CMS APPLICATIONS EFFORTS OVERVIEW

Stakeholder feedback and engagement provides a link to science development, that helps a product move from a research effort…
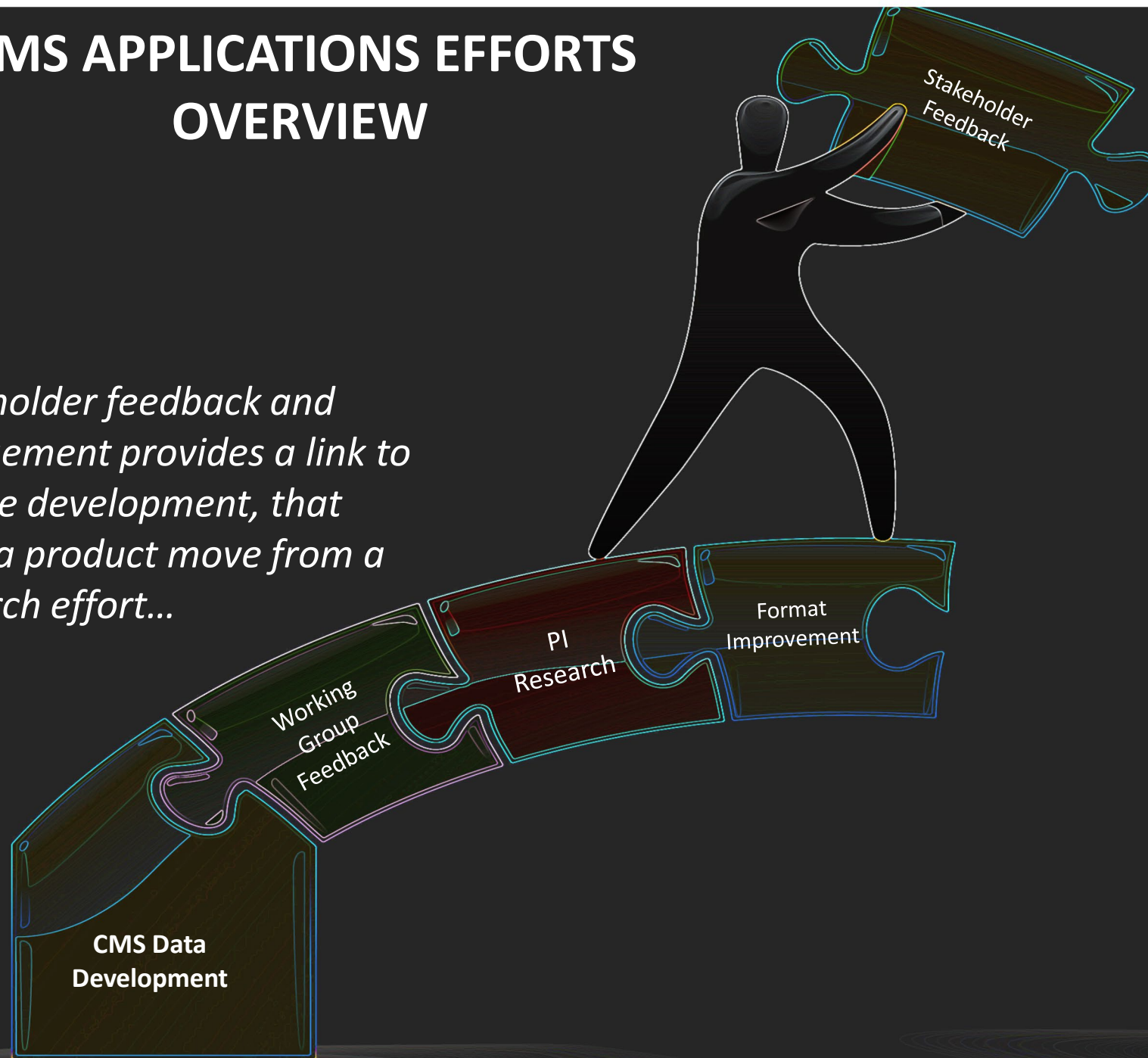
…to a user friendly decision support system

Stakeholder Feedback

Working Group Feedback

PI Research

Format Improvement

Lessons Learned

CMS Data Development

Improved Societal Applications

Goals of CMS Applications Efforts:

- Link Stakeholders to CMS science products.

- Provide a path for feedback and lessons learned for CMS PIs so CMS is more accessible and user friendly.

- Inform NASA HQ of the needs and requirements of the carbon science community.

- Leverage opportunities between NASA CMS and stakeholders in an effort to expand the knowledge and familiarity of CMS data products to help improve decision processes.

CMS Applications Program Framework

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.
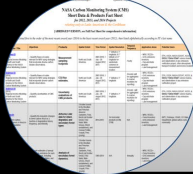
Application Readiness Levels (ARLs)

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.

Feedback to CMS Science Community and NASA HQ ESD

CMS Applications Efforts Examples. Tri-State Area Applications Workshop & Tutorial in Newtown Square, PA: CMS Application workshops and tutorials provide an opportunity for CMS Science Team members and stakeholders to engage on thematically detail objectives that help advance CMS science into appropriately scaled policy arenas.

