Coupled Carbon-Climate Simulations at IPSL

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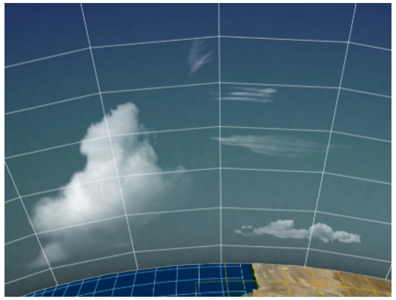
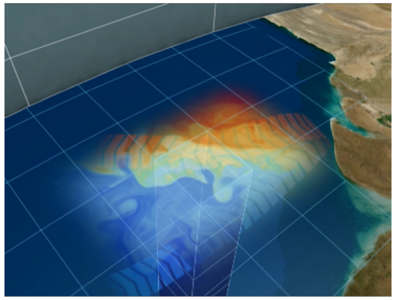
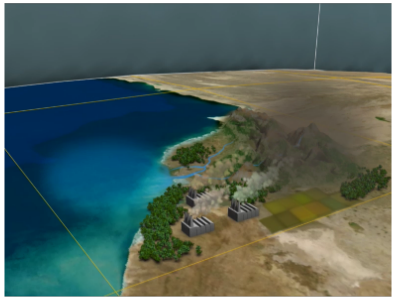
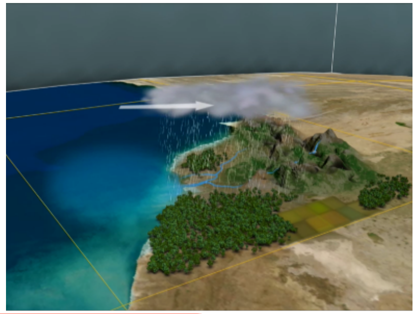
The Earth System Model of the IPSL





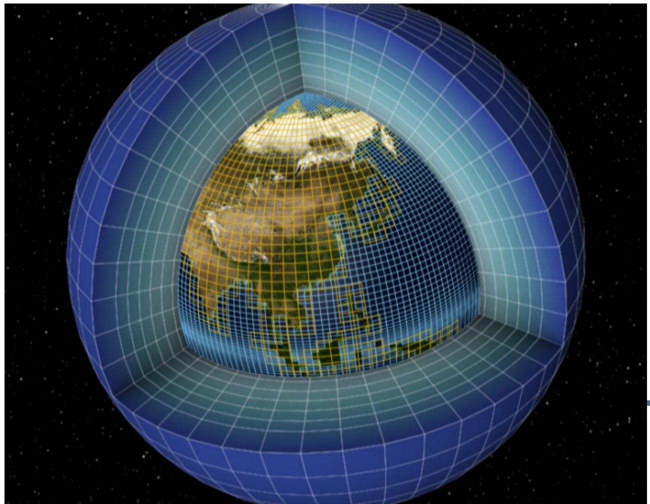




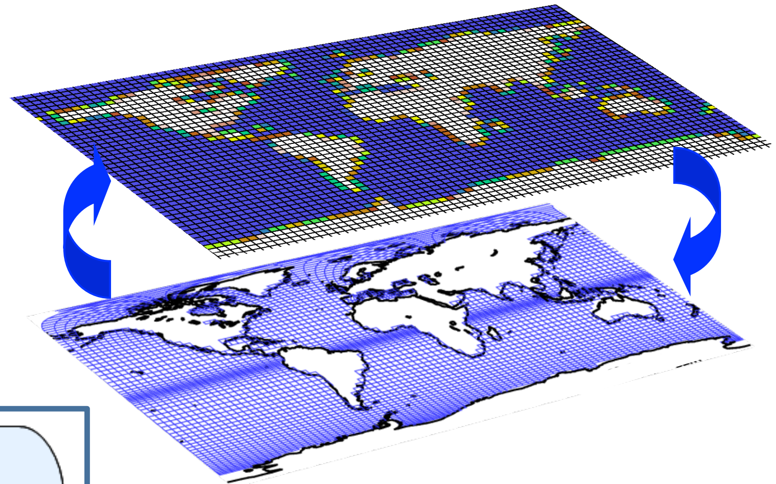
INCA / REPROBUS
(chimie atmosphérique)
(aérosol)

ORCHIDEE
(surfaces continentales)
(végétation)

LMDZ
(atmosphère)



OASIS
(coupleur)



OPA
(océan)

LIM
(glace de mer)

NEMO

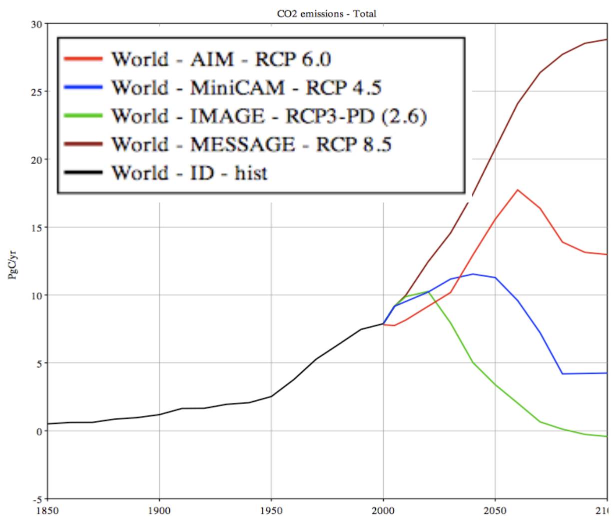
PISCES
(biogéochimie marine)

SOFIE
SINO-FRENCH INSTITUTE FOR EARTH SYST

Most components are developed at IPSL

courtesy of Dufresne

Climate Modelling

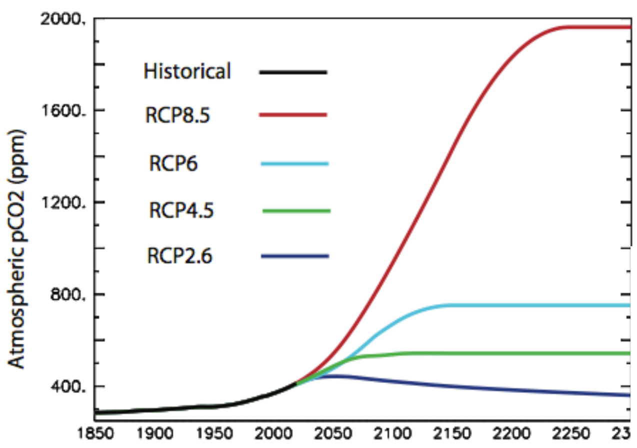


[RCP Database, version 2.0.3]

Emissions

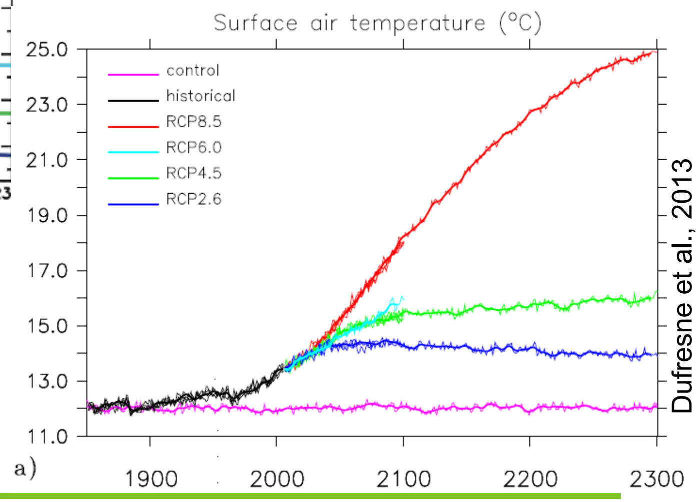
IAMs (Integrated Assessment Models)

