How Earth system models deals with vulnerabilities of the carbon cycle

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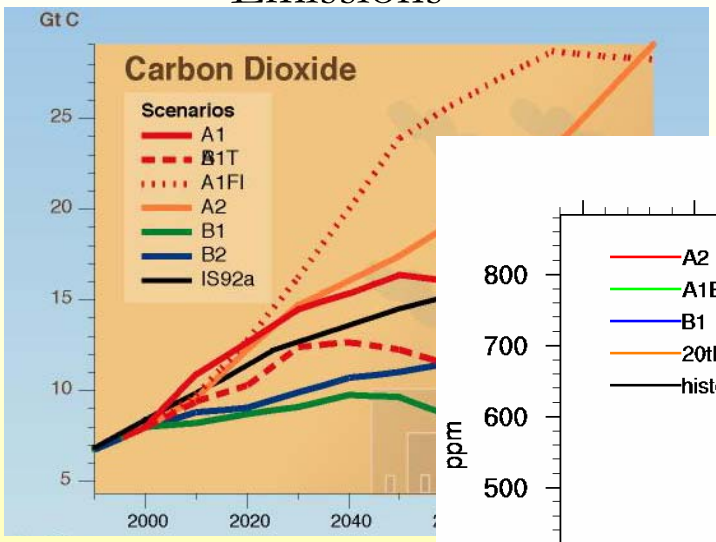
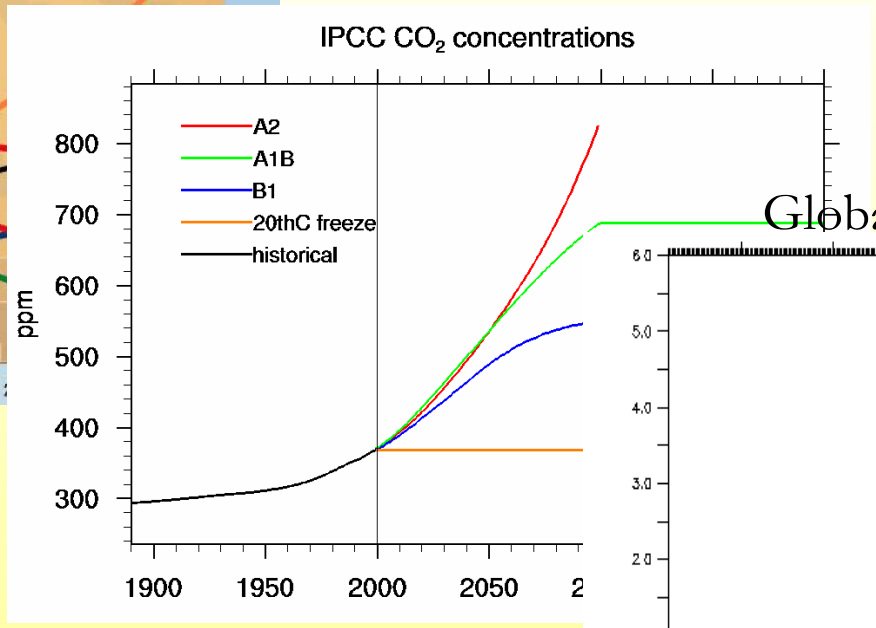
Institut Pierre Simon Laplace

GCP
UNESCO, June 15th 2005

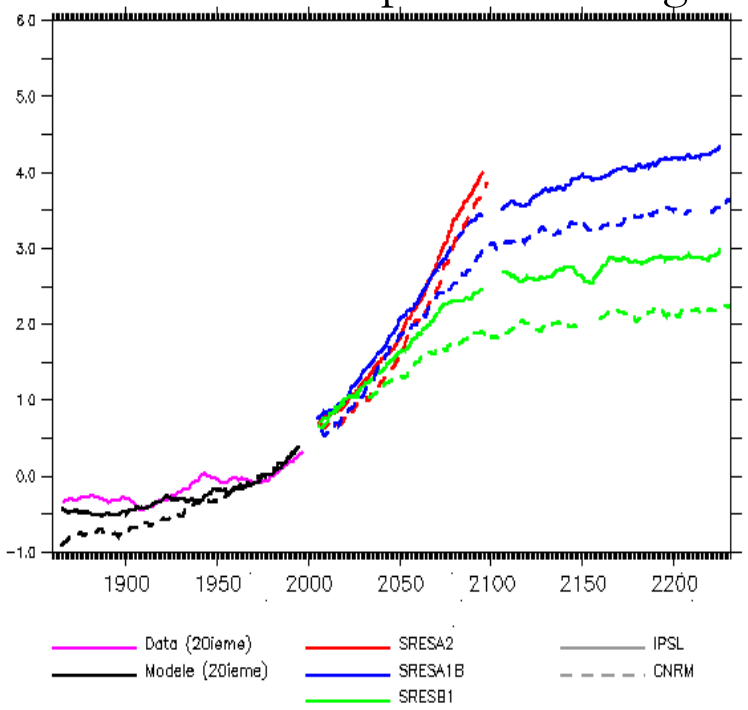
Climate change
(eg. IPCC AR4 simulations)

Emissions





Global temperature change



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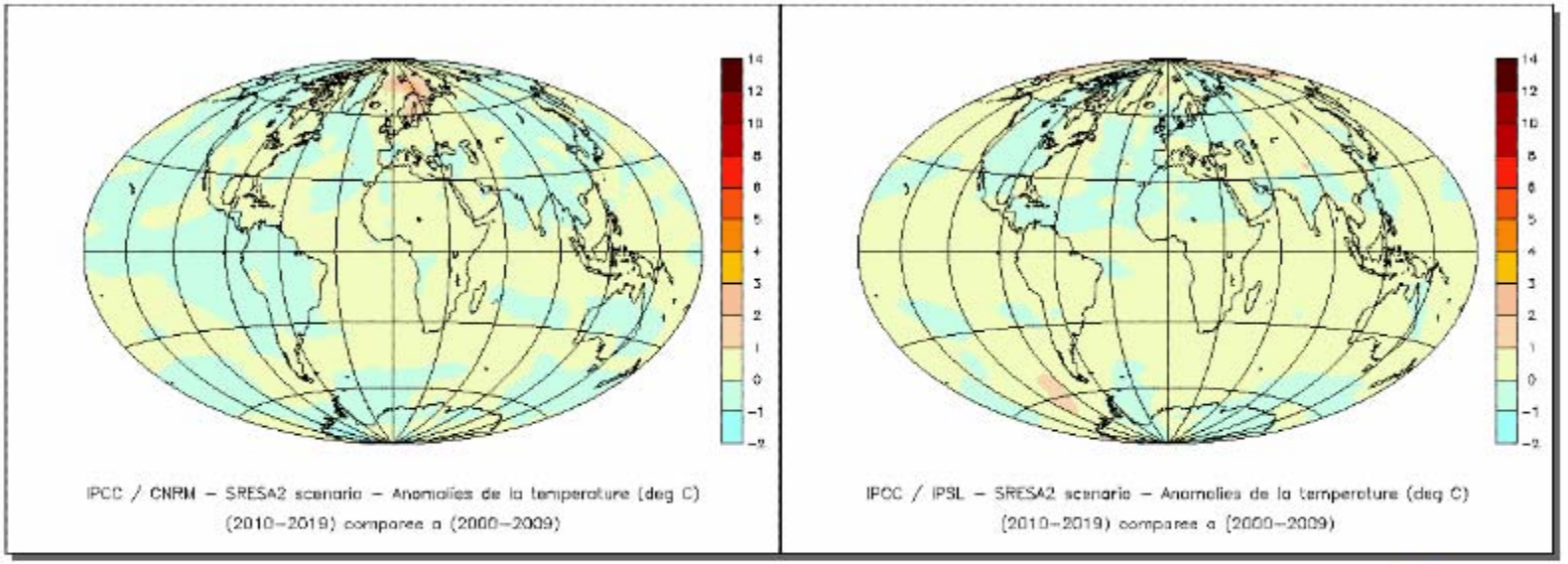
Scenario A2
CNRM vs IPSL



Goto | 1 | Prev | Fisrt | Slower
Play | Stop | Next | Last | Faster

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IGCMG - IPSL Groupe Climat et Modélisation Globale

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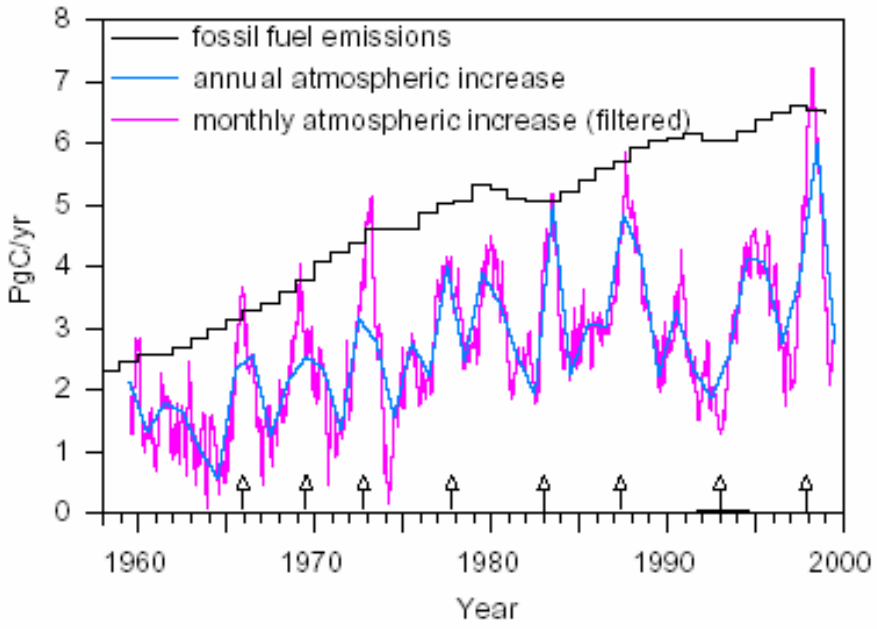
Fossil Emissions

