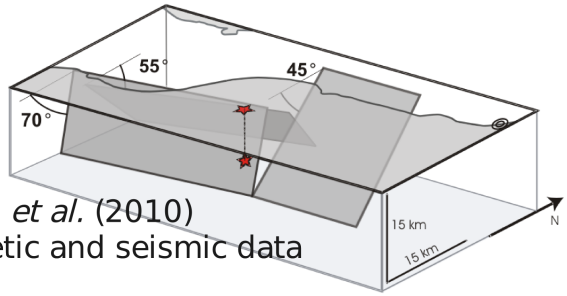


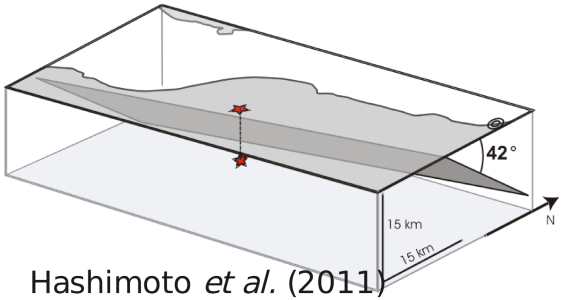
some Haiti earthquake models



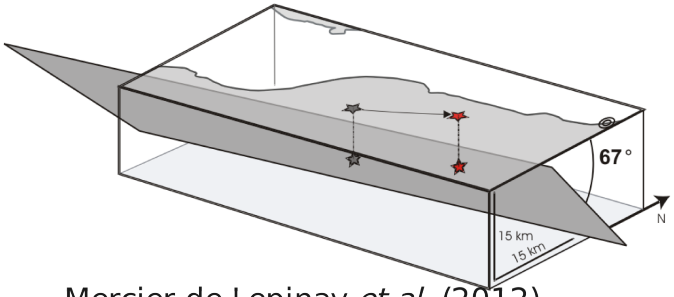
Calais *et al.* (2010)
geodetic data only



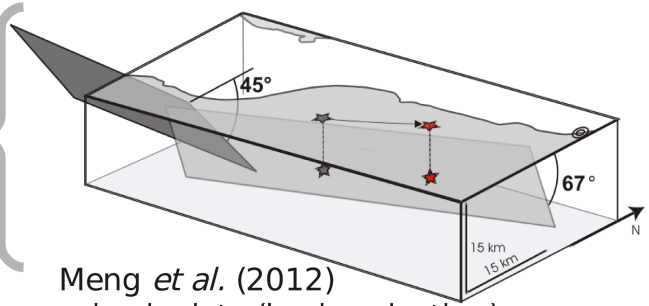
Hayes *et al.* (2010)
geodetic and seismic data



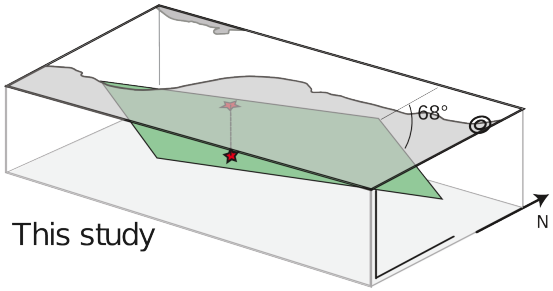
Hashimoto *et al.* (2011)
geodetic data only



Mercier de Lepinay *et al.* (2012)
geodetic and seismic data



Meng *et al.* (2012)
seismic data (backprojection)



This study

GFZ Helmholtz Centre Potsdam PROGRESS WEGENER 2012 Sudhaus & Heimann KIWI

Data: global seismic stations, GPS by Calais et al. (2010), ALOS-1 supersite SAR, TSX-1 pixel offsets by DLR

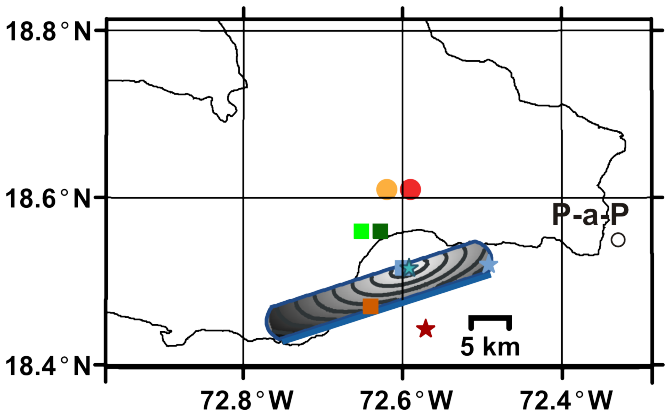
CAU BridGeS

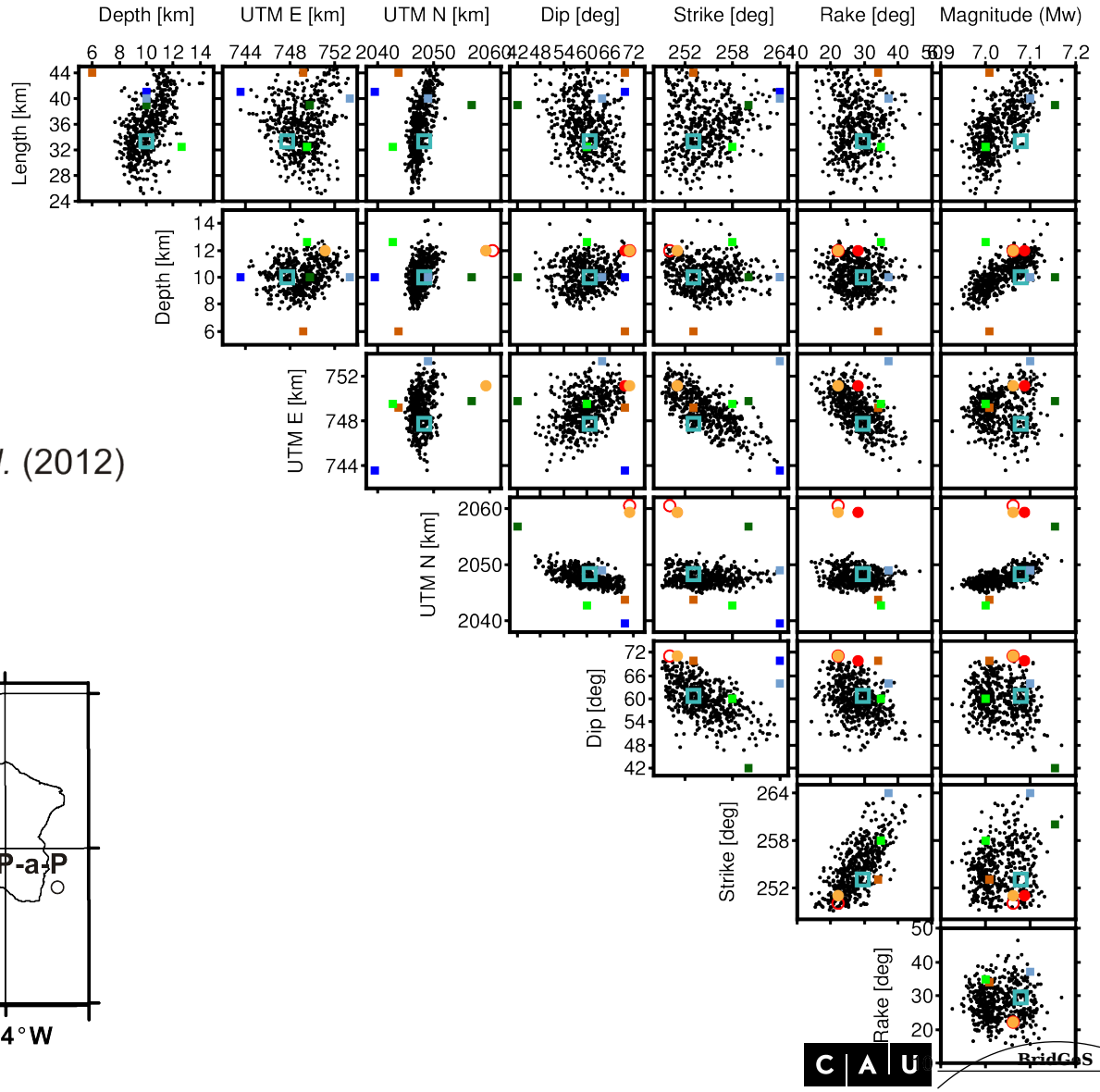
2012 MCMC results for Haiti

seismic data only
- gCMT parameters,
- after Nettles *et al.* (2010),
- after Heimann *et al.* (2011),

geodetic data only
- after Hashimoto *et al.* (2011),
- after Calais *et al.* (2010),

geodetic & seismic data
- after Hayes *et al.* (2010),
- after Mercier de Lepinay *et al.* (2012)
- This study



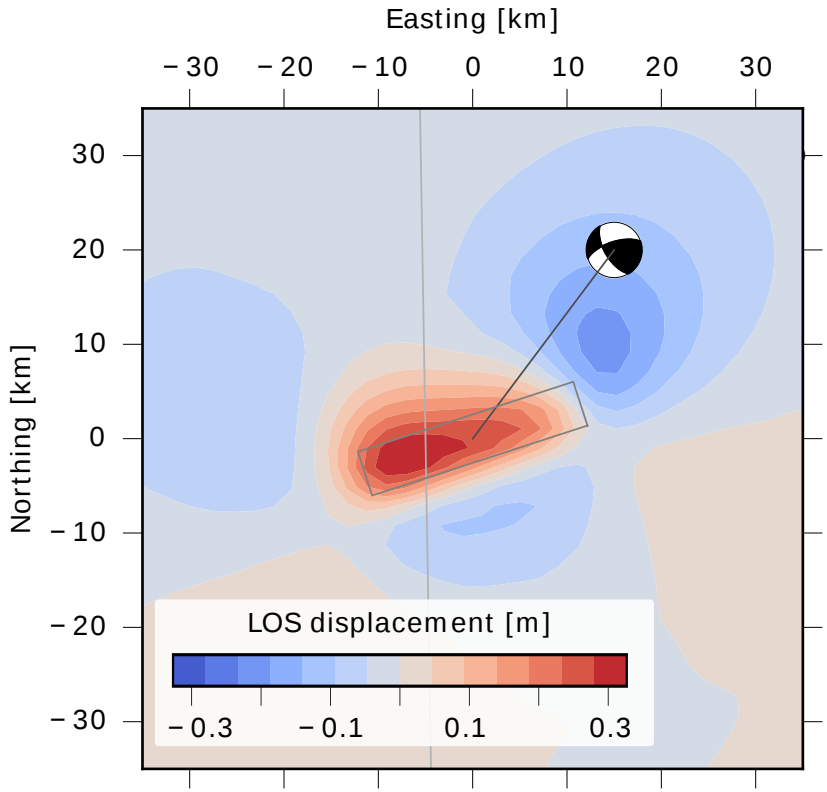


Outline

- Problems of the modelling
- Changes in the forward modelling
- Data weighting and bootstrapping (!)
- New results on the Haiti source
- Outlook

