NASA's Surface Topography and Vegetation Study

Mapping Earth's changing surface and overlying vegetation structure

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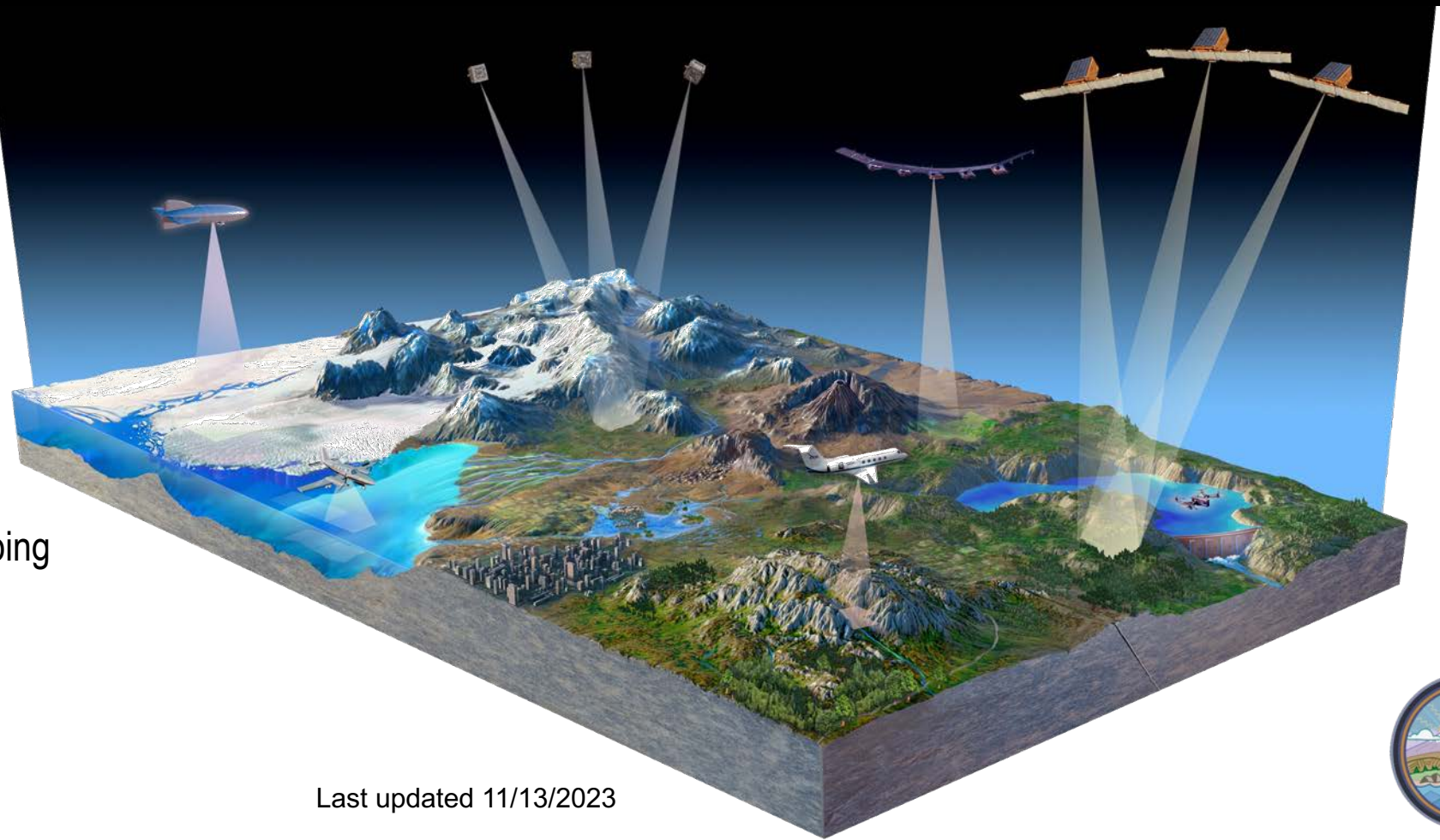

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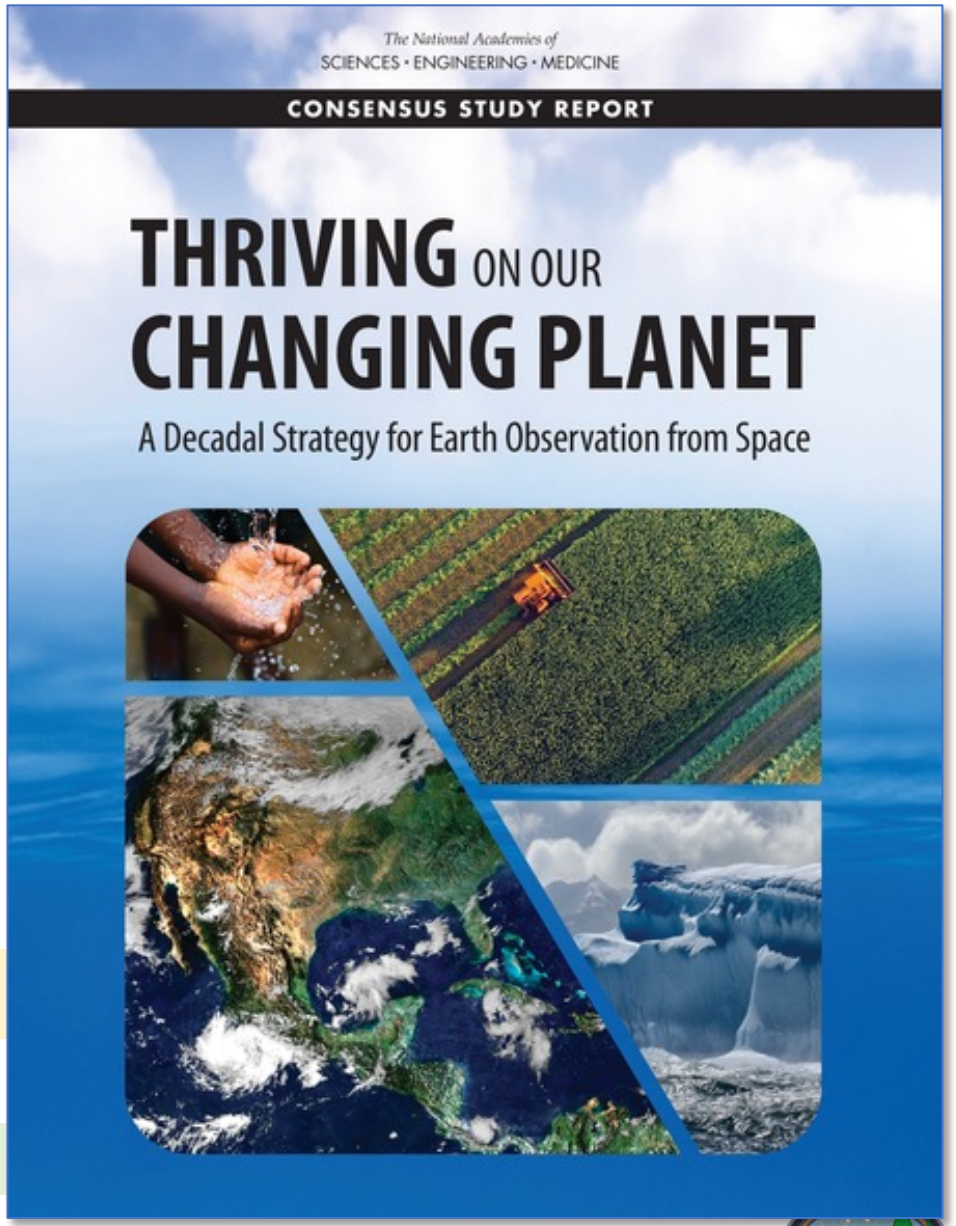
Decadal Survey

