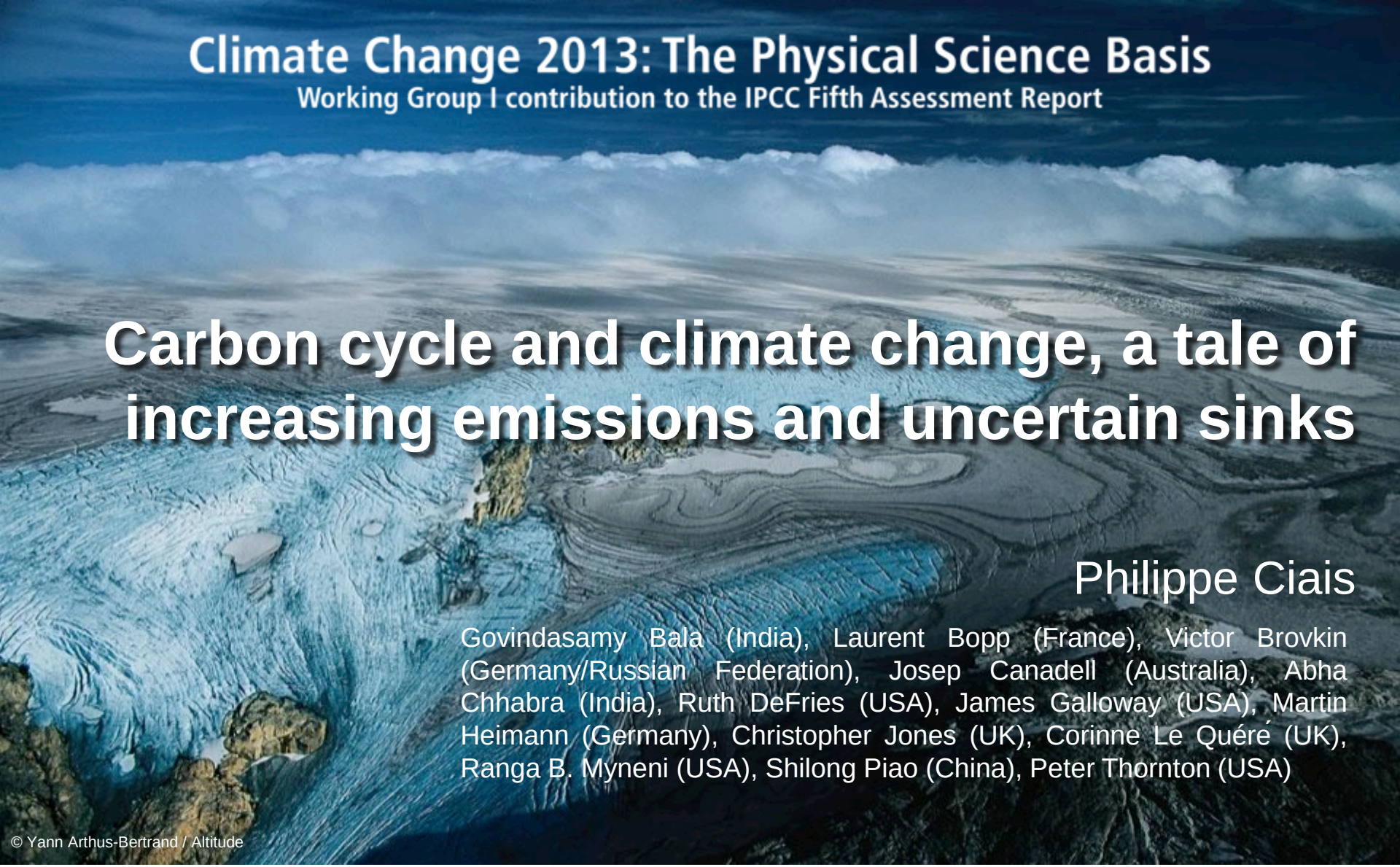
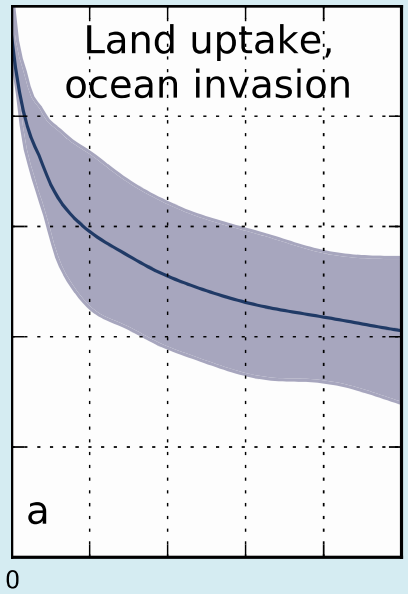


Carbon cycle and climate change, a tale of increasing emissions and uncertain sinks

