GEOSCIENCE INFORMATION FOR TEACHERS (GIFT) WORKSHOP

EGU General Assembly, Vienna, April 2008

The role of the biosphere for the carbon cycle in a changing climate

(Principles – Factors – Models – Uncertainties)

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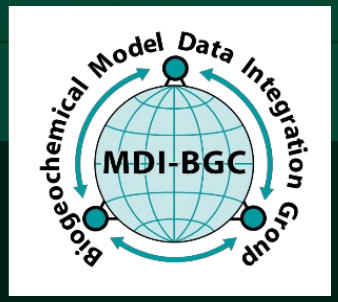
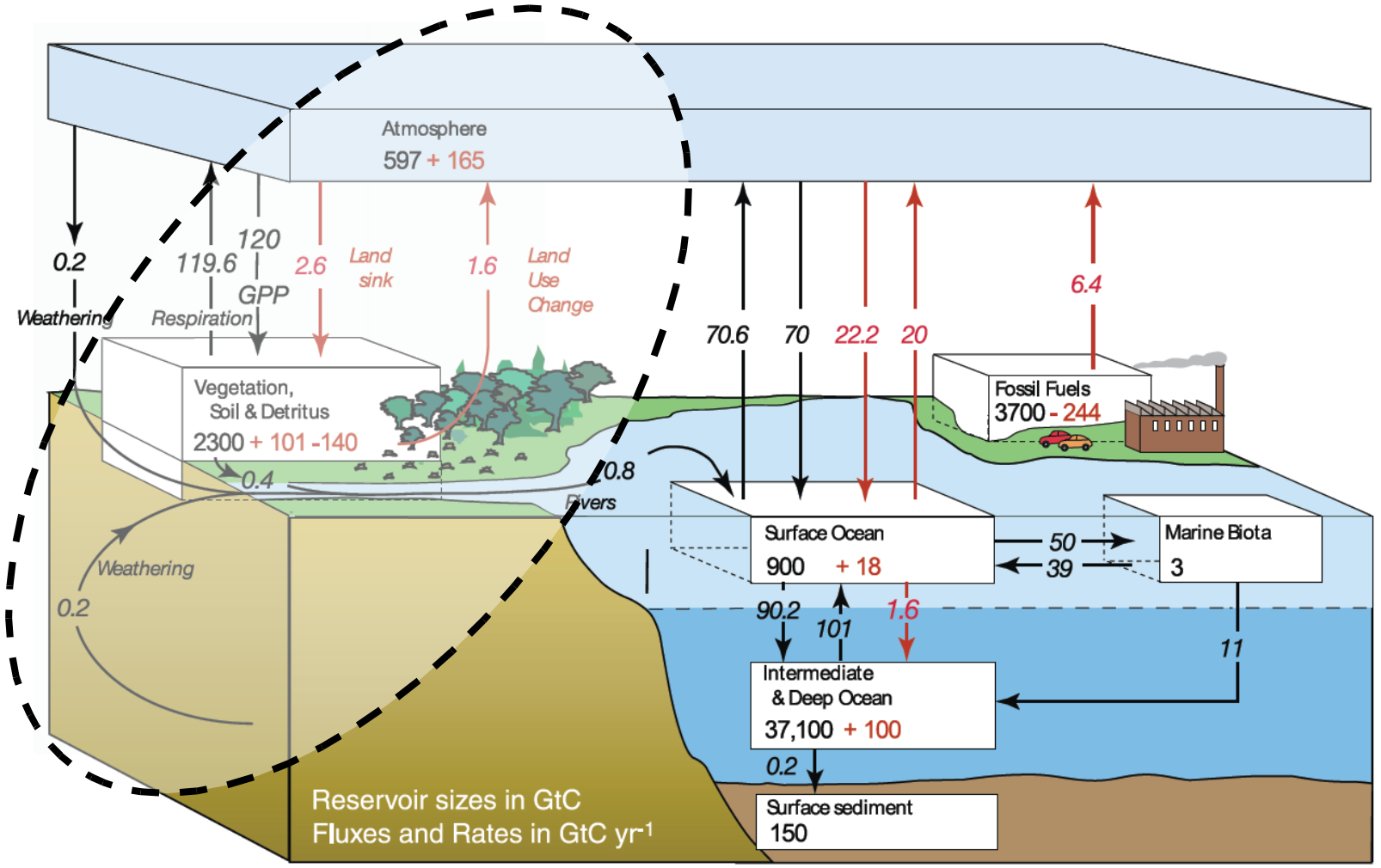


Context: global carbon cycle

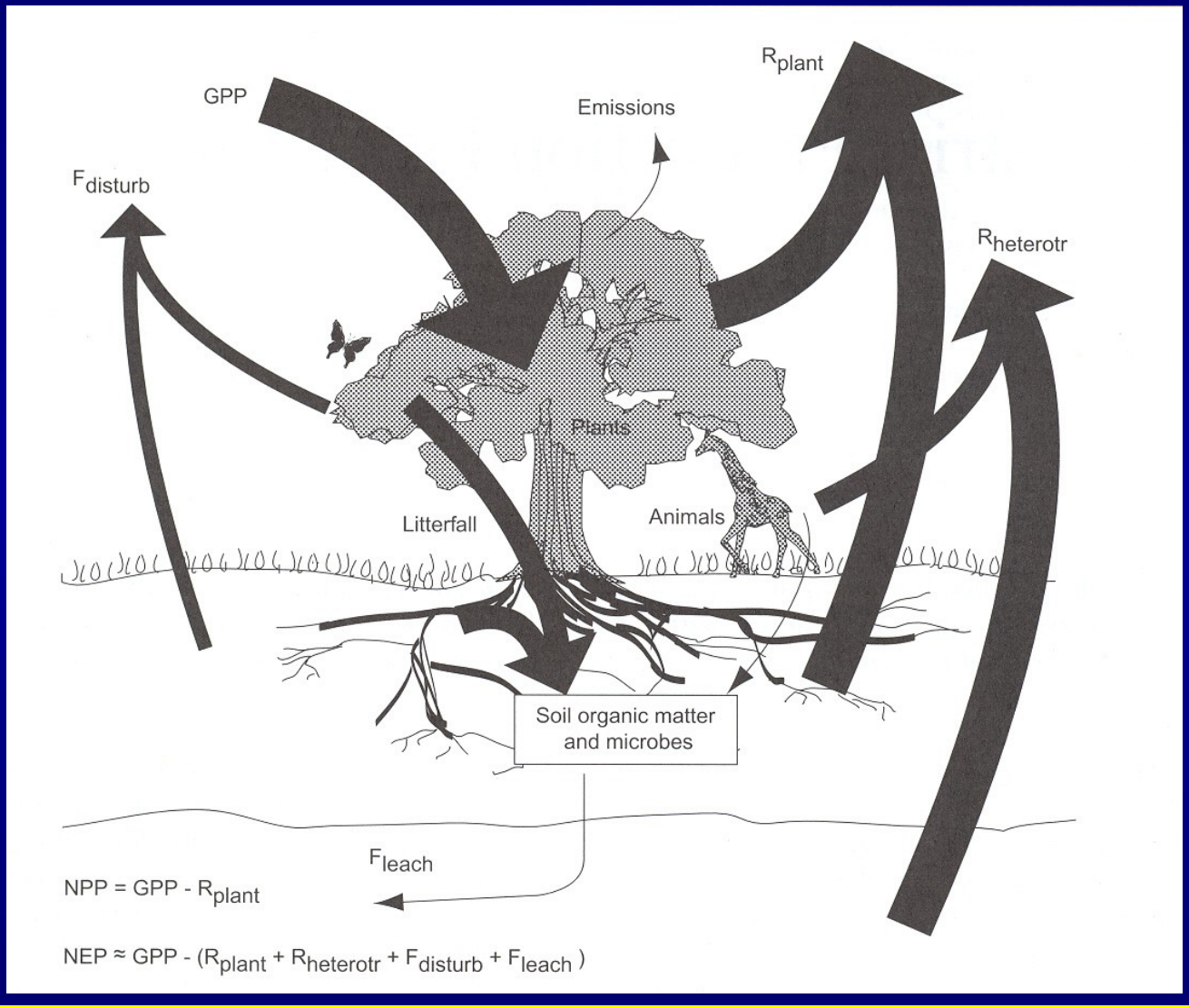


IPCC (2007) WG1, chap. 7

Soil and vegetation ?

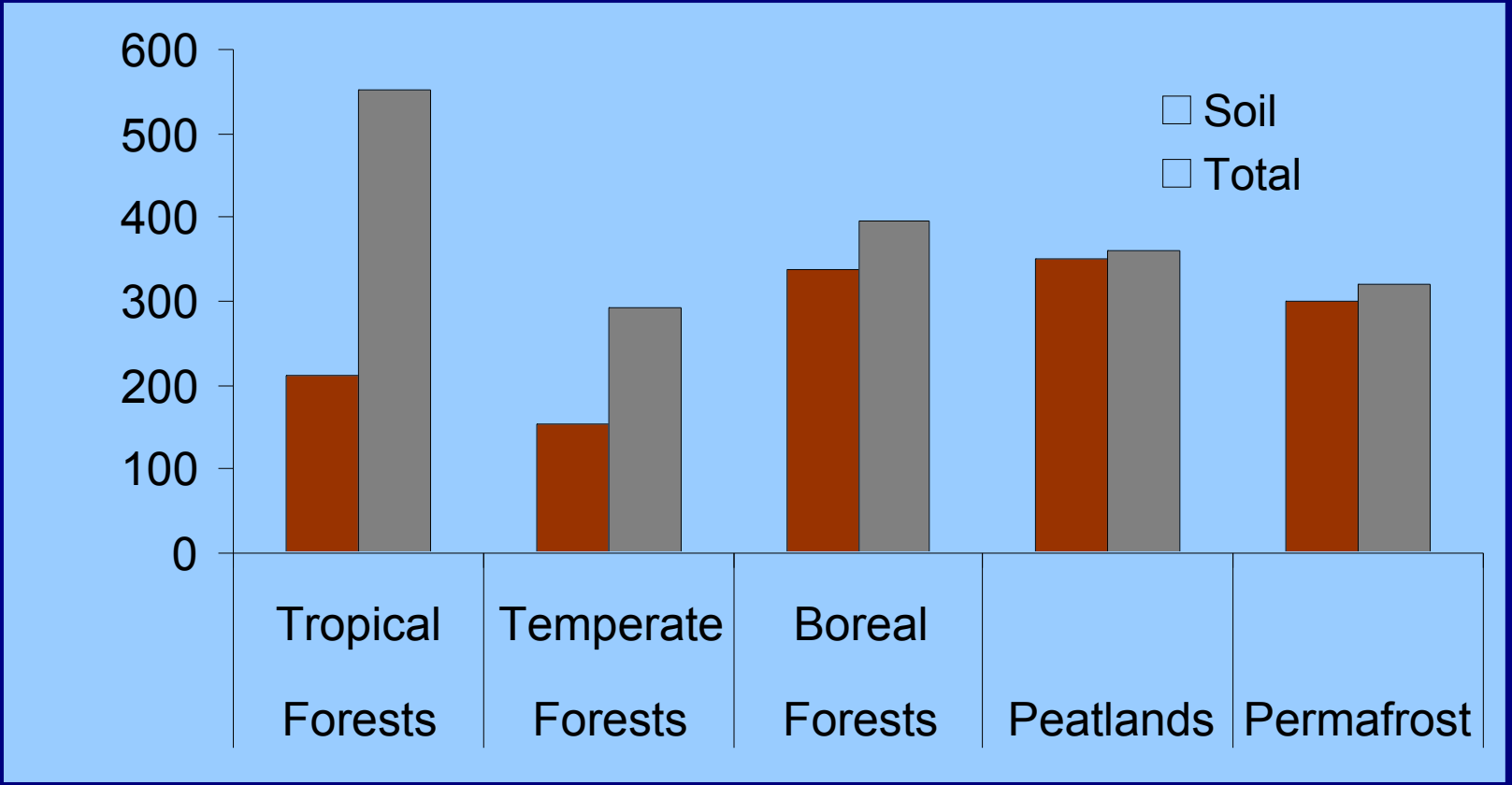
	Reservoir size [Pg]	Turnover time [yr]	Flux into atm. [Pg yr-1]
Sediments & rocks	77,000,000	>>1,000,000	<1
Deep ocean	37,000	2,000	18 (?)
Soils	2300 (+850 frozen and wet)	<1-5,000	52 (het.) 60-80 total
Vegetation	800	1-1000	60
Atmosphere	750	3-5	-
Fossil organic carbon	1200 (- >6000)	-	~5.6(-8.1)

