Forests as key drivers of local, regional and global climate

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“Managing forests in the 21st century”, Potsdam, 2020/03/05

Finally…

Geosci. Model Dev., 13, 185–200, 2020
https://doi.org/10.5194/gmd-13-185-2020

Geoscientific Model Development
Open Access

Accounting for forest age in the tile-based dynamic global vegetation model JSBACH4 (4.20p7; git feature/forests) – a land surface model for the ICON-ESM

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Received: 15 March 2019 – Discussion started: 4 April 2019
Revised: 22 November 2019 – Accepted: 27 November 2019 – Published: 27 January 2020

Story

① Humans change the extent of global forest cover immensely.

② For the future we hope for substantial carbon sinks.

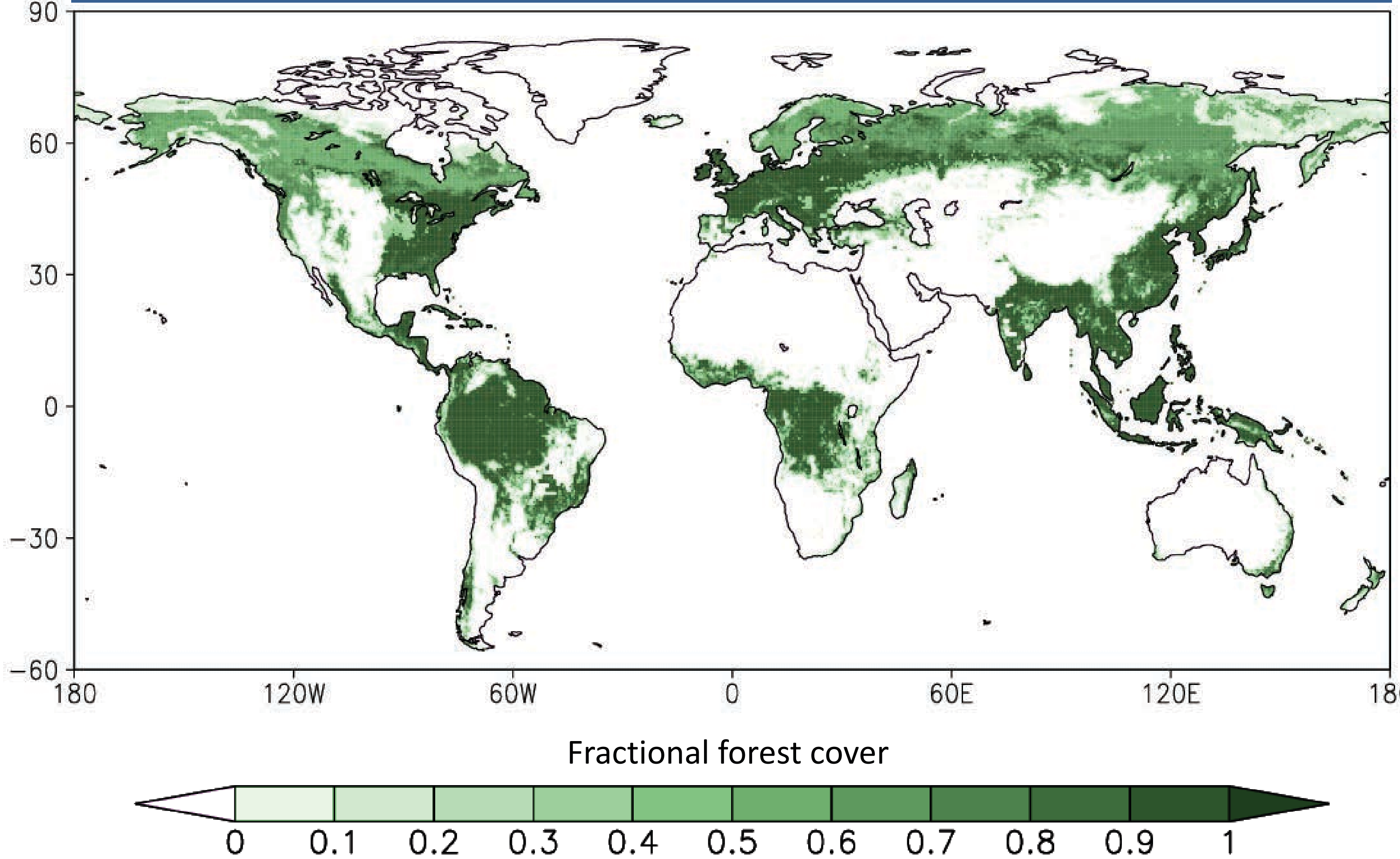
③ But biogeophysical effects have been shown to matter, too.
Why do models and observations disagree?

④ <u>Take-away message</u>:
Large mitigation potential is possible (but not very likely),
adaptation potential is huge

Note our perspective: global Earth system modeling!

Changes in forest cover extent by humans

Global potential forest cover



Data: Pongratz et al, *Global Biogeochem. Cycles*, 2009 – forest
Haberl et al, *PNAS*, 2007 – wilderness

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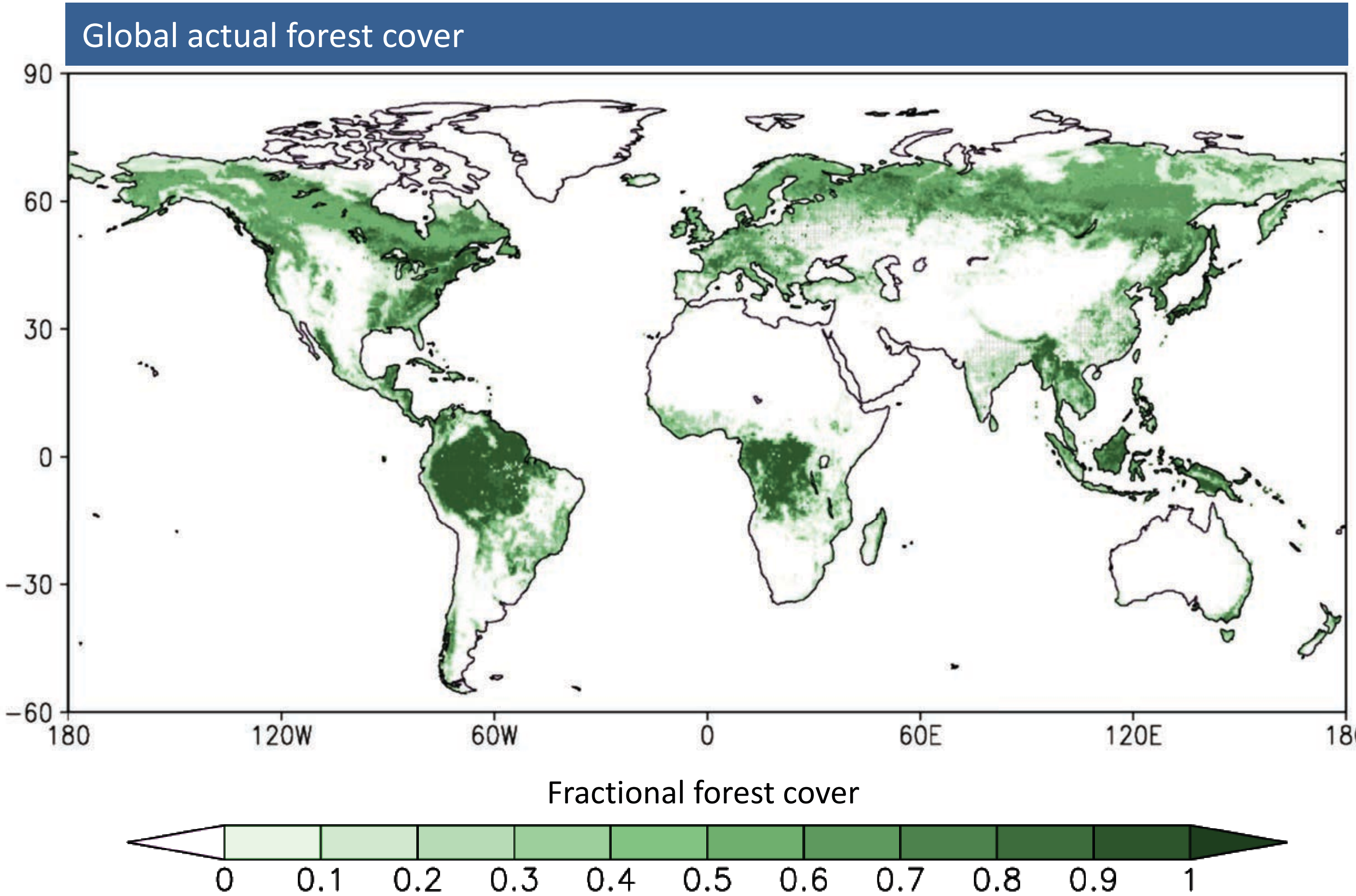