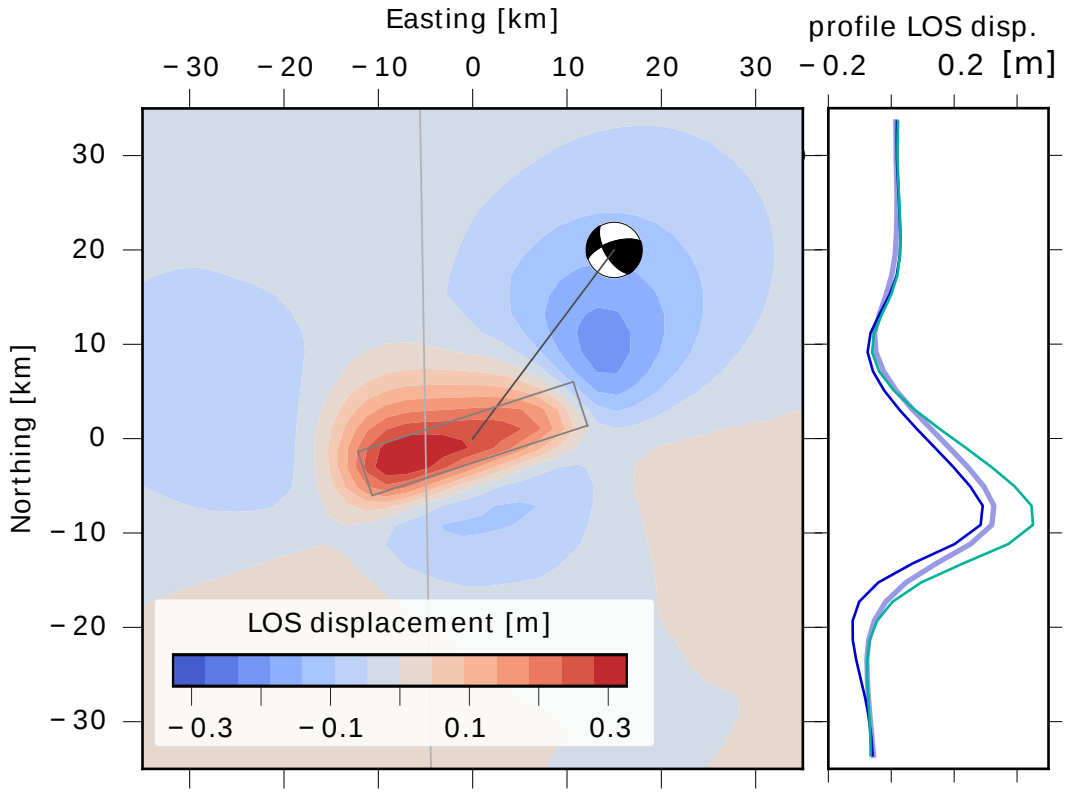
Medium

Rectangular slip-defined seismic source



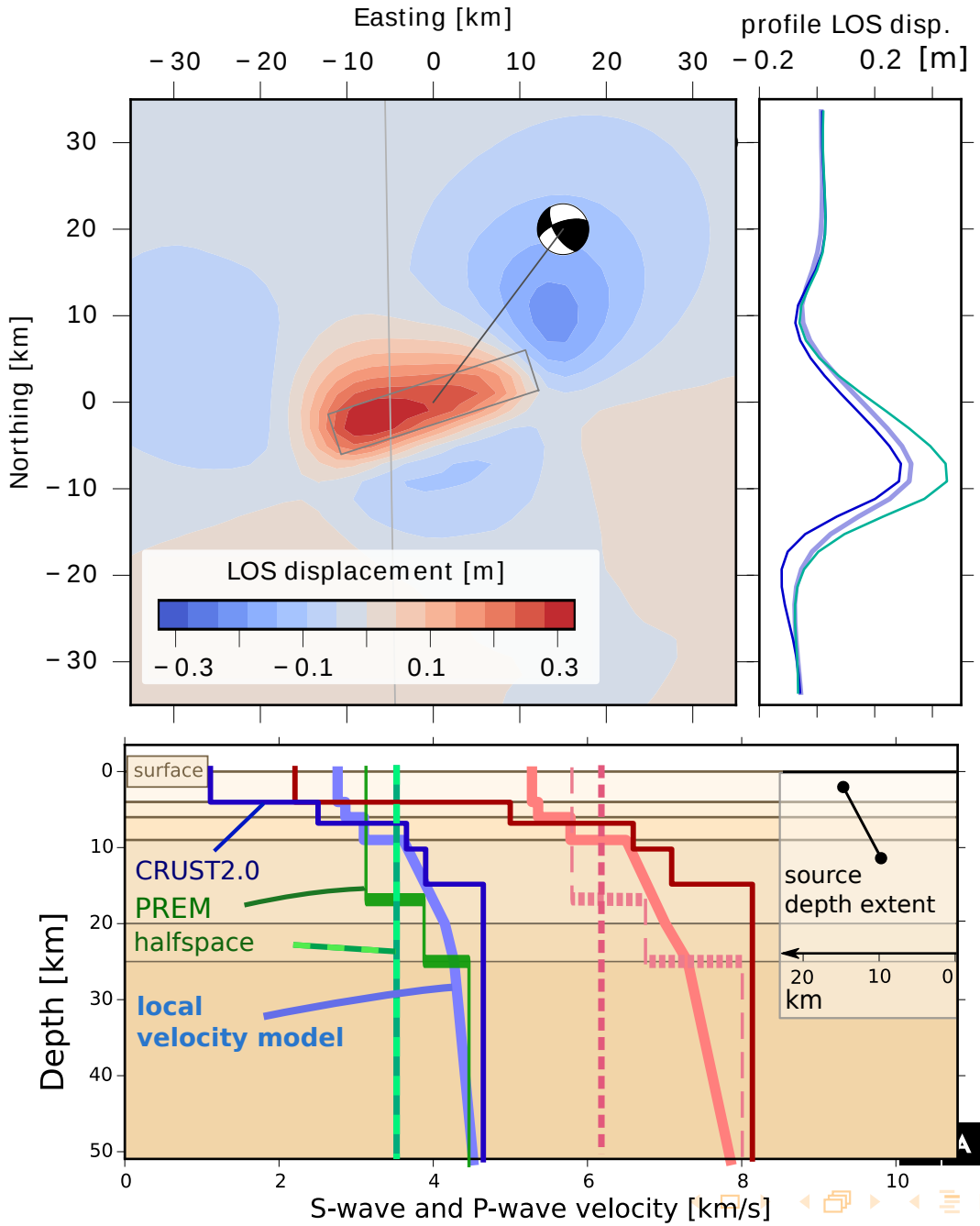
Medium

Rectangular slip-defined seismic source



Medium

Rectangular slip-defined seismic source

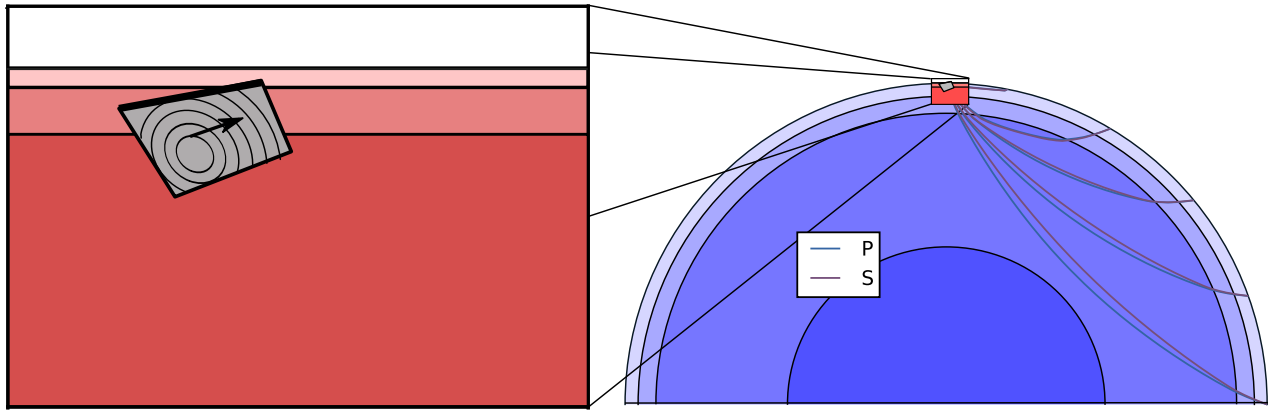


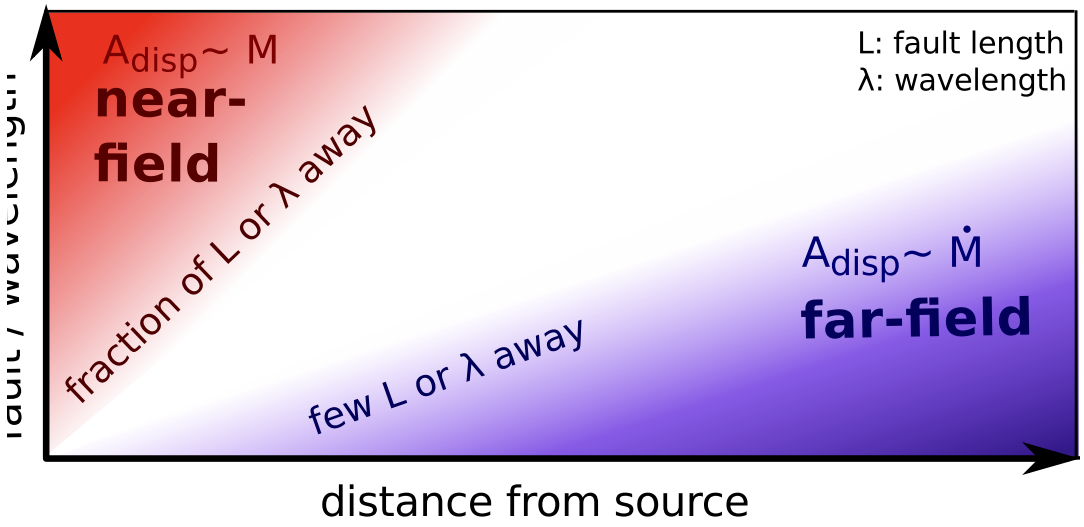
Mismodelling

MCMC relies on good (realistic and Gaussian) estimates of the mismodelling to include in the Covariance matrix. But where can we buy it?

Medium & source models harmonized in pyrocko

rectangular rupture model
layered 1d velocity model





Green's function methods used:

- Qseis/QSSP for waveforms
- PSGRN for static displacements

by Wang et al.,
http://www.gfz-potsdam.de/en/section/physics-of-earthquakes-and-volcanoes/data-products-services/downloads-software/

Objective functions for combined data

waveform targets: weighted misfit of data group X_1 in bootstrap chain b_1

data group misfit vector * noise weight vector * target-balancing weight vector * chain b_1 bootstrap weight vector * manual weights

satellite targets: weighted misfit of data group X_3 in bootstrap chain b_1

(data group misfit vector + chain b_1 bootstrap correlated noise) * noise weight vector * manual weights

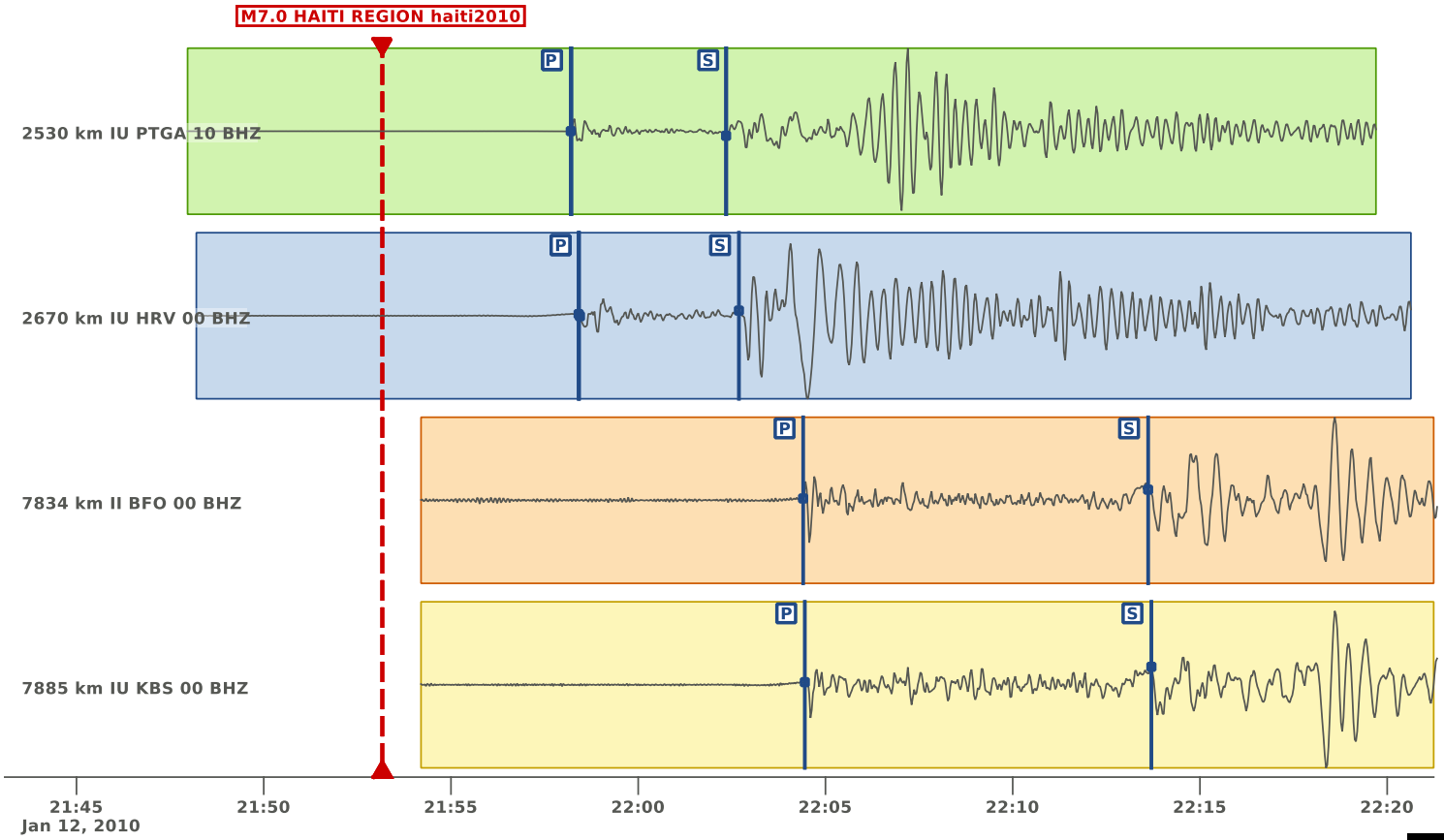
campaign GNSS targets: weighted misfit of data group X_4 in bootstrap chain b_1

