Biophysical effects of land use/cover change on climate

Alan Di Vittorio, Berkeley Lab

Impacts of land use and land management on Earth system evolution, biogeochemical cycles, extremes, and inter-sectoral dynamics
Aspen Global Change Institute, Snowmass, CO
16 September 2019

EARTH & ENVIRONMENTAL SCIENCES

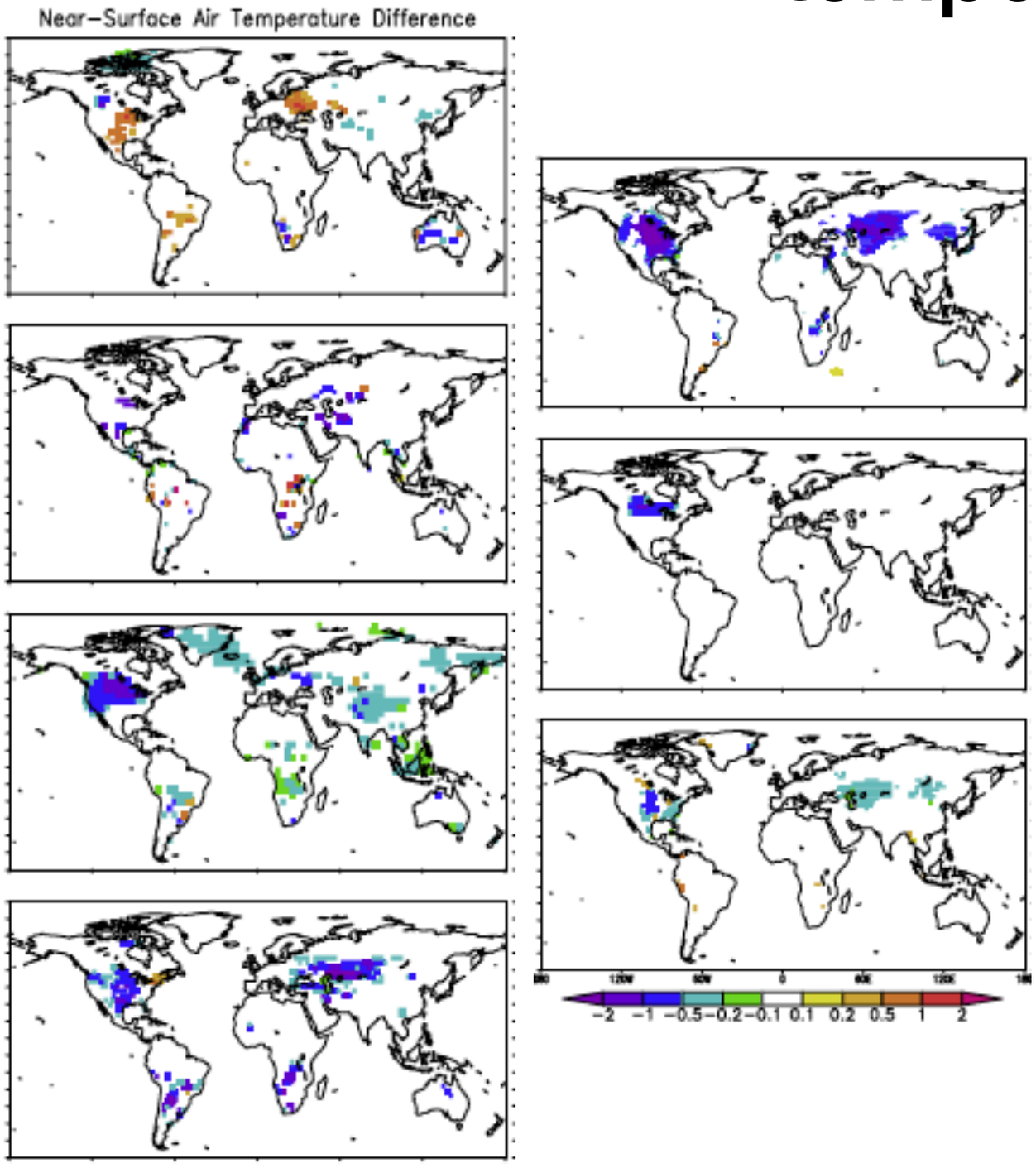
Earth Systems and Society Program

BERKELEY LAB

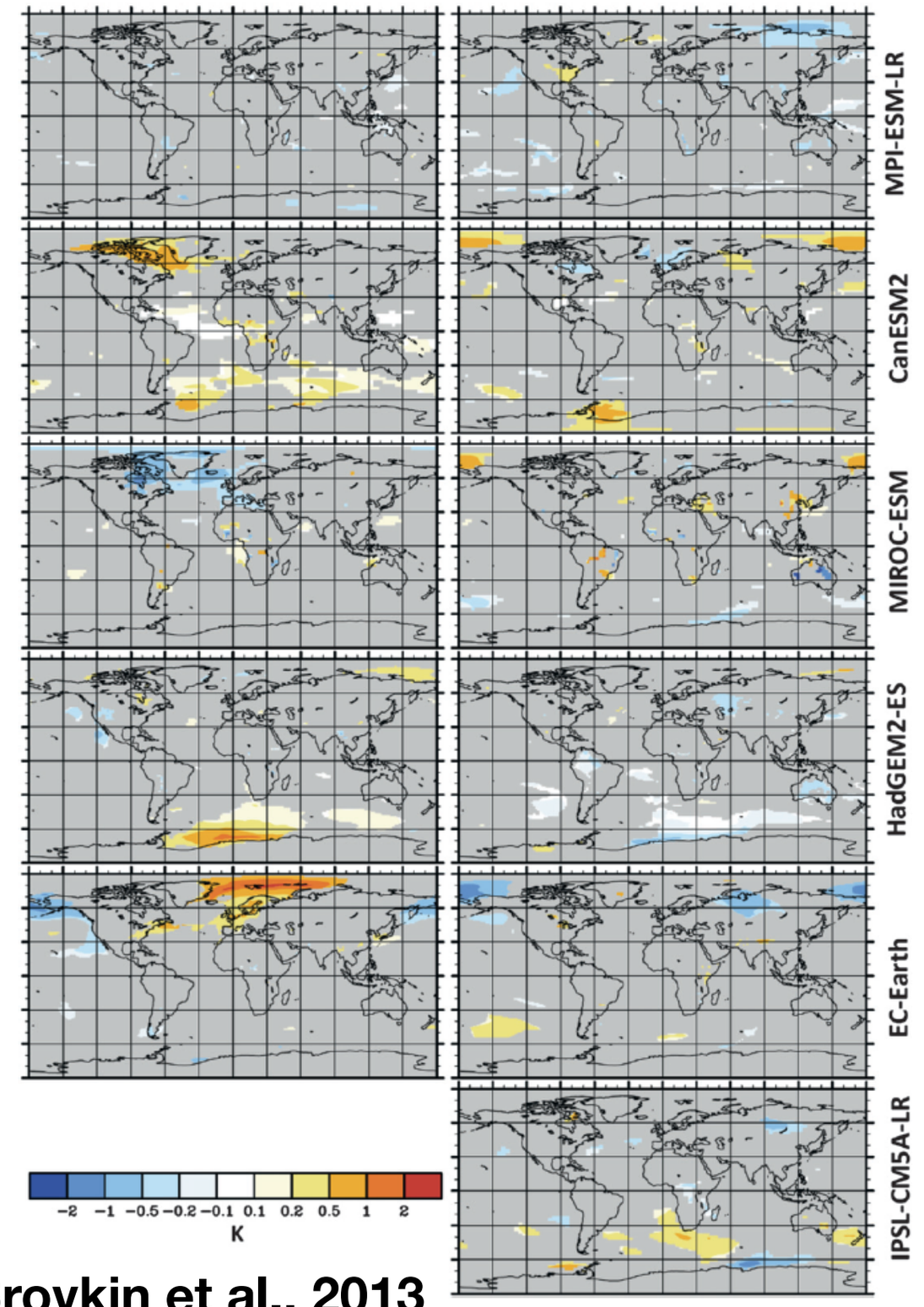
Overview

- A goal: consensus regarding LULCC impacts on climate
- Deforestation: Cooling vs warming
- Surface energy budget and drivers of temperature change
- Radiative vs non-radiative and local vs non-local
- Other LULCC effects on climate
- Opportunities for further research

