Welcome!

We are meeting on the traditional territory of the Kumeyaay people who have lived in this region for more than 10,000 years. The Kumeyaay Nation extends from San Diego and Imperial Counties in California to 60 miles south of the Mexican border.

Source:

https://native-land.ca/maps/territories/kumeyaay/

https://www.kumeyaay.com/about.html

Code of Conduct

- Effective w ROSES 19: A code of conduct is required for all NASA missions, meetings, and conferences
- NASA HQ leadership and the staff of the Carbon Cycle & Ecosystems Office are committed to providing safe, welcoming, and productive environments in the field and the lab, and at meetings and conferences, and have adopted the American Geophysical Union Meetings Code of Conduct. This Code includes information on expected behavior, unacceptable behavior, and consequences.
- If you have any concerns or need an ally, please contact Mike Falkowski, Peter Griffith, Libby Larson, Megan McGroddy, or Jessica Bussard

NASA Carbon Monitoring System Overview

George Hurtt

NASA-CMS Science Team Leader
Department of Geographical Sciences
University of Maryland
gchurtt@umd.edu

Congressional Direction (Summary)

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 development of a carbon monitoring system. Any pilot developed shall replicate state and national carbon and bio
at t
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…"pilot initiatives for the development of a carbon monitoring system…"

Cor

Nor

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

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…"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…."

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

Congressional Direction in 2014:

Carbon Monitoring- Of the funds provided within the Earth Science research and analysis activity, the Committee recommends $10,000,000 to continue efforts for the development of a carbon monitoring system. The majority of the funds should be directed toward acquisition, field sampling, quantification, and 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. The Committee is concerned that NASA

NASA-CMS Phase 1

Biomass Pilot. *The goals of the Biomass Pilot are to:*

- Utilize satellite and in situ data to produce quantitative estimates (and uncertainties) of aboveground terrestrial vegetation biomass on a national and local scale.
- Assess the ability of these results to meet the nations need for monitoring carbon storage/sequestration.

Flux Pilot. *The objectives of the Flux Pilot are to:*

- Combine satellite data with modeled atmospheric transport initiated by observationally-constrained terrestrial and oceanic models to tie the atmospheric observations to surface exchange processes.
- Estimate the atmosphere-biosphere CO_2 exchange.

Scoping Efforts. *The objectives of the Scoping Efforts are to:*

- Identify research, products, and analysis system evolutions required to support carbon policy and management as global observing capability increases.

National Aeronautics and Space Administration

NASA Carbon Monitoring System

Global Surface-Atmosphere Flux

2011: 2
2013: 3 (2)
2014: 1 (1)
2015: 1 (1)
2016: 2
2018: 2

Land-Atmosphere Flux

2011: 6 (5)
2013: 8 (6)
2014: 2 (2)
2015: 12 (10)
2016: 8 (4)
2018: 3

Land Biomass

2011: 7 (5)
2013: 9 (9)
2014: 9 (7)
2015: 7 (5)
2016: 8 (8)
2018: 6

Ocean-Atmosphere Flux

2011: 1
2016: 1

Ocean Biomass

2011: 3
2016: 1
2018: 3

Land-Ocean Flux

2011: 1
2014: 1 (1)

CMS Solicitation year:

2011: 20
2013: 17
2014: 15
2015: 15
2016: 14
2018: 15

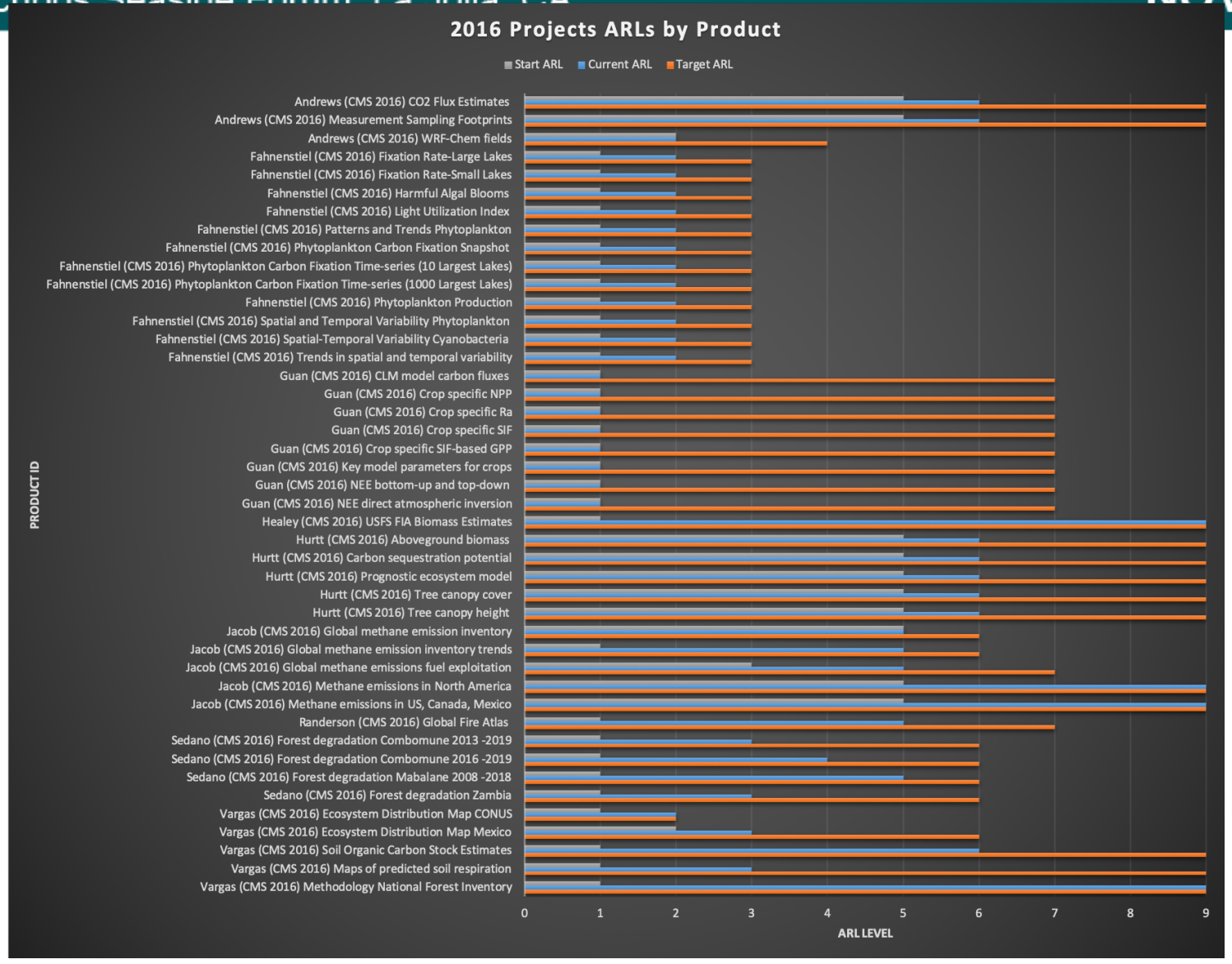
Solicitation Year and Themes Addressed

Year	Land biomass	Ocean biomass	Land-Atmos. Flux	Ocean-Atmos. Flux	Land-Ocean Flux	Global Flux	Decision Support	MRV	Atmos. Transport
2010	20%	20%	20%	40%	40%	20%	0%	0%	0%
2011	45%	15%	55%	30%	5%	10%	35%	15%	15%
2013	76%	0%	71%	0%	0%	0%	18%	82%	12%
2014	67%	0%	89%	27%	20%	20%	60%	80%	27%
2015	53%	0%	73%	0%	0%	7%	20%	100%	13%
2016	57%	7%	57%	7%	0%	14%	7%	50%	14%
2018	40%	13%	20%	0%	0%	13%	7%	60%	0%

Participants by Organization Type and Country

TYPE (# unique)	US	Can	UK/EU	Brazil	Mexico	Gabon	Indonesia	Total
University (43)	82	1	3	1	3		1	91
National (19)	102		2	2	1	1		108
State (2)	3							3
Private (11)	16		1					17
NGO (7)	10			1	2			14
Total	**213**	**1**	**7**	**3**	**7**	**1**	**1**	**233**

CMS Application Readiness Levels (ARLs)



NASA Application Readiness Levels (ARLs)

ARLs describe where the CMS product is currently in terms of readiness, as well as the desired and potential level as defined by the CMS Product Scientist.

The ARLs were provided by the CMS Product Scientist and represent the most accurate representation of the state of each product.

Products can start at any level. It is not expected they will start at ARL1 and end at ARL9.

CMS Products and Policy Support Examples

CMS PI and Product	Organization & POC	Policy of Interest
Fatoyinbo (CMS 2016) Global mangrove distribution, biomass, and canopy height	**USDA Forest Service**, Carl Trettin	REDD+, Le Gabon Emergent, Gabon Forest Carbon Assessment, Silvacarbon, GEO-FCT
Hudak (CMS 2014) Aboveground biomass maps	**Northwest Management, Inc.**, Mark Corrao	Forest Vegetation Simulator (FVS), SilvaCarbon, REDD+, NACP, IPCC
Hurtt (CMS 2016) Aboveground biomass maps, canopy height and forest/non-forest maps, land cover maps	**Maryland Department of Natural Resources**, Elliott Campbell	FIA, Federal Land Policy and Management Act (FLPMA), Maryland Greenhouse Gas Emissions Reduction Act Plan, Maryland Climate Action Plan, Chesapeake Bay TMDL, Maryland Forest Preservation Act, Maryland No Net Forest Loss Act, Climate Framework for Delaware, Forest Legacy Program, Pennsylvania Climate Change Act, TreeVitalize Program
Jacob (CMS 2016) Gridded inventory of North American methane emissions	**U.S. EPA**, Bill Irving	Global Climate Change and Clean Air Initiative of the US State Department, Global Methane Initiative of the US EPA, CAA, NGHGI, President Obama's Climate Action Plan (CAP), NALS, national methane inventory reports to UNFCCC
Windham-Myers (CMS 2014) Maps of coastal wetland carbon stocks	**U.S. EPA**, Tom Wirth	REDD+, NGHGI, Global Methane Initiative of the US EPA, Blue Carbon Initiative, Coastal Wetland Planning, Protection, and Restoration Act, NOAA Habitat Restoration Monitoring

CMS Products and Policy Support Examples Con't

CMS PI and Product	Organization & POC	Policy of Interest
Cochrane (CMS 2015 & 2018) Estimates of burned area, land cover changes, peat fire-related emissions, timing of fire activity	**Indonesia Ministry of Environment and Forestry**, Israr Albar **Indonesia's Peatland Restoration Agency**, Asmadi Saad	REDD+, Indonesian National Carbon Accounting System (INCAS), Mega Rice Project (MRP), NFMS, US-Indonesia Partnership, Indonesia-Australia Forest Carbon Partnership, Doha/Kyoto
Dubayah (CMS 2013) Canopy height and forest/non-forest maps for Sonoma County	**Sonoma County Agriculture & Open Space Preservation District**, Karen Gaffney	REDD+, Sonoma County initiatives, California Assembly Bill 32: Global Warming Solutions Act (CA-AB32), CAP
Duren (CMS 2015) California Methane Survey, Carbon Mapper	**California Air Resources Board**, Jorn Herner	Many (multi- and bi-lateral international agreements; domestic regulation and voluntary programs; sub-national federations; private markets)
Elvidge (CMS 2015) Global survey of natural gas flaring	**Watson Institute for International & Public Affairs of Brown University**, Deborah Gordon	Gas flaring regulations and reduction
Nehrkorn (CMS 2015) DARTE Annual On-road CO2 Emissions on a 1-km Grid	**Providence City Hall**, Leah Bamberger **Boston Planning Organization**, Scott Peterson	City emissions inventories, RGGI, C40 Cities Climate Leadership Group, ICLEI Local Governments for Sustainability, FLPMA, CAA

- 418 unique publications (papers, book chapters)
  - 34 publications in Nature, Science and PNAS including 16 currently on the NACP Citations Classics list with over 100 citations

- Baccini, A., Walker, W., Carvalho, L., Farina, M., Sulla-Menashe, D., Houghton, R. A. **2017**. Tropical forests are a net carbon source based on aboveground measurements of gain and loss. Science. 358(6360), 230-234. doi: 10.1126/science.aam5962 *(Baccini (CMS 2015) Walker (CMS 2014))*
- Bond-Lamberty, B., Bailey, V. L., Chen, M., Gough, C. M., Vargas, R. **2018**. Globally rising soil heterotrophic respiration over recent decades. Nature. 560(7716), 80-83. doi: 10.1038/s41586-018-0358-x *(Vargas (CMS 2016)*)
- Hengl, T., Mendes de Jesus, J., Heuvelink, G. B. M., Ruiperez Gonzalez, M., Kilibarda, M., Blagotic, A., Shangguan, W., Wright, M. N., Geng, X., Bauer-Marschallinger, B., Guevara, M. A., Vargas, R., MacMillan, R. A., Batjes, N. H., Leenaars, J. G. B., Ribeiro, E., Wheeler, I., Mantel, S., Kempen, B. **2017**. SoilGrids250m: Global gridded soil information based on machine learning. PLOS ONE. 12(2), e0169748. doi: 10.1371/journal.pone.0169748 *(Vargas (CMS 2013)*,) NACP Citation Classic with 317 Citations
- Houghton, R. A., House, J. I., Pongratz, J., van der Werf, G. R., DeFries, R. S., Hansen, M. C., Le Quere, C., Ramankutty, N. **2012**. Carbon emissions from land use and land-cover change. Biogeosciences. 9(12), 5125-5142. doi: 10.5194/bg-9-5125-2012 *(Houghton (CMS 2011)*, NACP Citation Classic with 394 Citations
- Sargent, M., Barrera, Y., Nehrkorn, T., Hutyra, L. R., Gately, C. K., Jones, T., McKain, K., Sweeney, C., Hegarty, J., Hardiman, B., Wofsy, S. C. **2018**. Anthropogenic and biogenic CO2fluxes in the Boston urban region. Proceedings of the National Academy of Sciences. 115(29), 7491-7496. doi: 10.1073/pnas.1803715115 *(Nehrkorn (CMS 2015))*
- Olofsson, P., Foody, G. M., Herold, M., Stehman, S. V., Woodcock, C. E., Wulder, M. A. **2014**. Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment. 148, 42-57. doi: 10.1016/j.rse.2014.02.015 *(Stehman (CMS 2013)*, NACP Citation Classic with 518 Citations

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;

The goal for NASA's CMS project is to prototype the development of carbon monitoring capabilities needed to support stakeholder needs for MRV.

*NASA-CMS (2014) Progress Report

Predicting biomass over large areas from GEDI lidar footprints

Patterson, P. L., Healey, S. P., Ståhl, G., Saarela, S.,and others. (2019). Statistical properties of hybrid estimators proposed for GEDI—NASA's Global Ecosystem Dynamics Investigation. Environmental Research Letters, 14(6)

Science Question

NASA's GEDI (Global Ecosystem Dynamics Investigation) Mission uses lidar to sample the Earth's surface at 25-m footprints (see figure). GEDI needs a method for making statistically viable biomass estimates for larger areas, accounting for uncertainty due to GEDI's sample and the fact that biomass is modeled, not measured, at each GEDI footprint.

Analysis

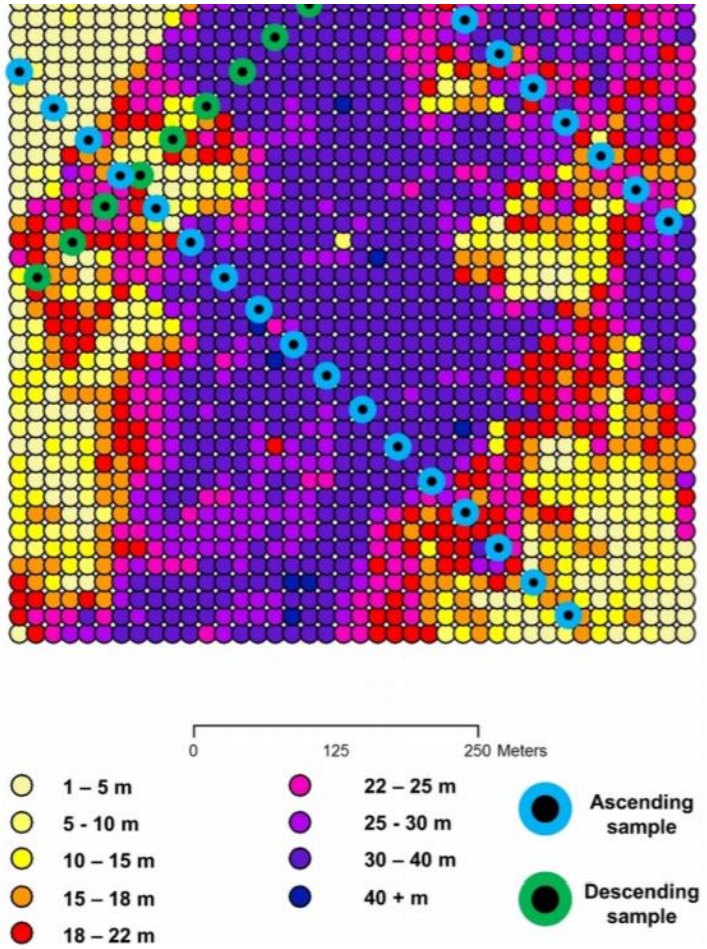
Using airborne lidar collected under a preceding CMS project (Cohen, 2012), we simulated GEDI waveforms and tested an approach to biomass inference called hybrid model-based estimation.

Results

Hybrid estimates of mean biomass are unbiased in the GEDI context, and estimates of the variance around those means are asymptotically unbiased (slightly low when only two or three overpasses are available).

Significance

Hybrid inference appropriately accounts for two important sources of uncertainty: how accurately GEDI predicts biomass at the footprint level; and how much of the target area is actually measured. Like all remote sensing-based approaches, hybrid inference is limited by a lack of field data in some areas.



GEDI's lidar based system will provide 25-m measurements of canopy height in a lattice patterr around the world. Our work shows that hybrid inference is an appropriate way to use those measurements to infer biomass in larger areas.

Enhanced North American uptake associated with El Niño

Lei Hu[1,2], Arlyn Andrews[2], Kirk W. Thoning[2], Colm Sweeney[2], John B. Miller[2], Anna M. Michalak[3], Ed Dlugokencky[2], Pieter P. Tans[2], Yoichi P. Shiga[3], Marikate Mountain[4], Thomas Nehrkorn[4], Stephen A. Montzka[2], Kathryn McKain[1,2], Jonathan Kofler[1,2], Michael Trudeau[1,2], Sylvia Michel[5], Sébastien C. Biraud[6], Marc L. Fischer[6], Doug E. J. Worthy[7], Bruce Vaughn[5], James White[5], Vineet Yadav[8], Sourish Basu[1,2], Ivar R van der Velde[1,2]
1. CIRES/CU; 2. NOAA/ESRL/GMD; 3. Carnegie Institution for Science; 4. AER; 5. INSTAAR/CU; 6. LBNL; 7. Environment and Climate Change Canada; 8. NASA/JPL

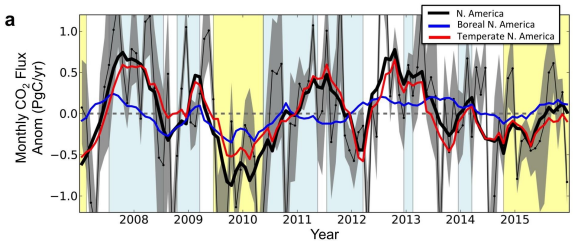
Correspondence to: lei.hu@noaa.gov

Significance

- The impact of the El Niño Southern Oscillation (ENSO) on land carbon uptake was thought primarily over the tropics. **We discovered strong and consistent responses of North American carbon uptake that are opposite to the carbon flux - ENSO relationships observed over the tropical land, highlighting the importance of improving quantification of regional carbon responses to ENSO in order to understand the true climate impact of ENSO.**

- Regional carbon-climate relationships represent a major uncertainty in future climate projections. **This study uses atmospheric observations to identify the dominant climate controls on the variability of North American carbon uptake. Our atmosphere-inferred climate-carbon relationships suggest such relationships have been poorly represented in terrestrial models. Our measurement-based carbon-flux relationships could be used to improve the terrestrial models and future climate projections.**

Large response of North American ecosystems to ENSO



Mean flux anomalies between El Nino and La Nina: -0.61 (-0.45 to -0.79 PgC/yr)

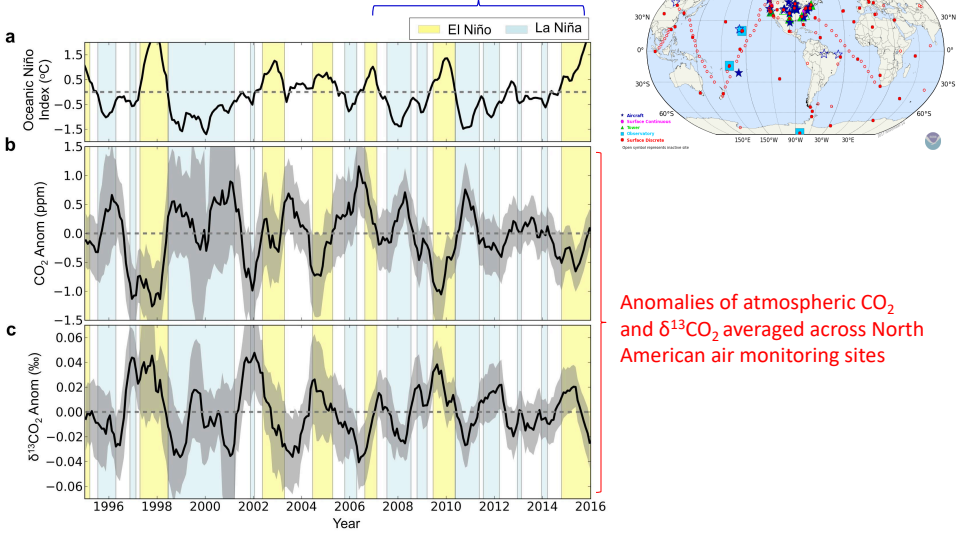
~= one third total fossil fuel emissions over North America

~= twice the total U.S. anthropogenic non-CO_2 GHG emissions

Observational evidence of North American terrestrial ecosystems to ENSO

Periods with the most abundant in situ air sampling sites

NOAA's Global Greenhouse Gas Reference Network



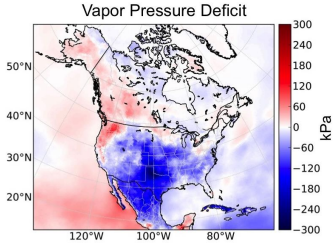
Anomalies of atmospheric CO_2 and $\delta^{13}CO_2$ averaged across North American air monitoring sites

Drivers for North American terrestrial ecosystem responses to ENSO

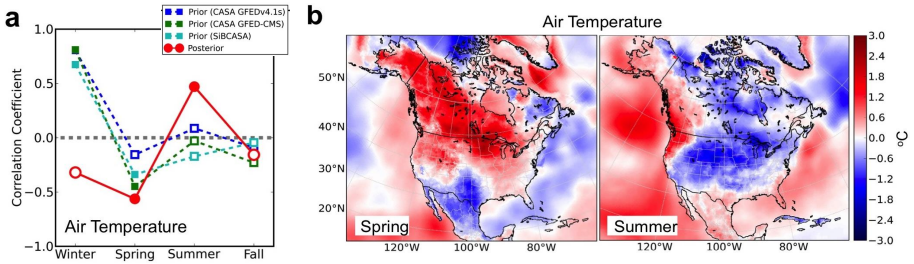
Correlation between yearly anomalies of climate variables and carbon fluxes

Climate Variables	Correlation	
	r	p
Vapor Pressure Deficit	0.75	0.02
Relative Humidity	-0.69	0.04
Soil Moisture	-0.66	0.05
Precipitation	-0.78	0.01
Air Temperature	0.30	0.43

Anomalies of VPD during El Nino compared to La Nina periods



Favorable temperature conditions also contribute to North American ecosystem responses to ENSO



CARBON MONITORING SYSTEM

Beyond MRV: High-resolution forest carbon modeling for climate mitigation planning over Maryland, USA

SCIENCE TEAM MEETING & APPLICATIONS WORKSHOP

Scripps Seaside Forum, La Jolla, CA

NOVEMBER 12-14, 2019

UNIVERSITY OF MARYLAND

Hurtt, G., Zhao, M., Sahajpal, R., Armstrong, A., Birdsey, R., Campbell, E., Dolan, K.A., Dubayah, R., Fisk, J.P., Flanagan, S.A., Huang, C., Huang, W., Johnson, K., Lamb, R., Ma, L., Marks, R., O'Leary, D., O'Neil-Dunne, J., Swatantran, A., Tang, H., 2019. *Environmental Research Letters*. https://doi.org/10.1088/1748-9326/ab0bbe

Science Questions

- How can we accurately monitor current forest cover and carbon stocks to aid policy efforts aimed at reducing deforestation and degradation as well as increasing afforestation and reforestation for climate mitigation?
- How can ecological modeling quantitatively estimate future carbon sequestration potential in response to land-use and management decisions?

Analysis

The study presents a new forest carbon monitoring and modeling system that combines high-resolution remote sensing of forest height, field data, optical remote sensing and ecological modeling (Ecosystem Demography model). We estimate contemporary above-ground forest carbon stocks, and project future forest carbon sequestration potential for the state of Maryland at 90 m resolution, over approximately 3.2 million grid cells. This is nearly 100,000 times the resolution at which global carbon models are run.

Results

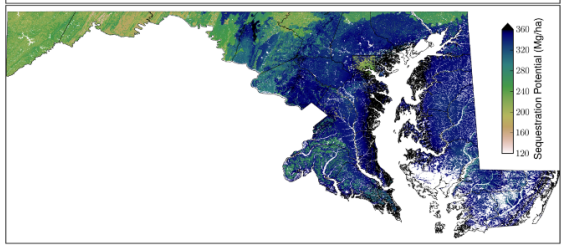
In Maryland, the contemporary above-ground carbon stock was estimated to be 110.8 Tg C (100.3-125.8 Tg C). The forest above-ground carbon sequestration potential for the state was estimated to be much larger at 314.8 Tg C, and the forest above-ground carbon sequestration potential gap was estimated to be 204.1 Tg C, nearly double the current stock. The time needed to reach this potential, or carbon sequestration potential time gap was estimated to be 228 years statewide, with 50% of the gap being realized in 80 years. These results imply a large statewide potential for future carbon sequestration from afforestation and reforestation activities.

Significance

With this approach, it is now possible to quantify both the forest carbon stock and future carbon sequestration potential over large policy relevant areas with sufficient accuracy and spatial resolution to significantly advance planning. These data products are now being used by the state of Maryland to plan for the Greenhouse Gas Reduction Act (GGRA). With the launch of NASA-GEDI mission, these analyses can be scaled to national, continental and global domains.

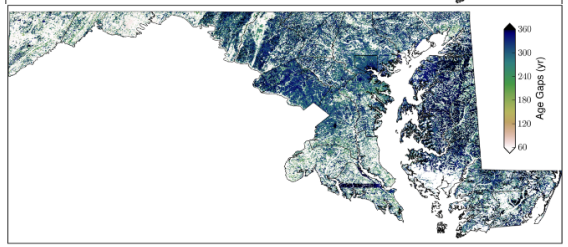
(a)

(b)



(c)

(d)



a) AGB Spatial pattern of 90-m biomass estimated by Lidar-initialized ED
b) CSP Map of carbon sequestration potential estimated by Lidar-initialized ED
c) CSPG Map of gap to carbon sequestration potential estimated by Lidar-initialized ED
d) CSPTG Map of carbon sequestration potential time gap estimated by Lidar-initialized ED

Lidar Facilitates Aboveground Biomass Carbon (AGBC) Estimation Across Space And Time

P. Fekety, M. Falkowski, A. Hudak (PI) (Project: 14-CMS14-0026; Award: NNH15AZ06I)

Background:
Regional forest planning is challenging for USFS managers faced with budget constraints.

Analysis:
Evaluated transferability of lidar-derived AGBC estimates from models trained with plot data that were collected neither locally (Fig. 1) nor contemporaneously (Fig. 2).

Findings:
Losses in accuracy and precision from AGBC models based on spatially or temporally disjunct observations are acceptable.

Significance:
Given consistently processed lidar collections, inventory plot data can be leveraged broadly in space and time to more efficiently manage regional forest AGBC sequestration.

Fig. 1. Six spatially disjunct project areas with lidar and forest inventory plot data.

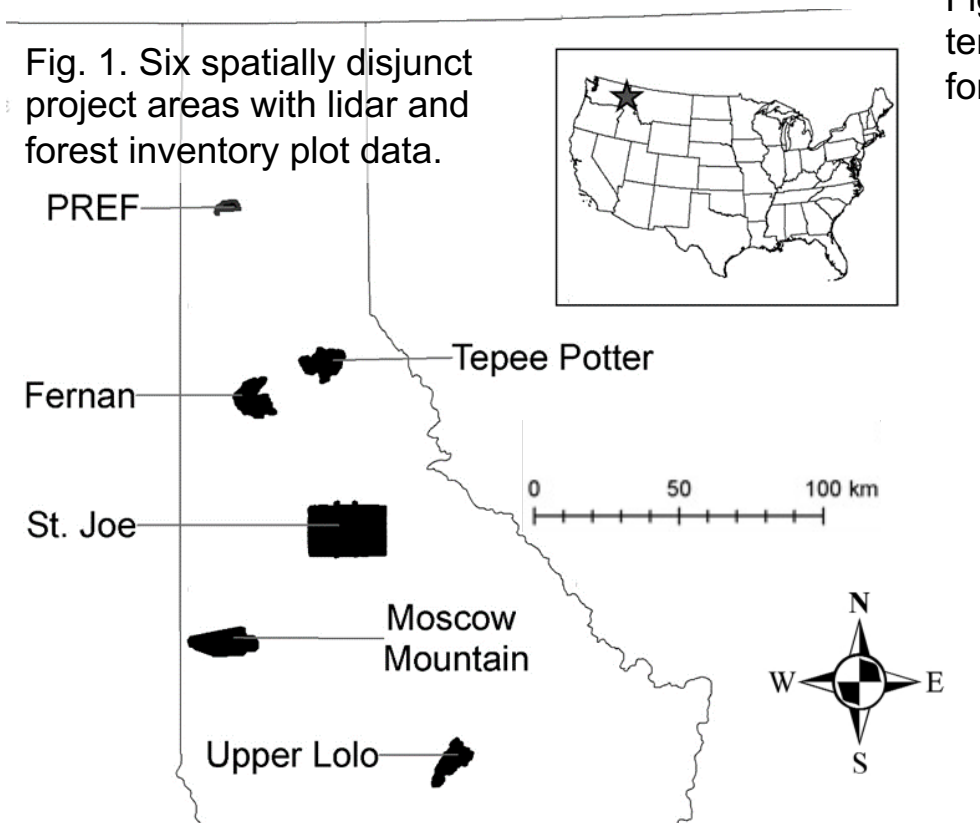
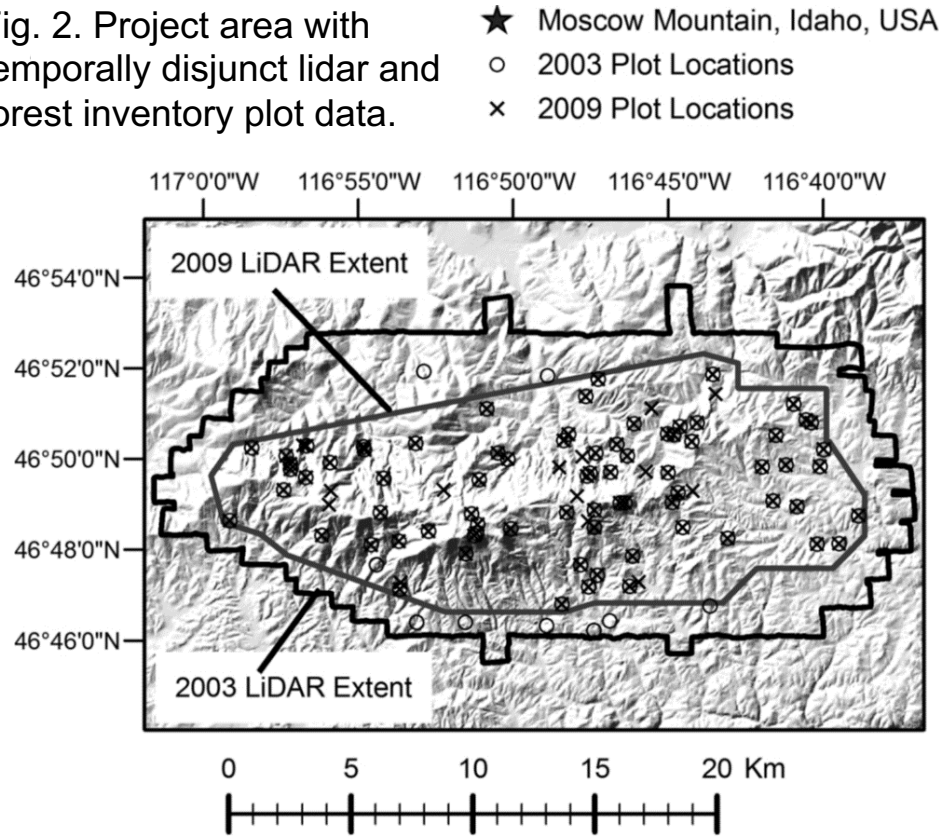


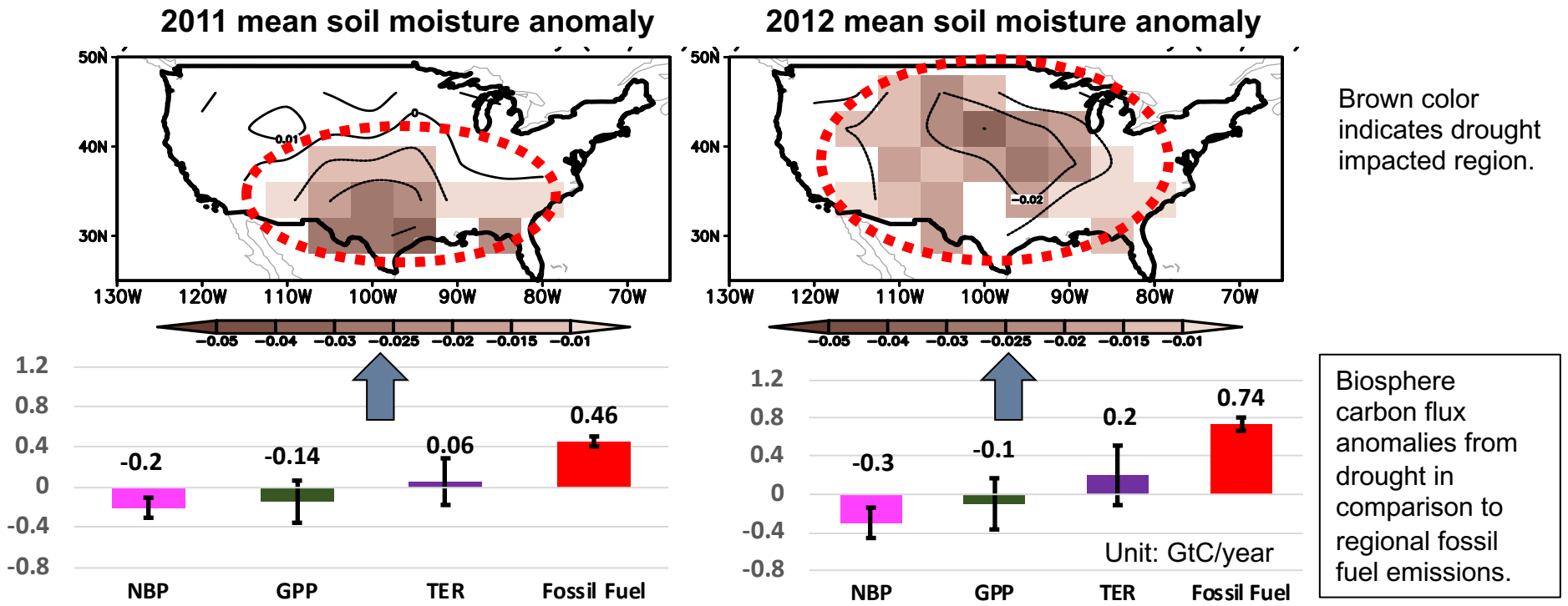
Fig. 2. Project area with temporally disjunct lidar and forest inventory plot data.



National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Detecting drought impact on terrestrial biosphere carbon fluxes over contiguous US with satellite observations

Liu, J. et al. (2018), Environ. Res. Lett., Vol 3



Brown color indicates drought impacted region.

Biosphere carbon flux anomalies from drought in comparison to regional fossil fuel emissions.

Science Question: The 2011 dry spell in Texas was the worst one-year period of drought since 1895, and the area span of 2012 summer drought was comparable to the dust bowl era. Liu et al addressed the following questions: 1) What are the impacts of these two severe droughts on terrestrial biosphere net biosphere production (NBP)? 2) what are the driving processes (growth vs. decomposition)? 3) How significant of the biosphere flux anomaly relative to regional fossil fuel emissions?

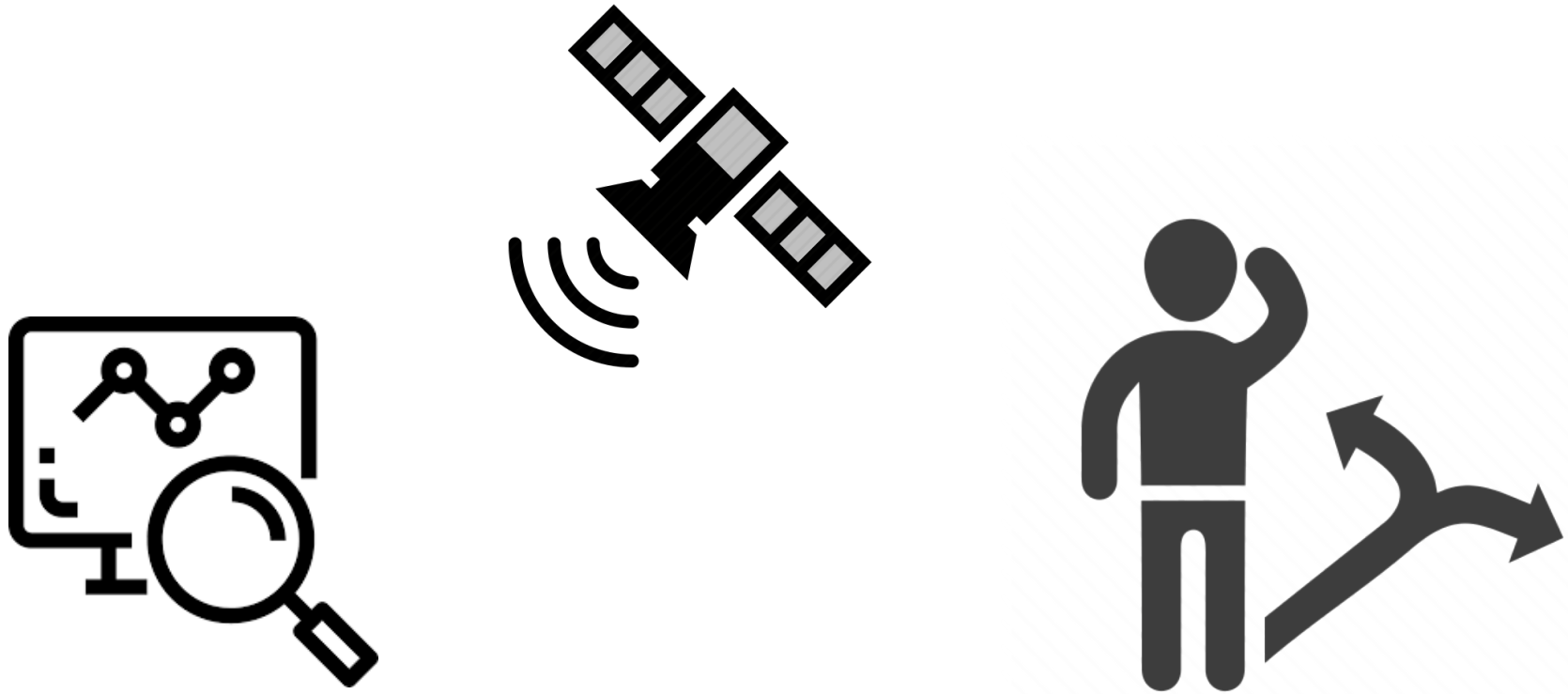
Data and Results: We used NASA CMS-Flux inversion system to infer monthly NBP and GPP from GOSAT B7.3 xCO2 and Solar induced fluorescence (SIF) over 2010-2015, calculating TER as a residual. Over the drought impacted region, the annual NBP decreased by 0.2 ± 0.1 GtC and 0.3 ± 0.16 GtC respectively in 2011 and 2012, equal to 40% of the mean fossil fuel emission over these regions. About half of the NBP reduction was due to a decrease of GPP, and the other half was due to an increase of respiration.

Significance: The large magnitude of natural biosphere carbon flux anomalies relative to regional fossil fuel emissions indicate that any mitigation policy to reduce regional contributions to atmospheric CO_2 growth needs to consider the interannual variability and long-term trend of the natural carbon cycle.

NASA Applied Sciences

From Research to Decisions – Empowering your science to impact society

Stephanie Schollaert Uz, Applied Science Manager

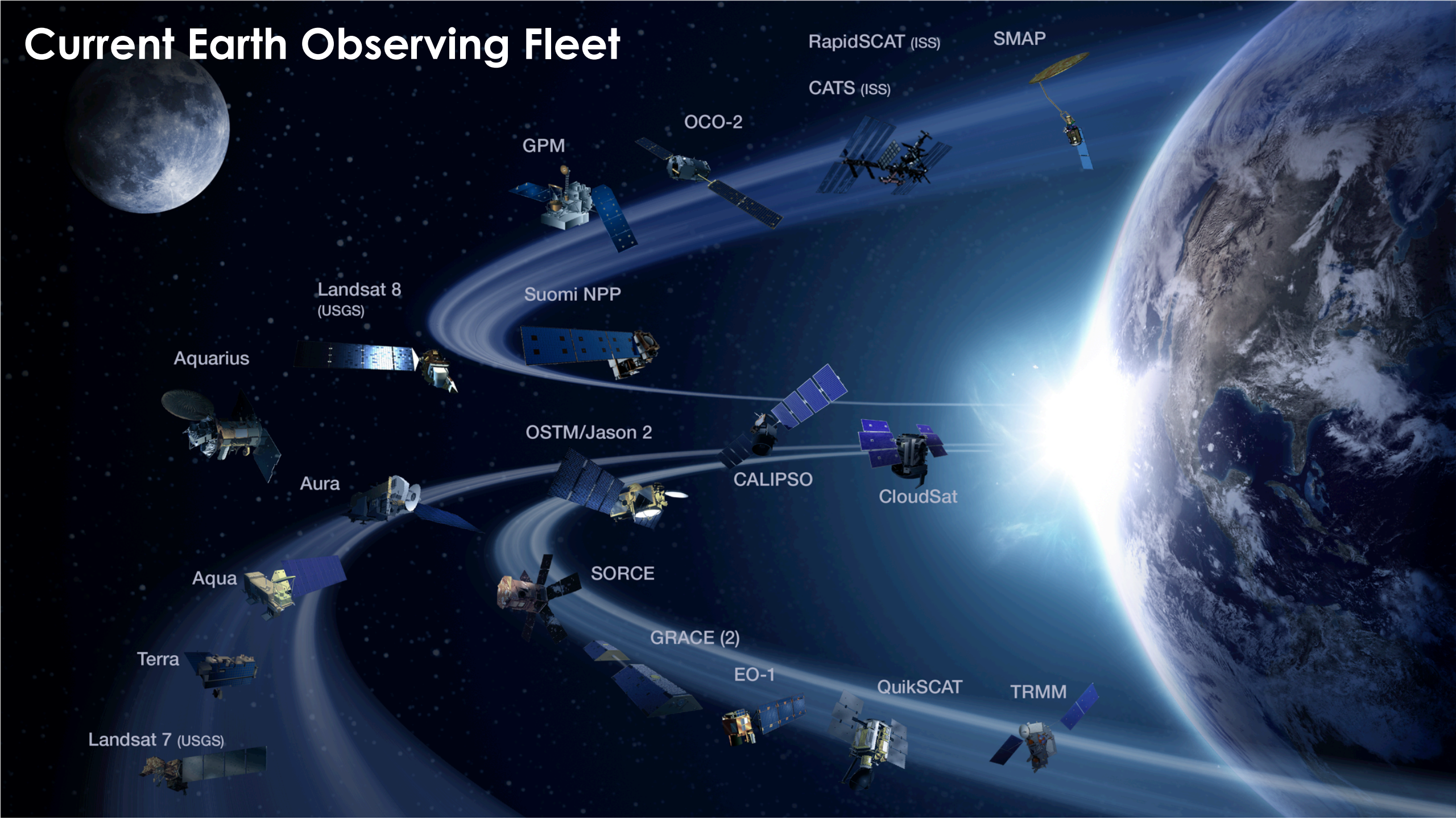


Goddard SPACE FLIGHT CENTER

Outline

- Science and applications called for NASA missions
- Applied Sciences Program overview
- Examples of applied research projects
- Applications opportunities and resources

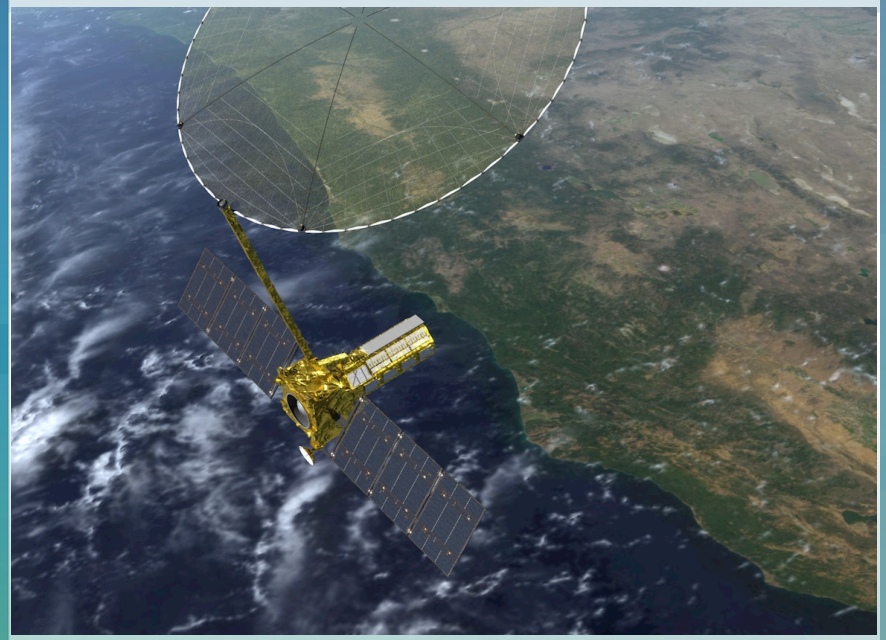
Current Earth Observing Fleet



Planned for Launch in 2020

NASA-ISRO Synthetic Aperture Radar (NISAR)

NISAR



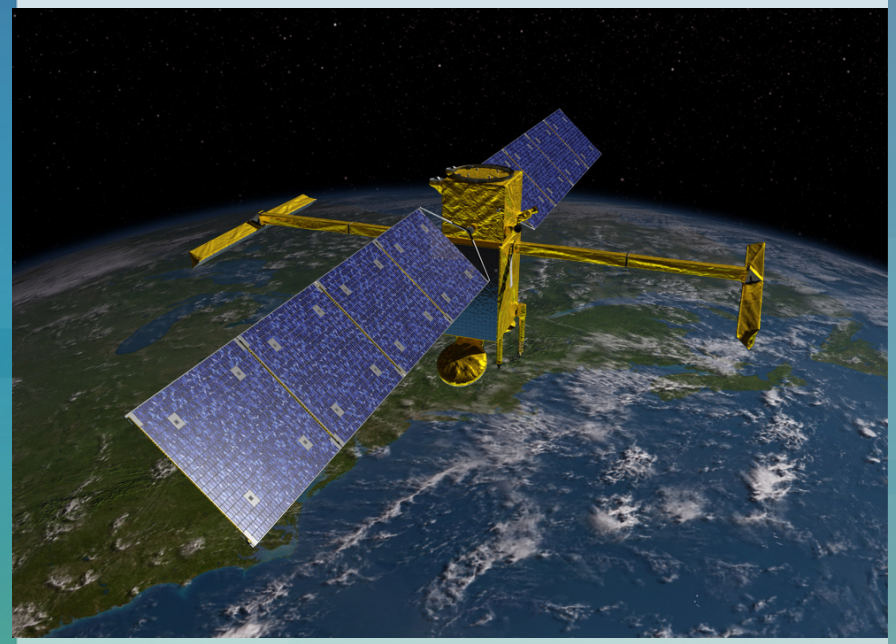
2020

Designed to observe and take measurements of ecosystem disturbances, ice-sheet collapse, and earthquakes, tsunamis, volcanoes and landslides

Planned for Launch in 2021

Surface Water and Ocean Topography (SWOT)

SWOT



2021

Joint international mission will make the first global survey of Earth's surface water, observe the ocean's surface topography, and measure how water bodies change.

Planned for Launch in 2022

Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)

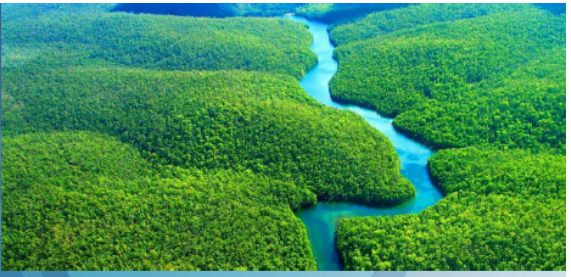
PACE

2022

Understand and quantify global biogeochemical cycling and ecosystem function in response to anthropogenic and natural environmental variability and change

Four Designated Observable Studies Underway

2017-2027 Decadal Survey for Earth Science & Applications from Space:



Surface Biology and Geology (SBG)

Aerosols, Clouds, Convection and Precipitation (A-CCP)

Mass Change (MC)

Surface Deformation and Change (SDC)

Applied Sciences Program within Earth Science

Bringing the benefits of space back to Earth

Current managed programs

Health & Air Quality

Water Resources

Ecological Forecasting

Disasters

Capacity Building

Multidisciplinary areas

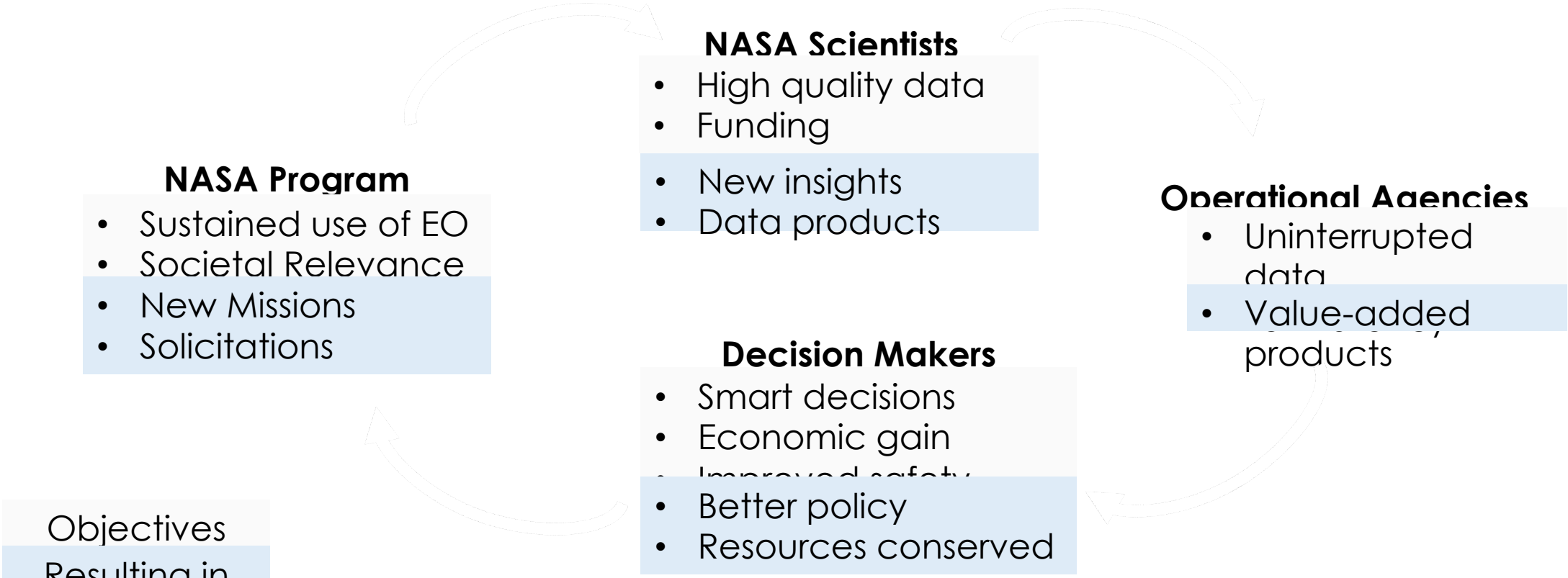
Food Security & Agriculture

New Missions

International Collaborations

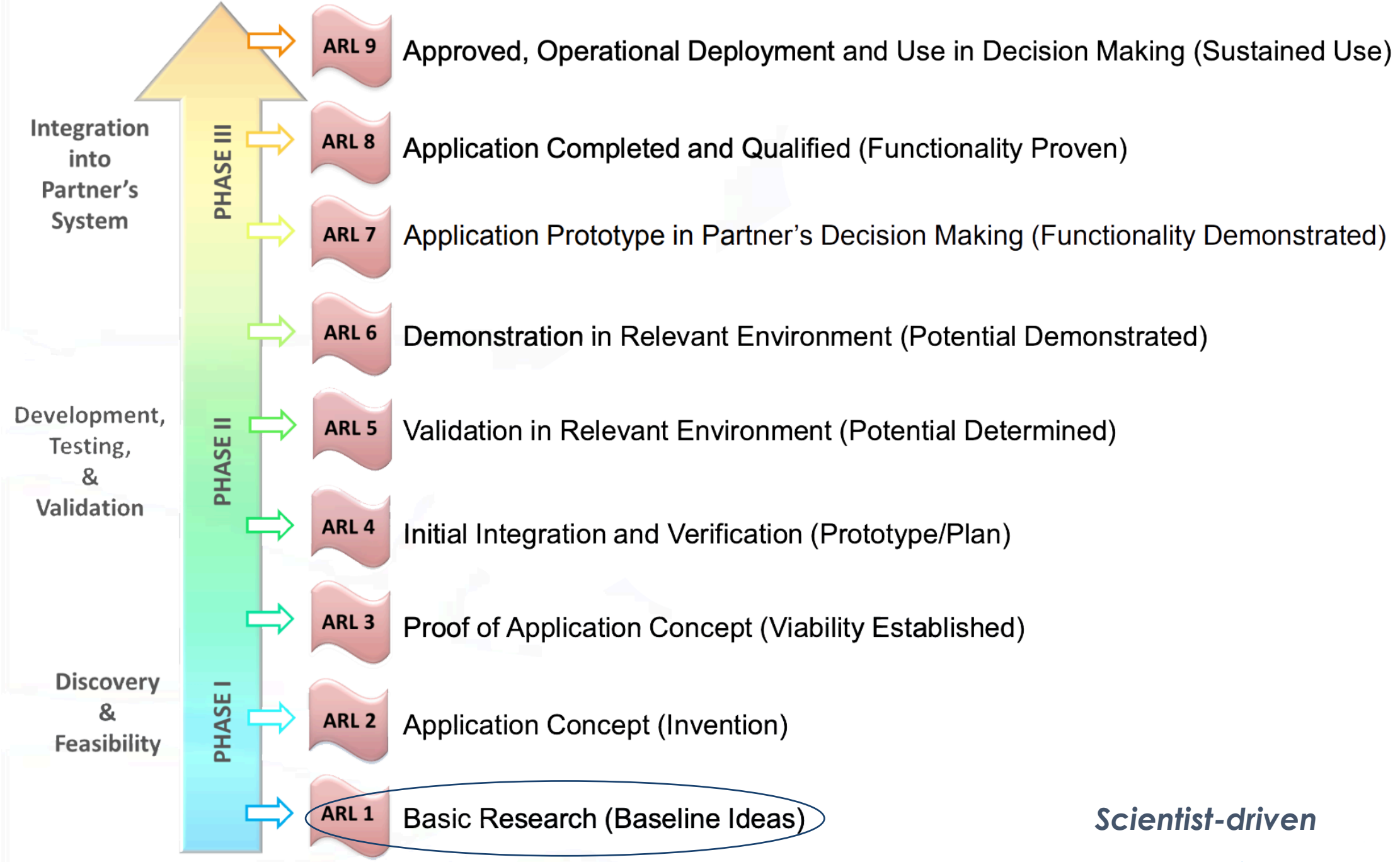
Identify your unique expertise and find a stakeholder with a practical problem

Connect around their challenge, iterate early and often



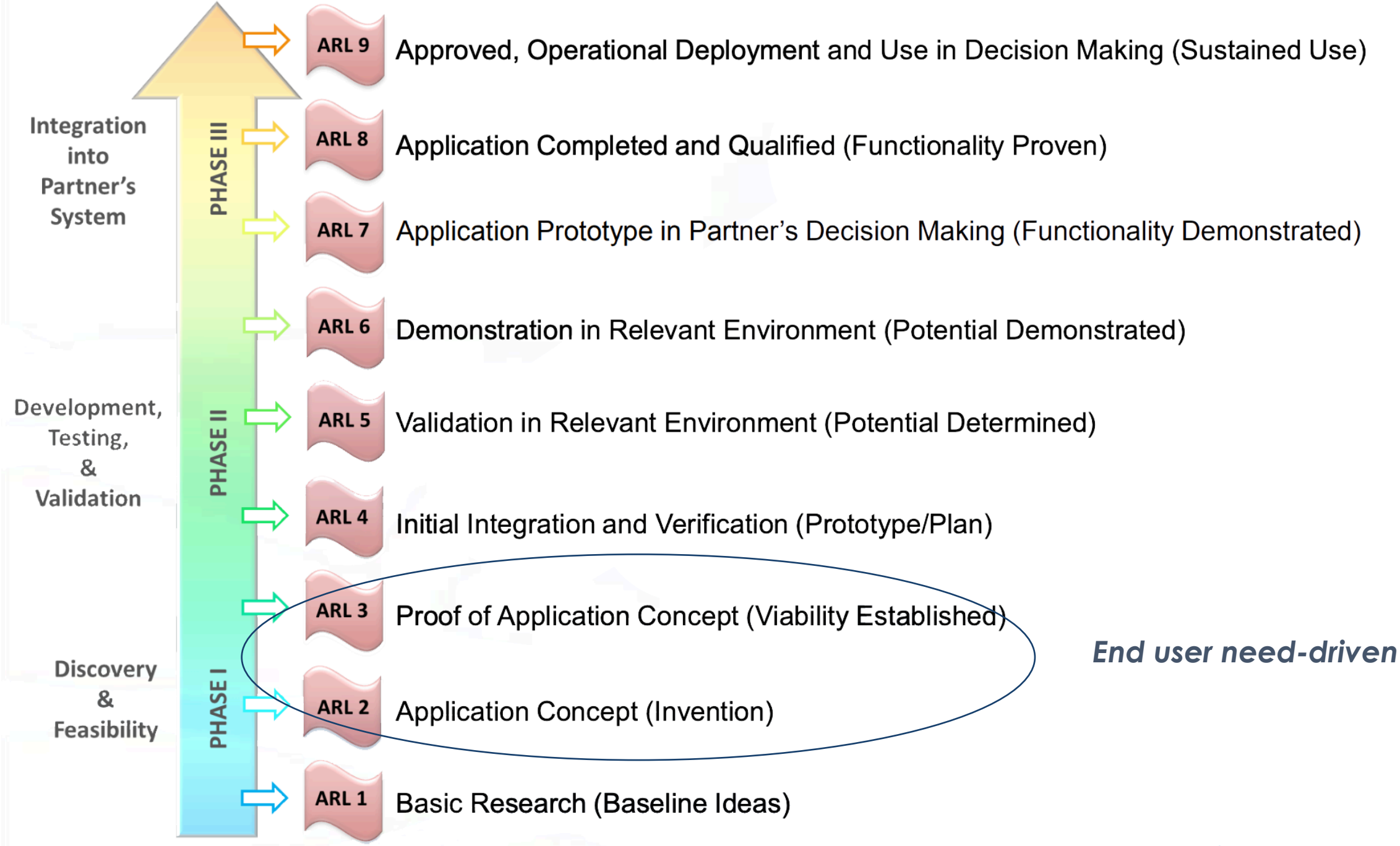
Applications Readiness Level (ARL) metrics

Basic research → Why is this important?



