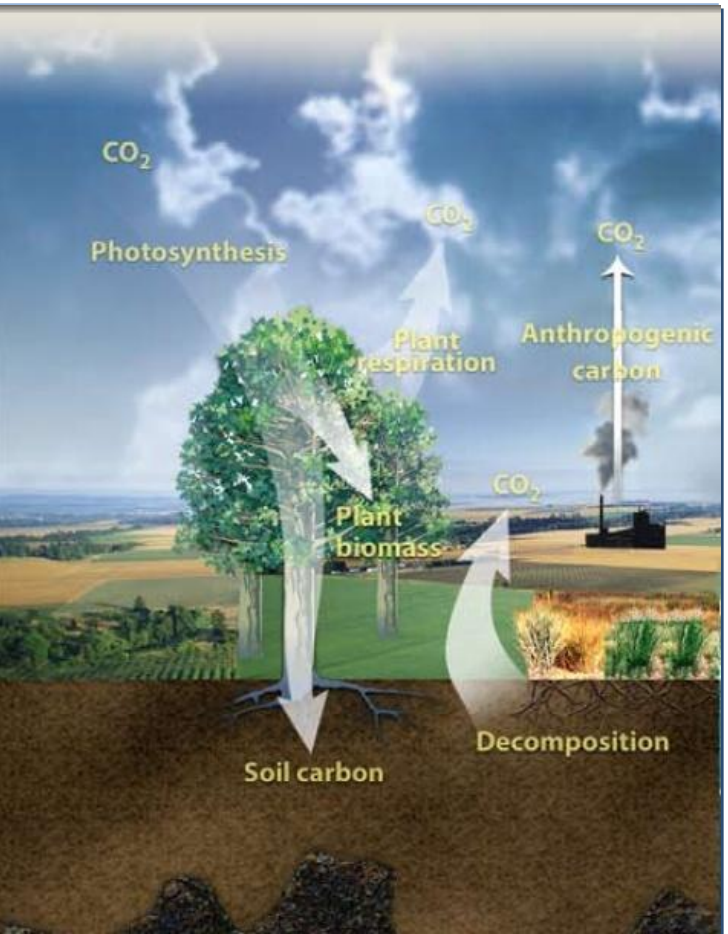
Integrating observations from remote sensing, inventories and flux data with models for estimating terrestrial carbon sources and sinks

IPCC expert meeting on uncertainty and validation of emission inventories

March 23-24, 2010

Beverly Law

Oregon State University



Topics

- Inventories, ancillary data and remote sensing data to determine net emissions
- Integration of inventories, remote sensing data and models for annual estimates of C stocks and net sources/sinks

First level of synthesis

Integration of inventories and data from ecosystem studies with remote sensing data

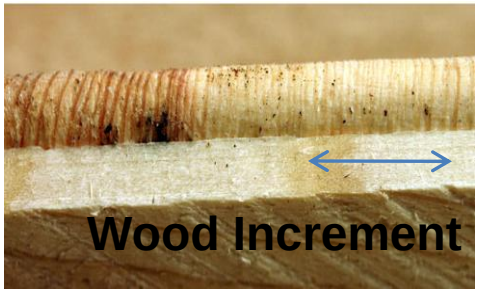
Inventory Data Approach

Biomass

- Inventory Data
- Ecosystem Studies
- Allometrics

NPP

- Wood Increment
- Ecosystem Studies



Respiration

- Decomposition →Rh

or

- Decomp + Rh component of soil respiration

NEP (NPP-Rh)

- Mass Balance

or

- Regression Model

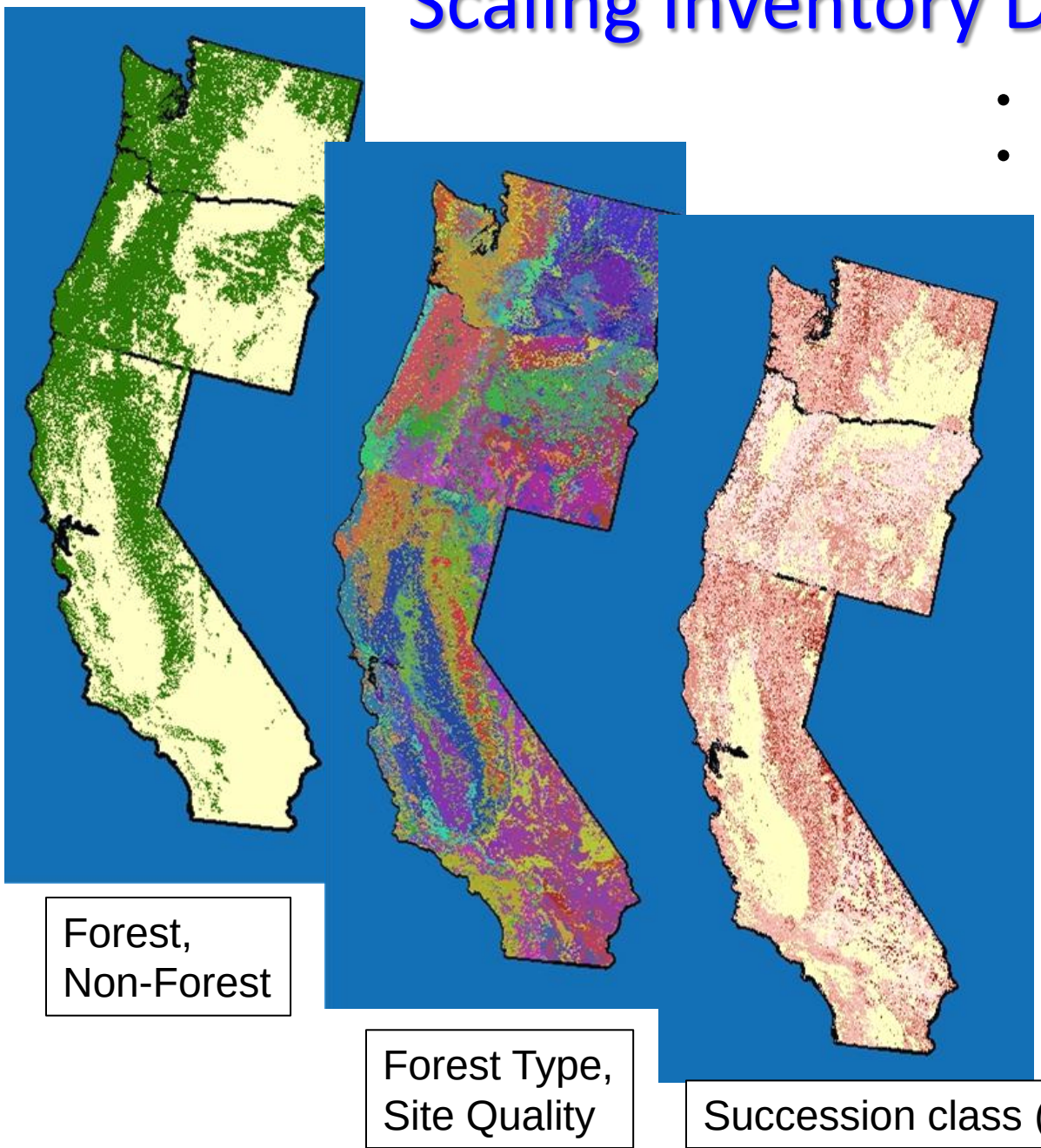
Mass balance NEP = ANPP – litterfall – dead wood decomposition + Δ root +Δ soil C
Alternate method: NEP = NPP – heterotrophic respiration (from soil and woody detritus)