Consensus goal: LULCC effects on temperature



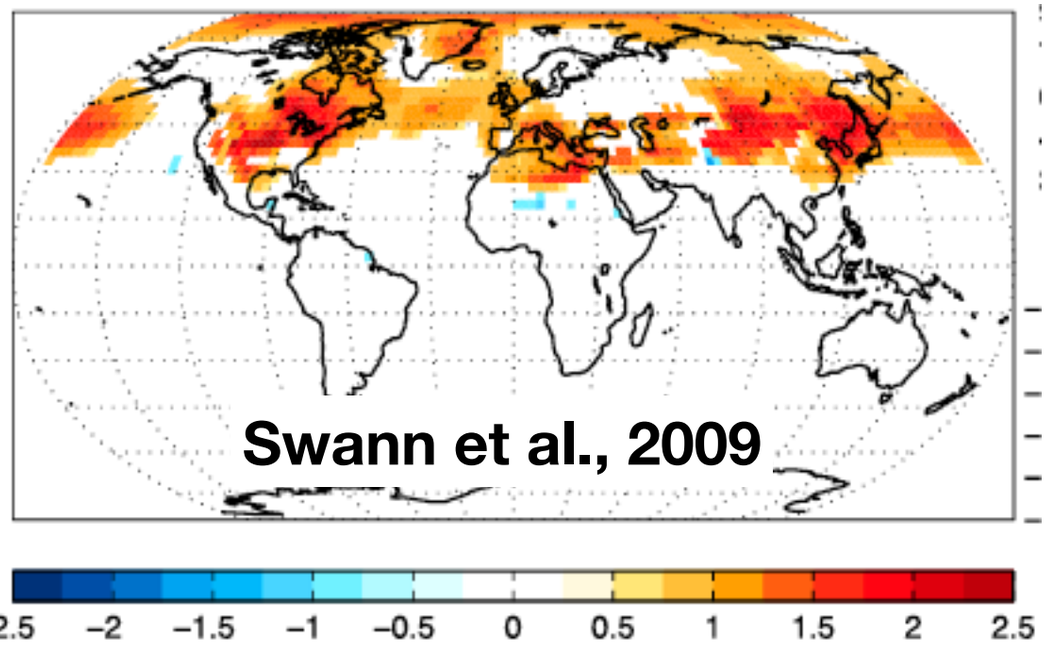
Pitman et al., 2009



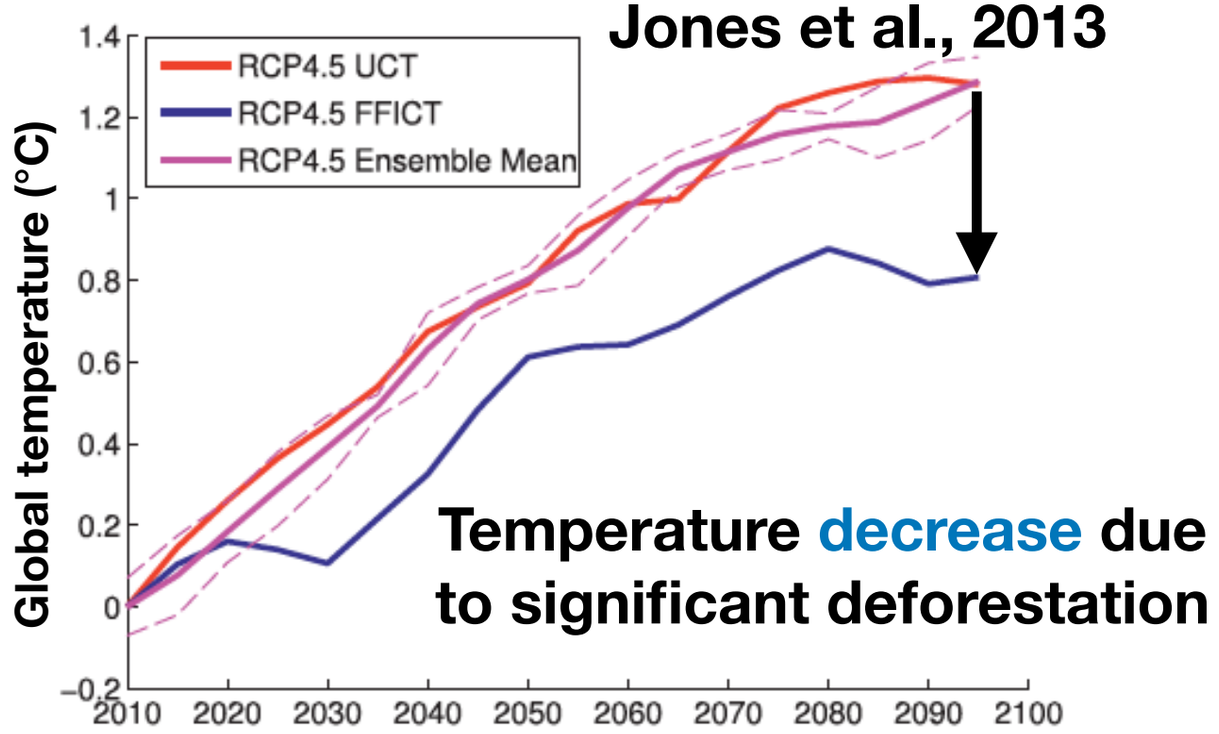
Brovkin et al., 2013

Trees warm the air, mostly

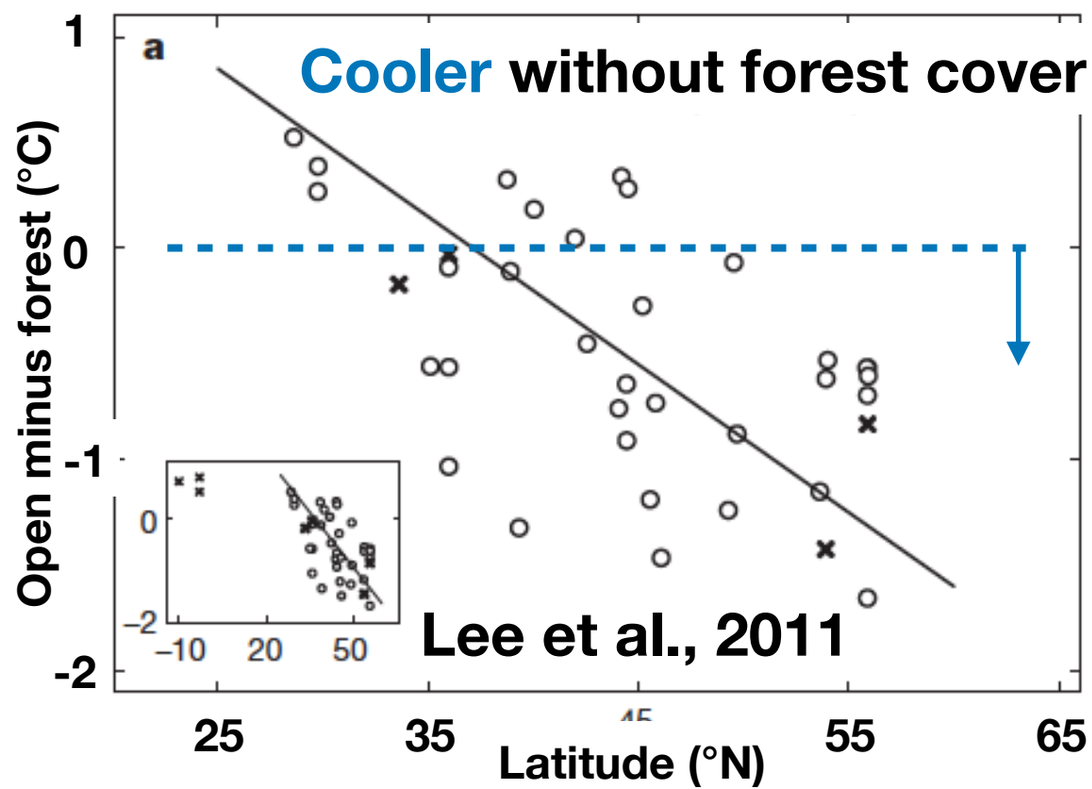
Temperature increase due to northern mid-latitude afforestation



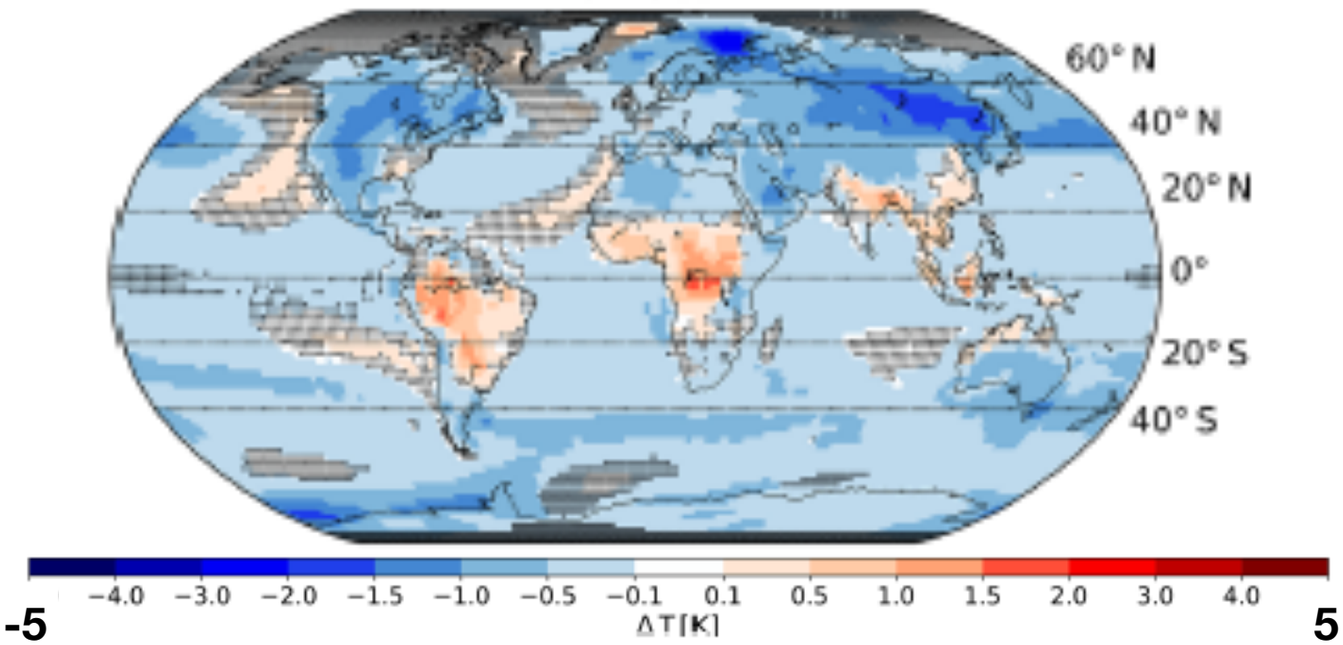
Jones et al., 2013



Temperature decrease due to significant deforestation

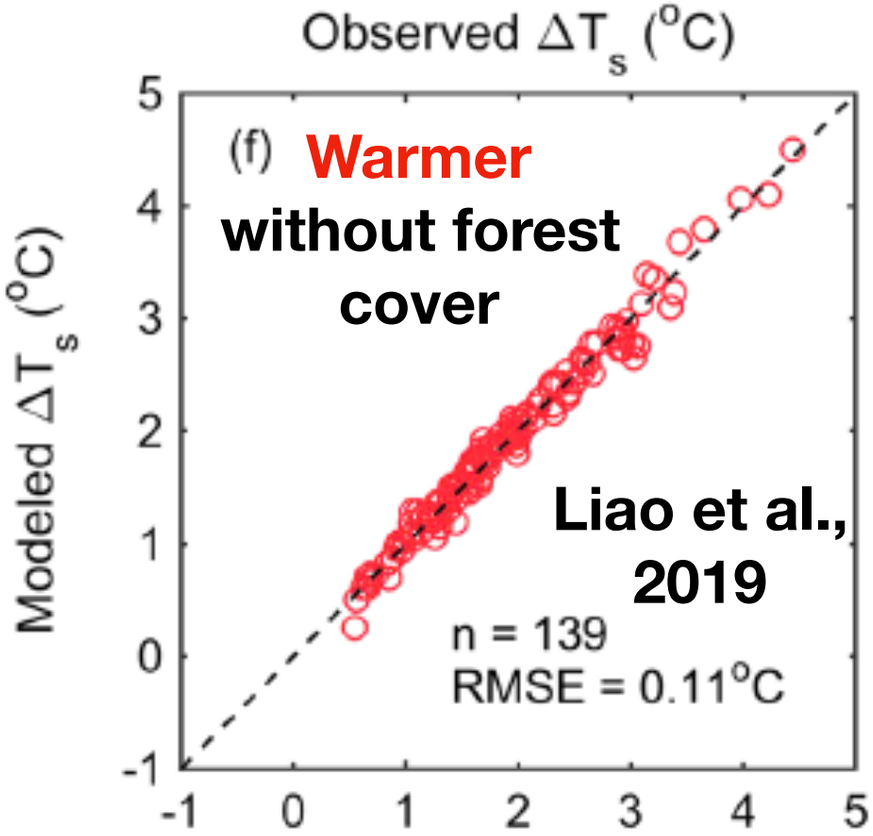


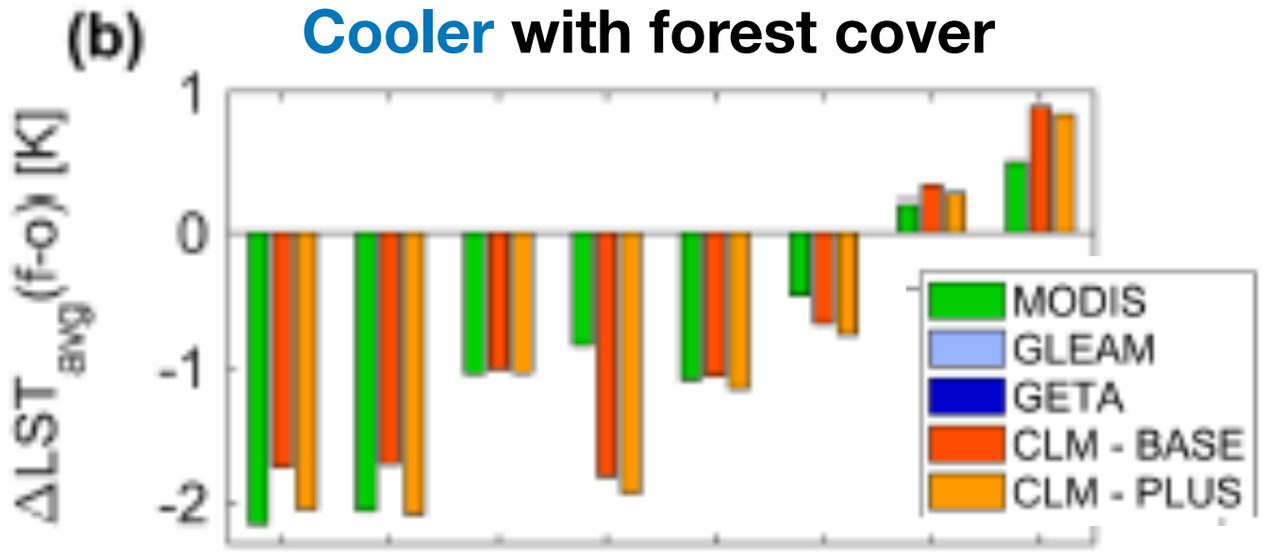
Atmos temp decrease due to 3/4 deforestation