1990's annual mean fluxes

IPCC-TAR, 2001



Airborne fraction ~ 0.5

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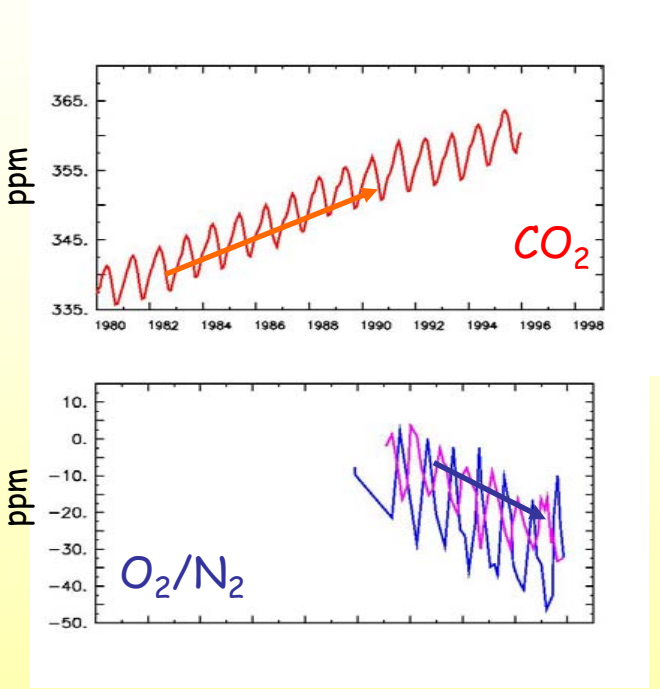
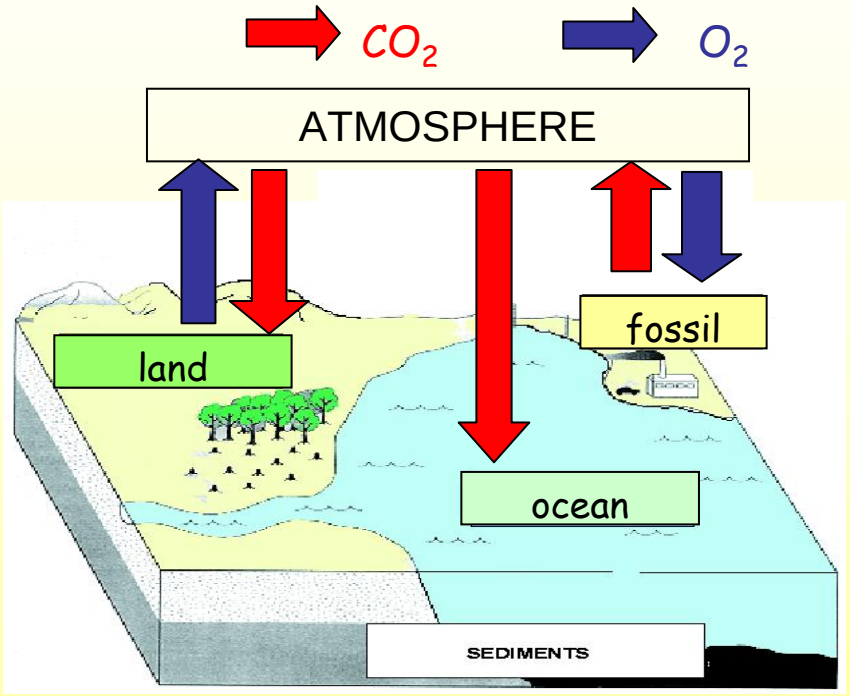
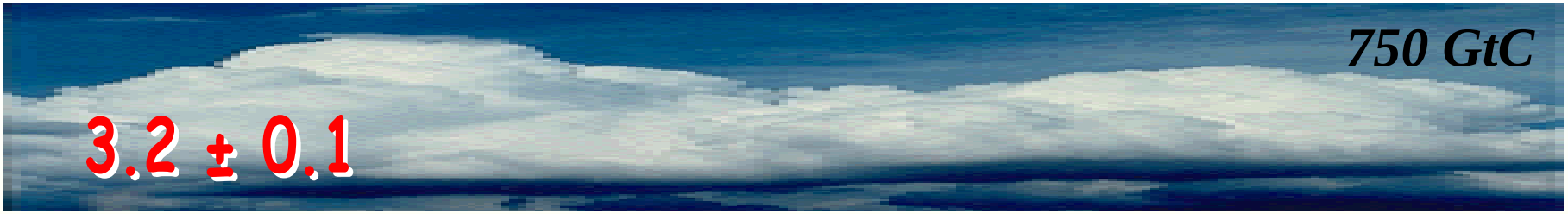
Global carbon budget





CO_2 = FF - Land - Ocean

O_2 = α FF - β Land



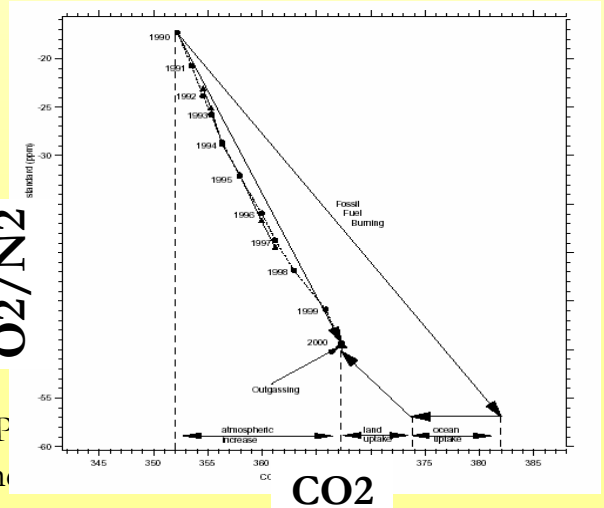
Fossil Emissions

Oceanic Uptake

Land Uptake

1990's annual mean fluxes

IPCC-TAR, 2001



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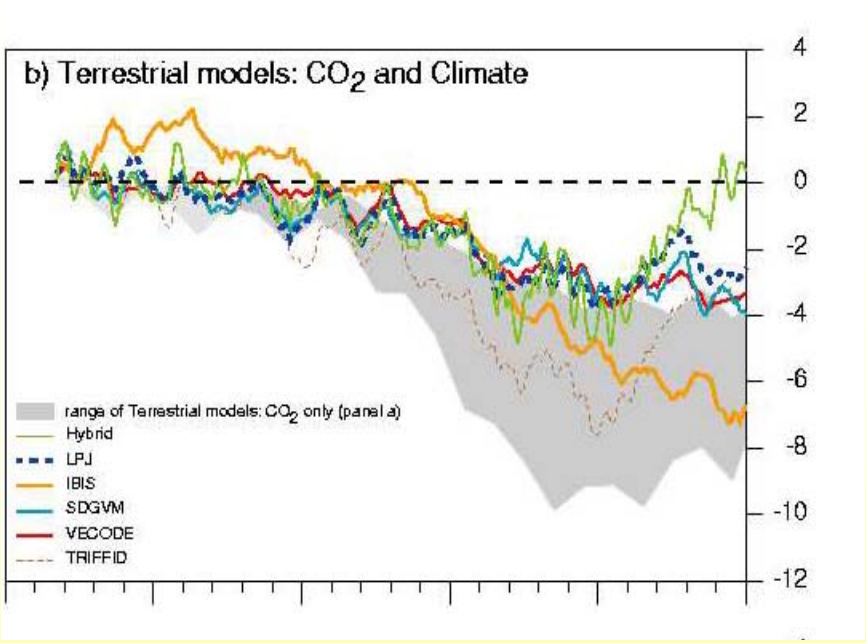
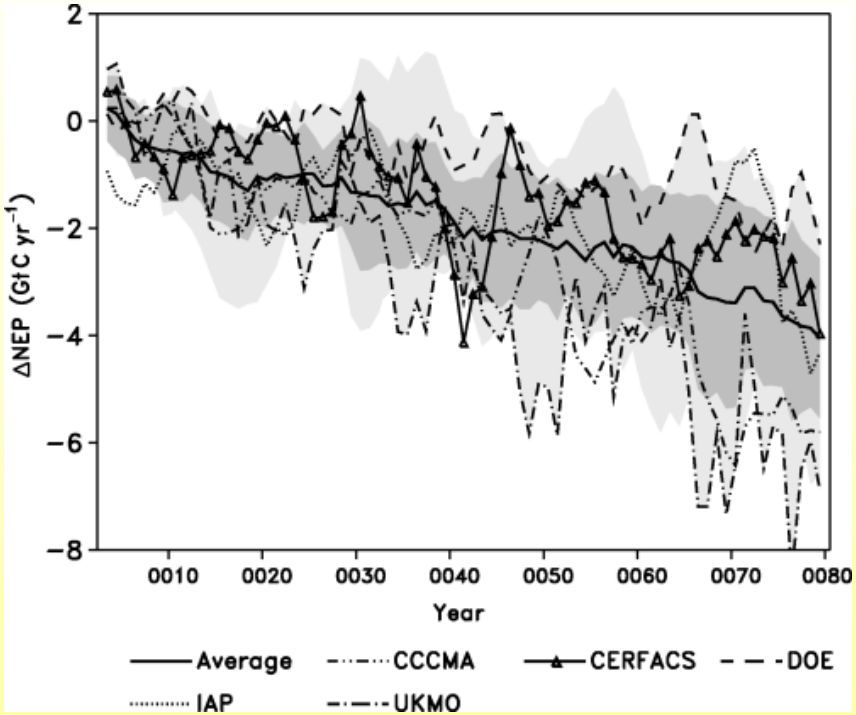
Will this last forever ?

- Will the land and the ocean keep vacuum cleaning half of our CO2 emissions
  - what are the processes behind
  - What is there sensitivity to climate

