Agriculture and the climate system: Is the representation in Earth-System Models sufficient?

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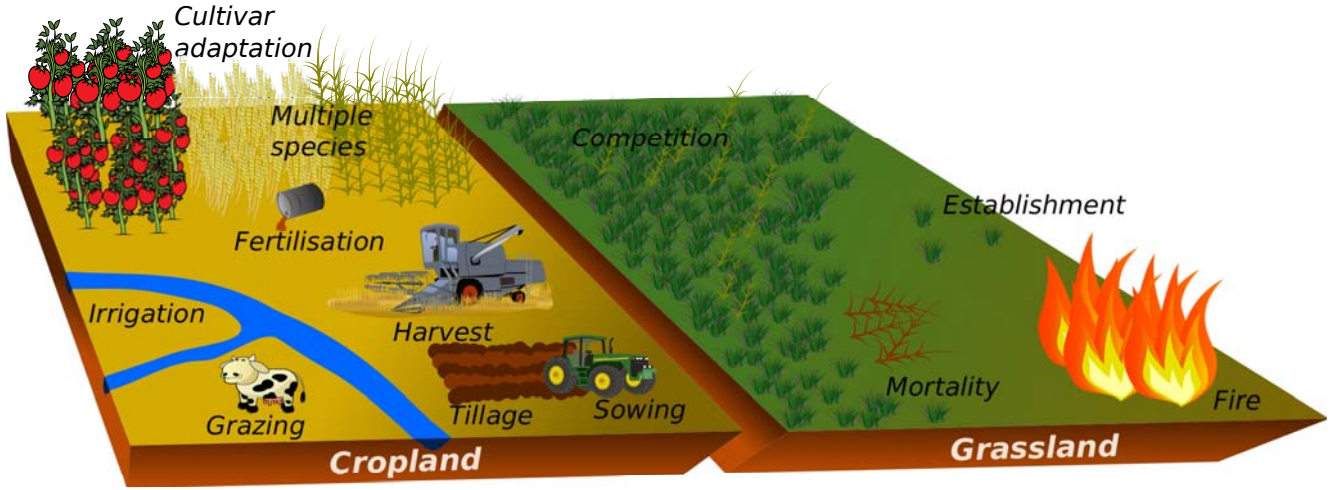
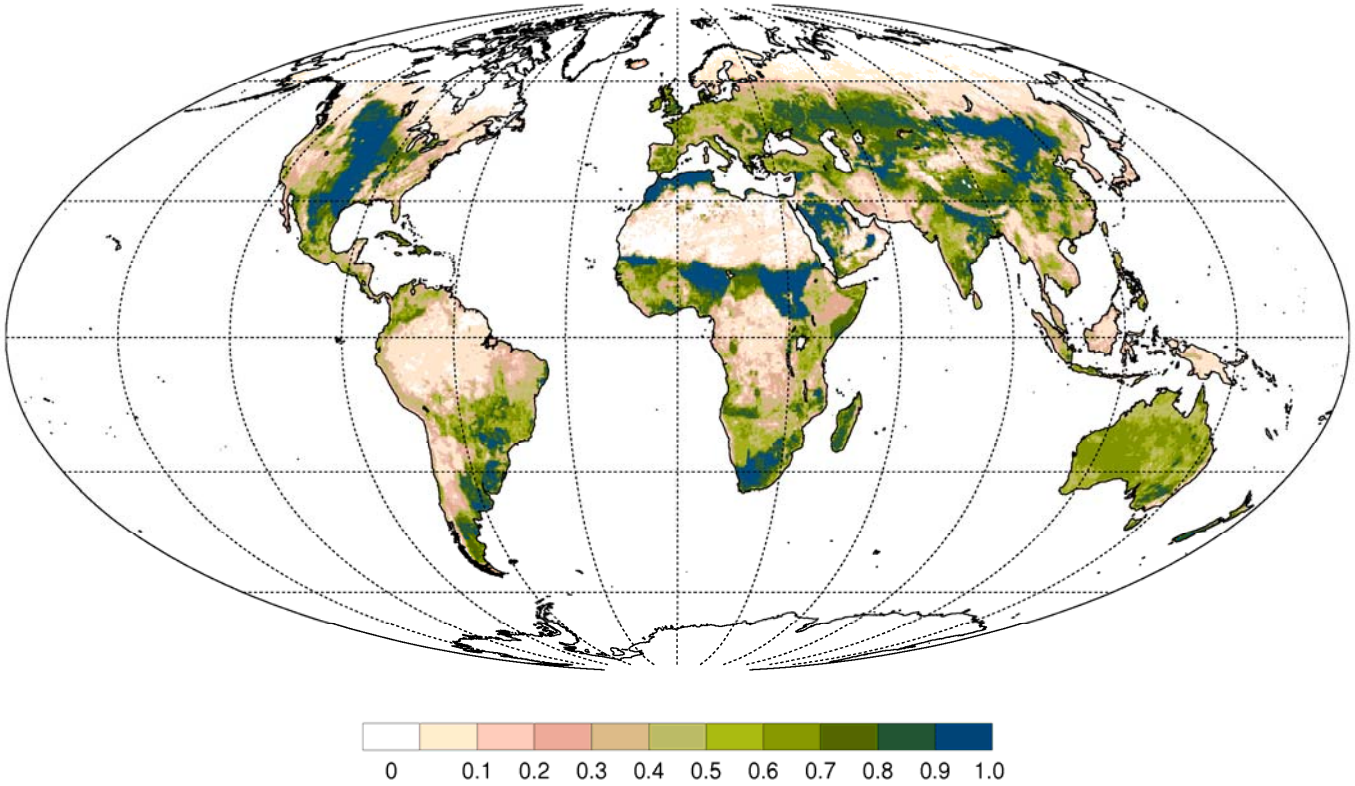
3 Utrecht University, The Netherlands and PBL Netherlands Environmental Assessment Agency, Bilthoven, The Netherlands



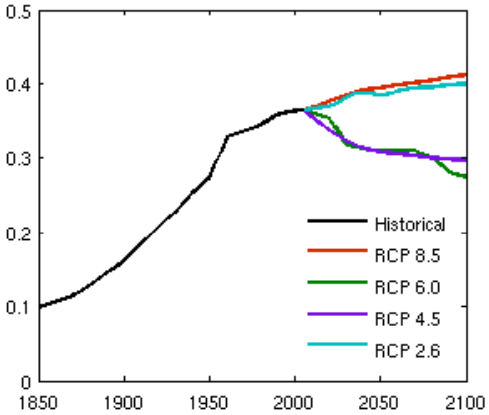
KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research
Karlsruhe Institute of Technology

3rd EMBRACE general assembly, Utrecht, May 2014

Quick history of land-cover change and global climate modelling



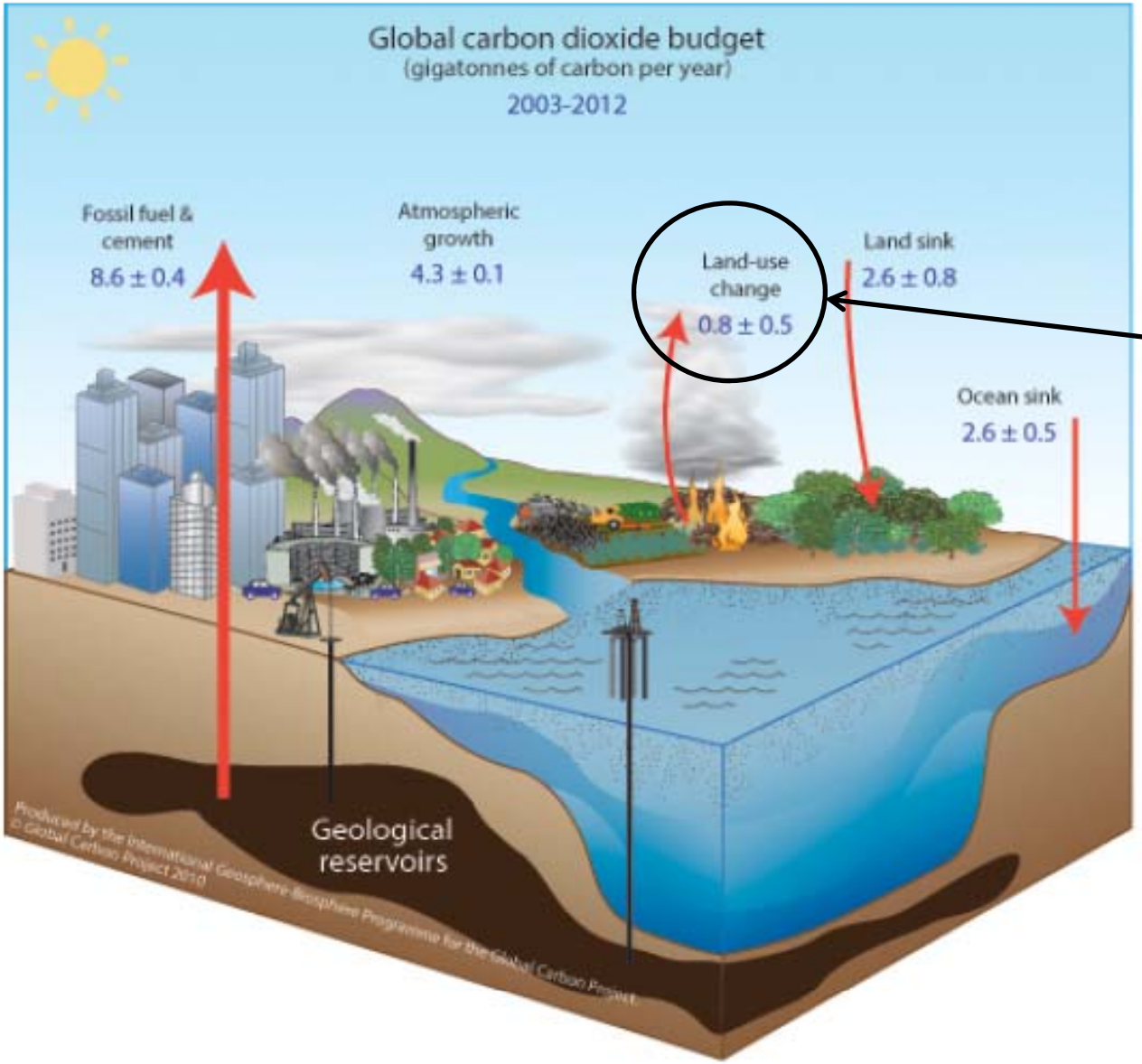
Estimated crop and pasture cover fraction in 2005.



