National Aeronautics and
Space Administration

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Committee on Science, Space, and Technology
Subcommittee on the Environment and Subcommittee on Research and Technology

U.S. House of Representatives

Statement of:
Dr. Karen M. St. Germain
Director, Earth Science Division
Science Mission Directorate
National Aeronautics and Space Administration

117th Congress

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Chairwoman Stevens, Ranking Member Feenstra, Chairwoman Sherrill, Ranking Member Bice, and Members of the Subcommittee and Committee:

I am Dr. Karen St. Germain, Director of NASA's Earth Science Division, and I am pleased to appear before you to share NASA's role in measuring, monitoring, and understanding the role of greenhouse gases in our warming climate.

My testimony will highlight how we intend to bring Federal capabilities like NASA's cutting-edge space-based instruments, airborne observations, climate modeling, and technology development together in support of an integrated national greenhouse gas emission monitoring and information system. Working with its Federal partners, NASA intends to bring demonstrated research capabilities into operational use, the kind of pathfinding role NASA has played since its founding. We recognize that Congress and other policymakers are eager for actionable information in support of efforts to mitigate greenhouse gases and respond to a changing climate.

<u>Defining the Challenge</u>

Since the 1980s, each decade has been warmer than the previous decade, with the past eight years the warmest collectively since modern record keeping began. It is unequivocal that our planet's climate is changing, that, these changes are driven by greenhouse gas emissions from human activity, and that future warming depends on future emissions. NASA's scientists, engineers, researchers, and innovators are working to understand the challenge and expand society's capacity to respond based on the best available information.

Efforts to decrease greenhouse gas emissions require a whole-of-government approach which you see reflected in the panel before you. Understanding the effects of greenhouse gases on the Earth as a system requires ongoing scientific inquiry; further translating what we know into actionable information will require a sustained Federal effort. NASA, NOAA, EPA, NIST, and many other Federal, international, and private partners are expanding efforts to cooperate in measuring, monitoring, reporting, and verifying the sources and sinks of greenhouse gases in our country and around the world.

Assessments of progress, like the 2023 Global Stocktake of Greenhouse Gas emissions and reductions, will require reliable, accurate, and prompt reporting. NASA's space-based and aerial capabilities, commitment to transparency and open data, world-class research in Earth science, sophisticated modeling, and applications can improve accuracy, support increased accountability and broaden the range of informed responses.

As NASA also works with our colleagues across the Federal government to address global and local effects of climate change like rising temperatures and the threat of wildfire, rising sea levels, inland flooding, and drought, we stand ready to assist decisionmakers as they face the challenges before us.

How We See it at NASA

NASA's mission is to provide the observations and foundational science that underpins our understanding of Earth as a system. This is essential in the context of greenhouse gases and climate change because the processes that drive climate change depend not only on human influences such as greenhouse gas and aerosol emissions, but also how the land biosphere and ocean respond to and absorb these emissions.

We use the unique vantage point of space to observe the Earth from our fleet of Earth observing satellites, the International Space Station, suborbital aircraft, and other assets to understand these feedback mechanisms and refine our ability to project future change. These feedback mechanisms represent a highly complex set of interlocking science challenges and a compelling basis for strategic partnerships with Europe, Japan, Canada, and a host of other international and domestic commercial partners.

NASA develops and operates several satellites and instruments that measure atmospheric carbon dioxide. Aura, one of the satellites in the multinational partnership of closely synchronized Earth observing satellites known colloquially as the 'A-Train,' observes carbon dioxide, methane, nitrogen dioxide, ozone, and water using several different instruments. The Orbiting Carbon Observatory 2 (OCO-2) measures atmospheric carbon dioxide. OCO-3, mounted on the International Space Station (ISS), provides carbon dioxide data like its sibling OCO-2.

NASA's Global Ecosystem Dynamics Investigation (GEDI), whose high-resolution surface and forest measurements have contributed significantly to understanding of the carbon cycle, is also currently mounted on the ISS. The Earth Surface Mineral Dust Source Investigation (EMIT), which will aid our understanding of how mineral dust affects the warming of our planet, will arrive at ISS later this summer. NASA also collaborates with other federal entities and international space organizations, including NOAA and the European Space Agency (ESA), to collect and distribute greenhouse gas data.

