National Aeronautics and Space Administration

EXPLORE EARTH

Viewing Earth's Global Environment from Space: From Scientific Knowledge to Societal Benefits*

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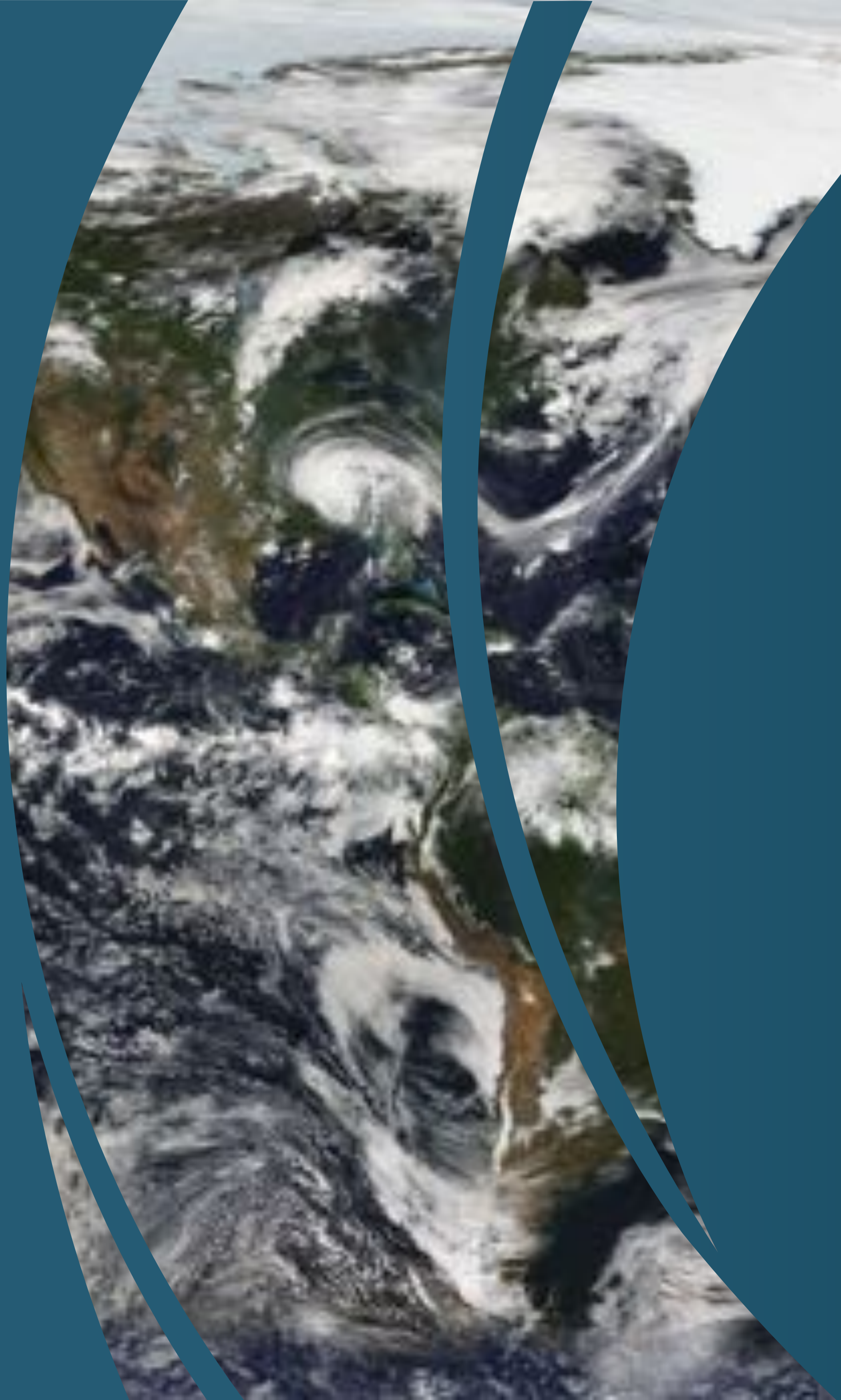
NASA Earth Science Division
April 26, 2019

* Prepared with inputs from numerous colleagues from NASA HQ, centers, and research community

Earth in Daytime from Suomi-NPP VIIRS

Earth at Night: “Black Marble” from Suomi-NPP VIIRS

https://www.nasa.gov/feature/goddard/2017/new-night-lights-maps-open-up-possible-real-time-applications



