EarthClim

Geofysisk institutt
Universitetet i Bergen

Bjerknes Centre
for Climate Research

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For WP4.1
Physical and biogeochemical feedback analysis of NorESM results

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OVERVIEW

WP4.1–Feedback quantifications and separation of feedbacks

Task description, physical feedbacks:
We will implement and apply the "partial radiative perturbation method" (Soden &Held 2006) for ESMs, to quantify the different radiative feedbacks (water vapour, lapse rate,surface albedo, clouds).

Task description, carbon cycle feedbacks:
The carbon cycle feedback will be assessed through full ESM simulations (full coupled simulations for pre-industrial CO_2 and anthropogenic CO_2 emissions and simulations where the carbon cycle does not see climate change but only increasing CO_2) in order to separate the feedback of climate change to the carbon fluxes (γ factors for land and ocean) and the feedback of atmospheric CO_2 itself on the carbon fluxes (ß factors for land and ocean) following
Friedlingstein *et al.* (2003, 2006).

Planned deliverables:
D4.1: Manuscript on radiative forcing/feedback quantifications for CMIP5 simulations (*Dec 2012*).
D4.2: Manuscript on carbon cycle feedback analysis in CMIP5 simulations (*Dec 2012*).

Climate Sensitivity and feedbacks

One approach is to assume the temperature change is directly related to the response in radiative forcing (F) at TOA (ΔR) in a linear way

$$\Delta R = F + \lambda \cdot \Delta T$$

F: Change in radiative forcing

λ is the **feedback factor**

Physical feedback analysis – status:

Still to be carried out for NorESM (post-doc has been hired for this).

Bu⁺

1% per year simulations Full carboncycle

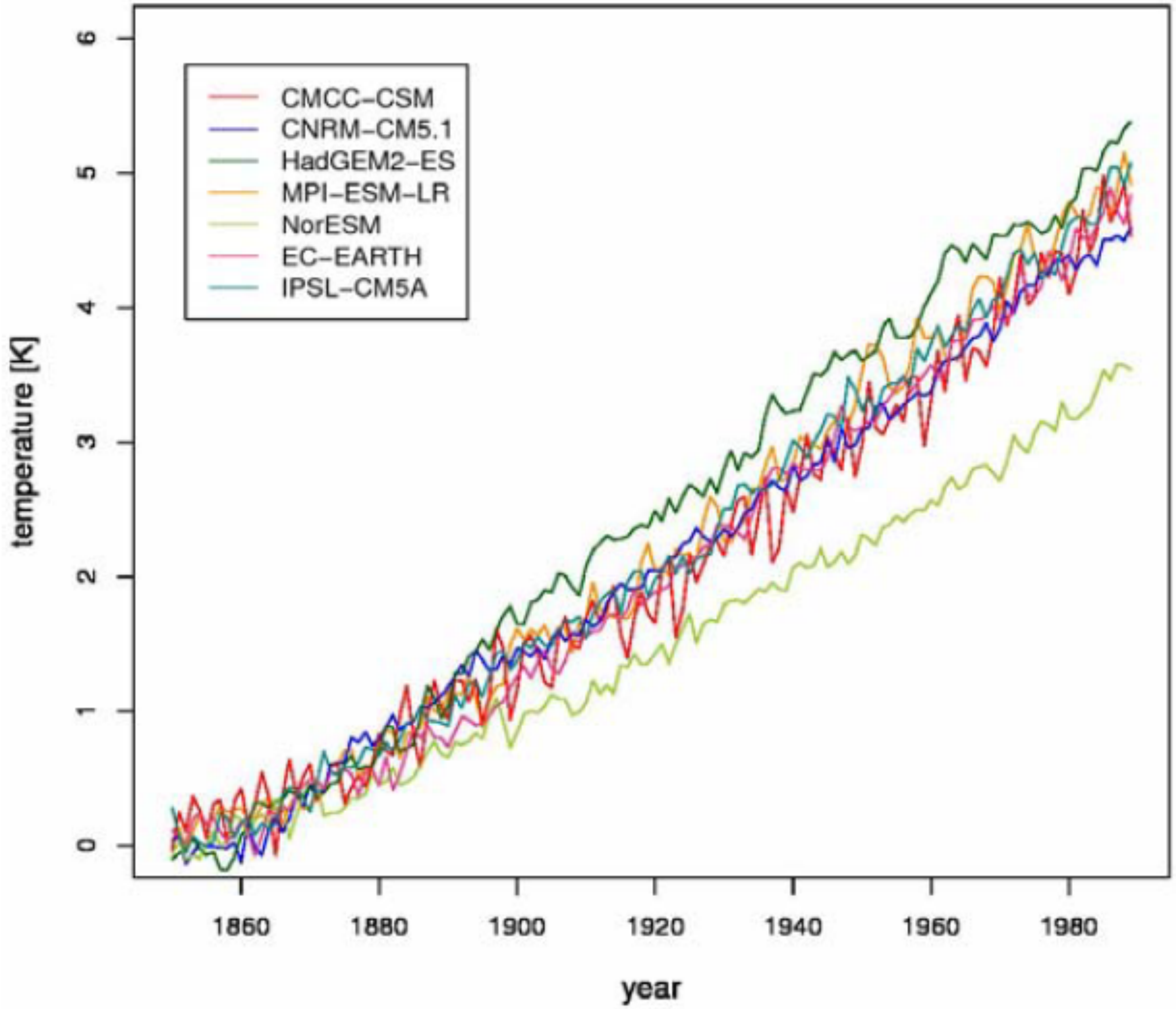
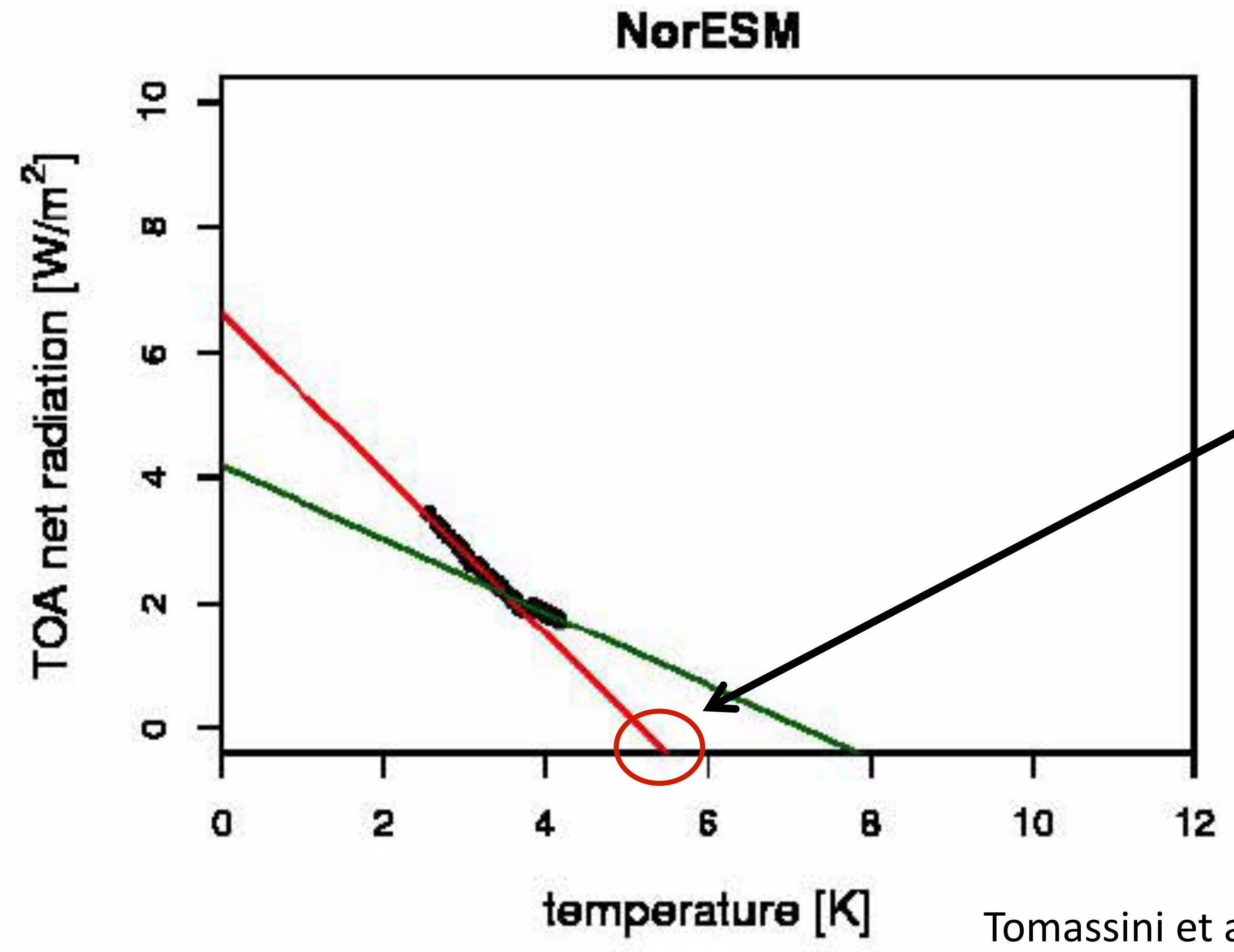


