Science Mission Directorate

Carbon Cycle & Ecosystems Roadmap – NACP

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Carbon Cycle & Ecosystems Focus Area

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Program Elements

Ocean Biology and Biogeochemistry
Paula Bontempi and Carlos Del Castillo

Terrestrial Ecology
Diane Wickland and Bill Emanuel

Land Cover and Land Use Change
Garik Gutman

Biodiversity and Conservation Biology
Woody Turner

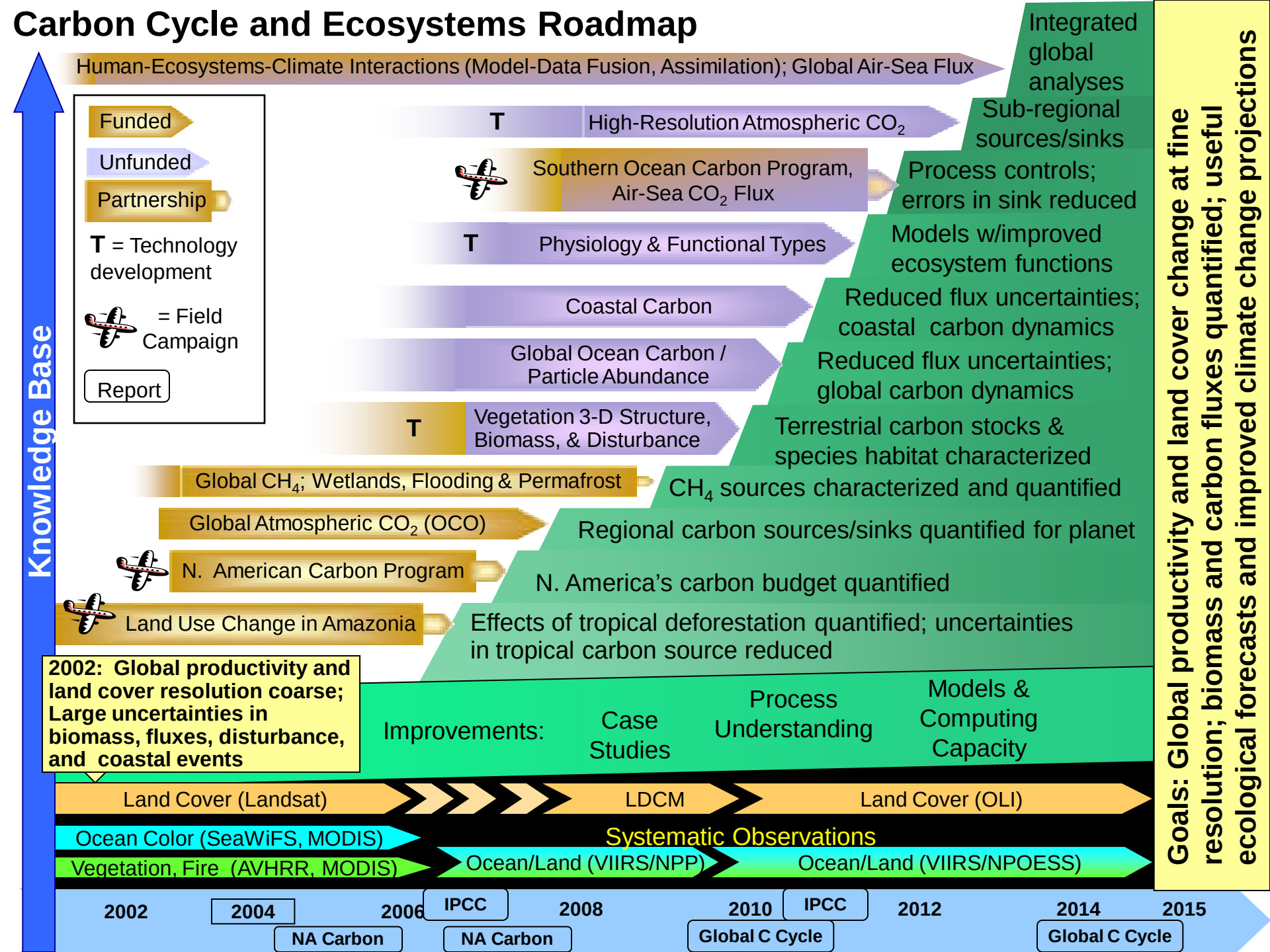
Diane Wickland, Focus Area Lead

Carbon Cycle & Ecosystems Science Questions

How is the Earth changing and what are the consequences for life on Earth?