Overview

How NASA studies Earth with remote sensing

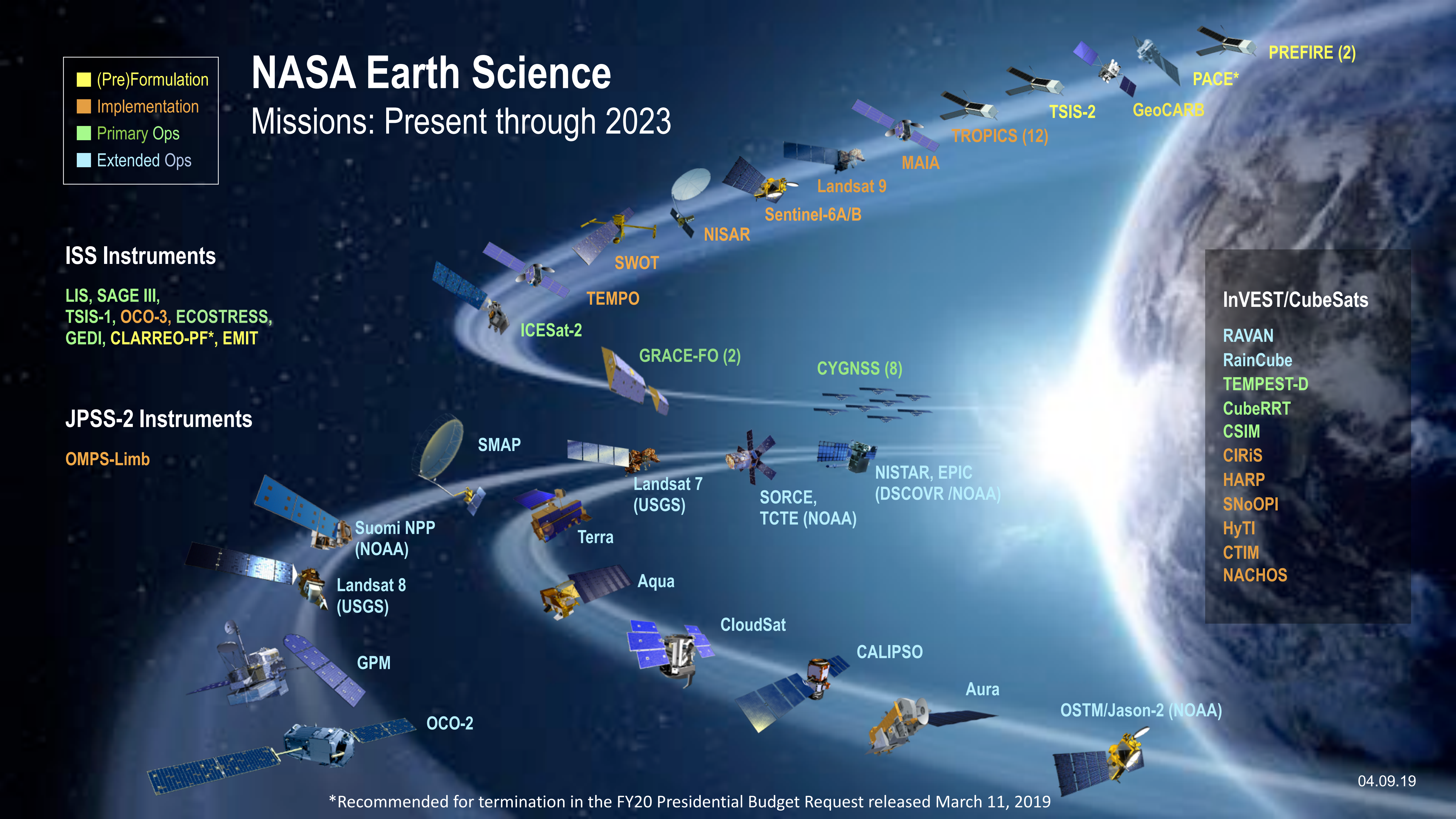
What we’re seeing – and learning

What we’ll be doing in the future

It’s not ALL satellites

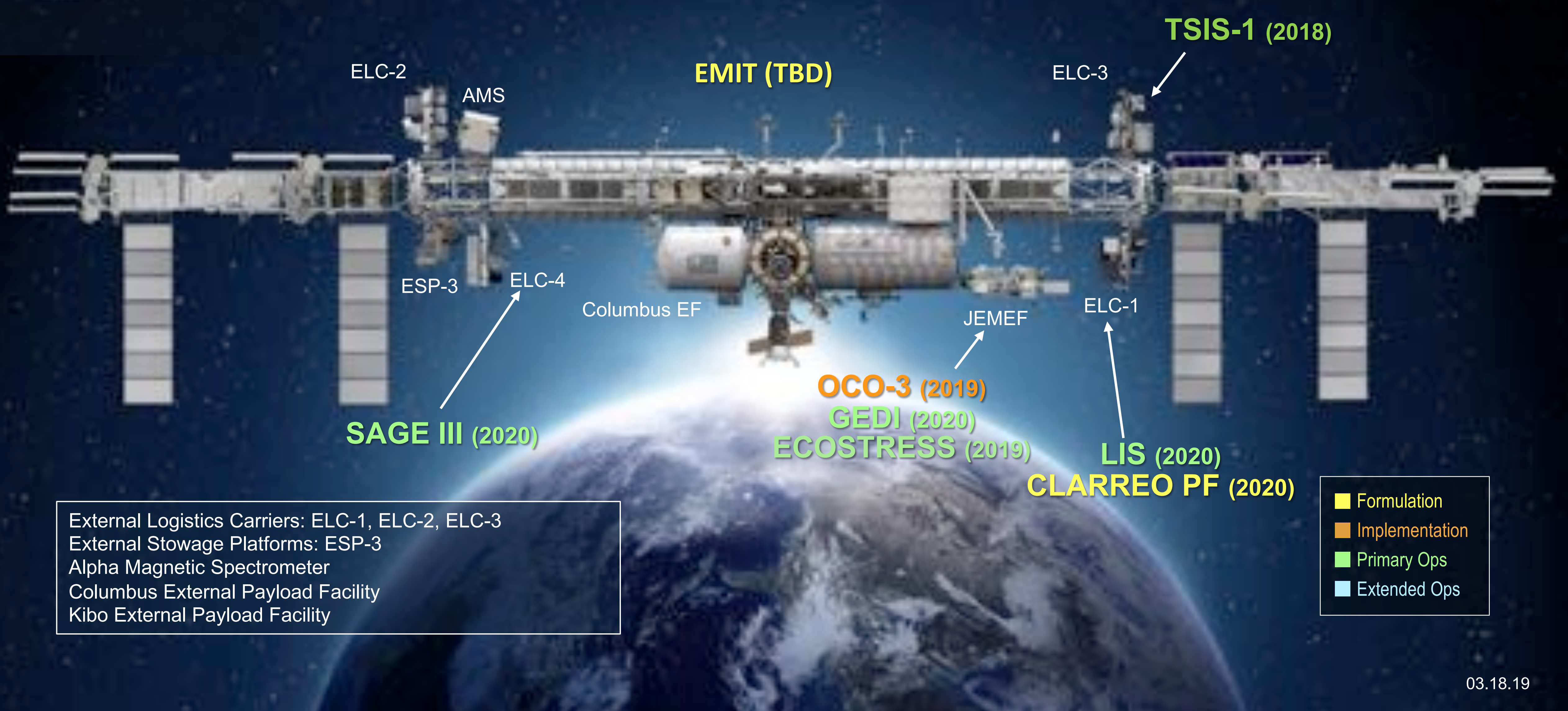
The broader context

Conclusion

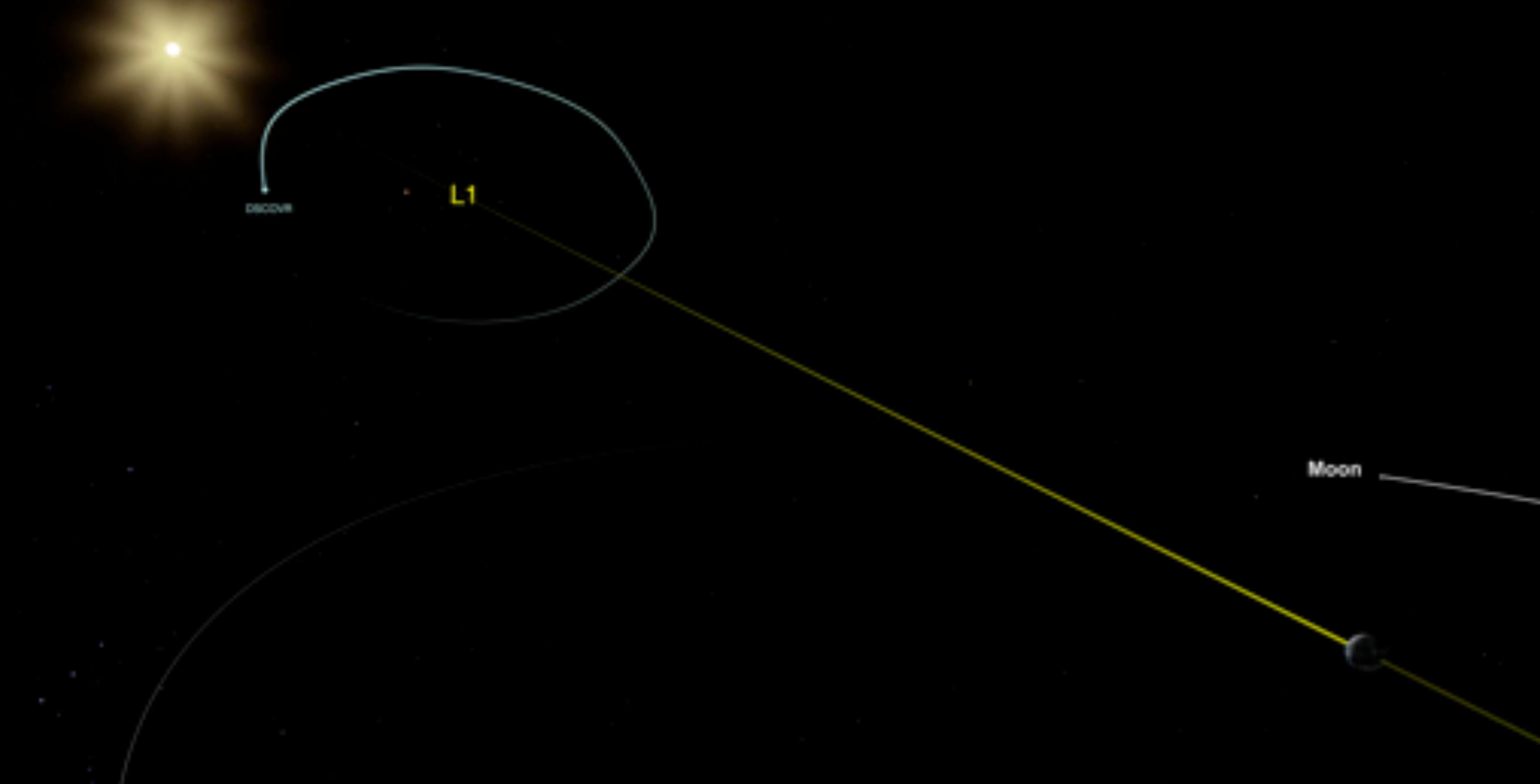


NASA Earth Science
Missions: Present through 2023
(Pre)Formulation
Implementation
Primary Ops
Extended Ops
ISS Instruments
LIS, SAGE III,
TSIS-1, OCO-3, ECOSTRESS,
GEDI, CLARREO-PF*, EMIT
JPSS-2 Instruments
OMPS-Limb
PREFIRE (2)
PACE*
GeoCARB
TSIS-2
TROPICS (12)
MAIA
Landsat 9
Sentinel-6A/B
NISAR
SWOT
TEMPO
ICESat-2
GRACE-FO (2)
CYGNSS (8)
SMAP
Landsat 7
(USGS)
SORCE,
TCTE (NOAA)
NISTAR, EPIC
(DSCOVR /NOAA)
Suomi NPP
(NOAA)
Terra
Landsat 8
(USGS)
Aqua
CloudSat
GPM
CALIPSO
Aura
OCO-2
OSTM/Jason-2 (NOAA)
InVEST/CubeSats
RAVAN
RainCube
TEMPEST-D
CubeRRT
CSIM
CIRiS
HARP
SNoOPI
HyTI
CTIM
NACHOS
04.09.19
*Recommended for termination in the FY20 Presidential Budget Request released March 11, 2019

International Space Station
Earth Science Operating Missions



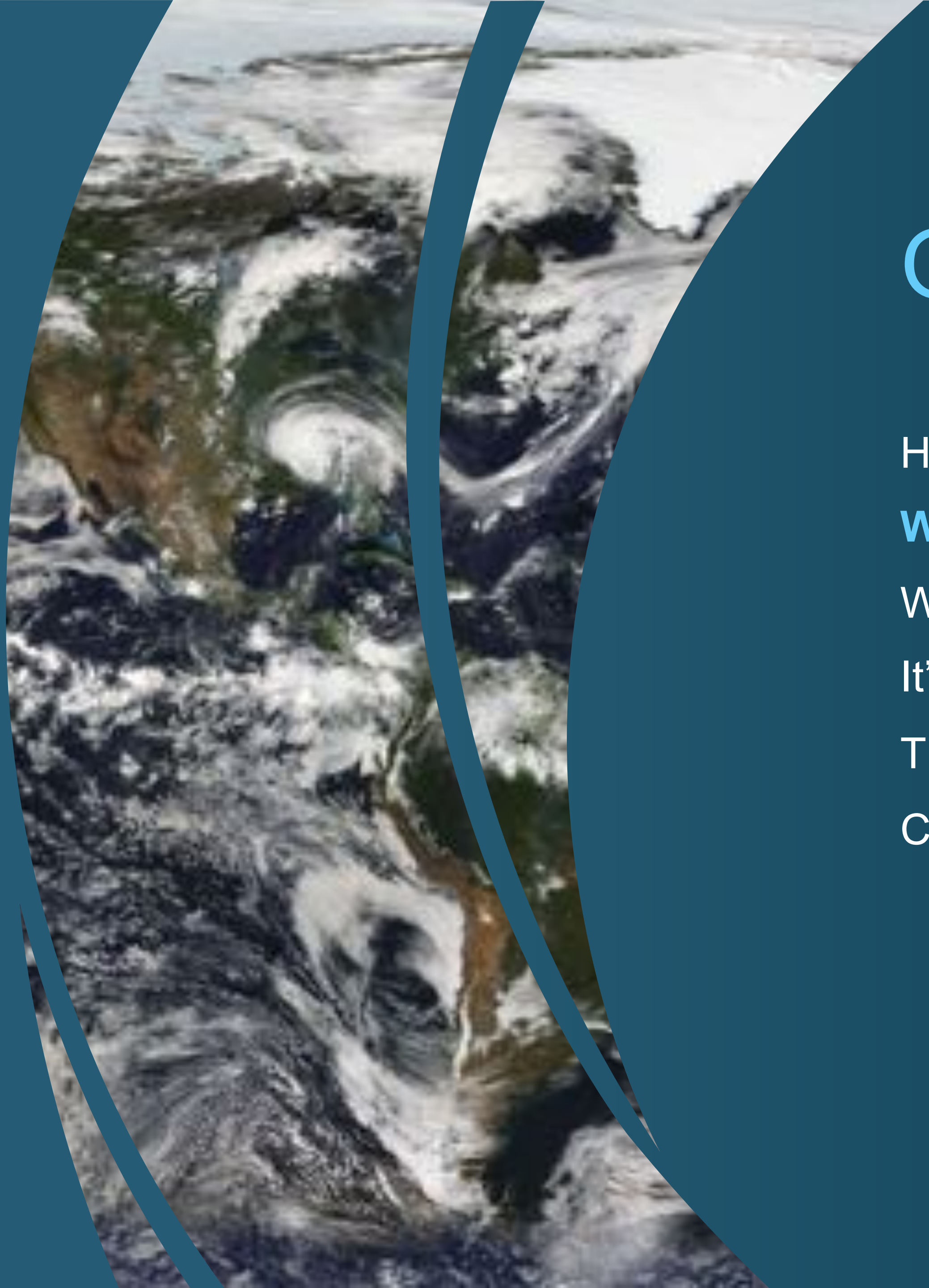
NASA Earth Observing Fleet, 2018



Some Recent Launches

GRACE FO (via SpaceX Falcon 9) May 22, 2018

ICESat-2 (via ULA Delta-II) September 15, 2018



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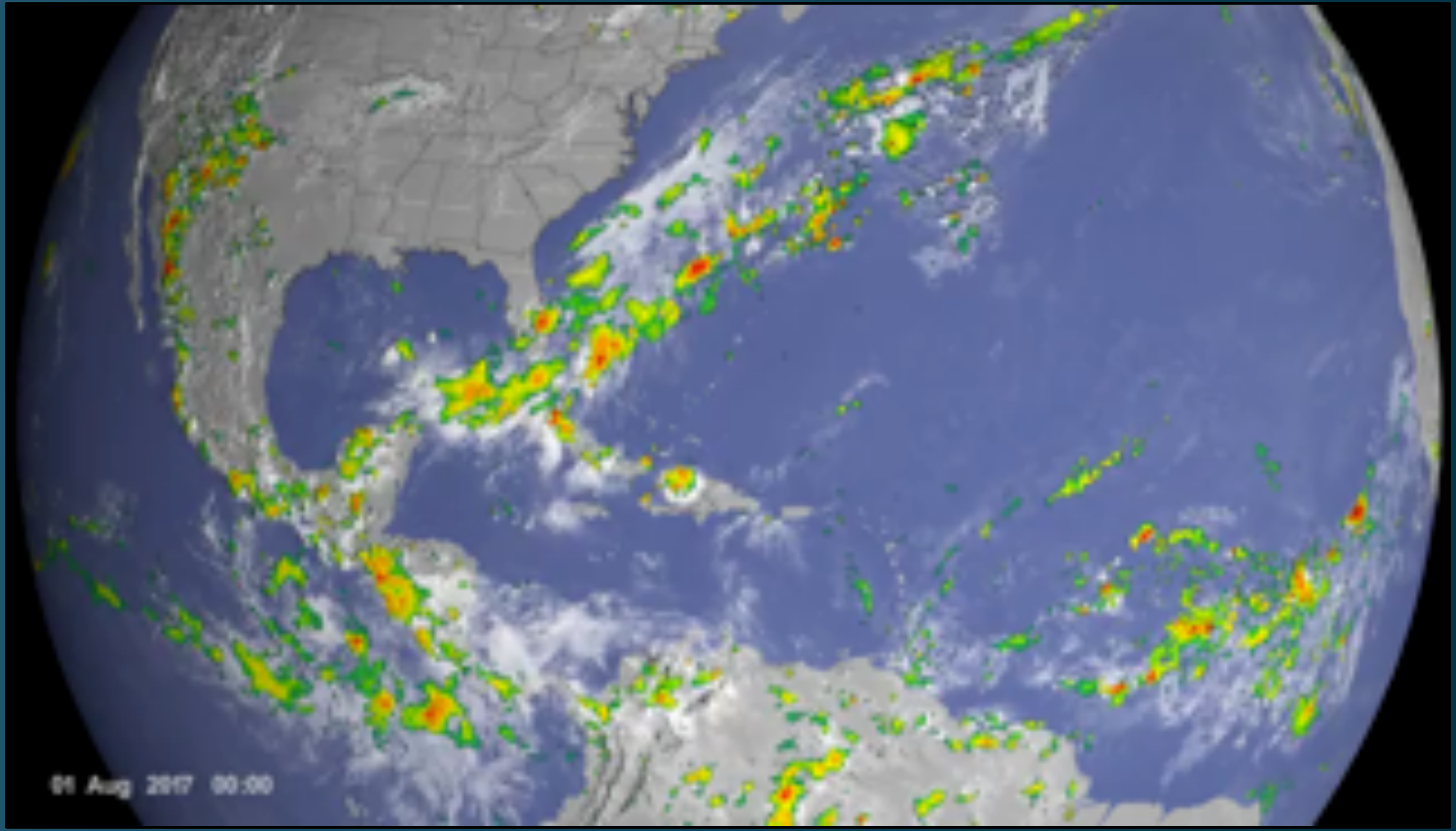
The Space-Based View: Over Different Time Scales

The vantage point of space lets us look at the Earth over a variety of time scales

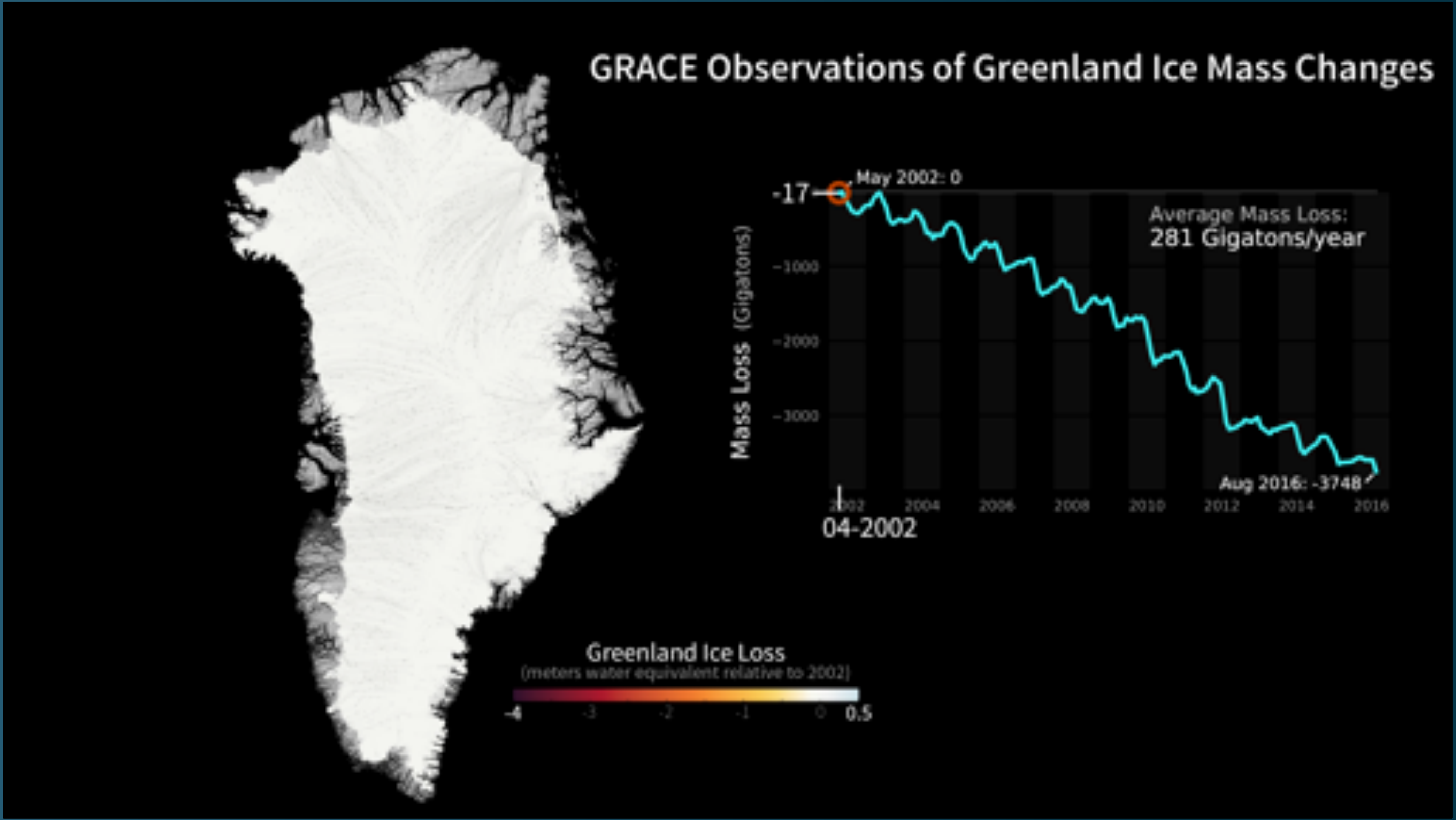
- Individual days*
- Day-to-day variability (weather)
- Seasonal variations
- Interannual variations
- Long-term trends

* Satellites in higher (e.g., geostationary) orbits and constellations of small satellites let us look at the Earth on shorter time scales. Examples include the new generation of geostationary satellites (NOAA GOES-16/17, Japan Himawari-8/9) and small satellite constellations (e.g., NASA CYGNSS).

