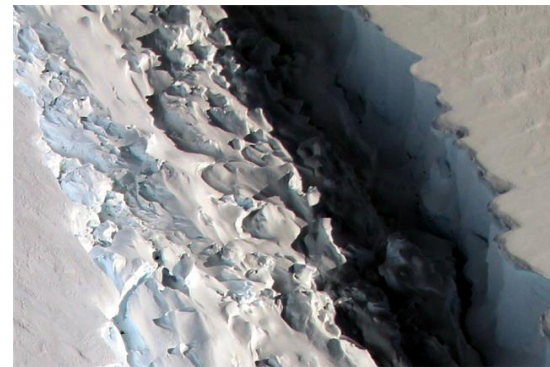
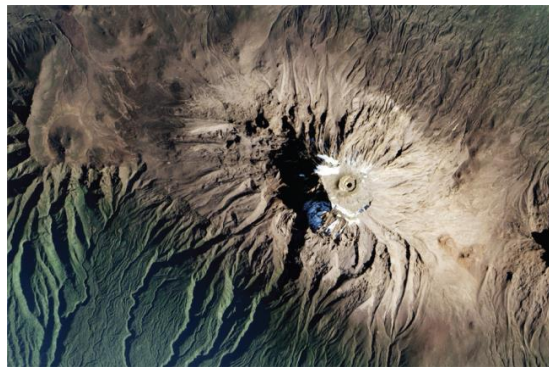


SCIENCE

National Aeronautics and
Space Administration



NASA's Activities and Plans Related to Water and Energy-Cycle

This talk is prepared with input and assistance from numerous colleagues at NASA HQ, NASA centers, and the broader research community.

