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Monitoring the Carbon Cycle: Lessons from the NASA Carbon Monitoring System

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NASA CMS^3 CARBON MONITORING SYSTEM

NAS
COP27

March 29, 2023

Congressional Direction in 2010:

Also included within the funds provided for other mission and data analysis, the conference agreement provides $6,000,000 for pre-phase A and pilot initiatives for the de… that provide statistical … ing a common …

Congressi…

None

Congressi…

The Comm… n fiscal year 2010. The…

Language…

Of the fur… evelopment of a carbo… uantification and devel… of precision and accur… ent to meet these obj… alidation datasets f… n and Forest Degradati… us far within the agenc…

Congressi…

Carbon M… inue efforts for the de… and developm… recision and accuracy … developm… n into its operating … t these objectives. Therefore, the use of commercial off-the-shelf technologies is recommended as these products could provide robust calibration validation datasets for future NASA missions.

.

…"pilot initiatives for the development of a carbon monitoring system…"

…"replicate state and national carbon and biomass inventory processes that provide statistical precision and accuracy with geospatially explicit associated attribute data…"

…"development of a prototype Monitoring Reporting and Verification (MRV) system which can provide transparent data products achieving levels of precision and accuracy required by current carbon trading protocols…."

…"[development of] a plan…incorporating such a [MRV] system into its operating plan and long-term budget projection…"

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NASA's Approach to CMS/MRV

- Recognizes that a sustained, observationally-driven carbon monitoring system using remote sensing data has the potential to significantly improve the relevant information base for the U.S. and world;
- Recognizes multiple users, multiple scales, multiple quantities, and multiple frameworks for MRV (e.g. International, national and subnational, markets);
- Recognizes the importance of user engagement to be responsive to stakeholder needs;

Hurtt et al. (2014) Progress and Future Plans

NASA Carbon Monitoring System

The goal for NASA's CMS project is to prototype the development of capabilities necessary to support stakeholder needs for Monitoring, Reporting, and Verification (MRV) of carbon stocks and fluxes.

Ocean-Atmosphere Flux

The exchange of carbon between the air and ocean is known as Ocean-Atmosphere Flux. The oceans exchange a large amount of carbon with the atmosphere. CMS projects funded under this activity seek to better estimate the exchange of carbon between the ocean and the air.

Land-Atmosphere Flux

The exchange of carbon between the land and the air is referred to as Land-Atmosphere flux. CMS scientists are collecting better estimates of land biomass to use in models which predict how much carbon is released through biomass burning and deforestation.

Ocean Biomass

Ocean Biomass refers to the total mass of all living matter, living in the oceans. CMS scientists are focusing their efforts in researching concentrations of phytoplankton and distribution of calcifiers in oceans and lakes, which play an important role in controlling how much carbon is exchanged between the oceans and the atmosphere.

Land-Ocean Flux

Land-Ocean Flux refers to the exchange of carbon between the land and coastal waters. In order to understand the dynamics that control the movement of carbon from land to the ocean. CMS scientists are using land-based and ocean-based models together to model terrestrial watershed processes in combination with coastal oceanic processes.

Land Biomass

Land Biomass is the total mass of all living matter on land, including all above ground grasses, trees, and shrubs. When biomass is removed through deforestation or burning, the carbon stored in the plants is released into the atmosphere. CMS scientists are improving current methods for measuring how much land biomass exists and it's role in the carbon cycle.

MRV | Decision Support

Many CMS Projects and data products are being designed for Measurement, Reporting, and Verification (MRV) Programs at local, regional, national, and international scale, as well as to provide timely and useful information to decision-makers.

Global Surface-Atmosphere Flux

Global Surface-Atmosphere Flux refers to the total amount of carbon being moved annually between the land and ocean surface and the atmosphere.

