Overview of the SBG Mission

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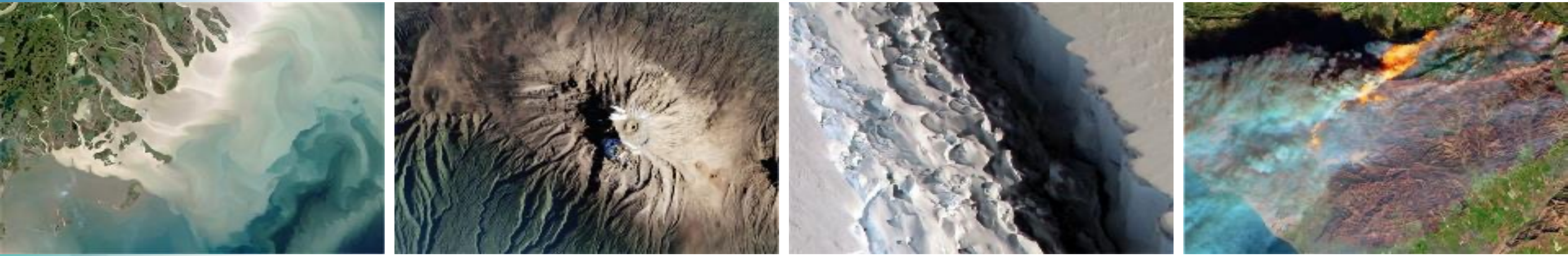


Surface Biology and Geology

An Observing System for Climate Impacts and Earth System Dynamics

with contributions from the SBG, ECOSTRESS and HyTES teams

Science

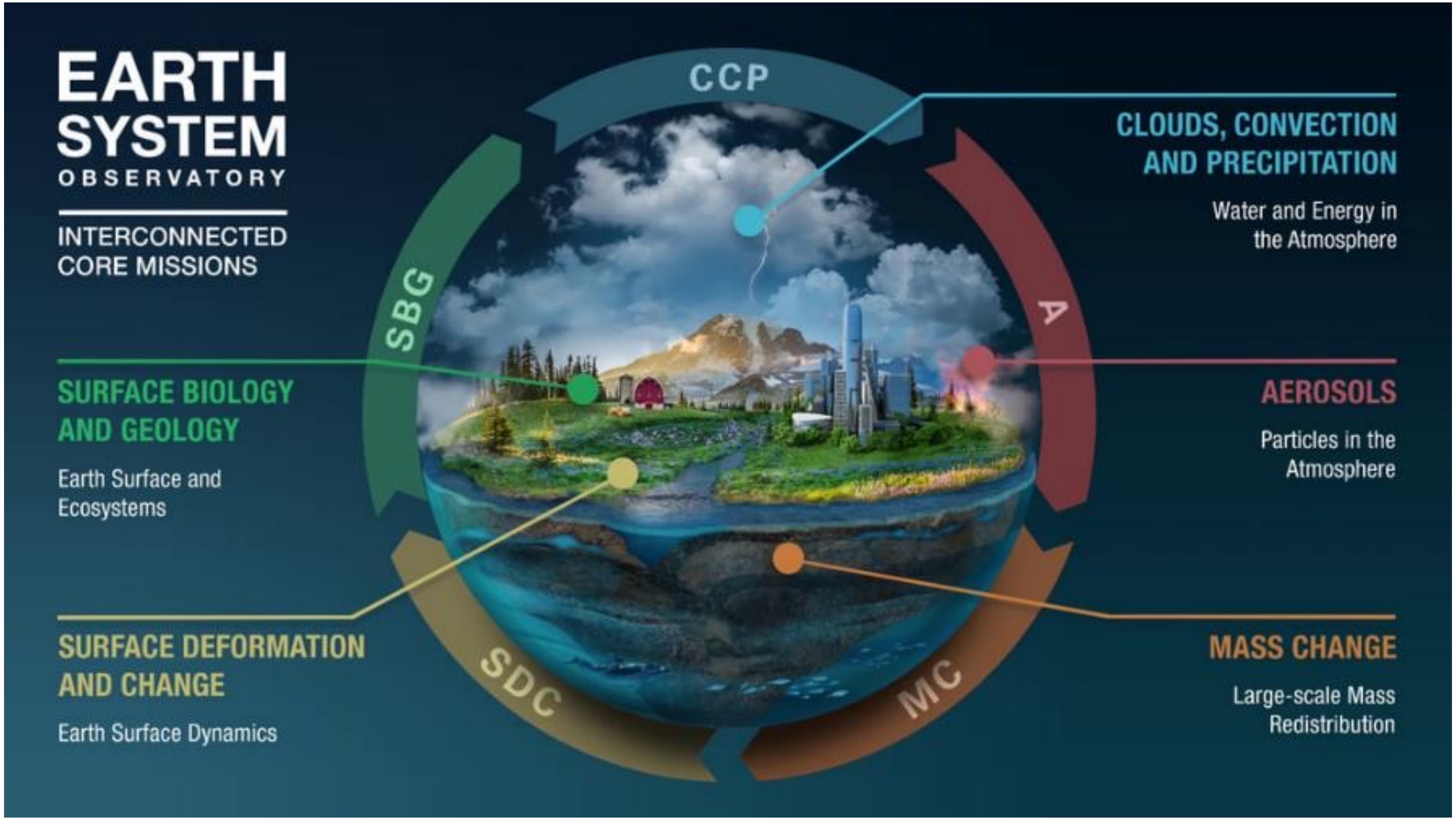
In 2017 Earth Science Decadal Survey Recommends Decadal Observables:

- Aerosols-Clouds, Convection &Precipitation (ACCP)
- Surface Biology and Geology (SBG)
- Mass Change (MC)
- Surface Deformation and Change (SDC)
  - Expected to begin development later in decade

In June 2021 NASA announced the new Earth System Observation with 4 main anchor tenants: NISAR, A-CCP, **SBG** and MC

