

Cascadia Subduction Zone Earthquake and Tsunami Modeling in Washington

by

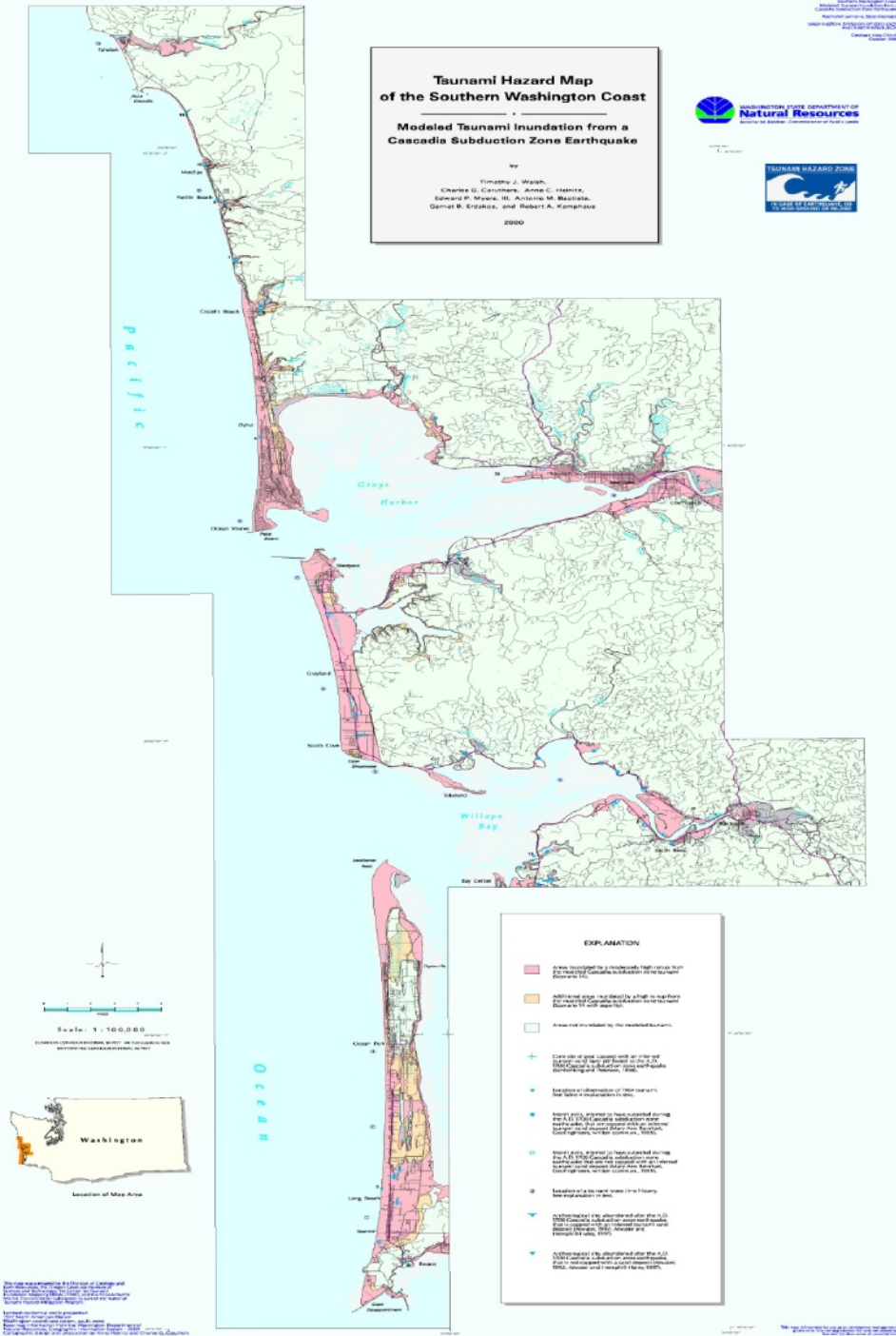
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Division of Geology and Earth Resources

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EXPLANATION

- Areas inundated by a moderately high runup from the modeled Cascadia subduction zone tsunami (Scenario 1A).
- Additional areas inundated by a high runup from the modeled Cascadia subduction zone tsunami (Scenario 1A with asperity).
- Areas not inundated by the modeled tsunami.
- Core site of peat capped with an inferred tsunami sand layer attributed to the A.D. 1700 Cascadia subduction zone earthquake (Schlichting and Peterson, 1998).
- Location of observation of 1964 tsunami. See Table 4 explanation in text.
- Marsh soils, inferred to have subsided during the A.D. 1700 Cascadia subduction zone earthquake, that are capped with an inferred tsunami sand deposit (Mary Ann Reinhart, GeoEngineers, written commun., 1999).
- Marsh soils, inferred to have subsided during the A.D. 1700 Cascadia subduction zone earthquake that are not capped with an inferred tsunami sand deposit (Mary Ann Reinhart, GeoEngineers, written commun., 1999).
- Location of a tsunami wave time history. See explanation in text.
- Archeological site, abandoned after the A.D. 1700 Cascadia subduction zone earthquake, that is capped with an inferred tsunami sand deposit (Atwater, 1992; Atwater and Hemphill-Haley, 1997).
- Archeological site, abandoned after the A.D. 1700 Cascadia subduction zone earthquake, that is not capped with a sand deposit (Atwater, 1992; Atwater and Hemphill-Haley, 1997).



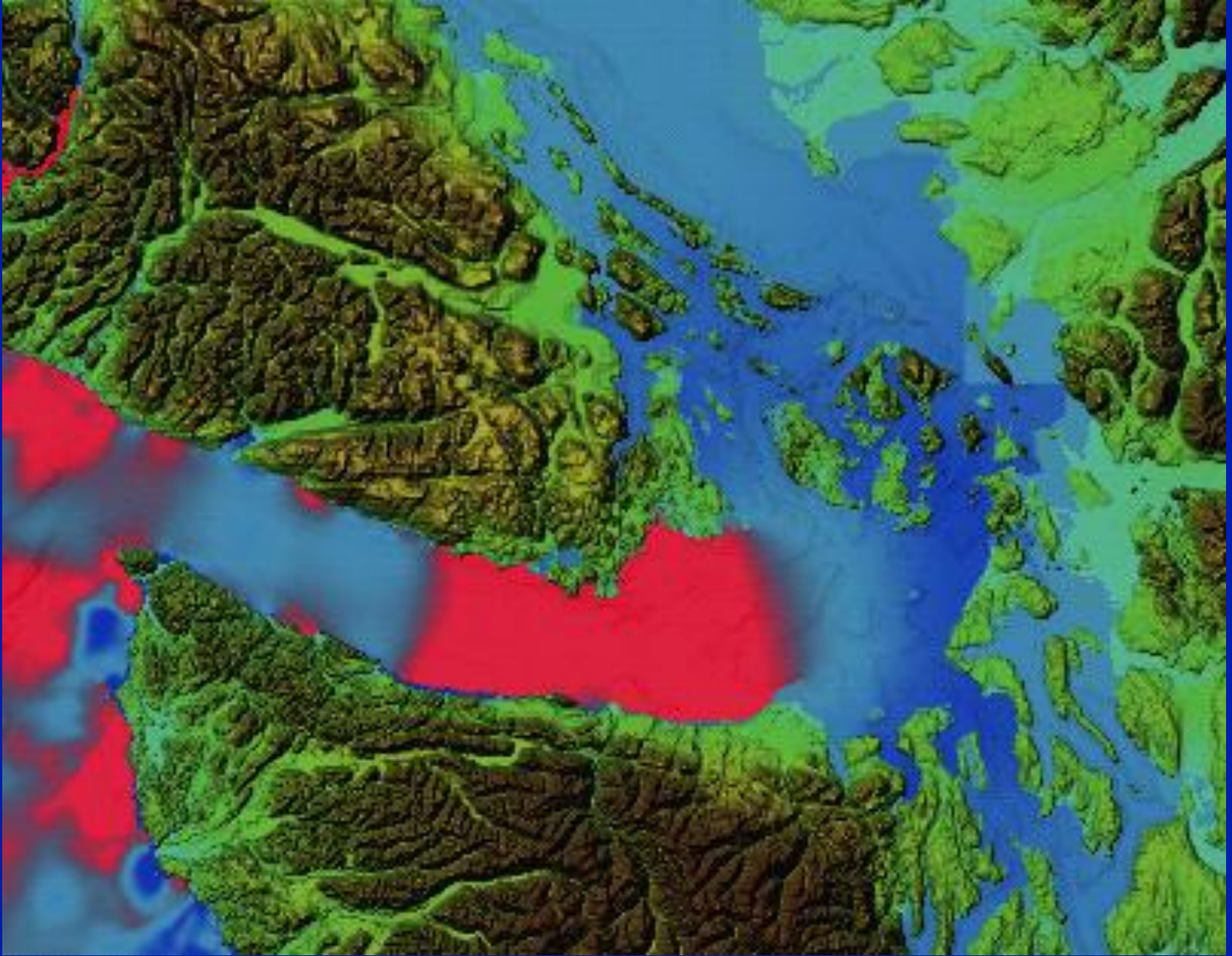
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SJDF propagation (0:30)



