Predicting tsunami waves and currents on the West Coast of Canada:

A case study for Ucluelet, BC

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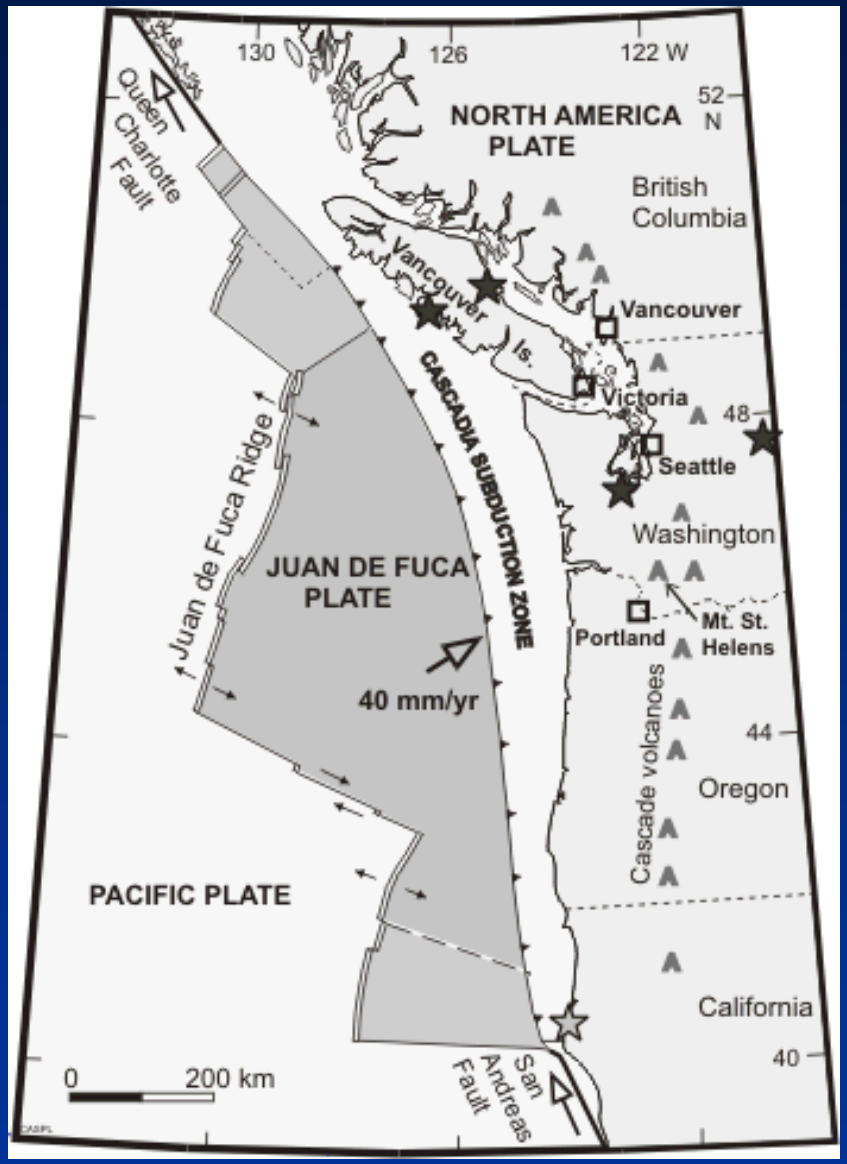
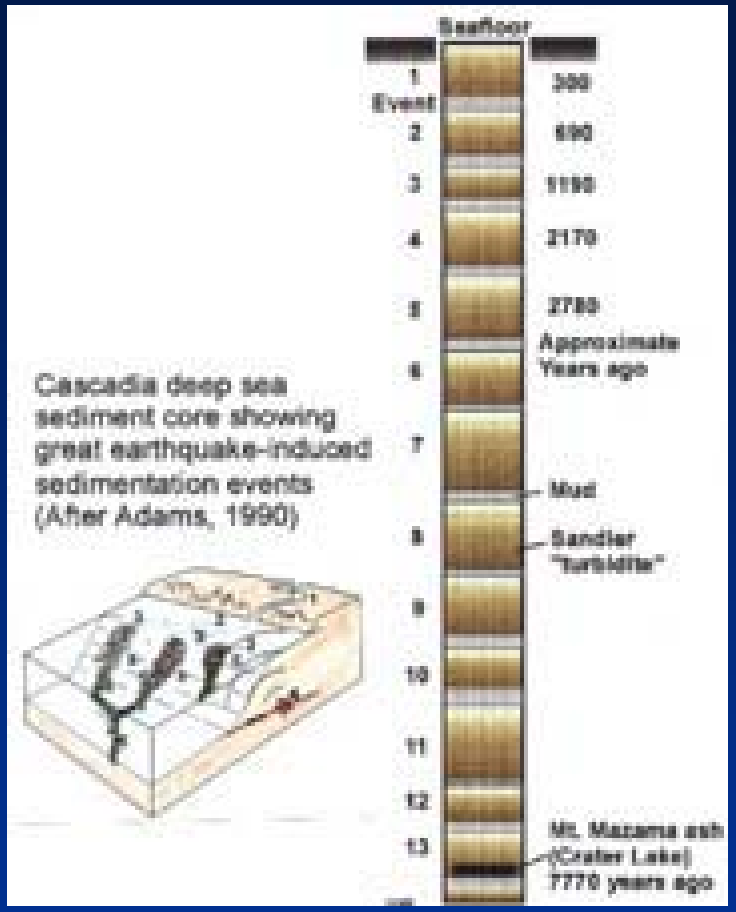
Vasily Titov (PMEL/NOAA): MOST3 tsunami model

Michel Breton (CHS/DFO): bathymetry and topography

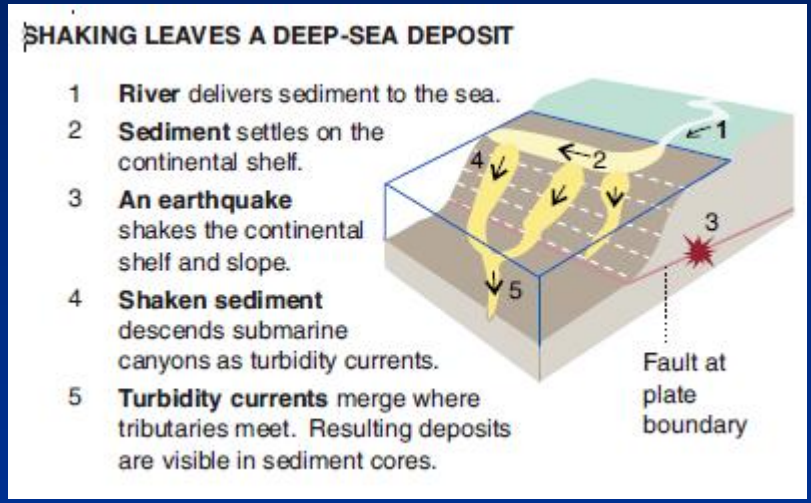
Cascadia subduction zone (CSZ)





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

みなしご元禄津波

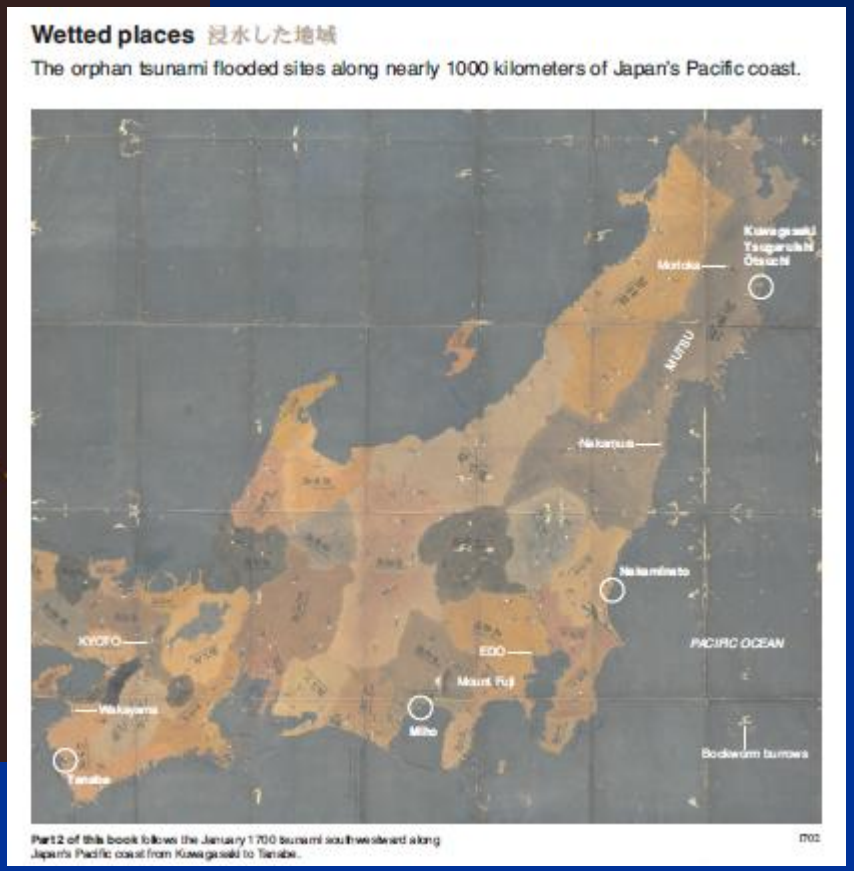
Japanese clues to a parent earthquake in North America

親地震は北米西海岸にいた

Brian F. ATWATER ブライアン・F・アトウォータ
MUSUMI-ROKKAKU Satoko 六角 聰子
SATAKE Kenji 佐竹 健治
TSUJI Yoshinobu 都司 嘉宣
UEDA Kazue 上田 和枝
David K. YAMAGUCHI デイビッド・K・ヤマグチ

Tsunami detectives:

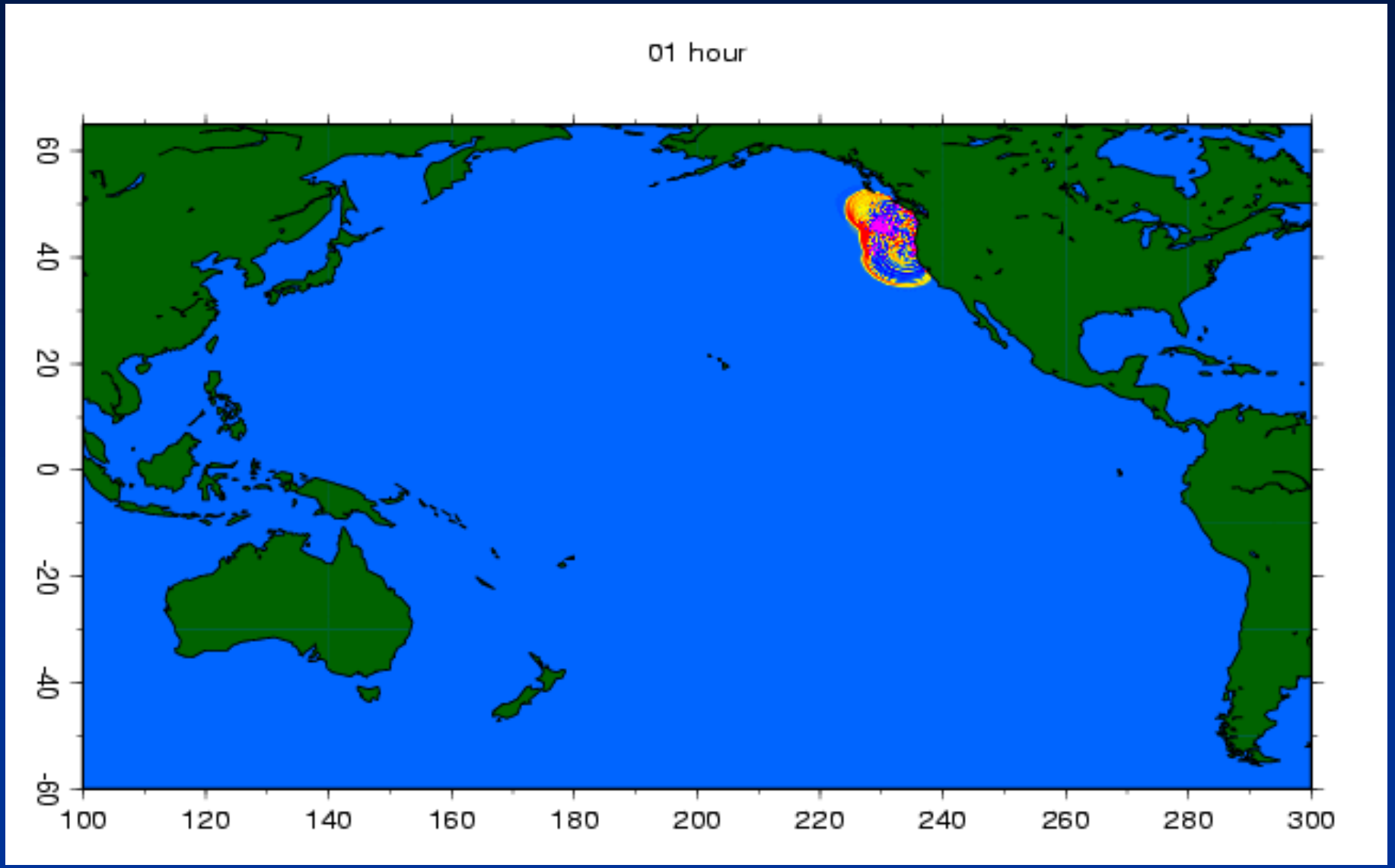
On January 26, 1700, a tsunami was recorded in Japanese villages along a 1000-km stretch of the Pacific coast