ARL Refresher

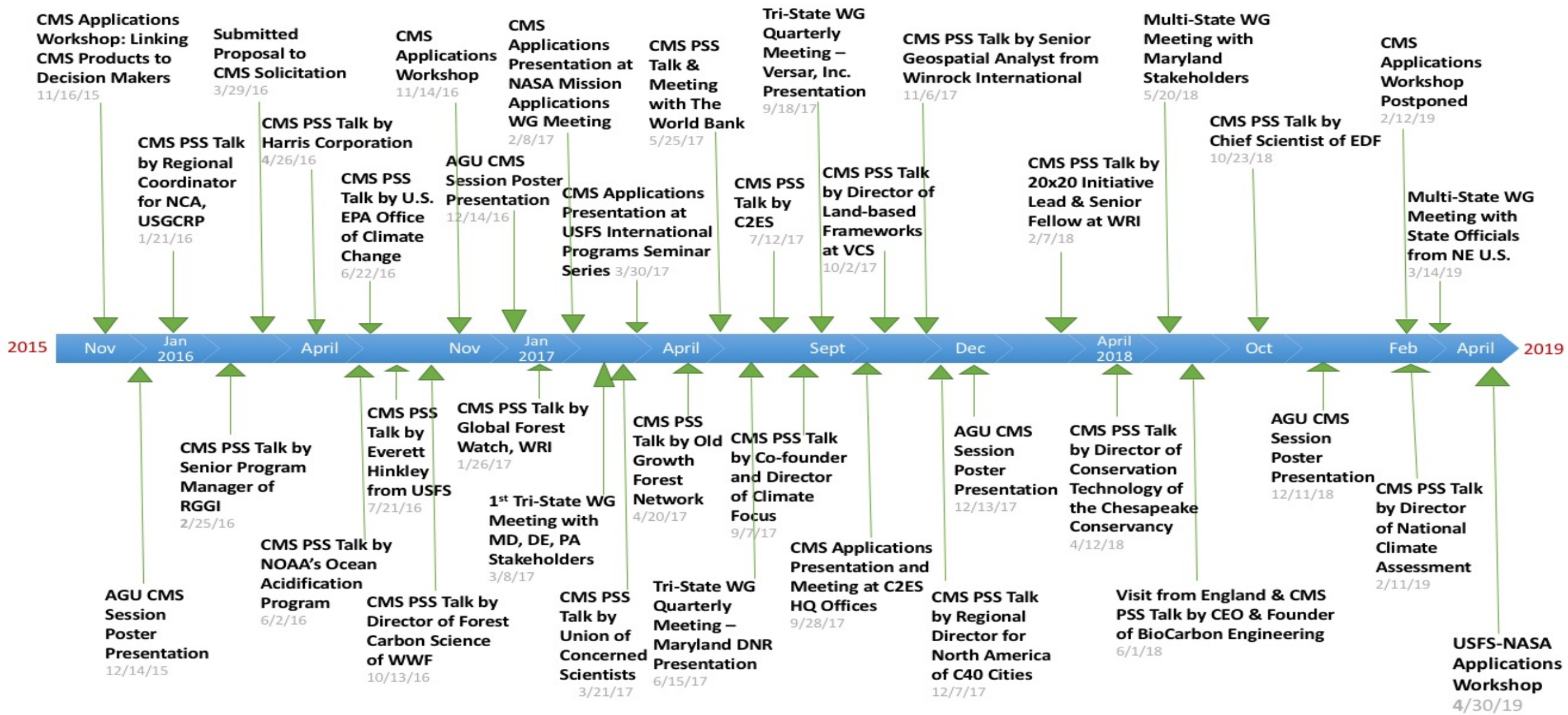| Phase	Stage	ARL	Description
PHASE III	Integration into Partner's System	ARL 9	Approved, Operational Deployment and Use in Decision Making (Sustained Use)
		ARL 8	Application Completed and Qualified (Functionality Proven)
		ARL 7	Application Prototype in Partner's Decision Making (Functionality Demonstrated)
PHASE II	Development, Testing, & Validation	ARL 6	Demonstration in Relevant Environment (Potential Demonstrated)
		ARL 5	Validation in Relevant Environment (Potential Determined)
		ARL 4	Initial Integration and Verification (Prototype/Plan)
PHASE I	Discovery & Feasibility	ARL 3	Proof of Application Concept (Viability Established)
		ARL 2	Application Concept (Invention)
		ARL 1	Basic Research (Baseline Ideas)

- Serve as a guide to user community

- Set expectations to user on how to use products and what feedback to provide

- ARL designated by the CMS PI

- Update as needed

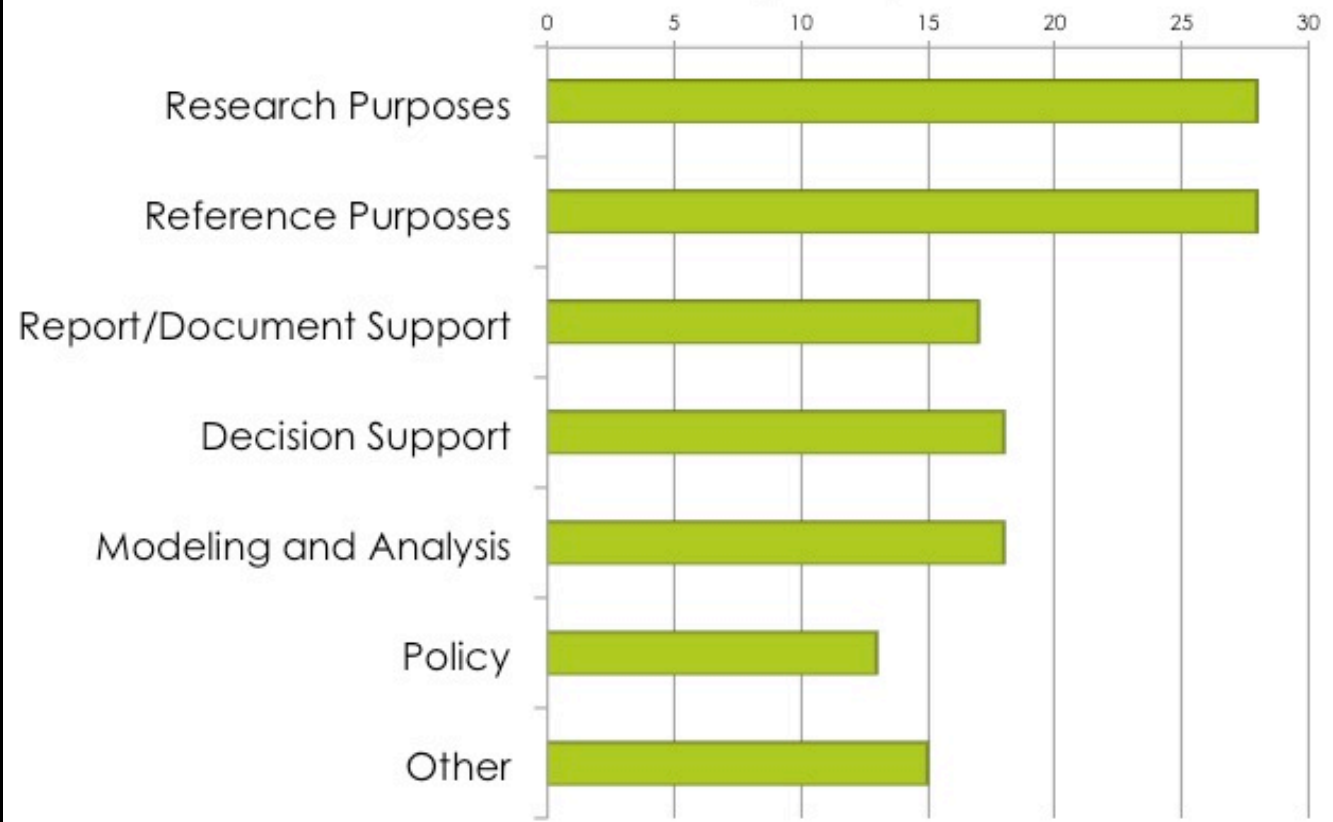- Intended to guide HQ and user community on the maturity of products