Pursuant to the 2017 National Academies of Sciences, Engineering, and Medicine Decadal Survey on Earth Science and Applications, NASA intends to launch five Earth System Observatory (ESO) missions to capture observations on aerosols, clouds, convection, and precipitation, mass change, surface biology and geology, and surface deformation and change. NASA is currently initiating the formulation phase of several of these missions. These combined capabilities will give us a better understanding of the Earth system as a whole and how it interacts with greenhouse gases.

NASA will augment the core of the ESO with a new class of mission, the Earth System Explorers (ESE), to make additional high-priority observations and encourage innovative solutions through competitive selection at the mission level. The Decadal Survey recommended that this competitive program include proposals related to greenhouse gases. These missions will conduct scientific investigations of modest and focused programmatic scope and can be developed relatively quickly, and NASA expects to release the first ESE Announcement of Opportunity late this year.

NASA conducts airborne and ground campaigns to obtain high-resolution temporal and spatial measurements of complex local processes, which can be coupled to global satellite observations for a better understanding of Earth system processes. These include airborne science campaigns like the Michigan-Ontario Ozone Source Experiment (MOOSE), to better understand ozone levels in southeast Michigan. Analyses of data from past airborne campaigns like the NASA Atmospheric Tomography (ATom) mission, focused on the distribution and atmospheric fate of short-lived climate forcers, and the Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) mission, aimed at Arctic carbon cycling, continue to contribute to our understanding of the roles played by greenhouse gases in the Earth system.

NASA surface-based measurements like the Advanced Global Atmospheric Gases Experiment (AGAGE) network are critical to documenting long-term changes in greenhouse gas concentrations, not just carbon dioxide and methane, but nitrous oxide, chlorofluorocarbons, hydrochlorofluorocarbons, and similar compounds, and are closely coordinated with related measurements by NOAA and our international partners.

<u>Advancing Technology</u>

Our goals for monitoring, measurement, and verification must be commensurate with our technical capabilities. NASA continues to advance technology for new measurement capabilities that can advance future generations of airborne and satellite-based measurements of greenhouse gases. The High Altitude LIDAR Observatory (HALO) instrument is an example of a technology already in development that uses active remote sensing/light detection and ranging (LIDAR) that can allow NASA airborne campaigns to detect methane enhancements up to 20 kilometers downwind of a point source.

In the FY23 President's Budget Request NASA is asking for funding for a focused activity using competitive approaches to advance the development and testing of new technologies for space-based greenhouse gas measurement.

Technologies NASA is investing in include photonic systems on a chip for LIDAR and radio frequency applications and spectrometers, detectors, and readout integrated circuits for focal plane arrays. A key effort will be in making these technologies reliable, affordable, and deployable everywhere from space-based telescopes to small aerial platforms.

Increased capabilities hold the prospect of improved measurements of carbon dioxide and methane fluxes and trends, global and regional quantification of point sources and identification of source types, better spectral and spatial coverage to understand carbon fluxes. New work will allow us to better assess greenhouse gas emissions in varying conditions of illumination, for example, measuring emissions in the Arctic during wintertime and methane emissions from tropical wetlands.

Science Supporting Mitigation

Through its Carbon Monitoring System (CMS), NASA supports prototyping of new data capabilities and product-oriented overlays to our existing programs that aid in the monitoring, reporting, and verification of carbon stocks and fluxes. CMS is an Earth system science approach that combines observations of greenhouse gases in the atmosphere with measurements of the biological processes responsible for surface emission and uptake, or absorption, of carbon dioxide. CMS looks at land and water along with critical markers of the transformation of vegetation like evapotranspiration and solar-induced fluorescence. By producing top-down and bottom-up greenhouse gas emissions estimates and comparing them, CMS can point towards what we are missing.

CMS projects have provided insight into the role of forests and cropland in greenhouse gas fluxes, including whether certain lands under agricultural use are carbon sinks, sources, or both, and under what conditions. For example, Midwestern cornfields have shown to be carbon sinks during certain years, while years of water stress, they have been shown to release carbon, even as Oklahoma winter wheat might show no notable change under the same conditions. Analyses of forest canopy height and above ground biomass can reveal carbon sequestration potential in Northeastern forests.