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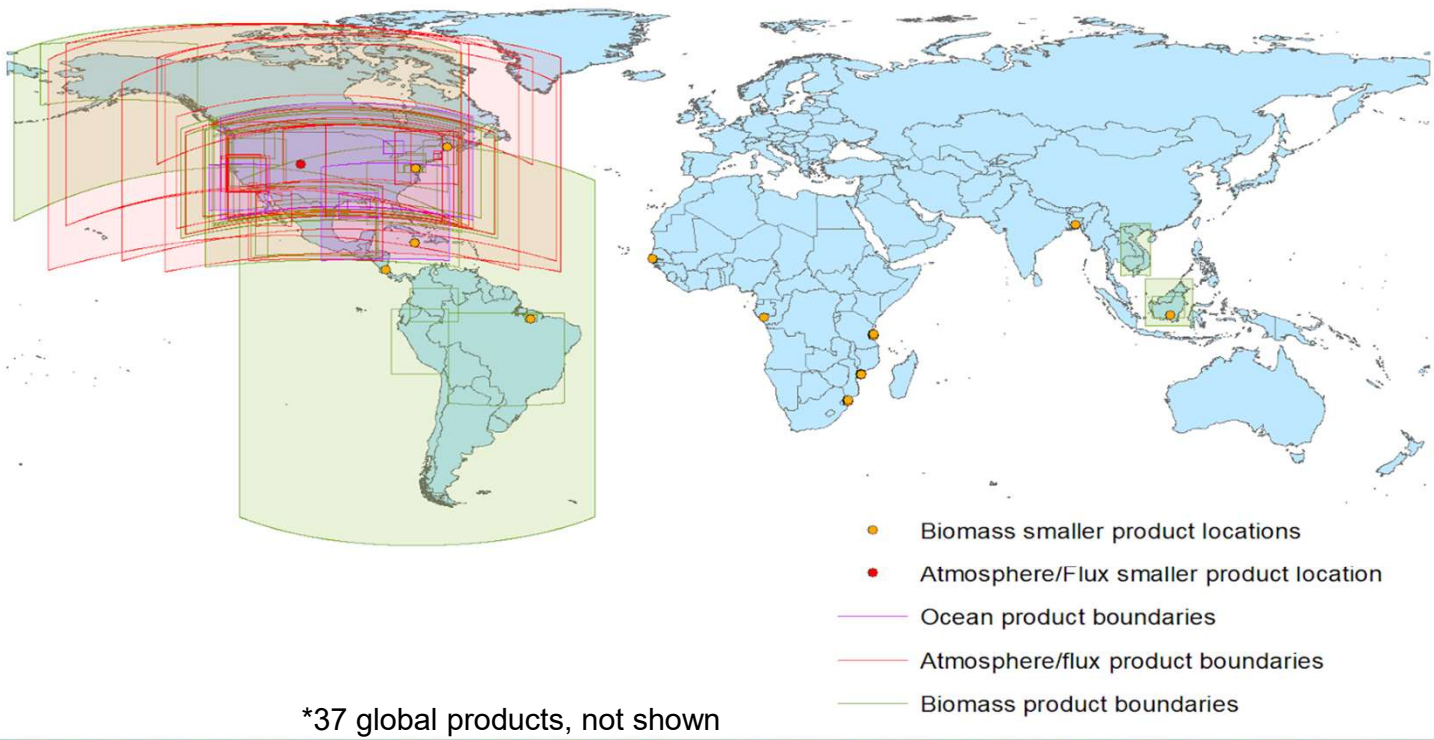
CMS Phase 2 Product Boundaries by Theme



*37 global products, not shown

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Hurtt et al (2022) Phase 2 Report

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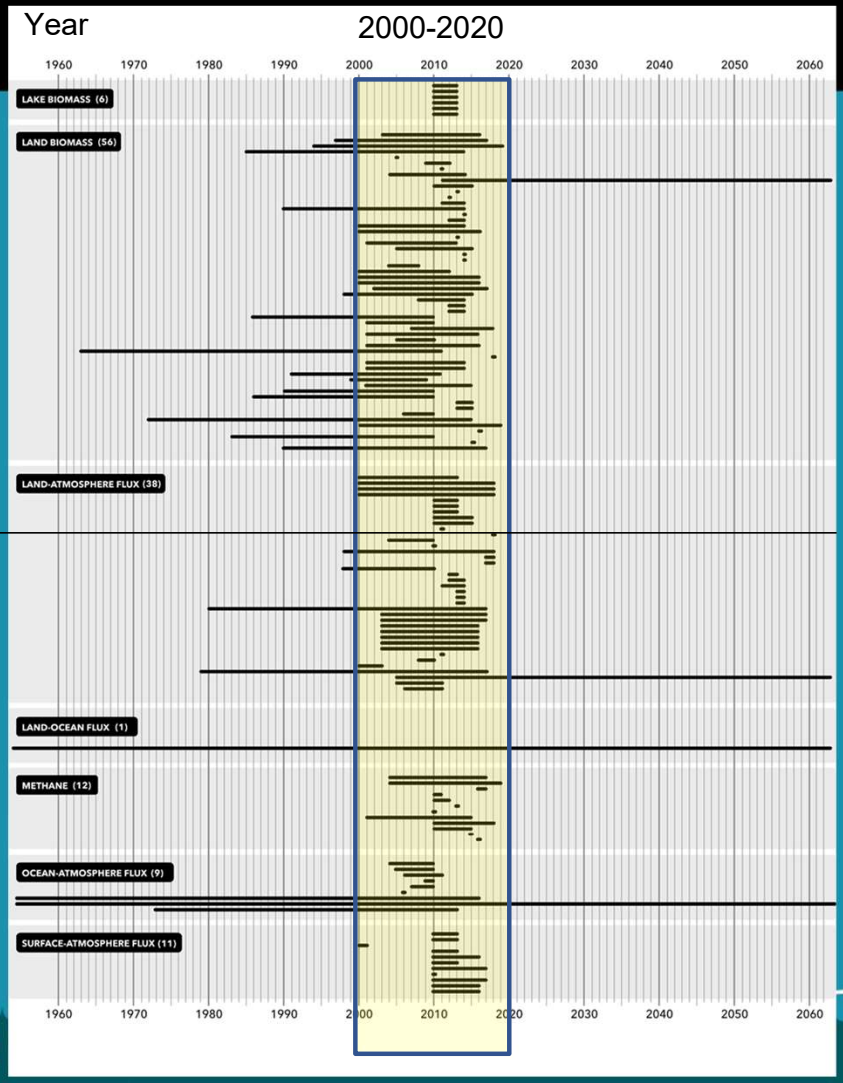
Phase 2
Product Time Domain

