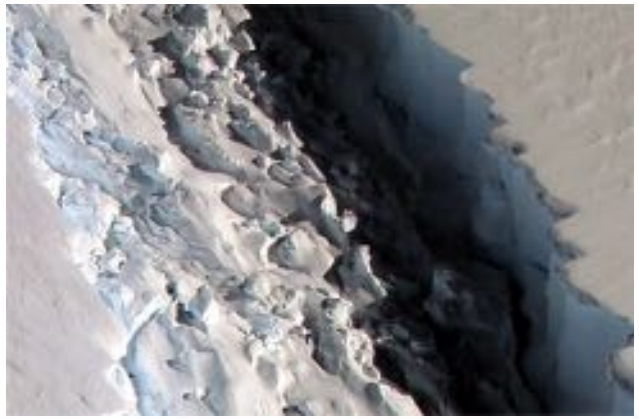
Jet Propulsion Laboratory
California Institute of Technology

SCIENCE






Surface Biology and Geology

7th Community Webinar

David Schimel and the SBG team

Jet Propulsion Laboratory, California Institute for Technology

Surface Biology & Geology

7th SBG Community Webinar

- SBG Introduction and Project Update
- Constellation Pathfinder
- Working Group Updates
  - Algorithms
  - Cal/Val
  - Applications
  - MEET-SBG Pathfinder
  - SISTER Pathfinder
  - Field Campaign
- SBG High-frequency Time Series (SHIFT) Campaign
- BioSCape Campaign
- Partner/Precursor Missions
  - EMIT
  - ECOSTRESS
  - Carbon Mapper

THE SURFACE BIOLOGY AND GEOLOGY DO IS DEFINED WITH CONSIDERABLE DETAIL IN THE DECADAL SURVEY

SBG is key to understanding in five research and applications focus areas:

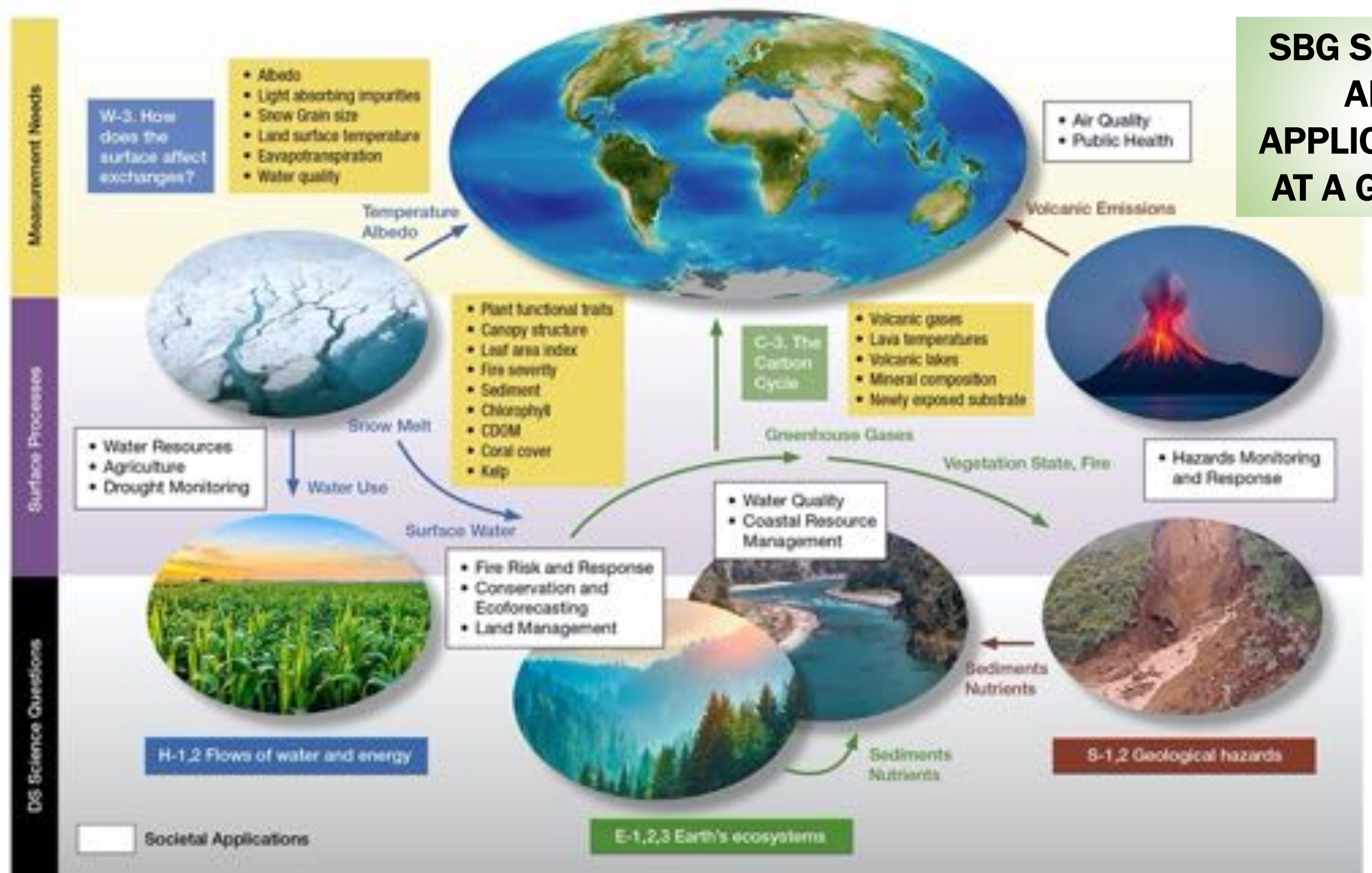
- Terrestrial and aquatic ecosystems
- Hydrology
- Weather
- Climate
- Solid Earth

The Decadal Survey defines the implementation as two sensors "*Hyperspectral imagery in the visible and shortwave infrared; multi- or hyperspectral imagery in the thermal IR*":

1. "….a moderate spatial resolution (30-45 m GSD), hyperspectral resolution (10 nm; 400-2500 nm), high fidelity (SNR = 400:1 VNIR/250:1 SWIR) imaging spectrometer is needed for characterizing land, inland aquatic, coastal zone, and shallow coral reef ecosystems"
2. "….30-60 m TIR observations in the 10.5-11.5 µm and 11.5-12.5 µm spectral regions are needed with a 2-4 day revisit frequency" [1]

1) Note, this specification was updated based on recent work and community engagement to optimize for the DS-specified science and applications.

SBG SCIENCE AND APPLICATIONS AT A GLANCE



SBG: MOST AND VERY IMPORTANT RESEARCH AND APPLICATIONS OBJECTIVES ACROSS ALL FIVE DS FOCUS AREAS

HYDROLOGY

H-1. How is the water cycle changing?

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.

H-4. Hazards, extremes, and sea level rise. How does the water cycle interact with other Earth system processes to change the predictability and impacts of hazardous events.

WEATHER

W-3. How do special variations in surface characteristics (influencing ocean and atmospheric dynamics, thermal inertia and water) modify transfer between domains?

ECOSYSTEMS AND NATURAL RESOURCES

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. Fluxes within ecosystems. What are the within ecosystems, and how and why are they changing?

CLIMATE

C-3. How large are the variations in the global carbon cycle and what are the associated climate and ecosystem impacts?

SOLID EARTH

S-1. How can large-scale geological hazards be accurately forecast in a socially relevant time frame?

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

SBG: MAJOR APPLIED SCIENCE ACROSS SECTORS

AGRICULTURE, FOOD SECURITY AND SURFACE WATER MANAGEMENT

Improve “crop per drop” by assessing vegetation water stress over irrigated agriculture

Improve water supply management through better characterization of snow properties and estimated reservoir inflows

Reduce the impacts of drought, such as crop loss and famine, on global scales

WATER QUALITY AND COASTAL ZONES

Support early detection of and response to harmful algal bloom formation

Protect sensitive aquatic habitats by monitoring/reducing water pollutant loading, particular in coral reefs and other sensitive ecosystems

Water surface temperature and impacts on marine biodiversity

CONSERVATION

Support biodiversity understanding and protections by mapping invasive species composition, structure, distribution; support removal and restoration efforts

Monitoring of endangered species habitat; provide alerts of disease mortality of impacted vegetation, including insect infestation

Biodiversity hotspots and priority conservation areas, 30 x 30 plans

WILDFIRE RISK AND RECOVERY

Fuel mapping (cover type, extent, status) for wildfire danger management

Post fire severity assessment and recovery, including prediction of areas with higher likelihood of debris flows

DISASTERS AND NATURAL HAZARDS

Detect and track oil spill events and

Support active fire mapping and response

Improve mitigation of heat wave events for vulnerable populations

GEOLOGY APPLICATIONS

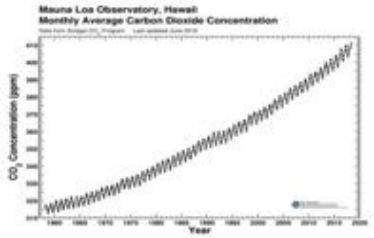
Mineral mapping for exploration efforts and reduction of environmental hazards

Forecast aviation hazards and support emergency response for volcanic eruptions

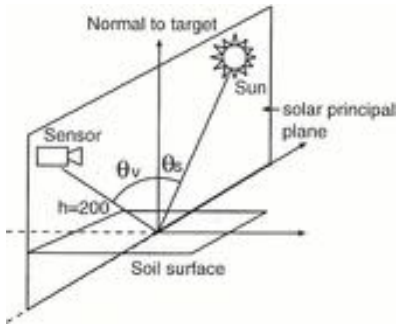
Landslide risk assessment with improved substrate map land cover maps

SBG: KEY RESEARCH AND APPLICATIONS REQUIREMENTS

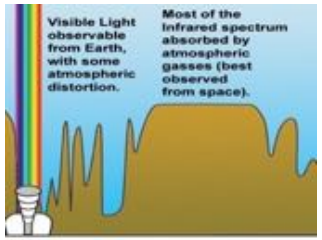
COVERAGE: The system must provide **global coverage** to address the global scope of the science including the coastal ocean and inland waters.



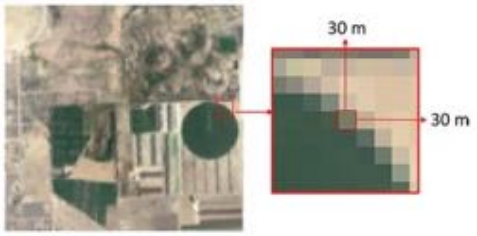
STABILITY AND DURATION: Measurements must be able to detect **long term changes** for addressing dynamics of the Earth System.



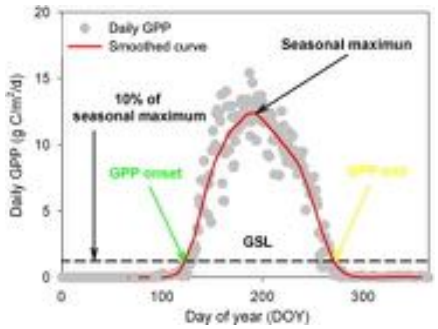
GEOMETRY: The system's orbit must allow for **consistent sun-sensor geometry** for consistency in retrievals and for calibration and validation, and provide for global coverage, as above (polar orbit).



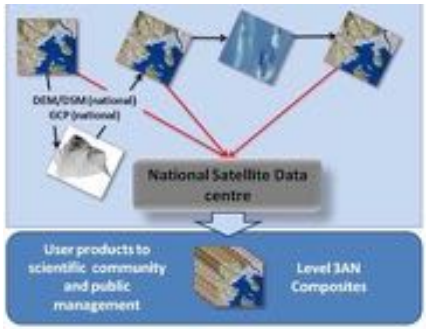
RANGE, RESOLUTION AND SENSITIVITY: Visible to Shortwave Infrared **(VSWIR; 400-2500 nm)** imaging spectroscopy and multi-spectral thermal infrared **(TIR; 4 - 12 μm)** measurements to observe "diversity" in ecosystem function. Radiometric performance driven by aquatic targets.



SPATIAL RESOLUTION: The observing system must provide **high spatial resolution** (30 and 60 m for VSWIR and TIR)



REVISIT: The SBG observing system temporal resolution must be adequate to capture **synoptic and seasonal variation** as well as observe **rapid or transient changes** related to Earth system events such as fires, landslides, volcanic activity and anthropogenic incidents.



LATENCY: **Low latency,** the time between an event and data access, must be low enough to support time-sensitive applications, ≤ 24 hours.

SBG Architecture

SBG Constellation Pathfinder

SBG Light

Wide-swath VSWIR spectrometer

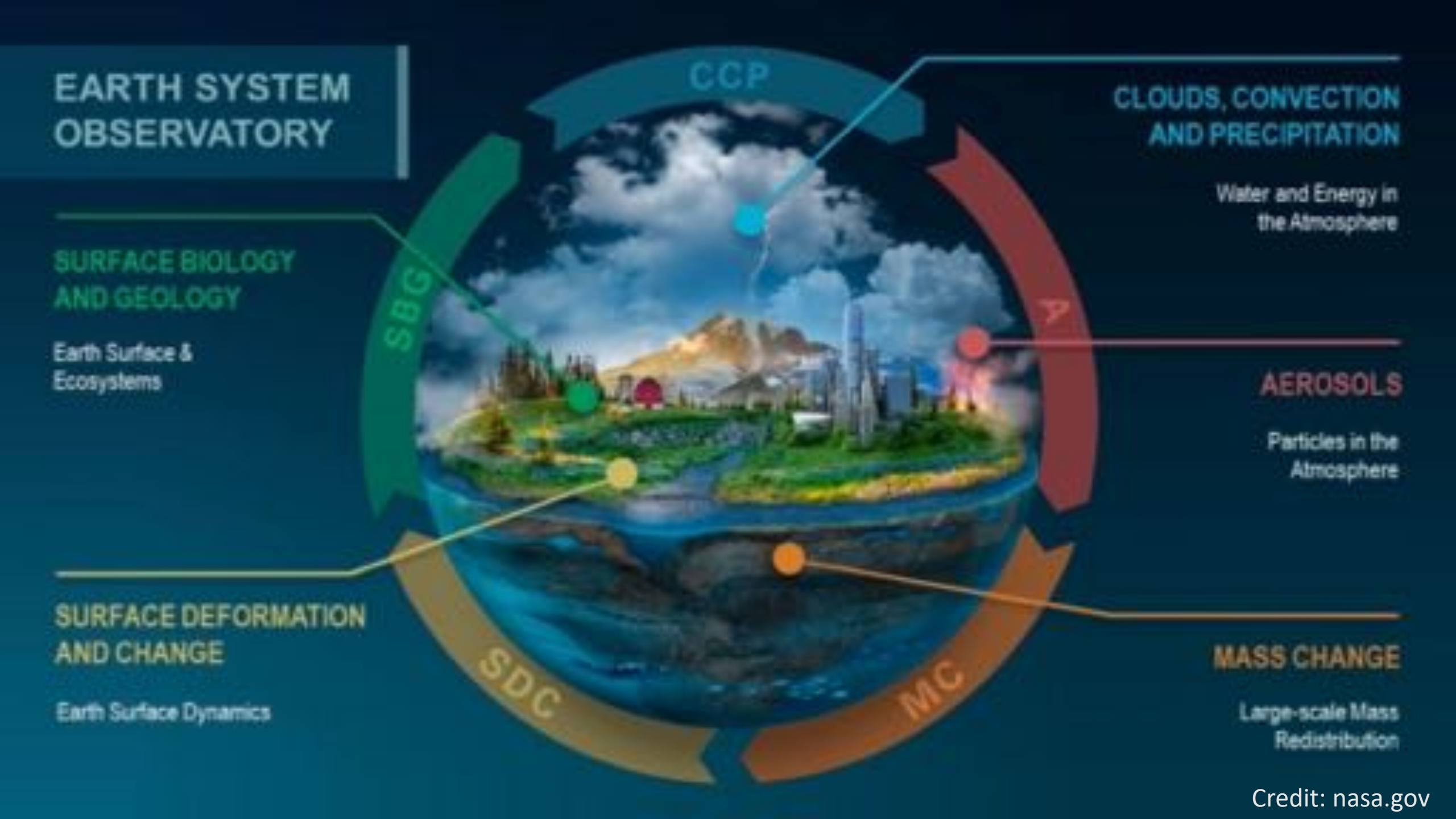
Sun-sync orbit (late AM)
185 km swath
16 day revisit
10 nm, 200+ bands
30 meter GSD
High SNR and radiometric performance

SBG Heat

Wide-swath TIR imager and ASI VNIR camera

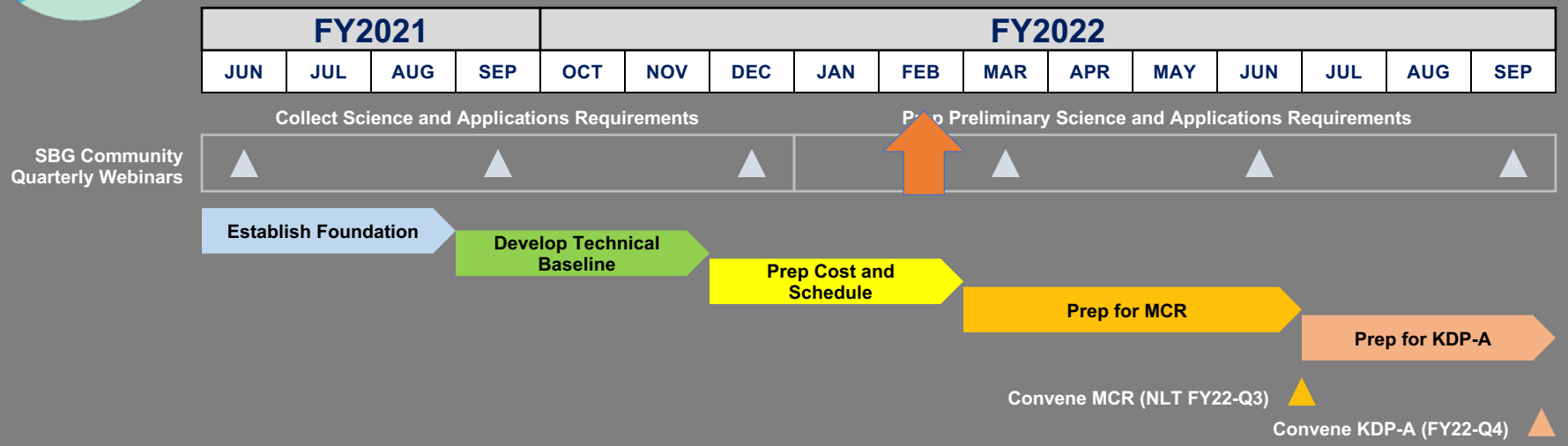
Sun-sync orbit (early PM)
5+ bands TIR, 2+ bands VNIR
935 km swath, 3 day revisit
60 meter GSD
0.2K NeDT

SBG on-orbit collaborations

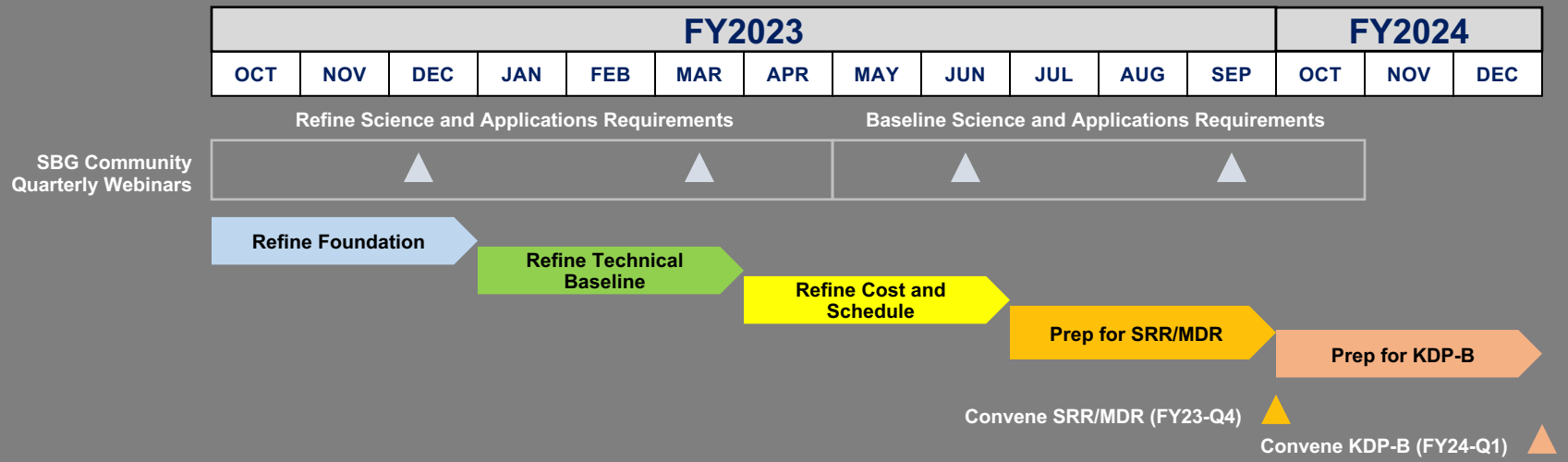

EARTH SYSTEM OBSERVATORY
CCP
CLOUDS, CONVECTION AND PRECIPITATION
Water and Energy in the Atmosphere
SBG
SURFACE BIOLOGY AND GEOLOGY
Earth Surface & Ecosystems
A
AEROSOLS
Particles in the Atmosphere
SDC
SURFACE DEFORMATION AND CHANGE
Earth Surface Dynamics
MC
MASS CHANGE
Large-scale Mass Redistribution
Credit: nasa.gov

Surface Biology and Geology (SBG)

Pre-Phase A (Pre-Concept Study Phase) Schedule



Phase A (Concept Study Phase) Schedule - Notional



Pre-Decisional Draft: For planning and discussion purposes only.

