1. Scope of Program

1.1 Overview

NASA’s Science Mission Directorate (SMD) supports a broad portfolio of research in the Earth Science Research Program. Within the Earth Science Research Program, the Modeling, Analysis, and Prediction (MAP) program seeks an understanding of the Earth as a complete, dynamic system, with particular emphasis on climate and weather. Key questions that drive the core research efforts include:

- How is the Earth system changing?
- What are the forcing mechanisms driving observed changes?
- How does the Earth system respond to natural and human-induced changes?
- What are the consequences of Earth system change to society?
- What further changes can be anticipated, and what can be done to improve our ability to predict such changes through improved remote sensing, data assimilation, and modeling?

The MAP program supports observation-driven modeling that integrates across all the research activities in NASA’s Earth Science Research Program. The research is distinguished by rigorous examination and incorporation of satellite-based observations, using models to bridge the spatial and temporal scales between satellite observations and observations from ground and air based campaigns. This contributes to the validation of the satellite observations and to observationally based improvements of Earth system model components. MAP strives to generate models and model components that are documented, evaluated, interoperable, and consistent with current coding standards and practices. An overview of the current program may be found at http://map.nasa.gov/.

1.2 Background

MAP funds several large projects and/or functional organizations that comprise the core activities of the program. These efforts include:

Goddard Institute for Space Studies (http://www.giss.nasa.gov/research/modeling/). GISS supports research on natural and man-made global climate change that may occur on the scale of decades to millennia. GISS makes use of analyses of comprehensive global datasets and planetary models of the atmosphere, the land surface, and the oceans. The research includes the study of paleoclimate and the study of other planets as an aid to prediction of future evolution of Earth on a planetary scale. The primary GISS modeling tool supported by the MAP program is the GISS Model E (http://www.giss.nasa.gov/tools/modelE/), a coupled atmosphere-ocean general circulation model (GCM).

NASA Goddard Global Modeling and Assimilation Office (http://gmao.gsfc.nasa.gov). GMAO addresses the optimal use of satellite and in situ observations to generate research quality data sets for climate analyses and also for weather, climate, and air quality forecasts. The modeling
and assimilation research includes coupling to and assimilation of atmospheric chemistry and ocean biology and carbon. GMAO is focused on developing and maintaining world-class data assimilation systems for purposes associated with maximizing satellite data utility and serving as a centralized resource for testing and validating as wide a range of modeling and observational efforts as possible. The goal is to undertake modeling and assimilation as components of an end-to-end process, from defining an instrument, characterizing its in-flight performance, through to the development of algorithms and forward models for data assimilation, integrating the data into assimilation products, and finally assessing the impact of the data on the products of the assimilation system. GMAO is supported by MAP to develop and utilizes the Goddard Earth Observing System, version 5 (GEOS 5). GEOS 5 includes both a coupled atmosphere-ocean GCM and a data assimilation system (DAS). More information is available at: http://gmao.gsfc.nasa.gov/systems/geos5/.

1.3 Modeling, Analysis, and Prediction Research Themes

The specific research themes included in this Modeling, Analysis, and Prediction solicitation are as follows:

1.3.1 Ocean Modeling and Data Assimilation

A long-term goal of the MAP program is the development of an Integrated Earth System Analysis (IESA) capability. IESA is the process of consistently combining all available observations of the Earth System (atmosphere, ocean, land surface, sea-ice, and biogeochemistry) at some time with a model of the Earth System in such a way to produce a best estimate of the state of the Earth System at that time. This capability is not currently available given the start-of-the-art in modeling the global Earth System and the high computational requirements necessary for such a task.

At the present time, MAP is funding efforts to produce atmospheric analyses and reanalyses, and funds a related effort aimed at developing a best estimate of the evolution of the ocean state and ice sheets over the time period when significant ocean observations are available.

In this solicitation, MAP seeks proposals aimed at furthering NASA's capabilities in the area of ocean modeling and data assimilation, with a particular focus on development toward an integrated Earth System analysis. Issues MAP is interested in addressing in the area of ocean modeling and data assimilation include:

- Improvements in coupled ocean/atmosphere GCMs which include ice sheets.
- Generating improved initial conditions of the ocean state for seasonal to decadal prediction.
- Improved understanding of atmosphere/ocean interaction, including exchanges of heat, momentum, and carbon dioxide.
- Improved understanding of ocean/ice sheet interactions.
- Combined ocean/atmosphere analysis.
Proposals funded under the ocean modeling and data assimilation research theme must demonstrate a tie to either the GISS Model E or GMAO GEOS5 GCM/Data Assimilation System.

1.3.2 Earth System Modeling Framework for MAP-supported modeling efforts

The MAP program has developed and implemented the philosophy of a shared "modeling environment," or MAP-ME, which includes a community pool of Earth modeling code that is available to MAP-funded scientists to utilize in pursuit of their scientific efforts. In addition, code that is developed using MAP funding is made available to the MAP community through the software repository. A goal of the program is that the code contained in the repository be written using standardized software tools that increase code interoperability and utility. The Earth System Modeling Framework (ESMF) is a software package designed to facilitate the development of Earth Science codes with increased interoperability, reuse, ease of use, and portability (see http://www.esmf.ucar.edu/) for a full description of the software.