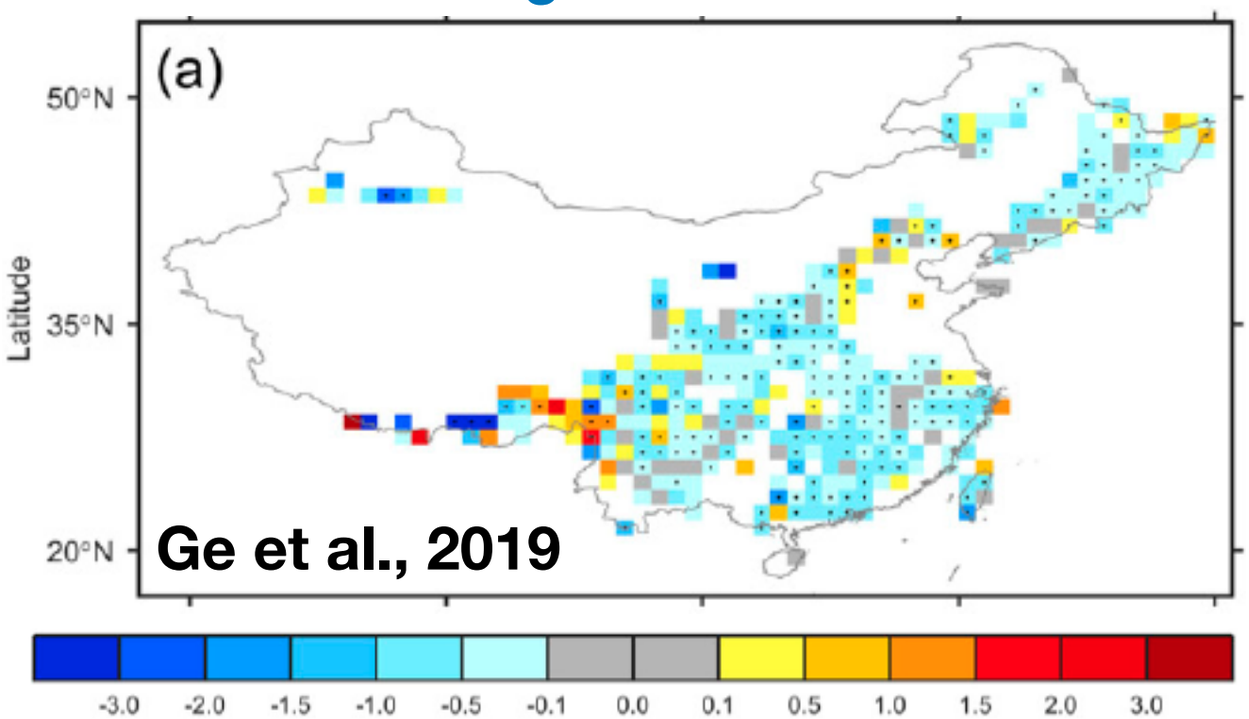
Winckler et al., 2019

Trees cool the surface, mostly

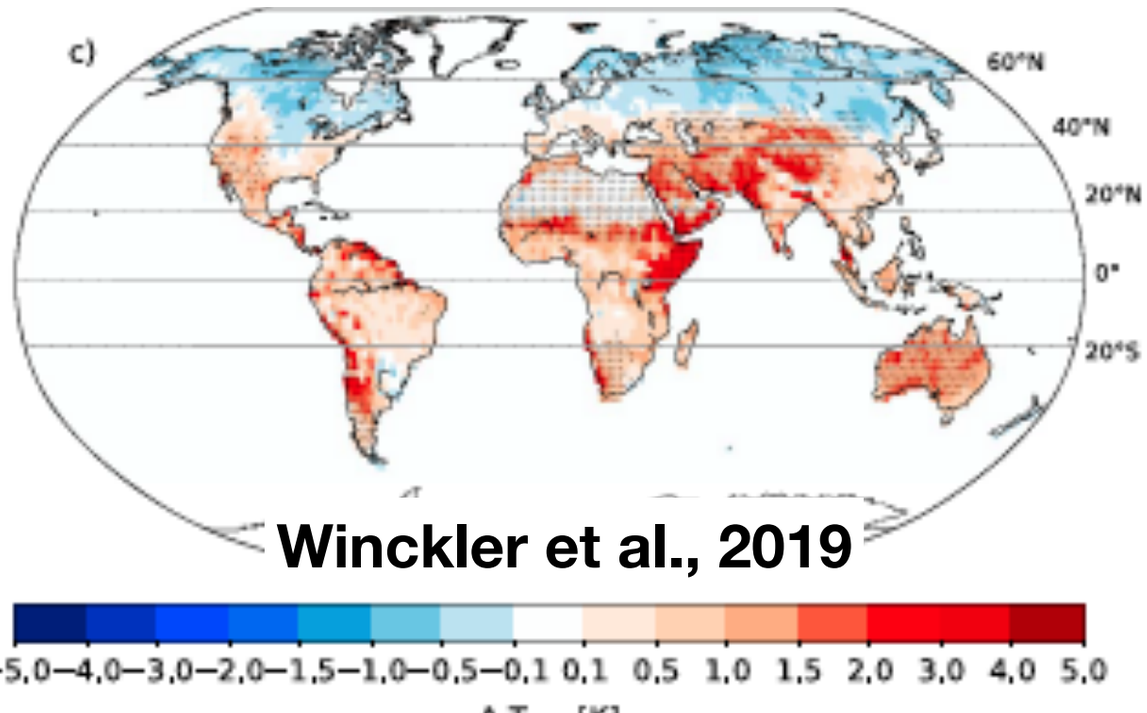




Local cooling due to afforestation

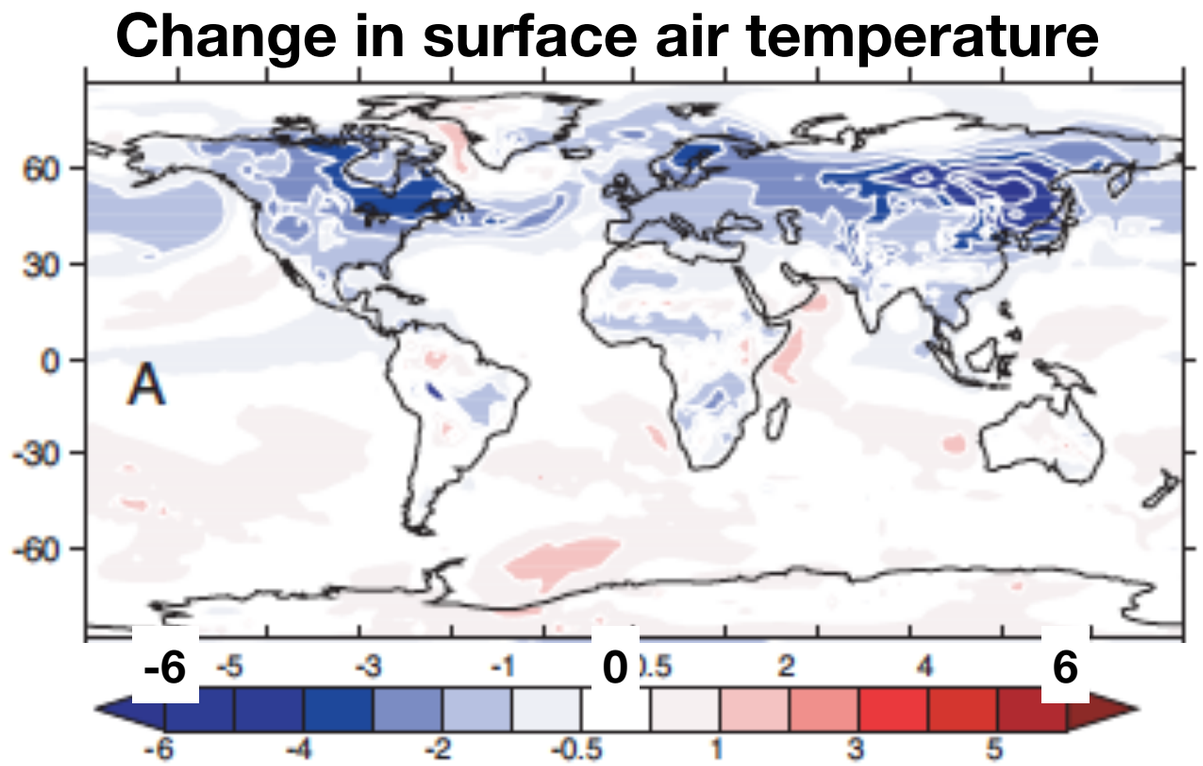


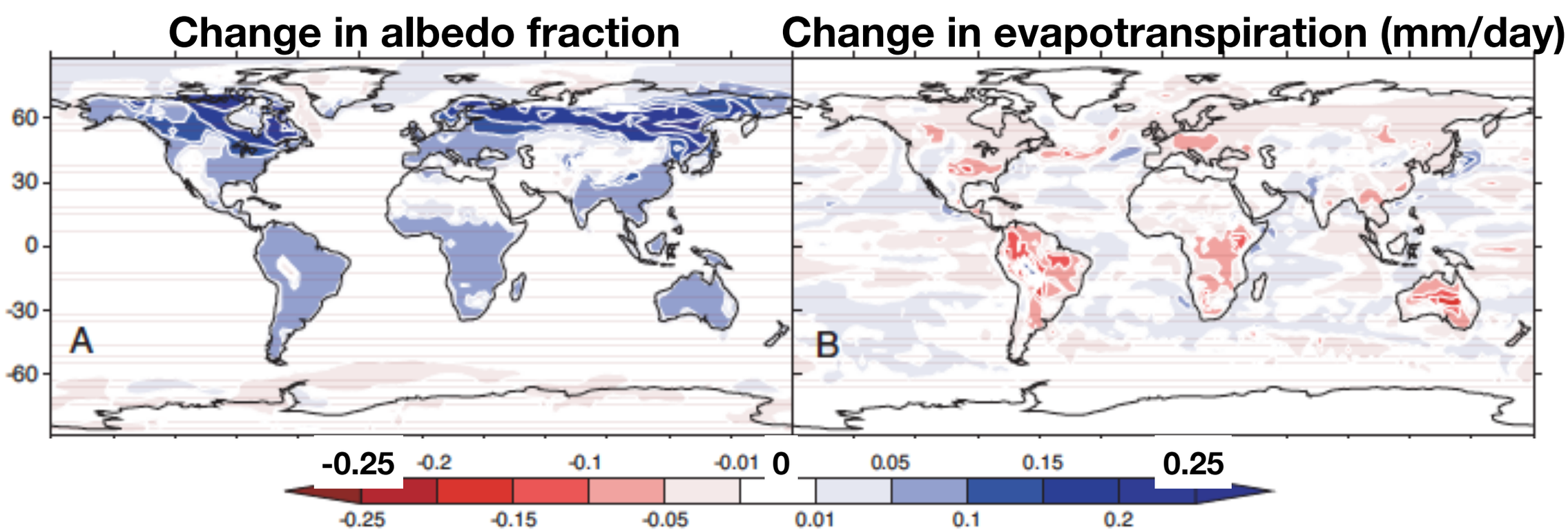
Local warming due to 3/4 deforestation



Latitudinal differences, modeled

Global deforestation experiment

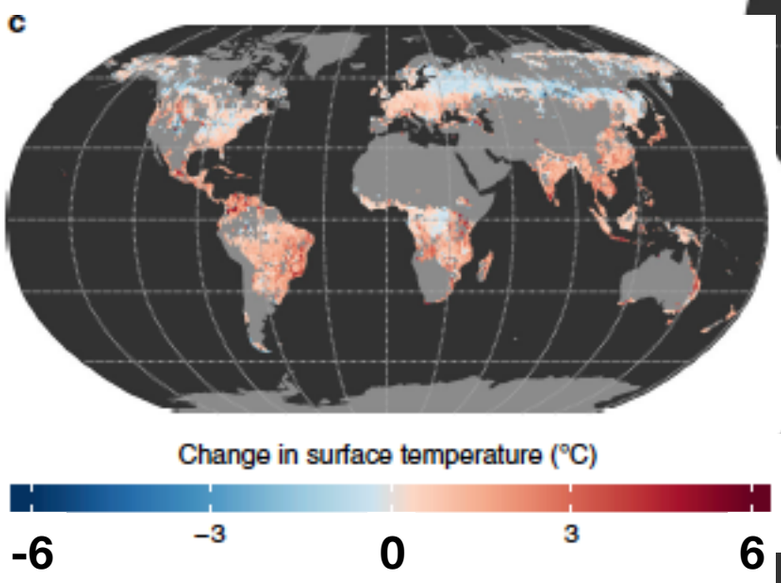




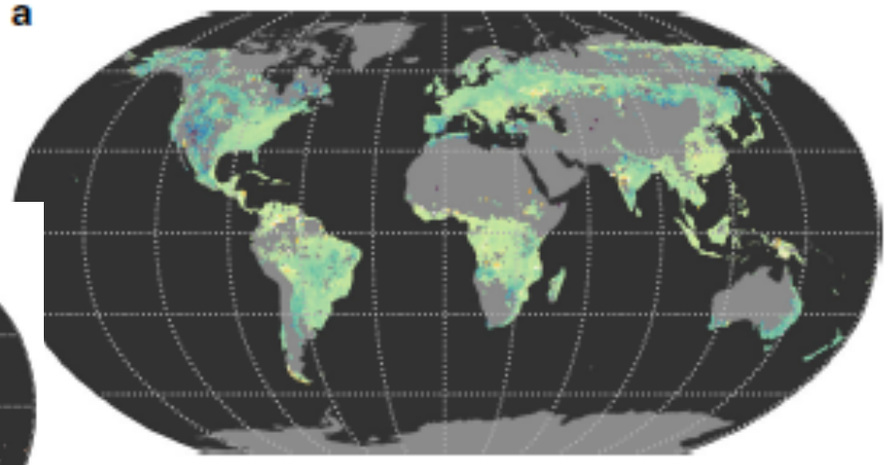
Bala et al., 2007

Latitudinal differences: RS+flux sites

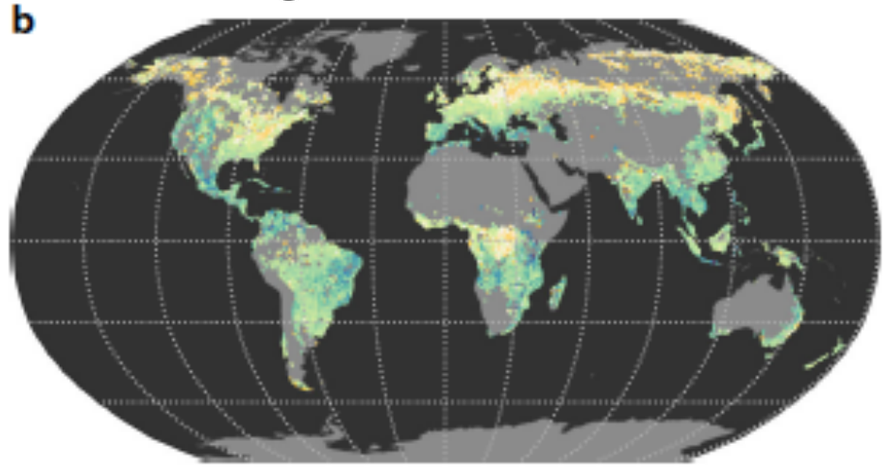
Change in land surface temperature

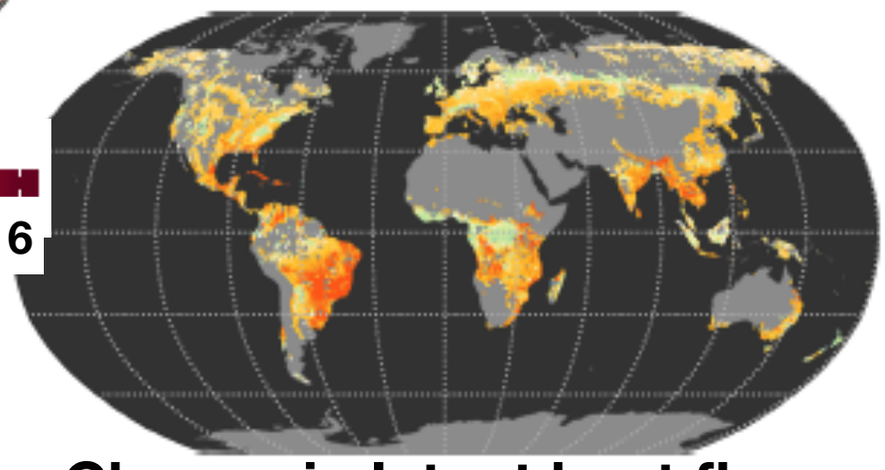


Change in SW reflected

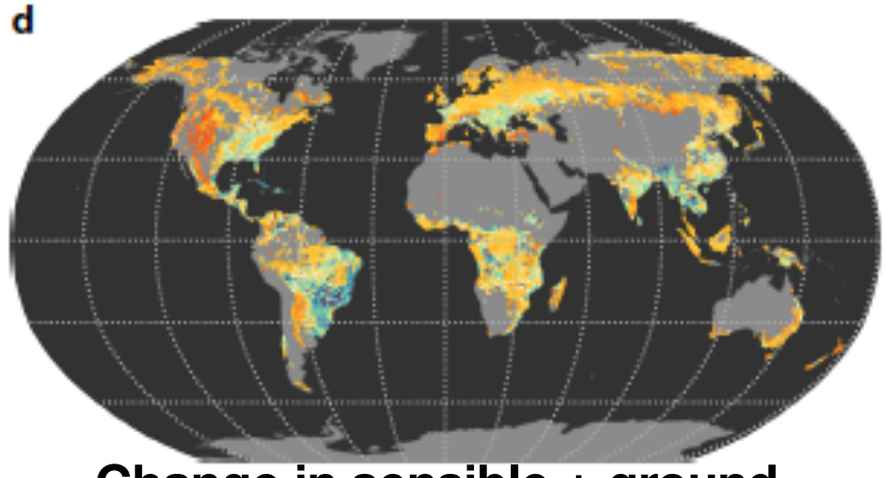


Change in LW emitted





Change in latent heat flux



Change in sensible + ground heat flux

Change in energy flux (W/m^2)

