2019 ***Surface Biology and Geology (SBG) Community Workshop***

SBG Applications Working Group:
Perspective on Roles of Applications for SBG

Jeffrey Luvall, NASA, MSFC
Natasha Stavros and Christine Lee, Jet Propulsion Laboratory, California Institute of Technology
Nancy Glenn, Boise State University

Perspective on Roles of Applications for SBG

1. Creating a vibrant community ready to go!
2. Open process; over 100 participants representing 15+ different types of organizations; in turn over 50 active engagement partners with more to come
3. Focus groups
   a. 6 completed so far, 2 additional focus groups
   b. Sub-groups encouraged - allow us to exceed our bandwidth
   c. Represent broad range of stakeholders
   d. Engaged with Decadal Survey : science is broad
4. We are always taking more, please invite others! Early career encouraged
5. Parallel process: interaction among SBG working groups

http://tinyurl.com/SBGApplicationsWG

Perspective on Roles of Applications for SBG

1. Science / applications intricately linked: Decadal Survey
2. Global theme: applications have international opportunities
3. Change theme: applications have agility
4. Events theme: applications can respond to disruptive events
5. *Opportunity for international collaboration through common applications and precursor studies
   a. CHIME, EnMAP, HISUI, PRISMA, etc along with airborne AVIRIS-NG, NEON, APEX, etc as precursors for feasibility studies; how do we be synergistic?

http://tinyurl.com/SBGApplicationsWG

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Updates on the SBG Applications Working Group

Applications-Working Group Team
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Natasha Stavros, JPL - California Institute of Technology
Nancy Glenn, Boise State University

with special thanks to the Applications-Working Group Community Co-Authors

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Ryan Avery, Louisiana State University
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Savannah Cooley, Columbus – JPL Affiliate
Michael Ramsey, Univ Pittsburg
Michael Abrams, JPL - California Institute of Technology
R. Greg Vaughn, U.S. Geological Survey

NASA HEADQUARTERS
SCIENCE MISSION DIRECTORATE (SMD)

EARTH SCIENCE DIVISION

DIRECTIVE ON PROJECT APPLICATIONS PROGRAM

Approved by:

Michael Freilich
Director, Earth Science Division
Science Mission Directorate, NASA Headquarters

29 June 2016
Date

Guidance

NASA
Earth Science

Early Stages of the DO Studies

Collect materials and information for preparing the Community Assessment Report *(upcoming slide on CAR)*

Identify, engage, and characterize communities that might relate to the DO topic

- Identify potential communities; explore *known unknowns* for orgs. new to NASA Earth Sci.
- Conduct studies and engagement activities, *especially where users are and where they gather*
- Characterize and analyze communities, organizations, and stakeholders (to help inform priority setting later)

Characterize potential needs for access to data products

Assess applications opportunities and impacts in context of architecture options

Identify potential applications objectives (along side research objectives)

Middle Stages

Complete the Community Assessment Report

Prioritize applications objectives (with research)

Prioritize communities and orgs for preferred engagement, including impacts for the DO, selected architecture(s), and eventual mission

Incorporate what's learned & collected into the value framework, trade studies, and trade-offs

Leading to MCR & KDP-A

Inform additional trade-offs

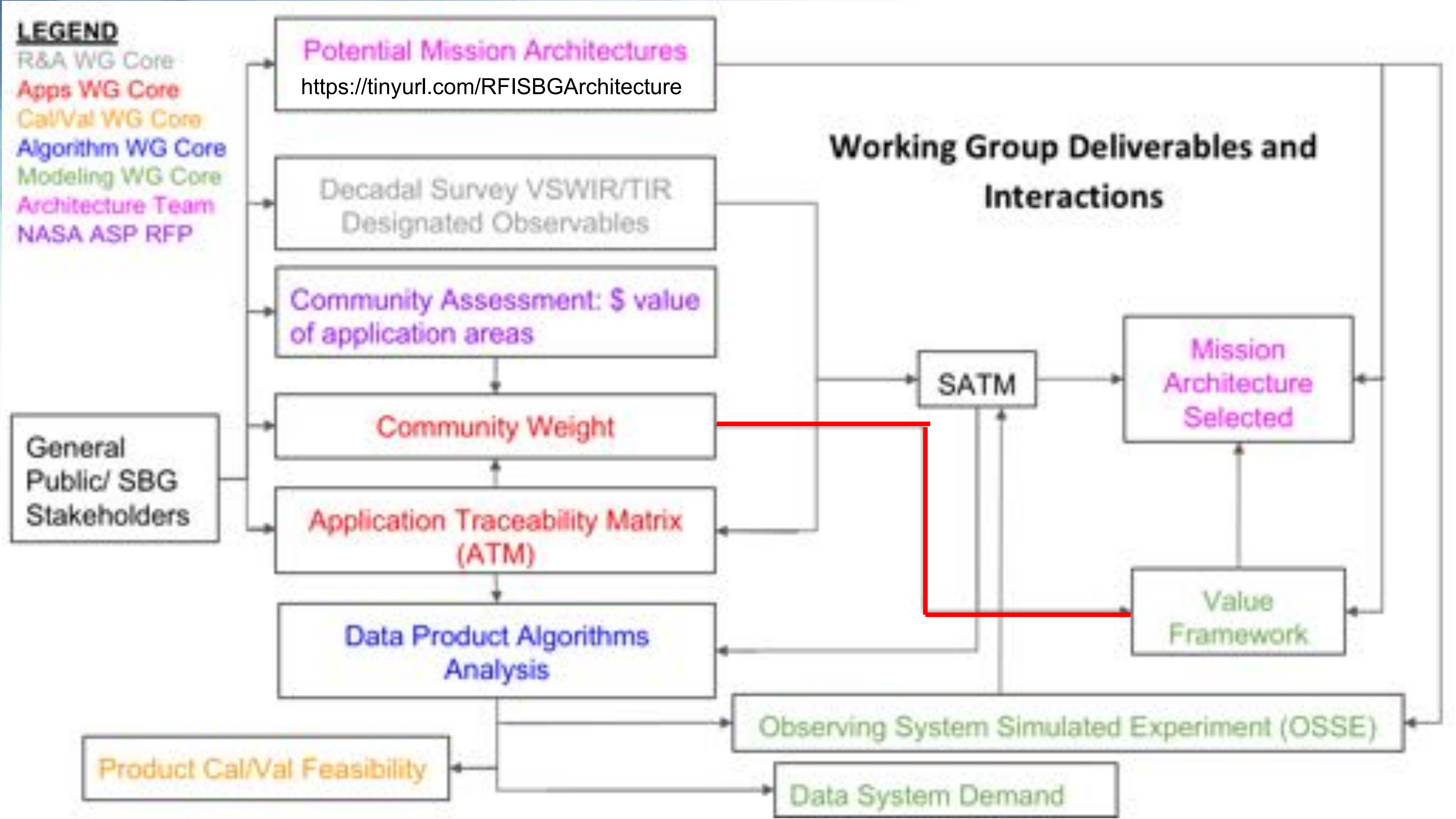
Incorporate applications into mission concept

Integrate users' impact prospects and statements

Charter

The Applications Working Group will recruit, coordinate and integrate input on applications needs, data product requirements and training/education and other needs:

- The AWG will identify key applications requirements, latency, revisit, specific products.
- The AWG will cultivate stakeholders and end users via joint activities, workshops, thematic working groups, and design and dissemination of tailored SBG data products.
- Characterize the SBG Communities of Practice and Potential and produce a SBG Community Assessment Report.



LEGEND
R&A WG Core
Apps WG Core
Cal/Val WG Core
Algorithm WG Core
Modeling WG Core
Architecture Team
NASA ASP RFP
Potential Mission Architectures
https://tinyurl.com/RFISBGArchitecture
Working Group Deliverables and Interactions
Decadal Survey VSWIR/TIR Designated Observables
Community Assessment: $ value of application areas
Community Weight
General Public/ SBG Stakeholders
Application Traceability Matrix (ATM)
Data Product Algorithms Analysis
SATM
Mission Architecture Selected
Value Framework
Observing System Simulated Experiment (OSSE)
Product Cal/Val Feasibility
Data System Demand

(Draft) Schedule for weekly SBG-Applications Discussions

working meetings that are focused on specific topics within STM

Date	Topic	Lead(s)
5/2/2019	Natural Hazards - Volcanoes and Landslides	Florian Schwandner / Christine Lee
5/10/2019	Terrestrial Ecosystems / Natural Hazards - Wildfires, Restoration	Dar Roberts / Nancy Glenn
5/16/2019	Terrestrial Ecosystems - Carbon Accounting, Conservation	Konrad / Natasha Stavros
5/23/2019	Public Health and Urban Planning / Urban Heat Islands, Heat Waves, Vectorborne Disease Habitats	Ryan Avery / Jeff Luvall
5/30/2019	Water Resources / Terrestrial Ecosystems - Agriculture, Snow	Forrest Melton and Chris Hain / Christine Lee
6/7/2019	Aquatic Ecosystems - Corals, Harmful Algal Blooms, Water Quality, Restoration	Maria Tzortziou and Stephanie Uz / Christine Lee
6/13/2019	None - Community Workshop in Washington DC	
TBD	Surface Composition and Mineralogy	
	Other topics Revisits?	

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working meetings that are focused on specific topics within SATM

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https://docs.google.com/spreadsheets/d/19zvuYdiiP4B6Bh2pRHHf0K7-c09GifwD/edit#gid=1431246766

Geological hazards SATM deep-dive exercise

Understanding and predicting geological hazards

Active surface geology (deformation, eruptions, landslides, and evolving landscapes)

DESIGNATED—*Targeted Observable:* **Surface Biology and Geology** [H-1c, 2a, 2b, 3a, 3b, 3c, 4a, 4c, 4d; W-3a; S-1a, 1c, 2b, 4b, 4c, 7a; E-1a, 1c, 1d, 2a, 3a, 5a, 5b, 5c; C-3a, 3c, 3d, 6b, 7e, 8f]

The **Surface Biology and Geology** Targeted Observable, corresponding to TO-18 in the Targeted Observables Table (Appendix C), enables improved measurements of Earth's surface characteristics that provide valuable information on a wide range of Earth System processes. Society is closely tied to the land surface for habitation, food, fiber and many other natural resources. The land surface, inland and near-coastal waters are changing rapidly due to direct human activities as well as natural climate variability and climate change. New opportunities arising from enhanced satellite remote sensing of Earth's surface provide multiple benefits for managing agriculture and natural habitats, water use and water quality, and urban development as well as understanding and predicting geological natural hazards. The Surface Biology and Geology observable is linked to one or more Most Important or Very Important science objectives from each panel and feeds into the three ESAS 2017 integrating themes: water and energy cycle, carbon cycle, and extreme event themes.

Science Considerations. This Targeted Observable will likely be addressed through hyperspectral measurements that support a multi-disciplinary set of science and applications objectives. Visible and shortwave infrared imagery addresses multiple objectives: active surface geology (e.g., surface deformation, eruptions, landslides, and evolving landscapes); snow and ice accumulation, melting, and albedo; hazard risks in rugged topography; effects of changing land-use on surface energy, water, momentum and carbon fluxes; physiology of primary producers; and functional traits of terrestrial vegetation and inland and near-coastal aquatic ecosystems. Thermal infrared imagery provides complementary information on ground, vegetation canopy, and water surface temperatures as well as ecosystem function and health. Depending on implementation specifics, the Targeted Observable may also contribute to hyperspectral ocean observation goals. However, such goals are met to a large degree by POR elements, in particular the hyperspectral PACE mission, and are not considered a priority for additional implementation (and thus are not recommended if they drive cost). Observations of the Earth's surface biology and geology, with the ability to detect detailed spectral signatures, provide a wide range of opportunities for Earth system science parameters across most of the panels and integrating themes. As such, this Targeted Observable maps to some of the highest panel priorities as well as the Integrating Themes.

SBG Geological Hazards / Disasters Objectives

EAS17 SBG TO-18: S-1a, 1c, 2b, 4b, 4c, 7a

QUESTION S-1 How can large-scale geological hazards be accurately **forecast** in a socially relevant timeframe?

QUESTION S-2 How do geological disasters directly **impact** the Earth system and society **following an event**?

QUESTION S-4 What processes and interactions determine the rates of landscape change?

QUESTION S-7 How do we improve discovery and management of energy, mineral, and soil resources?

Volcanic Eruptions

Calbuco eruption, Chile 2015

Landslides

Big Sur (California) 75-acre landslide May 2017. (image: CNN)

Other SBG geological hazards / disasters:

- Surface Deformation, Evolving Landscapes

Other program geological hazards / disasters:

- Earthquakes, Floods

Other related hazards / disasters:

- Oil Spills (ESAS 2017: 10-57 – multispectral)
- Mining Disasters, contaminant events

SBG Applications Working Group

*initial scoping

	ESAS-17 SBG ES&I (S) Objectives	Relevant quantities	Likely Application Community Partners
S-1c	**Forecast and monitor landslides, especially those near population centers.**	**Imaging of vegetation and rock/soil composition**	USGS, BLM, NPS, FEMA, USAID, SDR, WOVO, FS, commercial partners (technology, re-insurance), NGOs Integrating Themes (objectives): H-3b; E-2c, E-5b; C-5a, C-5d, C-7b; W-5a, W-6a
S-1a	**Measure the pre-, syn- and post-eruption** surface deformation and **products of Earth's entire active land volcano inventory with a time scale of days to weeks.**	**Temperature, composition and extent of erupted volcanic materials, including gases.**	
S-2b	Assess surface deformation (<10 mm), **extent of surface change (<100 m spatial resolution) and atmospheric contamination, and the composition and temperature of volcanic products following a volcanic eruption (hourly to daily temporal sampling).**	**Gases (CO_2, SO_2, H_2S, H_2O), ash, surface composition, lava flows & lakes, thermal emissions** (gases from direct emissions and their effects in volcanic lakes)	USGS, BLM, NPS, FEMA, USAID, SDR, WOVO, NOAA, commercial partners (technology, re-insurance), NGOs Integrating Themes (objectives): H-4; E-1b, E-1d; W-2a, W-4a, W-5a, W-6a
S-2a	Rapidly capture the transient processes following disasters for improved predictive modeling, as well as response and mitigation through op… analysis of space data. (not listed)		
S-4b	Quantify weather events, surface hy… changes in ice/water content of nea… that produce landscape change.		…FEMA, NOAA, EPA, WMO, USDA …ting Themes (objectives): …, H-1c, H-2a, H-3b, H-4a-d; E-1b, E-1d-e, E-3a, E-4a, E-5a-c; C-2e; W-1a, W-3a, W-4a
S-4c	Quantify ecosystem response to and causes of landscape change.	Biomass extent, composition, health; species composition, carbon stocks, nutrient composition, wildfire history	
S-7a	Map topography, surface mineralogic composition/ distribution, thermal properties, soil properties/water content, and solar irradiance for improved development and management of energy, mineral, agricultural, and natural resources	30-m or better hyperspectral VSWIR imaging, and TIR data	USGS, BLM, USDA, NPS, EPA, USDA, commercial partners (resources). Integrating Themes (objectives): H-1ª, H-4a; E-1b, E-3a, E-5b

How to understand & reconcile these observation frequency needs?