NASA Project Lifecycle

SBG Constellation Pathfinder - Objective

Determine whether there is a path to seamless[1] data using a constellation of lower-cost satellites[2] to meet all or most of the science objectives of SBG.

[1] Seamless – entire globe landmass and littoral regions over several years with a path to many decades

[2]Satellites – may be owned and operated by NASA or a commercial vendor or some combination

SBG Constellation Pathfinder - Plan

Develop a point-design for a SmallSat VSWIR-lite as a technology demonstration to buy-down risk for a future constellation to provide data continuity following the SBG mission.

We are currently developing requirements for SBG Constellation Pathfinder and conducting a concurrent engineering study using the Ames Mission Design Center to produce a point-design for cost estimation.

Also, to investigate options for procuring science quality data from commercial providers to provide data continuity following the SBG mission

SBG Constellation Pathfinder Schedule

SBG Constellation Pathfinder will execute to a schedule similar to the main SBG mission, with Phase A ending approximately July 2023.

We expect to be preparing RFPs during Phase A.




Algorithms Working Group

- Team: Phil Townsend, Kerry Cawse-Nicholson, 250+ community members
- Goals: support mission concept development by assessing the *status* of *existing algorithms*, identifying gaps and opportunities, and assisting in traceability studies.
- Deep dive – early outcomes:
  - Deep dive into proposed products to identify development needs
  - Many algorithms have been developed and tested locally, and will need maturing to be globally applicable
  - Desire for fieldwork and coincident airborne campaigns over historically poorly sampled biomes
  - Leverage advances made for PACE, EMIT, and others
  - Cross-disciplinary partnerships have been critical



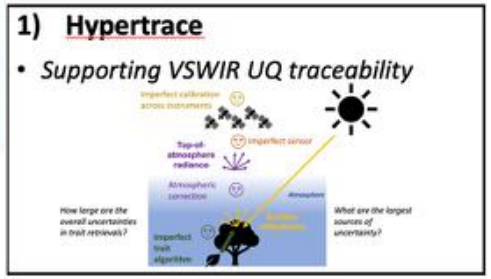

Cal/Val Working Group

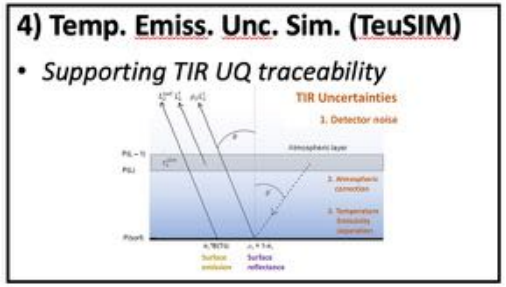
- Team: Kevin Turpie, Ray Kokaly, 100+ community members (government, industry and research institutions)
- Goals: Support mission development by recommending radiometric, thermal, spectral and geometric calibration and validation strategies and identifying resources, methods and standards supporting data product validation.
- Weekly meetings:
  - ~4-6 per general meetings year.
  - Webinar Series (weekly): 52 speakers on 2020 & 2021 schedules
- Recent Achievements:
  - Completed the 2021 Webinar Series; slides and records are available to the CVWG.
  - Developing manuscript regarding SBG Cal/Val concept for JGR-B.
  - Presented SBG calibration concepts at 2021 AGU annual meeting.
  - Orbit modeling for intercalibration SBG, CHIME, LSTM and TRISHA, Landsat, Sentinel 2, CLARREO pathfinder and SCR
  - Considering Cal/Val synergies with PACE and GLIMR.

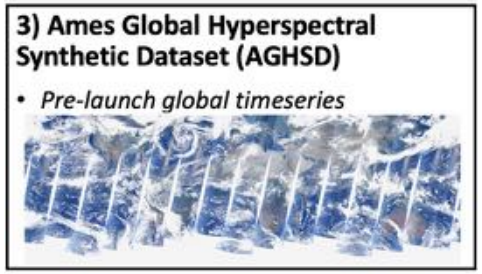


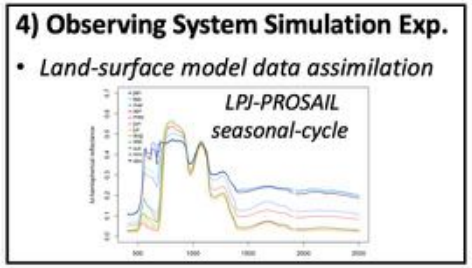

MEET-SBG: Modeling End-to-End Traceability in support of SBG

1. Science Value Trades Study
   - Hypertrace: VSWIR
   - TeuSIM: TIR
2. Observing system simulation experiment
3. Synthetic data generation
4. Science data system synergies with SISTER and SHIFT
5. International coordination with ESA CHIME





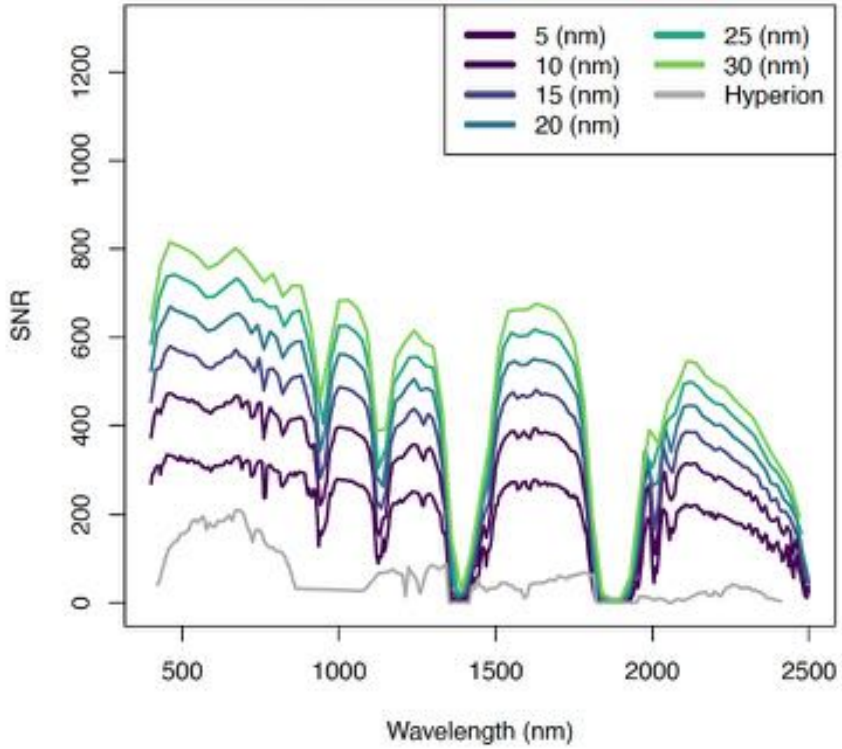


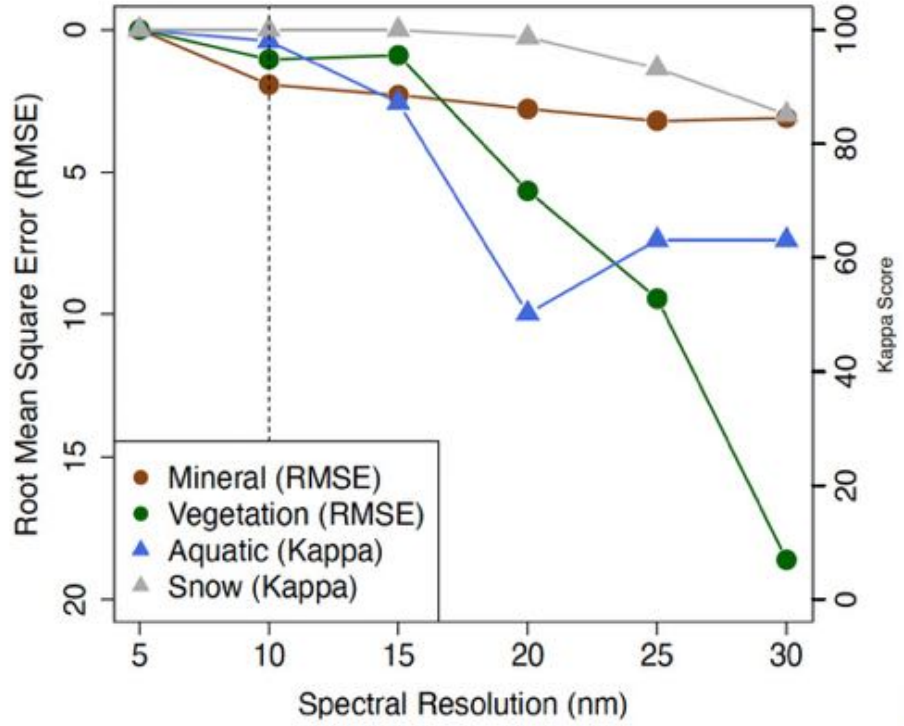





MEET-SBG: Modeling End-to-End Traceability in support of SBG

- **Science Value Trades Study:** Applying Hypertrace framework to evaluate VSWIR information content and algorithm performance with instrument SNR, spatial and spectral resolution, and revisit
- TeuSIM framework applied to TIR instrument and land surface temperature



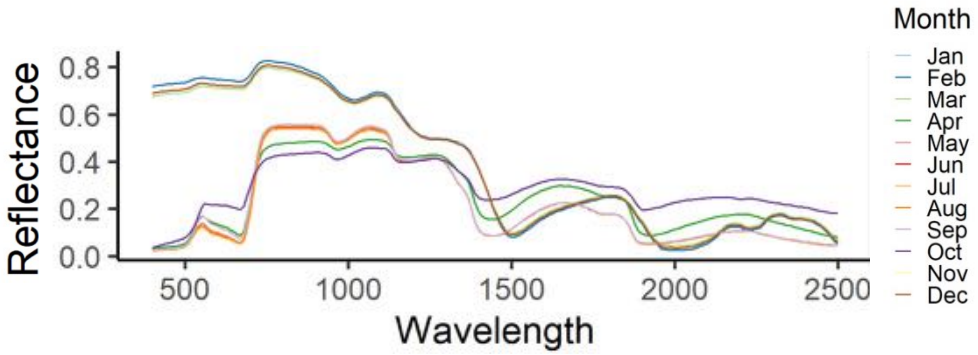


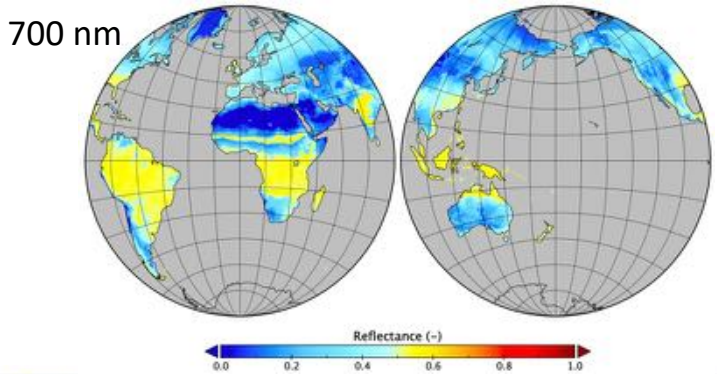
Raiho (submitted)
Cawse-Nicholson (in prep)

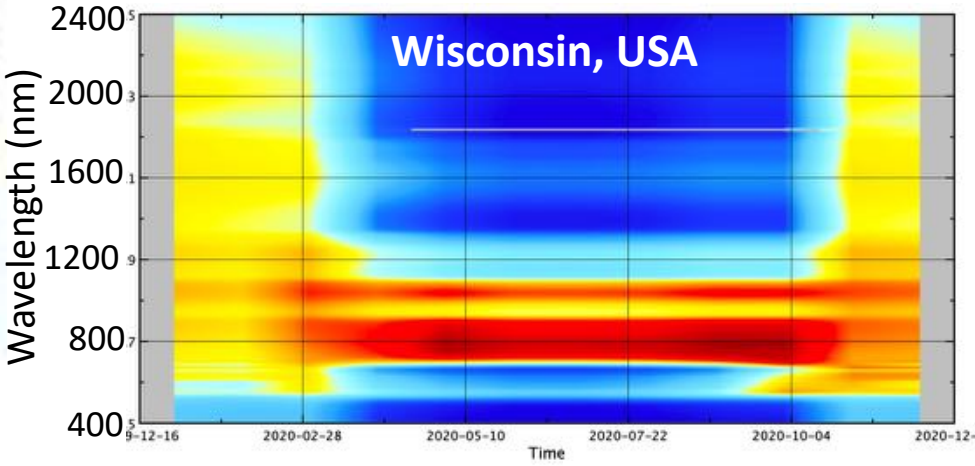


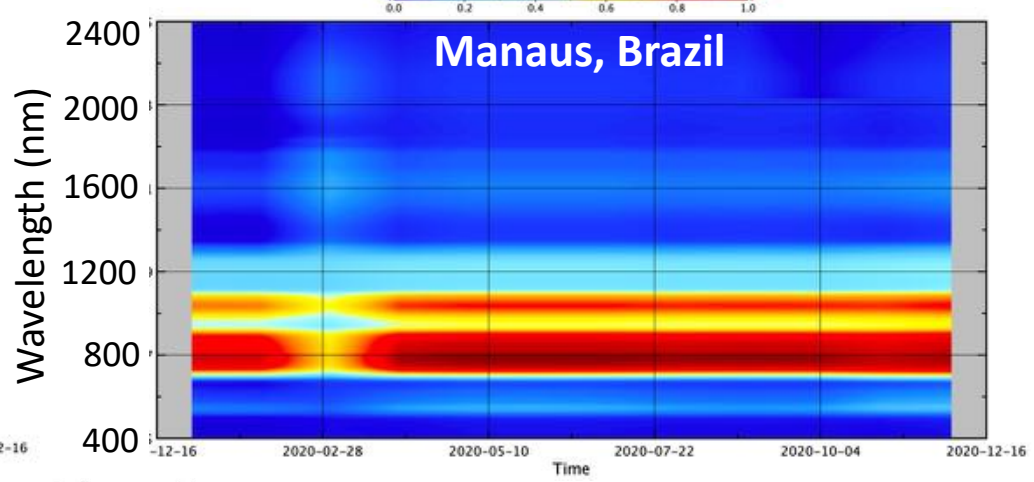

MEET-SBG: Modeling End-to-End Traceability in support of SBG

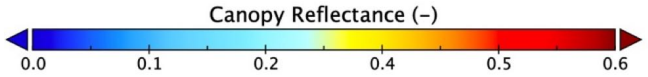
- **Observing system simulation experiment**: LPJ-Prosail
  - Spectra simulated each day for entire global land surface









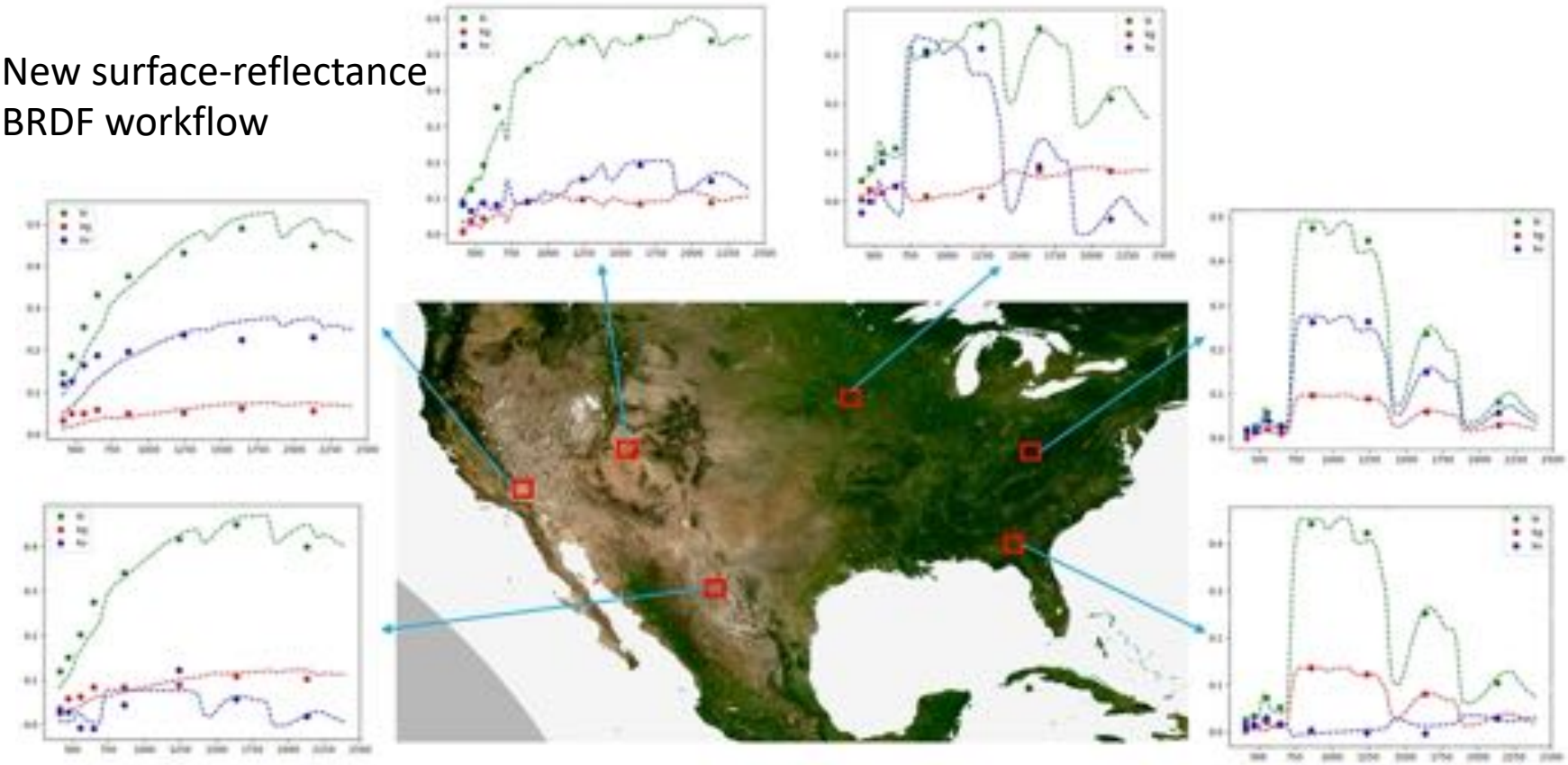





MEET-SBG: Modeling End-to-End Traceability in support of SBG

- **Synthetic data generation**: Ames Global Hyperspectral Synthetic Dataset (AGHSD) version 2: Surface Reflectance

New surface-reflectance BRDF workflow



NASA ARC: Weile Wang & Jennifer Dungan
https://data.nas.nasa.gov/aghsd/

SBG Applications

Team: Jeff Luvall (MSFC), Christine Lee (JPL), Stephanie Schollaert Uz (GSFC), Nancy Glenn (BSU), Karen Yuen (JPL) and 200+ community members

- Community Assessment Report
- RTI User Needs and Valuation studies
- SBG/GLEON fellowship applications open
- SBG Applications Working Group – next meeting March 24

To join the SBG Apps group, visit http://tinyurl.com/SBGApplicationsWG

Google Public Drive
https://tinyurl.com/SBGApplicationsWGPublicDrive

GLEON Fellowship Program

Lake Expedition 2022

Recruiting 10-12 graduate students

Why?

- Supports science formulation for SBG
- Creates a transdisciplinary team needed for the science of remote sensing of inland lake water quality
- Future of science requires collaboration

How?