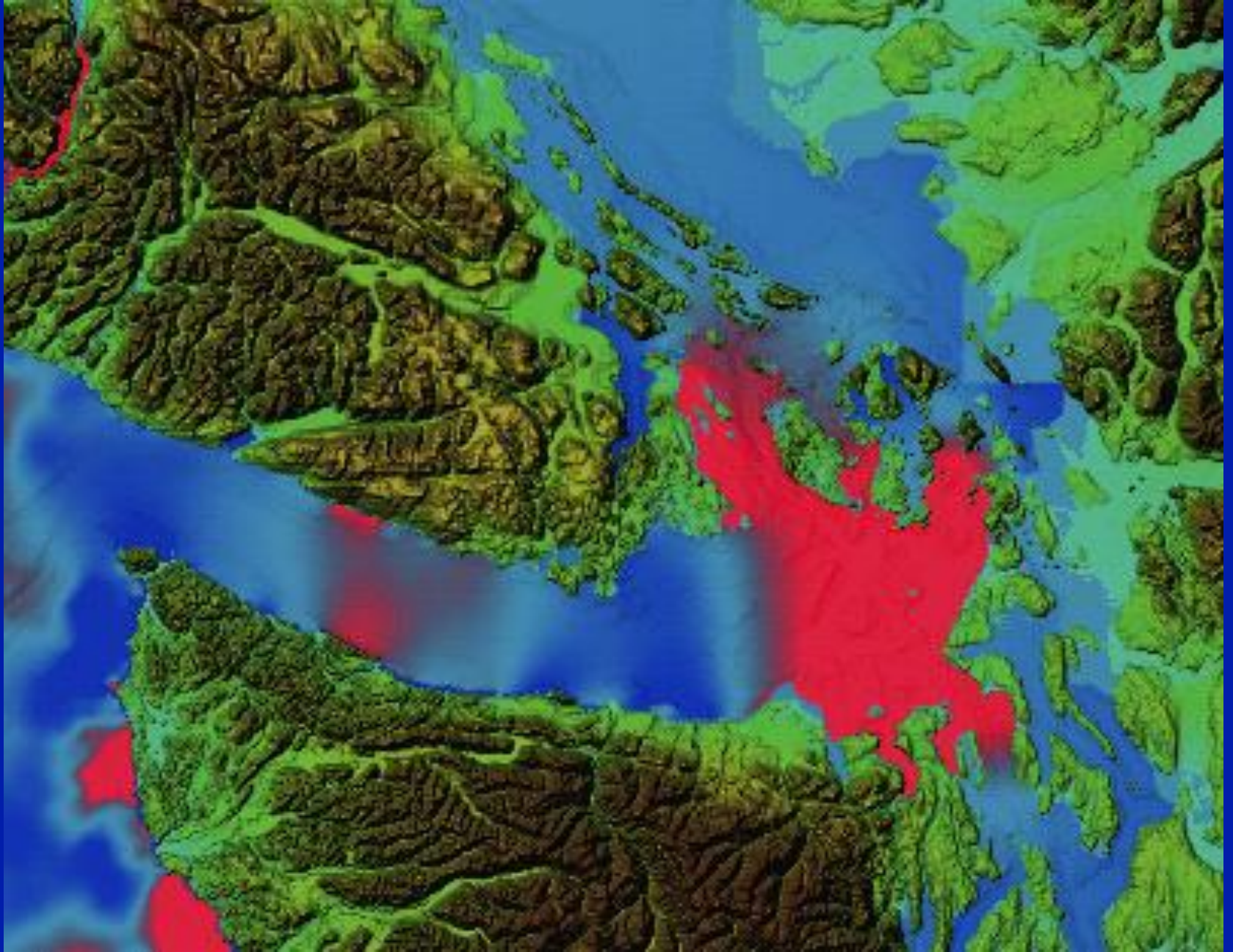
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SJDF propagation (1:00)



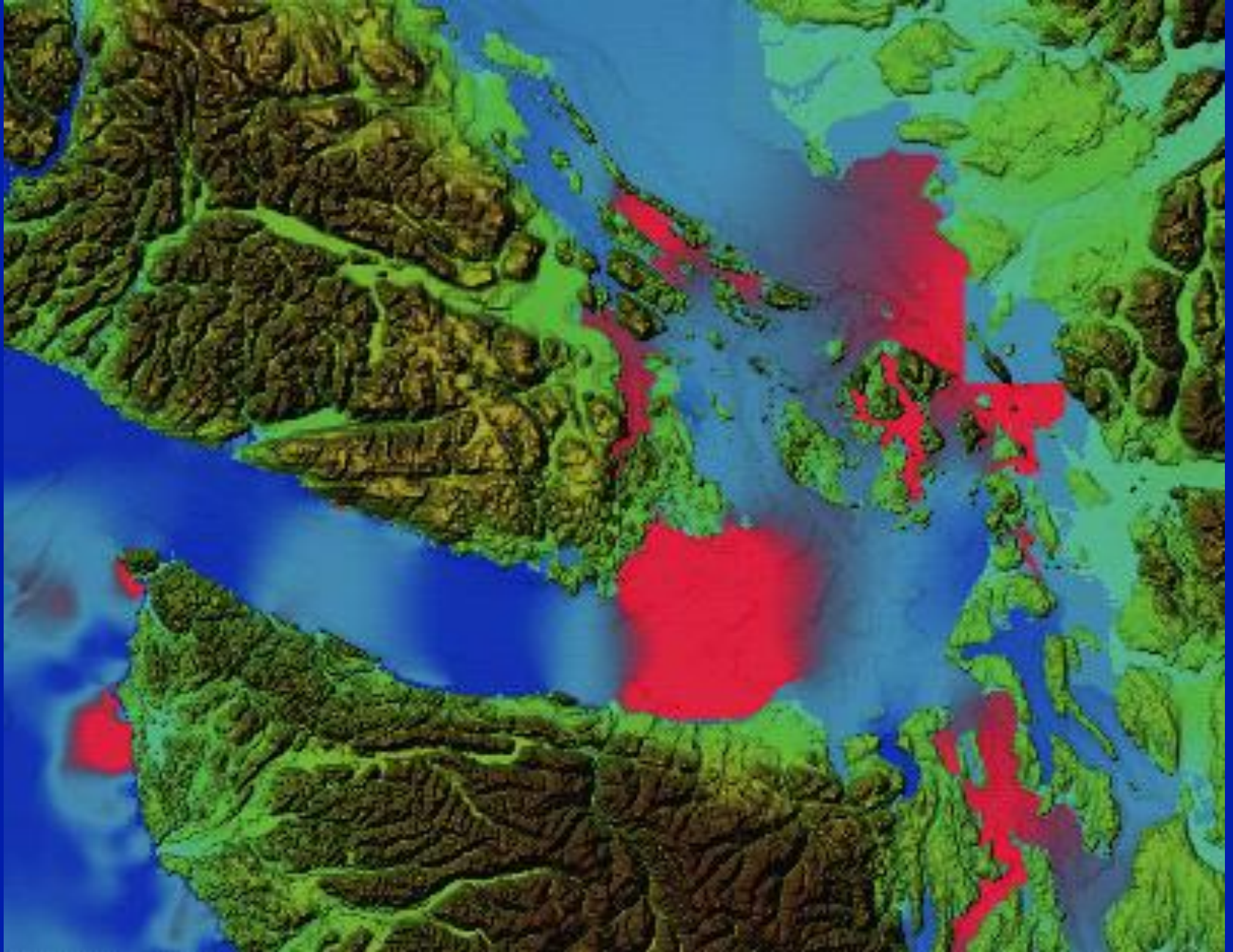
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SJDF propagation (1:30)