chain b_1 bootstrap weight vector * manual weights * noise weight vector * (chain b_1 bootstrap correlated noise + data group misfit vector)

waveform weighting and bootstrapping

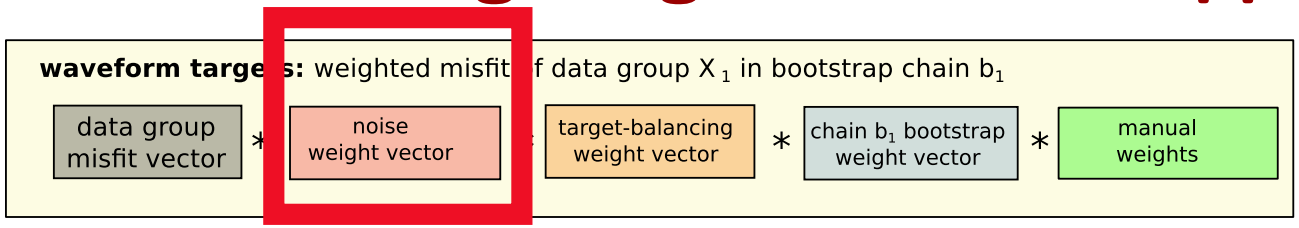
waveform targets: weighted misfit of data group X_1 in bootstrap chain b_1

data group misfit vector * noise weight vector * target-balancing weight vector * chain b_1 bootstrap weight vector * manual weights

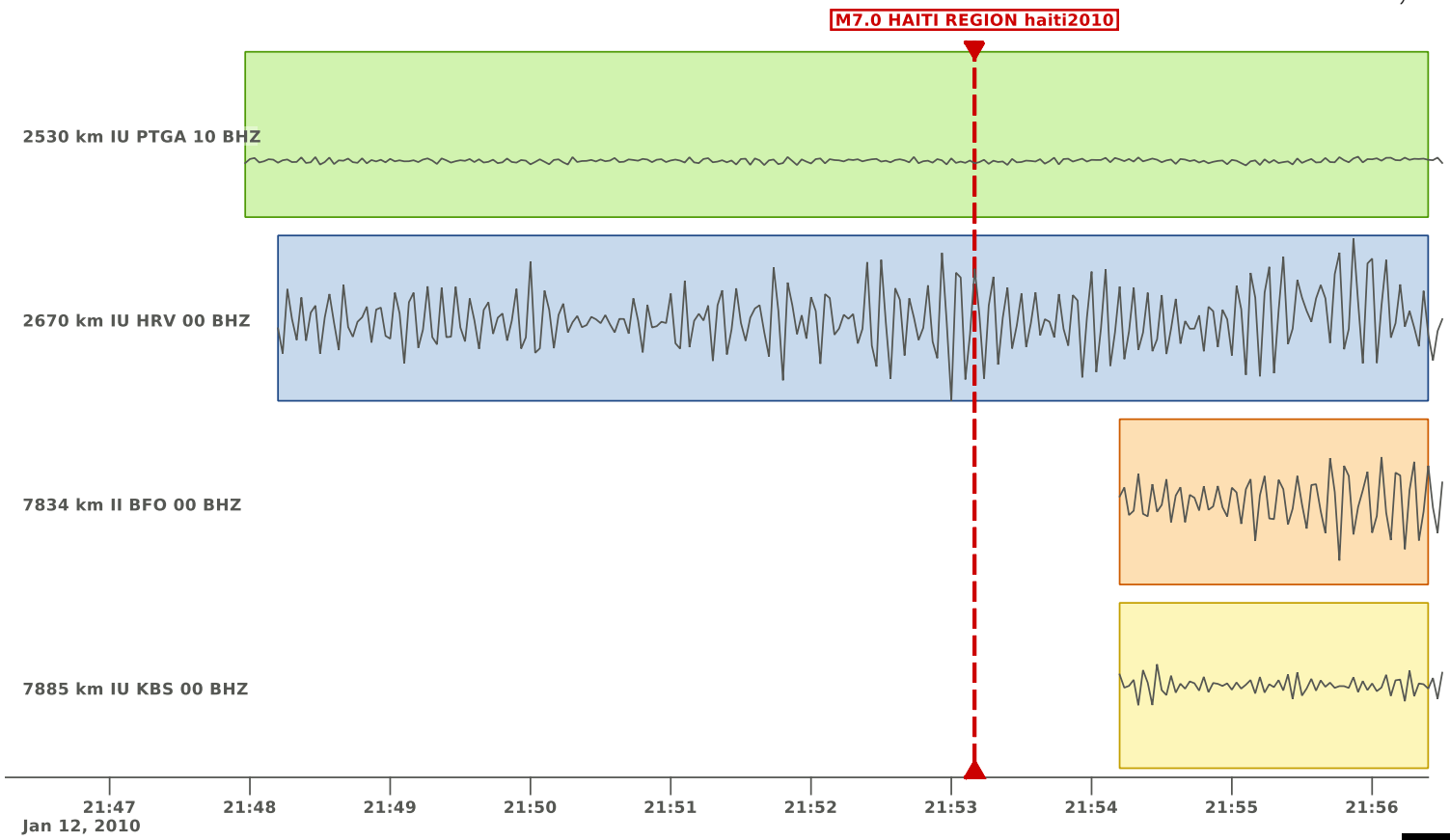


Seismograms of the 2010 Haiti earthquake (viewer: pyrocko snuffler)

waveform weighting and bootstrapping



$$w_{i,noise} = \frac{1}{\mathrm{var}(d_{noise})}$$



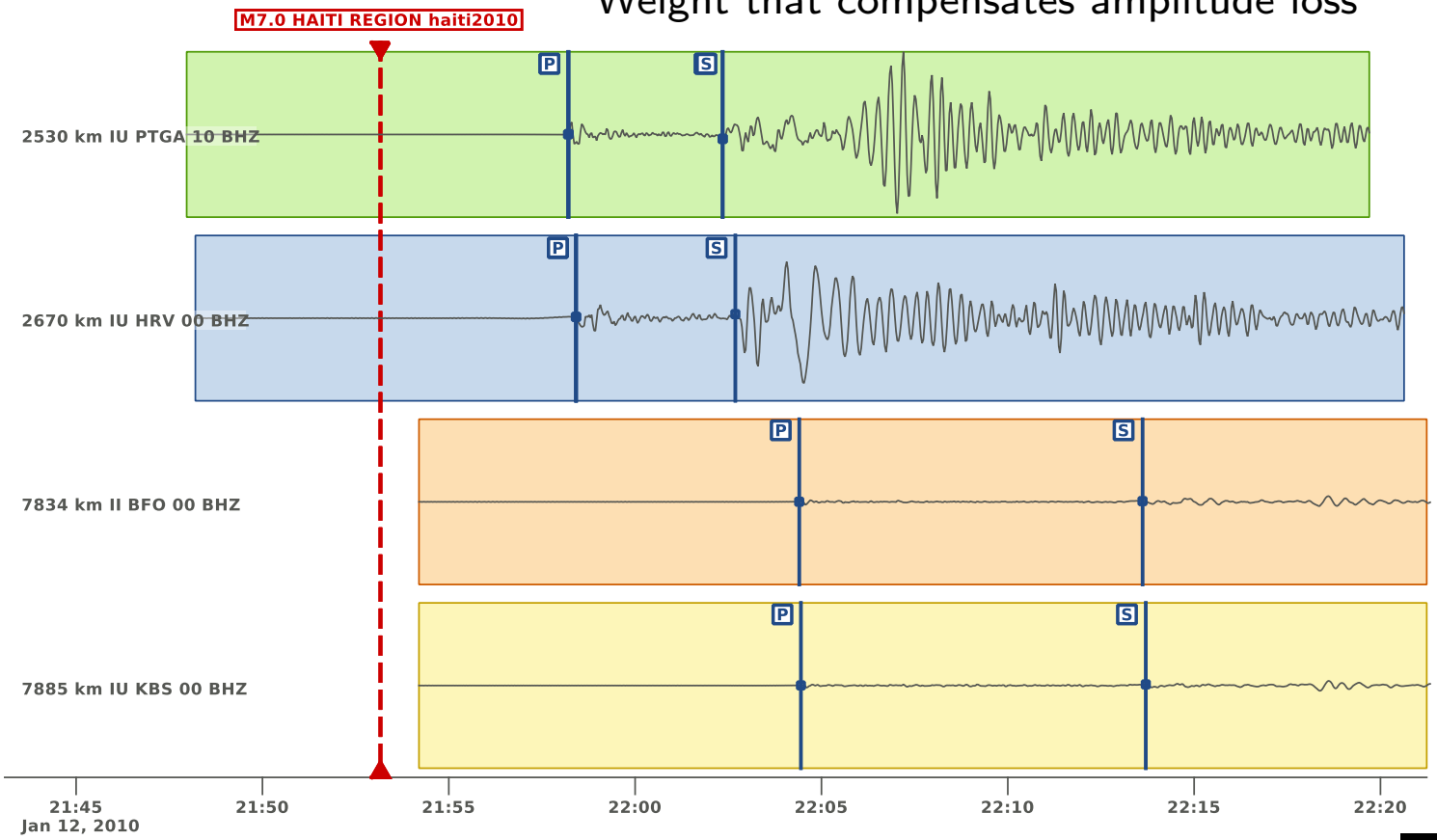
Seismograms of the 2010 Haiti earthquake (viewer: pyrocko snuffler)

waveform weighting and bootstrapping

waveform targets: weighted misfit of data group X_1 in bootstrap chain b_1

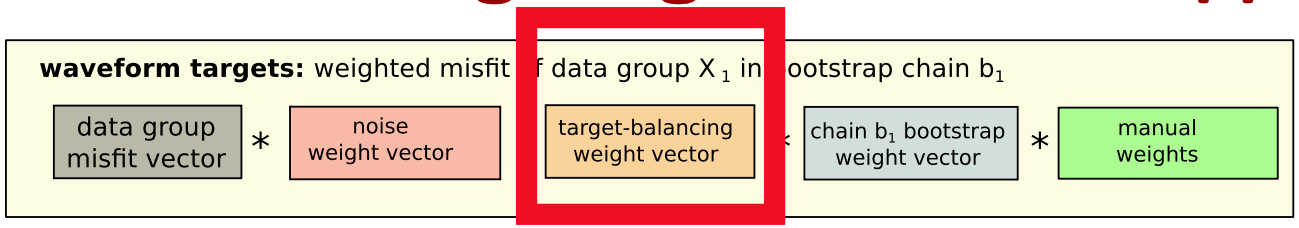
data group misfit vector * noise weight vector * target-balancing weight vector * chain b_1 bootstrap weight vector * manual weights

