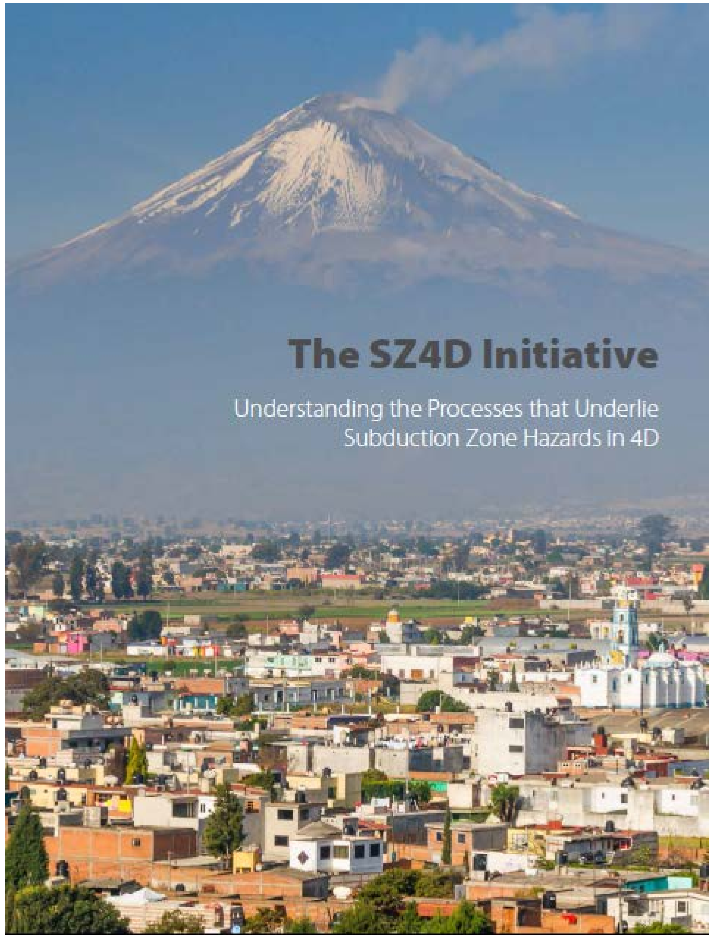
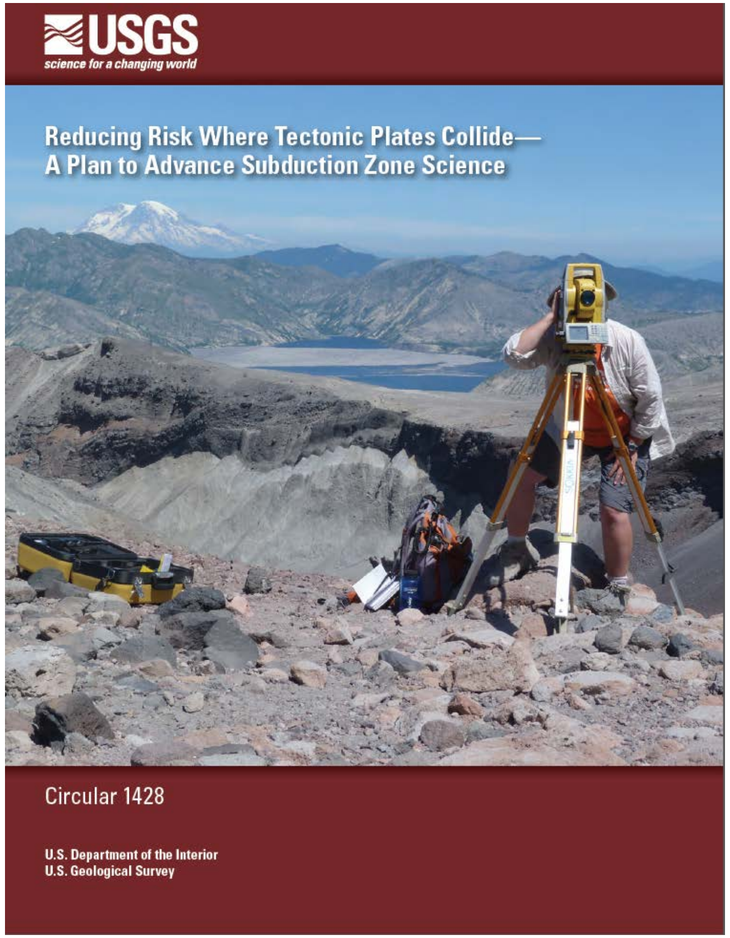
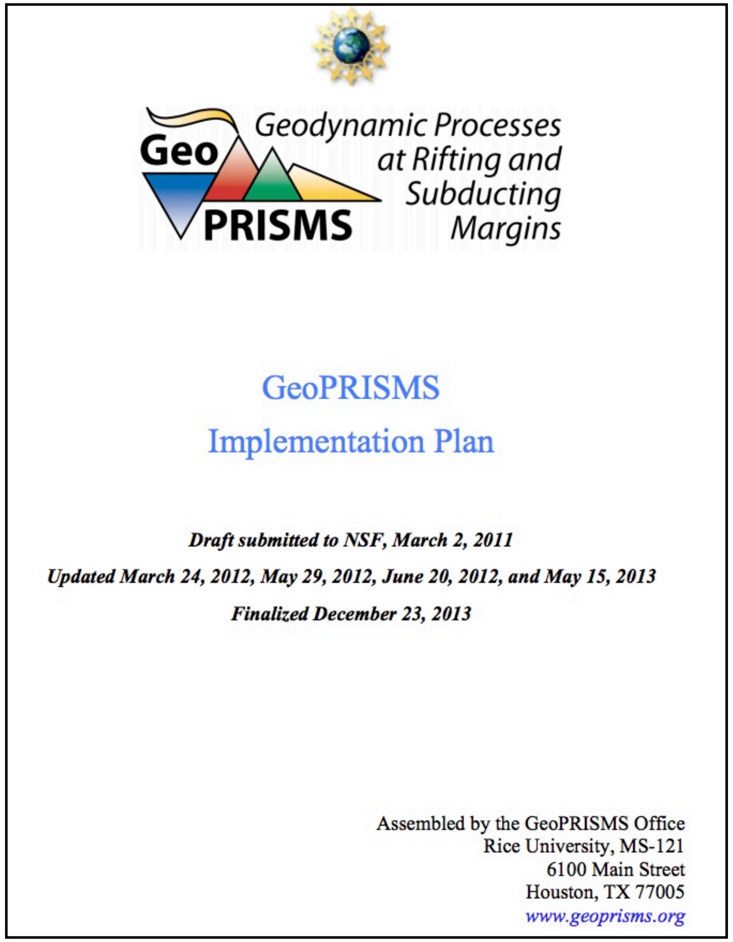
The USGS's Vision (for subduction zone science)

Joan Gomberg, Nathan Miller

Gotta' have a plan….





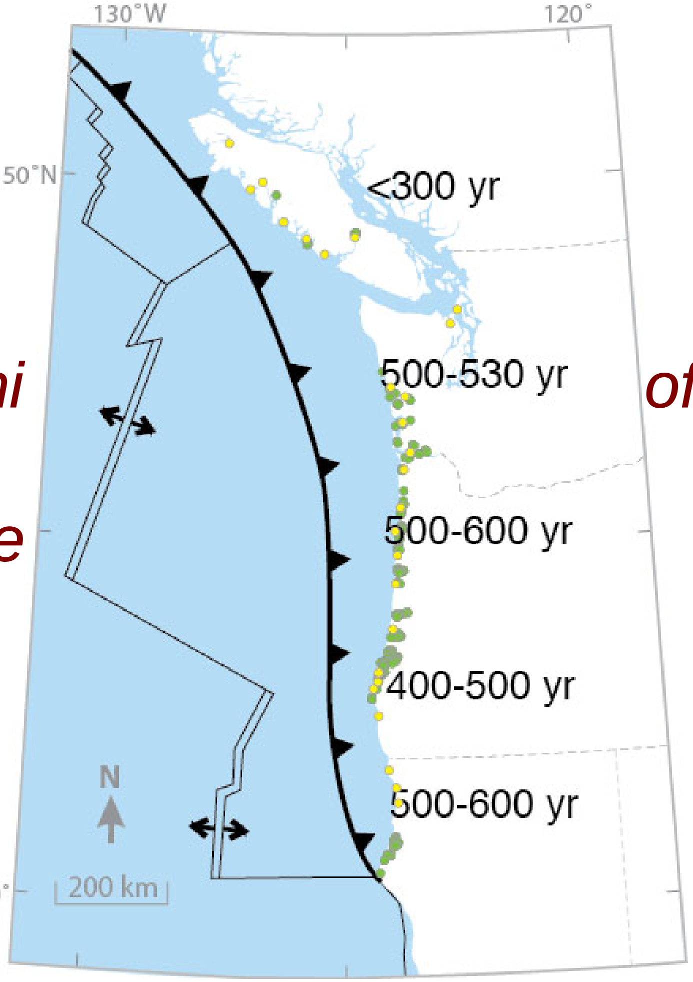


USGS
science for a changing world

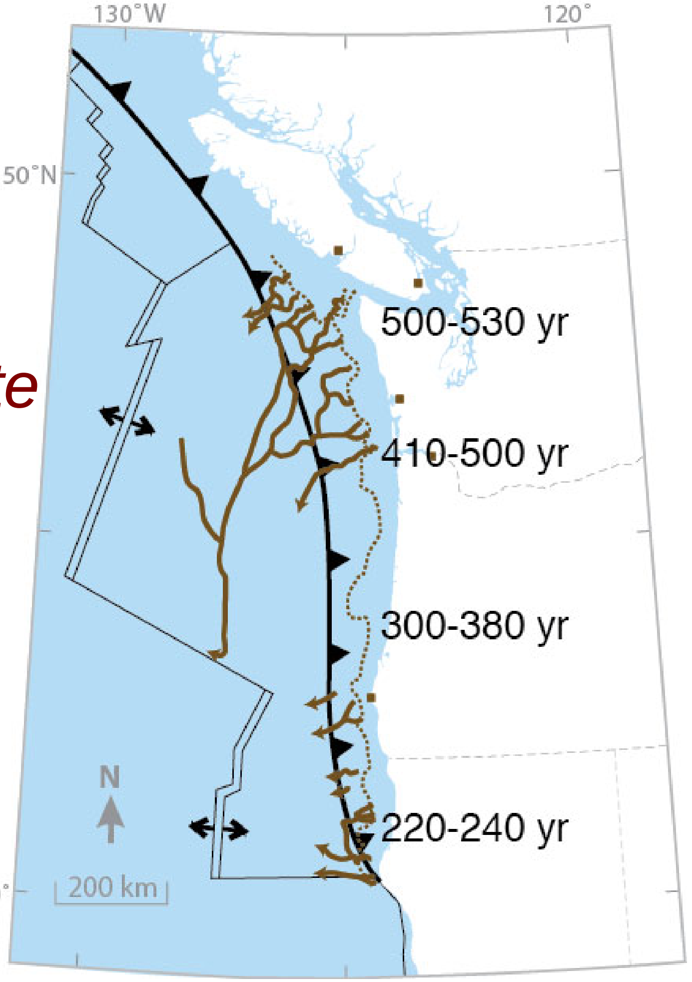
GeoPRISMS SCD asks what governs great subduction zone earthquakes' characteristics and interface slip behaviors? How does plate boundary deformation evolve?

