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HEARING CHARTER

NASA's Earth Science and Climate Change Activities: Current Roles and Future Opportunities

Tuesday, May 18, 2021
11:00 a.m.
Zoom

PURPOSE

The hearing will examine the National Aeronautics and Space Administration's Earth science and climate change activities and plans, including the role of space-based observations, partnerships, and other issues.

WITNESSES

- **Dr. Karen M. St. Germain,** Division Director, Earth Sciences Division, Science Mission Directorate, NASA
- **Dr. Gavin Schmidt,** Senior Climate Advisor (Acting) and Director of Goddard Institute for Space Studies, NASA
- **Mr. Riley Duren,** Research Scientist, Office of Research, Innovation, and Impact, University of Arizona; Chief Executive Officer, Carbon Mapper, Inc.
- **Mr. Robbie Schingler,** Co-Founder and Chief Strategy Officer, Planet

OVERARCHING QUESTIONS

- *What is the role of satellite observations in measuring, monitoring, and contributing to our scientific understanding of climate change and its impacts to Earth systems?*
- *Are there gaps or opportunities where NASA could or should be doing more to contribute to climate change activities and a science-based approach to mitigation?*
- *How should NASA partner with and coordinate on the space and airborne measurement contributions of non-federal entities to climate change efforts?*

BACKGROUND

To study and monitor climate change—the long-term changes in weather patterns and the range of observed effects of those changes on land, seas, ice, air, and life—scientists use measurements and data from instruments and platforms on the ground, in the air, and in space.[1] Scientists also

[1] NASA, "Overview: Weather, Global Warming, and Climate Change." Available at: https://climate.nasa.gov/resources/global-warming-vs-climate-change/.

use numerical and analytical models to better understand past climate change and forecast it into the future, and the measurements and data are also used to inform and improve those models.

NASA launched its first Earth-observing satellites more than seventy years ago; over the ensuing decades, space-based Earth observations have "transformed our 'scientific understanding' of the planet, revealing it to be an integrated system of dynamic interactions between the atmosphere, ocean, land, ice, and human society across a range of spatial and temporal scales irrespective of geographic, political, or disciplinary boundaries."[2] NASA is a leading federal agency in observing and understanding environmental changes on Earth; today, the agency operates more than two dozen space-based Earth observing missions, including six instruments aboard the International Space Station (ISS), and NASA also conducts airborne and terrestrial field campaigns to support Earth Science research and related technology development.[3] NASA data and research are significant pieces of the scientific basis that underlies national and international assessments of the indications, effects, and forecasting of climate change.

NASA's Earth Science Division

Within NASA's Science Mission Directorate, the Earth Science Division (ESD) supports activities to advance basic and applied research related to the nature of Earth's dynamics and phenomena at local, regional, and global scales. The division follows an interdisciplinary, Earth Systems approach by studying the nature of and interactions between the Earth's atmosphere, lithosphere (land, specifically the crust and upper mantle), hydrosphere (oceans and liquid waterways), cryosphere (ice), and biosphere (life). The strategic objective of the Earth Science Division is to "advance knowledge and prediction of the whole Earth system to meet the urgent demands of climate change."[4]

Program Elements

The Earth Science Division portfolio has six program elements (see Table 1 for budget allocations):

The *Research* program supports research investigations in Earth Science, including modeling work and analysis of observational data, by civil servant scientists as NASA centers and non-NASA scientists at universities and research institutes. Activities related to contributions to the national and international climate change assessments (e.g., the National Climate Assessment) are conducted within the Research program.

[2] National Academies of Sciences, Engineering, and Medicine. 2018. *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24938.

[3] Additionally, NASA manages the development and launch of many of the Nation's weather satellites on a reimbursable basis for the National Oceanic and Atmospheric Administration (NOAA).

[4] Presentation by Karen St. Germain at the Spring 2021 Meeting of the National Academies of Sciences, Engineering, and Medicine's Committee on Earth Science and Applications from Space, March 23, 2021. Available at: https://www.nationalacademies.org/event/03-23-2021/docs/DEDFDD99FD02696E317242BC6B881F62C01996942915.

