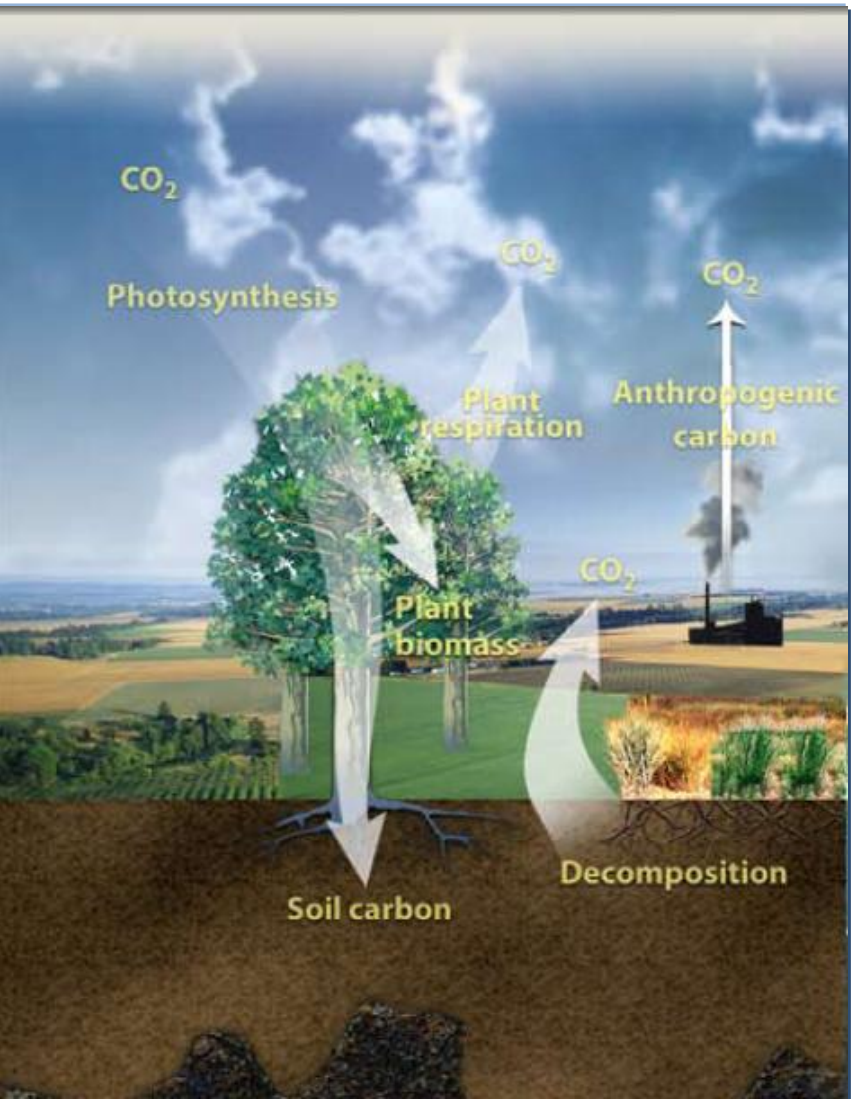
15th Annual AmeriFlux Meeting



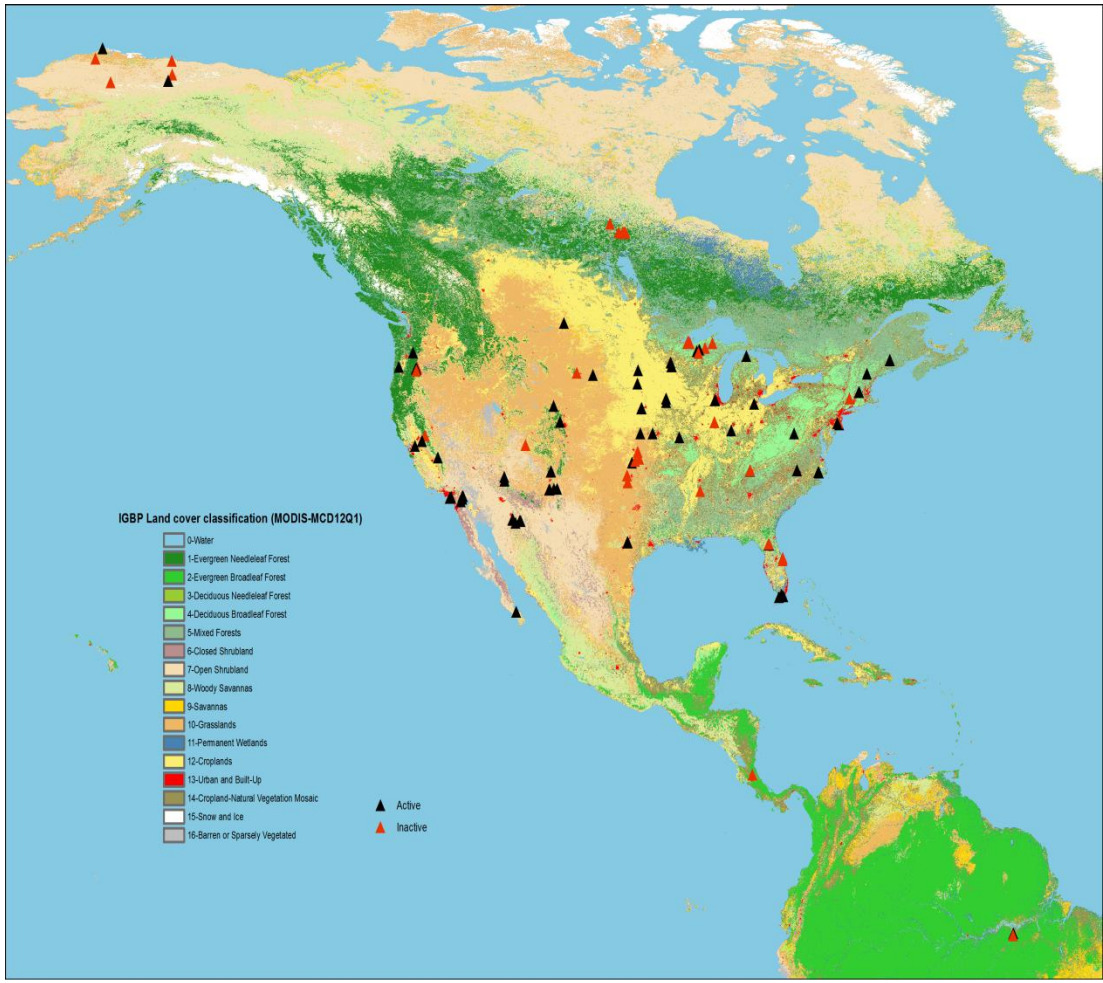
Bev Law
Prof. Global Change Forest Science
Oregon State University

New Orleans, LA Jan 31-Feb 1, 2011

State of the Network

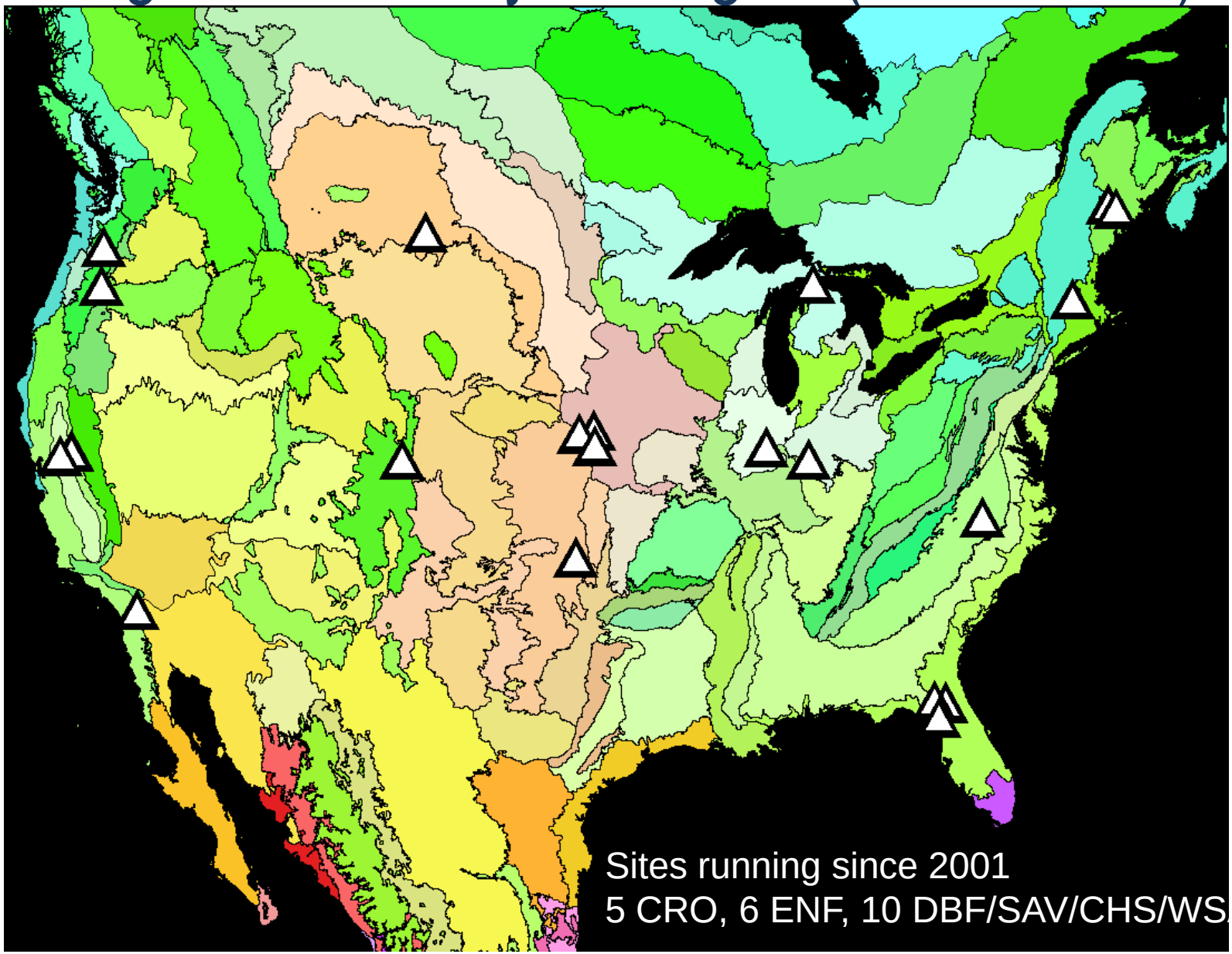
http://public.ornl.gov/ameriflux

- Inception: 1996
- ~93 active sites as of Jan '11 Most major ecoregions covered
- ~21 sites running > 10 years
- 45 sites funded by DOE, 19 NSF, 15 USDA, 8 NOAA, 3 universities, 1 NASA, 2 Mix



