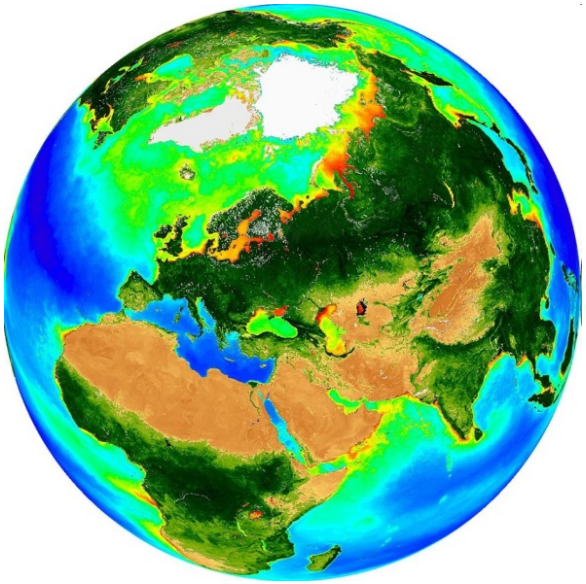
Vegetation: a global or regional player in the climate system?

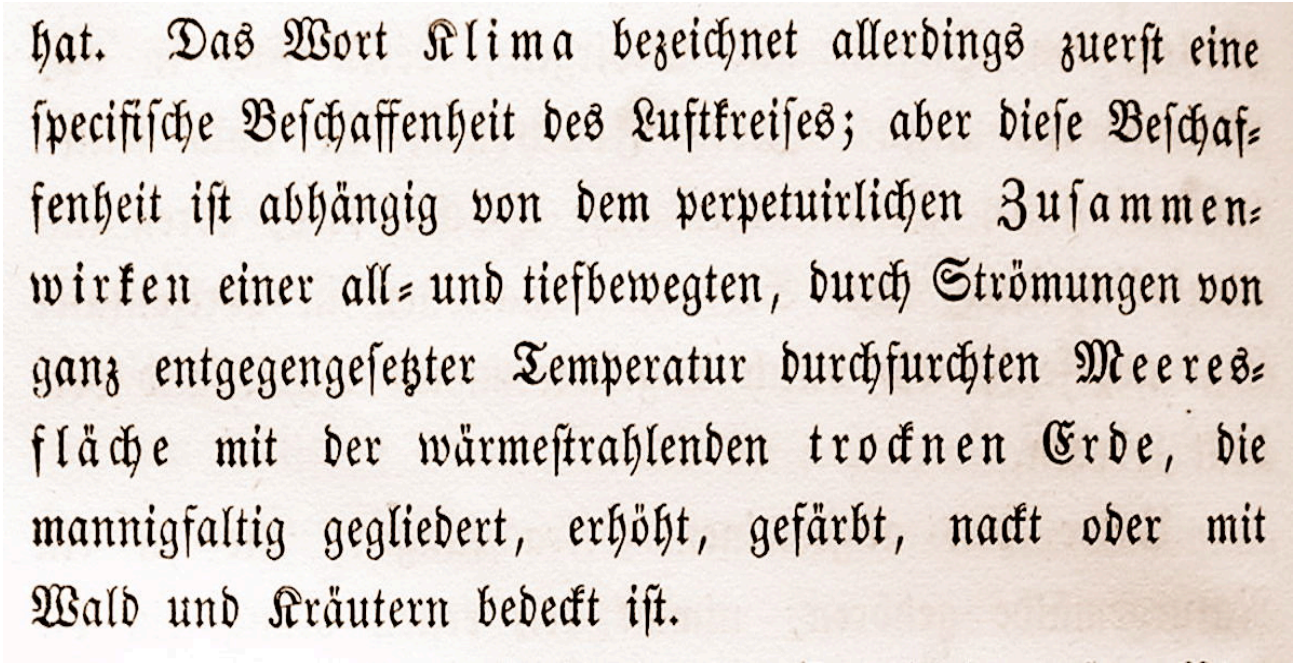


Martin Claussen

Max Planck Institute for Meteorology, University Hamburg

KlimaCampus Hamburg

Alexander von Humboldt, Kosmos (1845)

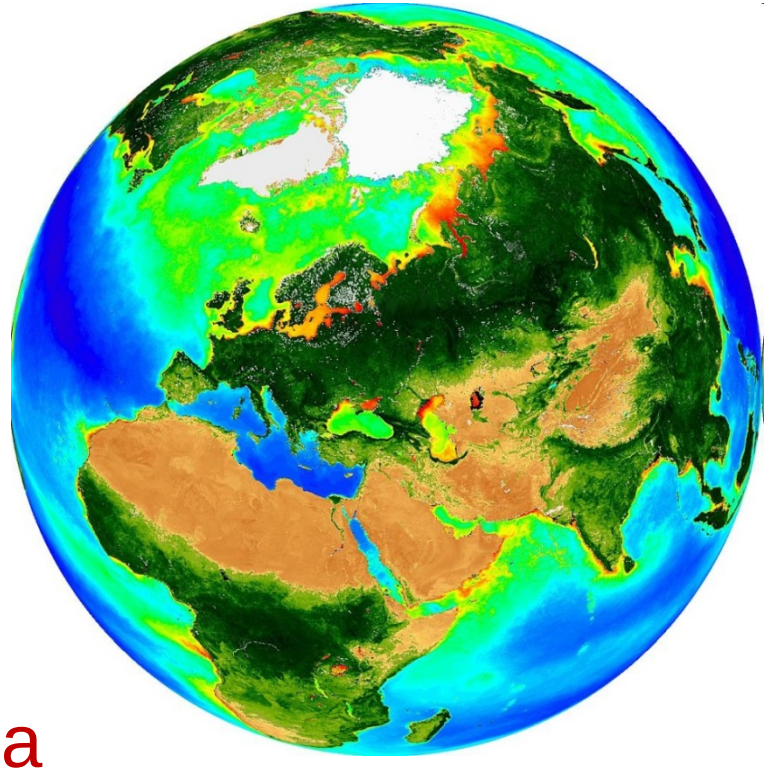


hat. Das Wort Klima bezeichnet allerdings zuerst eine ſpecifiſche Beſchaffenheit des Luftkreiſes; aber dieſe Beſchaffenheit iſt abhängig von dem perpetuirlichen Zuſammenwirken einer all- und tiefbewegten, durch Strömungen von ganz entgegengeſetzter Temperatur durchfurchten Meeresfläche mit der wärmeſtrahlenden trocknen Erde, die mannigfaltig gegliedert, erhöht, gefärbt, nackt oder mit Wald und Kräutern bedeckt iſt.

Vegetation – the „big flyweight“ in the Earthsystem

Mass:

vegetation ~ $\frac{1}{1000}$ atmosphere

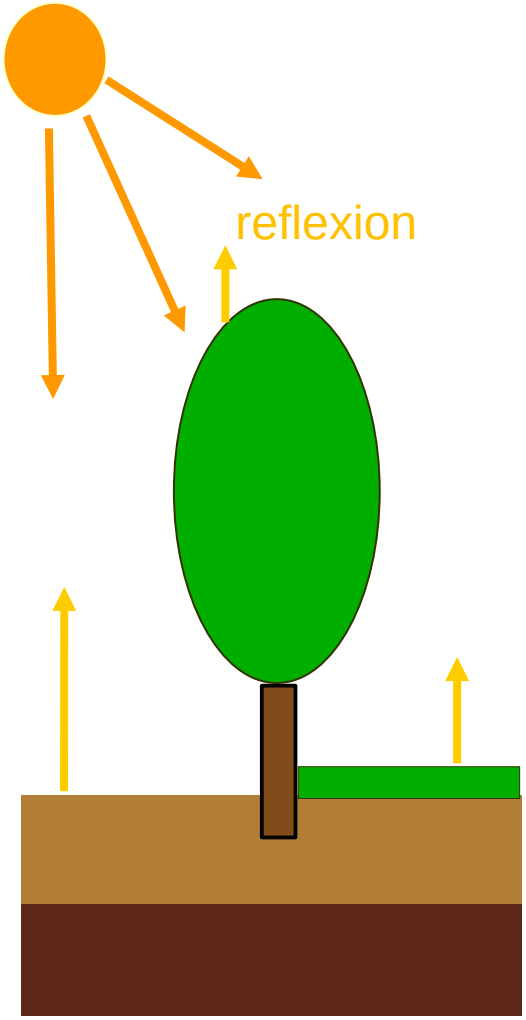


50 N 40E; Boreal Summer
oceancolor.gsfc.nasa.gov/SeaWiFS/

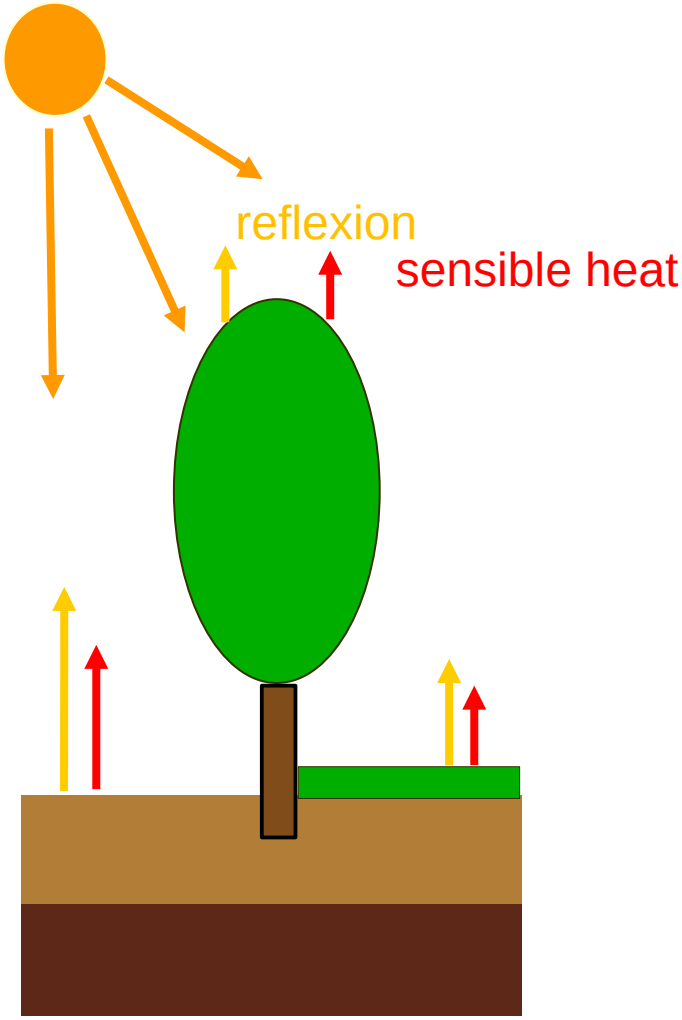
Area:

