NASA's Global Carbon Cycle Implementation Plan

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NASA's Global Carbon Cycle Implementation Plan

1.0 Introduction and Background

Purpose of Plan
What does the Plan address
How the Plan is organized

1.1 What is the Carbon Cycle?

Earth's carbon stocks – Land, Oceans, Atmosphere
Global carbon flow through oceans, lands and atmosphere
- Chemical Forms
- Sources and sinks
- Rates

Climate and Atmospheric Carbon Record -- the past 400,000 years
Human influences
- Earth's carbon stocks
- Climate and Atmospheric Carbon in the past 100 years

Current Forcings
- CO2, CH4, CFCs, O3, Aerosols, Clouds, Landcover, Volcanoes

1.2 Why is the carbon cycle important? (Plagiarize existing docs where possible)

Some <u>potential</u> future scenarios involving carbon-climate interactions
- Atmospheric CO2 (2000-3000ppm?)
- Atmospheric CH4
- Carbonaceous aerosols

Implications for land energy/water cycles and oceans
Climate-Land-Ocean feedbacks
Potential Implications for Humans
- Shifts in agricultural productivity (temperature and precipitation),
- Productivity of biosphere -sustainability
  - food: agriculture, ocean productivity
  - materials: forest products
- Recreation/aesthetics
- Sea level rise
- Health (weather extremes, climate sensitive diseases)
- Biodiversity

1.3 What We Know

1.3.1 History of Global Carbon Cycle Research: How we got where we are today

1.3.2 Current State of Understanding and Uncertainties

In 10^{15} grams of Carbon (Gigatons, Petagrams)

{Fossil Fuel + Land Use} - Atmospheric Storage - Ocean Uptake = Imbalance

$6.3 \pm 0.6 + 1.6 \pm 0.8 - 3.3 \pm 0.2 - 2.4 \pm 0.5 = 2.2 \pm 2.1$

1.3.2.1 Land

- Discussion of Major Components
  - Major carbon pools: soil, above ground vegetation
  - Major fluxes: photosynthesis, respiration, fires, land use, other disturbance
- Major Topics
  - Productivity
  - Land cover and land use including history
  - Soil and above-ground carbon stocks
  - Response to climate (variability, secular trends)
  - Response to CO2, N
  - Fire, non-human disturbance
  - Wetlands and agricultural production of CH4
  - Non-biological burial (erosion, reservoirs)
  - Carbon sequestration/management
- Current Capabilities
  - >20 year time series of satellite data (AVHRR, LandSat) for land cover change and photosynthetic productivity
  - Long term in situ data (continuous flux measurements, inventories, histories)
  - Validated land biogeochemical cycling models in boreal, temperate, and tropical ecosystems
  - A suite of land, atmosphere and ocean observing satellites
  - Satellite algorithms to extract boundary conditions and forcings for process models.
- Major Challenges
  - Coupling land biogeochemical cycling models to climate and ocean circulation models
  - Scaling of locally measurable processes to regional/continental/global scales, vertical/temporal variability in atmospheric CO2

1.3.2.2 Ocean

- Discussion of Major Components
  - Major carbon pools
  - Major Fluxes
- Major Topics
- Current Capabilities
- Major Challenges

1.3.2.3 Atmosphere

- Discussion of Major Components
  - Major carbon pools
  - Major Fluxes

Major Topics
Current Capabilities
Major Challenges

1.4 U.S. Carbon Cycling Activities

IPCC – USGCRP - IAWG Planning
Brief Description of agency activities
Brief description of questions formulated by USGCRP and IAWG

1.5 NASA ESE Science Questions

1.5.1 NASA General Earth Science Questions

How is the global Earth system changing?

What are the primary forcings of the Earth system?

How does the Earth system respond to natural and human-induced changes?

What are the consequences of change in the Earth system for human civilization?

How well can we predict the changes to the Earth system that will take place in the future?

1.5.2 NASA's ESE Science Questions Relevant to Global Carbon Cycle (in this section, we need to relate any additional INITIATIVE questions to these.)

How is the global ocean circulation varying on climatic time scales?

How are global ecosystems changing?

What trends in atmospheric constituents and solar radiation are driving global climate?

What are the changes in global land cover and land use, and what are their causes?

How do ecosystems respond to environmental change and affect the global carbon cycle?

Will climate variations induce major changes in the deep ocean?

What are the effects of regional pollution on the global atmosphere, and the effects of global chemical and climate changes on regional air quality?

What are the consequences of land cover and land use change?

To what extent can long-term climate trends be assessed or predicted?