EARTH SYSTEM OBSERVATORY

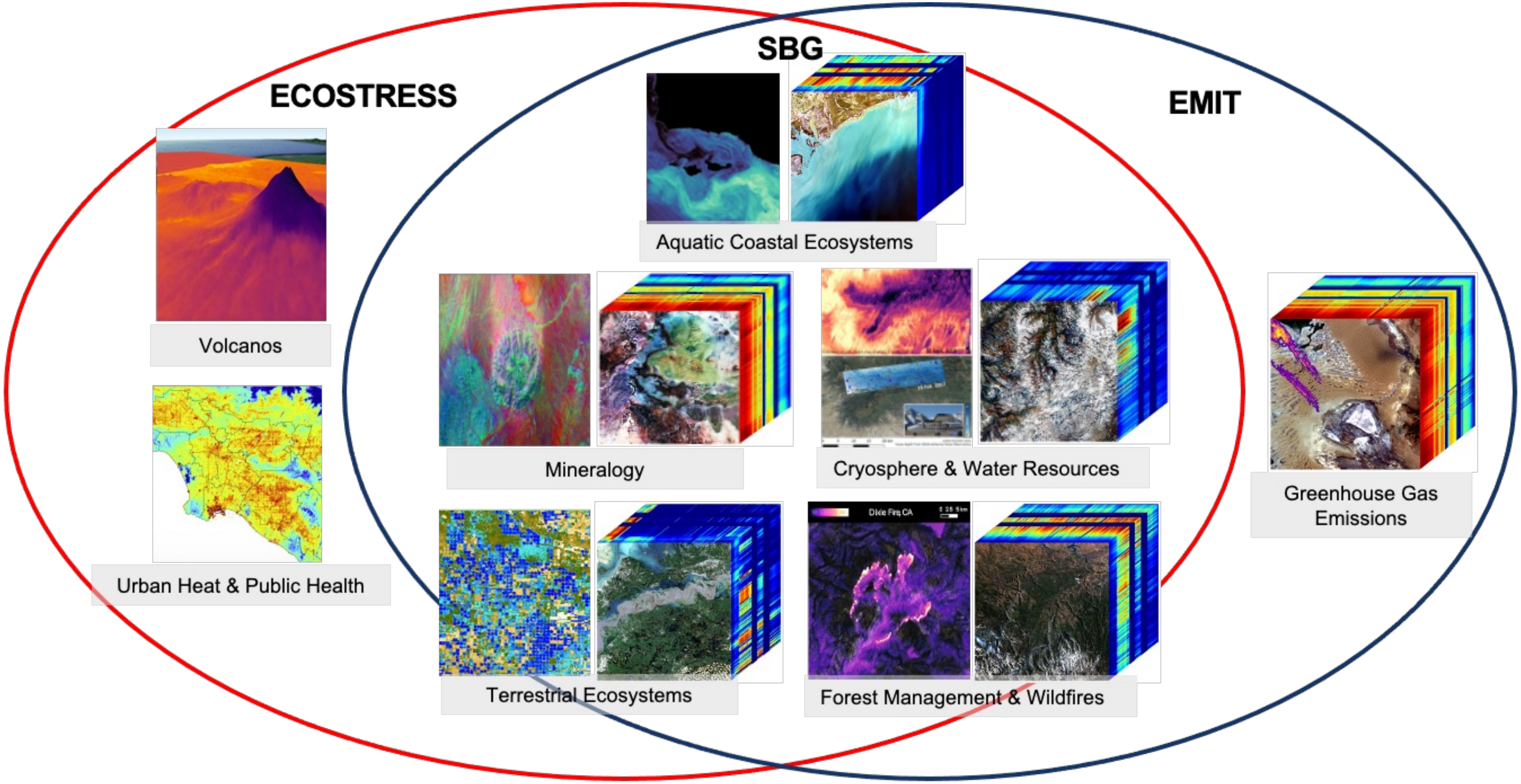
Earth System Observatory (ESO)



[Credit: National Aeronautics and Space Administration (NASA)]

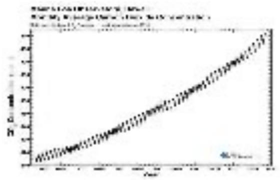
ESO was created in May 2021

SBG Builds on ECOSTRESS and EMIT

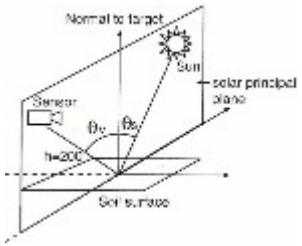


KEY RESEARCH AND APPLICATIONS MEASUREMENT REQUIREMENTS

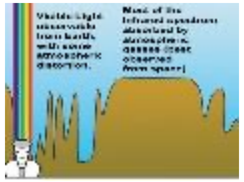
COVERAGE: The system must provide **global coverage** to address the global scope of the science including the coastal ocean and inland waters.



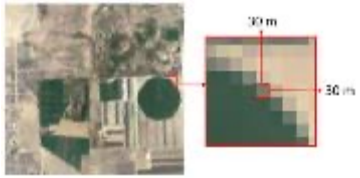
STABILITY AND DURATION: Measurements must be able to detect **long term changes** for addressing dynamics of the Earth System.



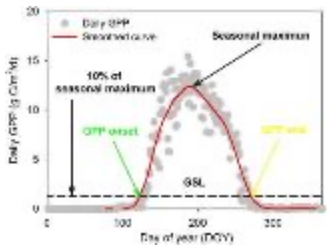
GEOMETRY: The system's orbit must allow for **consistent sun-sensor geometry** for consistency in retrievals and for calibration and validation, and provide for global coverage, as above (polar orbit).



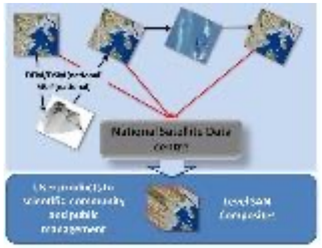
RANGE, RESOLUTION AND SENSITIVITY: Visible to Shortwave Infrared **(VSWIR; 400-2500 nm)** imaging spectroscopy and multi-spectral thermal infrared **(TIR; 4 - 12 μm)** measurements to observe "diversity" in ecosystem function. Radiometric performance driven by aquatic targets.



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



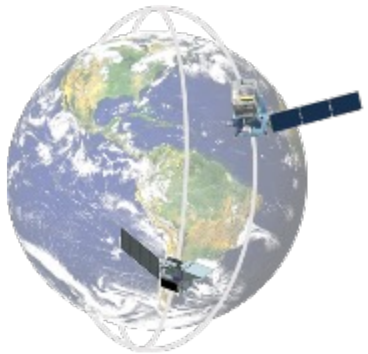
REVISIT: The SBG observing system temporal resolution must be adequate to capture **synoptic weekly and seasonal variation** as well as observe **rapid or transient changes** related to Earth system events such as fires, landslides, volcanic activity and anthropogenic incidents.



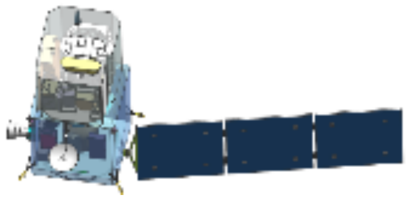
LATENCY: **Low latency,** the time between an event and data access, must be low enough to support time-sensitive applications, ≤ 24 hours.