Leaf area ~ Earth surface area

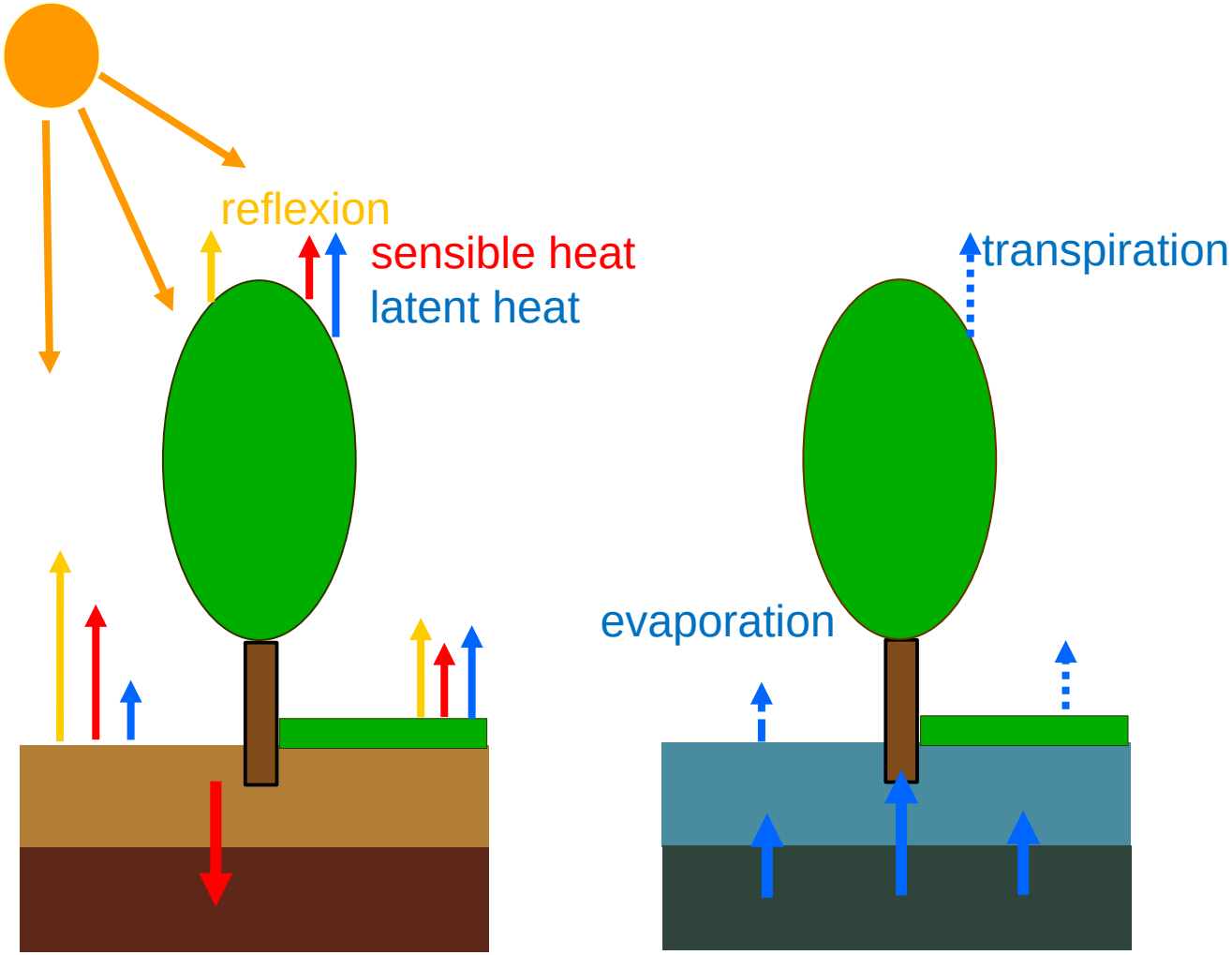
Vegetation – Atmosphere Exchange: Energy



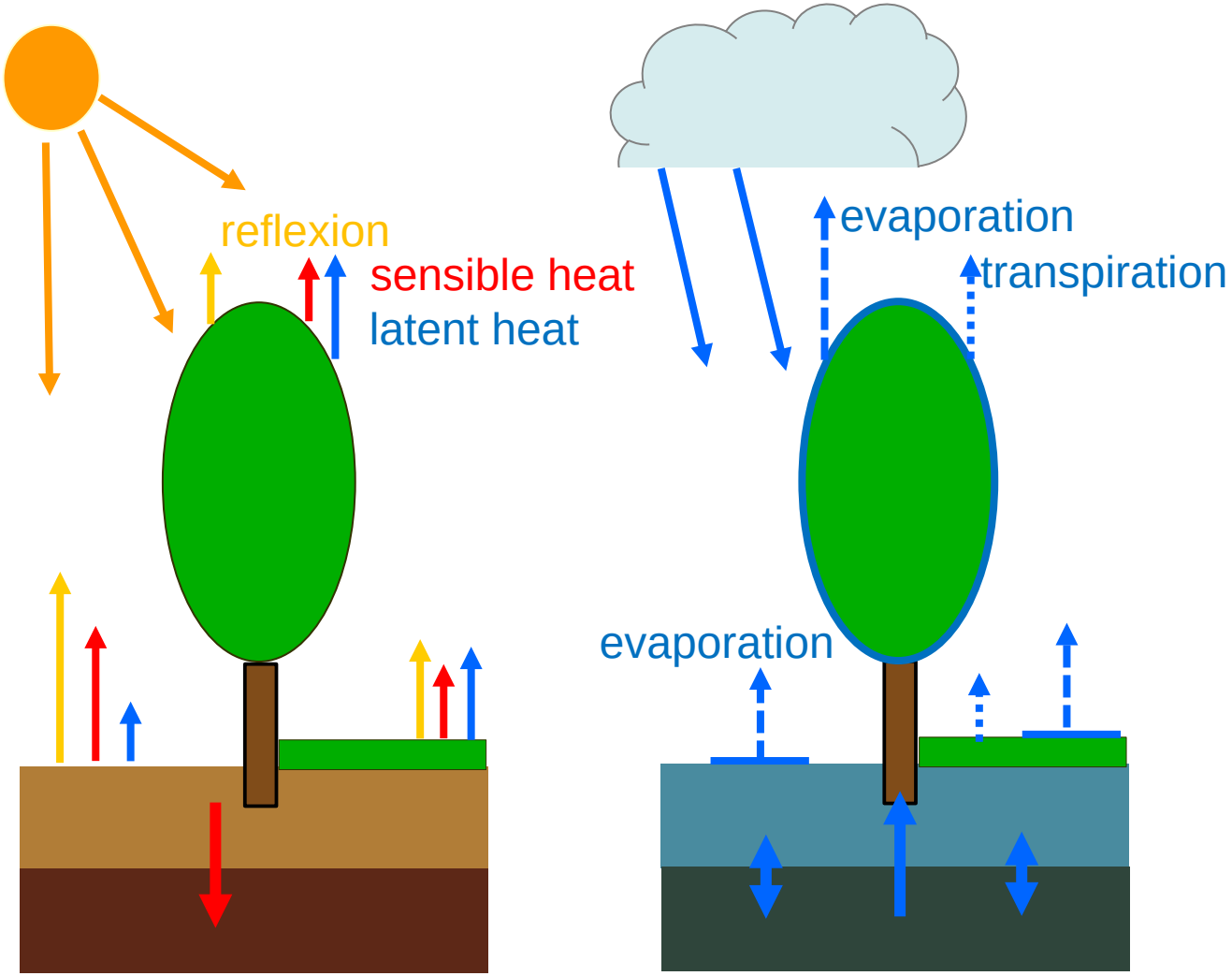
Vegetation – Atmosphere Exchange: Energy



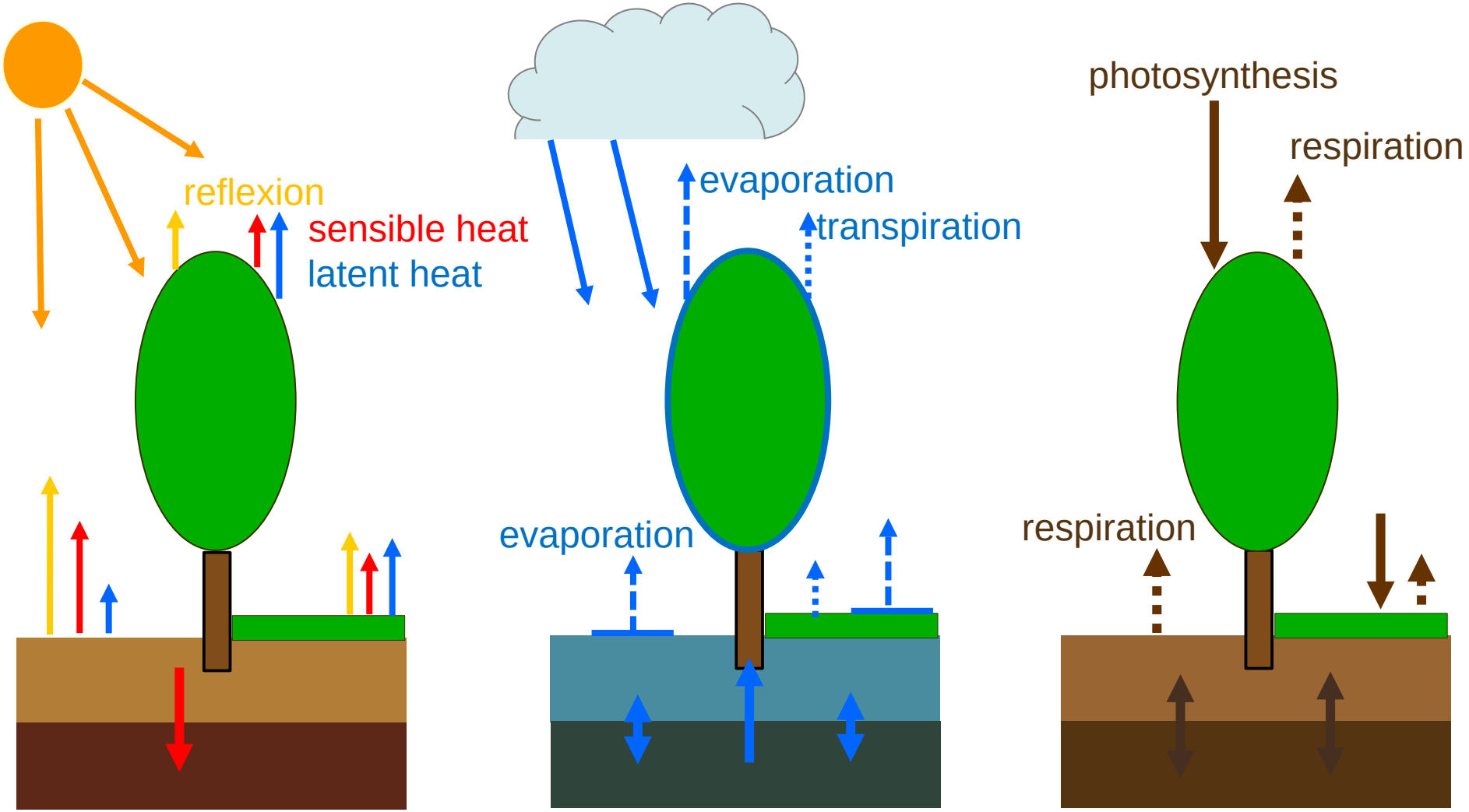
Vegetation – Atmosphere Exchange: Energy, Water



