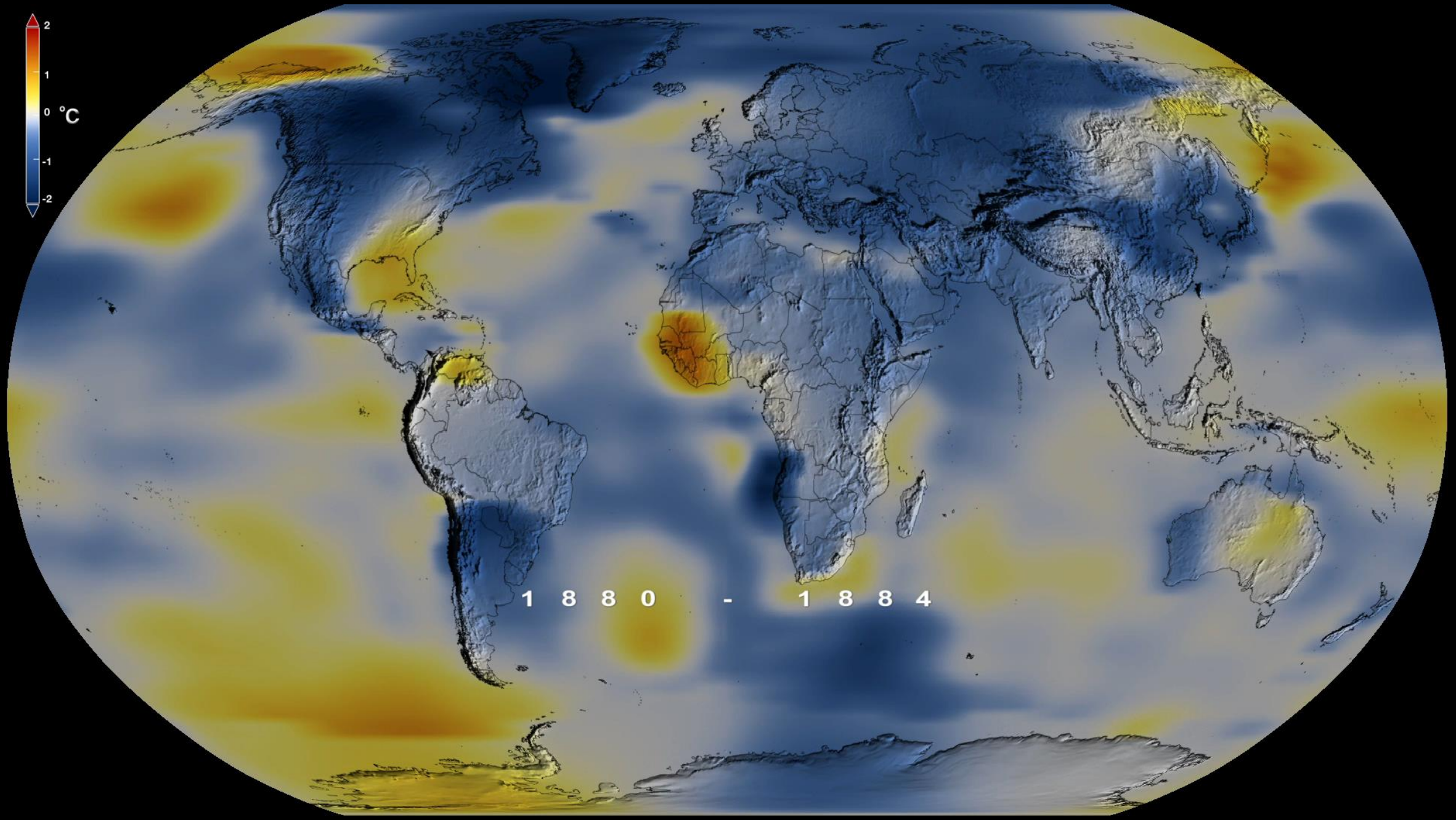
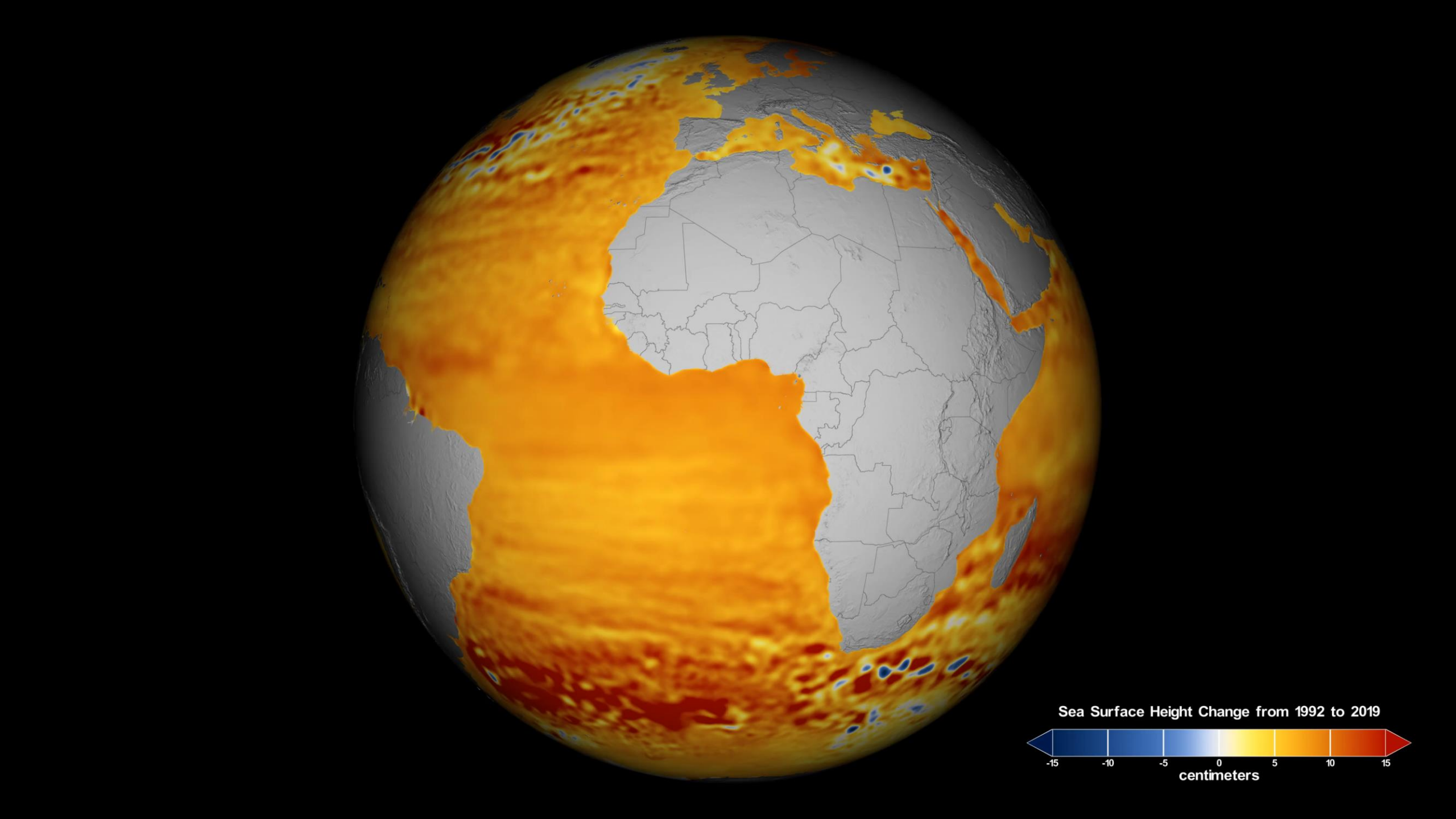
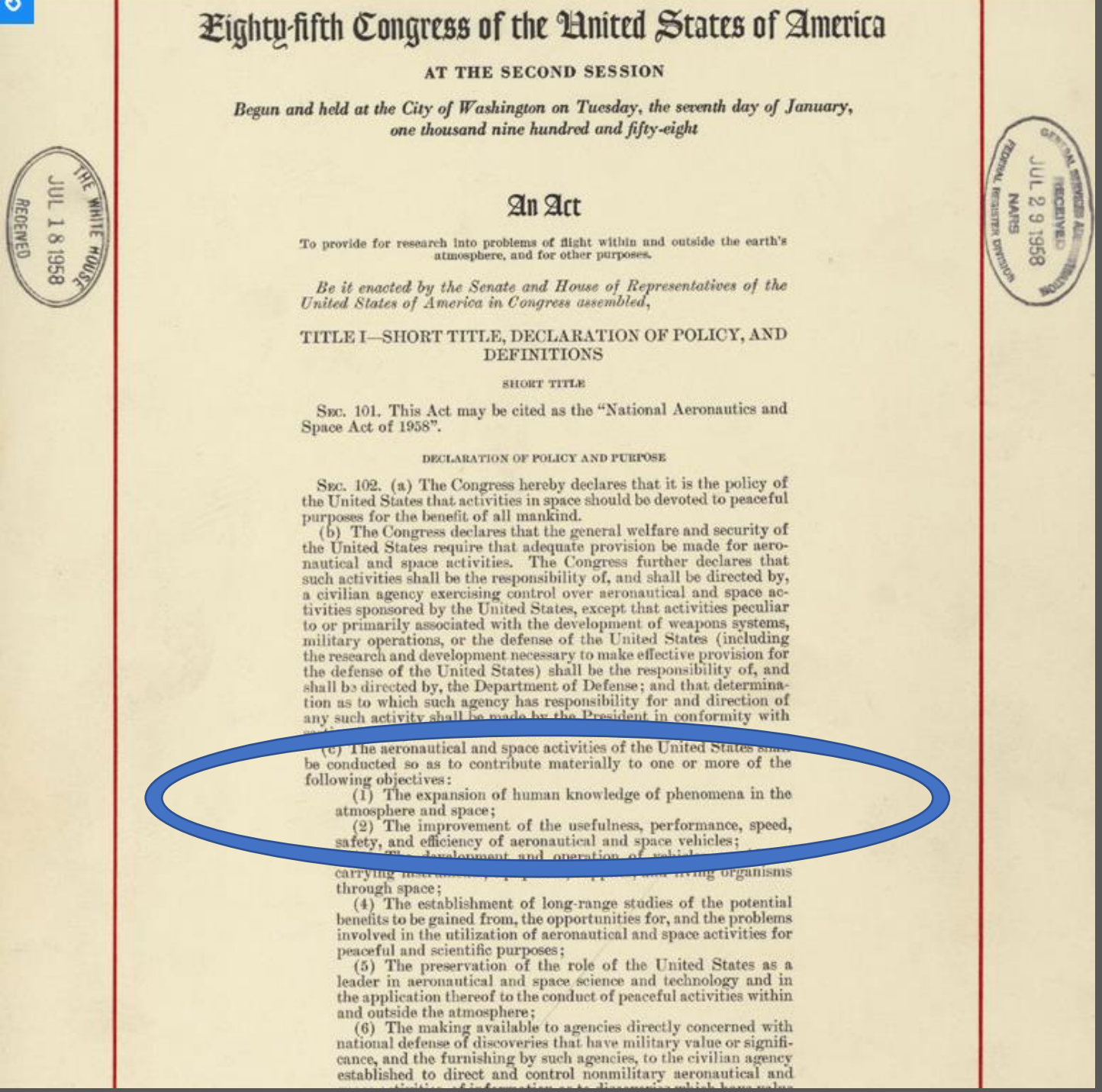
Game-Changing Science with SmallSats and Hosted Payloads

Florence Tan
Chair, Small Spacecraft Working Group
Science Mission Directorate (SMD)
Chair, Small Spacecraft Coordination Group
NASA Headquarters
IGARSS 2022 TIE Kuala Lumpur

Global Temperature Anomalies, 1880-2020




Sea Surface Height Change from 1992 to 2019
-15
-10
-5
0
5
10
15
centimeters



Eighty-fifth Congress of the United States of America

AT THE SECOND SESSION

Begun and held at the City of Washington on Tuesday, the seventh day of January, one thousand nine hundred and fifty-eight

THE WHITE HOUSE RECEIVED JUL 18 1958

GENERAL SERVICES ADMINISTRATION RECEIVED JUL 29 1958 NARS NATIONAL ARCHIVES AND RECORDS SERVICE

An Act

To provide for research into problems of flight within and outside the earth's atmosphere, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

TITLE I—SHORT TITLE, DECLARATION OF POLICY, AND DEFINITIONS

SHORT TITLE

SEC. 101. This Act may be cited as the "National Aeronautics and Space Act of 1958".

DECLARATION OF POLICY AND PURPOSE

SEC. 102. (a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

(b) The Congress declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities. The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with

(c) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles carrying instruments, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and

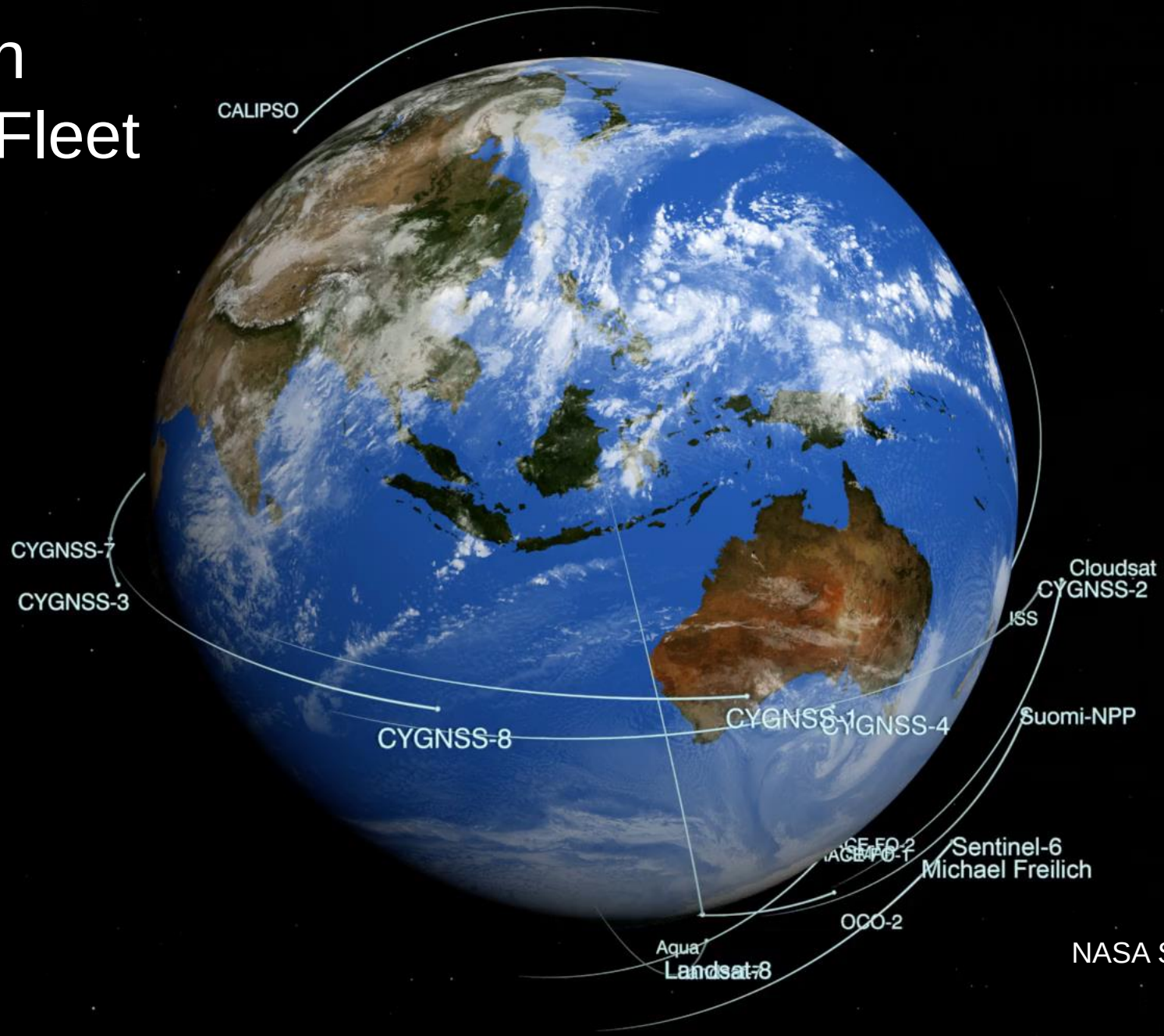
The National Aeronautics and Space Act of 1958,signed by President Dwight Eisenhower on July 29, 1958, and the origins of NASA's mandate for atmosphere and space research -- "NASA shall seek the expansion of human knowledge of phenomena in the atmosphere and space"

NASA Science theme

“Protect and improve life on earth and in space”

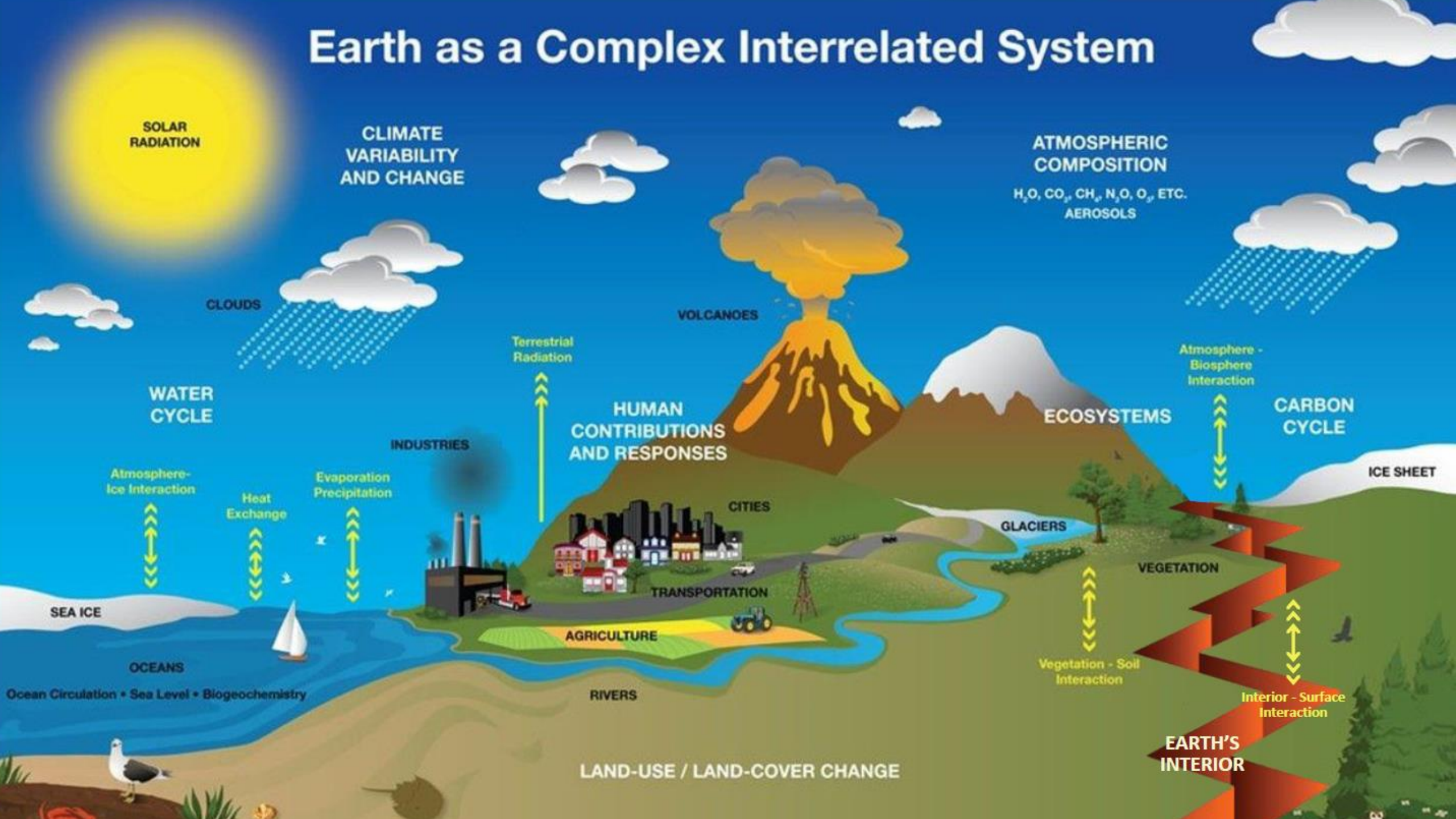
NASA Earth Observing Fleet

Active science partner with **134 nations,** engaged in more than **270 partnership activities**