Architecture : Two Primary Platforms

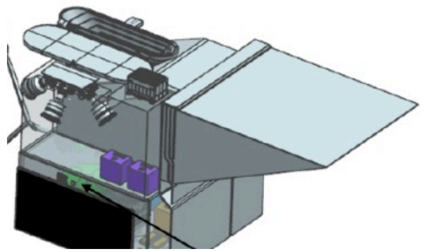
- Two vehicles in SSO
  - TIR 665 km, 12:30 equatorial crossing time descending node
  - VSWIR 632 km, 11:00 local time
- VSWIR on a NASA spacecraft
  - Launches aboard ISRO-contributed PSLV
- TIR hosted on an ASI-provided spacecraft with an ASI-provided VNIR camera
  - Launches aboard ASI-contributed VEGA-C



- NASA VSWIR
  - FoV: 25.5°
  - Spatial Res: 30 m
  - Swath: 185 km
  - Spectral Res: 10 nm
  - Range: 0.38 – 2.5 µm
  - Bands: 220
- NASA TIR
  - Spatial Res: 60 m
  - Swath: 935 km
  - Range: 3 – 12 µm
  - Bands: 8
- ASI VNIR
  - Spatial Res: 30 m and 60 m
  - Range: 665, 834 nm centers
  - Bands: 2 60m, 1 30m pan band



VSWIR-1 on NASA Bus



TIR on ASI Bus

- Science valuation
  - Two-Platform solution allows orbits to utilize optimum observing time coordinate with international efforts
    - VSWIR orbit can be coordinated with CHIME for reduced revisit
    - TIR orbit can be coordinated with CNES-ISRO TRISHNA and ESA-LSTM for daily revisit
  - ASI contributed VNIR provides full coincidence with NASA TIR and improved performance
- Estimated LRDs:
  - VSWIR: 2029
  - TIR: 2028

Today we are focused on the TIR component

Research Objectives and Priorities

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: DECADAL SURVEY MOST AND VERY IMPORTANT RESEARCH OBJECTIVES ACROSS ALL FIVE DS FOCUS AREAS

Applications Objectives and Priorities

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-TIR Particularly Valuable for Applications

SBG is about Research <u>and</u> Applications

NASA Earth Action Strategy

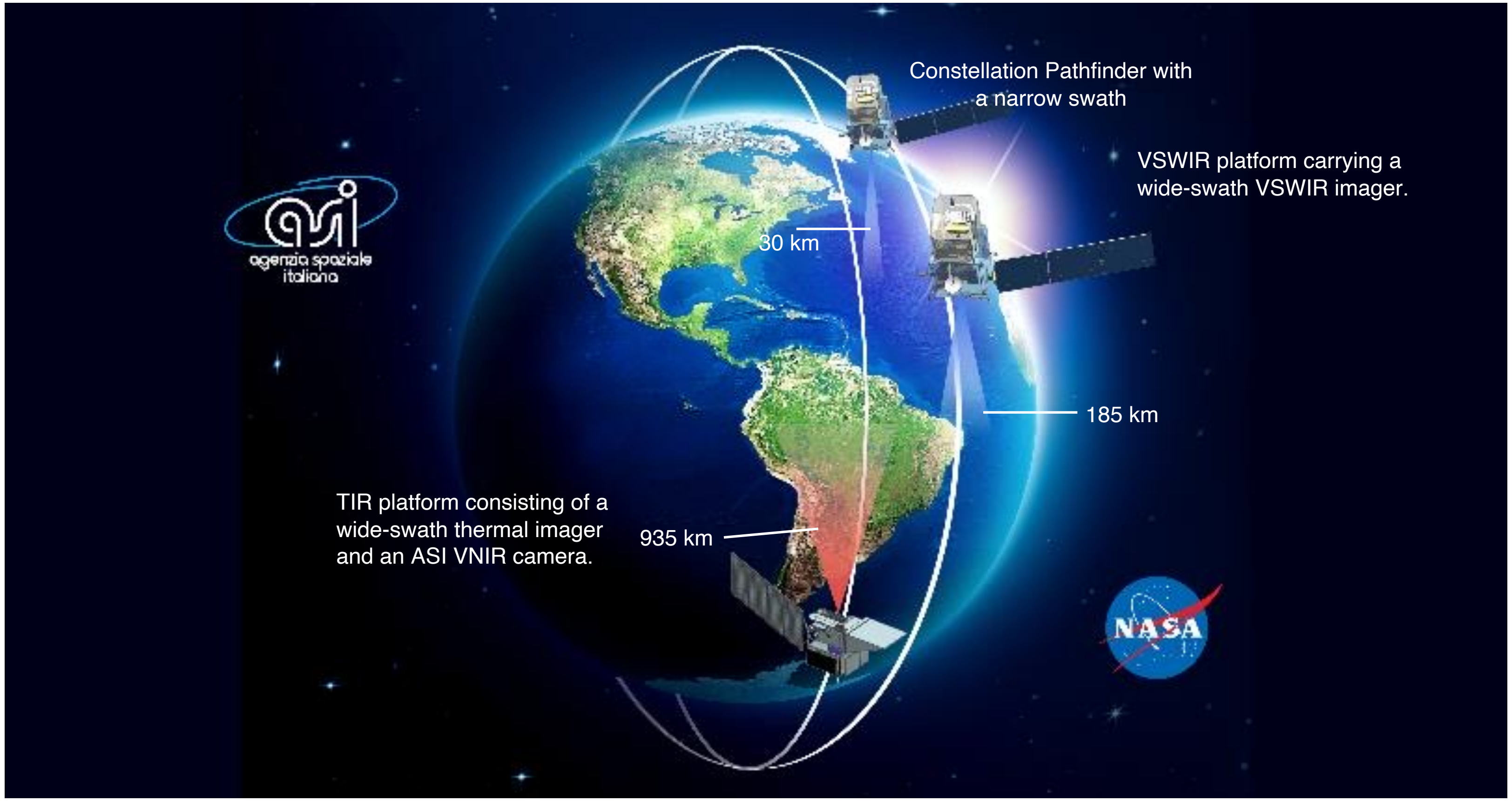
Driving impact from $1.5 B in NASA observations and research Delivering impact (including meeting the needs of Federal agencies, state, local, and tribal governments)

SBG has demonstrated capability to support all proposed Earth Action Themes and Needs

- Greenhouse gas monitoring
- Wildland fire risk & recovery
- Health & air quality
- Sea level & coastal risk
- Energy & sustainable infrastructure
- Agriculture
- Disasters & Extreme Events
- Water Resources
- Biodiversity & Ecosystem Change

