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Exploring the Sensitivity of Terrestrial Ecosystems and Atmospheric Exchange of CO_2 to Global Environmental Factor

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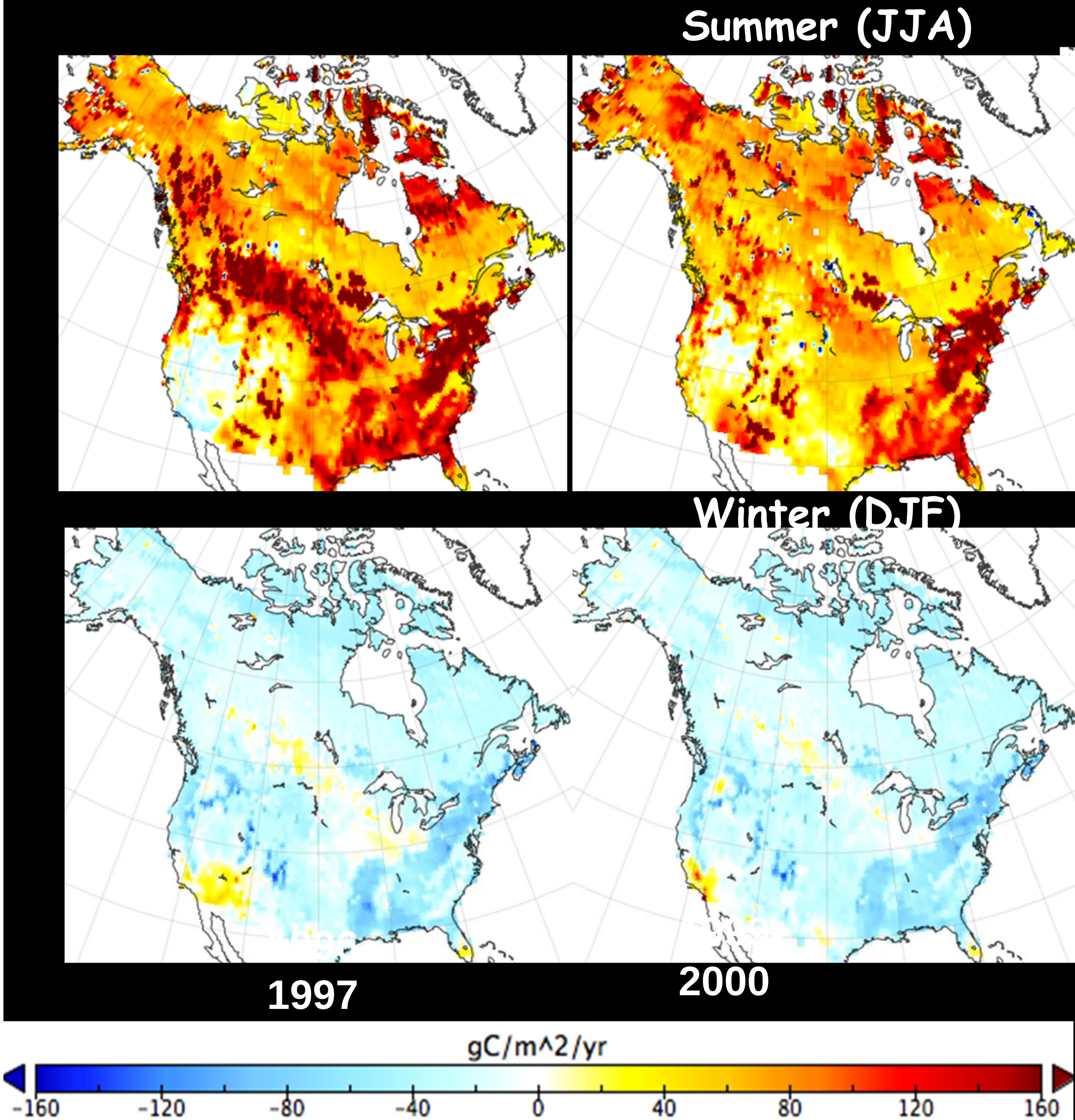
Acknowledgements

US DOE, NASA-LCLUC

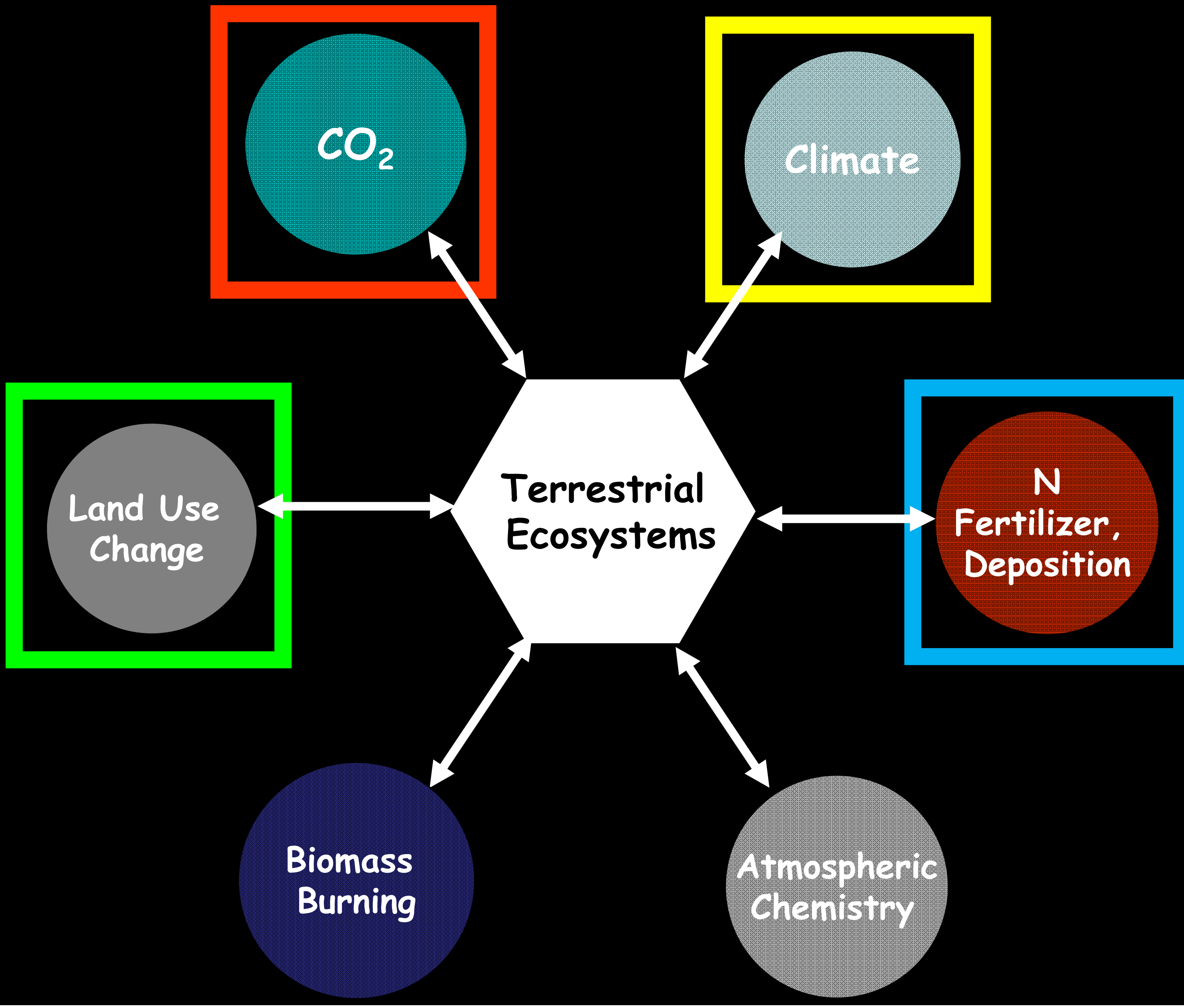
ISAM Estimated Net Ecosystem Exchange (NEE)



negative is net C gain by the terrestrial ecosystems

Environmental Factors Impacting the Exchange of CO_2 between Terrestrial Ecosystems and Atmosphere

Terrestrial Ecosystems and Environmental Factors

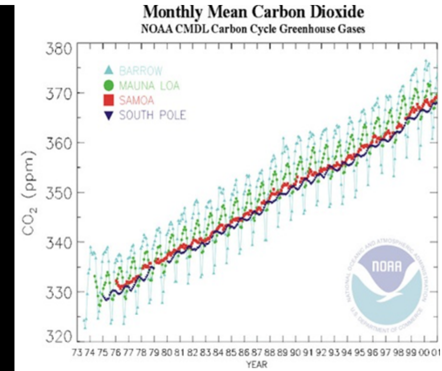


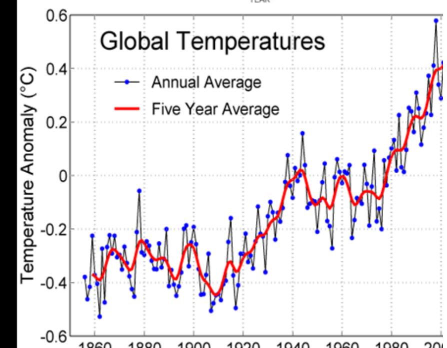
Questions?

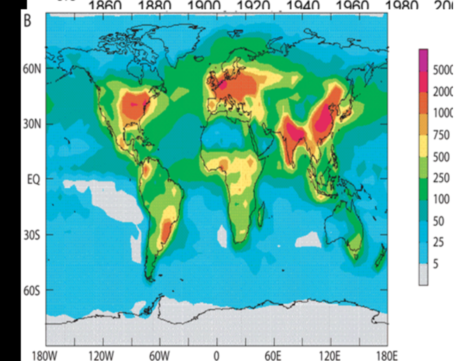
- What are the relative contributions of
  - Land use
  - natural ecosystem dynamics
  - climate variability
  - N deposition
  - agriculture management
  - fire

  on ecosystems and carbon dynamics

  What are their synergistic effects?
- What are their potential future trends?