Figure 1: Temperature response to a 1 % per year increase in CO_2 concentration for seven different CMIP 5 models.

In kind EU project COMBINE, Tomassini et al.

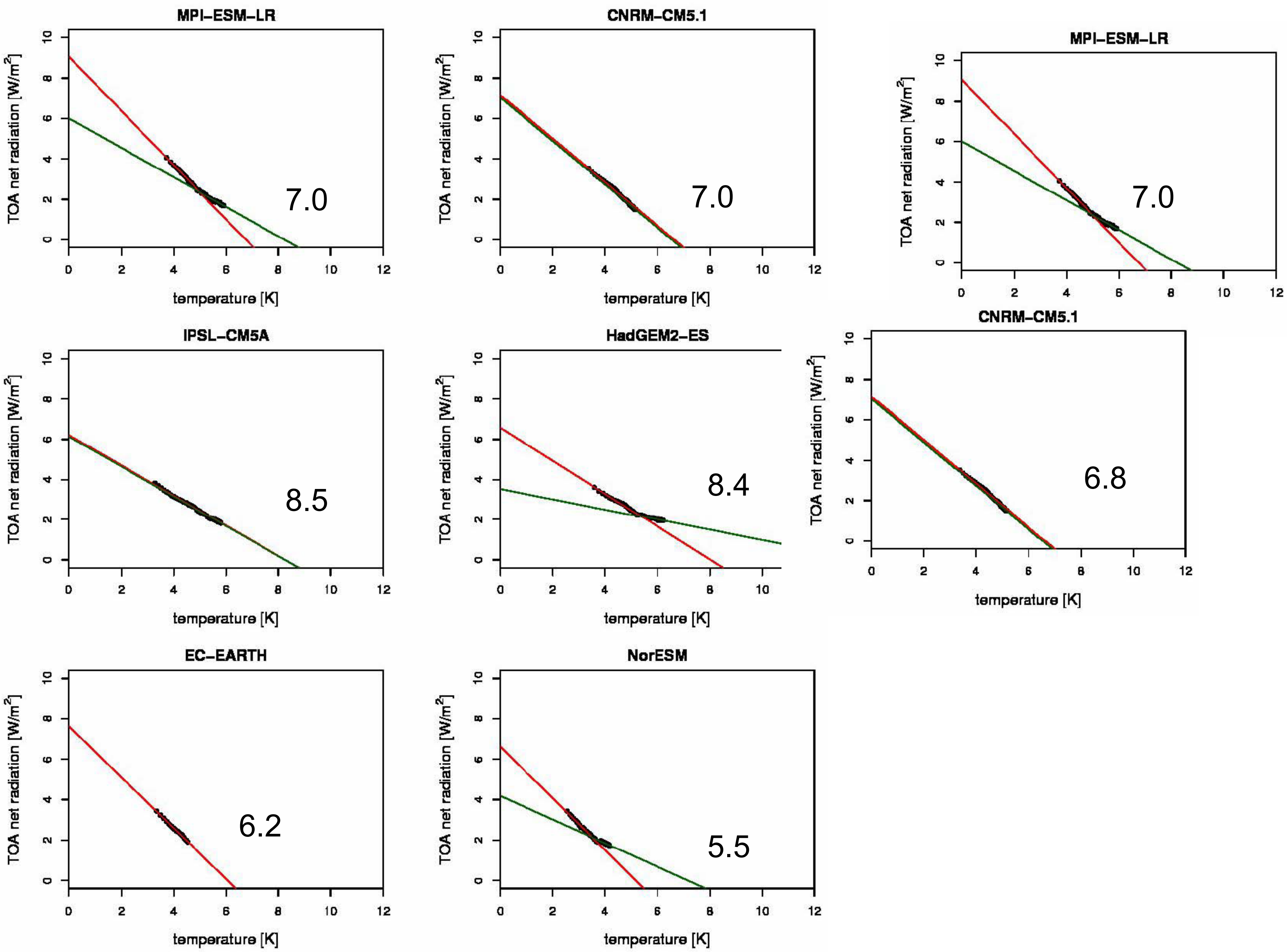
$$\Delta R = F + \lambda \cdot \Delta T$$