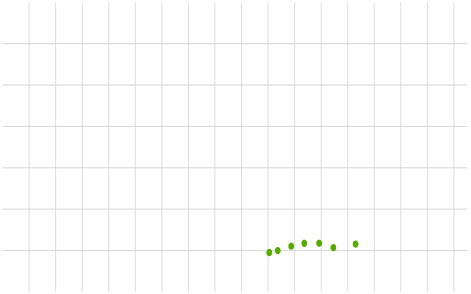
Philippe Ciais

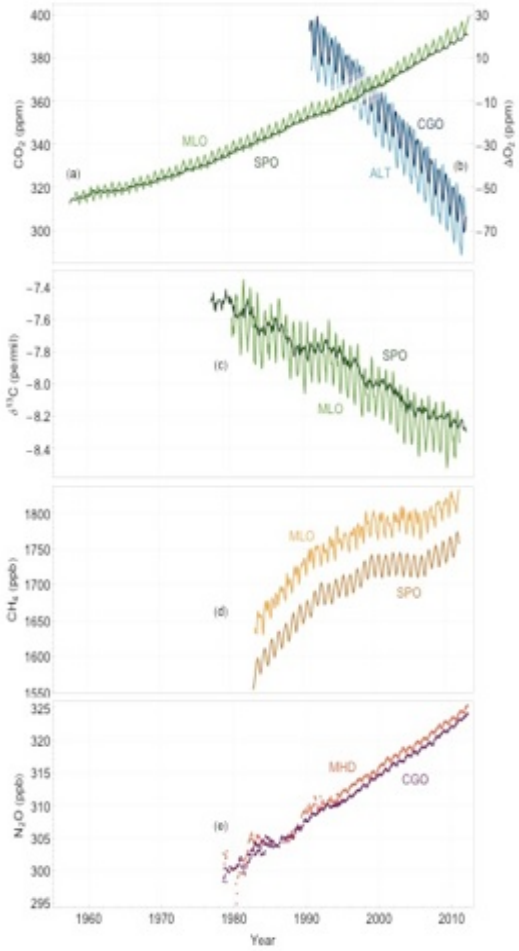
Govindasamy Bala (India), Laurent Bopp (France), Victor Brovkin (Germany/Russian Federation), Josep Canadell (Australia), Abha Chhabra (India), Ruth DeFries (USA), James Galloway (USA), Martin Heimann (Germany), Christopher Jones (UK), Corinne Le Quéré (UK), Ranga B. Myneni (USA), Shilong Piao (China), Peter Thornton (USA)

Never forget this : CO_2 remains in the atmosphere long after emissions



CO_2, CH_4 and N_2O increase in the Industrial Era

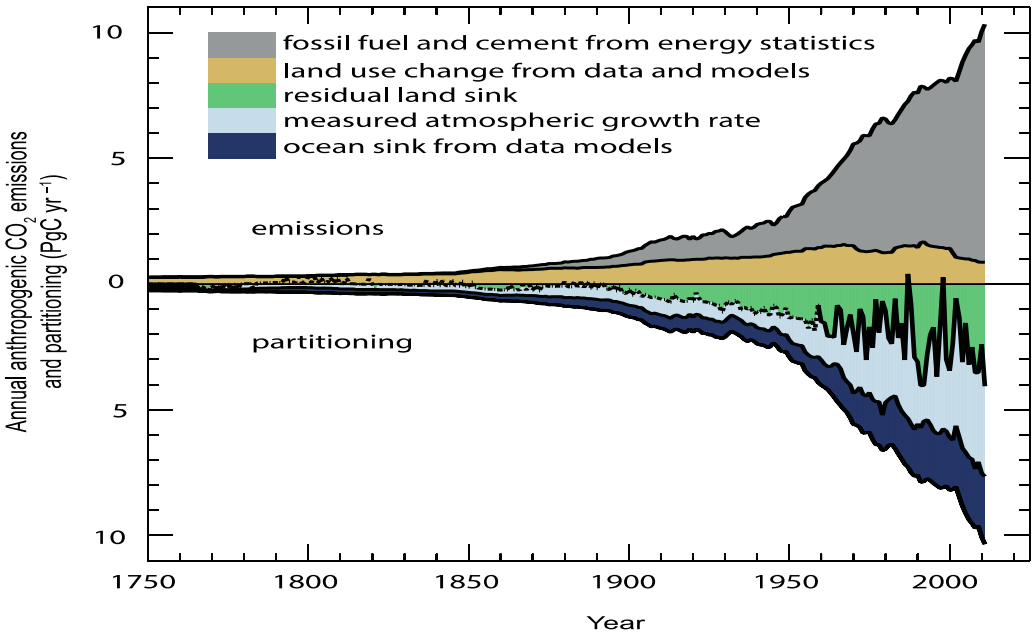




Ice core records

Atmospheric monitoring

Global Carbon Budget



Since 1750, human activities have emitted 555 ± 85 PgC from fossil fuel burning and land use change

Fossil fuel CO_2 emissions were 9.5 PgC yr-1 in 2011, 54% above their 1990 level

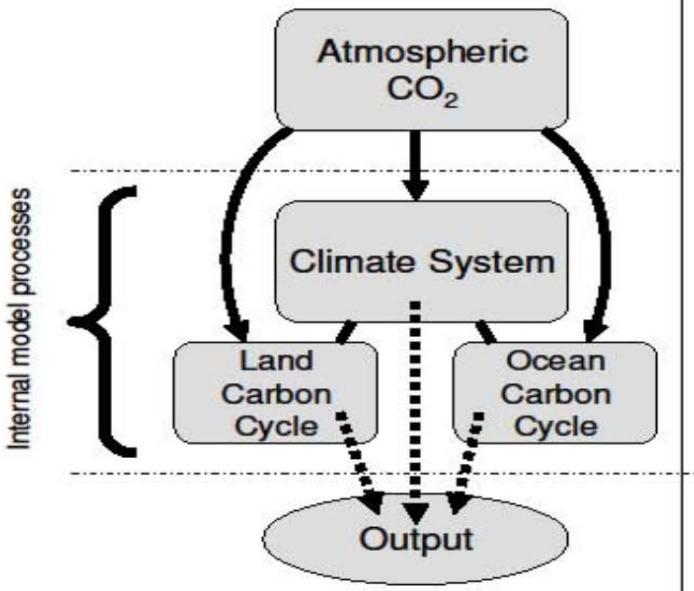
On average over the past 50 years, a fraction of 44 ± 6 % of emissions remains in the atmosphere, increasing the Earth's greenhouse effect