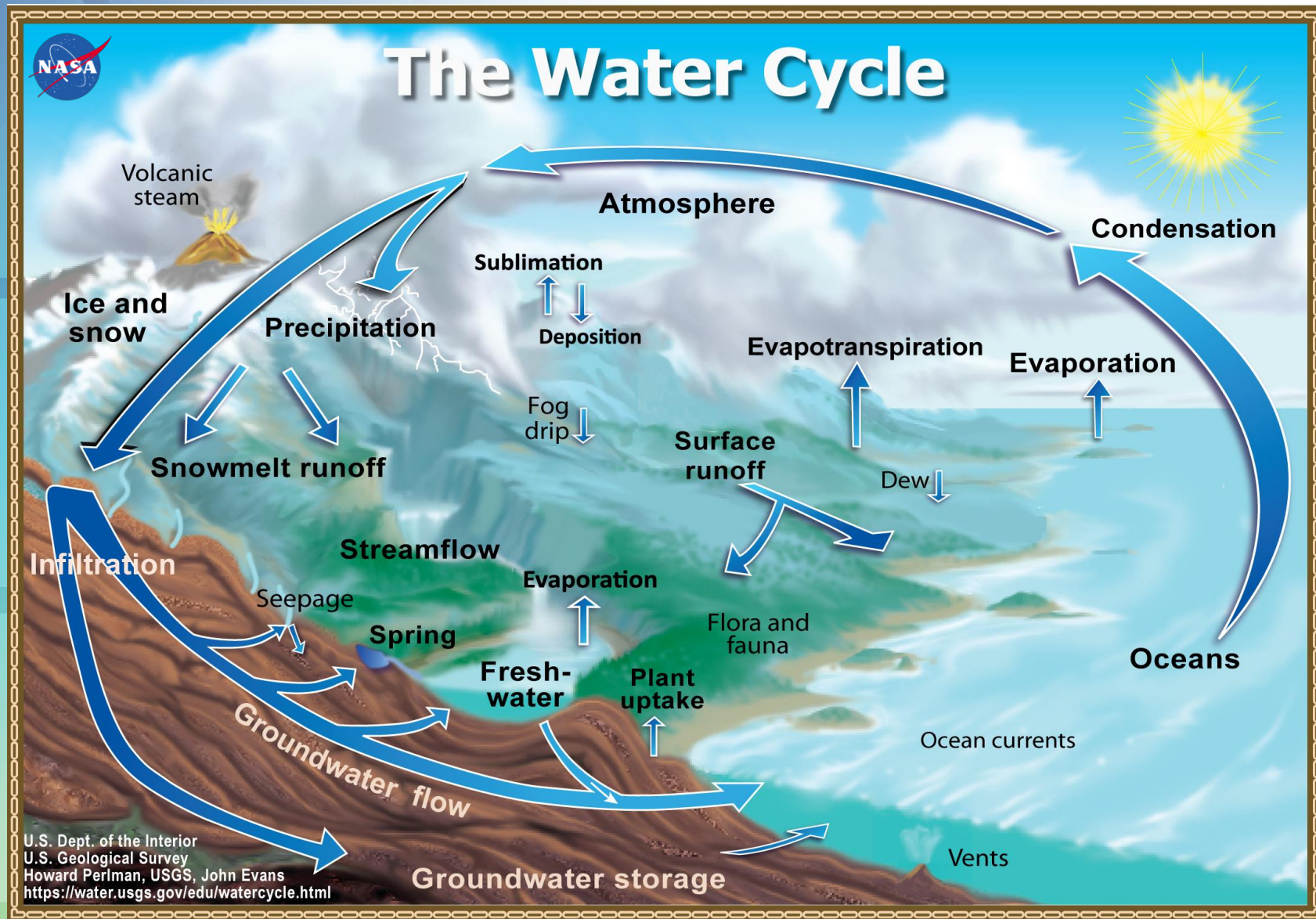
Jared Entin

Terrestrial Hydrology Program
Earth Science Division
Science Mission Directorate
NASA Headquarters
25 February 2019

Overview

- What We Do
- Program of Record
- New for Decadal Survey
- Conclusion







NASA's Earth System Science

Science from Satellites through All Phases

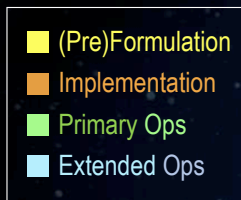
- Algorithm Development and Refinement
- Algorithm (and Model) testing via Field Campaigns
- Mission Planning
- Cal/Val of Missions
- Data Dissemination and Accessibility
- Mission Data Exploitation
- Multi-Mission Enabled Research
- Applied Sciences

Activities across NASA Earth Science Support and Are Aligned with GEWEX!