- IPCC AR4 Global Climate Model simulations ignored land-cover change.
- AR5 GCM simulations included simple representations of land-cover change.

Figures based on Hurtt et al.,Climatic Change, 2011.

Quick history of land-cover change and global climate modelling



Land-use change provides a substantial emission of C to the atmosphere.

Figure from Le Quéré et al., Earth System Science Dynamics Discussions, 2014.

Quick history of land-cover change and global climate modelling

But the uncertainty in land-use emission magnitude is huge.
There are no direct global measurement constraints.

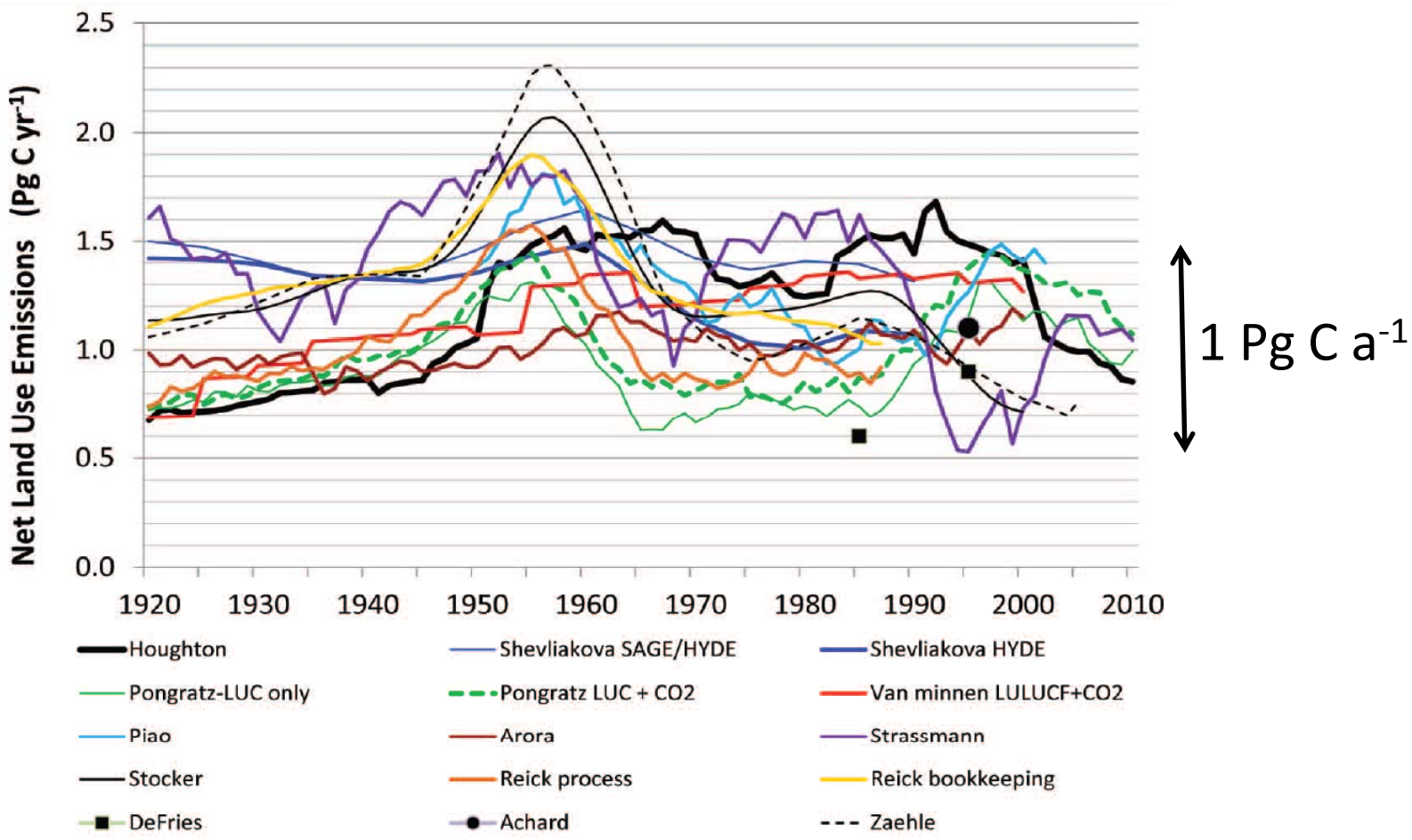


Figure from Houghton et al. Biogeosciences, 2012.

Quick history of land-cover change and global climate modelling

Differences in ESM terrestrial carbon storage between simulations with and without land-cover change can be large.

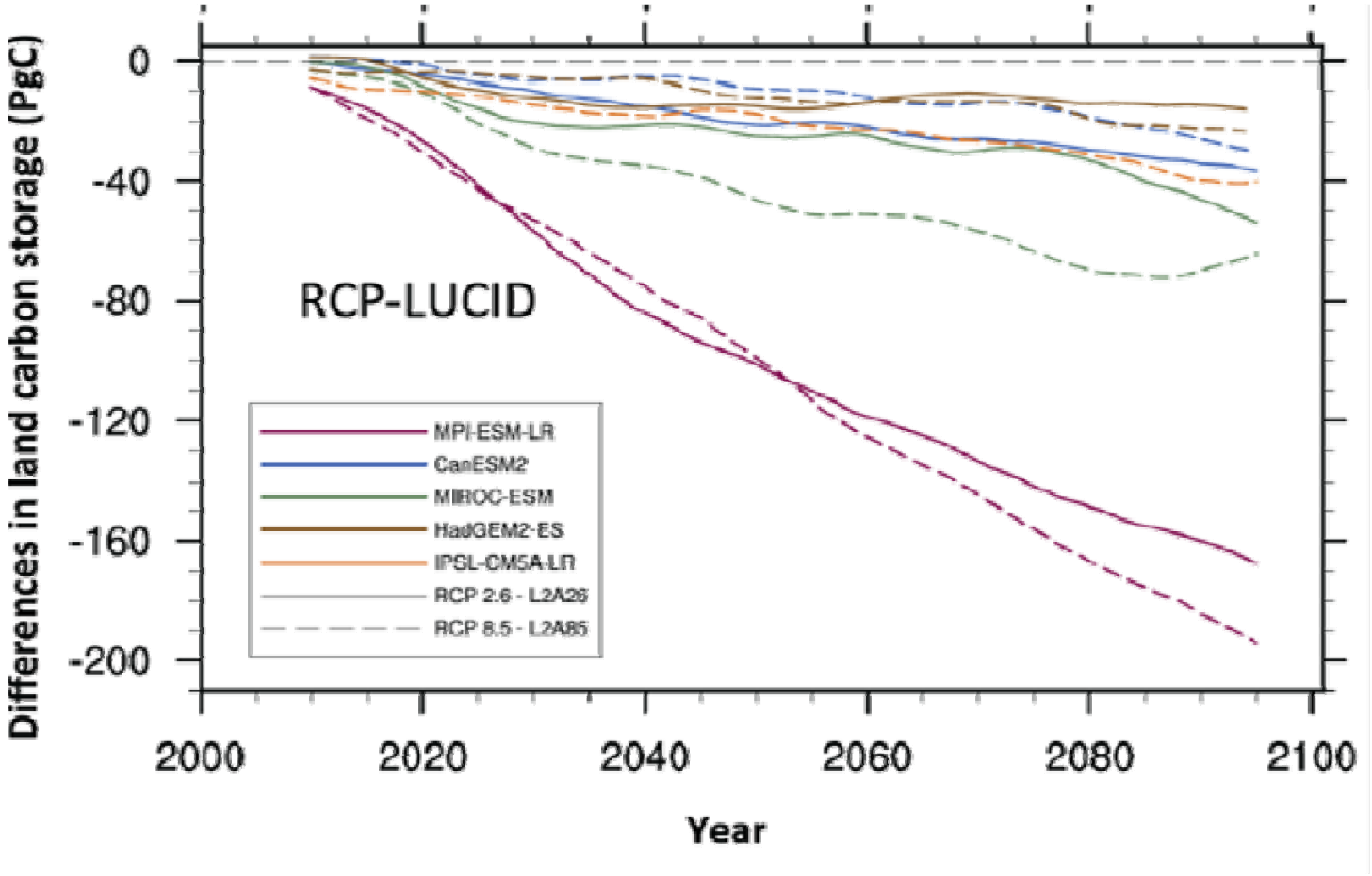
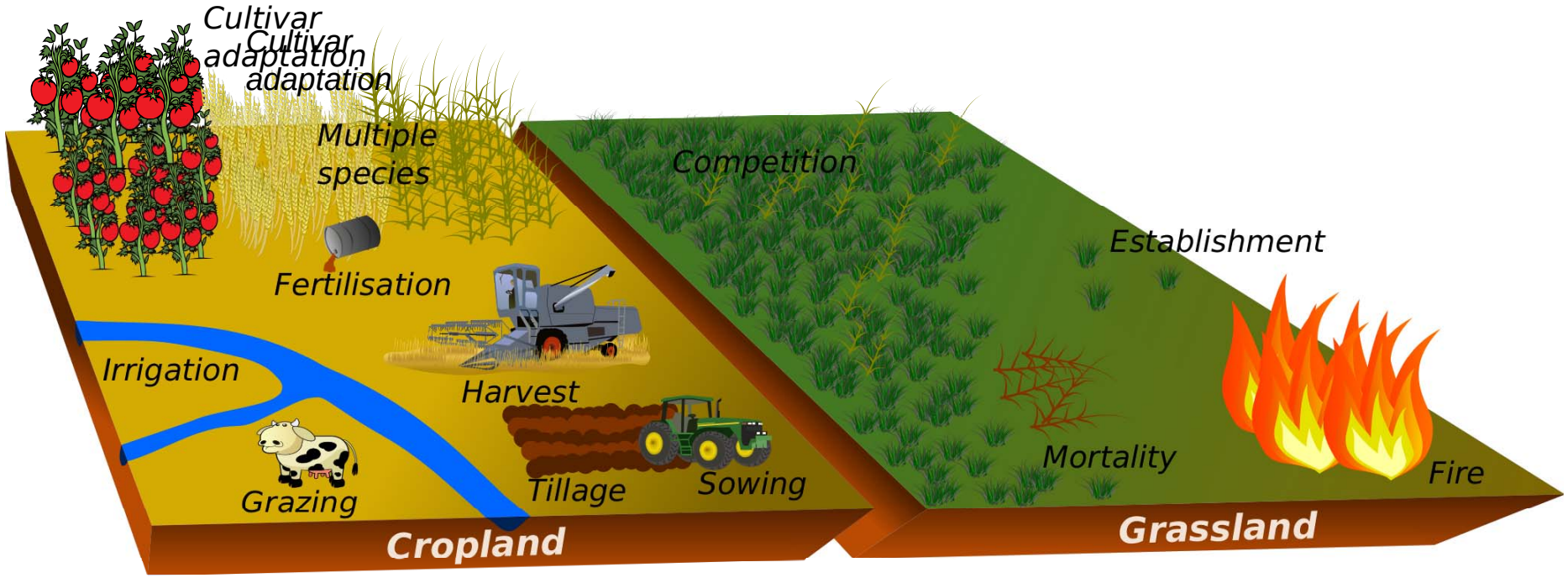


Figure from Brovkin et al. Journal of Climate, 2013.