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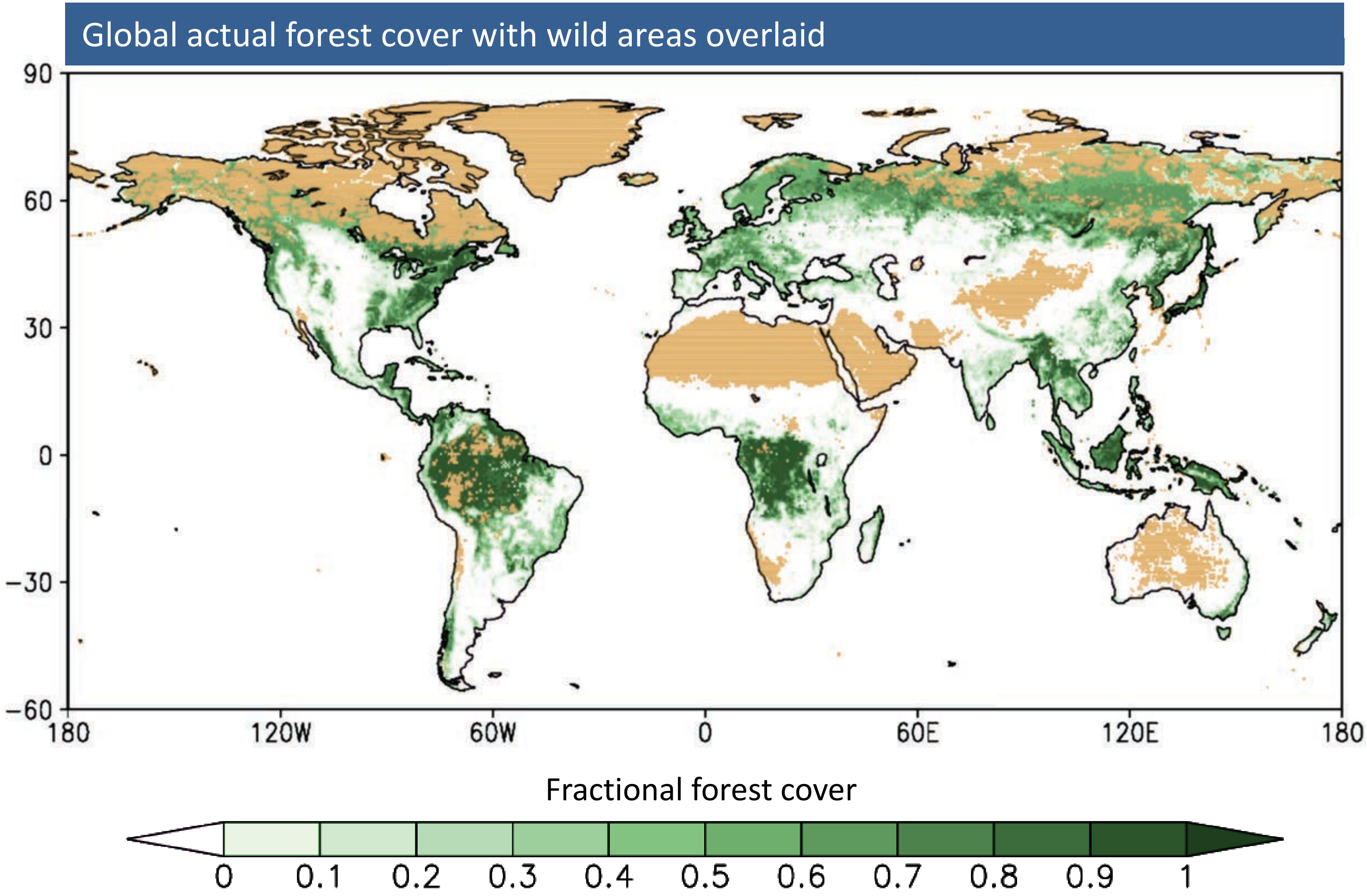

Data: Pongratz et al, *Global Biogeochem. Cycles*, 2009 – forest
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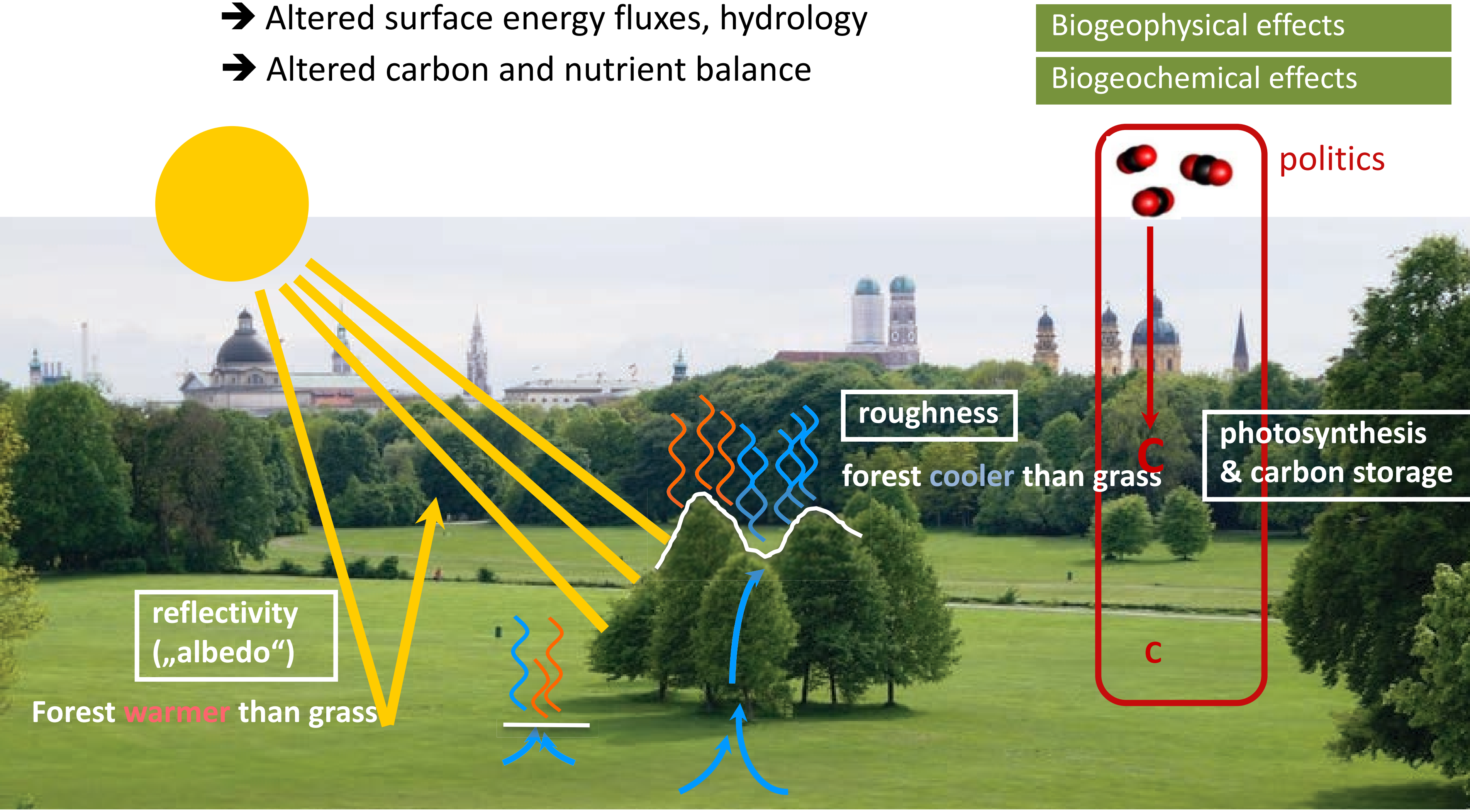
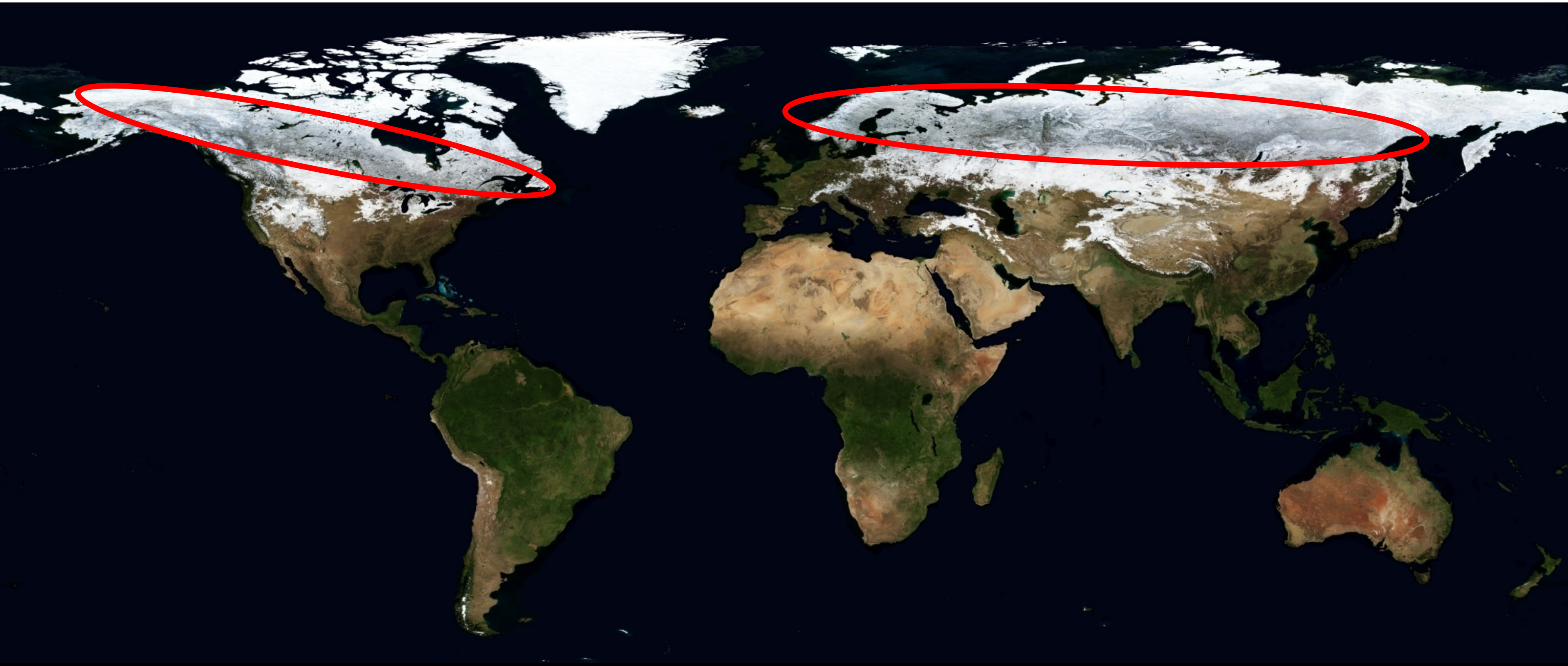
Land-atmosphere interactions

