National Aeronautics and Space Administration

EXPLORE EARTH

Earth Science Division Community Forum

Karen St. Germain, Ph.D.
Director, Earth Science Division
Science Mission Directorate, NASA

Sept 20, 2023

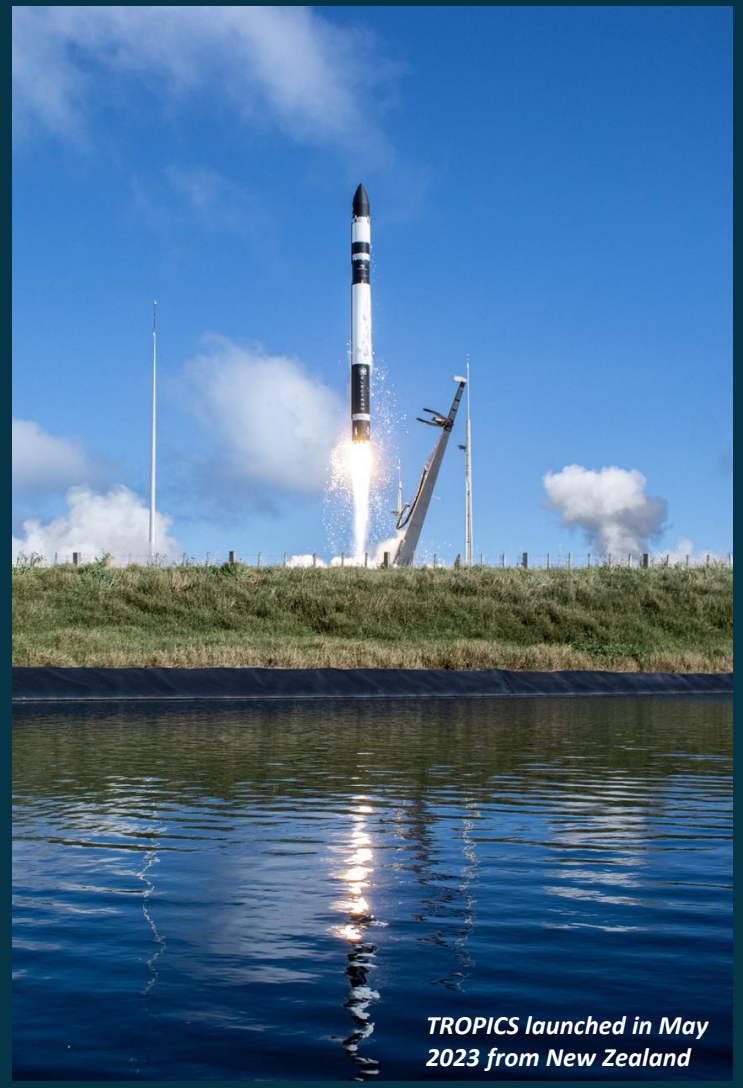
Click “CC” in the bottom left corner for Closed Captions

Enter your questions into the Q&A section

This webinar will be recorded

Accelerating Discovery and Understanding of Earth Science

- Budget
  Priorities & Challenges
- Mission Milestones
- Element Highlights
- Bridging to the Earth System Observatory
- Delivering Actionable Science



TROPICS launched in May 2023 from New Zealand

BUDGET PRIORITIES & CHALLENGES

Stewarding Public Investment into Earth Science

FY24 NASA ESD Budget Priorities

- Promote U.S. leadership in Earth system science
- Advance Open-Source Science
- Build an innovative and balanced program driven by the highest national priorities
- Implement the 2017 Decadal Survey Flight recommendations
- Address Sustained Climate Observations
- Fund the Program of Record, including known challenges
- Invest in Earth Science Infrastructure
- Balance commercial sector engagement

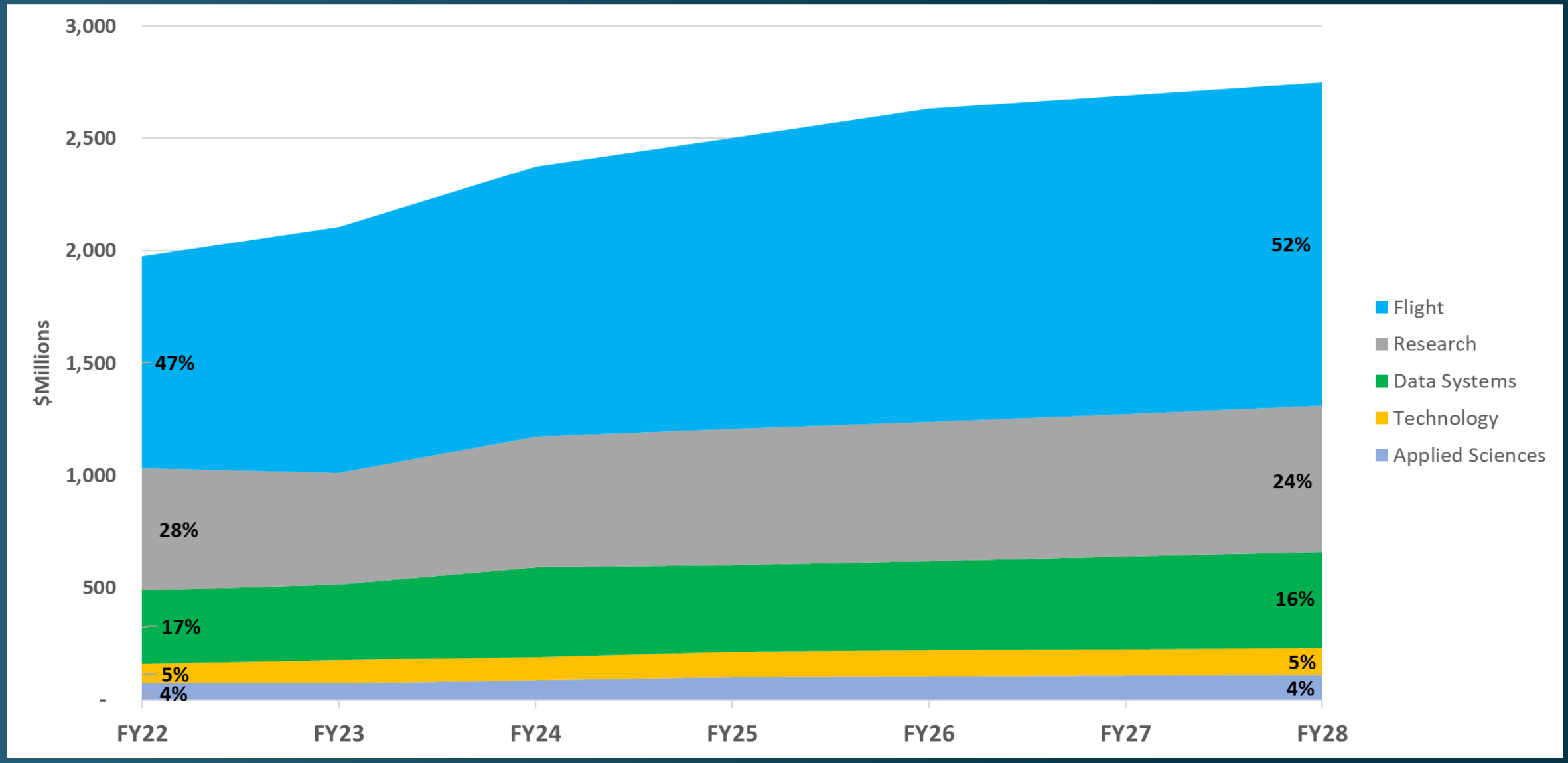
FY24 NASA ESD Budget Request by Program

			Request	Outyears			
($K)	FY22	FY23	FY24	FY25	FY26	FY27	FY28
Total Earth Science	**2,061,200**	**2,195,000**	**2,472,794**	**2,597,458**	**2,729,988**	**2,791,241**	**2,849,031**
Earth Systematic Missions	706,422	914,956	1,027,093	1,073,555	1,162,677	1,130,288	1,090,964
Earth System Science Pathfinder	312,686	232,116	235,629	298,565	290,534	282,460	290,274
Earth System Explorers	2,020	2,459	27,789	20,679	43,112	108,970	166,380
Earth Science Data Systems	339,357	366,087	411,681	398,919	408,140	423,762	439,583
Earth Science Technology	86,131	102,181	105,349	113,460	117,111	118,420	120,787
Applied Sciences	73,540	75,205	87,330	102,299	106,179	109,341	111,526
Earth Science Research	541,044	501,996	577,923	589,981	602,235	618,000	629,517

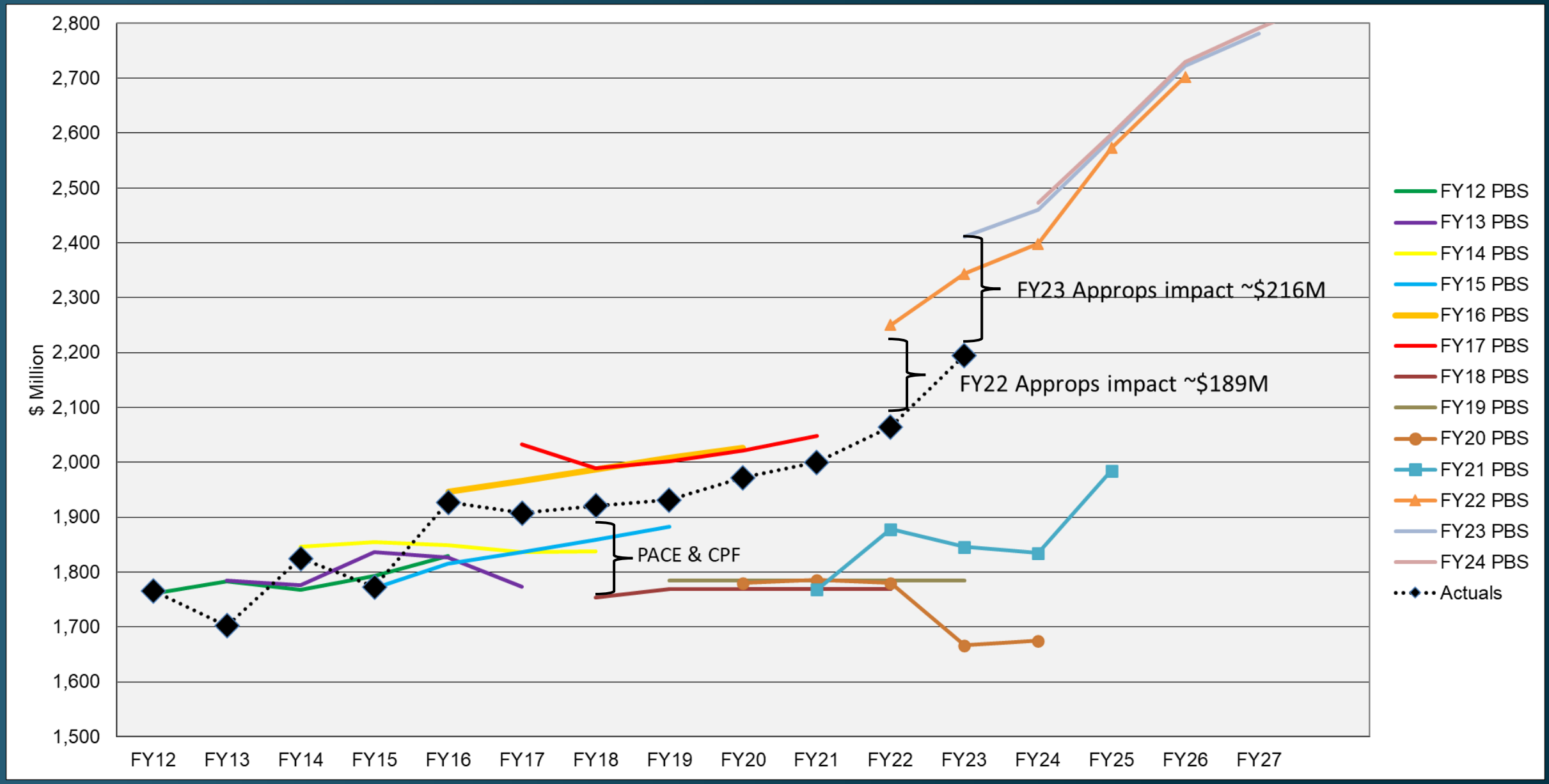
- *FY23 budget reflects latest approved Operating Plan*

- FY23 appropriation of $2.2B (increase of $134M) was the largest in ESD history
- President's FY24 Budget Request seeks $278M increase in Earth to fund Landsat Next and ESO