Timeline of CMS Applications Efforts & Activities 2015-19

CMS Applications Workshop: Linking CMS Products to Decision Makers
11/16/15

Submitted Proposal to CMS Solicitation
3/29/16

CMS PSS Talk by Harris Corporation
4/26/16

CMS Applications Workshop
11/14/16

CMS Applications Presentation at NASA Mission Applications WG Meeting
2/8/17

CMS PSS Talk & Meeting with The World Bank
5/25/17

Tri-State WG Quarterly Meeting – Versar, Inc. Presentation
9/18/17

CMS PSS Talk by Senior Geospatial Analyst from Winrock International
11/6/17

Multi-State WG Meeting with Maryland Stakeholders
5/20/18

CMS Applications Workshop Postponed
2/12/19

CMS PSS Talk by Regional Coordinator for NCA, USGCRP
1/21/16

AGU CMS Session Poster Presentation
12/14/16

CMS PSS Talk by U.S. EPA Office of Climate Change
6/22/16

CMS Applications Presentation at USFS International Programs Seminar Series 3/30/17

CMS PSS Talk by C2ES
7/12/17

CMS PSS Talk by Director of Land-based Frameworks at VCS
10/2/17

CMS PSS Talk by 20x20 Initiative Lead & Senior Fellow at WRI
2/7/18

CMS PSS Talk by Chief Scientist of EDF
10/23/18

Multi-State WG Meeting with State Officials from NE U.S.
3/14/19

2015 Nov | Jan 2016 | April | Nov | Jan 2017 | April | Sept | Dec | April 2018 | Oct | Feb | April **2019**

AGU CMS Session Poster Presentation
12/14/15

CMS PSS Talk by Senior Program Manager of RGGI
2/25/16

CMS PSS Talk by NOAA's Ocean Acidification Program
6/2/16

CMS PSS Talk by Everett Hinkley from USFS
7/21/16

CMS PSS Talk by Director of Forest Carbon Science of WWF
10/13/16

CMS PSS Talk by Global Forest Watch, WRI
1/26/17

1st Tri-State WG Meeting with MD, DE, PA Stakeholders
3/8/17

CMS PSS Talk by Union of Concerned Scientists
3/21/17

CMS PSS Talk by Old Growth Forest Network
4/20/17

Tri-State WG Quarterly Meeting – Maryland DNR Presentation
6/15/17

CMS PSS Talk by Co-founder and Director of Climate Focus
9/7/17

CMS Applications Presentation and Meeting at C2ES HQ Offices
9/28/17

CMS PSS Talk by Regional Director for North America of C40 Cities
12/7/17

AGU CMS Session Poster Presentation
12/13/17

CMS PSS Talk by Director of Conservation Technology of the Chesapeake Conservancy
4/12/18

Visit from England & CMS PSS Talk by CEO & Founder of BioCarbon Engineering
6/1/18

AGU CMS Session Poster Presentation
12/11/18

CMS PSS Talk by Director of National Climate Assessment
2/11/19

USFS-NASA Applications Workshop
4/30/19

CMS Stakeholder Survey for Science Team

How are stakeholders using CMS products?

- Research Purposes
- Reference Purposes
- Report/Document Support
- Decision Support
- Modeling and Analysis
- Policy
- Other

21 PIs responded
47 stakeholders identified

- Main stakeholders: US EPA, USDA Forest Service, NOAA, CA ARB
- Not all stakeholders are using CMS data products at this moment
- All products, be research or operational products, have feedback potential

Stakeholders engaged by CMS Applications Efforts through Applications Workshops, Policy Speaker Series, and other engagement activities

The overarching objective of the applications effort is to broaden and strengthen the knowledge and engagement of the research and applications communities within the Carbon Monitoring System (CMS) Initiative.

Data Products & Applications Highlights

CMS Data Products

81 Projects
170+ Data Products
Local to international scale

Aboveground biomass maps
30m Spatial Resolution
Status: Archived

Tree canopy cover map
1m Spatial Resolution
Status: Archived (some states) and In-Progress

Mangrove canopy height
1m Spatial Resolution
Status: Partially Archived

Maps of annual deforestation
30m Spatial Resolution
Status: In-Progress

Aboveground Biomass, Landcover and Degradation for Kalimantan
1-ha grid cells Spatial Resolution
Status: Archived

FOREST CANOPY HEIGHT
Lorey's Mean (meters)
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50

Global forest canopy height (Healey, 2015)
Archived at ORNL DAAC

Available at: https://doi.org/10.3334/ORNLDAAC/1271

Overview of CMS Data Products

- Where can CMS datasets be found?

