Seismic-afterslip characterisation of the 2010 Mw 8.8 Maule earthquake based on moment tensors inversion

Hans Agurto Detzel

Concepción, 5-March-2013

GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L20303, doi:10.1029/2012GL053434, 2012

Seismic-afterslip characterization of the 2010 M_W 8.8 Maule, Chile, earthquake based on moment tensor inversion

Hans Agurto,[1] Andreas Rietbrock,[1] Isabelle Ryder,[1] and Matthew Miller[2]

Received 10 August 2012; revised 9 September 2012; accepted 11 September 2012; published 17 October 2012.

[1] On February 27th 2010, a M_W8.8 earthquake struck the coast of south-central Chile, rupturing ~500 km along the subduction interface. Here we estimate the amount of seismically-released afterslip (SRA) and the mechanisms underlying the distribution of aftershocks of this megathrust

interior.gob.cl/filesapp/listado_fallecidos_desaparecidos_27Feb.pdf).

[3] The segment that ruptured in 2010 was previously identified as a mature seismic gap [*Campos et al.*, 2002; *Ruegg et al.*, 2009] and coincides with the region affected by

<u>Thanks to:</u> Andreas Rietbrock and Isabelle Ryder (Liverpool)
Matt Miller (Concepción)
Marcelo Assumpção (São Paulo)

Motivation and Hypothesis

- Agreement with published co-seismic slip models?
- Previous studies on aftershocks distribution. Goal ➔ Quantification
- Similarities with Tohoku-oki earthquake
- Seismic-afterslip modelling

Hypothesis: Aftershocks occur outside area of highest co-seismic slip

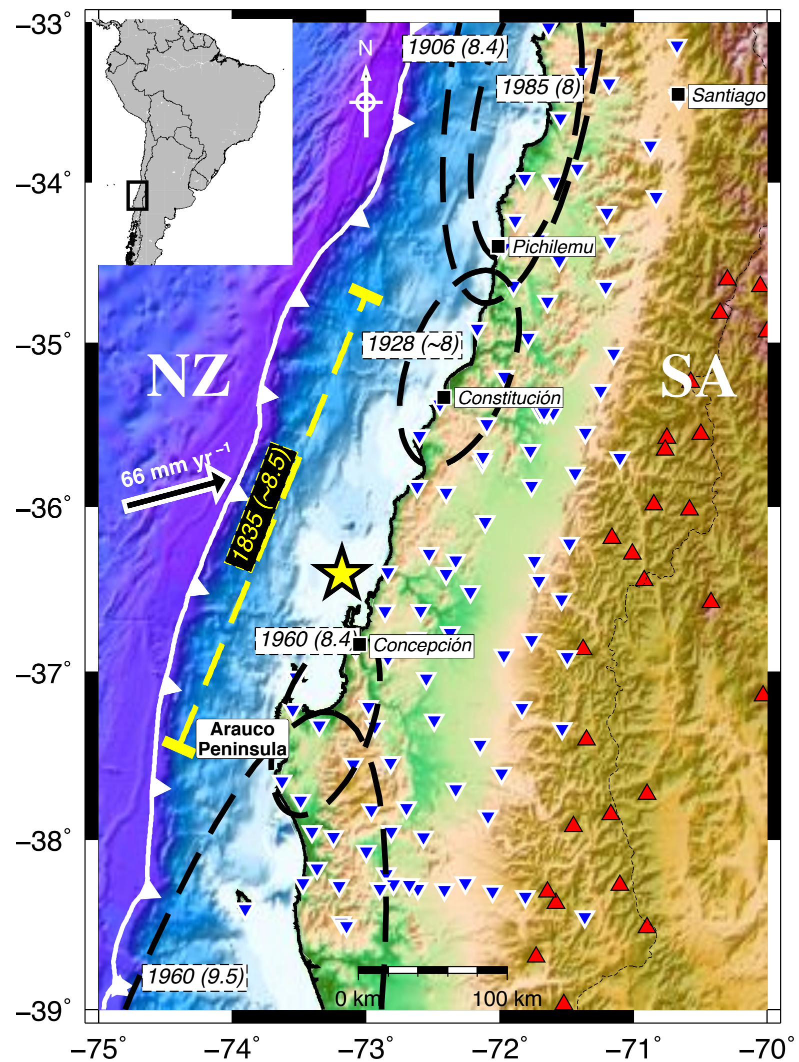
Introduction to the Study

- IMAD dataset

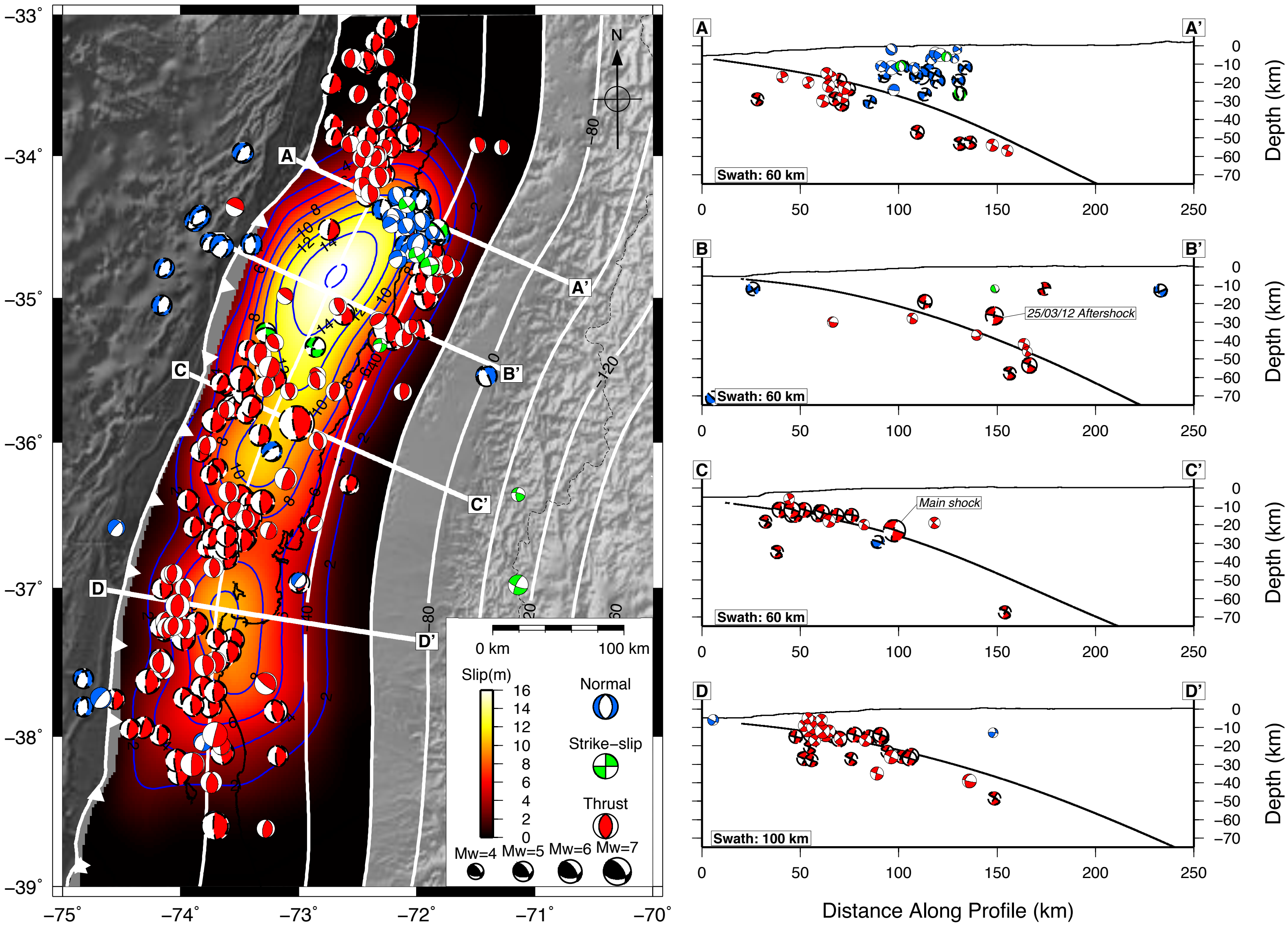
- Full-waveform moment tensor inversion
  ISOLA software (125 events)
  Sokos & Zahradnik, 2008. *Comput. Geosc.*