Scientist-driven

Applied research → How can this be used to solve a practical problem?



End user need-driven

Chesapeake Bay water quality project

Working with MDE shellfish division, DNR, VDH, UMD, NOAA, USDA-ARS: combine in situ sampling of biology, chemistry, optical measurements (in water, above water, satellite)

Photo credit: John 'Rusty' McKay/MDE

- Oyster aquaculture is a growing industry around the Chesapeake

- Elevated runoff causes closures

- Remote sensing may provide early warning poor water quality

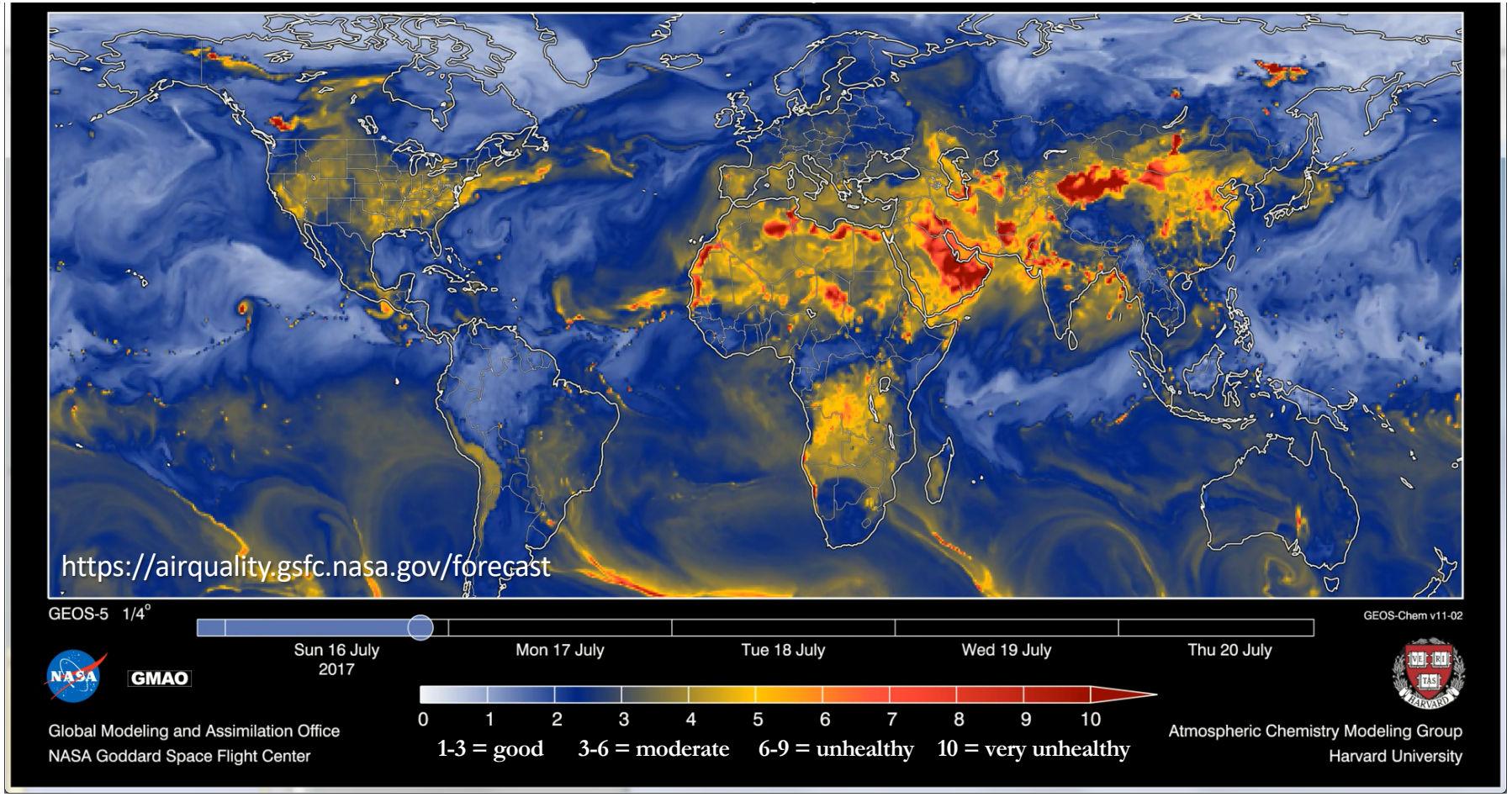
- Optical proxies are being explored

- New project to develop Artificial Intelligence/Machine Learning

- Oyster health by Northrup Grumman, Chesapeake Bay Foundation

Stephanie Schollaert Uz, Rossana Del Vecchio/Neil Blough (UMD), John McKay (MDE), Troy Ames,

Global Health Air Quality Index (HAQI) Forecasts



Partners:

Bryan Duncan (HAQAST), Christoph Keller and Emma Knowland (GMAO)
HAQI by Kevin Cromar (NYU; HAQAST)

Applied Sciences Opportunities

Proposal tips from Dr. Brad Doorn (Water Resources Program Manager):
https://science.gsfc.nasa.gov/610/applied-sciences/resources.html

- Read the entire solicitation
- Gauge progress with Applications Readiness Levels (ARL)
- NASA science and observations are essential
- Demonstrate knowledge of stakeholder's decision process
- Stakeholders should have substantial role (increasingly requires PI or Co-I)
- Readability is important
- Serve as a reviewer

Tips for engaging stakeholders

Approach stakeholder collaborations the same as for other research

Based upon your subject matter expertise, find problems that align with your passion

Build collaborations with end-users (sophisticated and not) to better understand challenges

Be realistic about limitations and uncertainties

Test initial ideas through feasibility study

Begin proposal process early and iterate with your team

Extend same courtesies to other scientist/stakeholder teams that you would for basic research

Don’t over-promise, be clear about data uncertainties and limitations

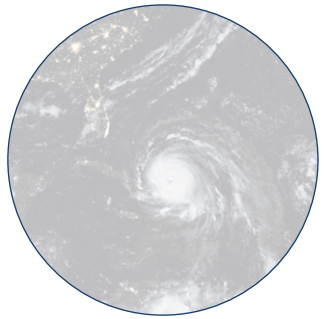
Applied Sciences at Goddard

Focused on developing interagency and external partnerships to accelerate broader adoption of NASA data and science for societal benefit

Connect with community issues through our workshops, seminars, webinars

Air Quality & Health

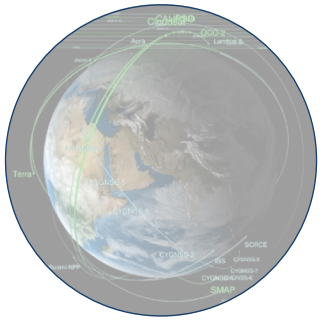
Chesapeake Bay



Climate Applications

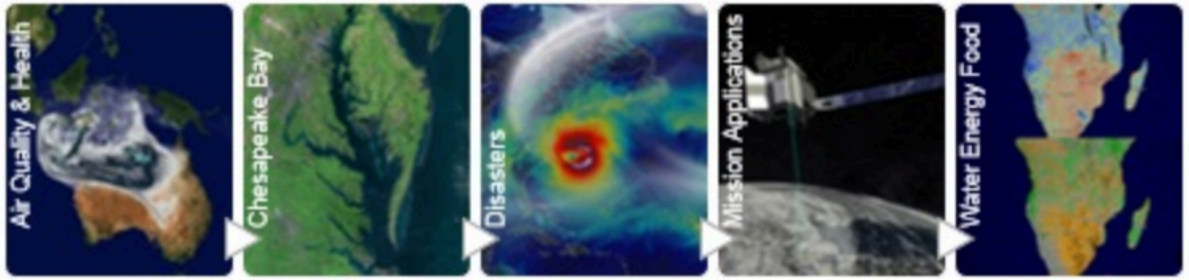
Disasters

Food Security



Missions

GODDARD APPLIED SCIENCES
SEMINAR SERIES



Upcoming Seminars

October 28 – Daniel Tong, UMD & GWU, Improving emissions estimates and air quality forecasts

November 18 – Ana Prados, GSFC/UMBC, 10 years of NASA Applied Remote Sensing Training Program

January 27 – Shanna McClain, NASA Disasters & Andrew Kruczkiewicz, Columbia & NOAA IRI

February 24 – Prof. Genl. Gerry Galloway, UMD, Water Resources Policy, Flood Risk Management

March 23 – Sergio Peçanha, Washington Post, The Societal Relevance of Satellite Data for Amazon Fires

April 20 – Blake Schaeffer, U.S. EPA R&D, Cyanobacteria Assessment Network

May 11 – Antonio Mannino, GSFC, Geostationary Littoral Imaging and Monitoring Radiometer (GLIMR)

NASA's Applied Remote Sensing Training Program (ARSET)

Train. Empower. Advance.

~25,000 people trained since 2009

Online and in person training by societal benefit area

Disasters

Overview of the Global Disaster Alert and Coordination System

Introduction to Synthetic Aperture Radar

Ecosystems

Advanced Webinar: Land Cover Classification

Remote Sensing of Land Indicators for UN SDG 15

Scenario-Based Ecoforecasting

Health + Air Quality

Satellite Derived Annual PM2.5 Data Sets in Support of UN SDGs

Advanced Webinar: Methods in Using NASA Remote Sensing for Health Applications

Water Resources

Advanced Webinar: Remote Sensing of Drought

Introduction to Remote Sensing of Harmful Algal Blooms

Satellite Observations of Water Quality for SDG 6

National Aeronautics and Space Administration

NASA Carbon Monitoring System

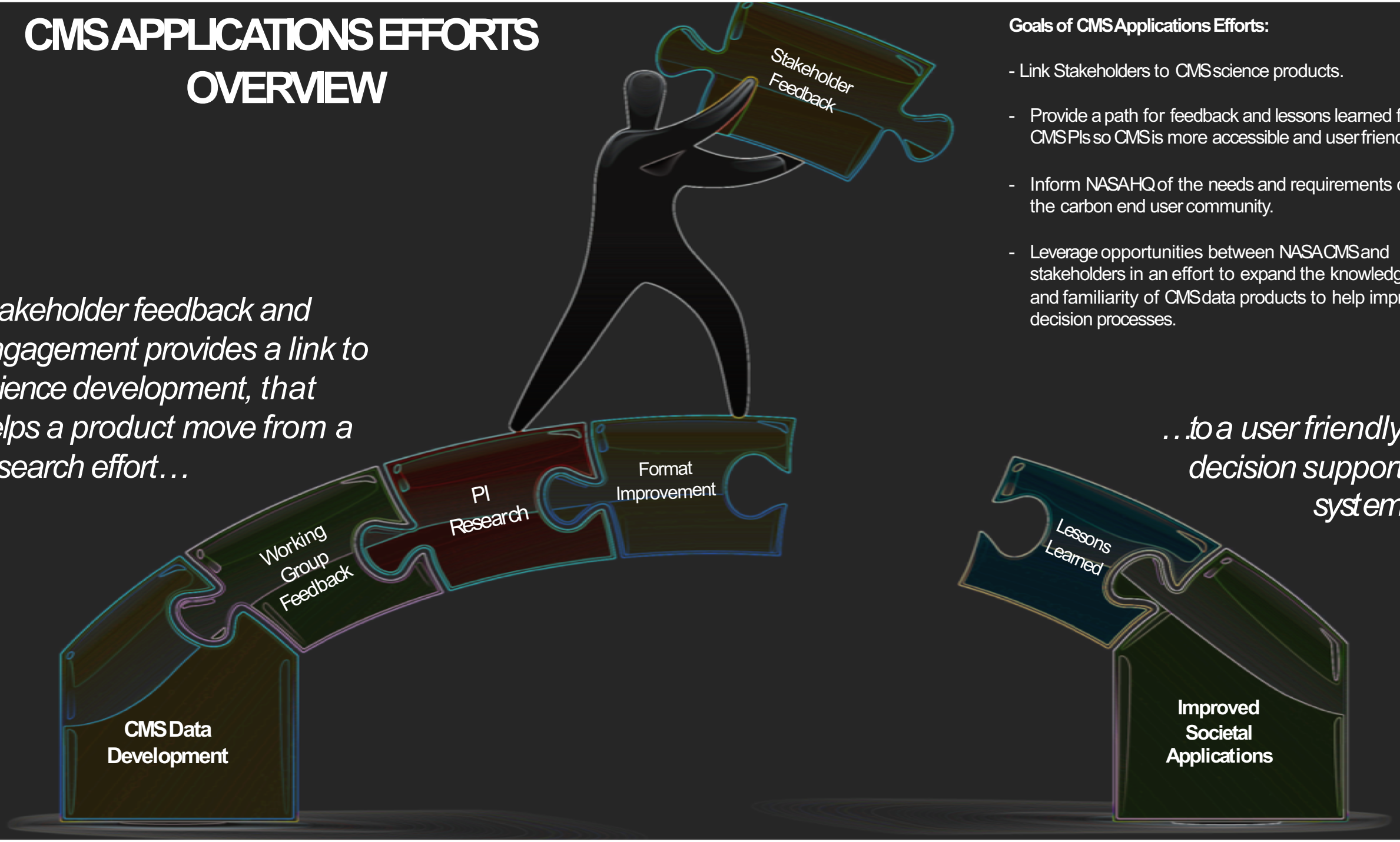
SCIENCE TEAM MEETING & APPLICATIONS WORKSHOP

Scripps Seaside Forum, La Jolla, CA

NOVEMBER 12-14, 2019

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

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 end user 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.

National Aeronautics and Space Administration

NASA Carbon Monitoring System

CMS Applications Program Framework

IONS WORKSHOP NOVEMBER 12-14, 2019

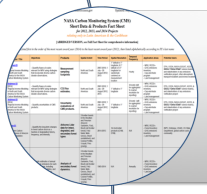
Policy Speaker Series

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.

Feedback to CMS Science Community and NASA HQ ESD



Data Products Fact Sheet

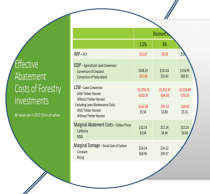
Collection of CMS metadata and policy data for each product (e.g. spatial extent, resolution, uncertainty, application areas, relevant policies), Integrated into CMS website database.

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.

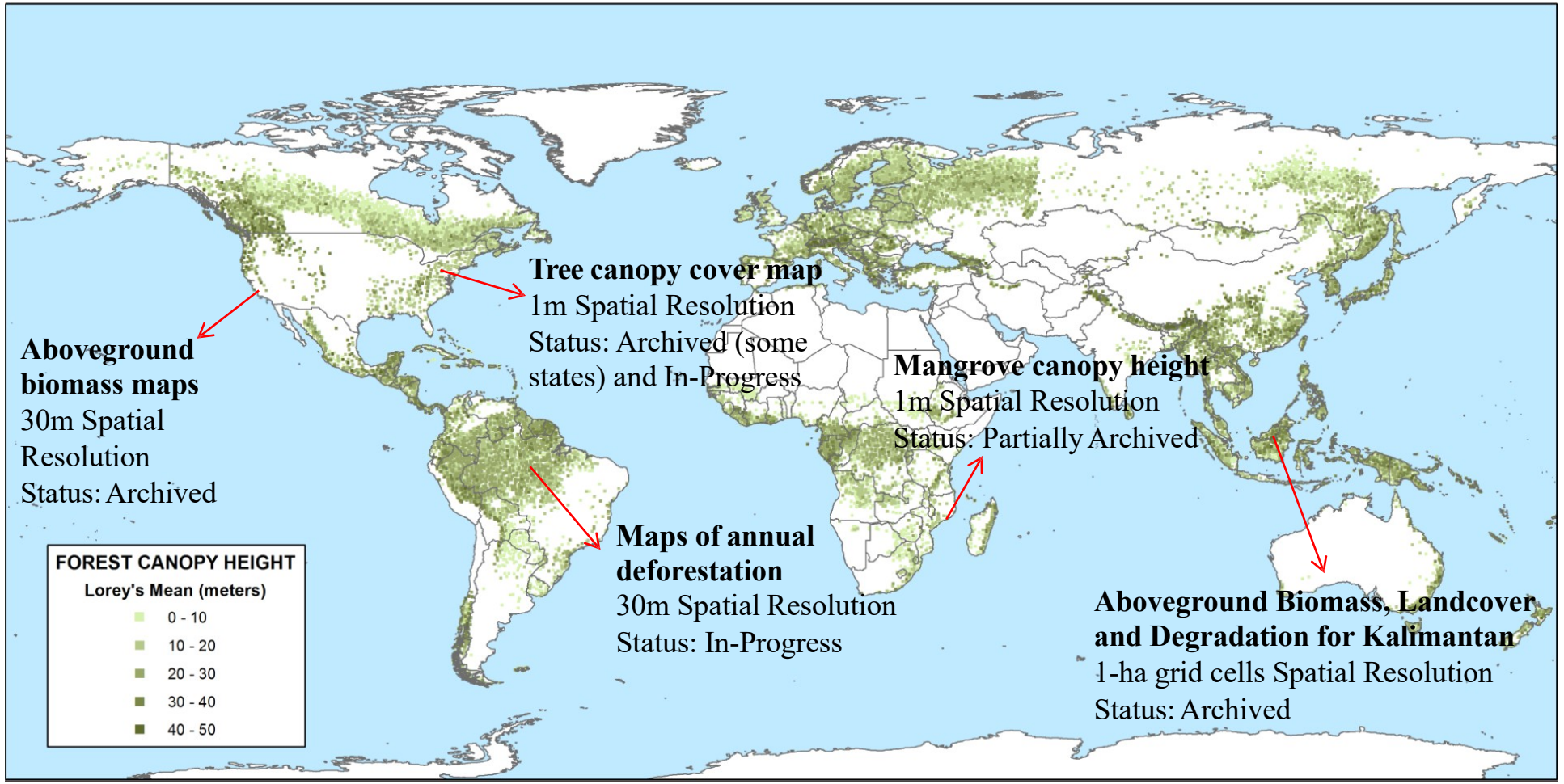


Socioeconomic Studies

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.

CMS Data Products

96 Projects
312 Data Products



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

National Aeronautics and Space Administration

NASA Carbon Monitoring System

SCIENCE TEAM MEETING & APPLICATIONS WORKSHOP

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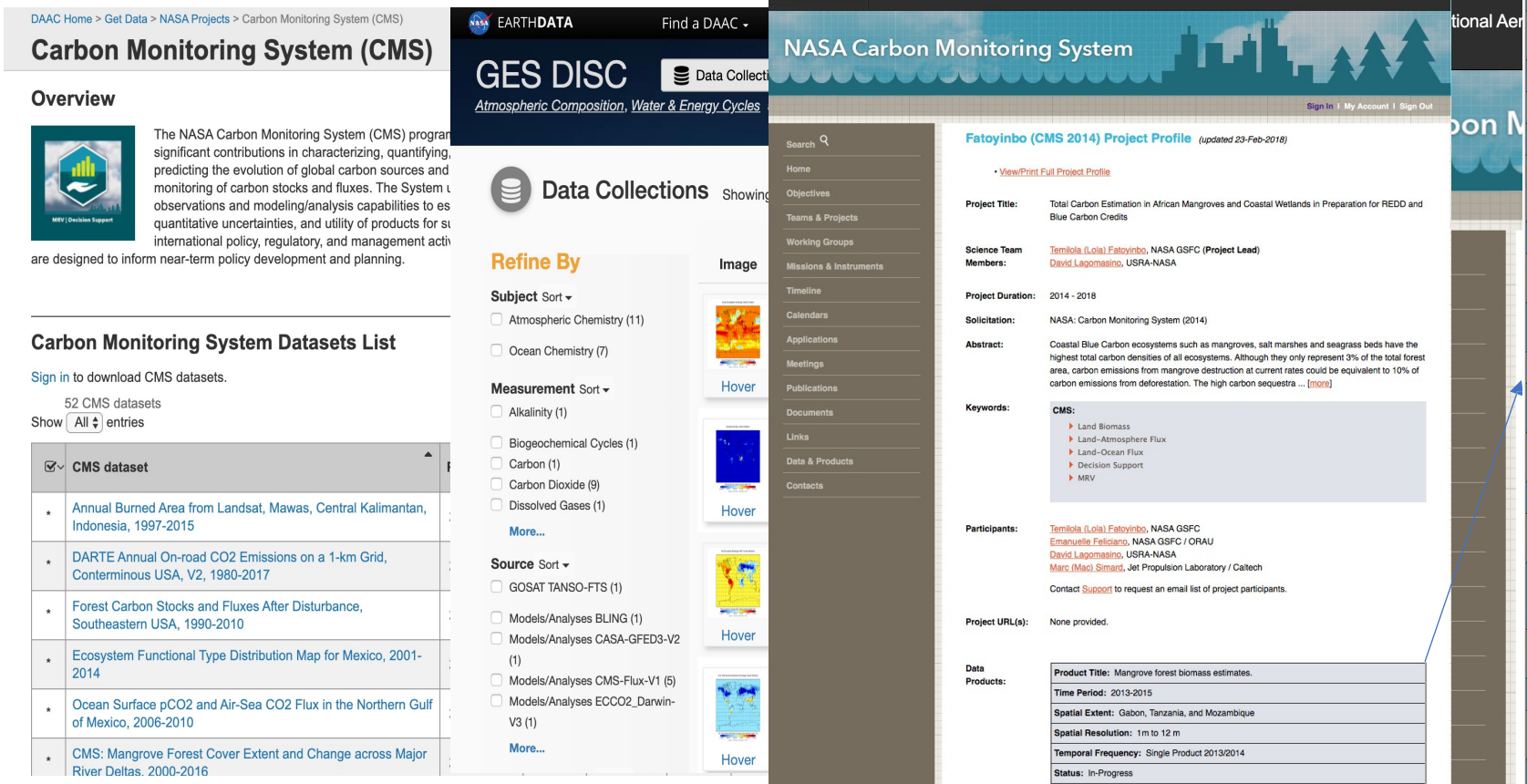
Overview of CMS Data Products



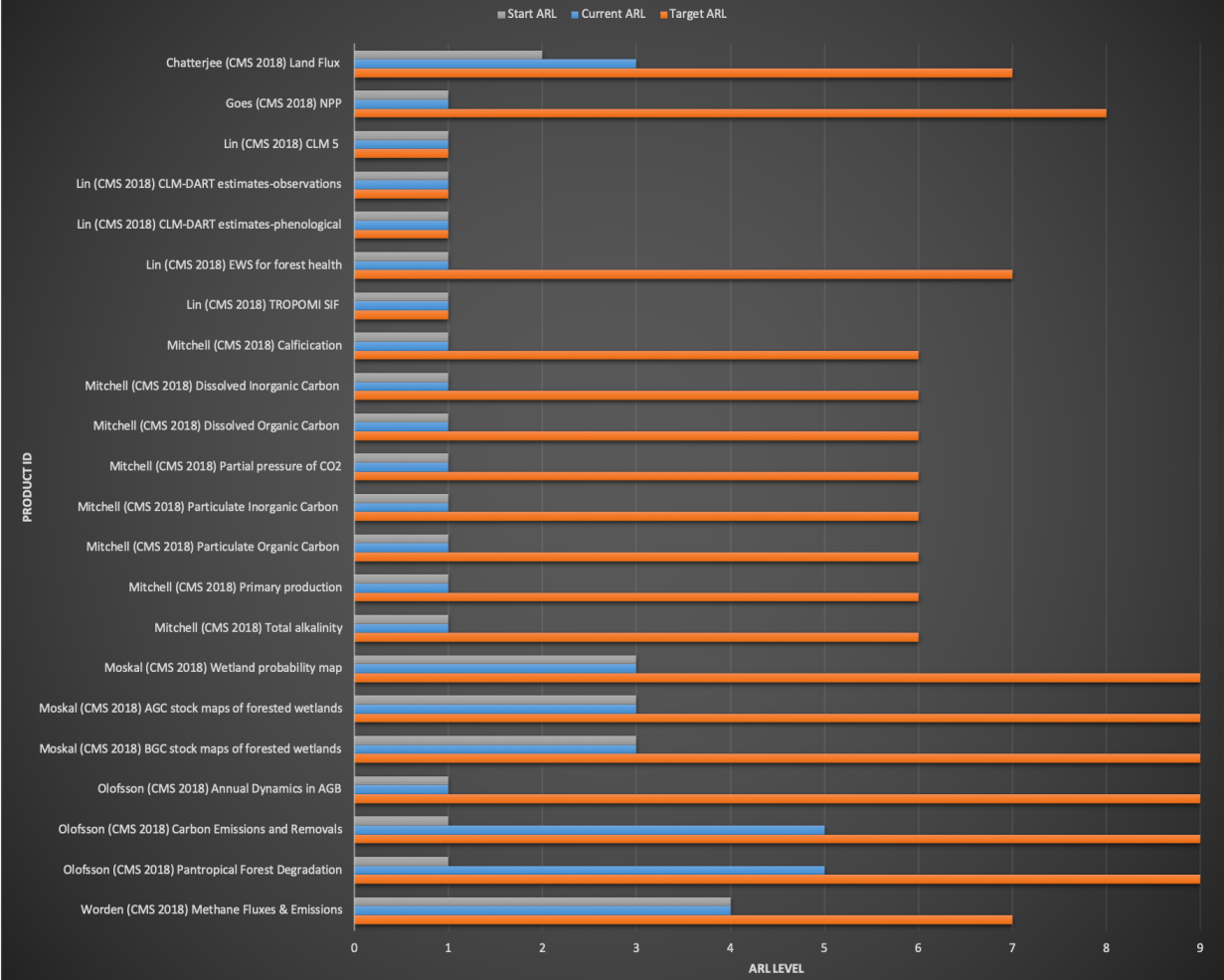
Metadata Fields	Explanation
Award Year	The year the funding was granted
Project ID	Principal Investigator's last name and project #
Objectives	Goals that the project seeks to attain by developing data and products
Science Theme	Type of data and products, according to components of carbon cycle research 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

ARL Refresher

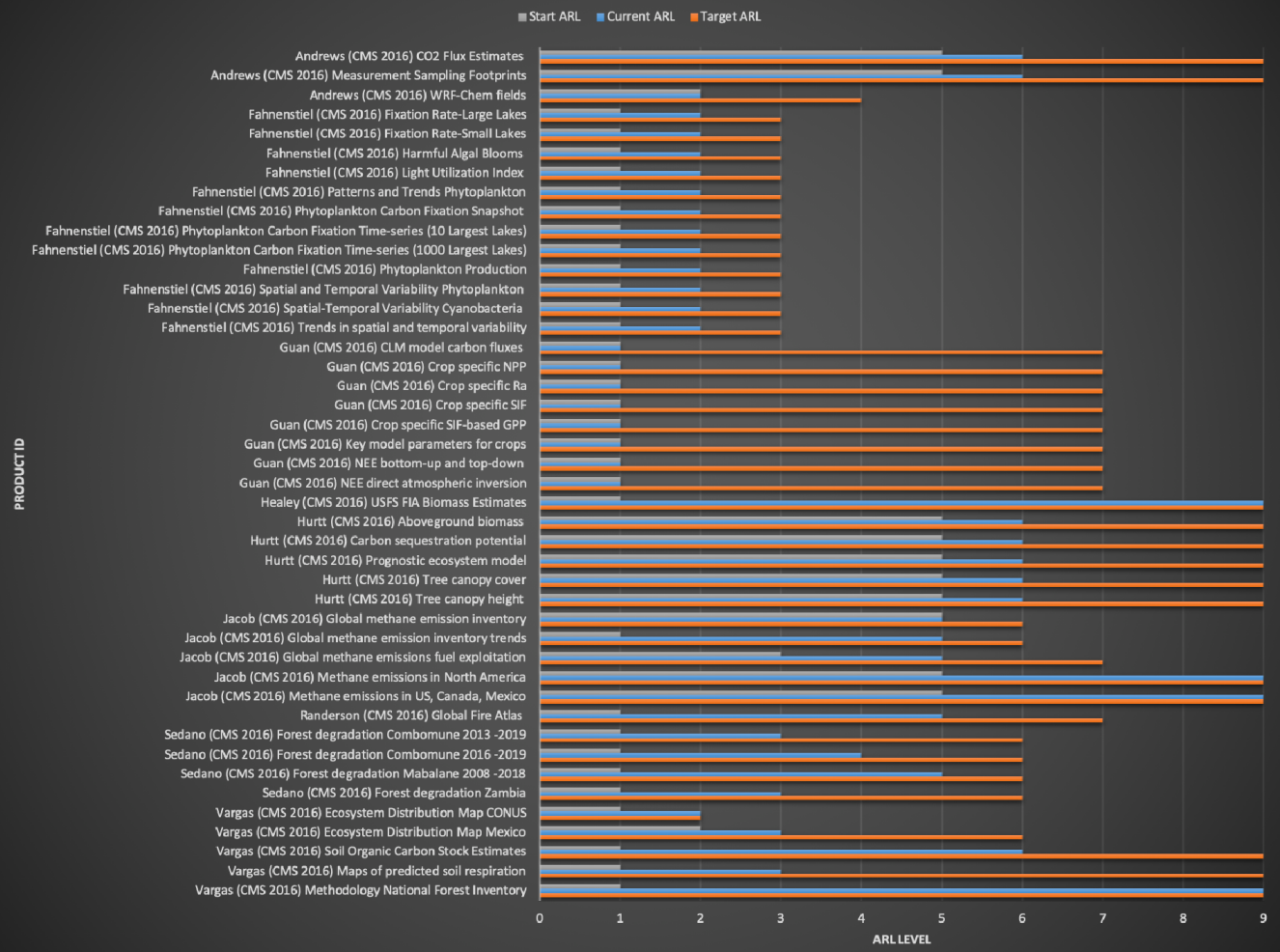
National Aeronautics and Space Administration

NASA Carbon Monitoring System

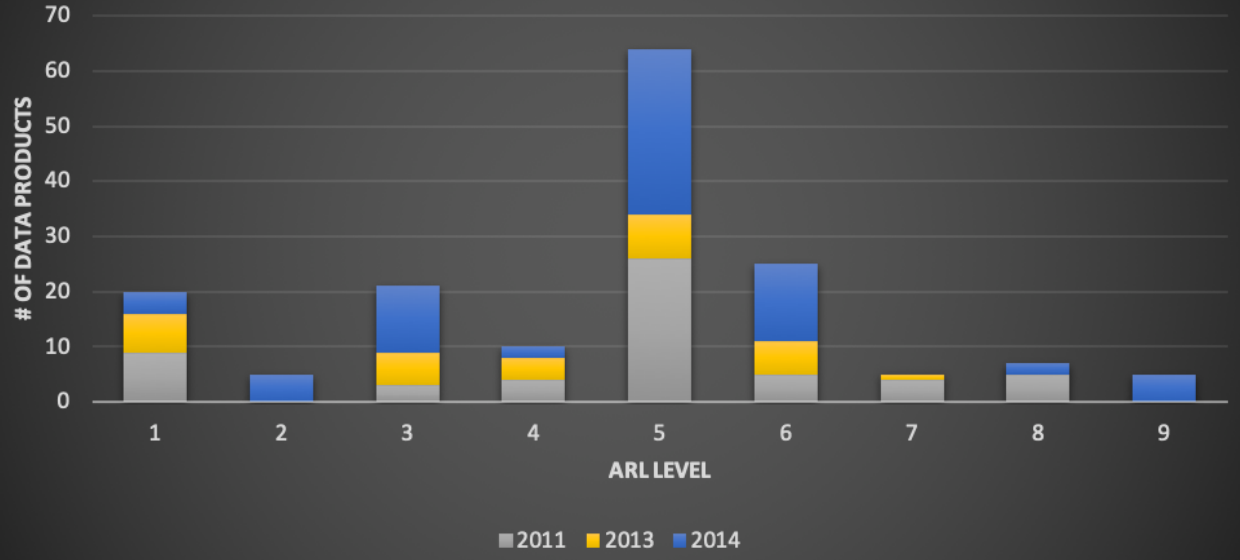
2018 Projects ARLs by Product

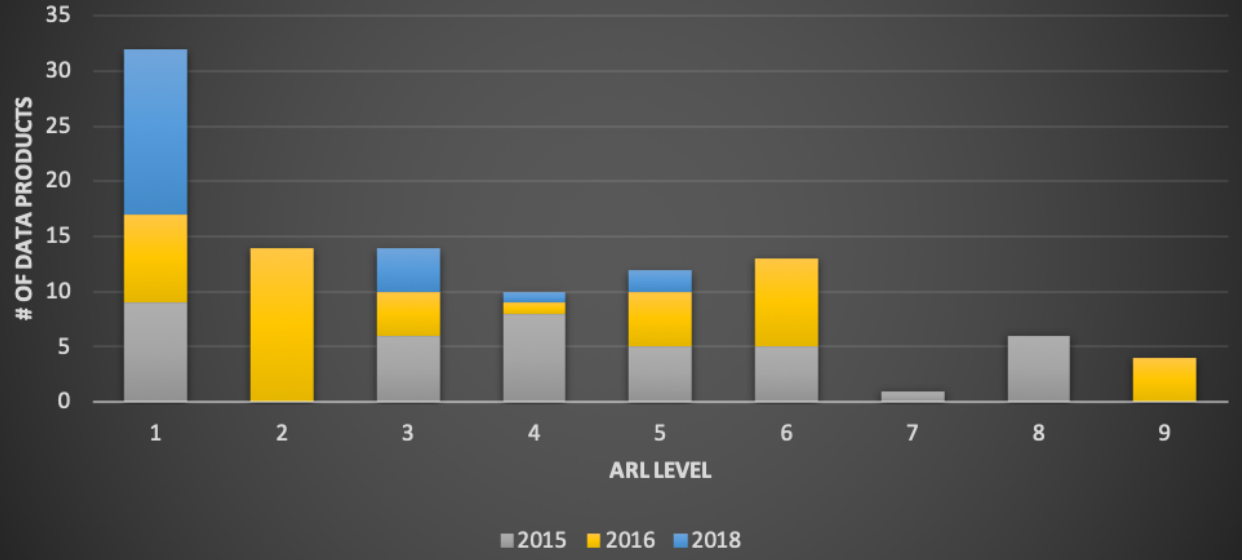


2016 Projects ARLs by Product



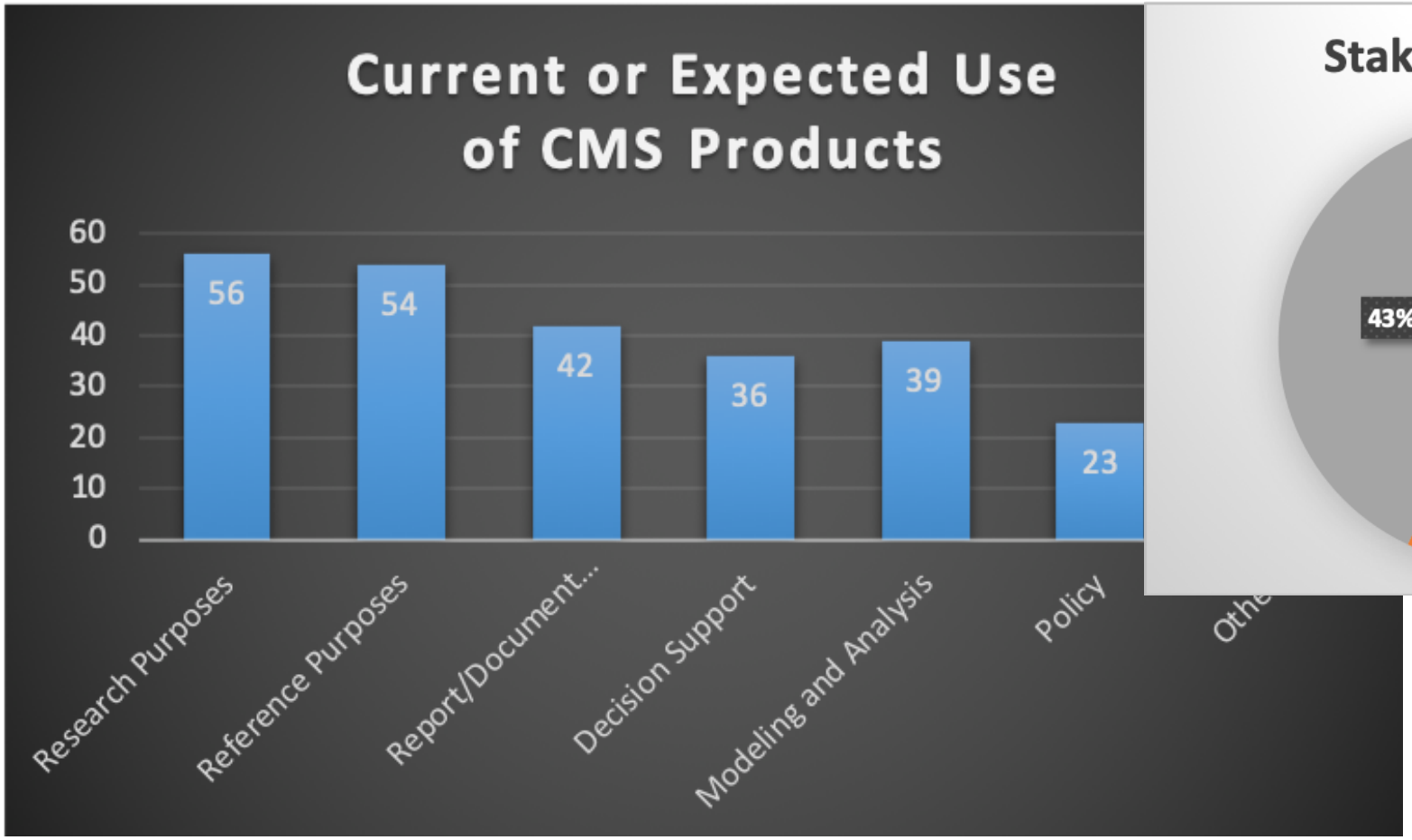
2011-2018 CMS Data Products by Current ARL

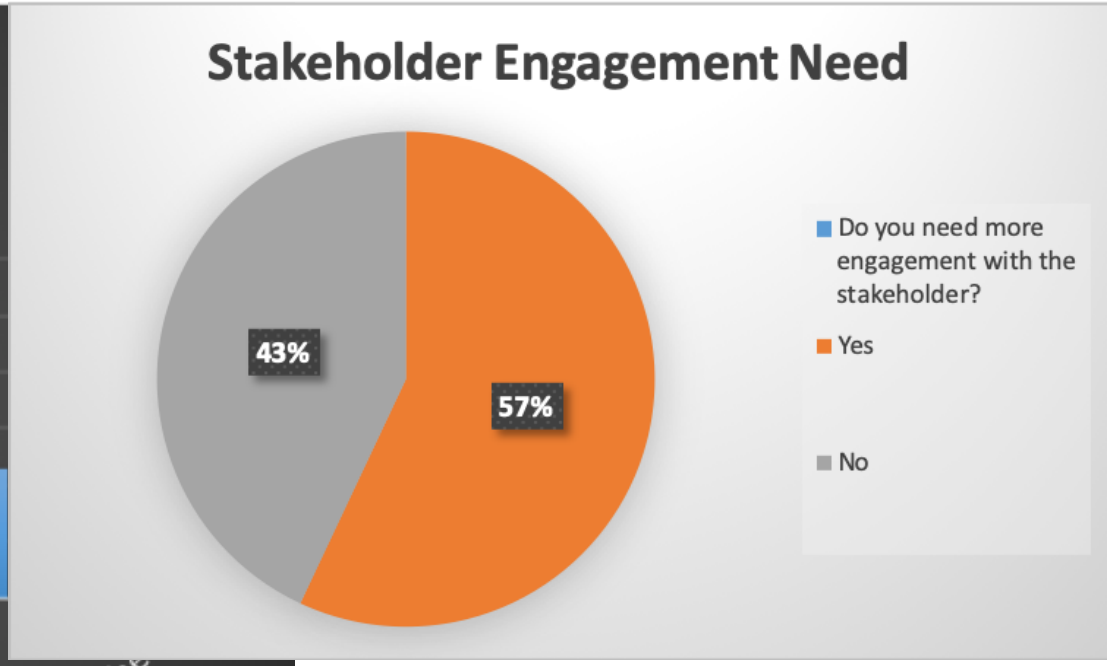




ARL LEVEL

2011 2013 2014 2015 2016 2018





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

G & APPLICATIONS WORKSHOP
olla, CA
NOVEMBER 12-14, 2019

uncertainty in the carbon-
stem

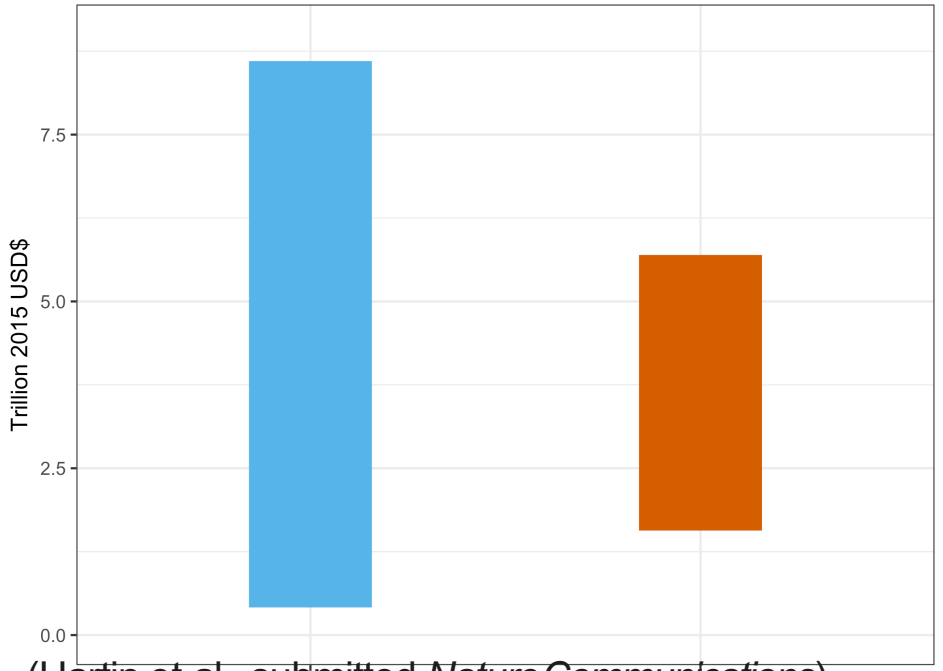
model (GCAM) and simple climate model

products (CO2, Ten
n the climate syster

rillion USD

rporate CMS data

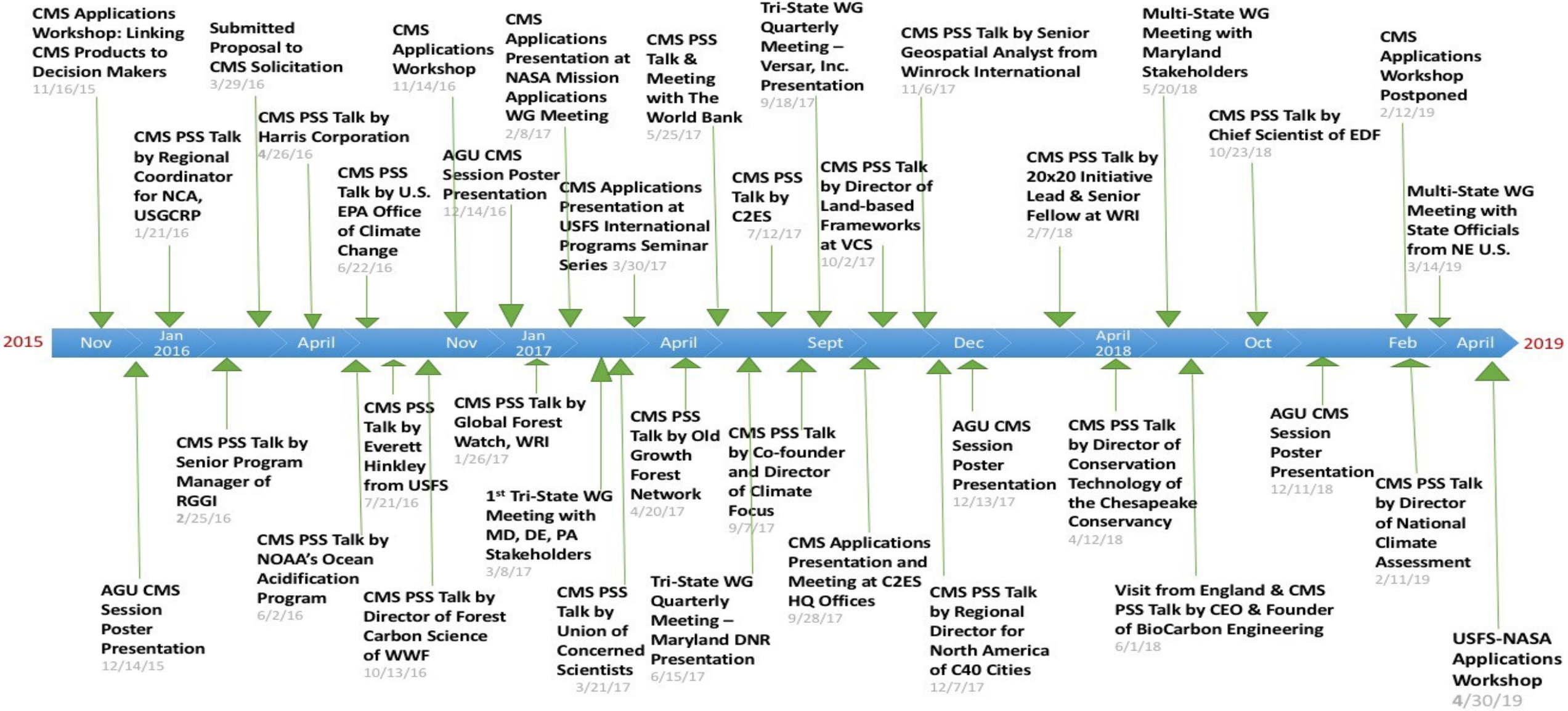
products



(Hartin et al., submitted *Nature Communications*)

National Aeronautics and Space Administration

NASA Carbon Monitoring System



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

Discussion Questions for Workshop

- How are you using the CMS data products?
- What application areas are been targeted?
- What are your decision making timelines?
- 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 with CMS or other NASA missions?

CONTACT INFORMATION
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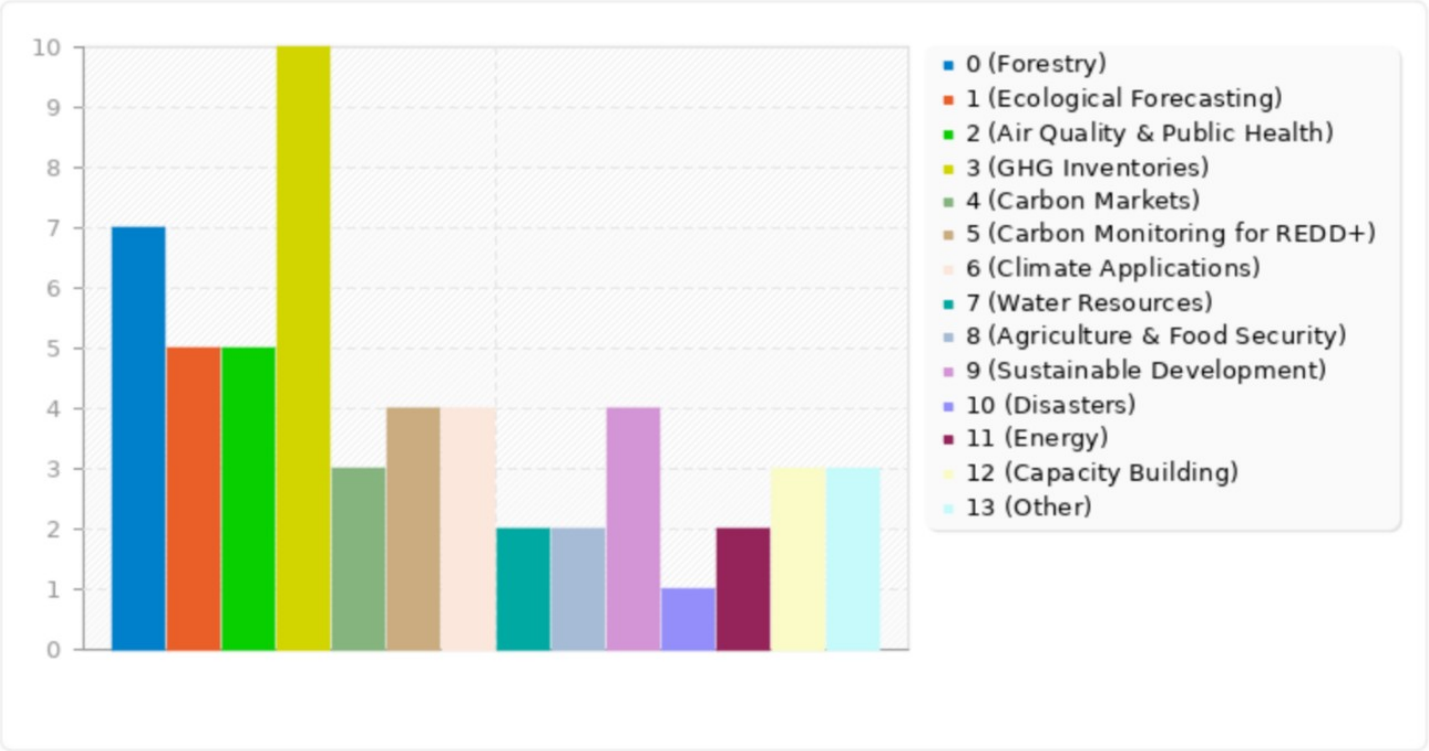
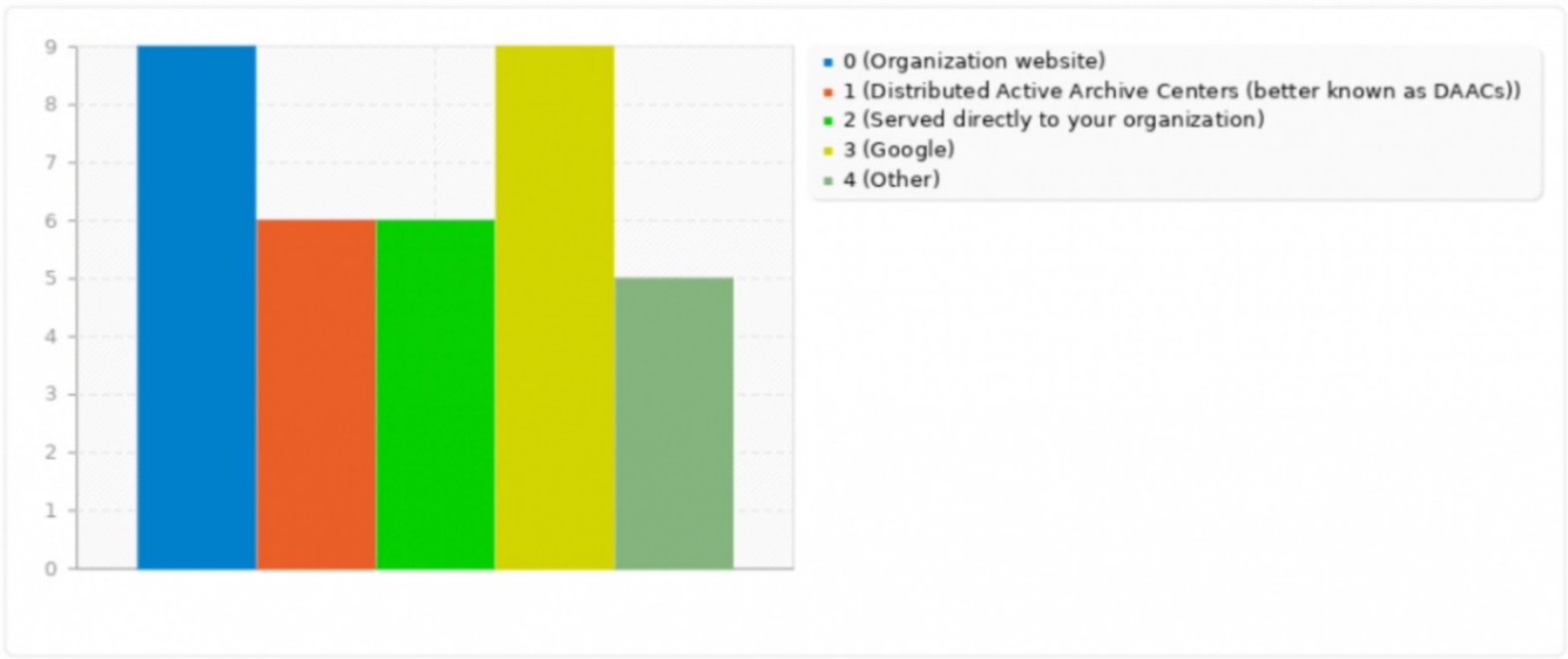
Stakeholder Feedback

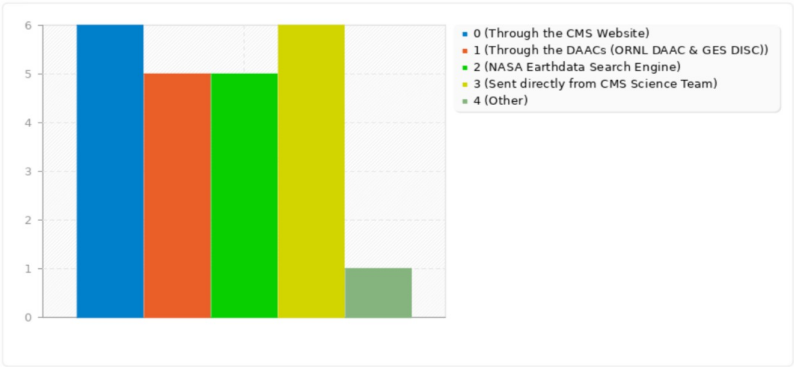
What are some of the applications you address with the carbon products?



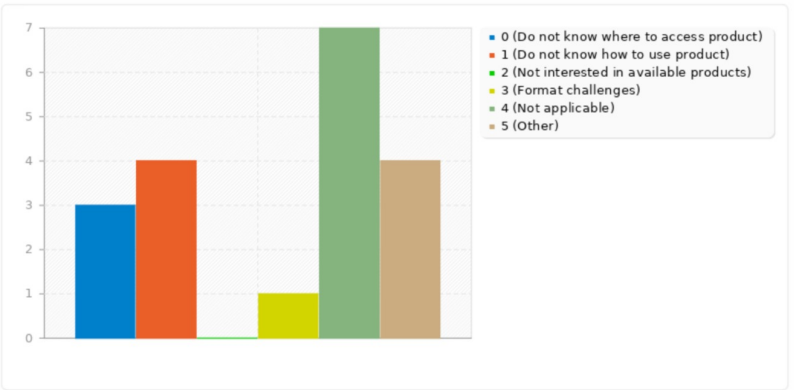
Where do you search for carbon data products?



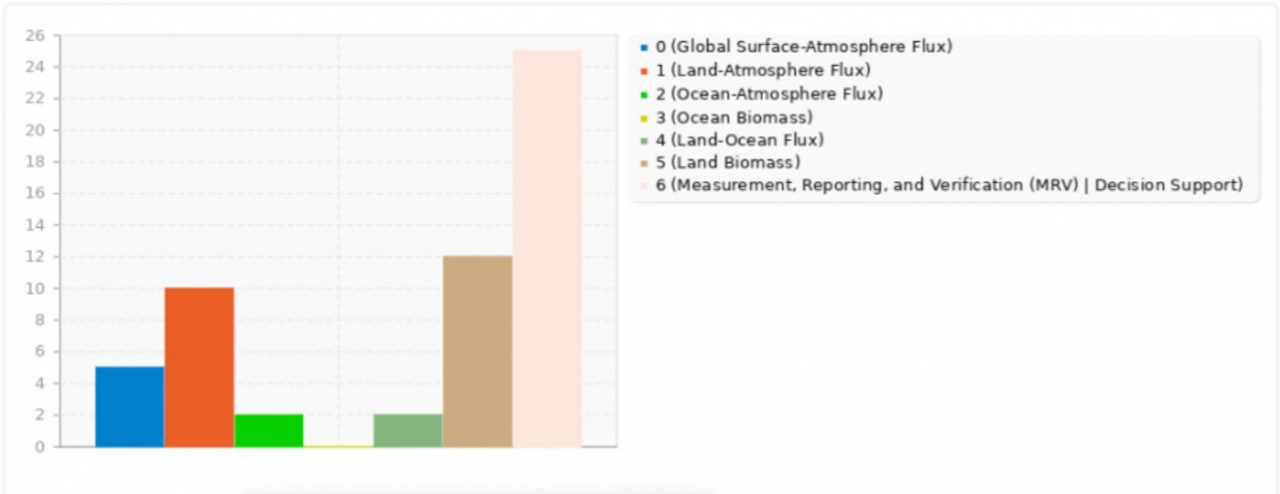
How do you access the products?



What prevents you from accessing CMS data products?



