Earthquake Source Complexity and its Impact in PTHA

Diego Melgar, University of Oregon & CRESCENT

Showcasing work from Bruno Adriano, Fernando Salazar-Monroy, Sean Santellanes, David Small, Amy Williamson, & Lynette Wotruba

PTHA in 60 seconds

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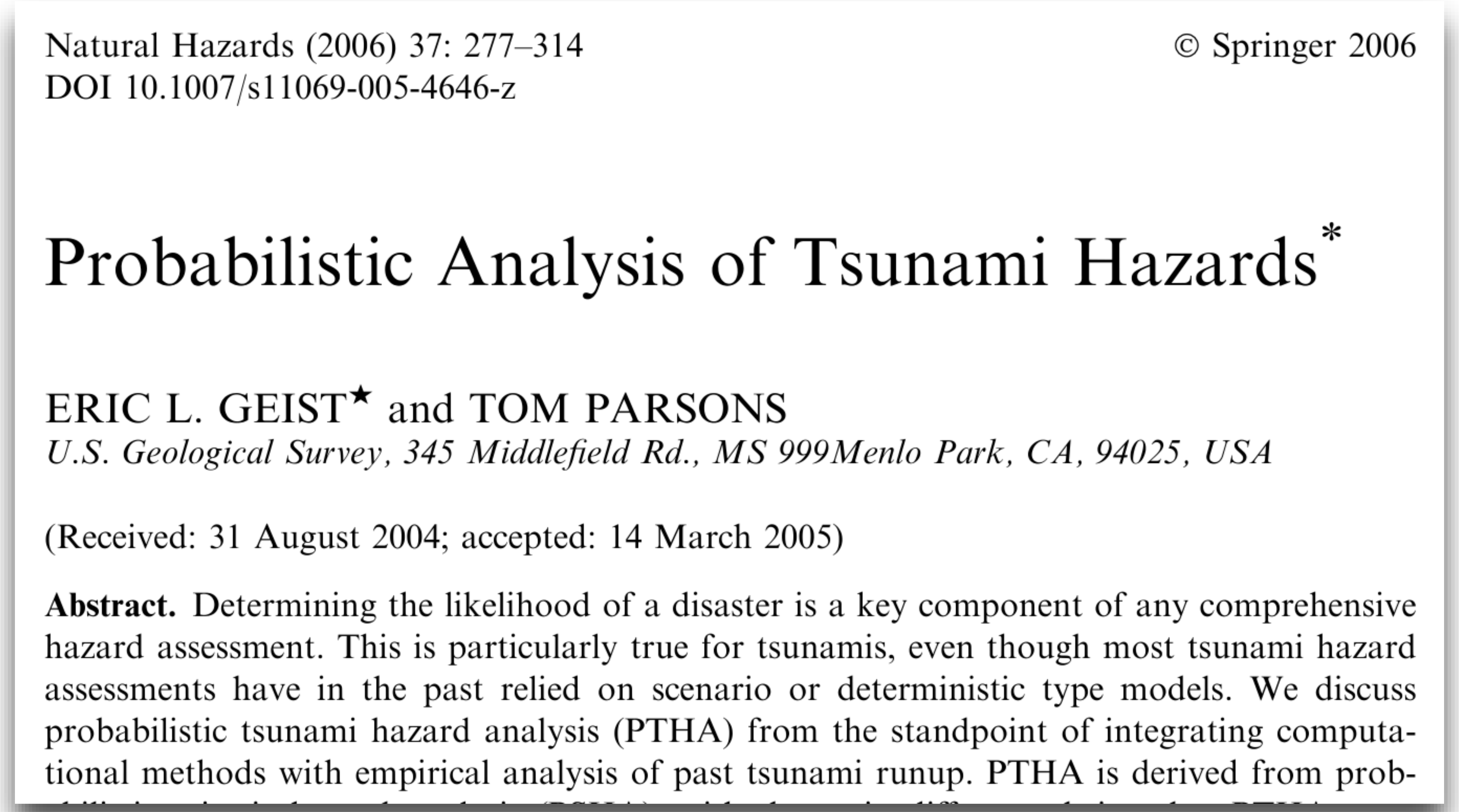
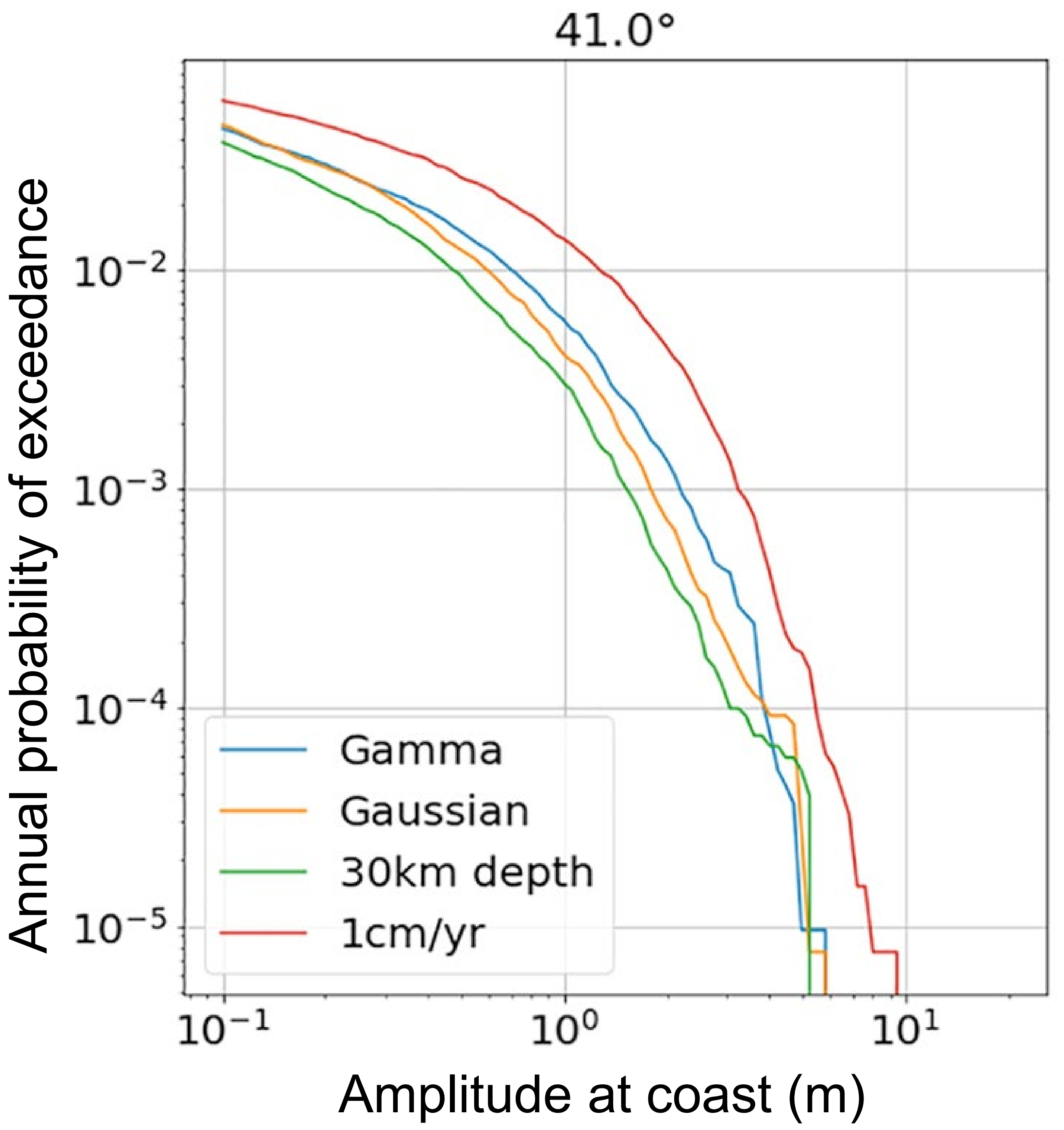

Natural Hazards (2006) 37: 277–314
DOI 10.1007/s11069-005-4646-z

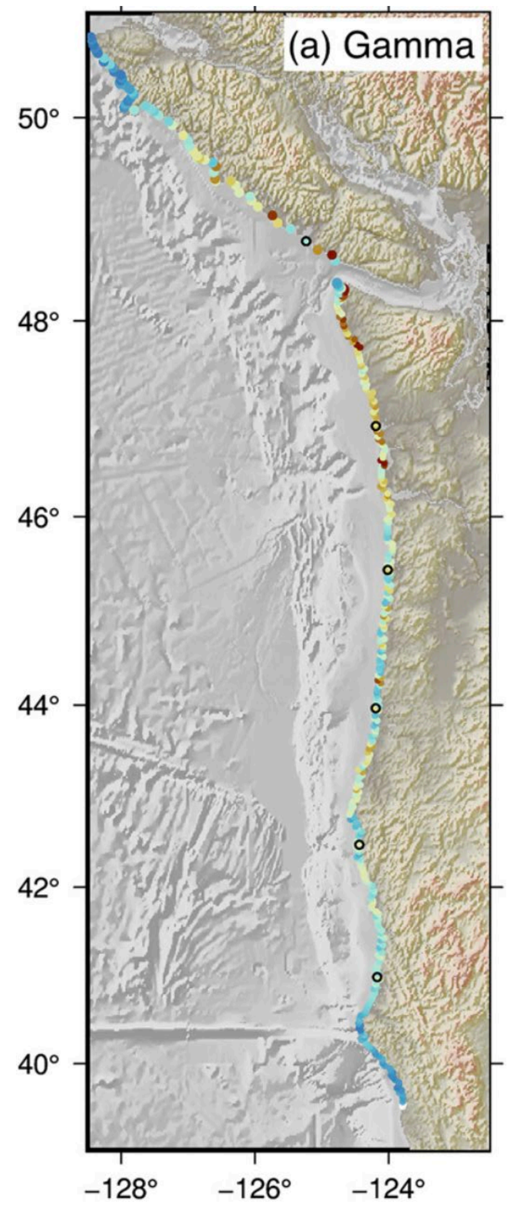
Probabilistic Analysis of Tsunami Hazards*

ERIC L. GEIST★ and TOM PARSONS
U.S. Geological Survey, 345 Middlefield Rd., MS 999Menlo Park, CA, 94025, USA

(Received: 31 August 2004; accepted: 14 March 2005)

Abstract. Determining the likelihood of a disaster is a key component of any comprehensive hazard assessment. This is particularly true for tsunamis, even though most tsunami hazard assessments have in the past relied on scenario or deterministic type models. We discuss probabilistic tsunami hazard analysis (PTHA) from the standpoint of integrating computational methods with empirical analysis of past tsunami runup. PTHA is derived from prob-





Small & Melgar, 2019

N ~ # of possible EQ magnitudes

Rate of occurrence and Return period of interest

η - tsunami amplitude

$$P(\eta > \eta_c) = 1 - \Pi_{i=1}^{N}[1 - (1 - e^{-\nu_i T})p(\eta > \eta_c|M_i)]$$

Probability of exceeding some amplitude of interest

Probability of exceeding threshold GIVEN an EQ of a specific magnitude

PTHA in 60 seconds

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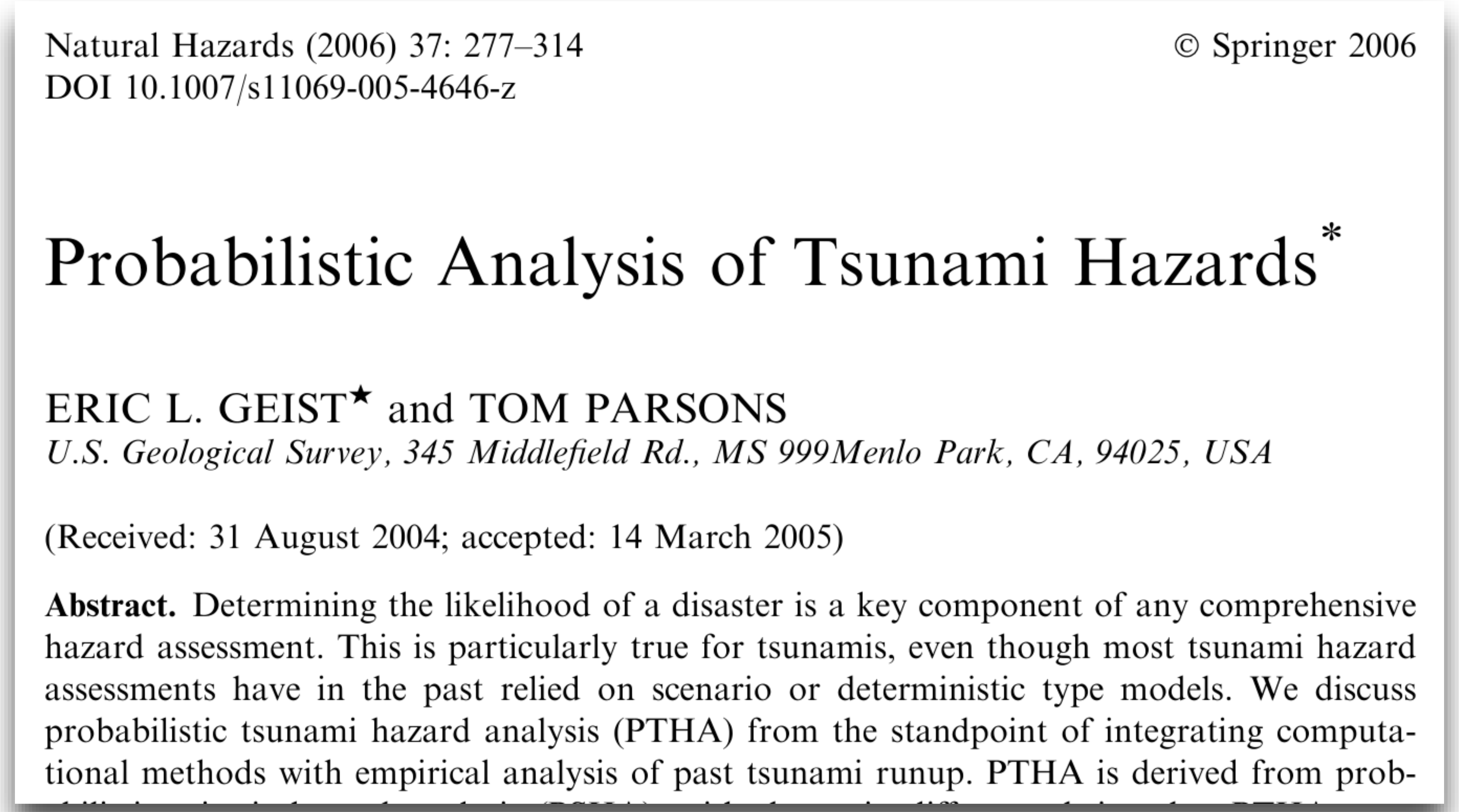
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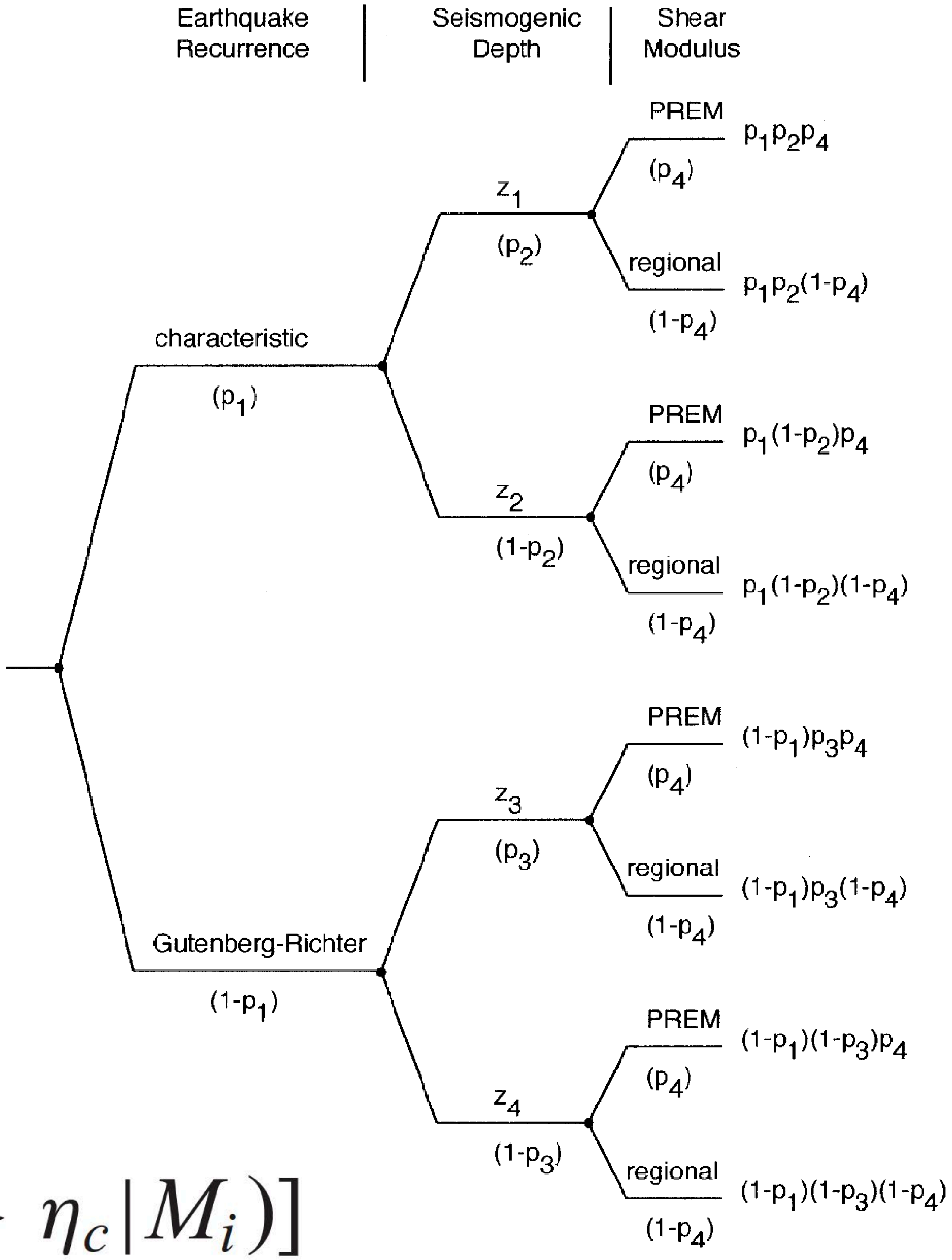
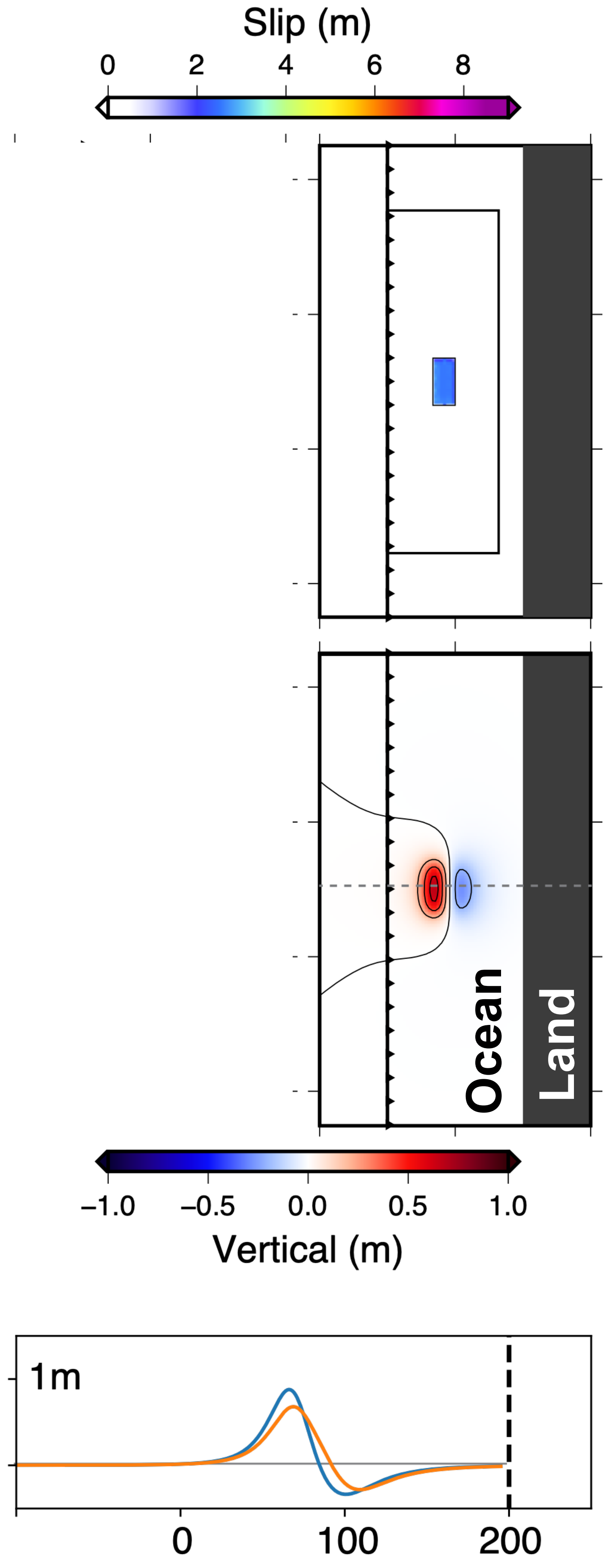