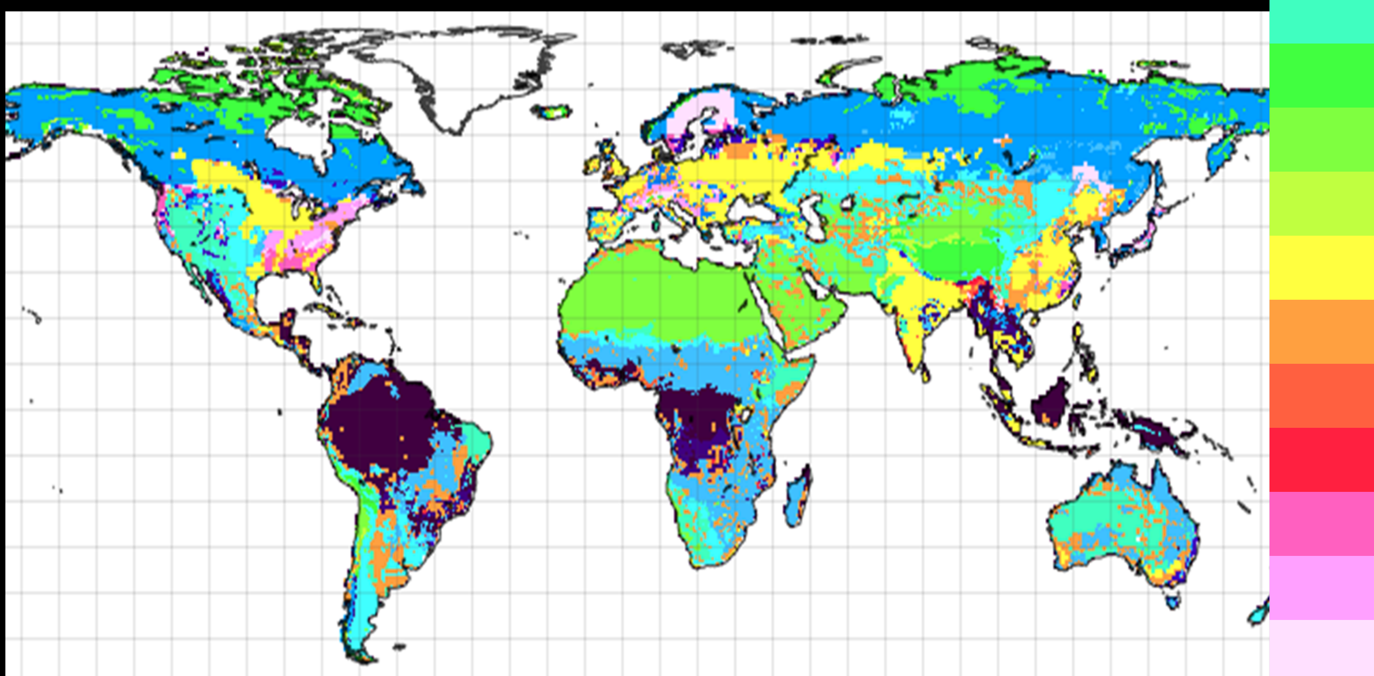


Methods

- We use the terrestrial component of the Integrated Science Assessment Model (ISAM), which simulates C and N fluxes within the terrestrial biosphere
- The model includes feedback processes such as CO2 fertilization, climate effects on photosynthesis and respiration and increased carbon fixation by nitrogen deposition.
- Changes in land cover classifications are driven by clearing forest for cropland, reforestation and abandonment (reforestations), pasturelands, wood harvest.
- Mineral nitrogen deposition rates are based on chemical transport model.
- Changes in temperature and precipitation, and CO_2 are based on observation data
- Soil carbon sequestration in soils is estimated using empirically-based sequestration estimates coupled with ISAM.

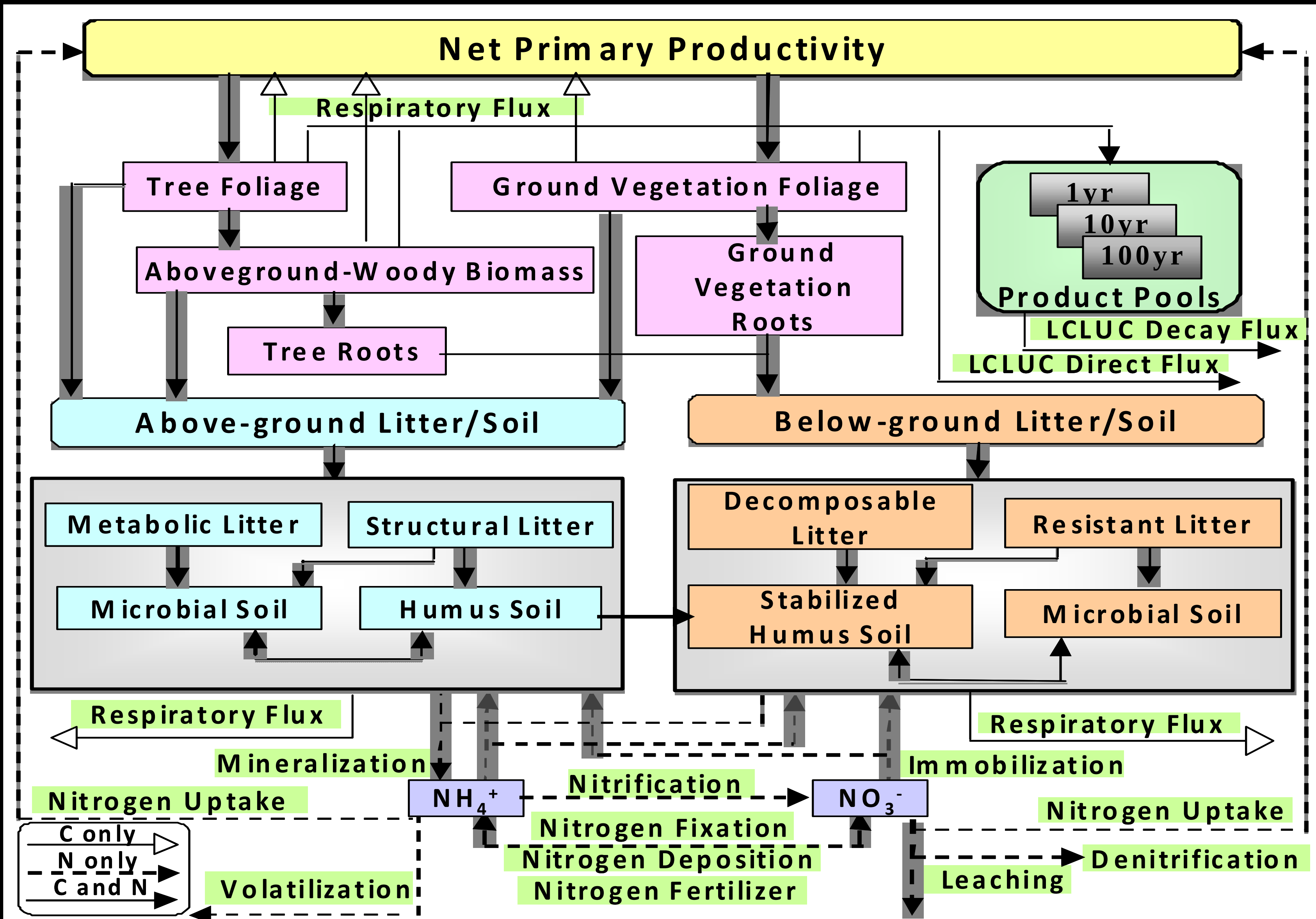
Global Terrestrial C-N ISAM

- 18 Biome types
- 0.5 x 0.5 degree resolution
- Carbon cycle
- Nitrogen cycle
- Feedbacks: Climate-C-N-LUC…



Yang et al. (2009, *GBC*)

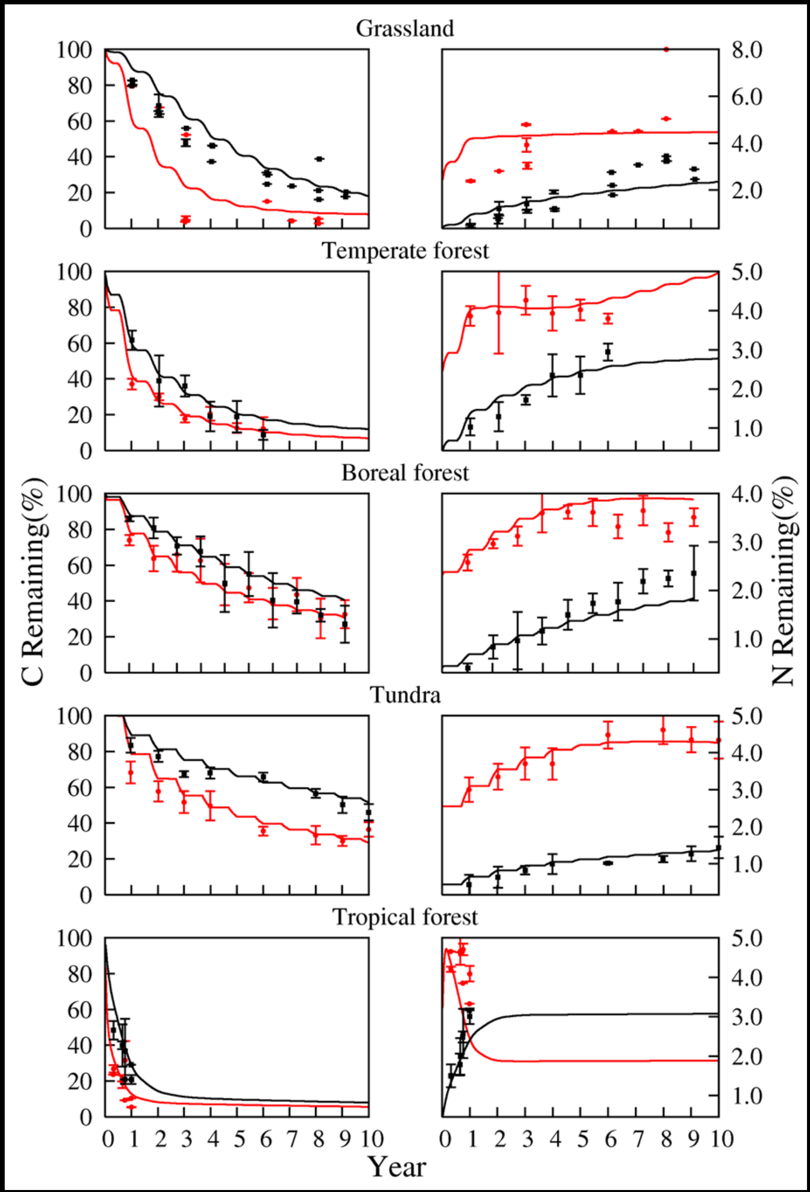
Global Terrestrial C-N ISAM



Yang *et al.* (2009)