Projecting future changes with Earth System Models

Concentration driven

Policy relevant objectives

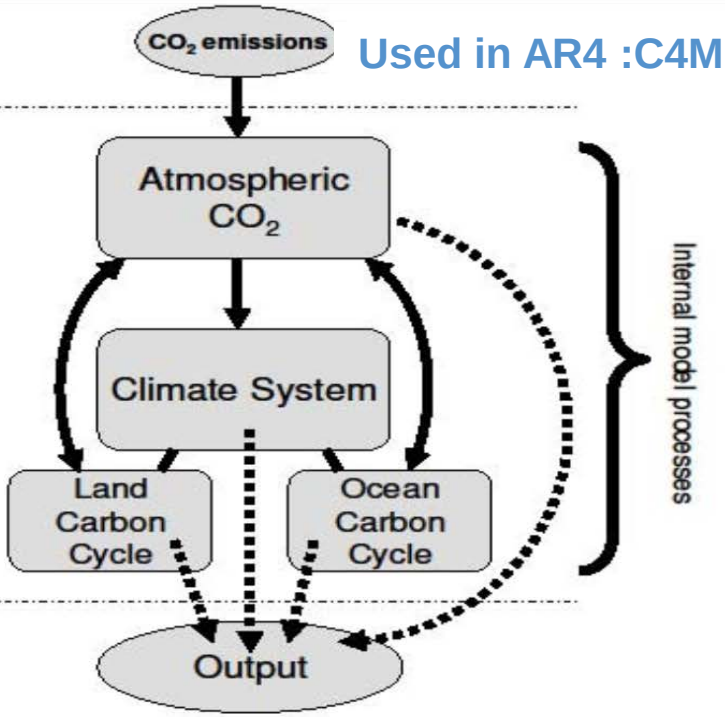
Used in AR5 : CMIP5



Emission driven

Free running coupled climate – carbon system

Used in AR4 :C4MIP



Carbon vs physical parameters uncertainty

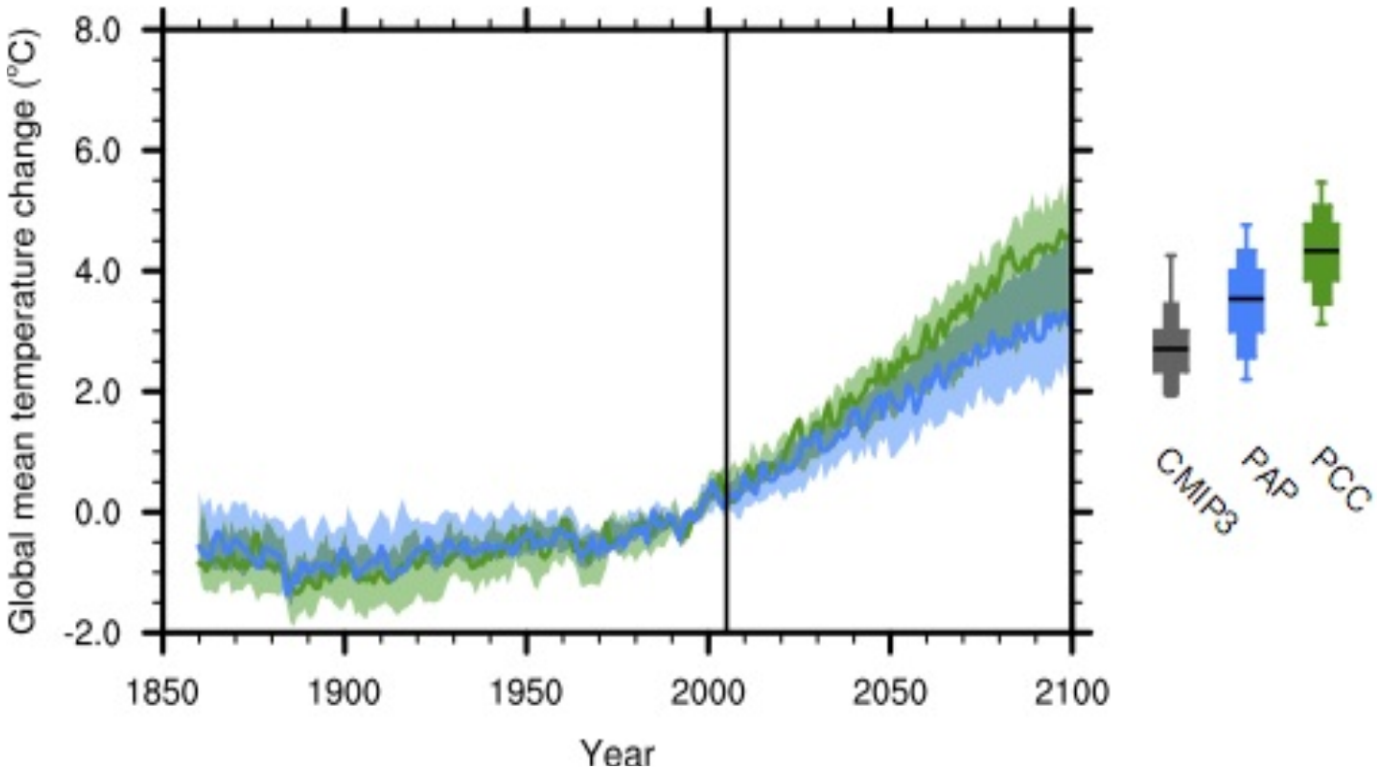
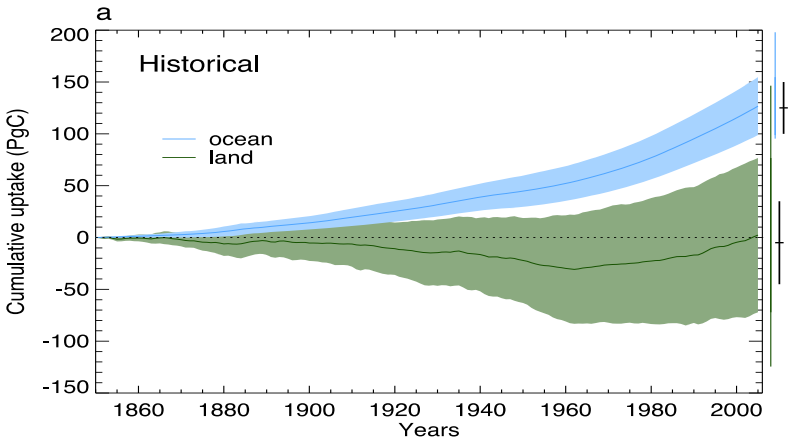