- Targeted Observable:
  Surface Topography and Vegetation
- *High-resolution global topography*, including bare surface land topography, ice topography, vegetation structure, and shallow water bathymetry
- Candidate Measurement Approach:
  radar or lidar *[Stereoimaging]*



Solid Earth ***Ecosystems*** ***Climate*** ***Hydrology*** ***Weather***

Solid Earth ***Vegetation Structure*** ***Cryosphere*** ***Hydrology*** ***Coastal Processes***

https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth

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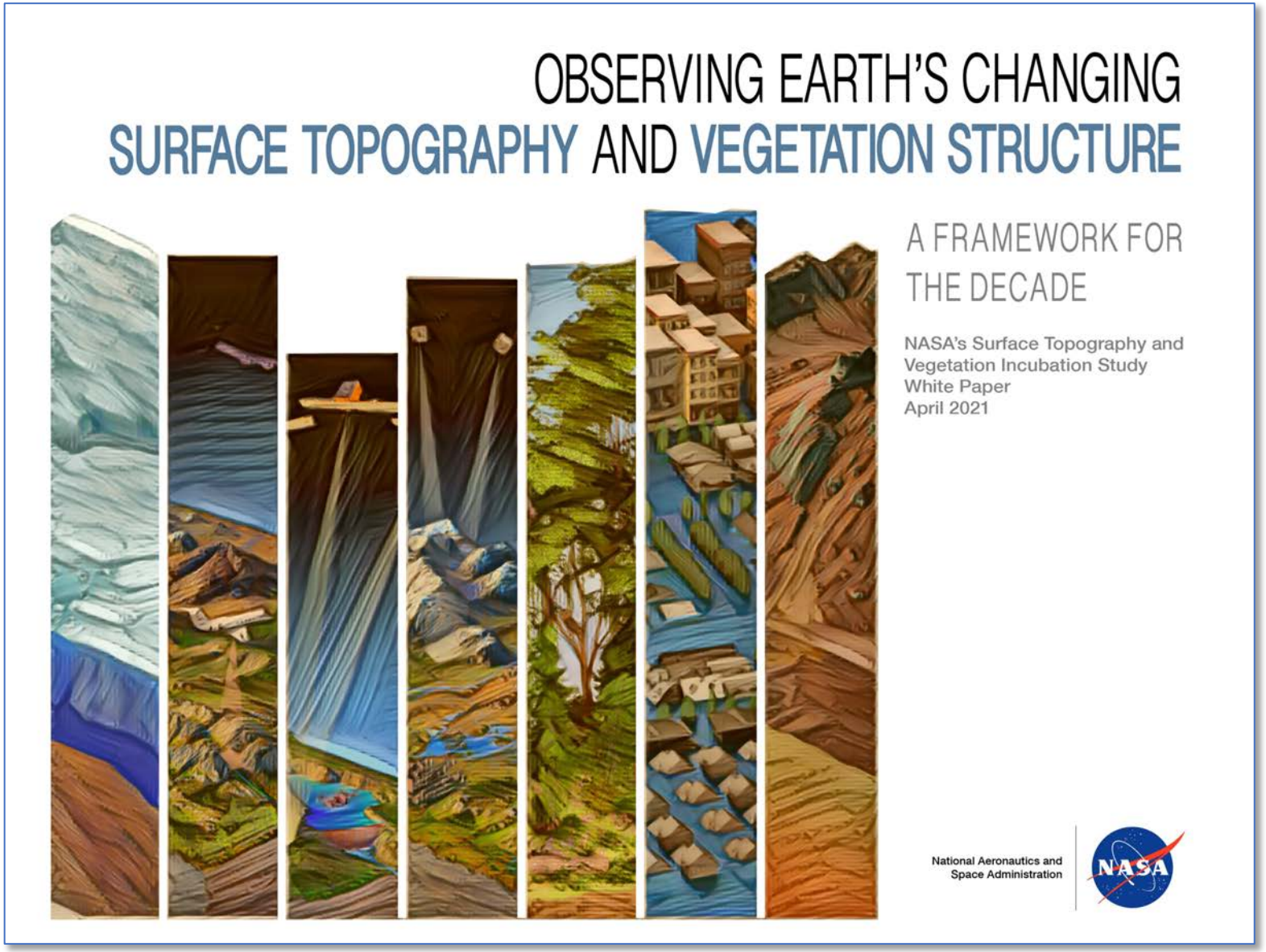
STV Incubation

- Decadal Survey: “A new program element called ‘Incubation,’ intended to accelerate readiness of high-priority observables *not yet feasible for cost-effective flight implementation*.”
- STV is not a mission or an observing system
- The STV Incubation Study is not a Designated Observables Study
- The STV Incubation Study is focused on:
  - **State-of-the-Art Evaluation**
  - **Identification of Gaps and Investment Needs**
  - **Preliminary Requirements Refinement**

- Managed by ESTO and run as a partnership with R&A
- Mix of activities:
  - Technology development
  - Modeling/system design and analysis
  - Small scale pilot demonstrations

2021 STV Incubation Study Report



https://science.nasa.gov/earth-science/decadal-stv

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STV Study Objectives

- Develop STV science and architecture as input to the next Earth Science Decadal Survey
- Advance each PI-led research projects
- Develop roles and responsibilities for team members to mature STV
- Coordinate STV projects
- Identify needed OSSEs, study areas, campaigns, and additional gaps
- Leverage existing data, missions, activities
- Build an STV community

STV Questions

How does Earth's changing surface structure inform us about climate change, natural hazards, ecosystem habitats, and water availability?

Solid Earth: How does Earth's surface structure respond to tectonic and climate forces and what are the implications for geologic hazards?

Vegetation Structure: How is Earth's vegetation responding to climate change and what are the feedbacks to the carbon cycle, hydrologic cycle, and ecosystems?

Cryosphere: How are the changing ice sheets and glaciers interacting with the global climate system and Earth's oceans?

Hydrology: How will water availability and flow change with climate and increasingly dynamic landscapes?

Coastal Geomorphology: How are coasts changing by natural and human influences and what are the impacts?

Applications: How does understanding changing topography and vegetation structure enable better hazard and resource management?