August 2021

NASA Scientific Visualization Studio
svs.gsfc.nasa.gov/4931

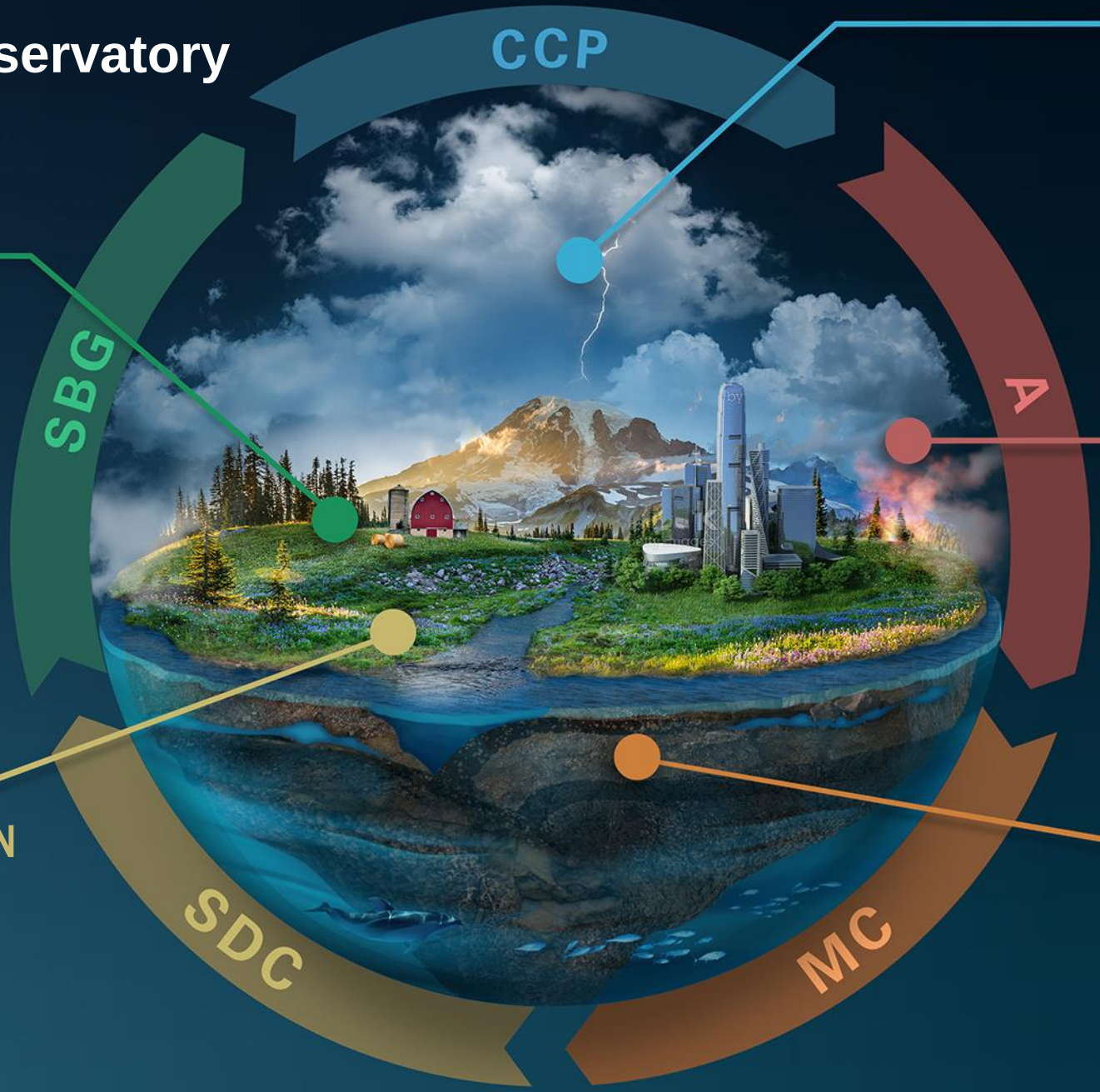

Earth as a Complex Interrelated System
SOLAR RADIATION
CLIMATE VARIABILITY AND CHANGE
ATMOSPHERIC COMPOSITION
H_2O, CO_2, CH_4, N_2O, O_3, ETC.
AEROSOLS
CLOUDS
VOLCANOES
Terrestrial Radiation
WATER CYCLE
HUMAN CONTRIBUTIONS AND RESPONSES
ECOSYSTEMS
Atmosphere - Biosphere Interaction
CARBON CYCLE
INDUSTRIES
ICE SHEET
Atmosphere-Ice Interaction
Heat Exchange
Evaporation Precipitation
CITIES
GLACIERS
VEGETATION
TRANSPORTATION
SEA ICE
AGRICULTURE
Vegetation - Soil Interaction
OCEANS
Ocean Circulation • Sea Level • Biogeochemistry
RIVERS
Interior - Surface Interaction
EARTH'S INTERIOR
LAND-USE / LAND-COVER CHANGE

Response to the accelerating need for information

- Observations
  - Investing in technology innovation
  - Exploring alternative technology platforms
  - Exploring new approaches to industry partnerships/services
  - Expanding collaboration with international partners
- Modeling and informatics
  - Creating data models and framework
    - Temporal scale: minutes to decades
    - Spatial scale: Continents to single fields
- Application and dissemination
  - Working through open science and accessibility to deliver data and information
  - Creating science applications

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

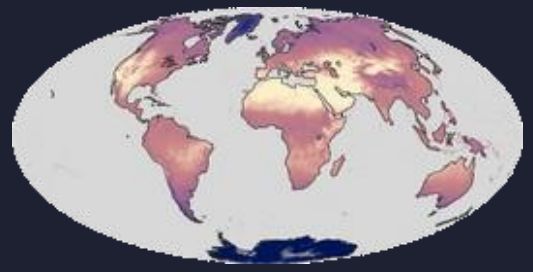
SURFACE BIOLOGY AND GEOLOGY

Earth Surface & Ecosystems

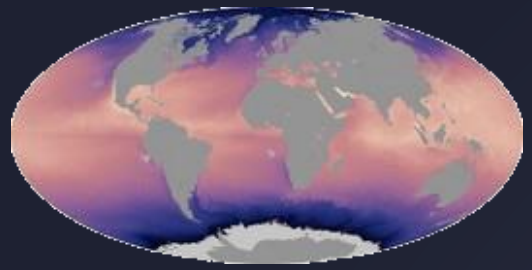
SURFACE DEFORMATION AND CHANGE

Earth Surface Dynamics

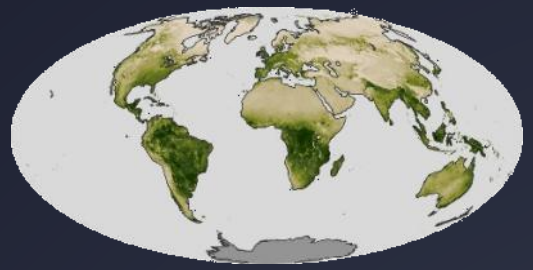
Various Types of Earth Observations



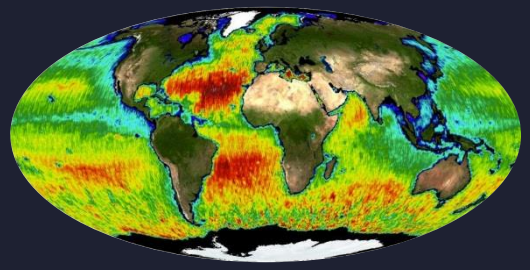
Land Temperature



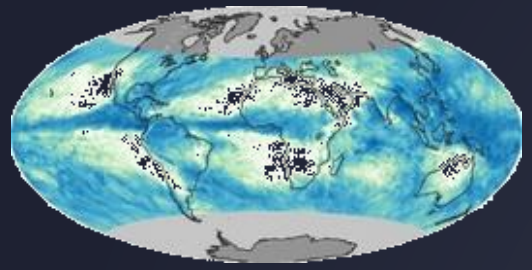
Sea Surface Temperature



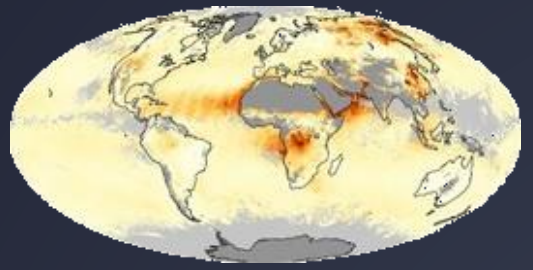
Vegetation



Sea Surface Salinity

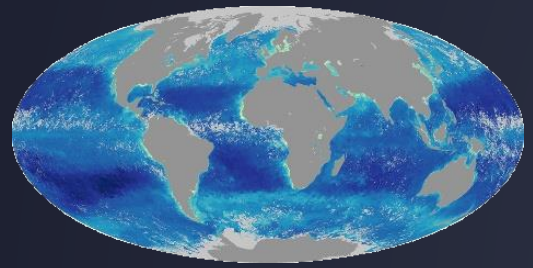


Total Rainfall

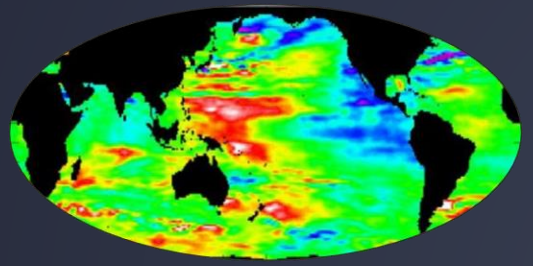


Aerosols

Fires & Thermal Anomalies

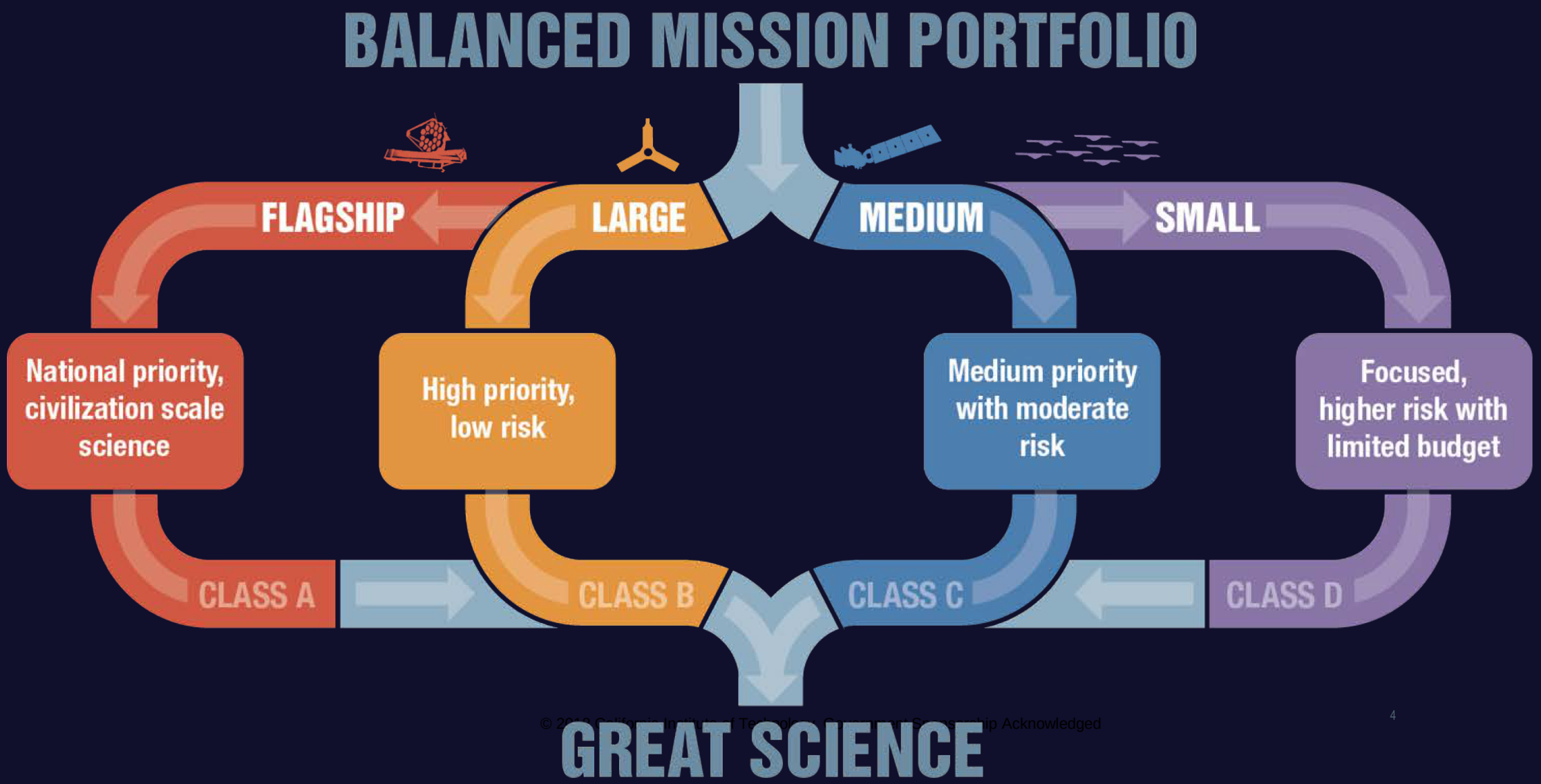


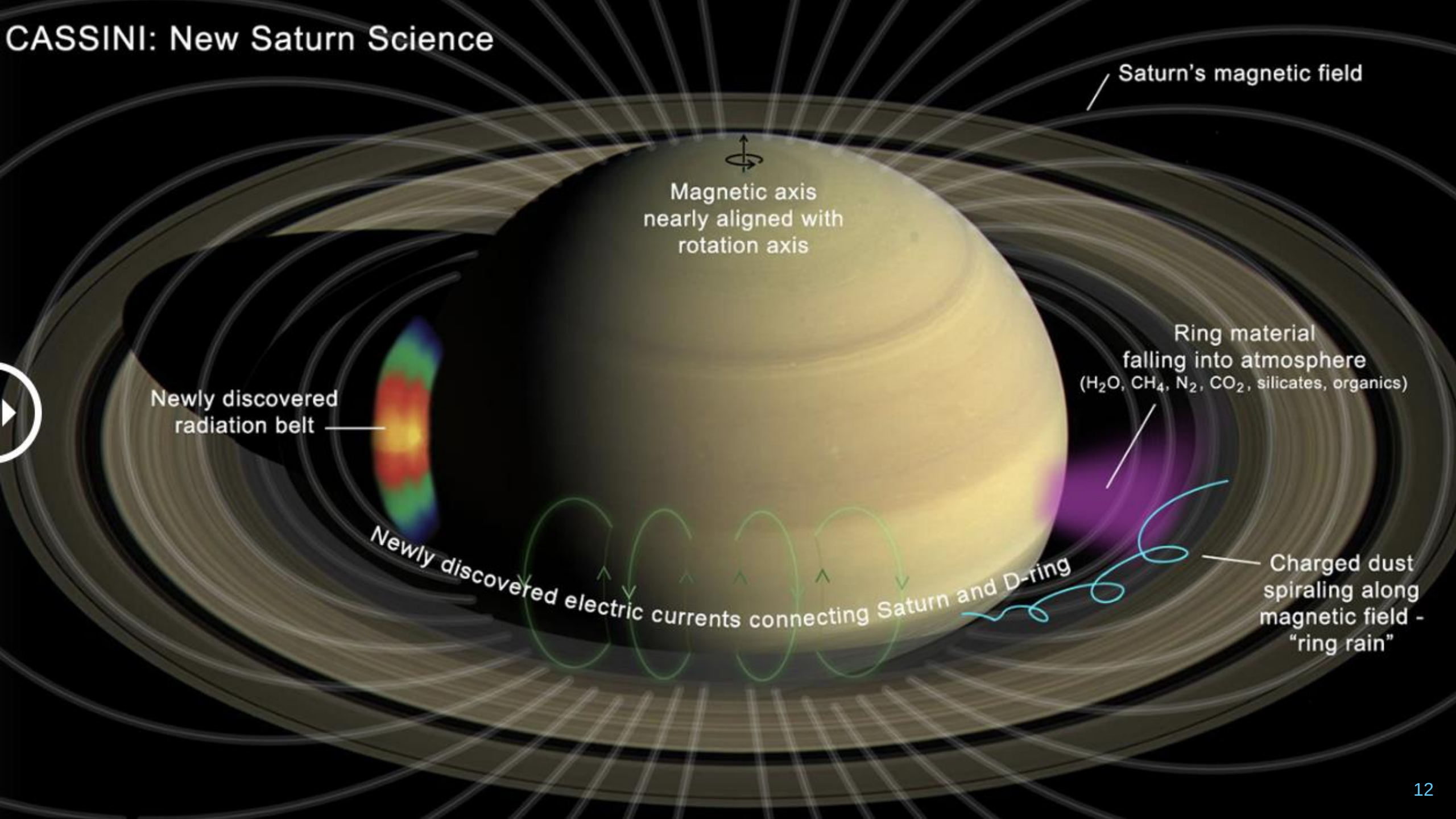
Chlorophyll



Sea Surface Height

NASA Earth Data, Open Access for Open Science: https://earthdata.nasa.gov/



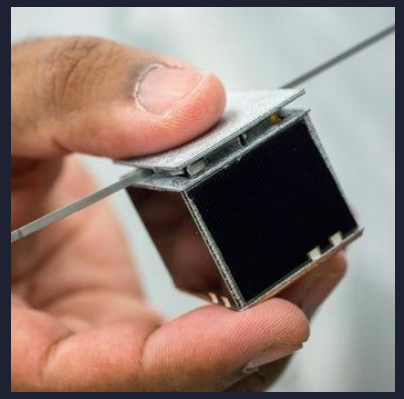

CASSINI: New Saturn Science
Saturn's magnetic field
Magnetic axis
nearly aligned with
rotation axis
Ring material
falling into atmosphere
(H_2O, CH_4, N_2, CO_2, silicates, organics)
Newly discovered
radiation belt
Newly discovered electric currents connecting Saturn and D-ring
Charged dust
spiraling along
magnetic field -
"ring rain"

NISAR as the “trailblazer” ESO mission

NASA-India Space Research Organisation Synthetic Aperture Radar (NISAR)

- Rising capabilities of our strategic partners
- Open and accessible data
- Innovative technology
- 3-Year mission focusing on hazard-prone areas of the globe

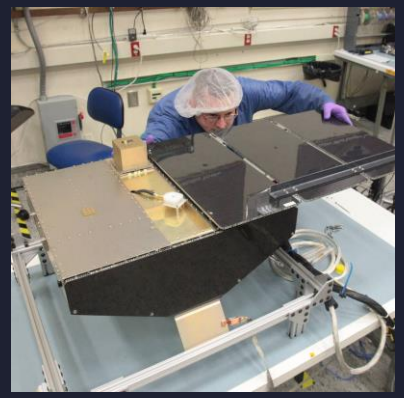
Fundamentals of Small Spacecraft
Spectrum of Satellite Development



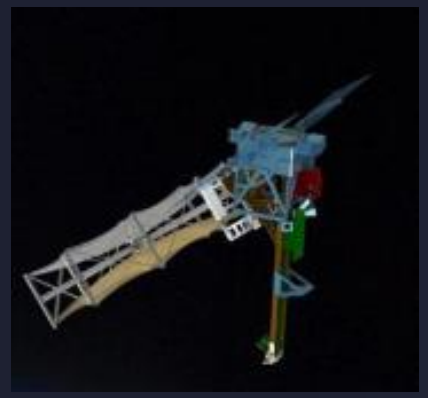
Picosatellite
PocketSat (0.1 – 1 kg)

CubeSat/Nanosatellite
TROPICS 3U/6U (1 – 10 kg)

ESPA-Ring
Payload Port Limit (450 kg)



Microsatellite
CYGNSS (10 – 100 kg)



Small Satellite
INCUS (100 – 500 kg)

SmallSat Definition

A spacecraft that is interface compatible with an SPA Ring, a dedicated small or medium-lift launch vehicle, or a containerized dispenser, and with an upper mass limit of approximately 500 kg

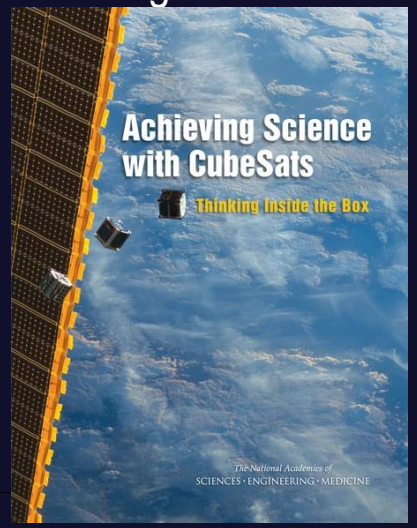
ISS

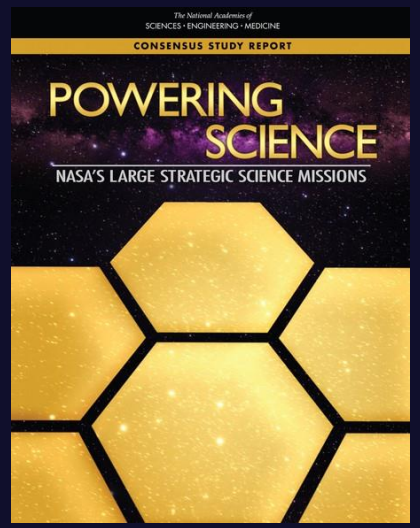
Rideshare

Dedicated

Establishing the Vision for Small Mission Science

Small satellite community can contribute to the scientific and technical rationale for a sustainable, productive, and relevant role within a balanced portfolio of strategic science missions





National Academies and NASA Reports Impact SmallSat/CubeSat Strategy

- NASA formed and chartered a Cross-Agency Coordination Group that Advises AAs on Strategy, Guidance, and Policy For Innovative Small Spacecraft Science and Technology Missions
- SMD, STMD, and SOMD's small spacecraft missions are actively pursuing science, space technology, and strategic knowledge gaps

