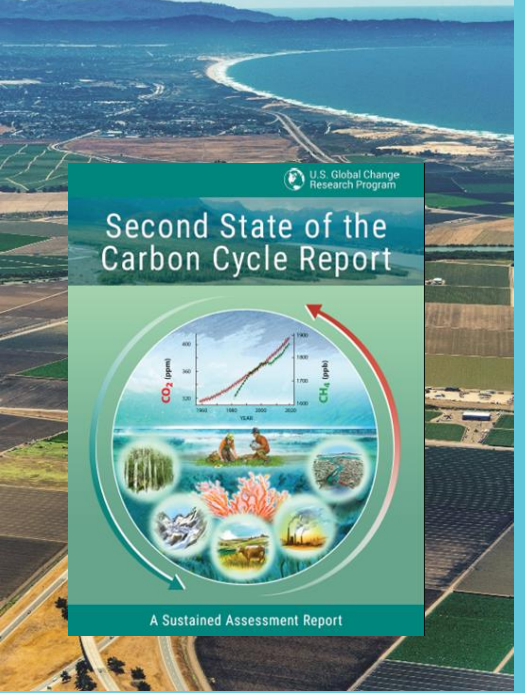
U.S. Carbon Cycle Science Program &
Carbon Cycle Interagency Working Group

Celebrating over 20 Years of Interagency Research Partnerships with the Carbon Cycle Science Community

CarbonCycleScience.us



20 years of U.S. interagency & cross-disciplinary research coordination on carbon: SOCCR2, current & future networks

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U.S. Geological Survey
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U.S. Department of Agriculture
James Butler
NOAA Global Monitoring Division
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NASA/North American Carbon Program
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NOAA Ocean Observing and Monitoring Division
Monika Kopacz, NOAA AC4

On behalf of the U.S. Carbon Cycle Science Program & Carbon Cycle Interagency Working Group (CCIWG)

EGU2019-13265
EGU General Assembly, Vienna, Austria, April 2019

SUMMARY: In this talk, we highlight….

Some achievements of the Carbon Cycle Interagency Working Group/U.S. Carbon Cycle Science Program

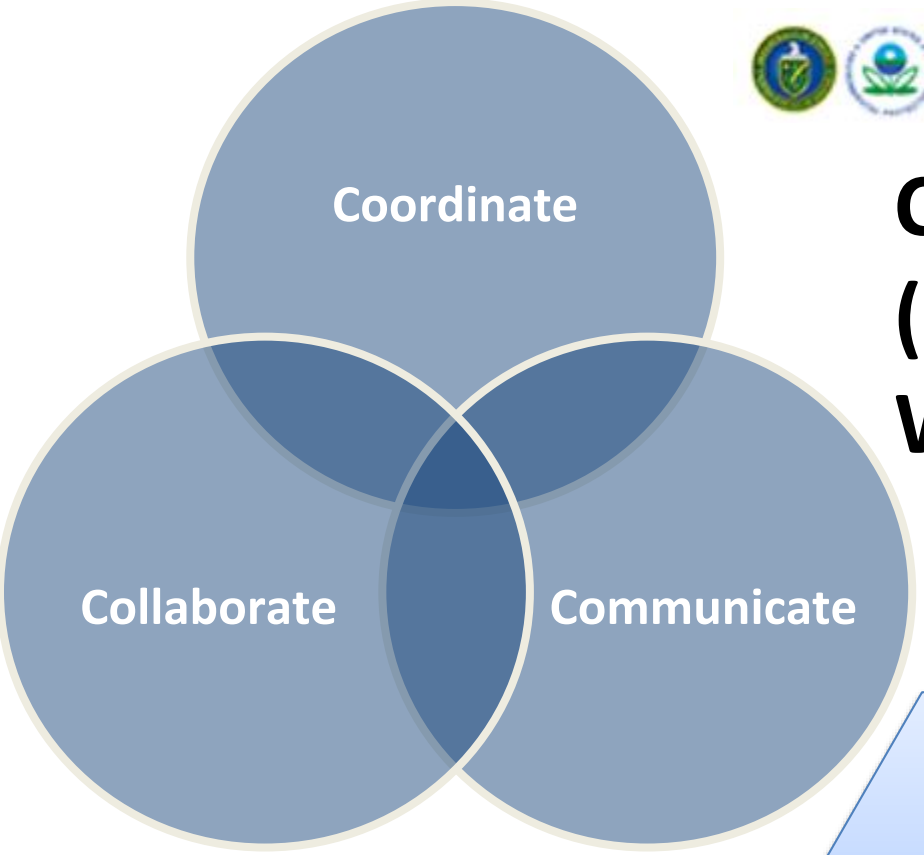
- Interconnections of diverse scientific communities
- Formal and informal networks for enhancing the quantity and quality of carbon observations & carbon management science

→ successful collaborations & productive outcomes in the U.S., North America, globally

Demonstrated via

- Second State of the Carbon Cycle Report (**SOCCR2**)-pertinent findings
- Long-term interagency activities in building pertinent current research and observational networks, focusing on U.S. & North American-led ones

Carbon Cycle Interagency Working Group (CCIWG) since 1998/99
What We Do



Promote interagency cooperation and coordination

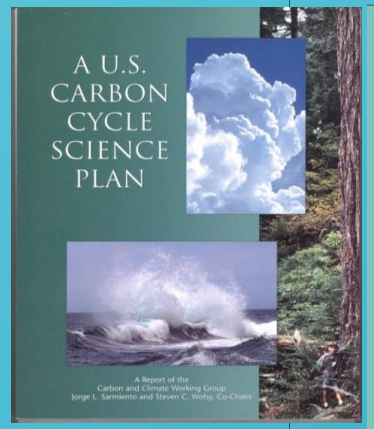
Atmosphere
Land
Water
Society
Interface

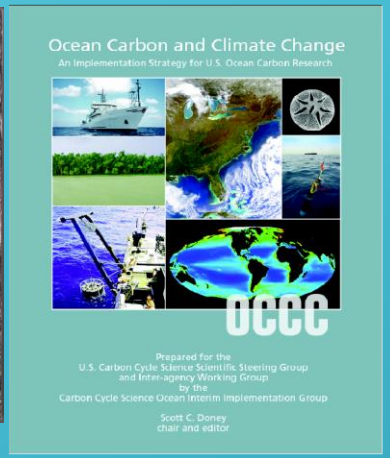
CCIWG instrumental in process of prioritization of U.S. govt. carbon cycle science research themes

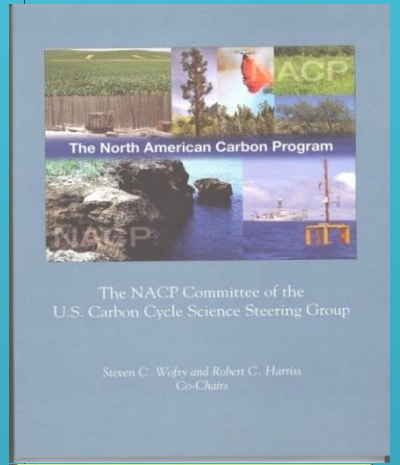
Help secure funding, prepare individual & joint agency initiatives & solicitation

Involve the scientific community in providing the needed science to understand the carbon cycle

Federal and community impetus for U.S. carbon science program and network building across North America since 1998



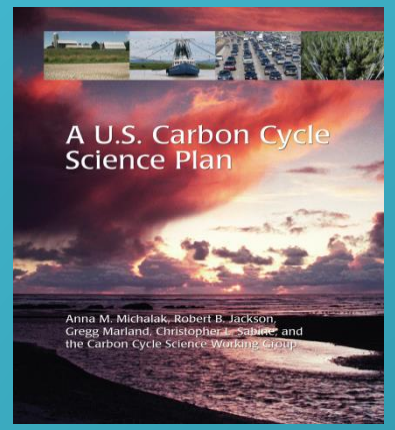


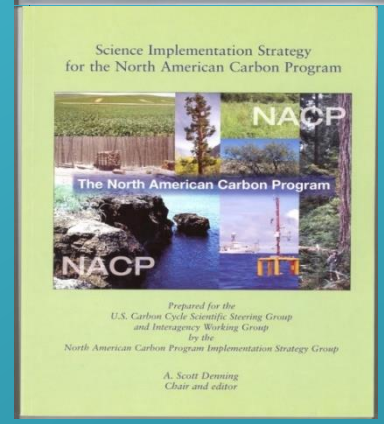


United States Carbon Cycle Science Program

An Interagency Partnership

Providing a coordinated & focused scientific strategy for conducting federal carbon cycle research





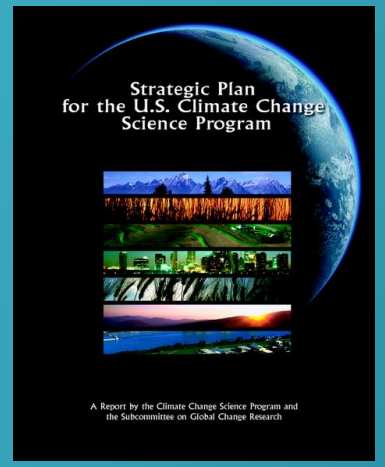
A Core Element of the U.S. Global Change Research Program

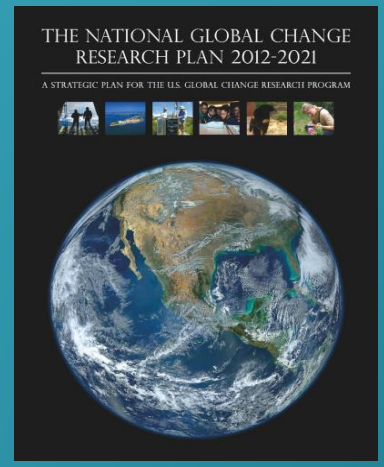
NORTH AMERICAN CARBON PROGRAM

CONTINENTAL CARBON BUDGETS • PROCESSES • MANAGEMENT

OCB

Ocean Carbon & Biogeochemistry



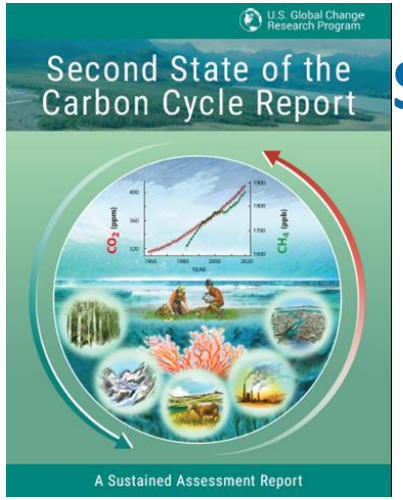


CarboNA

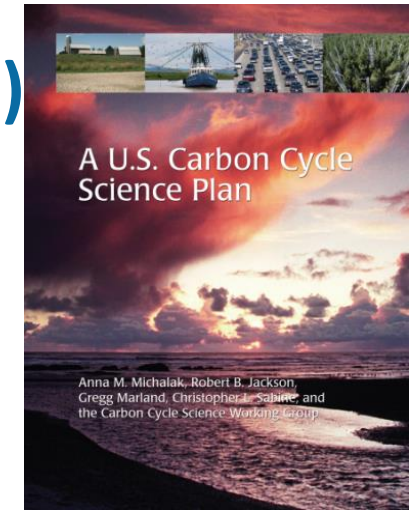
An international collaboration between Canada, Mexico, and the United States for carbon cycle science research throughout North America and adjacent ocean regions.

