Science from Satellites in Service to Society
NASA's Earth Science Division

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Earth Science Division

April 25, 2018

Outline

- Appropriation/Budget Status
- Flight Program Status and Plans
- *Small-Satellite Constellation Data Buy Pilot* - *Observational Needs Panel*
- Non-Flight Program Plans/Highlights
- 2017 *Earth Science and Applications from Space* Decadal Survey
- Follow the Water – Observing the Global Hydrologic Cycle from Space

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NASA/ESD Appropriation: FY18

- FY18 (1 Oct 2017 – 30 Sept 2018) funding is at the **FY16/FY17** level (~$1.92B)
- Continues operations and development of FY17 Program of Record (including DSCOVR EPIC/NISTAR, PACE, CLARREO-PF, OCO-3 (to launch as manifested in late CY2018-early CY19)
- Endorses ESD/SMD discontinuance of RBI

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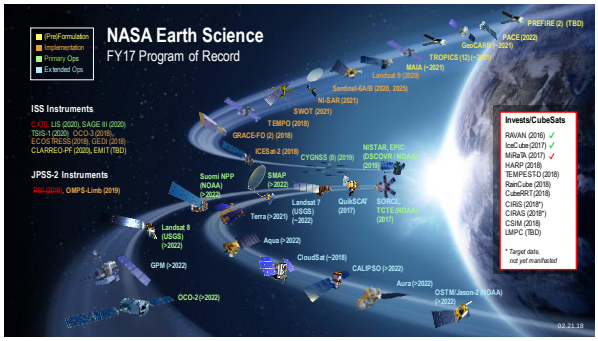

RECENT/UPCOMING FLIGHT PROGRAM EVENTS

- 2017 Senior Review recommended continuation of most on-orbit missions
- GRACE, CATS, missions ended; TES (Aura instrument) and QuikSCAT to be ended in FY18
- RBI discontinued by NASA for technical, cost, schedule issues; work underway to develop an affordable and capable replacement for launch in JPSS-3 timeframe (2026)
- Jason-2/OSTM moved to lower orbit (IMU redundancy/temperature issues) – continues to provide near-real-time and geodetic measurements
- CloudSat moved to safe orbit below A-Train (loss of hardware redundancy) – continues to provide science data
- TSIS-1 instrument successfully launched to ISS
- NOAA's JPSS-1 mission successfully launched and operating
- ICECube, MIRATA CubeSats launched (MIRATA failed once on-orbit); MicroMAS-2 CubeSat successful on JPSS-1 launch

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- OCO-3 completion and delivery to storage May, 2018 with Congressional direction to launch as planned (2018/2019)
- GRACE-FO on-track for launch May 19-20, 2018
- ICESat-2 on-track for launch September, 2018
- ECOSTRESS shipped to KSC and on track for launch June 28, 2018 (NET)
- GEDI delivery accelerated to allow launch as early as November, 2018
- TEMPEST-D, RainCube, CubeRRT CubeSats/SmallSats scheduled for launch on OA-9 (May 20, 2018)
- HARP, CSIM CubeSats/SmallSats manifested for launch later in 2018
- EVI-4 selections: EMIT (hyperspectral aerosol mineralogy/composition) and PREFIRE (Arctic Far-IR emissions from dual CubeSats)

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NASA Observing System *INNOVATIONS*

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Earth Science Division's Venture Opportunities

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	Instrument Only	2016	2018	Delivery NLT 2021
EVS-3	Suborbital Airborne Campaigns	2017	2018	N/A
EVI-5	Instrument Only	2018	2019	Delivery NLT 2023
EVM-3	Full Orbital	2019	2020	Launch ~2025
EVI-6	Instrument Only	2019	2020	Delivery NLT 2024

EMIT, PREFIRE selected for EVI-4

Open solicitation - In Review
Completed solicitation

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NASA Earth Science Division Elements

Flight (incl. Data Systems)

Develops, launches, and operates NASA's fleet of Earth-observing satellites, instruments, and aircraft. Manages data systems to make data and information products freely and openly available.

Research & Analysis

Supports integrative research that advances knowledge of the Earth as a system. Six focus areas plus field campaigns, modeling, and scientific computing.

