

A world map with a color-coded overlay representing carbon cycle data. The colors range from blue (low values) to red (high values), with green and yellow in between. The overlay is most prominent over the continents, particularly in the Northern Hemisphere. The text is overlaid on a semi-transparent white rectangular background.

GSFC Carbon Cycle Theme: Strategy Overview

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GSFC Carbon Research Contributions

Instruments (Missions):

- AVHRR (NOAA)
- Coastal Zone Color Scanner
- SeaWiFS
- Landsat
- MODIS (Terra, Aqua)
- VIIRS (NPP, future)

Community Software:

- Landsat Analysis System
- SEAPAK
- SeaWiFS Data Analysis System

Field Programs:

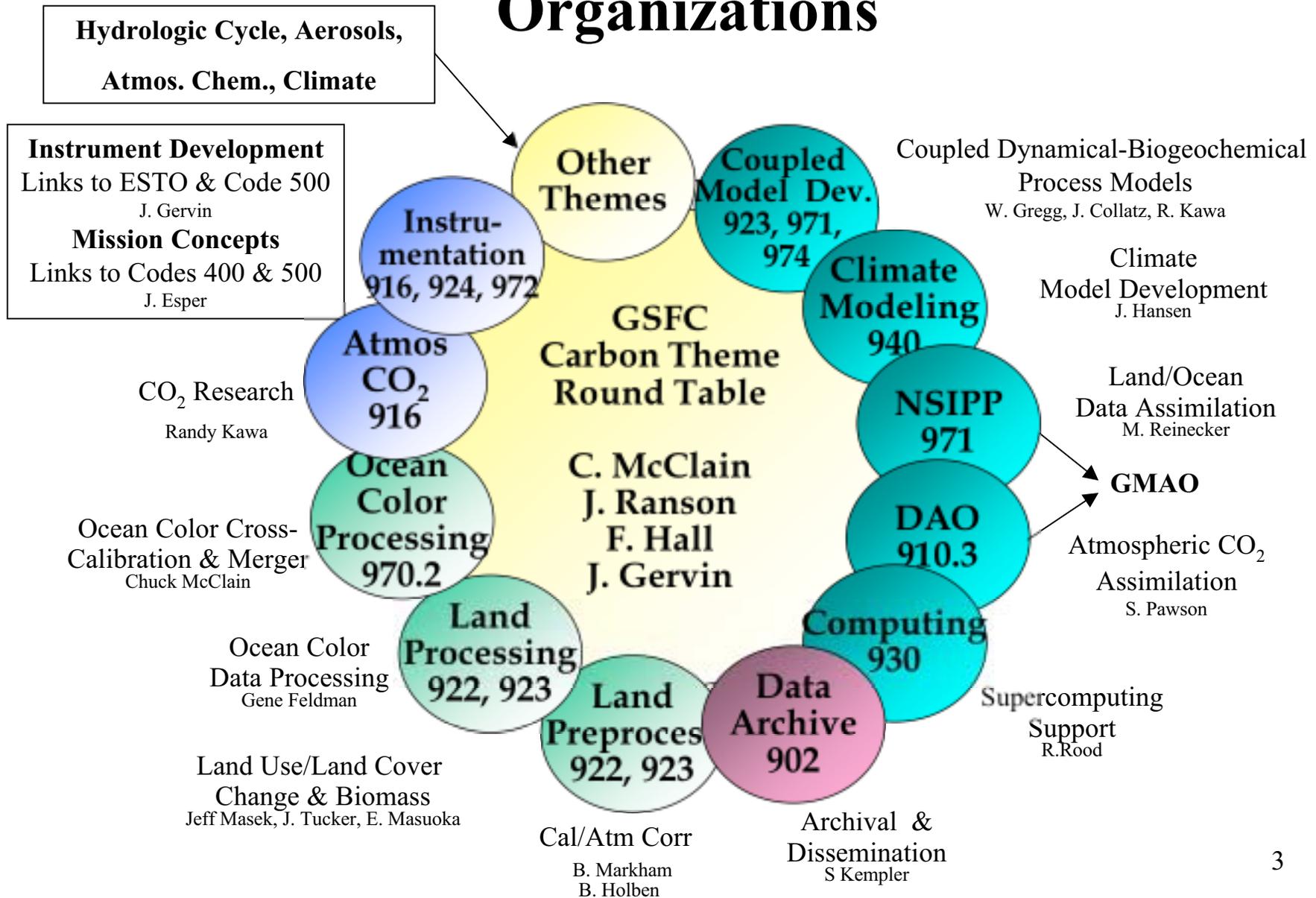
- First ISLSCP* Field Experiment
- Boreal Ecosystem-Atmosphere Study
- Large Scale BiosphereAtmosphere Experiment in Amazonia
- Atlantic Meridional Transect series