USGS asks can we distinguish between Cascadia megathrust earthquake recurrence models?

recurrence estimates: onshore tsunami & coastal uplift/subsidence record



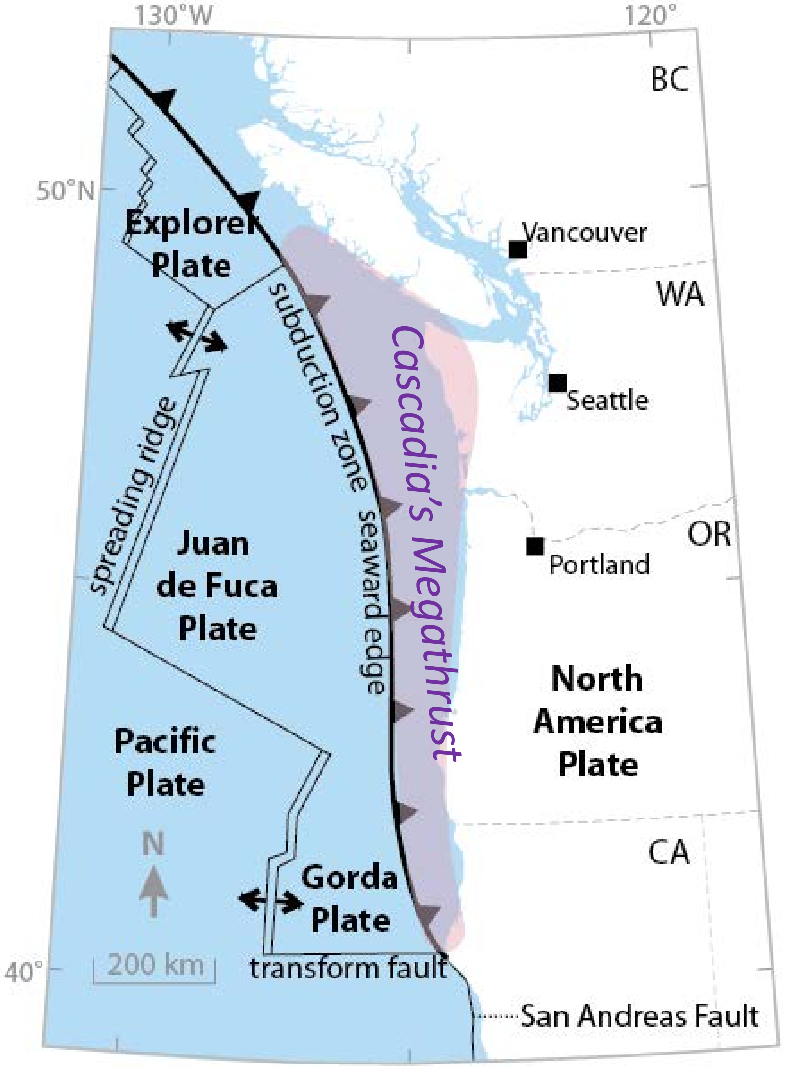
recurrence estimates: offshore turbidite & sediment record



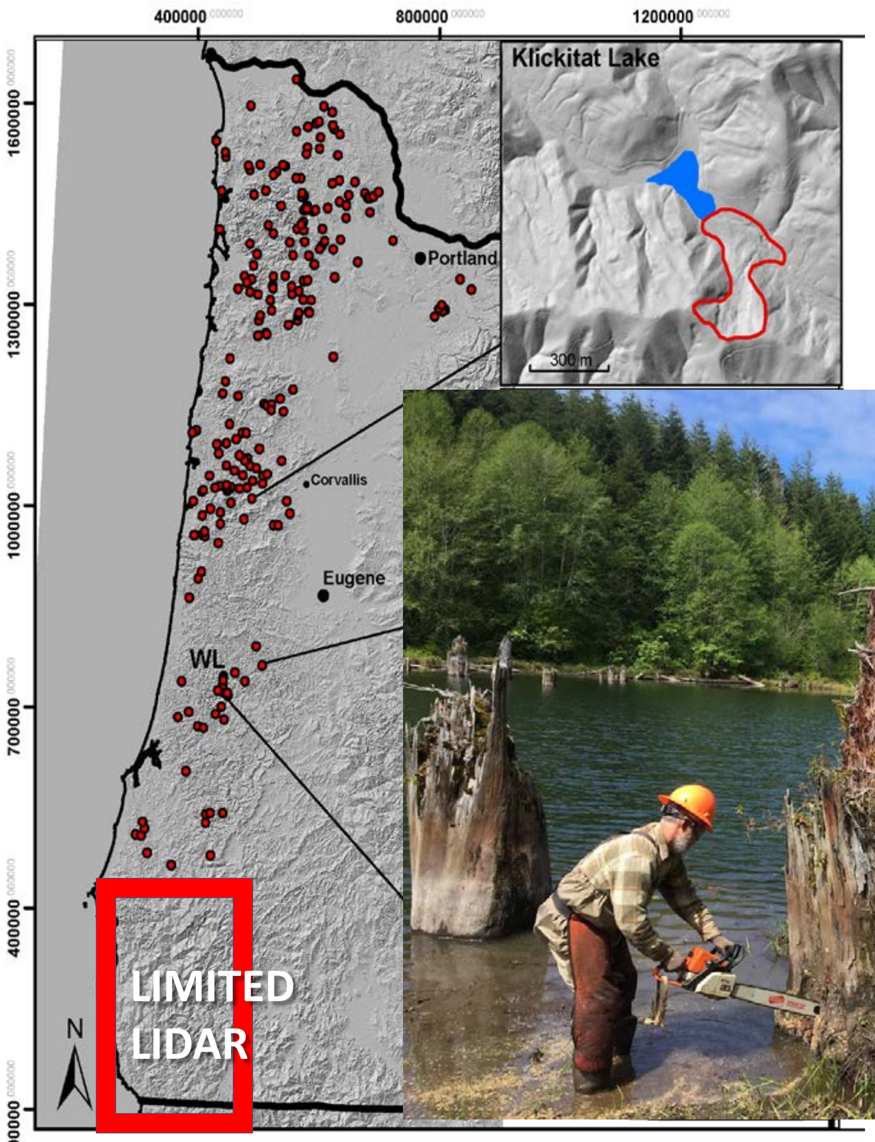
USGS asks can we distinguish between Cascadia megathrust earthquake recurrence models?

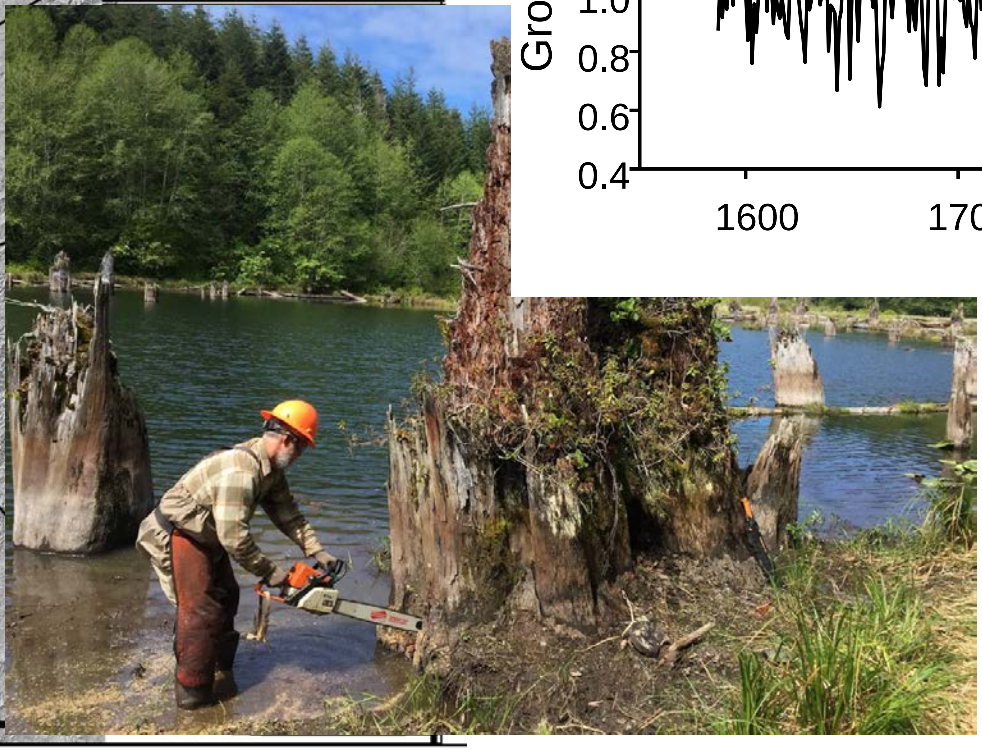
A holistic approach, linking studies

- Paleoseismology (geology)
  - land-level changes
  - tsunami deposition
  - upper-plate faulting
- Landslides
- Offshore
  - turbidites
  - geomorphology & structure
- Modern seismic record
- Geodesy
- Physical/structural controls

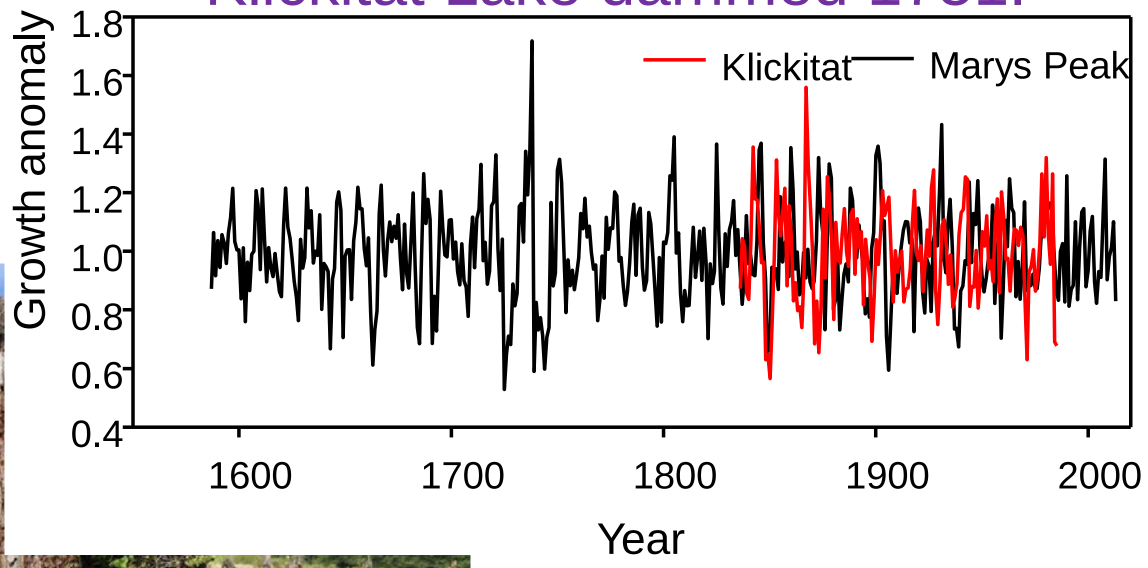


E.g., using dendrochronology to determine the year shaking-triggered landslides dammed lakes.





Correlated against reference –> Klickitat Lake dammed 1751.



with Universities of Oregon & Arizona, DOGAMI

GeoPRISMS SCD asks what governs great subduction zone earthquakes' characteristics and interface slip behaviors? How does plate boundary deformation evolve?

USGS invests in measuring transient slow fault slip on the seafloor, by

- hosting a multi-institutional workshop,
- installing 2 seafloor acoustic geodetic (GPS-A) sites in Cascadia

  3 per monuments per site, serviced with Wave-glider

  10 year lifetime, available for additional collaborations

  with Universities of CA (Scripps), WA, HI, & Humboldt State

- researching seafloor pressure geodetic measurement methods

  with Universities of WA, Texas, Columbia, NIWA (New Zealand), JAMSTEC & NEID (Japan)

GeoPRISMS SCD asks what governs great subduction zone earthquakes' characteristics and interface slip behaviors? How does plate boundary deformation evolve?

USGS asks can we observe slip over millenia (*e.g.*, at the bottom of lakes)?