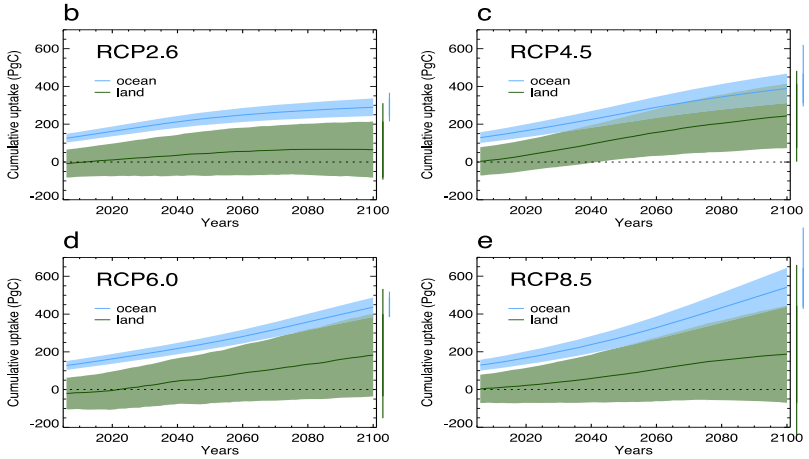
Figure 12.37: Uncertainty in global mean temperature from HadCM3 results exploring atmospheric physics and terrestrial carbon cycle parameter perturbations under the SRES A1B scenario (Booth et al., 2012; Murphy et al., 2004).

