A.6 CARBON MONITORING SYSTEM: CONTINUING PROTOTYPE PRODUCT DEVELOPMENT

NOTICE: The data management plan must be included within the 15-page limit for the Scientific/Technical/Management section of the proposal as it will be evaluated as part of Merit. Proposers must use Earth Science division templates for the required Summary Table of Work Effort and Current and Pending Support sections of the proposal, see Section 2.2.8.

1. Scope of Program

The NASA Carbon Monitoring System (CMS) is a forward-looking initiative designed to make significant contributions to characterizing, quantifying, understanding, and predicting the evolution of global carbon sources, sinks, and fluxes through improved monitoring of terrestrial and aquatic carbon stocks and fluxes. Initially implemented in response to language in NASA's 2010 Congressional Appropriation, this program is now considered to be an important part of NASA's Carbon Cycle and Ecosystem focus area, and as presently implemented, supports research and coordinates projects for the development of prototype carbon monitoring systems.

NASA's approach toward a carbon monitoring system has emphasized exploitation of current and future satellite remote sensing resources, computational capabilities, scientific knowledge, airborne science capabilities, and end-to-end system expertise that are major strengths of the NASA Earth Science program. Significant effort is being devoted to rigorous evaluation of the carbon monitoring products being generated, as well as to the characterization and quantification of errors and uncertainties in those products. The initial emphasis has been on regional, national, and global satellite-based carbon monitoring products relevant to national needs for completely transparent carbon and terrestrial biomass inventory processes that provide statistical precision and accuracy with geospatially explicit associated attribute data. NASA's approach considers data and expertise that are the domain of other U.S. Government agencies, and anticipates continuing close communication and/or partnerships with those agencies and their scientific and technical experts as U.S. national efforts toward integrated carbon monitoring mature.

NASA also recognizes a need for complementary local-scale (airborne and *in situ*) information to demonstrate quantitative remote sensing methods to evaluate carbon source, sink, and flux estimates; to aid in scaling up from project, county, and/or state levels on land and within different aquatic regions; and for essential evaluation of regional-, national-, and global-scale carbon monitoring products. Such work is critically important for advancing research capabilities toward an understanding of Earth's carbon cycle that is relevant for decision-making communities. Additionally, the current approach lays the groundwork for CMS-related applications of NASA and non-NASA satellite sensors currently on orbit (i.e., Orbiting Carbon Observatory-2 (OCO-2); ESA's Sentinel 5-Precursor; ECOSTRESS (launched June 29, 2018); Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2, launched September 15, 2018); Global Ecosystem Dynamics Investigation (GEDI, launched December 5, 2018), and the Orbiting Carbon Observatory-3 (OCO-3, launched in May 2019); missions in development (i.e., Plankton, Aerosol, Cloud, and ocean Ecosystem (PACE); NASA-ISRO Synthetic Aperture Radar

(NISAR); and ESA's Earth Explorer Biomass and FLuorescence EXplorer (FLEX) mission).

Accomplishments-to-date include the development of a continental U.S. terrestrial biomass data product and a global carbon flux product; demonstrations of local- and regional-scale carbon management projects; improvement of the CMS biomass and flux products; refinement and quantification of carbon in tropical peatlands relevant to "blue carbon"; assessing changes in terrestrial-ocean carbon fluxes and investigating global ocean CO_2 fluxes; and engagement of carbon monitoring stakeholders to better understand their needs for carbon data and information products. Projects supported by CMS have developed CMS-Flux, one of the most advanced carbon data assimilation systems in the world, which integrates satellite and surface observations related to anthropogenic, oceanic, terrestrial, and atmospheric carbon. For more information about the projects that have been funded through CMS, see the CMS website (https://carbon.nasa.gov/) and relevant links listed on that page (e.g., publications, documents).

NASA has established a Carbon Monitoring System Science Team (CMS ST) that will include members from all NASA CMS investigations. The CMS ST is responsible for providing broad research community involvement in the development and evaluation of NASA CMS products; coordinating their NASA-funded CMS activities to ensure maximum science, management, and policy return; and providing scientific, technical, and policy-relevant inputs to help identify potential future research topics for NASA CMS activities. As current proposals are completed, their Principal Investigators (PIs) will rotate off the CMS ST and be replaced by the newly selected investigators from this program element.

The work so far conducted in this CMS prototyping effort has leveraged the much larger investments currently made by NASA in remote sensing observations of carbon-related properties of the Earth, as well as in carbon cycle science research.