The NASA MAP program is interested in continuing the process of developing ESMF-compliance in MAP-supported codes, as well as in supporting continued development of the ESMF. The MAP program is therefore soliciting proposals that contribute to increased utilization of ESMF software within MAP-supported code, and work to further development of ESMF software in directions which are of benefit to NASA's modeling interests. Specific efforts of interest to NASA include:

1. Efforts to further develop the base ESMF implementation, for instance to develop a broader ESMF toolkit or improved grid conversion routines;
2. Development of "plug-ins" to the base ESMF implementation that expand its utility in ways that are demonstrably advantageous to codes currently or potentially within the MAP software repository;
3. Efforts to create or enhance the ESMF compliance of code whose development has been or is being supported by the MAP program; and
4. Efforts to utilize ESMF-compliant codes contained within the MAP software repository to expand the capabilities of the GEOS 5 or GISS Model E modeling systems to address scientific questions that cannot be currently approached with standard versions of the code.

2. Programmatic Information

2.1 Programmatic Priorities

Characterizing the limits of validity of models and model components and identifying the sources of uncertainties is important to realizing the goal of enabling whole Earth System Models. Therefore, preference will be given to proposals that; 1) characterize and/or help reduce uncertainties in the models and products; 2) extend the range of model or product validity by using new components; 3) exploit these products to address NASA Earth Science Division (ESD) research questions; 4) are in alignment with the goals and objectives of the core MAP elements described above; and 5) enable independent community validation and characterization of the core MAP elements leading to improvement of the models or products.
Proposals for new model component capabilities must include an evaluation activity that characterizes their limits of validity by comparing to observational data. In all cases, the proposer must explain how the validation methodology will help identify the source of uncertainty within the model or analysis product.

2.2 MAP Infrastructure

Adherence to the multiagency Earth System Modeling Framework (http://www.esmf.ucar.edu/), which provides a robust software infrastructure for coupling model elements, is desired by the program. Independent resources have been allocated to provide software engineering and interface support to successful proposals of this announcement to assure that the final product meets ESMF standards and investigator verification that the ESMF-compatible product yields desired results. Additional infrastructure support will be provided to the selected PIs as aids to increase productivity and to increase integration. There are three key types of support available:

- High-end computing (HEC) support from NASA Center for Computational Sciences (NCCS, https://nccs.nasa.gov/) and the NASA Advanced Supercomputing facility (NAS, http://www.nas.nasa.gov/) (see Section I(d) of the ROSES Summary of Solicitation);
- Expert assistance from computational scientists for optimization, porting, ESMF implementation, refactoring, testing, and other techniques to improve software; and
- Assistance with ancillary tools, including GUI-based workflow tools to assist in the set up and execution of model experiments with selected experiments preconfigured, assistance with visualization tools, support for access to modeling software, and an active collective learning repository of modeling development knowledge. A full list of services is available at the MAP Program web site (http://map.nasa.gov/).

Proposers who require computing time at NCCS or NAS must provide an estimate and justification of the number of node-hours required each year of the proposal. This is in addition to indicating on the NSPIRES cover pages that HEC resources are requested. Proposers should also identify their need, if any, for expert assistance resources. These requirements should be covered in clearly identified subsection of the Scientific/Technical/Management portion of the proposal.

2.3. Education and Public Outreach Opportunities

NASA policy strongly encourages participation in Education and Public Outreach (E/PO) activities by members of the science community. You may be eligible to propose a supplemental Education or Outreach effort if your research proposal is selected for award. The research award must have more than 12 months remaining at the time of submission of the supplement proposal. For additional details concerning the submission of Outreach or Education supplement proposals, please see Supplemental Outreach Awards for ROSES Investigators (Appendix E.5) and Supplemental Education Awards for ROSES Investigators (Appendix E.6).
### 3. Summary of Key Information

<table>
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<tr>
<th>Expected program budget for first year of new awards</th>
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<td>Number of new awards pending adequate proposals of merit</td>
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<td>Maximum duration of awards</td>
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<td>Planning date for start of investigation</td>
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<td>See Tables 2 and 3 in the ROSES Summary of Solicitation.</td>
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<tr>
<td>Due date for proposals</td>
<td>See Tables 2 and 3 in the ROSES Summary of Solicitation.</td>
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<td>Page limit for the central Science-Technical-Management section of proposal</td>
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<td>Relevance to NASA</td>
<td>This program is relevant to the Earth science strategic goals and subgoals in NASA’s Strategic Plan; see Table 1 and the references therein. Proposals that are relevant to this program are, by definition, relevant to NASA.</td>
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<tr>
<td>General information and overview of this solicitation</td>
<td>See the ROSES Summary of Solicitation.</td>
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<tr>
<td>Detailed instructions for the preparation and submission of proposals</td>
<td>See the NASA Guidebook for Proposers at <a href="http://www.hq.nasa.gov/office/procurement/nraguidebook/">http://www.hq.nasa.gov/office/procurement/nraguidebook/</a></td>
</tr>
<tr>
<td>Submission medium</td>
<td>Electronic proposal submission is required; no hard copy is required or permitted. See also Section IV of the ROSES Summary of Solicitation and Chapter 3 of the NASA Guidebook for Proposers.</td>
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<td>Web site for submission of proposal via NSPIRES</td>
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<td>Web site for submission of proposal via Grants.gov</td>
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<td>Funding opportunity number for downloading an application package from Grants.gov</td>
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</table>
| NASA point of contact concerning this program | Dr. David B. Considine  
Earth Science Division  
Science Mission Directorate  
National Aeronautics and Space Administration  
Washington, DC 20546-0001  
Telephone: (202) 358-2277  
E-mail: david.b.considine@nasa.gov |