Technology

Develops and demonstrates technologies for future satellite and airborne missions: Instruments, Information Systems, Components, InSpace Validation (cubesat and small-sat form factors).

Applied Sciences

Develops, tests, and supports innovative uses of Earth observations and scientific knowledge to inform private and public sector planning, decisions, and actions. Activities include disaster response support and capacity building.

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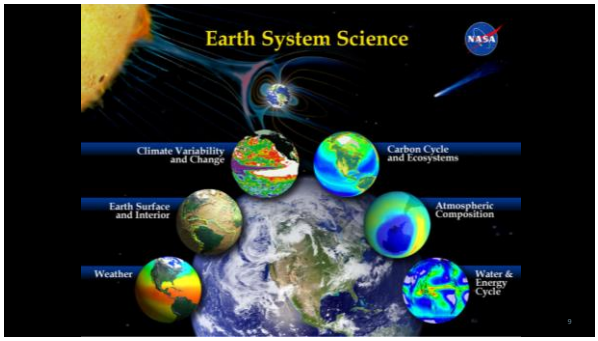

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R&A Selected Programmatic Highlights

- **Field Work**
  - 2018 *Cloud and Aerosol Monsoonal Processes Exp't* (near Philippines); *EXPORTS* field program (NE Pacific; in coordination with NSF), FLARE (Alaska), HyspIRI (Hawaii), ABoVE (surface only); 2019 *FIREChem* (Kansas; with NOAA)
- **New Competed Science Programs (highlights only – many ROSES calls)**
  - Selected new round of Interdisciplinary Science investigators – 28 principal investigators – 5 topics, $34M over three years
  - Solicited for competed science teams for newly launched missions/instruments (CYGNSS, SAGE III), new combined Terra/Aqua/Suomi-NPP science
- **Modeling and Data Assimilation**
  - GMAO evolved and transitioned to a "hybrid 4D VAR" data assimilation system
- **Enabling Capabilities**
  - Built a modular computing facility at ARC and expanded SMD's supercomputing capacity to 6 pflops; expanded capacity at NCCS to 3.5 pflops.
  - Installed antenna at MSFC for real-time receipt of GOES-16 for SPoRT (jointly with NOAA); antenna for GOES-S on order
  - Purchased 60 new/improved/reliable sensors for AERONET to replace ~20% of existing sensors in 2018

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Earth Science Technology

Advanced Technology Initiatives (ATI)

ACT

Advanced Component Technologies
Development of critical components and subsystems for instruments & platforms

12 projects awarded in 2018. Future solicitations/selections planned in FY 2020 and FY 2023

InVEST

In-Space Validation of Earth Science Tech.
On-orbit technology validation and risk reduction for small instruments and instrument systems that could not otherwise be fully tested on the ground or in airborne systems.

Future solicitations/selections planned in FY 2018 & FY 2021

IIP

Instrument Incubator Program
Robust new instrument developments and measurement techniques

17 new projects awarded in FY17. Future solicitations/ selections planned in FY 2019 and FY 2022

AIST

Advanced Information Systems Technology
Innovative advances in on-orbit and ground technologies to generate, manage, and exploit data in the 5-20 year horizon

22 new projects awarded in FY17. Future solicitations/selections planned in FY 2018, FY 2020 and FY 2022

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Applied Sciences Program: Selected Highlights–2018

Disasters
ROSES call for applications focused on a few disaster types – flood, hurricane, earthquake.

Water Resources
Call to support water resources management. Two-step process planned.

Sustainable Development Goals
Earth science call for applications and research on SDG 14 (oceans) and SDG 15 (life on land).

Food Security and Agriculture Consortium
New effort led by UMd to advance uses of Earth obs for humanitarian pursuits, economic growth, and resilience in food systems in U.S. and globally.

Impact Assessments
VALUABLES Consortium conducting economic studies on Earth science; also arranging venues for Earth scientists wanting to learn about policy and economic terms/methods.

SERVIR
New Amazonia regional hub for South America is planned to open in Spring.

DEVELOP
2018 marks the 20th year for this development, workforce & Earth science applications program.

ARSET Trainings
Over 15 professional-level hands-on and webinar trainings on remote sensing to reach people across all 50 U.S. States again in 2018.