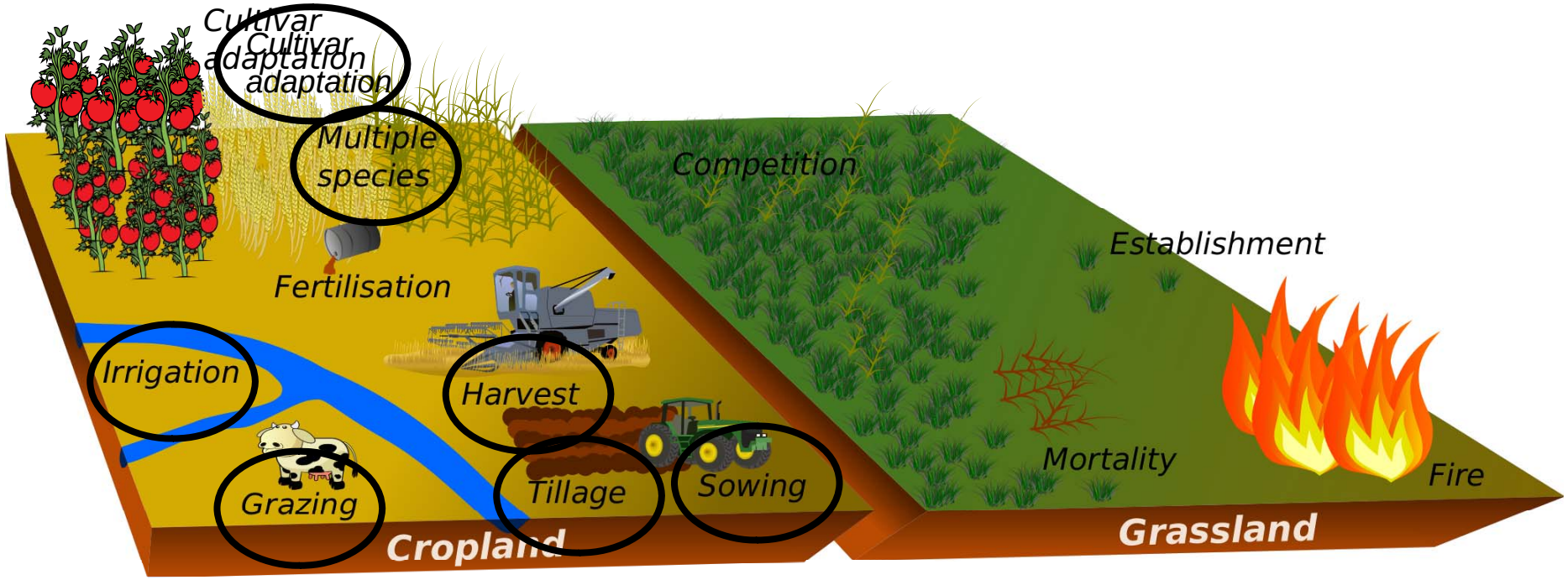
How much does agricultural representation affect the carbon cycle?

- AR5 ESMs and many DGVMs represented croplands as grasslands, broadly excluding the specific features of agricultural systems.
- However, in reality croplands (and to a lesser extent pasture lands) are very different from natural grassland ecosystems.



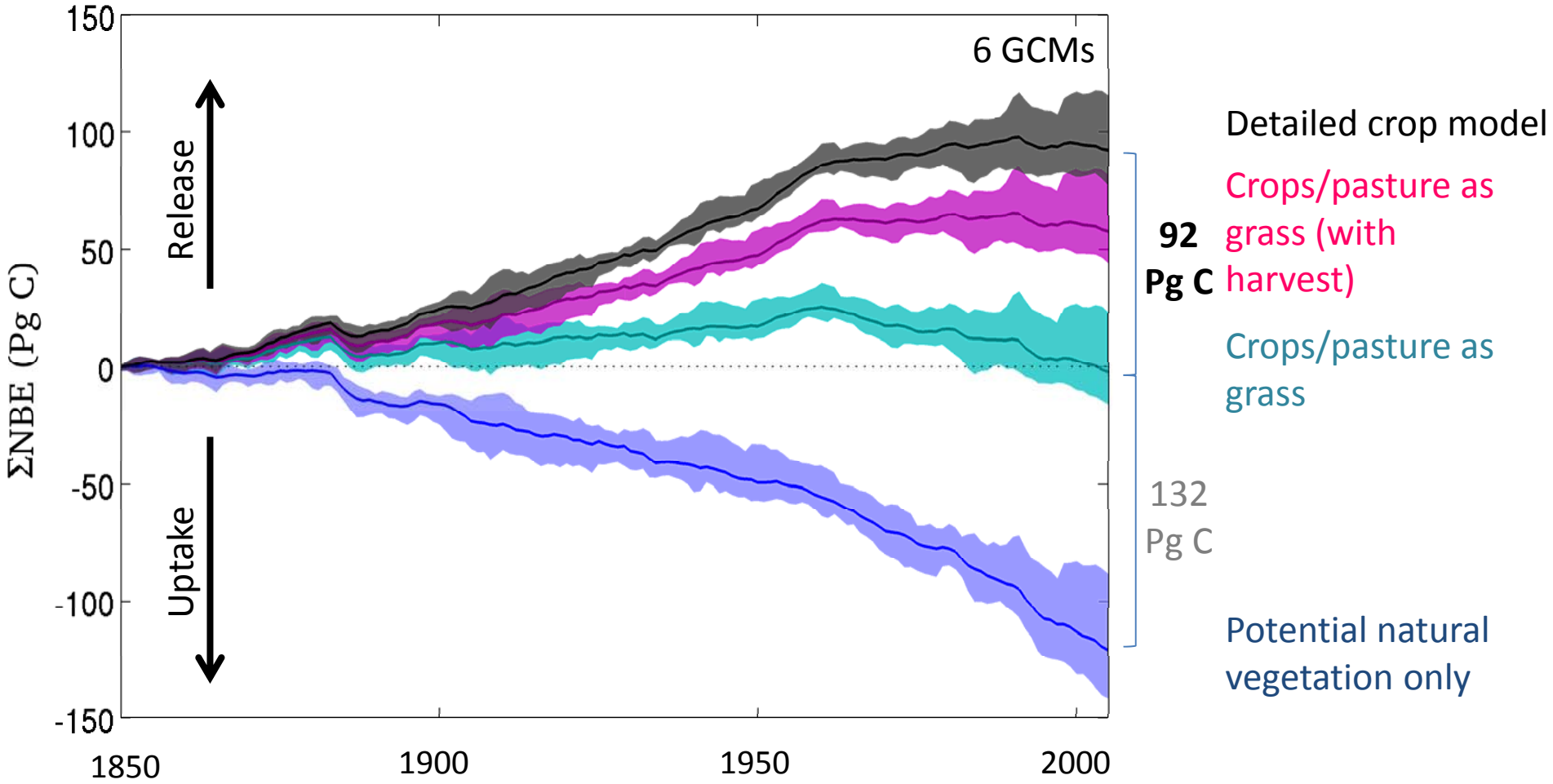
How much does agricultural representation affect the carbon cycle?

We used the LPJ-GUESS Dynamic Global Vegetation model with a detailed representation of agricultural processes (Lindeskog et al., Earth System Dynamics, 2013) to investigate how agricultural representation may affect the modelled land carbon sink.



How much does agricultural representation affect the carbon cycle?

