Carbon Thread

presented by

Mitch Goldberg (NOAA)

Need for GHG Observations and Understanding

Atmospheric carbon dioxide and methane are the largest climate forcing terms and contributes significantly to global warming

Need to understand and monitor sources and sinks and long term exchange between carbon pools (trees, oceans, fossil) to predict current and future atmospheric concentrations

Need to provide quantitative accurate information to decision makers

- Characterize global carbon cycle fluxes.
  - Geographic distribution
  - Seasonal and inter-annual variation
  - Atmosphere, land, ocean exchanges
- Determine climatic effects.
  - Variation
  - Long term trends
- Provide information
  - Policy (*e.g.,* energy)
  - Mitigation (*e.g.*, carbon sequestration)
  - Ecosystem management (*e.g.*, forests, coral reefs)

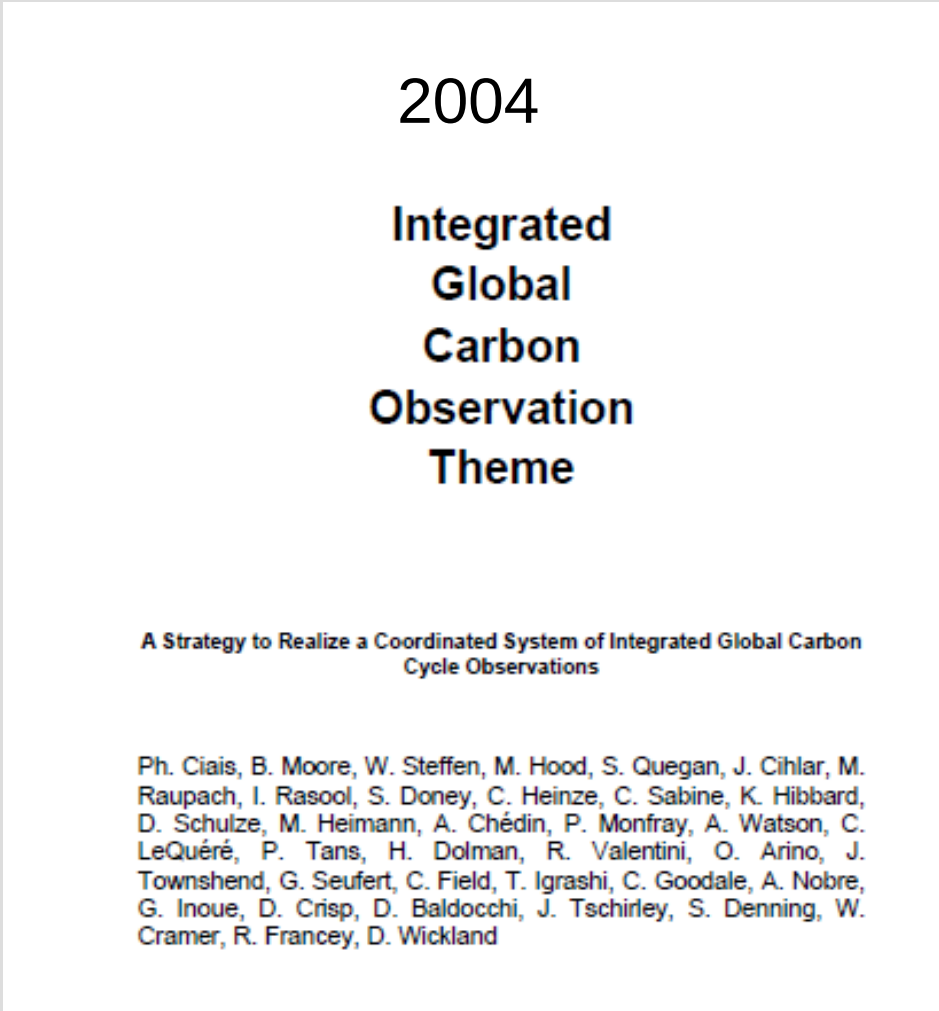
Without global CO_2 and CH_4 measurements, we do not have the scientific underpinning to manage climate change

Carbon Thread - Motivation

- Reliable information on GHG to identify sources and sinks to allow:
  - Better understanding of processes and impacts on climate change
  - Better decision making for carbon sequestration and land management.
  - Independent verification of national regulatory policy and international treaties
    - Cap and Trade

Strategy and need are well described in IGCO

- Excellent measurement strategy and roadmap
- Not a deployment plan
- Example:
  - Increase terrestrial ecosystem networks, in particular flux towers and soil/biomass carbon surveys especially in the Tropics. An increase of 50% of the number of available measurements is a feasible target



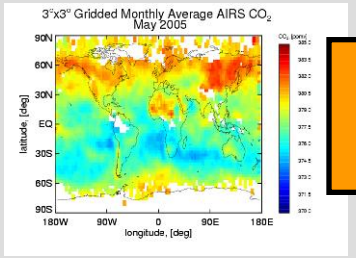
CEOS Carbon Thread

SIT-23
March 4-5, 2009
Cocoa Beach, Florida

Societal Benefit

Decision Topic

What knowledge of CO2 sources and sinks, including industrial emissions, land use changes and climate change feedbacks is necessary to ensure effective policy decisions by individual nations?

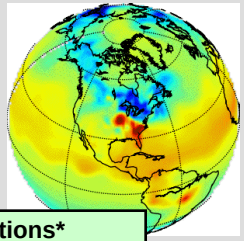


Information Products and Services

- Global Carbon Maps
- Fluxes of CO2 on a regional basis

→ Deforestation Reports

→ Regional Emission Reports



Science Knowledge and Models

- High resolution atmospheric transport models
- Ensemble biospheric modules
- Fossil fuel emission inventories
- Surface fluxes optimized using surface-based and remote measurements.