➔ Altered surface energy fluxes, hydrology
➔ Altered carbon and nutrient balance



Energy and heat fluxes due to land use change



January

Energy and heat fluxes due to land use change

“Rabbit fence” in Western Australia

Lyons, *Meteorology and Atmospheric Physics*, 2002

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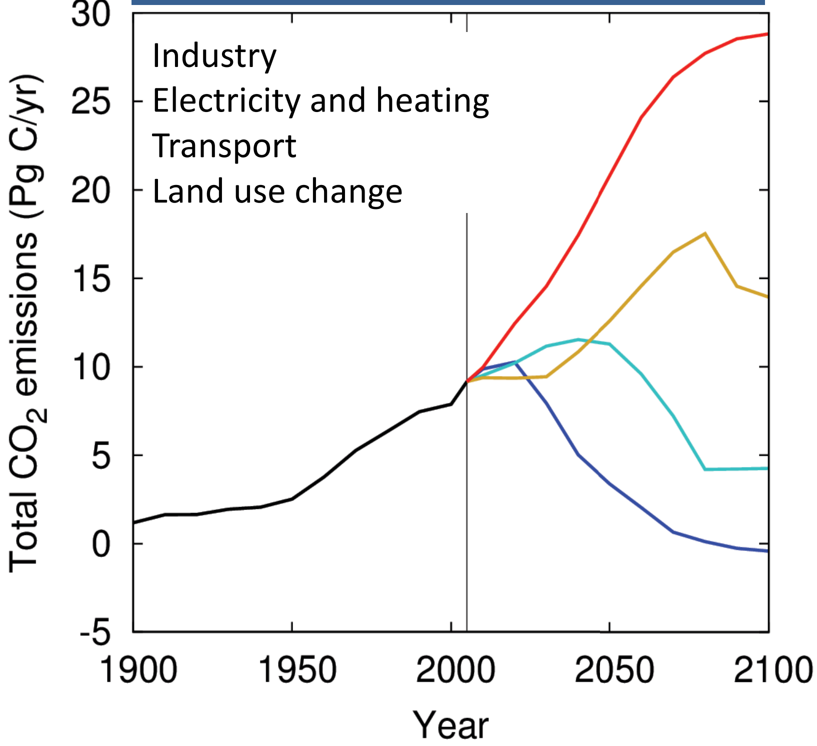
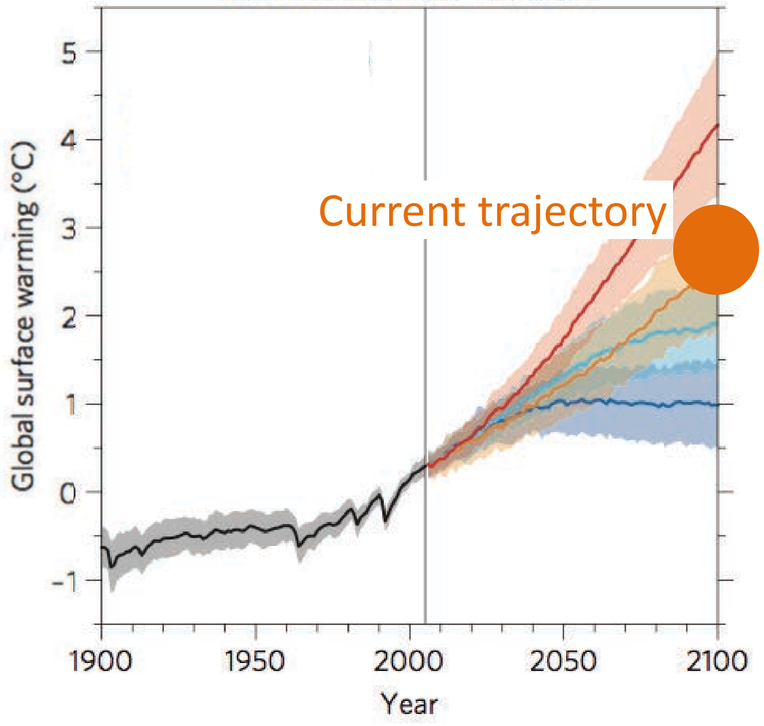
Land use in the context of future climate

Anthropogenic CO_2 emissions



Temperature rise projected by IPCC models

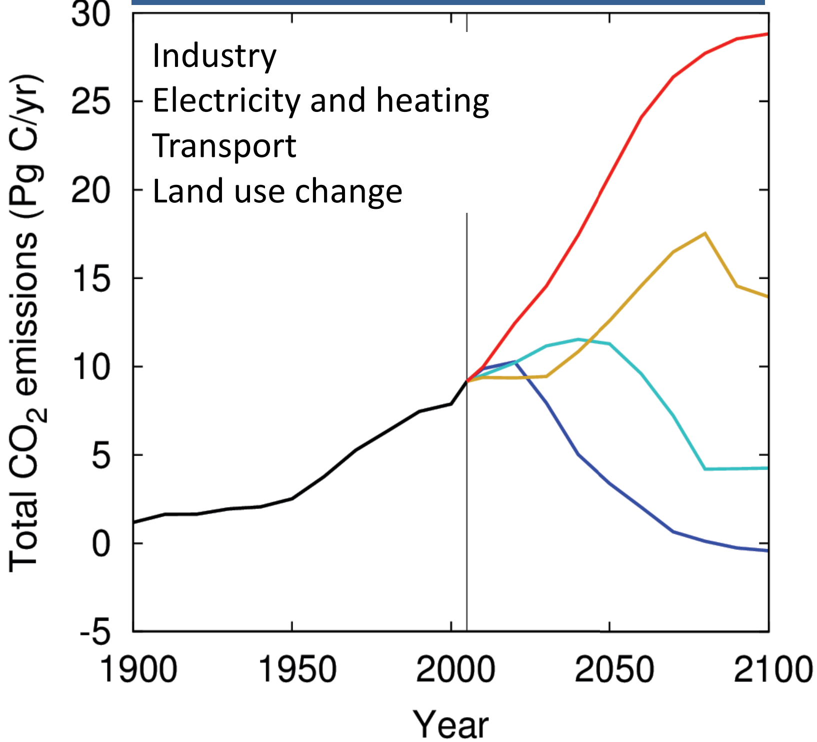


Knutti & Sedlacek, *Nature Climate Change*, 2012

Paris Agreement

The main driver of CO_2 increase:

Anthropogenic CO_2 emissions



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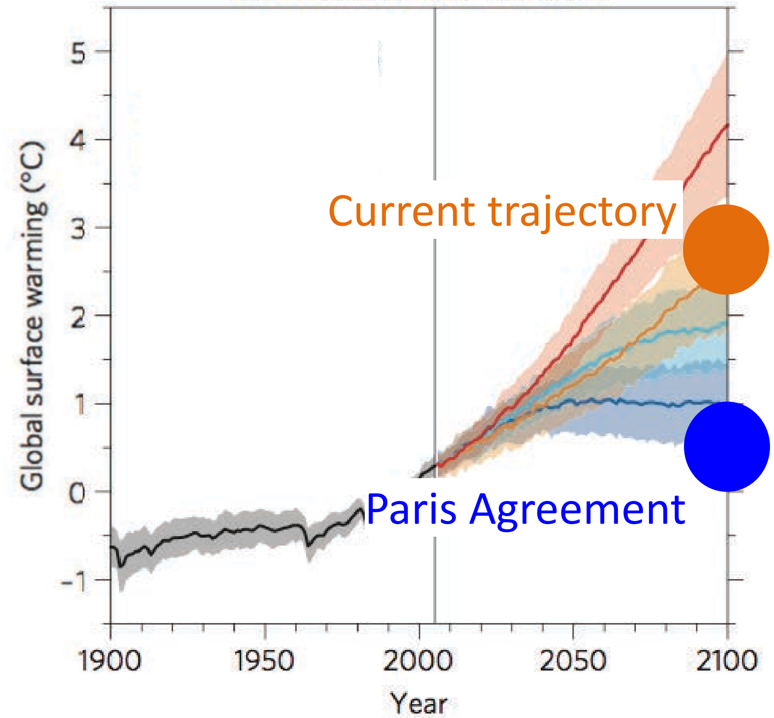
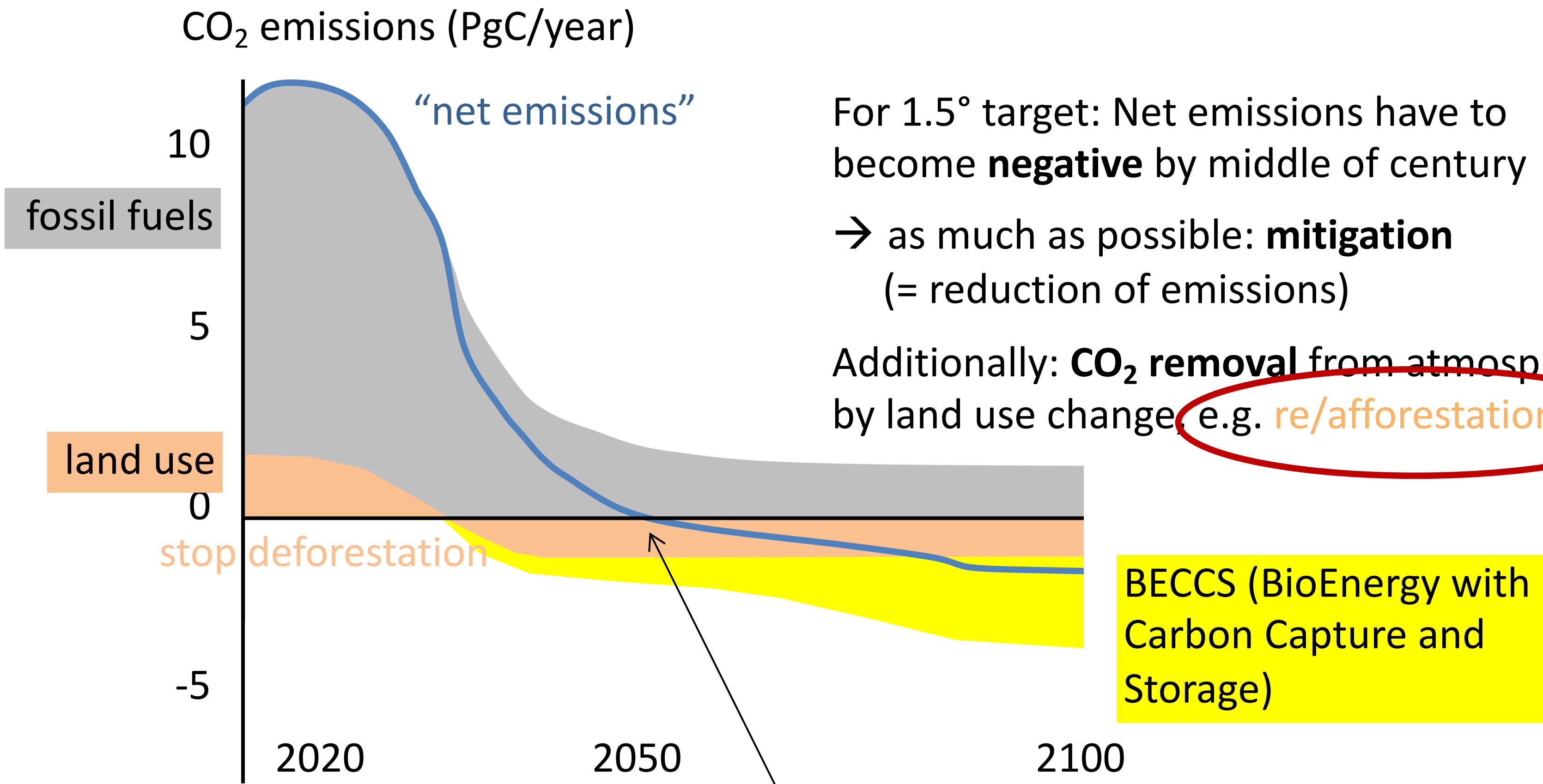