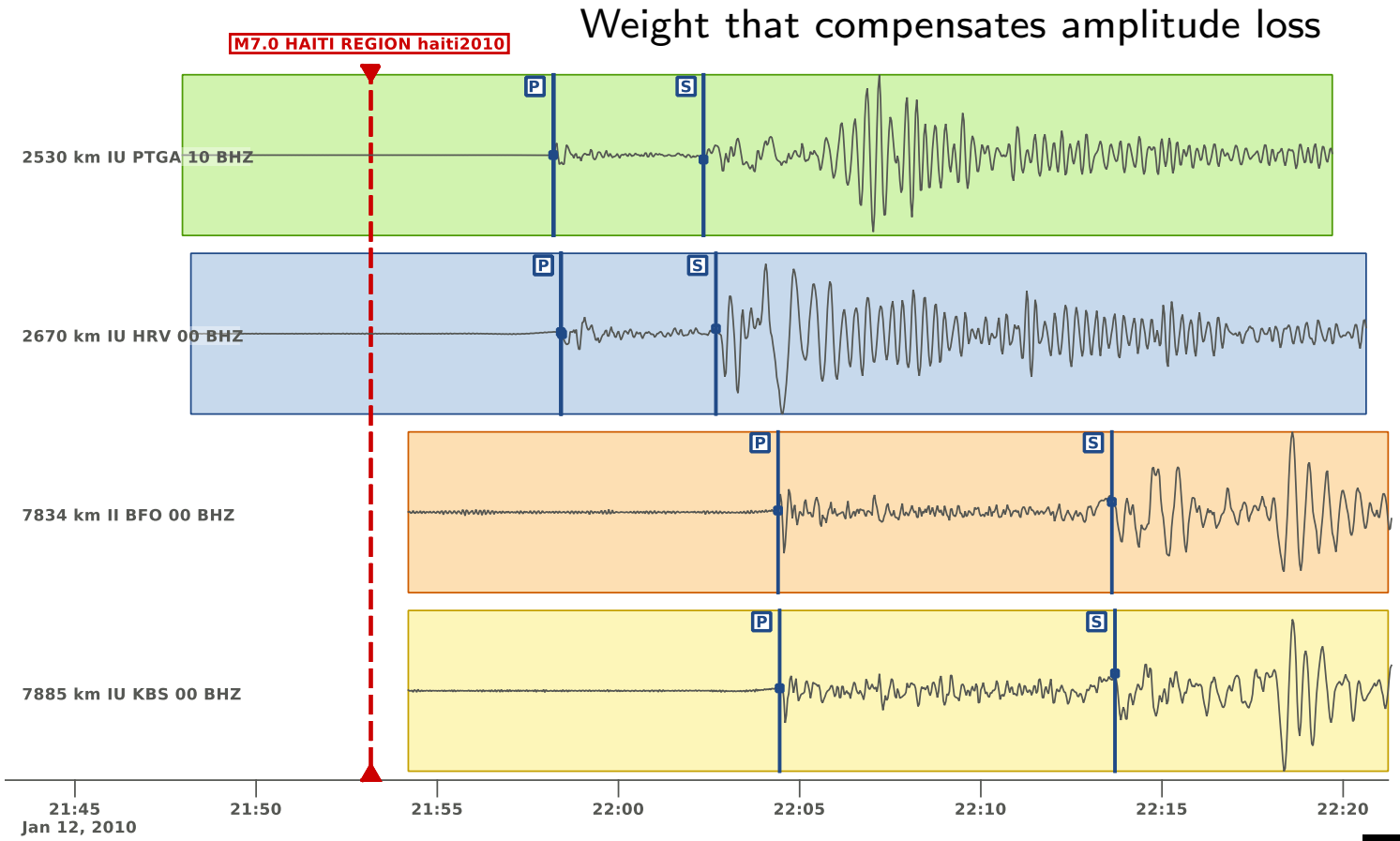
Weight that compensates amplitude loss



Seismograms of the 2010 Haiti earthquake (viewer: pyrocko snuffler)

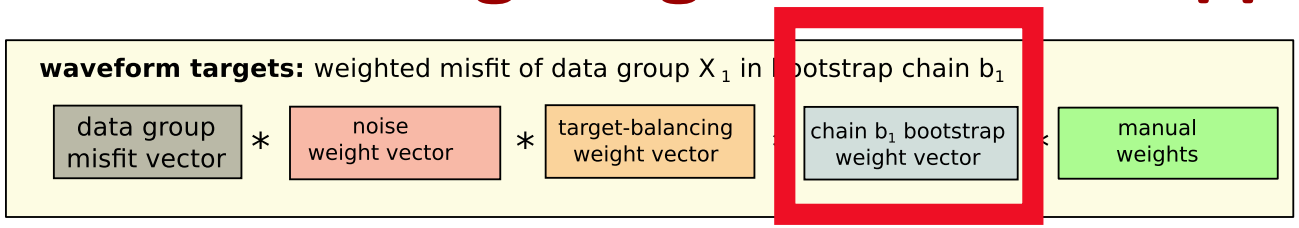
waveform weighting and bootstrapping

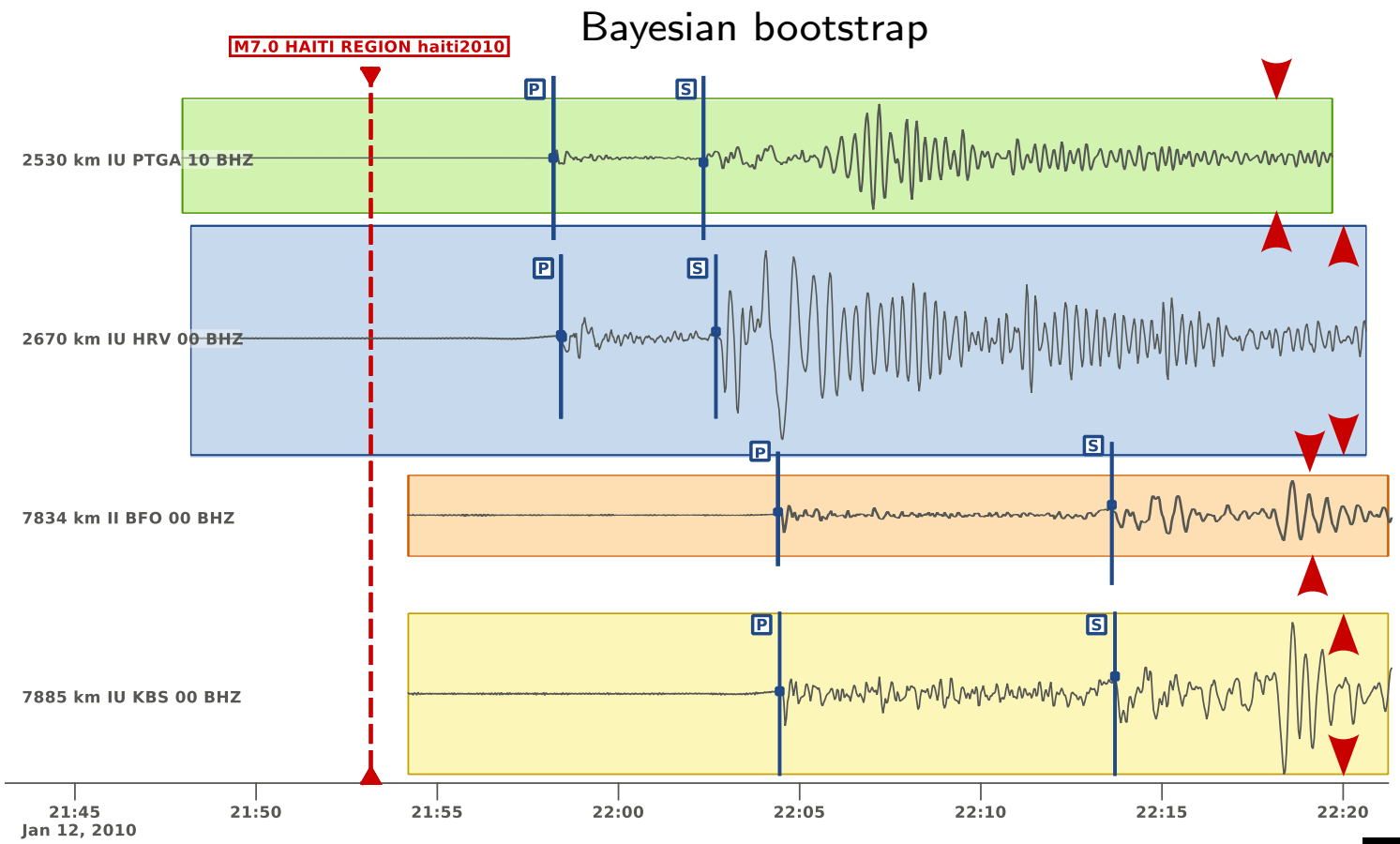




Seismograms of the 2010 Haiti earthquake (viewer: pyrocko snuffler)

waveform weighting and bootstrapping





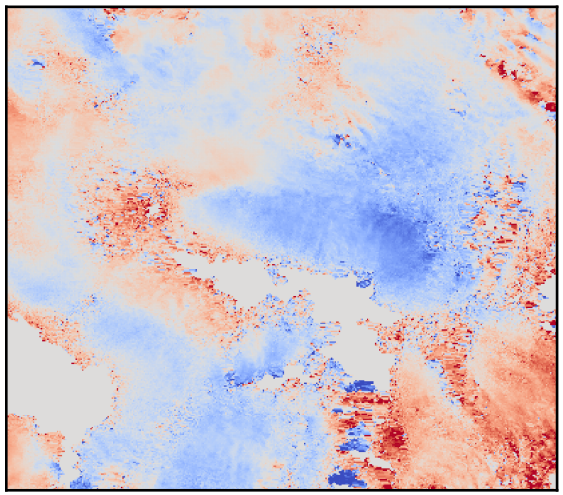
Seismograms of the 2010 Haiti earthquake (viewer: pyrocko snuffler)

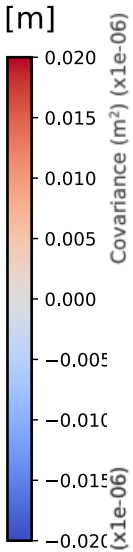
static displacement weighting and bootstrapping

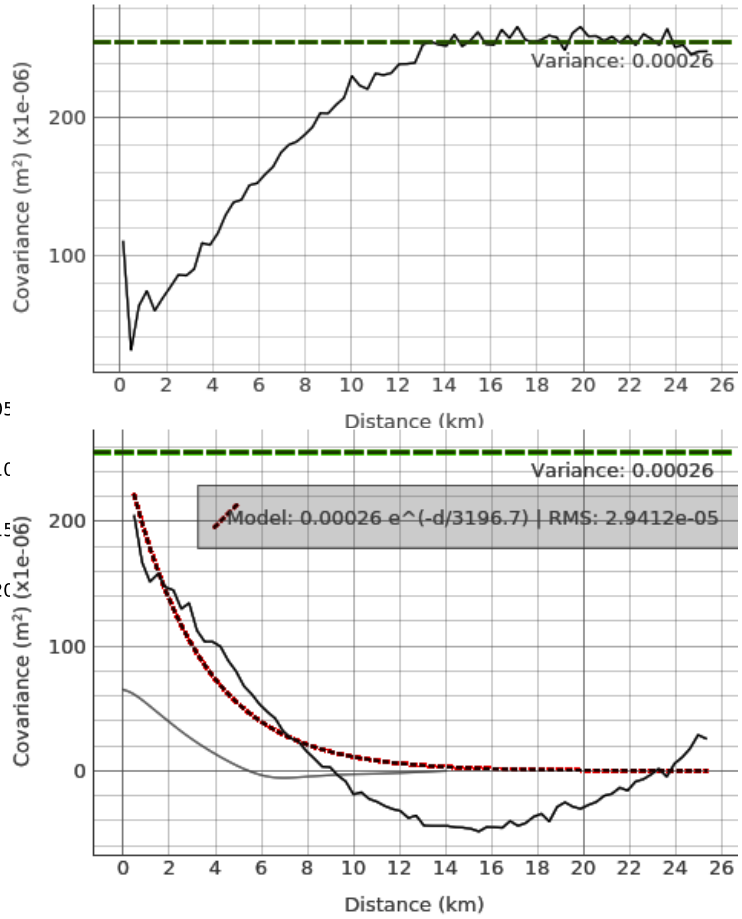
satellite targets: weighted misfit of data group X_3 in bootstrap chain b_1

$$\left(\text{data group misfit vector} + \text{chain } b_1 \text{ bootstrap correlated noise} \right) \text{noise weight vector} * \text{manual weights}$$