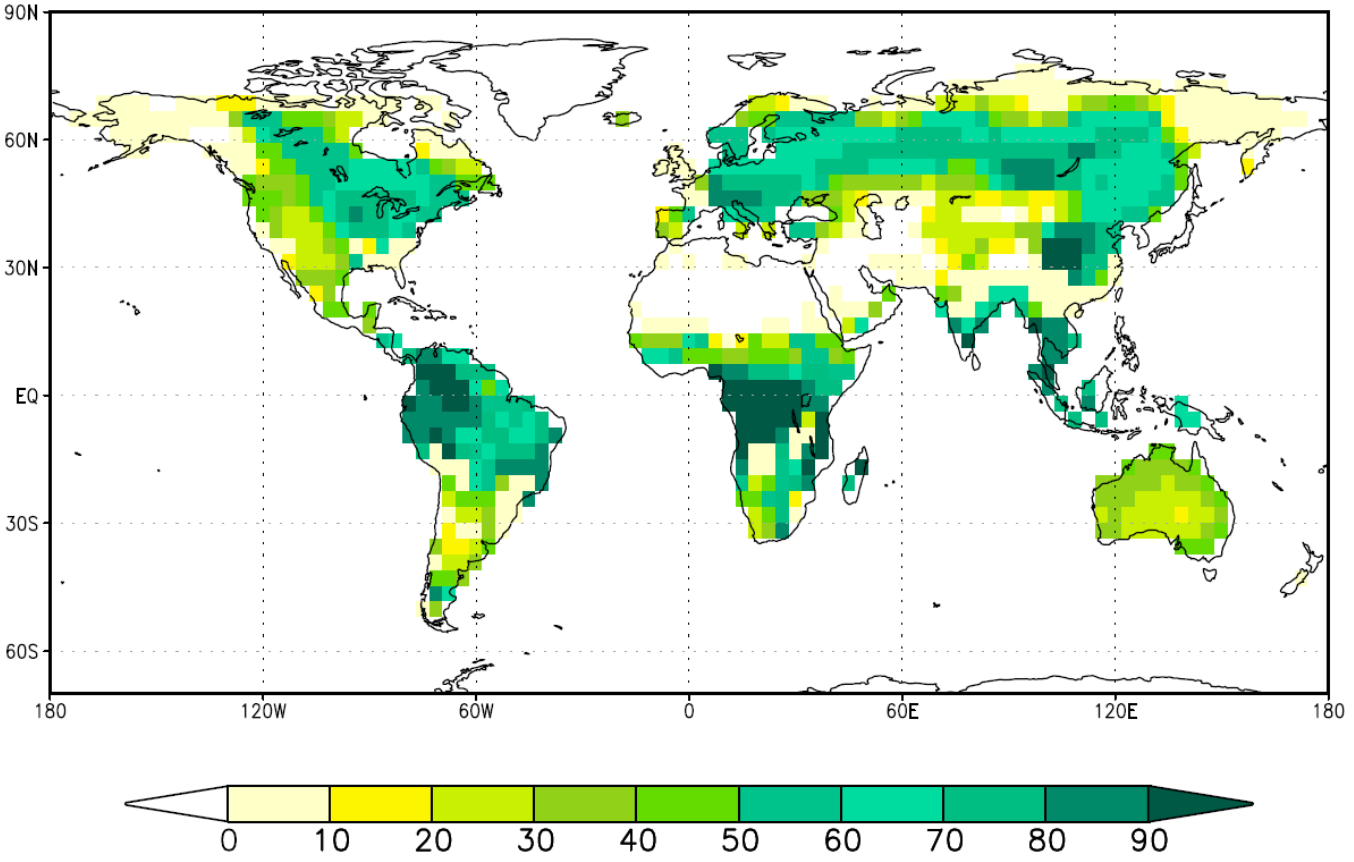
Vegetation – Atmosphere Exchange: Energy, Water



Vegetation – Atmosphere Exchange: Energy, Water, Carbon



Which effect wins?
Does vegetation cool or warm the climate?

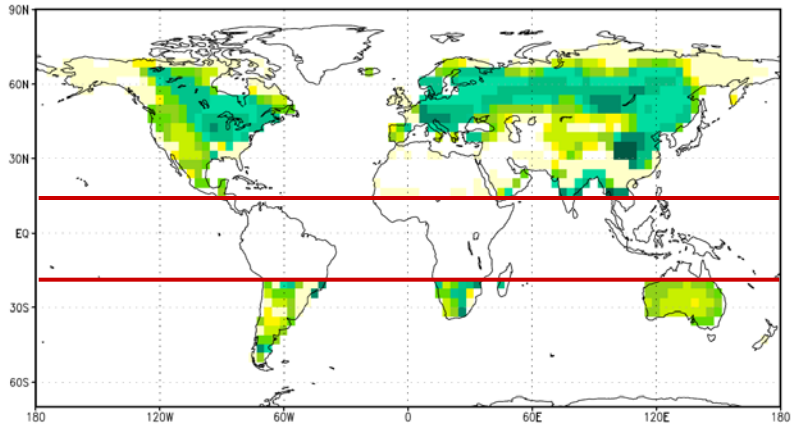


Simulated potential forest coverage in today's climate

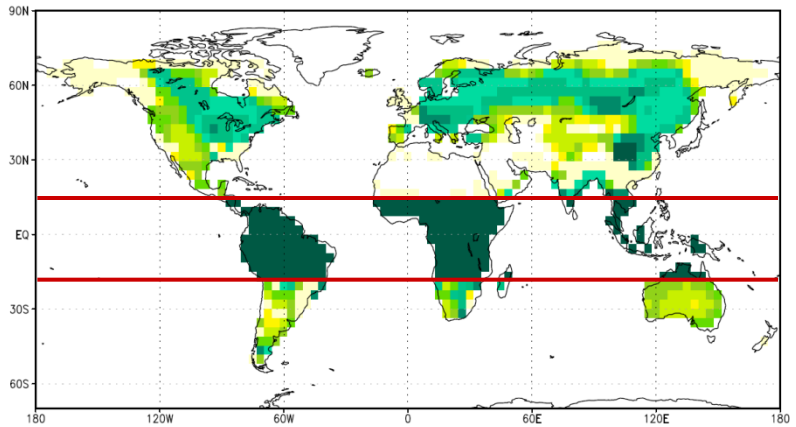
Bathiany et al., 2010

A thought experiment:

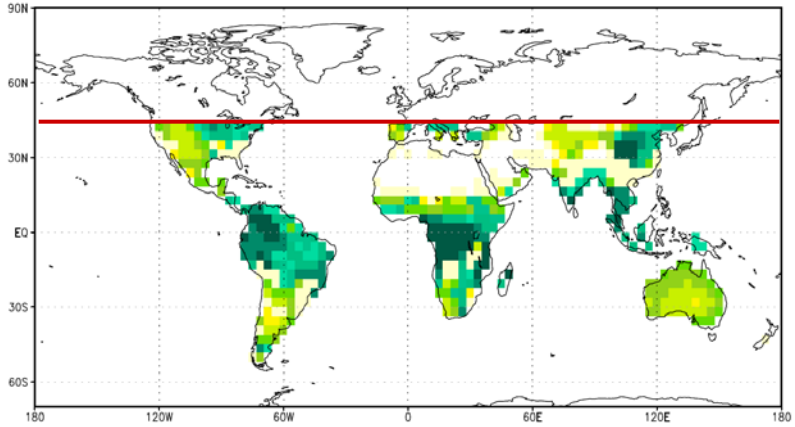
complete deforestation



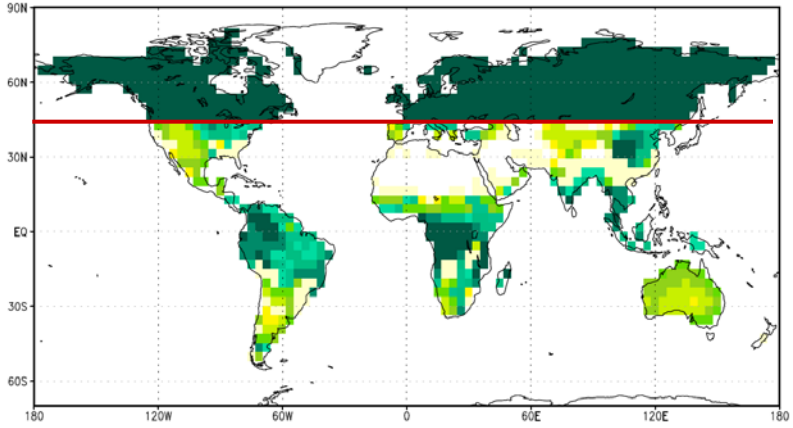
afforestation of the tropics

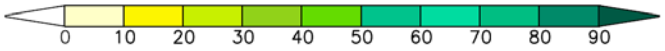


complete deforestation



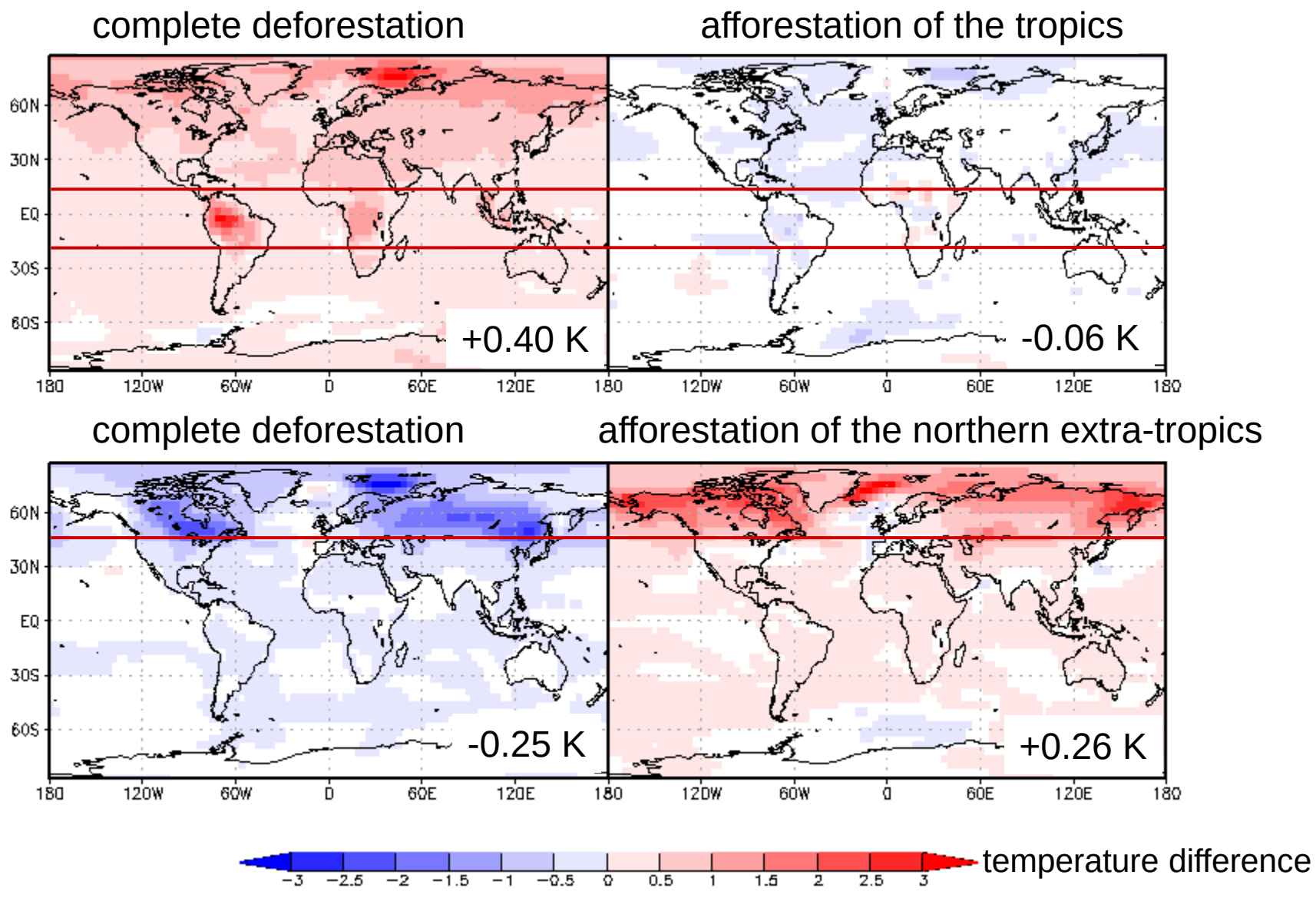
afforestation of the northern extra-tropics





Bathiany et al., 2010

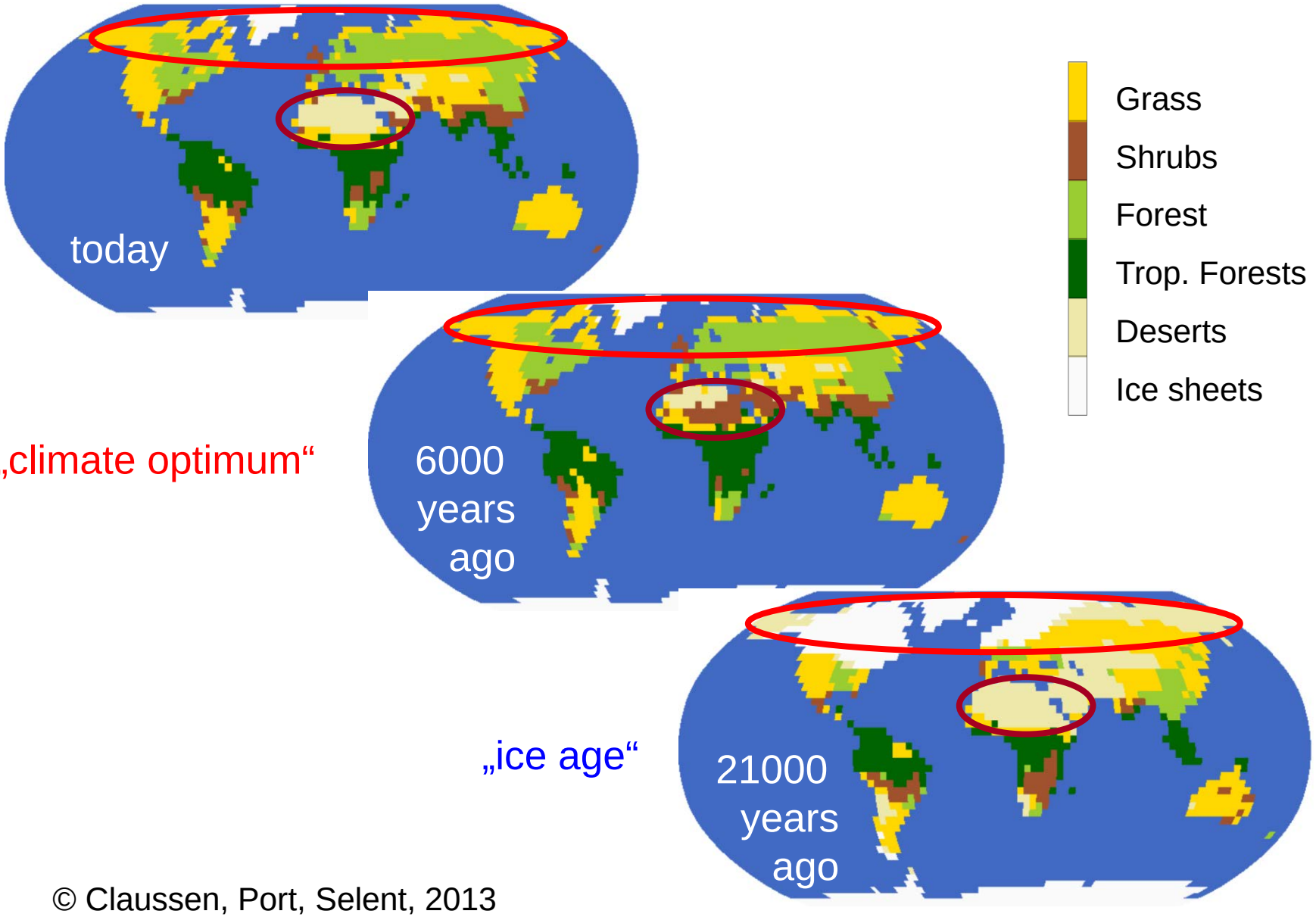
Tropical forests cool, boreal forests warm the climate



Bathiany et al., 2010

A more realistic setting: ice age cycles

Simulated dominant vegetation types

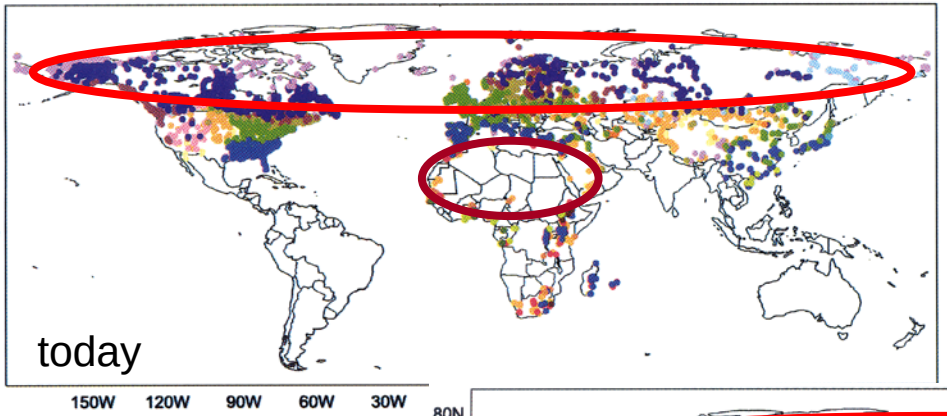


„climate optimum“

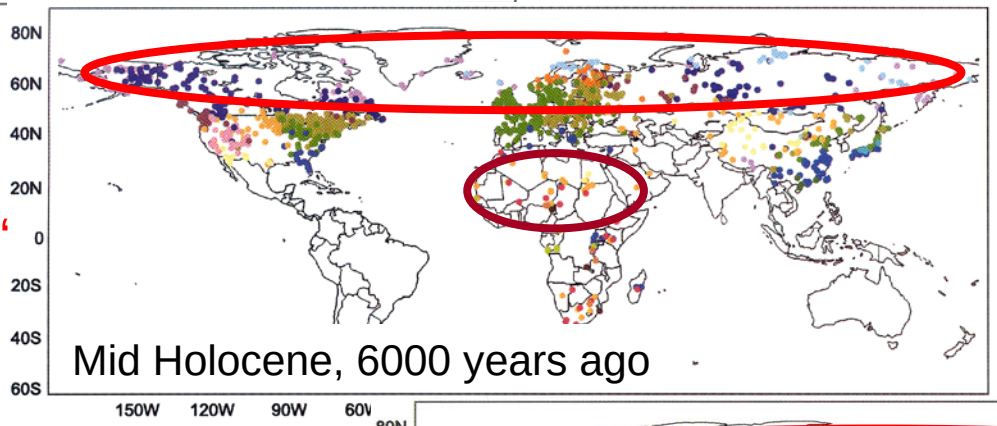
„ice age“

© Claussen, Port, Selent, 2013

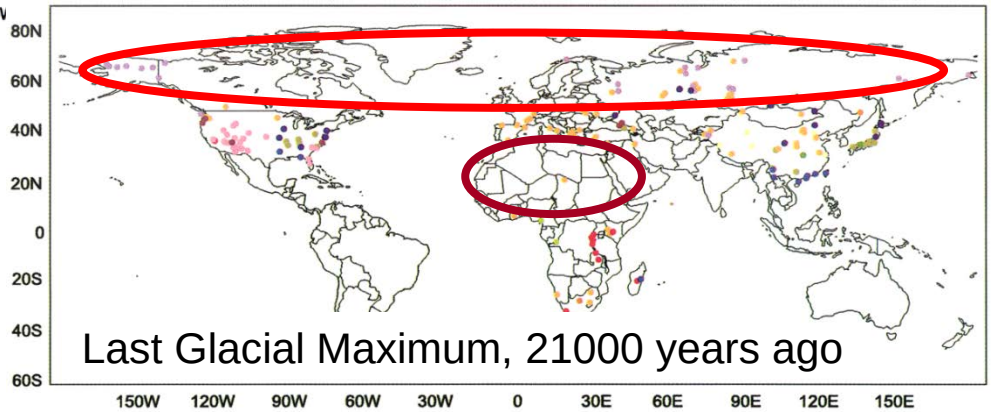
Computed and reconstructed biome patterns agree by and large