Biomass

Flux



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Productivity
(March 28,2023)

CMS BY THE NUMBERS

133
Total number of data products published

20
Total number of data products in development

54000+
Total number of of data products downloaded

631
Total number of publications

40413
Total number of citations

FEATURED IN HIGH IMPACT PUBLICATIONS

nature
20 publications | cited by 4521

Science
9 publications | cited by 6365

PNAS
14 publications | cited by 1109

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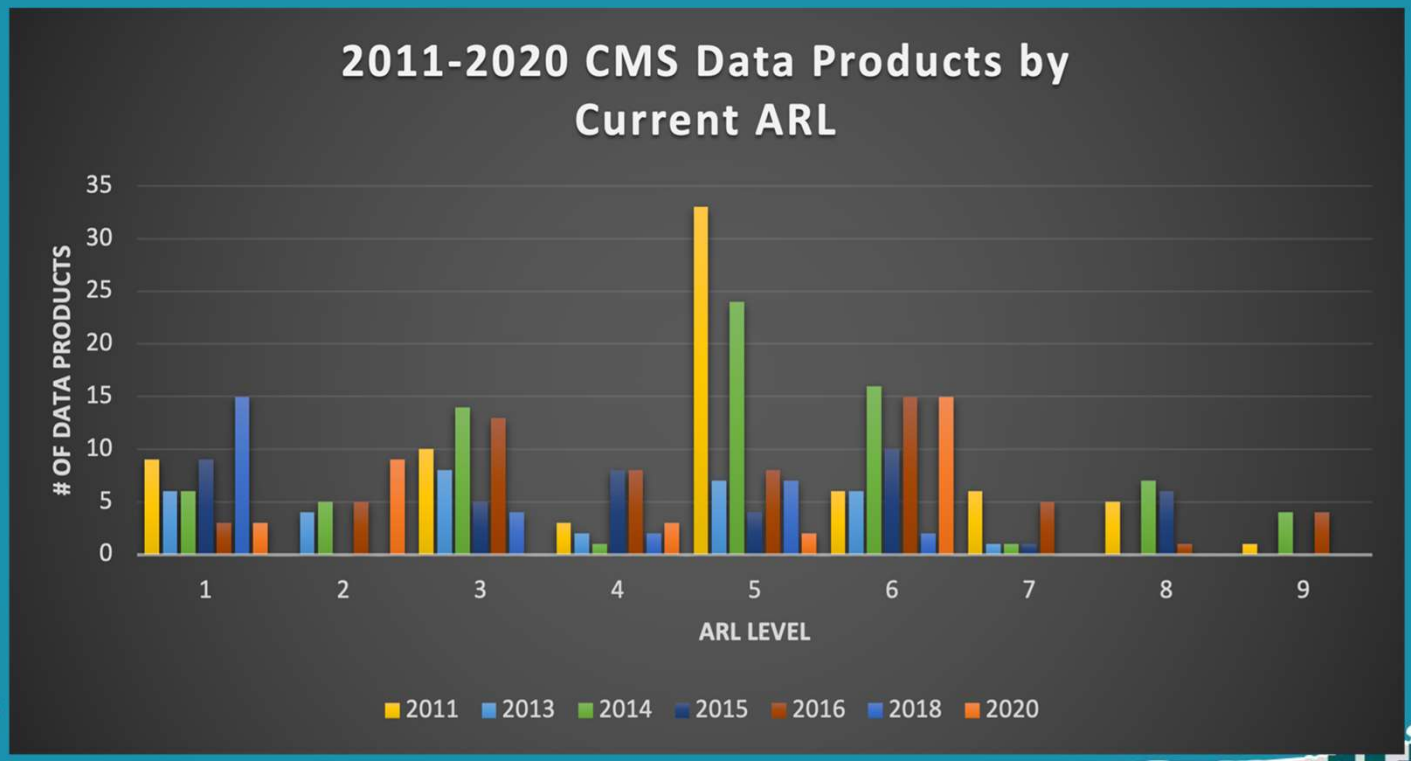
Application Readiness Levels (ARLs)



