Global biophysical climate change induced by bioenergy crop plantation

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Cland

Albedo
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& Climate Change Mitigation

Bioenergy crops

- Second generation high yield cultivars (grassy and woody)
- Main negative emission technology in low warming scenarios
- Large mitigation potential, especially if coupled to CCS
- Concerns about :
    - Feasibility
    - Equity
    - Land available
    - Water and nutrient resources
- What are the climate effects of large-scale BECCS cultivation considering a realistic land use scenario ?

Crops / bioenergy crops in global models

Default ORCHIDEE model

ORCHIDEE - Crop model

(Wang et al. prep.)
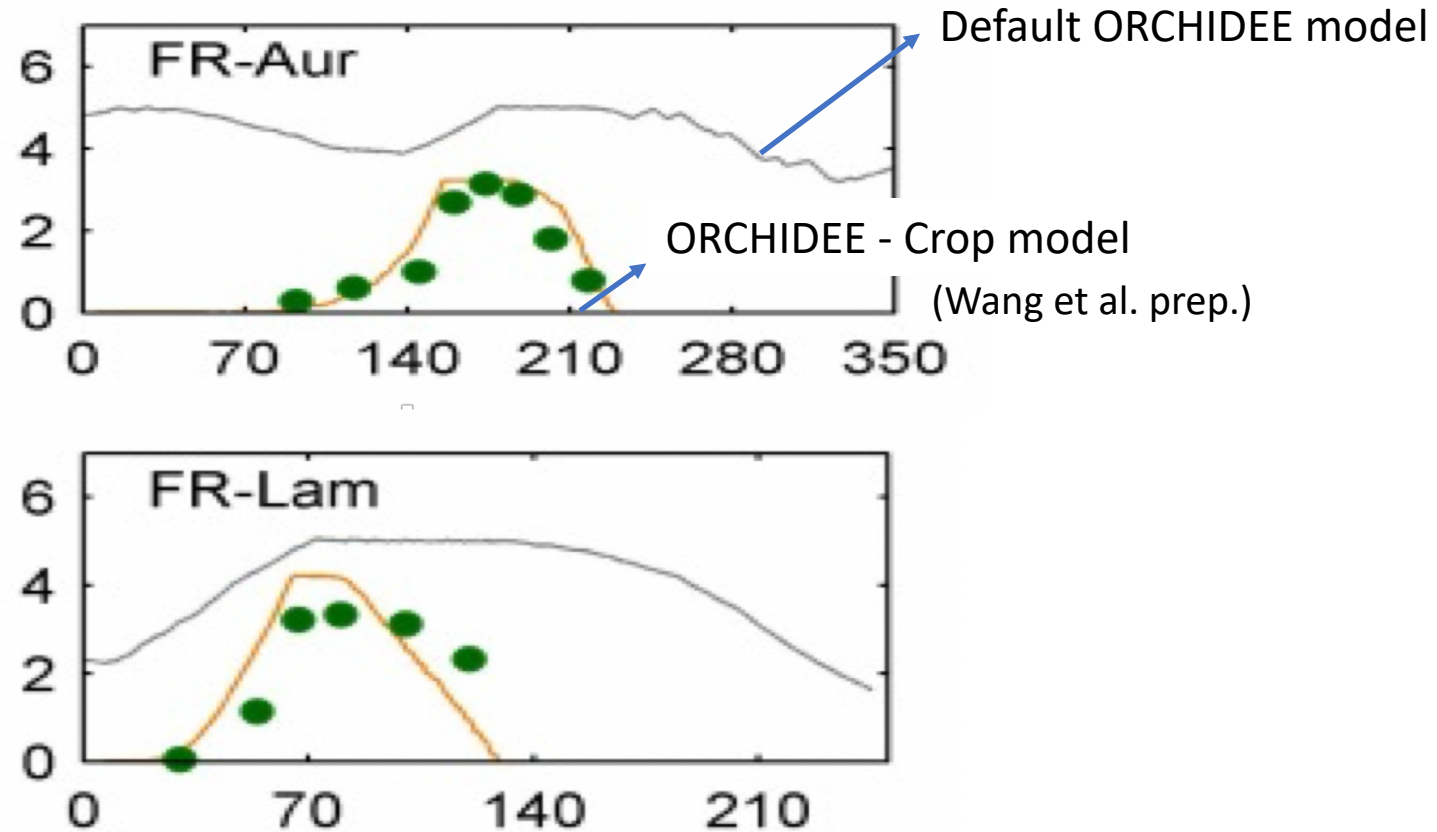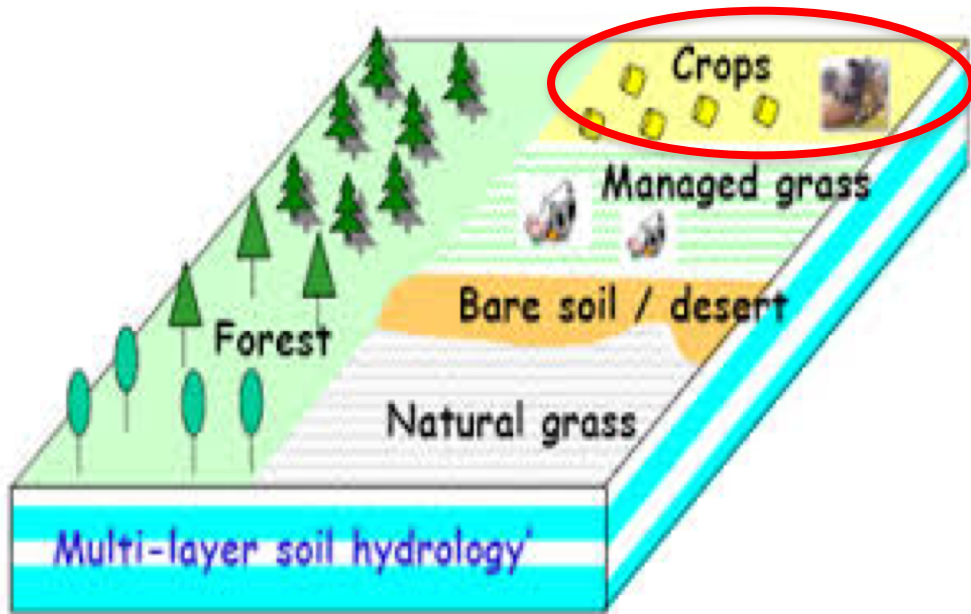
Models need major improvement & calibration to compute biophysical feedbacks from agriculture