„climate optimum“



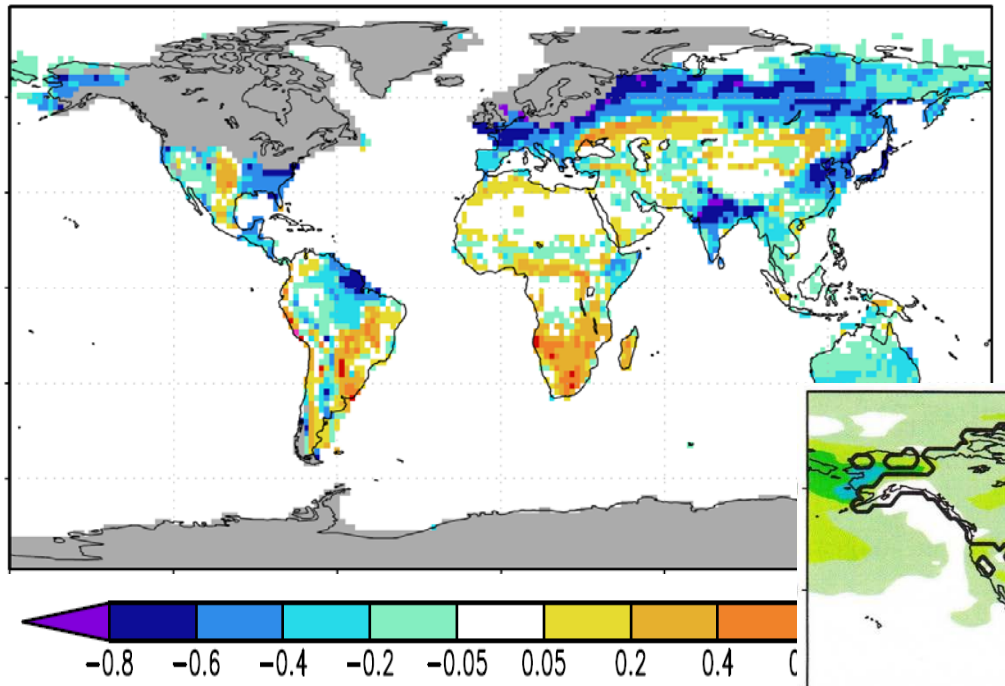
„ice age“

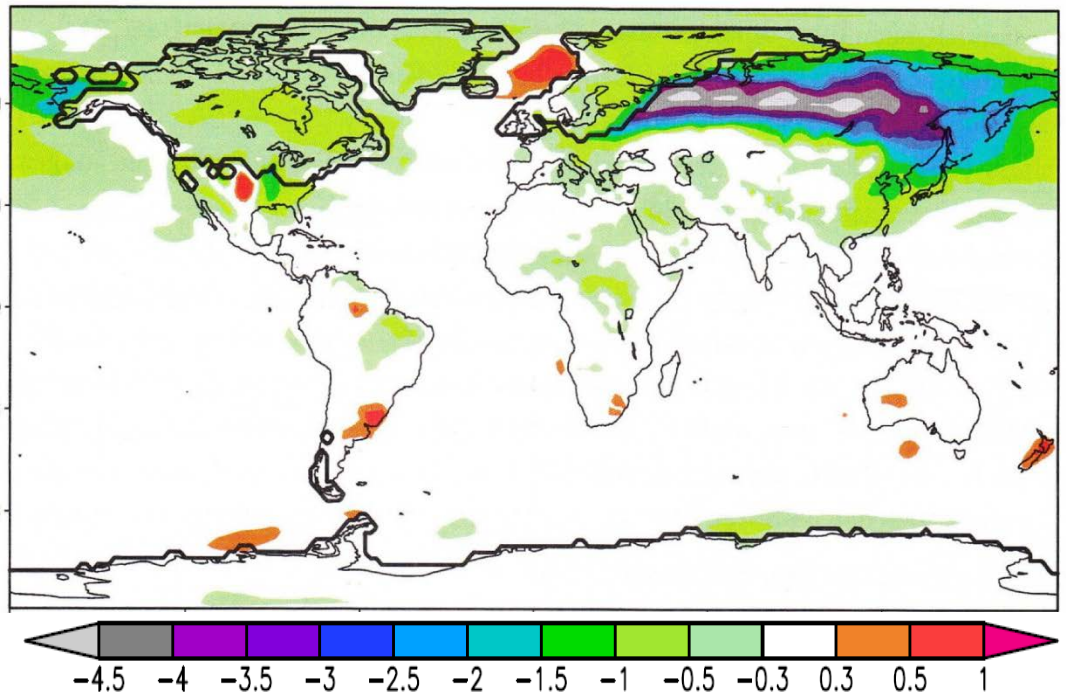


Prentice, Webb et al., J. Biogeogr., 2000

Contribution of vegetation changes **only** to temperature changes (last glacial maximum – today)

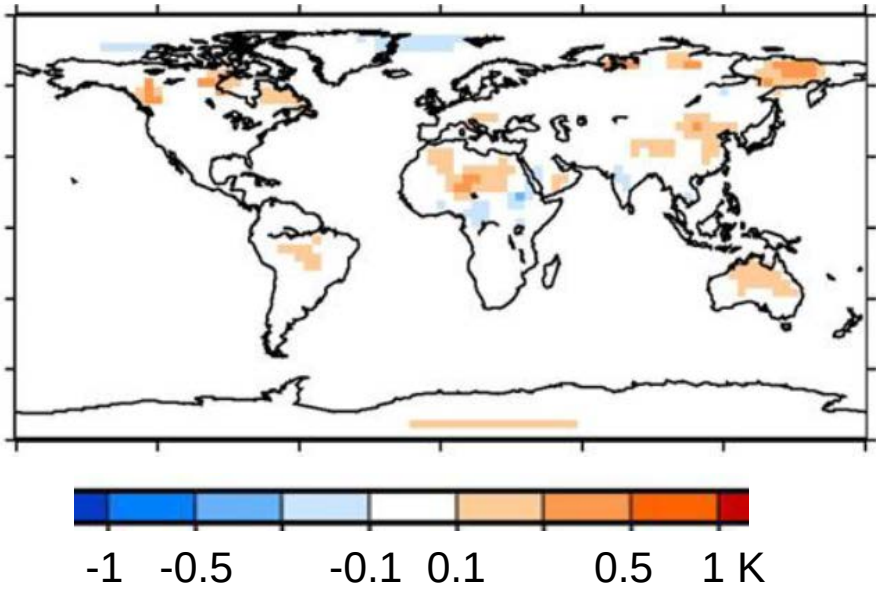
Differences in woody vegetation coverage



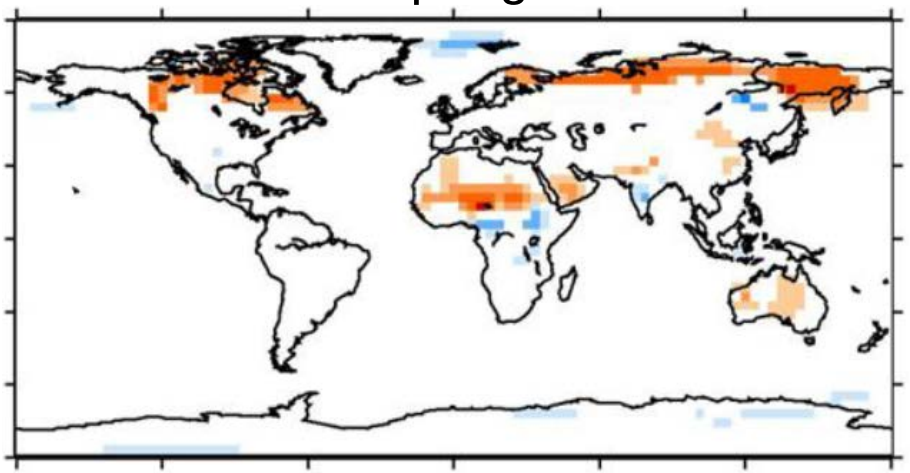


Contribution of vegetation changes **only** to temperature changes (mid-Holocene – today)