(black = active)

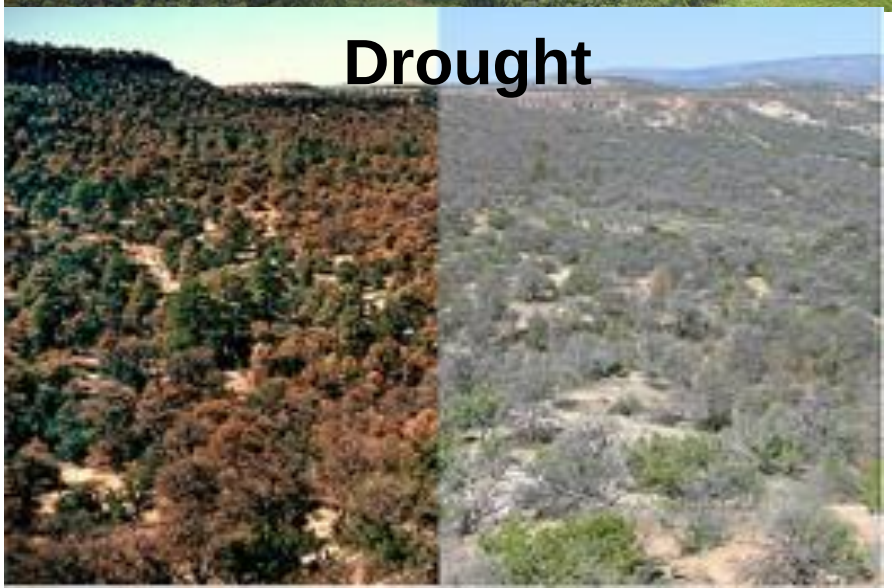
Long-term Sites by Ecoregion (Omernik L3)



Long-term Sites by Ecoregion

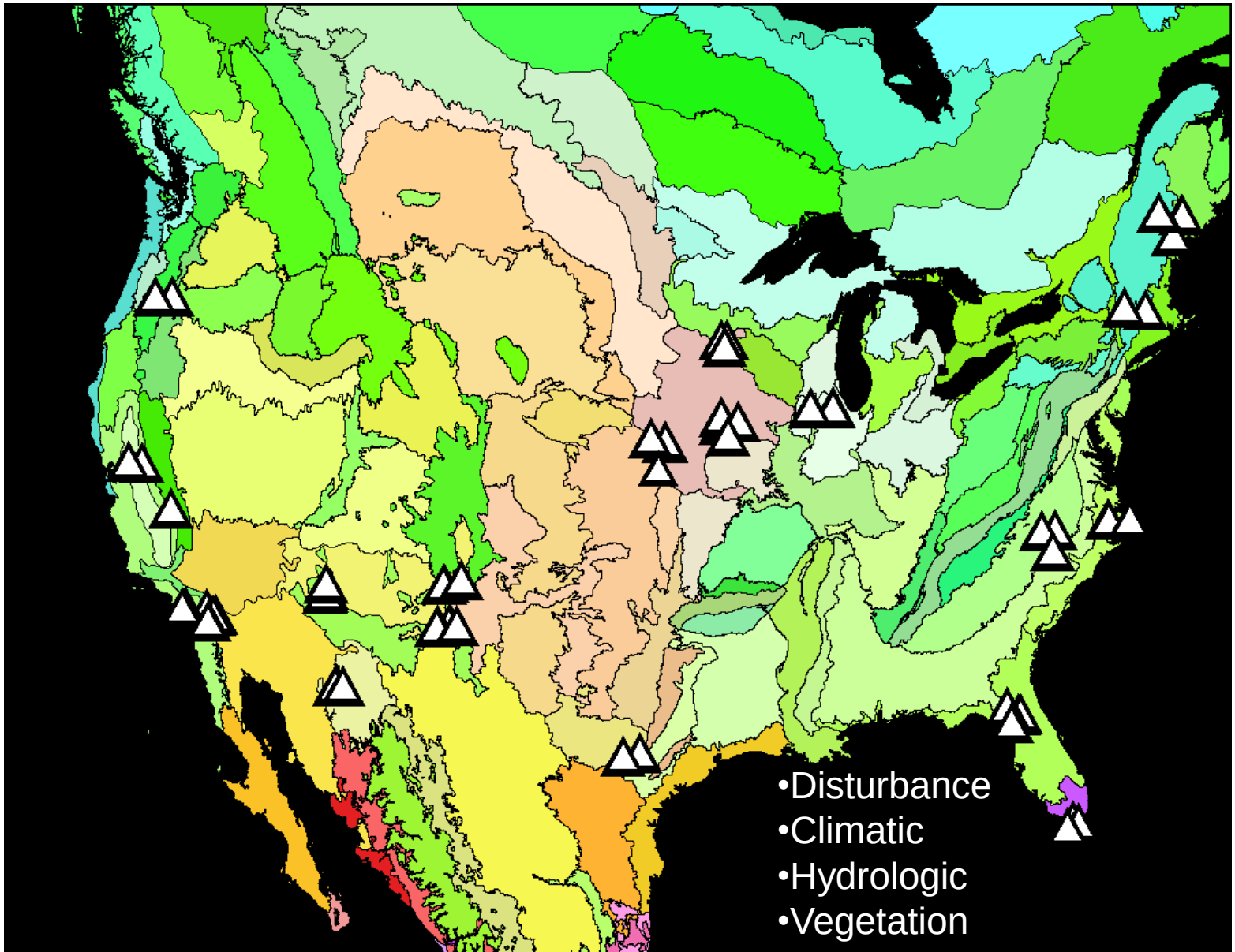
Ecoregion (I &III)	*Years of Data*	*# of Sites*
EASTERN TEMPERATE FORESTS	**87**	**8**
Acadian Plains and Hills	**25**	**2**
Central Corn Belt Plains	**15**	**1**
Interior Plateau	**10**	**1**
Piedmont	**8**	**1**
Southern Coastal Plain	**29**	**3**
GREAT PLAINS	**48**	**5**
Central Great Plains	**10**	**1**
Northwestern Glaciated Plains	**11**	**1**
Western Corn Belt Plains	**27**	**3**
MEDITERRANEAN CALIFORNIA	**31**	**3**
CA Coastal Sage, Chaparral, and Oak Woodlands	**19**	**2**
Southern and Baja California Pine-Oak Mountains	**12**	**1**
NORTHERN FORESTS	**30**	**2**
N Appalachian and Atlantic Maritime Highlands	**18**	**1**
Northern Lakes and Forests	**12**	**1**
NORTHWESTERN FORESTED MOUNTAINS	**29**	**3**
Cascades	**11**	**1**
Eastern Cascades Slopes and Foothills	**7**	**1**
Southern Rockies	**11**	**1**
Grand Total	**225**	**21**

Carbon in Plants and Soil Vulnerable to Land Use, Drought, Fire, Insects/Diseases



~16 Clusters of Sites Along Gradients

1 in NW, 5 in SW, 4 in NC, 1 in SC, 2 in NE, 3 in SE

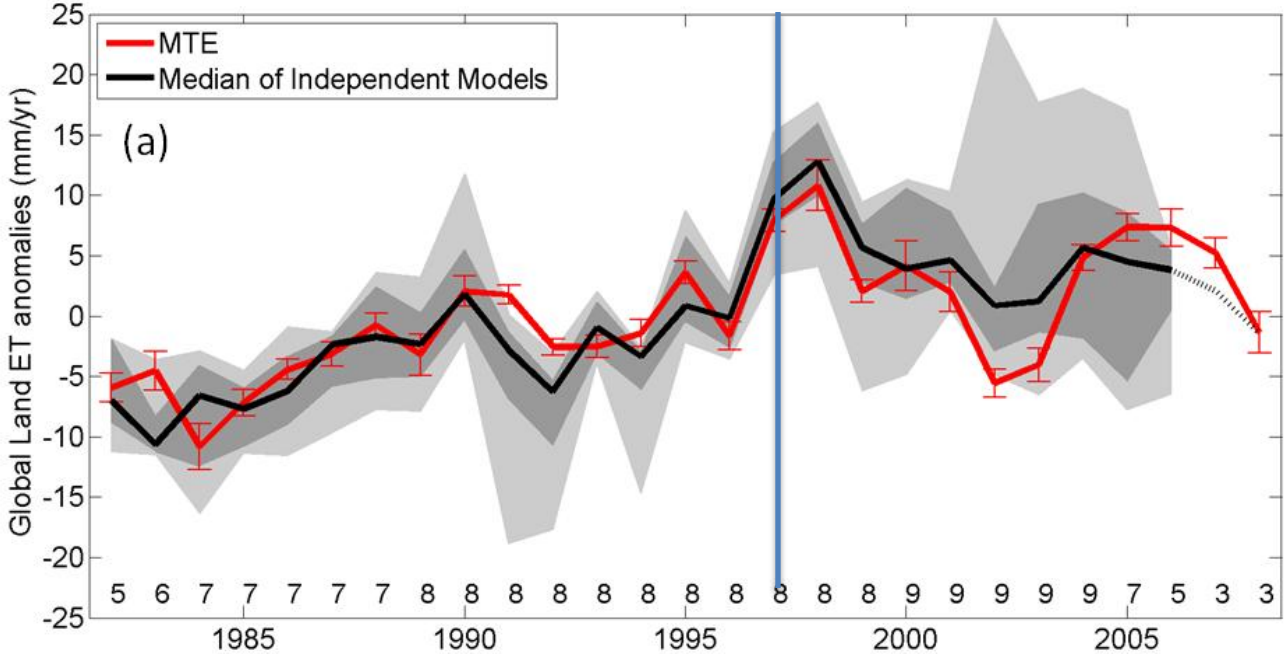


Key Findings - 2010

- Terrestrial GPP: Global distribution and covariation with climate
  - Tropical forests and savannahs account for 60% of global GPP
  - GPP over 40% of the vegetated land is associated with precipitation
  - Large among-model variation in GPP latitudinal patterns, higher correlations between GPP and precip than observed, suggesting missed processes or feedback mechanisms that would attenuate veg response