To what extent can future atmospheric concentrations of CO2 and CH4 be predicted?

INITIATIVE QUESTIONS (PROPOSED)

1.6 Why a New NASA Initiative?

The USGCRP requires synoptic, periodic, long-term observations of the Earth's land, oceans and atmosphere that requires NASA's science and space capabilities developed over the past 30 years.

An adequate characterization and understanding of the global carbon cycle will require new space initiatives that only NASA is capable of providing.

The Initiative will foster the coupling of numerical models of land, ocean and atmosphere processes with the historic and ongoing satellite observation stream to study the global carbon cycle.

A carbon cycle focus will serve as a needs-driven and science-driven roadmap for:

- NASA Technology
- NASA Science Programs
- NASA Facilities Development
- New Mission Development

2.0 NASA's Past and Current Contributions to Carbon Cycle Science

2.1 Land Summary (Details in Appendix 2)

2.1.1 Observing Systems (CJT)
2.1.2 Field Programs (FGH)
2.1.3 Science and Modeling (JC)

2.2 Oceans Summary (Details in Appendix 2)

2.2.1. Ocean Color Measurements
2.2.2 Satellite programs
2.2.3 Relevant Phys. Oceanography Measurements & Programs
2.2.4. NSIPP
2.2.5. Data Archive Projects
2.2.5 Research Programs

2.3 Atmospheres Summary (Details in Appendix 2)

2.4 Interdisciplinary Summary (Details in Appendix 2)

2.4.1 Atmosphere/Land
2.4.2 Ocean/Atmosphere
2.4.3Land/Ocean Interactions

2.5 Data and Information Systems Summary (Details in Appendix 2)

2.5.1 Data Products
2.5.2 Data Access, Archive, and Distribution Systems

2.6 What is missing? What is needed?

2.6.1 What is missing?

While our current space assets constitute a formidable capability with which to study the Earth's carbon cycle, without some additional observations we cannot

Track the precise geographic distribution, seasonal, and interannual variation of carbon exchanges between the atmosphere, land and oceans

Precisely estimate the carbon stocks tied up in land vegetation and the ocean chlorophyll

Determine how these patterns will change in response to changing climate

2.6.2 What is needed?

We need global, periodic observations of:

Atmospheric carbon dioxide concentrations seasonally and trends and variation over years.

Biomass in the Earth's land vegetation

Carbon dioxide uptake in the ocean's surface layer

Carbonaceous aerosols in the Earth's atmosphere

Vegetative and soil carbon uptake and release rates

We need to develop coupled interactive models that link the atmosphere, oceans, land masses and biosphere into a comprehensive whole.

Using data assimilation techniques, integrate existing observations of carbon dioxide, climate, ocean and land parameters to generate temporally and internally consistent fields of carbon transport to and from the atmosphere, oceans and land

3.0 The Initiative – Approach and Technical Roadmap

3.1 General Approach
3.2 Initiative in the next two years with existing/planned assets
3.3 The next five years with augmented programs
3.4 The next five to ten years with new programs and missions

4.0 Proposed Information Products

4.1 Data Sets
4.2 Models
4.3 Requirements Definition for User Information System

5.0 Performance Metrics

6.0 Institutional and Management Approach

7.0 Resources and Timelines

8.0 Acronyms and Appendices

Acronyms

Appendix 1

Documents Relevant to Intro and Background

Appendix 2 Details of NASA's Past and Current Contributions

2.1 Land

2.1.1 Observing Systems (CJT)

2.1.1.1. Landsat 1 --> Landsat-7
2.1.1.2. AVHRR NOAA-7 --> NOAA-16
2.1.1.3. SeaWiFS land products late 1997 ---> now
2.1.1.3 MODIS ... (just starting)

Theme #1: Discuss land cover change, deforestation, etc. with Landsat data. Mention SPOT to please the French. The emphasis here will be on carbon stocks on land in woody vegetation and conversion of natural systems to agriculture.

Theme #2: Discuss time series vegetation index or photosynthetic capacity studies using AVHRR, SeaWiFS, and MODIS for quantitative assessment of primary production. Mention SPOT Vegetation to please the French again.