- Fixed epicentral locations
  Rietbrock et al., 2012. *GRL*

- + relocated GCMT solutions Mw>5 (145 events)

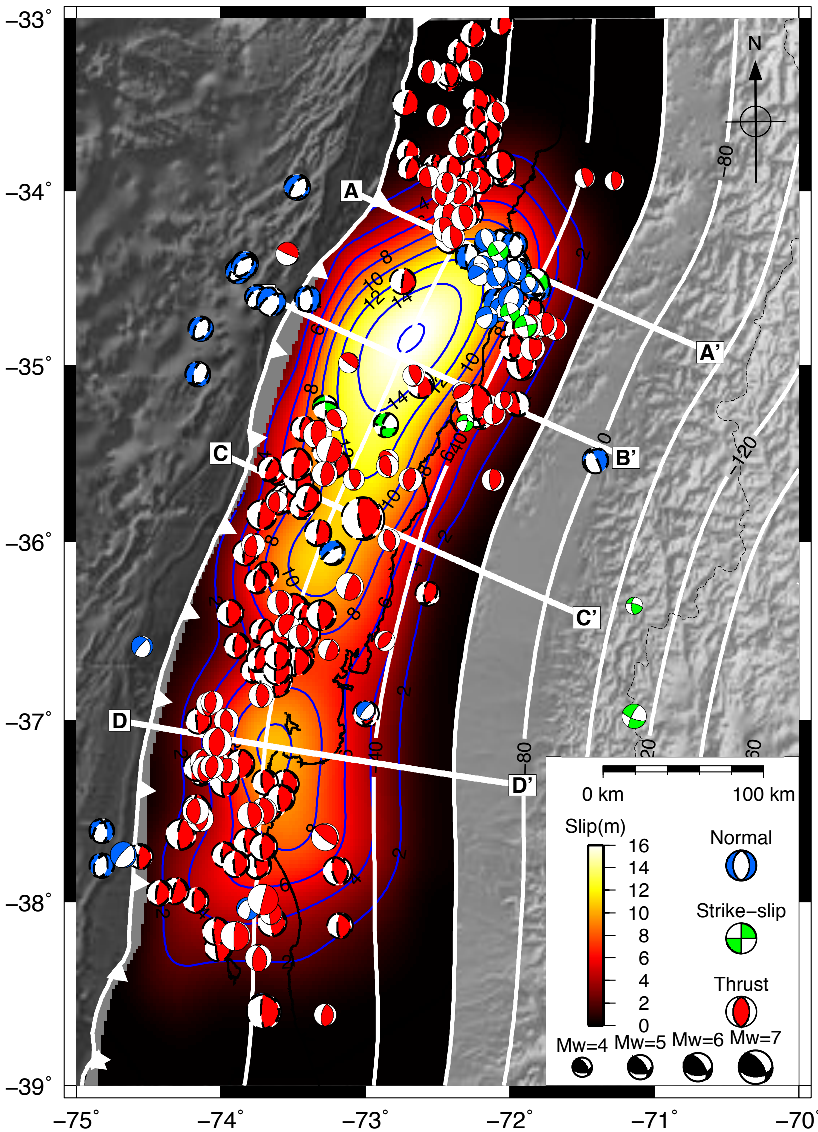


Results



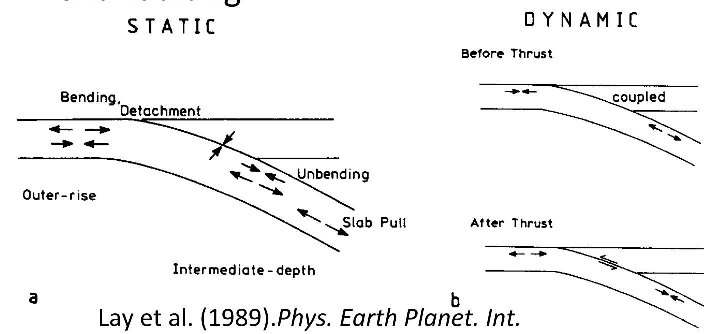
Coseismic slip model by Moreno et al. (2012). *EPSL*