(Beer et al. Science 2010)

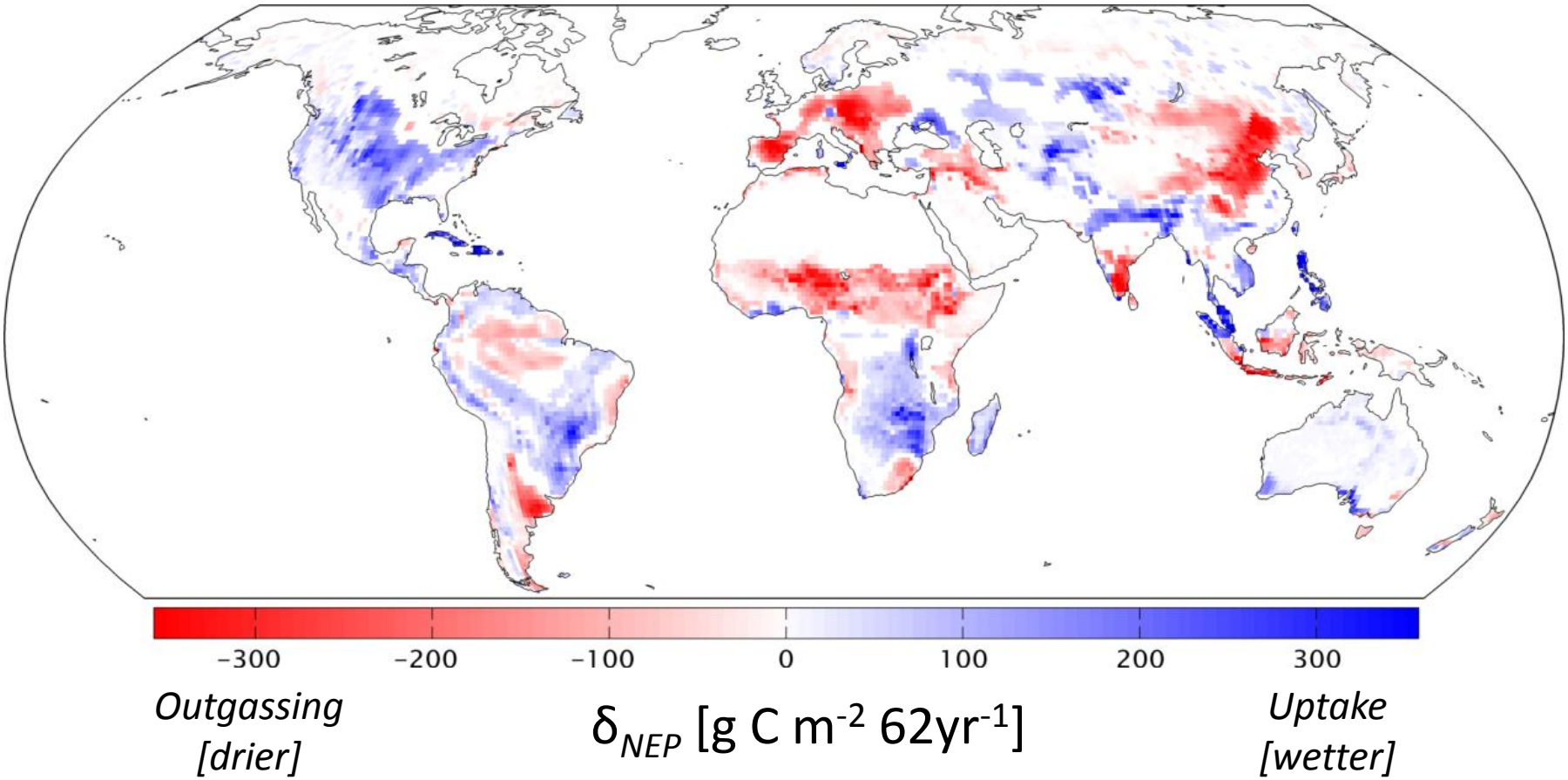
It's Not Just About CO_2:
Decline in Trend of Global Land Evapotranspiration



- Data-driven estimate using tower flux, meteology, remote sensing data and MTE compared with independent models
- Global ET increased from 1982 to 1997 then ceased until 2008, driven by moisture limitation in the S. Hemisphere
- Are changing patterns of ET representative of natural variability or a more permanent reorganization of the land water cycle?

(Jung et al. Nature. 2010)

NEP Trend (1948-2009) that is Solely Attributable to Hydroclimatic Change

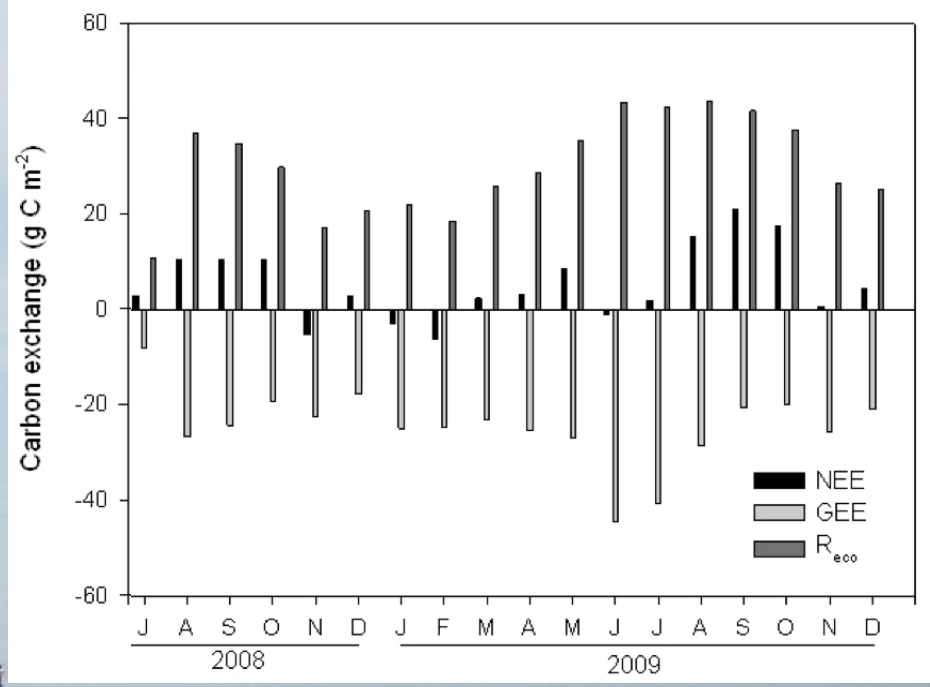


- Based on upscaling flux tower data (238 sites), NCEP Reanalysis Evap Fraction
- Caveat – emphasis on short-term dynamics misses lags, positive feedbacks
- Need more sites in Africa, Asia

(Schwalm et al. GCB 2010)

Everglades Hydroperiod Cluster of Sites

- Once part of one of the world's largest single bodies of peat soils, but subjected to 100 yr of hydrological disruption
- Long-hydroperiod marsh of the Everglades is a carbon source

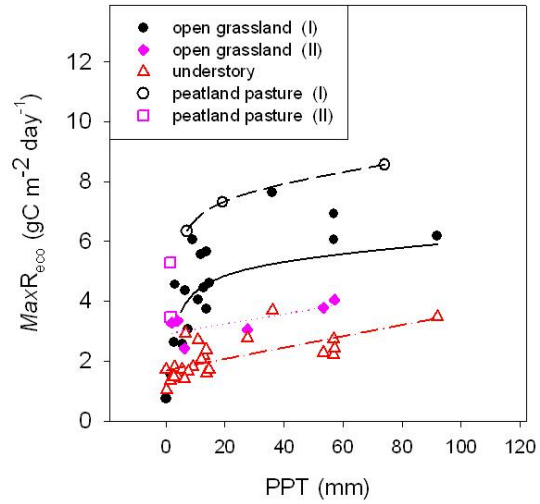


Jimenez et al. 2011. Carbon Dioxide Exchange Rates from Short- and Long-Hydroperiod Everglades Freshwater Marsh. (Near submission JGR-Biogeosciences) .

Respiration Response to Pulse Rain Events: Nonlinear and Highest After Drought

- First rain at semi-arid AmeriFlux sites experience extraordinary pulses of ecosystem respiration after summer drought – widely reported
- First pulse is greater than subsequent pulses
- Pulses in sunlit areas higher than understory
- Size of soil organic C pool matters
- With global warming/drying, effect may become more widespread and needs to be incorporated in coupled climate-carbon models

Greatest Pulses, 1st and at Sunniest Sites



- Type I pulse is the first pulse occurring right after summer drought;
- Type II pulse is the sequencing pulse.