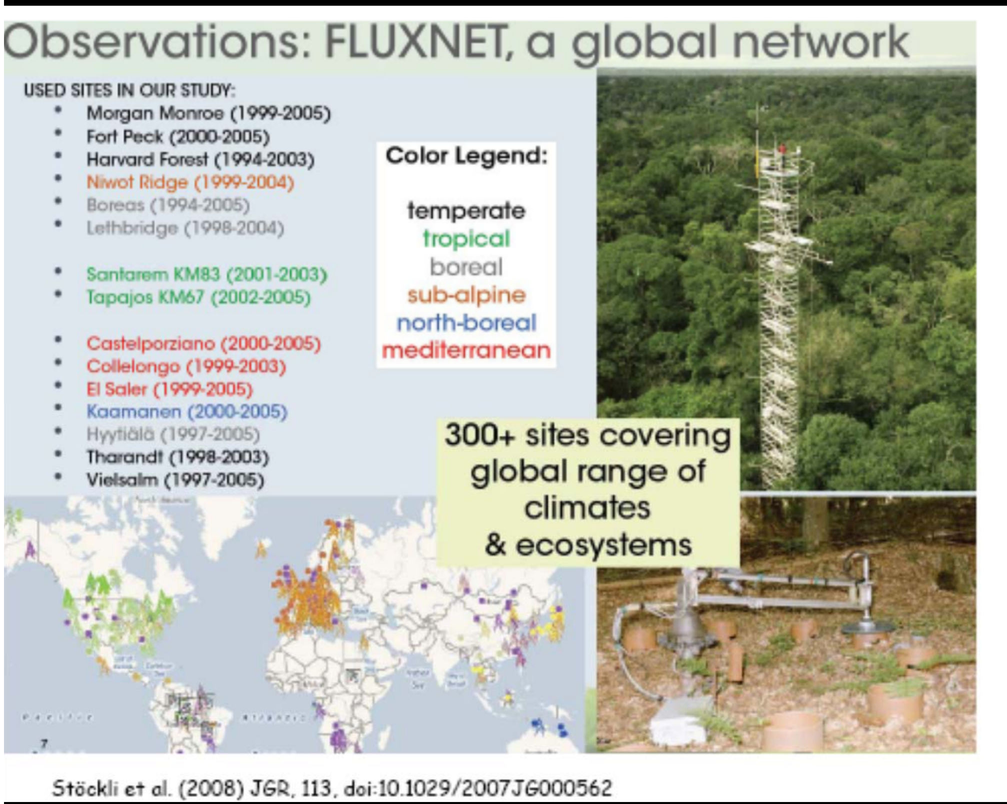
Model Evaluation

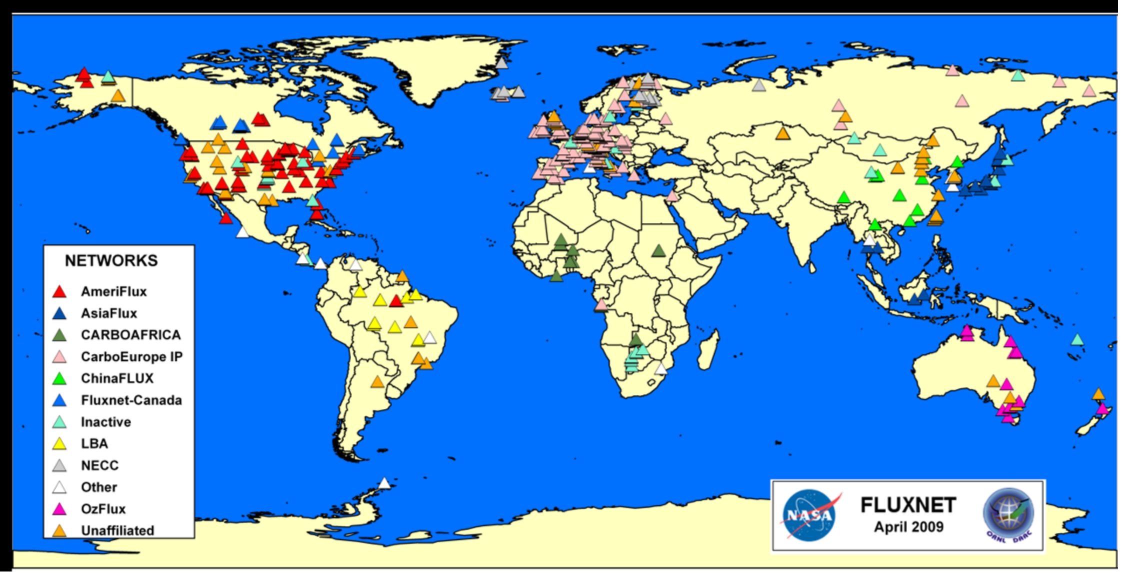
- Long-term Inter-site Decomposition Experiment (LIDET) and other site-specific data
- Leaf, wood and root litter decomposition data
  - C:N
  - Lignin:N
  - Climate



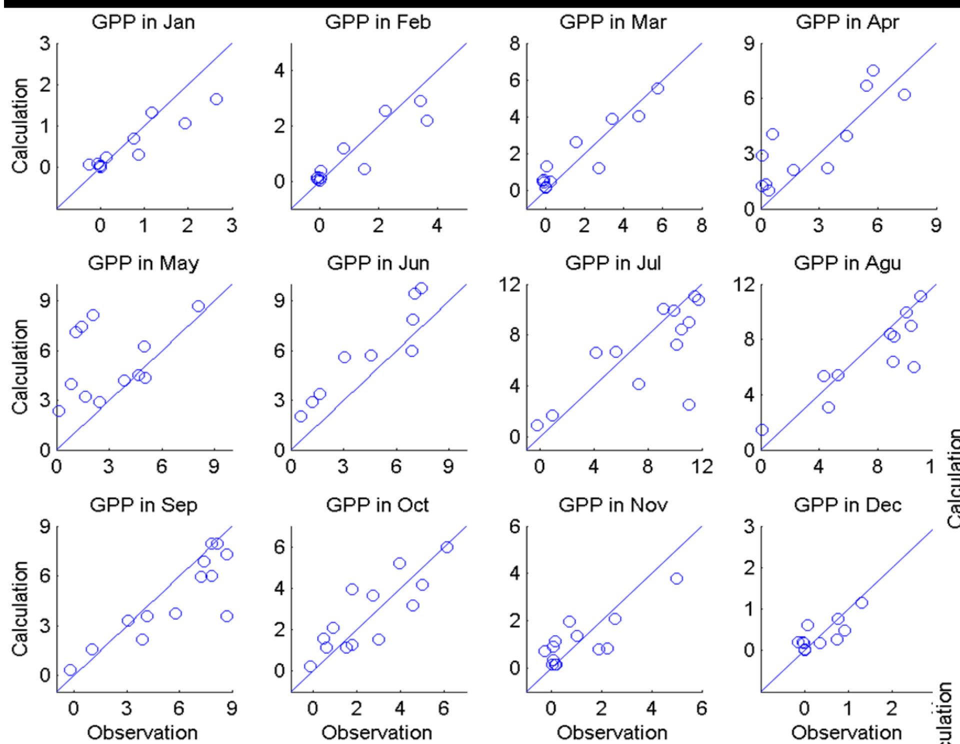
Yang *et al.* (2009)

Use of FLUXNET and Other Ground-Based Data in the ISAM Land Surface Model Development



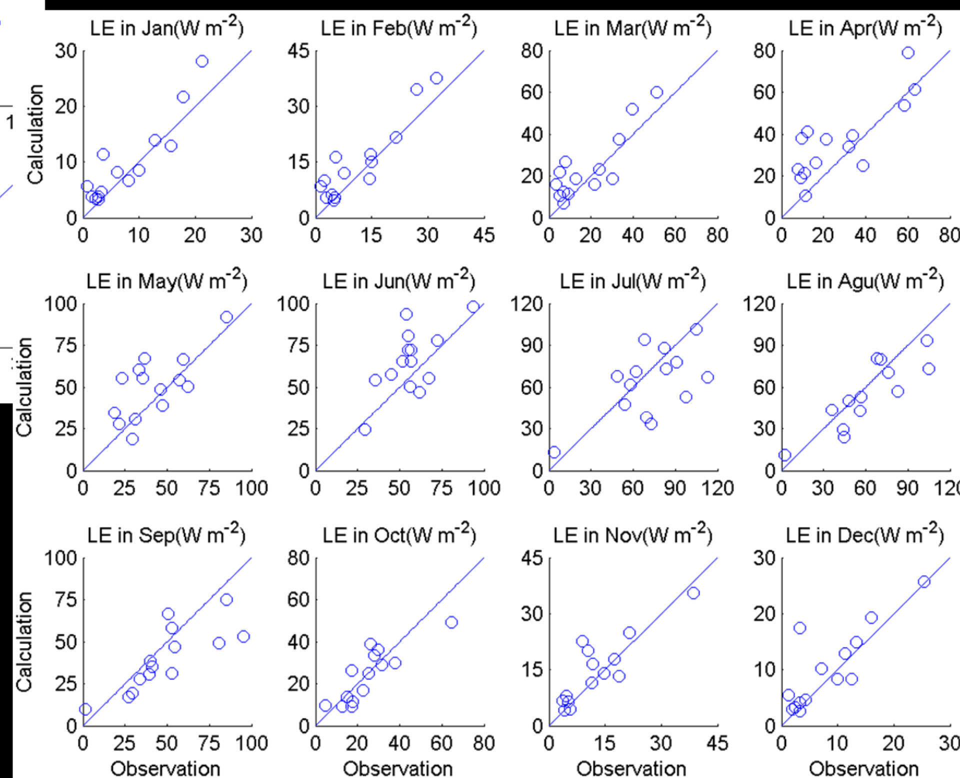


Modeled vs. Measured Data



Monthly GPP

Monthly LH

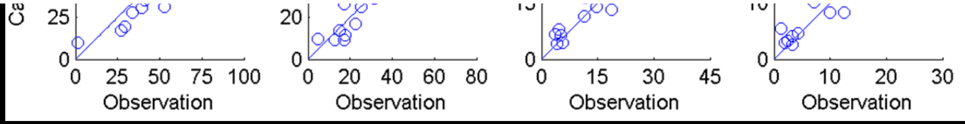


Modeled vs. Measured Data

<u>SESSION: B22D</u>. Improving Predictions of the Global Carbon Cycle and Climate in Earth System Models: New Mechanisms, Feedback Sensitivities, and Approaches for Model Benchmarking I 10:20 AM - 12:20 PM; Room 3012

11:05 AM - 11:20 AM
B22D-04. Studying Uncertainties in Climate-Terrestrial Biogeochemical Feedbacks in the Northern High Latitudes using a Flexible Earth System Modeling Framework

<u>Rahul Barman</u>; Forrest M. Hoffman; David M. Lawrence; Yang Song; Prasanth Meiyappan; Atul K. Jain; Robert L. Jacob; Mariana Vertenstein



