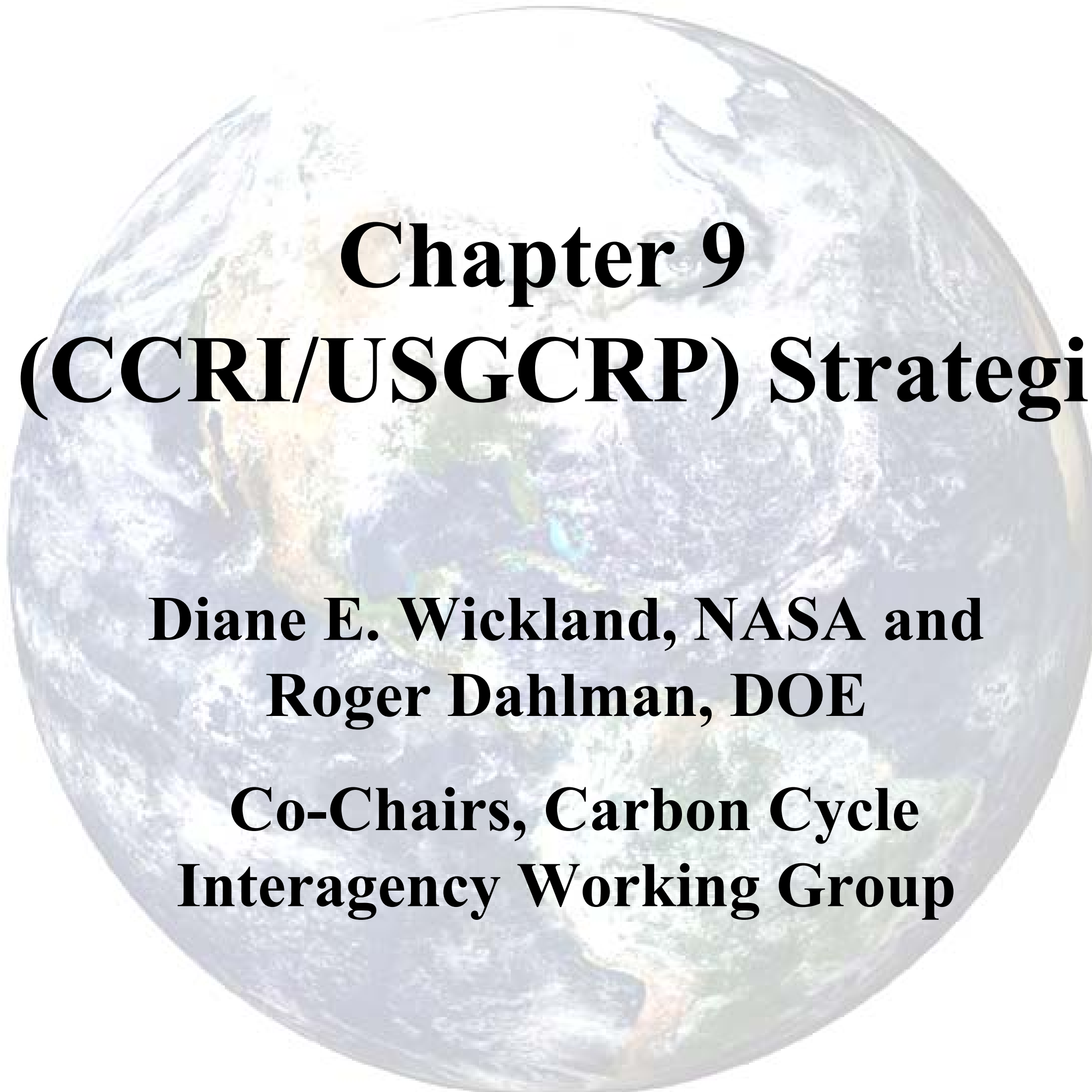
Purpose of “Carbon Cycle” Breakout Session

- Present overview of Chapter 9 in draft Plan
- Opportunity for prepared comments by invited reviewers of the draft Plan
- Opportunity for verbal questions, comments, and discussion from workshop attendees

IMPORTANT Reminder:

To be effective in improving the Strategic Plan, comments should be submitted electronically according to instructions on the website www.climatescience.gov; follow links to Strategic Plan)

Carbon Cycle



Chapter 9
CCSP (CCRI/USGCRP) Strategic Plan

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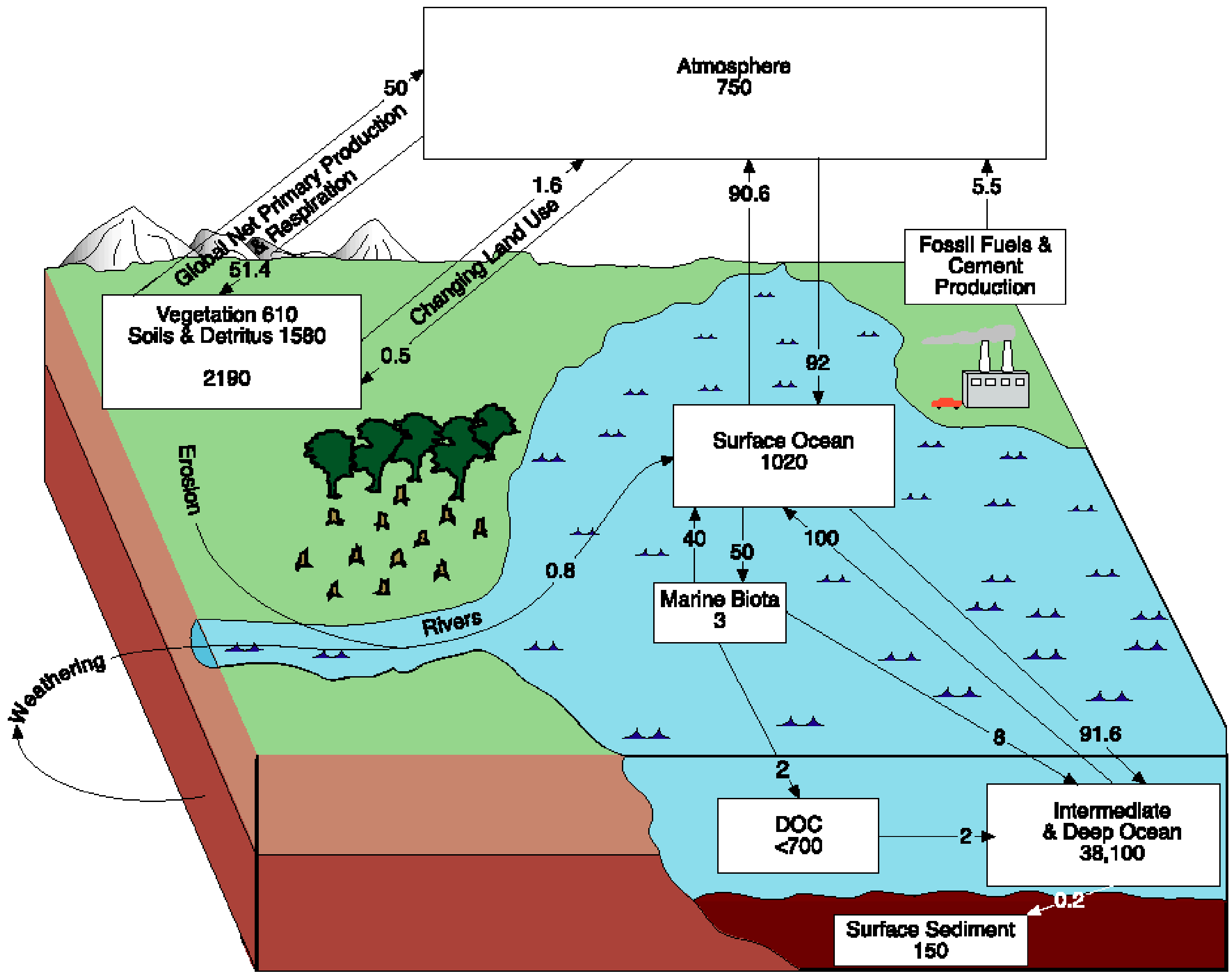
**Co-Chairs, Carbon Cycle
Interagency Working Group**