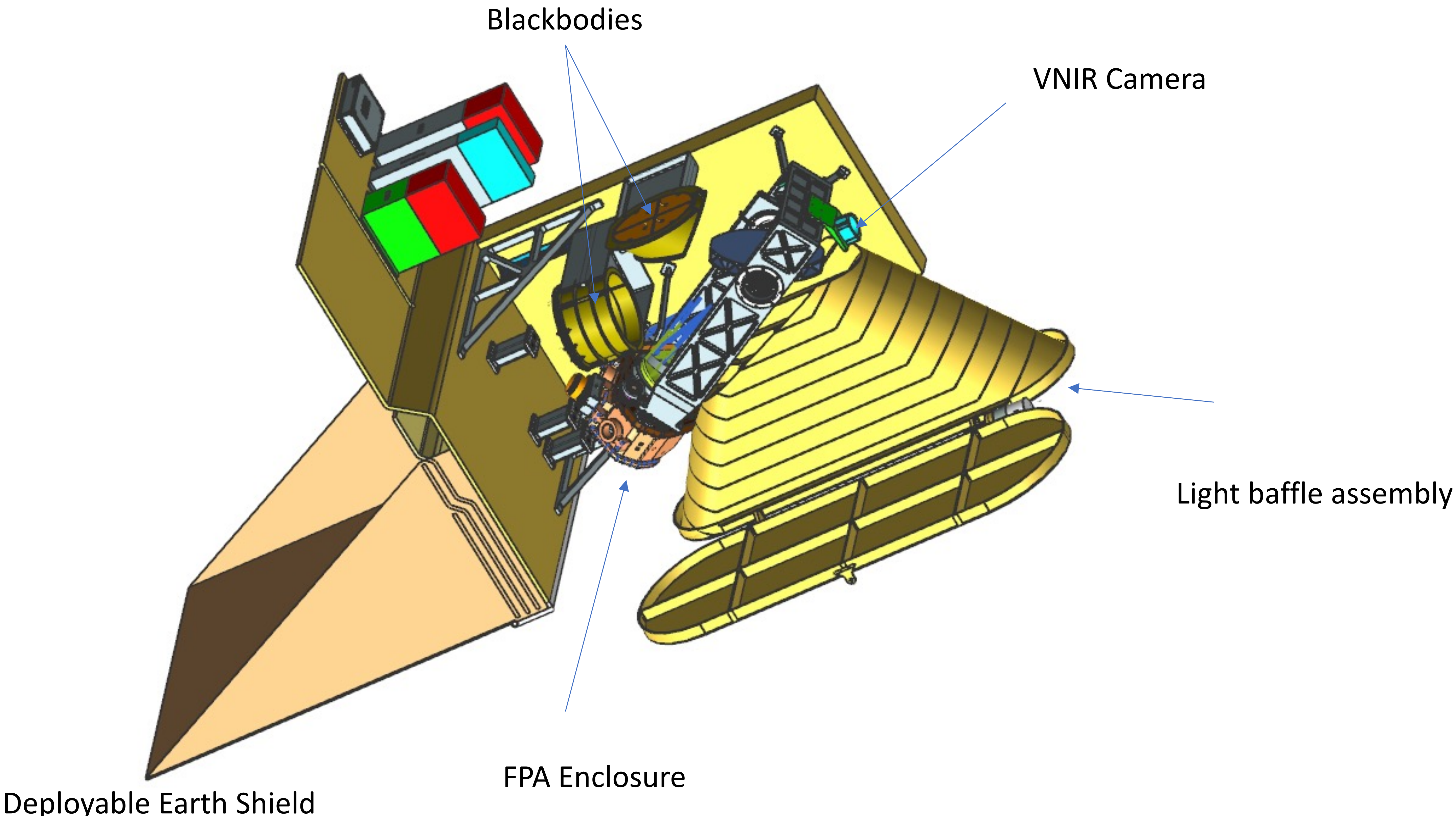
SBG-TIR Component and International Context