Simulated historical and future land and ocean carbon storage using CMIP5 models

Historical

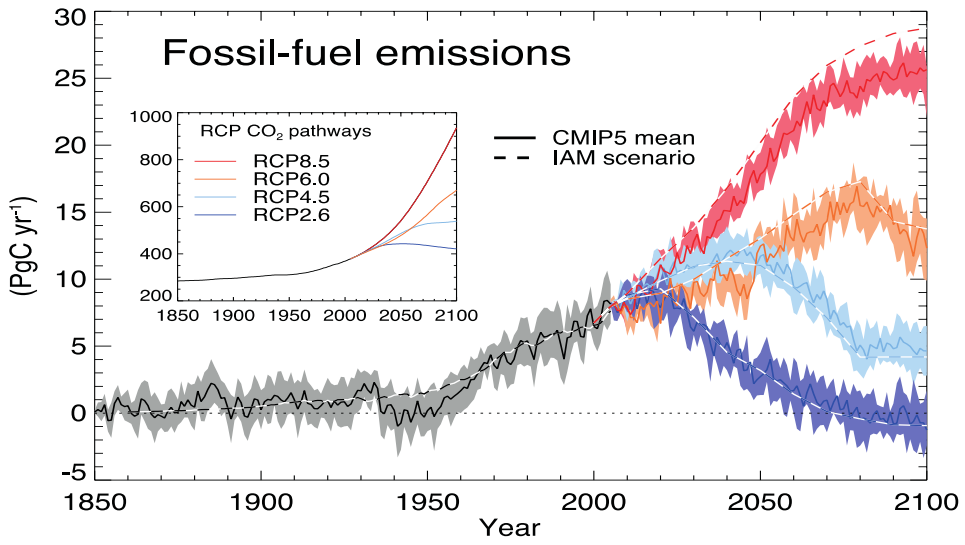


RCP future pathways

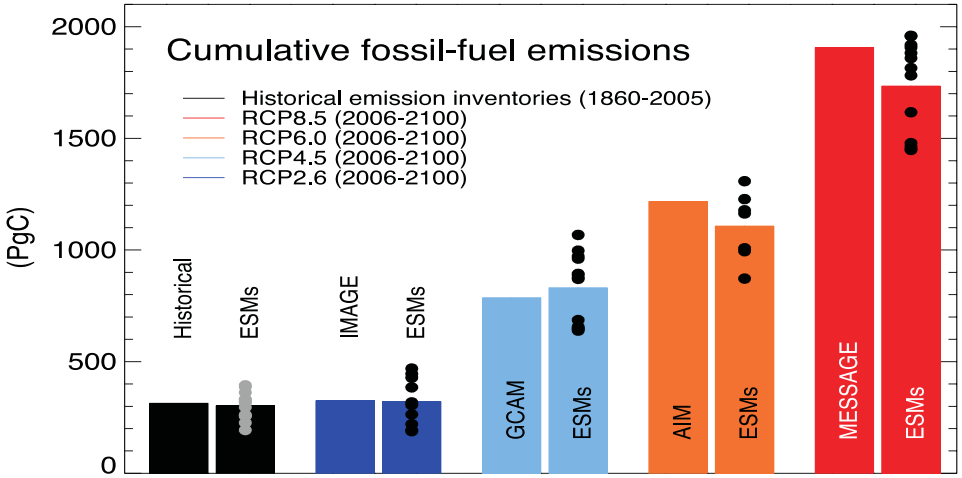


Very large uncertainty on projected changes in land carbon storage

Compatible emissions for the RCP pathways



Uncertainties in modeled land and ocean carbon storage translate into uncertain compatible emissions

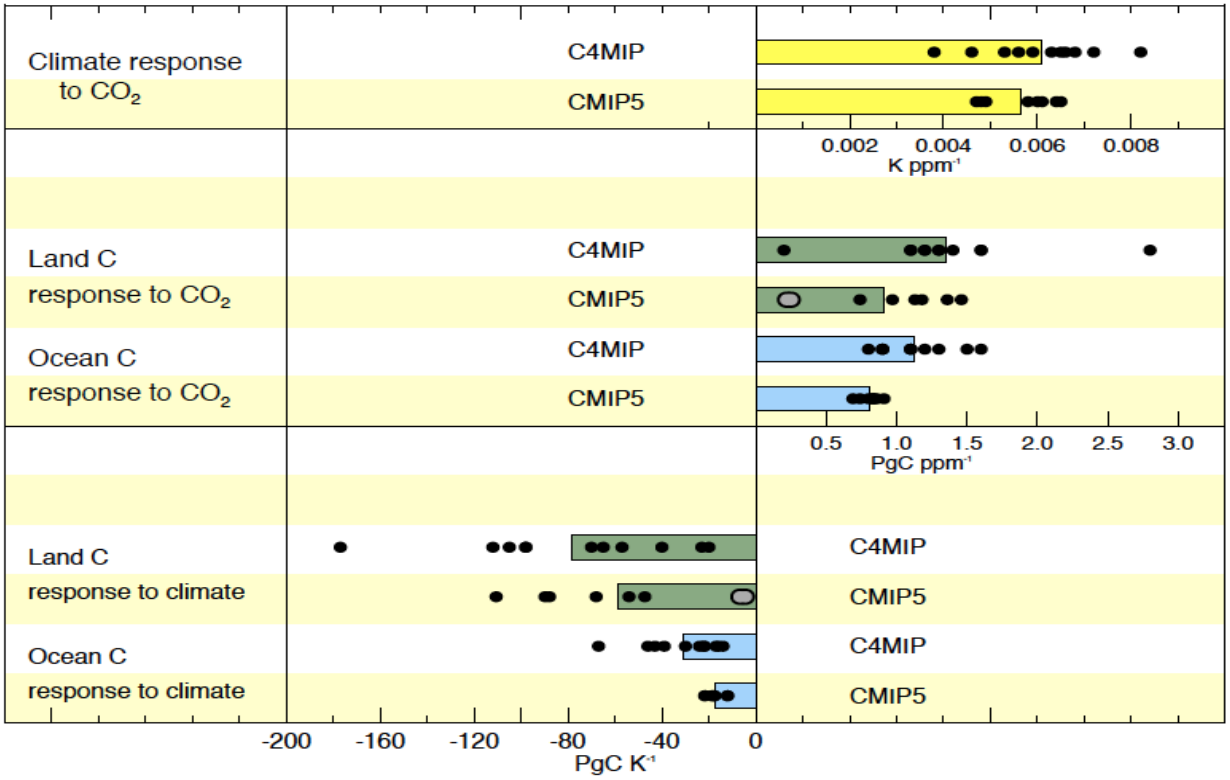


Positive carbon climate feedbacks confirmed in AR5

Climate response to CO_2

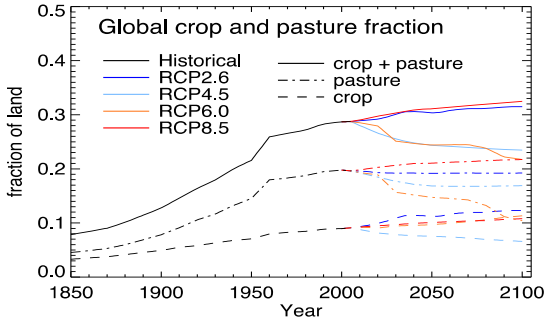
Sinks response to CO_2

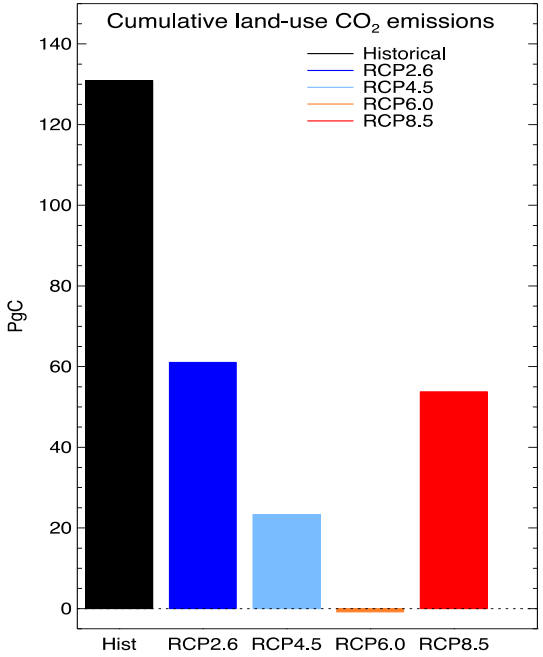
Sinks response to climate



Climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere (*high confidence*)