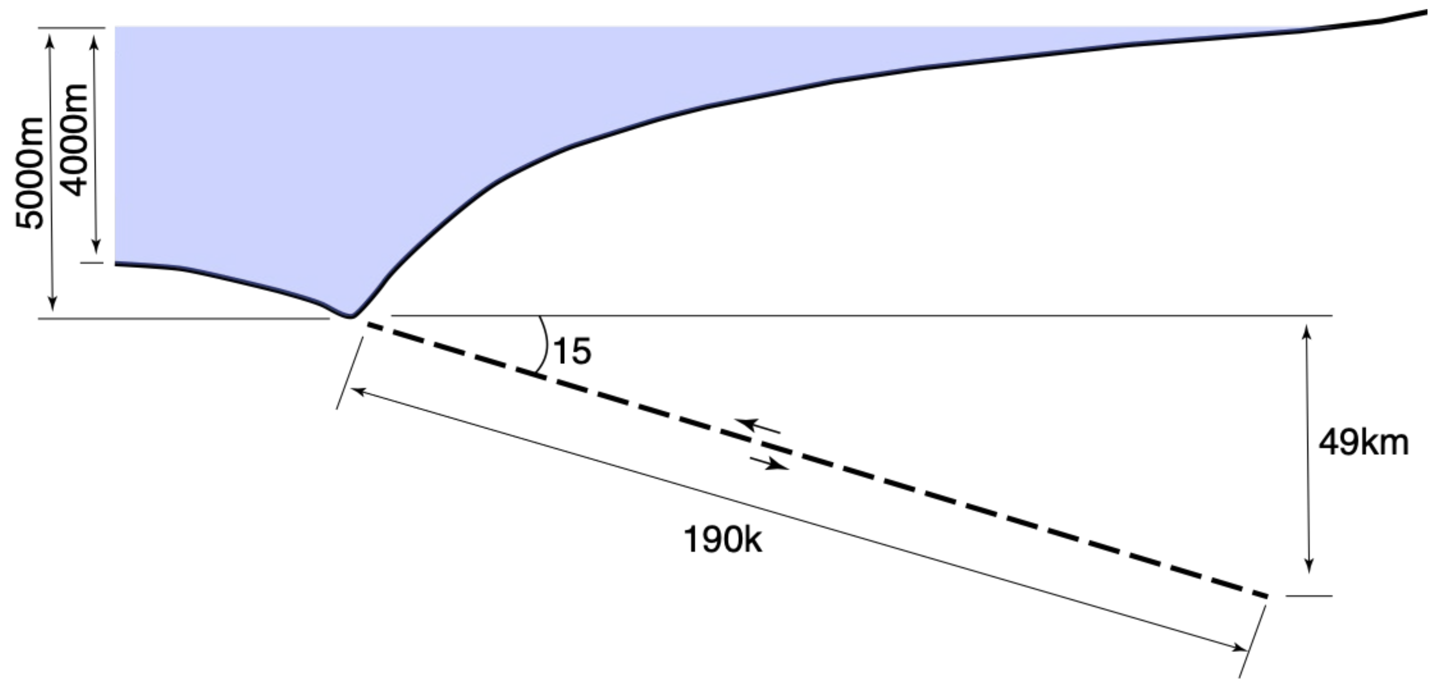
How is this conditional probability obtained?

$$P(\eta > \eta_c) = 1 - \Pi_{i=1}^{N}[1 - (1 - e^{-\nu_i T})p(\eta > \eta_c | M_i)]$$

Traditionally, with homogenous or simplified slip models



Melgar et al. 2019



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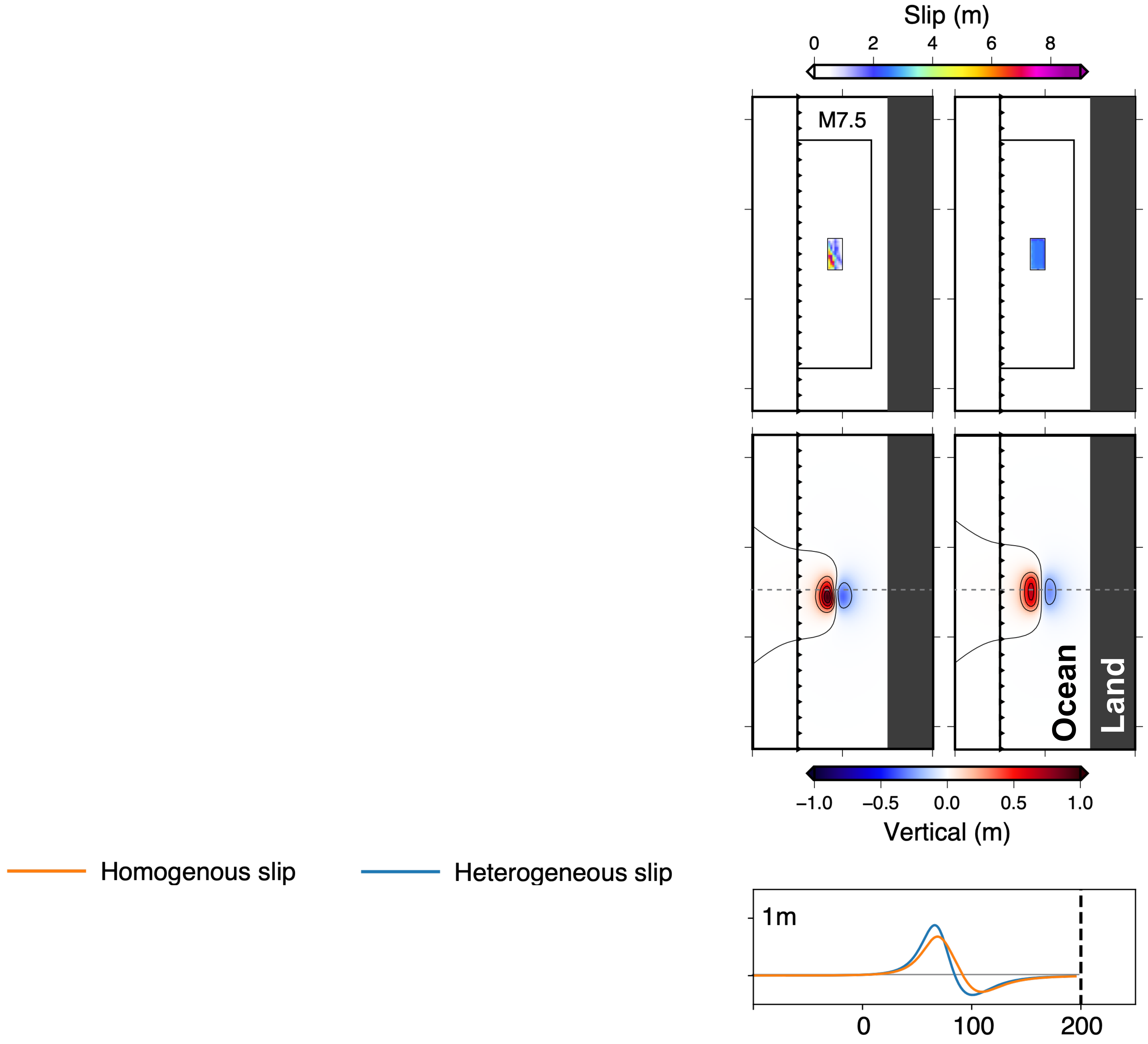
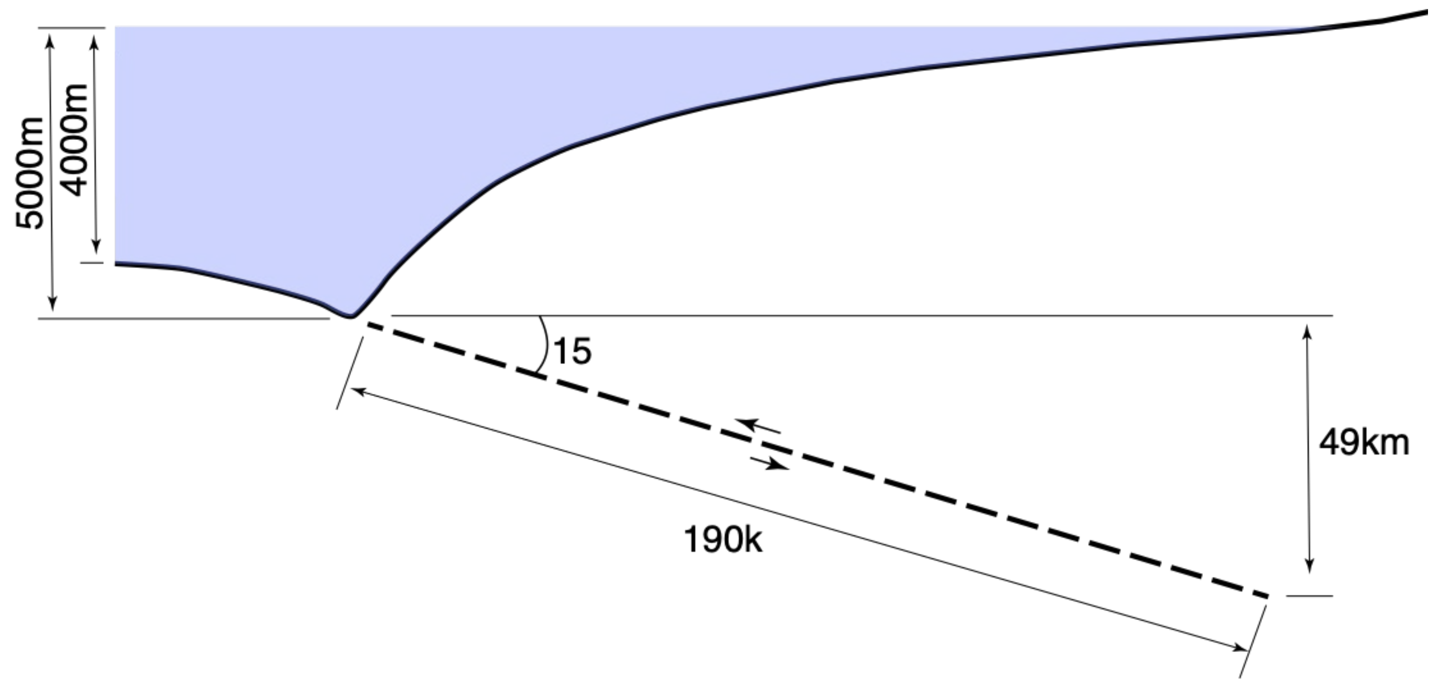