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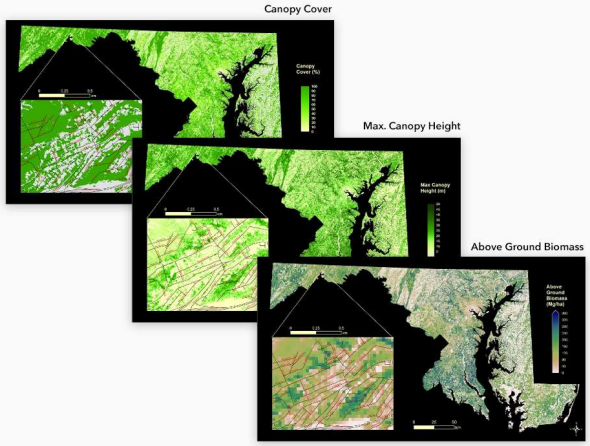
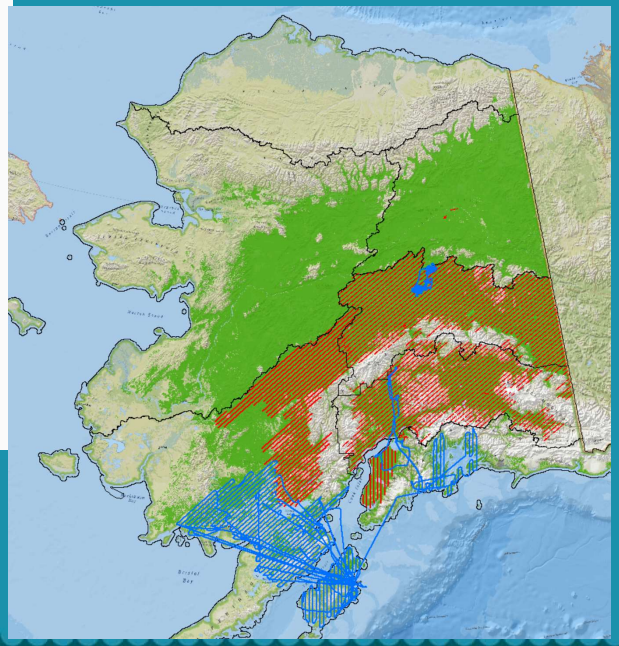
Example Success Stories

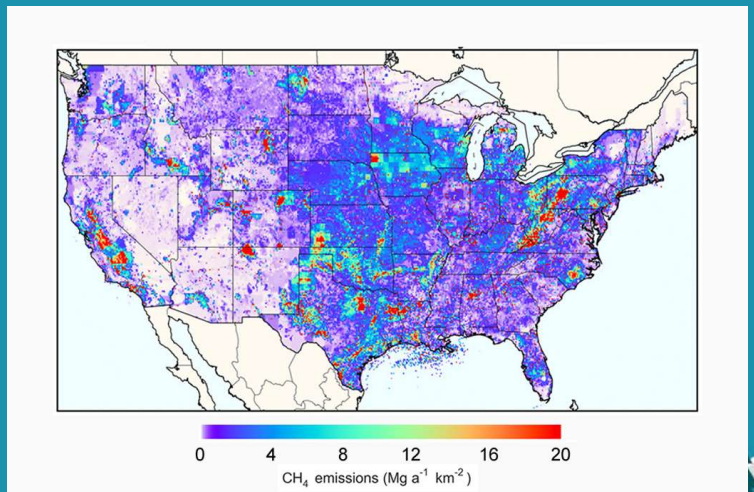
Maryland Department of Environment



USFS-Alaska



U.S. Environmental Protection Agency



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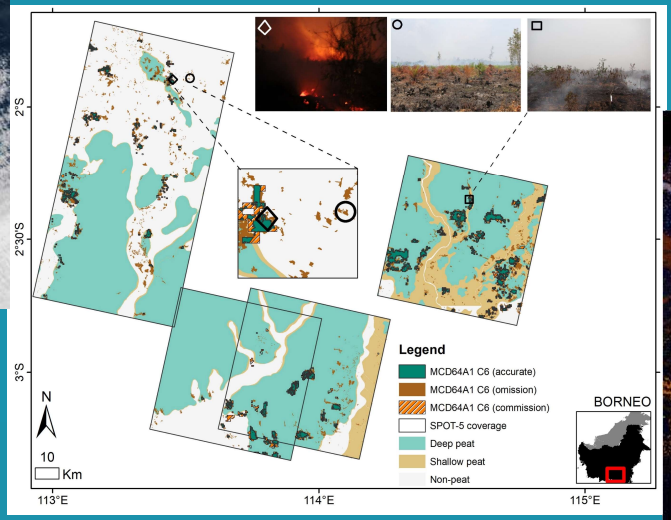
Example Success Stories

GNATS

Indonesia



Global (GEOS-5)