SBG Architecture and Instrumentation



Each platform/instrument has very different swaths and revisits

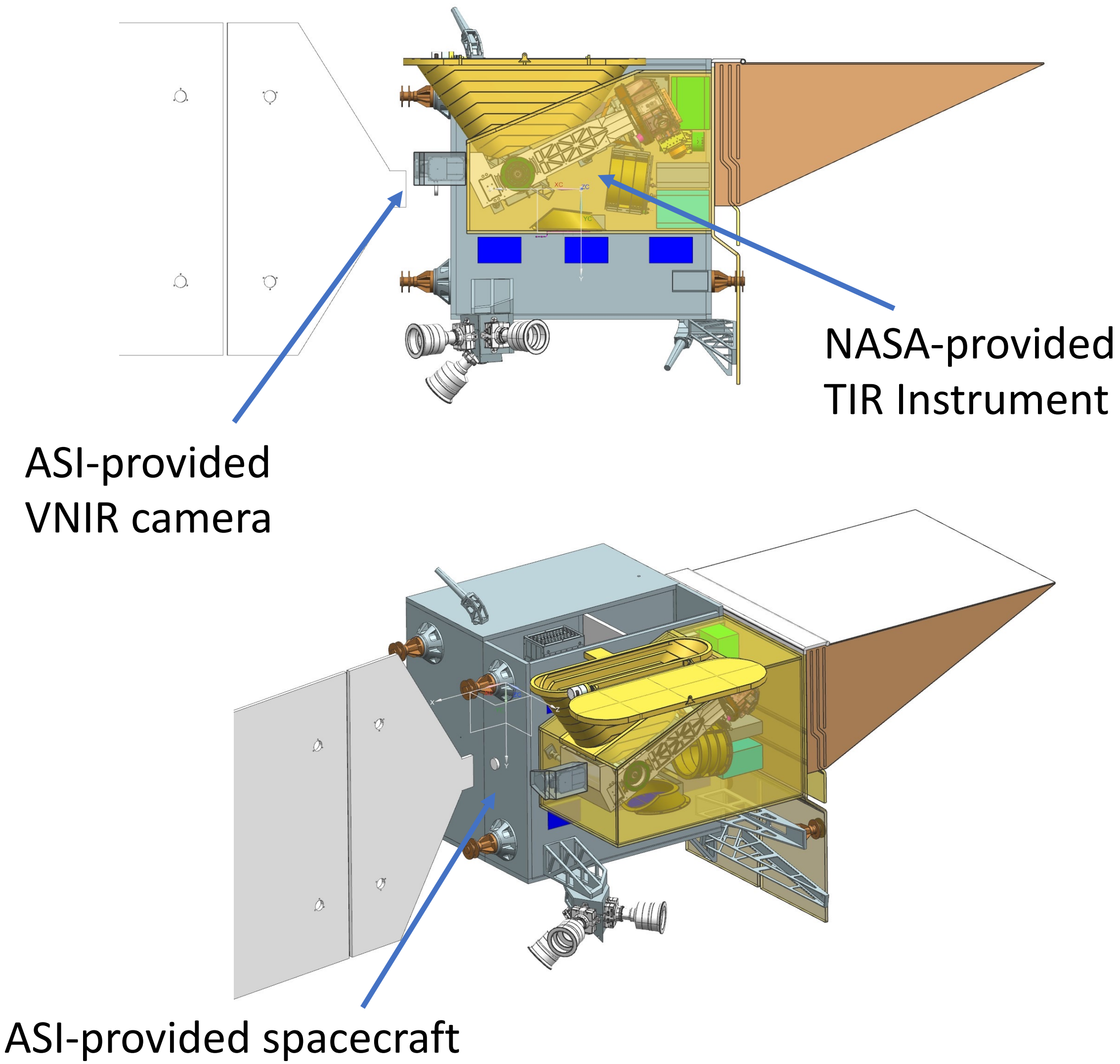
SBG-TIR Architecture



SBG TIR Key Instrument Parameters

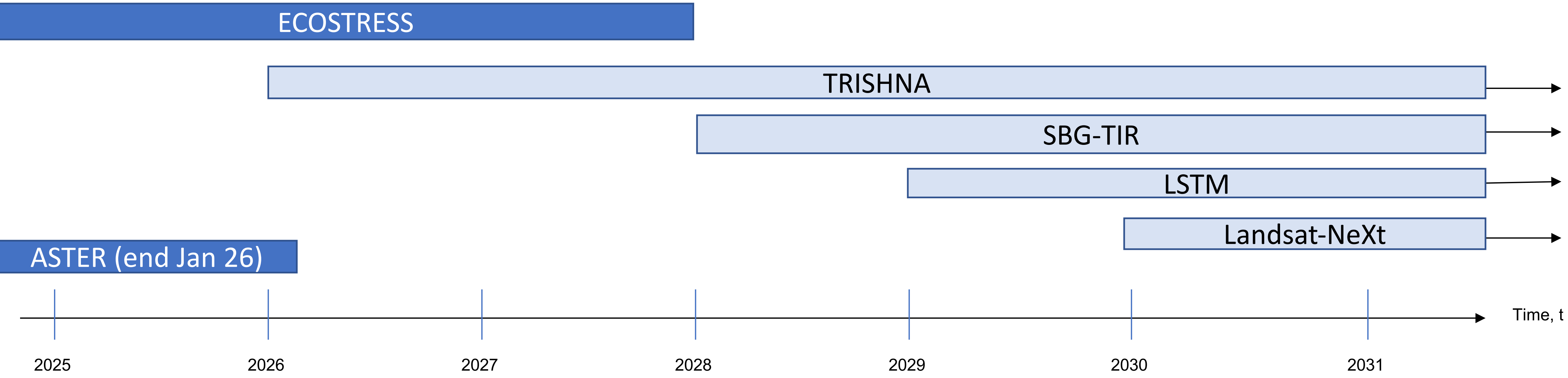
Key Parameters	SBG-TIR
Number of satellites	1
Combined revisit (days)	$\leq$ 3 (same obs. angles)
Nominal Altitude (km)	665
Orbit cycle (days)	3
GSD (nadir/edge of scan) (m)	TIR: $\leq$60 /93, VNIR: $\leq$30 /52*
FOV (degrees)	± 34.4
Swath (km)	935
Coverage	Land and Coastal
Day/Night	Day + Night
LTDN	12:30
LWIR bands (8-12 µm)	6
VNIR/SWIR/MWIR	2/0/2
Accuracy (K)	0.5
NeDT (K)	<0.2
Data latency (hours)	<24

* Based on angle will be less when combine with mask



International Partnerships and Data Continuity

TRISHNA, SBG-TIR and LSTM are staggered in order to produce a continuous record for climate studies and applications. TRISHNA launches in 2026, SBG-TIR in 2028 and LSTM in 2029. This allows for a **continuous record** and possibly some periods when all 3 satellites are available **which would allow daily coverage**. The current earliest launch for Landsat-N is the end of the decade, so SBG-TIR will be operating in a period when Landsat-N data is not yet available.



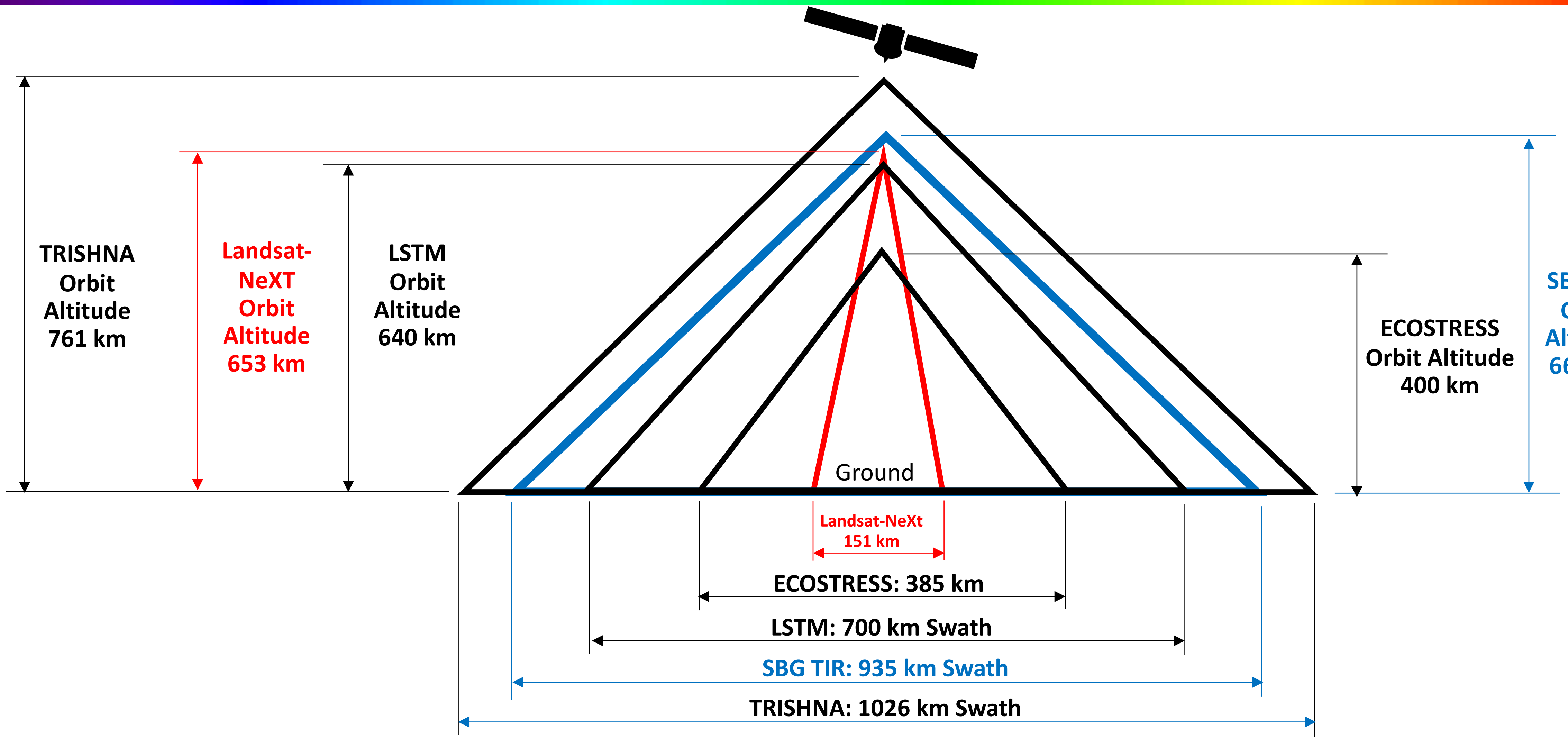
- Earliest possible launch dates shown, may launch later
- ASTER ends when orbit overpass degrades to 9 am

