Breakout Session 1: What sensor types and configuration are required for a reconnaissance level understanding of long-term and interseismic subduction margin processes

Discussion Leaders:

Group 1: Marcos Morenos & Ignacio Sepulveda
Group 2: Sergio Ruiz and Laura Wallace
Group 3: Eiichiro Araki and Wenyuan Fan

Please, use this space to take notes and summarize your breakout discussion. Leaders, please be attentive to running a balanced and equitable discussion. Everyone's view is valued and everyone is encouraged to speak up or put thoughts in chat or directly in the Google Doc.

Breakout Prompt:

We have been discussing long-term and interseismic observations at subduction zones, and we are considering what to undertake to get a reconnaissance-level understanding of megathrust earthquakes and subduction margin deformation processes. *Please discuss the following and be prepared to share your thoughts at the report back. During discussions, please be mindful of respecting the other participants and the variety of native languages at this meeting. Speak slowly and clearly, raise your hand and allow others to talk before raising your hand again.*

1. What innovations in ocean technology that you have heard about today are most exciting to you for addressing these issues? What challenges and opportunities are there here?
2. What feedback do you have for the current draft of the MutihazardArray offshore instrumentation Phase 1 from the point of view of the long-term, and interseismic issues. Your feedback might be on:
    a. scientific issues,
    b. array design,
    c. logistics and operational challenges.
3. What other opportunities do you see to address the scientific questions raised on long-term, geohazard behavior as discussed in the sessions thus far in this meeting? Please think globally.

Notes:

Group 1 [Noteaker: Ignacio Sepulveda]

1) Today's innovations you have heard

-First question about Sea-track and wave gliders: It seems the main differences are propulsion technologies.

-Intrigue about: GNSS-A grid configuration from Andy's presentation. In the application of mapping trench processes.
-Demian: There was a discussion about spatial density and the advantage of having shallow processes close to the trench.

-Anne Soqcuet: There is an alternative of using bathymetry correlation to improve accuracy of positioning (and revisit mapped locations in the future). However, be careful with sediments.

- It is impressive the level of density of instruments planned by Multi-Array. Many new research opportunities will show up.

-Semi-conductor technologies exist in Japan to measure absolute pressure. Though, other technical issues also exist (and still some drift problems).

-Some discussions about DAS. It is not in the MSRI but under discussion. Some participants have processed DAS data. It is easy to process data. Some attempts have been made in Chile (GTD). There is Geoazur research to extend the type of measurements in Italy.

-Strainmeter using optic fiber using an interferometric approach (at 500 m, presented in Day 2). It provides horizontal strain. Japan has several way to measure crustal deformation. This gives redundancy.

- C-DOG. Energy-consumption is a key aspect of this technology. Virtual v/s physical positioning is another key aspect.

- A way to reduce errors is by redundancy (e.g. 2 sea-tracks)

-Some prior test projects have tried to improve the way for seafloor positioning.

-Co-location is an important part of validating new technologies in deeper regions. Make our way to try to excel existing technologies.

2) Feedback

-Smart cables must be in the discussion, along with general DAS. Clarification from Demian and Diana: In terms of budget, it is not doable to install new cables (complicated). Perhaps analyze existing ones. In the future, people would like to co-locate in the future.

-Co-location seems a strong point, so MSRI can support future technologies.

- It would be good to identify hazards in Chile that can optimize the design of the multi-array.

- Further work on a realistic Phase 1 array. Local features of Chile need to be included. Include the actual existing information in Chile (state-of-the-art).

- Acoustic stations from shore to near-trench that can work as a baseline (several ones).

-Logistics and operational questions: No discussion about ship time (technicalities). There are some chats about authorizations to do campaigns. Typically allowed in deeper regions. Conversations with other agencies exist to define the budget model.

- OBS: second objective would be to use the data to see changes in velocity structures before and after an earthquake.

- Suggestion: more emphasis on hazards rather than research. Diana: More focus on research and the goals of SZ4D. Monitoring is valuable but it is not the main point.

-It would be good to see beyond the trench. This is important to see the whole picture.

-One suggested strategy is to gain more measurements in low-density areas.

3) Other opportunities

Clarification from scribe: Above we have commented on new opportunities. For example DAS and smart cables.

Opportunity to co-locate APG with GNSS-A (already implemented).

It would be good to increase density in some areas to do some new tests.

Group 2 [Noteaker: Laura Wallace]

Main tools people are excited about to address the questions raised today, and to implement reconnaissance-level investigation for stage 1:
GNSS-A
OBS
Oceanographic instruments to improve fidelity of seafloor geodetic observations—and/or complementary measurements to reduce noise. Chilean oceanographers could get involved (e.g., Marcos Moreno's current experiment)

Thoughts on design
What spacing do we really need for resolving along-strike variations at a reconnaissance level? Modeling work needs to be done to get the base level along-strike variations in coupling.

We should make sure the array can identify shallow tremor

GNSS-A is very important for the reconnaissance level data acquisition for the long-term and interseismic processes.

OBS are needed to understand the margin structure and basic properties (mostly imaging). Should we also be thinking about temporal changes in seismic velocities and getting long-time series–could use backbone sites as a starting point for this.