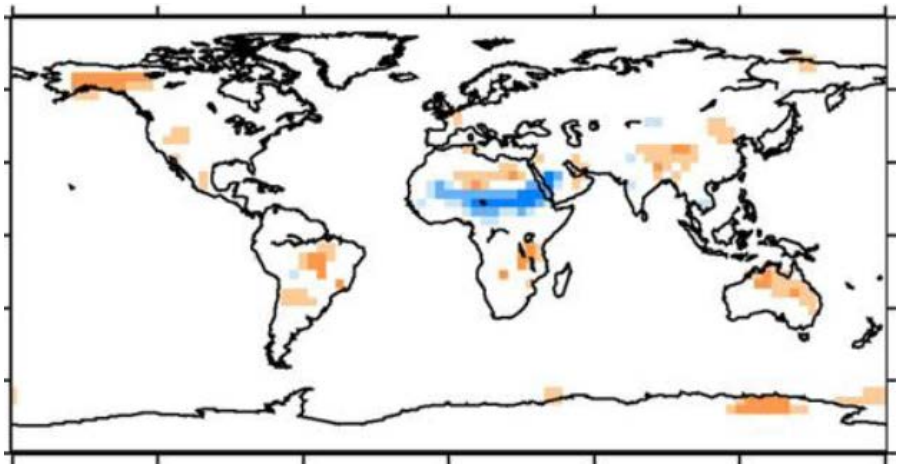
Annual mean



Spring



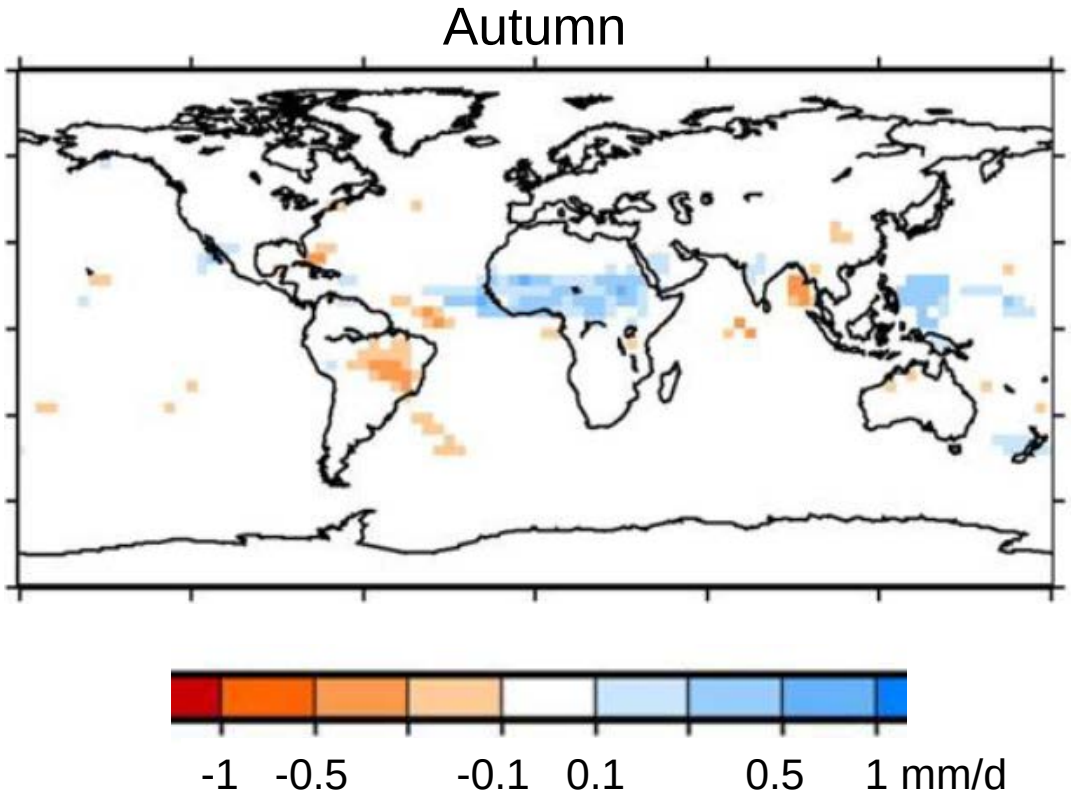
Autumn



Otto et al., 2009; Galfi, 2012

Contribution of vegetation changes **only** to precipitation changes (mid-Holocene – today)

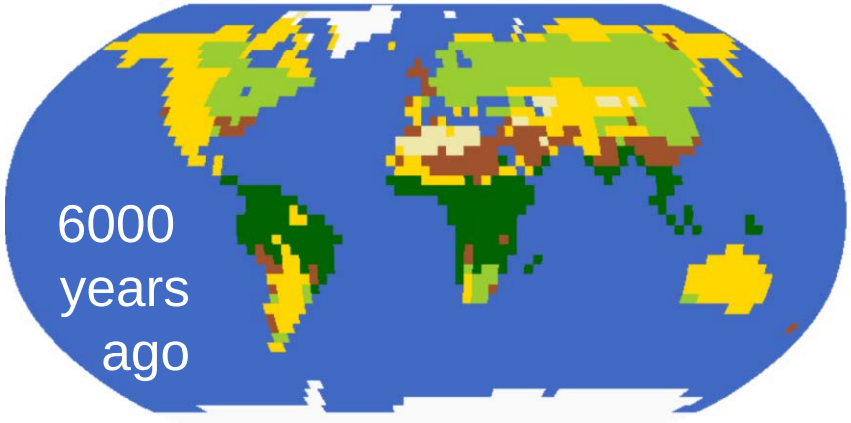
The strongest signal is the amplification of the West-Africa monsoon:



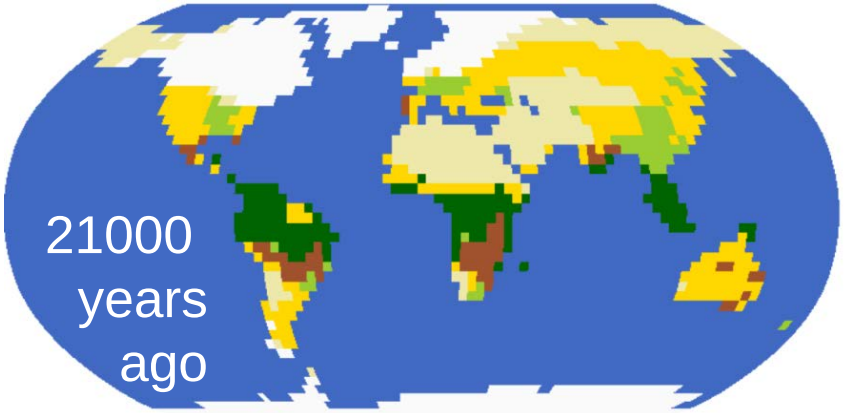
Otto et al., 2009; Galfi, 2013

Tentative conclusion: vegetation dynamics tends to amplify ice-age climate changes

global mean ΔT ~ 4 – 6 ^{o}C between ice age and warm age



→ global mean ΔT_{veg} ~ 0.x ^{o}C



Grass
Shrubs
Forest
Trop. Forests
Deserts
Ice sheets

→ autumn ΔP ~ + 20 - 40% in Sahara / Sahel

© Claussen, Port, Selent, 2013

Any regional surprises?

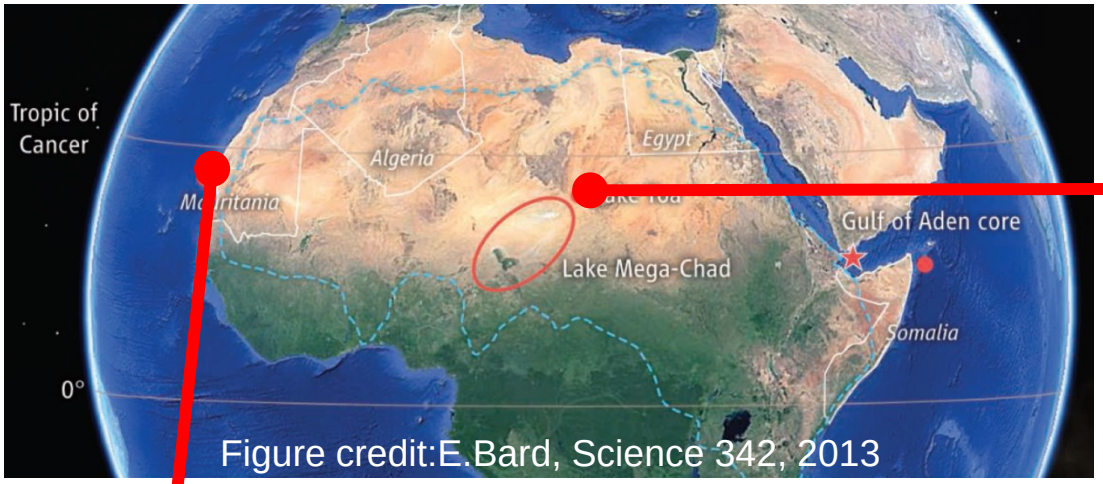
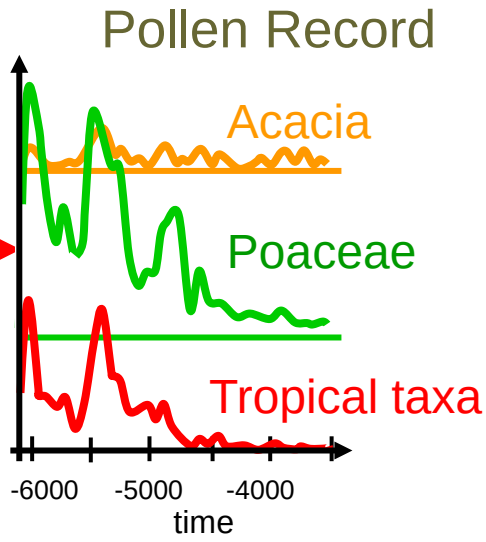
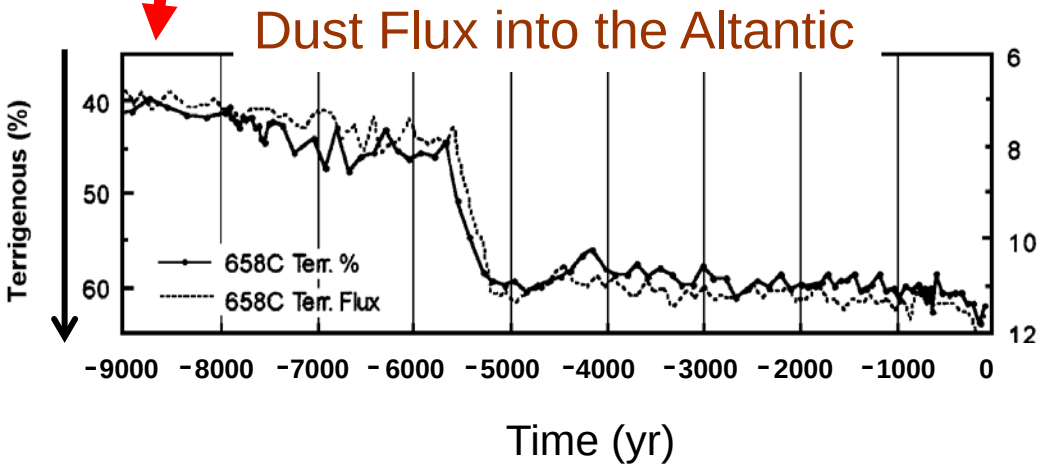
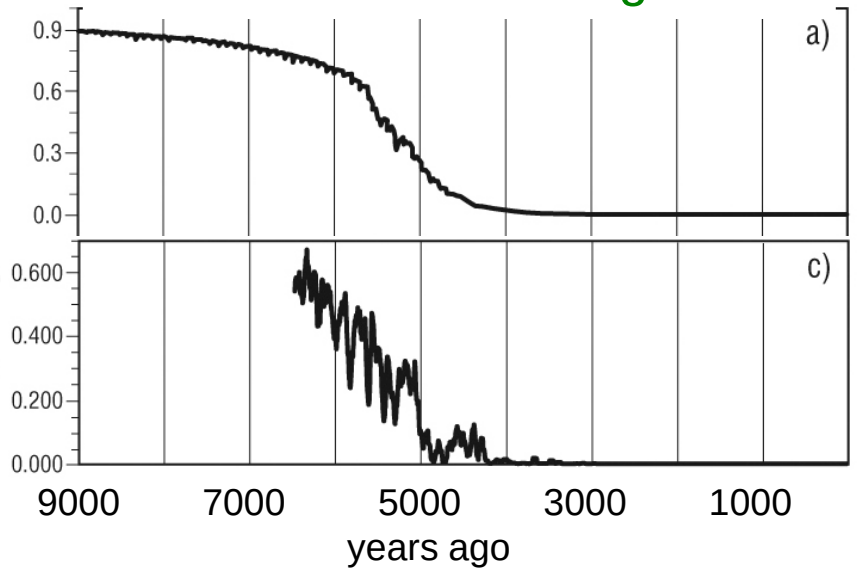


Figure credit:E.Bard, Science 342, 2013







de Menocal et al., 2000; Claussen et al., 1999; Liu et al., 2007; Kröpelin et al., 2008