A) Real data noise





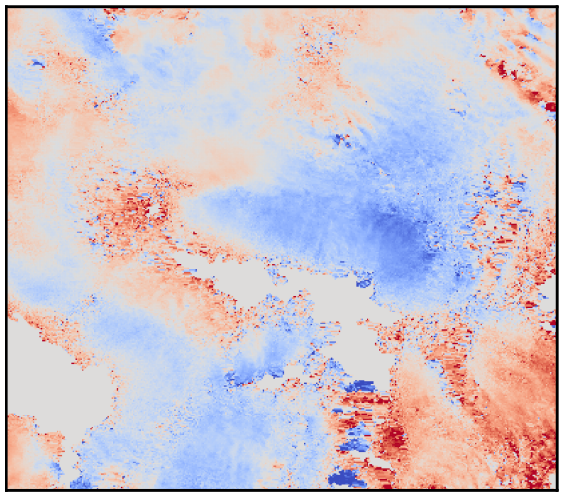


static displacement weighting and bootstrapping

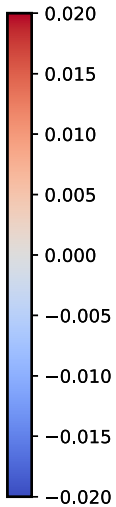
satellite target: weighted misfit of data group X_3 in bootstrap chain b_1

$$\left(\text{data group misfit vector} \cdot \text{chain } b_1 \text{ bootstrap correlated noise}\right) * \text{noise weight vector} * \text{manual weights}$$

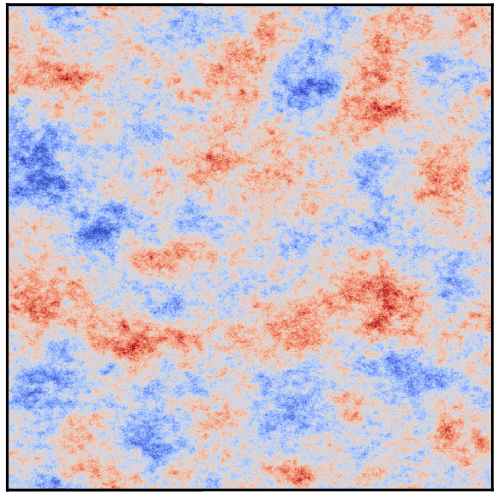
A) Real data noise



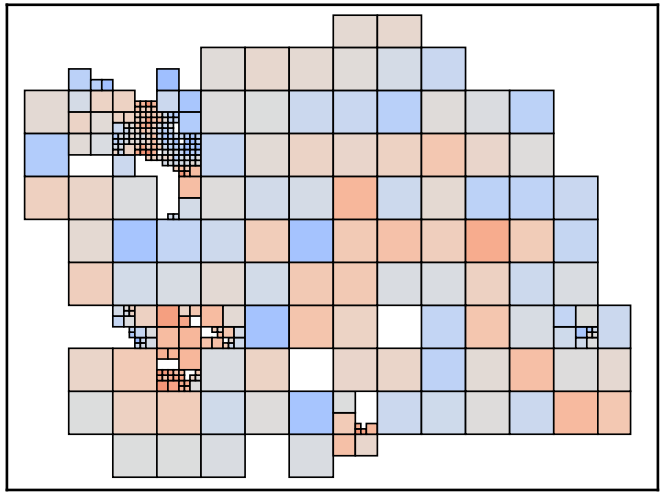
[m]