Coastal Carbon

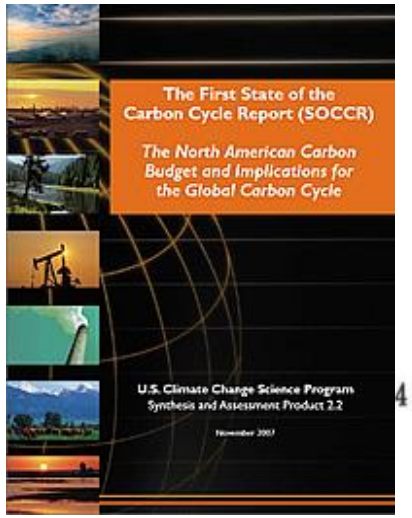
Research Coordination Network

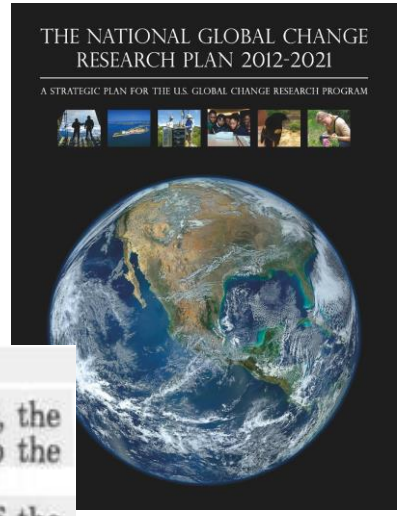


Second State of the Carbon Cycle Report (SOCCR2, 2018)



- Follow-up to the 1st SOCCR (2007)
- Led by Carbon Cycle Interagency Working Group (CCIWG)/U.S. Carbon Cycle Science Program
- Focus on U.S. and North American carbon stocks and fluxes in managed and unmanaged systems, but in a global context
- Includes relevant carbon management science perspectives and tools for supporting and informing decisions addressed in/related to U.S. Carbon Cycle Science Plan, National Climate Assessment, U.S. Global Change Research Program Strategic Plan and Global Change Research Act





4 STAT. 3096 PUBLIC LAW 101-606—NOV. 16, 1990

Public Law 101-606
101st Congress

An Act

To require the establishment of a United States Global Change Research Program aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes.

Nov. 16, 1990
[S. 169]

Global Change Research Act of 1990.
15 USC 2921 note.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Global Change Research Act of 1990".

SEC. 106. SCIENTIFIC ASSESSMENT.

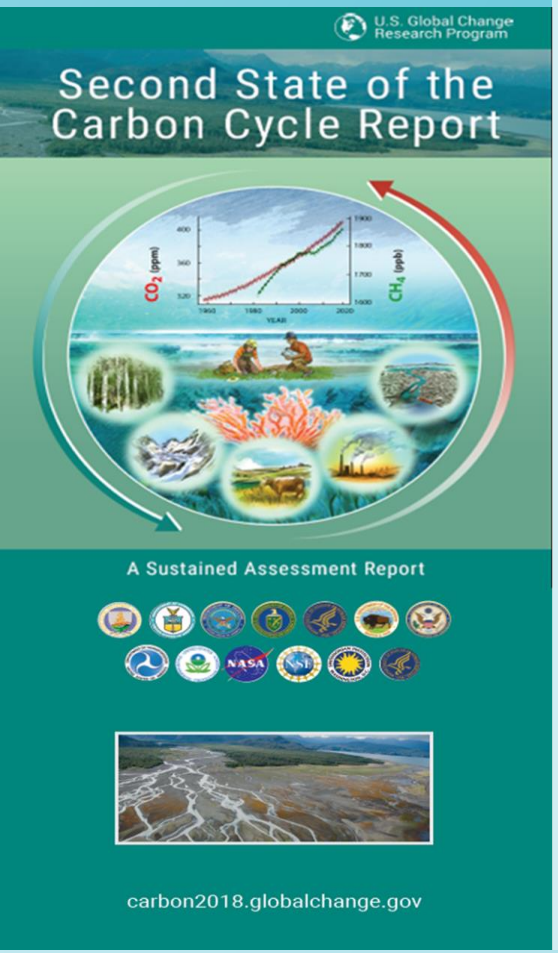
On a periodic basis (not less frequently than every 4 years), the Council, through the Committee, shall prepare and submit to the President and the Congress an assessment which—

(1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;

(2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and

(3) analyzes current trends in global change, both human-inducted and natural, and projects major trends for the subsequent 25 to 100 years.

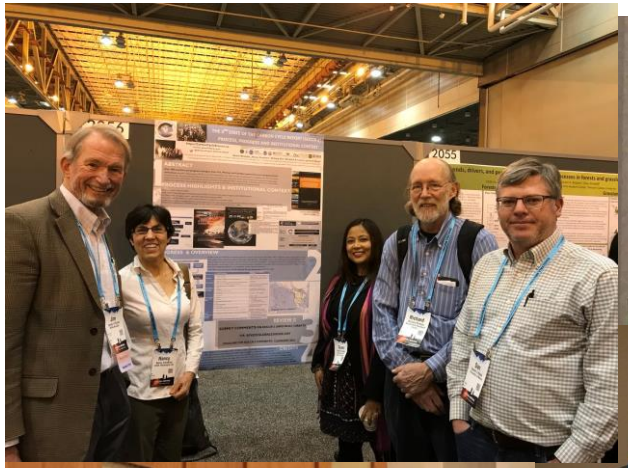
PRODUCTION FACTS

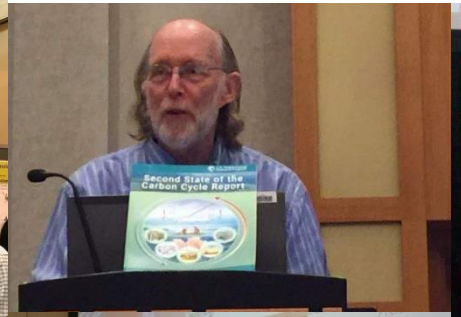


- Decadal U.S. Government Assessment of Carbon across North America – science, data, society, management – in global context
- The full decadal assessment contains 878 pages
  - Highlights (plain language) & Executive Summary (technical)
  - 4 sections (1. Synthesis, 2. Human Dimensions of the Carbon Cycle, 3. State of Air Land and Water, 4. Consequences and Ways Forward)
  - 19 chapters
  - 7 appendices
- Developed by 200+ diverse cross-sectoral experts from U.S., Mexico, Canada, Australia, Cyprus, Hong Kong
- 3764 publications cited
- 33 Chapter Leads
- 200 Contributing Authors
- 5 Science (cross-chapter section) Leads
- 11 Review Editors
- 3 years formulation & production (2015-18)
- Over 6 Drafts reviewed over 6 times incl. by Public, U.S. National Academy of Sciences, expert external reviewers, 21 Federal Steering Committee members.
- Final clearance by 13 U.S. Government Agencies and Departments leading to Friday Nov 23, 2018 Release

Recommended Citation: *USGCRP, 2018: Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report [Cavallaro, N., G. Shrestha, R . Birdsey, M. A. Mayes, R . G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (eds.)]. U.S. Global Change Research Program, Washington, D.C., USA, 878 pp., https://doi.org/10.7930/SOCCR2.2018.*

Part of U.S. Carbon Cycle Science Program & 200+ SOCCR2 team





SOCCR2 major themes & decadal carbon budget findings

- How Is the Global Carbon Cycle Changing?
- Carbon Sources, Sinks, and Stocks in North America
- Effects of Carbon Cycle Changes on North Americans and Their Environments
- A Systems Approach to Linking the Carbon Cycle and Society
- Projections of the Future Carbon Cycle, Potential Impacts, and Uncertainties
- Carbon Management and Mitigation

Based on assessment of science from the last decade, SOCCR2 finds that:

1. Fossil fuels are still the largest source of carbon in North America but can be reduced through dedicated effort.
2. Aquatic systems are both sources and sinks of carbon in North America (depending on type and conditions).
3. Land and coastal waters are sinks of carbon in North America, though some sinks at risk to diminish or become sources in the future.

Plus many scientifically significant and societally relevant key findings across all 19 chapters.

Boiling down major SOCCR2 highlights for North America

- The energy sector and transportation continue to be the largest source of carbon emissions

- Annual fossil fuel CO_2 emissions decreased by 1% -- Market, technology, and policy drivers

Net economic growth over same decade.

Cities largest emitters.

The United States is still currently responsible for 80% to 85% of fossil fuel emissions from North America.

On Carbon Removal….SOCCR2 SHOWS

Soils in croplands, rangelands, grasslands, and forests have strong potential for carbon sequestration with improved land-management practices;

Afforestation, reduced deforestation, restoration of coastal areas and terrestrial wetlands….

Some carbon sinks are diminishing in strength, many are at risk due to

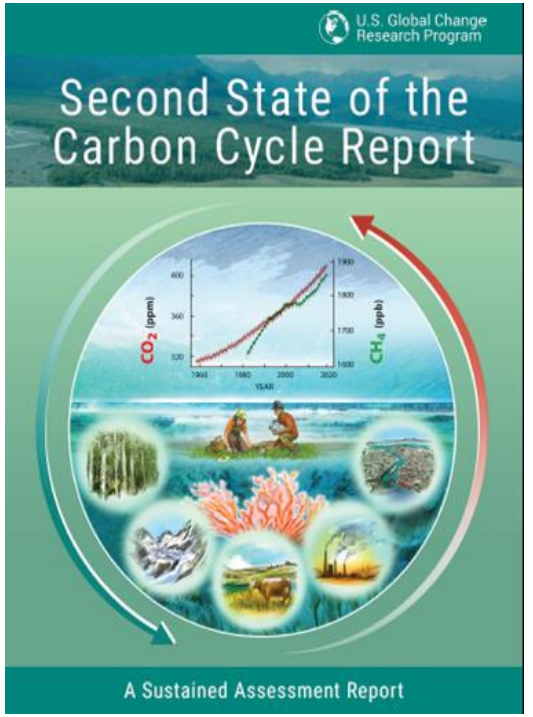
- increasing disturbance in forests
(e.g. fire, pests, invasive species)
- increasing land use pressure on ecosystems.

Conversion of peatland soils accounts for the largest emissions from soils.

Accelerated warming in Arctic regions creates vulnerability of large stores of carbon in permafrost soils.

Changes in climate, human activities, and ecosystem responses may alter future long-term removals of carbon by current land and ocean system sinks.

SOCCR2: Solutions-oriented perspectives based in improved observations over last decade



Enhanced integration of natural sciences and sustainability perspectives, promoting solutions-oriented science

- social science and tribal chapters
- carbon management sections in each chapter

Thanks to improved decadal carbon observations, SOCCR2 shows:

- Increased high-latitude data collections and synthesis
- Coastal wetlands, estuaries and coastal waters included in the decadal budget for the first time
- Lateral transports more consistently determined over space and time
- More complete and better attributed carbon budget in North America
- Convergence between top-down (atmospheric observations) and bottom-up (in-situ and inventories) estimations
- Future projections more robust with enhanced observations and tools for their interpretation

Beyond SOCCR2

LONG-TERM ACTIVITIES IN BUILDING PERTINENT CURRENT RESEARCH AND OBSERVATIONAL NETWORKS, FOCUSING ON U.S. & NORTH AMERICAN-LED ONES

Examples of interagency and international efforts and achievements

- NOAA-led
- NASA-led
- DOE-led
- USGS-led
- NACP
- OCB
- CarboNA-Canada, Mexico and US Partners in GCP

Example themes

- Atmospheric
- Urban
- Ocean Acidification
- Arctic
- U.S., North American, International network building
- Coastal
- Soils

U.S. Carbon Cycle Science Program

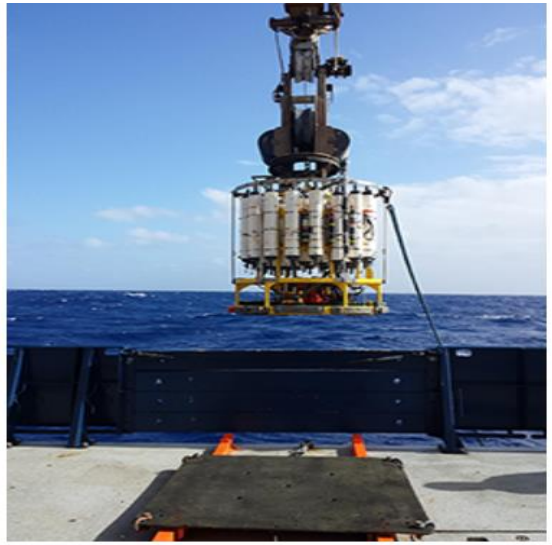
Sustained Carbon Observations

Andrews, A. (2017), Strengthening the observational basis for carbon science, policy, *Eos, 98,* 2017.