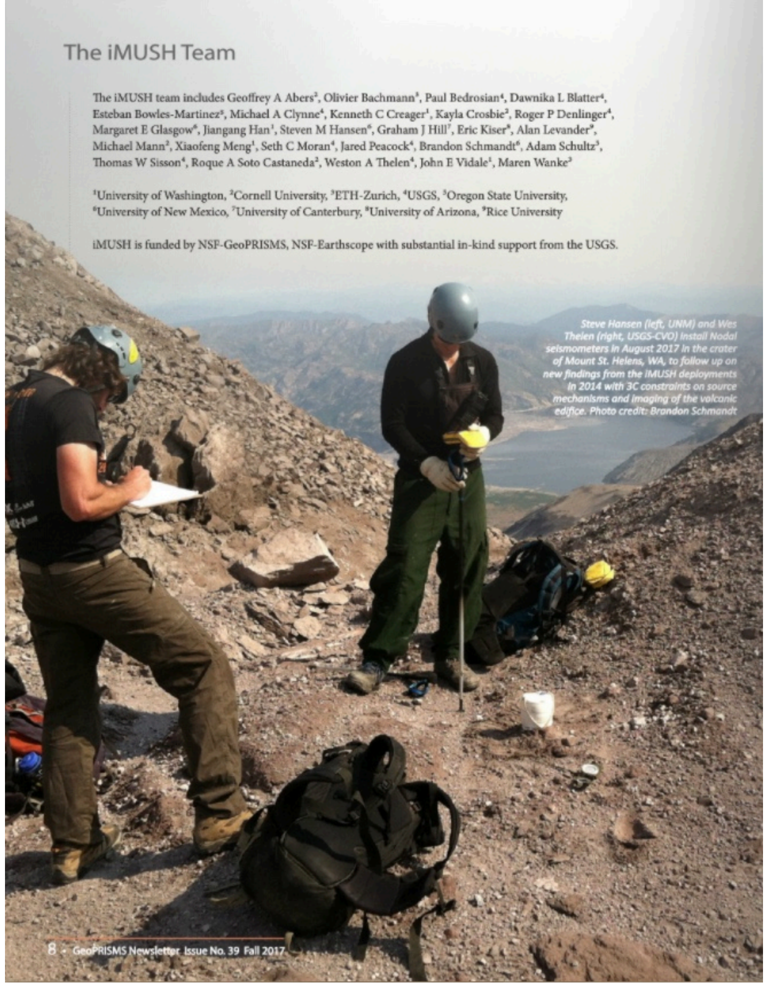
Deposit from M7 11/30/18 Anchorage earthquake

Deposits from historic and pre-earthquake (*not visible in photo*)

with University of Ghent

GeoPRISMS SCD asks how are volatiles, fluids, and melts stored, transferred, and released? What geochemical products, from mantle to surface reservoirs, influence continental crust formation?

USGS & GeoPRISMS address these questions collaboratively in Cascadia & Alaska.


The iMUSH Team

The iMUSH team includes Geoffrey A Abers[2], Olivier Bachmann[3], Paul Bedrosian[4], Dawnika L Blatter[4], Esteban Bowles-Martinez[5], Michael A Clynne[4], Kenneth C Creager[1], Kayla Crosbie[2], Roger P Denlinger[4], Margaret E Glasgow[6], Jiangang Han[1], Steven M Hansen[6], Graham J Hill[7], Eric Kiser[8], Alan Levander[9], Michael Mann[2], Xiaofeng Meng[1], Seth C Moran[4], Jared Peacock[4], Brandon Schmandt[6], Adam Schultz[5], Thomas W Sisson[4], Roque A Soto Castaneda[2], Weston A Thelen[4], John E Vidale[1], Maren Wanke[3]

[1]University of Washington, [2]Cornell University, [3]ETH-Zurich, [4]USGS, [5]Oregon State University, [6]University of New Mexico, [7]University of Canterbury, [8]University of Arizona, [9]Rice University

iMUSH is funded by NSF-GeoPRISMS, NSF-Earthscope with substantial in-kind support from the USGS.

Steve Hansen (left, UNM) and Wes Thelen (right, USGS-CVO) install Nodal seismometers in August 2017 in the crater of Mount St. Helens, WA, to follow up on new findings from the iMUSH deployments in 2014 with 3C constraints on source mechanisms and imaging of the volcanic edifice. Photo credit: Brandon Schmandt

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Report from the Field

Collaborative Research: Magnetotelluric and Seismic Investigation of Arc Melt Generation, Delivery, and Storage beneath Okmok Volcano

Kerry Key (Scripps Institution of Oceanography) and Ninfa Bennington (University Wisconsin-Madison)

Installation of a magnetotelluric station in the Okmok Caldera. Photo credit: Kerry Key.

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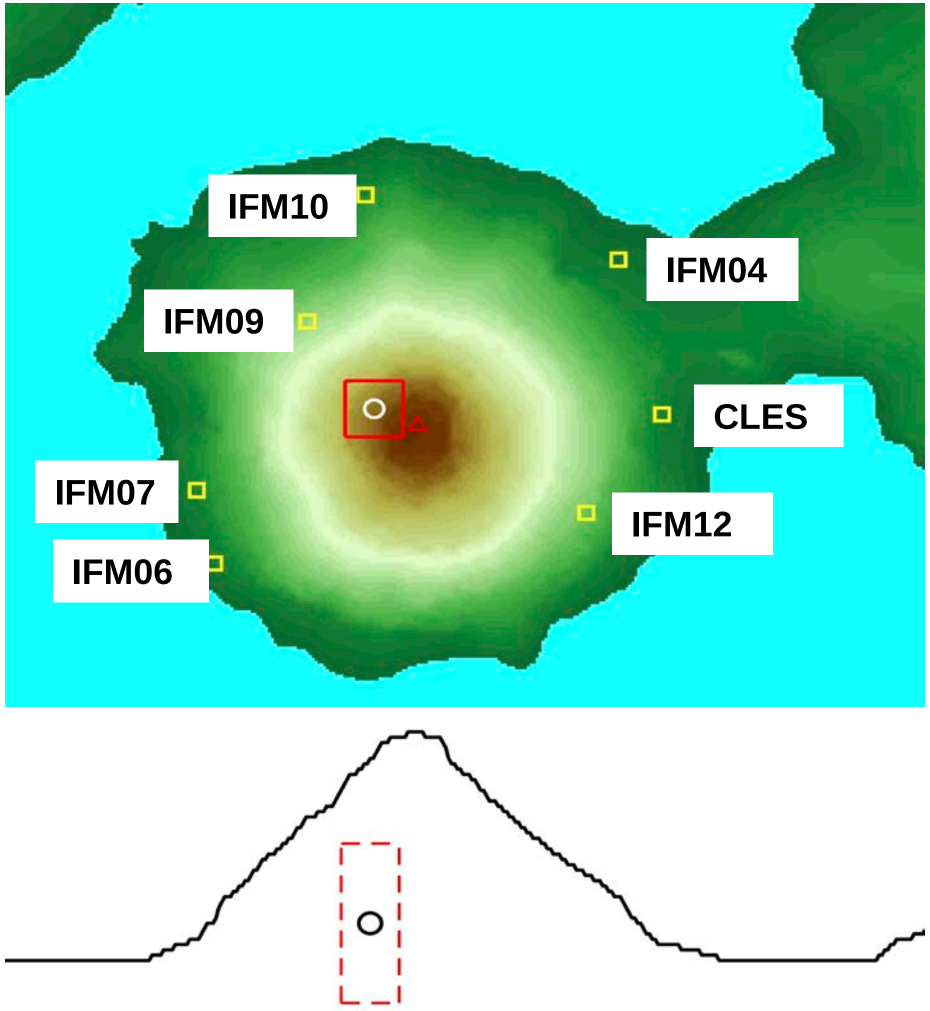
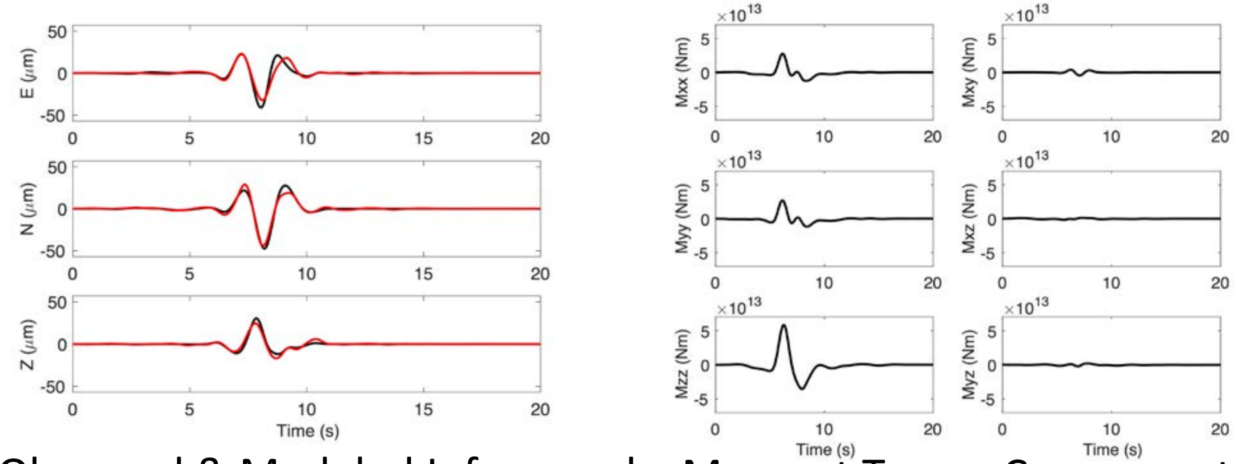
GeoPRISMS SCD asks how are volatiles, fluids, and melts stored, transferred, and released? What geochemical products, from mantle to surface reservoirs, influence continental crust formation?

USGS monitors and characterizes volcanic processes; *e.g.*



infrasound constrains a shallow source of April, 2016 explosions at Cleveland Volcano, Alaska

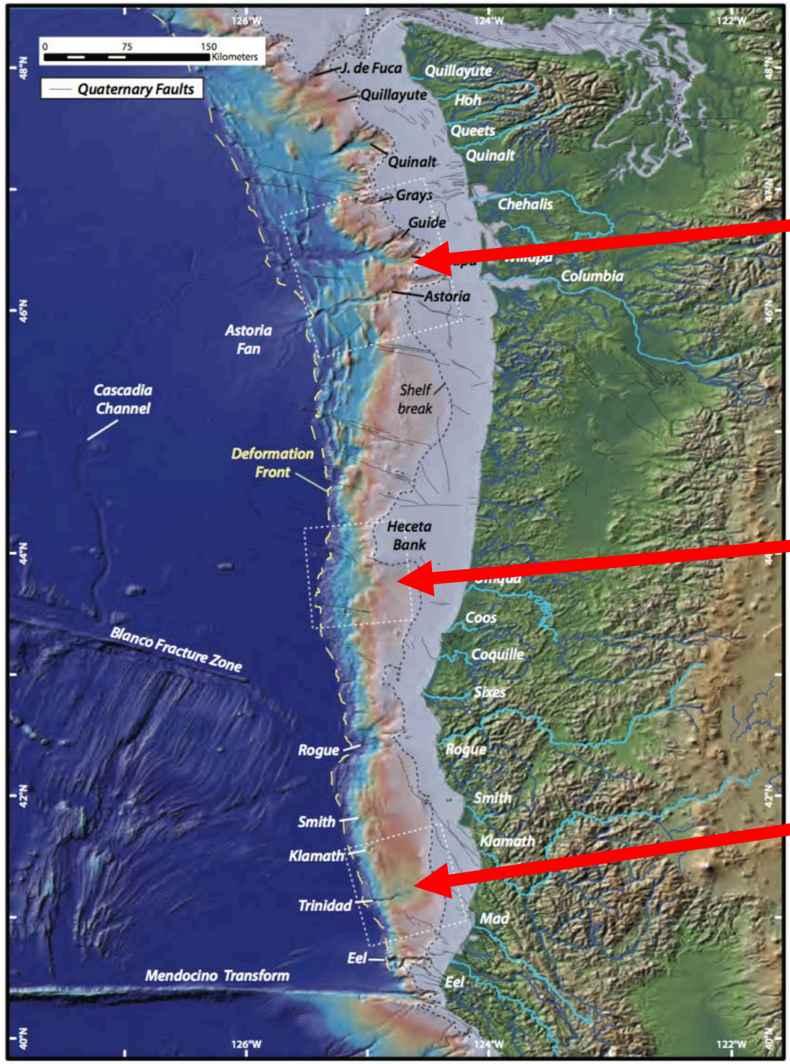


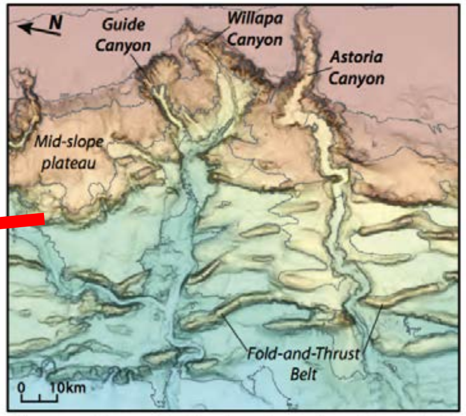
Observed & Modeled Infrasound   Moment Tensor Components

with Carnegie Institution, Connecticut College, University of Alaska Fairbanks

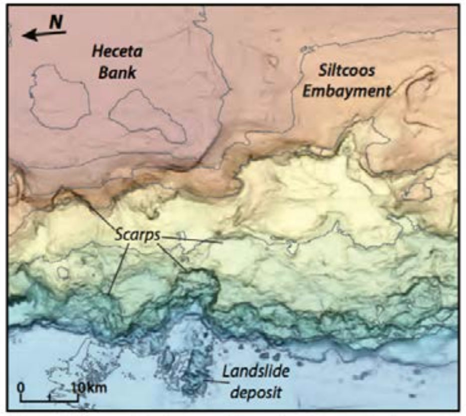
GeoPRISMS SCD asks about critical feedbacks between surface processes and subduction zone mechanics and dynamics?