→ CarbonTracker and other Reanalysis Products

Satellites, Aircraft, Ground-based, Towers →

Measurements

OCO, GOSAT, IASI, AIRS, ASCENDS

Surface and aircraft flasks
Carbon flux towers
Solar occultation FTS instruments,

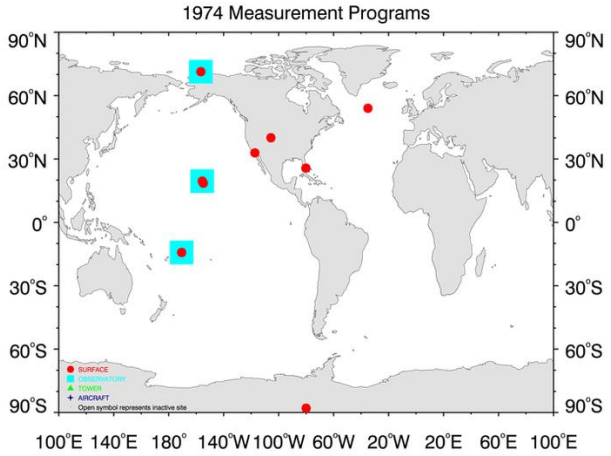
→ **Instruments and Missions**

Relevant GEO Tasks and CEOS Actions*

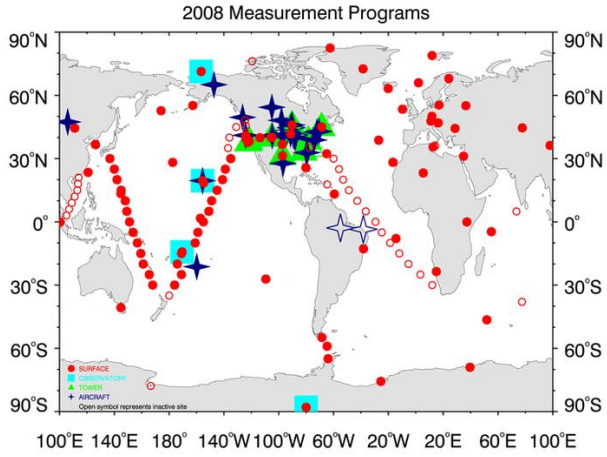
- CL-09-03 Global Carbon Observation and Analysis System
  a) Integrated Global Carbon Observation (IGCO) (former EC-06-01)
- b) Forest Carbon Tracking
- c) Global Monitoring of Greenhouse Gases from Space
- AR-09-03 Advocating for Sustained Observing Systems
  AR-09-03a_11* Global carbon dataset

Contacts: Goldberg, Butler, Barnet (NOAA), Moriyama (JAXA), Briggs (ESA), Husband (EUMETSAT), Berrien Moore, Hilsenrath Jucks, Miller (NASA) Per Erik Skrovseth (NSC), Alex Held (CSIRO), Simmons (ECMWF), Denning , GCOS (Bojinski)

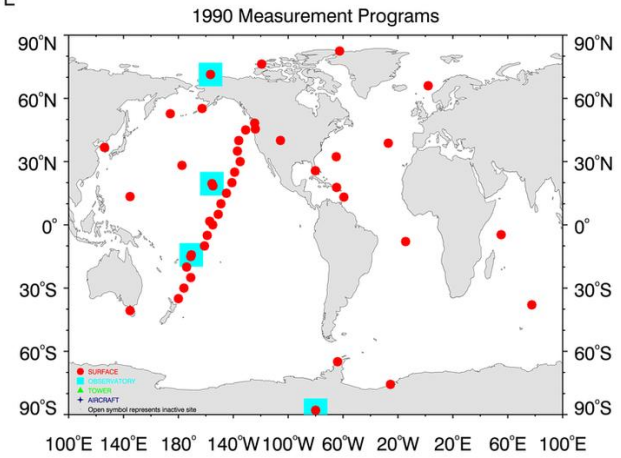
Evolution of NOAA's Global Carbon Cycle Monitoring Network



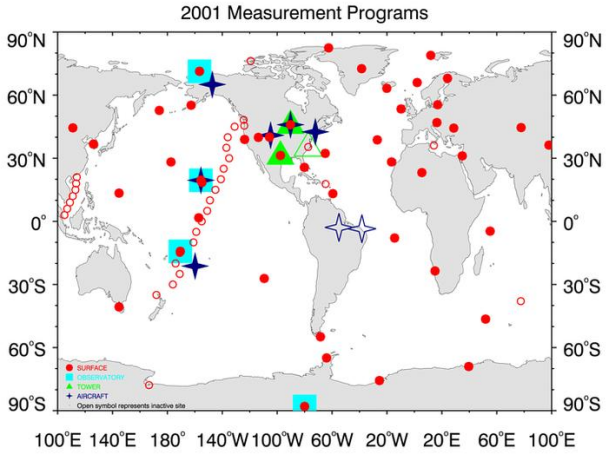
Goal (1970s): Determine global distributions and trends



Goal (1980s): Understand global distributions and trends (RITS, US-GCRP)



Goal (2000s): Estimate and track North American sources and sinks (CCRI, CCSP, NACP; Fan et al 1998)