Climate impact on land carbon

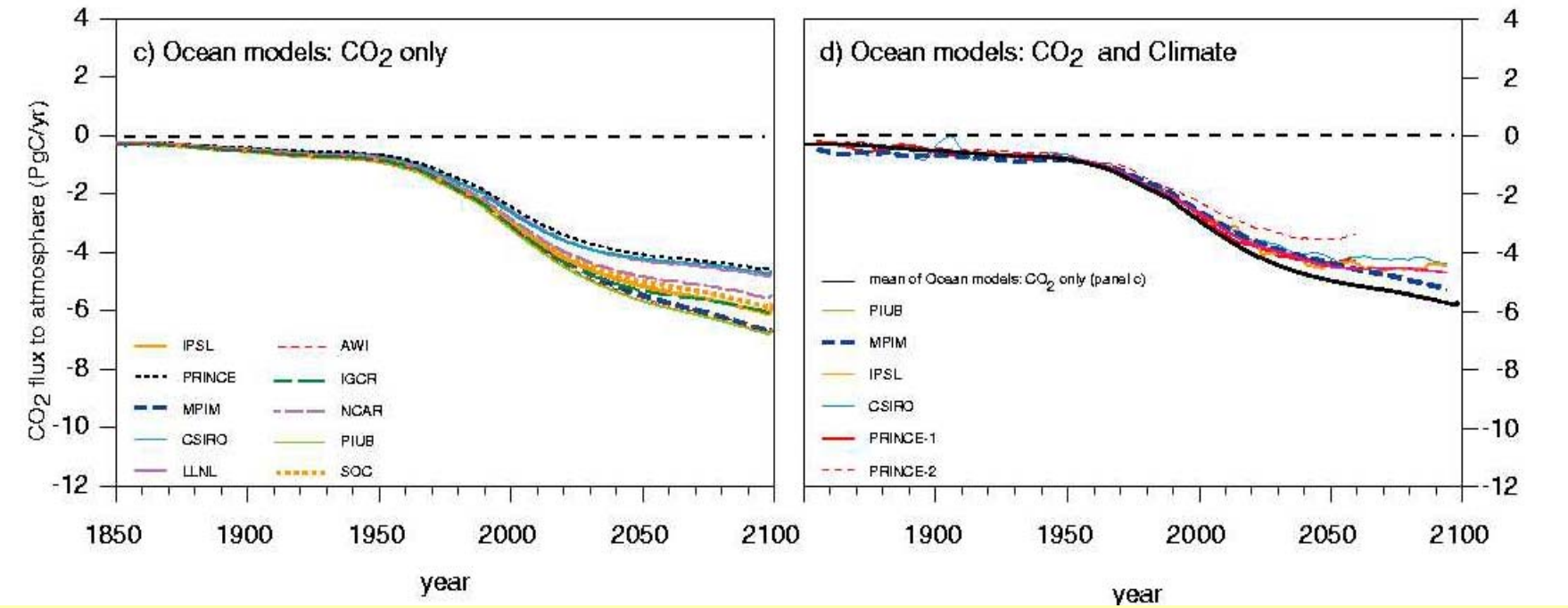


IPCC, TAR, 2001



Berthelot et al., 2005

Climate impact on ocean carbon



IPCC, TAR, 2001

More on this after lunch from C., C. and C.

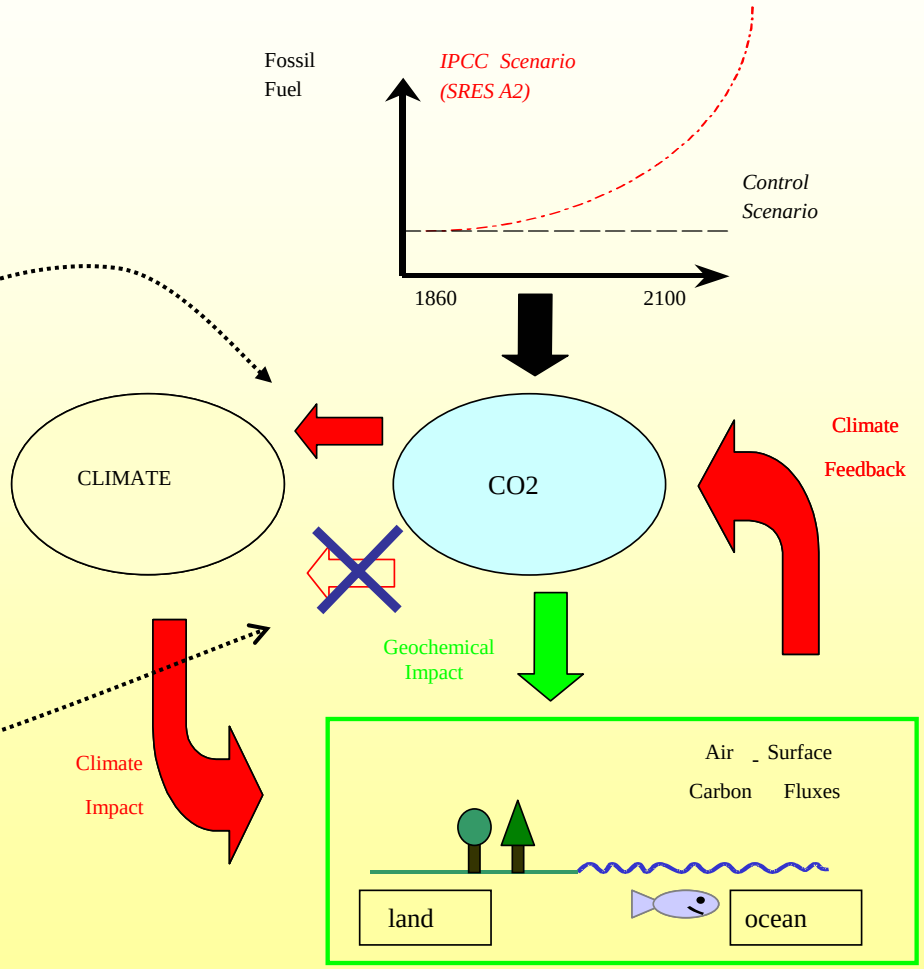
Climate and carbon cycle are coupled

- Atm. CO_2 affects climate
- Climate affects carbon fluxes
- Atm. CO_2 depends on carbon fluxes

Climate-carbon cycle coupled models (C^{4}MIP)

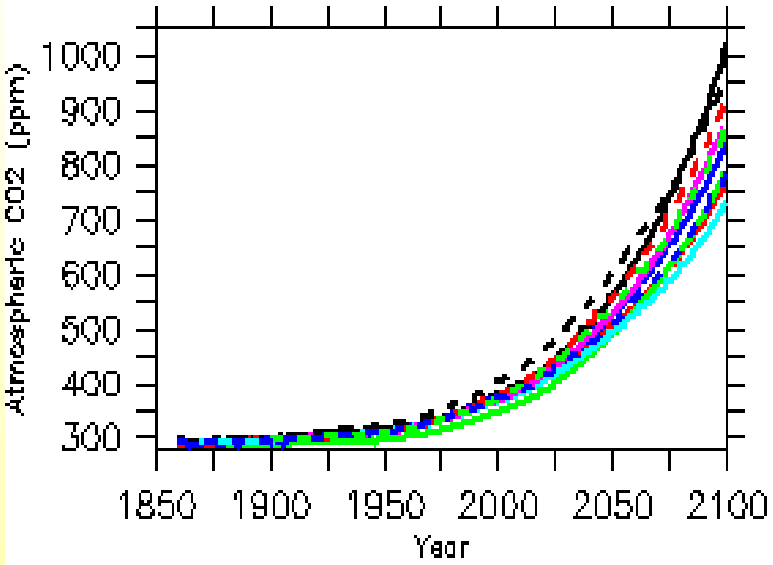
10 models:
6 GCMs, 4 EMICS
Common forcing: SRESA2
2 simulations :

- Coupled (radiative CO2)
- Uncoupled run (non-radiative CO2)