On the scenic spit at Miho, a village leader puzzled over a train of waves in January 1700 (p. 40, 78-79).

tsunami
Tsunami

The 1700 CSZ Earthquake and tsunami



(from Satake et al., 2003)

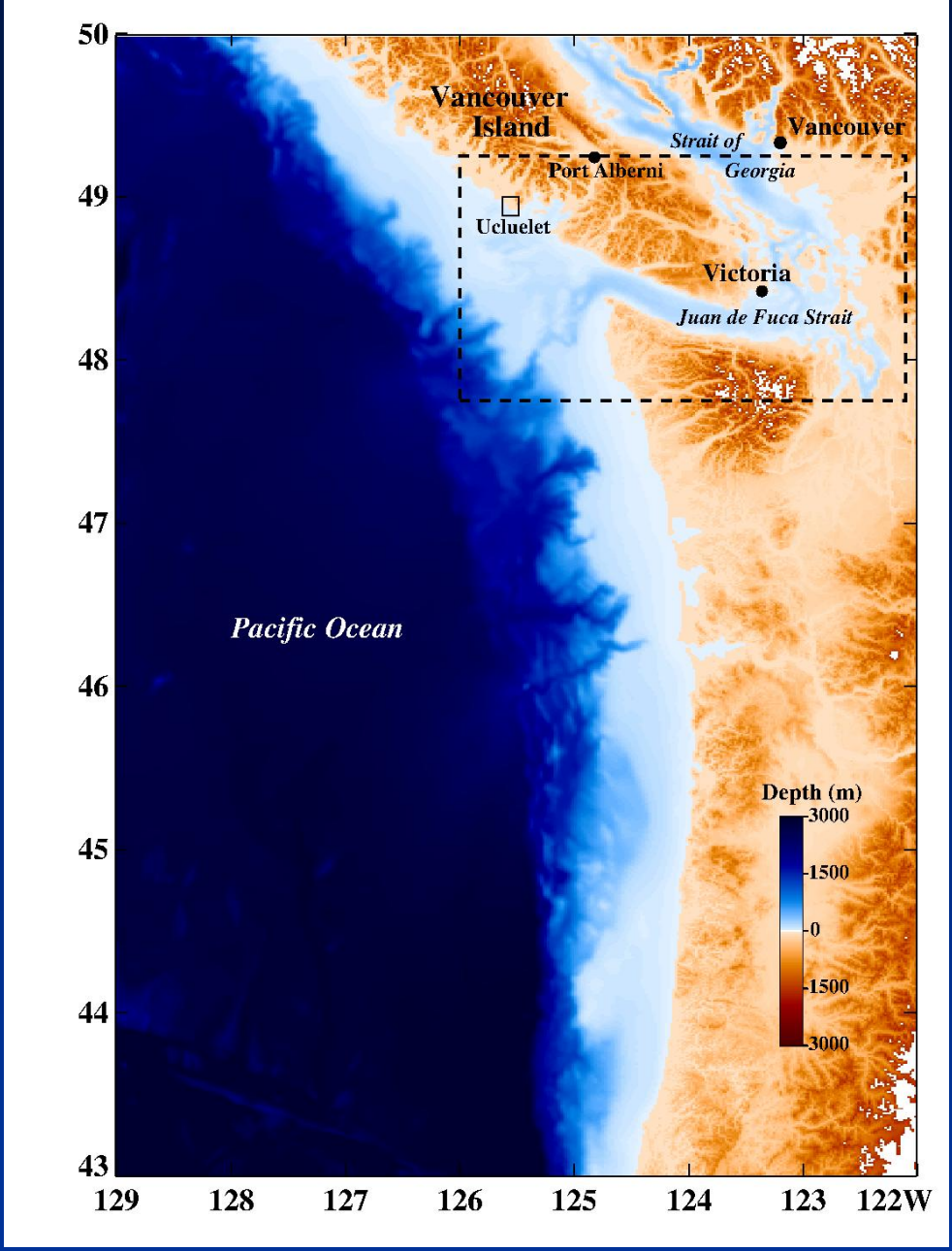
Modelling tsunami waves in 3 parts:

An earthquake deformation scenario

Bathymetry grid construction and editing

Computer model design and experiments

(*Cherniawsky et al., Pure & Applied Geophysics, 2007: CTWL2007*)

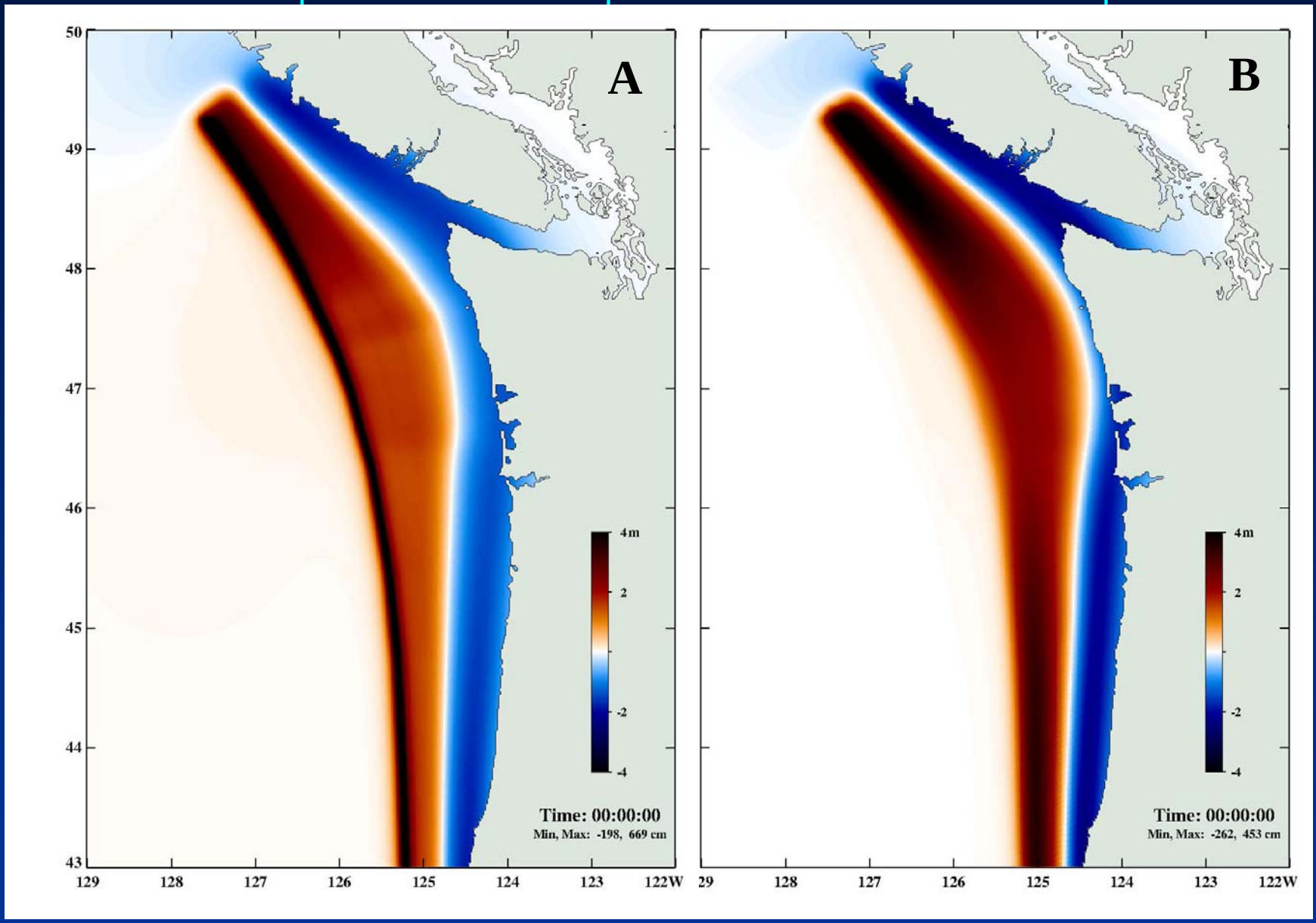


The area of the numerical model* covers most of the CSZ with 3 nested grids:

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

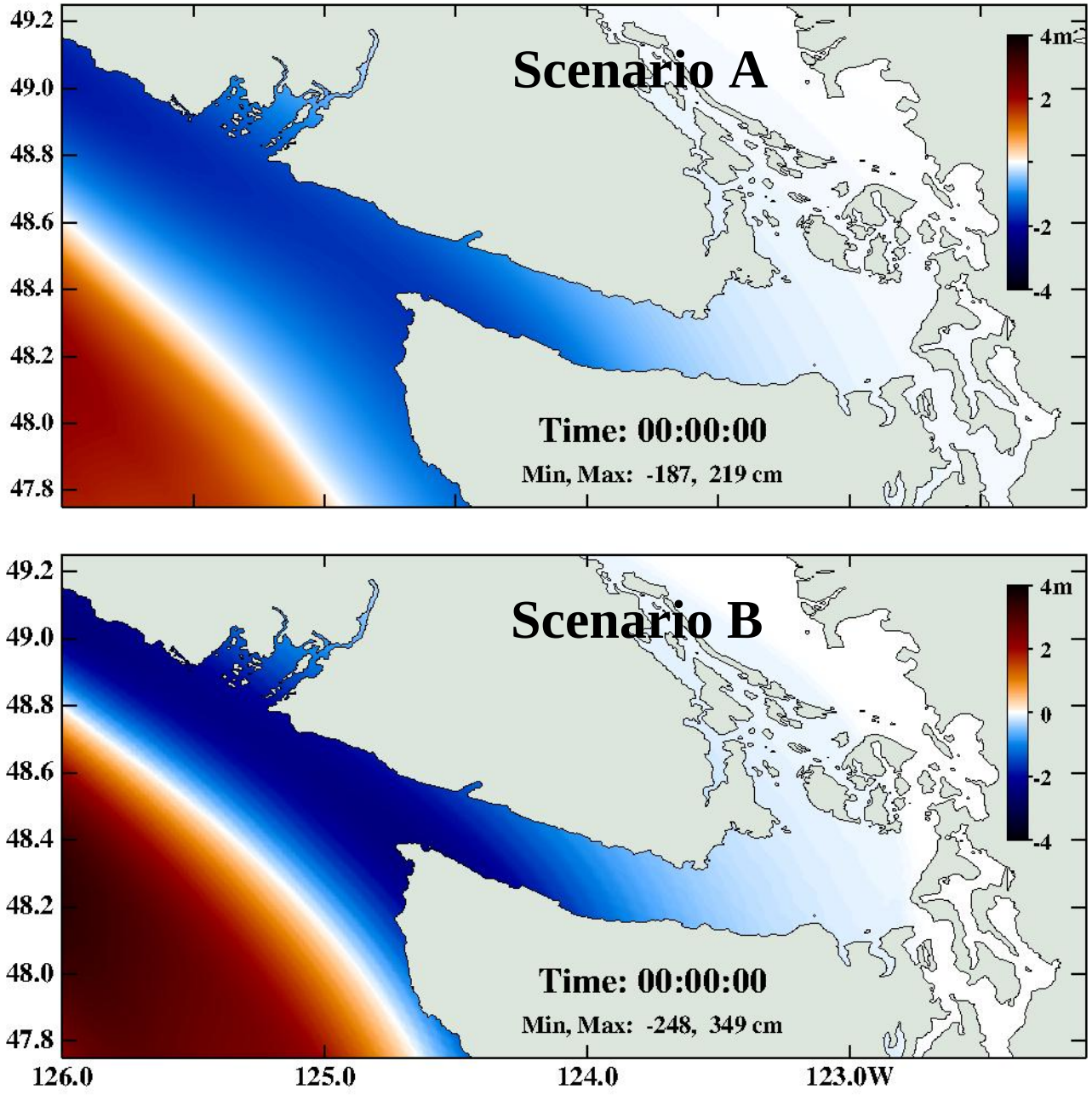
**Titov and Synolakis (1997, 1998)*

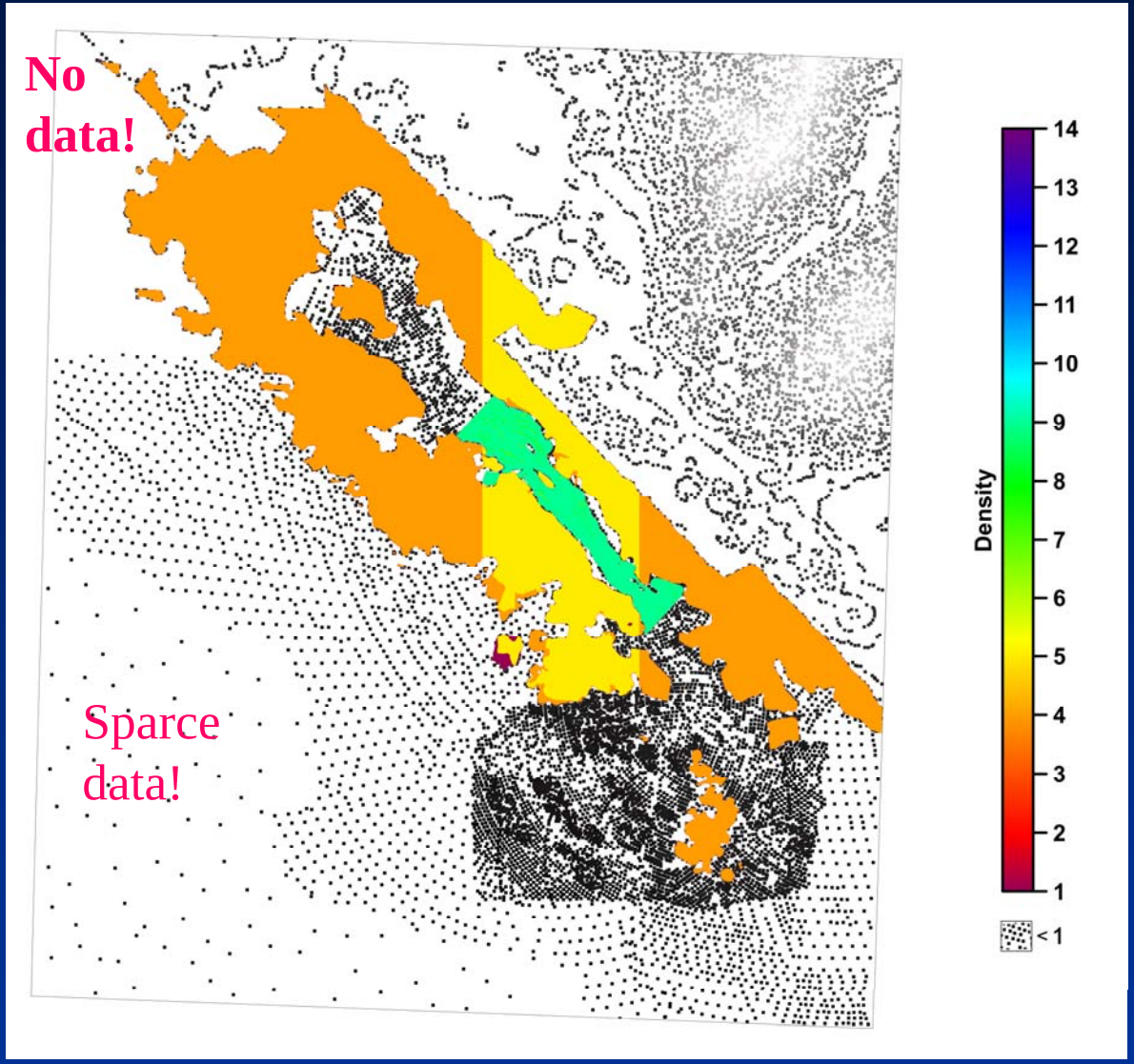
Two plausible vertical uplift scenarios for a CSZ earthquake



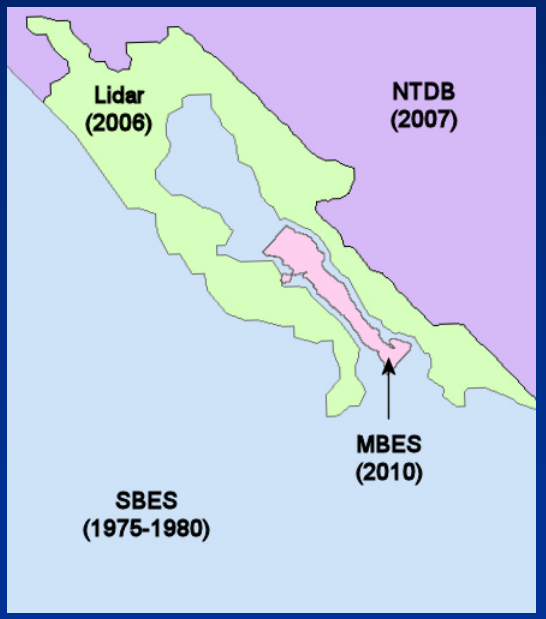
Scenario **A** *(Satake et al., JGR 2003; Wang et al., JGR 2003).* It was used in *CTWL2007*.

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

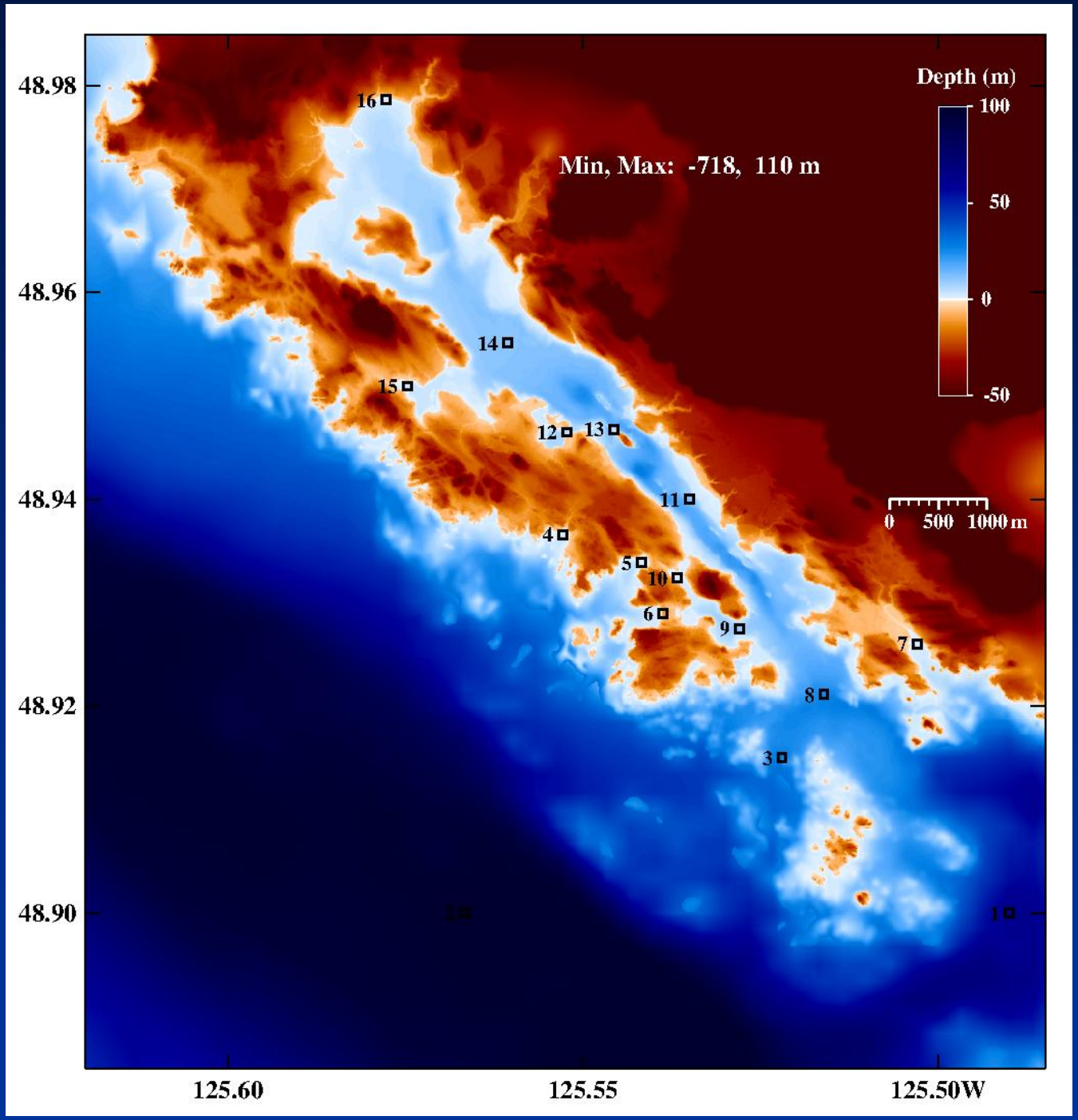

Scenario A
Time: 00:00:00
Min, Max: -187, 219 cm
4m
2
-2
-4
Scenario B
Time: 00:00:00
Min, Max: -248, 349 cm
4m
2
0
-2
-4
49.2
49.0
48.8
48.6
48.4
48.2
48.0
47.8
126.0
125.0
124.0
123.0W



