Seismic Modeling to Improve Tsunami Prediction in Geoclaw

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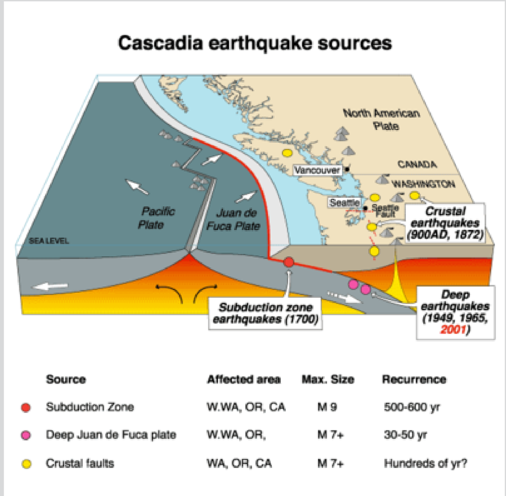
Motivation

Cascadia Subduction Zone

1. land mass is added to the Juan de Fuca plate
2. plate subducts under North American plate
3. locking/unlocking $\Rightarrow$ earthquakes
4. tsunamis are generated as a result

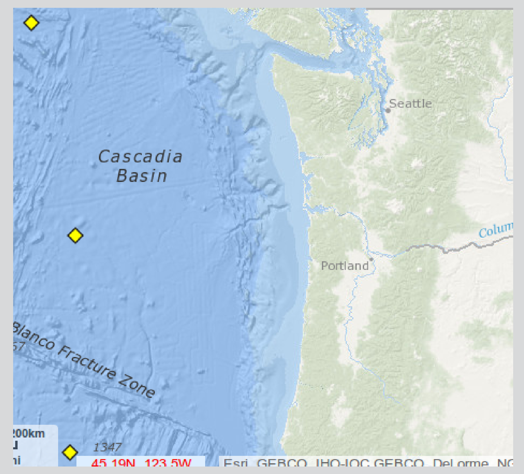


DART Buoys

- part of NOAA's Pacific warning system
- not ideal for near-shore event

Proposed Offshore Cable Network

- how many and where?
- what type of sensors?



Software & References

- *www.clawpack.org*
- *github.com/clawpack/seismic*
- preprint: arXiv:1701.01430

Model

Governing Equations

$$\bar{\sigma}_t = \lambda(\nabla \cdot \vec{u})\mathbf{I} + \mu(\nabla\vec{u} + \nabla^T\vec{u})$$

$$\rho\vec{u}_t = \nabla \cdot \bar{\sigma} - \frac{g\rho}{2\lambda}\text{tr}(\bar{\sigma})$$

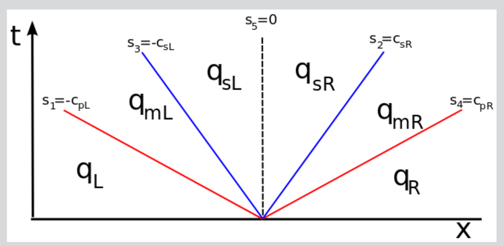
$\bar{\sigma}$ - stress $\quad \vec{u}$ - velocity $\quad \mathbf{I}$ - identity tensor

ρ - density $\quad \lambda, \mu$ - Lamé params $\quad g$ - gravity

The Riemann Problem

Interfaces between materials are handled naturally in Clawpack (denote $\vec{f} = \bar{\sigma}.\vec{n}$):

$$\vec{f}_L \cdot \vec{n} = \vec{f}_R \cdot \vec{n}$$
$$\vec{u}_L \cdot \vec{n} = \vec{u}_R \cdot \vec{n}$$
$$\vec{f}_L \cdot \vec{\tau} = \vec{f}_R \cdot \vec{\tau}$$
$$\vec{u}_L \cdot \vec{\tau} = \vec{u}_R \cdot \vec{\tau}$$

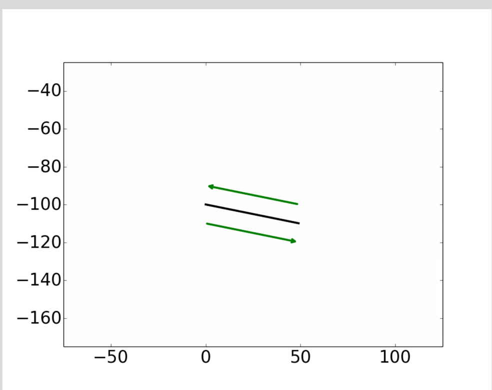


where $\vec{n}$ and $\vec{\tau}$ are the normal and tangent vectors to the interface.