Comparison of LSTM, TRISHNA and SBG-TIR

	LSTM	TRISHNA	SBG-TIR
Number of satellites	2	1	1
Combined revisit (days)	2 (same obs. angles)	≤ 3 (different obs. angles)	≤ 3 (same obs. angles)
Nominal Altitude (km)	649	761	665
Orbit cycle (days)	4 (for each sat.)	8	3
GSD (nadir/edge of scan) (m)	37/50	57/60	TIR: ≤60 /93, VNIR: ≤30 /52*
FOV (degrees)	± 28	± 34	± 34.4
Swath (km)	700	1000	935
Coverage	Land and Coastal	Land and Coastal	Land and Coastal
Day/Night	Day + Night	Day + Night	Day + Night
LTDN	12:30	12:30	12:30
LWIR bands (8-12 μm)	5	4	6
VNIR/SWIR/MWIR	4/2/0	5/2/0	2/0/2
Accuracy (K)	0.5	0.5	0.5
NeDT (K)	<0.15	<0.2	<0.2
Data latency (hours)	6-12	12 (demo)	<24

* Based on angle for SBG, for other instruments based on combination of angle and mask

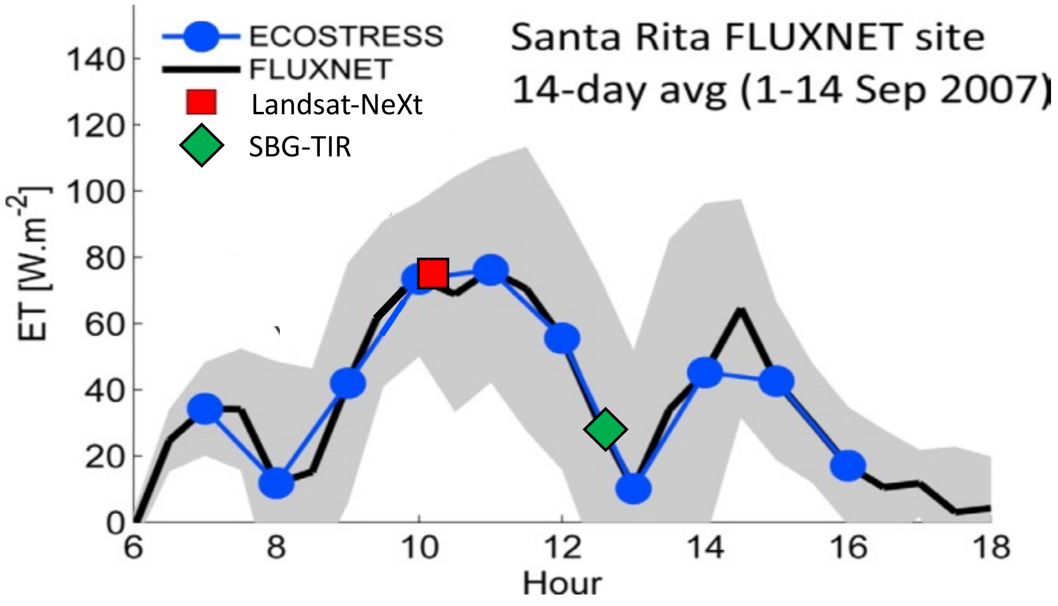
The SBG TIR, LSTM, and TRISHNA Swath Widths



TIR Overpass Time

SBG-TIR overpass time is at 12:30 pm on the descending node. This is similar to LSTM and TRISHNA. It was selected to capture the peak afternoon plant stress

Representative Evapotranspiration (ET) Plot



[Stavros, N. et al., ISS observations offer insights into plant function, September 2017, Nature Ecology & Evolution 1(10), DOI:10.1038/s41559-017-0327-z]

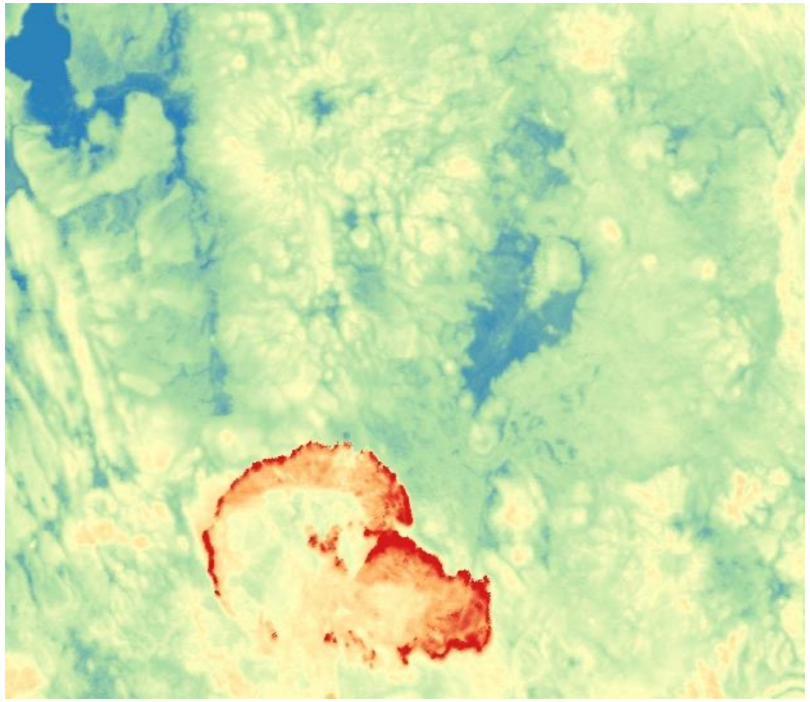
Plant stomata close in the early afternoon (max water stress and heat stress). The observed heat signature is highest during this time period.

