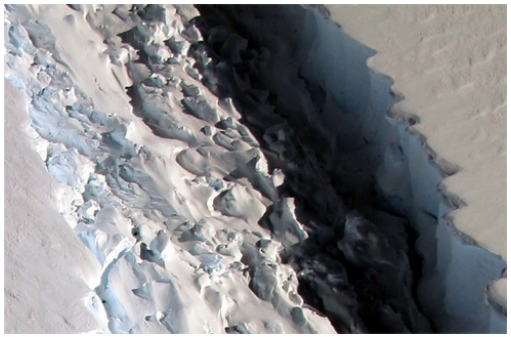
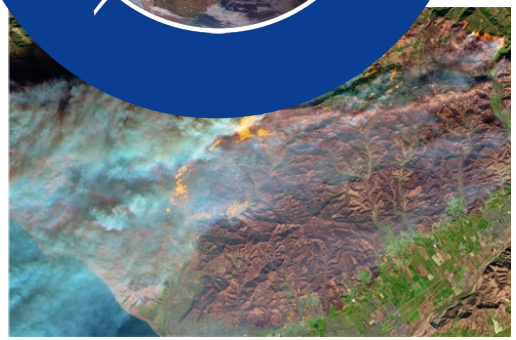
SCIENCE



Surface Biology and Geology

An Observing System for Climate Impacts and Earth System Dynamics

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.

NASA has authorized SBG to proceed to Pre-Phase A

"Based on the **successful completion** of the Surface Biology and Geology (SBG) mission study in 2020, **now part of the Earth System Observatory (ESO)** integrated missions recommended by the National Academies as "Designated Observables," you are hereby authorized to **establish a project office, select a project manager, and initiate Pre-Phase A activities** of the SBG observing system."






NASA has authorized SBG to proceed to Pre-Phase A

"The SBG study provided a number of potential architecture options for the SBG observing system. Pre-Phase A activities shall consist of an overarching trade study based on the two-platform architecture, with **separate Visual Shortwave Infrared (VSWIR) and Thermal Infrared (TIR) platforms, plus a VSWIR SmallSat**, leading to a final observing system concept."






NASA has authorized SBG to proceed to Pre-Phase A

"During Pre-Phase A, the SBG project shall also participate in two studies facilitated by Earth Science Data Systems (ESDS):

- In support of the Science Mission Directorate's (SMD's) goal of enabling Open Science, the *Open-Sourced Science Processing study* will develop architectural concepts for a **common science data processing system for generating Level 1-4 science data products.** These concepts will identify and evaluate options to expand participation in mission science beyond the funded science teams.

- The *Data Latency and Ground Segment study* will evaluate flight hardware and ground system architectures to **minimize product latency and support cross-ESO science product generation."**





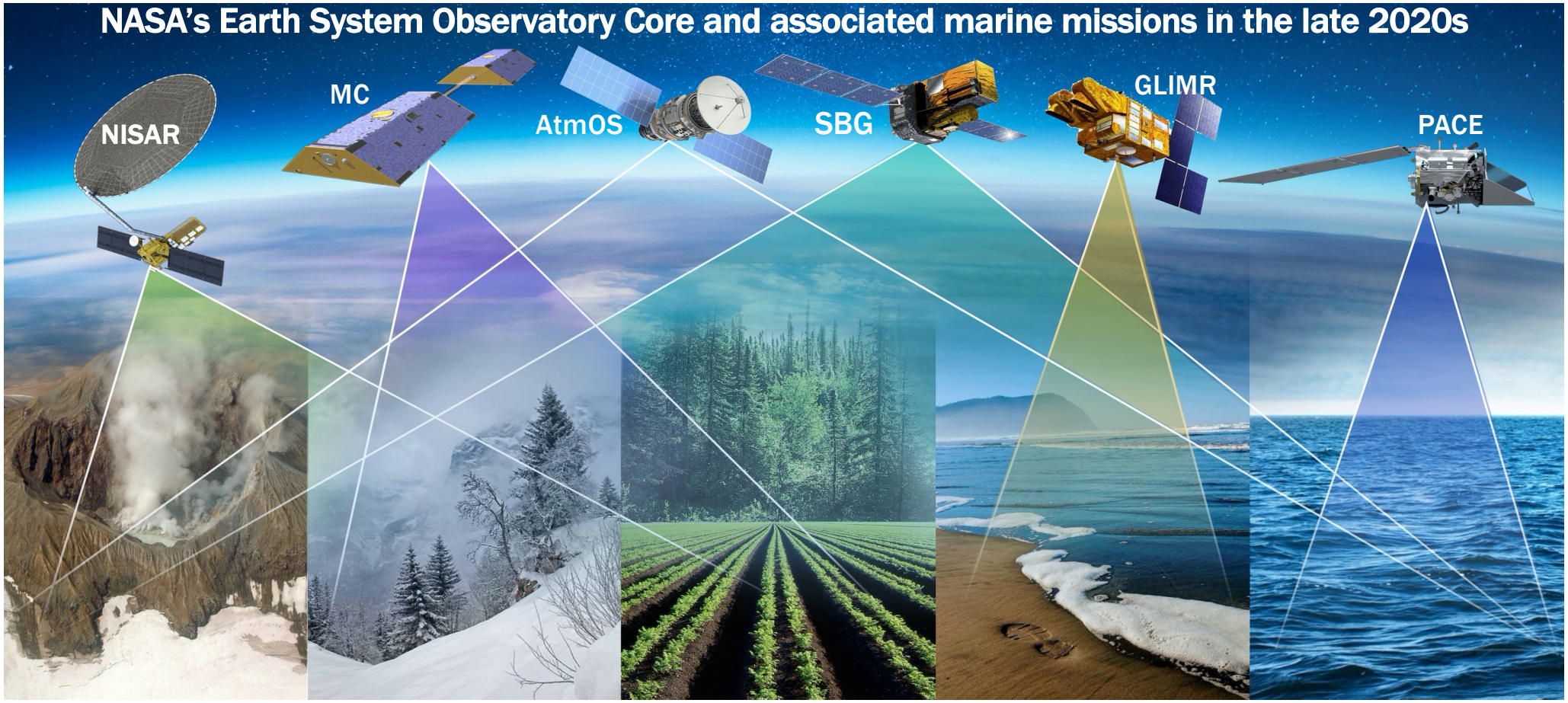

NASA has authorized SBG to proceed to Pre-Phase A

"During Pre-Phase A, the SBG project shall also complete the **Community Assessment Report (CAR)** in time to support the MCR. Based on, but not limited to, the CAR, the project shall explore and evaluate how **design choices, including mission architecture and concepts of operations** (e.g., latency, resolution, revisit frequency, overpass time, etc.), **enable applications and applications communities**. This information shall inform trade studies and the observing system concept."






NASA's Earth System Observatory Core and associated marine missions in the late 2020s



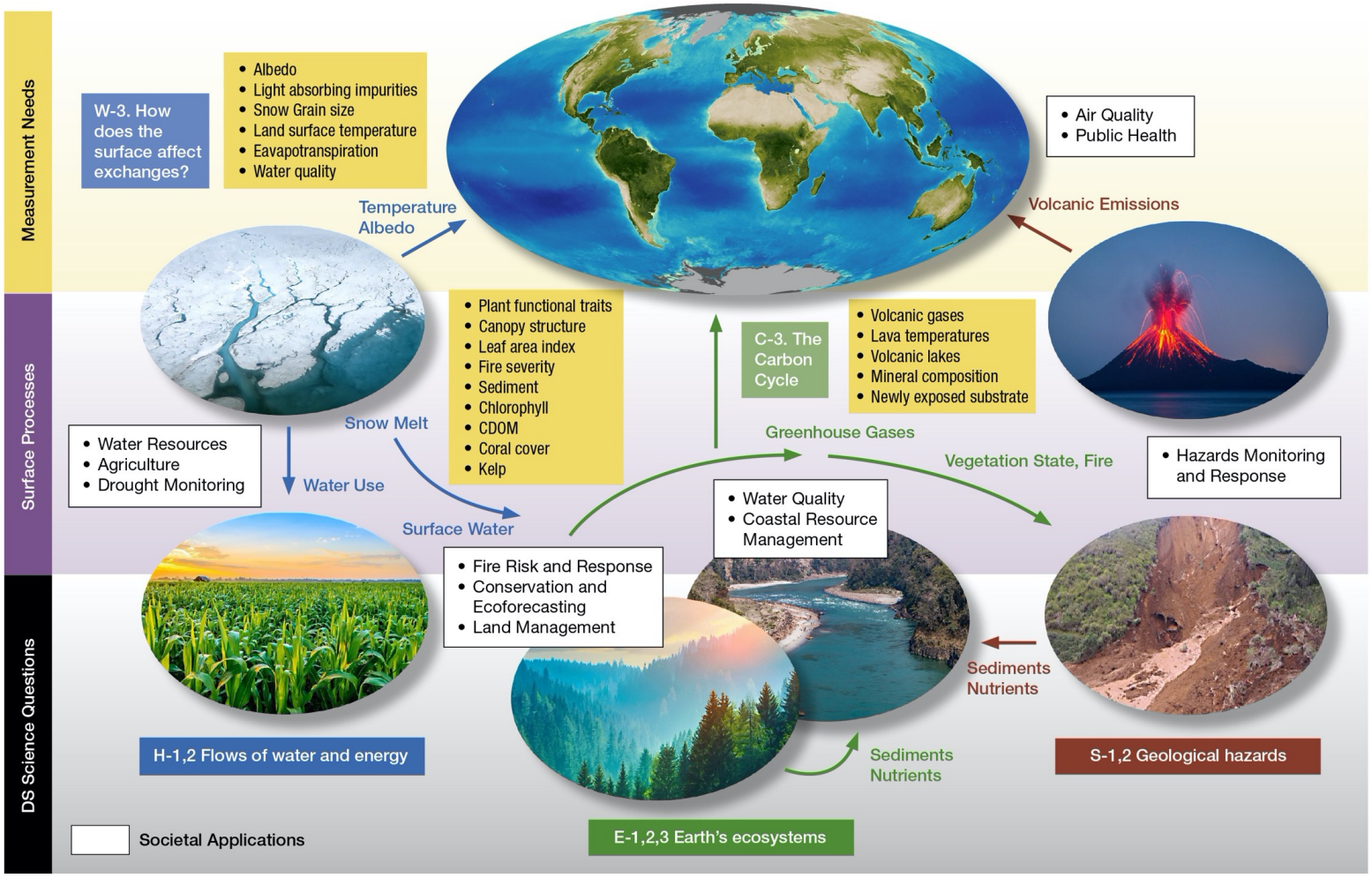
SOLID EARTH
Aerosols — ATMOS
Gases — SBG
Surface Deformation — NISAR
Surface Composition
and Geologic Hazards — SBG

WATER CYCLE
Precipitation — ATMOS
Ice Mass Evolution - NISAR
Snow Albedo and Melt — SBG
Total water storage - MC

ECOSYSTEMS AND NATURAL RESOURCES
Boundary Layers — ATMOS
Ecosystem Structure — NISAR
Vegetation Type/Physiology — SBG

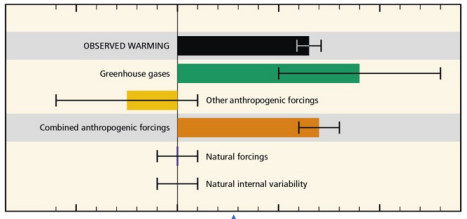
LAND-SEA CONTINUUM
Phytoplankton, Organic Matter, Sediment — SBG,GLIMR, PACE
Boundary layers-ATMOS

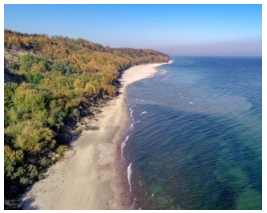
SBG SCIENCE AND APPLICATIONS AT A GLANCE



SBG: NASA's OBSERVING SYSTEM FOR CLIMATE IMPACTS

RADIATIVE FORCING





BIODIVERSE ECOSYSTEMS COASTAL ZONES

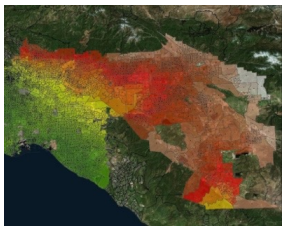
FLUXES WITHIN AND BETWEEN ECOSYSTEMS

THE CRYOSPHERE

CARBON STORAGE

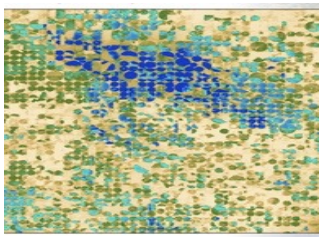
VOLCANIC GASES

GHGs



URBAN HEAT

WATER AND WATERSHEDS



AGRICULTURE, WATER MANAGEMENT

WETLAND CARBON

BLUE CARBON

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

HYDROLOGY

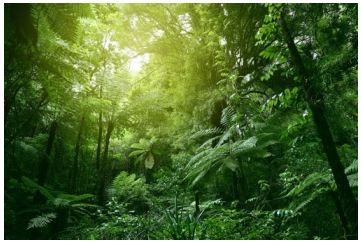
H-1. How is the water cycle changing?

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

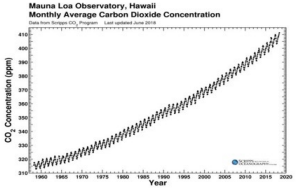
GEOLOGY APPLICATIONS

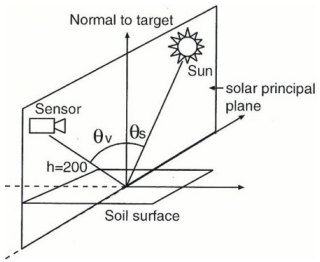
Mineral mapping for exploration efforts and reduction of environmental hazards

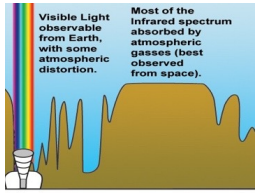
Forecast aviation hazards and support emergency response for volcanic eruptions

Landslide risk assessment with improved substrate map land cover maps

SBG: KEY RESEARCH AND APPLICATIONS REQUIREMENTS





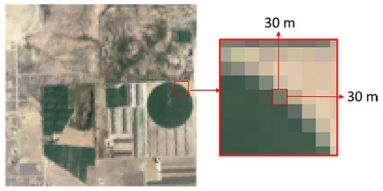


COVERAGE: The system must provide **global coverage** to address the global scope of the science including the coastal ocean and inland waters.

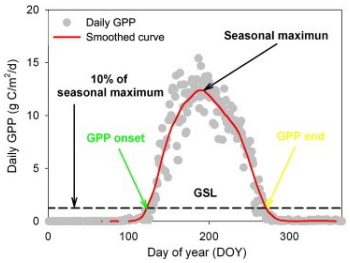
STABILITY AND DURATION: Measurements must be able to detect **long term changes** for addressing dynamics of the Earth System.

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).

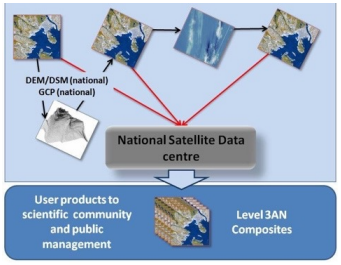
RANGE, RESOLUTION AND SENSITIVITY: Visible to Shortwave Infrared **(VSWIR; 400-2500 nm)** imaging spectroscopy and multi-spectral thermal infrared **(TIR; 4 - 12 μm)** measurements to observe "diversity" in ecosystem function. Radiometric performance driven by aquatic targets.



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

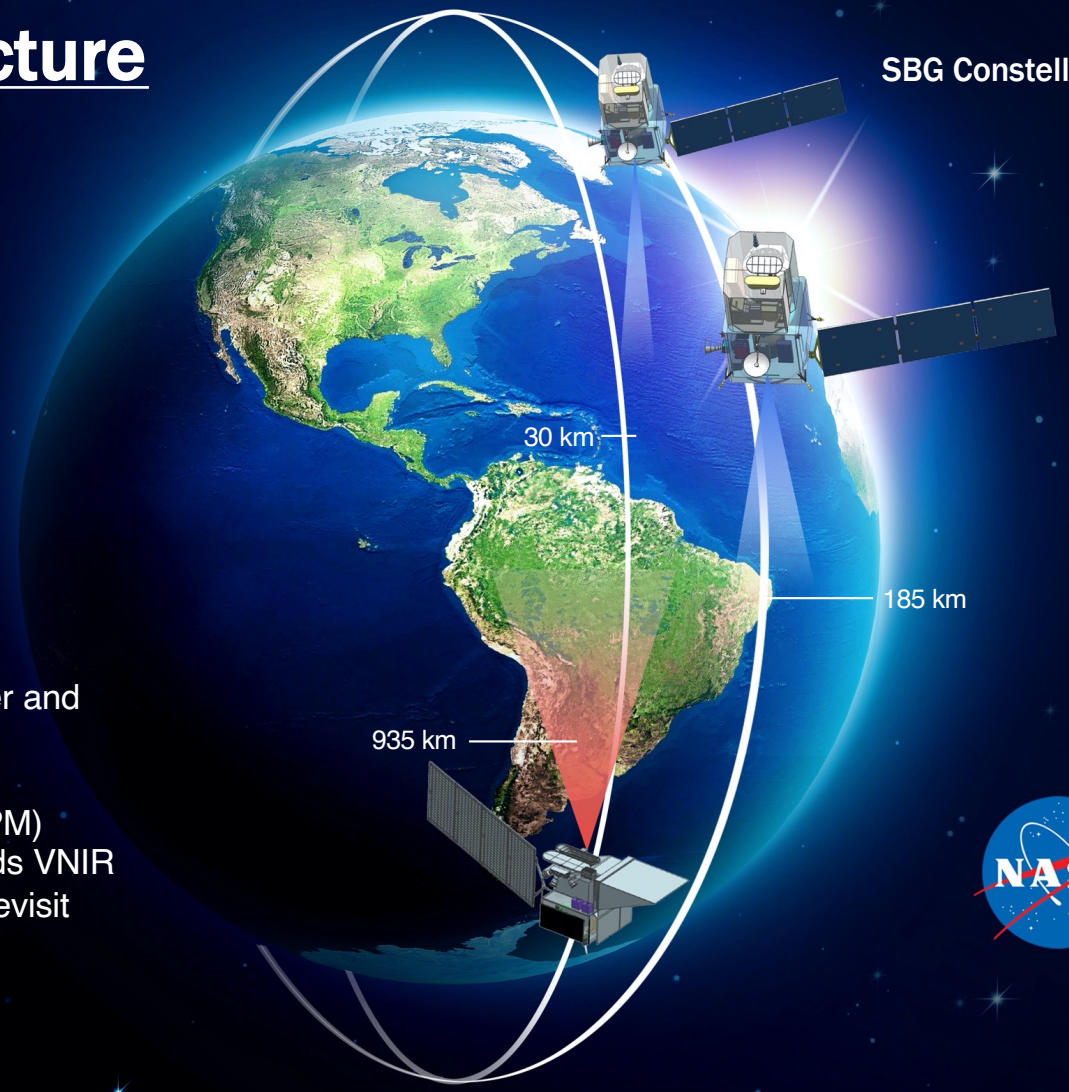


REVISIT: The SBG observing system temporal resolution must be adequate to capture **synoptic and seasonal variation** as well as observe **rapid or transient changes** related to Earth system events such as fires, landslides, volcanic activity and anthropogenic incidents.