Ma et al. Global Change Biology, in Review

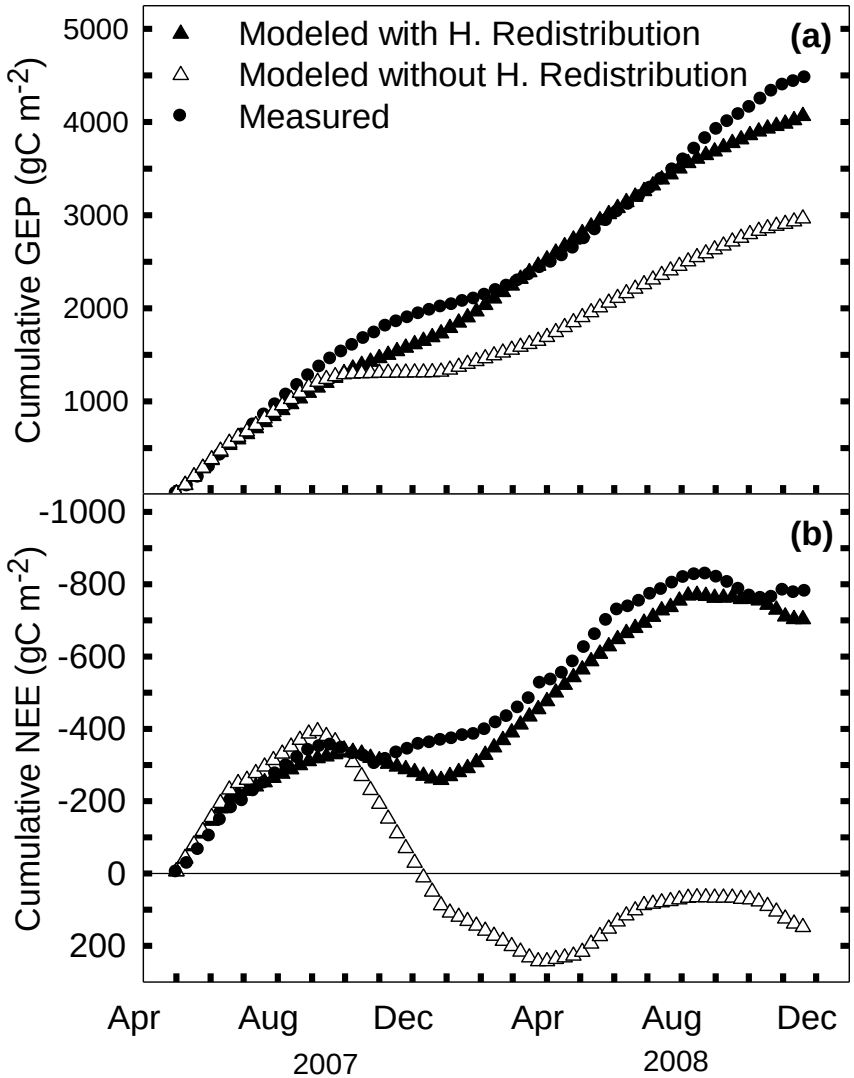
Tonzi/Vaira Ranches, Sherman Island CA
(Ma et al. GCB in review)

Hydraulic redistribution affects C uptake

Site: 17-yr old loblolly pine plantation in NC, US-NC2

Model: SPA

- High productivity through drought is sustained due to hydraulic redistribution
- Without hydraulic redistrib., the site would be a C source

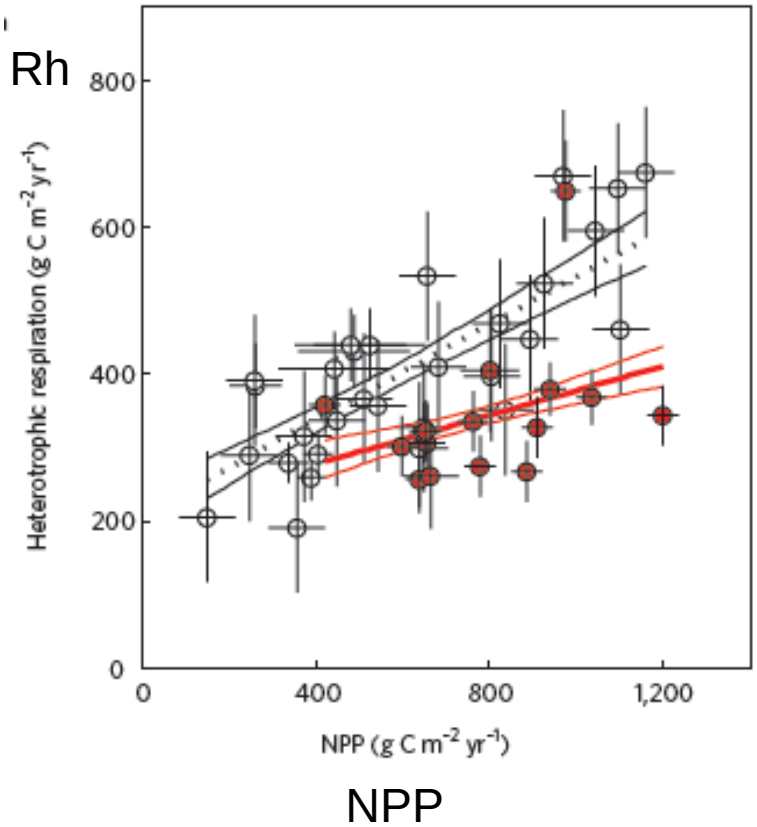


Domec JC, King JS, Noormets A, Treasure EA, Gavazzi MJ, Sun G, McNulty SG. 2010. Hydraulic redistribution of soil water affects whole stand evapotranspiration and net ecosystem carbon exchange. *New Phytologist* 187:171-83.

Highlighted in Forum:
Katul GG, Siqueira MB. 2010. Biotic and abiotic factors act in coordination to amplify hydraulic redistribution and lift. *New Phytologist* 187:4-6.

Microbial Mitigation of Soil Carbon Emission

- Meta-analysis suggests N dep impedes organic matter decomposition, stimulates C sequestration in temperate forest soils where N is not limiting microbial activity
- Reduction in soil C emissions is equivalent in magnitude to C uptake by trees due to N fertilization



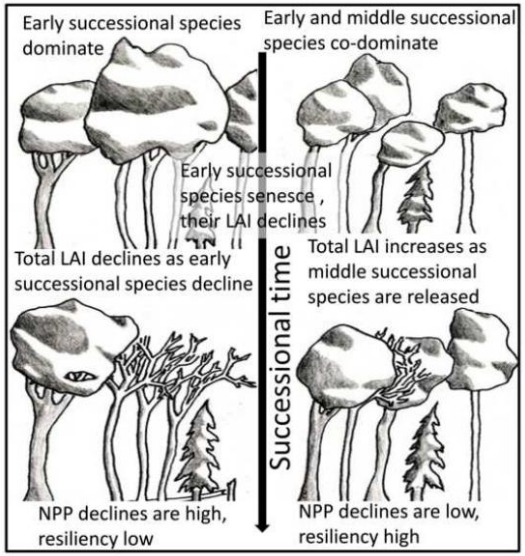
Red symbols: N dep > 5.5 Kg N/ha/yr

(Janssens et al. Nature GeoSci. 2010)

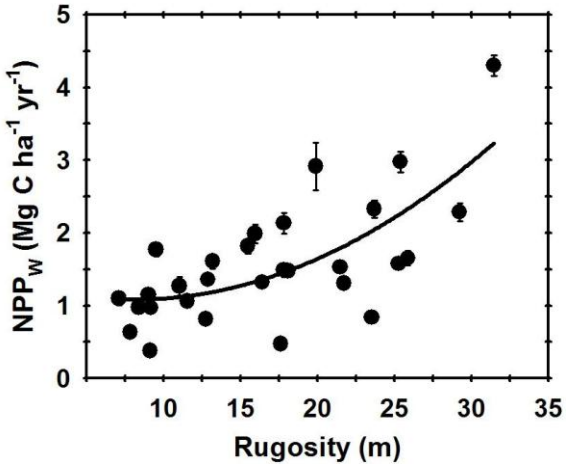
High rates of carbon storage in old deciduous forests: Emerging mechanisms from the Forest Accelerated Succession ExperimenT (FASET)

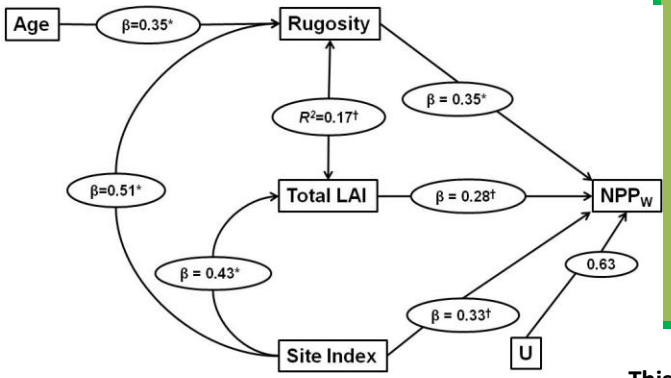
PIs: PS Curtis, CM Gough, K Nadelhoffer, G Bohrer

More diverse forest plots are more resilient to carbon storage declines with age (Gough *et al*. FEM 2010)



Older forest plots that are more structurally complex (more rugose) have higher wood NPP (Hardiman *et al*. Ecol, in review)



