APPENDIX A. EARTH SCIENCE RESEARCH PROGRAM

A.1 EARTH SCIENCE RESEARCH OVERVIEW

1. Introduction

NASA’s Earth Science Research Program supports research activities that address the Earth system and seek to characterize its properties on a broad range of spatial and temporal scales, to understand the naturally occurring and human-induced processes that drive them, and to improve our capability for predicting its future evolution. The focus of the Earth Science Research Program is the use of space-based measurements to provide information not available by other means. NASA’s program is an end-to-end one that starts with the development of observational techniques and the instrument technology needed to implement them; tests them in the laboratory and from an appropriate set of in situ, surface-, ship-, balloon-, aircraft-, and/or space-based platforms; uses the results to increase basic process knowledge; incorporates results into complex computational models that can be used to more fully characterize the present state and future evolution of the Earth system; and develops partnerships with other national and international organizations that can use the generated information in environmental forecasting and in policy, business, and management decisions.

The scientific documentation underlying the Earth Science Research Program provides a comprehensive background for the science solicited here. The Research Program addresses NASA’s Strategic Goal 1.1 to "Understand The Sun, Earth, Solar System, and Universe”. (See the most recent NASA Strategic Plan: https://www.nasa.gov/sites/default/files/atoms/files/nasa_2018_strategic_plan.pdf). In particular, it addresses the more specific Science Goals (see the Science Plan for NASA’s Science Mission Directorate (hereafter the NASA Science Plan), also available at https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/2014_Science_Plan_PDF_Update_508_TAGGED_1.pdf), which are to:

- Advance the understanding of changes in the Earth’s radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition;
- Improve the capability to predict weather and extreme weather events;
- Detect and predict changes in Earth’s ecosystems and biogeochemical cycles, including land cover, biodiversity, and the global carbon cycle;
- Enable better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change;
- Improve the ability to predict climate changes by better understanding the roles and interactions of the oceans, atmosphere, land, and ice in the climate system;
- Characterize the dynamics of the Earth’s surface and interior, improving the capability to assess and respond to natural hazards and extreme events; and
- Further the use of Earth system science research to inform decisions and provide benefits to society.

The most up-to-date description of the Earth Science Research Program may be found in Section 4.2 of the NASA Science Plan at http://science.nasa.gov/about-us/science-strategy. The most recent Decadal Survey covering NASA’s Earth science activities,
Thriving on our Changing Planet: A Decadal Strategy for Earth Observation from Space, was released on 1/5/2018 by the National Academies of Science, Engineering, and Medicine (see https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth). This 2017 Decadal Survey now serves as a foundational document for NASA’s Earth Science Division (ESD), and includes recommendations for the scopes, foci, and relative budgetary magnitudes of the R&A, Applications, and Technology portions of the ESD program. In addition, the Decadal Survey includes a specific endorsement of the NASA missions making up the 2017 Program of Record (comprehensively defined in the Survey’s Appendix A).

NASA’s Earth Science Research Program is a major contributor to several interagency efforts within the U.S. Government, most notably the U.S. Global Change Research Program (USGCRP, see http://www.globalchange.gov), to which NASA is the major contributor. This program released its strategic plan in 2012, the National Global Change Research Plan 2012-2021: A Strategic Plan for the U. S. Global Change Research Program (http://www.globalchange.gov/browse/reports/national-global-change-research-plan-2012–2021-strategic-plan-us-global-change). This plan is updated triennially; the most recent such update may be found at https://downloads.globalchange.gov/strategic-plan/2016/usgcrp-strategic-plan-2016.pdf.

Similarly, there are interagency programs related to Oceans and the Arctic. In addition, there are several other subgroups of the Committee on the Environment that serve to provide interagency coordination in areas covered by NASA’s Earth Science Research Program. NASA’s Earth Science Research Program has focused bilateral efforts with other Federal agencies on transitioning knowledge and approaches from research to operations, most notably with the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS).

Research is solicited in four major areas for the Earth Science Research Program: research and analysis (R&A), satellite missions, applied sciences, and enabling capabilities, with R&A containing the bulk of the solicited research. R&A emphasizes the development of new scientific knowledge, including the analysis of data from NASA satellite missions and the development and application of complex models that assimilate these science data products and/or use them for improving predictive capabilities. Within the Earth Science Research Program, the research and analysis activities include those historically coming under R&A, mission science team, interdisciplinary science, and calibration/validation activities.

The applied sciences area supports efforts to discover and demonstrate innovative and practical uses of NASA Earth science observations and research through applications projects carried out in partnership with end user organizations (http://AppliedSciences.nasa.gov/). Applied sciences, thus, serves as a bridge between the data, modeling, and knowledge generated by NASA Earth science and the information required by Government agencies, companies, and organizations to improve their products, services, and decision making.

Enabling capabilities include those programmatic elements with sufficient breadth to contribute to a broad range of activities within the Earth Science Research Program and typically involve the development of some kind of capability whose sustained availability is considered to be important for the Program’s future. These include focused activities
in support of education; data, information, and management; and airborne science, as well as some broadly-based technology-related elements (others which are very focused towards a single scientific area of the Earth Science Research Program will be solicited through the R&A area).

Most proposals to ROSES-2019 will require a data management plan (DMP) or an explanation of why one is not necessary given the nature of the work proposed. Proposers will satisfy this requirement by responding to the compulsory NSPIRES cover page question about the DMP, unless otherwise specified in a specific program element. The kinds of proposals that require a data management plan are described in the NASA Plan for increasing access to results of Federally funded research and in the SARA DMP Frequently Asked Questions (FAQs) for ROSES. Proposals to instrument development programs (Advanced Information Systems Technology, the Instrument Incubator Program, Advanced Component Technology, and In-Space Validation of Earth Science Technologies) do not require a DMP. Moreover, select calls, such as Advancing Collaborative Connections for Earth System Science (ACCESS), include data requirements in the text that make redundant the cover page DMP. Any proposal intending to submit data products for archival and public distribution by a NASA Distributed Active Archive Center (DAAC) should review guidelines on the Earthdata web site.

The overarching goal of NASA’s Earth Science program is to develop a scientific understanding of Earth as a system. Scientific knowledge is most robust and actionable when resulting from transparent, traceable, and reproducible methods, requiring open access to not only the data used in scientific analysis, but the software used to arrive at results as well. Additionally, software developed to be openly accessible, without restrictions on modification and distribution, enables reuse across Federal agencies, reduces overall costs to the Government, removes barriers to innovation, ensures consistency through the application of uniform standards, and facilitates collaboration between agencies and non-Federal institutions. NASA addresses these goals by encouraging the open development, access, and distribution of the source code used to generate, manipulate, and analyze science data and results.

Toward that end, NASA encourages software developed in response to Appendix A program elements be designated, developed, and distributed to the public as Open Source Software (OSS). This includes all software developed with ESD funding used in the production of data products, as well as software developed to discover, access, visualize, and transform NASA data. OSS is defined as software that can be accessed, used, modified, and shared by anyone. The definition of OSS, along with examples of OSS licensing and public code repositories, can be found on the Earthdata web site.