Concentrations



Climate Models

Climate



Climate Modelling
Biogeochemical approach

Carbon Cycle

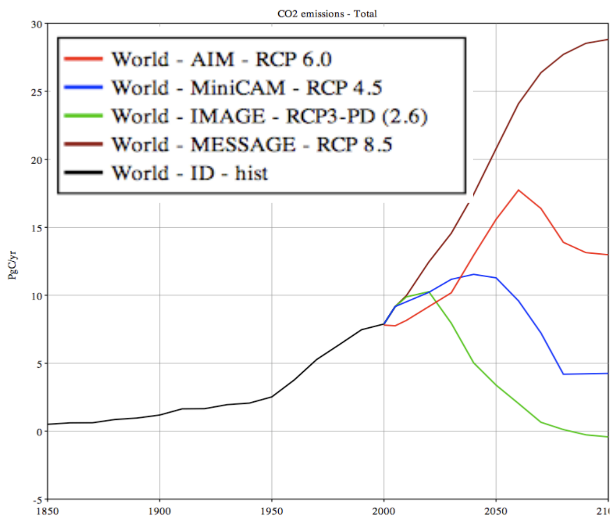
Compatible Emissions

Emissions

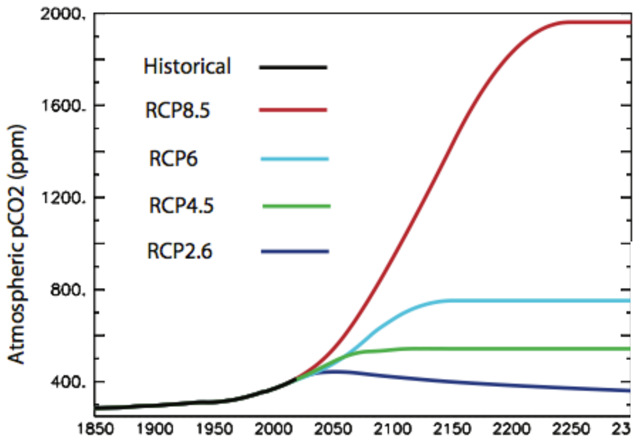
Concentrations

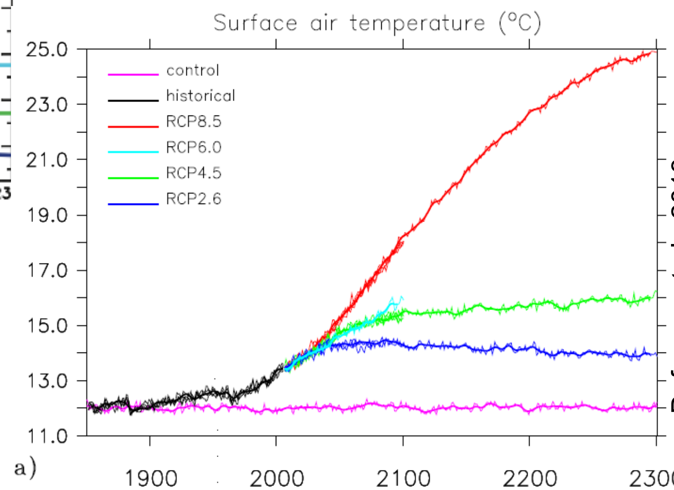
Carbon Climate Coupled Models

Climate



[RCP Database, version 2.0.3]