NASA research has also supported more advanced quality assurance and verification of methane estimates. Colorless and odorless, methane leaks are hard to detect without scientific instruments. CMS-funded research has used atmospheric observations to assess national inventories for the U.S., Canada, and Mexico. NASA airborne campaigns, especially those using AVIRIS-NG (the Airborne Visible InfraRed Imaging Spectrometer - Next Generation) and HyTES (the Hyperspectral Thermal Emission Spectrometer) have been critical to documenting methane emissions including 'super sources' and serve as precursors for future measurements.

A recent month-long NASA Jet Propulsion Laboratory (JPL) airborne study with partners from the University of Arizona and Arizona State University has shown that about half of the largest sources of methane in the Permian Basin oilfield in New Mexico and Texas are likely to be malfunctioning oilfield equipment.

CMS-funded scientists also built a new series of maps detailing the global geography of methane emissions from coal, oil, and gas, and other sources. Using publicly available data reported in 2016, the research team plotted fuel exploitation emissions that arise before the fuels are ever consumed, showing areas where further reductions in emissions might be possible.

NASA's greenhouse gas research and its applications depend significantly on open science and partnerships. In addition to assets like Aura, OCO-2, and OCO-3, NASA relies on information from NOAA's Suomi NPP, the Japan Aerospace Exploration Agency (JAXA)'s Greenhouse gases Observing Satellite (GOSAT), the European Space Agency (ESA)'s Tropospheric Monitoring Instrument (TROPOMI), and a host of other data sources, past and present.

NASA compares data between programs (including algorithm intercomparisons and mutual calibration/validation efforts) and combines data from these interagency and international sources, as well as others, to help understand the nature of greenhouse gas emissions, including the balance between biologically-emitted greenhouse gases and those from fossil fuel development and combustion.

NASA coordination with international partners includes the joint Committee on Earth Observation Satellites (CEOS))/Coordination Group for Meteorological Satellite (CGMS) working group on climate and its subgroup on carbon as well as bilateral approaches like work with ESA on a future Sentinel mission for monitoring carbon dioxide.

NASA also provides support for American scientific leadership of the World Meteorological Organization's Integrated Global Greenhouse Gas Information System, along with NIST and NOAA, and jointly supports the Arctic Methane and Permafrost Challenge with ESA. Relevant NASA data are routinely and freely shared with all of NASA's partners, and our commitment to open science is a scientific beacon to the entire world.

An important part of our open approach is to make our science available, understandable, and useable by the public. NASA's Applied Remote Sensing Training Program (ARSET) and similar training programs allow all communities, including those most affected by greenhouse gases and our changing climate, to participate in our science. In fact, NASA just concluded an ARSET training module on how combining bottom-up and top-down methods for tracking emissions and removals of carbon dioxide and methane can make the 2023 Global Stocktake more complete and transparent. We hope to tell you more about our plans as we work to make next year - 2023 - a Year of Open Science at NASA.

The ability to compare, combine, and analyze all available data involving multiple, complex, and coupled processes that occur on a continuum of spatial and temporal scales and affect our entire Earth system is at the core of what NASA does. NASA's modeling capabilities, especially data assimilation, are critical to the development and sharing of observation-informed model products. In addition to all the data sources cited above and in collaboration with NOAA, NASA has shown that there are ways to assimilate everything from nighttime lights, fire radiative power, vegetation greenness, to atmospheric circulation, and fill in information that satellites cannot observe directly.

Understanding climate sensitivity is also key to mitigation and adaptation. NASA scientists and our partners are working to improve climate models over time. We know from studies of the past that Earth's climate can change dramatically, and NASA scientists working at the Goddard Institute for Space Studies studied records from periods millions of years ago when carbon dioxide levels, global temperatures, and sea level were much higher, to help understand the range of possible futures. Quantifying climate sensitivity and narrowing the uncertainties can have big implications for understanding human mitigation and adaptation choices.

Collaboration Going Forward

NASA greenhouse gas work can be enhanced increasingly by higher spatial and temporal resolution data available from companies that image the Earth from space by way of our Commercial Smallsat Data Acquisition Program. We have used that Program to on-ramp new and innovative Earth observation data providers like Planet, Spire Global, and Maxar. We expect to on-ramp additional providers later this year.