Melgar et al. 2019



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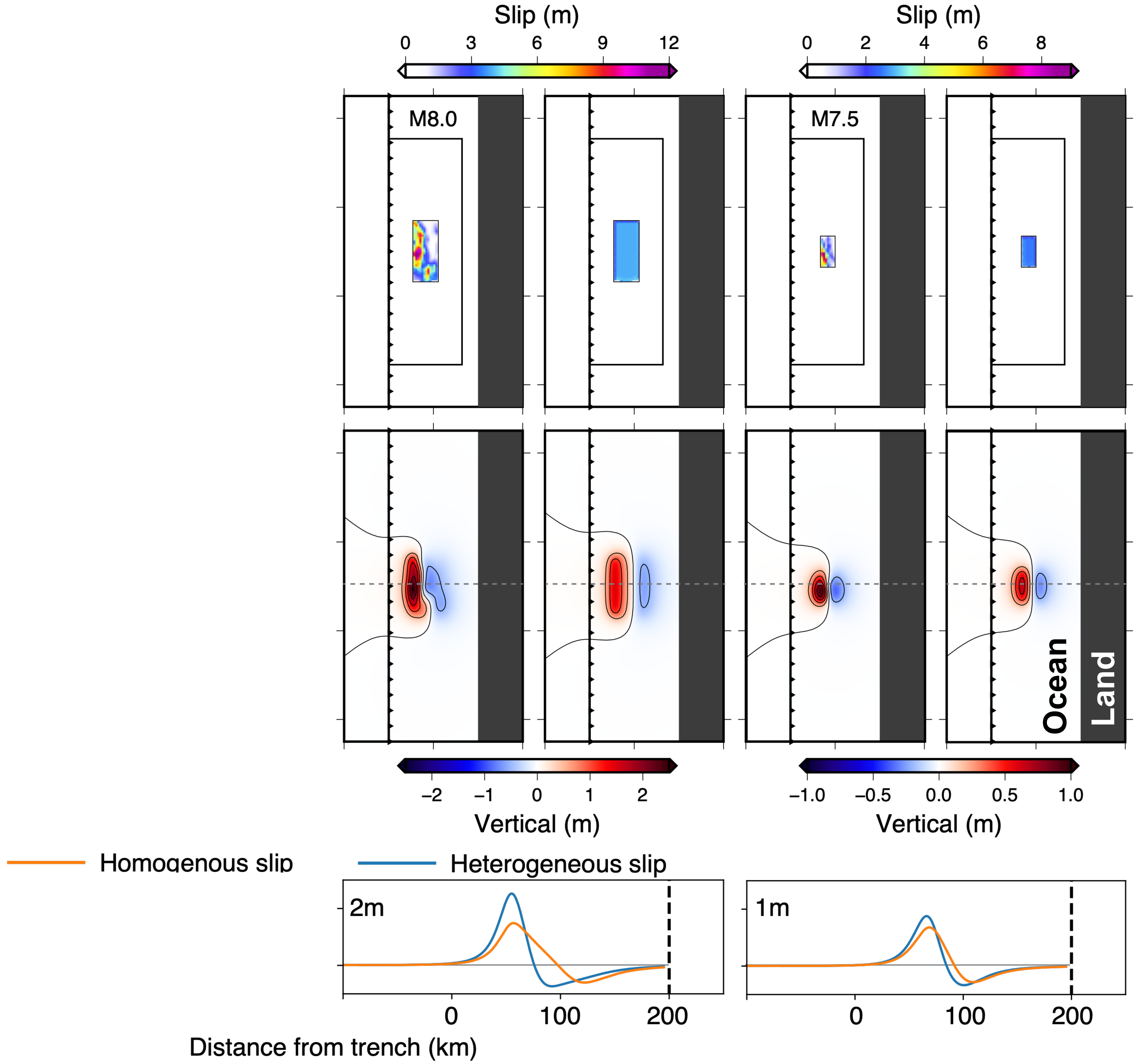

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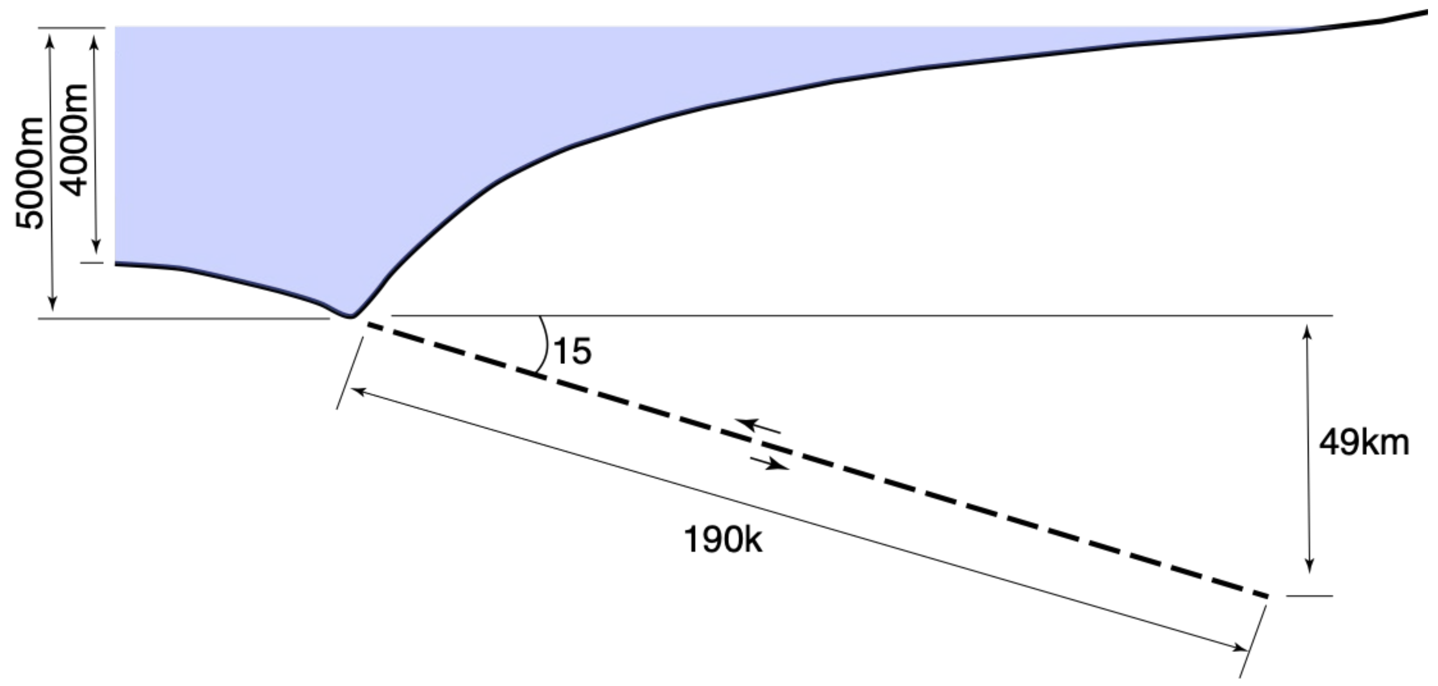

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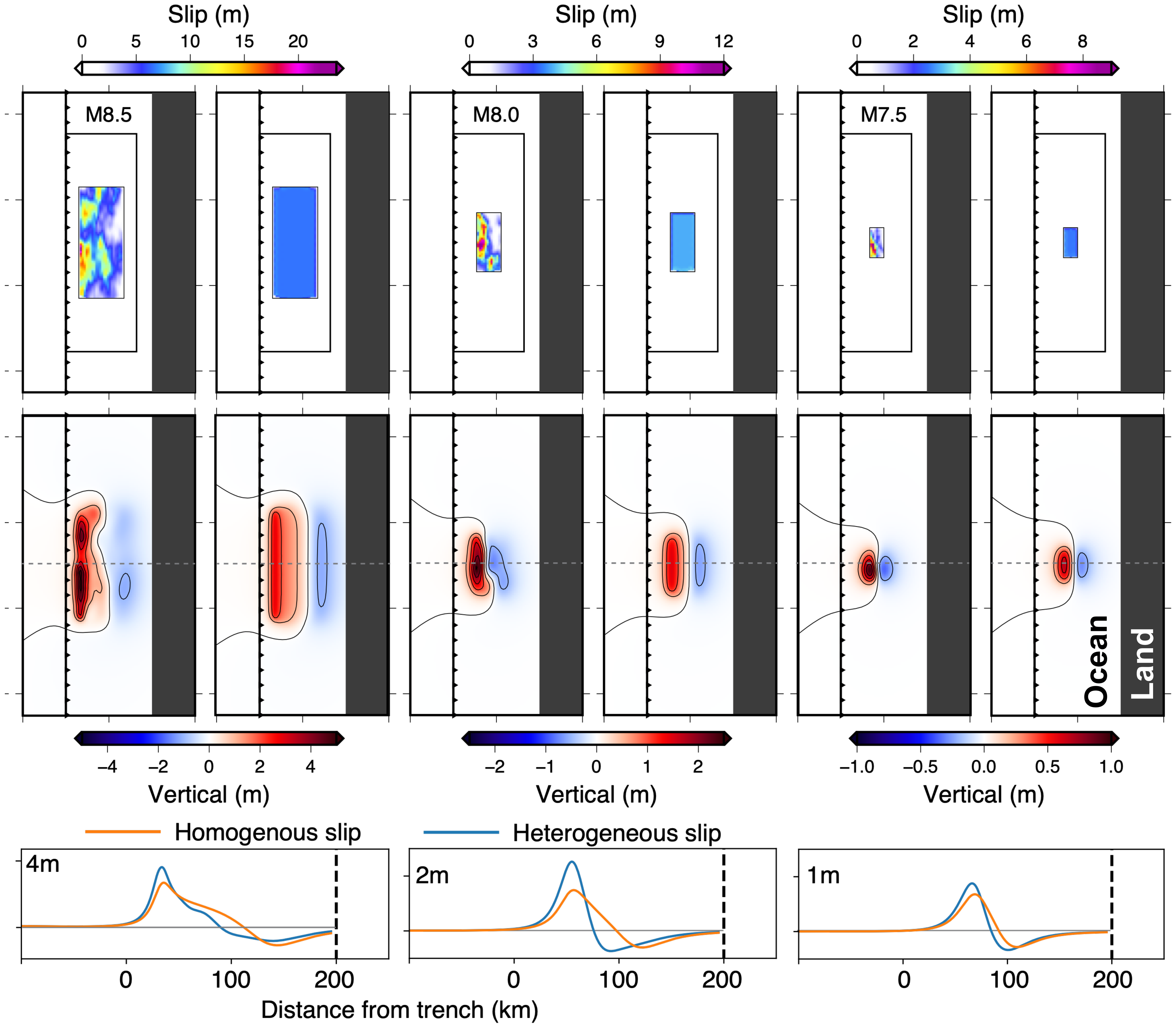

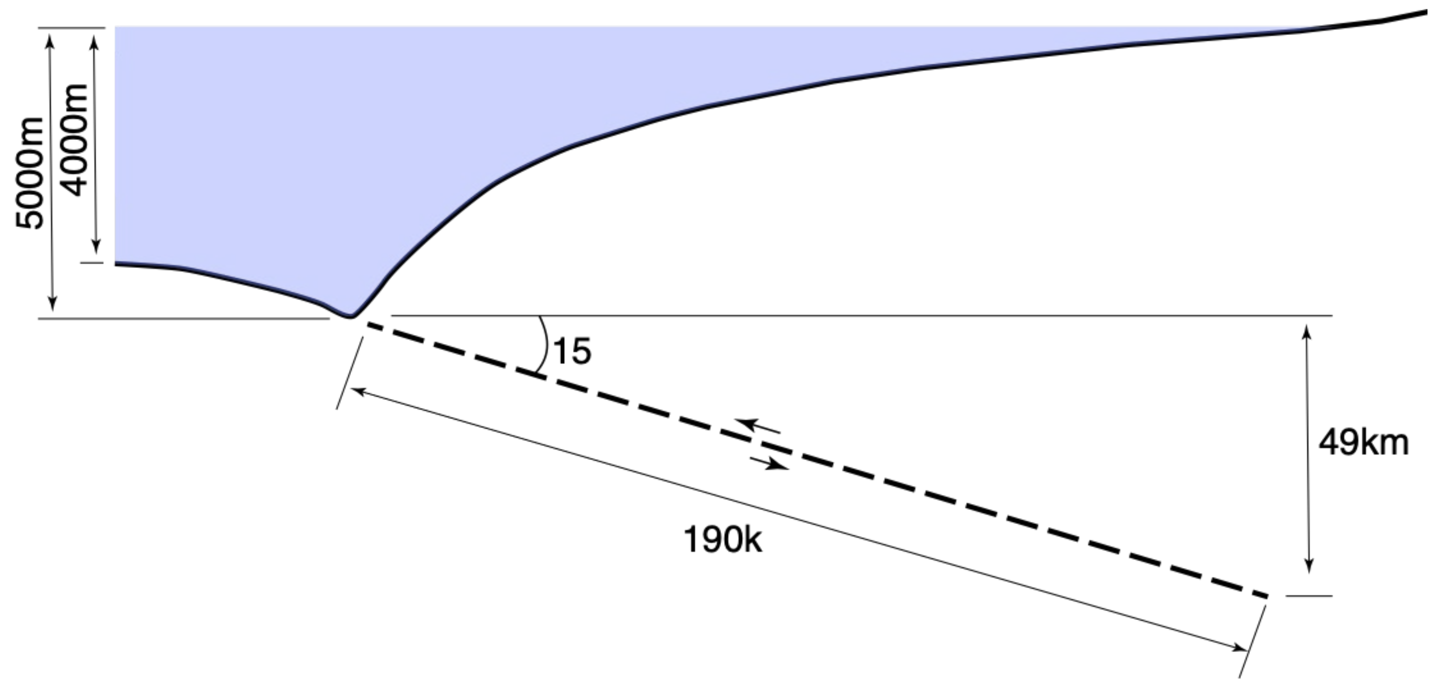

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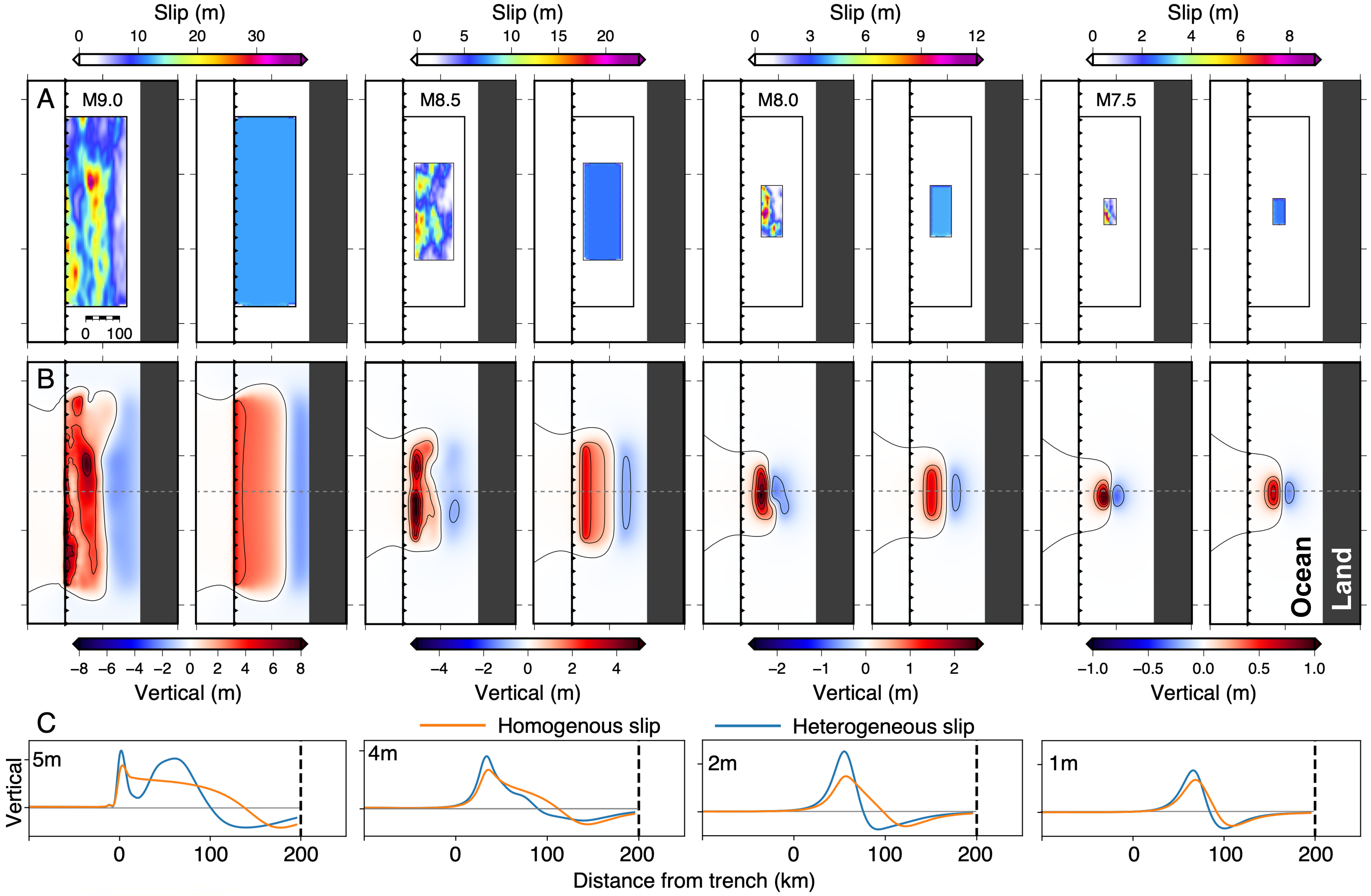
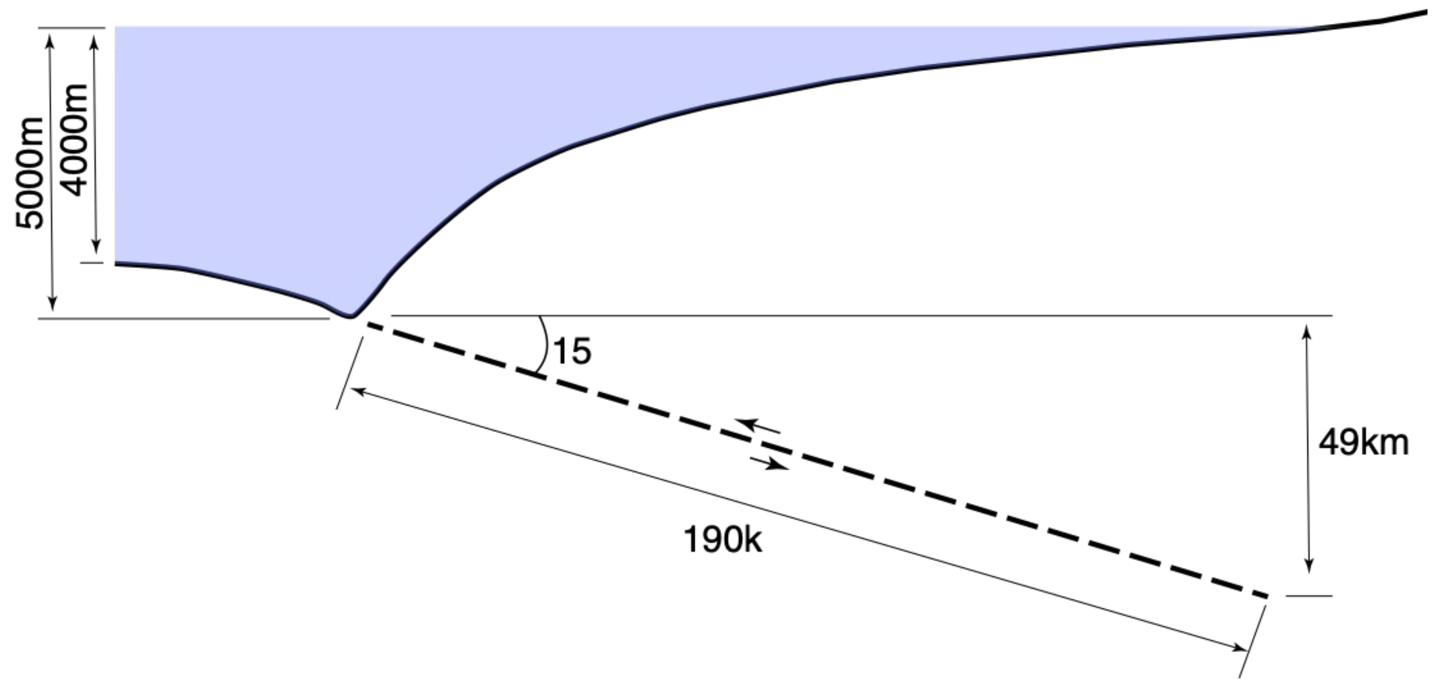