# Yields, biophysical properties & management data

- Global yield database

- Five main crop types

- Photosynthesis rates

- Allocation, SLA

- Albedo, turbulent fluxes

- Rotation frequency for woody crops
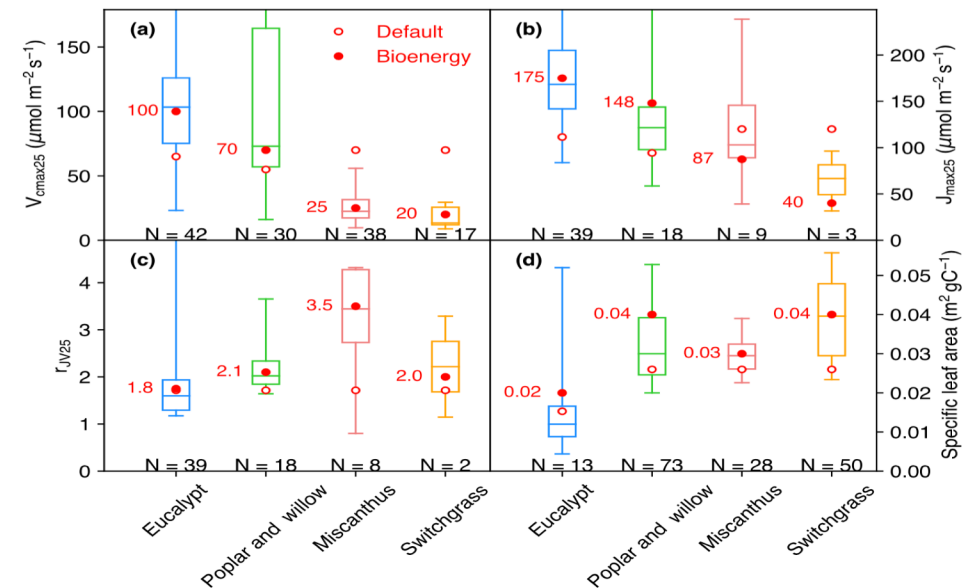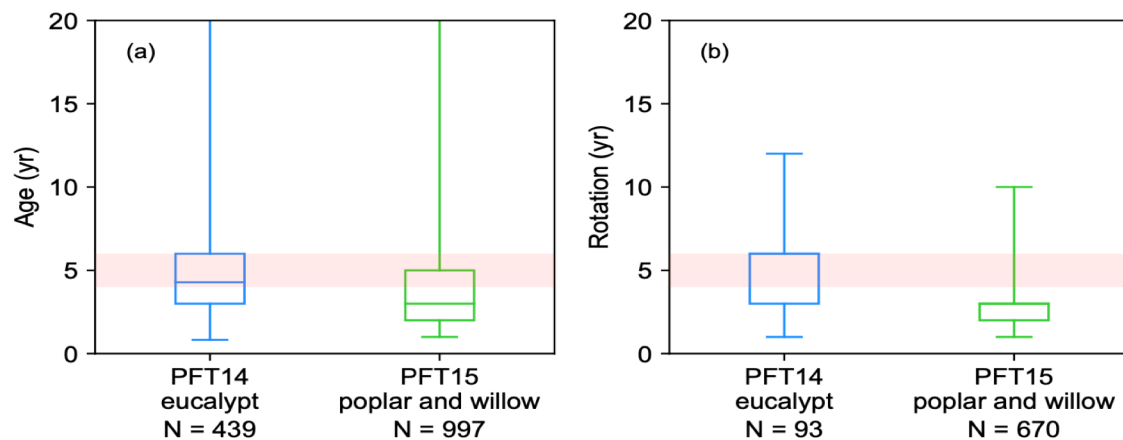
Incorporating BECCS in a global land surface model

Miscanthus

Switchgrass

Willow

Poplar

Eucalyptus
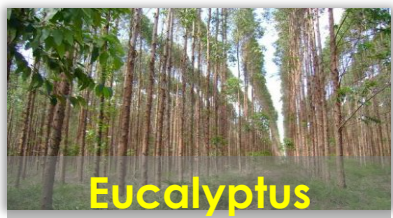
- ORCHIDEE MICT model
- Define 5 new functional types
- Structural changes
  - Harvest and age cohorts
  - Allocation
  - Phenology
- Parameter calibration
  - SLA, V_{cmax}
- Calibration data against
  - Yields
  - Harvest age data
  - Biomass growth for woody crops