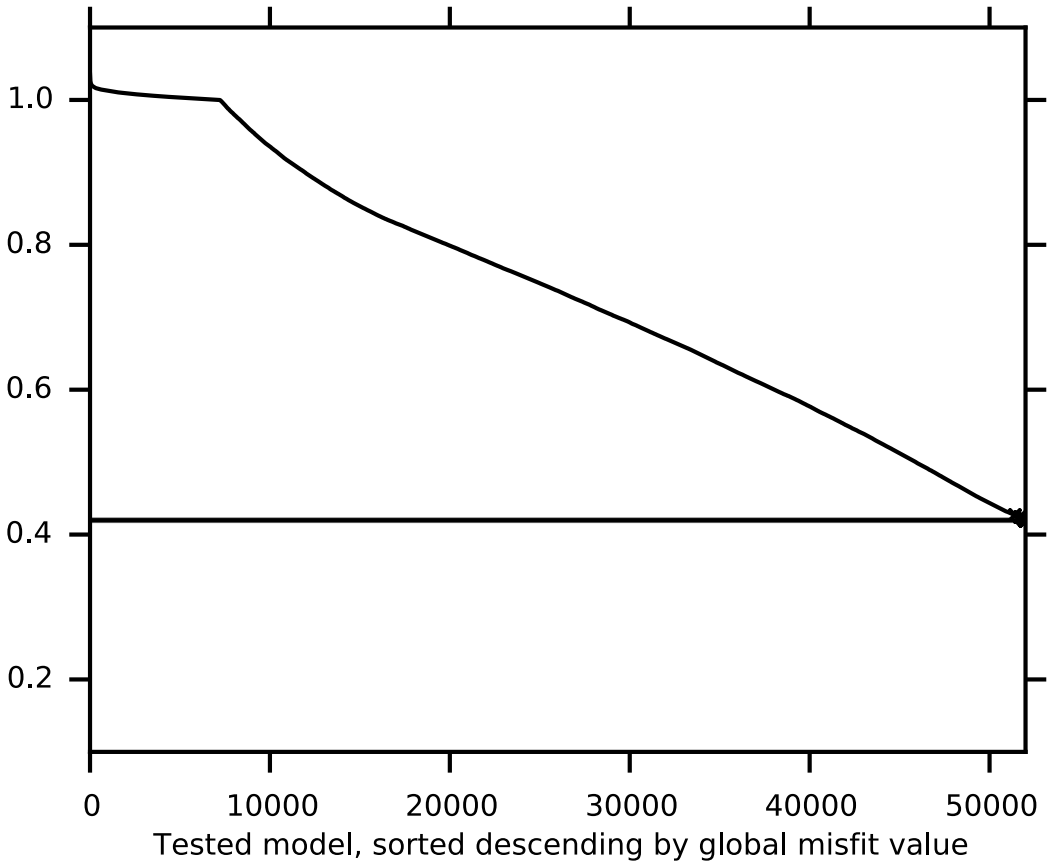
B) Synthesised noise



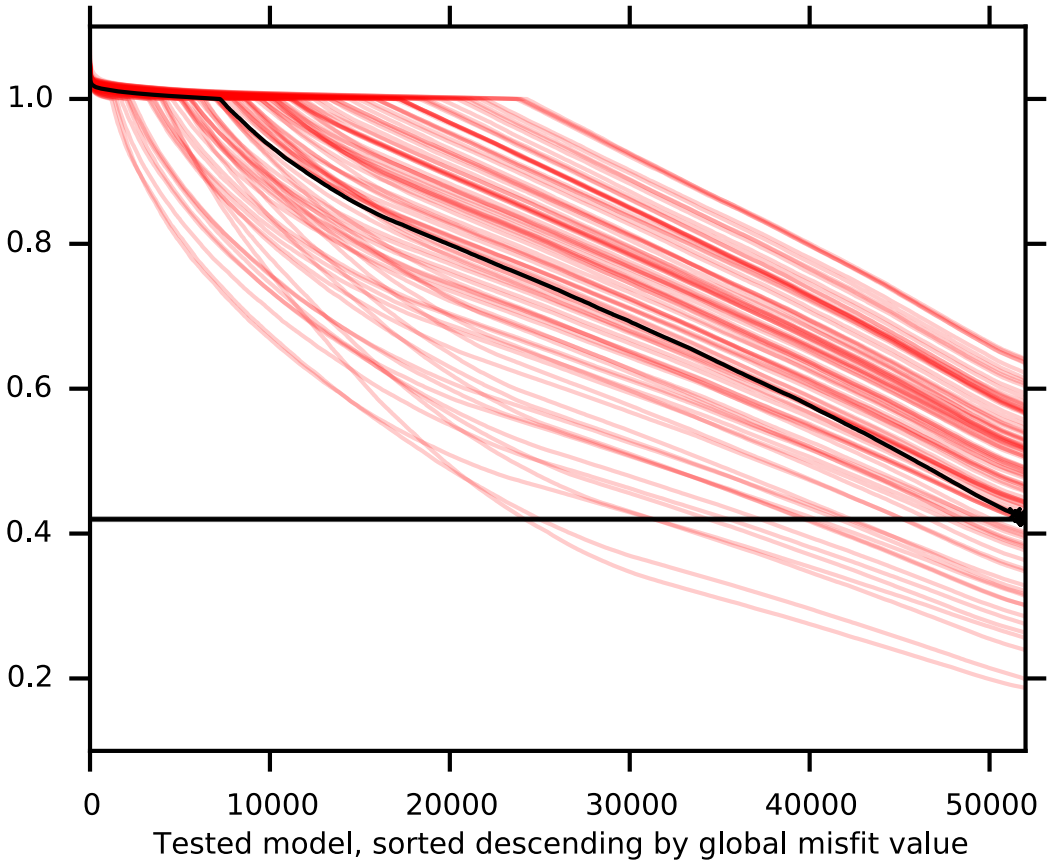
C) Data-like subsampled noise



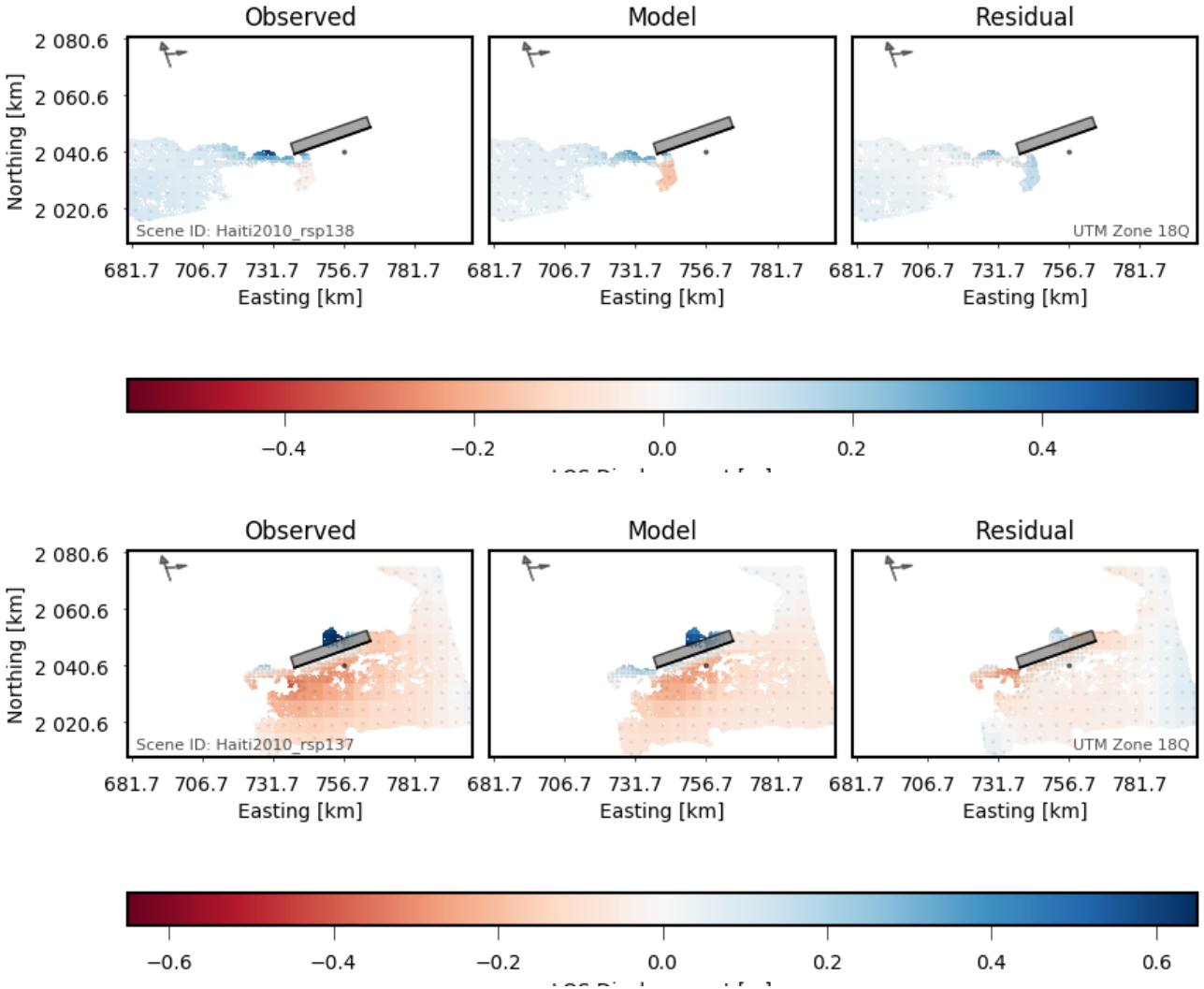
Bayesian bootstrap at work



Bayesian bootstrap at work

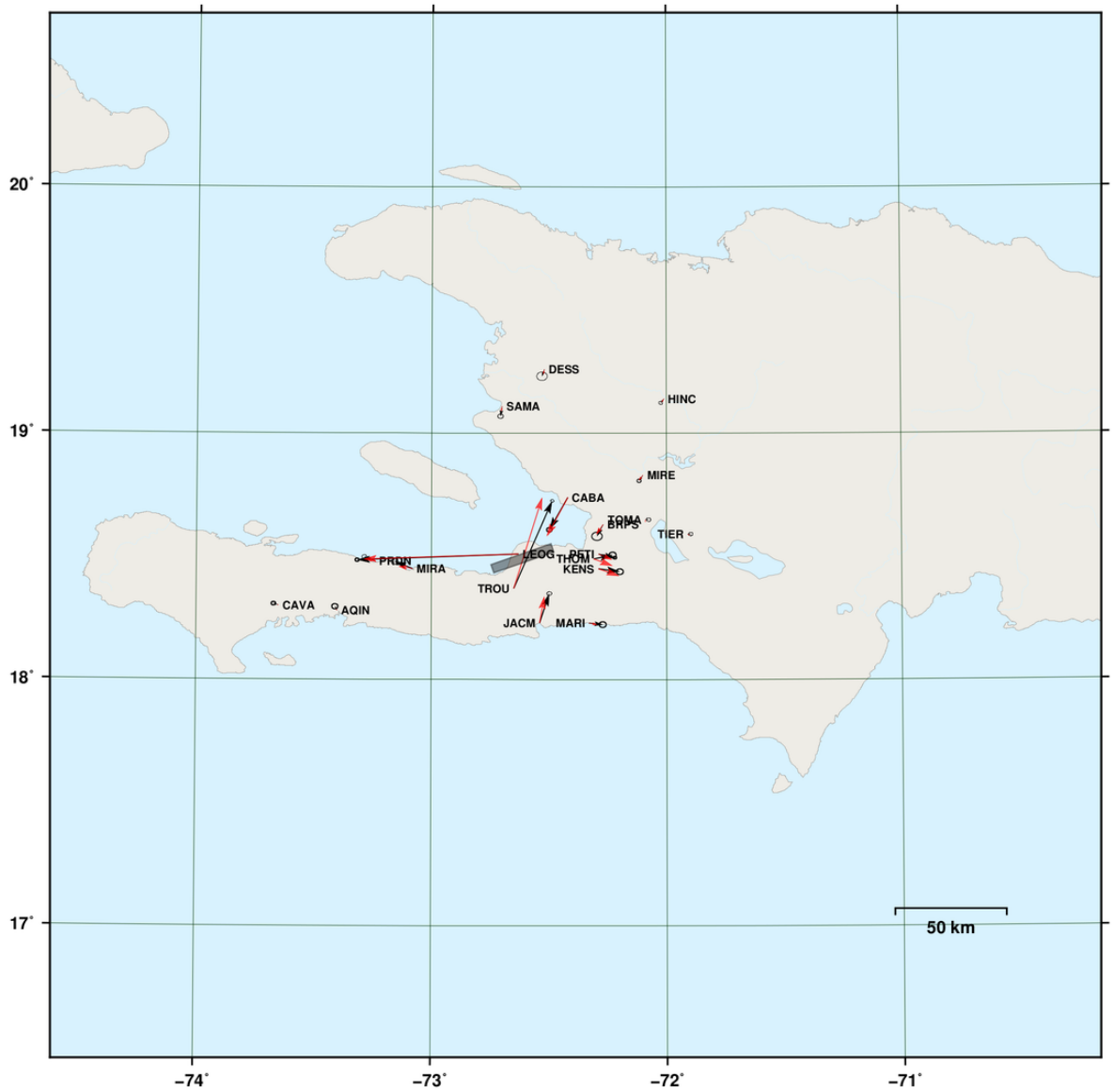


Fits - InSAR data

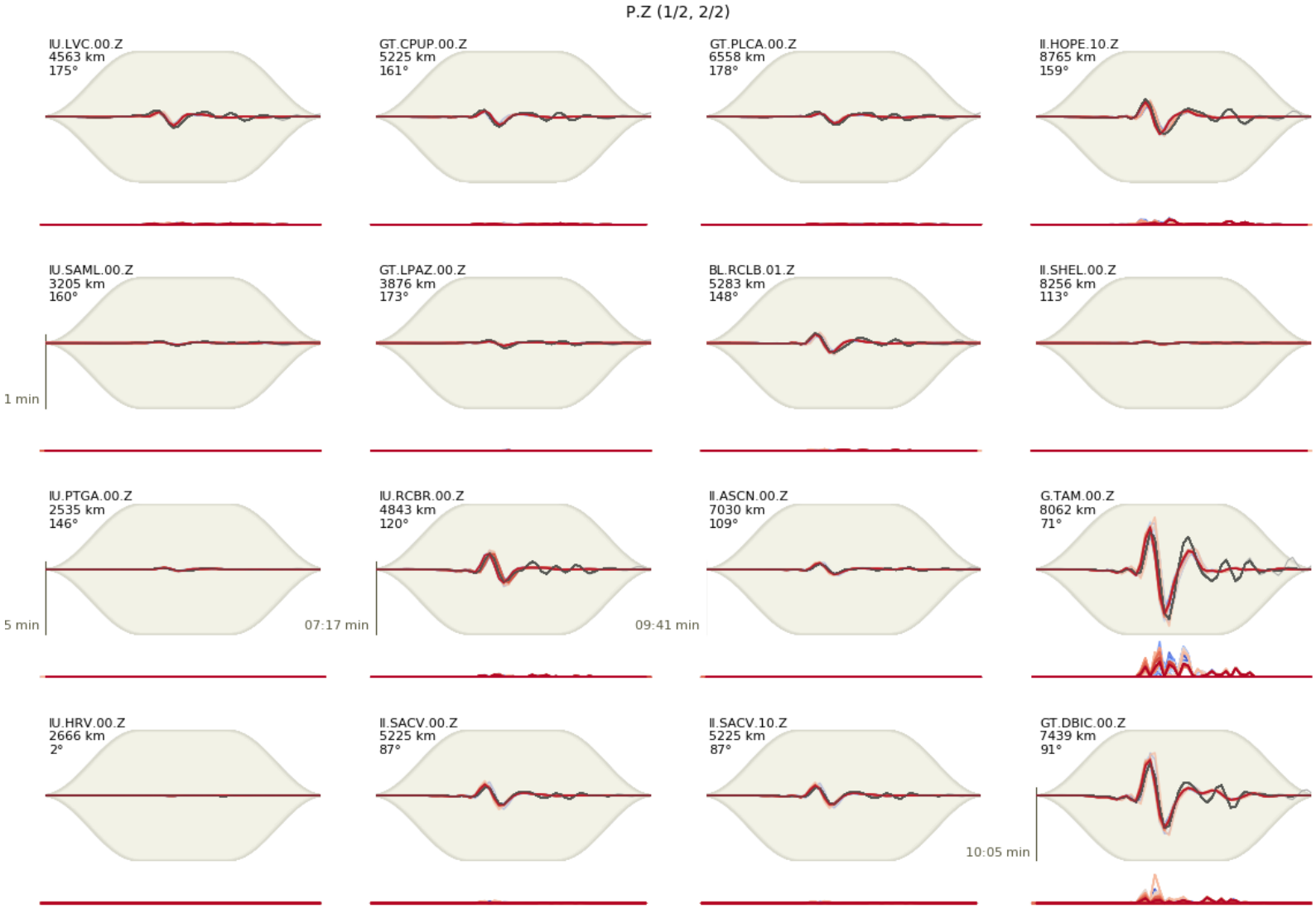


Fits - GPS

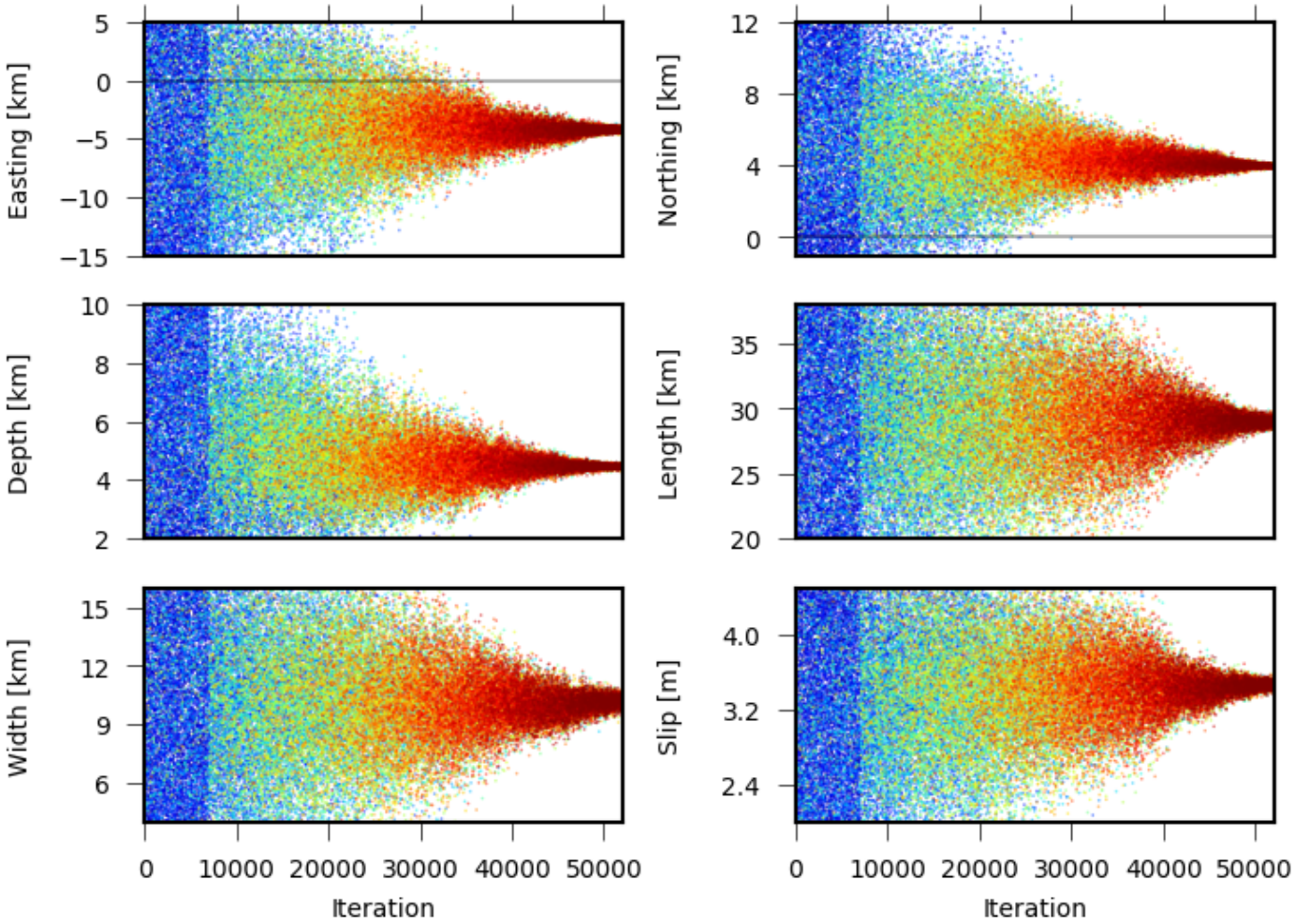
GPS from Calais et al. (2010)