Science
Hurricane observations via TROPICS constellation

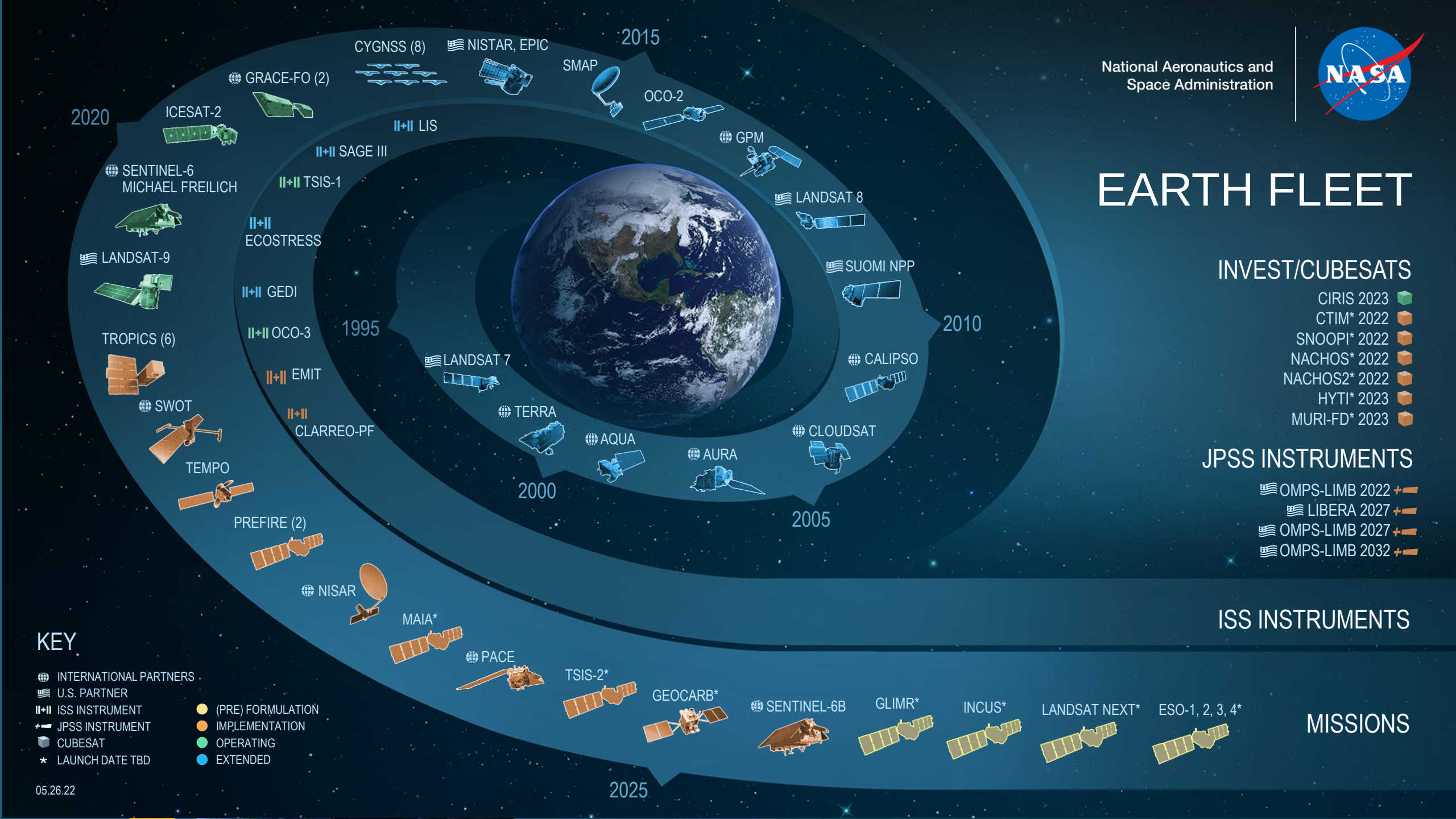
New Observation Methods

Exploration
Lunar volatiles via Lunar Flashlight mission

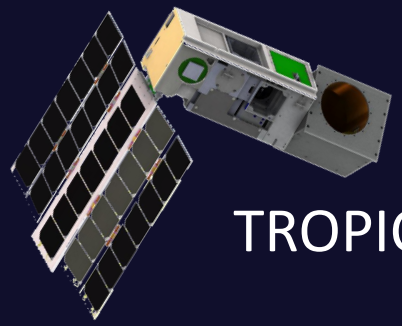
Strategic Knowledge Gaps

Technology
Spacecraft subsystem technology maturation via PTD, TDM, FO, GCD

Spacecraft Subsystems

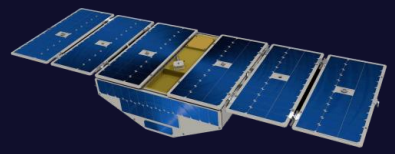

National Aeronautics and Space Administration
NASA
EARTH FLEET
2015
2020
1995
2010
2000
2005
2025
CYGNSS (8)
NISTAR, EPIC
SMAP
OCO-2
GRACE-FO (2)
ICESAT-2
LIS
SAGE III
GPM
SENTINEL-6 MICHAEL FREILICH
TSIS-1
LANDSAT 8
ECOSTRESS
LANDSAT-9
SUOMI NPP
GEDI
TROPICS (6)
OCO-3
LANDSAT 7
CALIPSO
EMIT
SWOT
TERRA
CLOUDSAT
CLARREO-PF
AQUA
AURA
TEMPO
PREFIRE (2)
NISAR
MAIA*
PACE
TSIS-2*
GEOCARB*
SENTINEL-6B
GLIMR*
INCUS*
LANDSAT NEXT*
ESO-1, 2, 3, 4*
INVEST/CUBESATS
CIRIS 2023
CTIM* 2022
SNOOPI* 2022
NACHOS* 2022
NACHOS2* 2022
HYTI* 2023
MURI-FD* 2023
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
05.26.22

SmallSats produce big science



TROPICS

- Constellation of 6 3U CubeSats.
- Scanning microwave radiometers will measure temperature, humidity, precipitation, and cloud properties.
- The CubeSats will be launched into three separate orbital planes to enable the overall constellation to monitor changes in tropical cyclones as frequently as every 21 minutes.

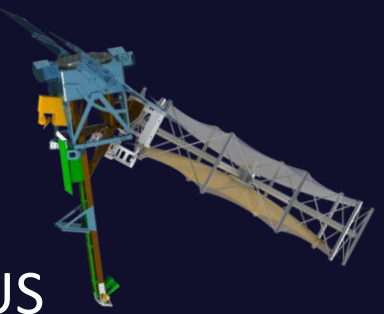


CYGNSS

- Constellation of 8 SmallSats.
- Uses GPS to measure wind speed over oceans to help understand and predict hurricanes and typhoons.
- Successive satellites pass over the same region every 12 minutes.
- Interaction with GPS results in a new image of wind speed over the entire tropics every few hours, compared to every few days for a single satellite.

PREFIRE

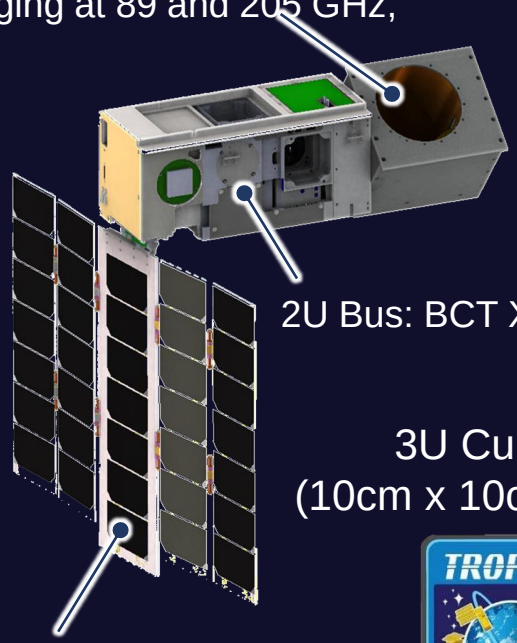
- 2 6U CubeSats
- Will systematically map Earth's far-infrared emission spectrum for the first time and observes the spectral fingerprints of surface and atmospheric processes.
- Will improve polar climate prediction by interfacing directly with ice sheet and climate models.



INCUS

- Constellations of 3 SmallSats.
- Make the first ever tropics-wide measurements of CMF to understand why, when, where tropical convective storms form, and why only some storms produce extreme weather.
- Evaluate relationship of CMF and environmental factors, high anvil clouds, and extreme weather in weather and climate models.

Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of SmallSats (TROPICS)

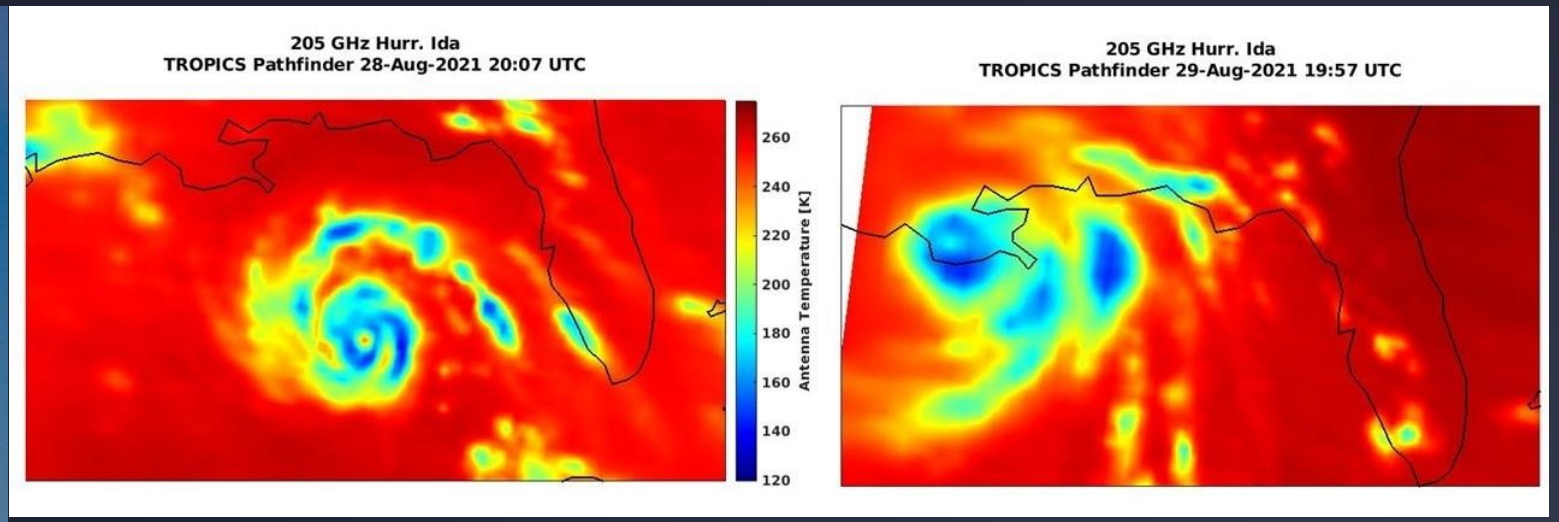


TROPICS Science

- Relates co-evolving precipitation structure, upper-level warm core and storm intensity changes
- Relates the occurrence of intense precipitation cores (convective bursts) to storm intensity evolution
- Relates environmental moisture measurements to coincident measures of storm structure (including size) and intensity
- Assimilates microwave radiances and/or retrievals in mesoscale and global numerical weather prediction models to assess impacts on storm track and intensity

- Constellation consists of 6 CubeSats in three orbital planes (30° Inclination / 550 km Altitude) with a 1-year operational life; launch in 2022
- Median revisit rate of 50 minutes
- Pathfinder Space Vehicle launched w Momentus' Vigoride in June 2021
- PI: William Blackwell/MIT

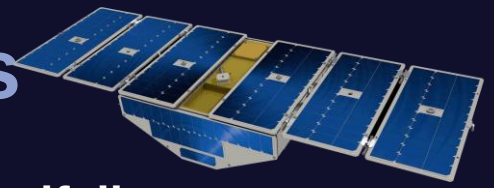
TROPICS Pathfinder (Qualification Unit) Launched June 30, 2021



Imagery of Hurricane Ida Before/After Landfall @ 205 GHz

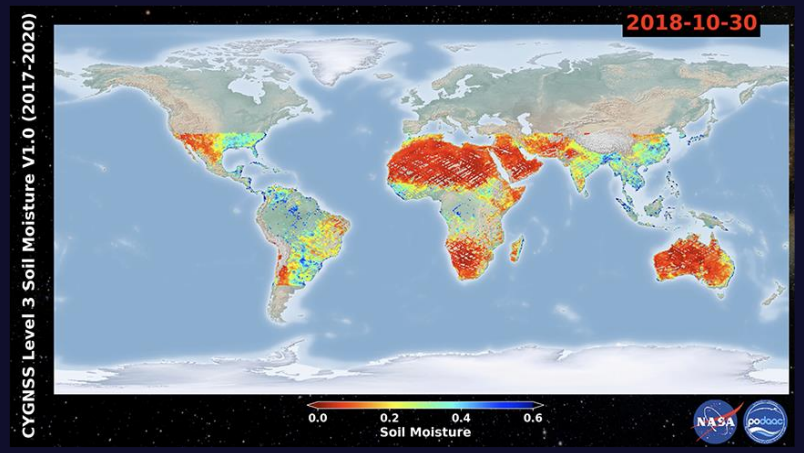
- Sun-synchronous orbit; 530 km altitude; 2:00 pm LTDN
- Satellite has been contacted and in excellent health
- Bus and Payload commissioning began in July and August
- Performance is excellent!
- NOAA-funded low-latency experiment to be conducted in October
- Data will be available to general public via GES-DISC

CYGNSS Scientific Results and Applications



Daily soil moisture data product

- Oct. 30, 2018



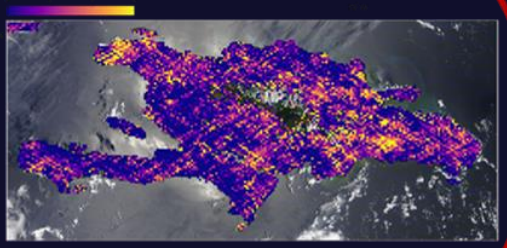
Map flood inundation after hurricane landfall

- Reflectivity before and after Hurricane Isaias landfall, July-August 2020

Before landfall

After

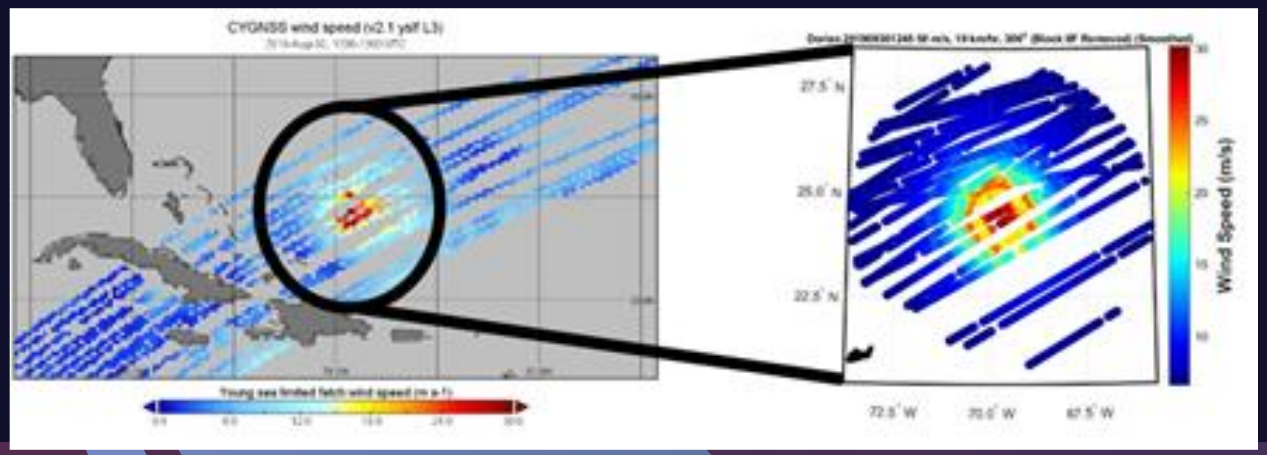
Delta

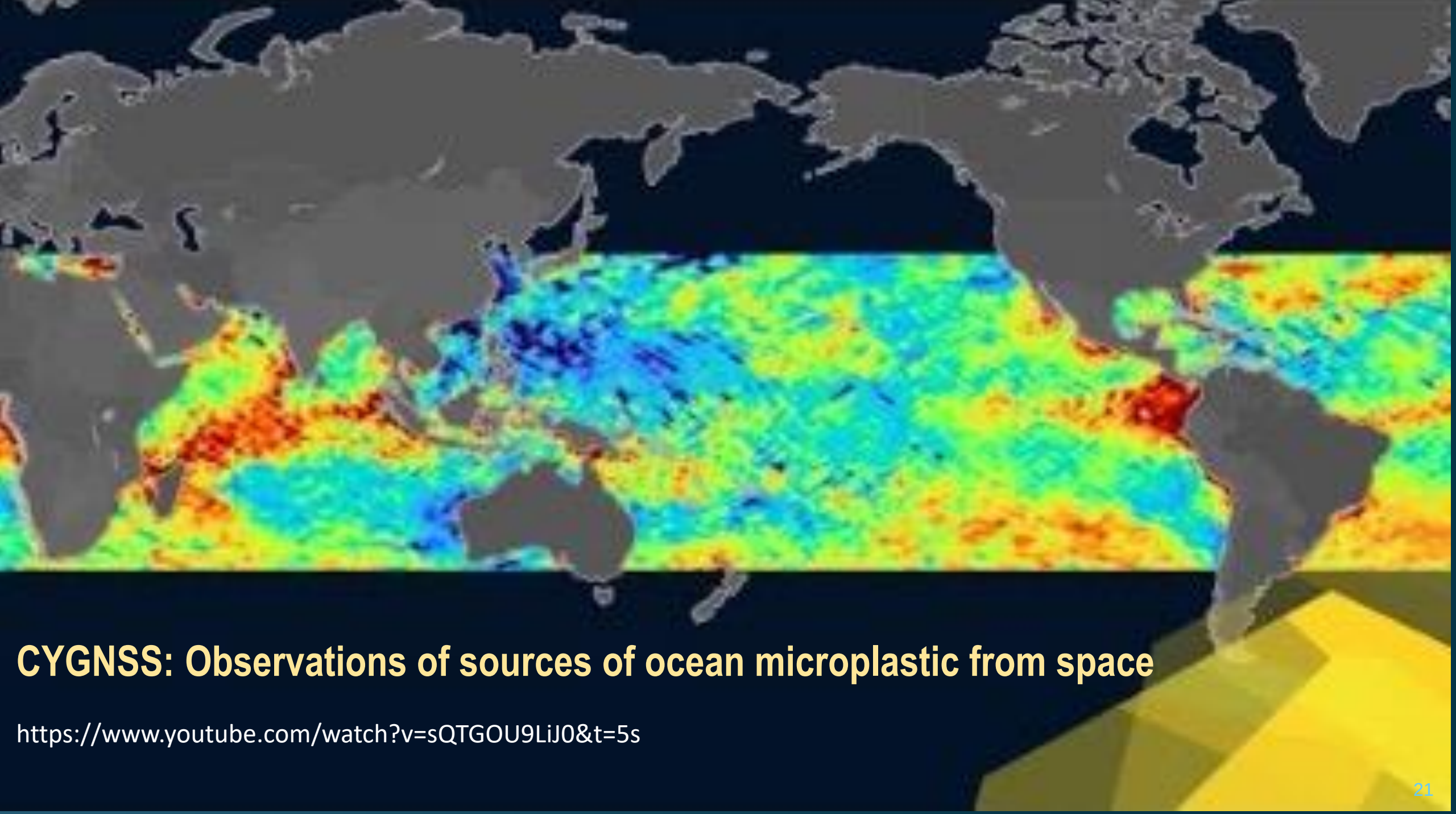


Extensive flooding in
the Dominican Republic

Measure winds in tropical cyclones

- Hurricane Dorian overpass, Aug. 30, 2019 at 02:45 UTC





CYGNSS: Observations of sources of ocean microplastic from space

https://www.youtube.com/watch?v=sQTGOU9LiJ0&t=5s

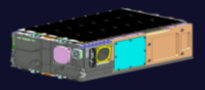
Polar Radiant Energy in the Far-Infrared Experiment (PREFIRE)

https://prefire.ssec.wisc.edu

Anticipated Timeline

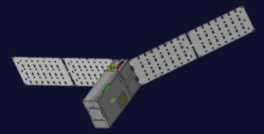
Fall 2022

Deliver to Launch Provider



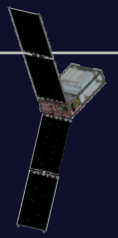
Launch to Polar Orbit
D = 0

Solar Array Deployment
D = +30 minutes



Up to 90 days

Detumble and Sun Acquisition



Checkout
BUS commissioning
TIRS commissioning
Nominally 30 days

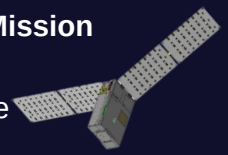
1 year

Nominal Operations
Continuous data collection
Downlink up to 4x to KSAT Lite Stations

Facts and Firsts

- PREFIRE systematically maps Earth's far-infrared emission spectrum for the first time.
- PREFIRE observes the spectral fingerprints of surface and atmospheric processes using two satellites.
- PREFIRE science data is collected entirely by two 6U CubeSats.
- PREFIRE improves polar climate prediction by interfacing directly with ice sheet and climate models.

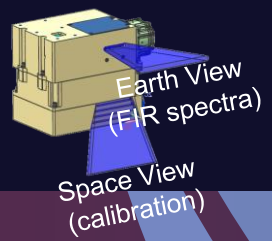
Spacecraft and Mission

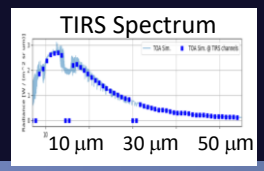


2 6U CubeSats
470-540 km altitude
82-98° inclination
1 year nominal lifetime

Thermal InfraRed Spectrometer (TIRS)

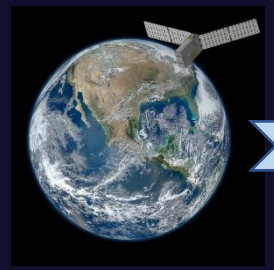
- 5 to 54 mm spectral range
- 0.84 mm sampling
- 8x64 spatial x spectral channels
- Size: 3U Mass: 3 kg Power: 4.5 W



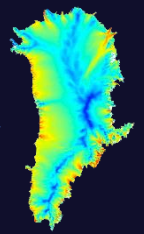


PREFIRE Science

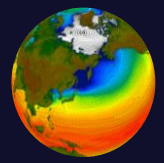
- PREFIRE connects observations, analyses, and models to improve polar climate prediction including rates of Arctic warming, sea ice decline, and ice sheet melt.



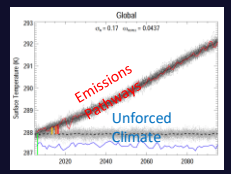
OBSERVE



ANALYZE



MODEL



PREDICT

Overlapping Measurements

- Co-located ground scenes separated by 1-12 hours.