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

SBG Architecture



agenzia spaziale italiana

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

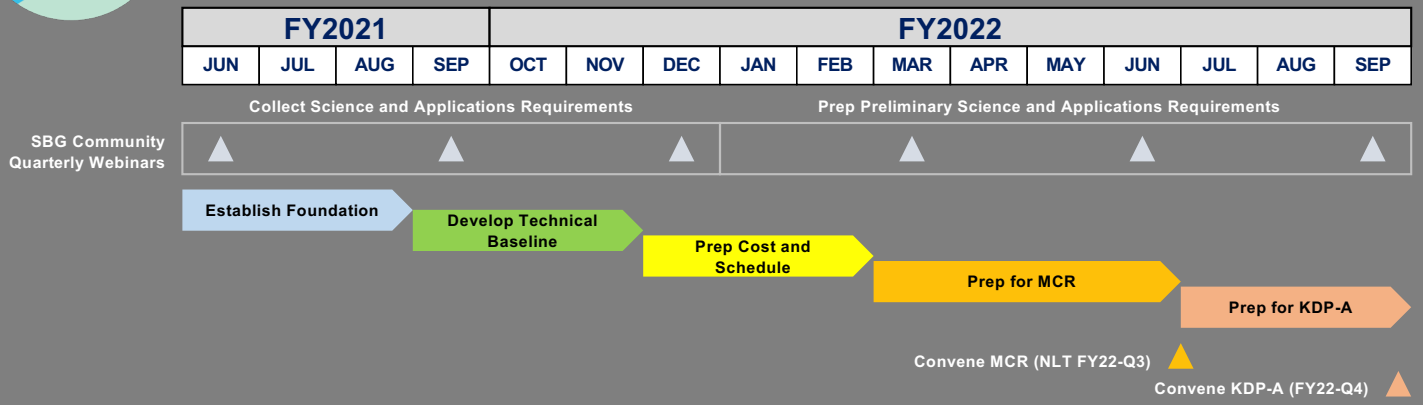
SBG Heat
Wide-swath TIR imager and ASI VNIR camera

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

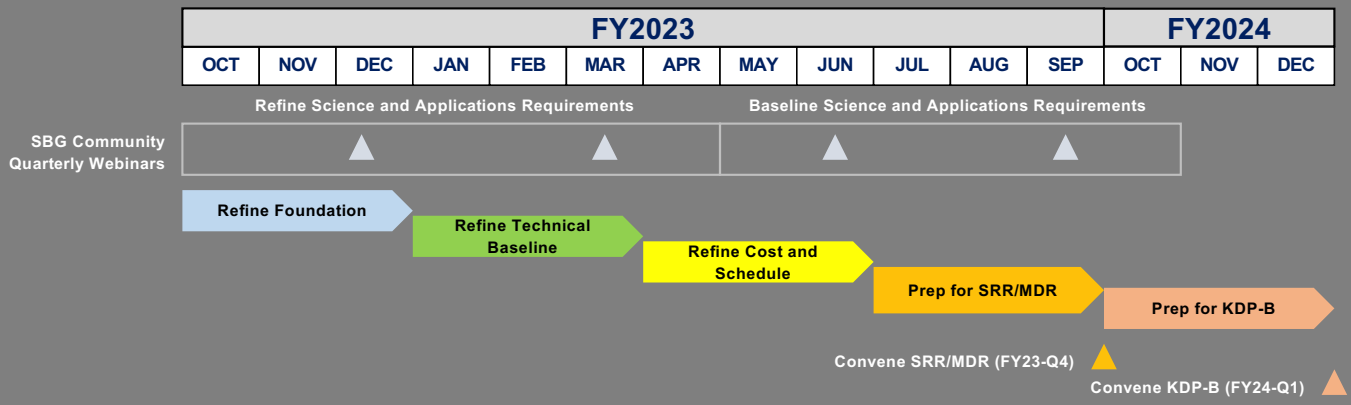
NASA

Surface Biology and Geology (SBG)

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

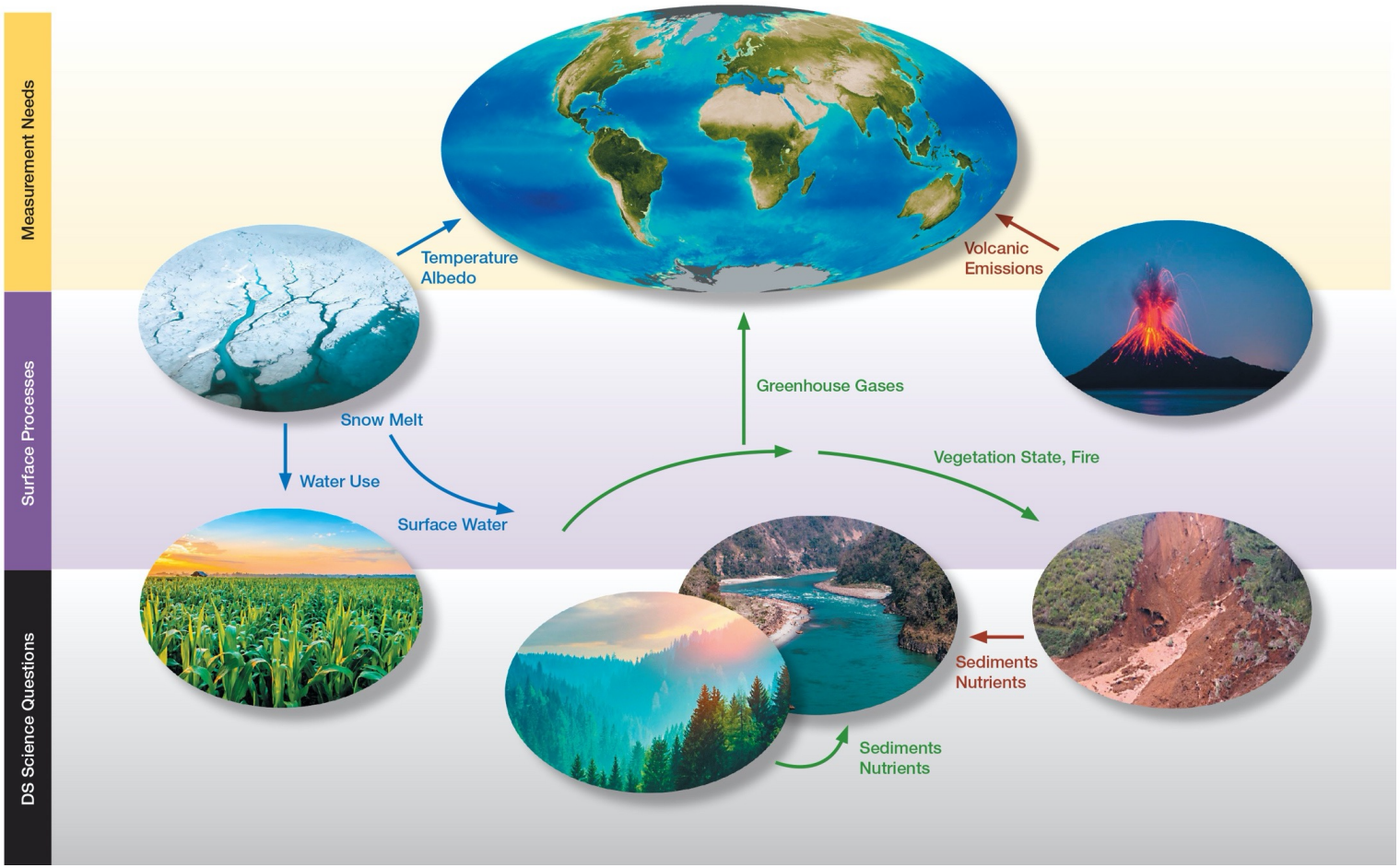


Phase A (Concept Study Phase) Schedule - Notional

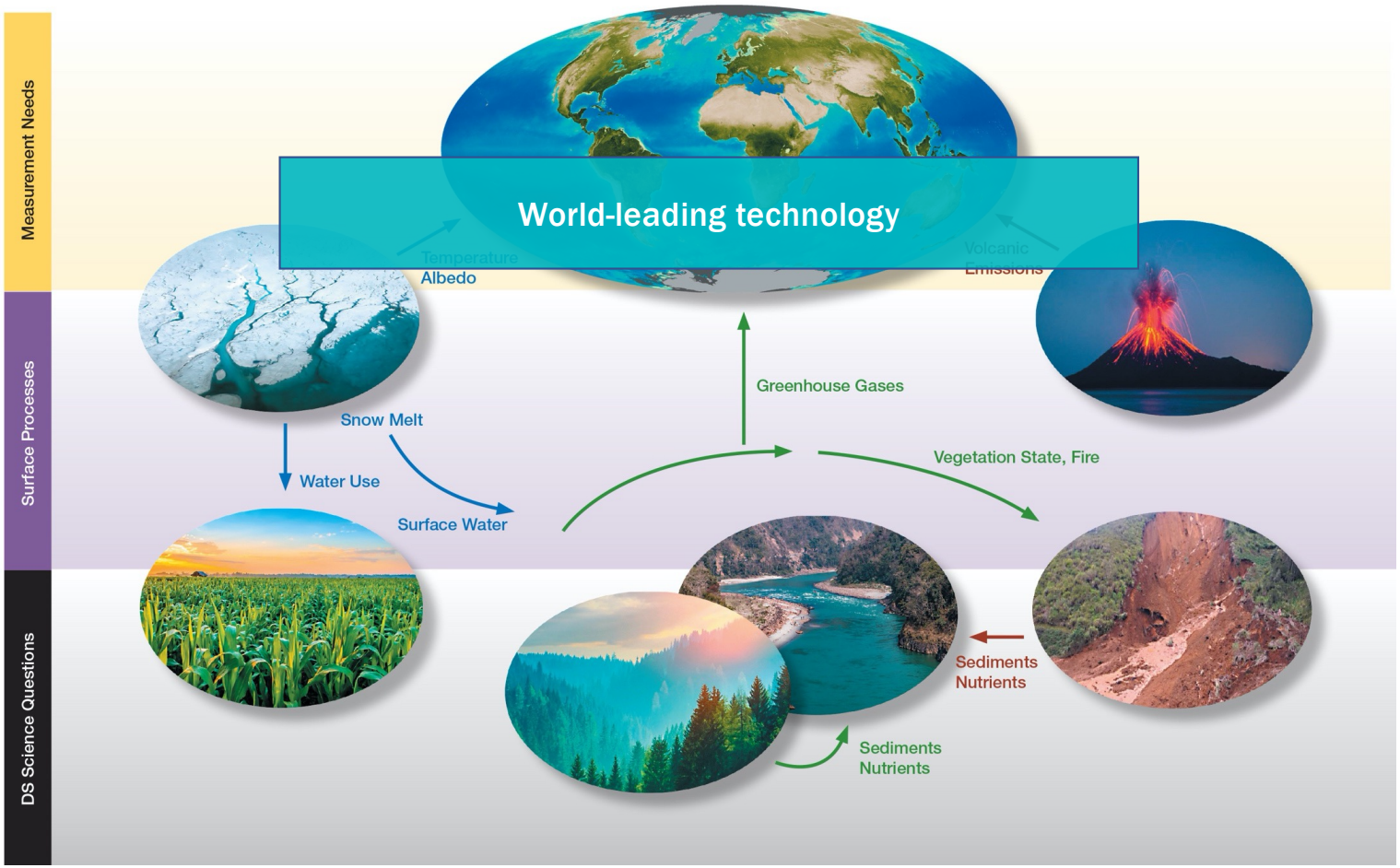


Pre-Decisional Draft: For planning and discussion purposes only.

THE SURFACE BIOLOGY AND GEOLOGY DESIGNATED OBSERVABLE



THE SURFACE BIOLOGY AND GEOLOGY DESIGNATED OBSERVABLE



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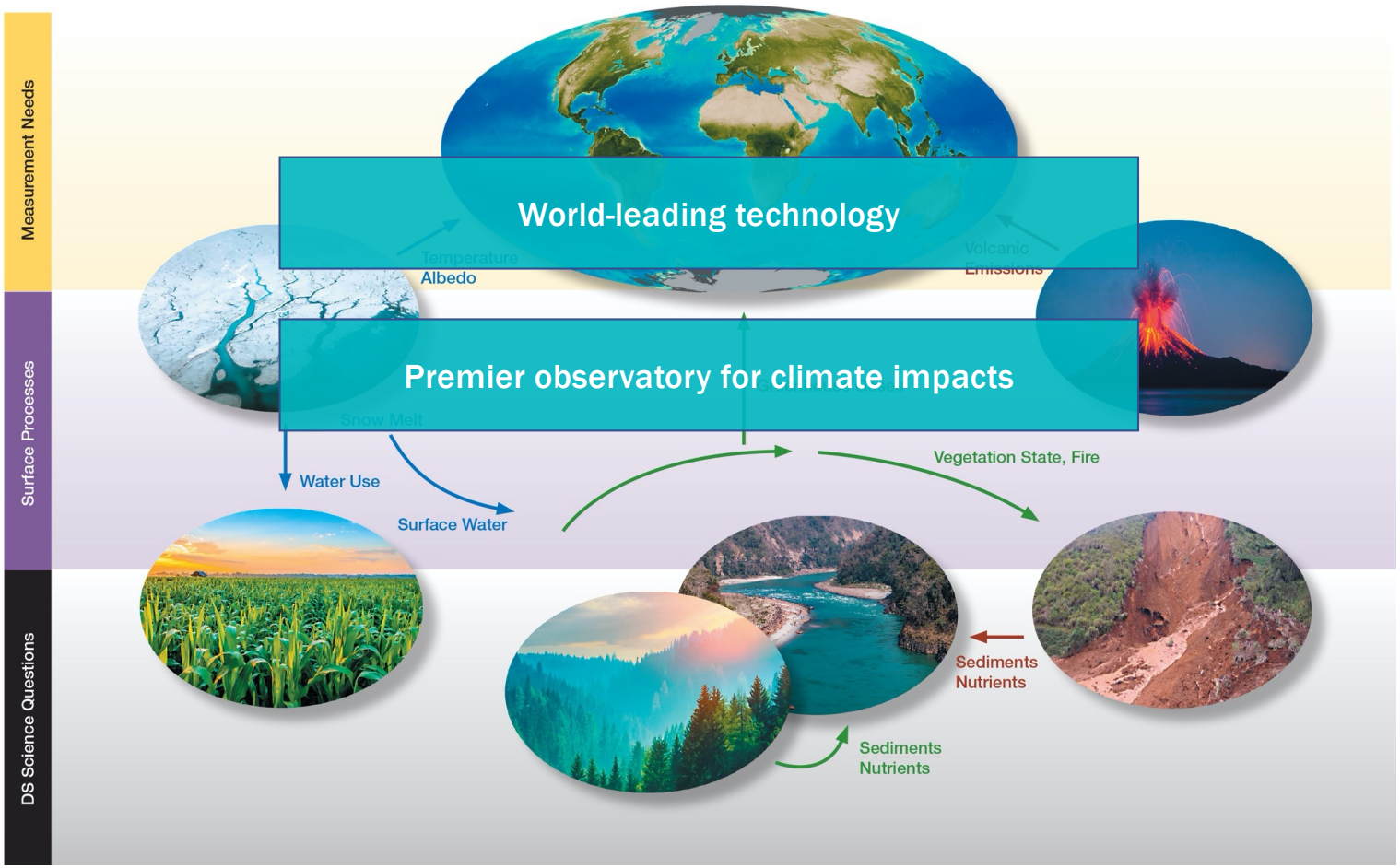