-30 −20 −10 0 10 20 30

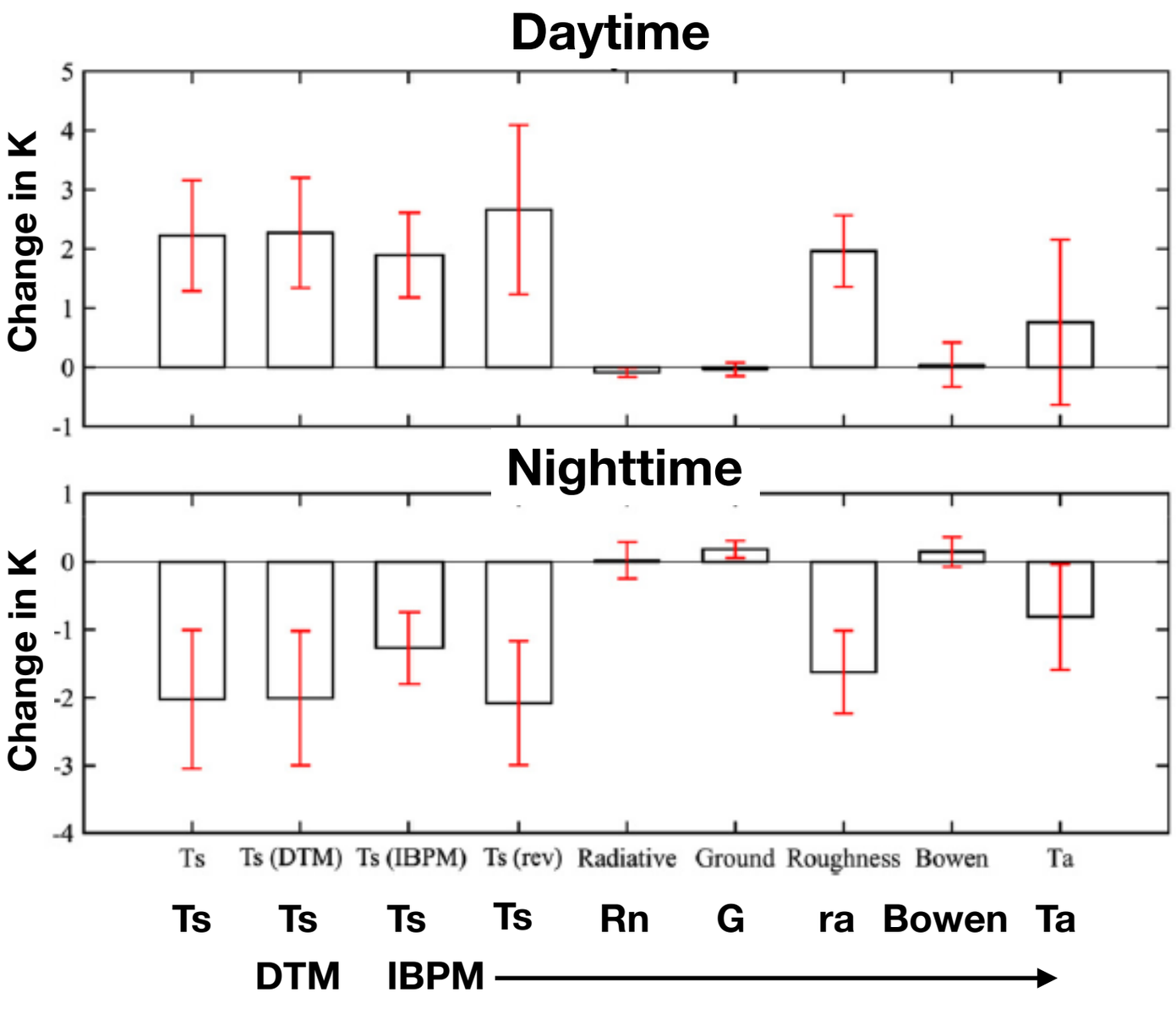
Change in energy flux in Wm^{-2}

Potential effects due to deforestation

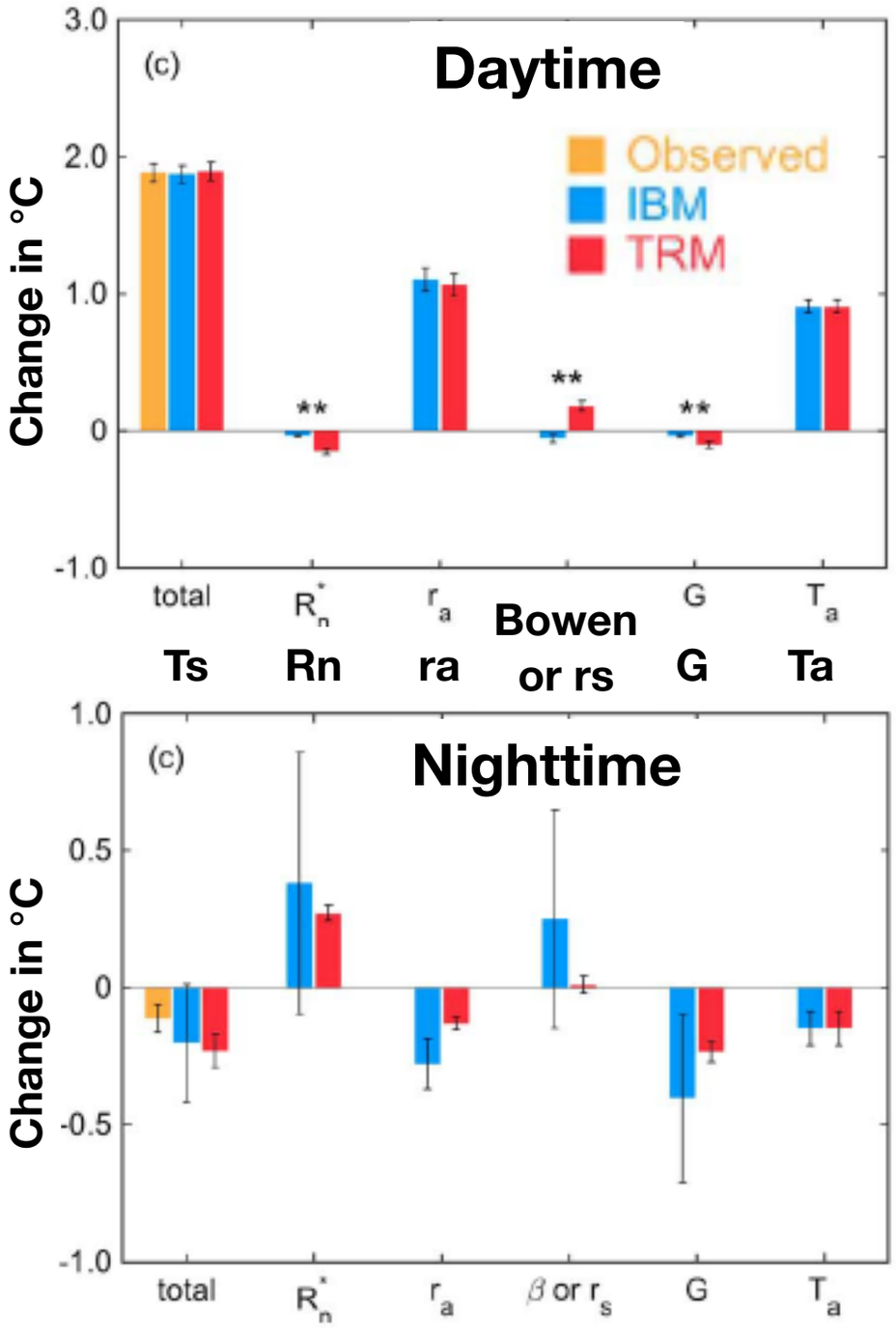
Duveiller et al., 2019

Surface non-radiative effects can be strong: flux sites

Non-forest minus forest
Multiple decomposition methods



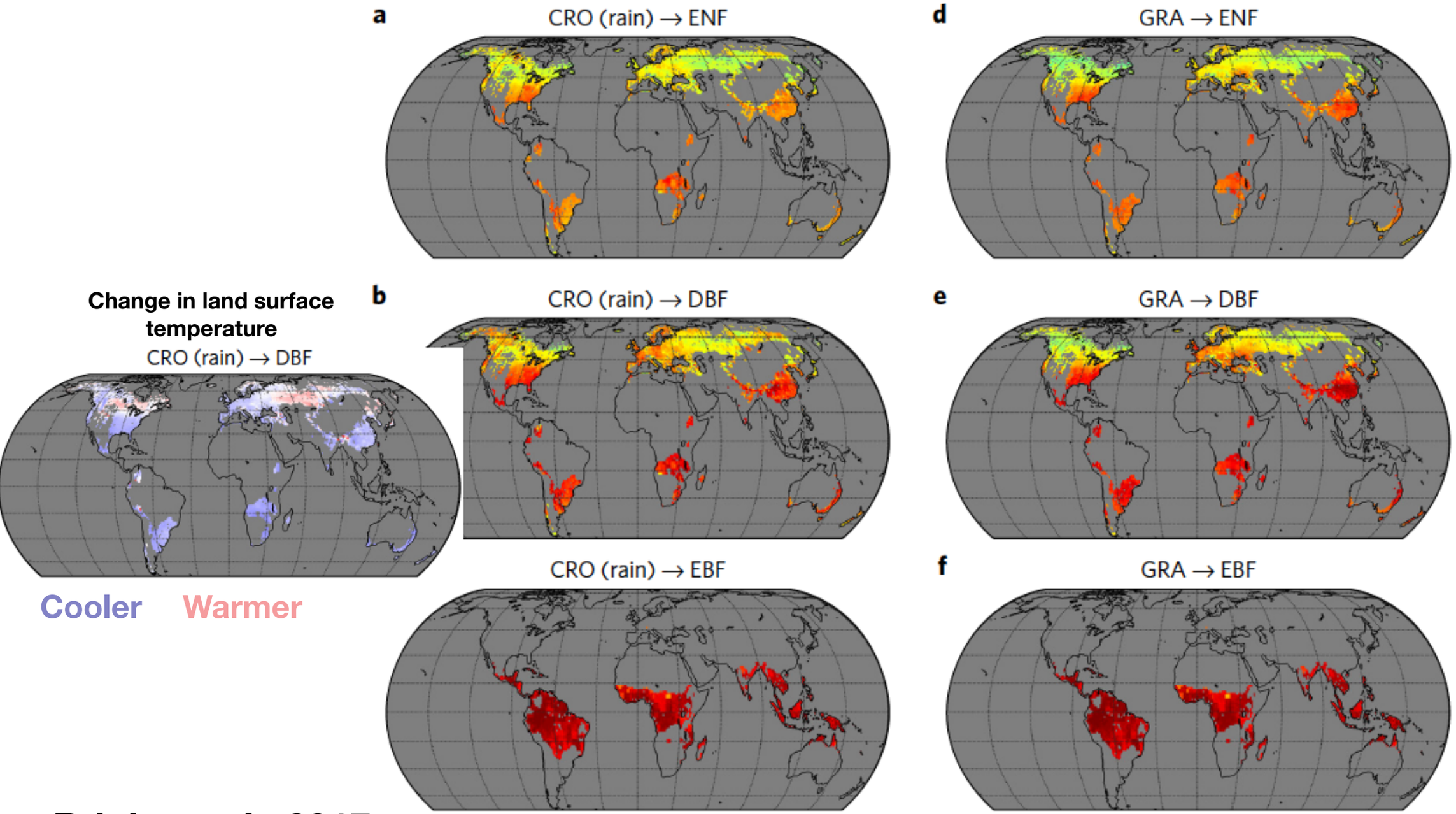
Chen et al., 2016



Liao et al., 2019

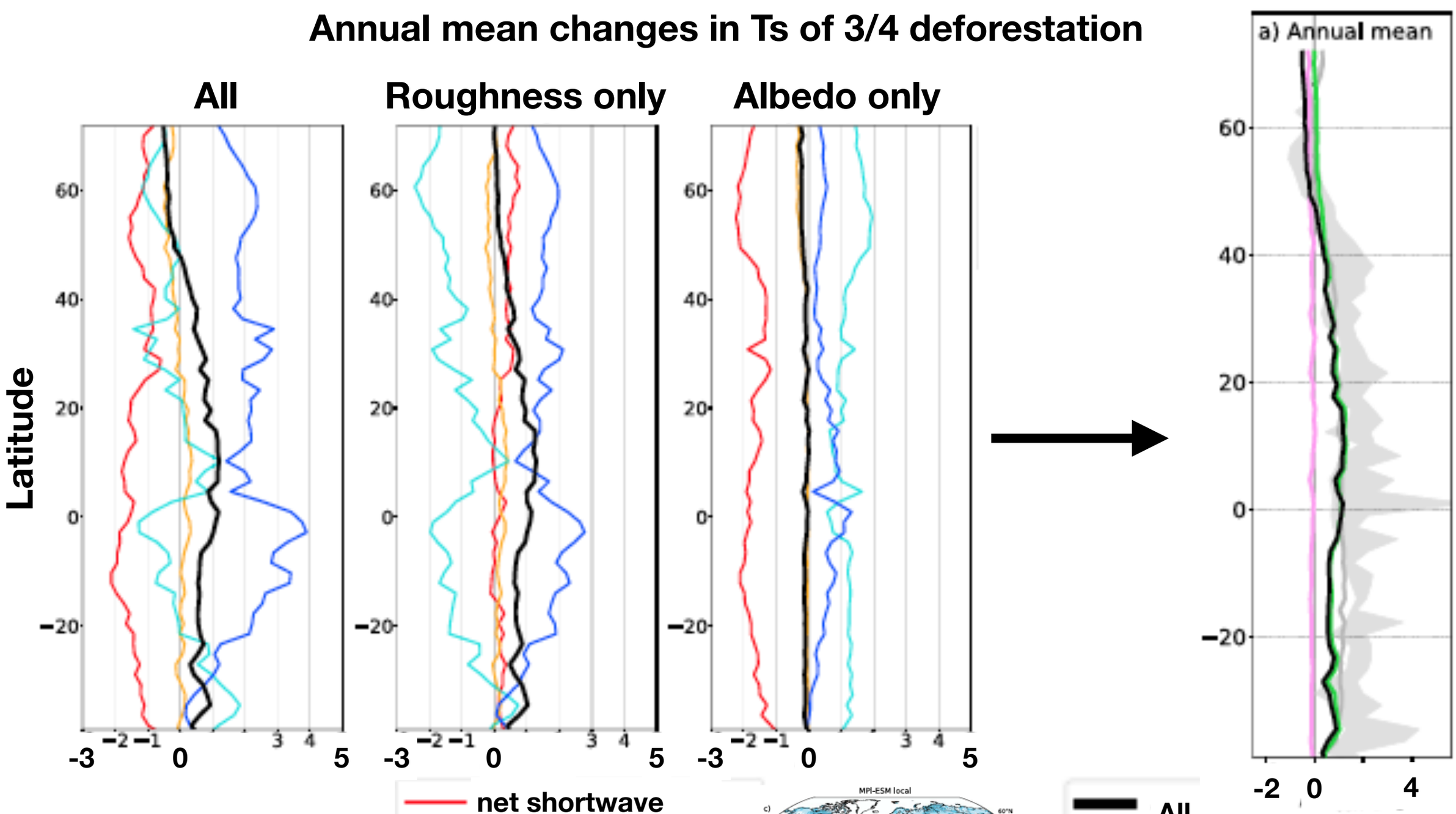