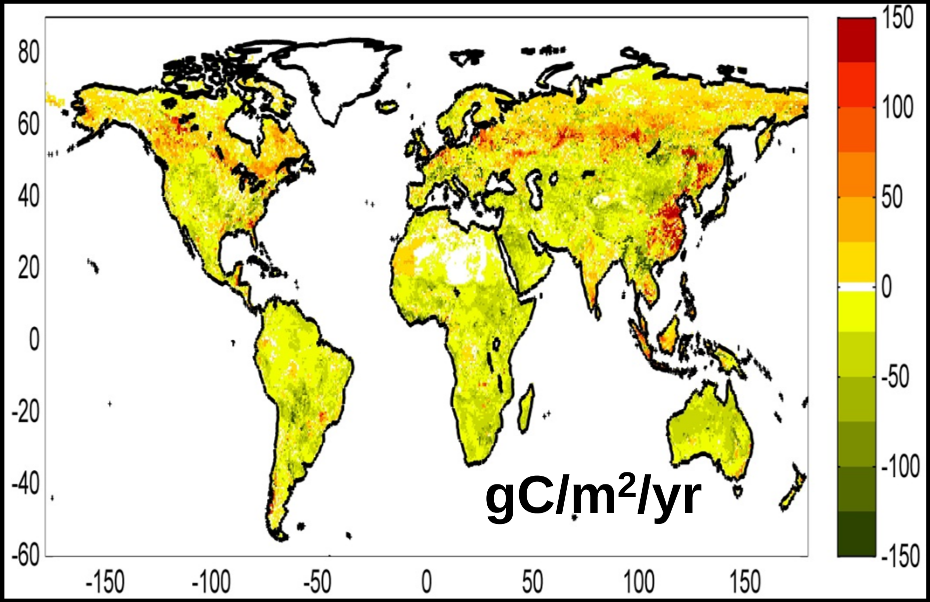
Experiments Performed

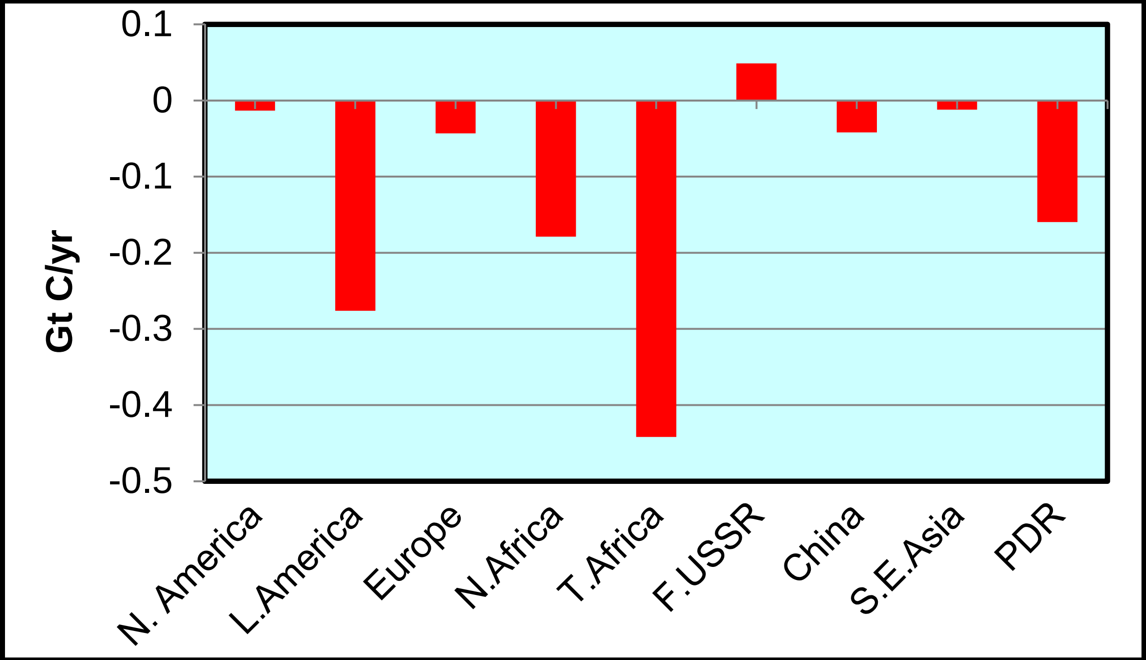
- ISAM run to equilibrium with [CO2] ~ 280 ppm and climate for early 1900s
- NEE is calculated with accounting all environmental factors (Case 1)
- Five scenarios examined <u>without</u> following changes (1765-2010) (Case 2)
  - Increasing CO2
  - Changes in N deposition
  - Climate variability (Temp. and Precip.)
  - Changes in land cover and land use (LCLUC)
  - Forest Fires
- The contribution of individual factor to NEE is calculated by subtracting Case2 from Case 1.
- Above five scenarios are extended until 2050 based on two IPCC scenarios: RCP 4.5 and RCP 8.5

Historical Data for Environmental Factors

- Climate Data (i.e., Temperature and precipitation) – Climate Research Unit Time series (CRU-TS) observation data
- CO2 Concentrations: CO_2 concentrations from the Mauna Loa (Hawaii) (CDIAC, 2011)
- LCLUCs: Sustainability and the Global Environment (SAGE), History Database (IPCC, AR5)
  - Cropland, Pastureland & Wood-harvest
- N Deposition: Both wet and dry atmospheric depositions (Galloway et al., 2004)