Minimum measurements for estimating C stocks/NPP/NEP on plots

Inventory Plots	Ecological studies	Remote Sensing
• Live and dead tree diameter, height, species • Increment or repeated measures, age • Woody Detritus (all) • Litter stocks • Understory	• Fine root data • Soil Respiration • Decomposition • Stump data • Soil carbon and bulk density • Foliage metrics	• Climate data • Forest Type • Forest age or surrogate • Soil fertility maps (Site Quality) • LAI

IPCC guidelines for Annex 1 countries: Net CO_2 release or uptake in managed lands is estimated from changes over time in five carbon stocks: above and below ground biomass, dead organic matter (coarse woody debris and litter), and soil organic matter

Scaling Inventory Data



Forest, Non-Forest

Forest Type, Site Quality

Succession class (age)

- Landsat data for scaling
- Extracted plot values are grouped based on these attributes and mean values for NEP (or biomass) are assigned to each pixel

Research and comprehensive ecosystem inventories to reduce uncertainty

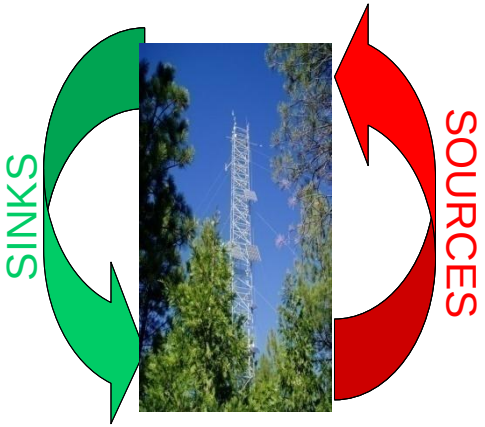
- Reduce uncertainty in estimates of change in ecosystem carbon
  - Improved allometrics for live mass (size classes, vegetation type)
  - Wood increment and age in forests
  - Coarse woody detritus pool, metadata on disturbance condition
  - Ecosystem studies on decomposition rates of woody detritus (by climate zone, vegetation type, disturbance condition)
  - Soil CO_2 fluxes – (soil chamber measurements by veg type, climate zone, disturbance condition - seasonal)
- Reduce uncertainty in remote sensing estimates
  - Land cover, forest age, burn severity classes; better accuracy assessments, more frequent coverage
  - In situ combustion factors by burn severity, pools from measurements of live and dead mass, soil, litter and duff (paired plots or before/after fire)

Intermediate level of synthesis

Integration of remote sensing
and inventories in
terrestrial process models

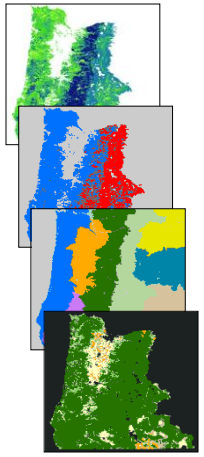
Integration for Regional Mapping of Terrestrial Carbon