The 2017 Atlantic Hurricane Season

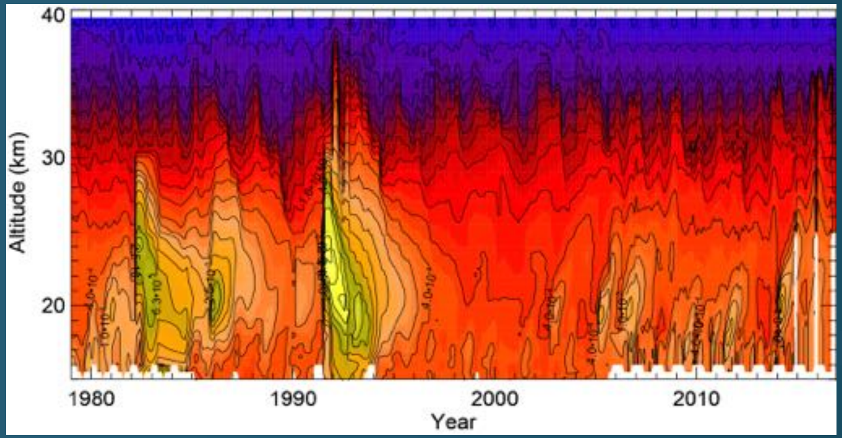


https://svs.gsfc.nasa.gov/4586 — uses IMERG precipitation product from Global Precipitation Mission and clouds from NOAA GOES-East satellite

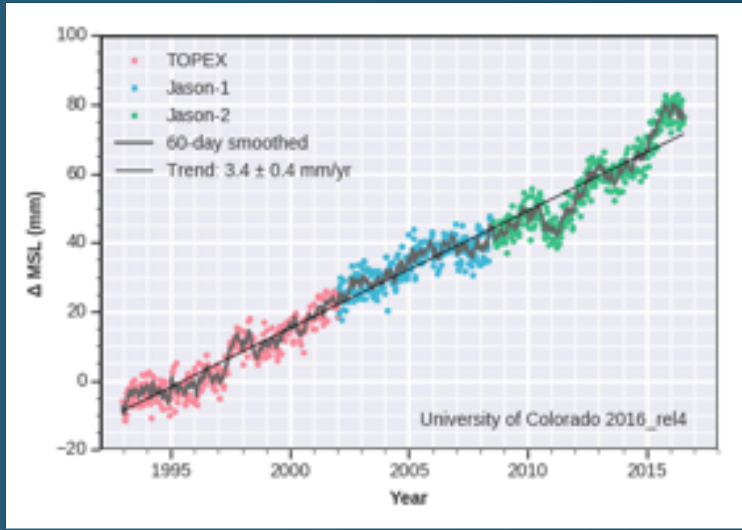


https://svs.gsfc.nasa.gov/30879

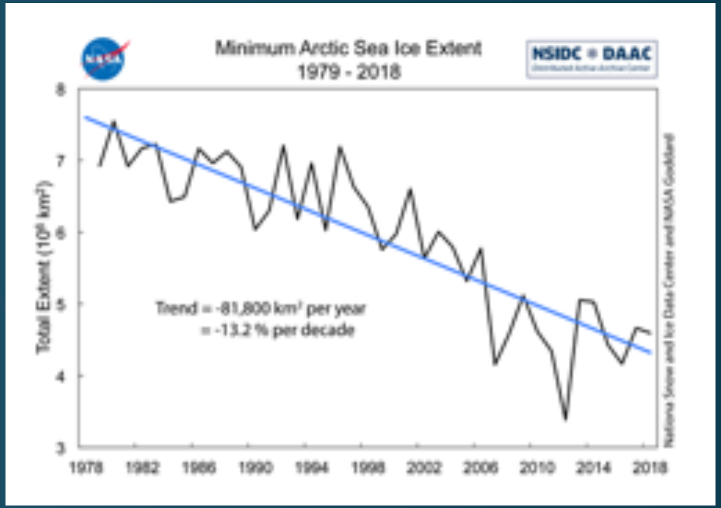
Long-Term Trends



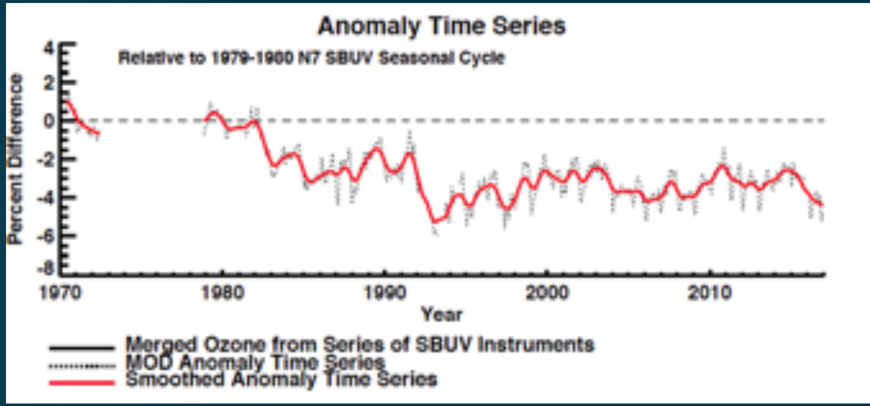
Long-Term Trends in Stratospheric Aerosols



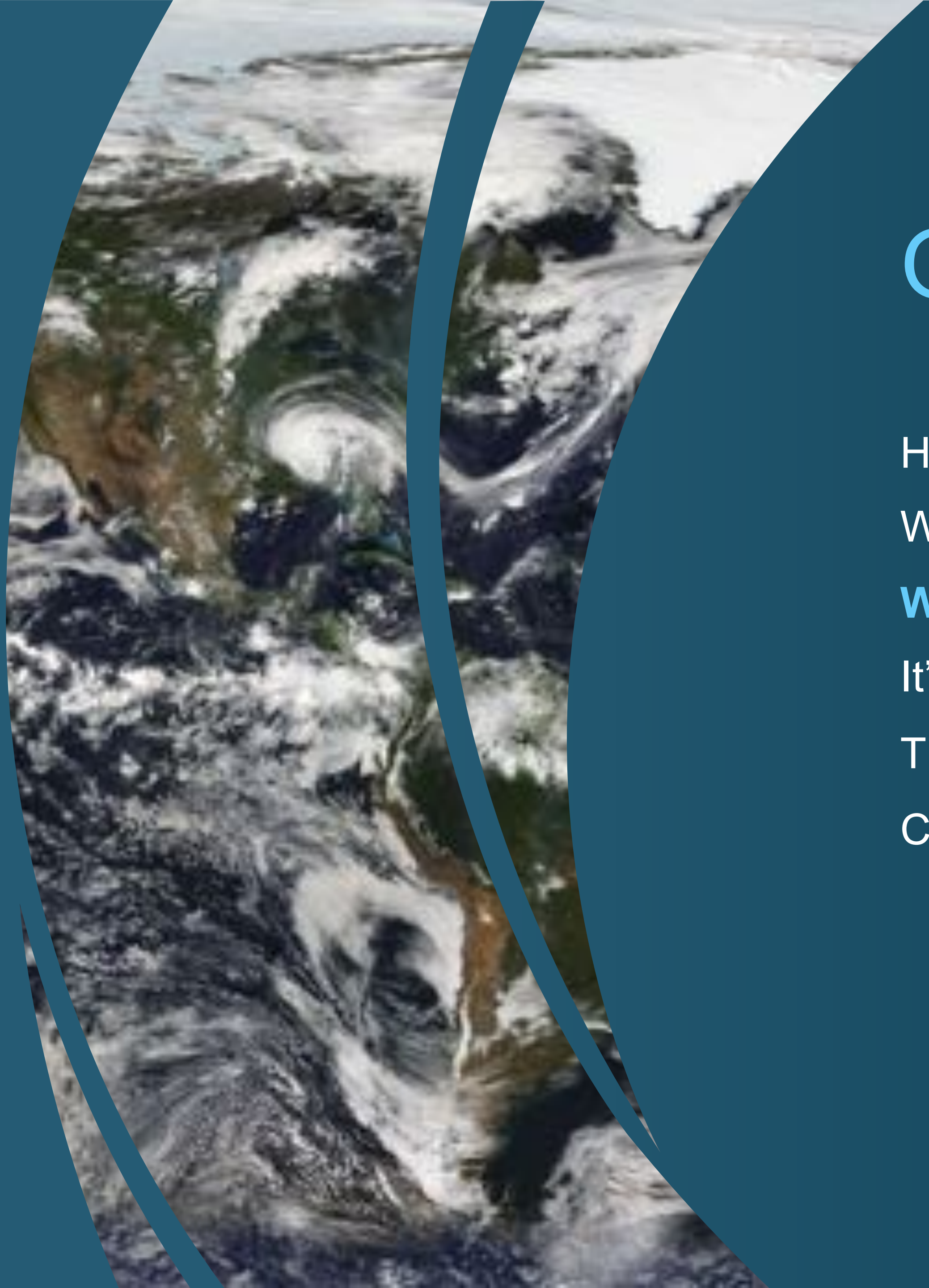
Global Sea Level Trend



Arctic Sea Ice Extent Changes



Stratospheric Ozone Trends



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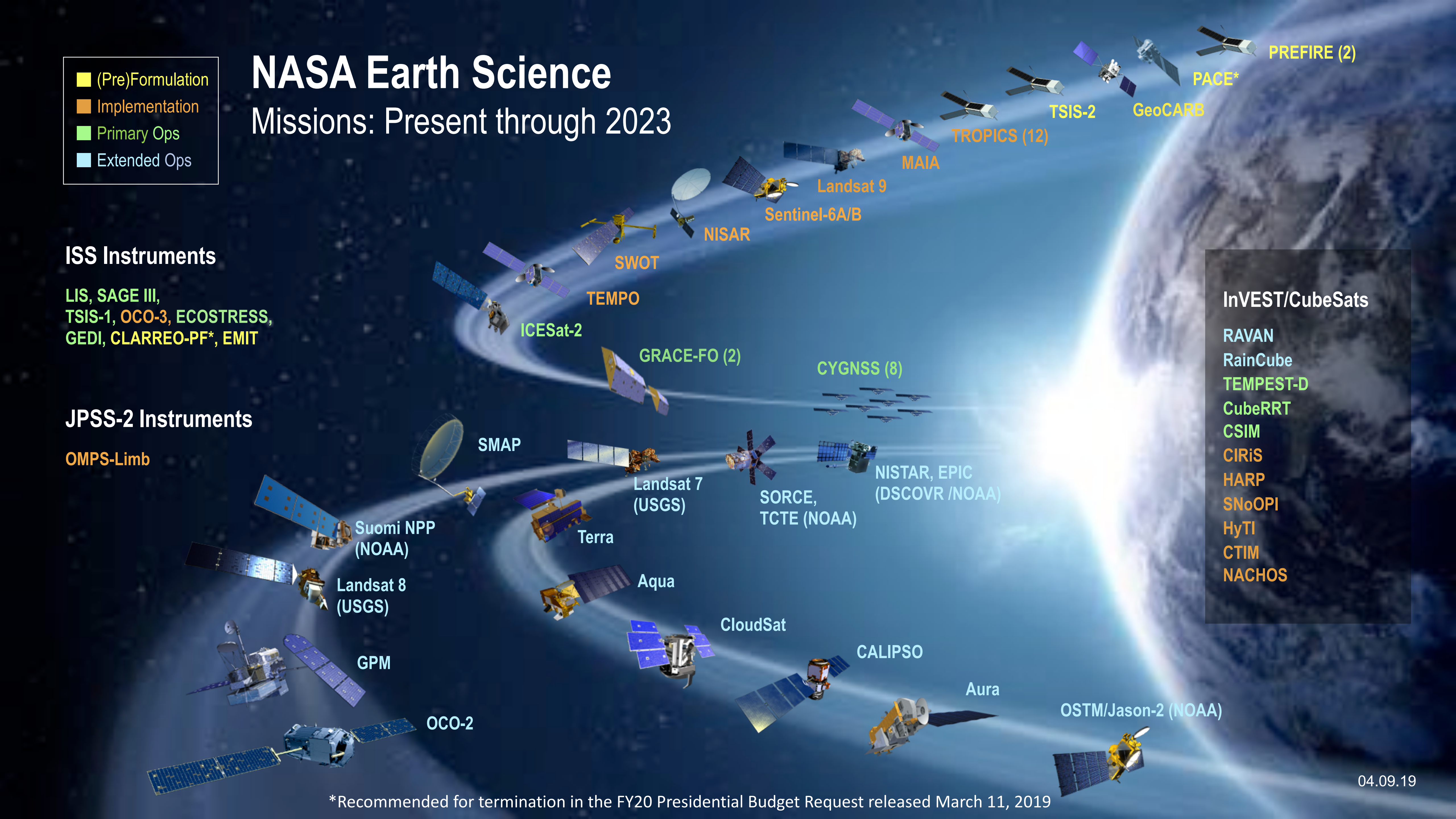