Program elements will give preference to proposals that include a plan for committing software as OSS, beginning at the inception of the proposed work. This plan will include the identification of software components developed as part of the proposed work, and designate a permissive, widely accepted OSS license and a public repository hosting service for these components. Please read the individual appendices and associated amendments carefully and contact the program officers if you have any questions regarding OSS development for a given call.
Contracts will not be issued in response to proposals submitted to the research program elements in Appendix A, unless otherwise noted (e.g., exceptions include calls for flight hardware). Instead, awards to non-governmental organizations will be made in the forms of grants or cooperative agreements, which are most appropriate given the nature of the work solicited. Awards internal to the government will be made through the usual Agency processes.

2. Earth Science Research and Analysis Focus Areas

The Earth Science R&A activity is built around the creation of new scientific knowledge about the Earth system. The analysis and interpretation of data from NASA’s satellites form the heart of the R&A program in the Earth Science Research Program, although a full range of underlying scientific activity needed to establish a rigorous base for the satellite data and their use in computational models, including those for assimilation and forecasting, is also included. The complexity of the Earth system, in which spatial and temporal variability exists on a range of scales, requires that an organized scientific approach be developed for addressing the complex, interdisciplinary problems that exist, taking good care that, in doing so, there is a recognition of the objective to integrate science across the programmatic elements towards a comprehensive understanding of the Earth system.

In the Earth system, these elements may be built around aspects of the Earth that emphasize the particular attributes that make it stand out among known planetary bodies. These include the presence of carbon-based life and their associated ecology; water in multiple, interacting phases; a fluid atmosphere and ocean that redistribute heat over the planetary surface; an oxidizing and protective atmosphere, *albeit* one subject to a wide range of fluctuations in its physical properties (especially temperature, moisture, and winds); a solid but dynamically active surface and interior that drive changes in the Earth’s shape, orientation, rotation, gravity, and surface and atmospheric composition; and an external environment driven by a large and varying star whose magnetic field also serves to shield the Earth from the broader astronomical environment. The resulting structure is comprised of six interdisciplinary science Focus Areas:

- Carbon Cycle and Ecosystems,
- Water and Energy Cycle,
- Climate Variability and Change,
- Atmospheric Composition,
- Weather, and
- Earth Surface and Interior.

These Focus Areas form the basis around which R&A activity is solicited for the Earth Science Research Program. Given the interconnectedness of these science Focus Areas, research that crosses individual Focus Areas is also sought, and a number of specific cases of such connectivity will be identified in some of the specific research opportunities identified below. In particular, several instrument science teams for NASA satellite missions are solicited through this NRA. These can contribute to scientific advances in several areas, and potential investigators may want to look carefully at all
such teams for opportunities that may be relevant to them. In addition, there are several cross-cutting elements included within this appendix, most notably one that solicits proposals that address rapid response to significant Earth system events, as well as truly novel work that doesn’t easily fit the active ROSES-2019 elements this year or in the recent past (Rapid Response and Novel Research in Earth Science – program element A.29).

Several elements solicited in prior years are not being solicited this year, but have program-specific ROSES-2019 elements for completeness, as well as to provide potential proposers with plans about the anticipated dates of the next solicitation.

- Ocean Biology and Biogeochemistry (program element A.3);
- Terrestrial Ecology (program element A.4);
- Carbon Cycle Science (program element A.5);
- Biodiversity (program element A.7);
- Ocean Surface Topography Science Team (program element A.14);
- Ocean Vector Winds Science Team (program element A.15);
- Cryospheric Science (program element A.17);
- Atmospheric Composition: Upper Atmosphere Research Program (program element A.18);
- Atmospheric Composition: Radiation Sciences Program (program element A.19);
- Atmospheric Composition: Modeling and Analysis (program element A.20);
- Atmospheric Composition: Tropospheric Composition Program (program element A.21);
- NASA Energy and Water Cycle Study (program element A.24);
- U.S. Participating Investigator (program element A.31);
- New (Early Career) Investigator Program in Earth Science (program element A.34);
- The Science of Terra, Aqua, and Suomi-NPP (program element A.35);
- Studies with ICESat-2 (program element A.36);
- The Plankton, Aerosol, Cloud, Ocean Ecosystem (PACE) Mission System Vicarious Calibration (program element A.39)
- Earth Science Applications: Water Resources (program element A.41);
- SERVIR Applied Sciences Team (program element A.42);
- Earth Science Applications: Disaster Risk Reduction and Response (program element A.43);
- Health and Air Quality Applied Sciences Team (program element A.44);
- Ecological Forecasting (program element A.45);
- Citizen Science for Earth Systems Program (program element A.47);
- Advanced Information Systems Technology (program element A.48);
- Advanced Component Technology (program element A.50);
- In-Space Validation of Earth Science Technologies (program element A.51); and
- Sustainable Land Imaging – Technology (program element A.52).
Elements for which it has not yet been decided whether or not to solicit during the period of applicability of ROSES-2019 are not included in this list, but are included by focus area and/or program component later in Appendix A. Note that not all elements which have been solicited in previous ROSES are included this year; some will reappear in future solicitations at an appropriate time that should allow for smooth transition between the currently funded tasks and those that would come out of the next solicitation.

2.1 Carbon Cycle and Ecosystems

The carbon cycle, which encompasses the flow and transformation of carbon between reservoirs, is the backbone that sustains life on planet Earth. The cycling of carbon dioxide and methane into the atmosphere contributes to the planetary greenhouse effect and global climate. Organic and inorganic carbon flow through ecosystems as part of food webs, and interact with the climate system. Earth’s carbon cycle and ecosystems are subject to human intervention and environmental changes on an unprecedented scale, in both rate and geographical extent. This has the potential to impact ecosystem services, which provide a wide variety of essential goods to human societies. Our ability to ameliorate, adapt to, or benefit from these rapid changes requires fundamental knowledge of the responses of the carbon cycle and terrestrial and marine ecosystems to global change. Also required is an understanding of the implications of these changes for food production, biodiversity, sustainable resource management, and the maintenance of a healthy, productive environment.

The Carbon Cycle and Ecosystems Focus Area addresses: (1) the distribution and cycling of carbon among the active terrestrial, marine, and atmospheric reservoirs and (2) ecosystems as they are affected by human activity, as they change due to their own intrinsic biogeochemical dynamics, and as they respond to climatic variations and, in turn, affect climate. Research activities focus on providing data and information derived from remote sensing systems to answer the following science questions:

- How are global ecosystems changing?
- What changes are occurring in global land cover and land use, and what are their causes?
- How do ecosystems, land cover and biogeochemical cycles respond to and affect global environmental change?
- What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?
- What are the consequences of climate change and increased human activities for coastal regions?
- How will carbon cycle dynamics and terrestrial and marine ecosystems change in the future?

Frequent, repeat observations from space, at both moderate and high spatial resolutions, are required to address the heterogeneity of living systems. Complementary airborne and in situ observations, intensive field campaigns and related process studies, fundamental research, data and information systems, and modeling are employed to interpret the satellite observations and answer the science questions.
The goal of the Carbon Cycle and Ecosystems Focus Area is to:

- Quantify, understand, and predict changes in Earth's ecosystems and biogeochemical cycles, including the global carbon cycle, land cover, and biodiversity.