Data Sets:

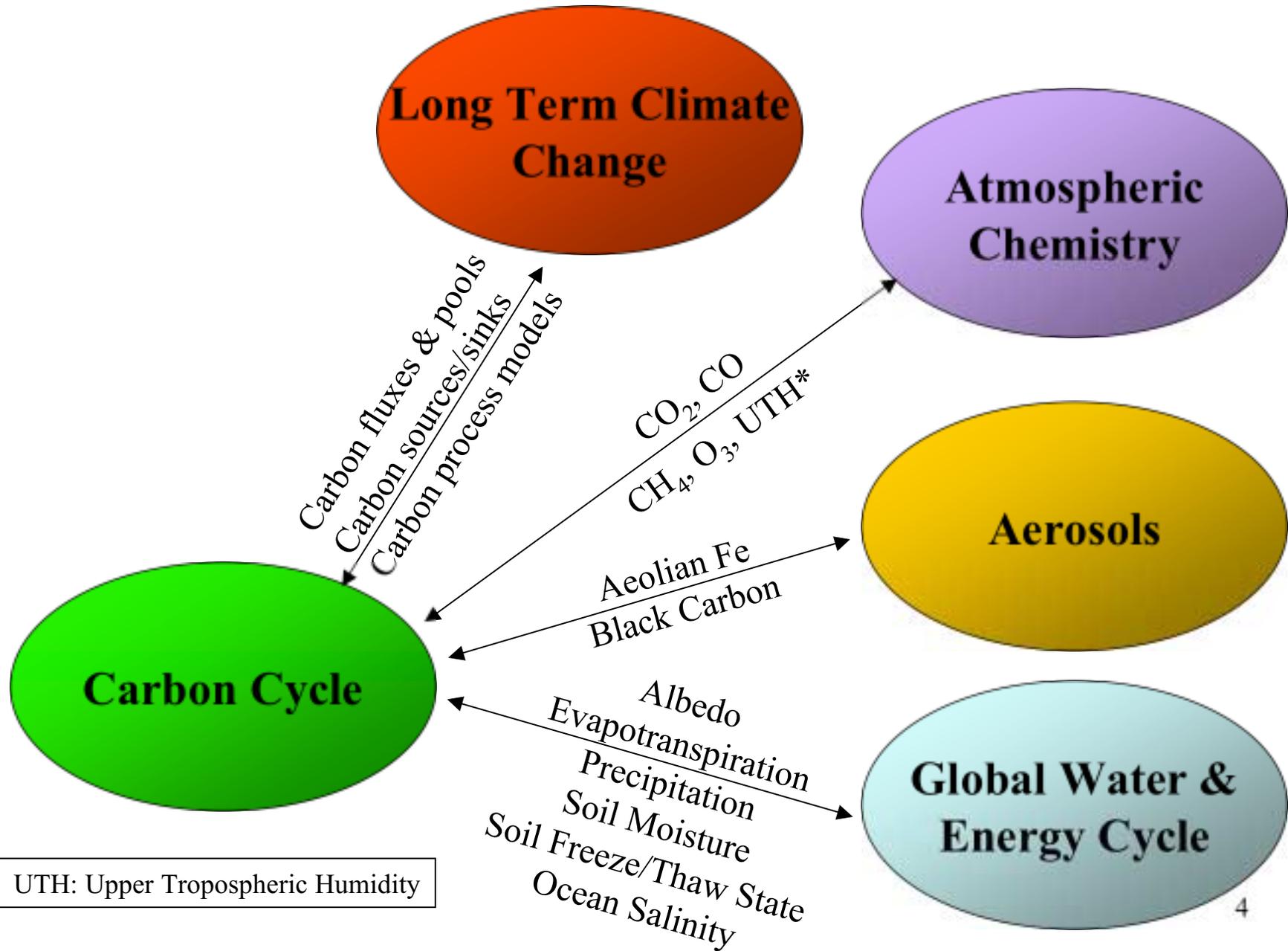
- NDVI time series (AVHRR, MODIS, SeaWiFS)
- Ocean Color global chlorophyll time series (CZCS, SeaWiFS, MODIS)
- ISLSCP multidisciplinary data set