NASA Earth Science Program Balance



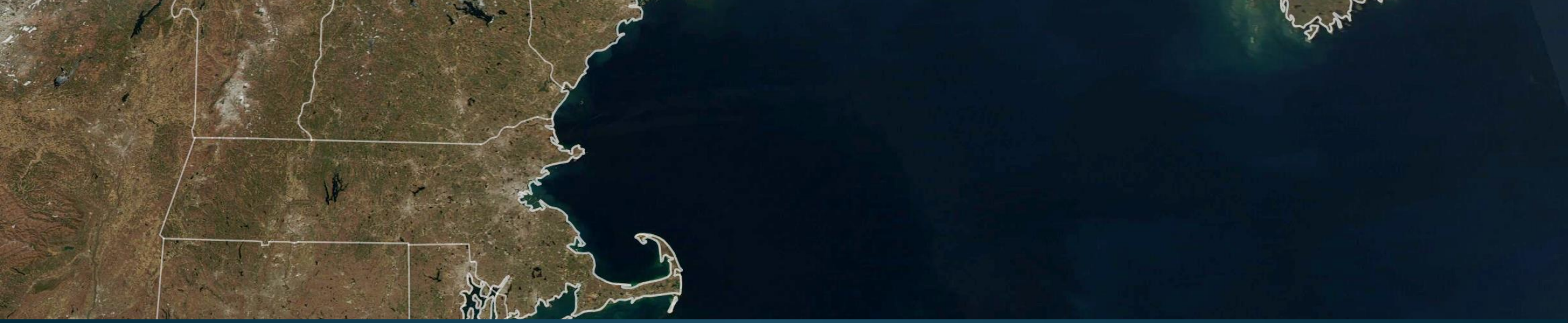
ESD President's Budget and Appropriations History



Accumulating Budget Challenges

Factor	Impact (approx.)
Growth assumptions	$1.74B
Landsat Next accounting	$450M
COVID-19	$300M
Tech challenges	$250M
Record inflation	$500M
Total impact	**$3.2B**

Melting on Humboldt Glacier *NASA Earth Observatory images by Wanmei Liang, using Landsat data from the U.S. Geological Survey.*



MILESTONES
Advancing Earth Science Program of Record

FY23-24 Milestones

2023

January

2023 Year of Open Science

April

Polarized Submillimeter Ice-cloud Radiometer (PolSIR) selected as Earth Venture Instrument-6 (EVI-6)

Earth Information Center Opening

July

Inaugural Earth System Explorer (ESE) AO Released

Initiate Decadal Survey Midterm Assessment

October

Release prototype version of Greenhouse Gas Information and Monitoring Center with interagency partners in November 2023

Launch new SERVIR Hub in Central America

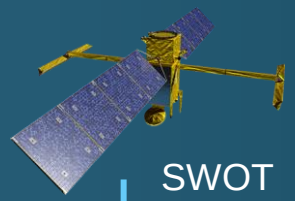
2024

January

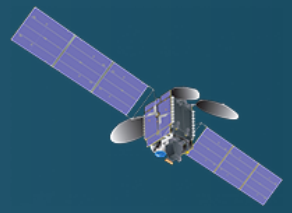
Make Earth System Explorers (ESE) Step-1 selections in Q3 FY24

05.18.23

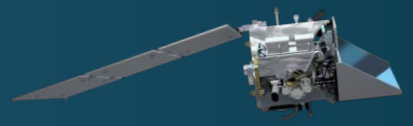
Recent and Upcoming Earth Science Launches



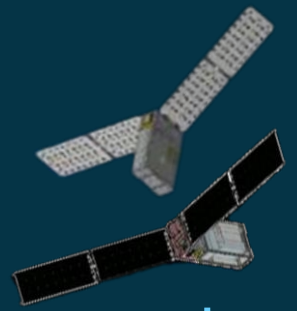
SWOT



TEMPO



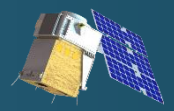
PACE**



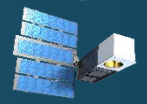
PREFIRE****

2022 | **2023** | **2024**

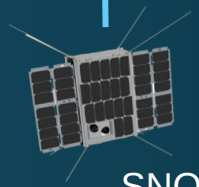
December | January | April | May | February | May | June | August | October



MURI

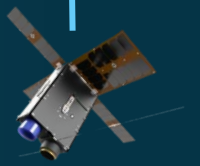


TROPICS 2, 3



SNOOPI*

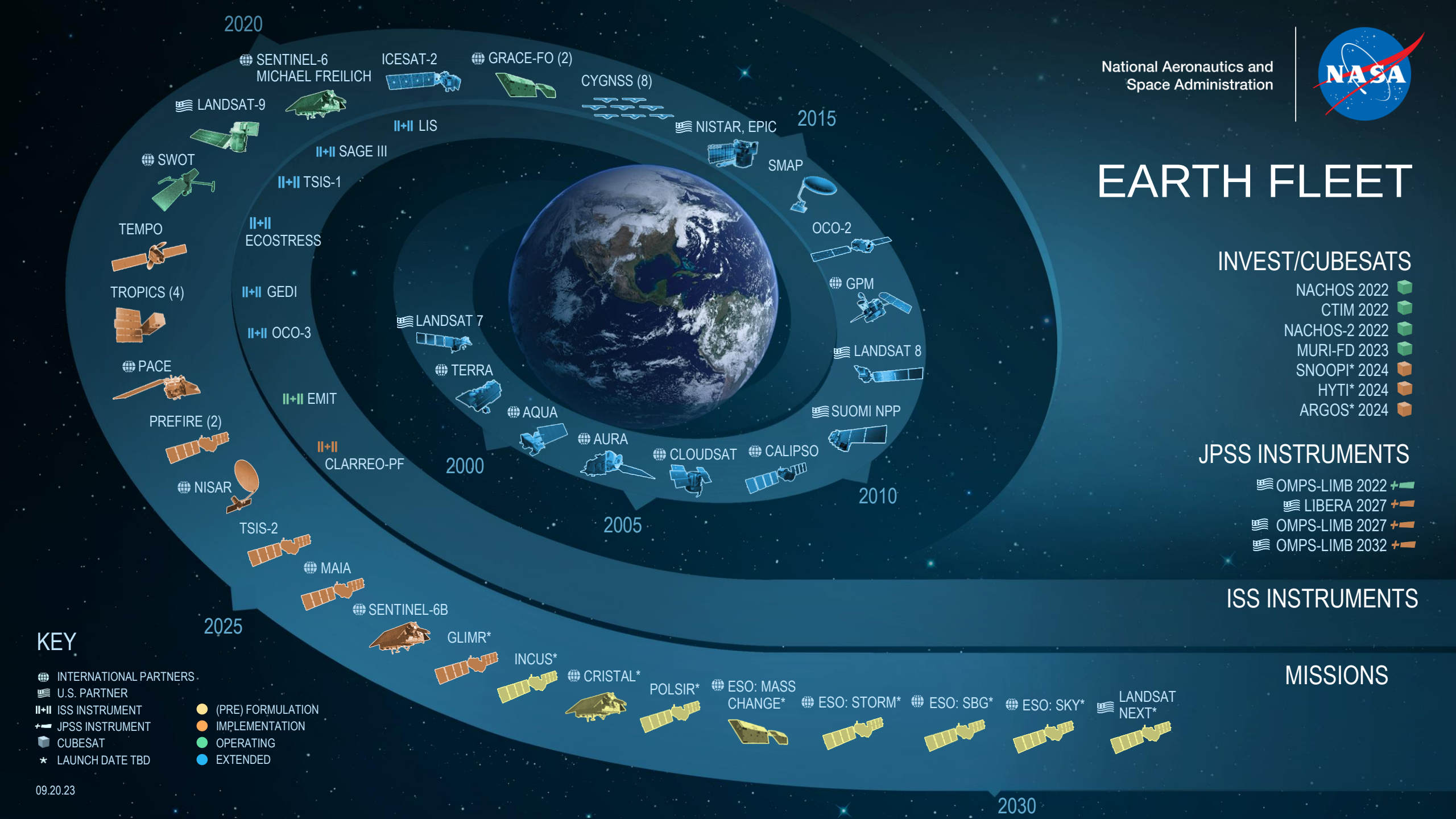
HyTI***



NISAR*****

*Launch Date NET February 2024
**Agency LRD May 2024
***Launch Date NET June 2024
****Agency LRD Aug 2024
*****Agency LRD Oct 2024

09.20.23


National Aeronautics and Space Administration
NASA
EARTH FLEET
2020
SENTINEL-6 MICHAEL FREILICH
ICESAT-2
GRACE-FO (2)
CYGNSS (8)
LANDSAT-9
LIS
NISTAR, EPIC
2015
SAGE III
SWOT
TSIS-1
SMAP
TEMPO
ECOSTRESS
OCO-2
TROPICS (4)
GEDI
GPM
LANDSAT 7
OCO-3
LANDSAT 8
PACE
TERRA
EMIT
SUOMI NPP
AQUA
PREFIRE (2)
AURA
CLOUDSAT
CALIPSO
CLARREO-PF
2000
2010
NISAR
2005
TSIS-2
MAIA
SENTINEL-6B
2025
GLIMR*
INCUS*
CRISTAL*
POLSIR*
ESO: MASS CHANGE*
ESO: STORM*
ESO: SBG*
ESO: SKY*
LANDSAT NEXT*
2030
INVEST/CUBESATS
NACHOS 2022
CTIM 2022
NACHOS-2 2022
MURI-FD 2023
SNOOPI* 2024
HYTI* 2024
ARGOS* 2024
JPSS INSTRUMENTS
OMPS-LIMB 2022
LIBERA 2027
OMPS-LIMB 2027
OMPS-LIMB 2032
ISS INSTRUMENTS
MISSIONS
KEY
INTERNATIONAL PARTNERS
U.S. PARTNER
ISS INSTRUMENT
JPSS INSTRUMENT
CUBESAT
LAUNCH DATE TBD
(PRE) FORMULATION
IMPLEMENTATION
OPERATING
EXTENDED
09.20.23

Earth Science Flight Opportunities

Open solicitation/In review | Completed solicitation

Mission	Mission Type	Release	Selection	Major Milestone
EVS-1 (EV-1) (AirMoss, ATTREX, CARVE, DISCOVER-AQ, HS3)	5 Suborbital Airborne Campaigns	2009	2010	Completed KDP-F
EVM-1 (CYGNSS)	Class D SmallSat Constellation	2011	2012	Launched Dec 2016
EVI-1 (TEMPO)	Class C Geostationary Hosted Instrument	2012	2012	Launched Apr 2023
EVI-2 (ECOSTRESS & GEDI)	Class C & Class D ISS-hosted Instruments	2013	2014	Launched Jun & Dec 2018
EVS-2 (ACT-America, ATOM, NAAMES, ORACLES, OMG, CORAL)	6 Suborbital Airborne Campaigns	2013	2014	Completed KDP-F
EVI-3 (MAIA & TROPICS)	Class C LEO Hosted Instrument & Class D CubeSat Constellation	2015	2016	MAIA Delivery 2022; TROPICS Launch launched May 2023
EVM-2 (GeoCarb)	Class D Geostationary Hosted Instrument	2015	2016	Cancelled
EVI-4 (EMIT & PREFIRE)	Class C ISS-hosted Instrument & Class D Twin CubeSats	2016	2018	EMIT launched to ISS Jul 2022; PREFIRE delivery NLT 2023
EVS-3 (ACTIVATE, DCOTSS, IMPACTS, Delta-X, SMODE)	5 Suborbital Airborne Campaigns	2017	2018	All in post-deployment phase
EVI-5 (GLIMR)	Class C Geostationary Hosted Instrument	2018	2019	Delivery NLT 2024
EVC-1 (Libera)	Class C JPSS-Hosted Radiation Budget Instrument	2018	2020	Delivery NLT 2025
EVM-3 (INCUS)	Full Orbital	2020	2021	Launch ~2026
EVI-6 (PolSIR)	Instruments and SmallSats	2022	2023	Delivery NLT 2027
ESE	Explorer Mission	2023	2025	Launch ~2031 & ~2033
EVS-4	Suborbital Airborne Campaigns	2023	2024	N/A
EVC-2	Continuity Measurements	2024	2025	Delivery NLT 2029
EVI-7	Instrument Only	2025	2026	Delivery NLT 2030
EVM-4	Full Orbital	2025	2026	Launch ~2031
ESE	Explorer Mission	2025	2027	Launch ~2034 & 2036
EVC-3	Continuity Measurements	2027	2028	Delivery NLT 2032
EVS-5	Suborbital Airborne Campaigns	2027	2028	N/A

