On the Possibility of Slip-to-trench Rupture in Cascadia Megathrust Earthquakes

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1. Introduction

Tsunamis may be generated by subduction zone earthquakes in four ways, as summarized in Fig. 1.1.

Cascadia megathrust rupture models previously developed for tsunami hazard assessment include scenarios (a) and (b). The 2011 Mw 9.0 Tohoku-oki earthquake raised a new question. Can the shallowest portion of the Cascadia megathrust also slip to trench in great earthquakes as in the Tohoku-oki earthquake (c) or would it normally resist coseimic rupture but creep aseismically afterwards as in the 2005 Mw 8.7 Nias earthquake (a)? To answer this question, we reanalyzed seismic images from marine multichannel seismic surveys conducted in 1985 and 1989 with a new focus on the accretionary wedge deformation front.

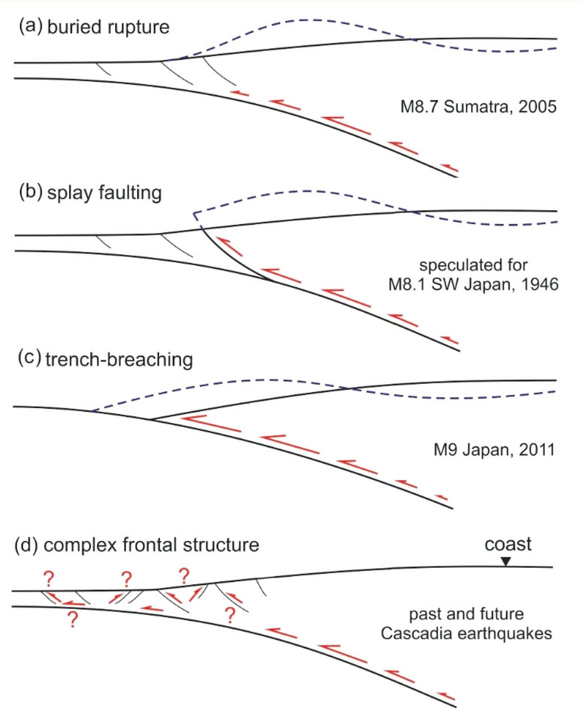


Fig. 1.1. Four rupture scenarios of subduction zone earthquakes in generating tsunamis [*Wang and Trehu*, 2015]. Red arrows represent coseismic slip.

