

Interactions of land use/land cover change with rising CO₂ and anthropogenic nitrogen deposition

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Sponsorship

- DOE Office of Science
- NSF
- NASA

Background

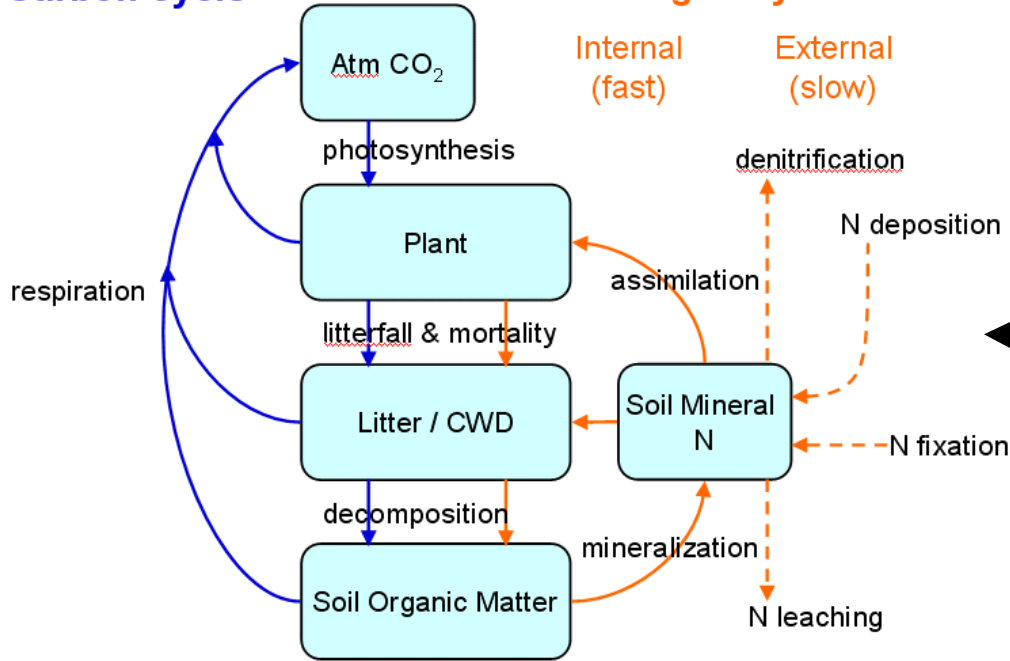
- IPCC AR4 carbon-climate simulations included LULCC as a prescribed forcing flux
 - Similar to treatment of fossil fuel emissions
- That approach generates inconsistencies between predicted state of land ecosystems and assumed forcing.
- Data are now available to drive a more mechanistic representation of LULCC

Motivation

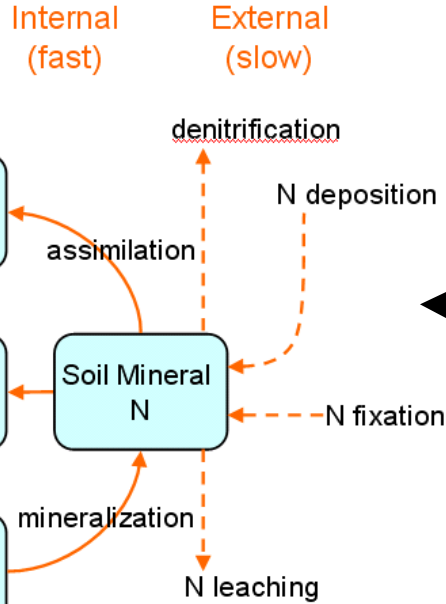
- Previous global-scale modeling suggests significant interactions between rising CO₂ and anthropogenic N deposition
 - Thornton et al. 2007, Sokolov et al. 2008, Zaehle et al. 2009, Shevliakova et al. 2009.
- Site-level modeling and measurements indicated strong interaction between disturbance history and C-N interactions
 - Thornton et al. 2002, Davidson and Janssens 2006
- C-N-LULCC interactions might therefore have significant impact on estimation of allowable emissions for AR5 carbon-climate analyses.

Prognostic biogeochemistry (CLM-CN)