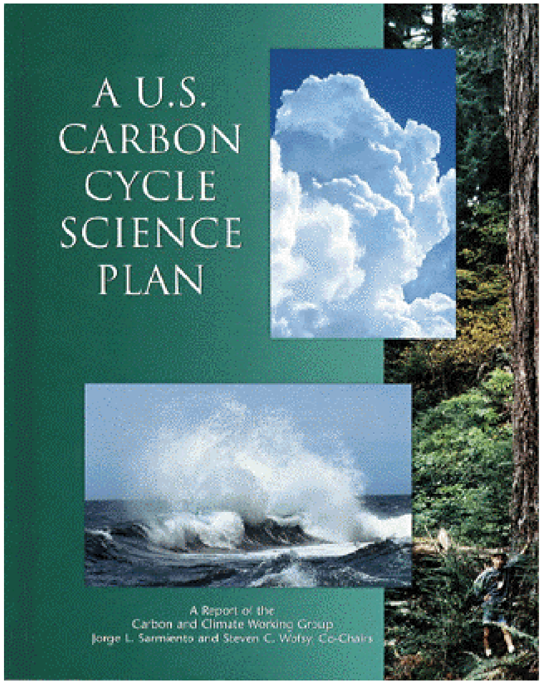
http://www.carboncyclescience.gov

Carbon Cycling is an Integrated Earth System Process



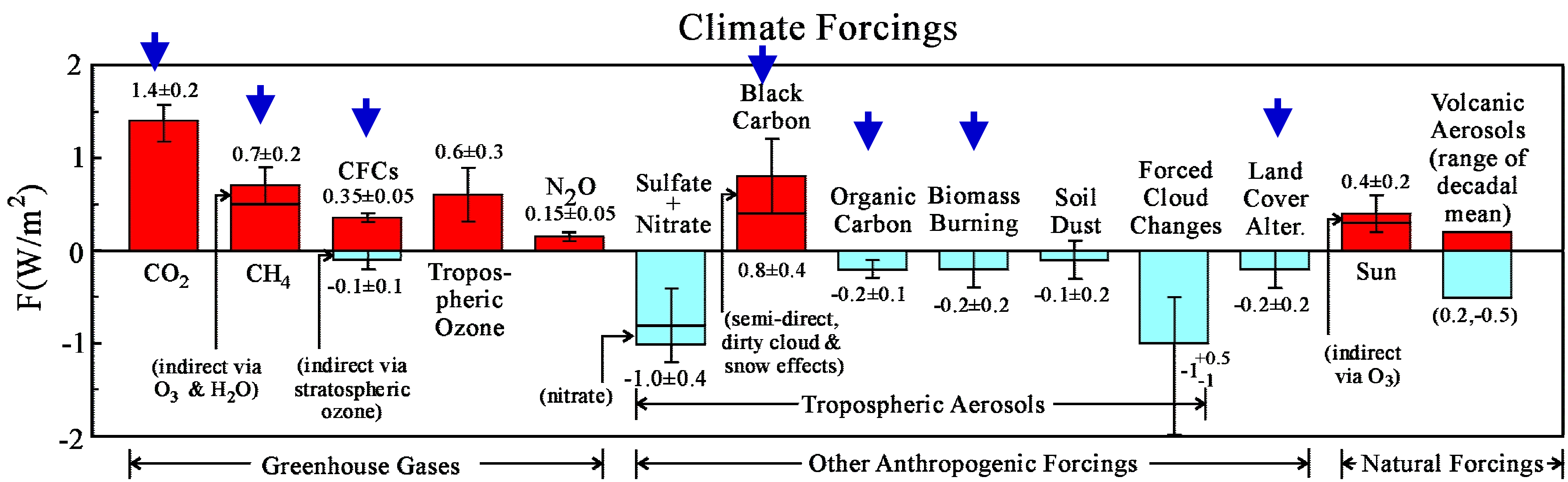
Background: Carbon Cycle Science

Atmospheric concentrations of carbon dioxide (CO_2) and methane (CH_4) have been increasing for about two centuries as a result of human activities. The need to understand how carbon cycles through the Earth system is critically important to our ability to assess the effects of these rising greenhouse gas concentrations and to project future concentrations and effects. **The U.S. needs comprehensive, unbiased scientific information about sources and sinks of carbon and how sources and sinks might change naturally over time or be altered by human activities.** In 1998, the U.S. Global Change Research Program established a Carbon Cycle Science research program to be coordinated by 6 government agencies through the Carbon Cycle Interagency Working Group (CCIWG). **Chapter 9 of the Climate Change Science Program Strategic Plan updates earlier plans for U.S. carbon cycle science research, responds to the President's call to reduce uncertainties about global climate change, and provides a research strategy for the next decade.**