Surface non-radiative effects are strong: RS+flux sites

Potential change in non-radiative forcing index due to afforestation



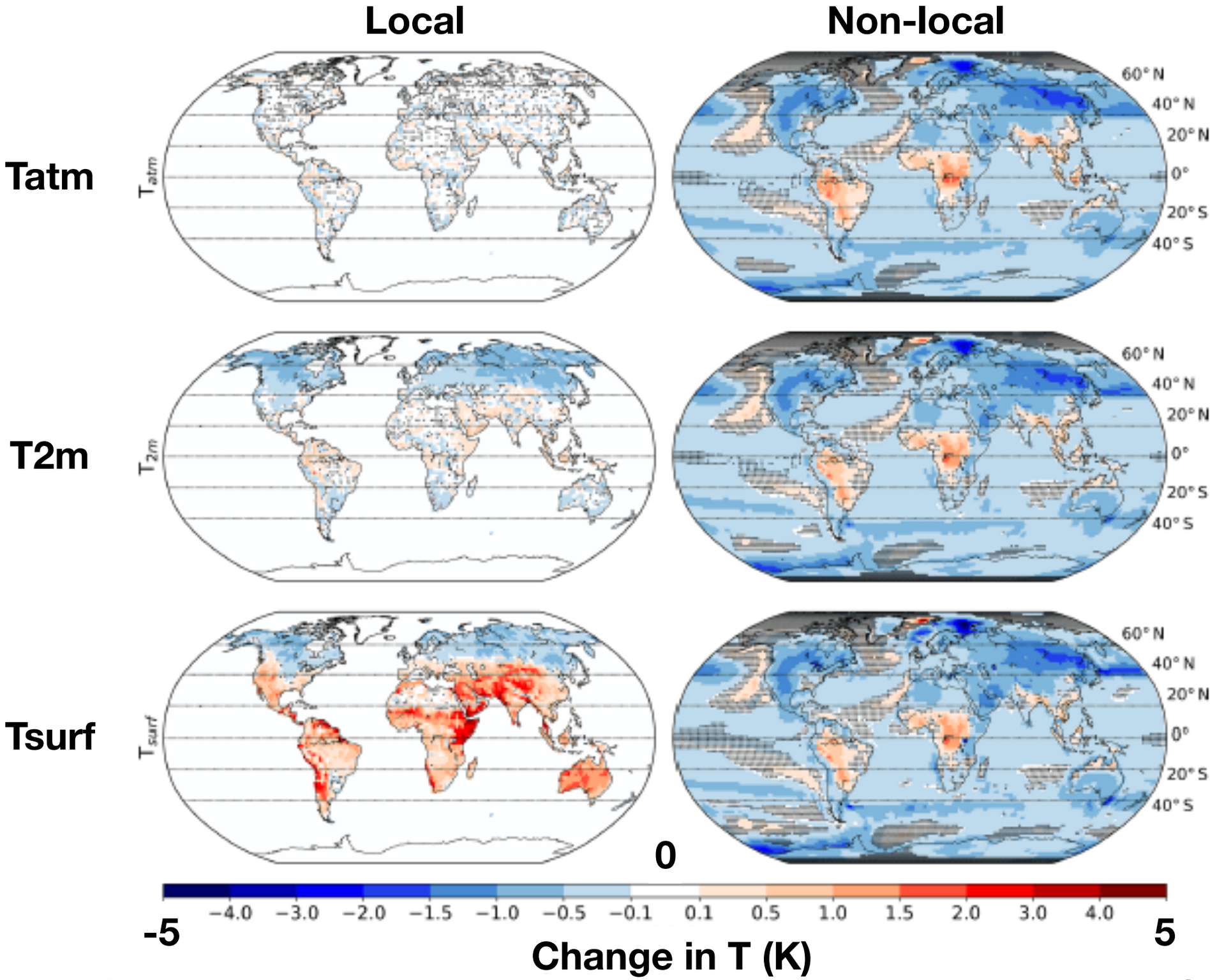
Bright et al., 2017

Surface non-radiative effects are strong due to surface properties: modeling



Winckler et al., 2019

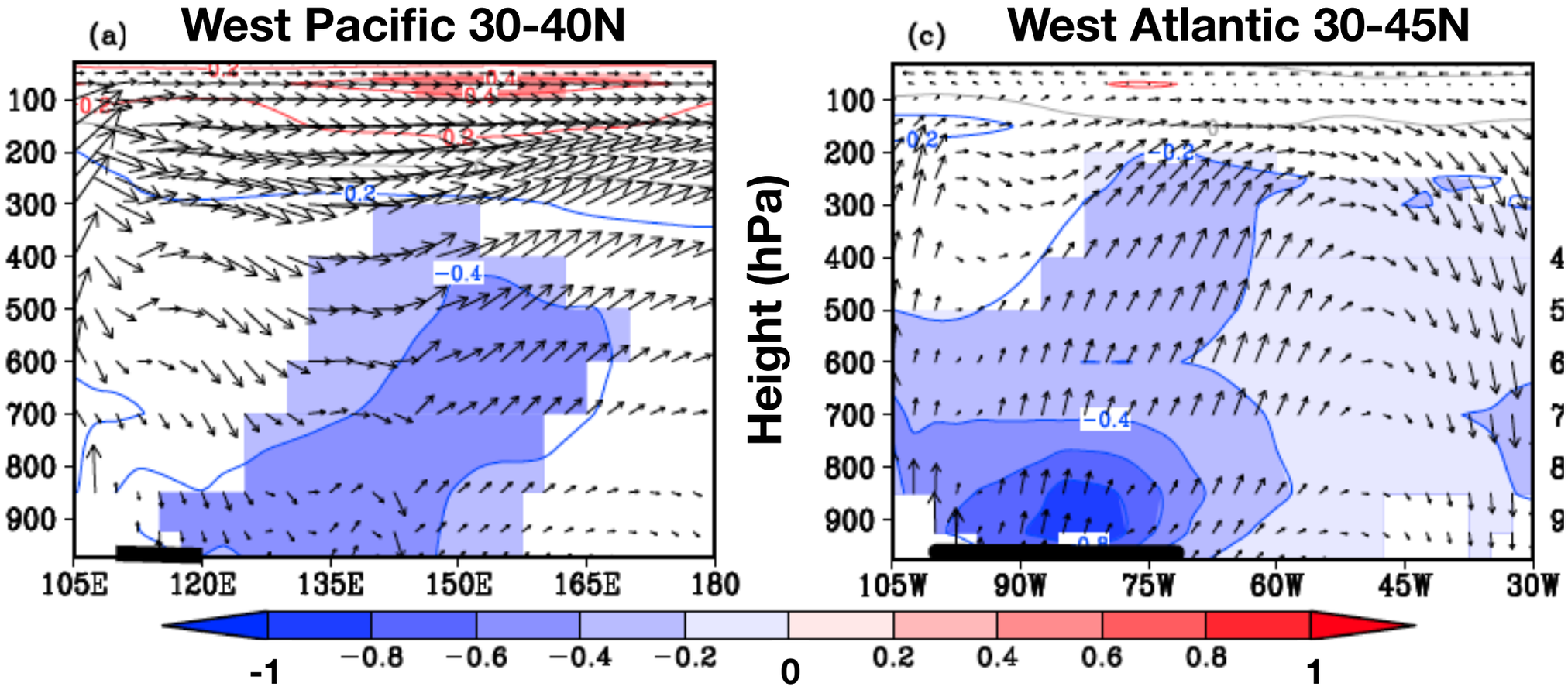
Local effects are strongest at the surface, non-local effects are more evenly distributed