Ecosystem carbon balance



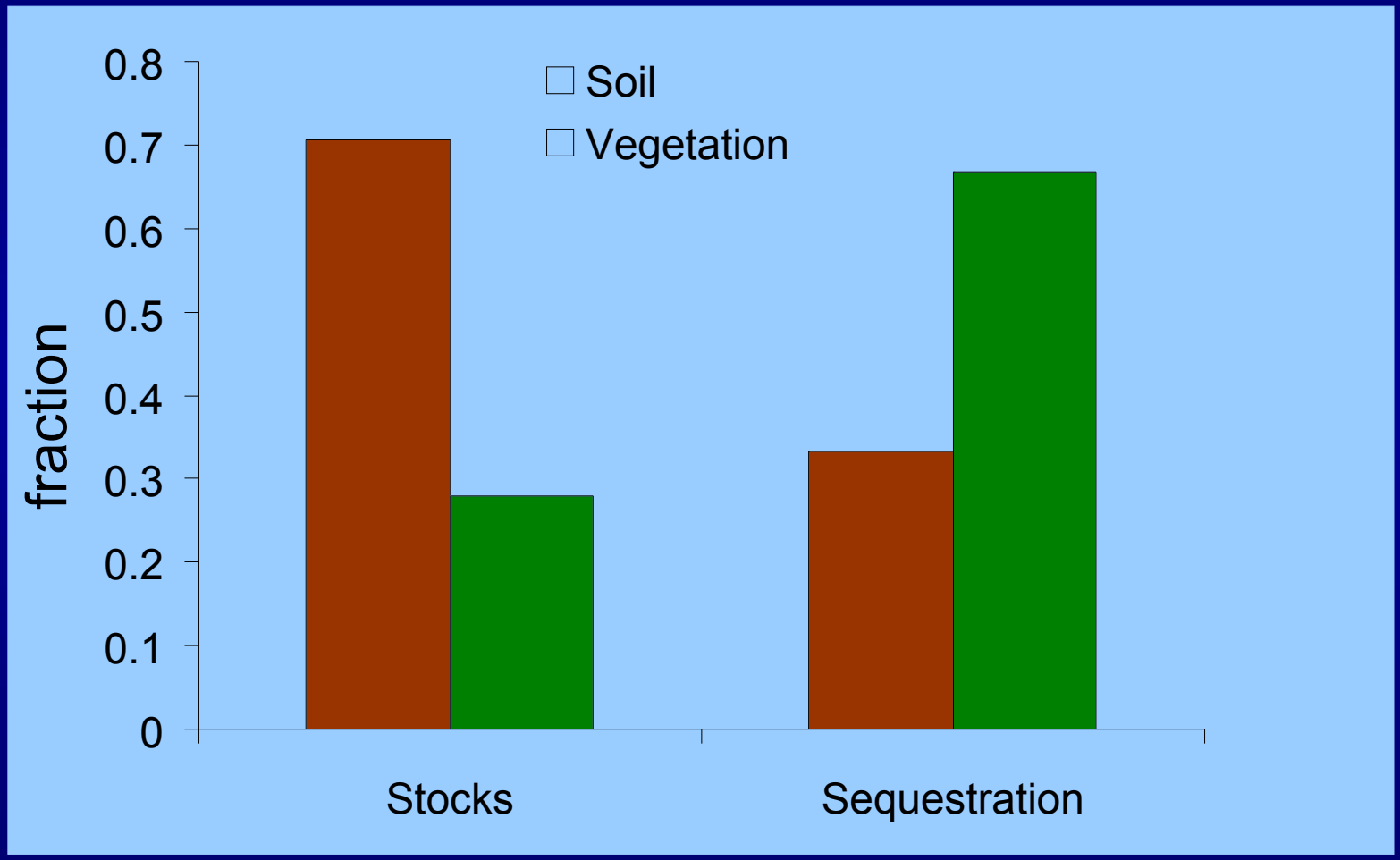
Chapin 2002

Global carbon stocks in ecosystems

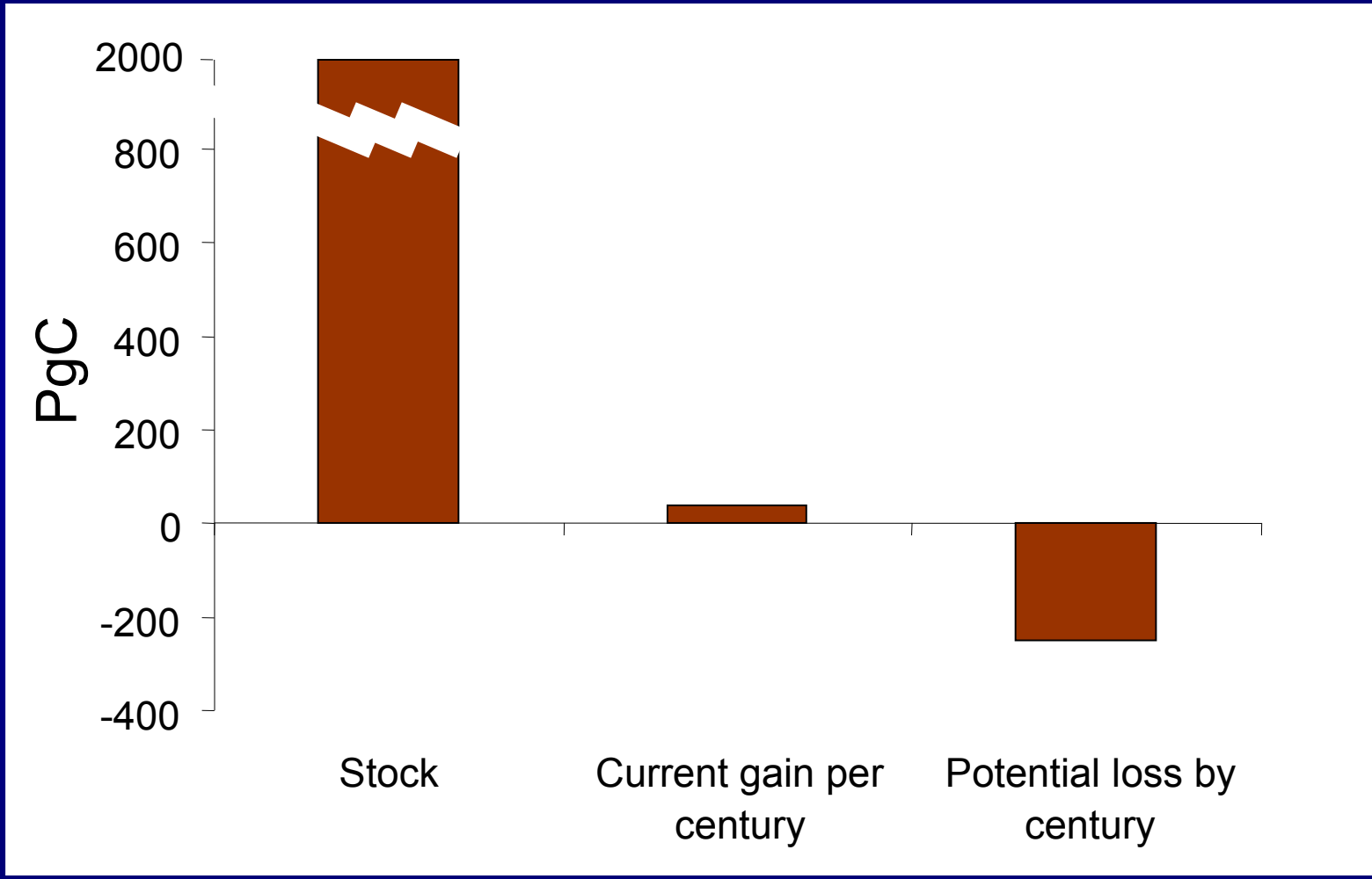


after Gruber et al. 2004, Lal, 2005, Davidson & Janssens 2006

Stock vs. sequestration: partitioning between vegetation and soil



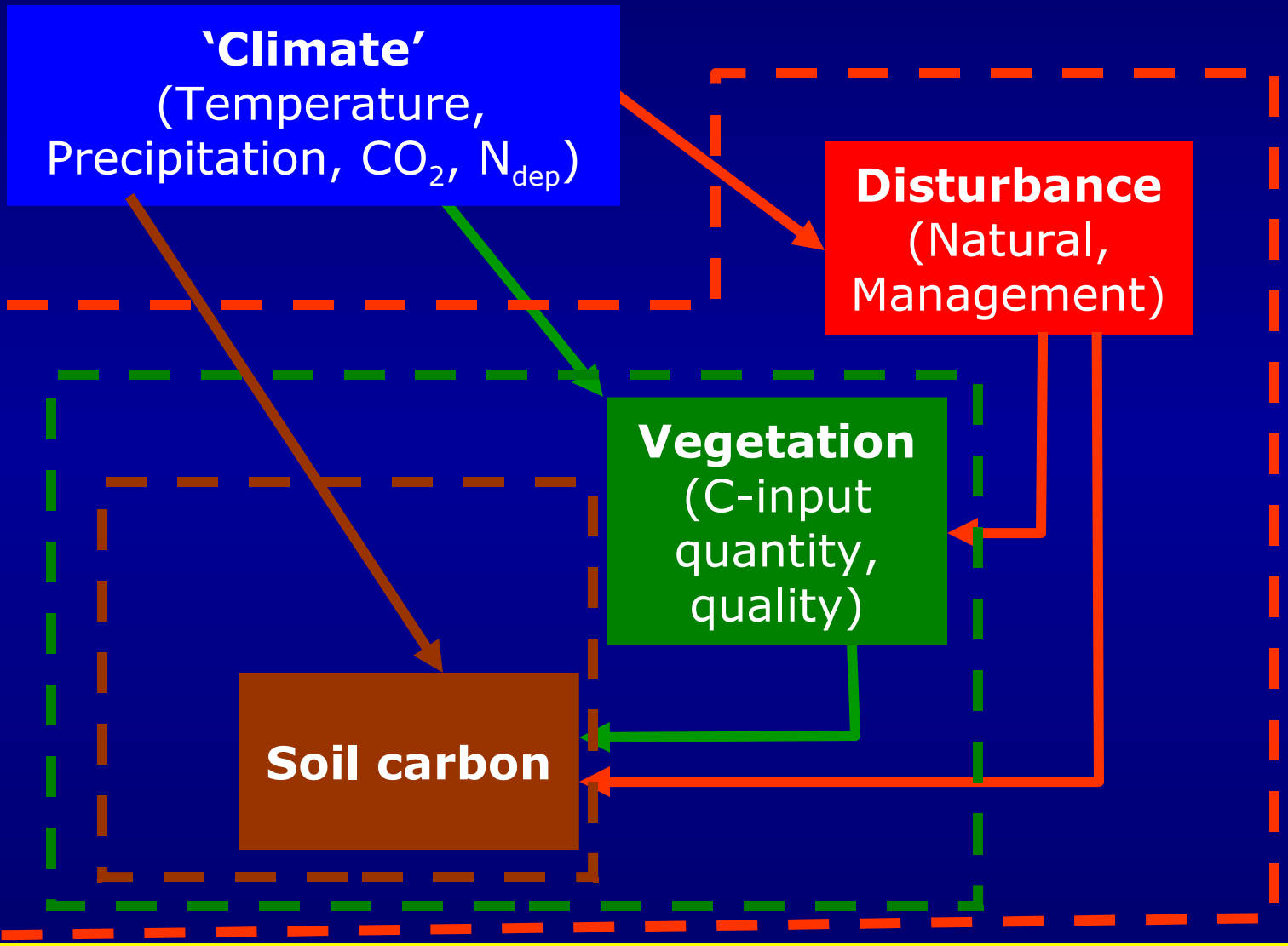
Soil carbon stock is large & vulnerable

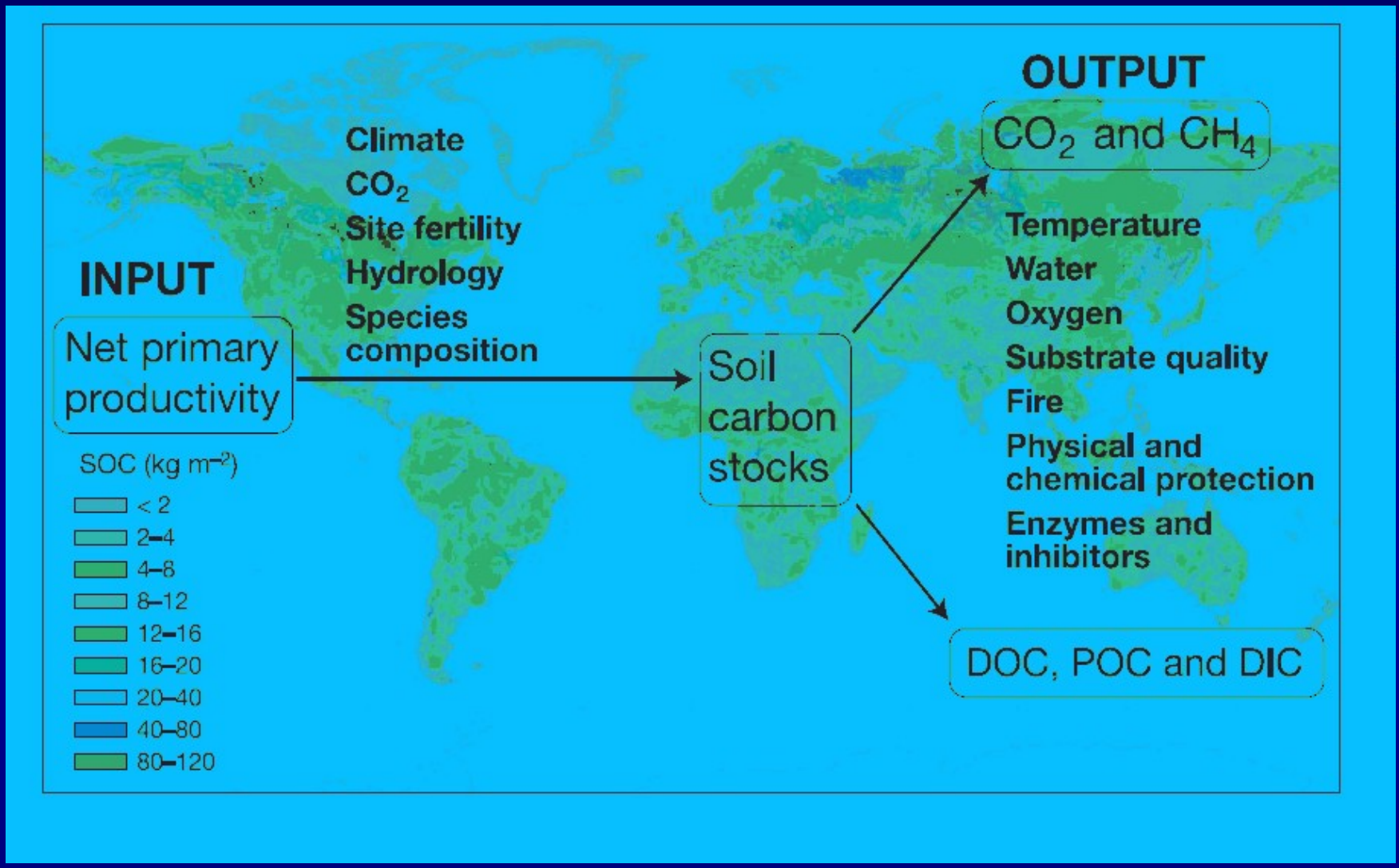


after Davidson & Janssens 2006

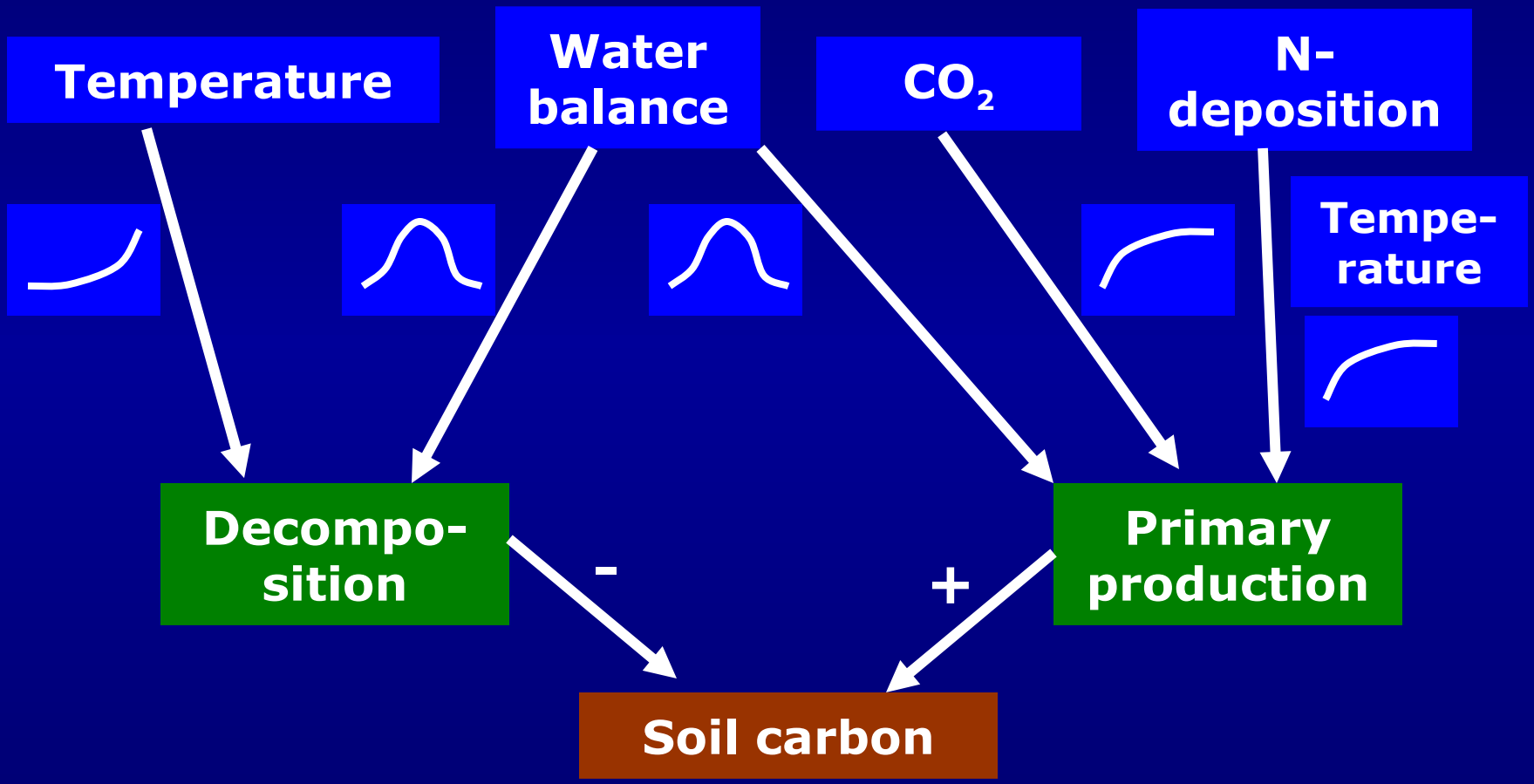
Climate Change effects on Ecosystem Carbon Balance

Direct and indirect effects




OUTPUT
CO_2 and CH_4
Climate
CO_2
Site fertility
Hydrology
Species composition
INPUT
Net primary productivity
Soil carbon stocks
Temperature
Water
Oxygen
Substrate quality
Fire
Physical and chemical protection
Enzymes and inhibitors
DOC, POC and DIC
SOC (kg m^{-2})
< 2
2–4
4–8
8–12
12–16
16–20
20–40
40–80
80–120

Climate factors affecting soil carbon
(simplified)