- Develop technical skills - interpretation of satellite data and high frequency/complex database synthesis and modeling
- Create products - Open source models, publications, presentations
- Learn, utilize leadership & collaborative skills - facilitation, conflict mediation, network science
- Engage GLEON and NASA networks toward sustained observing for calibration/validation of satellite products

https://gleon.wufoo.com/forms/lake-expedition-2022-application/

Team science
Modeling
Big data

Cohort 1, 2013
U.S. Water quality
Lake metabolism

Cohort 2, 2015
Carbon cycling
Lake salt

Cohort 3, 2017
Bayesian blooms

Cohort 4, 2020
Changing lake area
Machine learning

Systematic Integration of Applications into the Surface Biology and Geology Earth Mission Architecture Study

Key Points:

- Applications and science can be considered synergistically through the mission life cycle; at early stages, this integration produced a more representative and tailored set of measurement needs driving mission architecture
- Applications conferred unique technical needs, particularly around latency, that were carried through the architecture study
- Applications help advance discussions regarding international partnerships, which can help advance science and applications priorities beyond what is possible with a single agency and cost targets

Deliverable(s) Update: 1st Draft completed and presented to Lawrence Friedl at NASA HQ.

Community Assessment Report (CAR) serves numerous project functions

- Document the state of knowledge of SBG applications community
- Mission Concept Review (MCR) gate product
- Inform SBG community engagement strategy (who should we engage with, when should we engage, and what do we need to build capacity and skills to use SBG data for decisions)?
- Provide / support justification for specific Program Level Requirements Appendix (PLRA)
- Inform prototype SDS workflow development to ensure ability to respond to application needs
- Aligns with NASA Applied Sciences Strategy

By 2026, Applied Sciences will:

Pursue efforts to apply and integrate Earth science throughout communities' value chains.

Expand engagement of user communities with NASA Earth Science Teams and enhance applications throughout missions' lifecycles.

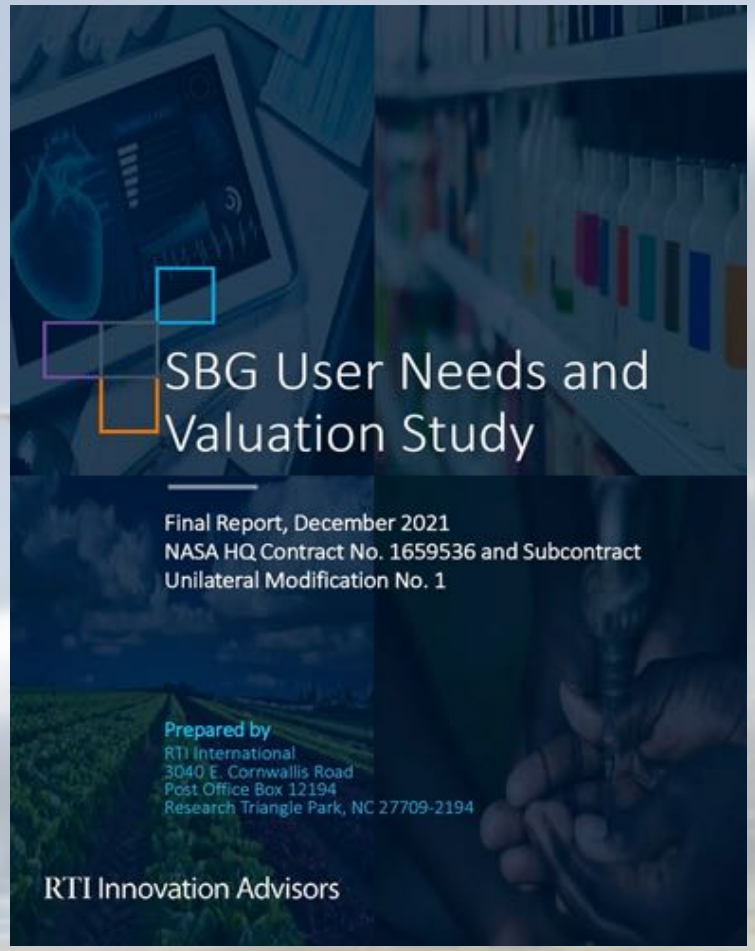
Integrate Earth observations into trusted portals and tools across communities, amplifying the reach of Earth science.

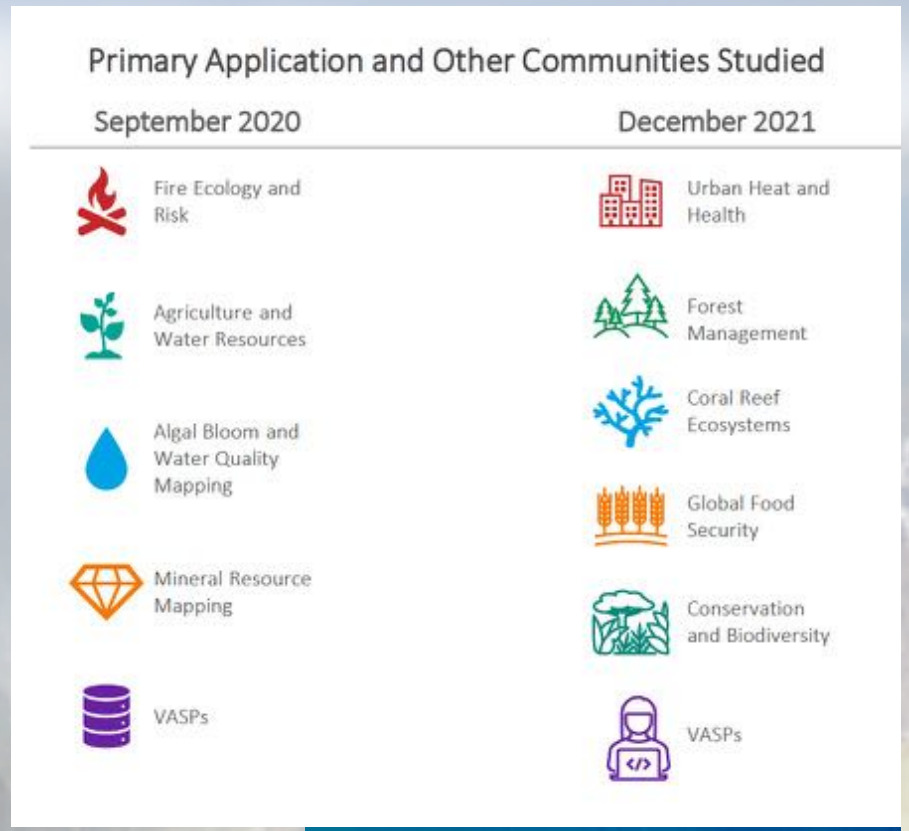
Re-examine solicitation mechanisms to identify highly effective approaches and pursue new funding models, supporting co-production and accelerating uptake of applications.

Optimize the replication of successful applications, especially domestically, and pursue opportunities to appropriately scale them.

Advance methods for successful transition of applications and sustained impact.

Deliverable(s) Update: 2nd RTI Survey Study completed and Final Report delivered.

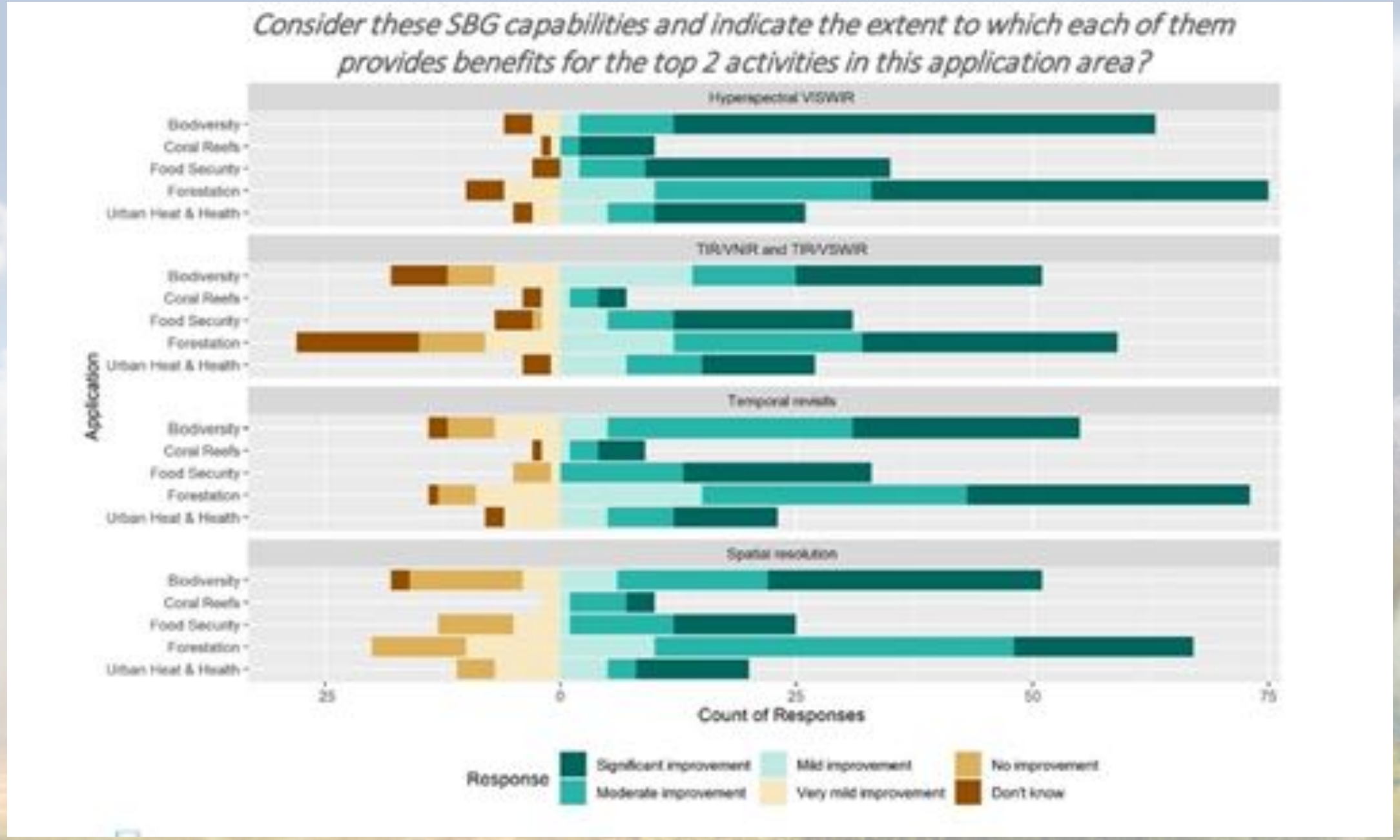




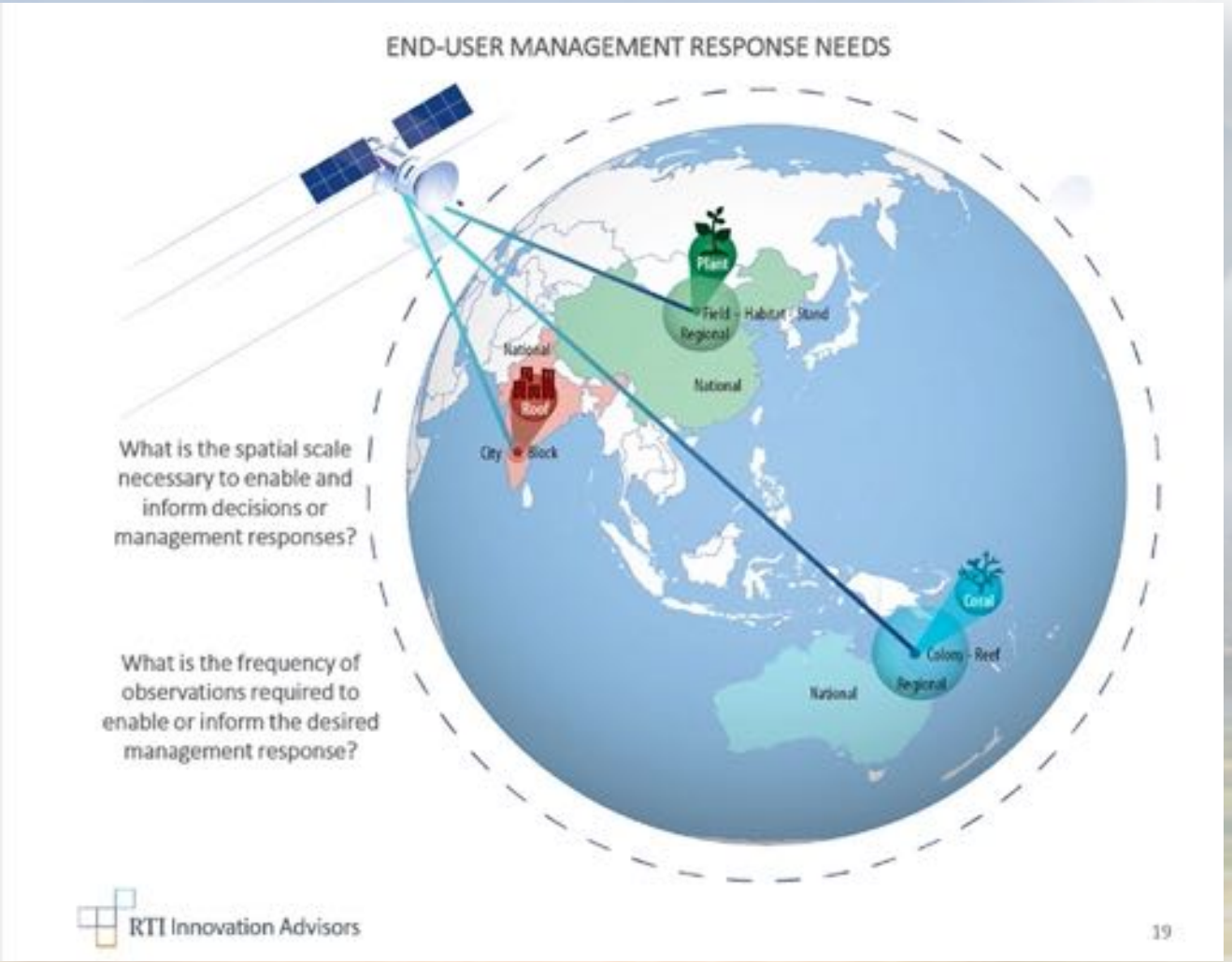
A fundamental aspect of these user studies was to engage private-sector, nongovernmental organizations (NGOs), and local municipal EO users not traditionally engaged by NASA for science mission planning. Categorically identifying and engaging this type of nontraditional user was paramount to successfully studying their respective needs and perceptions of SBG.

1st Study: https://sbg.jpl.nasa.gov/doc_links/user-needs-and-valuation-study/view
2nd Study: https://sbg.jpl.nasa.gov/doc_links/2nd-sbg-user-needs-and-valuation-study/view
Tom Culver's Presentation on 2nd study:
https://drive.google.com/file/d/1O6SwQHOR7fl_G81jllMybJRCOreEyQAX/view?usp=sharing

Deliverable(s) Update: Survey generated user data on application area needs and impacts.



Insights—Management Response Needs



Insights—Response Time Needs

"Jobs to be done" are operationalized or managed at different response times from years down to a day. The table below summarizes the findings of our primary research into the desired response times for SBG-relevant activities within the primary application areas, including the most important or highest impact* activities.

	Annual Seasonal	Monthly	Weekly	Daily
URBAN HEAT AND HEALTH				
Albedo/reflectivity/emissivity studies, urban infrastructure/surface surveys				
Mapping programs,* heat health and mitigation management, policy, MRV				
Targeted heat mitigations,* siting cool buildings, cool roads, urban vegetation				
Heat alerts,* high-resolution urban maps for heat alerts and policy making				
FOREST MANAGEMENT				
Forest inventories/certifications,* land/wood baselines and supply assessments				
Species classification,* substand classification and invasive/understory composition				
Forest health,* tree canopy height, phenology/leaf out timing, insects/disease				
Carbon market/offsets, MRV for owners/NGOs				
Functional diversity, functional properties across time and ecosystems/habitats				
Disturbance and regeneration, deforestation, disease, storm/fire; replanting, regrowth				
CORAL REEFS				
Marine spatial planning,* to sustain reefs and tourism				
Coastal resilience planning,* mapping and reef management				
Condition and composition, health, resiliency across time				
Restoration and replanting,* site and monitor				
Capture/predict bleaching events, monitor temperature and coral condition				
Disturbance monitoring, nutrient/pollution influx, wave action, temperature, etc.				
GLOBAL FOOD SECURITY				
Global/regional agriculture statistics,* estimates of crop yield and productivity				
Carbon markets,* improved indicators/models for soil carbon, certification, MRV				
Food insecurity interventions,* regional models for improved interventions				
Land quality surveys, for suitable land, soil maps, conversion, regenerative Ag				
Land and field assessments, cropland, crop type classification, monitoring				
Hazard events/trend monitoring,* onset, extent, and prediction of drought, floods, and anomaly detection				
CONSERVATION AND BIODIVERSITY				
National surveys,* mapping baselines, establish high value conservation areas				
Habitat management, conservation land management and geo-accounting				
Biodiversity compensatory mitigations,* mapping, compliance				
Species classification, plant/crop classification, baselines, invasive/understory				
Deforestation and degraded land,* monitoring major plantations/natural forests				
Agroforestry and carbon offsets, MRV of suppliers/small holders to support sustainable practices				

RTI Innovation Advisors

21

SISTER: SBG **S**pace-based **I**maging **S**pectroscopy and **T**hermal pathfind**ER**

SISTER is an active collaboration between Jet Propulsion Laboratory (JPL), Ames Research Center (ARC), Goddard Space Flight Center (GSFC), industry, academic institutions, and non-profit organizations

Phil Townsend (University of Wisconsin, Madison) – Co-Lead

Michelle Gierach (JPL) – Co-Lead, JPL Center Lead

Ben Poulter (GSFC) – GSFC Center Lead

Ian Brosnan (ARC) – ARC Center Lead

SISTER: SBG Space-based Imaging Spectroscopy and Thermal pathfindER

Primary Objectives & Timeline

- Prototype architectures and workflows to generate prototype high-dimensional, high-value SBG data
- Distribute prototype SBG data for community evaluation and training

FY21 (Oct 2020 – Sept 2021)

Prototype workflows & system components

Deliverable: *Distribute land & water reflectance for community evaluation / feedback*

FY22-23 (Oct 2021 – Sept 2023)

Implement select prototype L2B+ algorithms

Deliverable: *Distribute prototype L2B+ products for community evaluation / feedback*

FY24-25 (Oct 2023 – Sept 2025)

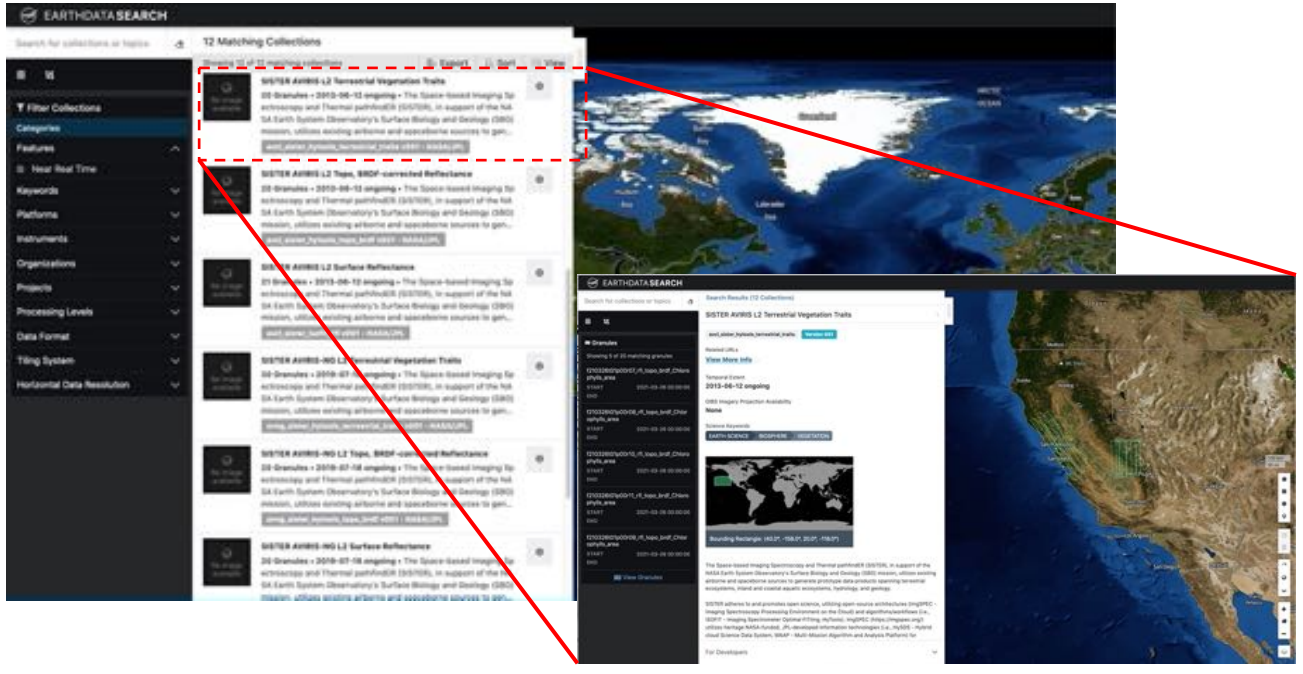
Adapt workflows based on emerging SBG ATBDs