Which CMS science theme is most relevant to your work? (Check all that apply)



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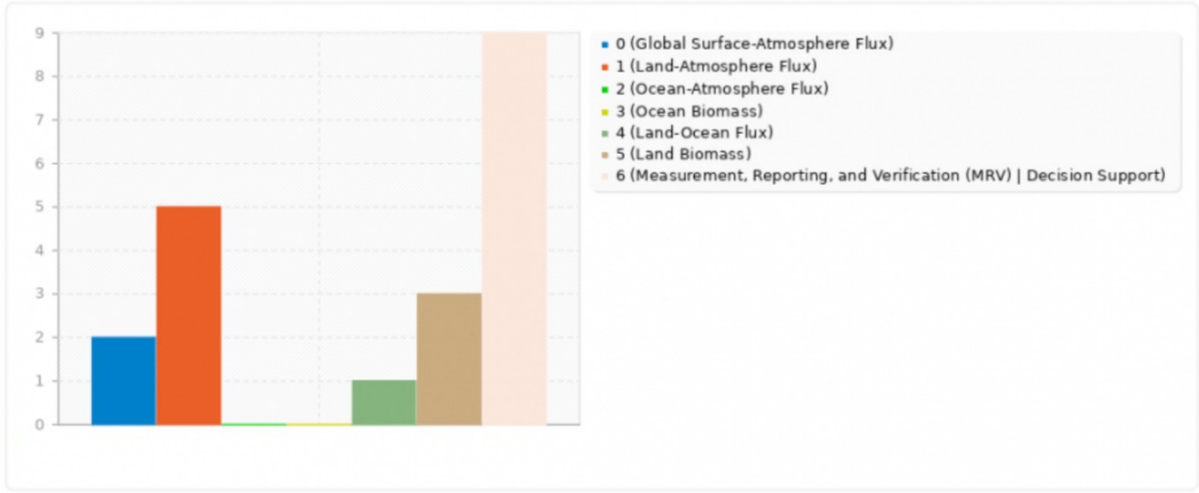
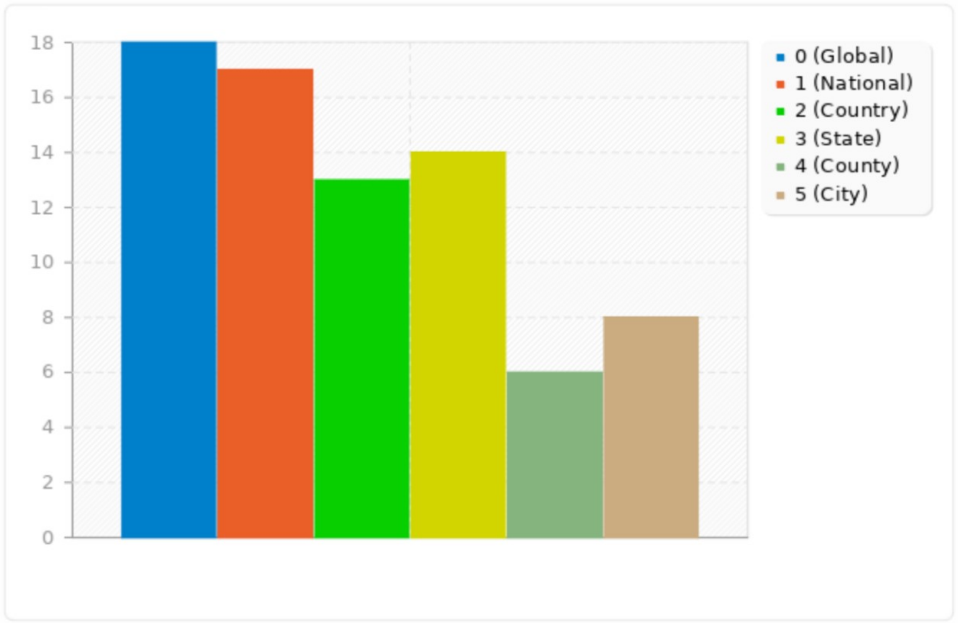


What is your geographical area of interest? (Check all that apply)



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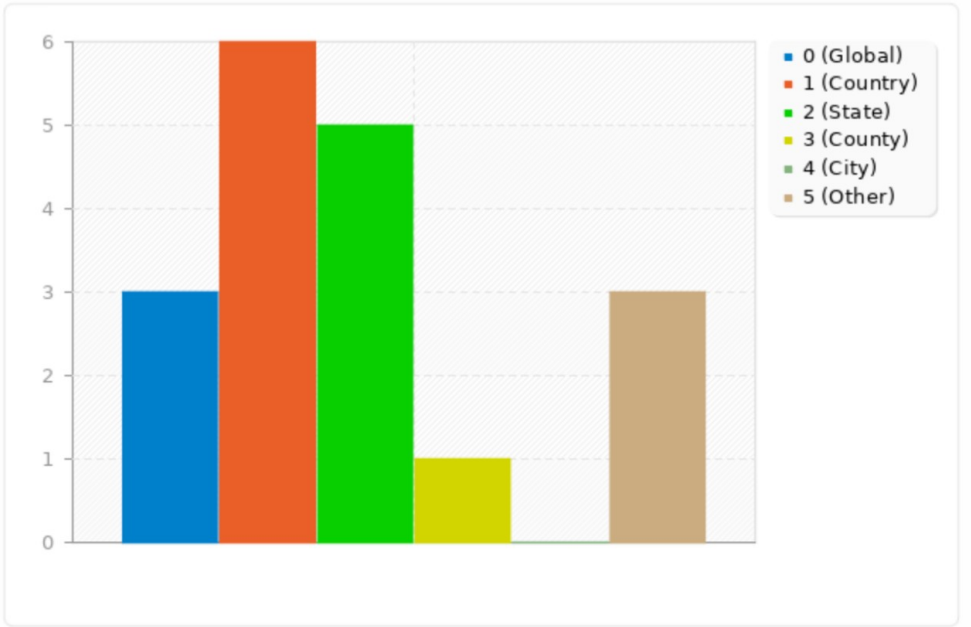
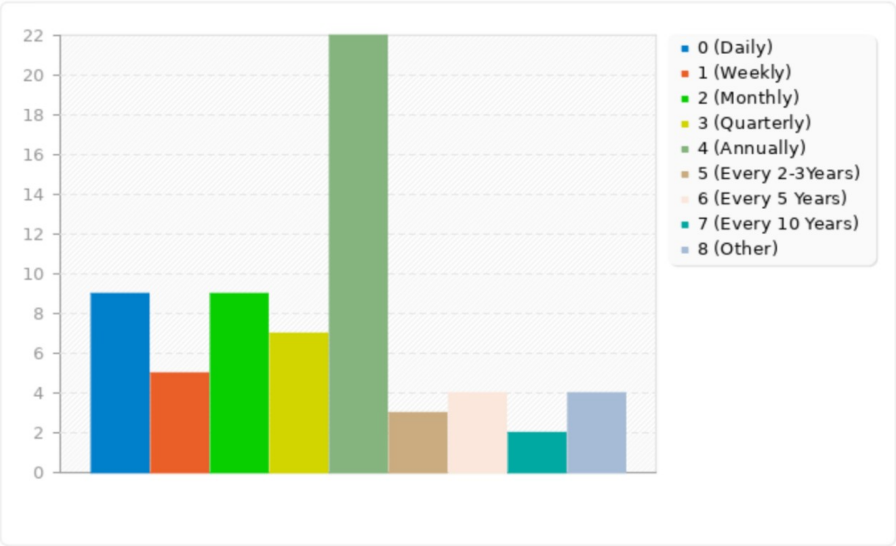


What is the ideal frequency of carbon information updates that you need in your work? (Check all that apply)



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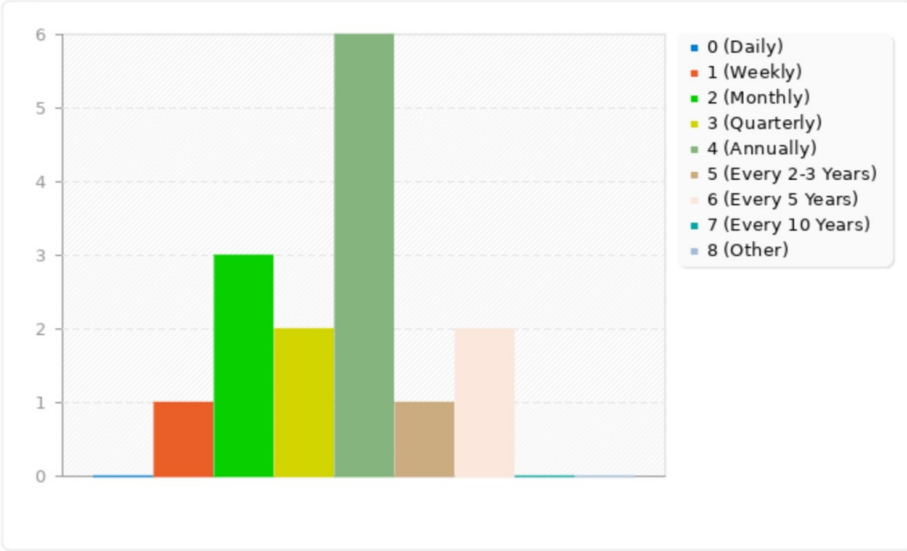
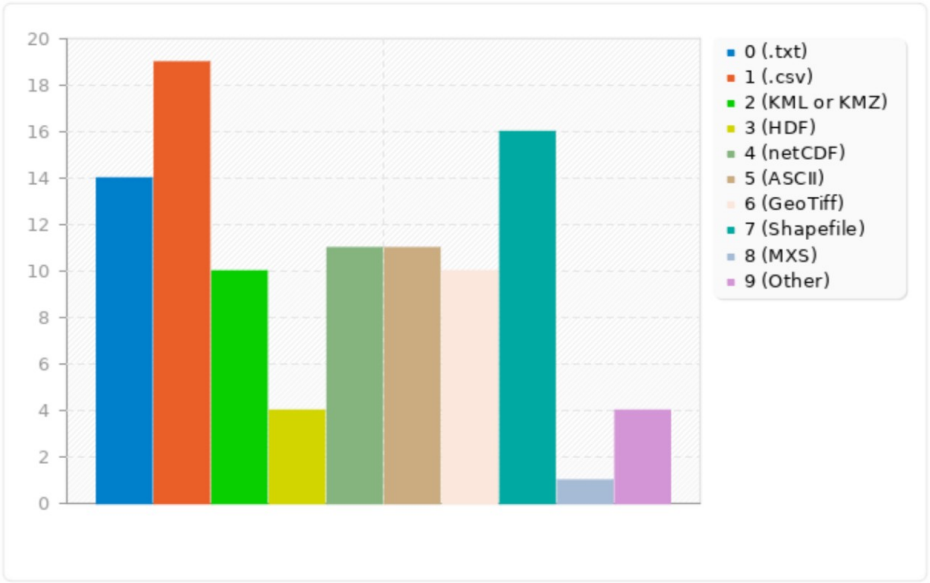


With regards on data modeling and processing for your organization, what is the ideal data format for your work? (Check all that apply)



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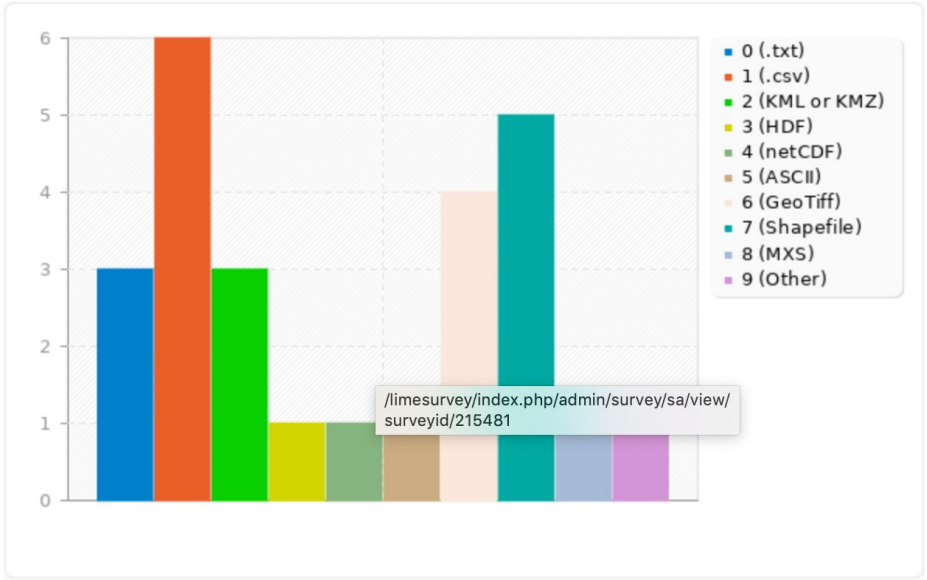

Outcomes & Actions Moving Forward

- Workshop Summary for The Earth Observer Newsletter and CMS Quarterly Newsletter – January 2020
- CMS Applications Workshop Report/Proceedings – February 2020
  - Stakeholders Interested in Contributing as Coauthors?
    - Provide Short Summary of Presentations
- CMS Stakeholder Fact Sheets with information about stakeholder organization, uses and applications, impact, and data needs – Spring 2020
- Agenda, Slides, Recording, and Report to be Published in CMS Website
- Potential Creation of CMS Stakeholder Working Group & Possible MoU with Stakeholder Organizations

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Upcoming Events 2019-2020

- Oral and Poster Presentations at 2019 AGU Fall Meeting
- CMS Policy Speaker Series in 2020 at NASA GSFC
  - CMS PIs are welcome to provide recommendations
- CMS Thematic Workshops: Climate Restoration Workshop in Spring 2020
- Stakeholder Workshops for CMS Projects {e.g. Hurtt (CMS 2016)} – March 2020
- Joint Workshops: NASA-USFS Applications Workshop – April 2020
- More Data Tutorials for CMS Stakeholders in 2020
  - How to use CMS datasets and scenario-based exercises (DAACs & ARSET)

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AG + OPEN SPACE
SONOMA COUNTY

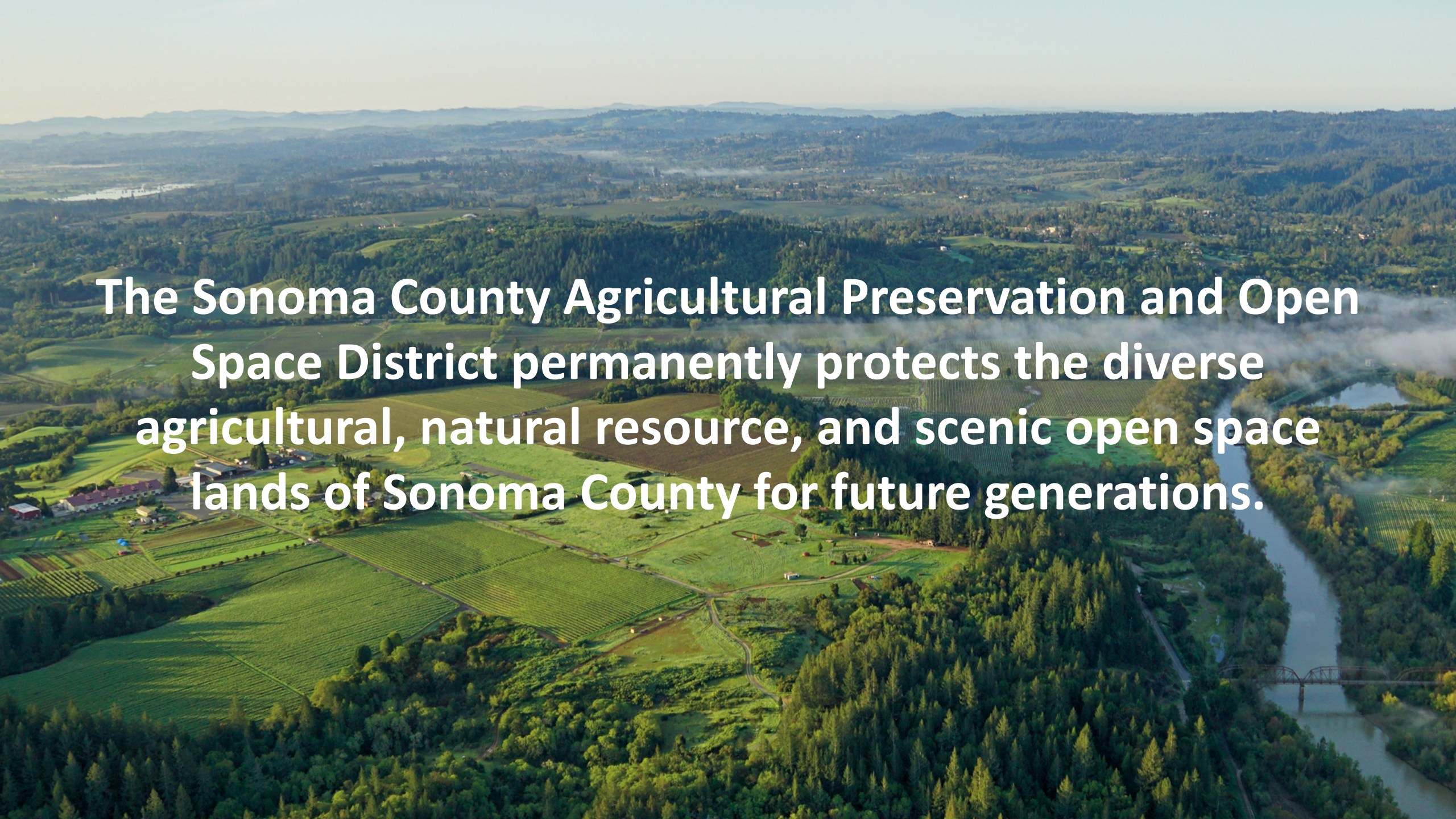
LAND FOR LIFE

CMS Data for Climate Action and Extreme Event Resiliency - Sonoma County, CA

NASA CMS Applications Workshop

November 12, 2019

Allison Schichtel | Senior Conservation Planner
Karen Gaffney | Conservation Planning Program Manager


The Sonoma County Agricultural Preservation and Open Space District permanently protects the diverse agricultural, natural resource, and scenic open space lands of Sonoma County for future generations.

Ag + Open Space Protected Land

- Conservation Easement
- Fee Title
- Open Space Easement
- Other Public or Protected Land
- Incorporated City

CLOVERDALE
HEALDSBURG
WINDSOR
SANTA ROSA
SEBASTOPOL
ROHNERT PARK
COTATI
SONOMA
PETALUMA

AG + OPEN SPACE
SONOMA COUNTY

Sonoma County Ag + Open Space

- **Prioritize conservation actions in a million-acre county**
  - Multi-objective
  - Efficient use of tax-payer dollars
- **Use science and data to inform our work**
- **Outcomes:**
  - Healthy and resilient ecosystems
  - Human health
  - Local food
  - Water supply and quality
  - Thriving economy

Sonoma County Ag + Open Space | Sonoma Veg Map

SONOMA VEG MAP

SONOMA COUNTY VEGETATION MAPPING & LIDAR PROGRAM

High-Quality Data for Planning, Conservation and Resource Management

CMS DATA PRODUCTS | Aboveground Biomass

Scripps

- Dubayah (CMS 2013): LiDAR-derived biomass, canopy height and cover, Sonoma County, CA
- Quantify GHG emissions of natural land conversion and benefits of conservation (avoided emissions & sequestration)
- Added habitat modeling capability through lidar-derived forest structure (size and canopy closure classes)

CMS DATA PRODUCTS | Lidar + Veg Map Products

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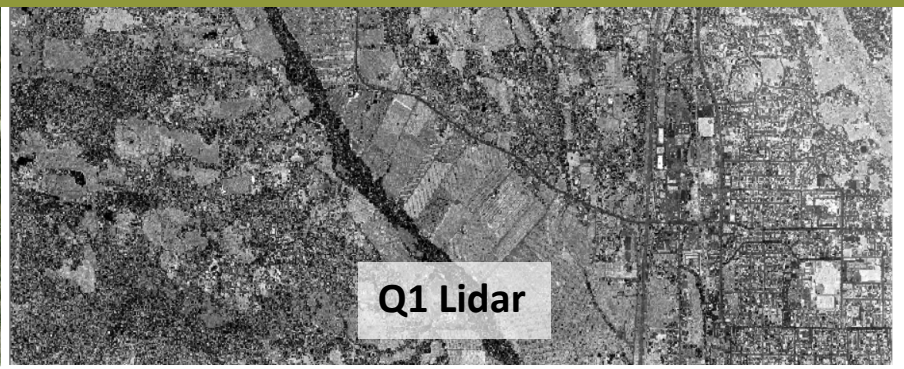
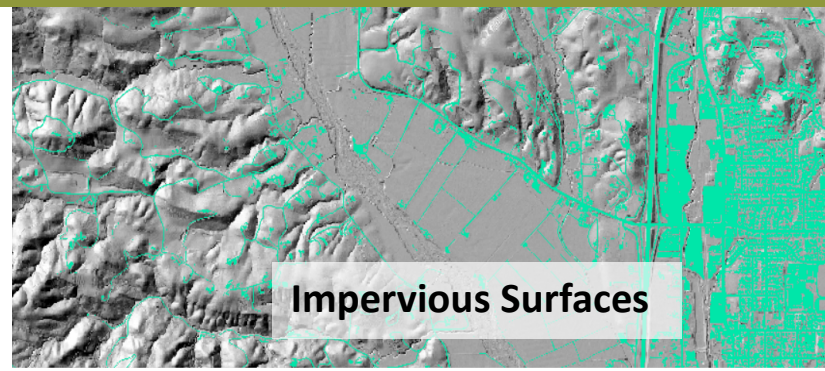
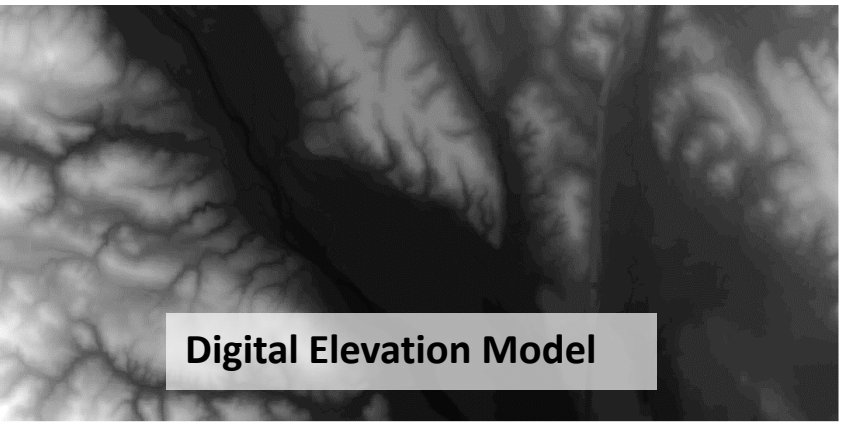
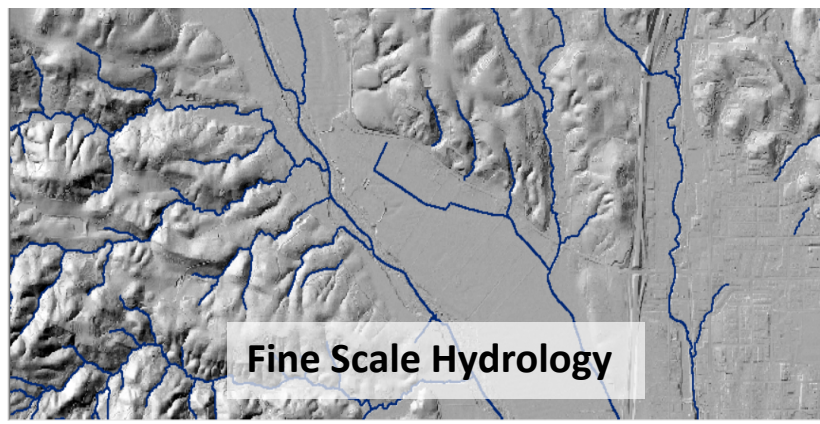
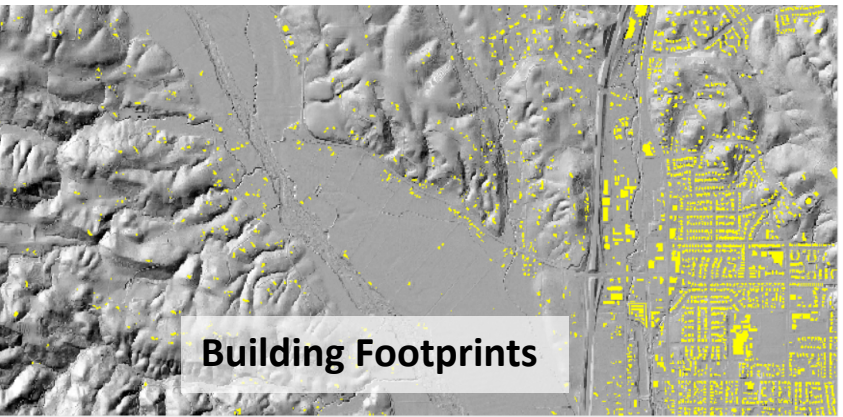
SONOMA COUNTY

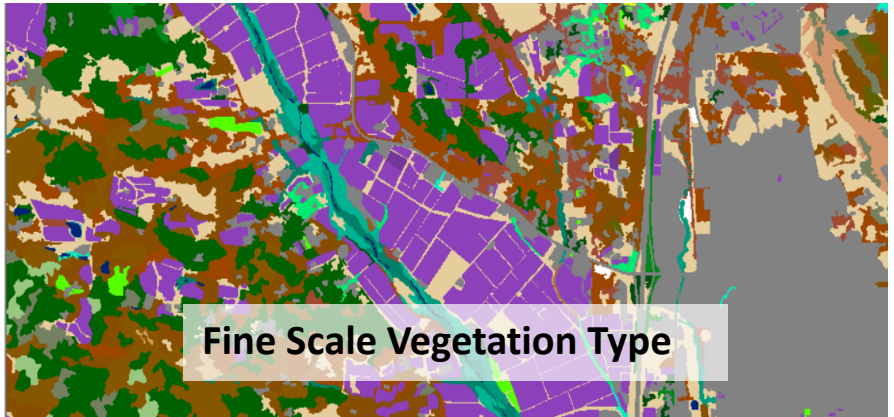


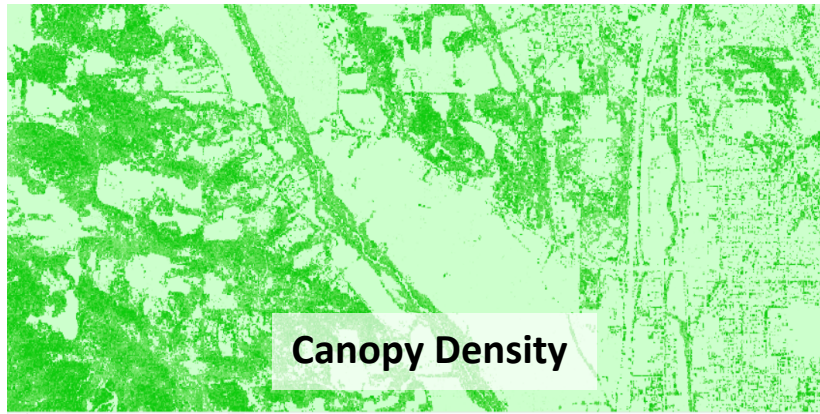












APPLICATIONS

- Land conservation planning & prioritization
- Extreme events
  - Wildfires
  - Flooding
  - Sea level rise
  - Drought
- Community resiliency
- Ecosystems & watershed health
- Agricultural applications
- Messaging & education
- Funding & policy
- Economic analysis

APPLICATIONS | Extreme Events

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SONOMA COUNTY

APPLICATIONS | Fire

- **$90,000 NASA Rapid Response & Novel Research in Earth Science Grant**
  - Analyze initial impacts from 2017 fires on vegetation
  - Discover relationship between canopy damage against landscape characteristics
  - Evaluate the value of NASA-funded Sonoma Veg Map data

APPLICATIONS | Fire

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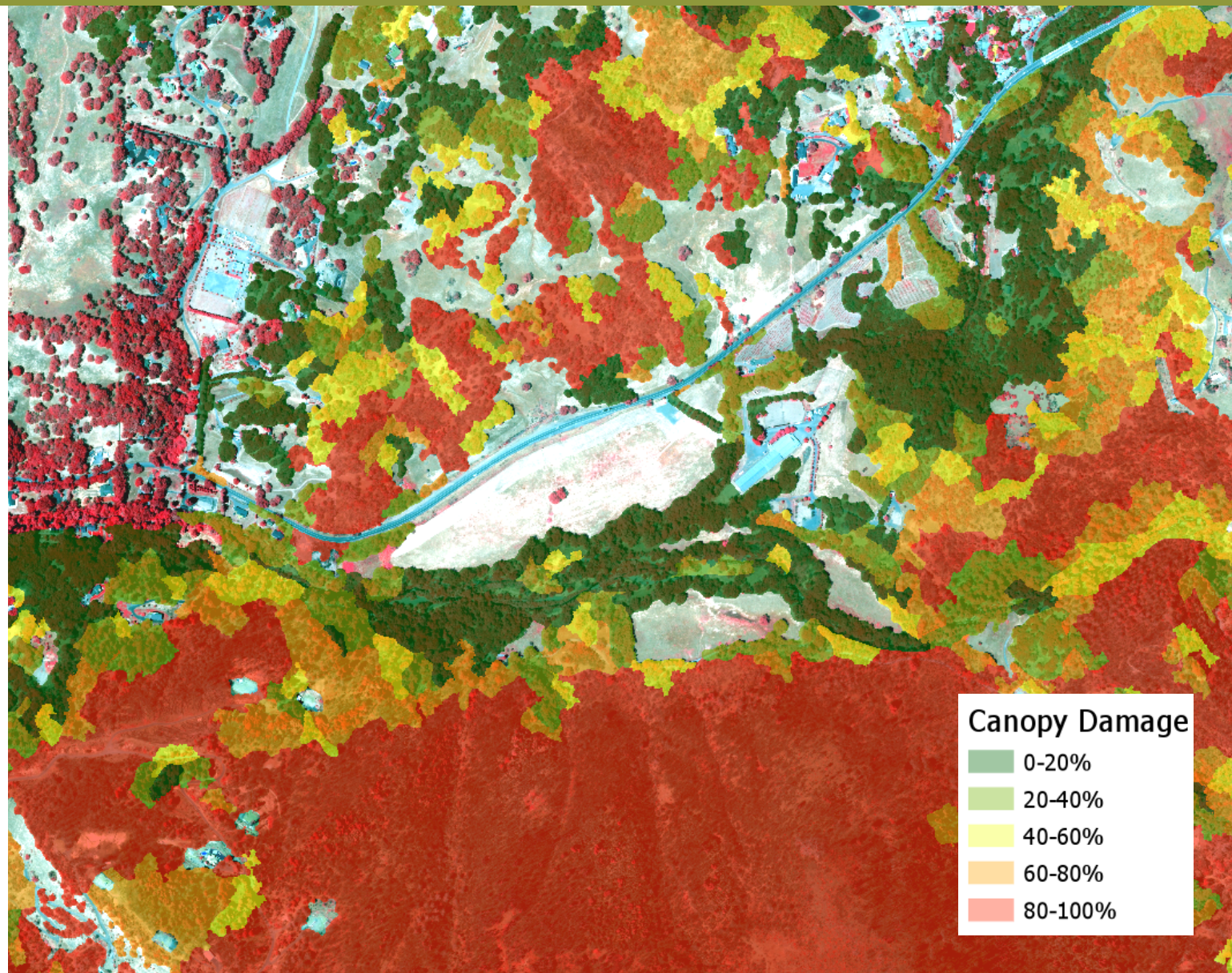
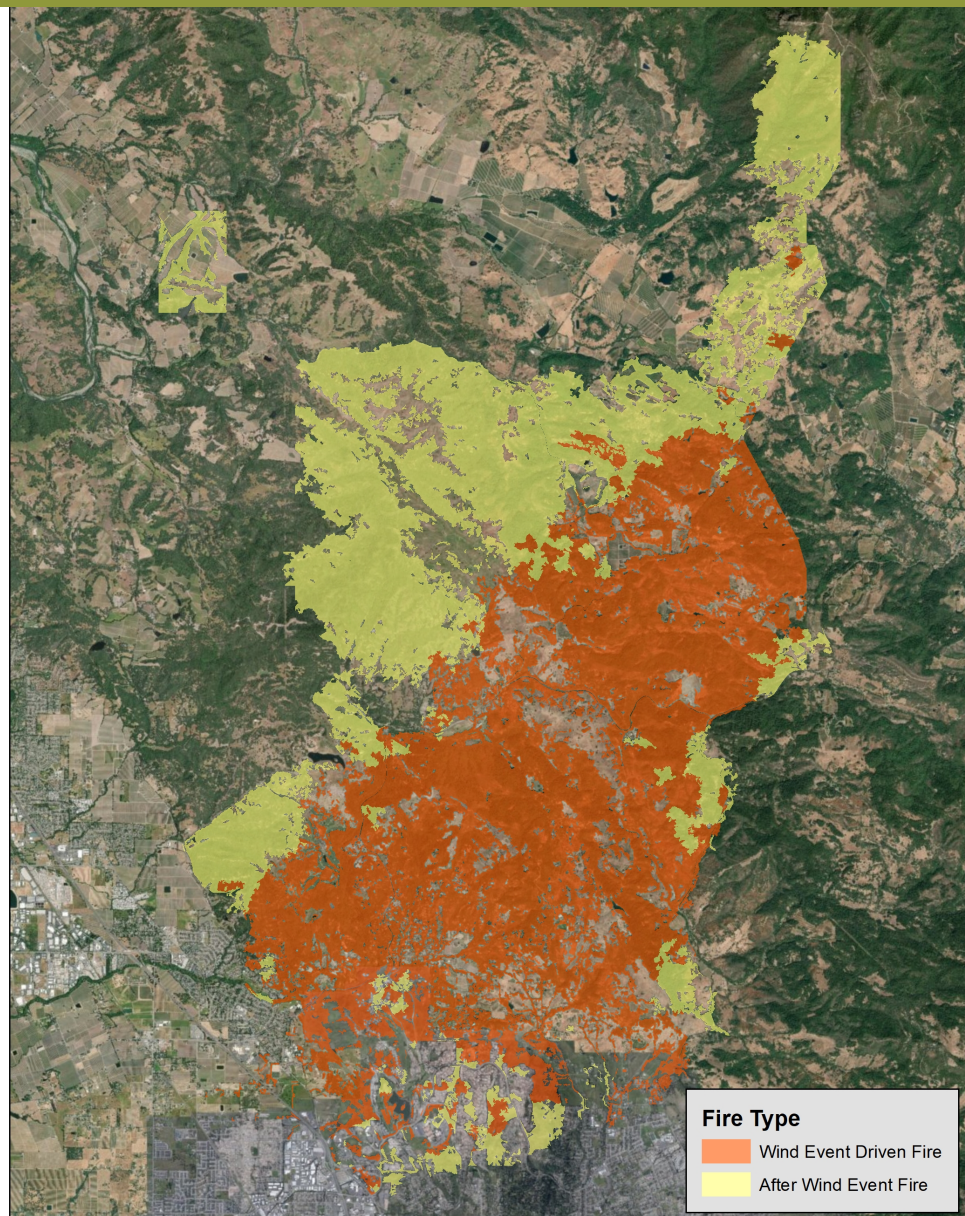


APPLICATIONS | Fire

Discover and quantify relationships between percent canopy damage against landscape characteristics

Analysis areas by areas burned during **wind driven** fire vs. **non-wind driven** fire



APPLICATIONS | Fire

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SONOMA COUNTY

Shrub/Forest Variables

- ★ Vegetation Type
- ★ Ladder Fuels
- ★ Canopy Height
- ★ Canopy Density
- Time Since Last Fire
- Slope and Aspect

Weather Variables

- Wind Direction
- Wind Speed

Climate Variables

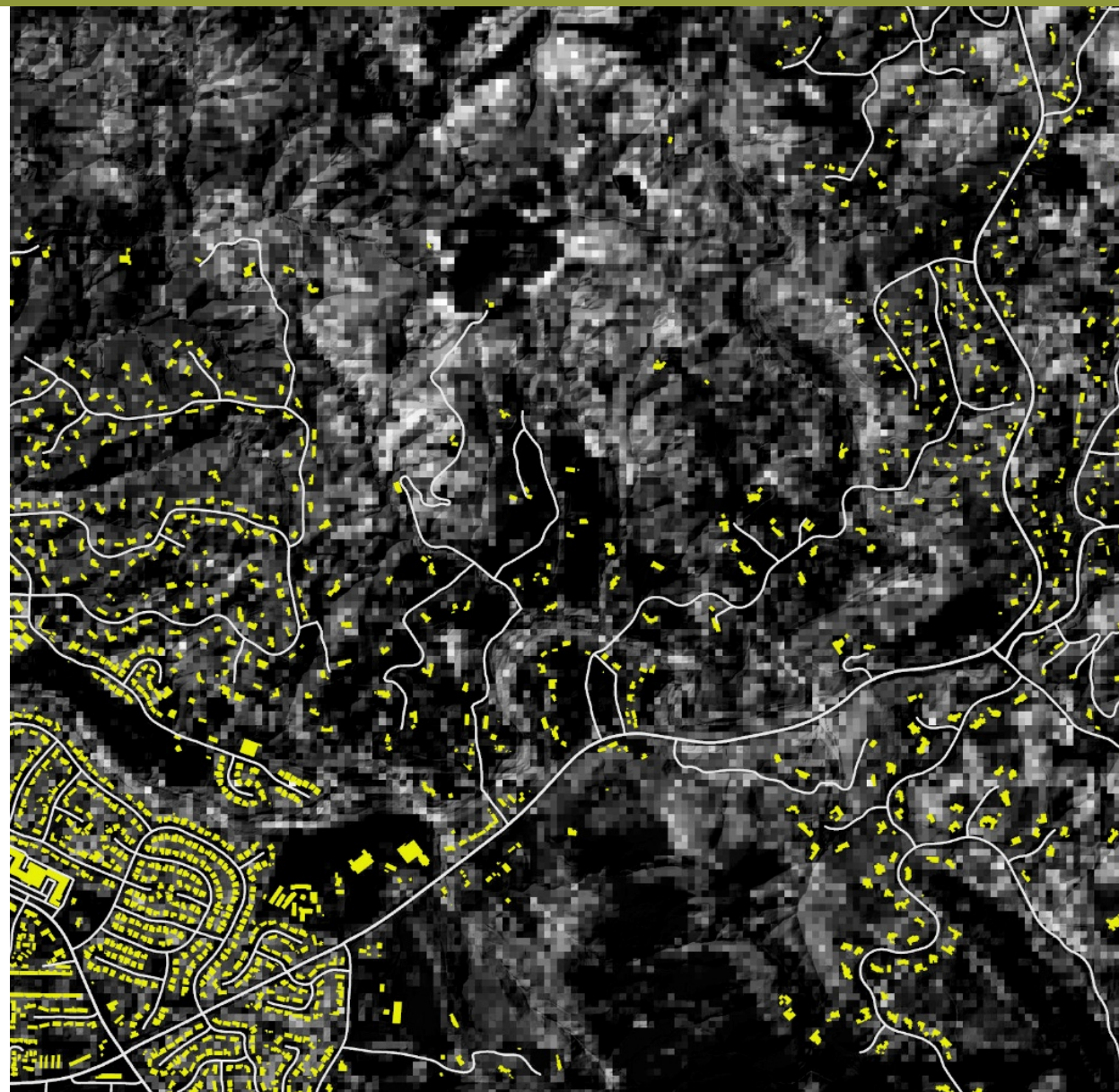
- Mean Climatic Water Deficit
- Mean Evapotranspiration
- Average Likelihood of Summer Fog

Proximity Variables

- ★ Distance to Nearest Stream
- Distance to Nearest Structure
- Distance to Nearest Conifer Stand
- Distance to Nearest Impervious Surface
- Distance to Nearest Irrigated Land Cover
- Majority Veg Class Around Stand

APPLICATIONS | Fire

- Pepperwood Preserve funded the development of **ladder fuels** and **wildland fuels maps** for all of Sonoma County which are being used to prioritize fuel treatments
- Marin and San Mateo Counties included ladder and wildland fuels in their fine-scale mapping projects; Santa Clara and Santa Cruz counties pursuing



APPLICATIONS | Fire

- Tie into emissions modeling & scenarios
  - How much CO_2e was lost in burned zones?
- What is the status of vegetative regrowth?
- What are the implications for vegetation management, land use planning, and water resources planning? For emergency response and human health and safety?

APPLICATIONS | Flood Mitigation + Riparian Habitat Restoration

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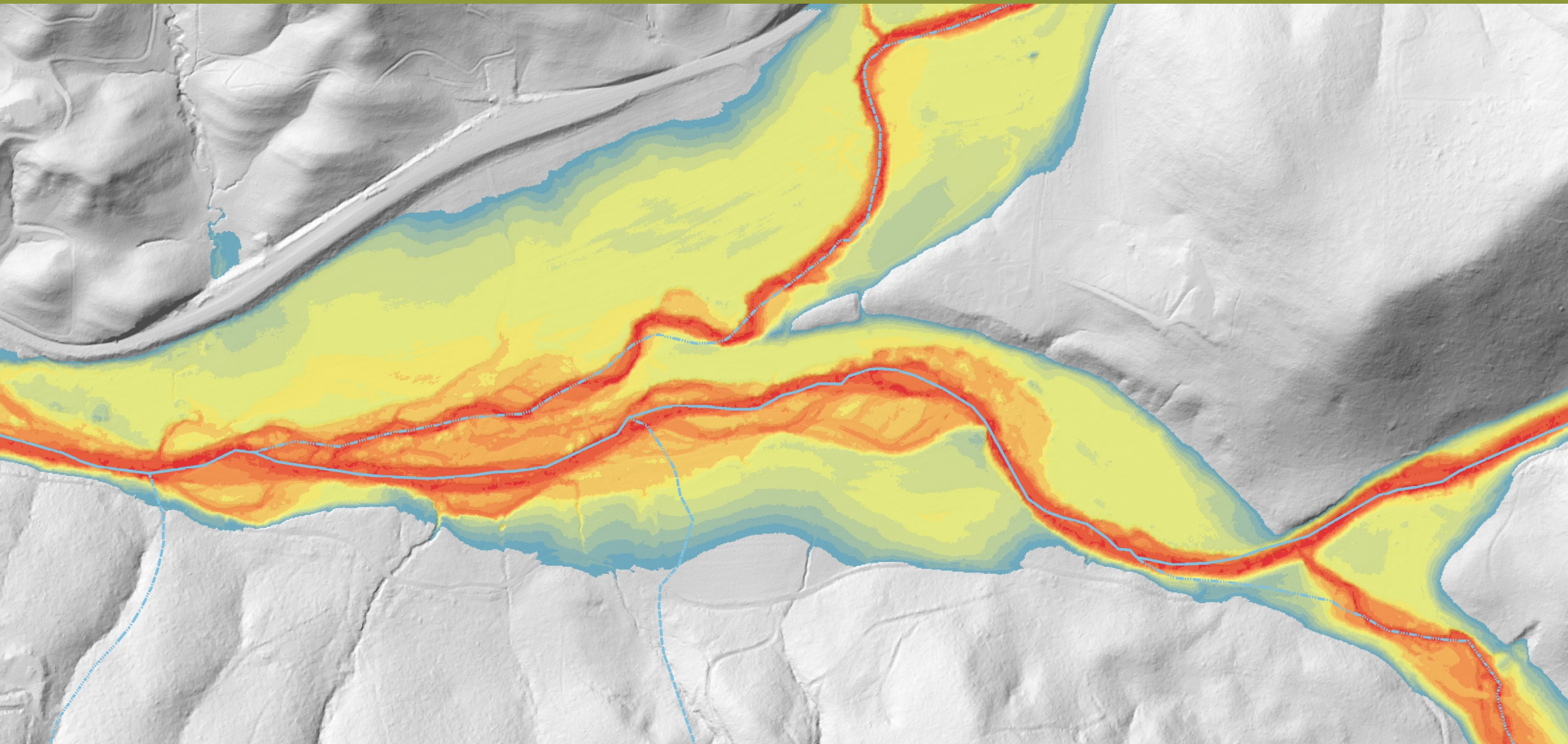
SONOMA COUNTY

APPLICATIONS | Riparian Corridor Modeling

AG + OPEN SPACE
SONOMA COUNTY

APPLICATIONS | Riparian Corridor Modeling

AG + OPEN SPACE
SONOMA COUNTY



APPLICATIONS | Riparian Ecosystem Valuation

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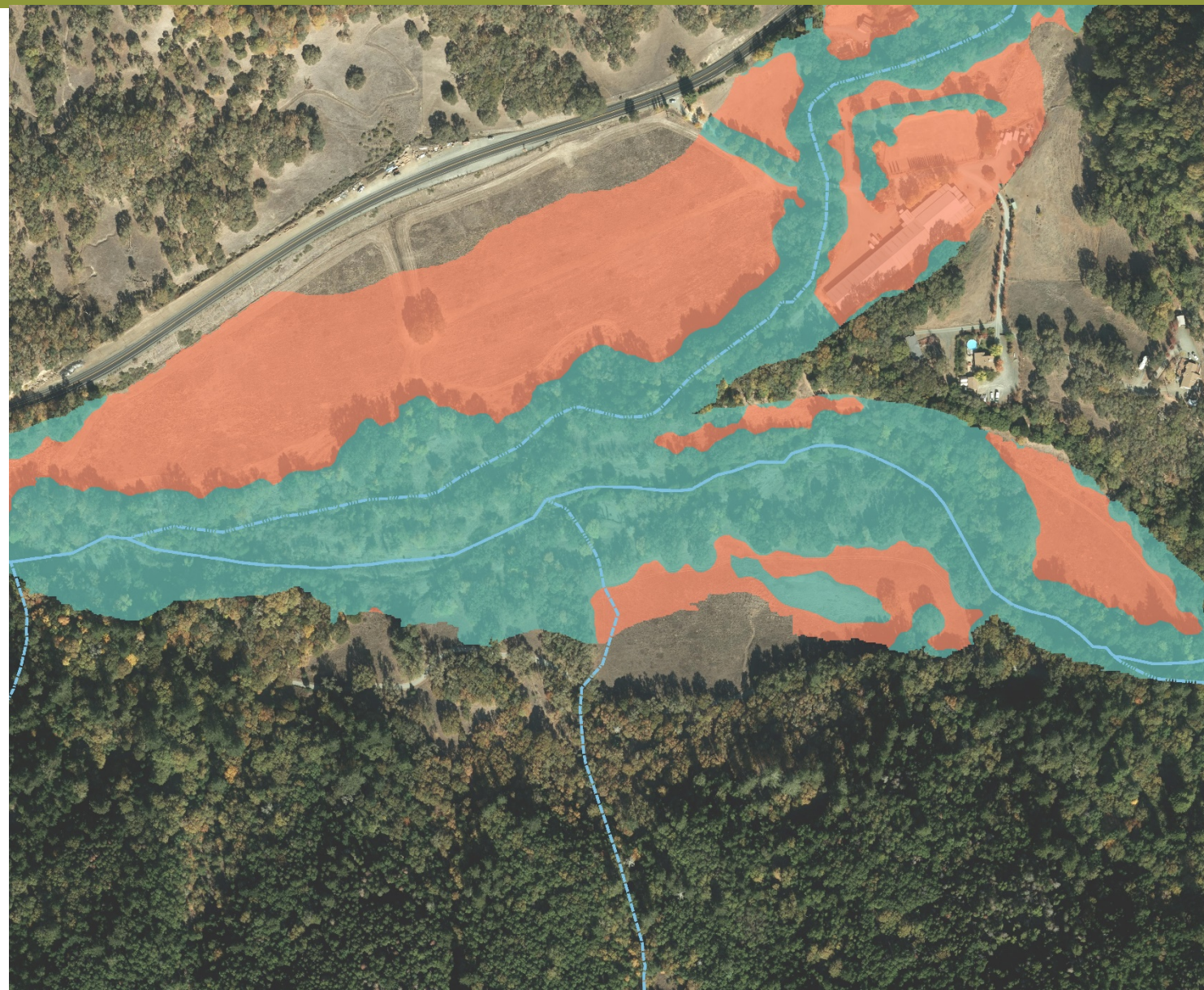
SONOMA COUNTY

- **38,000 acres total floodplain area in Sonoma County**
  - 18,000 acres **existing riparian habitat** stores **1.84 million tCO_2e** and is valued at **$27.6 million**
  - 20,000 acres with **potential for restoration** for total storage of **3.10 million tCO_2e** and value of **$46.5 million**



Sonoma County Ag + Open Space and Highland Economics. 2018. The Multiple Benefits and Values of Sonoma County Riparian Corridors. Report prepared for Sonoma County Ag + Open Space. Available at: www.sonomaopenspace.org/HLHE

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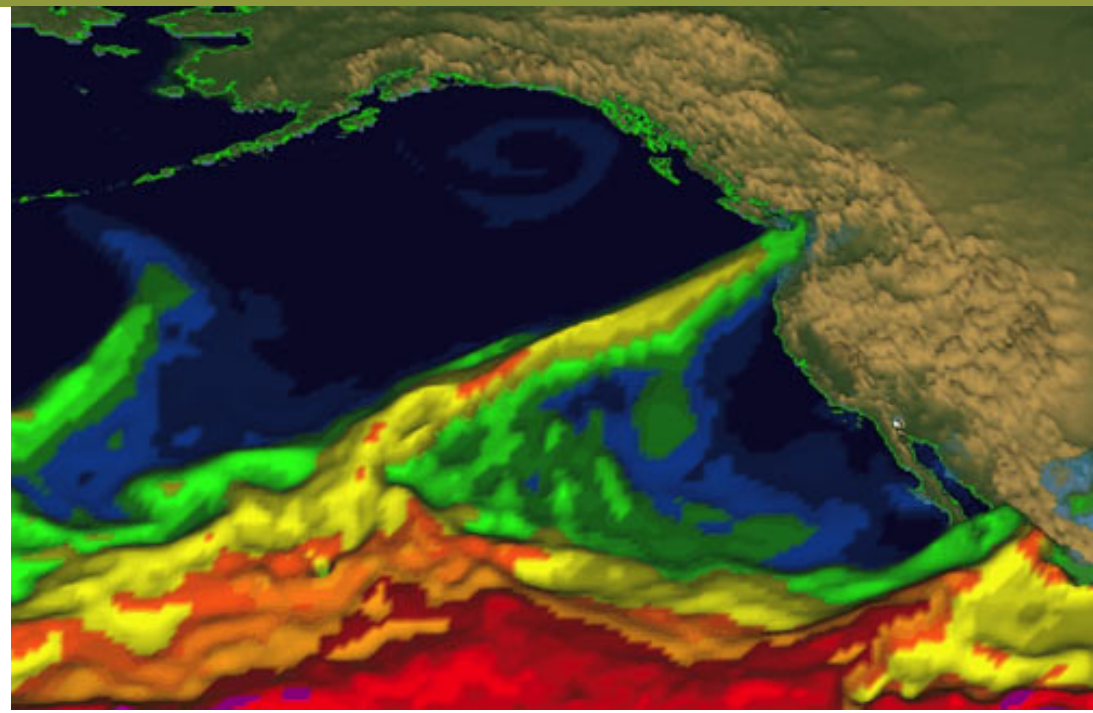
SONOMA COUNTY

APPLICATIONS | Riparian Habitat Modeling

- Integrate with Sonoma Water/Scripps Institute atmospheric river modeling
- Advanced Quantitative Precipitation Information (AQPI) system to better predict when an AR will make landfall and where
- What is necessary **width** for riparian corridor from a **climate adaptation** stand point?



CMS | Decision-making Timelines

- **Sonoma Ag + Open Space Vital Lands Initiative (through 2031)**
- **Sonoma County General Plan update**
- **State climate legislation**
  - Climate Adaptation & Resiliency
  - Greenhouse Gas Emission Reduction
  - Extreme events (fire & flood)

CMS | Carbon Data Needs/Gaps

- **Land use/emissions scenarios at local (county) scale**
- **Update frequency for change detection (3-5 years)**
- **Interested in applications with research by :**
  - Hurtt (CMS 2014/2016): High-res carbon monitoring and modeling
  - Healy (CMS 2016): GEDI-based forest carbon MRV tool
  - Greenburg (CMS 2016): 3D change detection of aboveground biomass

CMS | Challenges & Improvements

Scripps Seaside Forum, La Jolla, CA

- **Data product accessibility**
  - Lessons learned from Sonoma Veg Map user survey
  - Web apps/reporting tools (e.g. Ecometrica)
- **Update frequency (3-5 years)**
  - Volatility of fire/flood events
  - Rapidly changing landscape
- **More opportunities for partnership & capacity building**

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

- **Capacity building/partnership**
- **Unintended outcomes - beyond carbon**
  - Fire, flood, climate resiliency, habitat/biodiversity modeling, water balance modeling
  - And growing!
- **Enhanced accuracy and spatial scale of multi-benefit analysis**
- **Messaging and education**
  - General public, decision makers, funders
- **On the ground applications**

What is the next priority in your work?

- **Strategic, proactive land conservation**
  - Vital Lands Initiative
- **Research and applications related to:**
  - Change detection
    - Post-fire/flood ecosystem response
    - GHG emissions & reductions over time
  - Sea level rise & planned retreat
  - Climate refugia/climate strongholds
- **Expansion & sharing of research with state/national partners**
- **Enhanced economic analysis**

What scientific advancement(s) could contribute to your work? What data do you need?

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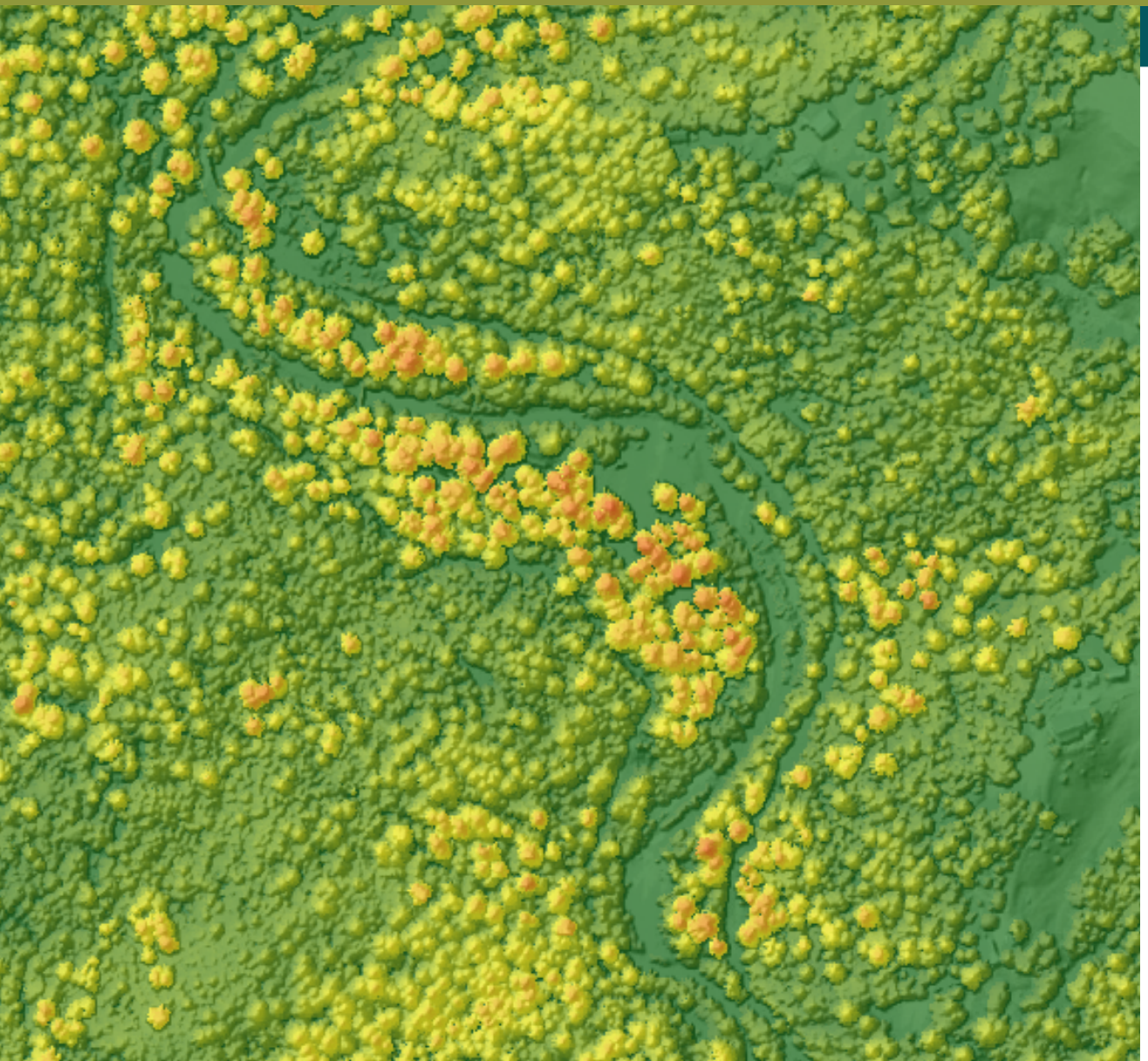
SONOMA COUNTY



NOVEMBER 12-14, 2019

- Vegetation & topographic metrics for biodiversity mapping
- Repeat Q1 lidar collect countywide
- Semi-automated fine-scale change monitoring methods to keep these valuable data sets current

NASA

AG + OPEN SPACE
SONOMA COUNTY

LAND FOR LIFE

THANK YOU

Allison Schichtel | Senior Conservation Planner | Allison.Schichtel@sonoma-county.org

Karen Gaffney | Conservation Planning Program Manager| Karen.Gaffney@sonoma-county.org

Current and Future use of Satellite Remote Sensing Data at the California Air Resources Board

November 12, 2019

CMS Applications Workshop, San Diego

Jorn Herner, Research Division
916-324-9299, Jorn.Herner@arb.ca.gov

California Air Resources Board

SCIENCE TEAM MEETING & APPLICATIONS WORKSHOP
Scripps Seaside Forum, La Jolla, CA
NOVEMBER 12-14, 2019

The California Air Resources Board (CARB) is charged with protecting the public from the harmful effects of air pollution and developing programs and actions to fight climate change.