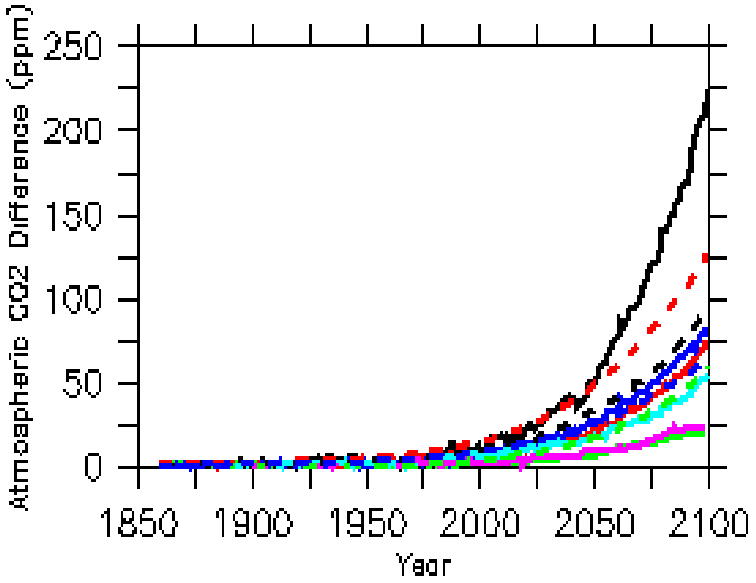


Simulated atmospheric CO2

coupled runs

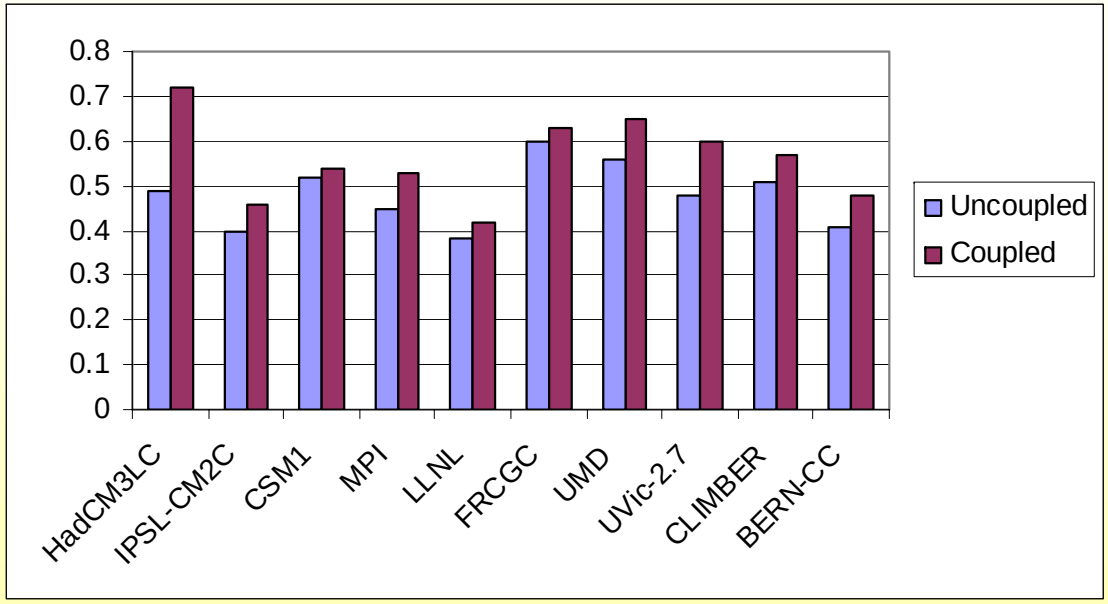


coupled - uncoupled



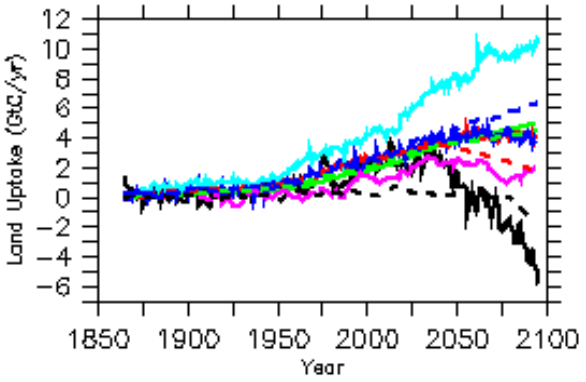
All models simulate a positive feedback

Change in airborne fraction

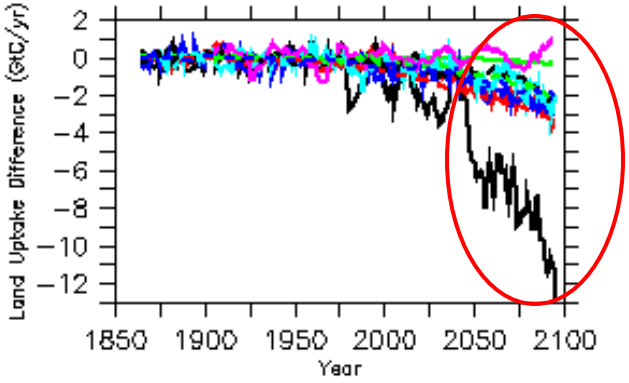


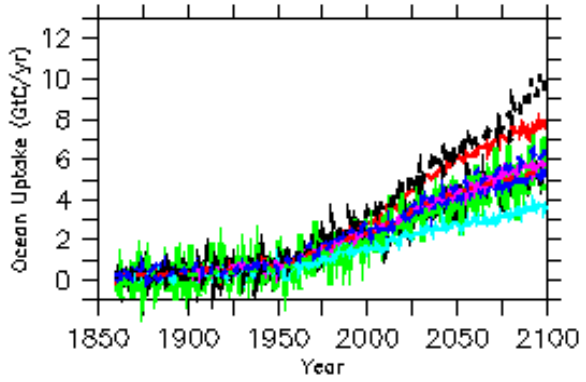
Change in carbon fluxes

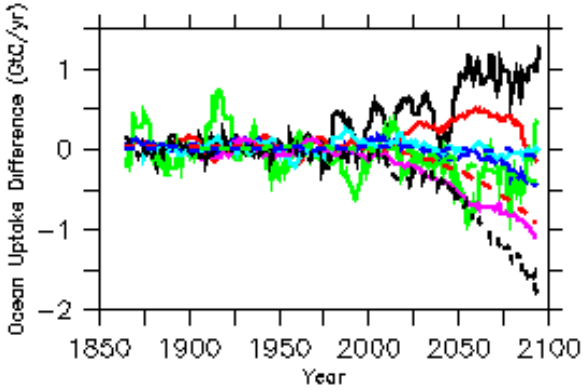
coupled runs



coupled - uncoupled







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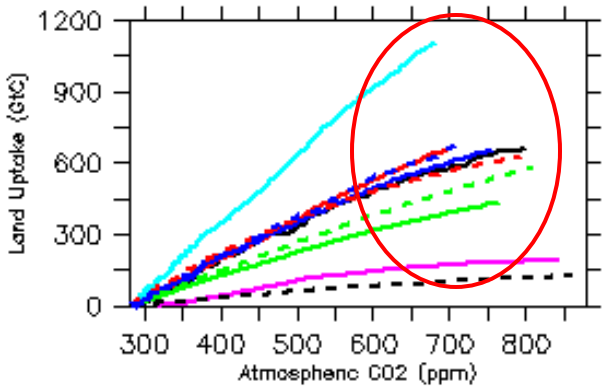
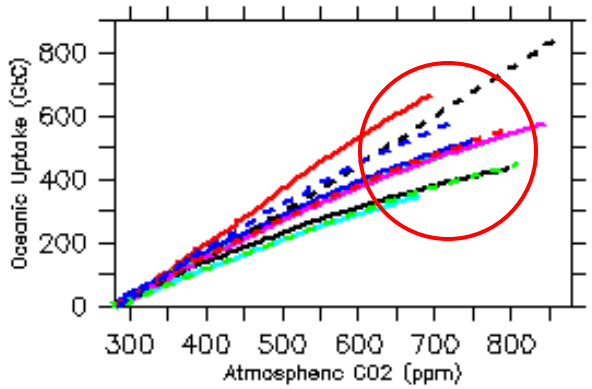
Sensitivity analysis

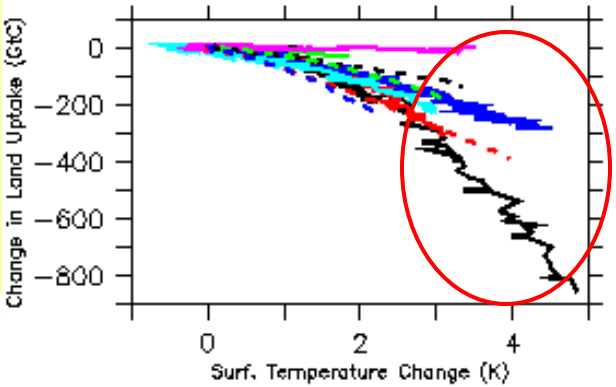
Land and ocean sensitivity to CO_2

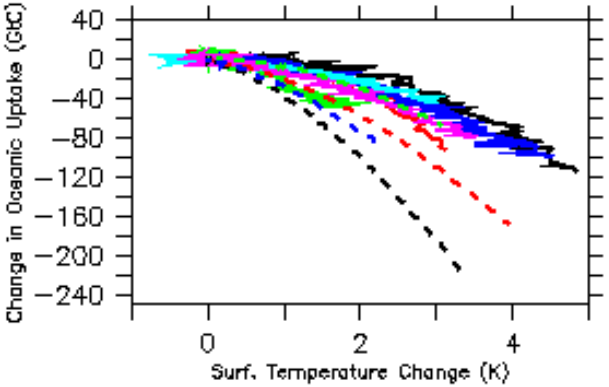




negative feedback

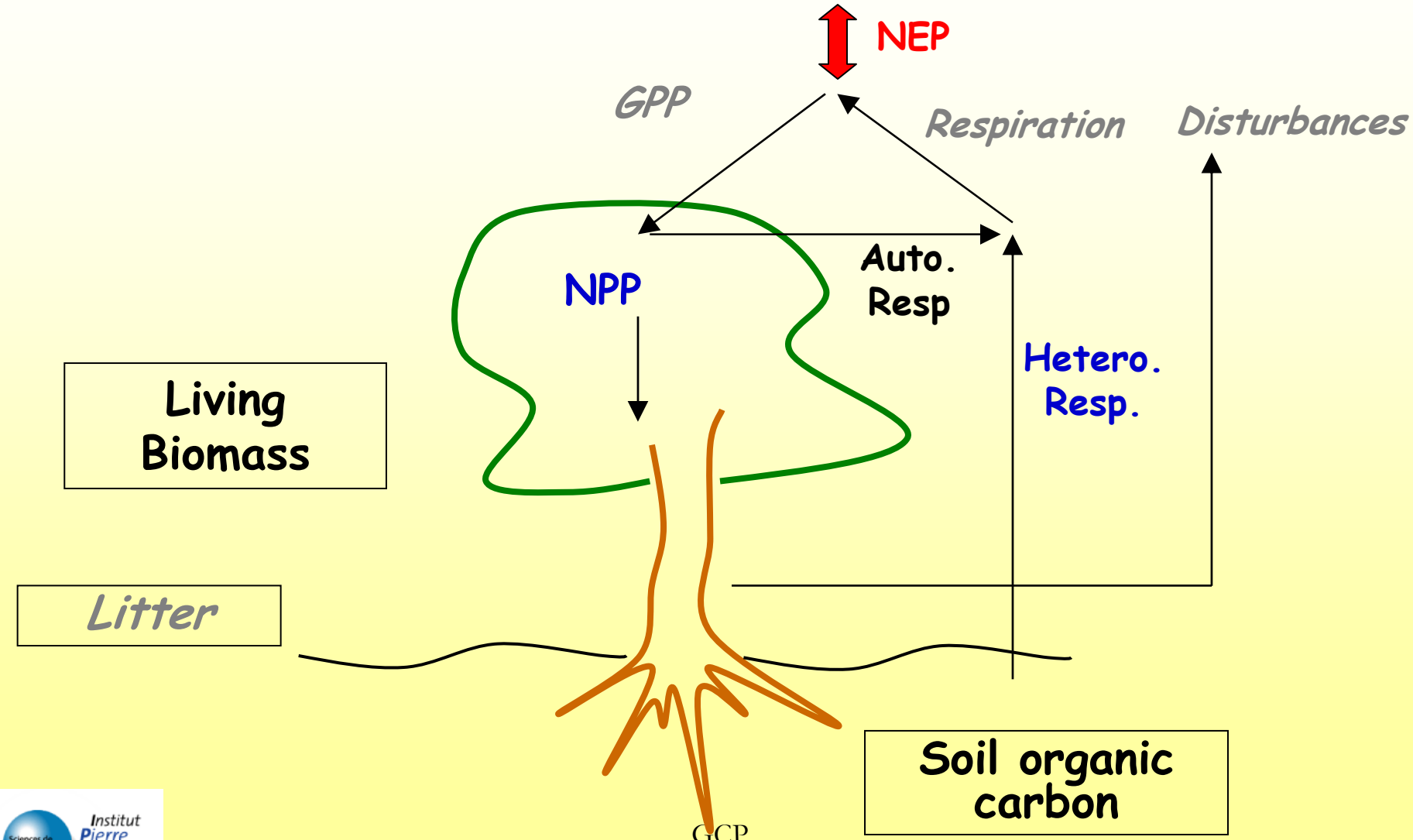
Land and ocean sensitivity to climate



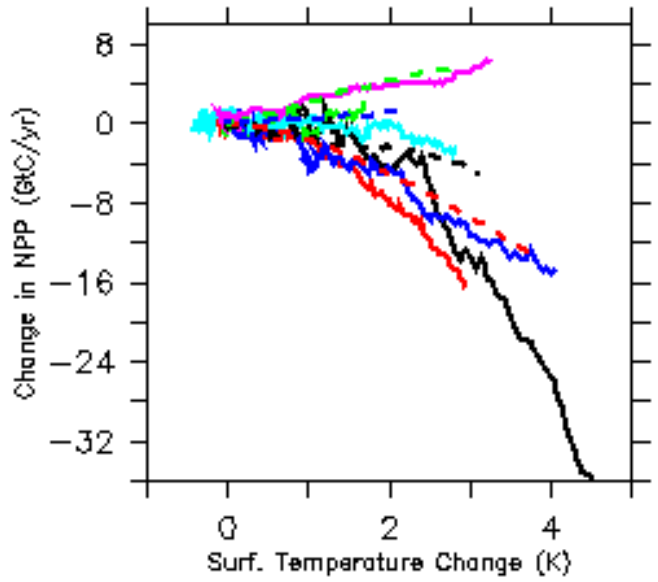


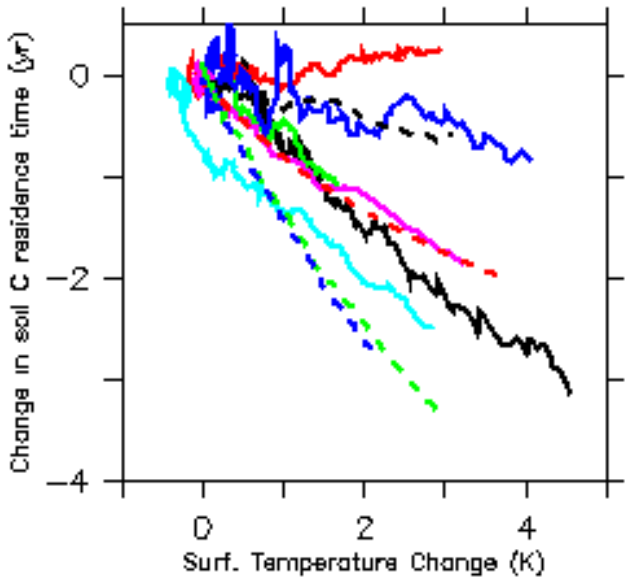
positive feedback

Land C cycle


NEP
GPP
Respiration
Disturbances
NPP
Auto.
Resp
Hetero.
Resp.
Living
Biomass
Litter
Soil organic
carbon

Productivity or Respiration ?