Winckler et al., 2019

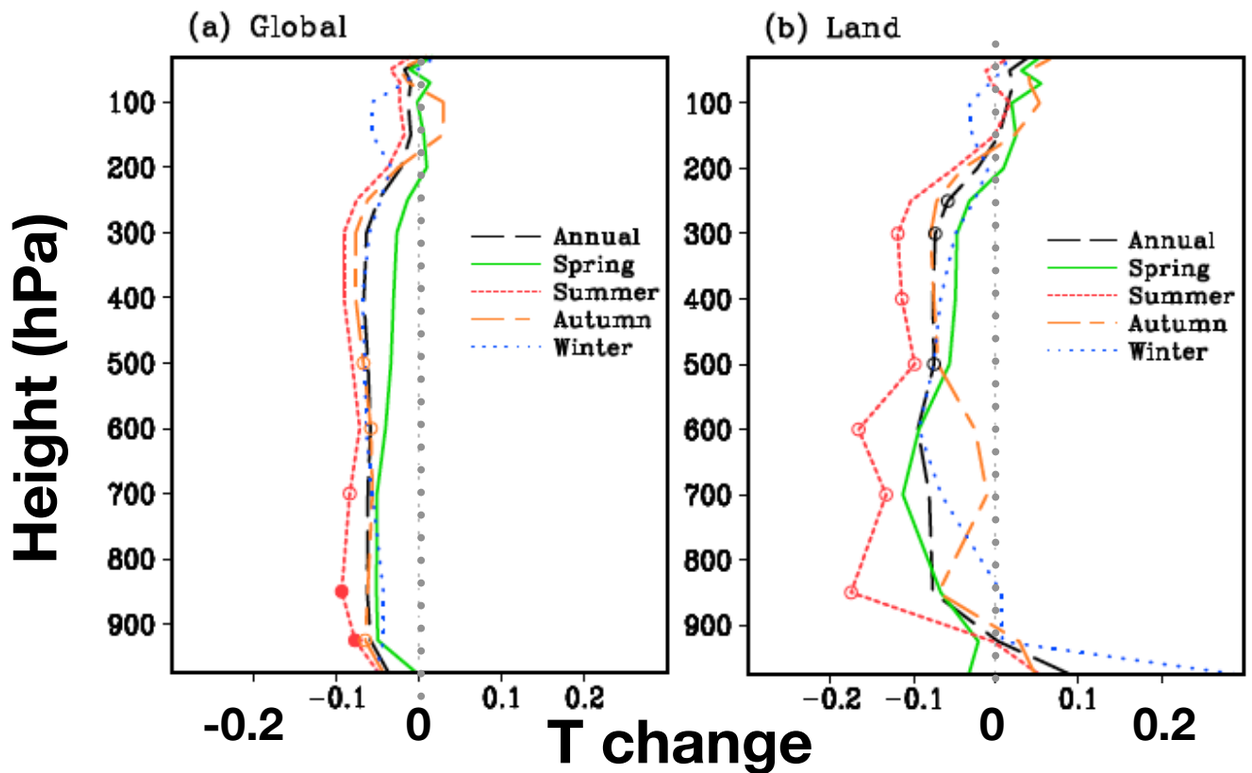
3/4 deforestation

Potential non-local mechanism



850 hPa temperature and wind changes

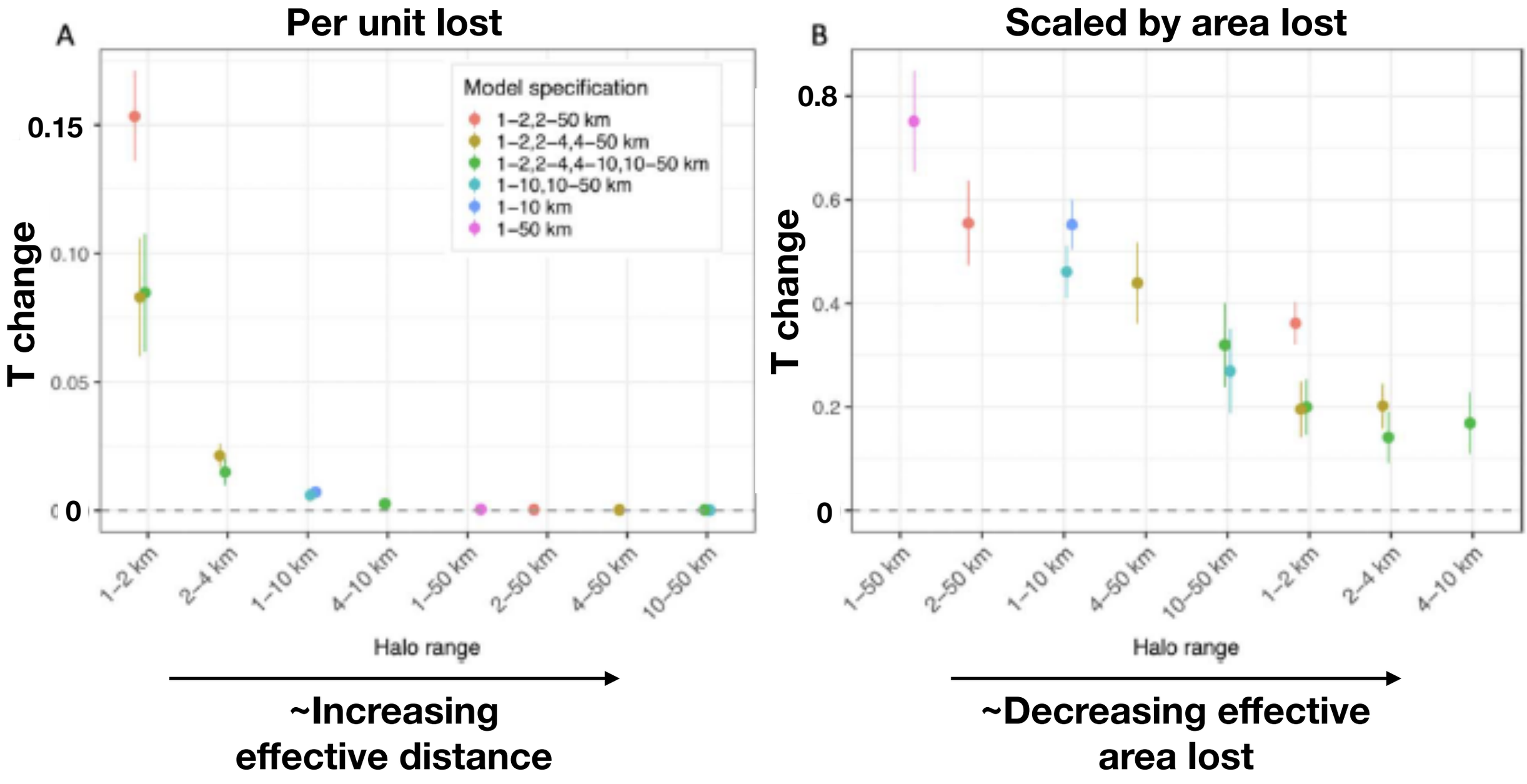
Simulated effects of modern land cover vs potential land cover (mostly deforestation)



Zhang et al., 2016

Non-local warming in Brazil

Observation-based non-local increases in air temperature due to deforestation in Brazil



Cohn et al., 2019

Summary

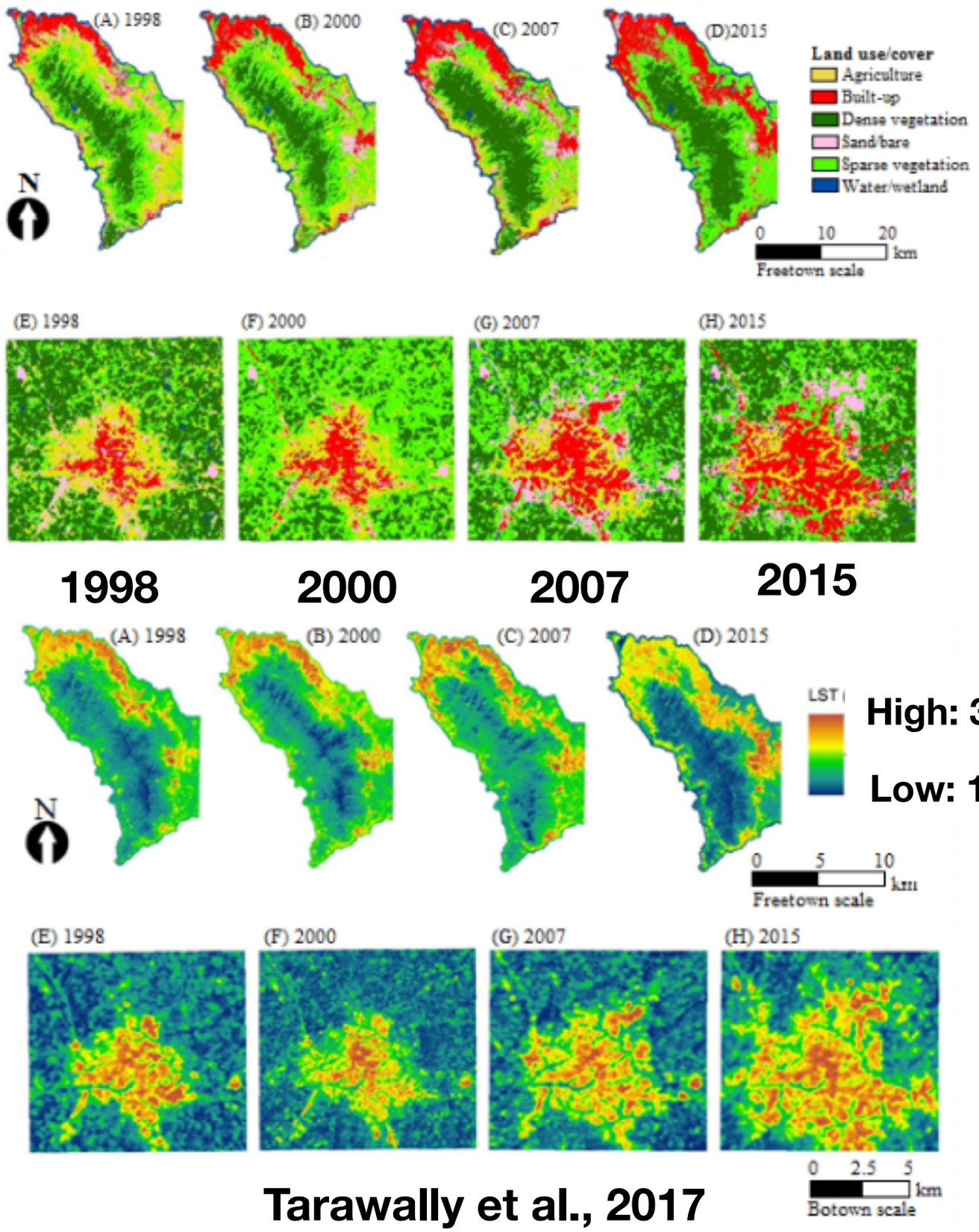
- **Tremendous progress in understanding the effects of LULCC on temperature:**
  - Surface effects are local and do influence near surface temperature
  - Surface effects are largely driven by non-radiative processes and properties, with albedo playing a nearly equal role in high latitudes
  - Non-local effects are likely driven more by reduction in net radiation and its greater effect on air temperature
  - Model and observation studies are coming into alignment

Summary

- **But**…
- Where is Ta? How does Ta location affect results?
- Driver of surface cooling with deforestation in high lats, cold regions/seasons, and at night
  - Related to vertical temperature profiles and longwave reabsorption in canopy?
- Mechanisms of non-local temperature effects