* International Satellite Land Surface Climatology Project

GSFC/ESD Carbon Theme Elements & Organizations



GSFC/ESD Theme Connections



GSFC/ESD Carbon Theme Responsibilities

	Observations	Satellite Carbon Data Processing, Archival, & Synthesis	Modeling & Data Assimilation
Infrastructure Support*			
Research			
Enabling Activities	<ul style="list-style-type: none"> • Field Campaign Coordination • Science Community Coordination 	<ul style="list-style-type: none"> • Ocean carbon data • Atmospheric carbon data • Land cover & biomass data • Integrated carbon data sets • Community processing SW 	<ul style="list-style-type: none"> • OSSE's • Operational demonstrations of satellite data assimilation
Technology Development Activities	<ul style="list-style-type: none"> • Land, ocean, atmosphere measurement protocols 	<ul style="list-style-type: none"> • Processing & data distribution system 	<ul style="list-style-type: none"> • Data assimilation method development • High speed computing technology
Research Activities	<ul style="list-style-type: none"> • Satellite CO₂ • Satellite Land Biomass • Satellite Ocean Carbon 	<ul style="list-style-type: none"> • Data synthesis 	<ul style="list-style-type: none"> • Coupled land, ocean, atmos. physical-biogeochemical models (inc. carbon) • Model development • Carbon cycle science
Programmatic Support	Foster cross-discipline collaboration Track Solicitations Identify Gaps, Measurement requirements Mission concept development Technology development planning		Coordination with Codes 400 & 500 HQ support Activity prioritization Facility requirements Hiring priorities

* "Infrastructure Support,, alludes to functions that are program enabling activities particularly suited for NASA Centers to conduct in collaboration with the science community, e.g. SIMBIOS and GMAO.

CCRP/USGCRP Carbon Science Goals

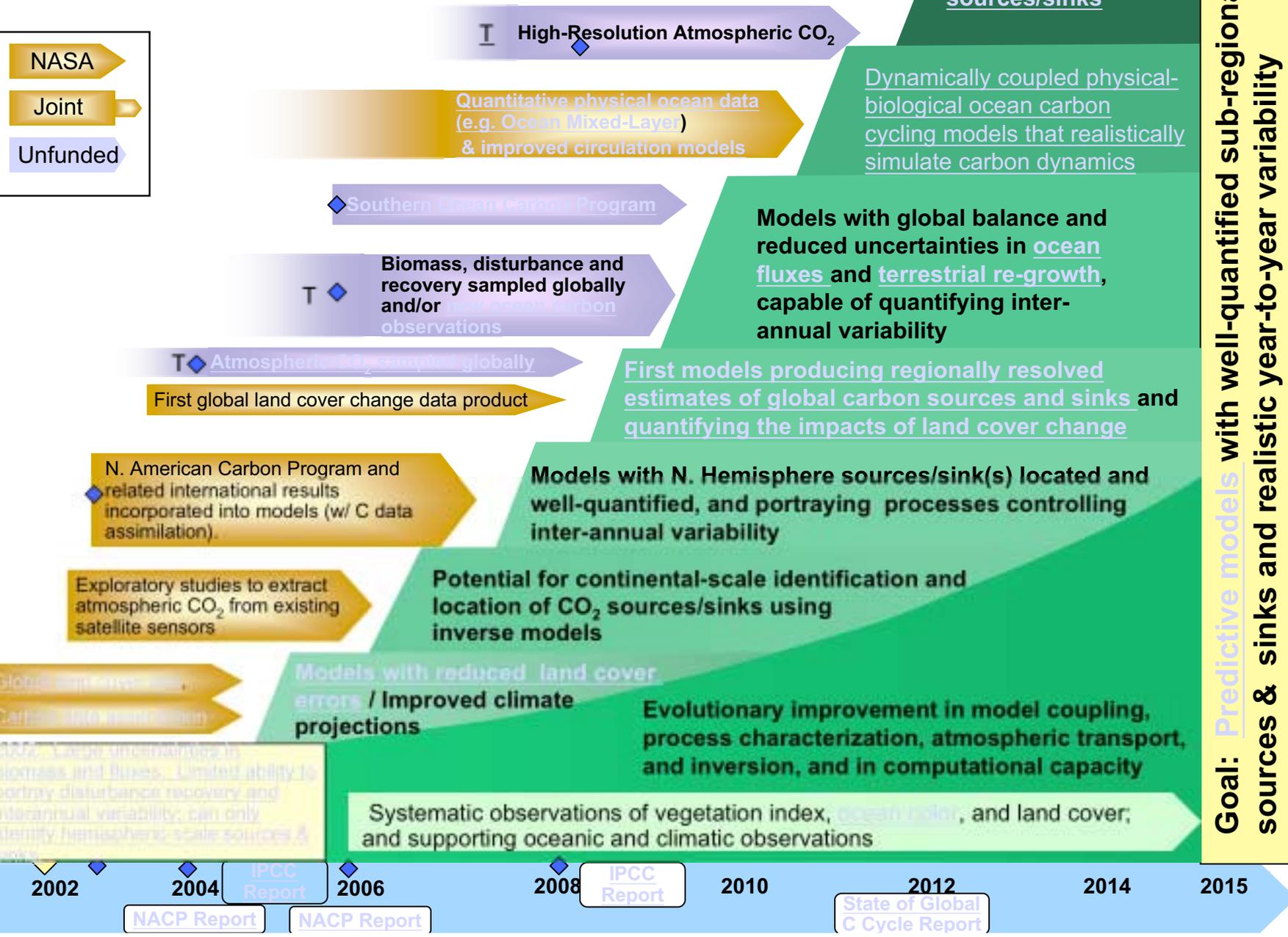
(Carbon Cycle Interagency Working Group)