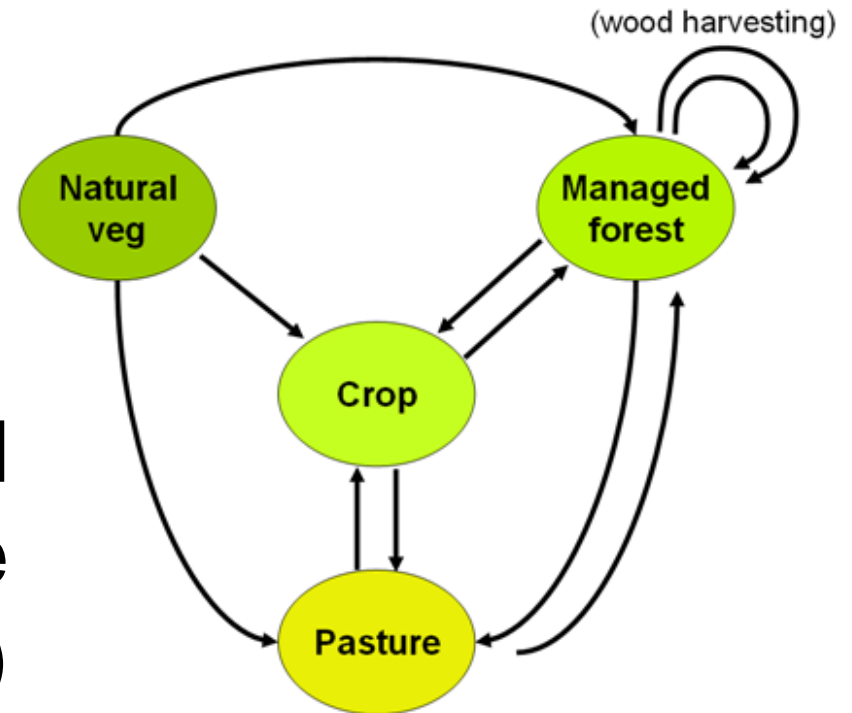
Carbon cycle



Nitrogen cycle

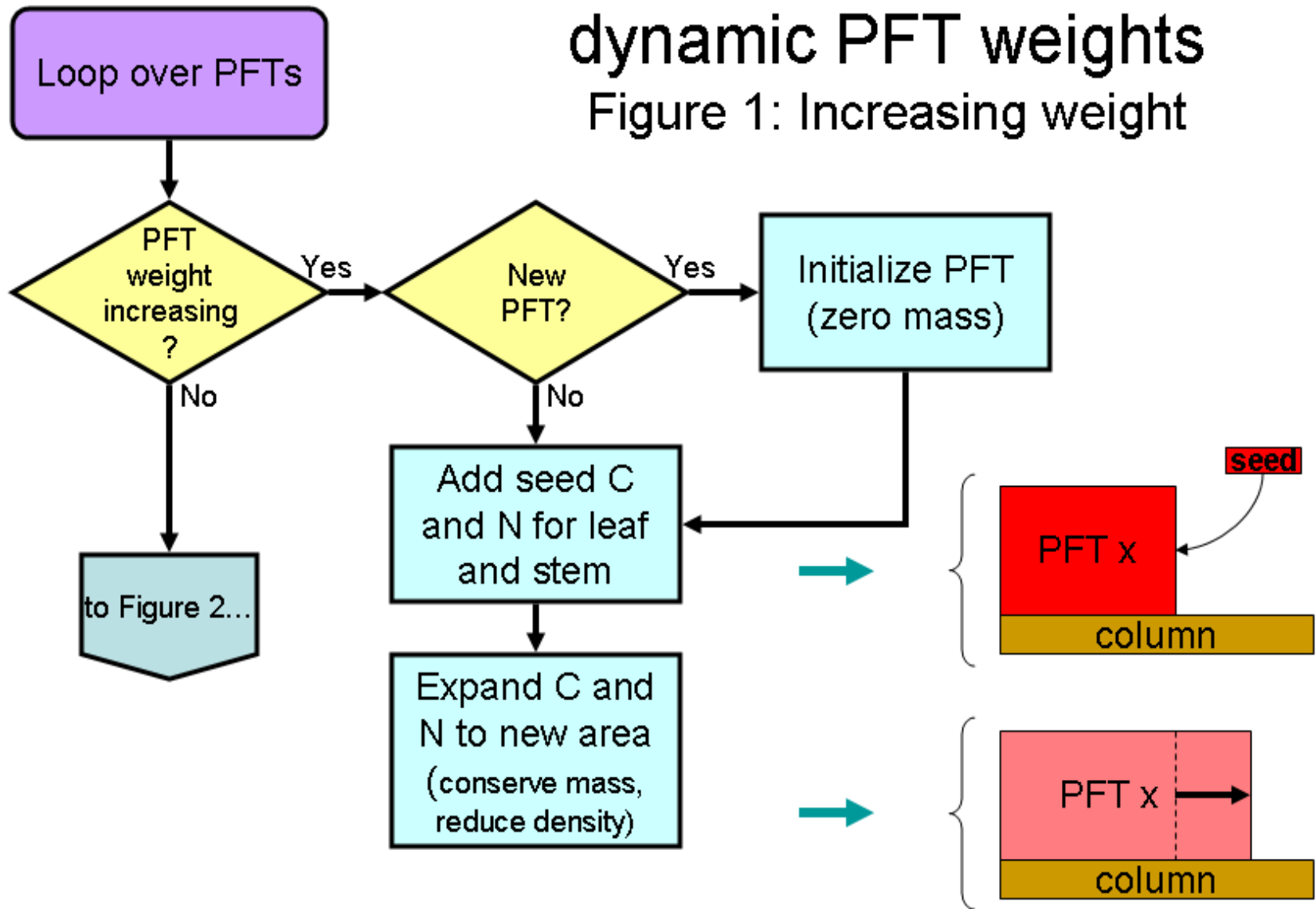


Land Use – Land Cover Change (GLM)



