Executive Summary of Conference Series: International Workshops on the Future of Geodetic-geophysical Observational Networks in Antarctica

Conference Proposal OPP-2235061 (total budget: $32,557)

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Key US Participants: Terry Wilson (2022,2024); Samantha Hansen (2022, 2024); Douglas Wiens (2022, 2024); Paul Winberry (2022, 2024); Andrew Loyd (2022, 2024); Duncan Young (2022,2024); Marianne Karplus (2022,2024); Zhongwen Zhan (2022); Eileen Martin (2022); John Goodge (2024); Wenbo Wu (2024); Wenyuan Fan (2024).

Key International Participants: Anya Reading (2022, 2024); Fausto Ferraccioli (2022, 2024); Matt King (2022); Mirko Scheinert (2022);

1. Introduction for the 2022-2024 Polar Geophysics Conferences Report

This Executive Summary is the summary of the key scientific and strategic discussions from the 2022 Fort Collins Workshop and the 2024 Washington, DC Workshop. It serves as guidance for structuring the conference report, emphasizing the solid Earth community's priorities and a unified path forward. In addition to scientific topics, the 2024 workshop gathered critical insights on fieldwork, inter-agency cooperation, and large-scale science strategies (e.g., SZ4D, RAID).

Exhibit 1: Key facts about the two polar geophysical workshops supported by this award.

Workshop on the Future Geodetic-Geophysical Observational Networks in Antarctica, Fort Collins, USA, Sep 29-Oct 1, 2022

Highlights of the 2022 Fort Collins workshop:

2-day workshop	21 Full-time oral presentations
6 Science Sessions	16 Lightning talks
2 Breakup Sessions	21 Poster Presentations

- >60 in-person and > 20 zoom-in participants
- 25 international participants;
- > 20 Early Career Participants

INSTANT II Follow-on Workshop on the Future of Geodetic-Geophysical Observational Networks in Antarctica, Washington DC, USA, September 28, 2024

Highlights of the 2024 Washington, DC workshop:

1-day workshop	12 oral presentations
4 Science Sessions	In-depth conversations with the agency

- >40 in-person and > 10 zoom-in participants
- 4 international participants;
- Specially engaged with polar geology and glaciology communities

2. The Scientific Imperative: Solid Earth as a Global Change Feedback

The stability of the Antarctic Ice Sheet (AIS) is a dominant factor in global sea-level rise, but projections are plagued by high uncertainty due to a lack of accurate knowledge of the sub-ice solid Earth regarding Glacial Isostatic Adjustment (GIA).

- **GIA Uncertainty:** GIA model uncertainty accounts for approximately one-third of the total uncertainty in AIS mass change estimates.
- **Rheological Control:** The solid Earth is an active component of the climate system. The underlying mantle rheology and lithospheric structure fundamentally control the rate of GIA (bedrock rebound).
- **Sub-ice Contact:** The physical and geological properties of the sub-ice contact also directly influence ice-sheet dynamics, while the direct information is sparse and inaccurate.

3. Current Status and Critical Observational Gaps

Since 2000, over 400 GNSS and seismic stations have been deployed across Antarctica, yet coverage remains critically uneven, compromising model resolution.

- Seismology's Role: Passive seismic tools (broadband, nodes, DAS) are critical for estimating 3-D mantle viscosity, geothermal heat flux, and understanding ice- and sub-ice structures.
- GNSS Contributions: Global Navigation Satellite Systems (GNSS) confirmed that solid-Earth processes are relevant at climate timescales. GNSS networks are critical to constrain current GIA and predict future sea-level rise.
- The Coverage Problem: Substantial observational gaps remain in regions with high scientific significance, including the Wilkes Basin (near Northern Victoria Land) and the southern Transantarctic Mountains, severely limiting the ability to robustly separate ice-load history from intrinsic Earth structure.

4. Workshop Consensus and Future Guidance: Strategy and Action

The consensus of the Fort Collins and Washington, DC workshops is that achieving integrated Earth System Science goals requires **strategic coordination, logistical innovation, and sustained national commitment**.

A. Core Scientific Priorities

1. Constraint on Mantle Rheology: Rigorously test and model realistic mantle rheology (including lateral inhomogeneities and transient relaxation) against a unified, multi-sensor geophysical dataset.