Change in modelled terrestrial carbon uptake since 1850



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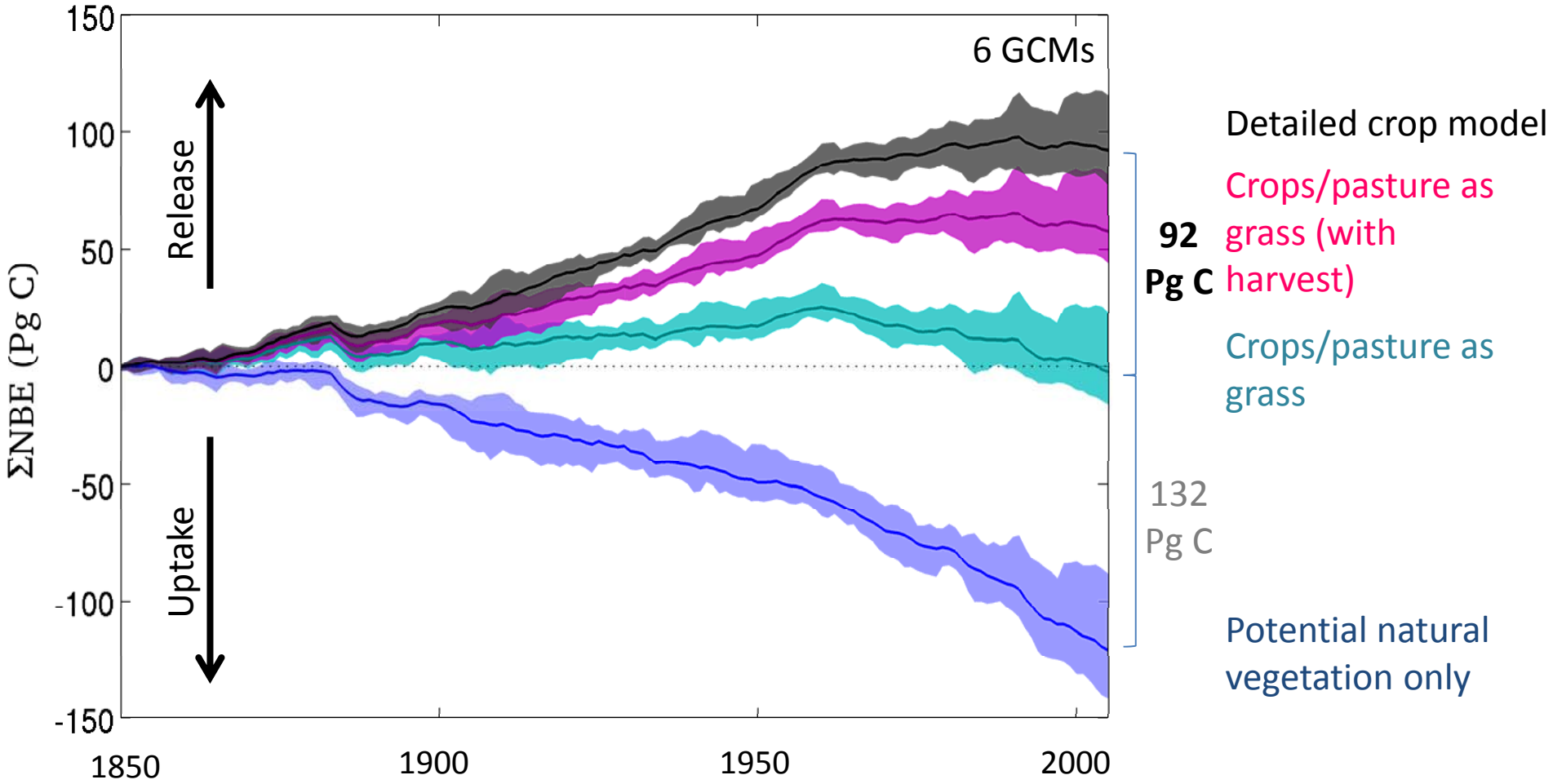
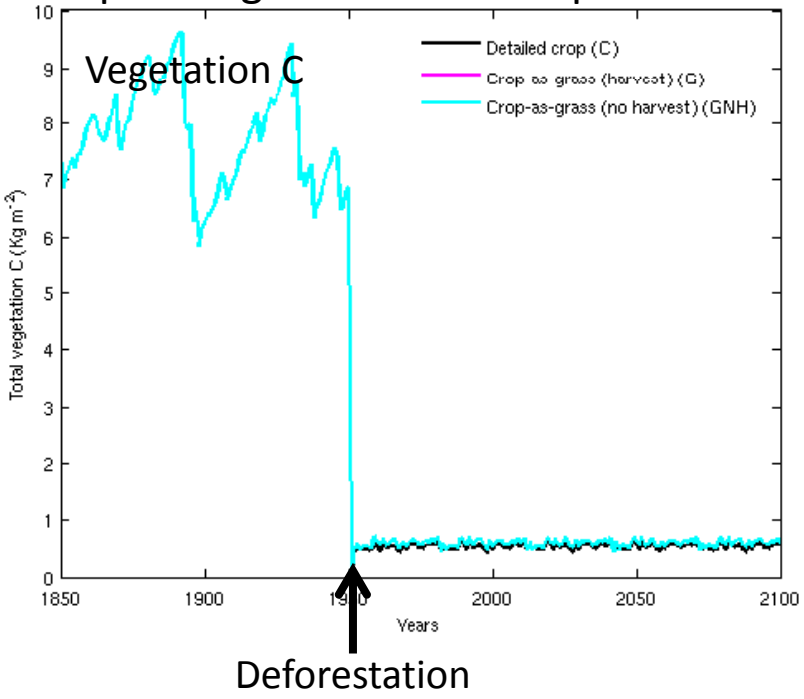


70% increase in overall LUC emissions

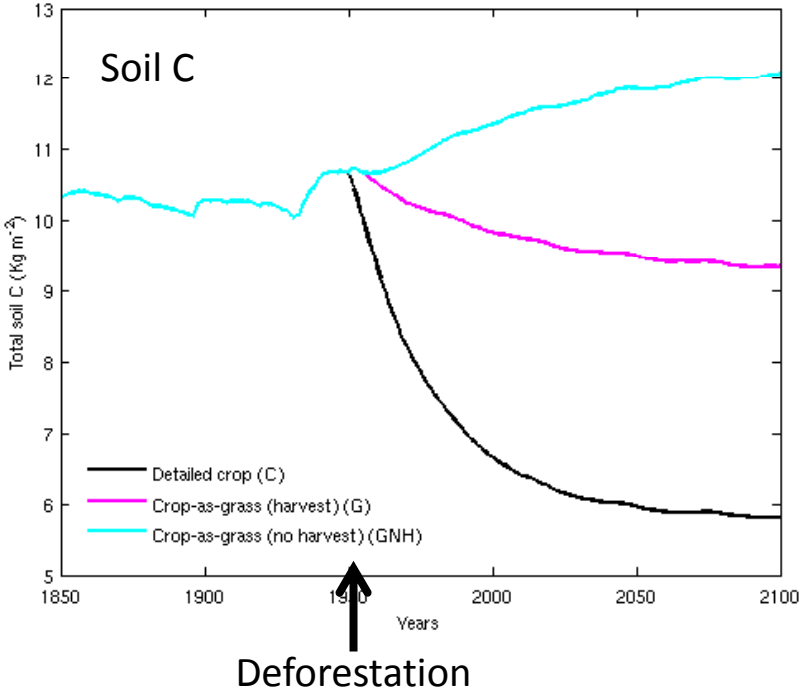
Why is the difference so large?

What is actually happening?

Example: Single site with complete conversion event at 1950.



Deforestation

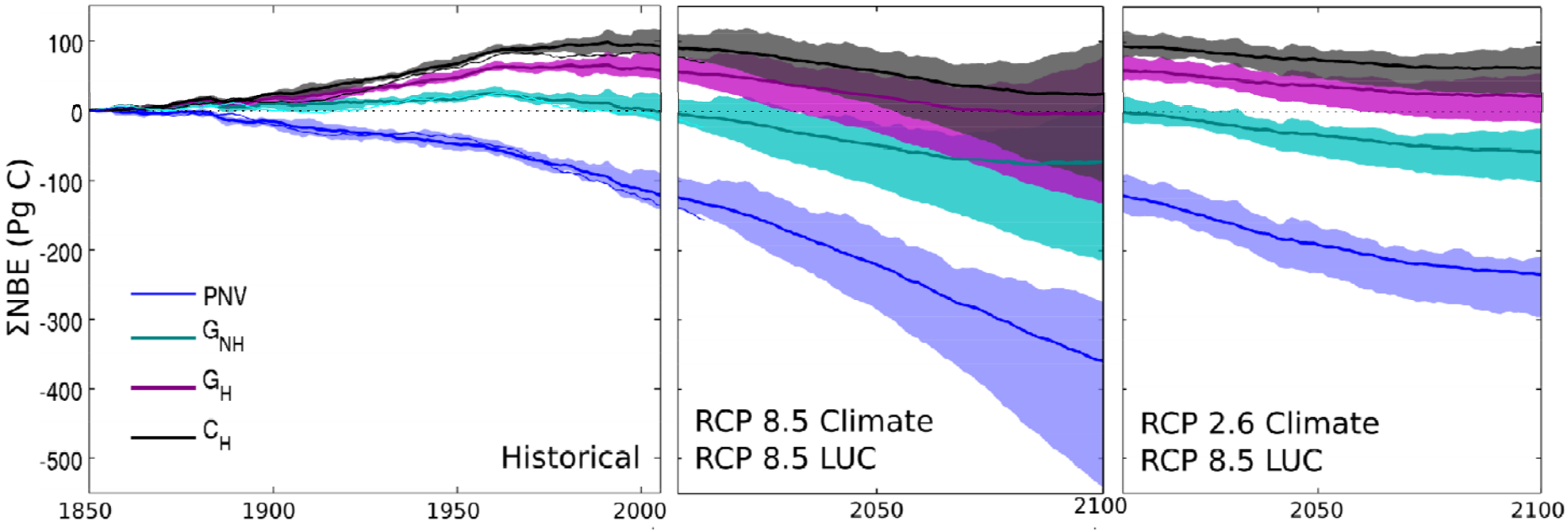


Deforestation

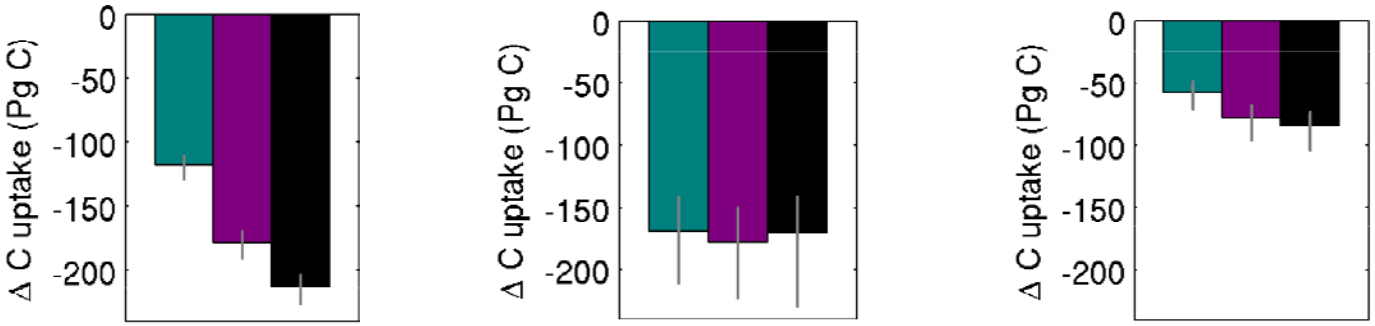
- Grassland actually accumulates more soil C than forest.
- But harvest results in “immediate” oxidation of C that would otherwise enter soil.
- Tillage gives higher soil respiration rates in cropland.
- C changes due to differences in productivity very small (due to harvest).

What about the future?