- **How are global ecosystems changing?**
- **What changes are occurring in global land cover and land use, and what are their causes?**
- **How do ecosystems, land cover and biogeochemical cycles respond to and affect global environmental change?**
- **What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?**
- **What are the consequences of climate change and increased human activities for coastal regions?**
- **How will carbon cycle dynamics and terrestrial and marine ecosystems change in the future?**

Carbon Cycle and Ecosystems Roadmap

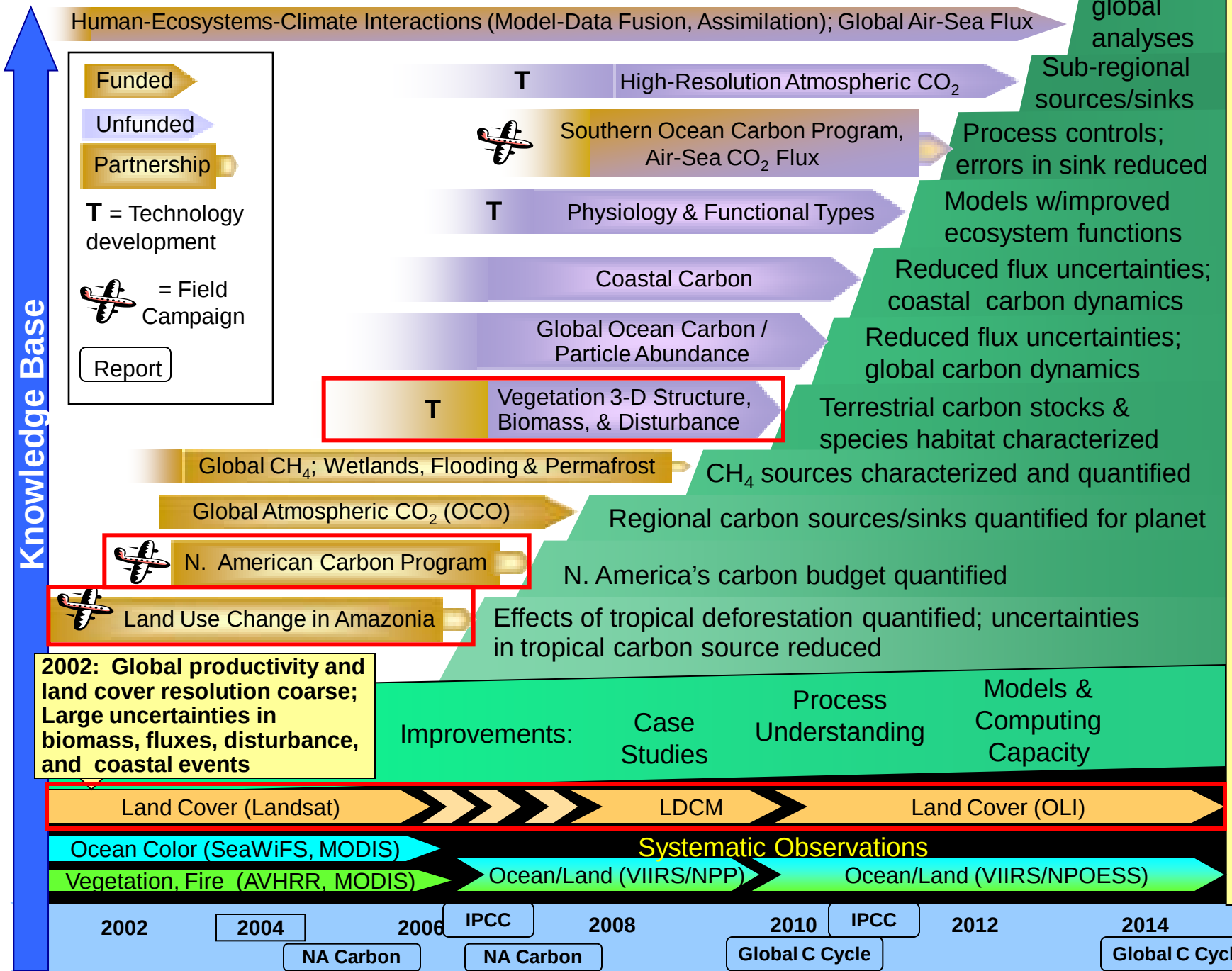


Anticipated Progress

Where we are now	Where we plan to be
Global primary productivity and land cover time series available at coarse (~8 km resolution); only short time periods and certain regions at higher resolutions.	Decadal variability in global productivity quantified at moderate (~1 km) resolution; Periodic global land cover change analyzed at fine (~30 m) resolution.
Available observations (*in situ*) of global CO_2, biomass, plant community vertical structure, and species functional groups insufficient to resolve many issues.	New observations (space-based) enable quantification of carbon and nutrient storage and fluxes, disturbance and recovery processes, and ecosystem health.
Large uncertainties in N. Hemisphere terrestrial carbon storage, ocean uptake and storage, permafrost outgassing, and tropical land use effects. Global carbon budget not balanced.	Carbon sources and sinks identified and quantified at sub-regional scales (~100 km), with small errors. Global carbon budget balanced on annual basis.
Ecosystem and carbon models resolve only large year-to-year variations; multiple controlling processes not well quantified. 50-year projections vary widely.	Earth system models able to correctly portray most interannual variations and multiple, interacting controlling processes, with sub-regional specificity and useful predictive capability.

2002 ~ 2015

Carbon Cycle and Ecosystems Roadmap