USGS asks interactions among upper plate offshore structure and interface properties & slip?

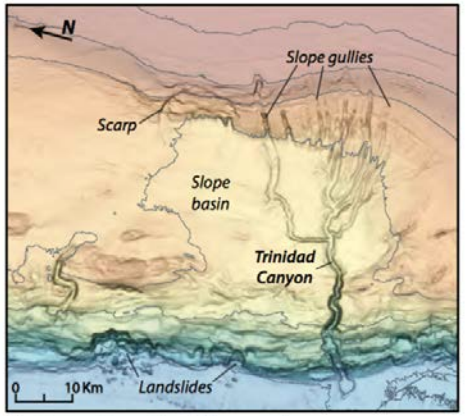




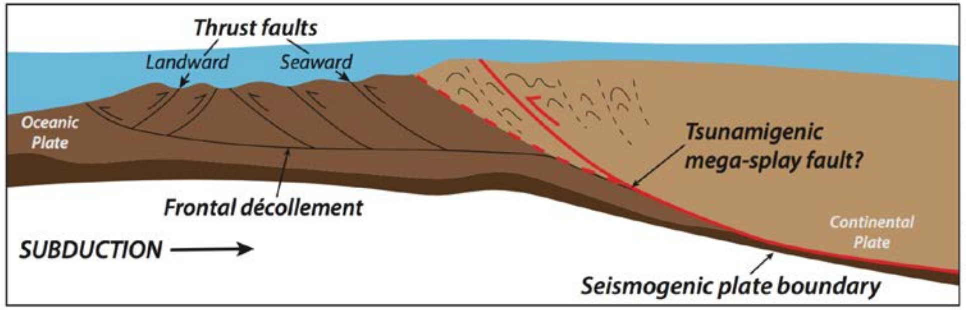
Northern Cascadia: Landward verging thrust faults expressed in a distinct fold belt across the prism.



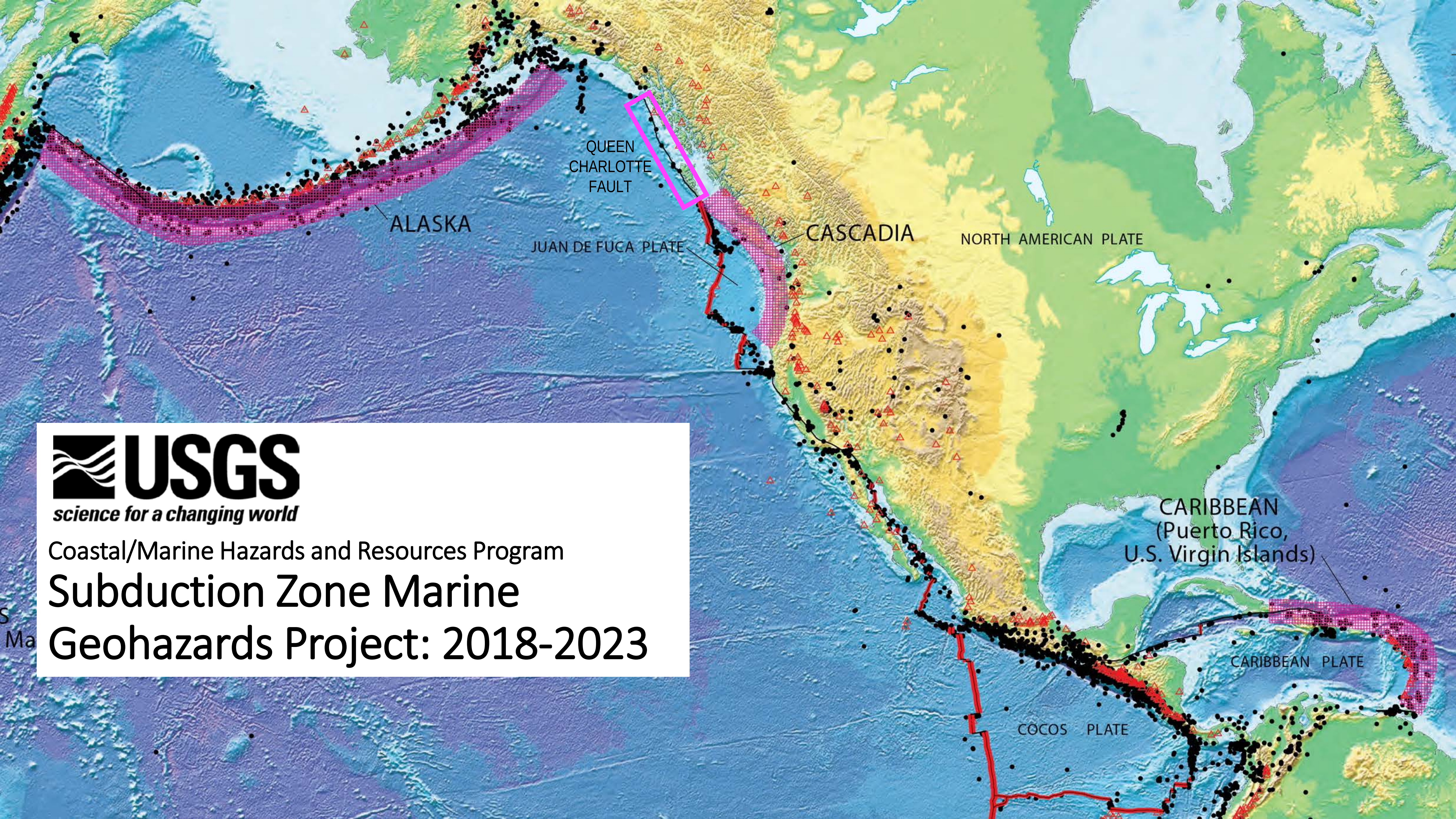
Central Cascadia: Seaward verging thrust faults result in a steep, irregular seafloor prone to landslides.



Southern Cascadia: Gullies and canyons cut across basins; landslides occur at the base of the slope.



Modified from Bangs et al., Science 2007



USGS
science for a changing world

Coastal/Marine Hazards and Resources Program

Subduction Zone Marine Geohazards Project: 2018-2023

A 5-year USGS Coastal/Marine Hazards and Resources Program focus on subduction zone marine geohazards: 2018-2023

Hazard knowledge gaps

- **Large earthquake recurrence**
- **Fault sources**
- **Tsunami sources**

- Rupture segmentation
- Locking model
- Shaking
- Co-seismic subsidence/uplift

Products

Hazard assessment
- Megathrust & upper plate rupture simulation
- End-member surface deformation models
- Coastal uplift/subsidence
- Submarine landslide

Recurrence History
- Lake paleoseismology record
  Tsunami deposit dates
- Improved turbidite dating precision

Event response plan
- Pre-event baseline data
- Rapid response OBS for aftershcocks
- Post-event seafloor mapping and coring (co-seismic deformation, turbidites)
- Rapid-response coastal uplift and tsunami mapping

Drilling targets
- Alaska
  Cascadia

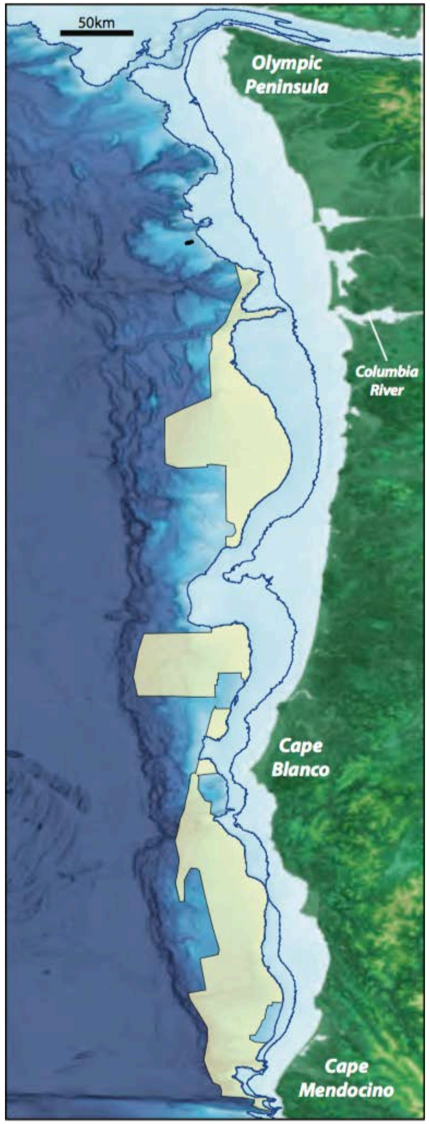
3D fault and geologic model
Tsunamis M>=6 (4x2 km rupture area)
Megathrust
Upper plate faults

Quaternary fault and fold database
- Slip rates and slip budget
- Extend QFFD to offshore
- Deformation & structure map (orientation of structures)
- Improve tsunami deposit & inundation map
- Seismic reflection atlas

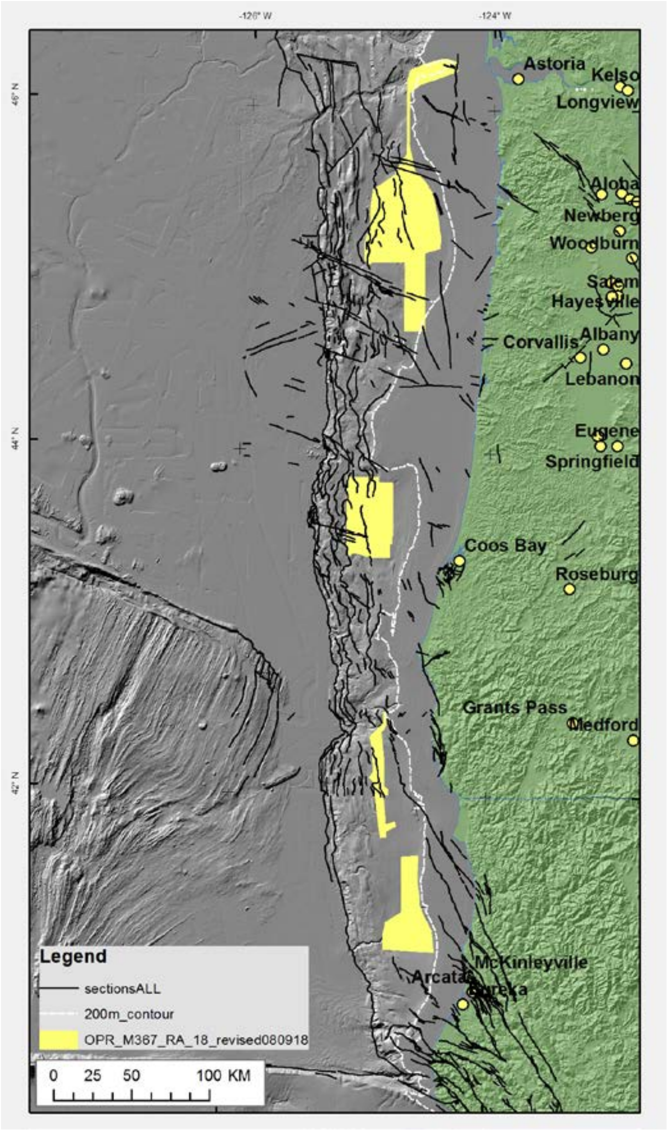
Comprehensive Bathymetry
- Existing MB compilation
- Backscatter
- Seep distribution