Deliverable: *Refine and redistribute prototype SBG products for community evaluation / feedback*

Prototype Data Available To-Date

- *NASA Ames Research Center*
  - Global Hyperspectral Synthetic Data (AGHSD) is available at https://data.nas.nasa.gov/aghsd/data.php
  - Hyperion L1 radiance
  - Hyperion L2 reflectance (in progress)
- *NASA Jet Propulsion Laboratory*
  - Select* AVIRIS-Classic, AVIRIS-Next Generation, and PRISMA scenes for surface reflectances and uncertainties; topo, BRDF-corrected reflectances; terrestrial vegetation traits

**More scenes, data streams, and workflows (e.g., aquatic, snow/ice, geology) will continuously be incorporated in FY22+*



SISTER: Prototype SBG Algorithms & Products

SISTER will implement select L2B+ algorithms (informed by the Algorithms and Applications Working Groups) to generate prototype SBG products for community evaluation and engagement

SBG Algorithm Class	SBG Algorithm Products (examples)
CORE Algorithms	
Earth Surface Temperature and Emissivity	Land Surface Temperature* and Emissivity
VSWIR Reflectance	Land and Water Reflectances, BRDF Corrections, Albedo
Cover Classifications	Cloud, Water, Land Cover, Plant Functional Types, etc.
PRODUCT Algorithms	
Terrestrial Ecosystems	
Vegetation Traits	Nitrogen, LMA, Chlorophyll, Canopy water
Evapotranspiration	ET*, Evaporative stress index
Proportional Cover	GV, NPV, Substrate, Snow/Ice, Burned Area
Geology/Earth Surface	
Substrate Composition	Mineral type*, Fractional abundance*, Soil types and constituents
Volcanic Gases and Plumes	SO2, Volcanic ash
High Temperature Features	Volcanic temperature anomalies (lava temperature), Forest fires
Aquatic and Coastal Ecosystems	
Water Biogeochemistry	Pigments, CDOM, Suspended particulate matter
Water Biophysics	Diffuse light attenuation, Inherent optical properties, Euphotic depth, PAR
Aquatic Classification	Phytoplankton functional types, Floating vegetation, Benthic cover, Wetlands
Snow and Ice	
Snow albedo	Albedo, Grain size, SSA, Light absorbing particles, Fractional cover

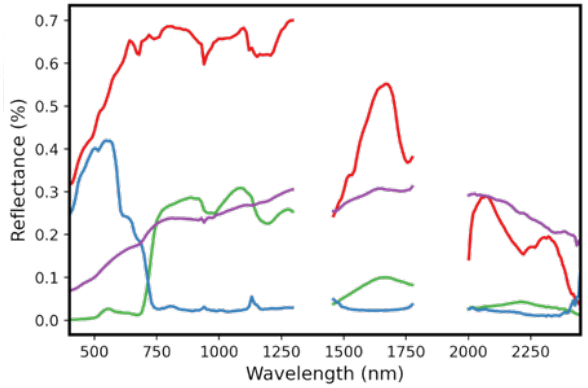
**Leverages ECOSTRESS and EMIT algorithms*

Cawse-Nicholson et al. 2021

SISTER: Prototyping SBG Algorithms using PRISMA and DESIS

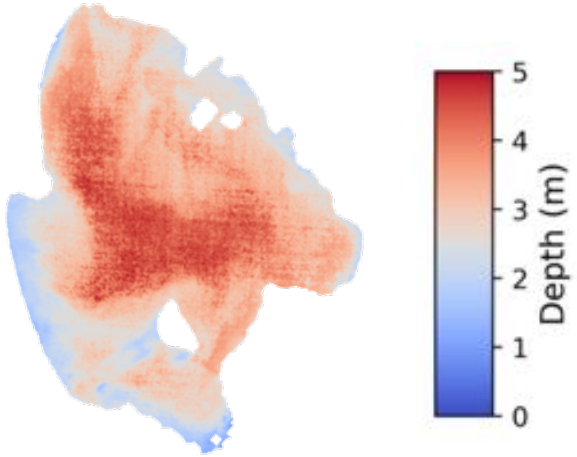
ISOFIT (Thompson et al. 2018)

PRISMA



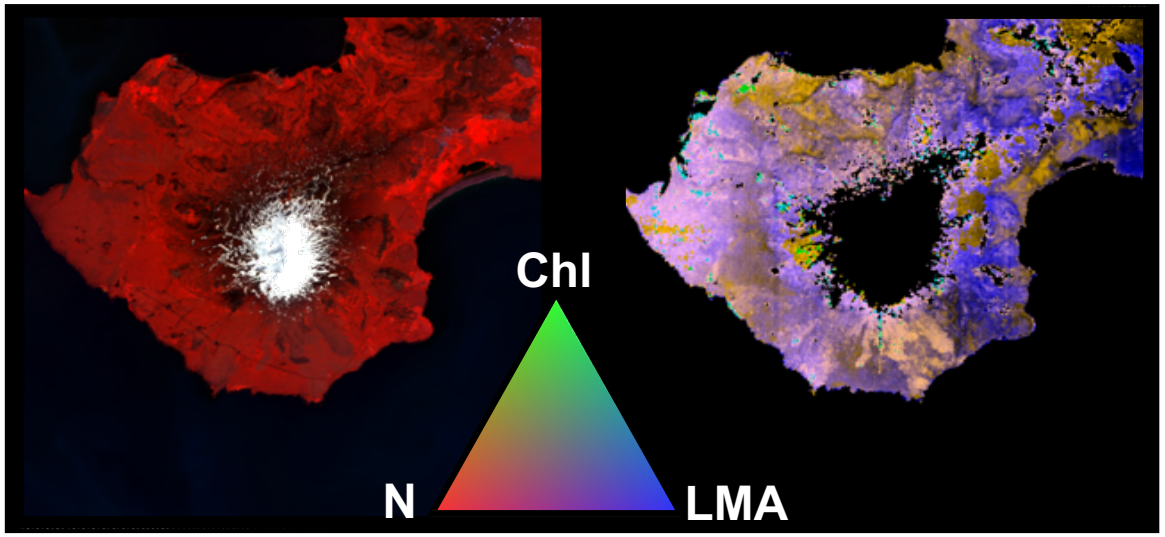
Bathymetry (Thompson et al. 2016)

DESIS Lago Trasimeno, Italy June 04, 2021



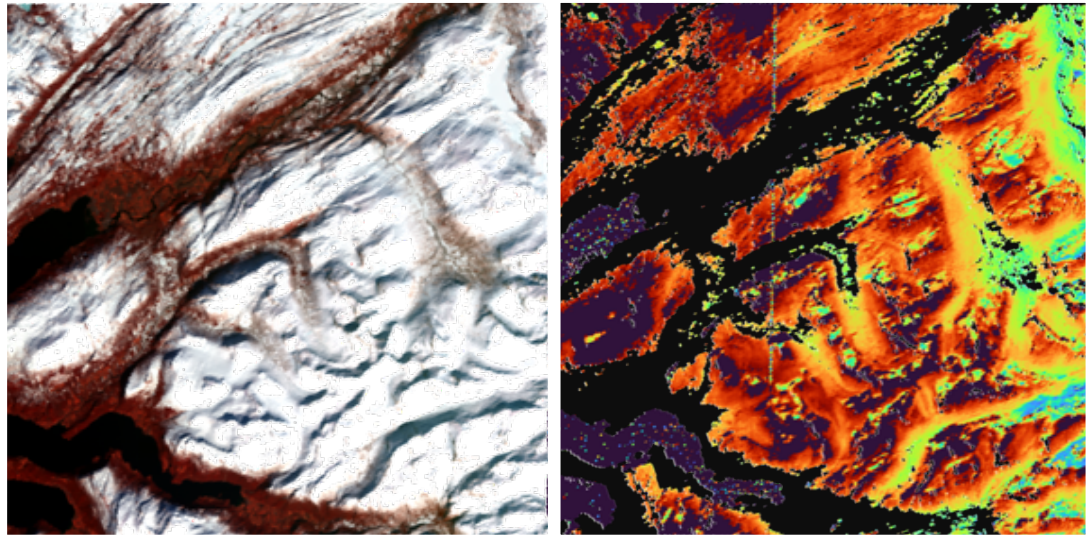
Vegetation Biochemistry

PRISMA Snæfellsjökull, Iceland July 02, 2020



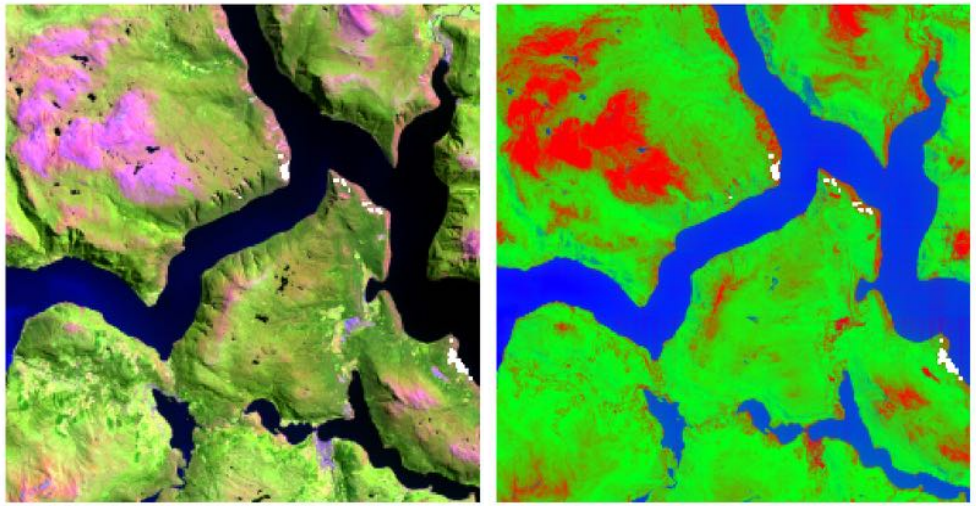
Snow grain size (Nolin and Dozier 2000)

PRISMA Surnadal, Norway April 21, 2020



SISTER: Prototyping SBG Algorithms using PRISMA and DESIS

Fractional Cover (EMIT Science Team)
PRISMA Luster Allmenning, Norway July 23, 2021

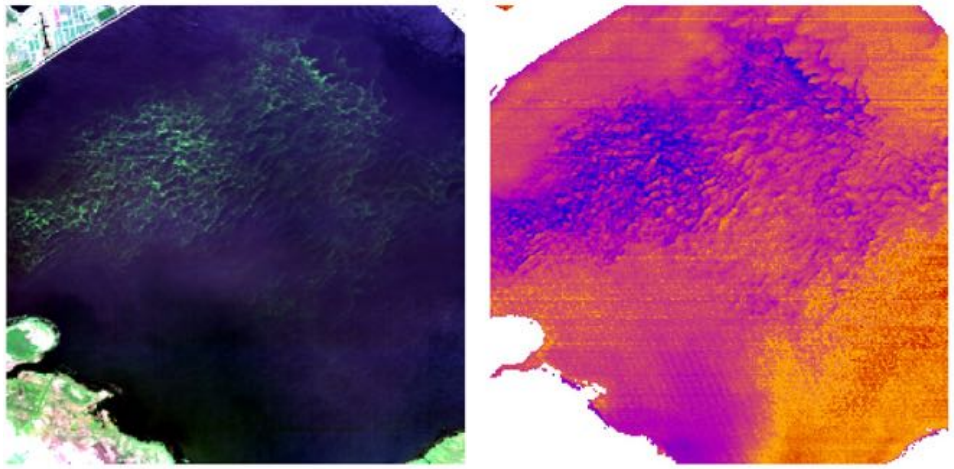


Soil

Vegetation

Water

Phycocyanin (O'Shea et al. 2021)
PRISMA Lake Okeechobee, Florida June 26, 2020



High

Low

SISTER: Pipeline infrastructure @Ames:

- Completed processing the 55-TB Hyperion data to top-of-atmosphere radiances (L1)
- Currently checking consistency of Hyperion surface reflectance results (L2, Figs 1&2)
- Initiated NASA process to make data pipeline control software (Ziggy) open-source
- Initiated Ziggy software testing on HPC and cloud platforms
- Future work: incorporate L3 algorithms for vegetative traits and/or aquatic studies

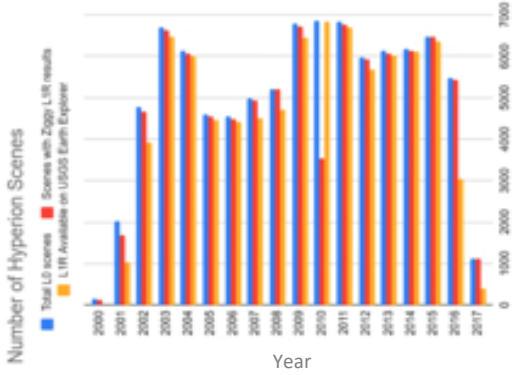


Fig 1. Comparison of RadCalNet measurements with Hyperion surface reflectance retrievals for scenes observed in Railroad Valley.

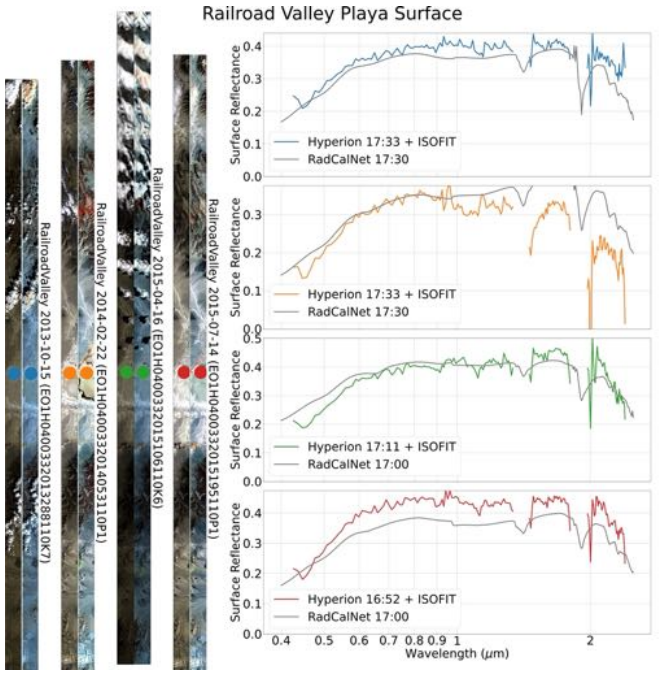
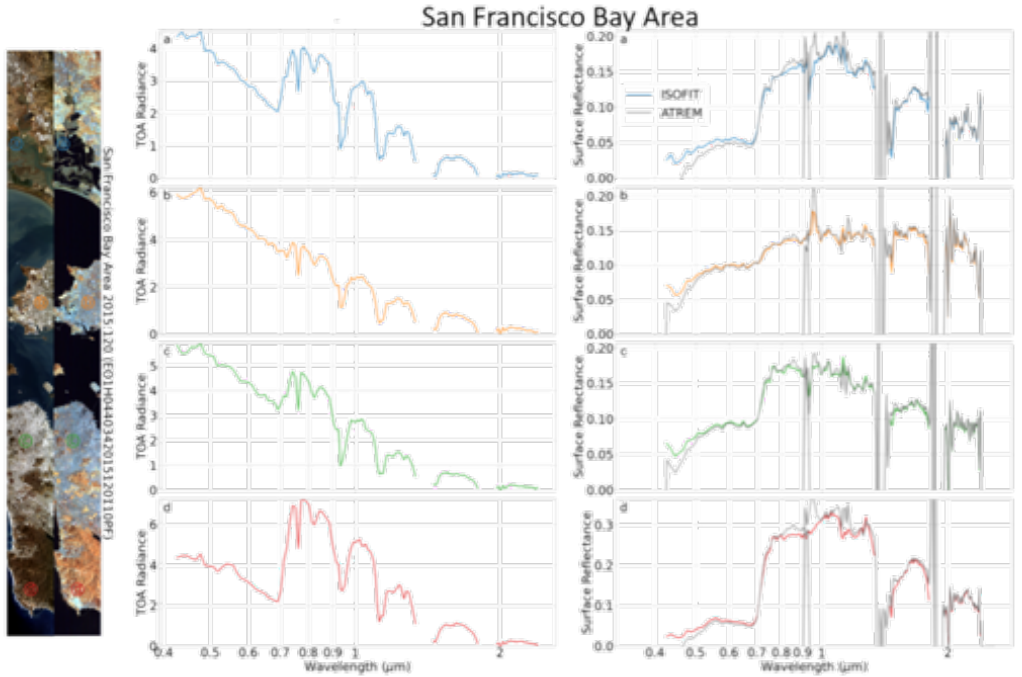


Fig 2. Hyperion TOA radiance results and comparison of ATREM and IsoFit retrievals of surface reflectance over San Francisco Bay.



How Can You Get Involved?

1. Join SBG Working Groups

2. Let us know if you have SBG-relevant ground truth data
   - Where, what, when?

3. Evaluate prototype SBG data for your science discipline

4. Use prototype SBG data in your own workflows/algorithms

If interested, please email sbg@jpl.nasa.gov ,
or mgierach@jpl.nasa.gov and ptownsend@wisc.edu directly




Field Campaign WG

- Co-leads: Ryan Pavlick, Dana Chadwick
- Goals: support mission concept development by scoping and executing SBG-led field campaigns and coordinating with other relevant field activities
- SBG High Frequency Timeseries
- Tracking/coordinating with ABoVE, BioSCape, SnowEX, HyTES Europe, ARCSIX, NEON AOP, CarbonMapper, etc
- Scoping potential campaigns to address/support:
  - Algorithm development/testing
  - Applications Early Adopters
  - Cal/Val prototyping and cross-calibration
  - Issues of scale
  - Synergies with other ESO missions

Surface Biology & Geology

SHIFT: **S**BG **HI**gh-**F**requency **T**ime series

Surface Biology & Geology

SHIFT campaign goals

- Collect the first openly-available airborne VSWIR spectral imagery dense time series at an approximately weekly cadence over a period of significant phenological change.
- Enable the NASA SBG team to conduct traceability analyses related to science value of revisit without relying on multispectral proxies.
- Enable testing algorithms for consistent performance over seasonal time scales, and testing end-to-end workflows including community distribution.
- Provide early adoption test cases to SHIFT application users, and incubate relationships with basic and applied science partners at the UC Santa Barbara Sedgwick Reserve and The Nature Conservancy.