EVS
Sustained sub-orbital investigations
(~4 years)

EVM
Complete, self-contained, small missions
(~4 years)

EVI
Full function, facility-class instruments Missions of Opportunity (MoO)
(~3 years)

EVC
Complete missions or hosted instruments targeting “continuity” measurements
(~3 years)

ESE *(NEW)*
Medium-size instruments and missions
(~2 years)

Earth Venture Instrument-6: PolSIR

(Polarized Submillimeter Ice-cloud Radiometer)

Will observe ice clouds' daily cycle of ice content at high altitudes throughout tropical and sub-tropical regions to improve climate models and forecasts

- Two identical CubeSats flying in orbits separated by three to nine hours
- GSFC will provide project management
- Two spacecraft to be built by Blue Canyon Technologies
- Space operations will be conducted by the Space Science and Engineering Center, University of Wisconsin - Madison

PI: Ralf Bennartz, Vanderbilt University
Deputy PI: Dong Wu, Goddard Space Flight Center

VANDERBILT UNIVERSITY

Goddard SPACE FLIGHT CENTER

BLUE CANYON TECHNOLOGIES

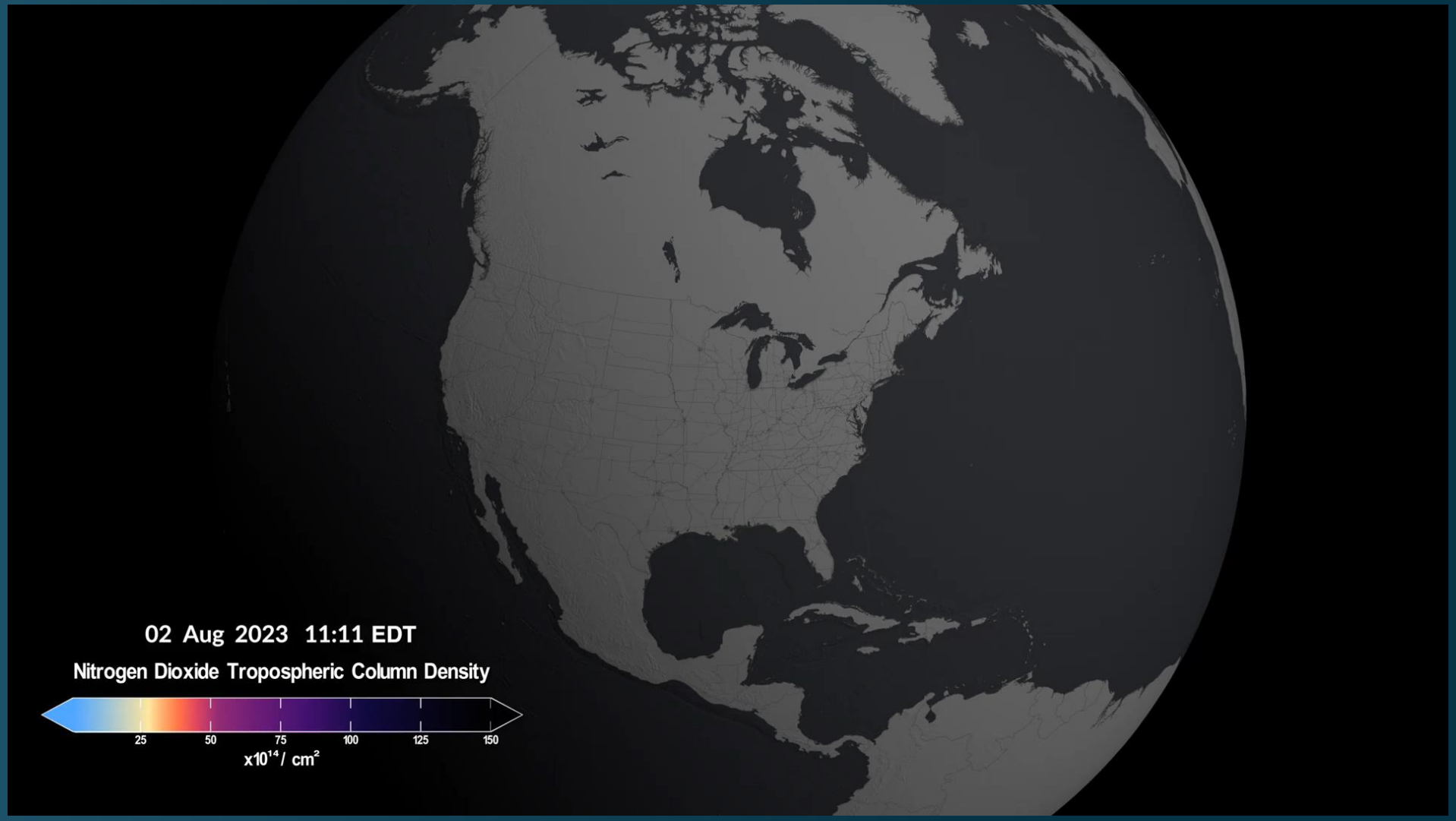
SSEC

TEMPO (EVI-1) First Light

Launched April 7, 2023 on a Maxar communications satellite

First light images released Aug 24, 2023

Tropospheric Emissions: Monitoring of Pollution (TEMPO) is monitoring air pollutants hourly across the North American continent during daytime

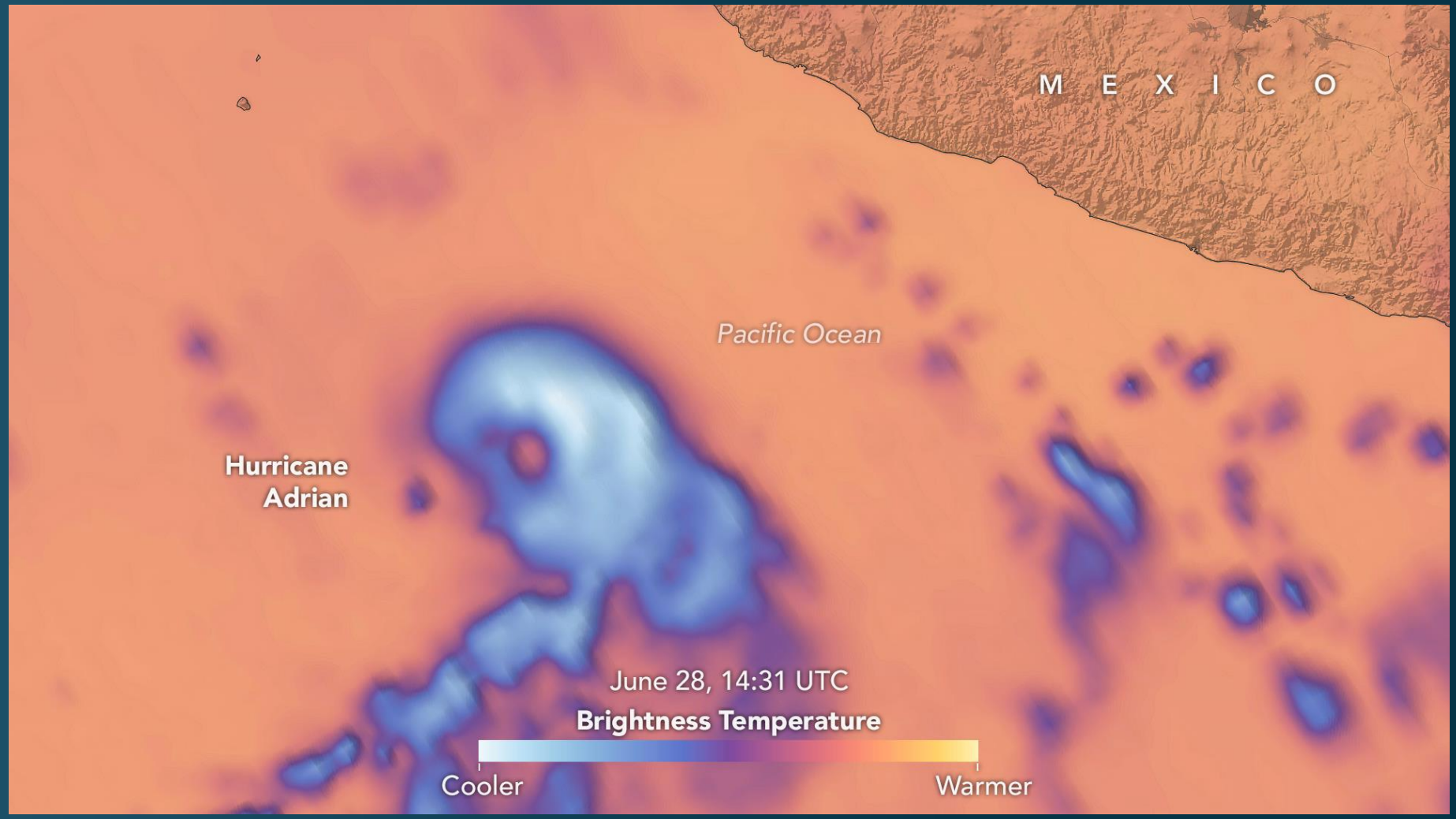


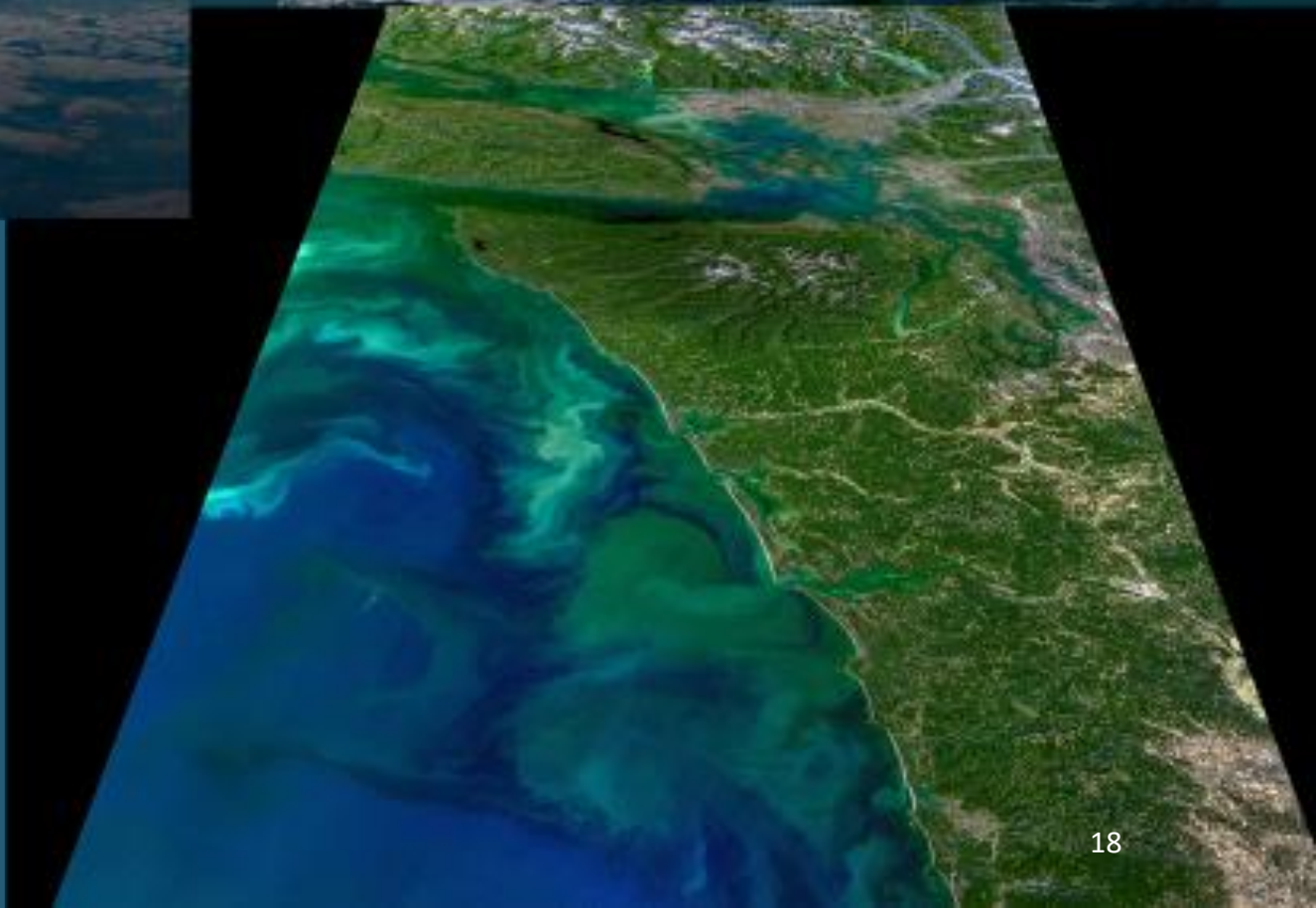
TROPICS (EVI-3) First Light

Constellation of four satellites successfully deployed on two separate Rocket Lab launches on May 8, 2023 and May 26, 2023