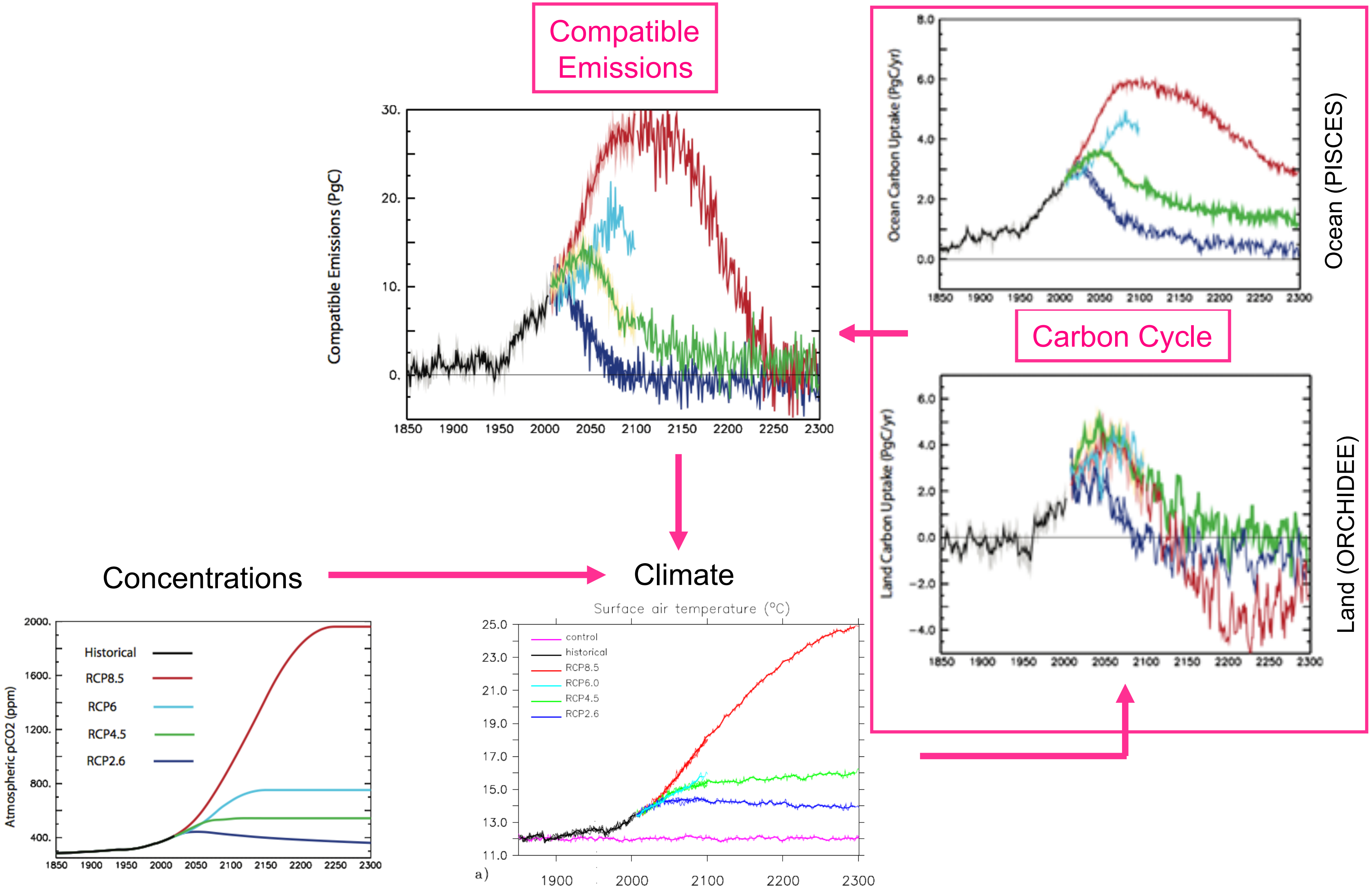


Dufresne et al., 2013

Feedback loop between climate and carbon cycle

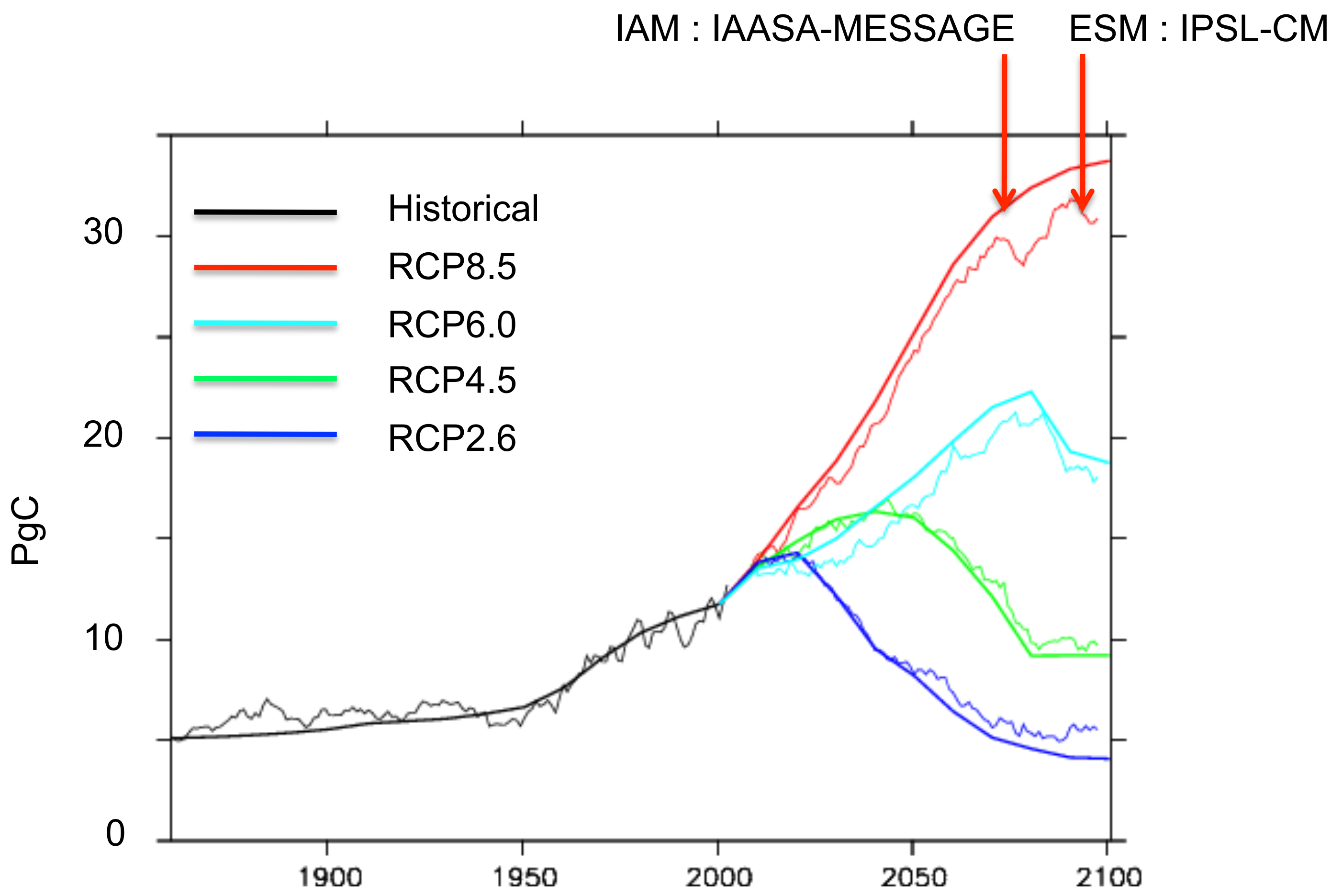
Fossil Fuel Compatible Emissions

IPSL model



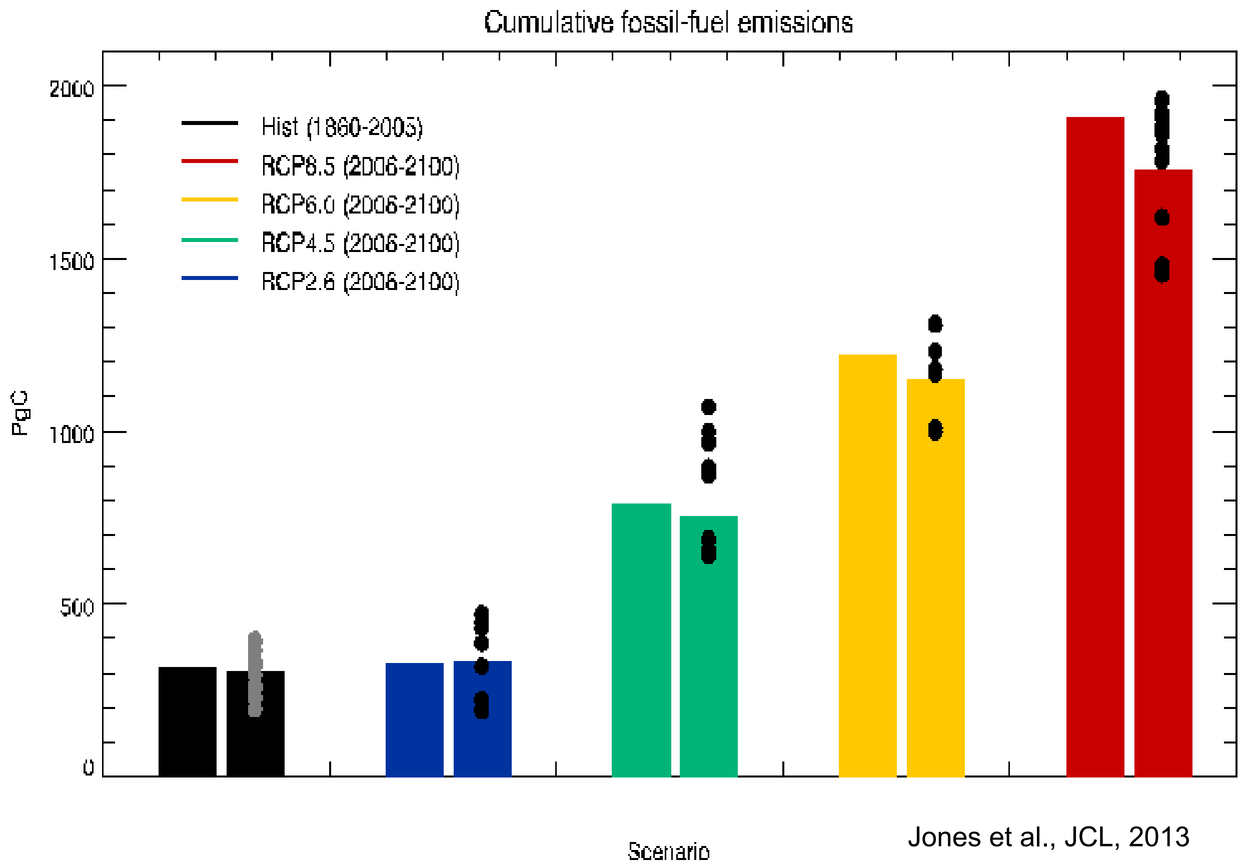
Fossil Fuel Compatible Emissions

IPSL Vs. IAM



Emissions computed by the IPSL model are substantially lower than IAMs for RCP8.5 and RCP6.0

Fossil Fuel Compatible Emissions
CMIP5



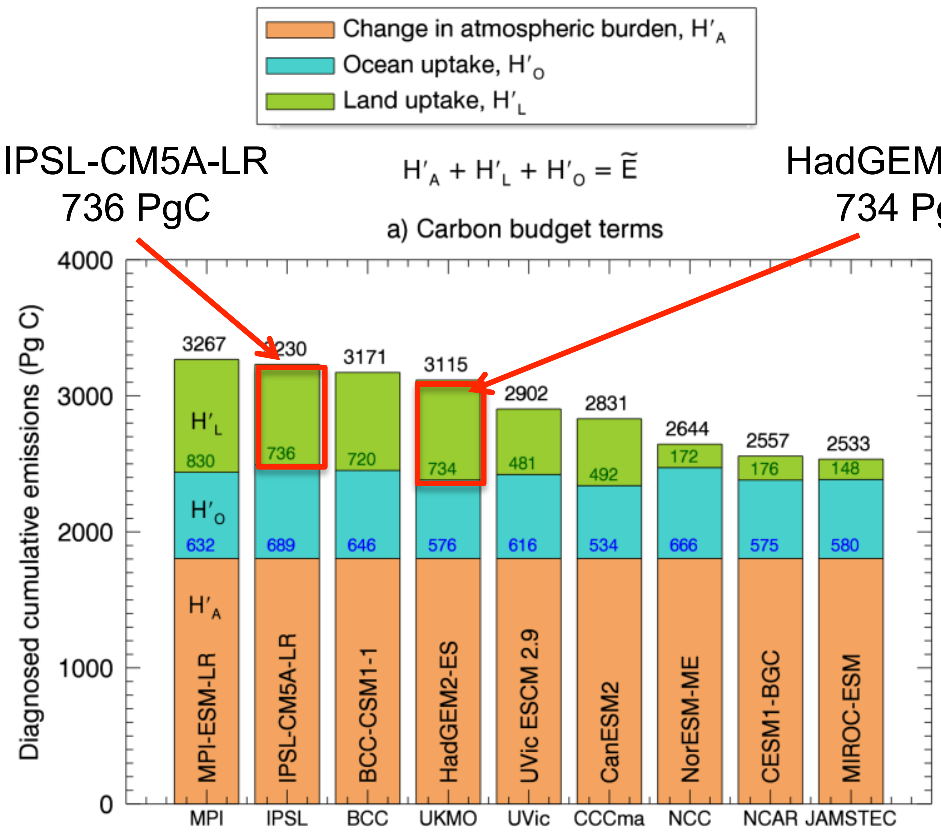
Jones et al., JCL, 2013

In the high-end scenarios, RCP 8.5 and to a lesser extent RCP6.0, the CMIP5 models on average project lower compatible emissions than the IAMs. This indicates that positive climate-carbon cycle feedback, which leads to reduced natural carbon uptake (Friedlingstein et al., 2006; Arora et al, 2012), is stronger in ES-GCMs than in the IAMs under higher levels of climate change