Anticipated products and payoffs include:

- Assessments of ecosystem response to climatic and other environmental changes and the effects on food, fiber, biodiversity, primary productivity, and other ecological goods and services;
- Quantitative carbon budgets for key ecosystems along with the identification of sources and sinks of carbon dioxide and other greenhouse gases;
- Documentation and prediction of land-cover and land-use change, as well as assessments of consequences to society and for resource sustainability;
- Understanding of ecosystem interactions with the atmosphere and hydrosphere leading to comprehensive modeling of the exchange of gases, aerosols, water, and energy among the components of the Earth system; and
- Improved representations of ecosystem and carbon cycling processes within global climate models leading to more credible predictions of climate and other Earth system functions.

Interdisciplinary collaborations with other Earth Science Research Program Focus Areas include:

- Work with the Water and Energy Cycle Focus Area on land-atmosphere exchanges of water and energy and the effects of land-cover and land-use change on water resources;
- Work with the Atmospheric Composition Focus Area on surface emissions and atmospheric transport of trace gases and aerosols and on measurement of carbon-containing greenhouse gases;
- Work with the Climate Variability and Change and Weather Focus Areas on air-sea CO₂ exchange and to share the observations of climate, weather, ecosystems, and land cover that are needed to drive Earth system models; and
- Coordinate with the Earth Surface and Interior Focus Area to advance and/or exploit radar, lidar, and hyperspectral remote sensing technologies for surface properties.

The ROSES elements most closely directed towards the Carbon Cycle and Ecosystems Focus Area that are or may be soliciting proposals in ROSES-2019 are:

- Land-Cover and Land-Use Change (program element A.2);
- Carbon Monitoring System (program element A.6); and
- GEDI Science Team (program element A.8).

Topics relevant to the Carbon Cycle and Ecosystems Focus Area that are actively or potentially soliciting in ROSES-2019 include the following program elements:

- Atmospheric Composition: Aura Science Team (program element A.22);
- SMAP Science Team (program element A.25);
- Rapid Response and Novel Research in Earth Science (program element A.29);
- Airborne Instrument Technology Transition (program element A.30);
• Interdisciplinary Research in Earth Science (program element A.32);
• Earth Science Research from Operational Geostationary Satellite Systems (program element A.33);
• PACE Science and Applications Team (program element A.38);
• High Mountain Asia Team (program element A.40);
• Advancing Collaborative Connections for Earth System Science (program element A.46);
• Instrument Incubator Program (program element A.49); and
• Topical Workshops, Symposia, and Conferences (program element E.2).

2.2 Climate Variability and Change

Climate change is one of the major themes guiding Earth System Science today. NASA is at the forefront of quantifying forcings and feedbacks of recent and future climate change. Our comprehensive end-to-end program ranges from global high-resolution observations to data assimilation and model predictions. Recently, the Climate Variability and Change Focus Area has directed its research toward addressing five specific questions:

• How is global ocean circulation varying on interannual, decadal, and longer time scales?
• What changes are occurring in the mass of the Earth's ice cover?
• How can climate variations induce changes in the global ocean circulation?
• How is global sea level affected by natural variability and human-induced change in the Earth system?
• How can predictions of climate variability and change be improved?

Climate-variability and change research is now not just a global issue, but also a research problem that directly impacts regional to local environments. In fact, local-to-regional anthropogenic-induced changes are having global impacts whose magnitudes are expected to increase in the future. Climate models have moved toward higher and higher spatial resolution as computer resources have improved. During the next decade, climate models are expected to approach the spatial resolution of weather and regional models as more details of Earth System processes are incorporated.

The oceans are a major part of the climate system and a unique NASA contribution to climate science is the near-global coverage of observations from space of selected ocean properties every two to ten days. Additionally, NASA provides observations of the vast expanses of polar ice, including both ice sheets and sea ice, on the temporal and spatial scales necessary to detect change and sampling of the other critical elements of the climate system that link climate to other Focus Areas, such as cloud distribution, snow cover, surface temperatures, humidity characteristics, etc.

NASA makes substantial investments to characterize and understand the nature and variability of the climate system. As part of those investments, NASA maintains an active research program to utilize data from satellites to both improve our understanding of these components of the Earth system and the interactions between them and to assess how satellite observations can be used to improve predictive capability. Current capabilities include global measurements of sea-surface topography, ocean-vector
winds, ice topography and motion, and mass movements of the Earth’s fluid envelope and cryosphere.

Understanding interactions within the climate system also requires strong modeling and analysis efforts. The climate system is dynamic and complex, and modeling is the only way we can effectively integrate the observations and current knowledge of individual components fully to characterize current conditions and underlying mechanisms, as well as to project the future states of the climate system. This modeling requires a concerted effort both to improve the representation of physical, chemical, and biological processes and to incorporate observations into climate models through data assimilation and other techniques. The ultimate objective is to enable a predictive capability of climate change on time scales ranging from seasonal to multidecadal.

The ROSES elements most closely directed towards the Climate Variability and Change Focus Area that are or may be soliciting proposals in ROSES-2019 are:

- Physical Oceanography (program element A.9);
- Ocean Salinity Science Team (program element A.10);
- Sea Level Change Science Team (program element A.11);
- SWOT Science Team (program element A.12);
- SWOT Calibration/Validation Field Campaigns (program element A.13); and

Topics relevant to the Climate Variability and Change Focus Area that are actively or potentially soliciting in ROSES-2019 include the following program elements:

- Carbon Monitoring System (program element A.6);
- Atmospheric Composition: Aura Science Team (program element A.22);
- SMAP Science Team (program element A.25);
- GRACE-FO Science Team (program element A.28);
- Rapid Response and Novel Research in Earth Science (program element A.29);
- Airborne Instrument Technology Transition (program element A.30);
- Interdisciplinary Research in Earth Science (program element A.32);
- Earth Science Research from Operational Geostationary Satellite Systems (program element A.33);
- GNSS Research (program element A.37);
- High Mountain Asia Team (program element A.40);
- Advancing Collaborative Connections for Earth System Science (program element A.46);
- Instrument Incubator Program (program element A.49); and
- Topical Workshops, Symposia, and Conferences (program element E.2).

2.3 Atmospheric Composition

Changes in atmospheric composition affect air quality, weather, climate, and critical constituents, such as ozone and aerosol particles. Atmospheric exchange links terrestrial and oceanic pools within the carbon cycle and other biogeochemical cycles. Solar radiation affects atmospheric chemistry and is, thus, a critical factor in atmospheric composition. Atmospheric composition, in turn, affects incoming solar and outgoing long wave radiation. Atmospheric composition is central to Earth system
dynamics, since the atmosphere integrates surface emissions globally on time scales from weeks to years and couples several environmental issues. NASA’s research for furthering our understanding of atmospheric composition is geared to providing an improved prognostic capability for such issues (e.g., the recovery of stratospheric ozone and its impacts on surface ultraviolet radiation, the evolution of greenhouse gases and their impacts on climate, the impact of clouds and aerosol particles on the Earth’s energy budget and the evolution of aerosols and tropospheric ozone and their impacts on climate and air quality). Toward this end, research within the Atmospheric Composition Focus Area addresses the following science questions:

- How is atmospheric composition changing?
- What trends in atmospheric composition and solar radiation are driving global climate?
- How does atmospheric composition respond to and affect global environmental change?
- What are the effects of global atmospheric composition and climate changes on regional air quality?
- How will future changes in atmospheric composition affect ozone, climate, and global air quality?