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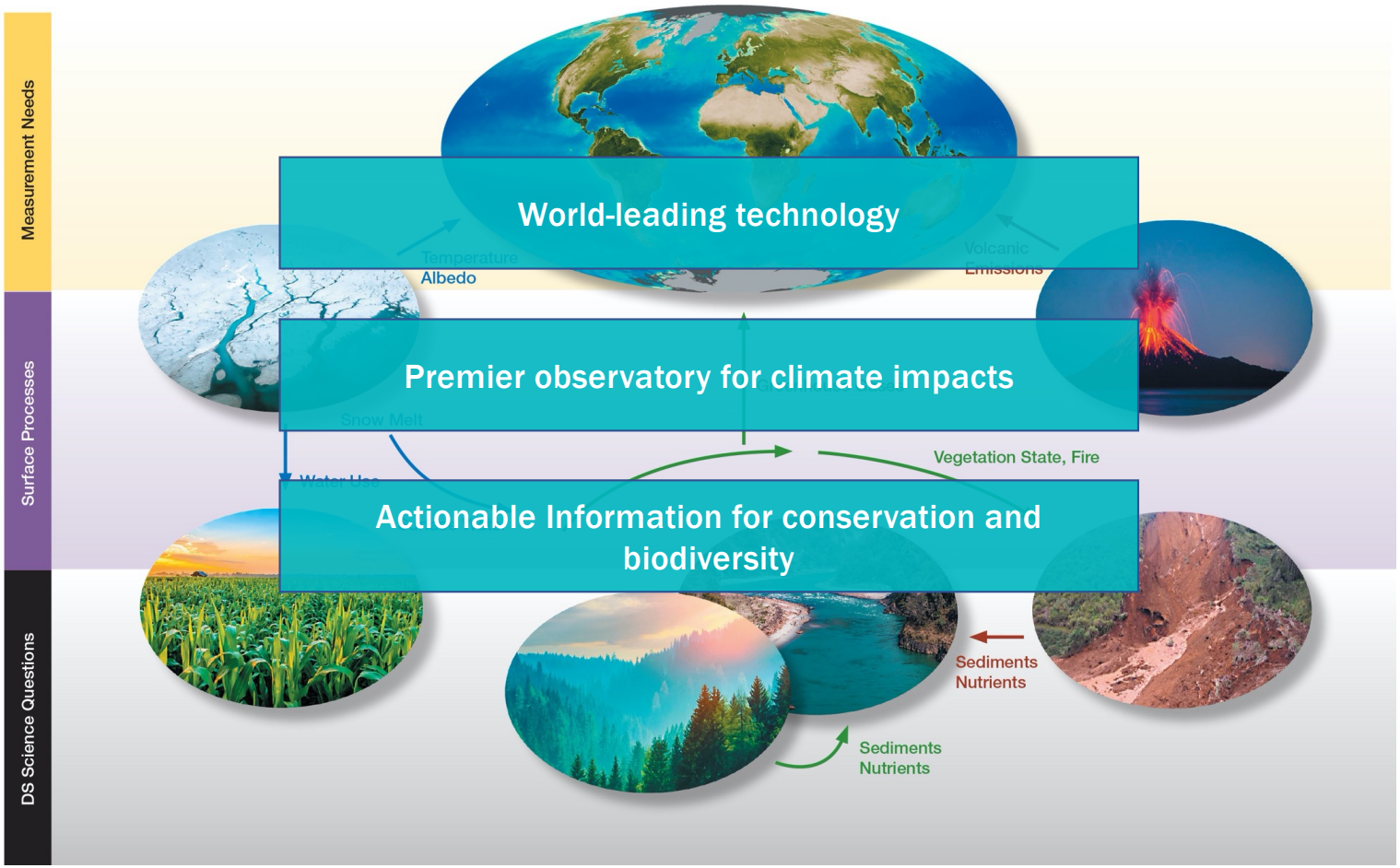

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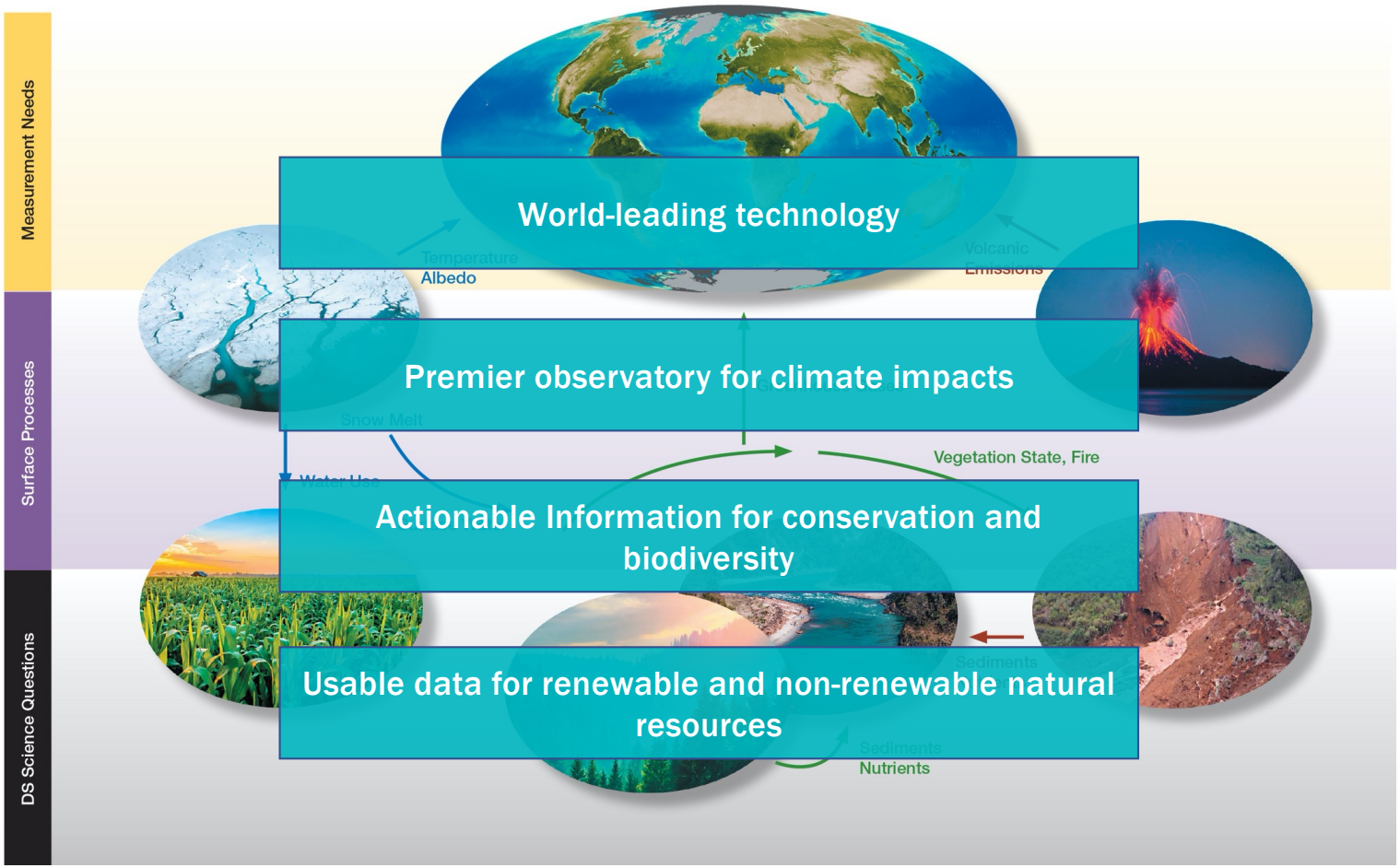

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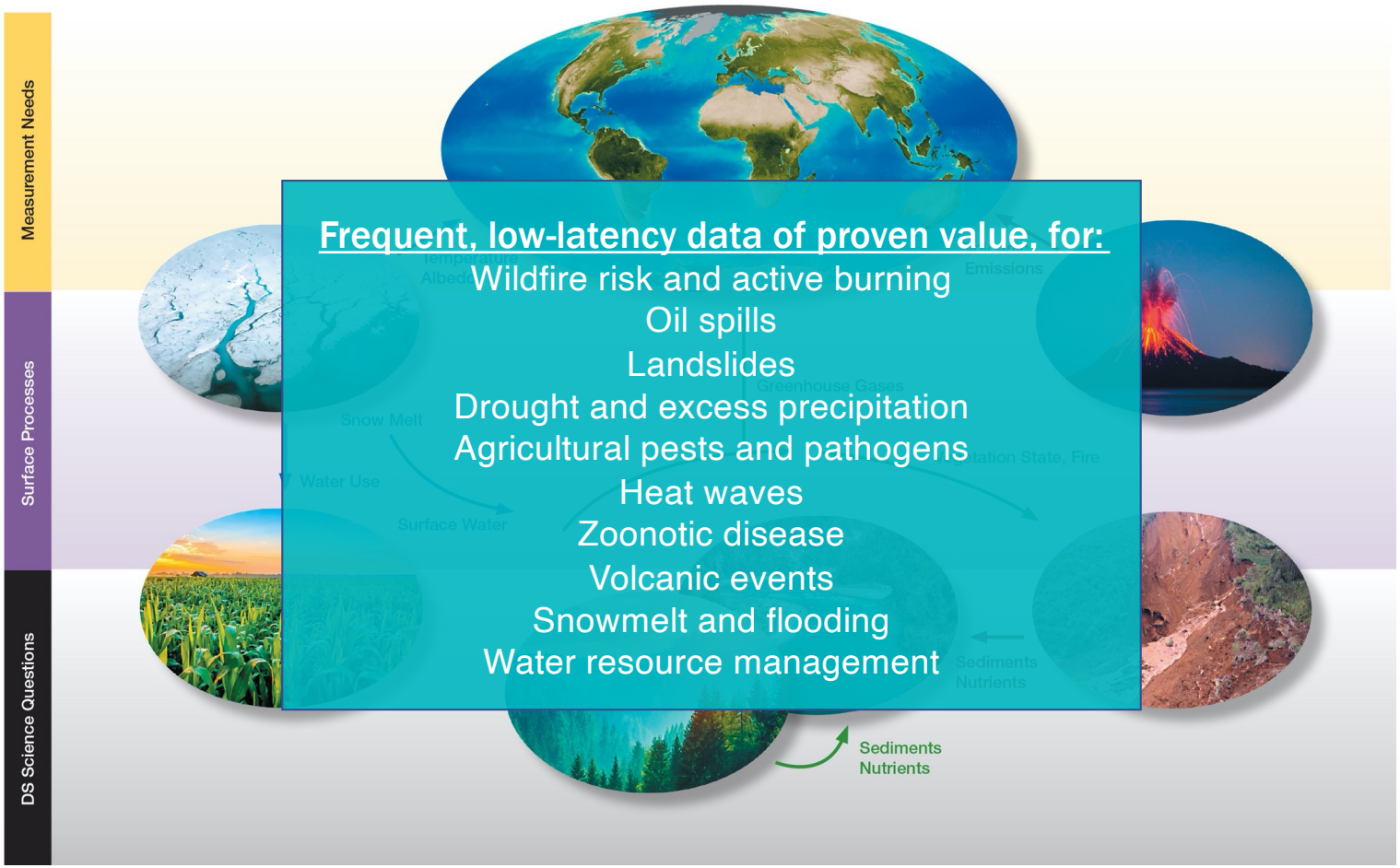

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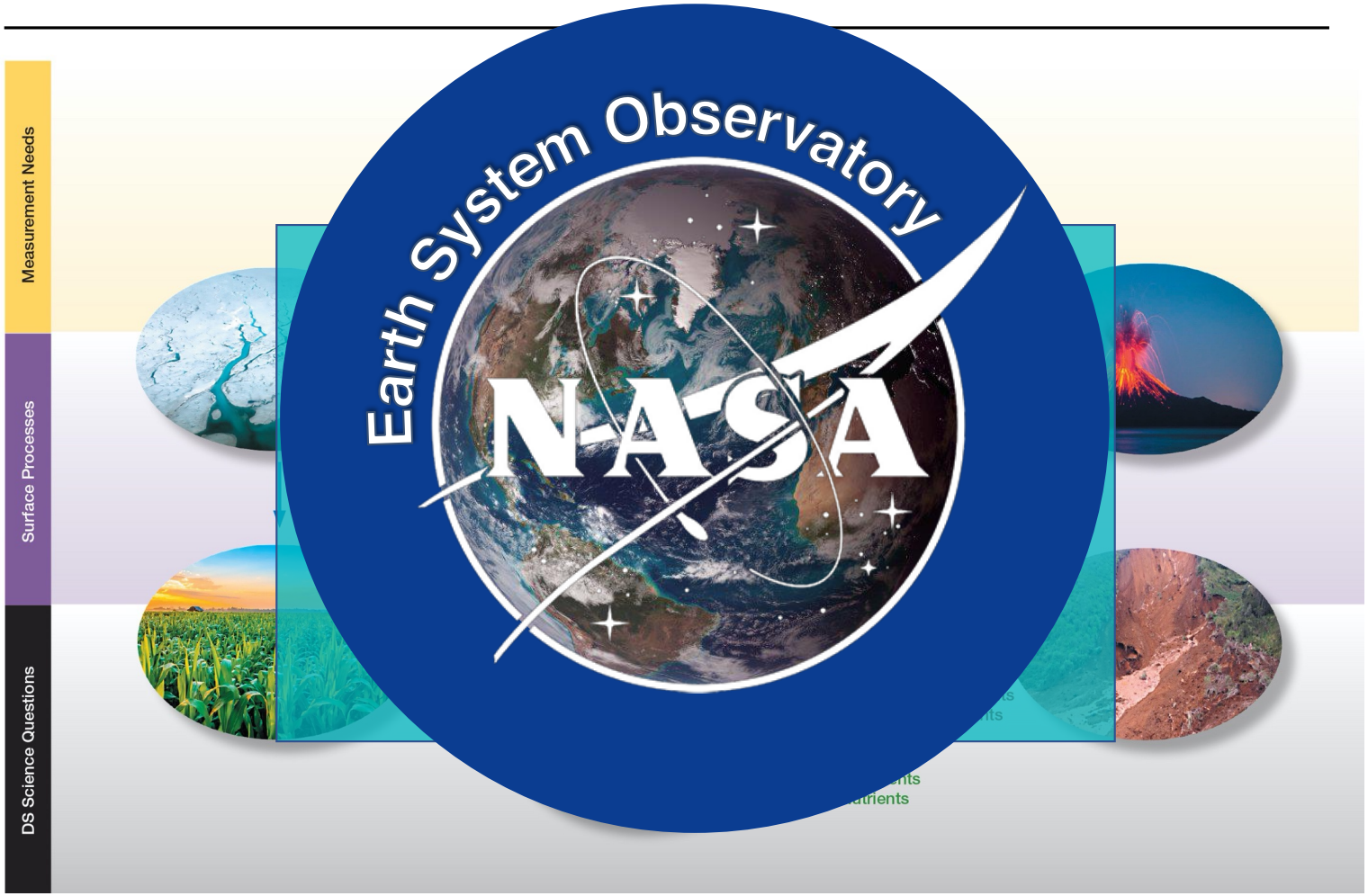


SISTER: SBG Space-based Imaging Spectroscopy and Thermal pathfindER

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

Primary Objectives

- Prototype architectures and workflows to generate prototype high-dimensional, high-value SBG data
  - Example data sources – AVIRIS, PRISM, HyTES, Hyperion, HISUI, PRISMA, DESIS, EMIT, ECOSTRESS
  - Implement ISOFIT atmospheric correction* and select L2B+ algorithms (*informed by the Algorithms and Applications Working Groups*)
- Distribute prototype SBG data to community, and develop community engagement strategy
- Assess and provide recommendations on cal/val network and instrumentation needs

**SISTER will not perform an atmospheric correction round robin, but will participate in the CEOS ACIX III activity underway for hyperspectral terrestrial and aquatic applications*

Prototype SBG Data Product Timeline

FY22 (Oct 2021 – Sept 2022)

Prototype workflows & system components
Implement ISOFIT atmospheric correction

↓

Distribute land & water reflectance for community evaluation / feedback

FY23-24 (Oct 2022 – Sept 2024)

Implement select prototype L2B+ algorithms

↓

Distribute prototype L2B+ products for community evaluation / feedback

FY25-26 (Oct 2024 – Sept 2025)

Adapt workflows based on emerging SBG ATBDs

↓

Refine and redistribute prototype SBG products for community evaluation / feedback