First light images were released July 19, 2023

TROPICS is helping weather researchers learn more about the environmental factors contributing to hurricane structure and intensity





PACE Advances Ocean Science

- Monitors fisheries
- Respond to toxic algae blooms
- Key ocean and atmosphere data for forecasting air quality and weather that will improve our understanding of Earth's Climate
- Anticipated launch early 2024

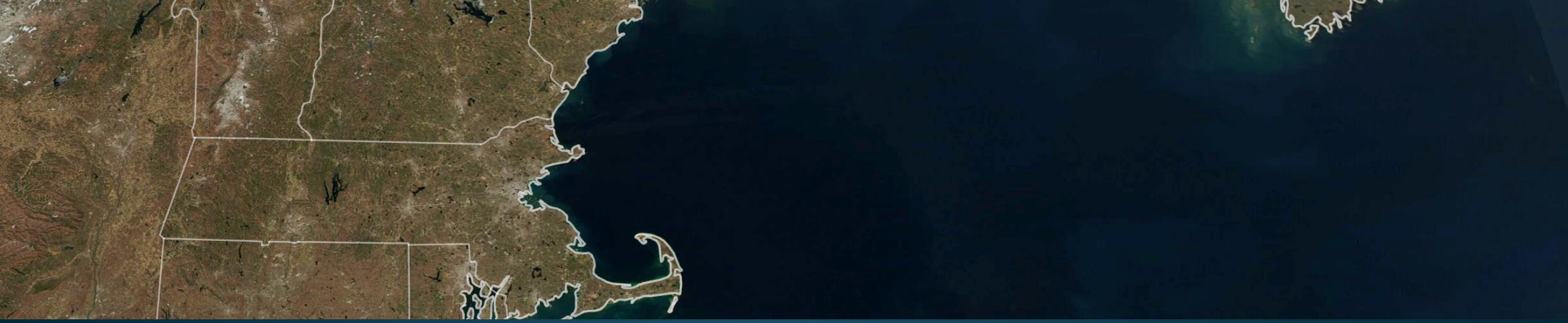
Jet Propulsion Laboratory
California Institute of Technology

NISAR

NASA-ISRO Synthetic Aperture Radar

Agency LRD: October 2024

Will measure some of the **planet's most complex processes** such as ice-sheet collapse and natural hazards such as earthquakes, volcanoes, and landslides. NISAR can **assist planners and decision makers** with managing both hazards and natural resources in the future



Earth Science Research and Technology Highlights

Mass Balance of the Greenland and Antarctic Ice Sheets from 1992 to 2020

Otosaka, I. N., Shepherd, A., Ivins, E. R., Schlegel, N.-J., et al. (2023). *Earth Syst. Sci. Data*, 15. https://doi.org/10.5194/essd-15-1597-2023
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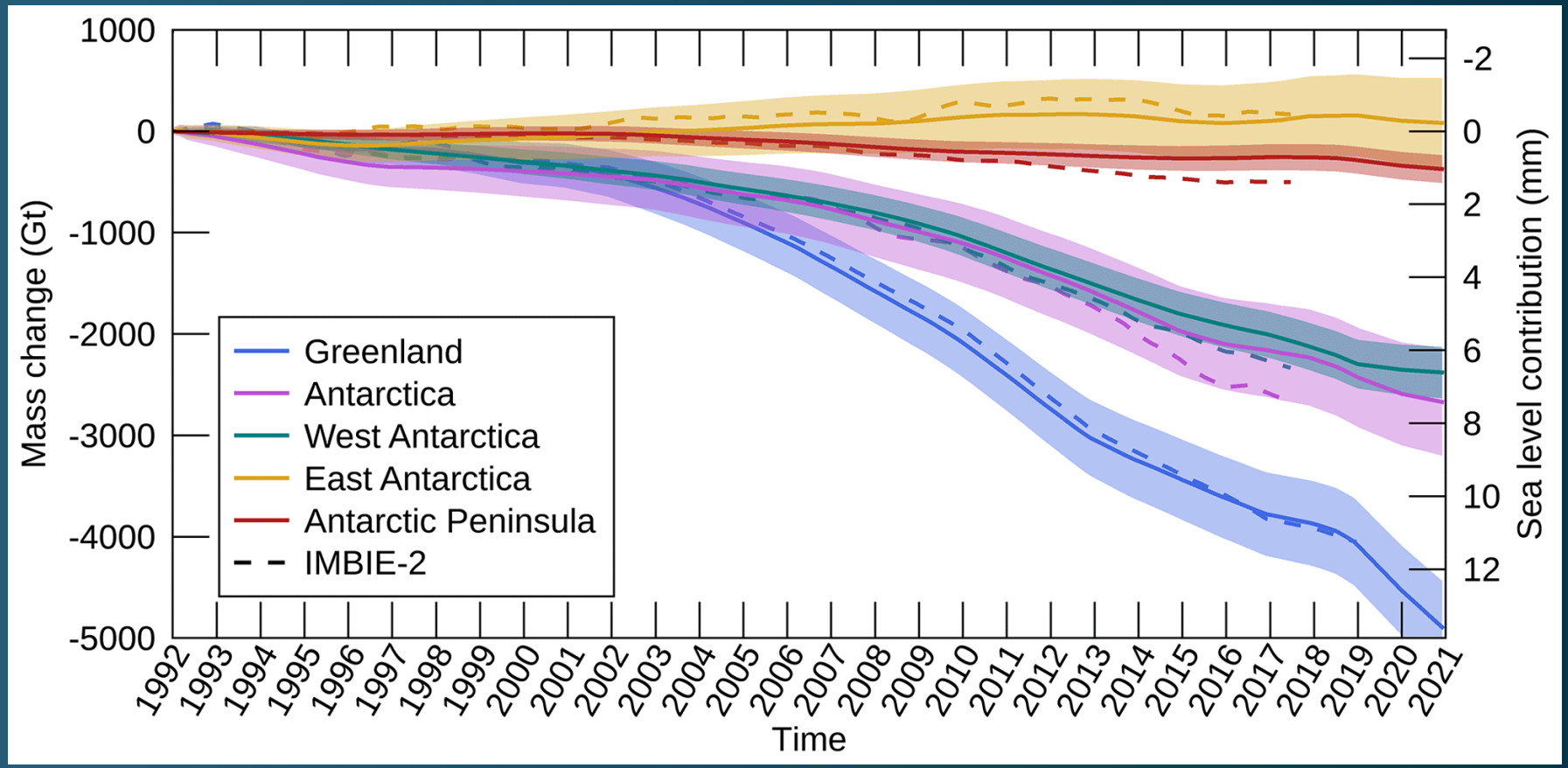


The Ice Sheet Mass Balance Inter-comparison Exercise (IMBIE) found:

- Ice sheets have lost 7,560 billion tons of ice from 1992 to 2020
- Ice sheet mass loss now accounts for a quarter of all sea-level rise - a fivefold increase since the 1990s.

Effectiveness of Global Protected Areas for Climate Change Mitigation

Duncanson, L., et al. (2023). *Nature Communications*, 14. https://doi.org/10.1038/s41467-023-380073-9.