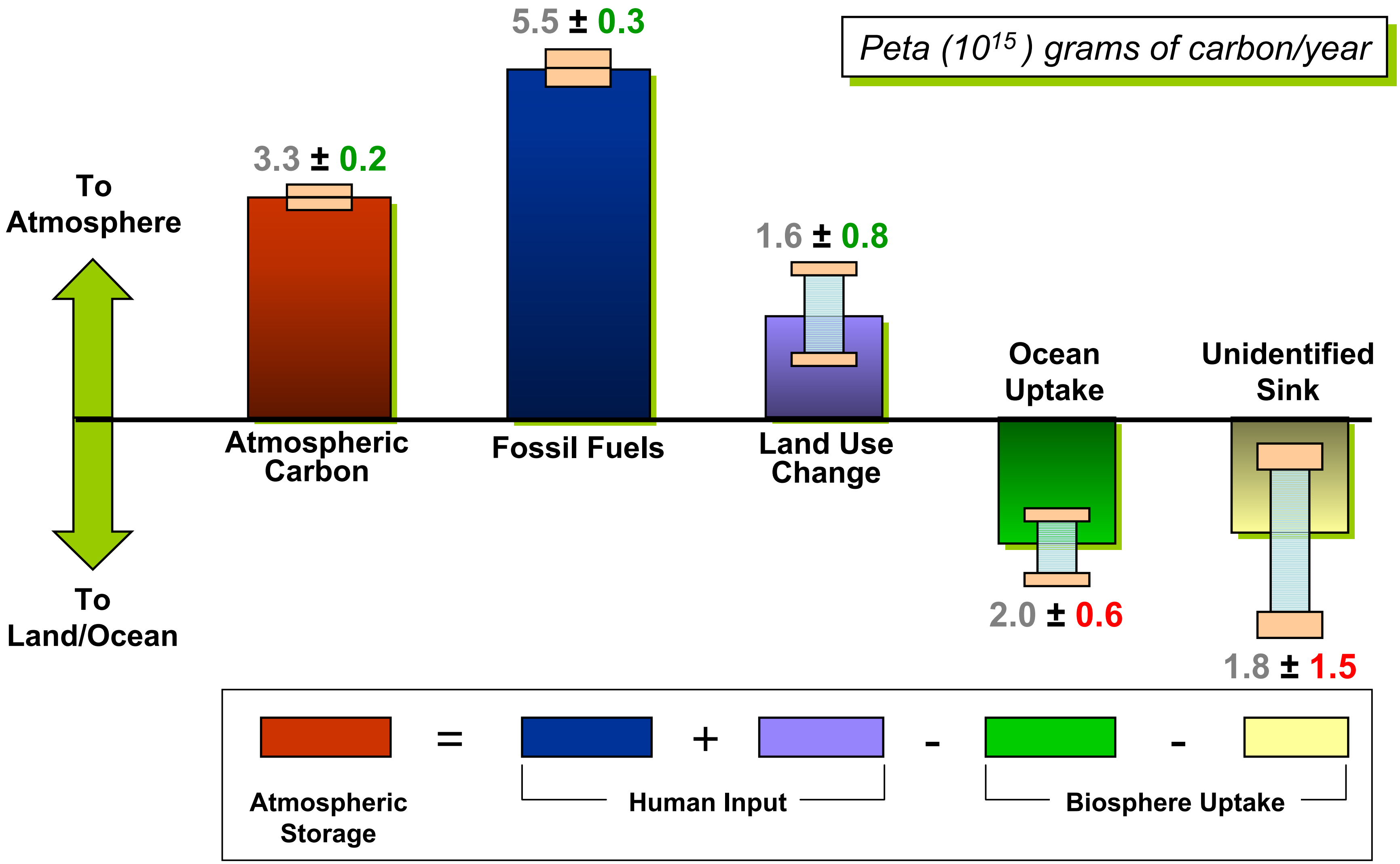
The first step toward achieving an integrated carbon cycle research strategy was the development of "**A U.S. Carbon Cycle Science Plan**" in 1999.