2. Reduction of Boundary Uncertainties: Focus on the reduction of uncertainties in key boundary conditions, such as geothermal heat flux and sub-ice geological properties.
3. Integrated Modeling Imperative: Develop coupled ice-sheet / gravity-rotation-deformation models that fully integrate the complex interactions between the solid Earth, ice sheets, and oceans for predictive sea-level projections.
4. Joint Deployments: Expand the use of joint deployments (Seismology, Magnetotellurics, GNSS) to provide robust, tightly coupled constraints on Earth properties.

B. Strategic and Logistical Enablers

1. Long-Term Strategy and IPY Readiness: The community must establish a multi-decadal long-term strategy with multiple 5-year priorities. Priority is given to preparing for the International Polar Year (IPY 2032-2033) by leveraging models like EarthScope to construct an inclusive but also tightly-knit, interdisciplinary "focus" community.
2. Logistical Innovation & Collaboration: Emphasis must be placed on securing robust field logistic support and executing complex deep field camps. The community must be nimble, exploiting supplemental resources via NGO collaborations (e.g., Arctic Trucks, ALE) and exploring structures for international proposals and resource pooling (e.g., ITGC, bilateral arrangements). PIs are encouraged to consider new methodologies and smaller fieldwork footprints.
3. Resource Identification and Commitment: Key resources identified include:
    a. Instrumentation Development: Dedicated support for developing next-generation polar geophysical instruments and encouraging continued efforts on Common Sensor Platforms (EarthScope, vendors).
    b. Workforce Development: Crucially, resources that support students' participation in fieldwork must be protected and enhanced, especially given fieldwork challenges (USAP Lull). The potential drawbacks of facility-led installation models, which risk compromising science and negatively impacting mentoring, must be actively discussed and mitigated.
    c. Long-Term Testing Sites: Support for long-term testing sites and arrays in key geological regions (e.g., Mt. Erebus) for instrument testing and continuous monitoring.
    d. NSF Call to Action: The community calls for a long-term commitment from the NSF in developing these instruments and sustaining general polar geophysics field explorations, encouraging alignment of long-term stations with specific science goals.

5. Conclusion and Priority Action: Roadmap Ahead

To achieve climate-relevant certainty in Antarctic mass loss predictions, sustained and strategically placed geophysical observations are essential. The solid-Earth community must

prioritize: closing observational gaps; advancing collaborative, long-term strategy planning; and securing national commitment for instrumentation, field exploration, and student training. The community has established the following immediate actions for implementing the strategic vision:

- **Community Planning:**
    - Very shortly, write a proposal for several major community workshops to discuss short-term actions, mid- and longer-term science goals, and technical roadmaps.
    - Explore pathways to keep the community connected (e.g., RCNs) and set up continuous communications channels (e.g., SLAC, Mattermost).
    - Write a proposal for more early-career workshops (e.g., next Cryoseismology school) to offset reduced field mentoring opportunities.
    - New community consensus processes are needed to advocate effectively for National Geophysical Facility (NGF) engagement with NSF-OPP, in light of EarthScope's evolving contractual model. Guidance is needed from OPP on how to build this consensus process.
- **Collaboration and Partnership:**
    - Engaging broader communities (e.g., Ice Cube, RAID, WAIS, IDP) must continue, with a focus on growing collaborations, prioritization, and operational structures.
    - General earth science projects such as RAID/geospace stations that require traverse/deepfield support should be expanded to better integrate geophysical observations with geological constraints.
    - The community should continue engaging international and interagency colleagues to explore greater international collaboration.
- **Technological Advancement:**
    - Encourage continued Polar Technology Conference attendance to connect PIs with new technologies and partners.
    - Closely work with community instrumentation centers (e.g., Earthscope) to assess, maintain, and improve the polar geophysical instrumentation pool.

6. Final Product/Publications

A review documentation, titled "*Probing the Solid Earth Beneath Antarctica and its Interactions with the Ice, Ocean, and Atmosphere,*" was drafted to summarize the scientific merit and needs are being prepared and is being submitted to the journal Solid Earth. The final draft is attached to this report.