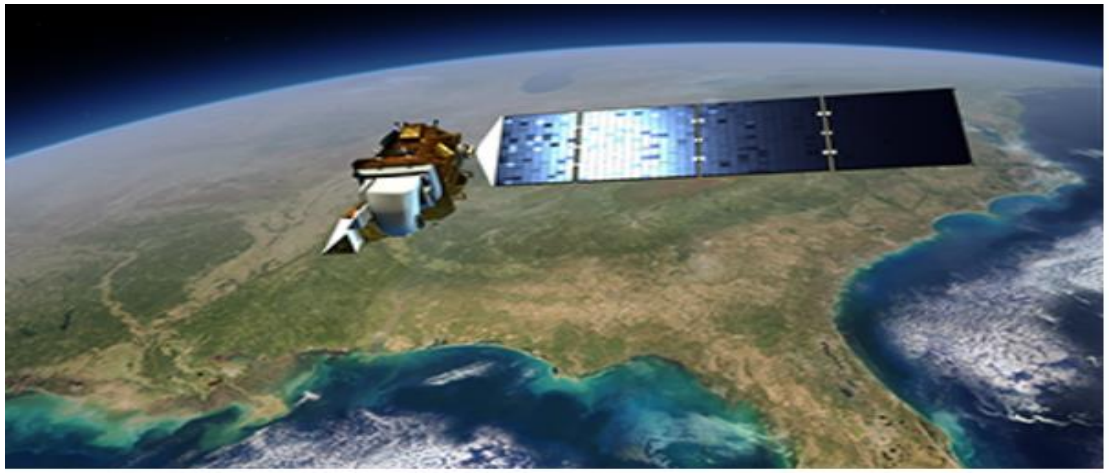
‘provide the foundation for understanding Earth’s carbon budget…seasonal to several decades…—data records must be of sufficient quality, density, and duration....’

Charles David Keeling began making ongoing atmospheric carbon dioxide measurements at the Mauna Loa Observatory in Hawaii, shown here, in 1958. Sustained carbon observations have led to profound scientific discoveries and support for policy decisions. Attendees at a 2016 workshop addressed interagency cooperation and the U.S. role in an international carbon observing system. Credit: Forrest M. Mims III, Mauna Loa Observatory

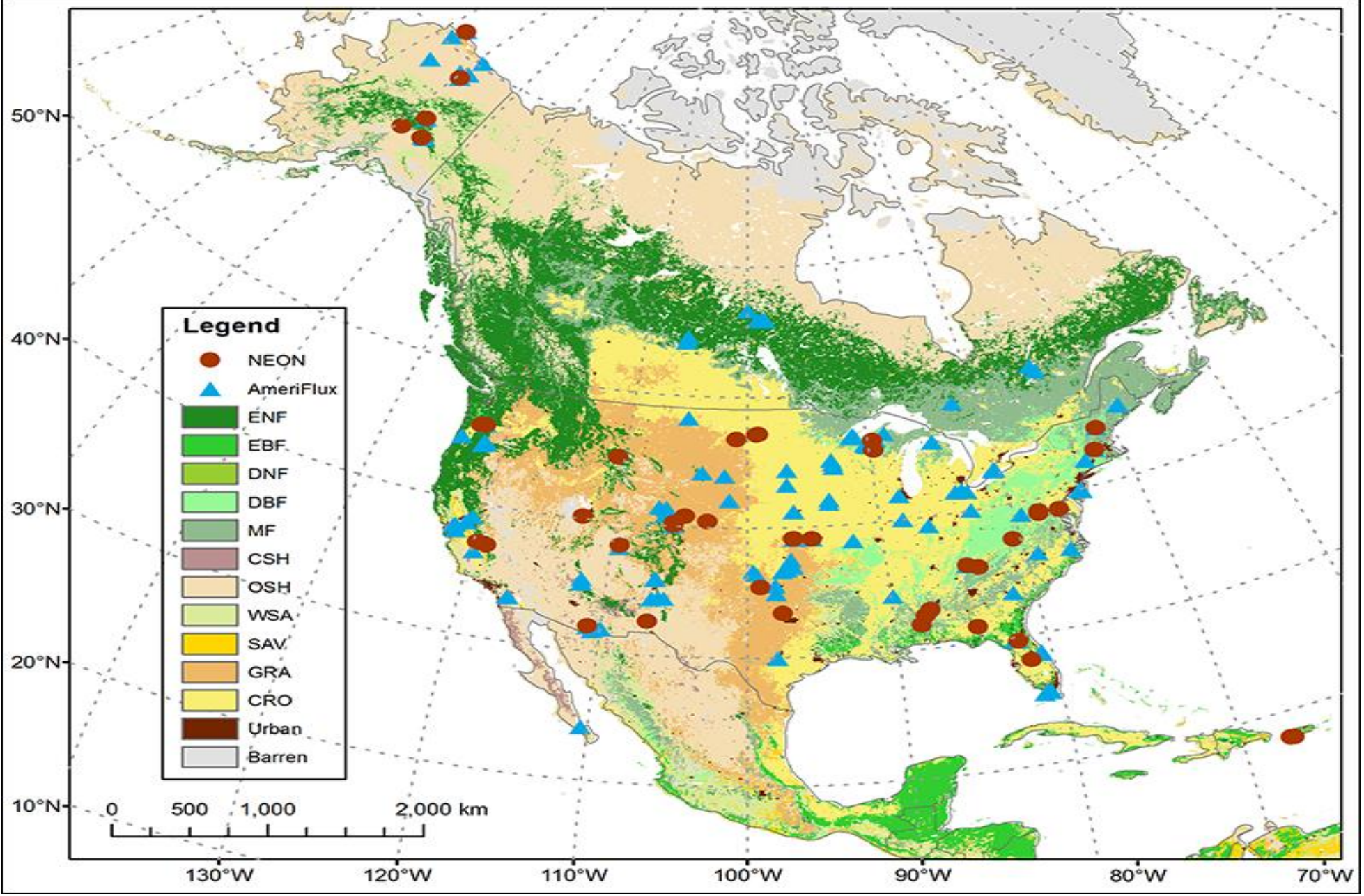
The AmeriFlux eddy covariance tower is used to measure gas and energy exchange between the ecosystem and atmosphere at the Harvard Forest in Massachusetts. Credit: Rick Wehr



The rosette water sampler is used for repeat hydrography cruises like those sponsored by the Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP) and ocean time series measurements. Credit: Leticia Barbero



Landsat 8 and its predecessors have provided continuous surface imagery since 1972. Credit: NASA Goddard Space Flight Center



AmeriFlux sites and NEON sites in North America measure the exchange of carbon dioxide between ecosystems and the atmosphere.

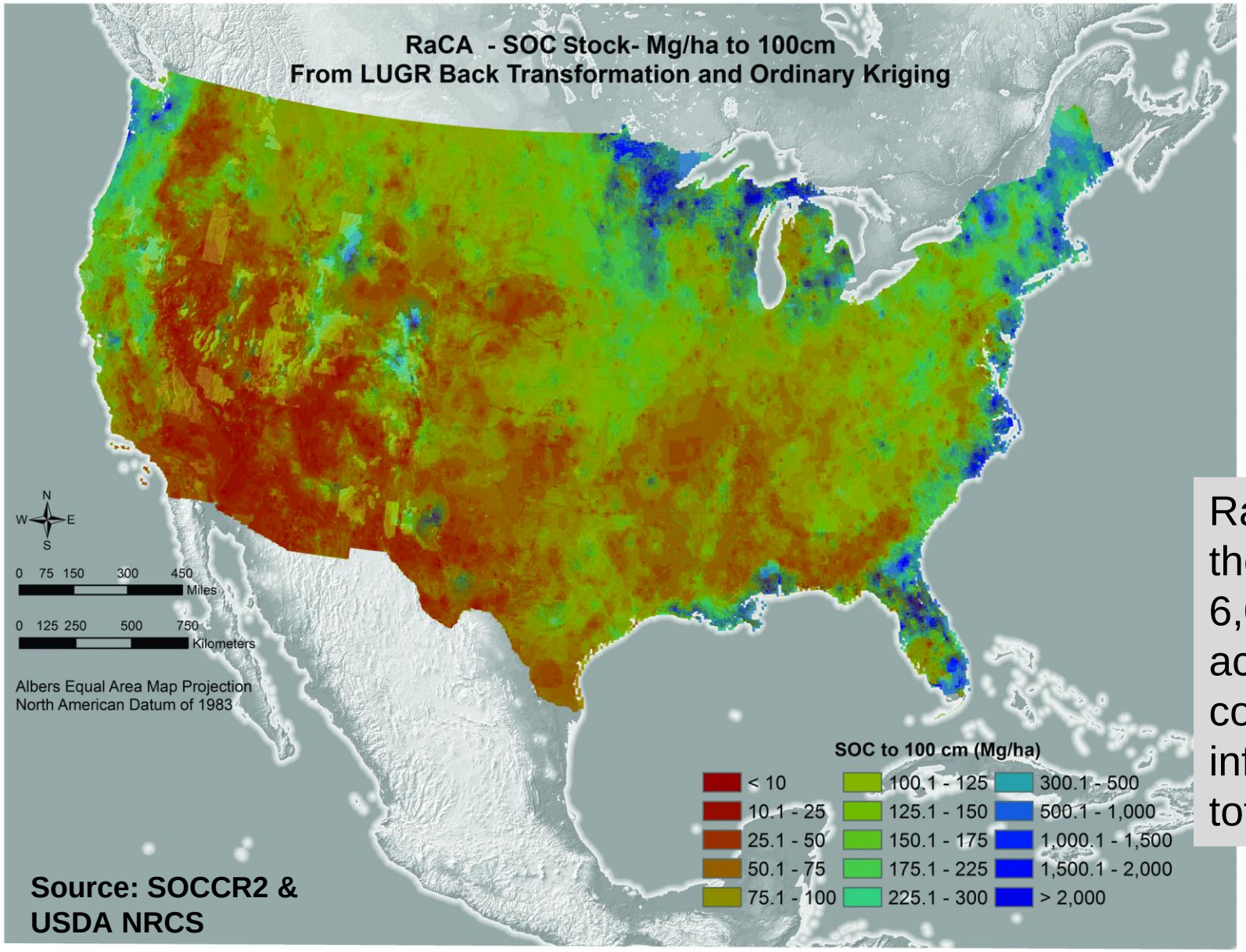
U.S. Carbon Cycle Science Program

Carbon Cycle Predictions

Xiao, J., Y. Luo, and G. Shrestha (2016), Improving carbon cycle projections for better carbon management, *Eos, 97*. 2016.

'One important step toward carbon management is developing the science that predicts carbon cycles….'

U.S. Carbon Cycle Science Program: SOILS data collection networks



International Decade of the Soil workshop, Soil Carbon studies—USDA, DOE, USGS, NASA etc. International Soil Carbon Network,
USDA-led Rapid Carbon Assessment (RaCA) of Soil Organic Carbon (SOC)

RaCA collected 144,833 samples from the upper 1 m of 32,084 soil profiles at 6,017 randomly selected locations across the United States. Results combined with land-use, land-cover information, yielding an estimate of the total carbon stock.