Overview

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NASA Earth Science

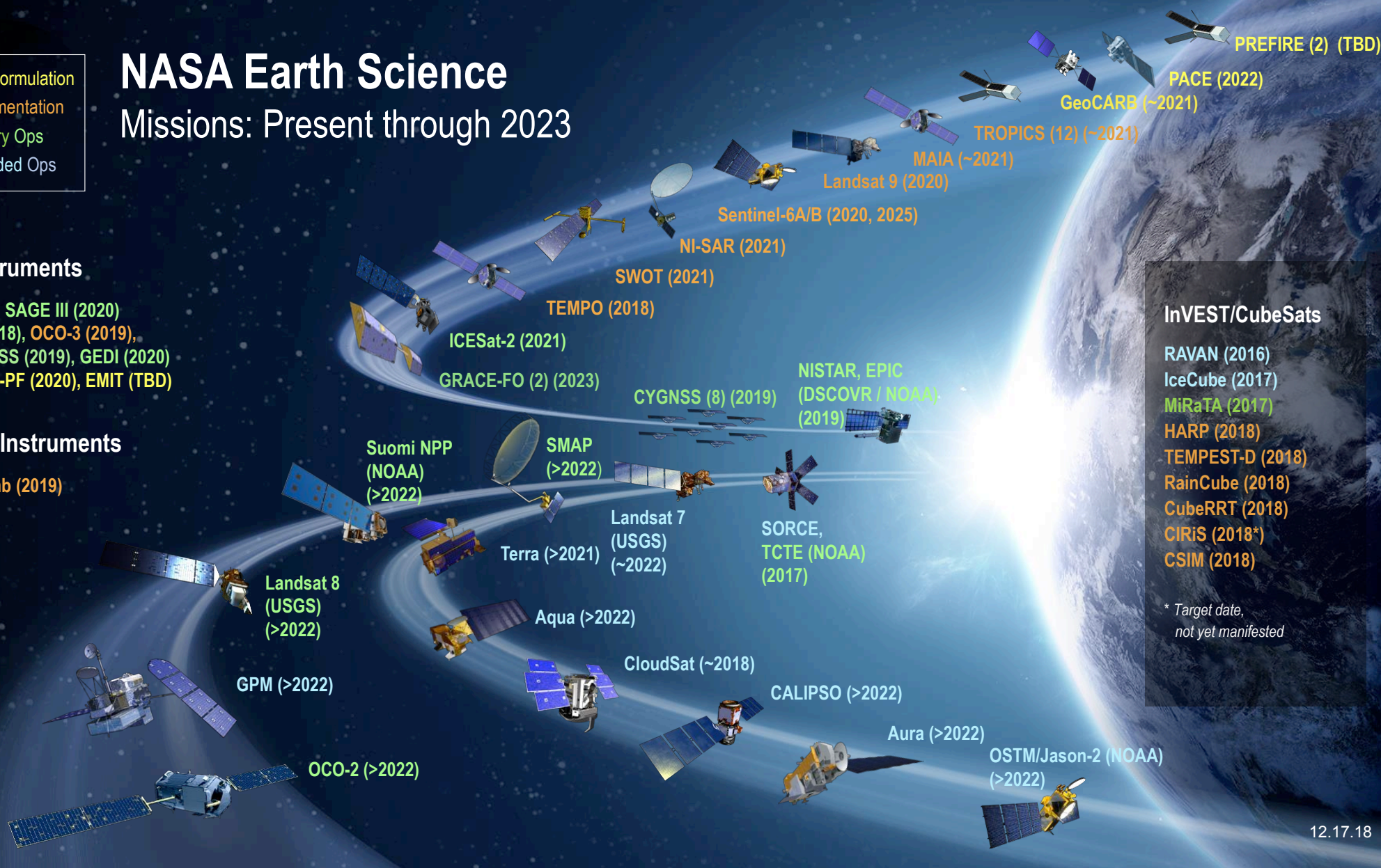
Missions: Present through 2023

ISS Instruments

LIS (2020), SAGE III (2020)
 TSIS-1 (2018), OCO-3 (2019),
 ECOSTRESS (2019), GEDI (2020)
 CLARREO-PF (2020), EMIT (TBD)

JPSS-2 Instruments

OMPS-Limb (2019)



InVEST/CubeSats

- RAVAN (2016)
- IceCube (2017)
- MiRaTA (2017)
- HARP (2018)
- TEMPEST-D (2018)
- RainCube (2018)
- CubeRRR (2018)
- CIRiS (2018*)
- CSIM (2018)

* Target date, not yet manifested

Earth Science Division's Venture Opportunities

EVS
Sustained Sub-Orbital
Investigations
(~4 years)

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

EVI
Full function, facility-class
instruments Missions of
Opportunity (MoO)
(~18 months)

Mission	Mission Type	Release Date	Selection Date	Major Milestone
EV-1, aka EVS-1	5 Suborbital Airborne Campaigns	2009	2010	N/A
EVM-1, CYGNSS	Smallsat constellation	2011	2012	Launched Dec 2016
EVI-1, TEMPO	Geosynchronous hosted payload	2011	2012	Delivery NLT 2017
EVI-2, ECOSTRESS & GEDI	Class C & Class D ISS-hosted Instruments	2013	2014	Delivery NLT 2019
EVS-2	6 Suborbital Airborne Campaigns	2013	2014	N/A
EVI-3, MAIA & TROPICS	Class C LEO Instrument & Class D Cubesat Constellation	2015	2016	Delivery NLT 2021
EVM-2, GeoCarb	Geostationary hosted payload	2015	2016	Launch ~2021
EVI-4, EMIT, PREFIRE	Instrument Only	2016	2017	Delivery NLT 2021
EVS-3	Suborbital Airborne Campaigns	2017	2018	N/A
EVI-5	Instrument Only	2018	2019	Delivery NLT 2023
EVC-1	Radiation Budget Measurement	2018	2019	Delivery NLT 2024
EVM-3	Full Orbital	2019	2020	Launch ~2025
EVS-4	Suborbital Airborne Campaigns	2021	2022	N/A
EVI-6	Instrument Only	2020	2021	Delivery NLT 2026
EVC-2	Continuity Measurement	2021	2022	Delivery NLT 2027