APPLICATIONS AREAS | MISSION SUPPORT | CAPACITY BUILDING

http://AppliedSciences.NASA.gov

Earth Science Partnerships

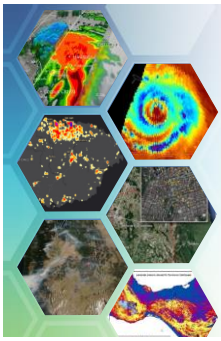
Harnessing commercial and NGO partnerships to amplify our work to understand the Earth as an integrated system and enable societal benefit by essentially leveraging the expertise of NASA and the partners to achieve together what neither could alone.

Current Partners

Conservation International, Google, MercyCorps, Microsoft

Activities

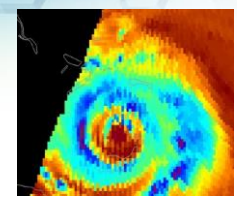
- Advancing the ability of remote sensing to inform economic valuation of ecosystem services
- Increasing the public's access to and use of Earth observations to explore our planet
- Integrating Earth observations into humanitarian decision making to strengthen global resilience to environmental shocks and stressors
- Supporting decision making in smart cities by integrating Earth observations into cloud-based services



September Disaster Response

- Harvey strikes Texas August 25
- Irma strikes the Keys September 10
- Maria strikes Puerto Rico September 20
- Raboso (M7.1) Earthquake September 19
- Western Wildfire Season from VIIRS and MODIS
- Chiapas (M8.1) Earthquake September 7

GPM Measurements Influence Hurricane Forecasts



Hurricane Irma Discussion Number 37
NWS National Hurricane Center Miami FL AL112017
500 AM EDT Fri Sep 08 2017

Microwave images and data from an Air Force Reserve Hurricane Hunter aircraft indicate that Irma is currently undergoing an eyewall replacement cycle. A recent GMI overpass showed an 50 nmi wide outer eyewall, with the inner eyewall weakening. The Hurricane Hunter aircraft reported peak 700-mb winds of 147 kt in the outer eyewall near 0500 UTC, and maximum SFMR winds were in the 125-130 kt range. Based on these data, the initial intensity is reduced to 135 kt.

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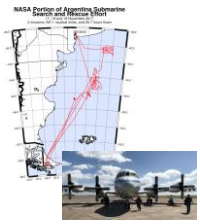
Operation IceBridge Support for Submarine *San Juan* Search

- The P-3 was the first non-domestic plane to begin the search and was later joined by an international team of planes and ships
- Within two hours of the call for assistance from the U.S. Embassy in Argentina the NASA P-3 launched the first of three SAR missions for the missing ARA San Juan submarine
- The former captain of the San Juan (Ernesto Blanco) was brought on board the P-3 for assistance (with US Embassy approval), information and coordination was also provided from the U.S. Embassy, DoD, US Navy, and Argentine Navy, relayed to the plane via the X-Chat system and Iridium
- Observers on all available windows were the primary means of search, with magnetometer, radar, visible and IR cameras monitored
- Argentinians paid for fuel for at least two flights
- Special recognition: Project Manager Nathan Kurtz and Deputy Project Manager Eugenia De Marco for their leadership and communications during this effort



The P-3 temporarily based in Bahia Blanca

2017 Decadal Survey Snapshot

- Publicly released January 5, 2018
- Supports the ESD (and international) Program of Record
- Prioritized observations rather than specific missions
- Emphasis on competition
- Explicitly allows implementation flexibility – encourages competition as cost-control method
- Explicitly notes value of, and encourages, international partnerships
- Endorsed existing balances in ESD portfolio

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Progress Since ESAS 2007 (from 2017 DS)