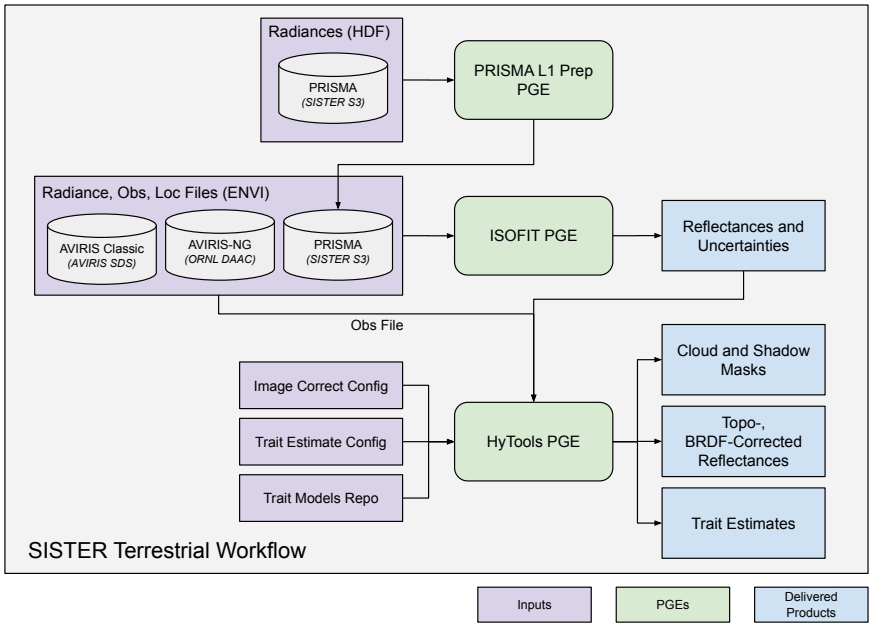
Prototype SBG Algorithms & Products

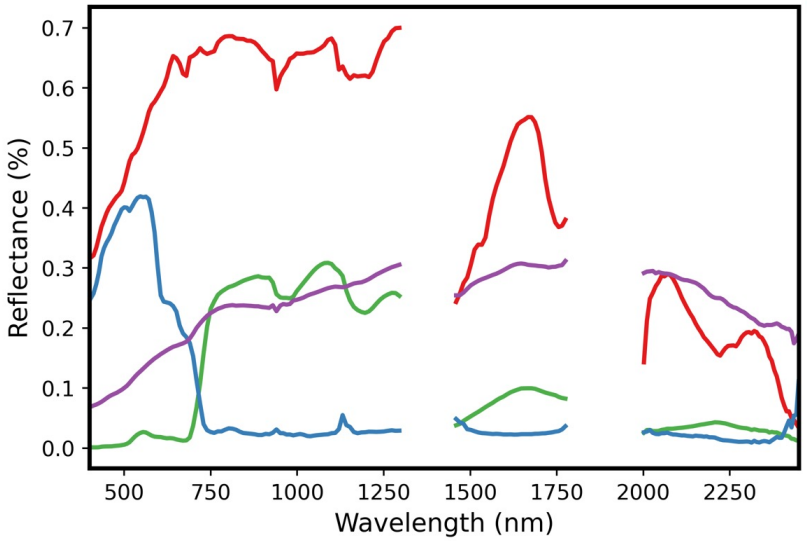
SISTER will implement select L2B+ algorithms (informed by the Algorithms and Applications Working Groups) to generate prototype SBG products for community evaluation and engagement

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*

Example SISTER Prototype Workflow for PRISMA

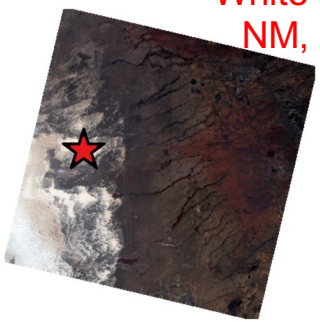




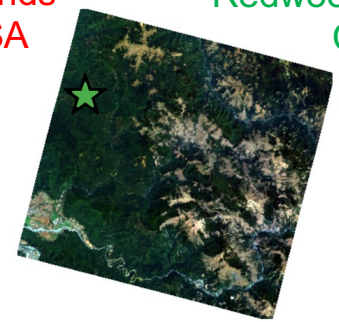
Westside National Park
Bahamas

Mojave Desert
CA, USA

White Sands
NM, USA



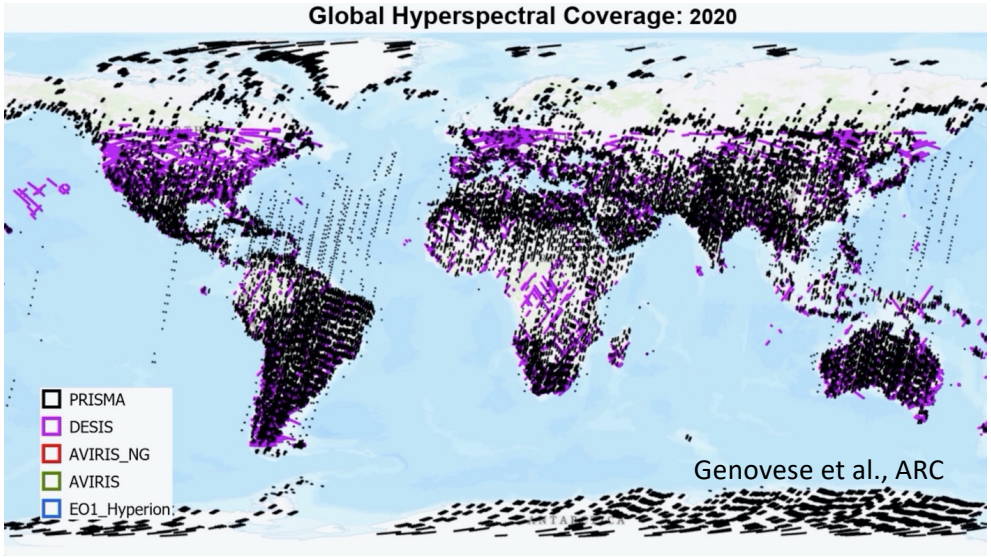
Redwood National Park
CA, USA



Chlus et al., JPL

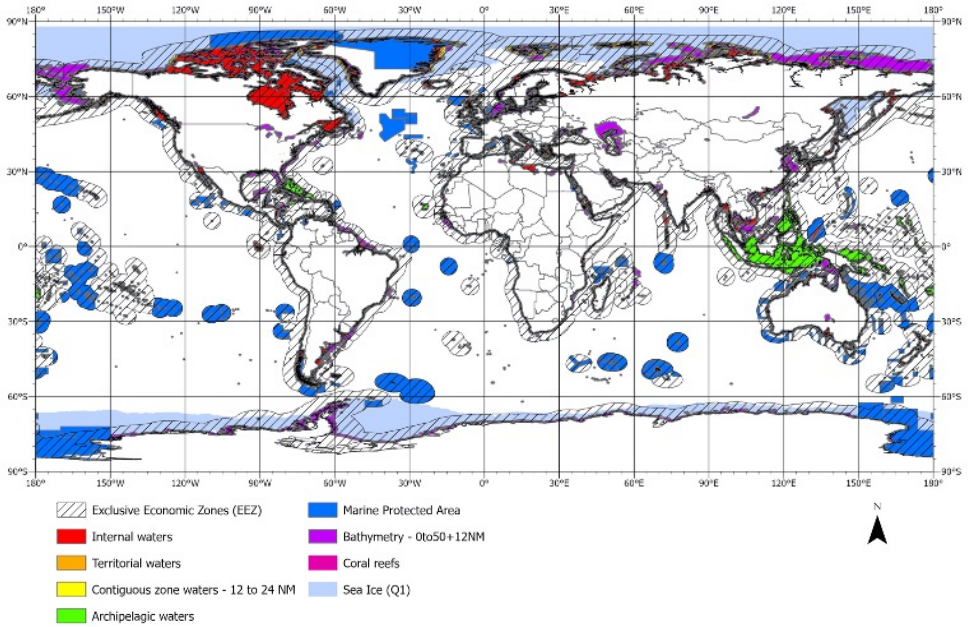
Other SISTER Tasks

GIS Database of Hyperspectral Sources



- GIS database contains scene boundaries for various hyperspectral airborne and spaceborne data since 2000
  - *HICO recently added*
  - *Land & aquatic cal/val targets are being added*
- Enables identification of coincident scenes
- Guides site selection for SISTER processing

SBG Coastal Mask



- This is an active Aquatic Studies Group (ASG) Special Focus Task
  - *Other active SBG-relevant ASG tasks include: definition of criteria/protocols for special observations; sun glint mitigation recommendations*
- The deliverable will be a community-recommended SBG coastal mask for data collection at native resolution

Goddard SPACE FLIGHT CENTER

JPL Jet Propulsion Laboratory California Institute of Technology

Ames Research Center

NASA Langley Research Center

NASA

MEET-SBG : *Modeling End-to-End Traceability for SBG*

Four Tasks

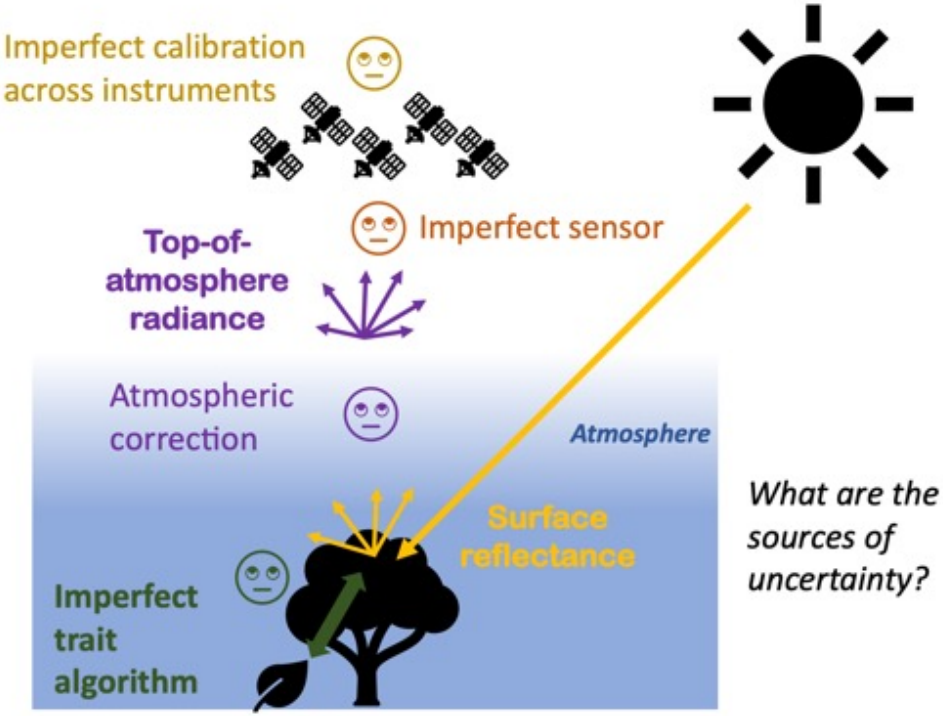
1. VSWIR Uncertainty Quantification
2. TIR Uncertainty Quantification
3. Synthetic SBG Production
4. Observing System Simulation Experiment

MEET-SBG Task 1: VSWIR UQ

- Hypertrace is a VSWIR uncertainty quantification workflow
- Traces uncertainty for aquatics, vegetation, snow, mineral retrievals

Sources of uncertainty in remote sensing of plant traits

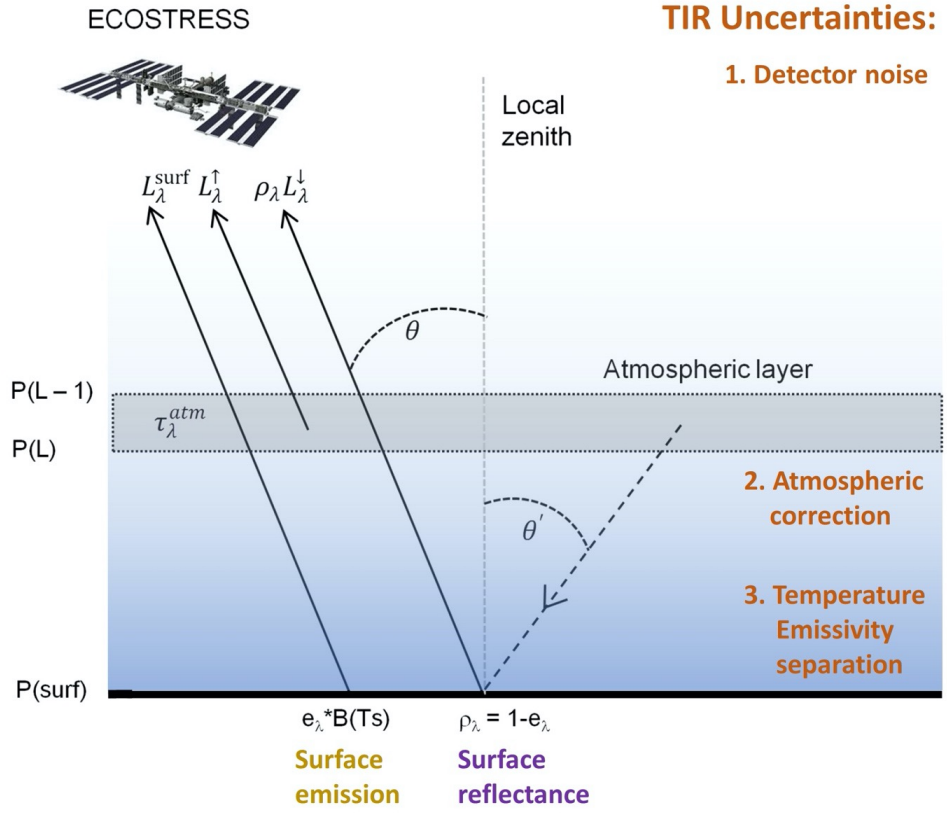
How large are the overall uncertainties in trait retrievals?



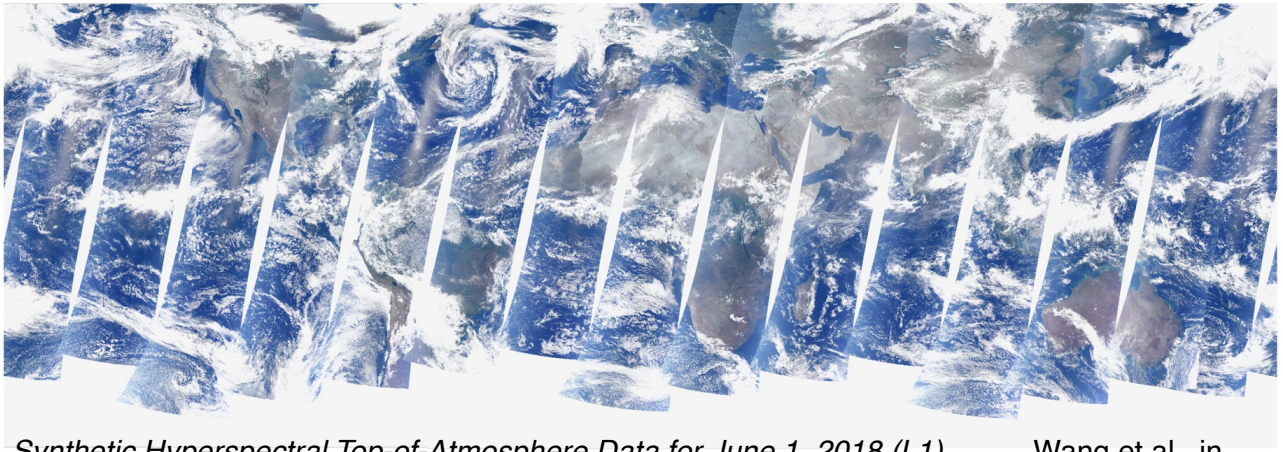
What are the largest sources of uncertainty?

MEET-SBG Task 2: TIR UQ

- The JPL Temperature Emissivity Uncertainty Simulator (TEUSim) traces LST and emissivity retrieval uncertainties for atm. conditions, sensor geometries, instruments, and algorithms.



MEET-SBG Task 3: Ames Global Hyperspectral Synthetic Dataset (AGHSD)



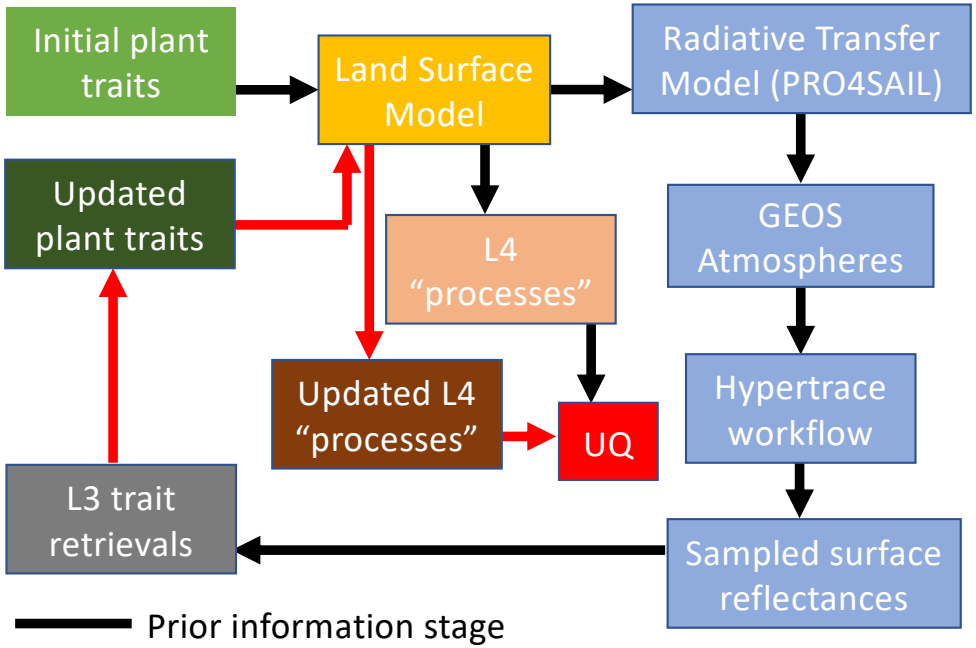
Synthetic Hyperspectral Top-of-Atmosphere Data for June 1, 2018 (L1) Wang et al., in progress

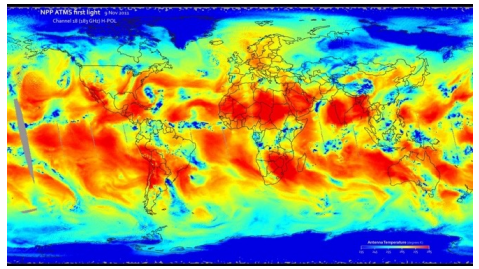
Ames Global Hyperspectral Synthetic Dataset (AGHSD, pronounced like August)