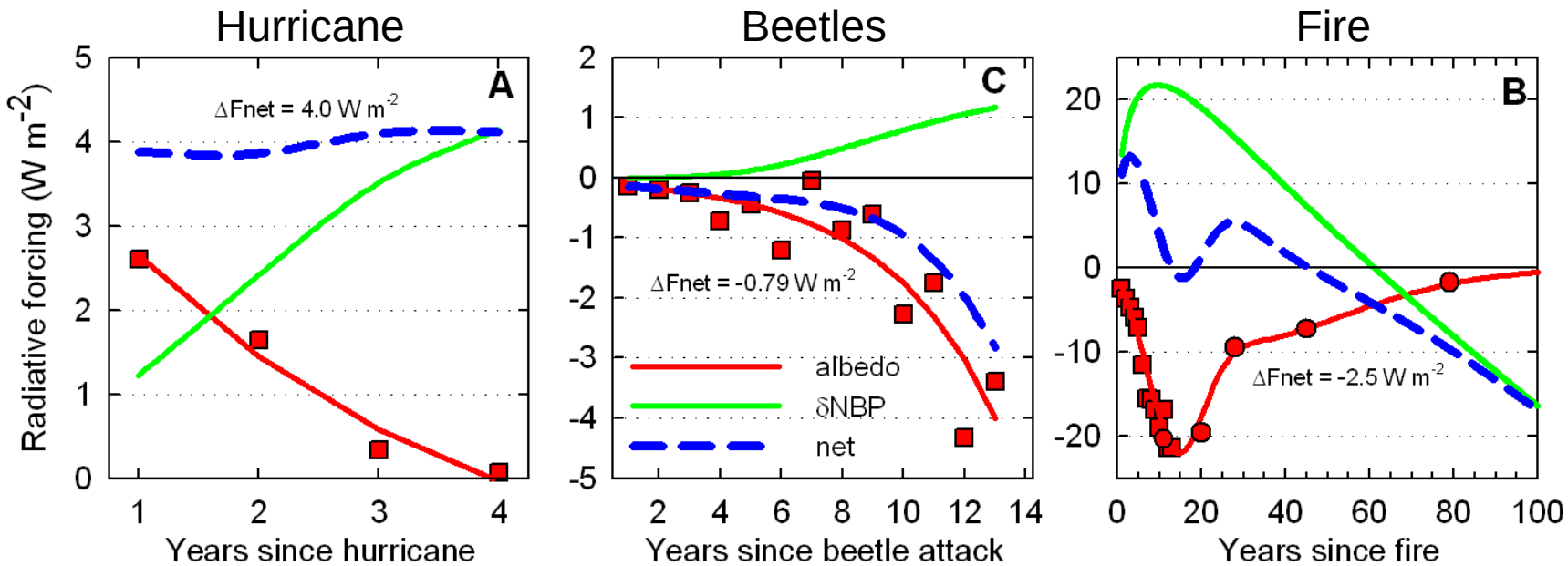


- ❑ **Evidence is accumulating that aging forests can maintain high rates of carbon sequestration**
- ❑ **At variance with conventional theory and the mechanisms are unclear**
- ❑ **Points strongly to age-related trends in biological and structural complexity as being involved**
- ❑ **Important for predicting future C sink activity in these forests and managing them for climate change mitigation**

UMBS Forest Carbon Cycle Research Program

This research is supported in part by the U.S. DOE, Office of Science under award No. DE-FC02-06ER64158.

It's Not Just About CO_2:
Significant change in albedo with 3 disturbance types



Beetle effect occurs mostly after snags fall

Albedo change produces radiative forcing of **same magnitude as CO_2 forcing** in case studies of forest mortality from **hurricane defoliation, pine beetles, and fire**.

O'Halloran talk 11:20 AM Tuesday

Delay in senescence and forest productivity

- A 30% increase in annual NEP is observed at the MMSF site (1998-2008)
- 50% of this increase is directly associated with a delay in senescence and extended assimilation season (almost 30 days since 1998)
- Delay in senescence can be an important (long-term) factor in determining carbon sequestration in deciduous forests

(Dragoni et al. GCB 2011)

Measurements and modeling of environmental impacts of biofuels on the cycles of carbon, water and nitrogen

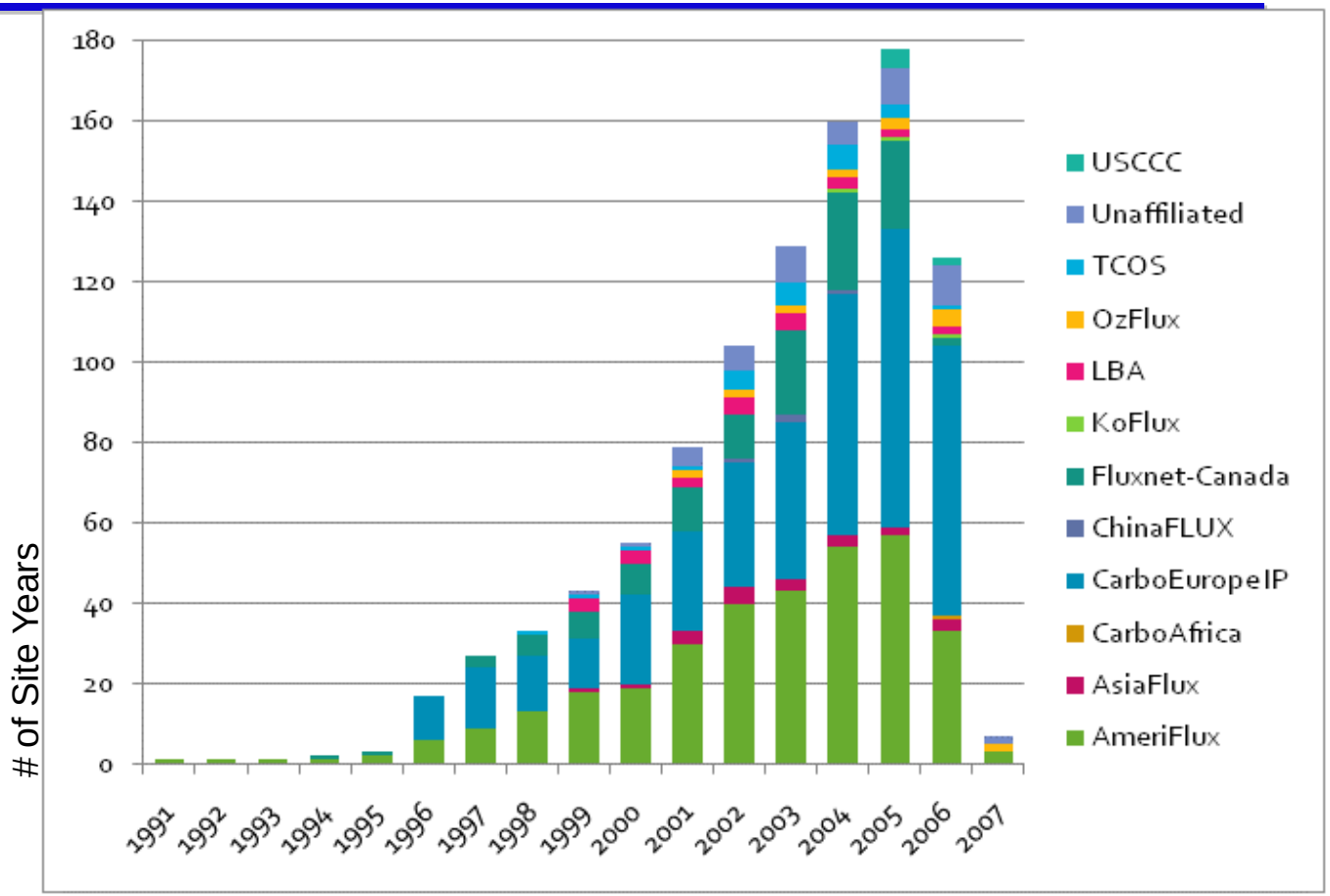
- 2010 Results
  - Measured (flux gradient technique) differences in water requirements and water use efficiency for miscanthus, switchgrass, and maize (Hickman et al., 2010)
  - Miscanthus predicted to significantly increase evapotranspiration throughout the Midwest when planted in > 25-50% coverage (VanLoocke et al., 2010)
- In review
  - Carbon balance for the first two years of establishment of perennial grass biofuel crops reveals net uptake of carbon
  - Miscanthus and native prairie species were carbon neutral while switchgrass was a sink of carbon after taking into account harvestable biomass (Zeri et al., submitted.)
- In preparation
  - Water balance and water use efficiency of biofuel crops observations (eddy covariance; Zeri et al., in prep.) and regional model prediction (VanLoocke et al. in prep.)
- This work shows that perennial grass bioenergy crops can provide environmental benefits through their potential to sequester carbon in roots and soil, however could potentially alter local to regional scale hydrologic cycle if produced in very high intensity.

Additional Key Papers 2010

- Multiscale analysis of temporal variability of soil CO_2 production. *Vargas et al.*
- Albedo estimates for land surface models and a new paradigm on foliage N concentration. *Hollinger et al.*
- Response of carbon fluxes to drought. *Noormets et al.*
- A continuous measure of GPP for the coterminous U.S. derived from MODIS and AmeriFlux data. *Xiao et al.*
- Ecosystem carbon dioxide fluxes after disturbance in forests of North America. *Amiro et al.*

AmeriFlux in a Global Context

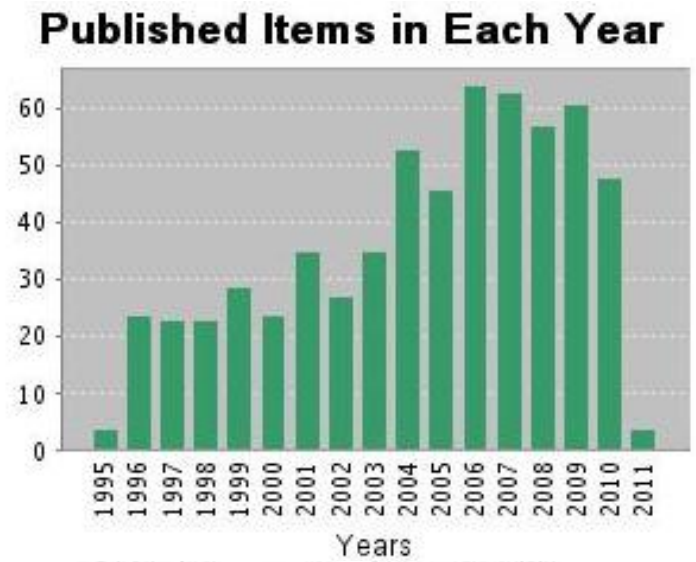
Number of sites contributing data to existing FLUXNET global synthesis project