Mission	Geophysical Variables	Status
OSTM/Jason-2**	Ocean Surface Topography	Launched 2008, operating
OCO**	CO_2	Launch failure
Glory**	Aerosol and cloud particle size and optical thickness	Launch failure
Aquarius**	Sea surface salinity	Mission ended
Suomi NPP**	Multiple variables (ATMS, VIIRS, CrIS, OMPS, CERES)	Launched 2011, operating
LDCM**	Land use and land surface temperature	Launched 2013, operating
GPM**	Precipitation (rain and snow)	Launched 2014, operating
OCO-2	CO_2	Launched 2014, operating
CYGNSS*	Hurricane Winds	Launched 2016, operating
SMAP*	Soil moisture, freeze/thaw state, surface salinity	Launched 2017, operating
SAGE-III (on ISS)	Stratospheric O_3, aerosols	Launched 2017, operating
GRACE-FO	Changes in Gravitational Field	In Development (2017)
ICESat-2*	Ice sheet elevation change, sea ice thickness, vegetation canopy height	In Development (2018)
ECOSTRESS*	Plant temperature and water stress	In Development (2018)
GEDI*	Ecosystem structure and dynamics	In Development (2018)
TEMPO*	Air pollution (O_3, NO_2, ...)	In Development (2018)
MAIA*	Aerosols	In Development (2021)
TROPICS*	Precipitation and storm intensity	In Development (2021)
GeoCARB*	Carbon exchanges between land and atmosphere	In Development (TBD)
PACE	Phytoplankton communities	In Development (2022)
NISAR*	Surface changes from ice-sheet collapse, earthquakes, tsunamis, volcanoes, and landslides	In Development (late 2021)
SWOT*	Ocean (and freshwater) high resolution elevation, providing water storage and ocean circulation	In Development (2021)
CLARREO-Pathfinder on ISS*	High accuracy spectral reflectance with on-board calibration	In Development (2021 timeframe)
OCO-3 (on ISS)	CO_2	In Development (2018)

Finding 2A: The **NASA ESD program has made important progress during the decade, partially recovering from the underfunded state it was in a decade ago . . .**

Finding 2B: NOAA progress during the decade was hampered by major programmatic adjustments . . .

Finding 2C: The **USGS has transformed the Landsat program via the Sustainable Land Imaging (SLI) program . . .**

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2017 Decadal Survey Snapshot (cont.)

2017 DECADAL SURVEY

- Identified 5 "Designated" observables for mandatory missions (*Aerosols; Clouds, Convection, & Precipitation; Mass Change; Surface Biology & Geology; Surface Deformation & Change*)
- Called for cost-capping on essentially all missions
- Introduced a new competed "Explorer" flight line with $350M cost constraint, 3 observables to be chosen by ESD from among 6 identified
- Recommended "Continuity Measurement" strand ($150M full mission cost cap) for existing Venture-class program
- Called for "Incubator Program" between Technology and Flight to mature specific technologies for important – but presently immature – measurements (preparation for next Decadal)
- ***ESD is conducting community forums for ~18 months to translate the recommendations into an executable program and, for Flight, a portfolio of specific, realistic, launch-ordered missions and solicitations.***
  - With 20 missions/instruments now in development for launch before 2023, Decadal budget wedge does not begin to open up until late FY21.

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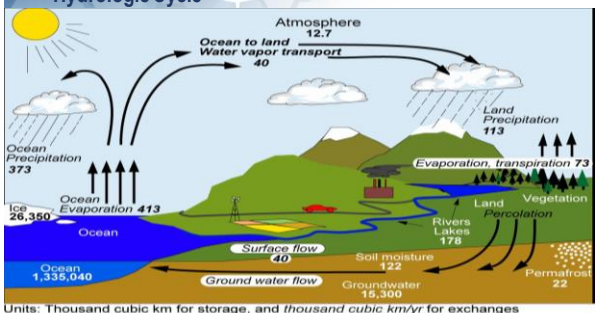
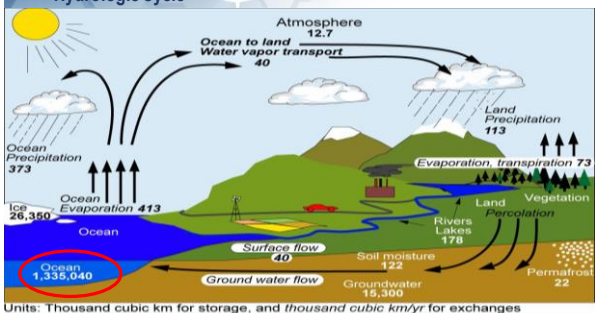
Hydrologic Cycle