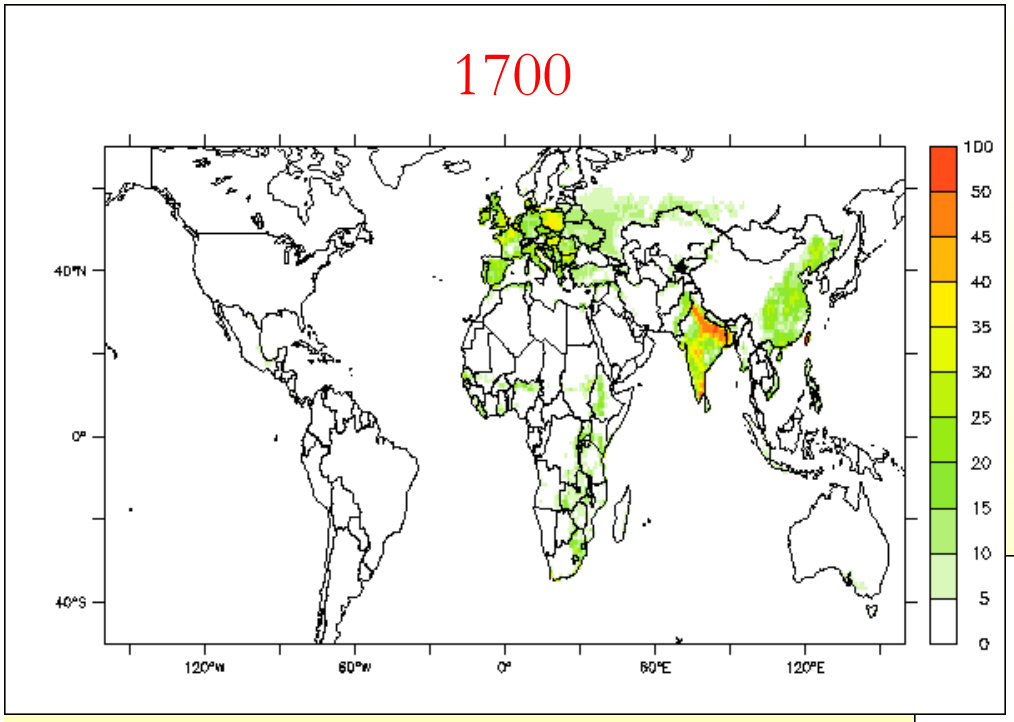




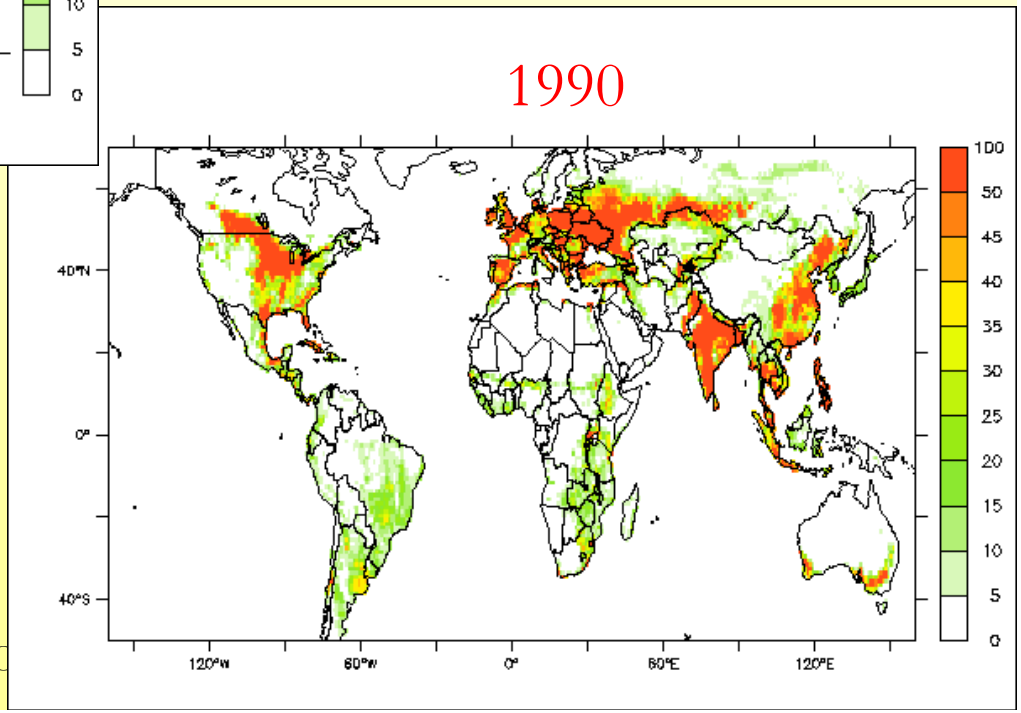
We don't know yet !

Land cover change

1700



1990



Taken from Ramankutty & Foley (1999), Goldewijk (2001)

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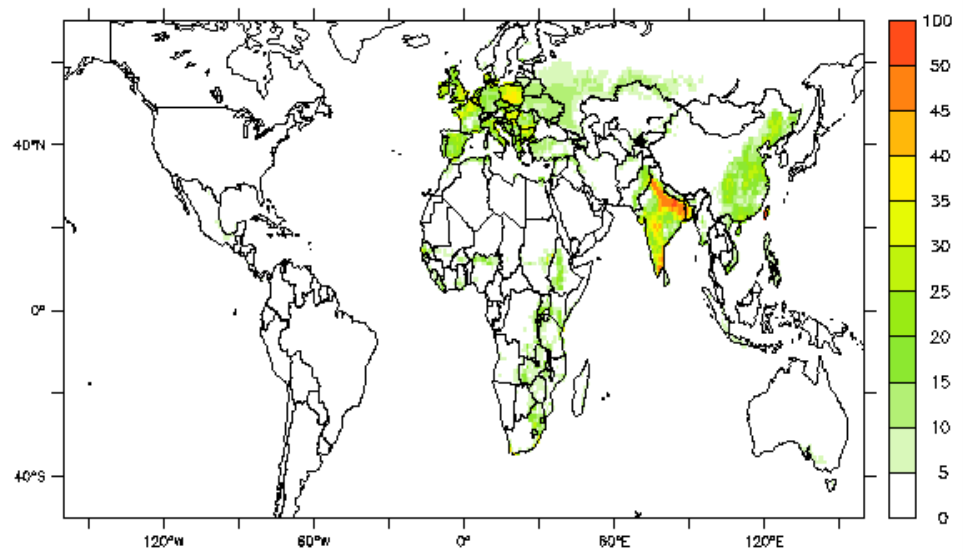
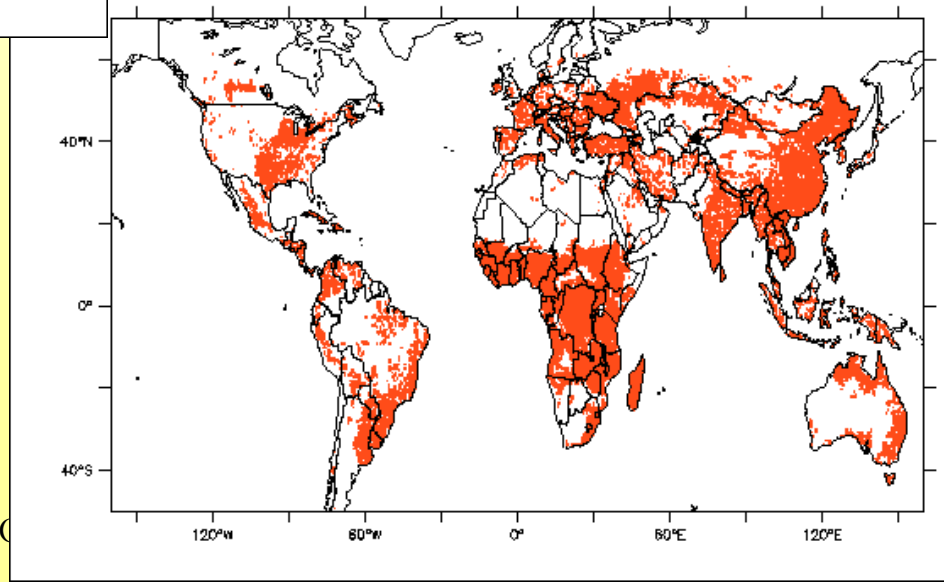
Land cover change

1700



and in 2100



Taken from Ramankutty & Foley (1999), Goldewijk (2001)