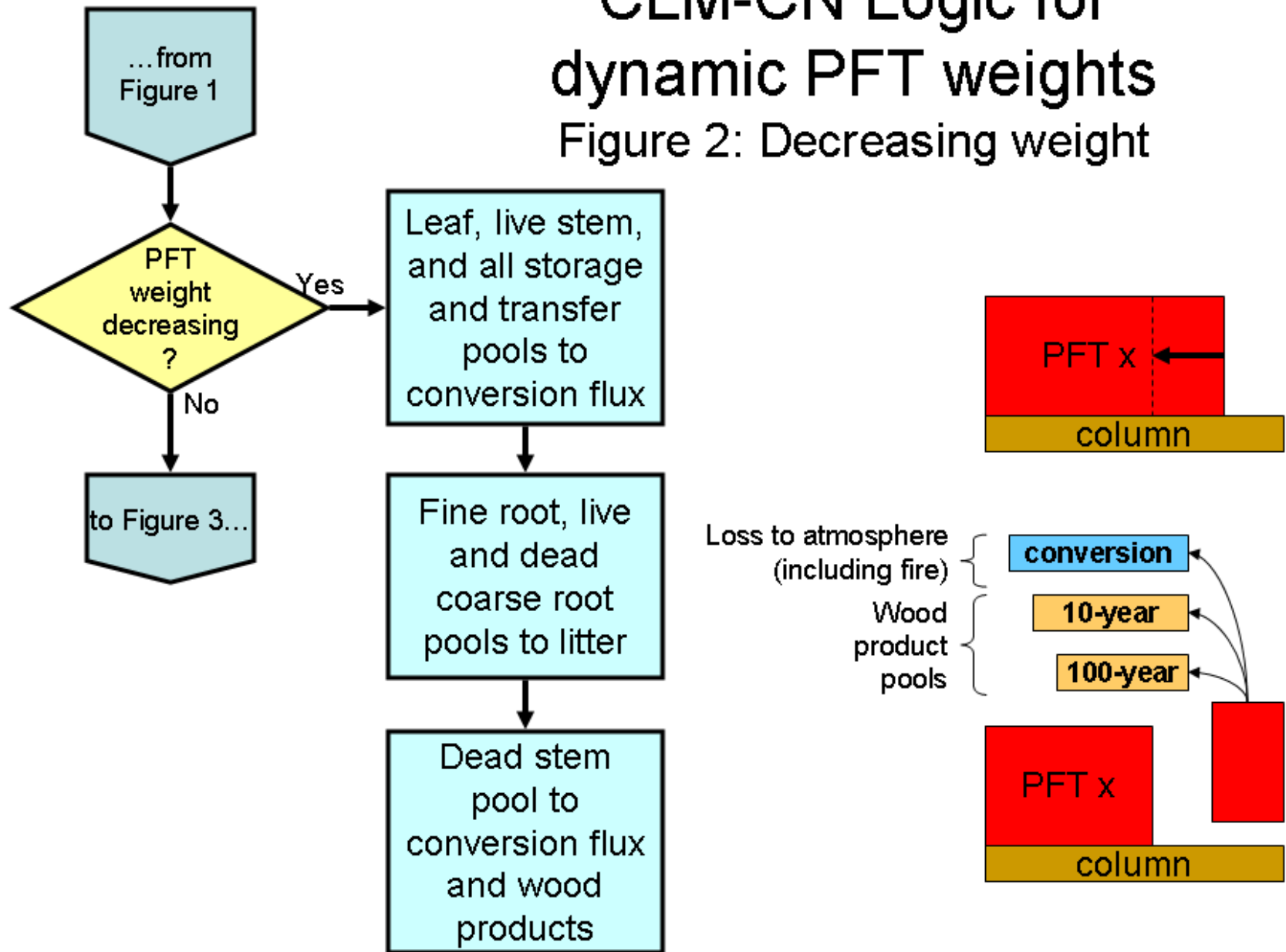
CLM-CN Logic for dynamic PFT weights

Figure 1: Increasing weight



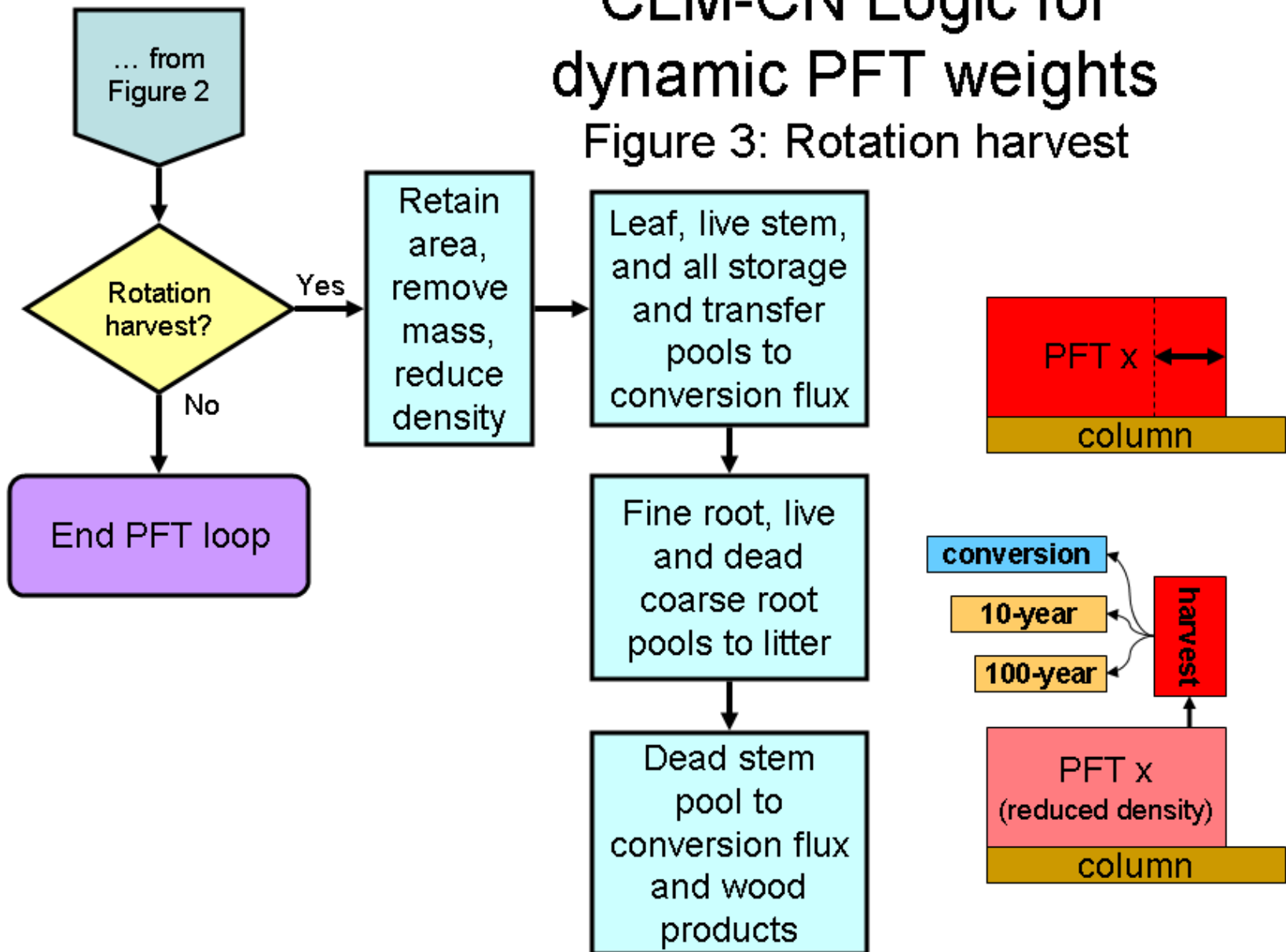
CLM-CN Logic for dynamic PFT weights

Figure 2: Decreasing weight



CLM-CN Logic for dynamic PFT weights

Figure 3: Rotation harvest



Summary of simulations

	Dynamic components		
Simulation	CO ₂	N _{dep}	LU/LCC
Control			
C	x		
N		x	
D			x
CN	x	x	
CD	x		x
ND		x	x
CND	x	x	x

Table 1. Historical global simulations (1850-2004). Used to evaluate independent and interaction effects of: increasing CO₂ (C), increasing anthropogenic nitrogen deposition (N), and land-cover change (D).

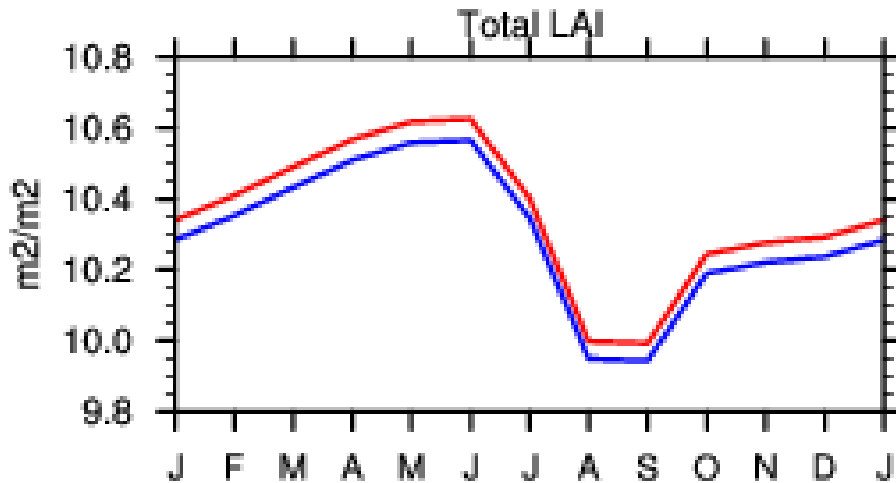
Effects of rotation harvest are included in the land cover change term.

Calculating interactions...

Analysis	Effect		Description
	Forcing	Interaction	
dC	x		C - Control
dN	x		N - Control
dL	x		L - Control
dCN	x		CN - Control
dCL	x		CL - Control
dNL	x		NL - Control
dCNL	x		CNL - Control
d[CN]		x	$dCN - (dC + dN)$
d[CL]		x	$dCL - (dC + dL)$
d[NL]		x	$dNL - (dN + dL)$
d[CNL]		x	$dCNL - (dC + dN + dL)$

Table 2. List of forcings and interaction effects investigated to date. Description shows the differencing of experiments from Table 1 used to isolate the forcing or interaction terms.

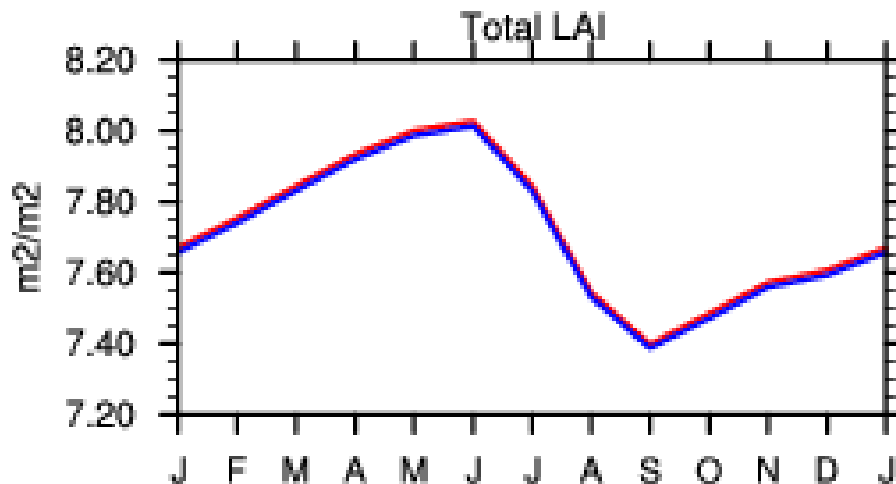
Quick aside: Amazon LAI



Spun-up to steady state with N deposition and CO₂ circa 2000.

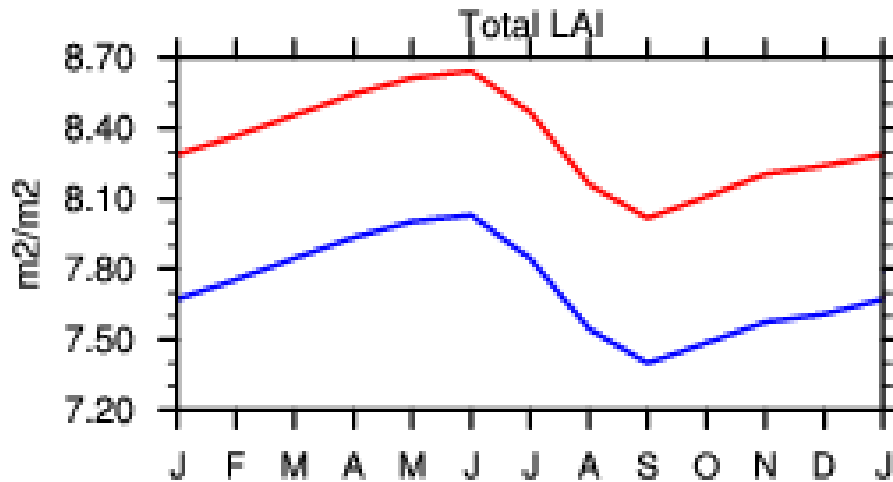


~+30%



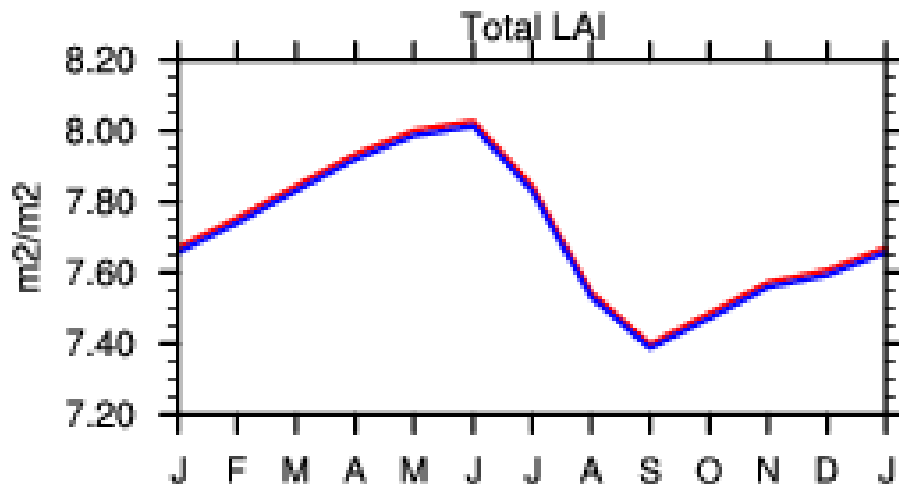
Spun-up to steady state with N deposition and CO₂ circa 1850.