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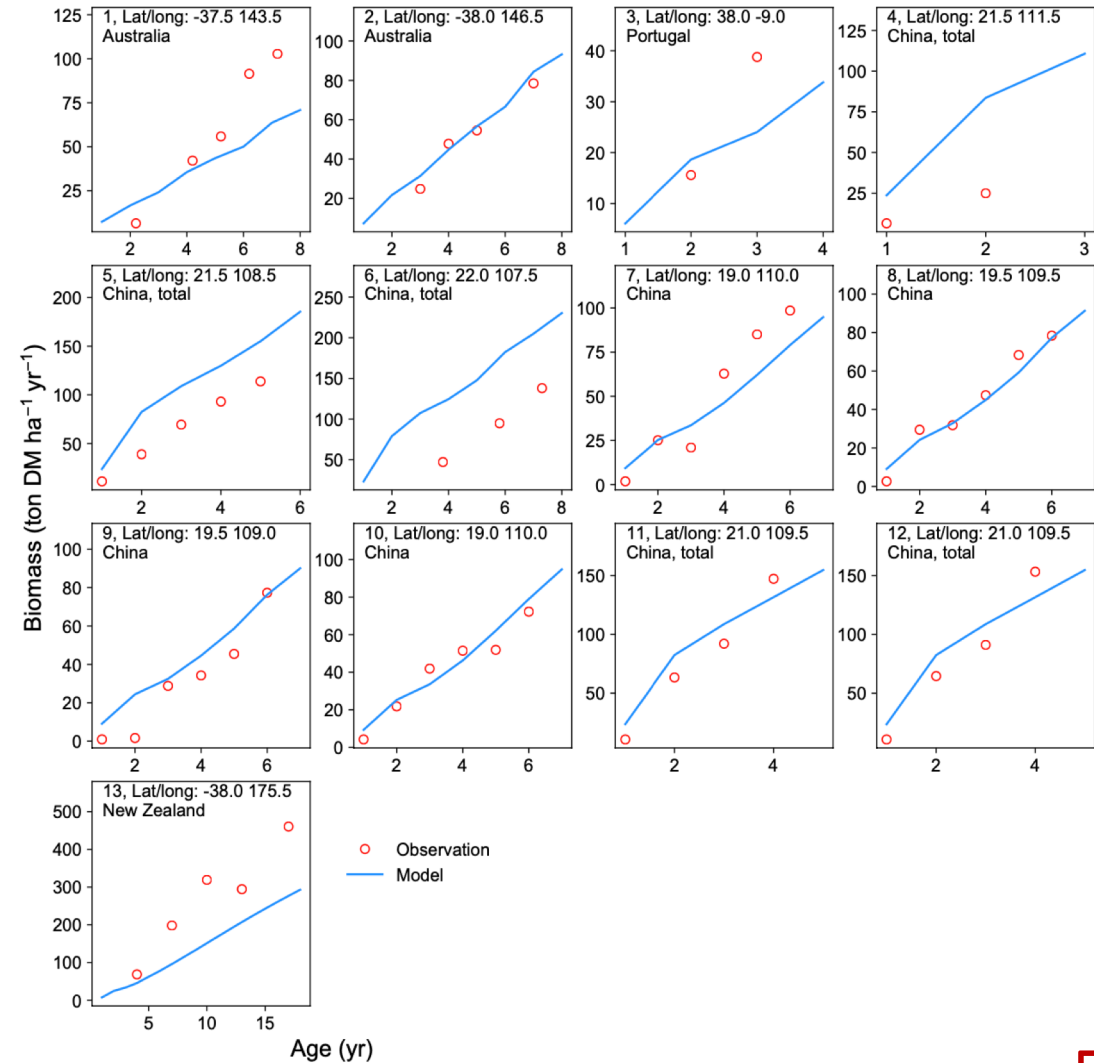
References

ORCHIDEE-MICT-BIOENERGY: an attempt to represent the production of lignocellulosic crops for bioenergy in a global vegetation model

Wei Li[1], Chao Yue[1], Philippe Ciais[1], Jinfeng Chang[1], Daniel Goll[1], Dan Zhu[1], Shushi Peng[2], and Albert Jornet-Puig[1]

[1]Laboratoire des Sciences du Climat et de l'Environnement, LSCE/IPSL, CEA-CNRS-UVSQ, Université Paris-Saclay, 91191 Gif-sur-Yvette, France
[2]Sino-French Institute for Earth System Science, College of Urban and Environmental Sciences, Peking University, Beijing 100871, China

Data Descriptor: A global yield dataset for major lignocellulosic bioenergy crops based on field measurements

Wei Li[1], Philippe Ciais[1], David Makowski[2] & Shushi Peng[3]

**Mapping the yields of lignocellulosic bioenergy crops from observations at the global scale**

Wei Li[1,2], Philippe Ciais[2], Elke Stehfest[3], Detlef van Vuuren[3], Alexander Popp[4], Almut Arneth[5], Fulvio Di Fulvio[6], Jonathan Doelman[3], Florian Humpenöder[4], Anna B. Harper[7,8], Taejin Park[9,13,14], David Makowski[10,11], Petr Havlik[6], Michael Obersteiner[6], Jingmeng Wang[1], Andreas Krause[5,12], and Wenfeng Liu[2]

Geoscientific Model Development

Open Access

SCIENTIFIC DATA

Earth System Science Data

Open Access

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So now, let's do climate modeling

- IPSL CM5 Earth System Model

- LMDZ AGCM coupled with ORCHIDEE-MICT-Bioenergy land surface model

- Land-atmosphere coupling with prescribed sea surface temperature

- Assume all marginal lands are covered one crop type
  - One coupled climate simulation per crop (50 years)
  - Analyze difference between bioenergy cover and a reference land cover (default crop) -> ΔT
  - Separate local biophysical feedbacks from large scale circulation related feedbacks