Results



- **Normal outer-rise events**

Bend-faulting



Lay et al. (1989). *Phys. Earth Planet. Int.*
Christensen & Ruff (1988). *JGR*

- **Normal events in Pichilemu area**

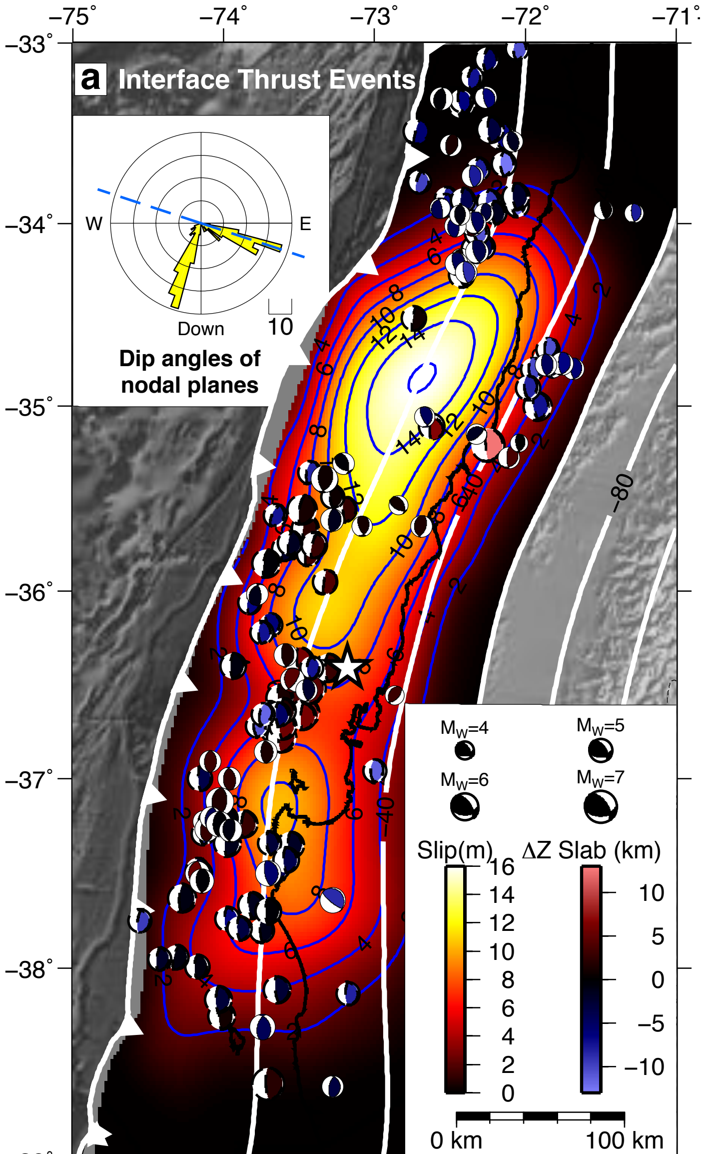
Ryder et al. (2012). *GJI*; Farías et al. (2011). *Tectonics*
Japan – Kato et al. (2011). *EPS*.

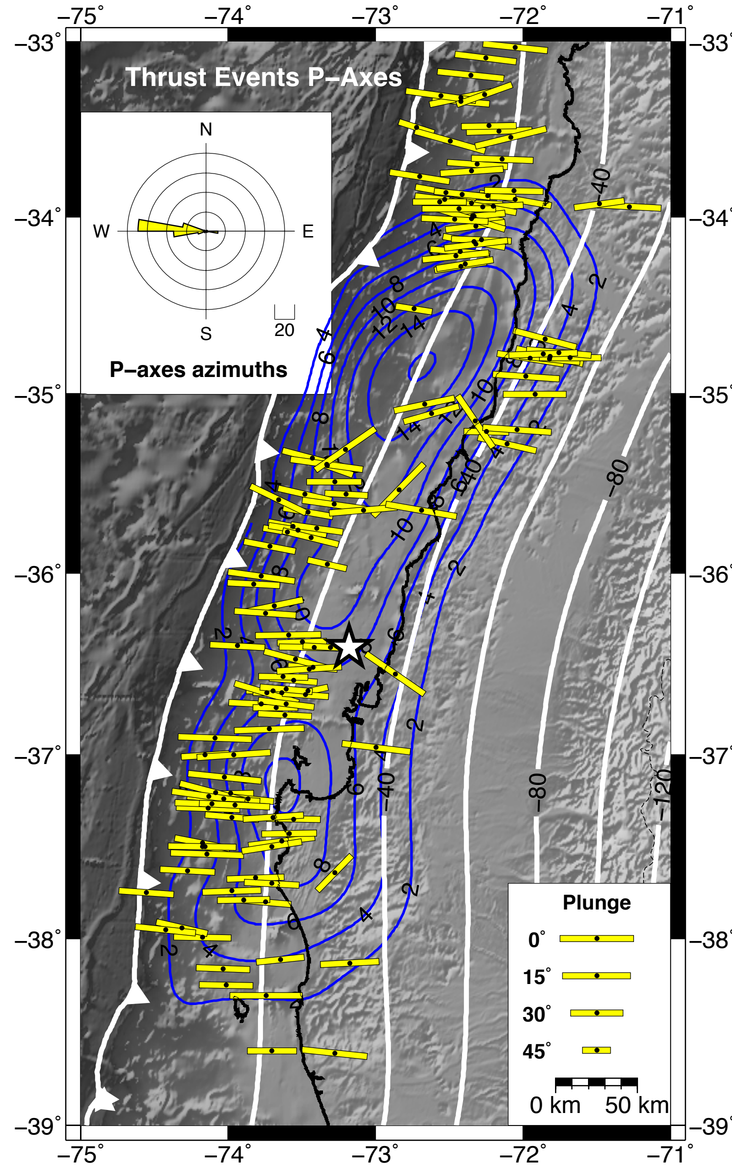
- **Crustal strike-slip events**

e.g.: Mw5.1 at ~37ºS/71ºW associated to NW structures in Nevados de Chillán volcano.