California Air Resources Board

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Air Quality

Toxics

Climate

Equity

California Air Resources Board

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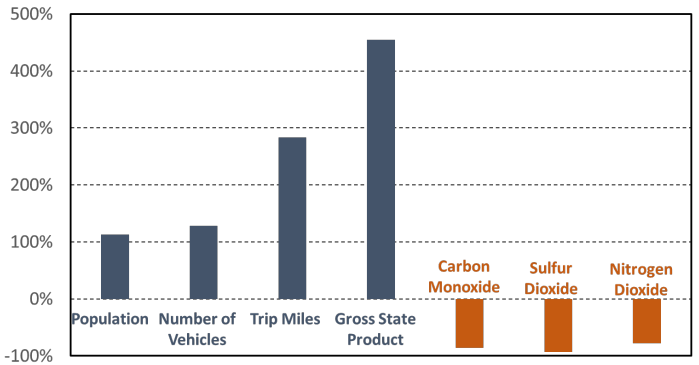
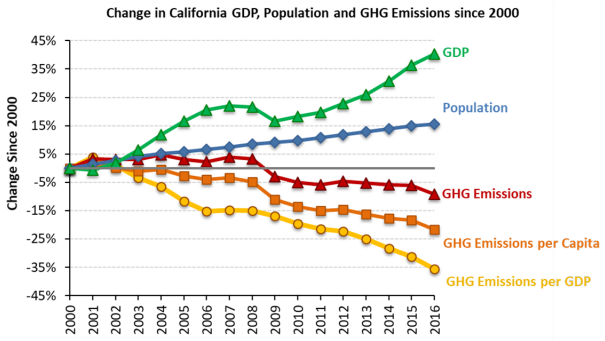
Los Angeles Smog in 1948

Decoupling of economic growth and emissions

Percent Change. 1972-2015





We've come a long way but still have lots to do

Roadmap and Requirements

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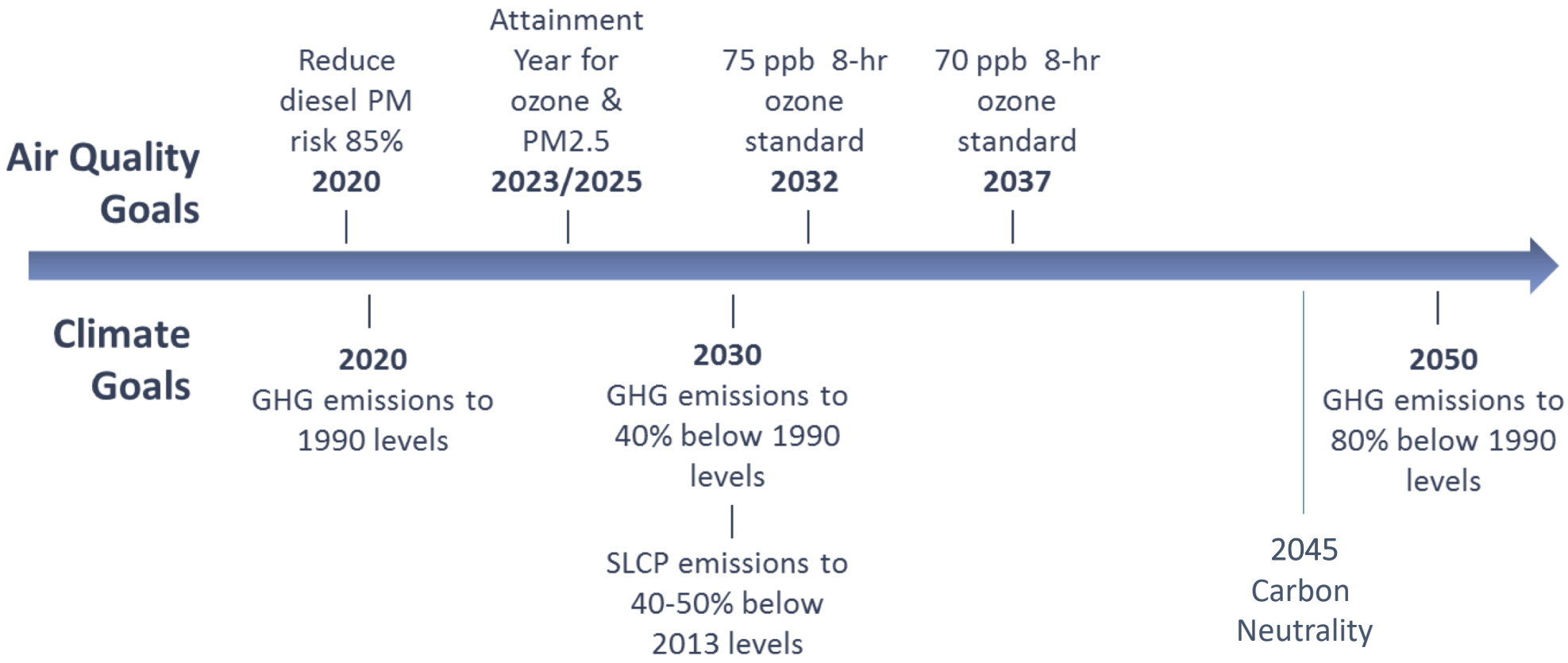

Range of monitoring applications are used to assess air quality

Air Monitoring Approaches

Federal Reference and Equivalent	Air Toxics	Air Sensors	Mobile Platform	Fenceline	Remote Sensing

Multiple tools and techniques required to measure pollutant concentrations

CARB's Satellite Research

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Health

Air Quality

Climate

ADVANTAGES

- Wide spatial coverage
- Complements ground monitors
- Data is publically accessible
- Cost-effective
- Consistent observations, globally

LIMITATIONS

- Daytime and cloud-free conditions
- Snapshot in time (if not geostationary satellite)
- Column (surface to satellite) measurements (e.g., difficult to correlate column O_3 to ground O_3)
- Data processing is complex, and only certain pollutants are covered

Appropriate use of satellite technology is key for future research

Air Quality and Toxics

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Forum, La Jolla, CA NOVEMBER

- Increase understanding of spatial distribution and exposures
- Increased understanding of chemistry, transportation and sources
- Important input into inventory models (land-use, etc)
- Tracking trends and effect of regulations
- Emergency response

Greater spatial and temporal resolution, VOCs

Satellite and Air Quality Trends

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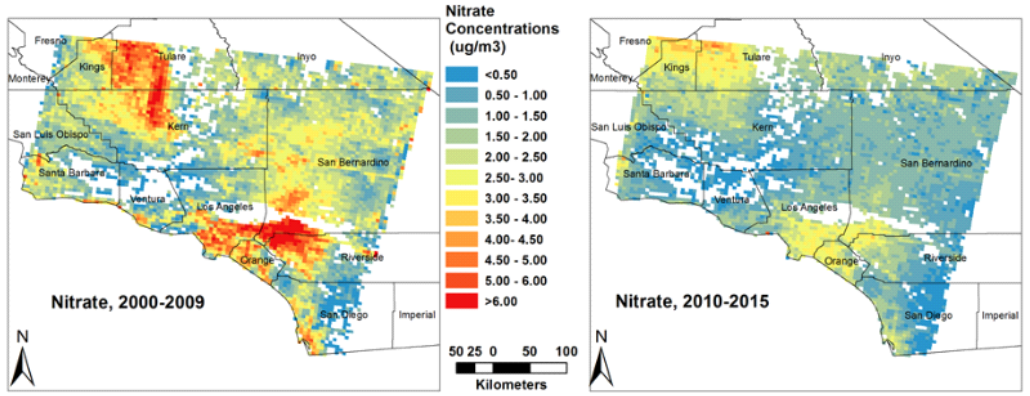
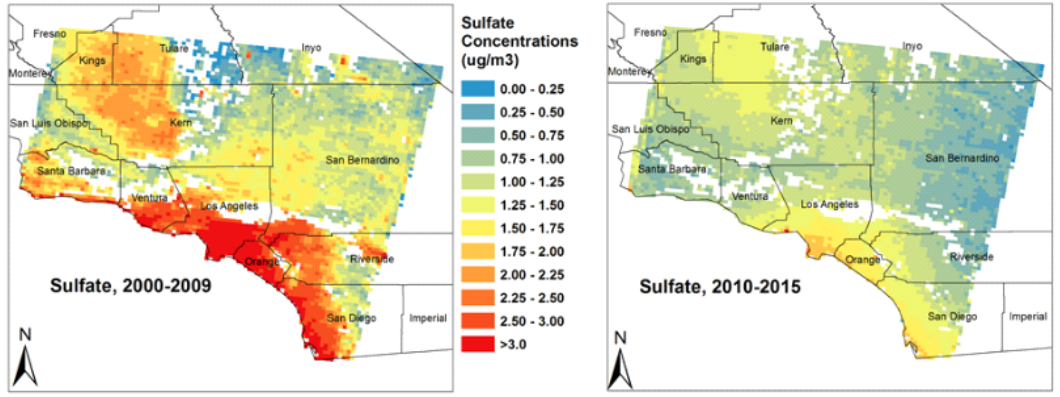
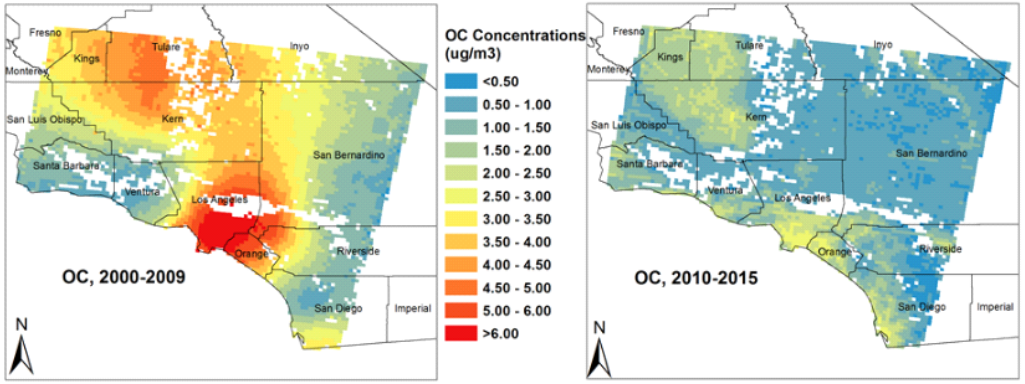
Nitrate



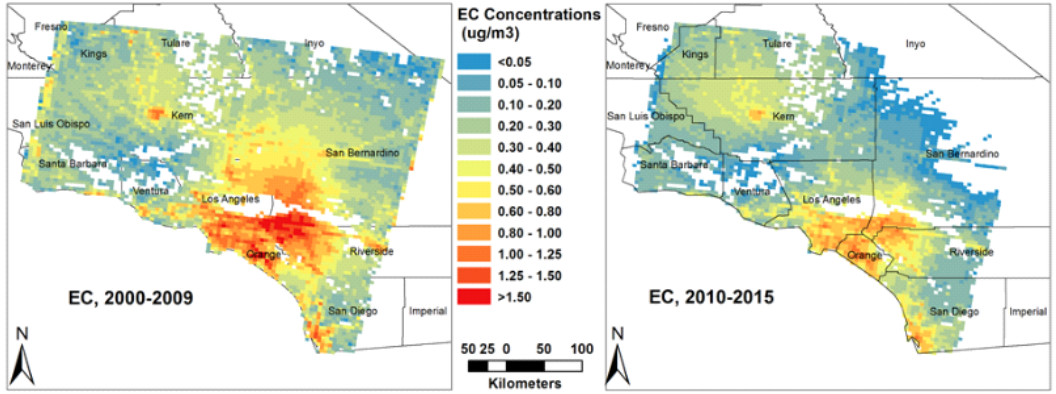
Sulfate



Organic Carbon



Elemental Carbon

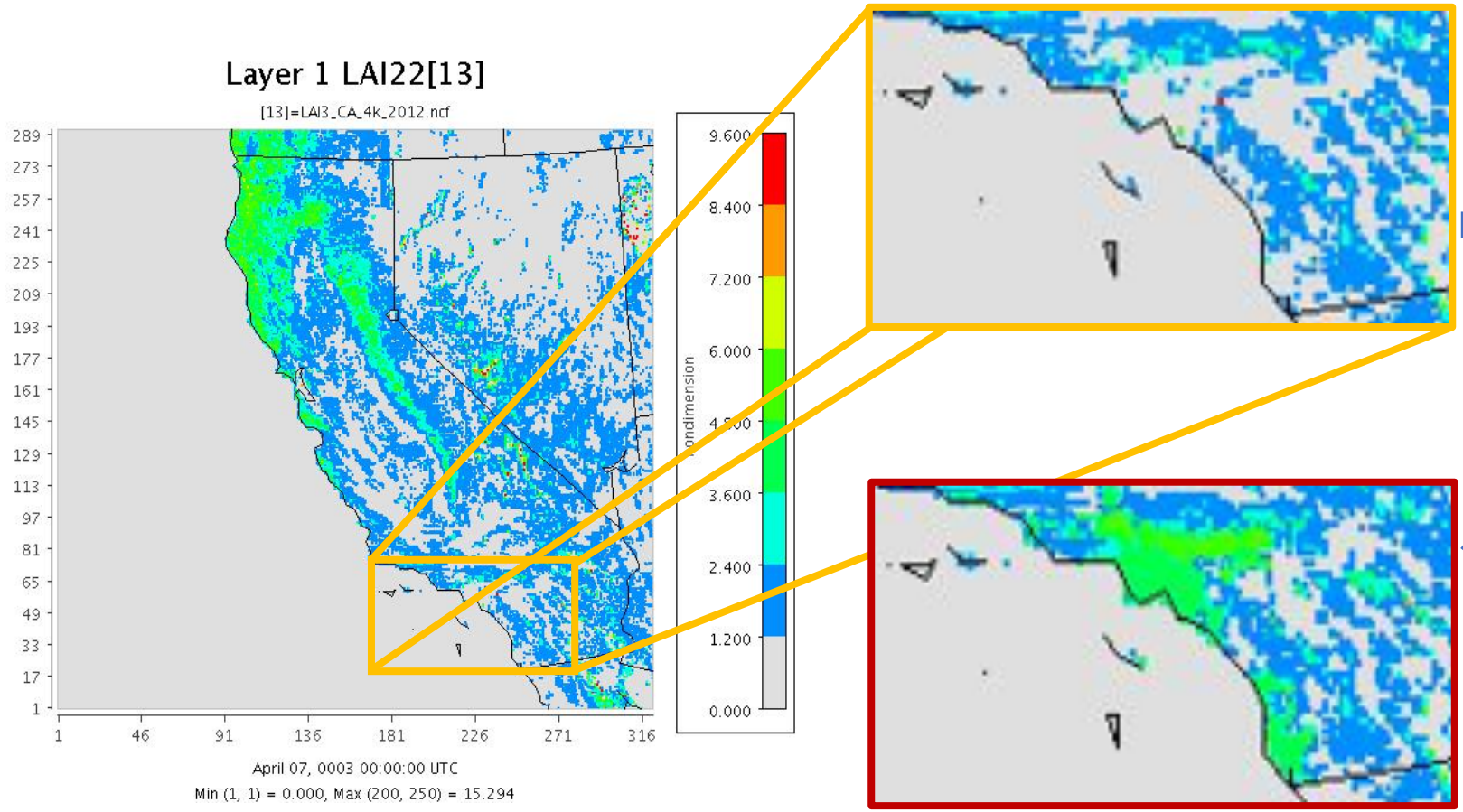


Meng et al. (2018) Estimating $PM_{2.5}$ speciation concentrations using prototype 4.4 km-resolution MISR aerosol properties over Southern California, *Atmos. Environ.*

Satellite data will be used to evaluate AQ improvement over time

- MODIS Leaf Area Index for developing CARB's biogenic VOC (BVOC) emissions inventory

MODIS does not provide LAI data over urban regions, but urban BVOC emission are critical in regions such as the LA basin, where ozone formation is VOC limited



MODIS LAI is missing for urban regions

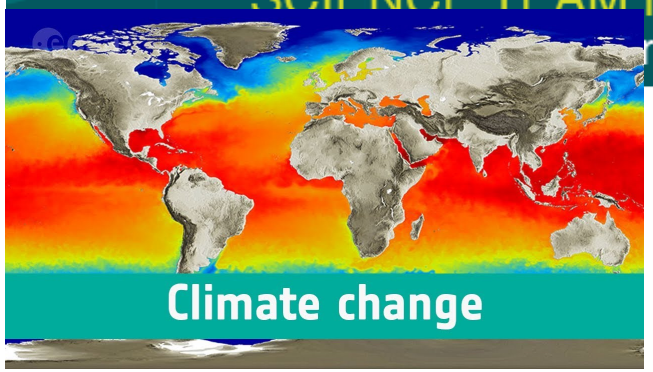
Urban LAIv filled with FIA/i-Tree data

Tracking wildfire smoke plumes

Source: MODIS Aqua, NASA Worldview

Satellites well positioned to track wildfire smoke plumes

Climate



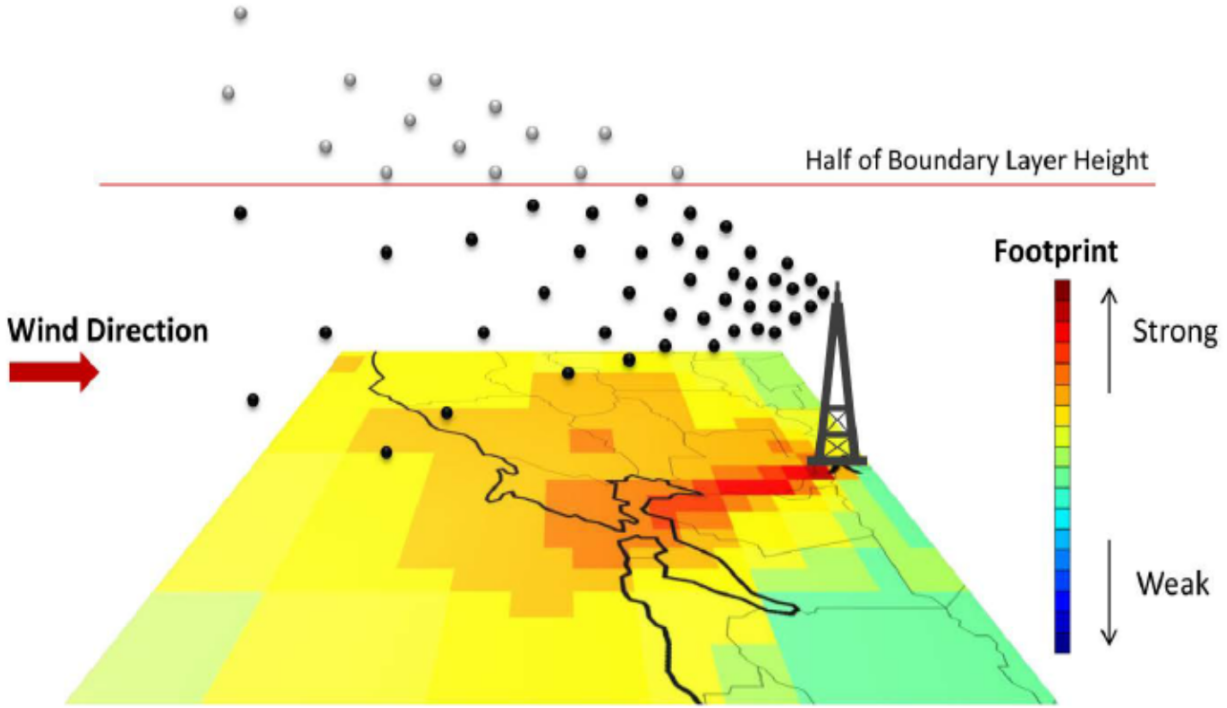
- Land use
- Inform greenhouse gas inventories
- Assess risk
- Mitigation

Evaluating CH_4 emission estimates using tower network

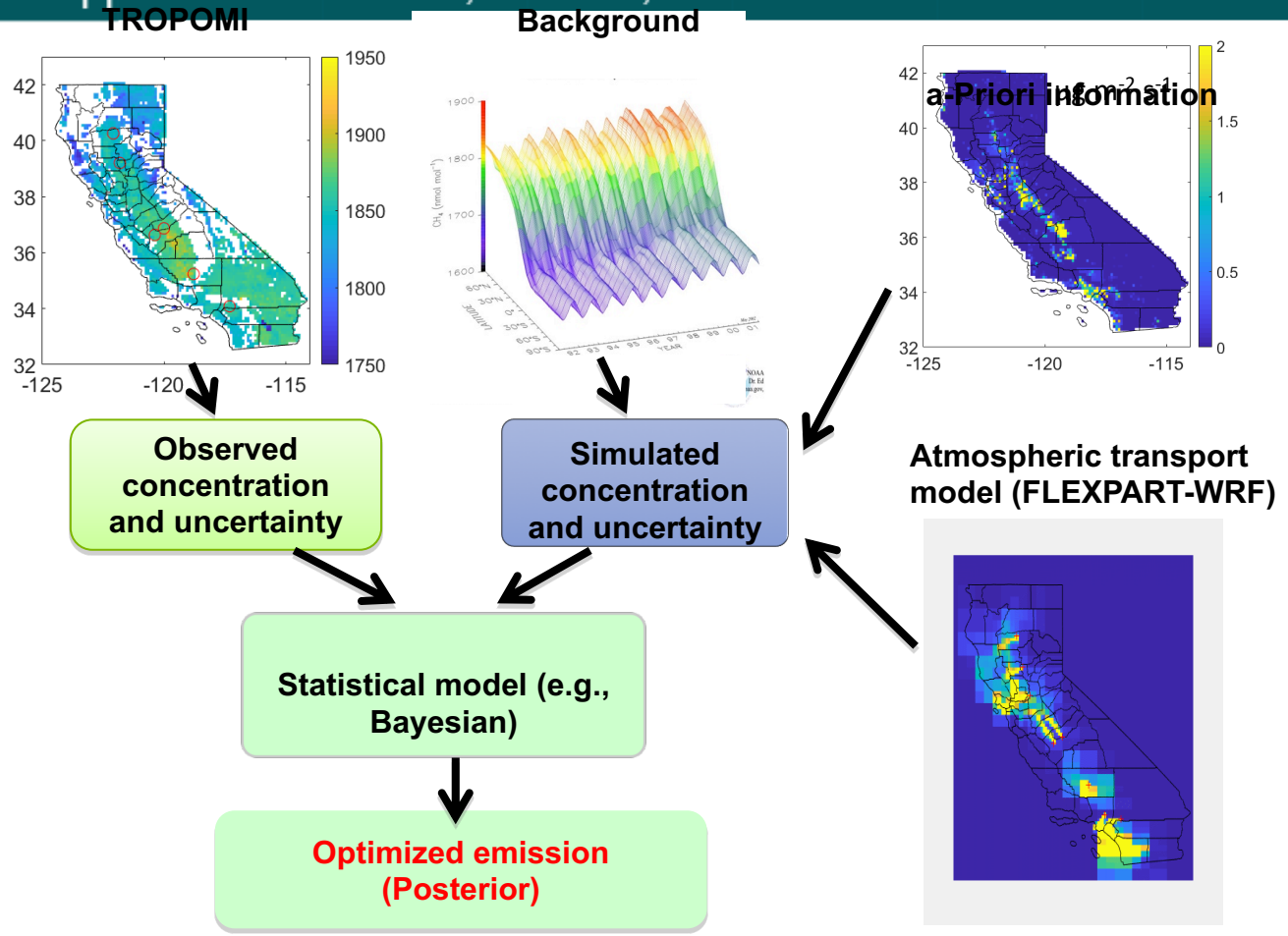
Environmental Science & Technology
Article
Cite This: Environ. Sci. Technol. 2019, 53, 9636–9645
pubs.acs.org/est

A Multiplatform Inversion Estimation of Statewide and Regional Methane Emissions in California during 2014–2016

Yu Yan Cui,[*,†] Abhilash Vijayan,[†] Matthias Falk,[†] Ying-Kuang Hsu,[†] Dazhong Yin,[†] Xue Meng C
Zhan Zhao,[†] Jeremy Avise,[†,‡] Yanju Chen,[†] Kristal Verhulst,[§] Riley Duren,[§] Vineet Yadav,[§]
Charles Miller,[§] Ray Weiss,[∥] Ralph Keeling,[∥] Jooil Kim,[∥] Laura T. Iraci,[⊥] Tomoaki Tanaka,[⊥,#]
Matthew S. Johnson,[⊥] Eric A. Kort,[@] Laura Bianco,[∇,○] Marc L. Fischer,[◆] Kenneth Stroud,[†]
Jorn Herner,[†] and Bart Croes[†]

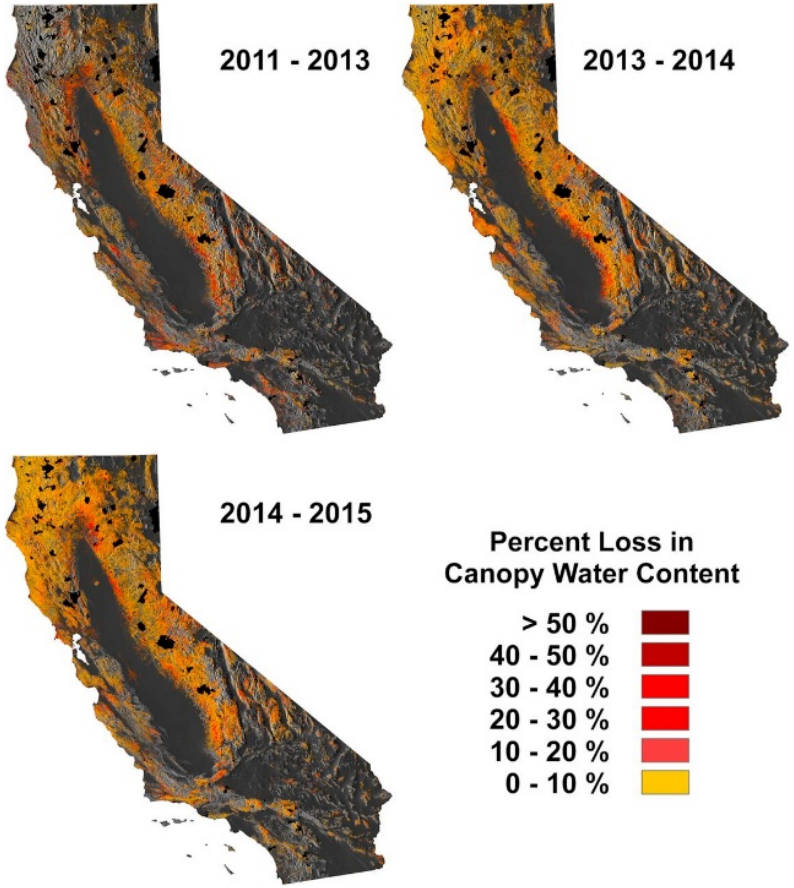


Inversely quantify statewide CH_4 emission estimates using TROPOMI and other satellites



- Assimilate satellite data to our inverse modeling system to implement the statewide and regional CH_4 emission quantification and emission trend analysis, in order to track and evaluate the reduction policies.

Potential Climate Indicators



- Water loss in California forests due to drought between 2012 and 2015

- Built environment – consistent with low carbon lifestyles?
- Forest area and carbon content
- Carbon dioxide exchange between atmosphere and biosphere
- Other greenhouse gases – N_2O, HFCs etc

Climate Change Mitigation

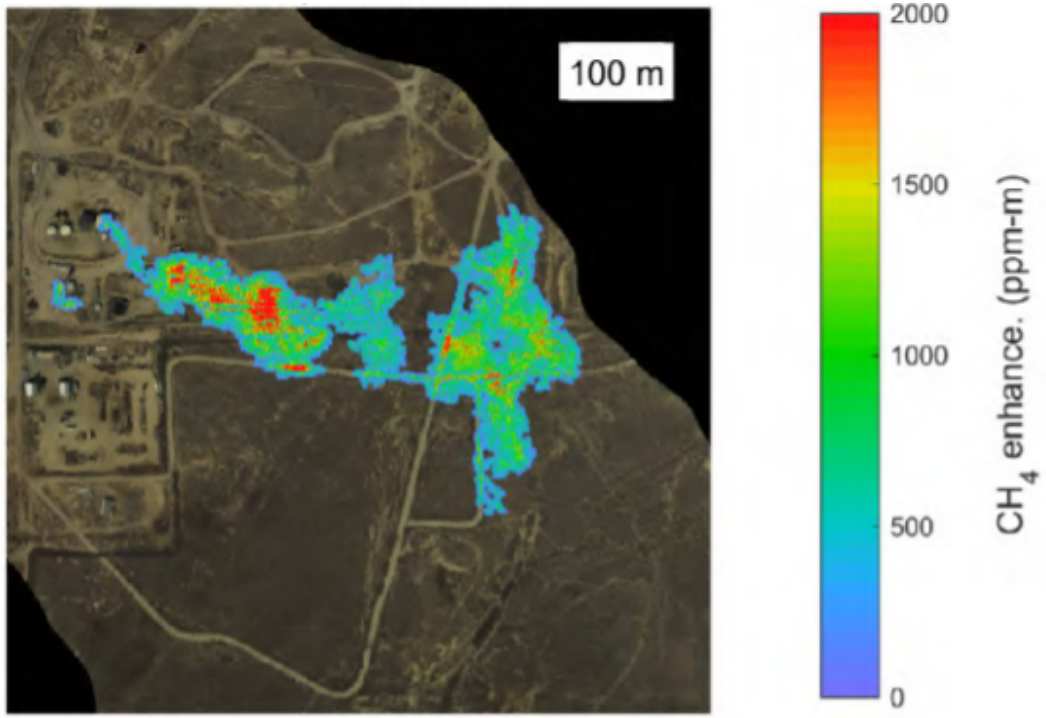
Can indicators be developed that can lead directly to mitigation, or enforcement of climate programs

Article

California's methane super-emitters

https://doi.org/10.1038/s41586-019-1720-3
Received: 5 December 2018
Accepted: 20 August 2019
Published online: 6 November 2019

Riley M. Duren[1,2*], Andrew K. Thorpe[1], Kelsey T. Foster[1], Talha Rafiq[3], Francesca M. Hopkins[3], Vineet Yadav[1], Brian D. Bue[1], David R. Thompson[1], Stephen Conley[4], Nadia K. Colombi[5], Christian Frankenberg[1,6], Ian B. McCubbin[1], Michael L. Eastwood[1], Matthias Falk[7], Jorn D. Herner[7], Bart E. Croes[7], Robert O. Green[1] & Charles E. Miller[1]



Air Quality Equity

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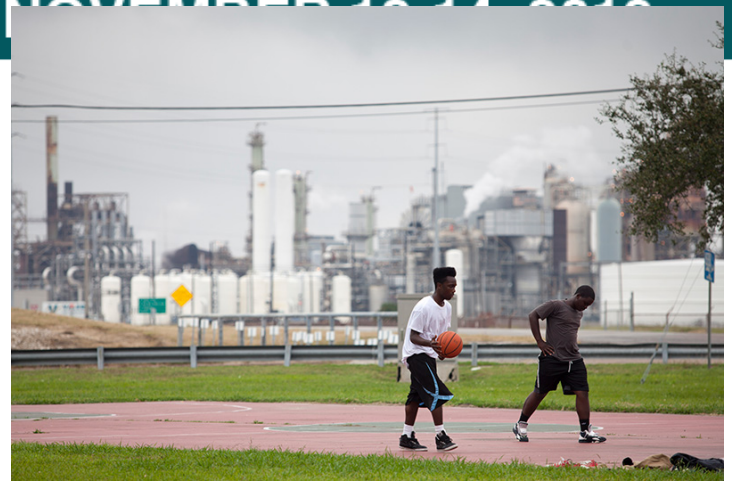
- Existing paradigm of meeting air quality standards based on regional monitors does not protect all equally from air pollution
- In response to Assembly Bill (AB) 617 (C. Garcia, Chapter 136, Statutes of 2017), CARB established the Community Air Protection Program (CAPP or Program). The Program's focus is to reduce exposure in communities most impacted by air pollution.



AB 617: Community Air Protection Program

Motivation for AB 617

- Regulatory agencies have historically focused on *regional* air quality
- While air quality has improved statewide, major discrepancies persist at *local* scales
  - Disadvantaged communities are often disproportionately affected by air pollution

Elements of the Community Air Protection Program

- Prioritize actions in the most polluted communities
- Improve public health
- Community-level air quality monitoring
- Community participation

Scientific Requirements for this program: An Integrated Air Quality Observation System

- ✓ Broad spatial coverage
- ✓ Long data history (multi-year temporal trends)
- ✓ Comparison with models/inventories
- ✓ Source Apportionment
- ✓ Explore the relative impacts of local vs upwind emissions

AB 617 Communities

CARBON MONITORING SYSTEM

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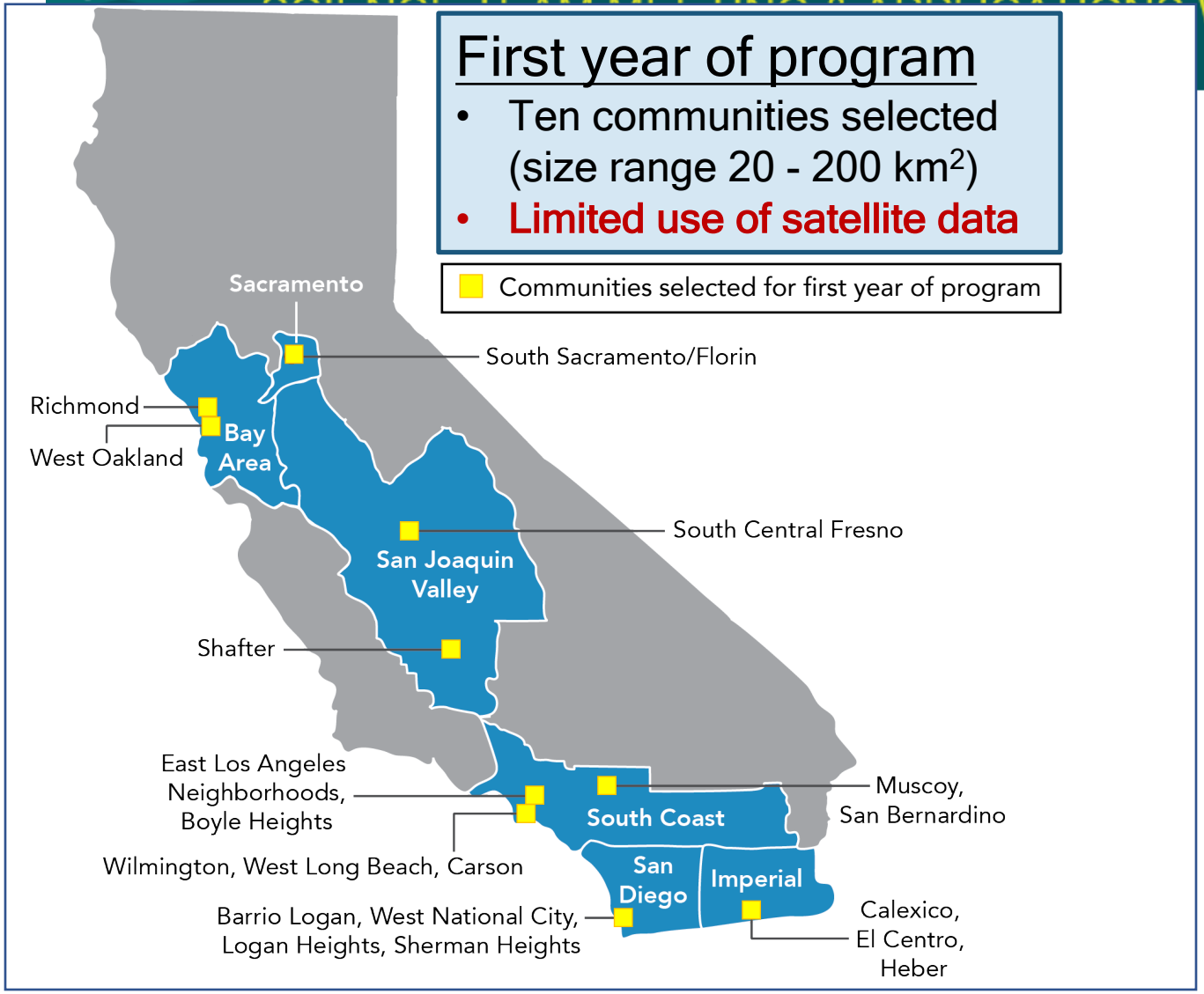
First year of program

- Ten communities selected (size range 20 - 200 km^2)
- **Limited use of satellite data**



Second year of program (current phase)

- 2-3 new communities to be selected
- We are currently exploring opportunities for integrating satellite data

As the program matures, how can satellite data be integrated into routine methodology?

Satellite high resolution PM maps

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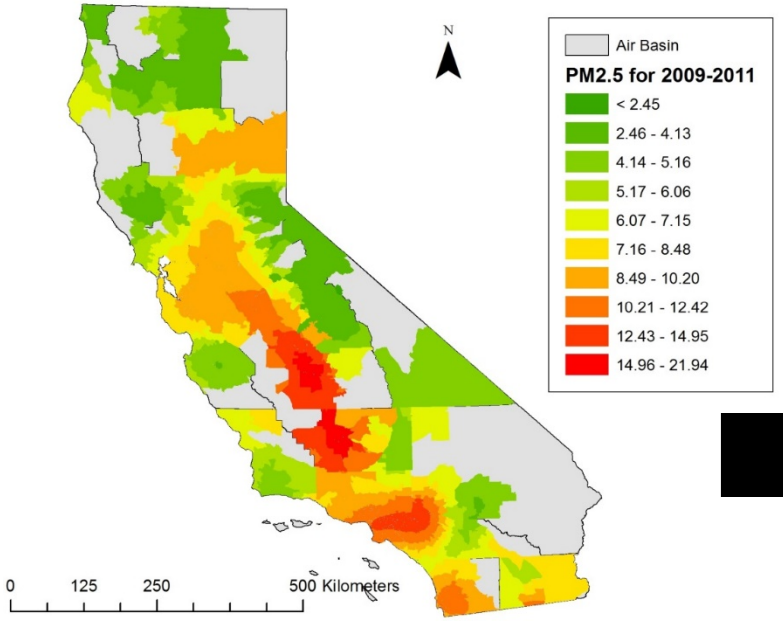
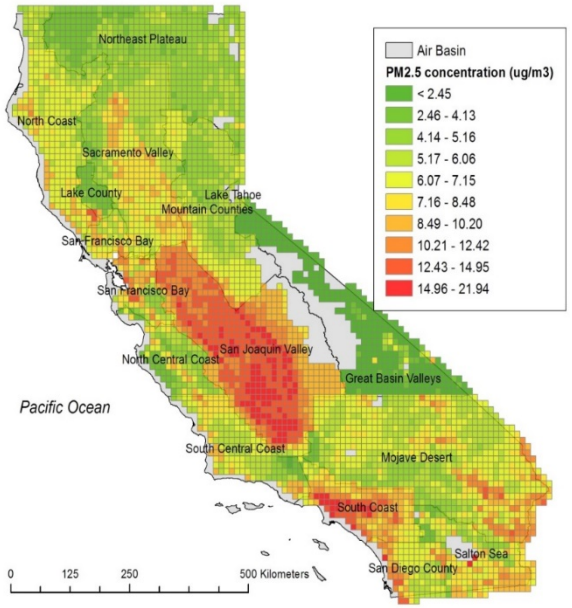
No satellite data
Ground monitoring only



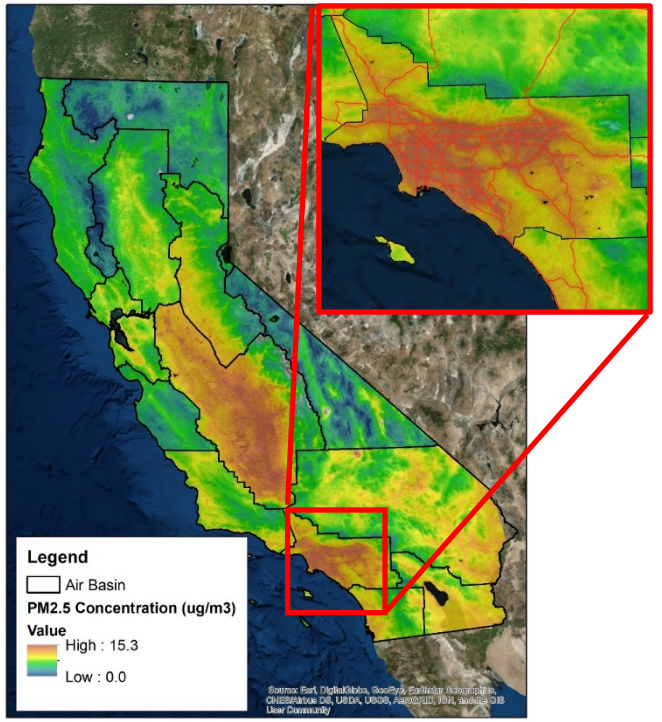
CalEnviroScreen 2.0

10 km $PM_{2.5}$
MODIS AOD (2006-2012)



CalEnviroScreen 3.0

1 km $PM_{2.5}$
MAIAC AOD (2016)



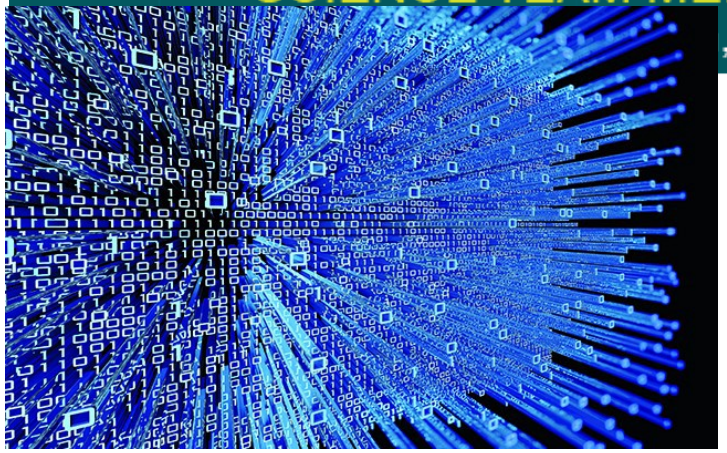
CalEnviroScreen 4.0 (in progress)

Satellite data is being used to improve health studies and identify hotspots

Challenges and Requests for Data

Challenges	Solution
1. No "standard format" for satellite data L2 data comes in various formats depending on the satellite platform. This adds another step into user workflows, where custom download/extraction/processing routines need to be written for each satellite platform being used. Example: MODIS atmosphere products are HDF4 format, while OMI products are HDF5 and TROPOMI products are netCDF.	As much as possible, standardize all L2 data into a common format.
2. Limited user input for generating L3 data Current NASA L3 data products offer limited user input for spatial or temporal subsetting. This often forces users to develop custom workflows to create L3 data for their specific project.	L3 data generation portals where users input: • Date range • Spatial sub-domain (manually entered coordinate box, uploaded shapefile or kml, etc.) • Desired output grid resolution (within reason, based on L2 data product's resolution) • Desired output projection system • QA parameters (some applications may require more aggressive filtering than others)

Big Data



- Combine data in new ways
- Integration of data from various sources
- Develop new meaningful indicators

Illinois Farmer Views and Use of CMS Data

Lauren Lurkins
Director of Environmental Policy
Illinois Farm Bureau

Illinois Farm Bureau

- Since 1916, Illinois Farm Bureau has provided education and information to help farmers, while supporting legislation and lobbying about agricultural issues.
- Today, IFB has 78,000 voting members. Three out of four Illinois farmers.
- Farmers join through their county Farm Bureau and engage in grassroots policy development process, programs and initiatives.

Illinois Farm Bureau – A Glimpse Into Policy

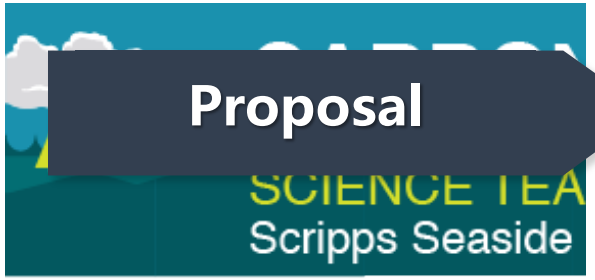
- Significant support for science-based policy and regulation
- Currently developing global climate change policy
  - Scientific research to support the continuous improvement and beneficial impact of agricultural efforts to date with regard to increasing climate resiliency, improving water quality and soil health, sequestering carbon in the soil, and preventing erosion.
  - Expanding and improving state and federal voluntary conservation programs
  - Market-based solutions
  - **Increased funding for research of farming practices that mitigate climate change while maintaining farm profitability**, as well as technical assistance and educational efforts that ensure the research outcomes are transferred effectively to farmers.

Illinois Farm Bureau – My Role

- Organizational policy
- Board of Director priorities
- Three types of people: farmers, regulators and scientists (few lawyers)
- Equal parts proactive, farmer education, and policy
- Have made a concerted effort over past several years to build relationships with researchers in our state universities with the goal of getting the best science in front of our farmers
    - Advisory boards
    - Conference presentations
    - Communications coverage
    - Farmer focus groups

CARBON
SCIENCE TEAM
Scripps Seaside Fo

CMS Data Products Used



Title: Improving the monitoring capability of carbon budget for the US Corn Belt - integrating multi-source satellite data with improved land surface modeling and atmospheric inversions

A proposal submitted to NASA ROSES 2016 Solicitation NNH16ZDA001N-CMS

A7: Carbon Monitoring System

PI

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Evan Delucia (University of Illinois at Urbana-Champaign)
Christian Frankenberg (California Institute of Technology/NASA Jet Propulsion Laboratory)
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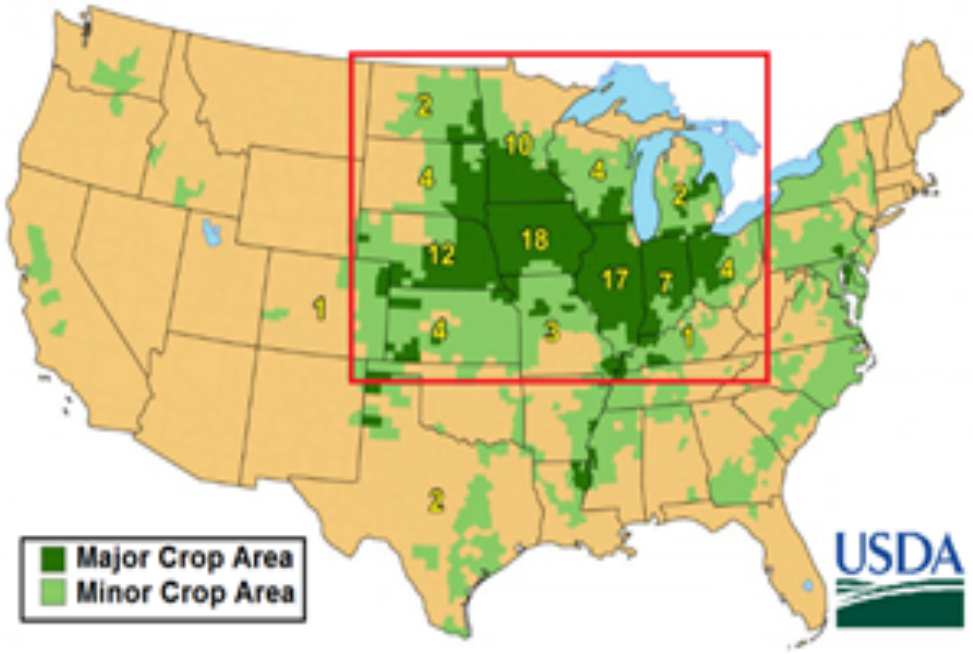
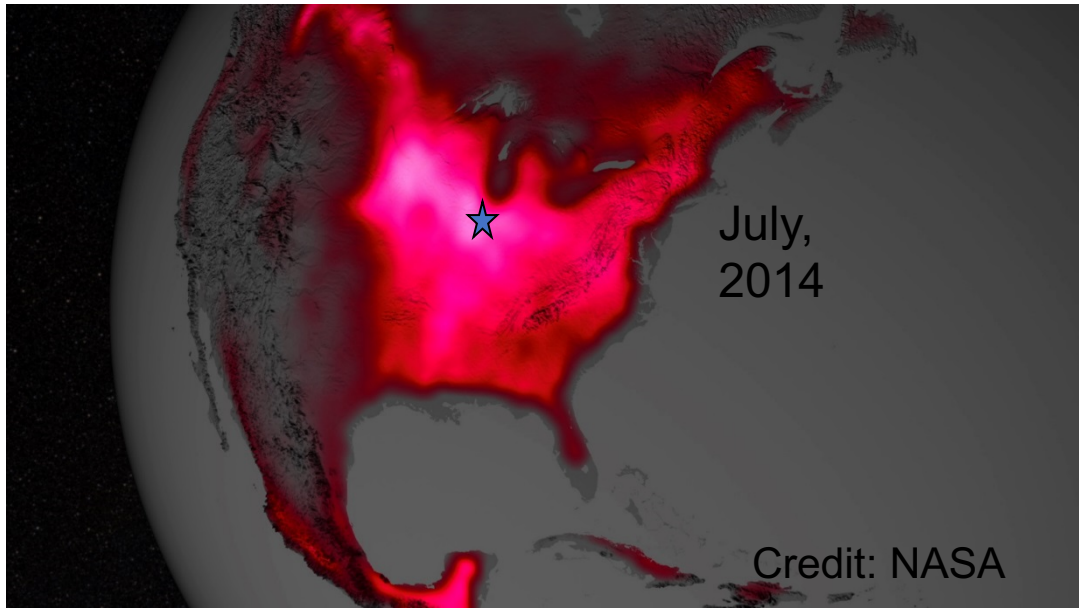
Postdoctoral Scholar:
Bin Peng (University of Illinois at Urbana-Champaign)

Collaborators:
John Miller (NOAA Earth System Research Laboratory)
Arlyn Andrews (NOAA Earth System Research Laboratory)
Xi Yang (University of Virginia)





Study domain in red box. The background shows the averaged corn production from 2007-2012, and the numbers indicate the percentage (%) of the state production to the national total corn production.

Sun-induced chlorophyll fluorescence (SIF) as a proxy of photosynthesis.

US Corn Belt produces ~35% of global corn production and ~30% of global soybean production.

Farmer's perceptive

We are willing to embrace new technologies.
We want to be part of the solution!

Pressure of climate change

- Increasing pressure of climate change challenges conventional agriculture system.
- Increased vapor pressure deficit; increased flooding/drought frequency.
- Farmers need to act!

Carbon Cycle

- Agriculture plays an important role in the global carbon cycle.
- Local information regarding carbon cycle is useful for farmers.

Climate Change

New technology (Satellite, Models)

- Help farmer better understand the agroecosystem.
- Bring information to cope and/or adapt to the changing weather/climate conditions.

Solutions towards Sustainability

- Farmers want to see crop yield improvements as well as improvement of their own land.
- Farmers need actionable information!

What we could know?

01

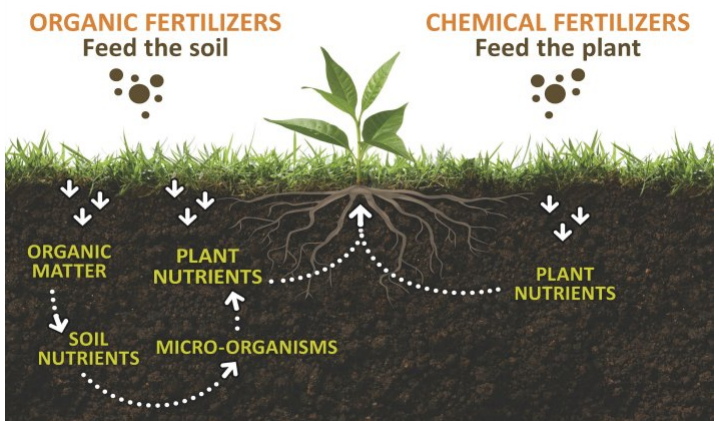
Aboveground --- Yield

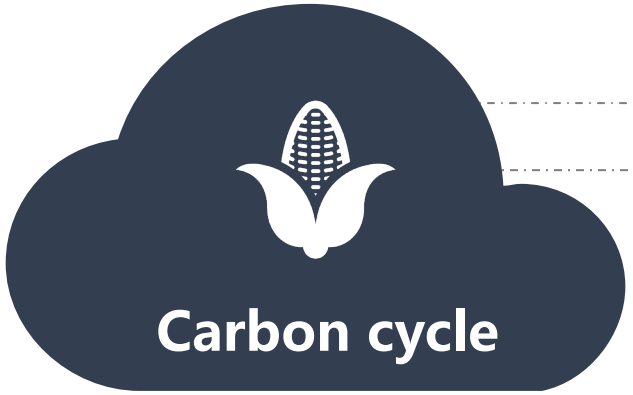
- Yield directly link with profits for farmers.

02

Belowground --- Soil organic carbon

- Provides reservoirs of nutrients
- Contributes to resilience of soil system
- Improve soil structure and soil health

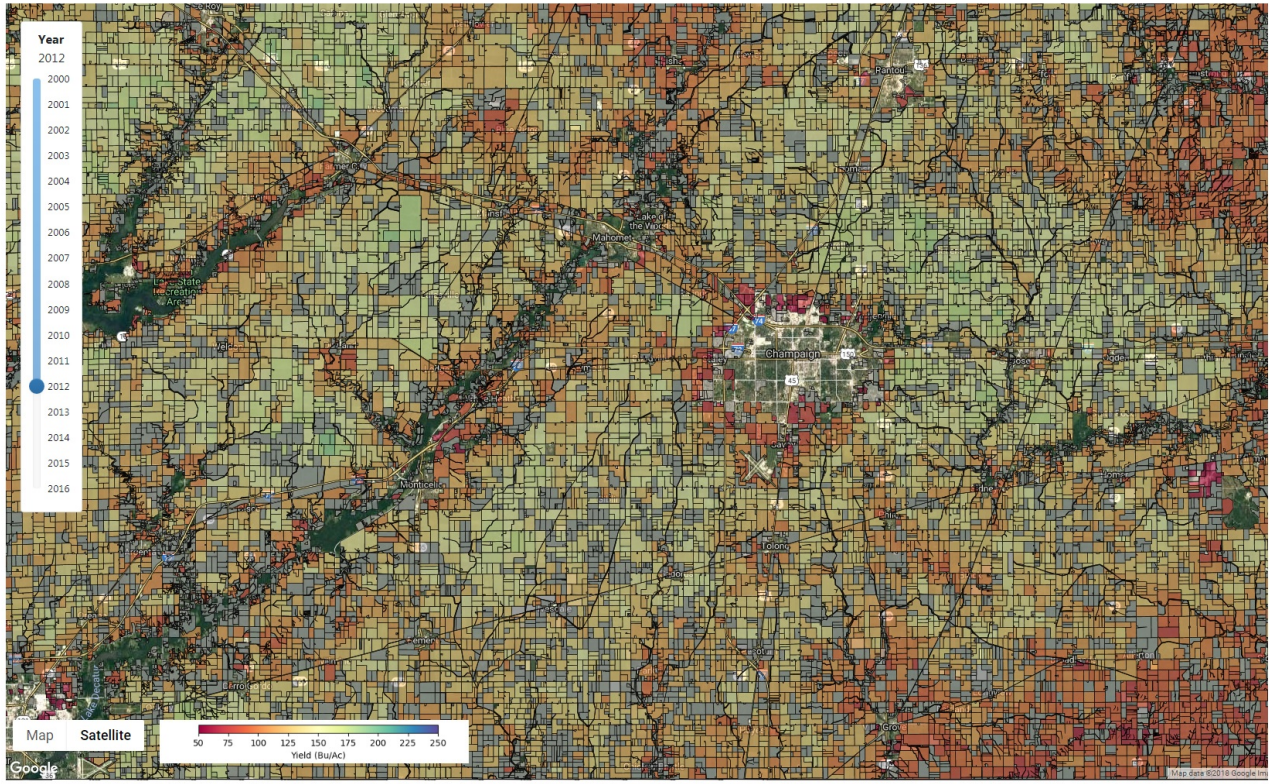


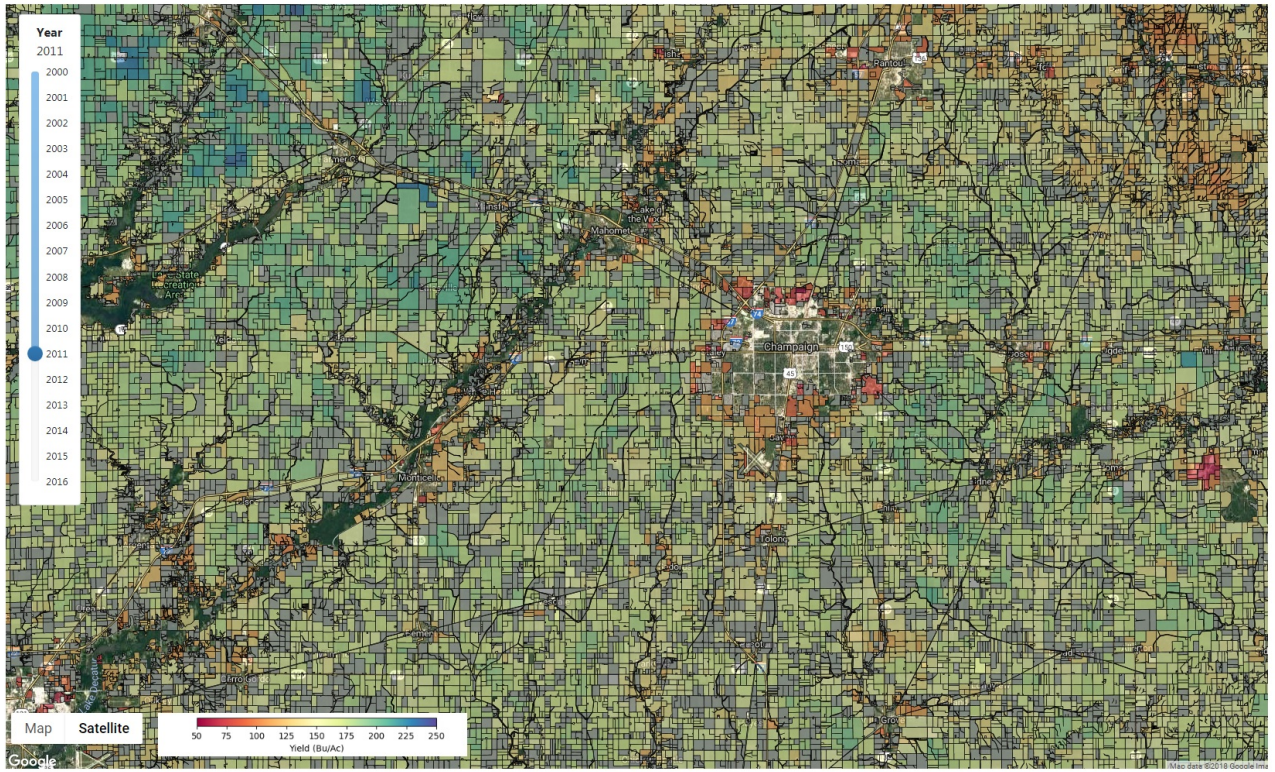


From satellite data and modeling

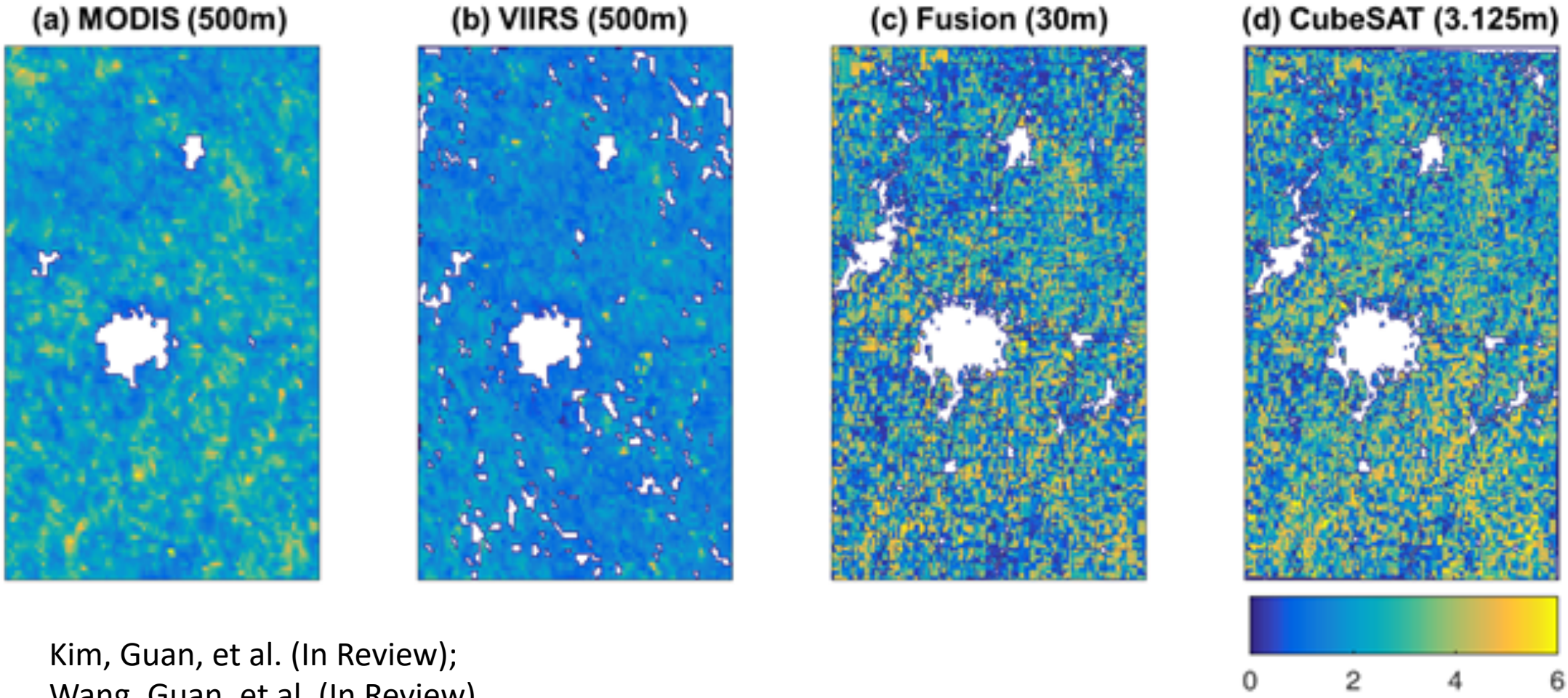
Aboveground --- Yield

Yield predicted by Satellite data



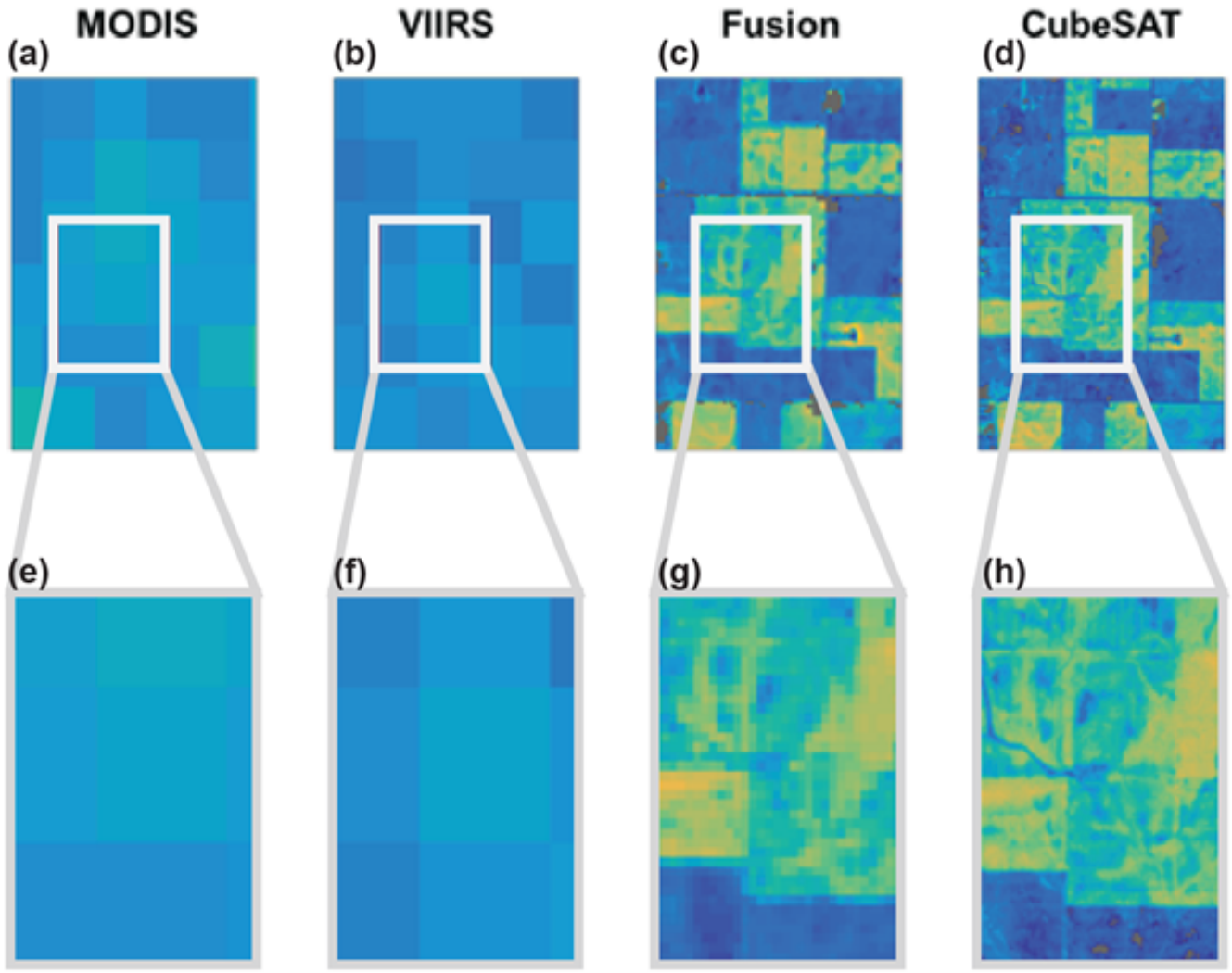


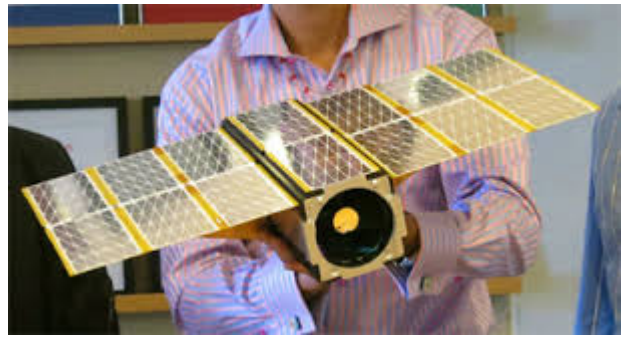
Leaf area index (LAI) estimations at high resolutions



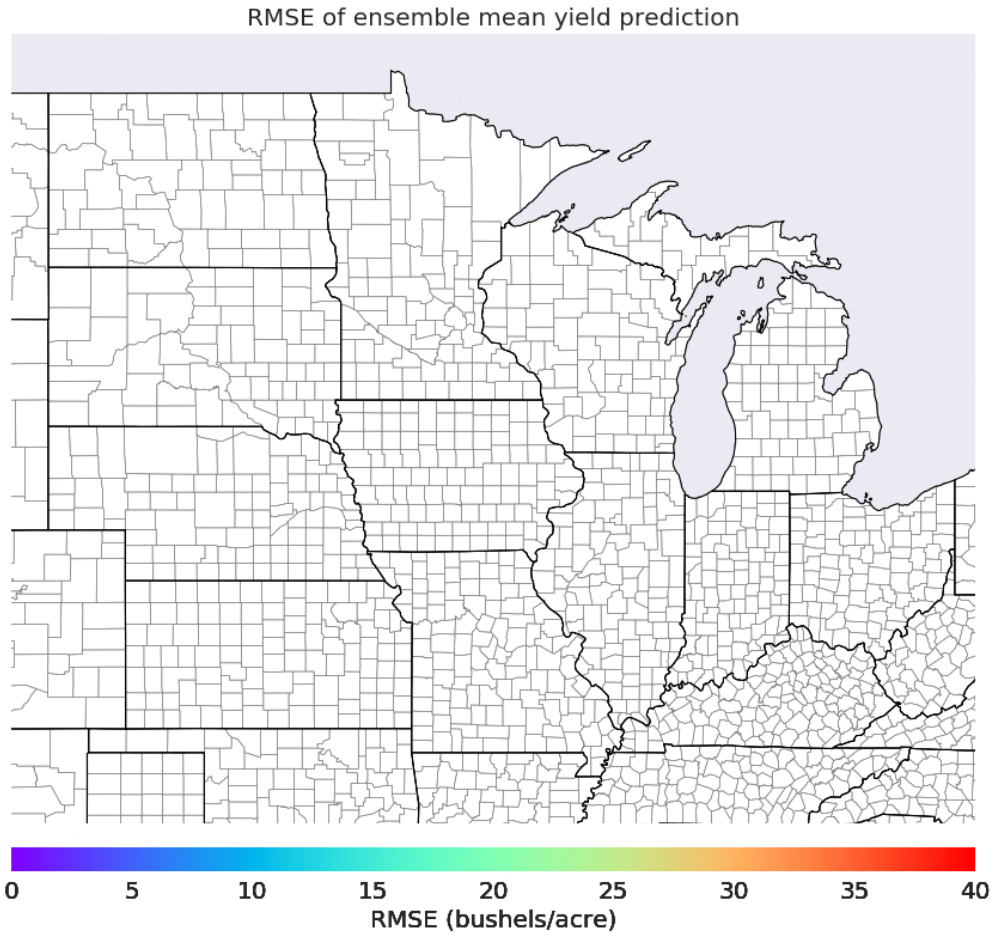
Kim, Guan, et al. (In Review);
Wang, Guan, et al. (In Review).