a

Bare land
Grassland
Cropland
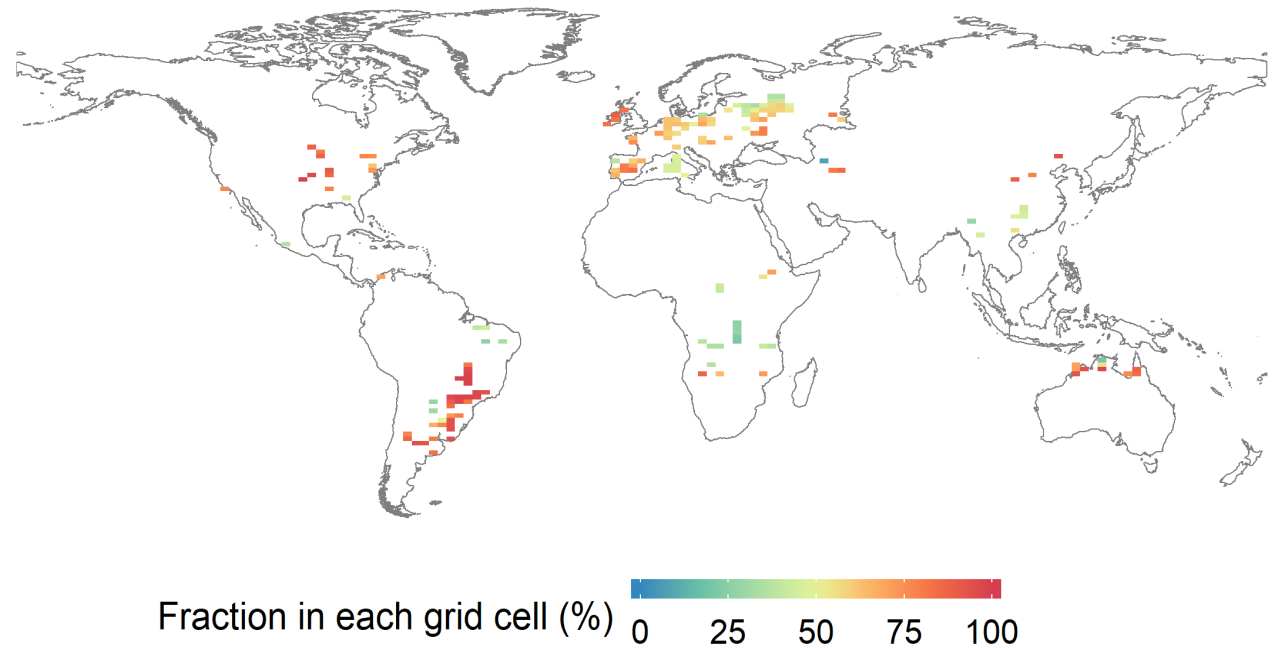Needleleaf forest
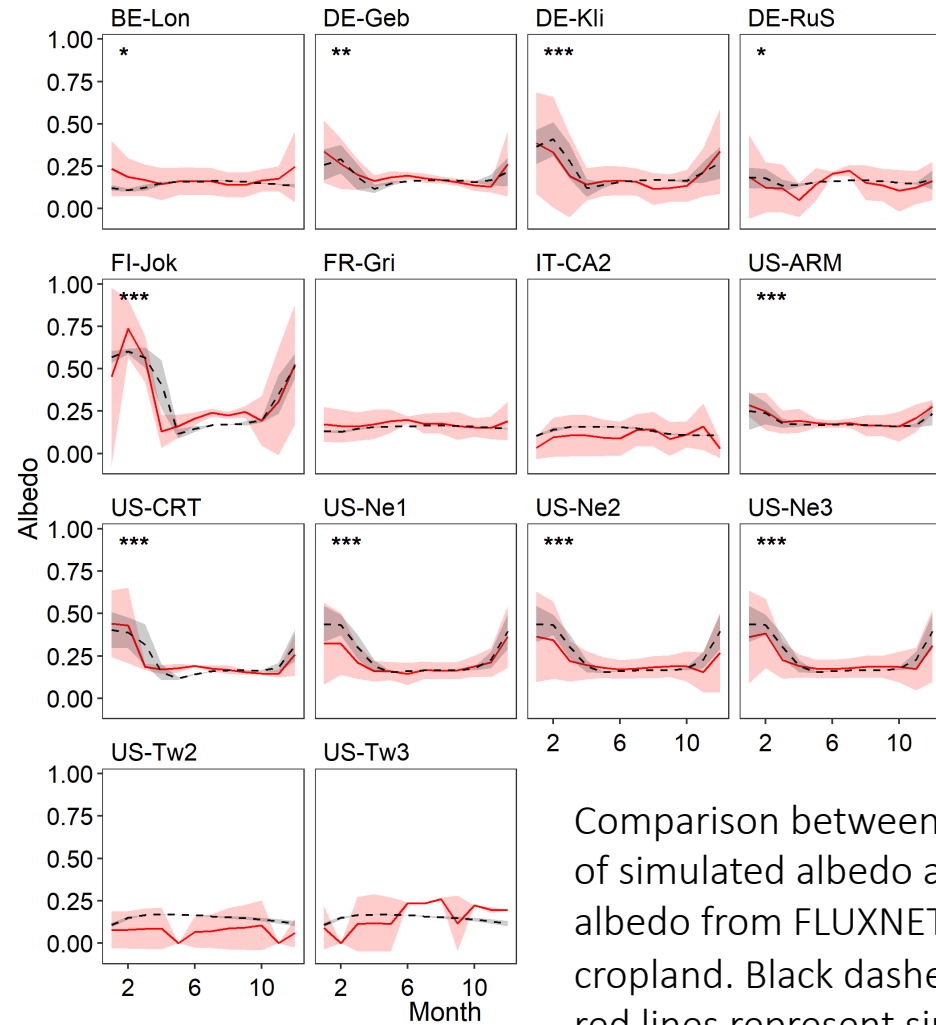Broad-leaved forest
BECCS
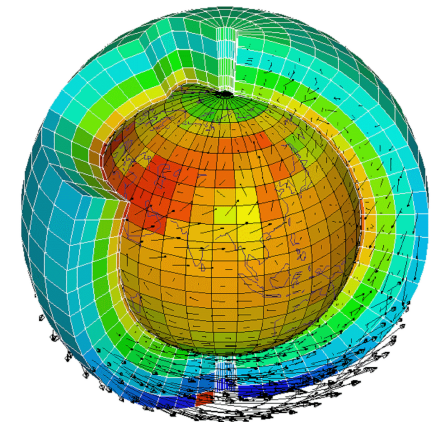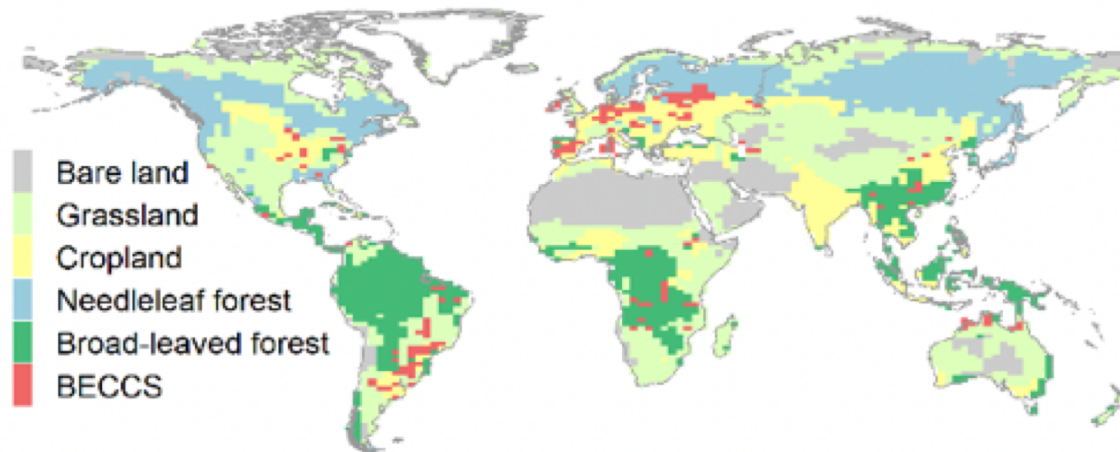
Land use scenarios