NASA expects to provide the necessary monitoring and evaluation tools to assess the effects of climate change on ozone recovery and future atmospheric composition, improved climate forecasts based on our understanding of the forcings of global environmental change, and air quality forecasts that take into account the feedbacks between regional air quality and global climate change. Achievements in these areas via advances in observations, data assimilation, and modeling enable improved predictive capabilities for describing how future changes in atmospheric composition affect ozone, climate, and air quality. Drawing on global observations from space, augmented by airborne, balloon, and ground-based measurements, NASA is uniquely poised to address these issues. This integrated observational strategy is furthered via studies of atmospheric processes using unique suborbital platform-sensor combinations to investigate, for example: (1) the processes responsible for the emission, uptake, transport, and chemical transformation of ozone and precursor molecules associated with its production in the troposphere and its destruction in the stratosphere; and (2) the formation, properties, and transport of aerosol particles in the Earth’s troposphere and stratosphere, as well as aerosol particle interaction with clouds. NASA’s research strategy for atmospheric composition encompasses an end-to-end approach for instrument design, data collection, analysis, interpretation, and prognostic studies.

No ROSES element exclusively focused on the Atmospheric Composition Focus Area that are or may be soliciting for proposals in ROSES-2019.

Topics relevant to the Atmospheric Composition Focus Area are actively or potentially soliciting in ROSES-2019 include the following program elements:

- Carbon Monitoring System (program element A.6);
- Atmospheric Composition: Aura Science Team (program element A.22);
- Rapid Response and Novel Research in Earth Science (program element A.29);
- Airborne Instrument Technology Transition (program element A.30);
• Interdisciplinary Research in Earth Science (program element A.32);
• Earth Science Research from Operational Geostationary Satellite Systems (program element A.33);
• PACE Science Team (program element A.38);
• High Mountain Asia Team (program element A.40);
• Advancing Collaborative Connections for Earth System Science (program element A.46);
• Instrument Incubator Program (program element A.49); and
• Topical Workshops, Symposia, and Conferences (program element E.2).

2.4 Water and Energy Cycle

Earth is a unique, living planet in our Solar System due to the abundance of water and the vigorous cycling of that water throughout its global environment. The global water cycle represents the transport and transformation of water within the Earth system, and, as such, distributes fresh water over the Earth’s surface. The water cycle operates on a continuum of time and space scales and exchanges large amounts of energy as water undergoes phase changes and is moved from one part of the Earth system to another. Through latent heat release from condensation and sublimation, the water cycle is a major driving agent of global atmospheric circulation. Clouds play a critical role in modulating the flow of energy into and out of the Earth system, while at the same time modulating the continuous supply of solar energy that keeps the water cycle in motion. So, while the water cycle delivers the hydrologic consequences of climate changes, the global water cycle is both a consequence of, and influence on, the global energy cycle.

The global water and energy cycles maintain a considerable influence upon the global pathways of biogeochemical cycles. The cycling of water and energy and nutrient exchanges among the atmosphere, ocean, and land help determine the Earth's climate and cause much of the climate’s natural variability. Natural and human-induced changes to the water and energy cycle have major impacts on industry, agriculture, and other human activities. For example, increased exposure and density of human settlements in vulnerable areas amplify the potential loss of life, property, and commodities that are at risk from intense precipitation events. Improved monitoring and prediction of the global water and energy cycle enable improved knowledge of the Earth system that must be nurtured to proactively mitigate future adversities. Current and forthcoming projections of such impacts will remain speculative unless fundamental understanding is assimilated into global prediction systems and effective decision-support tools applicable to local conditions.

The Terrestrial Hydrology Program resides exclusively within the Water and Energy Cycle Focus Area. Other programs (Radiation Sciences, Weather and Atmospheric Dynamics, and Land-Cover Land-Use Change) which contribute to this focus area are shared with other focus areas (Atmospheric Composition, Weather, and Carbon Cycle and Ecosystems, respectively). In brief, the Water and Energy Cycle Focus Area seeks to address the topics discussed above by enhancing our understanding of the transfer and storage of water and energy in the Earth system. For the water cycle, the Focus Area’s emphasis is on atmospheric and terrestrial stores, including seasonal snow cover. Permanent snow and ice, as well as ocean dynamics, are studied within the
Climate Variability and Change Focus Area. The Water and Energy Cycle Focus Area aims to resolve all fluxes of water and the corresponding energy fluxes involved with water changing phase. In addition to the study of the individual components of the water and energy cycle, this Focus Area places a high priority on integrating these components in a coherent fashion as is pursued by the NASA Energy and Water Cycle Study (NEWS), for which more information can be found at https://wec.gsfc.nasa.gov. NEWS has been established to create a mechanism to export and import information, results, and technology to and from other U.S. agencies and international partners concerned with the study and observation of water and energy cycles, such as the Global Energy and Water Cycle Exchanges project (GEWEX; http://www.gewex.org/).

All of the Focus Area’s activities should enhance the community’s ability to answer these research questions:

- How are global precipitation, evaporation, and the cycling of water changing?
- What are the effects of clouds and surface hydrologic processes on Earth’s climate?
- How are variations in local weather, precipitation, and water resources related to global climate variation?
- What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?
- How can weather forecast duration and reliability be improved?
- How can prediction of climate variability and change be improved?
- How will water cycle dynamics change in the future?

Pursuit of answers to these questions should lead to research products, such as satellite data and model outputs, that are useful to activities sponsored by the Applied Sciences Program, in particular, the Applications areas of water resources, disasters, and ecological forecasting (see Section 3 for more details on the Applied Sciences Program). Ultimately, Water and Energy Cycle Focus Area-sponsored activities will lead to the fulfillment of its goal: "Models capable of predicting the water cycle, including floods and droughts, down to tens of kilometers resolution."

The ROSES elements most closely directed towards the Water and Energy Cycle Focus Area that are or may be soliciting for proposals in ROSES-2019 are:

- Terrestrial Hydrology (program element A.23); and
- SMAP Science Team (program element A.25).

Topics relevant to the Water and Energy Cycle Focus Area that are actively or potentially soliciting in ROSES-2019 include the following program elements:

- Carbon Monitoring System (program element A.6);
- SWOT Science Team (program element A.12);
- SWOT Calibration/Validation Field Campaign (program element A.13);
- Atmospheric Dynamics (program element A.26);
- GRACE-FO Science Team (program element A.28);
- Rapid Response and Novel Research in Earth Science (program element A.29);
- Airborne Instrument Technology Transition (program element A.30);
• Interdisciplinary Research in Earth Science (program element A.32);
• Earth Science Research from Operational Geostationary Satellite Systems (program element A.33);
• GNSS Research (program element A.37);
• High Mountain Asia Team (program element A.40);
• Advancing Collaborative Connections for Earth System Science (program element A.46);
• Instrument Incubator Program (program element A.49); and
• Topical Workshops, Symposia, and Conferences (program element E.2).

2.5 Weather

The Weather Focus Area represents the cooperation among NASA programs for Atmospheric Dynamics, Weather Forecast Improvement, and Ocean and Land Remote Sensing. It has strong ties to other Focus Areas, especially Climate Variability and Change and Water and Energy Cycle, and it has a supporting role in Carbon Cycle and Ecosystems and the Atmospheric Composition Focus Areas.