Quick aside: Amazon LAI



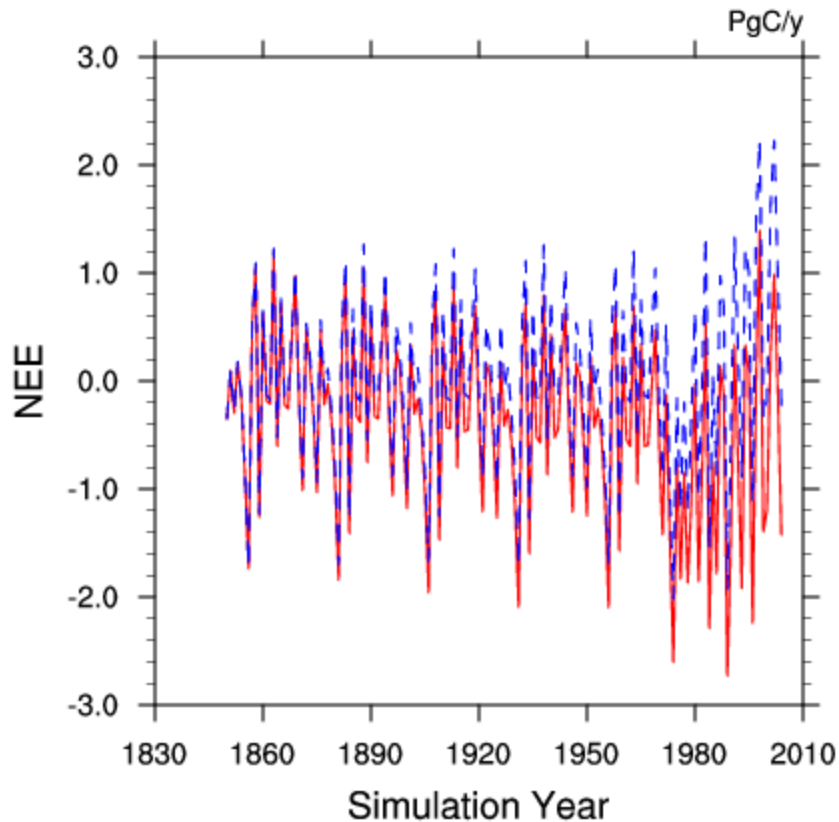
1850 spinup followed by CO₂, N dep, and landuse transients.

~+8%

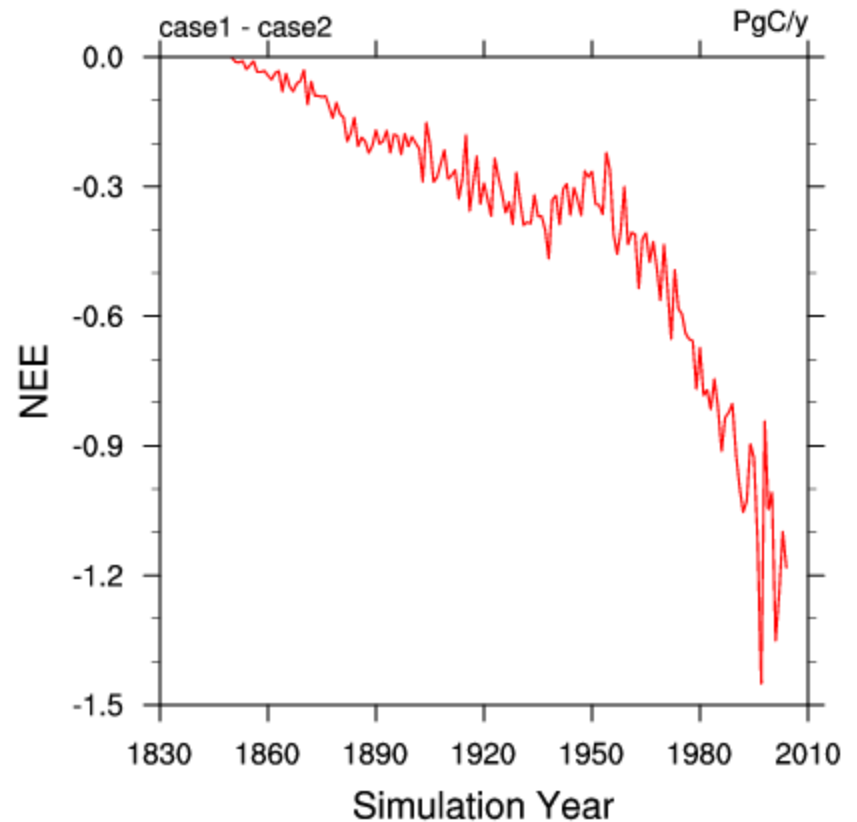


Spun-up to steady state with N deposition and CO₂ circa 1850.

Influence of rising CO₂ on NEE

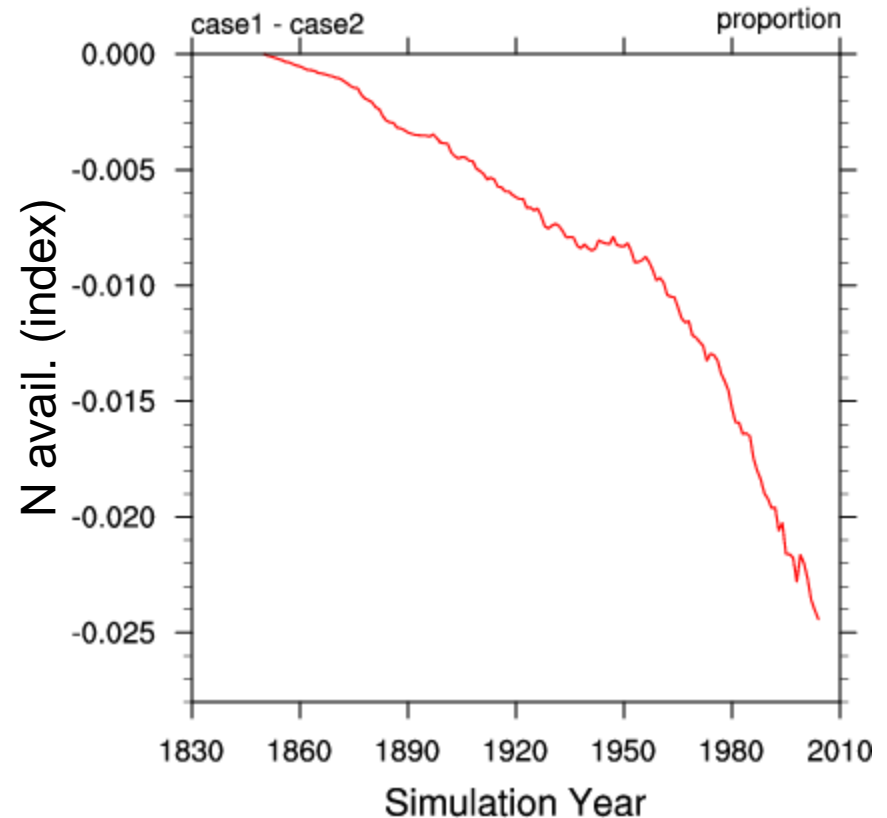
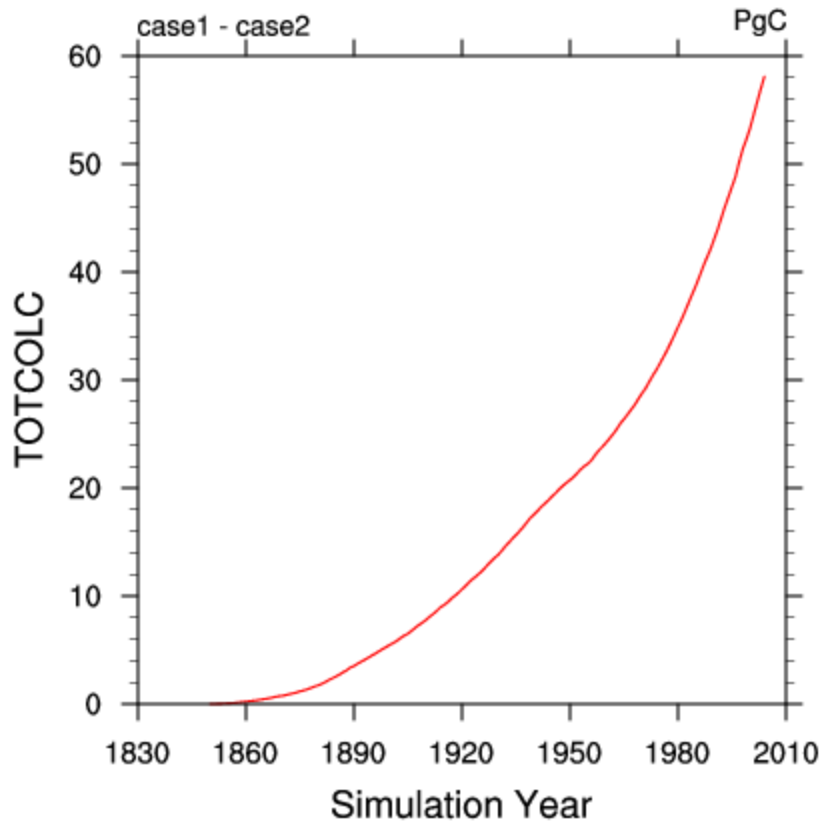