Leaf area index (LAI) estimations at hyper resolutions



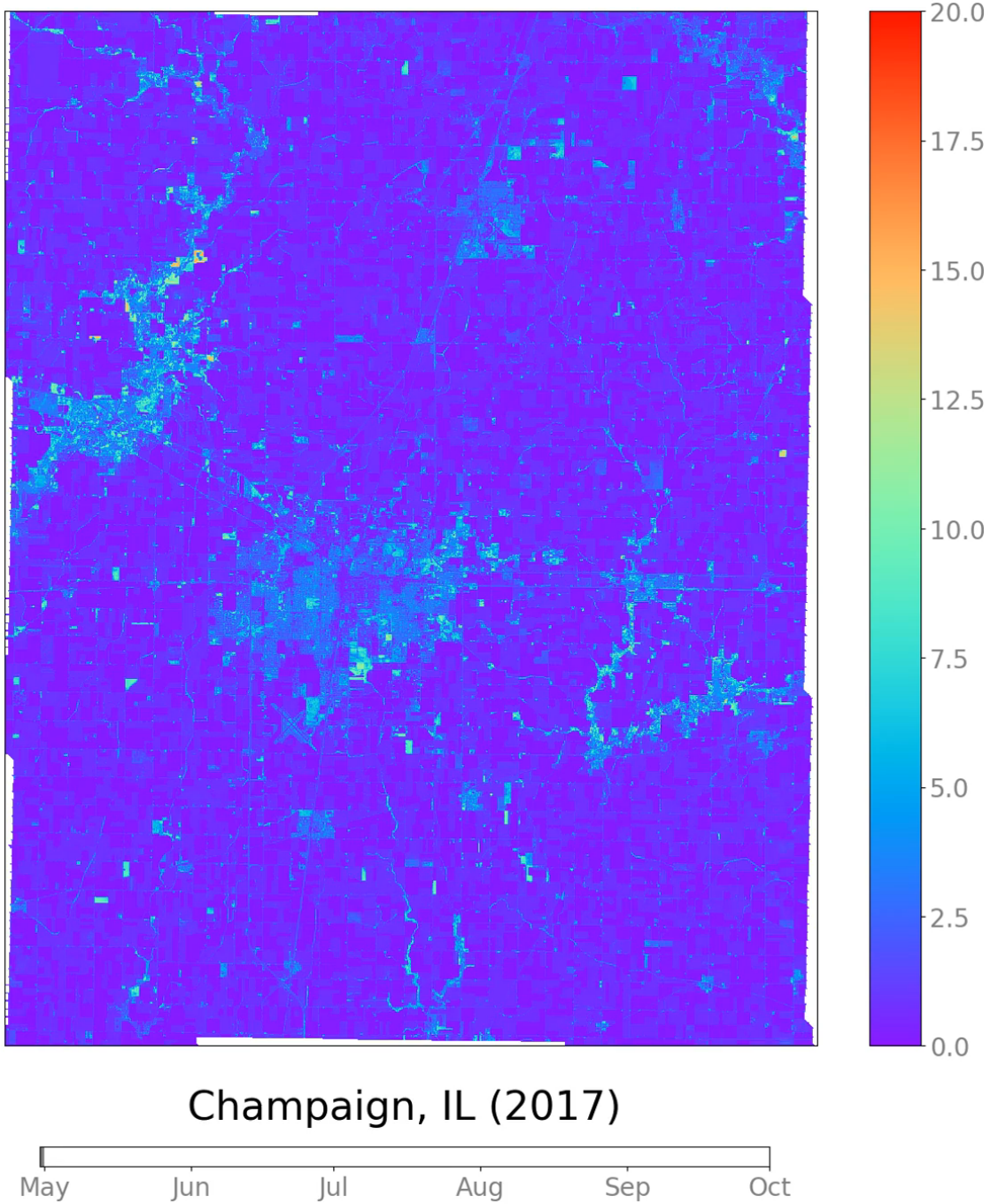


Statistical model based in-season maize yield forecasting using NCEP-CFSv2 and MODIS EVI—County level



Peng, B., Guan, K, Pan, M, Li, Y. (2018) Benefits of seasonal climate prediction and remote sensing data for forecasting US maize yield. Geophysical Research Letters. https://dx.doi.org/10.1029/2018GL079291

Photosynthesis (GPP)



Belowground --- Soil organic carbon

Conservation practices

- Increase whole ecosystem carbon sequestration

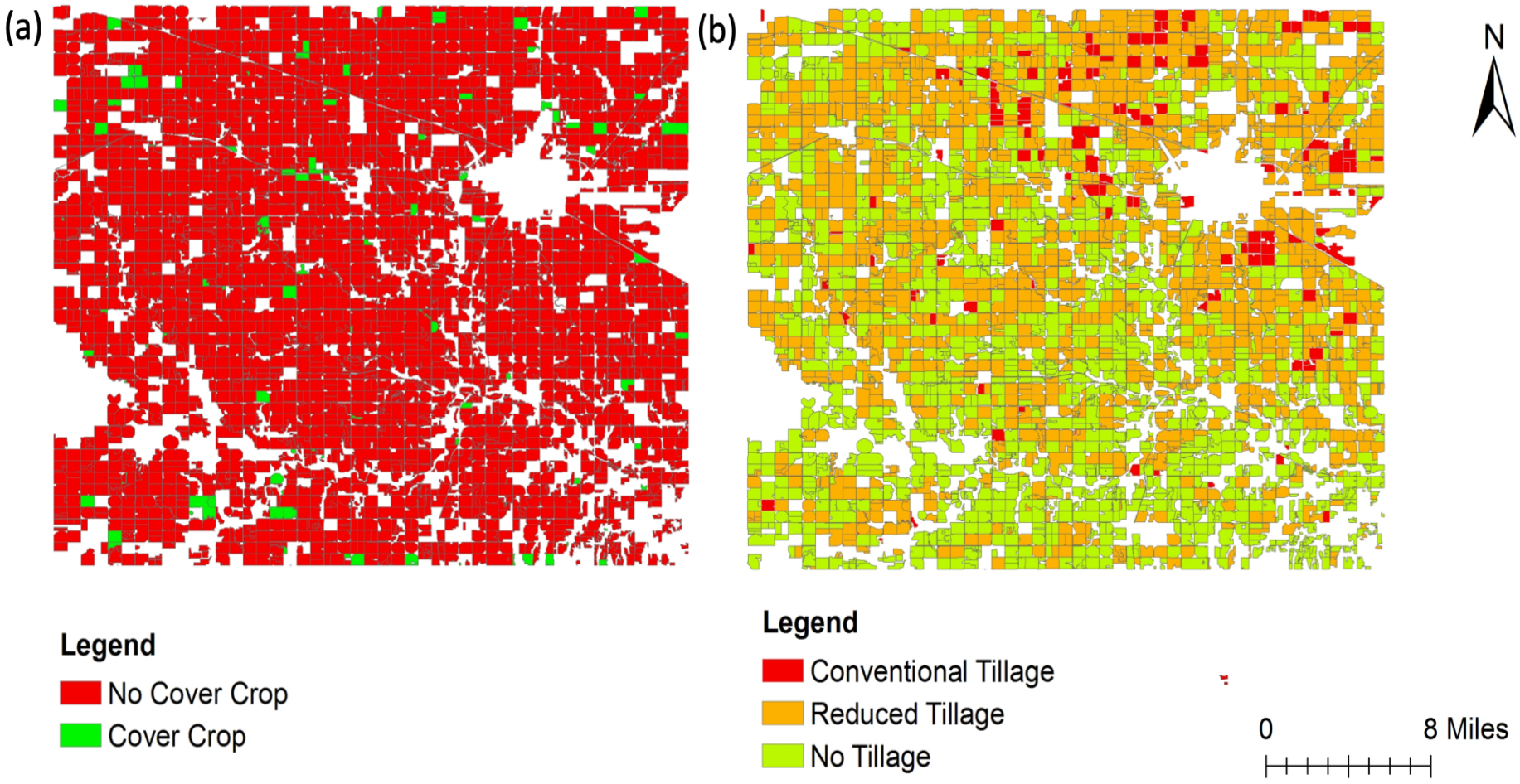
Non-till

- No-till will reduce the transfer of plant C to surface and subsurface residues, and hence reduce the amount of stable decomposition products of these residues relative to those in continuous cropping.

Cover crops

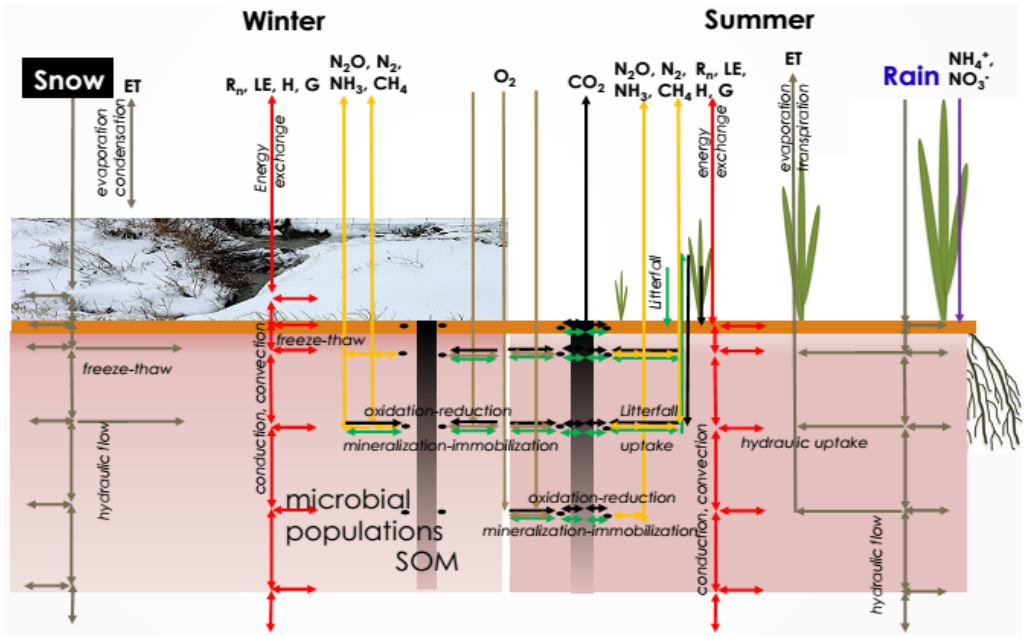
- Cover crops are crops planted during the conventional fallow time.
- Cover crops provide many benefits to agricultural systems including weed suppression and soil aggregation and are also known to promote soil C formation.

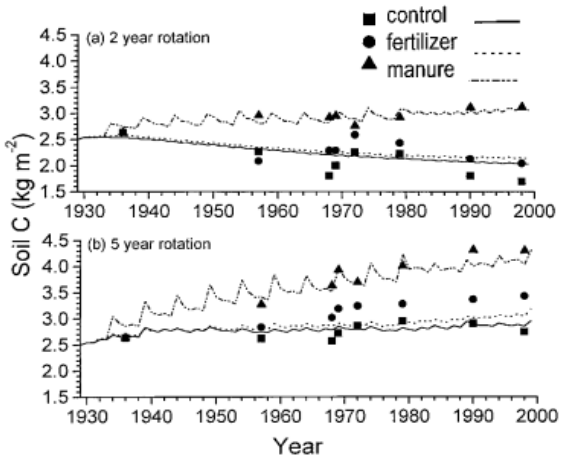
Tillage/Cover Crop mapping from satellite data

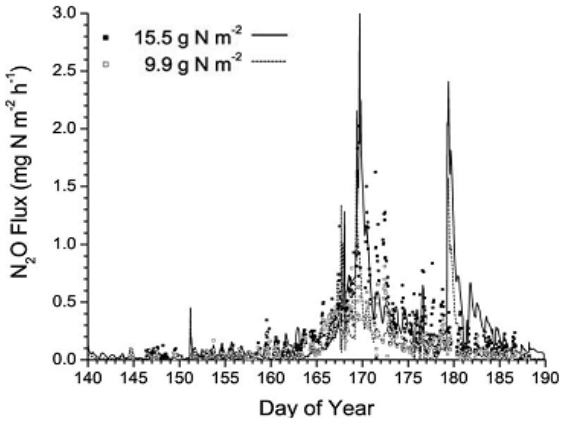


A crystal ball for predicting carbon cycle belowground?

- Models to simulate belowground carbon cycle







Satellite data is used to help constrain the process-based models for better prediction of belowground carbon dynamics.

In the future

➢ Studies of soil organic matter need to be verified

- There are seldom ground truth data on soil organic matter, the result derived from the model need further validation.

➢ Some practices only show benefits in the long period

- Some practices such as implementing cover crops in the agroecosystem may show benefits after a long period, which makes it impossible to do field trials and we have to use calibrated model to do further studies.

Positive Aspects of CMS Data for My Work

- The best science being put to use by and for farmers
- Field scale for their own decision-making
- Can meet them where they are – different tolerance for risk, different business models, different views of conservation, family businesses
- The more informed the individual farmers are, the more they will do to improve the environment.

Next Priority For My Work

- Since 2013, Nutrient Loss Reduction Strategy has been a priority.
- Soil health focus on cover crops has been related.
- More climate discussions in policy lately at state and federal level and involve “working lands” concepts.
- This science is helpful to know what IL farmers contribute, how they can improve, and what is a realistic goal.

What Scientific Advancement Could Contribute To My Work?

- Continuing this research in the Midwest in a corn and soybean rotation.
- Continuing to build tools that help them make decisions in absence of neutral third-parties or minimized technical expertise.
- Need the data interpreted into “plain language”.

Questions?

Lauren Lurkins

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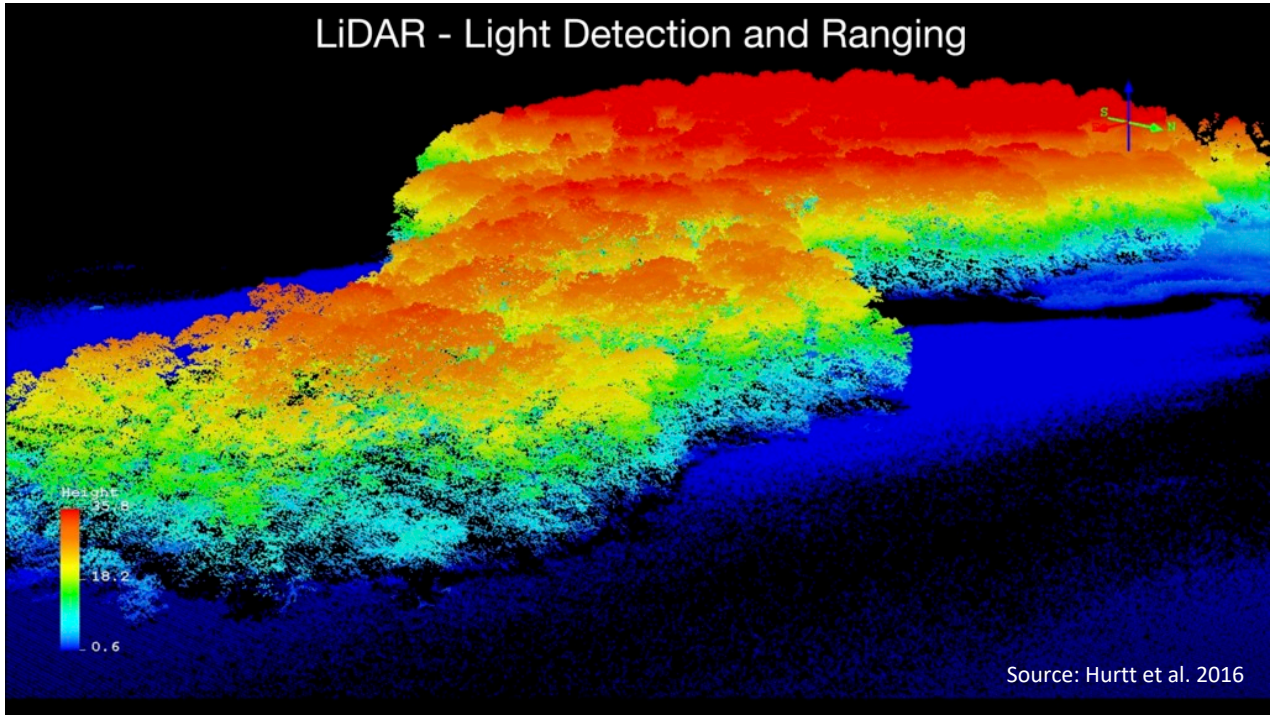
Utilizing NASA CMS Data on Forest Carbon for State Climate Action Planning



Elliott Campbell, PhD
Maryland Department of Natural Resources
Alexander Rudee
World Resource Institute

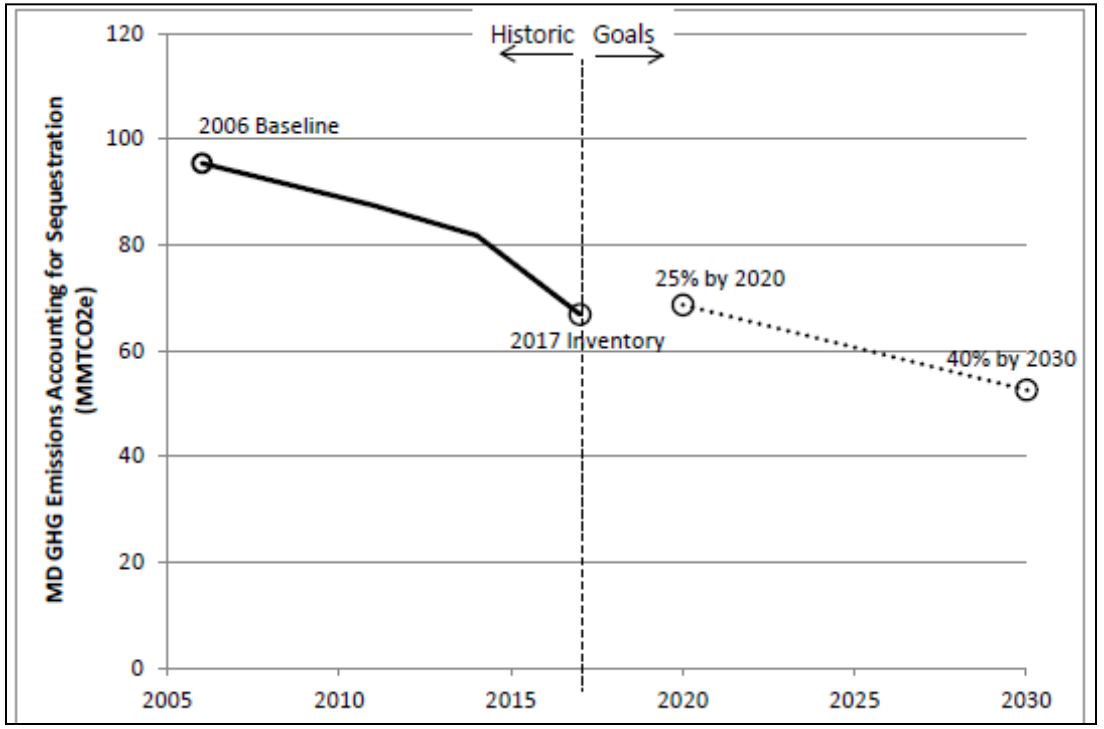
NASA Carbon Monitoring System 2019 Annual Meeting

Maryland's Greenhouse Gas Reduction Act (GGRA)

- 2009 Act requires 25% reduction in emissions by 2020 from 2006
- Reauthorized and enhanced GGRA of 2016 signed into law on April 4, 2016
- Builds from the recommendations of the MCCC
- Core elements of new law
  - 40% reduction by 2030
  - Must support a healthy economy and create new jobs
  - Maintains structure and safeguards from 2009 law
  - Outline path to 90% by 2050
- 2030 Plan currently in public comment period

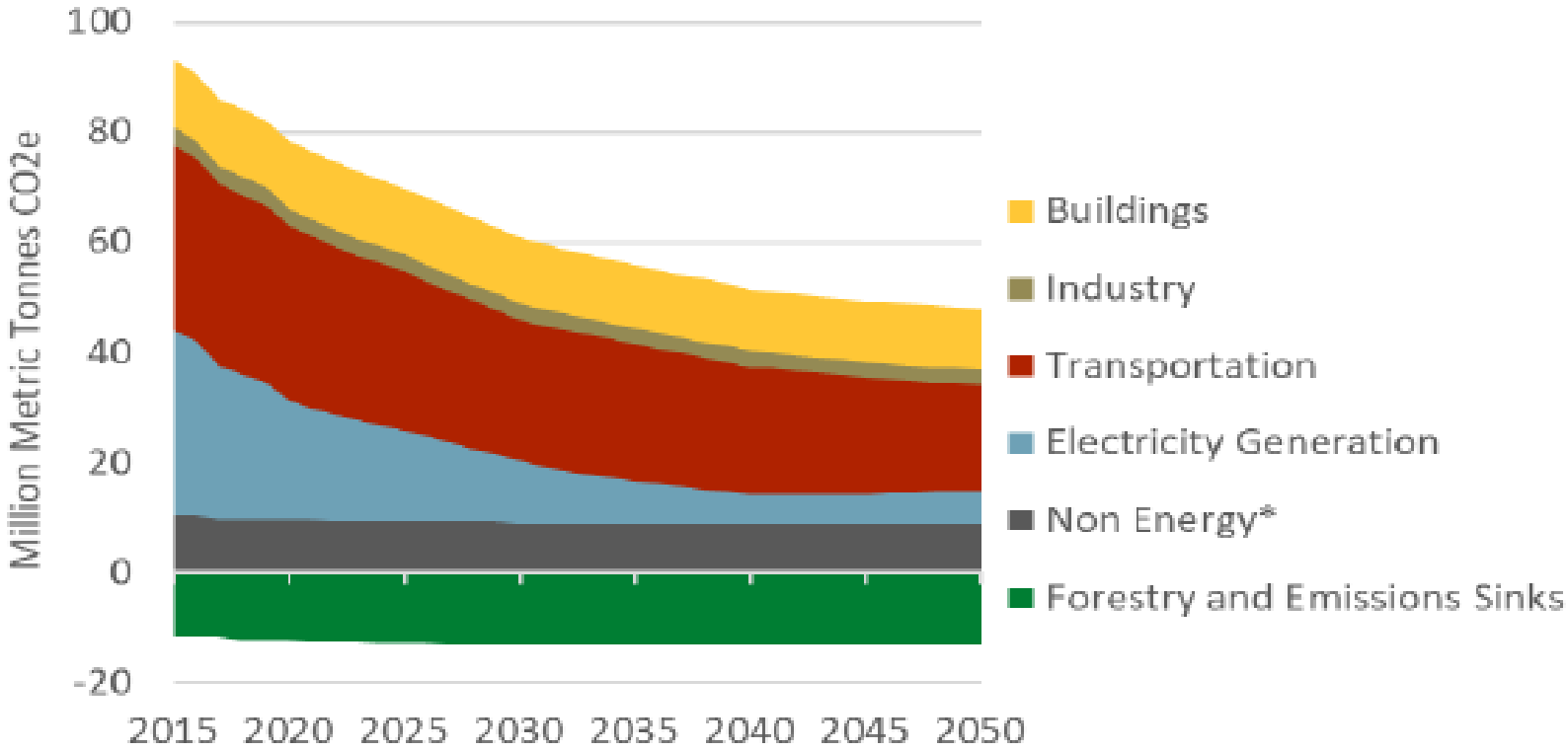
GGRA 2020 Requirement
The Bottom Line

- The 40% by 2030 Reduction Requirement = 42.89 $MMtCO_2e$*
- 2017 Inventory Reduction = 28.74 MMtCO2e



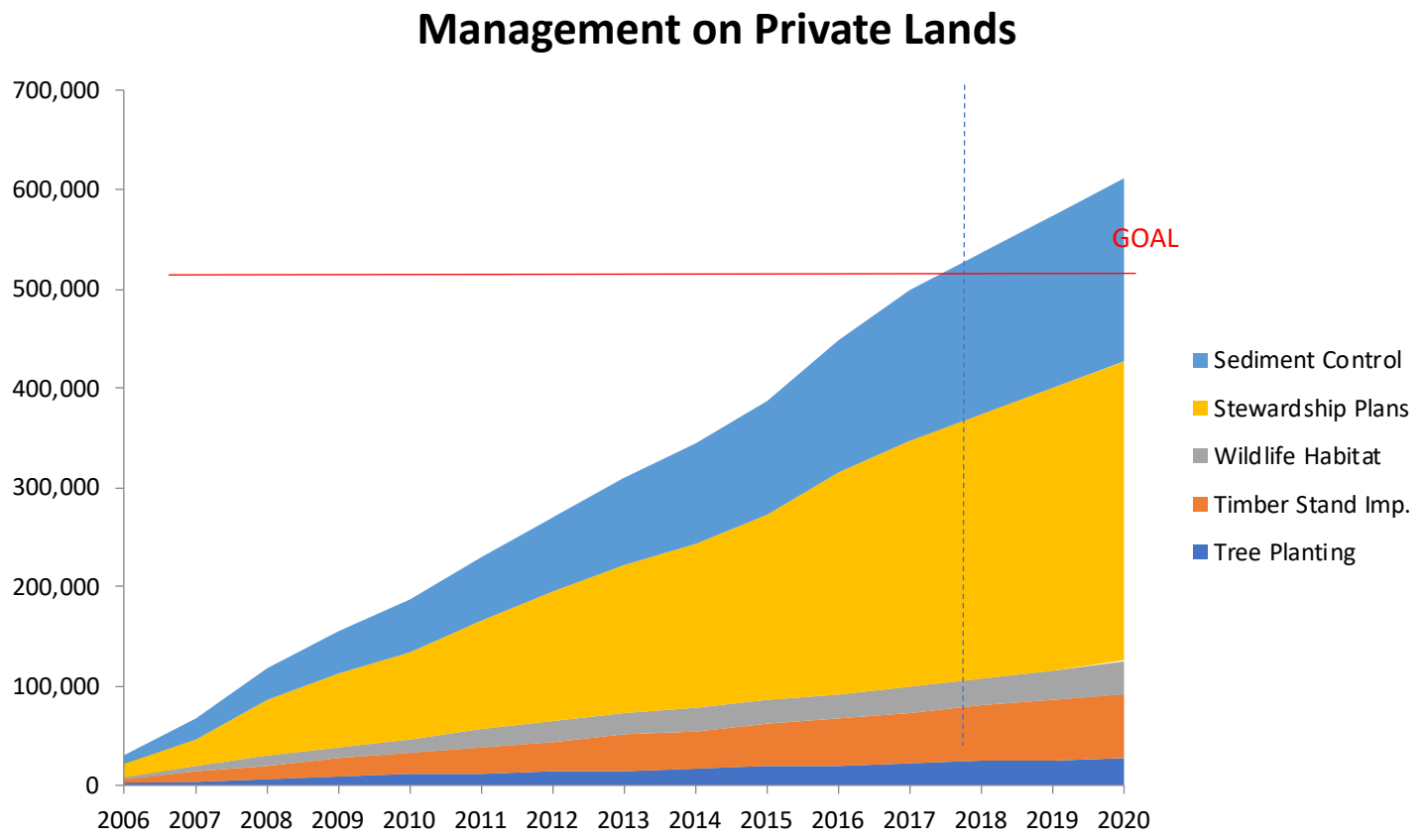
* MMtCO2e = Million Metric Tons of Carbon Dioxide Equivalents

Maryland GHG Projections

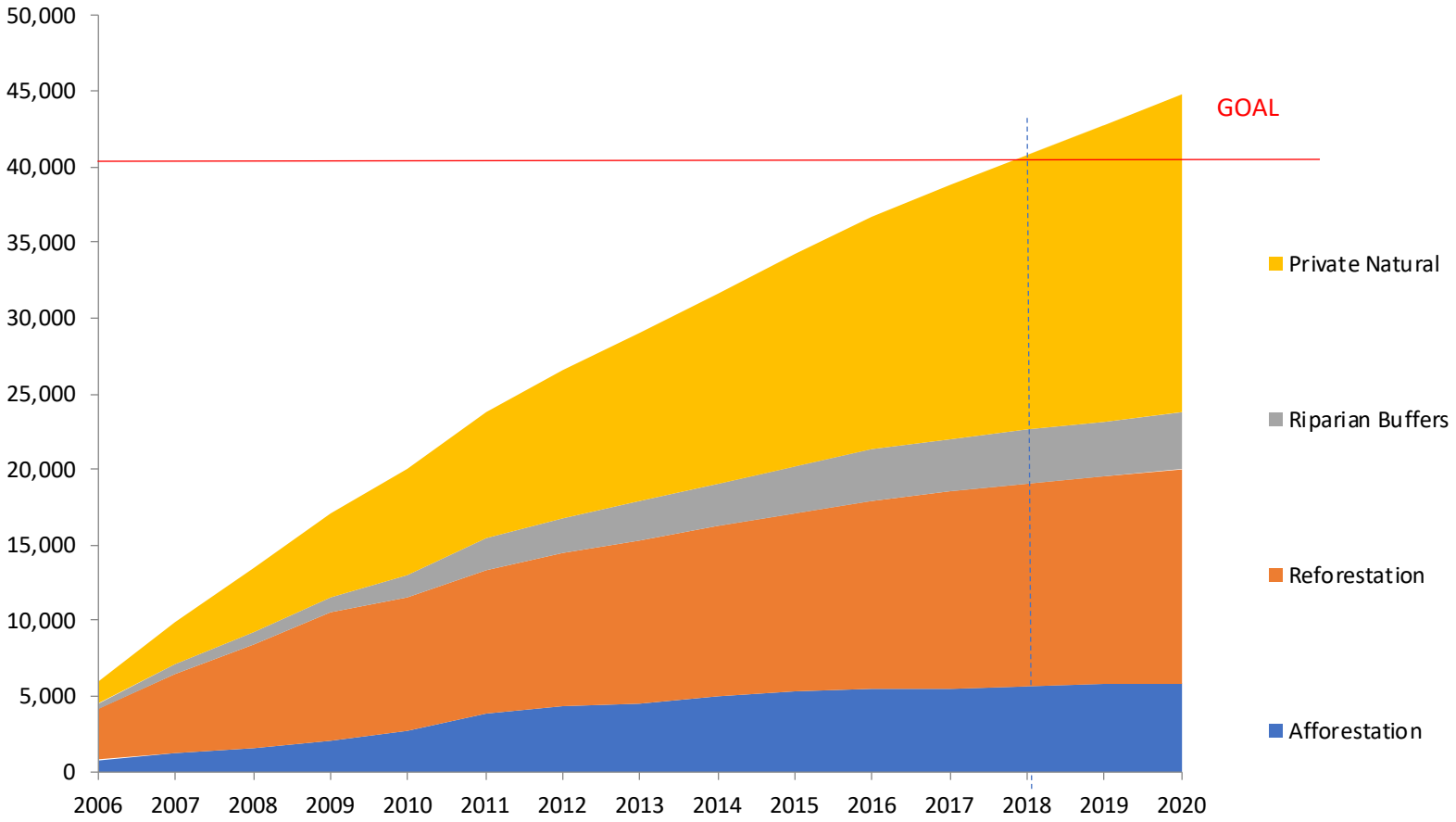


Managing Forests to Capture Carbon

- Public lands: acreage certified under FSC and SFI (211,000 acres, have exceeded goal of 50% of state owned forest land)



Planting Forests in Maryland



MD DNR 2030 GGRA Plan Projections

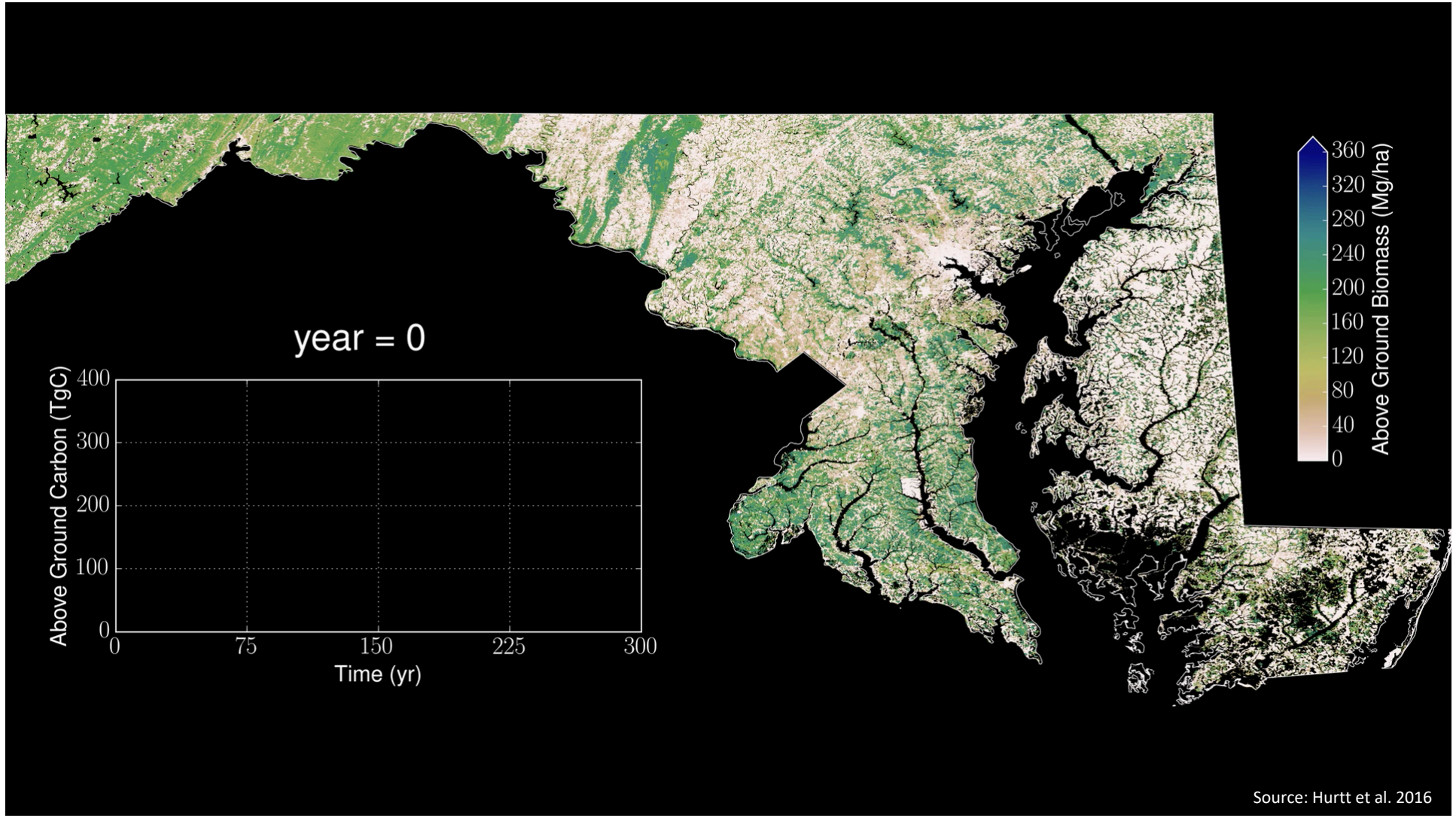
	Avg. Annual 2020-2030 Low	Avg. Annual 2020-2030 Medium	Avg. Annual 2020-2030 High	Avg. Annual 2020-2030 DNR Target		2030 Low	2030 Medium	2030 High	2030 DNR Target
Forest Management, public lands	1,500	2,000	3,000	1,600	acres per year	0.020	0.020	0.021	0.020
Forest Management, private lands	35,000	50,000	60,000	38,000	acres per year	0.86	1.04	1.16	0.92
Planting Forests	2,000	3,000	4,000	2,550	acres per year	0.28	0.32	0.36	0.30
Urban Tree Canopy	150,000	350,000	500,000	265,000	trees planted per year	0.003	0.004	0.005	0.0035
Avoided Forest Conversion	500	800	1,300	800	acres per year	0.10	0.15	0.24	0.15
Total (MMT CO2e per year)						1.26	1.53	1.78	1.39

Prior Limitations of Maryland's Forest Carbon Quantification

In the original 2006 GGRA plan we used

- EPA/USFS State Inventory Tool for our Greenhouse Gas Inventory
- Regional data for forest carbon storage and sequestration from USFS FIA
- Sequestration estimates that did not consider site specific information
- Did not account for loss of forest lands

UMD High Resolution Carbon Monitoring and Modeling

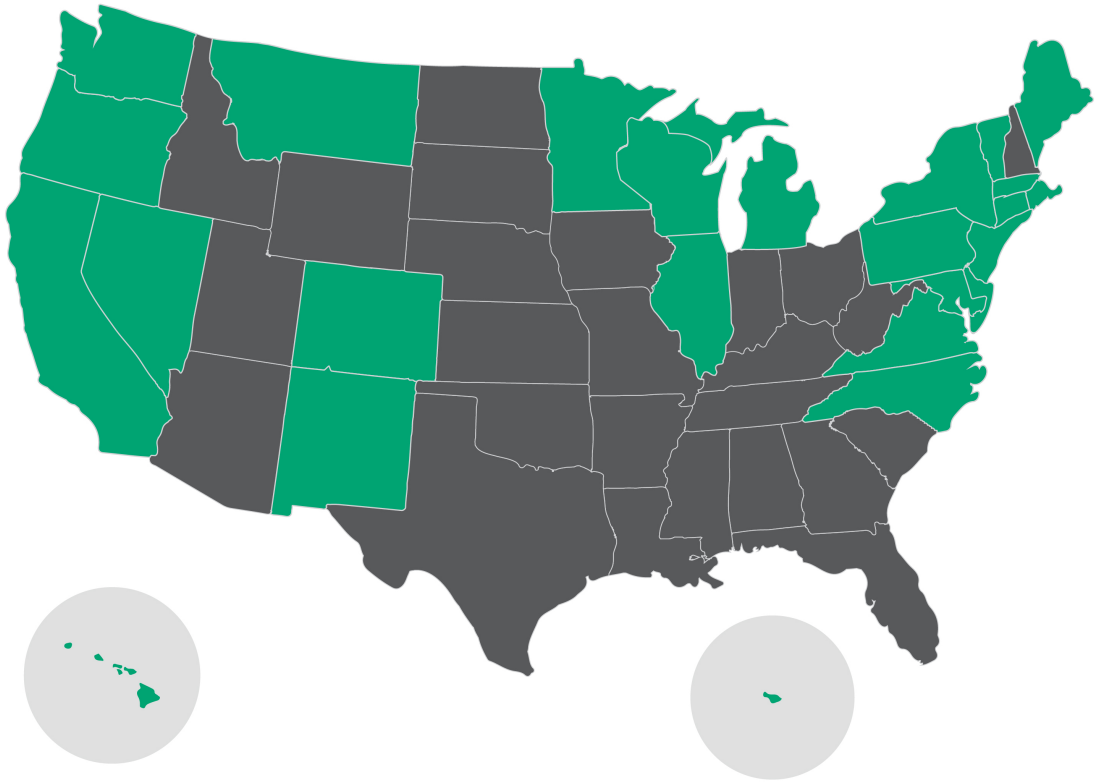


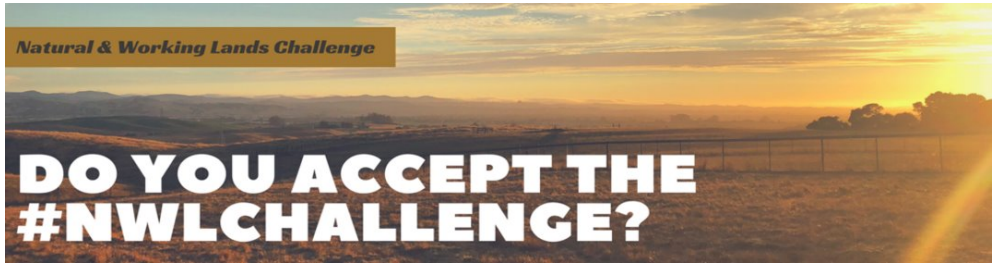
UMD NASA Carbon Monitoring System

- Hurtt (CMS 2014, 2016) produced high resolution (1m) forest cover maps, forest carbon modeled at 90 m (aboveground biomass, sequestration potential, etc.) for Maryland
- Better estimate of forest cover in the state because it captures trees outside of forests (~15% of forest cover in Maryland)
- Maryland is using this information for
  - Estimating the outcomes of our forest planting and management actions (2019 Plan)
  - Understanding current conditions for the sink portion of our GHG inventory
  - Incorporating into spatial tools to guide conservation and restoration

Opportunity for SCALE: US Climate Alliance

The U.S. Climate Alliance is a bipartisan coalition of governors cooperating to tackle the climate challenge.

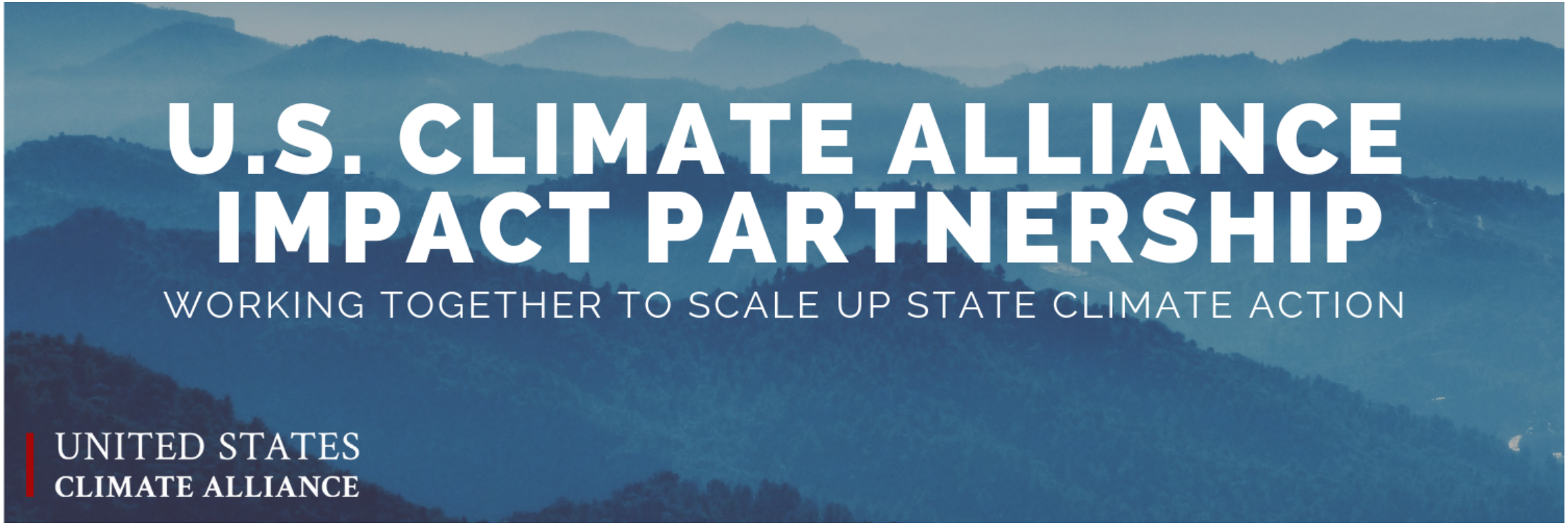




- Improve inventory methods
- Identify best practices for conservation and management
- Advance programs, policies, and incentives to reduce GHG emissions and enhance resilient carbon sequestration
- Integrate actions and pathways into state GHG mitigation plans

Source: US Climate Alliance

Opportunity for SCALE: US Climate Alliance



American Farmland Trust

AMERICAN FORESTS

C-AGG | Coalition on Agricultural Greenhouse Gases

The Nature Conservancy
Protecting nature. Preserving life.