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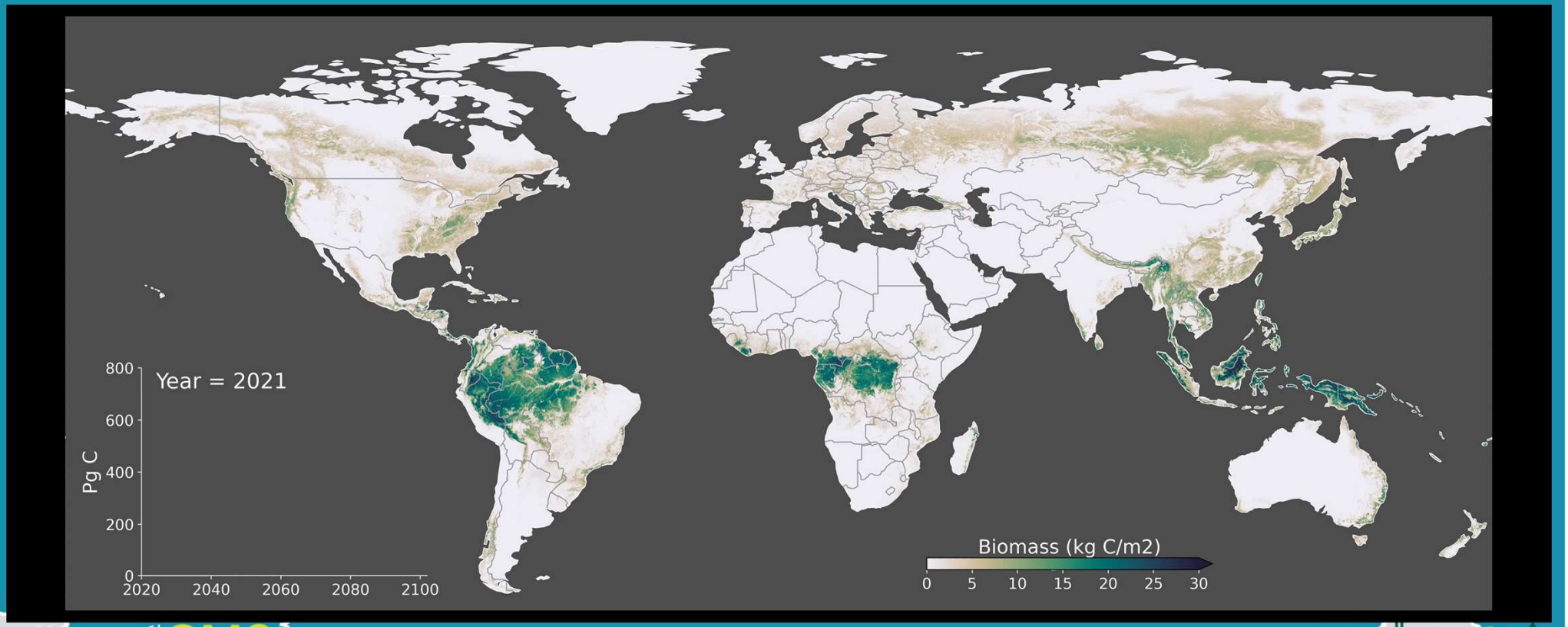

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(Ma et al, In prep)

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Scientists

Stakeholders

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Policy Speaker Series

Brings stakeholders to NASA to explain how carbon science data are applied to specific policies. Informs CMS science community of specific stakeholders data needs and collaboration opportunities.

Applications Workshops

Annual event with CMS Science Team and end users for a better understanding of stakeholder uses, needs and challenges for carbon monitoring and MRV as well as lessons learned.

Data Products Fact Sheet

Collection of CMS metadata and policy data for each product (e.g. spatial extent, resolution, uncertainty, application areas, relevant policies), Integrated into CMS website database.

Feedback to CMS Science Community and NASA HQ ESD

Application Readiness Levels (ARLs)

Provide transparency to HQ and user community on the maturity of each CMS product. Used as a communication tool for stakeholders to assess product maturity.

Surveys & Community Assessments

Evaluate thematic user challenges within the CMS. Assess impact of CMS data products for end user organizations.

Socioeconomic Studies

Development of socioeconomic case study addressing the social value of CMS Lidar in MD DNR policy, and an ongoing assessment of the contribution of CMS flux products to the reduction of uncertainty in the carbon cycle.