Biophysical marginal lands 'available'
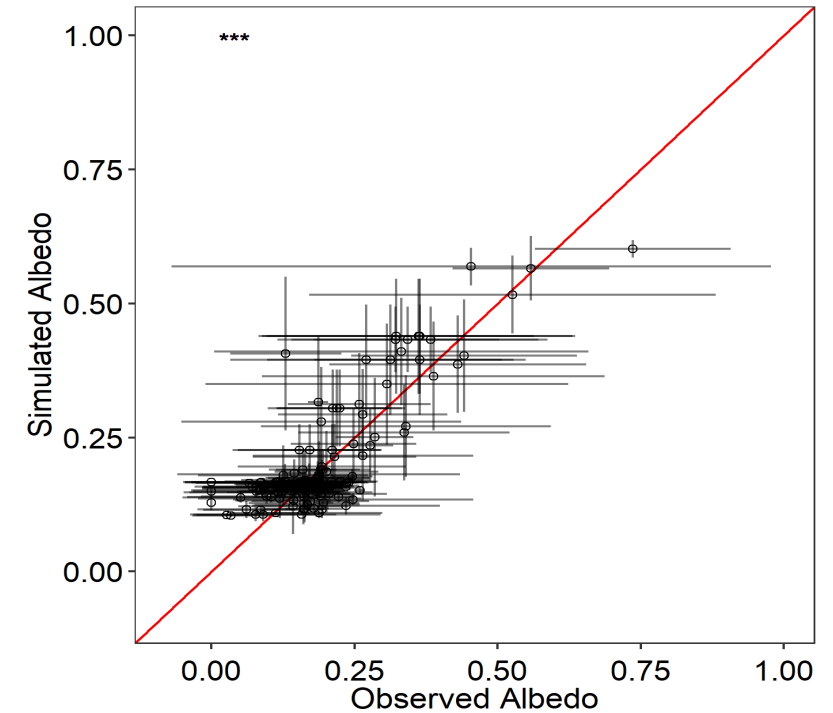And suitable land use from two IAM models
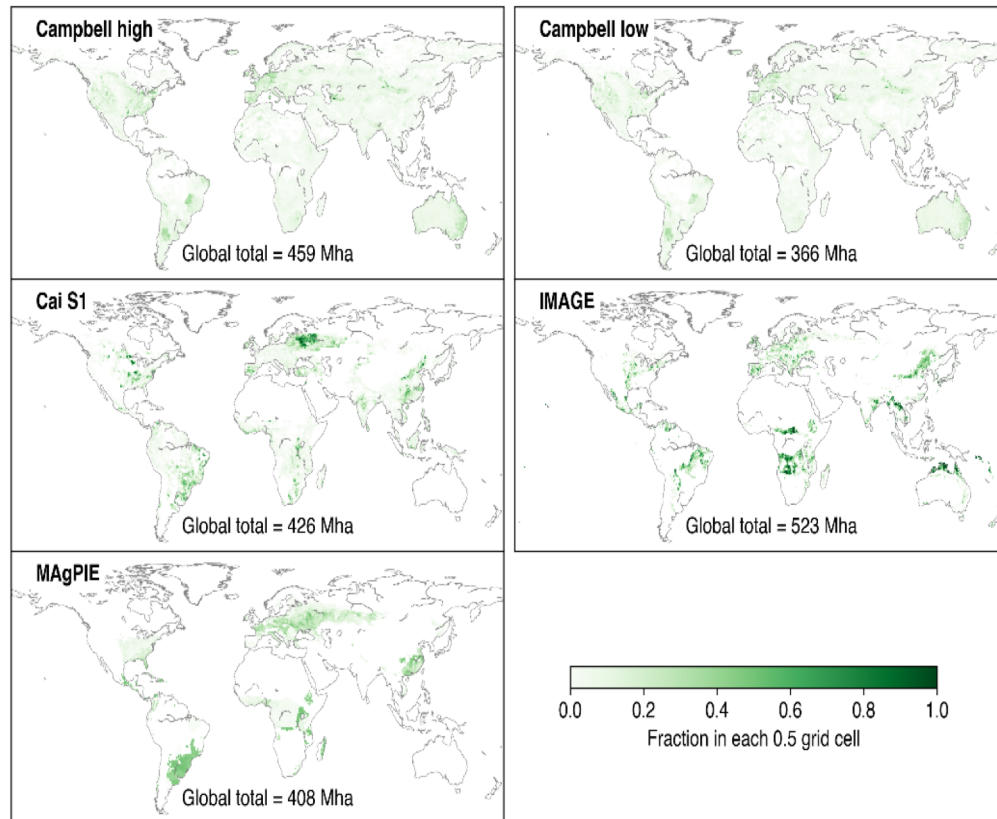
466 Mha in total from 38°S to 60°N
Mainly in Europe and South America
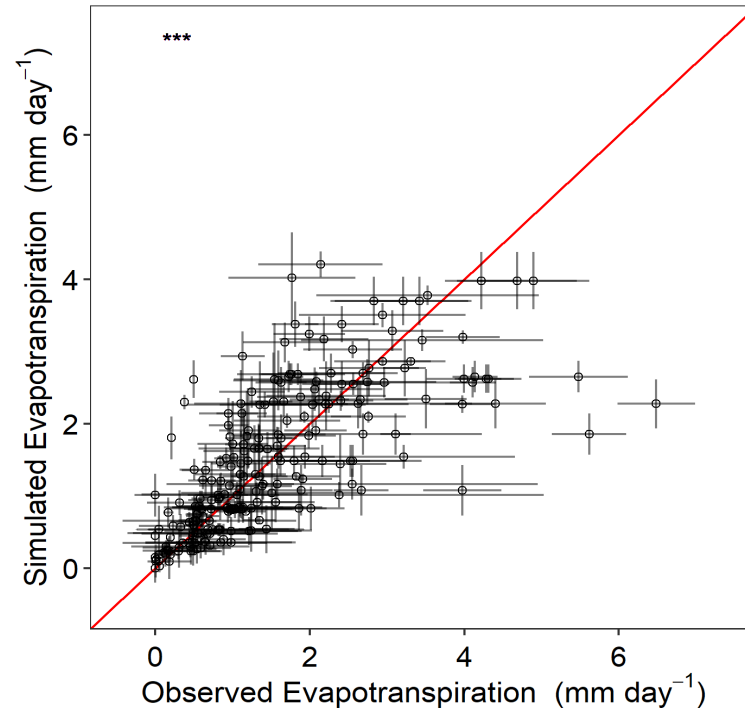
Model evaluation – crop albedo