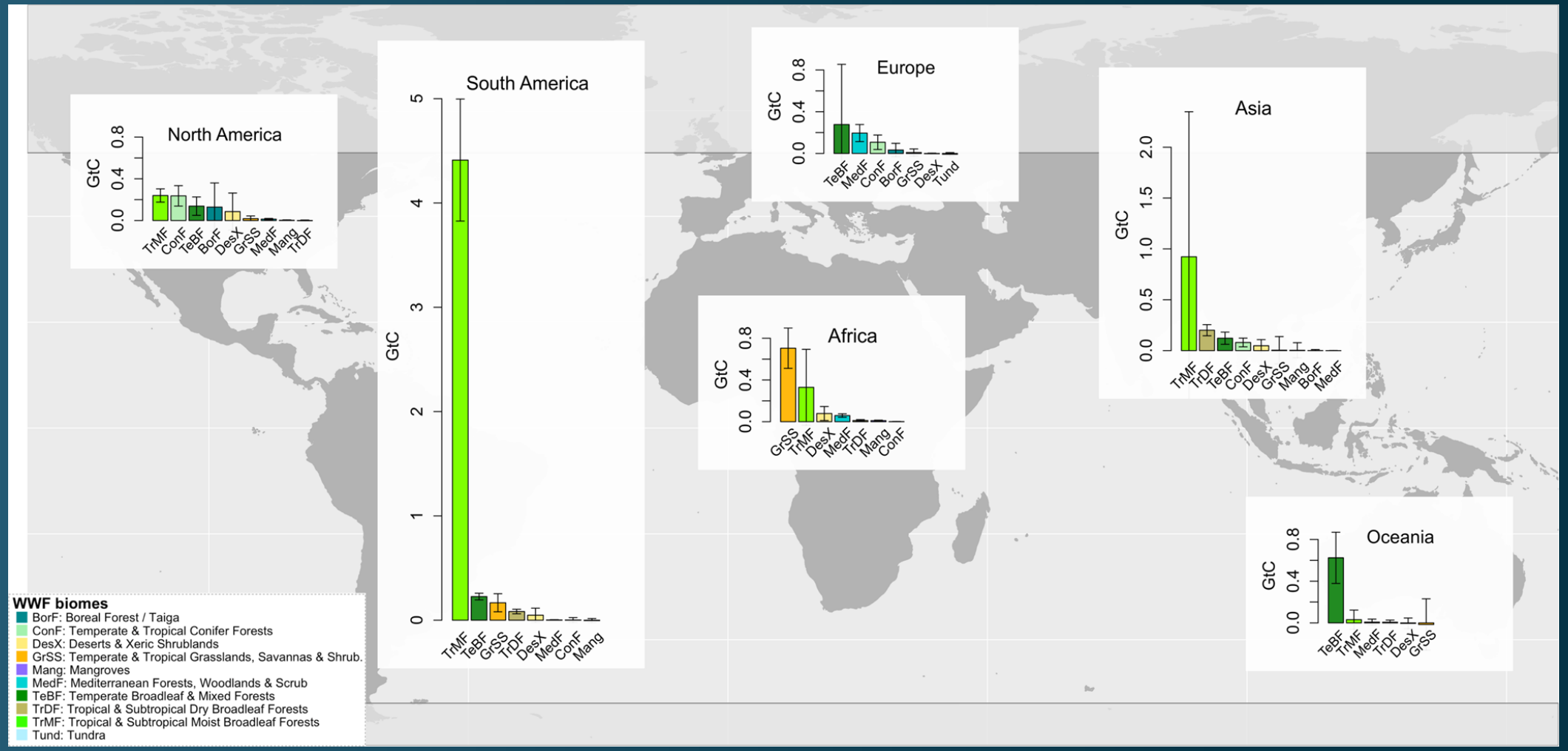


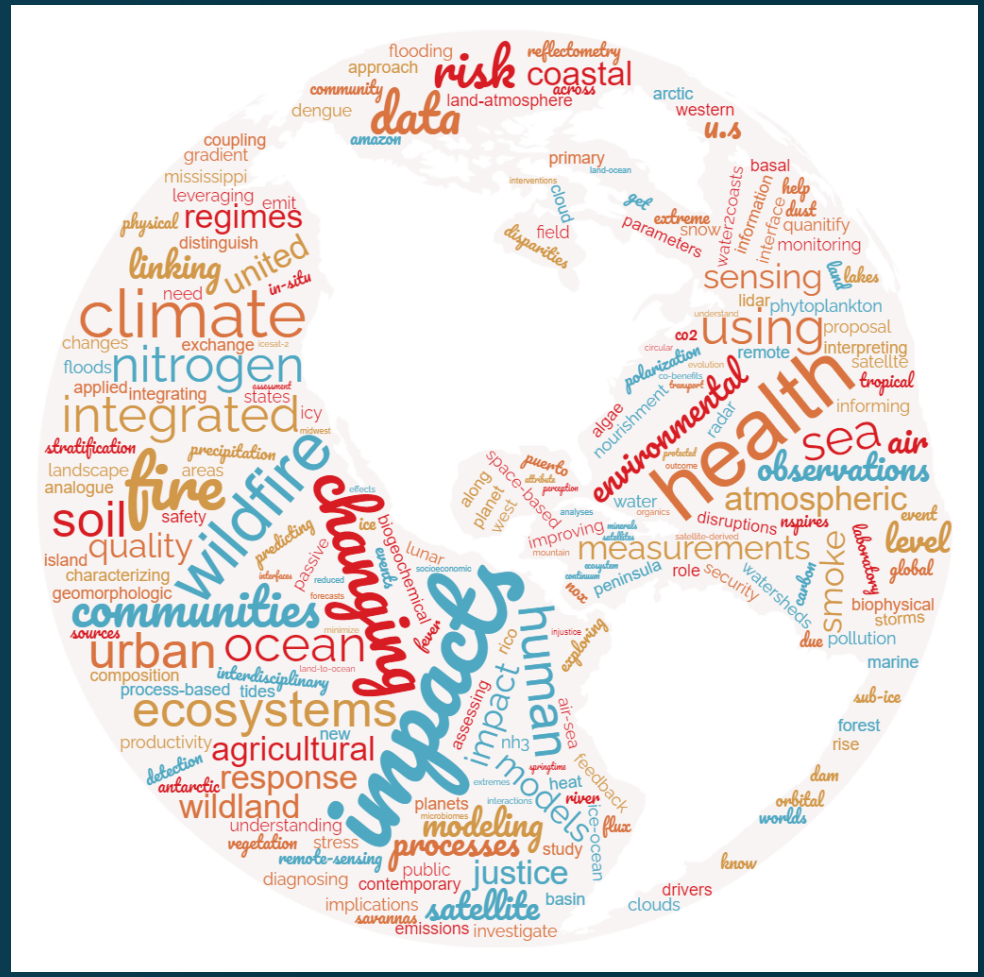
Figure shows total additionally preserved Above Ground Carbon (AGC) aggregated by continent and biome. PAs effectively preserve additional AGC across continents and biomes, with forest biomes dominating the global signal, particularly in South America. The additional preserved AGC (Gt) in WWF biome classes (total Gt + /− SEM area). Full set of analyzed GEDI data are represented in figure (n = 412,100,767).

ROSES ESD Updates and Highlights

- Proposals received for 12 ROSES-23 elements
  - Between April and September 2023, 11 element selections completed from ROSES-22 and -23.
  - 5 remaining elements in ROSES-23 with due dates between now and December

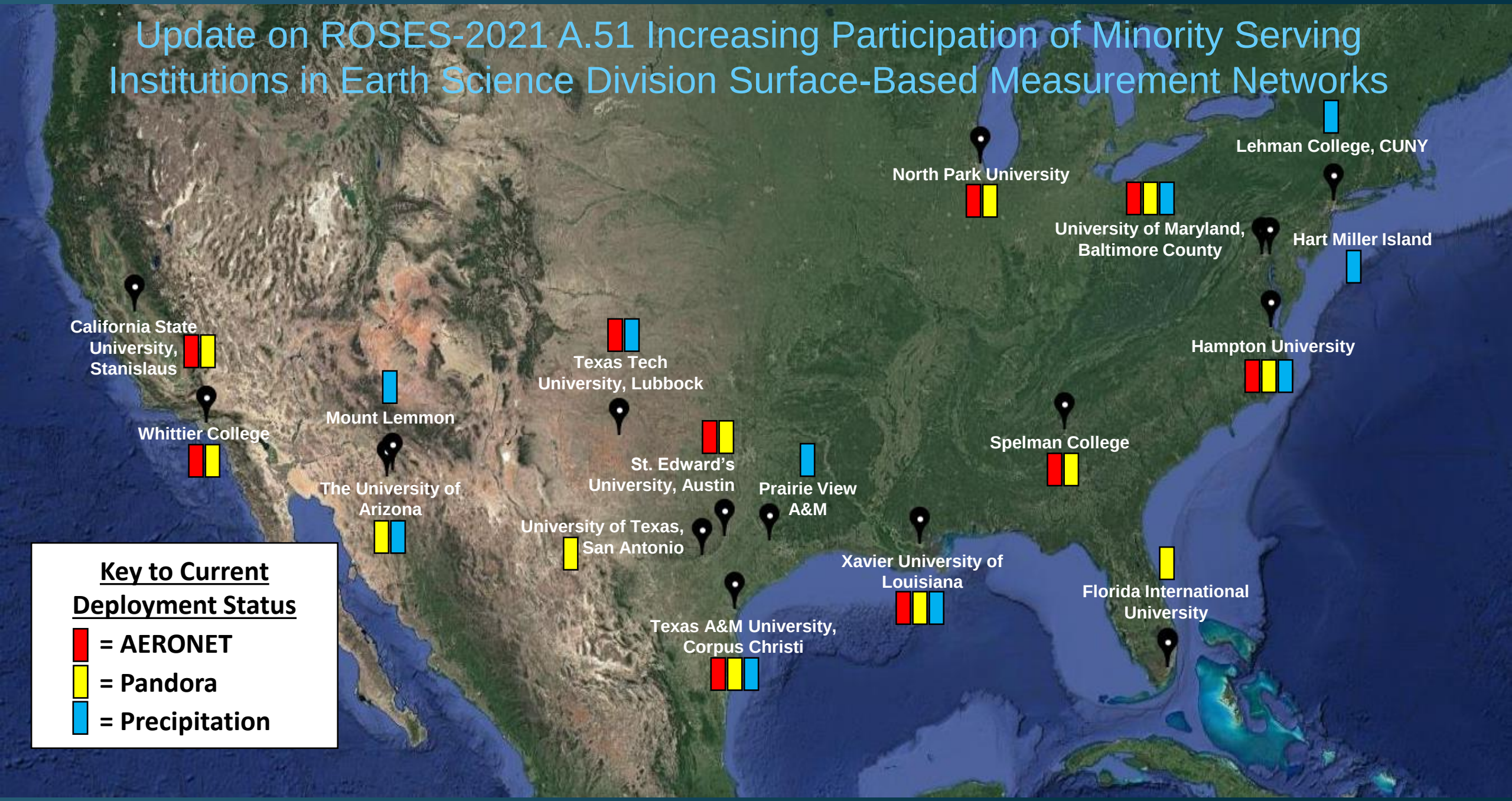
- In ROSES-23:
  - 5 elements used Dual Anonymous Peer Review
  - 1 element called for Inclusion Plan – A.24 Earth Surface and Interior

- 28 ROSES-22 A.28 Interdisciplinary Research in Earth Science (IDS) selections recently announced:
  - 23 funded by IDS + augmentations by FireSense (1); EarthAction-Fire (1); and Environmental/Climate Justice (3)

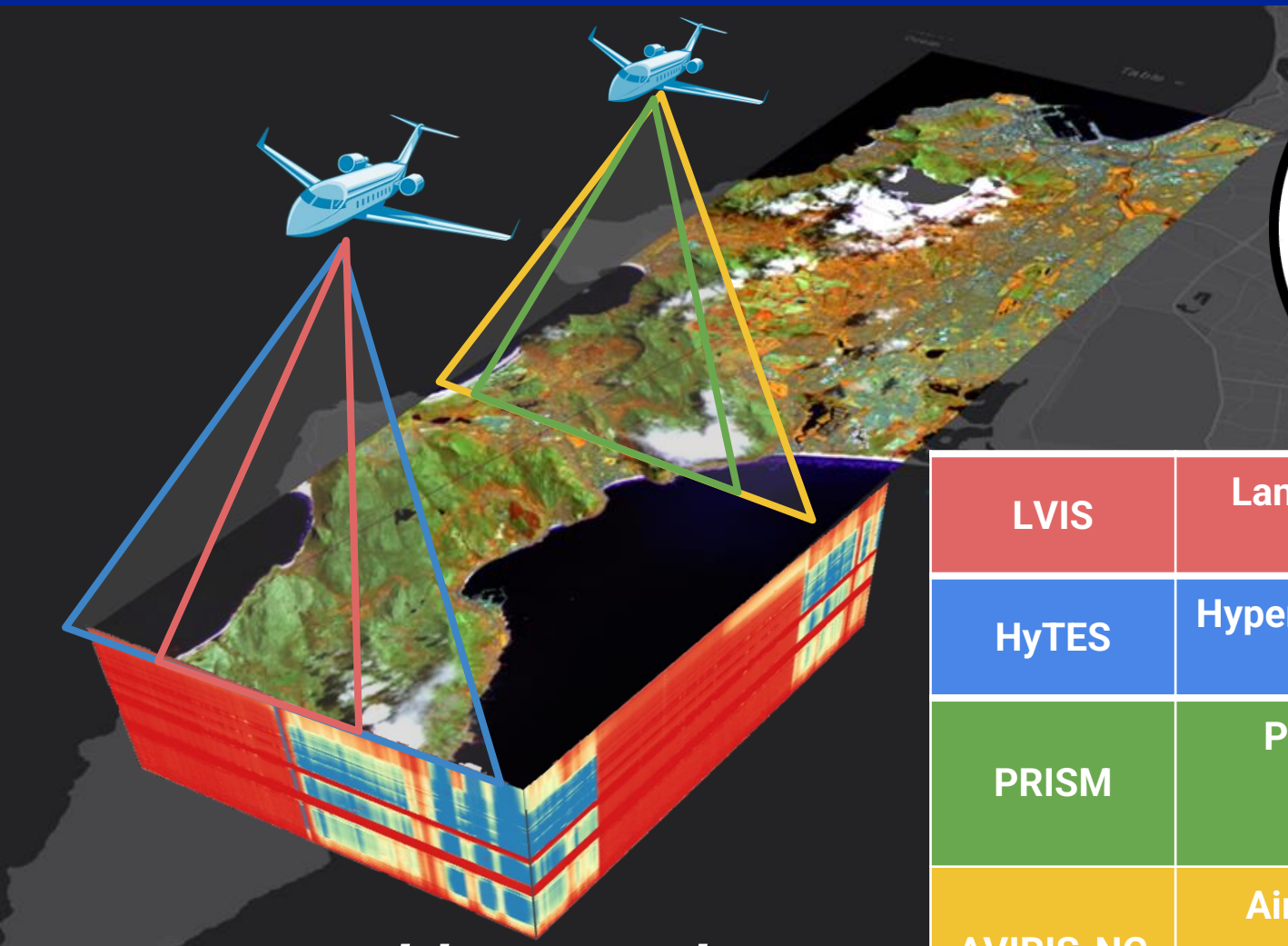


Word cloud representing A.28 IDS proposal topics.

Update on ROSES-2021 A.51 Increasing Participation of Minority Serving Institutions in Earth Science Division Surface-Based Measurement Networks