SHIFT campaign motivations

Temporal (revisit) and spatial resolution are the biggest VSWIR cost sensitivities for SBG

Mission & Instrument Parameter	International collaboration (26/28 observables fully met)	**Baseline (16/28 observables fully met)	Threshold (11/28 observables fully met)
Spatial Resolution	30 m	30 m	40 m
Temporal Resolution	8 days*	16 days*	22 days*
Spectral Resolution	10 nm	10 nm	20 nm
Wavelength Range	380-2500	380-2500	400-2500
Sensitivity (SnR)	400 (VNIR) / 250 (SWIR)	400 (VNIR) / 250 (SWIR)	300 (VNIR)/200 (SWIR)

Revisit and pixel size drive determination of spectrometer number, focal plane size, telescope size, and data volume

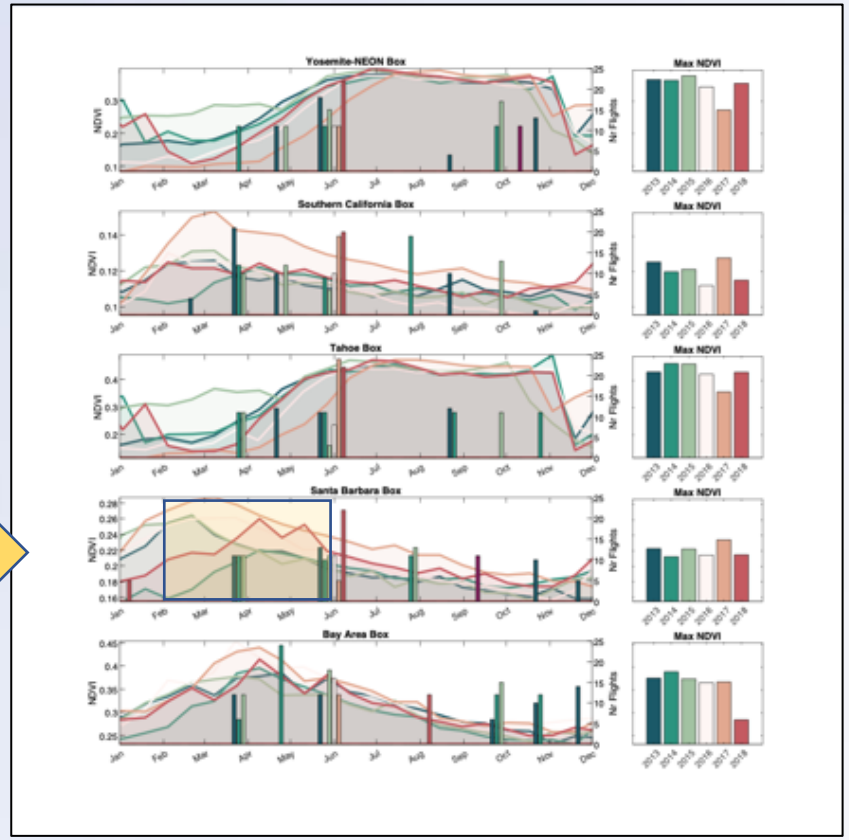
** Revisit assuming 50% global mean cloud cover*
*** Notional, final performance requirements TBD*

Surface Biology & Geology

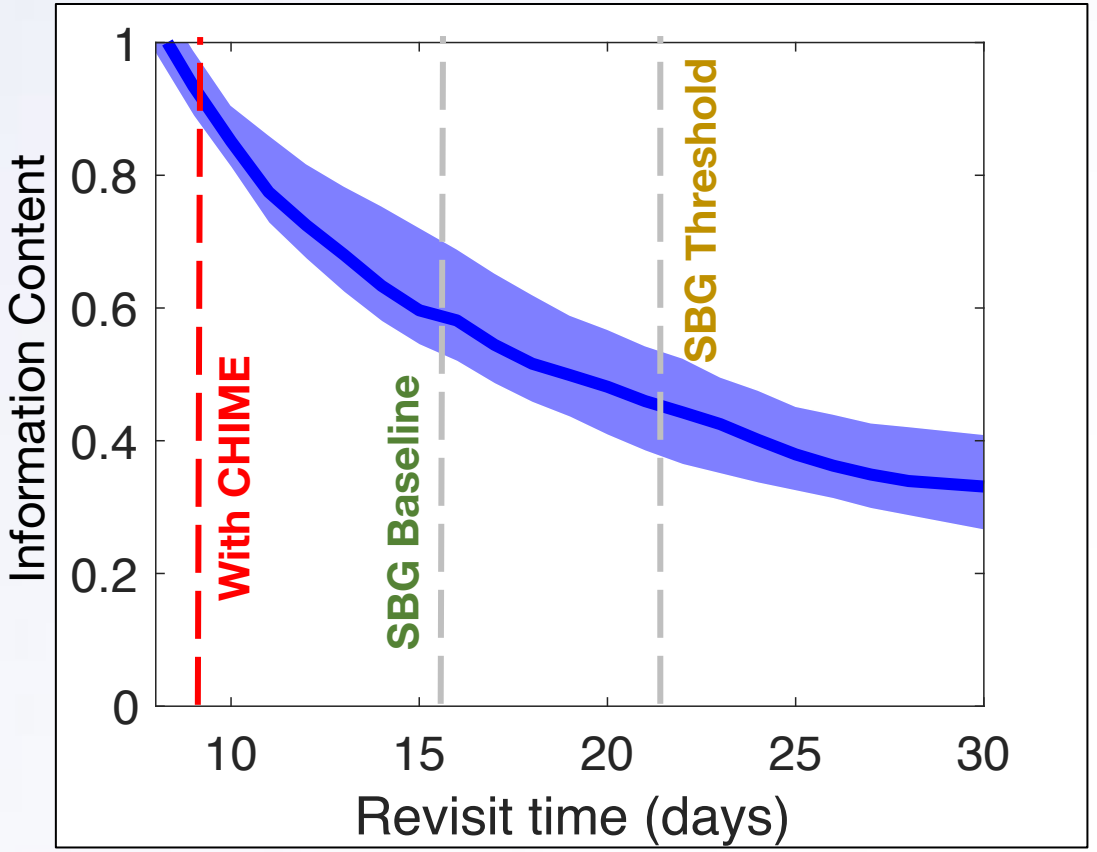
How much VSWIR IS information exists in the time domain?

NO time series exist at the anticipated SBG-CHIME time scales

SHIFT



PreHysPIRI sampled max 3x/year.
SHIFT will focus on the most dynamic time of year.



VIIRS proxy suggests high information content at high frequency and rapid loss as revisit lengthens

Surface Biology & Geology

SHIFT team & points of contact

- Site Co-PIs
  - Jack and Laura Dangermond Preserve-Mark Reynolds, TNC
  - UC Sedgwick Preserve-Frank Davis, UCSB
- SBG coordination - Kimberley Miner
- Field team coordination, terrestrial vegetation: Dana Chadwick
- Field teams, coastal vegetation: collaborator-led (POC Dana Chadwick)
- Field teams coastal aquatic: collaborator-led (POC Michelle Gierach)
- Field protocols - Phil Townsend-U of Wisconsin
- Airborne coordination - Ryan Pavlick
- Data processing - Michelle Gierach
- Rapid analysis – Phil Brodrick
- PI - Dave Schimel
- NASA HQ - Woody Turner

Surface Biology & Geology

SHIFT project partners

Study site partners

- UC Carpinteria Salt Marsh Reserve
- UC Coal Oil Point Reserve
- UCSB North Campus Open Space
- Brander Vineyard

Collaborating projects

- UCSB Plumes and Blooms project
- NSF Santa Barbara Channel Long Term Ecological Research Program
- NSF Sundowner Winds Experiment (SWEX)

Collaborating partners

- UCSB: ~8 self funded PIs, 10+ graduate students
- UCLA: 3 self funded PIs, 5 graduate students
- UC Merced: 1 self funded PI
- Cornell: 1 PI, 1 postdoc, 1 graduate student
- USGS: wetland vegetation & spectral calibration

Many more!

Surface Biology & Geology

SHIFT project domain

SHIFT will prototype planned SBG data and algorithm calibration.

In situ data collected on/around each WEEKLY flight day around each pinned location.

Surface Biology & Geology

SHIFT aircraft and sensor

Dynamic Aviation King Air B-200 (N53W)

- MTOW: 14500 lbs
- Service ceiling: 27000 ft
- Cruise speed: 225 kts
- Endurance: >5 hours

Advanced Visible to Infrared Imaging Spectrometer - Next Generation (AVIRIS-NG)

- 380 to 2510 nm
- 425 spectral bands (5 nm resolution)
- 600 across track elements, 34° swath
- 1 mrad spatial sampling, 100 fps

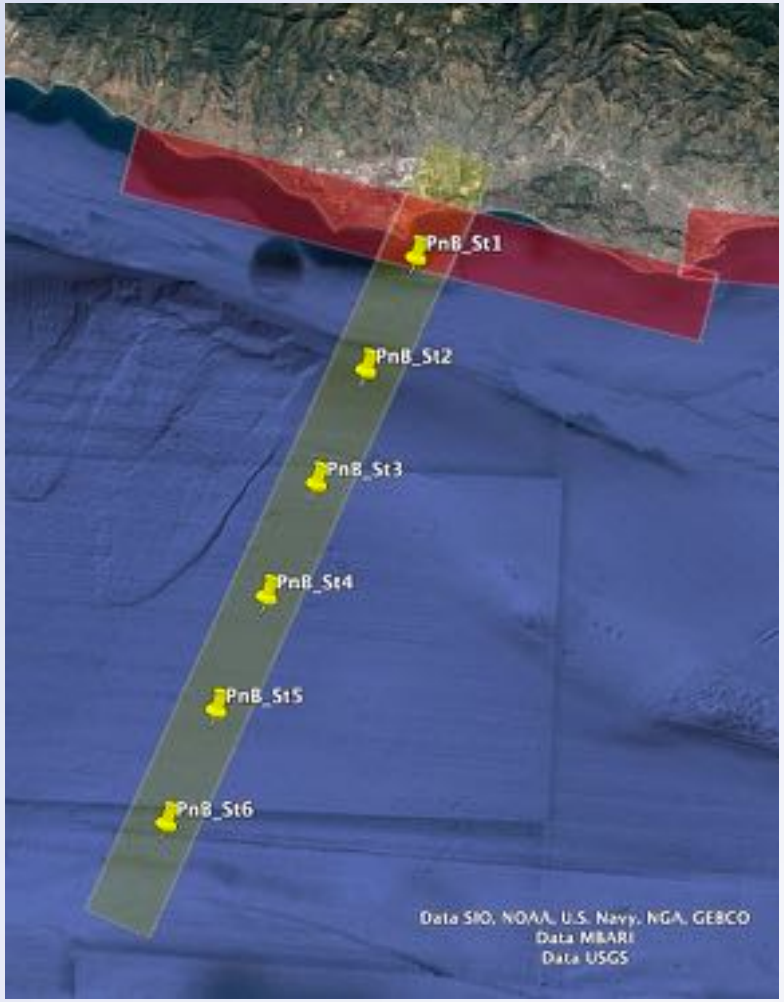
Surface Biology & Geology

SHIFT flight plans and design

- 8-12 flights from late Feb to May 2022
- Based out of Burbank airport
- 4.5 hours per flight, ~1 flight per week, nominally aiming for Tuesday flights
- Plan to straddle science acquisitions around solar noon

Surface Biology & Geology

SHIFT flight plans and design



- SHIFT will coordinate flights with the NSF “Plumes and Blooms” LTER transect in the Santa Barbara Channel
- Plumes and Blooms conducts day cruises to collect in-situ measurements to better understand, predict, and utilize changes in ocean color
- Three Wednesday cruises during SHIFT campaign period

Surface Biology & Geology

SHIFT field plans – inland terrestrial

Terrestrial Vegetation Traits

- In close collaboration with Co-Is Mark Reynolds (TNC), Frank Davis (SR), and Phil Townsend (UW), we will be sampling for fractional cover and vegetation traits across the diverse ecosystems that span this coastal-inland gradient.
- We aim to sample ~400 15m plots during the course of the campaign, with samples collected within ~3 days of an AVIRIS flight.


Sedgwick Reserve


Dangermond Preserve

Phenocams

- Kelly Easterday (TNC) has led the set up of phenocams at both JLDP and SR which will run for the duration of the project.

Ancillary Measurements

- Measurements, including gas exchange, spectra, hydraulic traits, and hydrologic monitoring will be collected by collaborators from UCSB & UCLA

Surface Biology & Geology

SHIFT field plans – coastal

Coastal wetland vegetation

- Collaborators from USGS, UCSB, and UC Merced are sampling wetland vegetation along salinity gradients at Coal Oil Point Reserve, UCSB North Campus Open Space, and Carpentaria Salt Marsh Reserve.
- They will utilizing protocols that are compatible with the terrestrial vegetation team to further increase sample size and assess the cross compatibility of trait models between wetlands and terrestrial vegetation.

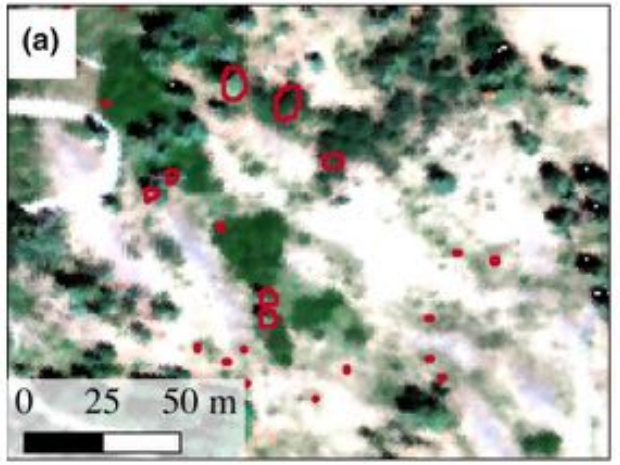
Coastal aquatic

- Collaborators from UCLA and UCSB will collect data on kelp species distributions using both in situ measurements and drone data collections
- Collaborators from SB Channel Long Term Ecological Research (LTER) Program will utilize these data.
- Collaboration w/ “Plumes & Blooms” project led by UCSB Pis David Siegel and Nathalie Guillocheau

Surface Biology & Geology

SHIFT data processing & availability

- Rapid turnaround products will be delivered to field teams to help support in field sampling and absolute geolocation
- Data will be hosted on the ORNL DAAC (conversations ongoing)
- Group data analyses will be supported with processing available adjacent to data on the NASA Science Managed Cloud Environment (SMCE)

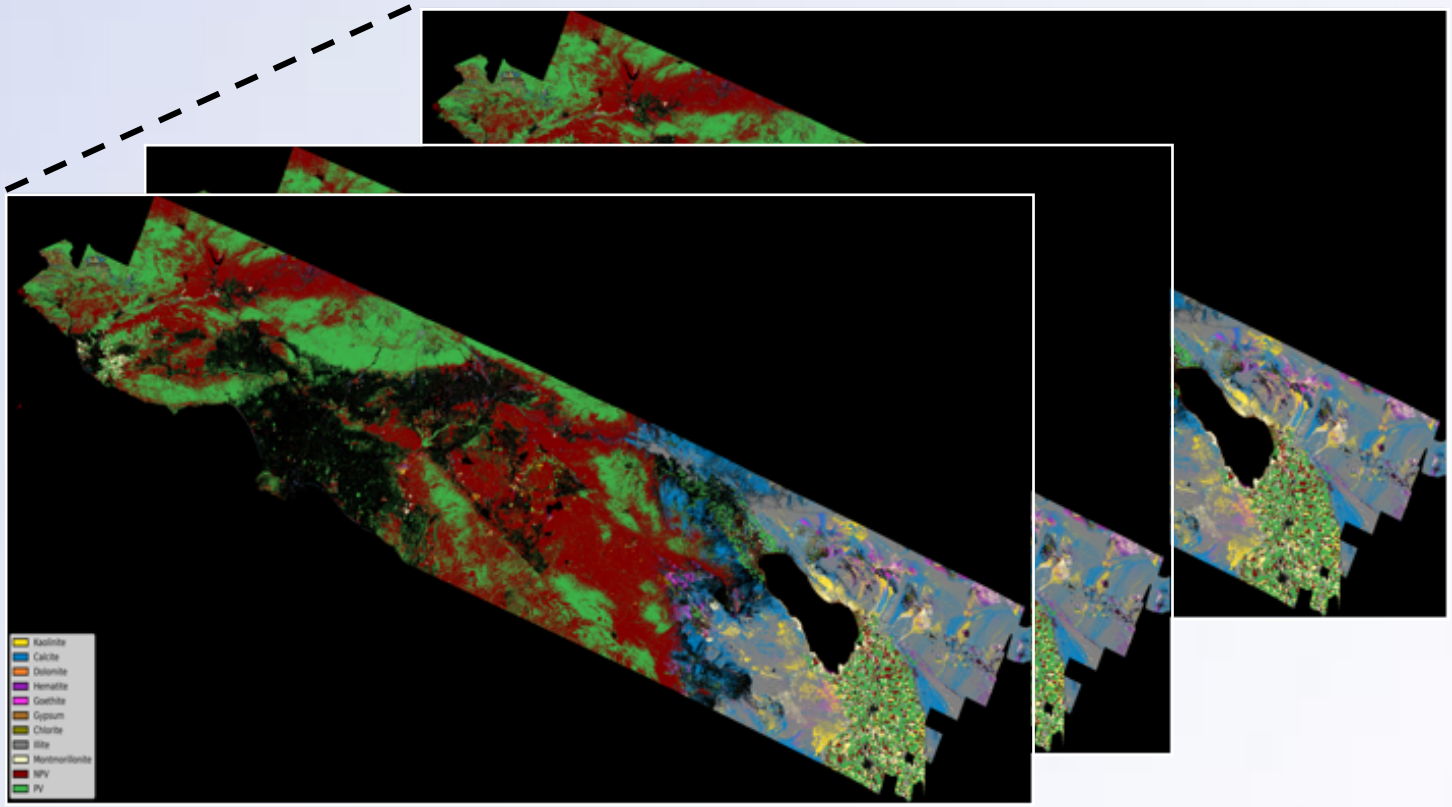


OAK RIDGE National Laboratory

Surface Biology & Geology

SHIFT data processing & availability

Biogeophysical properties will be estimated for the complete time series, on a co-registered grid at 5m resolution



Expected products include:

- Radiance
- Reflectance (isofit correction)
- Vegetation trait maps
- EMIT pipeline products:
  - Fractional cover
  - EMIT 10 minerals

Example from an EMIT demo using the Western Diversity Time Series

Surface Biology & Geology

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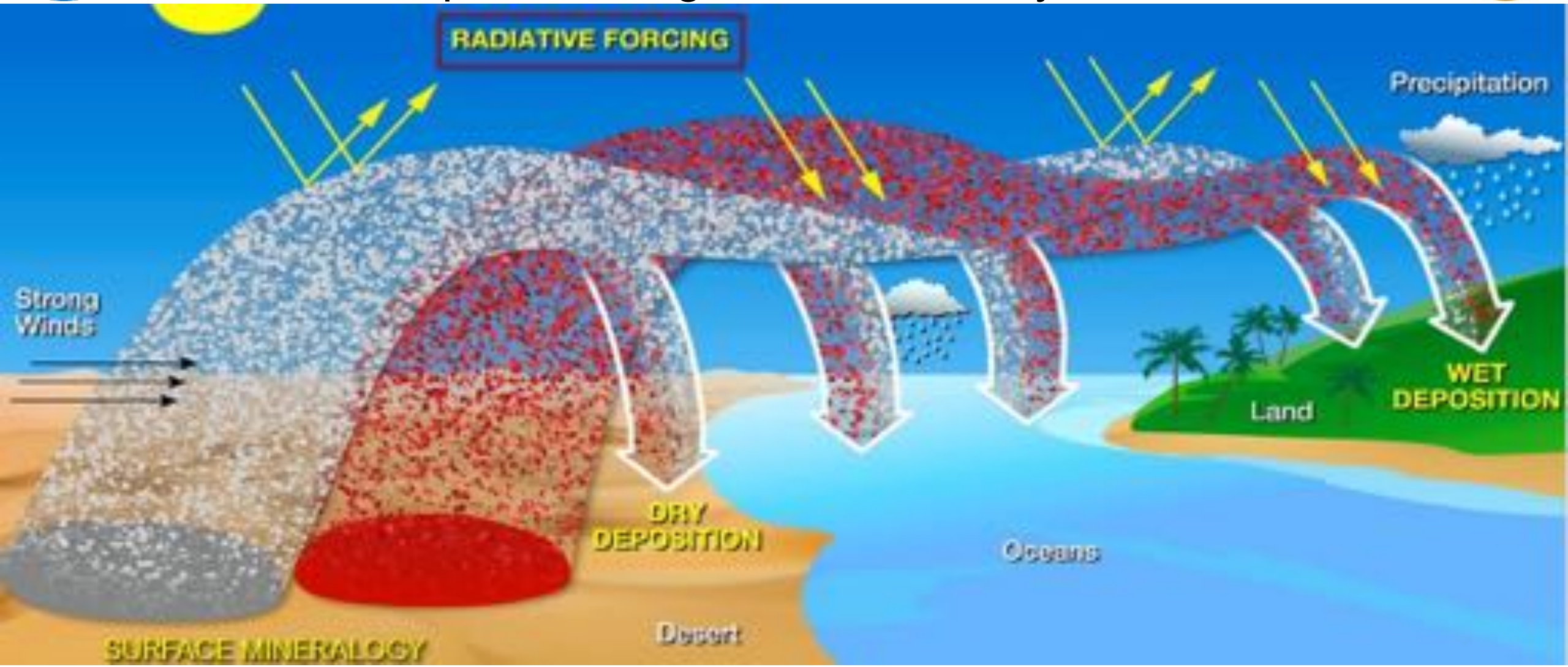
- Data processing - Michelle Gierach
- Rapid analysis – Phil Brodrick
- PI - Dave Schimel
- NASA HQ - Woody Turner

For more information on BioSCape, please go to bioscape.io or contact Anabelle Cardoso (anabelle@bioscope.io)

EARTH SURFACE MINERAL DUST SOURCE INVESTIGATION

PI: Robert O. Green
Robert.O.Green@NASA.GOV

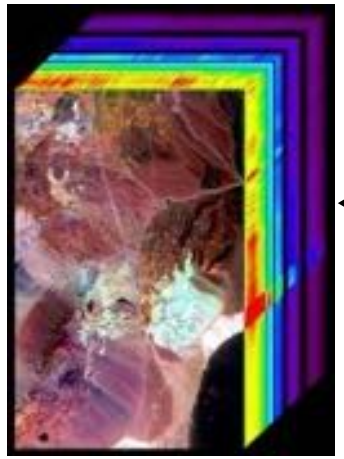
The Earth has a mineral dust cycle with many impacts throughout the Earth system.