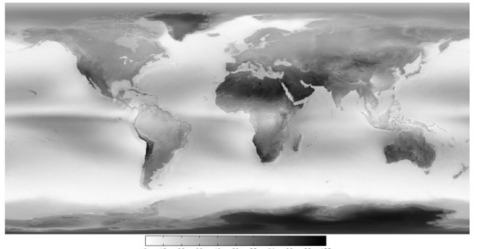
- 1 km spatial resolution, 224 bands (10 nm resolution), daily for 2019
- Derived from MODIS TOA reflectance (MOD02+MOD03) using a non-linear empirical model
- Intended for SBG OSSE & ground data system engineering
  - Suggests 8-day global coverage data volume of 2.1PB and 8.3PB per year at 60 and 30 m resolution, respectively (removing open ocean would result in a ~65% reduction)
- Global dataset will be released on **Aug. 1** available from **https://data.nas.nasa.gov/AGHSD**

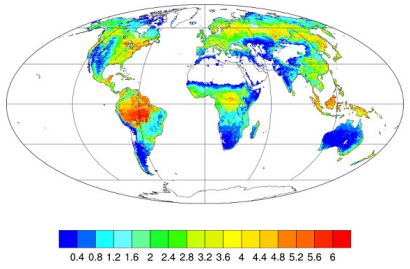
MEET-SBG Task 4: OSSE

- Address how SBG architecture can improve global Earth system processes
- Adapt to aquatic processes









Synergies Between NASA ESO Core Missions: SBG and the AtmOS missions

- ACCP, with the AtmOS mission, aims to improve understanding of atmospheric processes relevant to climate, weather, and air-quality, as well as other applications
- A series of workshops explored areas of potential synergy between the two DOs
- We are finalizing the recommendations as a manuscript for the forthcoming SBG special issue in JGR-B

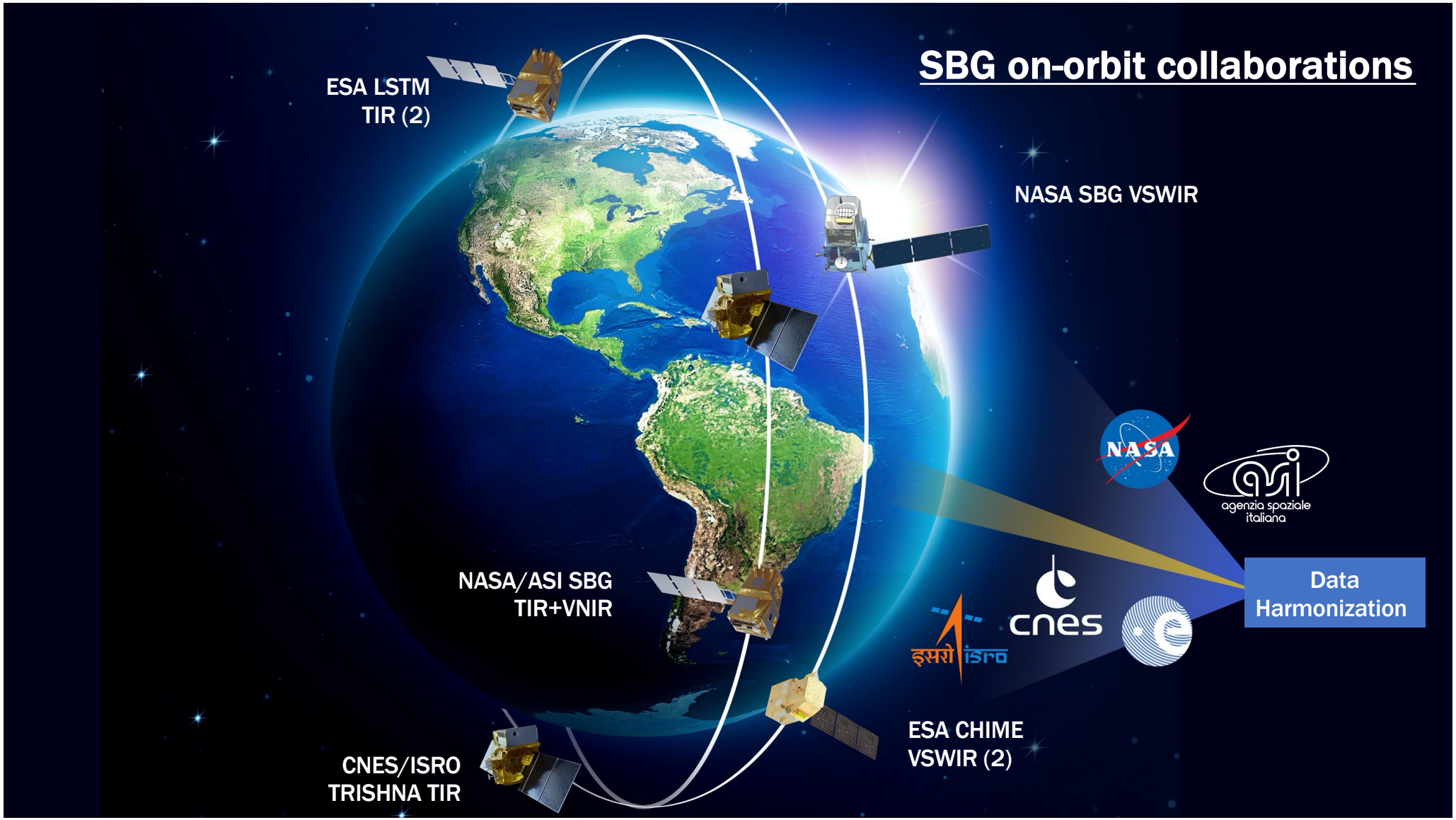
Categories	Synergies identified	Examples
Enabling Science	**4**	**Surface energy balance and broadband albedo**
Observations, Assets	**10**	Share resources for **radiometric calibration infrastructure,** combined observation of **aerosol/albedo properties and VSWIR**
Models	**3**	**Geophysical variables and simulators to inform and validate high resolution ESMs**
Retrieval Algorithms	**7**	**Validate atmospheric retrievals** – joint algorithms, campaigns, **Surface reflectance** from SBG as a basemap for lidar, etc.

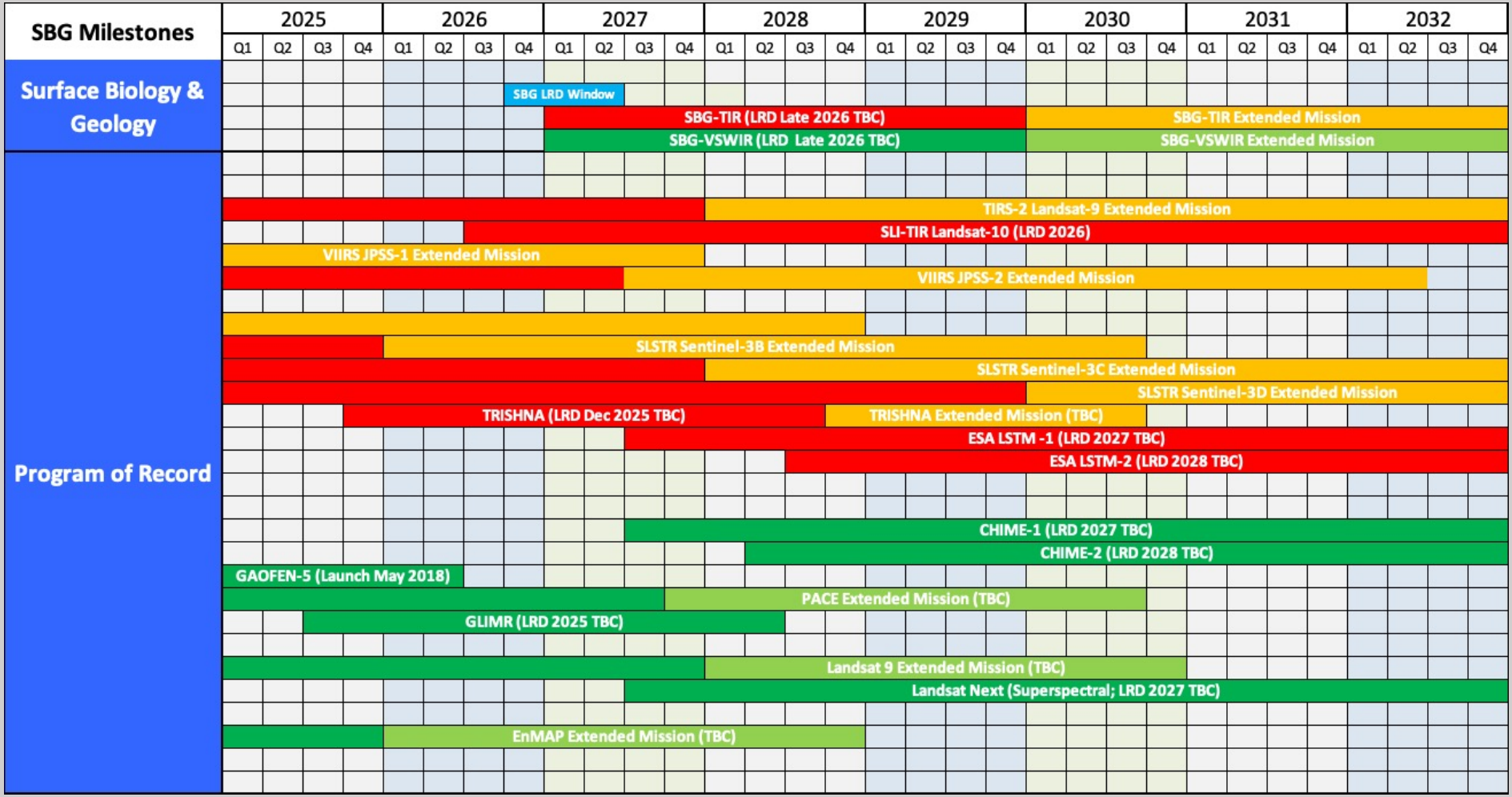
Short term priorities

1. Early planning for joint calibration and validation.
   - Exchange of calibration sources
   - Opening a dialogue with CEOS working groups to cultivate common vicarious calibration resources
   - Investigate lunar calibration options as a supplement to Earth surface sites.
2. Joint airborne campaigns (e.g. ARCSIX) with analogue instruments to demonstrate measurement methods
   - VSWIR cloud property estimates
   - Ancillary aerosol data for atmospheric correction
   - Surface albedo for radiation and energy budgets

Long term priorities

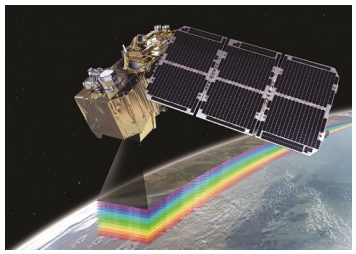
1. Common radiative transfer models for the visible shortwave infrared regime
2. Bring together designers of data products that could be useful to both observables.
   - Aerosol climatology to improve the accuracy of SBG surface reflectance retrievals.
   - Reflectance basemaps from SBG for ACCP AtmOS lidar or polarimeter retrievals.
   - SBG measurements of energy and water vapor fluxes from the surface could be invaluable for understanding PBL processes in the ACCP AtmOS mission.
3. Compatible SDS conventions to ensure interoperability
4. Global distribution of aerosol species and optical properties, Geophysical Variables and simulators to inform and validate high resolution ESMs


SBG on-orbit collaborations
ESA LSTM
TIR (2)
NASA SBG VSWIR
NASA/ASI SBG
TIR+VNIR
CNES/ISRO
TRISHNA TIR
ESA CHIME
VSWIR (2)
NASA
agenzia spaziale italiana
cnes
इसरो isro
Data
Harmonization

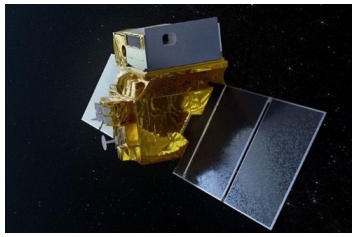

SBG Milestones
2025
2026
2027
2028
2029
2030
2031
2032
Q1 Q2 Q3 Q4
Surface Biology & Geology
SBG LRD Window
SBG-TIR (LRD Late 2026 TBC)
SBG-TIR Extended Mission
SBG-VSWIR (LRD Late 2026 TBC)
SBG-VSWIR Extended Mission
Program of Record
TIRS-2 Landsat-9 Extended Mission
SLI-TIR Landsat-10 (LRD 2026)
VIIRS JPSS-1 Extended Mission
VIIRS JPSS-2 Extended Mission
SLSTR Sentinel-3B Extended Mission
SLSTR Sentinel-3C Extended Mission
SLSTR Sentinel-3D Extended Mission
TRISHNA (LRD Dec 2025 TBC)
TRISHNA Extended Mission (TBC)
ESA LSTM -1 (LRD 2027 TBC)
ESA LSTM-2 (LRD 2028 TBC)
CHIME-1 (LRD 2027 TBC)
CHIME-2 (LRD 2028 TBC)
GAOFEN-5 (Launch May 2018)
PACE Extended Mission (TBC)
GLIMR (LRD 2025 TBC)
Landsat 9 Extended Mission (TBC)
Landsat Next (Superspectral; LRD 2027 TBC)
EnMAP Extended Mission (TBC)

SBG PARTNERSHIPS AND NASA OPEN SCIENCE LEADERSHIP

- **Enabling and enhancing: maximize science strength and cost effectiveness:** Joint mission with ASI provides science collaboration, VNIR camera, launch and spacecraft for TIR instrument.
- **Reducing revisit and observing events:** Open data sharing and product harmonization with CHIME (VSWIR), LSTM and TRISHNA (TIR) reduces intervals between observations, increases research and applications opportunities and length of data records.
- **International collaboration on calibration and validation:** unprecedented data quality and engagement through use of terrestrial and aquatic networks for vicarious calibration and validation activities on six continents.

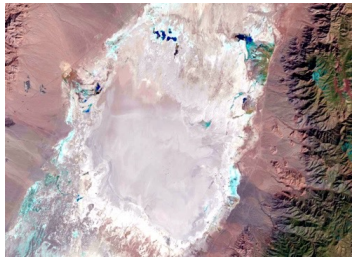


ESA CHIME

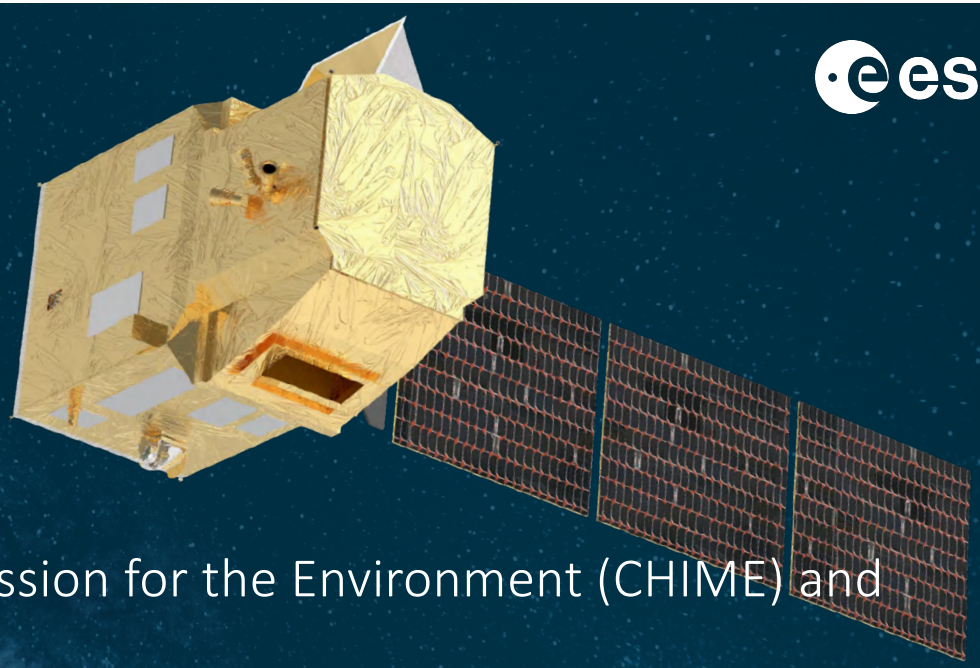


CNES/ISRO TRISHNA

ESA LSTM



CAL/VAL



The Copernicus Hyperspectral Imaging Mission for the Environment (CHIME) and cooperation with NASA - SBG

- **SBG Community Workshop, 15.06.2021**
-

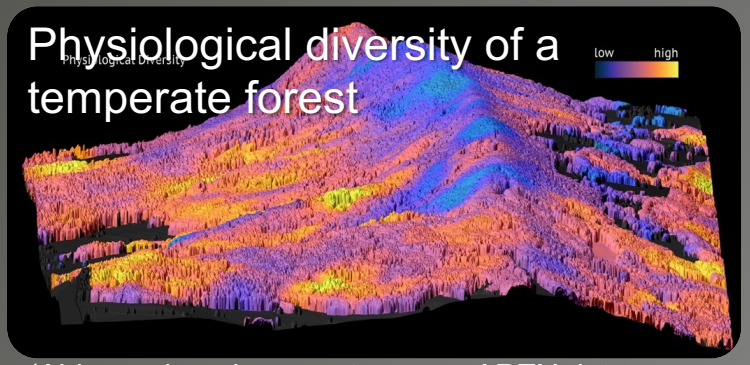
Copernicus Hyperspectral Imaging Mission (CHIME)

•Provide routine hyperspectral measurements in support of EU- and related policies for the management of natural resources & assets