Extend simulations into the future using RCP scenarios



Change in C uptake relative to PNV



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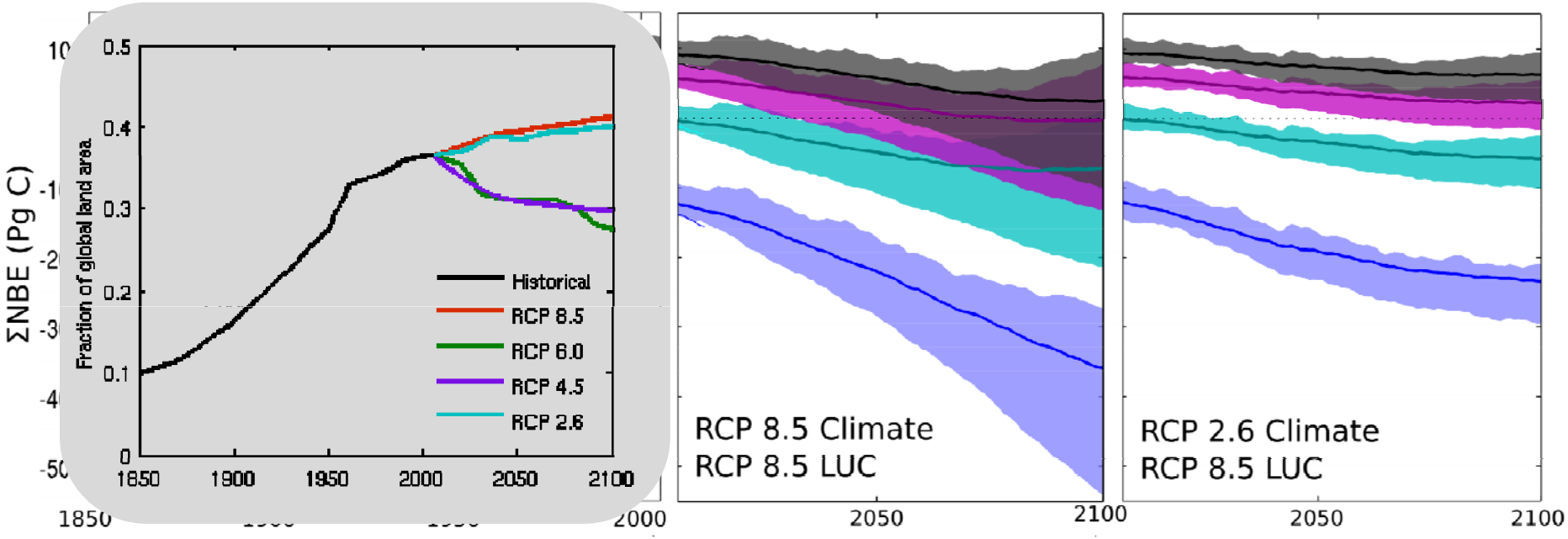

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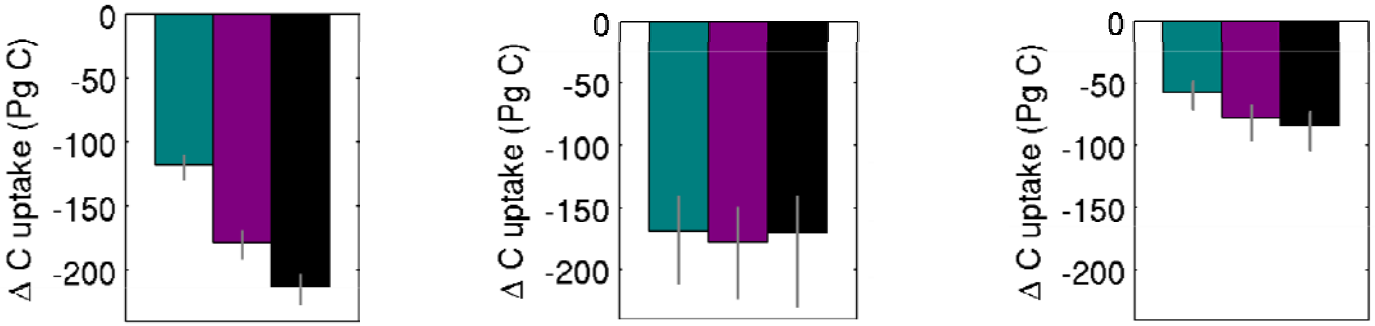
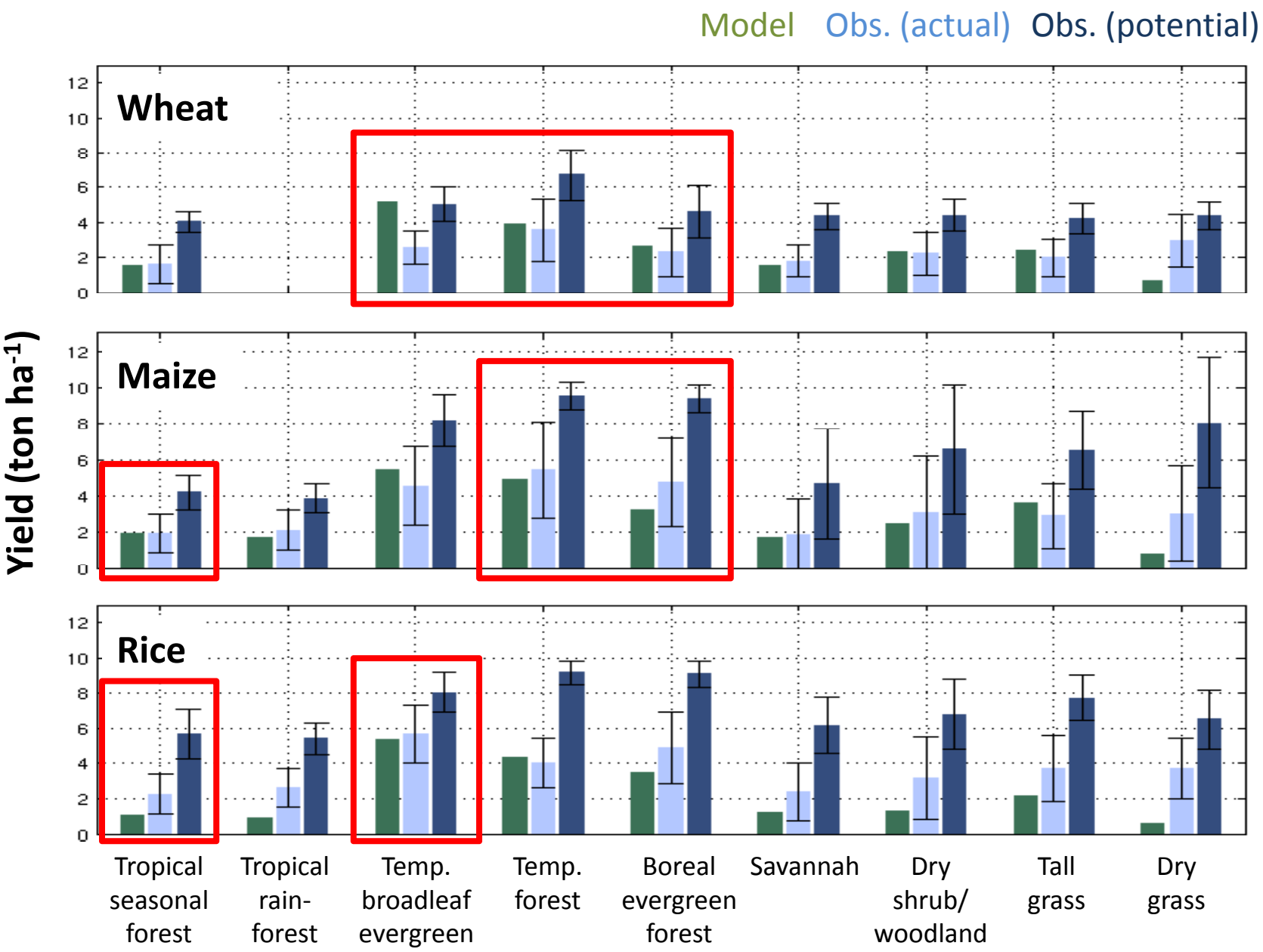
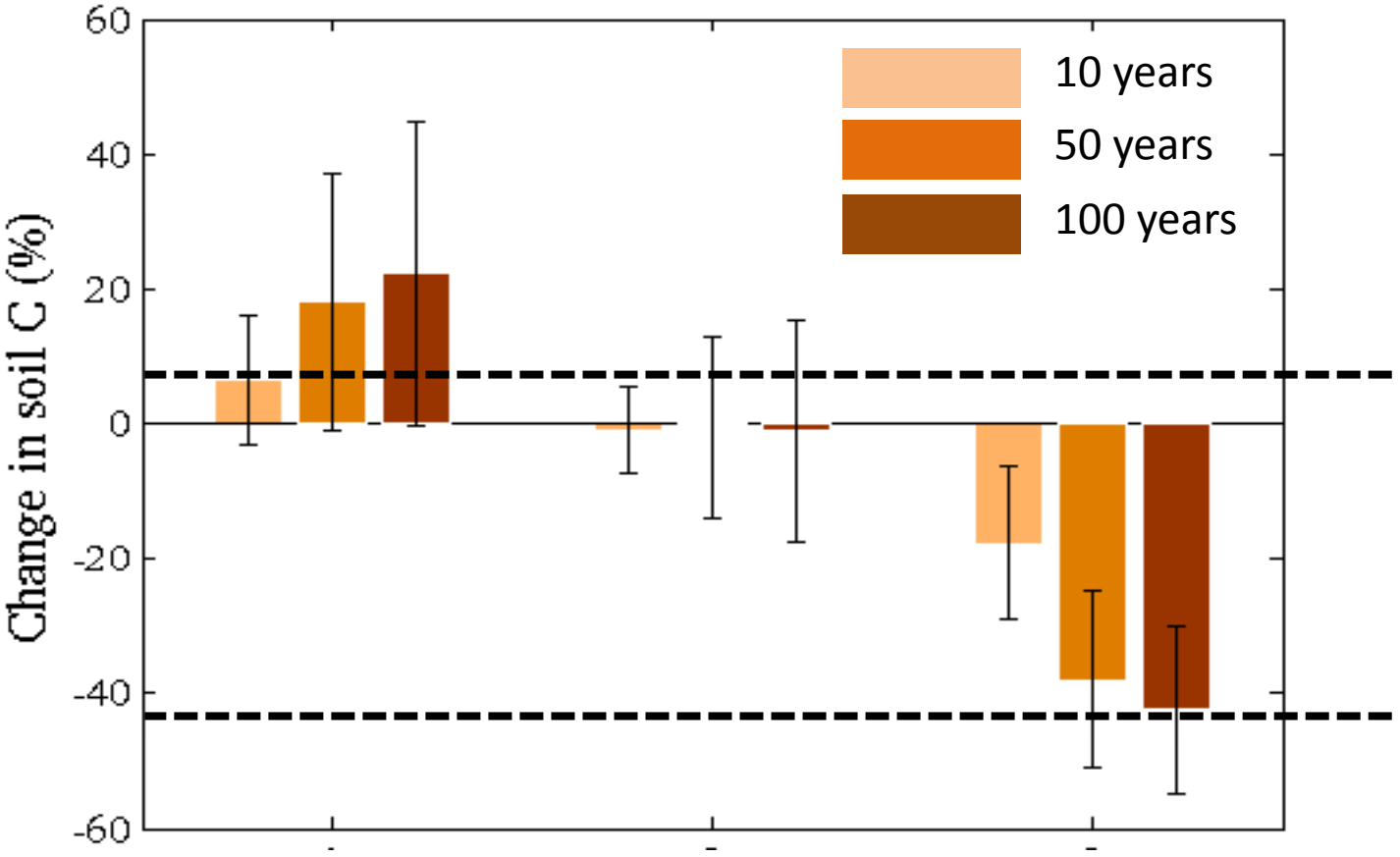


Is our model realistic?



