Bridging Geodesy and Seismology

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

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The Haiti 2010 earthquake (a short catch up)
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ALOS (RSP 137), acquisitions on 2008/09/02 and 2010/14/02

LOS displacement [m]
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

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

rectangle 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

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waveform weighting and bootstrapping

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Seismograms of the 2010 Haiti earthquake (viewer: pyrocko snuffler)
waveform weighting and bootstrapping

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Weight that compensates amplitude loss

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Weight that compensates amplitude loss

Seismograms of the 2010 Haiti earthquake (viewer: pyrocko snuffler)
waveform weighting and bootstrapping

Bayesian bootstrap

Seismograms of the 2010 Haiti earthquake (viewer: pyrocko snuffler)
static displacement weighting and bootstrapping

A) Real data noise
static displacement weighting and bootstrapping

A) Real data noise

B) Synthesised noise

C) Data-like subsampled noise

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

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- chain $b_1$ bootstrap correlated noise
- noise weight vector
- manual weights
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)
  - R.J. LVC 00 Z 4563 km 172°
  - G.T. CPUP 00 Z 5225 km 161°
  - G.T. PLCU 00 Z 6558 km 170°
  - G.T. HOPE 10 Z 8765 km 159°

- R.J. SAML 00 Z 3305 km 160°
  - G.T. LPAZ 00 Z 3976 km 173°
  - B.L. RCBL 01 Z 5223 km 140°
  - G.T. SHEL 00 Z 8256 km 113°

- R.J. PPTA 00 Z 2535 km 148°
  - R.J. RCBL 00 Z 4841 km 120°
  - I.A. SCZ 00 Z 7030 km 109°
  - G.T. TAM 00 Z 8002 km 71°

- R.J. HRV 00 Z 2666 km 2°
  - I.I. SAVZ 00 Z 5225 km 87°
  - I.S. SAVZ 10 Z 5225 km 87°
  - G.T. DBC 00 Z 7439 km 91°

1 min

5 min

07:17 min

09:41 min

10:05 min
Parameter Convergence
Parameter Convergence
Marginals

- Depth [km]
- Slip [m]
- Strike [deg]
- Rake [deg]
M6.8 Myanmar earthquake (24 Mar 2011)

Fits - InSAR

Observed  Model  Residual

Observed  Model  Residual

Scene ID: Myanmar_asc
Scene ID: pixoff_disc_asc

UTM Zone 470

H. Sudhaus et al.  pyrocko.org  Grenoble, Wegener September 2018
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 pyrocko.org

pyrocko.org - Software for Seismology

Pyrocko is an open source seismology toolbox and library, written in the Python programming language. It can be utilized flexibly for a variety of geophysical tasks, like seismological data processing and analysis, modelling of InSAR, GPS data and dynamic waveforms, or for seismic source characterization.

Development and support is coordinated at https://github.com/pyrocko.

Pyrocko framework

At its core, Pyrocko is a library and framework providing building blocks for researchers and students wishing to develop their own applications.

Pyrocko manual  Download and installation  Project page on GitHub  Support  Code examples
Match with aftershock results