Future of the assessment : land-use emissions scenarios & evaluati

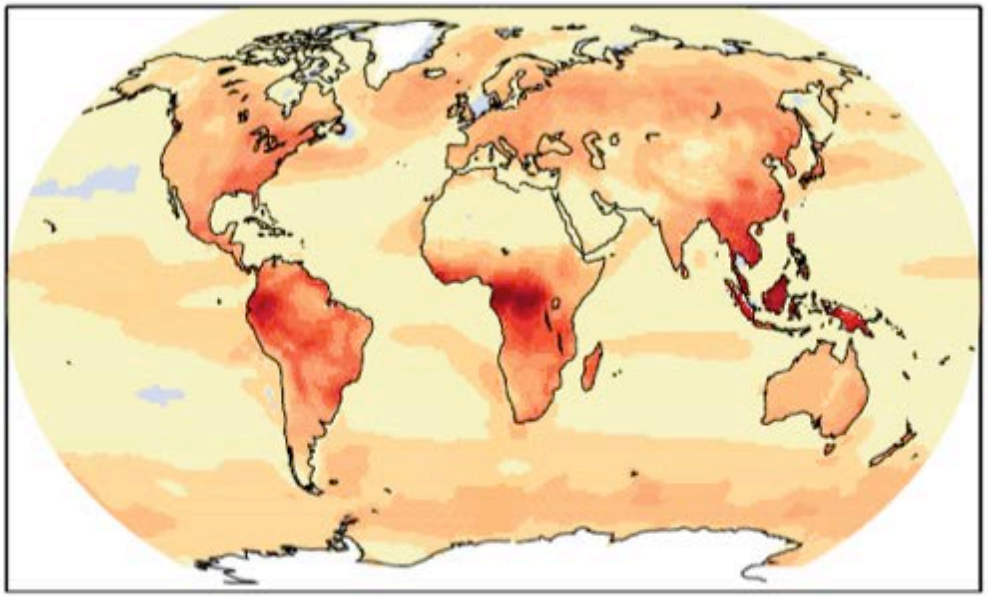


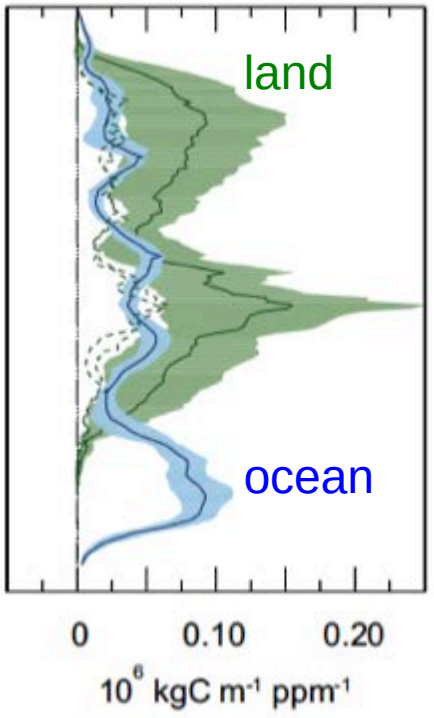


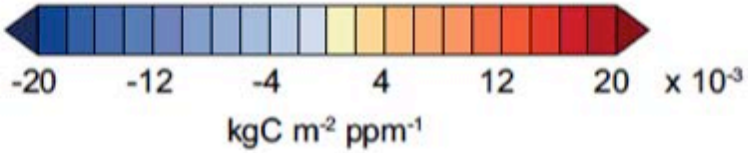
Land use emissions were not separated from net land flux in Earth System Models for CMIP5