4*CO_2 simulation
No carboncycle



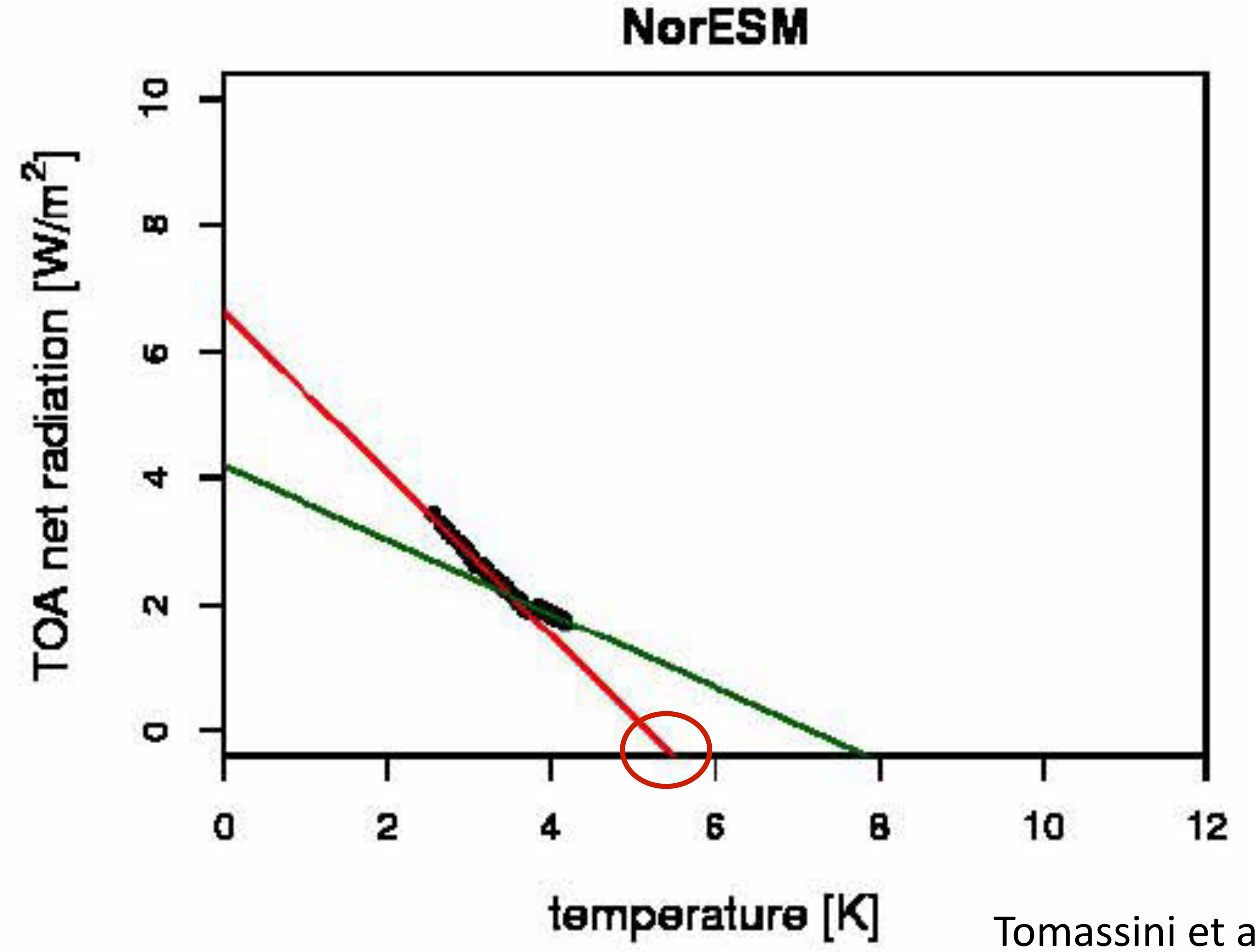
5.5°C

Tomassini et al.


MPI-ESM-LR
TOA net radiation [W/m^2]
temperature [K]
7.0
CNRM-CM5.1
TOA net radiation [W/m^2]
temperature [K]
7.0
MPI-ESM-LR
TOA net radiation [W/m^2]
temperature [K]
7.0
IPSL-CM5A
TOA net radiation [W/m^2]
temperature [K]
8.5
HadGEM2-ES
TOA net radiation [W/m^2]
temperature [K]
8.4
CNRM-CM5.1
TOA net radiation [W/m^2]
temperature [K]
6.8
EC-EARTH
TOA net radiation [W/m^2]
temperature [K]
6.2
NorESM
TOA net radiation [W/m^2]
temperature [K]
5.5

$$\Delta R = F + \lambda \cdot \Delta T$$

$4*CO_2$ simulation



Tomassini et al.

