2023 STV Community Meeting Findings

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Summary

The Surface Topography and Vegetation (STV) Community meeting was held November 14-15, 2023, in Pasadena, California. The meeting was convened by the STV team leads and members. The purpose of the meeting was to provide the Surface Topography and Vegetation (STV) community background on STV and inform the community on the status of STV progress toward an observing system. This meeting provided an opportunity for the broader community to inform an eventual STV observing system. The STV team sought input to refine the science questions and compelling applications for STV, establish observing priorities, identify measurement gaps, and discuss technology maturation. The meeting provided an opportunity for the STV team to draw on the diversity of expertise, experience, and backgrounds from the broader community. The current team carries out a wide array of science and technology activities for STV. The findings here largely identify gaps in activities that would further mature STV.

Science and Applications

Needed STV measurements include baseline and repeated. Global baseline topography shows that history of land surface processes. Baseline topography and vegetation structure followed by repeated measurements illuminates current processes. *The community should invest in articulating the science that can be gleaned from information written in landscapes and their change*. The following items should be emphasized in addition to ongoing activities.

Emphasize global baseline topographic map and science that can be accomplished:

- Articulate the science that will benefit from a global baseline map.
- Conduct studies to illustrate what would be learned from different resolutions of a global baseline map.
  - Show what can be learned with 5 m, 2 m, 1 m, and submeter topography.
  - Model the resolution needed for vegetation structure studies and show what can be learned with increasing resolution.
- Catalog existing topographic data sets and their coverage
  - For example, Tandem-X provides 12 m spatial resolution. Improved processing could bring the resolution to 6 m.
  - ArcticDEM/REMA/EarthDEM coverage at 2 m posting, timestamps between 2007 to present.
- Identify where STV could provide a foundational data product for other disciplines and observing systems.
  - ESO, PBL, NISAR, SBG, SWOT
  - Assess what baseline topography and quality will support other systems.
  - Connect with topographic working groups, such as the one for Surface Biology and Geology (SBG).

Understand where targeted repeat or high-resolution measurements are needed.

- Articulate distinction between deformation and topography change
  - Repeats are important in addition to Surface Deformation and Change (SDC)
  - What information will fill that gap?
  - Develop distinction between what SDC will provide versus STV change.
- Characterize rapidly changing landscapes
- Develop use cases.
  - Focus on specific processes.
  - Identify overlapping processes (e.g. tectonics and heavy vegetation).
  - Categorize needed temporal and spatial scales.
- Leverage commercial resources.
- Develop detailed observing strategy.
  - Identify spatial and temporal needs by region.
  - Identify processes requiring agile response and quantify response time and spatial field of view and resolution.
  - Identify objectives for specific types of events.
  - Identify conditions that would require intensive observation periods.
- Refine the maps from the study report.
  - Optimize the mission.
  - Identify science objectives for each region.
  - Identify regions where conditions drive measurement requirements.

Develop clear traceability from science objectives to observable/physical parameters.

- Articulate measurement needs independent of technology.

- Develop a comprehensive but concise science and applications traceability matrix (SATM).
- Define contemporaneous measurement needs for useful science.
    - For example: Ice flows move rapidly; Leaves blow in the wind.
    - Do measurements need to be contemporaneous, or can there be a delay between two measurements, and if so, what is an acceptable delay?
- Determine additional science, modeling, measurement gaps.
- Define use cases that set needs for different science goals.

Data

Analysis of data from new campaigns and existing sets will characterize and validate STV science and measurement needs.

Catalog existing data

- Platform
- Technology
- Coverage area
- Resolution
- Contemporaneous data
    - How far apart can data sets be in time and still be relevant to produce a valid measurement (discipline dependent)?

Conduct Airborne Campaigns

Airborne campaign objectives:

- Demonstrate measurement capabilities.
- Formulate scattering characteristics of targets.
- Evaluate and validate techniques and methodologies.
    - Consider data needs for evaluating potential mission sensors (are existing sensors good enough?)
    - Consider both measurements comparable to mission scenarios and measurements to drive simulations.
- Collect uniform contemporaneous data.
    - Concurrently collected data from different technologies.
    - Different relevant environments.
    - Fill data gaps for key STV environments.
- Create benchmark data sets for:
    - Data fusion.
    - Training machine learning.
    - Informing simulations.
    - Quantifying uncertainties.