Terrestrial Carbon Modeling

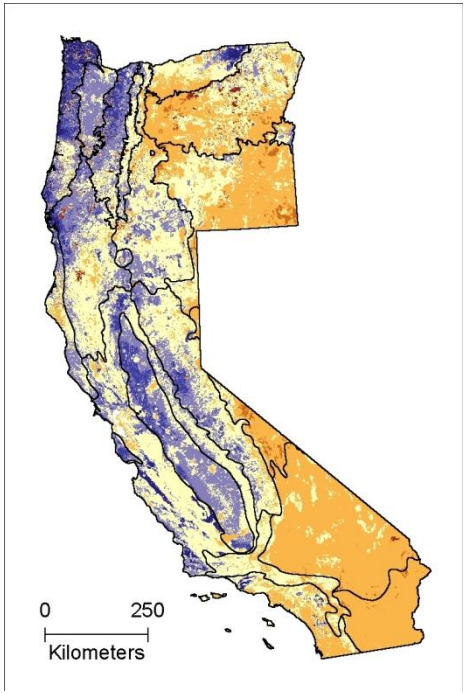


Biosphere CO_2 Flux Observations

Inventories: Biomass Carbon Soil Carbon



Spatial data: Land-cover/use, Fires, Harvest Meteorology

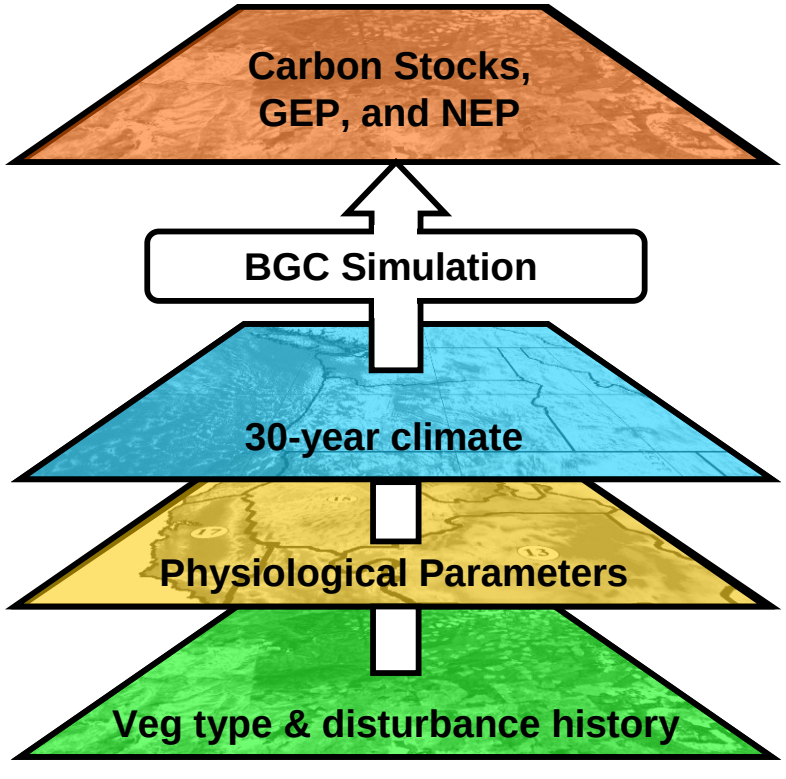


Maps of Terrestrial Carbon Stocks and Fluxes

Ecosystem studies: terrestrial processes

(Law et al. 2006)

Regional Carbon Budget Approach



Model inputs

Data Source:

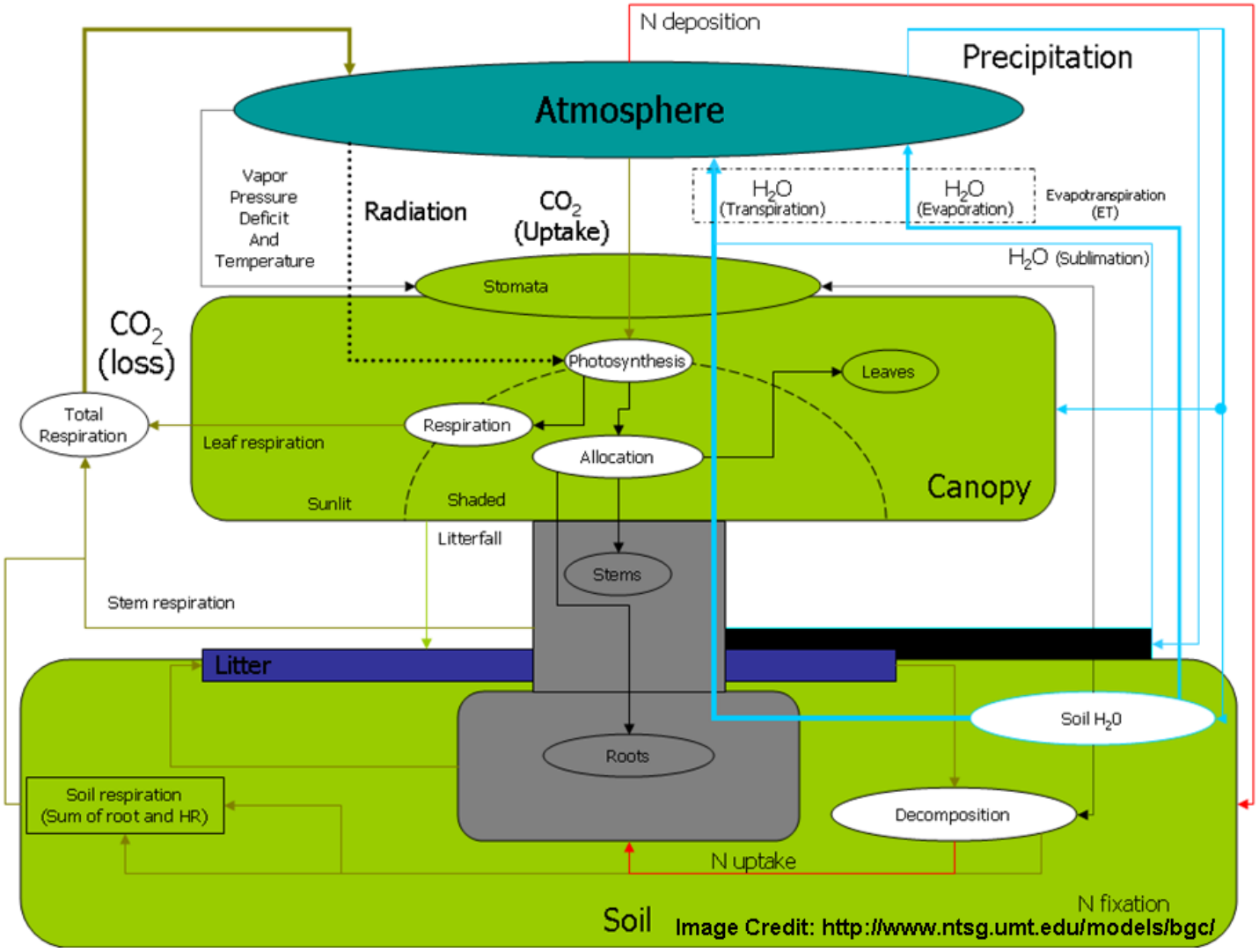
Spatial daily weather

Ecosystem studies

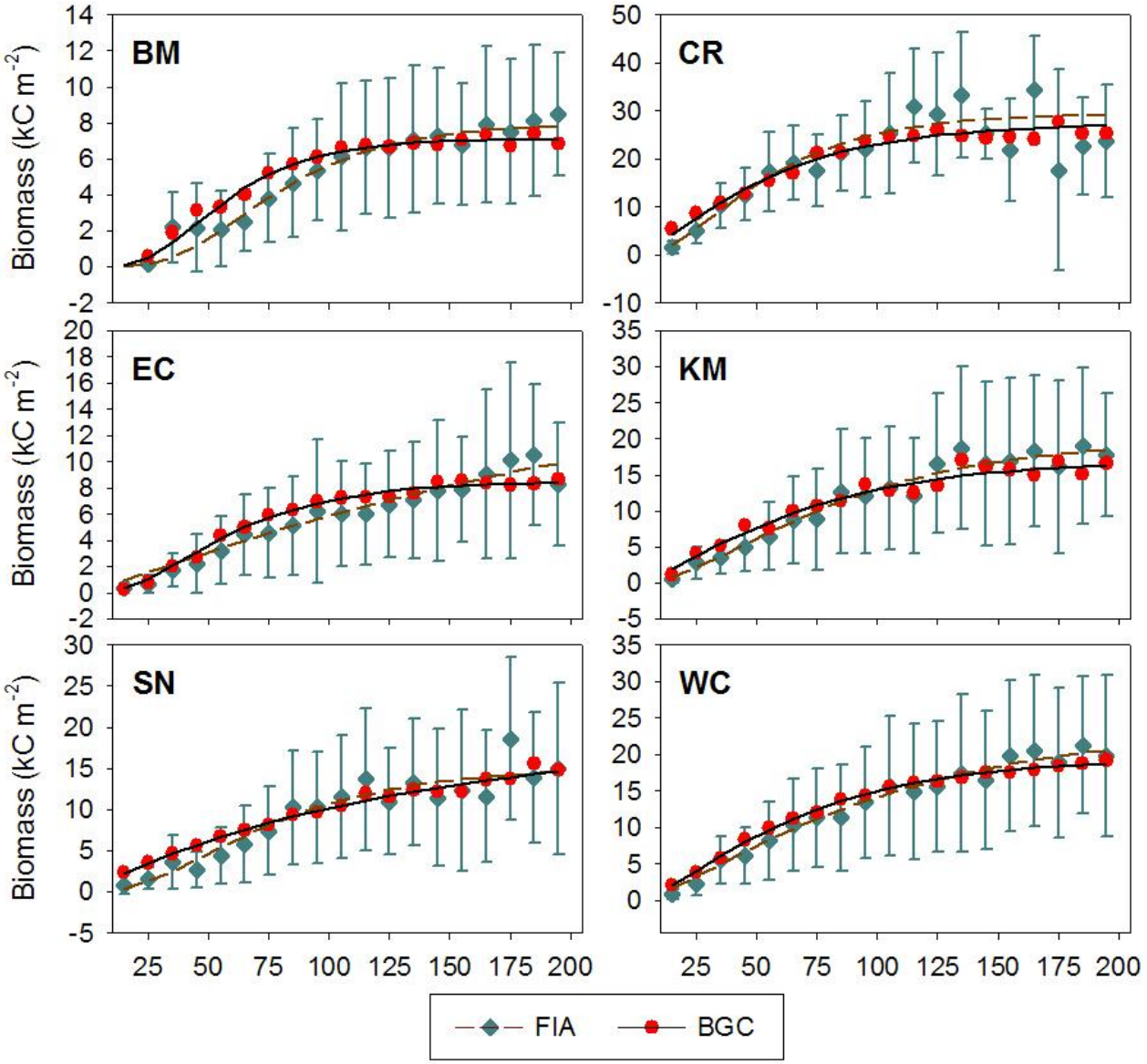
Remote sensing products

(Law et al. 2006)