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Suomi NPP
(NOAA)
Terra
Landsat 8
(USGS)
Aqua
CloudSat
GPM
CALIPSO
Aura
OCO-2
OSTM/Jason-2 (NOAA)
InVEST/CubeSats
RAVAN
RainCube
TEMPEST-D
CubeRRT
CSIM
CIRiS
HARP
SNoOPI
HyTI
CTIM
NACHOS
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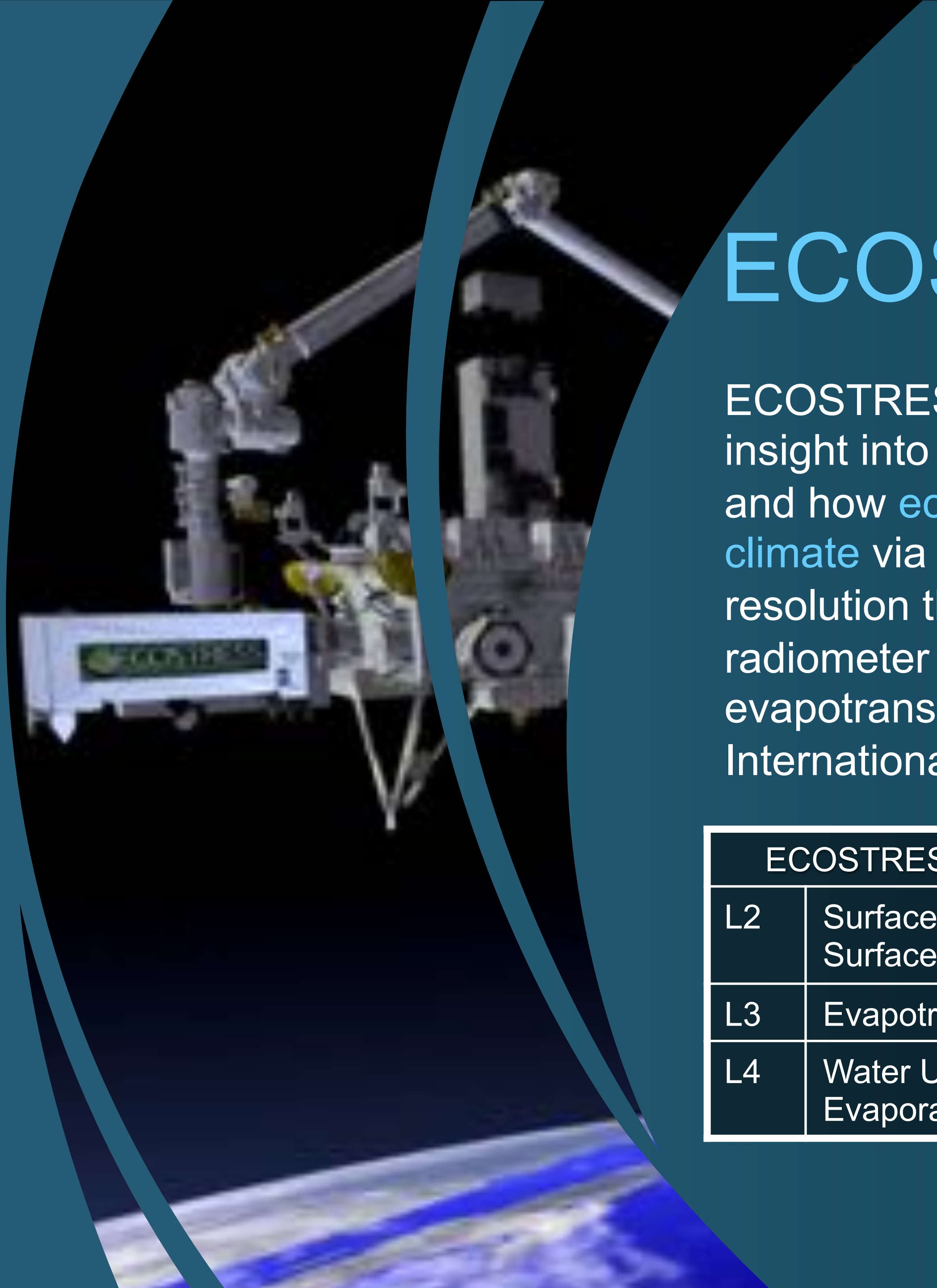
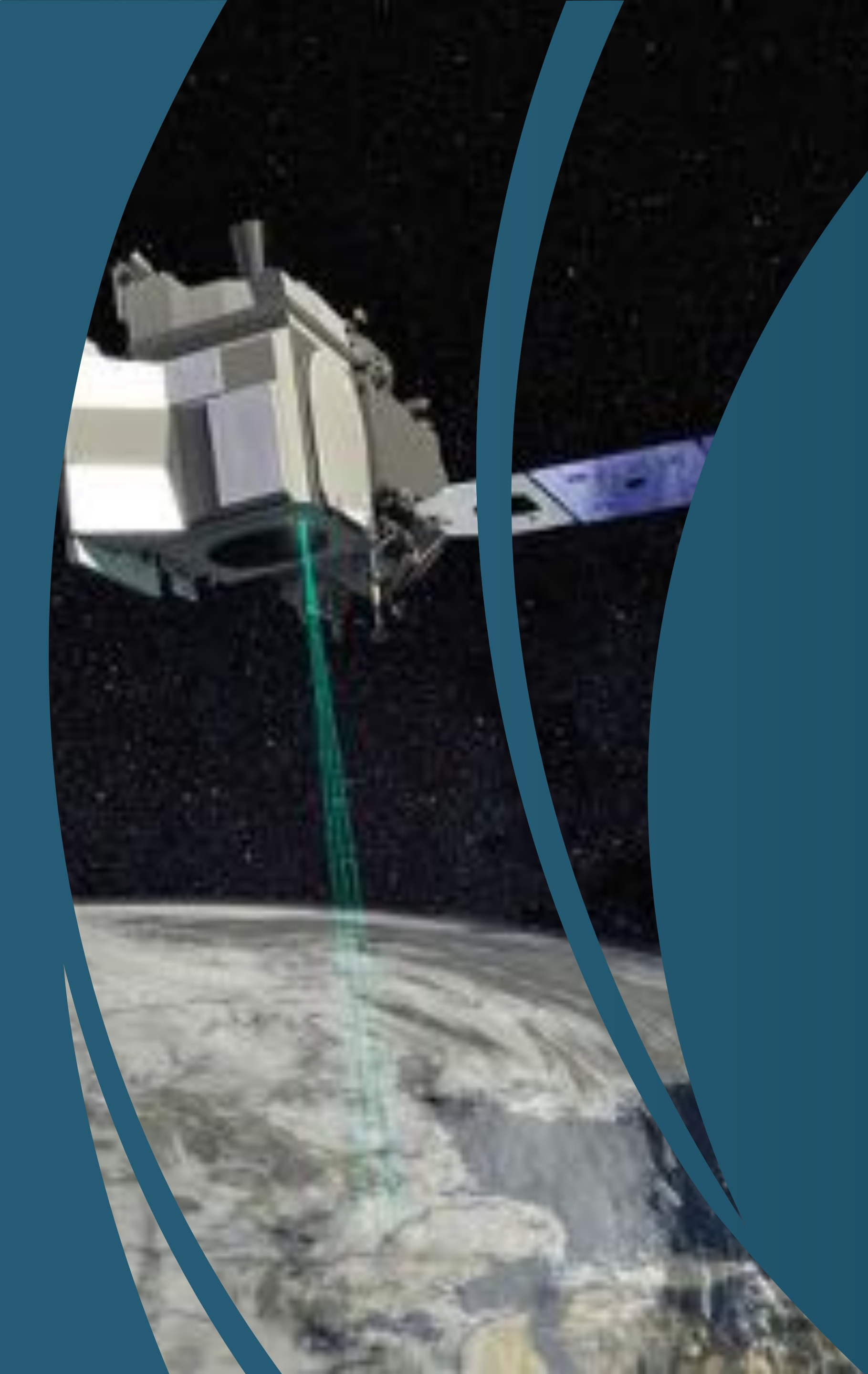


ECOSTRESS

ECOSTRESS will provide critical insight into plant-water dynamics and how ecosystems change with climate via high spatiotemporal resolution thermal infrared radiometer measurements of evapotranspiration from the International Space Station (ISS).

ECOSTRESS Science Data Products	
L2	Surface Temperature Surface Emissivity
L3	Evapotranspiration
L4	Water Use Efficiency Evaporative Stress Index



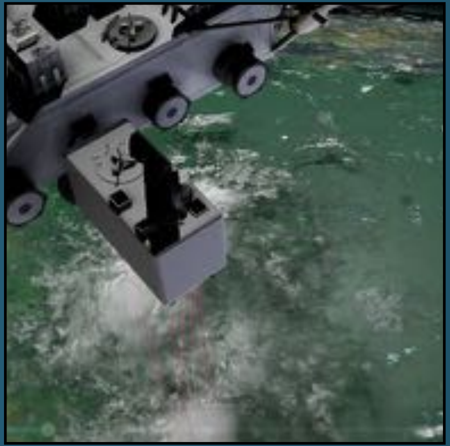
ICESat-2:
Next Generation Altimetry from Space

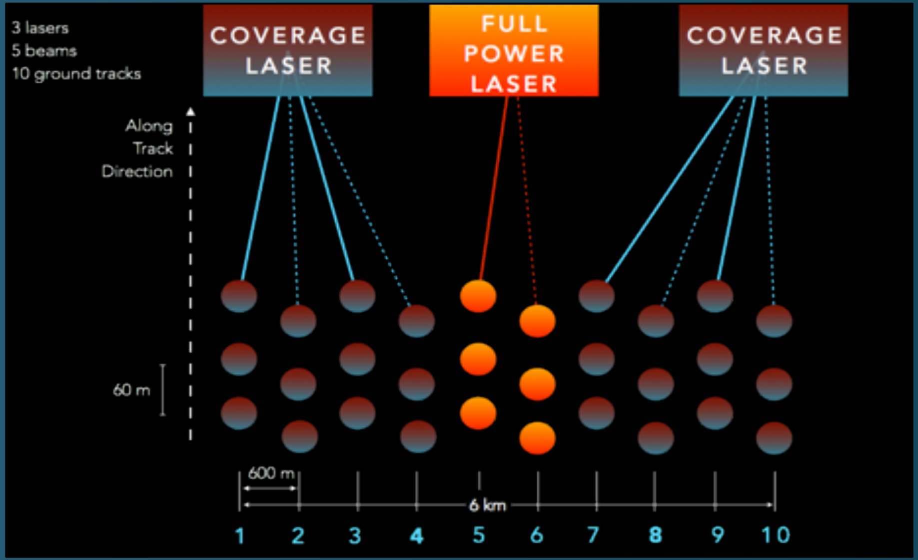
ICESat-2

- Launched on Sept. 15, 2018
- Near-polar orbit, ~500 km altitude
- 92-degree inclination (max latitudes of +/- 88 degrees)
- Year-round operation planned

Advanced Topographic Laser Altimeter System (ATLAS)

- Six beams, 532 nm (green)
- Single laser fires 10K shots per second, split into 6 beams
- Spots on surface 17 m in diameter, 70 cm separation
- Photon-counting detectors
- Beam pairs allow direct local slope determination





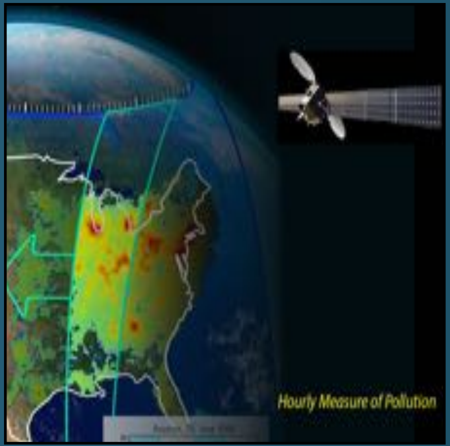
GEDI: High Resolution Laser Ranging of Earth's Forests and Topography on ISS

NASA's Global Ecosystem Dynamics Investigation (GEDI) is a full waveform lidar system that launched to the International Space Station on Dec. 5, 2018.

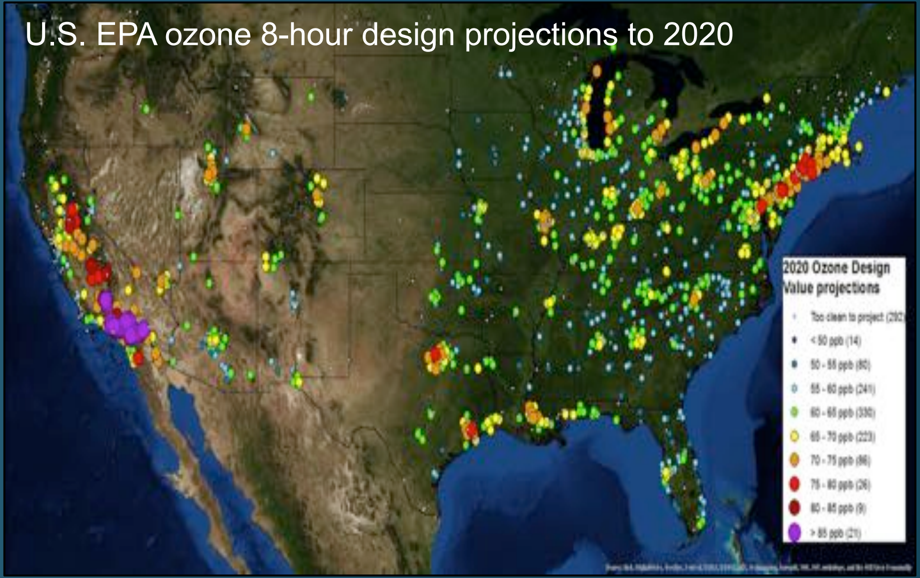
GEDI's 3 lasers will return 8 tracks of ~25 m waveform samples, providing ~10 billion surface structure observations.