Incorporating Slip

To induce slip at the fault, modify the Riemann problem as follows:

$$\vec{f}_L \cdot \vec{n} = \vec{f}_R \cdot \vec{n}$$
$$\vec{u}_L \cdot \vec{n} = \vec{u}_R \cdot \vec{n}$$
$$\vec{f}_{L,R} \cdot \vec{\tau} = 0$$
$$\vec{u}_{L,R} \cdot \vec{\tau} = u^s_{L,R}$$



Results

Seismic Results (no water, no gravity)

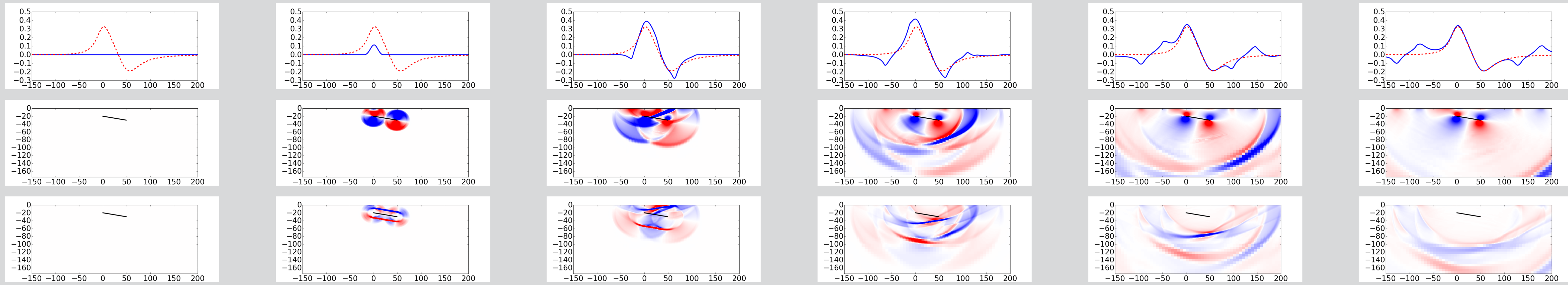
parameters: 1m slip and 1s rise time (top row - surface, middle row - tr($\bar{\sigma}$), bottom row - $\vec{u} \cdot \vec{\tau}$)

initial | 4 seconds | 10 seconds | 20 seconds | 30 seconds | 40 seconds

numerical / Okada

compression / tension

up dip / down dip



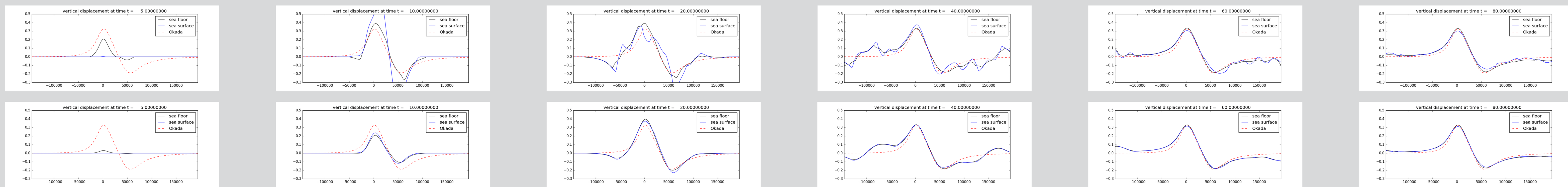
Seismic-Acoustic Results (no gravity)

parameters: 1m slip and 3km water

rise | 5 seconds | 10 seconds | 20 seconds | 40 seconds | 60 seconds | 80 seconds