Cont'd. LONG-TERM ACTIVITIES IN BUILDING PERTINENT CURRENT RESEARCH AND OBSERVATIONAL NETWORKS, FOCUSING ON U.S. & NORTH AMERICAN-LED ONES

Beyond SOCCR2

Examples of interagency and international efforts and achievements

- NOAA-led
- NASA-led
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Example themes

- Atmospheric
- Urban
- Ocean Acidification
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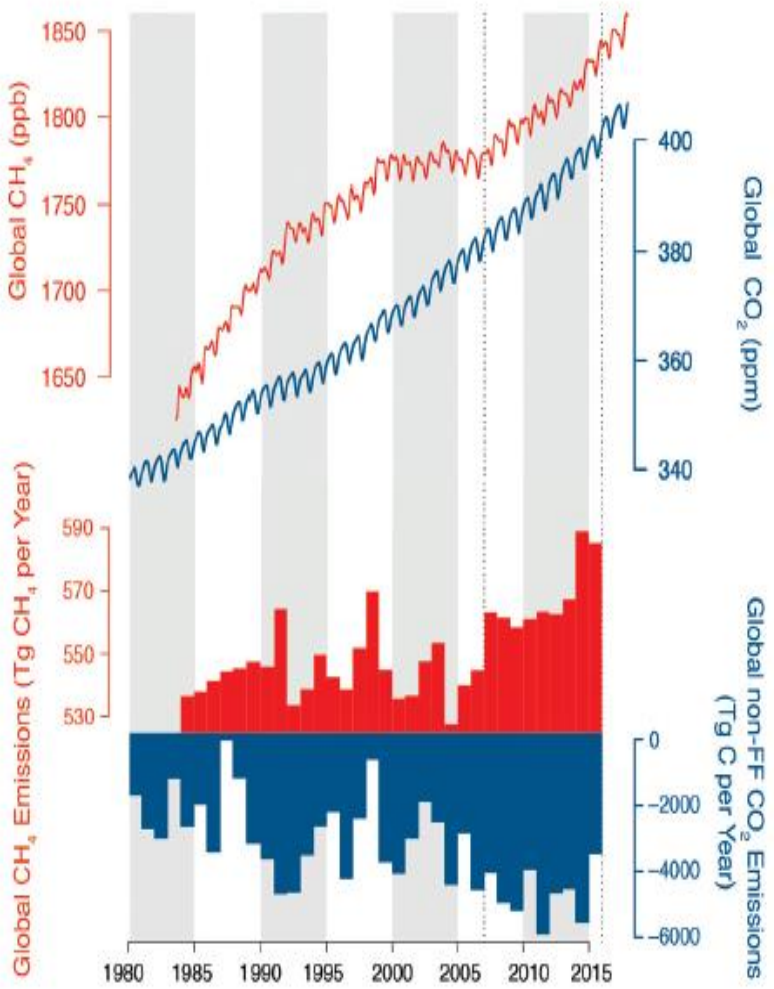
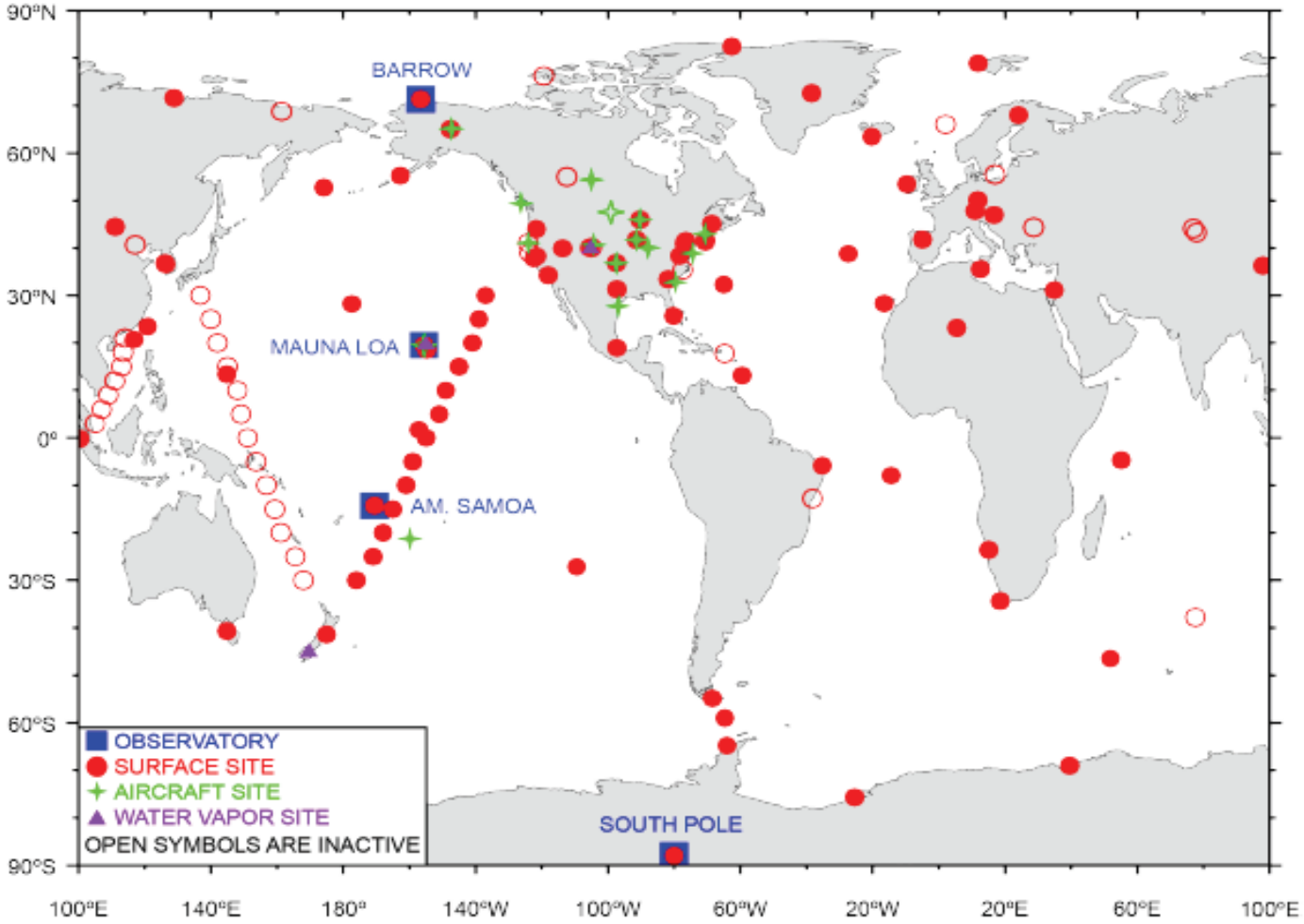
- U.S., North American, International network building
- Coastal
- Soils

NOAA-led Atmosphere Observations networks

- Atmospheric Observations of CO_2, CH_4





Ocean Carbon networks - NOAA Climate Observation

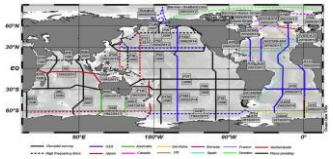
Sustained Observations | Management & Synthesis | Global Products & Publications

Repeat Hydrography

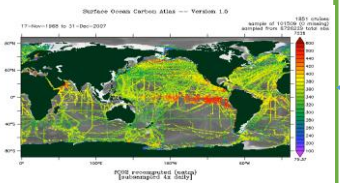
CO_2 from Moorings

CO_2 from Ships

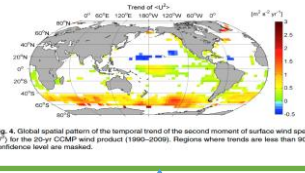
Ocean Interior



Surface Ocean



Remote sensing and model output



PICES | MIRC

PACIFICA Data Synthesis Project

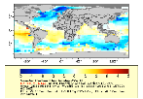
CARINA

GLODAPv2_19

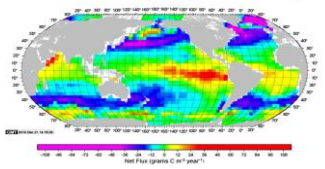
Global Ocean Data Analysis Project

Global Carbon Project

SOCAT V7



Takahashi 2019



Academic Partners and Global Outreach

Global Data Center

NOAA

NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

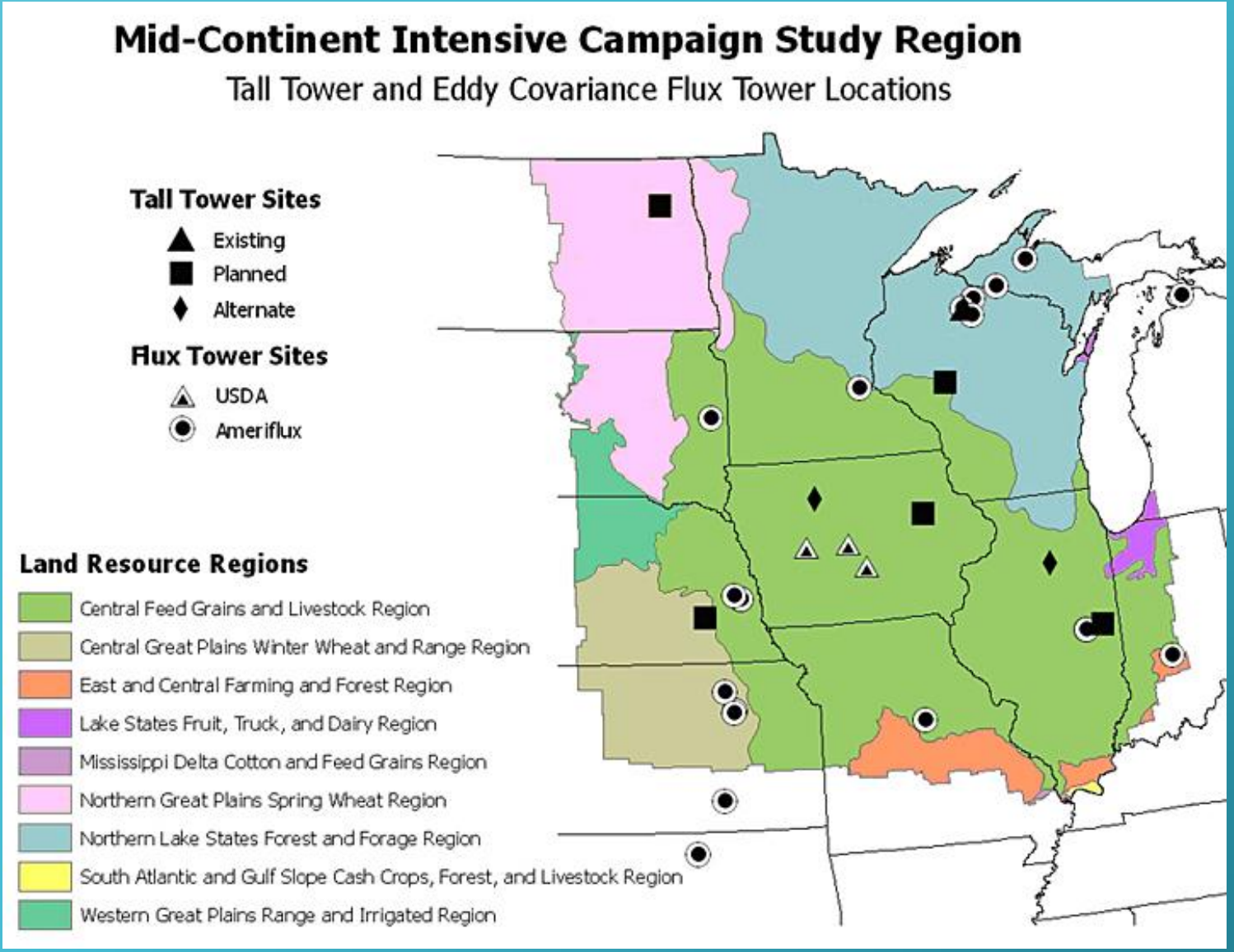
Long-term activities in building pertinent current research and observational networks, focusing on U.S. & North American-led ones