Comparison between the variation of simulated albedo and observed albedo from FLUXNET sites for cropland. Black dashed lines and red lines represent simulated and observed albedo
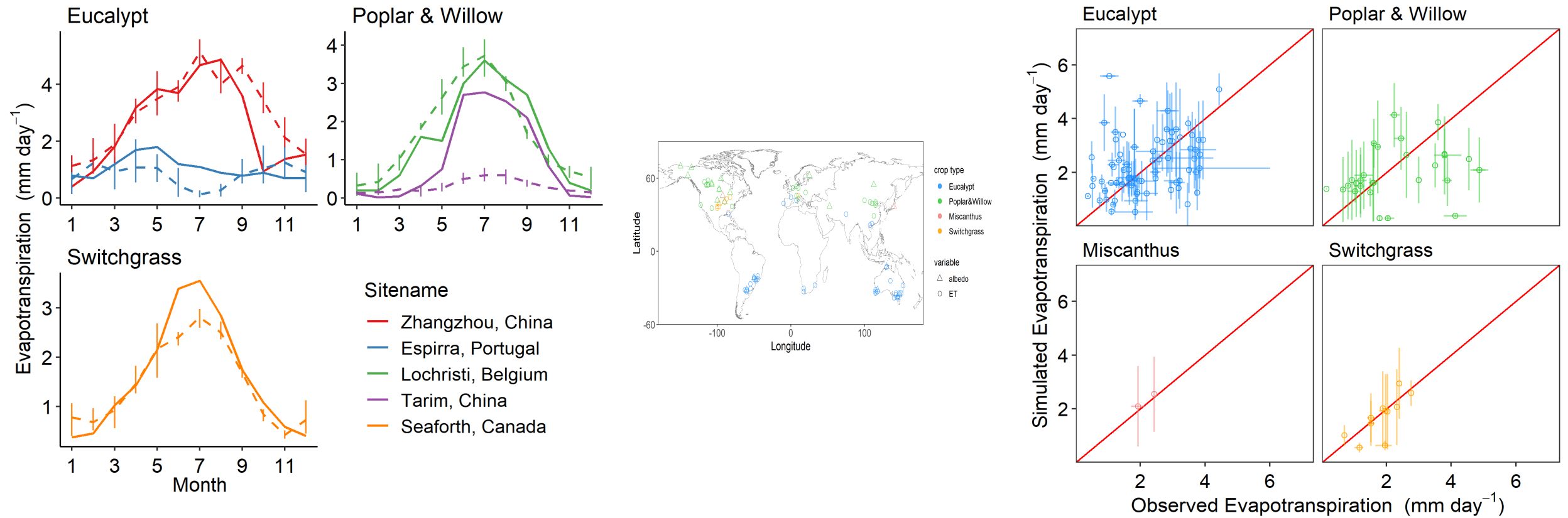

Comparison between monthly simulated albedo and observed albedo from FLUXNET sites for cropland

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Model evaluation – crop evapotranspiration

Comparison between monthly simulated evapotranspiration and observed evapotranspiration from FLUXNET sites for cropland.
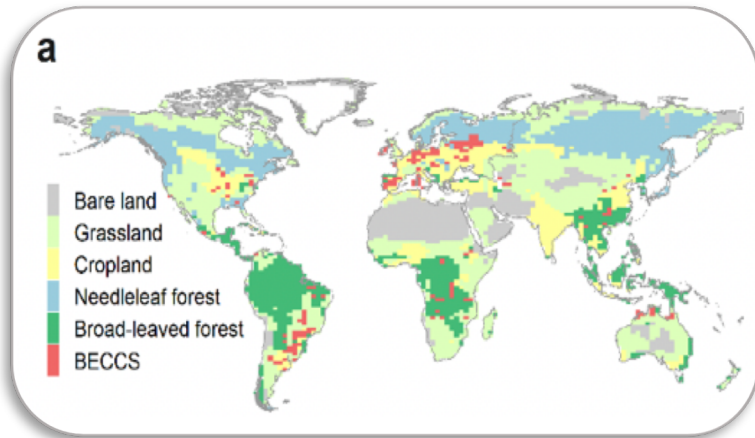
Model evaluation – bioenergy crops evapotranspiration