--- control
— +CO₂



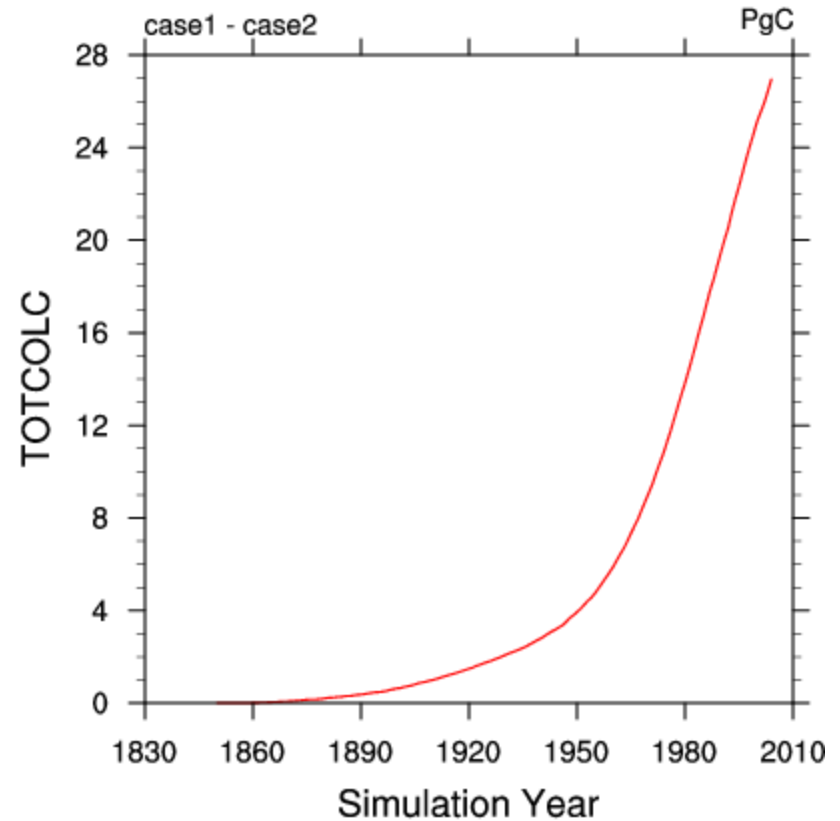
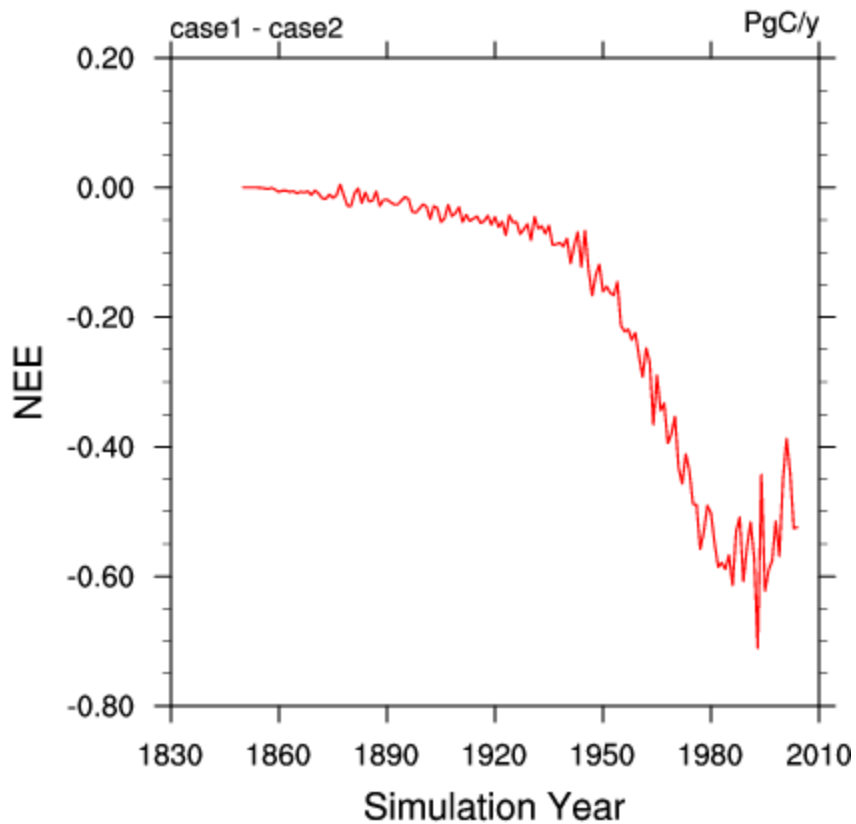
— (CO₂ - control)

Influence of rising CO₂ on total C and N availability



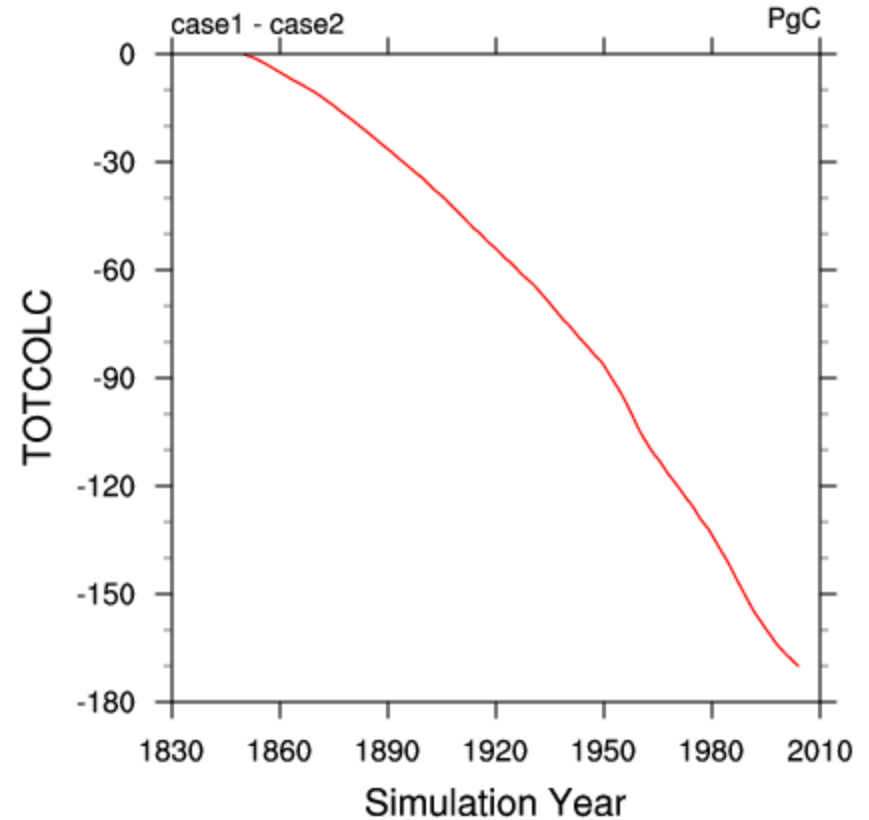
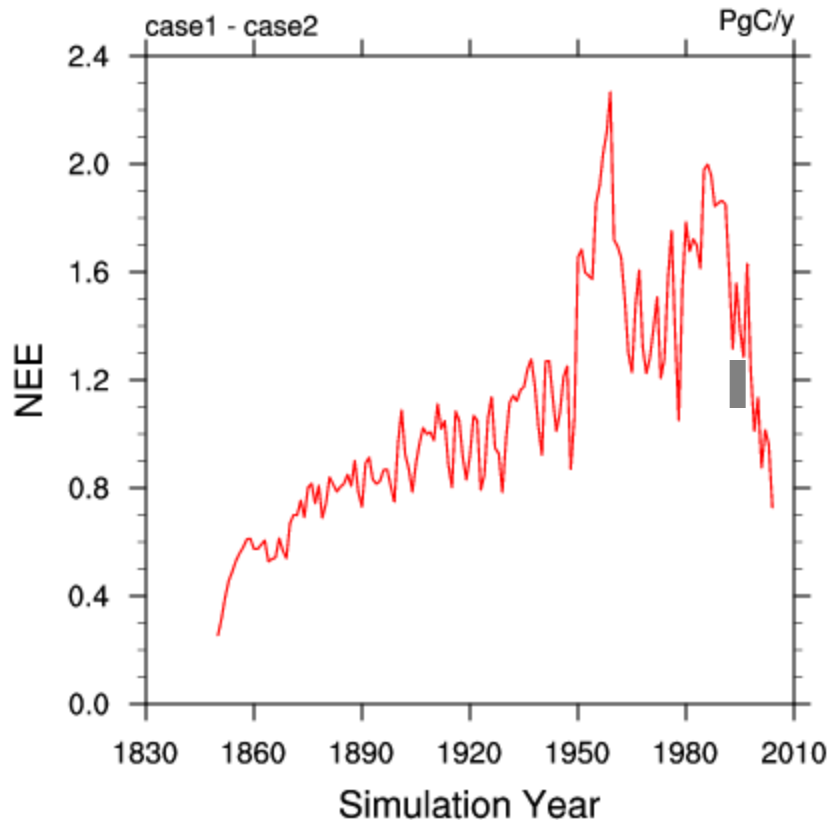
— (CO₂ – control)