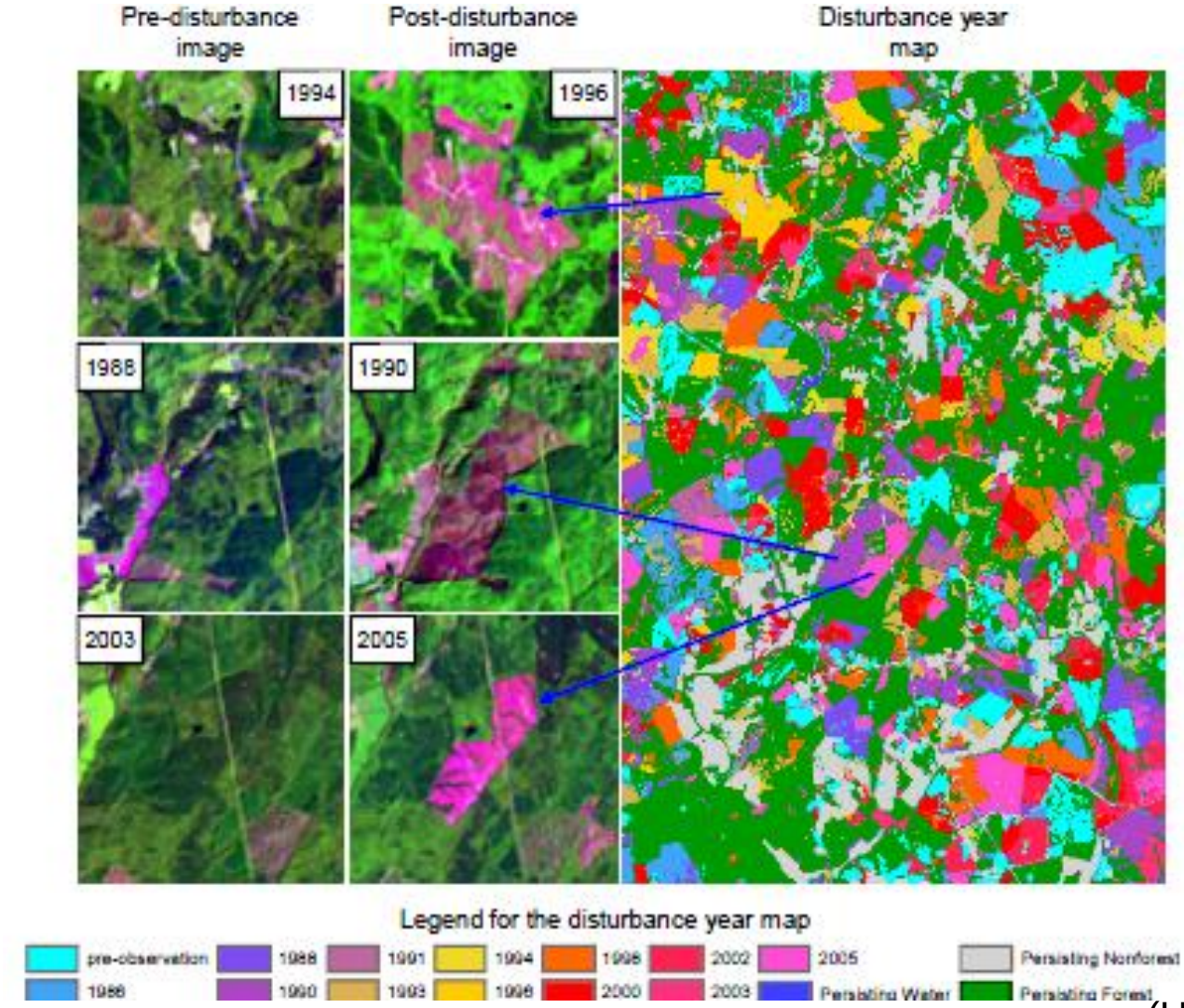
Biome-BGC Bottom-Up Process Model



Age Trends in Biomass by Ecoregion
Model Parameters Optimized w/Inventory Data

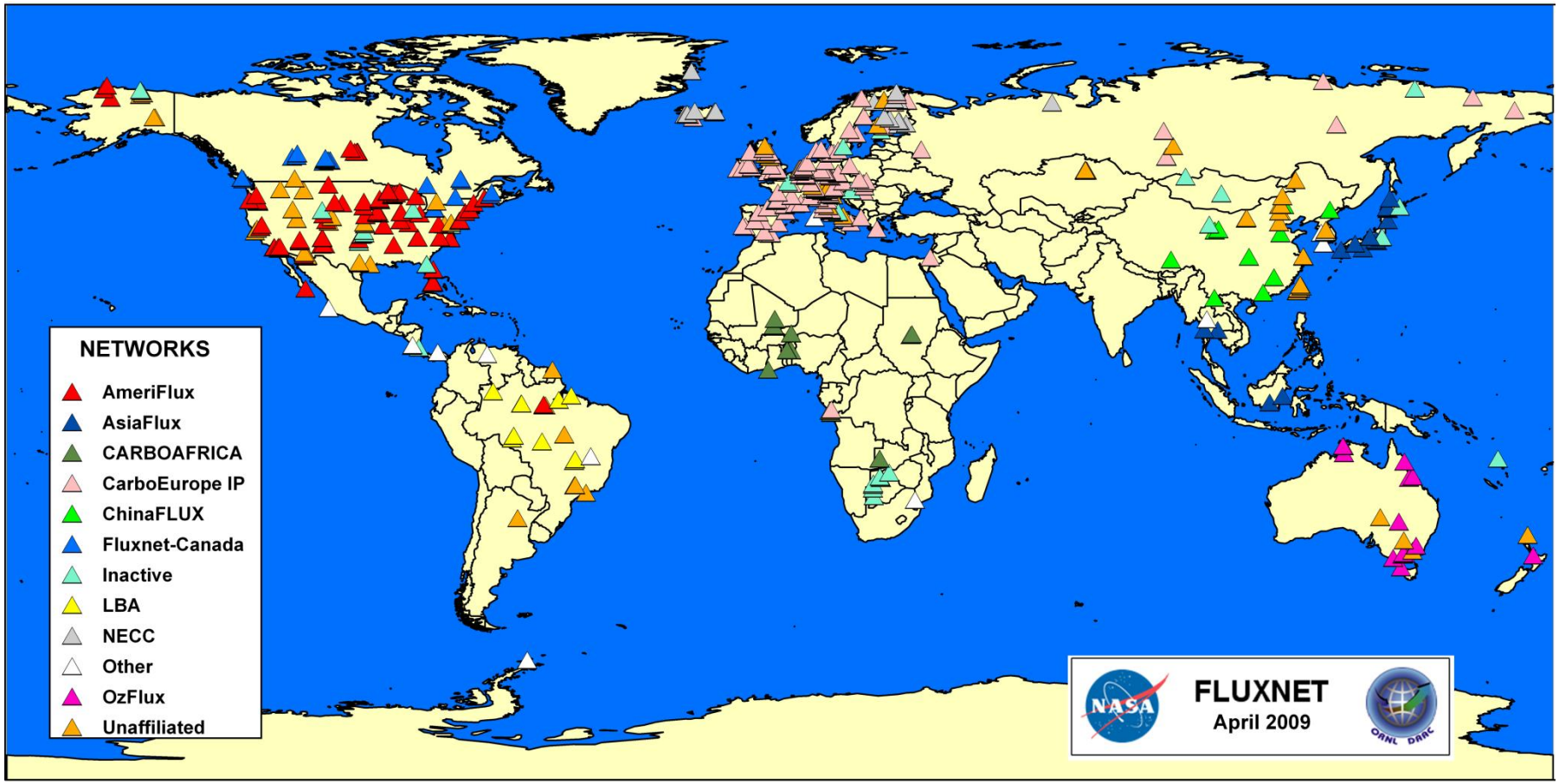


Moderate Resolution Remote Sensing: Deforestation (Landsat change detection, 2 yr interval)



(Huang et al. 2009)

FLUXNET: A Global Network of Observation Sites
500+ Sites, 10 Regional Networks, 45 Countries