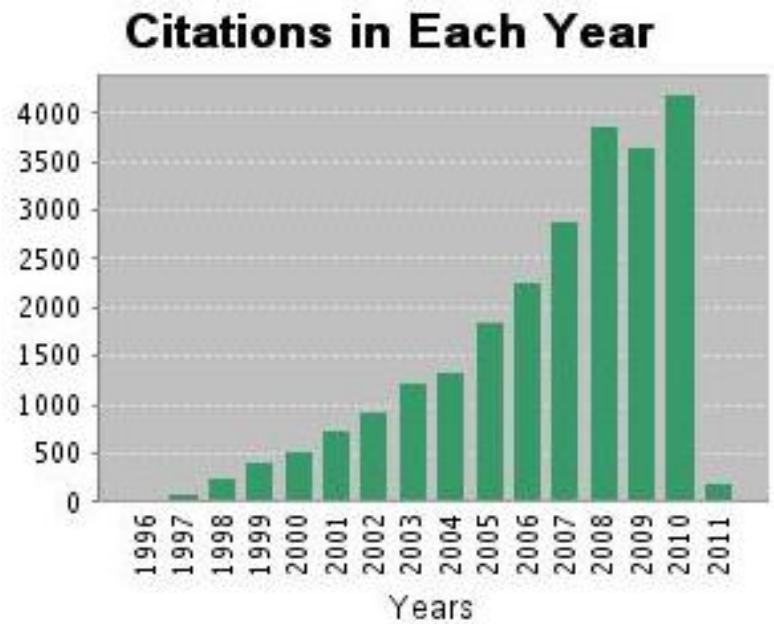


- 80 AmeriFlux sites (331 site-years, 70%) in Fluxnet dataset
- > 112 proposals for global synthesis papers
- FLUXNET dataset refresh underway (release in 2011)

Use of AmeriFlux Data in Publications

Web of Science
Topic = AmeriFlux or flux
Author = AmeriFlux PIs
Times cited since 1999: 24,518
Total papers: 620
Average cites per item: 40
H index: 82



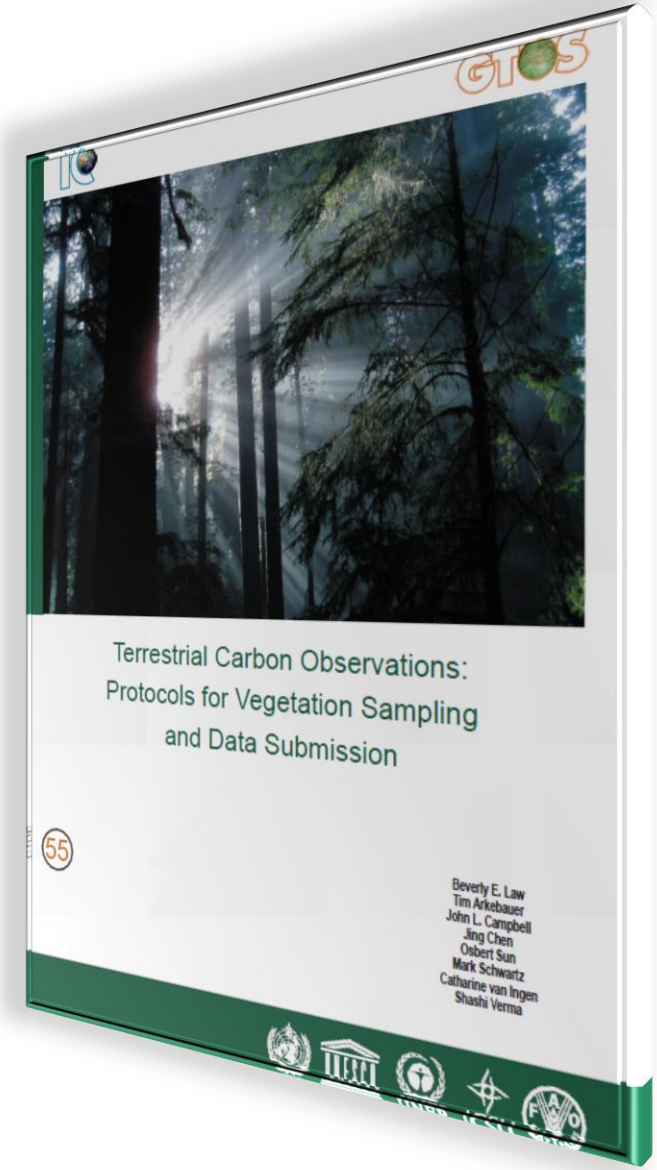


Biological, Ancillary and Meta-data (BADM)

- 145 BADM templates or other spreadsheets processed from 94 FLUXNET sites
- 78 AmeriFlux sheets from 43 AmeriFlux sites processed
  - 16041 data values extracted from spreadsheets
  - 365 updates received via the fluxdata.org web interface
- 28 of those templates were either submitted initially or updated at the NACP site synthesis submissions
  - 58 NACP sites: 19 active FluxnetCanada, 28 active AmeriFlux, 11 inactive AmeriFlux
  - 47 BADM submissions: 19 active FluxnetCanada, 25 active AmeriFlux, 3 inactive AmeriFlux

Protocols for Data Collection and Submission

- Why:
  - Uniform methods, standards for high quality observations
  - Uniform database for global assessments
- Important standards/definitions:
  - Carbon stocks in vegetation and soil, productivity, component fluxes
  - Vegetation types, structure
  - Land use
- Status – updating methods for subtropical/tropical systems, LAI computations
- Reference for other documents (ECV, GEO Carbon Report)



AmeriFlux QA

- Posters on determining flux drivers and PAR measurements (Schmidt, Kathilankal, Hanson)

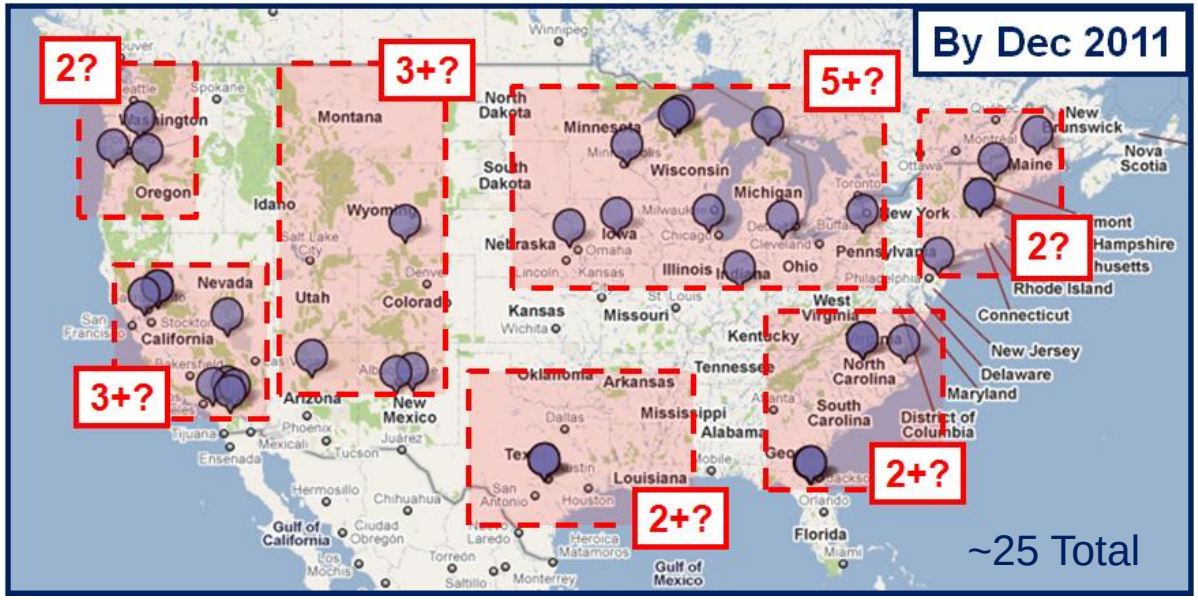
- Continue with longer site comparisons (10 d)
- Secondary CO_2 standards
- Temperature calibrations
- Network PAR standard calibrations
- Flux processing in Matlab program developed in the QA/QC lab and benchmarked against the gold files
- Emerging technologies
  - Diffuse radiation calibration standard in both PECS system
  - Li7200 (hybrid) in beta systems
  - Beta testing of high frequency laser gas analyzer for flux measurements

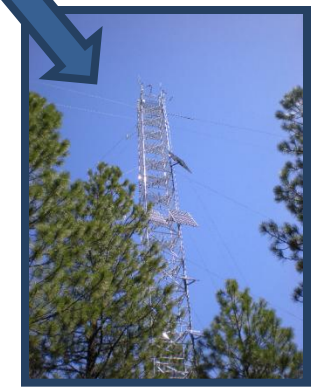
AmeriFlux Collaborators

- FLUXNET
- National Phenology Network – protocols, canopy cam network
- COSMOS
- SpecNet

COSMOS-AMERIFLUX Collaborative Research

- COSMOS Project seeks collaborative research at AMERIFLUX sites to explore carbon/water cycle linkages
- The COSMOS Probes:
  - measure area-avg soil moisture at ~700m horizontal scale, 15 -70 cm depths (depending on soil moisture) from above-ground cosmic-ray neutron count
  - self powered, no maintenance demand on local operators, remote data capture
- Rafael Rosolem < rosolem@email.arizona.edu >





Future: Informing Predictions

- Adaptation: How are terrestrial ecosystems responding to changing climate and can they adapt?
- Mitigation: Impacts? Feedbacks to climate?
- Policy decisions are being made – do we have the science to inform those decisions?
- Long-term data are needed to calibrate models
  - AmeriFlux baselines, climate/vegetation/disturbance gradients

OSTP US-GEO Report Recommendations

Achieving and Sustaining Earth Observations: A Preliminary Plan Based on a Strategic Assessment by the U.S. Group on Earth Observations (Sept 2010)

"Support the interagency AmeriFlux network that provides continuous observations of ecosystem level exchanges of CO_2, water, energy and momentum spanning diurnal, synoptic, seasonal, and interannual time scales and is currently composed of sites from North America, Central America, and South America."