- Support food security, agriculture and raw materials, soil properties

- Secondary Applications: biodiversity and ecosystem sustainability, forestry management, environmental degradation, lake/coastal ecosystems and water quality, snow grain size/albedo, snow impurities)

Hyperspectral data cube
(courtesy DLR)

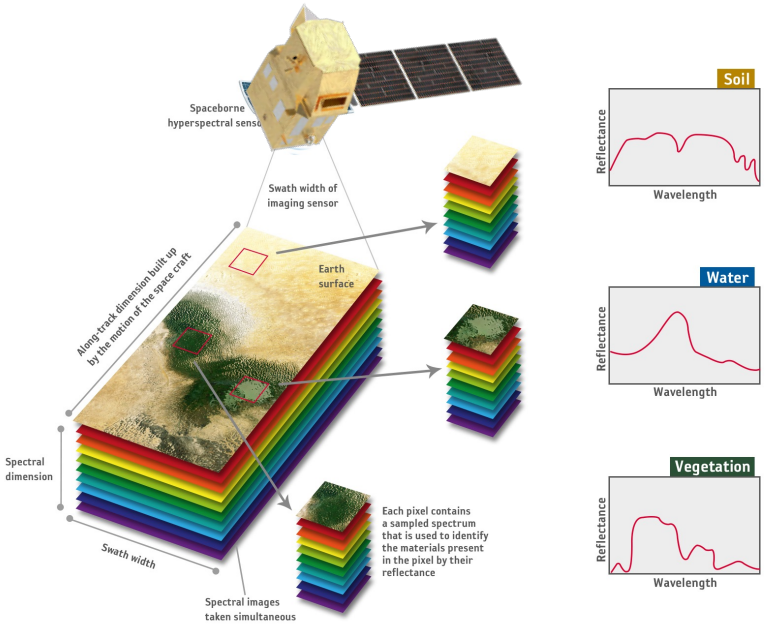


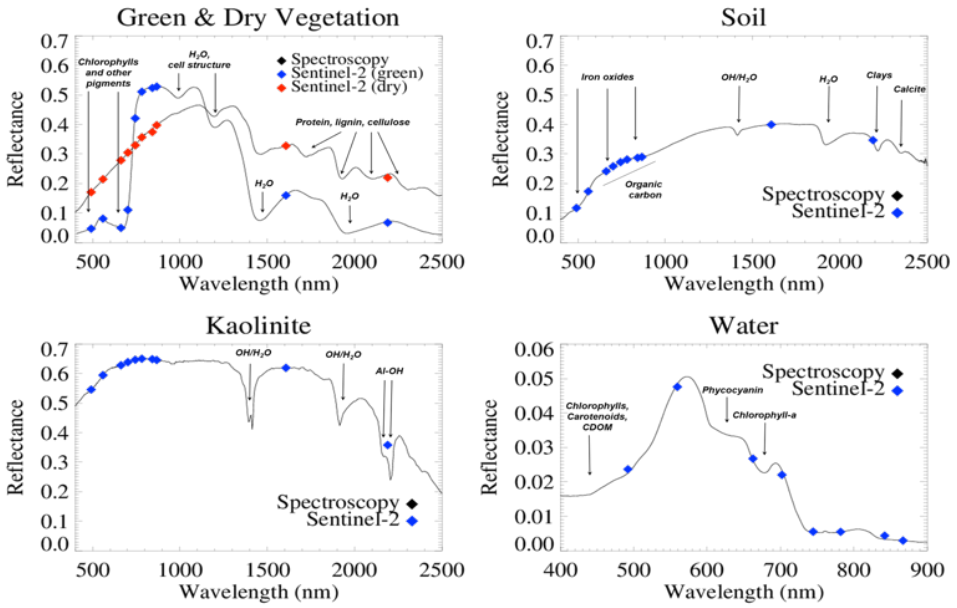
(Airborne imaging spectroscopy APEX data - Schaepman, Jehle et al. 2015)

Hyperspectral Imaging Mission (CHIME)

Key Mission requirements (MRD):

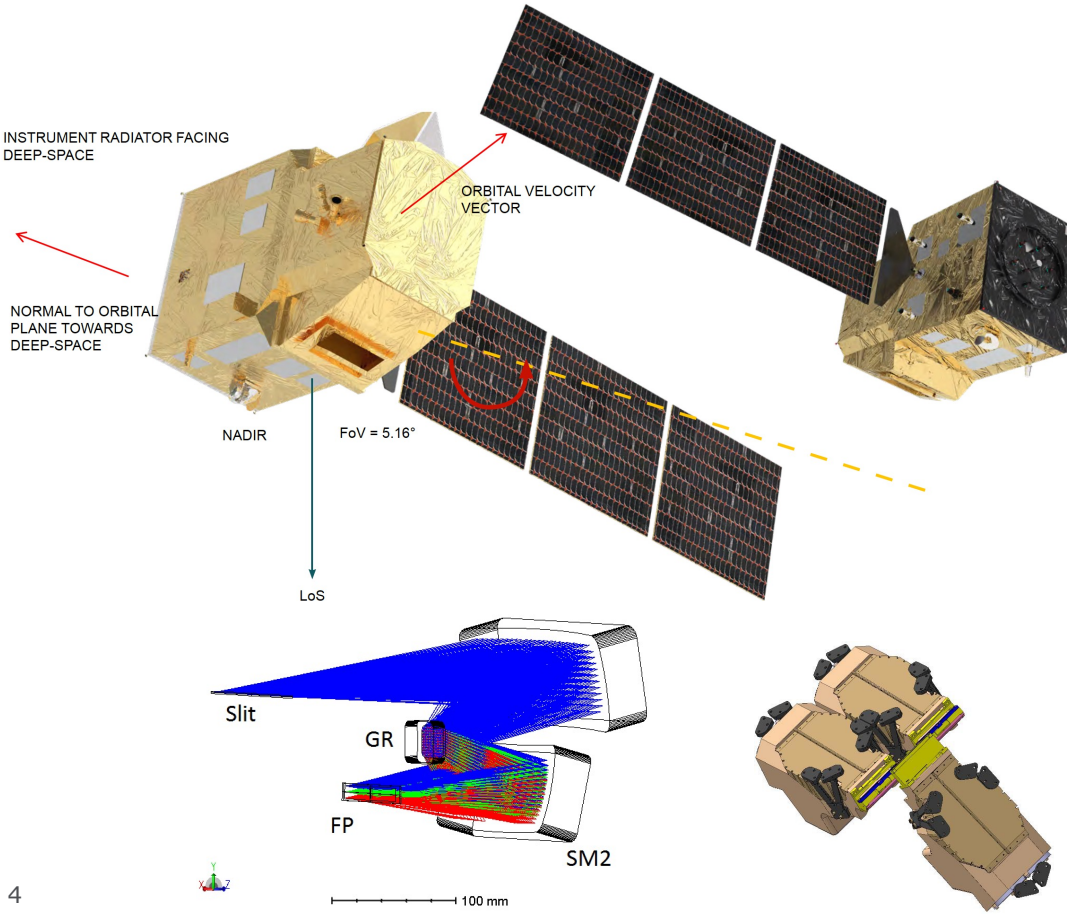
- Routine hyperspectral observations
- Sun synchronous orbit (LTDN 10:45)
- Revisit 12.5 days (for 2 satellites)
- Nadir view covering land surfaces, inland- and coastal waters
- Spectral range: 400 – 2500 nm,
- Spectral bandwidth ≤ 10nm
- SSD: 30m
- High radiometric accuracy, low spectral/spatial mis-registration
- Improved NeDL requirements to match performance of parallel missions (EnMap, PRISMA, SBG)





CHIME Space Segment – Key Features

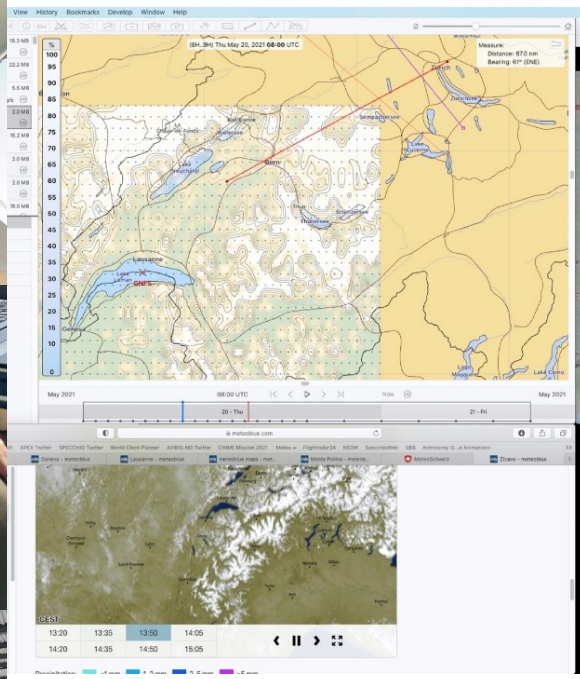
- **Platform**
  - Coordinated P/F development with CIMR and ROSE-L missions
  - Data Processing Unit (DPU) allowing cloud detection and compression using AI
- **HyperSpectral Instrument (HSI)**
  - Pushbroom-type grating Imaging Spectrometer with high Signal-to noise Ration (SNR) and data uniformity
- **Laser Communication Terminal (LCT)**
  - The use of a LCT (CHIME-GEO) for data transmission is being studied in phase B2
  - Decision on Embarkation by PDR
- **Industrial Consortium**
  - Prime Contractor: Thales Alenia Space France (TAS-F)
  - Instrument Prime: OHB (DE) with
    - LEONARDO (IT) for Focal Planes & E2E Calibration
    - AMOS (BE) for 3 x spectrometer, gratings and slits
  - Industrial Consortium: 44 Companies from 17 Countries

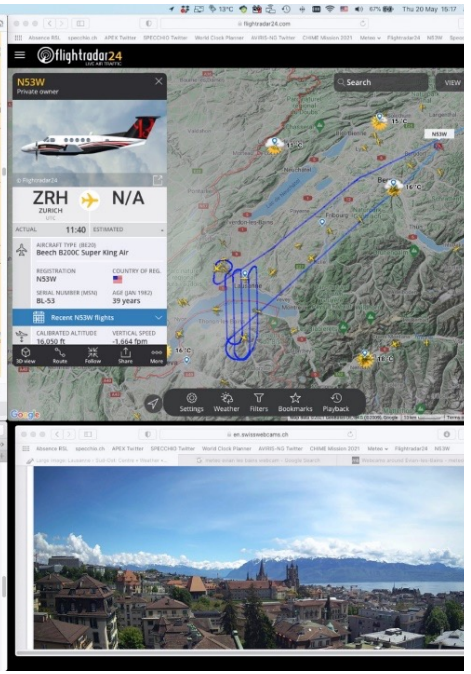


SBG – CHIME Data Product Crosswalk

	SBG Product	SBG SubProduct	CHIME Variable
BASE	Earth Surface Temperature and Emissivity	[2 subproducts]	
BASE	VSWIR Reflectance	Land Surface Reflectance	Surface Reflectance
		Albedo	
		[4 corrected reflectance subproducts]	
BASE	Cover Type Classification	Cover Types, Plant Functional types	
		[4 subproducts for cloud, water, glint]	
PRODUCTS	Vegetation Traits	Nitrogen concentration (%, g/g)	Canopy nitrogen content (uptake, kg/ha)
		Leaf mass per area (LMA, g/m2)	Specific leaf area (SLA, m2/kg)
		Total chlorophyll (A+B)	Leaf and canopy pigment content (chlorophyll)
		Canopy water content	Canopy water content (g/cm2)
			Leaf dry mass
	Evapotranspiration	[2 subproducts]	N/A
	Proportional Cover	GV	
		NPV	Quantification of non-photosynthetic vegetation
		Substrate	
		Snow/ice	
		burn area/severity	
	Substrate composition	Mineral areal fractional abundance	Mineral identification (Kaolinite, Smectite, Jarrosite, Dolomite)
			Kaolin Cristallinity
			Hematite-goethite distribution
			Ferric oxide contents
		Soil type and soil constituents	Soil textural and structural composition (e.g clay, silt, sand, iron oxides, gypsum and carbonate contents)
			Soil organic carbon content
		Substrate changes	

‘Hypersense’ Campaign with AVIRIS-NG in 2021





NASA

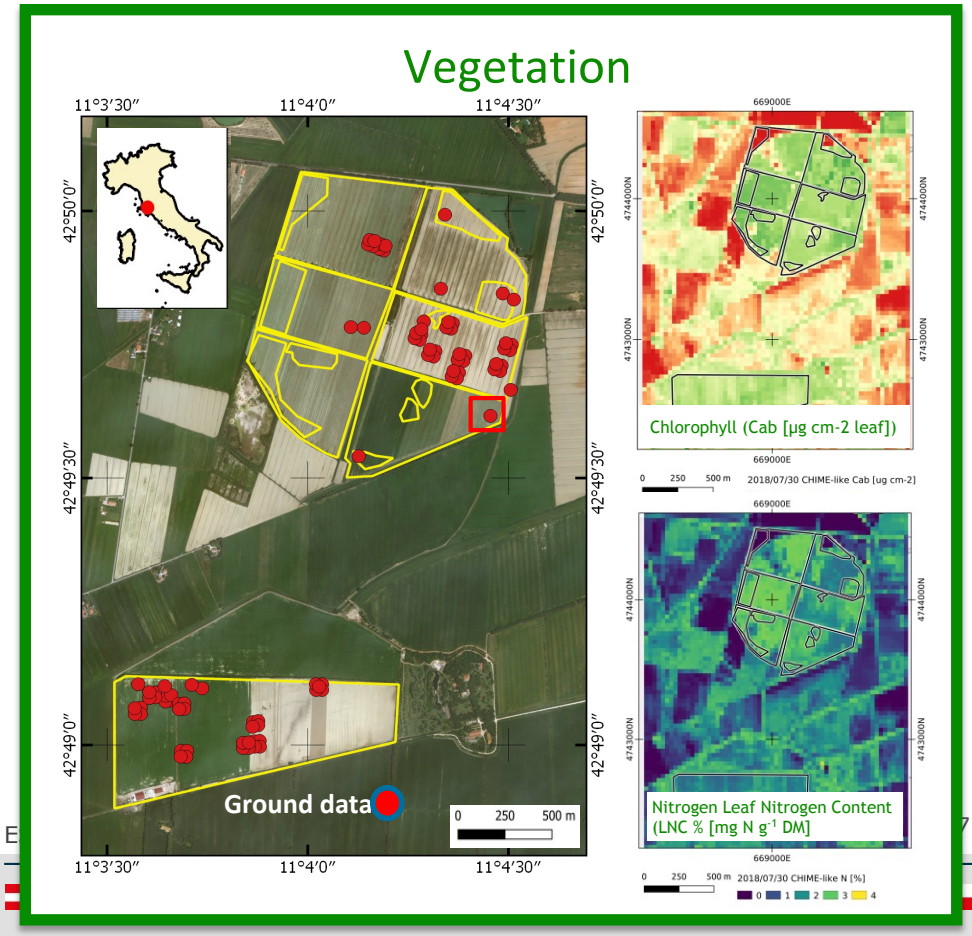
University of Zurich[UZH]

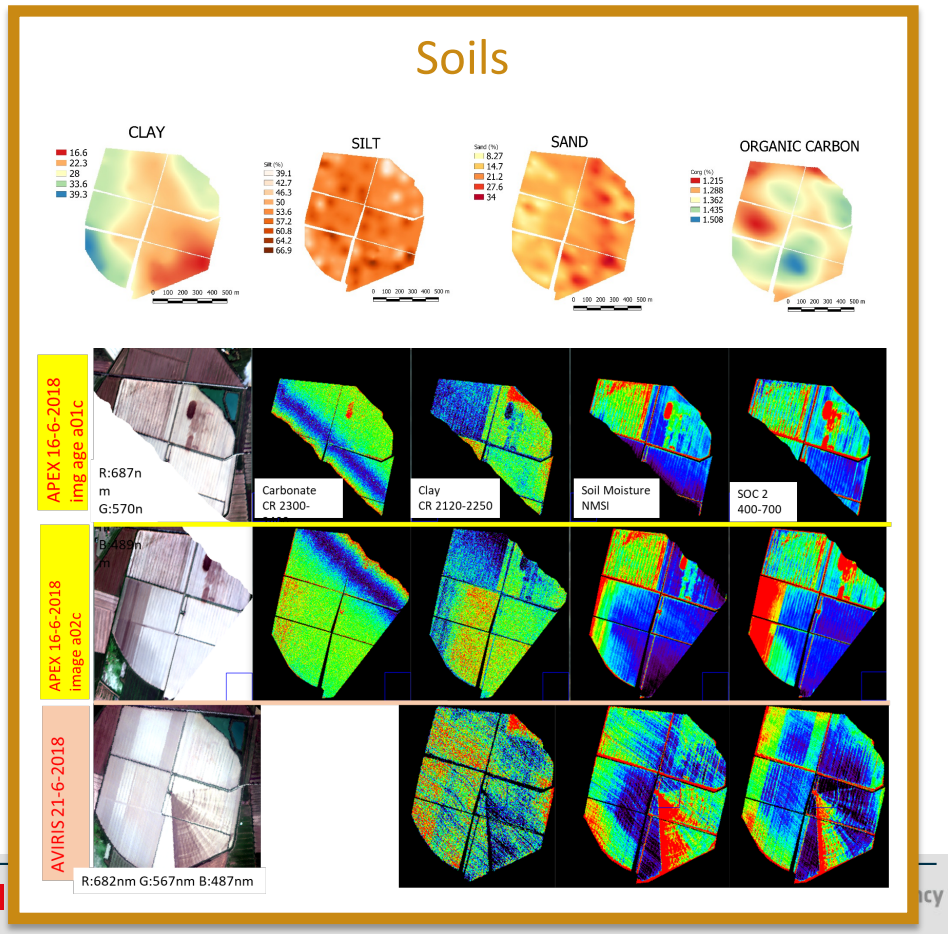
esa

European Space Agency

AI based retrieval of CHIME Priority Products: Nitrogen, Chlorophyll and Soils

Based on Experimental AVIRIS Campaign-Grosseto, IT, 2018





CHIME – SBG collaboration opportunity in a nutshell

Programmatics

- How to implement the collaboration
- Working Groups on Cal/Val, Product Harmonisation and Modelling/e2e Simulation
- Identify added value to Decadal Survey and EO programmes
- Harmonisation of Practices and procedures for coordinated operations and exploitation