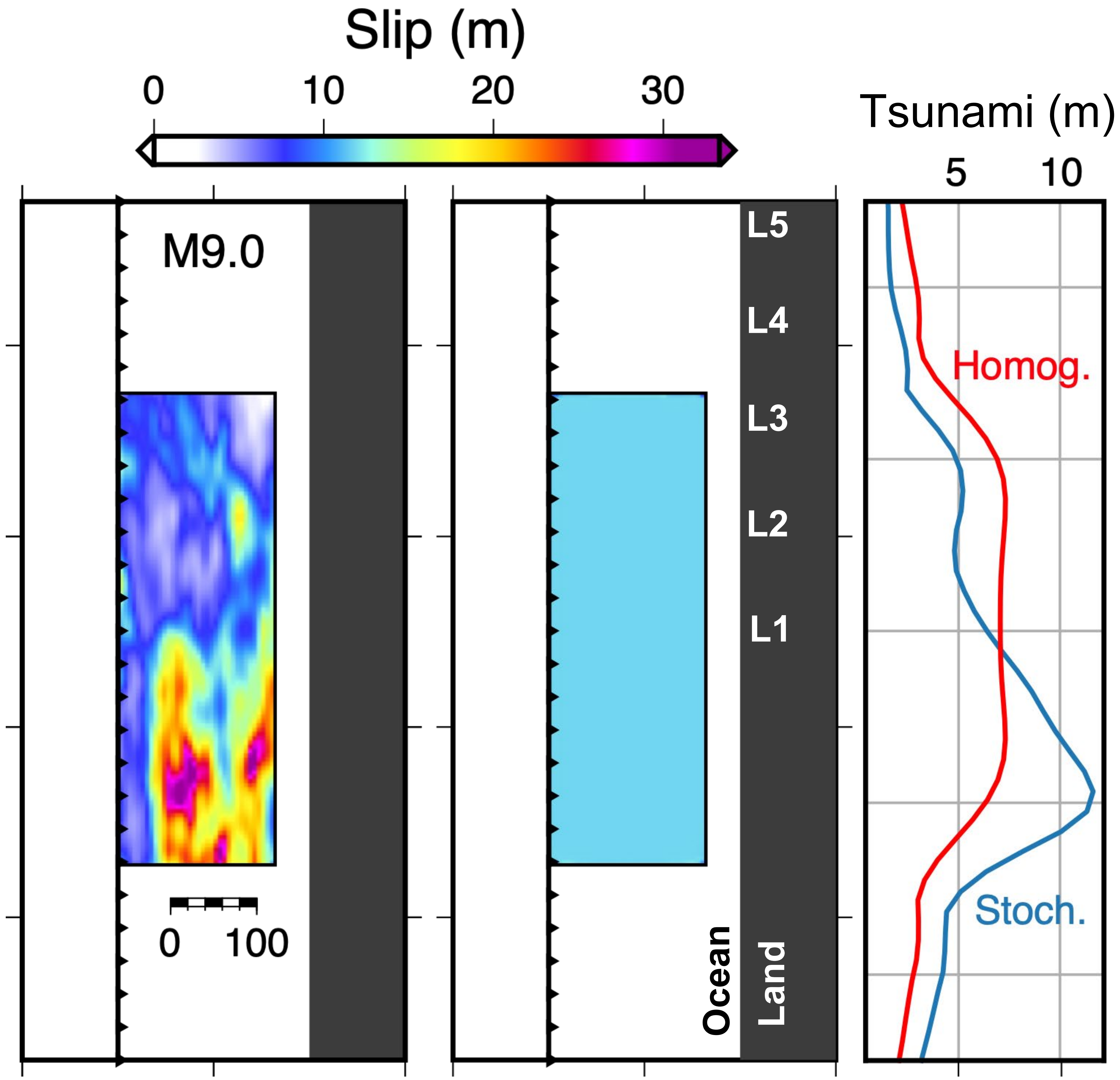
Melgar et al. 2019



Heterogenous slip can lead to *very* different deformation of the seafloor and coastline

The effect is magnified as magnitude gets larger

This impacts tsunami amplitudes



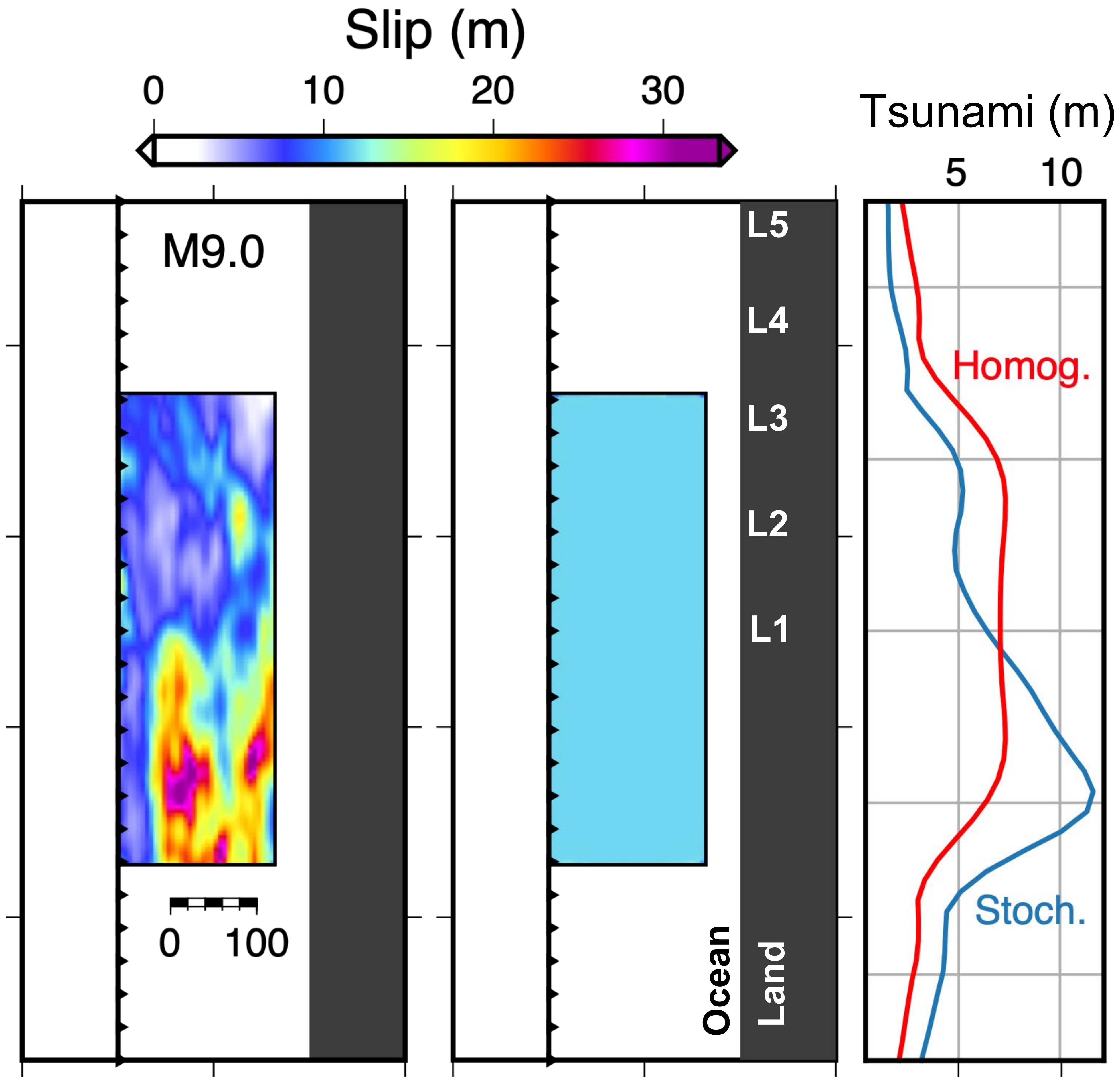
Melgar et al. 2019

But how different are they?

We model 4200 ruptures between M7.0 and M9.0 in. M0.1 bins (200 per bin)

Calculate tsunami amplitudes for each rupture at 5 locations (L1-L5) in the "near-field"

This impacts tsunami amplitudes



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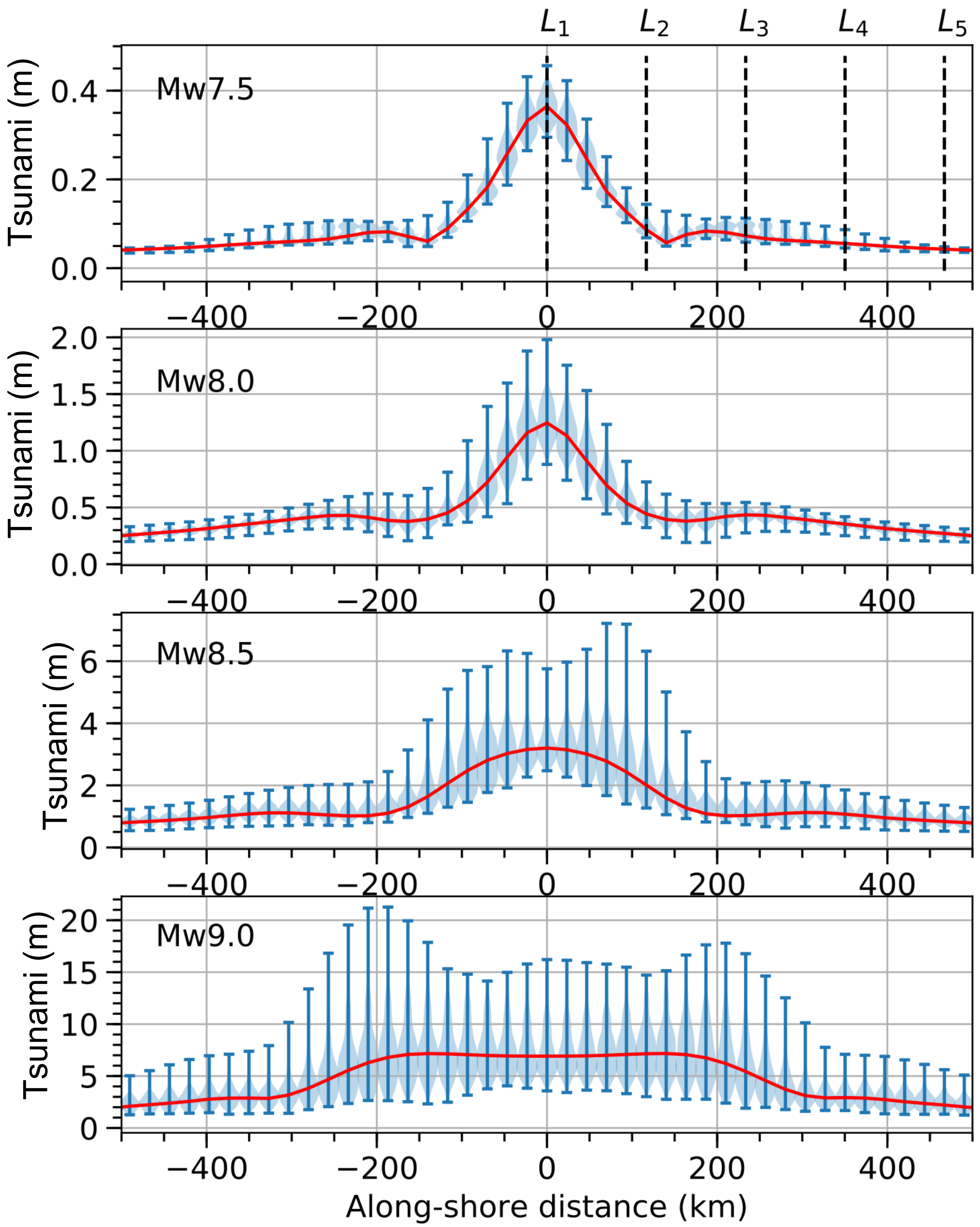
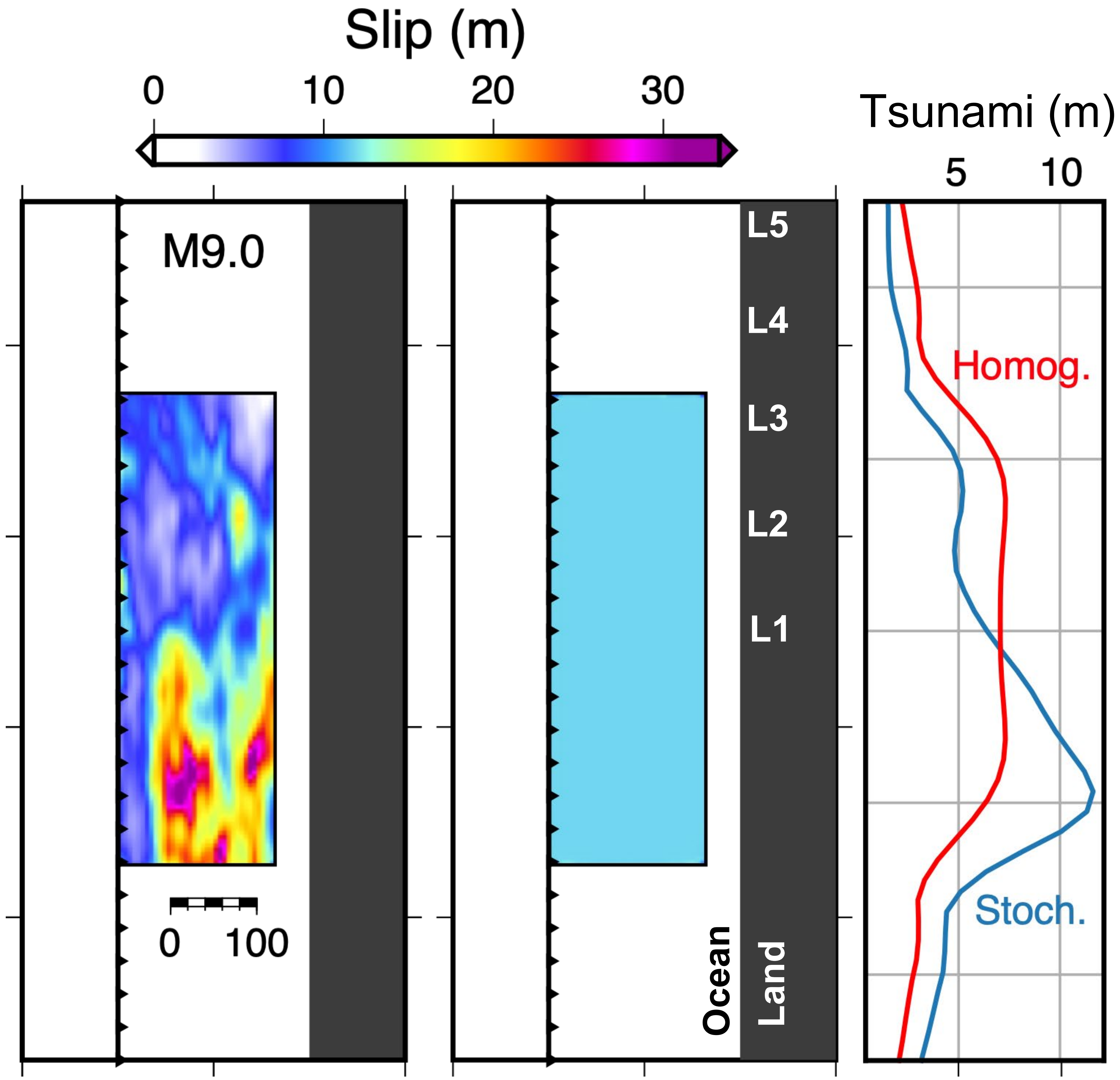