North American Carbon Program (NACP) examples

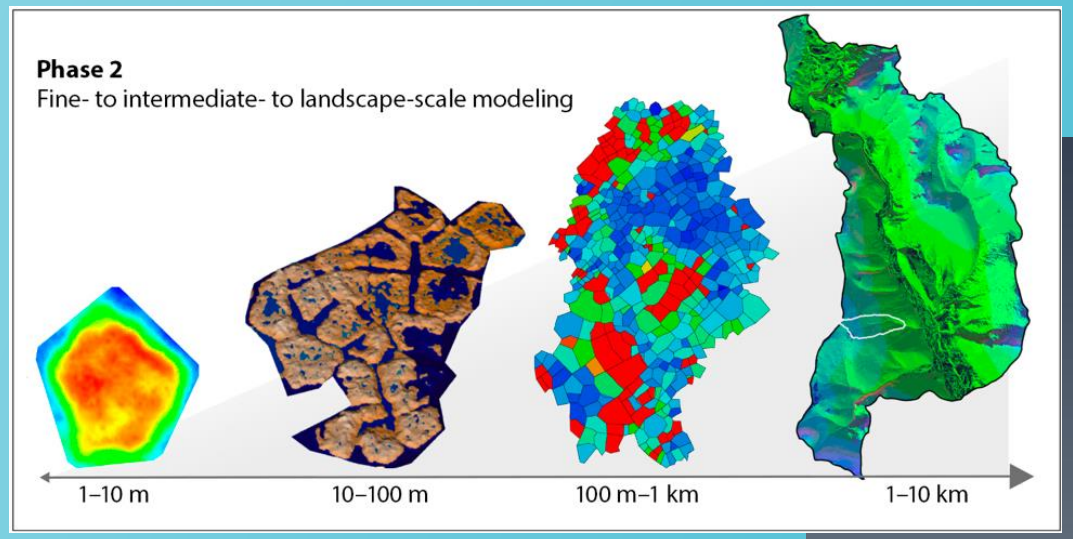
- Multi-agency, multidisciplinary research program focused on carbon sources and sinks in North America and adjacent oceans
- Community-led activities:
  - Intensive campaigns
  - Synthesis activities
  - Workshops w/CCIWG
- Since inception (2002) **227 publications with 100+ citations**
- 150+ active projects
- Coordinates with Canada and Mexico on CarboNA

North American Carbon Program Intensives
U.S. **Mid-Continent Intensive (MCI)**

- 2003 – 2007
- Test-bed for methodologies to determine carbon flux between land and atmosphere
- Essential for understanding and reconciling top-down vs. bottom up estimates
- Multi-agency funding: DOE, NASA, NOAA, NSF, USDA ARS, USDA FS, USDA NIFA, USGS

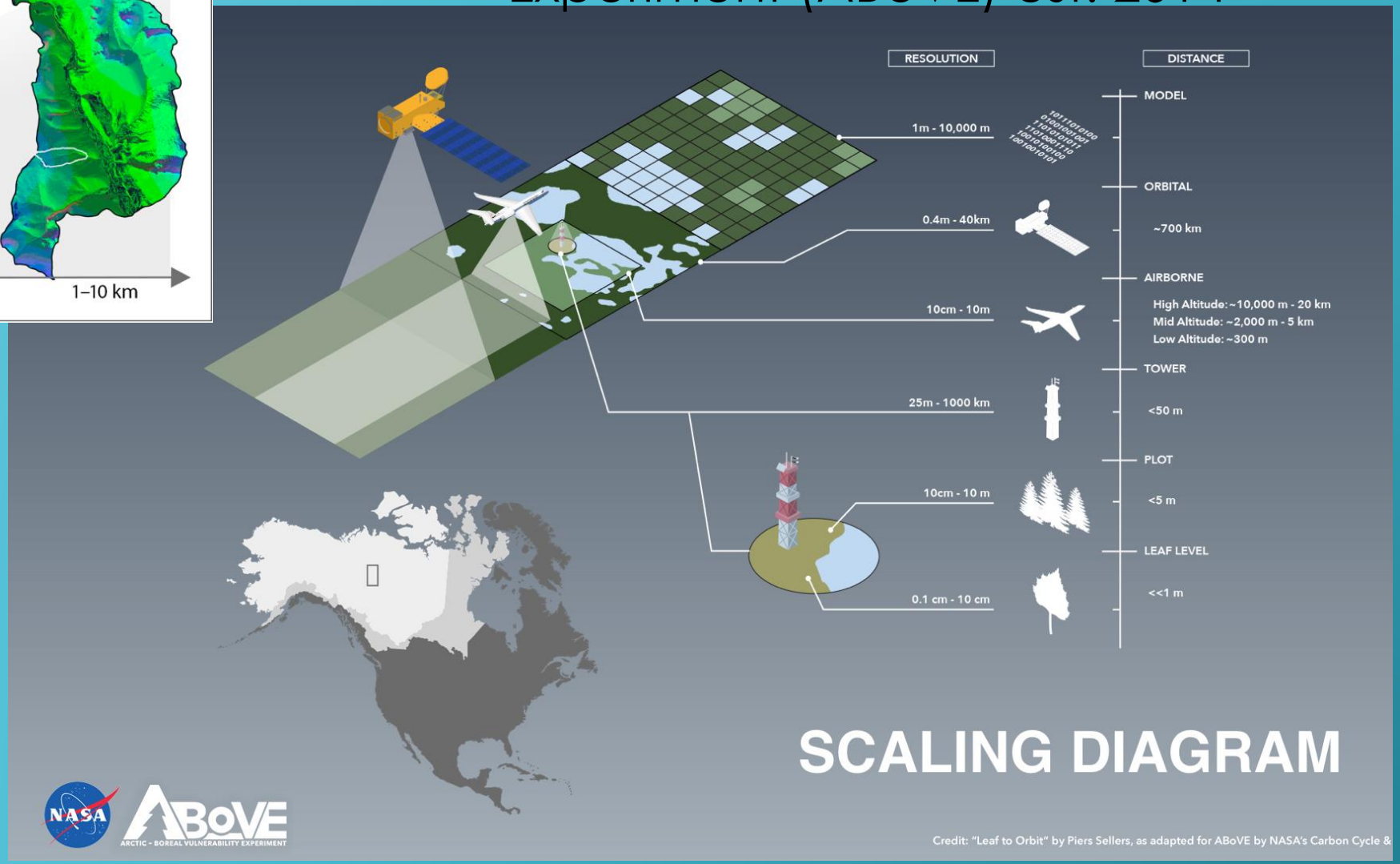


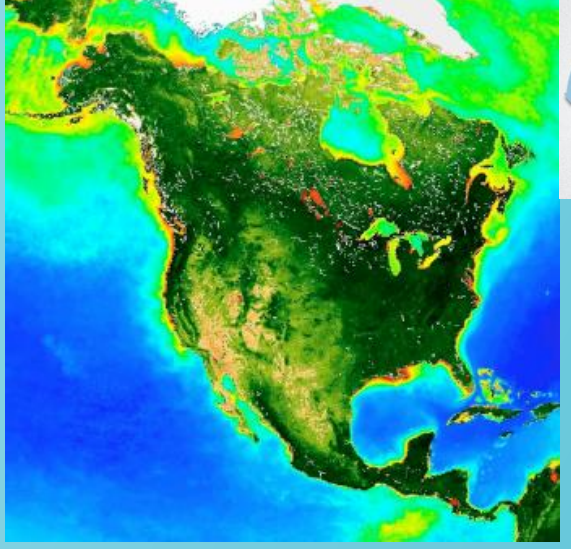
North American Carbon Program Intensives
Arctic Campaigns



DOE's Next-Generation Ecosystem Experiment (NGEE-Arctic) est. 2012

NASA's Arctic-Boreal Vulnerability Experiment (ABoVE) est. 2014





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CONTINENTAL CARBON BUDGETS • PROCESSES • MANAGEMENT

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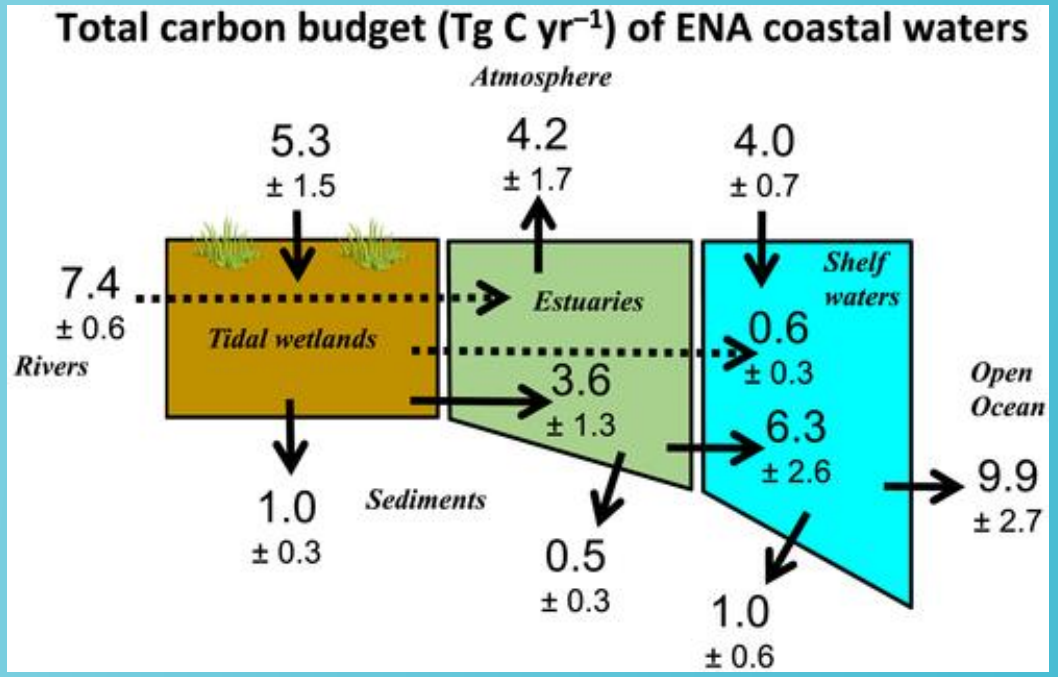
Ocean Carbon & Biogeochemistry

North American Carbon Program & Ocean Carbon and Biogeochemistry Program Syntheses Examples

Coastal Carbon Synthesis & Science Plan 2012 – 2015

- Multi-scale Synthesis and Terrestrial Model Intercomparison Project (MsTMIP) 2014 – 2017
- Regional-Continental 2012 – 2015
- Site-level 2008 – 2013
- Disturbance 2009 – 2013



Global Biogeochemical Cycles, Volume: 32, Issue: 3, Pages: 389-416,
First published: 20 February 2018, DOI: (10.1002/2017GB005790)

Vulnerability of Inland Waters and the Aquatic Carbon Cycle to Permafrost Change across Boreal Northwestern North America

Collaborative research led by U.S. Geological Survey with NASA, U.S. Fish and Wildlife Service, Alaska Ecoscience, Florida State University, University of Washington, University of Minnesota

