A.11 SEA LEVEL CHANGE SCIENCE TEAM

NOTICE: Amended May 30, 2019. This amendment releases the final text for this program element. Notices of intent to propose are requested by September 26, 2019, and the due date for proposals is October 31, 2019.

1. Introduction

Rising seas are one of the most disruptive consequences of climate change, impacting highly-populated coastal communities through an increased occurrence and intensity of flooding events, storm surges, coastal erosion, salt-water intrusion, losses of biodiversity and freshwater resources.[1] Understanding the physical processes behind these changes is key to predicting the potential impact of rising seas and extreme events on coastal communities, the national and global economy, and is recognized as one of the Grand Challenges of our time by the World Climate Research Programme (WCRP).

To address this challenge, NASA has assembled a multi-disciplinary Sea Level Change Science Team (N-SLCT) consisting of leading experts in the fields of oceanography, geodesy, cryosphere, hydrology, modeling, statistics, and science communication.[2] Multiple NASA science programs have contributed to various aspects of this research including programs in Physical Oceanography, Cryospheric Sciences, Interdisciplinary Sciences, Earth Surface and Interior, and Earth Science Data and Information System (ESDIS). Since 2014, the N-SLCT has been conducting interdisciplinary sea level science by collecting and analyzing observational evidence of sea level change, quantifying the underlying causes and driving mechanisms, producing projections of future changes in sea level, as well as communicating NASA's latest discoveries to the public through NASA's Sea Level Portal at https://sealevel.nasa.gov. As a result, progress has been made on a number of important problems in sea level science, resulting in a better understanding of ice sheet dynamics, the development of tools and assessments of the impacts of mass loss from ice sheets and glaciers on coastal cities, and improved representation of vertical land motion related to coastal subsidence, tectonics, and Earth's post-glacial rebound.

Building on the progress of the previous N-SLCT, NASA is soliciting proposals to continue the work of the Team in order to address remaining open questions as outlined below.

2. Scope of Program

The program is intended to integrate research results, data sets, and model outputs to improve the accuracy of sea level estimates and its components, to integrate results into better forecasts of sea level rise, and to communicate the results of NASA's sea level research in a simplified manner to the science community and the public.

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[1] USGCRP (2018), Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II, *U.S. Global Change Research Program*, Washington, DC, 1515, doi:10.7930/NCA4.2018.

[2] See previous NASA solicitations ROSES-2013 (A.15) and ROSES-2016 (A.10) for details, including abstracts of selected proposals.

To achieve these goals, the specific objectives that appear in the following subsections have been identified for proposers.

2.1 Provide observational evidence of sea level change with improved accuracy

Satellite radar altimetry from TOPEX/Poseidon, Jason-1, 2, and 3 and *in situ* tide-gauge records offer important observations that allow measurement of sea level change directly and characterization of its spatial and temporal variability. Gravitational measurements have been used to measure mass change in the ice sheets and oceans, and mass movement within the solid Earth. Laser altimetry, Interferometric-Synthetic Aperture Radar (InSAR), the Global Navigation Satellite System (GNSS), including Global Positioning System (GPS) have been used to characterize dynamic aspects of ice loss and monitor vertical land motion due to natural and anthropogenic processes. New observations from recently launched NASA missions such as the Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) and Gravity Recovery and Climate Experiment Follow-On (GRACE-FO), and from future missions such as the Sentinel-6 (Jason-CS), the NASA-ISRO SAR (NISAR) mission and the Surface Water and Ocean Topography (SWOT) mission will add to the existing methods for detecting sea level change and the physical processes driving the change.

Continued efforts to provide updated datasets of best estimates of sea level and its components are critical to assess sea level change from a variety of independent measurements and missions. Furthermore, advances in monitoring and predicting sea level rise rely upon our ability to resolve small, sub-mm signals in the data, such as secular trends and acceleration. These measurements depend on a precise terrestrial reference frame, to which NASA's space geodesy network data and analyses contribute. This program element seeks to provide updated estimates of relative (with respect to the land) sea level change on regional and global scales with improved accuracy and resolution. Synergistic use of NASA observations, data products, and/or NASA's ocean-ice state estimates (e.g., ECCO – Estimating the Circulation and Climate of the Oceans) is encouraged.

2.2 Quantify contribution of underlying physical mechanisms of sea level variability

Although the main drivers of sea level change are generally known, the specific details of interaction between the components are still poorly constrained. Improving our understanding of regional sea level fluctuations requires consideration of changes in the ocean, cryosphere, solid Earth, and terrestrial storage of water, as well as characterizing the forcing, response, and feedback mechanisms within the ocean-land-atmosphere system. Examples of areas where new N-SLCT investigations can build on or improve previous advances are given below.