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

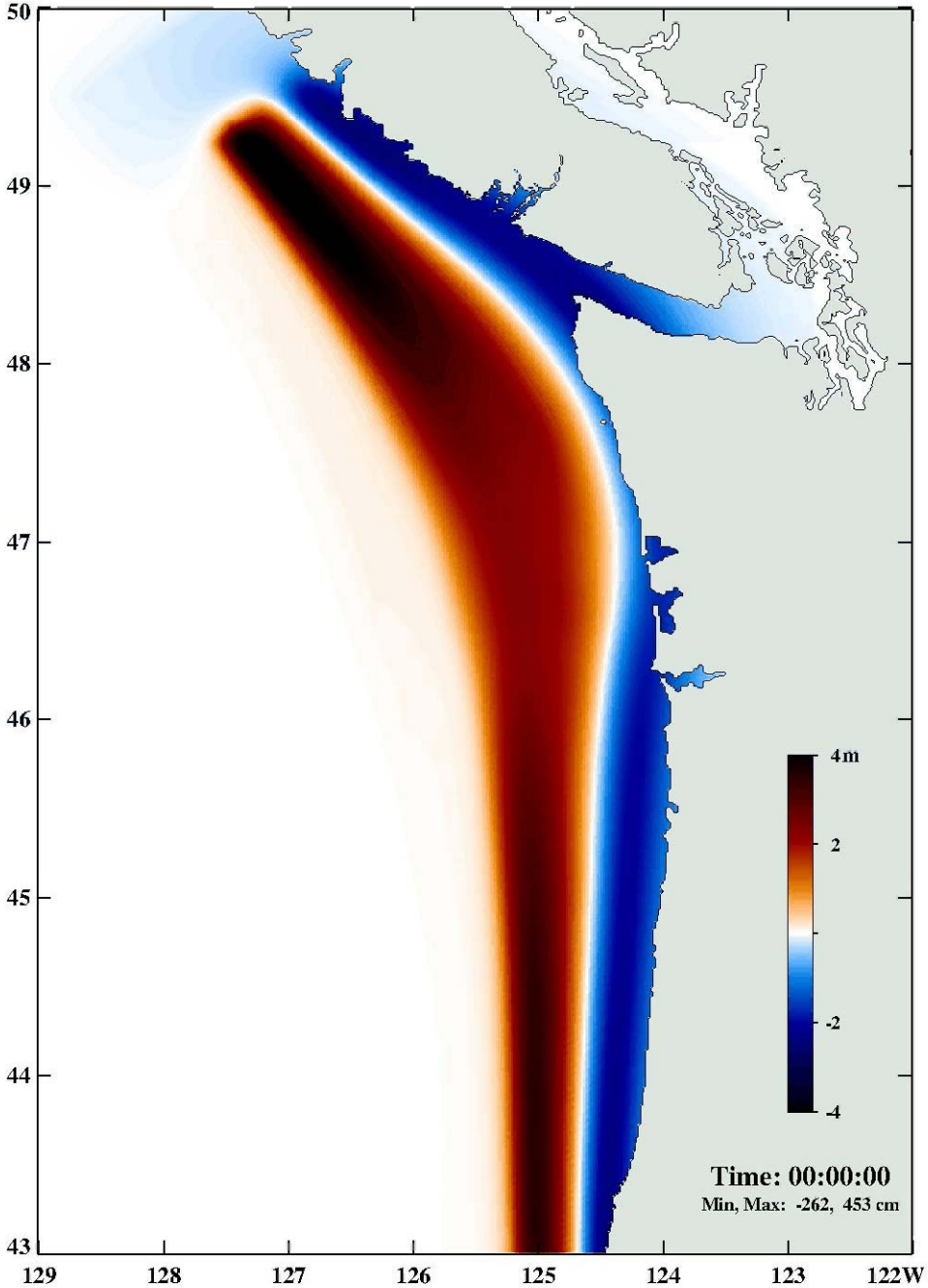


Gridded bathymetry

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

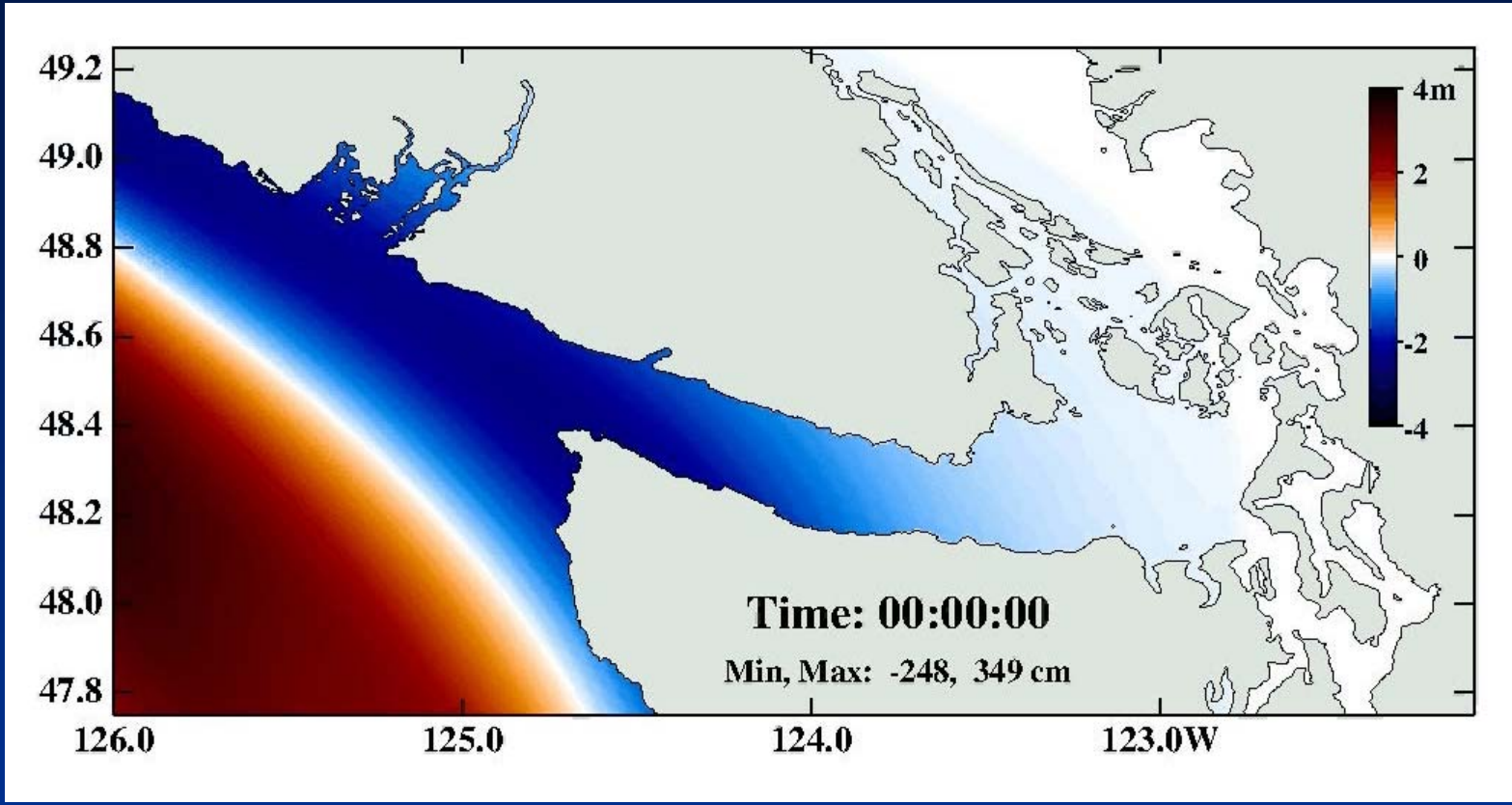


Model Results:

(Scenario B)

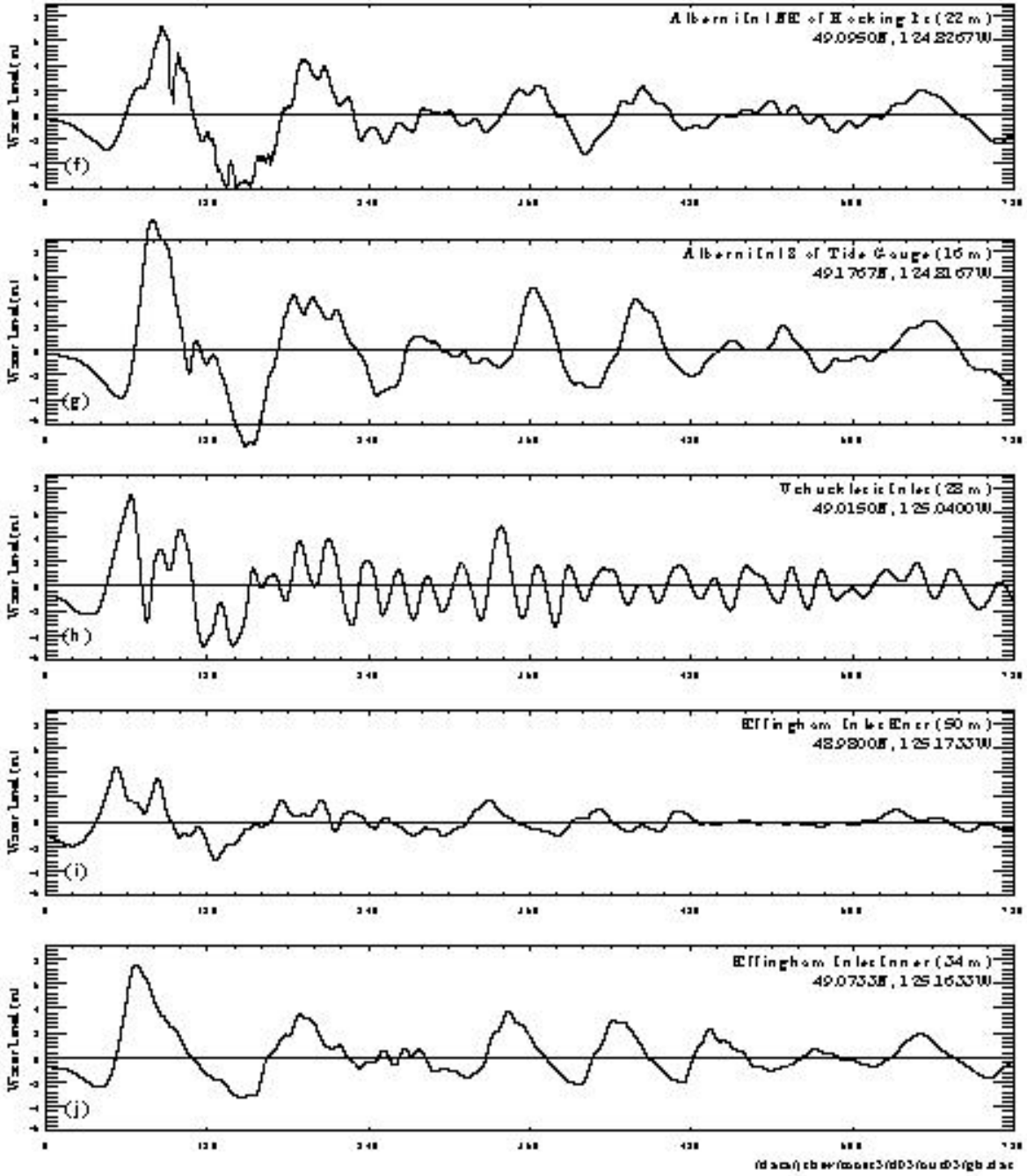
Wave propagation on a coarse grid

Coastal trapped edge waves and leaky modes move along the coast and gradually leak energy into the open ocean