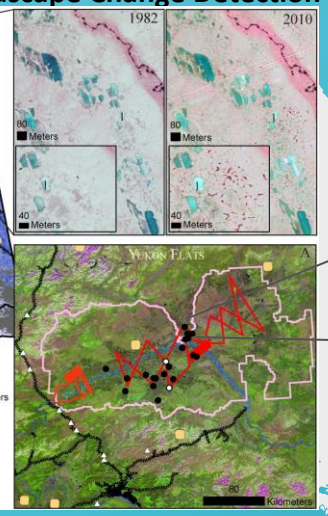
USGS science for a changing world

ABoVE Arctic Boreal Vulnerability Experiment

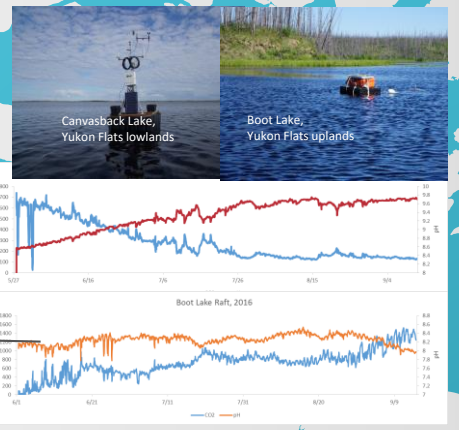
NASA

Near Surface Permafrost Mapping

Landscape Change Detection

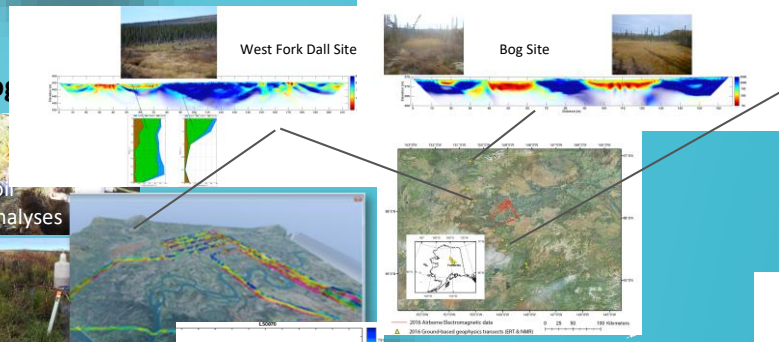


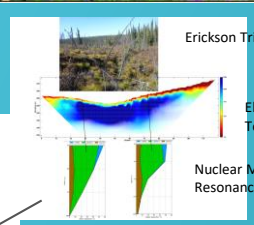
Lake Greenhouse Gases



Subsurface Characterization

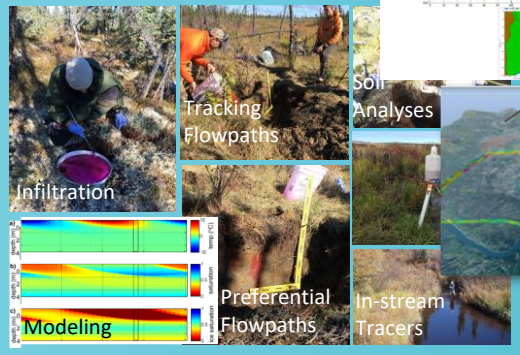
Deep Permafrost Mapping



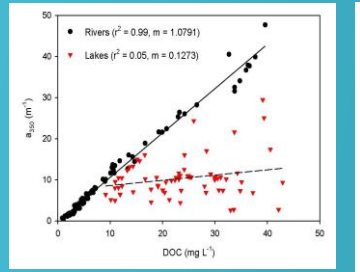


Stream Discharge and Chemistry

Subsurface Hydrolog



Lake and River Chemistry



An interdisciplinary investigation of Carbon Biogeochemistry, Greenhouse Gas Exchange, Hydrology, Geography, Geophysics & Remote Sensing

USGS Contacts:

Rob Striegl rstriegl@usgs.gov

Michelle Walvoord walvoord@usgs.gov

Zhiliang Zhu zzhu@usgs.gov

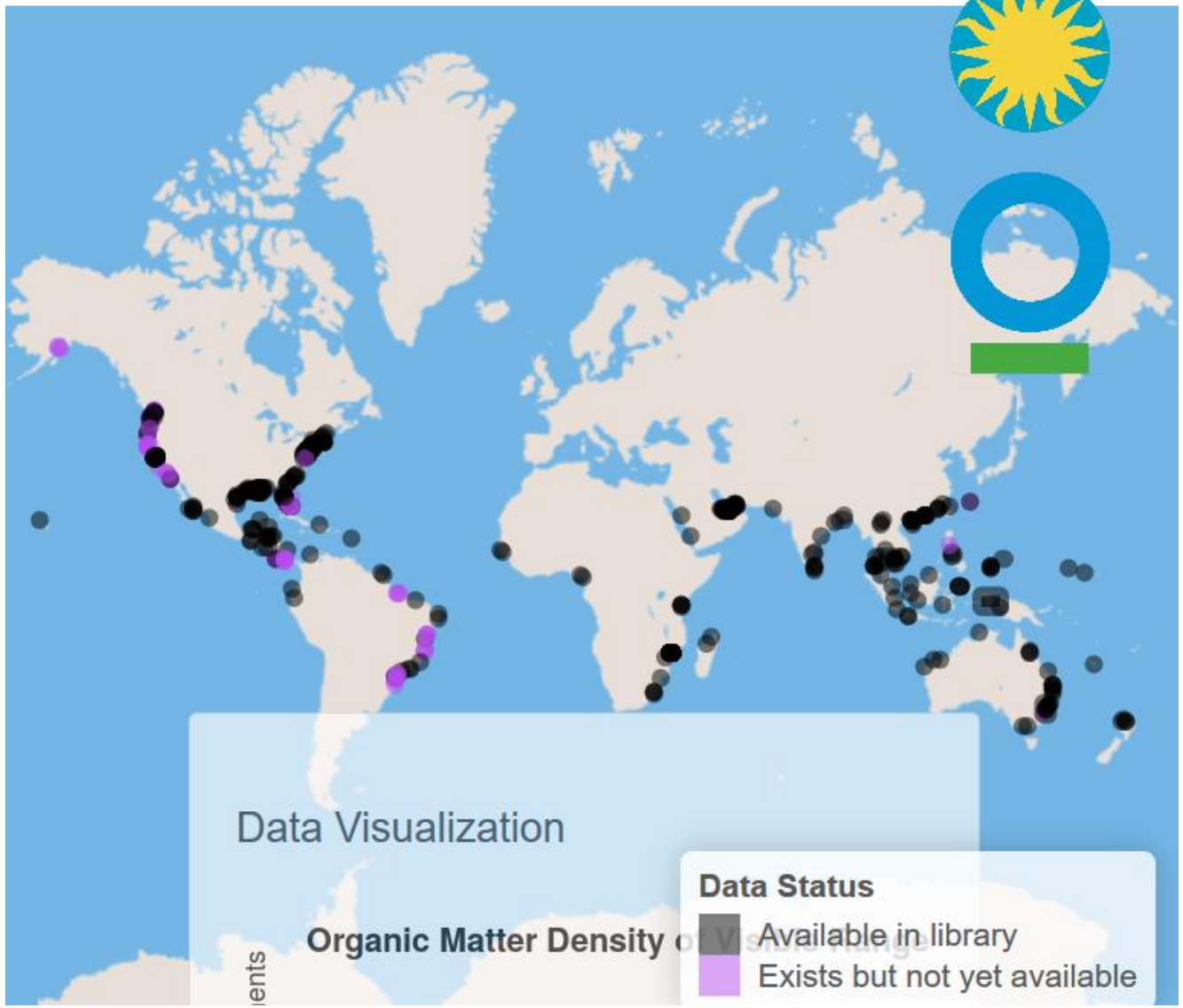
New interagency and community networks….

Coastal Carbon Research Coordination Network

New data visualization atlas - Global Coastal organic matter measurements/mapping

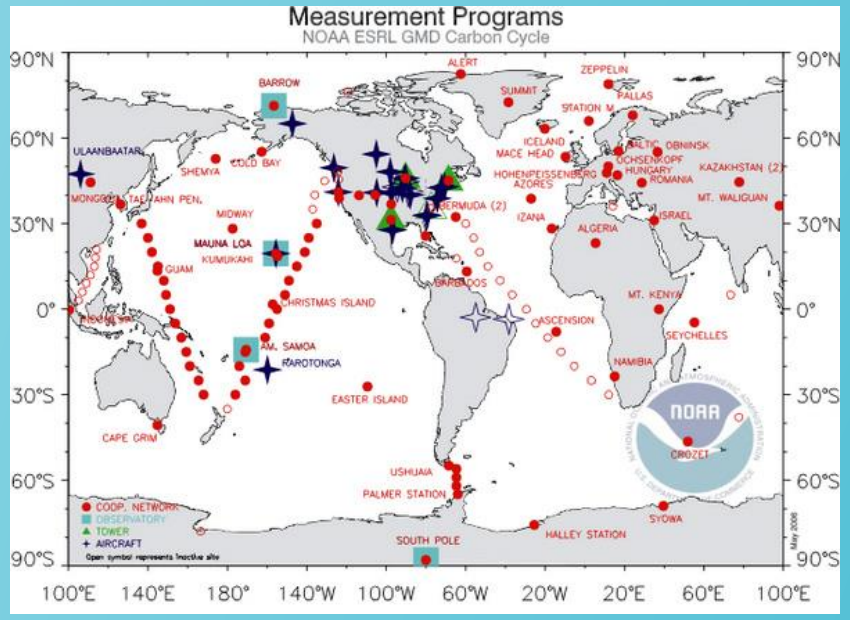
National Science Foundation Research Coordination Network

U.S. Carbon Cycle Science Program facilitated (international **Global Science and Data Network for Coastal Blue Carbon Workshop** sponsored in 2016 with Commission of Environmental Cooperation)



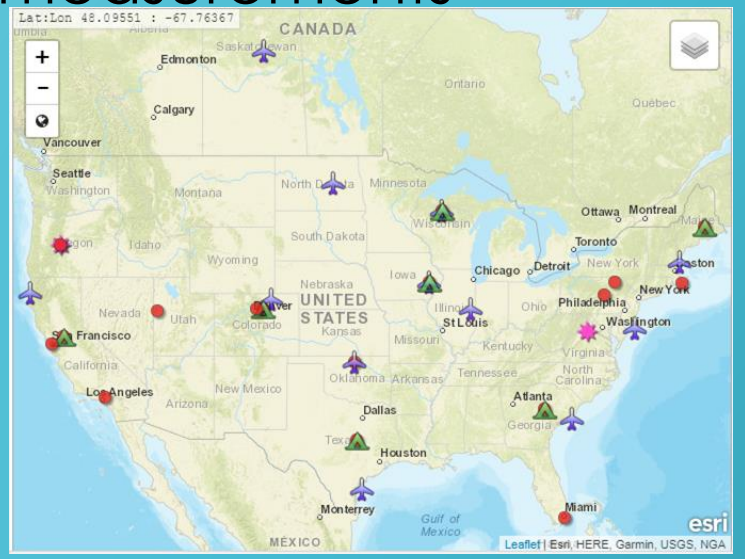
Urban carbon: How did we get here?