Modelling approaches

Conceptual model of soil carbon feedback to temperature and CO_2

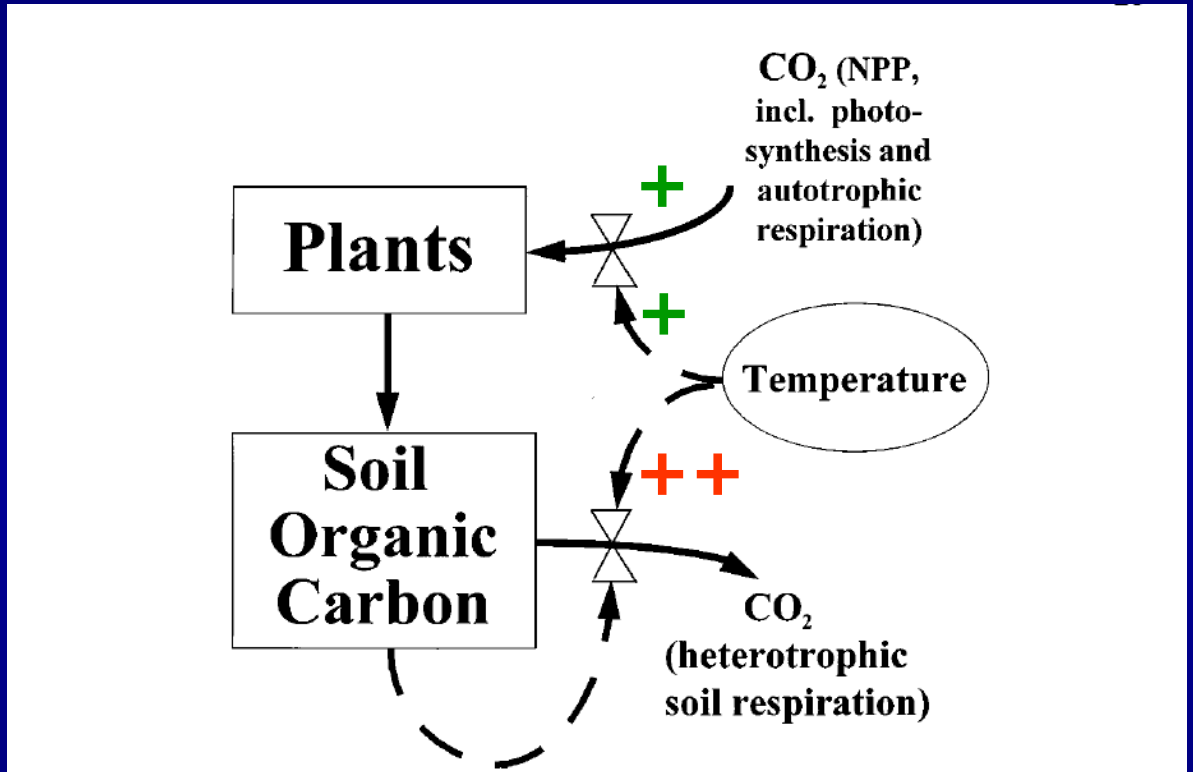
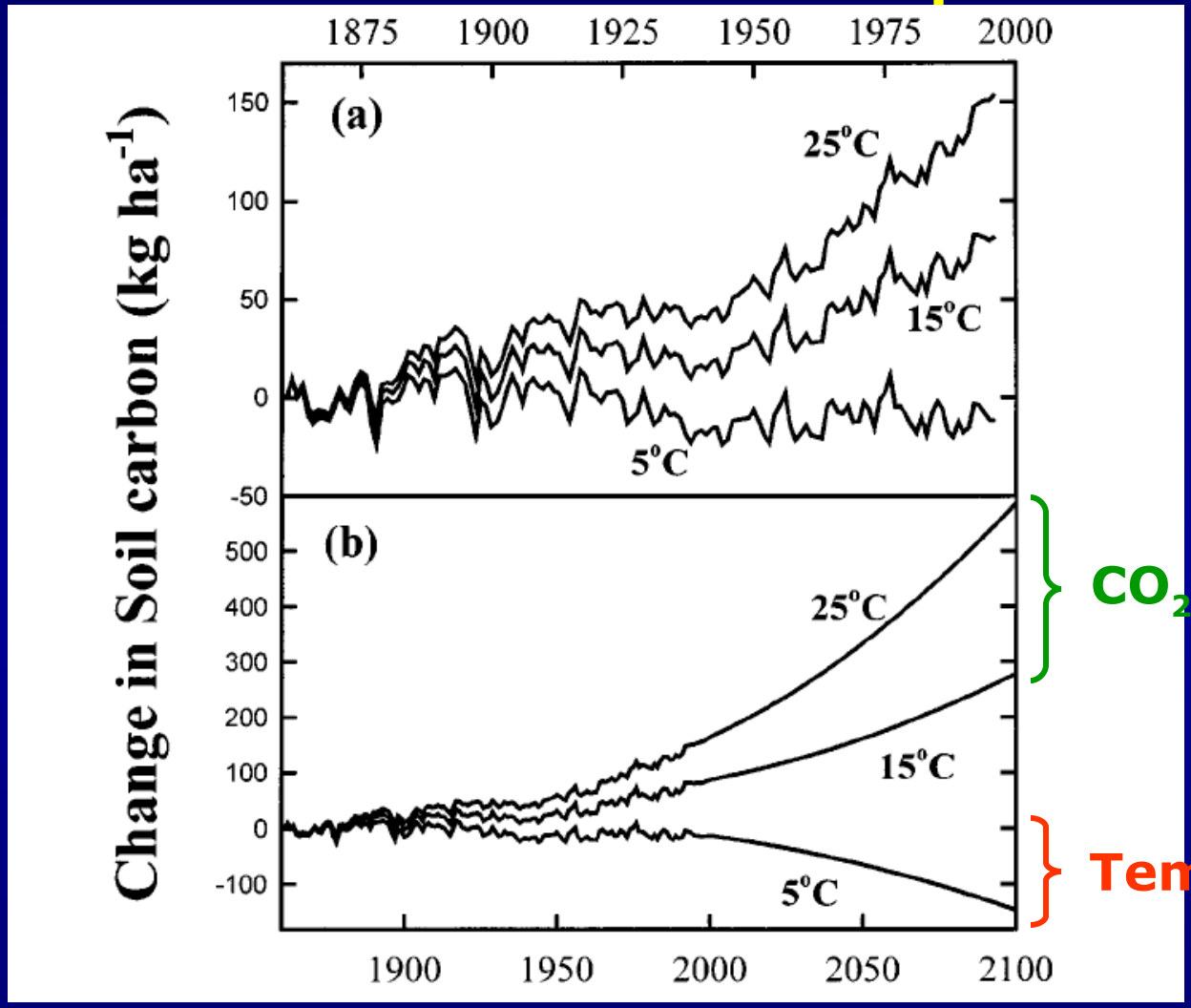


Figure 1. Diagrammatic representation of the basic relationship between carbon gain and carbon loss from whole ecosystems.