- Goal 1: Quantify **North American carbon sources and sinks** and the **processes** controlling their dynamics.
- Goal 2: Quantify the **ocean carbon sink** and the **processes** controlling its dynamics.
- Goal 3: Report the “state of the global carbon cycle” annually.
- Goal 4: Evaluate the impact of **land use change** and land and marine resource management practices on carbon sources and sinks.
- Goal 5: **Forecast** future atmospheric CO₂ concentrations and changes in terrestrial and marine carbon sinks.
- Goal 6: Provide the **scientific underpinning**, and evaluations from specific test cases, for management of carbon in the environment.

Carbon Cycle & Ecosystems

Knowledge Base

- NASA
- Joint
- Unfunded



2002: Large uncertainties in biomass and fluxes. Limited ability to portray disturbance recovery and interannual variability; can only identify hemispheric-scale sources & sinks.

GSFC Carbon Theme Activity Priorities

- **NASA Program Infrastructure Support Activities**
 - **In situ carbon observation support (land, ocean, atmos.)**
 - Field measurement protocol development
 - Ocean color ongoing*; Land & atmospheric carbon protocols to be defined
 - In situ instrument evaluation & development
 - Ocean color ongoing*; Land & atmospheric carbon measurement activities TBD
 - Calibration round robins
 - Ocean color ongoing*; EOS program ongoing
 - **Carbon data processing**
 - Ocean color data processing facility**
 - Land data processing facility**
 - **Carbon data assimilation*****
 - Atmospheric data: GMAO
 - Land & ocean data: GMAO
- * Previously supported under SIMBIOS; future activities TBD.
- ** Includes basic sensor calibration, product validation & quality control analyses.
- *** Includes resources for implementation of process models designed for carbon data assimilation in collaboration with science team (competed).

GSFC Carbon Theme Activity Priorities (*cont.*)

- **Research Activities**
 - **NACP**
 - Ocean, land, & atmosphere field observations
 - Ocean, land, & oceans modeling & data assimilation
 - **Land and ocean carbon cycle process model development**
 - **Land, ocean, & atmosphere mission calibration/validation (activities not covered under “core” & algorithm development), i.e.,**
 - Ocean & Land: MODIS, NPP/VIIRS
 - Atmosphere: AIRS
 - **Carbon data synthesis and distribution**
 - **Land, ocean, & atmosphere technology development and carbon missions**
 - Atmospheric CO₂ (active & passive)
 - Land cover, biomass, & productivity (active & passive)
 - Ocean carbon (active & passive)

Measurement concept &/or instrument development underway in all cases.

GSFC Carbon Theme Activity Priorities (*cont.*)

- **Mission Concepts**
 - Atmospheric CO₂ (active & passive)
 - Lidar sounder
 - Fabry-Perot interferometer (not to mission concept development yet)
 - Land cover, biomass, and productivity (active & passive)
 - Biomass dual-wavelength lidar
 - SpectraSat (hyperspectral, low Earth orbit)
 - GeoHype (hyperspectral, geostationary)
 - Ocean carbon and productivity (active & passive)
 - GeoHype (hyperspectral, geostationary)
 - Physiology Lidar-Multispectral Mission (PhyLM)

Measurement concept &/or
instrument development underway
in all cases.

GSFC Carbon Theme External Links*

- Processing, Archiving and Synthesis of Carbon Data
 - Integration of Satellite Data Streams
 - IPO/NPP & NPOESS
 - USGS/EDC, LCDM, EarthSat, MEA
 - MERIS, POLDER, GLI, etc. (ESA, France, Japan, etc.)
 - Land Cover, Land Cover Change Protocols
 - USGS/EDC
 - MEA
 - FIA (USFS)
 - UMD/CP
 - Data Synthesis
 - GEWEX
 - IGBP
 - NODC, NIDC (NOAA)
 - CDIAC (DOE)
- Modeling & Data Assimilation
 - GMAO
 - GODAE
 - UMD/CP
 - ODU, Rutgers, Penn State, SUNY, URI (NASA IDS)
- Observations, Field Experiments, Data Networks
 - Ocean Biogeochemistry Science Team
 - Combined Cal/Val & Applications
 - MODIS Ocean & Land Teams
 - NACP (USGCRP)
 - CO₂: Drexel U.
 - Global Ocean Observing System
 - Global Terrestrial Observing System
 - AERONET