GEDI ECOSYSTEM LIDAR

TEMPO Science Overview



U.S. EPA ozone 8-hour design projections to 2020

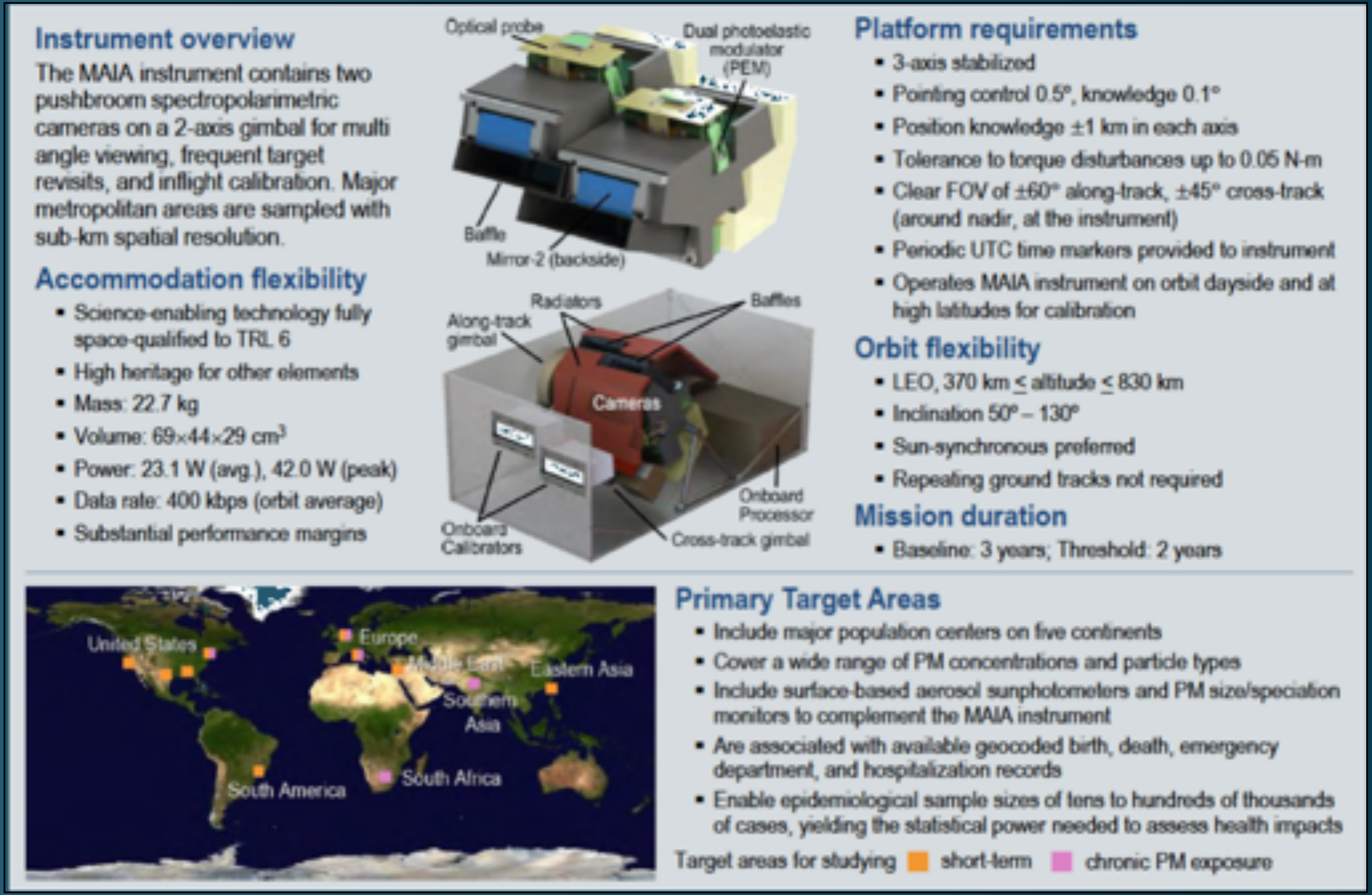


- U.S. air quality standards continue to become more stringent
- New and transient pollution sources (e.g., vehicular traffic, oil and gas development, trans-boundary pollution) are growing in importance, yet are difficult to monitor from ground networks
- Many areas that are not currently monitored are expected to violate proposed ozone standards
- TEMPO measurements will provide data to help solve this national challenge

TEMPO Science Questions

1. What are the temporal and spatial variations of emissions of gases and aerosols important for air quality and climate?
2. How do physical, chemical, and dynamical processes determine tropospheric composition and air quality over scales ranging from urban to continental, diurnally to seasonally?
3. How does air pollution drive climate forcing and how does climate change affect air quality on a continental scale?
4. How can observations from space improve air quality forecasts and assessments?
5. How does intercontinental transport affect air quality?
6. How do episodic events, such as wild fires, dust outbreaks, and volcanic eruptions, affect atmospheric composition and air quality?

MAIA Instrument Overview and Objective

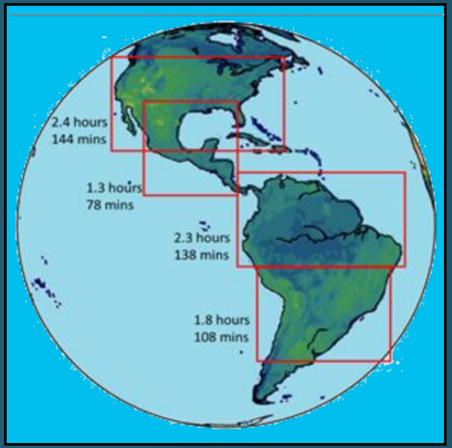


Why Observe from Space?

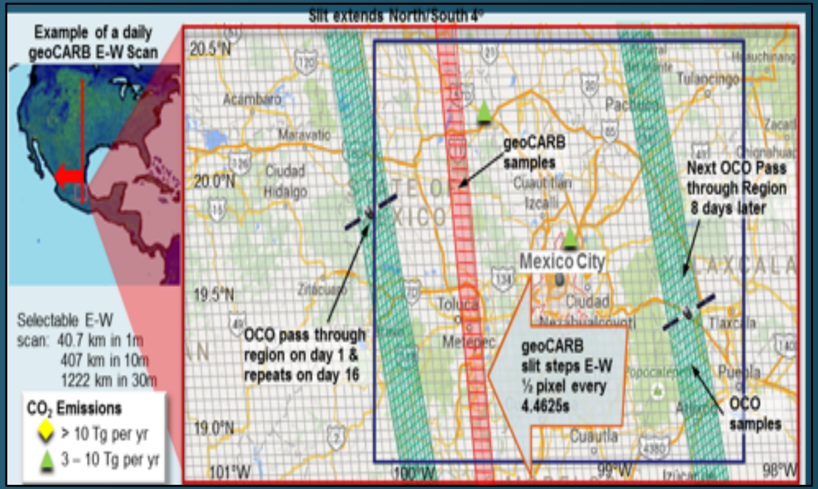
It is the only practical way to obtain the necessary spatial details to estimate PM exposure.

Surface monitors are too sparse and do not exist in many places where air quality is deteriorating and health impacts are greatest.

Objectives of GeoCARB



Possible scan blocks at an 85°West orbital slot



Moving the slit from East to West, GeoCARB provides continental-scale "mapping-like" coverage

Science Objective 1: Significantly improve knowledge of terrestrial fluxes of CO_2 at science and policy relevant scales.

Science Objective 2: Significantly improve knowledge of terrestrial fluxes of CH_4 at science and policy relevant scales.

Application Objective is to study vegetation health (e.g., photosynthesis, ecosystem respiration, etc.) by measuring solar induced fluorescence (SIF) and working with agricultural and forestry end-users to develop useful products (e.g. indicators of plant stress).

GeoCARB PI: Berrien Moore, University of Oklahoma

Observing System Priorities from NASEM 2017 Decadal Survey

Targeted Observable	Science/Applications Summary	Candidate Measurement Approach	Designated	Explorer	Incubation
Aerosols	Aerosol properties, aerosol vertical profiles, and cloud properties to understand their direct and indirect effects on climate and air quality	Backscatter lidar and multi-channel/multi-angle polarization imaging radiometer flown together on the same platform	X		
Clouds, Convection and Precipitation	Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	X		
Mass Change	Large-scale Earth dynamics measured by the changing mass distribution within and between Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	X		
Surface Biology and Geology	Earth surface geology and biology, ground/water temperature, snow reflectivity, active geological processes, vegetation traits and algal biomass	Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR	X		
Surface Deformation and Change	Earth surface dynamics from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	X		
Greenhouse Gases	CO2 and methane fluxes and trends, global and regional with quantification of point sources and identification of source types	Multispectral short wave IR and thermal IR sounders; or lidar **		X	
Ice Elevation	Global ice characterization including elevation change of land ice to assess sea level contributions and freeboard height of sea ice to assess sea ice/ocean/atmosphere interaction	Lidar **		X	
Ocean Surface Winds and Currents	Coincident high-accuracy currents and vector winder to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift	Radar scatterometer		X	

*** Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables*

Observing System Priorities from NASEM 2017 Decadal Survey (*cont.*)

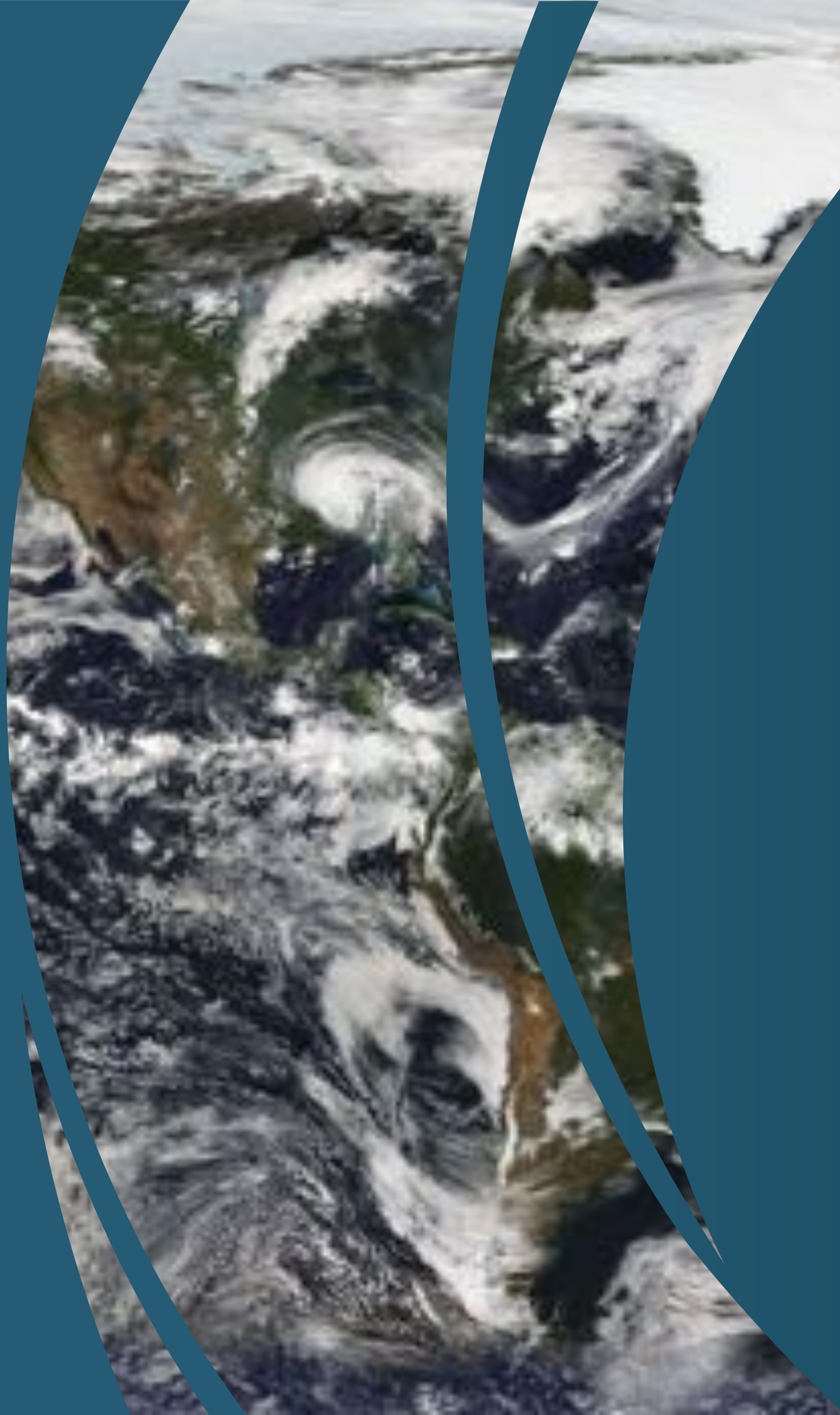
Targeted Observable	Science/Applications Summary	Candidate Measurement Approach	Designated	Explorer	Incubation
Ozone and Trace Gases	Vertical profiles of ozone and trace gases (including water vapor, CO, NO2, methane, and N20) globally and with high spatial resolution	UV/IR/microwave limb/nadir sounding and UV/IR solar/stellar occultation		X	
Snow Depth and Snow Water Equivalent	Snow depth and snow water equivalent including high spatial resolution in mountain areas	Radar (Ka/Ku band) altimeter; or lidar**		X	
Terrestrial Ecosystem Structure	3D structure of terrestrial ecosystem including forest canopy and above ground biomass and changes in above ground carbon stock from processes such as deforestation and forest degradation	Lidar**		X	
Atmospheric Winds	3D winds in troposphere/PBL for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		X	$\boxed{X}$
Planetary Boundary Layer	Diurnal 3D PBL thermodynamic properties and 2D PBL structure to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights	Microwave, hyperspectral IR sounder(s) (e.g., in geo or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling and DIAL lidar; and lidar** for PBL height			X
Surface Topography and Vegetation	High-resolution global topography including bare surface land topography, ice topography, vegetation structure, and shallow water bathymetry	Radar; or lidar**			X

*** Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables*

Other ESAS 2017 Targeted Observables not allocated to a Flight Program element: Aquatic Biogeochemistry, Magnetic Field Changes, Ocean Ecosystem Structure, Radiance Intercallibration, Sea Surface Salinity, Soil Moisture

See: https://science.nasa.gov/earth-science/decadal-surveys

ESD has decided to treat Atmospheric Winds as Explorer



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What we’ll be doing in the future

It’s not ALL satellites

- **Surface measurement networks**
- **Airborne measurements**
- **Computational modeling (*not included in this presentation in the interest of time*)**