Science Goals

- Decadal Survey
- ESA Living Planet Strategy
- CHIME Sust. Agri./Food security

Applications and services

- Copernicus Services
- EU Directives/Policies/Green Deal
- NOAA, USGS, US EPA, USDA

Improved Observations

- Revisit
- Coverage
- Continuity
- Core and Priority Products
- Atmospheric Correction
- Information Content (ATBD/algorithm development)

Implementation

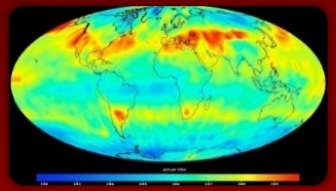
- Orbit definition
- Tandem flight manoeuvres
- Schedule
- Joint Campaigns
- End-to-End Simulator/Observation Simulation System Experiments
- Common ground data system elements

Land Surface Temperature Monitoring LSTM Mission

Benjamin Koetz, Björn Baschek, Wim Bastiaanssen, Michael Berger, Joris Blommaert, Ana Bolea Alamañac, Maria Buongiorno, Raphael D'Andrimont, Pierre Defourney, Umberto Del Bello, Matthias Drusch, Mark Drinkwater, Ricardo Duca, Phillipe Gamet, Ferran Gascon, Darren Ghent, Radoslaw Guzinski, Jippe Hoogeveen, Simon Hook, Yann Kerr, Jean-Pierre Lagouarde, Ilias Manolis, Philippe Martimort, Jeff Masek, Michel Massart, Massimo Mementi, Claudia Notarnicola, Albert Olioso, Inge Sandholt, Dirk Schuettemeyer, Jose Sobrino, Peter Strobl, Thomas Udelhoven

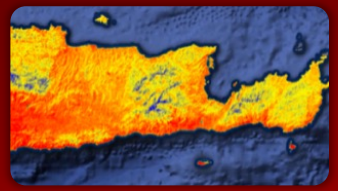
Copernicus 2.0 – New Monitoring Missions

Anthropogenic CO_2 Mon. Mission



Causes of Climate Change

Land Surface Temperature Mission

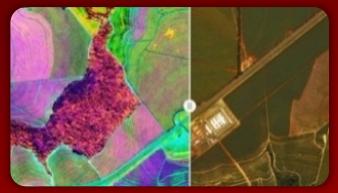


Agriculture & Water Productivity

CRISTAL – Polar Ice & Snow Topography

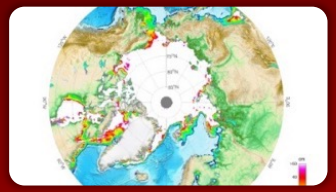
Effects of Climate Change

CHIME – Hyperspectral Imaging Mission



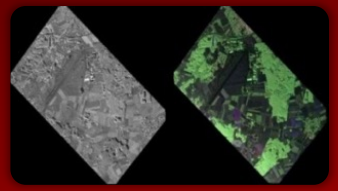
Food Security, Soil, Biodiversity

CIMR – Passive Microwave Radiometer



Sea: Surface Temp. & Ice Concentration

L-band SAR Mission



Vegetation & Ground Motion & Moisture

LSTM Phase B2

- Contract signed with Airbus Spain (prime), 380 Meuro for 2 LSTM satellites
- LSTM phase B2 started, successful System Requirements Review (April 2021)

LSTM Mission Objective:

Provide high spatio-temporal resolution Thermal Infra-Red observations over land and coastal regions ***in support of agriculture management services***, and a range of additional applications

Prototype Flight Model QAR:
Oct 2028

opernicus
Europe's eyes on Earth

LSTM System Design

Key requirement*	
Geometrical revisit	2 days/2 satellites
Local time	13:00 (Europe) & night observations
SSD	50 m (37m at nadir)
Spectral Bands	5 TIR, 4 VNIR, 2 SWIR
Nominal swath	687 km, at 651 km altitude
Acquisition system	Whiskbroom scanner
Geo-location L1c	1 SSD (without GCP)
MTF	0.2-0.3
Data latency (L2)	6-12 hours
NeDT	< 0.15 K
ARA	< 0.5 K

User requirement**
Evapotranspiration (goal)

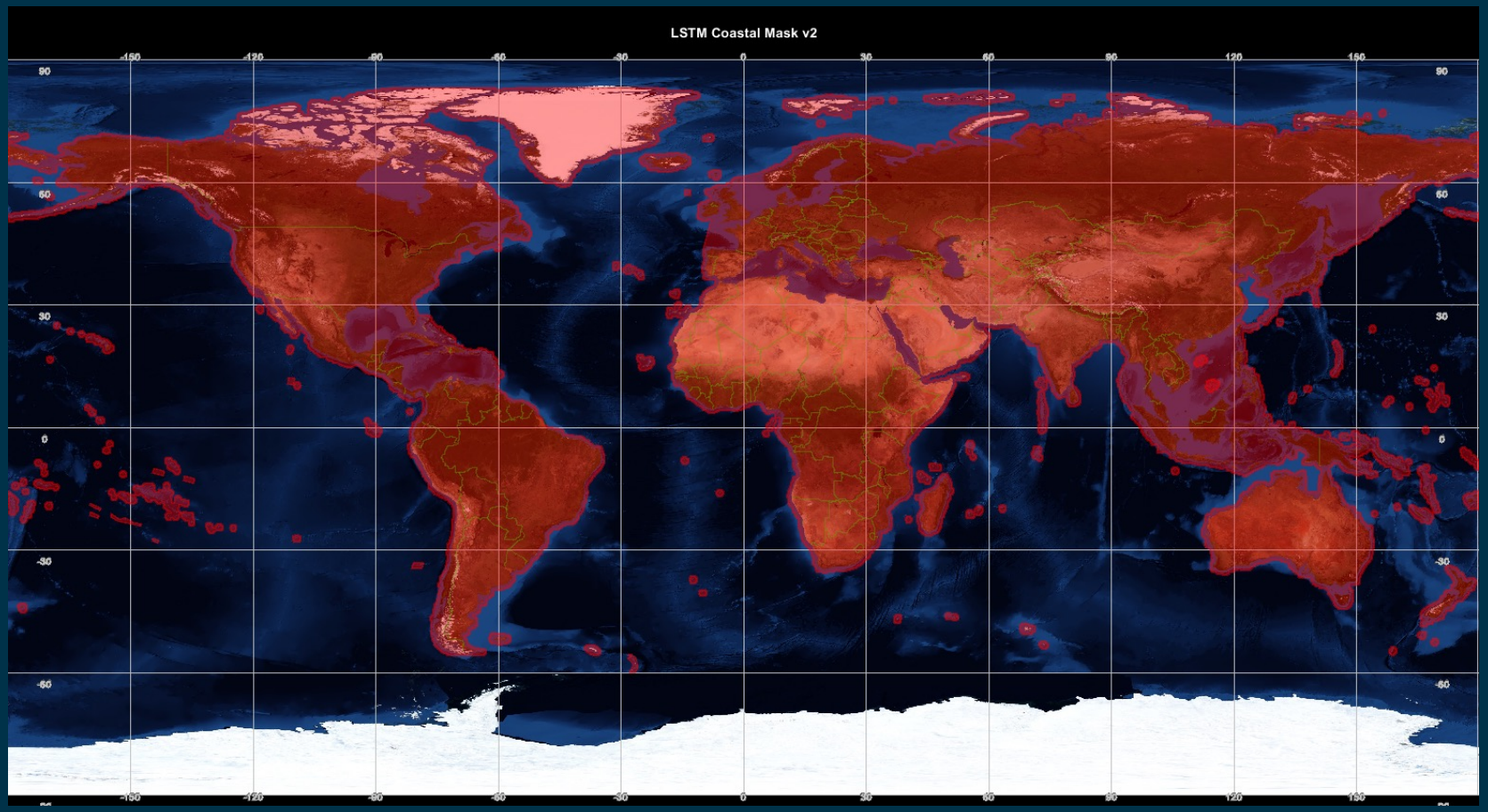
- Accuracy 15% [mm/day]
- Precision 5%
- Field scale [0.5 ha]
- Daily observations

LST observations**

- 50 meters resolution
- 1-3 days revisit
- 1-1.5 K LST accuracy

* Copernicus LSTM Phase B2/C/D/E1 System Requirements Document
**Mission Requirement Document V2
https://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Candidate_missions

LSTM Acquisition Mask



NASA-ESA Collaboration Preparing LSTM

European ECOSTRESS Hub
Algorithm prototyping

NASA-ESA Airborne Campaign
NET-Sense 2019 & 2021

BBC article: https://www.bbc.com/news/science-environment-48527188

LSTM & SBG Synergies

- Compatible mission objectives:
  - LSTM: Improved water productivity & agriculture management
  - SBG: Ecosystem science - stress and water use
- User requirement for ET: daily effective observation (cloud free)
  - Combined use of LSTM, SBG, TRISHNA, Landsat-9/Next & small-sats
- Possible cooperation
  - Scientific collaboration – algorithm development, campaigns, ECOSTRESS
  - Common Cal/Val approach, protocol, sites
  - Multi-mission in-flight inter-comparison
  - Setup of working groups: Data Harmonization, Simulators, Cal/Val, Synergy
  - Cooperation in user & science community engagement

5th SBG Community Webinar
June 15, 2021

TRISHNA PROJECT STATUS
Synergies with SBG

Ph. GAMET (CNES / CESBIO)

C. SALCEDO (CNES)

Th. CARLIER (CNES)

L. BUFFET (CNES)

S. MARCQ (CNES)

Ph. MAISONGRANDE (CNES)

Philippe GAMET
CNES/CESBIO
TRISHNA Project Scientist
TRISHNA Science Team secretary
Philippe.Gamet@cnes.fr

TRISHNA Mission datasheet

- ISRO/CNES cooperation, launch end of 2024, 5-year lifetime
- Scientific & operational applications
- Focus on **ecosystem stress and water use** + **coastal & inland waters**
- Global coverage
- 4 TIR bands + 5 VNIR bands + 2 SWIR bands
- Revisit : 3 acquisitions at equator per 8 days period
  761km-8day orbit reducing hot spot constraints in intertropical zone
- ± 34° scan angle, 1030km swath
- Nadir spatial resolution (VIS-NIR-SWIR-TIR):
  57 m for continental and coastal areas, binned at 1 km over open ocean
- Overpass time : 1 PM (LTDN)
- NeDT 0.2K
- Indo-French(*) Joint Science Team, synergies with ECOSTRESS, SBG, LSTM science & application teams
  (*) with other contributors
- Free and open data policy for worldwide scientific community

ISRO / CNES cooperation status on TRISHNA

Corinne Salcedo (CNES)

Covid-19 has slowed down the technical exchanges between CNES and ISRO. However:

- The Science Plan, the Product Definition document and preliminary ATBDs are under review
- The interfaces between the TIR instrument and platform are kept under discussions to harmonize the instrument and the platform designs : the outputs of the preliminary design phase from Airbus Defence and Space shall be discussed with ISRO
- The preliminary Payload Ground Segment documentation is initiated

TRISHNA ongoing activities on CNES side:

- The instrument Preliminary definition phase started in April 2020 is under completion with the current corresponding review @ AIRBUS DEFENCE AND SPACE
- The System phase B activities started in April 2020
- The Ground Segment Phase B activities started in October 2020

→ System and Ground Segment PDR to be arranged in T1 2022

Synergy SBG / TRISHNA

- TRISHNA + SBG + LSTM: improve temporal revisit for LST
- TRISHNA and LSTM: simultaneity of VNIR-SWIR data with TIR data
- SBG : spectral richness in VNIR

- Consistency in mission designs
- CAL/VAL
- Products

Synergy SBG / TRISHNA

Monthly meetings between JPL SBG team and CNES TRISHNA Team covering the following topics :

- Joint calibration-validation opportunities and protocols, including the potential implementation of JPL sensors in France
- ATBDs
- SwathSense/HyTES airborne shared campaign in Europe (with ESA) during summer 2021

→ Cooperation between CNES and JPL to be officially arranged, including ISRO Approval, through an exchange of letters between CNES (ISRO) and NASA to elevate the recognition of our collaboration within the respective space agencies

Cooperation for In-Orbit Calibration sites

Sébastien Marcq (CNES)

- Development of a CNES **multi-mission** L1 calibration and L2 validation **permanent** site in the TIR
- Site location: low cloud coverage & high spatial homogeneity (& easy access)

→ La Crau

- Several meetings with JPL (+ KIT)
- Installation of the JPL radiometer is planned over the summer (thank you Simon!)
- On-going definition of the CNES permanent instrumentation

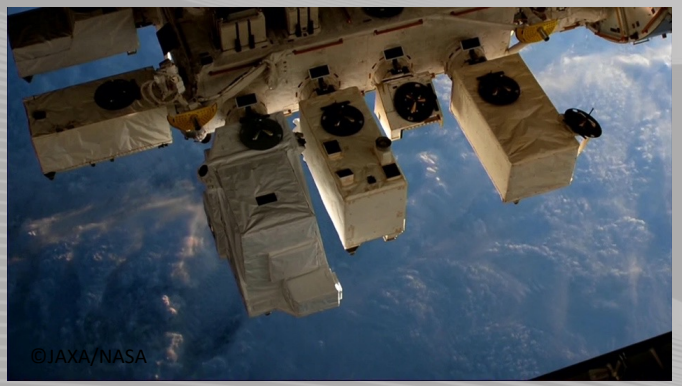
HISUI Status update: 18 months after launch

Tsuneo Matsunaga,

National institute for environmental studies, japan

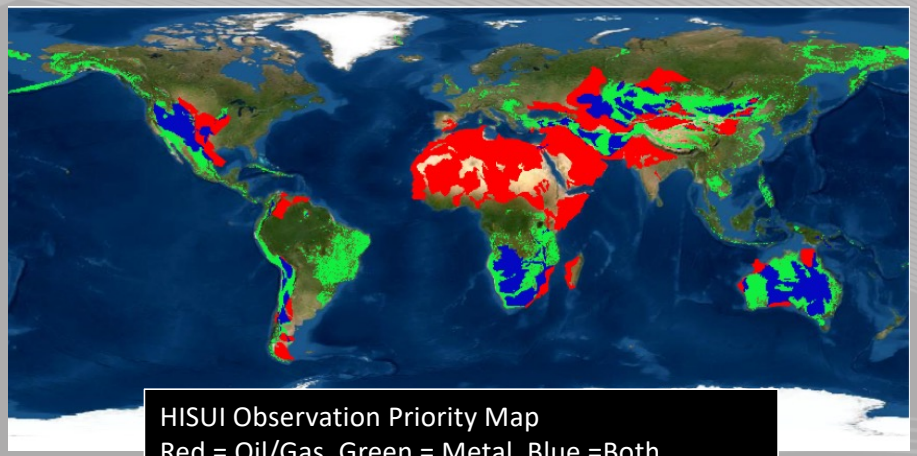
EVENTS

- ✓ Successfully launched on Dec. 6 and installed on ISS JEM/EF on Dec. 13, 2019.
- ✓ More than six months were spent to solve data communication problems including repair part delivery.
- ✓ Observation resumed on Sept. 4, 2020.
- ✓ First onboard calibration data were acquired on Sept. 11, 2020. To be presented by Urai-san, AIST, at IGARSS 2021.
- ✓ The first HDD delivery from ISS will be occurred in July 2021. Data will be more than 20 TB.
- ✓ Negotiation with the funding agency for HISUI's extended mission is ongoing.