Earth System Feedbacks: A fair amount of progress has been made by previous N-SLCT efforts to improve our knowledge of the mass of glaciers and ice sheets of Greenland and Antarctica (see at https://sealevel.nasa.gov for the latest N-SLCT discoveries). The results indicate that ice surface mass balance, ice-ocean, and ice-solid Earth interactions are important factors controlling sea level rise, and thus warrant further attention by the Team. To continue to advance our understanding in this area, NASA welcomes investigations of the impact of land ice melt on sea level patterns that goes beyond gravitational effects (fingerprints), which are relatively well-understood by

the Team's previous efforts. For example, this program element seeks proposals that consider dynamical ocean-ice coupling and quantify the ocean's response and feedbacks across the range of scales – from rapid, barotropic adjustments over a few days to longer baroclinic responses occurring over decades driven by various wave dynamics, changes in ocean density and circulation. Similarly, while regional feedbacks associated with glacial isostatic adjustment (GIA) on timescales of millennia are sufficiently understood, proposals addressing new feedbacks between ice melt and solid-Earth processes, such as those that include shorter spatial and temporal scales of kilometers and centuries, respectively, are welcomed.

Hydrological Cycle and Terrestrial Water Storage: The ongoing changes in the hydrological cycle, including changes in river runoff, changes in the amount of water stored in the ground or its surface, and general amplification of atmospheric moisture transport, further contribute to sea level changes at regional and global scales. With this program element, NASA aims to expand N-SLCT investigations of the impacts of hydrological cycle and terrestrial water storage on sea level change. Anticipating the launch of the SWOT mission in 2021, exploration of hydrological observations for sea level research is of interest to NASA. In particular, NASA encourages regional case studies (e.g., along the US East coast and other urban coastlines) that couple regional hydrologic, oceanographic, cryospheric, and geodynamic processes that affect sea level dynamics and associated coastal inundation processes.

Solid Earth Dynamics: NASA continues to support studies that improve representation of vertical land motion related to solid-Earth dynamics, including isostacy, tectonics, local land subsidence; and other processes affecting the height of the existing solid surface that cause submergence (or emergence) of land, alteration of the coastlines, and additional variations in relative sea level. Self-consistent models that include the full range of solid-Earth processes contributing to sea level variation, from GIA, to rotational dynamics, to other processes driving vertical land motion, are critical to the objectives of this Team. This program element seeks proposals that improve the description of the vertical motion of land surfaces due to various local-to-global processes, and quantify the impact of solid-Earth dynamics in shaping patterns of regional and local relative sea level.

2.3 Develop projections of global and regional relative sea level change on various time horizons

Projections of future sea level rise suggest dramatic implications for coastal communities, with even a relatively small rise potentially displacing millions of people and threatening America's trillion-dollar coastal property market and public infrastructure.[1] Observations from satellite altimetry and tide gauges show that the current projections are approaching the upper end of the model projections of sea level for the highest representative carbon dioxide concentration pathways in the IPCC Fifth Assessment Report, increasing the need for updated estimates of future sea level rise.

NASA is charging the N-SLCT to develop improved sea level projections on global and regional levels. Driven by societal and economic demand, there is a strong need to develop projections on multiple time horizons, associated with various modes of climate variability ranging from seasonal and interannual to sustained sea level changes over

decades to centuries. Given NASA's overall mission and strategic goals, this program element encourages investigators to produce observation-based and physics-based projections with uncertainties informed by our best knowledge of the system and the outcomes from new research conducted in response to Objectives 2.1 and 2.2. Production of a common set of projections as well as individual estimates from different groups is expected. The Team is encouraged to analyze differences among various Team-generated projections to provide insight into the uncertainties and sensitivities of various approaches.

Unified, science-based estimates of future sea level rise (with uncertainty estimates) produced by the Team are meant to serve as a contribution to various assessment frameworks, such as the U.S. Global Change Research Program (USGCRP) National Climate Assessment (NCA) studies, as well as international IPCC assessment and special reports related to sea level science. Projections produced with regional resolution can also serve as guides for the development of public policy and investments in regional adaptation. These projections must provide probabilistic estimates of accuracy so as to properly present this information to the public and decision-makers.

2.4 Synthesis of disciplinary results enabling a team product

An overarching goal of the Team is to break the barriers between sea level scientists from different disciplines in order to address this multi-faced problem. Therefore, an important element of this program element is the production of a common product by the Team informed by the most recent knowledge from various disciplines. An example of a common product could be the development of regional sea level projection on range of timescales – a unifying target that was identified by the previous N-SLCT members. As a multi-disciplinary team of experts, the Team is also positioned and expected to make a significant contribution to international (e.g., WCRP) and national (e.g., US CLVIAR) sea level activities by providing an integrated view of the current observing system, data, and tools that will inform the decadal surveys of the future.

NASA's Sea Level Portal at https://sealevel.nasa.gov will serve as the Team's face to the public as well as a vehicle for the cross-team collaboration and integration of the results. Therefore, the role of the Portal is to provide an infrastructure that:

- promotes coordination among the Team members by creating tools to work on a common science product (e.g., sea level budget tools, regional assessments and projections, etc.);
- allows the Team to share knowledge and recent results;
- helps untangle complex physics of sea level science for the public by translating the Team's discoveries into accessible, actionable results and aligning them with specific decision-making contexts;
- reuses the existing portal system at the current web location

The web Portal team selected through this announcement is expected to work closely with the Earth Science Data and Information Systems (ESDIS) Project, which operates

and maintains the sea level Portal, and will provide support in integrating new portal capabilities into the existing system following NASA's integration policies[3].