- **Interface Thrust aftershocks**

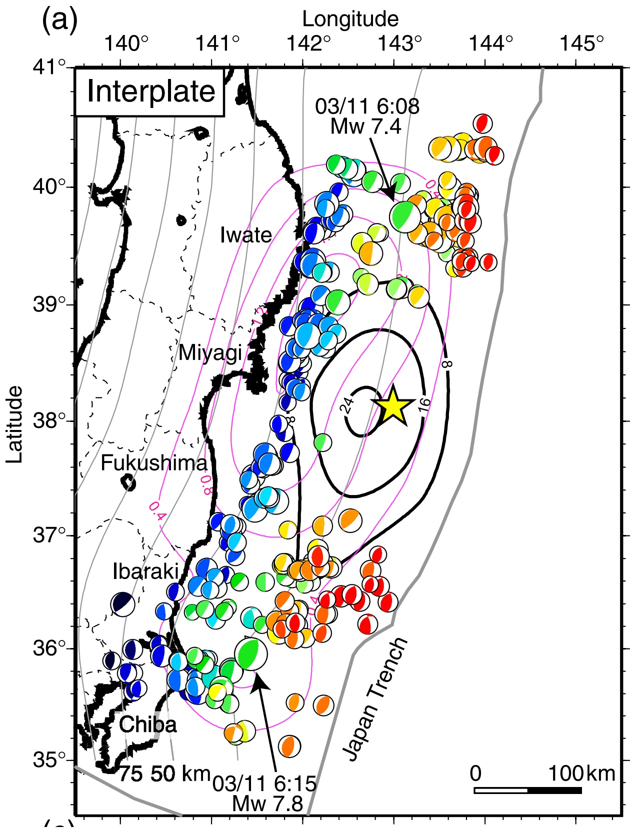
Interface Thrust Aftershocks





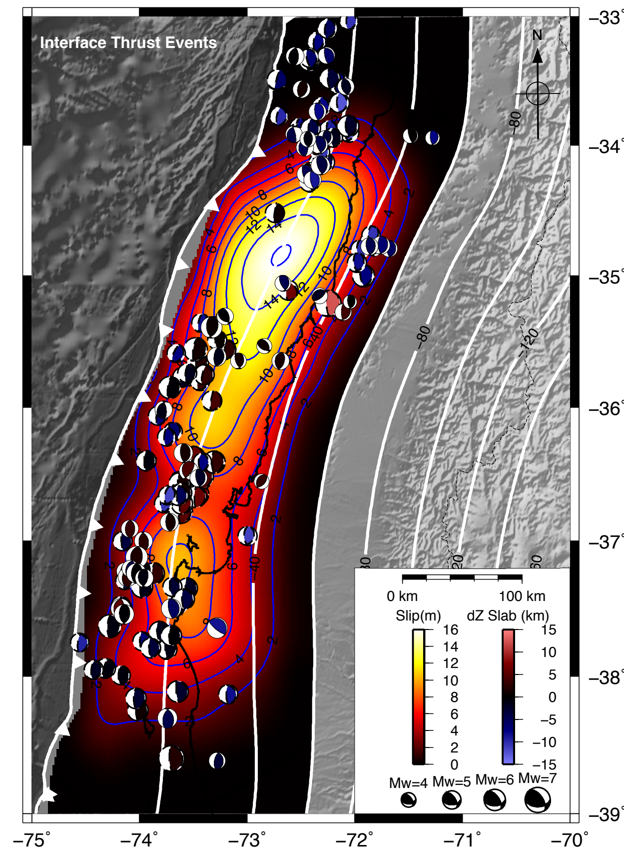
Interface Thrust Aftershocks

Japan, 2011

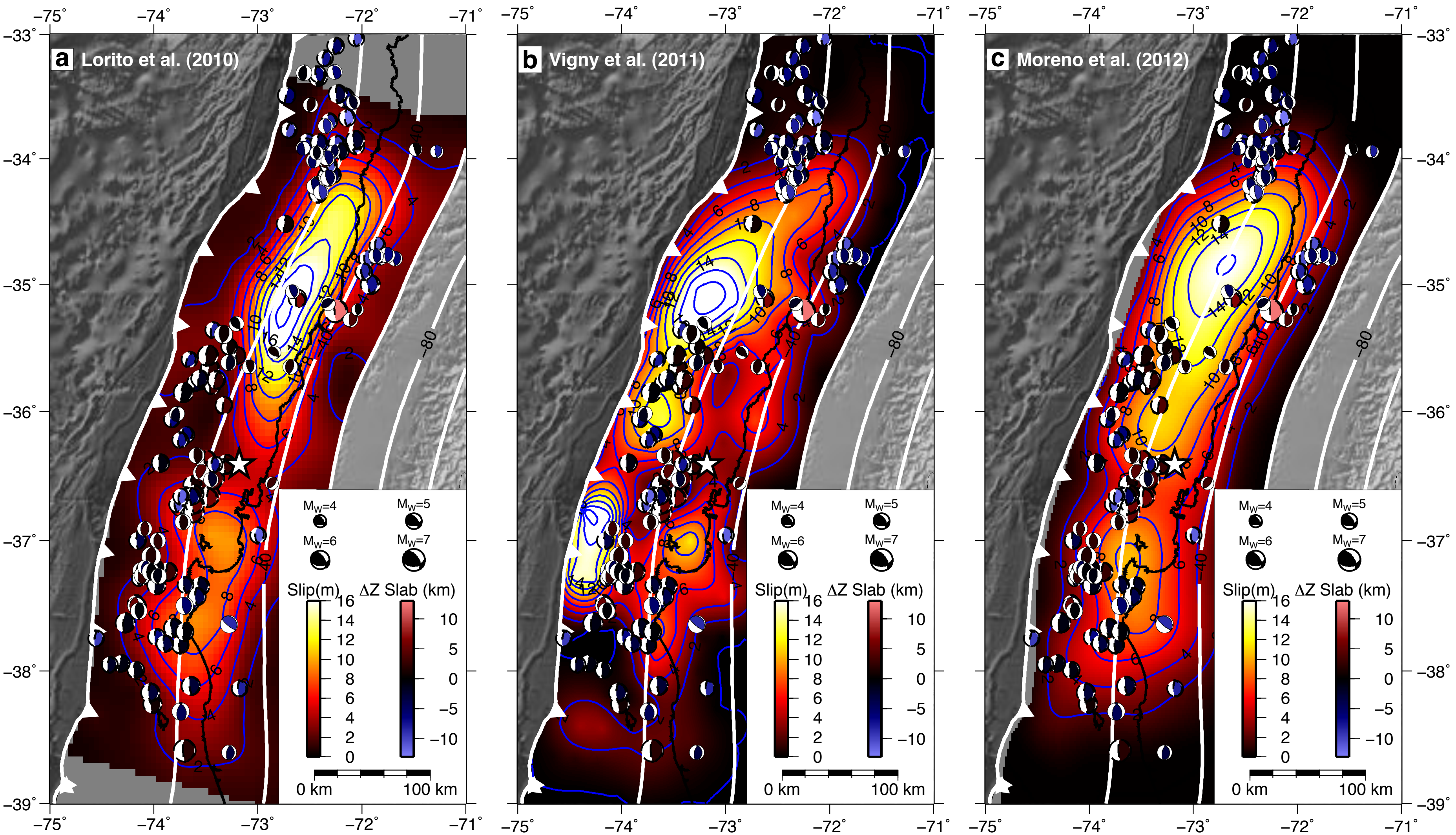


Asano et al. (2011). *EPS*

Chile, 2010



Distribution of Thrust Aftershocks VS Published Co-seismic Slip Models



Seismically-released Afterslip (SRA) Modelling

Mw **from MT inversion**	ISOLA Sokos & Zahradnik, 2008.