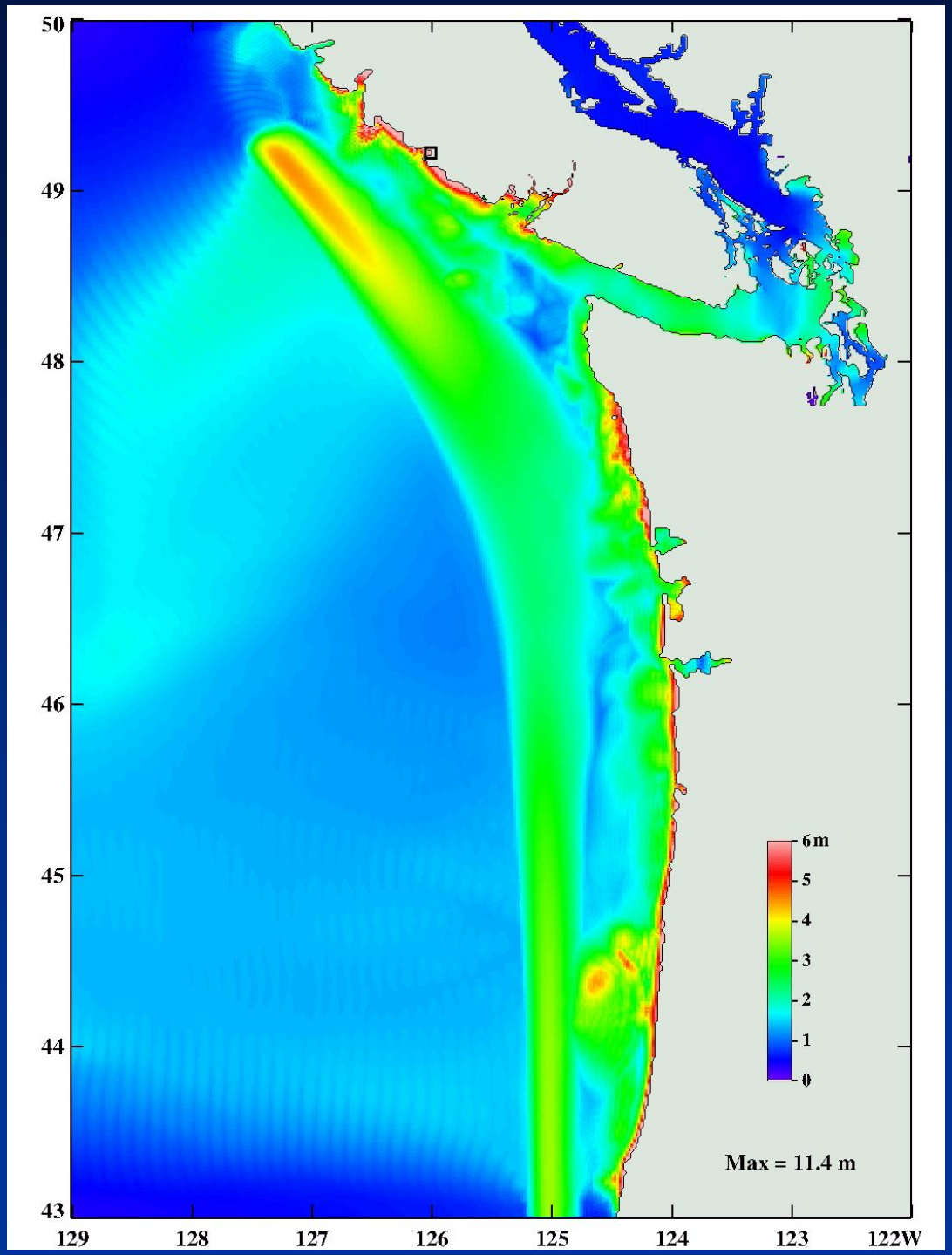


Propagation on a medium grid

Waves move into Juan de Fuca Strait, Puget Sound and Salish Sea (Strait of Georgia)

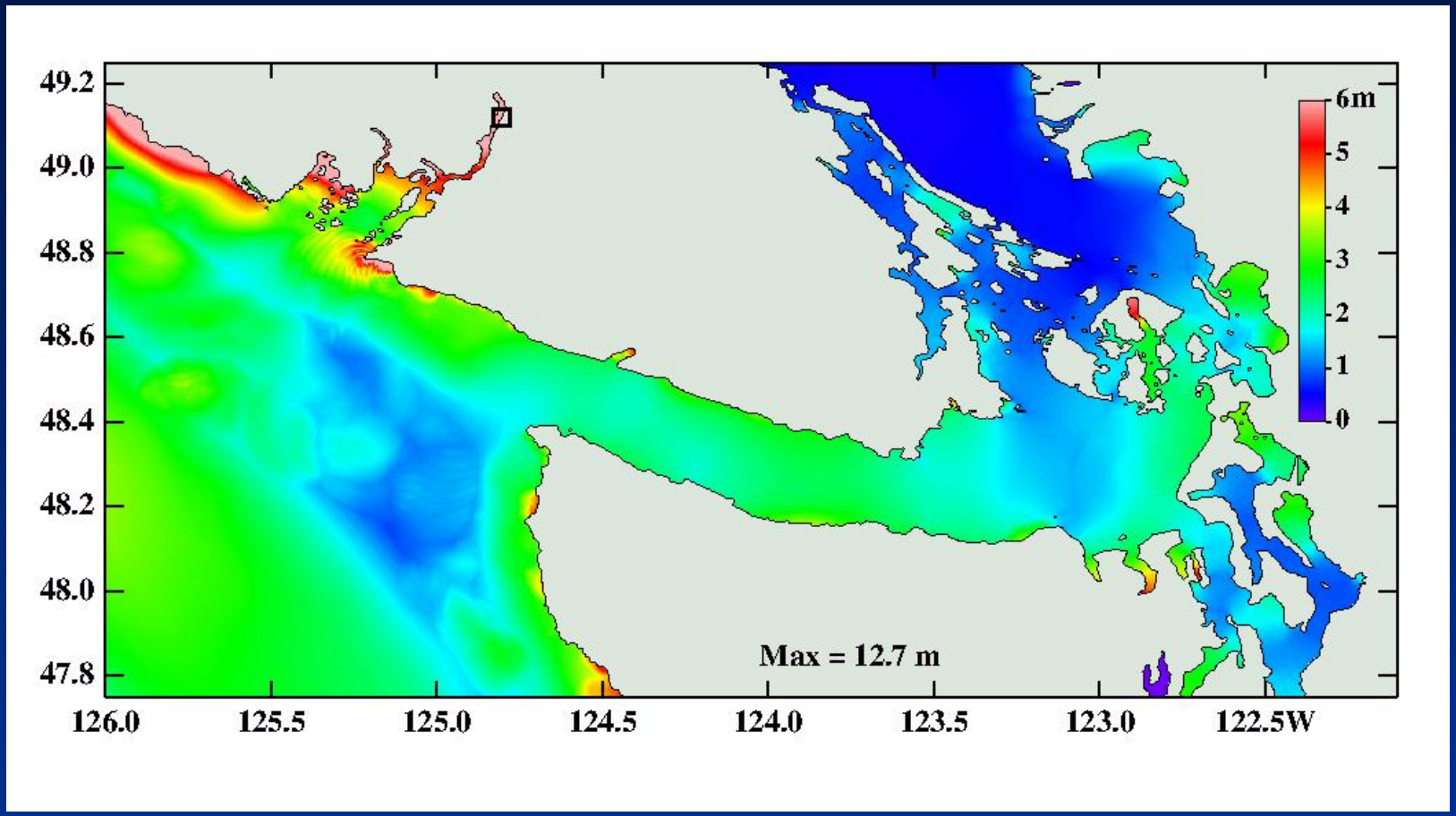


Sea level time series in some inlets in the medium grid

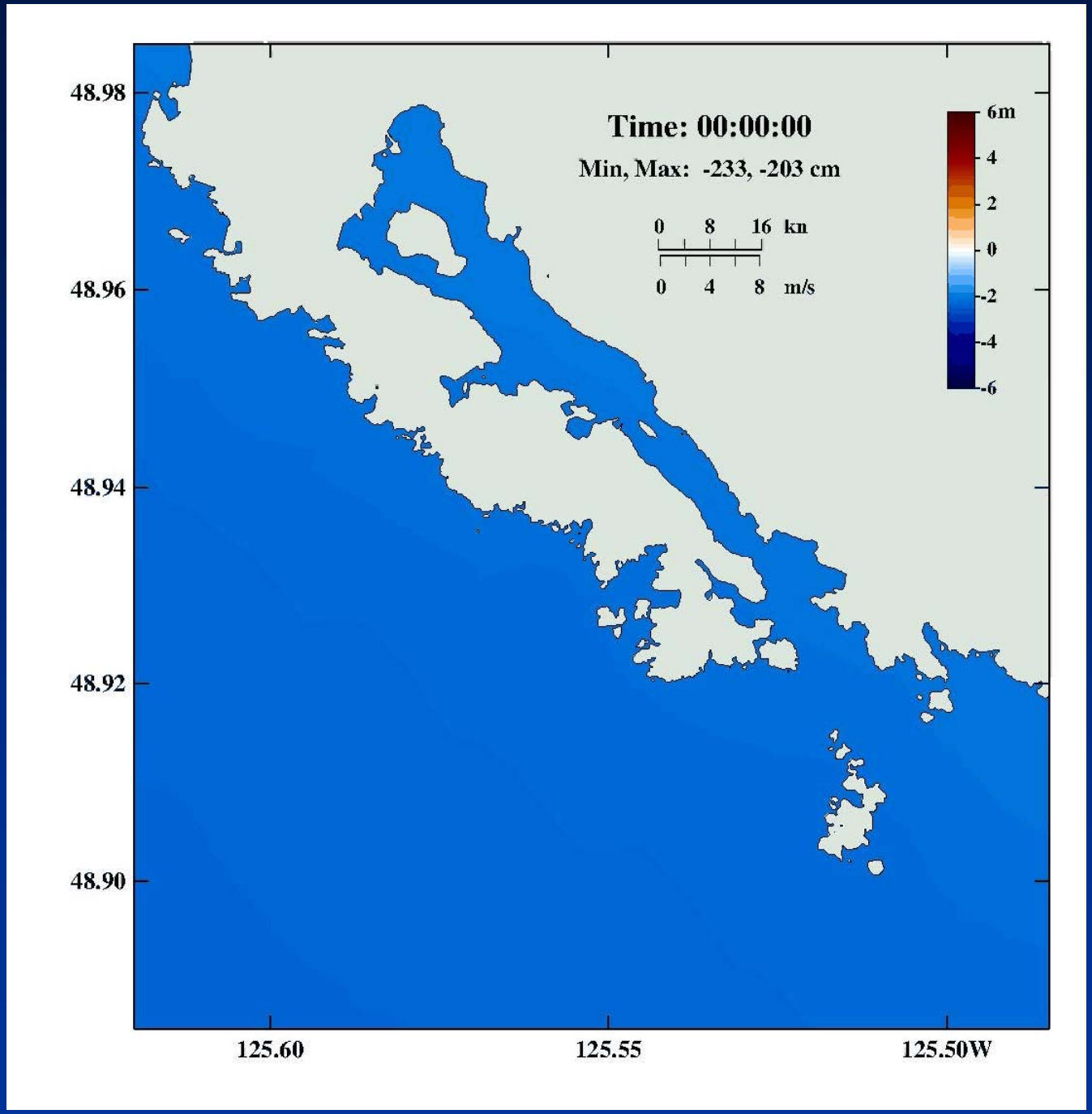


Maximum sea level heights on the coarse grid are near Tofino on the west coast of Vancouver Island

(12 hours)