How do we get down to +1.5 or 2°C?

Data: IIASA RCP database

Knutti & Sedlacek, *Nature Climate Change,* 2012

Scenarios compatible with 1.5˚C target



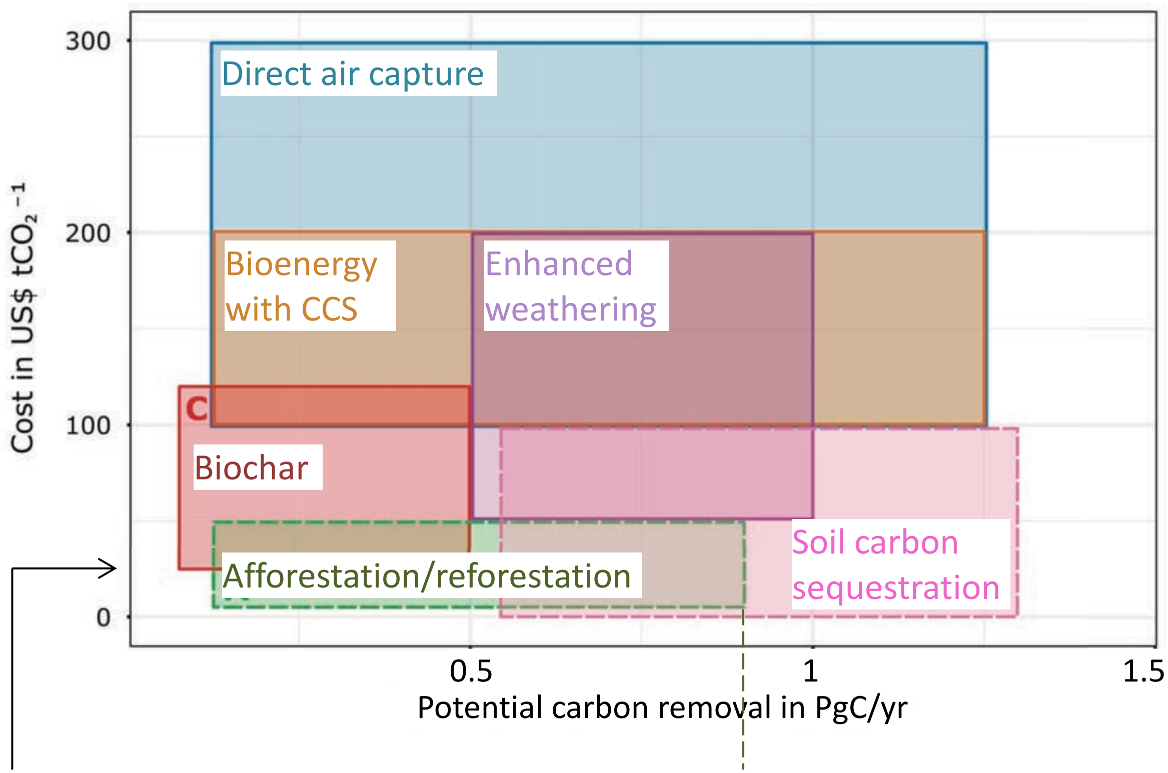
For 1.5° target: Net emissions have to become **negative** by middle of century

→ as much as possible: **mitigation** (= reduction of emissions)

Additionally: **CO_2 removal** from atmosphere by land use change, e.g. re/afforestation

→ ~2050 negative emissions

Negative emission technologies on land



current price for compensation:
~$25 / tCO_2

Until 2100: ~80 PgC
(<10a current emissions)

Minx et al., *Environ. Res. Lett.*, 2018

RESEARCH | *REPORT*

Science

Science 05 Jul 2019:
Vol. 365, Issue 6448, pp. 76-79
DOI: 10.1126/science.aax0848

RESTORATION ECOLOGY

The global tree restoration potential

Jean-Francois Bastin[1*], Yelena Finegold[2], Claude Garcia[3,4], Danilo Mollicone[2], Marcelo Rezende[2], Devin Routh[1], Constantin M. Zohner[1], Thomas W. Crowther[1]

The restoration of trees remains among the most effective strategies for climate change mitigation. We mapped the global potential tree coverage to show that 4.4 billion hectares of canopy cover could exist under the current climate. Excluding existing trees and agricultural and urban areas, we found that there is room for an extra 0.9 billion hectares of canopy cover, which could store 205 gigatonnes of carbon in areas that would naturally support woodlands and forests. This highlights global tree restoration as our most effective carbon drawdown ~~climate change~~ solution to date. However, climate change will alter this potential tree coverage. We estimate that if we cannot deviate from the current trajectory, the global potential canopy cover may shrink by ~223 million hectares by 2050, with the vast majority of losses occurring in the tropics. Our results highlight the opportunity of climate change mitigation through global tree restoration but also the urgent need for action.

[mentioned re previous slide:

Bastin et al study overestimated realistic potential of CO_2 uptake because they allow all pasture/grazing land to be reforested; see Letter by Delzeit et al in Science. Also carbon stocks of pre-existing vegetation was ignored, see technical comments in Science.

But CO_2 uptake potentials of ~200 PgC are not out of the world – other studies find such potential with socioeconomically plausible scenario and process-based simulation of carbon stocks → Sonntag et al next slide.]

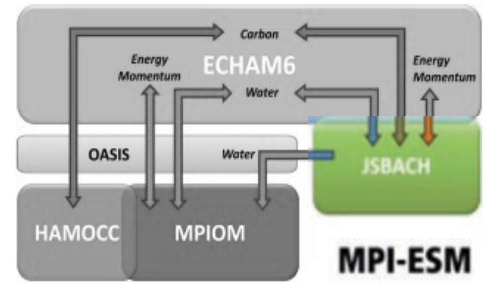
Reforestation in a benign high-CO_2 world

RCP4.5: 800 Mha
land abandonment

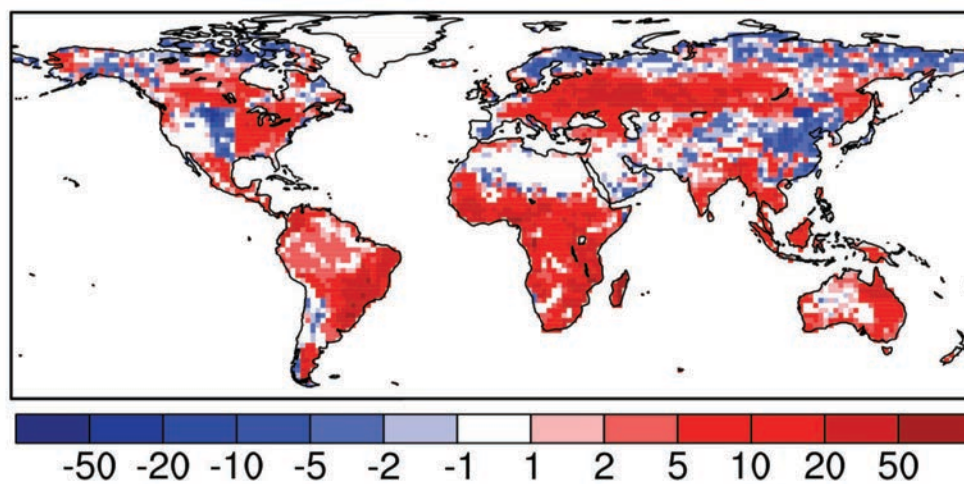
Reforestation

"BAU"
climate

Coupled model



High CO_2 price
→ ag. Intensification & reforestation
→ reduced deforestation (as compared to RCP8.5)



Forest cover change by 2100 (%)