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

Hydrologic Cycle



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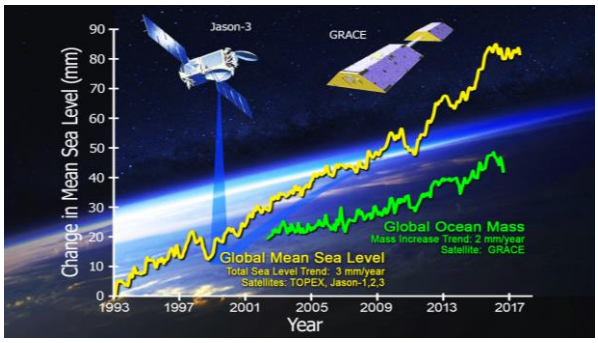
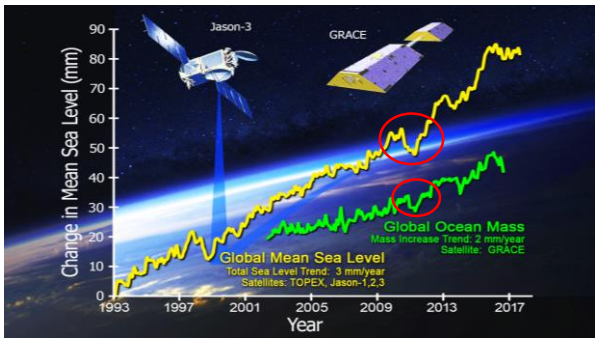
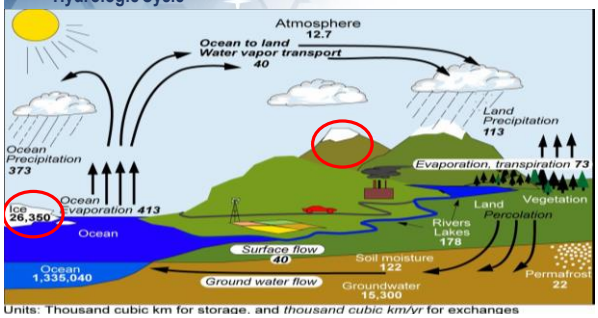