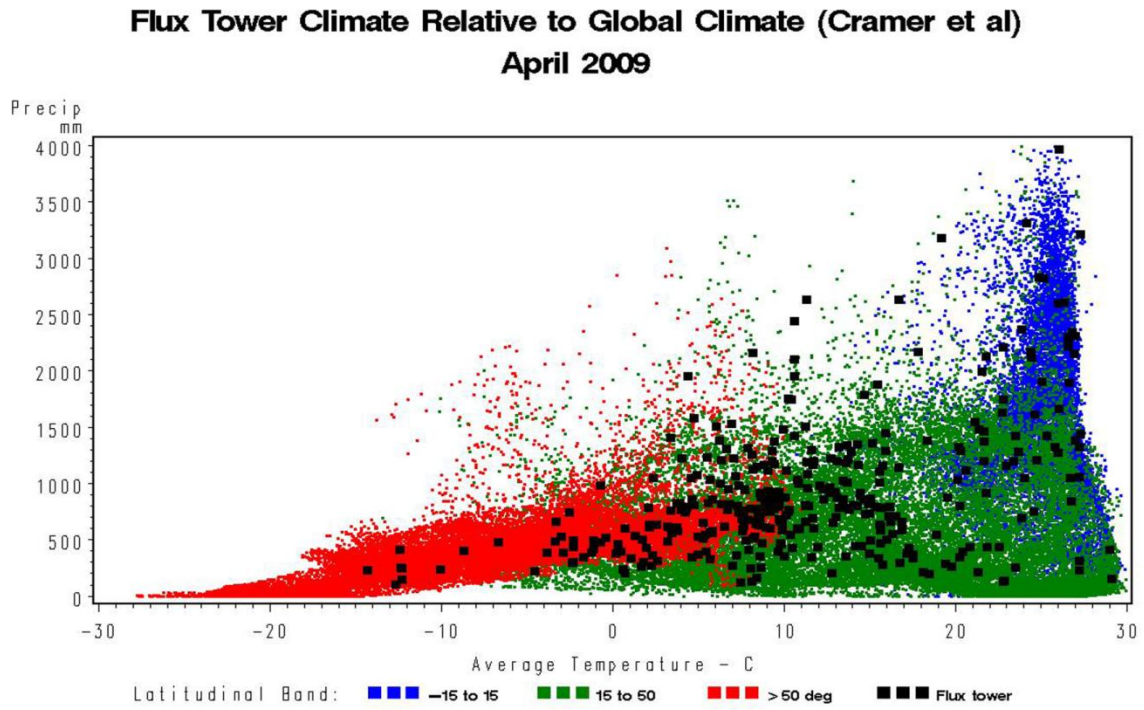


Quantify and understand causes of variation in terrestrial exchange of carbon, water and energy with atmosphere

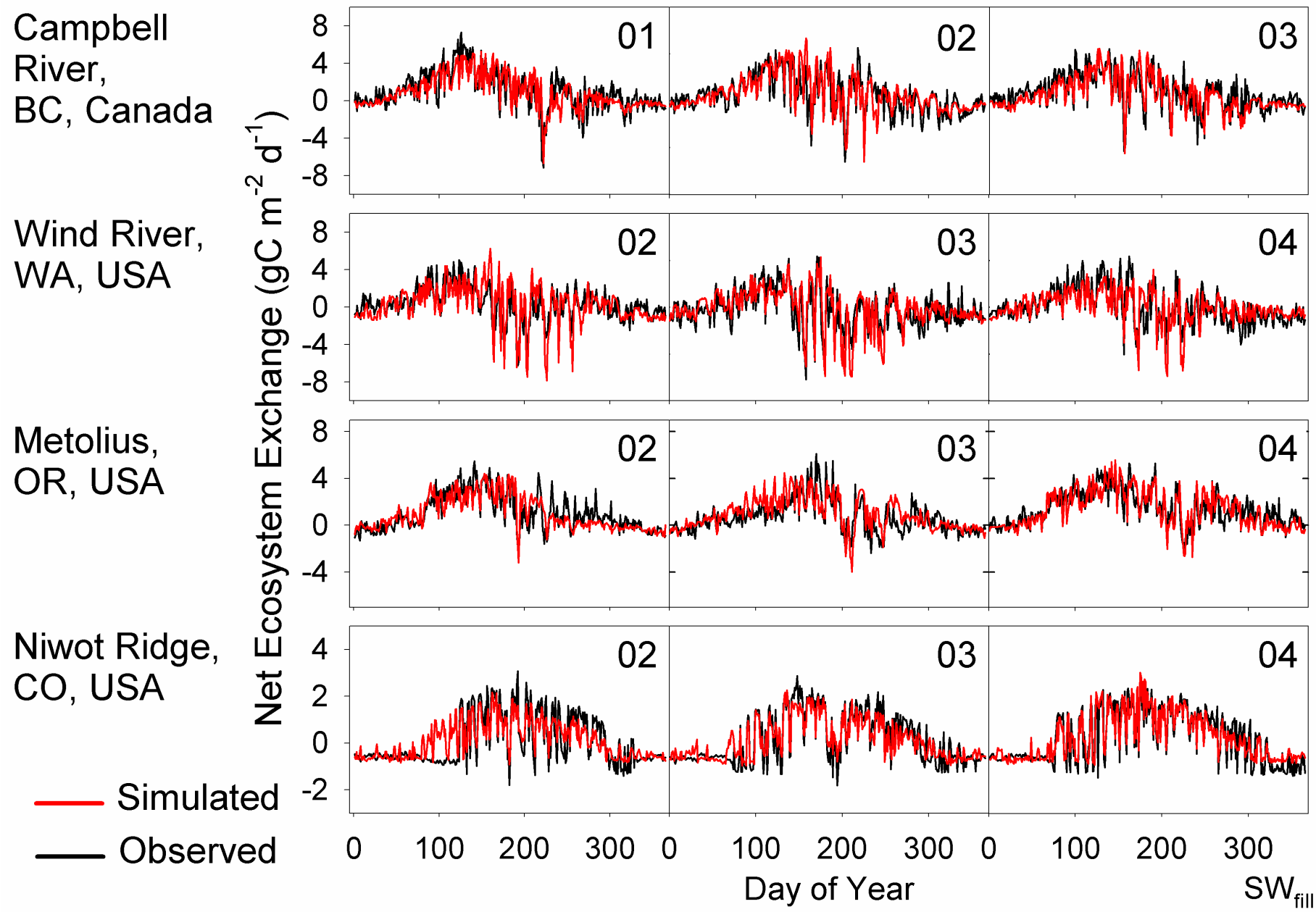
www.fluxdata.org

FLUXNET: Global Terrestrial Flux Observations

- Carbon/water/energy fluxes
- Meteorology, soil and plant variables
- Multiple biomes and disturbances in a broad range of climate
- Standardized database, shared protocols (Law et al. FAO 2008)