Reforestation in a benign high-CO_2 world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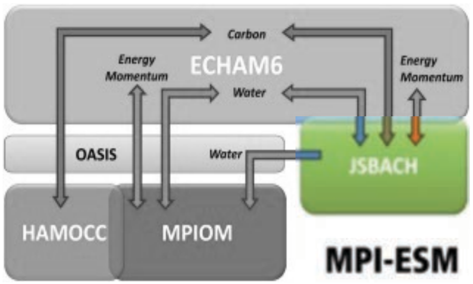
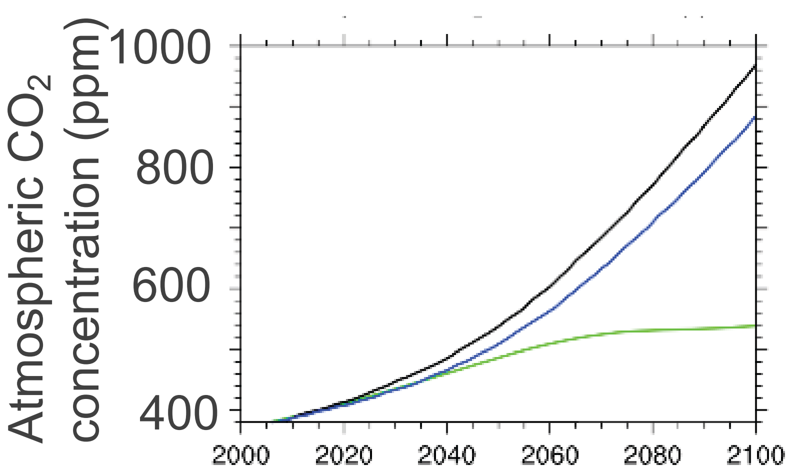




RCP8.5 climate

+ RCP4.5 Afforestation | **+215 PgC** -85 ppm (-0.3 K)

RCP4.5 Climate+ Afforestation

Sonntag et al., *Geophys. Res. Lett.*, 2016

[mentioned re previous slide:

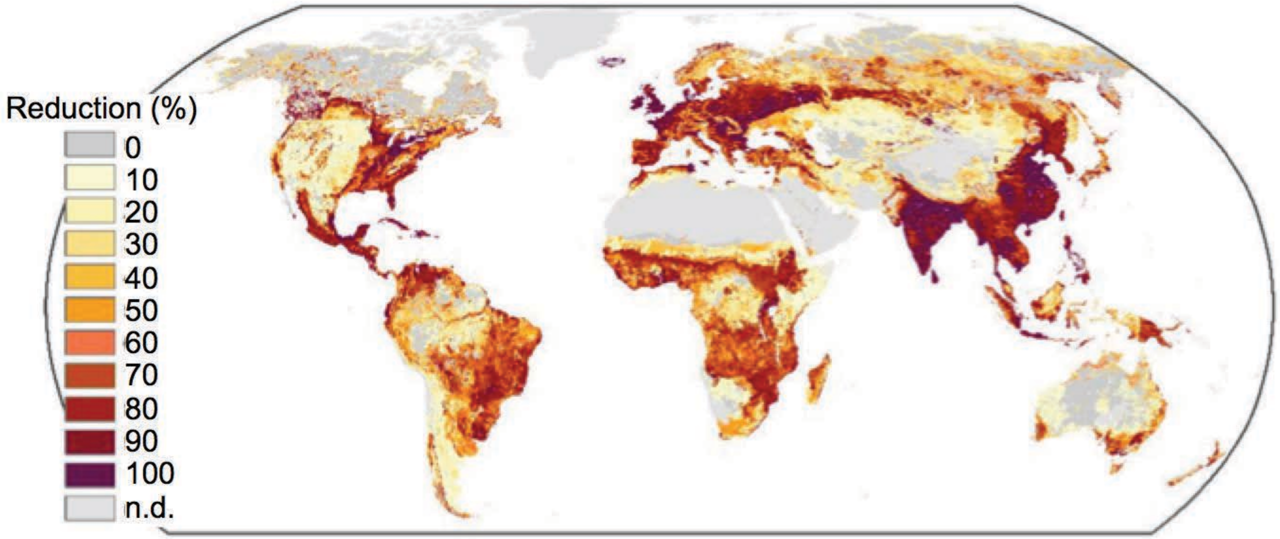
Fire, wind and the evolution of climatic extremes is in principle captured by these models – but there are model deficiencies. Also parts of the physiological plant response is not included in all such models (e.g. most don’t have hydraulic failure).

Progress is being made – see Hao-wei’s study the day before on how to improve drought response in the Amazon.]

Also globally, forest management matters hugely

Half of the vegetation biomass has been removed by humans

Remote sensing
+
inventories

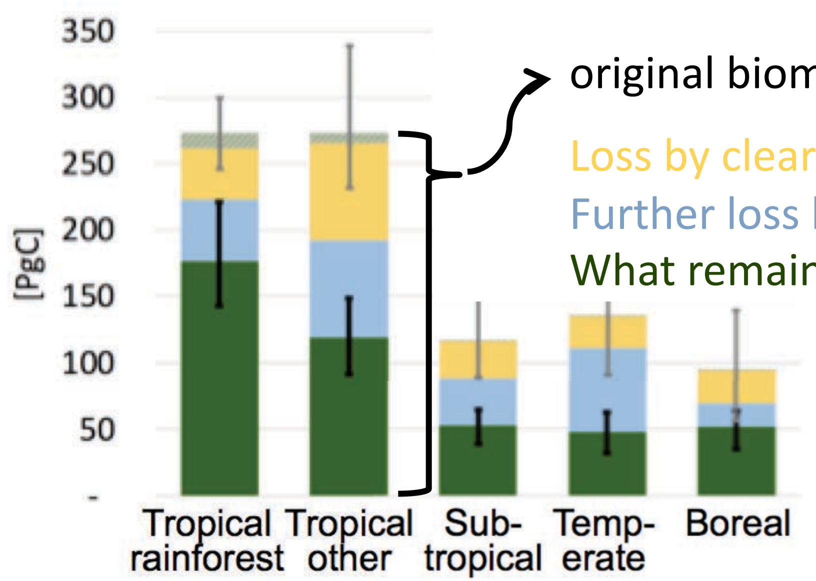


Also globally, forest management matters hugely

Half of the vegetation biomass has been removed by humans
Half of that by land management

→ stopping deforestation is not enough

→ large potential in how we manage

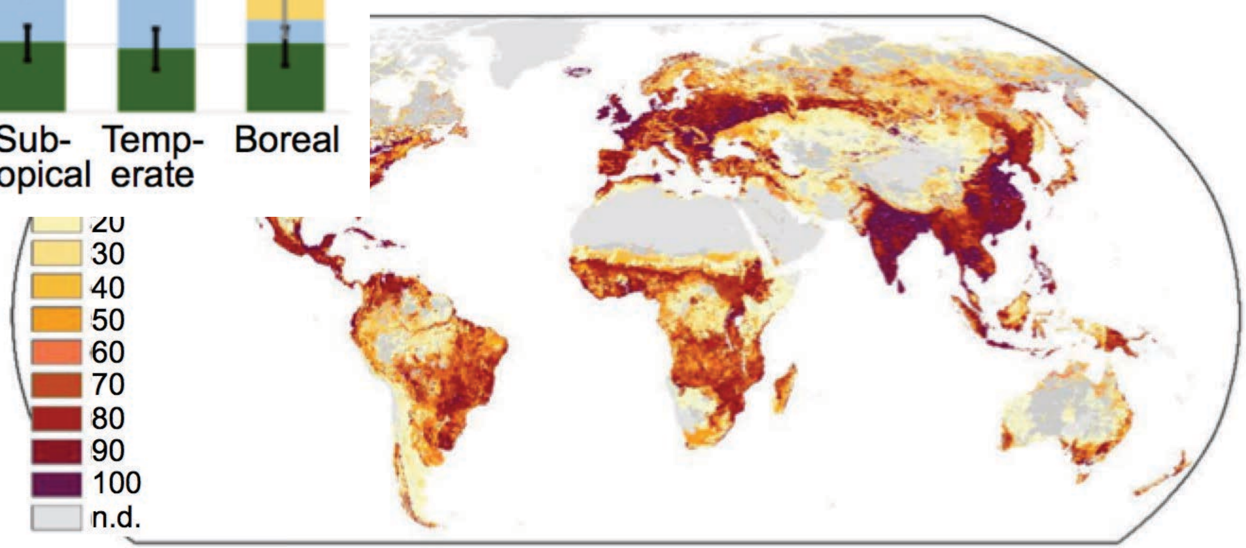


original biomass

Loss by clearing of natural v

Further loss by managemen

What remains



Remote sensing
+
inventories

Erb et al, *Nature*, 2017

Story

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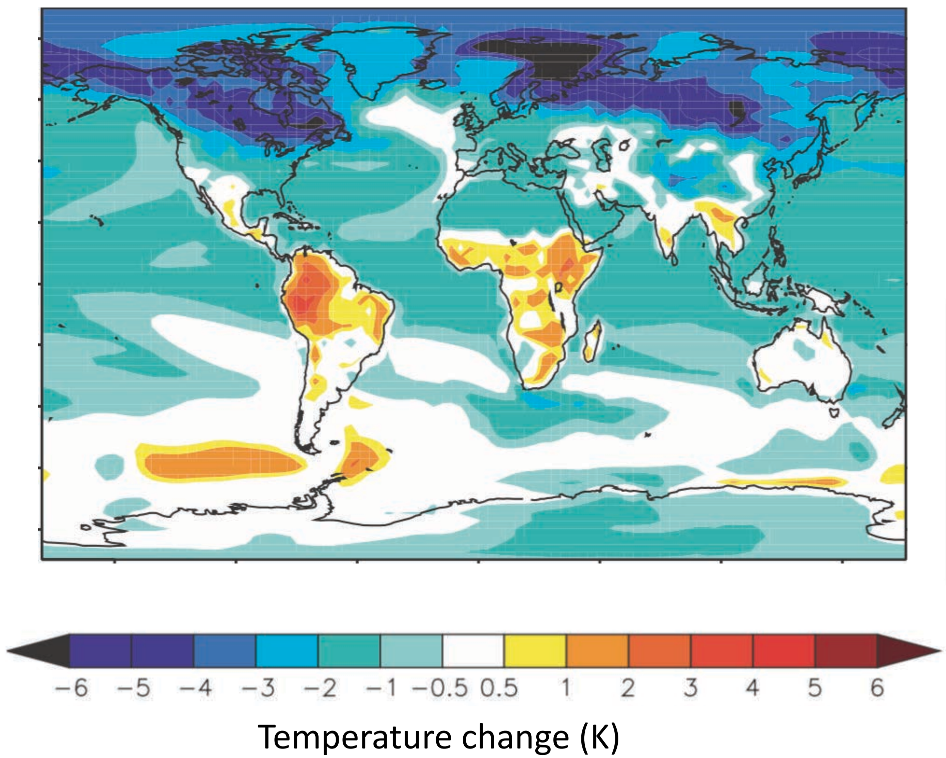
Biogeophysical effects of deforestation