Science Breakouts

Solid Earth

- Tectonics/deposition/ erosion/climate coupled processes
- Earthquake, volcano and landslide assessment, response, mitigation and modeling
- Anthropogenic and natural change detection

Vegetation Structure

- Ecosystem structure and function
- Carbon accounting
- Biomass inventory, dynamics, monitoring
- Biodiversity, habitat structure and response to disturbance
- Forest resources management
- Wildfire, fuel, risk and post-fire recovery

Cryosphere

- Glacier and ice sheet mass gain and loss processes and impacts on sea level change
- Glacier and ice sheet ocean and atmosphere heat and mass exchanges
- Atmosphere-ice-ocean momentum, heat and mass exchange over the polar oceans
- Polar ocean circulation

Hydrology

- Lake and reservoir heights and shallow bathymetry
- Snow depth and melt impact on water resources
- Stream and river flow
- Flooding and inundation modeling
- Wetland processes and management

Coastal Geomorphology

- Storm surge and tsunami inundation hazards
- Shoreline erosion and sediment transport
- Benthic habitat and marine ecosystems
- Tidal interaction with mangroves and salt marshes
- Shallow water navigation and hazards

Applications

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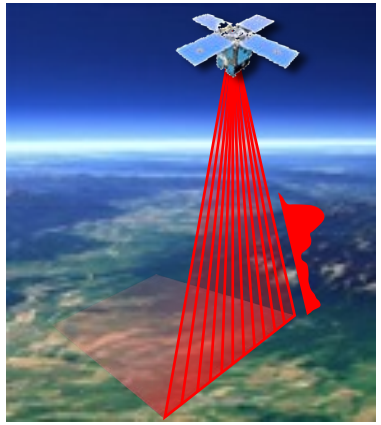
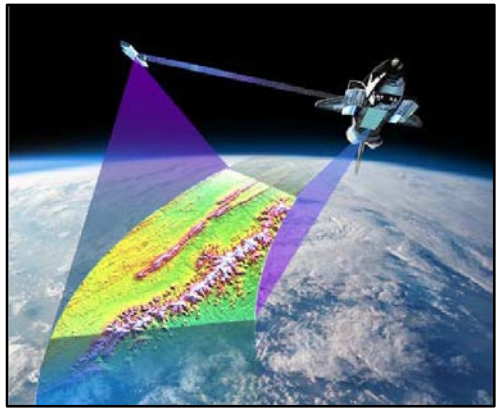
Technology Breakouts

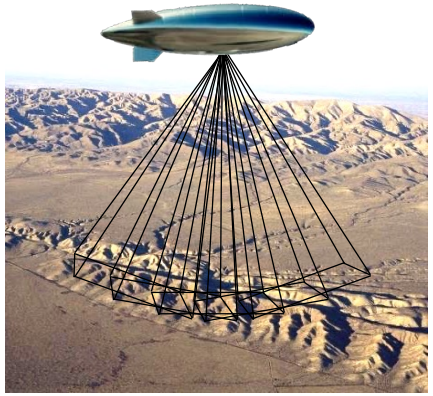
Architecture



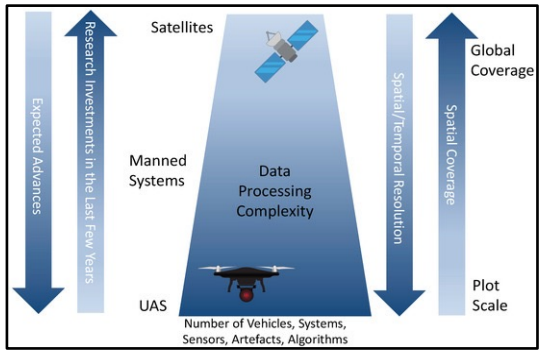
Lidar



Radar



Stereoimaging



OSSEs

Platforms

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2023 STV Study Leads

Lead
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NASA/JPL/Caltech

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NASA/GSFC

Hydrology
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Radar
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Lidar
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Stereoimaging
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OSSEs
Marco Lavalle
NASA/JPL/Caltech

Platforms
Matt Fladeland
NASA Ames

Architecture
Joe Green
NASA/JPL/Caltech

Architecture
Mark Stephen
NASA/GSFC

Remaining team members participate in one or more teams

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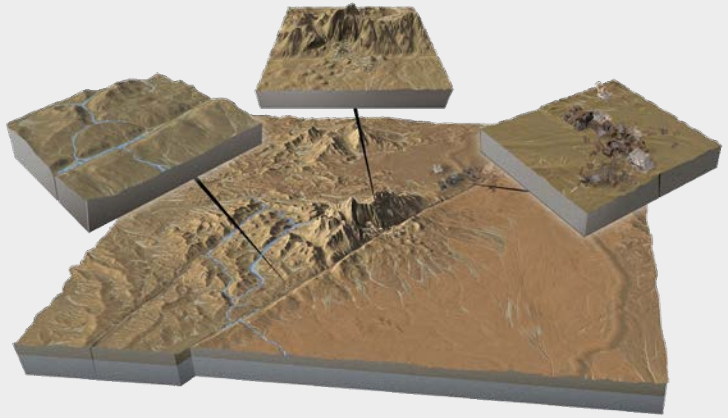
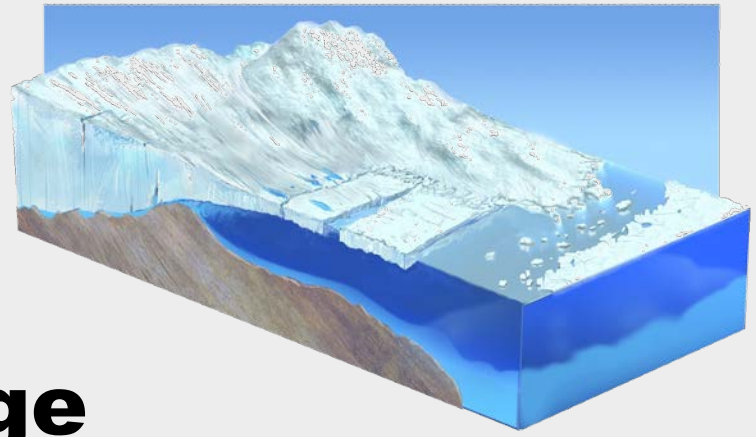
STV Science and Applications Measurements