↓

Length $\log_{10} L = -2.37 + 0.57 Mw$	**Width** $\log_{10} W = -1.86 + 0.46 Mw$	Scaling Relations Blaser et al., 2010. *BSSA*

↓

$$s = \frac{M_0}{\mu A}$$

s = slip (m)

Seismic Moment → $M_0 = 10^{(1.5*Mw+16.1)}$

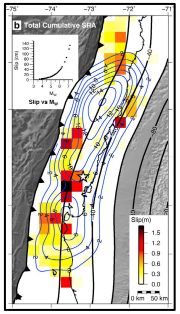
Shear Modulus → μ = 39 Gpa

Fault Area → A = L×W

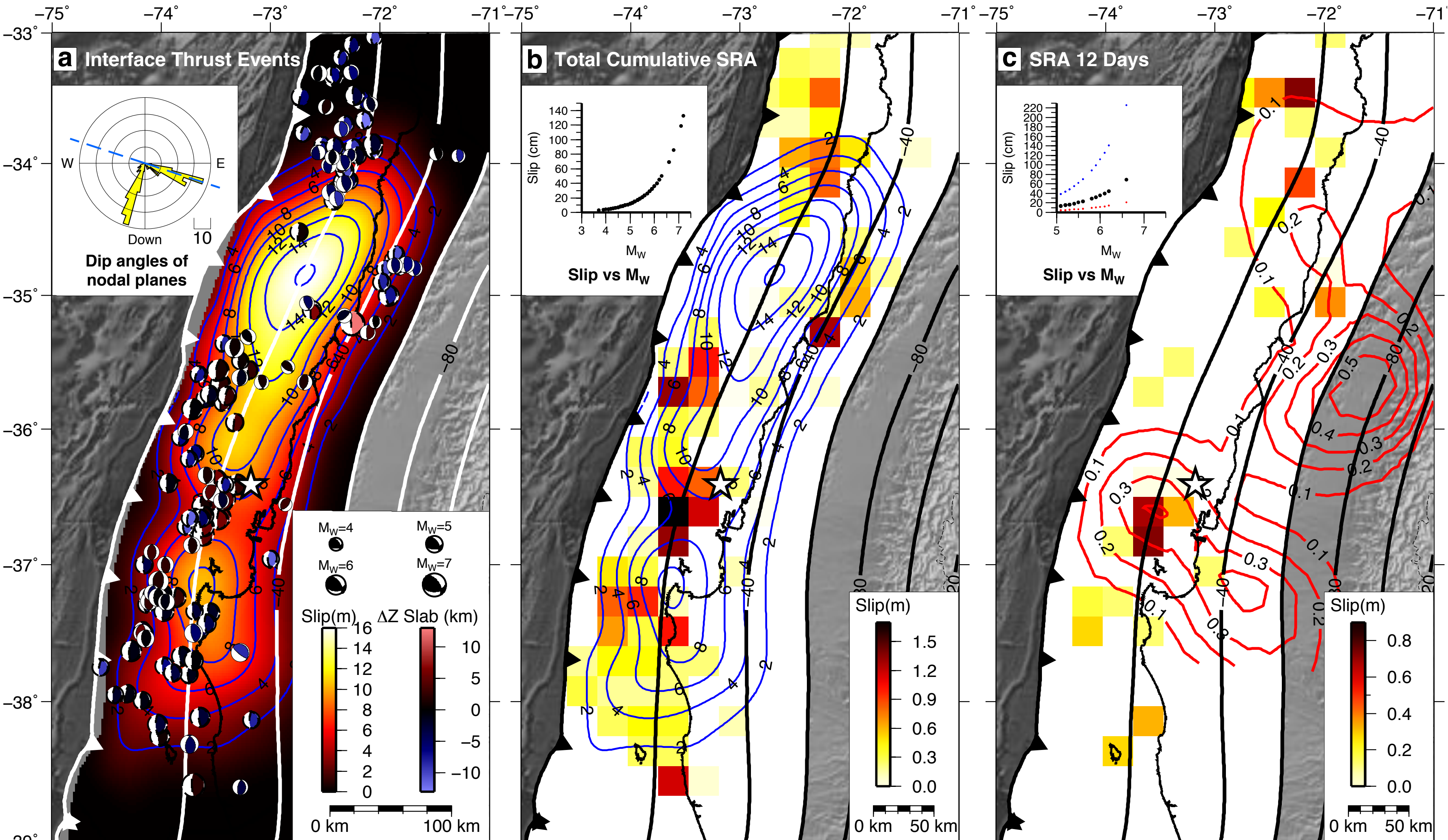
Seismic Moment Equation
Aki, 1966

↓

Modelling of cumulative slip in tiles of 25×25 km →

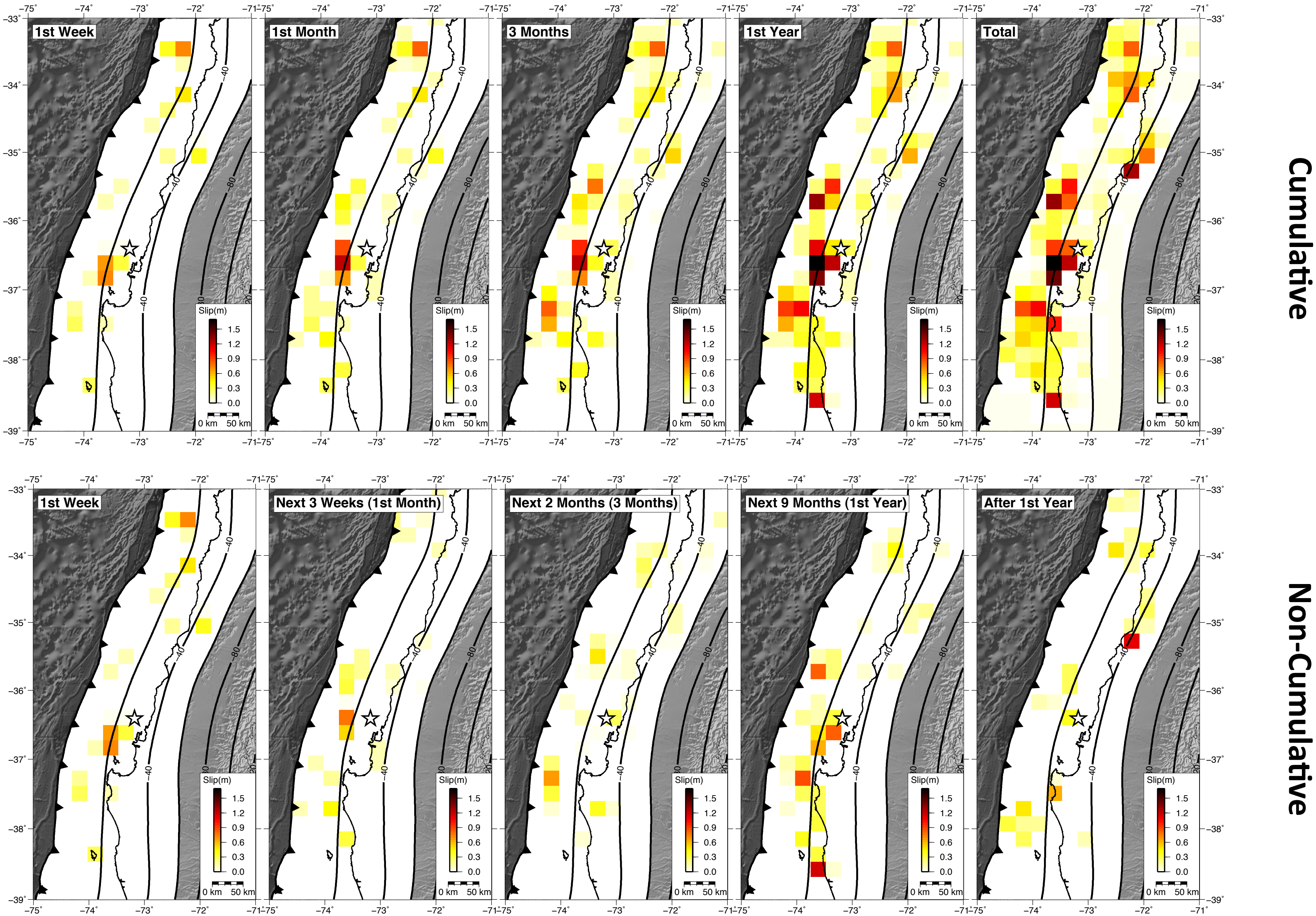


SRA Model



Interface thrust events and SRA model. Interface events were defined as those located at depths within 13 km (GCMT) and 6 km (this work) from the top of the slab respectively. **a)** Coseismic slip model [Moreno et al., 2012] and interface thrust events colored by vertical distance from the top of the slab. Inset: histogram of frequency of thrust events according to their nodal planes' dip angles; dashed blue line indicates dip angle of mainshock (megathrust plane). **b)** Cumulative SRA. Inset: exponential relationship between calculated M_W and slip. **c)** Cumulative SRA model for the 12-day period following the mainshock. Red contour lines show the 12-day postseismic afterslip model proposed by Vigny et al. [2011] every 0.1 m. Inset: same as 3b, including 1σ of slip from scaling relationships (blue and red dots).