Table 1: NASA Earth Science Division FY2021 Budget

Account	FY2021 Spend Plan
Earth Science Division	$2 billion
Research	$480 million
Systematic Missions	$781 million
Earth System Science Pathfinder	$344 million
Data Systems	$251 million
Technology	$82 million
Applied Sciences	$63 million

Source: NASA[5]

The *Systematic Missions* program develops NASA-led Earth-observing satellite missions, operates missions in orbit, and produces mission data products. Systematic Missions in operation include Landsats 7 and 8, in partnership with the U.S. Geological Survey, and the recently-launched Sentinel 6 Michael Freilich, a mission in partnership with the European Space Agency (ESA) to measure ocean heights at high precision. Systematic Missions in development include and the Surface Water and Ocean Topography (SWOT) Mission, the Plankton, Aerosols, Clouds, Ocean, Ecosystem (PACE) mission, and the NASA/Indian Space Research Organization Synthetic Aperture Radar (NISAR) mission, which will make the first-ever global survey of Earth's surface water.

The *Earth System Science Pathfinder* program supports competed, principal-investigator-led projects with schedule and budget constraints, including small- and medium-class satellite missions or space-based instruments, extended airborne science campaigns, and related scientific investigations. The scientific scope focuses on emerging areas of research or technology. Space-based Pathfinder elements are competed through Earth Venture missions and instruments.

The *Data Systems* program acquires, processes, preserves, and distributes observational Earth science data from all sources that support ESD research. The data are primarily archived and accessed through the Earth Observing System Data and Information System (EOSDIS), which has provided all Earth Science data freely to the public since 1994. In Fiscal Year 2020 alone, the archive grew by 12 petabytes (PB) and received three million site visits; the current archive total volume is approximately 42 PB, and the annual growth of the archive is expected to accelerate.[6] Most of the data are stored across twelve Distributed Active Archive Centers (DAACs) across the country, which are located at NASA Centers, universities, and other federal agencies. ESD assigns data to individual DAACs based on scientific discipline, application, data type, and/or mission. DAACs are responsible for processing, archiving, and distributing data and ultimately making the data publicly available to end users.[7]

The *Earth Science Technology Office (ESTO)* supports technology development, primarily through competed investigations, that advances capabilities with application to Earth Science research needs.

The *Applied Sciences* program leverages the observational data and scientific findings of ESD activities to enable near-term uses by non-NASA organizations in the public and private sector.

[5] NASA, FY2021 Spend Plan, Available at: https://www.nasa.gov/sites/default/files/atoms/files/fy_2021_spend_plan_march_2021.pdf.
[6] NASA EOSDIS Metrics, FY2020 (Oct 1, 2019 to Sept 30, 2020). Available at: https://earthdata.nasa.gov/eosdis/system-performance.
[7] https://oig.nasa.gov/docs/IG-20-011.pdf.

Applied Sciences projects support decision-making and communities with capacity building, disaster response, ecological forecasting for conservation and resource management, food security and agriculture, health and air quality, and water management. Applied Sciences projects include the Cyanobacteria Assessment Network (CyAN), which recently contributed to global standards for monitoring harmful algal blooms;[8] the Disasters Mapping Portal, which serves as the entry point and hub for near real-time and event-specific data products for natural disasters such as hurricanes;[9] and the NASA Harvest Consortium, made up of over 40 partners, which connects researchers, humanitarian aid organizations, economists, policymakers, and other leaders to information they need to prepare for and respond to spikes in food prices or weather-related food shortages.