The Weather Focus Area is primarily designed to apply NASA scientific remote sensing expertise to the problem of obtaining accurate and globally distributed measurements of the atmosphere and the use of these measurements in retrievals, research, and operational weather forecast models in order to both enhance our understanding of weather systems and their role(s) in the Earth system, as well as to improve and extend U.S. and global weather prediction. This Focus Area is implemented in coordination with other U.S. agencies’ programs and it is guided by the question from the 2003 Earth Science Enterprise Strategy:

• How can weather forecast duration and reliability be improved?

NASA sponsored research continues to gain new insight into weather and extreme-weather events by the utilization of data obtained from a variety of NASA- and partner satellite platforms and hurricane field experiments. Major numerical weather prediction (NWP) centers both outside (European Centre for Medium Range Weather Forecasts (ECMWF) and in the U.S. – NOAA/National Centers for Environmental Prediction (NCEP), NASA Global Modeling and Assimilation Office (GMAO), and the U.S. Navy – have shown notable improvements from the assimilation of Atmospheric Infrared Sounder (AIRS) data into their operational forecast systems.

An extra benefit of AIRS data assimilation at NWP centers is its use in establishing readiness to assimilate data from other current and future operational instruments, as has been demonstrated for the Crosstrack Infrared Sounder (CrIS) on the Suomi National Polar-orbiting Partnership (NPP) and Joint Polar Satellite System-1 satellite launched in October 2011 and November, 2017, respectively. Recent advancement in the Nation’s operational geostationary capability, especially the Advanced Baseline Imager (ABI) and Geostationary Lightning Mapper (GLM) on the Geostationary Operational Environmental Satellite (GOES) – R series are of interest to the Weather Focus Area. Currently NASA is prioritizing on assimilating all-sky radiance into GEOS-5 to take advantage of the GPM data.
The study and analysis of the dynamics of the atmosphere and its interaction with the oceans and land is also an important component of the Weather Focus Area. Improvement of our knowledge of weather processes and related phenomena is crucial in gaining a better understanding of the Earth system. Applying NASA Scientific remote sensing data such as from the Global Precipitation Measurement (GPM) mission, GOES, ATMS, SMAP, and CYGNSS could lead to improved retrieval algorithms, increased knowledge of atmospheric dynamical processes, and assimilation of these measurements into NASA’s research investigations, cloud and climate models, and quasi-operational weather models should improve global weather prediction, climate change studies, and information on the interactions within the Earth System.

Two major investments in the Weather Forcus Area form the integrator and transition centers of research results in this area. Through collaborations in the Joint Center for Satellite Data Assimilation (JCSDA) (https://www.star.nesdis.noaa.gov/jcsda/), observations from Suomi-NPP were assimilated into the operational weather forecast systems in a record seven months after the satellite launch. Observation impact analyses conducted with NASA Goddard Earth Observing System model, version 5 (GEOS-5) in the NASA Global Modeling and Assimilation Office, showed that, in concert with other observations, the Advanced Technology Microwave Sounder (ATMS) and CrIS have made positive impacts on a global integrated forecast metric.

On the short time scale, the NASA Short-term Prediction Research and Transition (SPoRT) (http://weather.msfc.nasa.gov/sport/) program is an end-to-end research-to-operations (R2O) activity focused on improving weather forecasts through the use of unique high-resolution, multispectral observations from NASA and NOAA satellites, nowcasting tools, and advanced modeling and data assimilation techniques. The SPoRT program has established a successful R2O paradigm in which the end-users (mainly forecasters at NOAA/NWS forecast offices and National Centers) are involved in the entire process. SPoRT also partners with universities and other Government agencies to develop new products that are transitioned to applicable end user decision support systems. SPoRT has recently succeeded in broadening its activities to other National Weather Service (NWS) Regions and its active participation in NOAA Proving Ground activities and Testbeds.

The ROSES element most closely directed towards the Weather Focus Area that are or may be soliciting for proposals in ROSES-2019 are:

- Weather and Atmospheric Dynamics (program element A.26); and

Topics relevant to the Weather Focus Area that are actively or potentially soliciting in ROSES-2019 include the following program elements:

- Carbon Monitoring System (program element A.6);
- Atmospheric Composition: Aura Science Team (program element A.22);
- SMAP Science Team (program element A.25);
- Rapid Response and Novel Research in Earth Science (program element A.29);
- Interdisciplinary Research in Earth Science (program element A.32);
- Earth Science Research from Operational Geostationary Satellite Systems (program element A.33).
- High Mountain Asia Team (program element A.40);
• Advancing Collaborative Connections for Earth System Science (program element A.46);
• Instrument Incubator Program (program element A.49); and
• Topical Workshops, Symposia, and Conferences (program element E.2).

2.6 Earth Surface and Interior

The Earth Surface and Interior Focus Area promotes the development and application of remote sensing to better understand core, mantle, and lithospheric structure and dynamics, and interactions between these processes and Earth's fluid envelopes. ESI studies provide the basic understanding and data products needed to inform the assessment, mitigation, and forecasting of natural hazards, including phenomena such as earthquakes, tsunamis, landslides, and volcanic eruptions. These investigations also exploit the time-variable signals associated with other natural and anthropogenic perturbations to the Earth system, including those associated with the production and management of natural resources. Space-based remote sensing is vital to forecasting in the solid Earth sciences, providing a truly comprehensive perspective for monitoring the entire solid Earth system. ESI seeks to address the questions:

1. What is the nature of deformation associated with plate boundaries and what are the implications for earthquakes, tsunamis, and other related natural hazards?
2. How do tectonic processes and climate variability interact to shape Earth’s surface and create natural hazards?
3. How does the solid Earth respond to climate-driven exchange of water among Earth systems and what are the implications for sea-level change?
4. How do magmatic systems evolve, under what conditions do volcanoes erupt, and how do eruptions and volcano hazards develop?
5. What are the dynamics of Earth’s deep interior and how does Earth’s surface respond?
6. What are the dynamics of Earth’s magnetic field and its interactions with the rest of Earth’s systems?
7. How do human activities impact and interact with Earth’s surface and interior?

ESI’s Space Geodesy Program (SGP) produces observations that refine our knowledge of Earth’s shape, rotation, orientation, and gravity, advancing our understanding of the motion and rotation of tectonic plates, elastic properties of the crust and mantle, mantle-core interactions, solid Earth tides, and the effects of surface loading resulting from surface water, ground water, glaciers, and ice sheets. SGP infrastructure enables the establishment and maintenance of a precise terrestrial reference frame that is foundational to many Earth missions and location-based observations.

Modeling, calibration, and validation are essential components in advancing the above solid-Earth science objectives. ESI views natural laboratories as a critical component for the validation and verification of remote sensing algorithms. For example, NASA joins with the National Science Foundation (NSF) in support of the Geodetic Facility for the Advancement of Geoscience (GAGE) initiative to maintain and operate a set of foundational geodetic capabilities that are essential for current research efforts to measure Earth changes with unprecedented spatial and temporal resolution, enabling advances in our understanding of tectonic processes; earthquakes and tsunami;
magmatic processes; landslide hazards; continental water storage; atmospheric, ice sheet and glacier dynamics; and interactions among these components of the Earth system.