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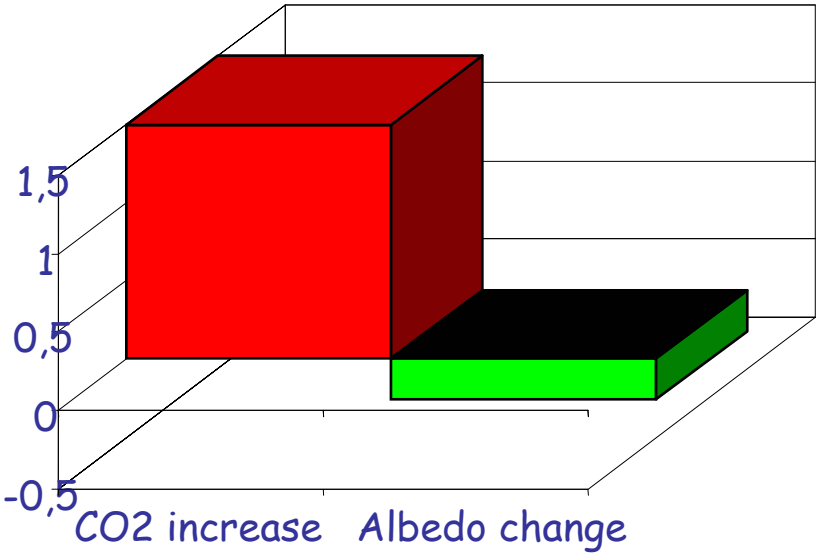
Land cover change and climate (albedo)

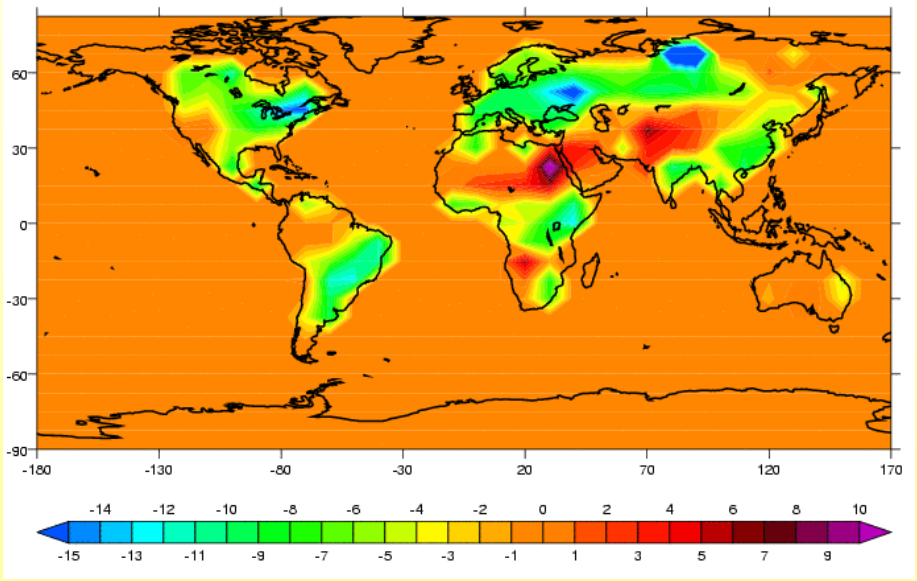
Present-day – Pre Industrial

+ 1,5 W/m²

- 0,26 W/m²



RF at tropopause (W/m²)



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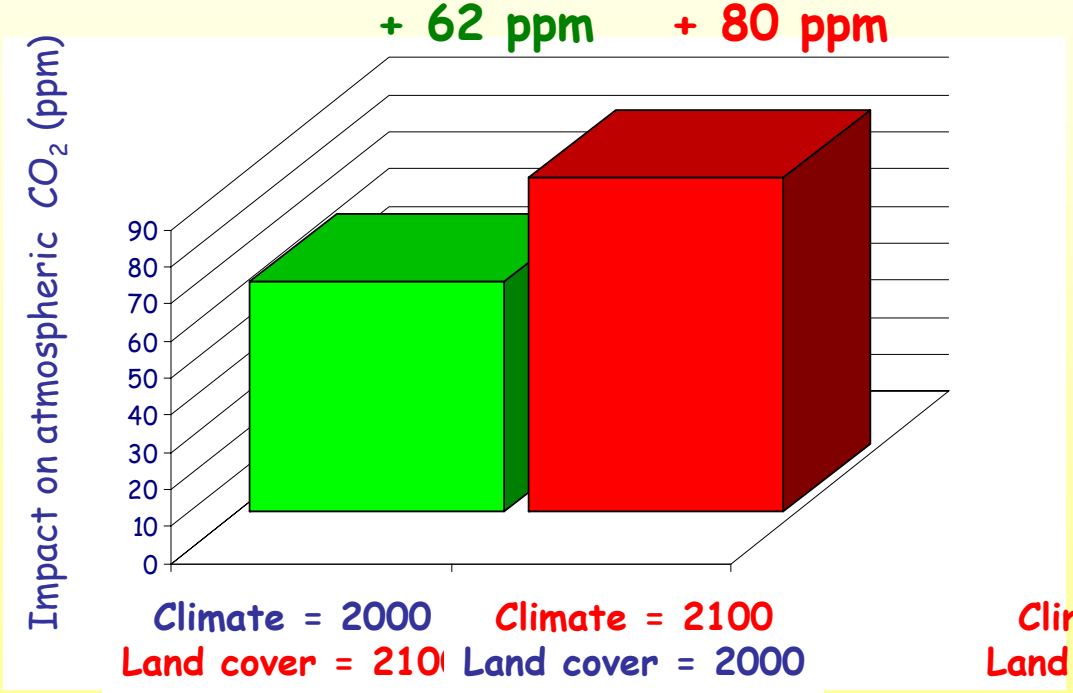
E. Davin thesis

Land cover change and carbon cycle

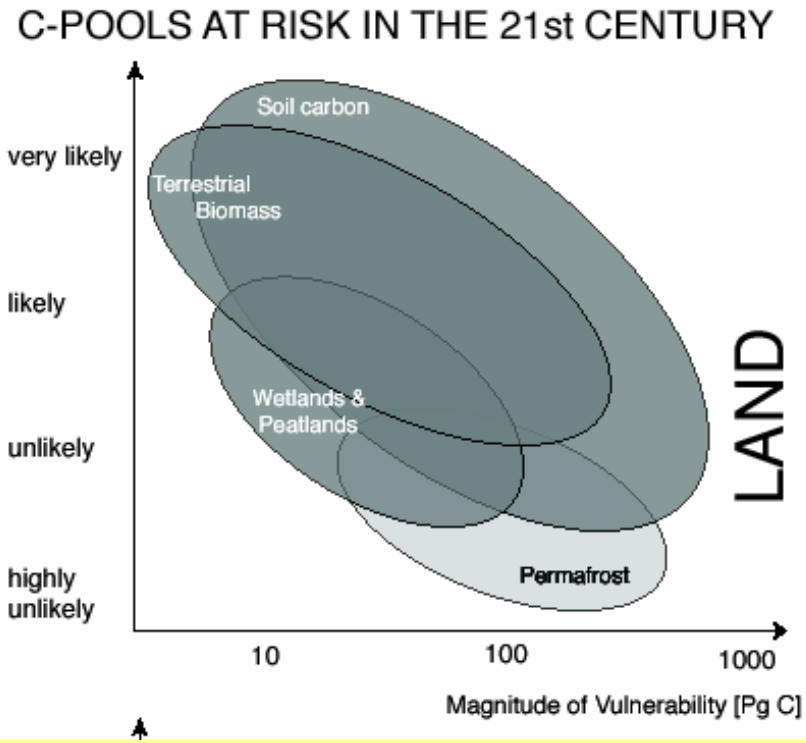
- deforestation releases carbon to the atmosphere
- deforestation reduces land efficiency to take up carbon

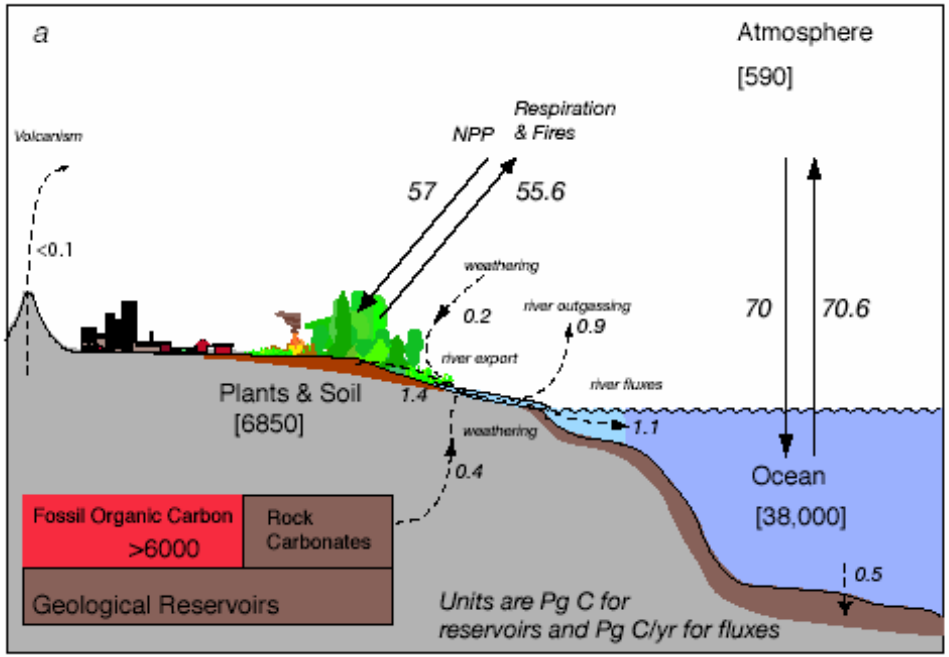


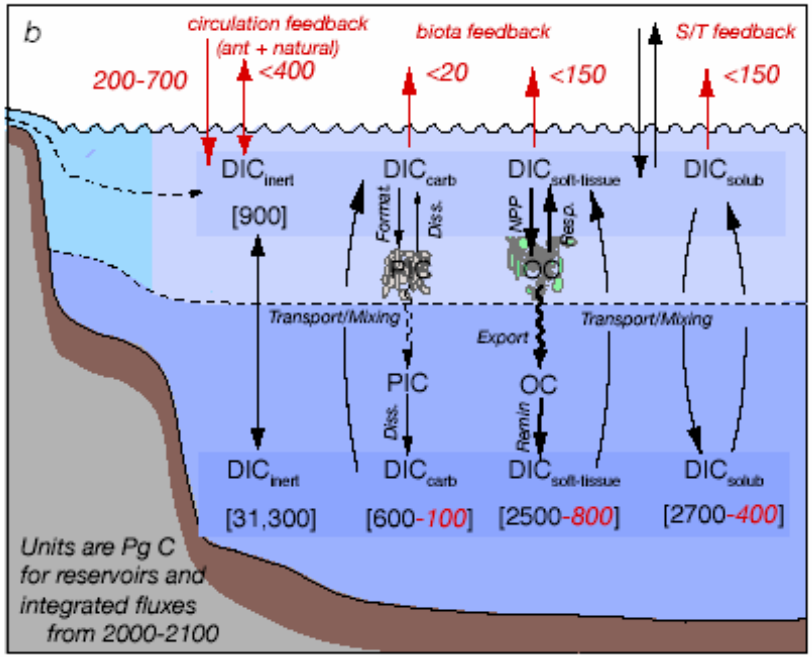
Gitz et Ciais, GBC (2003) *Friedlingstein et al. (2003)*