Volcanoes

Societal Challenge: globally, > 450 volcanoes with on-going eruptions/activity + increasing human population that could be severely impacted.

Opportunity: CO_2 & SO_2 precursor detection that is *global, targeted, and at variable frequency would enable improved forecasting, detection, and response to volcanic activity to minimize loss of property and life, and understand post-eruption impacts*

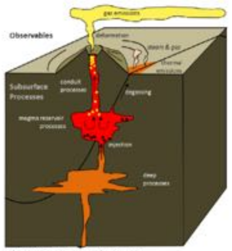
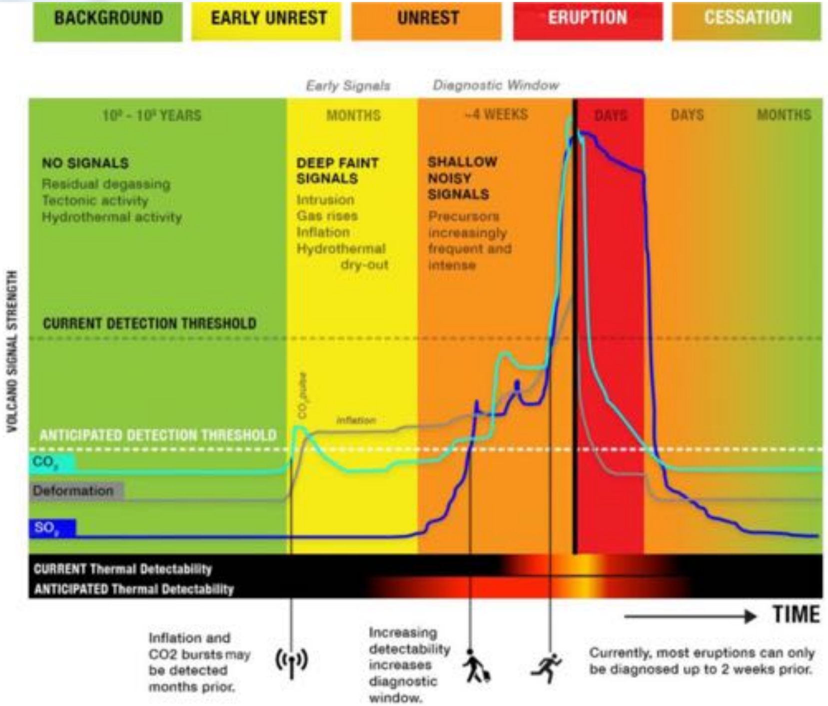


Fig. 1. Volcanoes give surface signals, which reflect subsurface processes.

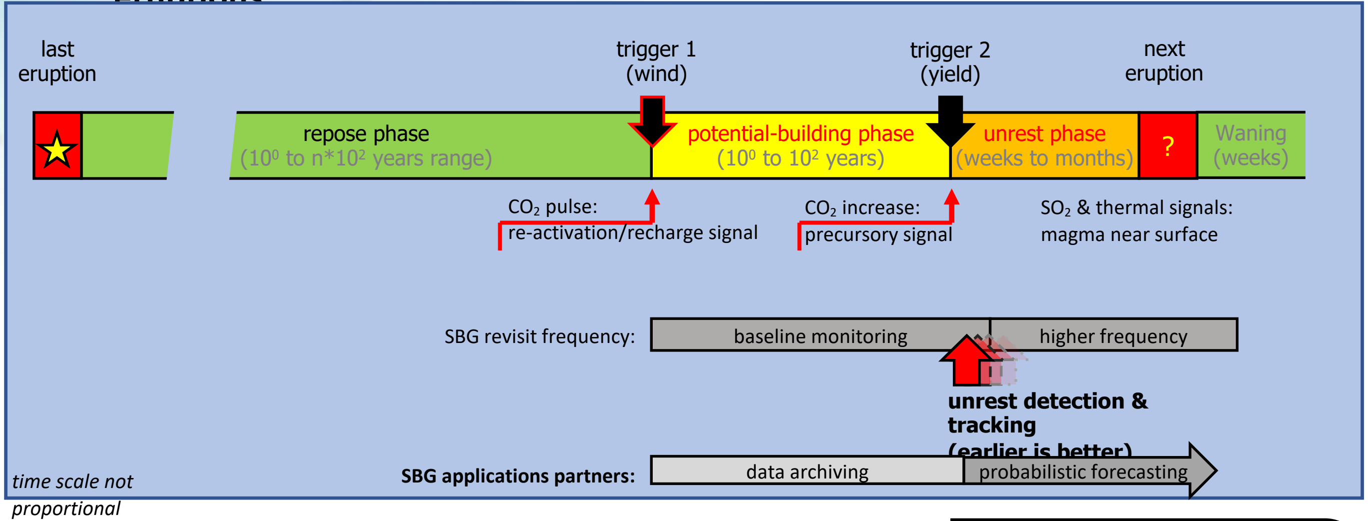


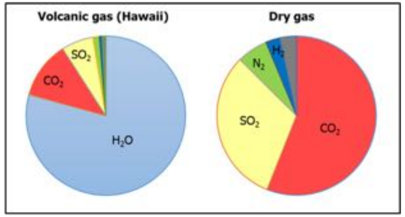
Observatories conduct background monitoring	Observatories under heightened alert &

Decision relevant information from SBG:
Unrest detection & confirmation based on observables;
Decision support data from observables

From: D. Pieri, F. Schwandner, V. Realmuto, P. Lundgren, S. Hook, K. Anderson, A. Miklius, J. Pallister, M. Poland, S. Self, S. de Silva, P. Webley, F. Sigmundsson, M. Pritchard, F. Prata, L. Pulgar, P. Mouginis-Mark, A. Gillespie, A. Diaz, M. Buongiorno.
Enabling a global perspective for deterministic modeling of volcanic unrest. NASA JPL led community whitepaper, 2015.

S-1a. Volcano applications: observations before, during, and after eruptions





Volcanic CO_2 & SO_2 [S-1a "Most Important"]

Application partners:
Volcano observatories (>150 globally) do: monitoring & hazards assessment, monitoring on the ground, conduct probabilistic forecasts, issue alert levels, and recommend mitigating actions like evacuations.

Geological Hazards / Disasters: Landslide Risk

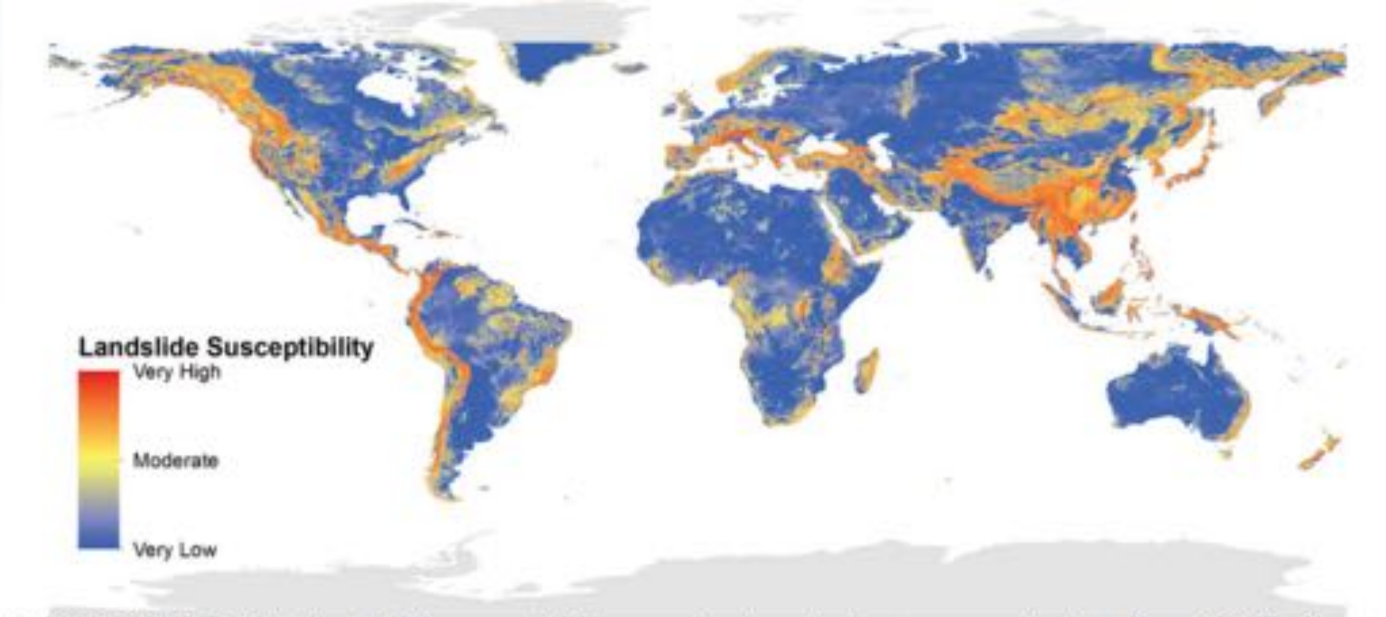


FIGURE 10.12 Global landslide susceptibility map developed using topography data from SRTM, forest loss information from Landsat, and other geophysical variables. SOURCE: Stanley and Kirschbaum (2017).

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Terrestrial Ecosystems – Wildfires and Restoration

A PRIORITIZED PROGRAM FOR SCIENCE, APPLICATIONS, AND OBSERVATIONS 135

Surface Biology and Geology

Earth Science/Applications Objectives for the Designated Targeted Observable: Surface Biology and Geology

	Most Important	Very Important	Important
Hydrology	1c	2a, 4a	2b, 3a, 3b, 3c, 4c, 4d
Weather		3a	
Ecosystems	1c, 2a, 3a	1a	1d, 5a, 5b, 5c
Climate		3a	3c, 3d, 6b, 7e, 8f
Solid Earth	1a	1c, 2b	4b, 4c, 7a

The Surface Biology and Geology Targeted Observable, corresponding to TO-18 in the Targeted Observables table (Appendix C), enables improved measurements of Earth's surface characteristics that provide valuable information on a wide range of Earth System processes associated with geological dynamics and terrestial and marine ecosystem changes. Society is closely tied to the land surface for habitation, food, fiber, and many other natural resources. The land surface, inland, and near-coastal waters are changing rapidly due to direct human activities as well as natural climate variability and climate change. New opportunities arising from enhanced satellite remote sensing of Earth's surface provide multiple benefits for managing agriculture and natural habitats, water use and water quality, and urban development, as well as understanding and predicting geological natural hazards. The Surface Biology and Geology observable is linked to one or more Most Important or Very Important science objectives from each panel and feeds into the three ESAS 2017 integrating themes: water and energy cycle, carbon cycle, and extreme events.

- *Science Considerations*. This Targeted Observable will likely be addressed through hyperspectral measurements that support a multidisciplinary set of science and applications objectives. Visible and shortwave infrared imagery addresses multiple objectives: active surface geology (e.g., surface deformation, eruptions, landslides, and evolving landscapes); snow and ice accumulation, melting, and albedo; hazard risks in rugged topography; effects of changing land use on surface energy, water, momentum and carbon fluxes; physiology of primary producers; and functional traits of terrestrial vegetation and inland and near-coastal aquatic ecosystems. Thermal infrared imagery provides complementary information on ground, vegetation canopy, and water surface temperatures as well as ecosystem function and health. Depending on implementation specifics, the Targeted Observable may also contribute to hyperspectral open-ocean observation goals. However, such goals are met to a large degree by POR elements, in particular the hyperspectral PACE mission, and are not considered a priority for additional implementation (and thus are not recommended if they drive cost). Observations of the Earth's surface biology and geology, with the ability to detect detailed spectral signatures, provide a wide range of opportunities for Earth system science parameters across most of the panels and integrating themes. As such, this Targeted Observable maps to some of the highest panel priorities as well as the Integrating Themes.
- *Candidate Measurement Approaches*. High spectral resolution (or hyperspectral) imagery provides the desired capabilities to address important geological, hydrological, and ecological questions, building on a successful history of past and ongoing multispectral remote sensing (e.g., MODIS). Consequently, hyperspectral imagery with moderate spatial resolution (30-60 m) is identified as a priority for implementation.
- *CATE Evaluation*. The CATE evaluation considered the Hyperspectral Infrared Imager (HyspIRI) concept, which was developed by NASA Science Mission Directorate following a recommendation

Decadal Survey

Global forest mapping……

"Fire is one of the largest sources of forest loss and also one of the biggest unknowns for the future." p.101

- Accurately characterizing the levels of air pollution exposure globally, and developing effective strategies to mitigate the risks, relies on a combination of satellite information, atmospheric models, and ground-based observations, and an understanding of the dynamics of the boundary layer and atmospheric transport.

Marine and Terrestrial Ecosystems and Natural Resource Management

Land and ocean ecosystems are essential to human well-being, providing food, timber, fiber, and many other natural resources. Healthy ecosystems also help support clean air, clean water, and biodiversity among a wide range of benefits often referred to as "ecosystem services." Ecosystems play a pivotal role in the planet's cycling of carbon, nutrients, and water as well as energy exchange with the atmosphere. One key aspect is the removal of excess carbon dioxide by the ocean and land biosphere, acting to slow the buildup in the atmosphere of a major greenhouse gas. Ecosystem questions are thus closely related to climate, weather, hydrology, and solid Earth questions.

Information on ecosystems, and how they are changing over time, is increasingly relevant to decision making by individuals, businesses, and governments. In part, this decision-making need reflects the fact that human activities and ecosystems are so often closely intertwined. Many ecosystems are directly managed by people: croplands and rangelands for agriculture; forests harvested for timber; wetlands and coasts used for fishing, aquaculture, and protection from flooding; and coral reefs that support valuable tourism and recreation industries. The boundary between natural and managed ecosystems is becoming more blurred with time. For example, the threat of wildfires is changing with time, because of past land management decisions, because of choices about investments in suppression, and because communities commonly begin to abut forests and rangeland as they grow.

The Ecosystems Panel identified 15 science and application objectives corresponding to 5 questions. Priorities related broadly to the composition and dynamics of both land and freshwater/marine ecosystems, and how composition and dynamics are evolving with time in response to human and natural perturbations. Several of the priority ecosystem objectives spring from a growing body of evidence that ecosystem function depends in a variety of ways on vegetation and plankton composition, how the ecosystem is organized in space, and the factors governing photosynthesis or primary production. Five central interrelated objectives, four identified as Most Important and one as Very Important, are summarized here:

- *(E-1a) Distribution.* Quantify the distribution of the functional traits, functional types, and composition of terrestrial and shallow aquatic vegetation and marine biomass, spatially and over time.
- *(E-1b) Structure.* Quantify the three-dimensional (3D) structure of terrestrial vegetation and 3D distribution of marine biomass within the euphotic zone, spatially and over time.
- *(E-1c) Primary Production.* Quantify the physiological dynamics of terrestrial and aquatic primary producers.
- *(E-2a) Fluxes of CO_2 and CH_4.* Quantify the fluxes of CO_2 and CH_4 globally at spatial scales of 100 to 500 km and monthly temporal resolution with uncertainty <25 percent between land ecosystems and atmosphere and between ocean ecosystems and atmosphere.
- *(E-3a) Flows Sustaining Ecosystem Life Cycles.* Quantify the flows of energy, carbon, water, nutrients, and so on, sustaining the life cycle of terrestrial and marine ecosystems and partitioning into functional types.