Principal Investigator: Tristan L'Ecuyer, University of Wisconsin

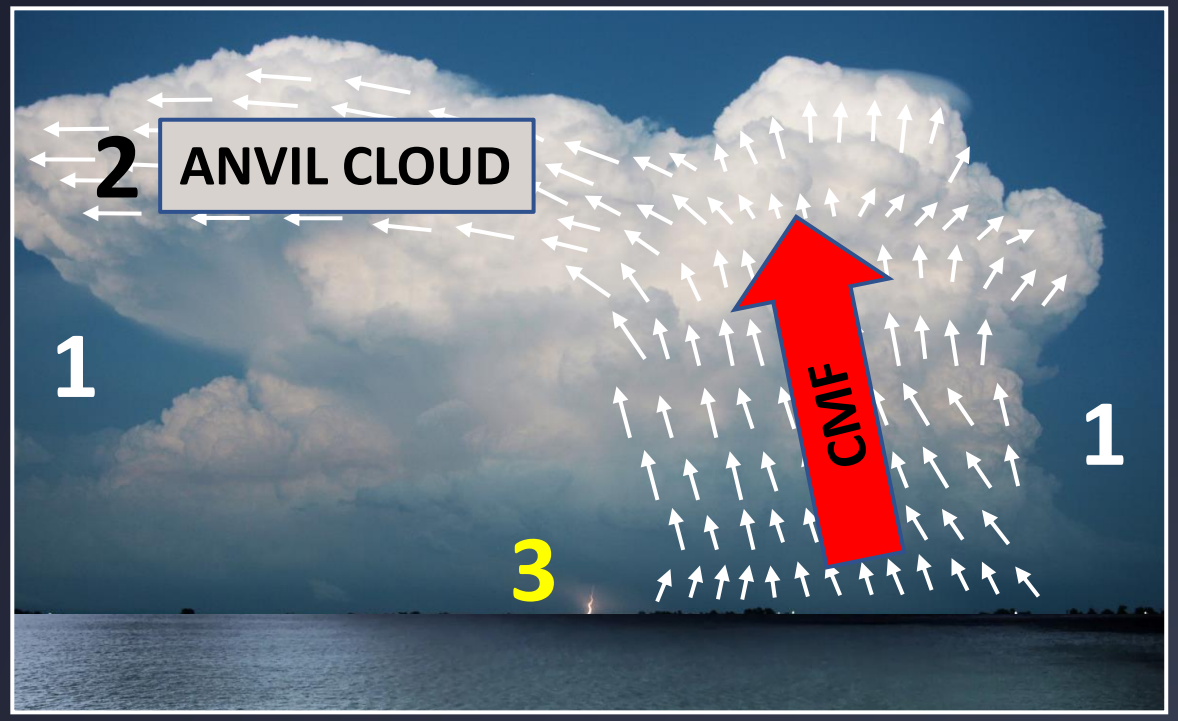
INCUS Investigation of Convective Updrafts

INCUS Goal

To understand why, when, where tropical convective storms form, and why only some storms produce extreme weather.

- *Storms begin with rapidly rising water and air that create towering clouds primed for rain, hail, and lighting.*
- *The greater the mass of water and air that is transported upwards, the larger the risk of extreme weather.*
- *This vertical transport of air and water, known as convective mass flux (CMF), remains one of the great unknowns in weather and climate.*
- *Systematic CMF measurements would improve the representation of storm intensity and constrain high cloud feedbacks in weather and climate models.*

NASA's Storm Chaser

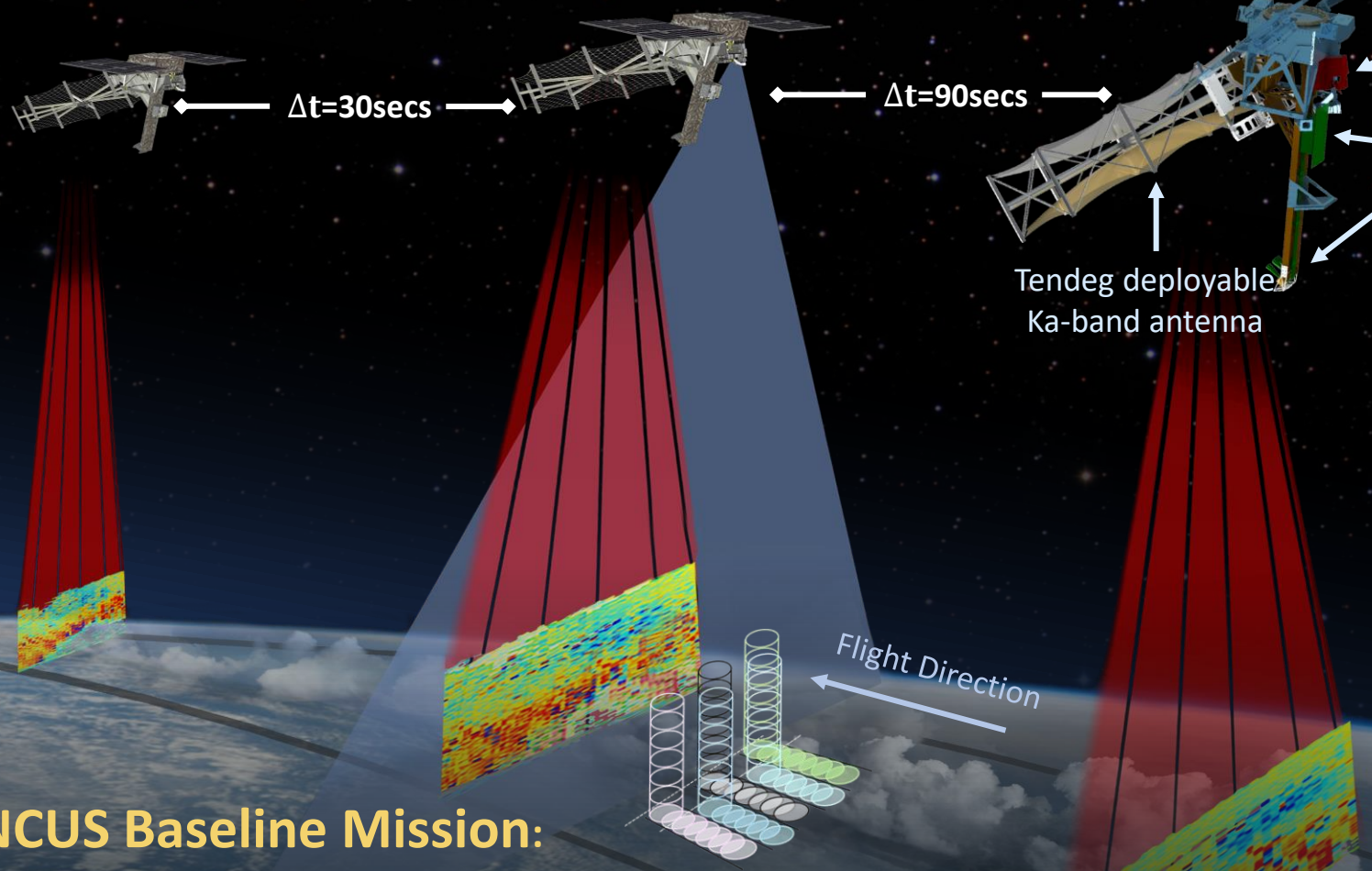


Science Objectives

To determine:

1. The predominant environmental properties (RH, temperature, wind shear) controlling CMF in tropical convective storms;
2. The relationship between CMF and high anvil clouds (critical to cloud-climate feedbacks);
3. The relationship between CMF and the type (lightning, rainfall) and intensity of the extreme weather produced; and
4. Evaluate these observationally determined relationships between CMF and environmental factors, high anvil clouds, and extreme weather in weather and climate models.

INCUS Investigation of Convective Updrafts



PI: Susan van den Heever, CSU
Deputy PI: Ziad Haddad, JPL
Project Scientist: Simone Tanelli, JPL

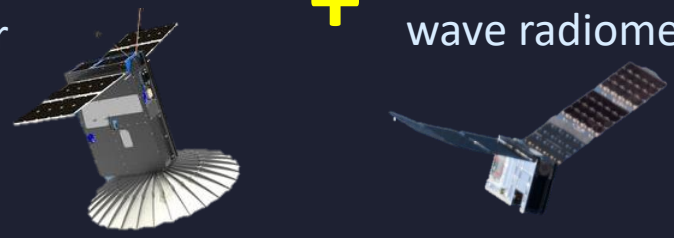
Mission Management & Participating Organizations
CSU: PI Org, Science Data Processing
JPL: Instruments & Mission Management
Tendeg: Deployable Antennas
BCT: Spacecraft, Mission Ops
CCNY, GSFC, MSFC, NOAA, SBU, TAMU: Science Co-Is

Colorado State University
NASA Jet Propulsion Laboratory California Institute of Technology

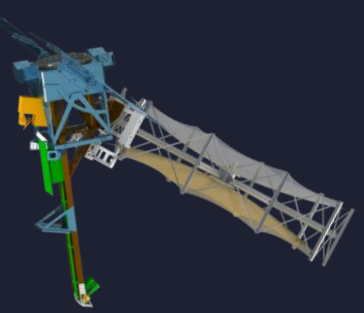
The INCUS Baseline Mission:

- Flies 3 SmallSats carrying RainCube-like radars with cross-track scanning capabilities and a TEMPEST-D-like radiometer
- Applies a novel time-differencing (Δt) approach
- Provides the first ever tropics-wide measurements of CMF

RainCube Ka-band radar + TEMPEST-D mm-wave radiometer



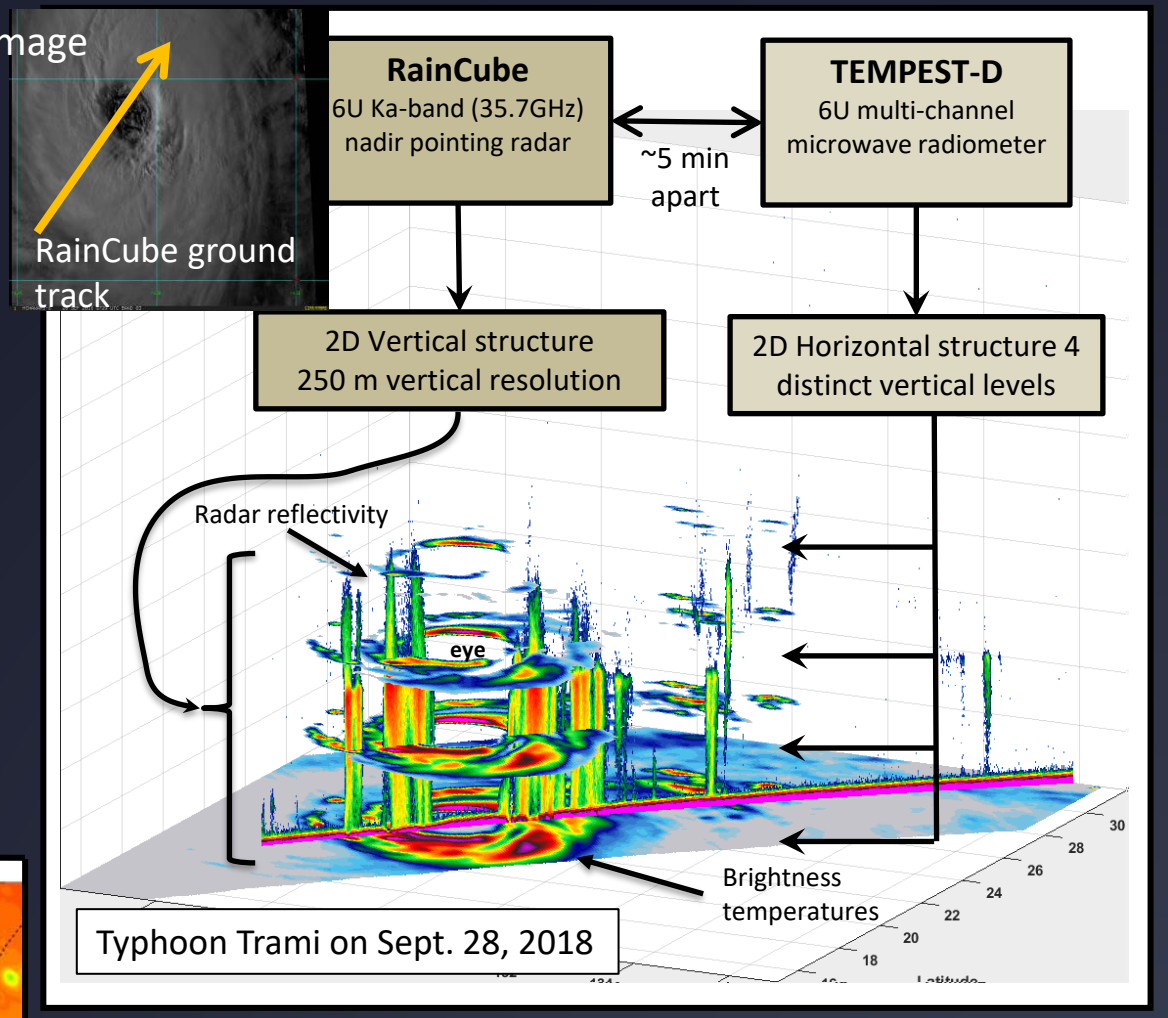
INCUS

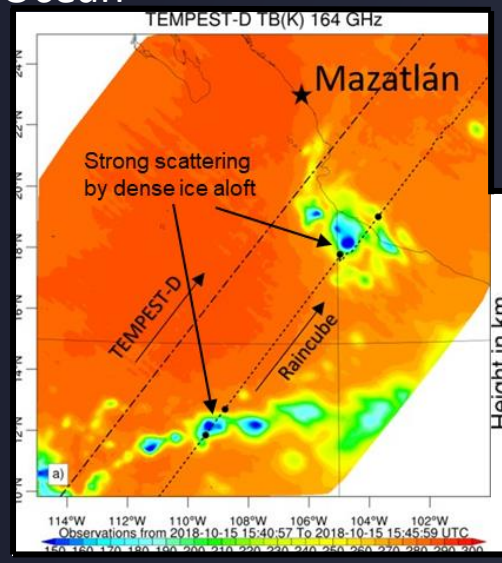


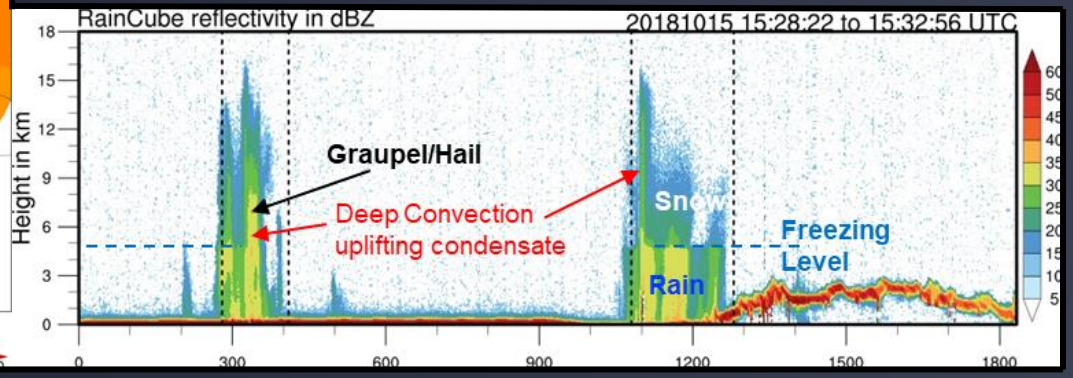
INCUS draws on the strengths of BOTH RainCube and TEMPEST-D to provide unprecedented vertical and horizontal views of storm structure and processes.

Figures and animations by Simone Tanelli, Shannon Brown and Steve Reising

(Right) On September 28, 2018, TEMPEST-D and RainCube overflew Typhoon Trami < 5 minutes apart (Bottom) Correlated storm measurements from RainCube radar and TEMPEST-D radiometer over Texas, Mexico and Pacific Ocean







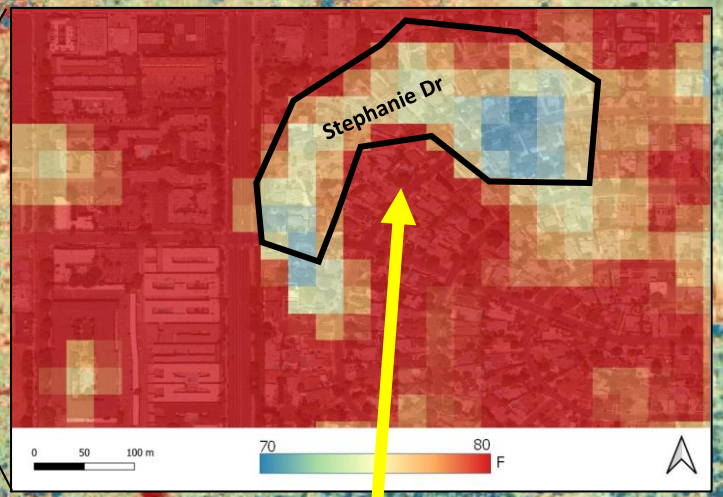
Hosted Payloads and Commercial Data deliver data for science understanding to meet the needs of our communities

Investments in Commercial Data Buys

President's Budget double investments on commercial data buys

- NASA Earth Science analysis demonstrated the usefulness of commercial data and imagery
- Commercial SmallSat Data Acquisition Program (Continuous and repeatable process to onramp commercial data)
- Standardizing End User License Agreements

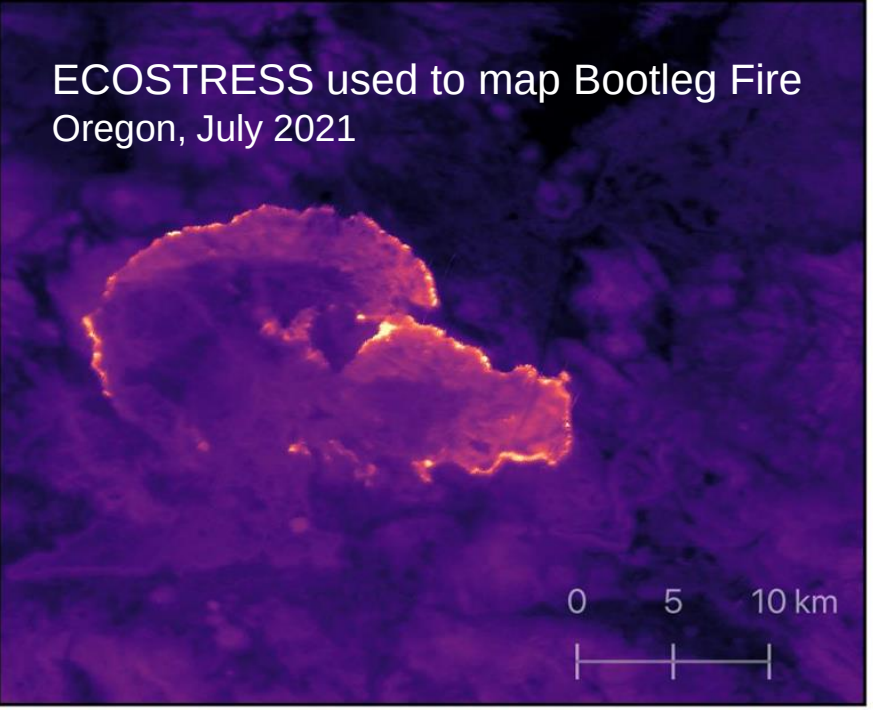
The City of Los Angeles is using ECOSTRESS to identify hotspots and quantify the effects of heat mitigation strategies such as cool roads

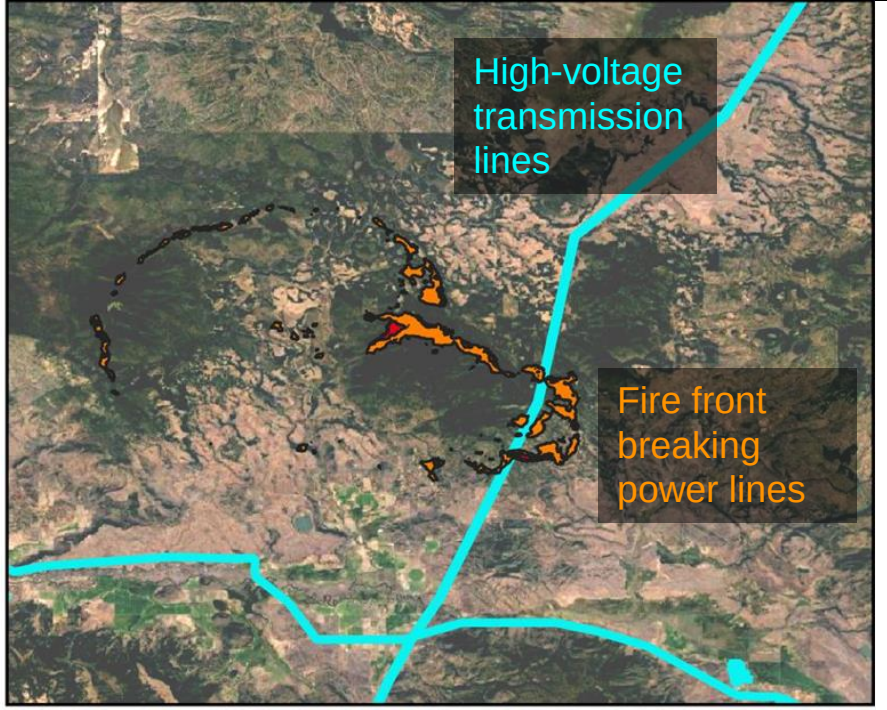


City of Los Angeles is testing road surface coatings to minimize urban heat. ECOSTRESS shows cooling effect on local streets.