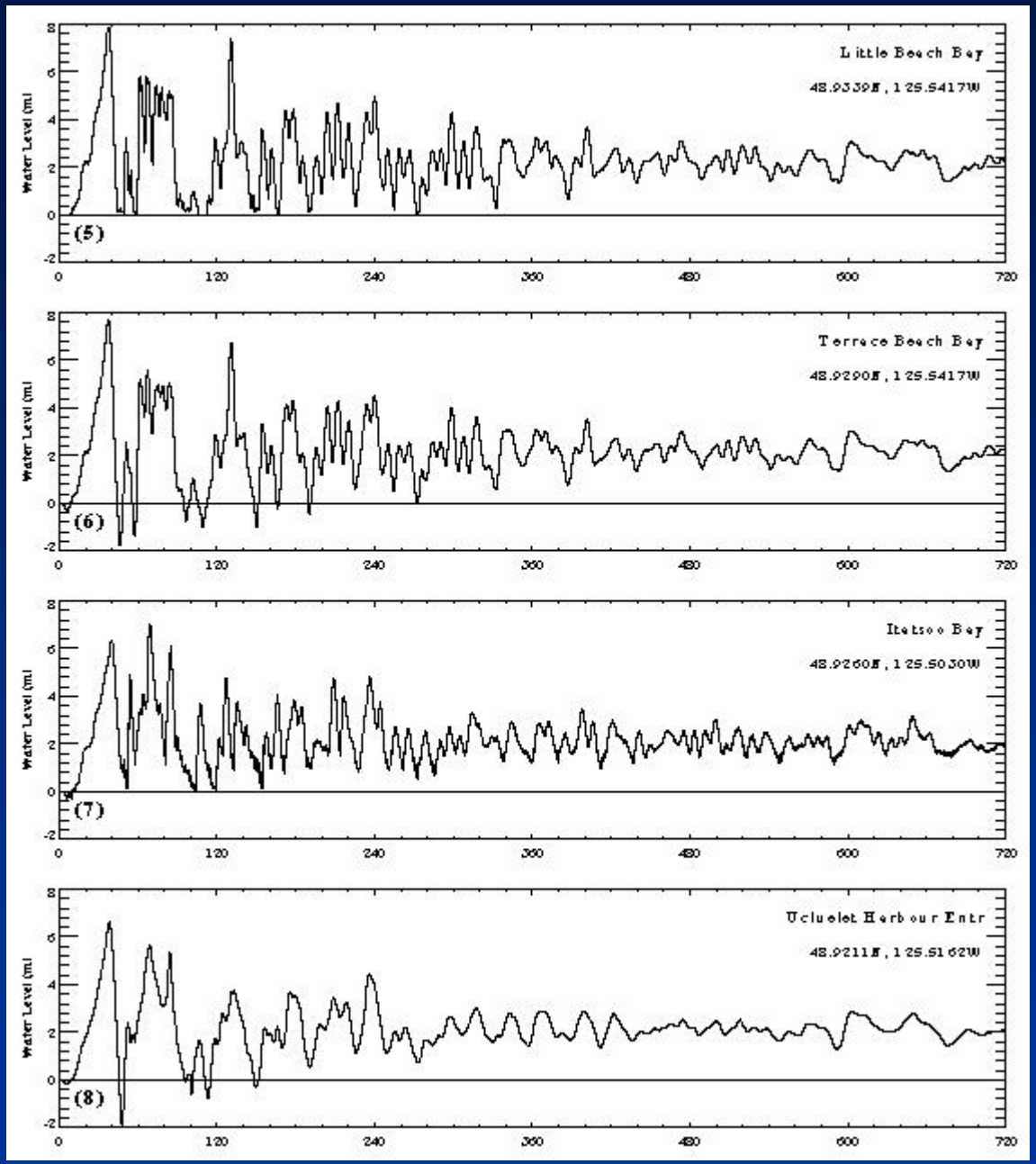
Maximum sea level heights on the medium grid are inside Alberni Inlet



Initial deformation, waves and currents

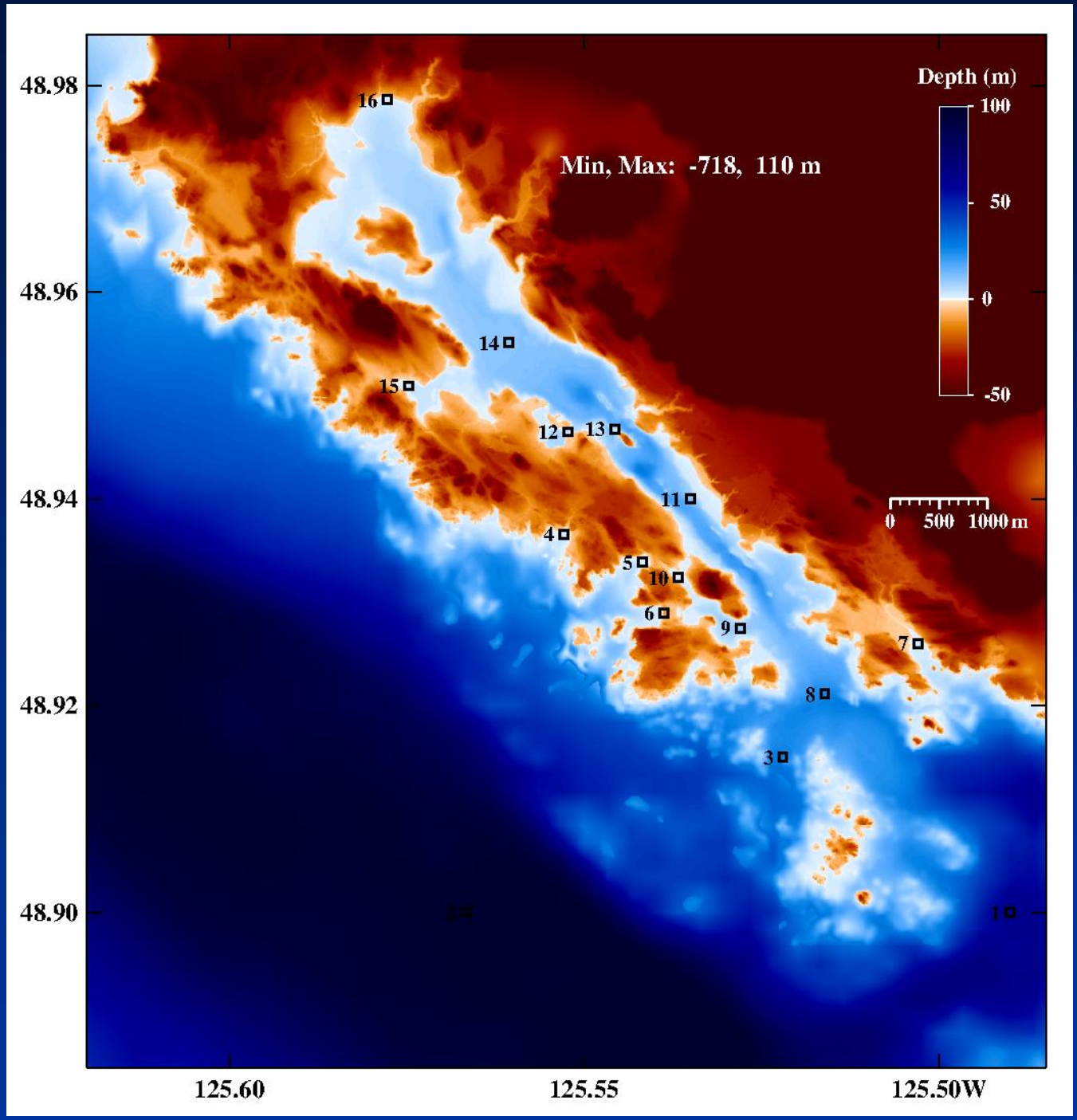
(high-resolution grid)

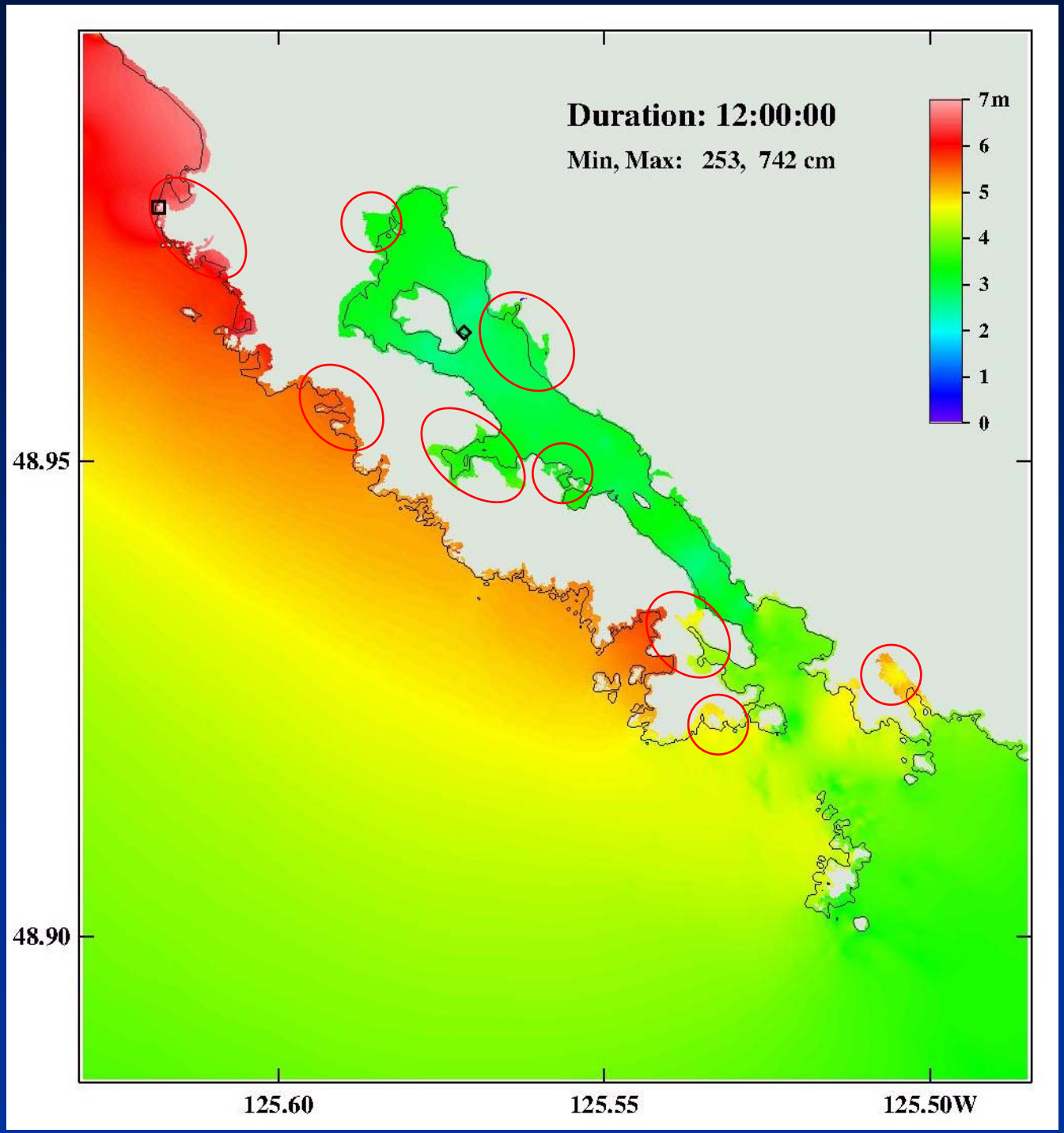
After the earthquake local land and sea bottom drop by more than 2 m



Some sea level time series inside the high-resolution grid

(stations 5, 6, 7 and 8)


Depth (m)
100
50
0
-50
Min, Max: -718, 110 m
0 500 1000 m
16
14
15
12
13
11
4
5
10
6
9
7
8
3
2
1
48.98
48.96
48.94
48.92
48.90
125.60
125.55
125.50W