Bare-surface Topography



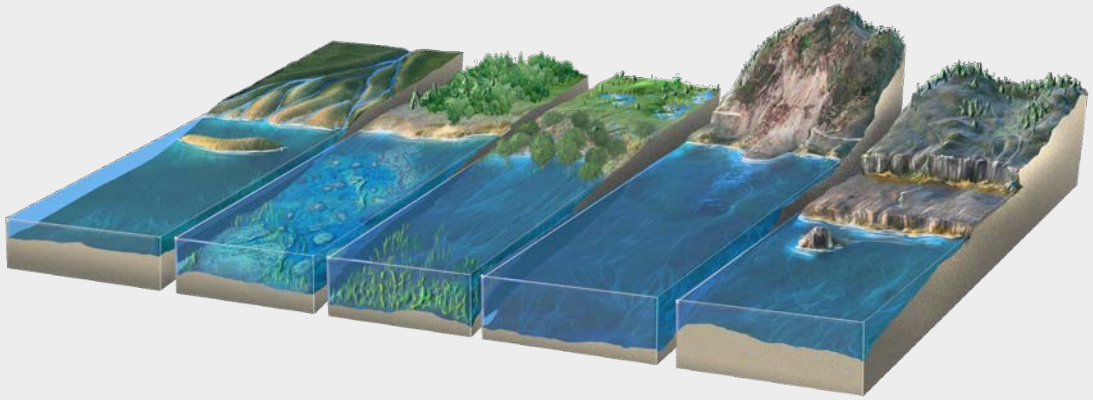
Ice Topography



+change

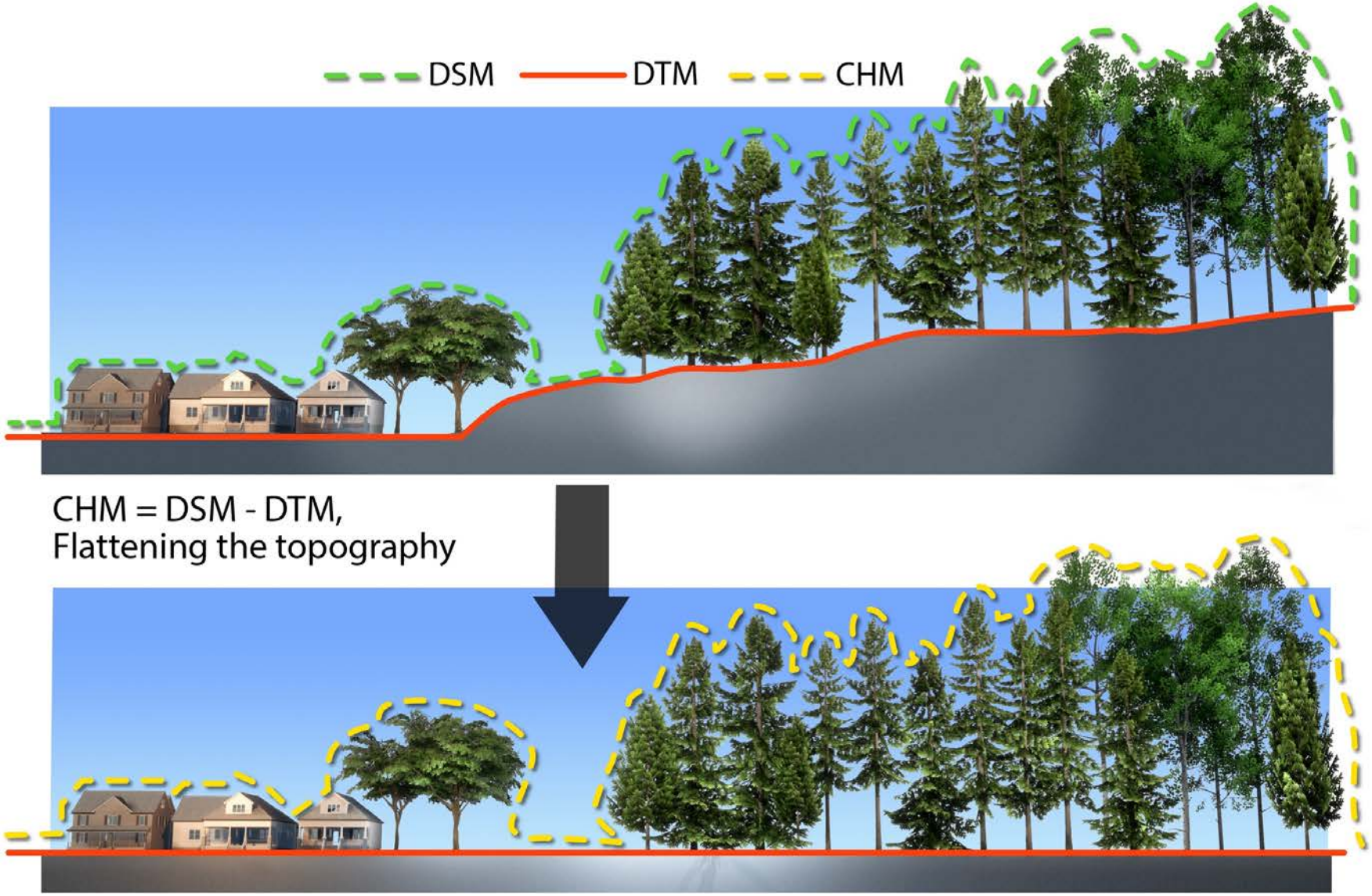
Vegetation Structure

Shallow-water Bathymetry



Measurement Challenge: Separating vegetation from bare Earth topography

Elevation Models Relevant to STV

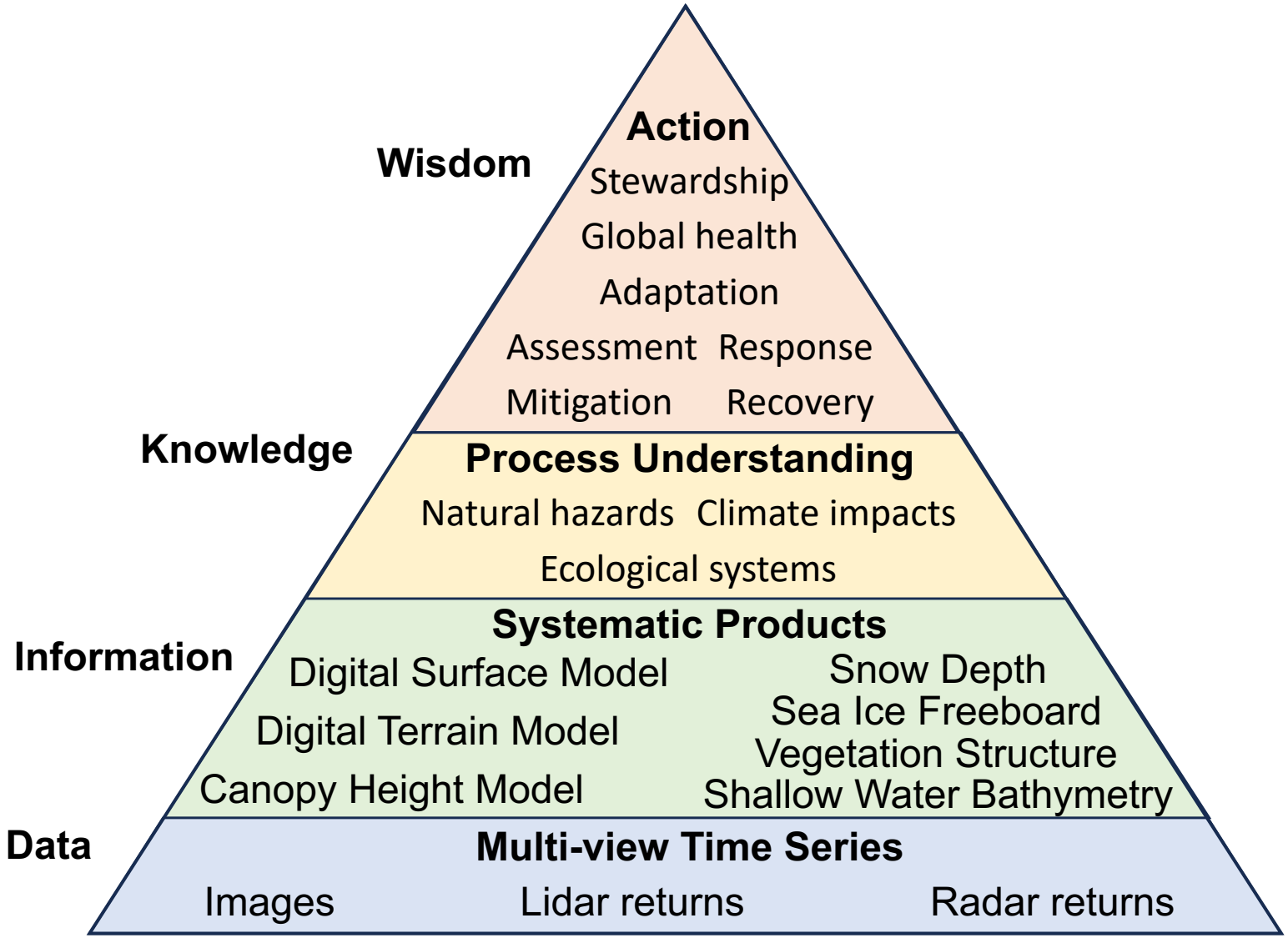


DSM = Digital Surface Model

DTM = Digital Terrain Model

CHM = Canopy Height Model