NorESM: 5.5°C
AVG: 7.1°C

Carbon cycle feedbacks - methodology:

3 runs instead of only 2 as planned. (The RAD run is a “bonus track”.)

- COU: fully coupled 1% CO_2 increase y^{-1}
- BGC: as COU but radiation code “see” preindustrial CO_2
- RAD: as COU but land and ocean “sees” preindustrial CO_2 models, this exercise is new in CMIP5)

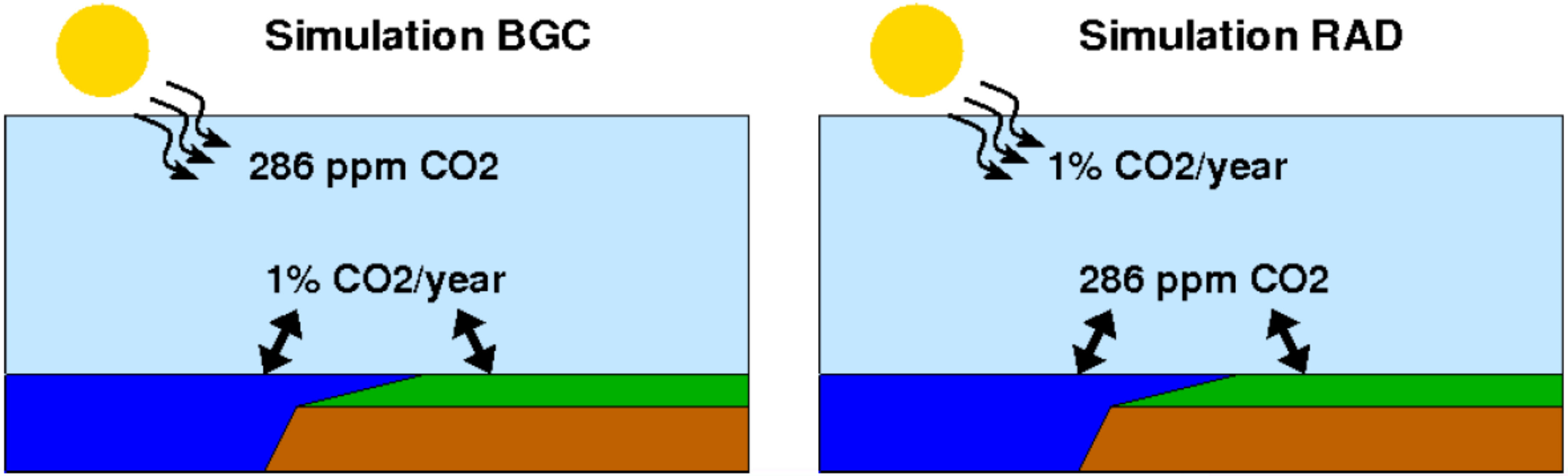


Figure and text courtesy: Jörg Schwinger, UiB

Carbon cycle feedbacks - methodology:

- Here: Not a true feedback-analysis, since atmospheric CO_2 is fixed (1% CO_2 per year increase).
- Assumptions:
  - Total change in carbon storage ΔC is a linear combination of contributions due to rising antropogenic atmospheric CO_2 and due to climate change:

$$\Delta C = \Delta C_{CO2} + \Delta C_{Clim}.$$

  - ΔC_{CO2} is a linear function of atmospheric CO_2 concentration:

$$\Delta C_{CO2} = \beta \, \Delta CO_2.$$

  - ΔC_{Clim} is a linear function of temperature change ΔT (that is ΔT serves as a proxy for climate change)

$$\Delta C_{Clim} = \gamma \, \Delta T.$$

Text courtesy: Jörg Schwinger, UiB

Carbon cycle feedbacks - methodology:

Due to the fact that we not only have the COU and BGC runs, but also the RAD run, we can determine the feedback factors through different combinations.
Unfortunately, γ^{cou} and γ^{rad} do not coincide.

Assuming $\Delta T^{bgc} \approx 0$ (no climate change in BGC simulation):

$$\Delta C^{cou} = \beta^{cou} \Delta CO_2^{cou} + \gamma^{cou} \Delta T^{cou}$$

$$\Delta C^{bgc} = \beta^{bgc} \Delta CO_2^{bgc}$$

Assuming $\beta^{cou} = \beta^{bgc} = \beta$

$$\Delta C^{cou} - \Delta C^{bgc} = \beta(\Delta CO_2^{cou} - \Delta CO_2^{bgc}) + \gamma^{cou} \Delta T^{cou}$$