Measuring and Forecasting Indicators of Climate Change

The data and research investigations within ESD contribute to measurements of the key indicators of climate change, including on surface and ocean temperatures, sea level height, and ice sheet size and distribution. As an example, NASA and NOAA conduct independent analyses of Earth's global surface temperature and release their findings concurrently every year; NASA recently reported 2020 to be tied for the warmest year on record, continuing the trend of warming surface temperatures.[10]

NASA is one of thirteen federal agencies that participate in the U.S. Global Change Research Program (USGCRP);[11] NASA contributions make up sixty percent of the total USGCRP agency budget contributions to the National Climate Assessment and other USCRP activities. On an international level, ESD also contributes to the work of the Intergovernmental Panel on Climate Change (IPCC) and the World Climate Research Programme.

NASA's Goddard Institute for Space Studies (GISS), an ESD laboratory of Goddard Space Flight Center (GSFC), leads much of the agency's work in assimilating measurements of climate indicators into numerical models to aid in study of past climate change and improve our ability to forecast future climate change.

Measuring Greenhouse Gas Emissions

A considerable focus of climate change research is the role of atmospheric greenhouse gases driving warming. Greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), absorb and then re-radiate heat in Earth's atmosphere, which causes warming, a method of "climate forcing," or initial driving of climate change. NASA's ESD uses sensors on

[8] NASA, "Setting New Global Standards for Monitoring Algal Blooms," April 2, 2021. Available at: https://appliedsciences.nasa.gov/our-impact/news/setting-new-global-standards-monitoring-algal-blooms.
[9] NASA, "NASA Helps the World Weather the 2020 Hurricane Season," February 25, 2021. Available at: https://appliedsciences.nasa.gov/our-impact/story/nasa-helps-world-weather-2020-hurricane-season.
[10] https://www.nasa.gov/press-release/2020-tied-for-warmest-year-on-record-nasa-analysis-shows.
[11] The USGCRP is mandated by Congress in the Global Change Research Act (GCRA) of 1990 (Title 15 of U.S. Code, Chapter 56A) to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change." The Fourth National Climate Assessment is available at: https://nca2018.globalchange.gov/.

the ground, on aircraft, and in space to monitor greenhouse gases to better understand their origins and lifetimes, how they interact with Earth systems, and to inform climate change predictions, and study the human and natural processes that create and destroy greenhouse gases. On the ground, for example, the Advanced Global Atmospheric Gases Experiment (AGAGE) is a network of 15 ground sensors supported by NASA, NOAA, and agencies in Europe and Asia that have measured greenhouse gases and other trace gases, like the kinds that contribute to ozone depletion, continuously since 1978. NASA's space-based Orbital Carbon Observatories, OCO-2 in low Earth orbit and OCO-3 mounted on the ISS, measure carbon dioxide in the atmosphere on regional scales, and can, when used jointly, measure CO_2 over city-scale regions. In addition, NASA is currently developing the GeoCarb, a PI-led mission due to launch in the early 2020s and continuously monitor carbon emissions of the entire U.S. from a geostationary orbit, with a spatial resolution of 3-6 miles.

NASA's Carbon Monitoring System (CMS) is a program that offers competitive grants to support development of prototype observational and analysis capabilities that can support monitoring, reporting, and verification of carbon stocks and fluxes.

Non-Federal Space-based Measurements and NASA Partnerships

Several non-Federal entities are obtaining space-based and airborne measurements to address key climate change challenges. For example, the nonprofit Environmental Defense Fund is developing MethaneSat, an Earth-observing satellite that will carry an imaging spectrometer to measure methane emissions from specific regions around the Earth with significant oil- and gas-producing operations, known to be significant contributors to overall global methane levels. GHGSat is a commercial venture, based in Canada, working toward a constellation of hyperspectral imaging satellites that can provide greenhouse gas measurements and monitoring for commercial customers.