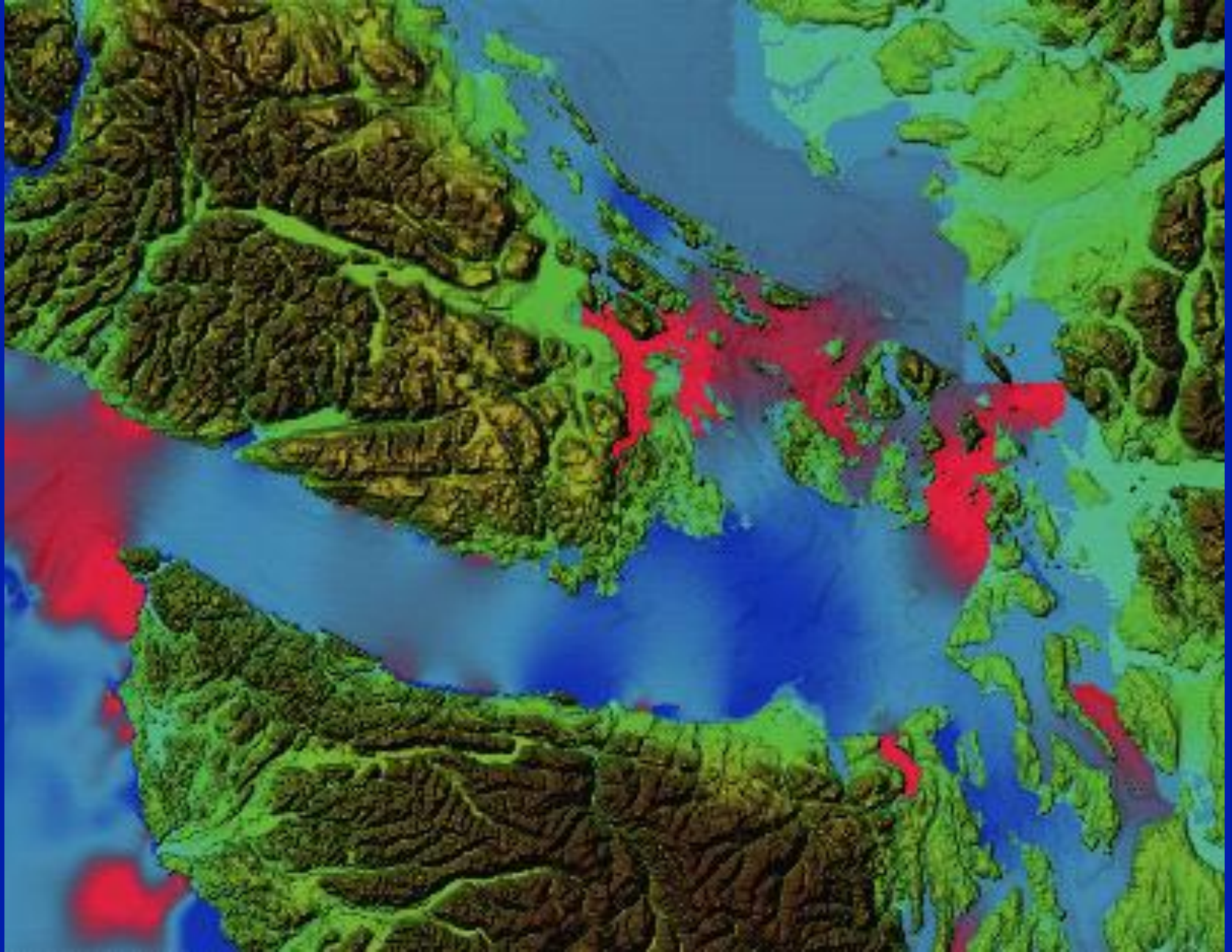
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SJDF propagation (2:00)



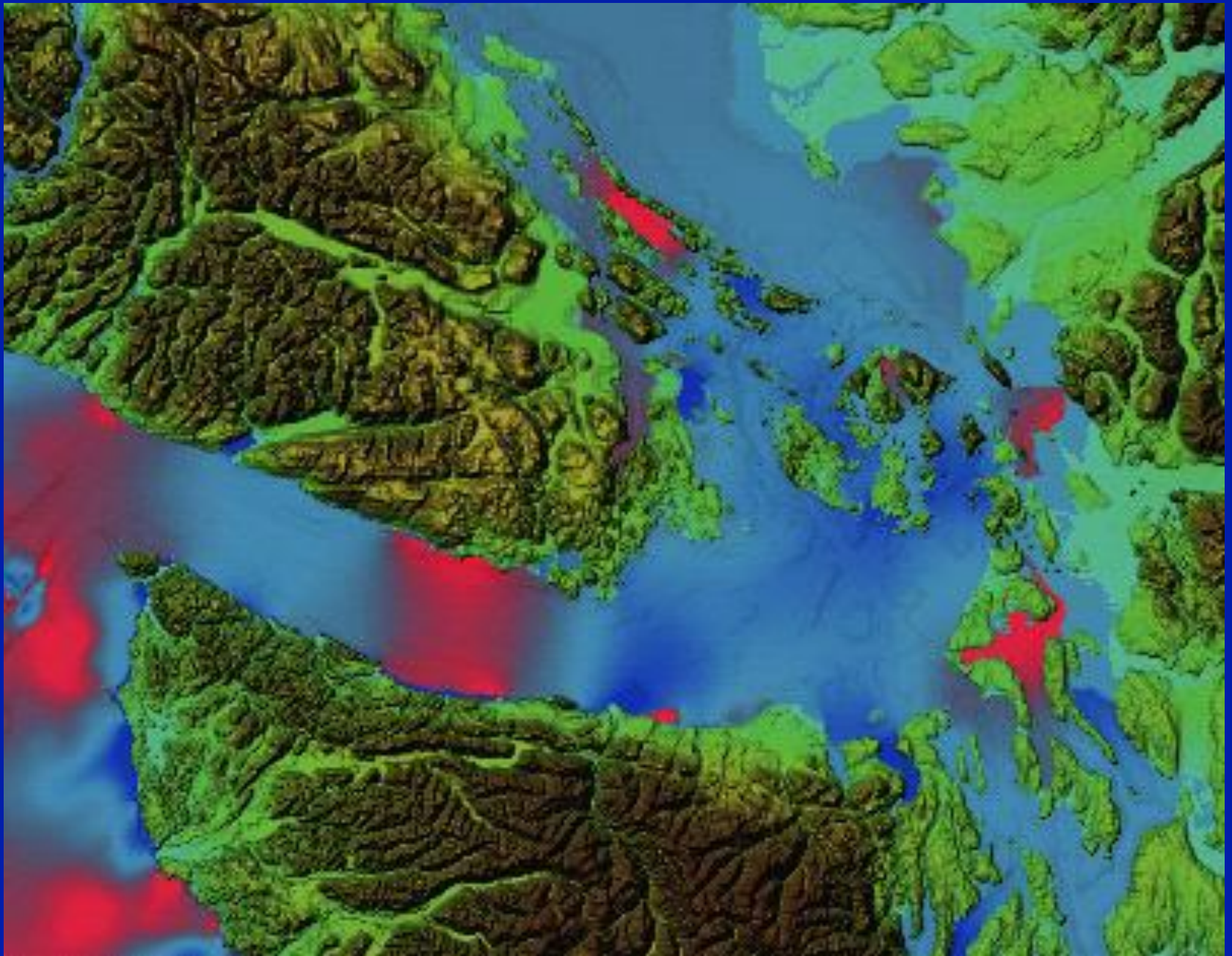
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SJDF propagation (2:30)