Model simulations of 100% deforestation



Models say: Deforestation leads to
Tropical warming
Temperate cooling
Boreal cooling

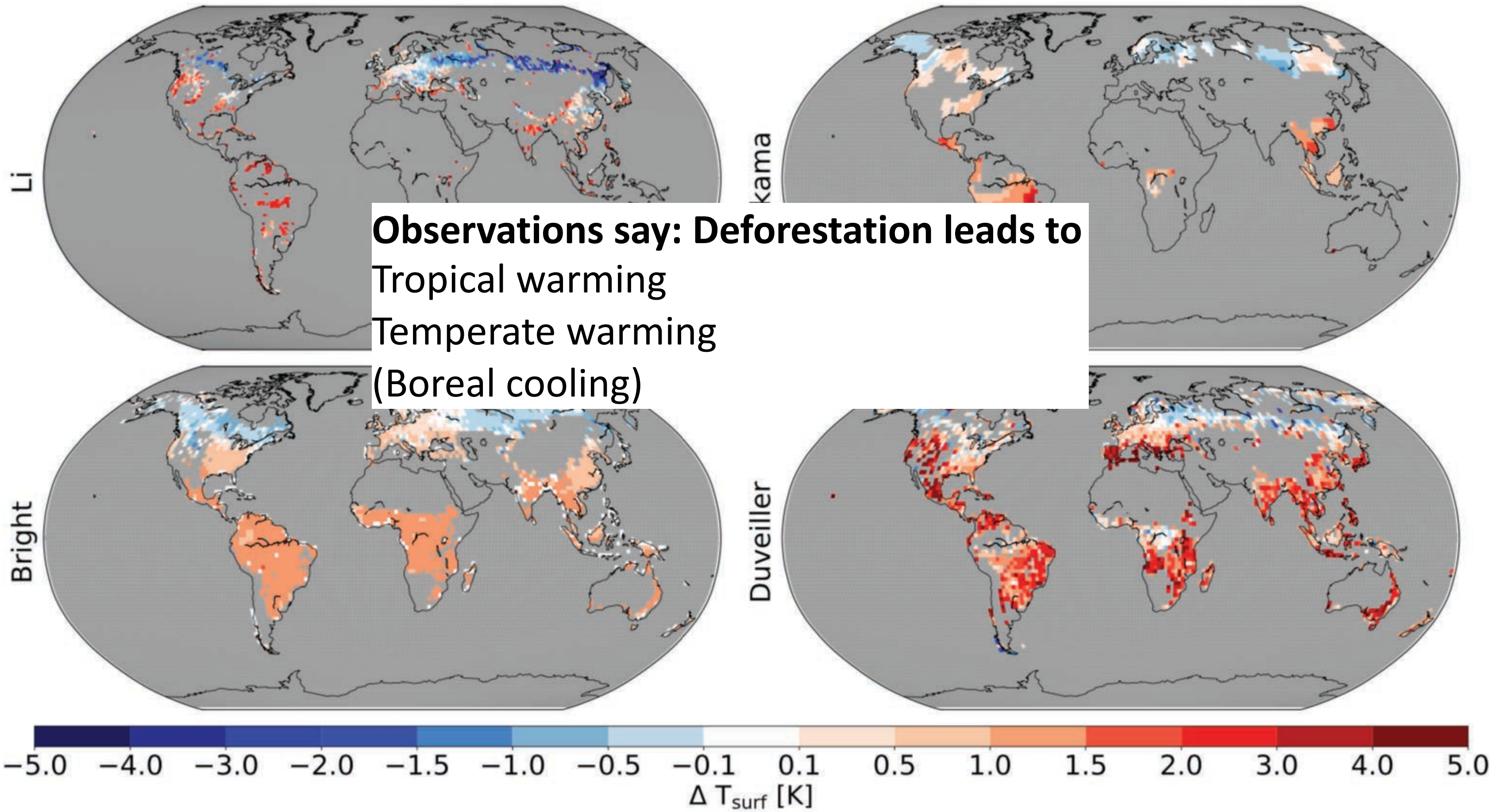
Offset of the potential carbon sink from boreal forestation by decreases in surface albedo

Richard A. Betts

Nature, 2000

Biogeophysical effects of deforestation

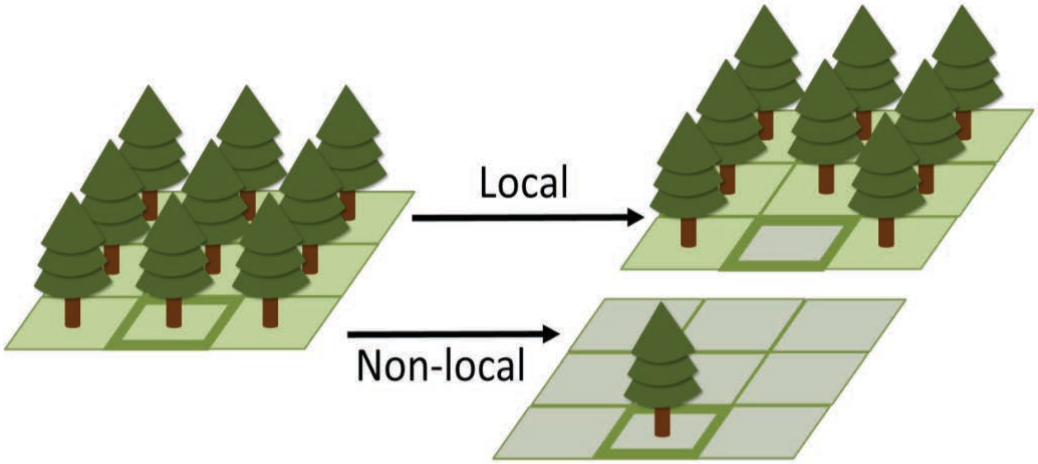
Remote-sensing/Fluxnet-based estimates of deforestation



Observations say: Deforestation leads to
Tropical warming
Temperate warming
(Boreal cooling)

Winckler, Lejeune, Reick, and Pongratz, *Geophys. Research Letters,* 2018

Local vs non-local effects of deforestation



Local effects

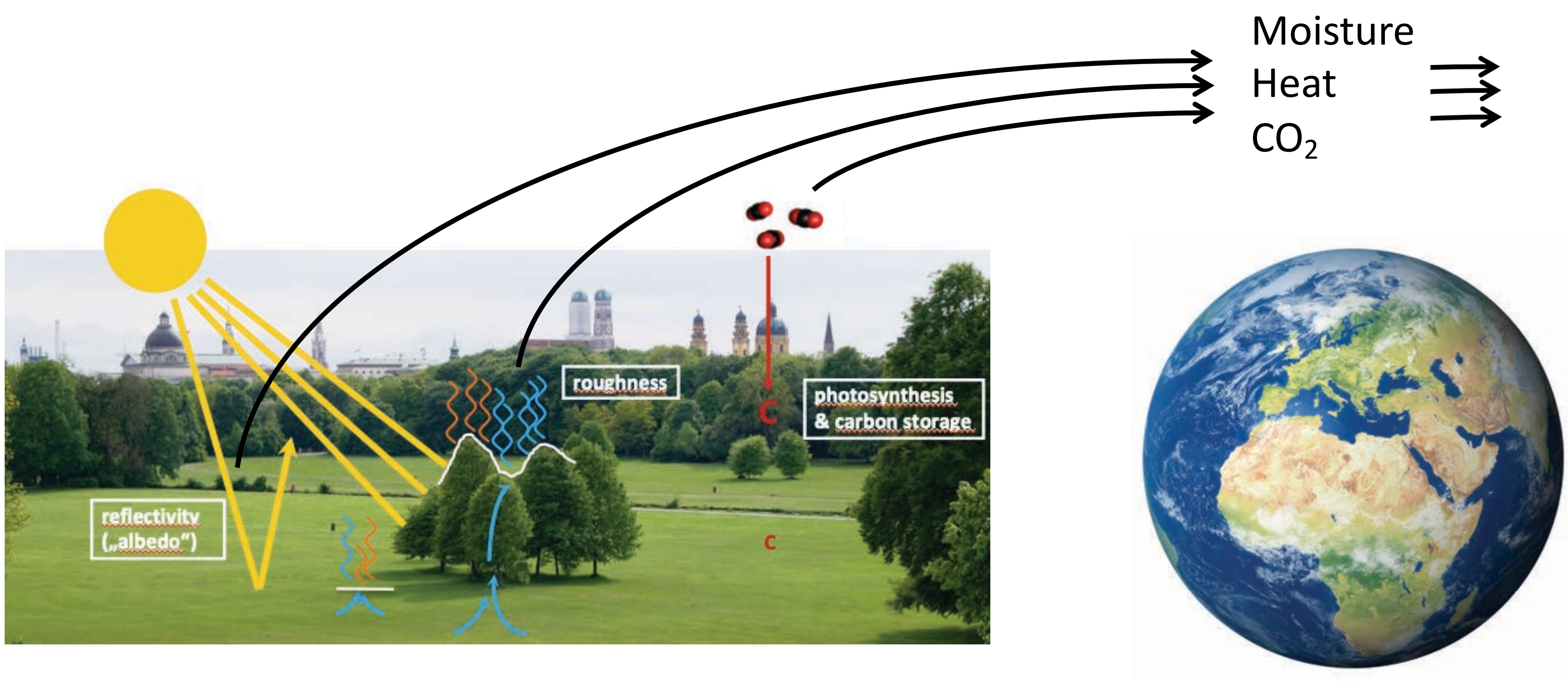
- affect local living conditions → adaptation