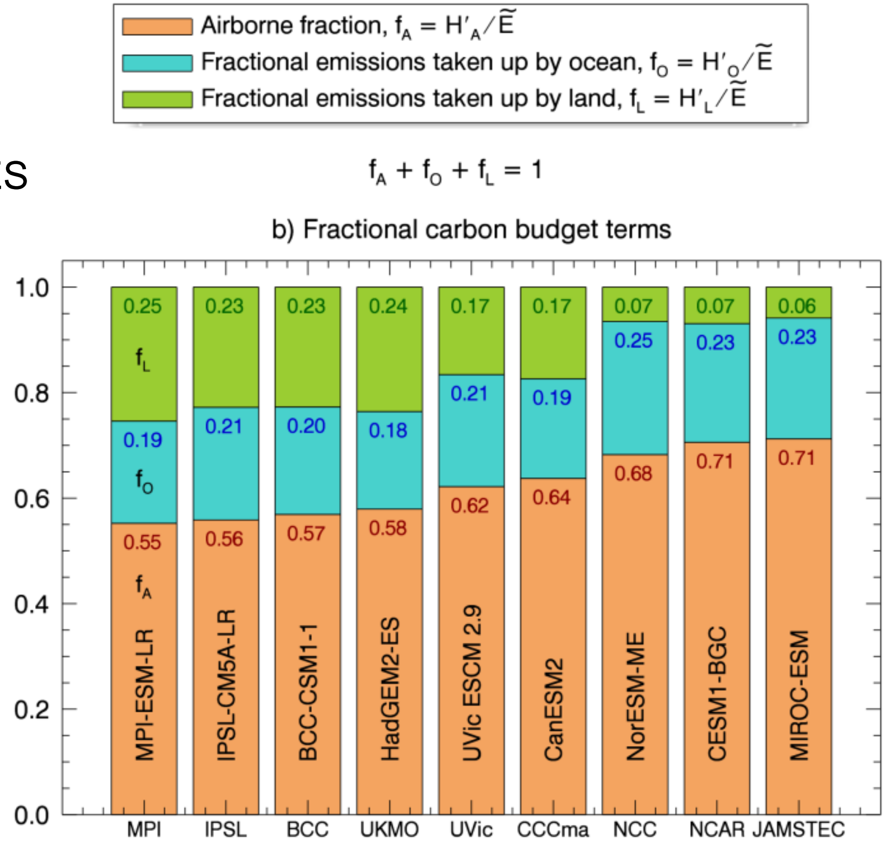
Compatible fossil fuel emissions from CMIP5 models for the historical period (black) and the 4 RCP scenarios for the 21st century (colours)

Fossil Fuel Compatible Emissions

CMIP5



Arora et al., 2013

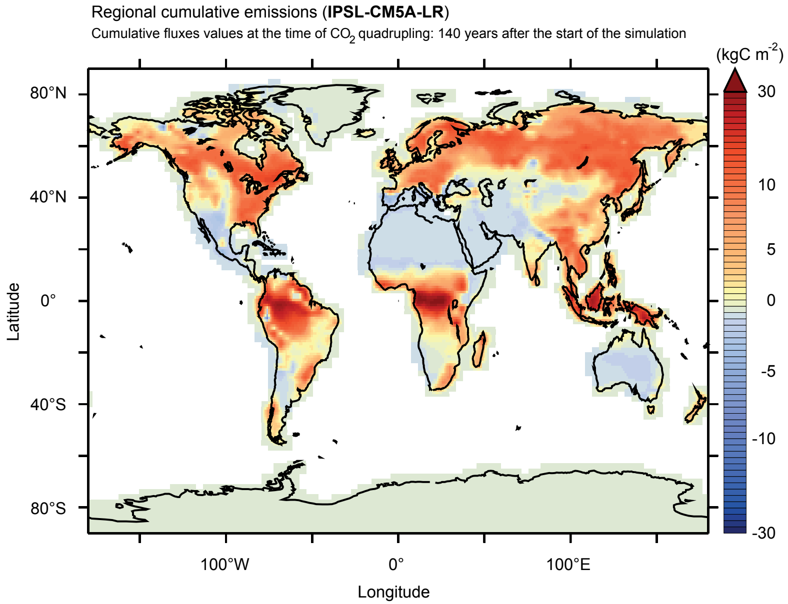


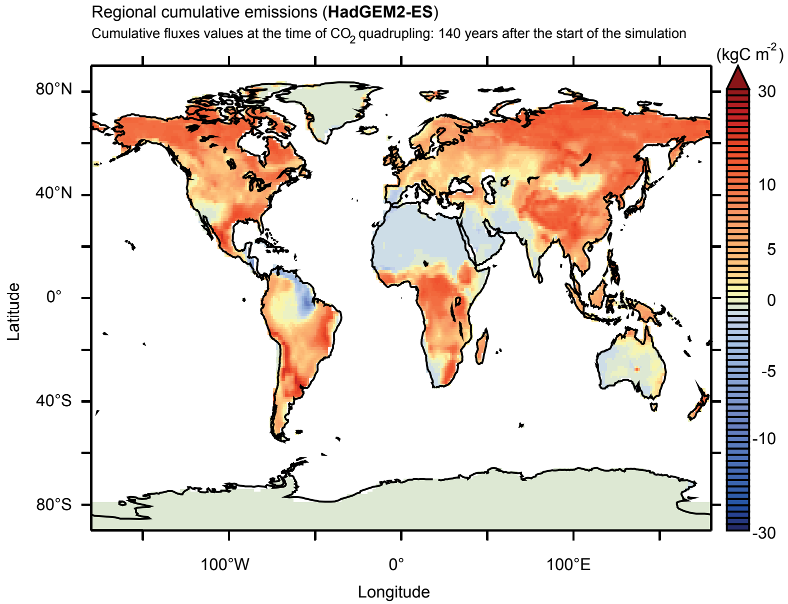
Arora et al., 2013

Wide variety of responses of the terrestrial biosphere

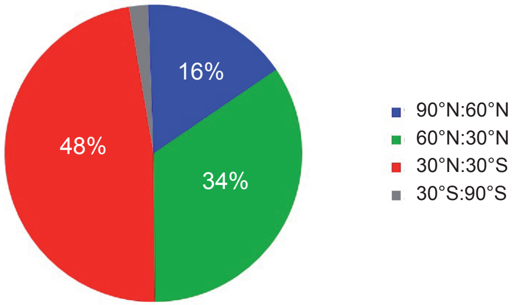
The differences among models are primarily due to the diverse response of the land carbon cycle components