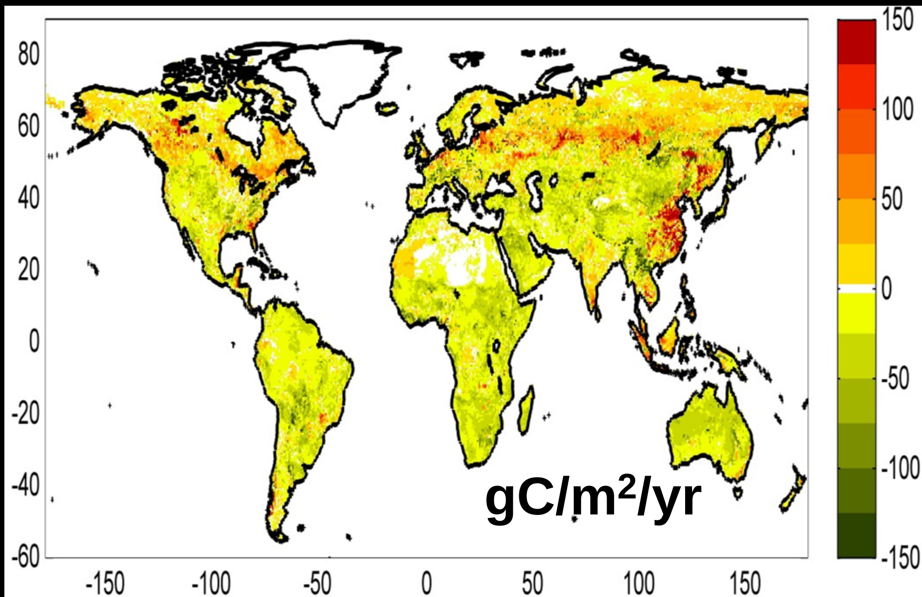
Estimated NEE
Average for 2000-2009

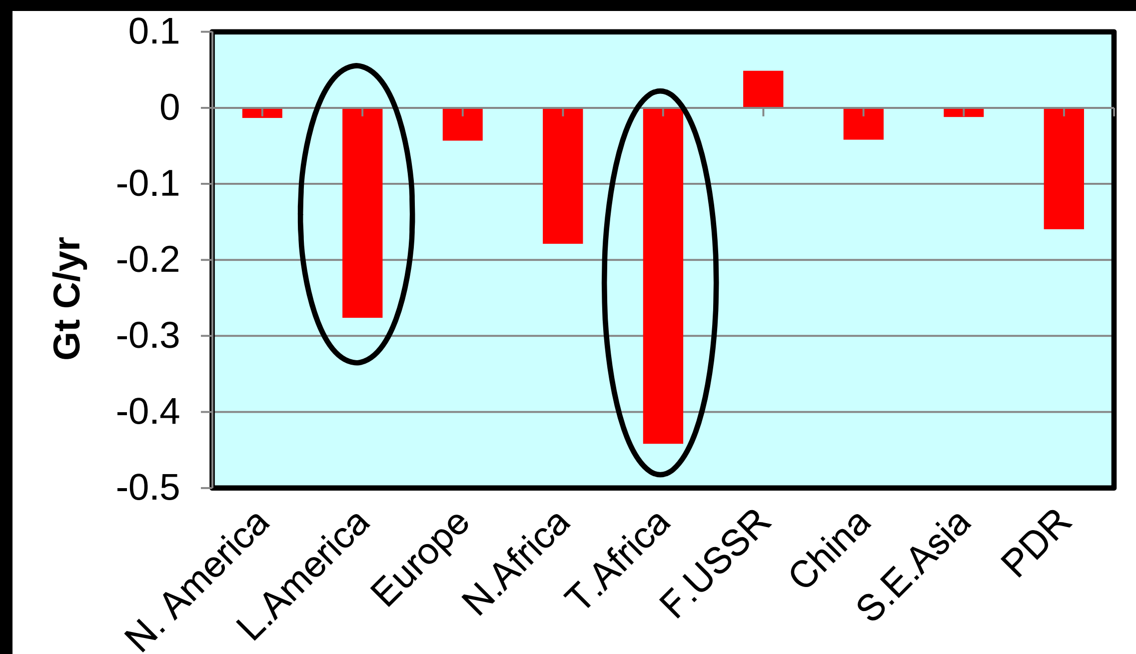




negative is net C gain by the terrestrial ecosystems

Estimated NEE
Average for 2000-2009





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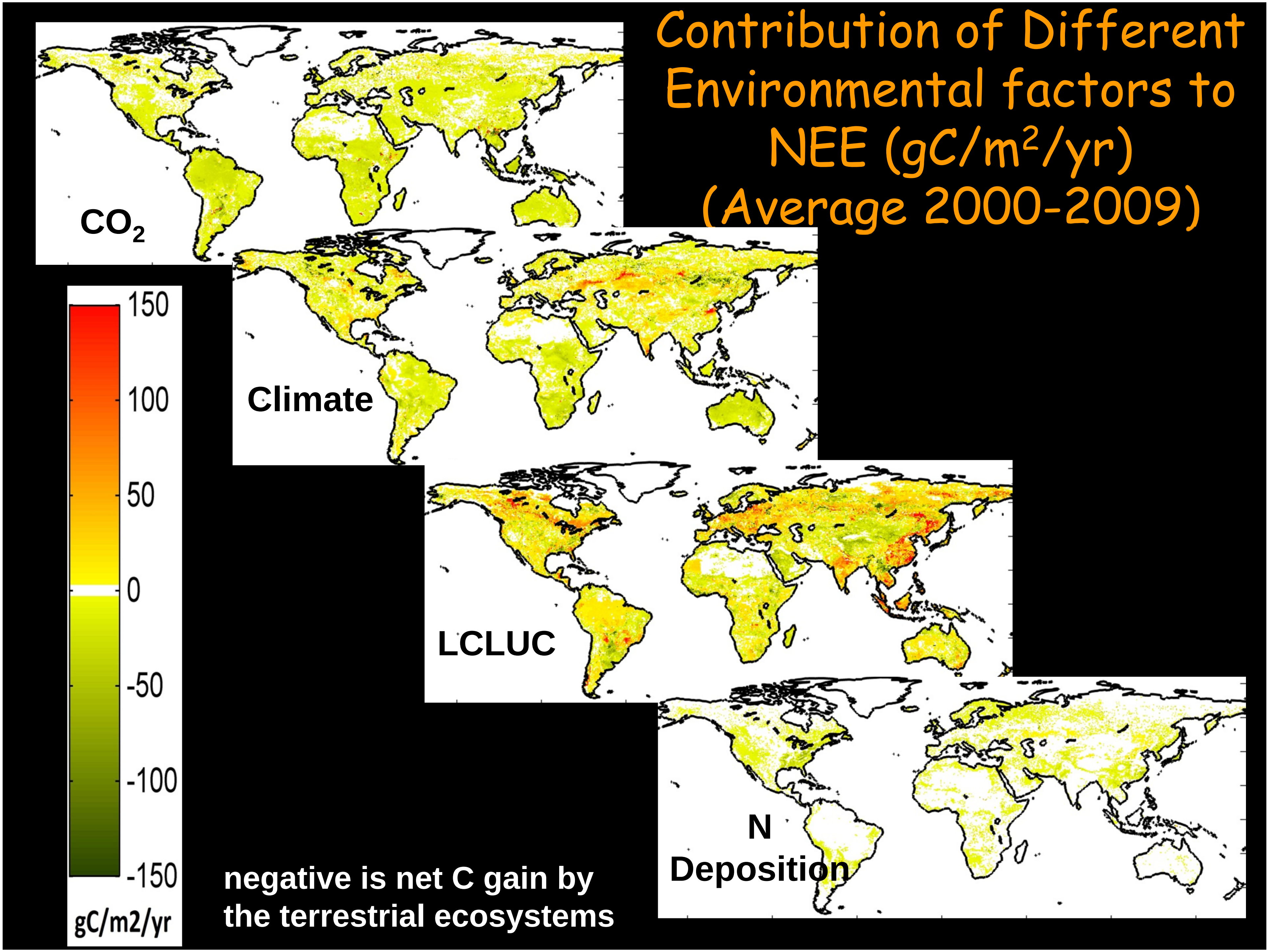
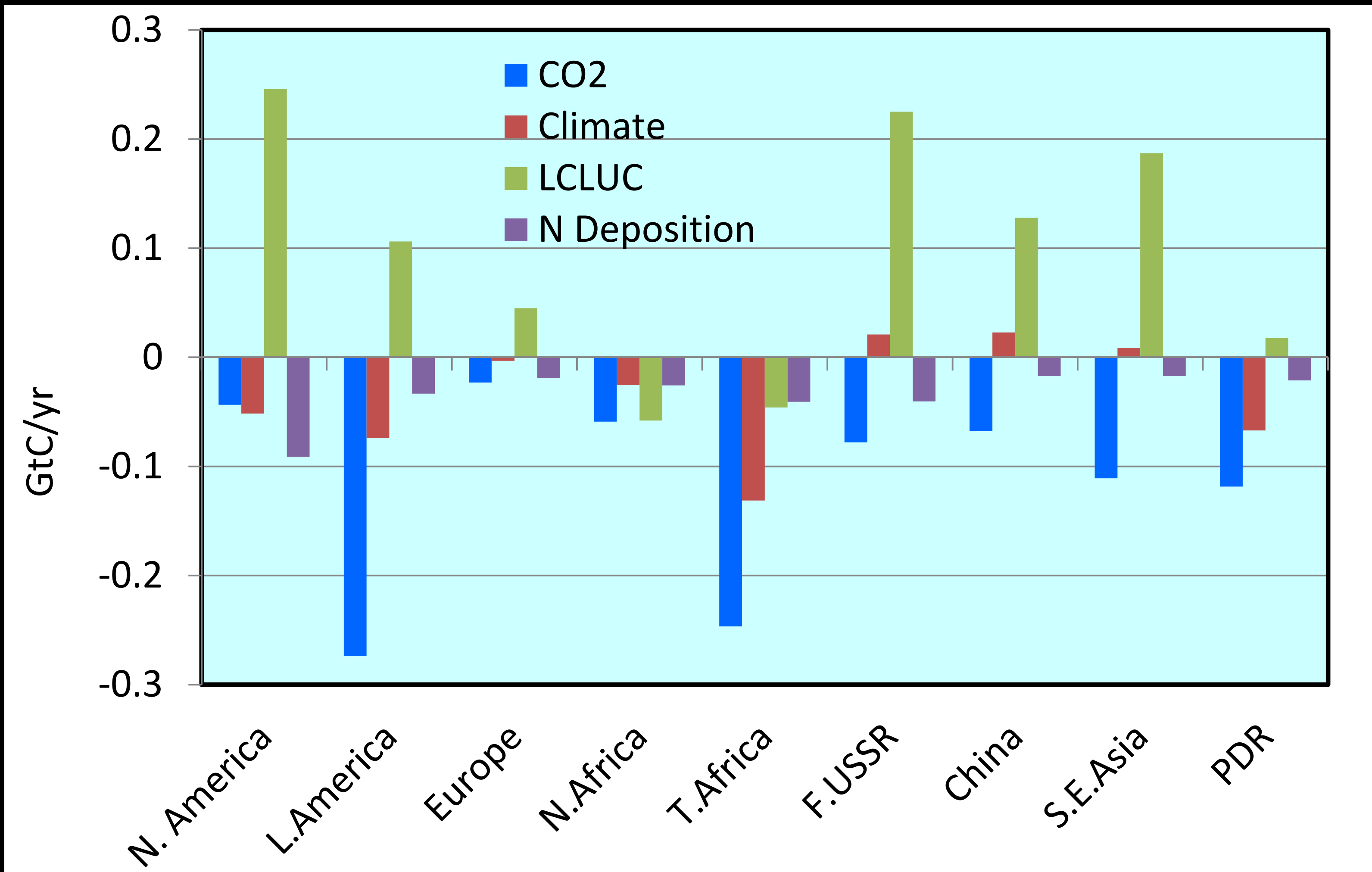
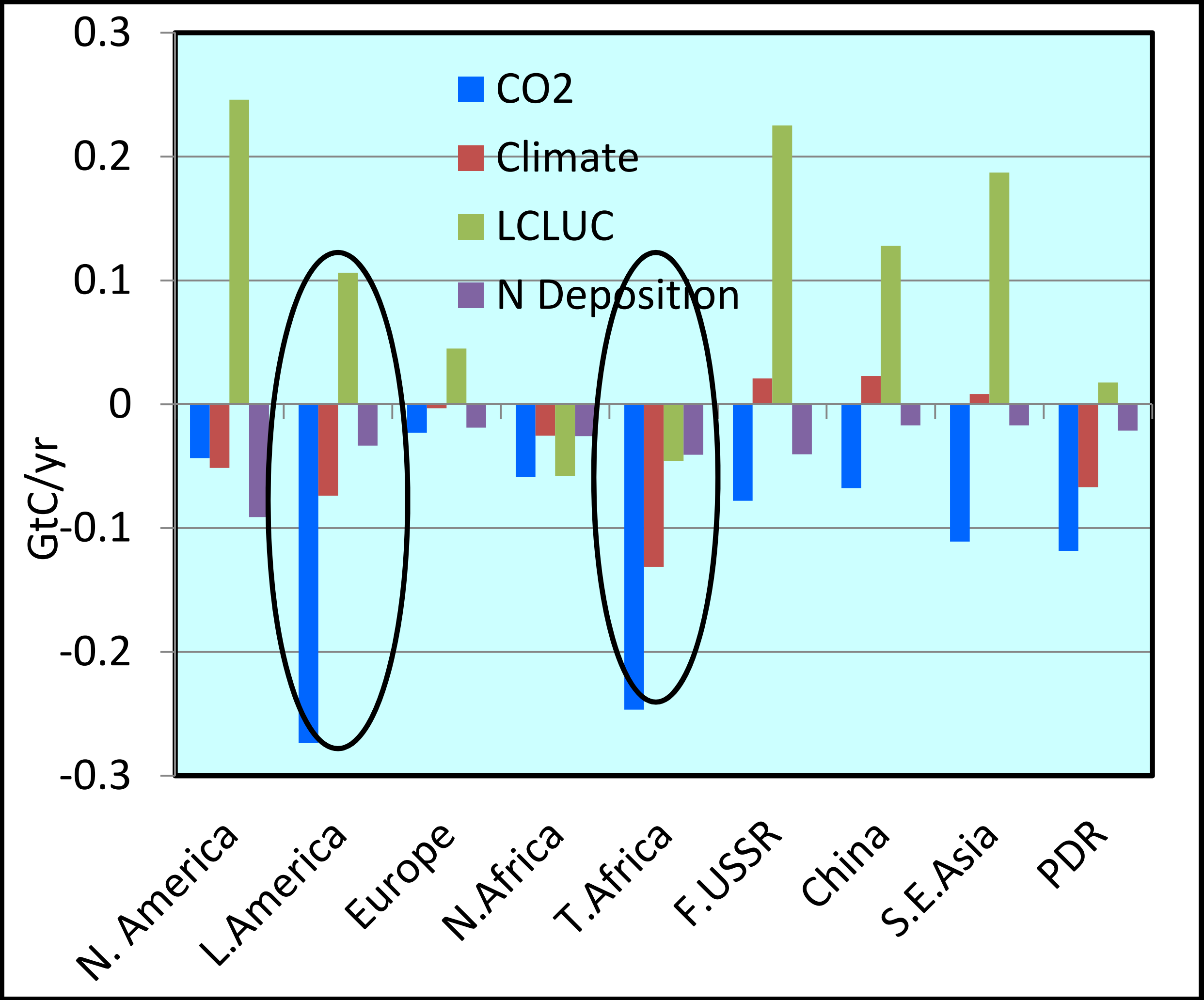

Contribution of Different Environmental factors to NEE (gC/m²/yr) (Average 2000-2009)
CO2
Climate
LCLUC
N Deposition
150
100
50
0
-50
-100
-150
gC/m2/yr
negative is net C gain by the terrestrial ecosystems

Regional Contribution of Different Environmental Factors to NEE ($gC/m^2/yr$) (Average 2000-2009)