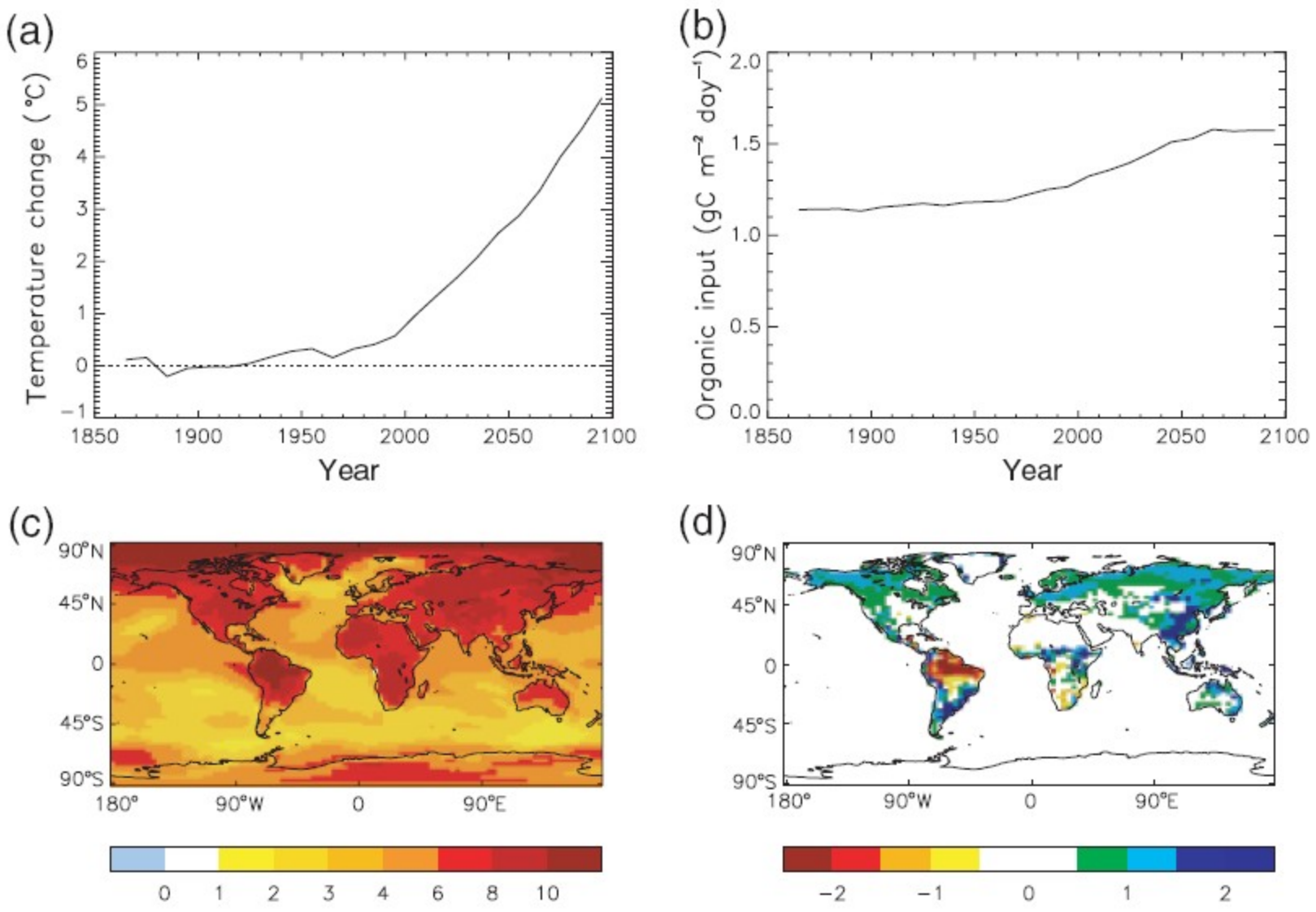
Kirschbaum, 1993, 2000

Predictions of simple model



Kirschbaum, 2000

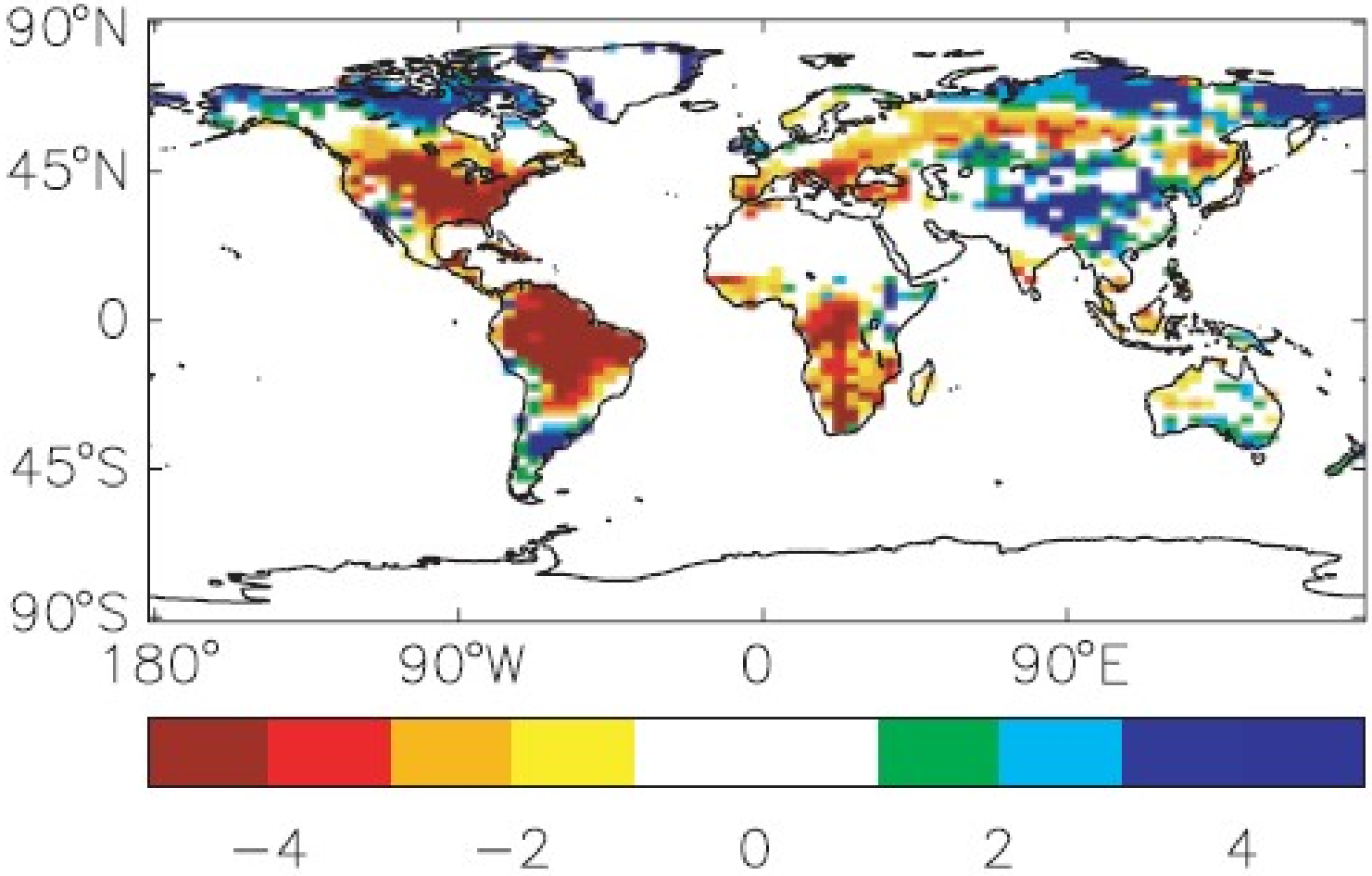
Results from more comprehensive models



HADCM3 model

Jones et al. 2005

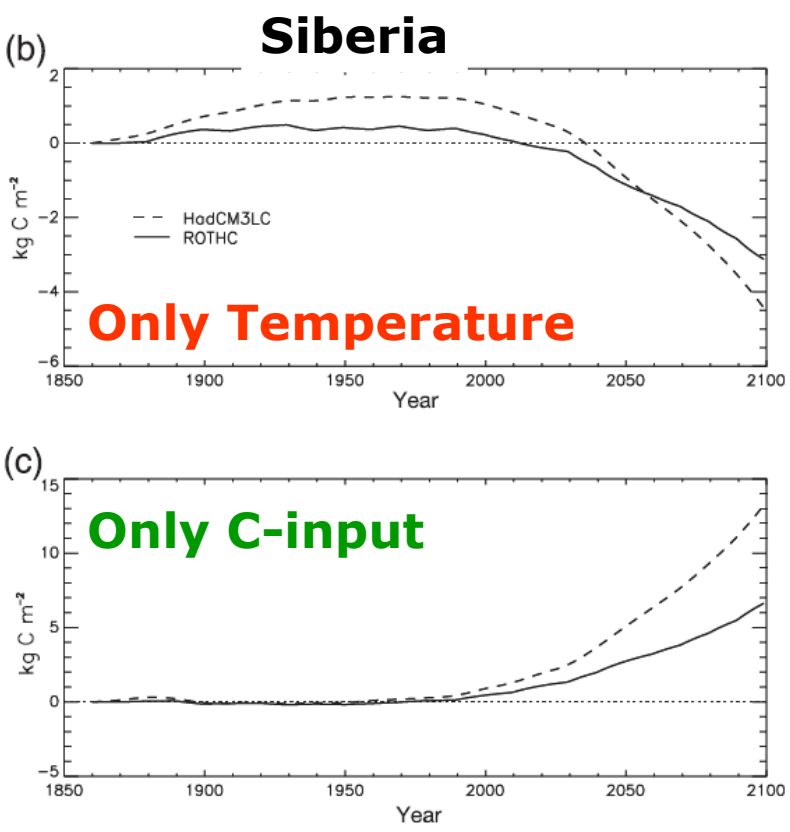
Predicted change in soil C stock



HADCM3LC model

Jones et al. 2005

Separating temperature and C-input effects



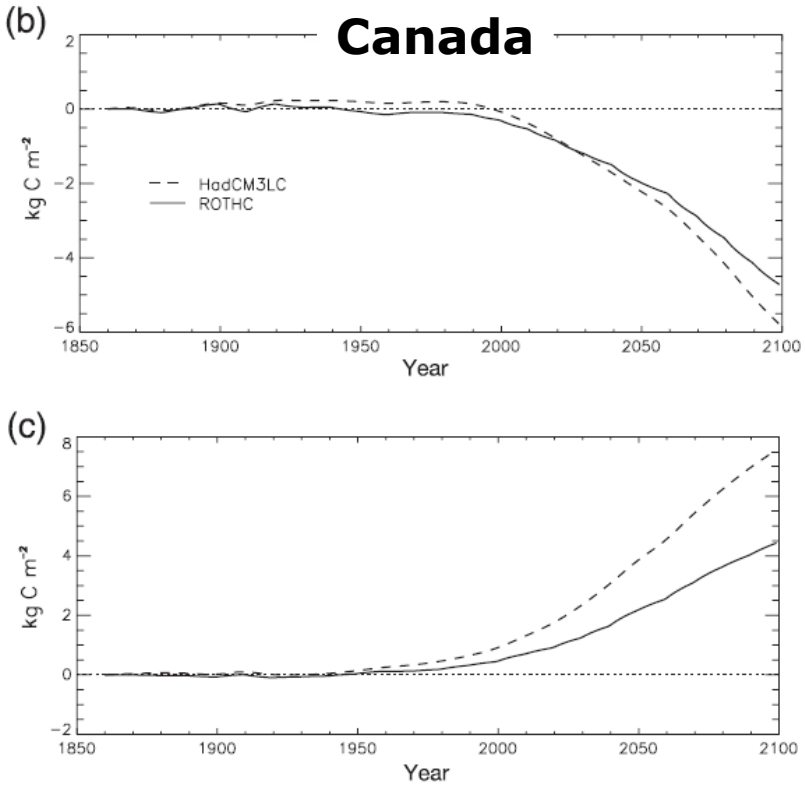
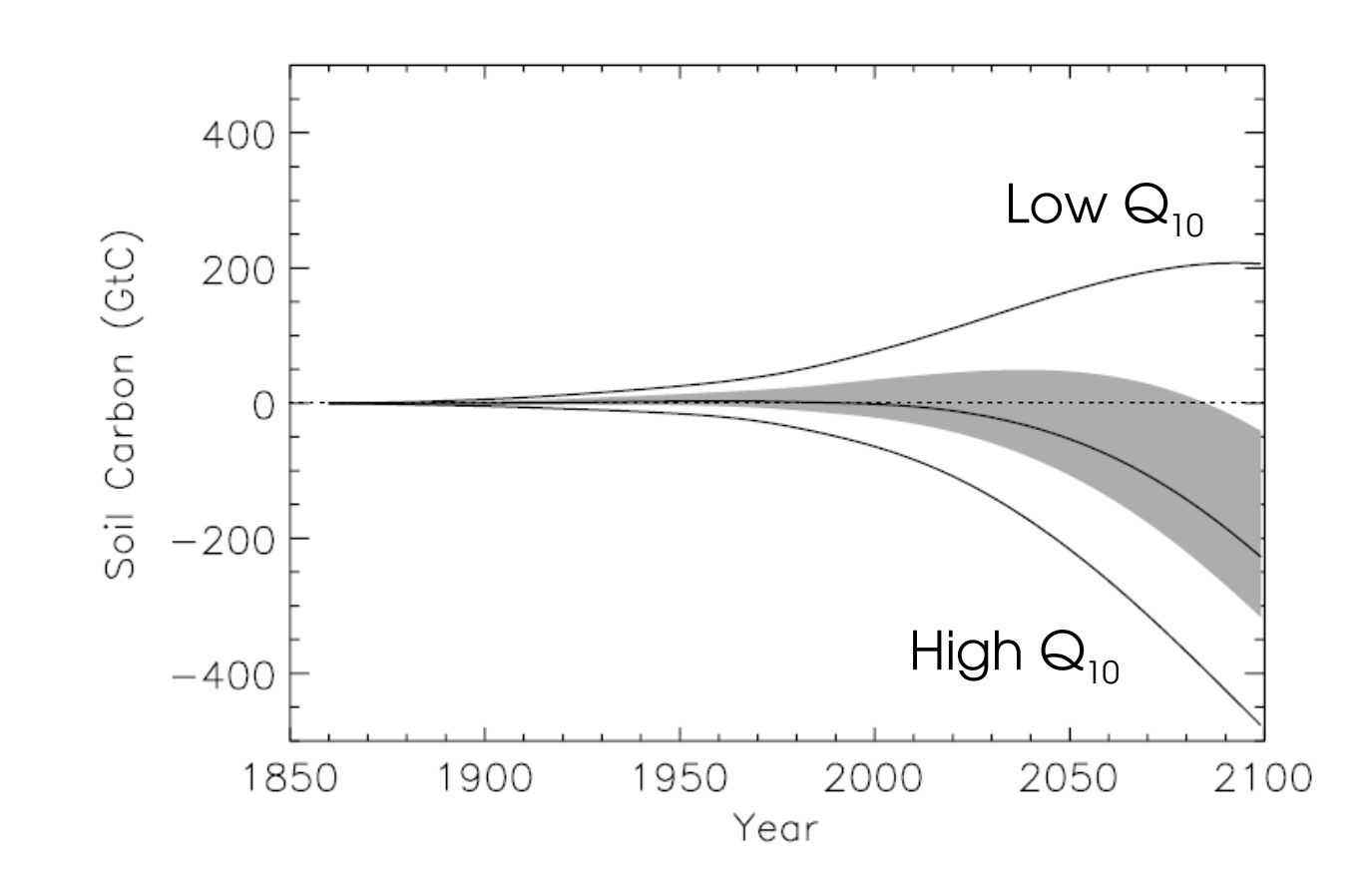


Fig. 8 As for Fig. 7, but for point 2 in Saskatchewan, Canada

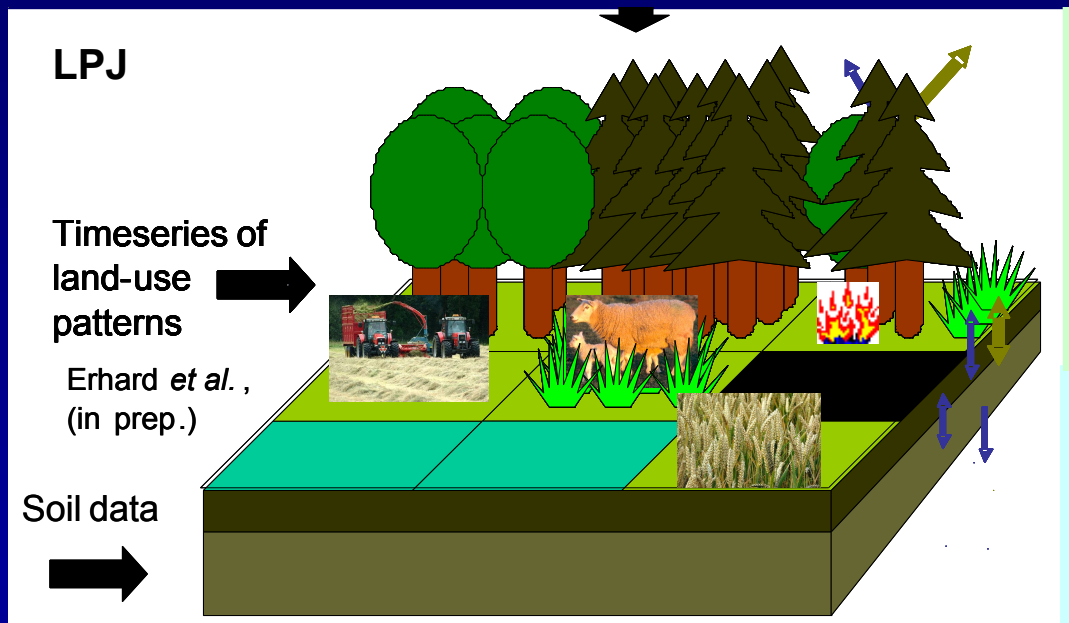
Results depend on temperature sensitvity



Q_{10}: factor by which process rates increase with ΔT=10°C

Friedlingstein et al. (2004)

LPJ-DGVM offline runs



Photosynthesis /Transpiration
Maintenance Respiration
Water balance
Litter fall
Heterotrophic respiration

Annual processes include:

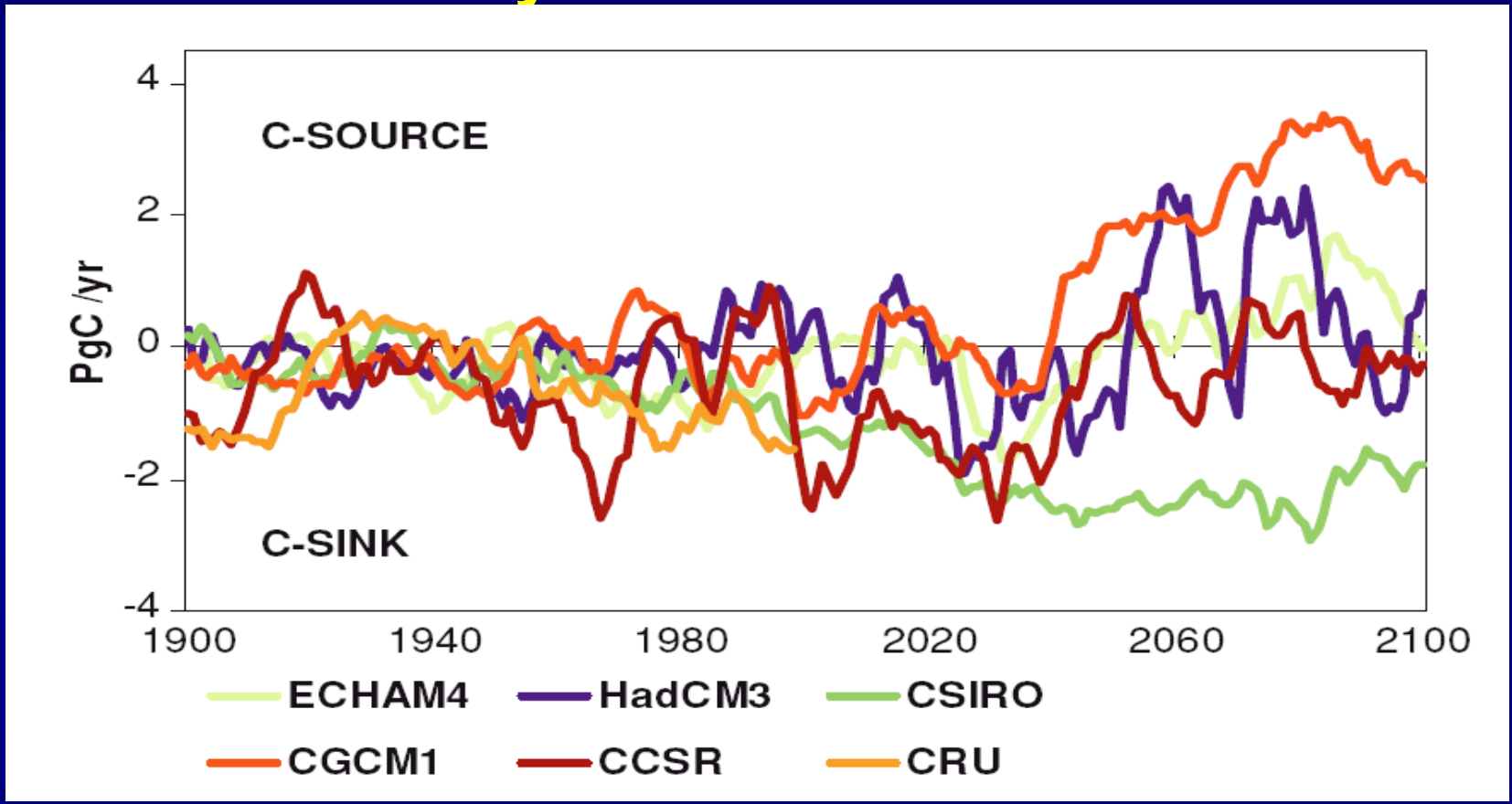
- ¥ Allocation & Turnover
- ¥ Resource competition
- ¥ Vegetation dynamics
- ¥ Disturbance (fire)
- ¥ Management (crops, forest)

LPJlanduse classes: Cropland, pasture, managed forests, natural vegetation, barren land
13 crop functional types, 8 tree functional types, 2 herbaceous functional types

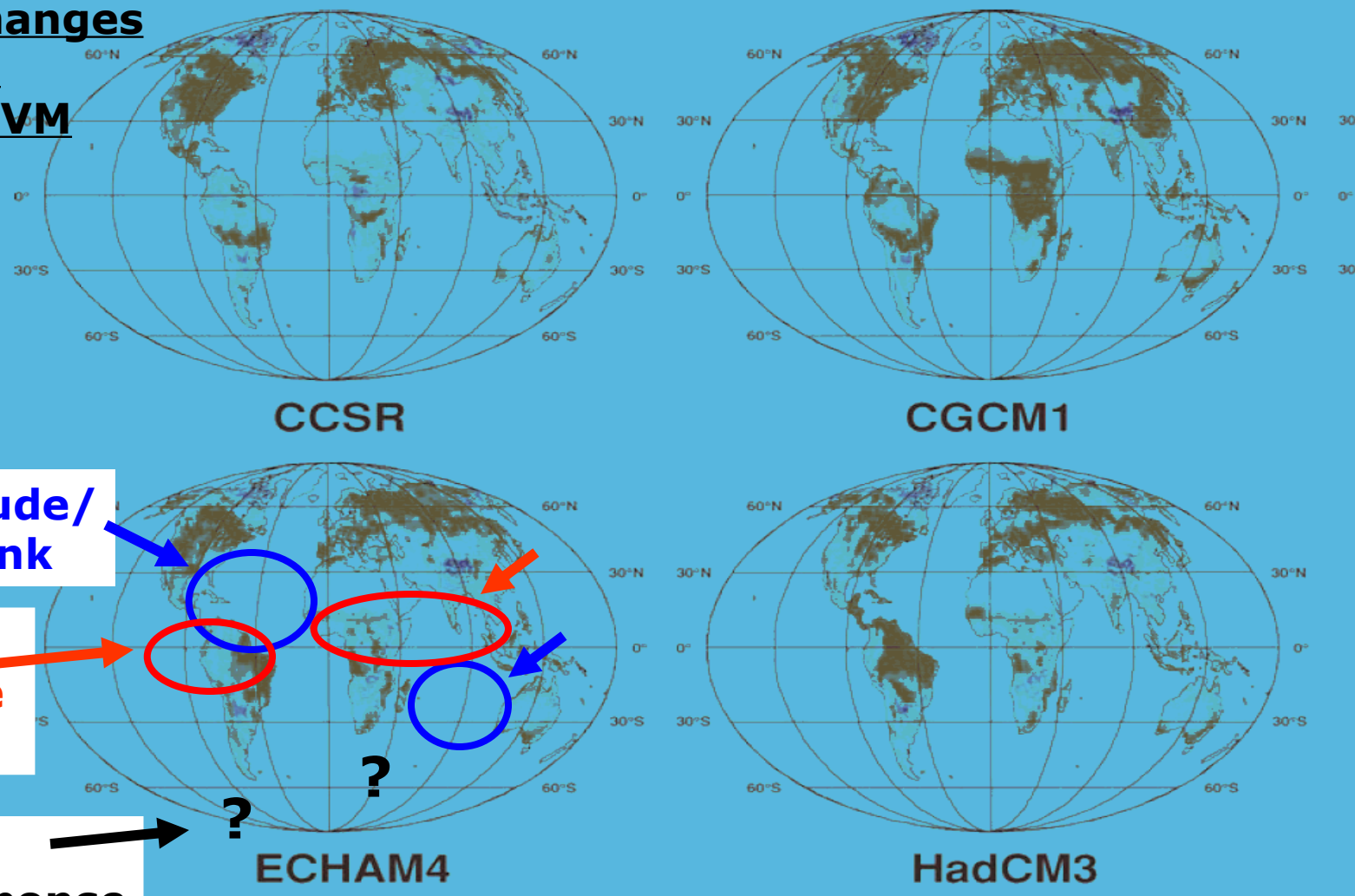
LPJ compared to HADCM3LC:

- Multiple soil pools
- More sophisticated vegetation dynamics
- Inclusion of fire

LPJ-DGVM global carbon dynamics driven by various GCMs



C-stock changes until 2100 by LPJ-DGVM



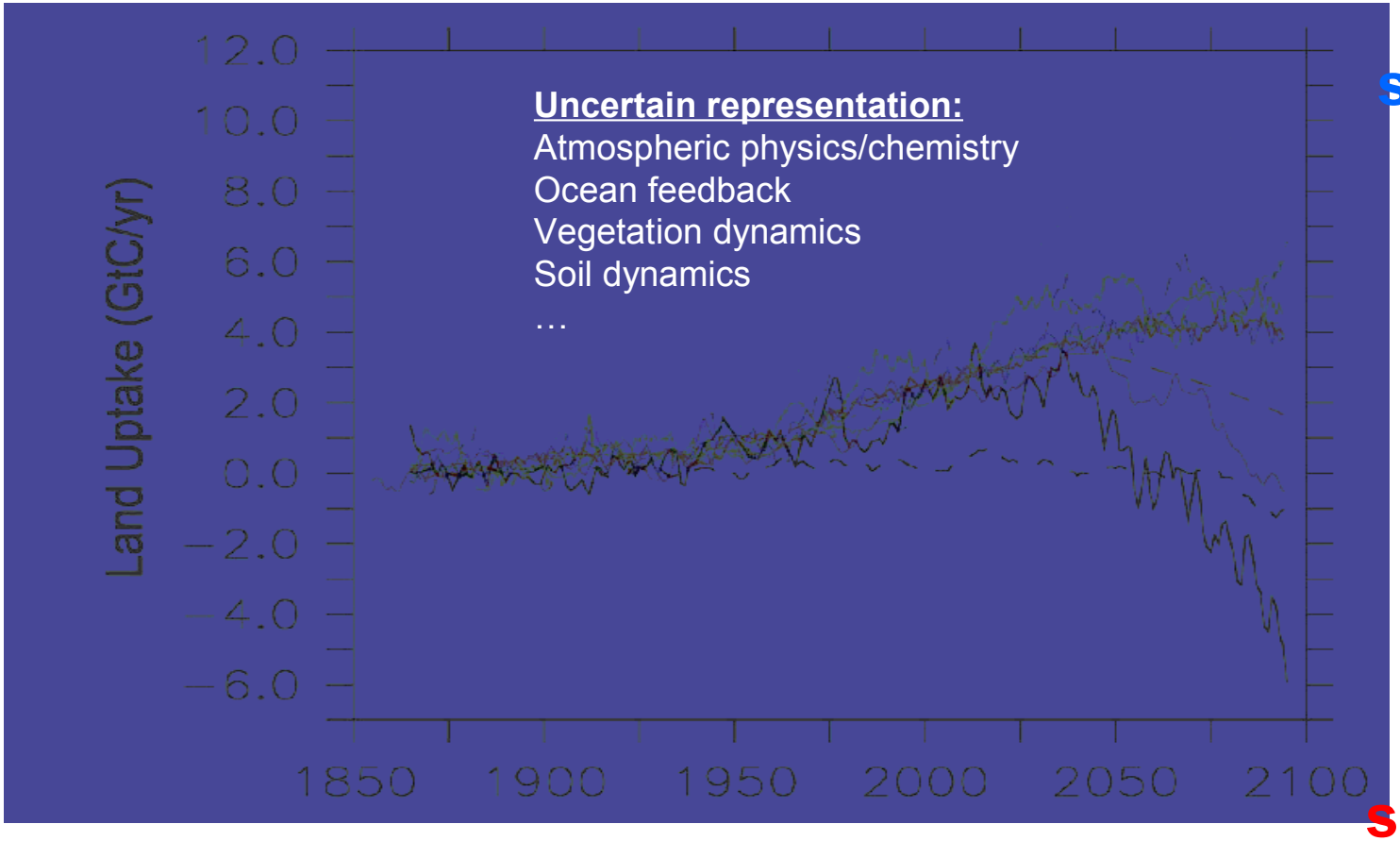
High-latitude/ altitude sink

Boreal-temperate source

Tropics: Mixed response

Changes of global terrestrial carbon storage (2071–2100 vs. 1971–2000) estimated by LPJ und
the sum of all carbon pools in soil, litter and vegetation).