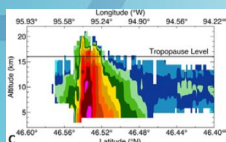
EMIT, PREFIRE
selected for
EVI-4

EVS-3
Selections
Next Slide

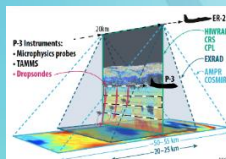
EVS-3 Investigations



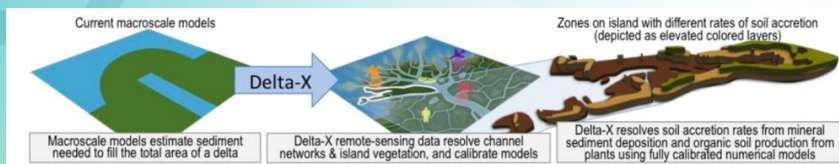
ACTIVATE - Aerosol Cloud meTeorology Interactions oVer the western ATlantic investigates how aerosol particles change cloud properties in ways that affect Earth's climate system. The investigation will focus on marine boundary layer clouds over the western North Atlantic Ocean



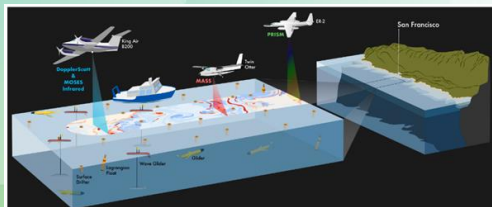
DCOTTS - Dynamics and Chemistry of the Summer Stratosphere investigates how strong summertime convective storms over North America can change the chemistry of the stratosphere



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

Field Campaigns

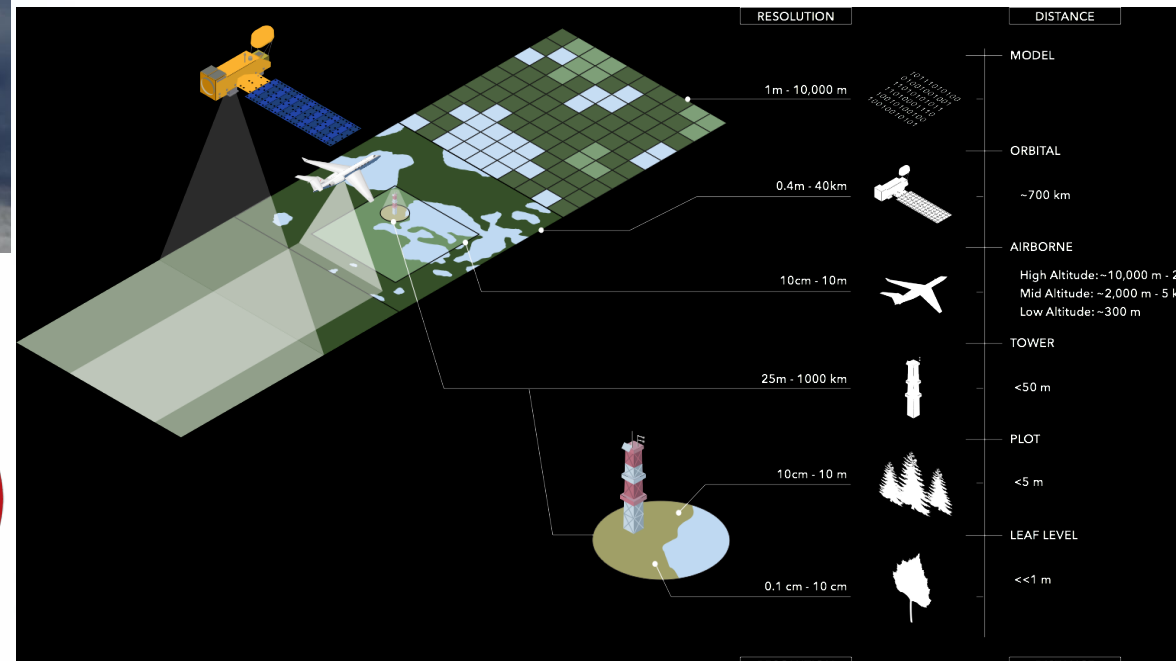
Airborne Science Program

Observing Platforms for Earth System Science Investigations
<http://airbornescience.nasa.gov>