2. Structures near Deformation Front

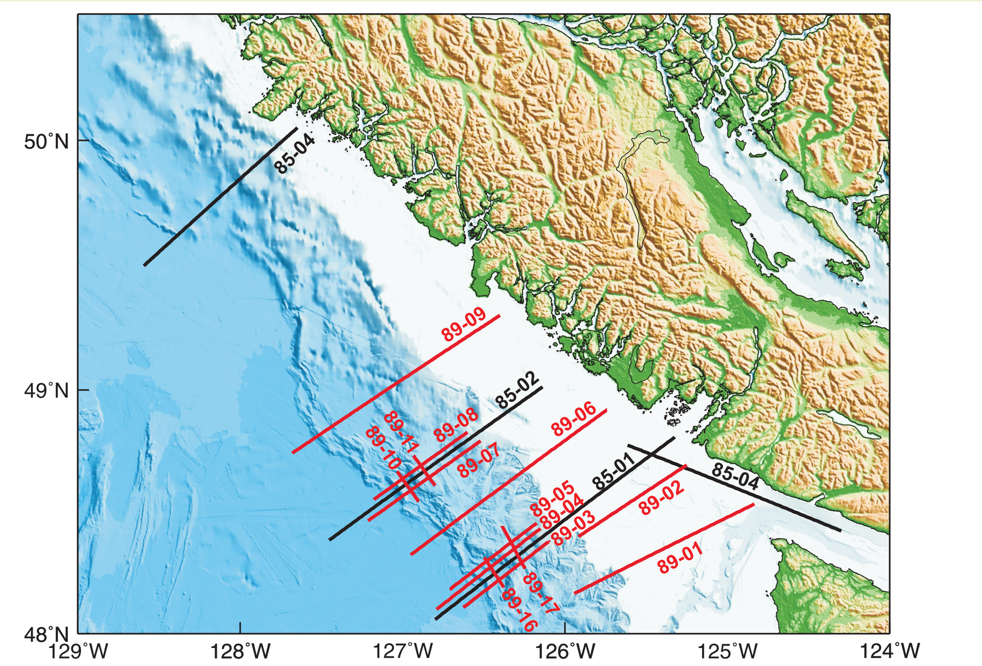


Fig. 2.1. The 1985 (black lines) [*Yorath et al.*, 1987; *Clowes et al.*, 1987; *Davis and Hyndman*, 1989] and 1989 (red lines) [*Spence et al.*, 1991a, 1991b; *Hyndman et al.*, 1994; *Yuan et al.*, 1994] marine multichannel reflection profiles.

2.1 Comparison with Japan

Japan

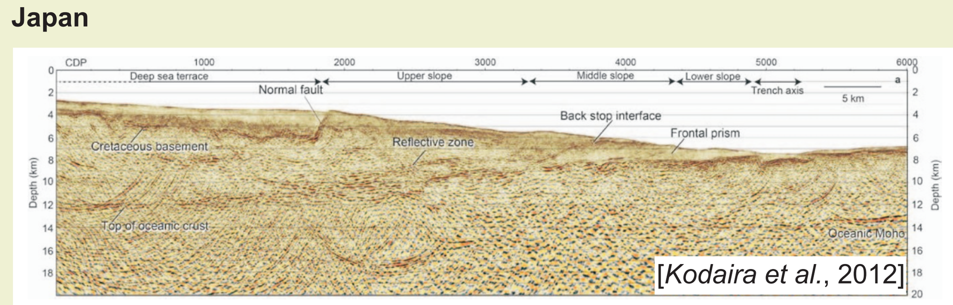


Fig. 2.2. Seismic image crossing the Japan trench. See the sketch in Fig 1.1c.

Cascadia

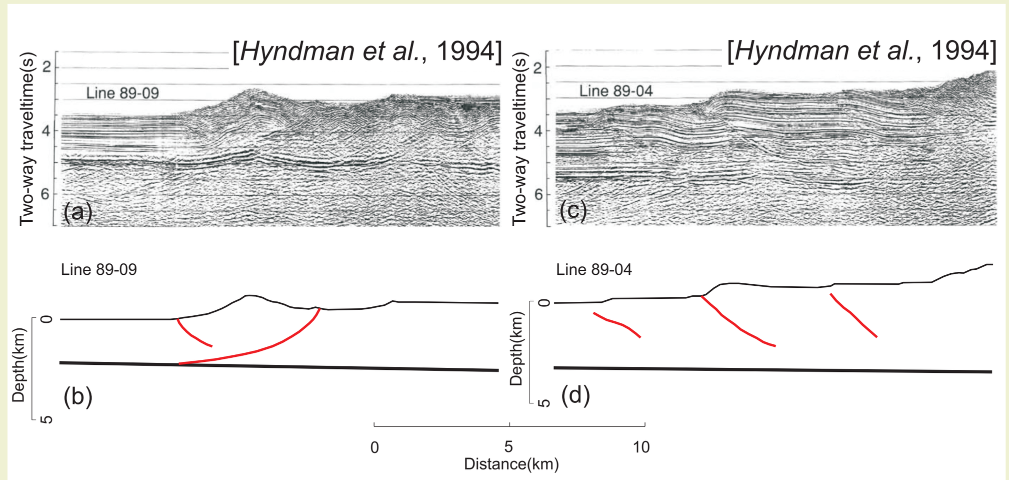


Fig. 2.3. Two examples of seismic profiles at Cascadia.