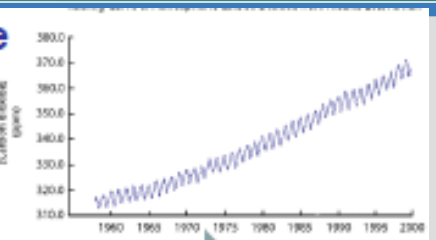


Goal (1990s): Understand regional sources and sinks (US-GCRP; Tans et al 1990)

Current Shortfalls

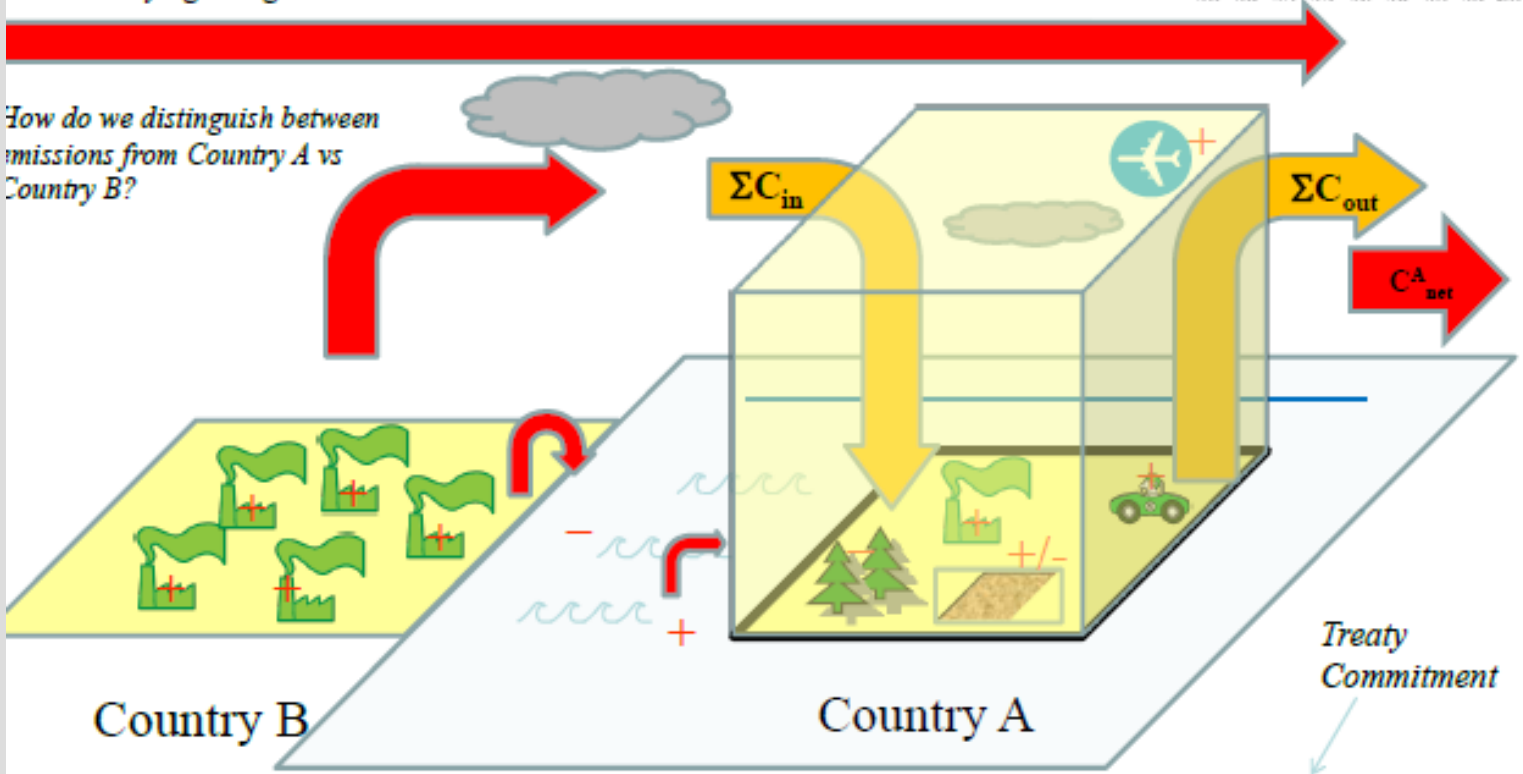
- Sparse network of observations
- No OCO
- Uncertainties in emission inventories
- Uncertainties in modeling and analysis
- Uncertainties in biospheric models (surface – air fluxes)

Challenge: quantifying Country A's treaty compliance in the presence of confounding sources



How do we distinguish between Country A's total carbon emissions and the global time-varying background?

How do we distinguish between emissions from Country A vs Country B?



How do we distinguish between Country A's anthropogenic emissions and the natural, local time-varying background?