Cloud and Aerosol Monsoonal Processes: Philippines Experiments (CAMP²Ex)

Airborne Field Campaign Planned for late Aug – Early Oct 2019



SnowEx (2017, 2019-20, TBP - 2020+)
 Ongoing Field Experiments to Develop and Test Snow Retrieval Algorithms in a Variety of Climates



NASA Energy and Water Cycle Study (NEWS)

ROSES 2018 A.22

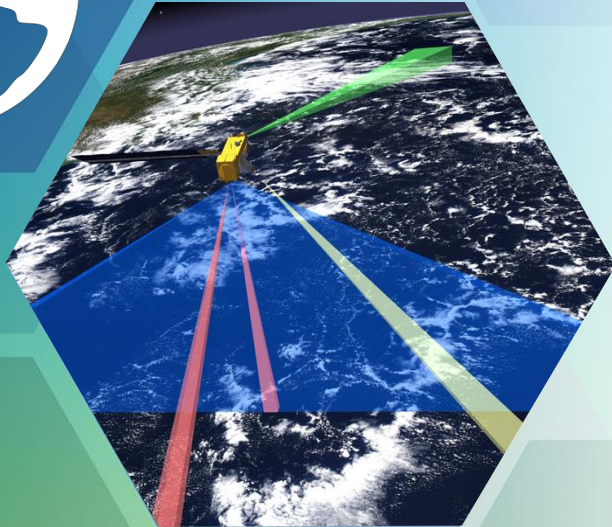
Solicited for proposals to form NEWS Process Teams to understand interaction between at least two major reservoirs of water (aka 2 of Land-Atm-Ocean).

Proposed research should result in targeted, cutting-edge diagnostics for global climate models and weather forecast centers

Proposals should include how the NEWS process team supports and is supported by GEWEX!

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.

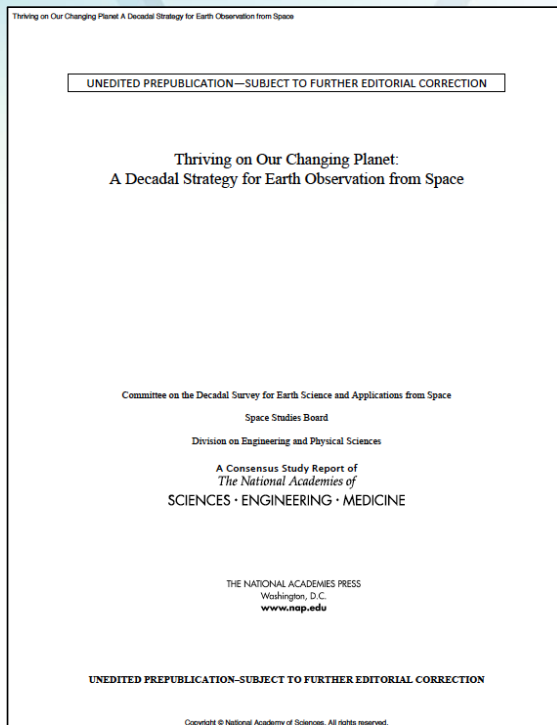
Overview

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ESD Implementation of 2017 Decadal Survey