2.2 Deformation Styles along Northernmost Cascadia

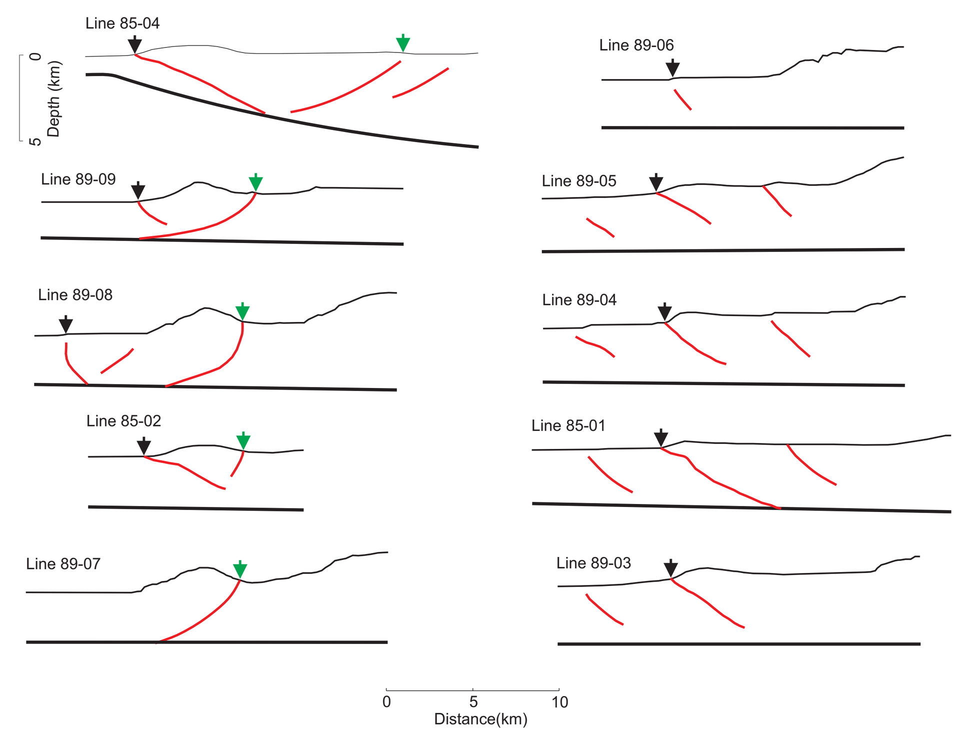


Fig. 2.4. Deformation styles. Black and green arrows denote the dominant frontal thrust and/or back-thrust, respectively, in each profile.

Slip-to-trech rupture: not very likely at Cascadia

2.3 How do frontal thrusts and back-thrusts contribute to tsunami generation?

Hypothetical frontal thrust and back-thrust models

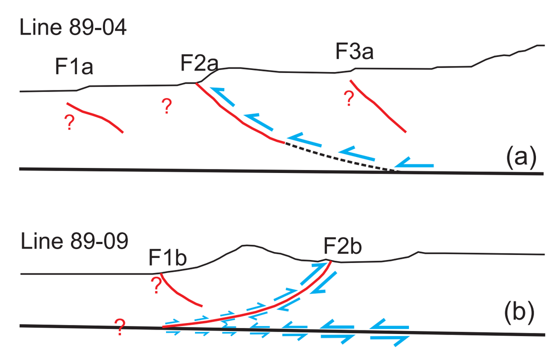
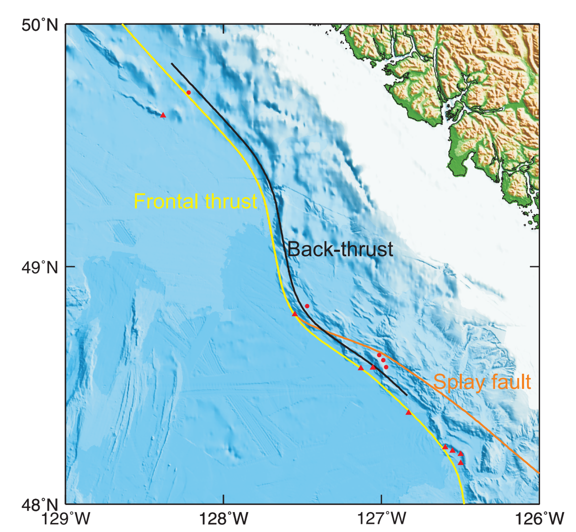


Fig. 2.5. (a) Frontal thrust example. Blue arrows: assumed coseismic slip in megathrust earthquakes. We assume that the dominant thrust F2a connects to the decollement. (b) Back-thrust example.