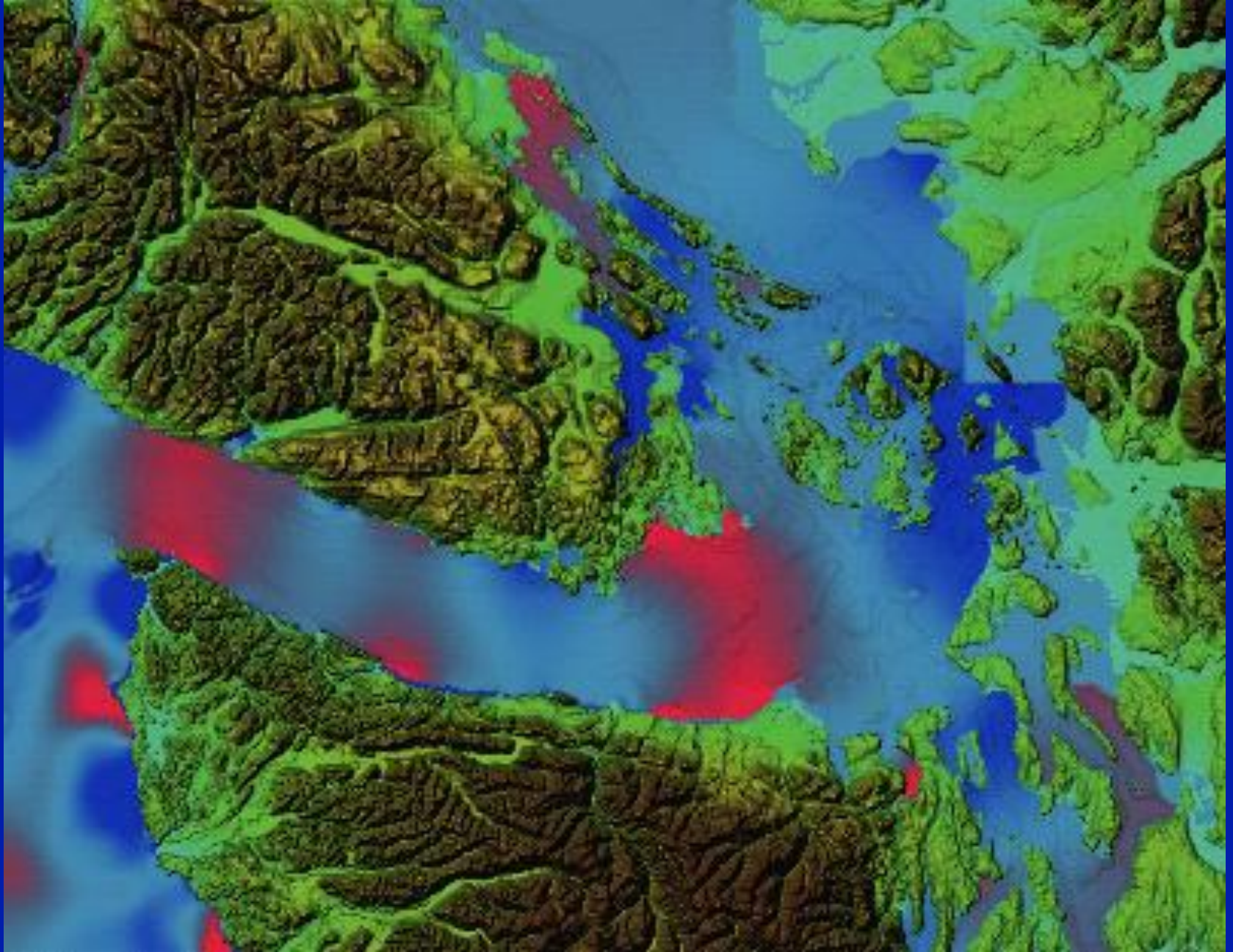
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SJDF propagation (3:00)



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SJDF propagation (3:30)



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SJDF propagation (4:00)

Tsunami Inundation Map of the Port Townsend, Washington, Area

by
Timothy J. Walsh, Edward P. Myers III, and Antonio M. Baptista

August 2002

We made a number of these hazard maps, including this one of the Port Townsend area

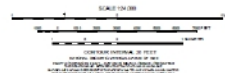
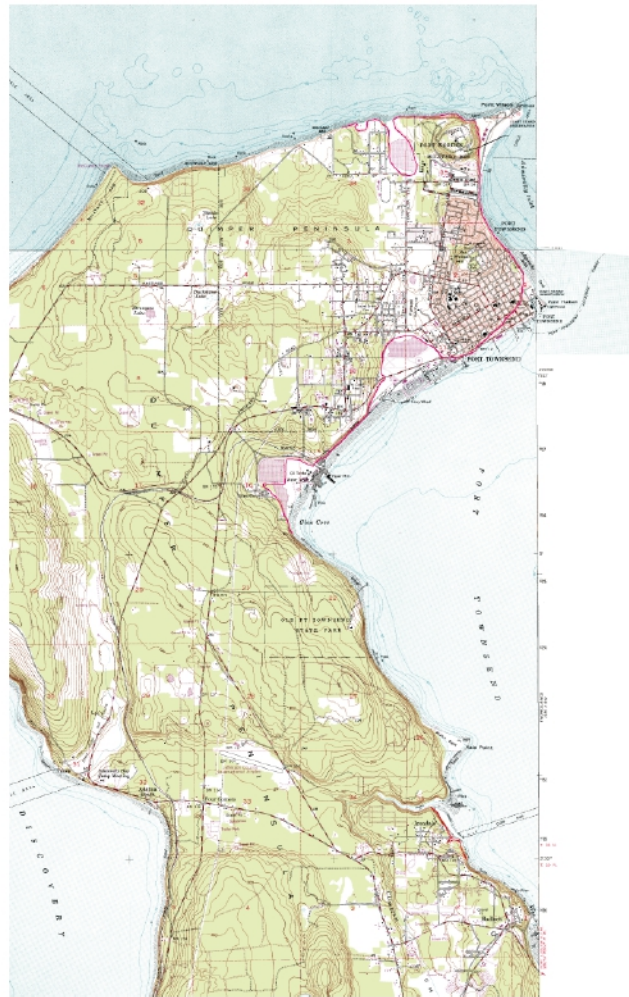
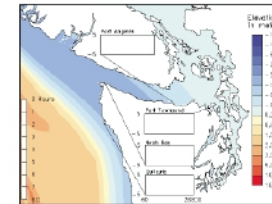
Landward limit of
expected inundation

Figure 5. Initial deformation model for scenario 1A. The red colors are areas of uplift and the blue areas are subsidence.