2. Research Solicited

NASA requests proposals for investigations that will advance products toward the CMS end goal: development of prototype carbon monitoring systems from an Earth's system perspective. Areas of interest include terrestrial, atmospheric, and aquatic realms. Proposal emphasis must be directed toward continued development of the established CMS pilot studies (see https://carbon.nasa.gov), synergistic advancements from past CMS activities, as well as acquisition, quantification, and development of prototype CMS system capabilities that can improve existing and develop new data products toward achieving the levels of precision and accuracy required by current carbon trading activities (e.g., certification of emissions reductions). Successful applicants will also become NASA CMS Science Team (ST) members.

2.1 Research Topics

With this program element, NASA CMS will continue to refine, evaluate, and integrate suborbital, airborne, and satellite data, providing products that overlay previous research within a user-defined prototype monitoring system. These data sources include, but are not limited to, field campaigns with extensive NASA support.

All proposals are required to target a CMS prototyping activity and not focus solely on carbon cycle science research. This requirement will be factored into the relevance criterion evaluation. Proposals that do not address a CMS prototyping activity and clearly show the use of derived remote sensing data will be considered non-responsive and thus may be returned without review.

NASA requests proposals for three types of carbon monitoring prototyping and product development activities. NASA is soliciting:

- Studies that address research needs to advance (a) remote sensing-based approaches to quantifying forest degradation and forest regrowth; (b) independent assessment of the accuracy of satellite or airborne remote sensing observations of biomass and carbon stocks; and (c) the use of satellite remote sensing as an alternative or a supplement to ground-based methods for quantifying net carbon emissions and/or storage; and (d) the accounting of blue carbon ecosystems (quantification and change - e.g. regional/global extent and temporal distribution).
- Studies that build upon, extend, evaluate and/or improve the existing CMS products for biomass and flux resulting from NASA's earlier phases of CMS pilot studies; such studies may include, for example, product improvements, refined characterization and quantification of errors and uncertainties, and/or preparation and delivery of a mature product for long-term archive at an established NASA DAAC or equivalent data center.
- Studies using remote sensing data that evaluate and enhance national reported carbon emissions inventories from bottom-up estimates from various sectors of emissions within the United States and have the potential to be applied to reported national inventories from other nations.
- Studies that build upon and improve quantification of terrestrial-ocean carbon fluxes in areas that have been subject to considerable perturbations for accounting purposes. Inclusion/delineation of anthropogenic carbon contributions to existing flux estimates are encouraged.

Data from airborne or spaceborne remote sensing is required as a primary research tool in all proposed carbon monitoring investigations. All sources of remotely sensed data must be well justified in terms of their importance and appropriateness for the work to be conducted, as well as their overall utility for monitoring carbon for science, management, and policy.

The NASA CMS program continues to emphasize the importance of characterizing and quantifying uncertainties and errors in all CMS products and analyses, and such work must be included in all investigations proposed (see Section 2.2.7).

Proposals must explain the societal relevance of the carbon monitoring activities proposed and provide justification regarding the importance of this work to U.S. national interests in current or potential carbon monitoring for science, management, and policy. Proposals must clearly explain how the proposed work will address stakeholder interests in their studies. Proposers are encouraged to work with stakeholders to better understand stakeholder interests and requirements. Stakeholders are defined as those that utilize products outside the normal scientific research realm. In addition, proposers must indicate how they will contribute to CMS ST activities to understand and engage

the user community for carbon monitoring products. Many of the studies funded through the ROSES-2018 CMS program element (A.7; see PDF document with titles and abstracts of ROSES-2018 awards) have two additional year of funding remaining. Proposals to further develop or expand upon funded ROSES-2018 activities are, therefore, not currently as high a priority as the research topics listed in this program element.

2.2 Additional Proposal Requirements

2.2.1 *Requirements Regarding the Duration of Award*

The proposed scientific tasks must be of no more than three years duration and proposers may not propose a study with a longer period of performance. If the proposed research can be conducted in less than three years, a shorter period of performance is encouraged.

2.2.2 *Carbon Monitoring System Science Team Membership*

All proposals must request CMS ST membership for one or more key investigators and include one to two paragraphs describing the contributions they anticipate making to the activities of the CMS ST. This section should address one or more of the following:

- Representing concerns of the broad carbon monitoring community with respect to the nature, quality, and utility of existing or new NASA CMS products;
- Coordinating their CMS activities to ensure maximum returns and enhance or create complementarity, integration, and synergy;
- Providing important perspectives on product development, implementation, and evaluation;
- Providing insights on the relative merits of alternative approaches and products;
- Making connections to ongoing and newly developing activities with similar and/or complementary objectives being undertaken by other entities, especially other U.S. agencies; and/or
- Providing scientific, technical, and policy-relevant inputs to help set priorities and directions for future NASA CMS activities, including with existing working groups within CMS.