* “Links” implies research collaborations &/or participation in working groups

Accomplishments: General

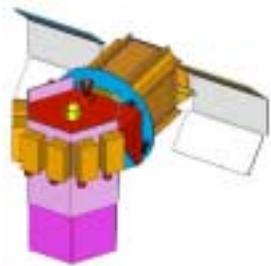
- **Have stimulated a number of innovative concepts for new ocean and land carbon missions**
 - Geostationary hyperspectral mission (GeoHype)
 - Land & ocean observations
 - Ocean physiology lidar-multispectral mission (PhyLM)
 - Ocean & aerosol observations (includes terrestrial coverage)
 - LEO terrestrial hyperspectral mission (SpectraSat)
- **Have been awarded a number of key carbon cycle science and applications investigations**
 - Ocean & land REASoN-CAN product generation proposals
- **Have significantly increased GSFC interdisciplinary interactions across 900, 500, and 400**
- **Have assisted Code Y and Carbon Cycle IWG in carbon research strategies**

2003 Accomplishments: Specific

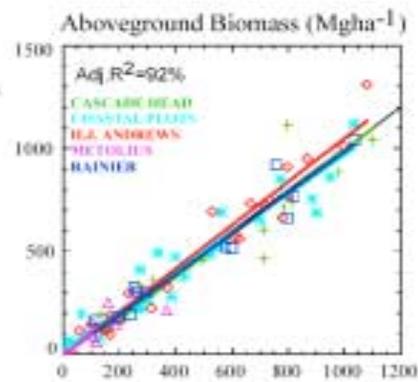
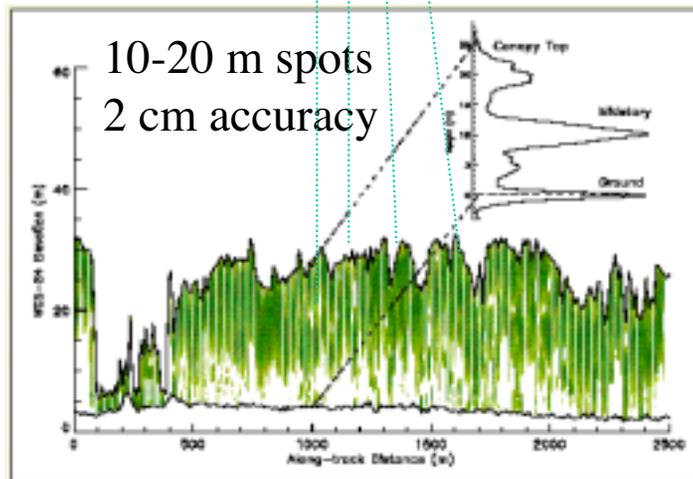
- Submitted land and ocean proposals in response to the ReaSON-CAN to generate carbon data sets (both funded).
- Participated in the Climate Change Research Program (CCRP) community workshop and subsequent recommendations.
- Hosted 2 GSFC carbon lidar workshops and published summary technical memorandum.
- Completed geostationary hyperspectral land-ocean carbon mission formulation (including journal article and ISAL)
- Participated in the Ocean Carbon Plan formulation and document for the Carbon Cycle Interagency Working Group (CCIWG).
- Generated long and short versions (documents and presentations) of the GSFC Carbon Theme strategy.
- Provided carbon requirement inputs to the SBIR & subsequent assistance in reviewing in situ measurement proposals)
- Development of an earth science discipline processing strategy for NASA HQ (under the auspices of with the NPOES Preparatory Project)
- Assisted Diane Wickland (HQ, Code Y) develop the CarbonCycle & Ecosystems Roadmap
- Participated in the North American Carbon Program (NACP) community workshop
- Submitted two carbon theme IR&D proposals (in support of technology development for geostationary hyperspectral observations).
- Submitted several DDF proposals for carbon research and development (new and renewals)
- Developed the PhyLM mission concept with presentations to HQ and Code 900.
- Submitted B&P proposals in support of various land and ocean carbon mission concepts.
- Tracked and facilitated individual responses to NPP, IDS, and EOS solicitations.
- Reviewed GOES-R hyperspectral suite specifications for coastal oceans and land and provided recommendations
- Provided terrestrial science rationale for SpectraSat.
- Provided ESTO with carbon technology development recommendations
- Worked with Code 500 and NRL on two separate proposals in response to Code R technology development solicitation in support of a geostationary hyperspectral land-ocean carbon mission
- Submitted two white papers to CCIWG for NACP intensive sites
- Specific presentations: Carbon Cycle MTR, Code 900 Mini-retreat, Code Y Applications Program (Ed Sheffner), HQ Carbon Cycle review (ocean carbon processes), Code 900 Visiting Committee