What Are the Key Climate Uncertainties?



- **Uncertainty in forcing agents**
  - Aerosol impact on clouds
  - **Carbon sequestration in land & oceans**
  - Tropospheric ozone change
  - Aerosol composition and microstructure
  - **Smoke and other black carbon sources**
- **Uncertainties in climate response**
  - **Global climate sensitivity (feedbacks:** clouds, water vapor, sea ice, **ecosystems**)
  - Regional patterns of climate change (crucial for practical impacts)
  - **Missing carbon and aerosol data**
  - **Realistic process representations**
  - Spatial and temporal resolution

Current Carbon Cycle Uncertainties



- Current source and sink strengths are uncertain.
- Prediction of future climate forcing is therefore uncertain as well.

Why Carbon Cycle Science?

Information on carbon cycling is needed:

• to reduce uncertainties concerning the potential for climate change

- projections of future atmospheric CO_2 and CH_4 concentrations
- improved process controls for climate models

• to evaluate carbon management options being considered by society

- effects of changes in emissions of CO_2 and CH_4
- effects of deliberate carbon sequestration through enhancement of biospheric storage processes or engineering approaches

•for effective natural resource management in a changing world

Carbon Cycle Science: Overarching Questions

Scientific Question: **How large and variable are the dynamic reservoirs and fluxes of carbon within the Earth system, and how might carbon cycling change and be managed in future years, decades, and centuries?**

Societal question**:** **What are our options for managing carbon sources and sinks to achieve an appropriate balance of risk, cost and benefits to society?**

Carbon Cycle Science Questions

1. What are the magnitudes and distributions of North American carbon sources and sinks and what are the processes controlling their dynamics?
2. What are the magnitudes and distributions of ocean carbon sources and sinks on seasonal to centennial time-scales, and which processes control their dynamics?
3. What are the magnitudes and distributions of global terrestrial, oceanic, and atmospheric carbon sources and sinks and how are they changing over time?
4. What are the effects of past, present, and future land use change and resource management practices on carbon sources and sinks?
5. What will be the future atmospheric CO_2 and CH_4 concentrations, and how will terrestrial and marine carbon sources and sinks change in the future?
6. How will the Earth system, and its different components, respond to various options being considered by society for managing carbon in the environment, and what scientific information is needed for evaluating these options?

Key Linkages for Carbon Cycle Science

Q1 – Atmospheric Composition, Human Contributions and Responses, Ecosystems, Land Use/Land Cover Change; Canada & Mexico

Q2 –Climate Variability and Change, Atmospheric Composition, Human Contributions and Responses, Ecosystems; National Oceanography Partnership Program; GOOS, WOCE, CLIVAR, IGBP

Q3 – Observations, Monitoring and Data Management, Climate Variability and Change, Applied Climate Modeling, Human Contributions and Responses, Scenario Development; IGOS-P, GOOS, GTOS, GCOS, IGBP, IHDP, Global Carbon Project

Q4 – Land Use/Land Cover Change, Ecosystems; NCCTI; IGBP, IHDP, GOFC/GOLD

Q5 - Human Contributions and Responses, Climate Variability and Change, Applied Climate Modeling, Scenario Development, Atmospheric Composition; IGBP GAIM, IHDP