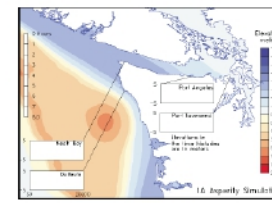


Figure 2. Initial deformation model for scenario 1A with thin upperly crust of 40 km and split lateral west of the core of the Olympics. Warmer colors are areas of uplift and cooler areas are subsidence.

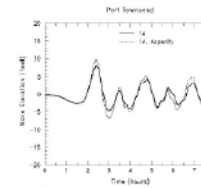


Figure 3. Elevation time history of base of wave in open water on West Wall. Elevation number indicates measurement point and wave.

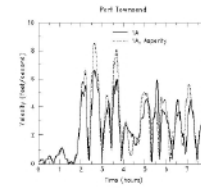


Figure 2. Current velocity with time off Point Wilson, in feet per second which is about half a knot.

Introduction

Recent research about the occurrence of great earthquakes off the Washington, Oregon, and northern California coasts is of continuing interest to AASA and others. The 1980 to the present era of tectonic research has produced a number of new insights. Some local issues would most likely be fully and clearly communicated within members of the earthquake, there will be little or no time to look at local variations. Transatlantic and research II should be planned well in advance. This map was prepared by staff of the National Tides and Mitigation Program (NTAMP) to aid local governments in developing evacuation plans for areas at risk from potentially damaging tsunamis.

Map Design

[illegible]

The model does not take into the influence of changes in industrial use, a large decline of forest fire, the large major windfall currents can strongly be reduced the impact of a tsunami on a specific community.

These models also do not include potential scenarios from landslides or an early coastal breach, which are not well enough understood to the modeler, although Whitham and Macgregor (1989) believe that there is evidence of locally generated tsunamis on Whitham Island. The occurrence of tsunamis in addition to earthquakes ranges from a few centuries to a single month, according about 400 years (Whitham and Macgregor, 1989). It is estimated that the earthquake on Canada in AD 1794 was about the same magnitude as the Gales and other 1975. It is to be known, however, if this is a characteristic magnitude for this field.

These Materials

The arrival time and duration of flooding are key factors to be considered for evacuation strategies. No studies or estimates of the modeled wave directions and velocities (Figs. 3 and 4) or the open ocean water level. The direction time history shows the change in wave direction and duration with time for eight levels of modeling. Negative durations are waves troughs, that is, times when water is not flowing out to sea. Positive duration segments were zero. Note that the first wave arrived at predicted location 90 minutes after the earthquake, but continued flooding contributed the most evacuating evacuation time available. Actual flooding depth and extent will depend on the tide height at the time of tsunami arrival. The velocity values in Fig. 6(b) are also approximately half a knot.

Limitations of the Map

Source of error and uncertainty in the PCE and ANOVA (1997). Because the nature of the function depends on the initial distribution of the stochastic variable, it is poorly understood, the largest source of uncertainty in the input stochastic variable. The stochastic simulation used in this modelling appears to be usually based on the Gaussian distribution, but the next step is to replace the Gaussian distribution by a more general one (N), with a special fit, modelling a more complex function (as for the surface function). In addition, but close to each other, by Piant and others (1997) locally closed local functions.

Acknowledgements

This project was supported by the National Invasive Species Management Program (NISMP) in cooperation with Jefferson County and Washington Emergency Management Division. Information about NISMP is available at <http://www.great.wa.gov/invasivespecies/>.

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Alvarez, R. F., Worsley-Haley, H. M., 1997. Bootstrap intervals for good or bad quality of the past. *Symposium on Mathematics*, No. 10, Washington U.S. Geological Survey Professional Paper 1276, 108 p.

Myers, R. P., III, Pagliaro, A. M., Frost, D. R., 1989, *Finite element modeling of potential Q-tectonic subduction zone tectonics in the case of Taiwan*, *Basins*, v. 17, no. 1, p. 3-8.

Frost, D. R., Myers, R. P., III, Pagliaro, A. M., Piller, Paul, Wang, Kuo-Cheng, Kuo, H. A., Andrews, C. D., 1997, *Case 4: subduction zone tectonics*, *Basins*, v. 25, no. 1, p. 3-8.

Open-File Report 97-36, U.S. Geological Survey, Department of Geology and Mineral Industries, Open-File Report 97-36, 344 p.

Benker, Kenji, Shimomaki, Kazuhiko, Teiji, Yoshihisa Ueda, Kazuo, 1996, Time and place of a giant megathrust in Okanada Island, From Japanese tsunami records of January 1700, *Nature*, 379, no. 6552, p. 246-249.

Nalib, T. F., Cavallaro, C. L., Hensler, A. C., Myers, E. P., Ell, Reginos, A. M., Pedroni, D. R., Campbell, R. A., 2008, *Stratigraphic correlation of the carboniferous Vaca Muerta basin: Modeling transient transients from a Canadian subduction zone analogue*, Washington Division of Geology and Earth Resources in Geologic Map (GM44), 1 sheet, scale 1:500,000, with 7 figs. text.



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P/30/02

The phenomenon we call "lake ice" (and *NAKAL*!) is a series of freezing or snow waves of extremely long length governed by GCM-based oscillations primarily with our frequency occurring below or near the ocean EAM. Underneath such an oscillation and turbulence within a given season, in the deep ocean, this length from year to year is not and may be a hundred miles or more but with a sea height of only a few feet or less. They cannot be felt about ships nor can they be seen from the air in the open ocean. In deep water, the water may reach speeds exceeding 500 refrigerer/hour.