Differences in spatial repartion of cummulative emissions

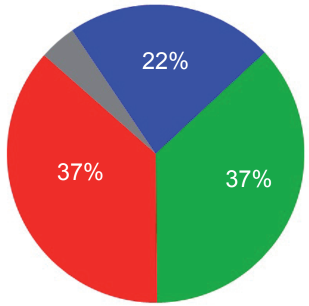




IPSL-CM5A-LR
736 PgC



IPSL-CM5A-LR

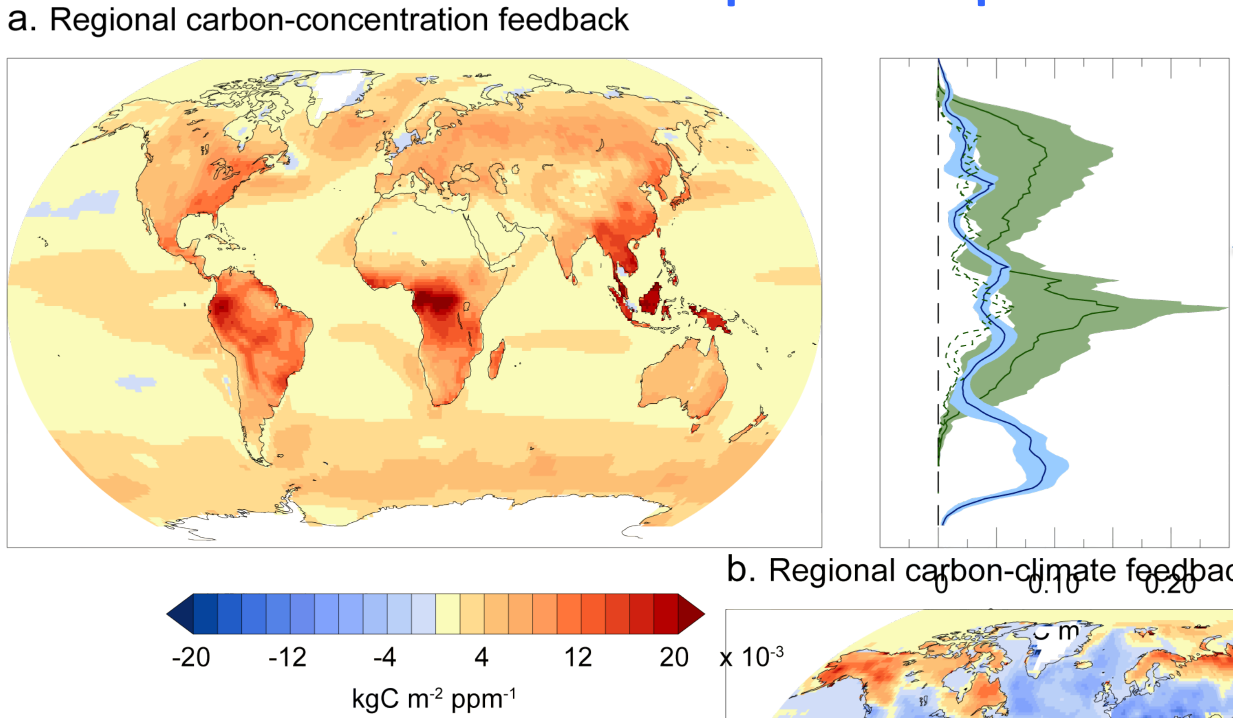


HadGEM2-ES

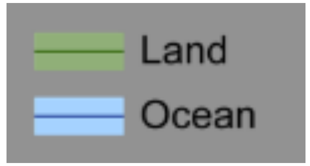
HadGEM2-ES
734 PgC

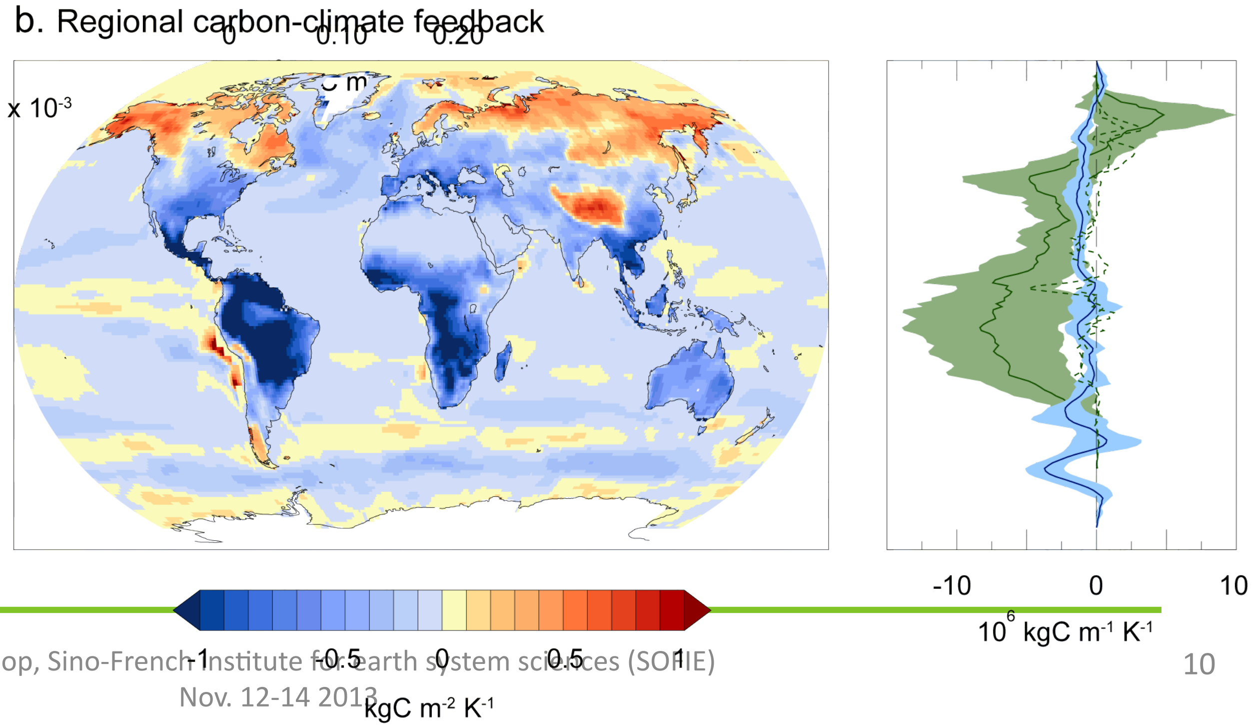
IPSL-CM5A-LR accumulates more carbon in Europe and in the Amazonian bassin than HadGEM2-ES

Spatial distributions of multi model-mean land and ocean β and γ



Carbon Concentration Feedback (beta)

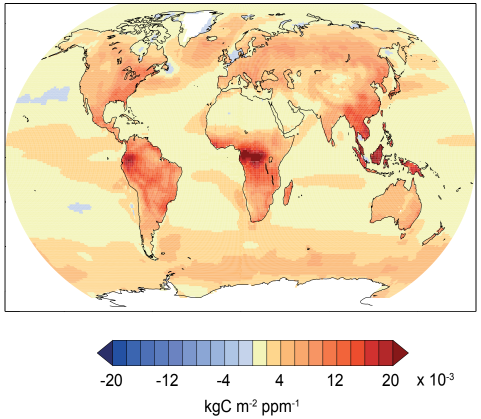




Carbon Climate Feedback (gamma)

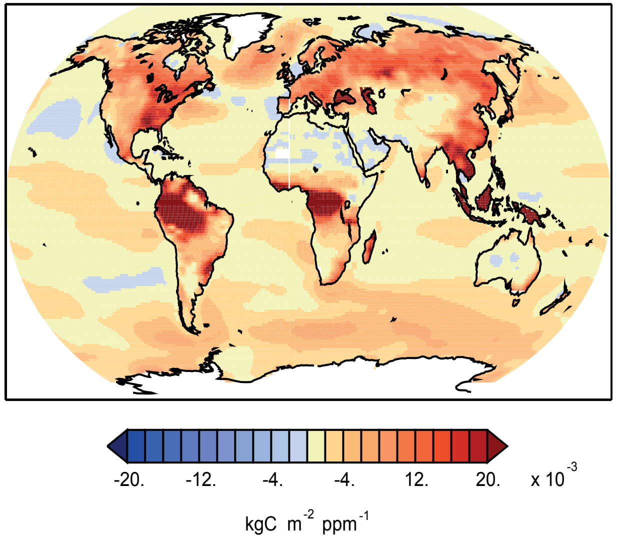
Spatial distributions of multi model-mean land and ocean β and γ

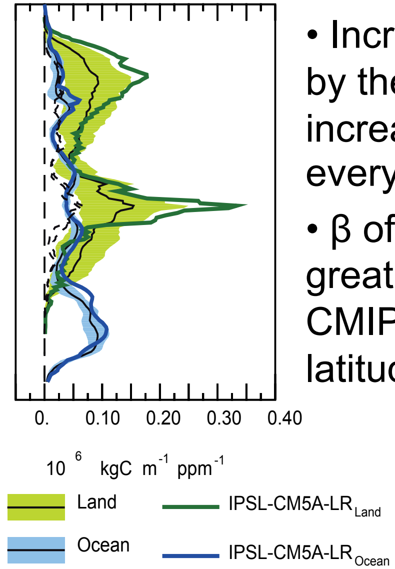
Regional carbon-concentration feedback (CMIP5 models)



IPCC, 2013

Regional carbon-concentration feedback (IPSL-CM5A-LR)

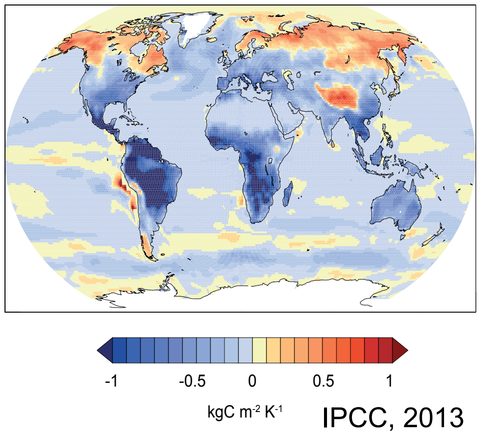




- Increased CO_2 is projected by the CMIP5 models to increase land CO_2 sinks everywhere (positive β)
- β of IPSL-CM5A-LR is greater than of the other CMIP5 models (in High latitudes and Tropics)

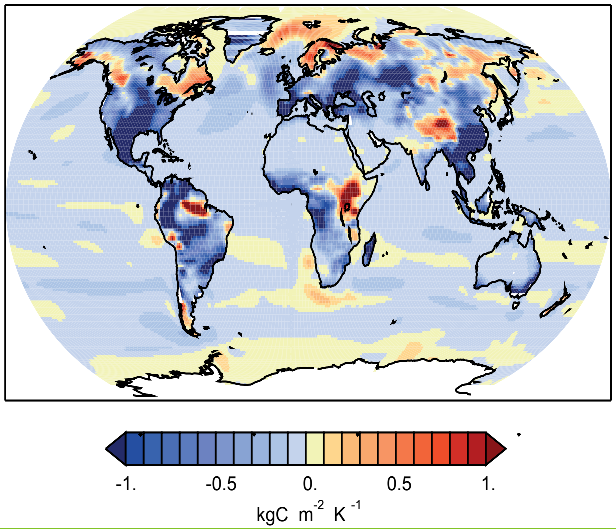
CMIP5

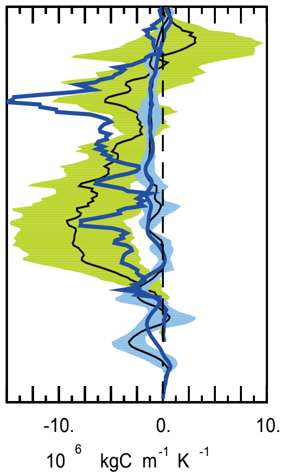
Regional carbon-climate feedback (CMIP5 models)