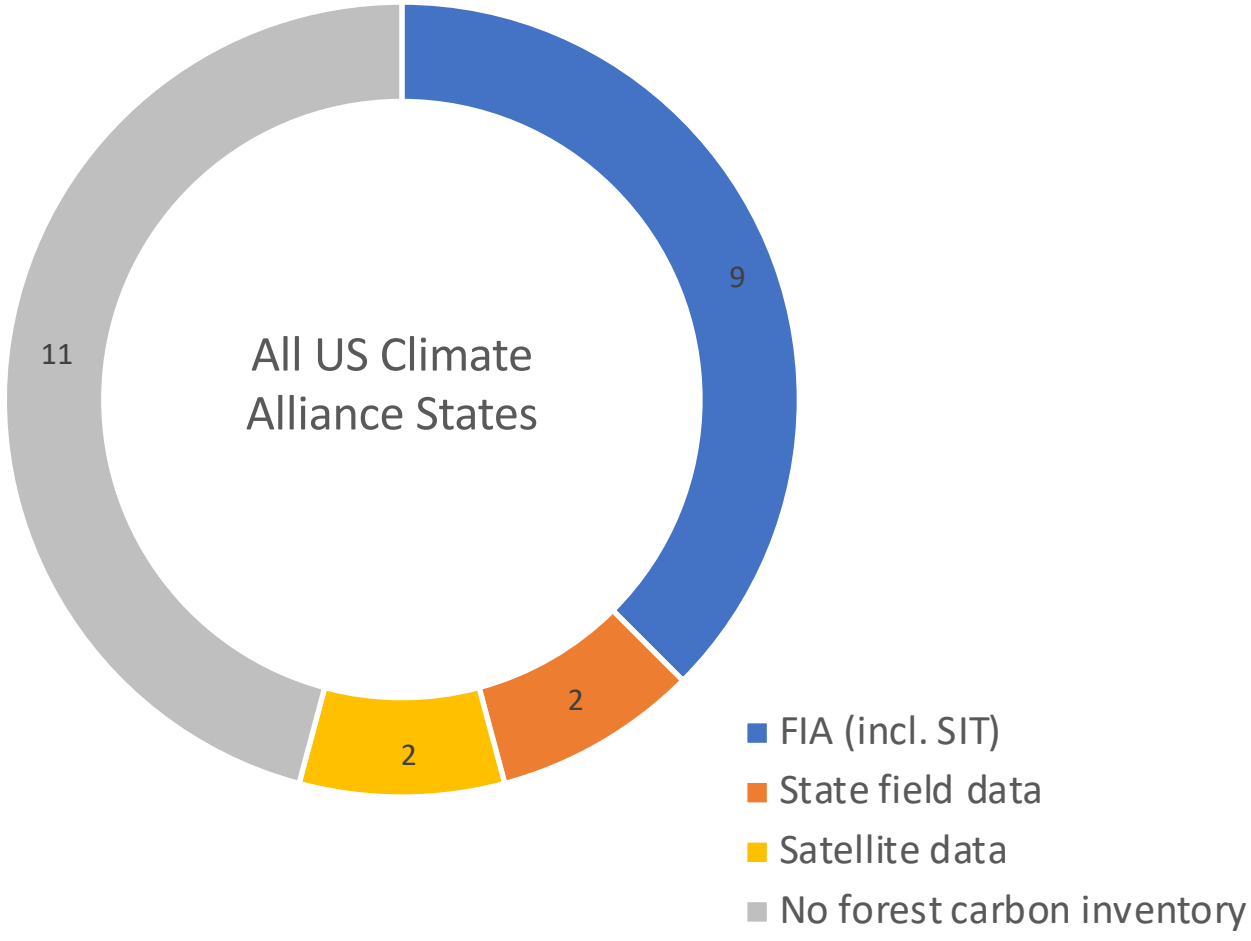
THE TRUST FOR PUBLIC LAND

WORLD RESOURCES INSTITUTE

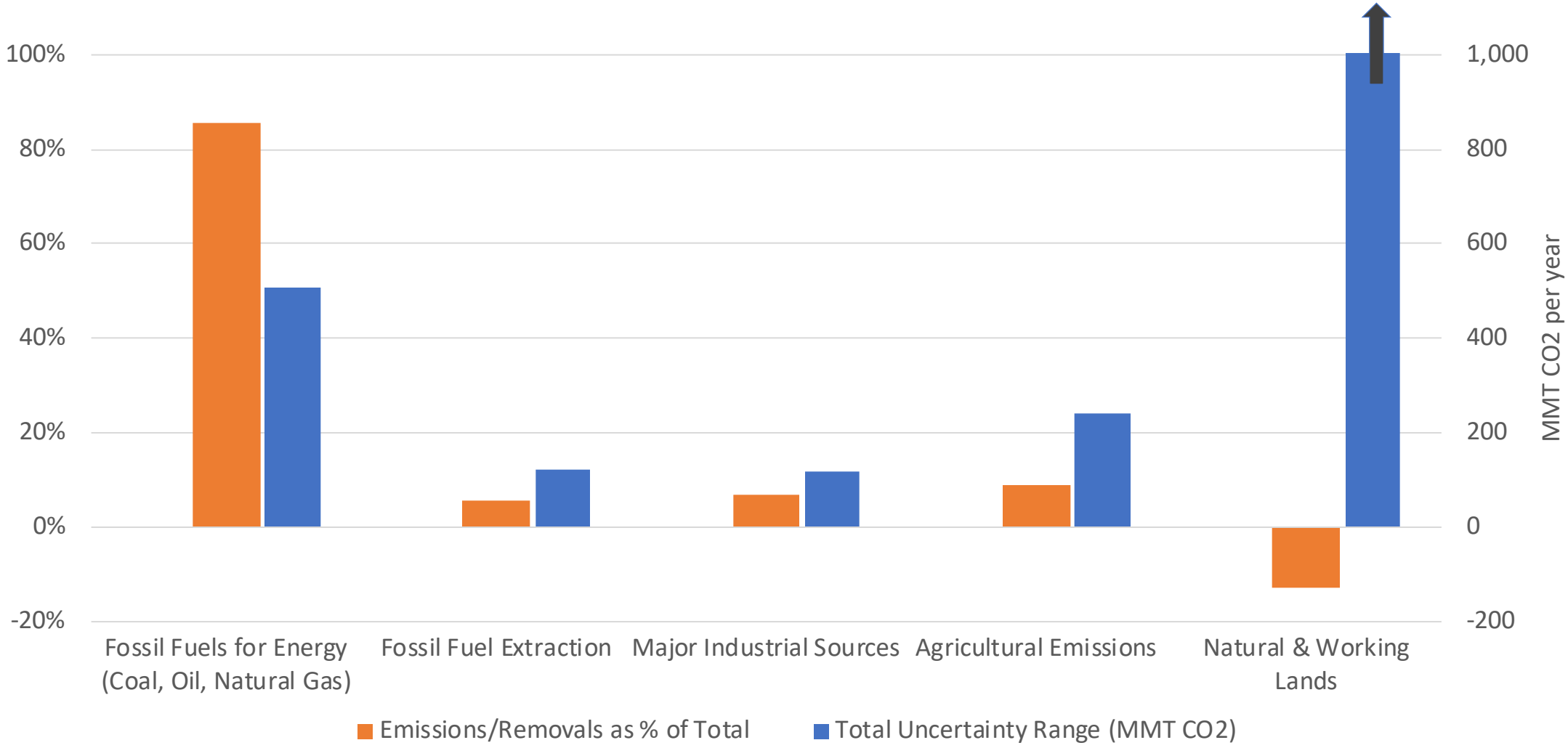
Source: US Climate Alliance

Lidar represents a step up in inventory methods

State inventory methods for forest carbon:



Forest Carbon Uncertainty is a big deal



Data from National GHG Inventory (US EPA 2019)

Lidar integration can improve state ghg inventories

- **Reduce uncertainty:** pairing FIA plots with lidar results in precision equivalent to a 2-4x intensification of FIA plot density
- Captures **trees outside forests:** 15% of tree biomass is in non-forest areas in Maryland
- Provides **spatial data:** can inform local decision-making and land-use planning
- More **cost-effective** than intensifying field-based inventory: 70-80% savings for Washington State forest lands
  - Lidar costs range from $0.50-$2.00/acre
- Can also underlie **projected baselines** or scenario modeling for future forest conditions

Stand delineation using field data

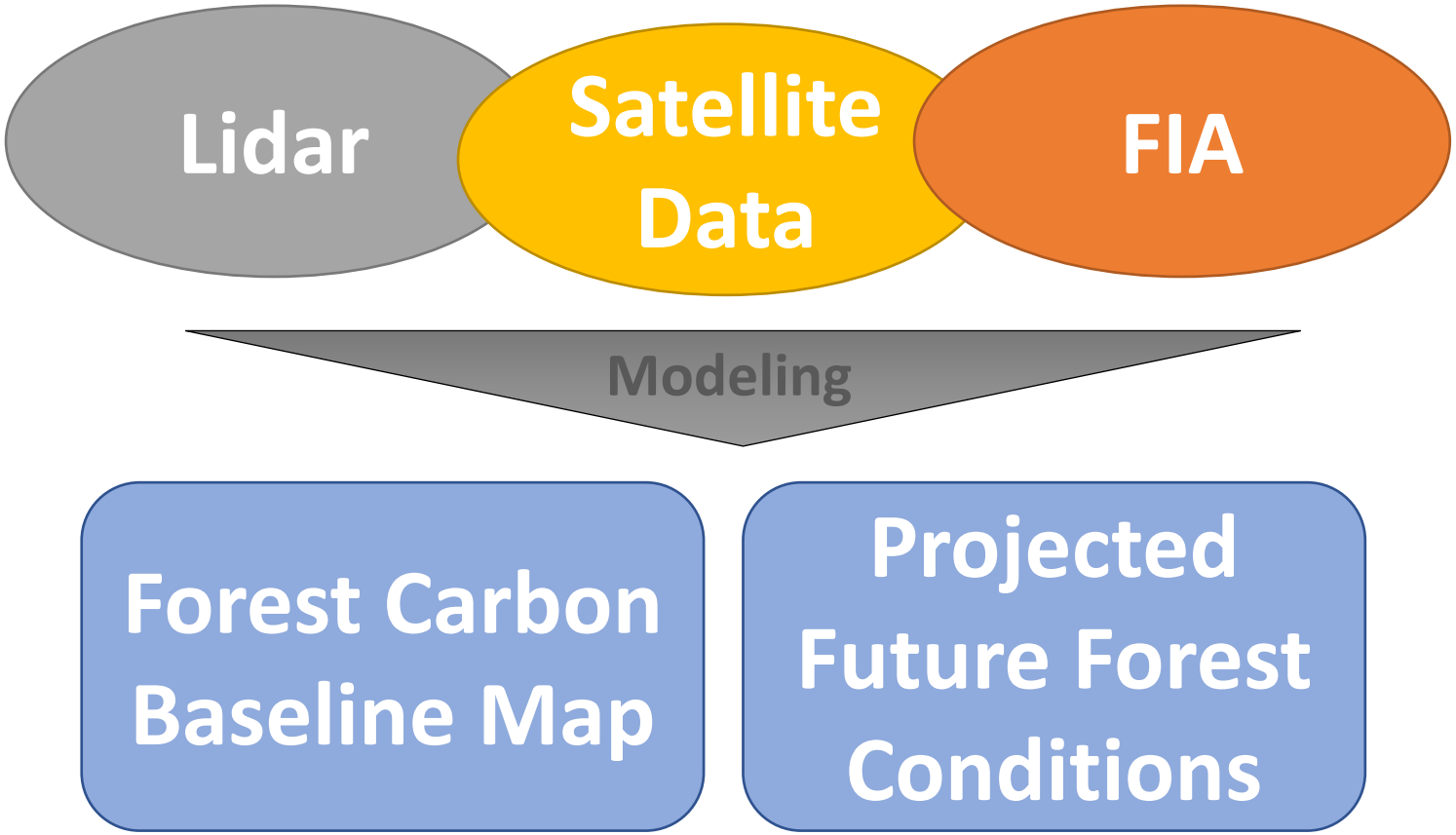
Stand delineation using lidar

Image sources: Gould & Strunk 2016

Maryland & Delaware are piloting a new approach

Current system:

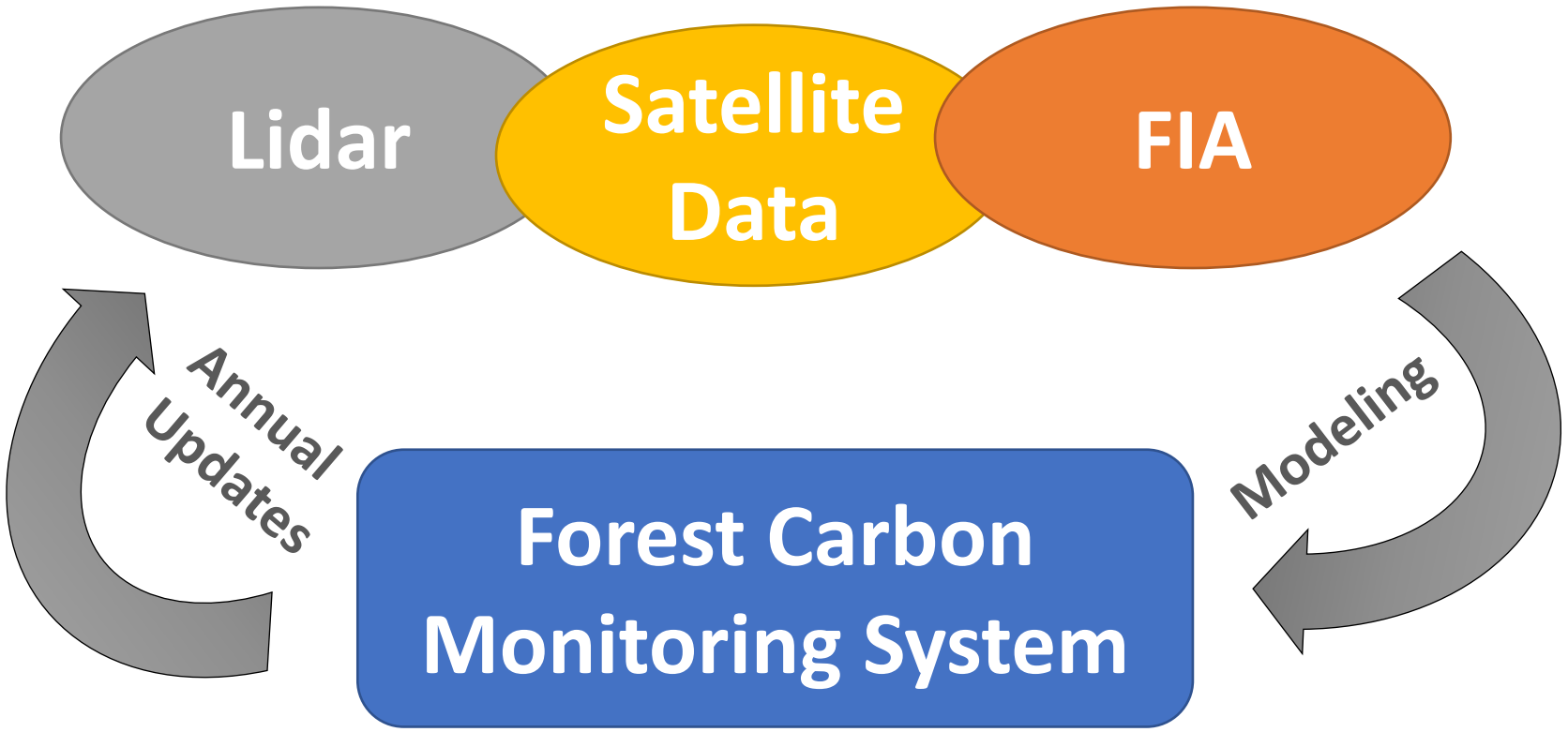
(MD, DE, PA; planned expansion through Northeast)



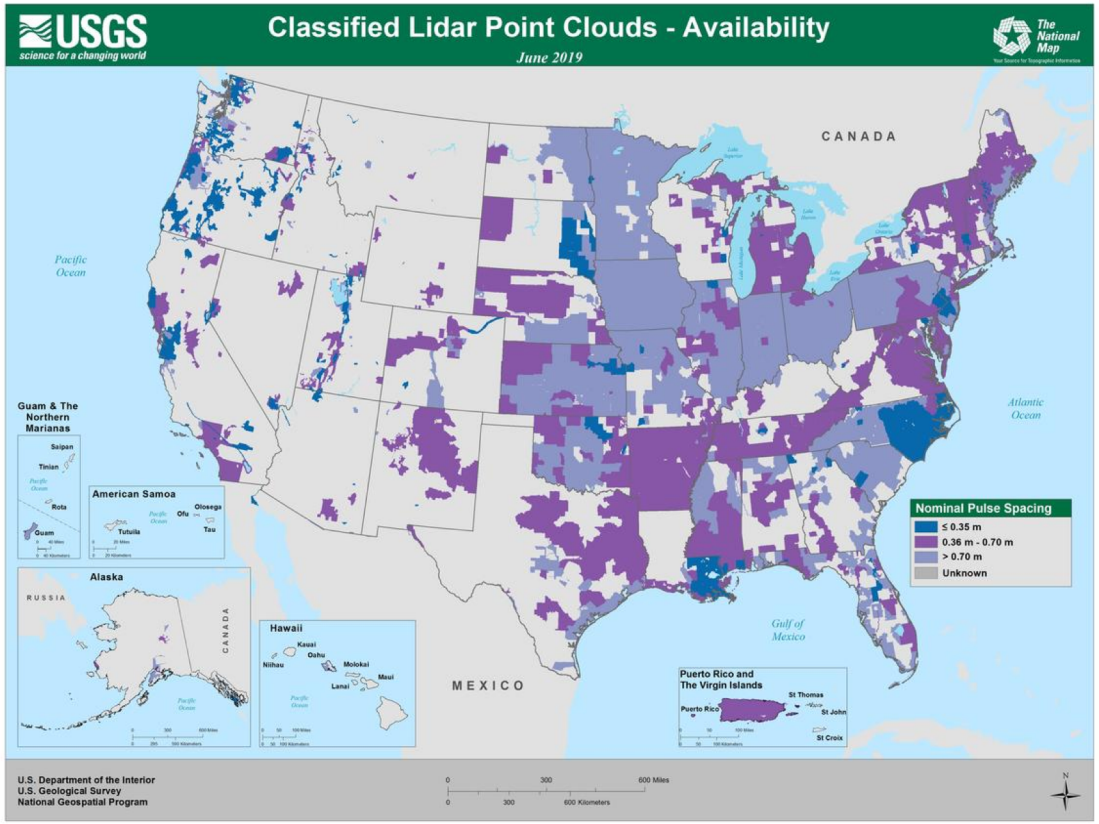
Maryland & Delaware are piloting a new approach

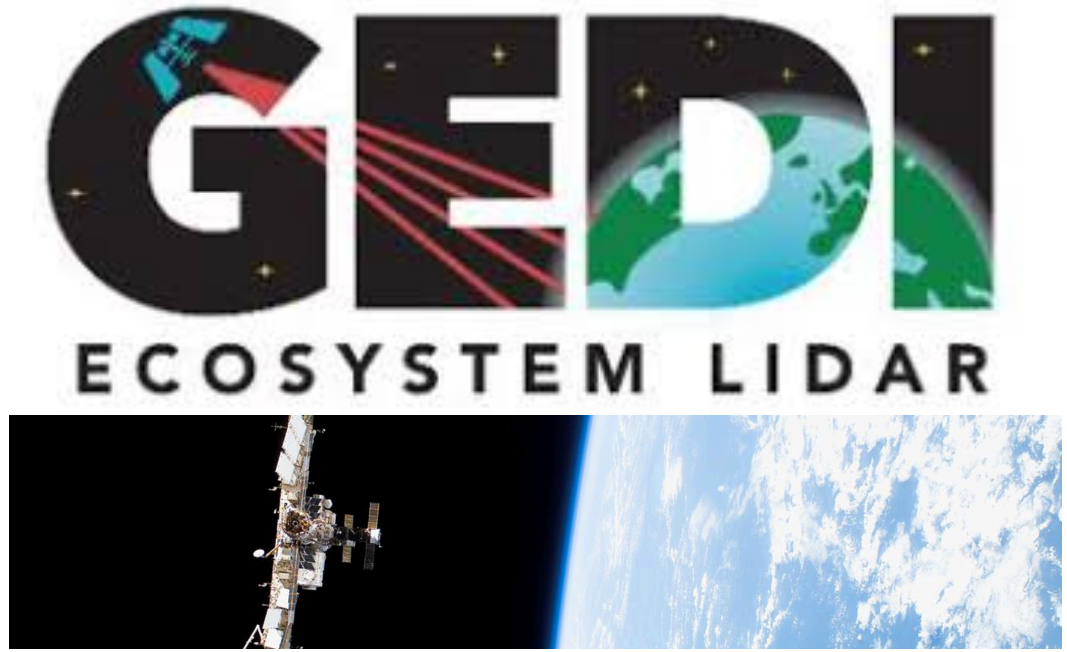
Planned new system:

(MD & DE)



Future expansion?





Questions?

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Alex Rudee, World Resources Institute
alexander.rudee@wri.org

Photo: M. Mack

CMS Data Access Tutorial

Debjani Singh, Bruce Wilson, Alison Boyer, & Tammy Walker

ORNL Distributed Active Archive Center

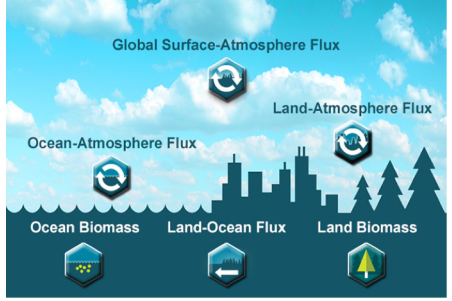
Thomas Hearty, Dave Meyer, Dana Ostrenga & Jennifer Wei

Goddard Earth Sciences Data and Information Services Center

CMS Science Team Meeting November 2019

Outline

- Where the CMS products are located
- How to find CMS data sets
  - DAAC main pages
  - search.earthdata.nasa.gov
- How to get help
- A few examples based on the survey
- Tools from ORNL DAAC and GES DISC



Archival of CMS Data

Goddard DAAC (GES DISC)

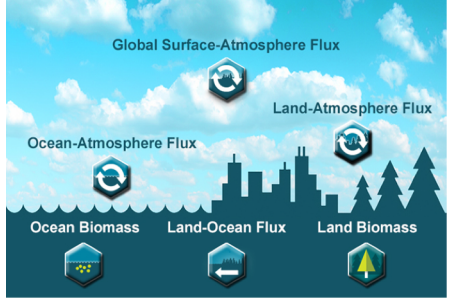
Global Climate

- Global Surface-Atmosphere Flux
- Ocean-Atmosphere Flux
- Land-Atmosphere Flux
- Ocean Biomass

ORNL DAAC

Terrestrial Ecology

- Land Biomass
- Land-Ocean Flux
- Land-Atmosphere Flux

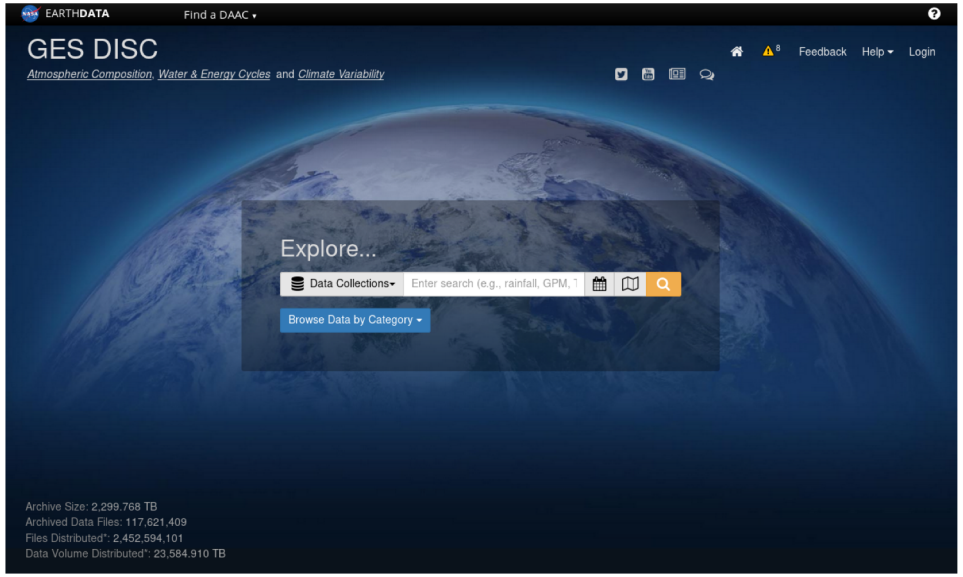


Archival of CMS Data

"Goddard DAAC" (GES DISC*)

Global Climate

https://disc.gsfc.nasa.gov

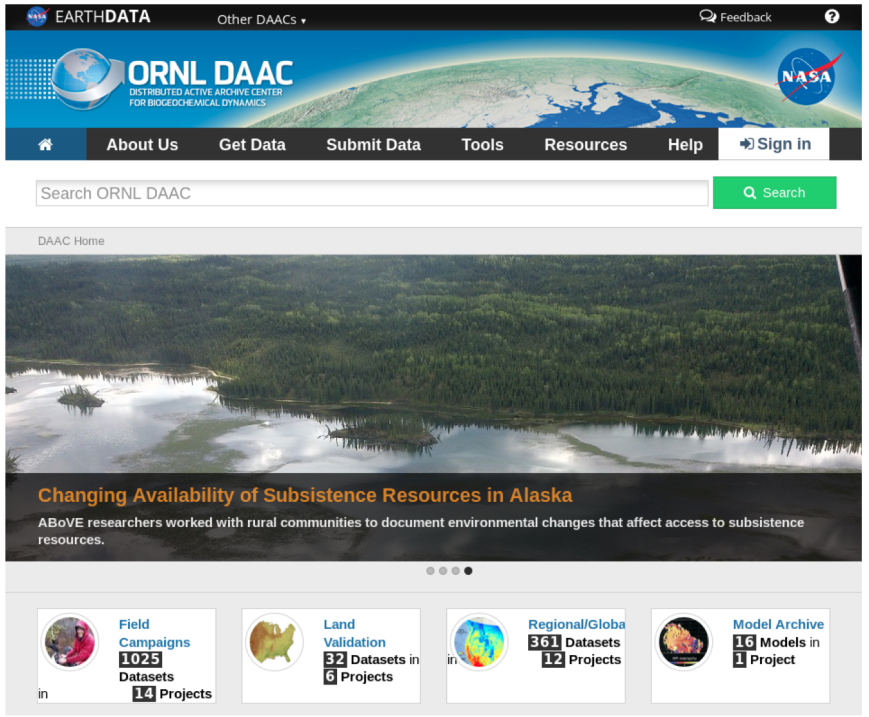


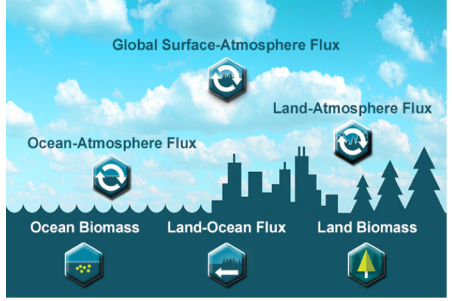
*Goddard Earth Sciences Data Information and Services Center

ORNL DAAC

Terrestrial Ecology

https://daac.ornl.gov





Archival of CMS Data

Goddard DAAC (GES DISC)

Global Climate

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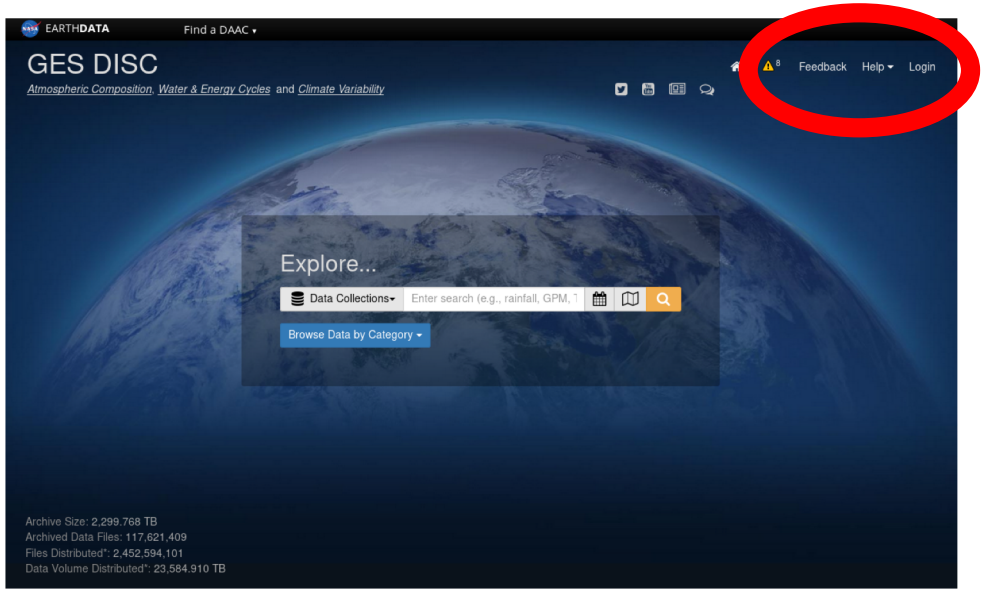
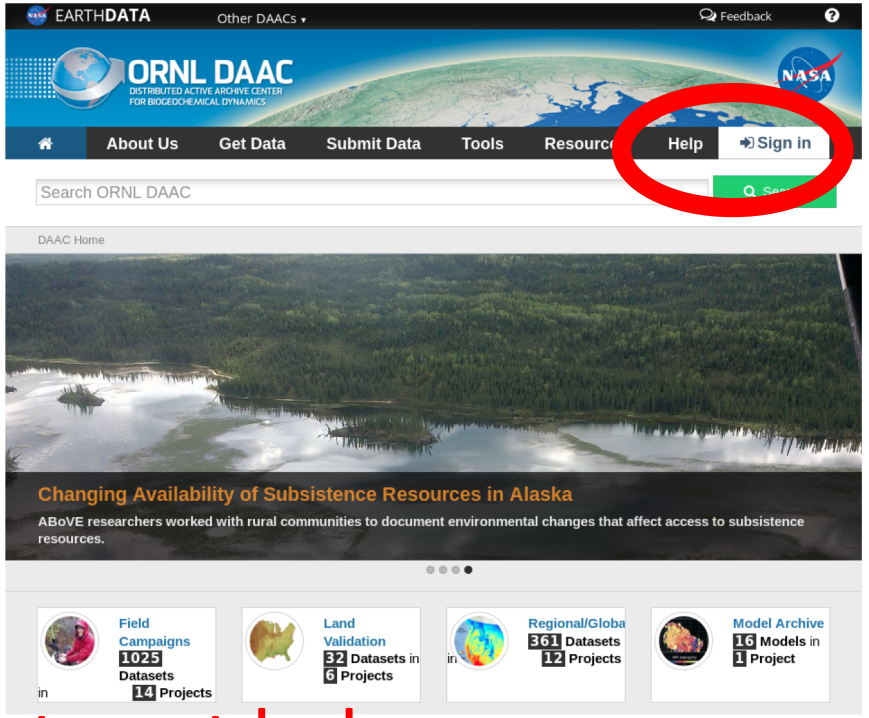


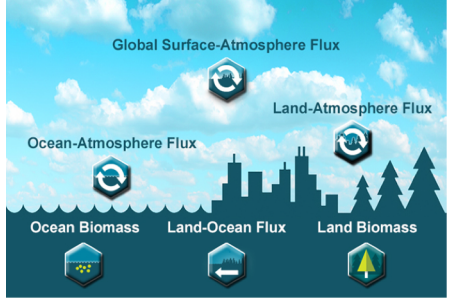
ORNL DAAC

Terrestrial Ecology

https://daac.ornl.gov



- Both DAACs have ways to get help
- Both use the same Earthdata login

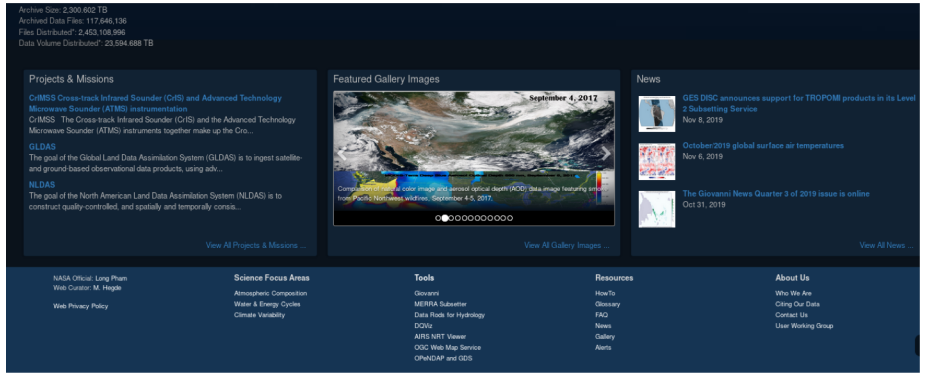


Archival of CMS Data

Goddard DAAC (GES DISC)

Global Climate

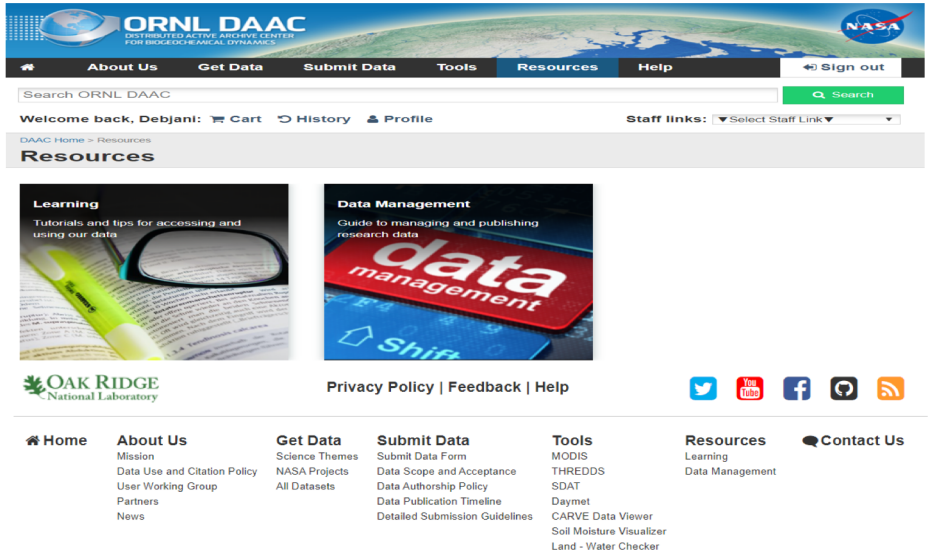
https://disc.gsfc.nasa.gov



ORNL DAAC

Terrestrial Ecology

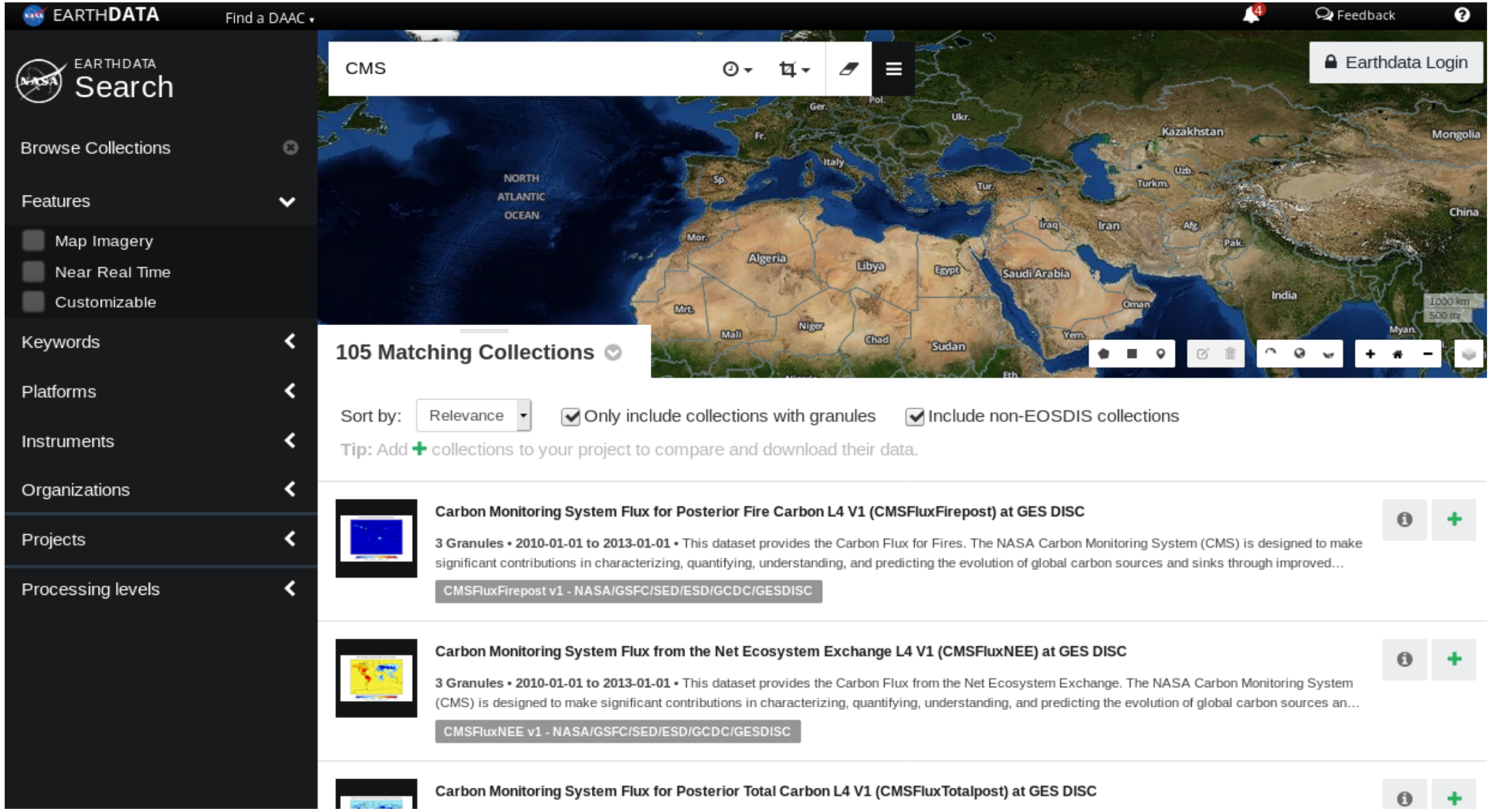
https://daac.ornl.gov/resources



Both DAACs also have tutorials, how-to documents, News Items, and use multiple forms of social media.

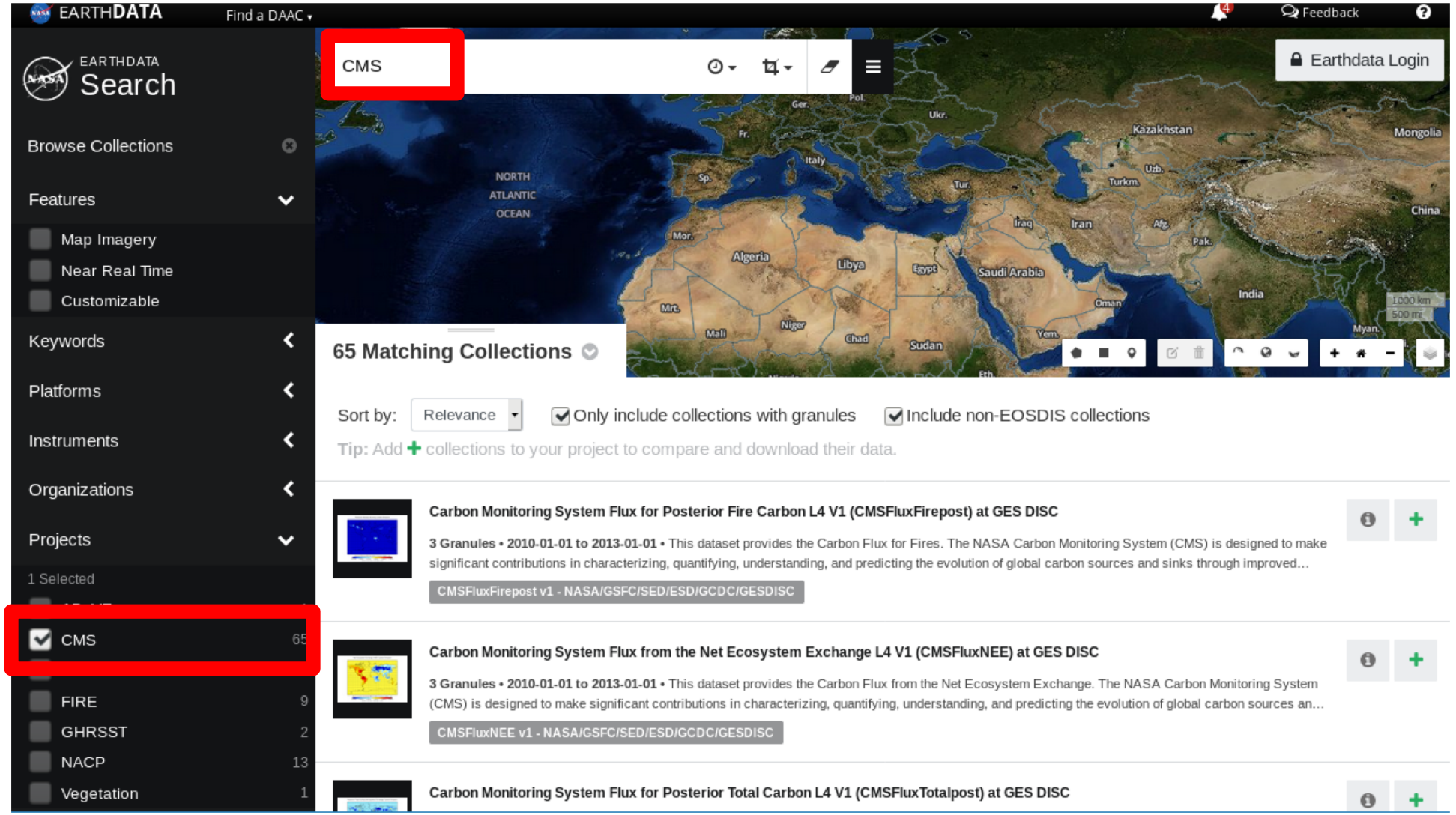
“Earthdata Search Client”

(https://search.earthdata.nasa.gov/)



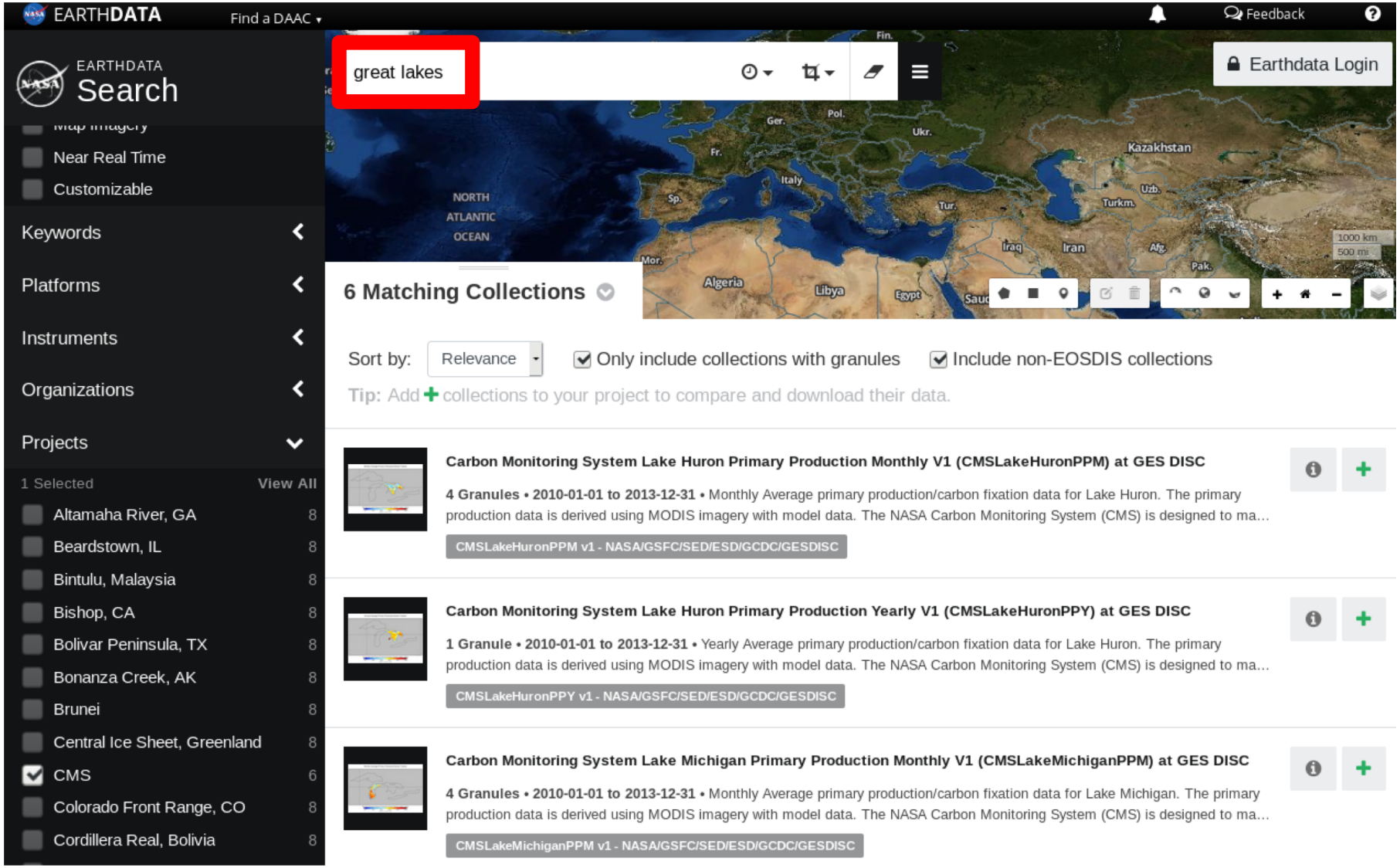
Using the “Earth Data Search Client” You don't have to know which DAAC archives the data

Earthdata Search Client*



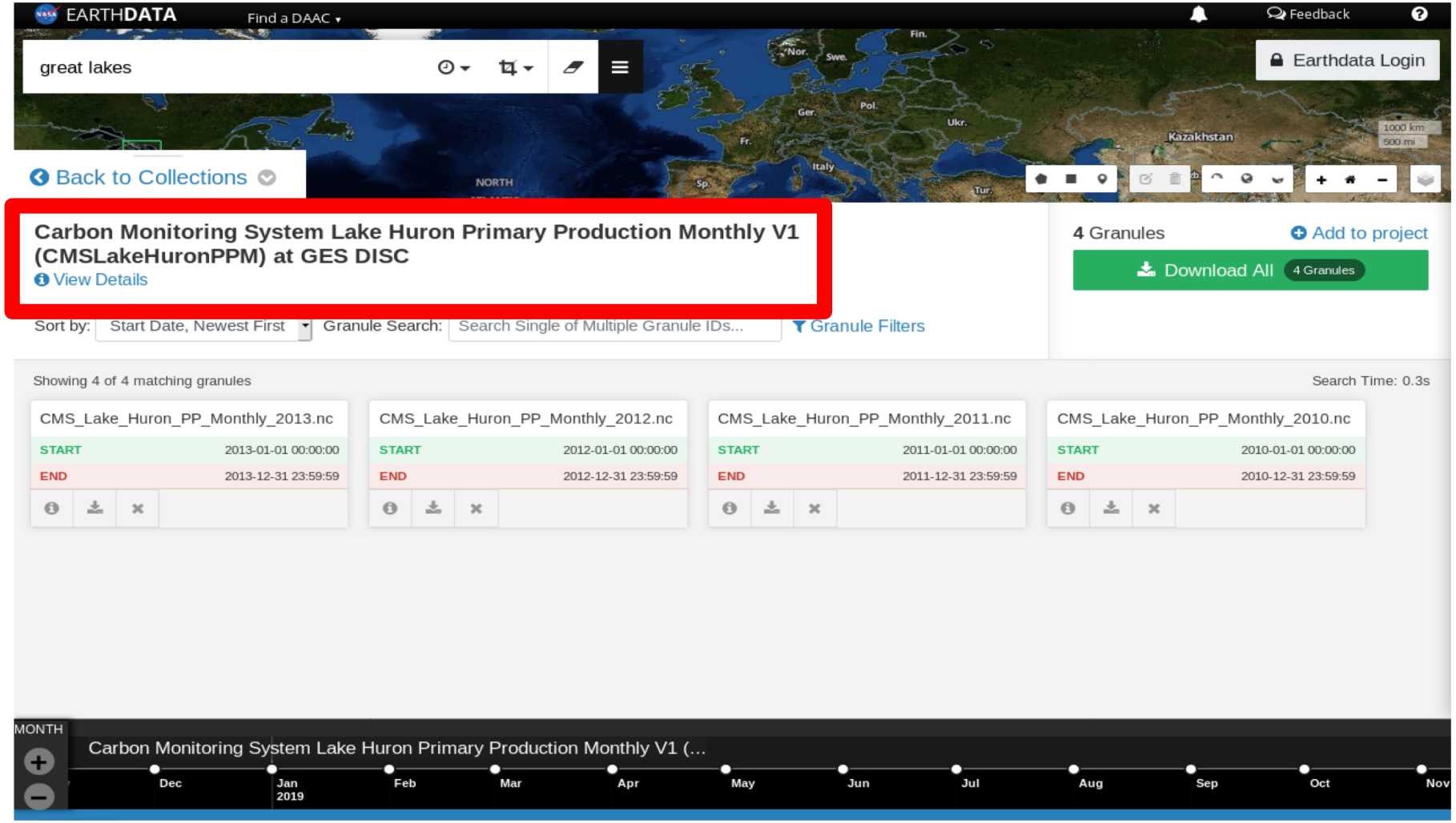
* This slide is a few days old. There are 71 CMS products now.

Earthdata Search Client



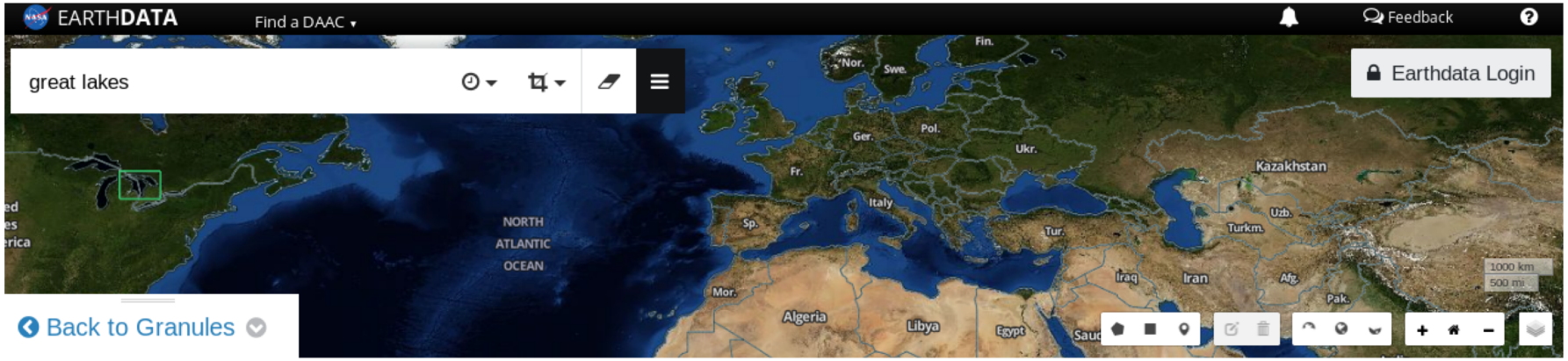
It is also possible to search by keywords (e.g., “great lakes”)

Earthdata Search Client



- This particular dataset has 4 “granules”.
- The link to “View Details” will have additional information

Earthdata Search Client



Carbon Monitoring System Lake Huron Primary Production Monthly V1 (CMSLakeHuronPPM) at GES DISC CMSLakeHuronPPM Version 1

Bounding Rectangle: (46.591°, -84.762°, 43.001°, -79.652°)

DOI 10.5067/CZ39JIR4ZAT4

Data Set Landing Page
View All Related URLs
View More Info

2010-01-01 to 2013-12-31

GIBS Imagery Projection Availability:
None

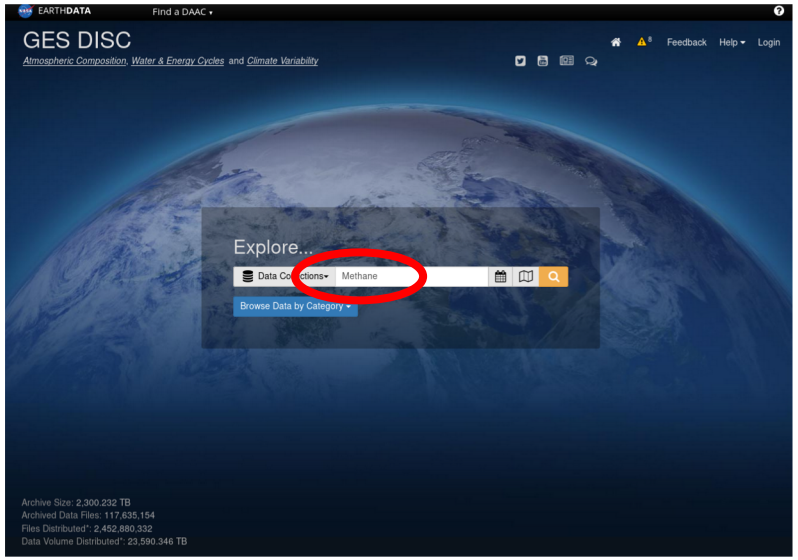
Science Keywords:
EARTH SCIENCE > BIOSPHERE > ECOLOGICAL DYNAMICS

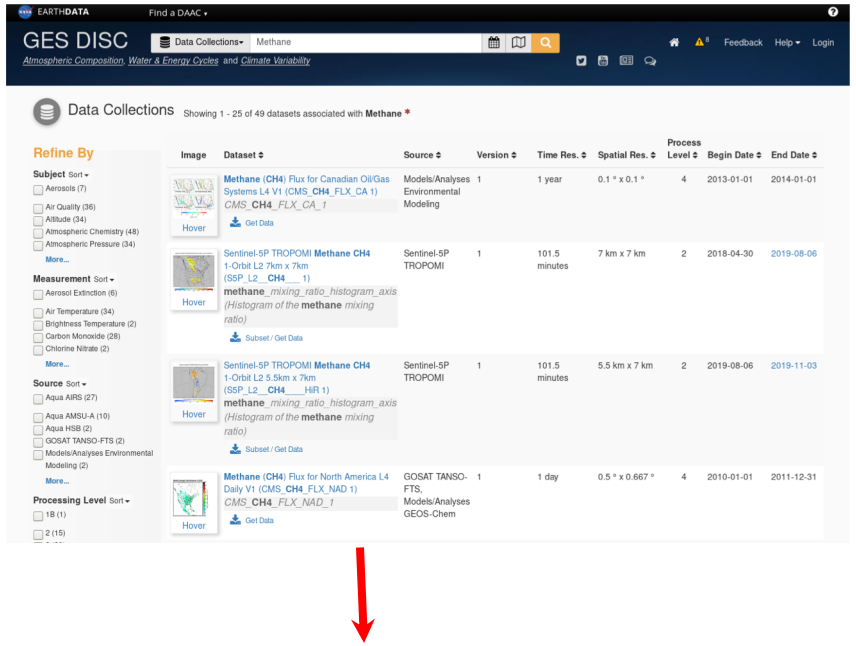
Monthly Average primary production/carbon fixation data for Lake Huron. The primary production data is derived using MODIS imagery with model data.

The NASA Carbon Monitoring System (CMS) is designed to make significant contributions in characterizing, quantifying, understanding, and predicting the evolution of global carbon sources and sinks through improved monitoring of carbon stocks and fluxes. The System will use the full range of NASA satellite observations and modeling/analysis capabilities to establish the accuracy, quantitative uncertainties, and utility of products for supporting national and international policy, regulatory, and management activities. CMS will maintain a global emphasis while providing finer scale regional information, utilizing space-based and surface-based data and will rapidly initiate generation and distribution of products both for user evaluation and to inform near-term policy development and planning.

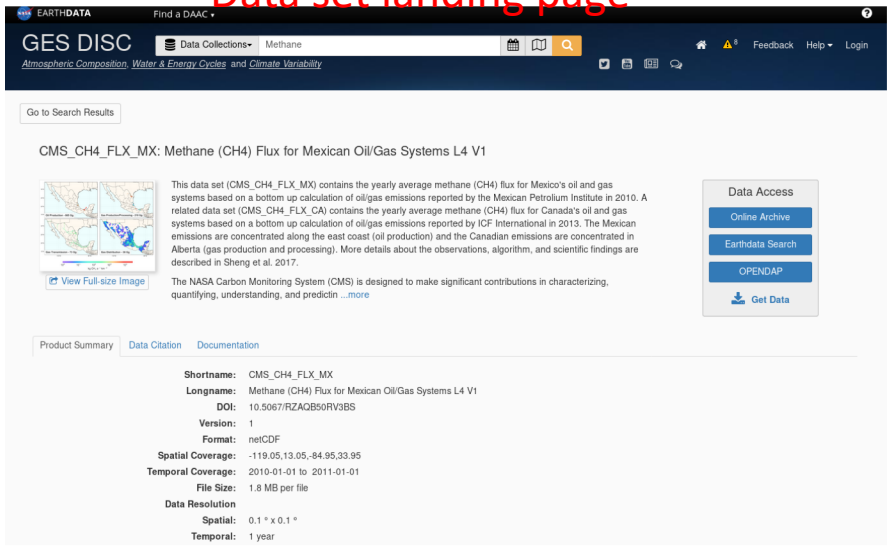
The link to the “Data Set Landing Page” will bring you to the DAAC where additional services are available

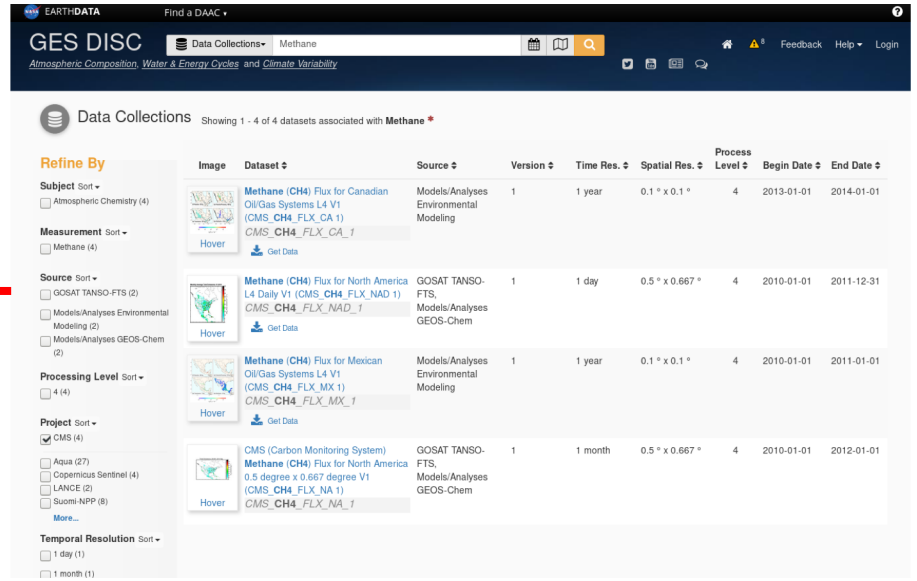
Searching for Data at the GES DISC



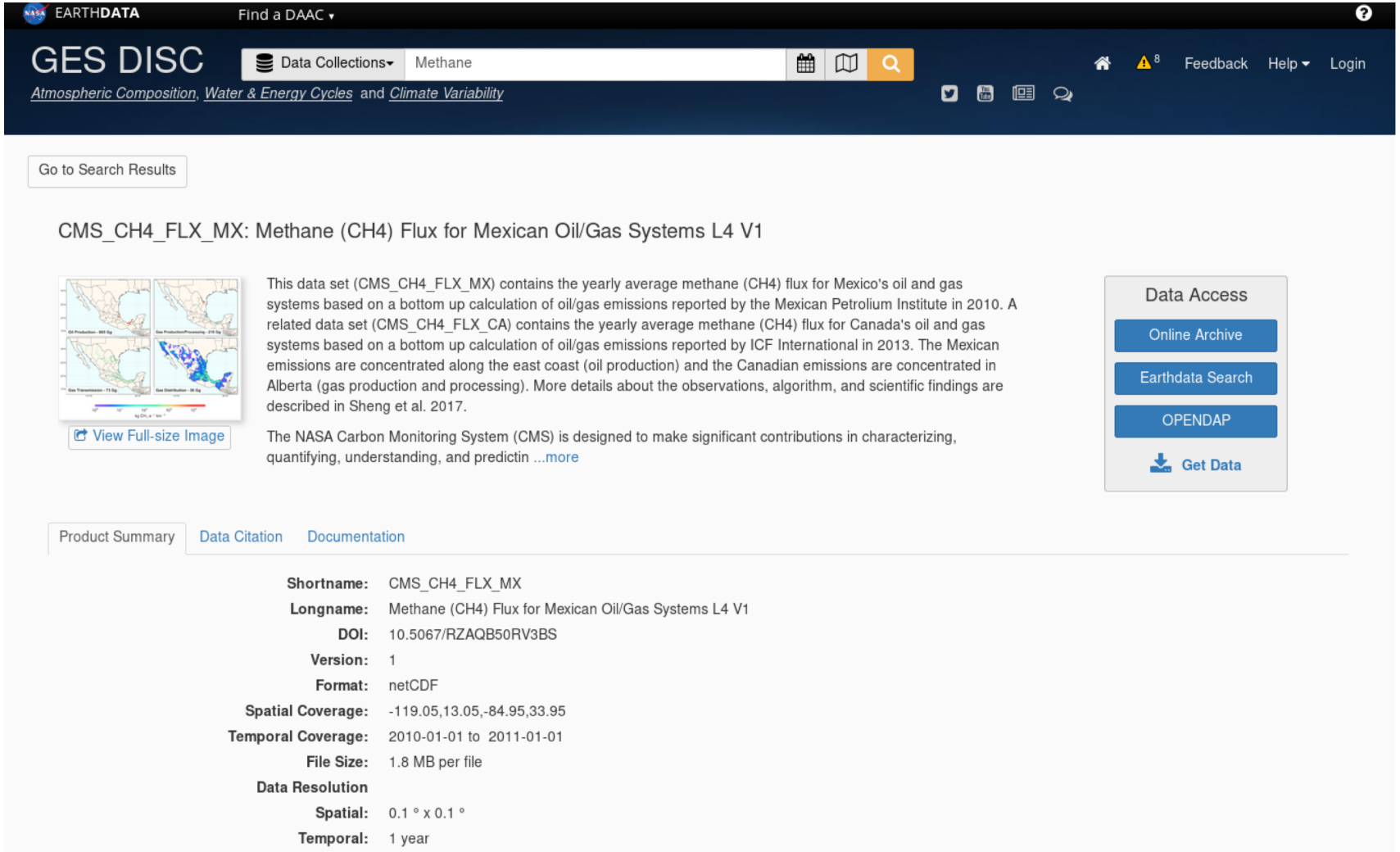


Data set landing page



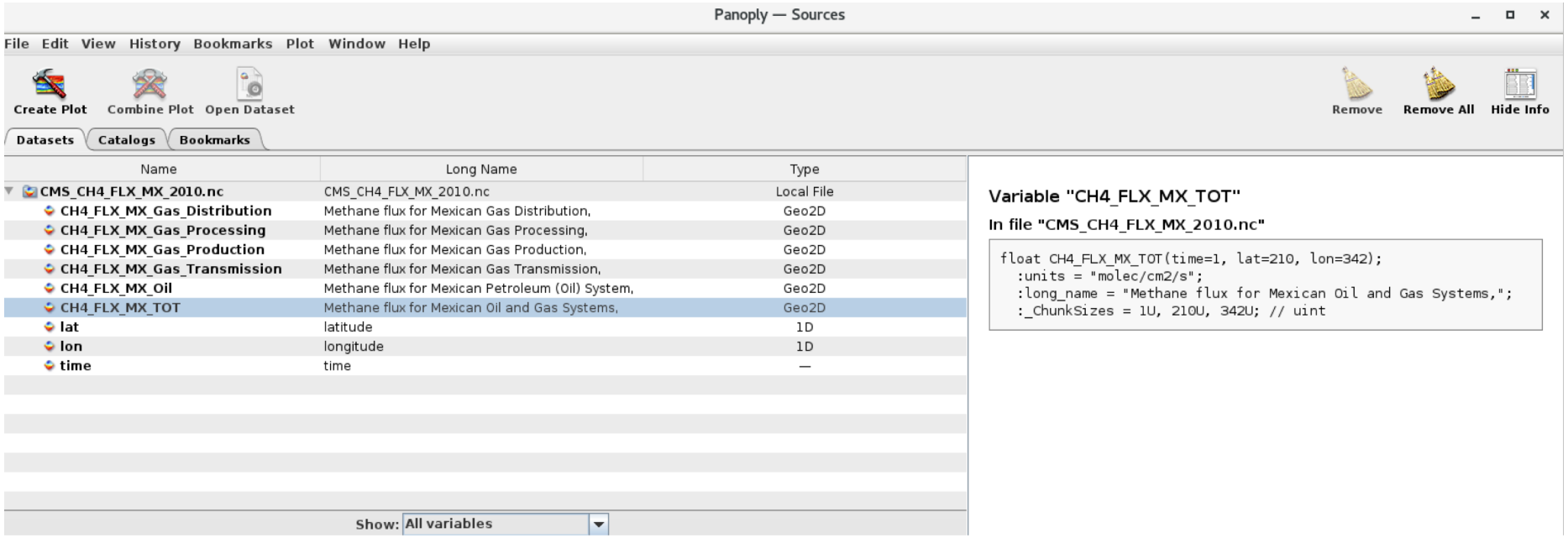


Dataset landing page

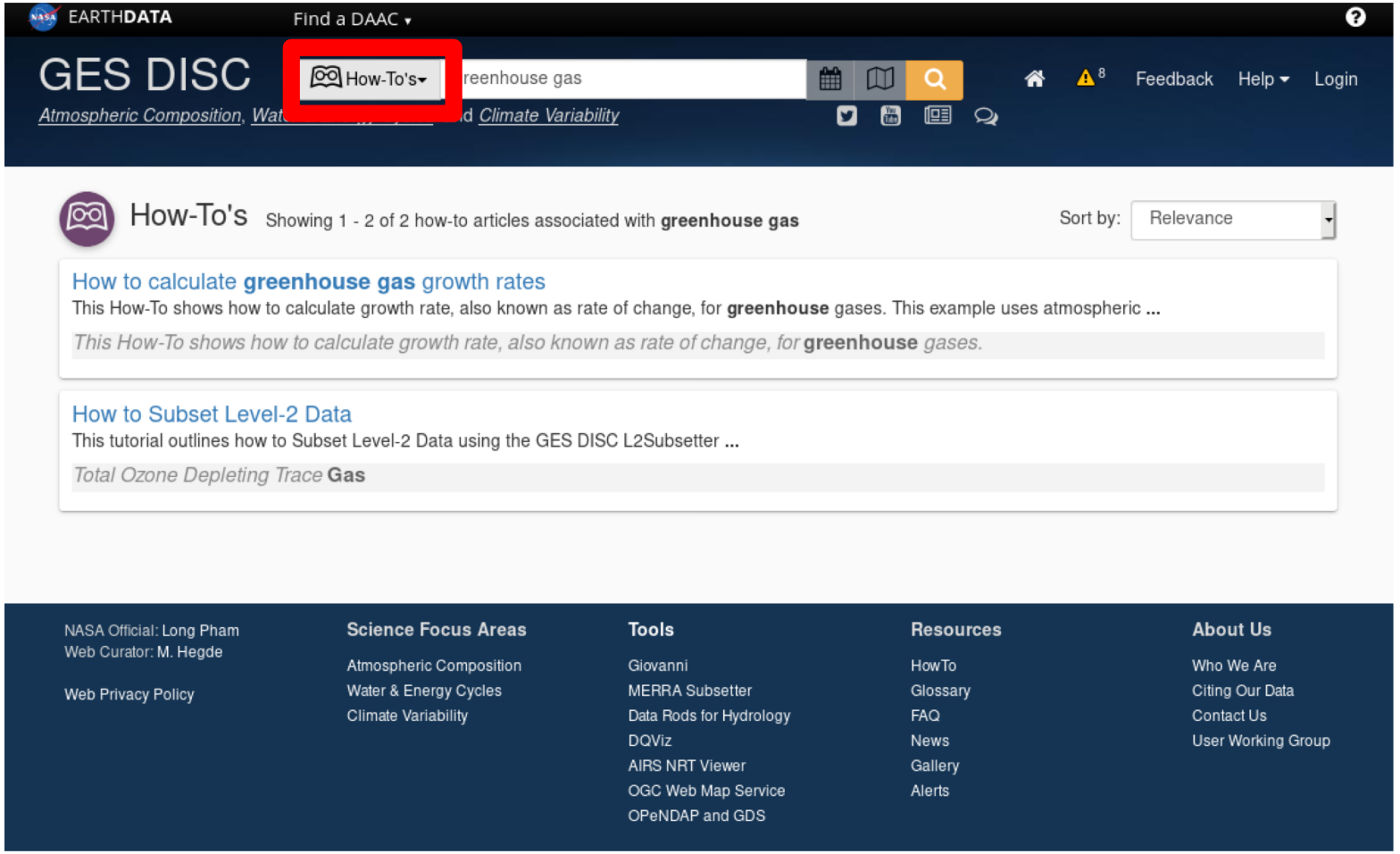


Information and Services for the data set is available from the data set landing page.
Note: OPENDAP link for converting to other formats (including ASCII, try it).