SRA Progression In Time



Hans Agurto - Seismic-afterslip characterisation of the 2010 Mw 8.8 Maule earthquake

Quantification of Aftershocks Distribution

$$R_{ds} = \frac{(N_{ds} / N_t)}{(A_{ds} / A_t)}$$

R_{ds} ➔ Normalized seismicity occurring within a given slip range (ds) relative to its areal distribution

N_{ds} ➔ Number of events occurring within a given slip range ds

N_t ➔ Total number of events

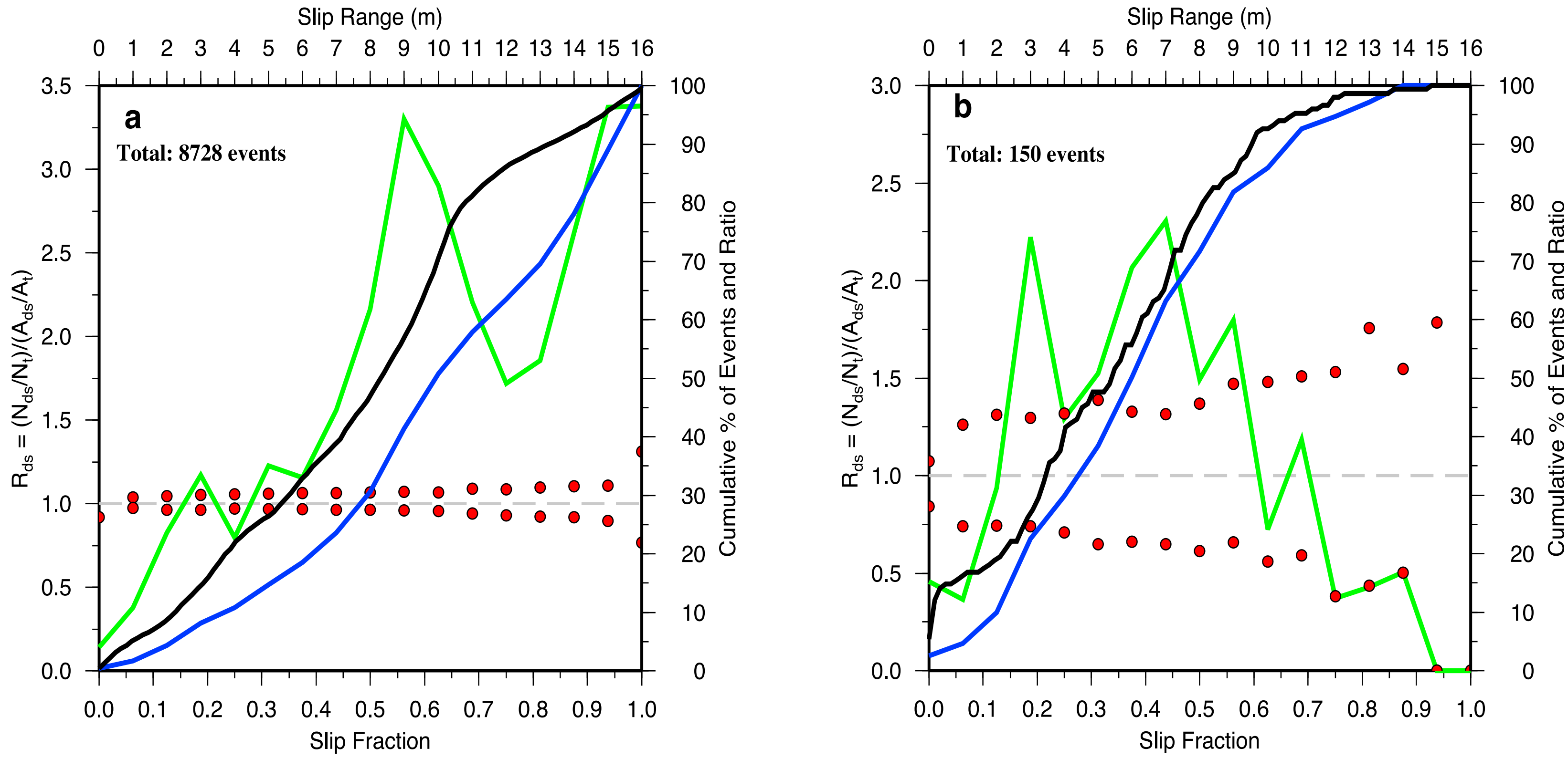
A_{ds} ➔ Area covered within a given slip range ds

A_t ➔ Total area

If $R_{ds} > 1$ ➔ Seismicity greater than average

If $R_{ds} < 1$ ➔ Seismicity smaller than average

Quantification of Aftershocks Distribution



Histograms of aftershock distribution for **(a)** interface events from expanded catalogue published by Rietbrock et al. [2012], **(b)** largest interface thrust events. Green line shows R_{ds} values (left axis), blue line corresponds to the cumulative percentage of R_{ds} values (right axis), black line is the cumulative percentage of events (right axis). Red dots indicate one standard deviation values of R_{ds} for randomly distributed events test.