2.1.2 Field Programs (FGH)

2.1.2.1 Philosophy (measurements, modeling and algorithms)
2.1.2.2 Experiment Design for scaling from plot to region
2.1.2.3 Hapex, FIFE, BOREAS and LBA
2.1.3.4 Science Results Summary

2.1.3 Information Systems (SW)

2.1.4 Science and Modeling (JC)

2.2 Oceans

2.2.1. Ocean Color Measurements

2.2.1.1 Early aircraft instrument and algorithm development
- 2.1.1.1.1. Programs at Langley, GSFC, WWF, Ames, JPL, and Lewis
- 2.1.1.1.2. Airborne Oceanographic Lidar
- 2.1.1.1.3. U-2/Ocean Color Scanner
- 2.1.1.1.4. AVIRIS

2.2.2 Satellite programs

2.2.2 1. Nimbus-7 Coastal Zone Color Scanner
2.2.2 2. SeaWiFS
2.2.2 3. MODIS
2.2.2 4. SIMBIOS

2.2.3 Relevant Phys. Oceanography Measurements & Programs

2.2.3.1 Sea Surface Temperature (ecosystem dynamics & carbon chemistry)
- 2.2.3.1.1 VHRR and AVHRR development
- 2.2.3.1.2 SST Pathfinder

2.2.3.2 Altimetry (coupled circulation-ecosystem dynamics)
- 2.2.3.2.1. GEOS-3
- 2.2.3.2.2. SeaSat altimeter
- 2.2.3.2.3. TOPEX

2.2.3.2 Scatterometry (coupled circulation-ecosystem dynamics, CO2 fluxes)
- 2.2.3.2.1. SeaSat
- 2.2.3.2.2. ADEOS-1 NSCAT
- 2.2.3.2.3. QuikScat

2.2.4. NSIPP

2.2.5. Data Archive Projects

2.2.5.1. CZCS data recovery, reprocessing, & archive program
2.2.5.2 Goddard and JPL DAACs
- 2.2.5.2.1 Pilot Ocean Data Center (JPL DAAC predecessor)
- 2.2.5.2.2 NASA Climate Data Center (GSFC DAAC predecessor)

2.2.6 Research Programs

2.2.6 .1 Ocean Biochemistry Program
2.2.6 .1.1 process studies
2.2.6 .1.2 coupled physical-biological models
2.2.6 .1.3 JGOFS participation (SMP)
2.2.6 .1.4 data assimilation studies
2.2.6 .2 Distributed satellite data analysis software support
2.2.6 .2.1 Miami DSP
2.2.6 .2.2 SEAPAK (GSFC)
2.2.6 .2.3 SeaDAS (GSFC)
2.2.6.3. Other Related Contributions
2.2.6.3.1. WWF Wave Tank (gas flux studies)
2.2.6.3.2. WWF Rain-sea interactions (gas flux studies)

2.3 Atmospheres

2.4 Interdisciplinary

2.4.1 Atmosphere/Land

2.4.2 Ocean/Atmosphere

2.4.2.1. NSIPP (Rienecker/Suarez)
2.4.2.2 SeaWiFS
- A. Atmospheric corrections (Wang, McClain)
- B. PAR (Frouin, McClain)

2.4.2.3. Ocean radiative modeling
- A. Ocean/Atmosphere Radiative Model (OARM) (Gregg)
- B. Radtran (Gregg)

2.4.2.4. Iron biogeochemistry
- A. Aerosol dust transport modeling
  1. Global (Ginoux)
  2. Equatorial Pacific (McClain, Christian, Busalacchi, Murtugudde)
- B. Incorporation of iron into ocean biogeochemical models
  1. Global (Gregg)
  2. Equatorial Pacific (McClain, Christian, Busalacchi, Murtugudde)

2.4.2.5. Gas fluxes
- A. Carbon fluxes across the air/sea interface (McClain, Signorini)
- B. DMS fluxes across the air/sea interface (Erickson, Gregg)
- C. Laboratory analyses of gas transfer across the air/sea interface (Long, Huang)

2.4.3 Land/Ocean Interactions

2.4.3.1. Stennis work (Rick Miller)
2.4.3.2 Estimates of combined land + ocean primary production (Behrenfeld)
2.4.3.3. Analyses of riverine influences (Murtugudde)

2.5 Data and Information Systems

2.5.1 Data Products

2.5.1.1. Products from Science Missions
- ASTER
- ETM (Landsat 7)
- MISR
- MODIS

2.5.1.2 Pathfinder Products

- o Production of the Pathfinder Global Land 1-km AVHRR Data Set
- o Global Land Cover Characterization with AVHRR Data
- o A Version 2 AVHRR Multiresolution Land Pathfinder Data Set

2.5.1.3 Field Experiments

FIFE
BOREAS
LBA

2.5.2 Data Access, Archive, and Distribution Systems

2.5.2 1. EDC DAAC
2.5.2 2. GSFC DAAC
2.5.2 3. GCMD
2.5.2 4. GCDIS