***"I call this the 4 million dollar image"* – Greg Spotts, City of Los Angeles**

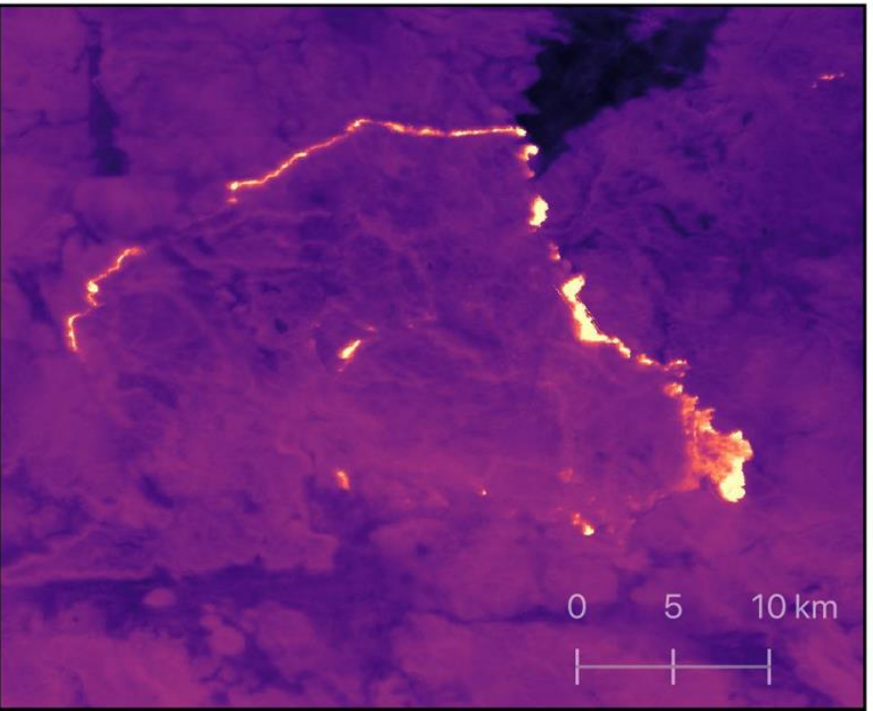
ECOSTRESS imagery used by City of LA to secure funding for urban heat mitigation solutions for heat-vulnerable neighborhoods

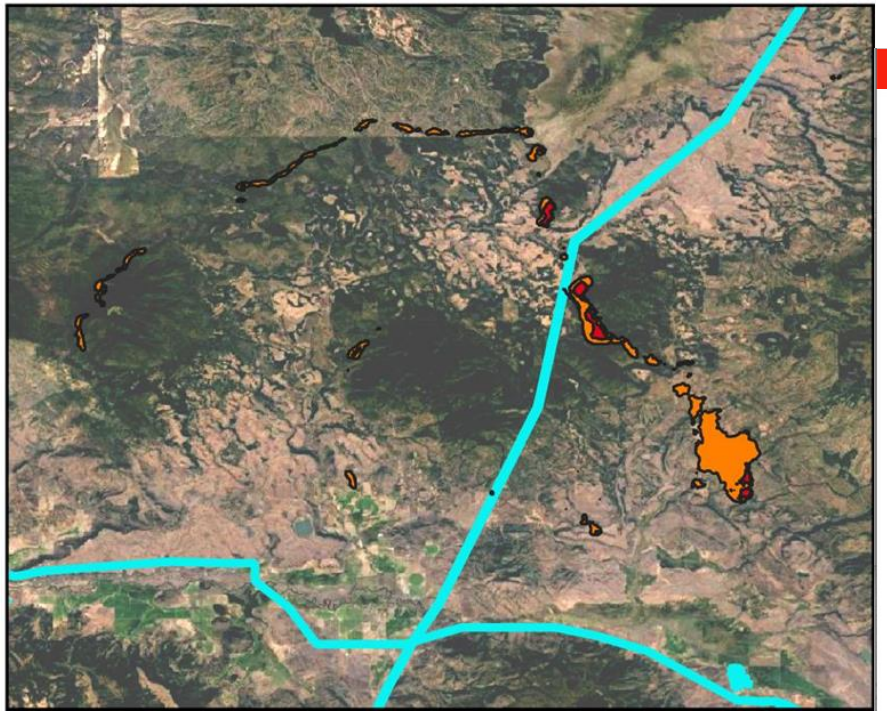




"ECOSTRESS allows us to use the [fire maps] from last night in the morning…this is what's required if you're going to put data into the hands of incident commanders." -- USGS podcast with PNNL and USFS

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





ECOSTRESS helps deliver irrigation advisories to farmers in 25 countries around the world

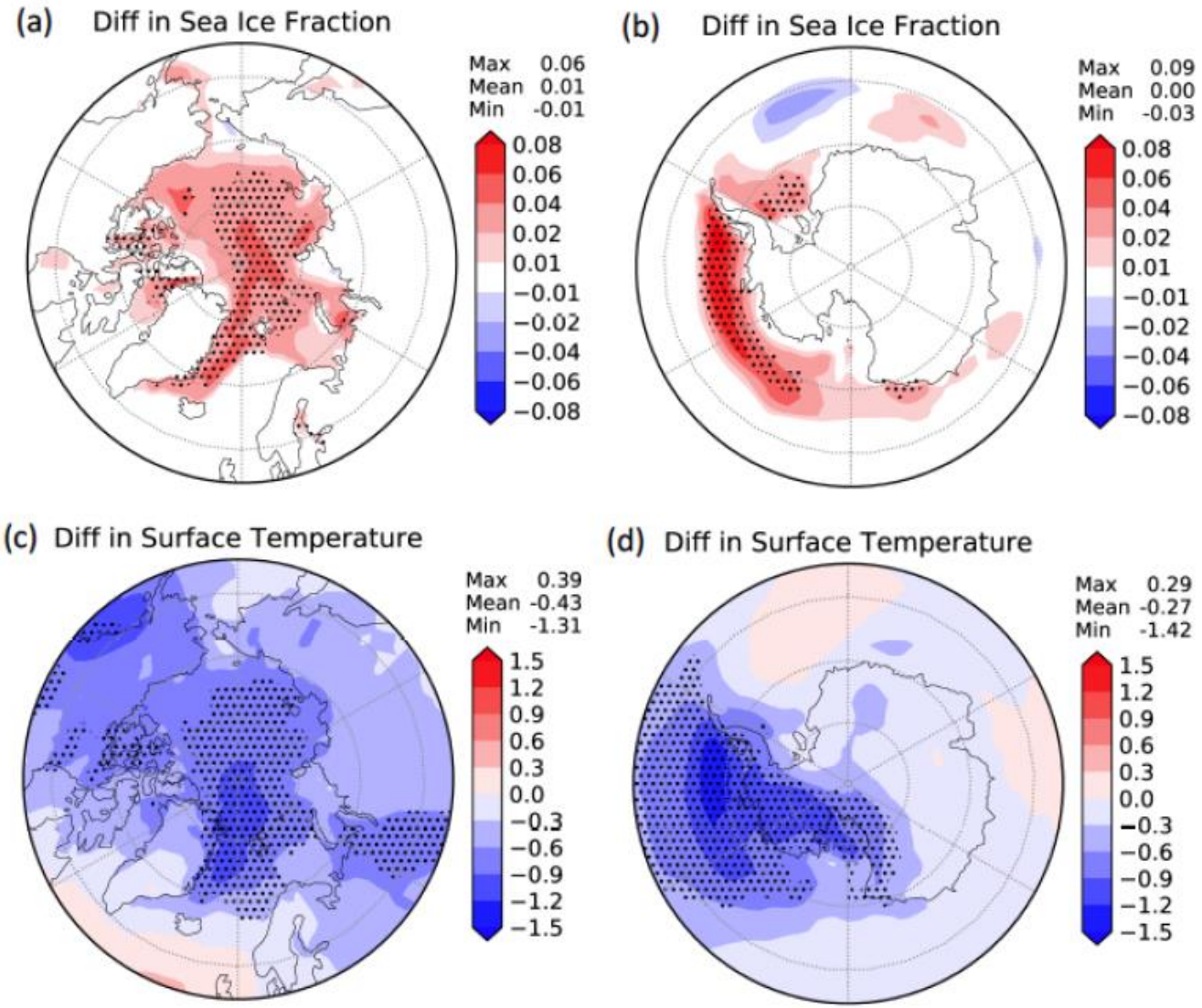
IrriWatch

“Using Landsat thermal data only is no option. Until SBG, LSTM and TRISHNA are online, ECOSTRESS is an absolute necessity.”

Irriwatch CEO, Wim Bastiaanssen (PhD)

Solar Irradiance Spectrum Has Significant Impacts on Arctic Sea Ice Fraction and Surface Temperature

(Jing, et al., *Journal of Climate*, 2021)



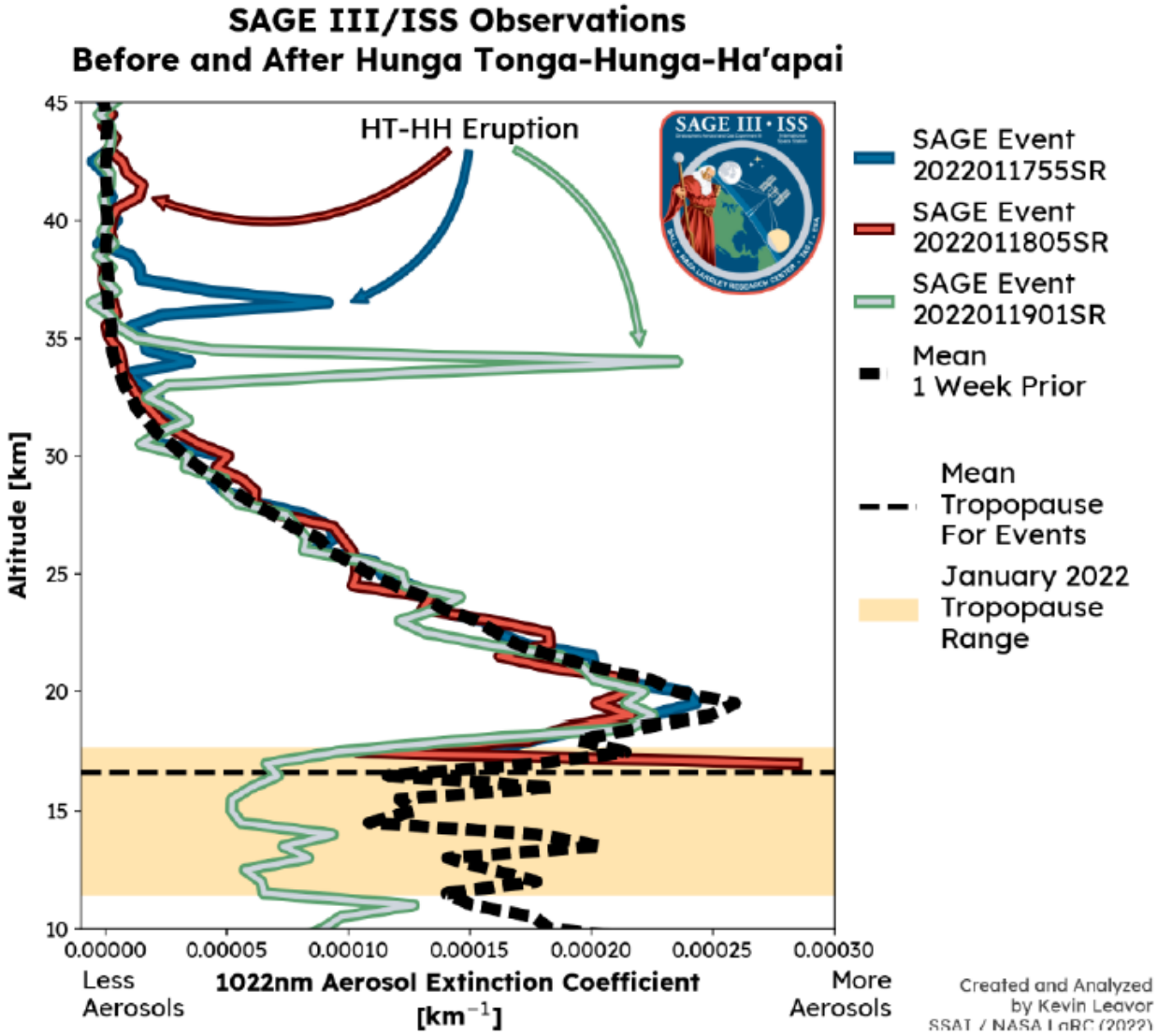
NCAR CESM2 Simulations

Method: The recent TSIS-1 mission has provided more accurate SSI observations than before. The SSI difference in a given VIS or NIR band can be as large as 4 W m^{-2}.

Impact: The results show that, due to different spectral reflectance of sea ice and water surfaces in the VIS and NIR, the set of simulations with more SSI in the VIS has less solar absorption by the high-latitude surfaces, ending up with colder polar surface temperature and larger sea ice coverage.

Hunga Tonga-Hunga Ha'apai Eruption

- Spectacular Hunga Tonga-Hunga Ha'apai undersea volcanic eruption hurled ash, water and volcanic gases tens of thousands of meters into the sky
- SAGE III/ISS observed (Jan 2022) aerosols as high as 42 km; surpassing SAGE II record for the Mt. Pinatubo eruption (Jun 1991), which was the largest in the satellite era
- Water vapor within stratospheric eruption plume 10-30 times normal
- Stratospheric aerosols from this eruption, which shade/cool the Earth's surface, projected to have a slight effect
- More uncertain outcome is potential reduction in ozone facilitated by aerosols and perturbation of large-scale atmospheric dynamics by exceptionally moist layer
- SAGE continued observations supplying vital information for scientist to forecast future impacts



Using UAS for routine large-scale environmental monitoring

Medium altitude, long endurance (MALE) UAS are able to survey large areas at low/medium altitude providing unique opportunities to obtain high resolution data with flexible flight paths and observation strategies.

In fall 2021, NASA successfully tested this type of UAS to monitor sea ice conditions in the Arctic:

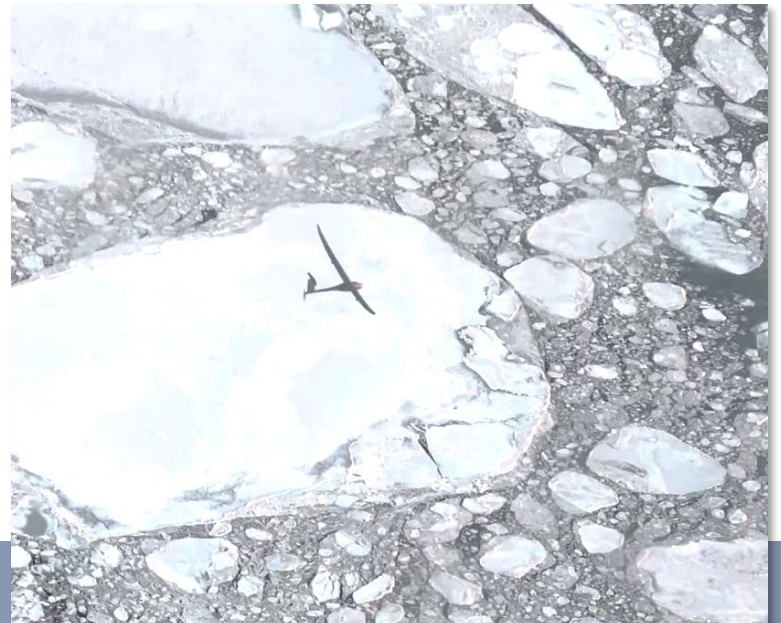
- **UAS:** Platform Aerospace LLC Vanilla aircraft (wing span of ~12 m; endurance up to 10 days; payload capability: 40 lb).
- **Payload:** radar developed by the University of Kansas that measures the snow depth on sea ice.

The system underwent modifications and special testing for operation at very cold temperatures.

While not yet mature enough of routine operations…

⇒ Path towards ”green aviation”
(average fuel economy = ~250 miles per gallon; 2lb per hour)
⇒ Potential low-cost alternative to crewed aircraft

Other potential applications for this type of UAS are monitoring of coastal waters, large-scale surveys of forest conditions (for example, early wild fire detection), observations of very remote locations etc.



High Altitude Long Endurance Experiments (HALE-X1)

Persistent IR imaging of wildfires

A USFS-NASA partnership with Swift Engineering to demonstrate IR observations for weeks to months using next generation solar-electric UAS

Goals:

- Provide **continuous realtime updates on fire location** and perimeter to save lives and property and improve fire management.
- Demonstrate technical and procedural feasibility of the concept of operations, logistics, and cost of operations for HALE UAS.
- Identify barriers to introducing this capability across the Nation for disaster response.

Swift Ultra Long Endurance UAS releasing from launch vehicle during first flight in July 2020 in New Mexico
The vehicle was designed to stay aloft for 30 days at 20km with a 5kg payload.

VIS-SWIR-LWIR payload
(Sensor Labs and Lucent)

NASA SBIR funded platform; NASA Ames is supporting Airworthiness/Safety and Airspace Integration with NASA ASP Project management

USDA/USFS/NIFC funded the payload development, integration and flight demonstration from New Mexico SpacePort

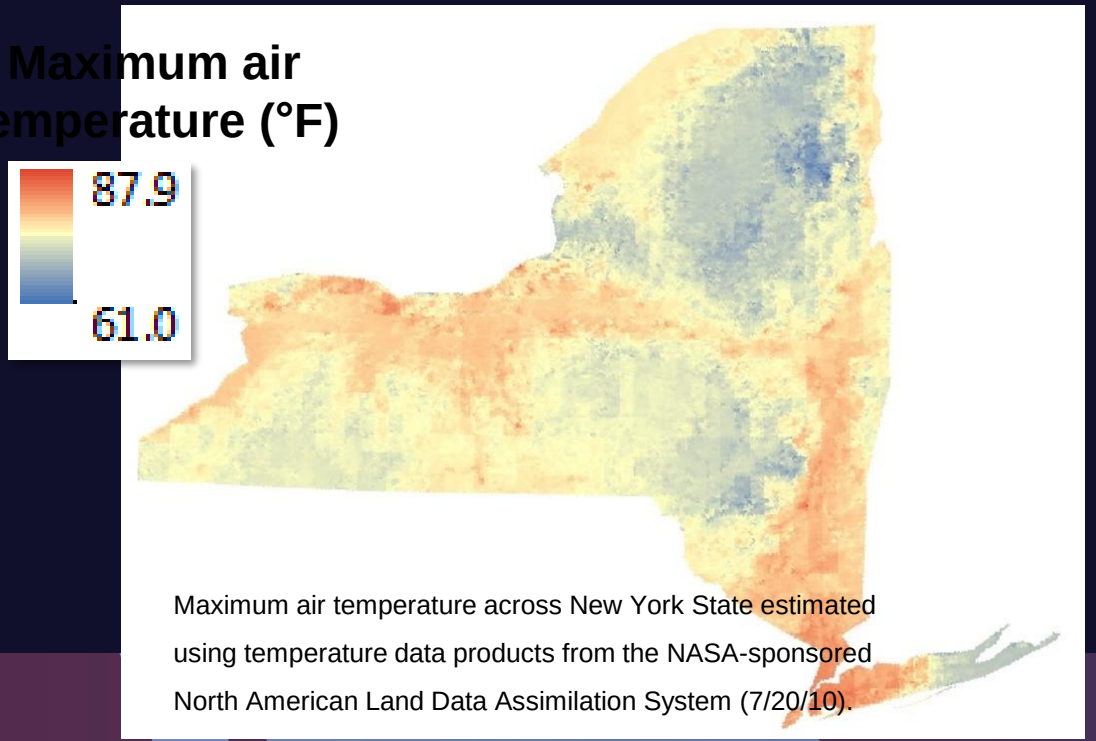
Next milestones:

- **Stratospheric tests in August 2022 and**
- **Flight demonstration in October 2022**

USDA Swift Engineering NASA

Helping New Yorkers Better Cope with Heat

A partnership with the New York State Department of Health, NOAA, and NASA's Health and Air Quality Applications program found that heat-related illnesses occurred at lower temperatures than previously thought in the Empire State. This prompted several of New York State's National Weather Service Forecast Offices to lower their threshold for issuing Heat Advisories in the summer of 2018, helping keep New Yorkers safe when the temperature rises.



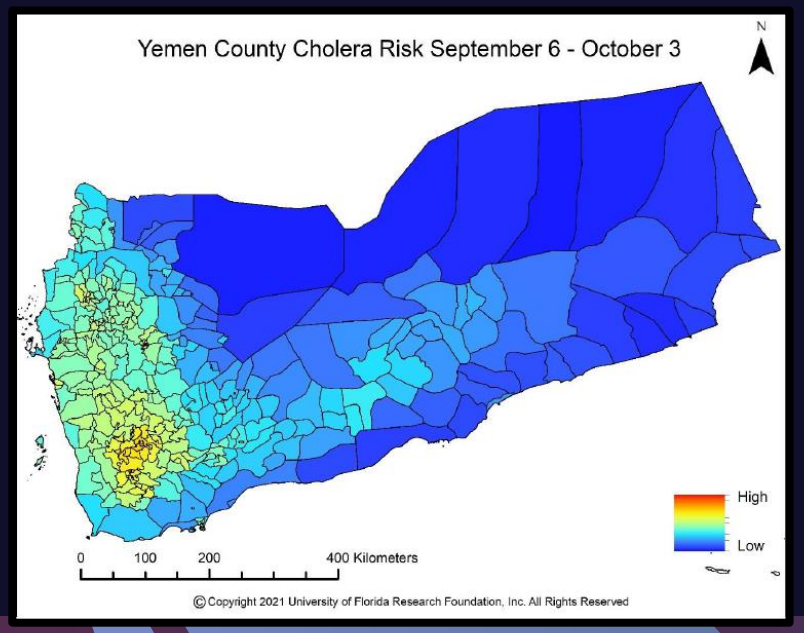
Maximum air temperature across New York State estimated using temperature data products from the NASA-sponsored North American Land Data Assimilation System (7/20/10).