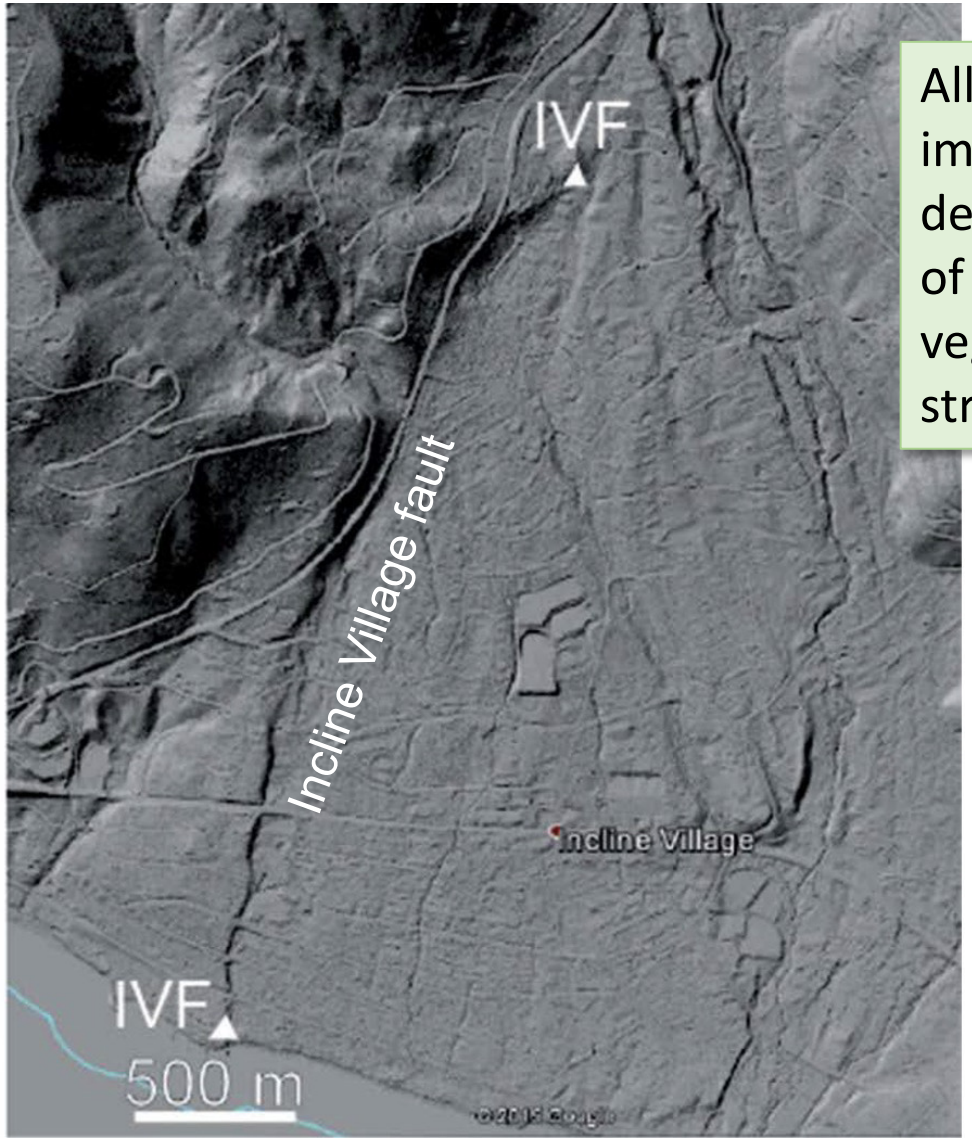
STV Data to Wisdom



Bare Earth Highlights Geophysical Processes

Full-feature

Bare Earth



Allows improved determination of overlying vegetation structure

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Donnellan et al, 2016; STV Study Report

Bare Earth Highlights Geophysical Processes

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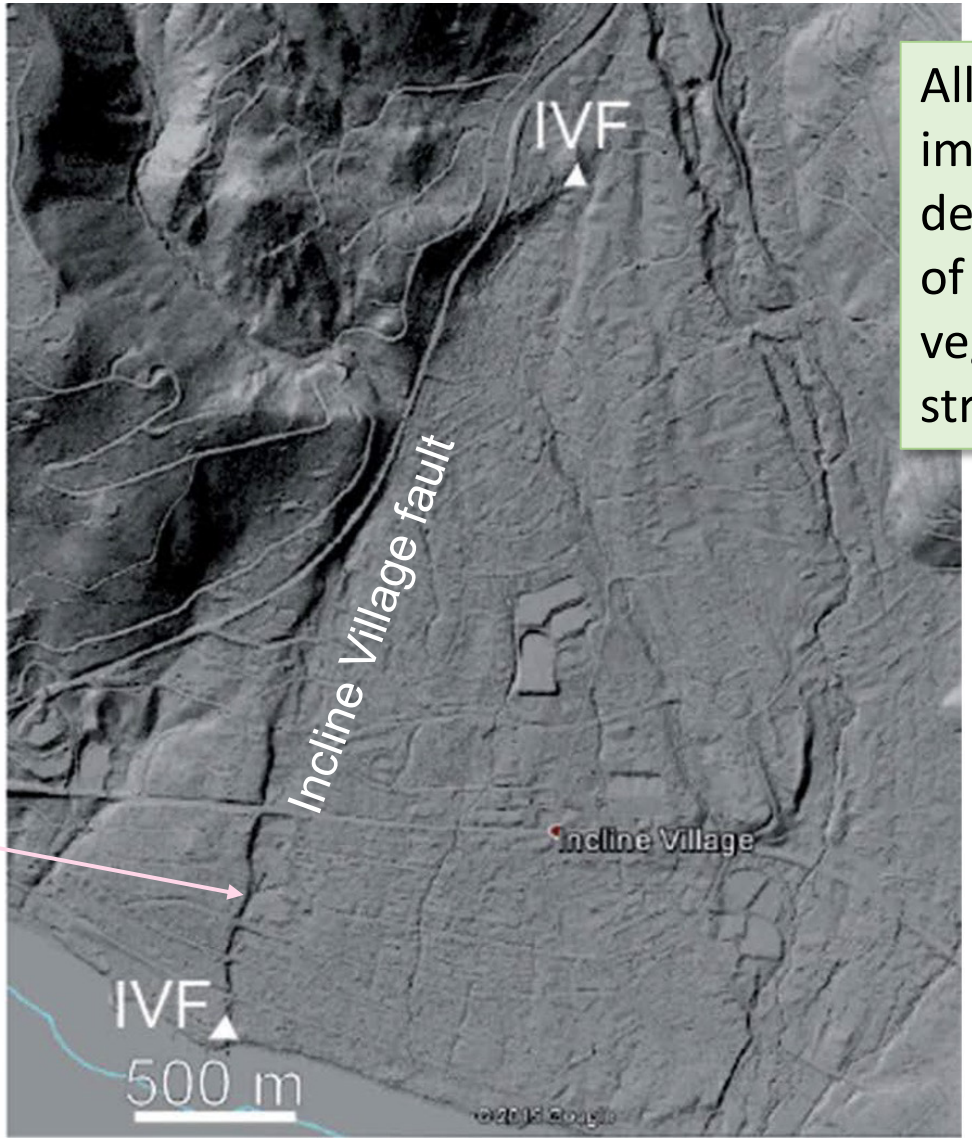