2017 DECADAL SURVEY



- ESD is conducted focused community forums to translate the recommendations into an executable program and, for Flight, a portfolio of specific, realistic, launch-ordered missions and solicitations.
- ESAS(2017) calls for “cost-capping” essentially all missions
- Earth Venture Continuity (EVC) Measurements - an addition to the existing Venture-class program. EVC-1 competition commencing.
- Designated observables (DOs) for mandatory acquisition – four multi-center DO Studies are underway (*Surface Biology & Geology; Combined Aerosols / Clouds, Convection, & Precipitation; Surface Deformation & Change; Mass Change*)
- New competed Earth System Explorer (ESE) flight line with \$350M cost constraint, 3 observables to be chosen by ESD from among 7 identified
- Incubator Program between Technology, R&A, and Flight to mature specific technologies for important – but presently immature – measurements – framework in development as preparation for next Decadal
- Decadal Survey new mission budget wedge begins to open in late FY21

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, & 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 the Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	X		
Surface Biology & Geology	Earth surface geology and biology, ground/water temperature, snow reflectivity, active geologic 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 & Change	Earth surface dynamics from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	X		
Greenhouse Gases	CO ₂ and methane fluxes and trends, global and regional with quantification of point sources and identification of source types	Multispectral shortwave IR and thermal IR sounders; or lidar**		X	
Ice Elevation	Global ice characterization including elevation change to assess sea level contributions and ice sheet height to assess sea ice/ocean/atmosphere interaction	Lidar**		X	
Ocean Surface Winds & Currents	Coincident high-accuracy currents and vector winds to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea ice drift	Radar scatterometer		X	

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

Ozone & Trace Gases	Vertical profiles of ozone and trace gases including water vapor, CO, NO ₂ , methane, and N ₂ O globally and with high spatial resolution	UV/IR/microwave limb/nadir sounding and UV/IR solar/stellar occultation		X	
Snow Depth & 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 & 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	X
Planetary Boundary Layer	Diurnal 3D PBL thermodynamic properties and 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 geostationary satellite constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling DIAL lidar; and lidar** for PBL height			X
Surface Topography & Vegetation	High-resolution global topography including bare surface and 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	Radiance Intercalibration
Magnetic Field Changes	Sea Surface Salinity
Ocean Ecosystem Structure	Soil Moisture



ESD has decided to treat Atmos. Winds as Explorer.



Designated Observables Studies

- Surface Biology and Geology (SBG)
- Aerosols and Clouds, Convection and Precipitation (ACCP)
- Surface Deformation and Change
- Mass Change

All studies are composed of multi-center teams.

Designated Observables Studies (2)

- Develop Candidate (Mission) Architectures
- Explore International Interest for Partnership
- Work with Industry
- Interact w/Wider Community
- Consider Applications/User community

In Later Study Phases

- Collapse Possible Architectures to 2-3 options
- Deliver to ESD Mission Capabilities

NASA Would Transform Capabilities into Requirements for Solicitation Purposes

Other Decadal Survey Outcomes

- Creation of Earth Venture Continuity Line
 - 1st competition open now
 - Seeking: "...observing system to enable retrieval of top of the atmosphere short wave, long wave, and total radiative fluxes. Measured top of atmosphere radiances and any necessary algorithms will be used by NASA to seamlessly extend and continue the Earth Radiation Budget (ERB) Climate Data Records."
Solicitation #: NNH17ZDA004O-EVC1
Final Deadline: July 26, 2019
- Incubation Program (joint ESTO-R&A)
AKA Technology Development for Subsequent DS Period
 - Planetary Boundary Layer Remote Sensing
 - Surface Topography and Vegetation

Other DS Outcomes (2)

- ESD Leadership Team is continuing to address additional DS topics
 - Explorer Category (?)
- Stakeholder Community Forum (3rd in the series) – Monday, March 4, 1:00-3:00 EDT, in person and Webex
 - See <https://science.nasa.gov/earth-science/decadal-survey-community-forum> for details
- Monthly NASA Center Forums
- Check the ESD Decadal Survey web page and Inside NASA page to:
 - Find meeting schedules and details
 - Ask questions and see answers as they become available
 - Review information in previous sets of charts
 - <https://science.nasa.gov/earth-science/decadal-surveys>



Closing Remarks

- NASA continues to develop the science around current and future satellite missions
- Open to International (and Interagency) Partnership
- Developing and Expanding Role to Meet Science and Non-Science User Needs