NASA partners, as appropriate, with non-governmental entities to enhance or complement its wide portfolio of Earth Science data. NASA established the Commercial Smallsat Data Acquisition Program to "identify, evaluate, and acquire data from commercial sources that support NASA's Earth science research and application goals."[12] NASA and its Jet Propulsion Laboratory are partnering with the nonprofit organization, Carbon Mapper, by providing an instrument that will enable Carbon Mapper's satellites to pinpoint and measure methane and carbon dioxide point-sources from space.[13]

Decadal Survey for Earth Observations in Space

NASA's ESD program is guided by the priorities and recommendations of the National Academies decadal surveys. The most recent, 2018 *Thriving On Our Changing Planet: A*

[12] https://earthdata.nasa.gov/esds/csdap.
[13] https://www.nasa.gov/feature/jpl/nasa-built-instrument-will-help-to-spot-greenhouse-gas-super-emitters.

Decadal Strategy for Earth Observation in Space[14] identified 35 key science and applications questions for the next decade spanning the following six areas:

- Coupling of the water and energy cycles
- Ecosystem change
- Extending and improving weather and air quality forecasts
- Reducing climate uncertainty and informing societal response
- Sea-level rise
- Surface dynamics, geological hazards, and disasters

To measure and observe these key science and applications questions, the decadal survey recommended that NASA establish a range of small-, medium, and large-size satellite mission and technology development lines that would focus on identified priority measurements or "targeted observables" (Table 2).

Table 1: Earth Science Decadal Priorities for NASA Observation Capabilities	
Program	*Notes*
1. Program of Record	The series of existing or previously planned observations, which must be completed as planned.
2. Designated	A program element for cost-capped, competed or directed, medium- and large-size missions to address observables essential to the overall program: aerosols; clouds, convection, and precipitation; mass change; surface biology and geology; and surface deformation and change.
3. Earth System Explorer	A *new* program element for competitive, cost-capped medium-size instruments and missions targeting: Greenhouse gases, Ice elevation, Ocean surface winds and currents, ozone and trace gases, snow depth and snow water equivalent; and terrestrial ecosystem structure.
4. Incubation	A *new* program element focused on investment for capabilities for priority observations: atmospheric winds, planetary boundary layer, and surface topography and vegetation, with an innovation fund to respond to emerging needs.
5. Earth Venture	Add *new* "Venture-continuity" component to existing Earth Venture program element.

Sustained, Long Time-Series Research Measurements

Long-term (multi-year or, in many cases, multi-decade) measurements are necessary for climate change research. In 2000, a National Academies of Sciences study noted this, saying that "long-term, consistent time series are essential for the study of many critical climate processes, which vary over inherently long time scales."[15] Therefore, "both climate research and climate monitoring require a long-term commitment to consistent data sets and short-term flexibility to pursue new science and technology directions."[16]

[14] National Academies of Sciences, Engineering, and Medicine. 2018. *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24938.
[15] National Research Council. 2000. *Issues in the Integration of Research and Operational Satellite Systems for Climate Research: Part II. Implementation*. Washington, DC: The National Academies Press. https://doi.org/10.17226/9966.
[16] *Ibid.*

In a 2015 report, another National Academies committee reiterated the critical need for sustained, or continuous, observations for climate change research, finding that "detection and attribution of climatic changes and long-term trends in the Earth system—addressing, for example, land cover and land use, storm intensity, ground water change, aerosols, ozone pollution and recovery, ice mass loss, and sea level change—require sustained measurements. Such measurements are also necessary to understand climate processes characterized by low-frequency variability."[17] The report went on to recommend a quantitative, value framework that could assist NASA's ESD in determining when a measurement or dataset should be collected for durations longer than the typical lifetimes of single satellite missions.

The Decadal Survey also described, as part of a strategic framework to implement the decadal, the need to commit to sustained science and applications enabled by continuous observing for timespans that require multiple generations of spacecraft. Additional, unique scientific return comes from continuous, sustained observations, and they are particularly important for studying and understanding climate change. The decadal finds sustained observations as "central to the progress of Earth science, and integral to the long-term achievement of societal benefits."[18]

[17] National Academies of Sciences, Engineering, and Medicine. 2015. *Continuity of NASA Earth Observations from Space: A Value Framework*. Washington, DC: The National Academies Press. https://doi.org/10.17226/21789.
[18] National Academies of Sciences, Engineering, and Medicine. 2018. *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24938.