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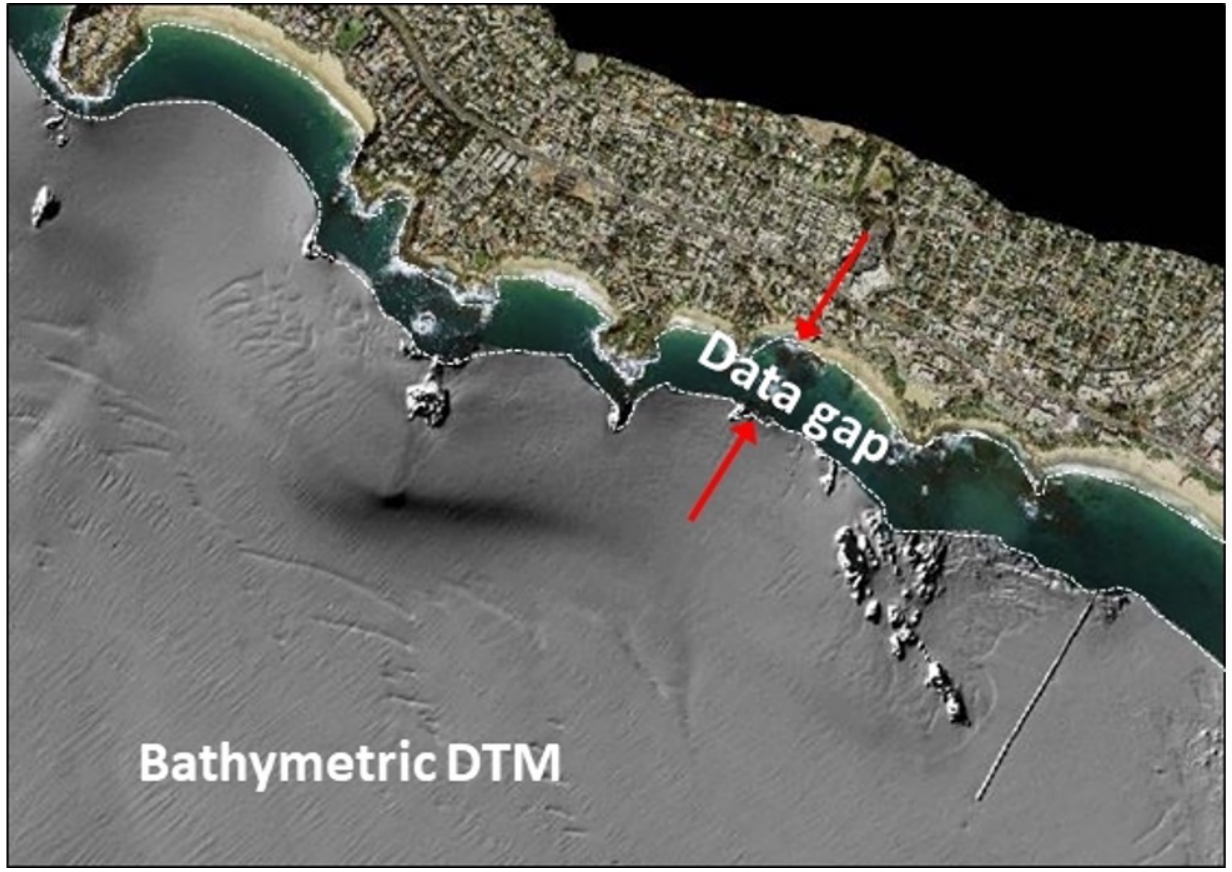
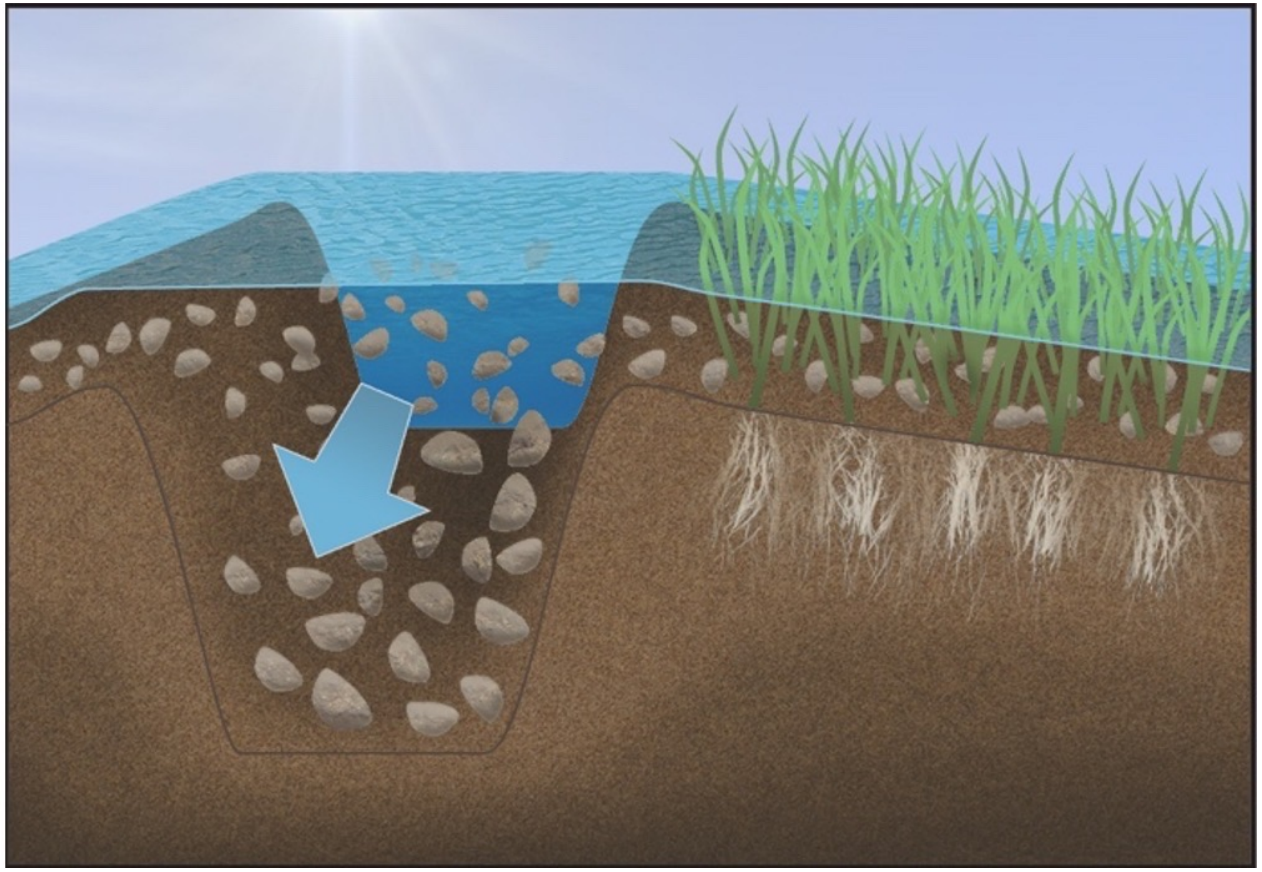
Shallow Water Bathymetry is a Data Gap