North American Carbon Program (NACP)

The central objective of the North American Carbon Program is to measure and understand the sources and sinks of CO_2, CH_4, and CO in North America and in adjacent ocean regions.

NACP Goals

- **Develop quantitative scientific knowledge, robust observations, and models to determine the emissions and uptake of CO_2, CH_4, and CO, changes in carbon stocks, and the factors regulating these processes for North America and adjacent ocean basins.**
- **Develop the scientific basis to implement full carbon accounting on regional and continental scales. This is the knowledge base needed to design monitoring programs for natural and managed CO_2 sinks and emissions of CH_4.**
- **Support long-term quantitative measurements of fluxes, sources, and sinks of atmospheric CO_2 and CH_4, and develop forecasts for future trends.**

NACP Questions

1. What is the carbon balance of North America and adjacent oceans? What are the geographic patterns of fluxes of CO_2, CH_4, and CO? How is the balance changing over time? (Diagnosis)

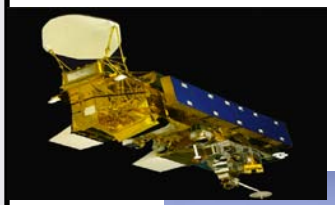
2. What processes control the sources and sinks of CO_2, CH_4, and CO, and how do the controls change with time? (Attribution/Processes)

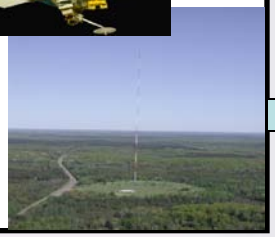
3. Are there potential surprises (could sources increase or sinks disappear)? (Prediction)

4. How can we enhance and manage long-lived carbon sinks ("sequestration"), and provide resources to support decision makers? (Decision support)

NACP Approach

Observations



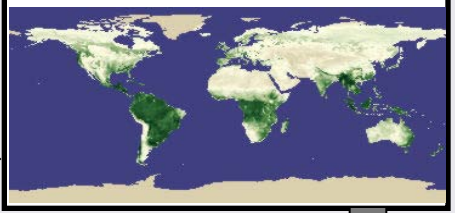


Experiments

Model-Data Fusion

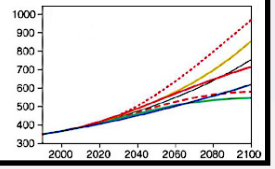
Diagnostic Models

Dynamic Maps



Decision Support

Predictive Models



Observations & Experiments ⇨ Science Results ⇨ Estimates-Uncertainties

NACP Hierarchical Measurements Over Land

Continental "wall-to-wall" by remote sensing

- 80 projects involving satellite and aircraft remote sensing
- NASA supports 65

Extensive inventories (FIA and NRI)