Metadata Fields	Explanation
Award Year	The year the funding was granted
Project ID	Principal Investigator's last name and project #
Objectives	Goals that the project seeks to attain by developing data and products
Science Theme	Type of data and products, according to components of carbon cycle research that are most relevant: Global Flux, Ocean-Atmosphere Flux, Land-Atmosphere Flux, Land-Ocean Flux, Land Biomass, Ocean Biomass, Lake Biomass, MRV, and Decision Support
Products Keywords	Keywords that will help stakeholders identify data and products appropriate to their needs. See below for a table that explains each product keyword.
Data Products	A description of output data and products that will be publicly available upon completion of the project
Spatial Extent	The geographical area that the data and products cover
Coordinates	Coordinates can be approximate. They can be the center of Spatial Extent or study sites. Shape files are welcome.
Time Period	The time period that the data and products cover
Spatial Resolution	Finest spatial resolution of data and products
Temporal Frequency	Time intervals of data products
Input Data Products	Any satellite, airborne, field, and modeled data products used. If airborne Lidar data was used, please indicate where, when, which instruments, and how much data (area, dimensions, or number and length of lines).
Algorithm/Models Used	Any algorithm or models used to develop data and products
Evaluation	Any efforts to evaluate the accuracy, robustness, and/or performance of data and products
Intercomparison Efforts/Gaps	Any key intercomparison effort(s) that have been undertaken or gaps where future intercomparison efforts are warranted
Uncertainty Estimates	Plans to quantify data uncertainty, if any
Uncertainty Categories	1. Ensemble (e.g. stochastic), 2. Deterministic, 3. Model-Data Comparison, 4. Model-Model Comparison, and/or 5. Data-Data Comparison
Application Areas	Areas with policy or societally relevant decision processes, which may benefit from the usage of data and products
Potential Users	Possible end users of data and products once fully developed
Stakeholders	End users engaged with CMS PIs who are using or plan to use data and products in the future
Application Readiness Level (ARL)	The NASA index that assesses applications potential of data and products in operational settings. Detailed explanation. Principal Investigators specified the ARLs of their own projects
Future Developments	Future plans to engage stakeholders, share data and products, and raise awareness of the product development efforts
Limitations	Any shortcoming of data and products that users must be aware of
Date When Data/Product Available	The date (MM/DD/YY - if possible) on which data and products will be made publicly available
Data Server URL	The URL address where a user may access data and products
Metadata URL	The URL address where a user may access metadata

CMS: Forest Carbon Stocks, Emissions, and Net Flux for the Conterminous US: 2005-2010
PI: Sassan Saatchi, NASA JPL

Description: This data set provides maps of estimated carbon in forests of the 48 continental states of the US for the years 2005-2010.

Spatial Coverage: Conterminous USA (CONUS)

Spatial Resolution: 100-m resolution and county level
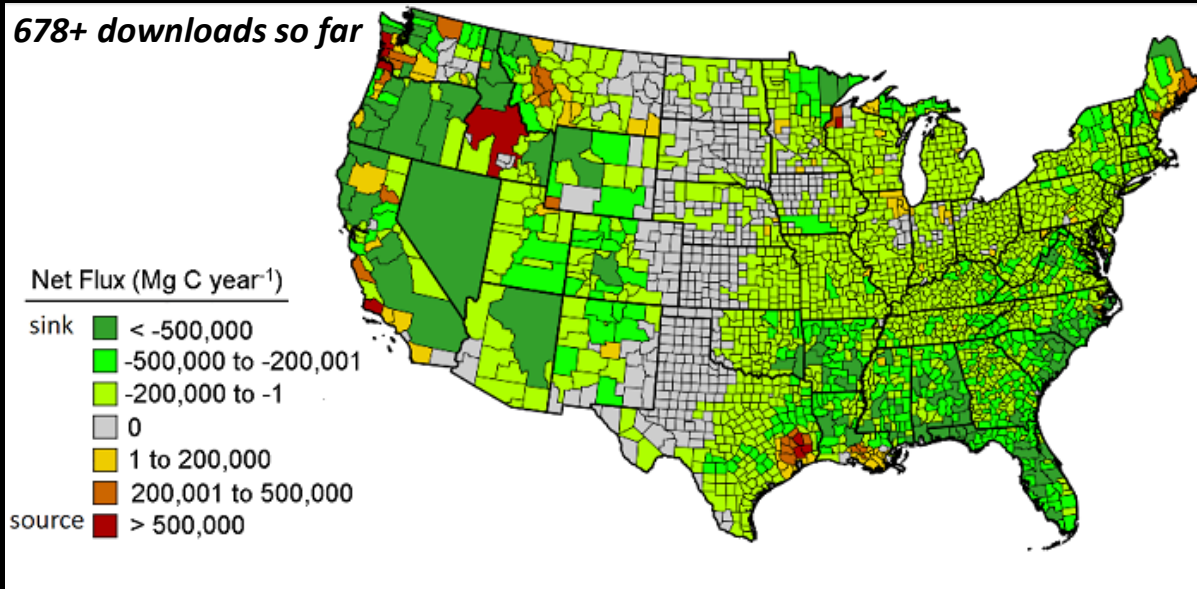
Temporal Coverage: 2005 - 2010

Temporal Resolution: Annual

ARL: 7

Users & Purpose: used extensively within the science community for reference purposes, and USFS has already used the data for validation of spatial variation of carbon for couple of states

678+ downloads so far

Average annual committed net carbon flux (Mg C/yr) at the combined country scale (from Hagen et al.)

USFS Potential Applications:
- A land manager at a regional level could use these data products to gain insight into changes in carbon in their regional forests
- Prioritization of forest management and land use policies
- Plan by the USFS to include this methodology for Mexico and other countries with limited or no national inventory approaches
- New IPCCC guidelines about the use of RS data for carbon accounting

Limitations & Future Work: Limitations include reduced (a) spatial resolution of logging information (only at combined county-level) and (b) limited temporal resolution (5-year increment). Working to resolve limitations: moving to annual carbon mapping, and extending some of the products to Alaska.

Lidar-Derived Aboveground Biomass and Uncertainty for California Forests, 2005-2014

PI: Jonathan Greenberg, University of Nevada, Reno

Description: This dataset provides estimates of aboveground biomass and spatially explicit uncertainty from 53 airborne LiDAR surveys of locations throughout California between 2005 and 2014.