The CMS ST will conduct its business through periodic meetings, with frequent interactions through monthly teleconference calls and frequent email communications.

2.2.3 *Carbon Monitoring System Science Team Leader*

Proposals are requested for a CMS ST Leader. CMS has had a Science Team Leader for the past six years and NASA desires to continue having an individual from among the Science Team serve in this role. The CMS ST Leader will be responsible for providing scientific leadership and direction to the CMS ST and scientific inputs regarding CMS activities to NASA management. He/she will be responsible for calling and organizing ST meetings and related activities in coordination with NASA CMS managers and Carbon Cycle and Ecosystems Office staff. He/she will be responsible for organizing and delivering to NASA a final report summarizing the findings of the CMS ST regarding CMS Phase 2 activities and recommended next steps.

Team Leader proposals should include a separate section of up to three additional

pages in the Scientific/Technical/Management section that describes only the activities to be undertaken as CMS ST Leader and addresses the following aspects of team leadership:

- The carbon science, carbon management, and/or carbon policy qualifications and leadership skills of the proposing Team Leader;
- A clear articulation of the proposed Team Leader's vision for the NASA CMS and its contribution to science and society;
- The ability of the proposing Team Leader to represent CMS's overall goals and objectives to the broader community and to decision makers in need of carbon monitoring information; and
- A management plan that describes the approach to science team leadership, how interactions with the ST and NASA management will be conducted, and how science team business and meetings will be organized and conducted.

In addition, the Budget Justification: Narrative and Details section of the proposal and/or the Total Budget file, as appropriate, must include a detailed budget for only the Team Leader activities and a narrative and justification for the Team Leader work that are separate from those for their CMS ST member activities. It is anticipated that the level of effort for Team Leader is one to three months per year.

Proposers who wish to be considered for CMS ST Leader also should indicate their candidacy by answering the relevant cover sheet question.

NASA reserves the option to select a Team Leader from among the existing ST members should new Team Leader proposals of adequate merit and suitability not be received in response to this solicitation.

2.2.4 *Requirements for the Cost Plan*

Given the varying types of investigations solicited, NASA expects to fund a range of investigation sizes. It is expected that proposals requiring acquisition of new airborne or commercial satellite data will have budget profiles that have a significant peak during the year of data purchase/acquisition, but for the other years of such studies and for all other investigation types, NASA would not expect the per year budget, even for the most ambitious of investigations, to exceed $500,000. However, lower cost proposals of high scientific merit are very much encouraged. All data purchases, including commercial, must be itemized and justified within the scope of CMS. Cost plans must include resources for activities undertaken as a CMS ST member, including funds for travel to ST meetings. The proposed budget should include funds to participate in two CMS-related meetings per year, each lasting three days. For planning purposes, proposers should budget each year for one meeting in the western U.S. and one meeting in the Washington, DC area.

2.2.5 *Requirements for Proposals Requesting Acquisition of New Airborne Data*

Proposals requiring acquisition of data from airborne sensors must detail in their budget all costs associated with data set acquisition, including costs for aircraft hours, deployment costs, mission peculiar costs, data processing, and other costs associated with deploying the sensors, aircraft, and personnel. (This provision applies to all sensors and platforms, including any NASA sensors and platforms, as well as non-NASA

sensors and platforms). If the instrument or aircraft platform is not a NASA asset, proposers must take responsibility for making all arrangements to secure the availability of the needed sensors and aircraft and explain these plans in the proposal.

All proposers must submit a Flight Request to the NASA Airborne Science Flight Request system at http://airbornescience.nasa.gov (and then click on "Flight Request"). This is required for all proposals, whether it involves NASA sensors, platforms, and personnel or not, because a flight request is used to help NASA understand and track all of the airborne science it supports. Address any flight request system or process questions directly to Marilyn Vasques, Flight Request Manager (Marilyn.Vasques@nasa.gov or 650-604-6120).

2.2.6 *Requirements for International Agreements, Permissions, and Flight Clearances*

CMS activities proposing airborne and *in situ* data acquisitions outside the U.S. and/or in cooperation with interagency and international activities and programs (e.g., SilvaCarbon, REDD, REDD+-related projects) may require international agreements, permissions (e.g., research/data collection permits), overflight clearances, or other formal arrangements. Proposals must detail plans for meeting such requirements.