Is our model realistic?

Global mean change in soil C after conversion from natural vegetation:



Forest to pasture conversion (meta analysis)

Forest to crop conversion (meta analysis)

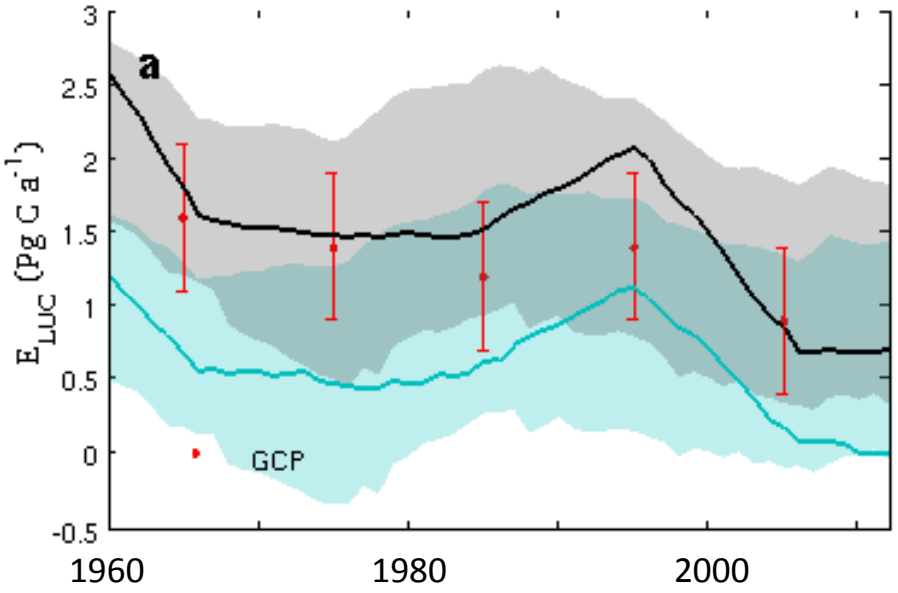
Crops/pasture as grass

Crops/pasture as grass (with harvest)

Detailed crop model

Guo and Gifford (2002)

Is the net terrestrial carbon exchange in climate models very wrong?



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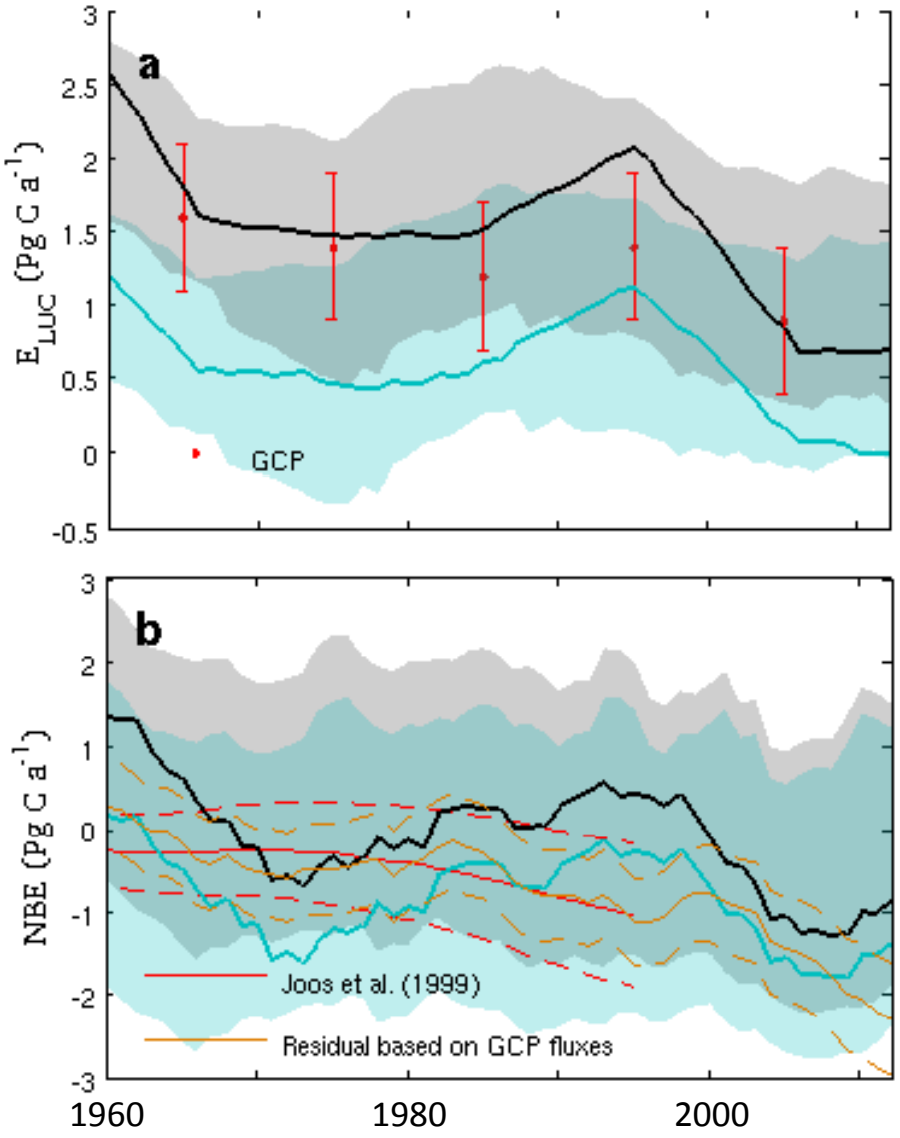

$$NBE = E_{LUC} + S_L$$

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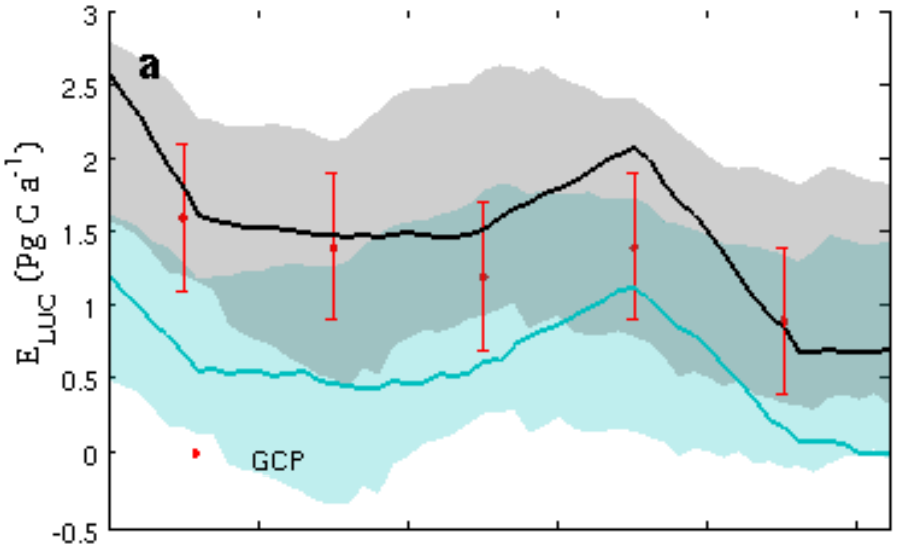

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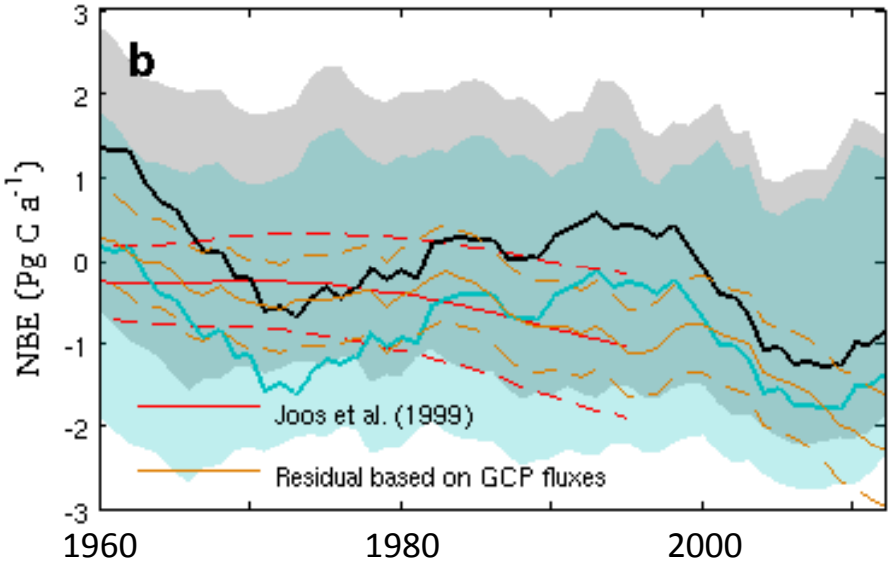