- More than 170,000 sites at 5-10 yr intervals
- Improved sampling for carbon

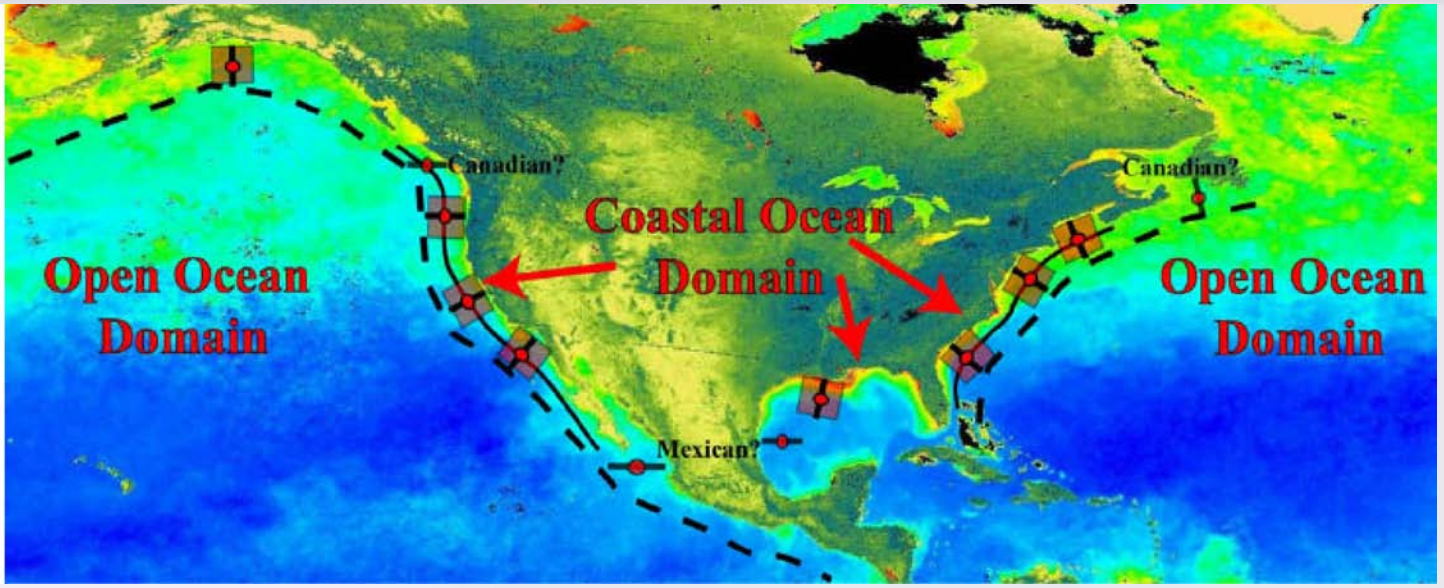
Intermediate intensity with systematic sampling

- Pilot Forest Service projects
- Potential NEON contributions
- Requires substantial additional funding

Very intensive process investigations

- ~100 AmeriFlux, Agriflux, LTER, and similar sites

NACP Ocean Observations and Modeling



- Adjacent open oceans are major sources and sinks for carbon transported across North America through the atmosphere.
- River-dominated margins and coastal upwelling regions merit special attention due as boundaries on North America.
- Coordination with Ocean Carbon and Climate Change Program (OCCC).

NACP Intensive Campaigns

- The North American Carbon Program (NACP) conducts intensive experimental and field campaigns to:
  - Address specific science issues, questions and hypotheses;
  - Reduce specific, major uncertainties;
  - Develop and test methods and models;
  - Calibrate and validate remote sensing observations relevant to NACP objectives; and
  - Produce critical data or analyses.
- NACP intensive campaigns may focus on a specific region or regions within North America.

- But the NACP is not a collection of intensive campaigns.

