Breakout Session III

Evolving landscapes and global environmental change

1. Hydrology and critical zone imaging
2. Glaciology: Instrumenting glaciers and ice sheets
3. Polar networks and glacial isostatic adjustment
4. Tectonic geomorphology and 4D topographic imaging
5. Strengthening broad understanding of Earth and Earth science: K-12 education, informal education, and public outreach

1. Hydrology and critical zone imaging

A. Key questions

Connect water at all scales, pore to catchment to watershed to continent

- How can we best observe all components of total water storage?
- What is the flux of terrestrial water into the coastal environment?
- How does water interact with volcanoes?
- What defines and controls the base of the critical zone?
- How does porosity, permeability and transmissivity vary?
- How can geodetic and geophysical observations be used to assess structural damage induced by groundwater extraction?

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B. Foundational Capabilities

- Continue GPS networks for building long time series.
- Incorporate geodetic data in state, commercial, surveying networks into geodetic archives AND processing flows.
- Maintain current seismic instrument pool.
- Maintain human resources needed to operate networks/pools.
- Maintain archive for GPS, InSAR, seismic and additional data.
- Continue to provide access to instruments capable of acquiring high-resolution topographic data.

(yellow = cross-cutting theme)

1. Hydrology and critical zone imaging

C. Frontier Capabilities

- Adopt technologies beyond seismic/geodetic for observing water
- Conduct 4D imaging of the critical zone (observables and modeling)
- Acquire data from polarimetric InSAR missions (e.g. NISAR) and combine with SMAP soil moisture.
- Create a national pool of diverse, portable, campaign-deployable near-surface geophysical instrumentation beyond current seismic/GNSS
- Provide dedicated instrumentation for long-term, in-situ geophysical monitoring of critical zone processes.
- Deploy large arrays for critical zone science.

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D. Broader Impacts

- Assessment of current and future subsidence hazards
- Extend campaign geophysics pool to educational arena
- Coordination with NEON, USGS and other agencies/programs
- Teach hydrological techniques to community via short courses, etc.
- Expansion of techniques to global scope, especially data poor regions
- Crowdsource hazards data to augment geophysical observations.

(yellow = cross-cutting theme)

2. Glaciology: Instrumenting glaciers and ice sheets

Motivating Topics Glaciers and Ice Sheets
MT1. Improved prediction of future ice change and sea level through improved mechanical models of glacier physics across all time and length scales.
MT1.1 Understanding ice-ocean Interaction and the retreat of ice shelves Essential Facility Requirements: All Foundation Facilities Desired Facility Requirements: Frontier Facilities 1-16 MT1.2 The response of grounded ice depends to the changes discussed in MT1.1 depends on subglacial and englacial processes associated with fast moving regions. Essential Facility Requirements: All Foundation Facilities Desired Facility Requirements: Frontier Facilities 1-15 MT1.3 Extract fundamental physics of glacial systems by studying external drivers of flow variability such as tidally induced changes in buttressing and supraglacial lake discharge. Essential Facility Requirements: All Foundation Facilities Desired Facility Requirements: Frontier Facilities 1-15 MT1.4 Continued observations of flow speed that constrain the of role inter-annual behavior in the long-term change in glaciated regions Essential Facility Requirements: All Foundation Facilities Desired Facility Requirements: Frontier Facilities 1-7,13,14,16
MT2. What is the relative contribution of surface mass balance to long-term glacier and ice sheet change.
Essential Facility Requirements: All Foundation Facilities Desired Facility Requirements: Frontier Facilities 2-7,13,14,16
MT3. Ice-Volcano Interaction
Essential Facility Requirements: All Foundation Facilities Desired Facility Requirements: Frontier Facilities 2-14,16

2. Glaciology: Instrumenting glaciers and ice sheets

Foundation Facilities for Glaciers and Ice Sheets
★ 1) Continued O&M of high quality instruments for temporary deployments
★ 2) Responsive and agile field support (including power systems and deployment strategies)
★ 3) Hiring and retention of quality personnel

(★ = cross-cutting theme)

2. Glaciology: Instrumenting glaciers and ice sheets

	Frontier Facilities for Glaciers and Ice Sheets
★	1) Community driven experiments that expand permanent coverage in dynamic regions (glacier fronts, subglacial lakes, etc.....) that are in part supported by the facility(s) 1.1 Coupled with physical oceanography
★	2) Lighter cheaper polar GPS receiver
★	3) Obtain data and produce remote sensing products that provide spatially extensions observations of glacier and ice sheet change including velocity and topography
★	4) Processing (real-time?) of GPS time-series relevant to glacial processes
★	5) Training (both installation and processing)
★	6) Improved telemetry
★	7) Improved power systems
	8) Fiber optic seismology
	9) High Rate Seismometer
	10) Near situ TLS and Ground Based InSAR
	11) Ice penetrating radar for ice thickness and bed topography
	12) Phase sensitive radar for basal melting and internal deformation.
★	13) Low cost units (seismic and geodetic)
	14) Large N (both seismic and GPS)
★	15) Autonomous capability including drones and AUV for measuring sub ice shelf melting
★	16) Low weight long term (~2-3 years) telemetered autonomous station

(★ = cross-cutting theme)