- Leverage existing data
    - Identify gaps from existing data
- Evaluate technologies for achieving regional to global high-resolution bare Earth coverage
- Determine resolution needs for science disciplines (e.g. fault and some geomorphology studies generally require ~1 m horizontal resolution or better)

Environments for data collection:

- Cryo environments
    - Permafrost
    - Bare ice
    - Sea ice (cold, melting, deformed)
    - Snow in various climate and vegetation classes
        - Cold, dry snow (polar/alpine)
        - Wet, deep snow (maritime)
        - Snow beneath canopy
- Vegetation
    - Boreal
    - Temperate
    - Tropical
    - Dryland
    - Wetland
- Shallow water bathymetry
    - Coastal
    - Lakes
    - Rivers
    - Wetlands
    - Varying turbidity
- Urban
- Landscape mapping
    - Slopes
    - Roughness
    - Texture
    - Scattering characteristics, dialectric, dynamic range
- Different lighting conditions, contrast

Airborne Targets:

Prioritize target areas based on data availability and data need.

- Eastern Sierra including Lake Tahoe
    - Snow
    - Steep slopes
    - Temperate eastern conifers

    - Lakes
- Southern California
    - Urban
    - Grassland
    - Cropland
    - Coastline
- Potential high-albedo, stable calibration/validation sites
    - White Sands
    - Bonneville
- Cascade volcanoes
    - Steep slopes
    - Snow
    - Vegetation
    - Glacial ice
    - Landslides
- Harvard forest, Maine, Quebec
    - Temperate to boreal forest
    - Flat to undulating surfaces
    - Well-characterized
- Amazon
    - Moist tropical rainforest
- Costa Rica
    - Wet tropical forest
- Alaskan North Slope and Mackenzie Delta in Canada
    - Mountainous
    - Coastal
    - Sea ice
    - Permafrost
- Southeast Alaska/inside passage
    - High-elevation ice fields
    - Dense conifer vegetation in steep terrain
    - Melting glacier ice
    - Crevassed and calving ice
- Lake Mead
    - Shallow water bathymetry
    - Turbid
- Mississippi Delta
    - Turbid
    - Wetlands
    - Tidal
- Other
    - CRREL permafrost test sites near Fairbanks
    - Mangrove forest in central Florida (near Tampa Bay) that has been well-monitored for more than a decade.

    - Everglades
    - Caribbean and other parts of developing world in need of high-resolution baseline data
        - Dominican Republic and Haiti - tropical vegetation and heavy land use, hurricanes as environmental driver, high earthquake hazard requires high resolution topography (e.g. Puerto Rico well surveyed after Hurricane Maria)

Develop a schedule that includes timeframe and any repeats that are needed.

- Times of campaigns.
- Repeat frequency if needed.
- Validation approach.
- Feature classification.
- Topo differencing.

Platforms

- Aircraft
- Altitudes, airspeed
- Balloon tethered or untethered
- Drones
- HALE demonstration
- Rideshare opportunities

Validate airborne measurements:

- Cross data validation
- Field validation
- Calibration
- sUAS/Drones
    - High resolution coverage areas
    - Better precision and coverage extent than ground based individual measurements
    - High point density from sUAS lidar over vegetation

Data Processing and Analysis

Best served by and information system and centralized repository (DAAC)

- Manage high data volumes
- Easy to locate data products
- Standardized processing
- Standardized harmonized products

- Consistent coordinate reference systems, datums, geoid models, ITRF realizations, epochs

    - 3D CRS definitions and transformations are essential for combination with other existing products
- Example
    - https://deltax.jpl.nasa.gov/cgi-bin/data-search.pl#campaigns=pre-delta-x?products=1,2,3,4,5,6