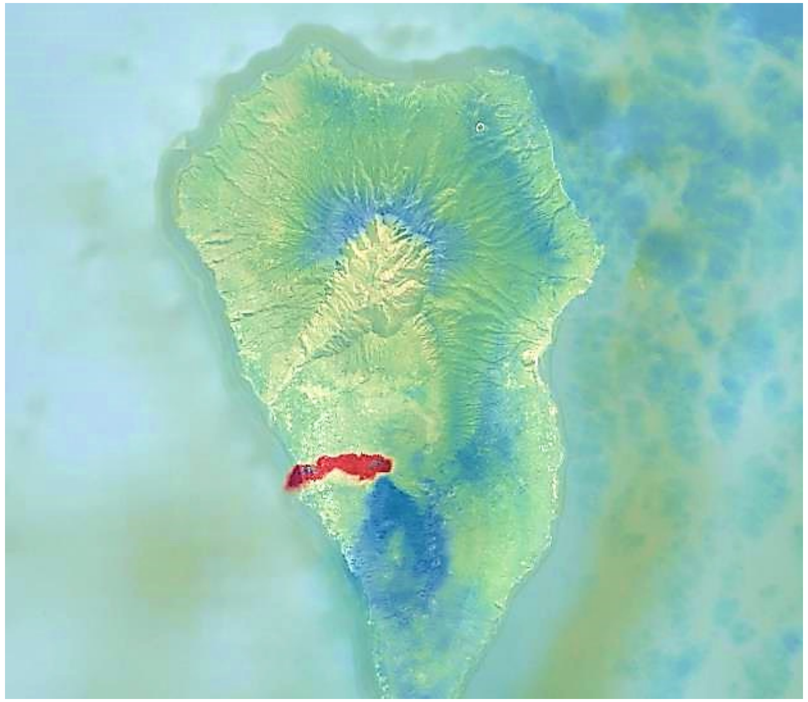
BASED ON ECOSTRESS

SBG-TIR Measures High Temperature Features

Ability to see hot spots and measure fire radiative power (FRP) - SBG-TIR is the only mission out of TRISHNA, SBG-TIR, LSTM and Landsat-N that includes mid infrared (MIR: 3-5 um) bands. These bands have been selected to address 2 critical issues:

1. **Active wildfires** - one MIR band measures FRP – critical to understanding the impact of fire on climate; and provides added utility to those actively battling wildfires
2. **Active volcanoes** - one MIR band is designed not to saturate until very high temperatures ~1200K. This is needed to detect changes in the fumarolic activity from volcanoes as well as track active fires. TRISHNA, LSTM and Landsat-N do not have MIR bands and their TIR bands will all saturate at much lower temperatures.





HyTES –2023 European Campaign

• NASA and ESA recently completed a joint Thermal Infrared (TIR) science campaigns in Europe in 2023. The campaign is the 3rd campaign with the other campaigns conducted in 2019 and 2021. The campaigns are being used to develop preparatory datasets for the NASA Surface Biology and Geology (SBG) and ESA Land Surface Temperature Monitoring (LSTM) missions scheduled for launch in 2028 and 2029 respectively. The data are also being used by the CNES-ISRO TRISHNA mission, scheduled for launch in 2026. The preparatory datasets, acquired over a variety of cover types, are being used to test standard product algorithms such as land surface temperature and evapotranspiration.

•The 2023 campaign is focused on evaluating angular effects expected in the satellite data. The campaign involves 2 Twin Otter (TO) aircraft. The British Antarctic Survey (BAS) TO includes the OWL instrument and the Canadian BOREK TO includes the HyTES instrument. Additional equipment will be provided by the UK including a high resolution visible camera and an imaging spectrometer. The 2023 European campaign, is underway beginning in May and ending in early July

• All data from the 2019 and 2021 campaigns are available from the HyTES website: https://hytes.jpl.nasa.gov
• Quicklooks and data from the 2023 Campaign are available on the same website.