Remote sensing has allowed for bulk measures of land vegetation cover (Box 3.5) and phytoplankton biomass (Box 2.8, in Chapter 2) as well as the rate of primary production. Only recently, however, has

Earth Surface and Interior: Dynamics and Hazards

(2) characterization of the precursors, impacts,
and key thresholds of disruptive events (e.g., volcanic eruptions or wildfires); (

(S-2a) Response to Disasters. Rapidly capture the transient processes following disasters for improved
predictive modeling, as well as for response and mitigation through optimal retasking and analysis
of space data.

Landscape Change:
In addition, much more abrupt changes in landscapes due to wildfire, earthquakes, landslides,
floods, deforestation, urbanization, and agricultural practices can be uniquely quantified as a time series of
change using sustained and continual satellite observations

SBG Applications Working Group

Questions

E-1. Ecosystem Structure, Function, and Biodiversity. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?

E-2. Fluxes Between Ecosystems, Atmosphere, Oceans, and Solid Earth. What are the fluxes (of carbon, water, nutrients, and energy) between ecosystems and the atmosphere, the ocean, and solid Earth, and how and why are they changing?

E-3. Fluxes Within Ecosystems. What are the fluxes (of carbon, water, nutrients, and energy) within ecosystems, and how and why are they changing?

E-5. Carbon Sinks. Are carbon sinks stable, are they changing, and why?

TABLE C.1 (Continued)

Targeted Observable	Science and Applications Summary	Science/Applications Priorities by Panel[a]			
			MI	VI	I
TO-18 Surface Biology and Geology	- Surface geology and biology - Active geologic processes - Ground and water temperature - GPP - Snow spectral albedo - Functional traits of terrestrial vegetation and inland and near-coastal aquatic ecosystems	H	1c	2a, 4a	2b, 3a, 3b, 3c, 4c, 4d
		W		3a	
		E	1c, 2a, 3a	3a	1d, 5a, 5b, 5c
		C		3a	3c, 3d, 6b, 7e, 8f
		S	1a	1c, 2b	4b, 4c, 7a
TO-19 Surface Deformation and Change	- Surface change monitoring - Ice-sheet dynamics - Antarctic grounding line - Permafrost thaw subsidence	H	1c, 2c	4a	4b
		W			
		E			
		C	1c		7b, 8f
		S	1a, 1b, 2a, 3a, 3b, 4a	1c, 2b, 2c, 5a, 6a	4b, 6b, 6c, 6d, 7a
TO-20 Surface Topography and Vegetation	- Bare surface land topography - Ice topography - Vegetation structure - Shallow water bathymetry	H	2c		2b, 3c, 4b, 4d
		W		3a	
		E	1b		1e
		C	1c		8f
		S	1a, 1b, 3a, 3b, 4a	1c, 2b, 2c	1d, 4b, 4c, 6b, 7a
TO-21 Surface Water Height	- Horizontal structure of ocean surface height - Two-dimensional geostrophic velocities - Bathymetry/gravity - Significant wave height - Tsunami height - Inland waters/ecosystems - Tides and dissipation of tidal energy - Sea-ice thickness - River flow and terrestrial water storage - River height variations for transport of material from land to ocean	H	1c		
		W		3a	
		E			
		C	1a, 1b	1d, 4a, 6a, 7a, 8a, 8b, 8c	4b, 8g, 8i
		S	3a		1d

SBG Terrestrial Ecosystems: Wildfires and Restoration

Societal or Science Question related to Wildfires and Restoration:

E-1. Ecosystem Structure, Function, and Biodiversity. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?
E-2. Fluxes Between Ecosystems, Atmosphere, Oceans, and Solid Earth. What are the fluxes (of carbon, water, nutrients, and energy) between ecosystems and the atmosphere, the ocean, and solid Earth, and how and why are they changing?
E-3. Fluxes Within Ecosystems. What are the fluxes (of carbon, water, nutrients, and energy) within ecosystems, and how and why are they changing?
E-5. Carbon Sinks. Are carbon sinks stable, are they changing, and why?

Also several Global Hydrological Cycles & Water Resources Questions (H-2, H-3, H-4) and Earth Surface & Interior Questions(S-2, S-4)

SBG Applications Working Group

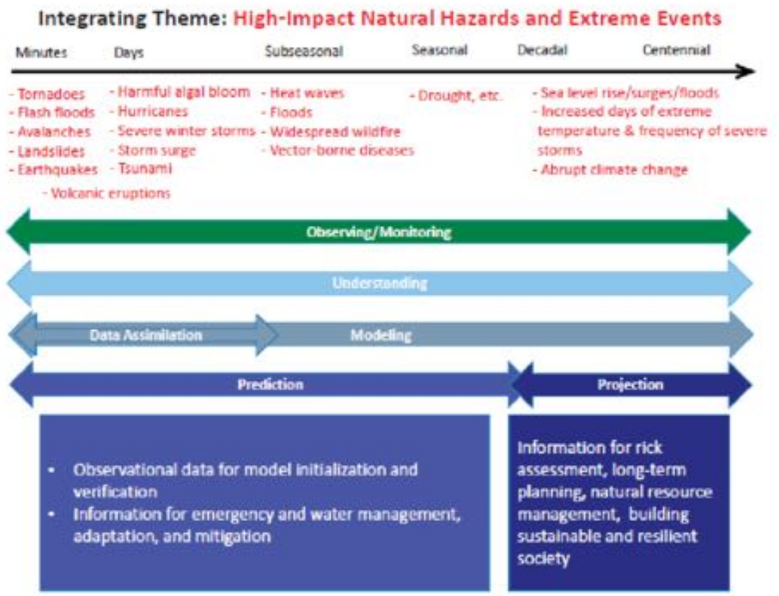


FIGURE 3.8.1 High-impact weather-climate extreme events occur on time scales from minutes to centuries and beyond. Observing, monitoring, and predicting these complex extreme events requires an integrated Earth system approach with interdisciplinary and transdisciplinary innovations to advance our capability to better understand and predict them and prevent natural hazards from becoming human disasters. This chart shows how Earth system observations, modeling, and data assimilation can be best used together for building a weather-climate prediction and long-term projection system to inform decision-making processes in response to natural hazards and to meet societal needs.

SBG Functional Traits/Dynamics/Disturbance and Recovery

E1C:Quantify the physiological dynamics of terrestrial primary producers

Pre-fire Fuels (Loads, Condition, Types) and Moisture content (Also E1A)

E-2a. Quantify the fluxes of CO_2 and CH_4 globally at spatial scales of 100 to 500 km

Fuel Loads and Condition, Active Fire Products

E-3a. Quantify the flows of energy, carbon, water, nutrients … sustaining the life cycle of terrestrial ecosystems and partitioning into functional types

Active Fire Products, Post-fire Severity, Post-fire Recovery

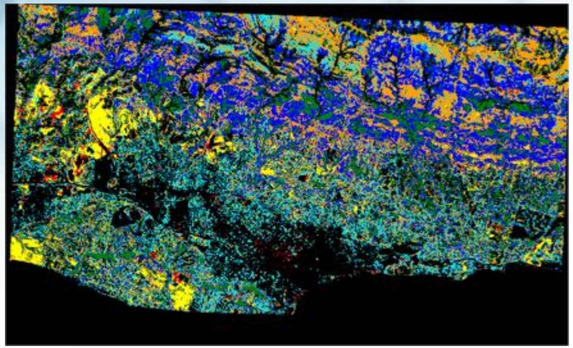
E-5b. Discover cascading perturbations in ecosystems related to carbon storage.

Pre-fire Fuels, Drought, Biotic Attack (Bark Beetles)

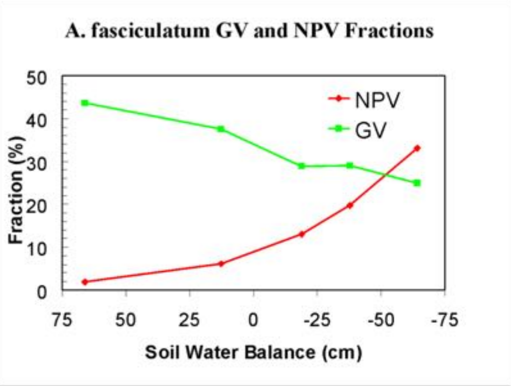
H-4d. Understand linkages between anthropogenic modification of the land, including fire suppression, land use, and urbanization, on frequency of and response to hazards.

Burned Area, Fire Severity, Post-fire Recovery

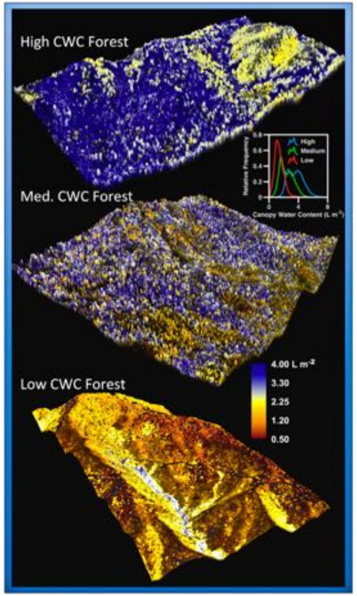
Pre-fire Fuels (and Moisture content: E1C/E1A)



Plant Species/Fuel Types
Dennison and Roberts, 2003

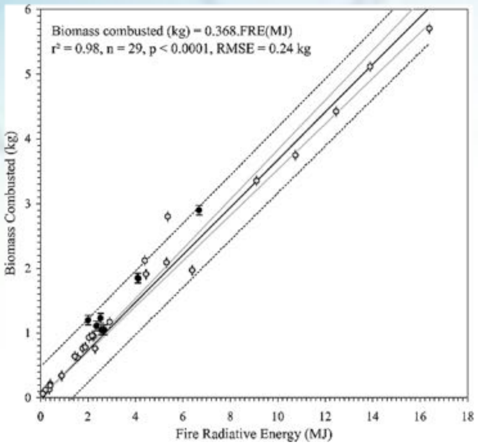


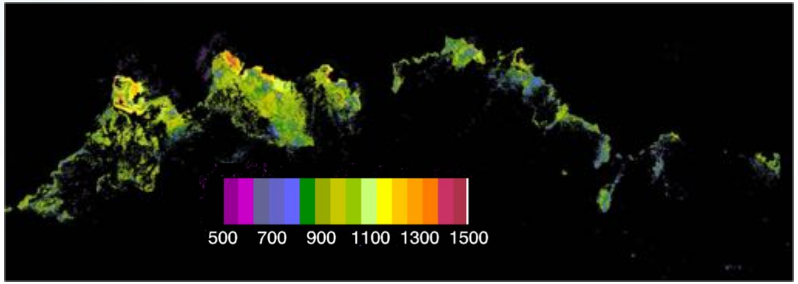
Changing Fuel Condition

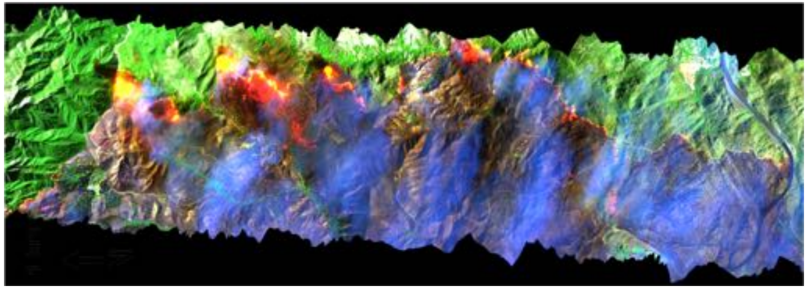


Measures of canopy moisture
During the California Drought
Asner et al., (2016)

Active Fire Products: (E2A/E3A)







Fire Radiative Power (Wooster et al., 2005)

Near linear relationship between biomass Consumed and FRP

$$FRP = 4.34 \times 10^{-19}\ \mathrm{W\ m^{-2}\ K^{-8}}\ [(T4)^8 - (T4_b)^8]$$

T4 = brightness temperature of hot pixel

T4b = brightness temperature, cool background

AVIRIS-derived Fire Temperature and Fractional area: Dennison et al., (2006)

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Needs: Fire Severity, Post Fire Recovery

Beetle mortality

Drought impacts, Seasonal Dynamics

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6/7/2019	Aquatic Ecosystems - Corals, Harmful Algal Blooms, Water Quality, Restoration	Maria Tzortziou and Stephanie Uz / Christine Lee

Terrestrial Ecosystems – Carbon Accounting and Conservation

The Surface Biology and Geology Targeted Observable, corresponding to TO-18 in the Targeted Observables table (Appendix C), enables improved measurements of Earth's surface characteristics that provide valuable information on a wide range of Earth System processes associated with geological dynamics and terrestial and marine ecosystem changes. Society is closely tied to the land surface for habitation, food, fiber, and many other natural resources. The land surface, inland, and near-coastal waters are changing rapidly due to direct human activities as well as natural climate variability and climate change. New opportunities arising from enhanced satellite remote sensing of Earth's surface provide multiple benefits for managing agriculture and natural habitats, water use and water quality, and urban development, as well as understanding and predicting geological natural hazards. The Surface Biology and Geology observable is linked to one or more Most Important or Very Important science objectives from each panel and feeds into the three ESAS 2017 integrating themes: water and energy cycle, carbon cycle, and extreme events.

- *Science Considerations*. This Targeted Observable will likely be addressed through hyperspectral measurements that support a multidisciplinary set of science and applications objectives. Visible and shortwave infrared imagery addresses multiple objectives: active surface geology (e.g., surface deformation, eruptions, landslides, and evolving landscapes); snow and ice accumulation, melting, and albedo; hazard risks in rugged topography; effects of changing land use on surface energy, water, momentum and carbon fluxes; physiology of primary producers; and functional traits of terrestrial vegetation and inland and near-coastal aquatic ecosystems. Thermal infrared imagery provides complementary information on ground, vegetation canopy, and water surface temperatures as well as ecosystem function and health. Depending on implementation specifics, the Targeted Observable may also contribute to hyperspectral open-ocean observation goals. However, such goals are met to a large degree by POR elements, in particular the hyperspectral PACE mission, and are not considered a priority for additional implementation (and thus are not recommended if they drive cost).

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Decadal Survey

within three primary topic areas that remote sensing can contribute to in the coming decade. Those broad topic areas are (1) structure, function, and biodiversity; (2) fluxes of carbon, water, nutrients, and energy; and (3) carbon accounting, monitoring, and management.