Proposals requesting use of NASA aircraft, NASA sensors, and/or NASA personnel in international work are required to follow all relevant NASA policies and procedures. In some cases, it may either be required or preferable for NASA to lead securing all or certain types of required agreements, permissions, or clearances. In most cases, where the use of NASA aircraft or sensors is not requested and NASA personnel are not involved, proposers will be fully responsible for securing their own arrangements.

Research involving participants at foreign organizations must be proposed and performed on a no-exchange-of-funds basis, whether through a proposal from a foreign or a U.S.

2.2.7 Requirements to Address Errors, Uncertainties, and Instrument Calibration

Given the importance of carbon cycle data and information for decision-making, it is essential that the research supported under NASA's CMS program characterize uncertainties and quantify errors associated with data and derived information products, as well as with analytical approaches, model results, and/or scientific interpretations.

When new data are acquired as part of the proposed activities, it is equally important that instrument calibration be documented and traceable so different types of data and data products can be intercompared with a high degree of confidence. Therefore, all proposals submitted in response to this program element must describe how errors and uncertainties will be addressed within their research project, including, if relevant to their study, errors and uncertainties associated with instrument calibration. The characterization of errors and uncertainties must be described in a separate subsection of the Scientific/Technical/Management section of the proposal. If new observations are to be made in the study, then this subsection should also describe their calibration, accuracy, and traceability.

2.2.8 Work Effort and Current and Pending Support

Proposers must use The Earth Science Division's standard template for detailing the level of work effort for project participants and for the current and pending support of project participants. The template is available at

https://science.nasa.gov/researchers/templates-for-earth-science-division-appendix-a-roses-proposals

2.2.9 *Data Policy and Data Management Plan Requirements*

All data and information acquired and data products produced under the NASA CMS program must be made publicly available, with no period of exclusive use, in compliance with NASA's Earth Science data policy (http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/). Any data proposed to be analyzed 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.

Proposals must include a data management plan of no more than two pages that addresses the dissemination and sharing of research results, how data and information will be provided, and the proposer's compliance with the NASA Earth Science data policy (https://science.nasa.gov/earth-science/earth-science-data/data-information-policy). The data management plan must include the types of data and data products, algorithms, models and model outputs, or other materials to be produced in the course of the project; the standards to be used for data and metadata formats; the types of errors and uncertainties to be quantified and how they will be reported; and plans for providing access to and/or archiving the data and other research products. For any proposed new data products, the data management plan must include provisions for quality assessment, timely public release consistent with NASA policies, and long-term archive of the data product(s).

The data management plan must be included within the 15-page limit for the Scientific/Technical/Management section of the proposal.

3. Programmatic Information

3.1 Funding Allocations

Of the $10M of Fiscal Year 2021 funding identified for CMS efforts, $5.6M is already allocated to ongoing research commitments from prior years. Therefore, $4.4M in FY 2021 funding is available to support new research under this program element.

3.2 Evaluation Criteria

Proposals will be evaluated according to the criteria specified in the *NASA Guidebook for Proposers*, with additional factors noted in this section.

In addition to the factors given in the *Guidebook for Proposers*, the determination of a proposal's intrinsic merit shall also consider the following:

- The quality and appropriateness of the proposed approach to product prototyping,

product evaluation, and/or characterization of uncertainties and quantification of errors, including those associated with instrument calibration, and

- The quality and completeness of the data management plan.

The determination of a proposal's relevance shall be based on the extent to which it applies to the topics listed in Section 2.1. NASA will consider the relative priority of the activities proposed for support of carbon monitoring-related decision-making.

4. Summary of Key Information

Expected program budget for first year of new awards	$~4.4M
Number of new awards pending adequate proposals of merit	~12-16
Maximum duration of awards	3 years
Due date for Notice of Intent (NOI) to propose	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	December 2020
Page limit for the central Science/Technical/Management section of proposal	15 pages; see also Table 1 of the ROSES *Summary of Solicitation* and the *NASA Guidebook for Proposers*.
Relevance	This program is relevant to the Earth Science questions and goals in the NASA Science Plan. Proposals 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 Table 1 of 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.
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	NNH20ZDA001N-CMS

Points of contact concerning this program, all of whom share the following postal address: Earth Science Division Science Mission Directorate NASA Headquarters Washington, DC 20546-0001	Kathy A. Hibbard Telephone: (202) 358-0682 Email: Kathleen.A.Hibbard@nasa.gov Kenneth W. Jucks Telephone: 202-358-0476 Email: Kenneth.W.Jucks@nasa.gov Laura Lorenzoni Telephone: 202-358-0917 Email: laura.lorenzoni@nasa.gov Hank A. Margolis Telephone: (202) 358-4760 Email: Hank.A.Margolis@nasa.gov