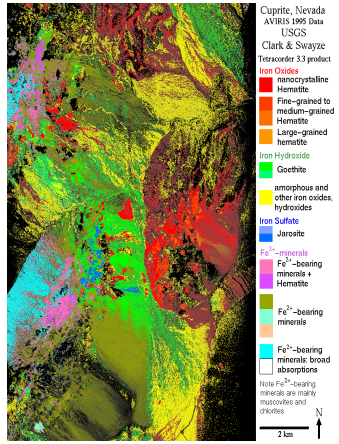
Knowledge of dust source mineral composition is poor and needed to better understand current and future impacts.

EMIT will use NASA invented Imaging Spectroscopy to measure the mineral composition of the Earths arid lands

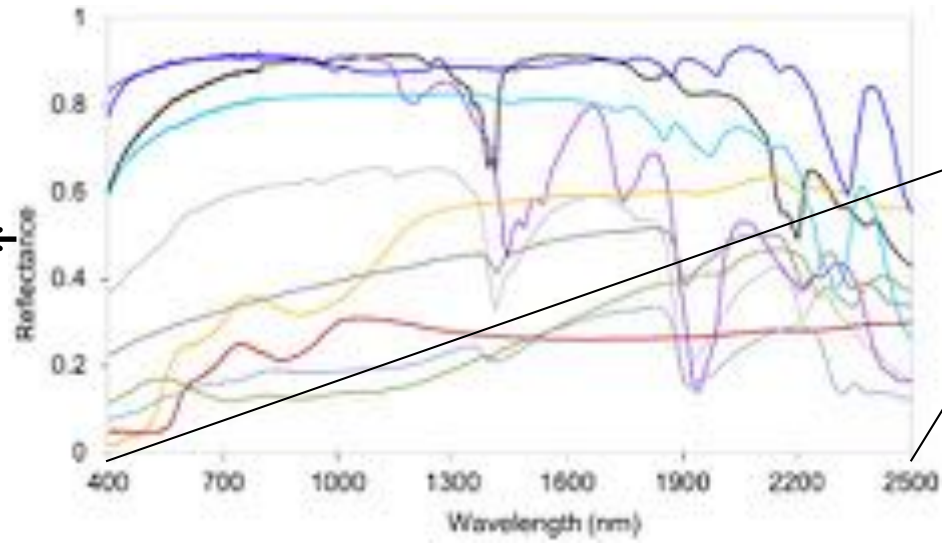
Calibrated Image Cube



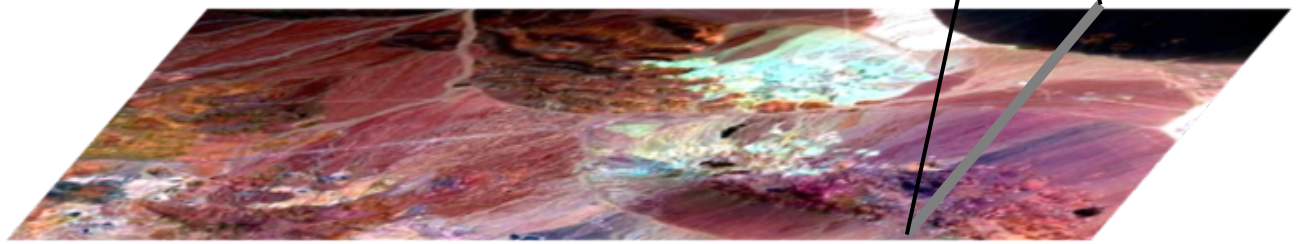
Mineral Map



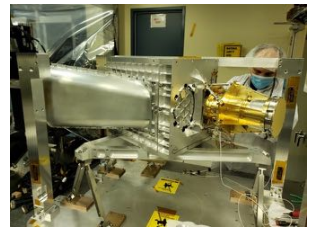
Mineral Spectral Signatures



Kaolinite Al4[Si4O10[(OH)8
Goethite FeO.OH
Dolomite CaMg(CO3)2
Illite (K,H3O)(Al,Mg,Fe)2(Si,Al)4O10[(OH)2,(H2O)]
Vermiculite (Mg,Fe+2,Al)3(Al,Si)4O10(OH)2*4H2O
Montmorillonite (Na,Ca)0.33(Al,Mg)2Si4O10(OH)2*nH2O
Gypsum CaSO4.2H2O
Calcite CaCO3
Hematite Fe2O3
Chlorite (Mg,Fe)3(Si,Al)4O10(OH)2-(Mg,Fe)3(OH)6



EMIT



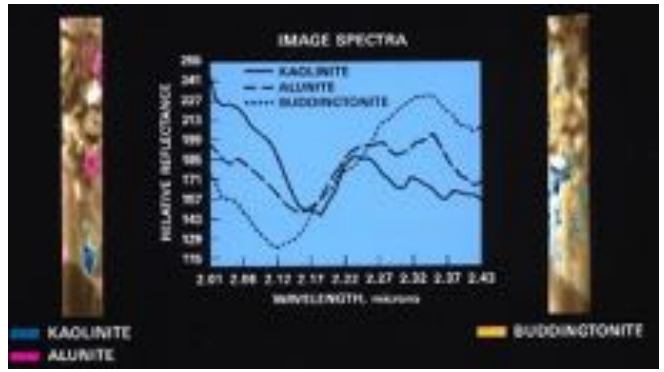
Detector Array

Spectrometer

Slit

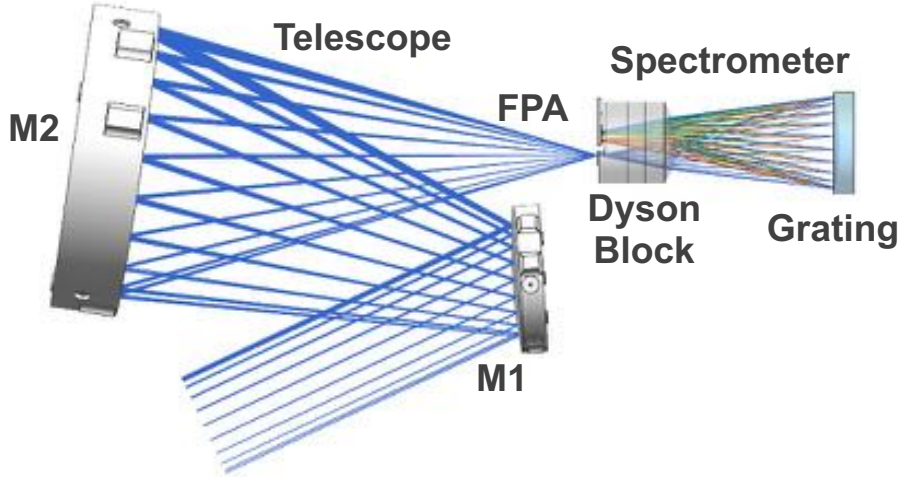
Telescope

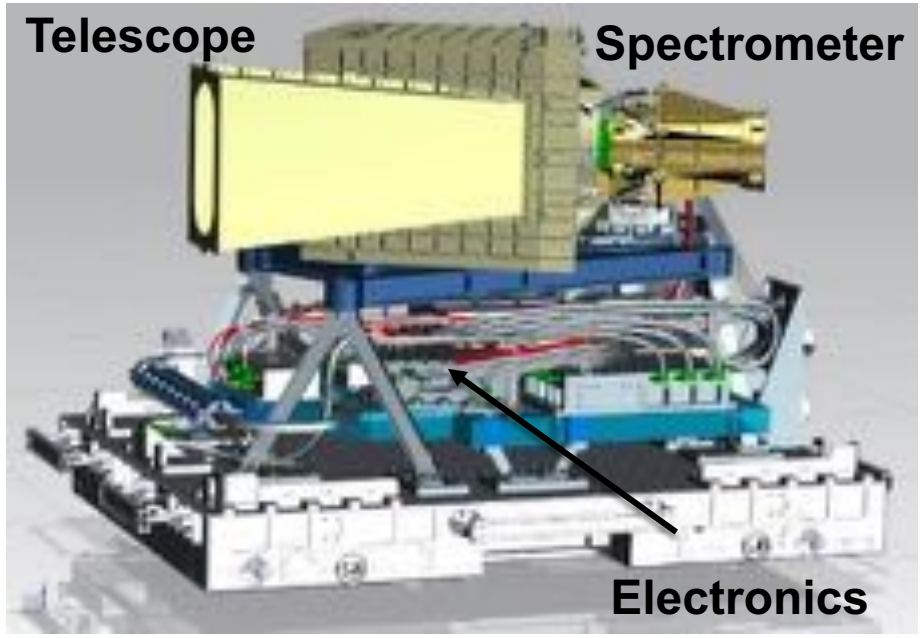
First Imaging Spectrometer (AIS)



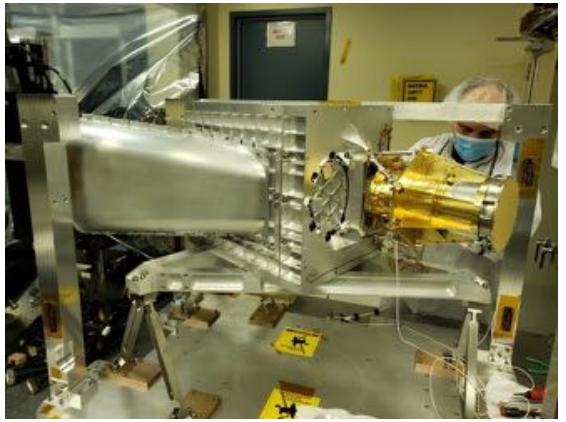
The EMIT Imaging Spectrometer is State-of-the-Art and in the Final Stages of Integration and Test

Optically Fast F/1.8 Dyson Imaging Spectrometer





Optical Bench

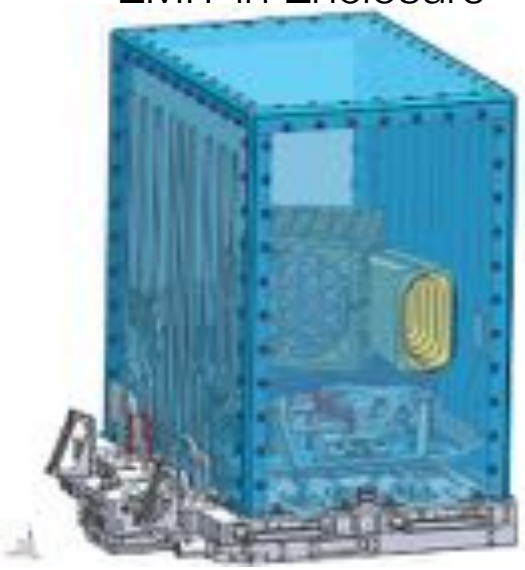


Alignment

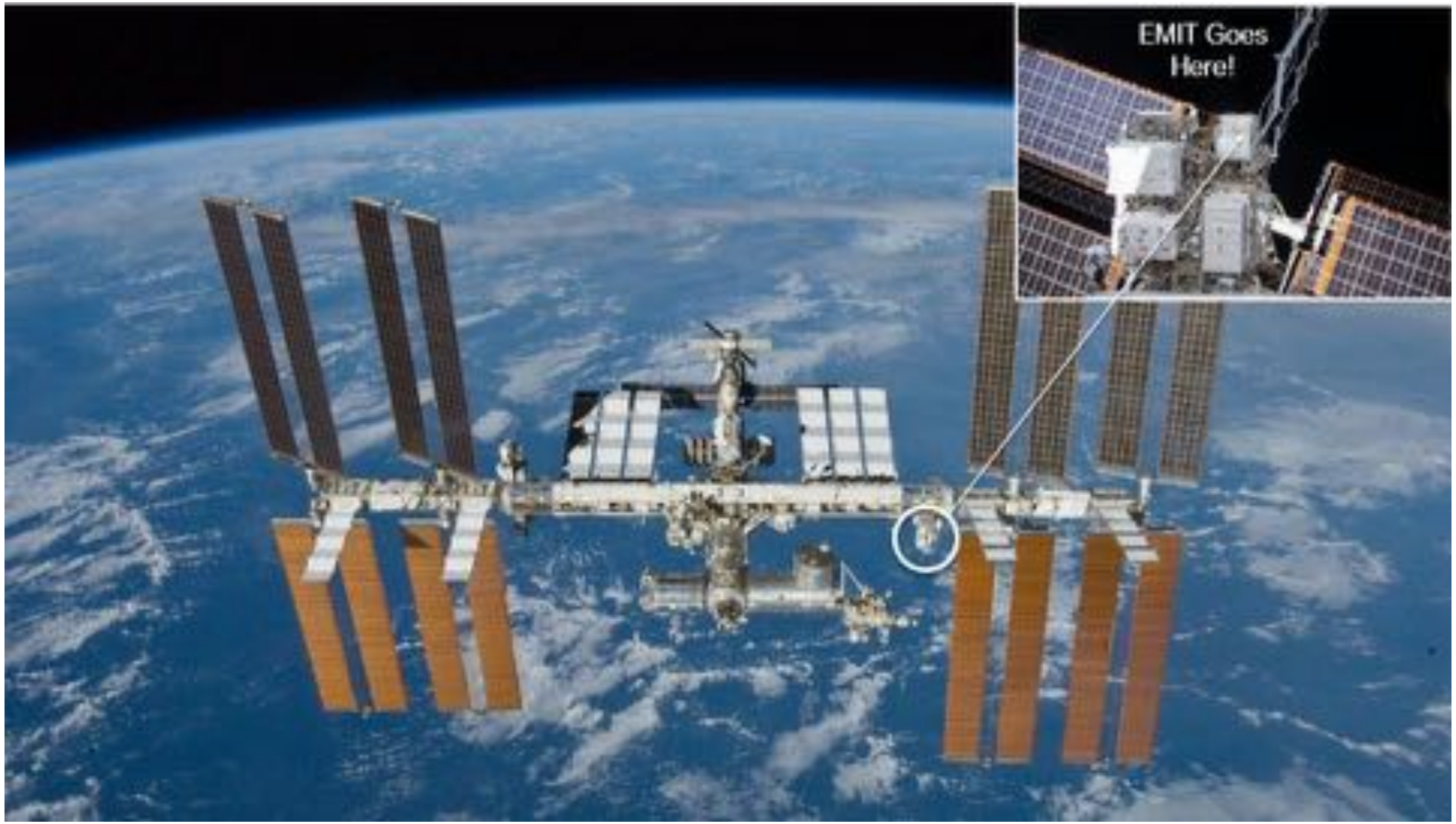
Electronics

EMIT will begin measuring spectra from the ISS in 2022

EMIT in Enclosure



Planned SpaceX 25 Launch



All measurements will be available from the NASA Land Processes Archive

Summary: Earth Surface Mineral Dust Source (EMIT)

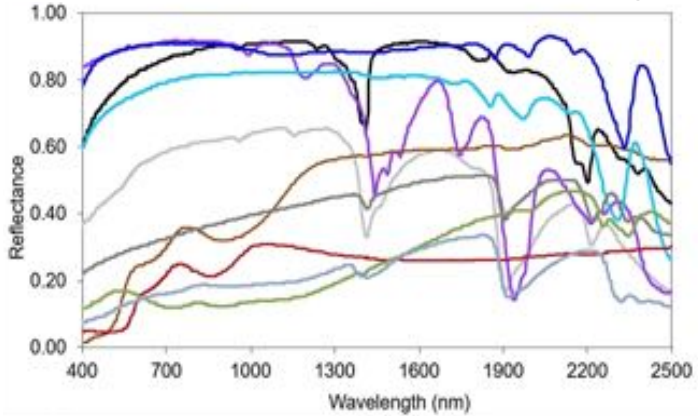
Science Goal

Close the gap in our understanding of mineral dust heating or cooling of the Earth now and in the future.

Mineral Dust Emission

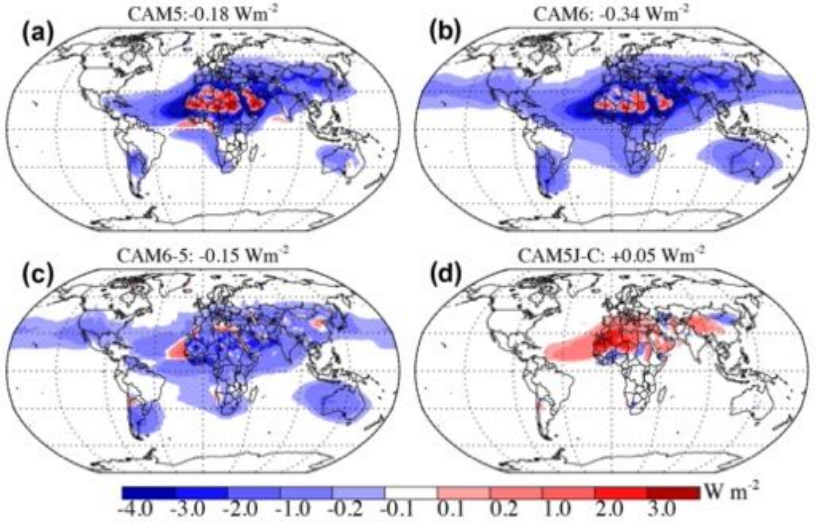
Dust Source Regions

Advanced Spectroscopy



Global Arid Land Mineral Composition

Updated Earth System Models to Assess Radiative Forcing for EMIT



Additional Value from EMIT Earth System Spectroscopy

- Geology and Resources
- Biodiversity and Ecosystems
- Agriculture
- Fire Fuels and Burn Severity
- Hazards
- Surface Plastic
- Mid-Lat snow/ice
- Algal blooms
- Methane and CO2

Jet Propulsion Laboratory
California Institute of Technology

ECOSTRESS: Science Summary

Presented by Simon J. Hook

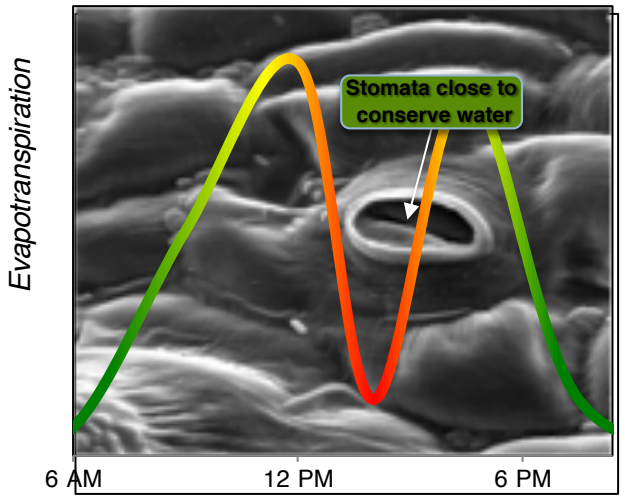
On behalf of the ECOSTRESS Science and Applications Team

Jet Propulsion Laboratory, California Institute of Technology

Credit: NASA

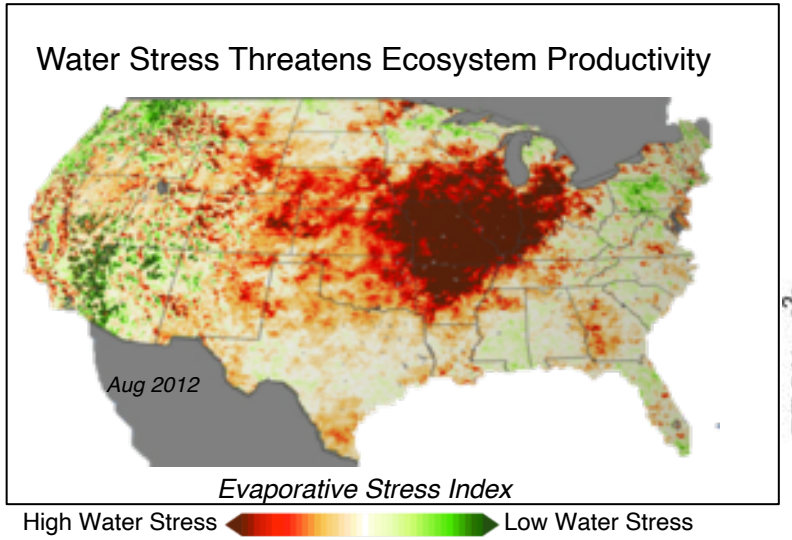
The Science

Water Stress Drives Plant Behavior

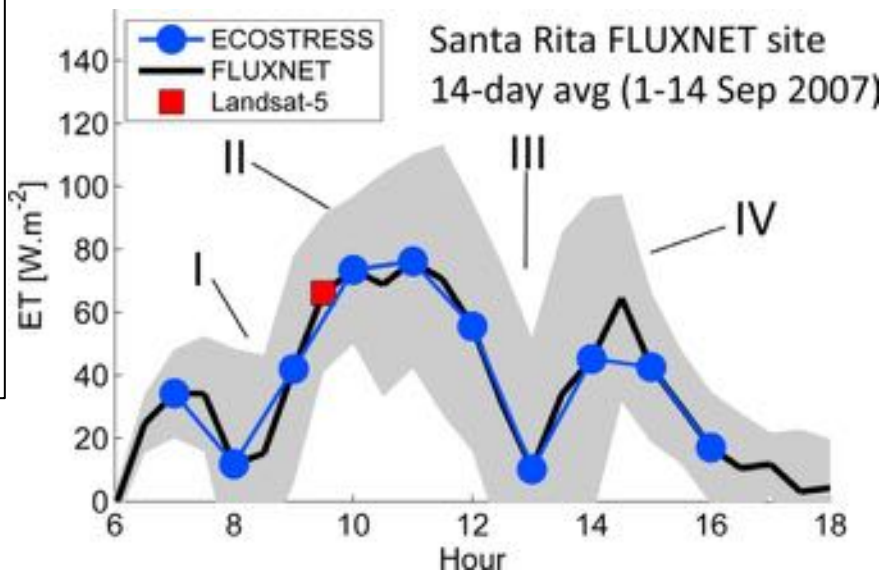


When stomata close, CO_2 uptake and evapotranspiration are halted and plants risk starvation, overheating and death.