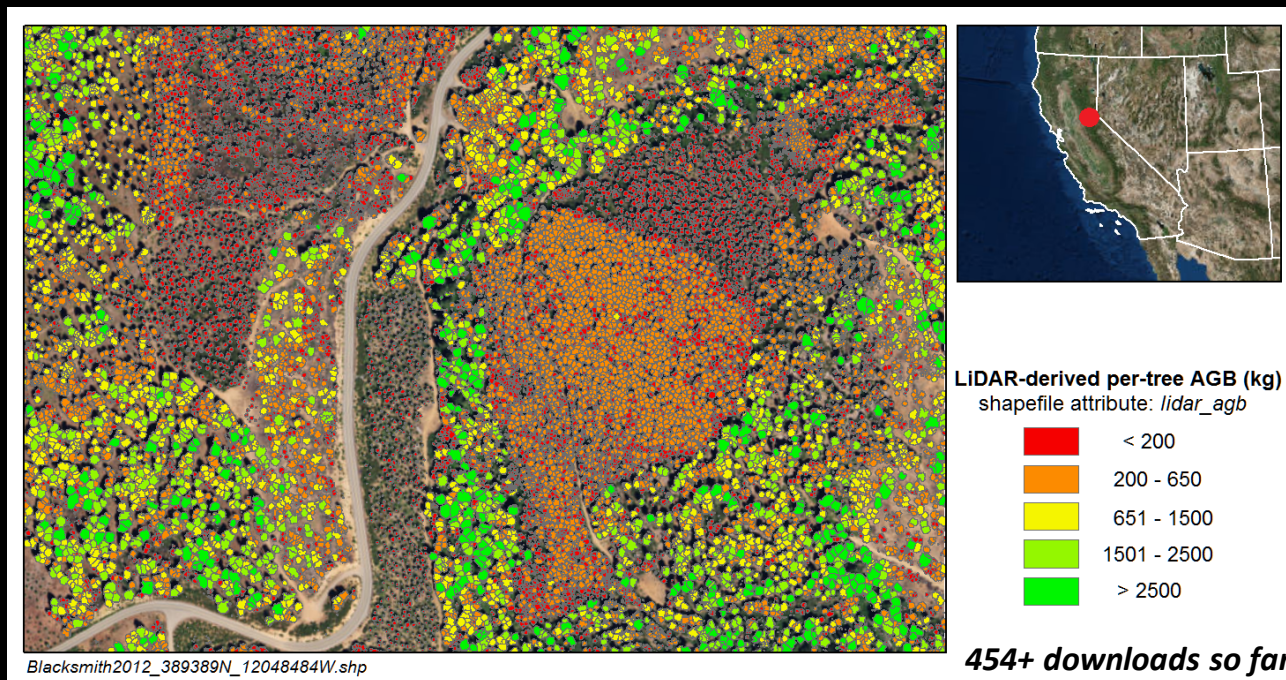**Spatial Coverage**: Surveyed areas throughout California

Spatial Resolution: 30-m*

Temporal Coverage: 2005 - 2014

Temporal Resolution: Once

ARL: 4

Users: Carlos Ramirez from USDA Forest Service

LiDAR-derived per-tree AGB (kg)
shapefile attribute: *lidar_agb*

🟥	< 200
🟧	200 - 650
🟨	651 - 1500
🟩	1501 - 2500
🟢	> 2500

Blacksmith2012_389389N_12048484W.shp

454+ downloads so far

Per-tree aboveground biomass (kg) derived from LiDAR-measured tree heights for the Blacksmith site in 2012 (from Blacksmith2012_389389N_12048484W.zip).

USFS Potential Applications:
 - Aboveground biomass is an important metric for assessing carbon sequestration in forests.

CMS: LiDAR-derived Biomass, Canopy Height and Cover, Sonoma County, California, 2013
PI: Ralph Dubayah, University of Maryland

Description: This data set provides estimates of above-ground biomass (AGB), canopy height, and percent tree cover at 30-m spatial resolution for Sonoma County, California, USA, for the nominal year 2013.

**Spatial Coverage**: Sonoma County, CA, USA

Spatial Resolution: Grid cells at 30-meter resolution

Temporal Coverage: 2013

Temporal Resolution: One time

ARL: 9

Users & Purpose: The products have supported all facets of **Sonoma County Agricultural Preservation and Open Space District's** work: field reconnaissance, conservation planning and prioritization, conservation easement design, easement monitoring and enforcement, and fee land management.

377+ downloads so far
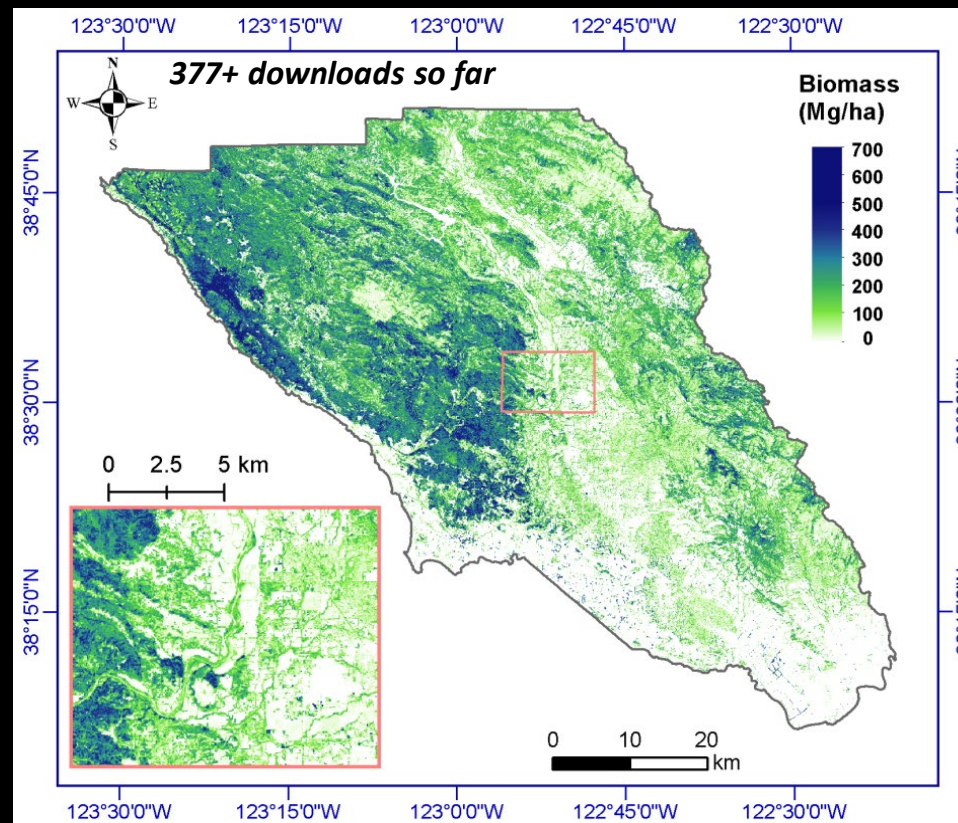
Estimated aboveground biomass (Mg/ha) for Sonoma County at 30-m spatial resolution using the random forest method. Zoom-in figure is a subset near Santa Rosa, the largest city in California's North Coast.