Sediment properties
- Quaternery sedimentation distribution map
- Quaternery basin map
- Site response & Vs map
- Hydrate/BSR map

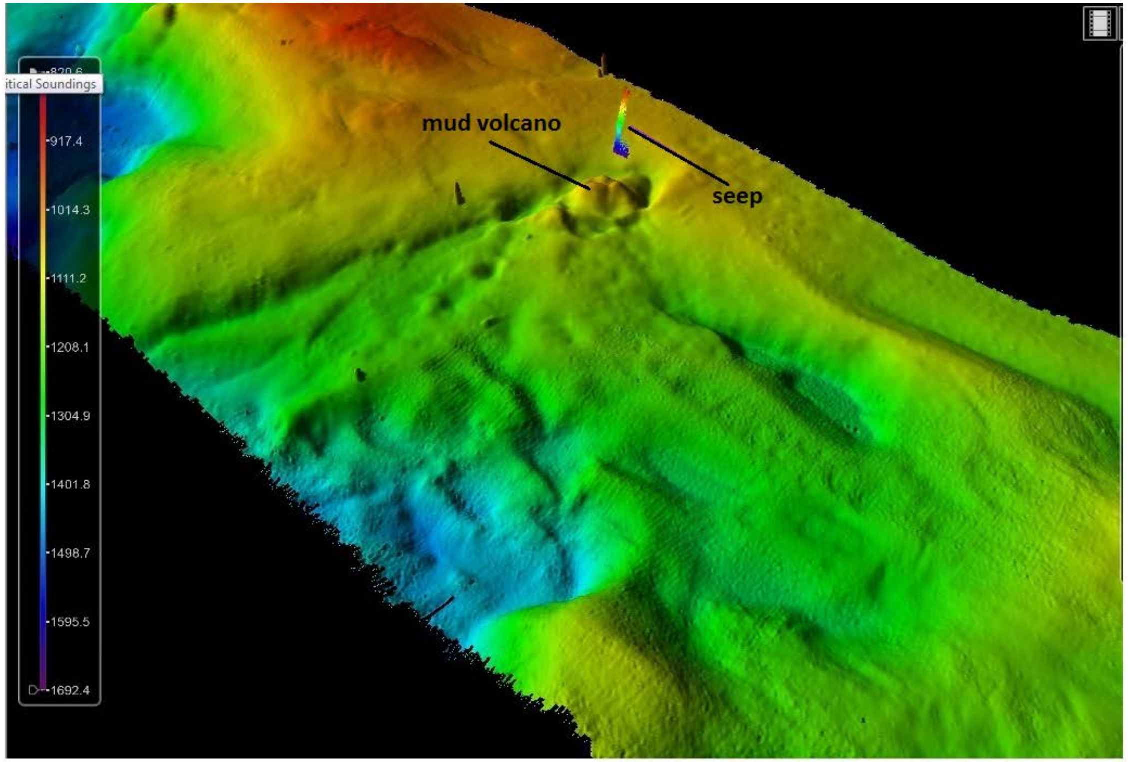
2018-2019: Comprehensive multibeam coverage of the Cascadia forearc



Pre-2018 gaps



2018 Rainier survey



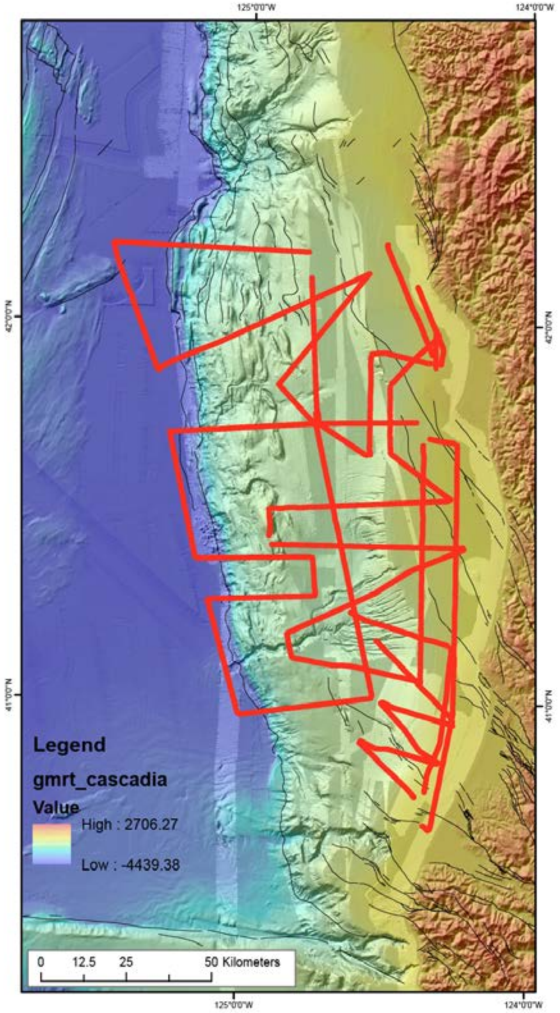
[P. Dartnell, USGS]

- 2018 survey on NOAA Ship Rainier
- More mid-water + deep work in 2019

2018-2019: High resolution, systematic MCS survey of the Cascadia forearc

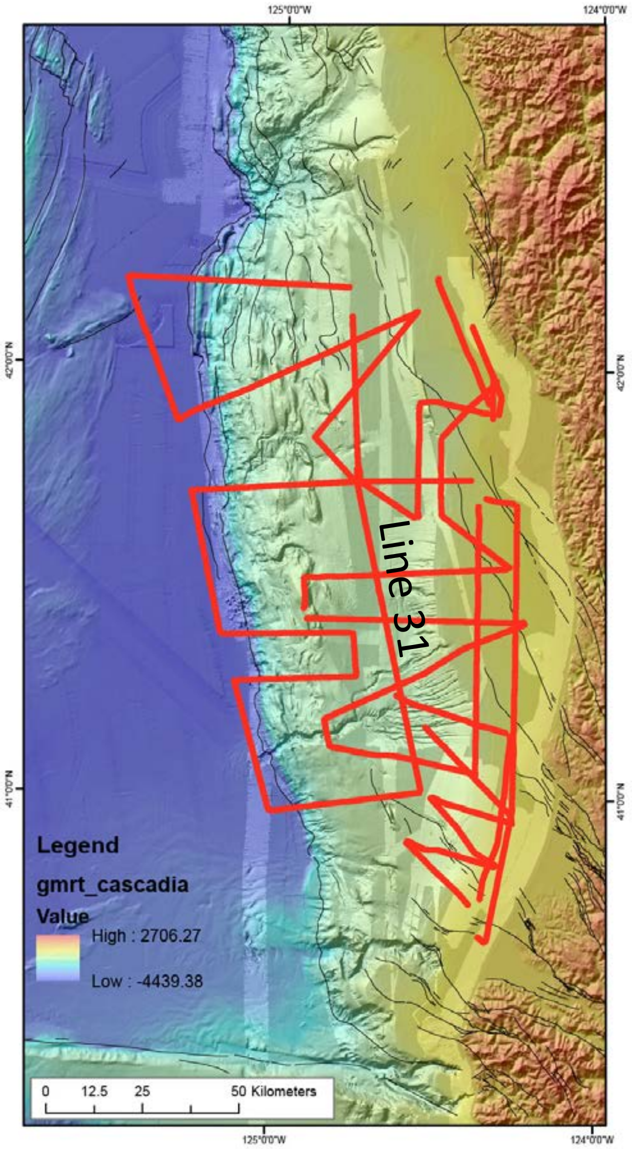
- ***Do potentially tsunamigenic upper plate structures rupture with the megathrust?***
- ***How do along strike variations in the morphology and structure of the overriding plate relate to possible segmentation of the megathrust?***
- ***How is sediment delivered and redistributed across the continental shelf and slope?***
- ***Where are the most active upper plate faults located?***