Influence of anthropogenic N deposition on NEE and total C



— (Ndep – control)

Influence of LULCC on NEE and total C



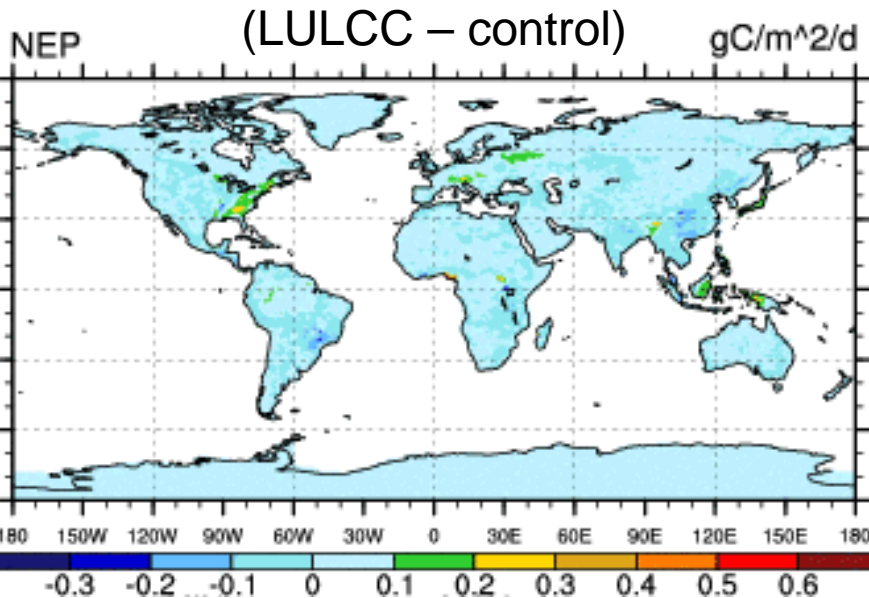
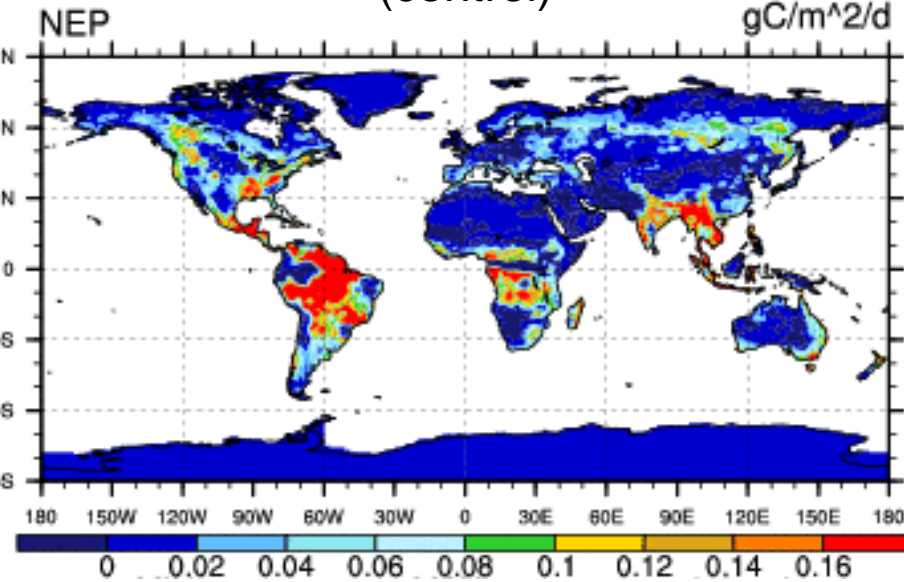
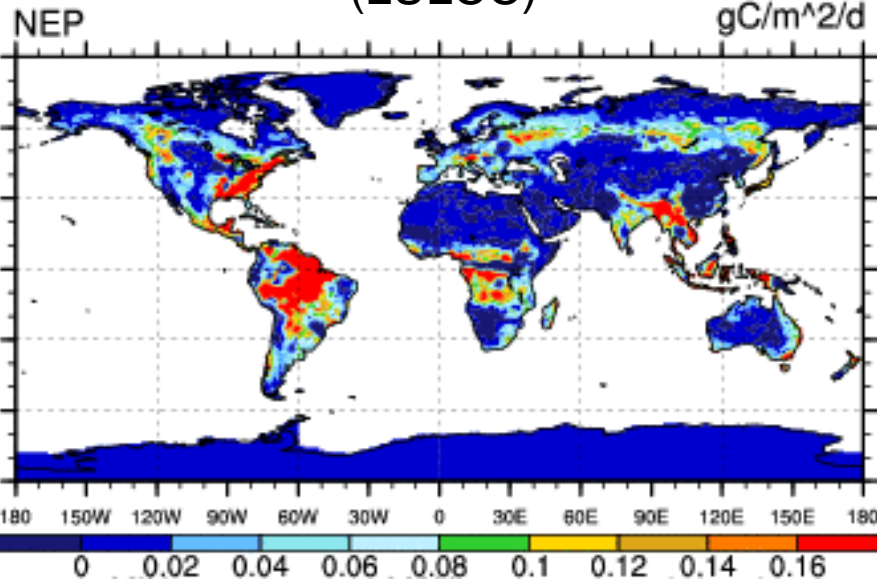
— (LULCC – control)

■ Shevliakova 2009 (LM3V model result)

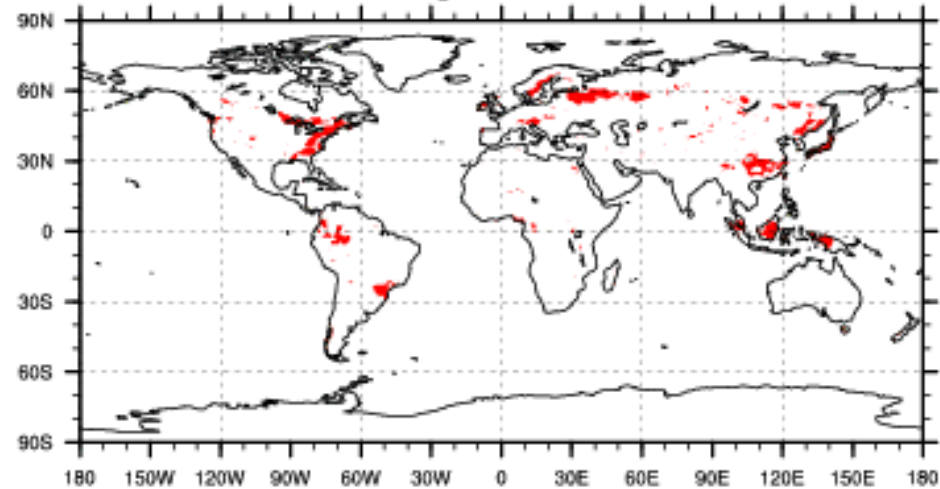
LULCC effect on NEP: temperate forest regrowth