USFS Potential Applications:
-Habitat mapping and modeling
-Forest inventorying
-As an input to wildfire modeling/fuel modeling
-Disease hazard/risk

Feedback from Stakeholders – Successes:
- The data are being used widely, for applications in forest management, disaster response, education and outreach, scientific research, conservation, among others.
- Survey showed that 13 out of 59 respondents indicated that the data are mission critical or very important; and 33 indicated that they are important or nice to have.
- These data are being used to map priority areas for land conservation, and enable Ag + Open Space and their conservation partners to write competitive grant proposals and to demonstrate the value of habitat protection to our community and funders.

LiDAR-derived Biomass, Canopy Height and Cover for Tri-State (MD, PA, DE) Region, V2
PI: George Hurtt, University of Maryland

Description: This dataset provides 30-meter gridded estimates of aboveground biomass (AGB), forest canopy height, and canopy coverage for Maryland, Pennsylvania, and Delaware in 2011. **ARL:** 9

Spatial Coverage: Maryland, Pennsylvania, Delaware

Spatial Resolution: 30-meter or 90-meter

Temporal Coverage: 2004 – 2014

Temporal Resolution: Annual

Users in Maryland	Purpose
Maryland Department of Natural Resources	- Using the CMS forest cover layer in their ecosystem service valuation work, and to develop the state forest carbon sequestration map - Also looking into ways that CMS can inform the state's forestry and sequestration sector, and help achieve the goals of the Greenhouse Gas Reduction Act
Maryland Forest Service	- Habitat location analyses for Golden Wing Warbler - Estimating the amount of stream buffer by county - Various metrics for a multitude of smaller projects
Maryland Department of the Environment	- Modeling land cover in the Chesapeake Bay model
Baltimore City Department of Recreation & Parks (TreeBaltimore Partnership)	- To monitor Urban Tree Canopy goals in the city
The Nature Conservancy	- Map 'mature' forest, prioritize locations for forest inventory and inform restoration projects - Looking at forest connectivity for climate resilience in the central Appalachian portion of western Maryland
Queen Anne's, Baltimore, Worcester, Caroline, and Talbot Counties	- For use in routine planning

382+ downloads so far

Aboveground biomass (Mg ha-1) at 30-m resolution for the tri-state region of Maryland, Pennsylvania, and Delaware in 2011.

Biomass (Mg/ha)

360 320 280 240 200 160 120 80 40 0
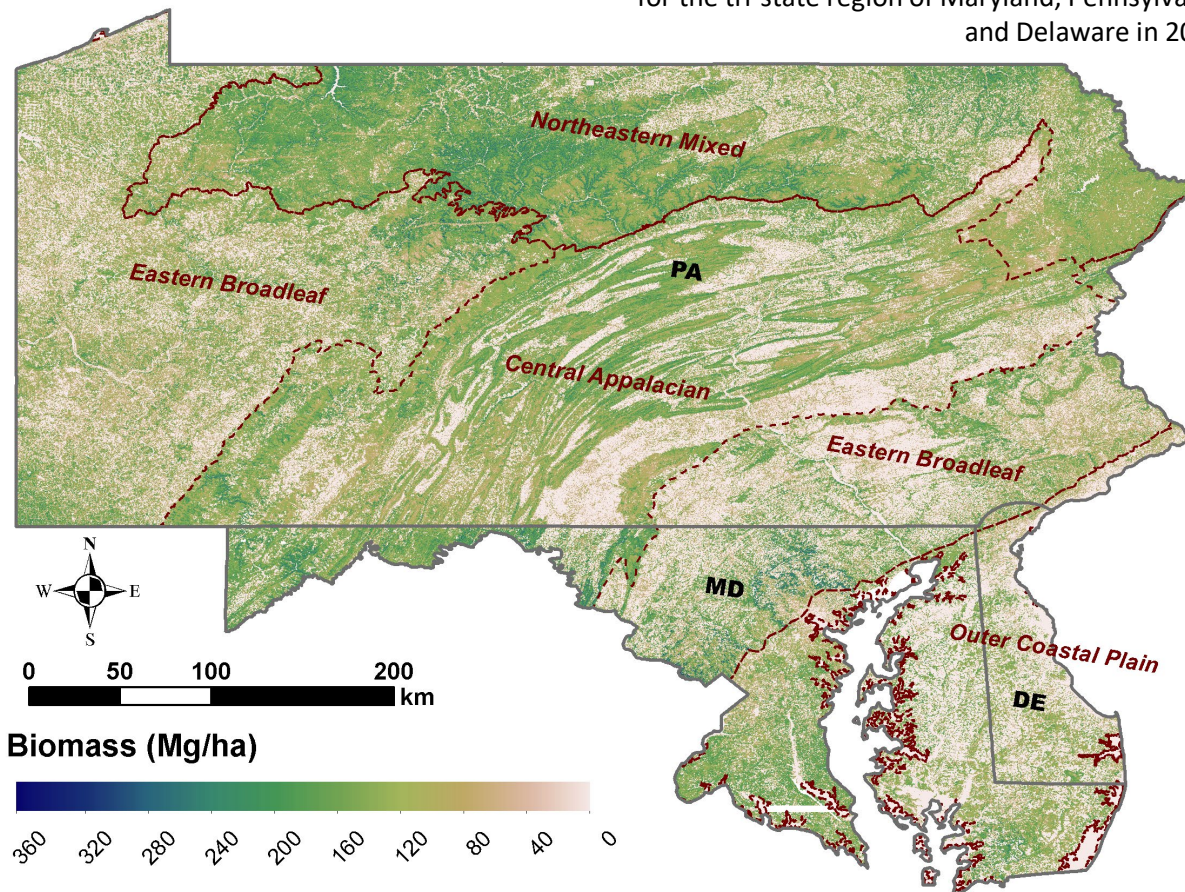
National Scale Forest Disturbance Map
PI: Christopher Williams, Clark University