Increasingly regional focus

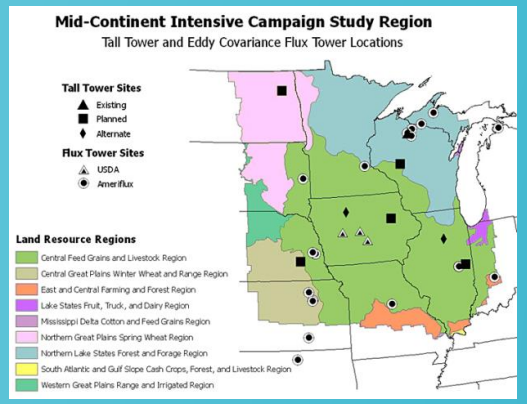


50+ years:
NOAA's **global** carbon monitoring network

Tall tower and aircraft measurements



2002 -
North American Carbon Program

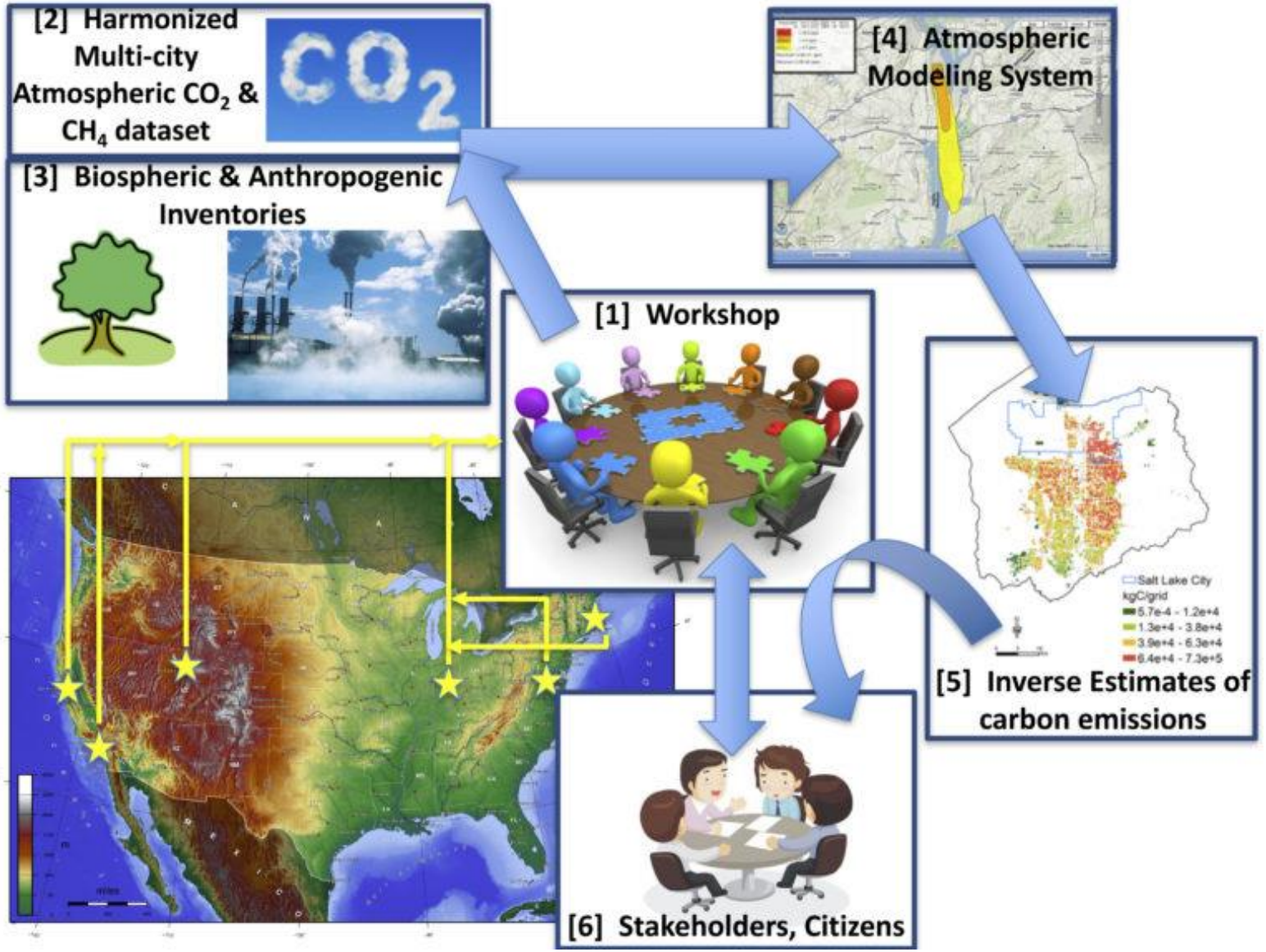


Midcontinent Intensive

Urban scale measurements: Indianapolis, LA, Boston, San Francisco, …

global → urban

Community-led science and scientists essential for successful and sustainable observations network.



Another new interagency and community network….

“CO_2-USA” Network

NOAA & NIST led interagency, science community-led network

To foster a community of urban carbon cycle researchers and generate collaborative studies; Engage stakeholders to link them with data, syntheses, and insights into urban emissions.

Solutions-oriented interagency science based on improved observations over 20 years

Thanks to interagency & international research partnerships with the community:

- Enhanced quantity and quality of research and observation infrastructure & networks across North America, globally
  - More complete and better attributed carbon budget in North America
  - Convergence between top-down and bottom-up estimations
  - Future projections more robust with enhanced observations and tools for their interpretation

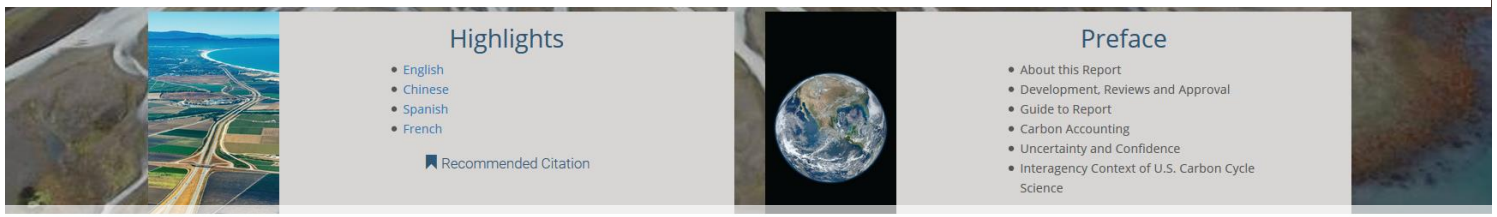
….described in the **State of the Carbon Cycle Report (Carbon2018.globalchange.gov)** &

U.S. Carbon Cycle Science Program website (CarbonCycleScience.us)

What else can we do?

How can we connect, collaborate and coordinate better among ourselves and among other networks and partners…for solutions-oriented sustained carbon observations and informed decision-making?

carbon2018.globalchange.gov



Segundo Reporte sobre el Estado del Ciclo del Carbon O Mensajes Clave

北美 第二期碳循环现状报告 主要重点

Le Deuxième Rapport Sur l'Etat du Cycle du Carbone: Faits saillants

Thank you. Merci. Danke. धन्यवाद. Gracia. 谢谢.

Questions? Contact:

United States Carbon Cycle Science Program

An Interagency Partnership

Providing a coordinated & focused scientific strategy for conducting federal carbon cycle research

Dr. Gyami Shrestha,

Director, U.S. Carbon Cycle Science Program Office

Email: **gshrestha@usgcrp.gov**

Web: **carboncyclescience.us**

Extra

Domain of The Second State of the Carbon Cycle Report

Carbon Cycle: Inherently interdisciplinary, important to many disciplines, U.S. science agencies = CCIWG

United States Carbon Cycle Science Program

An Interagency Partnership

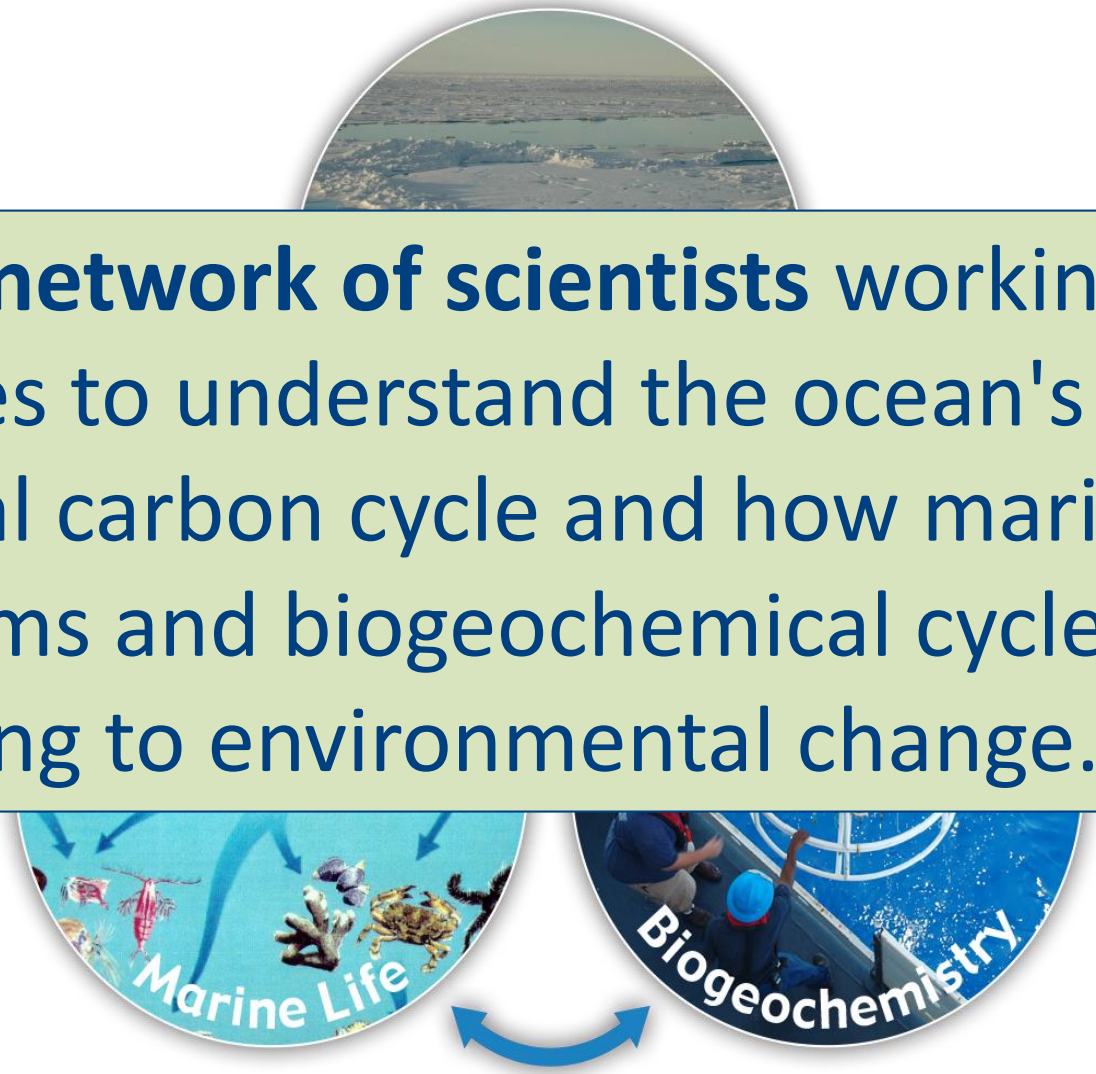
Providing a coordinated & focused scientific strategy for conducting federal carbon cycle research

- National Aeronautics and Space Administration;
- Department of Agriculture (4 agencies, including Forest Service);
- Environmental Protection Agency;
- Agency for International Development;
- Department of Energy;
- National Ocean and Atmospheric Administration;
- National Science Foundation
- Smithsonian Institute
- National Institute for Standards and Technology

Discussions…..in U.S. and International Context of collaborations (current/potential)

- Why is there need for coordinated federal response to carbon cycle research?
- What roles does the U.S. Carbon Cycle Science Program and Carbon Cycle Interagency Working Group play that cannot been fulfilled individually by organizations?
- What roles and activities should the U.S. Carbon Cycle Science Program and Carbon Cycle Interagency Working Group do that we are not doing, or not doing so well right now?