IPCC, 2013

Regional carbon-climate feedback (IPSL-CM5A-LR)



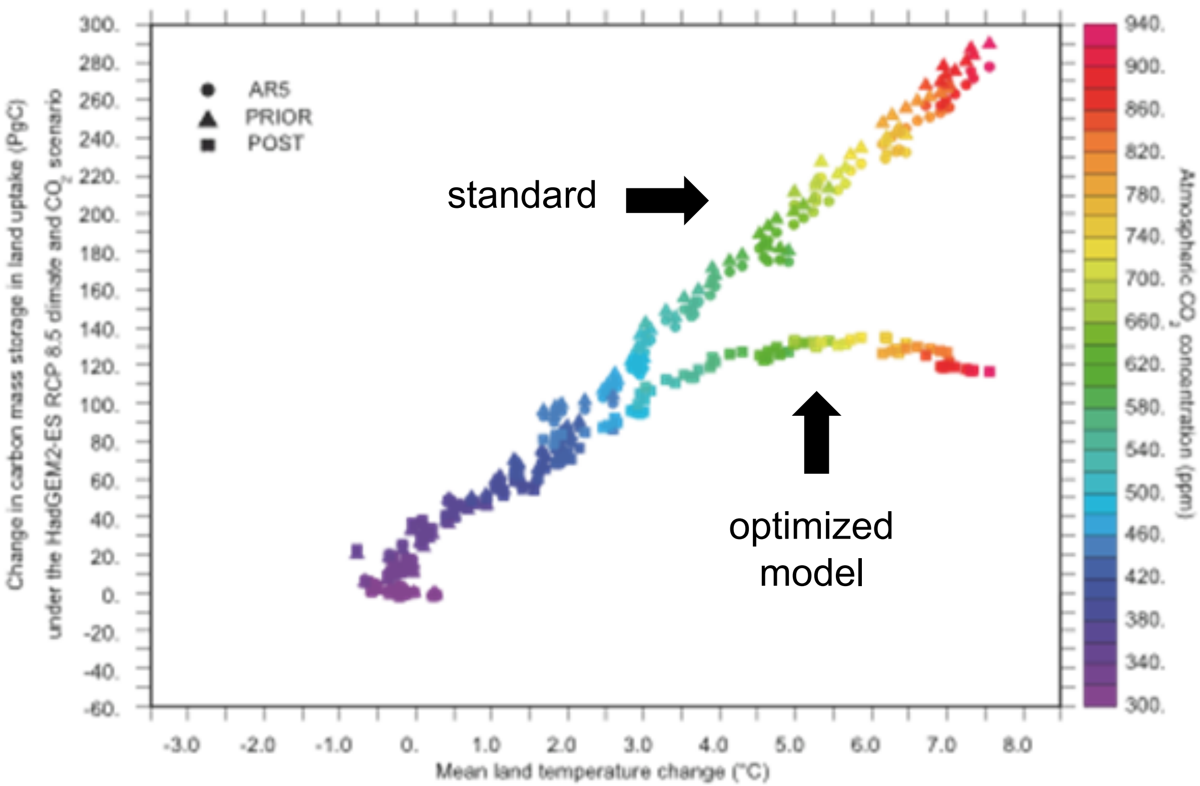


- The climate effect alone is projected by the CMIP5 models to reduce land CO_2 sinks in Tropics and mid-latitudes (negative γ)
- γ is lower in mid-latitudes (greater reduction of the sink) and higher in the Tropics (less important sink reduction)

Data assimilation (optimized parameters)

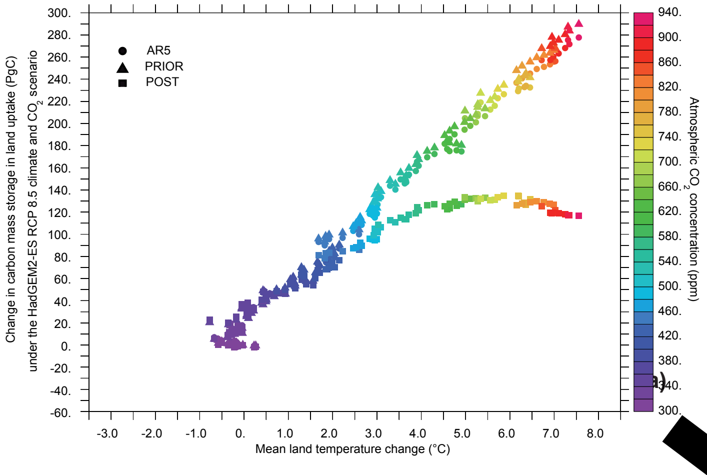
Impact on prognostic simulations

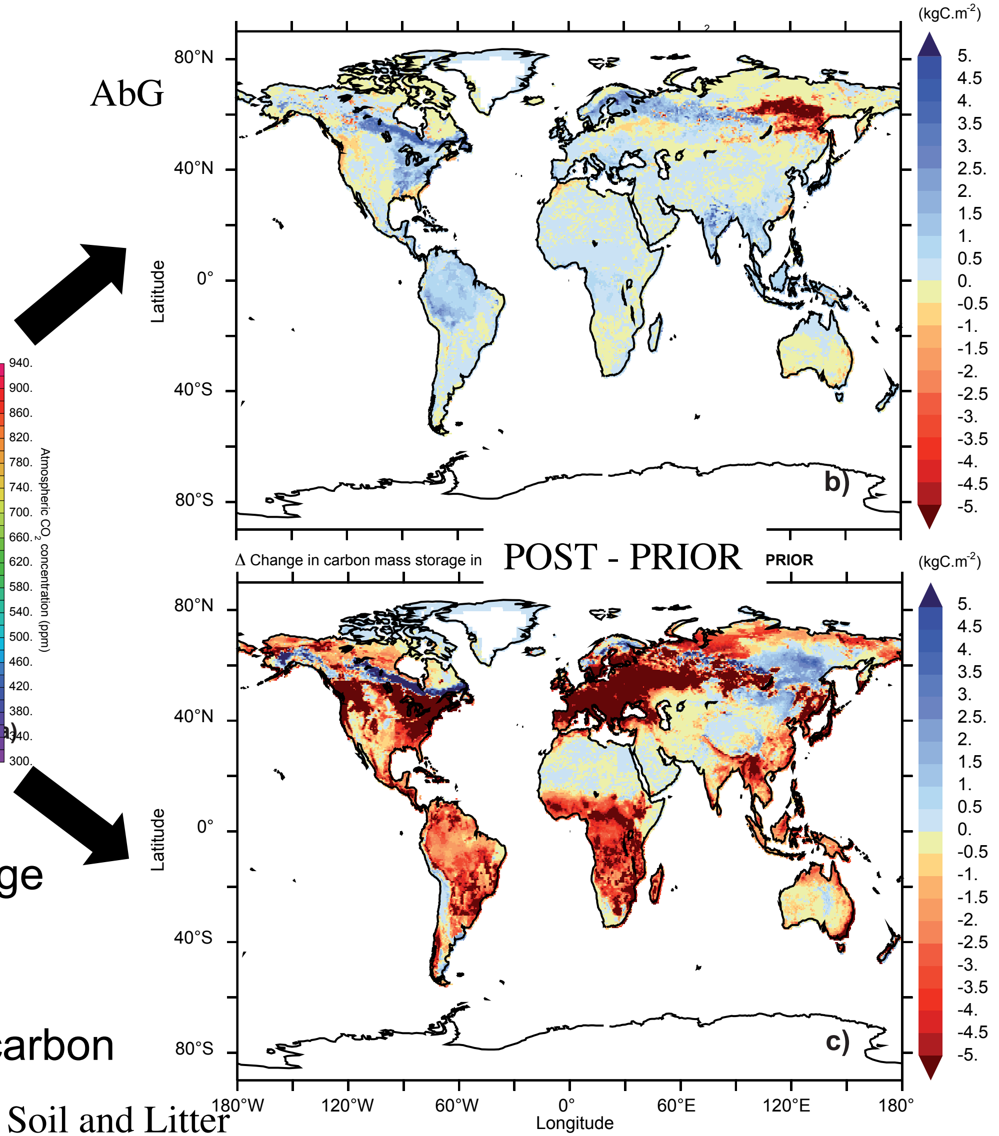
- Using CMIP5 climate scenario (HadGEM2) bias corrected with RCP8.5 CO_2 concentration
- Run ORCHIDEE: Standard vs optimized parameters