… and the resulting hazard curves/maps



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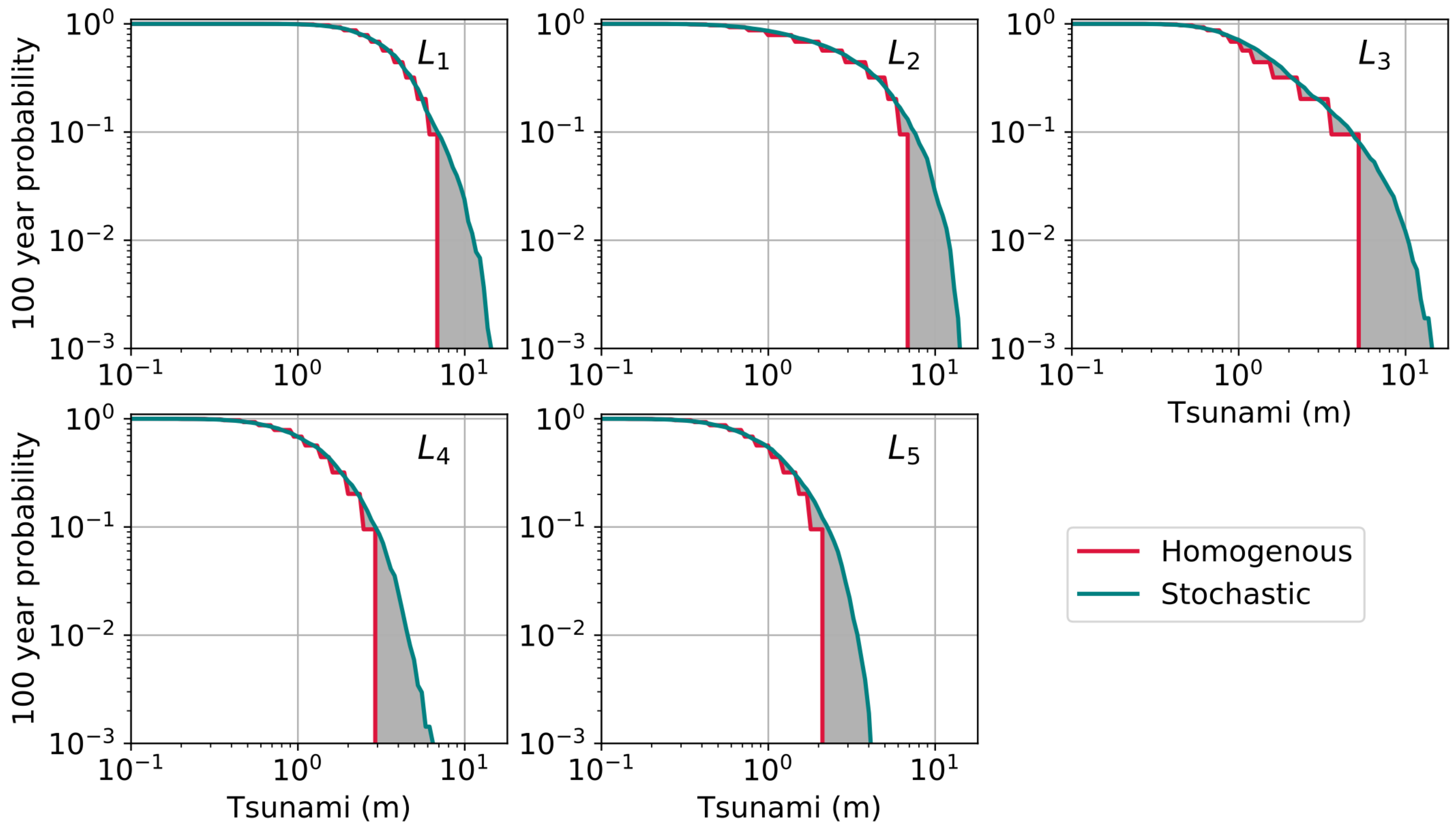


Homogenous (and simplified) slip models do not capture the full range of possible earthquake behaviors

As a result they systematically *underestimate* the resulting *near-field* tsunami hazards

The issue is exacerbated as magnitude increases

(i) How many ruptures do we need to model?

(ii) Do we know that our current rupture models approximate reality well enough?

(iii) Is this also an issue for far-field modeling?

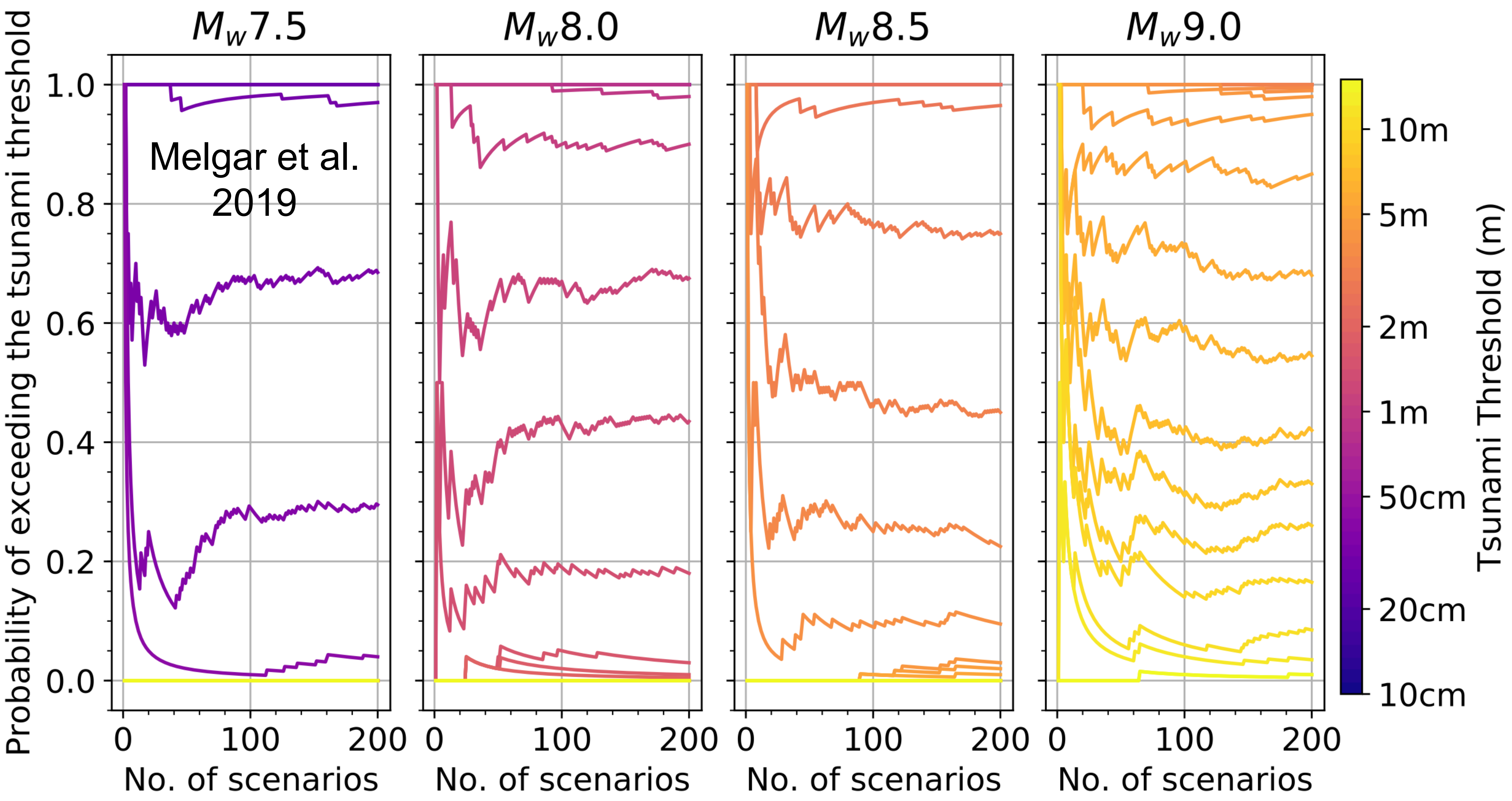
(iv) What about *inundation* modeling?

(i) How many ruptures do we need to model?

"At least a few hundred"

If the conditional probability is not stable you've not modeled enough!

The

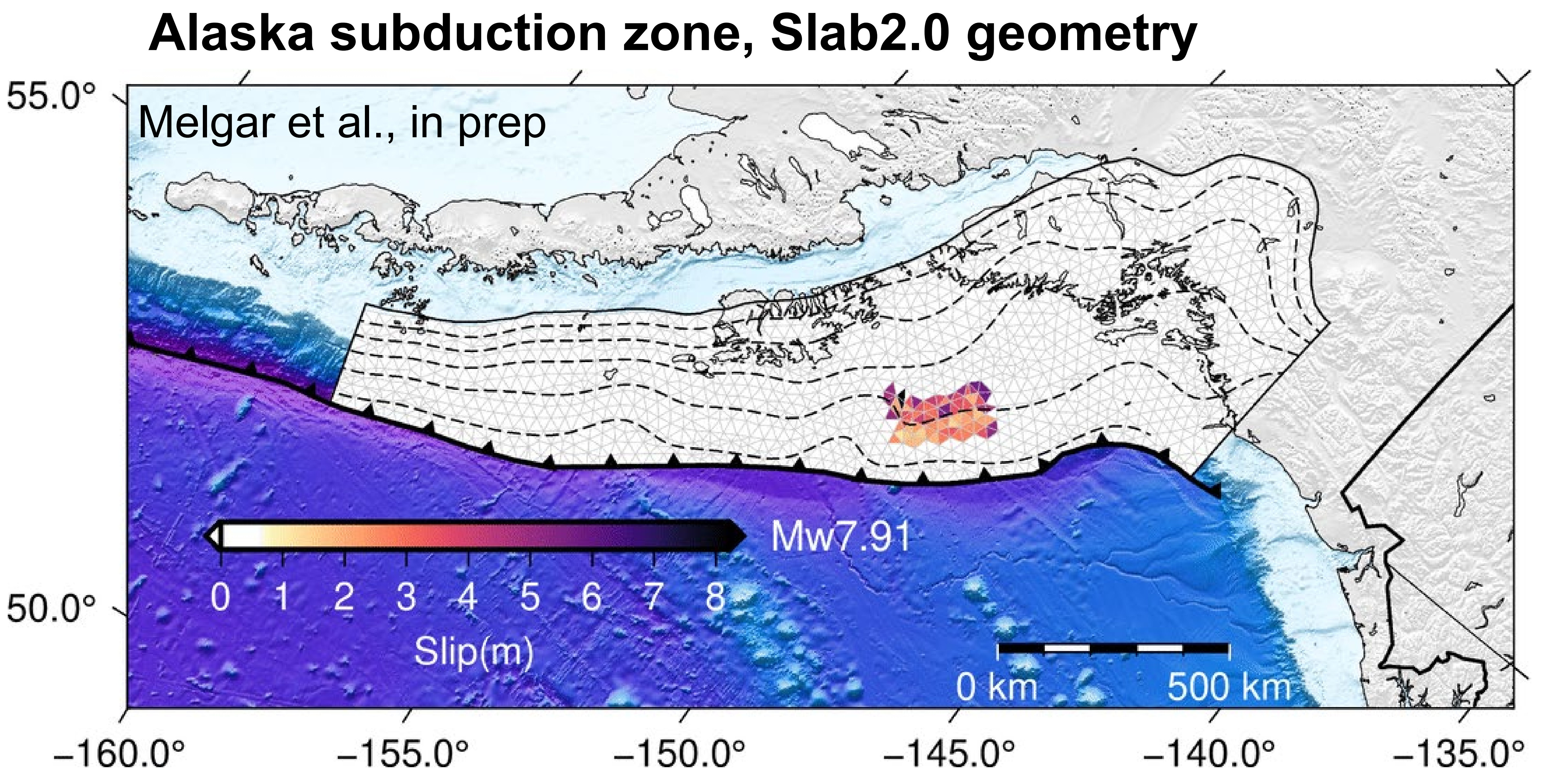


Assuming earthquakes of some type have happened what is the P of a tsunami exceeding some threshold?

$$P(\eta > \eta_c) = 1 - \Pi_{i=1}^{N}[1 - (1 - e^{-\nu_i T})p(\eta > \eta_c|M_i)]$$

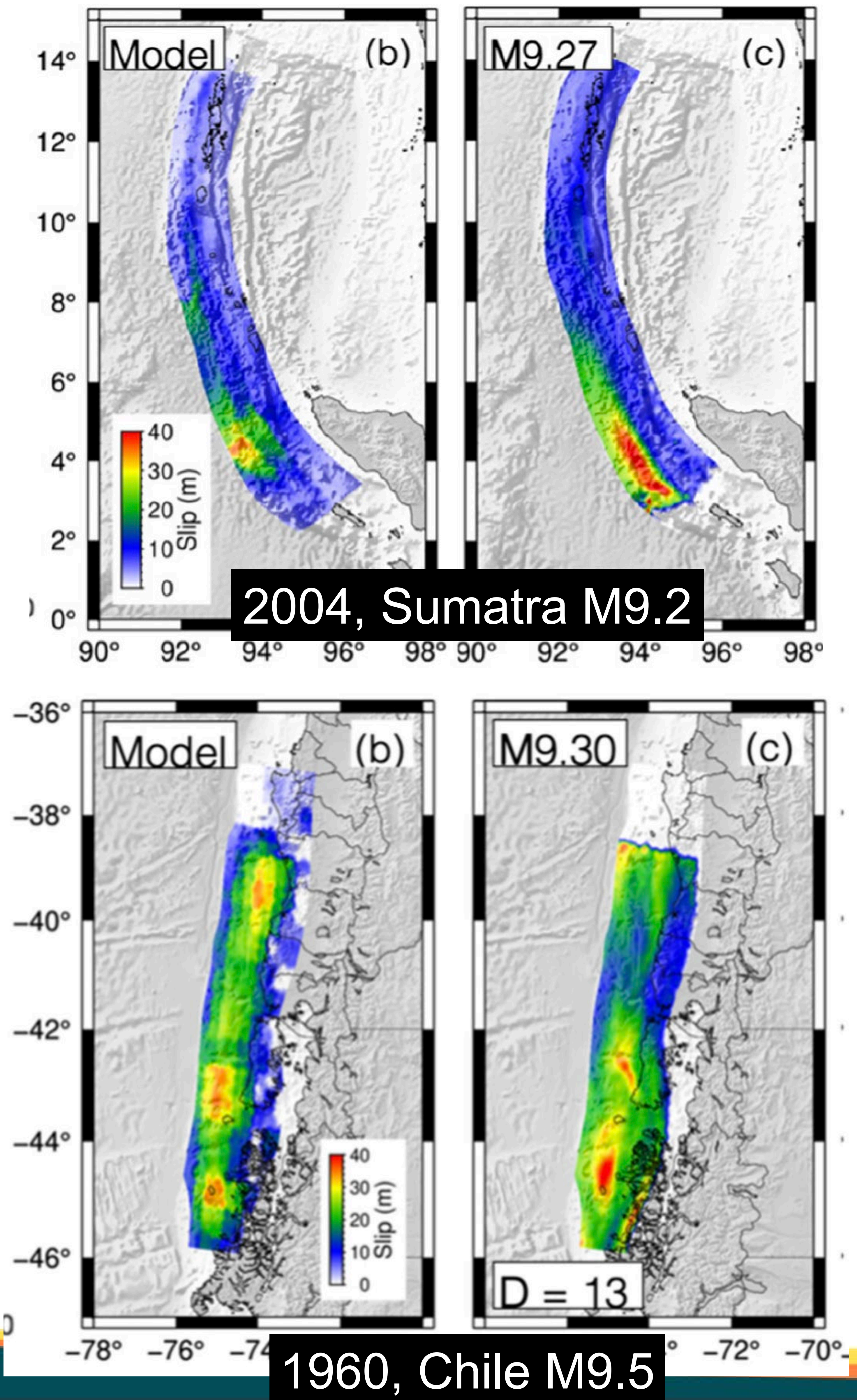
(ii) Can we model realistic ruptures?