Fig. 2.6. Hypothetical frontal thrust (yellow line) and back-thrust (black line), obtained using the dominant thrust/back-thrust from each seismic profile shown in Fig. 2.4. Orange line: splay fault.

Red triangles: dominant thrust
Red dots: dominant back-thrust



3. Method: 3D Dislocation Model

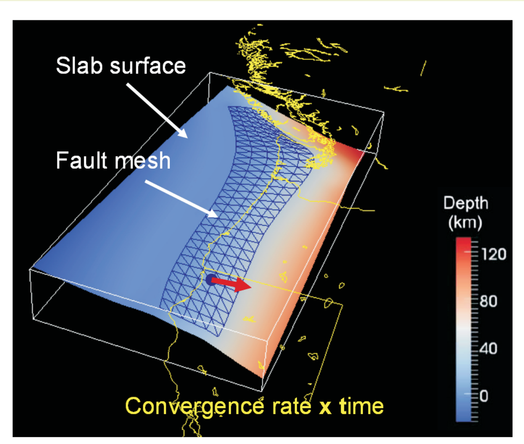


Fig. 3.1. Dislocation model. The triangles actually used for numerical integration are too small to be shown here.

Tsunami sources are simulated with a 3-D numerical dislocation model in a uniform elastic half-space. The code numerically integrates the point-source dislocation solution of *Okada* [1985] over a three-dimensionally curved megathrust and yields displacement at surface observation points. Details of the modelling method are given by *Wang et al.* [2003].