Conclusion

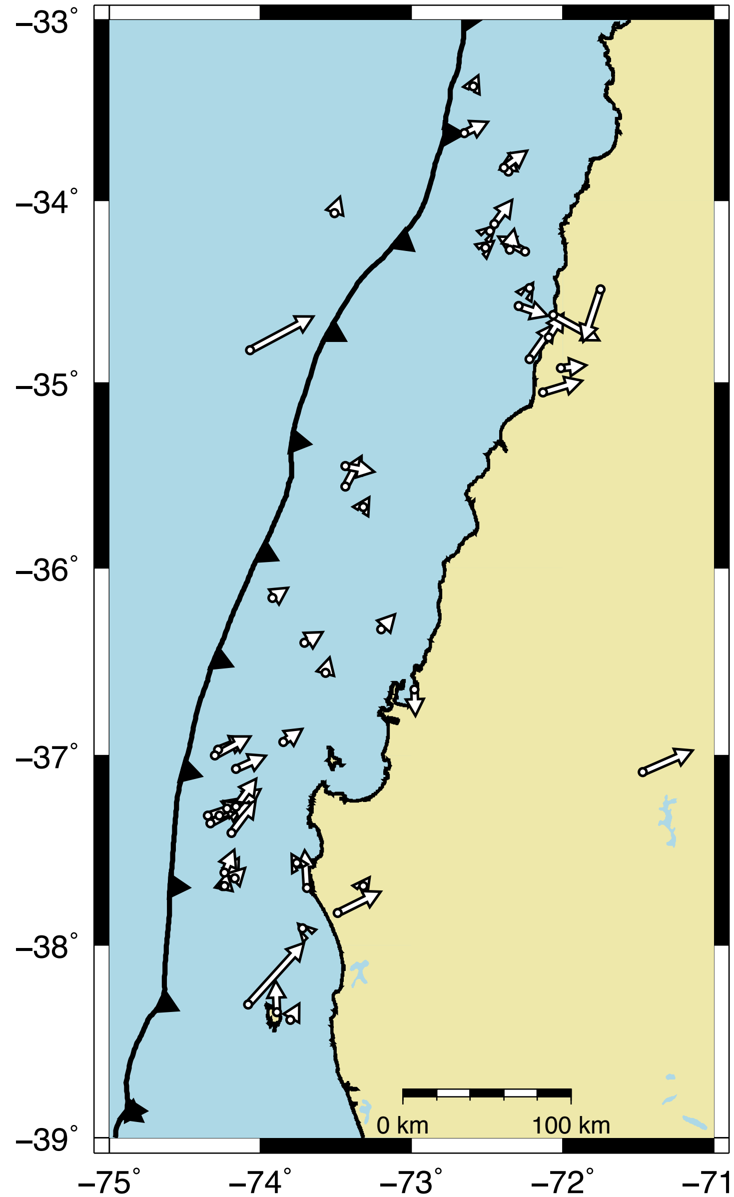
- Catalogue of 270 RMT solutions
- Thrust faulting dominates (70%). Normal faulting in the Pichilemu area
- Absence of major thrust aftershocks in main coseismic slip patches
  - ➔ Bulk of intraplate stress released co-seismically
  - ➔ No major slip can occur post-seismically
- Interplate thrust aftershocks located on dislocation tips
- Highest SRA value (1.7 m) located in between the two main patches of coseismic slip

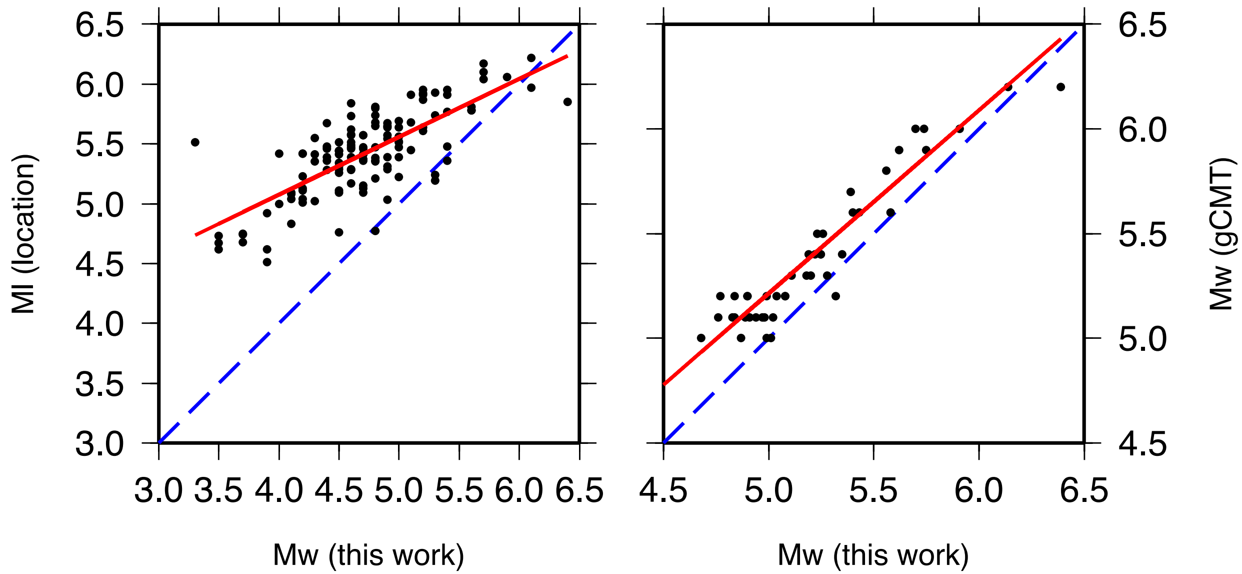
Distribution Quantification:

- Largest thrust aftershocks (>M4) occur in intermediate coseismic slip areas (0.2-0.7 S_{max})
- Smaller events in areas of larger coseismic slip (>0.85 S_{max}) associated to damage zone
- Method transferable to other tectonic environments/major earthquake.