BioSCape: Exploring Biodiversity's Role in Ecosystem Function and Services



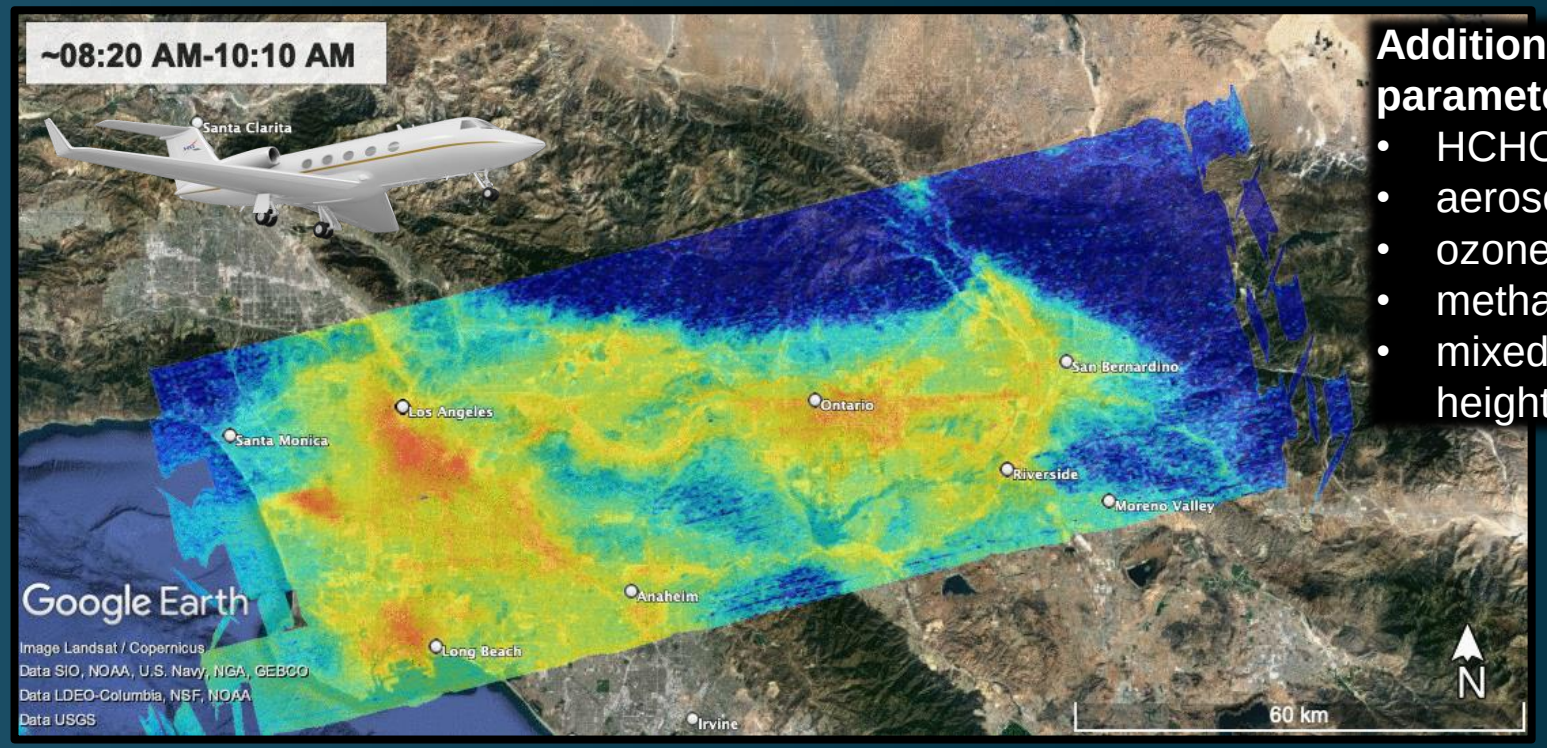
BIOSCAPE
Biodiversity Survey of the Cape

Flights in South Africa
Oct-Nov 2023

LVIS	**Land, Vegetation, and Ice Sensor (Laser altimeter: 1064nm)** ***3D Vegetation Structure***
HyTES	**Hyperspectral Thermal Emission Spectrometer (TIR: 7.5-12µm)** ***Land and Water Surface Temperatures, Plant ET***
PRISM	**Portable Remote Imaging Spectrometer (UV-VNIR: 350-1050nm)** ***Composition of Aquatic Constituents, H2O Quality***
AVIRIS-NG	**Airborne Visible-Infrared Imaging Spectrometer-Next Gen (VSWIR: 380-2510nm)** ***Ecosystem Vegetation Composition, H2O Quality, Geology***

www.bioscape.io

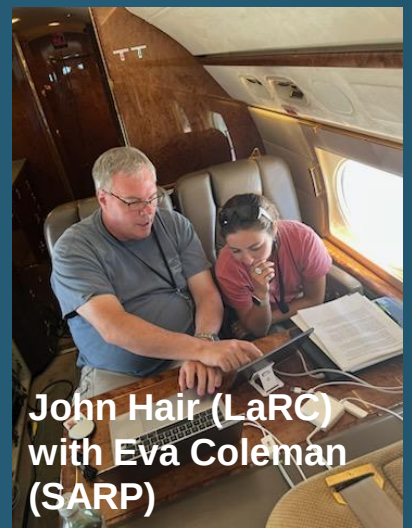
Synergistic TEMPO Air Quality Science



Additional parameters :

- HCHO
- aerosols
- ozone
- methane
- mixed layer height

Preliminary NO_2 slant columns from August 23, 2023 collected from GCAS (airborne TEMPO proxy) on the LaRC GIII in LA.



John Hair (LaRC) with Eva Coleman (SARP)

SARP Alumni involved in AEROMMA/STAQS with some of the 2023 SARPians

NOAA AEROMMA/NASA STAQS Group Photo
Collaboration list: https://csl.noaa.gov/projects/ages/

Student Airborne Research Program - 2023

For the first time there were TWO locations: SARP West, the ongoing one in Palmdale/UC Irvine; and “SARP East” based in Virginia with LaRC, GSFC, WFF and partners collaboration.

SARP West: June 18- Aug 11

- 15th year
- 24 students, 4 Faculty and 5 mentors

SARP East: June 5-July 28

- Inaugural year
- 22 students, 5 Faculty and 5 mentors

SARP West sampling around Central CA Valley dairy and at AFRC with DC-8.

SARP East class conducting field research, studying in classroom, & preparing for deployment.

Technology: Earth Systems Digital Twins

Earth Systems Digital Twins (ESDTs) are an emerging capability for understanding, forecasting, and conjecturing the complex interconnections among Earth systems, including anthropomorphic forcings and impacts to humanity.

Recent and ongoing activities:

- 16 current ESDT technology development projects funded under the AIST program.
- Workshops and other community meetings to explore science use cases, enabling technologies, frameworks, prototyping, interoperability, and federation:
  - AIST ESDT Workshop: Oct 26-28, 2022. Report: https://go.nasa.gov/3RhezAr
  - Standards for Interoperable Digital Twins Workshop: Sep 18, 2023
- Collaboration with ESA, Destination Earth, CNES, and others

Visit the dedicated ESDT webpage here: https://esto.nasa.gov/earth-system-digital-twin/

BRIDGING TO THE NEXT-GENERATION
Developments in the Earth System Observatory

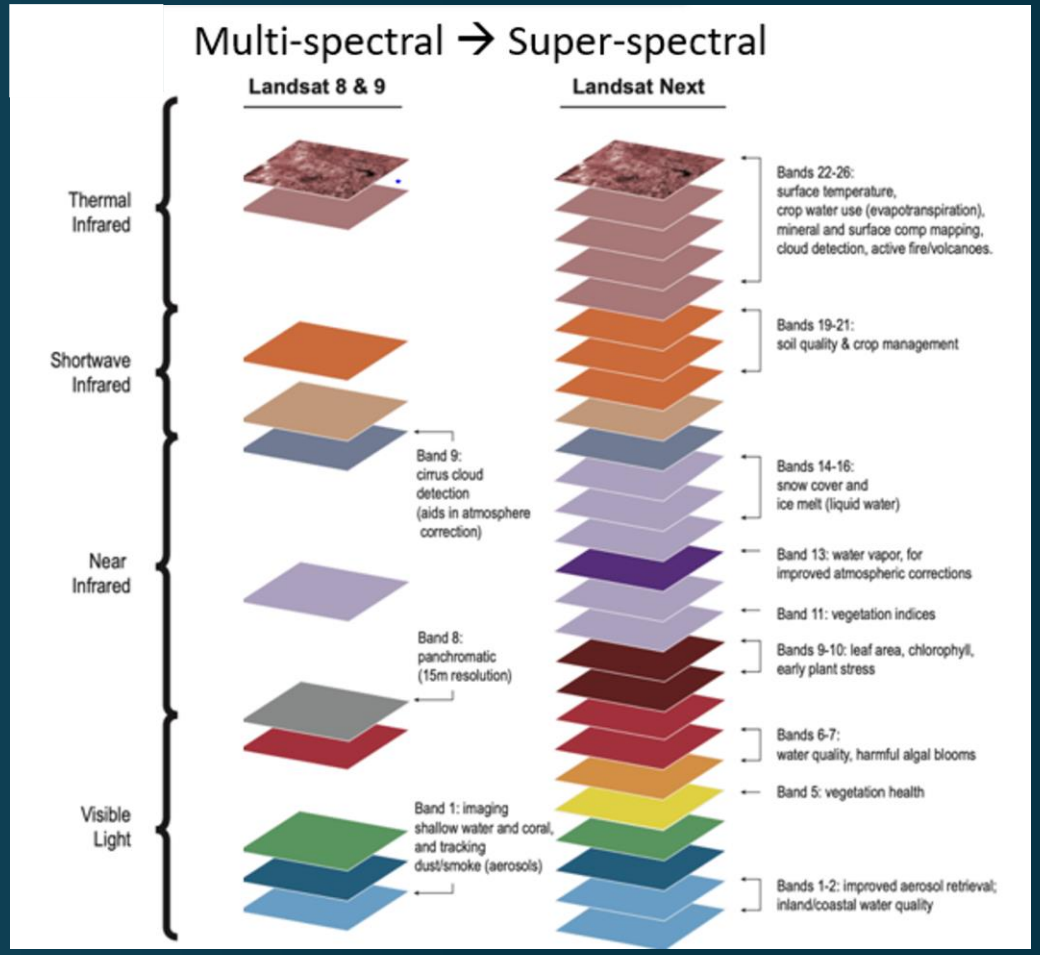
Landsat Next

Landsat Next mission is a constellation of three identical satellites, approximately equally distributed in orbit

- ≤ 9 day global land revisit frequency
- 26 spectral bands (21 VSWIR; 5 TIR)
- Target Launch Readiness Date: November 2030

Status and next steps:

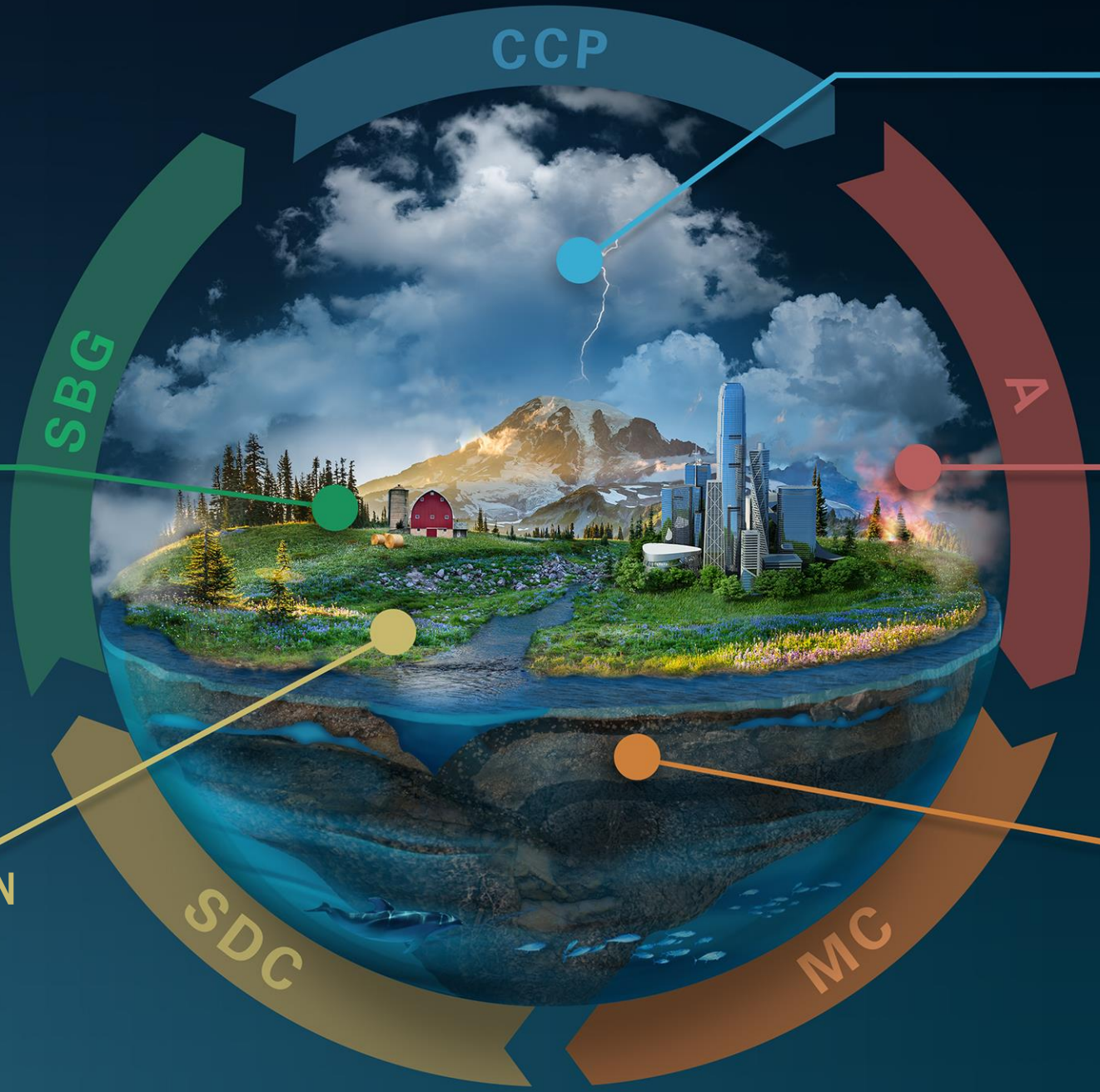
- Held KDP-A Program Management Council on Nov. 2
- Landsat Instrument Suite proposals currently under evaluation with award planned in spring of 2024.



