The USGS’s Vision (for subduction zone science)

Joan Gomberg, Nathan Miller

Gotta’ have a plan....
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?
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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.
**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?
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

Products

<table>
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<tr>
<th>Hazard assessment</th>
<th>Products</th>
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<tr>
<td>Megathrust &amp; upper plate rupture simulation</td>
<td>3D fault and geologic model</td>
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<tr>
<td>End-member surface deformation models</td>
<td>Tsunami M~7+ (4x2 km rupture area)</td>
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<tr>
<td>Coastal uplift/subsidence</td>
<td>Megathrust</td>
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<tr>
<td>Submarine landslide</td>
<td>Upper plate faults</td>
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<tr>
<th>Recurrence History</th>
<th>Quaternary fault and fold database</th>
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<tr>
<td>Lake paleoseismology record</td>
<td>Slip rates and slip budget</td>
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<tr>
<td>Tsunami deposit dates</td>
<td>Extend OFFD to offshore</td>
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<tr>
<td>Improved turbidite dating precision</td>
<td>Deformation &amp; structure map (orientation of structures)</td>
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<tr>
<th>Event response plan</th>
<th>Improve tsunami deposit &amp; inundation map</th>
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<tbody>
<tr>
<td>Pre-event baseline data</td>
<td>Seismic reflection atlas</td>
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<tr>
<td>Rapid response OBS for aftershocks</td>
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<tr>
<td>Post-event seafloor mapping and coring (co-seismic deformation, turbidities)</td>
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<tr>
<td>Rapid-response coastal uplift and tsunami mapping</td>
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<th>Drilling targets</th>
<th>Comprehensive Bathymetry</th>
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<tr>
<td>Alaska</td>
<td>Existing MB compilation</td>
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<tr>
<td>Cascadia</td>
<td>Backscatter</td>
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<tr>
<th>Sediment properties</th>
<th>Seep distribution</th>
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<tbody>
<tr>
<td>Quaternary sedimentation distribution map</td>
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<tr>
<td>Quaternary basin map</td>
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<tr>
<td>Site response &amp; Vs map</td>
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<tr>
<td>Hydrate/BSR map</td>
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2018-2019: Comprehensive multibeam coverage of the Cascadia forearc

- 2018 survey on NOAA Ship Rainier
- More mid-water + deep work in 2019
2018-2019: High resolution, systematic MCS survey of the Cascadia forearc

2019 survey on R/V Coral Sea

Co-op with Humbolt State University

- 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?
2018-2019: High resolution, systematic MCS survey of the Cascadia forearc
2018-2020: High-resolution + large source long-streamer MCS + OBS

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?

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

- 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

High-resolution Vs from active-source OBS data

[Gomberg, 2018]

[Zhu et al.]
Multi-resolution, systematic seismic survey of the Cascadia forearc

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.*

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<th>Products</th>
<th>Description</th>
<th>Scientific Input</th>
<th>Application</th>
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<tr>
<td>High-resolution hazard maps</td>
<td>Maps of expected neighborhood-scale variations in earthquake shaking and ground-failure, tsunami inundation, landslide potential, volcanic eruptions and lahars</td>
<td>High-resolution topography, onshore and offshore, three dimensional (3-D) models of Earth’s structure, well-characterized faults, unstable slopes, active volcanoes</td>
<td>Building design codes, prioritized retrofitting, urban planning, and evacuation routing</td>
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<tr>
<td>Simulations</td>
<td>Science-based scenarios conveying hypothetical subduction zone events</td>
<td>Geologic field and laboratory studies, chronologies of past subduction zone events</td>
<td>Improved mitigation strategies</td>
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<tr>
<td>Warning systems</td>
<td>Advance notice of strong earthquake shaking, volcanic eruptions, tsunamis, and landslides</td>
<td>Multidisciplinary monitoring systems, onshore and offshore</td>
<td>Rapidly implemented life- and property-saving measures</td>
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<td>New types of forecasts</td>
<td>Updated projections of aftershocks, landslides and ground failures, volcanic lahars and ash clouds</td>
<td>Rapidly acquired satellite and surface measurements</td>
<td>Safer, faster, and more cost-effective response and recovery</td>
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<tr>
<td>Novel assessments of cascading subduction zone events</td>
<td>Likelihoods of landslide-triggered tsunamis; earthquake-induced coastal land level changes, flooding and erosion</td>
<td>Computer models simulating linked processes</td>
<td>Rapid and effective mitigation, response and recovery</td>
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![USGS Circular 1444: Science for a Risky World — A U.S. Geological Survey Plan for Risk Research and Applications](image-url)
Examples of science to risk mitigation.

Earthquake shaking science guides URM retrofit prioritization

Volcano lahar science guides warning system & evacuation routing

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**