Description: 30-m resolution map with moderate to high intensity harvesting, bark beetle outbreaks, and wildfires, including year of disturbance, and for beetle outbreak and fire disturbances

Spatial Coverage: Conterminous USA (CONUS)
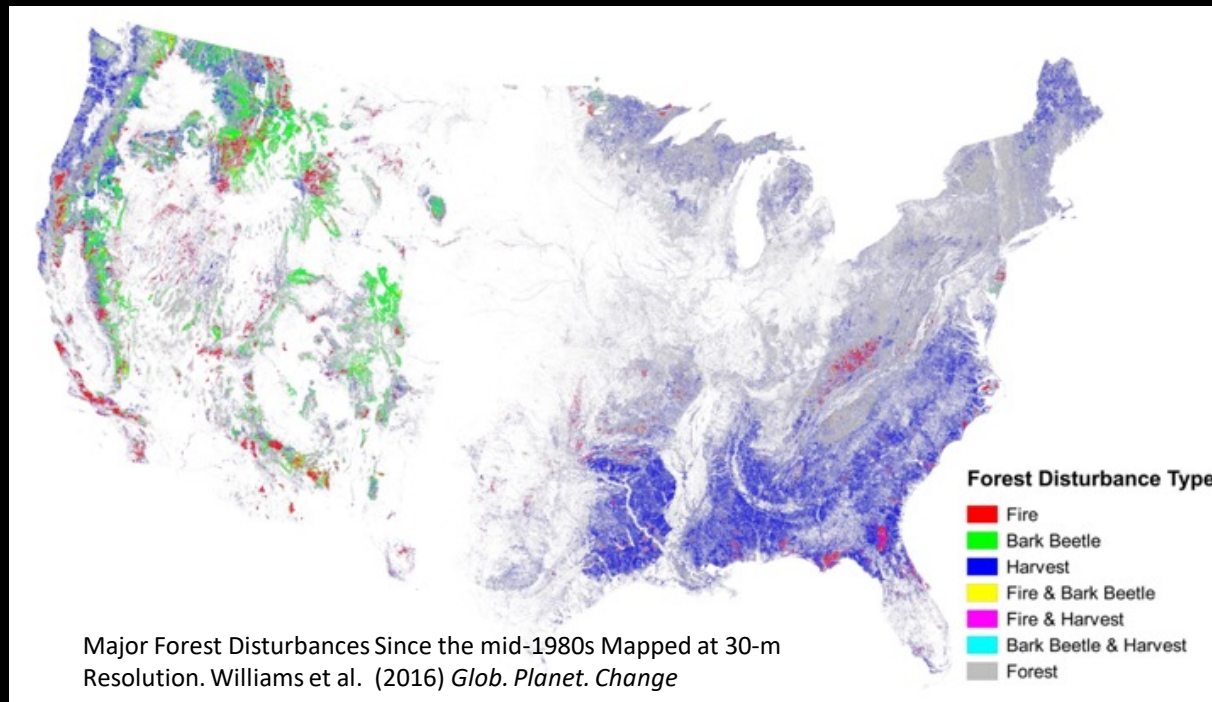
Spatial Resolution: 30-m resolution

Temporal Coverage: 1986 - 2010

Temporal Resolution: Annual

ARL: 7

Users & Purpose: TNC and the Climate Alliance have used / are using this dataset to assess opportunities for afforestation/reforestation as a natural climate solution pathway

Major Forest Disturbances Since the mid-1980s Mapped at 30-m Resolution. Williams et al. (2016) *Glob. Planet. Change*

Forest Disturbance Type
- Fire
- Bark Beetle
- Harvest
- Fire & Bark Beetle
- Fire & Harvest
- Bark Beetle & Harvest
- Forest

USFS Potential Applications:
- To assess forest carbon uptake rates in diverse climate and forest type settings
- To assess the sustainability of timber resource management at state to regional levels
- To perform regional to national scale UNFCCC National Inventory Reporting
- To assess disturbance threats to US forests and impacts on the carbon balance of forested landscapes
- To assess the potential climate benefits of afforestation/reforestation
- To perform full forest sector carbon balance accounting

Limitations: (1) attribution to disturbance type (harvest, fire, beetle outbreaks, wind, other) remains far from perfect – collaborators should be developing better alternatives; (2) partial disturbance events are likely to be missing, including modest severity tree mortality events of scale smaller than 60 m x 60 m

Aboveground Biomass Maps for NW USA, 2000-2016
PI: Andrew Hudak, USDA Forest Service

Description: AGB wall-to-wall maps and lidar-based AGB maps for NW United States.

Spatial Coverage: Northwestern U.S. (WA, OR, ID)