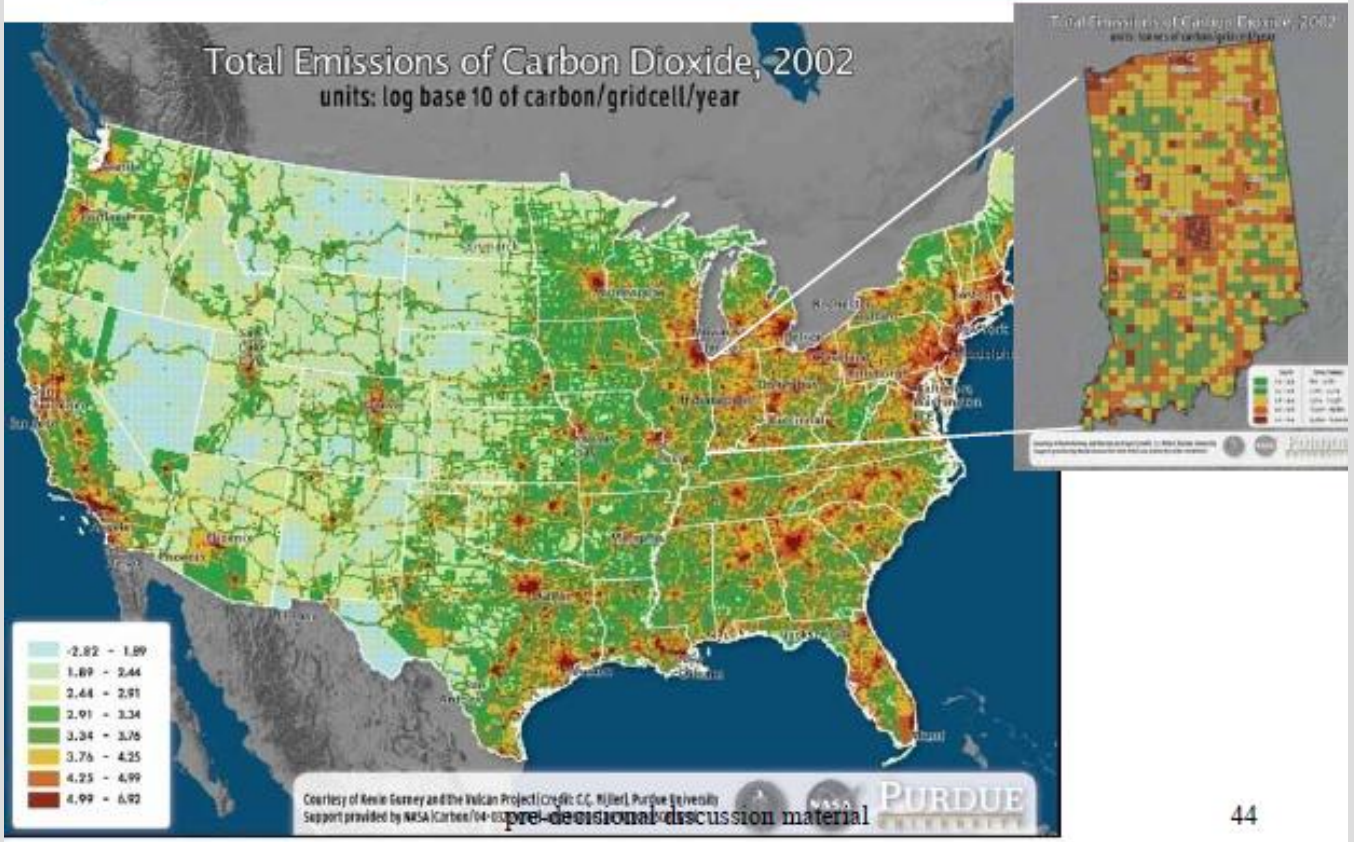
$$C^{A}_{net} = \Sigma C_{out} - \Sigma C_{in} = C^{A}_{anth}(t) + C^{A}_{nat}(t)$$

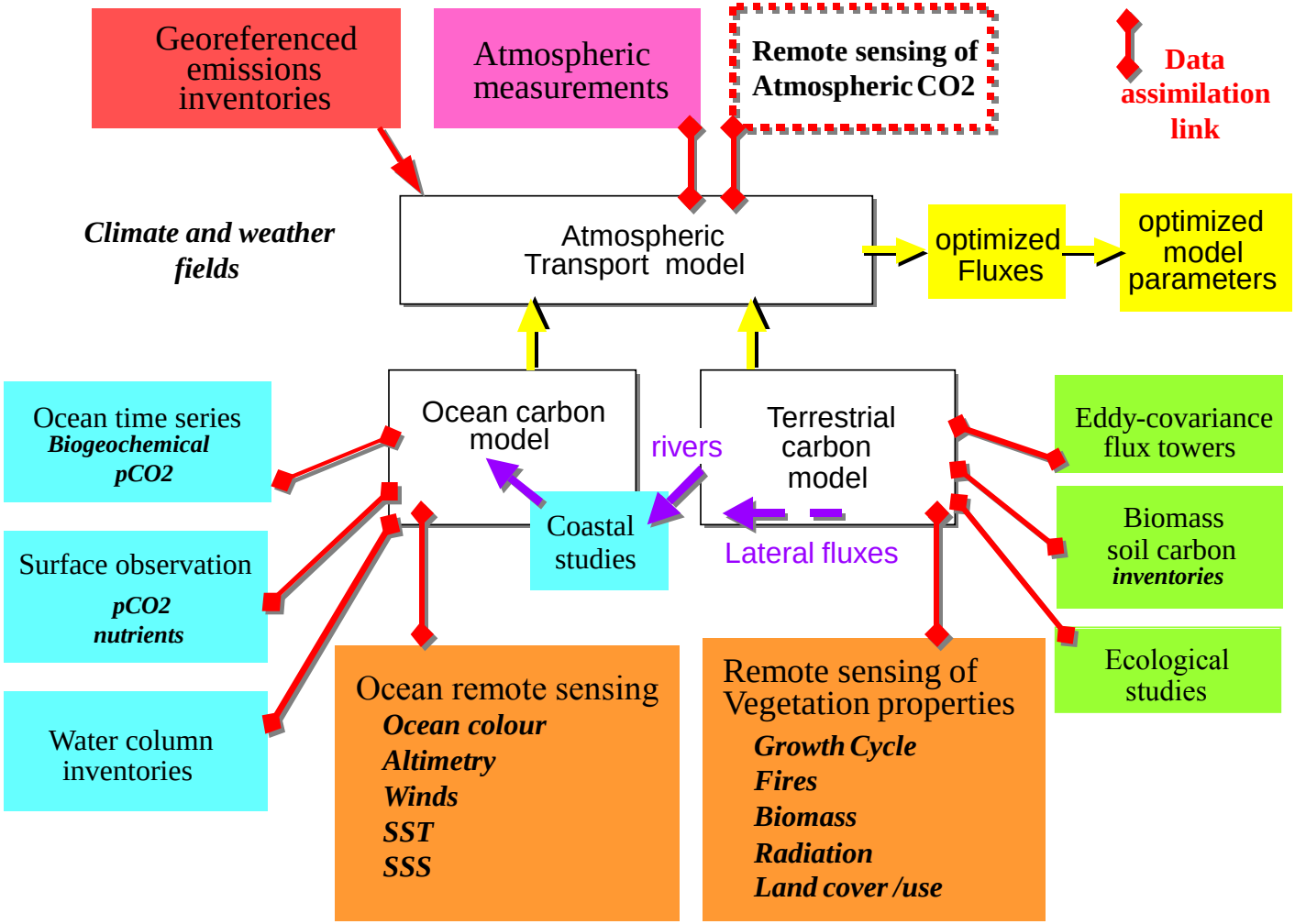
From Riley Duren, NASA/JPL - NOAA/NASA-GHGIS meeting Feb 09