3. Polar networks and glacial isostatic adjustment

A. Key questions

- ice sheet mass balance and projections
- ice sheet/shelf/sea level history since the LGM
- relative contribution to sea level change
- 3D mantle structure and response to ice mass changes
- geothermal heat flux beneath the ice sheets
- surface/englacial/subglacial processes

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B. Foundational Capabilities

- LONG TERM, CONTINUOUS seismic & geodetic networks at flexural scale lengths (100s of km)
- Integrate polar regional networks into global networks (including InSAR)
- Responsive/adaptive and specialized polar engineering
- Planning/funding modes to replace/upgrade instrumentation prior to failure

(yellow = cross-cutting theme)

3. Polar networks and glacial isostatic adjustment

C. Frontier Capabilities

- Polar-capable OBS, etc
- Denser arrays of GPS and seismic sensors on the scale of major geological and ice flow features (50-100 km), and 10s of km for targeted regions
- High data rate real-time capabilities for all instruments
- Portable, long-term, low-power continued development

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D. Broader Impacts

- Workforce development
- Strong access/collaborative/technical ties to communities, agencies, etc.
- Polar developments for extreme power and environmental factors

4. Tectonic geomorphology and 4D topographic imaging

A. Key questions

1. What is the long-term [geomorphic, geologic] record of surface uplift and subsidence?
   - How do we invert topography for tectonic history?
   - What does topography tell us about lithospheric structure and mantle buoyancy?
   - How do surface processes influence lithospheric tectonics and mantle convection?

2. How can changes to earth's surface constrain geophysical processes and resultant hazards?
   - By what mechanisms does permanent deformation accrue over the EQ cycle?
   - How do we quantify earthquake cycle and volcano deformation at high resolution?
   - How are short-term processes (e.g., earthquake deformation, landscape evolution) linked with the longer-term (geology)?

3. How can geophysical techniques measure mass fluxes and improve geomorphic transport laws?
   - Tracking sediment flux in extreme events?
   - What is the role of temporal and spatial variability in alluvial bed cover?
   - How does the EQ cycle impact surface processes?
   - How does the Critical Zone influence flood frequency?

4. Tectonic geomorphology and 4D topographic imaging

B. Foundational Capabilities

- Long-term geodetic monitoring for referencing topographic changes.
- Maintain terrestrial lidar capacity and training:
  - Expand opportunities for discovery-mode, exploratory science
  - Pilot data program, student mini-grants, E&O to field camps.
- Continued support for InSAR data archive, consortia, related products from GPS.
- Open topography needs to be maintained for access to high-quality point-cloud data and derived products.

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4. Tectonic geomorphology and 4D topographic imaging

C. Frontier Capabilities

- Characterization of land cover as well as bare earth.
- Use of high-resolution topography to improve InSAR processing.
- Infrastructure for rapid response (instruments, communication platforms, community planning, low-cost drone-based imaging).
- Broaden TLS community, opportunities for discovery-style research.
- New approaches to data access and archiving across agencies, dealing with massive data volumes.
- High-resolution topography worldwide for active deformation zones (global geoearthscope) — airborne lidar and Tandem-X.
- More access to modeling codes (lowering the bar for use). Wrapping of data products / data integration / data streams.
- Near-surface geophysics (refraction, resistivity, self-potential, NMR, MT, CSEM, GPR, bore-logging, seismic geomorphology).
- Gazing satellite technology for photogrammetry and video.

(yellow = cross-cutting theme)

4. Tectonic geomorphology and 4D topographic imaging

D. Broader Impacts

- Topographic changes are often directly related to identifying hazardous geologic processes and predicting their impact.
- High-resolution topography and near-surface geophysics are highly accessible for place-based teaching (high-school and undergraduate) and general public use.
- Topographic analysis, high-resolution topographic imaging, and near-surface geophysics open up geoscience career opportunities.
- Topographic change detection demonstrated scientific applications of widely available commercial technology, such as drones and structure-from-motion photogrammetry.
- SAGE/GAGE could take a lead on ensuring that the use of new technology (e.g. drones, high-resolution imaging) for science is socially acceptable.

5. Strengthening broad understanding of Earth and Earth science: K-12 education, informal education, and public outreach

Question 1: What are the key challenges?
Implementing the Next Generation Science Standards (NGSS). • Encouraging adoption of the new standards. • Empowering K-12 geoscience educators.
Communicating with society at all levels. • The tools of communication are rapidly changing. • The challenge of shaping public perceptions.
Finding the funding and resources to meet the existing needs.

5. Strengthening broad understanding of Earth and Earth science: K-12 education, informal education, and public outreach

Question II: What foundational capabilities will we need in a facility?

★ Facility staff play a critical role in supporting education and outreach activities.

★ Data and Data products to support instruction at all levels.

- Resources for K-16 educators (e.g. animations, teaching plans).
- Materials that take advantage of teachable moments.

★ A facility that serves as a communication hub.

- Showcase the science through human stories.
- Partner with other organizations (e.g. USGS).

(★ = cross-cutting theme)

5. Strengthening broad understanding of Earth and Earth science: K-12 education, informal education, and public outreach

Question III: What <u>frontier</u> capabilities will we need in a facility?
★ Exploit new forms of communication and engagement. • social media, apps and games, crowd sourcing.
★ Improve the visualization of data and concepts.
★ Provide opportunities that bring together scientists, educators, and journalists.
★ Develop programs that maximize research-like experiences for students, and articulate a career pathway.