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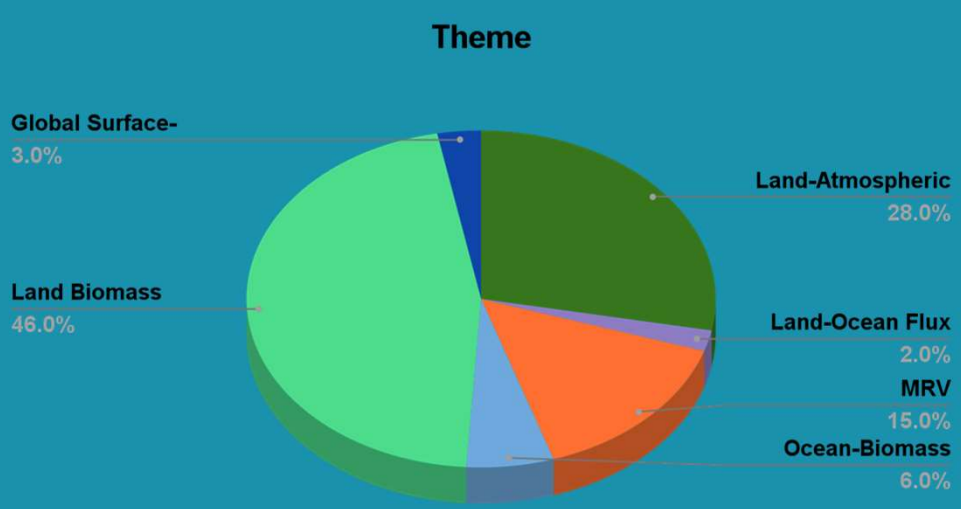
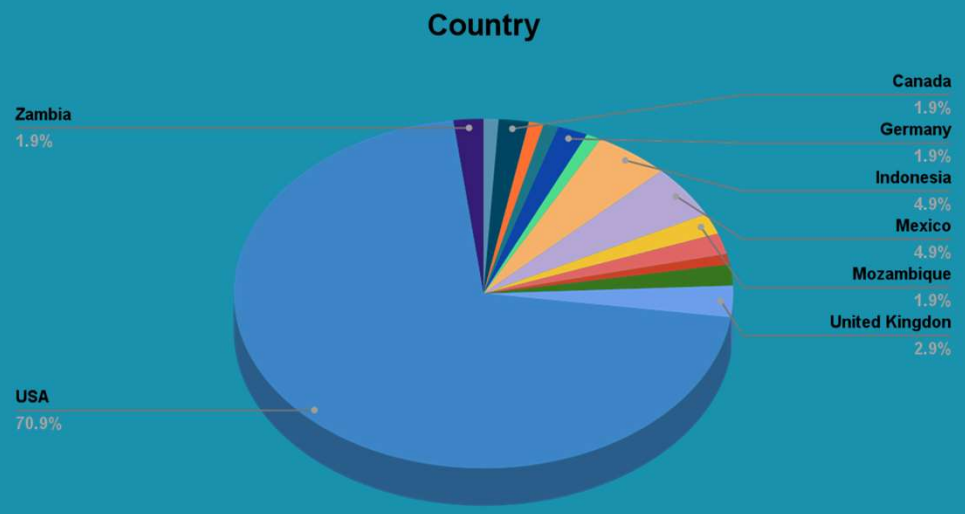
NASA CMS All Stakeholders





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NASA CMS Participants

TYPE (# unique)	US	UK/EU	Canada	Mexico	Brazil	Indonesia	Other	Total
University (105)	266	8	3	6	1	4	17	305
Federal Agency (34)	230	1	2	4	3	1	7	248
State Agency (24)	38							38
Local Agency (8)	12							12
Company (31)	31	1	2	2			4	40
NGO (14)	27					1		28
Research Institute (20)	29	1			1		14	45
Other (21)	18	2	1	1		1	3	26
Total	651	13	8	13	5	7	45	742