Water Stress Threatens Ecosystem Productivity



Water stress is quantified by the Evaporative Stress Index, which relies on evapotranspiration measurements.



Science Objectives

- Identify **critical thresholds of water use and water stress** in key climate-sensitive biomes
- Detect the timing, location, and predictive factors leading to plant **water uptake decline** and/or cessation over the **diurnal cycle**
- Measure **agricultural water consumptive use** over the contiguous United States (CONUS) at spatiotemporal scales applicable to improve drought estimation accuracy

Mission Overview

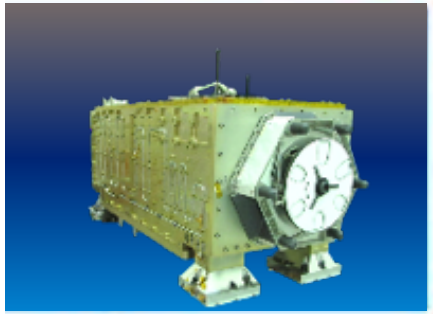
Overview:

- **Cost-Capped, $29.942M Cat 3/Risk class D**
- **8–12.5 µm radiometer with a 400km swath, 69 x 38 m resolution**
- **Measure brightness temperatures of Earth at selected locations**
- **Launch in 2018** on SpX-15 and deploy on ISS JEM-EFU 10
- **First use of WiFi on JEM-EF for science payload**
- **Prime Mission Phase E:** 1 year
- **Extended Phase E: possible**

Highlights:

- We originally planned to acquire an average of 74 scenes per day but have now acquired an average of 221 scenes per day.
- We originally planned to acquire ~27,000scenes over a 1-year Mission and have now acquired 250,000+ scenes.
- Highest spatial resolution multispectral thermal infrared radiometer NASA has ever built
- Ideal instrument for providing data suitable for evaluating data for the Decadal Survey SBG TIR mission.
- **Due to the ongoing success of the mission, NASA has decided to have a second ROSES call for external investigators – check out the ROSES call**


ISS JEM-EF

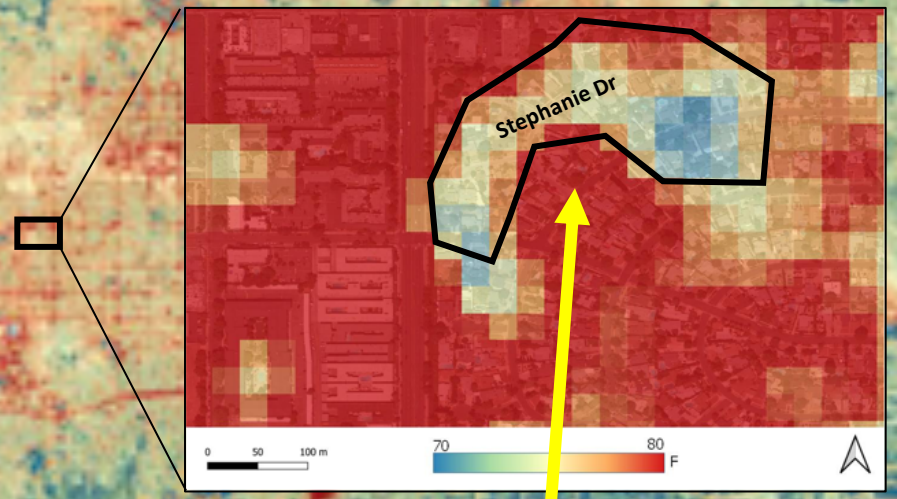

ECOSTRESS


Falcon-9

Instrument Specifications

Description	Value	Units	Notes
Spectral bands acquired	6		3 bands currently downloaded (Oct 2021)
Band centers	Band 1 - 8.29, *Band 2 - 8.78, Band 3 - 9.20, *Band 4 - 10.49, *Band 5 - 12.09	µm	*After May 15, 2019, only these bands are downloaded
Pixel size at nadir	69 x 38	m	Products available at 70m
Swath width	384	m	Varies with ISS height, assumes height of 400 km
Radiometric accuracy at 300K	0.5	K	Values vary by wavelength

The City of Los Angeles is using ECOSTRESS to identify hotspots and quantify the effects of heat mitigation strategies such as cool roads – PI: G. Hulley



City of Los Angeles is testing road surface coatings to minimize urban heat.

ECOSTRESS shows cooling effect on local streets.

***"I call this the 8 million dollar image"* – Greg Spotts, City of Los Angeles**

ECOSTRESS imagery used by City of LA to secure funding for urban heat mitigation solutions for heat-vulnerable neighborhoods

Water temperature in San Francisco Estuary Measured by ECOSTRESS
PI: C. Lee

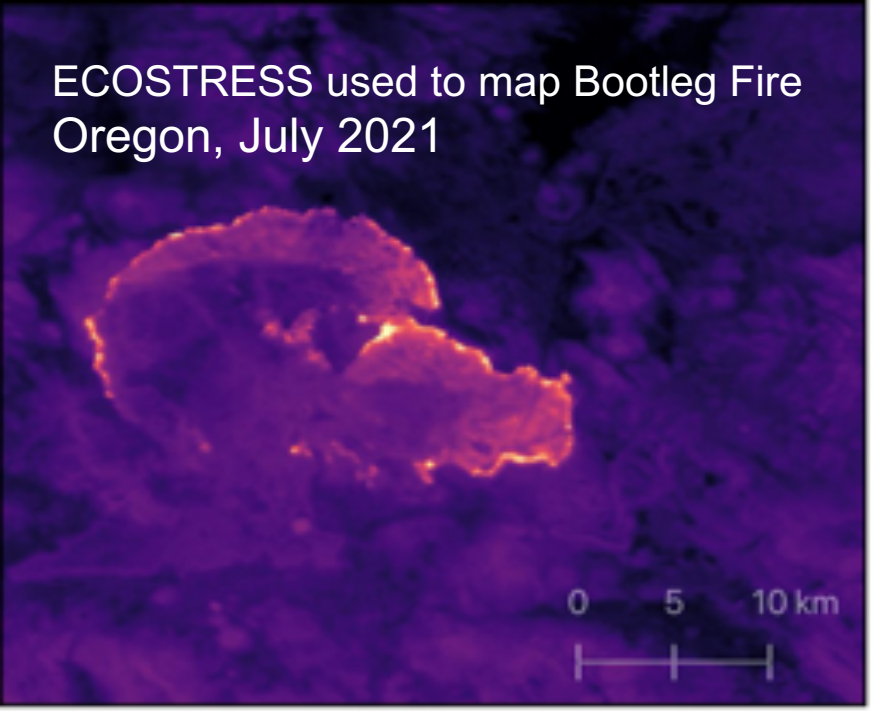
Temperatures in light yellow denote conditions harmful for endangered fish

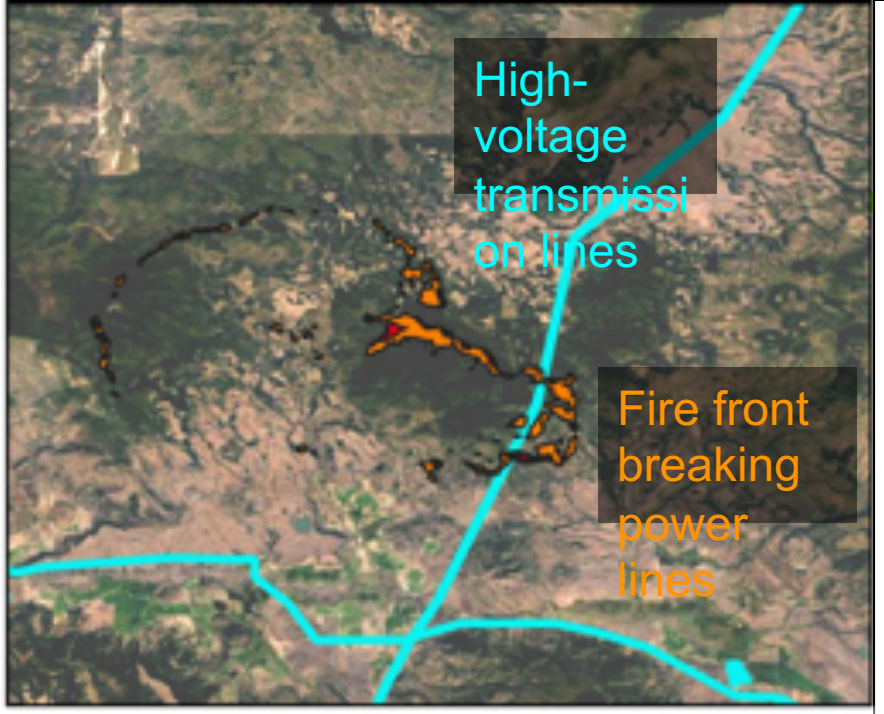
0 10 20 km

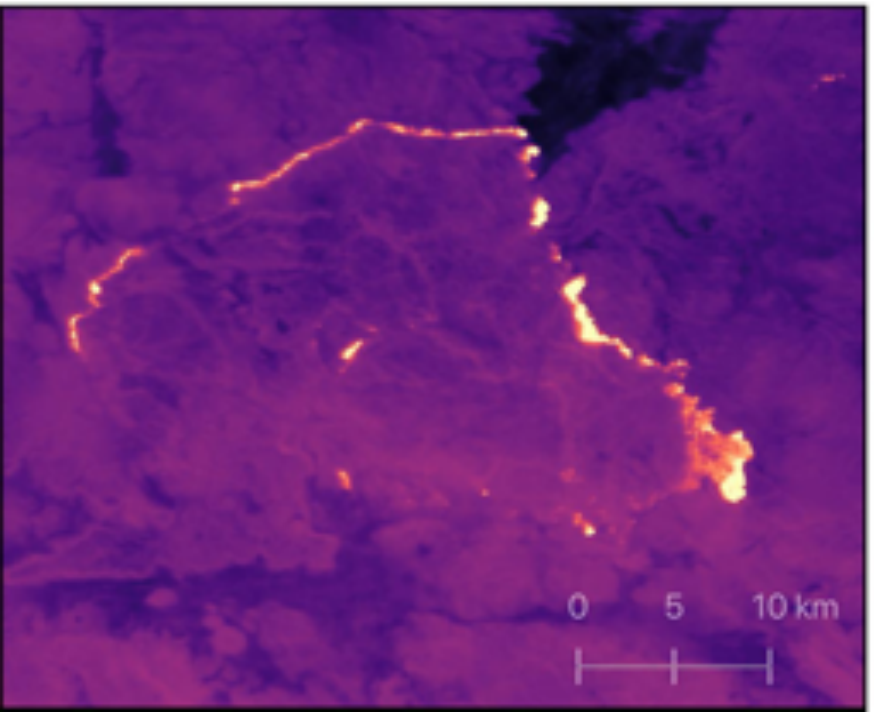
ECOSTRESS reveals hotspots of degraded habitat for endangered Delta smelt

Much of Southern California's water is conveyed through sensitive habitat, such has the San Francisco Estuary. ECOSTRESS partners with regional stakeholders to mitigate these impacts.

Gustine et al, 2021
DOI: 10.1109/TGRS.2021.3133411







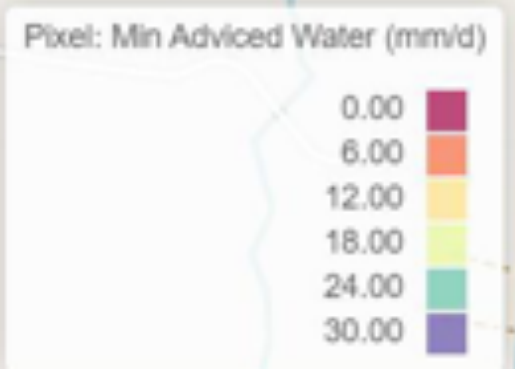
"ECOSTRESS allows us to use the [fire maps] from last night in the morning…this is what's required if you're going to put data into the hands of incident commanders." -- USGS podcast with PNNL and USFS

ECOSTRESS imagery is integrated into an operational active fire response tool by PNNL to support USFS fire operators and

ECOSTRESS used to deliver irrigation advisories to farmers

"Bringing ECOSTRESS Information to farmers" - Irriwatch CEO Wim Bastiaanssen

Irriwatch integrates ECOSTRESS data into high quality estimates of water use and delivers irrigation advisories to over 18,000 fields in 25 countries around the world.



IrriWatch

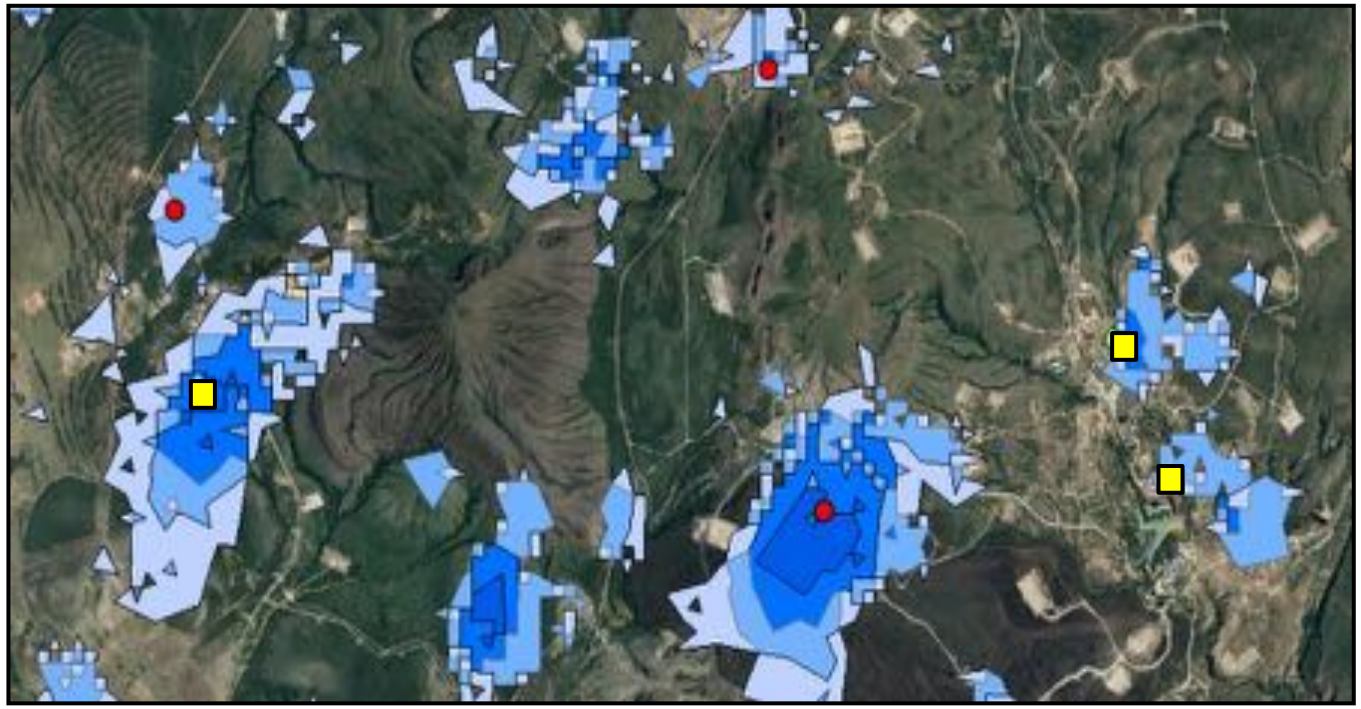
Geothermal Hotspot Detection from ISS-based ECOSTRESS data

(PI: C. Hecker, U. of Twente)

- *Preliminary results (Kenya):*
  - ECOSTRESS thermal anomaly detection results (blue)
  - Red dots: known fumaroles; Yellow squares: power plants
  - => Several previously unknown hotspots detected

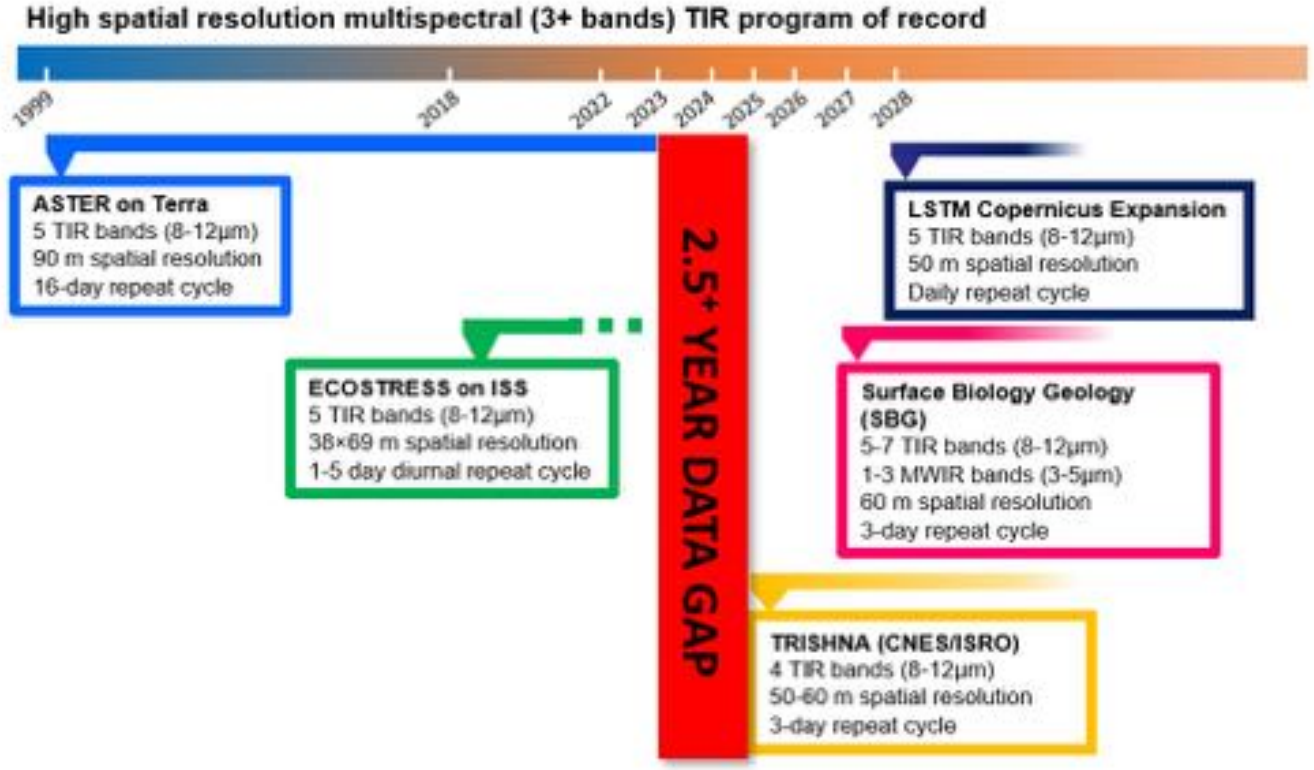
- *Using ECOSTRESS to empower the Energy Transition by:*
  - Detecting subtle geothermal anomalies at surface
  - Approach uses unique (precessing) ISS orbit for short time series
  - => starting point for development of new geothermal systems for electricity production

Press coverage: www.utoday.nl/science/68910



Olkaria study area, Kenya. Background image: GoogleEarth
Source: Soszynska et al. (ongoing work)

Potential multispectral TIR data gap



Exciting future with TRISHNA, SBG and LSTM; however, ECOSTRESS, while funded to provide data through CY2023, may be decommissioned in CY2022. With TRISHNA scheduled to launch no earlier than end of CY2024, there could be a **2.5 year data gap**. Aircraft TIR instruments will play a critical role; however they cannot fill the gap that would be left by ECOSTRESS.