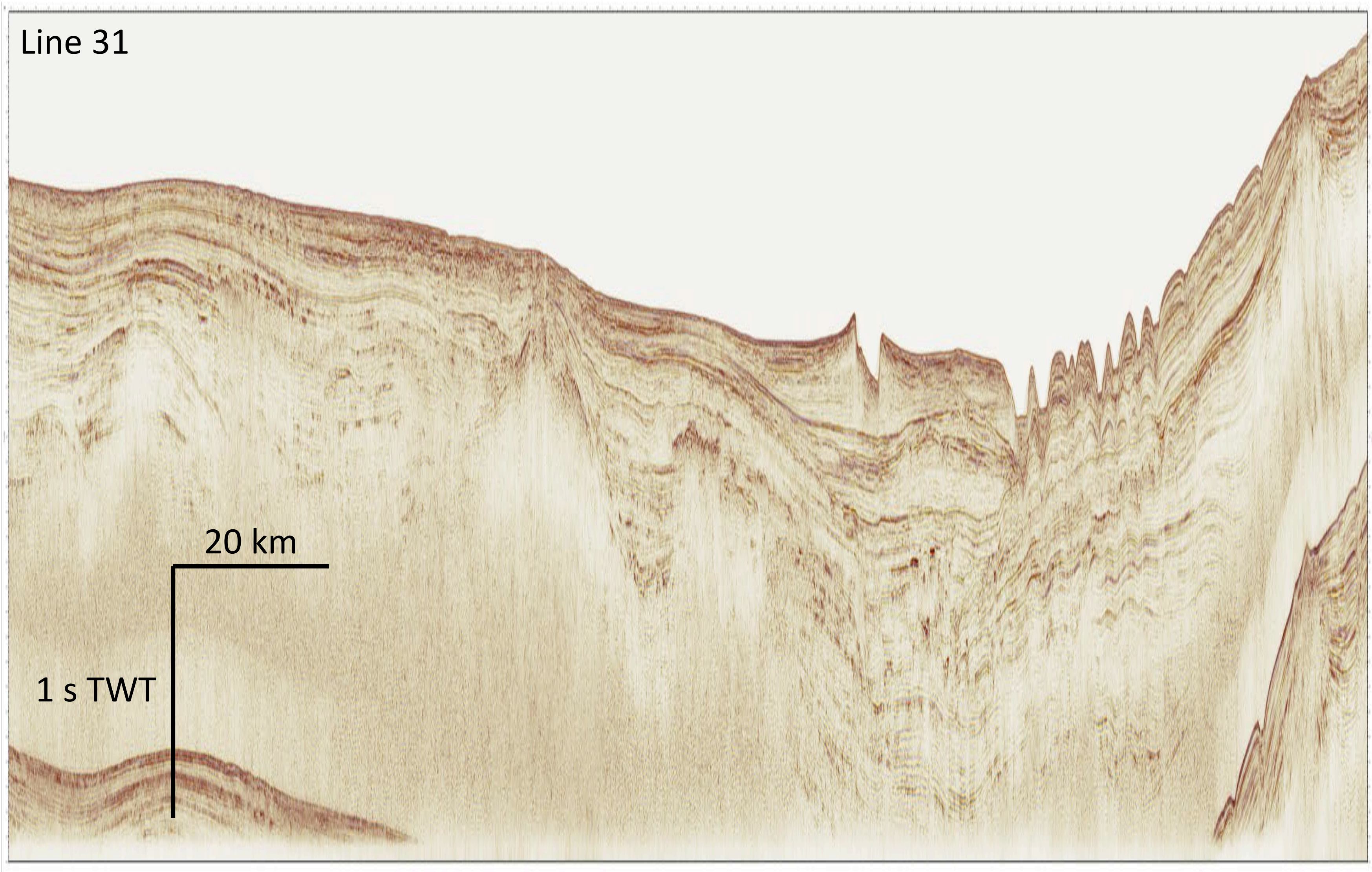
2019 survey on R/V Coral Sea



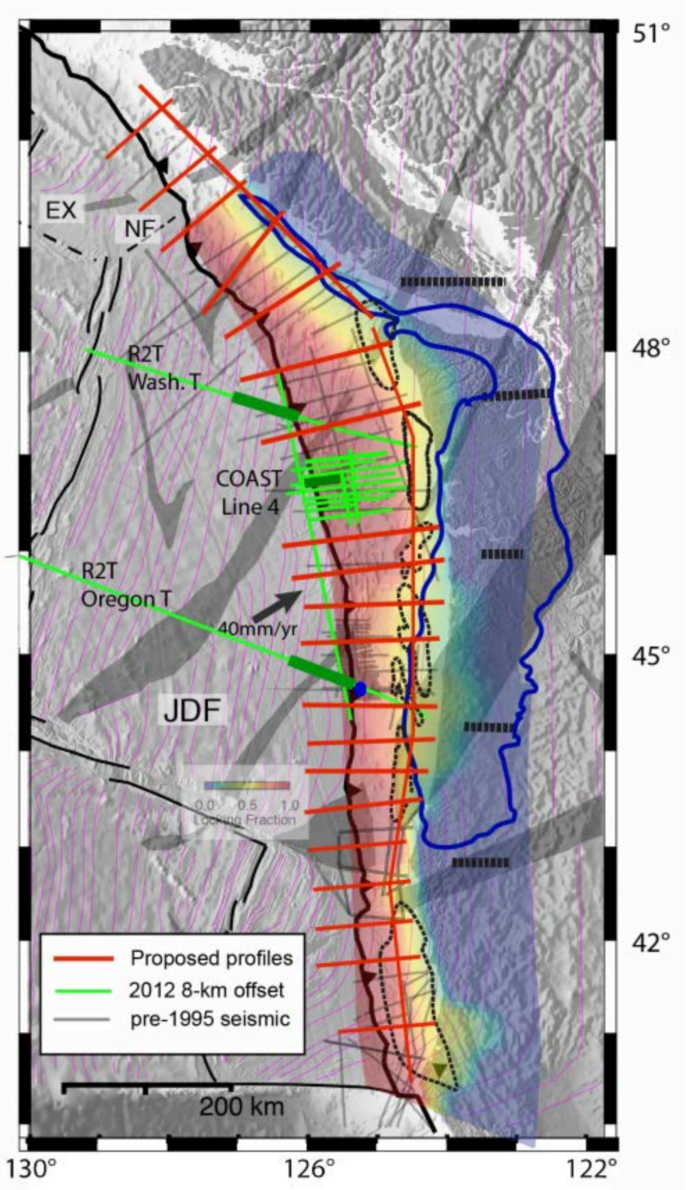
Co-op with Humbolt State University

2018-2019: High resolution, systematic MCS survey of the Cascadia forearc





2018-2020: High-resolution + large source long-streamer MCS + OBS



[Carbotte et al.]

Do potentially tsunamigenic upper plate structures rupture with the megathrust?

How do along strike variations in the morphology and structure of the overriding plate relate to possible segmentation of the megathrust?

How is sediment delivered and redistributed across the continental shelf and slope?

Where are the most active upper plate faults located?

2020: Long-streamer/large source MCS

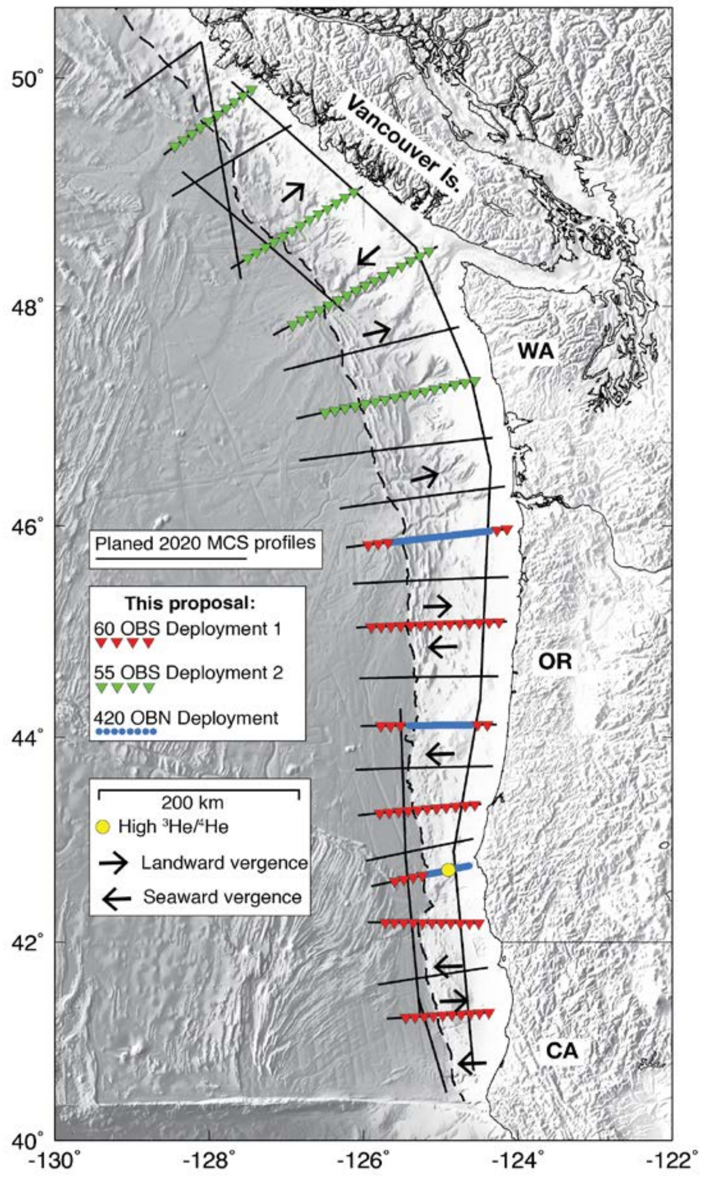
- Carbotte et al. on R/V Langseth
- 15 km streamer, 6600 cu. in array

2019: High-res MCS

- USGS led
- R/V Rachel Carson via co-op with UW
- ~400 m streamer, 6 kJ sparker

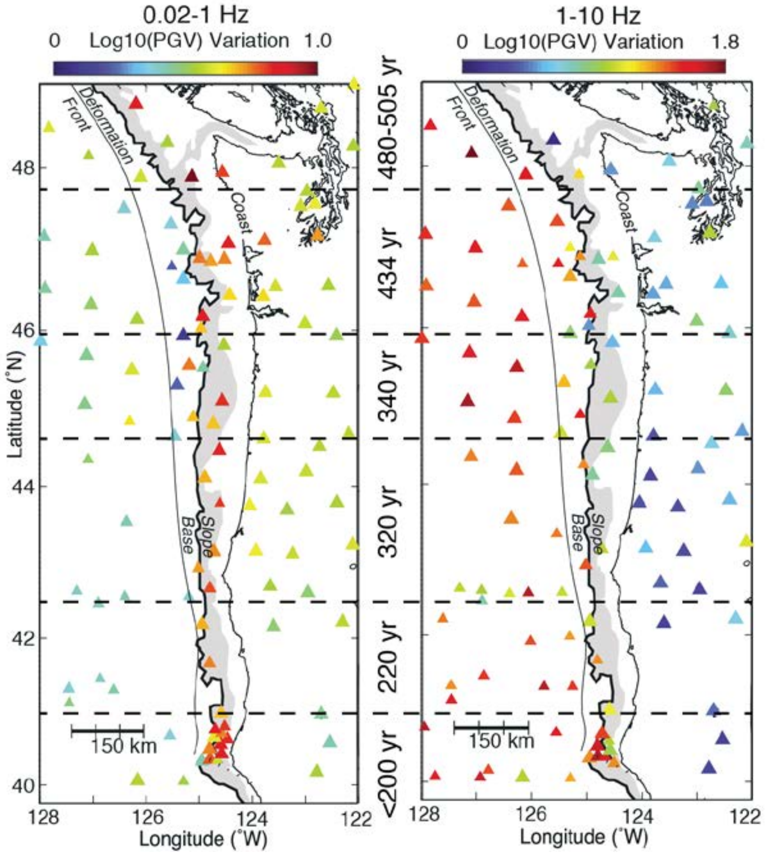
Multi-resolution*, *systematic seismic survey of the Cascadia forearc

2020: OBS recording of Langseth shots



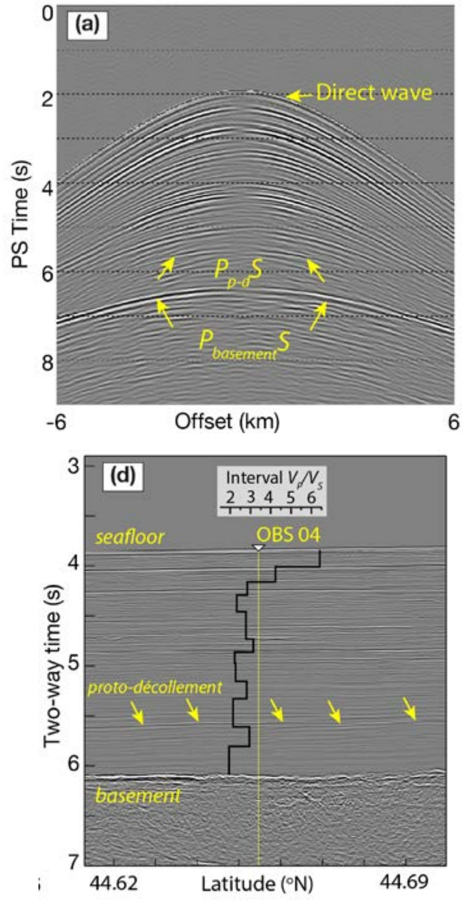
How well does the turbidite record capture earthquake recurrence?
How does the forearc respond to earthquake shaking?

Ground motion during earthquakes on widely-spaced OBS



[Gomberg, 2018]

High-resolution Vs from active-source OBS data

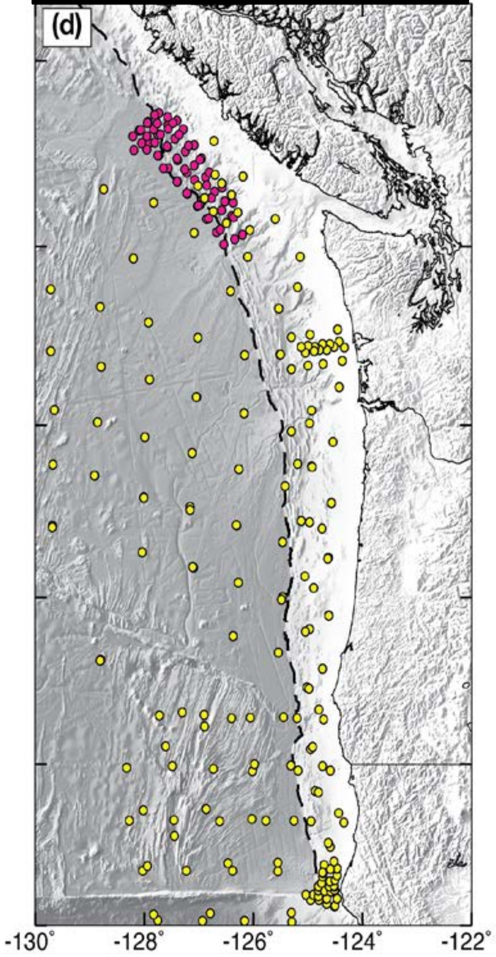


[Zhu et al.]