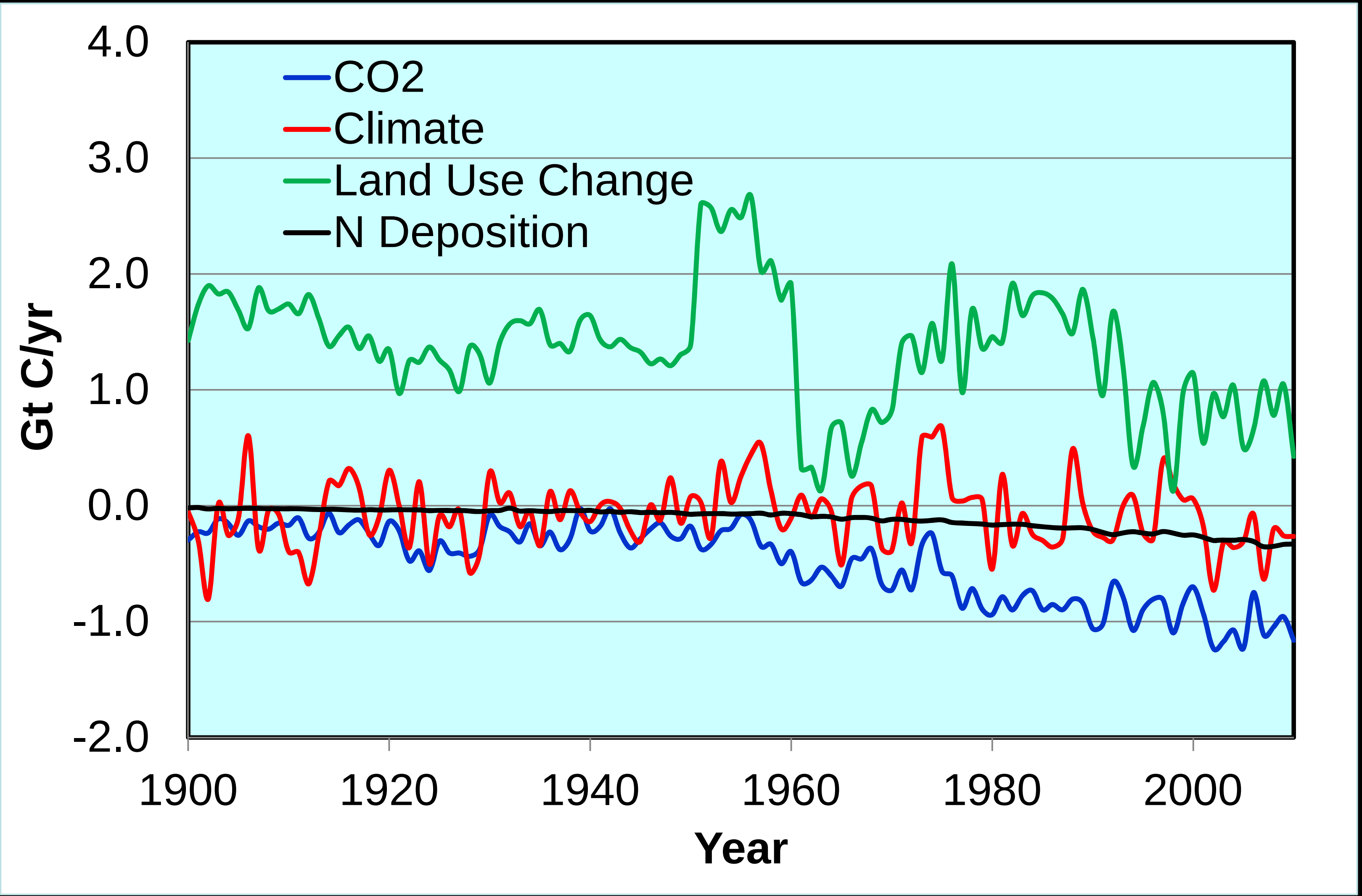


Regional Contribution of Different Environmental Factors to NEE ($gC/m^2/yr$) (Average 2000-2009)



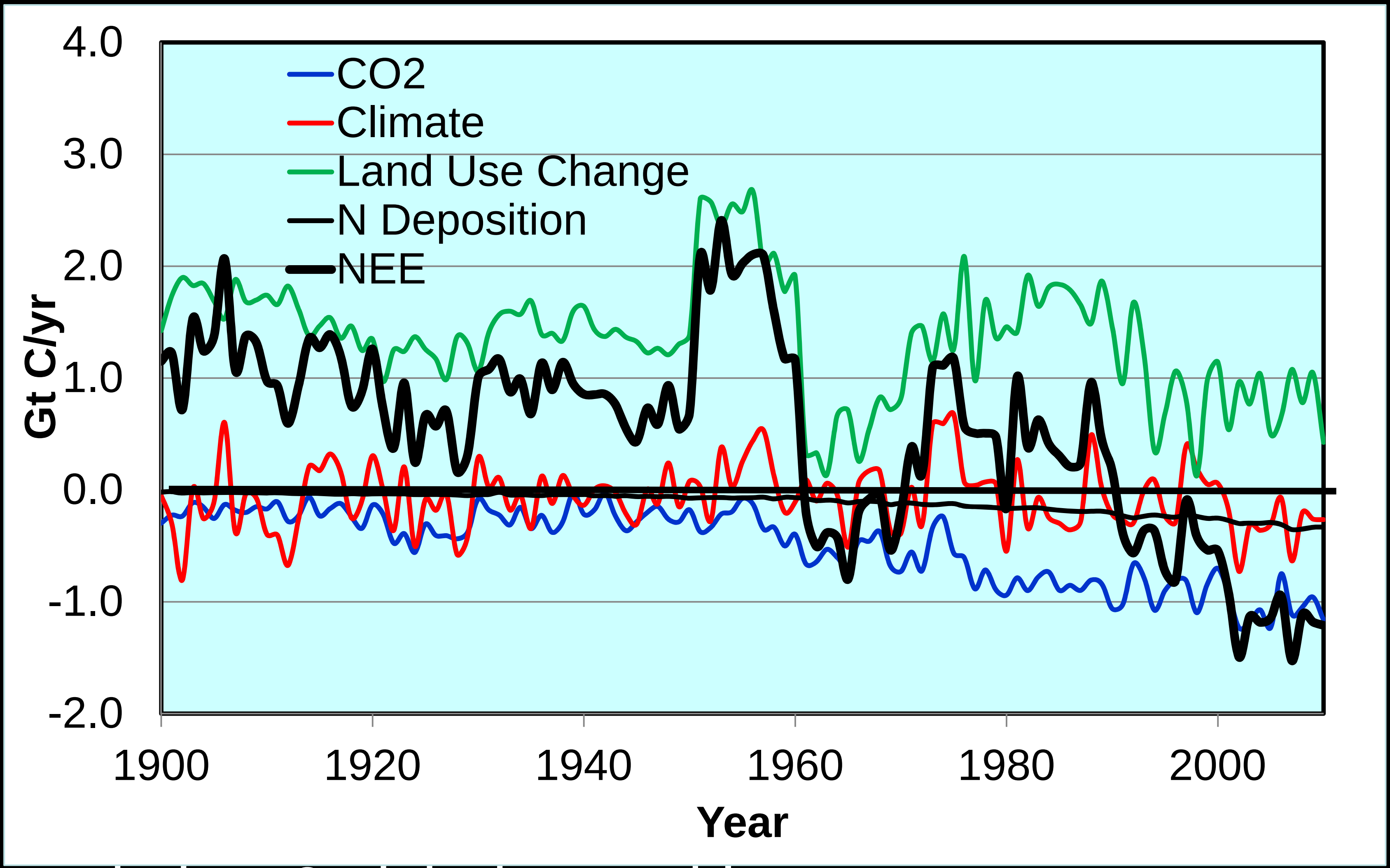
- Higher CO2 increase in plant-derived carbon input into soils from leaf and root detritus.
- No N-limitation
- No Land use change, but abandonment and reforestation
- Climate change: warm and moist climate leads to rapid litter decomposition

Contribution of Various Environmental Factors to NEE



negative is net C gain by the terrestrial ecosystems

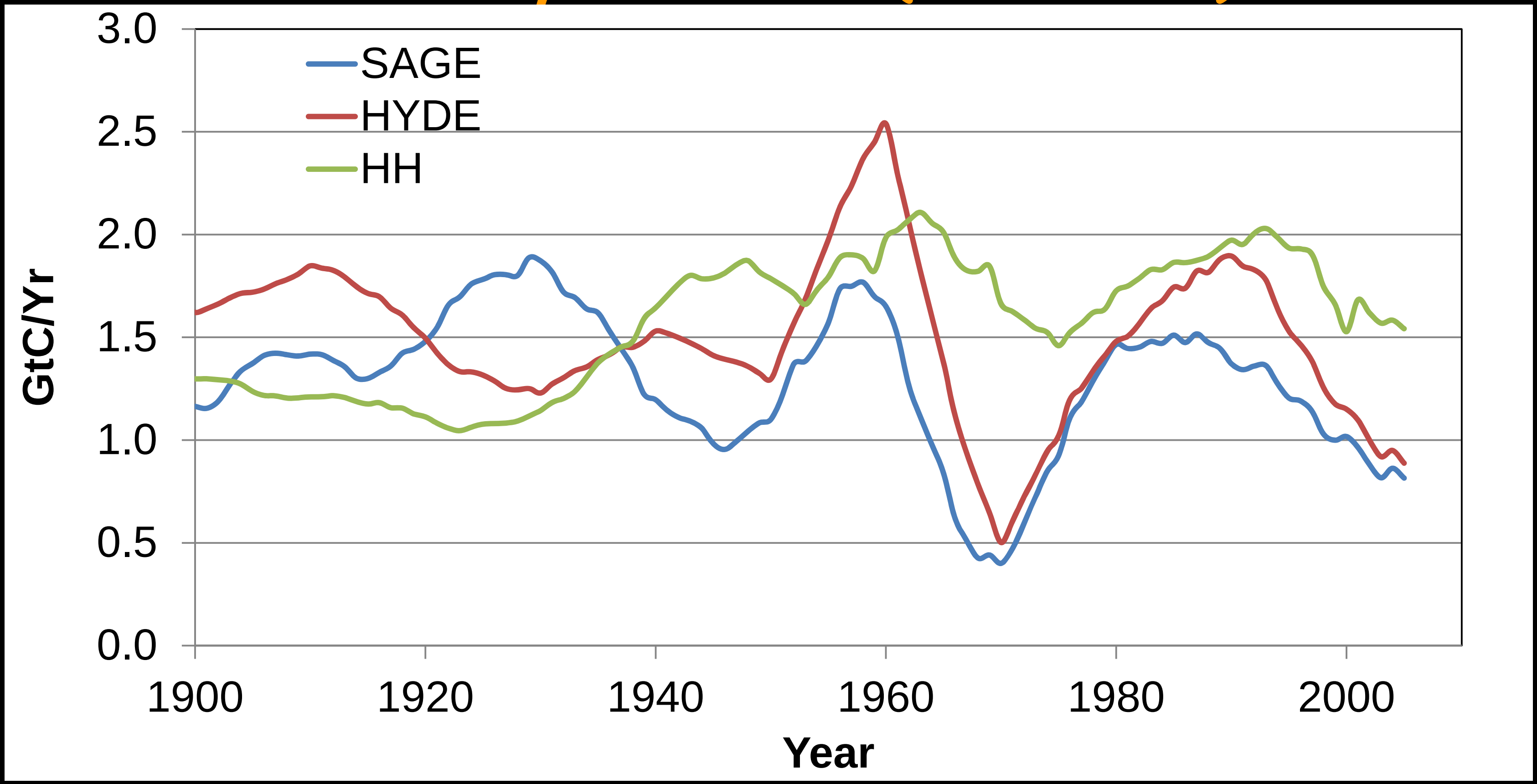
Contribution of Various Environmental Factors to NEE



negative is net C gain by the terrestrial ecosystems

Jain et. al. (2011, GBC)