Biomass & Productivity from Space

Lidar
Concept



1064 nm



Hyperspectral
Concepts from
GEO, LEO



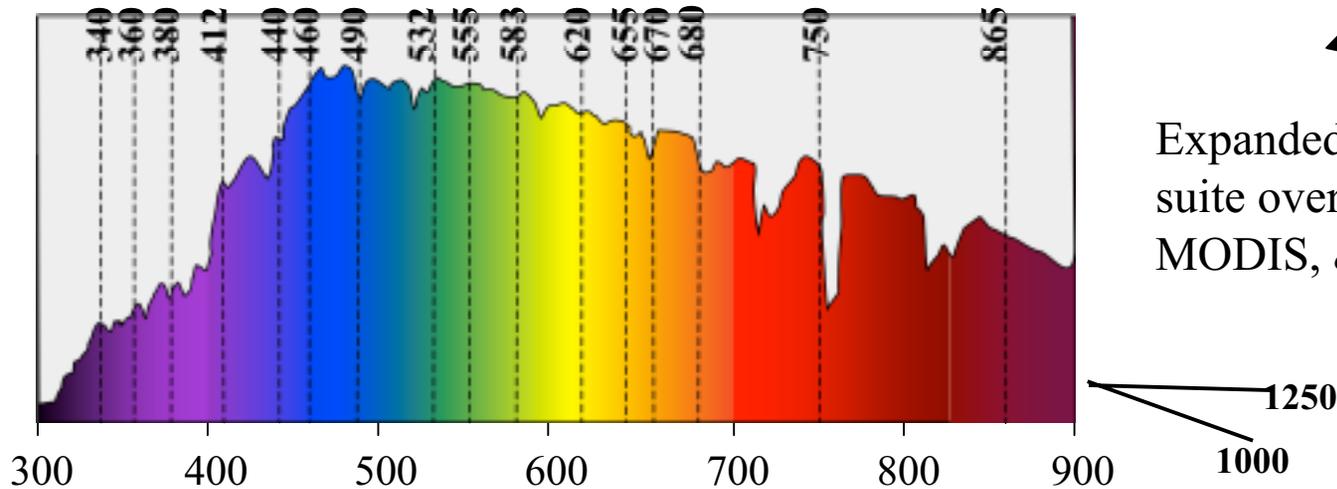
Mixture decomposition
Stand geometry, LUE



Physiology Lidar-Multispectral Mission

An Ocean Biogeochemistry Mission with Aerosol Observations

- ✓ Passive technology well-developed
- ✓ Active technology builds from GLAS & Calypso
- ✓ Benefits VIIRS & continues GLAS-Calypso time series



Expanded measurement suite over SeaWiFS, MODIS, & VIIRS

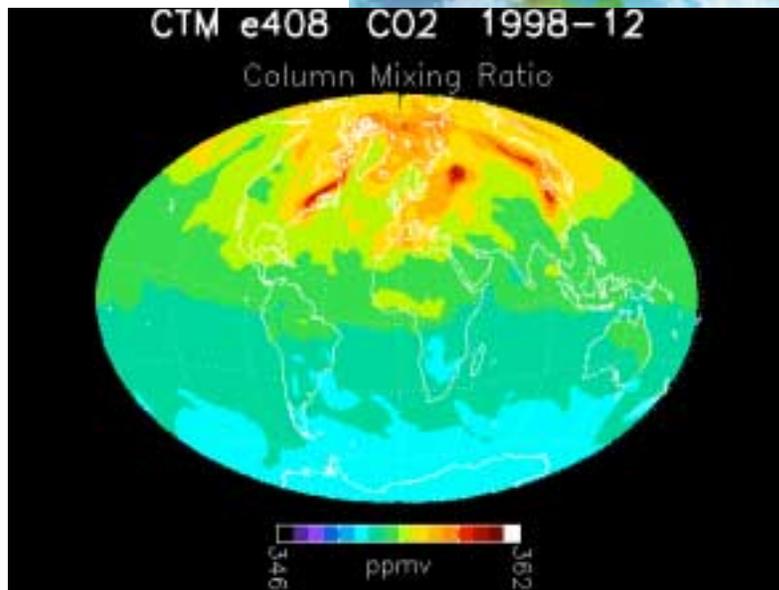
- ✓ Builds on GSFC experience in Ocean Color & Aerosols
- ✓ Major data quality improvements particularly in coastal/shelf regions
- ✓ Addresses multiple NASA Carbon Cycle goals identified as priorities
- ✓ Products for Atmosphere, Land, & Ocean science