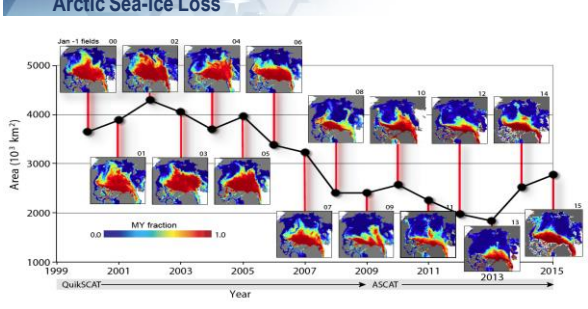


Hydrologic Cycle

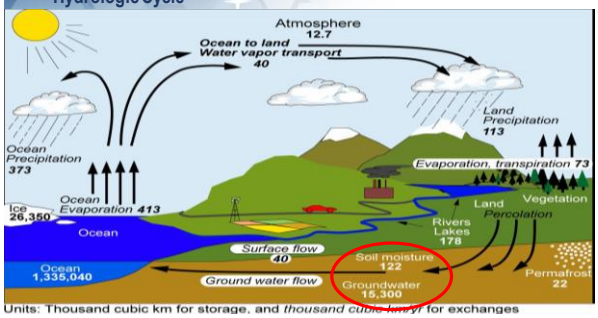


Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

Arctic Sea-Ice Loss



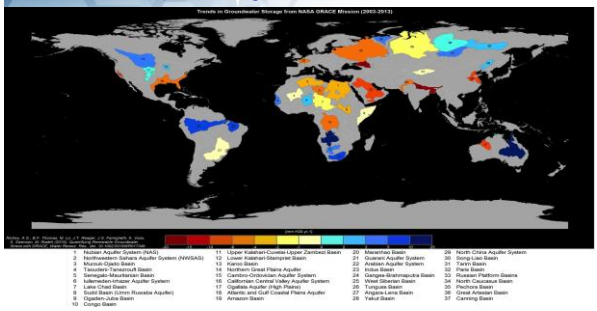
Hydrologic Cycle



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

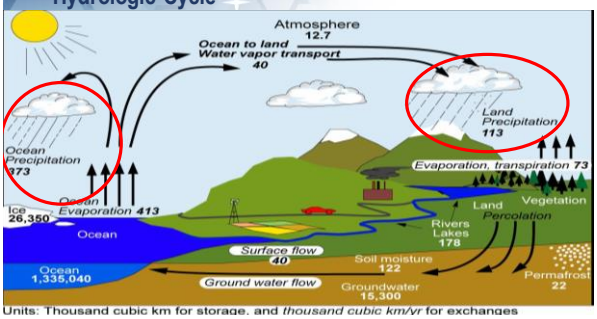
India Groundwater Loss from GRACE: 2002-2008

GRACE ***Global*** Aquifer Storage Trends 2003-2013



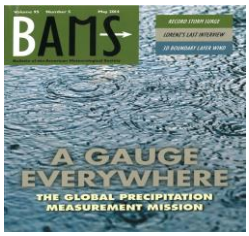
1 Nubian Aquifer System (NAS)
2 Northwestern Sahara Aquifer System (NWSAS)
3 Murzuk-Djado Basin
4 Taoudeni/Tanezrouft Basin
5 Senegalo-Mauritanian Basin
6 Iullemeden-Irhazer Aquifer System
7 Lake Chad Basin
8 Sudd Basin (Umm Ruwaba Aquifer)
9 Ogaden-Juba Basin
10 Congo Basin
11 Upper Kalahari-Cuvelai-Upper Zambezi Basin
12 Lower Kalahari-Stampriet Basin
13 Karoo Basin
14 Great Artesian Basin Plains Aquifer
15 Cambro-Ordovician Aquifer System
16 Californian Central Valley Aquifer System
17 Ogallala Aquifer (High Plains)
18 Atlantic and Gulf Coastal Plains Aquifer
19 Amazon Basin
20 Maranhao Basin
21 Guarani Aquifer System
22 Arabian Aquifer System
23 Indus Basin
24 Ganges-Brahmaputra Basin
25 West Siberian Basin
26 Tunguss Basin
27 Angara-Lena Basin
28 Yakut Basin
29 North China Aquifer System
30 Song-Liao Basin
31 Tarim Basin
32 Bohai Basin
33 Russian Platform Basins
34 North Caucasus Basin
35 Pechora Basin
36 Great Artesian Basin
37 Canning Basin

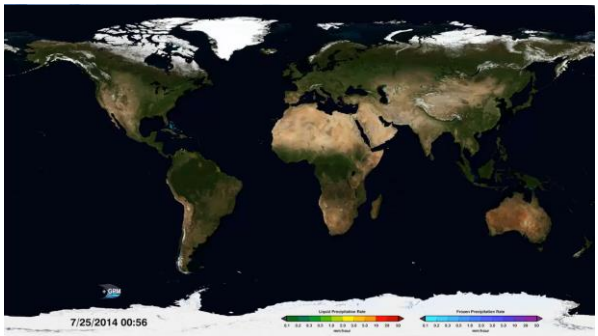
Hydrologic Cycle



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

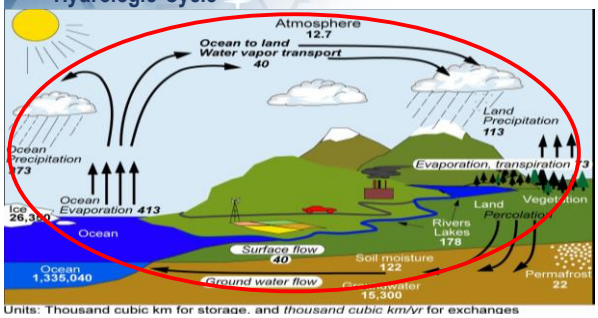
Global Precipitation Measurement Mission