Panoply

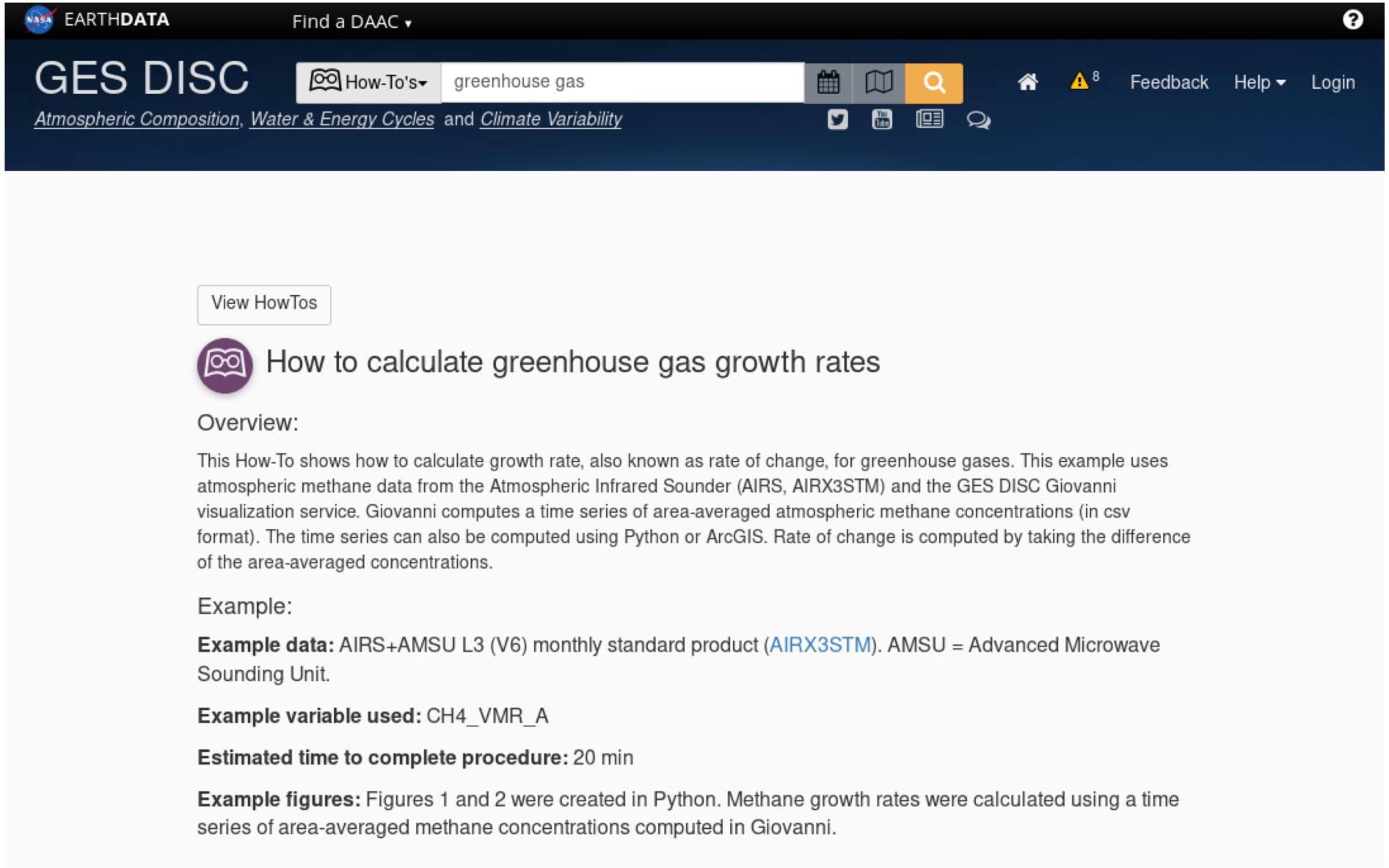

Panoply — Sources
File Edit View History Bookmarks Plot Window Help
Create Plot
Combine Plot
Open Dataset
Remove
Remove All
Hide Info
Datasets
Catalogs
Bookmarks
Name
Long Name
Type
CMS_CH4_FLX_MX_2010.nc
CMS_CH4_FLX_MX_2010.nc
Local File
CH4_FLX_MX_Gas_Distribution
Methane flux for Mexican Gas Distribution,
Geo2D
CH4_FLX_MX_Gas_Processing
Methane flux for Mexican Gas Processing,
Geo2D
CH4_FLX_MX_Gas_Production
Methane flux for Mexican Gas Production,
Geo2D
CH4_FLX_MX_Gas_Transmission
Methane flux for Mexican Gas Transmission,
Geo2D
CH4_FLX_MX_Oil
Methane flux for Mexican Petroleum (Oil) System,
Geo2D
CH4_FLX_MX_TOT
Methane flux for Mexican Oil and Gas Systems,
Geo2D
lat
latitude
1D
lon
longitude
1D
time
time
—
Show: All variables
Variable "CH4_FLX_MX_TOT"
In file "CMS_CH4_FLX_MX_2010.nc"
float CH4_FLX_MX_TOT(time=1, lat=210, lon=342);
:units = "molec/cm2/s";
:long_name = "Methane flux for Mexican Oil and Gas Systems,";
:_ChunkSizes = 1U, 210U, 342U; // uint

How-To Documents

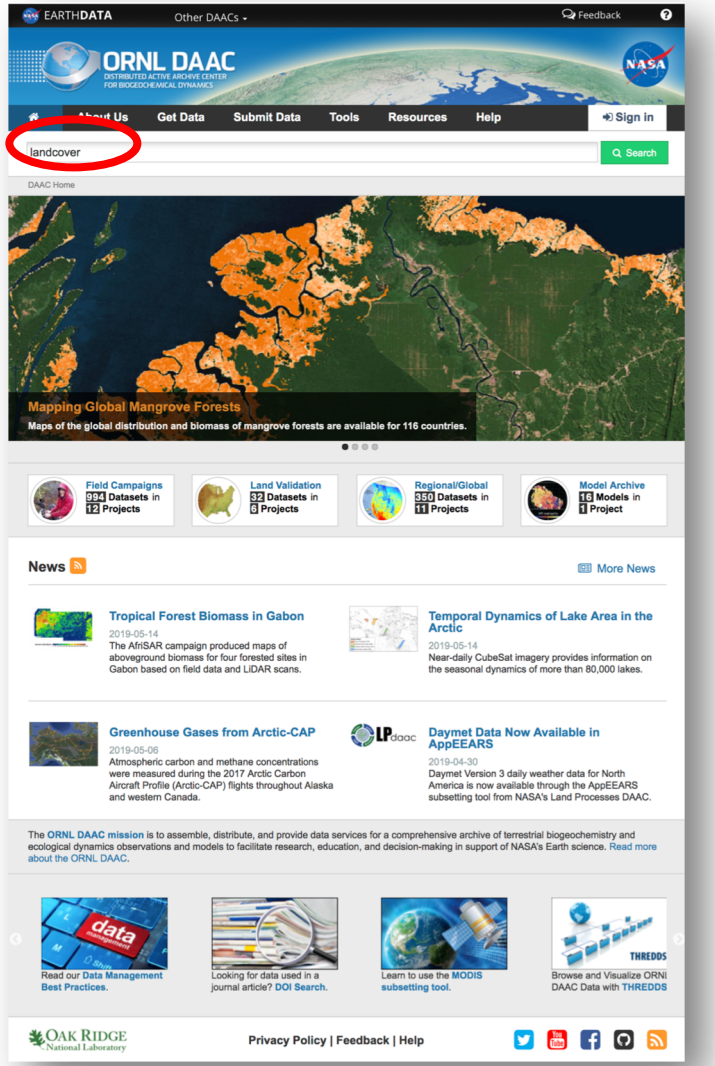


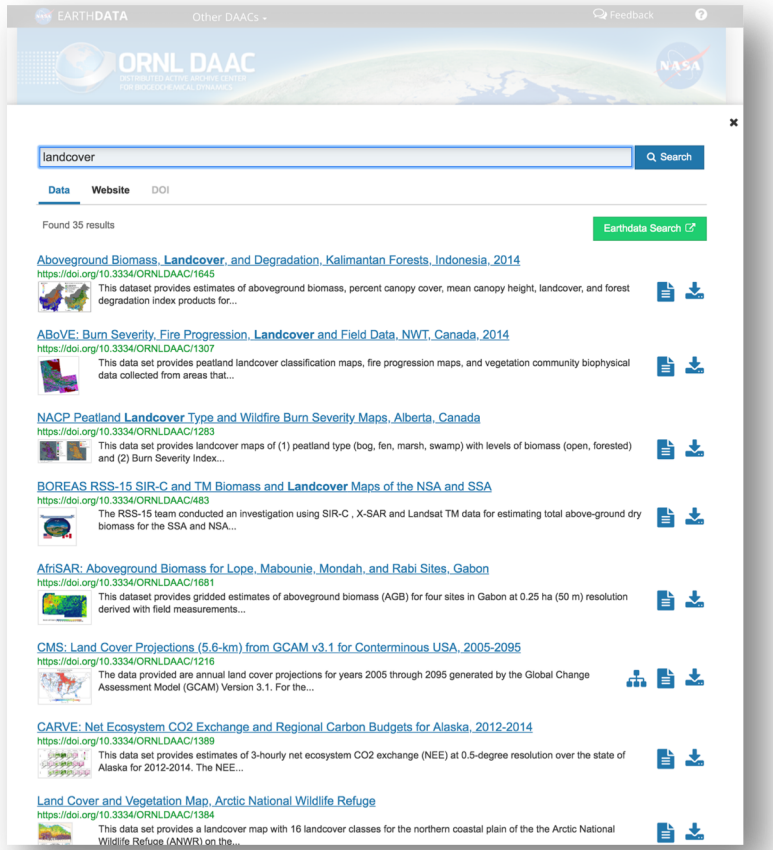
It is also possible to search for “How-To” documents by changes the search from “Data Collections” to “How Tos”.

How-To Documents

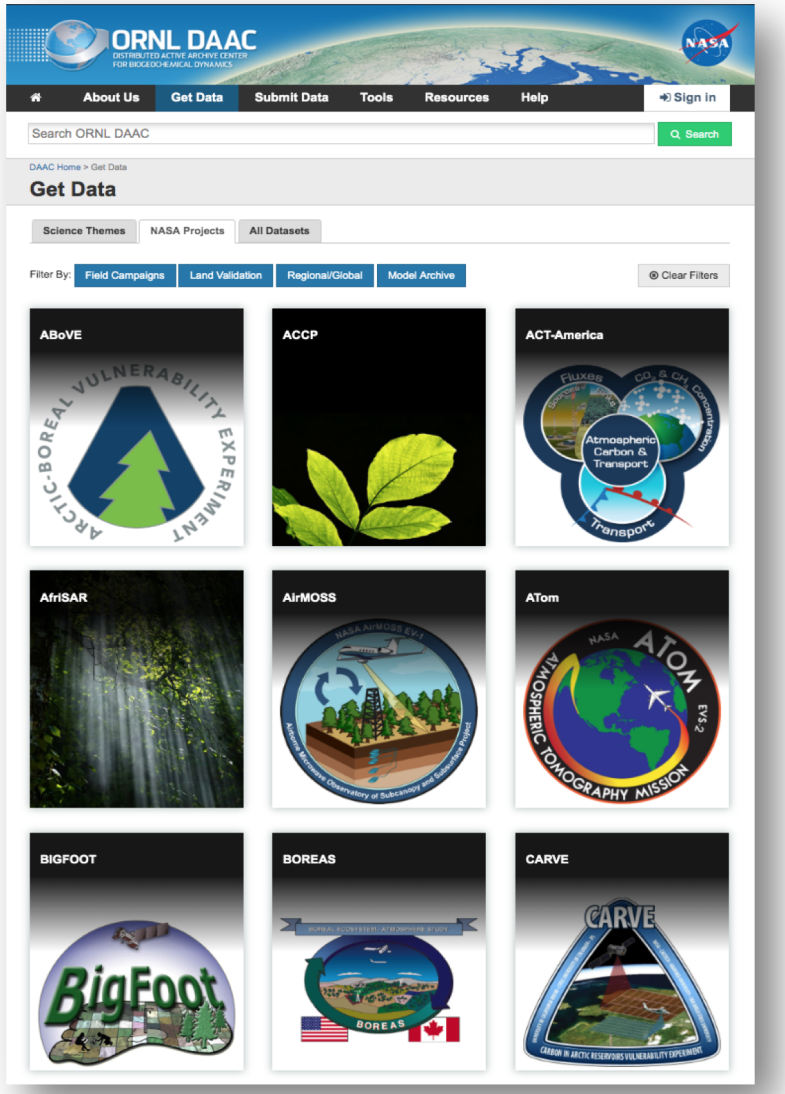


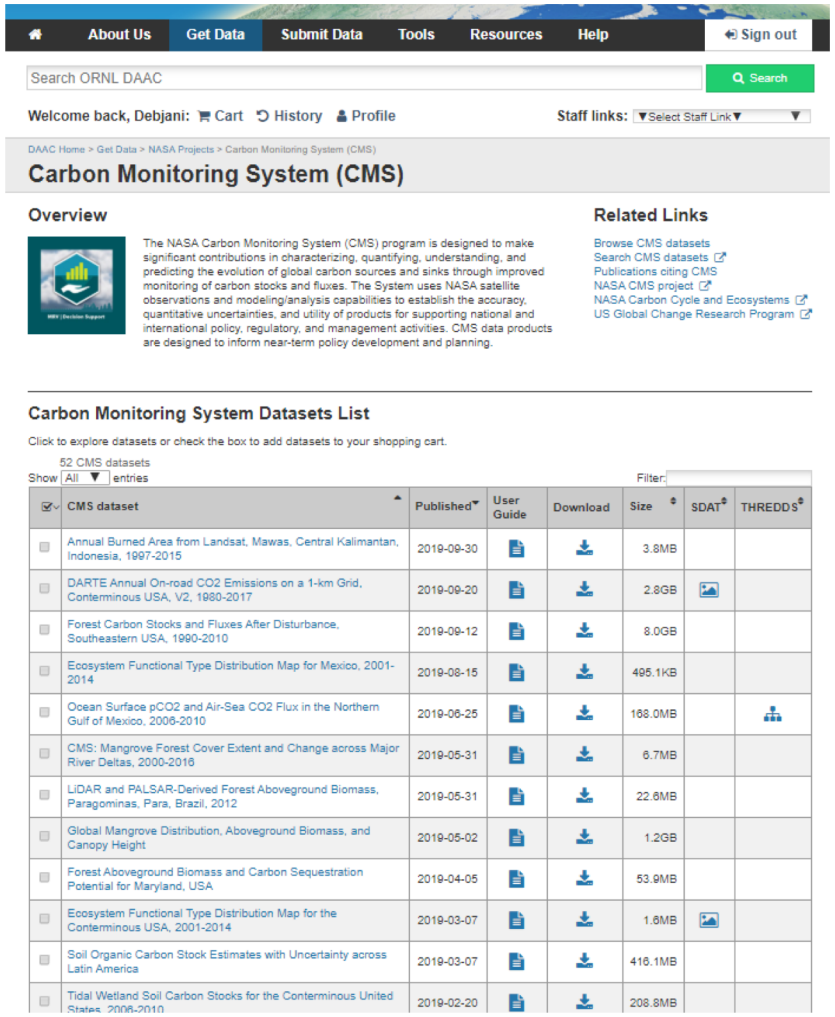
Searching for Data at ORNL DAAC



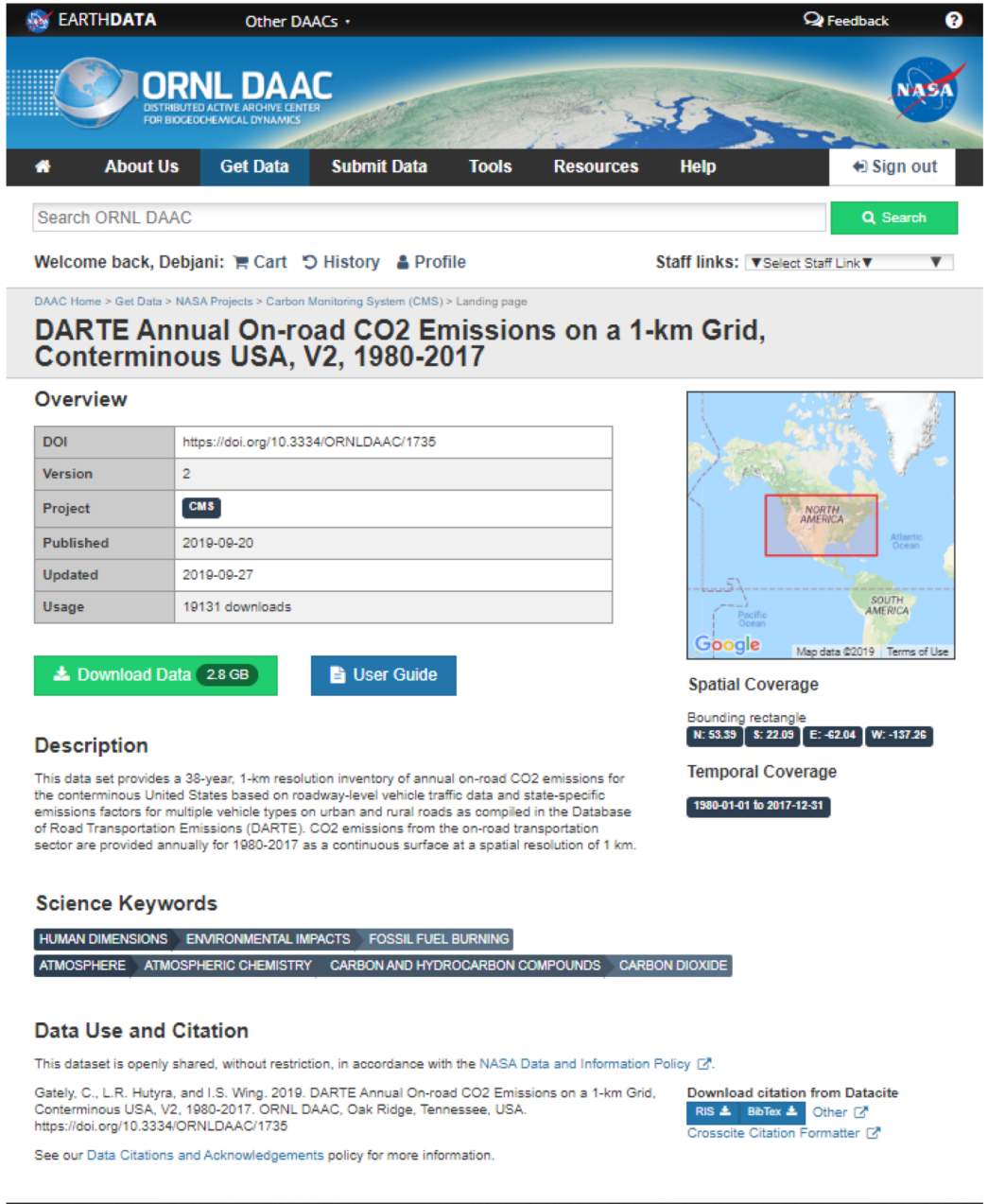


Data organization by NASA program





Dataset Landing Page



Tools from ORNL DAAC

https://webmap.ornl.gov/ogc

Spatial Data Access Tool (SDAT)

Visualize

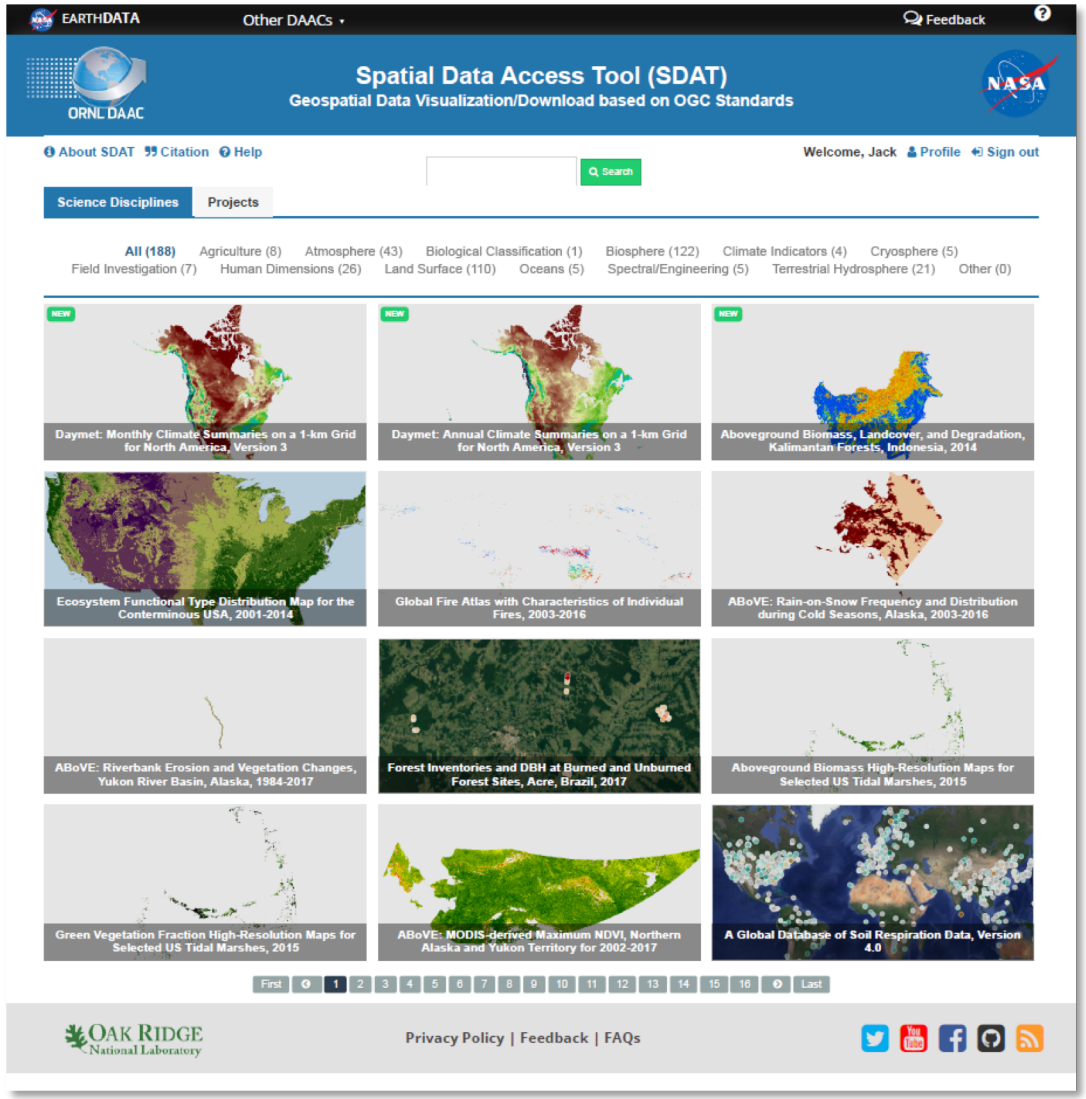
Subset

Regrid

Reformat

Reproject

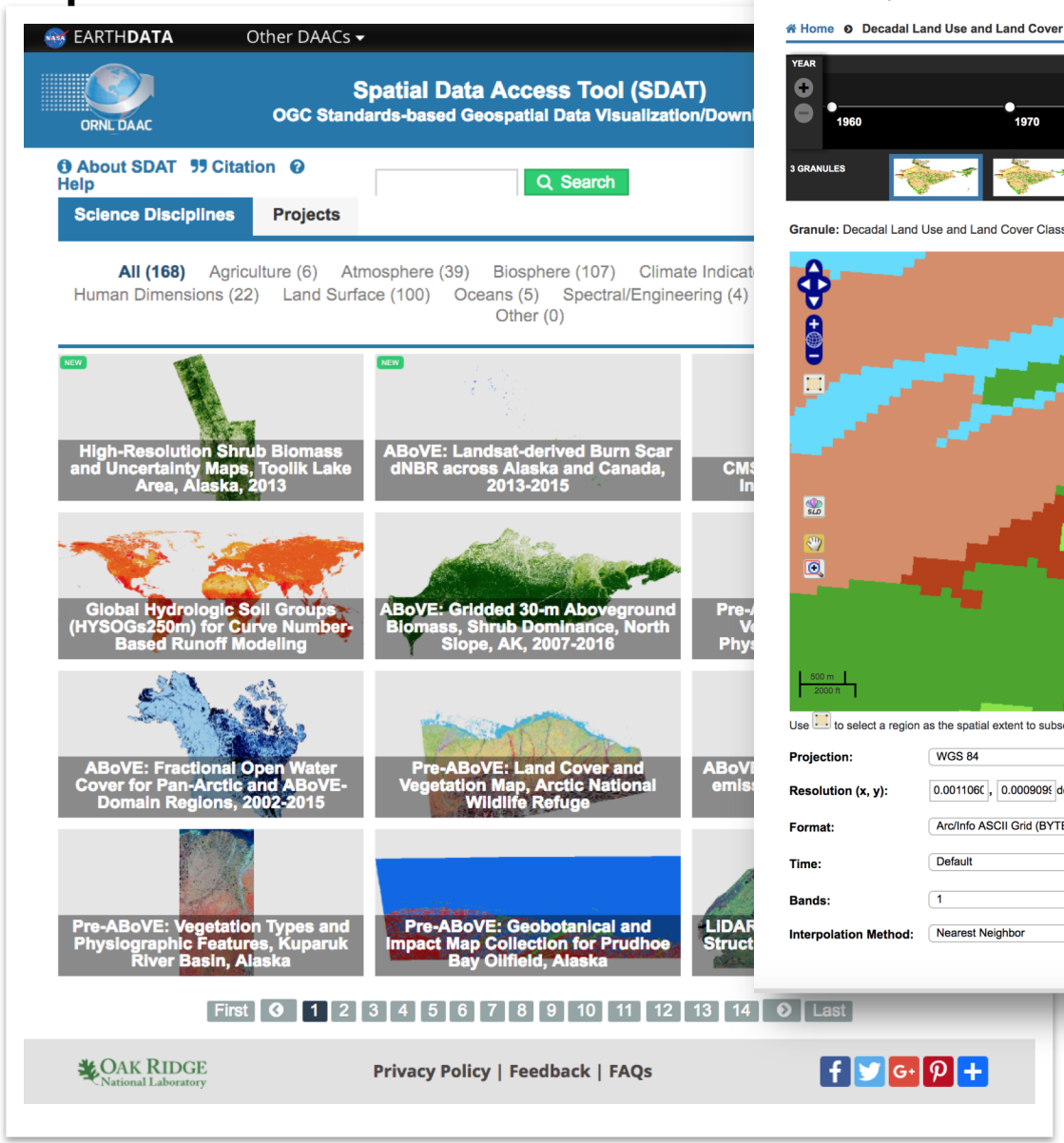
… all from your web browser!

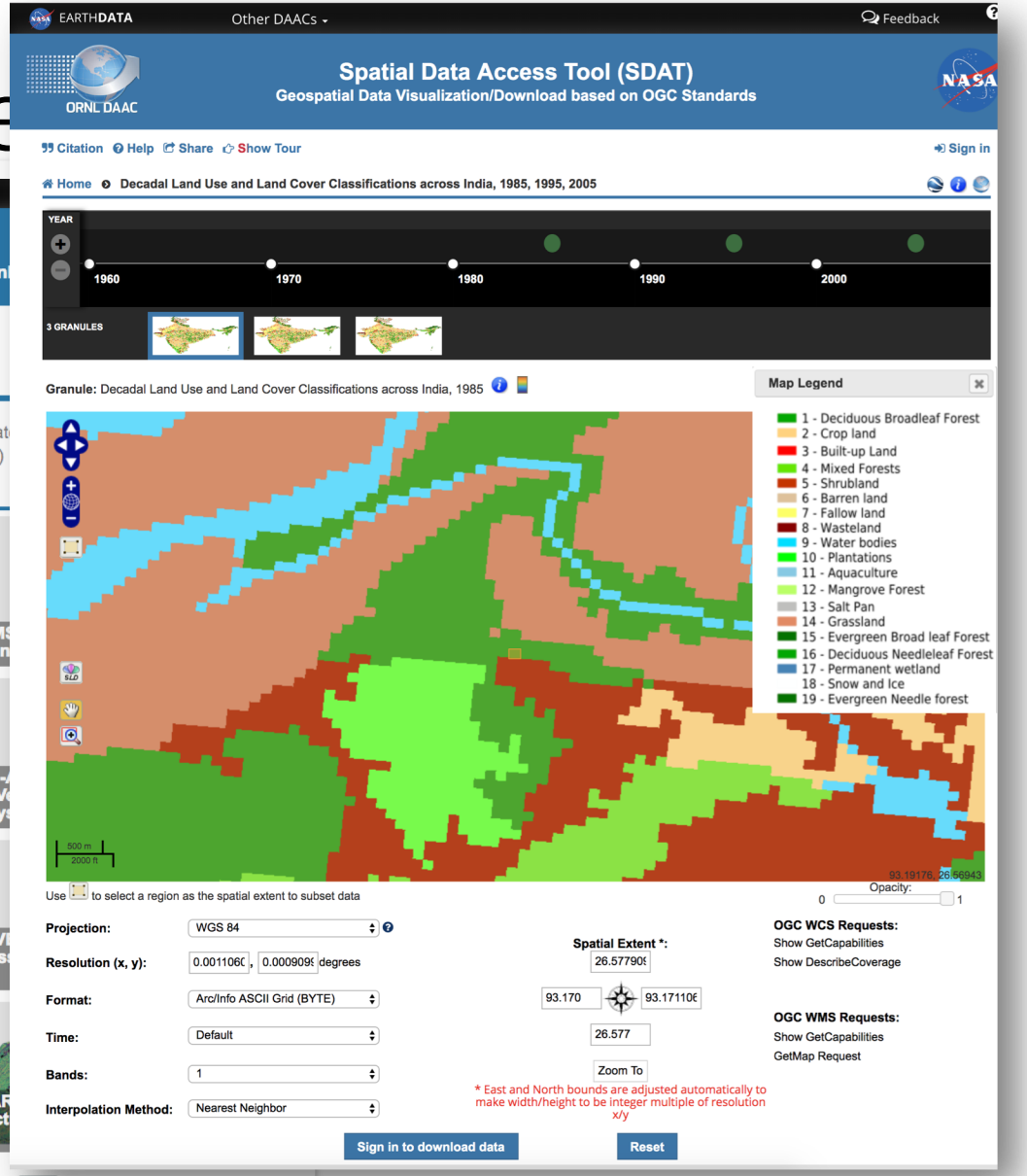


https://webmap.ornl.gov/ogc

Spatial Data Access Tool

Spatial Data Acce



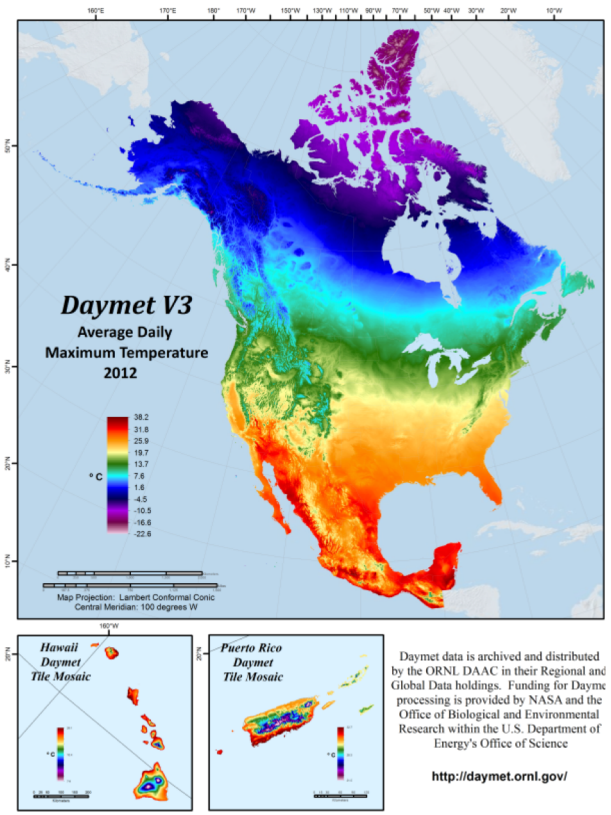


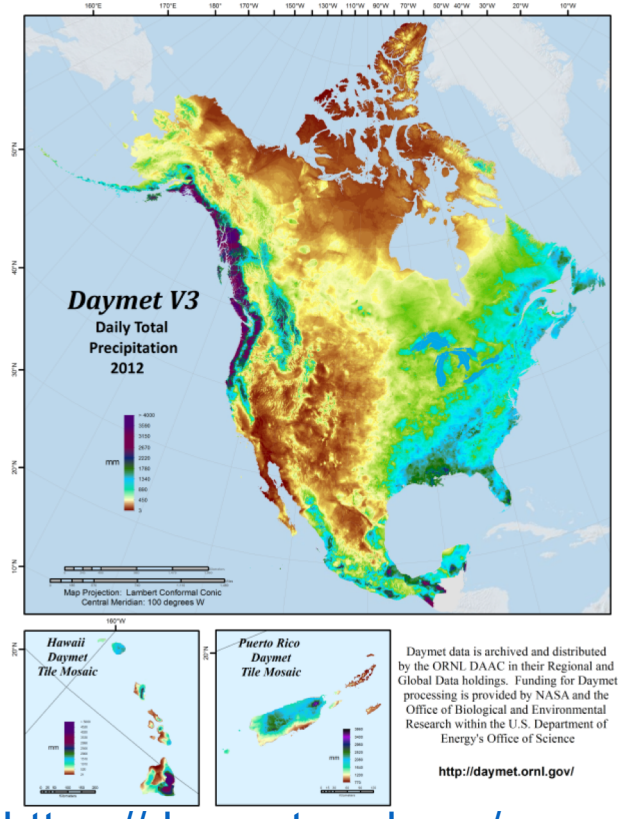
DAYMET
DAILY SURFACE WEATHER AND CLIMATOLOGICAL SUMMARIES
ORNL DAAC

Daymet provides gridded estimates of daily weather parameters for North America.

Annual and Monthly climatologies from 1980 – 2018.

Access via web tools, WebGIS, and API. https://daymet.ornl.gov/web_services





https://daymet.ornl.gov/

Data Characteristics

Spatial Resolution ….. 1km x 1 km

Temporal Resolution ….. Daily

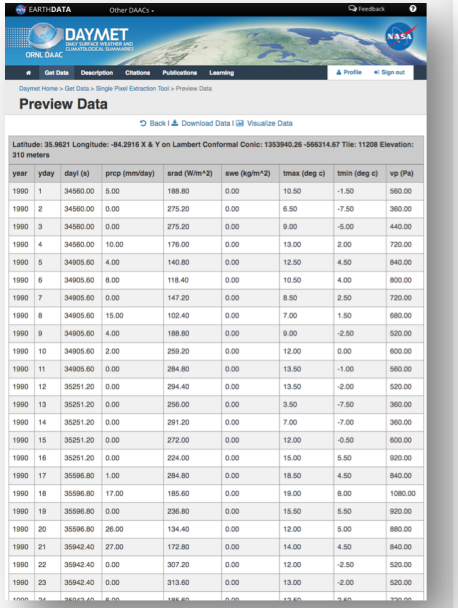
Years Available ….. 1980 – 2018

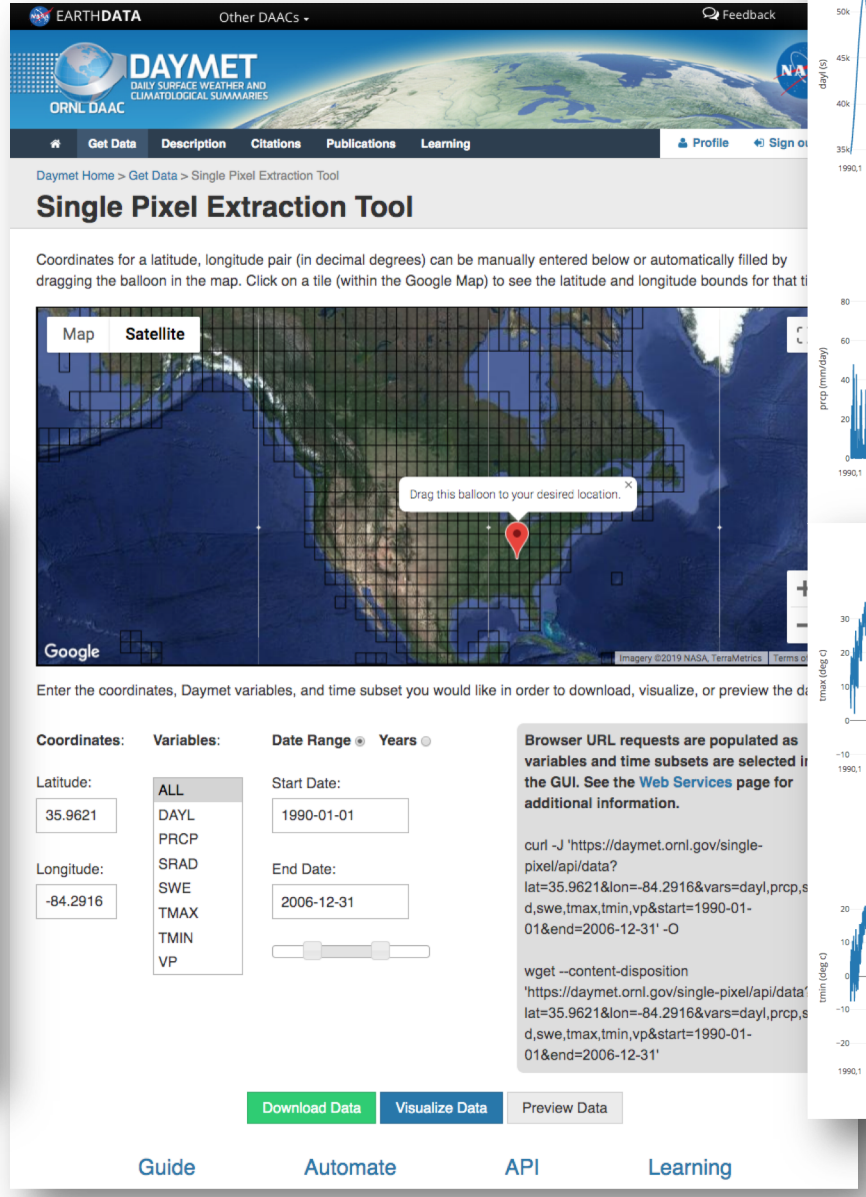
Spatial Region ….. North America

Daymet Data Products	
Variable	Units
maximum temperature	°C
minimum temperature	°C
shortwave radiation	W/m^2
vapor pressure	Pa
snow water equivalent	kg/m^2
precipitation	mm/day
day length	s/day

Get Daymet at a point location

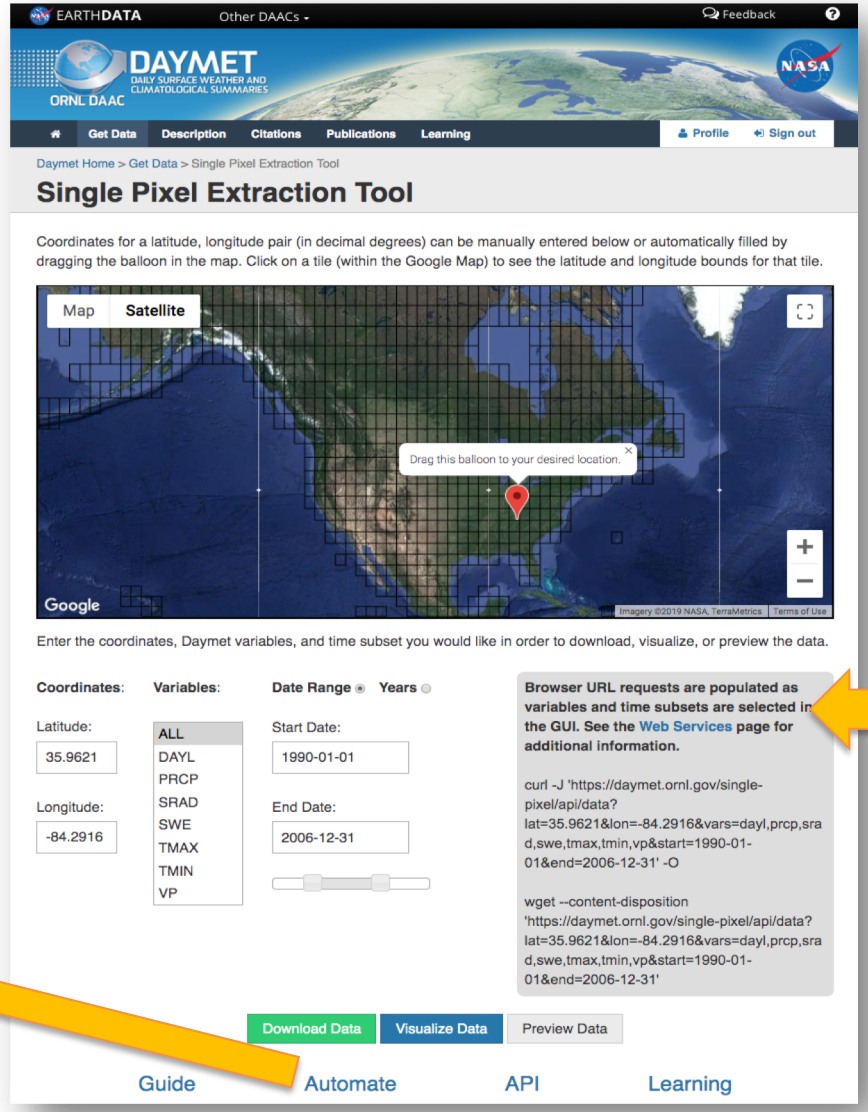
https://daymet.ornl.gov/single-pixel/





Get Daymet at multiple point locations

https://daymet.ornl.gov/single-pixel/

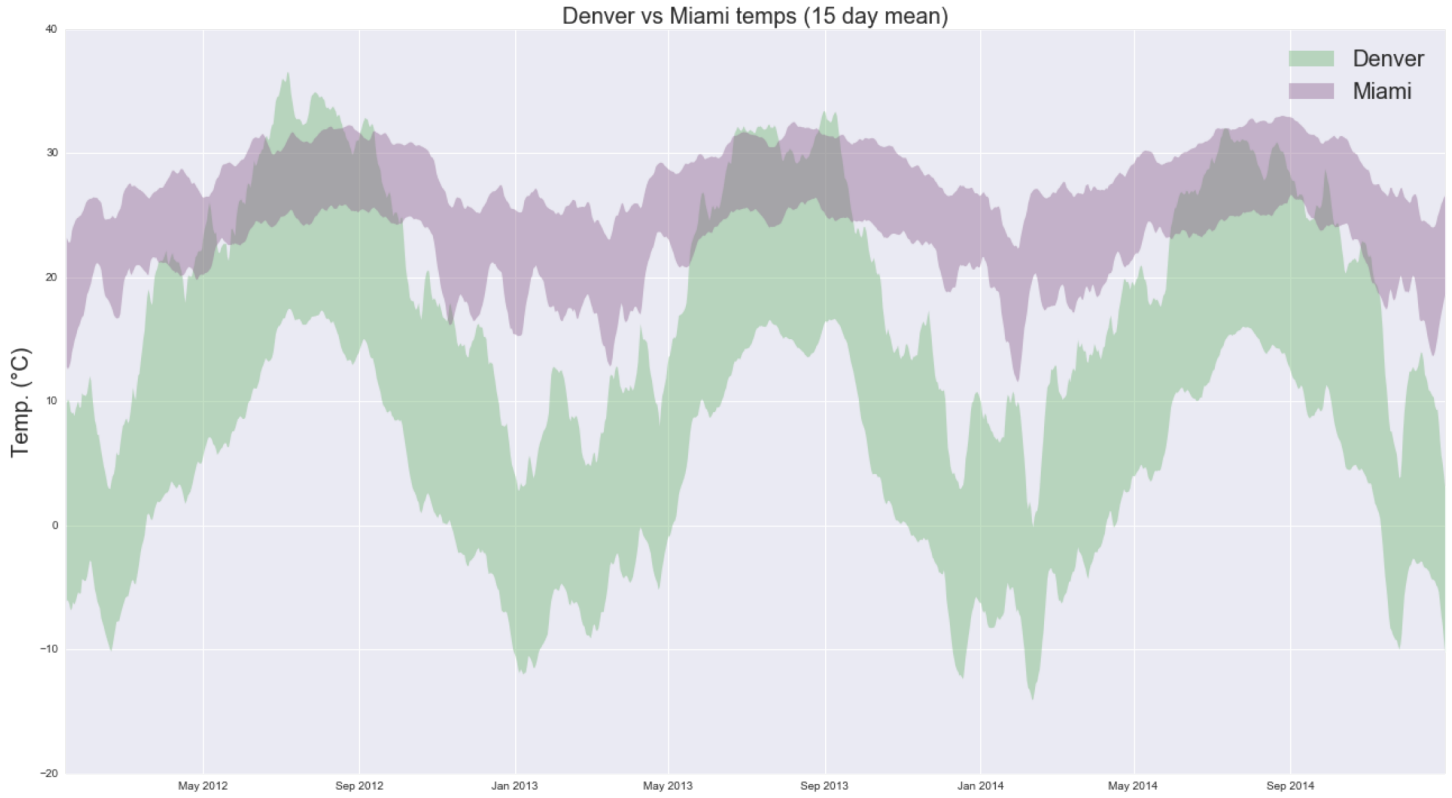


https://github.com/ornldaac/daymet-single-pixel-batch

Daymet for point locations: R and Python

R: daymetr package (https://cran.r-project.org/web/packages/...)
Python: daymetpy (https://github.com/khufkens/daymetpy/...)

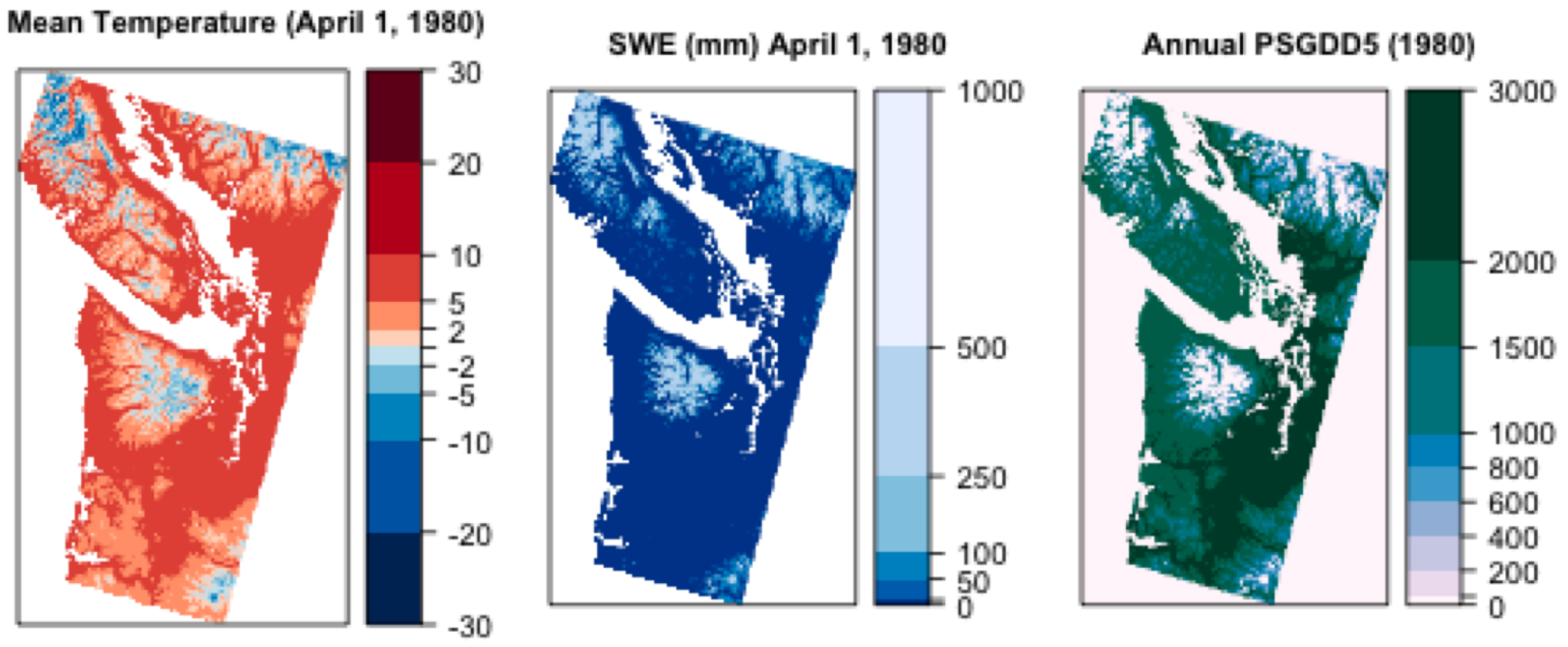
More examples: https://daymet.ornl.gov/learning



Daymet data across a region

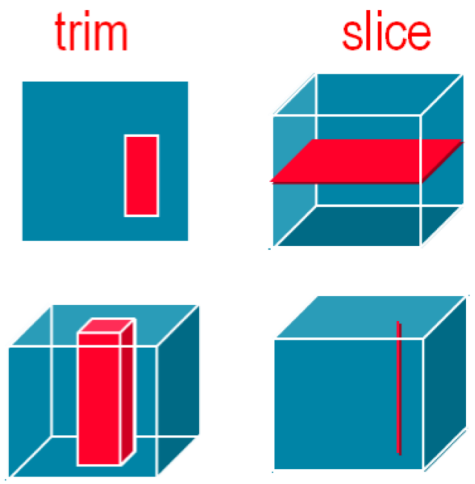
Calculate Post-Snow Growing Degree-Days (PSGDD5) over Olympic Peninsula, Washington

https://davemfish.wordpress.com/code/rexample1/

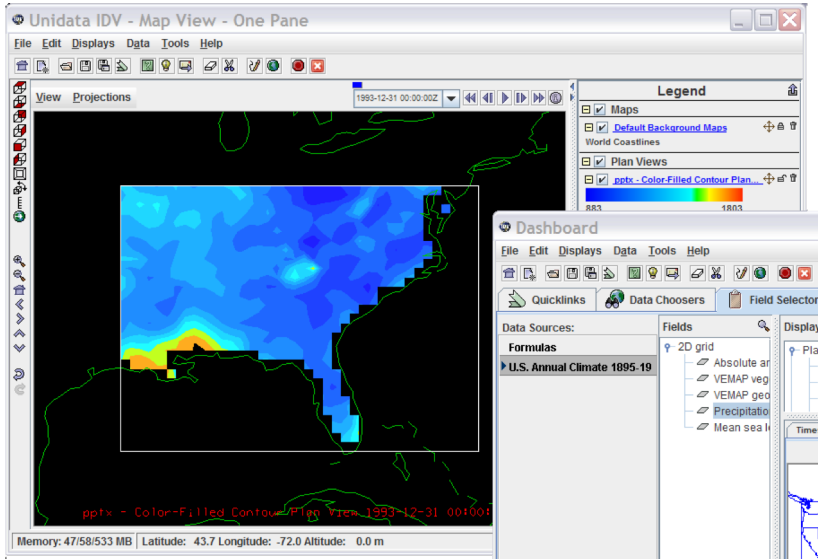


Thematic Real-time Environmental Distributed Data Services (THREDDS)

Multi-dimensional Data Subset



Use Remote Data like Local



Modelers

Annual Precipitation in south-eastern U.S., year 1993

parameter subset: "Precipitation" from 5 options

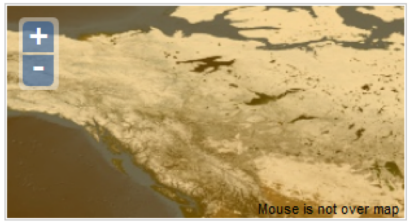
spatial subset: south-eastern area from whole U.S.

temporal subset: year 1993 from 99 years (1895-1993)

THREDDS NetCDF subset service

ORNL DAAC THREDDS NetCDF Subset

Choose Spatial Subset:



Lat/lon subset **Coordinate subset**

Bounding box, in decimal degrees (initial extents are approximate):

north 56.73

west -125.46 -121.46 east

52.73 south

Disable horizontal subsetting

reset to full extension

Horizontal Stride: 1

Choose Time Subset:

Time range **Single time**

Start: 1980-01-01T12:00:00Z

End: 1980-12-30T12:00:00Z

Stride: 1

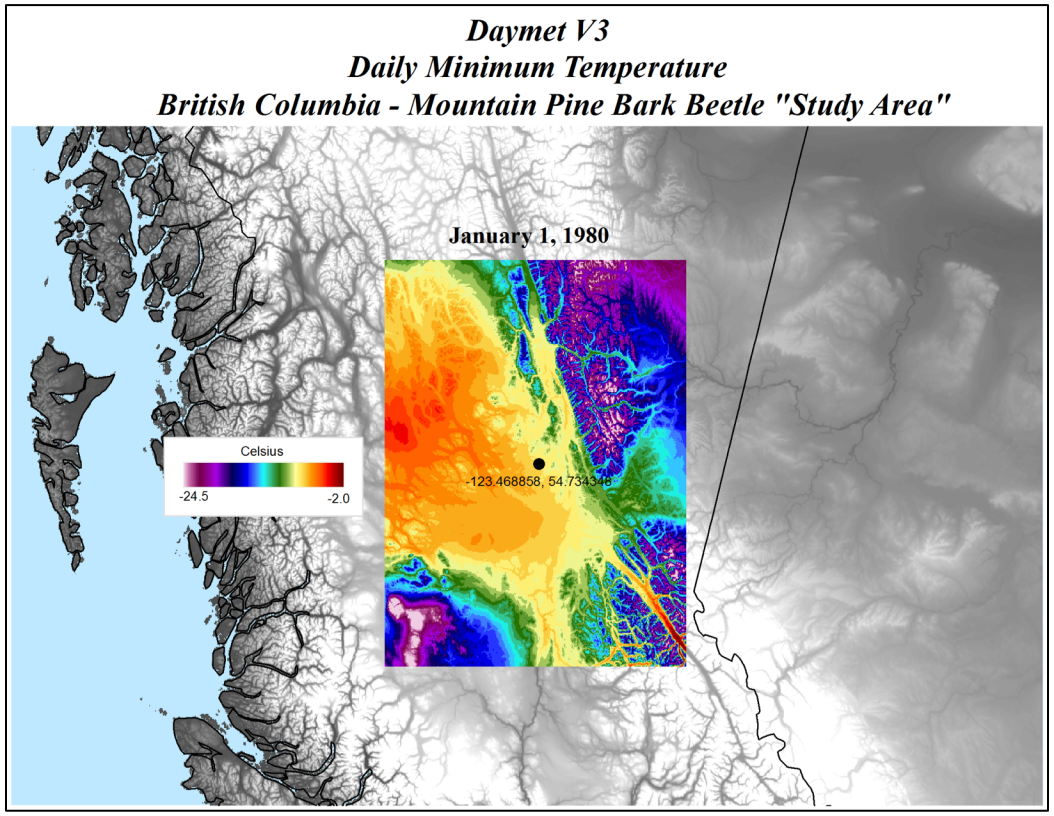
reset to full extension

Add 2D Lat/Lon to file (if needed for CF compliance)

Add Lat/Lon variables

Choose Output Format:

Format: netcdf



Automate !

