Global Carbon Data Sets
An Overview of Carbon Cycle Science Observations and Networks

K.A. Hibbard NCAR 2002
Types of Global Carbon Data

- Historic and Atmospheric (monthly - 1K yr)
- Emissions (annual - decadal)
- Satellite-Derived Model Inputs (instantaneous)
- Terrestrial (sub-hourly - decadal)
- Oceans (hourly - decadal)
- Networks
Measured Global Carbon Data

- Atmospheric concentration measurements
- Emissions (fluxes, intensity, demographics)
- Satellite-Derived Model Inputs
- Terrestrial (sites and inventories)
- Oceans (sections, buoys, VOS)
Ocean Uptake: 2.3 ± 0.8

Terrestrial Uptake
Inferred Sink: 2.3 ± 1.3

Net Emissions from Tropical Land-Use Change:
1.6 ± 0.8

Fossil Fuel Plus Cement Production:
6.3 ± 0.6

Storage in Atmosphere: 3.3 ± 0.2

Decade of the 1990’s
Historic and Atmospheric Concentration Data

Ice cores: CO$_2$, CH$_4$ and MORE

- Vostok
- Greenland Ice Core Project (GISP)
- Continental (e.g. Yukon, Asia)

Flask Network: CO$_2$ and tracers

- NOAA/CMDL, CSIRO, JAPAN, EU

Airborne Campaigns: CO$_2$, CO, NO, O$_3$, CH$_4$, NMHC

- ABLE, TRACE-A,P, PEM, COBRA, COMMERCIAL
4 glacial cycles recorded in the Vostok ice core


Unloading fresh core, Siple Dome, Antarctica. This is a section from a 300 meter core drilled at Siple Dome, Antarctica to help assess recent climate history. Photo courtesy of Climate Change Research Center, University of New Hampshire.
Global Tropospheric Experiment Mission
TRACE-A Carbon Monoxide (CO) Vertical Profiles
Global Emissions

Demographics, e.g. Urbanized Regions

Representative Nitrogen, Carbon, Other:

- Global Emissions Inventory Activity (GEIA)
- Emission Database for Global Atmospheric Research (EDGAR)
- CO$_2$ Emissions : National and Global Compilations

Biomass Combustion, Cement Production

Elemental and Compounds: CO$_2$, CO, CH$_4$, NO$_x$, SO$_x$, Black Carbon
City Lights
Data Currently Available
Source-Specific Emissions
* Nitrogen Oxides in Soils
* NOX Lightning data
* Volcanic Sulfur Emissions

Compounds
* Ammonia
* Black Carbon
  1. Black Carbon from Fossil Fuel Combustion
  2. Fossil Fuel & Biomass Burning Black Carbon
* Carbon Dioxide (fossil fuels)
* Carbon Monoxide
* Chlorofluorocarbons
* Lead
* Mercury
* Methane
  1. Anthropogenic (preliminary)
  2. Natural
* Nitrous Oxide
* Nitrogen Oxides, Annual
* Nitrogen Oxides, Seasonal
* Reactive Chlorine Emissions
* Sulfur Dioxide, Annual
* Sulfur Dioxide, Seasonal
* Volatile Organic Compounds
  1. Anthropogenic: Non-Methane VOC’s
  2. Natural

Other Data
* Population
* Cropland

Global Emissions Inventory Activity
(http://geiacenter.org/)

1987 Biomass Burning Black Carbon Emissions (Tonnes/ 1° x 1°)

NO$_x$ Emission Database for Global Atmospheric Research - EDGAR
(http://www.rivm.nl/env/int/coredata/edgar/)

Global total: 30.7 Tg No$_x$ -N
Unit: kg No$_x$ -N/cell
Legend: kg * 10$^6$
Global, Regional, and National CO2 Emissions. In Trends: 
A Compendium of Data on Global Change. 
Carbon Dioxide Information Analysis Center, 
ORNL, US DOE 
(http://cdiac.esd.ornl.gov/trends/emis/tre_glob.htm)
Satellite Derived Datasets

- Terra
- Aqua
- Landsat
- GOES
- NOAA 11
- VCL
IGBP LAND COVER CLASSIFICATION

QuickTime™ and a Photo - JPEG decompressor are needed to see this picture.
Forest Extent

IGBP Forest Class
- Evergreen Needleleaf Forest
- Evergreen Broadleaf Forest
- Deciduous Needleleaf Forest
- Deciduous Broadleaf Forest
- Mixed Forest
- Non-vegetated
**Percent Tree Cover**

MODIS Land Rapid Response Fire Detection: Fires in Grasslands and Savannas
Gross Primary Production (GPP)
7 km from TERRA MODIS

Numerical Terradynamic Simulation Group
School of Forestry; The University of Montana

May 1-9 2001

May 25 - June 2 2001

Nov 9 - 25 2001

Average Daily GPP
(gC/m²/day)
Dust over Western Africa; February 26, 2000
MODIS Ocean

Sea Surface Temperature

May 2001

-2 5 10 15 20 25 30 35 °C

MODIS/Ocean Group
U.Miami/RSMAS

PAR December 2000

Derived from GSFC Data Assimilation Office 3 hr retrievals.