4. Buried and Splay Faulting Rupture Scenarios for Tsunami Hazard Assessment

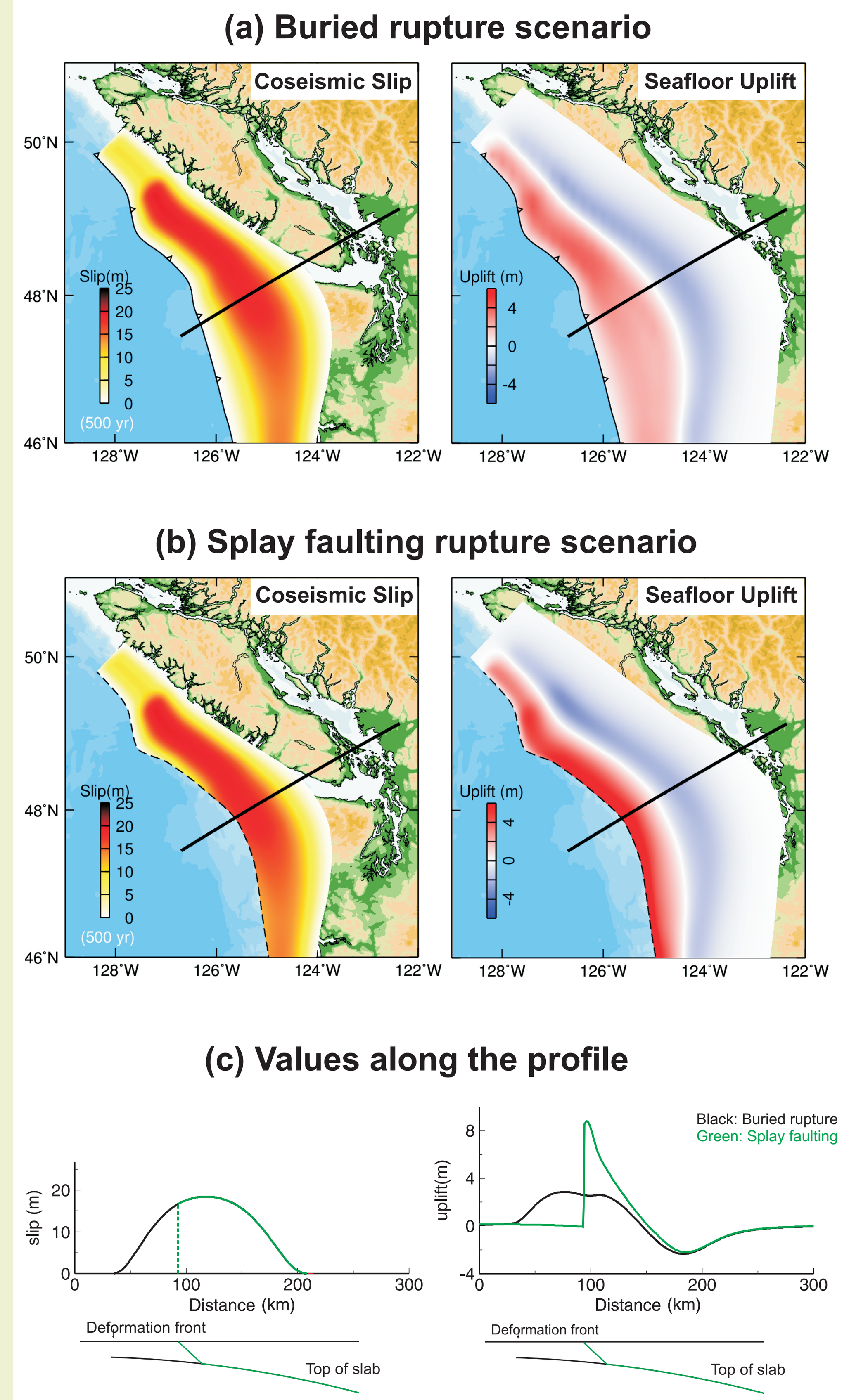


Fig. 4.1. Two rupture scenarios for tsunami hazard assessment.

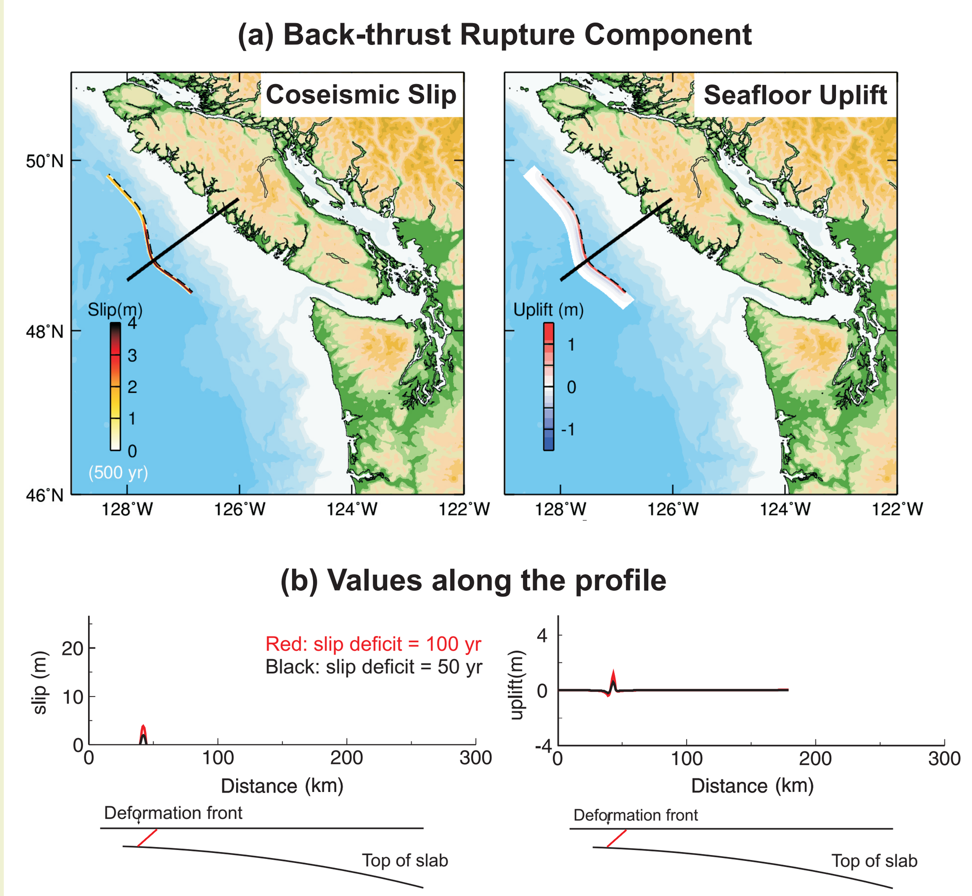


Fig. 5.2. Tests showing the unimportance of back-thrust rupture component.