The broader context

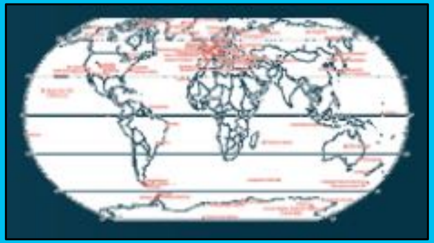
Conclusion

Examples of NASA-supported Ground Networks

AGAGE

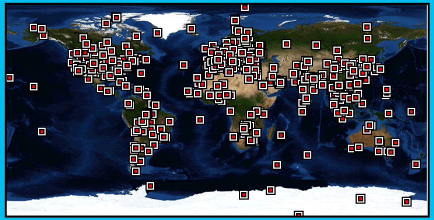
GGN

NDACC



NSGN

AERONET



SHADOZ

MPLNet

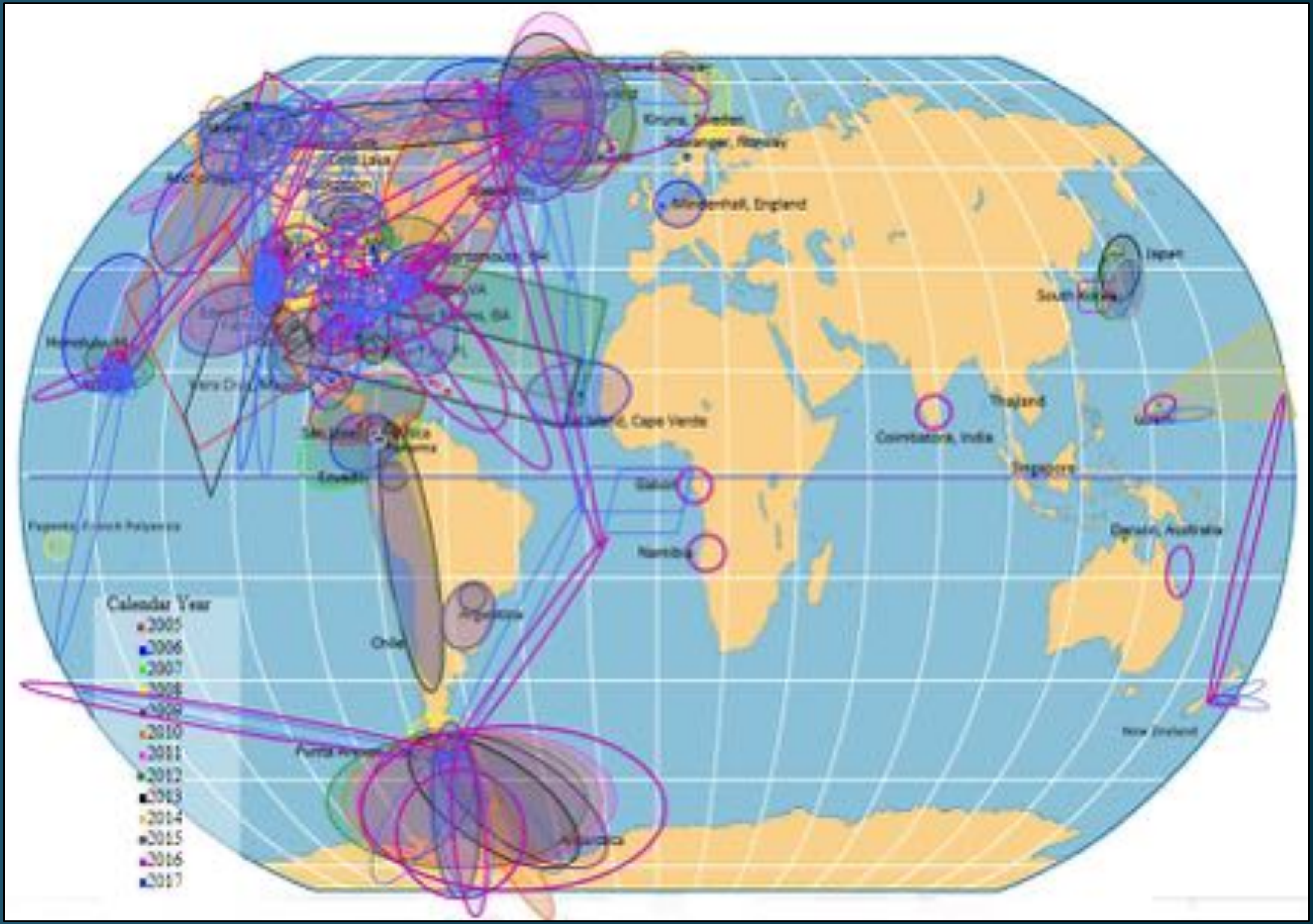
TCCON

PANDORA

TOLNet


Airborne Science Program
Observing Platforms for Earth System Science Investigations
http://airbornescience.nasa.gov
ER-2
G III
G V
P-3
DC-8
Other Available Aircraft
C-130
B-200
C-23 Sherpa
Global Hawk
WB-57
HU-25C Falcon
Twin Otter
SIERRA
IKHANA
S-3B

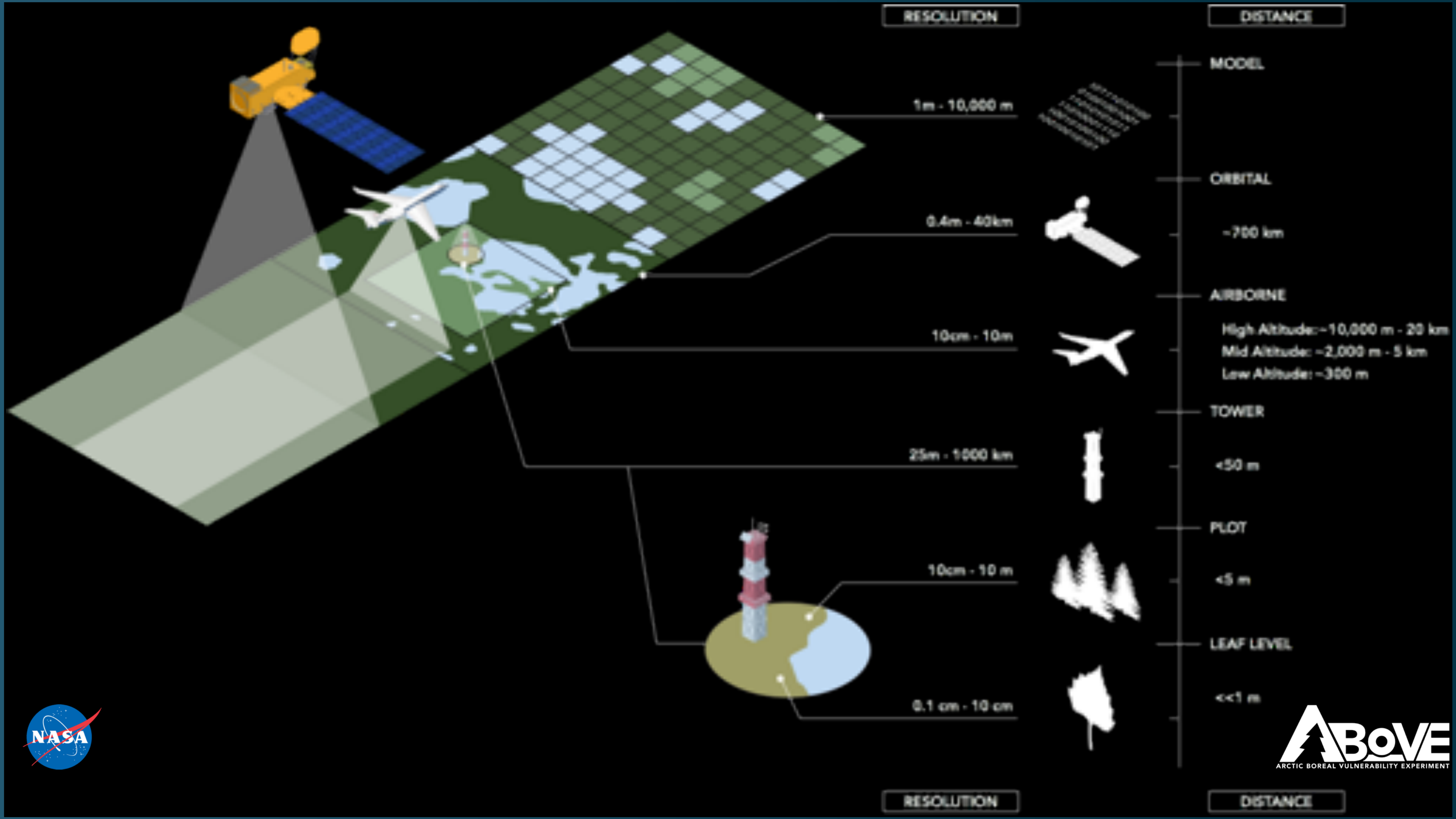
2005-2017 Airborne Campaigns



What Airborne Science Means at NASA

- Airborne Science at NASA integrates unique capabilities in the following areas:
  - Platforms: airborne platforms that can fly instrument packages (from a single instrument to several dozen) to locations needed for the desired observations
  - Sensors: remote sensing and/or *in situ* sensors that can work individually or collectively to address science and/or technology questions and opportunities
  - Systems: data, information, and operational systems that enable data to be acquired, transmitted, shared, and to allow investigator interactions with crew to optimize flight trajectories
  - People: the human capital that allows airborne missions to be carried out safely and effectively in remote locations, frequently under harsh conditions with little indigenous local support; also the ability to design experiments/campaigns and turn acquired data into knowledge
  - Opportunities: program-directed and competitive solicitations for mission/campaign development and also instrument development/evolution; well-defined flight request approach for use of platforms/facility sensors
- The linkage among these is critical – especially the “marriage” between platforms and sensors (pods/viewing ports for remote sensing instruments, well-characterized inlets for *in situ* sensors)
- Airborne Science is fully integrated with space-based measurements, surface-based measurements and modeling into an “integrated whole” with involvement of all components included in planning/design

Scaling Strategy for Field Campaigns



CAMP^{2}Ex: Clouds, Aerosol and Monsoon Processes Philippines Experiment

An airborne field campaign planned for mid-August to October 2019

CAMP^{2}Ex Science Questions:

- To what extent are aerosol particles responsible for modulating warm and mixed phase precipitation in tropical environments?
- To what extent do aerosol induced changes in clouds and precipitation feedback into aerosol lifecycle?
- How does the aerosol and cloud influence on radiation co-vary and interact?
- How does land use change affect cloud and precipitation change? Is land use change a confounder for aerosol impacts?

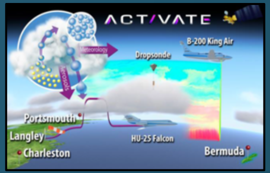
Priority Measurements:

- Aerosol in-situ microphysics:
- Cloud in-situ microphysics
- Cloud/precip remote sensing
- Trace Gases
- Aerosol and wind profiles (lidar)
- Radiation: Solar and IR
- State variables

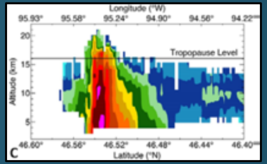
FIREX-AQ:
A cooperative wildfire air quality field study

- A NASA-NOAA cooperative field study (July 22-September 15, 2019) that will focus on the links between satellite and ground-based measurements of both fresh and aged biomass burning plumes in the continental United States.
- Efforts underway to coordinate with the Joint Fire Science Program FASMEE field campaign. FIREX-AQ team is working with NSF and EPA to leverage opportunities for additional aircraft and ground-based measurements.
- FIREX-AQ includes both NASA DC-8 and NOAA Twin Otter aircraft for airborne *in situ* sampling of Western wildfires, as well as agricultural/land-management fires in the Central and Southeastern U.S.
- The DC-8 aircraft will have several remote sensing instruments to detect fire temperature, fire radiative power (FRP) and plume height, as well as HSRL and ozone lidars.
- Goals: 1.) improve our understanding of the transport of and chemical transformations in biomass burning plumes and their impact on air quality, and 2.) improve the ability to incorporate wildfires into air quality forecast models using satellite products.

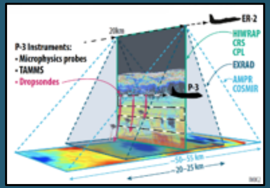
EVS-3 Investigations



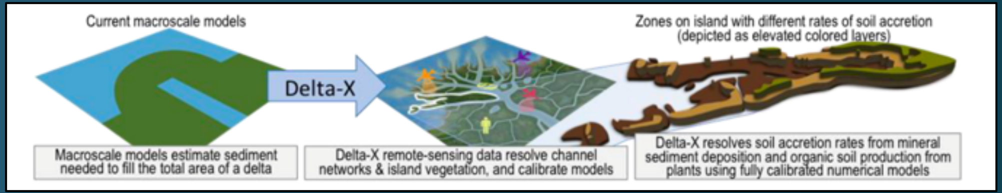
ACTIVATE - Aerosol Cloud meTeorology Interactions oVer the western ATlantic investigates how aerosol particles change cloud properties in ways that affect Earth's climate system. The investigation will focus on marine boundary layer clouds over the western North Atlantic Ocean



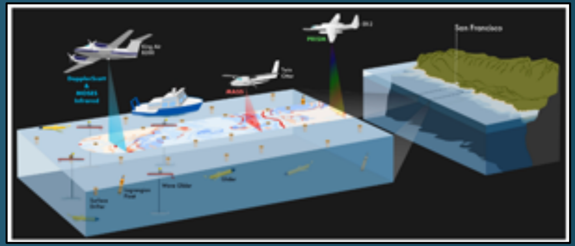
DCOTTS - Dynamics and Chemistry of the Summer Stratosphere investigates how strong summertime convective storms over North America can change the chemistry of the stratosphere



IMPACTS **-** Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms study the formation of snow bands in East Coast winter storms**.**