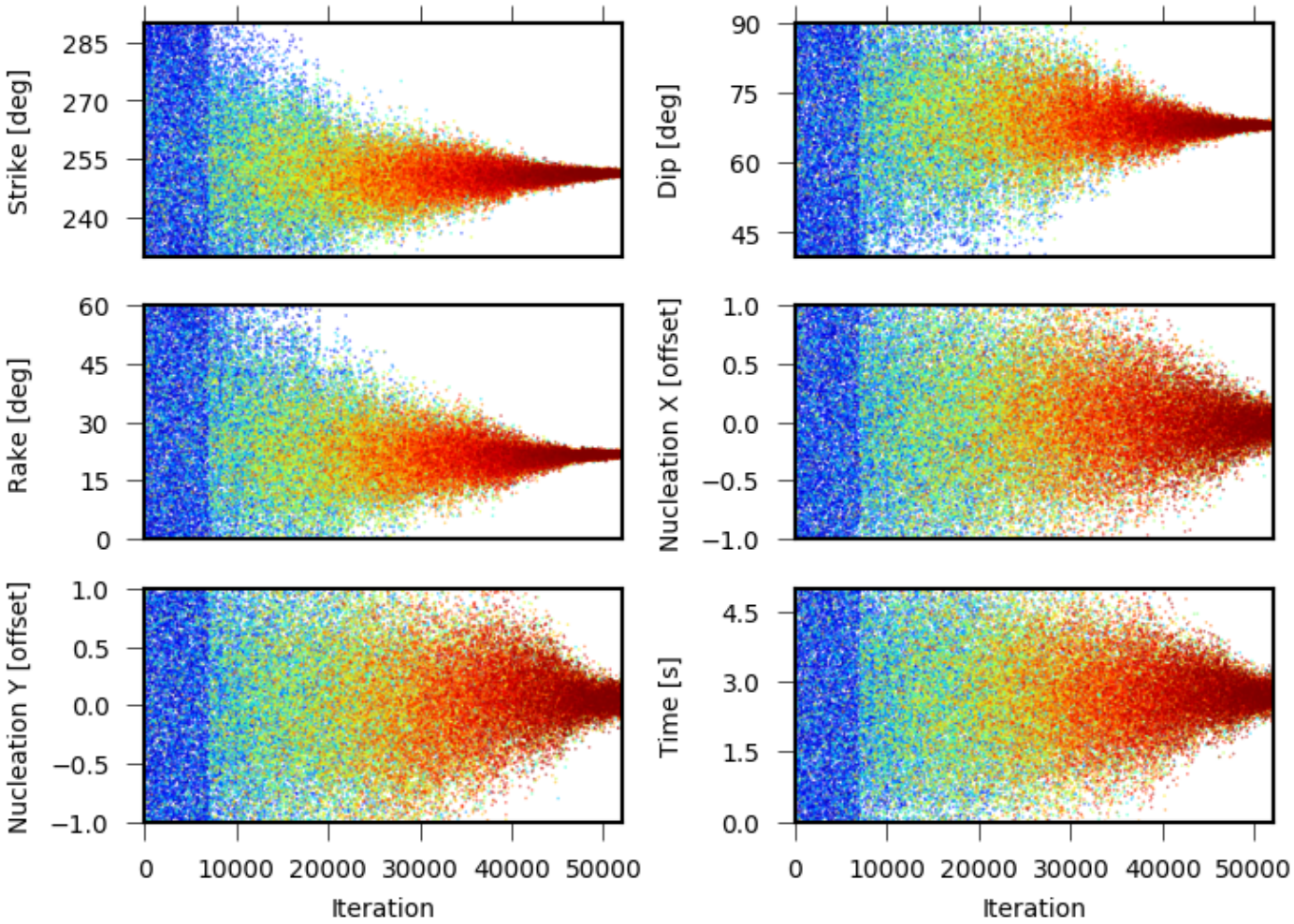
Fits - P waves


P.Z (1/2, 2/2)
IU.LVC.00.Z
4563 km
175°
GT.CPUP.00.Z
5225 km
161°
GT.PLCA.00.Z
6558 km
178°
II.HOPE.10.Z
8765 km
159°
IU.SAML.00.Z
3205 km
160°
GT.LPAZ.00.Z
3876 km
173°
BL.RCLB.01.Z
5283 km
148°
II.SHEL.00.Z
8256 km
113°
1 min
IU.PTGA.00.Z
2535 km
146°
IU.RCBR.00.Z
4843 km
120°
II.ASCN.00.Z
7030 km
109°
G.TAM.00.Z
8062 km
71°
5 min
07:17 min
09:41 min
IU.HRV.00.Z
2666 km
2°
II.SACV.00.Z
5225 km
87°
II.SACV.10.Z
5225 km
87°
GT.DBIC.00.Z
7439 km
91°
10:05 min

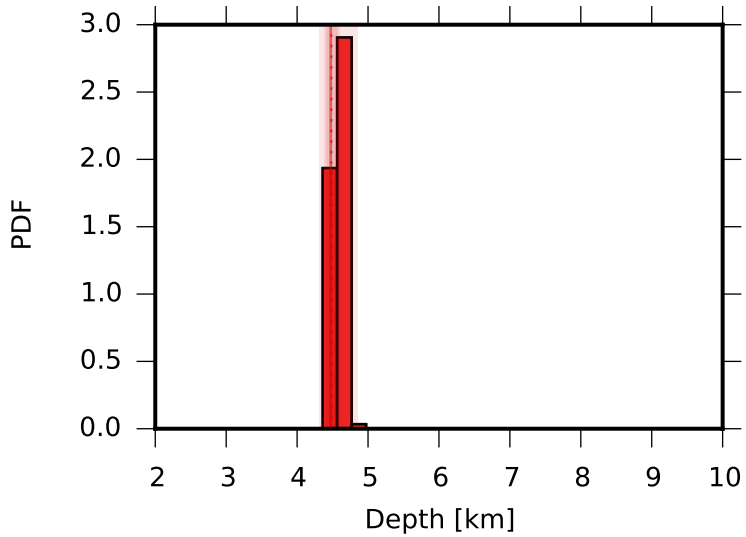
Parameter Convergence



Parameter Convergence



Marginals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0.5
0.0
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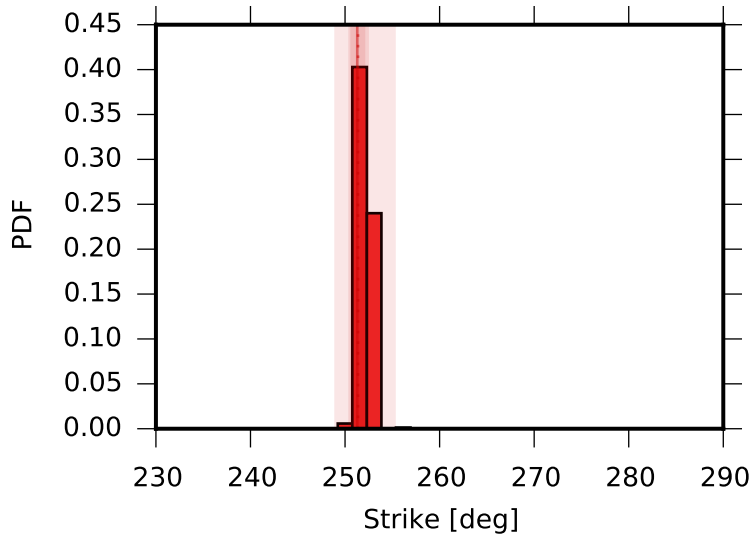
PDF
Strike [deg]
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0.00
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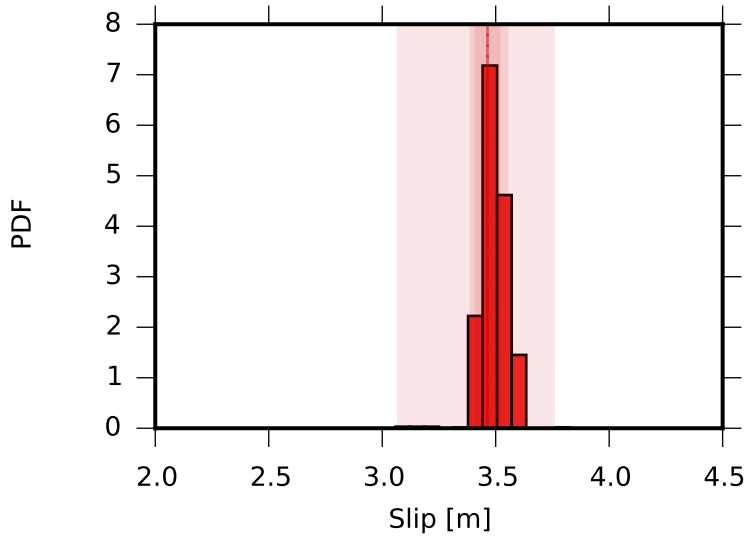
PDF
Slip [m]
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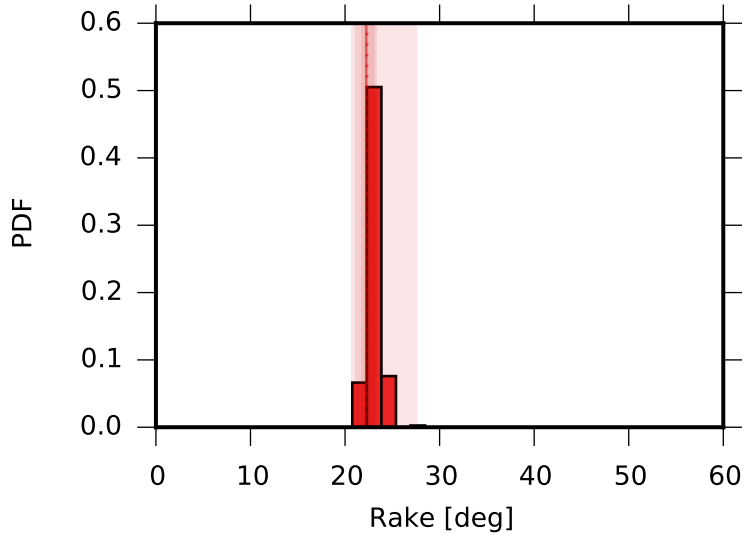
4.0
4.5


PDF
Rake [deg]
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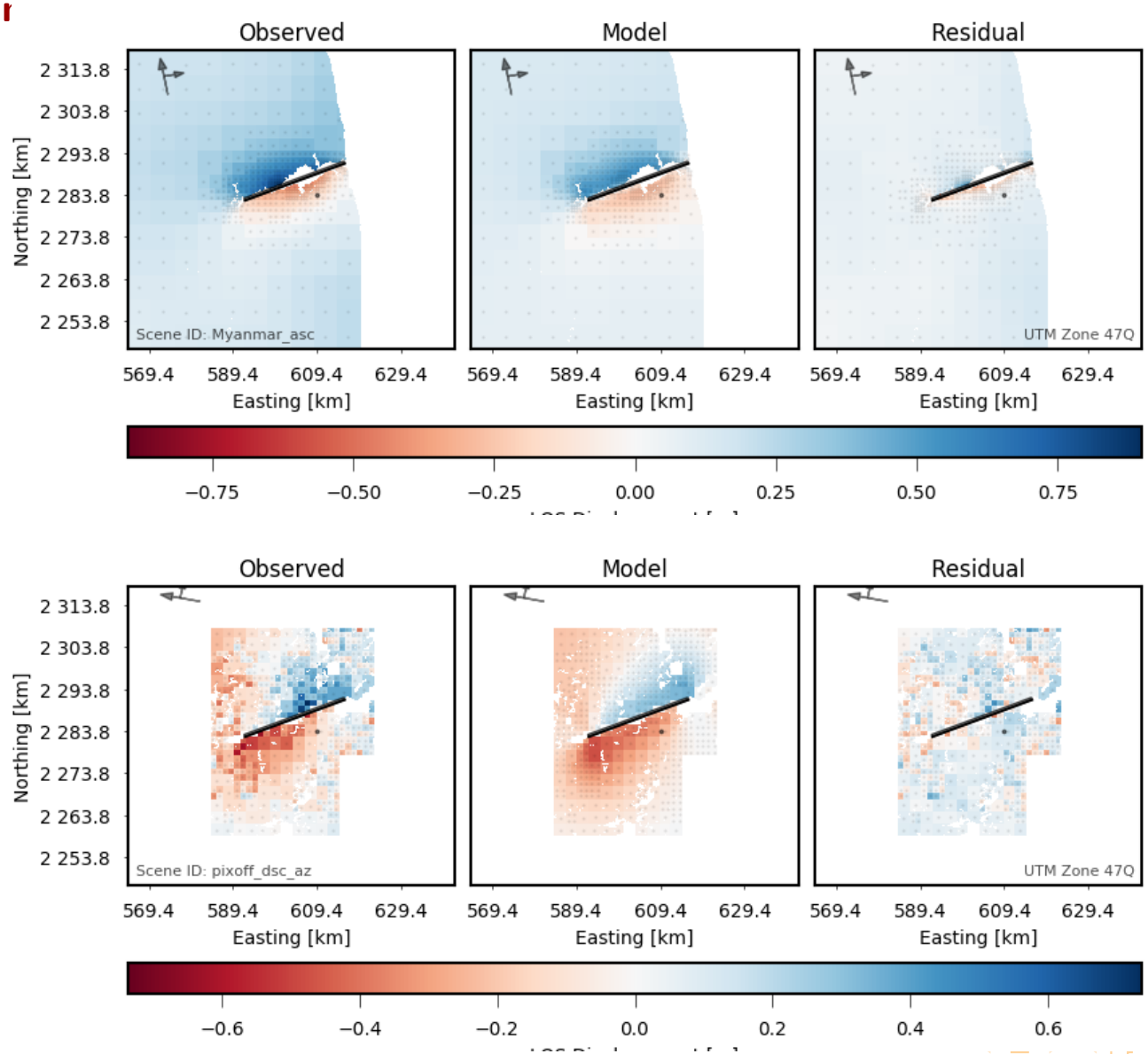
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
60