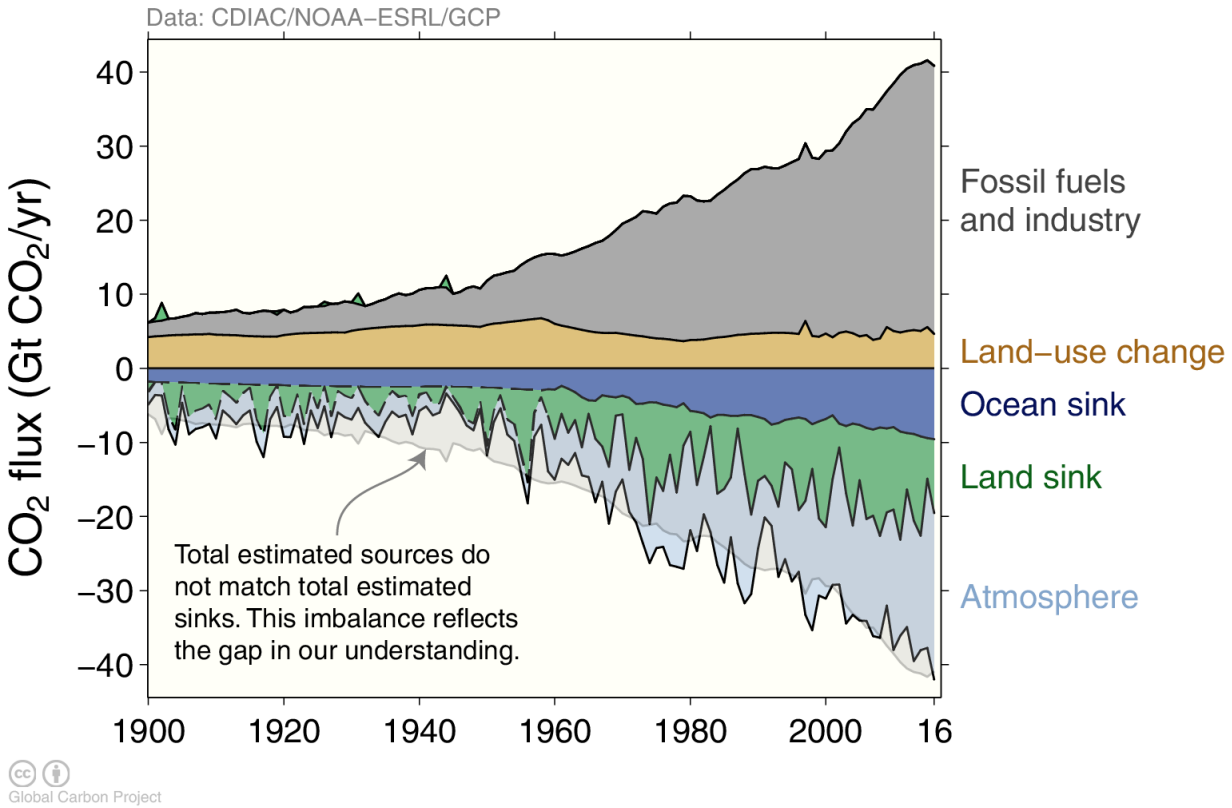
WHAT IS OCB?



OCB is a **network of scientists** working across disciplines to understand the ocean's role in the global carbon cycle and how marine ecosystems and biogeochemical cycles are responding to environmental change.

The Global Carbon Budget

Le Quéré et al 2018



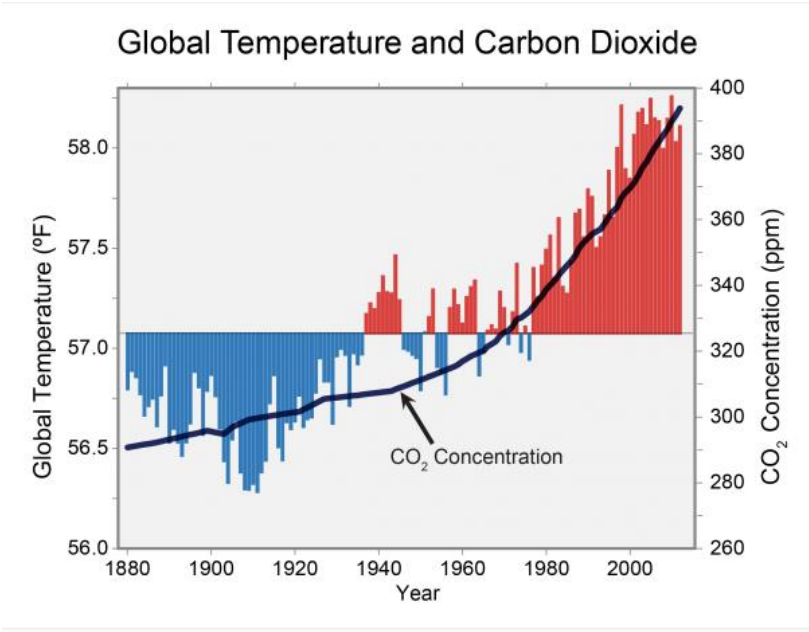
Carbon emissions are partitioned among the atmosphere and carbon sinks on land and in the ocean

The "imbalance" between total emissions and total sinks reflects the gap in our understanding

Ocean Carbon Observing Network

Major Scientific Questions

- Can the ocean keep up this pace?
- What controls the seasonal and decadal variations in carbon uptake?
- How will future changes (biology, circulation) affect uptake mechanisms, global
- How will this excess CO_2 affect organisms and ecosystems?



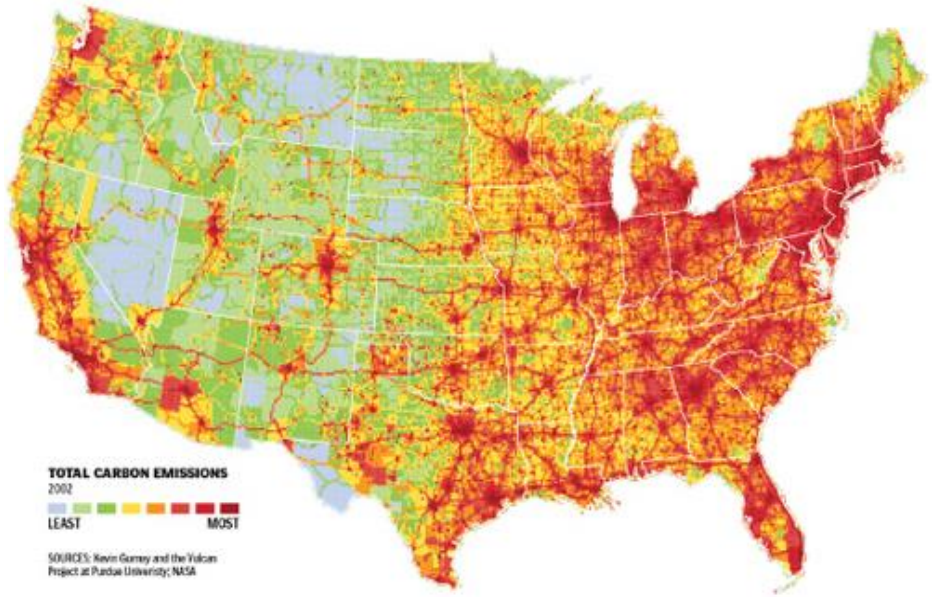
NOAA Contributions – Ocean Acidification

- Fosters, directs, & coordinates efforts to understand the impact of CO_2 on ocean acidity
  - interdisciplinary research
  - long-term monitoring program
  - research supporting adaptation strategies
  - educational opportunities
  - national public outreach
- Coordinates ocean acidification monitoring and impacts research
- Primary mission is to assess the vulnerability of the US to ocean acidification impacts

URBAN CARBON

As urban expansion continues, the following key questions arise:

- How can CO_2 emissions (fluxes) from urban regions be determined and verified?
- How does the long-term trajectory of carbon emissions impact decisions about urban architecture, land use, and infrastructure?
- What are the co-benefits of carbon and air pollution mitigation at the local scale



C40 CITIES
CLIMATE LEADERSHIP GROUP

ABoVE 2: Crossing the divide: Inundation drives hotspots of carbon flux

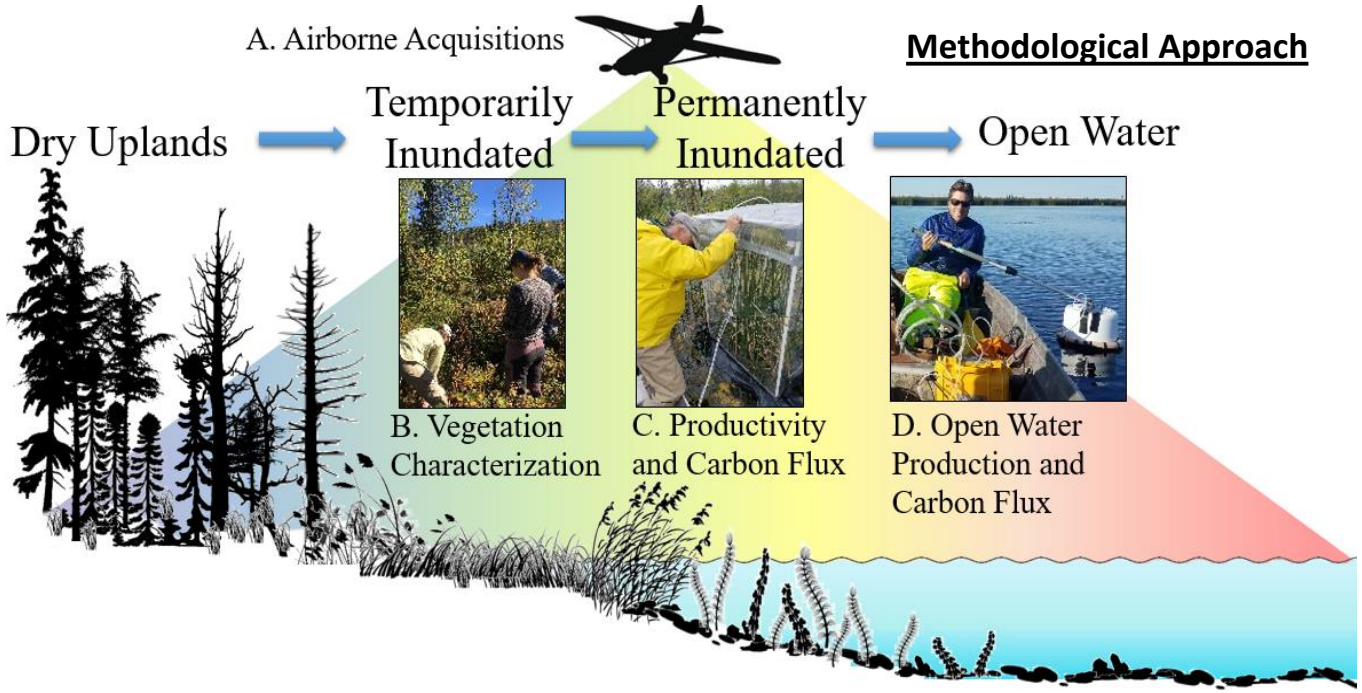
USGS (2019-2022) with

NASA J.P.L, U.S. Geological Survey, U.S. Fish and Wildlife Service, Environment & Climate Change Canada, Government of Northwest Territories, University of Washington (Seattle), University of North Carolina (Chapel Hill), Brown University, Florida State University, University of Waterloo (Canada)

Example inundated landscape

12-Mile Lake in the Yukon Flats National Wildlife Refuge recently inundated forested land from ice jams on the Yukon River (D. Butman)

Methodological Approach



1. NASA Airborne Remote Sensing data from ABoVE for vegetation composition and structure
2. Obtain CO_2 and CH_4 flux measurements from open waters to uplands
3. Develop scaling relationships between field fluxes and remote sensing across changing landscapes susceptible to inundation