Landsat Next will provide more than twice as many spectral bands, with resolution improved by a factor of 2, and with the repeat coverage of Landsats 8 and 9, *combined*

EARTH SYSTEM OBSERVATORY

INTERCONNECTED CORE MISSIONS



CLOUDS, CONVECTION AND PRECIPITATION

Water and Energy in the Atmosphere

AEROSOLS

Particles in the Atmosphere

MASS CHANGE

Large-scale Mass Redistribution

SURFACE DEFORMATION AND CHANGE

Earth Surface Dynamics

SURFACE BIOLOGY AND GEOLOGY

Earth Surface & Ecosystems

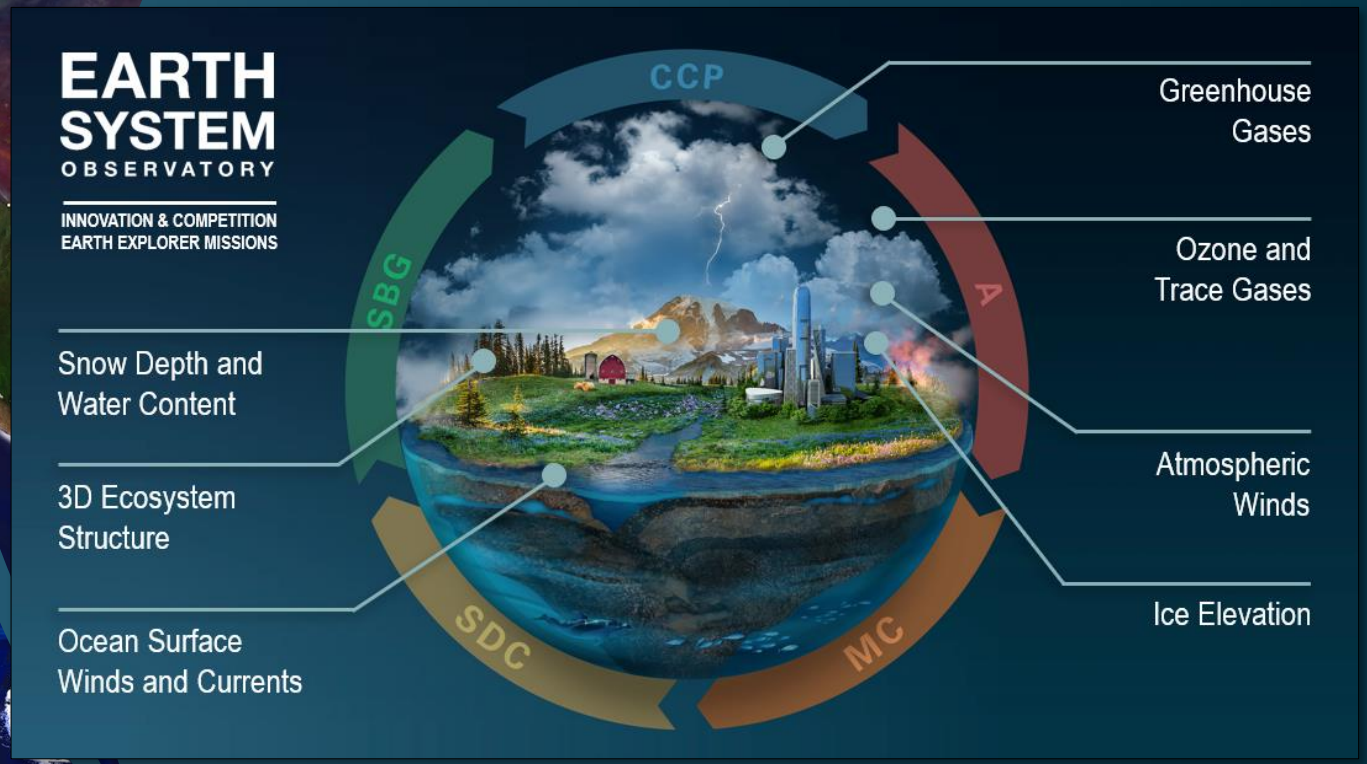
ESO Core Missions

- Successfully completed Mission Concept Reviews summer 2022
- Missions passed KDP-A and now in Formulation
- ESO Independent Review Board, July-October
  - IRB report and NASA response posted at nasa.gov/reports
- AOS-Storm and AOS-Sky have Phase A trade studies under way.
- SDC will remain in extended study phase to take advantage of NISAR mission lessons learned

AOS-Storm AOS-Sky	SBG	GRACE-C	SDC
MCR: May 2022 KPD-A: Jan 2023	MCR: June 2022 KDP-A: Nov 2022	MCR: Jun 2022 KDP-B: Sept 2023	Remaining in Extended Study Phase

Earth System Explorers (ESE)

EARTH SYSTEM OBSERVATORY



- Final Announcement of Opportunity (AO) released on May 2, 2023
- AO closed August 2, 2023
- Step 1 selection anticipated Q3 FY24
- PI-Managed Mission Cost (PIMMC) cap of $310M (FY24 $)
- NASA will provide launch vehicle services
- Two-step selection process

- New Earth System Explorers Program Office established at GSFC; SRR/SDR completed in March 2023 and KDP-I in June 2023

DELIVERING ACTIONABLE SCIENCE

Showing People our Earth as NASA Sees It

Earth Science to Action Strategy

06.27.23

NASA Open-Source Science Initiative

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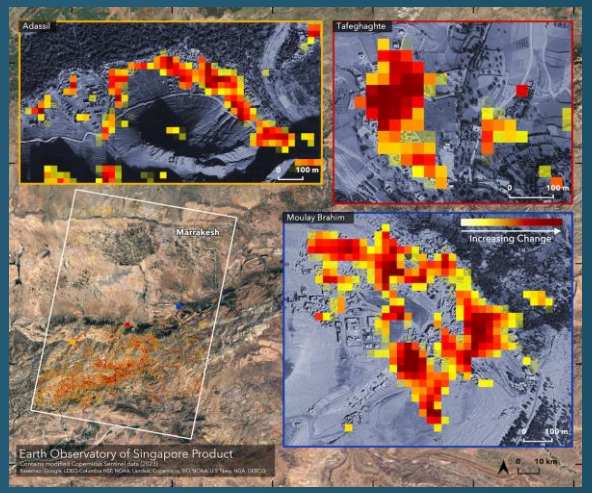
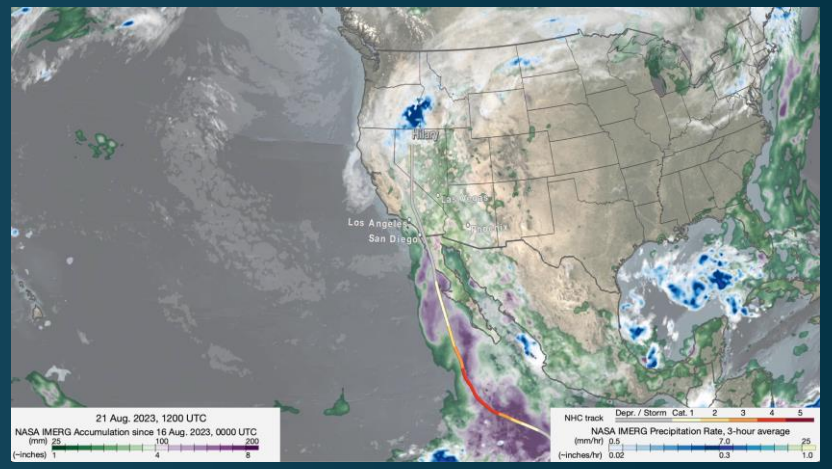
Images by Freepik

Recent Disaster Response Support

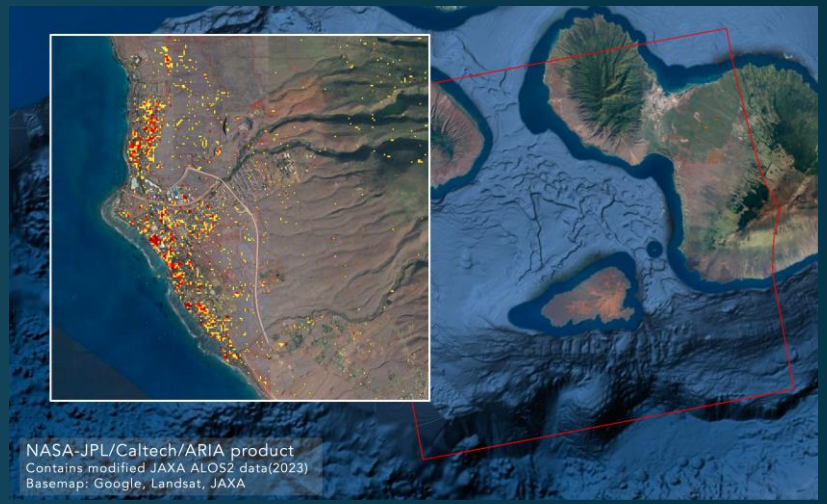


Earthquake in Morocco
Damage proxy maps delivered by partners at the Earth Observatory Singapore using recent Sentinel-1 SAR overpasses. Stakeholders: Bureau of Humanitarian Affairs at the U.S. State Dept., and ESRI Disasters Response



Hurricane Hillary
Provided expedited pre- and post-event Sentinel-2 imagery for FEMA's situational awareness during this event. Stakeholders: FEMA HQ

Hurricane Idalia
MODIS acquired this image of Idalia. At this time, Idalia was moving north, and the National Hurricane Center reported wind speeds of about 85 miles per hour. Stakeholders: FEMA, Florida Division of Emergency Management (FDEM)



Wildfires in Hawaii
Damage proxy map depicting buildings likely damaged in Maui, derived from synthetic aperture radar imagery acquired by JAXA ALOS-2 satellites. Stakeholders: Pacific Disaster Center, World Central Kitchen, FEMA Region 9, and Esri Disaster Response

Upcoming FireSense Airborne Campaign

NASA FireSense

partnership US Forest Service (USFS) and
Fish Lake National Forest (FLNF) and
USFS FASMEE
(Fire And Smoke Model Evaluation Experiment)

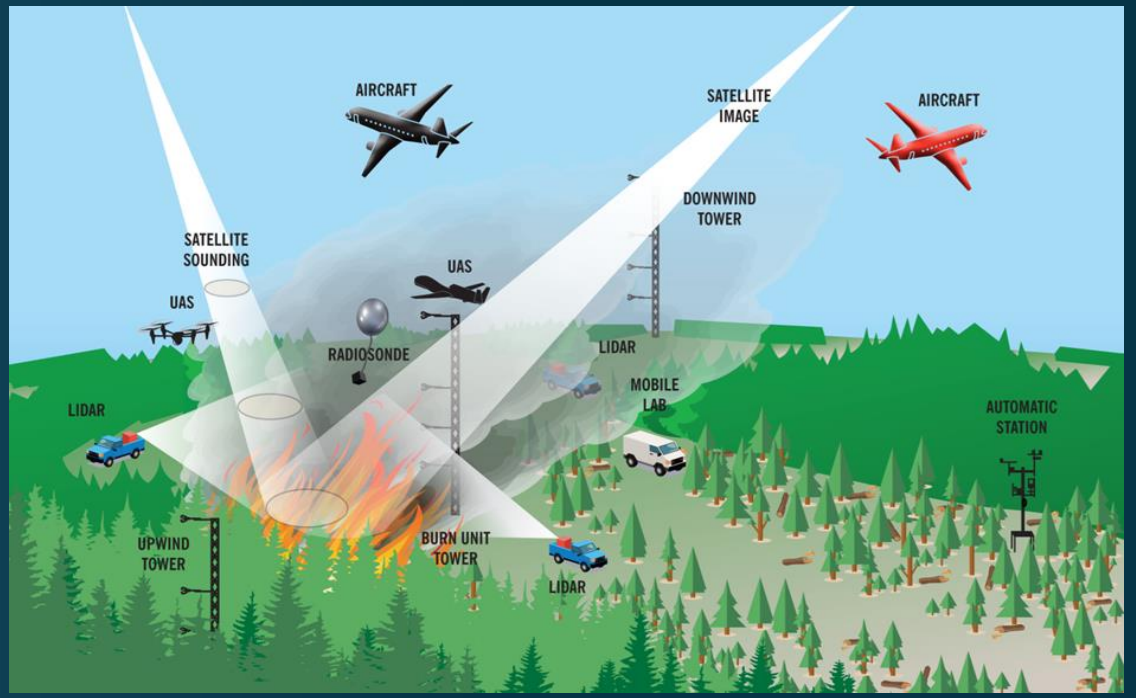
2023 fall prescribed burn

stand replacing crown fire
restore aspen to improve elk habitat
reduce hazardous fire fuels
measure extreme fire behavior and smoke plumes
improve fire behavior and smoke models