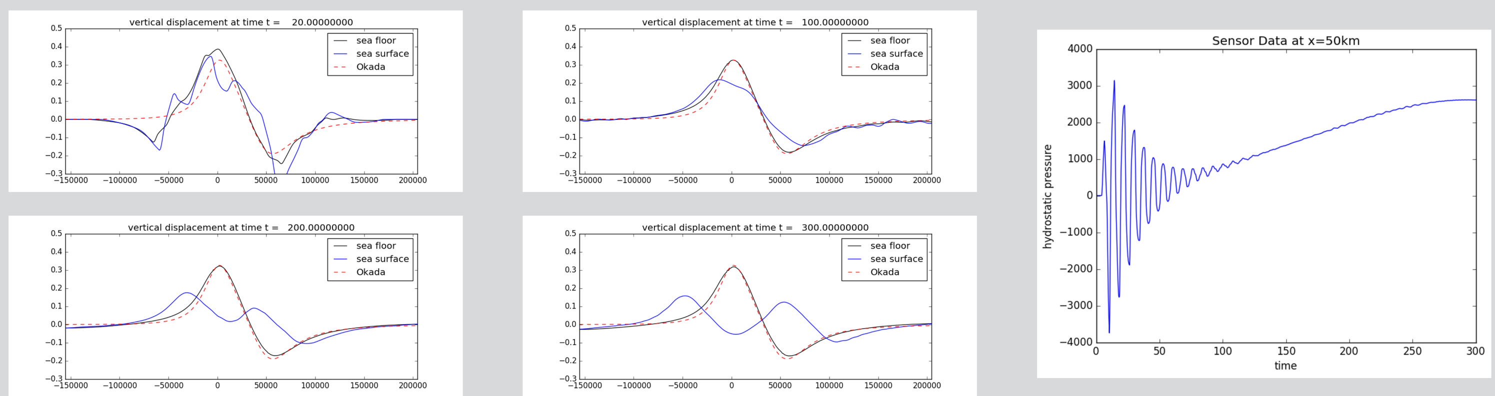
1s

10s

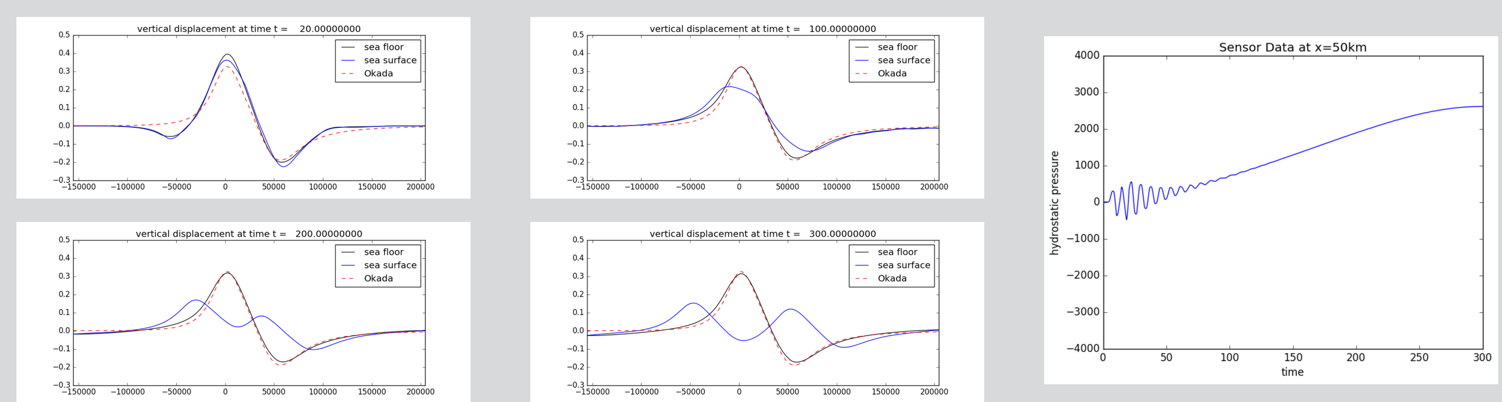


Seismic-Tsunami Results

parameters: 1m slip, 1s rise time, and 3km water



parameters: 1m slip, 10s rise time, and 3km water



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