NCSS Request URL:

```
https://thredds.daac.ornl.gov/thredds/ncss/ornldaac/1328/1980/daymet_v3_tmin_1980_na.nc4?var=tmin&north=56.73&west=-125.46&east=-121.46&south=52.73&disableProjSubset=on&
horizStride=1&time_start=1980-01-01T12%3A00%3A00Z&time_end=1980-12-30T12%3A00%3A00Z&timeStride=1&accept=netcdf
```

Subsetting Tools

Fixed Sites Subsets

pre-processed subsets for 2000+ field and flux tower sites

Global Subsets

request a subset for any location on earth

Web Service

Retrieve subset data for any location, time period and area programmatically

MODIS and VIIRS Land Products

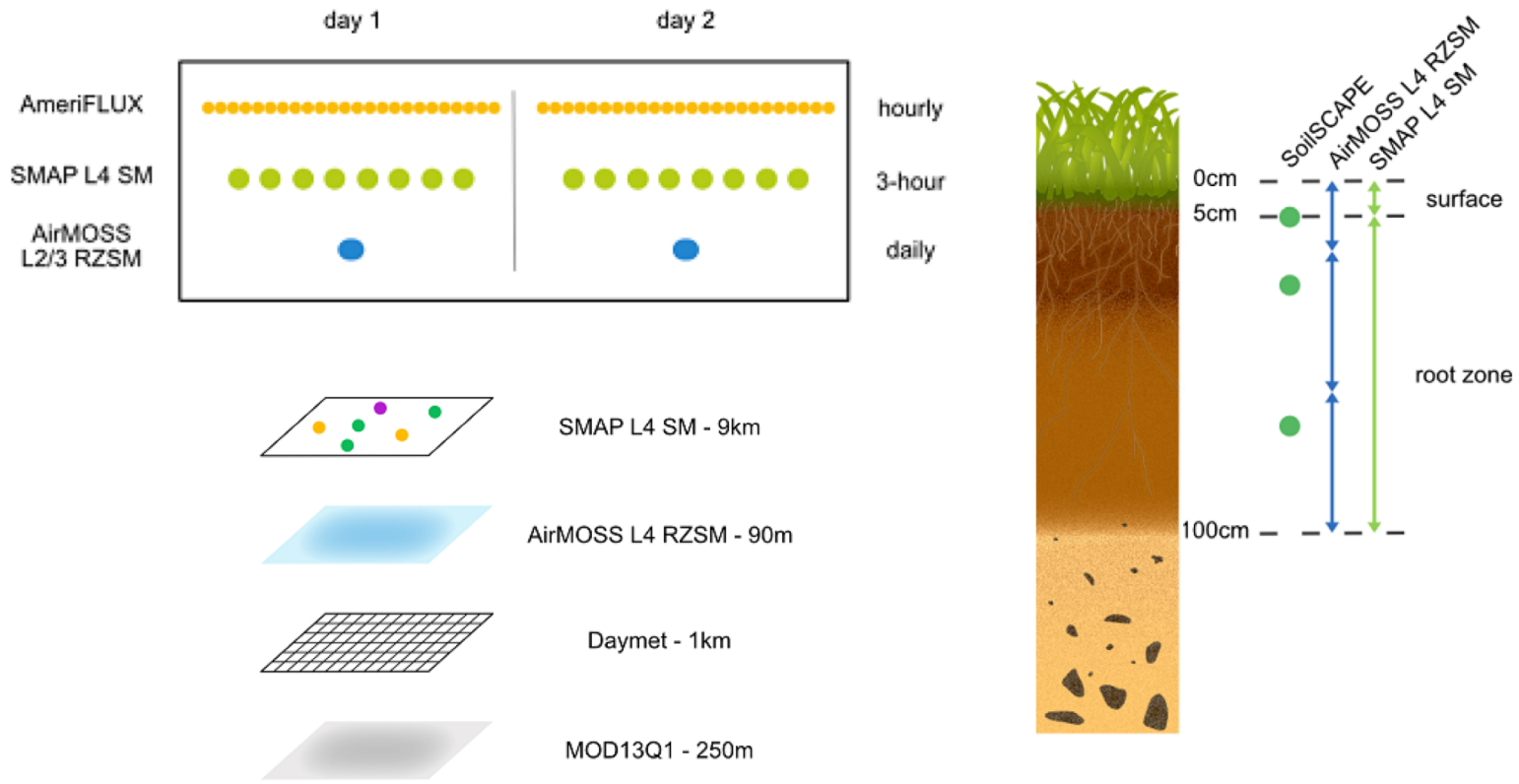
MOD09, MYD09, VNP09	Surface Reflectance
MCD12	Land Cover Type and Dynamics
MCD19	MAIAC Albedo
MCD43	Albedo/BRDF/NBAR
MOD11, MYD11	Land Surface Temperature/Emissivity
MCD64	Burned Area
MOD13, MYD13, VNP13	Vegetation Indices
MOD14, MYD14	Thermal Anomalies/Fire
MCD15, VNP15	Leaf Area Index/FPAR
MOD16, MYD16	Evapotranspiration
MOD17, MYD17	Gross/Net Primary Productivity

Daymet

Daily Surface Weather Data, 1 km^2

Soil Moisture Visualizer (SMV)

Harmonizes surface and root zone soil moisture data sets from multiple sources that encompass a range of spatial footprints, soil depths and measurement frequencies.

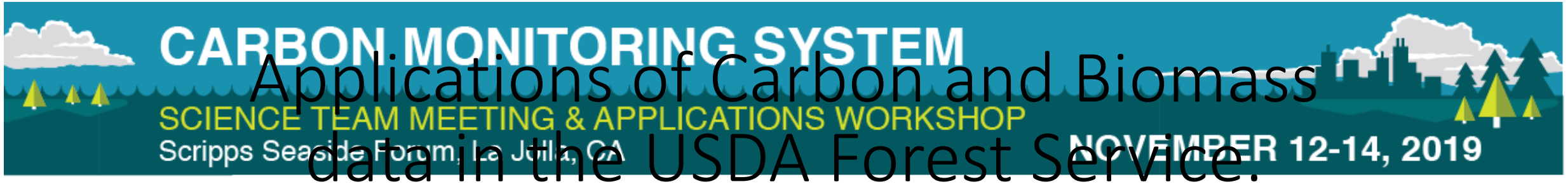


(https://daac.ornl.gov/soilmoisture/)

Get more from the ORNL DAAC and GES DISC

- ORNL DAAC (https://daac.ornl.gov) Social Media
  - Twitter @ORNLDAAC
  - Facebook @OakRidgeDAAC
  - YouTube ORNL DAAC
  - GitHub ORNL DAAC
  - Recent NASA Earthdata Webinar
    - NetCDF: Why and How?
    - Introduction to Geospatial Analysis in R

- GES DISC (https://disc.gsfc.nasa.gov) Social Media handles:
  - Twitter: @NASA_GESDISC
  - Youtube: NASAGESDISC



Applications of Carbon and Biomass data in the USDA Forest Service.

Kevin Halverson

Regional Analyst

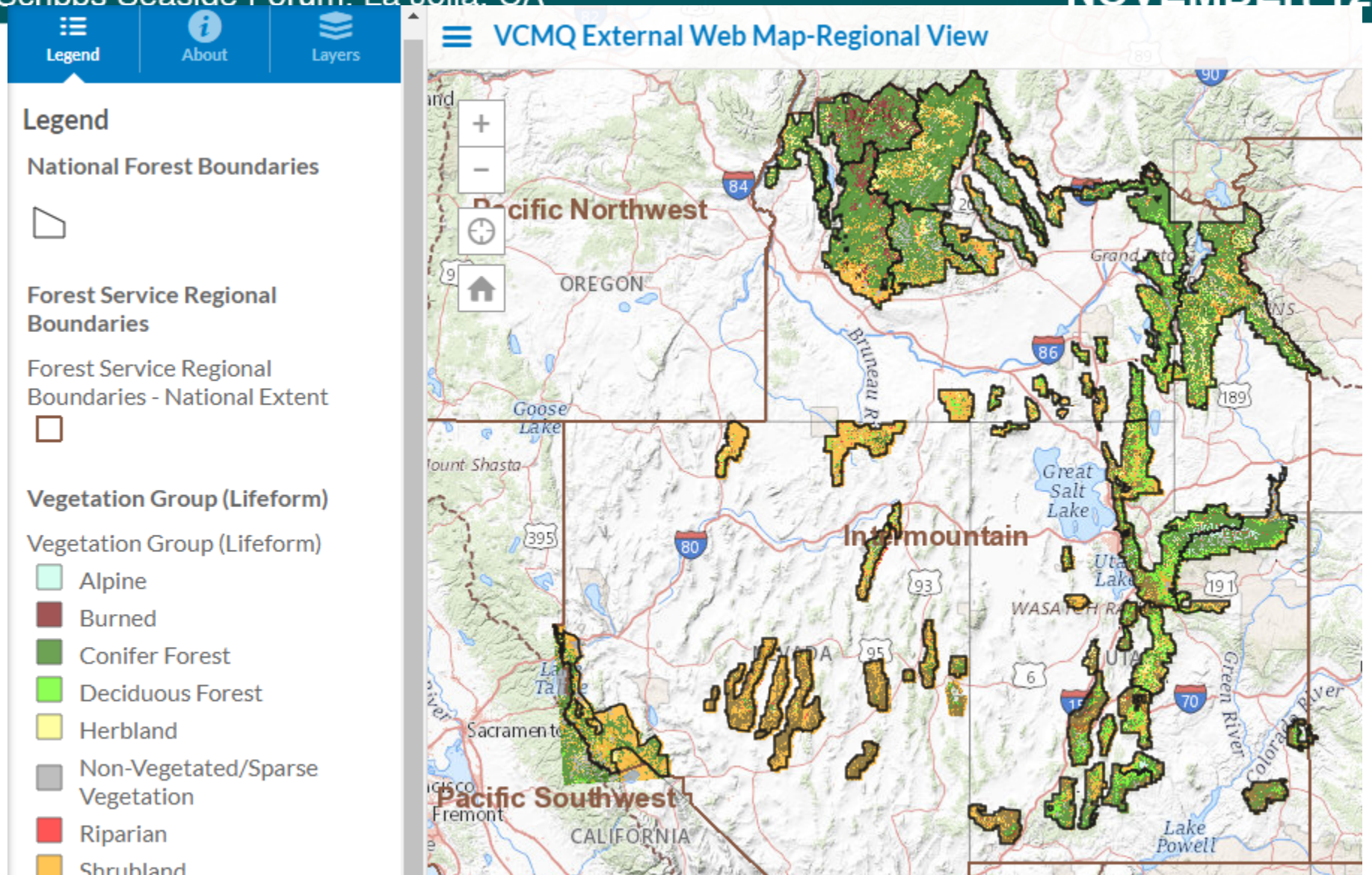
USDA Intermountain Mountain Region

Presentation at NASA CMS Applications Workshop 2019

Scripps Seaside Forum, La Jolla, CA

Tuesday, November 12, 2019

Intermountain Region: Vegetation



Existing vegetation: Regional statistics

@ 32 million acres

Forest Name	Alpine	Burned	Conifer Forest	Deciduous Forest	Herbland	Sparse Vegetation	Riparian	Shrubland	Woodland
Ashley National Forest	5%	0%	42%	13%	5%	12%	3%	13%	7%
Boise National Forest	0%	11%	60%	1%	3%	2%	2%	21%	0%
Bridger-Teton National Forest	0%	0%	55%	5%	17%	7%	3%	13%	0%
Caribou-Targhee National Forest	0%	0%	50%	14%	5%	3%	1%	20%	7%
Dixie National Forest	0%	0%	30%	10%	2%	3%	1%	19%	35%
Fishlake National Forest	1%	0%	16%	15%	5%	3%	1%	16%	44%
Humboldt-Toiyabe National Forest	0%	0%	13%	3%	2%	3%	1%	45%	33%
Manti-La Sal National Forest	0%	0%	23%	17%	8%	2%	1%	13%	36%
Payette National Forest	0%	18%	64%	0%	9%	3%	1%	5%	0%
Salmon-Challis National Forest	1%	0%	61%	1%	6%	6%	1%	22%	2%
Sawtooth National Forest	1%	0%	41%	5%	5%	8%	2%	36%	3%
Uinta-Wasatch-Cache National Forest	2%	0%	28%	20%	5%	3%	2%	19%	22%
Regional Totals	**1%**	**2%**	**40%**	**7%**	**6%**	**4%**	**1%**	**24%**	**15%**

Description of Work

- Support Broadscale Monitoring Strategy for the Region
- Support Regional Vegetation Mapping Team
- Geospatial Analysis support to Forest Plan Revision Efforts
- Support Shared Stewardship partnerships with States.
- Gear work toward current agency priorities: Active Management Philosophy and ambitious Restoration Goals.

CMS data products being used, or planning to be used

- Evaluation of effectiveness of Landscape Treatment Options and Shared Stewardship initiatives.
- Depictions of current trends on the landscape
- Supplemental product in Data Library
- Evaluation of Existing Vegetation Mapping products
- Fuels mapping
- Broadscale Monitoring
- Forest Plan Revision: Assessment of current state and trends

Application areas being targeted

- Wildfire Hazard
- Water Quality
- Ecological Forecasting
- Air Quality
- Timber Treatment Assessments
- Landscape Prioritization

Policy and decision making timelines related to your work

- Forest Plan Revision Schedule: 12 National Forests. 3 are in Revision
- Annual Review of Regional Vegetation Mapping team budget and Program of Work. Prior to Fiscal Year
- National Office may have timelines for measurement of Priority Landscapes.

Additional carbon data needs/gaps in your work for which the CMS community could contribute data

- Wall-to-wall annual products in Standard GIS raster formats.
- Products that can help us refine coarse-level mapping products such as Forest Insect and Disease and Forest Activities.
- Rangeland products (grass, shrub, woodland).
- Fuels mapping.

Are there any CMS products we can offer for your needs?

- Dashboards for standard reporting
- Products depicting seasonal fluctuations.
- Simple, easy-to-use tools for data access and manipulation for field users.

What are some of the challenges?

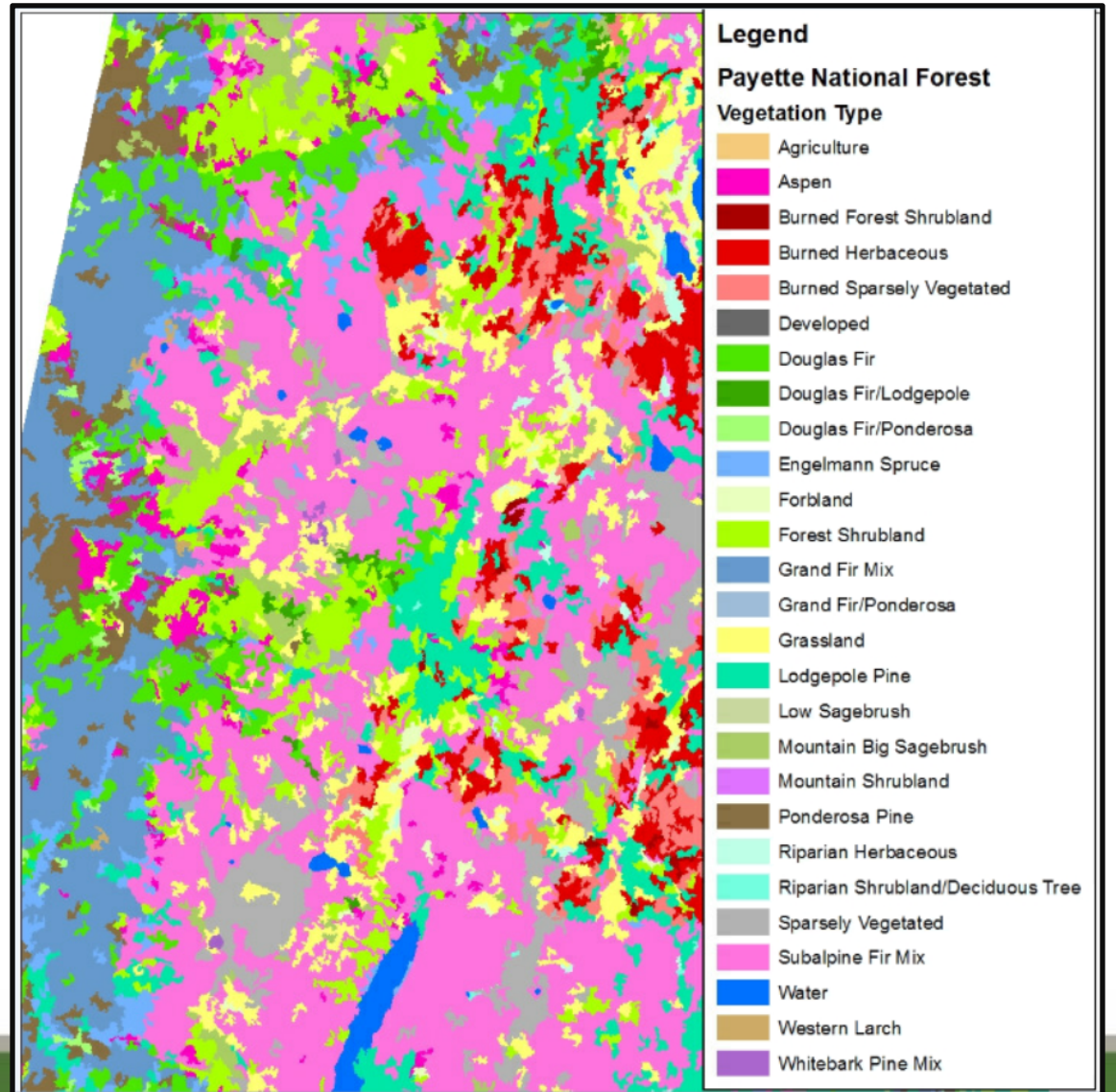
- Teaching Forest Service field managers how to use and apply these products. Many are technologically adverse and wish to do business using the standard techniques.
- Many are overwhelmed by data and data products.
- Lack of analytical capability. Few know how to use raster products.
- Single point access of products for users
- Ability to plan forward with uncertain availability in the future

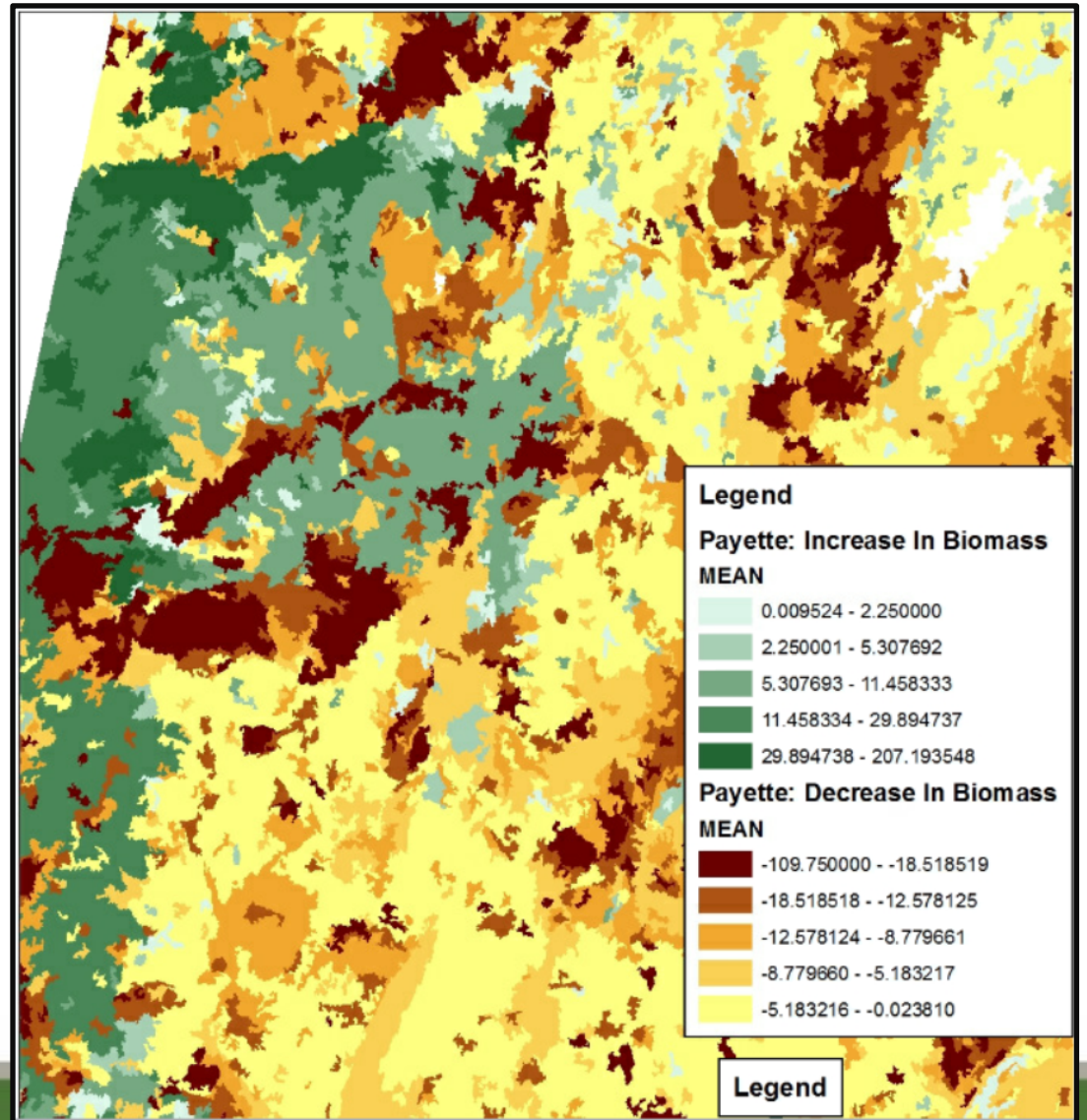
FACTS: USFS Tracking Database

- FACTS is the official database of record of landscape treatments
- Table show sample of treatments based upon average change score of Hudak et al. biomass product on a sample area on the Payette National Forest
- CMS products allow us to understand biomass impacts of common treatments
- CMS Products may provide non-biased metric of intentional change from active management.

ACTIVITY	Average Change	Number of Sample
Two-aged Shelterwood Establishment Cut (w/res) (2A/RH/NFH)	106	10
Two-aged Shelterwood Final Removal Cut (w/res) (2A/NRH/FH)	89	18
Stand Clearcut (EA/RH/FH)	86	56
Stocking Survey	75	500
Slashing - Pre-Site Preparation	72	69
Reforestation Need Created by Fire	71	70
Stand Clearcut (w/ leave trees) (EA/RH/FH)	69	163
Reforestation Need Created by Harvest	68	150
Site Preparation for Planting - Burning	63	28
Plant Trees	62	536
Stand Silviculture Prescription	60	23
Site Preparation for Planting - Mechanical	60	73
Shelterwood Preparatory Cut (EA/NRH/NFH)	60	24
Burning of Piled Material	52	188
Plantation Survival Survey	49	447
Maintenance of Animal Damage Control for Reforestation	48	17
Jackpot Burning - Scattered concentrations	44	14
Salvage Cut (intermediate treatment, not regeneration)	43	18
Single-tree Selection Cut (UA/RH/FH)	41	26
TSI Need Created- Release or Weeding	39	41
Reforestation Need Change due to Stocking Changes	39	22
Certification-Planted	37	570
Improvement Cut	35	36
Piling of Fuels, Hand or Machine	33	120
Site Preparation for Natural Regeneration - Mechanical	32	27
Certification of Natural Regeneration without Site Prep	32	13
Animal Damage Control for Reforestation	32	54
TSI Certification - Release/weeding	31	38
Stand Diagnosis Prepared	31	15
Chipping of Fuels	30	193
Shelterwood Establishment Cut (with or without leave trees) (EA/RH/NFH)	30	41
Tree Release and Weed	29	108
Wildfire - Natural Ignition	29	10
Control of Understory Vegetation	28	42
Yarding - Removal of Fuels by Carrying or Dragging	26	429
TSI Need (precommercial thinning) Eliminated	26	10
TSI Need Created- Precommercial Thin	26	207
Certification of Natural Regeneration with Site Prep	25	33
TSI Certification - Thinning	25	279
Precommercial Thin	23	1106
Commercial Thin	22	465
Rearrangement of Fuels	22	827
Reforestation Need Change due to Other (windthrow, etc)	21	75
Invasives - Pesticide Application	20	886
Underburn - Low Intensity (Majority of Unit)	19	97
Pruning to Raise Canopy Height and Discourage Crown Fire	18	86
Leave Tree Protection	17	119
Fill-in or Replant Trees	17	59
Silvicultural Stand Examination	14	242
Thinning for Hazardous Fuels Reduction	13	156
Seed-tree Removal Cut (w/ leave trees) (EA/NRH/FH)	12	16

Existing Vegetation Mapping: Updates





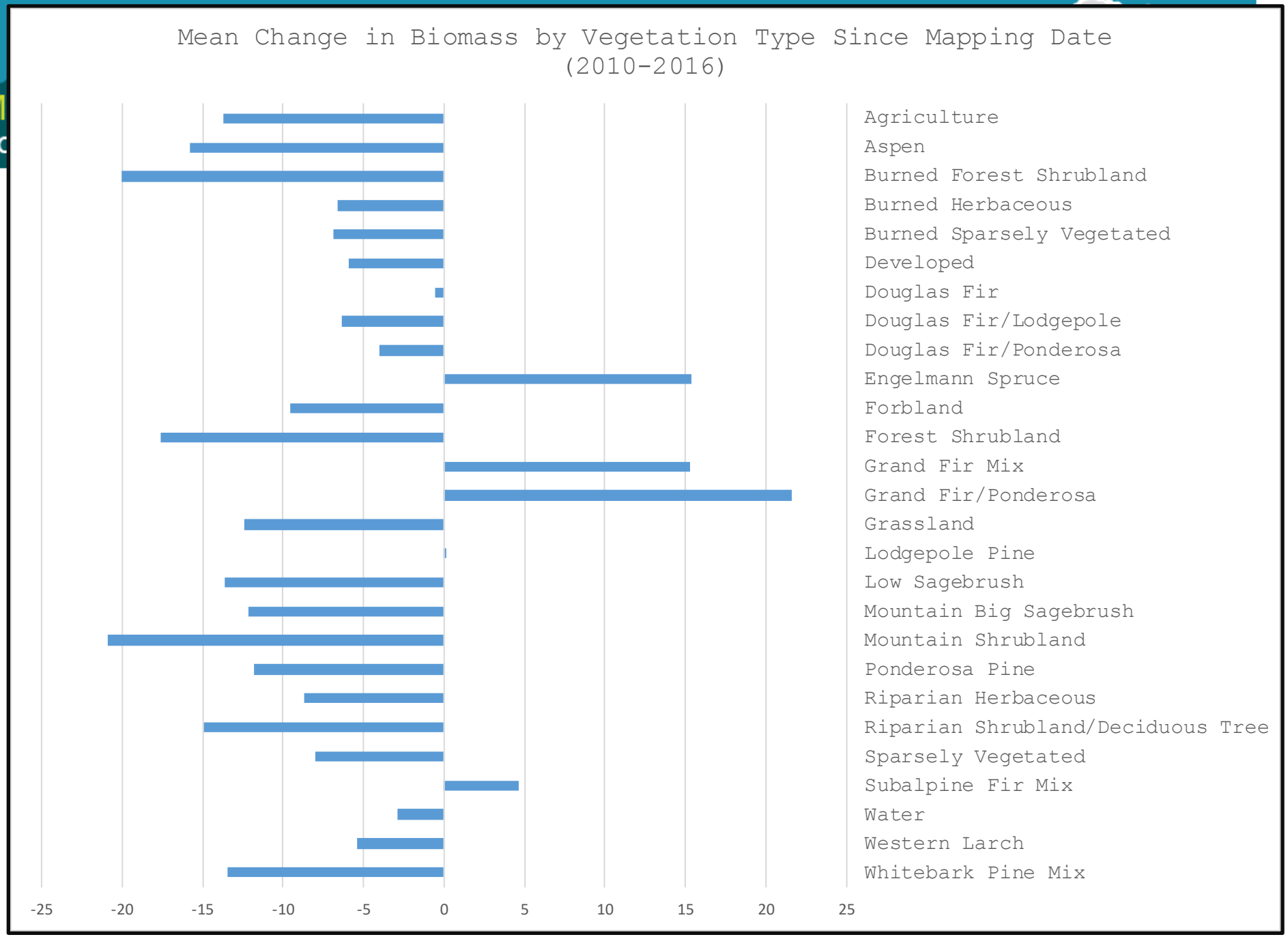
CARBON

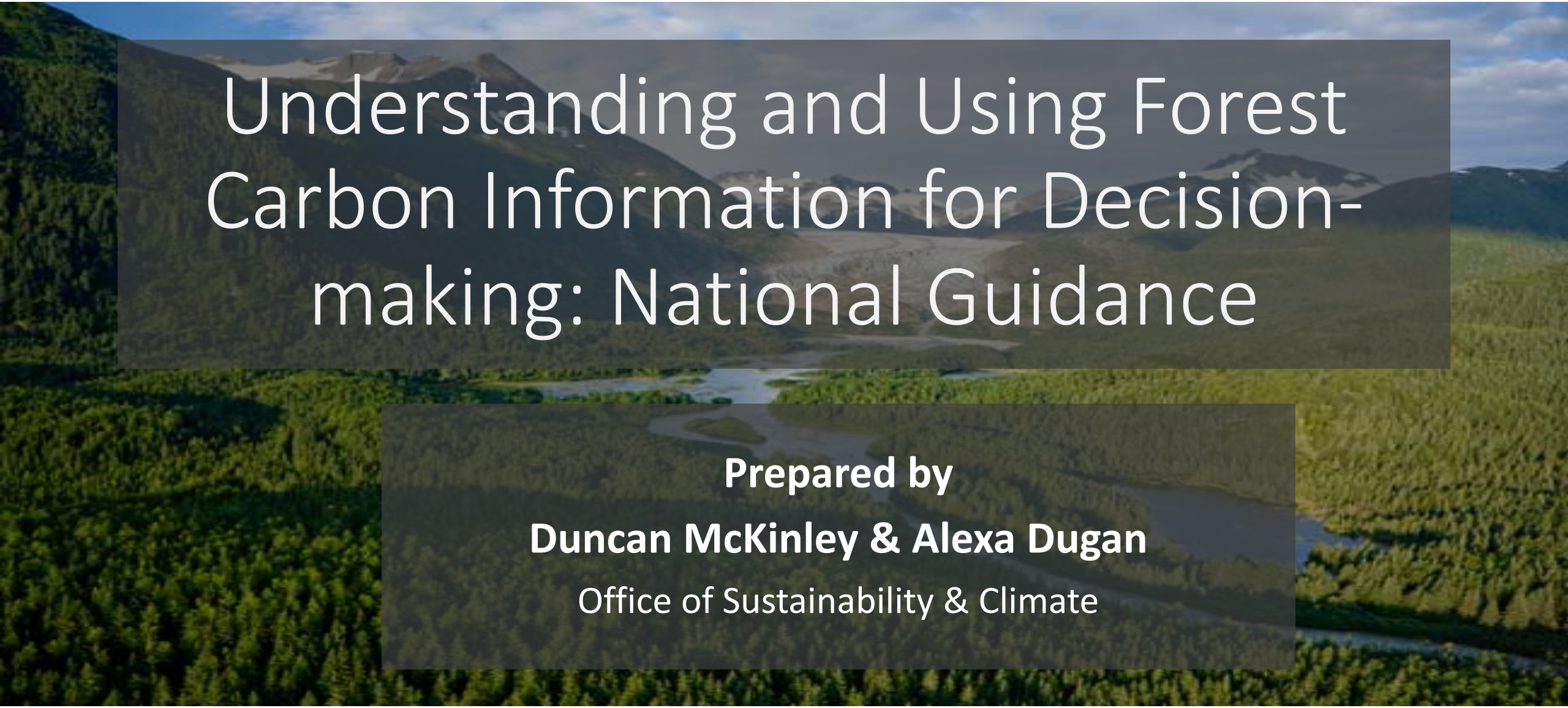
SCIENCE TEAM

Scripps Seaside Fo

Estimating Trends in Vegetation Cover

*Sample Area on the Payette National Forest





Understanding and Using Forest Carbon Information for Decision-making: National Guidance

Prepared by

Duncan McKinley & Alexa Dugan

Office of Sustainability & Climate

International: Major Decisions Related to Forests

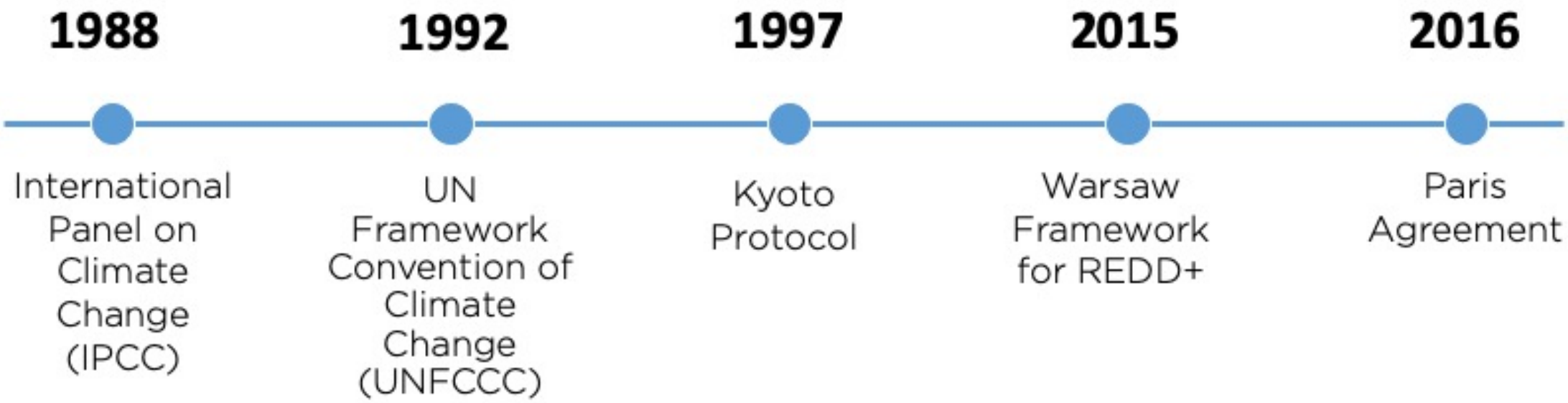


Image source: UNFCCC, 2016

Forest management can produce a carbon benefit

But how?

Three different ways…

1) Increase area of forest land/avoid loss

2) Increase carbon stocks/sequestration in forest ecosystems

3) Increase carbon storage in harvested wood products and displace of fossil fuels:

   - Biomass energy
   - For more energy-intensive products

What is the Forest Service's role in climate and carbon?
Photo by Mike Ryan

FS Polices and Direction drive the need for data

Previous

1) 2011 Climate Change Performance Scorecard (to measure progress towards goals in CC Roadmap)
   - A baseline assessment of carbon stocks
   - An assessment of the influence of disturbance and management activities on C stocks?

Current

2) 2012 Planning Rule
   - Assessment of carbon stocks

3) NEPA disclosures
   - Effects of projects/management on climate (carbon)

Roll-out

4) NEW Sustainability Scorecard
   - Carbon is a key scorecard element

Scorecard Element	Unit Name	Yes/No
Organizational Capacity		
1. Employee Education	Are all employees provided with training on the basics of climate change, impacts on forests and grasslands, and the Forest Service response? Are resource specialists made aware of the potential contribution of their own work to climate change response?	
2. Designated Climate Change Coordinators	Is at least one employee assigned to coordinate climate change activities and be a resource for climate change questions and issues? Is this employee provided with the training, time, and resources to make his/her assignment successful?	
3. Program Guidance	Does the Unit have written guidance for progressively integrating climate change considerations and activities into Unit-level operations?	
Engagement		
4. Science and Management Partnerships	Does the Unit actively engage with scientists and scientific organizations to improve its ability to respond to climate change?	
5. Other Partnerships	Have climate change related considerations and activities been incorporated into existing or new partnerships (other than science partnerships)?	
Adaptation		
6. Assessing Vulnerability	Has the Unit engaged in developing relevant information about the vulnerability of key resources, such as human communities and ecosystem elements, to the impacts of climate change?	
7. Adaptation Actions	Does the Unit conduct management actions that reduce the vulnerability of resources and places to climate change?	
8. Monitoring	Is monitoring being conducted to track climate change impacts and the effectiveness of adaptation activities?	
Mitigation and Sustainable Consumption		
9. Carbon Assessment and Stewardship	Does the Unit have a baseline assessment of carbon stocks and an assessment of the influence of disturbance and management activities on these stocks? Is the Unit integrating carbon stewardship with the management of other benefits being provided by the Unit?	
10. Sustainable Operations	Is progress being made toward achieving sustainable operations requirements to reduce the environmental footprint and increase the resilience of agency operations and assets?	

Current FS Policy

2012 Planning Rule (FSH 1909.12.4)

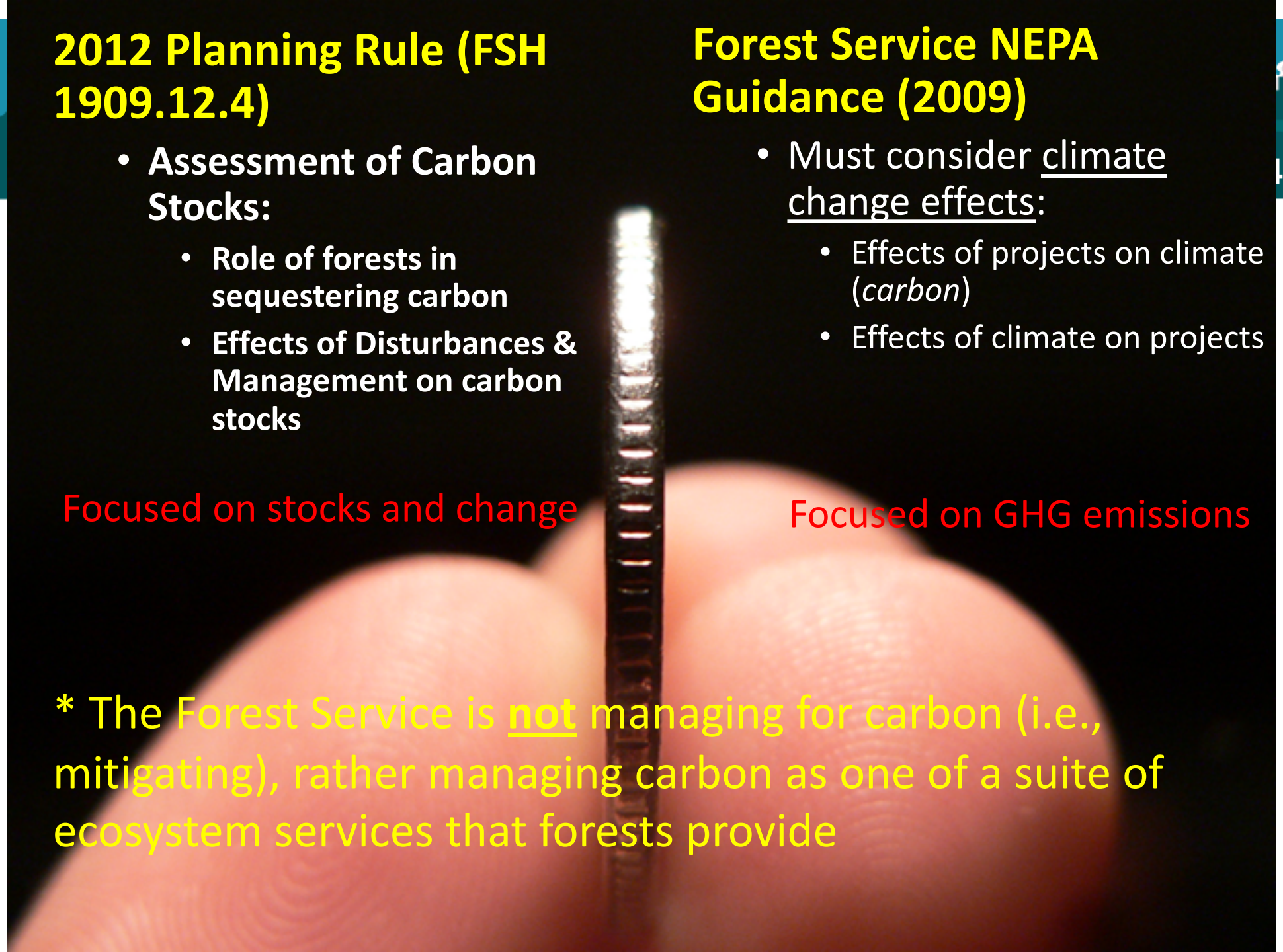
- **Assessment of Carbon Stocks:**
  - **Role of forests in sequestering carbon**
  - **Effects of Disturbances & Management on carbon stocks**

Focused on stocks and change

Forest Service NEPA Guidance (2009)

- Must consider <u>climate change effects</u>:
  - Effects of projects on climate (*carbon*)
  - Effects of climate on projects

Focused on GHG emissions



* The Forest Service is **<u>not</u>** managing for carbon (i.e., mitigating), rather managing carbon as one of a suite of ecosystem services that forests provide

CARBON MONITORING SYSTEM

MEETING &

um, La Jolla, C

HOP

NO

Differing perspectives on how to conceptualize the forest system is the greatest source of confusion and conflict!

Some big questions that we struggle with that's related to how we view the forest system…

- How to reconcile the scale of decision making (i.e. project or forest level) with best spatial scale to evaluate patterns and trends in carbon dynamics?

- How to reconcile the temporal scale of decision making with the long-term dynamics of carbon?

- How much detail on carbon is necessary to fully inform decision making and make a reasoned choice among alternatives?

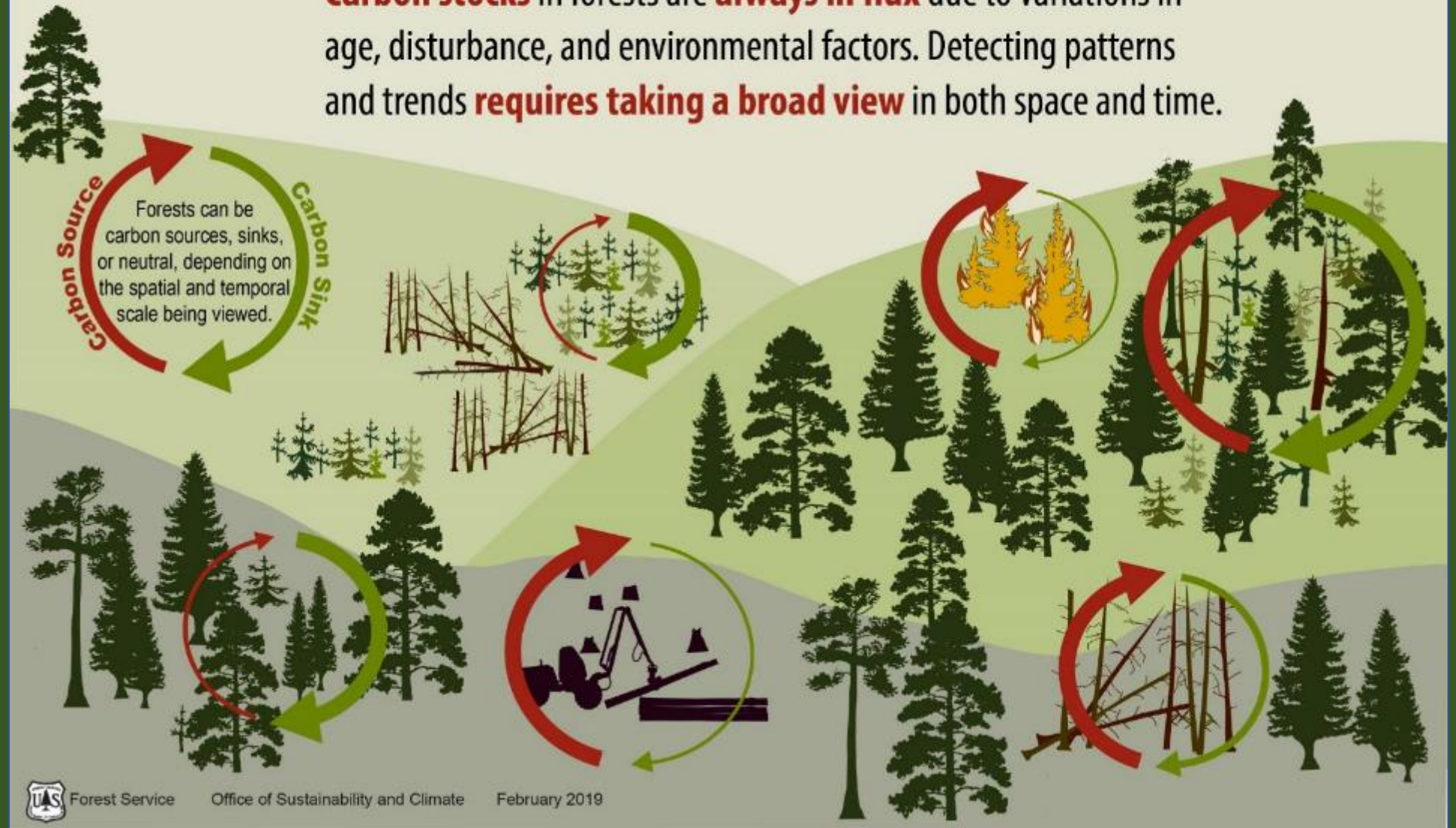
SCALE!!!

USDA United States Department of Agriculture

A spatial and temporal view

Carbon in Time and Space

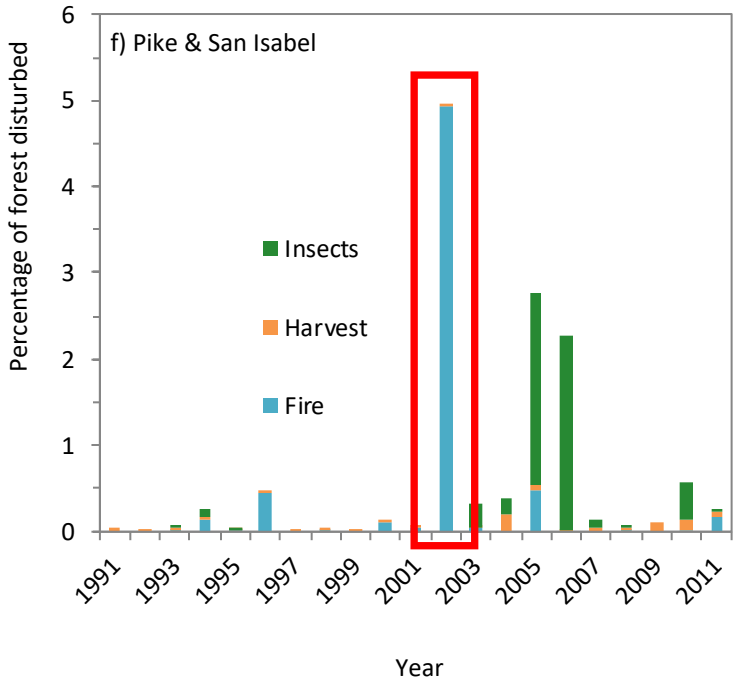
Carbon stocks in forests are **always in flux** due to variations in age, disturbance, and environmental factors. Detecting patterns and trends **requires taking a broad view** in both space and time.



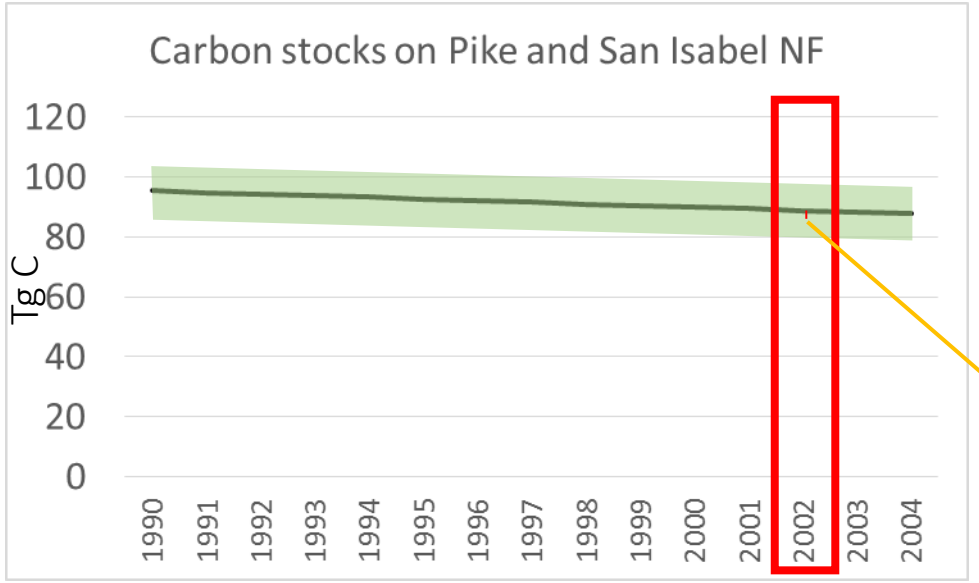
Forest Service Office of Sustainability and Climate February 2019

Detecting changes in carbon stocks after large disturbances: “Hayman fire”

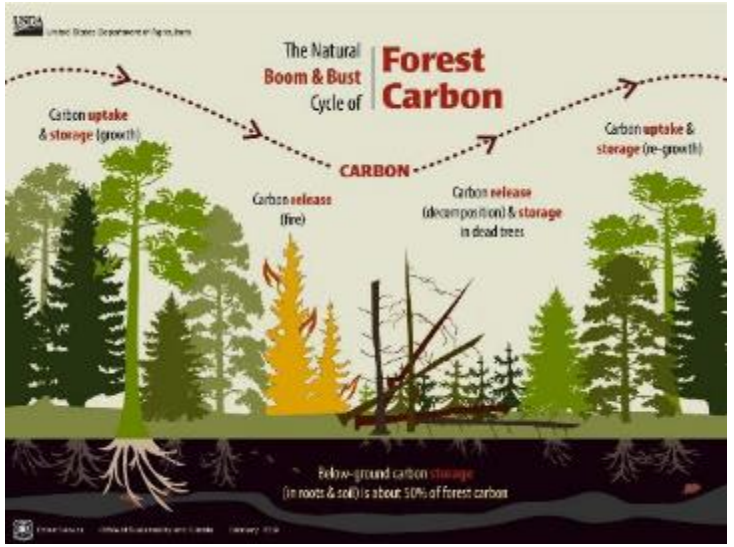
- Burned about 135,000 acres (211 sq. miles) in the Pike & San Isabel National Forest, largest fire in CO state’s history
- Although stunning visually, only about 4.9 percent of the total forested area was affected by fire.
- Assuming high-severity fire on all acres burned, about 1.76 Tg C could have been volatilized during wildfire.
- In 2013, total carbon stocks were 82.7 Tg C ± 8 Tg C
- Consistent downward trend since 1990, suggests broad-scale change



Disturbance assessments



Baseline assessments



Approximate immediate impact of wildfire on carbon stocks

Carbon trends on a regional scale: forest carbon stocks are increasing…

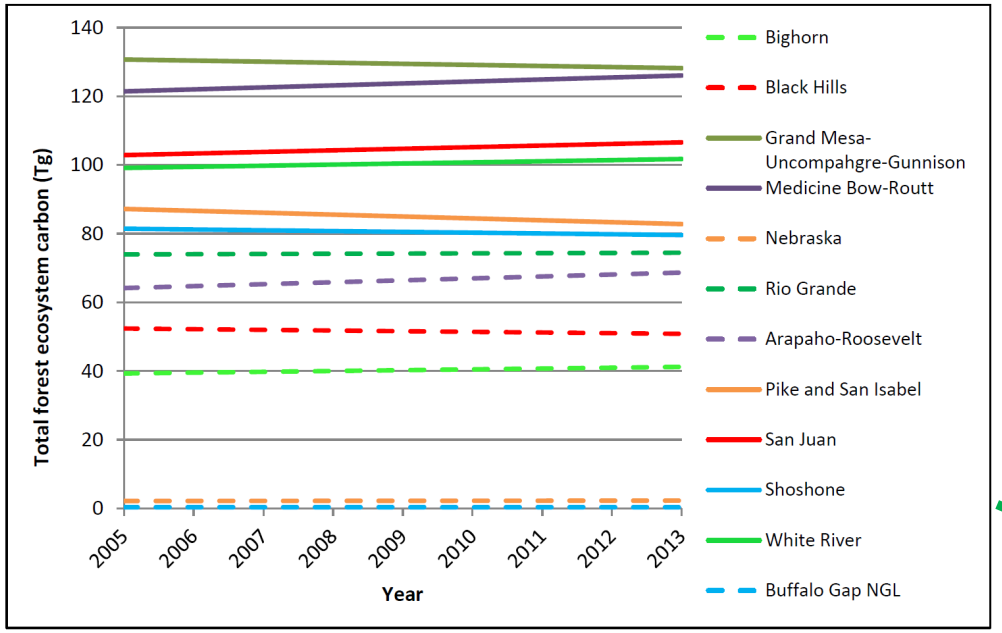
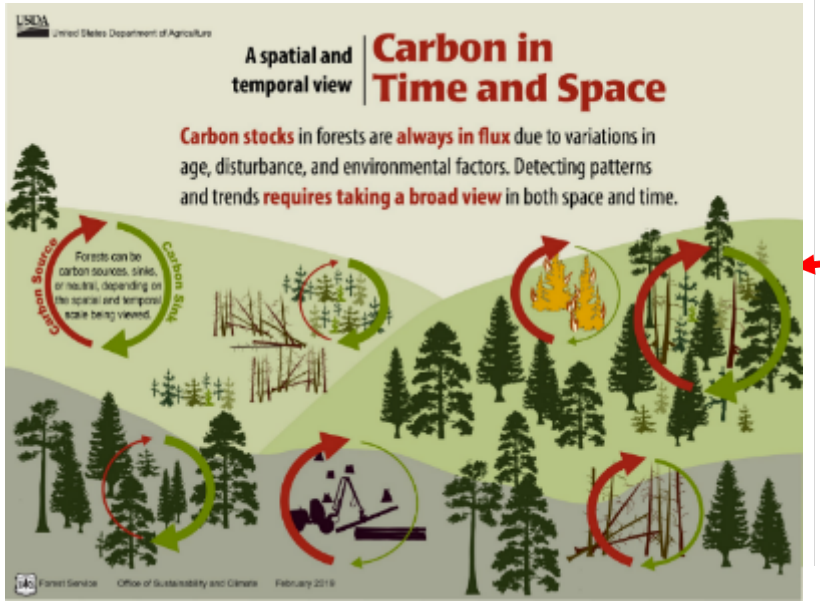


Figure 4. Total forest ecosystem carbon (Tg) for the national forests and grassland in the Rocky Mountain Region from 2005 to 2013.

- Pike & San Isabel and Grande Mesa-Uncompahgre-Gunnision trending downward
- All other forests and region trending upwards



Best scale to identify trends related to environmental change and land-use

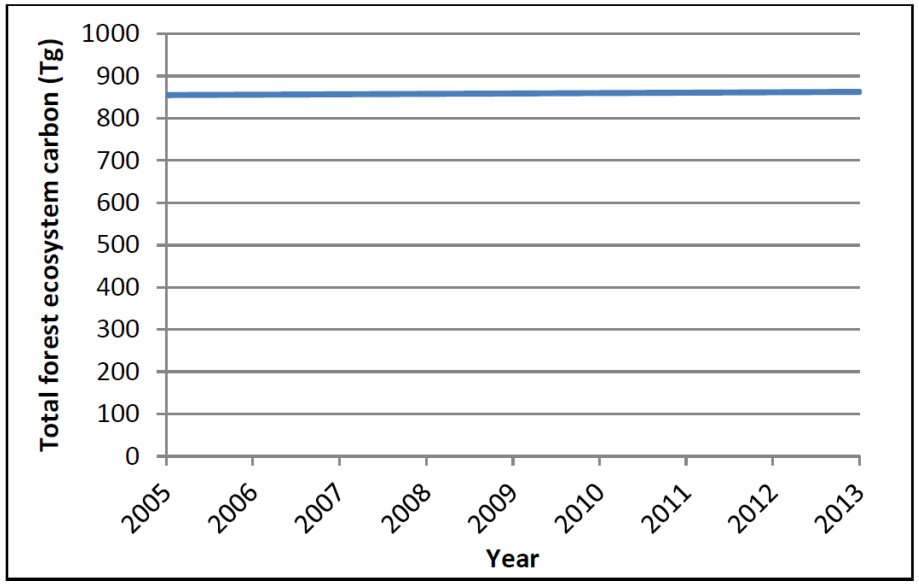
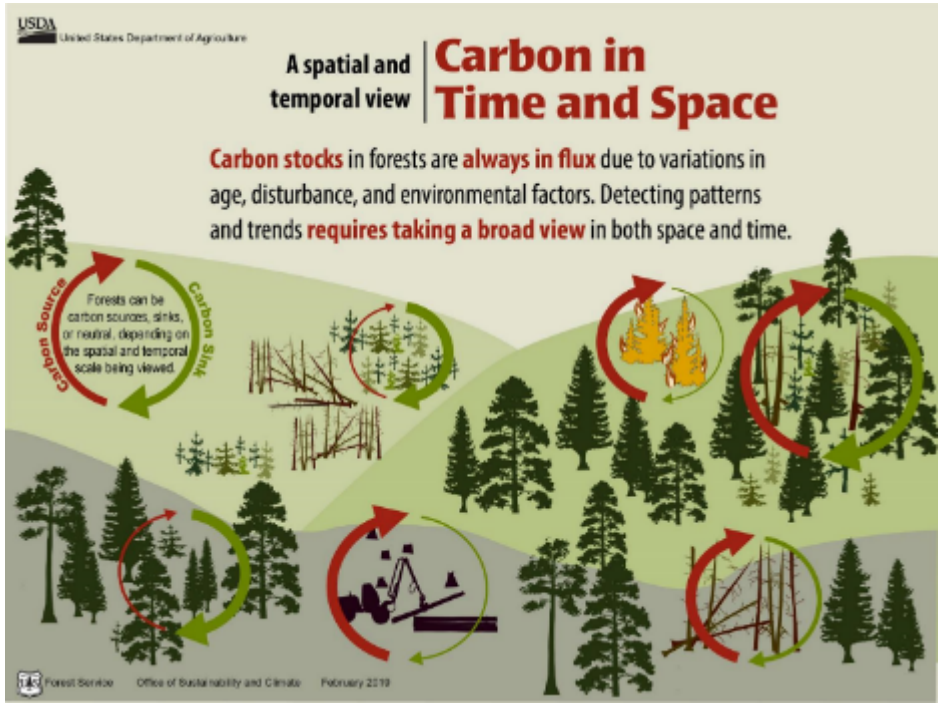


Figure 3. Total forest ecosystem carbon (Tg) for the Rocky Mountain Region from 2005 to 2013.

Can we put *individual* management actions or disturbances in context of forest-level dynamics?

Not in a meaningful way at current level of management!

- Patterns and trends are determined by many events over space and time.
- Massive and sustained human inputs/underlining environmental conditions are needed to move the needle enough (signal) to see effects on carbon.
- Determining the trajectory of carbon (carbon loss or carbon gain) from a cause requires the ability to detect a “signal” from background noise.



Delivering carbon science to inform decision making

Closing Thoughts

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

- Helps us fill in monitoring data gaps where didn't have data before
- We can use it to depict trends on our National Forests
- Non-biased metric of outcomes of landscape treatments.

Closing Thoughts

What is the next priority in your work? Provide keywords.

- Shared Stewardship: Collaborating with States on Landscape Prioritization
- Active Management: Making decisions about where Restoration Treatments will take place.
- Existing Vegetation Mapping updates.
- Reforestation Needs Assessments.

Closing Thoughts

What scientific advancement(s) could contribute to your work?

- Near-real time product delivery. Refreshed products depicting landscape conditions (green-up, soil moisture, etc.)
- Geofencing and Livestock Grazing: The ability to manage livestock with Geospatial Intelligence along with high quality map products.

Closing Thoughts

What data do you need? When? Be as specific as possible.

- Disturbance products for die-off and treatments. We need to fill in the gaps.

Closing Thoughts

- • What are some positive aspects of CMS data for your work?
- • What is the next priority in your work? Provide keywords.
- • What scientific advancement(s) could contribute to your work?
- • What data do you need? When? Be as specific as possible.