How accurate are emission inventories?

Example of current inventory-based product

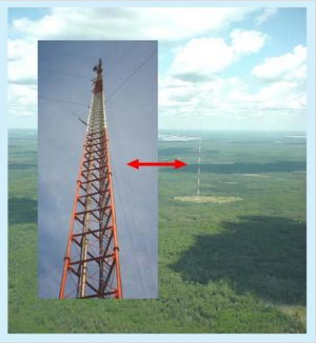
(Purdue/DOE/NASA's Project Vulcan, 10km grid, uncertainties: 10% CO2, 30% CH4)



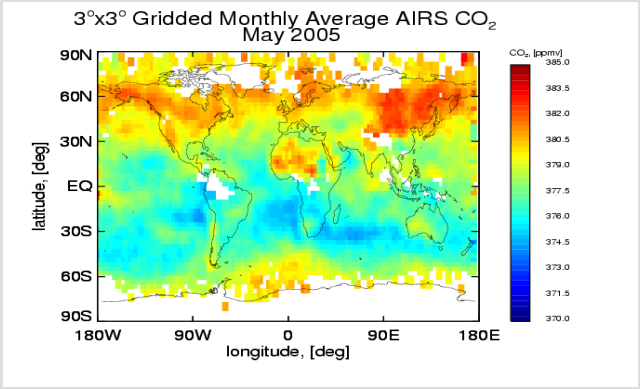

Georeferenced emissions inventories
Atmospheric measurements
Remote sensing of Atmospheric CO2
Data assimilation link
Climate and weather fields
Atmospheric Transport model
optimized Fluxes
optimized model parameters
Ocean time series
Biogeochemical
pCO2
Surface observation
pCO2
nutrients
Water column inventories
Ocean carbon model
rivers
Coastal studies
Terrestrial carbon model
Lateral fluxes
Eddy-covariance flux towers
Biomass soil carbon
inventories
Ecological studies
Ocean remote sensing
Ocean colour
Altimetry
Winds
SST
SSS
Remote sensing of Vegetation properties
Growth Cycle
Fires
Biomass
Radiation
Land cover /use

To meet objectives (1)

- Need adequate in-situ networks
  - Boundary layer measurements.
  - Vertical profiles (aircraft)
  - Process studies
  - Validation of satellite products.

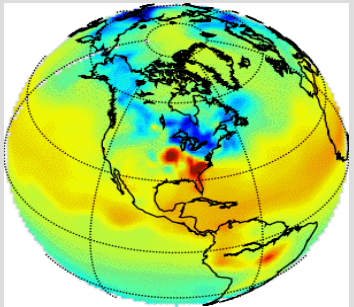


- Need adequate GHG satellite observations
  - Global coverage
  - Good spatial/temporal sampling
  - Good precision 1-2 ppm



- Need Earth space-based observations of ecosystems (land, ocean, coastal)

- Need improved modeling
  - Assimilation of measurements
  - High resolution transport models
  - Flux on regional scales



CO2 Surface Flux from CarbonTracker

To meet objectives (2)

- Need collaboration and coordination of:
  - Satellite community (CEOS – Global Monitoring GHG (GMGG) Working Group)/ACC)
    - Validate GHG products with in-situ data
    - Provide future sustained observations
  - In Situ community
    - Provide campaigns to better validate satellite GHG products
    - Improve density of observations
  - Modeling community
    - Work with satellite community to assimilate GHG products and understand error characteristics.
    - Improve biospheric modules
    - Improve transport
- Need to run Observation System Simulation Experiments to determine optimal measurement(s) strategy for future measurement needs.
- Need commitment of funds from agency for the required deployment

Recommendation

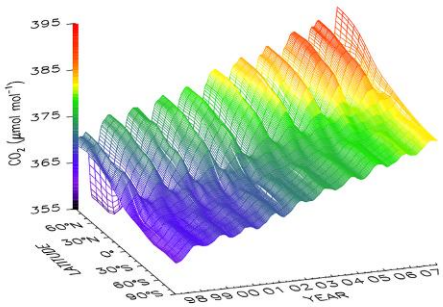
- Need a cross-cutting task team representing all communities (led by WMO GAW??)
  - In-situ, modeling, and satellite.
- Need internationally integrated deployment plans and funding to implement the recommendations of IGCO.
- Need steady implementation of the deployment plans
  - Need to expand in-situ sites – more towers
  - Need satellite technology demonstrations.
- Need validation campaigns of satellite GHG products using in-situ, aircraft.
- Need improvement and expansion of modeling efforts because the key product is based on model output.
- Need satellite technology incubator programs to increase the capability of the satellite component.