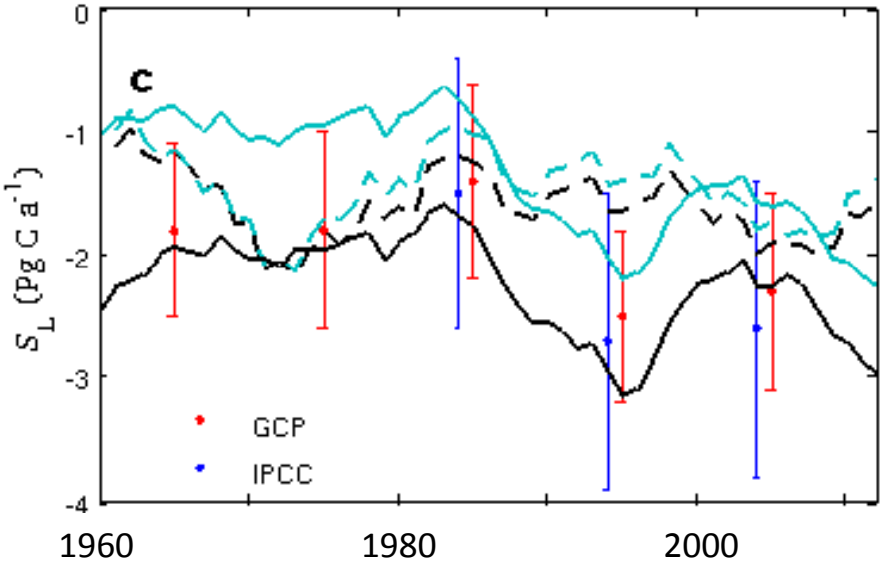

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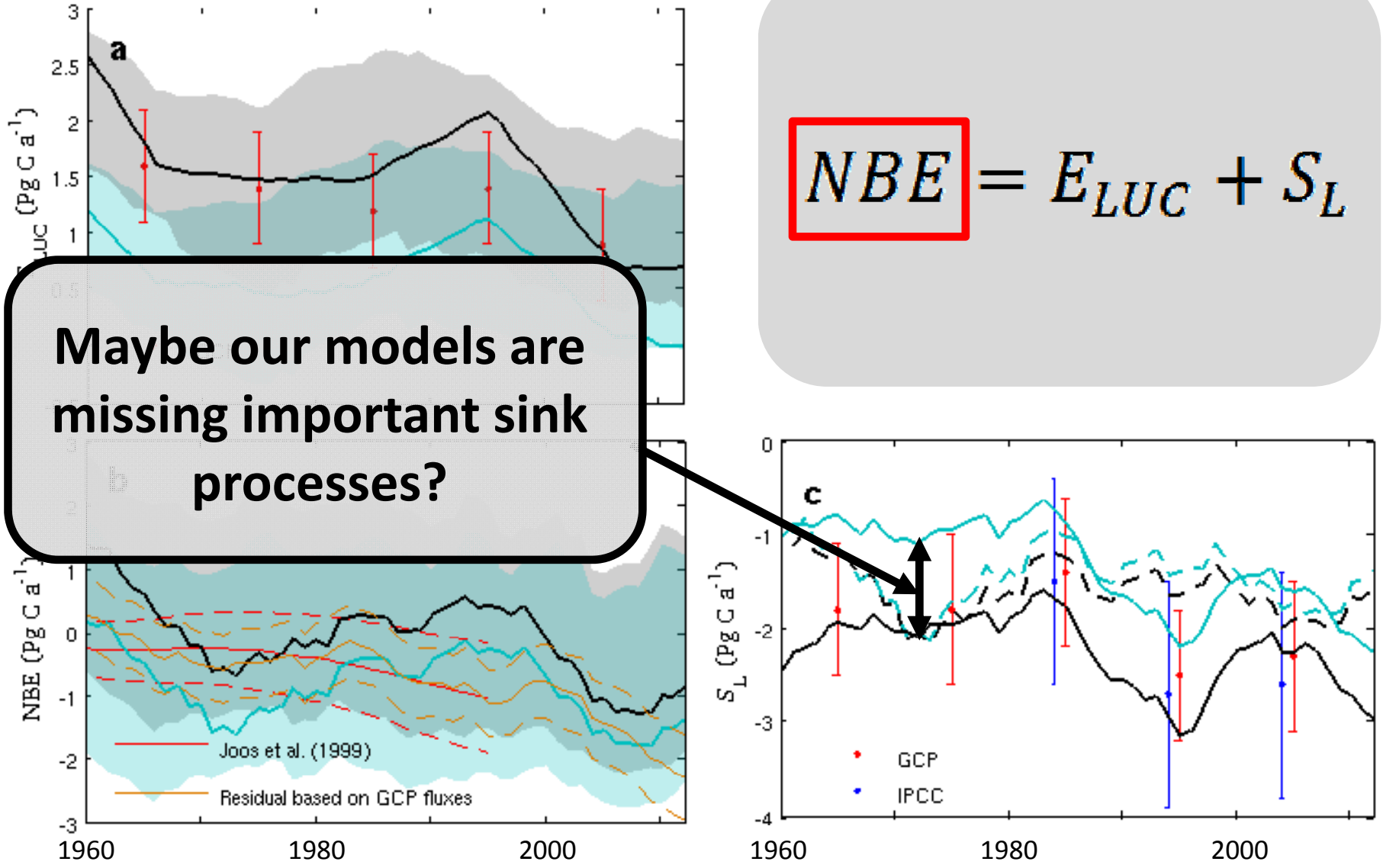

$$NBE = E_{LUC} + S_L$$

Maybe our models are missing important sink processes?

Summary

Agriculture-specific processes are not generally considered in AR5 ESMs.

Agricultural representation, especially harvest/grazing, can greatly influence the simulated terrestial carbon sink.

Effect of agriculture on carbon fluxes is tied to date of land-use transition, rather than an ongoing source.

It is not clear whether these results imply an overestimation of the terrestrial carbon sink, or missing sink processes in ESMs.

Summary

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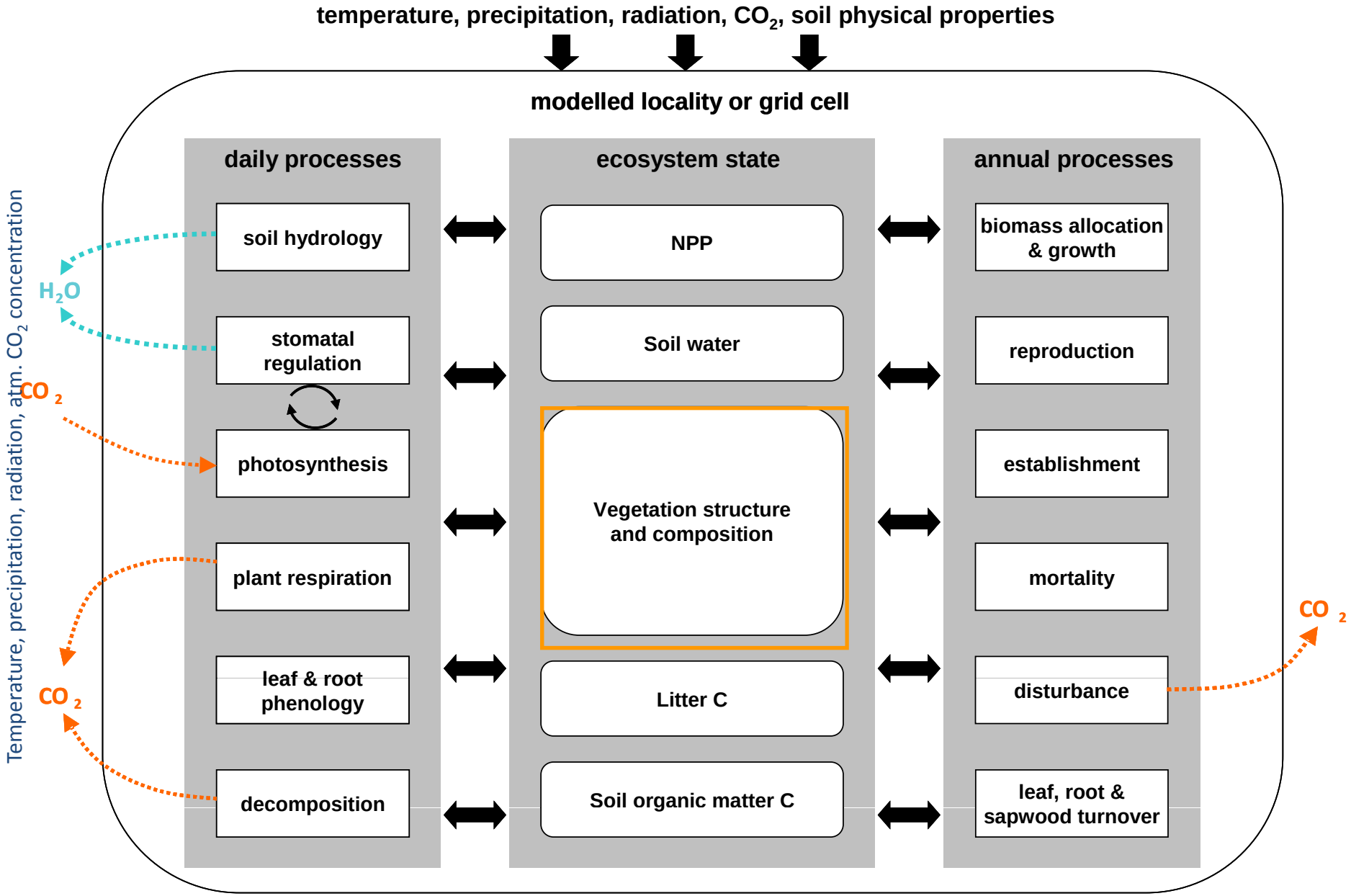
It is not clear whether these results imply an overestimation of the terrestrial carbon sink, or missing sink processes in ESMs.

Must also consider biophysical effects and non-CO_2 greenhouse gases...