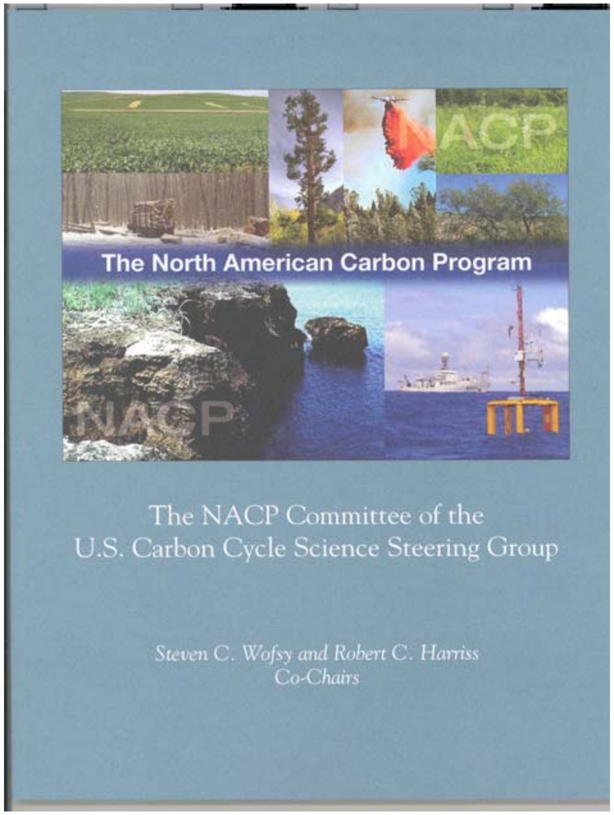
Q6 – Ecosystems, Human Contributions and Responses, Land Use/Land Cover Change; NCCTI, many U.S. agency programs outside CCSP

All – Observations, Monitoring and Data Management, Human Contributions and Responses, Water Cycle, Climate Variability and Change, Atmospheric Composition, Decision Support Resources, Grand Challenges; IGBP, IHDP, IGOS-P

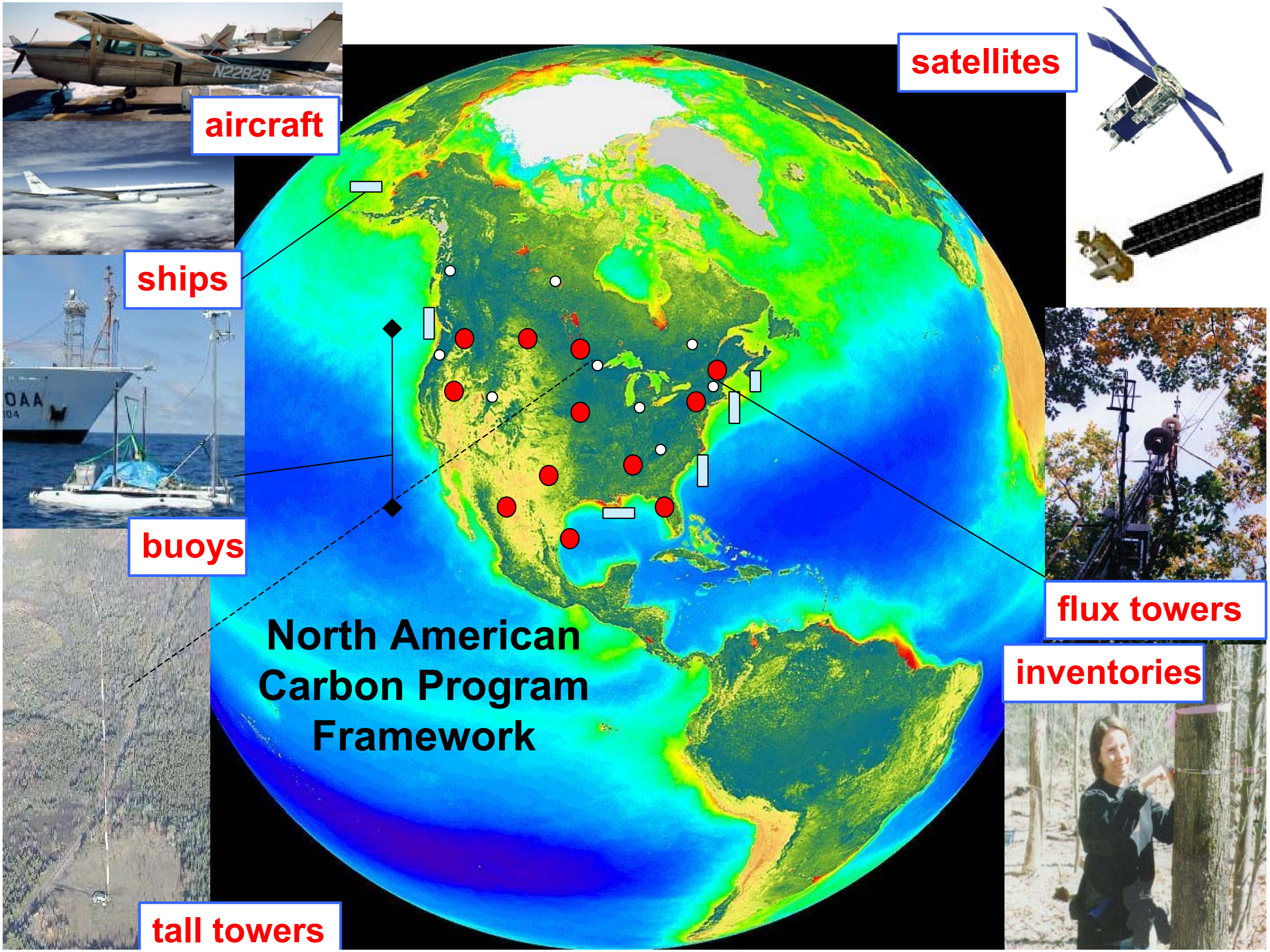
North American Carbon Program (NACP)