Understanding the composition, structure, and functioning of ecosystems is essential to understanding the services they provide and how they are changing. The functional traits of terrestrial plants (structure, physiology, phenology, reproduction, and biochemistry) determine the patterns of energy, carbon, water, and nutrient fluxes for terrestrial ecosystems, and they provide a direct, mechanistic link to biological diversity. The same holds true for coastal and shallow aquatic ecosystems. The structure of marine ecosystems

SBG Terrestrial Ecosystems: Conservation and Carbon

Societal or Science Question related to Wildfires and Restoration:

E-1. Ecosystem Structure, Function, and Biodiversity. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?
E-2. Fluxes Between Ecosystems, Atmosphere, Oceans, and Solid Earth. What are the fluxes (of carbon, water, nutrients, and energy) between ecosystems and the atmosphere, the ocean, and solid Earth, and how and why are they changing?
E-3. Fluxes Within Ecosystems. What are the fluxes (of carbon, water, nutrients, and energy) within ecosystems, and how and why are they changing?
E-4 Carbon Accounting. How is carbon accounted for through carbon storage, turnover, and accumulated biomass? Have all of the major carbon sinks been quantified, and how are they changing in time?
E-5. Carbon Sinks. Are carbon sinks stable, are they changing, and why?

Terrestrial Ecosystems: Conservation
Application example: Mapping Alien Invasive Plants Species

DS Question: E-1. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?

Focused science topic: Ecosystem traits and biodiversity - terrestrial

Decision Approach: Map alien invasive plant species for eradication and post-treatment monitoring. Distinguish alien species from indigenous species.

Tamarisk NASA GSFC

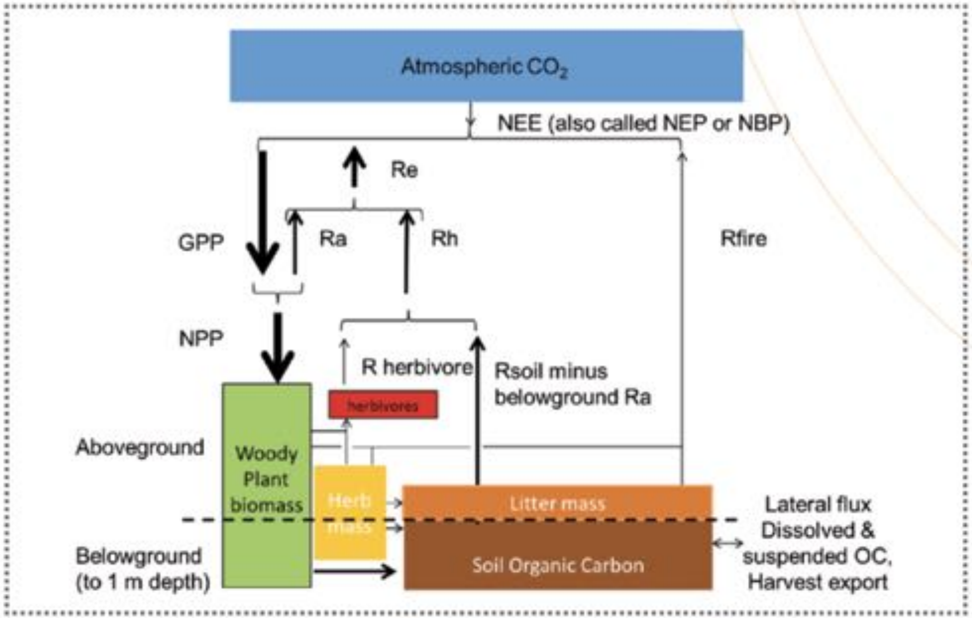
Products:
L3/L4 - Invasive Species Mapping
L3 - Vegetation Functional Traits
L2 - Surface Reflectance
L4 - Local Species maps

Users: BLM, NRCS, FWS, NPS, USDA, USFS?

Spatial resolution: 20-30m

Temporal: 90-120 days

Terrestrial Ecosystems: Carbon



National Terrestrial Carbon Sink Assessment (2015) Department of Environmental Affairs, Pretoria, South Africa.

Applications Traceability Matrix for Conservation and Carbon include:

•Insect infestations / Diseases
•Precision conservation – endangered habitat mapping
•Alien Invasive plants mapping
•Rangeland quality monitoring for livestock and wildlife
•Monitoring Reporting and Verification (MRV) of carbon stocks and change
•Attribution of forest biomass change: degradation, regrowth, afforestation, shrub encroachment.
•Estimating GHG emissions from land cover changes
•Measuring ecosystem function, FPAR, GPP, NPP

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Public Health and Urban Environments

TABLE 3.2 Continued

GLOBAL HYDROLOGICAL CYCLES AND WATER RESOURCES PANEL

Societal or Science Question/Goal	Earth Science/Applications Objective	Science/ Applications Importance
QUESTION H-2. How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally, and globally, and what are the short- and long-term consequences?	**H-2a.** Quantify how changes in land use, water use, and water storage affect evapotranspiration rates, and how these in turn affect local and regional precipitation systems, groundwater recharge, temperature extremes, and carbon cycling.	Very Important
	H-2b. Quantify the magnitude of anthropogenic processes that cause changes in radiative forcing, temperature, snowmelt, and ice melt, as they alter downstream water quantity and quality.	Important
	H-2c. Quantify how changes in land use, land cover, and water use related to agricultural activities, food production, and forest management affect water quality and especially groundwater recharge, threatening sustainability of future water supplies.	Most Important
QUESTION H-3. How do changes in the water cycle impact local and regional freshwater availability, alter the biotic life of streams, and affect ecosystems and the services these provide?	**H-3a.** Develop methods and systems for monitoring water quality for human health and ecosystem services.	Important
	H-3b. Monitor and understand the coupled natural and anthropogenic processes that change water quality, fluxes, and storages in and between all reservoirs (atmosphere, rivers, lakes, groundwater, and glaciers) and the response to extreme events.	Important
	H-3c. Determine structure, productivity, and health of plants to constrain estimates of evapotranspiration.	Important
QUESTION H-4. How does the water cycle interact with other Earth system processes to change the predictability and impacts of hazardous events and hazard chains (e.g., floods, wildfires, landslides, coastal loss, subsidence, droughts, human health, and ecosystem health), and how do we improve preparedness and mitigation of water-related extreme events?	**H-4a.** Monitor and understand hazard response in rugged terrain and land margins to heavy rainfall, temperature, and evaporation extremes, and strong winds at multiple temporal and spatial scales.	Very Important
	H-4b. Quantify key meteorological, glaciological, and solid Earth dynamical and state variables and processes controlling flash floods and rapid hazard chains to improve detection, prediction, and preparedness. (This is a critical socioeconomic priority that depends on success of addressing H-1c and H-4a.)	Important
	H-4c. Improve drought monitoring to forecast short-term impacts more accurately and to assess potential mitigations.	Important
	H-4d. Understand linkages between anthropogenic modification of the land, including fire suppression, land use, and urbanization on frequency of, and response to, hazards. (This is tightly linked to H-2a, H-2b, H-4a, H-4b, and H-4c.)	Important

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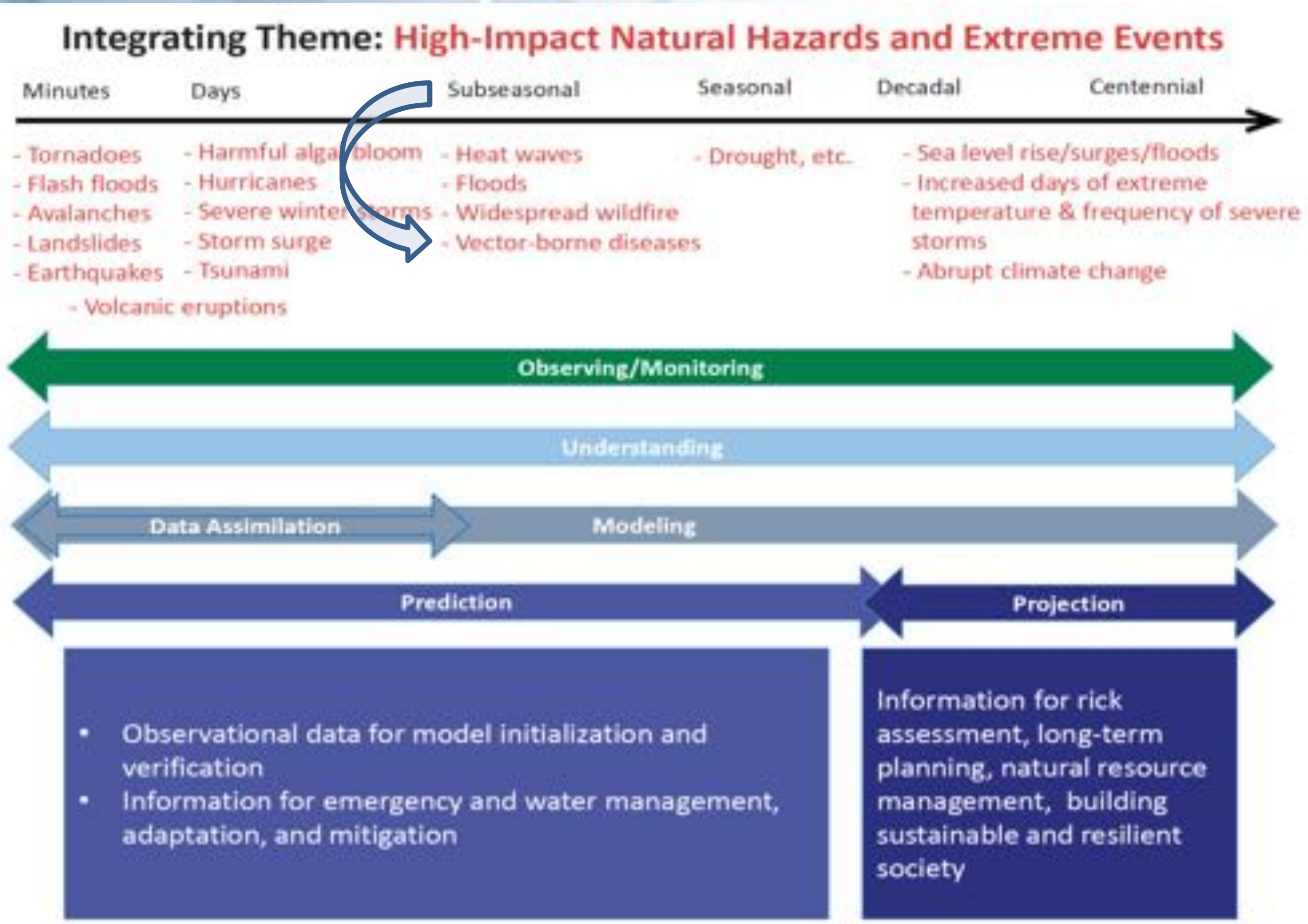

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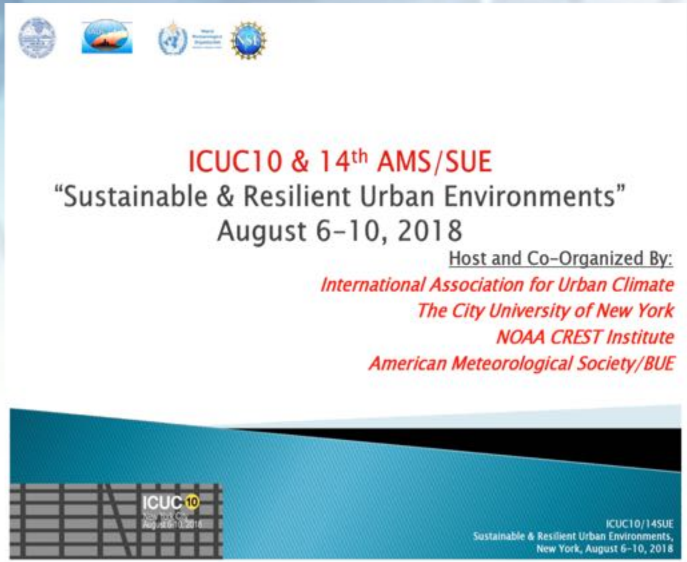

SCIENCE QUESTIONS of interest to the WG

- *Q1*. How can we effectively observe, predict, and model both 3-D near surface atmospheric turbulence at multiple scales under mean and extreme conditions, as well as its associated planetary boundary layer (PBL) variables, and how are these influenced by the unique topological and energetic surface heterogeneity characteristic of complex cities?
- *Q2*. How can we use these observations and models to gain an improved understanding of the diurnal cycle of environmental flows in a range of natural and urban systems, including tropical, subtropical, and cold climate, and how can this understanding serve to advance near-term weather forecasting and long-term climate forecasting under extreme conditions?
- *Q3*. How can we exploit the participation of a large number of concerned citizens and urban stakeholders in the collection of disaggregated information about urban ecosystems, and then in the prediction of behavioral changes resulting from environmental changes?
- *Q4*. How can these advanced short- and long-term forecasting tools be leveraged to enhance human wellbeing (re air and water quality, human health, energy demands, and urban planning) and ecosystem responses in cities?
- *Q5*. How can this advanced knowledge be translated into useful and actionable information for: resilient urban planning and policy, improving health conditions, and to enable technological and economic development?

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Recommendation 3.1: NASA, NOAA, and USGS, working in coordination, according to their appropriate roles and recognizing their agency mission and priorities, should implement an integrated programmatic approach to advancing Earth science and applications that is based on the questions and objectives listed in Table 3.2, "Science and Applications Priorities for the Decade 2017-2027."

A major component of the committee's observing program recommendations is a commitment to a set of observation capabilities, outlined in the next section that will enable substantial progress in all of the following science and applications areas:

• Providing critical information on the make-up and distribution of aerosols and clouds, which in turn improve predictions of future climate conditions and help us assess the ***impacts of aerosols on human health***;
• Addressing key questions about how changing cloud cover and precipitation will affect climate, weather, and Earth's energy balance in the future, advancing understanding of the movement of air and energy in the atmosphere and its impact on weather, precipitation, and severe storms;
• Determining the extent to which the shrinking of glaciers and ice sheets, and their contributions to sea-level rise, is accelerating, decelerating, or remaining unchanged;
• Quantifying trends in water stored on land (e.g., in aquifers) and the implications for issues such as water availability for human consumption and irrigation;
• Understanding alterations to surface characteristics and landscapes (e.g., snow cover, snowmelt, landslides, earthquakes, eruptions, ***urbanization,*** land-cover, and land use) and the implications for applications such as risk management and resource management;
• Assessing the evolving characteristics and health of terrestrial vegetation and aquatic ecosystems, which is important for understanding key consequences such as crop yields, carbon uptake, and biodiversity; and
• Examining movement of land and ice surfaces to determine, in the case of ice, the likelihood of rapid ice loss and significantly accelerated rates of sea-level rise, and in the case of land, changes in strain rates that impact and provide critical insights into earthquakes, volcanic eruptions, landslides, and tectonic plate deformation.