Non-local effects

- relevant for global mitigation potential

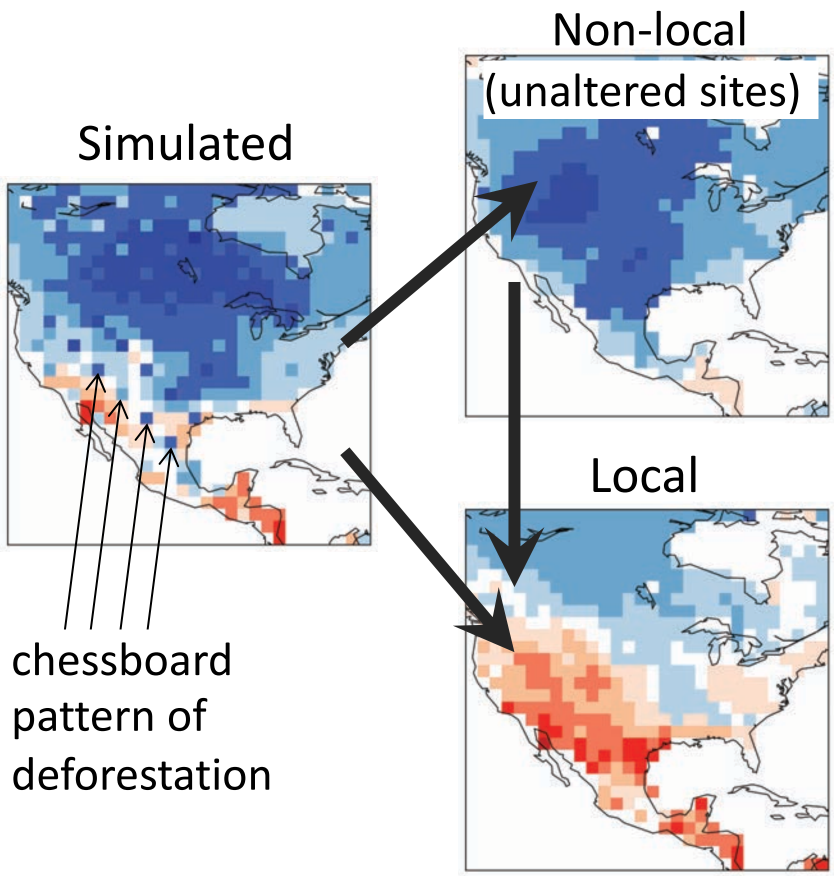
Local vs non-local effects of deforestation

Local effects... become non-local.



Local vs non-local effects of deforestation

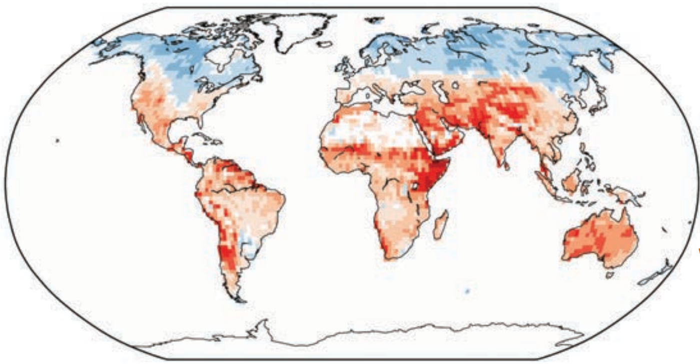
Method



Local vs non-local effects of deforestation

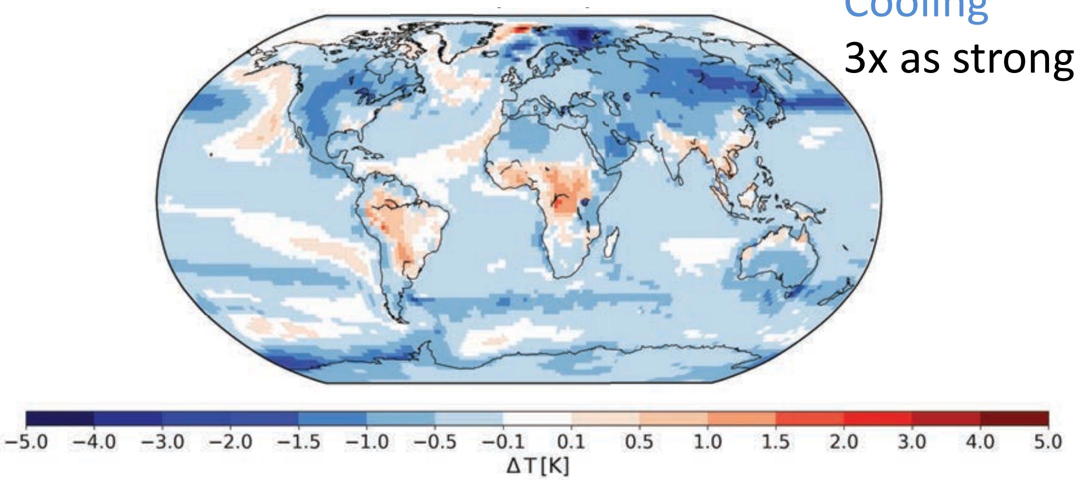
Surface temperature change for global deforestation

Local



Warming

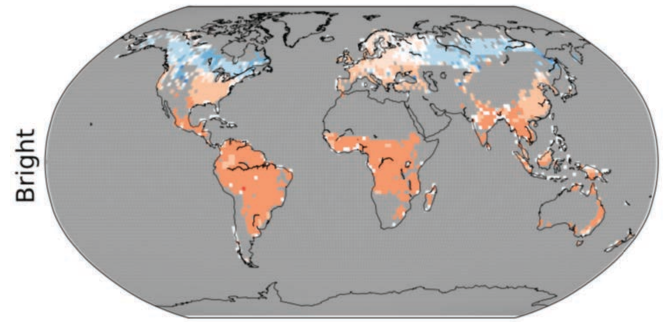
Non-Local



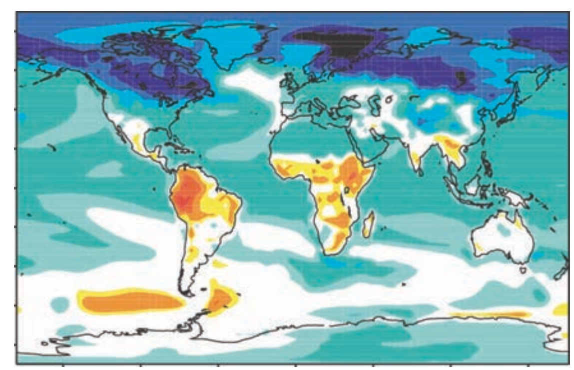
Cooling

3x as strong!

Observations: local effects only!



Models: local + non-local effects



[discussed on previous slide:

The conundrum that models show much more cooling than observations is resolved:

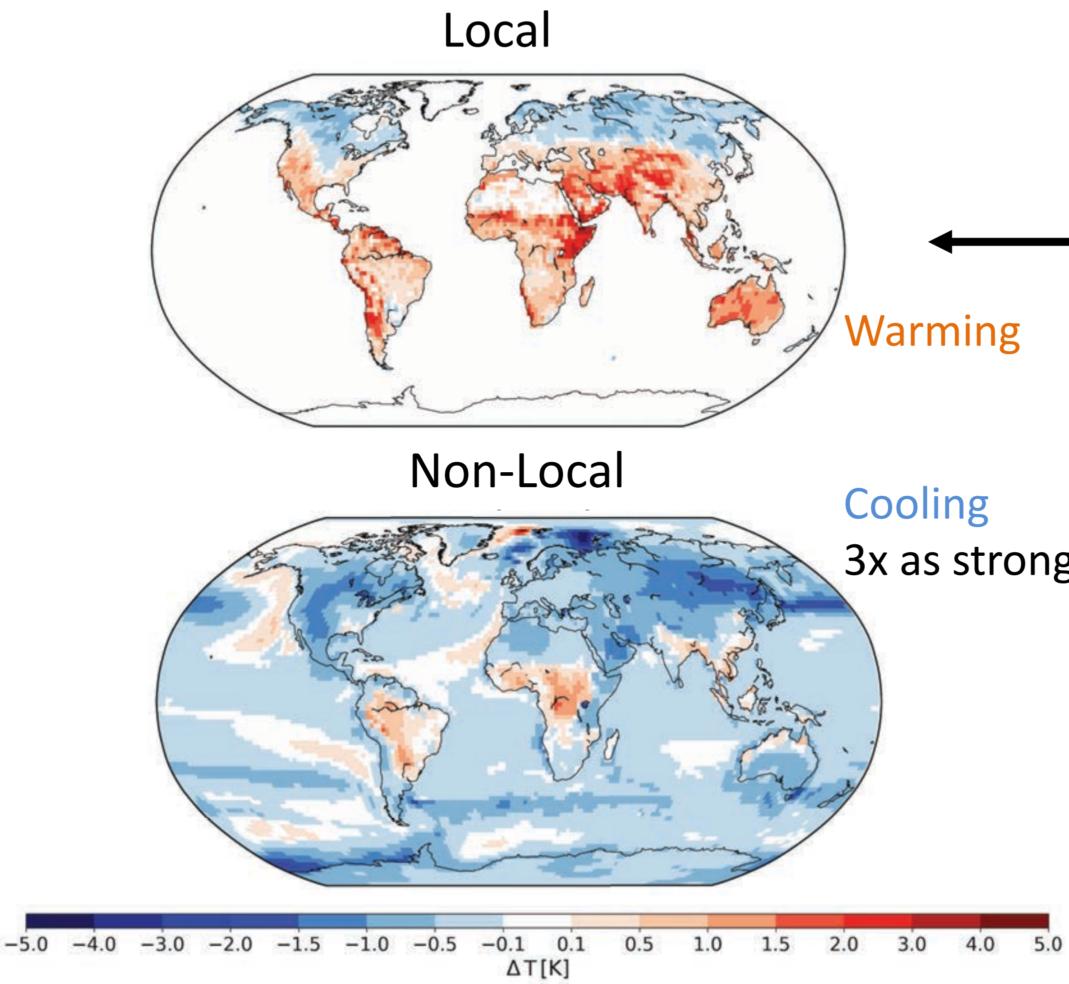
Observations by way they are set up exclude non-local effects (e.g. by subtracting forest from neighboring grassland flux tower the non-local effects (because they are the same if they are neighboring sites) cancel out).