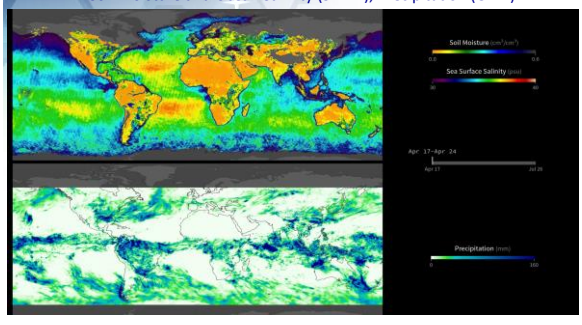
GPM Observes Details of Hurricane Irma (2017)

Hydrologic Cycle

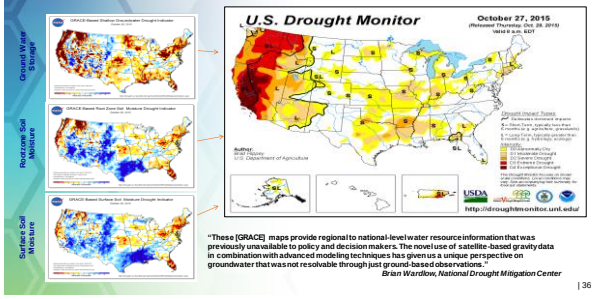


Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

Soil Moisture and Ocean Salinity (SMAP); Precipitation (GPM)



NASA GRACE, SMAP, GPM Products Support Official U.S. Drought Assessments



"These [GRACE] maps provide regional to national-level water resource information that was previously unavailable to policy and decision makers. The novel use of satellite-based gravity data in combination with advanced modeling techniques has given us a unique perspective on groundwater that was not resolvable through just ground-based observations."
Brian Wardlow, National Drought Mitigation Center

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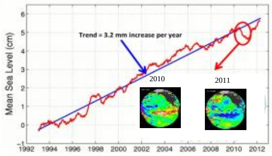
Satellite Measurements Detect and Diagnose 5 mm Sea-Level Drop in 2011

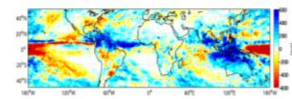
Precise global sea-level measurements from NASA and international spaceborne altimeters have shown that average sea-level has been rising at a rate of ~3.2 mm/year.

In 2010-2011, however, the altimeter missions detected that average sea-level has ***fallen*** by ~5 mm.

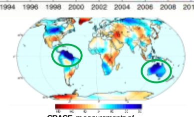
Only 40% of the change results from ocean cooling (and contraction) during the onset of the 2011 La Nina.

The international GRACE and TRMM missions show that most of the sea-level drop results from changed global precipitation patterns, with increasing tropical rainfall in South America and Australia – with increased ground water. **Water has moved from the ocean to the land.**





NASA-JAXA TRMM measurements of Precipitation change, 2010-2011



GRACE measurements of Ground Water change, 2010-2011

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Quick Summary of Recommendations

1 VISION & STRATEGY

"Thriving on our Changing Planet"

2 SCIENCE & APPLICATIONS

Address **35 key science/applications questions,** from among hundreds suggested. Highest priority objectives fell into **six categories**:

- Coupling of the Water and Energy Cycles
- Ecosystem Change
- Extending & Improving Weather and Air Quality Forecasts
- Sea Level Rise
- Reducing Climate Uncertainty & Informing Societal Response
- Surface Dynamics, Geological Hazards and Disasters

3 OBSERVATIONS

Augment the **Program of Record** with **eight priority observables**:

- **Five** that are specified/designated to be implemented:
  - *Aerosols*
  - *Clouds, Convection, & Precipitation*
  - *Mass Change*
  - *Surface Biology & Geology*
  - *Surface Deformation & Change*
- **Three** others to be selected competitively from among six candidates
- Structure **new mission program elements** to accomplish this

4 PROGRAMMATICS

- CROSS-AGENCY
- NASA
  - Flight
  - Technology
  - Applications
- NOAA
- USGS

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Summary of Top Science and Applications Priorities*