Among the many activities carried out by ESI are the following:

- Geodetic and thermal imaging of the precise metrology of Earth’s surface and its changes through GNSS, lidar, radar constellations, and optical arrays, coupled with geopotential field measurements to understand the dynamics of the Earth’s surface and interior;
- Development of a stable terrestrial reference frame, highly precise realization of topography and topographic change, and understanding of changes in the Earth’s angular momentum and gravity fields, which can be applied to issues such as sea-level change, polar mass balance, and land subsidence;
- Use of gravitational and magnetic observables for studying the inner dynamics of the Earth, as well as for studies of how the ionosphere responds to changes in the Earth’s surface; and
- Improved forecasts and early warnings for earthquakes, tsunamis, landslides, and volcanic eruptions through the use of a broad range of Earth surface remote sensing and space geodesy approaches.

The ROSES element most closely directed towards the Earth Surface and Interior Focus Area that are or may be soliciting for proposals in ROSES-2019 is:

- Earth Surface and Interior (program element A.27).

Topics relevant to the Earth Surface and Interior Focus Area that are actively or potentially soliciting in ROSES-2019 include the following program elements:

- Carbon Monitoring System (program element A.6);
- Sea Level Change Science Team (program element A.11);
- Atmospheric Composition: Aura Science Team (program element A.22);
- SMAP Science Team (program element A.25);
- GRACE-FO Science Team (program element A.28);
- Rapid Response and Novel Research in Earth Science (program element A.29);
- Airborne Instrument Technology Transition (program element A.30);
- Interdisciplinary Research in Earth Science (program element A.32);
- Earth Science Research from Operational Geostationary Satellite Systems (program element A.33);
- GNSS Research (program element A.37);
- High Mountain Asia Team (program element A.40);
- Advancing Collaborative Connetions for Earth System Science (program element A.46);
- Instrument Incubator Program (program element A.49); and
- Topical Workshops, Symposia, and Conferences (program element E.2).
2.7 Cross-Cutting and Interdisciplinary

There are several cross-cutting and interdisciplinary elements in ROSES-2019, all of which have been identified as related elements to specific research focus areas in Sections 2.1 through 2.6 (and also briefly summarized in the overview to Section 2). These elements, all of which are being actively solicited in ROSES-2019 or are being evaluated for possible solicitation, are:

- **GRACE FO Science Team (program element A.28)** - This ROSES element seeks proposals that will advance the development of new methods, algorithms, and models for the exploitation of gravity field observations to be made by GRACE, GRACE-Follow on (FO), and future space based gravity field missions for the broad spectrum of Earth system science challenges. This solicitation also seeks the development of techniques and algorithms capable of bridging gravity field observation across different gravity missions.

- **Rapid Response and Novel Research in Earth Science (program element A.29)** – This program element allows for two types of proposals not normally solicited through ROSES – (a) immediate research activity to take advantage of a target of opportunity due to an unforeseen event in the Earth system, and (b) exceptionally novel and innovative ideas to advance Earth remote sensing that do not fit within ESD’s current slate of solicitations and or programs;

- **Airborne Instrument Technology Transition (program element A.30)** – This announcement seeks to upgrade mature instruments developed under NASA’s Instrument Incubator Program (IIP – see Appendix A.49 for details on this program), or by similar NASA or externally-supported (e.g., corporate, other federal agency, internal institution funding) programs or activities. This opportunity provides for engineering activities leading to the integration of instruments to airborne platforms that will deploy them as part of organized airborne science campaigns that typically involve multiple instruments and/or platforms. The goal is to upgrade existing operating instruments to campaign-ready airborne configuration(s). Management of the tasks selected in response to these Airborne Instrument Technology Transition calls is carried out in conjunction with the Earth Science Technology Office (ESTO).

- **Interdisciplinary Research in Earth Science (program element A.32)** - This solicitation is for new and successor interdisciplinary research investigations within NASA’s Interdisciplinary Research in Earth Science (IDS) program. Proposed research investigations will meet the following criteria: a) offer a fundamental advance to our understanding of the Earth system; b) be based on remote sensing data, especially satellite observations, but including suborbital sensors as appropriate; c) go beyond correlation of data sets and seek to understand the underlying causality of change through determination of the specific physical, chemical, and/or biological processes involved; d) be truly interdisciplinary in scope by involving traditionally disparate disciplines of the Earth sciences; and e) address at least one of the specific themes listed in any particular IDS solicitation.

- **Earth Science Research from Operational Geostationary Satellite Systems (program element A.33)** – This announcement is to provide an opportunity for the earth science research community to develop additional products from the new
generation of operational geostationary satellites (e.g., Japan’s Himawari, NOAA’s Global Operational Environmental Satellites, ...) beyond those produced by the operational agencies that implement them. These products could be for earth system parameters not produced by those agencies, or could use algorithms different from those currently used. The element also allows for the use of currently produced and/or future operational geostationary satellite data to address research questions till now addressed only with low earth orbit (LEO) satellites.

- **GNSS Research (program element A.37)** – This announcement seeks innovative approaches to the development of GNSS remote sensing techniques and algorithms to advance NASA’s Earth Science program as described in Appendix A.1; the National Academy of Sciences, Engineering, and Medicine Decadal Survey, *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space* (2018) ([https://www.nap.edu/catalog/24938](https://www.nap.edu/catalog/24938)), and NASA’s *Challenges and Opportunities for Research in ESI (CORE) Report* (2016) ([http://go.nasa.gov/2hmZLQO](http://go.nasa.gov/2hmZLQO)). Proposals that develop new processing and analysis approaches; improve positioning, navigation, and timing (PNT) using GNSS and Regional Navigation Satellite Systems (RNSS) signals; and develop truly multi-GNSS capabilities are encouraged. Potential areas of consideration include, but are not limited to, rapid characterization of transient processes, probing of ionospheric structure, improvements to the international terrestrial reference frame, leveraging Signals of Opportunity (SoOp), GNSS reflectometry for recovery of Earth surface or atmospheric characteristics, and GNSS radio occultation for recovery of atmospheric structure.

- **PACE Science and Applications Team (program element A.38)** – This announcement solicits for the next phase of a science team for the planned Plankton, Aerosol, Cloud, Ocean Ecosystem (PACE) mission, which is to include an ocean color sensor and one or more aerosol/cloud polarimeters, in order to produce data to maintain a time series of critical climate and Earth system variables;

- **High Mountain Asia Team (program element A.40)** - This solicitation funds investigations into High Mountain Asia’s (HMA’s) glaciers, snow, permafrost, and precipitation to improve our understanding of regional changes, water resources, and induced impacts, while furthering NASA’s strategic goals in Earth system science and societal applications. Through expanded knowledge of the processes controlling change in HMA, the program intends to improve regional forecasts and address vulnerabilities in human and biogeoophysical systems.