Atmospheric CO₂

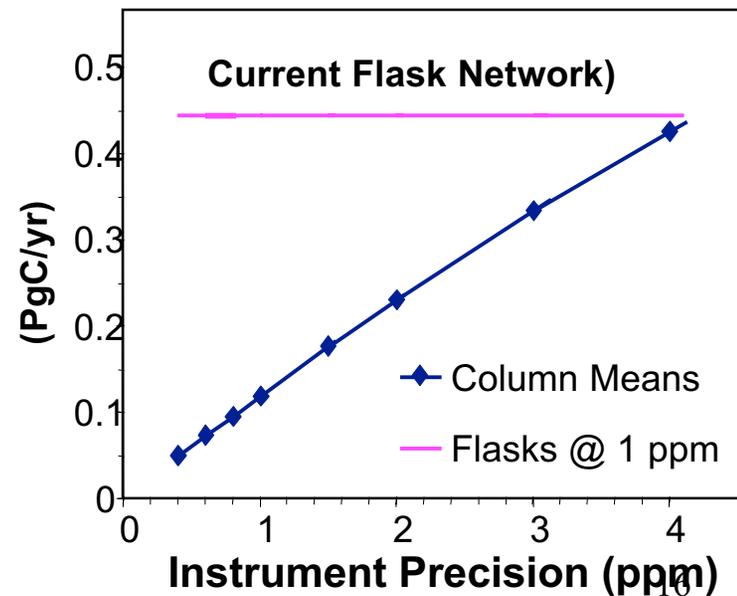
Lidar
Concept
1.5 microns



Spectrometer Concept



Mean Inversion Error Per Region
(PgC/yr)



Current Instrument Systems, Concepts, & Component Development Activities

- Oceans (shipboard & A/C)
 - Shipboard particulate lidar (Behrenfeld)
 - Shipboard bicarbonate lidar (Hoge)
 - A/C pulse & probe fluorescence lidar (Chekalyuk)
- Land
 - Dual-frequency biomass lidar (Rall & Knox)
 - Laser vegetation imaging sensor (Blair)
- Atmosphere
 - CO₂ lidar (Abshire & Krainak)
 - Fabry-Perot CO₂ interferometer (Heaps & Kawa)
 - Raman scattering CO₂ lidar (Whiteman)
- Components (Code R program with GSFC & LaRC): laser transmitters, laser diodes, wavelength conversion, injection seeding

Carbon Theme Team Responses to Recent Solicitations

Proposals in **green** were selected/funded.

- **IIP**
 - Kawa 916& Heaps554: Passive CO₂ Fabry-Perot Interferometer aircraft demonstration
- **DDF (FY03 selected proposals; FY04 proposals in preparation/not listed)**
 - Hoge 972: Bicarbonate Lidar
 - Moisan 972 : Ocean color curriculum applications
 - Mannino 971: Optical properties of black carbon and CDOM in coastal ocean
 - Knox & Rall 923: Spectral ratio biospheric lidar
 - Behrenfeld 972: Particulate organic carbon lidar
- **AIST**
 - Code 500 & 972: Multi-platform autonomous platform command & control S/W
 - Code 500 & 972: OSSE S/W development for coastal oceans
- **Unsolicited Proposals**
 - Imhoff & Nelson 923: Combined VHF SAR & Lidar for Biomass Measurement
 - Masek & Ranson 923: A Sampling Approach to Forest-cover Dynamics in Northern Eurasia
- **REASoN CAN**
 - Collatz & Hall 923: Carbon, water, and energy data set synthesis & validation
 - Masek & Hall 923: North American 30-yr land disturbance satellite data record development
 - Gregg & other GSFC co-I's, 971: Ocean color time series development & maintenance
 - Masuoka 922: Reprocessing of AVHRR data series using MODIS-Compatible Algorithms.
 - Knox 923 : Geographic hot spot detection & prioritization
- **NPP**
 - Privette 923: Assessment of NPP VIIRS Land Biophysical EDRs
 - Ranson & de Colstoun 923: Assessment of the VIIRS Surface Type Environmental Data Record
 - Hoge 972: NPP VIIRS Chlorophyll EDR Assessment: New Correction Procedure to Produce CDR Quality
 - McClain & other GSFC co-Is: 970.2 End-to-End Assessment of NPP/VIIRS Ocean Color Data: From Sensor to Derived Products