Decadal Survey

TABLE 3.2 Continued

GLOBAL HYDROLOGICAL CYCLES AND WATER RESOURCES PANEL

Societal or Science Question/Goal	Earth Science/Applications Objective	Science/ Applications Importance
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	H-2b. Quantify the magnitude of anthropogenic processes that cause changes in radiative forcing, temperature, snowmelt, and ice melt, as they alter downstream water quantity and quality.	Important
	H-2c. Quantify how changes in land use, land cover, and water use related to agricultural activities, food production, and forest management affect water quality and especially groundwater recharge, threatening sustainability of future water supplies.	Most Important
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	H-3c. Determine structure, productivity, and health of plants to constrain estimates of evapotranspiration.	Important
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	H-4c. Improve drought monitoring to forecast short-term impacts more accurately and to assess potential mitigations.	Important
	H-4d. Understand linkages between anthropogenic modification of the land, including fire suppression, land use, and urbanization on frequency of, and response to, hazards. (This is tightly linked to H-2a, H-2b, H-4a, H-4b, and H-4c.)	Important

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WEATHER AND AIR QUALITY PANEL

QUESTION W-5. What processes determine the spatiotemporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?	**W-5a.** Improve the understanding of the processes that determine air pollution distributions and aid estimation of global air pollution impacts on human health and ecosystems by reducing uncertainty to <10% of vertically resolved tropospheric fields (including surface concentrations) of speciated particulate matter (PM), ozone (O_3), and nitrogen dioxide (NO_2).	Most Important

Decadal Survey

TABLE 3.2 Continued

MARINE AND TERRESTRIAL ECOSYSTEMS AND NATURAL RESOURCES MANAGEMENT PANEL

Societal or Science Question/Goal	Earth Science/Applications Objective	Science/ Application Importance
QUESTION E-1. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?[a]	**E-1a.** Quantify the distribution of the functional traits, functional types, and composition of terrestrial and shallow aquatic vegetation and marine biomass, spatially and over time.	Very Important
	E-1b. Quantify the global three-dimensional (3D) structure of terrestrial vegetation and 3D distribution of marine biomass within the euphotic zone, spatially and over time.	Most Important
	E-1c. Quantify the physiological dynamics of terrestrial and aquatic primary producers.	Most Important
	E-1d. Quantify moisture status of soils.	Important
	E-1e. Support targeted species detection and analysis (e.g., foundation species, invasive species, indicator species, etc.).	Important
QUESTION E-2. What are the fluxes (of carbon, water, nutrients, and energy) *between* ecosystems and the atmosphere, the ocean, and the solid Earth, and how and why are they changing?	**E-2a.** Quantify the fluxes of CO_2 and CH_4 globally at spatial scales of 100 to 500 km and monthly temporal resolution with uncertainty < 25% between land ecosystems and atmosphere and between ocean ecosystems and atmosphere.	Most Important
	E-2b. Quantify the fluxes from land ecosystems between aquatic ecosystems.	Important
	E-2c. Assess ecosystem subsidies from solid Earth.	Important
QUESTION E-3. What are the fluxes (of carbon, water, nutrients, and energy) *within* ecosystems, and how and why are they changing?	**E-3a.** Quantify the flows of energy, carbon, water, nutrients, and so on, sustaining the life cycle of terrestrial and marine ecosystems and partitioning into functional types.	Most Important
	E-3b. Understand how ecosystems support higher trophic levels of food webs.	Important
QUESTION E-4. How is carbon accounted for through carbon storage, turnover, and accumulated biomass. Have all of the major carbon sinks been qualified and how they are changing in time?	**E-4a.** Improve assessments of the global inventory of terrestrial carbon pools and their rate of turnover.	Important
	E-4b. Constrain ocean carbon storage and turnover.	Important
QUESTION E-5. Are carbon sinks stable, are they changing, and why?	**E-5a.** Discover ecosystem thresholds in altering carbon storage.	Important
	E-5b. Discover cascading perturbations in ecosystems related to carbon storage.	Important
	E-5c. Understand ecosystem response to fire events.	Important

Information Important for Public Health

- **High-resolution ≤30 m:** allows assessment of vector habitat suitability and municipality-level risk modeling of disease

- **For vector/infectious disease biology:**
  - Temperature
  - Precipitation
  - Soil Type (clay, loam, etc.)
  - Vegetation cover
  - Soil moisture

- **For vector expansion and disease epidemiology:**
  - Land use/cover change
  - Urban density
  - Urban expansion

- **Geospatial data is paired with socioeconomic and vector/disease prevalence data to:**
  - Create maps of current vector expansion/disease transmission
  - Create predictive risk models for vectors/infectious diseases

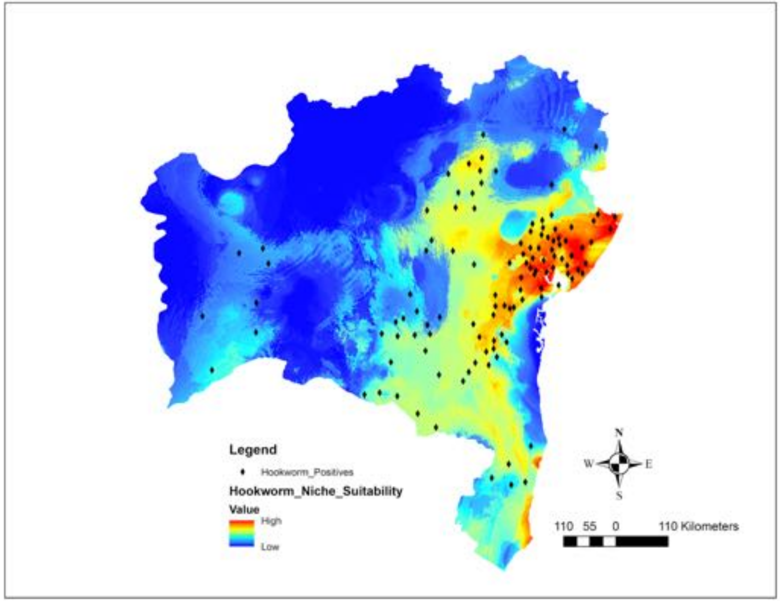
- **Used by Health Ministries and public policy-makers to:**
  - Alter land use and development procedures to combat vector expansion/disease transmission
  - Predict disease hotspots and target treatment and control interventions

Predictive Modeling Example

- **Predicting hookworm niche suitability in Bahia state, Brazil using Maximum Entropy Species Distribution Modeling (Maxent) software**

- **Model Variables:**
  - Hookworm prevalence data collected from 2000-2009
  - 19 Bioclimatic variables

- **Top contributing Bioclimatic variables to Maxent model:**
  - BIO4-Temperature Seasonality
  - BIO19-Precipitation of Coldest Quarter
  - BIO2-Mean Diurnal Range



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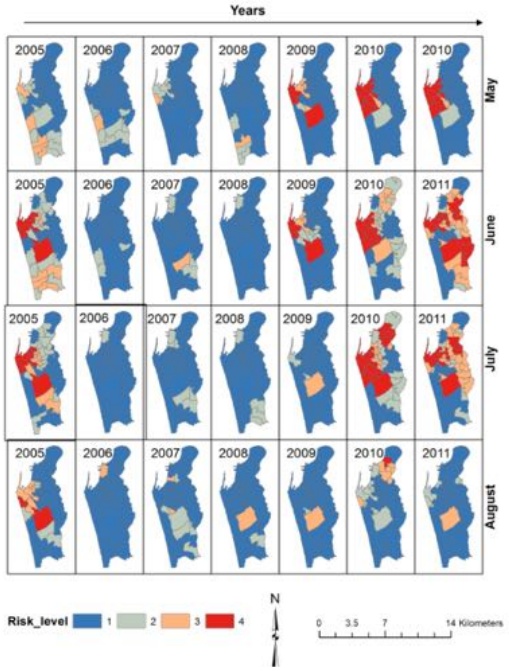
Terrestrial Ecosystems: Public Health and Urban Environment

Application example: Role of local environmental factors on dengue transmission

DS Question: H-2, H4d. Prediction of Changes, Hazards. How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally, and globally, and what are the short- and long-term consequences?

Focused Science Topic: Impact of urbanization along with climate variables, local environmental factors, such as the type of housing, housing density, and peri-urban and peri-domestic areas can provide favorable conditions for the breeding of dengue mosquitoes.

Decision Approach: Developing a dengue risk prediction model, that integrates data on environmental and socio-economic variables obtained from various sources within a GIS framework. Sources include, satellite imagery (LCLU, vegetation, surface energy budgets, etc), meteorological and census statistics.



Spatio-temporal monthly dengue risk models of the Gram Niladaris Divisions (GNDs), Colombo, Sri Lanka May - August, 2005 to 2011. Tipre 2014

Products:

L4 - Albedo

L3 - Vegetation - Impervious Surface Fraction

L3 - Evapotranspiration

L2 - Surface Reflectance

L2 - Land Surface Temperature

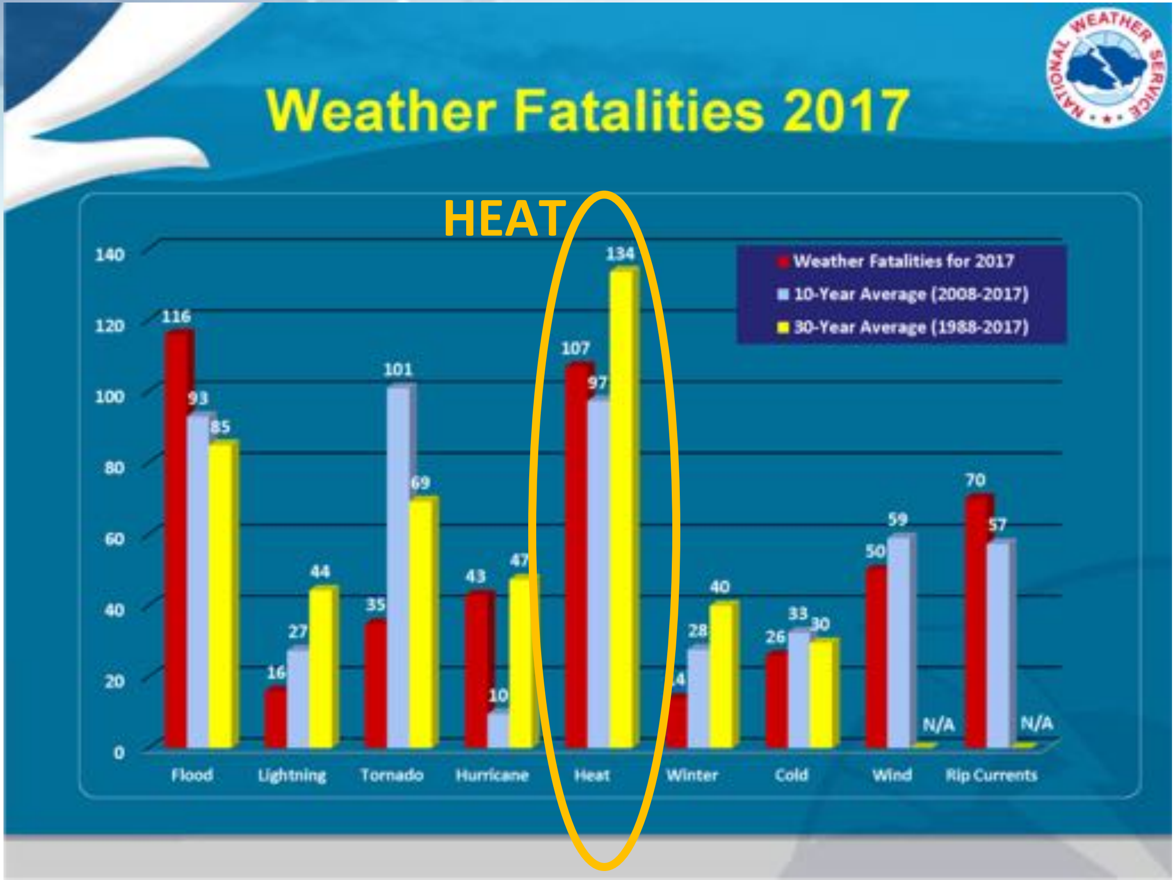
L2 - Land Surface Emissivity

L2- Land Cover-Land use

Spatial resolution: 20-50m

Temporal: 5-16 days

Users: Public Health departments, urban planners, epidemiological researchers



Source: http://www.nws.noaa.gov/om/hazstats.shtml

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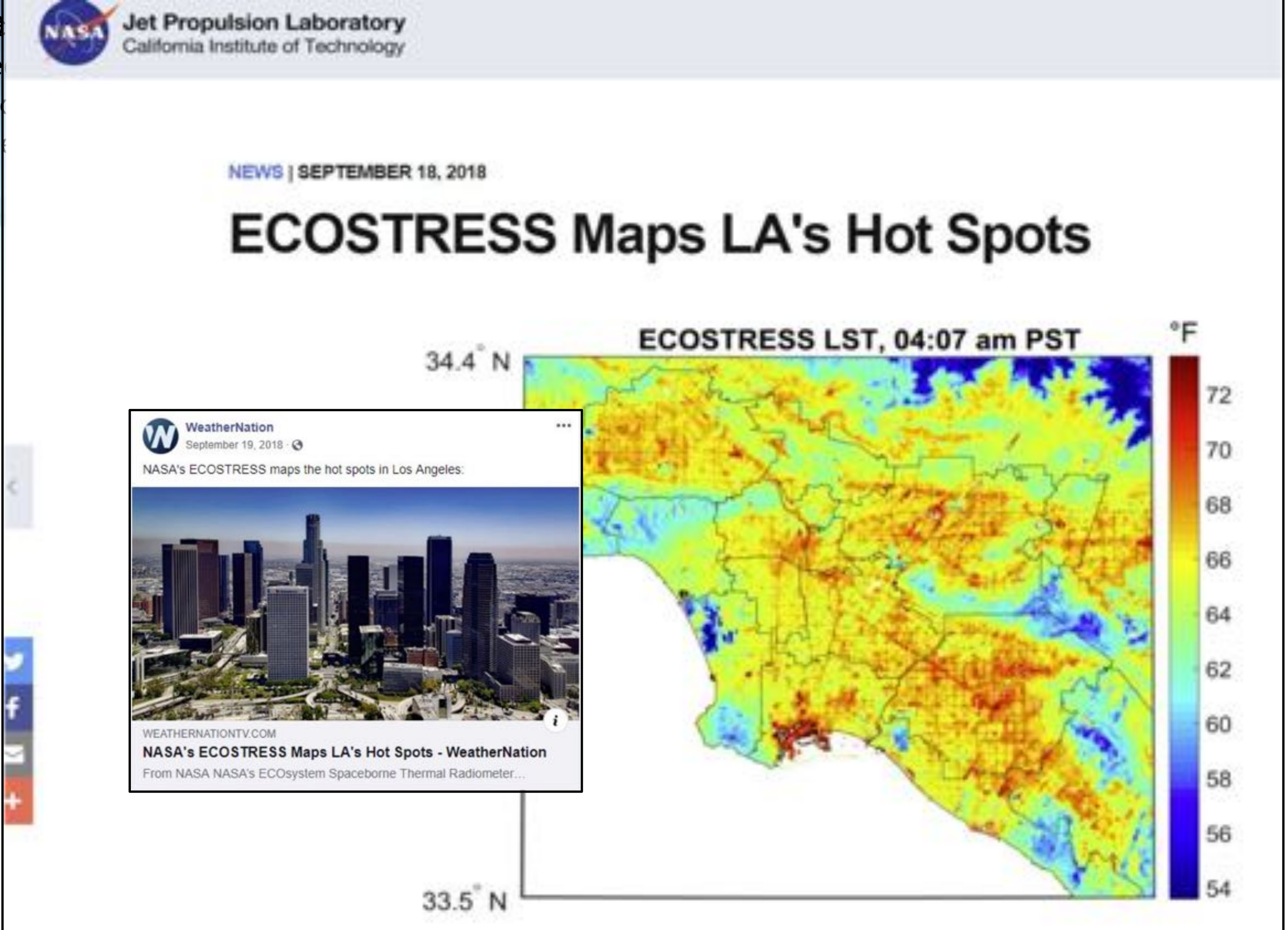
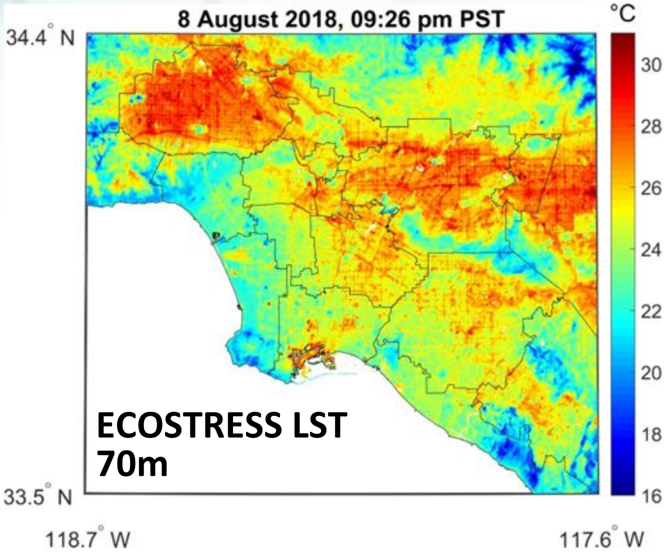
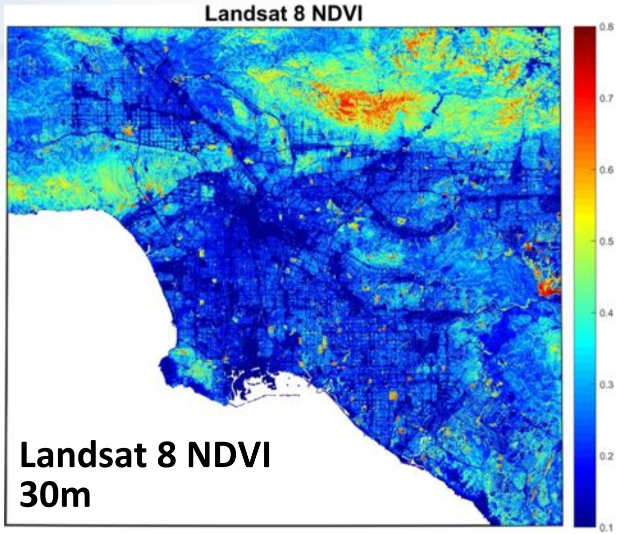
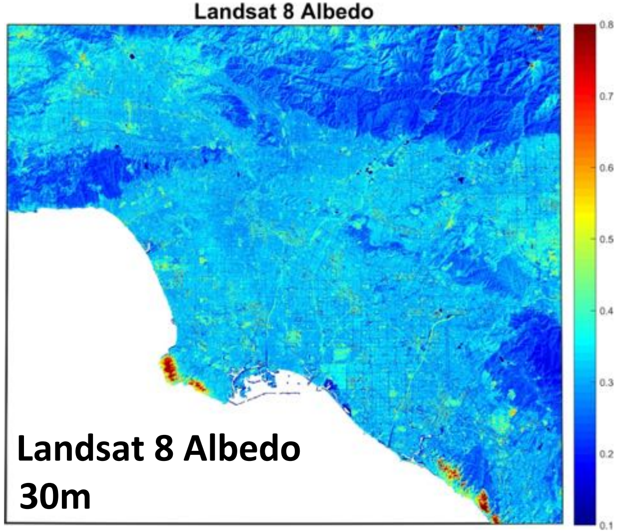


Are there physical relationships between LST, NDVI and Albedo over the urban environment?







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Panagiotis Sismanidis[3], Iphigenia Keramitsoglou[3]
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2. NASA Marshall Space Flight Center, Huntsville, AL
3. National Observatory of Athens, Athens, Greece

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Water Resources
Agriculture, Snow

Targeted Observable	Science/Applications Summary	Candidate Measurement Approach	Designated	Explorer	Incubation
Surface Biology and Geology	*Earth surface geology and biology,* ground/water temperature, snow reflectivity, active geologic processes, vegetation traits, and algal biomass	Hyperspectral imagery in the visible and shortwave infrared (IR), multi- or hyperspectral imagery in the thermal IR	X		

Surface Biology and Geology	CATE Cap $650 million	Key to understanding active surface changes (eruptions, landslides, and evolving landscapes); snow and ice accumulation, melting, and albedo; hazard risks in rugged topography; effects of changing land use on surface energy, water, momentum, and carbon fluxes; physiology of primary producers; and functional traits and health of terrestrial vegetation and inland and near-coastal aquatic ecosystems. Further contributes to managing agriculture and natural habitats, water use and water quality, and urban development as well as understanding and predicting geological natural hazards and land-surface interactions with weather and climate. Depending on implementation specifics, the Targeted Observable may also contribute to hyperspectral open-ocean observation goals. Addresses many "Most Important" objectives of the Ecosystem, Hydrology, and Solid Earth panels, and addresses key components of the Water and Energy Cycle, Carbon Cycle, and Extreme Events integrating themes.

Surface Biology and Geology

Earth Science/Applications Objectives for the Designated Targeted Observable: Surface Biology and Geology

	Most Important	Very Important	Important
Hydrology	1c	2a, 4a	2b, 3a, 3b, 3c, 4c, 4d
Weather		3a	
Ecosystems	1c, 2a, 3a	1a	1d, 5a, 5b, 5c
Climate		3a	3c, 3d, 6b, 7e, 8f
Solid Earth	1a	1c, 2b	4b, 4c, 7a

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H-1c. Quantify rates of snow accumulation, snowmelt, ice melt, and sublimation from snow and ice worldwide at scales driven by topographic variability.	Most Important
H-2a. Quantify how changes in land use, water use, and water storage affect evapotranspiration rates, and how these in turn affect local and regional precipitation systems, groundwater recharge, temperature extremes, and carbon cycling.	Very Important
H-4a. Monitor and understand hazard response in rugged terrain and land margins to heavy rainfall, temperature, and evaporation extremes, and strong winds at multiple temporal and spatial scales.	Very Important
H-2b. Quantify the magnitude of anthropogenic processes that cause changes in radiative forcing, temperature, snowmelt, and ice melt, as they alter downstream water quantity and quality.	Important
H-3a. Develop methods and systems for monitoring water quality for human health and ecosystem services.	Important
H-3b. Monitor and understand the coupled natural and anthropogenic processes that change water quality, fluxes, and storages in and between all reservoirs (atmosphere, rivers, lakes, groundwater, and glaciers) and the response to extreme events.	Important
H-3c. Determine structure, productivity, and health of plants to constrain estimates of evapotranspiration.	Important
H-4c. Improve drought monitoring to forecast short-term impacts more accurately and to assess potential mitigations.	Important
H-4d. Understand linkages between anthropogenic modification of the land, including fire suppression, land use, and urbanization on frequency of, and response to, hazards. (This is tightly linked to H-2a, H-2b, H-4a, H-4b, and H-4c.)	Important

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H-1c. Quantify rates of snow accumulation, snowmelt, ice melt, and sublimation from snow and ice worldwide at scales driven by topographic variability.	Most Important
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H-4c. Improve drought monitoring to forecast short-term impacts more accurately and to assess potential mitigations.	Important
H-4d. Understand linkages between anthropogenic modification of the land, including fire suppression, land use, and urbanization on frequency of, and response to, hazards. (This is tightly linked to H-2a, H-2b, H-4a, H-4b, and H-4c.)	Important
H-2c. Quantify how changes in land use, land cover, and water use related to agricultural activities, food production, and forest management affect water quality and especially groundwater recharge, threatening sustainability of future water supplies.	Most Important

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SBG hydrology and agriculture objectives

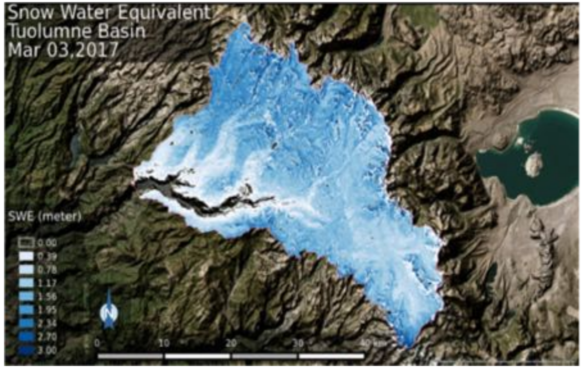
EAS17 SBG TO-18: H-1, H-2, H-3, H-4

H-1: How is the water cycle changing? Are changes in ET and precip accelerating, with greater rates of ET and precip, and how are these changes expressed in the space-time distribution of rainfall, snowfall, ET, frequency of extremes, such as floods and droughts?

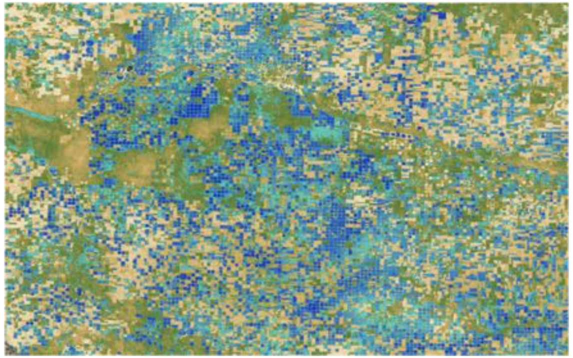
H-2: How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally, globally, and what are the short and long term consequences?

H-3: How do changes in the water cycle impact local and regional freshwater availability, alter biotic life of streams, and affect ecosystems and the services these provide?

H-4: How does the water cycle interact with other Earth system processes to change the predictability and impacts of hazardous events and hazard chains (eg, floods, wildfires, landslides, coastal loss, subsidence, droughts, human health, ecosystem health) and how do we improve preparedness and mitigation of water-related extreme events?



Hydrology – snow / ice properties and predicted streamflow for reservoir operations and allocations planning

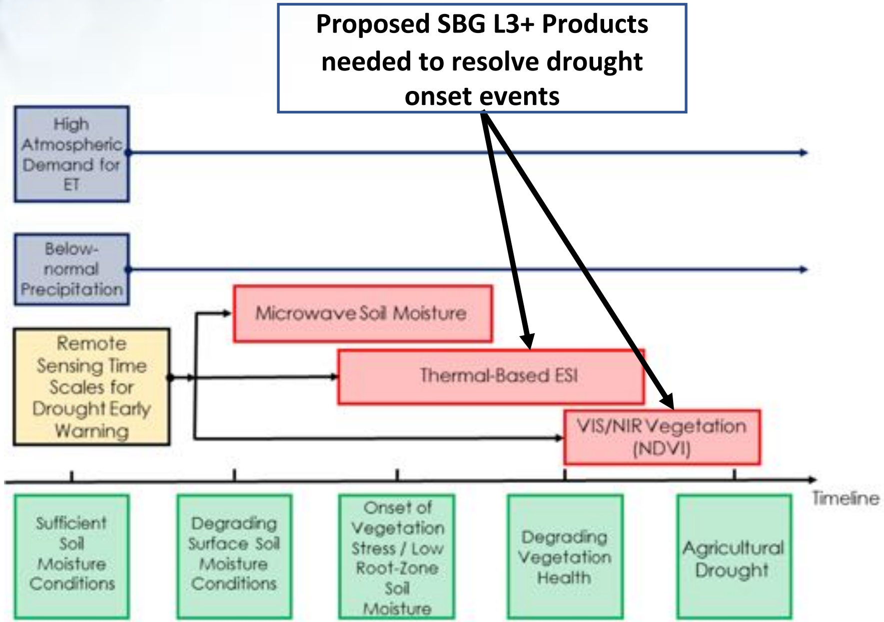


Agriculture – evapotranspiration, crop condition/class/properties for improved ag and irrigation practices and drought mgmt

Drought Onset

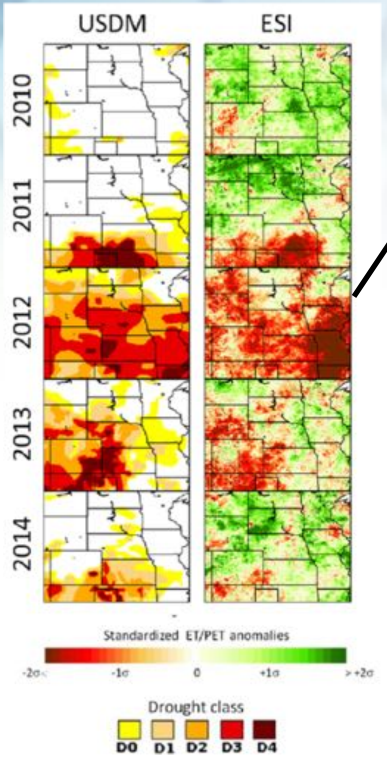
Societal Challenge: water availability and management continues to be one of the greatest risks we face, particularly as it relates to food insecurity and responding / adapting to weather extremes (droughts and floods)

Opportunity: improved detection and characterization of key freshwater sources and the single largest use of freshwater (agriculture) could improve our ability to address and mitigate effects of drought, especially rapid onset droughts and their impacts on agricultural systems



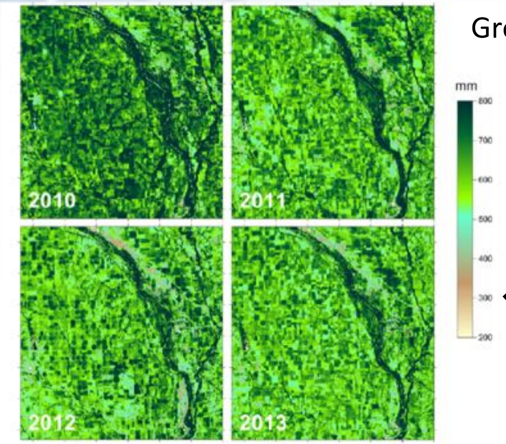
Decision relevant information from SBG:
TIR and VSWIR data are necessary for high-resolution impacts of drought and vegetation stress on agricultural systems.