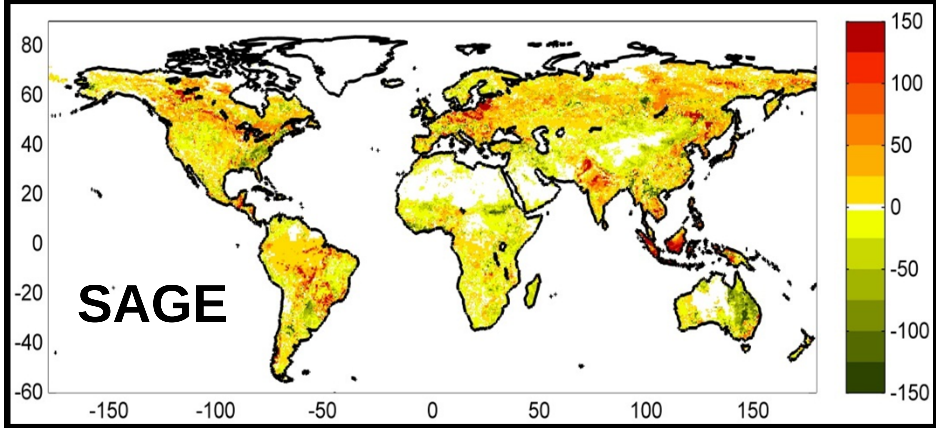
Net Land Use Emissions Based on Three Different Data sets 10-yr Mean (GtC/Yr)

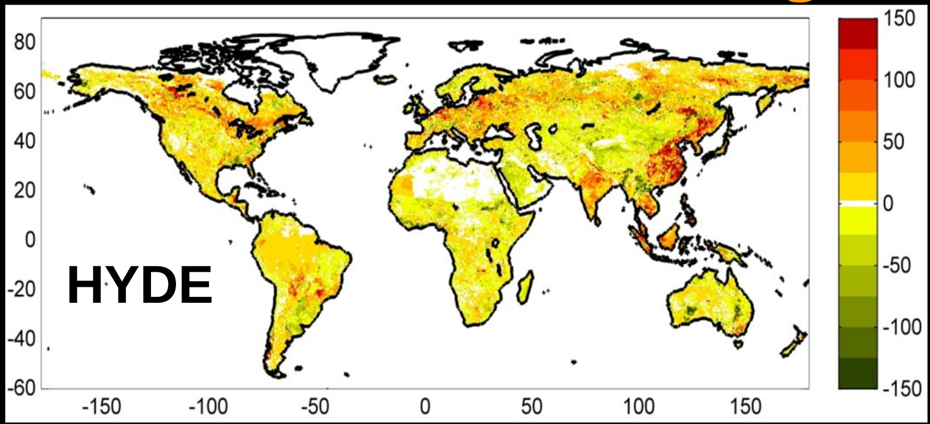


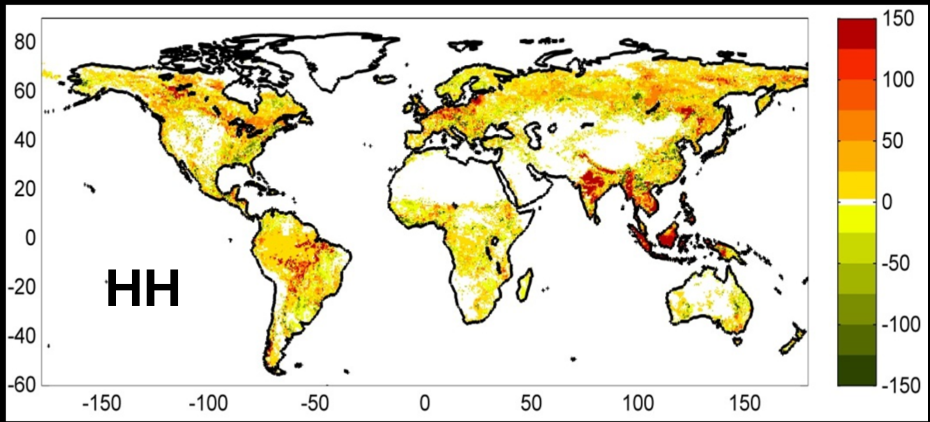
SAGE: Ramankutty et al. (2008)
HYDE: Goldewijk et al. 2011
HH: Houghton (2008)

Net Land Use Emissions Based on Three Different Data Sets ($gC/m^2/yr$)

Average for 2000-2009





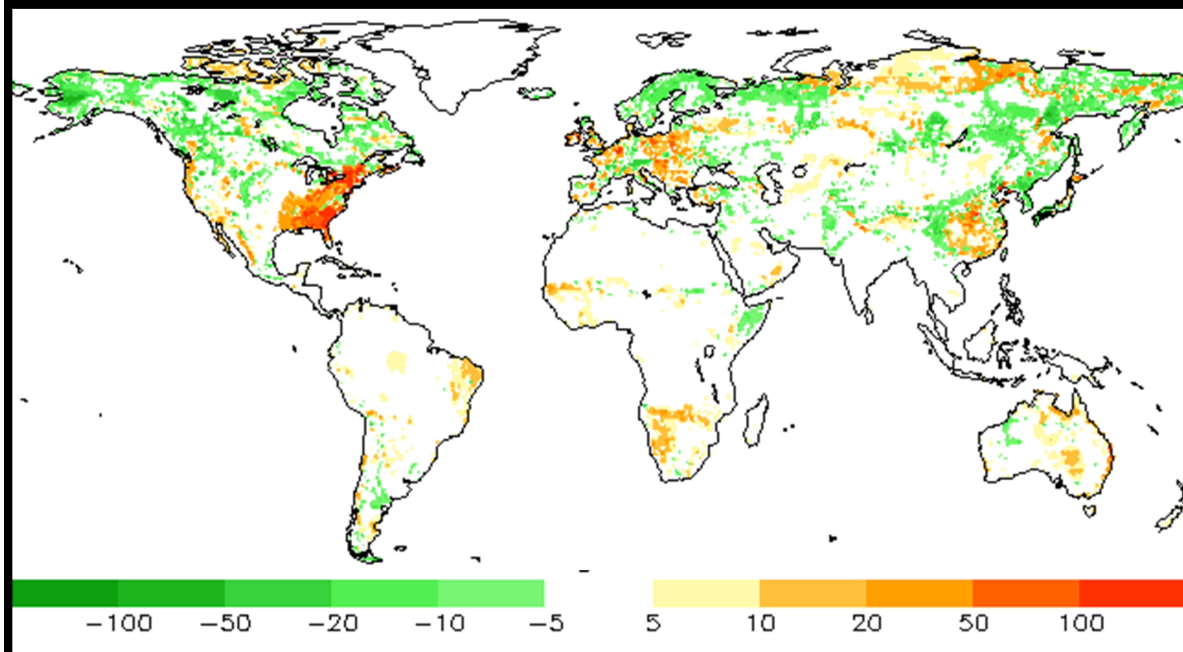


negative is net C gain by the terrestrial ecosystems

Jain et. al. (2011, GBC)

Estimated Impact of N Dynamics on Terrestrial C Uptake ($gC/m^2/yr$)

Average for 2000s

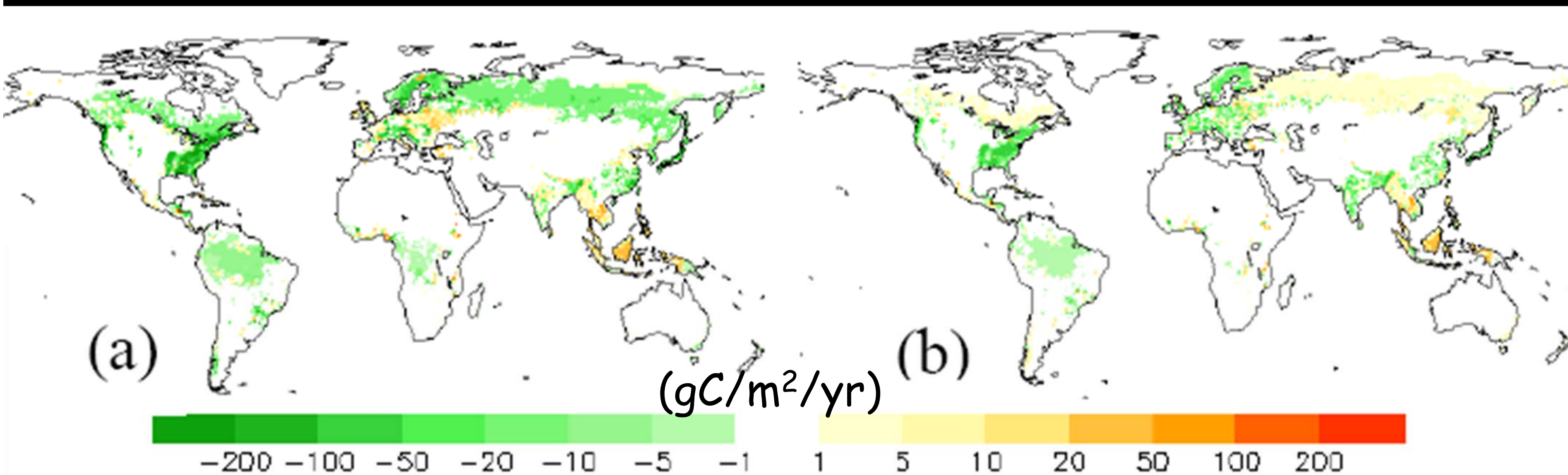


negative is net C gain by the terrestrial ecosystems

- N dynamics reduces CO_2 fertilization effect
- Climate change increase mineral N available to the plants
  - Less of a source with N dynamics
- N dynamics result in less C storage

Jain et. al. (2009, GBC)

The Net Exchange of C for the 2000s in Secondary Forests (SAGE Data)



C fluxes are not constrained by N dynamics

- In some regions accumulation of carbon is reduced where nitrogen is a limiting nutrient or enhanced if the additional N is deposited in the forest regrowing regions