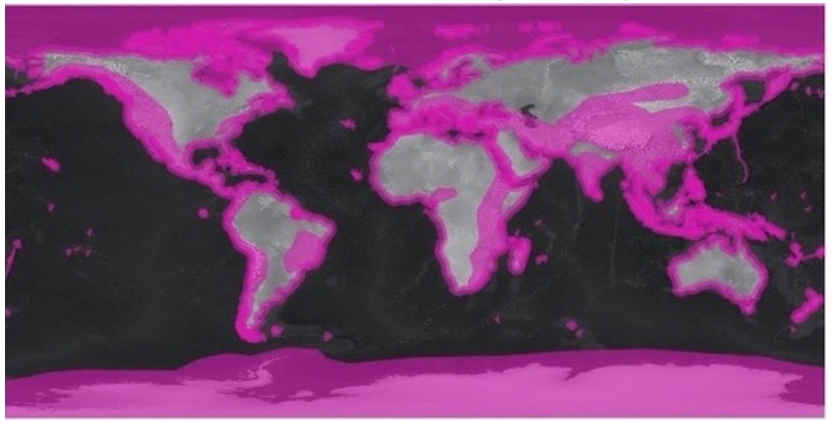


STV Observables Coverage Maps

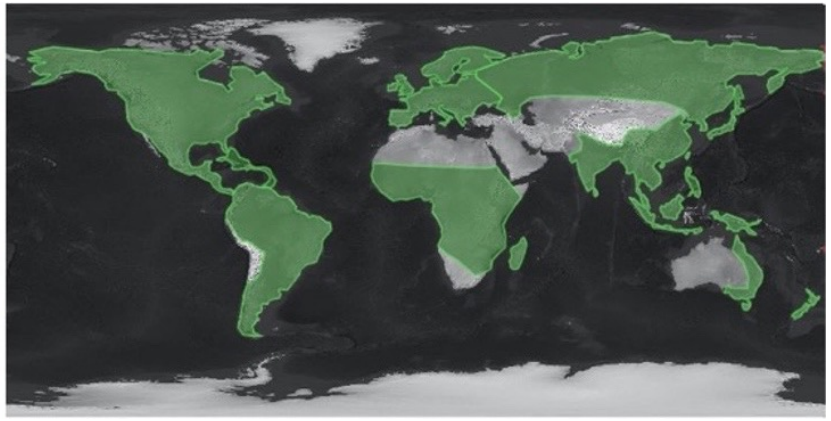
Baseline

Repeat

Surface Topography

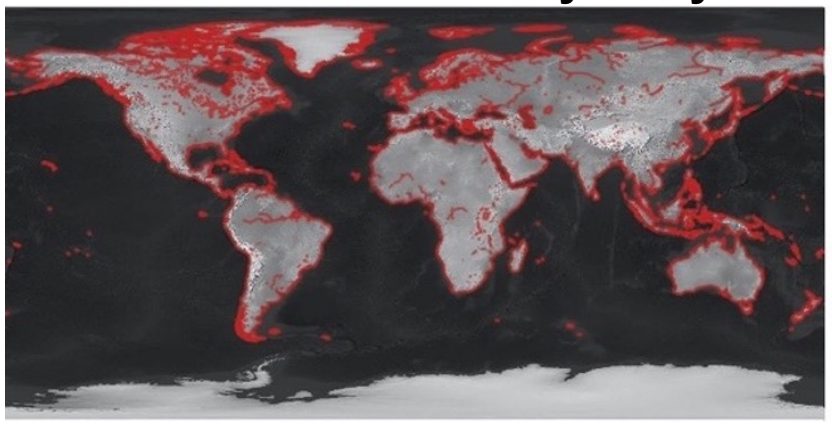


Vegetation Structure

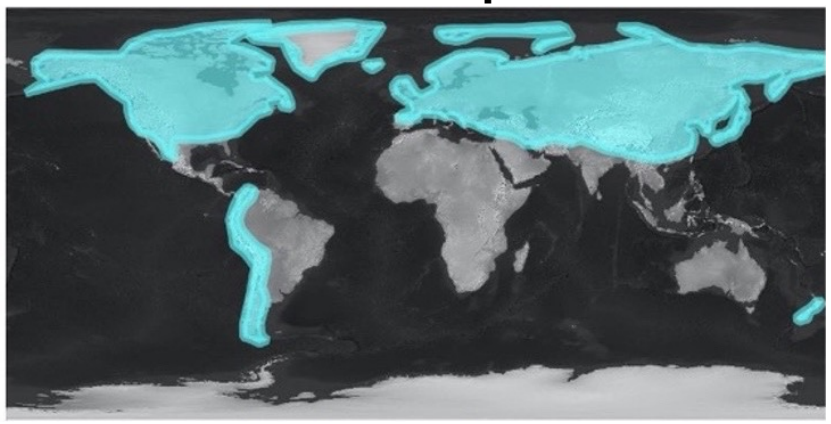


Baseline
Surface Topography
Vegetation Structure
Shallow Water Bathymetry
Snow Depth