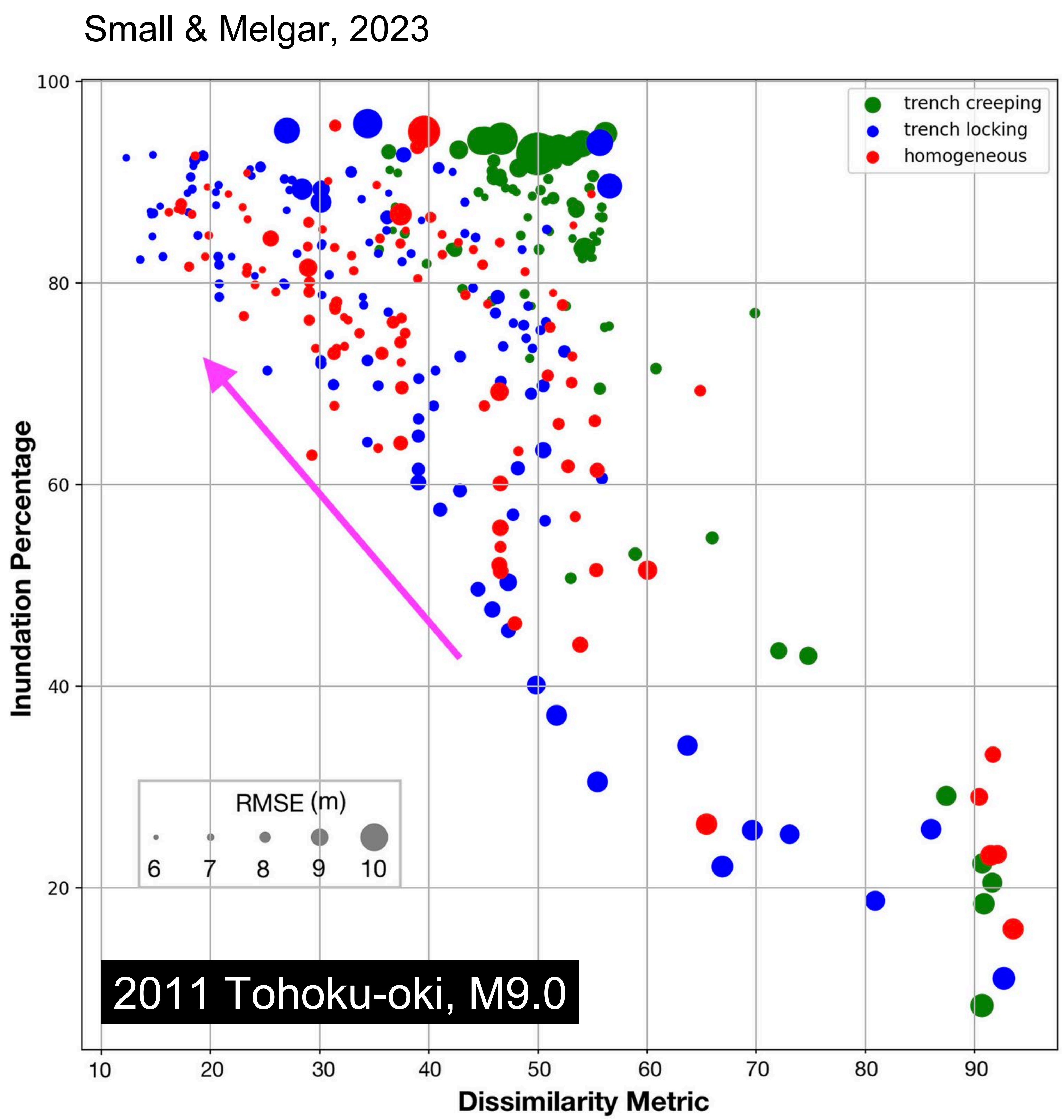
- Semi-stochastic kinematic rupture modeling has two decades of development
- Used in other settings (PSHA/cyberhsake)
- Advances allow us to apply it to complex geometries
- Computationally much more thrifty than fully dynamic



(ii) Can we model realistic ruptures?

- Small & Melgar, 2023 compared stochastic simulations to large historical ruptures





(iii) What about far-field sources?

Pure Appl. Geophys. 177 (2020), 1521–1548

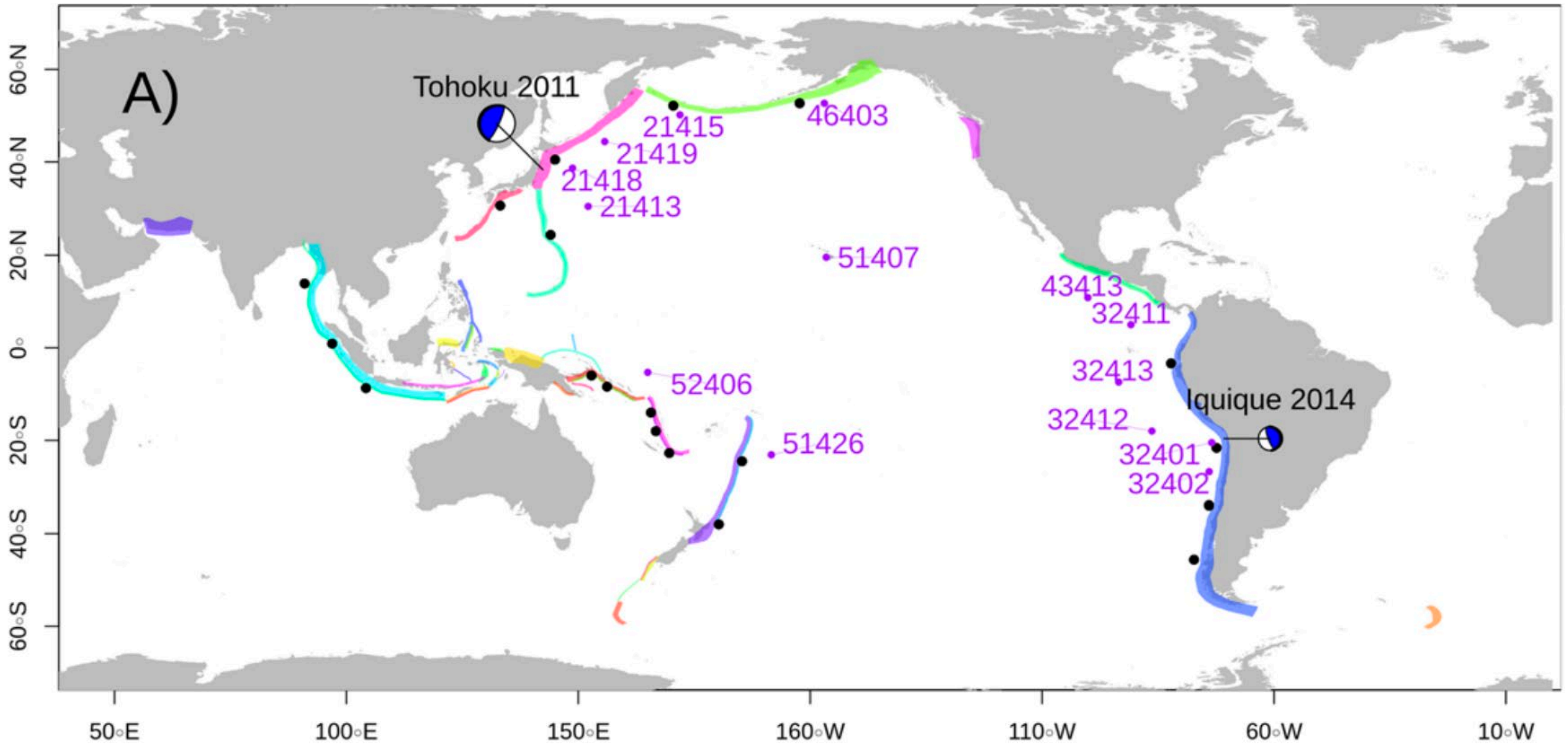
https://doi.org/10.1007/s00024-019-02299-w

Pure and Applied Geophysics

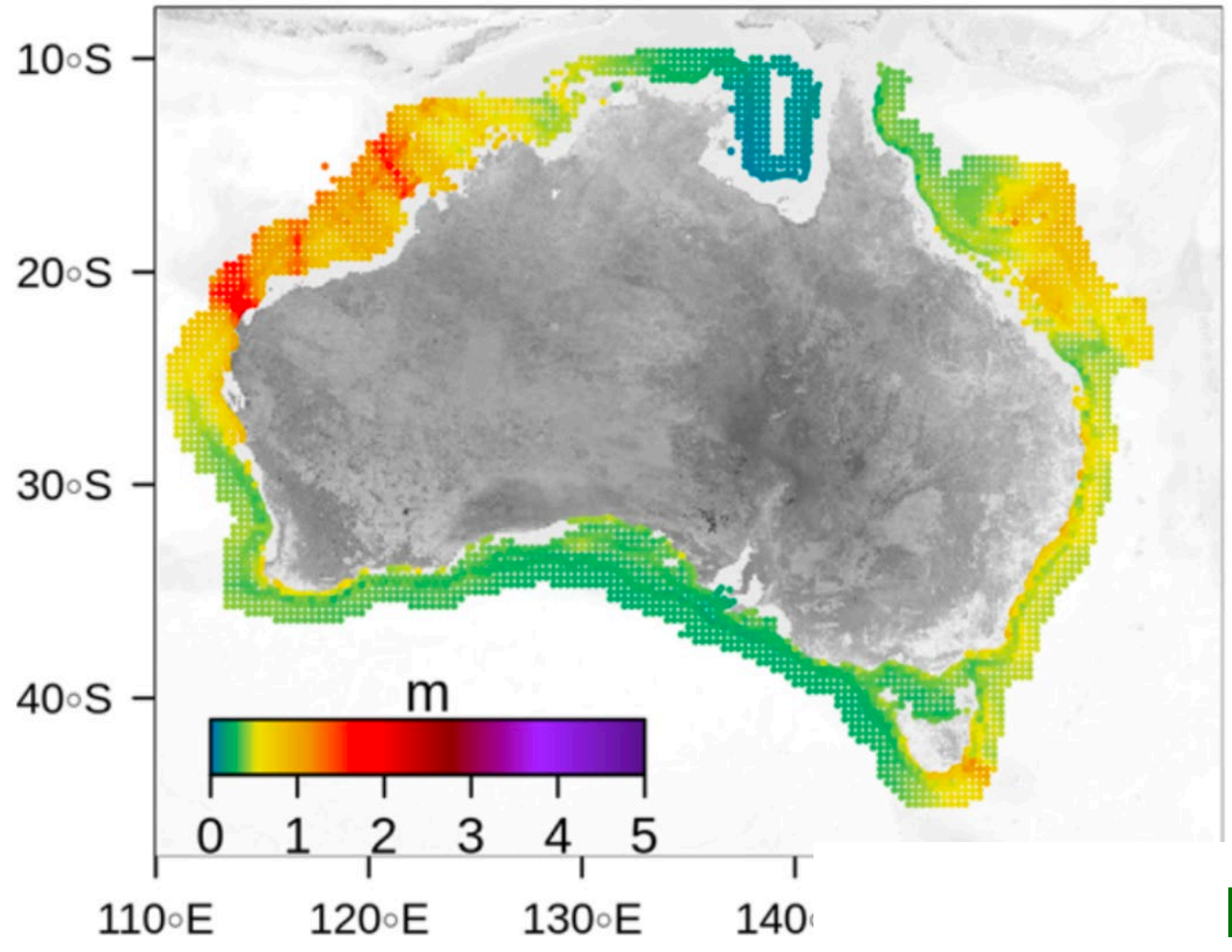
Check for updates

Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

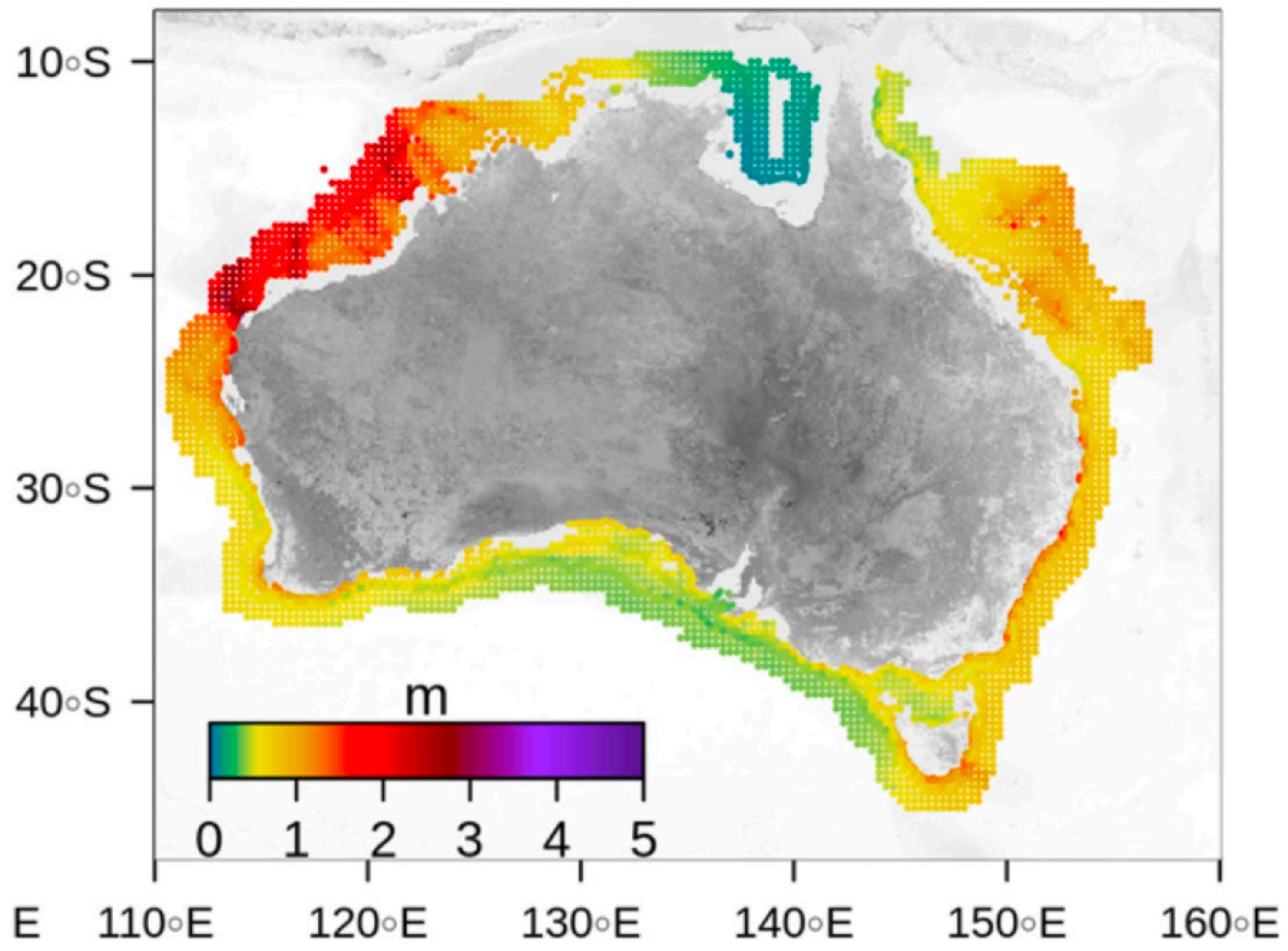
Gareth Davies[1] and Jonathan Griffin[1,2]