Carbon Theme Team Responses to Recent Solicitations

Proposals in **green** were selected/funded

- **EOS TERRA/AQUA/ACRIM**

- Andrews & Kawa, An adjoint-based carbon budget analysis using AIRS CO₂ and CO research products
- Andrews & Burris: Ground-based DIAL for boundary layer profiling of CO₂.
- Whiteman 912: Boundary layer carbon dioxide profiling using Raman lidar.
- Middleton and Hall 923: Direct Satellite Inference of Ecosystem Light Use Efficiency for Carbon Exchange using MODIS on Terra and Aqua
- **Morisette 923: Maintaining and Refining NASA's Land Product Validation Infrastructure**
- **Hall JCET: Physically-Based Continuous Fields Algorithm**
- **Ranson & Kahasuk 923: Boreal Forest Type and Structure from EOS Data Sets**
- **Collatz (co-I) 923: Using satellite and inverse techniques to constrain regional and global fire emissions from 1997-2005: An approach based on the carbon isotope ratio of fire emissions**
- McClain (co-I) 970.2: Refinement of the MODIS Atmospheric Correction Algorithm for the Ocean Color Products
- **McClain & Feldman 970.2: MODIS Ocean Color Calibration and Validation Support**
- Mannino & Hoge (co-I) 971: Applying MODIS Data to Estimate Photobleaching of CDOM and the Inputs of Black Carbon Aerosols
- Hooker 970.2: Refinement and Maintenance of EOS Ocean Color Algorithms
- McClain & Esaias 970.2/971 (co-Is): Research & Application Using MODIS Data to Study Spatial & Temporal Variability of the Chesapeake Bay Ecosystem
- Hoge 972: Hurricane-Ocean Response and Prediction: Application of MODIS CDOM/Gelbstoff Global Imagery to Upper Mixed Layer Heat Content Estimation
- Hoge 972: Continuing Airborne Laser Validation of MODIS Ocean Products from Terra and Aqua: Fluorescence Line Height, Chlorophyll, and DOC
- Hoge 972: Continued Algorithm Refinement of the Phycoeythrin Product
- J. Moisan 972: Use of Satellite-Derived CDOM Absorption to Estimate Ocean Mixed Layer Depths
- T. Moisan 972: MODIS Ocean Color Remote Sensing of Phaeocystis Blooms
- Hoge (co-I) 972: Assessment of Phytoplankton Physiology, and Primary Productivity from MODIS CFE, ARP, and IPAR Products

Responses to Recent Solicitations (cont.)

- **EOS IDS (selections to be announced)**

- Pawson 910: Global Modeling and Assimilation for the Carbon Cycle
- Middleton 923: Temporal & Spatial Structure in Terrestrial Primary Production "Hot Spots" and their Underlying Environmental Factors
- Hanan & Privette 923: The role of Africa in terrestrial carbon exchange and atmospheric CO₂
- **Shugart & Privette 923: Hydrologic and Nutrient Controls on the Structure and Function of Southern African Savannas**
- Knox & Patil 923: Detecting and Characterizing Ecological Disturbances and Initial Responses in Global Terrestrial Ecosystems
- Collatz, Masek & Knox 923: Effects of disturbance type, age since disturbance and climate interannual variability on regional carbon fluxes: Merging satellite time series data with a dynamic vegetation recovery model.
- Gregg 971: Decadal Changes in Ocean Biogeochemistry: Where did the carbon go?
- McClain (co-I) 970.2: Satellite-Based Quantification of Air-Sea Exchange of CO₂
- **McClain, Mannino, & J. Moisan (co-Is) 970.2: Eastern US Continental Shelf Carbon Budget: Modeling, Data Assimilation, and Analysis**
- Behrenfeld & Mannino (co-I) 972: The Equatorial Box Project
- Gregg & other GSFC coI's 971: Development of an Ocean Biogeochemical EOS Assimilation Model
- T. Moisan 972: Development of a Coastal Primary Productivity Model in the Middle Atlantic Bight

- **NOAA Office of Global Programs**

- Gregg 971: Decadal Changes in Ocean Biogeochemistry: Where did the carbon go?
- Mannino 971: Inventories, Sources, and Sinks of Dissolved Organic Carbon in the Ocean

- **NASA New Investigator (selections to be announced)**

- Mannino 971: Dynamics of Coastal Ocean Dissolved Organic Matter

Responses to Recent Solicitations (cont.)

- **GSFC IR&D (selections to be announced)**
 - Carbon Theme team: Advanced telescope design
 - Carbon Theme team: Advanced focal plane design
- **GSFC Bid & Proposal (selections to be announced)**
 - Behrenfeld & McClain: [Physiology Lidar-Multispectral Mission \(PhyLM\)](#)
 - Carbon Theme team: Geostationary land-ocean carbon mission
- **Mission & Science Measurement Technology (Code R; Proposals in preparation)**
 - Code 500 & Carbon Theme team: Advanced telescope design
 - Naval Research Lab & Carbon Theme team: A/D converter - focal plane integration

Current Status & Challenges

- Carbon theme leadership are increasingly occupied with funded efforts.
- Full cost accounting imposes limits on participation in voluntary Carbon Theme activities.
 - FTE & contractor support required
- Downscaling of many Carbon Theme efforts already occurring.
- Theme and Earth Science Directorate organization structure not entirely consistent.