Shallow Water Bathymetry



Snow Depth



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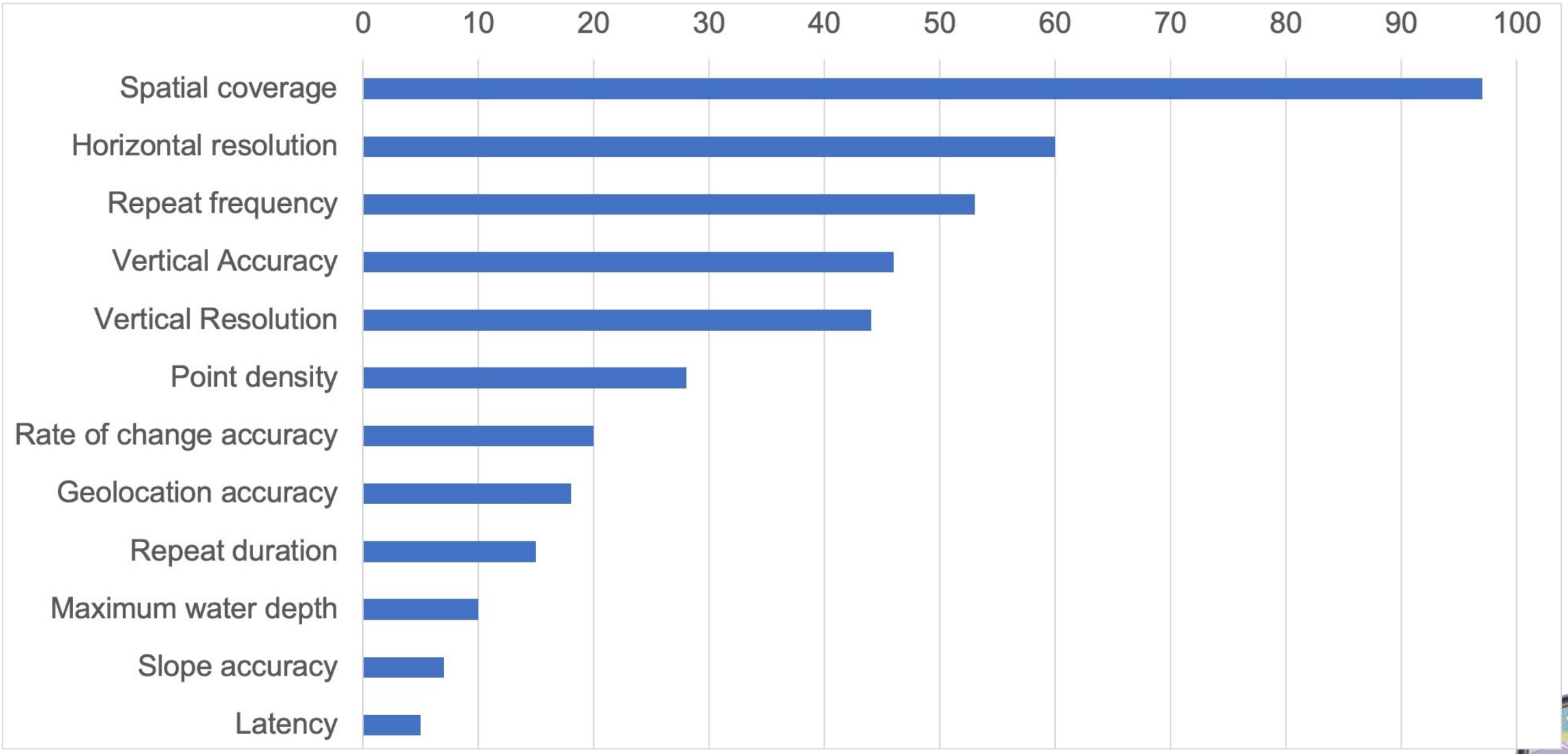
Needs Ranked by Importance



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Preliminary STV Measurement Needs

Parameter		Aspirational			Threshold		
		Median Need (rounded)	Most Stringent Need	Most Stringent Discipline	Median Need (rounded)	Most Stringent Need	Most Stringent Discipline
Coverage Area of Interest	%	90	95	C, H	55	90	C
Latency	Days	5	0.5	SE	60	1	SE
Duration	Years	9	10	SE, C, A	3	3	SE, V, C, CP
Repeat Frequency	Months	0.1	0.03	SE, A	3	0.2	SE
Horizontal Resolution	m	1	1	SE, C, H, A	20	3	SE
Vertical Accuracy	m	0.2	0.03	SE, C, H	0.5	0.1	C
Vegetation Vertical Resolution	m	1	0.5	H, A	2	0.2	CP
Bathymetry Max Depth	m	25	30	C, CP	10	10	SE, C, CP
Geolocation Accuracy	m	1	1.0	SE, V, H, A	5	3	SE, V
Rate of Change Accuracy	cm/yr	5	1	SE, C, A	35	1	SE

A set of product needs for all science and applications could be met by an STV mission

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STV Roadmap

Maturity

- Uncertainty Quantification
- Smart Tasking
- Onboard Processing Algorithms
- Architecture Trade Studies
- Change Detection Algorithms
- Data Fusion Methodologies
- Reduced Size, Weight and Power Sensor Development
- In Situ and Airborne Campaigns
- Sensor and Platform Maturation
- Sensor Web and New Observing Strategies Design Studies
- Observing System Simulation Experiments (OSSEs)
- Geophysical Process Modeling and Sensitivity Studies

Immediate 1-3 years

Near-Term 3-7 years

Long-Term 7-10 years

New observing strategies that employ flexible multi-source measurements from a variety of orbital and sub-orbital assets would best meet STV objectives

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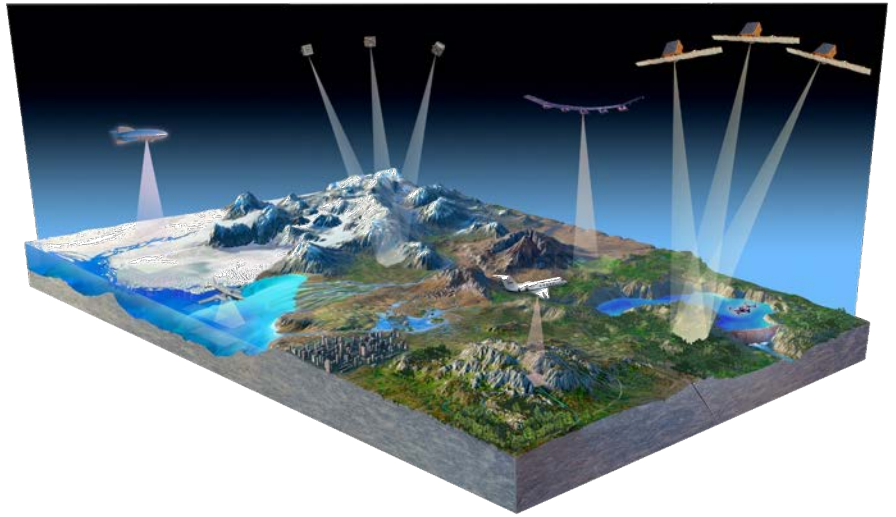
Summary

- An orbital observing system could meet a set of STV science and applications needs serving all STV disciplines
- An architecture of multiple platforms and sensors on orbital and suborbital assets would address STV needs more thoroughly



- All science and applications disciplines need accurate repeat measurements to measure temporal changes
- A global baseline topographic map and overlying vegetation structure is needed followed by targeted repeated measurements
- STV Community Workshop: November 14-15, 2023, Pasadena, CA

Charge to Workshop

- Science
  - Compelling questions and objectives
  - Justification of science needs
  - Data fusion and separating vegetation and ground
  - Joint experiments
- Technology
  - Flow science needs to capabilities
  - Mature technologies as needed
  - Processing advances
- Architecture
  - Coverage, resolution, latency
  - Performance modeling
  - Airborne and spaceborne capabilities
  - Concept of operations