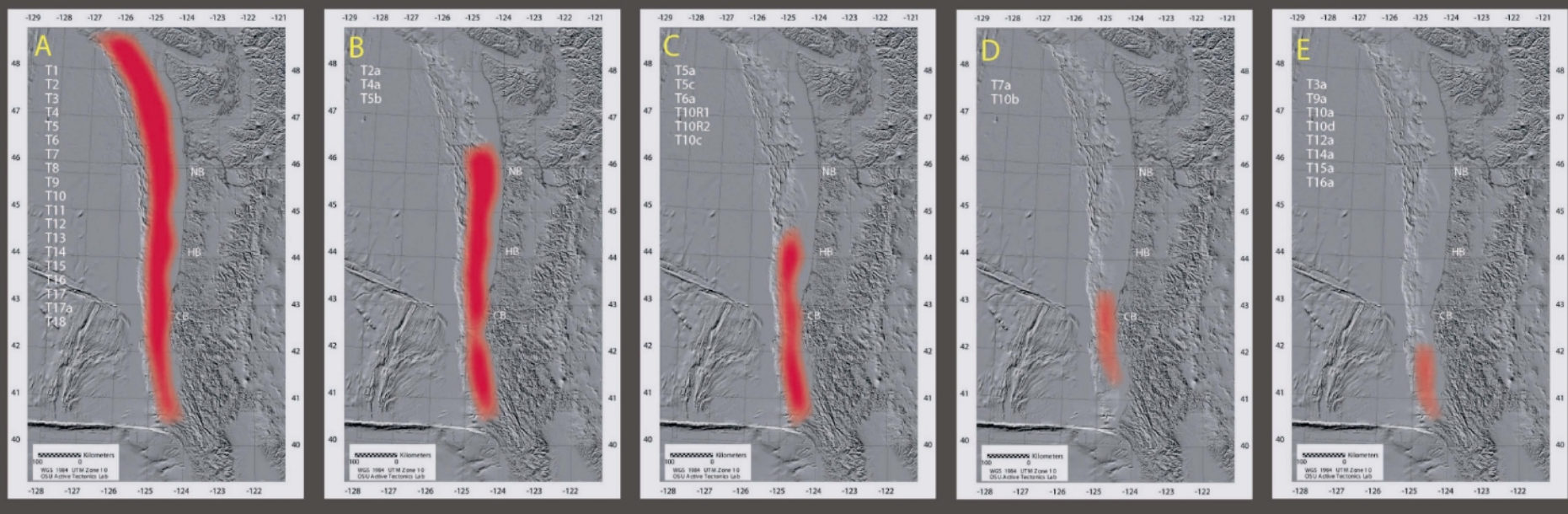
Tsunami hit a third toll: endoproperty for a system living near the ocean. For example, in 1992 and 1993 more than 2,000 people were killed by tsunami occurring in Nicaragua, Indonesia, and Japan. Property damage was nearly one billion dollars. The 1960 earthquake in Chile generated a Pacific-wide tsunami that caused widespread death and destruction not only in Chile, but also in Hawaii, Japan, and other areas in the Pacific. Large tsunamis have been known to kill as many as 100,000 people (see Figure 18-7).

Book Review: *The One Way* by
J. A. Thompson, University of Connecticut

National Character and Ideology Institute for the Americas,
 National Youth Service,
 Interpersonal Development, Communication,
 International Training Information Center
 International Children's Bureau, 1000 17th Street, N.W., Washington, D.C. 20036

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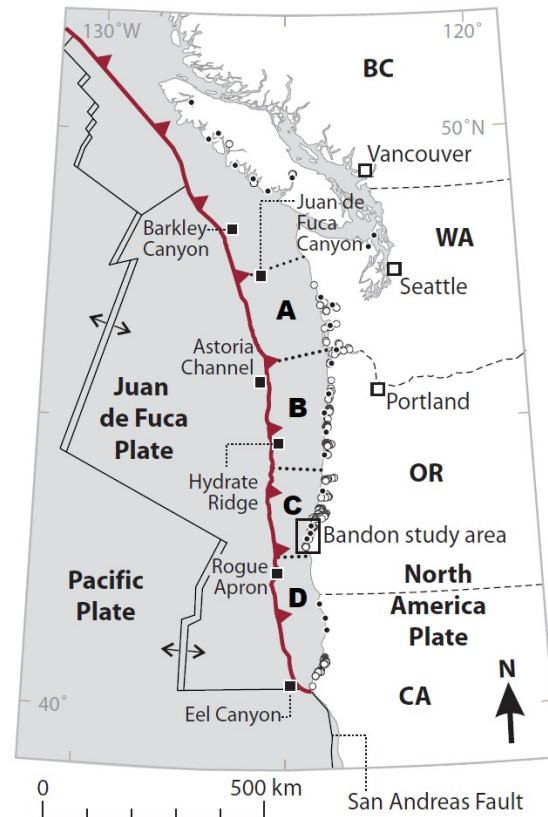


This led them to conclude that 21 turbidites were simultaneously triggered along the entire Cascadia margin, while another 20 or so had shorter spans. This, Adams earlier work, and Atwater's work all led to the conclusion that the full length of Cascadia ruptured, on average, with a 550 yr recurrence interval. Goldfinger et al. further proposed that smaller ruptures occurred between the larger ones and were confined to the south.

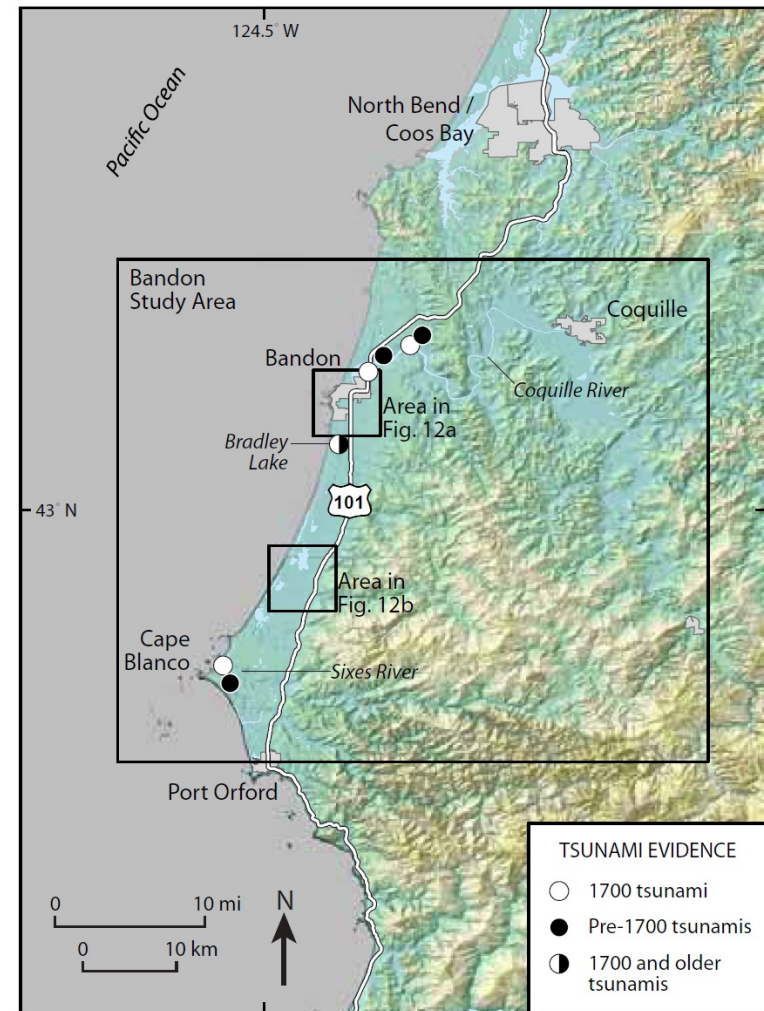
From Chris Goldfinger
and others



Witter and others combined data from Goldfinger, from Bandon, and Bradley Lake to infer that some tsunamis over the last 10,000 years had been larger than the one in AD 1700. They constructed hypothetical earthquake scenarios simulated tsunamis, then compared them to these data.



- EXPLANATION
- Seaward edge of subduction zone
 - Seafloor spreading ridge
 - Vertical strike-slip fault
 - Turbidite cores
 - Sand sheets
 - Coastal subsidence



TSUNAMI EVIDENCE

- 1700 tsunami
- Pre-1700 tsunamis
- 1700 and older tsunamis

Figure 2. Relief map of the Bandon, Oregon, project area showing locations of human population centers and major coastal rivers. Sites of deposits left by the AD 1700 tsunami are shown by white circles; sites of older Cascadia tsunami deposits are shown as black circles; sites preserving both types of evidence are shown by circles half white and half black.