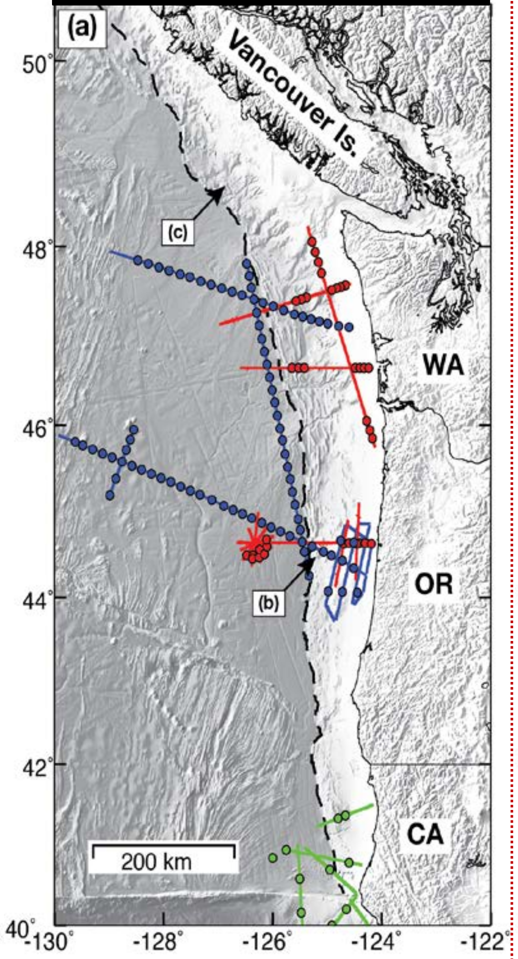
Multi-resolution*, *systematic seismic survey of the Cascadia forearc

2020 | 2020 | 2018 - 2019

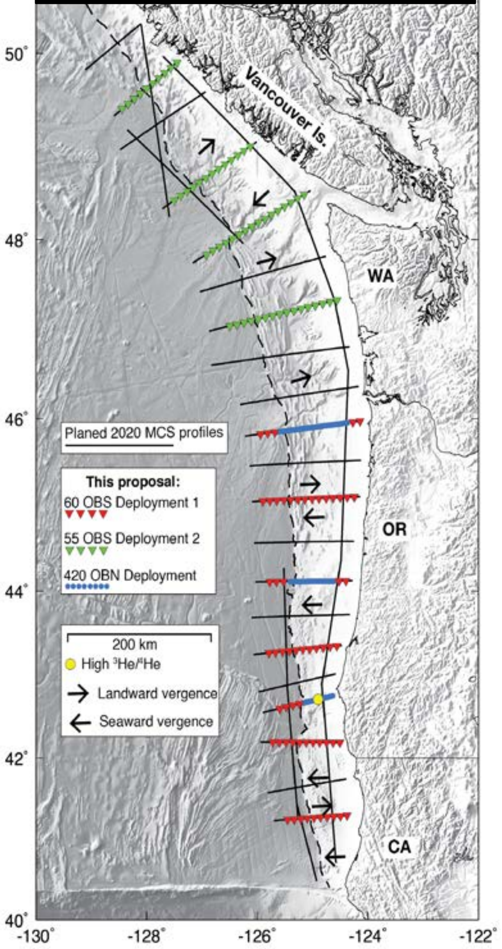
Passive OBS:
Cascadia Initiative + Sea Jade



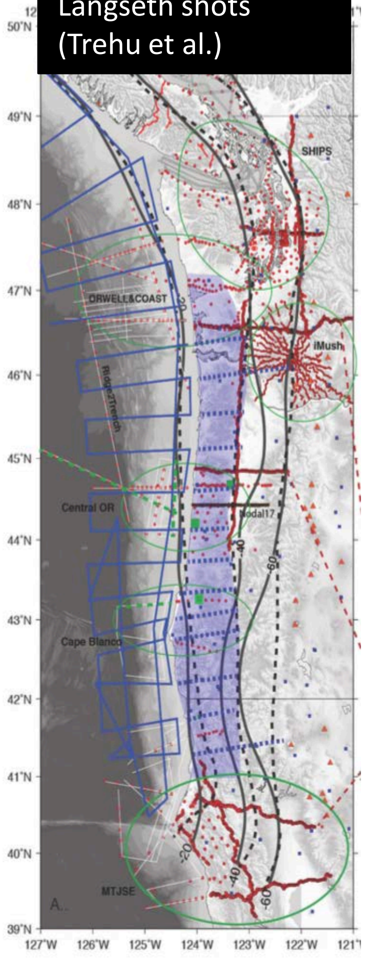
Active MCS + OBS:
Ridge-to-Trench + ORWELL



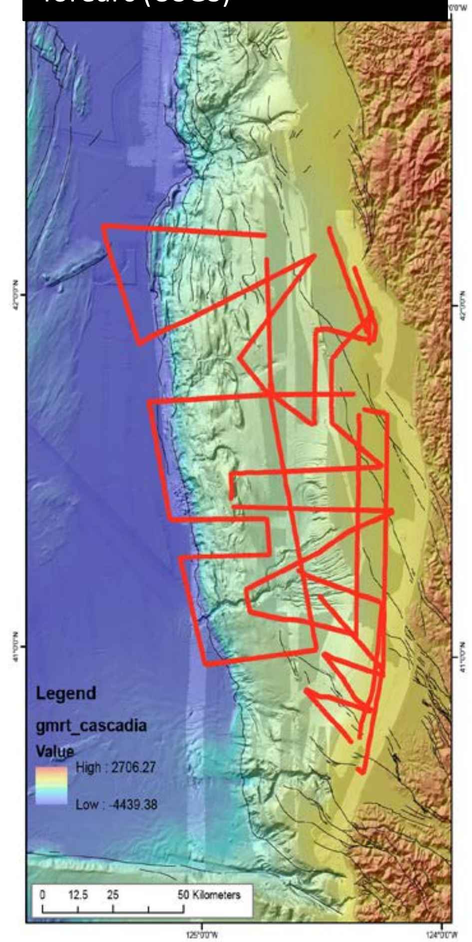
Langseth MCS (Carbotte et al.)
OBS (Canales et al. + USGS)



Land recording of Langseth shots (Trehu et al.)

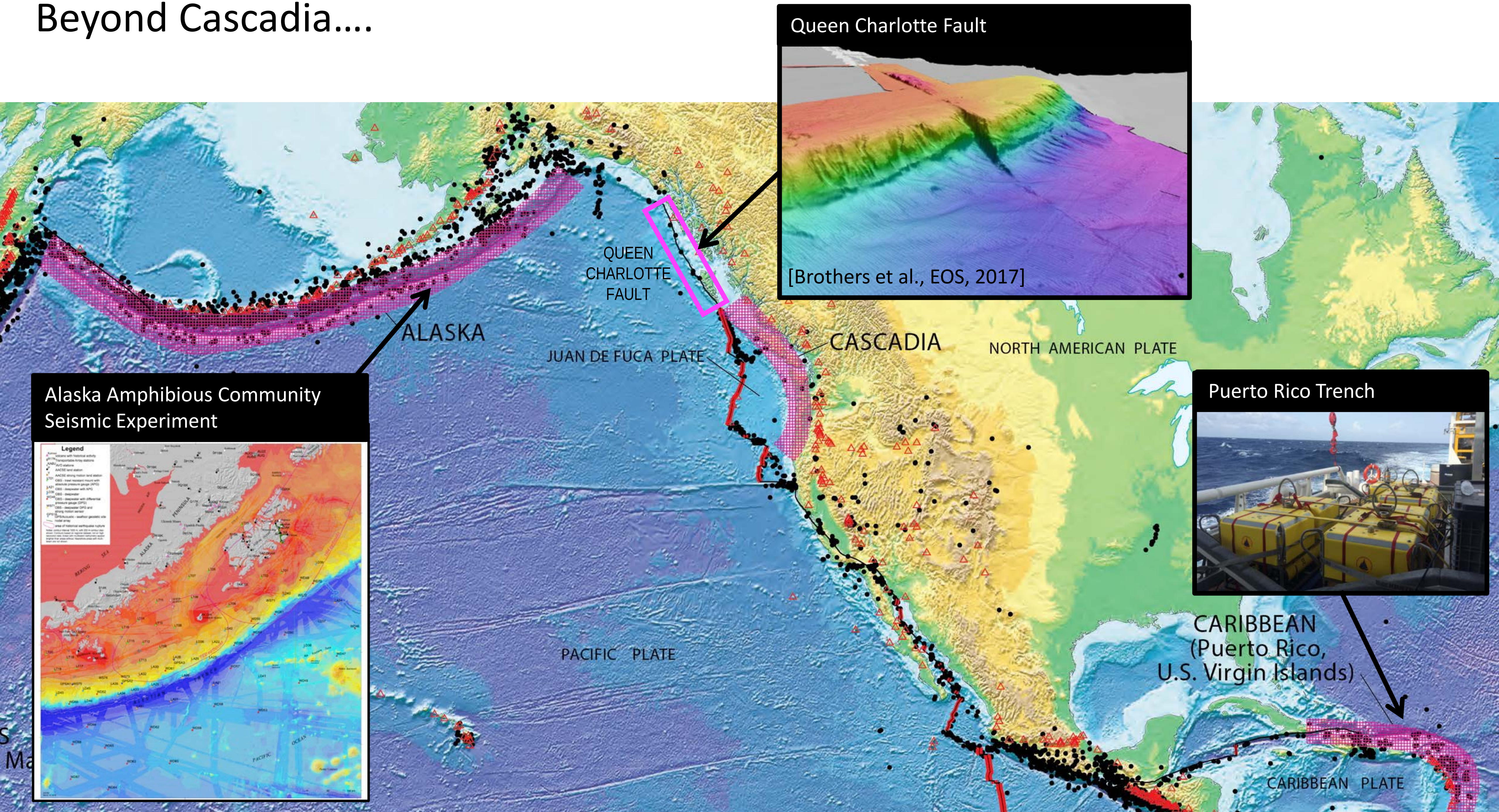


High—res MCS of entire forearc (USGS)

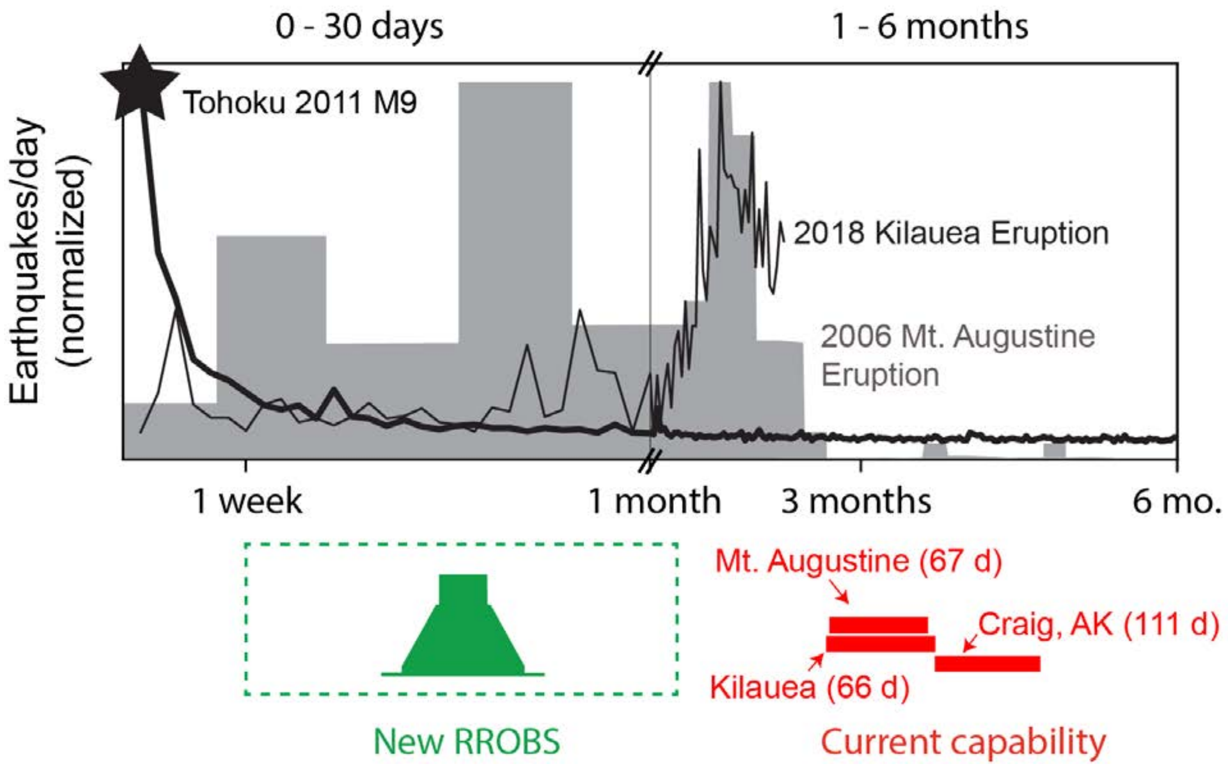


Lithosphere + deep slab → Oceanic plate + some forearc → Deep forearc + slab → Shallow + seafloor

Beyond Cascadia....