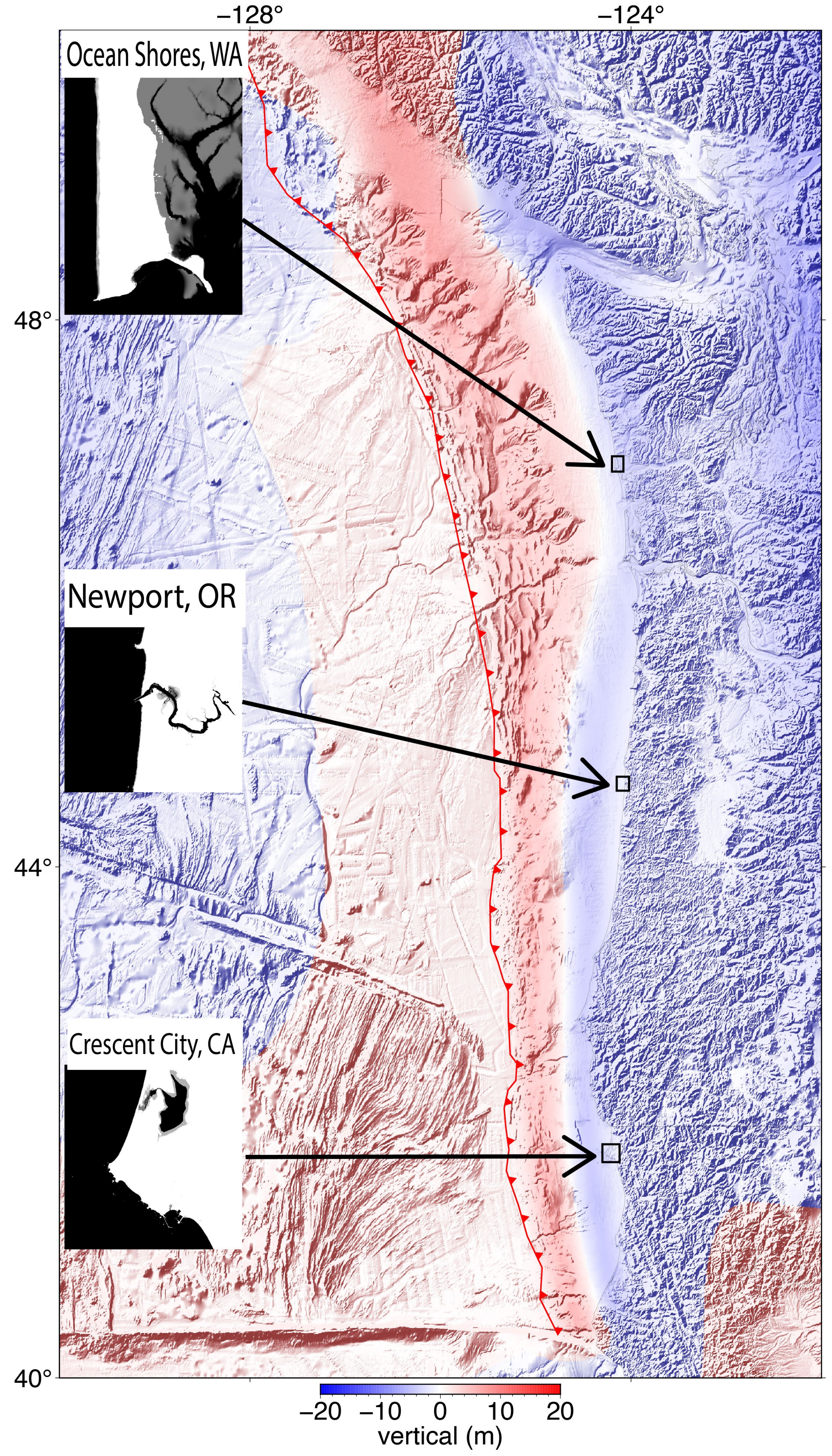
Homogenous slip

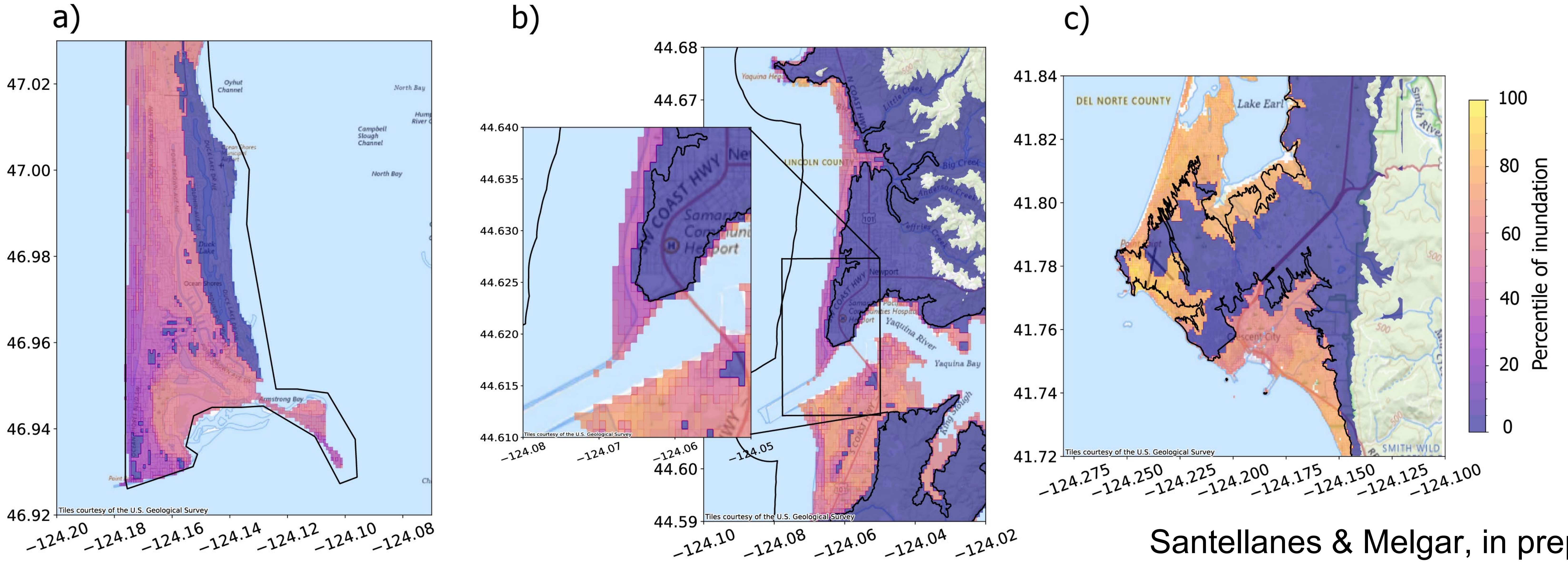


Heterogenous slip



(iv) What about inundation modeling?





Santellanes & Melgar, in prep

(iv) What about inundation modeling?

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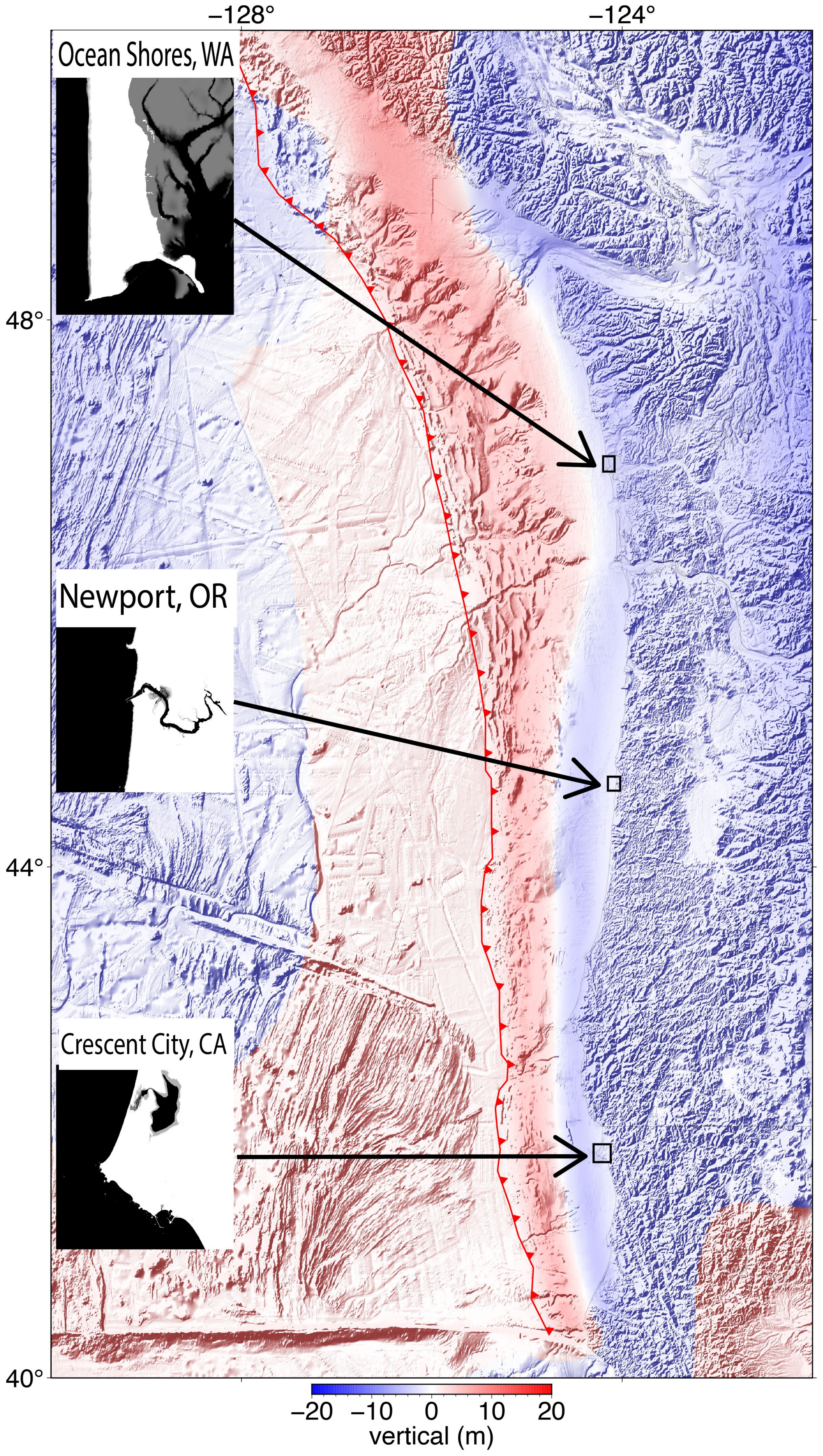
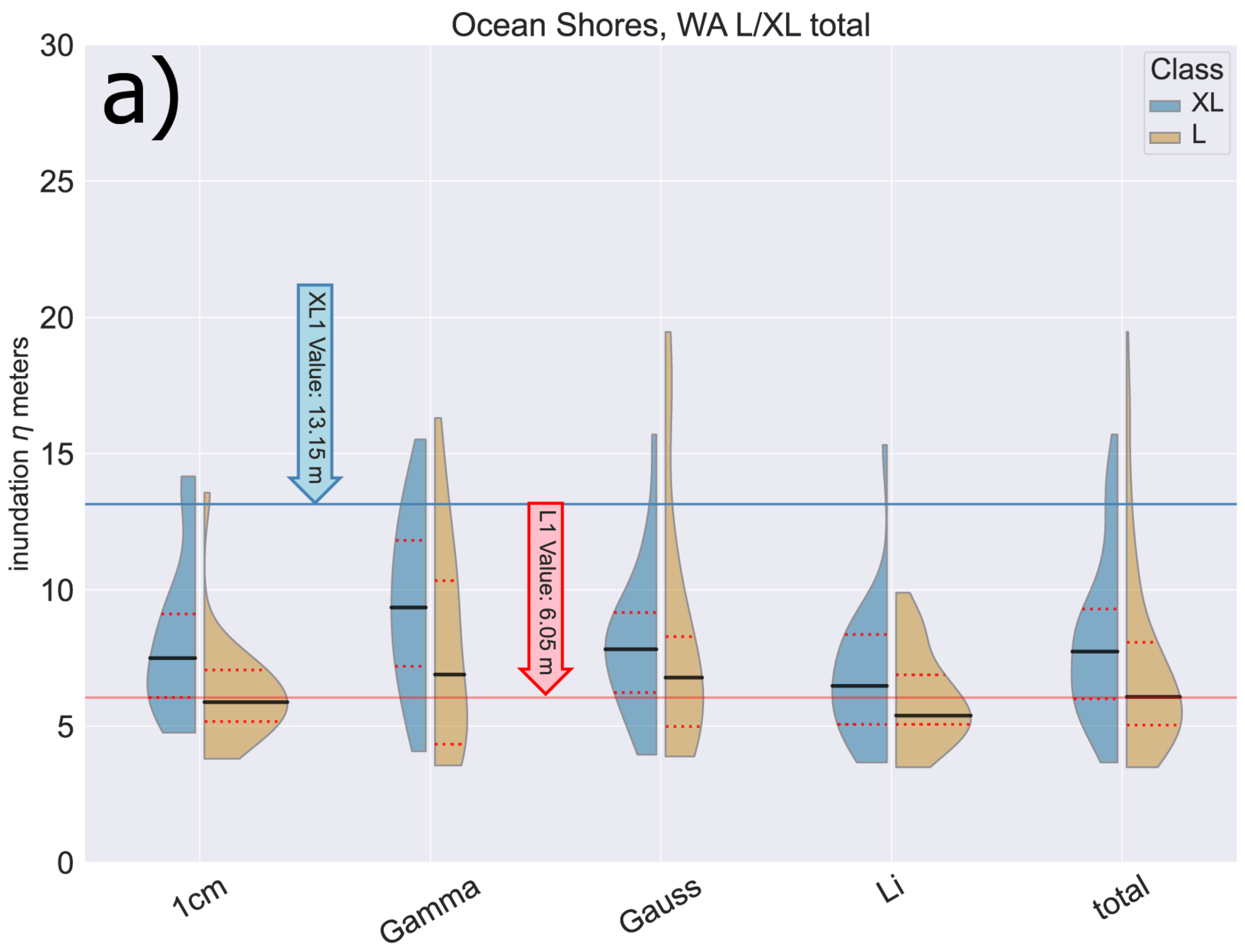
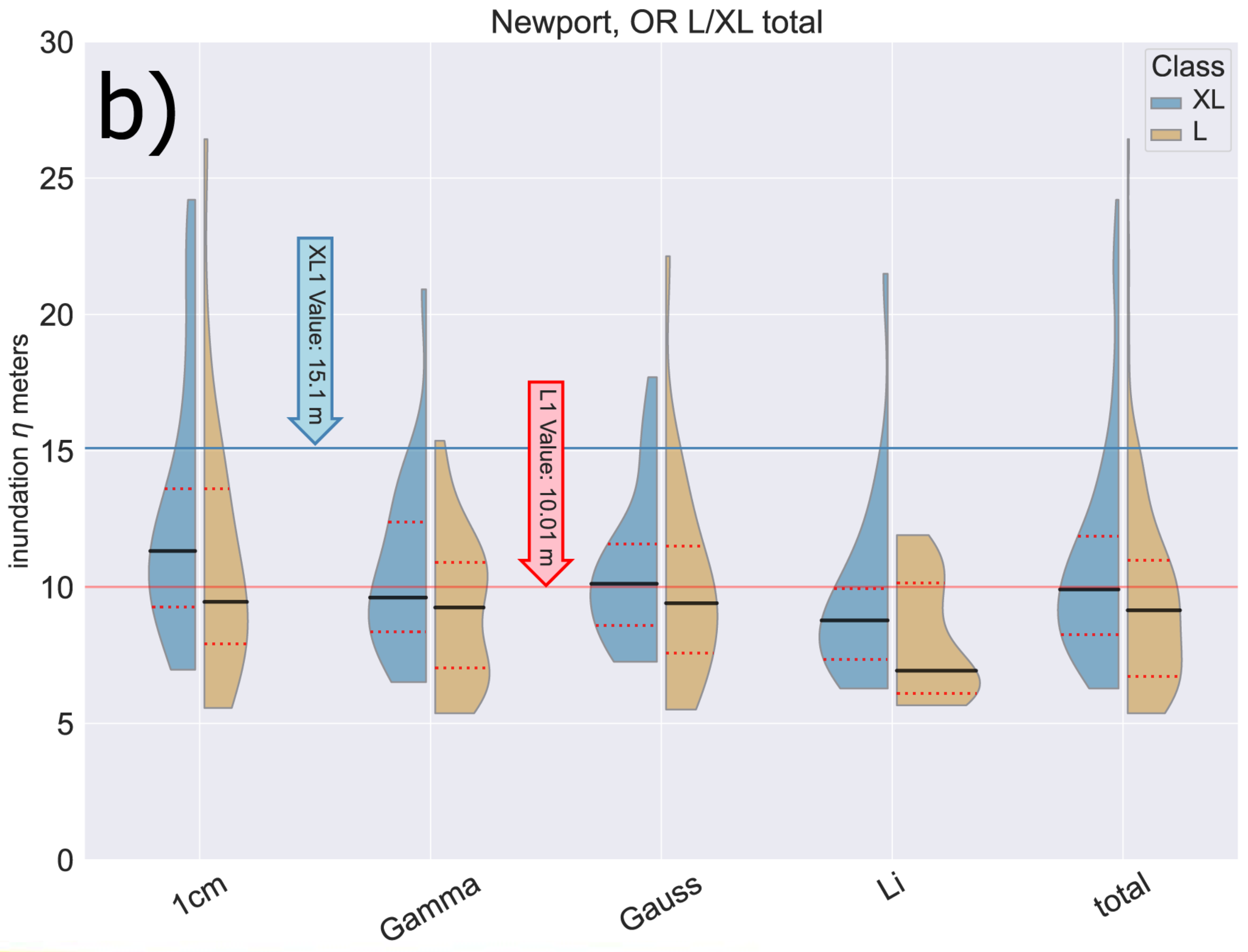
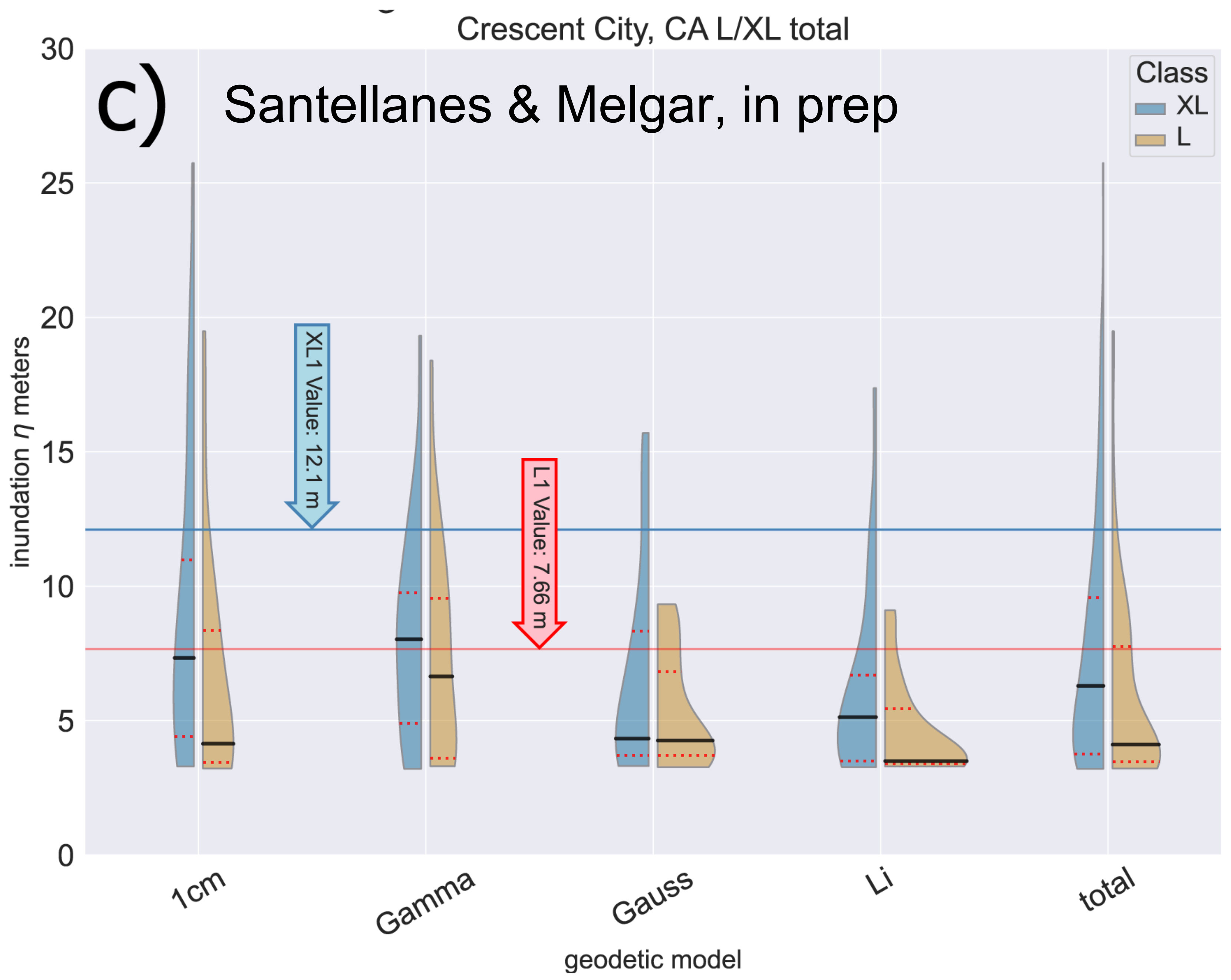