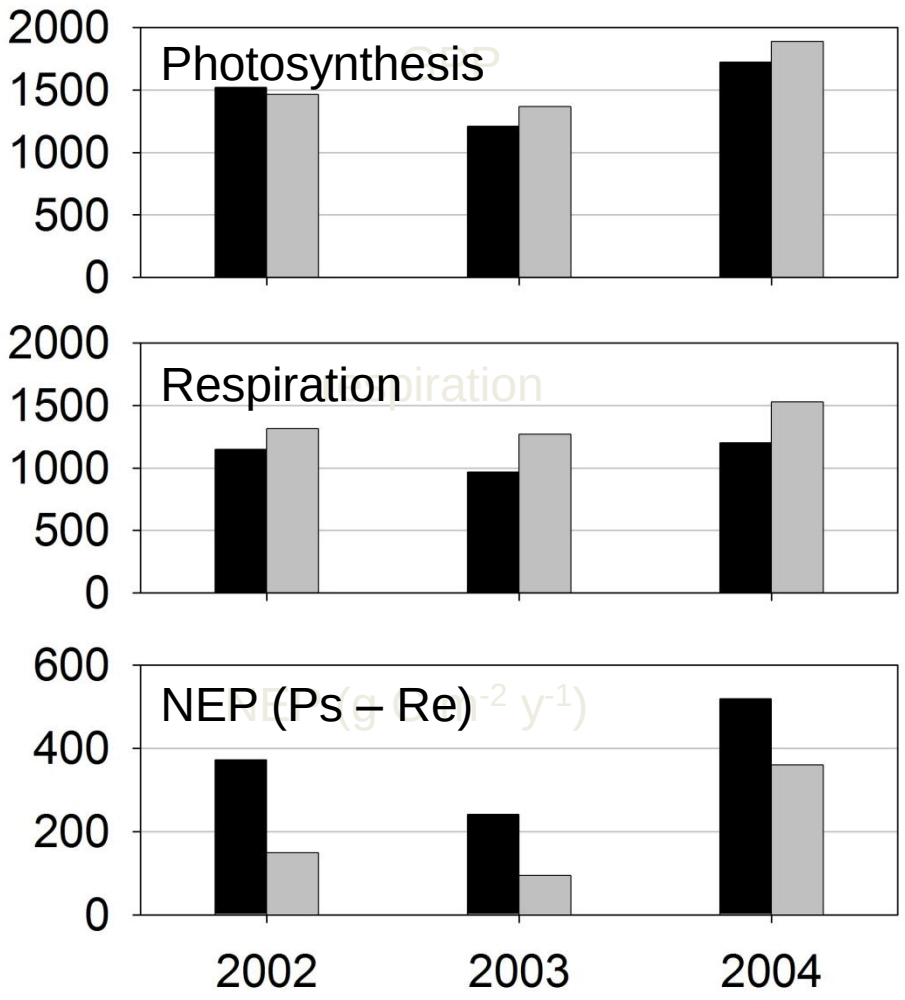


Comparison of Tower & Modeled NEE



Tower Flux Data Used to Evaluate Model

- Long-term data used to evaluate ability to capture interannual variability in component processes and net carbon uptake



Black = tower obs
Gray = model

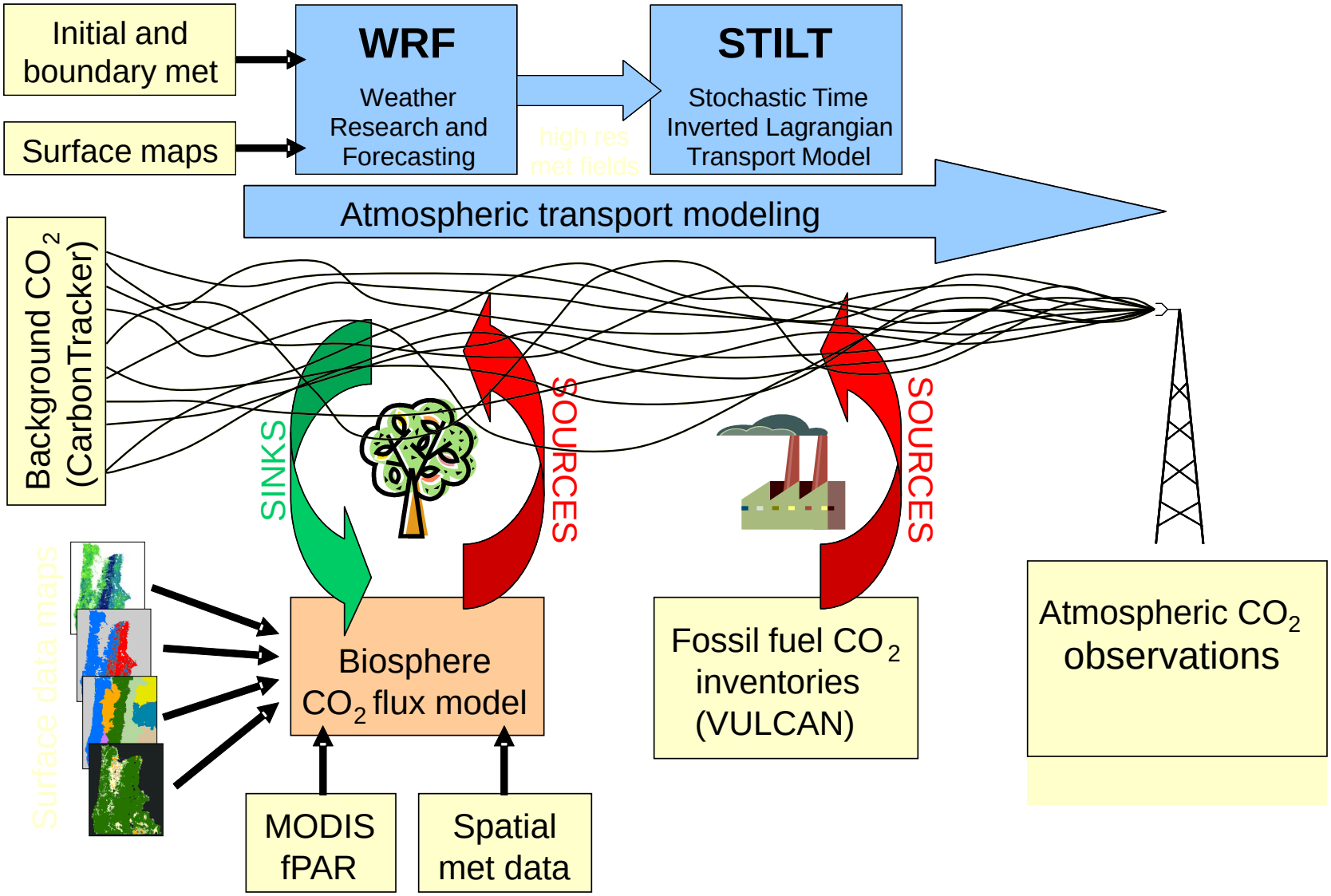
Uncertainty, improvements in bottom-up model-data integration