Relocation of GCMT events

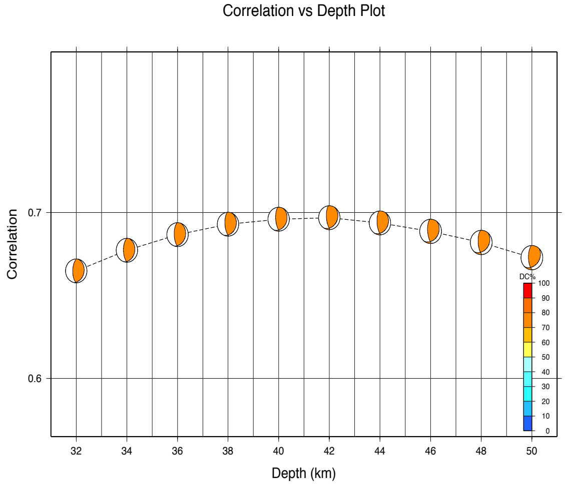
- GCMT events are biased to the south-west, towards the trench, for central-south Chile
- Similar biases for PDE (USGS) and PTWC (NOAA) catalogues (but different directions)
- Important for early tsunami warnings specially when close to the coastline!



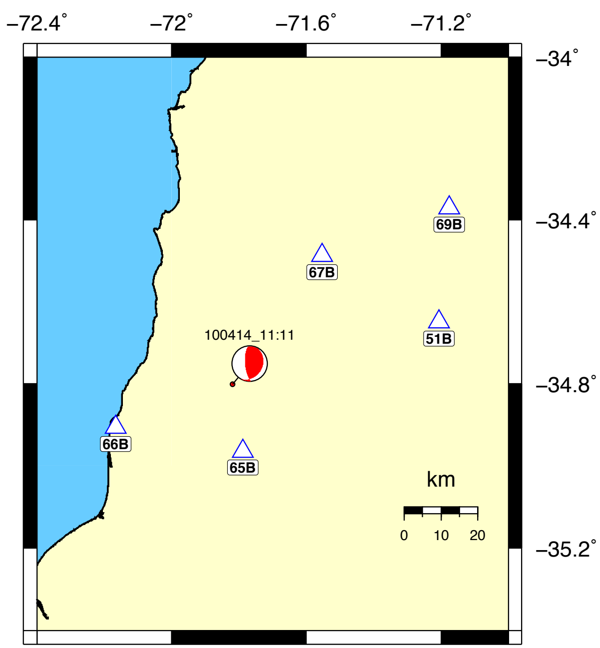


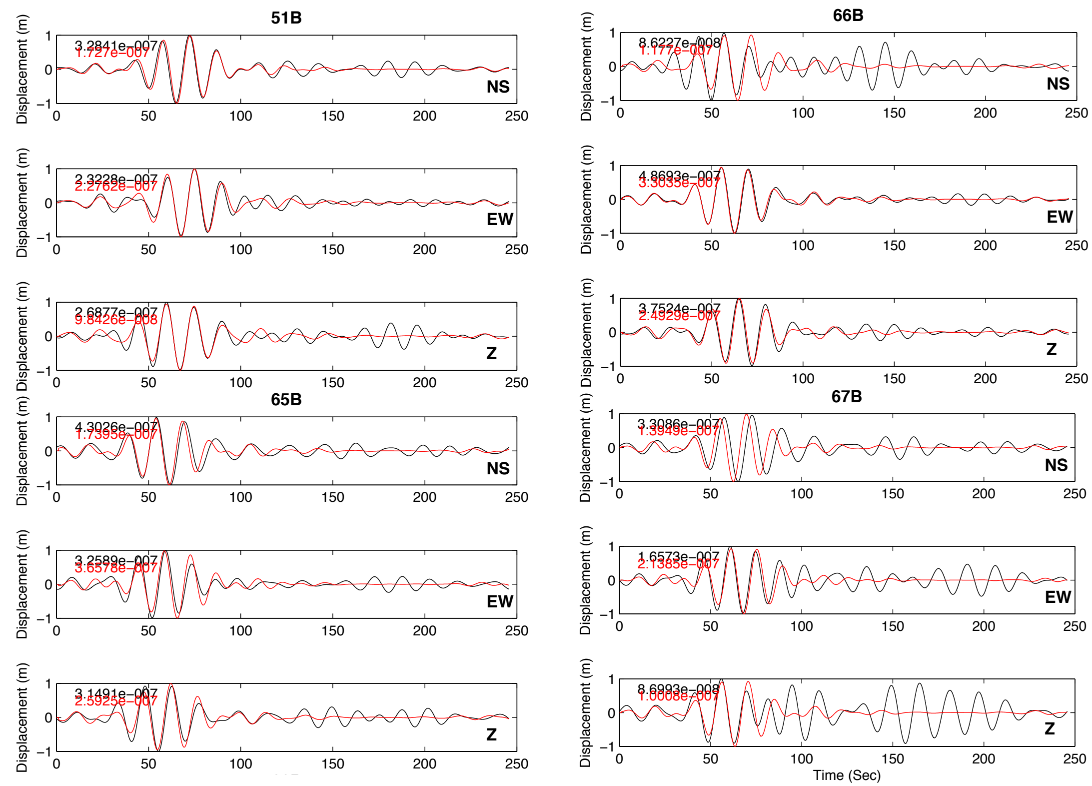
Supplementary Figure 2. Comparison of obtained magnitudes. Left plot shows local magnitudes [Rietbrock et al., 2012] versus M_W obtained in this work. Right plot shows GCMT magnitudes versus this work's magnitudes.

Example 1

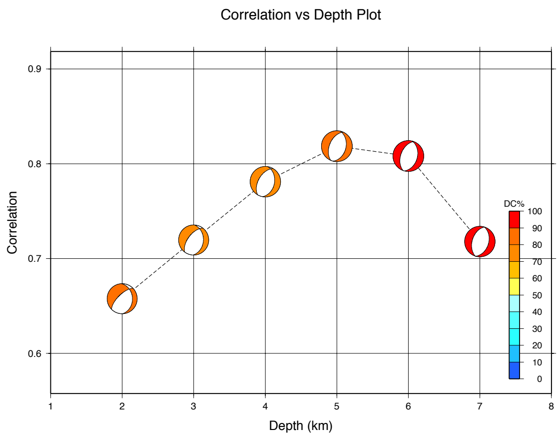


Origin Time: 2010-04-14 11:11:48.05
Centroid Time: +1.14 s
Centroid Location: −34.80S −71.82W
Centroid Depth: 42 km
Mw: 3.7 DC%: 77.3 CLVD%: 22.7
Variance Reduction: 0.60
Correlation: 69%





Example 2



Origin Time: 2010-05-21 18:52:07.40
Centroid Time: +0.06 s
Centroid Location: −34.62S −71.99W
Centroid Depth: 5 km
Mw: 5.3 DC%: 94.3 CLVD%: 5.7
Variance Reduction: 0.89
Correlation: 87%