We eagerly look forward to new greenhouse gas data providers like GHGSat of Canada and the public-private partnership Carbon Mapper from California, expected to launch in 2023. NASA JPL has contributed a state-of-the-art imaging spectrometer to the Carbon Mapper project similar to ones used to identify major methane emitters in California and the Four Corners region. NASA experience has shown that where new data providers have arrived, science users are eager to validate and use whatever information they can offer.

In addition to the host of collaborations in observations, modeling, research, and other areas, NASA is working with other agencies through the new Greenhouse Gas Monitoring and Measurement Interagency Working Group. Coordination through this interagency working group will be essential to maximize the impact of agency resources, enhance the Nation's ability to measure and monitor GHG emissions and removals, and accelerate the transition of relevant research capabilities to operational use. NASA also just initiated Cycle 3 of the interagency Satellite Needs Working Group process to determine what measurement or data products needed by our interagency partners can be provided by NASA.

As part of a renewed emphasis on providing actionable data and information to a broad range of users, NASA is planning an Earth Information Center with an initial focus on prototyping capabilities for a greenhouse gas monitoring and information system that will integrate data from a variety of sources with a goal of making data more accessible and usable to Federal, state, and local governments, researchers, the public, and other users. These efforts will be implemented in coordination with other agencies and partners.

With $2.4 billion requested for NASA Earth Science in the fiscal year 2023 President's Budget, NASA will continue to make strong progress in observing and understanding the Earth as a system, including greenhouse gas emissions. NASA stands ready to work with our federal, state, tribal, local, and commercial partners to address the challenges posed by greenhouse gases and their effects. I want to thank this Committee and the Congress for its support for Earth science and the entire Federal government's efforts to tackle the challenges we discuss today, and I welcome your questions.

Dr. Karen M. St. Germain

Dr. St. Germain is the Division Director of the Earth Science Division, in the Science Mission Directorate at the National Aeronautics and Space Administration (NASA) Headquarters. She provides executive leadership, strategic direction, and overall management for the entire agency's Earth Science portfolio, from technology development, applied science, research, mission implementation and operation.

Prior to coming to NASA, Dr. St. Germain was the Deputy Assistant Administrator, Systems (DAAS), for NOAA's Satellite and Information Service. She guided the ongoing development and deployment of NOAA's two major satellite programs (the Joint Polar Satellite System and Geostationary Operational Environment Satellite – R series), the COSMIC-2 mission, and the Space Weather Follow-On. She also led the development of the next-generation capabilities that will replenish and augment these systems in the future.

Prior to becoming the DAAS, Dr. St. Germain served as the Director of the Office of Systems Architecture and Advanced Planning (OSAAP) where she led NOAA's enterprise-level architecture development to define NOAA future spaceborne capabilities. Dr. St. Germain is a leader in enterprise-level planning and multi-organizational programs of national significance. She is also an expert in major systems acquisition, with particular proficiency in transitioning new technology into operational systems. Prior work for NOAA included leading all aspects of system performance during the development of the Suomi-NPP system, from 2006 to 2011.

From 2011 to 2016, Dr. St. Germain served in the Space, Strategic and Intelligence Systems (SSI) Office, Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (OUSD AT&L). There, she led the DoD 2014 Strategic Portfolio Review for Space, a special assignment task for the Deputy Secretary of Defense to develop a strategy and implementation plan for adapting to evolving challenges in the space domain. Dr. St. Germain also led the Remote Sensing and Prompt Strike Division within SSI, where she was responsible for acquisition shaping and oversight of DoD strategic missile warning and space-based environmental monitoring portfolio.

Dr. St. Germain had a successful research career at the University of Massachusetts, the University of Nebraska, and the Naval Research Laboratory. She has performed research aboard ice-breakers in the Arctic and Antarctic, flown through hurricanes and tropical storms on NOAA's P-3 airplanes and measured glacial ice on a snowmobile traverse of the Greenland ice sheet. She also led the modeling and calibration of the WindSat Coriolis mission, the first space-borne radiometer to measure ocean surface wind direction.

Dr. St. Germain holds a Bachelor of Science degree in electrical engineering from Union College (1987) and a Doctor of Philosophy degree in Electrical Engineering from the University of Massachusetts (1993). She is also a Distinguished Graduate of the National War College, National Defense University where she earned a Master of Science degree in National Security Strategy in 2013.