- Remote sensing inputs
  - Disturbance mapping (fire, harvest) – frequency of change detection (1-2 yr, multi-season for selective harvest)
  - Land cover – frequency
- Model parameters from ecosystem studies
  - Biomass by forest age from inventories (veg type within ecoregion)
  - Foliar nitrogen, sla from ecosystem studies for bgc-type models
- Ecosystem studies to evaluate models or use in data assimilation
  - Tower eddy covariance flux data – direct measure of net carbon uptake
  - Post-disturbance trajectories of annual net carbon uptake
  - Research on data assimilation methods for quantifying terrestrial fluxes
- Quantifying uncertainty, aggregation errors

Highest level of synthesis

Integration of bottom-up and top-down approaches

Top-Down Modeling

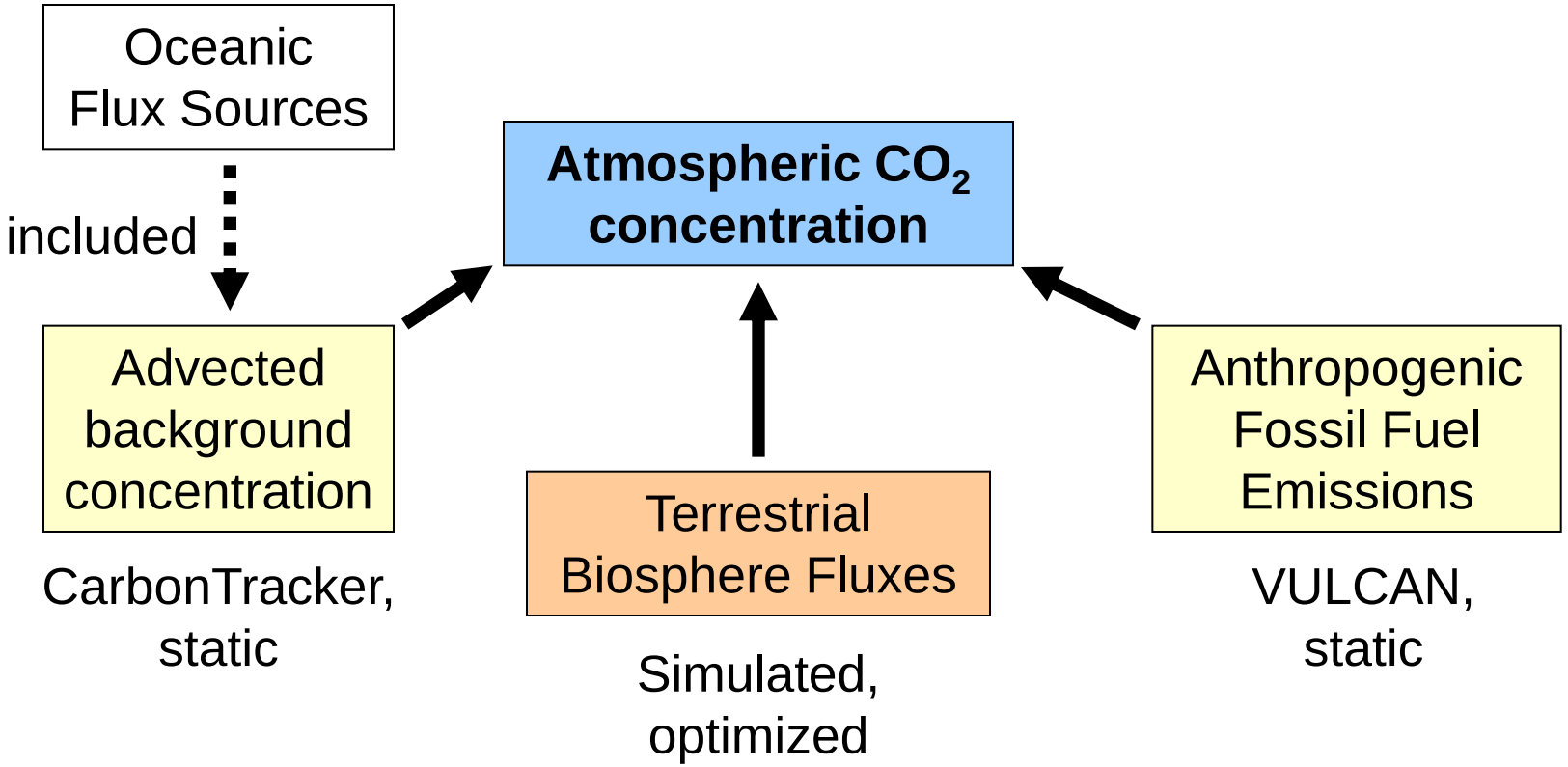


Uncertainty, improvements in top-down model-data integration

- Atmospheric transport modeling
  - Boundary layer depth / Vertical mixing processes
  - Advected boundary conditions (for scales < global)
- Density of CO_2 observations
  - New, accurate instruments for continuous observations
  - More sites needed, optimized locations in network setup
- Simulation of surface CO_2 fluxes
  - Consideration of drought stress and disturbance in models
  - Scale dependency, aggregation errors
  - Temporal resolution, in relation to atm. sampling frequency
- Additional surface CO_2 fluxes
  - Temporal and spatial resolution of fossil fuel inventories
  - Consideration of biomass burning events (fires)

Extras

Top-Down Flux Sources



Top-Down vs. Bottom-Up CO_2 fluxes

	Top-Down	Bottom-Up
C-Cycle	Simple flux model or biophysics – biogeochemistry	Biogeochemistry many pools, derived through spin-up
N-Cycle	-	Fully coupled with C
Phenology	Remote-sensing driven (fPAR)	Prognostic
Optimized against	Ecosystem flux data, atmospheric CO_2 observations	Inventory datasets (biomass, etc)