Much discussion on whether we need offshore OBS for reconnaissance level stage 1 deployment. Do we really need such a large network of backbone OBS deployed for so long? Onshore seismology can still give the gross picture with respect to seismicity, maybe we don't need OBS for the recon stage 1 (except for structure and properties). OBS close to the trench are a major priority, for seismological phenomena not observable onshore (like shallow tremor). We should also consider whether we need variable spacing of OBS, rather than just a uniform grid.

One approach to take could be a minimalist phase 1 approach of just doing the basic GNSS-A needed to identify the primary coupling transitions in the larger footprint, with a basic perhaps migrating OBS deployment (20 instruments?) to get context in terms of structure and properties of the margin and some additional information on potential areas of tremor, etc.
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Should we be able to adjust the reconnaissance-level plan on the fly based on new observations through the recon phase? What if large earthquakes happen, should we move the array to that area (or to adjacent areas)?

What opportunities do you see to address the scientific questions raised on long-term geohazard behavior?
SZ4D should produce a nice comparative analysis between systems–this already exists to a degree in previous documents. We should revisit these to decide on specific areas of each margin (esp. For Chile, Alaska, Cascadia) that can uniquely answer major questions about subduction earthquakes, and perhaps focus on those corridors.

Some additional issues discussed:
Candidate for tsunami eq in chile in 1849—we should make sure to span an area of tsunami eq. (near 30 South)?

The contrast in plate boundary properties north and south of the Juan Fernandez Ridge. Address ridge/seamount subduction, and also a large change in incoming sediment sequences—could be a plate boundary transition.

What is the role of ridges in controllling earthquake segmentation in Chile? Should we target these (e.g., Copiapo, Juan Fernandez)?

Group 3 [Noteaker: Wenyuan Fan]

- Question 1
    - MERMAID:
        - Andy: what do OBS folks think about the MERMAIDs?
        - James: evaluating data would be a critical step before using it more broadly.
        - Ito-san: what's Mc or detection threshold?
        - Emerging technology, too experimental for MSRI?
        - Distribution of seismicity proxy of megathrust deformation? Considering transient aseismic, would it be useful for seismicity?
    - Araki-san: Do we need stable long term observations to understand the tectonic scale processes?
        - Andy: 2-3 years can yield insights regarding fully locked or creeping for GNSS-A
        - How to better use existing info as prior
        - Maybe no need to divide into two phases
        - Shawn: what's the state-of-art understanding of the offshore structures, seismicity catalog, tectonics?

        - Andy: new slab model, new locking map, and new catalogs, all from onshore stations
        - Andreas: compiling existing knowledge to design experiments
        - Ongoing offshore geodetic experiments, APGs + oceanography anknors, observing new oceanographical instruments
    - Araki-san: are APGs the promising direction for seafloor geodesy?
        - JIm: APGs appear to be promising, isobath correction is promising, APG can be a powerful tool. How to integrate seismic and pressure measurements. New three-feet OBS, why are the horizontal instruments not better? Promising new directions.
        - Matt Wei: how to better improve temporal resolution of GNSS-A? ASV technique is promising.
        - Andy: 2-way travel time in the water is critical.
        - Borehole observatory is very impressive. Why not more?
            - Incredibly expensive + only one RV.
        - Noel: borehole can deal with a broad range of temporal scales. Sea level and climate change impacts on APGs. Ocean models are reanalysis (?) models, and there is a lag.
        - Shawn: using OBS tilt to constrain the ocean currents. Noise can be further explored to collaborate with physical oceanographers.
        - Araki-san: sea-floor temperature change is a good observable for currents.
- Question 2:
    - William: we need it to be transformative, the multihazard array that can observe subduction zone systems over an extended period. How can we make it (the array design) relevant? Pinning down the stations and dont move them to resolve the temporal changes, such as ambient noise interferometry.
    - Araki-san: very long range DAS, 1000 km cable. Have a cable from the coast to the trench.
    - William: seismometers provide unique info about earthquakes.
    - Andy: appreciating cables. What are the concerns? Clock drift.
    - James: atomic clock. Checking it regularly. Ongoing research. Data needs to be transferred back timely, not for 5 years of waiting period.
    - Engaging the community with real time data is invaluable.
    - S-net is derived, but the cost would be over $300M, $40k per mile just for cables
    - Maybe try to include commercial cables. A focused design of the cable route.
    - William: It's not a given that MSRI will be funded. The science needs to be transformational
    - Phase 1 is too coarse ?, S-net 30 km vs 80 km. Good to get a tectonic scale, not enough for earthquake locations.
    - Andy: can we scale down the spatial footprint?

    - William: More focused questions.
    - Araki-san: nearby multi-instrument, dense array. DONET analogy. Less than 15 km. Coherent signals across multiple instruments.
    - Timely, frequent observations would make the most impact. Cost/return analysis. Time series is critical. Be reactive to events.
- Question 3:
    - Ito-san: sea surface changes. Glacial rebound can cause long term deformation.
    - Noel: what about ocean-ocean subduction zone? Expanding the ocean-continent subduction zone.
    - Matt: Oceanic transform faults. GNSS-A will be useful for studying OTF earthquake cycles.
    - Ito-san: bottom acoustic ranging techniques.
    - Araki-san: cable to measure deformation at triple-junction.
    - Andy: calibrated pressure sensors. Check APGs across the trench.
    - Araki-san: DONET pressure gauges cross the trench.
    - Andy: GNSS-A in Alaska cross trench. Only horizontal motion. Needs for vertical motion.
    - Shawn: what controls the limit of the water depth for GNSS-A. Andy: housing and transponder.