All RCP pathways have low land use emissions

Response to atmospheric CO_2 only





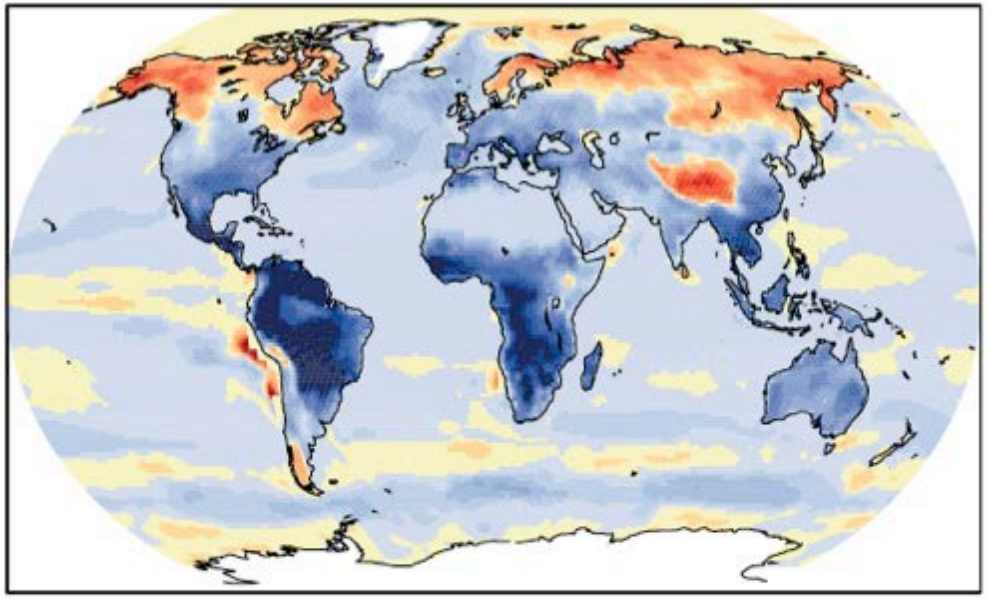


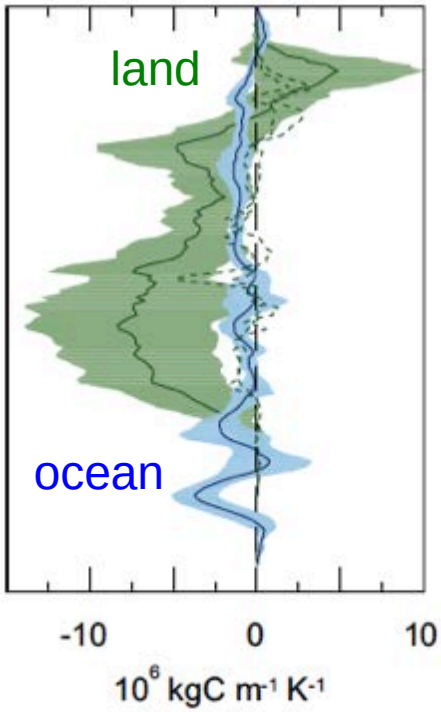
decreasing sink

increasing sink

source: Ciais et al. 2013 IPCC AR5

Response to climate change only





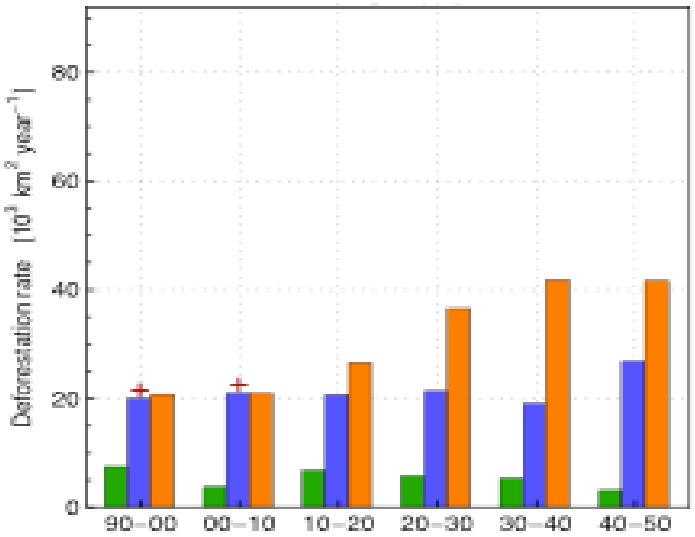
decreasing sink

increasing sink

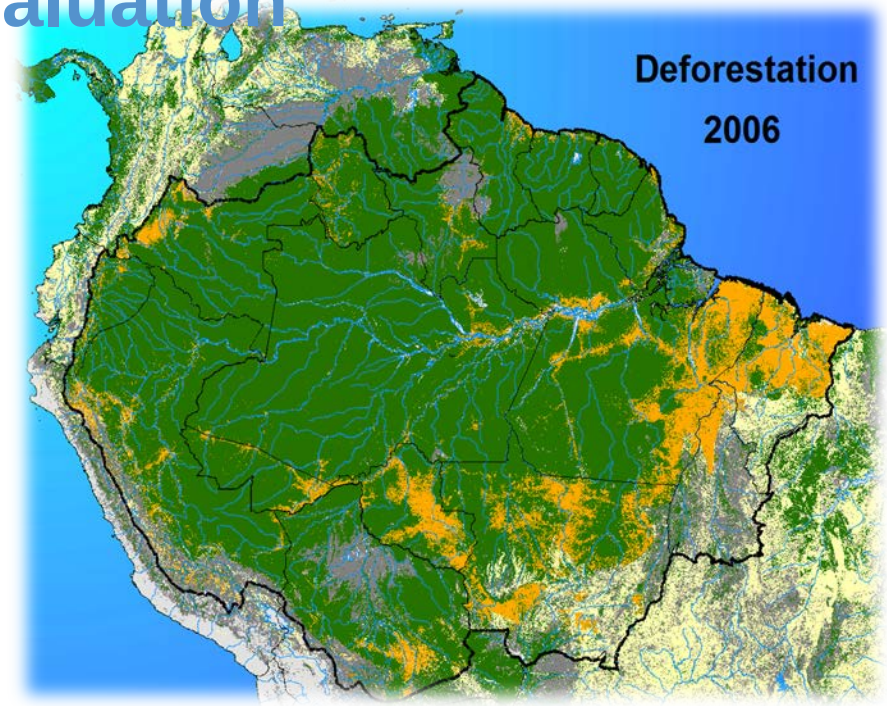
models do not include the release of permafrost C

source: Ciais et al. 2013 IPCC AR5

Future of the assessment : land-use emissions scenarios & evaluation



Green : RCP8.5 scenario over Amazon
Blue & Orange : Brazilian projections
(LUCCME in blue and SIMAMAZONIA)