Data assimilation

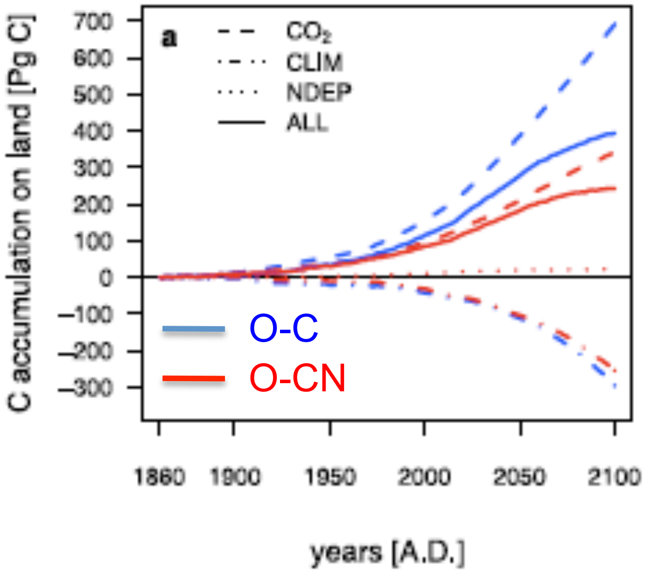
Impact on prognostic simulations

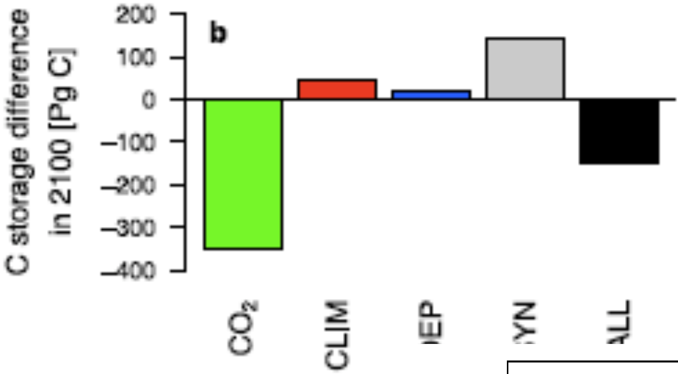




- Large decrease of soil carbon storage above + 3° (changes in input & mineralisation)
- Only small decrease of vegetation carbon stock

The Nitrogen Cycle

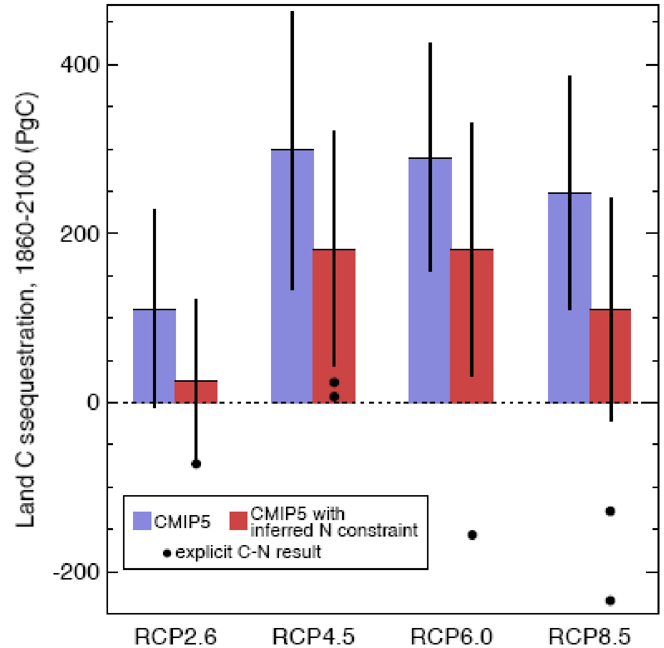




Zaehle et al., GBC, 2010

Nitrogen Dynamics:

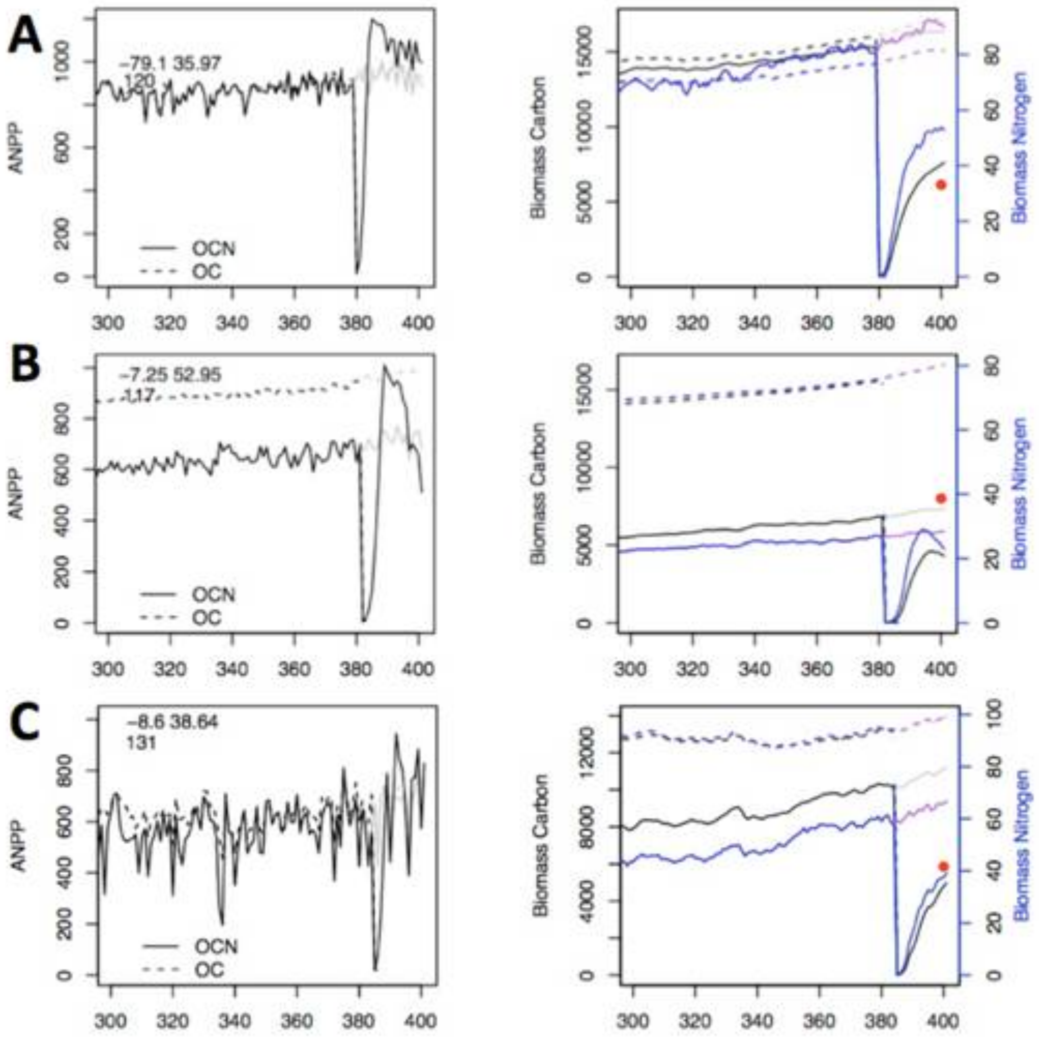
Reduction of carbon storage in terrestrial biosphere due to a nitrogen limiting CO_2 fertilization in the ecosystems of the boreal and temperate regions