Building a rapid-response OBS capability

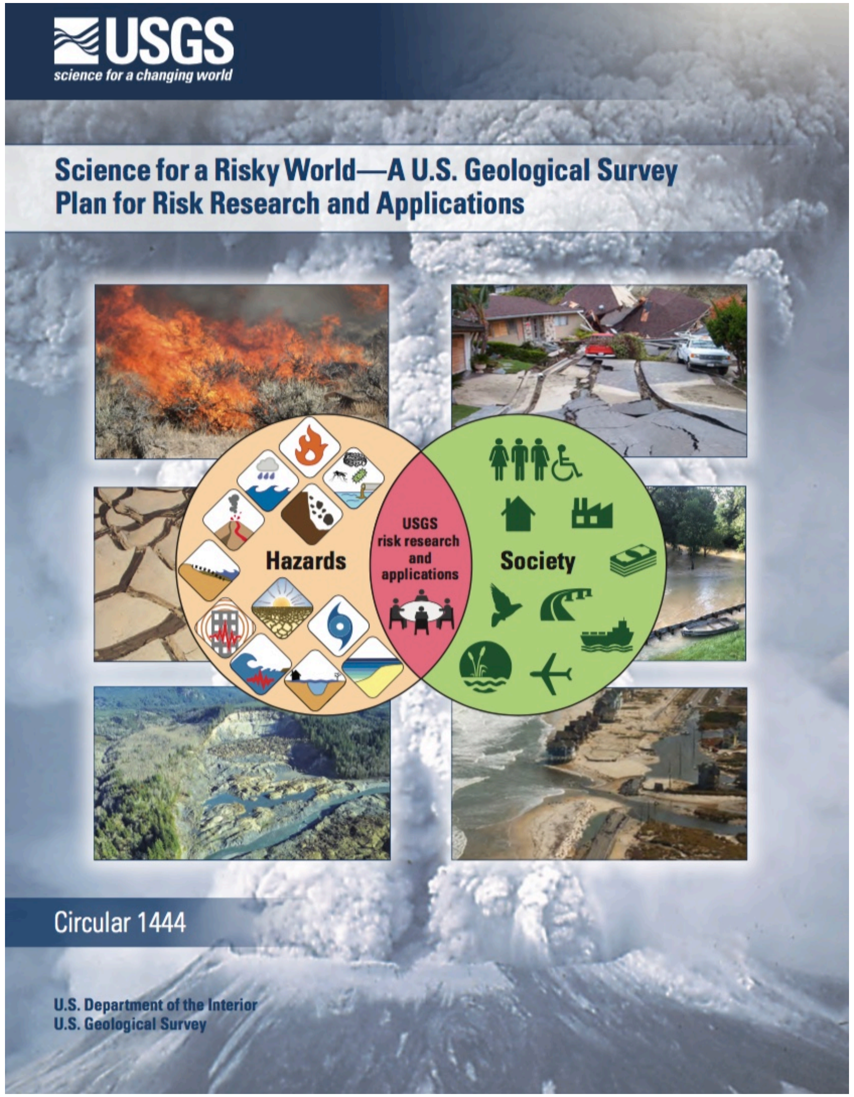


- Building a fleet of new instruments designed for rapid response experiments
- Engineering partnership with WHOI
- Instruments will be made available for academic projects of US national interest

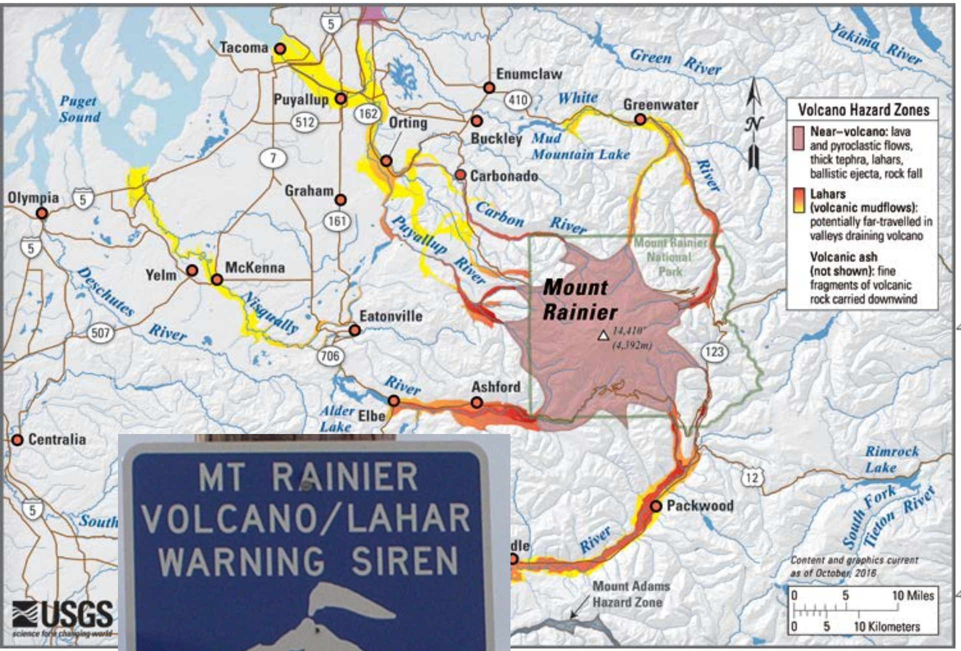
USGS's focus on hazard and risk complements *NSF's broader scientific focus*.

From science to risk … we gotta' plan.

Products	Description	Scientific Input	Application
High-resolution hazard maps	Maps of expected neighborhood-scale variations in earthquake shaking and ground-failure, tsunami inundation, landslide potential, volcanic eruptions and lahars	High-resolution topography, onshore and offshore; three dimensional (3-D) models of Earth's structure; well-characterized faults, unstable slopes, active volcanoes	Building design codes, prioritized retrofitting, urban planning, and evacuation routing
Simulations	Science-based scenarios conveying hypothetical subduction zone events	Geologic field and laboratory studies, chronologies of past subduction zone events	Improved mitigation strategies
Warning systems	Advance notice of strong earthquake shaking, volcanic eruptions, tsunamis, and landslides	Multidisciplinary monitoring systems, onshore and offshore	Rapidly implemented life- and property-saving measures
New types of forecasts	Updated projections of aftershocks, landslides and ground failures, volcanic lahars and ash clouds	Rapidly acquired satellite and surface measurements	Safer, faster, and more cost-effective response and recovery
Novel assessments of cascading subduction zone events	Likelihoods of landslide-triggered tsunamis; earthquake-induced coastal land-level changes, flooding and erosion	Computer models simulating linked processes	Rapid and effective mitigation, response and recovery

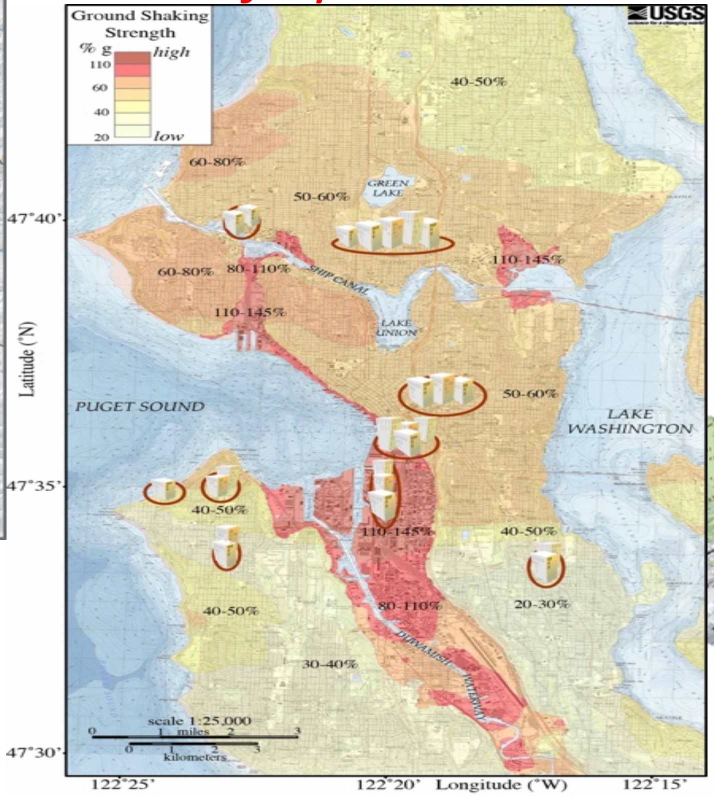


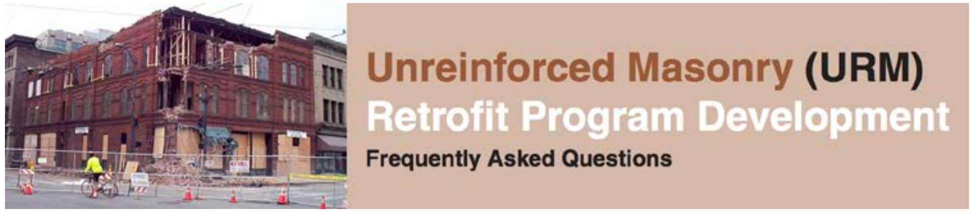
Examples of science to risk mitigation.

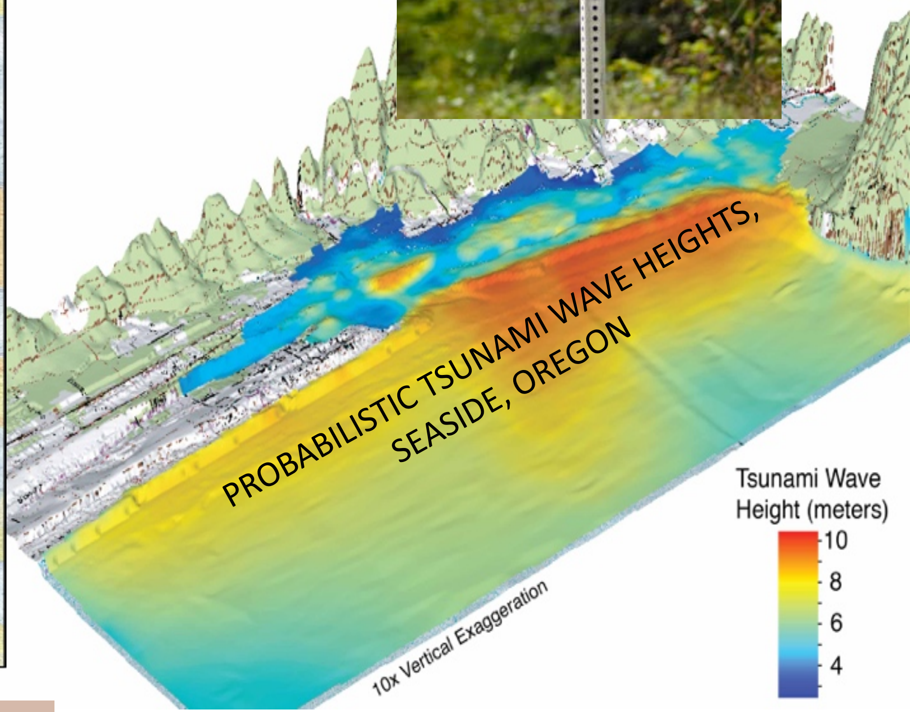


Volcano lahar science guides warning system & evacuation routing

Earthquake shaking science guides URM retrofit prioritization





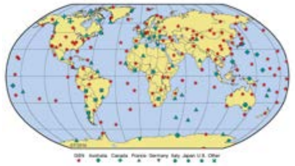


Tsunami science guides evacuation routing & coastal development

USGS's Vision is built on partnerships!

UNIVERSITIES

- *MEXICO*
- *JAPAN*
- *CANADA*
- *CHILE*
- *CARIBBEAN*
- *NEW ZEALAND*



STATE & LOCAL AGENCIES

PRIVATE COMPANIES, FOUNDATIONS