Drought Onset

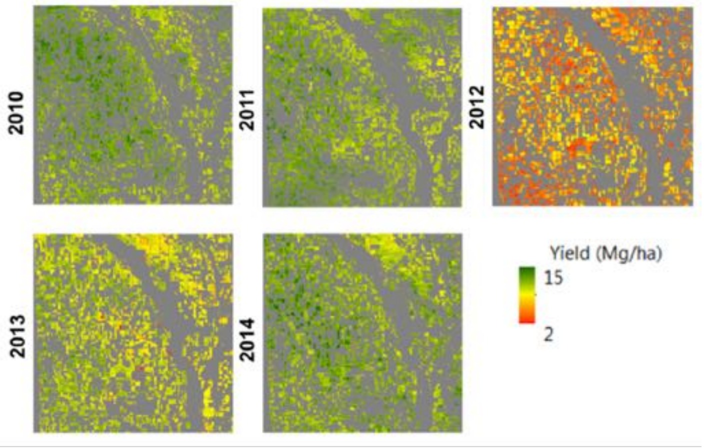


Taken from Yang et al. 2018

Growing Season Evapotranspiration



Estimated Crop Yield from Field-Scale Stress Indicators

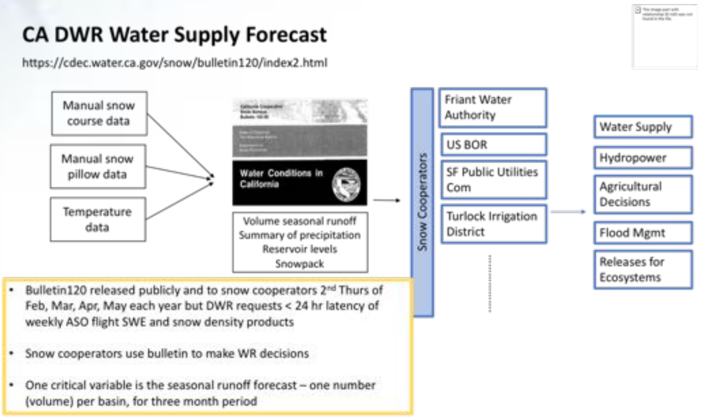


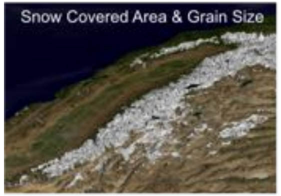
Applying Snow Data

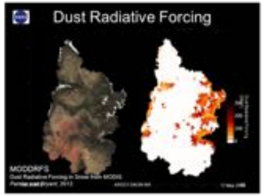
Societal Challenge:

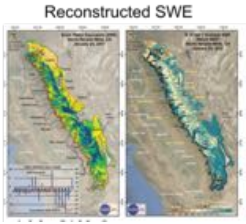
water availability and management continues to be one of the greatest risks we face, particularly as it relates to food insecurity and responding / adapting to weather extremes (droughts and floods)

Opportunity: Optimizing reservoir operations for water supply, flood protection, and hydropower production requires accurate predictions of runoff at different lead times.









Decision relevant information from SBG:
TIR and VSWIR data are important for improved characterization of snow properties, such as albedo and dust on snow, as well as for prediction of snowmelt and streamflow for improved operations.

Schedule for weekly SBG-Applications Discussions

working meetings that are focused on specific topics within SATM

Date	Applications Topic	Lead(s)
5/2/2019	Natural Hazards - Volcanoes and Landslides	Florian Schwandner / Christine Lee
5/10/2019	Terrestrial Ecosystems / Natural Hazards - Wildfires, Restoration	Dar Roberts / Nancy Glenn
5/16/2019	Terrestrial Ecosystems - Carbon Accounting, Conservation	Konrad Wessels / Natasha Stavros
5/23/2019	Public Health and Urban Planning / Urban Heat Islands, Heat Waves, Vectorborne Disease Habitats	Ryan Avery / Jeff Luvall
5/30/2019	Water Resources / Terrestrial Ecosystems - Agriculture, Snow	Forrest Melton and Chris Hain / Christine Lee
6/7/2019	Aquatic Ecosystems - Corals, Harmful Algal Blooms, Water Quality, Restoration	Maria Tzortziou and Stephanie Uz / Christine Lee

Aquatic Ecosystems Applications

Targeted Observable	Science/Applications Summary	Candidate Measurement Approach	Designated	Explorer	Incubation
Surface Biology and Geology	*Earth surface geology and biology,* ground/water temperature, snow reflectivity, active geologic processes, vegetation traits, and algal biomass	Hyperspectral imagery in the visible and shortwave infrared (IR), multi- or hyperspectral imagery in the thermal IR	X		

Surface Biology and Geology	CATE Cap $650 million	Key to understanding active surface changes (eruptions, landslides, and evolving landscapes); snow and ice accumulation, melting, and albedo; hazard risks in rugged topography; effects of changing land use on surface energy, water, momentum, and carbon fluxes; physiology of primary producers; and functional traits and health of terrestrial vegetation and inland and near-coastal aquatic ecosystems. Further contributes to managing agriculture and natural habitats, water use and water quality, and urban development as well as understanding and predicting geological natural hazards and land-surface interactions with weather and climate. Depending on implementation specifics, the Targeted Observable may also contribute to hyperspectral open-ocean observation goals. Addresses many "Most Important" objectives of the Ecosystem, Hydrology, and Solid Earth panels, and addresses key components of the Water and Energy Cycle, Carbon Cycle, and Extreme Events integrating themes.

Surface Biology and Geology

Earth Science/Applications Objectives for the Designated Targeted Observable: Surface Biology and Geology

	Most Important	Very Important	Important
Hydrology	1c	2a, 4a	2b, 3a, 3b, 3c, 4c, 4d
Weather		3a	
Ecosystems	1c, 2a, 3a	1a	1d, 5a, 5b, 5c
Climate		3a	3c, 3d, 6b, 7e, 8f
Solid Earth	1a	1c, 2b	4b, 4c, 7a

TABLE S.1 Science and Applications Priorities for the Decade 2017-2027

Science and Applications Area	Science and Applications Questions Addressed by **MOST IMPORTANT** Objectives
Coupling of the Water and Energy Cycles	**(H-1)** How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as droughts and floods?
	(H-2) How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?
Ecosystem Change	**(E-1)** What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?
	(E-2) What are the fluxes (of carbon, water, nutrients, and energy) *between* ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing?
	(E-3) What are the fluxes (of carbon, water, nutrients, and energy) *within* ecosystems, and how and why are they changing?
Extending and Improving Weather and Air Quality Forecasts	**(W-1)** What planetary boundary layer (PBL) processes are integral to the air-surface (land, ocean and sea ice) exchanges of energy, momentum and mass, and how do these impact weather forecasts and air quality simulations?
	(W-2) How can environmental predictions of weather and air quality be extended to forecast Earth System conditions at lead times of 1 week to 2 months?
	(W-4) Why do convective storms, heavy precipitation, and clouds occur exactly when and where they do?
	(W-5) What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?
Reducing Climate Uncertainty and Informing Societal Response	**(C-2)** How can we reduce the uncertainty in the amount of future warming of the Earth as a function of fossil fuel emissions, improve our ability to predict local and regional climate response to natural and anthropogenic forcings, and reduce the uncertainty in global climate sensitivity that drives uncertainty in future economic impacts and mitigation/adaptation strategies?
Sea Level Rise	**(C-1)** How much will sea level rise, globally and regionally, over the next decade and beyond, and what will be the role of ice sheets and ocean heat storage?
	(S-3) How will local sea level change along coastlines around the world in the next decade to century?
Surface Dynamics	**(S-1)** How can large-scale geological hazards be accurately forecasted and

GLOBAL HYDROLOGICAL CYCLES AND WATER RESOURCES PANEL		
Societal or Science Question/Goal	**Earth Science/Application Objective**	**Sci/App Importance**
QUESTION H-1. How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as droughts and floods?	**H-1a.** Develop and evaluate an integrated Earth System analysis with sufficient observational input to accurately quantify the components of the water and energy cycles and their interactions, and to close the water balance from headwater catchments to continental-scale river basins.	Most Important
	H-1b. Quantify rates of precipitation and its phase (rain and snow/ice) worldwide at convective and orographic scales suitable to capture flash floods and beyond.	Most Important
	H-1c. Quantify rates of snow accumulation, snowmelt, ice melt, and sublimation from snow and ice worldwide at scales driven by topographic variability.	Most Important
QUESTION H-2. How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?	**H-2a.** Quantify how changes in land use, water use, and water storage affect evapotranspiration rates, and how these in turn affect local and regional precipitation systems, groundwater recharge, temperature extremes, and carbon cycling.	Very Important
	H-2b. Quantify the magnitude of anthropogenic processes that cause changes in radiative forcing, temperature, snowmelt, and ice melt, as they alter downstream water quantity and quality.	Important
	H-2c. Quantify how changes in land use, land cover, and water use related to agricultural activities, food production, and forest management affect water quality and especially groundwater recharge, threatening sustainability of future water supplies.	Most Important
QUESTION H-3. How do changes in the water cycle impact local and regional freshwater availability, alter the biotic life of streams, and affect ecosystems and the services these provide?	**H-3a.** Develop methods and systems for monitoring water quality for human health and ecosystem services.	Important
	H-3b. Monitor and understand the coupled natural and anthropogenic processes that change water quality, fluxes, and storages in and between all reservoirs (atmosphere, rivers, lakes, groundwater, and glaciers), and response to extreme events.	Important
	H-3c. Determine structure, productivity, and health of plants to constrain estimates of evapotranspiration.	Important
QUESTION H-4. How does the water cycle interact with other Earth System processes to change the predictability and impacts of hazardous events and hazard-chains (e.g. floods, wildfires, landslides, coastal loss, subsidence, droughts, human health, and ecosystem health), and how do we improve preparedness and mitigation of water-related extreme events?	**H-4a.** Monitor and understand hazard response in rugged terrain and land-margins to heavy rainfall, temperature and evaporation extremes, and strong winds at multiple temporal and spatial scales.	Very Important
	H-4b. Quantify key meteorological, glaciological, and solid Earth dynamical and state variables and processes controlling flash floods and rapid hazard-chains to improve detection, prediction, and preparedness. (This is a critical socio- economic priority that depends on success of addressing H1b, H1c and H4a).	Important
	H-4c. Improve drought monitoring to forecast short-term impacts more accurately and to assess potential mitigations.	Important
	H-4d. Understand linkages between anthropogenic modification of the land, including fire suppression, land use, and urbanization on frequency of and response to hazards. This is tightly linked to H2a, H2b, H4a, H4b, H4, and H4d.	Important

MARINE AND TERRESTRIAL ECOSYSTEMS AND NATURAL RESOURCES MANAGEMENT PANEL

Societal or Science Question/Goal	Earth Science/Application Objective	Sci/App Importance
QUESTION E-1. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?	**E-1a.** Quantify the global distribution of the functional traits, functional types, and composition of vegetation and marine biomass, spatially and over time.	Very Important
	E-1b. Quantify the global three-dimensional (3-D) structure of terrestrial vegetation and 3-D distribution of marine biomass within the euphotic zone, spatially and over time.	Most Important
	E-1c. Quantify the physiological dynamics of terrestrial and aquatic primary producers.	Most Important
	E-1d. Quantify moisture status of soils.	**Important**
	E-1e. Support targeted species detection and analysis (e.g., foundation species, invasive species, indicator species, etc.)	Important
QUESTION E-2. What are the fluxes (of carbon, water, nutrients, and energy) between ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing?	**E-2a. Quantify the fluxes of CO_2 and CH_4 globally at spatial scales of 100-500 km and monthly temporal resolution with uncertainty < 25% between land ecosystems and atmosphere and between ocean ecosystems and atmosphere.**	**Most Important**
	E-2b. Quantify the fluxes from land ecosystems between aquatic ecosystems.	Important
	E-2c. Assess ecosystem subsidies from solid Earth.	**Important**
QUESTION E-3. What are the fluxes (of carbon, water, nutrients, and energy) within ecosystems, and how and why are they changing?	**E-3a.** Quantify the flows of energy, carbon, water, nutrients, etc. sustaining the life cycle of terrestrial and marine ecosystems and partitioning into functional types.	Most Important
	E-3b. Understand how ecosystems support higher trophic levels of food webs.	Important
QUESTION E-4. How is carbon accounted for through carbon storage, turnover, and accumulated biomass, and have we quantified all of the major carbon sinks and how are they changing in time?	**E-4a.** Improve assessments of the global inventory of terrestrial C pools and their rate of turnover.	Important
	E-4b. Constrain ocean C storage and turnover.	Important
QUESTION E-5. Are carbon sinks stable, are they changing, and why?	**E-5a.** Discover ecosystem thresholds in altering C storage.	Important
	E-5b. Discover cascading perturbations in ecosystems related to carbon storage.	Important
	E-5c. Understand ecosystem response to fire events.	Important

DESIGNATED—*Targeted Observable:* **Surface Biology and Geology** [**H-1c**, 2a, 2b, 3a, 3b, 3c, 4a, 4c, 4d; W-3a; **S-1a**, 1c, 2b, 4b, 4c, 7a; E-1a, **1c**, 1d, **2a**, **3a**, 5a, 5b, 5c; C-3a, 3c, 3d, 6b, 7e, 8f]

The **Surface Biology and Geology** Targeted Observable, corresponding to TO-18 in the Targeted Observables Table (Appendix C), enables improved measurements of Earth's surface characteristics that provide valuable information on a wide range of Earth System processes. Society is closely tied to the land surface for habitation, food, fiber and many other natural resources. The land surface, inland and near-coastal waters are changing rapidly due to direct human activities as well as natural climate variability and climate change. New opportunities arising from enhanced satellite remote sensing of Earth's surface provide multiple benefits for managing agriculture and natural habitats, water use and water quality, and urban development as well as understanding and predicting geological natural hazards. The Surface Biology and Geology observable is linked to one or more Most Important or Very Important science objectives from each panel and feeds into the three ESAS 2017 integrating themes: water and energy cycle, carbon cycle, and extreme event themes.

Science Considerations. This Targeted Observable will likely be addressed through hyperspectral measurements that support a multi-disciplinary set of science and applications objectives.Visible and shortwave infrared imagery addresses multiple objectives: active surface geology (e.g., surface deformation, eruptions, landslides, and evolving landscapes); snow and ice accumulation, melting, and albedo; hazard risks in rugged topography; effects of changing land-use on surface energy, water, momentum and carbon fluxes; physiology of primary producers; and functional traits of terrestrial vegetation and inland and near-coastal aquatic ecosystems. Thermal infrared imagery provides complementary information on ground, vegetation canopy, and water surface temperatures as well as ecosystem function and health. Depending on implementation specifics, the Targeted Observable may also contribute to hyperspectral ocean observation goals. However, such goals are met to a large degree by POR elements, in particular the hyperspectral PACE mission, and are not considered a priority for additional implementation (and thus are not recommended if they drive cost). Observations of the Earth's surface biology and geology, with the ability to detect detailed spectral signatures, provide a wide range of opportunities for Earth system science parameters across most of the panels and integrating themes. As such, this Targeted Observable maps to some of the highest panel priorities as well as the Integrating Themes.

Candidate Measurement Approaches. High spectral resolution (or hyperspectral) imagery provides the desired capabilities to address important geological, hydrological, and ecological questions, building on a successful history of past and ongoing multispectral remote sensing (e.g., MODIS).