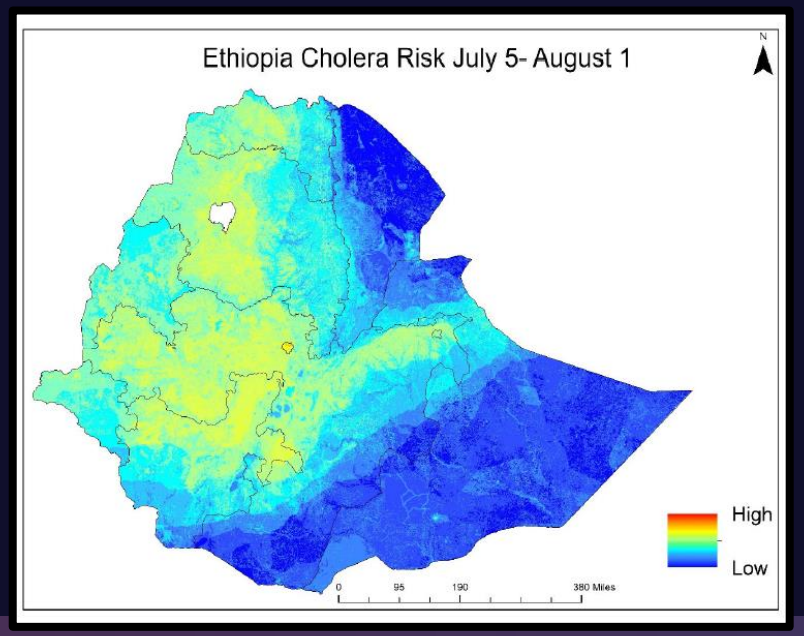
NASA Web Feature: https://www.nasa.gov/feature/nasa-helps-new-yorkers-cope-with-summer-swelter

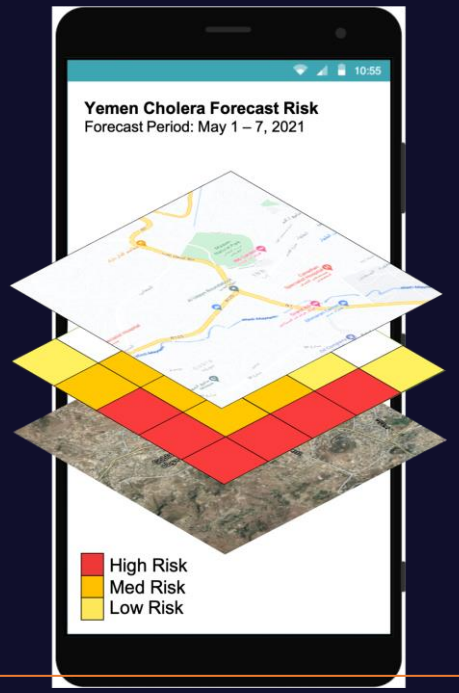
Enhancing Cholera Forecasts to Protect Communities

Dr. Antar Jutla (University of Florida)

With an estimated 40-80 million people living in cholera hotspots in Africa, underreporting remains a significant challenge to predict high-risk areas for cholera outbreaks. Robust applied research and international partnerships were formed to develop a cholera forecasting tool that will inform cholera risk reduction in Yemen and other African nations.







Future Steps: Cholera Risk Communication to Decision-Makers

Data: MODIS, GPM, MERRA-2, ORNL LandScan

NASA: https://www.nasa.gov/press-release/nasa-investment-in-cholera-forecasts-helps-save-lives-in-yemen/

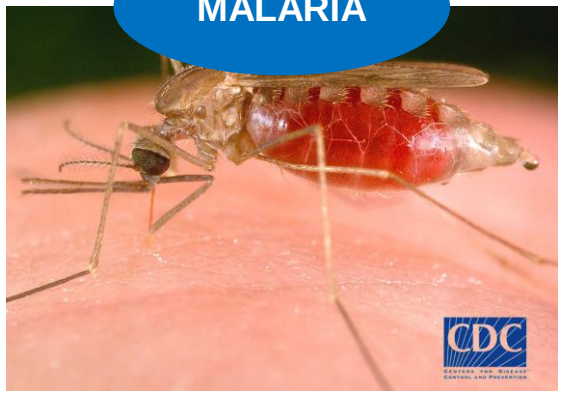
Public Health Risks Associated with Mosquitoes

DENGUE

Aedes aegypti

Aedes albopictus

MALARIA



Anopheles freeborni

WEST NILE VIRUS

Culex quinquefasciatus

Credits: CDC

Global Health Burden

Environmental Influence: Mosquito-breeding sites are favored by certain environmental factors (temperature, precipitation, humidity, land cover)

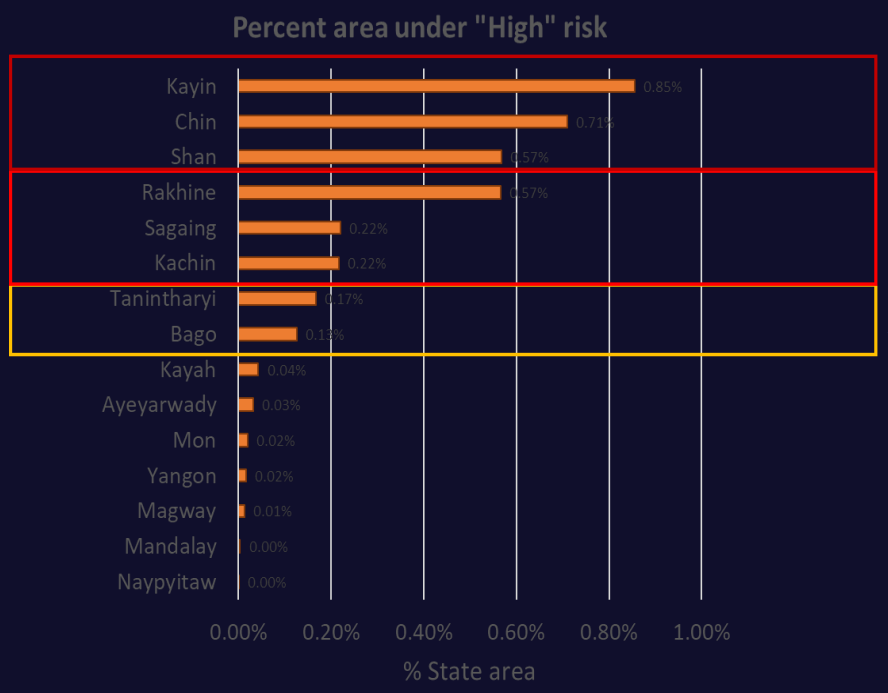
Risk to Human Health: Climate change will influence the distribution, abundance, and prevalence of infection in the mosquitoes that transmit West Nile virus and other pathogens by altering habitat availability and mosquito and viral reproduction rates. Alterations in the distribution, abundance, and infection rate of mosquitoes will influence human exposure to bites from infected mosquitoes, which is expected to alter risk for human disease (USGCRP, 2016)

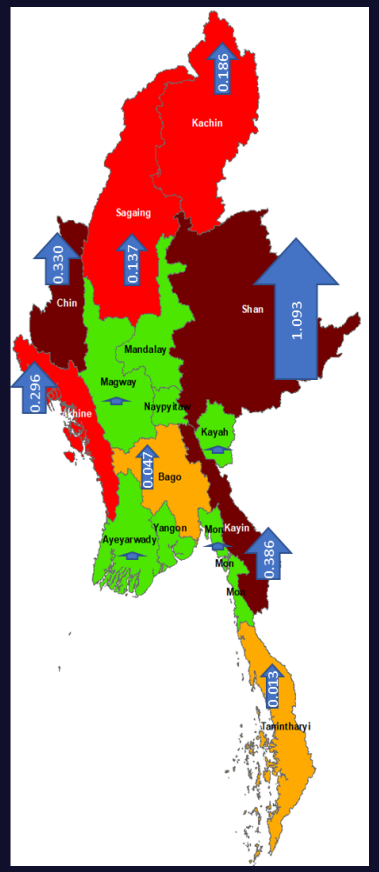
Potential Strategies

Holistic View of Health: Incorporation of the “One Health” concept to emphasize the interconnectedness of human, animal, and environmental health

Data Integration: Satellite data allows further examination of environmental factors and relationships that influence mosquito-breeding sites. Complements traditional integrated vector management applications. Enhances health decision-making to coordinate vector surveillance. health promotion activities, and capacity building. Fosters collaborations with end-users in public health communities.

Forecasting Malaria Risk to Protect Communities





With an estimated 220 million malaria cases and 409,000 deaths each year, malaria control efforts are challenged with the emergence of artemisinin drug resistance and the inability to predict high-risk areas for malaria outbreaks. International partnerships were formed to develop a malaria early warning system that will strengthen vector surveillance, inform policy decisions, and support public health initiatives in Myanmar.

Data: Landsat, MODIS, Sentinel 2

The Malaria Burden Potential variable shows a notable positive five-year trend across Myanmar, suggesting an increase in habitat suitability for Anopheles spp.

PI: Tatiana Loboda (Univ. of Maryland-College Park)

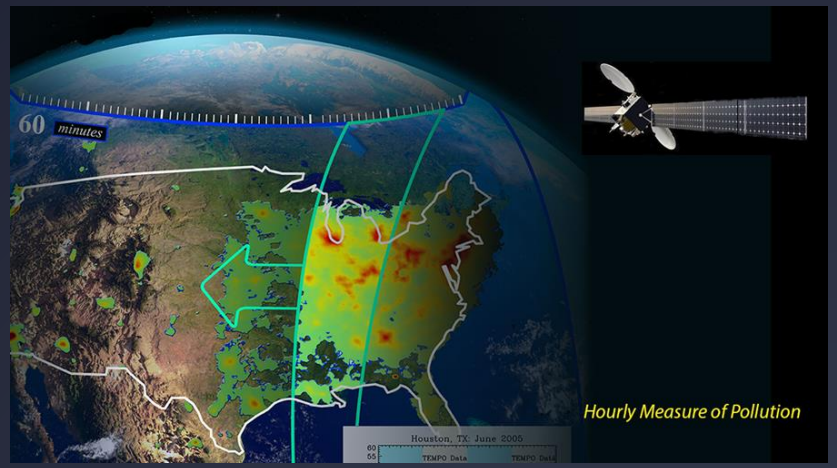
https://appliedsciences.nasa.gov/our-impact/people/gathering-ground-data-tatiana-loboda

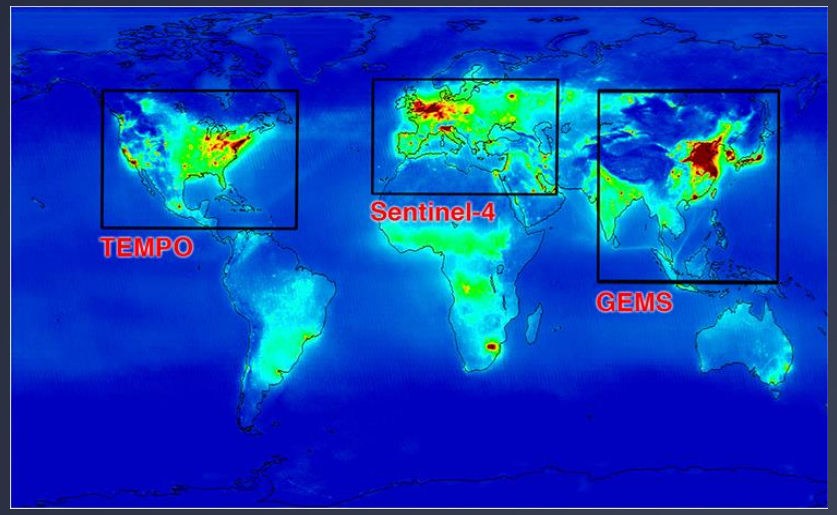
Earth Venture Instrument-1: Tropospheric Emissions: Monitoring of Pollution (TEMPO)

"Monitoring the air we breathe, hour by hour"

- **TEMPO is a pathfinder to using hosted commercial payloads from GEO**
- Represents the North American component, forming a global Air Quality constellation with Copernicus Sentinel-4 (ESA) and GEMS (KARI).
- Aims to improve pollution emission inventories, monitor population exposure, and evaluate effective emission-control strategies.
- Will collect **tropospheric pollution observations** (O_3, NO_2, CH_2O) every daylight hour at high spatial resolution from the Geostationary Orbit.
- Includes science team members: EPA, NCAR, NOAA, universities.
- Instrument delivered in 2018; Launch January 2023.

http://tempo.si.edu/



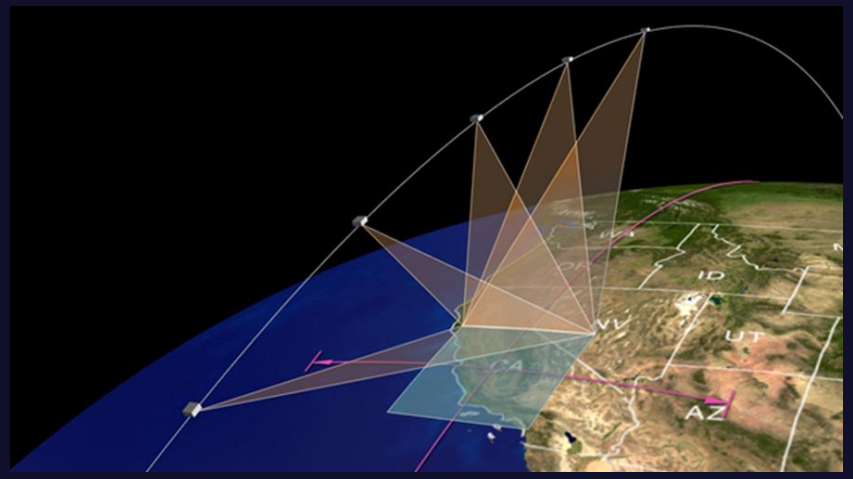


Credits: TEMPO website

Earth Venture Instrument-3: Multi-Angle Imager for Aerosols (MAIA)

- **MAIA represents the first time NASA has partnered with epidemiologists and health organizations on a satellite mission to study human health and improve lives.**
- Aims to examine the impacts of different size and compositional mixtures of airborne particulate matter on adverse birth outcomes, premature deaths, and cardiovascular and respiratory diseases.
- Will collect **radiometric and polarimetric observations (aerosol optical depth, total PM_{10}, total $PM_{2.5}$, and $PM_{2.5}$ for sulfates, nitrates, black carbon, organic carbon, dust)** through the multi-angle spectropolarimetric imaging instrument in a sun-synchronous Earth orbit.
- Includes science team members: CDC, EPA, NIH, NOAA, WHO, universities.
- Launch expected NET late 2023.

http://maia.jpl.nasa.gov



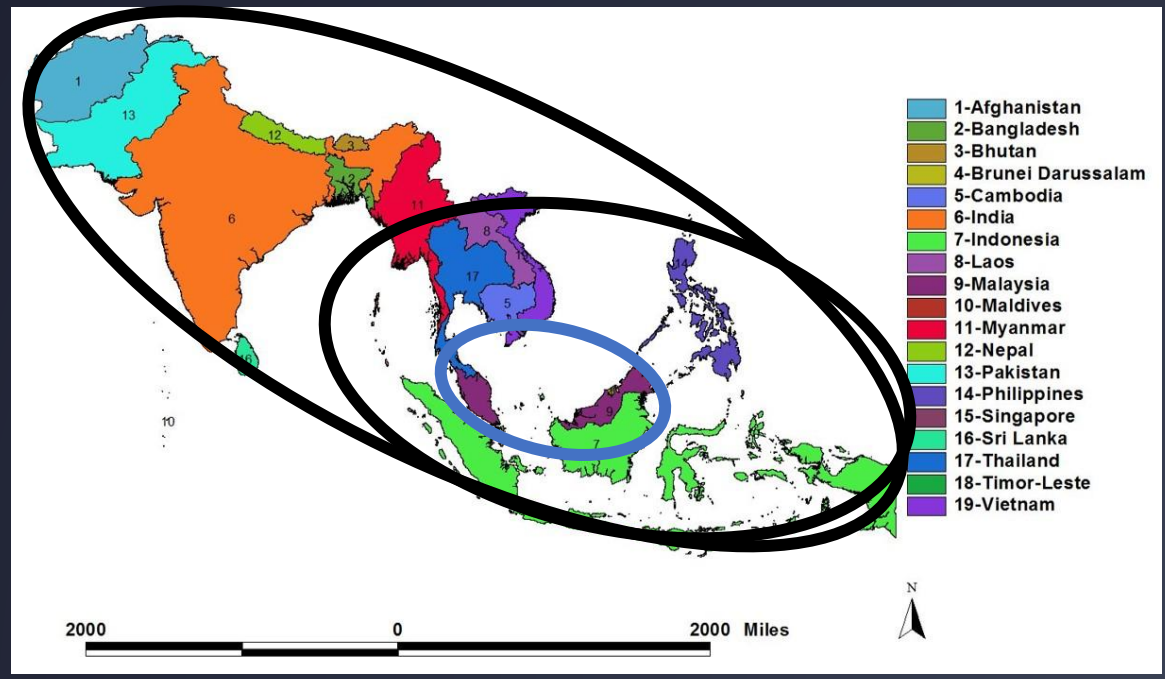
Credits: MAIA website

NASA Remote Sensing Studies of Land-Cover/Land-Use Change in Southeast Asia: The South/SE Asia Research Initiative (SARI)

Goal: Develop an innovative regional research, education, and capacity building program involving state-of-the-art remote sensing, natural sciences, engineering and social sciences to enrich Land Cover/Land Use Change (LCLUC) science in South/Southeast Asia

20+ recent projects on SARI region (13 **in SE Asia)**

Series of regional SARI workshops and trainings



Data Sources in Southeast Asia

Malaysian Space Agency (MYSA)

Established in Feb 20, 2019

By merging Malaysian Remote Sensing Agency (MRSA) and National Space Agency (ANGKASA)

Ground Receiving Station in Temerloh, Pahang (since 2003)

Radarsat-1, SPOT 1,2,4 & 5, NOAA, Terra and Aqua (MODIS), IRS-P4 (OCM)

China - ASEAN Remote Sensing CBERS-4 Satellite Data Sharing Service Platform

Regional sources in addition to Landsat , Terra and
ESA Sentinel-1 and -2

- Vietnam (LotusSat)
- Thailand (THEOS)
- Japan (ALOS)

Zooming-in: Very High Resolution (VHR) Observations

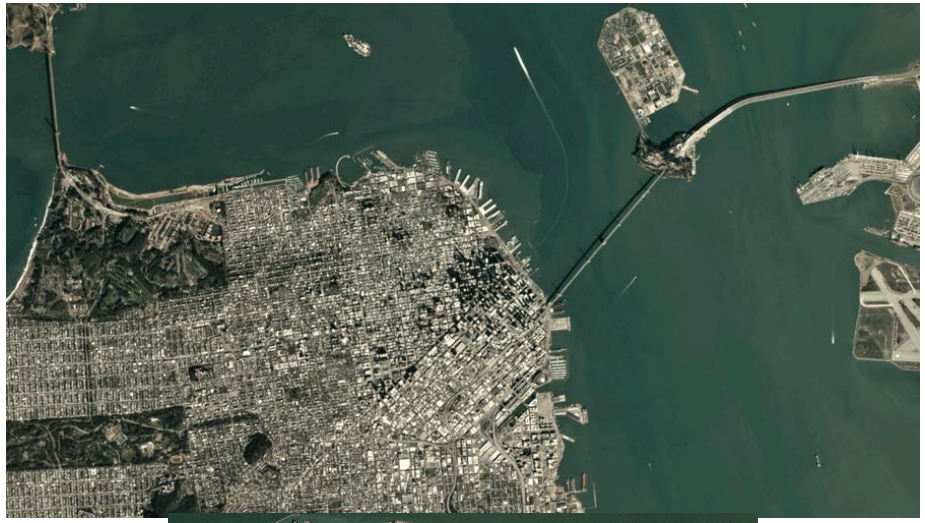
Commercial satellites offer images at fine spatial scale and high temporal resolution

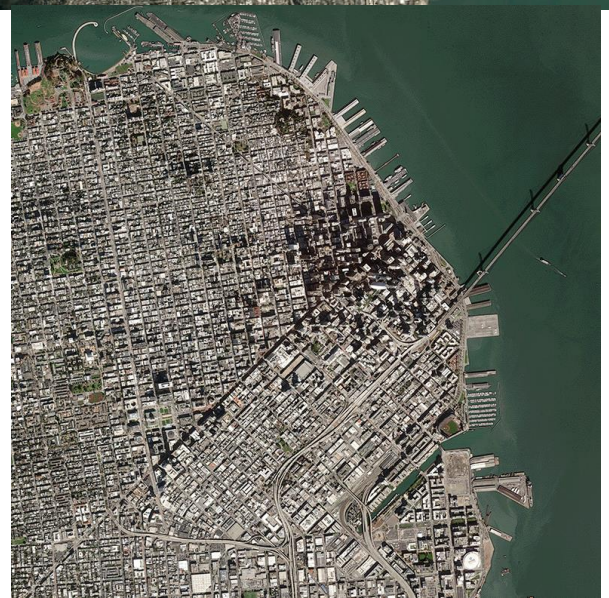
- The first NASA Data Buy 2003 –Ikonos
- Planet Labs constellation (>200 sats) acquire daily images of the Earth with 3-m resolution
- Maxar (Digital Globe, WorldView) with 1m resolution

NASA Commercial Smallsat Data Acquisition (CSDA)

- Limited Planet datasets available for free at Universities
- Wall-to-wall VHR data over tropics purchased by the government of Norway (to tackle tropical deforestation)
- Special Issue in Remote Sensing (2020) on applications of VHR data in LCLUC studies (Editors: Gutman, Vadrevu, Justice)

https://www.mdpi.com/journal/remotesensing/special_issues/LULC_VHR (ISSN 2072-4292)