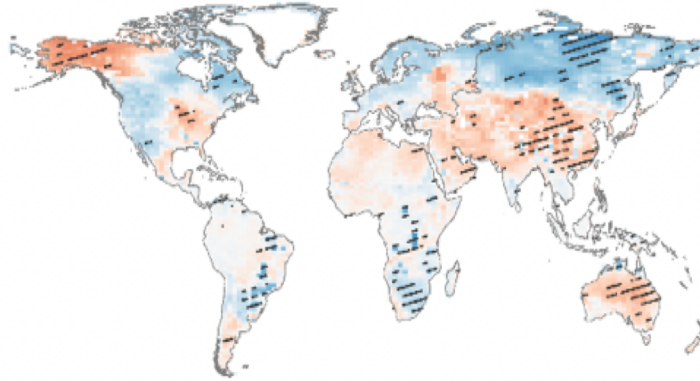# Biophysical climate feedbacks
Here temperature change

- All crops produce a similar pattern of ΔT

- Mainly cooling of mid latitudes

- Warming of the Mediterranean & tropics
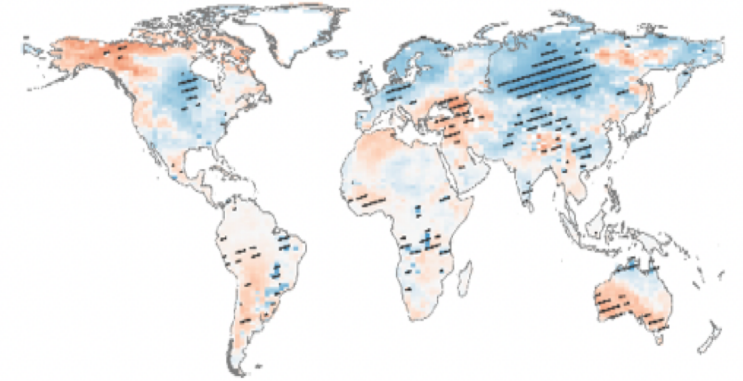
- Remote effects appear larger than local ones

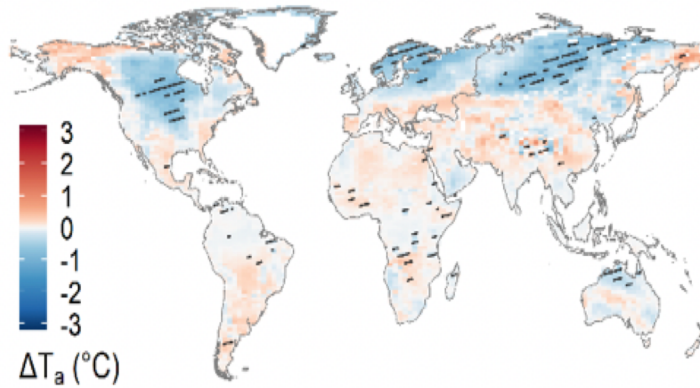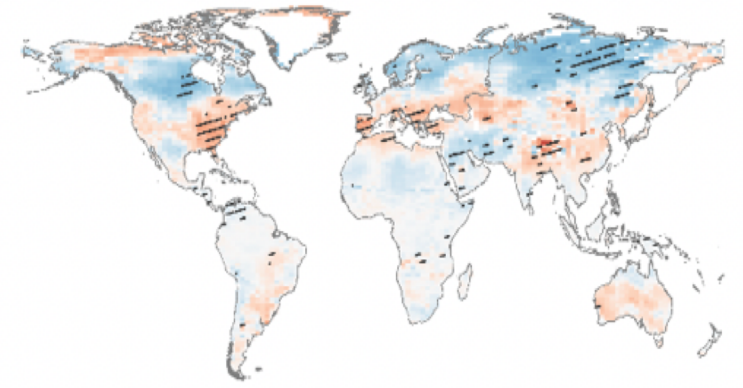Land cover change to BECCS (orange dots)