Additional Slides

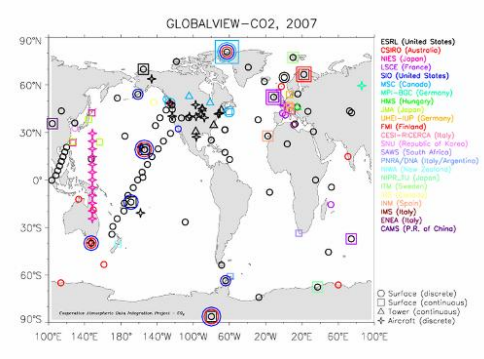
Showing growth of NOAA and International in-situ observations in response to new decision topics and services

Similar approach needed for required satellite observations

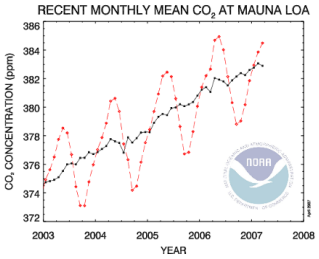
Data sets & Visual displays (variable)



Global view, (annual)



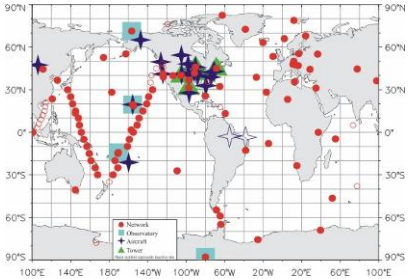
Global trends (monthly)



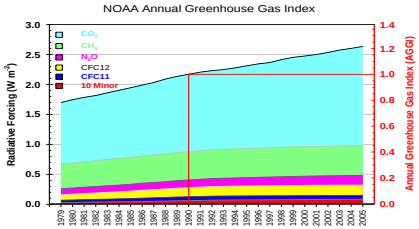
DATA

Products Services

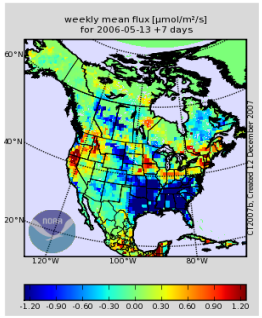
Data Visualization (daily)



Annual Greenhouse Gas Index (annual)

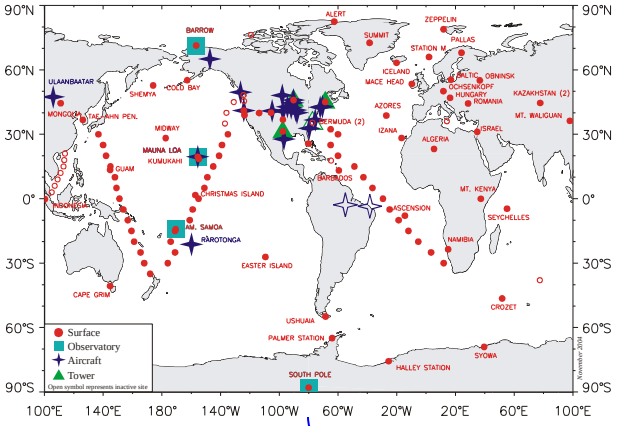


CarbonTracker (annual)

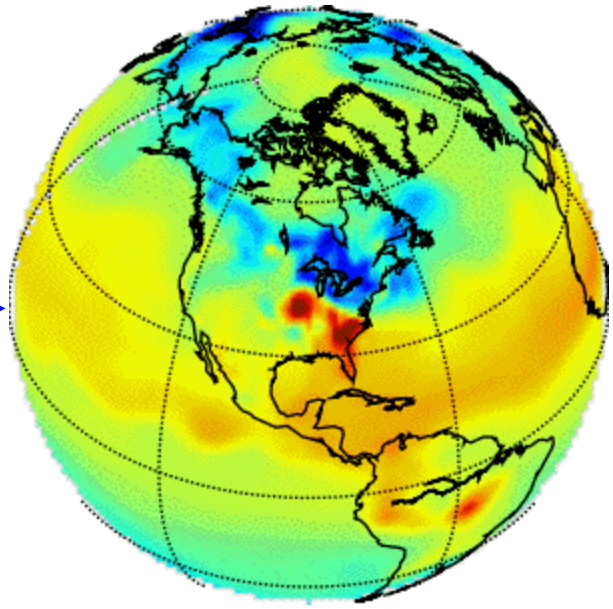


CarbonTracker

(carbontracker.noaa.gov)