IPCC, 2013

The Nitrogen Cycle and forest age classes

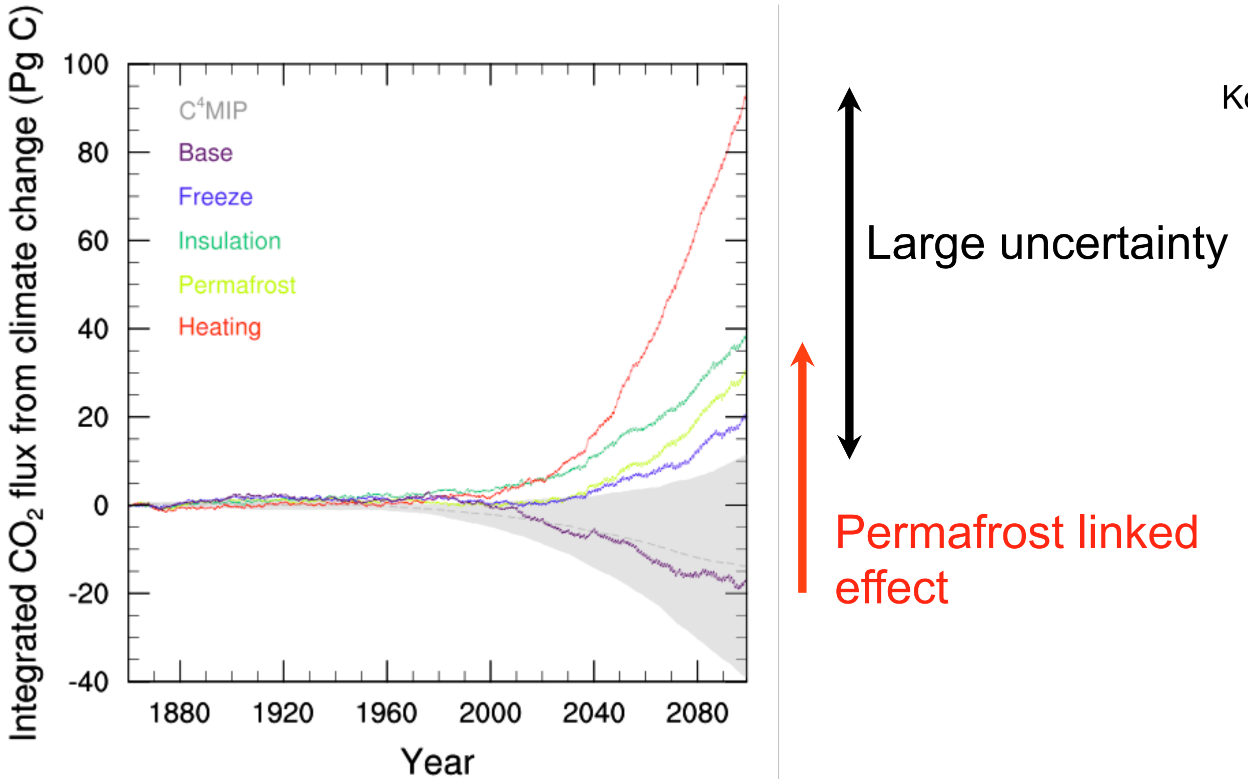
These results indicate that for young forests (< 30 years) there is a crucial need to account for the age effect and that without such effect the forest AgB tends to be overestimated by the model. This appears to affect the model's behaviour for a large part of the investigated sites. On the other hand, accounting for the nitrogen cycle has a direct impact on old forests and by reducing the AgB, the nitrogen availability is a key driver to explain the observed variation of forest biomass content



courtesy of Poulter

Permafrost

60°N:90°N



Koven et al., 2010

The processes linked to permafrost modify the sensibility of the terrestrial biosphere to climate change

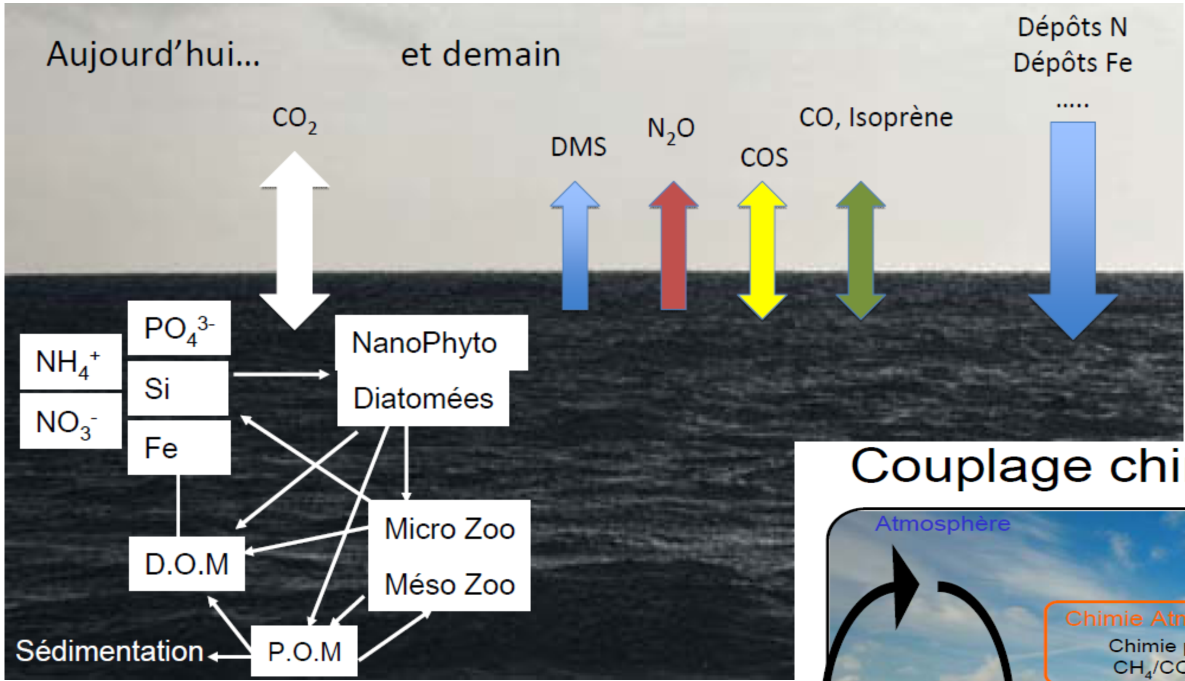
► From a carbon sink to a carbon source

Conclusions

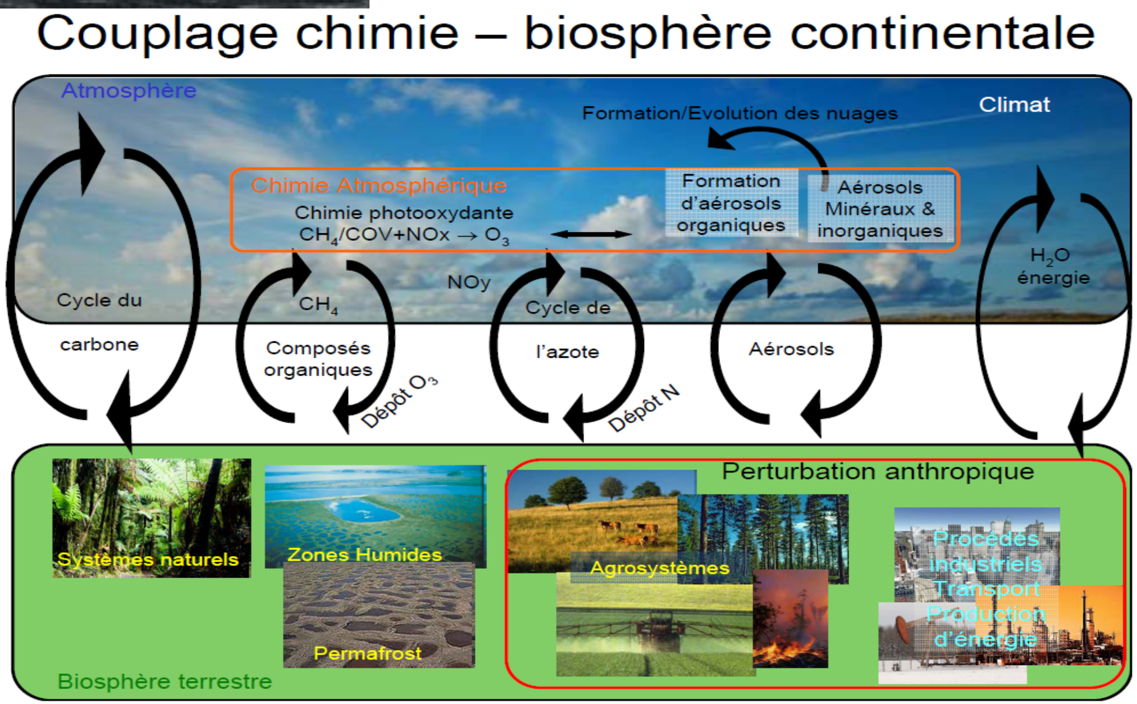
- For RCP6.0 and 8.5 the models simulate lower compatible emissions than the IAMs, indicating a more important climate-carbon feedback in these scenarios
- Differences exist amongst the simulated compatible emissions. This mainly pertains to the diverse responses of the terrestrial biosphere to climate change and change in CO_2 concentration, and to the missing processes

- Upcoming Improvements (future Earth System Model)
  - A forest management module including a new carbon allocation scheme that fulfils specific allometric relations for each Plant Functional Types has been implemented. Model is under evaluation.
  - Integration of a fire module, working on the coupling with the management module and the ability of the model to simulate age/diameter classes. Fires indeed affect differently young and old trees. This step is under completion
  - Plan to include the nitrogen cycle to study its impact on the plant productivity as well as the allocation of carbon in the different reservoirs accounting for the different forest age classes simulated by the model. This step only started.

Better representation of processes



- More complete process representation
- Link with marine resources
- Tighter link with aerosols and chemistry



- New hydrology
- Nitrogen Cyle
- Fires
- High latitudes (snow, permafrost)
- Energy budgets
- Forests and agrosystems

ISI-MIP Protocol