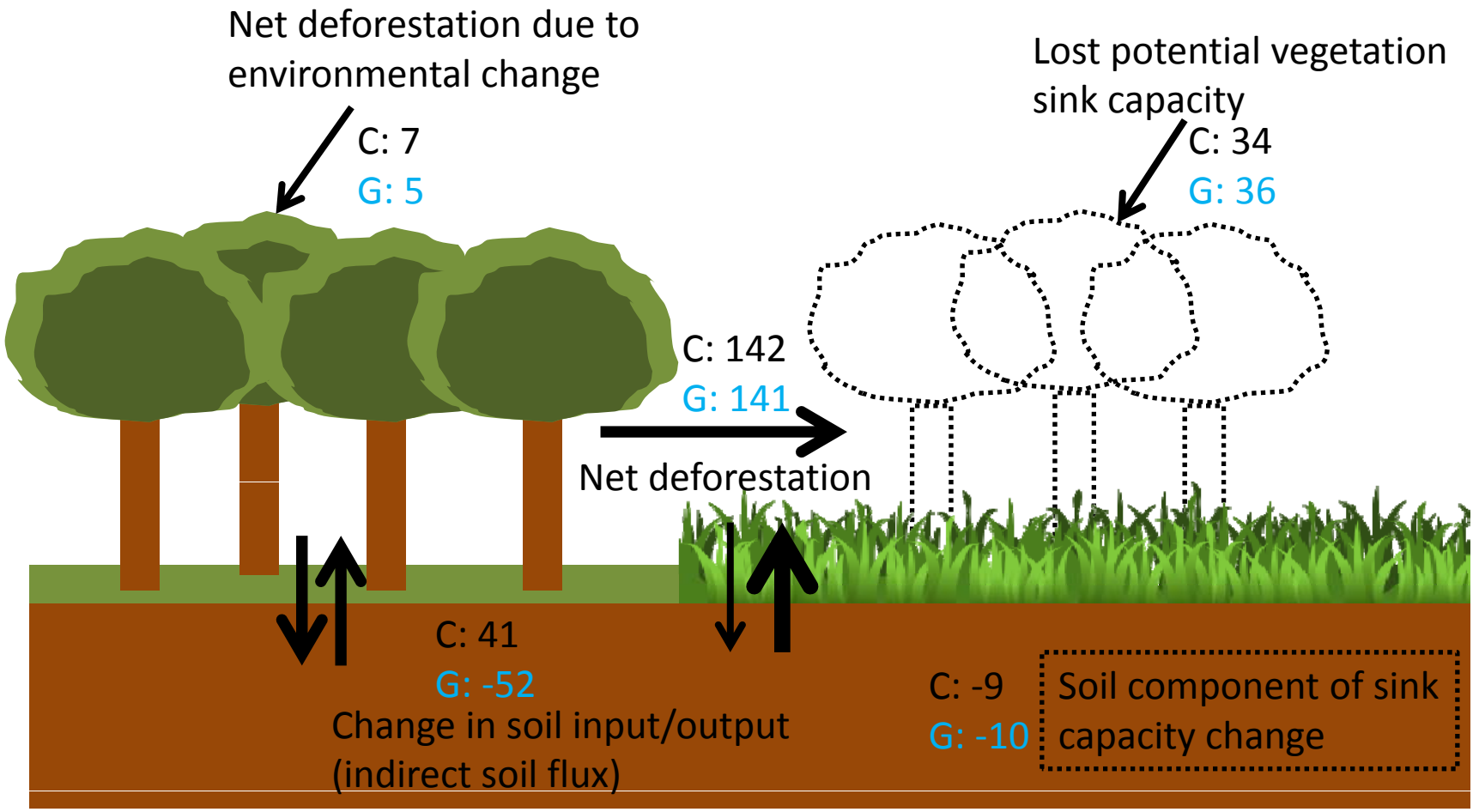

Cheers for listening!

LPJ-GUESS structure



Why is the difference so large?

Components of LUC flux:
(1850-2012 accumulated fluxes,Pg C)



Harvest and tillage are the key processes

Why is the difference so large?

Using factorial simulations we can isolate the different elements of the LUC emission:

1850-2012 accumulated LUC fluxes (Pg C)

Flux	Detailed crops	Crops-as-grass
Net deforestation (pre-ind. biomass)	142	141
Net deforestation (env. change)	7	5
Lost potential sink capacity (veg.)	34	36
Indirect soil flux	**41**	**-52**
Lost potential sink capacity (soil)	-9	-10
Total	**215**	**120**

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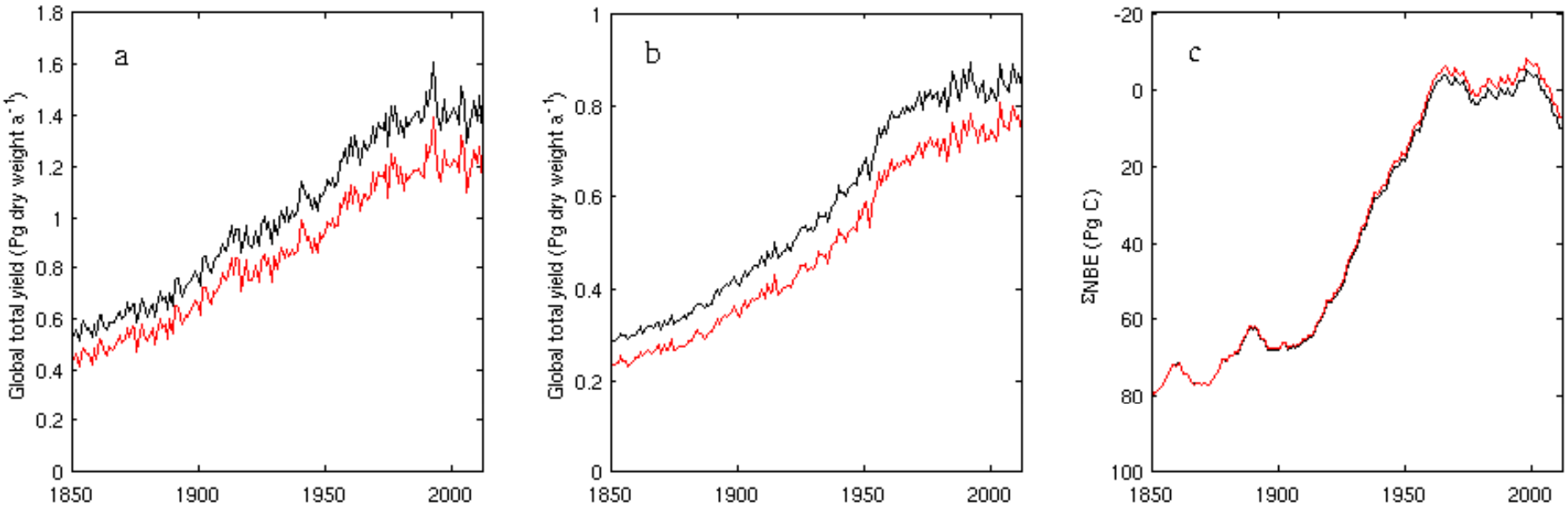
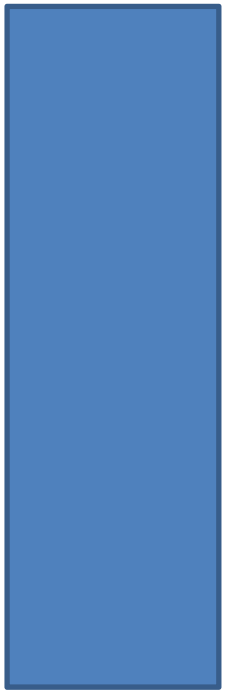


Influence of crop representation on the carbon cycle

Uncertainty:

~160 Pg C

Direct emissions from land-use change 1850-2005, i.e. Deforestation in LPJ-GUESS simulations (process included in IPCC AR5 GCMs)

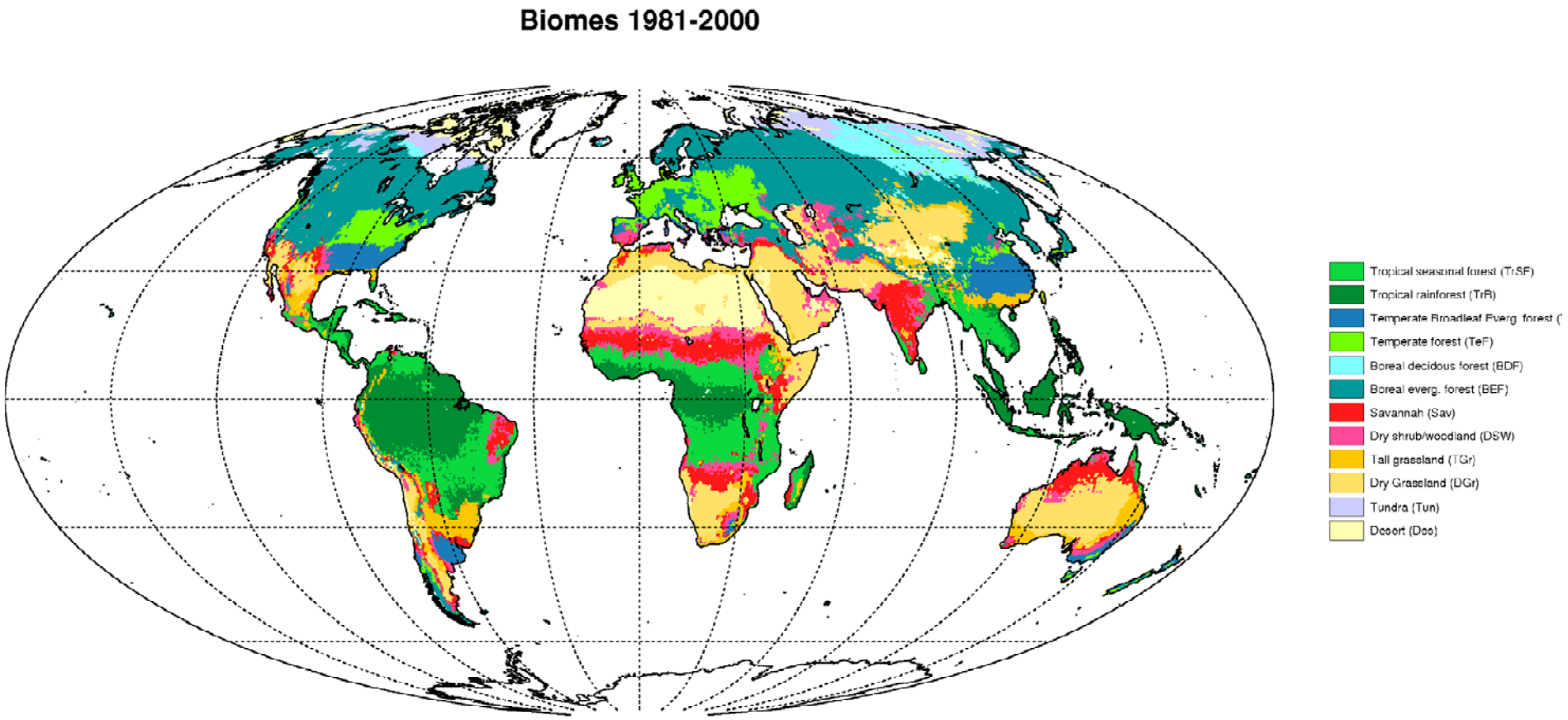


~880 Pg C

Emissions from harvest/grazing 1850-2005 in LPJ-GUESS simulations (mostly balanced by decrease in soil respiration flux)

Harvest is a massive gross flux of carbon to the atmosphere. Ignoring harvest not only ignores a substantial net flux, but all the uncertainties associated with the gross flux (and the balancing soil respiration flux)

Biomes map


Biomes 1981-2000
Tropical seasonal forest (TrSF)
Tropical rainforest (TrR)
Temperate Broadleaf Everg. forest (
Temperate forest (TeF)
Boreal decidous forest (BDF)
Boreal everg. forest (BEF)
Savannah (Sav)
Dry shrub/woodland (DSW)
Tall grassland (TGr)
Dry Grassland (DGr)
Tundra (Tun)
Desert (Des)