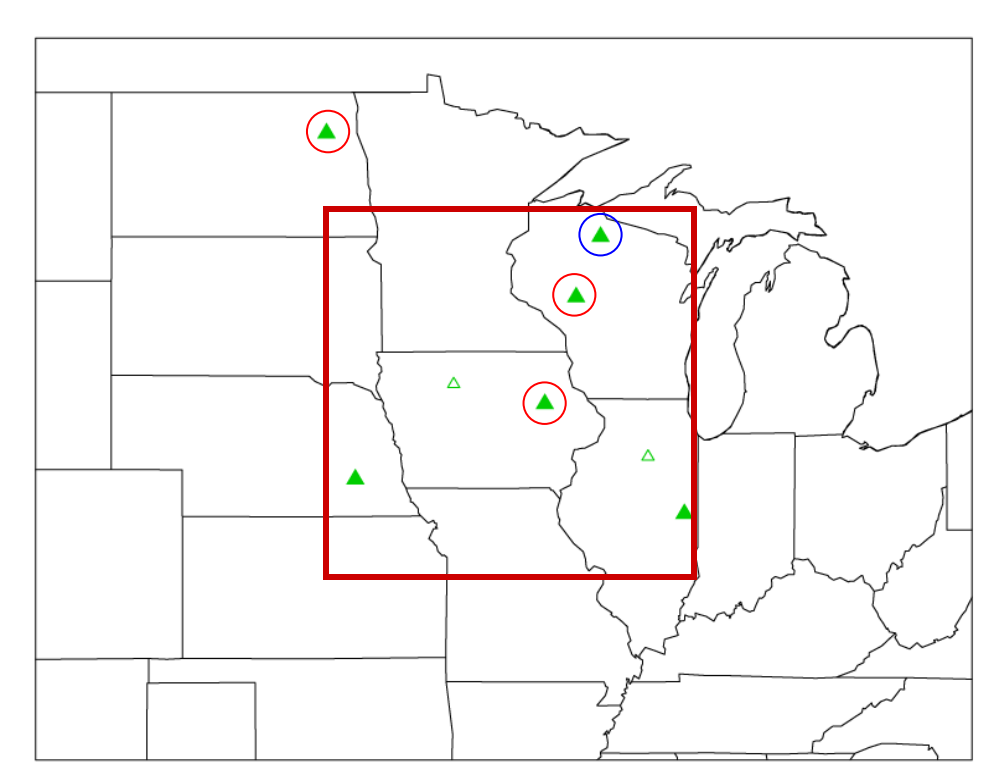
Mid-Continent Intensive Campaign

Pieter Tans, NOAA-CMDL

- Develop optimized sampling schemes for field and atmospheric measurements to efficiently monitor regional carbon stocks and fluxes.
- Use top-down approaches to provide a region-level estimate of net carbon fluxes during short periods (weeks) with an accuracy of 10% by increasing spatial and temporal coverage of atmospheric measurements and by enabling improvements in the parameterization of transport/mixing processes in the lower atmosphere.
- Use a variety of bottom-up techniques to provide daily to annual estimates of carbon stocks and fluxes over a region by improving process model structure and parameterization. A hierarchy of field and remote sensing observations should be used for model testing, development of data assimilation techniques, and model parameterization.
- Compare the top-down and bottom-up approaches and iteratively improve the independent approaches on daily to annual time scales.
- Produce carbon stock and flux maps at various levels of spatial and temporal detail, and compare the results of the top-down and bottom-up approaches to diagnose methods.

NOAA-CMDL Geographic Domain

The multi-state area of the upper Midwestern United States comprising eastern South Dakota, eastern Nebraska, eastern Kansas, northern Missouri, Iowa, southern Minnesota, southern Wisconsin, and Illinois.