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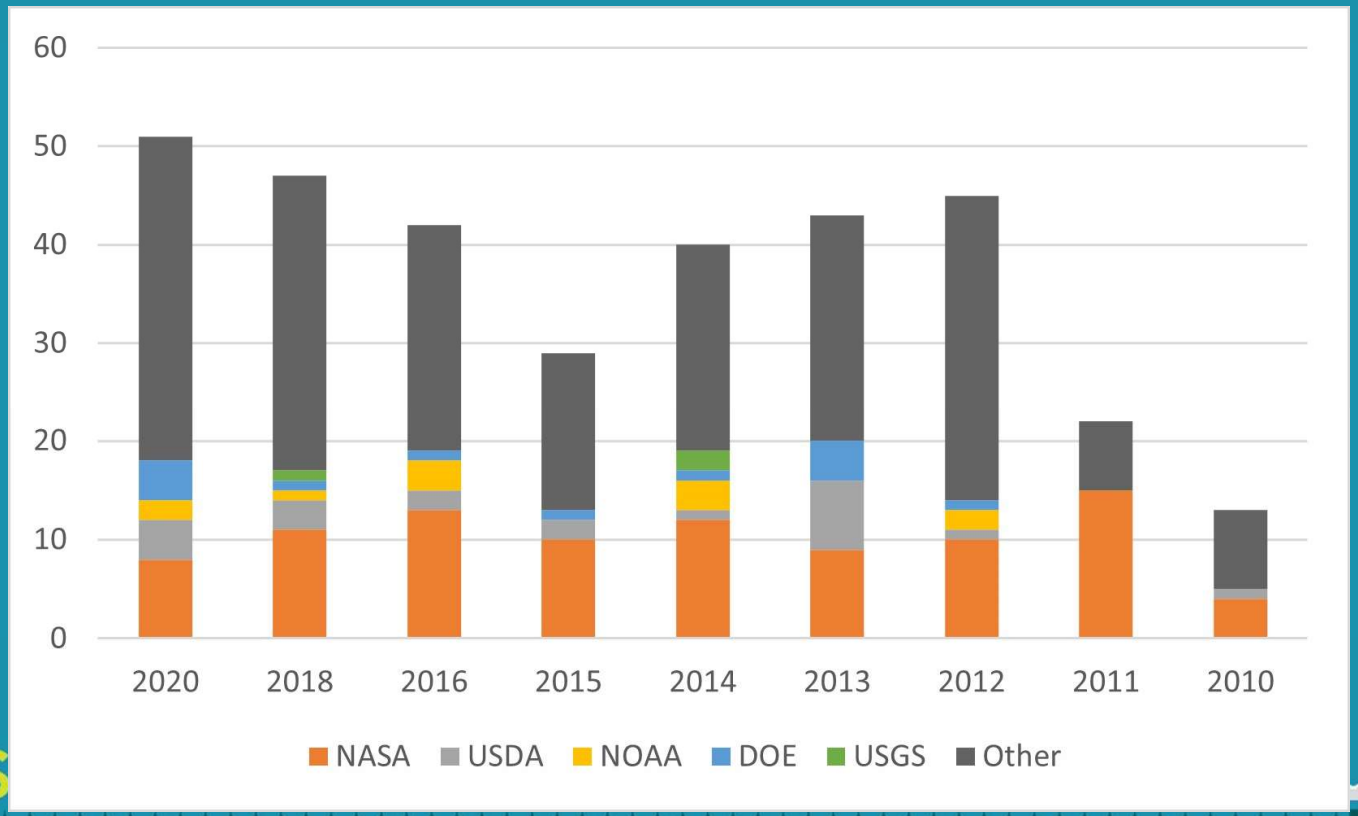
NASA CMS Science Team Members (Federal Agency)



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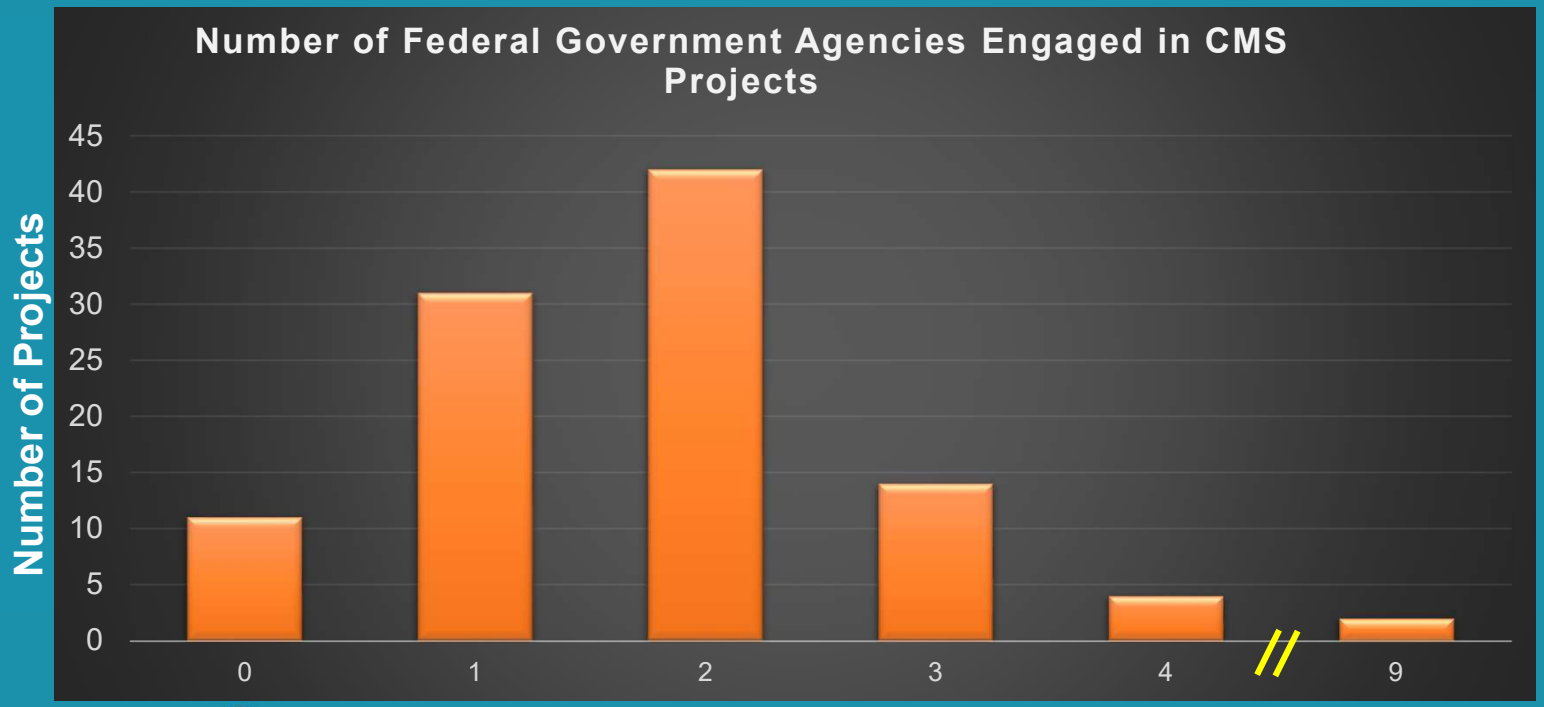
NASA CMS Participants (Federal Agency)



