A.13 MODELING, ANALYSIS, AND PREDICTION

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. Key questions that drive the core research efforts of the Earth Science Division within SMD include:

- How is the Earth system changing?
- What are the sources of change in the Earth system and their magnitudes and trends?
- How will the Earth system change in the future?
- How can Earth system science improve mitigation of and adaptation to global change?

Within Earth Science Research, the Modeling, Analysis, and Prediction (MAP) program seeks an understanding of the Earth as a complete, dynamic system. The program has a historical and continuing emphasis on climate and weather, but addresses broader Earth system research as well.

The MAP program supports observation-driven modeling and data assimilation. The modeling is distinguished by rigorous examination and utilization of observations in a global Earth system context. The modeling integrates across all the research activities in NASA's Earth science research program and spans the spatial and temporal scales that characterize satellite observations and observations from ground and air based campaigns. This approach facilitates the validation of the satellite observations and observationally-based improvements of Earth system model components, leading to models that accurately represent the Earth system with diagnostic and predictive skill. MAP strives to generate models and model components that are well documented, thoroughly evaluated, interoperable, robust, 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 two primary projects and/or functional organizations that comprise the core activities of the program. These efforts are:

Goddard Institute for Space Studies (GISS) (http://www.giss.nasa.gov/research/modeling/). GISS engages in research on global climate change occurring on the decadal to centennial timescale. GISS makes use of analyses of comprehensive global datasets and develops and utilizes integrated global models of the Earth system. 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. GISS has a long-term involvement in the Coupled Model Intercomparison Project (CMIP) that forms the basis of International Panel on Climate Change (IPCC) assessments of climate change. 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 (GMAO) (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 aerosols and 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 utilize 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/.

MAP also funds several smaller but still substantial projects that further core program interests. These efforts include:

Global Modeling Initiative (GMI) (http://gmi.gsfc.nasa.gov/). GMI develops, maintains, and utilizes a state-of-the-art modular global 3D chemistry and transport model (CTM) that includes full chemistry for both the troposphere and stratosphere, as well as a coupled representation of stratospheric aerosols. The GMI model serves as a testbed for different meteorological fields, emissions, chemical mechanisms, deposition schemes, and other processes determining atmospheric composition, both gas-phase and aerosols. In this role, GMI seeks to understand and constrain the uncertainties in model results through intercomparison of simulations and testing with observations. Since many of these processes are also included in general circulation models (GCMs), GMI is also a tool to expand the parameter space in sensitivity studies and test the parameterizations in GCMs with measurements of atmospheric composition.

NASA Unified Weather Research Forecast Model (NU-WRF). The NU-WRF model is an effort to unify the Weather Research and Forecasting (WRF) model, a next-generation multi-agency supported mesoscale NWP system, with NASA's existing weather models and assimilation systems, such as GEOS-5 and the Land Information System (LIS). Several parameterizations of physical processes developed by NASA scientists have been implemented into NU-WRF to better represent/simulate cloud/aerosol/precipitation/land surface processes. The goals for this effort are to robustly connect the global scale to the regional and mesoscale, and the use of NASA high-resolution satellite data for research into short-term climate and weather.

1.3 Modeling, Analysis, and Prediction Research Themes

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

- Model investigations designed to examine the role of processes within the Earth system and improve their representation in global models. Studies leading to implementable improvements are preferred. This includes representation of the weather-to-climate continuum of high impact events such as tropical systems, floods, droughts, heat waves, and extreme storms. Note that the focus of such an investigation should be on improving model representation of classes of events. Investigations involving case studies should explain the tie to general classes.
- Proposals to develop, implement, and evaluate new parameterizations for global models which would either expand the representation of the Earth system or replace modules which have been shown to have significant deficiencies. Parameterizations should be seamless, that is capable of spanning the weather to climate continuum of time scales. Examples include modules for boundary layer clouds, cloud superparameterizations, ice sheets, sea ice dynamics, dynamic vegetation, carbon cycle, aerosol indirect effects, etc.
- Studies to understand regional and local scale climate change in the context of global climate change: Improved understanding and modeling of the regional and local effects of global climate change is listed as a priority in the draft USGCRP strategic plan for the next decade. The MAP program seeks proposals to understand local and regional responses to global climate forcings and improve their model representation in global models. MAP also seeks proposals addressing the regional and global effects of local and regional climate forcing (such as occurs with aerosol or albedo forcing of climate.)
- Investigations using and/or evaluating the Modern Era Retrospective – analysis for Research and Applications (MERRA) reanalysis data (http://gmao.gsfc.nasa.gov/research/merra/intro.php). MERRA uses state-of-the-art GMAO data assimilation and modeling techniques towards production of a long-term reanalysis data set covering 1979-present and including observations from conventional (ship, aircraft, balloon, surface, etc.) and space-based observations. Investigations should address core MAP goals and objectives.
- Investigations utilizing observations which are aimed at identifying, characterizing, and reducing uncertainties in model predictions of climate change on seasonal to multidecadal time scales. This includes investigation and model representation of feedbacks, and components of the climate system which may provide predictive capability, for instance ocean circulations, the Northern and Southern Annular Modes, the NAO and PDO, etc.
- Constituents in the climate system: Constituents in the atmosphere (aerosols and chemical species) will respond to climate change, and changes in constituent concentrations can have climatic consequences as well. A MAP program goal is to expand our understanding of the role of atmospheric constituents in the context of the climate system, as well as utilization of constituent observations to better understand global processes and their model representation. Proposals are sought to understand the role of climate change on atmospheric constituent distributions and the influences of constituent change on climate. Proposals are sought to conduct hindcasts using