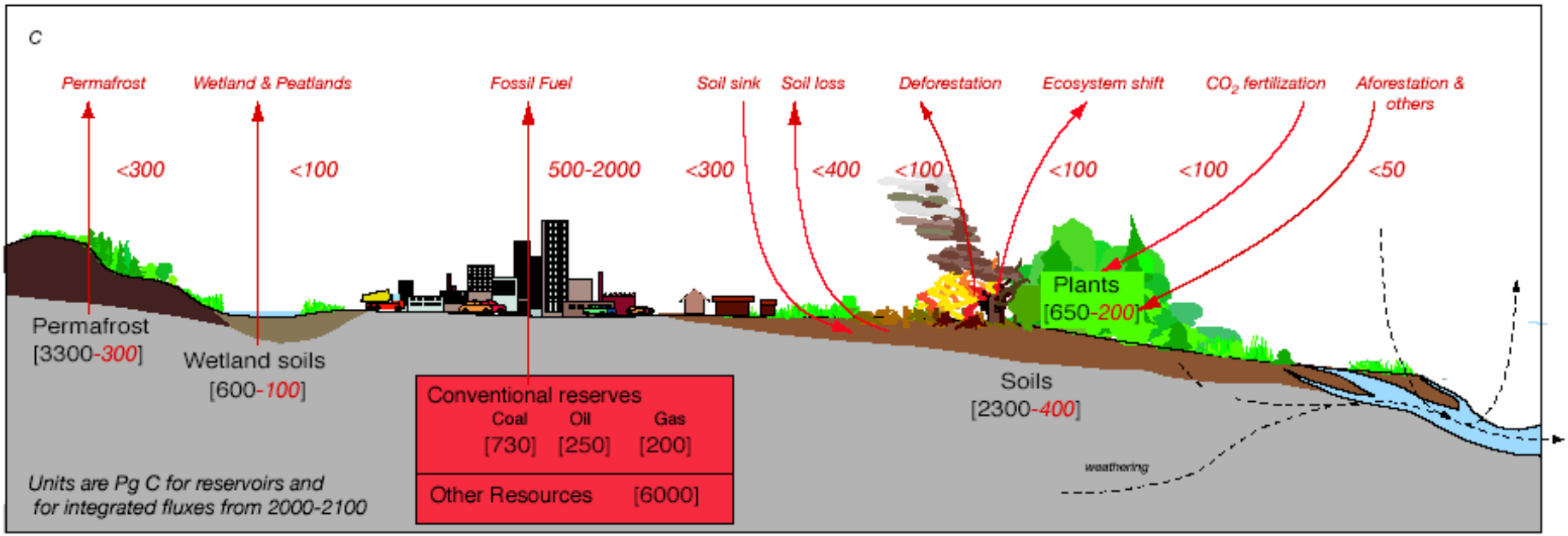
What else ?

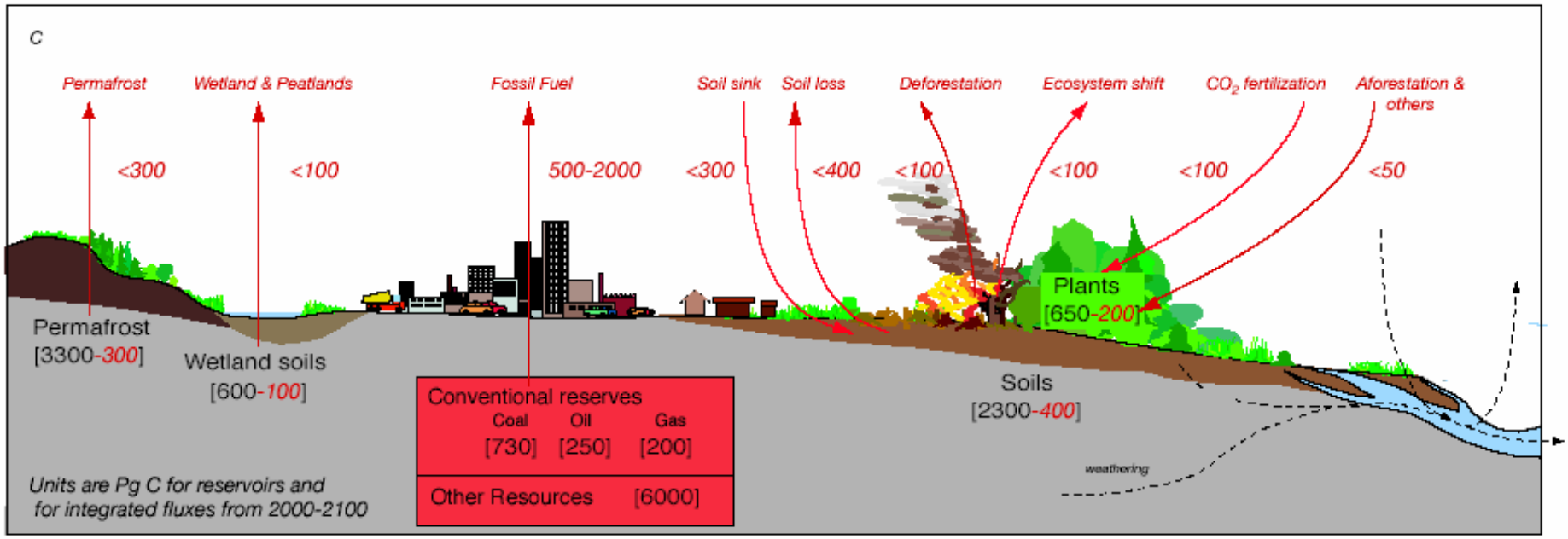
- Permafrost melting
  (cf. Dimitry)
- Change in wetlands distribution/functioning
- Ozone deposition,
  impact on photosynthesis
- …



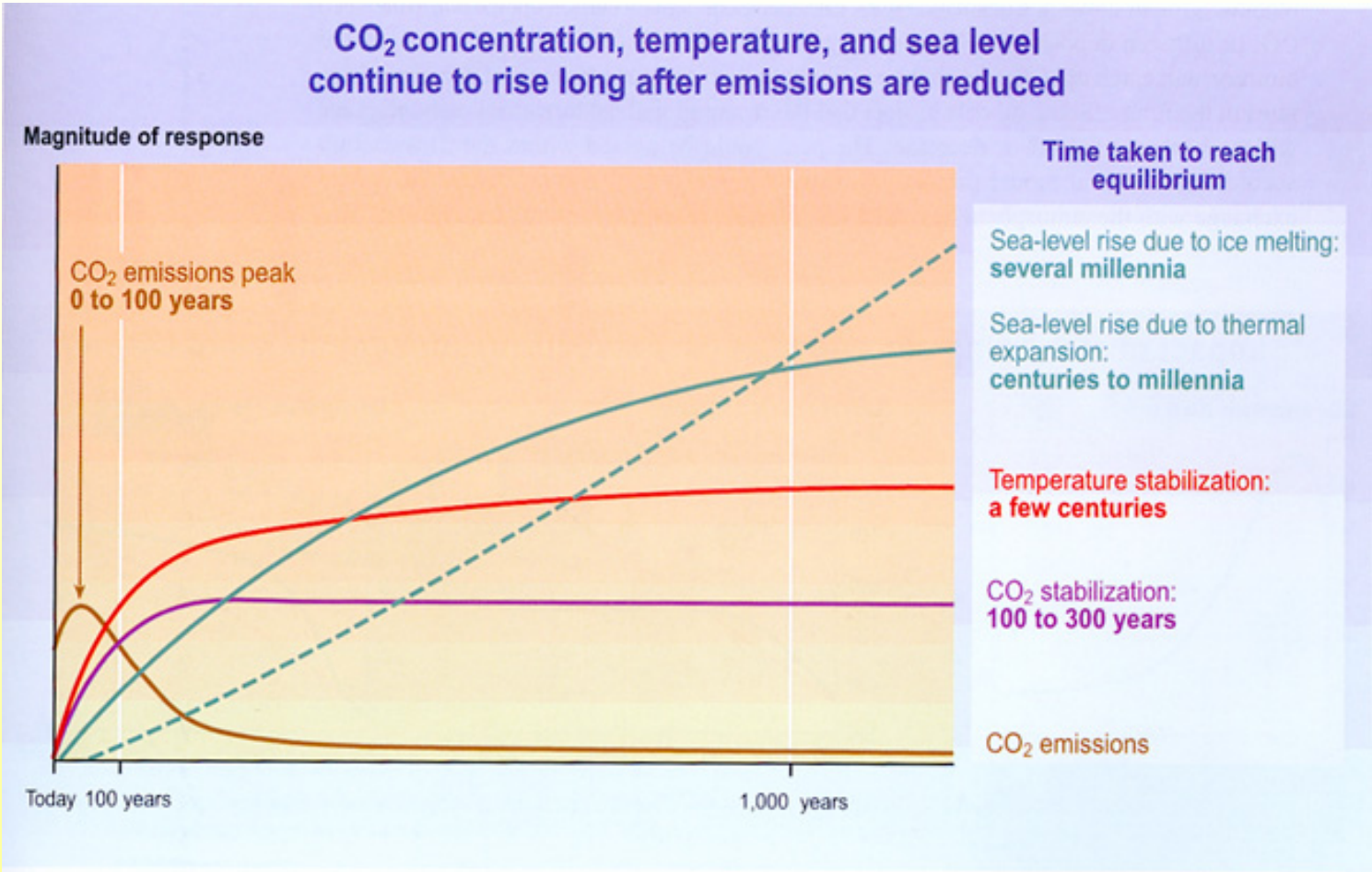

a
Atmosphere
[590]
Volcanism
<0.1
NPP
Respiration
& Fires
57
55.6
weathering
0.2
river outgassing
0.9
river export
river fluxes
70
70.6
Plants & Soil
[6850]
1.4
1.1
weathering
0.4
Ocean
[38,000]
0.5
Fossil Organic Carbon
>6000
Rock
Carbonates
Geological Reservoirs
Units are Pg C for
reservoirs and Pg C/yr for fluxes


b
circulation feedback
(ant + natural)
biota feedback
S/T feedback
200-700
<400
<20
<150
<150
DIC inert
[900]
DIC carb
DIC soft-tissue
DIC solub
Format
Diss.
NPP
Resp.
PIC
OC
Transport/Mixing
Export
Transport/Mixing
PIC
OC
Diss.
Remin
DIC inert
[31,300]
DIC carb
[600-100]
DIC soft-tissue
[2500-800]
DIC solub
[2700-400]
Units are Pg C
for reservoirs and
integrated fluxes
from 2000-2100