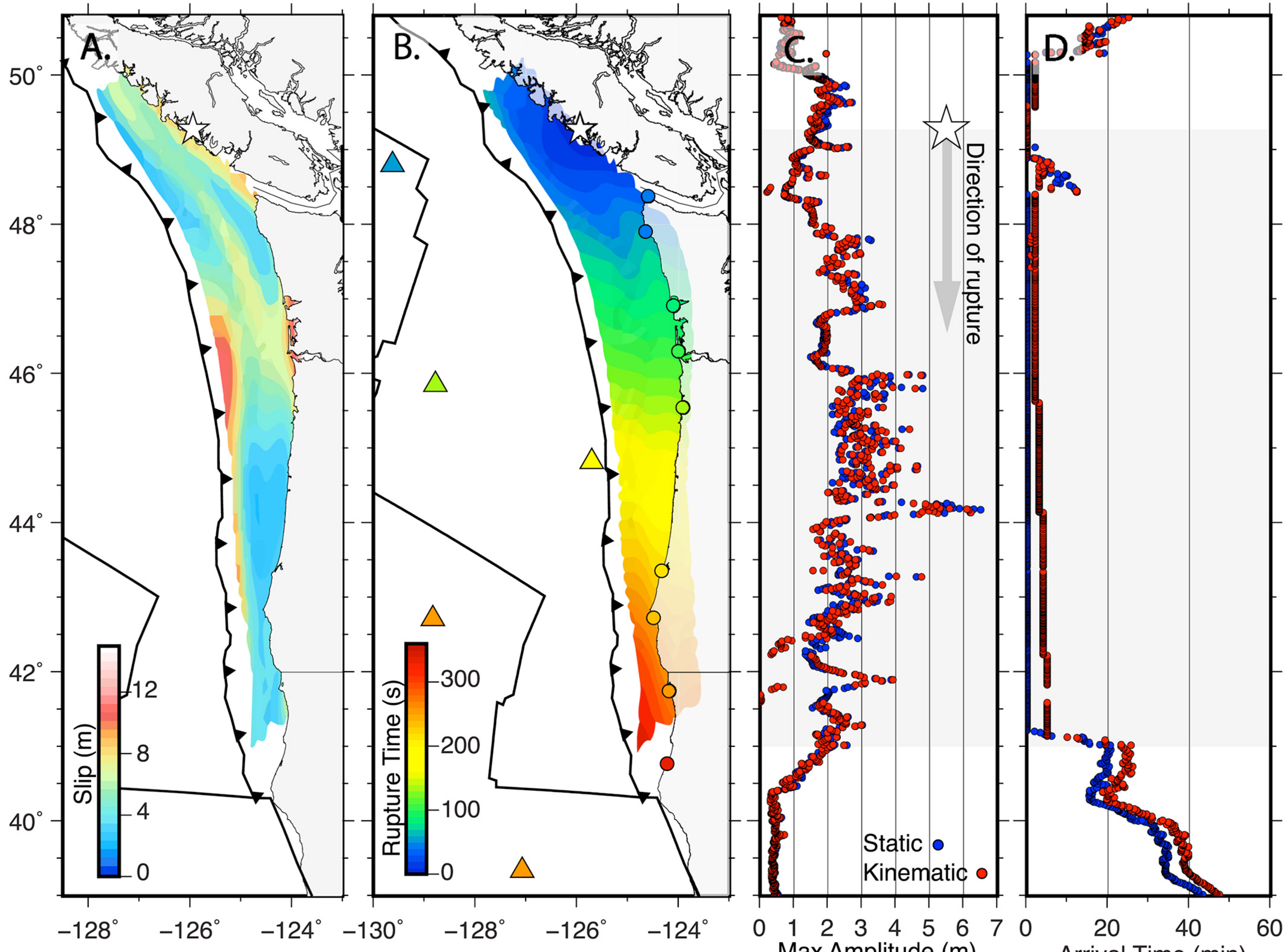




Some conclusions about heterogenous slip go here

What about other source complexities like slip kinematics?

The time evolution of rupture likely doesn't matter in the near-field

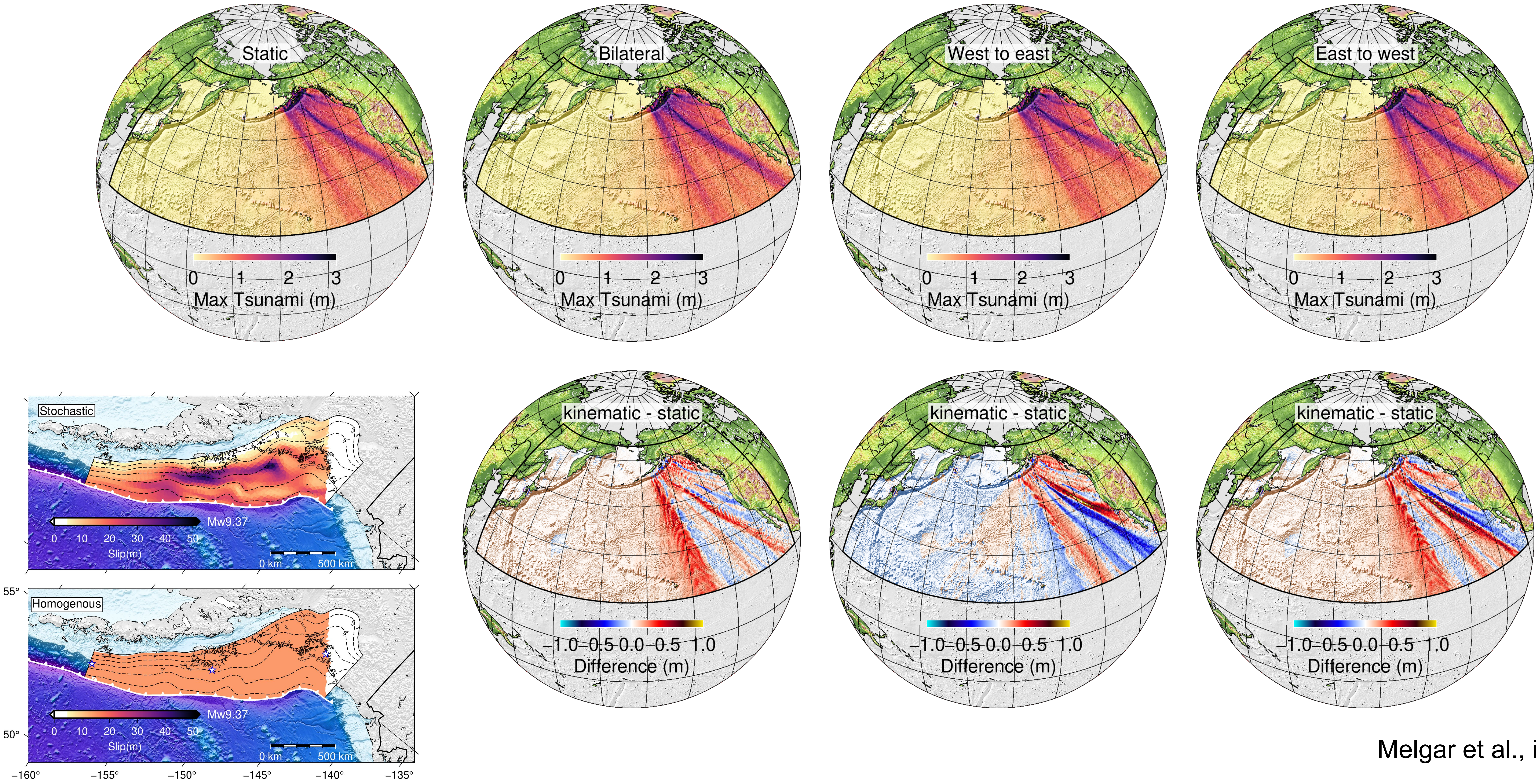


Williamson et al., 2020

… but it might matter in the far-field

Williamson et al., 2020

In fact it, almost certainly does



Melgar et al., in prep

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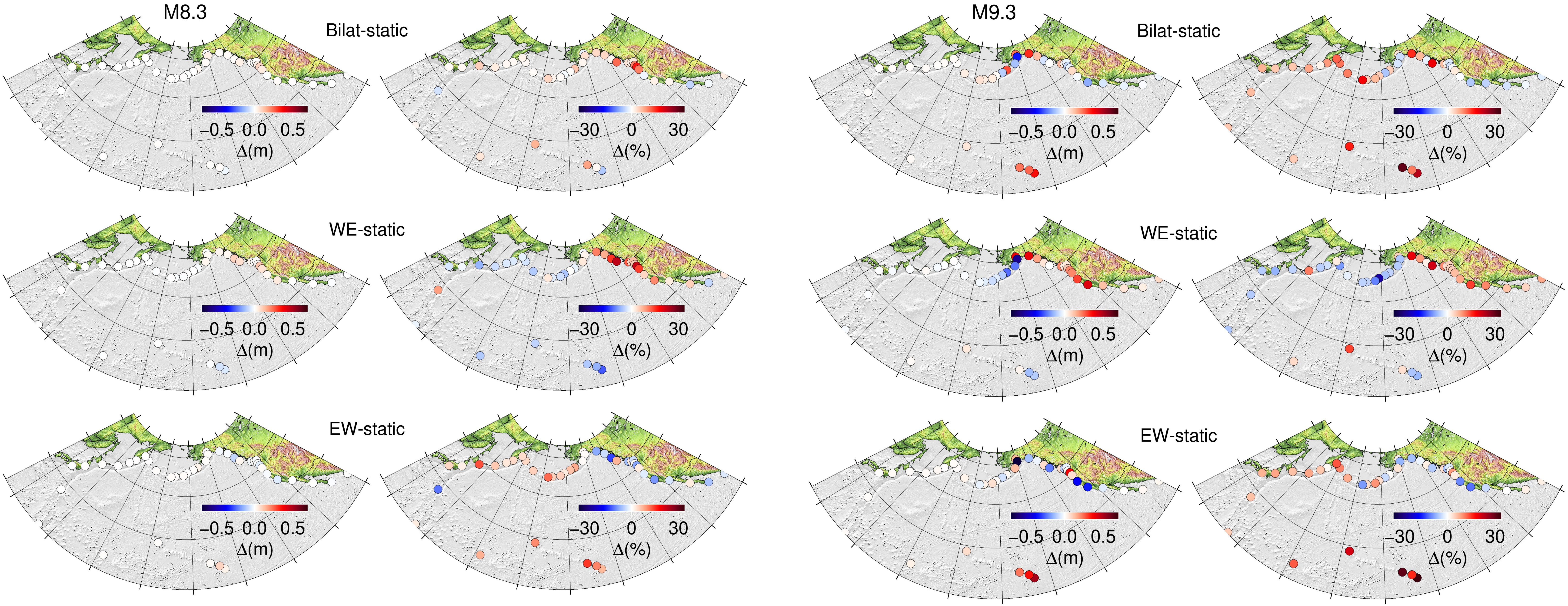

Melgar et al., in prep

What does this mean? Conclusions

- Back tot he logic tree and conditional probabilities
- For each branch we need to model many stochastic sources to capture the full range of behavior
- Other complexities like splays can be included int his formalism
- It increases computational load no way round that
- We need to move past modeling tot he coast or some isobxathy contour and do proper INUNDATION modeling
- Other uncertainties like magnitude/frequency PALEOSEISMOLOGY