### 3. Applied Sciences

The Applied Sciences Program supports efforts to discover and demonstrate innovative and practical uses of NASA Earth science data, knowledge, and technology. The program ([http://AppliedSciences.NASA.gov/](http://AppliedSciences.NASA.gov/)) develops applications knowledge and understanding of how Earth science can be applied to serve society, increasing the benefits of the nation’s investments in NASA Earth science. The Program funds applied science research and applications projects to enable near-term uses of Earth science, transition applied knowledge to public and private organizations, and integrate Earth
science and satellite observations as inputs to organizations’ decision-making and services. The projects are carried out in partnership with end user organizations. The Program, thus, serves as a bridge between the data and knowledge generated by NASA Earth science and the information needs and decision making of Government agencies, companies, regional associations, international organizations, not-for-profit organizations, and others.

The Program’s applications themes align with the U.S. Group on Earth Observations (USGEO) Societal Benefit Areas, with current emphasis on Water Resources, Health and Air Quality, Disasters, and Ecological Forecasting. Applied Sciences projects leverage products, knowledge, and outcomes of Research and Analysis activities described in Section 2.

There are no ROSES elements primarily focused towards Applied Sciences that are or may be soliciting for proposals in ROSES-2019. Topics relevant to the Applied Sciences Program that are actively or potentially soliciting in ROSES-2019 include the following program elements:

- Carbon Monitoring System (program element A.6);
- GEDI Science Team (program element A.8);
- Sea Level Change Team (program element A.11);
- SWOT Science Team (program element A.12);
- Atmospheric Composition: Aura Science Team (program element A.22);
- SMAP Science Team (program element A.25);
- GRACE-FO Science Team (program element A.28);
- Rapid Response and Novel Research in Earth Science (program element A.29);
- Airborne Instrument Technology Transition (program element A.30);
- Earth Science Research from Operational Geostationary Satellite Systems (program element A.33);
- GNSS Research (program element A.37);
- PACE Science and Applications Team (program element A.38);
- High Mountain Asia (program element A.40);
- Advancing Collaborative Connections for Earth System Science (program element A.46);
- Instrument Incubator Program (program element A.49); and
- Topical Workshops, Symposia, and Conferences (program element E.2).

4. Technology

Advanced technology plays a major role in enabling Earth research and applications. The Earth Science Technology Program (ESTP) enables previously infeasible science investigations, improves existing measurement capabilities, and reduces the cost, risk, and/or development times for Earth science instruments.

As the implementer of the ESTP, the Earth Science Technology Office (ESTO) performs strategic technology planning and manages the development of a range of advanced technologies to enable new science observations or reduce the cost of current observations. ESTO employs an open, flexible, science-driven strategy that relies on
competitive solicitations and peer-review to produce a portfolio of cutting-edge technologies for NASA Earth science endeavors. This is done through:

- Planning investments by careful analyses of science requirements
- Selecting and funding technologies through competitive solicitations and partnership opportunities
- Actively managing the progress of funded projects
- Facilitating the infusion of mature technologies into science measurements

Needs for advanced technology development are based on Earth science measurement and system requirements articulated in chapter 4 of the *Science Plan for NASA’s Science Mission Directorate* and the most recent Decadal Survey covering NASA’s Earth science activities, *Thriving on our Changing Planet: A Decadal Strategy for Earth Observation from Space*, which was released on 1/5/2018 by the National Academies of Science, Engineering, and Medicine (see [https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth](https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth)). This 2017 Decadal Survey now serves as a foundational document for NASA’s Earth Science Division (ESD), and includes recommendations for the scopes, foci, and relative budgetary magnitudes of the R&A, Applications, and Technology portions of the ESD program.

The Earth Science Technology Office ([http://esto.nasa.gov](http://esto.nasa.gov)) maintains several program lines through which technology investments are regularly competed through ROSES, and that cover a range of technology readiness levels (TRLs). Currently, the Instrument Incubator Program will be solicited in ROSES-2019:

- Instrument Incubator Program (program element A.49): The Instrument Incubator Program (IIP) funds technology development that leads directly to new Earth observing instruments, sensors, and systems. From concept through field demonstrations and infusion, IIP developments yield smaller, less resource intensive, and easier-to-build flight instruments.

Other ESTO programs that are periodically solicited are NOT being solicited in ROSES-2019:

- AIST (program element A.48): The Advanced Information Systems Technology program advances information systems that are used to process, archive, access, visualize, and communicate science data. The Instrument Incubator Program funds technology development that leads directly to new Earth observing instruments, sensors, and systems. From concept through field demonstrations and infusion, IIP developments yield smaller, less resource intensive, and easier-to-build flight instruments;
- ACT (program element A.50): The Advanced Component Technology program develops a broad array of components and subsystems for instruments and observing systems;
- InVEST (program element A.51): The In-Space Validation of Earth Science Technologies program provides a path for some new technologies to be validated in space prior to use in science mission; and
- SLIT (program element A.52): The Sustainable Land Imaging Technology
Program - The Sustainable Land Imaging Technology program develops
technologies leading to new SLI instruments, sensors, systems, components,
data systems, measurement concepts, and architectures in support of the
nation’s future SLI activities.

5. Enabling Capability

Enabling capabilities include those programmatic elements that are of sufficient breadth
that they contribute to a broad range of activities within the Earth Science Research
Program. They typically involve the development of some kind of capability whose
sustained availability is considered to be important for the Earth Science Research
Program’s future. These include focused activities in support of education; data,
information, and management; and airborne science, as well as some broadly-based
technology-related elements (others which are very focused towards a single scientific
area of the Earth Science Research Program will be solicited through the research and
analysis area).

5.1 Education

The Earth Science Research Program recognizes its essential role in NASA’s mission
to inspire the scientists and engineers of tomorrow. The Earth system science concept
pioneered by NASA is changing not only how science research is conducted, but also
the way Earth and space science education is taught at elementary through
postgraduate levels, as well as the way space exploration is presented to the public by
the media and informal learning communities.

In 2015, SMD announced selections from the Science Education Cooperative
Agreement Notice. These organizations (https://science.nasa.gov/science-activation-
team) are collaborating with SMD in the execution of its science education efforts. The
desired outcome is to increase the overall coherence of the SMD science education
program leading to more effective, sustainable, and efficient utilization of SMD science
discoveries and learning experiences to meet overall SMD science education
objectives. Fundamental to achieving this outcome is to enable NASA scientists and
engineers to engage more effectively with learners of all ages. In addition, SMD is
moving away from mission-by-mission products and services and towards aggregating
efforts into science-based disciplines aligned with SMD Divisions.

The Earth Science Research Program will continue its management of the Global
Learning and Observations to Benefit the Environment (GLOBE) Program
(https://www.globe.gov/) and oversight of the GLOBE Implementation Office that is
responsible for the coordination of the worldwide community in relation to GLOBE
science, education, evaluation, communication, and other common functions. It will also
continue to oversee the GLOBE Data and Information System. ESD welcomes
proposals that incorporate the use of GLOBE observations, where appropriate.
Observations can be accessed via the GLOBE Visualization System
(https://vis.globe.gov/GLOBE/) and the GLOBE Advanced Data Access Tool
(ADAT; https://datasearch.globe.gov/).
5.2 Graduate and Early-Career Research

The NASA Earth Science Division recognizes the importance of workforce enrichment. To this end, the Earth Science Division sponsors the Earth component of the Future Investigators in NASA Earth and Space Science and Technology (FINESST) program, which replaces the NASA Earth and Space Science Fellowship (NESSF) program. FINESST supports graduate student-designed research projects that contribute to SMD’s science, technology, and exploration goals. Previous awardees of NESSF will be able to submit renewal proposals to a NESSF renewal solicitation for the 2019/2020 and 2020/2021 school years for a maximum of three years of total support (see NESSF19R for the 2019/2020 school year). FINESST and NESSF are currently solicited outside of ROSES with applications typically due each year in February for new awards and March for renewals. For 2019 the due dates are March 11 and March 15, respectively.