(LULCC)

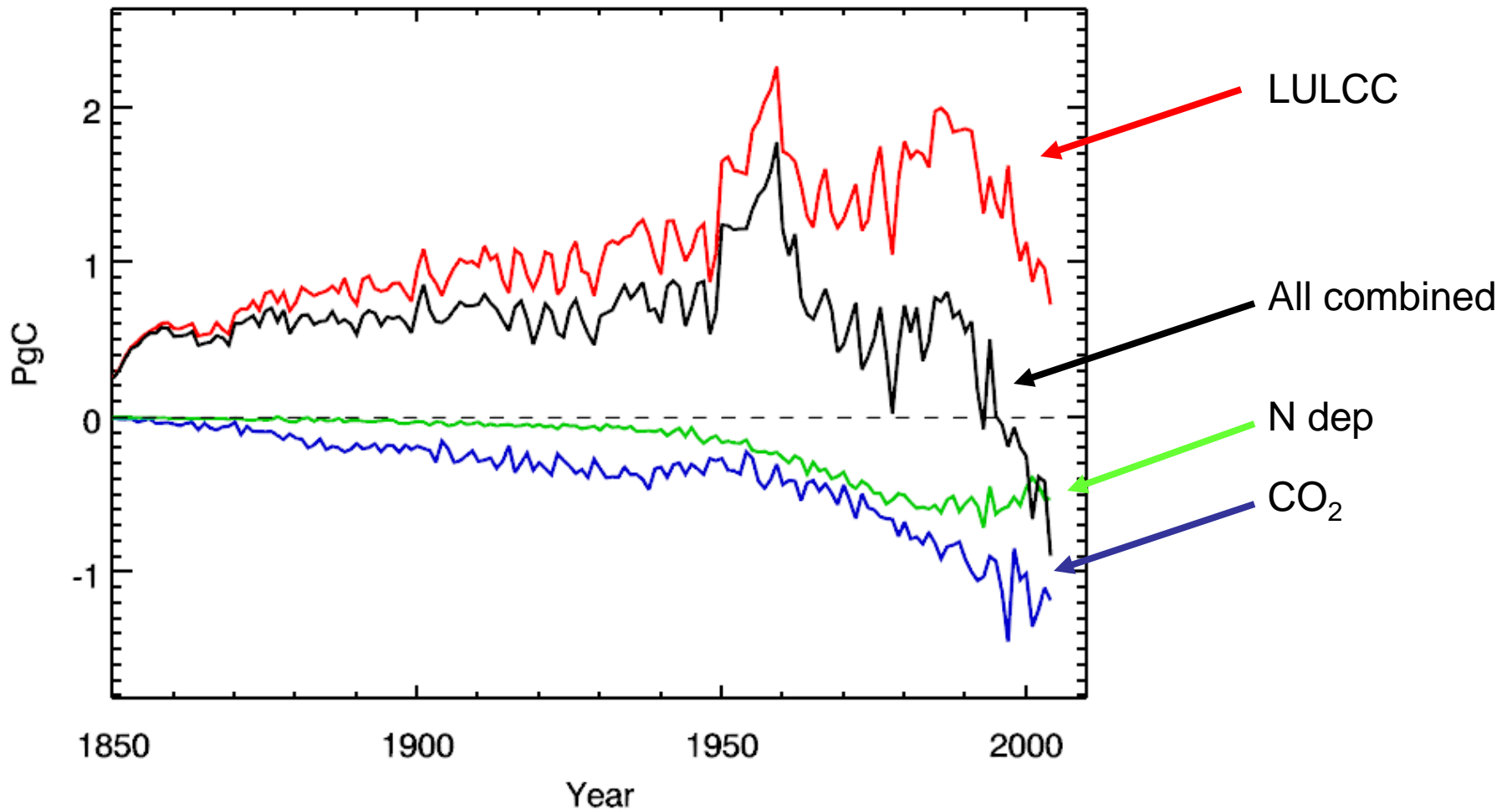
(control)