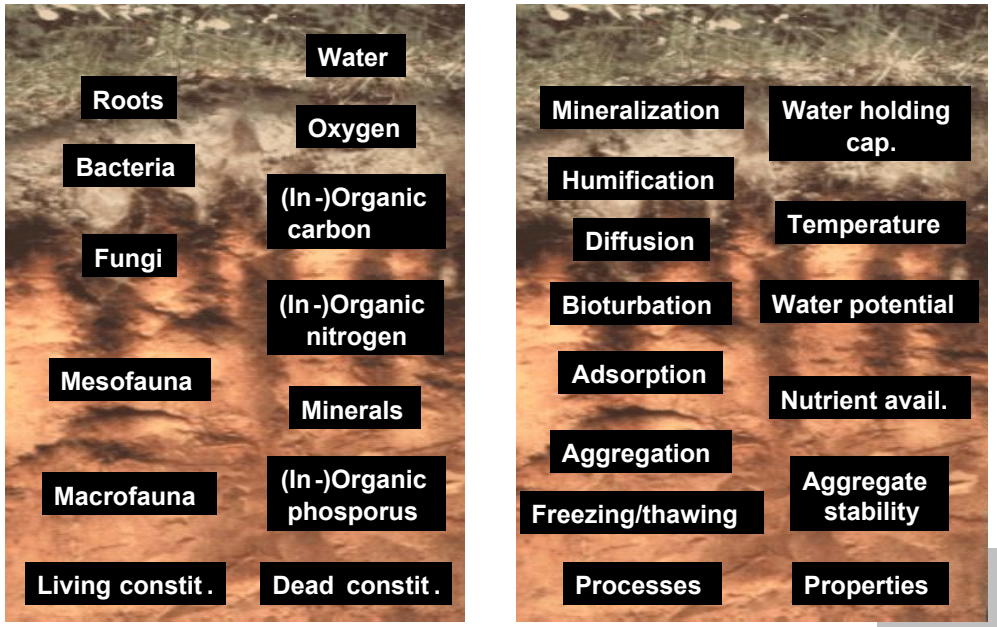
Uncertain model representation: partly terrestrial biosphere

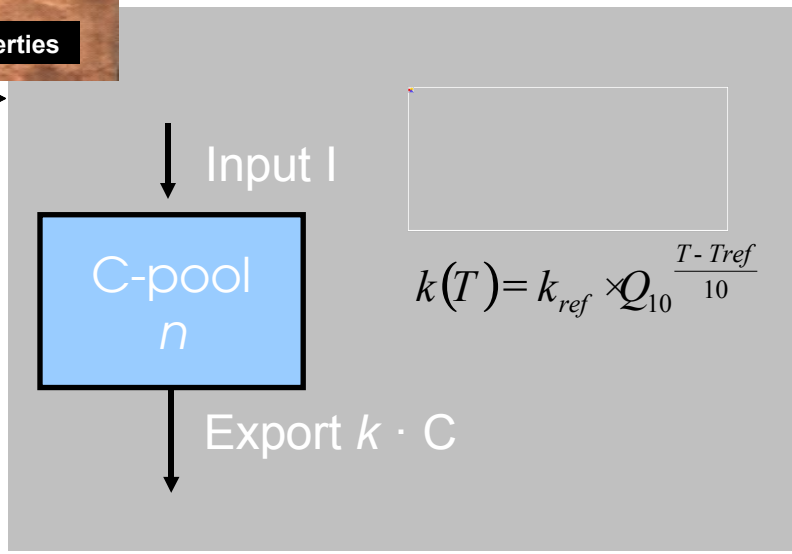


sink

source

Missing representations of biosphere in global models: the soil

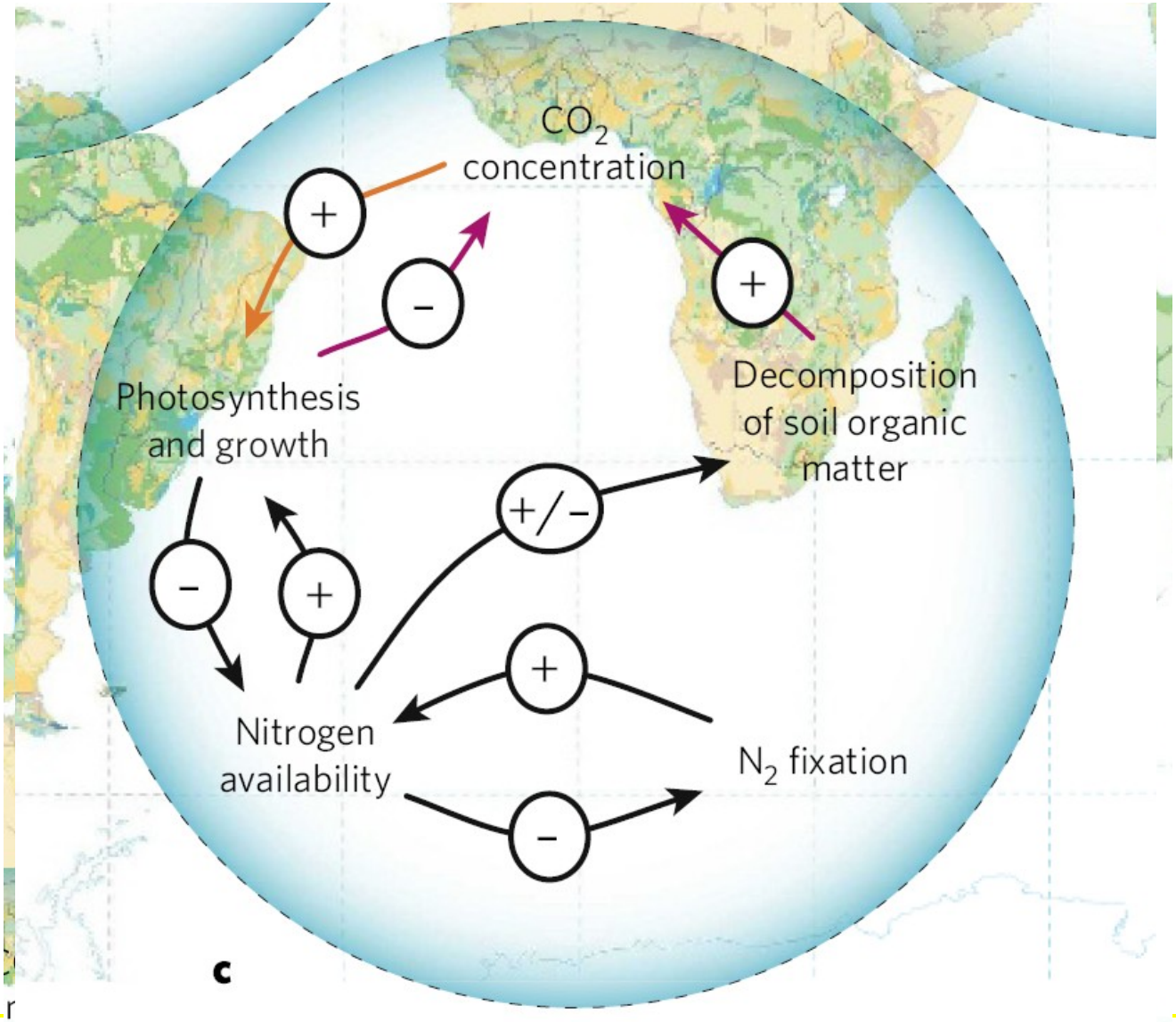




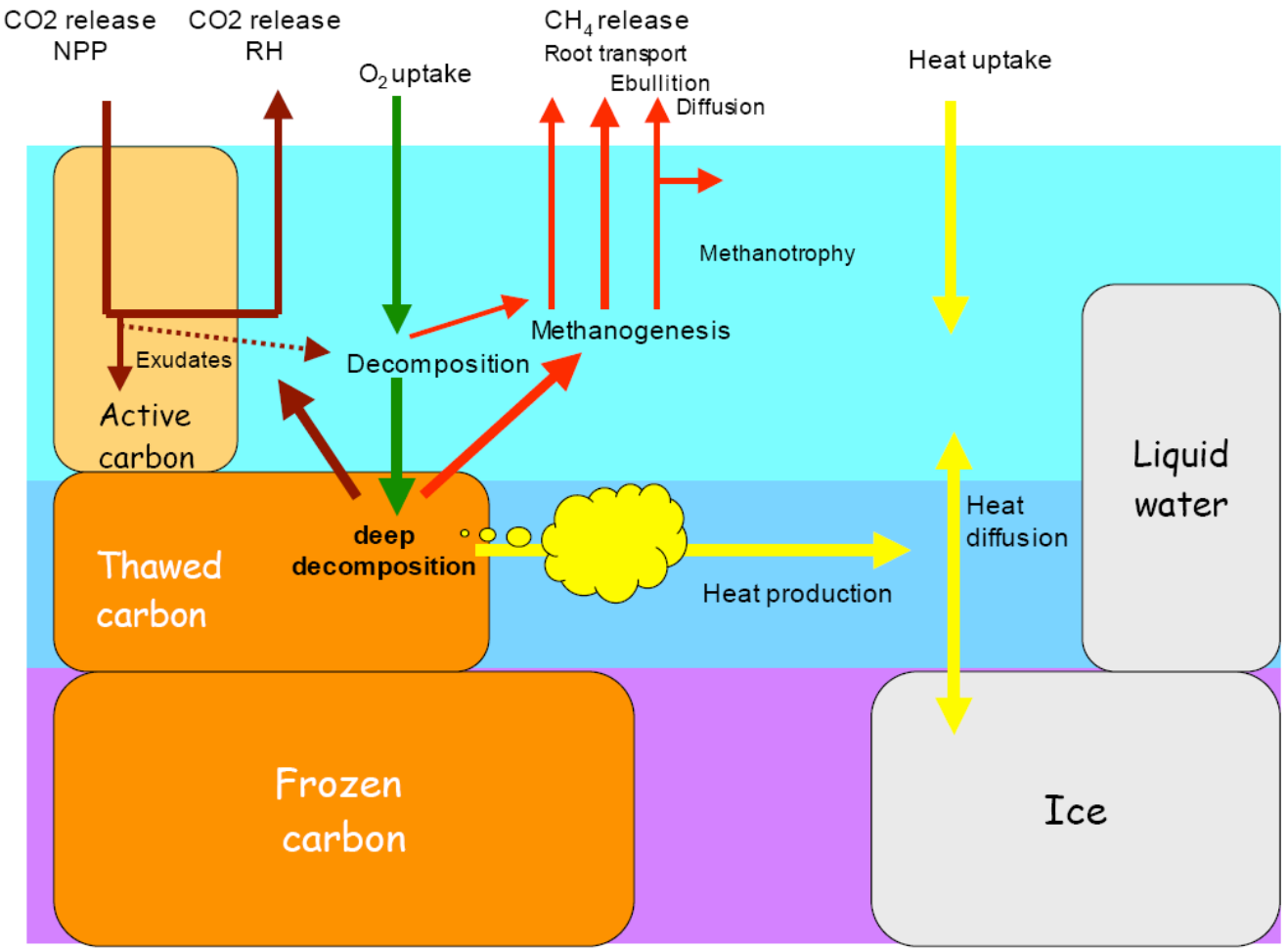
➔ **"Dead-soil paradigm models"**

Empirical falsification indicators appearing (e.g. Reichstein et al. 2007, GRL; Fontaine et al., Nature 2007)