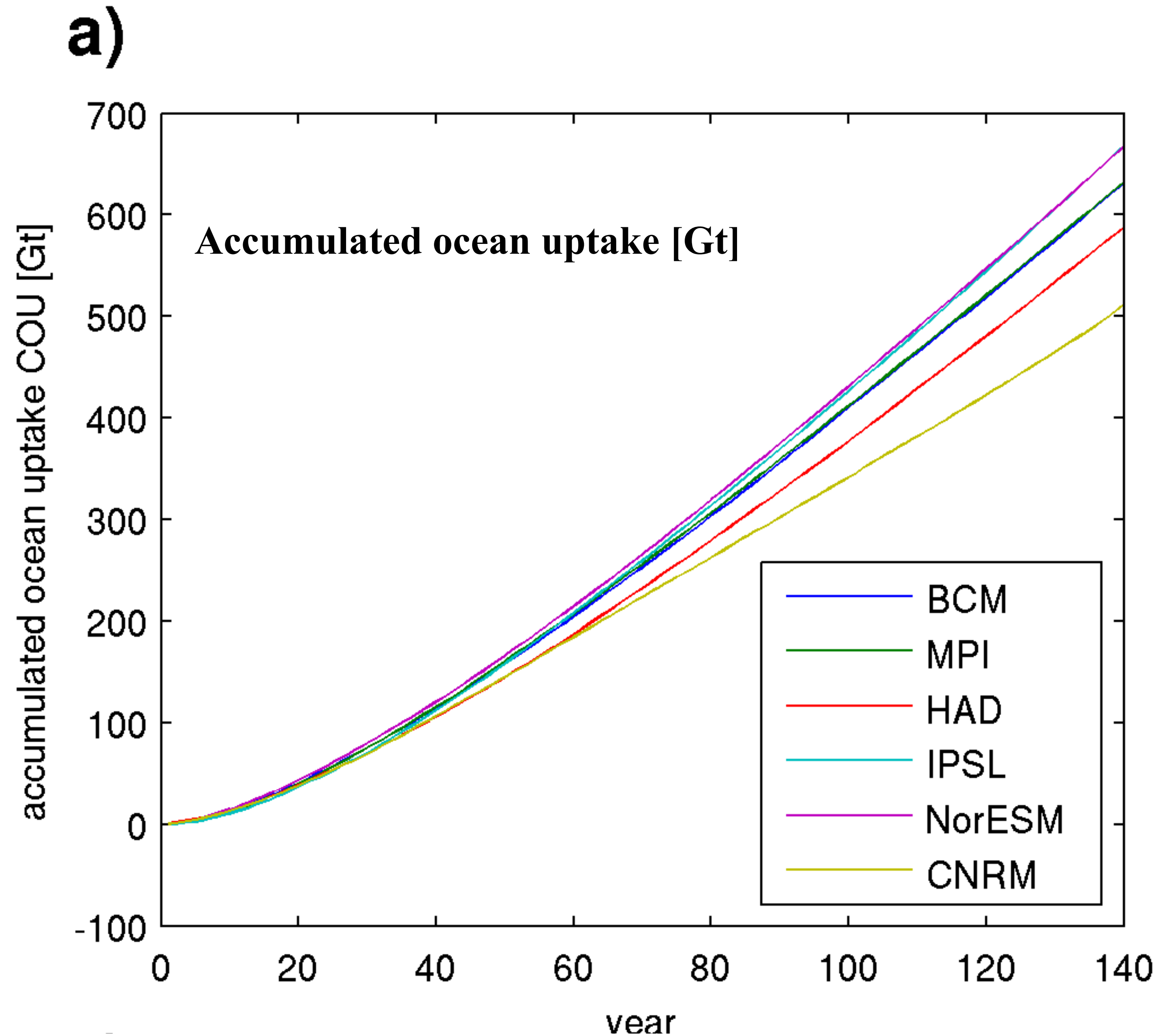
Here: prescribed atmospheric CO_2 => $\Delta CO_2^{cou} - \Delta CO_2^{bgc} = 0$

$$\Delta C^{cou} - \Delta C^{bgc} = \gamma^{cou} \Delta T^{cou}$$

$$\Delta C^{rad} = \gamma^{rad} \Delta T^{rad}$$

Text courtesy: Jörg Schwinger, UiB

Carbon cycle feedbacks - status:



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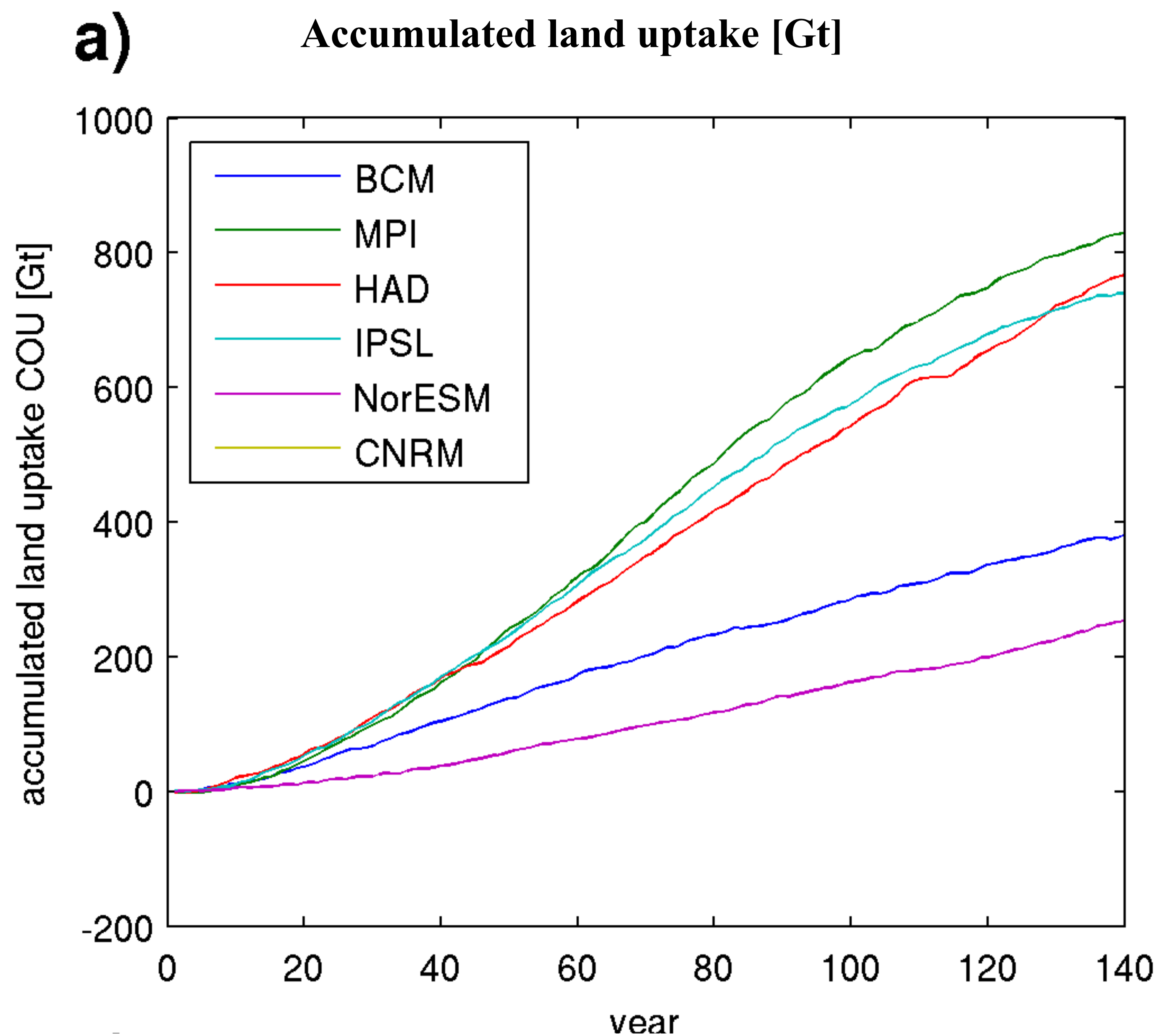
Carbon cycle feedbacks - status:



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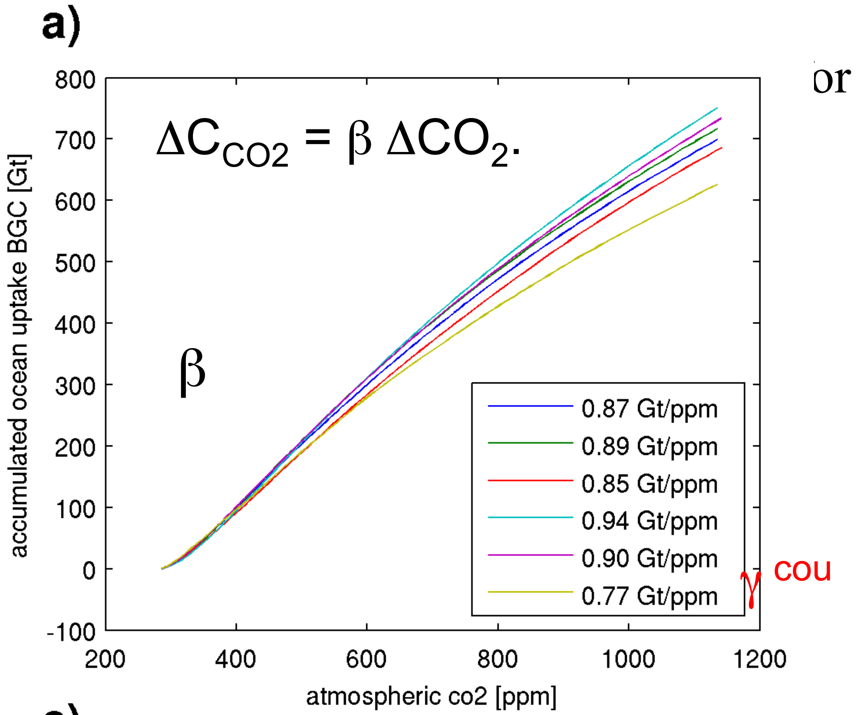
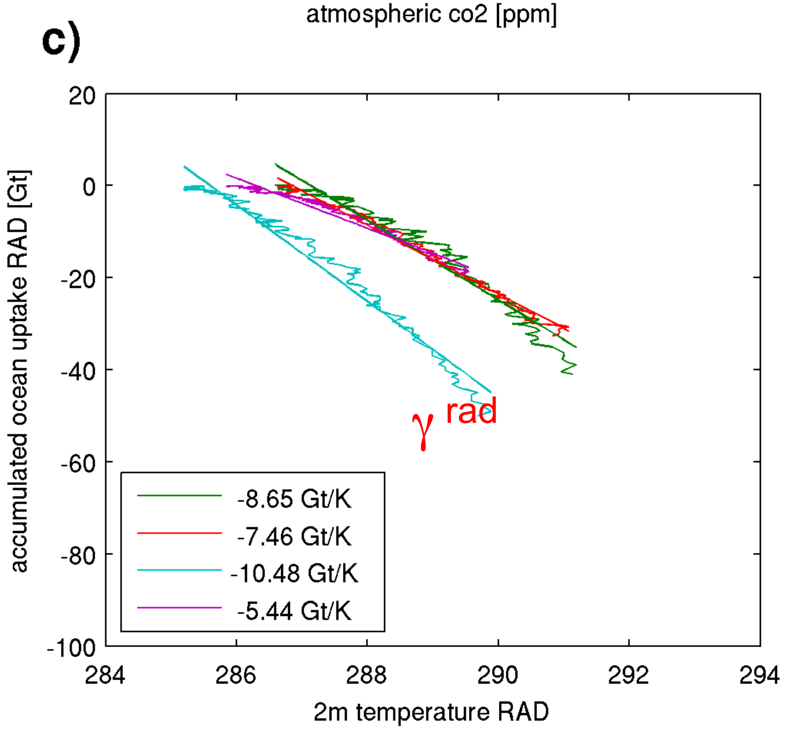
Carbon cycle feedbacks - status:

Rur… …or the 1%CO_2 scenario. Ocean

fact…





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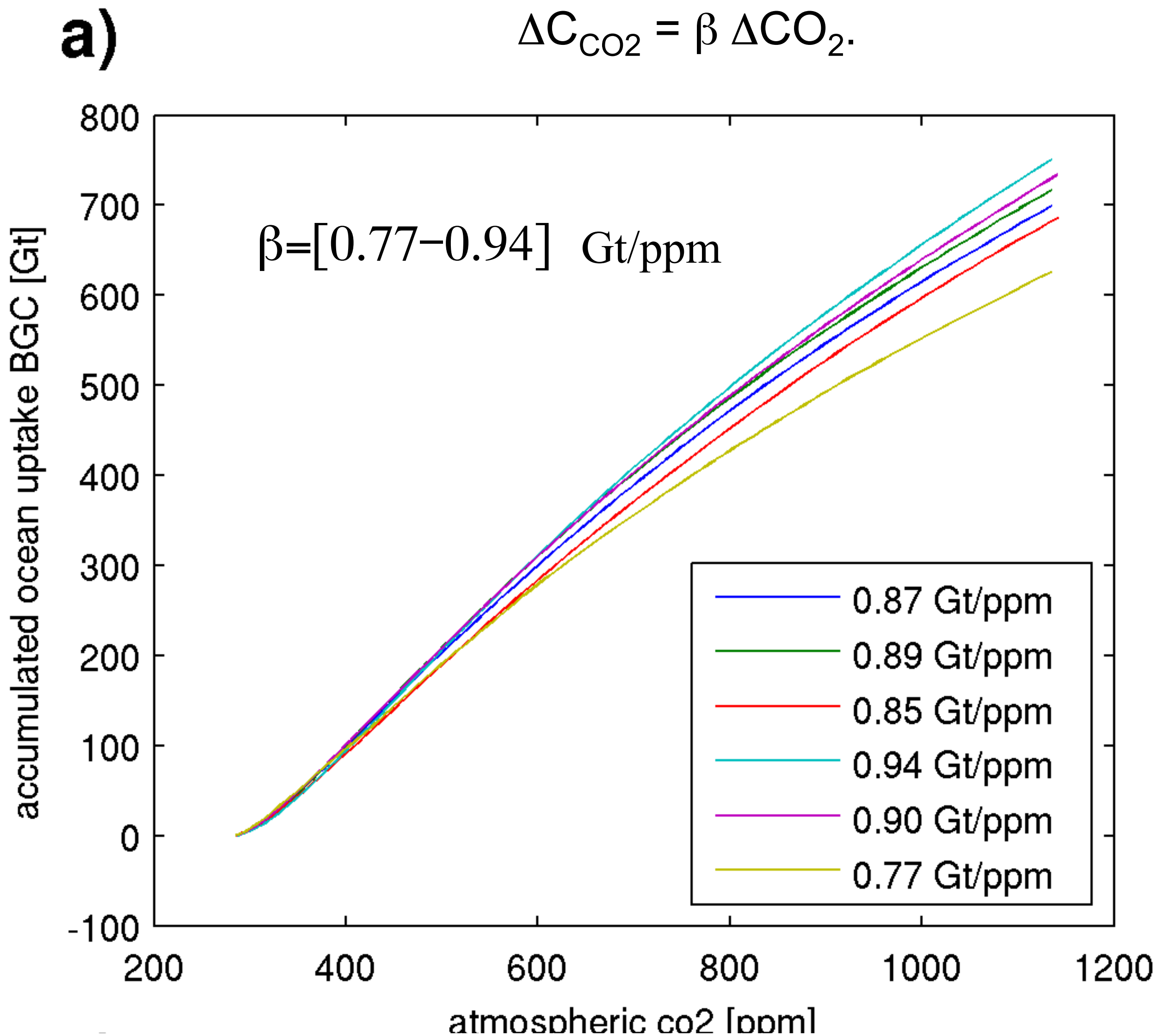
Ocean uptake [Gt] due to increased co_2, not temp change

$$\Delta C_{CO2} = \beta \, \Delta CO_2.$$



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Carbon cycle feedbacks - status:

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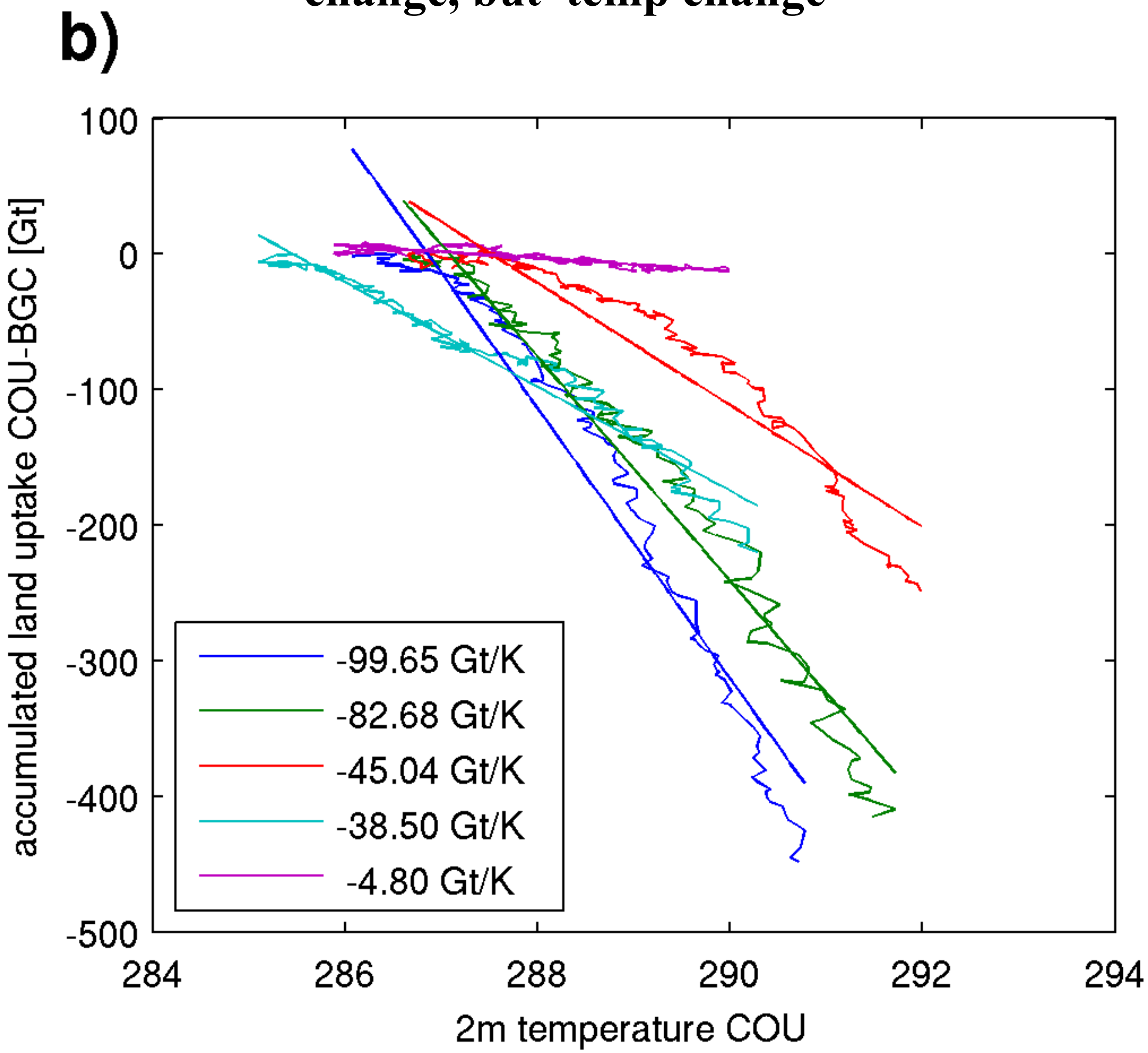
Land uptake [Gt] due to no co_2 change, but temp change