Urban heat island

Expansion of developed land



1998 2000 2007 2015

Expansion of urban heat island

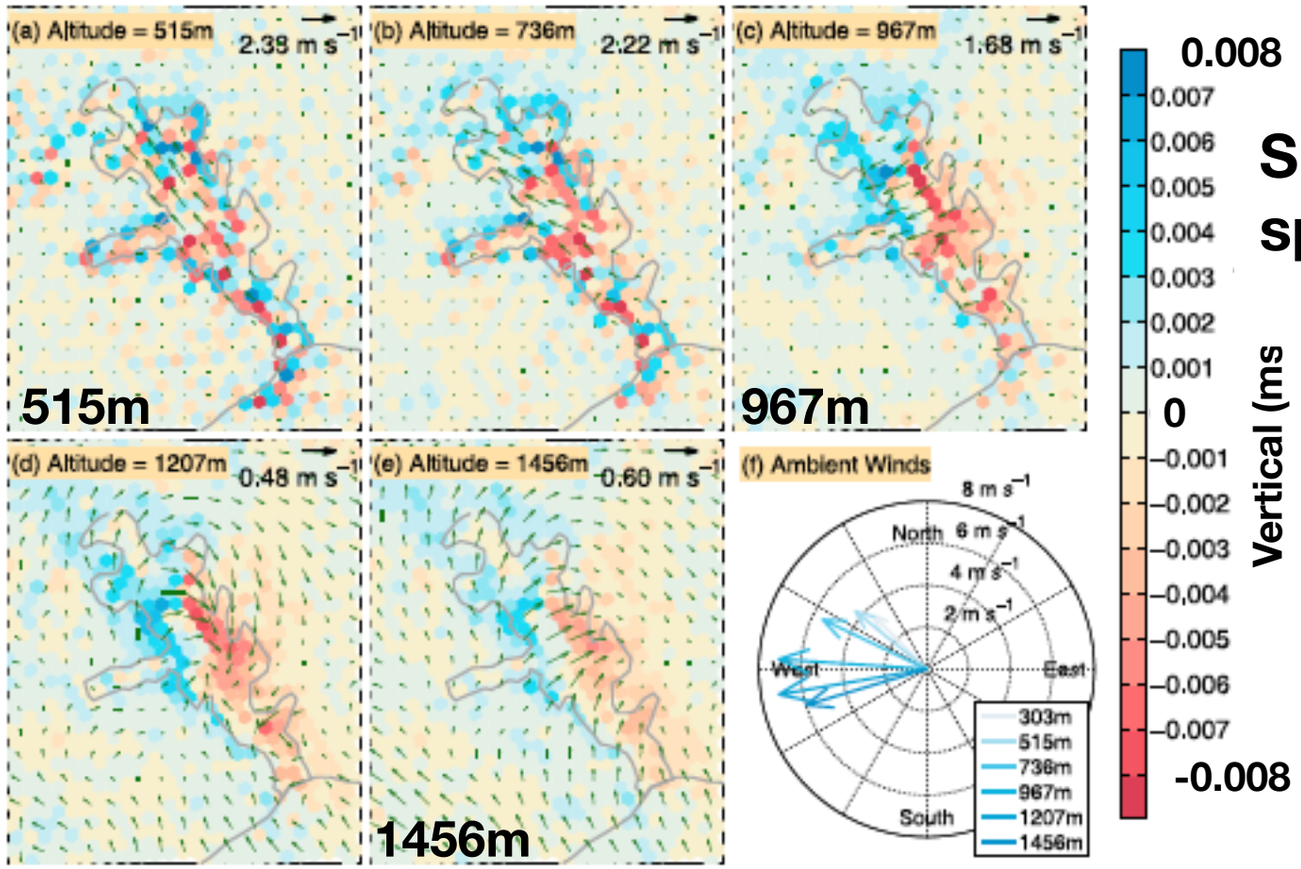
High: 36.75

Low: 19.28

LST in °C

Tarawally et al., 2017

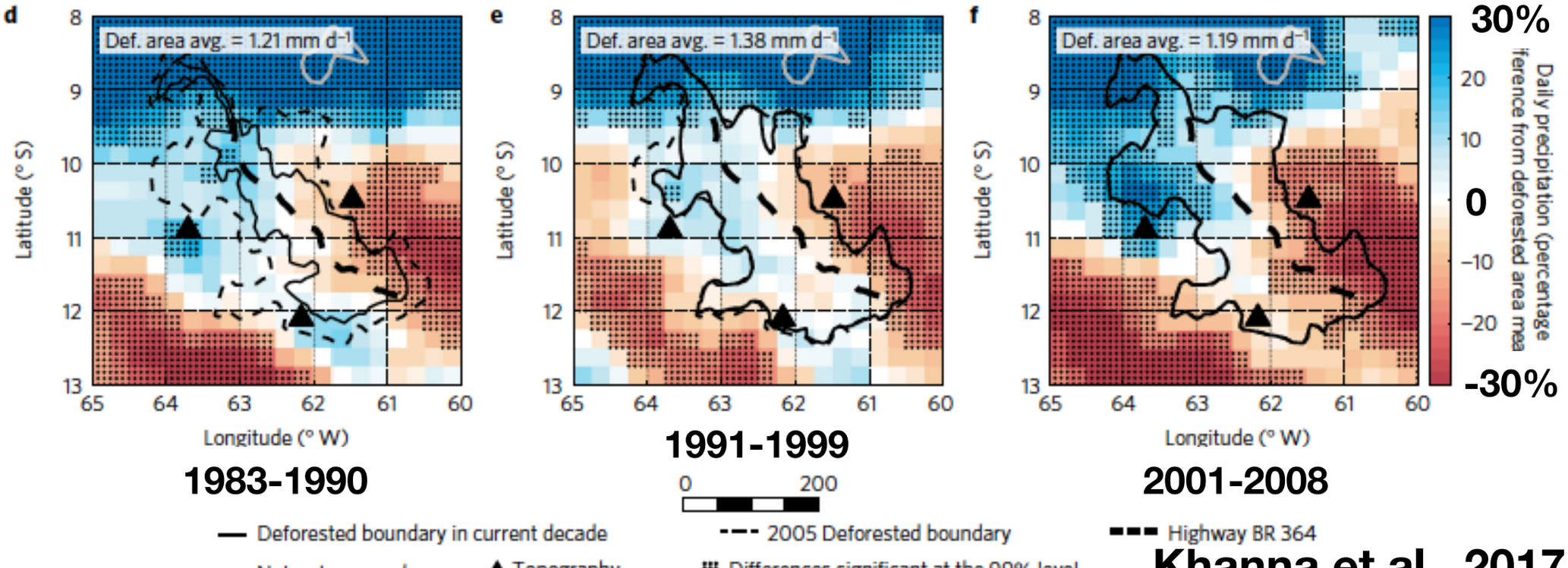
Circulation and precipitation



Khanna et al., 2014

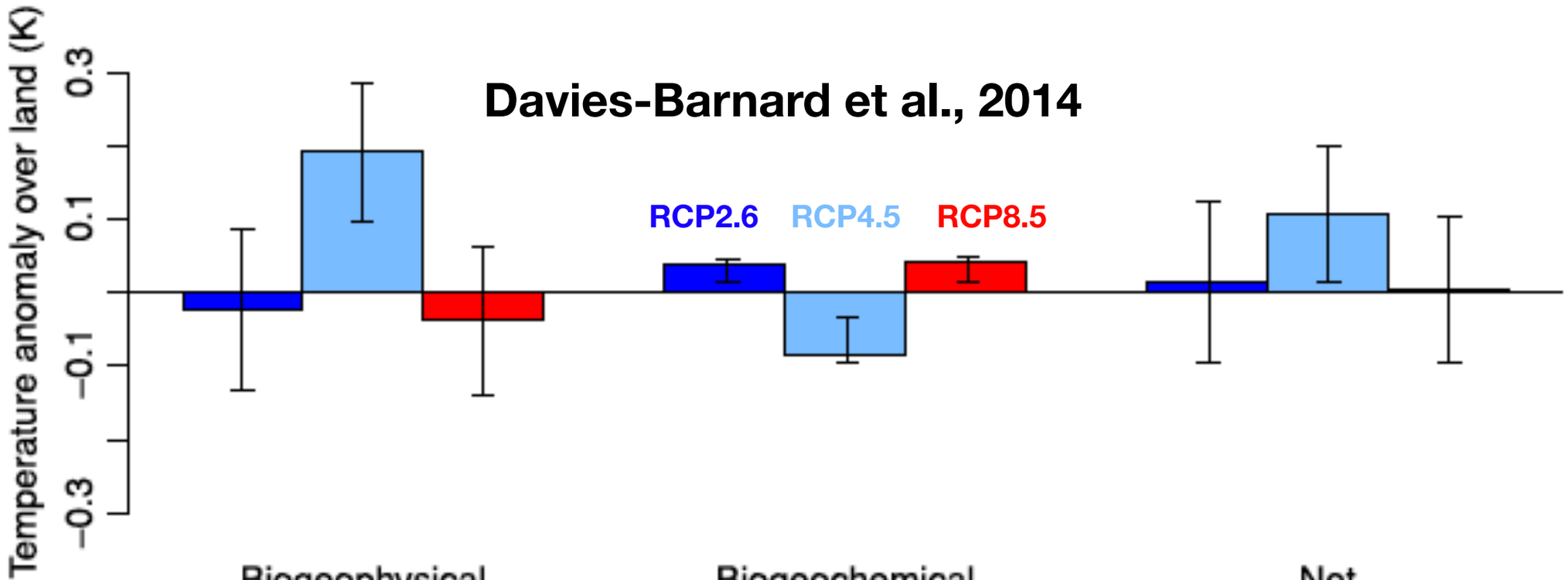
Simulated changes in wind speed due to deforestation at different altitudes

Precipitation anomaly as percent of area mean based on PERSIANN data



Khanna et al., 2017

Biophysical vs Biochemical effects



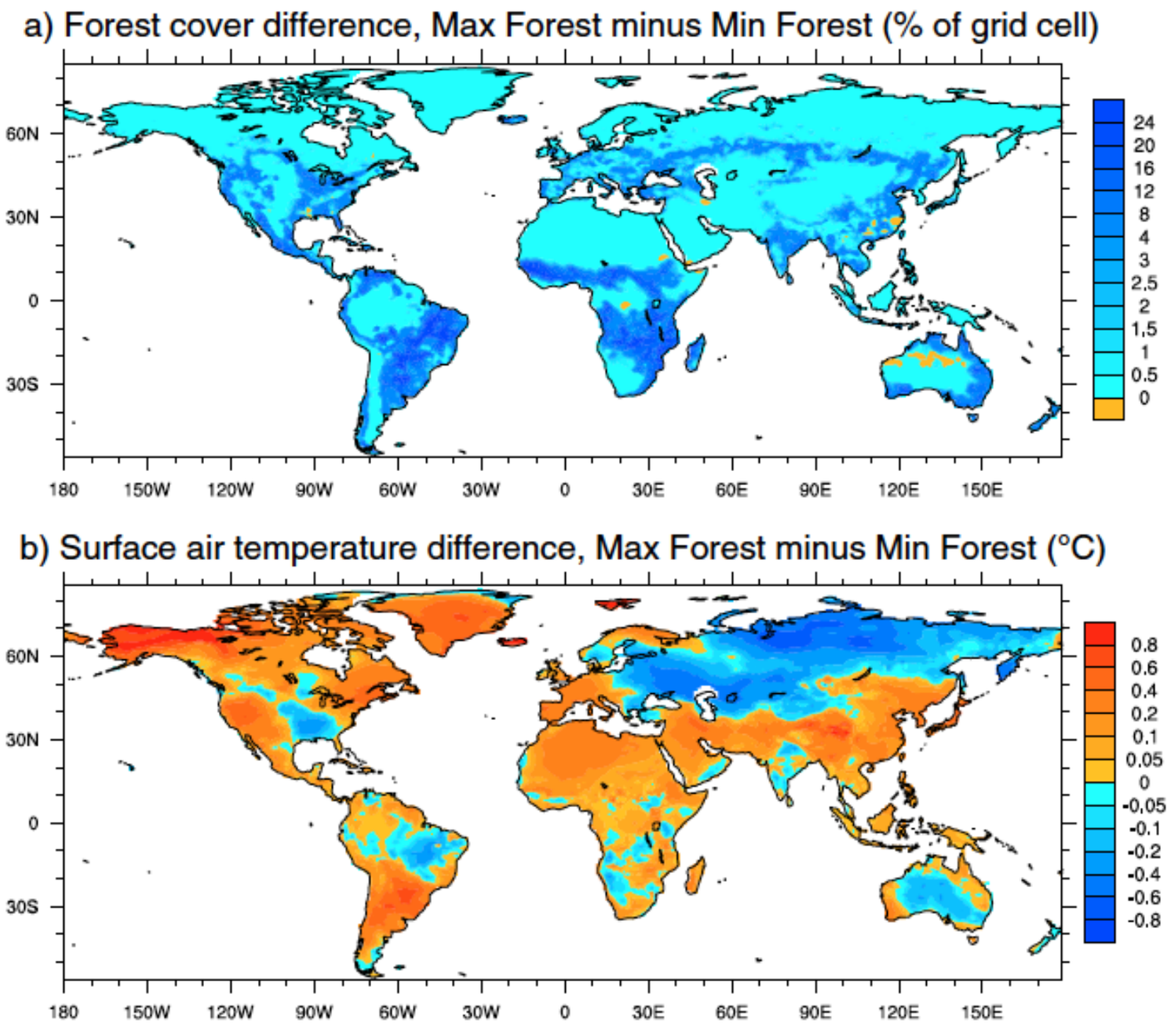
Linear slope of transient climate response to emissions (°C/Tt C) for 1750–2000			
	Total ΔT	Geochemical ΔT	Biophysical ΔT
LUC-only	−0.35 ($r^2 = 0.511$)	+1.67 ($r^2 = 0.975$)	−2.02 ($r^2 = 0.972$)

Linear slope of transient climate response to emissions (°C/Tt C) calculated with total ΔT for 1750–2100				
	With RCP2.6	With RCP4.5	With RCP6.0	With RCP8.5
LUC-only	−0.18 ($r^2 = 0.153$)	−0.10 ($r^2 = 0.287$)	−0.13 ($r^2 = 0.212$)	−0.20 ($r^2 = 0.254$)

Simmons et al., 2016

Effects of LULCC uncertainties are as large as estimated LULCC effects

Difference in 1985-2004 annual average uncertainty due to land cover conversion assumptions



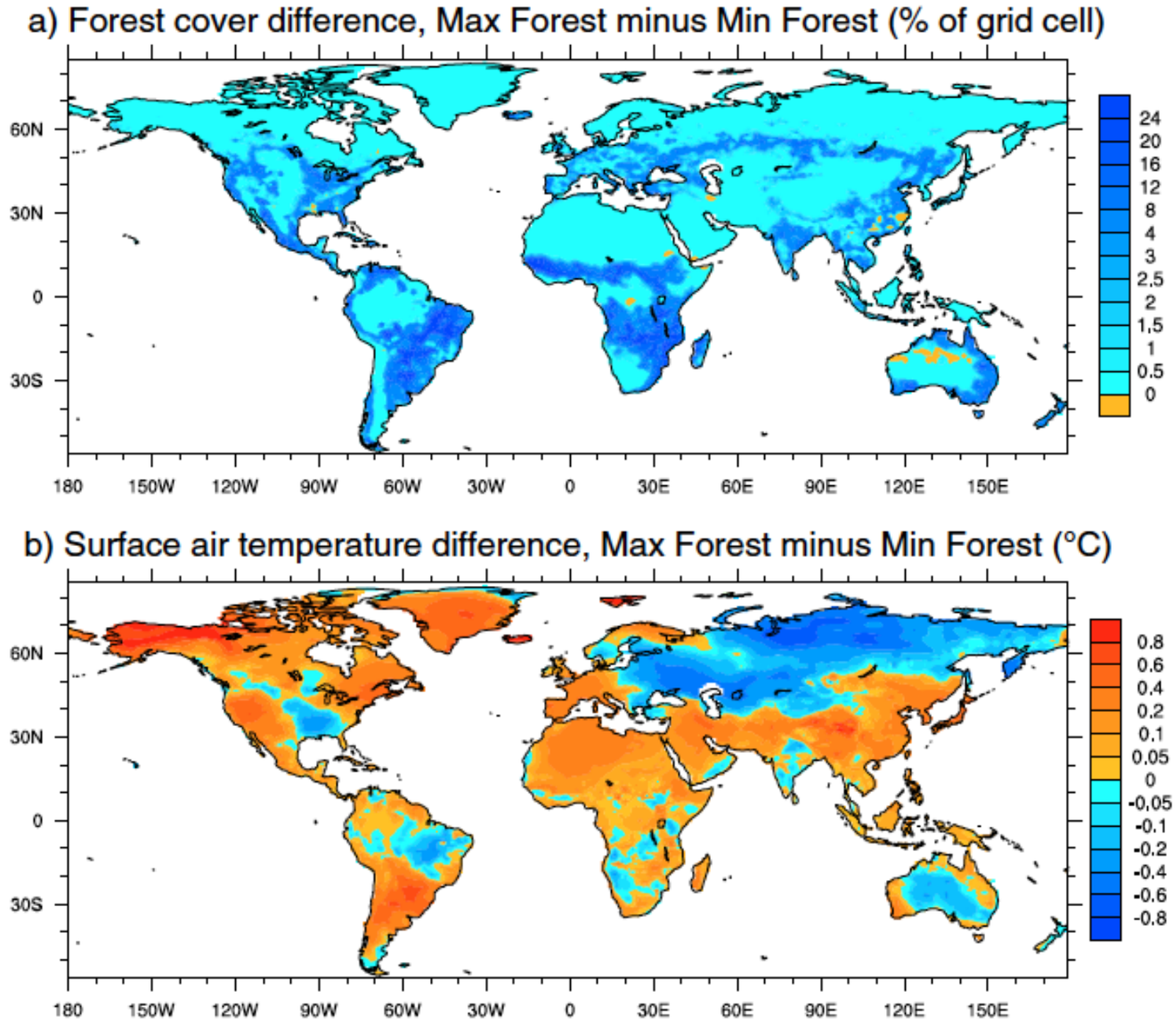
Di Vittorio et al., 2018

Additional opportunities

- Effects on circulation, clouds, and precipitation
- Land management effects
- Biophysical vs Biochemical effects
- Land emissions vs other anthropogenic emissions
- Historical and projected LULCC effects
- LULCC uncertainty

Thank you!