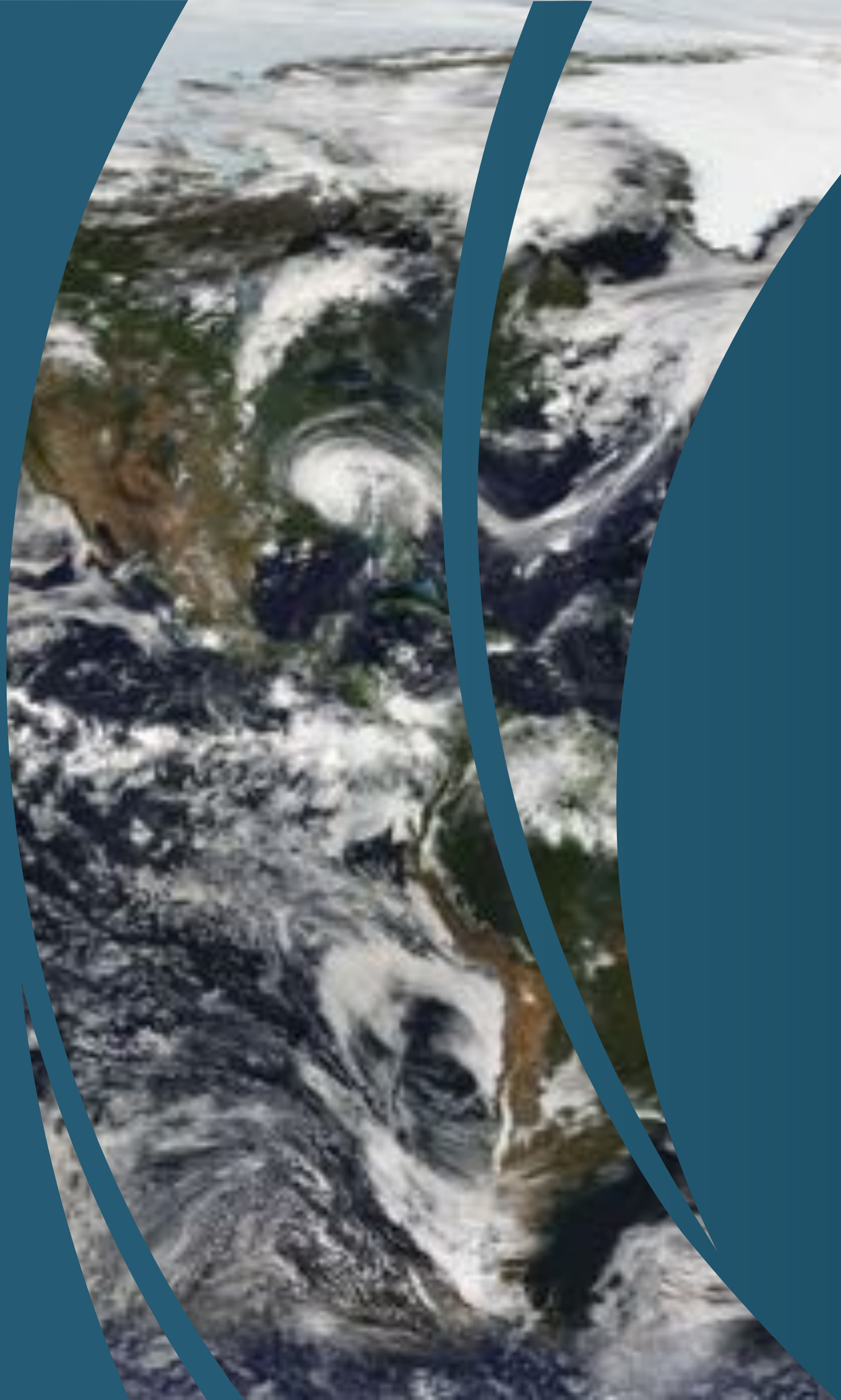


Delta-X investigates the natural processes that maintain and build land in major river deltas threatened by rising seas



SMODE **-** Submesoscale Ocean Dynamics and Vertical Transport investigation to explore the potentially large influence that small-scale ocean eddies have on the exchange of heat between the ocean and the atmosphere

A total of six NASA centers and 27 educational institutions are participating in these five Earth Venture projects. The 5-year investigations were selected from 30 proposals.



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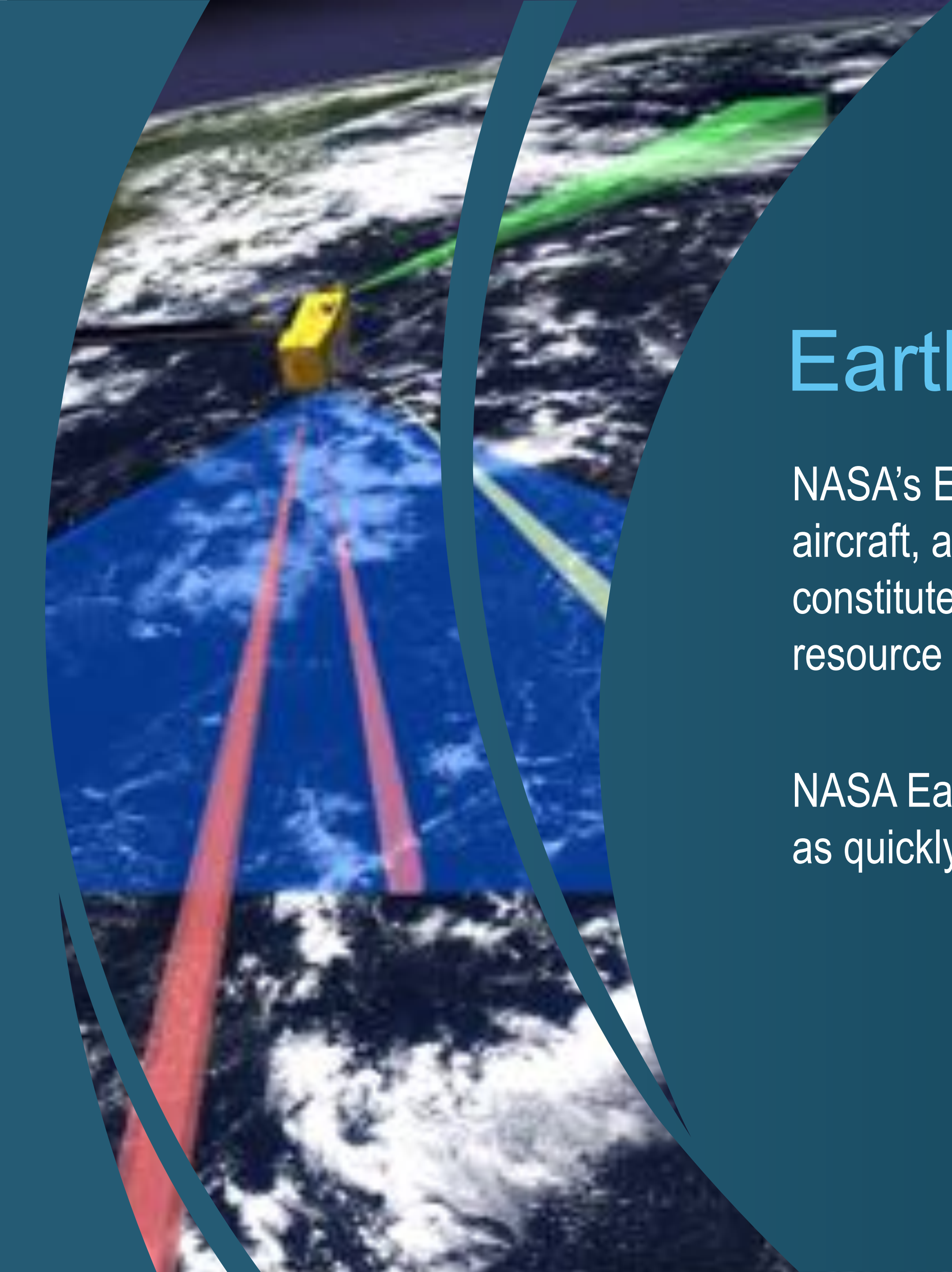
- **Data**
- **Modeling and assimilation**
- **Applications**
- **Technology**
- **Research opportunities**
- **Interagency coordination**
- **International coordination**
- **Communications and education**

Conclusion



Earth Science Open Data Policy

Since 1994

NASA’s Earth Observation data is collected continuously from satellites, aircraft, and ground-based missions for more than a half-century constitute an invaluable record of Earth processes and a critical resource for scientists and researchers.

NASA Earth Science data are free and open to all users for any purpose as quickly as practical after instrument checkout and calibration.

Lines of Business: NASA Applied Sciences Program

Societal & Economic Applications

Generate, test, develop, enable adoption, and extol applications ideas for sustained uses of Earth observations in decisions and actions.

Capacity Building

Build skills, workforce, and capabilities in US and developing countries to apply Earth obs. to benefit society and build economies.

Applications in Mission Planning

Identify applications early and throughout mission lifecycle, integrate end-user needs in design and development, enable user feedback, and broaden advocacy.

Innovative and practical uses of Earth observations

NASA Earth Science Applied Sciences Program

Applied Sciences serves a fundamental role to advance global knowledge about effective ways to extend and apply Earth science and inform decisions and actions.

Emphasis in Applications Areas

- Health and Air Quality
- Water Resources
- Ecological Forecasting
- Disasters
- Agriculture/Food Security
- Wildland Fires (through 2017)

Support opportunities in additional areas

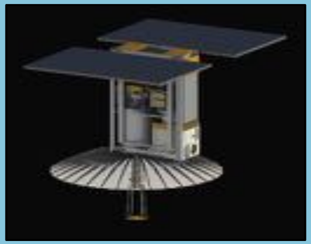
- Energy
- Urban Development
- Transportation/Infrastructure

Wildfires will be covered in Ecological Forecasting and Disasters; climate and weather play into all areas.

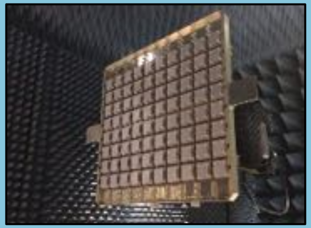
Earth Science Technology Program Elements

ESTO manages, on average, 120 active technology development projects. Most are funded through the primary program lines below. Nearly 800 projects have completed since 1998.

Advanced Technology Initiatives (ATI)



In-Space Validation of Earth Science Technologies (InVEST)
on-orbit technology validation and risk reduction for small instruments and instrument systems that could not otherwise be fully tested on the ground or airborne systems
(average award: $1-1.8M per year over three years)

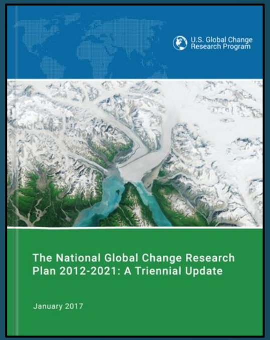


Advanced Component Technologies (ACT)
critical components and subsystems for advanced instruments and observing systems
(average award: $400K/$600K per year over two/three years)

Instrument Incubator Program (IIP)
innovative remote sensing instrument development from concept through breadboard and demonstration
(average award: $1.5M per year over three years and $750K for 18 months for instrument concepts)

Advanced Information Systems Technology (AIST)
innovative on-orbit and ground capabilities for communication, processing, and management of remotely sensed data and the efficient generation of data products
(average award: $600K per year over two years)

Interagency Coordination Efforts in Earth Science*



Committee on Environment Co-Chairs: EPA, NOAA, OSTP	
Polar Research*	Earth Observations (USGEO)
Global Change (USGCRP)*	Ocean Science & Tech (SOST)
Water Availability & Quality	Aquaculture*

National Science And Technology Council (NSTC)

Committee on Environment (CoE)

Subcommittee on Global Change Research (SGCR)

U.S. Global Change Research Program (USGCRP)

The USGCRP Vision and Mission

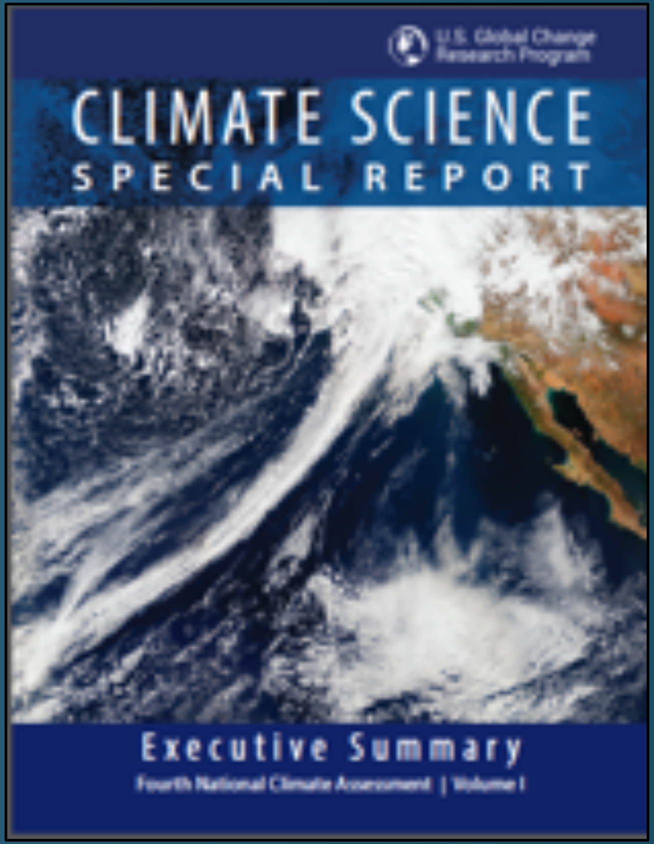
Vision: "A nation, globally engaged and guided by science, meeting the challenges of climate and global change."

Mission: "To build a knowledge base that informs human responses to climate and global change through coordinated and integrated federal programs of research, education, communication, and decision support."