Discussion

Model Needs

- Environmental drivers
  - Soil properties
  - Air temperature + humidity
  - Precipitation
  - Incident radiation (diffuse + direct)
  - [CO2]
  - Supplemental: soil depth, wind speed
- Land use, disturbance history – timing and type
  - Forest management – age class, harvest type/year, burning (slash removal), bioenergy plantations
  - Crop detailed history, e.g. crop changes, residues, irrigation, fertilization (amt, type), tillage
  - Fire combustion factors

Model Needs – Evaluation Data

- Met data
  - Predicted vs observed temp, precip…
- Biometric
  - NPP
  - Aboveground biomass
  - Soil C (tend to stay away from this one)
- Flux
  - GPP, Ra, Rh, NEP
  - LE
- Land use/disturbance effects
  - Fire C emissions (e.g. Δbiomass)
  - Loss of productivity, biomass due to insects, fire, harvest

Clusters Along Gradients

- Disturbance clusters – forest age classes with soil/climate held constant
- Climatic gradient – different PFTs, same PFTs
- Currently ~16 clusters, depending on intent
- Clusters by region (2-7 sites/cluster)
  - NW 1 cluster: OR pine (ME2&5: 20y, 90y)
  - SW 5 clusters: SC climate/veg gradient (7 sites); Tonzi/Vaira SC veg composition (2 sites); SC chaparral fire gradient (3 sites); AZ fire gradient (0y, 100y, 100y); NM veg composition (6 sites)
  - NC 4 clusters: BR1-3 agric crop (3 soybean/corn sites), NE1-3 agric crop (irrig., irrig. rotation, rain fed) , RO1-3 agric crop (management effects), IB1-2 land-use (restored prairie, soybean/corn)
  - SC 1 cluster: FR1-3 land cover (grass, juniper/shrub, juniper)
  - NE 2 clusters: HO1-3 (80, 109, 109), HA1-2 (insect defoliation vs ctrl)
  - SE 3 clusters: DK1-3 pine (<1, 25, ~90y), FL SP1-3 pine (10, 18, 80y), FL Everglades (3 sites hydro gradient)

Growth-and-yield allometric modeling of slash pine plantation management system carbon balance

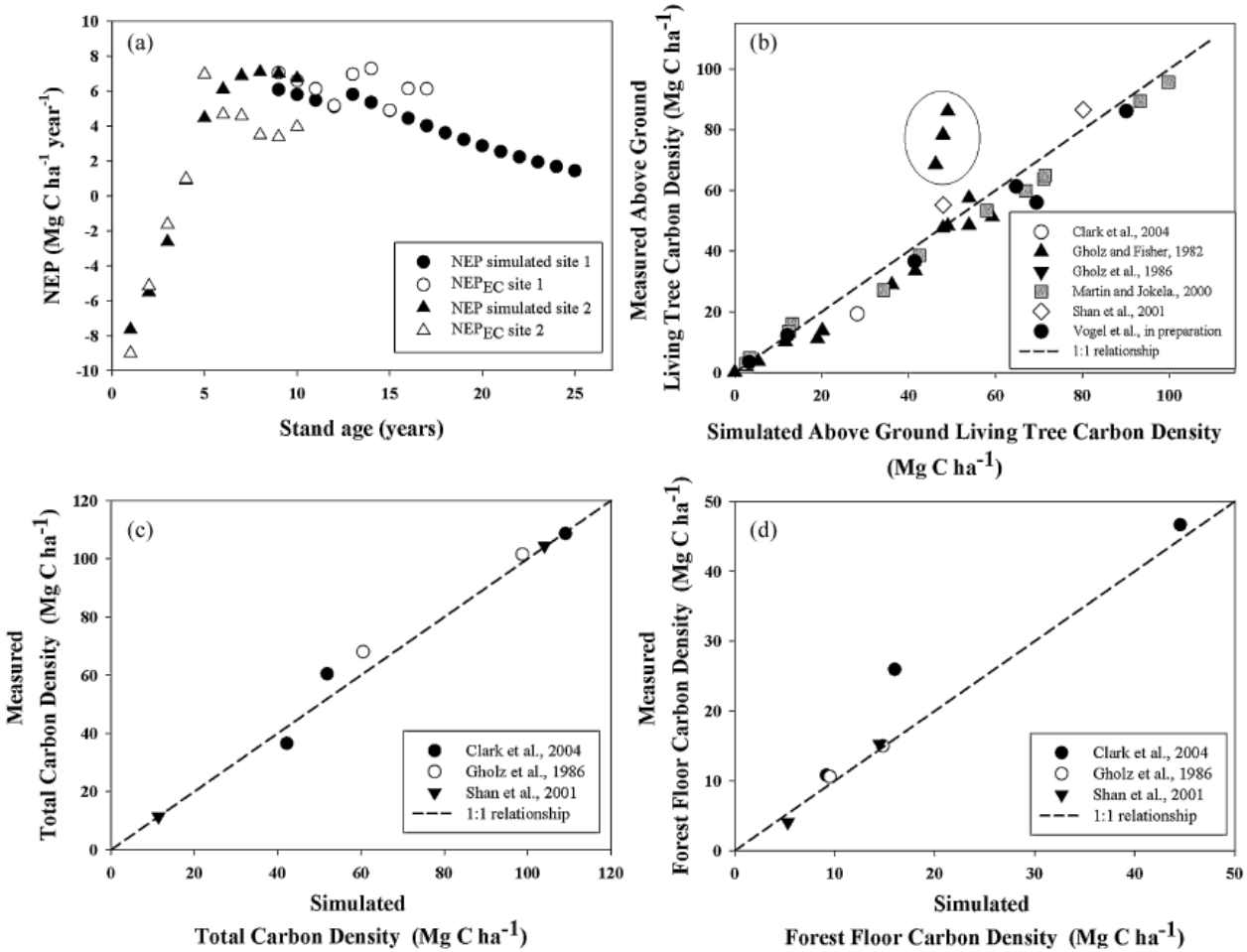


Fig. 1. Validation of model outputs: (a) Time series of simulated versus observed NEP at 2 sites; (b) Simulated versus measured aboveground living tree C stock (circled values were not included in validation regressions, see text for details); (c) Simulated versus measured total ecosystem C stock (not including soil); (d) Simulated versus measured C stock in forest floor.

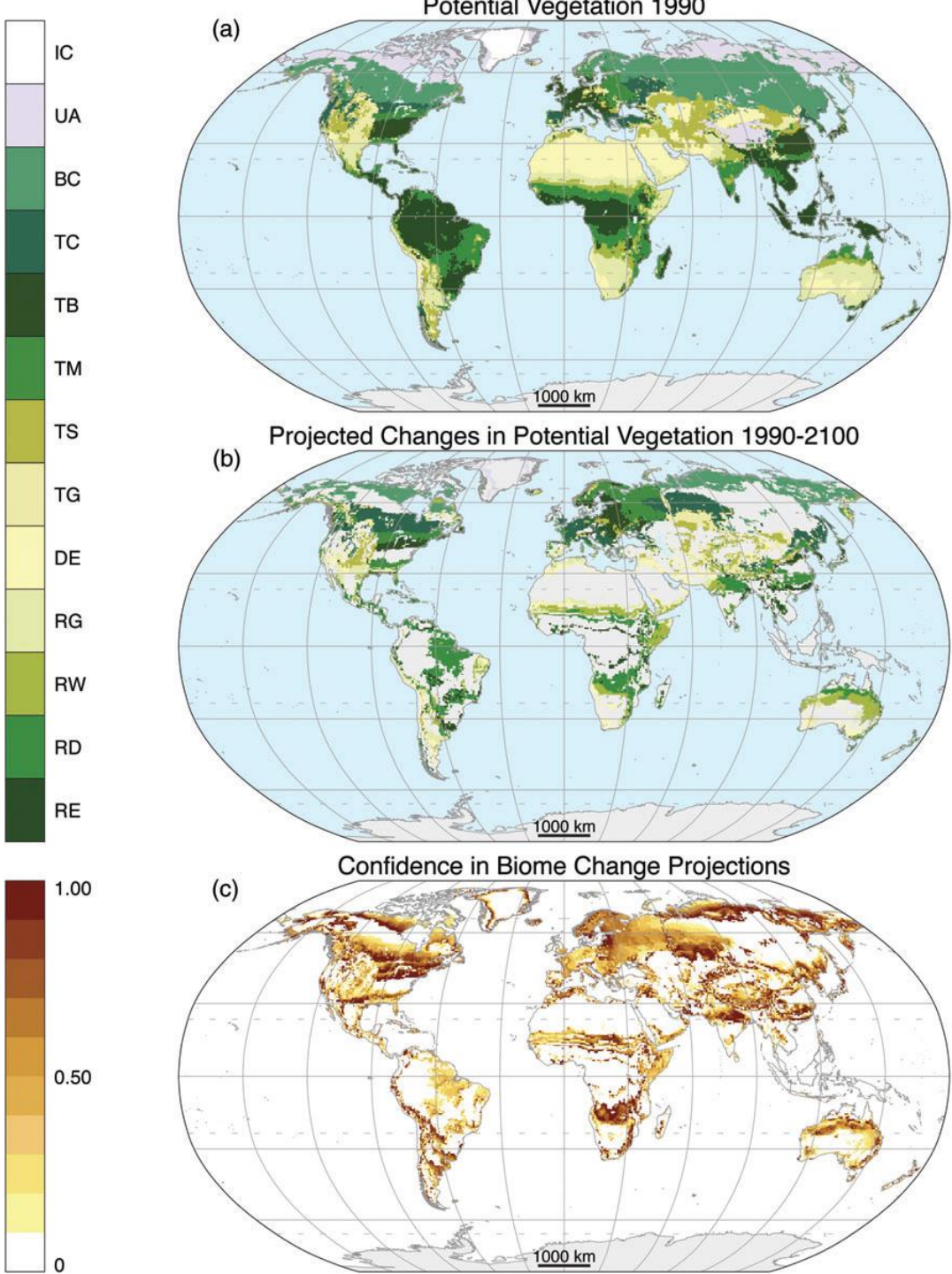
Simulated Vulnerability to Biome Changes (1990-2100)