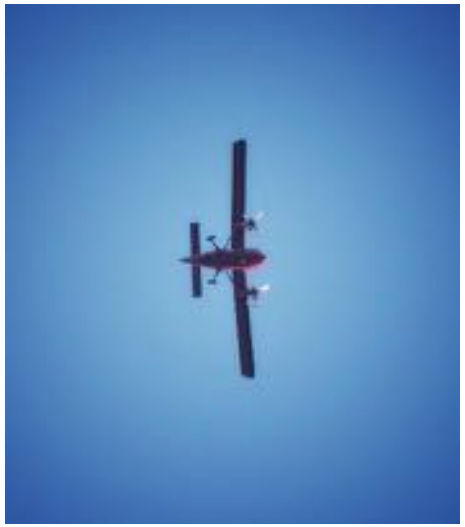
ECOSTRESS is currently acquiring 216 scenes / day, amounting to 32M sq km and **nearly 3x the number of scenes originally proposed** (74 scenes / day). For reference, Landsat-8 acquires 24M sq km / day or, in ECOSTRESS terms, 162 scenes.

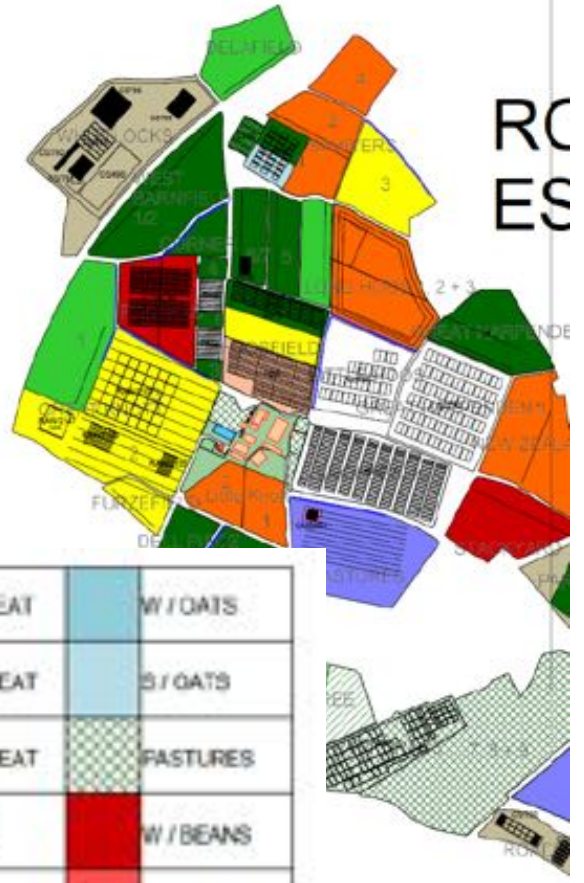
ECOSTRESS is extremely popular – in the last 12 months, the ECOSTRESS Land Surface Temperature and Emissivity product was the 2nd most requested product in the LP DAAC AppEEARS data access tool. The MODIS Terra Land Surface Temperature/Emissivity product was the 1st. There are 120+ products in the tool

NASA-ESA 2021 European HyTES Campaign

2021-07-20
11:25:22

Rothamsted Research station showing the experimental fields and JPL measurements in barley field



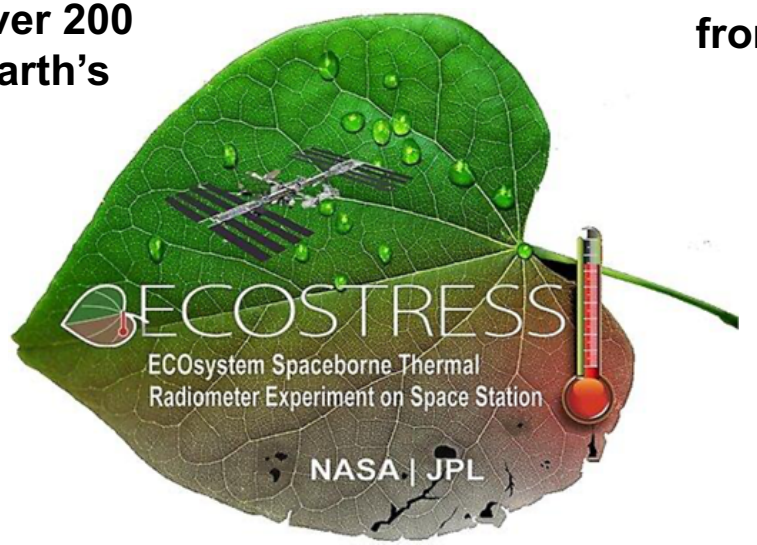


ECOSTRESS Data: Quick Facts and Stats

As of 2/16/2021, 250,000+ scenes have been acquired since launch, an area over 200 times the area of the Earth's land surface

We originally planned to acquire an average of 74 scenes per day but have now acquired an average of 216 scenes per day.

We originally planned to acquire ~27,000 scenes over a 1-year Mission and have now acquired 250,000 scenes.



Successful negotiations between ISS and JAXA have secured JEM-EF site 10 for ECOSTRESS until January 2023.

In the last quarter, ECOSTRESS surface temperature and evapotranspiration were among top 20% of most requested products from LP DAAC AppEEARS which hosts MODIS and Landsat products

Highest spatial resolution multispectral thermal infrared radiometer NASA has ever built

Only spaceborne instrument capable of providing data suitable for evaluating data for the Decadal Survey SBG TIR mission.

In addition, JAXA recently made a preliminary assessment that allows ECOSTRESS to stay on JEM EFU 10 until September 2023!

Questions?

Understanding Diurnal Cycles of Plant Water Use and Carbon Uptake with Existing and New Products Based on ECOSTRESS, MODIS, and FLUXNET (PI: J. Xiao; University of New Hampshire)

- ECOSTRESS allows us to assess how plants use water and absorb carbon over the course of the diurnal cycle.
- e.g., ET images acquired in the early morning and afternoon indicate that some agricultural fields (likely irrigated) show much more ET while some fields are drying out (with plants under water stress) in the afternoon. This has never been possible in the history of remote sensing before ECOSTRESS. (*left panel*)
- l biomass fixed by the vegetation in a unit area within a times of day and to assess how plant *el*)

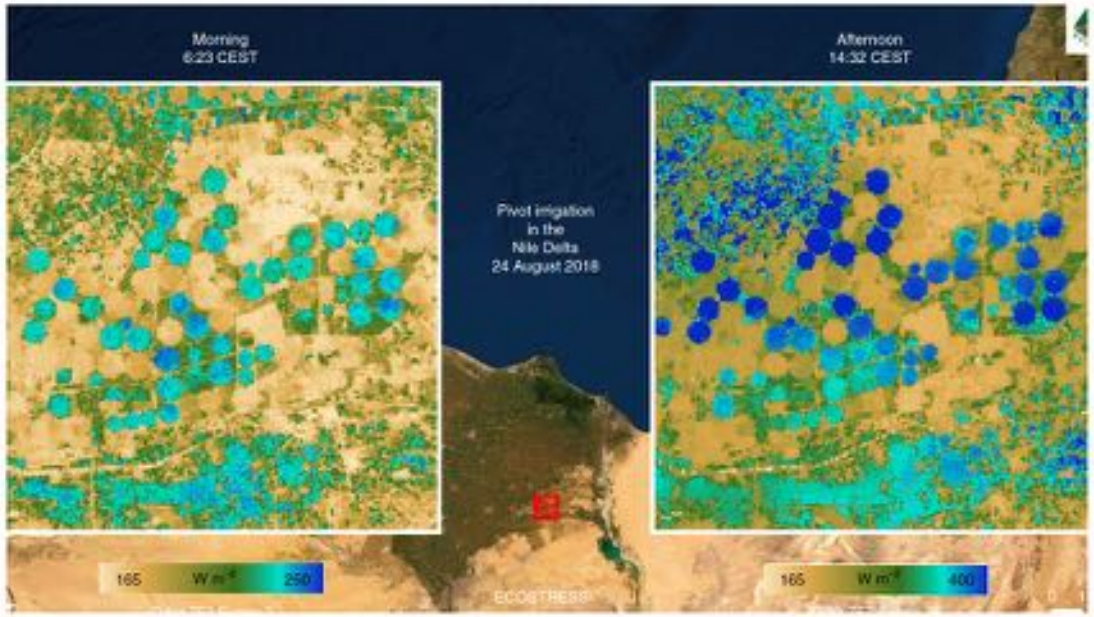


Fig. 2 | ECOSTRESS images from the Nile Delta within the same day. NASA's ECOSTRESS captured changes in ET from agricultural fields of the Nile Delta, Egypt, from the ISS in the morning and afternoon on 24 August 2018. The image on the left is from 6:23 central European summer time (CEST) and the image on the right is from 14:32 CEST. There are larger differences in ET between the agricultural fields in the afternoon than in the morning. Some fields show much more ET while some fields are drying out in the afternoon. The geographical coordinates of the centre of the ECOSTRESS images Orbit 752, Scene 2 (left) and Orbit 757, Scene 26 (right) are 30.54°N and 31.85°E, respectively. The scale bar applies to the background map; the pixel size of the inset maps is 70 m.

Xiao et al., Nature Plants, 2021

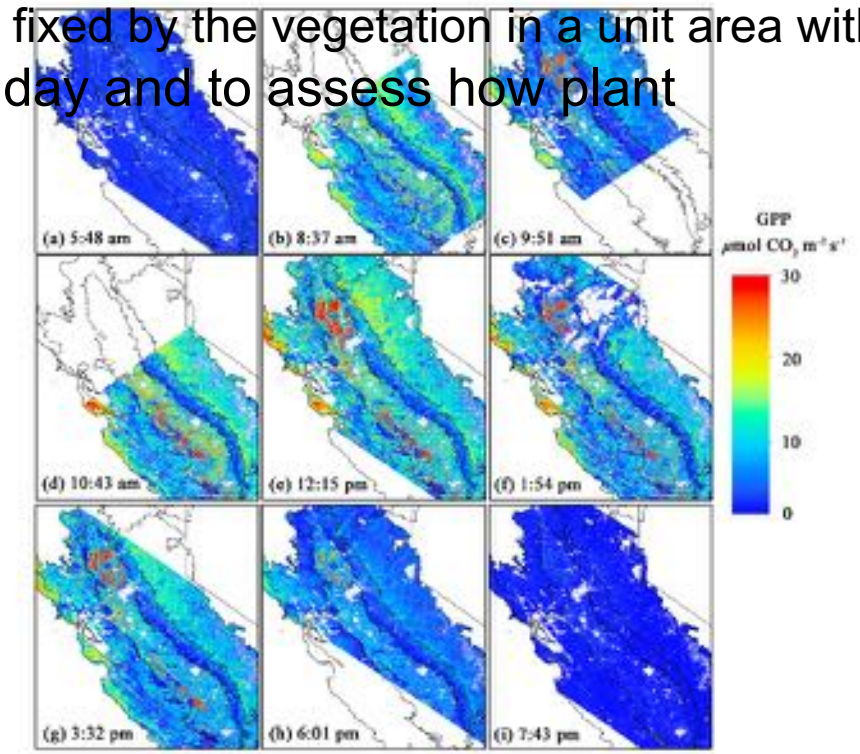


Fig. 5. Magnitude and spatial patterns of predicted ECOSTRESS GPP at different times of day in summer 2019 across the Central Foothills and Coastal Mountains, Central Valley, Sierra Nevada and Coast Range in California.

Li, Xiao, et al., RSE, 2021

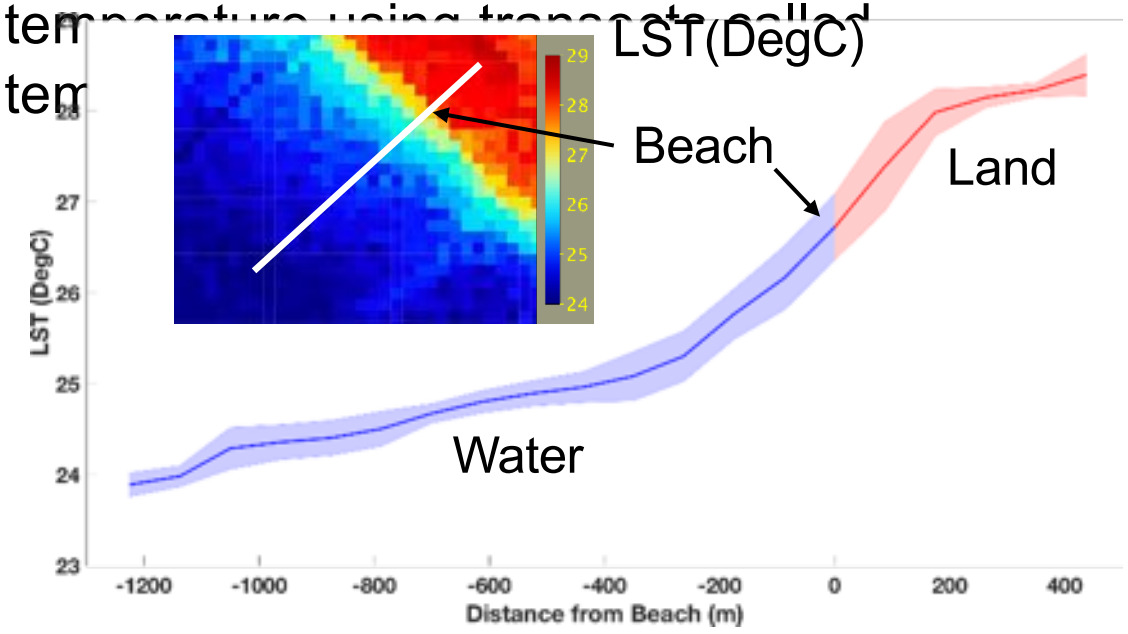
Using ECOSTRESS to measure surface temperature at the shoreline and over w

(PI: D. Otis - University of South Florida, College of Marine Science)

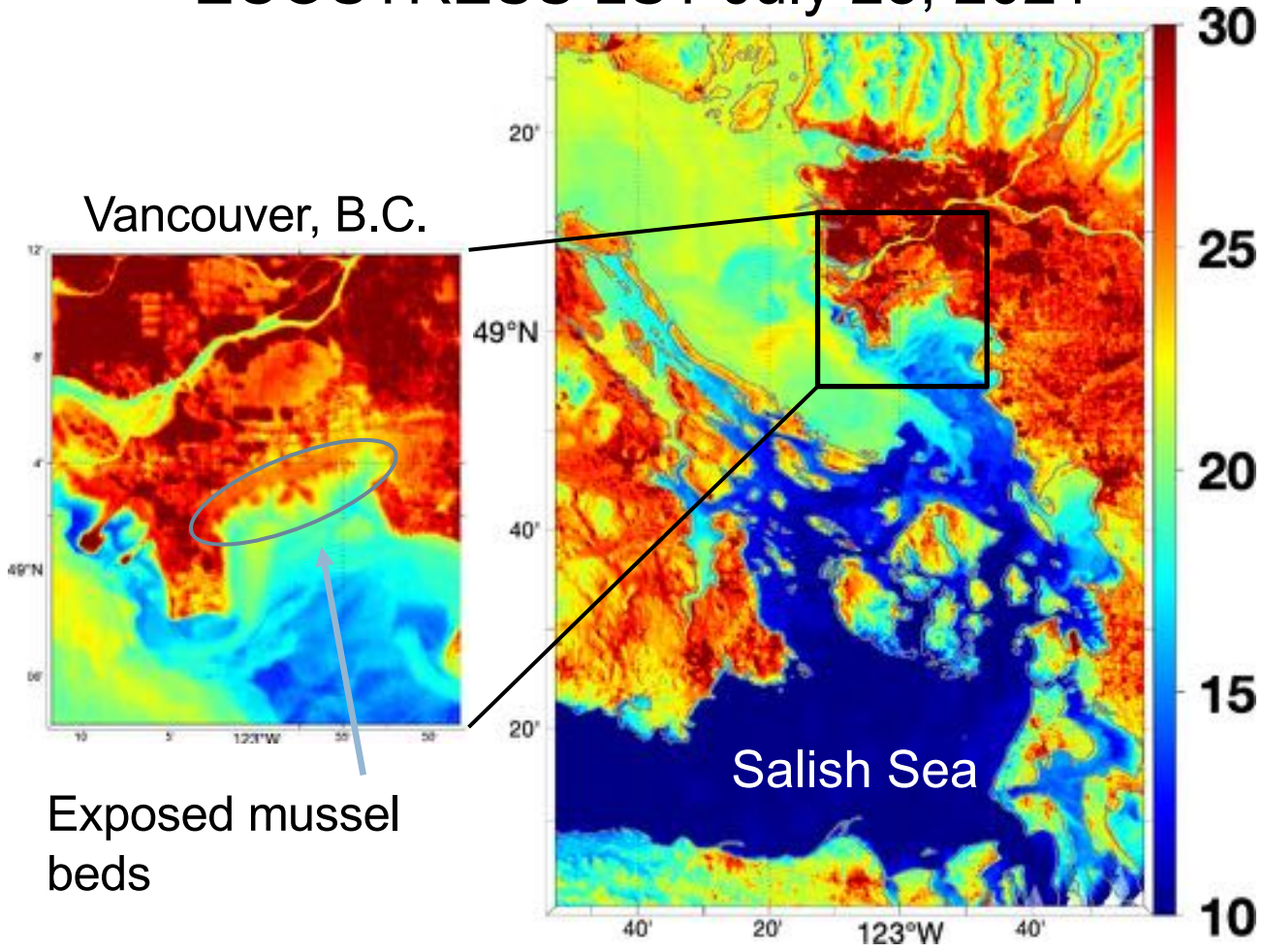
Project goals:

- Utilize the high spatial resolution of ECOSTRESS to measure surface temperature at the land-water interface, which is not possible with sensors like MODIS.

- Shoreline habitats are rich in biodiversity. We characterize them in terms of tem
tem



ECOSTRESS LST July 28, 2021



In late June and July, beaches here experienced elevated surface temperatures and widespread mortality of mussel beds.

For more information on CarbonMapper, please visit carbonmapper.org or contact info@carbonmapper.org

ACIX-III Atmospheric Correction Intercomparison Exercise

ACIX-III is the third Atmospheric Correction Intercomparison Exercise, and includes comparison activities for land and water. ACIX-III is specifically focused on hyperspectral imagery, and intercomparisons of methods will employ data from PRISMA. This is an important activity moving forward for understanding differences among approaches that may be used by forthcoming spaceborne missions. This website provides details on participation in ACIX-III:

https://earth.esa.int/eogateway/events/1st-workshop-of-acix-iii-land-aqua-and-cmix-ii

Important information: There will be a workshop of ACIX-III (and CMIX-II, focused on cloud masking on 20-21 June 2022 at ESA/ESRIN in Frascati, Italy.Participation in ACIX and CMIX activities are open to all scientists who:

1 are the original developers of the atmospheric correction and/or cloud-masking processor to be inter-compared,

2 are authorized by the original developer to run the AC/CM processor on his/her behalf,

3 agree on submitting the AC/CM processing results within the required constraints (deadline, format, etc.).

SBG Opportunities for Involvement

- In-person SBG community workshop in 2022 (TBD)
- Internship programs at JPL and other NASA centers:
  - Dave Schimel (dschimel@jpl.nasa.gov)
  - Ben Poulter (Benjamin.poulter@nasa.gov)
- SBG working groups: ongoing, regular meetings and seminars
  - Algorithms (kcawseni@jpl.nasa.gov)
  - Modeling (benjamin.poulter@nasa.gov)
  - Calibration/Validation (kturpie@umbc.edu)
  - Applications (christine.m.lee@jpl.nasa.gov
  - SHIFT (katherine.d.chadwick@jpl.nasa.gov)
- Email us (seriously we want to hear from you): sbg@jpl.nasa.gov
- Join the conversation at the SBG Community Slack