BAS Twin Otter with OWL

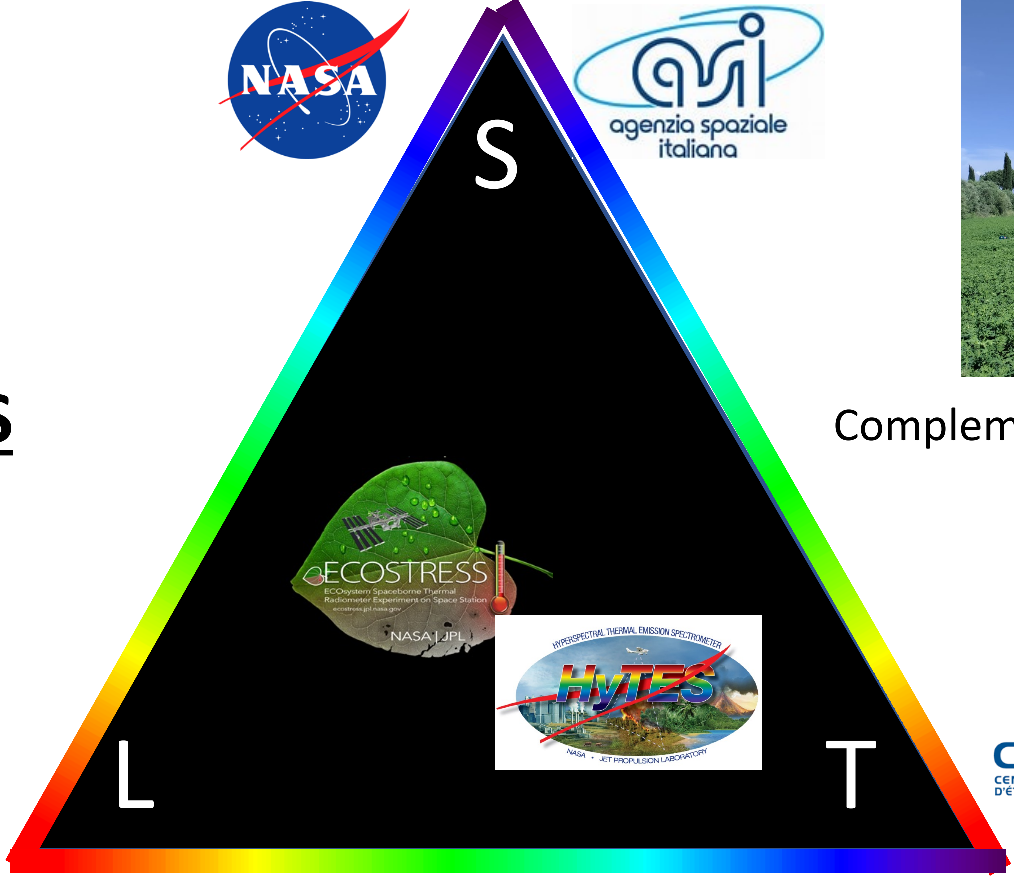
BOREK Twin Otter with HyTES

LSTM-SBG-Trishna (the LST Suite)

3 New Satellite Instruments:
LSTM – SBG - TRISHNA

Existing instruments:
<u>ECOSTRESS and HyTES</u>
provide Precursor Datasets

SBG

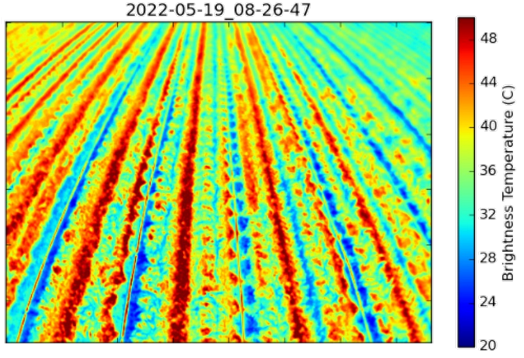


LSTM

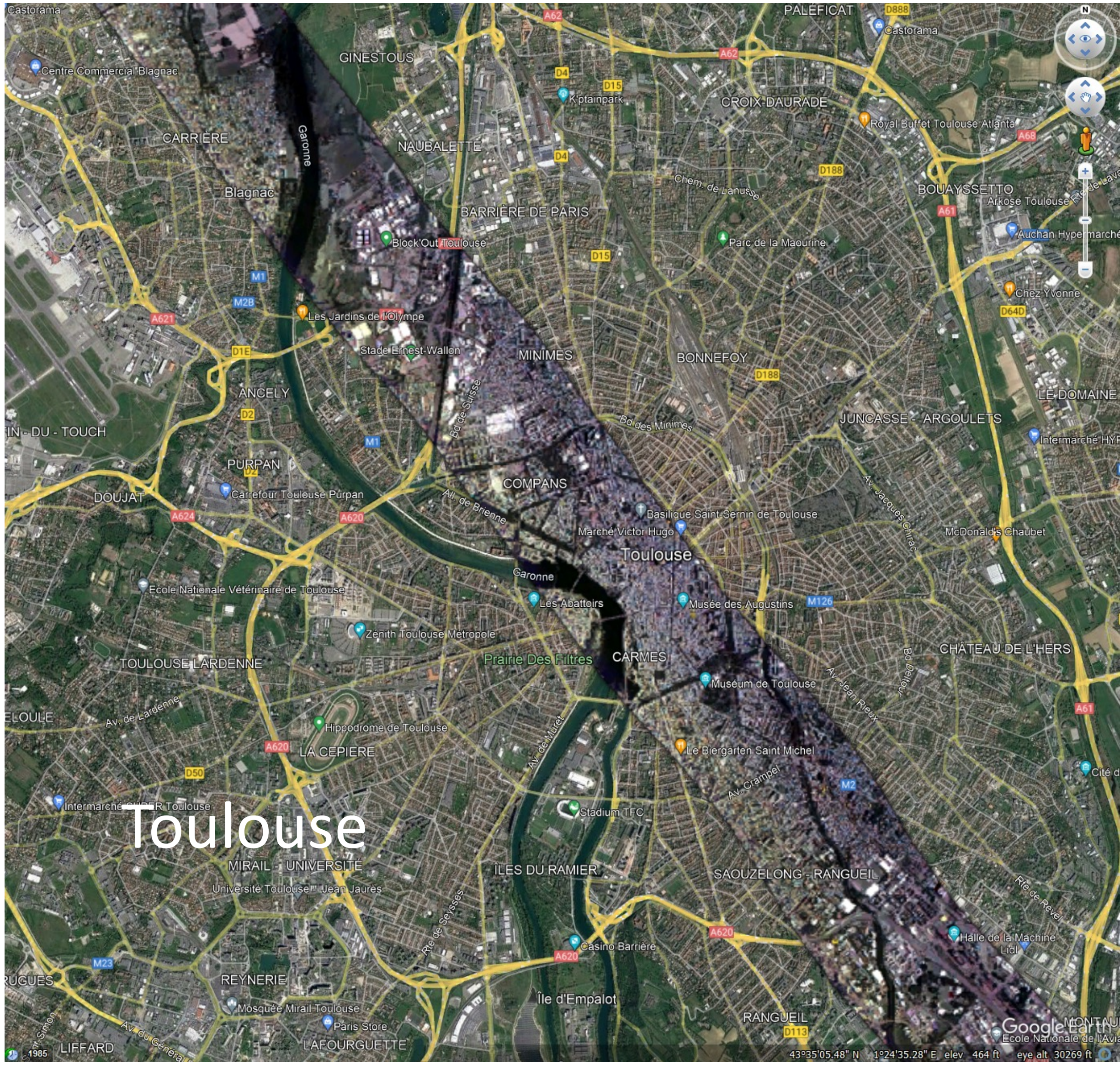
TRISHNA

Multi-Angular Ground Measurements

Complement Satellite, Airborne Measurement



Example Quicklooks



https://hytes.jpl.nasa.gov/order

Summary

- ECOSTRESS working well, manifest until 2028
- SBG is under development consists of a VSWIR instrument and a TIR instrument. TIR is a partnership between Italian Space Agency (ASI) and NASA
- Two other missions being developed at same time as SBG:
  - TRISHNA (CNES-ISRO)
  - LSTM (ESA
- ECOSTRESS is the basis for many approaches on SBG-TIR
  - Measurement approach
  - Calibration and validation
  - Majority of data products
- Products and Exemplar Datasets under development

With all 3 missions, we will have 60 m data per day globally!

Questions?