reanalyzed meteorological fields over the past twenty to thirty years to investigate the capability to capture observed characteristics (e.g., secular trends, seasonal and interannual variability) of inert tracers (e.g., N_2O) and radiatively and chemically active species. Proposals are sought to utilize constituent observations to investigate important transport processes within the troposphere and stratosphere, such as the relative roles of large scale vs. convective transport, the role of long range transport on regional and local constituent concentrations, and the influence of the stratosphere on the troposphere. A desirable feature of such investigations would be to understand the implications for the climate system. Proposals are sought to utilize observations to better understand uncertainties in global simulations of atmospheric composition, due to model formulation or process representation, for example of resolution, meteorology, emissions, or deposition. Proposals are also sought to investigate model/measurement comparison methodologies: Evaluating CCMs and CTMs with observations require different approaches due to the fact that the meteorology of the CCM does not correspond to the meteorology of the observations. Studies are, therefore, sought which demonstrate using CTM simulations the validity of the evaluation methodology for CCMs.

- Advanced numerics: The MAP program seeks investigations of grids and fluid dynamical formulations that support high resolution simulation of the Earth's climate. Techniques that contribute to the development of a modeling environment that can be configured in both global and regional applications are of specific interest. Proposals should consider accuracy, physical consistency, nonhydrostatic simulation, computational robustness, and be consistent with component-based model architectures.
- Model-based methods for establishing appropriate measurement requirements for climate monitoring to reduce uncertainties in global climate model projections. Current climate models exhibit a broad range of projections of climate change over the next few centuries, and this wide uncertainty envelope limits the utility of the model projections. Methods to better characterize and reduce this uncertainty are sought, in particular through the use of current observational capabilities and by determining and establishing requirements for key measurements to which the climate projections are most sensitive.

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.

New model components which are proposed should be Earth System Modeling Framework (ESMF) compliant and make use of ESMF utilities where appropriate. 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. Proposals for new or improved model components for NASA MAP supported models and proposals which utilize NASA MAP-supported models or model output will be preferred over those that do not.

2.2 MAP Infrastructure

Adherence to the multiagency ESMF (http://www.earthsystemmodeling.org/), 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 for 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 a clearly identified subsection of the Scientific/Technical/Management portion of the proposal.

The MAP program maintains a code repository for all code whose development has been funded by MAP.

3. Summary of Key Information

Expected program budget for first year of new awards	~ $9M
Number of new awards pending adequate proposals of merit	~40
Maximum duration of awards	4 years

Due date for Notice of Intent	See Tables 2 and 3 in the *ROSES Summary of Solicitation*.
Due date for Proposals	See Tables 2 and 3 in the *ROSES Summary of Solicitation*.
Planning date for start of investigation	January 1, 2013
Page limit for the central Science-Technical-Management section of proposal	15 pp; see also Chapter 2 of the *NASA Guidebook for Proposers*
Relevance to NASA	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.
General information and overview of this solicitation	See the *ROSES Summary of Solicitation*.
Detailed instructions for the preparation and submission of proposals	See the *NASA Guidebook for Proposers* at http://www.hq.nasa.gov/office/procurement/nraguidebook/.
Submission medium	Electronic proposal submission is required; no hard copy is required or permitted. See Section IV of the *ROSES Summary of Solicitation* and Chapter 3 of the *NASA Guidebook for Proposers*.
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)
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