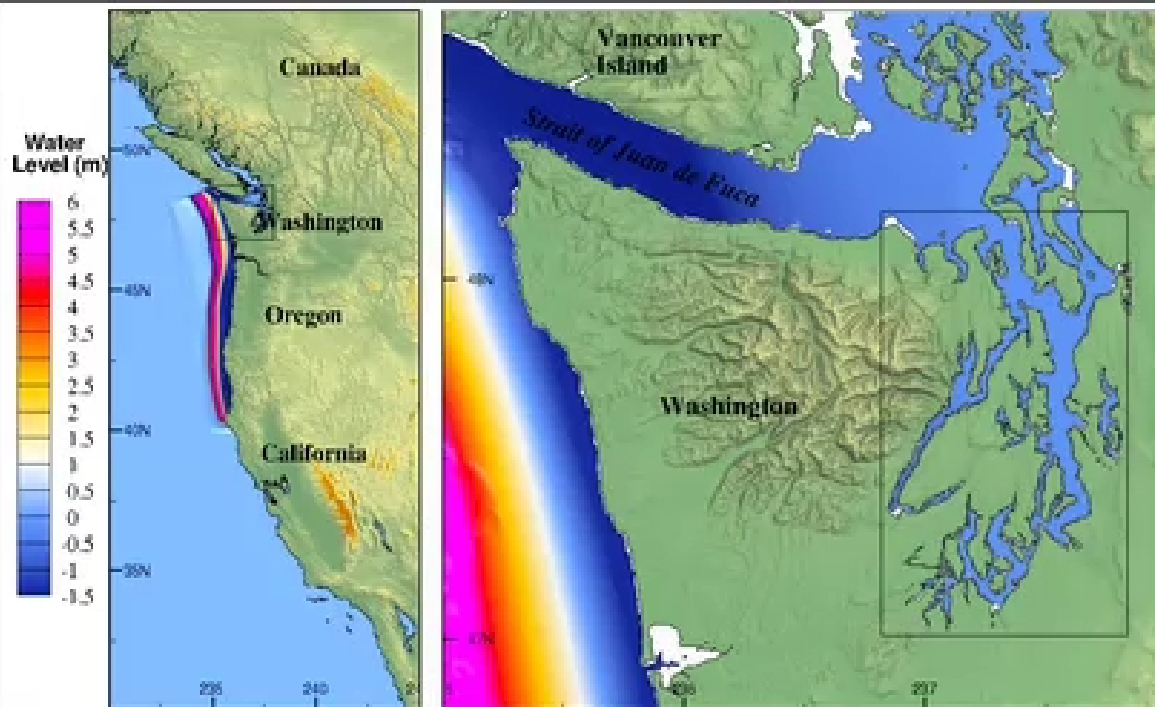


Table 3. Cascadia earthquake source parameters used to define 15 rupture scenarios. Logic tree branch weights shown in parentheses. Total scenario weight listed in right column.

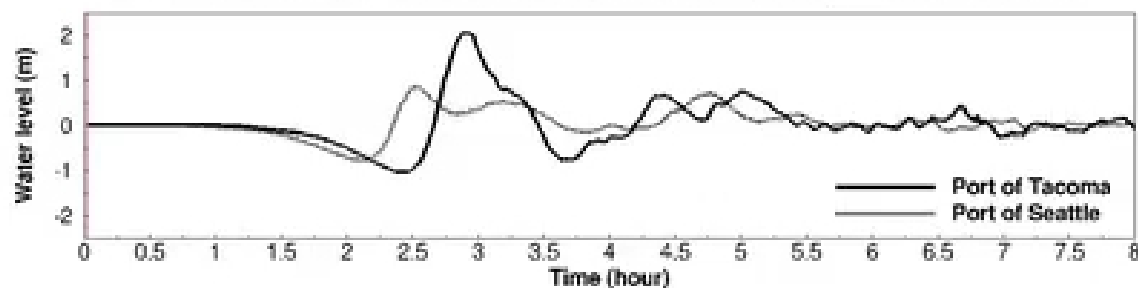
| Earthquake Size | Interevent Time (yrs) | Fault Geometry | Slip Range (m) | | M _w | Scenario Name | Total Weight |
|-------------------------------------|-----------------------|------------------------------|----------------|---------|----------------|---------------|--------------|
| | | | Maximum | Average | | | |
| Extra Extra Large (0.025) | 1,200 | Splay fault (0.8) | 36–44 | 18–22 | ~9.1 | XXL 1 | 0.02 |
| | | Shallow buried rupture (0.1) | 36–44 | 18–22 | ~9.2 | XXL 2 | 0.0025 |
| | | Deep buried rupture (0.1) | 36–44 | 18–22 | ~9.1 | XXL 3 | 0.0025 |
| Extra Large (0.025) | 1,050–1,200 | Splay fault (0.8) | 35–44 | 17–22 | ~9.1 | XL 1 | 0.02 |
| | | Shallow buried rupture (0.1) | 35–44 | 17–22 | ~9.2 | XL 2 | 0.0025 |
| | | Deep buried rupture (0.1) | 35–44 | 17–22 | ~9.1 | XL 3 | 0.0025 |
| Large (0.16) | 650–800 | Splay fault (0.8) | 22–30 | 11–15 | ~9.0 | L 1 | 0.128 |
| | | Shallow buried rupture (0.1) | 22–30 | 11–15 | ~9.1 | L 2 | 0.016 |
| | | Deep buried rupture (0.1) | 22–30 | 11–15 | ~9.0 | L 3 | 0.016 |
| Medium (0.53) | 425–525 | Splay fault (0.6) | 14–19 | 7–9 | ~8.9 | M 1 | 0.318* |
| | | Shallow buried rupture (0.2) | 14–19 | 7–9 | ~9.0 | M 2 | 0.106 |
| | | Deep buried rupture (0.2) | 14–19 | 7–9 | ~8.9 | M 3 | 0.106 |
| Small (0.26) | 275–300 | Splay fault (0.4) | 9–11 | 4–5 | ~8.7 | SM 1 | 0.104 |
| | | Shallow buried rupture (0.3) | 9–11 | 4–5 | ~8.8 | SM 2 | 0.078 |
| | | Deep buried rupture (0.3) | 9–11 | 4–5 | ~8.7 | SM 3 | 0.078 |

*Scenario M1 carries the highest weight and represents the “most likely” event in our analysis.