Chlorophyll

May 2001

0.01 0.1 1.0 10.0 20.0 Chlor_a_2 (mg m⁻³)

MODIS/Ocean Group

http://modis-ocean.gsfc.nasa.gov
http://opp.gsfc.nasa.gov
Falkowski Behrenfeld depth integrated model calculates total euphotic zone productivity to 1% surface irradiance. Primary inputs are PAR, SST, Chlor_a_3. (gC/m²/yr).
Global Terrestrial Datasets

- PROCESS STUDIES
- FLUX TOWERS
- LAND USE AND INTENSITY
- FOREST INVENTORY ANALYSIS
Quantifying Terrestrial C Fluxes

1) Inverse modeling of atmospheric chemistry
   • Constrain C sinks; little info on why or exactly where

2) Biogeochemical models
   • Test physiological changes; little land use or disturbance

3) Land-use bookkeeping models
   • Track land-use change, but no climate or physiology

4) Flux towers
   • Integrated site-level measurements, but relatively few sites

5) Forest inventories
Soil Carbon Density

IGBP (DIS) Global Soils (2000)
Flux Towers

- Calibration
  - IRGA - WMO gas stds.
  - Temperature
  - Net Radiation
  - PPFD
- Intercomparisons
  - Fluxes: H, LE, CO2
  - Met: T, Rn, PPFD
  - 30 sites, 8 countries

Photo courtesy of Ameriflux Website
Cropland Intensity
Agricultural Suitability

Atlas of the Biosphere
Center for Sustainability and the Global Environment
University of Wisconsin - Madison
Extent of Agriculture

DRAFT: Based on EDC’s Seasonal Land Cover Characteristics Data
Inventory Carbon Budgets: the Pros

• Real data!

• Extensive, spatially representative, often extending back several decades

• Automatically reflects effects of many factors
  – **Losses**: insects, fire, harvests, disease, windthrow, etc.
  – **Gains**: improved management, CO\textsubscript{2} or N fertilization, growing season length, etc.
Inventory Carbon Budgets: the Cons

- Uncertainties converting from surveyed variables to carbon stocks & fluxes:
  - Converting tree measurements to whole-tree C
    - However allometries can be quite good.
  - Few measurements of non-tree C pools
    - However, models & auxiliary data sets can help greatly
  - Treatment of dead organic matter highly inconsistent
    - Changes in soil pools particularly uncertain, but have improved greatly.
Focus Regions

- Canada
- China
- Europe
- Russia
- USA
- Other: Baltics, Other CIS, Other Asia
Northern Hemisphere Forest C Sink = ~0.6-0.7 Pg/yr

North America: ~0.24 (~40%)
Eurasia: ~0.33 (~60%)
Global Ocean Datasets

- PROCESS STUDIES
  - $pCO_2$, pH, SALINITY, TEMPERATURE
- BUOYS
- VOLUNTEER OBSERVING SHIPS
- DEDICATED CRUISES
International CLIVAR/CO$_2$ Lines (including US)

NCAR Model Anthropogenic CO$_2$ for 2005 with proposed repeat lines
Black = proposed US lines; White = committed international lines
Black and White = international lines where US involvement may be needed

Surface Anthropogenic CO$_2$
Concentration (µmol kg$^{-1}$)

CO$_2$ Clivar Repeat Hydrographic Sections
SOMMA System for measuring TCO$_2$
Anthropogenic CO$_2$ Column Inventory (mol m$^{-2}$)
Net CO$_2$ Flux from Takahashi et al., 2002
Global Carbon Networks

TERRESTRIAL:
NPP, CO$_2$, Soil Warming, Trace Gas, FluxNet

OCEAN:
CLIVAR, WOCE, JGOFS, WMO, Buoys
Space / time coverage of carbon observing networks

- **time**
  - centuries
  - decadal
  - interannual
  - seasonal
  - synoptic

- **space**
  - 1 ha
  - 1 km²
  - Regional
  - Continents
  - Globe

- **Remote sensing**

- **Forest Inventories**

- **Soil carbon**

- **Ecological site studies**

- **Eddy Flux Towers**

- **Atm Boundary layer measurements**

- **One atm station**

- **Flask network**

* uneven geographic coverage

**available as pilot studies only
Free Air CO$_2$ Enrichment (FACE)
Vegetation Productivity Measurement Sites
FluxNet Tower Sites
Global Monitoring Networks
Space and time coverage of ocean carbon observing networks

- centuries
- decadal
- Inter-annual
- seasonal
- daily
- hourly

- 1 m²
- 1 km²
- Regional (10⁶ km²)
- Ocean Basin
- Globe

Remote sensing
- Repeat Trans-basin Sections
- VOS surface pCO₂
- Shipboard Time-Series
- Moored Time-Series
- Process Studies
- Time-Series
WOCE/JGOFS/OACES Global Survey Data
Station 42041 - North Mid Gulf
27.50 N 90.50 W

Air temp height: 4 m above site elevation
Anemometer height: 5 m above site elevation
Barometer elevation: sea level
Sea temp depth: 0.6 m below site elevation
Water depth: 1,435.6 m
Watch circle radius: 1.500 yards

Launching a drifting buoy
Take Home Messages

There is a LOT of data out there!

Concept of Multiple Constraints - Data and Models CAN co-evolve

The challenge lies in disparate spatial and temporal scales:

Integrating multiple temporal and spatial flux and ancillary data is NON-TRIVIAL