Models capture both local and non-local effects (as reality does) (but are even better than reality because they can be used to isolate each ☺). Including the non-local effects explains the much larger cooling in temperate and boreal regions in models.

Re audience question on model evaluation: models are evaluated against the local effects (see observational datasets 4 slides earlier – our model results match well (but note the big spread in obs data…), and against the total (local + non-local) effect from Earth observation (overlaid by general climate change; e.g. done regularly within CMIP (“IPCC simulations”).]

Local vs non-local effects of deforestation

Surface temperature change for global deforestation



Warming

Cooling
3x as strong!

Huge adaptation potential by reforestation!

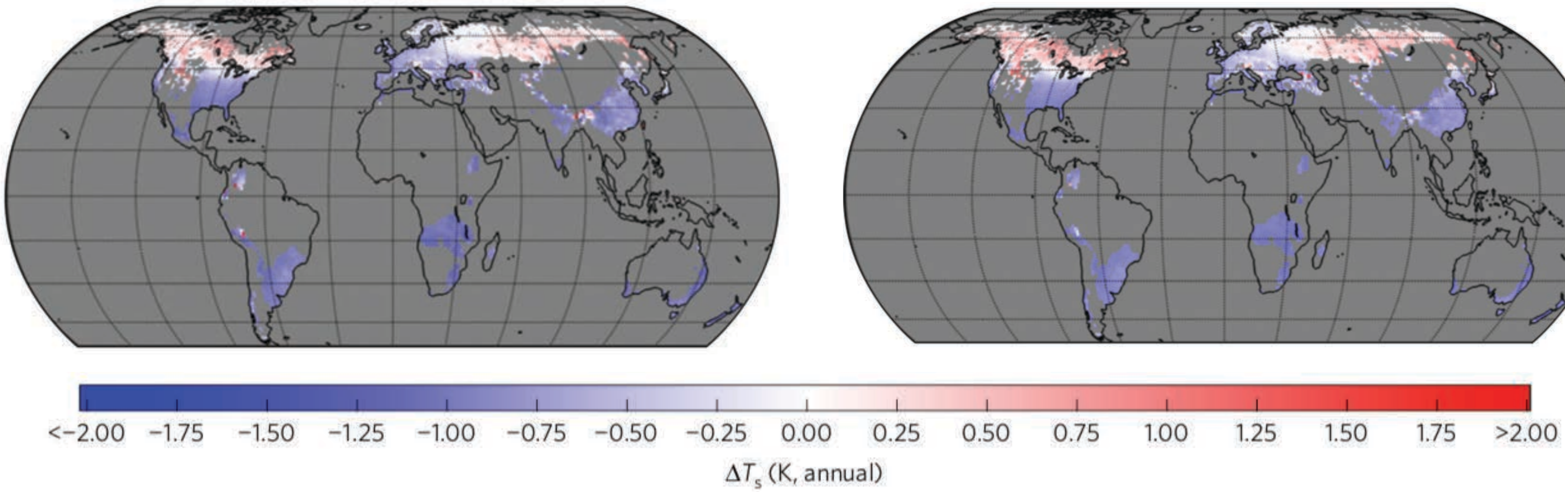
Winckler, Reick, and Pongratz, *J. Clim.*, 2017 & *GRL*, 2018

Dominant property for biogeophysics: roughness

Study using satellite-based temperature and radiative fluxes to infer temperature changes

Grassland > broadleaf forest

Grassland > needleleaf forest



Bright et al, *Nature Climate Change,* 2017

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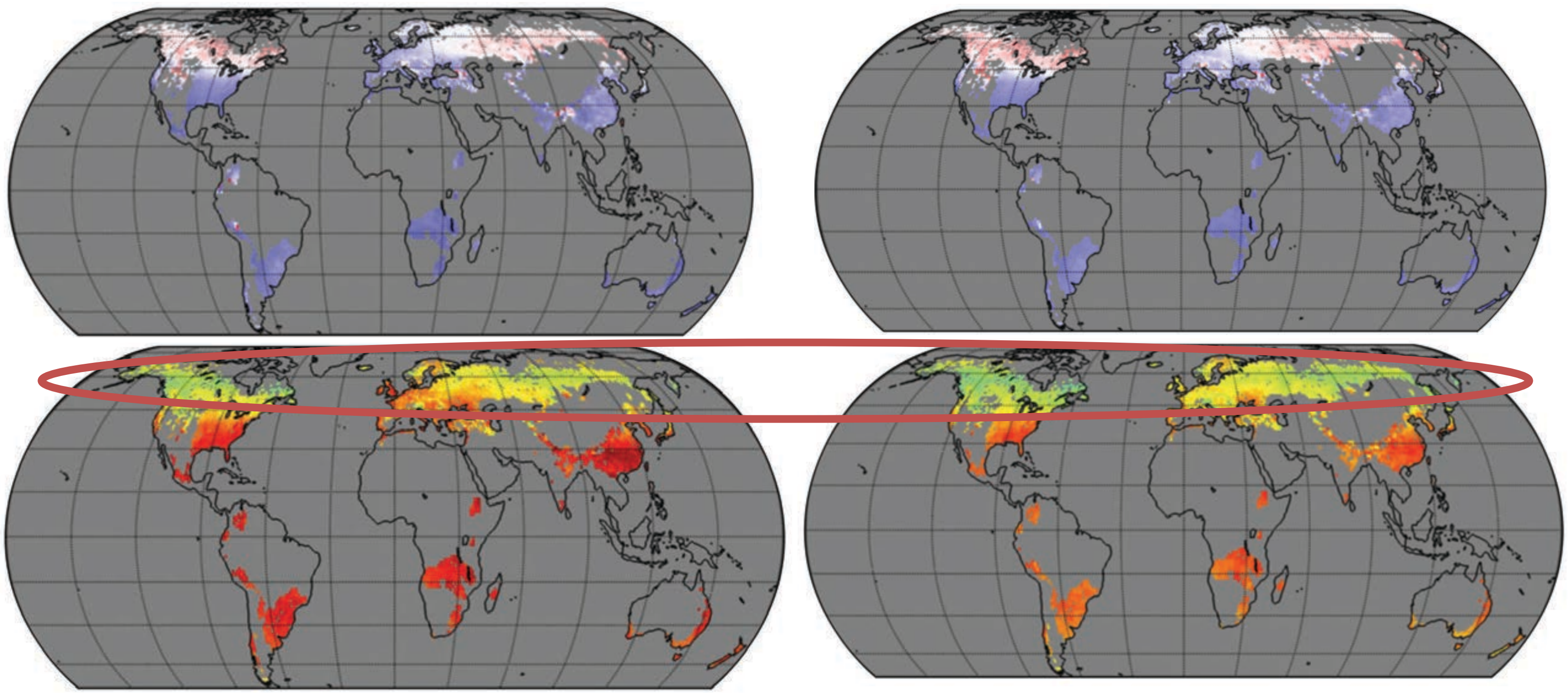
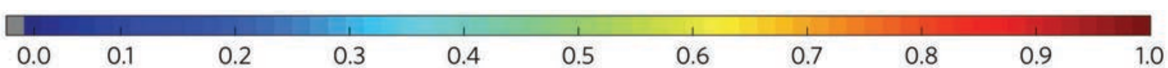


dominance of albedo ← | → dominance of non-radiative terms



"non-radiative forcing index"

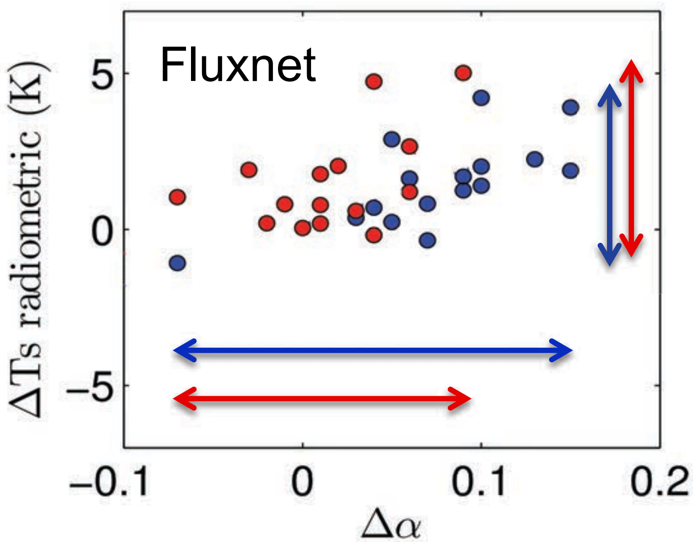
Forest management equally powerful

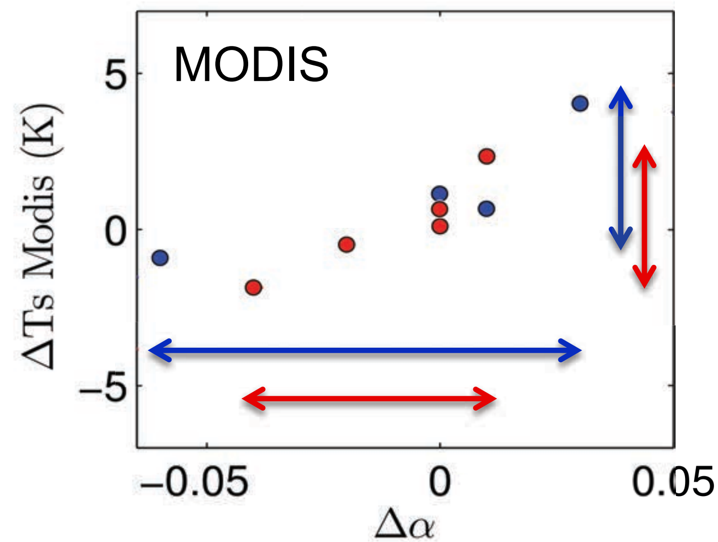
Forest (Argentina)

Cropland (Brazil)

Natural forest (Tabin Wildlife Preserve, Malaysia)

Managed forest





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