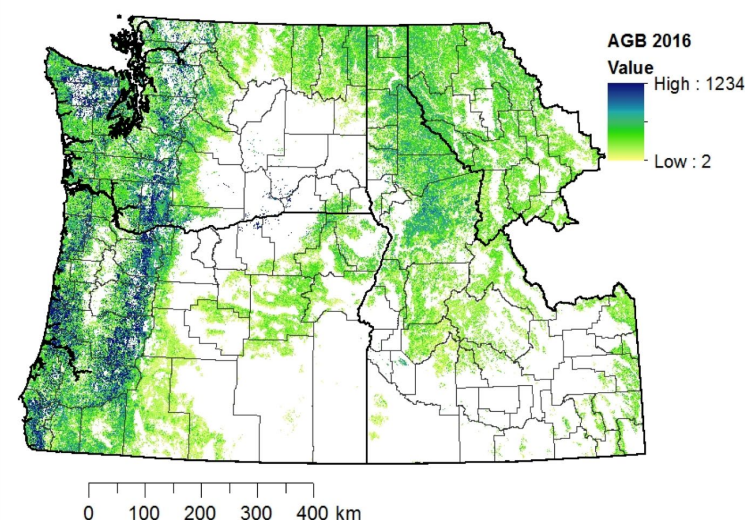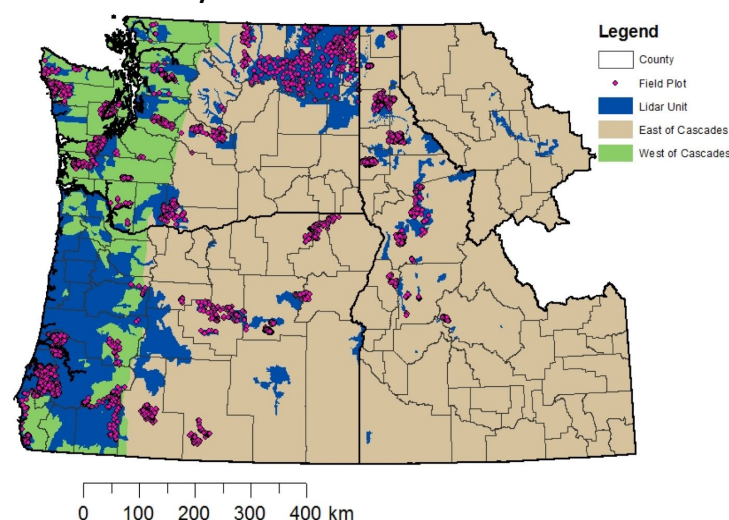**Spatial Resolution: 30**-m

Temporal Coverage: 2000 – 2016

Temporal Resolution: Annual

ARL: 5

Users & Purpose: Northwest Management, Colville Tribe in WA, USFS Idaho Panhandle National Forest in ID for forest level analysis/management

Hudak CMS Study Area

Legend
- County
- Field Plot
- Lidar Unit
- East of Cascades
- West of Cascades

AGB 2016 Value — High : 1234, Low : 2

2016 AGB wall-to-wall map from Landsat time series (2000-2016) processed through LandTrendr (Kennedy et al. 2010)

USFS Potential Applications:
- Wall-to-wall AGB maps would provide sufficient information for forest level analysis/management; Lidar-based AGB maps would be preferred for project level analysis
- Can help in the development of the Five-Year-Action-Plan (5-YAP) (e.g. USFS Region 4 & 6)
- Forest management for carbon sequestration

Lessons Learned: The needs and objectives of forest managers will remain local, centered on the lands they are charge to manage; because lidar is so informative for multiple natural resource management objectives, we can expect demand for lidar-derived products will continue, regardless of political priorities.

Highlighting Relevant CMS Tools for USFS
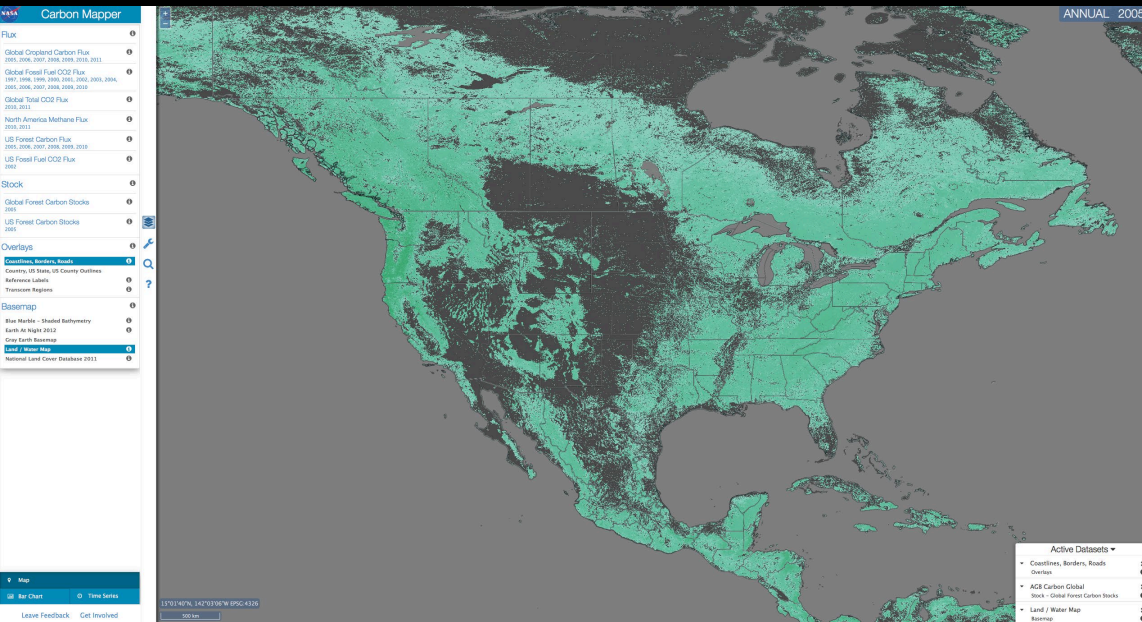
Carbon Mapper
PI: Riley Duren, NASA JPL
Description: a prototype data portal and analysis tool, which provides a common platform for visualizing information contained in selected CMS data sets.

WFEIS Online Modeling Tool, PI: Nancy French
Products for CMS were developed with the tool

AREA² developed by CMS PI Pontus Olofsson, BU

Discussion Questions for Workshop

- What are your carbon data needs and interests?

- What are some positive aspects of CMS data for your work?

- What scientific advancement(s) could contribute to your work?
    - What data do you need? When? Be as specific as possible.

- Are there any improvements that can be made short term? Accessibility, time domain, spatial scale, and frequency of data updates?

- What are other success stories you can share from partnerships/collaborations between NASA and USFS?

- What are some ongoing or planned USFS initiatives in which CMS could contribute data and/or expertise?

- Would you be interested in presenting at the CMS Policy Speaker Series, or other CMS Applications events?

- Any other feedback, ideas, and suggestions on stakeholders to engage, or activities to include in our efforts?

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