Processing and analysis of airborne sets and algorithm development

- Processing capability and accessibility
- Data proximate computing (spin up processing next to data archives)
- On-demand data query (e.g., STAC, AWS Open Data Registry, OpenTopography), subsetting to return only points for area of interest, and on-the-fly processing/analysis
    - No local downloads of huge files!
- Best practices, public, documented.
    - Jupyter notebooks
    - Github

Data fusion

- Different instruments
- Varying product levels
- Different temporal or spatial scales
- Non-contemporaneous data in time
- Parameter estimation

Machine learning and AI

- Feature classification
- Automate feature extraction from data
- Geomorphic metrics
- Automatic change detection
- Vegetation classification and counting
- Feature tracking
- Super resolution
- Intelligent interpolation routines

Observing System Simulation Experiments (OSSEs)

Establish OSEE infrastructure framework

Assess capabilities

- Current and future commercial constellations
- Candidate instrument configurations and architectures
- Output product quality for variable processing software parameters using synthetic datasets
- Technologies

- Mapping of locations / environments driving science requirements

Produce surrogate data

- Forward modeling
- How does the physical system present itself (characteristics of targets)
- Hardware configuration
- How fly and process

Derive requirements

- Test performance
- Find crosscutting themes.
- Minimize top-level requirements.

OSSE Types

- Physical model to address impacts of data quality on physical process to be retrieved or constrained.
    - Transform to synthetic data.
- Instrument approach looks at capability to product quality and uncertainties.

Physical based modeling gaps. Each puts out standardized data products.

- Solid Earth
    - Landslides
    - Fault mechanics
    - Landscape evolution
- Cryosphere
    - Mountain glaciers
    - Permafrost cold shoulder season dynamics and surface hydrology
    - Ice sheet and sea ice surface processes
- Coastal Geomorphology and Hydrology
    - Wetland phenology
    - Change in bathymetry from sediment deposition and erosion
    - Water flow such as tides

Modeling of system options

- Synthetic data (from above)
- Instrument performance metrics
- Mission performance
    - Concept of operations
    - Year in the life analysis
    - Completeness
        - Limitations and impedances
        - Outages for calibration

        - Changes in mission operations (campaigns)
    - Design reference missions
        - Different instrument configurations

Technology

Target is TRL5 around 2027 timeframe. *TRL 5: Component and/or breadboard validation in relevant environment. Flow down science traceability to the measurements.*

Map technology capability to measurement capability

- Single technologies
- Fused technologies

Radar

- Multifrequency
- Low mass/volume
- Autonomous coordinated swarms
- Electronic beam steering for better swath coverage

Lidar

- Cross track scanning to increase coverage (100 beams)
- More efficient lasers
- Improved bathymetry and vegetation penetration
- Scanning mechanisms
- Component technologies
- Wavelengths

Stereoimaging

- Detector options (line scanner, framing, pushbroom, bands)
- Number of looks (2-image vs. triplet vs. multi-view stereo)
- Acquisition geometry and look-angle diversity
- Low mass/volume high resolution capability
- Increasing swath width, field of view
- Access versus target statistics

Sensor fusion

- Inform from other techniques
- Optimize data collection and analysis
- Low-level fusion of instrument measurements
- High-level fusion of derived products for science

Architecture

Assess global coverage from existing or emerging spaceborne capabilities.

Geolocation

- Deduced reckoning of the sensor
    - Ephemeris attitude
- Automate ground control

Reference system/datum

Sensor fusion

Develop concept of operations

- Sensors and platforms
- Access
- Coverage
- Resolution

Determine data rate

- Downlink
- Onboard processing
- Smart tasking
    - Responsiveness to events
    - Coordination with other platforms

Orbits

- Optimal solutions

Platform type

- Large
- Small
- Constellation
- Suborbital

Mission planning system

- Optimize data collection
- Planning and scheduling
- Cloud planning
    - Performance model based on quality assessment
    - Cloud avoidance onboard, another spacecraft, or via weather service
- Sunglint and other lighting conditions