5. Trench-breaching Rupture Scenarios for Tsunami Hazard Assessment

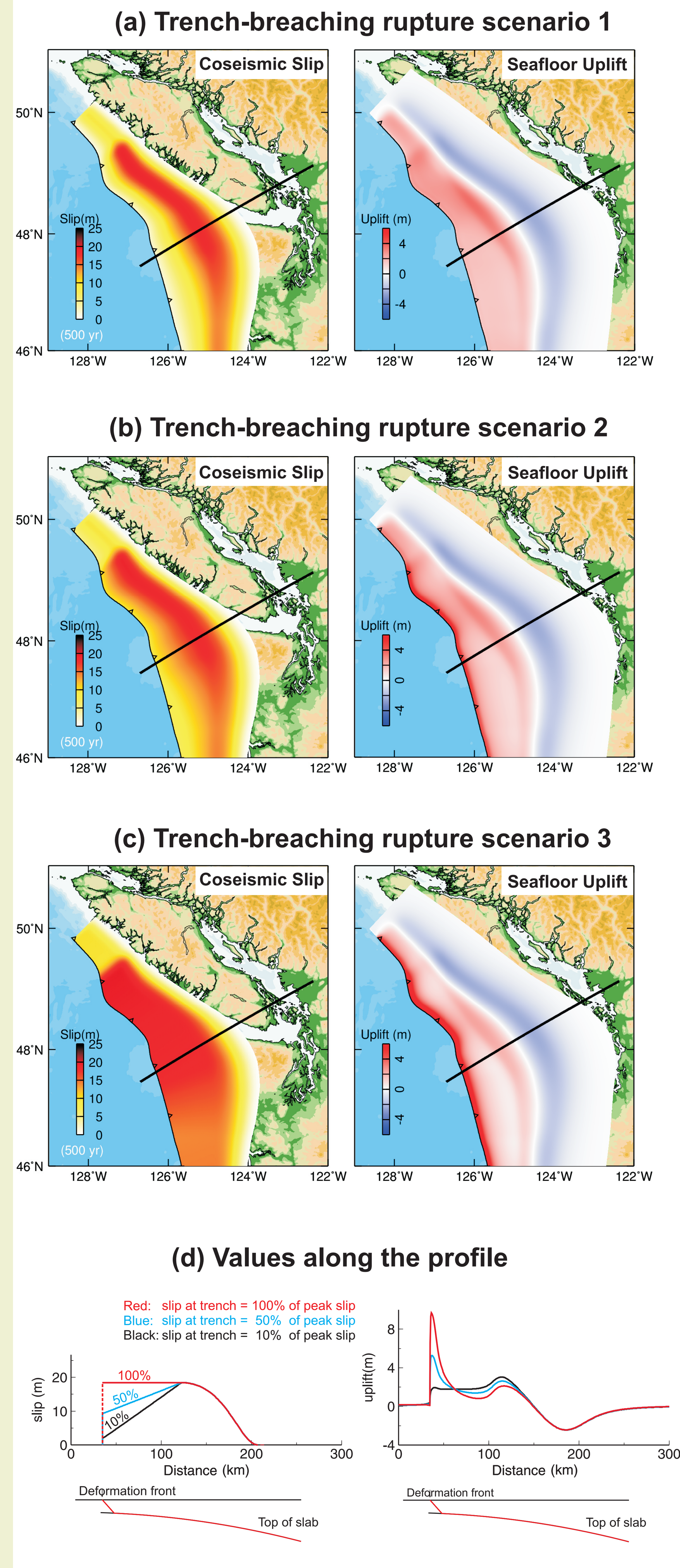


Fig. 5.1. Three trench-breaching rupture scenarios for tsunami hazard assessment.