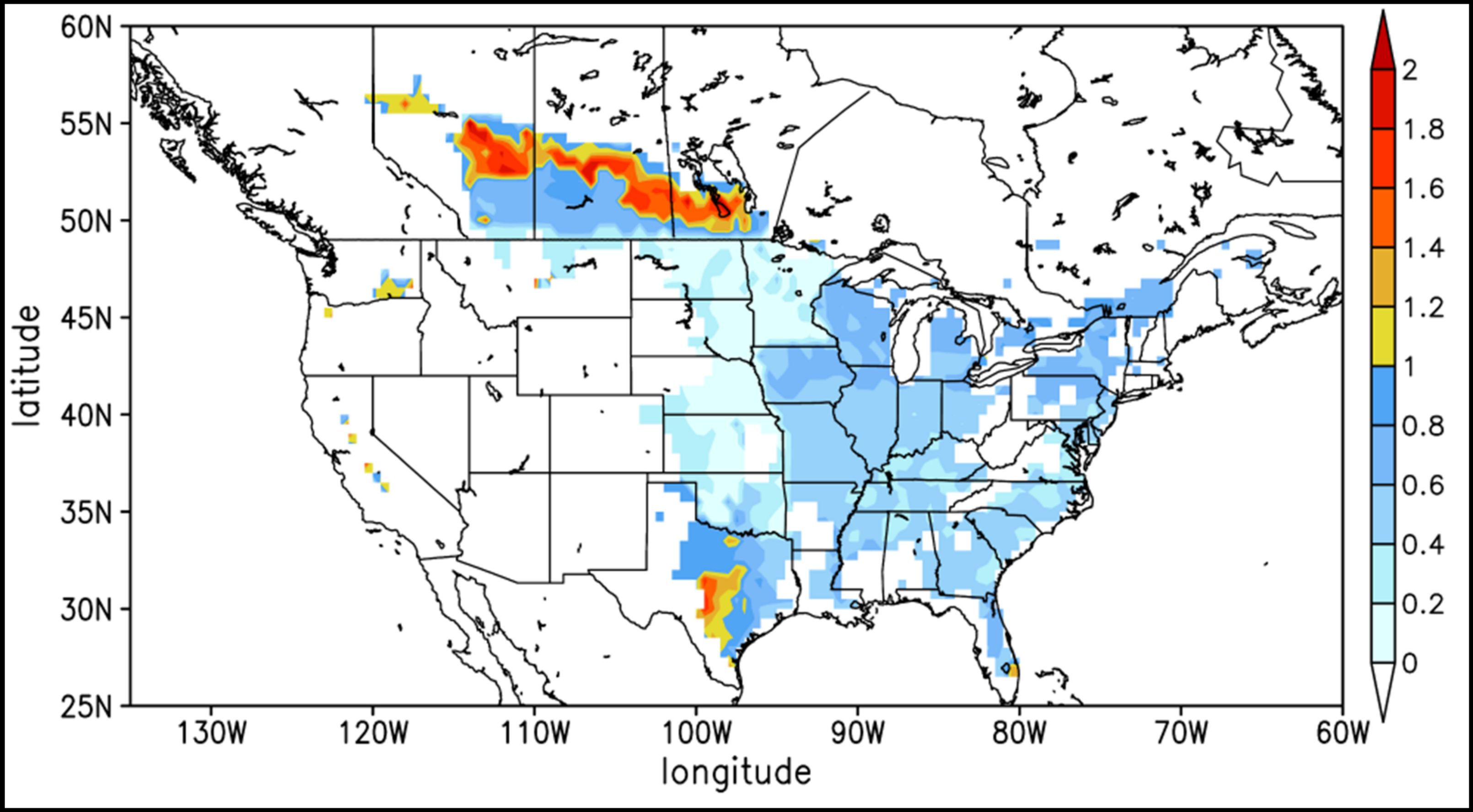
Yang et. al. (2010, Biogeosciences)

Management: Soil Carbon Sequestration

Modeled Soil Carbon Sequestration Potential (Conventional Tillage to No Tillage)

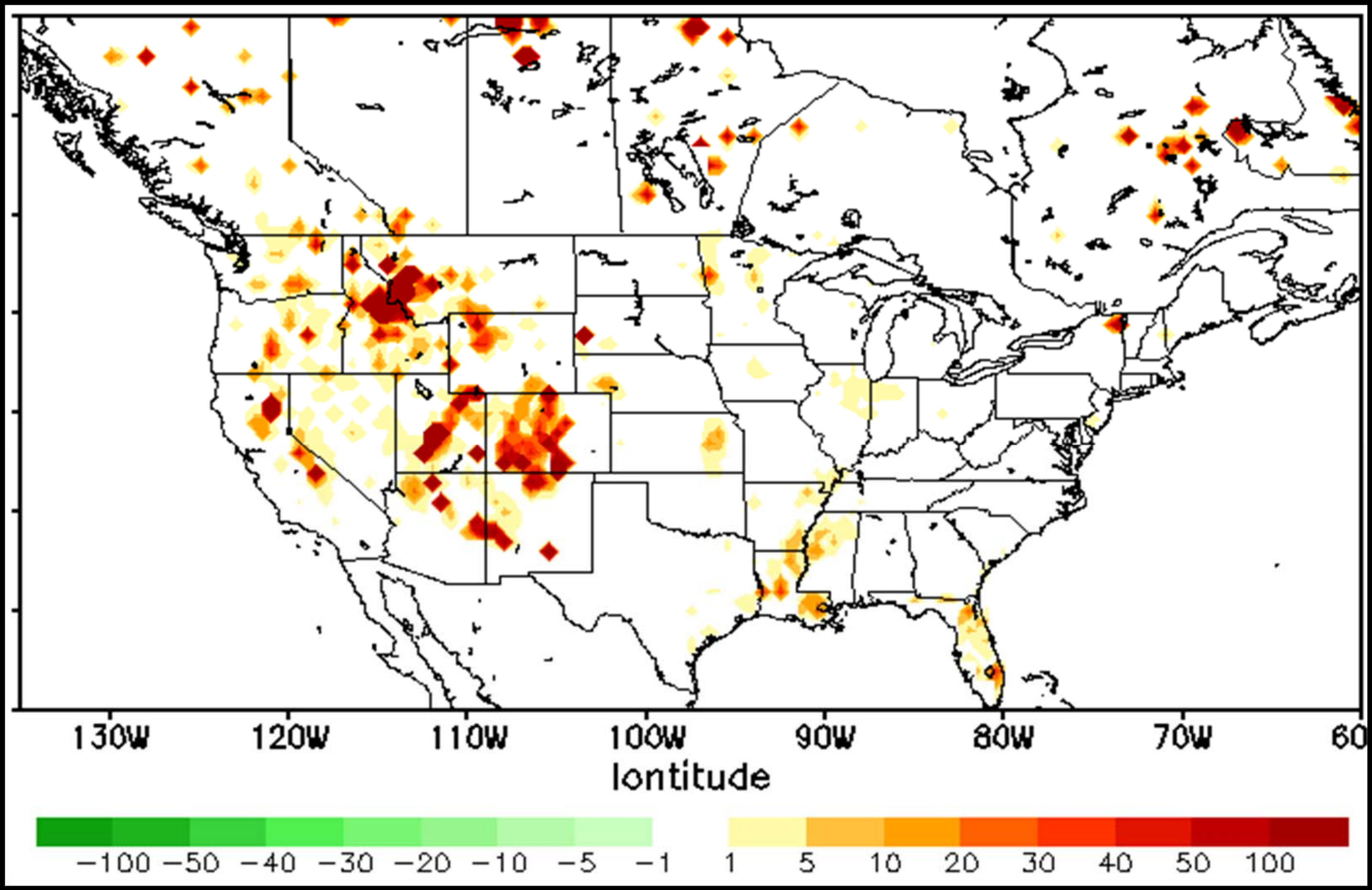
Averaged Over the Period 1981-2000

(MgC/ha/yr)



Jain et al. (GRL, 2005)

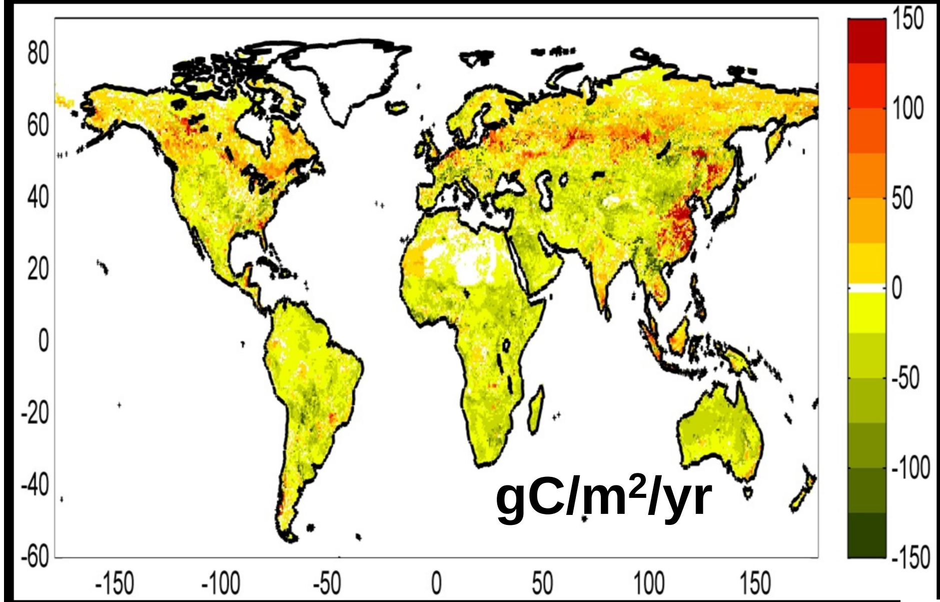
Estimated Distribution of Net C Exchange Attributed to Biomass Burning ($gC/m^2/year$)



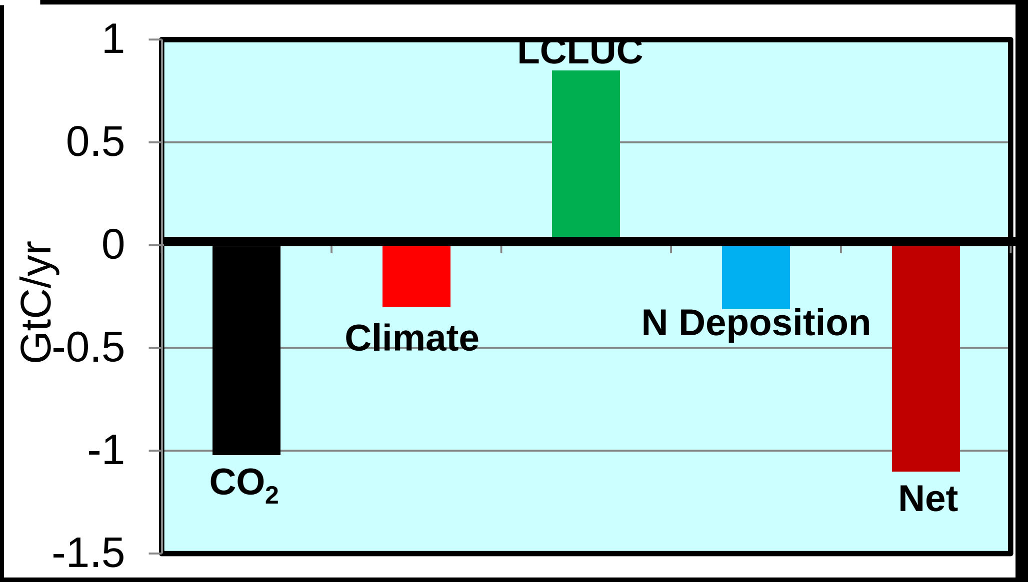
1990s

Positive fluxes represent a net loss of CO2 to the atmospheric

Terrestrial Response to Changes in CO2, Climate, LUC, N Deposition



2000s NEE



Negative flux is net C gain by the terrestrial ecosystem

Conclusions

- Global ecosystems and soils absorbed about 1.1 GtC/yr during the 2000s compared to the 8 GtC/yr release of C due to fossil fuel burning
- The dominated sink is located in the secondary temperate forests along the East Coast in the US and Latin America and Africa
  - Uncertainty in these estimates are large, because the uncertainty in the input data for environmental factors
- CO2 fertilization accounts for a major portion of today's carbon sink
- Other factors such as forest regrowth (secondary forest), agriculture soils and N deposition also contributed to the net C sink.

Thank you..