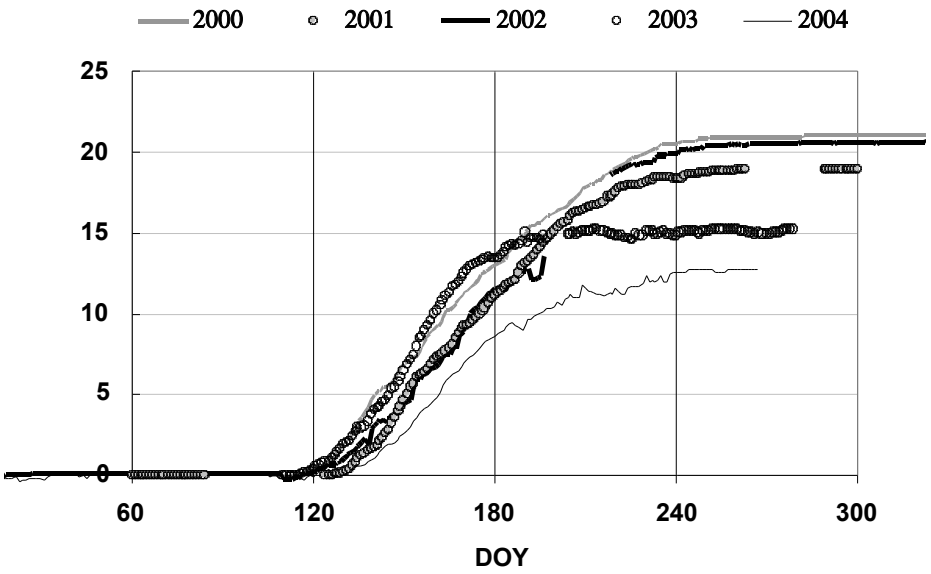
Missing representations of biosphere in global models: terrestrial feedback loops – nitrogen-water-carbon



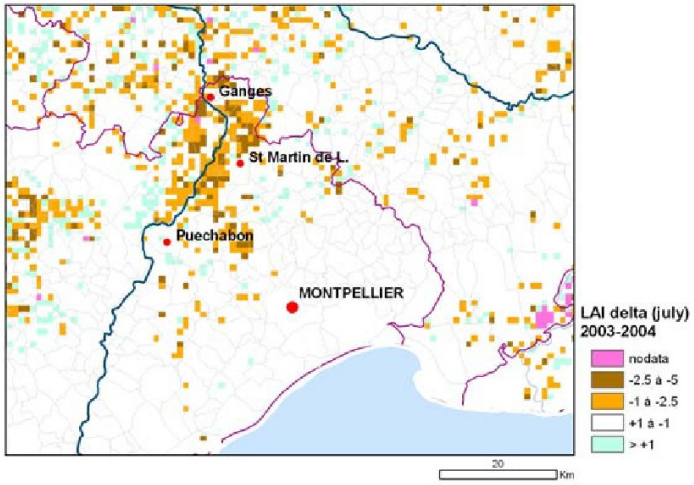
Missing representations of biosphere in global models: permafrost carbon dynamics and the role of biota



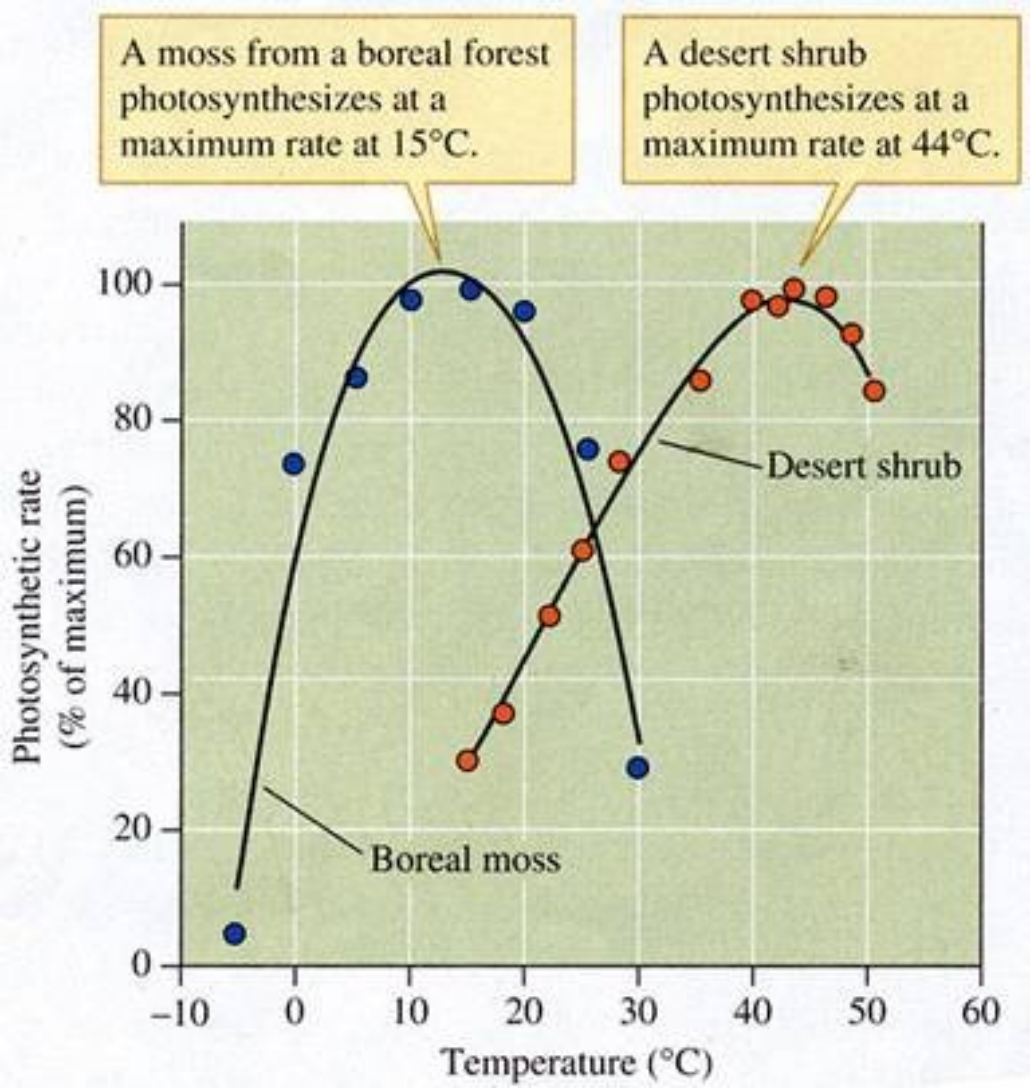
Missing representations of biosphere in global models: extreme events and lag-effects



LAI difference

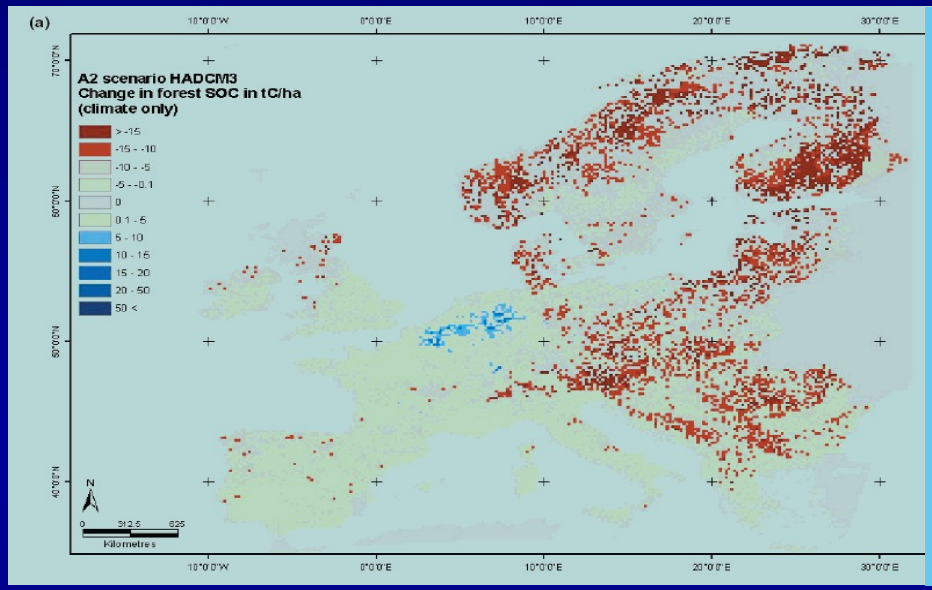


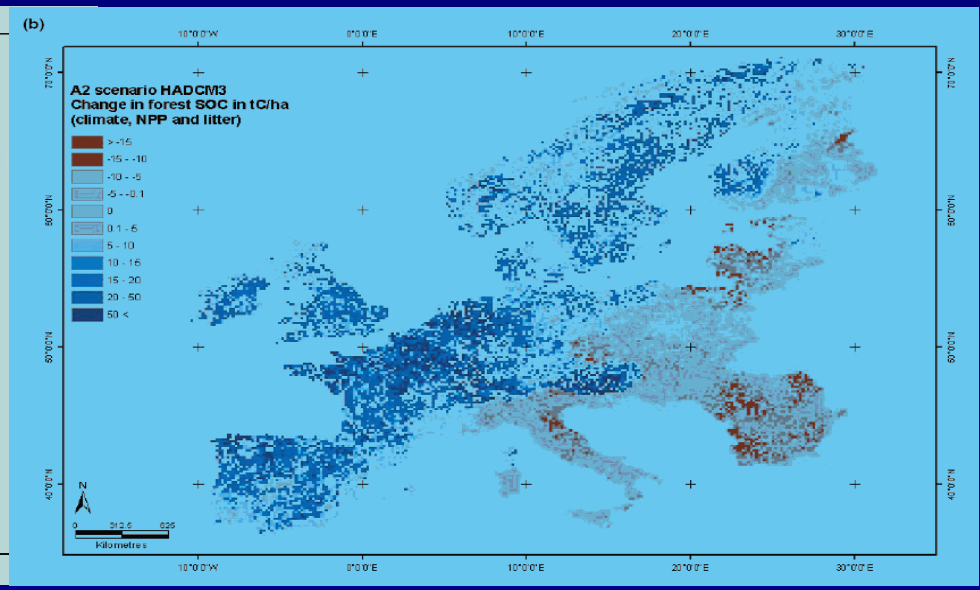
Missing representations of biosphere in global models: acclimation?



Missing representations of biosphere in global models: fire ?

Projected change in European carbon stocks: Management effects





Climate change only

Climate change + management

Smith et al. (2006)

Model uncertainties / omissions

Factor or mechanism	Likely effect on soil C if process represented
– CO_2 effect / Interactions with the N cycle	↓
– Permafrost dynamics	↓
– Extreme events	↓
– Temp. sens. / Interactions with H_2O cycle	↑
– Interactions with biota and soil-vegetation feedback	↕
– Dynamics of the forest floor and deeper soil horizons not accounted	↕

Conclusions

- Terrestrial ecosystems and in particular soils already contain a large amount of carbon (that is highly vulnerable)
  - Need for protection
- Models tend to see an overall negative direct effect of climate change on forest carbon stocks (T signal)
- Models tend to see mixed total effect of CC on the ecosystem carbon stocks (CO_2 signal versus T signal)
  - Specific to region also
  - Depends on time-scale
- Uncertainties large
  - Climate models
  - Global Ecosystem models and missing representations
  - Management effects

Thanks for your attention!