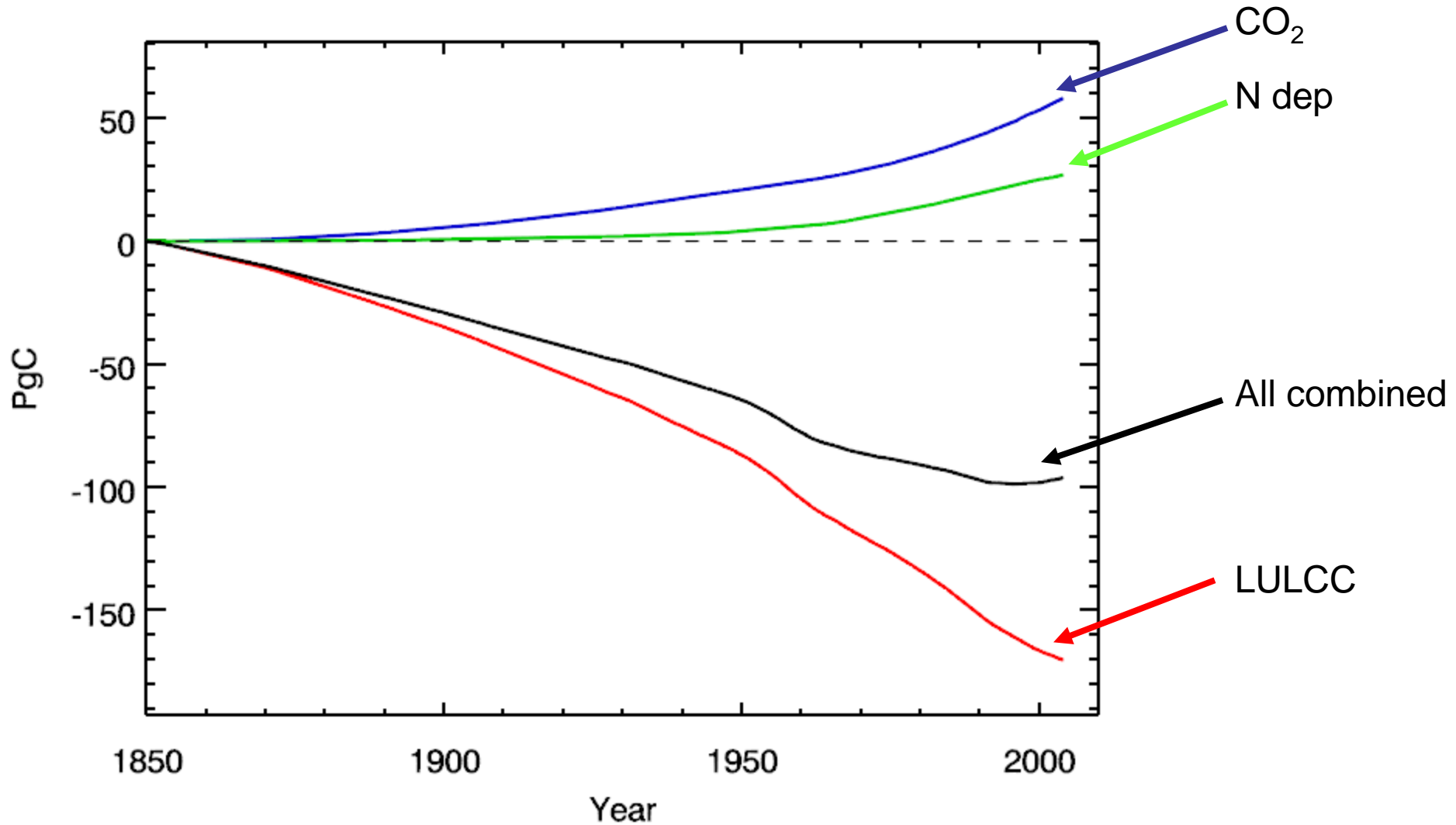
Cells are significant at 0.1 level



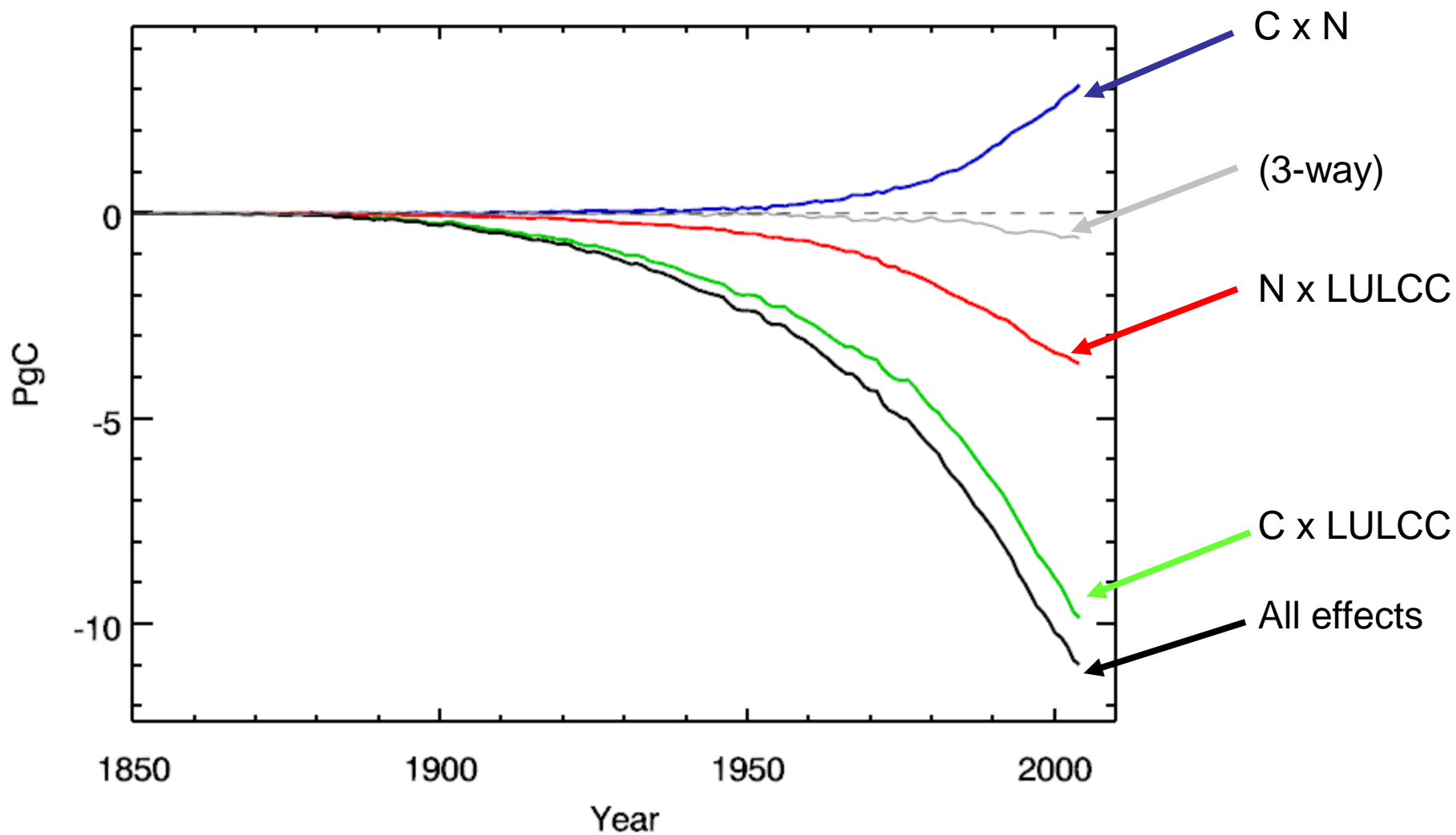
Single and combined effects on NEE



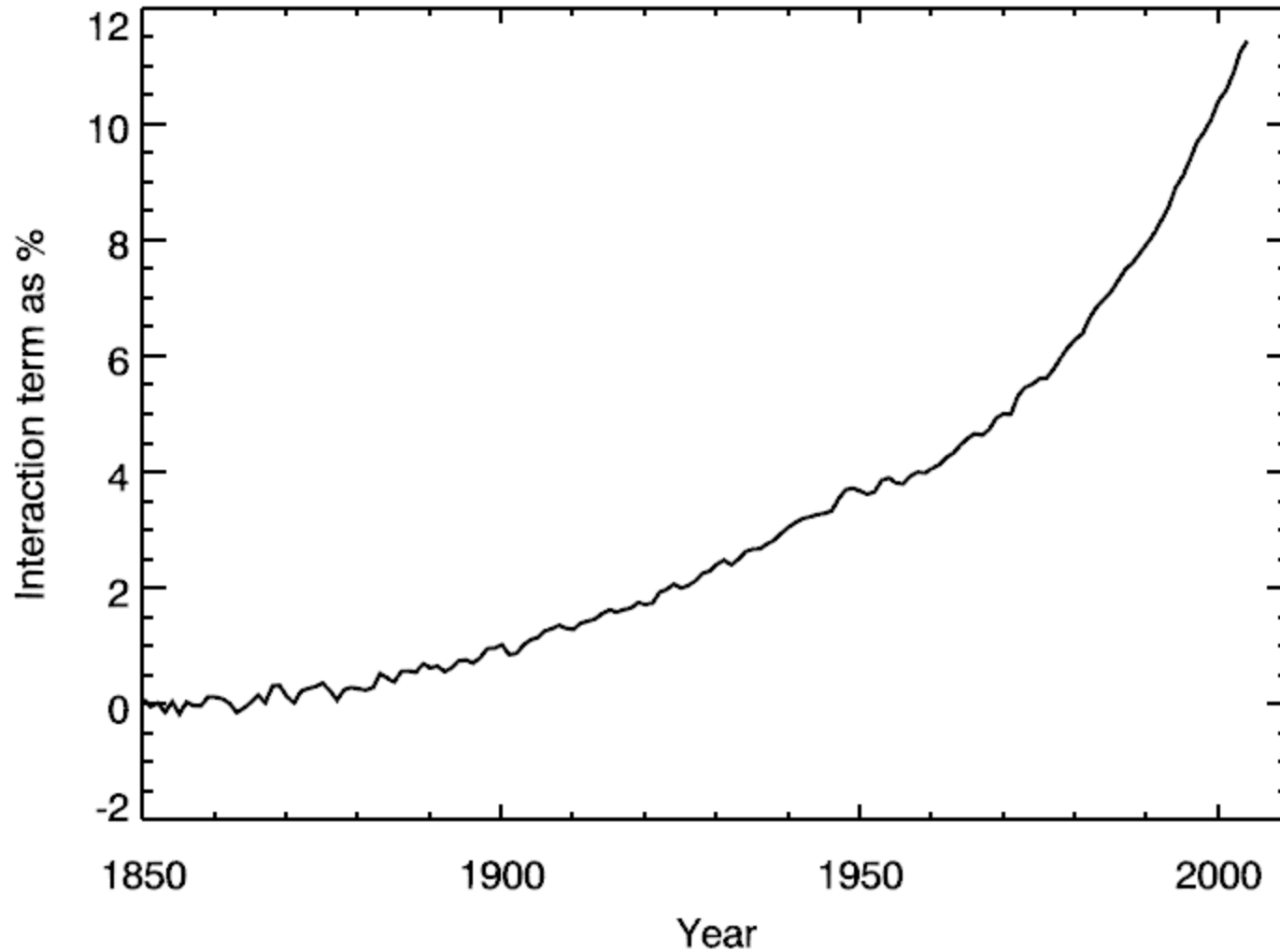
Single and combined effects on total land C



Interaction effects for total land C



Interaction as % of total C+N+LULCC effect



Conclusions

- Strong interaction effects argue for integration of LULCC drivers in ESM for simulations based on future scenarios
 - Currently offline forcing from integrated assessment models
- Two projects underway to make this coupling in CCSM (with GCAM and IMAGE models).