Soares Filho et al., 2006

Research needs:
Understand differences between global and regional land use scenarios
Reconcile food security scenarios (MA, FAO) with climate scenarios (IPCC)

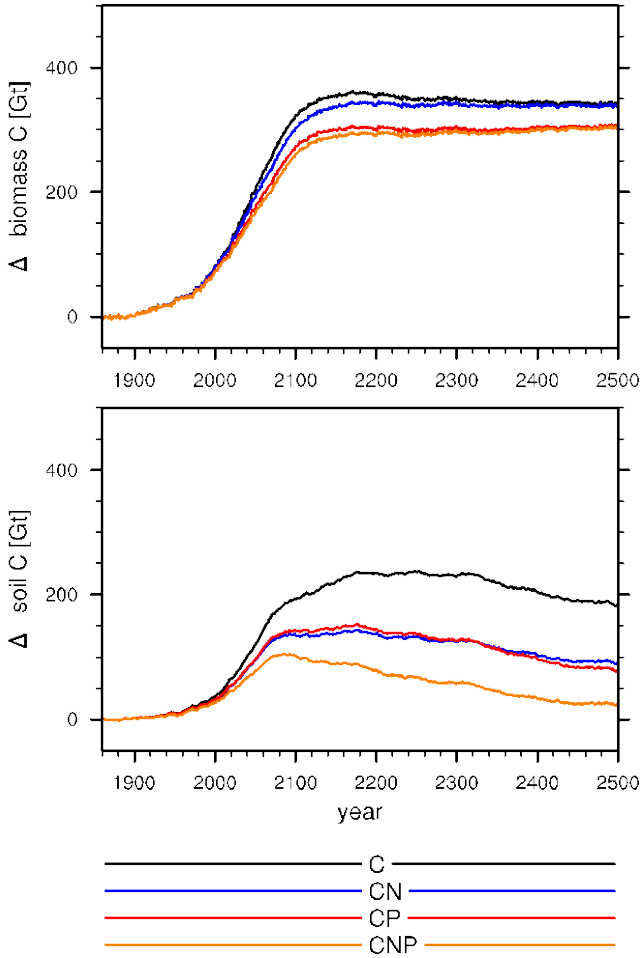
Future of the assessment : Nutrients limitations of terrestrial C storage

Only 1-2 Earth System Models included N-limitations in CMIP5 and found a smaller sink response to CO_2 and climate

Future biomass C storage

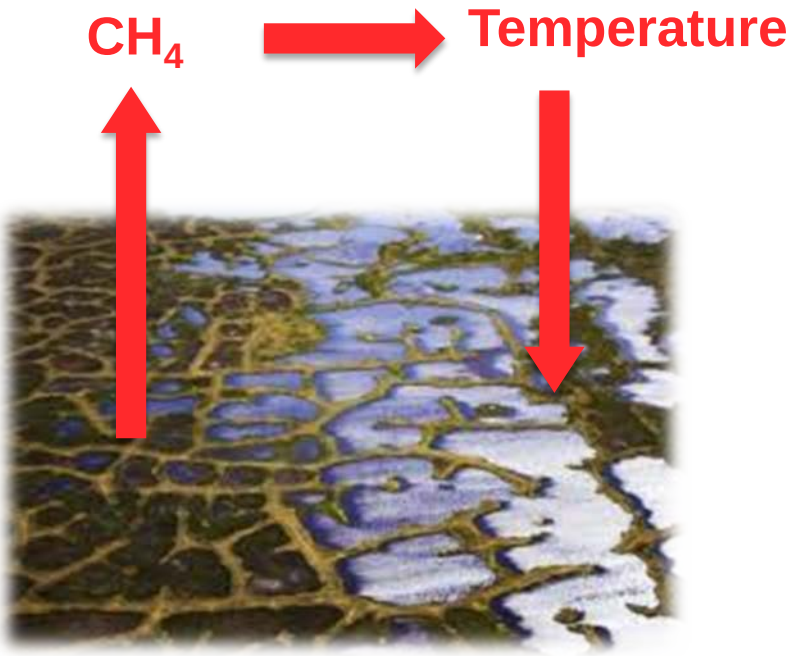
From an offline model with N & P limitations

Future soil C storage



Goll et al. 2012

Future of the assessment : CH_4 and N_2O climate feedbacks



Feedbacks that were not included in CMIP5 models:
Climate sensitivity of wetland CH_4 emissions
Stability of ocean CH_4 hydrate pools
Response of soil N_2O emission processes to climate and elevated CO_2
Response of ocean N_2O emissions to changes in O_2 & circulation

Future of the assessment : ‘cold’ carbon processes, permafrost C

1670 Pg C
In permafrost

Mc Dougall et al. 2013

Here an Earth System Model with permafrost carbon processes was driven forward by RCP emissions

Result: higher projected warming (0.13 to 1.7° C) and CO_2 release (70 to 500 PgC)

Key « missing » processes : soil ice, soil C vertical distribution, soil C pools decomposition rates [C:N], fire & thermokarst

Conclusions, future IPCC challenges

Few good guys

CO_2 fertilization of NPP (-) - Level of understanding in parenthesis
CO_2 driven ocean uptake (+)
Longer northern growing seasons (+)
Land management (-)

Many potentially bad guys

Intense land use scenarios (- -)
Permafrost C emissions (- -)
Wetland emissions increase (- -)
Fire emissions increase (- -)
Emerging Nutrient limitations (- -)

Research should focus on reducing uncertainties using measurements and on quantifying the net effect of good guys and bad guys for a range different scenarios

Thank you for your attention