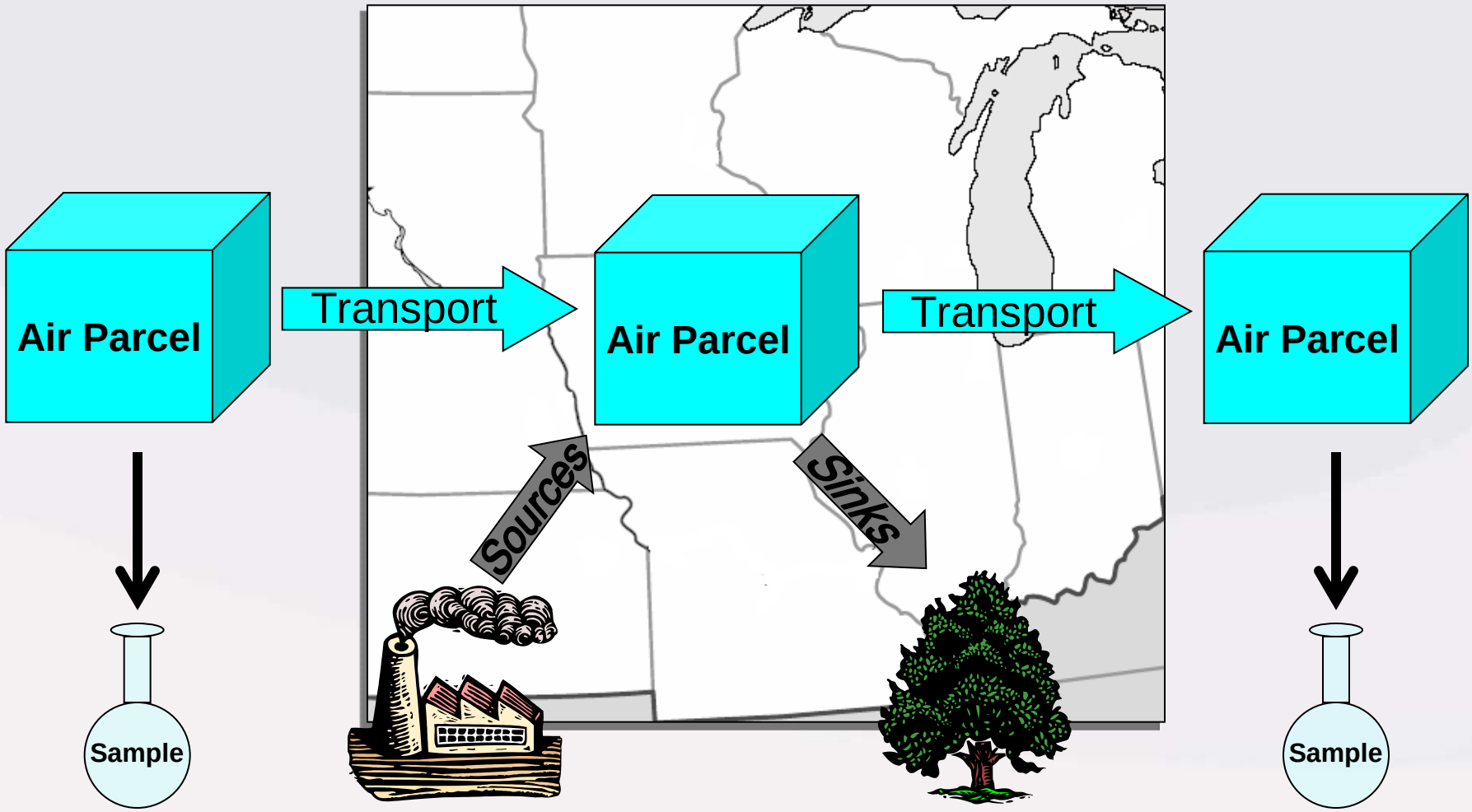
▲ Planned Tower Site

△ Alternate Tower Site

○ Current

○ Highest Priority

Inverse Model Solutions for Sources and Sinks



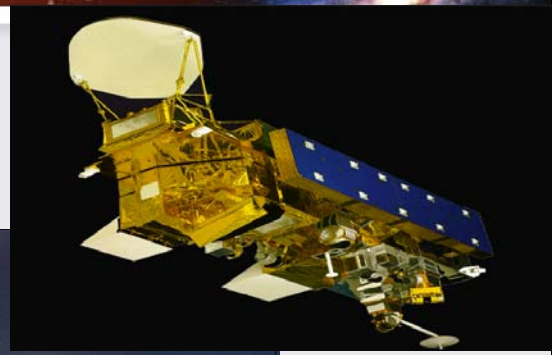
Multiple Scale Observations

1000 km

Up-scaling

Prediction

10 km



ha

m

µm

Downscaling

Verification

Advance Planning

Requirements

- **Updated program plan and roadmap chart**
- **Renewed input from the broad community and a fresh look at priorities**
- **Critical evaluation in light of new NASA (e.g., Exploration and agency-wide roadmapping) and other (e.g., CCSP, GEOSS) priorities**

Approach

- **Participation by NASA Ocean Biogeochemistry, Land Cover and Land Use Change, Terrestrial Ecology, and Biodiversity program managers and researchers (parallel working groups, coordinated by focus area steering committee)**
- **~18 months to seek broad inputs, assess and prioritize, write and iterate, as necessary**
- **White papers, workshops, major community conference(s) – use existing science team meetings, as appropriate, to produce one integrated program plan for the focus area**

Land Measurements Team

Transition from Missions to Time-Series Measurements

- **Form one team combining requirements for measurements of land cover/change (including snow cover), vegetation biophysical properties & indices, land surface temperature, and fire.**
- **Build on experience of past and present mission teams and data system activities. Start with currently funded team members and PIs doing relevant research; compete membership as needs and opportunities arise.**
- **Scientists using the data as well as algorithm developers and data system managers must be on the team.**
- **The team must include representatives from other U.S. agencies with responsibilities for operational measurements or end uses.**
- **NASA HQ will appoint a steering committee soon.**
- **Early activities will identify climate-quality data records, evaluate quality/utility of data products, and assess data system, service, and archive needs**