The initial condition in the model is the L1 Scenario (Fig. 2) (Witter and others, 2011) which is a splay fault model in which some slip is partitioned into a thrust fault in the accretionary wedge that is subparallel to and with the same sense of movement as the plate interface, resulting in a broader uplift than a simple fault rupture. The land surface at Port Townsend is modeled to subside during ground shaking only minimally or not at all

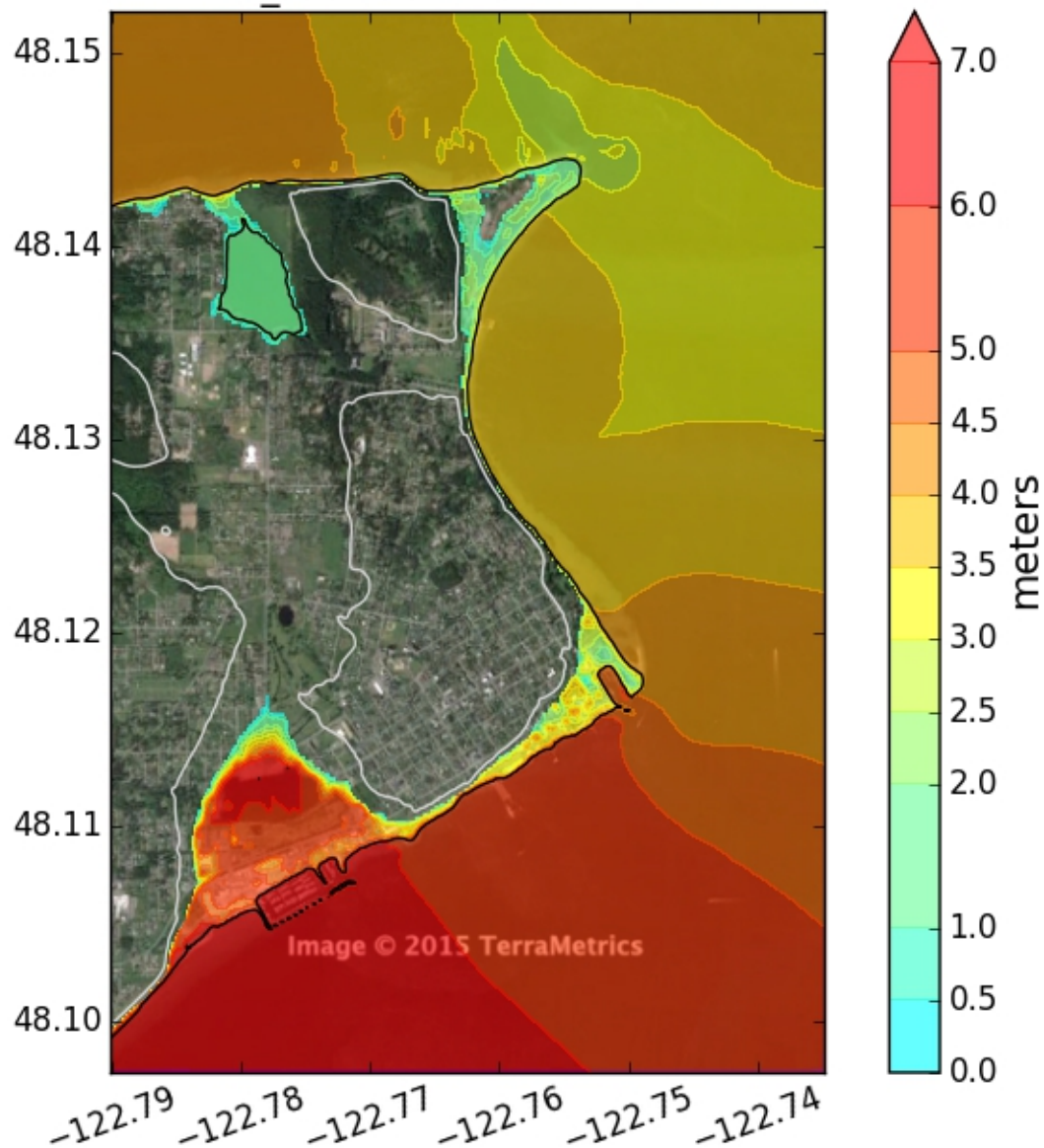


Tsunami impact along the Puget Sound Caused by the M_w 9.0 L1 EQ scenario

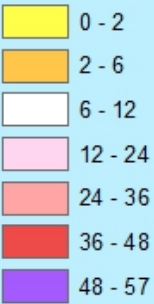




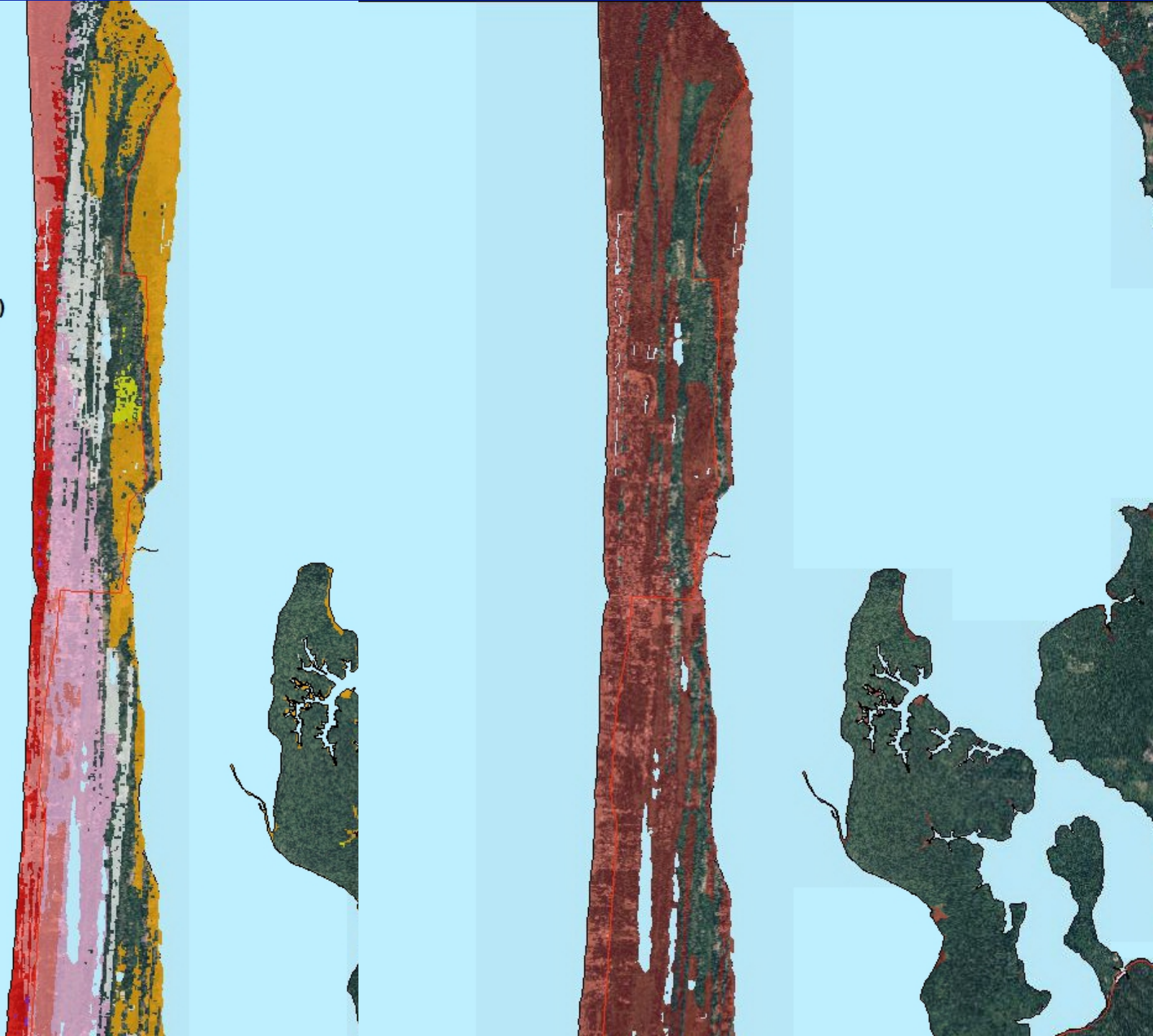
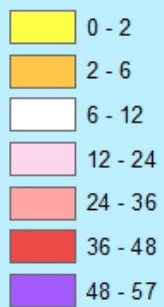
Port_Townsend Zeta Maximum



Inundation Depth (ft)



Inundation Depth (ft)



Inundation Depth (ft)