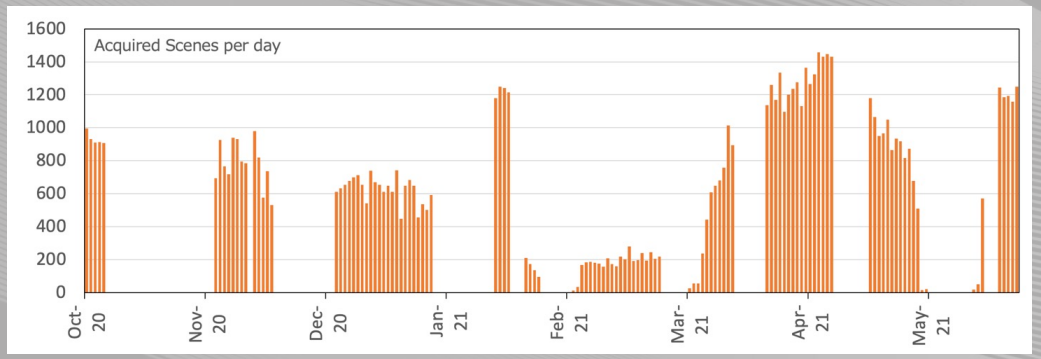


T. Matsunaga (NIES)

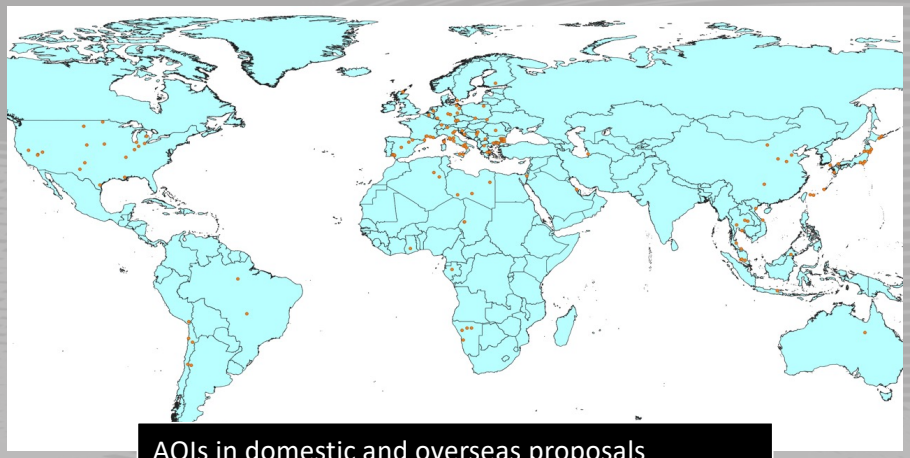
MAPS and CHARTs



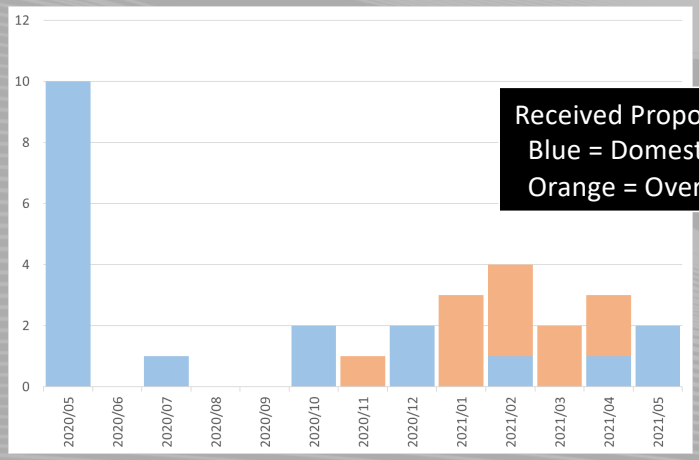
HISUI Observation Priority Map
Red = Oil/Gas, Green = Metal, Blue =Both



HISUI has acquired 83000 scenes (≈ 18.5 Tbyte, ≈ 50M km^2) since October 2020.



AOIs in domestic and overseas proposals



Received Proposals
Blue = Domestic (19)
Orange = Overseas (11)

T. Matsunaga (NIES)

SPECTRA

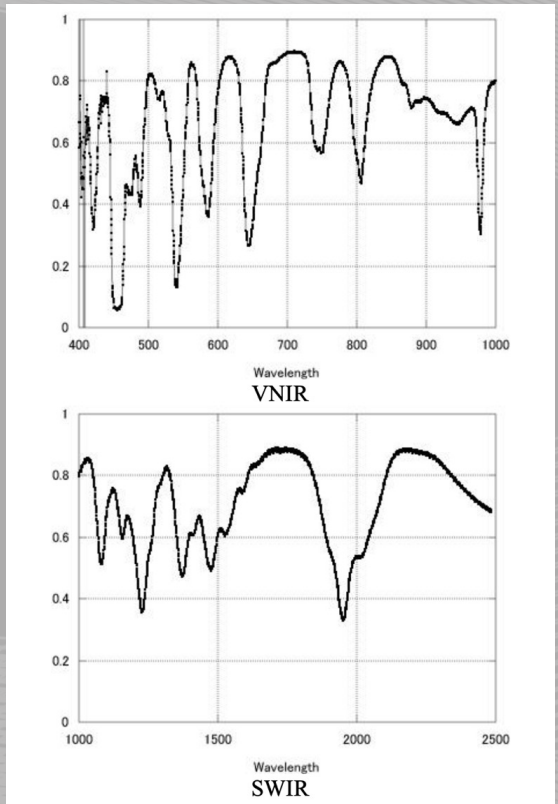
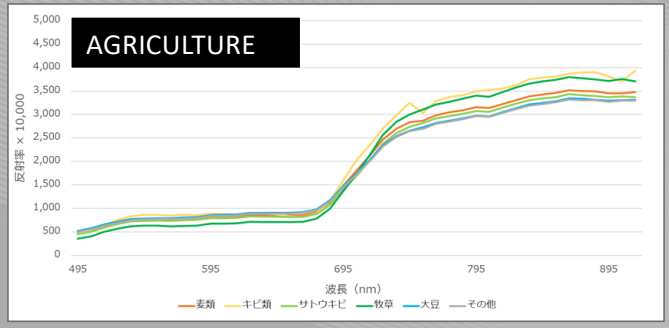
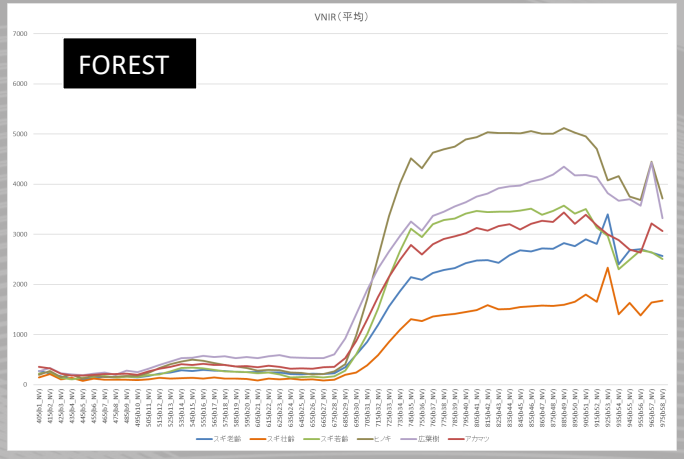
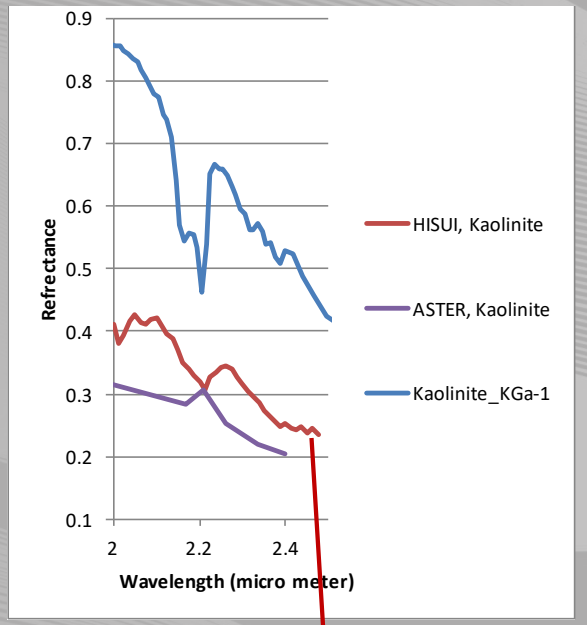


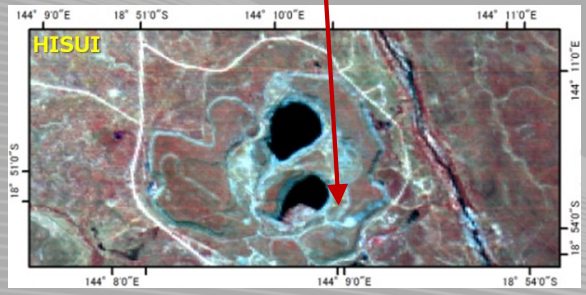
Fig. 2: SRM2035a transmittance observed by HISUI on September 11, 2020.

Spectral transmittance of SRM2035a wavelength calibration filter measured by HISUI on Sept. 11, 2020









T. Matsunaga (NIES)

SBG Items of Interest

- **EnMAP-Box Workshop** (June 21-23 2021)
  - Registration still open!
- **AGU Call for Papers:** The Earth in Living Color
  - Open through August **2022**
- **12th EARSeL Imaging Spectroscopy Workshop** (March 23-25 2022)
  - Abstract deadline: November 17 2021
- **1st DESIS User Workshop** (29 Sep – Oct 1)
  - Abstract deadline: July 23rd
- **Ecological Society of America 2021**:
  - Organized Oral 1: ***Advances in Biodiversity Science with Remote Sensing***
    Monday, August 2, 2021, 8:30 AM-9:30 AM Pacific Time
  - Special Session 9: ***How NASA's Surface Biology and Geology Mission Will Support the Next Generation of Global Ecosystem and Biodiversity Scie***
    Tuesday, August 3rd, 2021, 9:30 AM – 10:30 AM Pacific Time

SBG Opportunities for Involvement

- In-person SBG community workshop in early 2022 (more details to come)
- Internship programs at JPL and other NASA centers
- 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
  - SBG/AtMOS synergy activities (david.r.thompson@jpl.nasa.gov)

And, as always:

sbg@jpl.nasa.gov
Dave Schimel (dschimel@jpl.nasa.gov)
Ben Poulter (Benjamin.poulter@nasa.gov)

BACKUP

TRISHNA Spectral bands

Band name	Wavelength Center (nm)	FWHM (nm)	Purpose
Blue	485	70	Detection of low clouds
Green	555	70	Coastal, sediments, snow
Red	670	60	Vegetation (LAI, fCOVER, NDVI, …)
NIR	860	40	Vegetation (LAI, fCOVER, NDVI, …)
WV	910	20-25	Water vapour content estimation
Cirrus	1380	30	Detection of thin cirrus clouds
SWIR	1610	100	AOD, snow/cloud discrimination, vgt stress, burnt areas

Band name	Wavelength Center (µm)	FWHM (µm)	Purpose
TIR 1	8.65	0.35	Temperature/emissivity separation
TIR 2	9.0	0.35	Temperature/emissivity separation
TIR 3	10.6	0.7	Split-window
TIR 4	11.6	1.0	Split-window

TRISHNA: main System Milestones (To be confirmed with ISRO)

- System Interfaces, Performances and Validation Review (SIPVR)

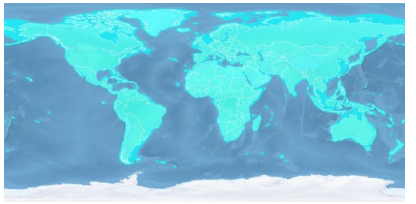
  → Part 1 : beginning of 2022

  - Assessment of the definition of the interfaces at system level: S-Band and X-Band satellite to ground interfaces, interfaces between ground segment entities.
  - Assessment of the ATBD of the system products
  - Assessment of the definition of the algorithm processing chain of the system products
  - Preliminary assessment of the mission performance budget
  - Preliminary System Validation Plan

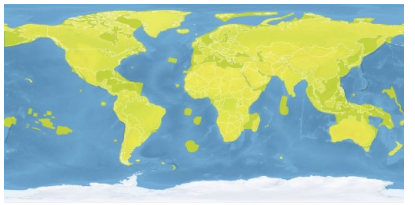
Criteria for the construction of the full resolution mask (ongoing process):

- All continental land surfaces (including inland waters): **yes**
- Closed or semi-closed seas: **yes**
- Coastal waters up to [Distance TBD, 10 to 100km] from the shore
- Ocean waters with depth lower than [depth TBD, 100m to 250m]
- EU Islands of more than [Surface TBD, typically 100km^2]
- Consistency with Sentinel-2 / SWOT coverage mask: TBD
- Antarctica coastline [Coverage TBD]
- Arctic Ocean coastline [Laptev Sea, other areas TBD]

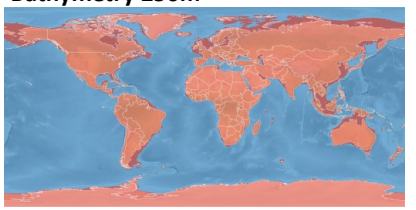
TRISHNA baseline



Sentinel-2

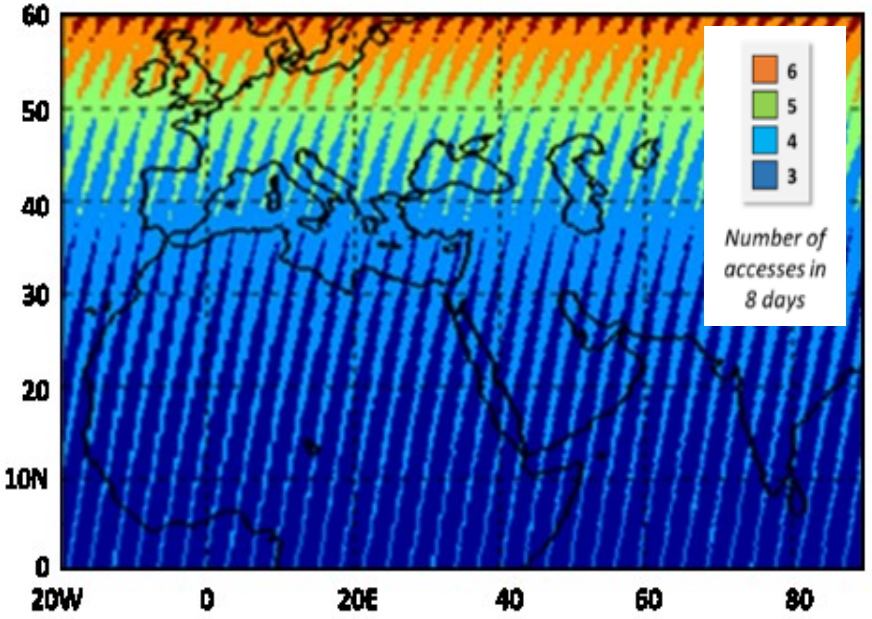


Bathymetry 250m



TRISHNA geometric revisit frequency
due to the overlap between adjacent orbits

- 3 accesses in 8 days at Equator, with 3 different view angles
- Revisit frequency increases with latitude due to the overlap between adjacent orbits
- Revisit frequency is limited to 3 accesses in 8 days for polar regions (latitudes over 60 degrees)

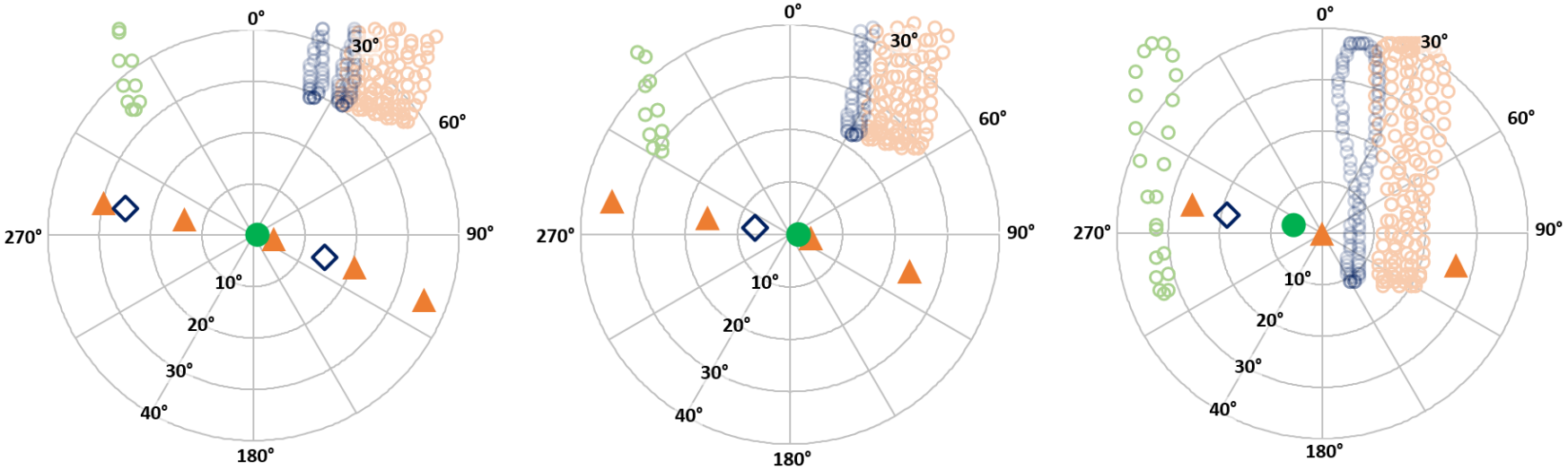


TRISHNA geometry of the acquisitions

Typical (*) geometry of daylight accesses for **TRISHNA**, **LANDSAT8** and **LSTM**

(*) Actual values and patterns depend on selected longitudes of nodes and time lag between start of cycles

Polar plots of satellite and hot-spot directions over 1 year



LONZEE **GROSSETO** **WANKAMA**

Overview of TRISHNA level-2 candidate variables

Selection of relevant variables is under process

Level 2a
Radiative variables at surface level

Surface reflectance
Surface reflectance normalized to nadir
Surface albedo (spectral)
Surface albedo (broadband)
Surface temperature
Surface emissivity
Surface temperature normalized to nadir
Surface thermal emissivity (broadband)

Level 2b
Biophysical variables at surface level

NDVI	Gross Primary Productivity (GPP)
Vegetation variables for ET computation: - Green Fraction (GF) - Green Area Index (GAI)	Water Use Efficiency (WUE)
fAPAR	Fire products (detection & monitoring)
EvapoTranspiration at time of acquisition - Near Real Time	Water color biophysical variables
Daily EvapoTranspiration - Near Real Time	Urban LST
Daily Stress Factor (SF) - Near Real Time	Urban Air Temperature
Intermediate ET variables associated to ET products	