Simulations suggest 10-50% of global land may be highly vulnerable (fair comparison with remote sensing land cover)

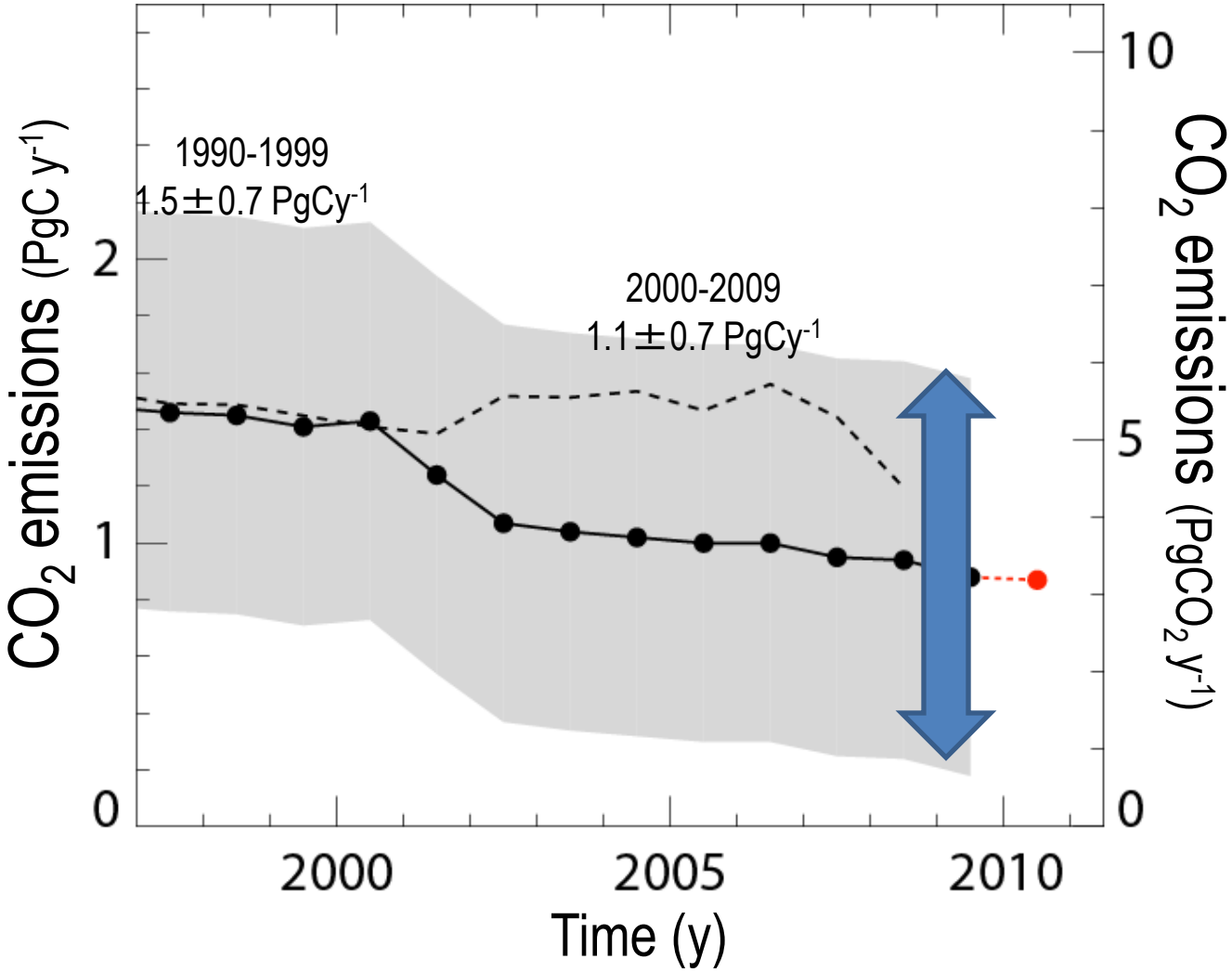
Field observations detected biome changes in 20th - century, yet there is a lack of spatial data on vulnerability

Hinders identification of priority areas for adaptation measures

(Gonzalez et al. 2010)



CO_2 Emissions from Land Use Change
Uncertainty as large as the estimate



1990s
Emissions: 1.5±0.7 PgC

2000-2005
Emissions: 1.3±0.7 PgC

2006-2010:
Emissions: 0.9±0.7 PgC

Friedlingstein et al. 2010, Nature Geoscience; Data: RA Houghton, GFRA 2010

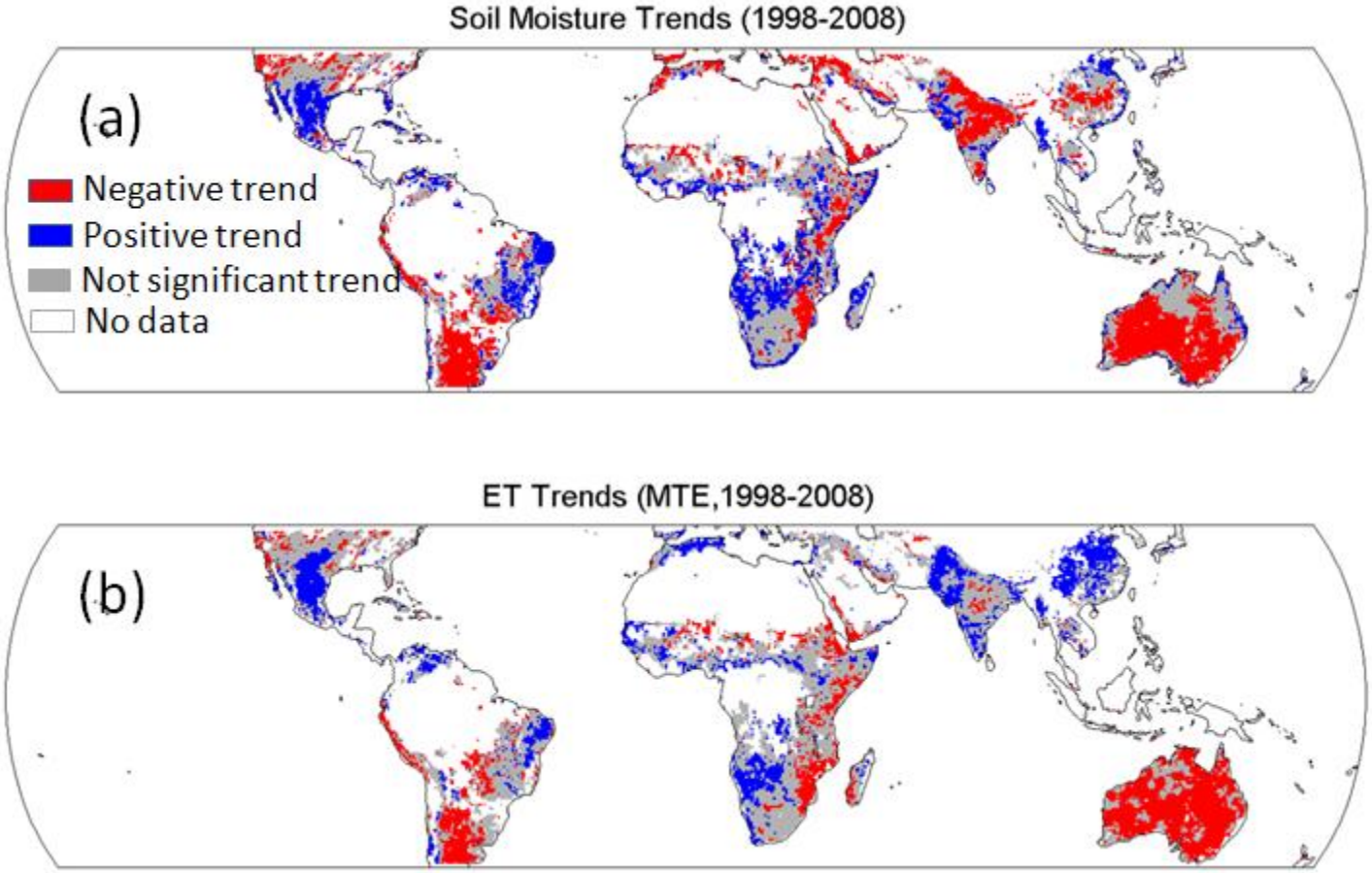
Global Science Objectives to Address Policy & Management Needs

Detect and understand changes in ecosystems, feedbacks to climate

- Effects of deforestation, afforestation, and degradation on the land-based carbon sink
  - Carbon budgets (soil, above and belowground vegetation)
  - Interaction with changing climate (e.g. water cycle)
- Effects of climate and management on natural adaptation
  - Vulnerability to shifts in distribution of species, biomes
  - Mitigation effects in the face of climate change

Soil Moisture Limits Evapotranspiration Trends

Identified by integration of tower fluxes, remote sensing & models



Negative trend (red) = drier soil

(Jung et al. Nature. 2010)