The NACP is a coordinated research effort to:

- **develop quantitative scientific knowledge of the emissions and uptake of CO_2, and CH_4, the changes in carbon stocks, and the factors regulating them for North America and adjacent ocean basins**
- **develop the scientific basis for full carbon accounting**
- **support long-term quantitative measurements of carbon sources and sinks and develop forecasts for future trends**



A major step toward implementing the NACP was achieved with the publication of *The North American Carbon Program (NACP)* in 2002.


aircraft
N22825
satellites
ships
buoys
flux towers
inventories
tall towers
North American
Carbon Program
Framework

North American Carbon Program: Observations, Models, Decision Relevance

Observations: atmosphere (in situ network, aircraft, spacecraft)
land surface: land cover, vegetation state
ocean: physical, biological, pCO_2

Diagnostic Models: Atmosphere (transport, clouds, precipitation, temperature)
Land and Ocean: net fluxes, response processes

Data Fusion: assimilate diverse information

Carbon budget for North America (regionally resolved)

Carbon cycle response to climate, human activities

Present, Past

Predictive Models: **Carbon source/sink projections, responses to policy scenarios, verification of outcomes**

Future

Critical Agency Dependencies

USDA
- Forest & soil inventories
- Agricultural & forest managemt.
- Carbon sequestration

NOAA
- Meteorological observations
- Ocean surface temperature and land cover observations
- Atm. CO_2 flask/tall tower network
- Weather models (NCEP)
- Air-Sea CO_2 exchange studies
- Integrated carbon modeling
- Ship-based ocean CO_2 surveys

DOE
- Fossil fuel emissions
- AmeriFlux
- FACE and other CO_2 expts.
- Carbon databases (CDIAC)
- Carbon modeling
- Carbon sequestration

USGS
- Landsat data & data products
- Topography & land cover maps
- Stream gauge network

NASA
- Remote sensing: satellite time series (Landsat, SeaWiFS and EOS); expt. airborne sensors
- Remote sensing research
- Field campaigns--SAFARI, LBA
- Ocean, land, atmosphere and coupled carbon-climate modeling;
- Data sets & DISS

NSF
- Fundamental Earth science research
- Ocean field campaigns
- Process studies
- NCAR, NCEAS, LTER

1. What are the magnitudes and distributions of North American carbon sources and sinks and what are the processes controlling their dynamics?

Research Needs: A **North American Carbon Program** to

- measure carbon stocks and fluxes across **North America and adjacent ocean basins** (enhanced networks, inventories, & surveys)
- characterize key ecosystem and ocean margin processes controlling carbon
- improve models of the carbon cycle

Key Products and Payoffs:

- ***State of North American Carbon Report*** (prototype - 2 yrs.; full - > 4 yrs.)
- **carbon fluxes and stocks** for managed & unmanaged ecosystems, with regional specificity and uncertainties quantified (> 4 yrs.)
- carbon cycle **models with improved processes** (2 yrs.) and the first use of **data assimilation** (2-4 yrs.)