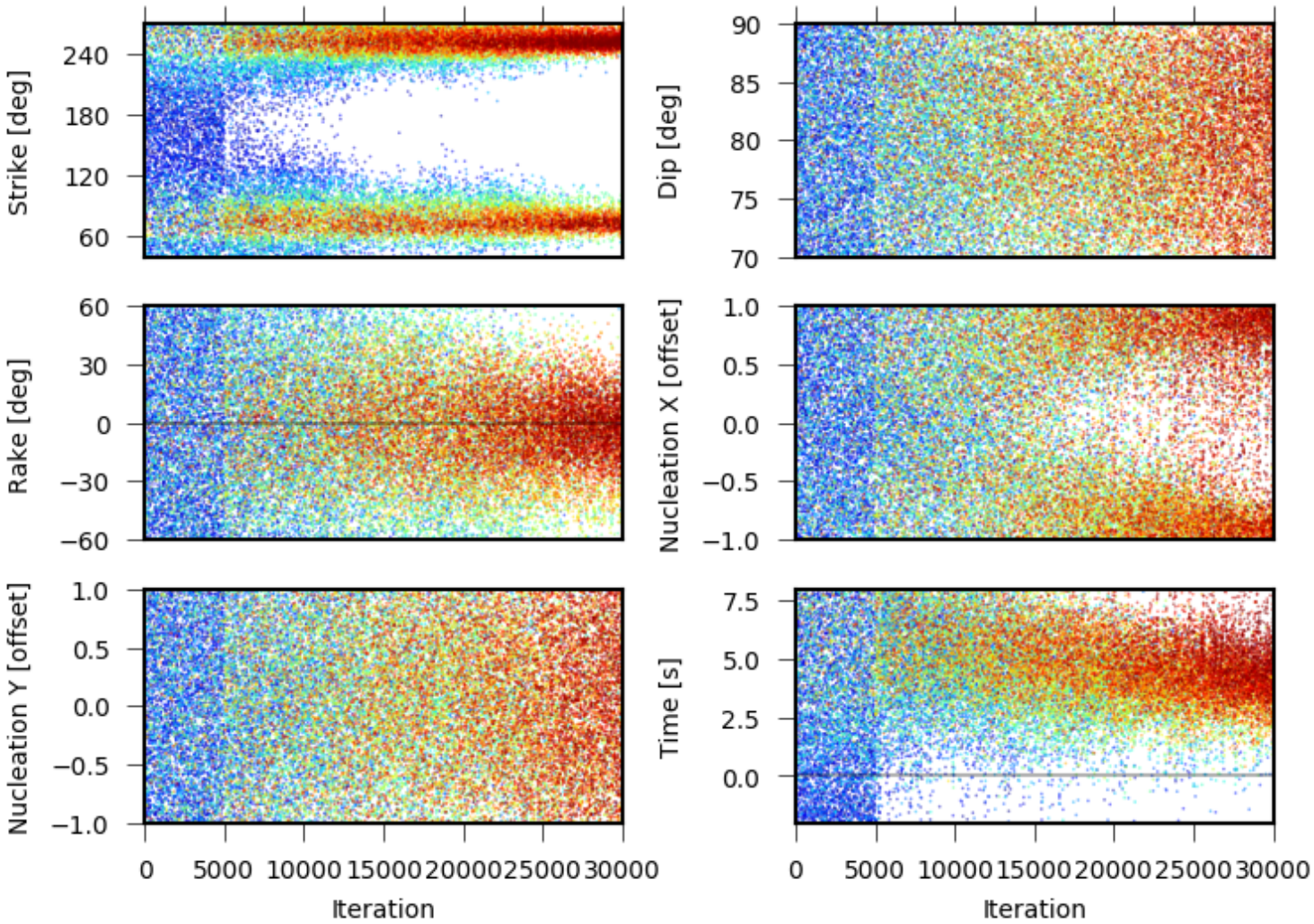
M6.8 Myanmar earthquake (24 Mar 2011)

Fits - Ir



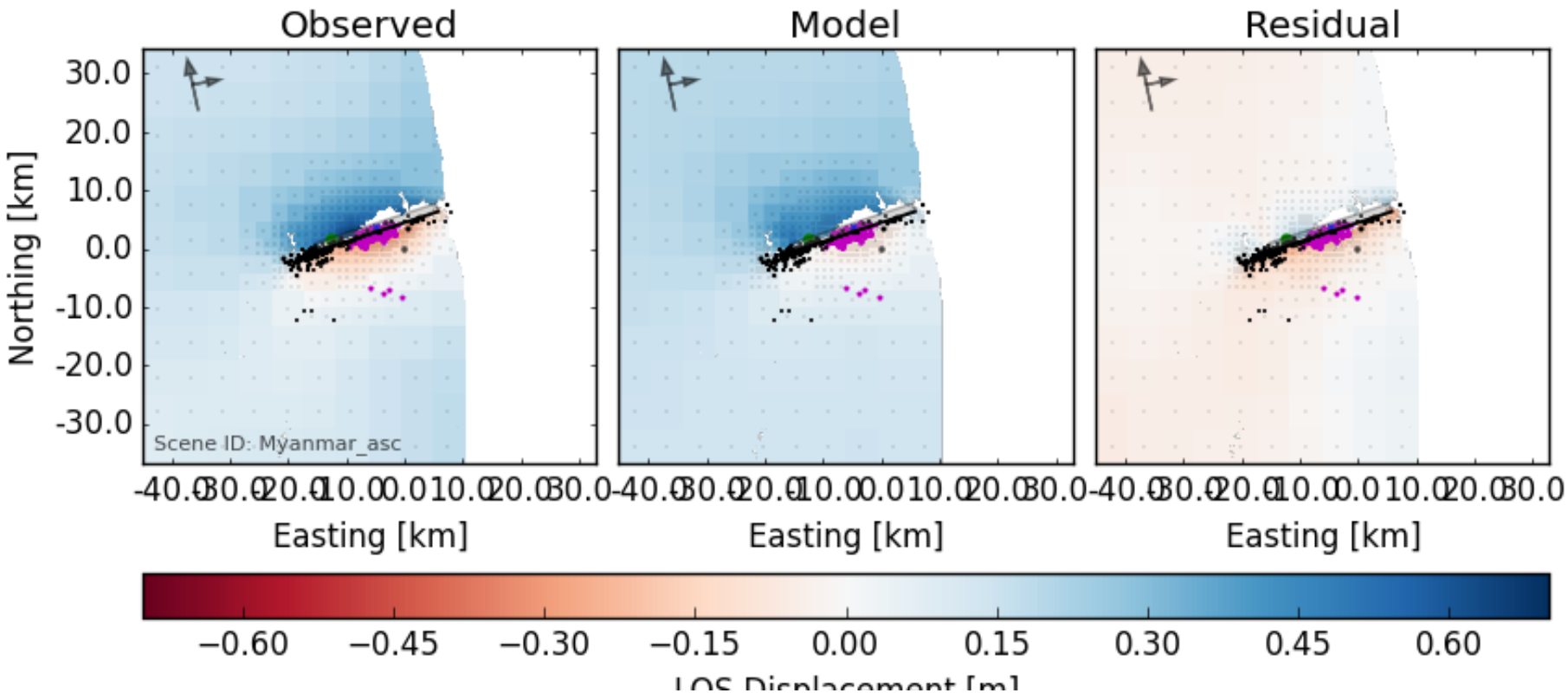
M6.8 Myanmar earthquake (24 Mar 2011)

Parameter Convergence



M6.8 Myanmar earthquake (24 Mar 2011)

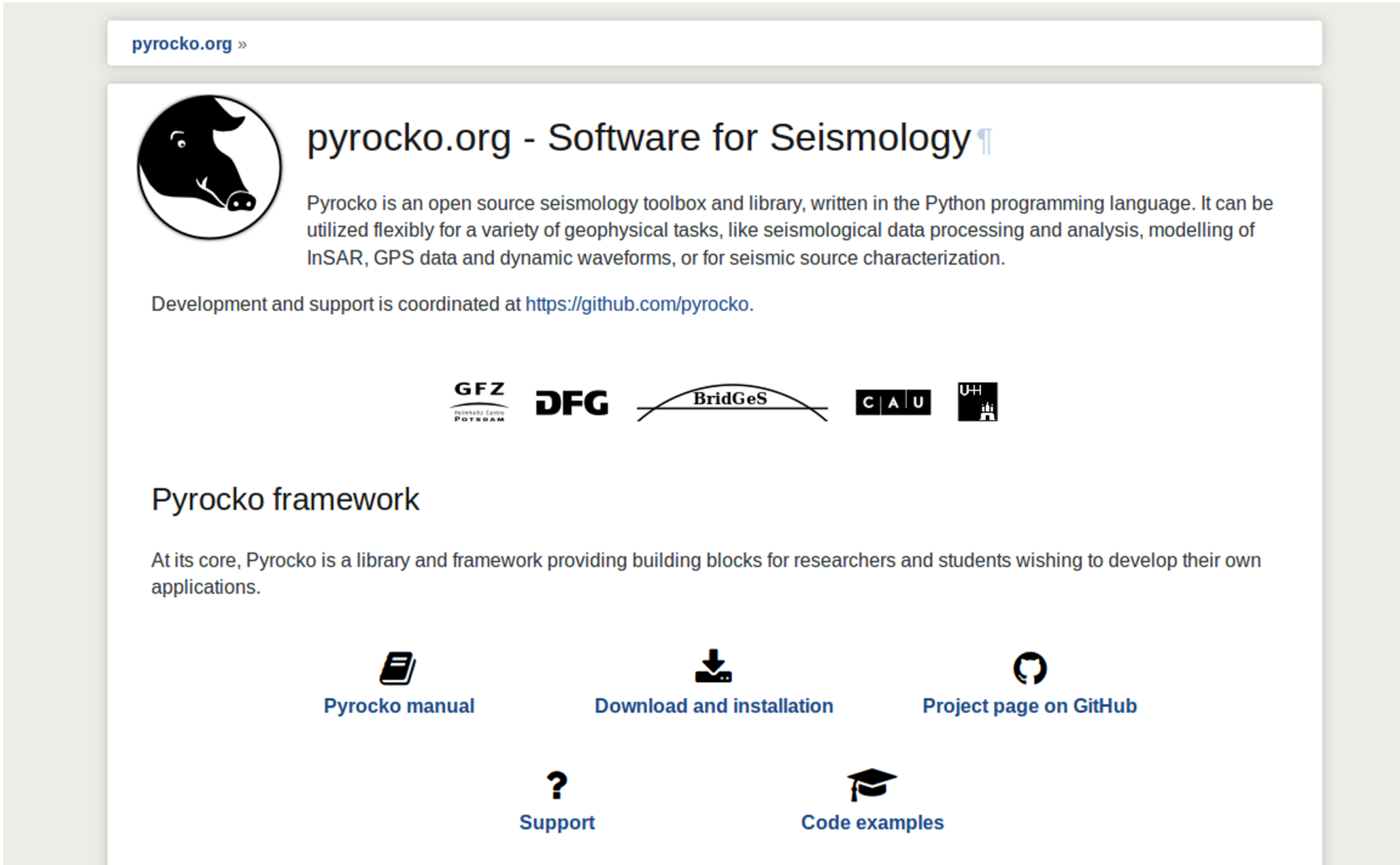
Epicenter solution



Summary

- We have a toolbox to easy and fast combine near-field and far-field data
- We get self-sustained, robust rupture models
- A lot of details are still to test

Check us out at



Match with aftershock results