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Co-Sponsored By

Applied Earth Observations Innovation Partnership

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Our mission:

By connecting Earth observation science & technology experts with land management experts, we seek to increase awareness of new Earth Observation (EO) capabilities, as well as research and operational management challenges, in order to help formulate solutions through effective integration of data.

To support sustainable natural resource management, satellite data products must address key agency monitoring and assessment needs. A primary objective of the collaboration between NASA and the land management community is to identify decision-support needs, existing gaps in those needs and close those gaps.

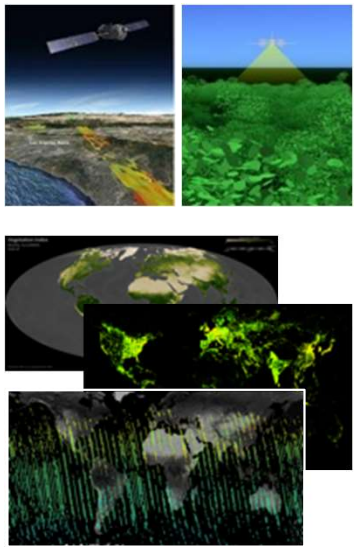
For more information: www.aeoip.com

Prototype: FROM DATA TO NEW INSIGHTS

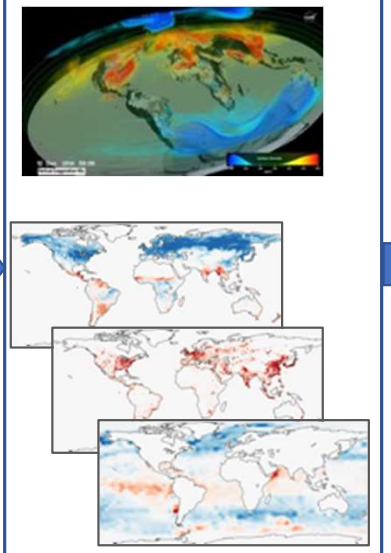
Examples of Data and Needs from Partners*

USDA NIST NOAA U.S. DEPARTMENT OF COMMERCE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Earth Observations



Modeling



GHG System Integration

Research & Applications

Leverages ESDS/ VEDA capabilities

Test bedding of modeling, integration approaches

Thorough evaluation of new observations before transition

Advanced users

End user system (Front End)

Leverages ESDS/VEDA

Public-facing

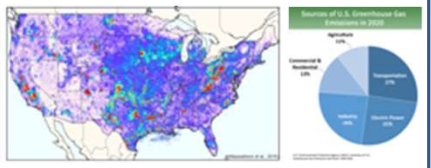
Curated, mature products representing consensus view

Science and non-science users

Enhanced help desk support

New Insights

Gridded anthropogenic emissions



Natural GHG Emissions

Detecting and tracking high emission events

Improvement of modeling, observing techniques

Incorporation of stakeholder needs and feedback

* Representative, but not comprehensive list

Examples of Data and Needs from Partners*

Prototype: FROM DATA TO NEW INSIGHTS

CMS
Pathway to innovation from research community

EIS
Open system focused on integration and testing of new approaches, Earth system understanding and discoveries

GHG Center
End-user driven, reliable delivery of mature GHG monitoring products and tools, enhanced support for stakeholder engagement

Earth Observations

Modeling

GHG System Integration

Research & Applications

Test bedding of modeling, integration approaches

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Summary and Foundation for Progress

- NASA CMS has produced one of the largest collections of applied carbon monitoring research to date.
- Key to this effort has been exploitation of the remote sensing and modeling expertise, collaboration with other agencies, and the end-to-end focus on stake-holder engagement to meet societal needs.
- Future carbon monitoring, therefore, should continue to expand on this approach while building toward system integration and end-user support. Success requires a strong foundation of ongoing relevant data, modeling, and engagement.
- Recent progress providing an overarching framework and encouraging more interagency coordination are very encouraging.

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https://carbon.nasa.gov