6. Applications to Tsunami Wave Propagation

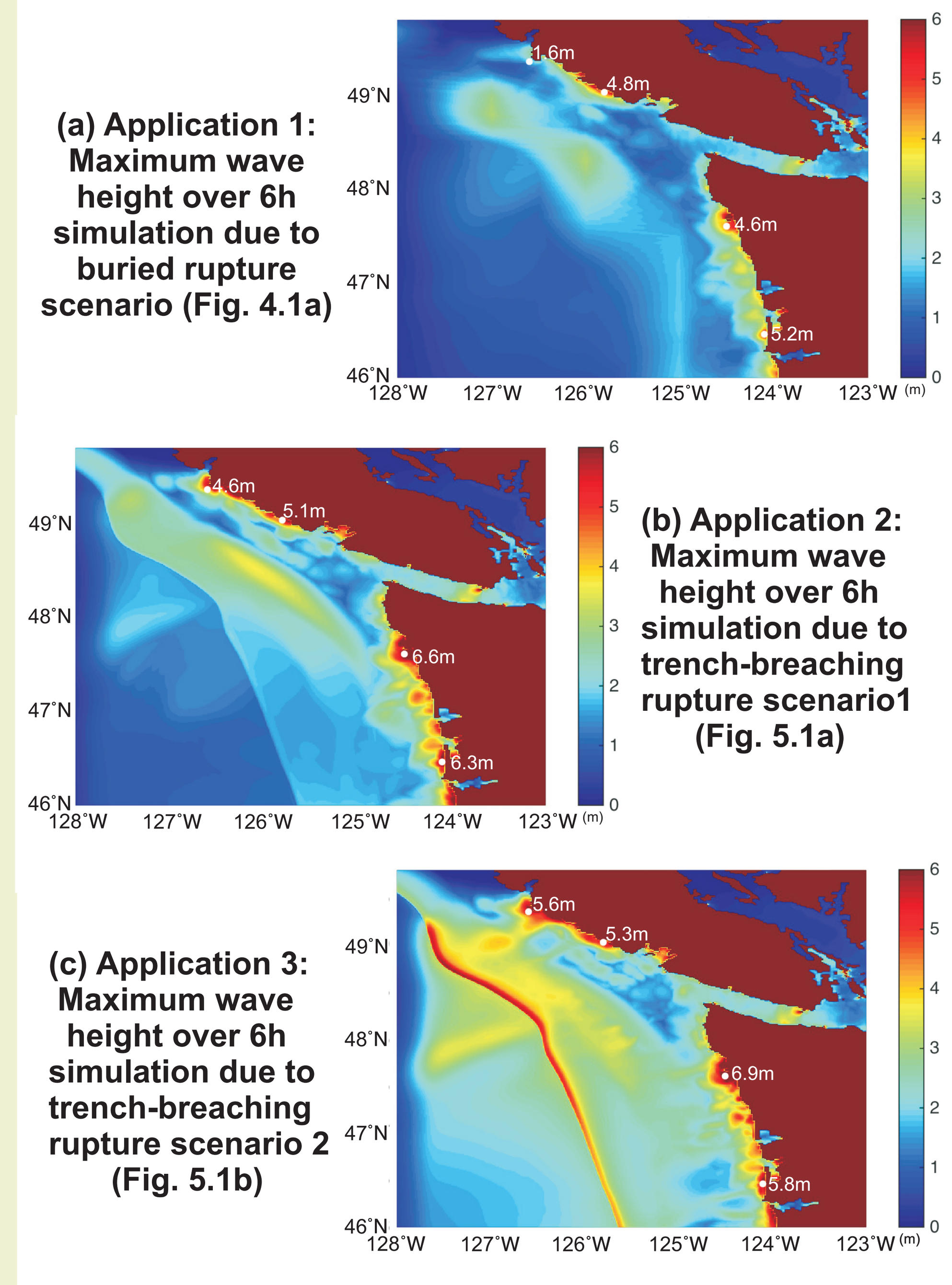


Fig. 6.1. Maximum wave height during the first 6 hours based on different rupture scenarios. Reference: mean sea level (MSL).

7. Conclusions

1. Given the complex structure at Cascadia's deformation front, slip-to-trench rupture is not a very likely scenario. Buried rupture and activation of multiple thrusts may be more likely scenarios.

2. Back-thrust rupture near deformation front is unimportant for tsunami generation.

3. For tsunami hazard assessment, we should consider all the rupture scenarios, including the low probability slip-to-trench rupture involving frontal thrusts.

8. References

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