2. What are the magnitudes and distributions of ocean carbon sources and sinks on seasonal to centennial time-scales, and which processes control their dynamics?

Research Needs:

- enhanced observations of carbon fluxes and the fate of carbon
- focused process studies in the N. Atlantic and N. Pacific basins and margins
- an intensive **Southern Ocean Carbon Program** (in ~5-10 years)
- models linking climate, circulation, and biogeochemistry

Key Products and Payoffs:

- quantification of global **air-sea CO_2 fluxes**, and **land to ocean carbon fluxes** (> 4 yrs.)
- greater understanding of the roles of nutrients, species groups, and primary productivity on **deep sea carbon storage** (2-4 yrs.)
- models of **ocean carbon sequestration** incorporating key physical, chemical, and biological processes and ecosystem impacts (> 4 yrs.)

3. What are the magnitudes and distributions of global terrestrial, oceanic, and atmospheric carbon sources and sinks and how are they changing over time?

Research Needs:

- **global monitoring of carbon stocks and fluxes**, new remote sensing observations, and effective international coordination
- characterization of key controls on carbon cycling around the world
- development of innovative new modeling techniques, with **rigorous testing, evaluation, and periodic inter-comparison**

Key Products and Payoffs:

- ***State of the Global Carbon Cycle Report*** (prototype - 4 yrs.)
- **Global maps of carbon storage** derived from model analyses of actual land cover
- Estimates of **carbon flux strength in remaining regions of high uncertainty** (e.g, Amazon: 2-4 yrs.; balanced global budget: > 4 yrs.)
- Evaluation of **potential for dramatic changes and feedbacks** to climate (> 4 yrs.)

4. What are the effects of past, present, and future land use change and resource management practices on carbon sources and sinks?

Research Needs:

- **long-term experimental and monitoring data** for agricultural lands, forests, & other ecosystems, including carbon storage & fluxes
- process studies linked with observations and manipulative experiments to identify **cause-effect relationships**
- models linking ecosystem, management, policy, and socioeconomic factors to project future changes in resource use and carbon

Key Products and Payoffs:

- database on **agricultural management effects on carbon emissions and sequestration** in the U.S. (2 years)
- analysis of the effects of **disturbance** (2 yrs.) and different **land uses & management practices** (4 yrs.) on **biomass and soil carbon**
- **linked ecosystem, resource management, and human dimensions models** (> 4 yrs.)

5. What will be the future atmospheric CO_2 and CH_4 concentrations, and how will terrestrial and marine carbon sources and sinks change in the future?

Research Needs:

- **manipulative field experiments** to determine ecosystem responses to changing environmental factors (e.g., CO_2, temperature, precipitation, nitrogen, iron)
- development of new carbon models and **Earth system models** with dynamic coupling between carbon cycle processes and climate

Key Products and Payoffs:

- synthesis of our understanding of whole **ecosystem response to increasing CO_2** (2-4 yrs.) & **CO_2 combined with warming** (> 4 yrs.)
- carbon cycle models that include land use history, interannual variability, and new process understanding (2-4 yrs.)
- **projections of climate change forcings** and quantification of **feedbacks** among carbon cycle, human actions, & climate (> 4 yrs.)

6. How will the Earth system, and its different components, respond to various options being considered by society for managing carbon in the environment, and what scientific information is needed for evaluating these options?

Research Needs:

- ecosystem observations and experiments at **field sites where new carbon management approaches are being demonstrated**
- **new monitoring techniques and strategies** to measure effectiveness
- models to 1) incorporate basic processes in evaluation of carbon management and 2) assess the economics of management options

Key Products and Payoffs:

- monitoring techniques and strategies to **quantify the efficacy of carbon management** activities (2-4 yrs.)
- evaluation of the **capacity of U.S. ecosystems to sequester carbon** (2-4 yrs.)
- identification of the **effects of enhanced nutrients and elevated CO_2 on carbon storage** in marine and terrestrial ecosystems (> 4 yrs.)