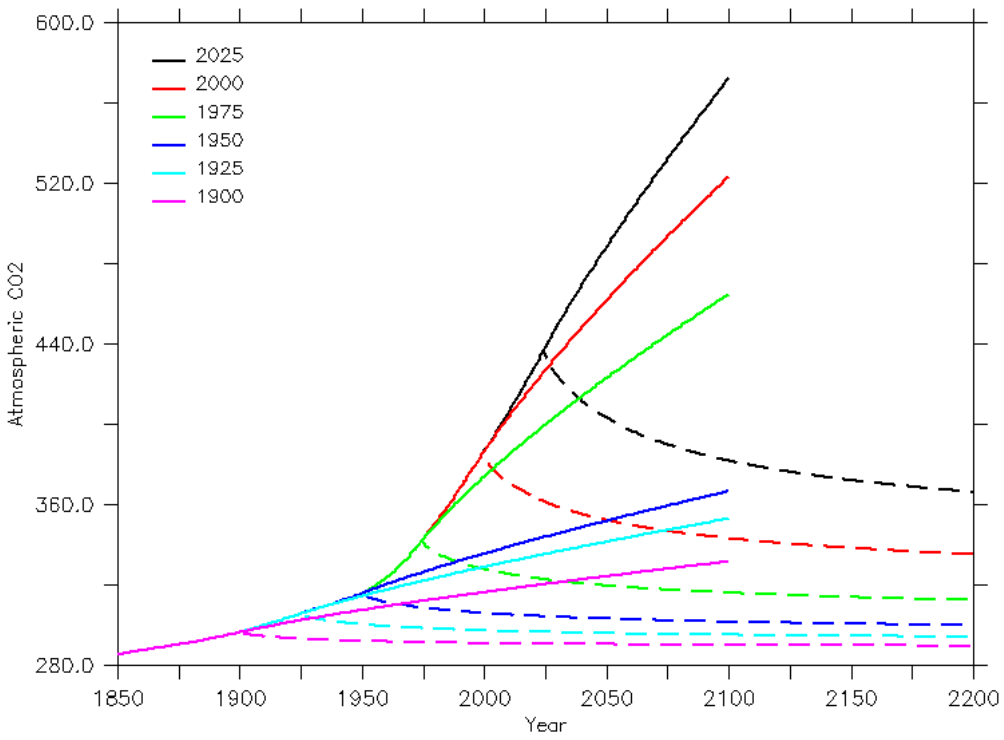

c
Permafrost
Wetland & Peatlands
Fossil Fuel
Soil sink
Soil loss
Deforestation
Ecosystem shift
CO2 fertilization
Aforestation &
others
<300
<100
500-2000
<300
<400
<100
<100
<100
<50
Plants
[650-200]
Permafrost
[3300-300]
Wetland soils
[600-100]
Conventional reserves
Coal
Oil
Gas
[730]
[250]
[200]
Other Resources
[6000]
Soils
[2300-400]
weathering
Units are Pg C for reservoirs and
for integrated fluxes from 2000-2100


C
Permafrost
Wetland & Peatlands
Fossil Fuel
Soil sink
Soil loss
Deforestation
Ecosystem shift
CO_2 fertilization
Aforestation & others
<300
<100
500-2000
<300
<400
<100
<100
<100
<50
Plants
[650-200]
Permafrost
[3300-300]
Wetland soils
[600-100]
Conventional reserves
Coal Oil Gas
[730] [250] [200]
Other Resources [6000]
Soils
[2300-400]
weathering
Units are Pg C for reservoirs and
for integrated fluxes from 2000-2100

Time scale issue



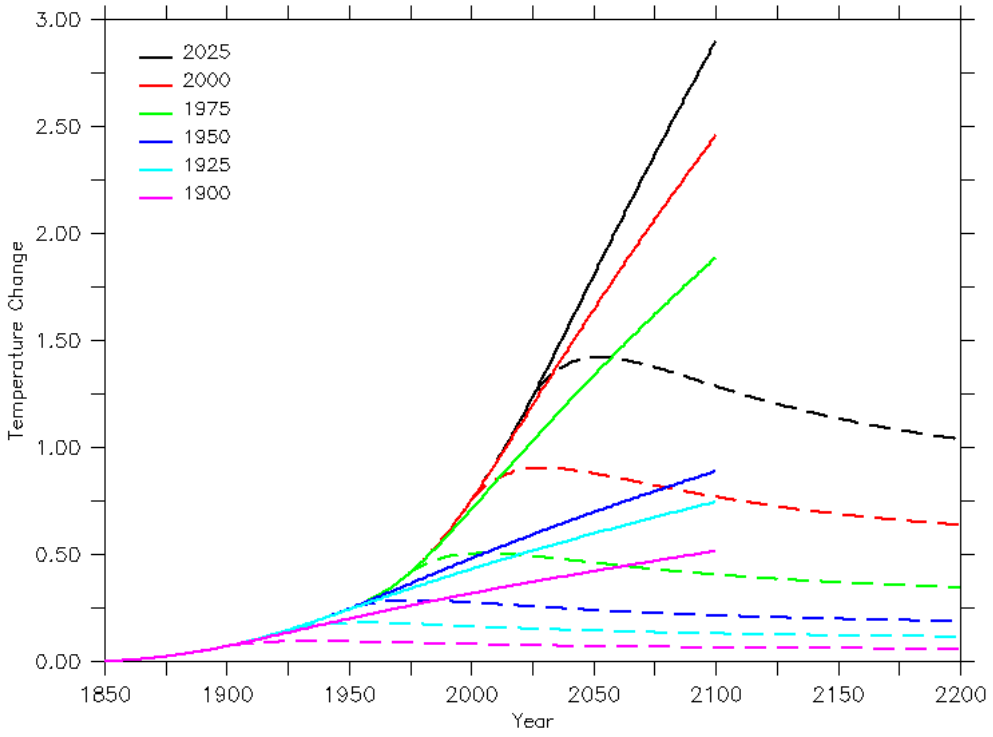
Time scale issue



—— Cst emission

- - - - Zero emission

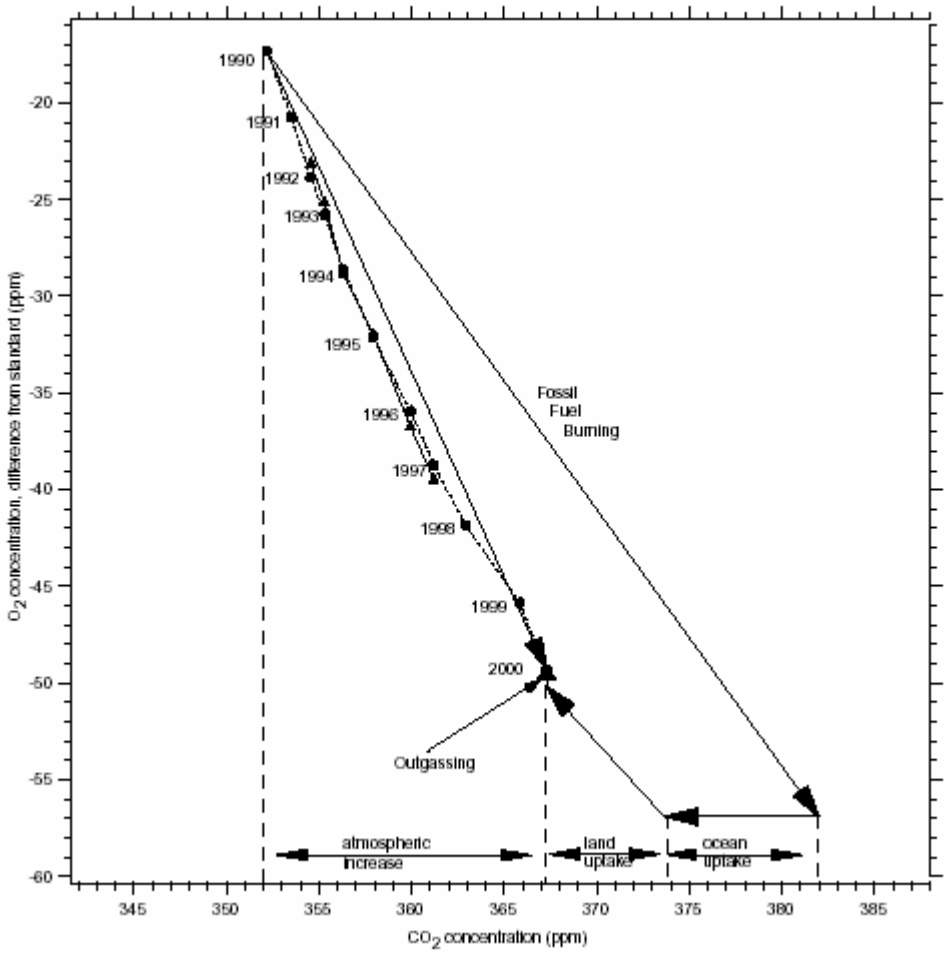
Time scale issue

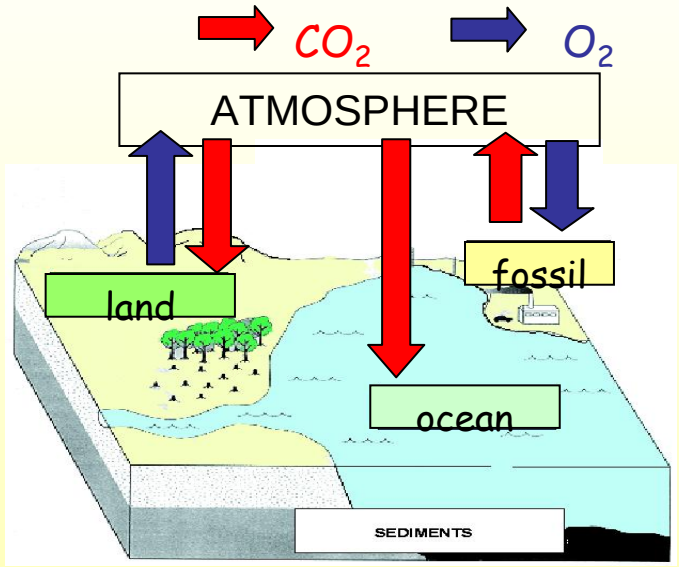


—— Cst emission

- - - - Zero emission

Global carbon budget





CO_2 = FF - Land - Ocean

O_2 = α FF - β Land

15th 2005