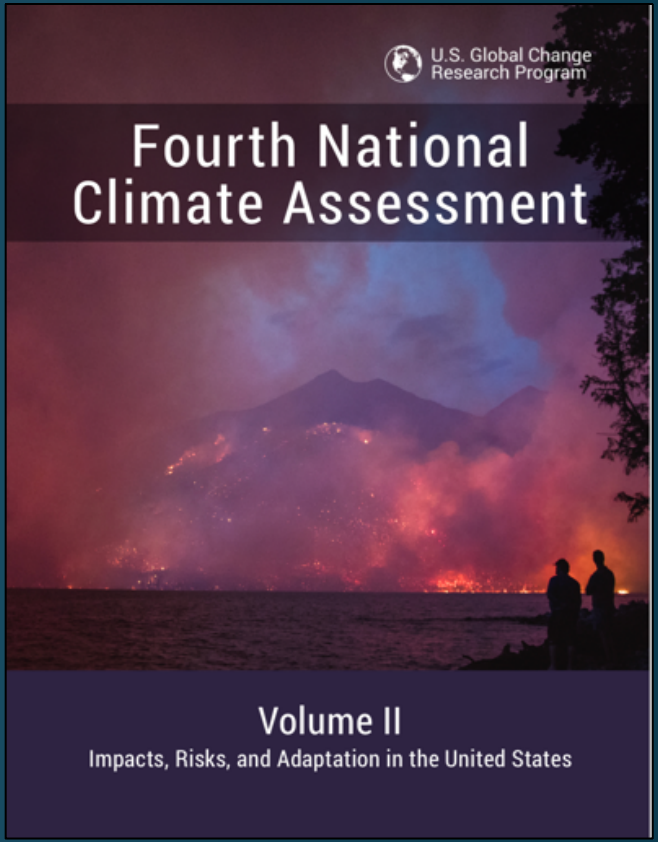
Goals	Objectives
1. Advance Science	1.1 Earth System Understanding 1.2 Science for Adaptation and Mitigation 1.3 Integrated Observations 1.4 Integrated Modeling 1.5 Information Management and Sharing
2. Inform Decisions	2.1 Inform Adaptation Decisions 2.2 Inform Mitigation Decisions 2.3 Enhance Global Change Information
3. Conduct Sustained Assessments	3.1 Scientific Integration 3.2 Ongoing Capacity 3.3 Inform Responses 3.4 Evaluate Progress
4. Communicate & Educate	4.1 Strengthen Communication and Education Research 4.2 Reach Diverse Audiences 4.3 Increase Engagement 4.4 Cultivate Scientific Workforce

USGCRP Reports

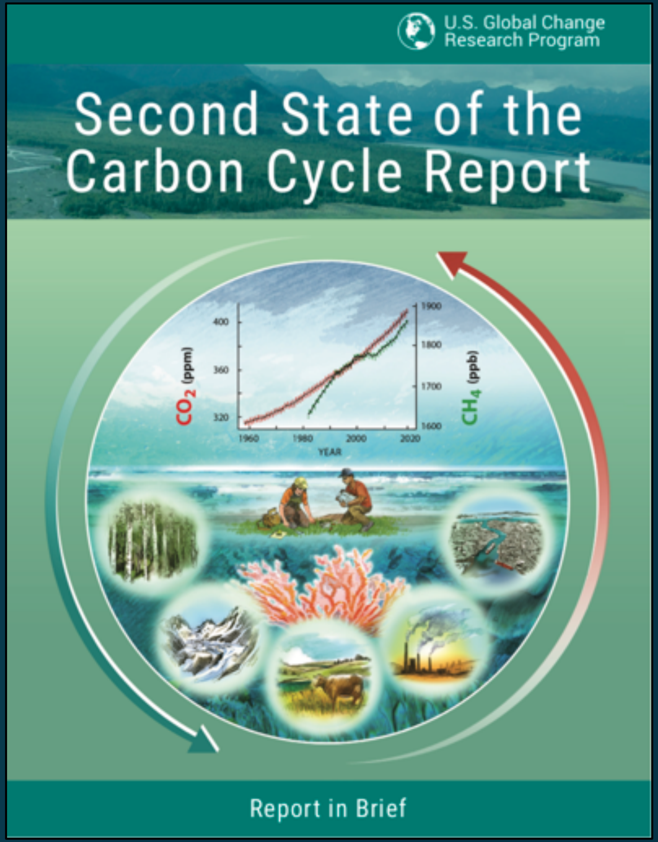
NCA4 Vol. 1 Released 11/3/17



NCA4 Vol. 2 Released 11/23/18



SOCCR-2 RIB Released 11/23/18



NCA4V2: Summary Findings (Abridged) *(1 of 2)*

- Communities: Climate change creates new risks and exacerbates existing vulnerabilities in communities across the United States, presenting growing challenges to human health and safety, quality of life, and the rate of economic growth.
- Economy: Without substantial and sustained global mitigation and regional adaptation efforts, climate change is expected to cause growing losses to American infrastructure and property and impede the rate of economic growth over this century.
- Interconnected Impacts: Climate change affects the natural, built, and social systems we rely on individually and through their connections to one another. These interconnected systems are increasingly vulnerable to cascading impacts that are often difficult to predict, threatening essential services within and beyond the Nation’s borders.
- Actions to Reduce Risks: Communities, governments, and businesses are working to reduce risks from and costs associated with climate change by taking action to lower greenhouse gas emissions and implement adaptation strategies. While mitigation and adaptation efforts have expanded substantially in the last four years, they do not yet approach the scale considered necessary to avoid substantial damages to the economy, environment, and human health over the coming decades.
- Water: The quality and quantity of water available for use by people and ecosystems across the country are being affected by climate change, increasing risks and costs to agriculture, energy production, industry, recreation, and the environment.
- Health: Impacts from climate change on extreme weather and climate-related events, air quality, and the transmission of disease through insects and pests, food, and water increasingly threaten the health and well-being of the American people, particularly populations that are already vulnerable.

NCA4V2: Summary Findings (Abridged) *(2 of 2)*

- Indigenous Peoples: Climate change increasingly threatens Indigenous communities' livelihoods, economies, health, and cultural identities by disrupting interconnected social, physical, and ecological systems.
- Ecosystems and Ecosystem Services: Ecosystems and the benefits they provide to society are being altered by climate change, and these impacts are projected to continue. Without substantial and sustained reductions in global greenhouse gas emissions, transformative impacts on some ecosystems will occur; some coral reef and sea ice ecosystems are already experiencing such transformational changes.
- Agriculture and Food: Rising temperatures, extreme heat, drought, wildfire on rangelands, and heavy downpours are expected to increasingly disrupt agricultural productivity in the United States. Expected increases in challenges to livestock health, declines in crop yields and quality, and changes in extreme events in the United States and abroad threaten rural livelihoods, sustainable food security, and price stability.
- Infrastructure: Our Nation's aging and deteriorating infrastructure is further stressed by increases in heavy precipitation events, coastal flooding, heat, wildfires, and other extreme events, as well as changes to average precipitation and temperature. Without adaptation, climate change will continue to de- grade infrastructure performance over the rest of the century, with the potential for cascading impacts that threaten our economy, national security, essential services, and health and well-being.
- Oceans and Coasts: Coastal communities and the ecosystems that support them are increasingly threatened by the impacts of climate change. Without significant reductions in global greenhouse gas emissions and regional adaptation measures, many coastal regions will be transformed by the latter part of this century, with impacts affecting other regions and sectors. Even in a future with lower green- house gas emissions, many communities are expected to suffer financial impacts as chronic high-tide flooding leads to higher costs and lower property values.
- Tourism and Recreation: Outdoor recreation, tourist economies, and quality of life are reliant on benefits provided by our natural environment that will be degraded by the impacts of climate change in many ways.

Key Types of International Engagement

Observations

- Bilateral cooperation in missions and related science
- Multi-lateral organizationally-mediated cooperation
- Field work (airborne, balloon, surface, shipborne)
- Surface-based measurement networks

Research, Applications, and Assessment

- Research: WCRP, Future Earth
- Applications: UN/SDGs, Disasters
- Assessment: IPCC, WMO/UNEP, IPBES, WOA, AMAP
- Internationally-Focused Opportunities

Education and Capacity Building

- Education: GLOBE
- Capacity Building: SERVIR, ARSET, others

** Treated in previous talk, so only partially included here*

The International Effort in Space-Based and Global Observations

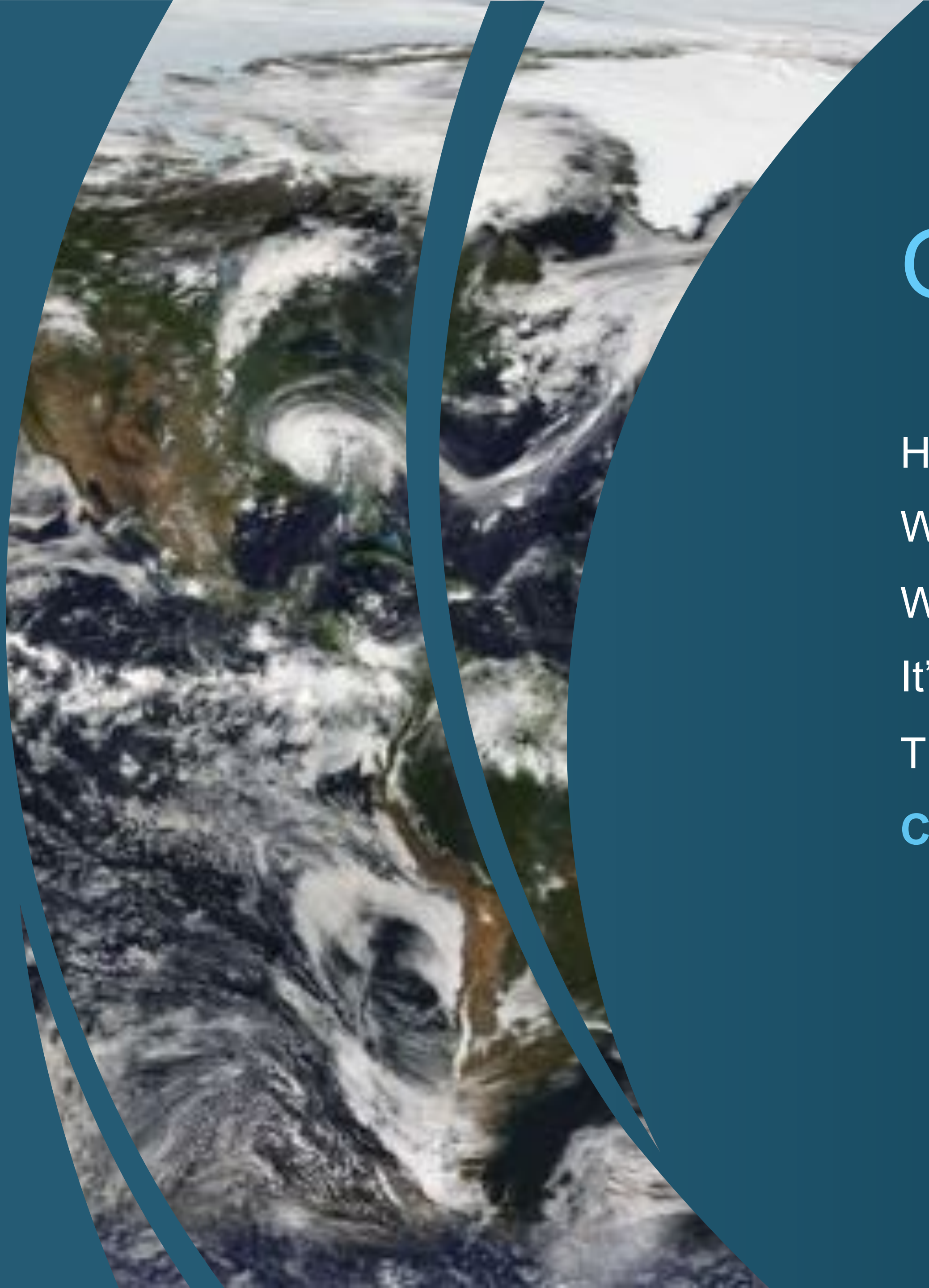
- Space-based perspective provides unequalled vantage point for observing entire Earth system
- Efforts of all countries are needed to provide needed breadth, resilience and innovation
- Cooperation among nations, including data sharing calibration/validation and assessment, enhances value of all nations’ efforts
- Satellite data can support both long-term climate and near-term operational requirements, and be used to improve quality of life for all the world’s citizens
- Numerous entities and mechanisms exist that are facilitating this coordination

NASA Earth Science
International Collaborations

Selected Recent Earth System Satellite Launches

Mission	Agency/Country	Launch Date
Kanopus-V3/V4	ROSHYDROMET	02/01/18
PAZ	Spain	02/22/18
GOES-17	NOAA	03/01/18
Sentinel-3B	ESA, EC	04/25/18
GRACE-FO	NASA, GFZ	05/22/18
GF-5	China	05/09/18
FY-2H	CMA	06/05/18
GF-6	CNSA/CAST	06/06/18
DESIS/ISS	DLR	06/29/18
ECOSTRESS/ISS	NASA	06/29/18
ADM/Aeolus	ESA	08/22/18
HY-1C	CAST/NSOAS	09/07/18
ICESat-2	NASA	09/15/18
NovaSAR	UKSA	09/16/18
Beijing-2 (DMC-3-D)	NRSCC	09/16/18
SAOCOM-1A	CONAE, ASI	10/08/18
HY-2B	CAST,NSOAS	10/24/18
GOSAT-2	JAXA	10/29/19
CFOSat	CNES	10/29/18
KhalifaSat	UAE	10/29/18
Metop-C	EUMETSAT/NOAA/CNES/ESA	11/07/18
HYSIS	ISRO	11/27/18
GEO-KOMPSAT-2A	KARI, KMA, Harris	12/04/18
GEDI/ISS	NASA	12/05/18

Input from Brian Kil**lough**
NASA/LaRC
(CEOS System Engineering Office)



Overview

How NASA studies Earth with remote sensing

What we’re seeing – and learning

What we’ll be doing in the future

It’s not ALL satellites

The broader context

Conclusion

Concluding Messages

- The vantage point of space provides a good approach to watch the whole planet evolve on a variety of time scales and explore the interconnections between physics, chemistry and biology, as well as the interplay between human and naturally caused change.
- The current and projected suite of space-based environmental measurement capability enables scientific discovery and (for many parameters) monitoring, and is being enhanced by introduction of new technology.
- Current observations show significant changes in many aspects of Earth system, with the potential for even more significant changes in the future.
- Investments in space measurements are synergistic with surface-, aircraft- and balloon-based measurements, along with models.
- International cooperation is an important component of all efforts, including space observations, field campaigns, surface measurements, research, and assessment

DSCOVR Earth View with Lunar Transit July 16, 2015