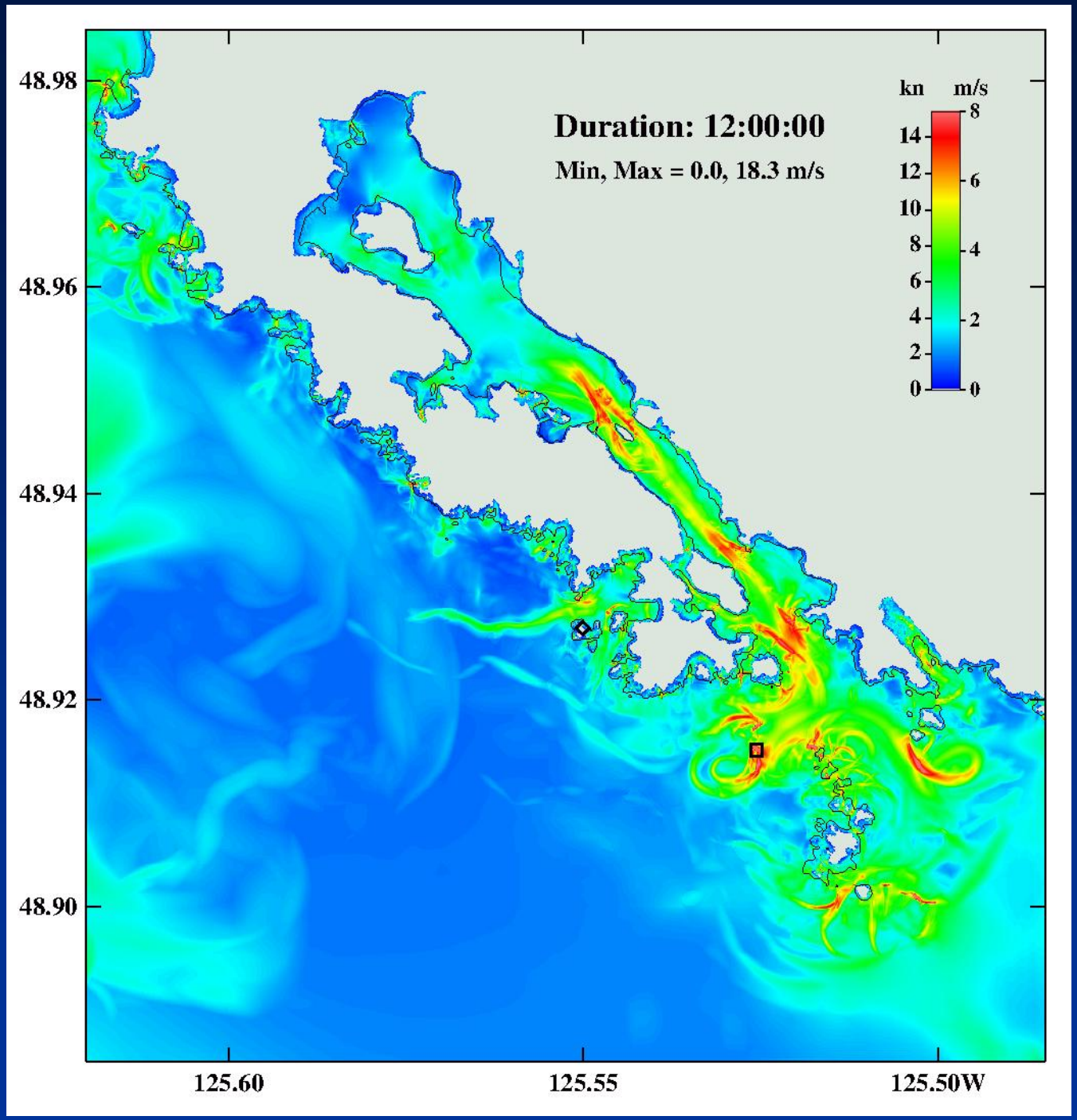


Maximum sea levels during the 12-hour simulation:

Solid line marks the original coastline

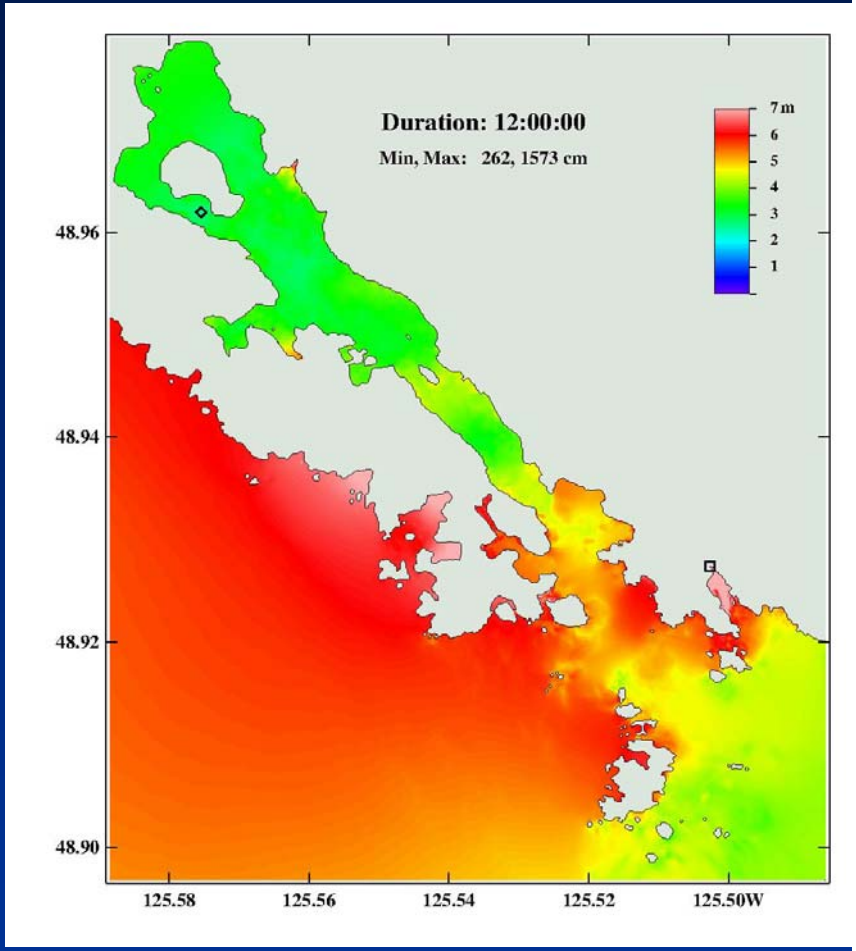
Inundation is visible in several low-lying areas

Largest run-up heights are along the NW coast, where there is little bathymetric data!

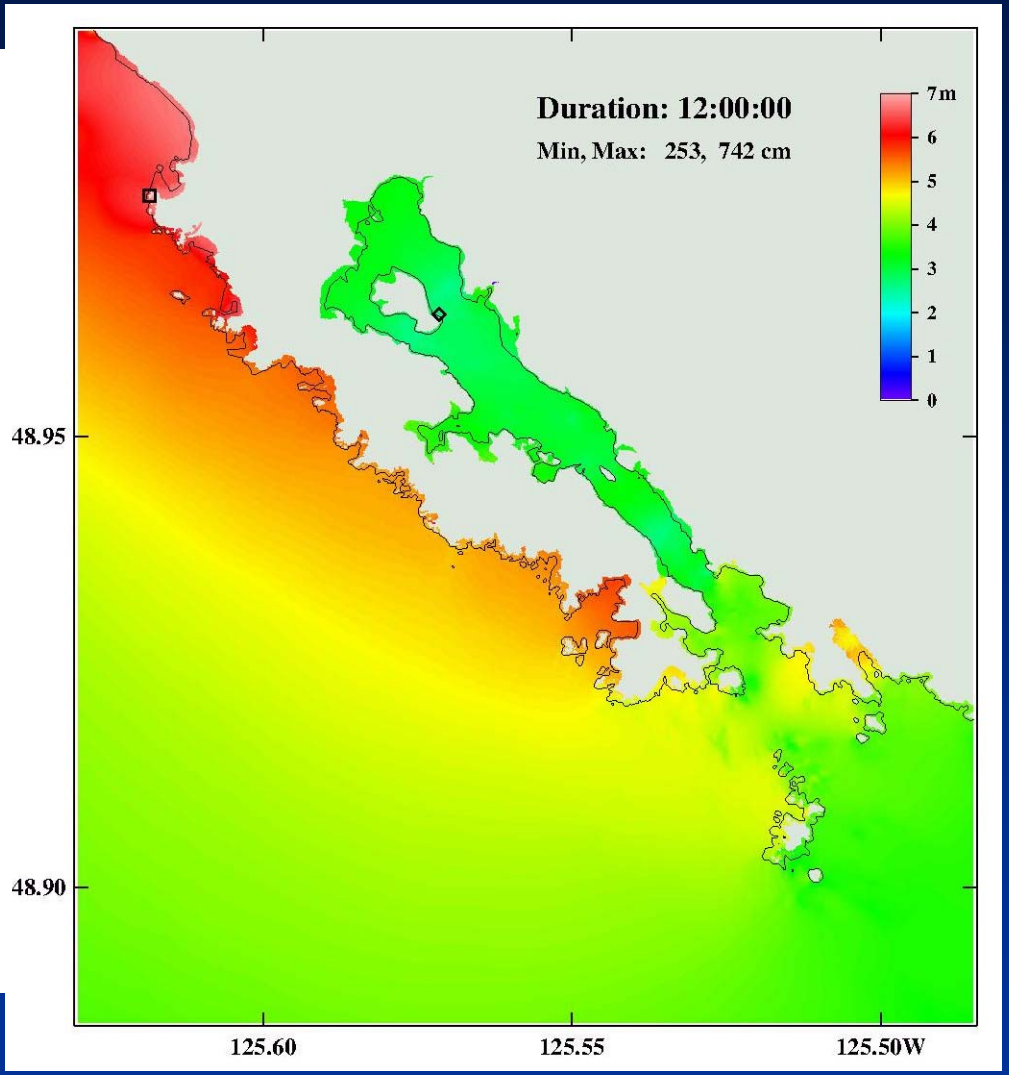


Maximum current speeds during the 12 hours

Maximum heights: Comparison to a different earthquake scenario

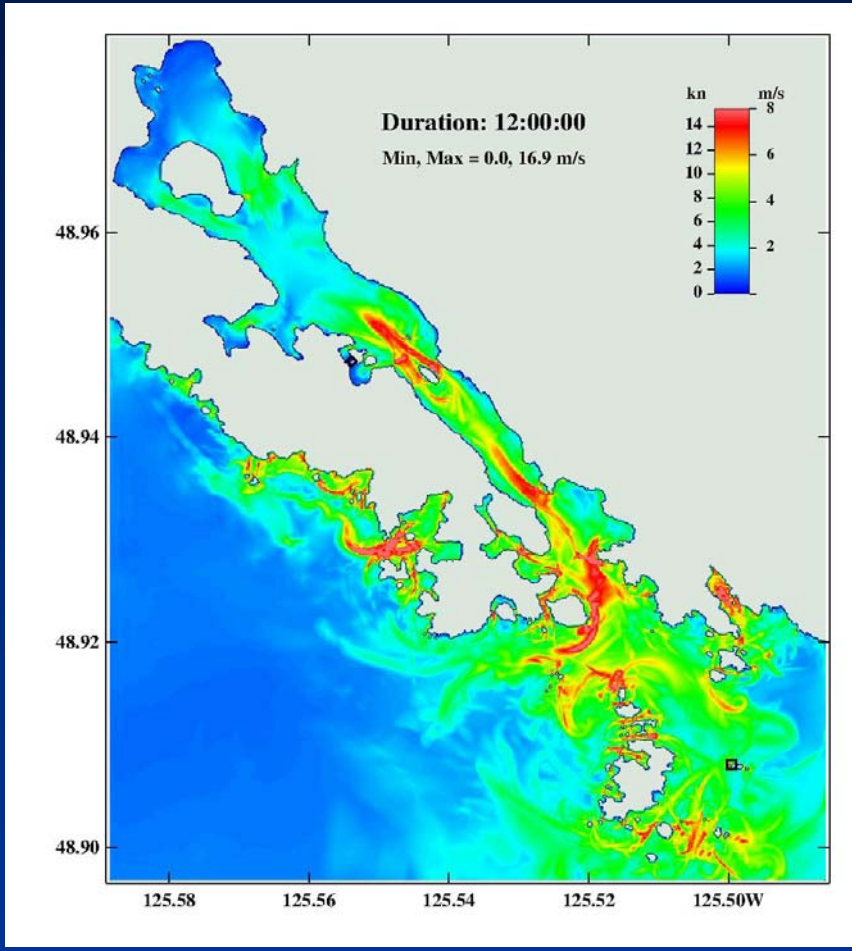


Scenario **A** and without run-up
(from *CTWL2007*)