The New (Early Career) Investigator Program in Earth Science (program element A.34), which is directed towards scientists and/or engineers within six years of their receipt of a Ph.D. degree, is solicited every three years. It is not being solicited in ROSES 2019.

5.3 Data and Information Management

NASA’s space observation capabilities are a central part of the Agency’s contribution to Earth system science, along with the science information systems that compile and organize observations and related data for research purposes. The Earth Science Research Program has established a number of strategic principles for the development and deployment of its observing and information systems, recognizing the importance of providing active and informed stewardship for the large volumes of data that are returned to Earth every day. The broad range of uses to which the data are put and the large and diverse user community require multiple temporal and spatial scales, emphasize the need for having a range of data products, and place stringent requirements on NASA for its data processing, archival, and data dissemination activities. These products and services will be variously useful to multiple classes of users, from sophisticated scientific users to other Government and private sector entities that use NASA’s information for policy and resource management decisions and including scientifically attentive members of the public who utilize data and information for general information and recreation.

Two program elements related to Data and Information Management have been solicited periodically by the Earth Science Division in recent years – The Advancing Collaborative Connections for Earth System Science (ACCESS, program element A.46), the Making Earth System Data Records for Use in Research Environments (MEaSUREs, most recently solicited in ROSES 2017 as program element A.43), and the Citizen Science for Earth Science Program (program element A.47). The only one of these solicited in ROSES 2019 is ACCESS (program element A.46).

Unless otherwise specified, any data proposed to be analyzed in response to Appendix A program elements from any source, including NASA and other satellite data, ancillary data, and data from commercial sources, must use publicly available data, in the sense that they are openly accessible. Commercial data need not be free, but it must be purchasable by all potential investigators. Proposals that utilize any data that is not, or
not yet, publicly available will not be considered unless permitted by the call for proposals or associated Frequently Asked Questions. Please read the individual appendices and associated amendments to ROSES carefully and contact the program officers if you have any questions regarding whether a restricted dataset is permissible for a given call.

Data, model results and other information created is subject to NASA’s Earth Science Data policy (see [http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/](http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/) for the policy). All data will be released along with the source code for algorithm software, coefficients, and ancillary data used to generate products.

5.4 High-End Computing, Networking, and Storage

High-end computing, networking, and storage are critical enabling capabilities for Earth system science. Satellite observations must be converted into scientific data products through retrieval and/or data assimilation processes. Long-term data sets must be synthesized together and become a physically consistent climate-research quality data set through reanalysis. These data products, in turn, provide initial and boundary conditions, validation and verification references, and internal and external constraints to the models that describe the behavior of the Earth system. None of the above will be possible without advanced techniques in high-end computing, networking, and storage.

SMD recognizes the need of such an enabling capability and maintains the high-end computing, networking, and storage within its programs. Computing resources are provided through various program elements. Over the past several years, computational resources have become significantly constrained. Starting in ROSES-2016, SMD began implementing a more rigorous resource allocation process. Proposals should include up to a one-page justification (not counted against the technical proposal page limit) for the computational resource requirement and this will be used during the proposal evaluation and selection processes. This justification should include how the computational resources may support the investigation and a multiyear resource-phasing plan, in annual increments, identifying the computing system and facility location where the computational project will be accomplished for the duration of the proposed award period. Proposers to this NRA must follow the instructions in Section I(d) of the Summary of Solicitation of this NRA to request computing resources, including explicit descriptions of computing resource needs.

NASA also supports computational science research and development, including parallelization of codes to an advanced computing architecture for the advancement of Earth system modeling and data assimilation.

In ROSES-2019, no program elements specifically targeted towards High End Computing, Networking, and Storage will be solicited.

5.5 NASA Earth Exchange

For large-scale global high-resolution Earth science data analysis and modeling projects, especially in areas of land surface hydrology, land cover, land use, carbon management, and terrestrial ecosystems, NASA encourages using the new NASA Earth Exchange (NEX) collaboration facility. The NEX facility includes a state-of-the-art Earth system modeling and data analytics system for the use of remote sensing data from
NASA and other agencies. It is supported by a world-class supercomputing and data storage system. Much of the global Landsat, MODIS, AVHRR and related data have been staged online for easy access. NEX (http://nex.nasa.gov) represents a scientific collaboration platform to deliver a complete work environment, in which users can explore and analyze large Earth science data sets, run modeling codes, collaborate on new or existing projects, and share results.

Since it is a unique platform for large-scale data analyses that cannot be easily accommodated by a single Principal Investigator (PI) or small research group-based data analysis system, PIs who require the use of such a system are encouraged to register on the NEX Website at https://nex.nasa.gov/nex/auth/register/. Proposals should include a section that justifies the need for using NEX, specifies the data storage and processing needs, and includes a data management plan as described above in Section 1. The resource availability will be considered during the proposal review and selection process.

Proposals that involve the use of NEX must be submitted to the appropriate ROSES program element depending on the science addressed by the proposed investigation. Additional constraints and requirements for proposals to use NEX are available at https://nex.nasa.gov/nex/resource_updates.

In ROSES-2019, no program elements directed towards the enhancement of NEX are being solicited.

5.6 Airborne Science

The Earth Science Research Program airborne science program provides access to airborne platforms that can be used to obtain measurements of the Earth. Airborne platforms may be used to test new measurement approaches, collect detailed in situ and remote sensing observations that are needed to better document and test models of Earth system processes, and/or provide calibration/validation information for satellites. Airborne platforms can also be an important part of training the next generation of scientists, because students can be engaged in all aspects of scientific investigations, from sensor development, through utilization, to completing analysis of data obtained.

Aircraft have proven to be of significant value in Earth system science research, particularly for investigation into atmospheric processes. NASA makes use of several existing aircraft, including the NASA-owned DC-8, G-III, GV, ER-2, and P-3B, as well as several independently owned aircraft, including, but not limited to, those operated by other Federal agencies and commercial aircraft providers. Proposers that utilize commercial aircraft service providers must ensure real time position tracking of the aircraft and provide flight reports after the completion of flights. Information regarding the utilization and reporting requirements of airborne assets to support proposals can be found at https://airbornescience.nasa.gov/.

Proposals that require the acquisition of new airborne data may be submitted in response to other active ROSES elements, unless otherwise specified in the element. In any such cases, proposers are encouraged to contact the program manager indicated prior to submitting such proposals.
The NASA Headquarters science concurrence is provided by the manager of the NASA Research Program under which the grant or contract is issued. User fees are paid by the investigator's funding source's research program or directly from the investigator's grant funds.

Any airborne science experiment using NASA assets, personnel, instruments, or funds, must be in compliance with NASA Policy Directive 7900 and NASA Procedural Requirement Series 7900. It is NASA policy that when utilizing other than NASA aircraft, including foreign owned or leased aircraft, those aircraft are subject to the same compliance requirements.