3. Team Structure and Evaluation

3.1 Team Structure

As with the previous N-SLCT, the Team is intended to consist of four to six interdisciplinary research teams and a web portal science coordination team. The announcement also serves to continue the work of the Team initiated in 2014 and continued in 2017 onward. It is envisioned that the N-SLCT will build on the achievements and groundwork laid by the previous Team members, under the guidance of a Team Leader who is expected to ensure continuity of the ongoing activities, foster integration of results, and oversee the production of a common science product. NASA will appoint a Team Leader among the investigators outside of this solicitation process, and thus is not soliciting Team Leaders here.

3.2 Evaluation

The three primary evaluation criteria (Merit, Relevance, and Cost) are presented and defined in Appendix D of the *NASA Guidebook for Proposers* and some information on how they are evaluated are presented in Section VI.(a) of the *ROSES-2019 Summary of Solicitation*. In addition, to be considered responsive:

a) Proposals must include investigators from two or more of the core scientific disciplines of oceanography, geodesy, cryosphere, Earth surface and interior, and hydrology.
b) Proposals must address Objective 2.4 and include appropriate work effort, resources, and deliverables that support regular cross-team activities and synthesis of the results across the Team. As with previous N-SLCT, willingness to be a team player is essential. All members are expected to work collectively for the common success of the Team by sharing results, interacting with the broader team, and contributing to a production of a common product.
c) Work must be based on NASA's satellite observations and, if appropriate, based on NASA's sub-orbital sensors, models, and ocean state estimates.
d) Proposals must provide clear management plans that include milestones and schedule of deliverables to the web Portal that aid production of a common science product and communication of new results to the public (see data and software requirements below).

Most favorable consideration will be given to those proposals that can integrate work on the objectives and interact constructively with the web portal and across the members of the Team.

[3] https://earthdata.nasa.gov/earth-science-data-systems-program/competitive-programs/access/community-data-system-capabilities-overview

4. Data and Software Policy

Data, model results, and other information created under this announcement are subject to NASA's Earth Science Data policy.[4] Proposals to develop products and software must provide a data management plan[5] and open source software development plan,[6] identifying an open source software license and stating an open source software release milestones. Appropriate deliverables will be archived by ESDS at a NASA Distributed Active Archive Center (DAAC) in formats that can be readily used for a range of research needs. All data products must meet applicable U.S. Government-mandated standards adhering to requirements by NASA Earth Science Data Products[7]. All software along with source code for the web portal development element must be released by the grantee to the NASA Github per the NASA Open Source Software (OSS) policy and is subject to the NASA Earth Science Alternate Data Rights language to be included into award agreements. This includes all software developed with ESDS Program funding used in the production of data products, as well as software developed to discover, access, analyze, visualize, and transform NASA data. OSS is defined as software that can be accessed, used, modified, and shared by anyone. OSS is often distributed under licenses that comply with the definition of "Open Source" provided by the Open Source Initiative[8] or meet the definition of "Free Software" provided by the Free Software Foundation.[9]

5. Summary of Key Information

Expected program budget	~$2.5M/year
Number of new awards pending adequate proposals of merit	~4-6
Maximum duration of awards	4 years
Due date for Notice of Intent to propose (NOI)	See Tables 2 and 3 of this ROSES NRA
Due date for proposals	See Tables 2 and 3 of this ROSES NRA
Planning date for start of investigation	May 2020
Page limit for the central technical section of the proposal	15 pp; See also Chapter 3 of the *NASA Guidebook for Proposers*
Relevance to NASA	Proposals that are relevant to this program are, by definition, relevant to NASA
General information and overview of this solicitation	See the *ROSES Summary of Solicitation*
Detailed instructions for the preparation and submission of proposals	See the *ROSES Summary of Solicitation* and the NASA Guidebook for Proposers
Submission medium	Electronic proposal submission is required; no hard copy is required or permitted.

[4] http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/
[5] https://science.nasa.gov/researchers/sara/faqs/dmp-faq-roses
[6] https://earthdata.nasa.gov/collaborate/open-data-services-and-software/esds-open-source-policy
[7] https://earthdata.nasa.gov/about/esdis-project/eso/standards-and-references
[8] https://opensource.org/osd
[9] https://www.gnu.org/philosophy/free-sw.html

Web site for submission of proposal via NSPIRES	http://nspires.nasaprs.com/ (help desk available at nspires-help@nasaprs.com or (202) 479-9376)
Web site for submission of proposal via Grants.gov	http://grants.gov (help desk available at support@grants.gov or (800) 518-4726)
Funding opportunity number for downloading an application package from Grants.gov	NNH19ZDA001N-SLCST
Main point of contact concerning this program	Nadya Vinogradova Shiffer Phone: (202) 358-0976 Email: nadya@nasa.gov

General questions about the Sea Level Change Program should be directed to the main point of contact above. Additional questions related to specific disciplines may be addressed to those listed below all of whom share the following postal address:

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