Ich hätte diese Betrachtungen über das Absorptions-

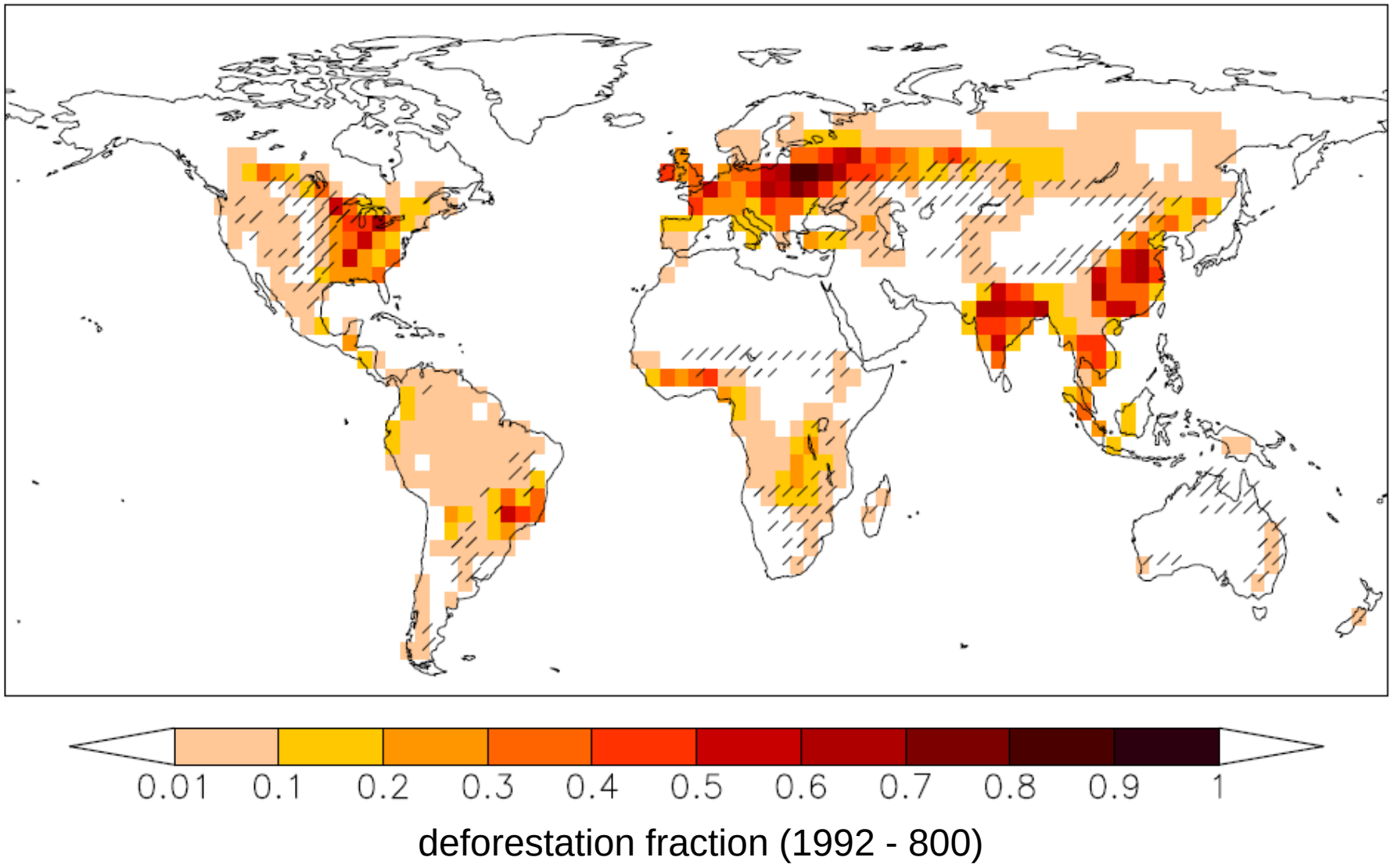
…climate changes which humans cause by deforestation, by changing water bodies, by emission of vapour and gas in the industrial centres.

These changes are without doubt more important than commonly assumed.

gen sind ohne Zweifel wichtiger, als man allgemein annimmt;

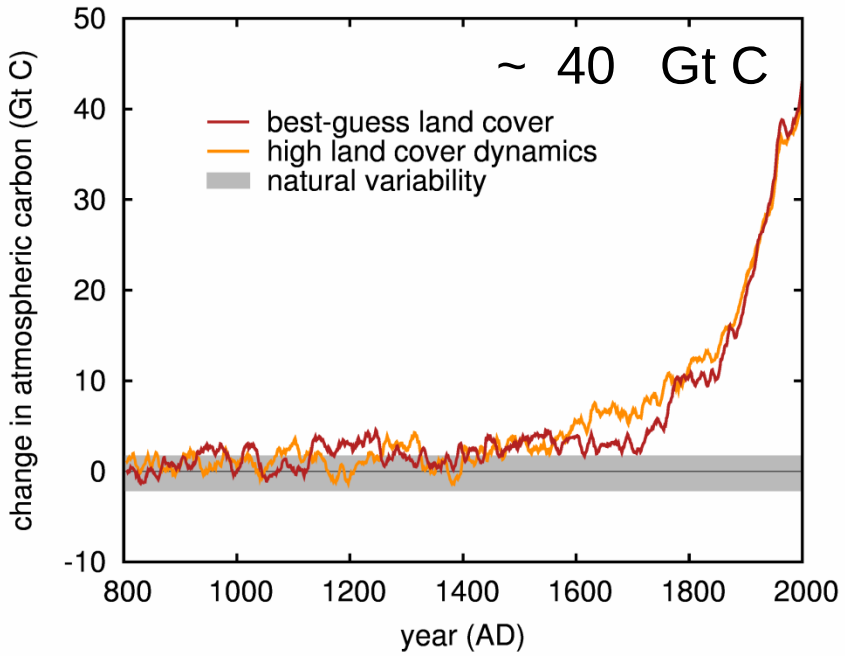
Alexander von Humboldt, Zentralasien (1844), p.214

Deforestation (color), change from grassland to pasture (////)



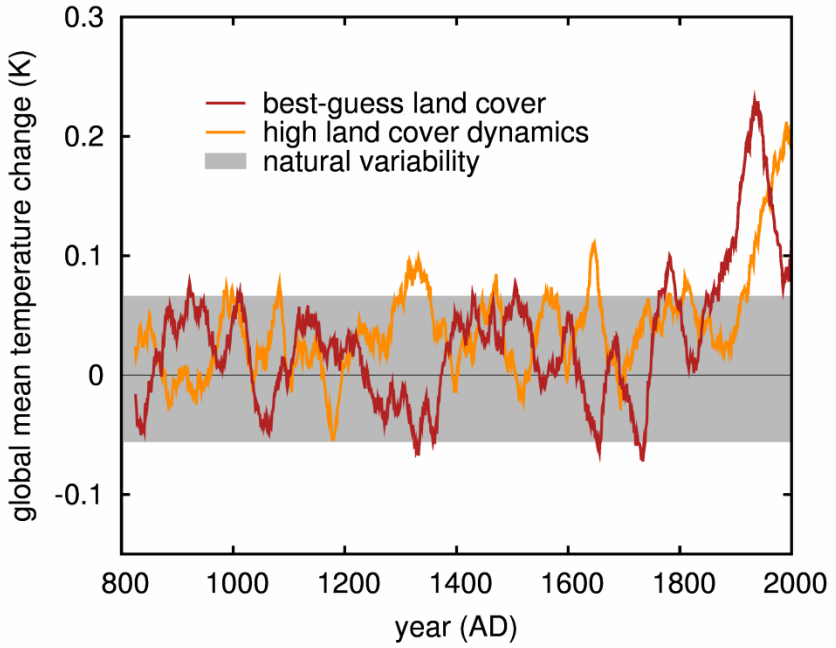
Pongratz et al., 2011

Change in atmospheric carbon



(to be compared with total increase of ~ 250 Gt C due to fossil fuel burning.)

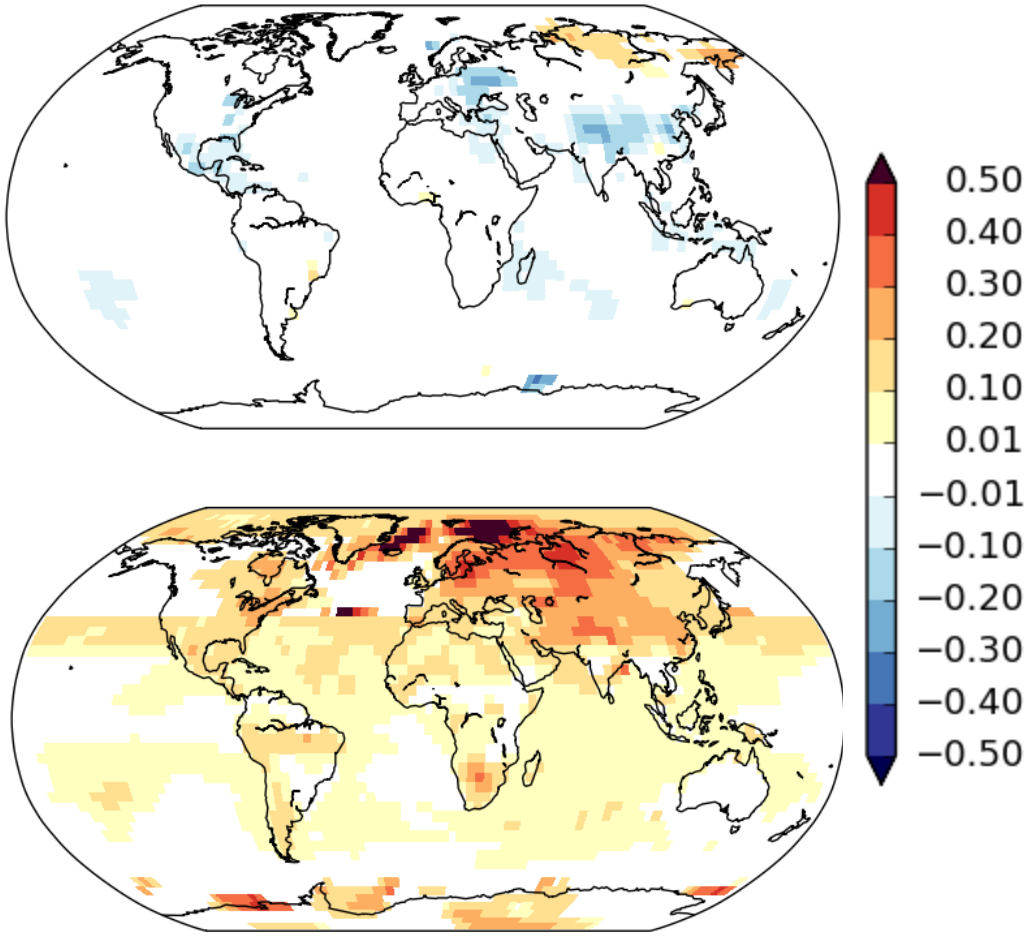
change in
global mean temperature



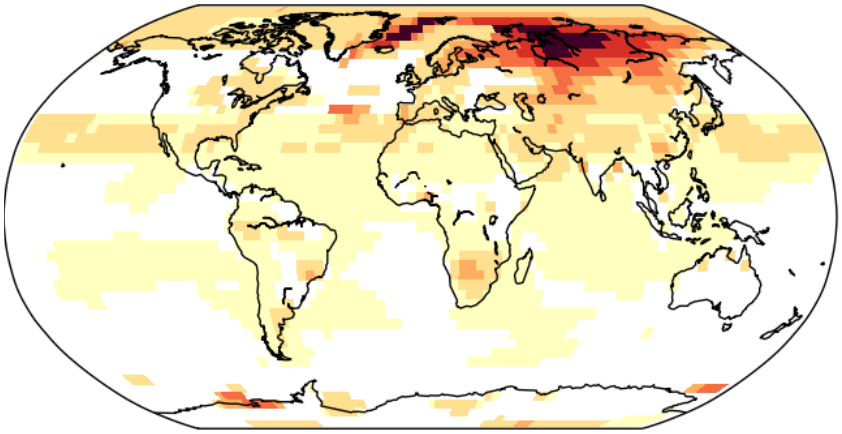
Pongratz et al., 2009

Essential factors of land use on local temperature:

Effects due to changes in energy and water exchange



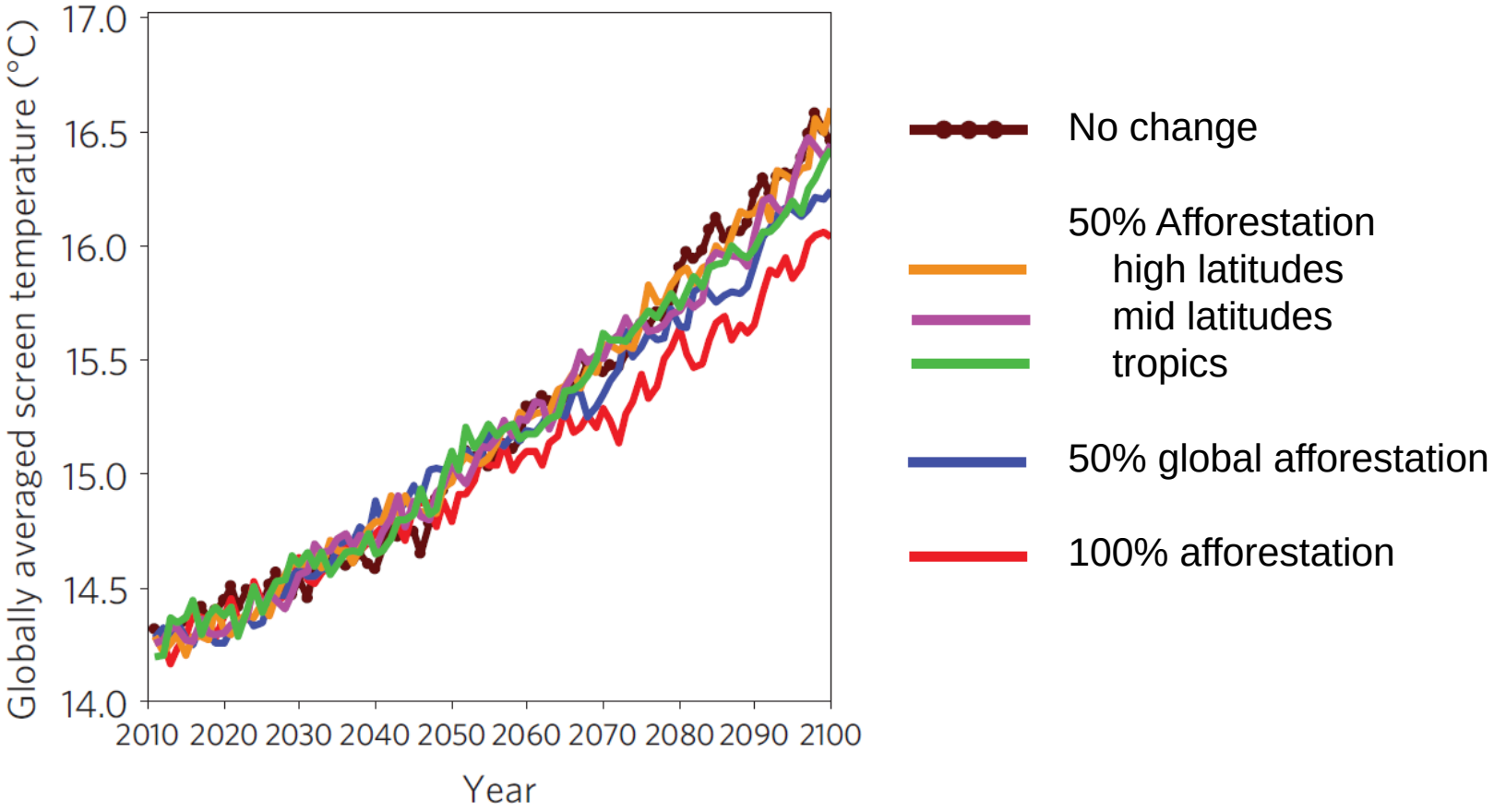
sum



Effects due to changes in carbon emission

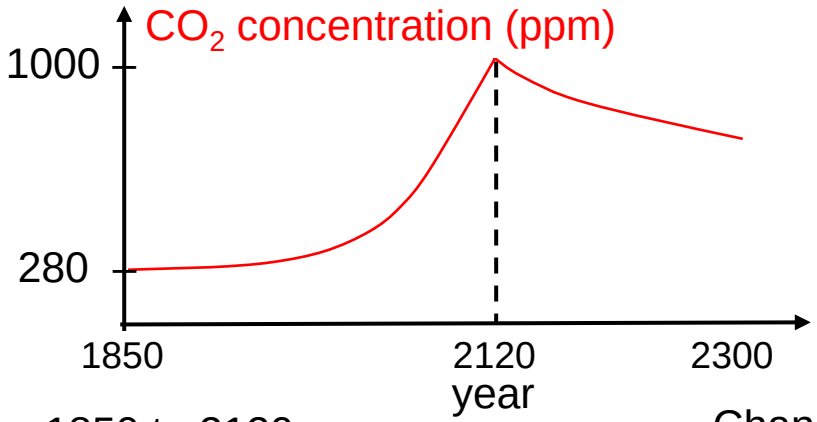
Pongratz et al., 2011

The expected *global* cooling to curb global warming by use of due to afforestation is small



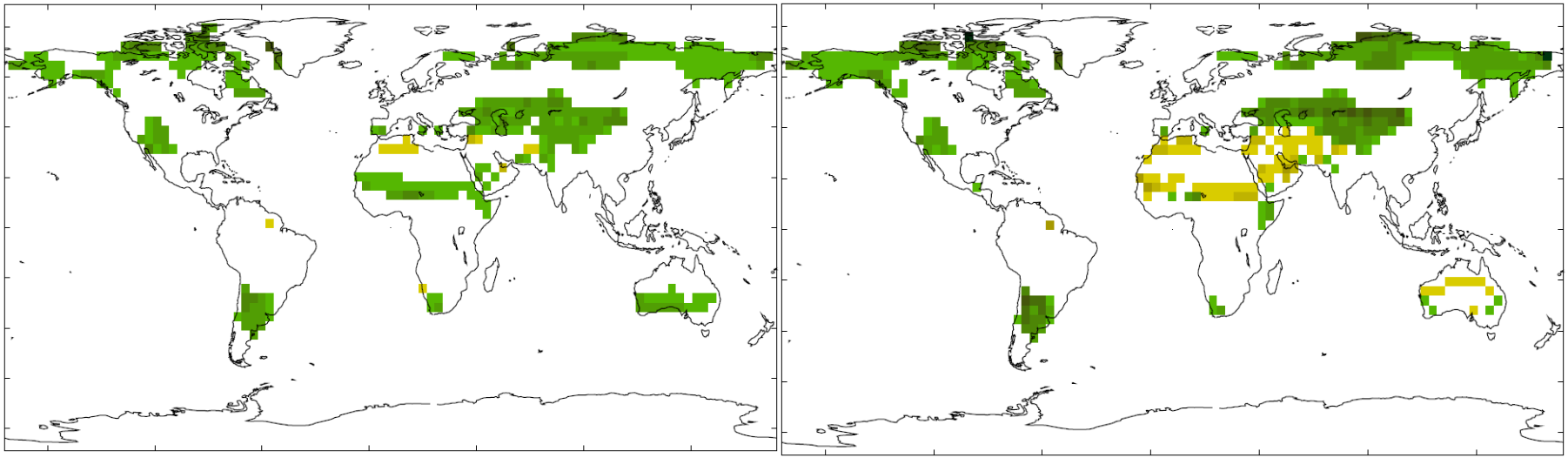
Arora and Montenegro, 2011

Hot climate, green deserts?



Change from 1850 to 2120

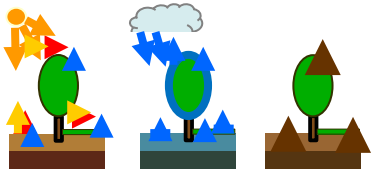
Change from 2120 to 2300



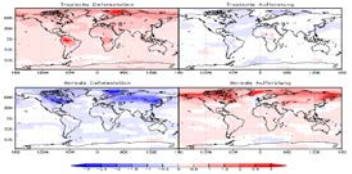
Change in **desert** fraction

Port et al. 2012

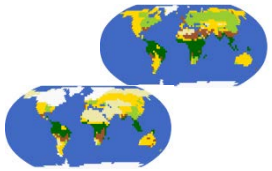
Conclusion:



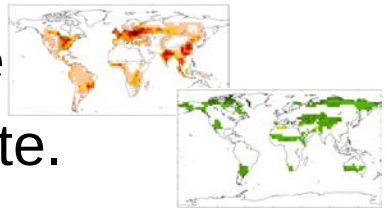
- Although vegetation is a **big flyweight** in the Earth system, it modifies local and global climate via the exchange of energy, water and carbon between the land and the atmosphere.



- **Tropical forest cool, boreal forest warm the climate.**
- Vegetation dynamics tend to **amplify ice-age climate change**: warm climate gets warmer, cold glacials colder; Sahara gets greener



- It is theoretically possible that regionally, vegetation changes fast.



- **Land use** has affected, and will affect, regional climate and the carbon cycle and, to some extent, global climate.
- “Green climate engineering” is good for regional climate.