NASA instruments coordinated with ground sampling

airborne sampling with
UAVSAR, AVIRIS, SLAP, MASTER
measurements of pre-fire fuel type and moisture
active fire dynamics (e.g., intensity)
post-fire effects (e.g., burn severity)

Photos from a previous FASME Prescribed Fire



Field Campaign Graphic from FASMEE

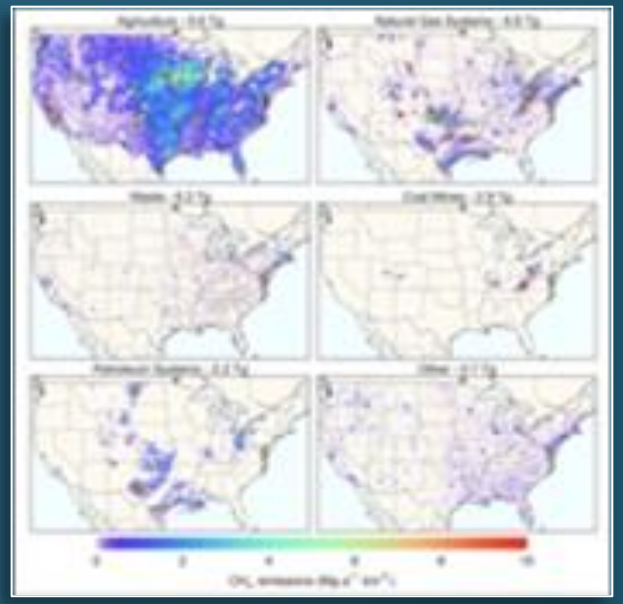
U.S. Greenhouse Gas Center

Mission: To extend accessible and integrated greenhouse gas (GHG) data and modeling capabilities from US government and non-public sources for scalable impact

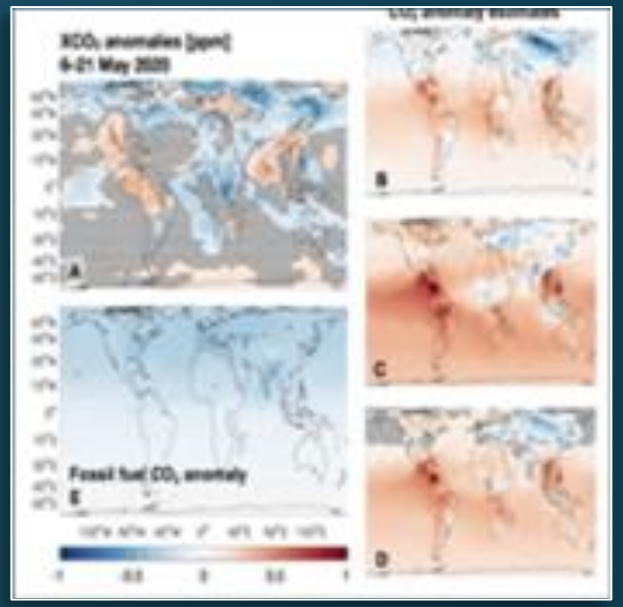
Upcoming Milestones

- **Oct. 2, 2023**: soft launch of Center, beta portal release
- **Nov. 28, 2023**: Targeted Stakeholder Workshop (invitation-only, hybrid virtual / in-person in D.C.)

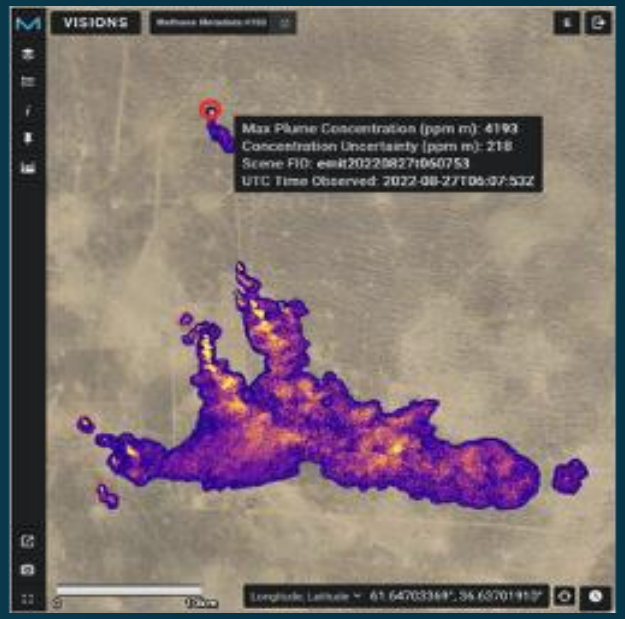
Use Cases



Credit: Maasakkers et al., Env. Sci. and Tech., 2016



Credit: Weir et al., Env. Res. Lett., 2022



Credit: EMIT Interim Open Data Portal

Use Case 1

Improve access and latency to gridding of anthropogenic CH_4 inventory

Use Case 2

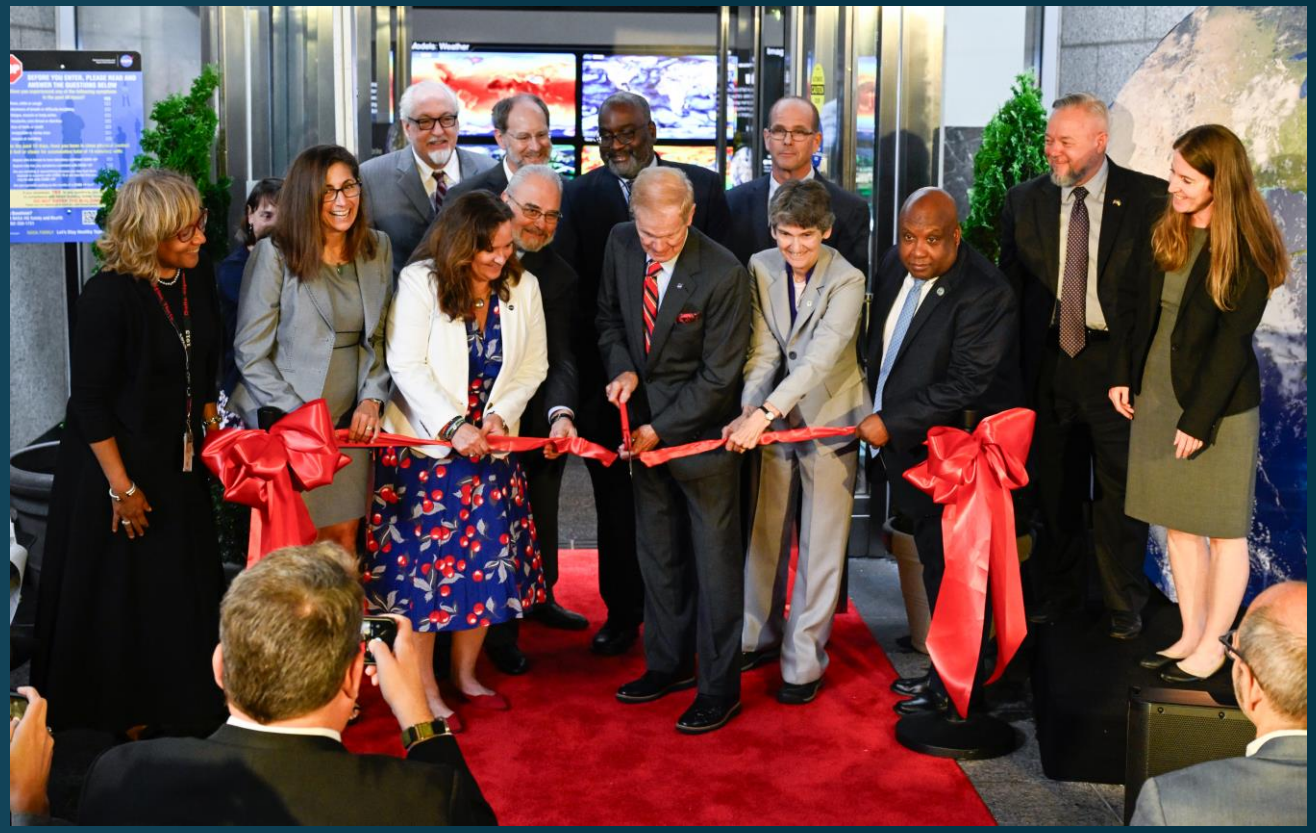
Complement anthropogenic GHG emissions with natural GHG emissions and fluxes

Use Case 3

Identify, and quantify estimates from super emitting events, leveraging aircraft and satellite data.

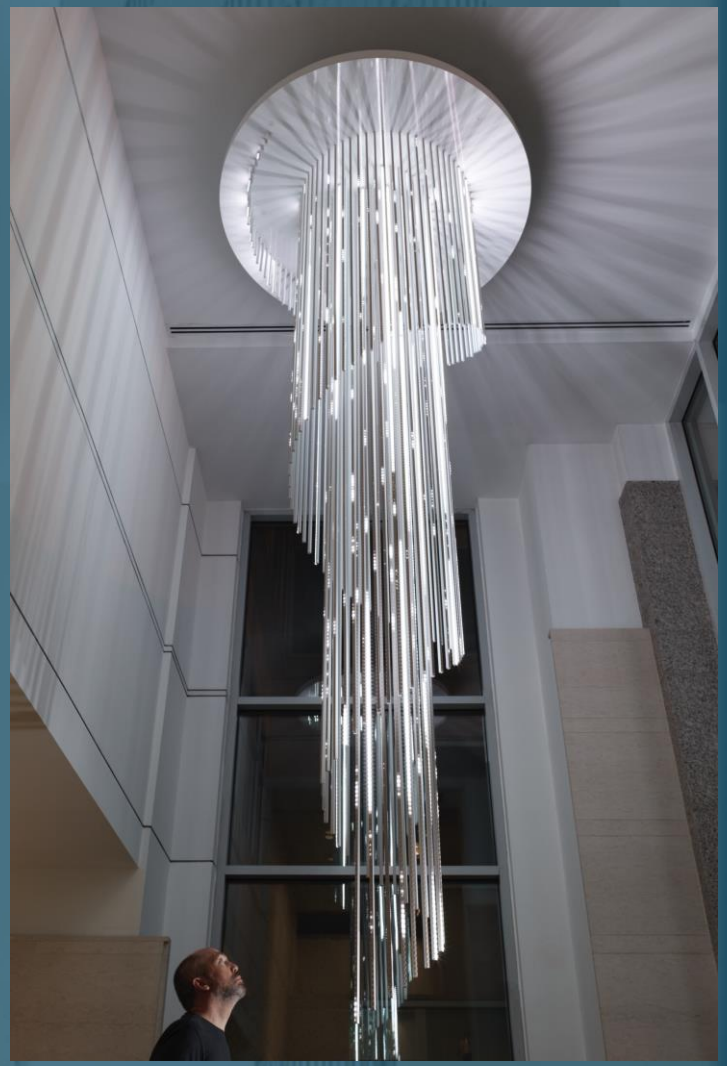
Earth Information Center Now Open

The Earth Information Center (EIC) opened on June 21, 2023, at the Mary W. Jackson NASA Headquarters building in Washington, DC.



NASA created the Earth Information Center with founding partners FEMA, EPA, NOAA, USAID, USDA and USGS. The EIC draws data from research conducted by NASA's centers and government and industry partners.

Earth Information Center



Earth Pulse:
Near real time tracking of data transfer between satellites and Earth

Space for Earth: An immersive installation where viewers can experience Earth's interconnected systems and imagine Earth from Space.

Hyperwall: A 22-foot LED hyperwall framed by two circular 4K screens, featuring videos, dashboards with real-time data on Earth science, and dazzling imagery of our planet.

More EICs Coming Soon!

February 2024: Smithsonian Museum of Natural History EIC opens, featuring a 30' Hyperwall

June 2024: Kennedy Space Center Visitor Complex EIC exhibit opens at the LC-39 Gantry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