* Complete set of Questions and Objectives in Table 3.3

Science & Applications Topic	Science & Applications Questions addressed by **MOST IMPORTANT** Objectives
Coupling of the Water and Energy Cycles	**(H-1)** How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as droughts and floods? **(H-2)** How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?
Ecosystem Change	**(E-1)** What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space? **(E-2)** What are the fluxes (of carbon, water, nutrients, and energy) *between* ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing? **(E-3)** What are the fluxes (of carbon, water, nutrients, and energy) *within* ecosystems, and how and why are they changing?
Extending & Improving Weather and Air Quality Forecasts	**(W-1)** What planetary boundary layer (PBL) processes are integral to the air-surface (land, ocean and sea ice) exchanges of energy, momentum and mass, and how do these impact weather forecasts and air quality simulations? **(W-2)** How can environmental predictions of weather and air quality be extended to seamlessly forecast Earth System conditions at lead times of 1 week to 2 months? **(W-4)** Why do convective storms, heavy precipitation, and clouds occur exactly when and where they do? **(W-5)** What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?
Reducing Climate Uncertainty & Informing Societal Response	**(C-2)** How can we reduce the uncertainty in the amount of future warming of the Earth as a function of fossil fuel emissions, improve our ability to predict local and regional climate response to natural and anthropogenic forcings, and reduce the uncertainty in global climate sensitivity that drives uncertainty in future economic impacts and mitigation/adaptation strategies?
Sea Level Rise	**(C-1)** How much will sea level rise, globally and regionally, over the next decade and beyond, and what will be the role of ice sheets and ocean heat storage? **(S-3)** How will local sea level change along coastlines around the world in the next decade to century?
Surface Dynamics, Geological Hazards	**(S-1)** How can large-scale geological hazards be accurately forecasted and eventually predicted in a socially relevant timeframe?

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Observing System Priorities

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 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 & 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	
Ozone & Trace Gases	**Vertical profiles of ozone and trace gases** (including water vapor, CO, NO_2, methane, and N_2O) 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 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 DIAL lidar; and lidar** for PBL height			X
Surface Topography & 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	Radiance Intercalibration
Magnetic Field Changes	Sea Surface Salinity
Ocean Ecosystem Structure	Soil Moisture

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Comparison to ESAS 2007

- **Prioritization Method.** Prioritize science and applications targets instead of missions
- **Budget Resources.** Align with planned budgets instead of aspirational
- **Large Missions.** Avoid having one recommended activity grow at expense of all others
- **Innovation.** Consider "new space" technology and business ideas
- **Policy.** Existence of recent high-level US government policy guidance regarding Earth observations
- **International.** Increased recognition of important role of international partners

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Programmatics – General Considerations

Rec 4.1	Reduce barriers to **applications**
Rec 4.2	Improve **modeling and assimilation**
Rec 4.3	Advance **data science**
Rec 4.4	Complete **Global Geodetic Observing System**
Rec 4.5	Build and expand **international partnerships**

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Programmatics - NASA

Rec 4.6	Apply **decision rules** (included) to maintain programmatic balance (programmatic balance was a high priority)
Rec 4.7	Small scope changes to **applications & technology programs**
Rec 4.8	Reevaluate **Ventures structure** at mid-term
Rec 4.9	**Avoiding cost growth** is critical to program's success (capability and reliability are where the flexibility must be found)

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NASA/ESD Funding/Appropriation: FY19

- President's **FY19-23** detailed budget proposal released 12 February 2018
  - Proposes **FY18 ESD funding at $1.8B**
  - Continues to propose termination of **DSCOVR** EO instruments **EPIC, NISTAR; OCO-3; PACE; CLARREO-PF; RBI** (discontinued by ESD/SMD in February, 2018 owing to high cost-to-complete and technical issues); **Carbon Monitoring System (R&A);** modest (undirected) cut to other R&A activities
- FY19-23 President's Budget Proposal ***does allow continuation of a balanced ESD portfolio of activities***
  - Funding for all remaining elements of the ongoing Flight Program of Record
  - Landsat-9 remains on-track for 12/2020 launch; NASA portion of Sustainable Land Imaging Program funded
  - Venture-Class remains fully funded and on-track for planned solicitations and selections
  - Applied Sciences and Earth Science Technology Office programs flat-funded, including InVEST CubeSat validation program
  - Small-satellite Constellation Data Buy Pilot funded
- Overall impact of FY19 President's Budget Proposal is unclear, as FY18 Appropriation has not been completed

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