γ^{cou}= [-4.8 -99.65]Gt/K

γ^{rad}= [-16.6 -82.1]Gt/K

Unfortunately, γ^{cou} and γ^{rad} do not coincide.

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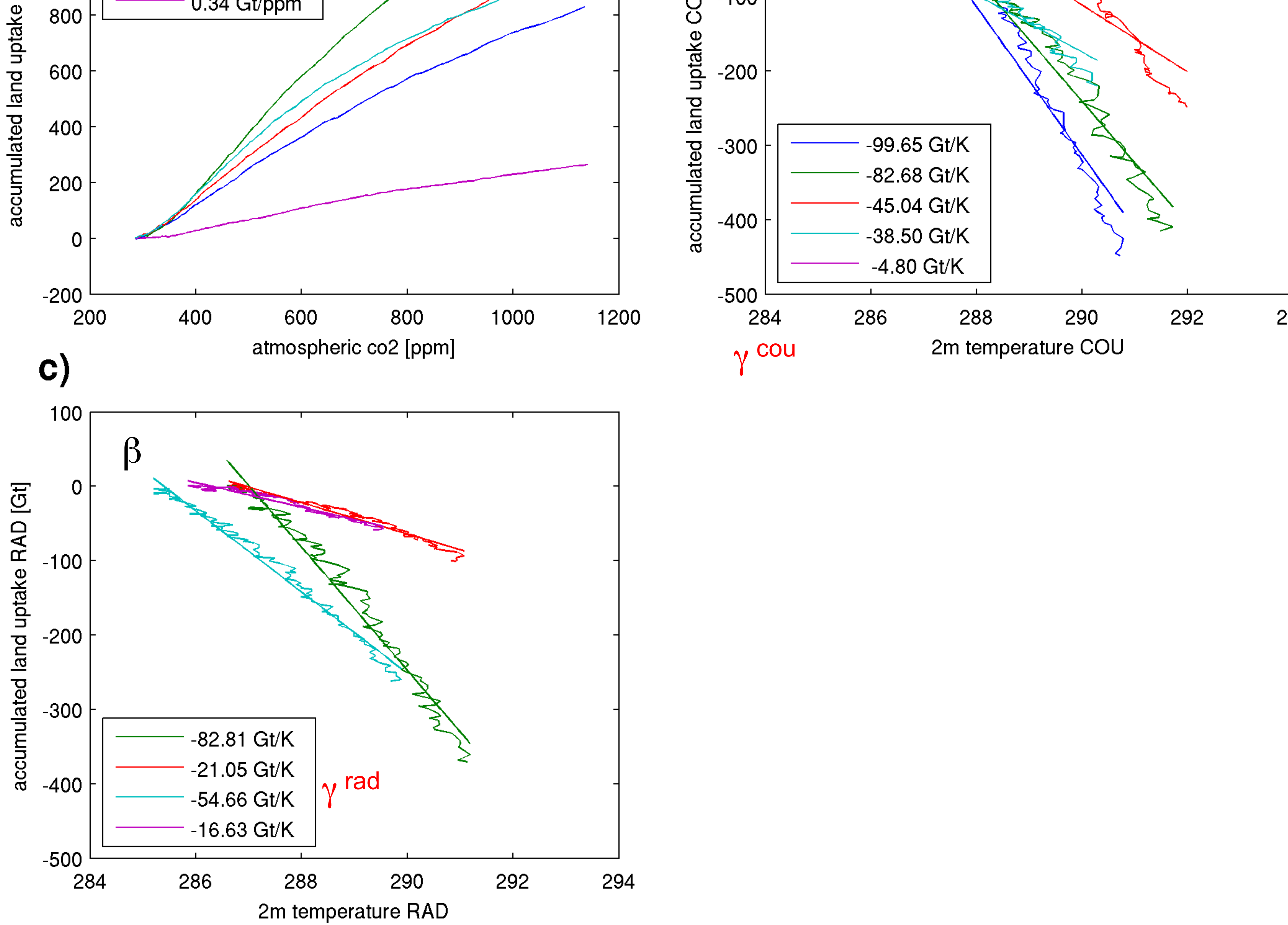

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Adjustment of the time table in view of the extension:

Physical feedback analysis is delayed by ca. 6 months and will be carried out during the extended second phase of EarthClim.

The carbon cycle feedback analysis for NorESM has been carried. Due to the (new and not yet known) discrepancy concerning the feedback separation of the carbon cycle feedbacks (climate effect on C cycle, biogeochemical effect on C cycle) some further thoughts are necessary to provide an explanation for the uncertainties in the γ-factor.

The two deliverables will be somewhat delayed:
D4.1: Manuscript on radiative forcing/feedback quantifications for CMIP5 simulations (*Dec 2013* instead of *Dec 2012*).
D4.2: Manuscript on carbon cycle feedback analysis in CMIP5 simulations (*June 2013* instead of *Dec 2012*).