Very High Resolution (VHR) Commercial Data

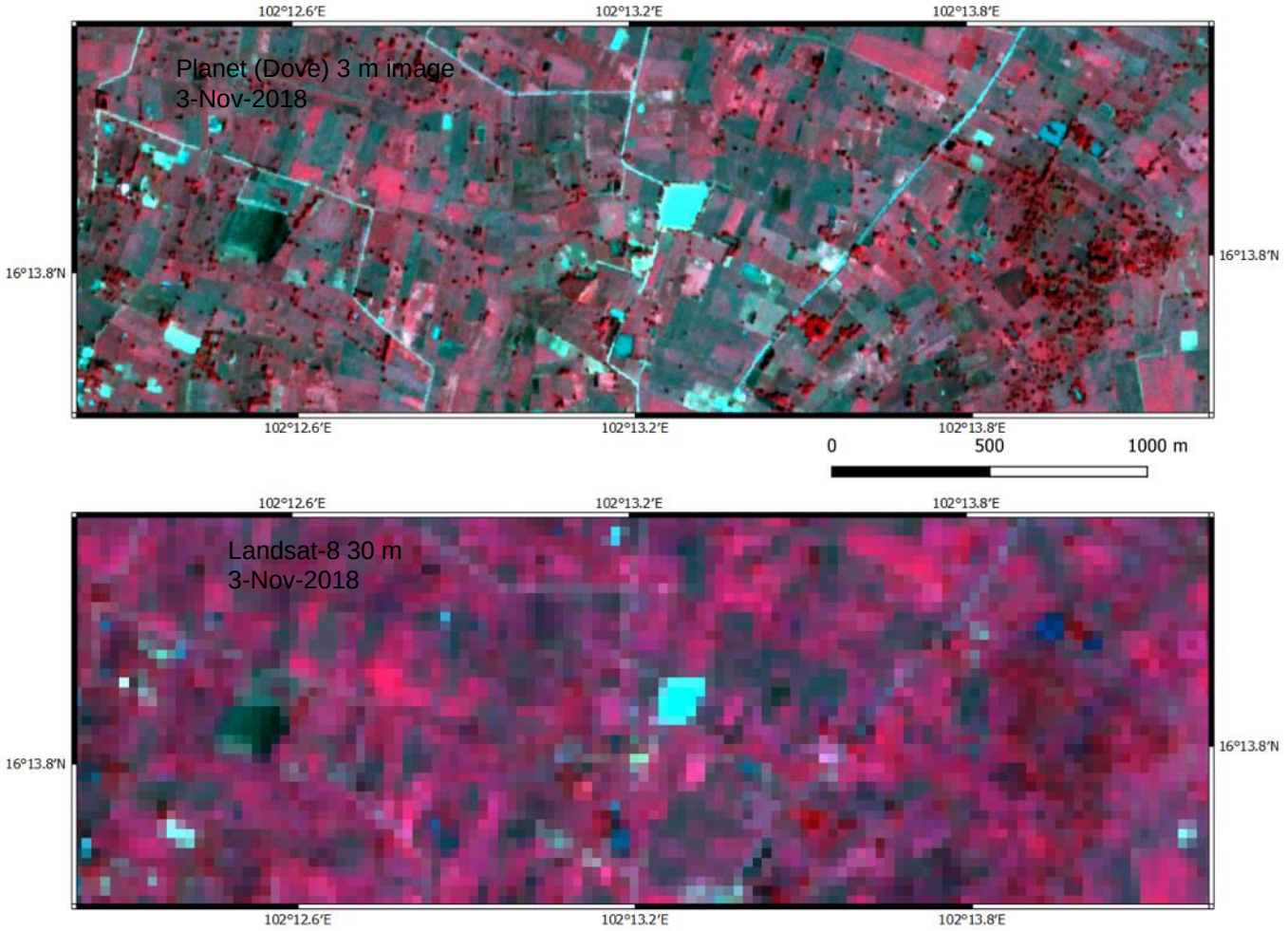
NASA-affiliated investigators have free access to very high spatial resolution data within the next couple of years from satellite constellations of both **Planet Lab** and **Digital Globe** over land including coastal zone and cryosphere

Limited Planet datasets are available for free already now at Universities

Samut Sakhon, Thailand seen by Ikonos on Dec. 20, 2014

Next step: fusing the DG Worldview images having higher spatial resolution but low revisit time with Planet images having lower spatial resolution but daily re-visit times

Effect of Spatial Resolution on Field Boundaries: Thailand

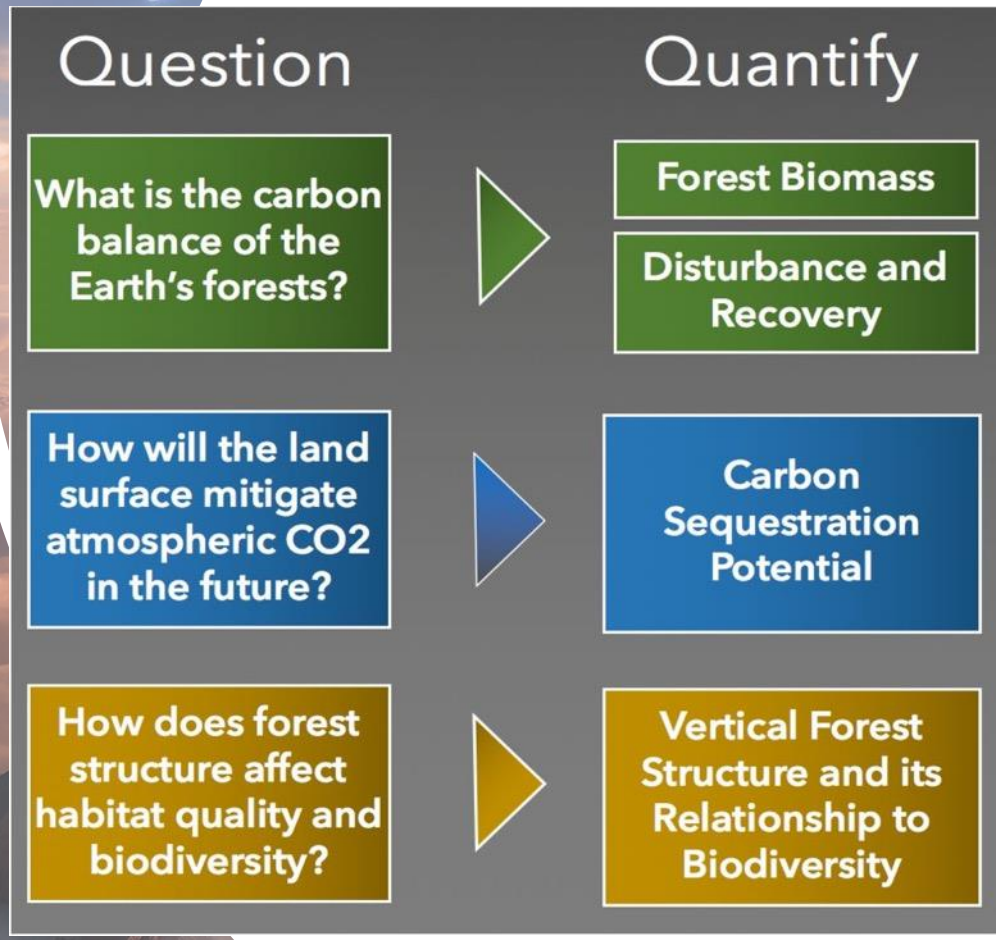


Agricultural fields (mostly sugarcane) in the Chaiyaphum province, Thailand

Courtesy: Sergii Skakun (U. Maryland)

The small agricultural fields in Thailand can only be resolved with VHR data

Global Ecosystem Dynamics Investigation
GEDI on board ISS since 2018



https://gedi.umd.edu/science/objectives-overview/

- Deployed on ISS June 29, 2018

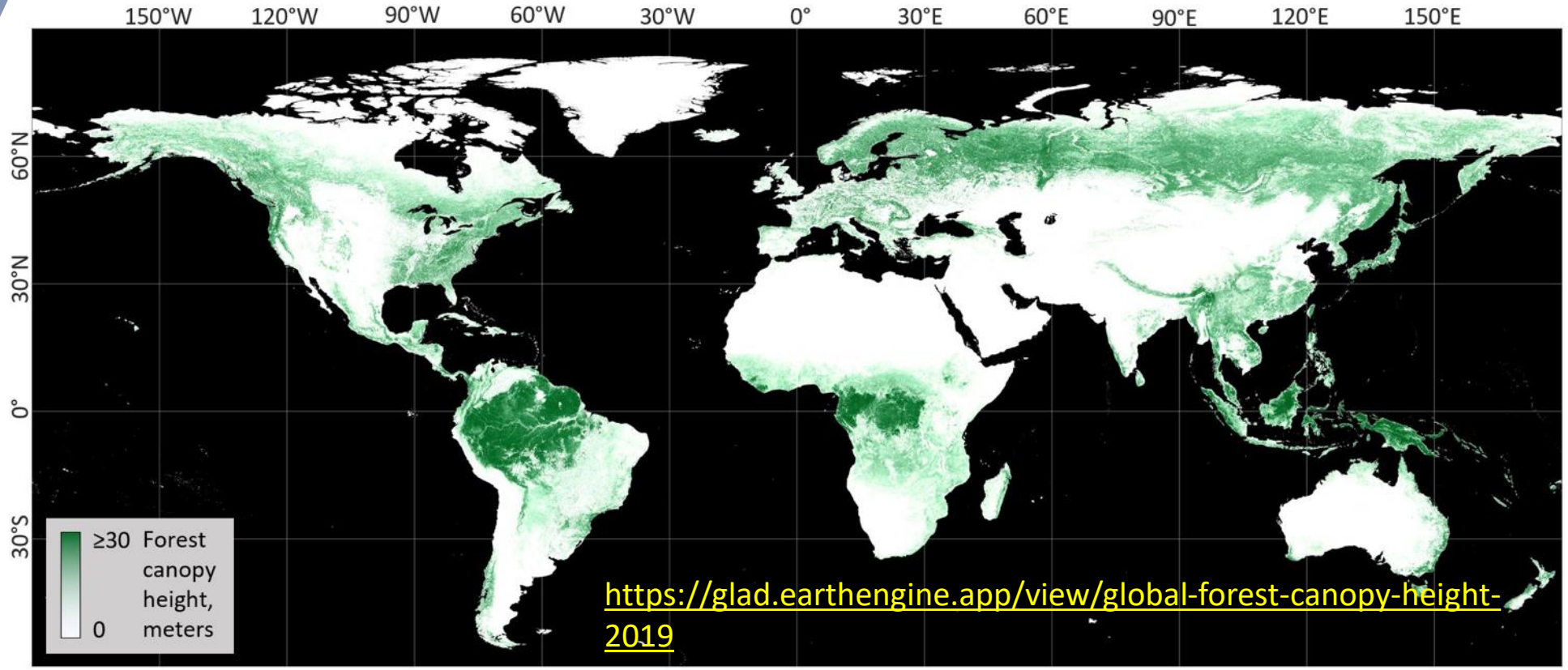
High resolution laser ranging observations

- three lasers produce eight parallel tracks of observations
- each laser fires 242 times per second and illuminates a 25 m spot (a footprint) on the surface

Global Forest Canopy Height, 2019

Global Land Analysis & Discovery

https://glad.umd.edu/dataset/gedi



P. Potapov, X. Li, A. Hernandez-Serna, A. Tyukavina, M.C. Hansen, A. Kommareddy, A. Pickens, S. Turubanova, H. Tang, C.E. Silva, J. Armston, R. Dubayah, J. B. Blair, M. Hofton (2020) Mapping and monitoring global forest canopy height through integration of GEDI and Landsat data. *Remote Sensing of Environment,* 112165. https://doi.org/10.1016/j.rse.2020.112165

Integration of the Global Ecosystem Dynamics Investigation (GEDI) lidar forest structure measurements and Landsat analysis-ready data time-series

Multi-Source Land Imaging (MuSLI) Approach
Fusing Mid-Resolution Data: Sentinel2 + Landsat Data

•Sentinel-2a: launched in Jun 2015

•Sentinel-2b: launched in Mar 2017

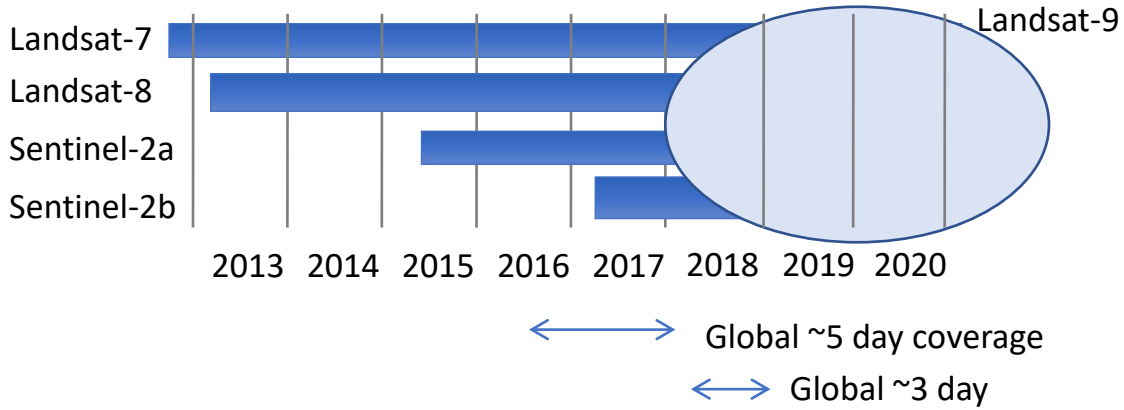
•Landsat-7: launched in Apr 1999

•Landsat-8: launched in Feb 2013

•Landsat-9: planned for Dec 2020

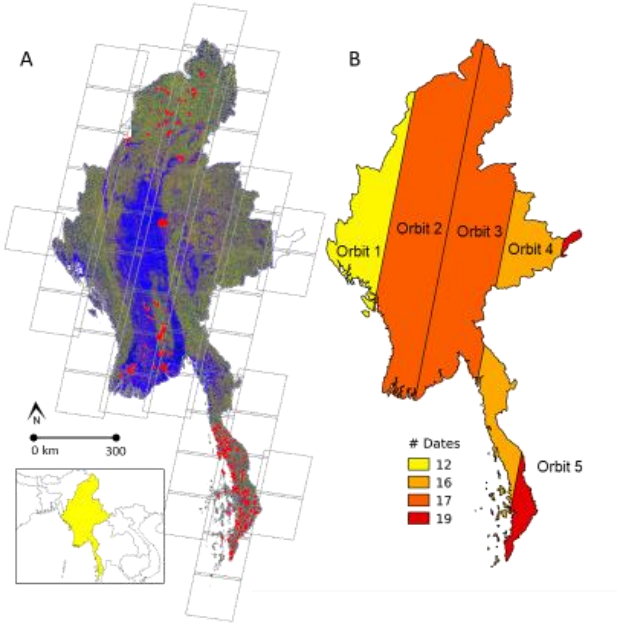
Merging Sentinel-2 and Landsat data streams could provide < 5-day coverage required for Ag monitoring

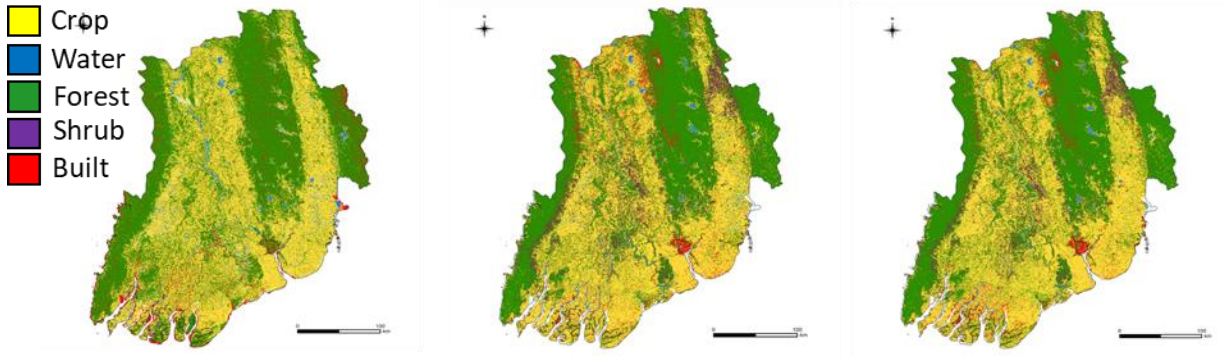
- Both sensors have 10-30m coverage in VNIR-SWIR
- Satellite orbits complementary
  - Landsat-7 & -8 8 days out of phase
  - Sentinel-2a & 2b 5 days out of phase
  - Landsat and Sentinel sun synch orbits precess relative to each other



Operational Algorithms and Products for Near-Real-Time Maps of Rice Extent and Rice Crop Growth Stage Using Multi-Source Remote Sensing

PI: Salas, Applied Geosolutions





P2+S1

P2+S1

L8+P2

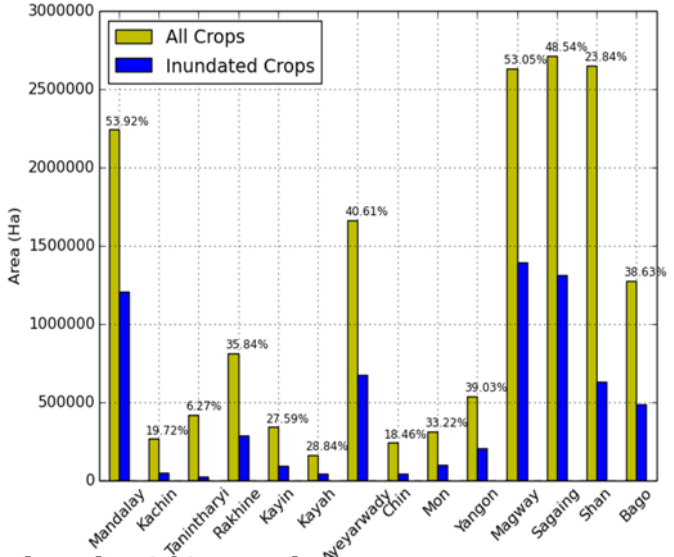
P2+L8

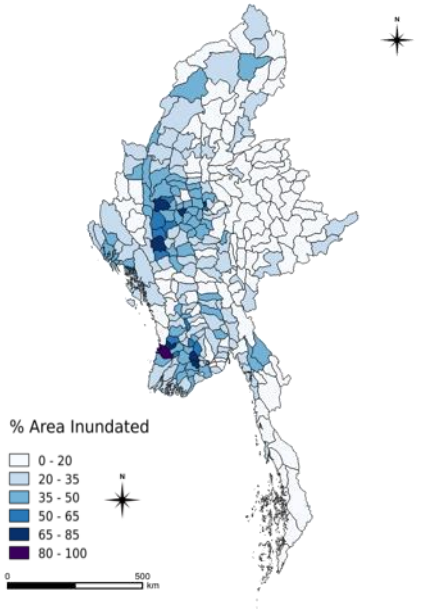
L8+P2+S1

P2+L8+S1

Courtesy of Nathan Torbick, AG

P2 – PALSAR-2
L8 – LANDSAT-8
S1 – SENTINEL-1



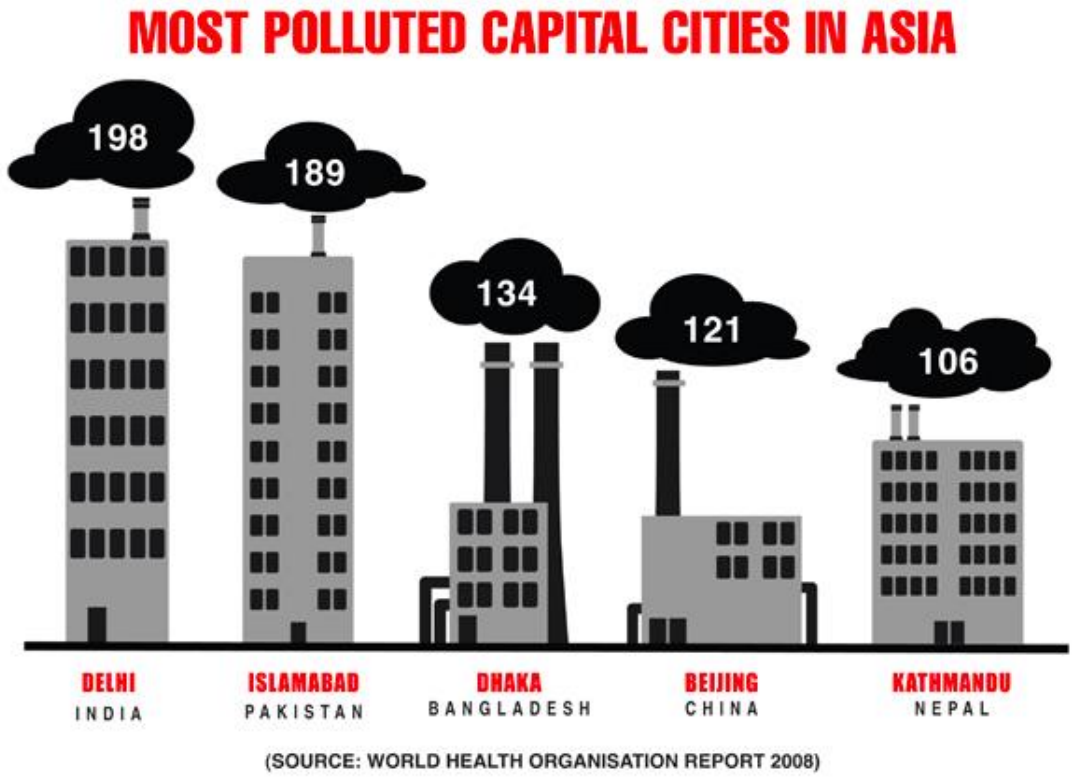


MuSLI approach improves food security mapping in S/SE Asia

Air Pollution in Asia

City	PM
Delhi	153
Karachi	117
Dhaka	8
Beijing	56
Colombo	28
Jakarta	21
Singapore	17

Air pollution in city reaches alarming level
(The Jakarta Post, Jakarta, Mon, June 10 2013)



The WHO advises that fine particles of less than 2.5 micrometres in diameter (PM2.5) should not exceed 10 micrograms per cubic metre

Impact of Lockdown on Aerosols and Pollutants over Southeast Asia

Over urban centers in Southeast Asia:

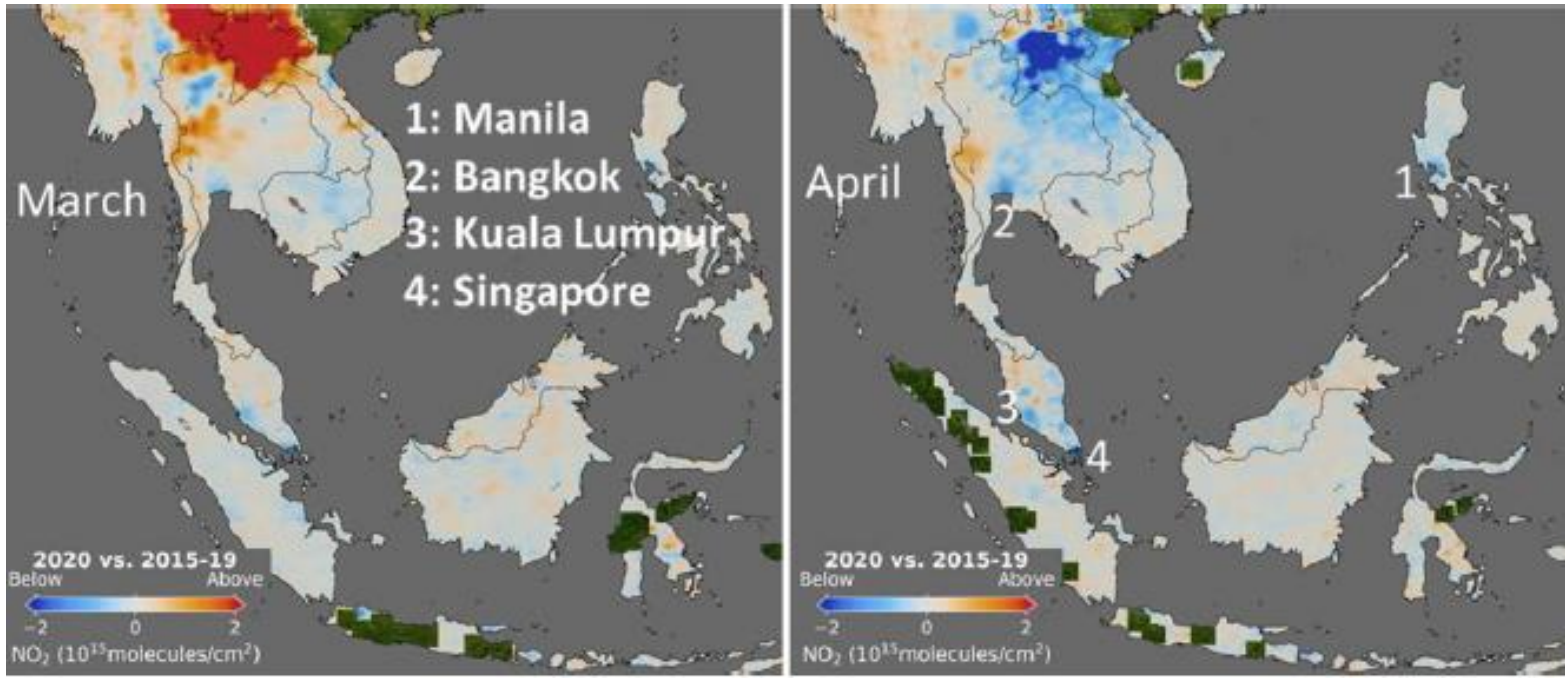
- Reduction by about 1/3 of tropospheric NO_2

In urban Malaysia reductions:

- about 1/3 in PM_{10}, $PM_{2.5}$, and CO
- Up to 20% in SO_2
- over 60% in NO_2

Data

- NASA Aura/OMI for NO2 concentrations
- Jaxa Himawari-8 AOD (aerosol optical depth)



COVID-19's impact on the atmospheric environment in the Southeast Asia region. **Kanniah et al. 2020** *Science of the Total Environment 736*

Courtesy: Prof. Kasturi Kanniah, UTM

The GLOBE Program

GLOBE is an international, hands-on science and education program that for over 26 years has enabled students, teachers, and the public worldwide to participate in data collection and the scientific process and contribute to our understanding of the Earth system and global environment

Sponsors include, NASA, NOAA, U.S. Department of State & the National Science Foundation

GLOBE by the Numbers

126	Countries
37,878	Schools
42,295	Teachers
215,600	GLOBE Observers
212,048,745	Measurements

www.globe.gov

GLOBE received the 2021 AGU Excellence in Earth and Space Science Education Award

CONNECTING **SPACE** TO **VILLAGE**

SERVIR is a joint initiative of NASA, USAID, and leading geospatial organizations in Asia, Africa, and Latin America, that partners with countries and organizations in these regions to address critical challenges in climate change, food security, water and related disasters, land use, and air quality.

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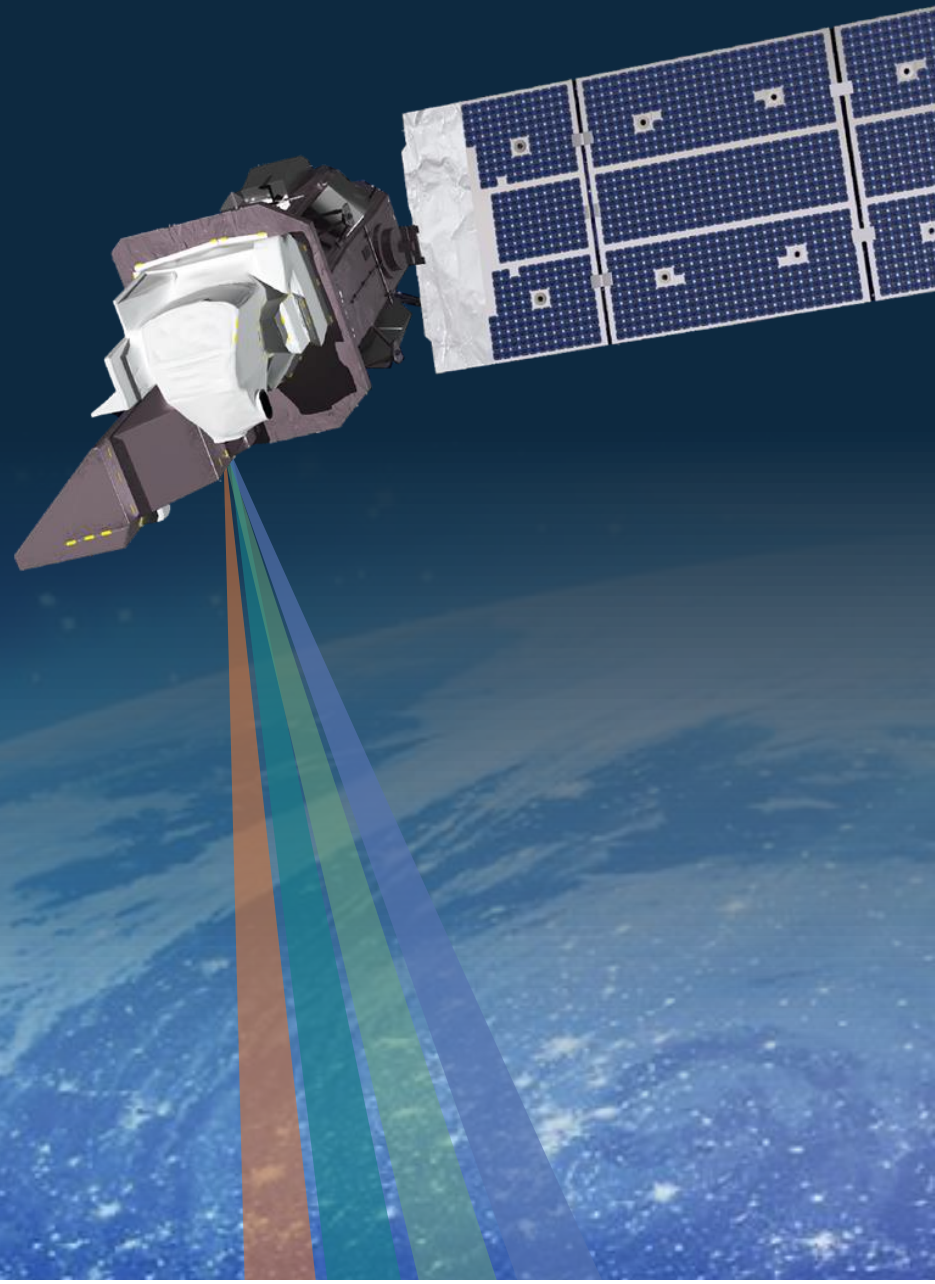


USAID FROM THE AMERICAN PEOPLE | NASA | SERVIR | CILSS | RCMRD | ICIMOD | adpc | ALLIANCE Bioversity International | CIAT

Countries Around the World Need Satellite Data

CHALLENGE:

Climate change impacts are accelerating around the world

Disadvantaged and marginalized people are most adversely affected

OPPORTUNITY:

The power of satellite data helps partner countries identify and manage climate risks

Support access, innovation, and capacity to use satellite data

CONNECTING **SPACE** TO **VILLAGE**

Agriculture & Food Security

Water & Water-Related Disasters

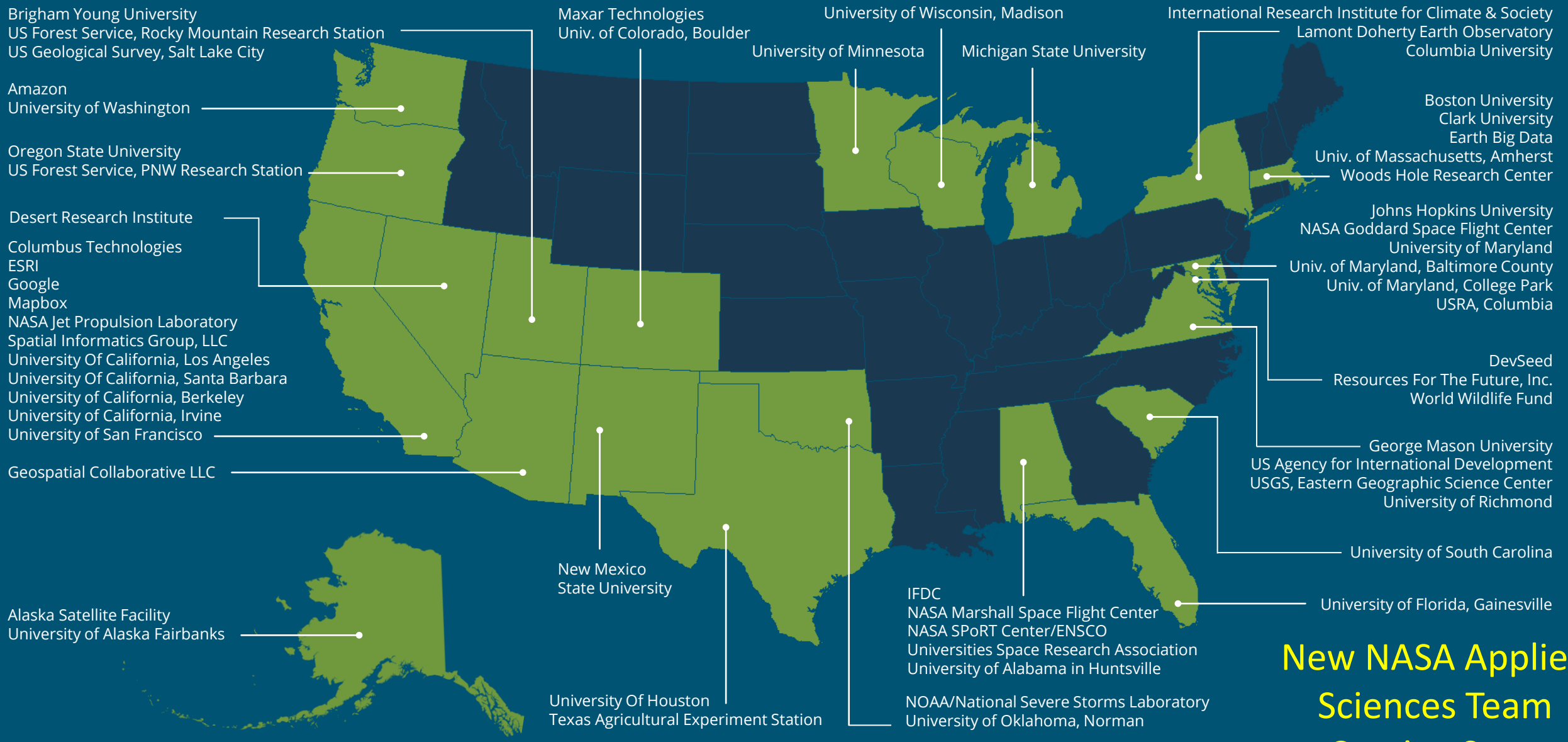
Land Cover, Land Use Change & Ecosystems

Weather & Climate

USAID FROM THE AMERICAN PEOPLE | NASA | SERVIR | CILSS | RCMRD | ICIMOD | adpc | ALLIANCE Bioversity International | CIAT

SERVIR Focuses on Countries in Asia, Africa, & the Americas

SERVIR Connects US Science to Global Development Challenges



New NASA Applied Sciences Team Coming Soon

Who Is SERVIR?

- Poverty reduction & resilience
- Data-dependent issues in data-scarce places
- International field presence

- 30+ Earth observing satellite missions, free & open data
- Major research portfolio
- Societal benefit from space

Private sector collaborators:

USG collaborators:

Intergovernmental, NGO collaborators:

Research collaborators: 20+ US universities & research centers through the SERVIR Applied Sciences Team; ITC, in-region university networks

Regional Hub Host Institutions:

Hub Consortium Members:

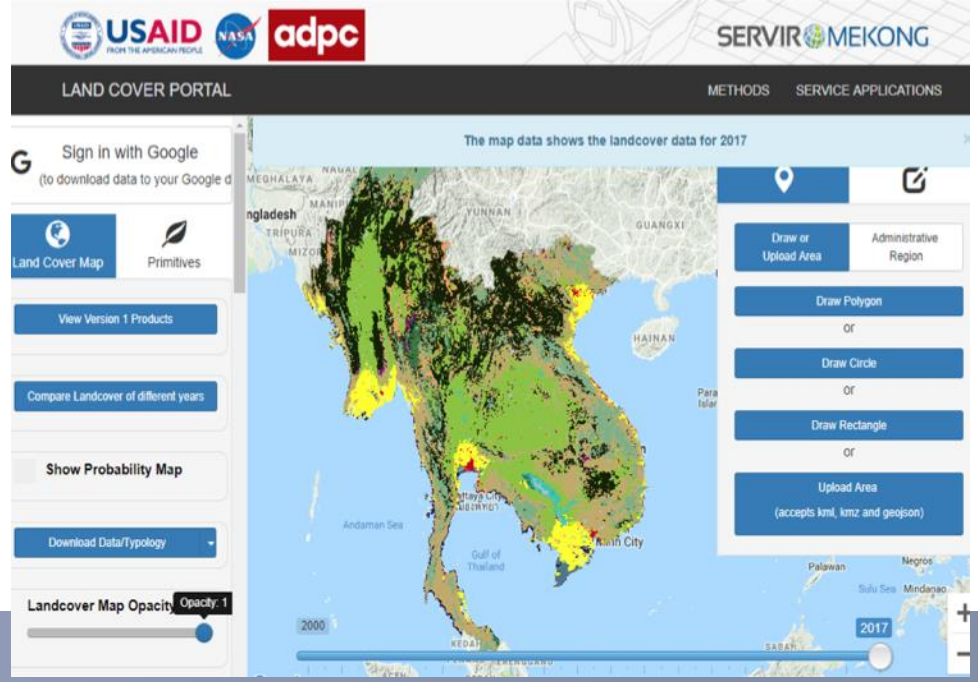
SERVIR Brings Climate Adaptation and Mitigation

Each of SERVIR's 49 services address climate adaptation, mitigation, or both

SERVIR services support implementation of partner countries' climate priorities

SERVIR contributes to the goal, objectives, and targets of:

- USAID's Climate Strategy
- PREPARE
- Forest Data Partnership
- plus engaged in other important initiatives: LACI, the Quad, AIM4C



45 *Countries directly served by SERVIR products, applications or trainings*

35 *Satellites and sensors providing data used by SERVIR*

49 *Custom services in development or delivery stages*

20+

US-based university & research center collaborators

800+

Partnering institutions worldwide

12,000+

Individuals trained to develop local solutions

* *Cumulative as of 2022*

SERVIR **leverages US research investments** and USAID's **existing international infrastructure** to maximize every dollar spent

- Over the lifetime of SERVIR, NASA and USAID equally contribute

NASA Applied Remote Sensing Training Program (ARSET)

Online Courses

- Presentations and **hands-on guided computer exercises** on how to access, interpret, and use NASA satellite images for decision-support

Participants will also have a basic understanding of NASA satellites, sensors, data, tools, portals, and applications to environmental monitoring and management.

https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

GROUP ON EARTH OBSERVATIONS

GEO HEALTH COMMUNITY OF PRACTICE

Improving Health Decision-Making Using Environmental Observations

Global network of governments, organizations, and observers, who seek to use Earth observation data to improve health decision-making at the international, regional, country, and district levels

Work Groups

- **Heat-related Health Risks**
- **Infectious Diseases**
- **Air Quality, Wildfires, and Respiratory Health**
- **Food Security and Safety**
- **Health Care Infrastructure**

- **Bi-Weekly Teleconferences**
- **GEO Symposium**
- **Quarterly Community Webinars per Region on Work Group topics:**
  - September 2021 – Americas Region
  - March/April 2022 – African Region
  - Fall 2022 – Asian Region

Engagement Opportunities with the Global Scientific Community

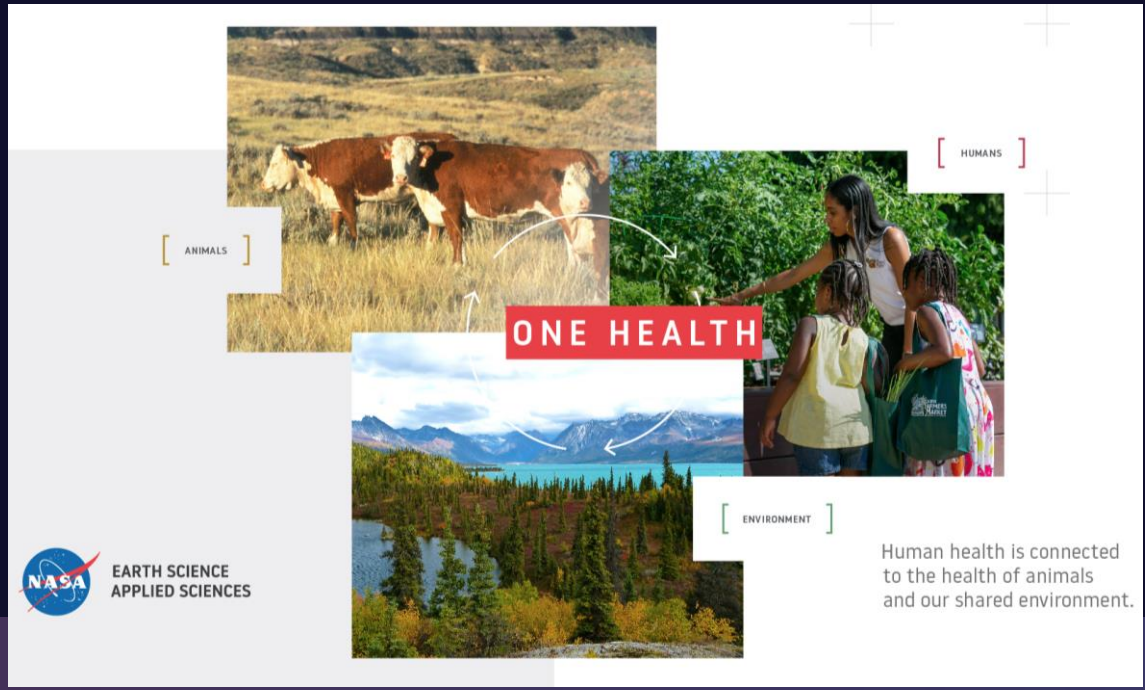
- Join professional associations and communities of practices and present your work at upcoming events
- Engage with Small Work Groups
- Connect with international groups (GEO, GHHIN, Data dashboards)
- Explore joint training and collaborations to leverage expertise and align objectives with the 2030 Agenda for Sustainable Development
- Seek training courses (NASA ARSET) and global hackathons (NASA Space Apps Challenge)

GEO GROUP ON EARTH OBSERVATIONS

GEO HEALTH COMMUNITY OF PRACTICE

GLOBAL HEAT HEALTH INFORMATION NETWORK

NASA SPACE APPS CHALLENGE



EXPLORE

with us

Applied Sciences
Strategic Plan 2021-2026

GOALS

IMPACTFUL APPLICATIONS

KNOWLEDGEABLE AND SKILLED COMMUNITIES

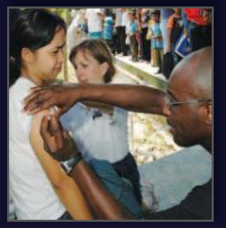
THRIVING PARTNERSHIPS AND PRIVATE SECTOR VENTURES

PROGRAM ELEMENTS

Agriculture

Disasters

Ecological Forecasting



Health & Air Quality

Water Resources

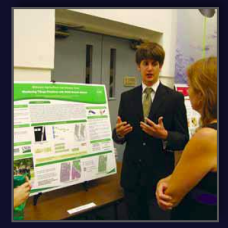
New Areas with FY22 Presidents Budget Request:

Climate Resilience ***Wildfires***

Environmental Justice

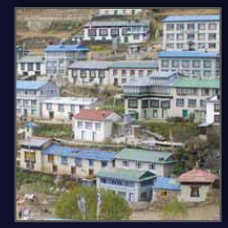
ARSET

Professional-oriented Trainings



DEVELOP

Workforce & Feasibility Projects



SERVIR

International Development

USAID FROM THE AMERICAN PEOPLE

https://appliedsciences.nasa.gov/