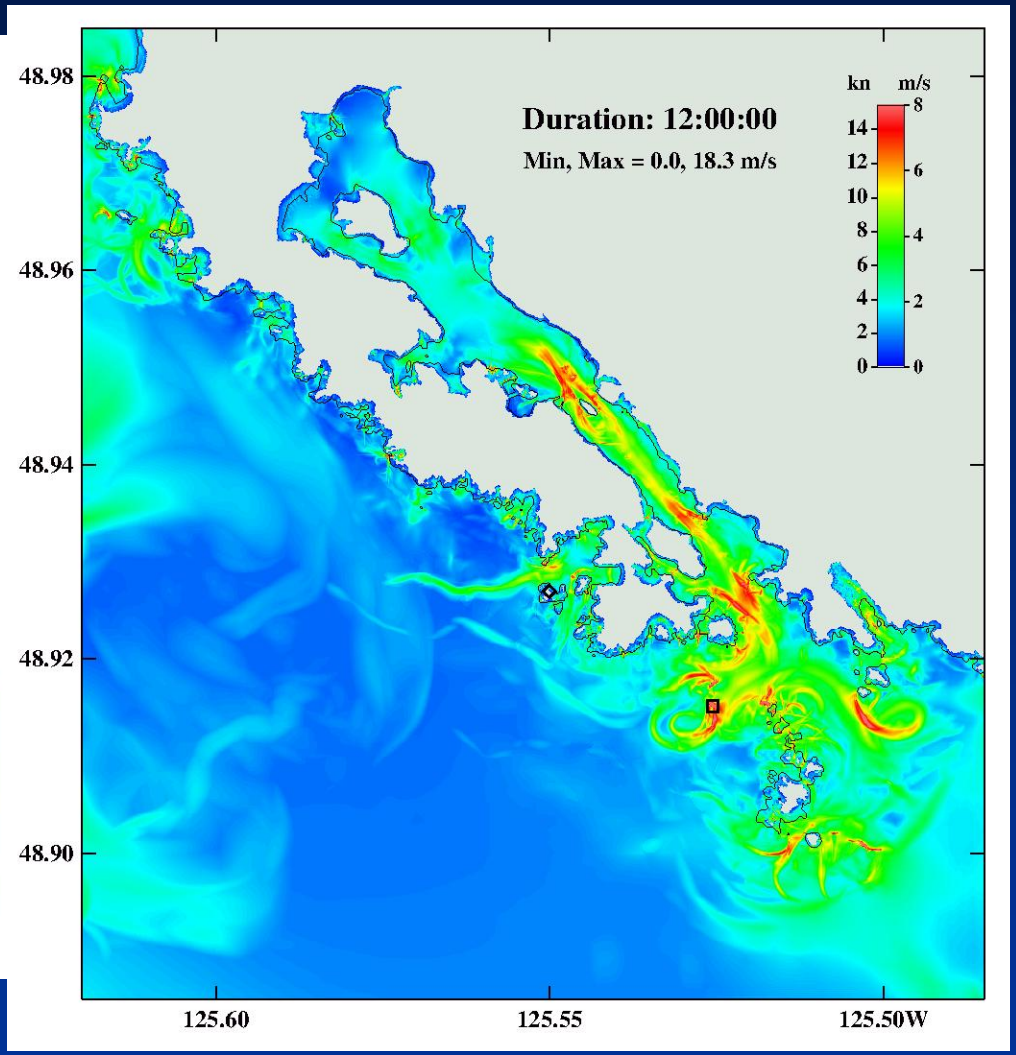


Scenario **B** with run-up

Maximum currents

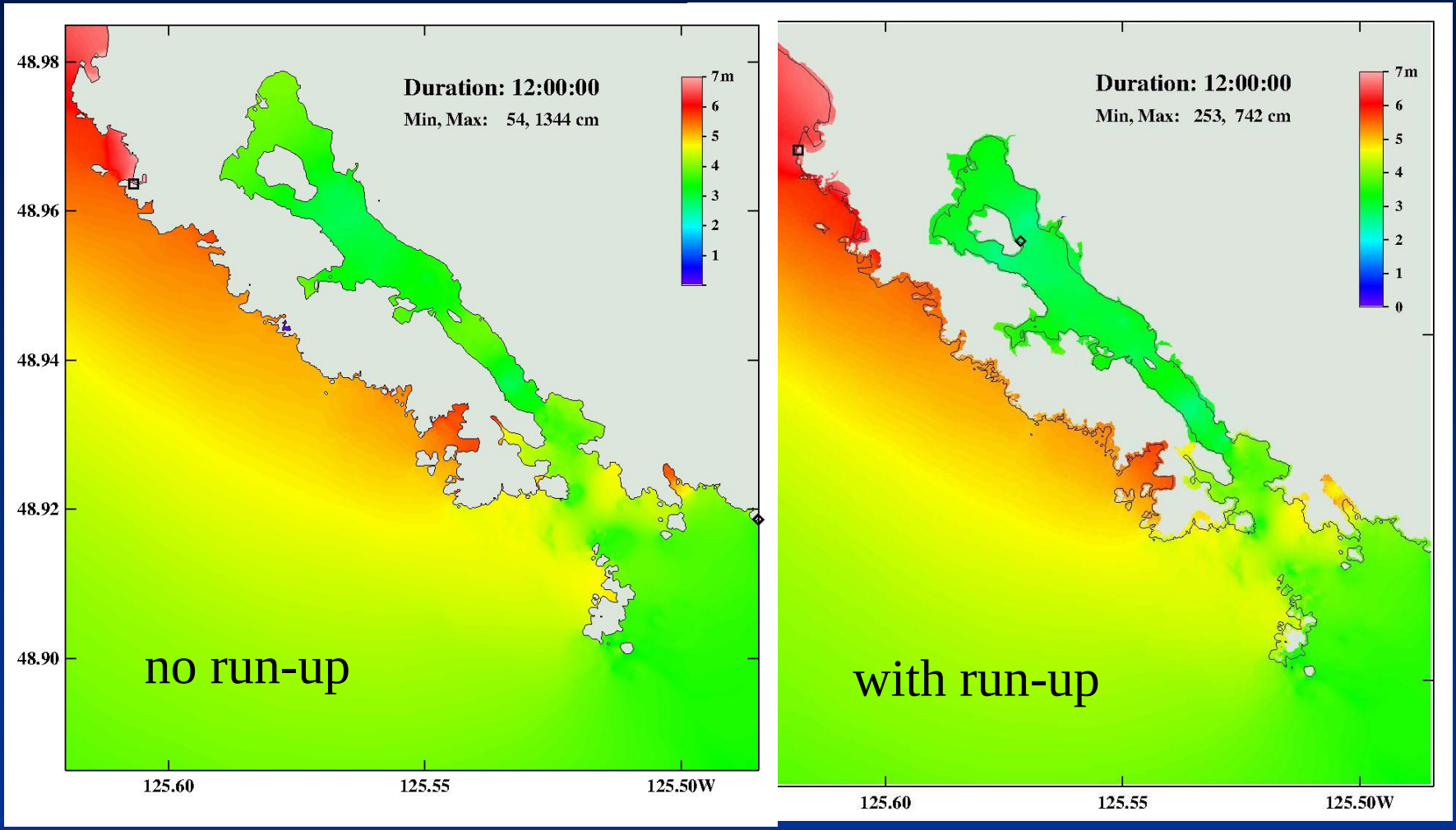


Scenario **A** without run-up
(from *CTWL2007*)



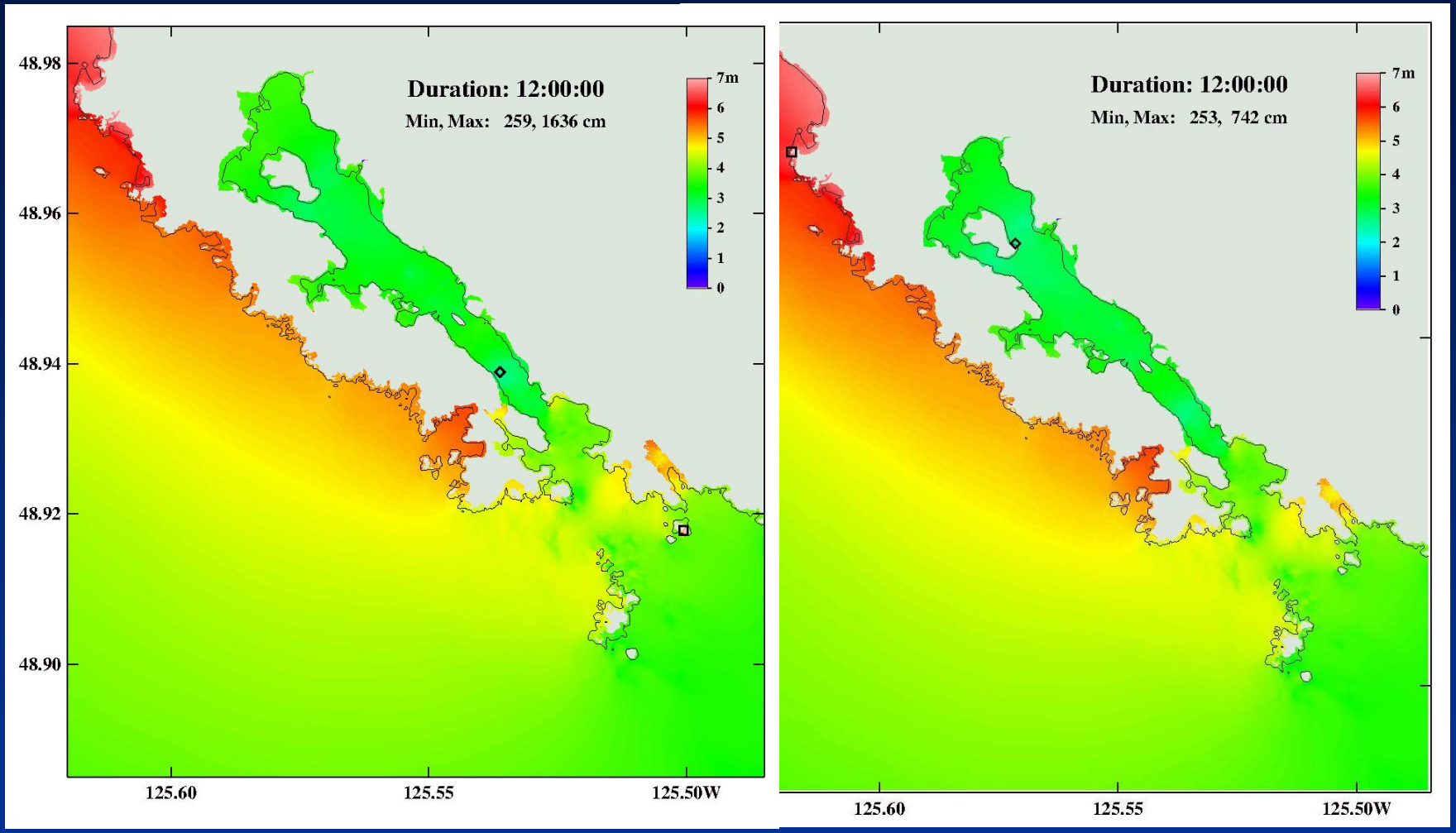
Scenario **B** with run-up

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*



$$\frac{\partial h}{\partial t} + \nabla \cdot (\mathbf{u}h) = 0$$

$$\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} + g\nabla h = g\nabla d - \mathbf{R} \qquad \mathbf{R} = C_f |\mathbf{u}| \mathbf{u}/h \qquad C_f = g/C^2 = gn^2/h^{1/3}$$

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

Arougatö