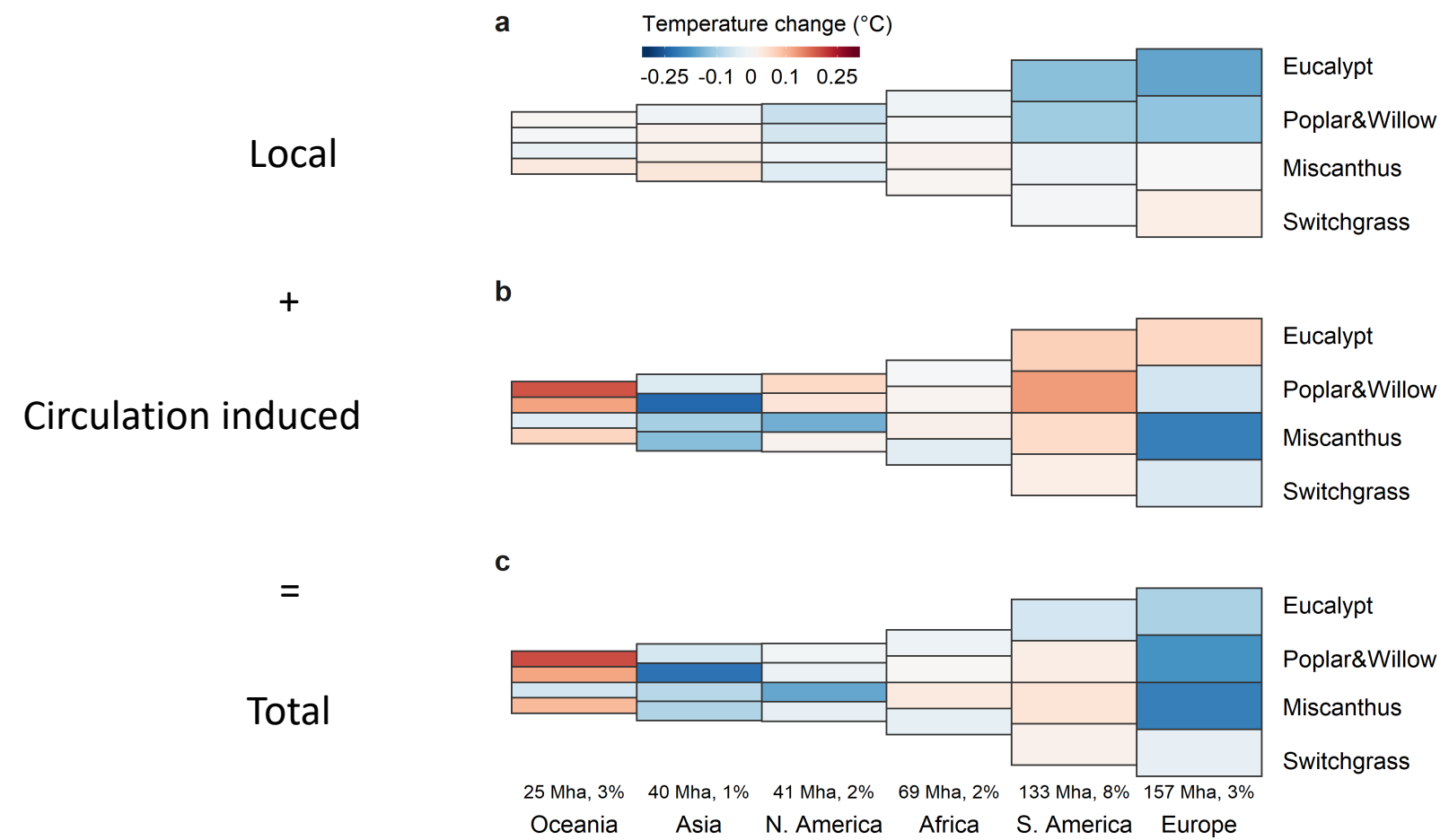# Separating local and 'teleconnections' effects

BECCS area and mean temperature change (ΔT_{local} a, ΔT_{cir} a, and ΔT_a) in each continent. Air temperature change induced by altered local surface energy balance (ΔT_{local} a, **a**) and by atmospheric circulation (ΔT_{cir} a, **b**) and total air temperature change (ΔT_a, **c**) are the average values over the whole continent. Sizes of rectangles represent relative BECCS areas in different continents, and color gradients indicate temperature change. 13
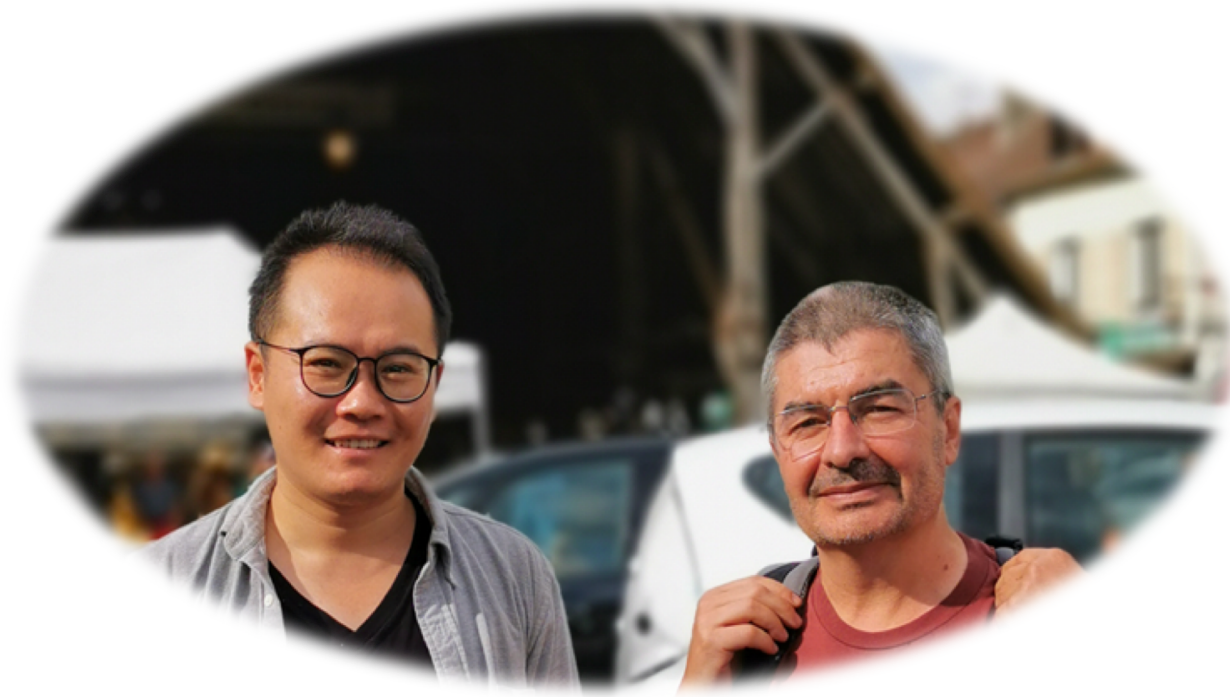
Conclusions

- Relatively large biophysical cooling from highly productive bioenergy crops
- Crop types matters : local warming from switchgrass, largest local cooling from eucalypt
- Local effects smaller than indirect circulation effects, but effect sign generally similar
- The large indirect effects poses another climate justice question about BECCS

Perspectives

- Nutrient demand from bioenergy crops and increased N_2O emissions
- Irrigation requirements to reach economically viable yields
- Energy input and GHG emissions to produce BECCS
- New climate metrics of BECCS including CO_2 removal, N_2O emissions & biophysical effects

Thank you for your attention

+ Great support from all the team