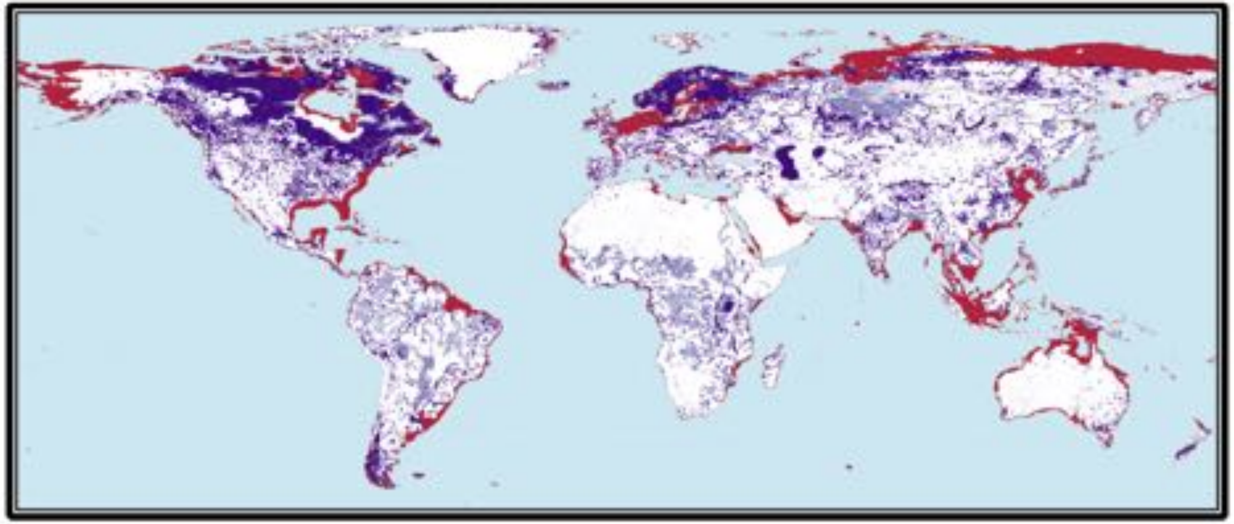
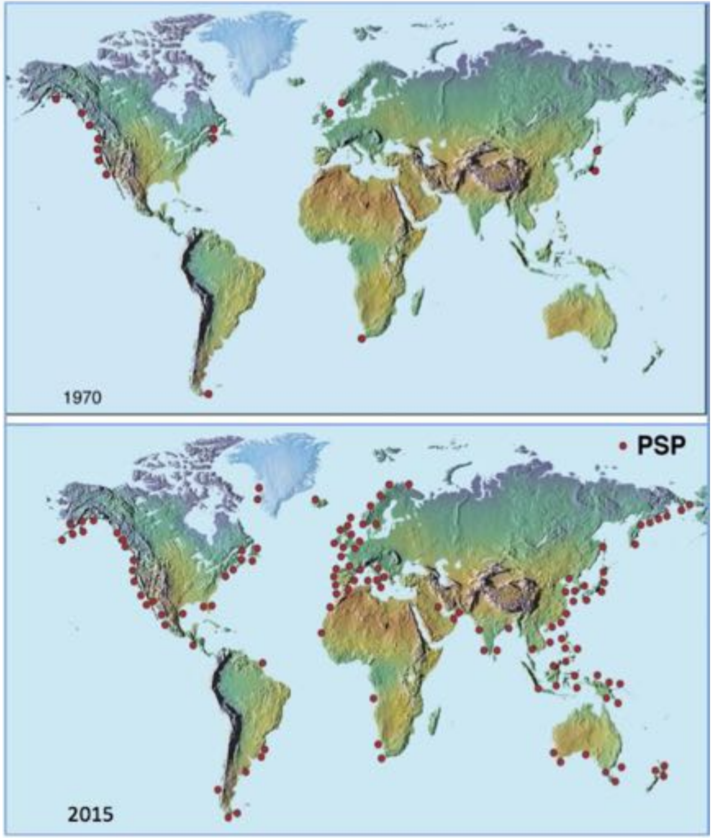


Figure 1 – Global distribution of coastal and inland aquatic ecosystems. Red indicates regions where water depth is less than 50 m and where land elevation is less than 50 m. Light to dark violent gives the concentration of inland wetlands, lakes, rivers and other aquatic systems. Increased darkness means greater percentage of areal coverage for inland aquatic ecosystems (UNEP-WCMC, 2005).

Turpie et al 2016, Global Observations of Coastal and Inland Aquatic Systems

Societal Challenge: Coastal HAB events have been estimated to result in economic impacts in the United States of at least $82 million each year.
The impacts of HABs range from environmental, to human health (e.g., illness through shellfish consumption, asthma attacks through inhalation of airborne HAB toxins), to socio-economic and cultural (e.g., commercial fisheries, tourism, recreation).

Opportunity: improved identification and quantification of specific phytoplankton groups, with ***hyperspectral observations*** would allow us to identify HABs and track their evolution and variability over seasonal to interannual time scales. ***High spatial resolution*** measurements (better than 100 m) would allow to capture intense small patches of HABs in estuaries and inland waters.). 30-m needed for estuaries and inland waters, aquaculture.
Temporal. Weekly to bi-weekly. Targeting for HAB events/oil spills.



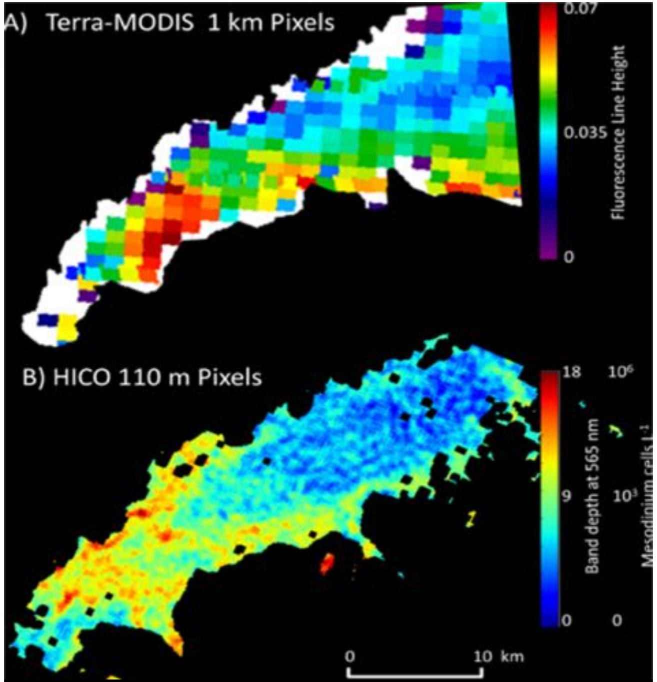
Distribution of events where PSP (Paralytic shellfish poisoning) toxins were detected in shellfish or fish– 1970 versus 2009

Spatial resolution requirements

End Users: NOAA, USGS, EPA (e.g., Gulf of Mexico Program), and other state environmental agencies and local health departments are interested in improved monitoring and understanding of HAB events.

Among the main goals of these end-users is to provide coastal communities with advance warning, so they can adequately plan and deal with the adverse environmental and health effects associated with a harmful bloom.

*Compared with the 1-km MODIS image, the **higher spatial resolution (110 m) of the HICO image revealed intense small patches** of yellow fluorescing Mesodinium in WLIS*



Dense and patchy near-surface blooms of *Mesodinium rubrum* in the western Long Island Sound (Dierssen et al 2015)

Inland Water Quality Assessment

Societal Challenge:

Lake conditions affect property values, drinking water supplies, recreational activities, and the economic status of entire communities. Lake St. Clair in Michigan provides **approximately 5 million people with fresh drinking water**, and boating-related activities alone generate **$260 million**.

Satellite ocean color imagery currently lacks the spectral and spatial resolution required to monitor water-quality indicators in lakes.

DS: H2b, 2c, E1a, 1b, 1c, E2a, E3a, 3b, 5b

Opportunity:

High spectral resolution observations can substantially improve retrieval of parameters such as chlorophyll-a, CDOM, turbidity, color, phytoplankton groups and cyanobacteria that are key indicators of the ecological condition, trophic state, and recreational value of lakes.

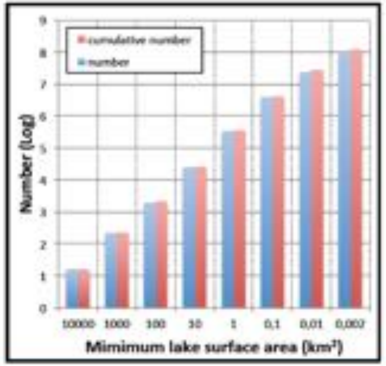
High spatial resolution measurements (target 30-100 m) for global to local scale applications, such as water quality monitoring and aquaculture.

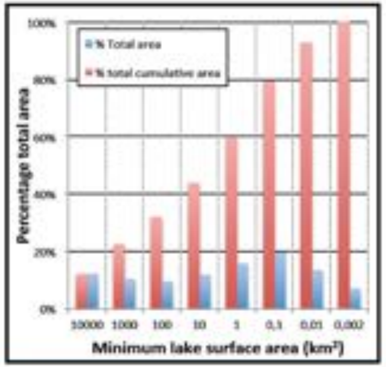
Temporal. Weekly to bi-weekly. Targeting for HABs or oil spill monitoring and detection.

State and federal agencies are interested in monitoring and protecting their inland water resources. EPA's National Lakes Assessment (NLA) program provides national and regional estimates of the biological, chemical, physical and recreational condition of lakes. Such information is needed by decision makers and the public to decide the best allocation of available funds for environmental protection and restoration. This is done every five years, based on field sampling conducted every 5 years.

Satellite ocean color imagery at 100 m resolution from HICO (Hyperspectral Imager for the Coastal Ocean, 2009-2014)

Spatial resolution requirements





Lake size	Required GSD*	% Total Area	Total Number
≥ 1 km²	333 m	60	353,552
≥ 0.1 km²	**105 m**	80	4,123,552
≥ 0.01 km²	33 m	90	**27,523,552**
≥ 0.002 km²	15 m	100	**117,423,552**

- GSD less than 30 m likely too high
- GSD of 100 m likely sufficient for 80% surface area of world lakes
- Sheer number of lakes means GSD < 100 m prohibitive without pre-selection criterion (but desirable for regional implementations)
- Rivers currently excluded.

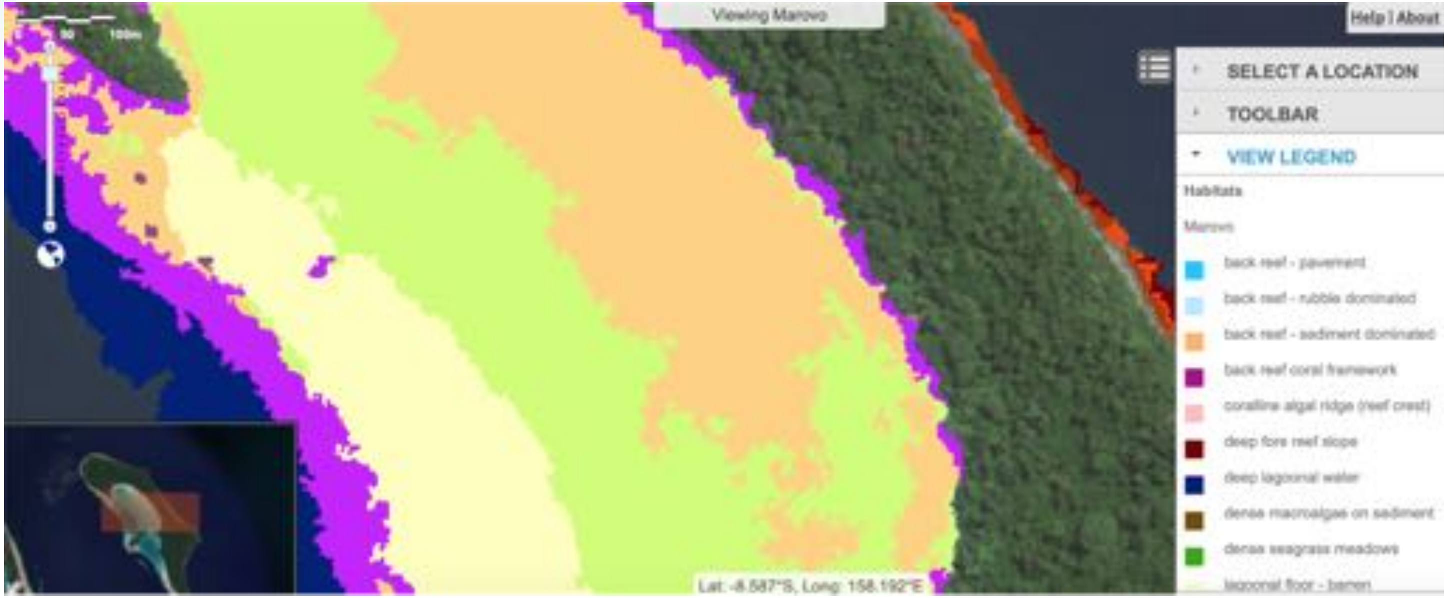
Data from Verpoorter at al. (2014) * calculated for a box of nine pixels

Verpoorter, C., Kutser, T., Seekell, D. a., & Tranvik, L. J. (2014). A Global Inventory of Lakes Based on High-Resolution Satellite Imagery. Geophysical Research Letters

by Mark Mattthews (CyanoLakes)

Societal Challenge: Coral reefs are threatened by warming temperatures, acidification, physical damage, and land based pollutants such as sediments, nutrients, and contaminants.

Opportunity: ***High spatial resolution hyperspectral observations*** (< 30 m) enable identification and quantification of benthic composition, i.e. shallow reefs (< 40m depth) at monthly to interannual scales. Assessing reef health and species requires higher resolution hyperspectral (< 1m). ***DS: E1a, 1b, 1c, 1e, E2b,***



The Global Reef Expedition characterized coral reef ecosystems [Purkis et al., 2019]

Societal Challenge: Coastal fishing and shellfish industries are impacted by eutrophication and harmful algal blooms that kill fish and contaminate shellfish. Nutrient pollution causes dead zones with little or no oxygen where aquatic life cannot survive. Aquatic animals - particularly young fish and benthic species like crabs - move to survive. Annual losses to these industries from nutrient pollution are estimated in the tens of millions of dollars.

Opportunity: improved identification and quantification of total maximum daily load and phytoplankton groups with ***high spatial resolution hyperspectral observations*** (20-30 m) at daily to weekly time scales would capture features into estuaries and inland waters.

DS: H2b, 2c, E1a, 1b, 1c, E2a, E3a, 3b, 5b

Some algal blooms reduce the ability of fish and other aquatic life to find food and can cause entire populations to leave an area or even die. Credit: EPA

2019 ***Surface Biology and Geology (SBG) Community Workshop***

SBG Applications Working Group

Lessons Learned

Sign up for the SBG applications working group

- tinyurl.com/SBGApplicationsWG

- Contacts

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