Observations



Inversion Analysis

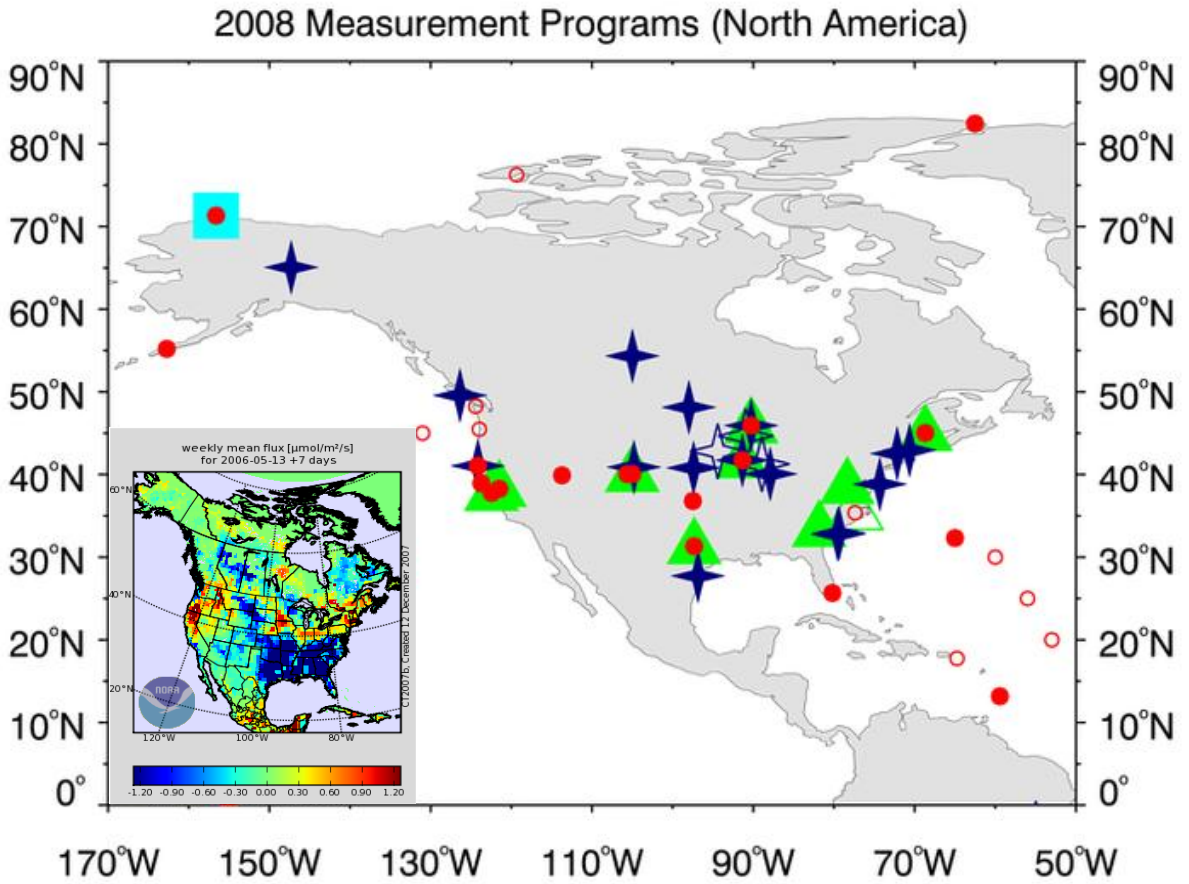
Accounting

Atmospheric CO_2 Account		10^{15} grams of carbon per year*
Date	**Origin**	**Balance**
annual	Biosphere	− 3
annual	Ocean	− 2
annual	Fossil Fuel Burning	+ 7
annual	Deforestation	+ 2
Annually Reported Atmospheric Balance		**+ 4**

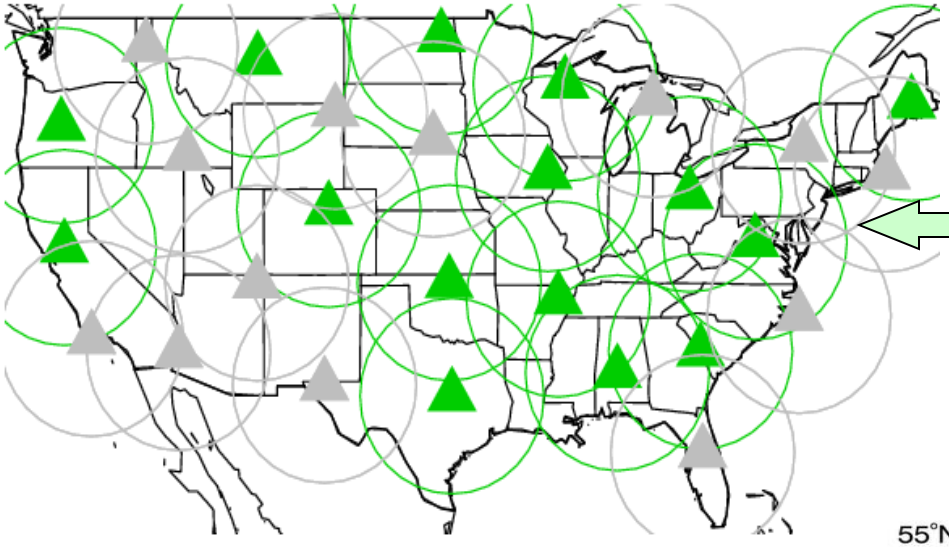
* These numbers are approximate and are for the whole globe

CTOS -- North America

- Current Observations
  - 13+ surface sampling sites (weekly; assmilated)
  - 6 tall tower sites (continuous measurements; assimilated)
  - 14 aircraft sites, (bi-weekly; validation)
- Needed Observations
  - More surface sites
  - 12 more tall towers
  - 24 aircraft, sampling weekly

