Predicting tsunami waves and currents on the West Coast of Canada: A case study for Ucluelet, BC

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Cascadia subduction zone (CSZ)
Deep-sea deposits from megathrust earthquakes yield chronology of these events, which tend to occur every 250-850 years.

The last CSZ was in 1700 CE.
The Orphan Tsunami of 1700

Japanese clues to a parent earthquake in North America

Tsunami detectives:

On January 26, 1700, a tsunami was recorded in Japanese villages along a 1000-km stretch of the Pacific coast.
On the scenic spit at Miho, a village leader puzzled over a train of waves in January 1700 (p. 40, 78-79). 

Tsunami
The 1700 CSZ Earthquake and tsunami

(from Satake et al., 2003)
Modelling tsunami waves in 3 parts:

A  An earthquake deformation scenario
B  Bathymetry grid construction and editing
C  Computer model design and experiments

The area of the numerical model* covers most of the CSZ with 3 nested grids:

a) coarse grid: ~500 m grid size  
b) medium grid: ~180 m grid size  
c) fine grid: ~10 m grid size

Two plausible vertical uplift scenarios for a CSZ earthquake

**Scenario A** (Satake et al., JGR 2003; Wang et al., JGR 2003). It was used in **CTWL2007**.

**Scenario B** (Wang and He, BSSA 2008). It is used in the current study.
Scenario A

Time: 00:00:00
Min, Max: -187, 219 cm

Scenario B

Time: 00:00:00
Min, Max: -248, 349 cm
Construction of the fine (~10 m) grid for Ucluelet Inlet from various data sets

Data availability: Lidar and NTDB on land, multibeam and single-beam in water
Gridded bathymetry

A ‘final’ high-resolution (10-m) grid:

Local topography has relatively steep banks and limited low-lying areas where could have significant run-up

Numbered symbols mark locations of recorded sea-level time series
Model Results:

(Scenario B)

Wave propagation on a coarse grid

Coastal trapped edge waves and leaky modes move along the coast and gradually leak energy into the open ocean.
Propagation on a medium grid

Waves move into Juan de Fuca Strait, Puget Sound and Salish Sea (Strait of Georgia)
Sea level time series in some inlets in the medium grid
Maximum sea level heights on the coarse grid are near Tofino on the west coast of Vancouver Island (12 hours)
Maximum sea level heights on the medium grid are inside Alberni Inlet
Initial deformation, waves and currents (high-resolution grid)

After the earthquake local land and sea bottom drop by more than 2 m
Some sea level time series inside the high-resolution grid

(stations 5, 6, 7 and 8)
Maximum sea levels during the 12-hour simulation:

- Solid line marks the original coastline.
- Inundation is visible in several low-lying areas.
- Largest run-up heights are along the NW coast, where there is little bathymetric data!
Maximum current speeds during the 12 hours
Maximum heights: Comparison to a different earthquake scenario

Scenario A and without run-up (from CTWL2007)  
Scenario B with run-up
Maximum currents

Scenario A without run-up (from CTWL2007)

Scenario B with run-up
Maximum heights: scenario B without and with run-up

Similar patterns, but without run-up (vertical walls) the maximum is 13.4 m, compared to 7.4 m with run-up
Changing the Manning friction coefficient $n$

\[
\frac{\partial h}{\partial t} + \nabla \cdot (uh) = 0
\]

\[
\frac{\partial u}{\partial t} + u \cdot \nabla u + gh = g \nabla d - R
\]

\[R = C_f |u| u/h\]

\[C_f = g/C^2 = g \mu^2/h^{1/3}\]
Preliminary conclusions from CSZ tsunami model experiments as applied to the Ucluelet Inlet area

• While the timing of the next CSZ earthquake is not known, it will have undoubtedly very serious consequences for the West Coast of North America and, in particular, of Vancouver Island

• Large tsunami waves (up to 15 m) and currents will flood coastal area and will seriously damage communities and installations

• The actual maximum run-ups and their locations depend on the initial deformation scenario, while numerical model results are also sensitive to the details of bathymetric and topographic data

• For this particular model (MOST3), the value of the friction coefficient appears to have a secondary effect on the simulation of run-ups
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