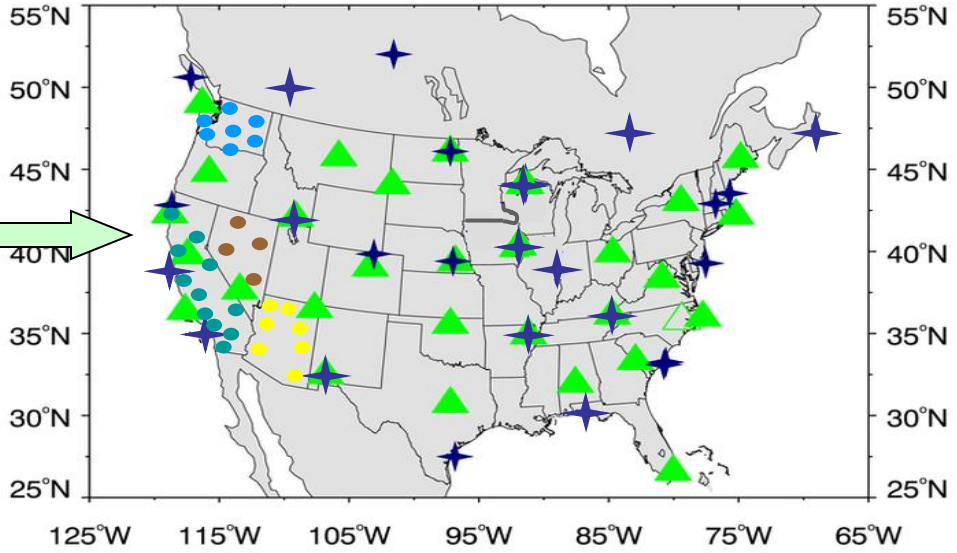


Building a Surface-based Network for the Future

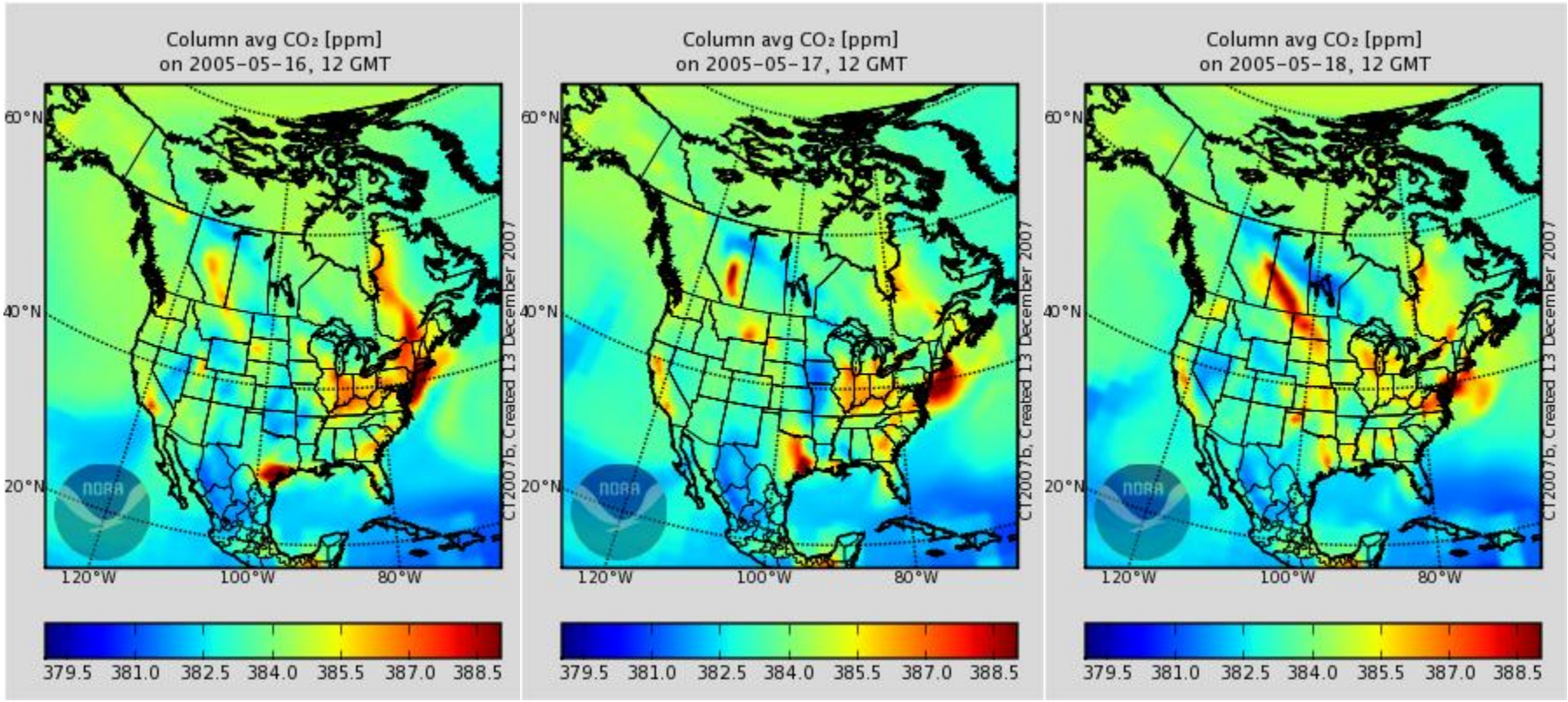


- Recent studies show that tall towers have about a 1000 km footprint
- Covering the US could call for as many as 28 tall towers

- State and regional partners can and do contribute to this system
- Expanding and connecting state systems could dramatically increase resolution



How to provide the best regional information?



May 16, 2005

May 17, 2005

May 18, 2005

(Carbontracker.noaa.gov)

Validation

(Independent Vertical Measurements)