Difference in 1985-2004 annual average uncertainty due to land cover conversion assumptions

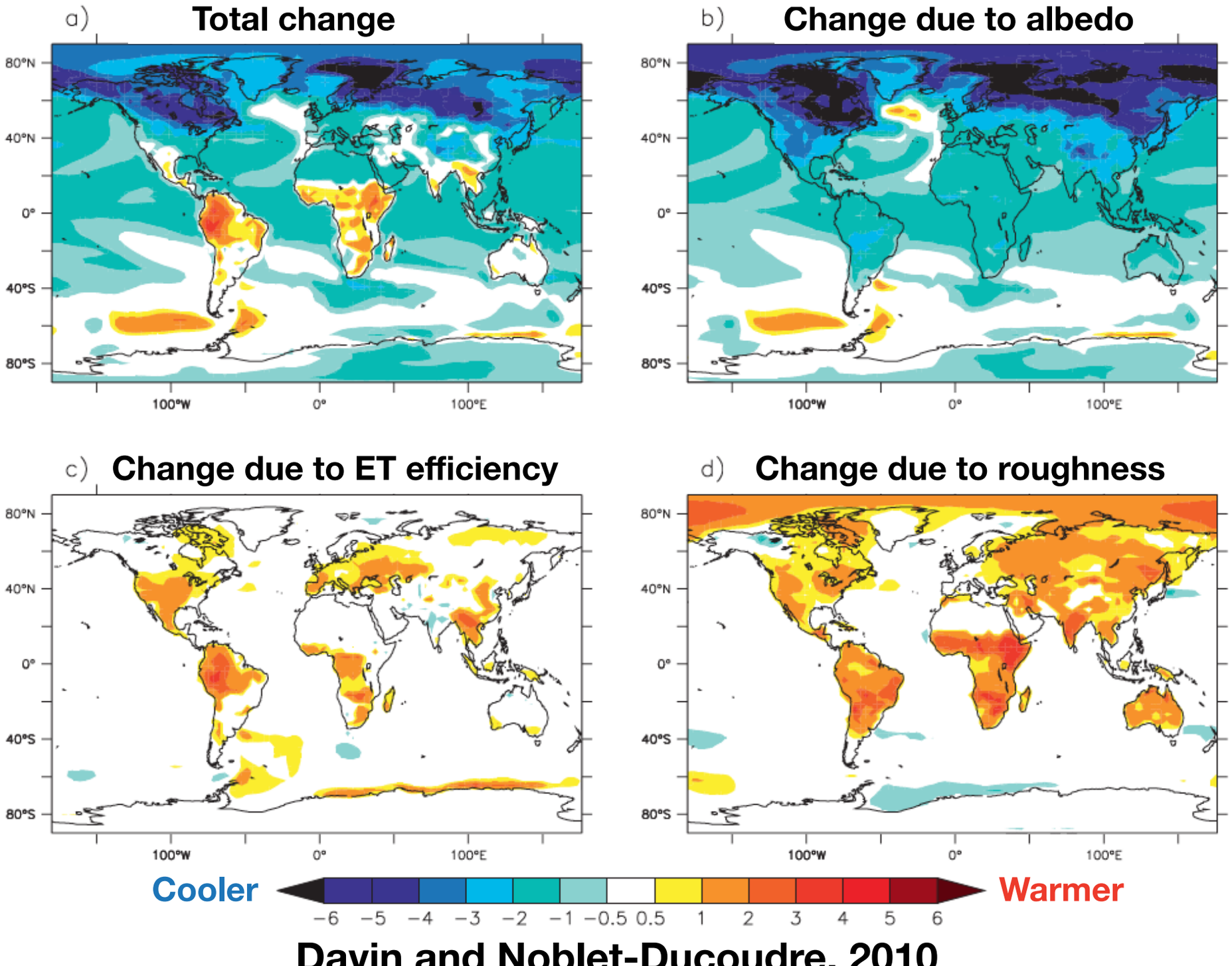


Di Vittorio et al., 2018

I thank you for your attention, the organizers for inviting me to participate, and the Aspen Global Change Institute for supporting this conference.

Latitudinal differences: modeled

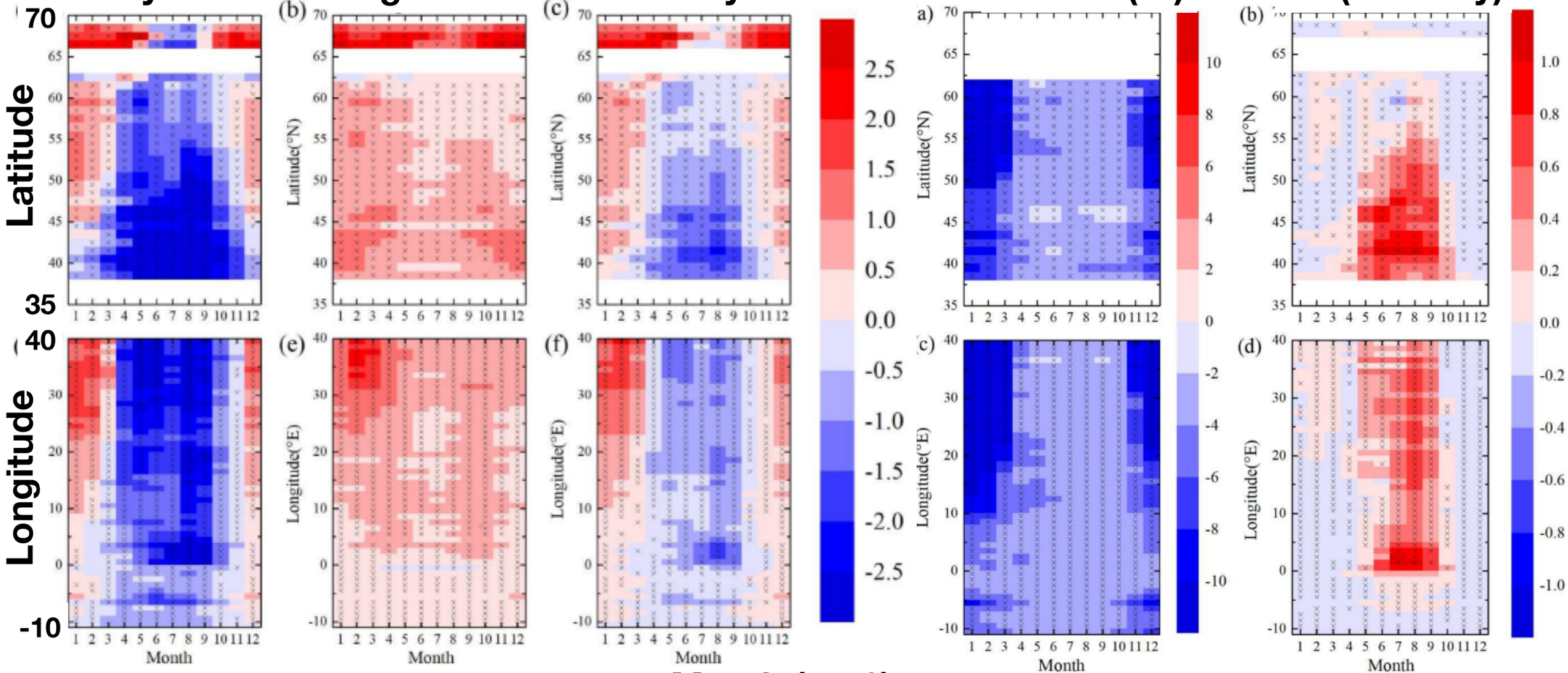
Change in surface air temperature due to deforestation



Davin and Noblet-Ducoudre, 2010

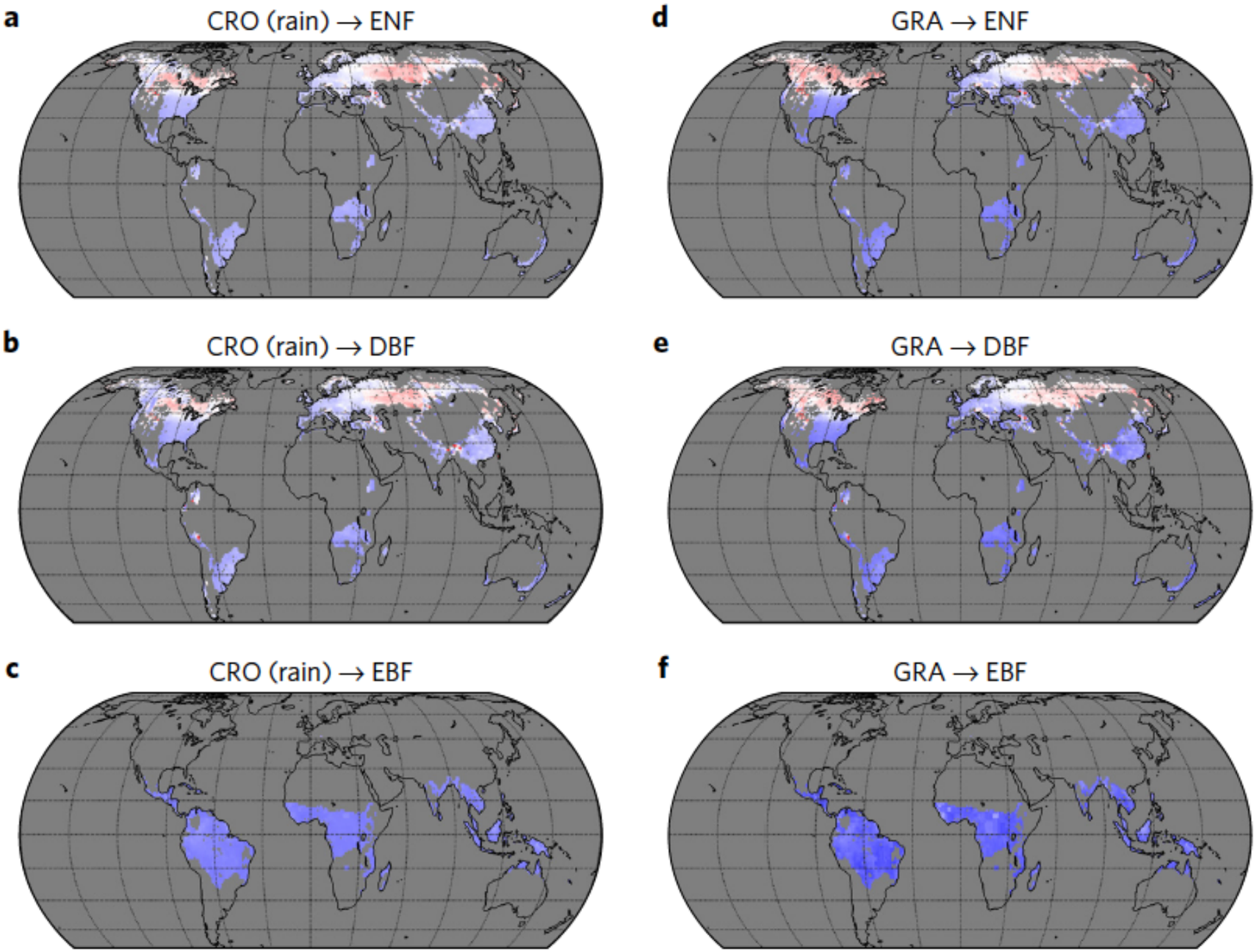
Diurnal and seasonal cycles: RS

Afforestation effects in Europe



Tang et al., 2018

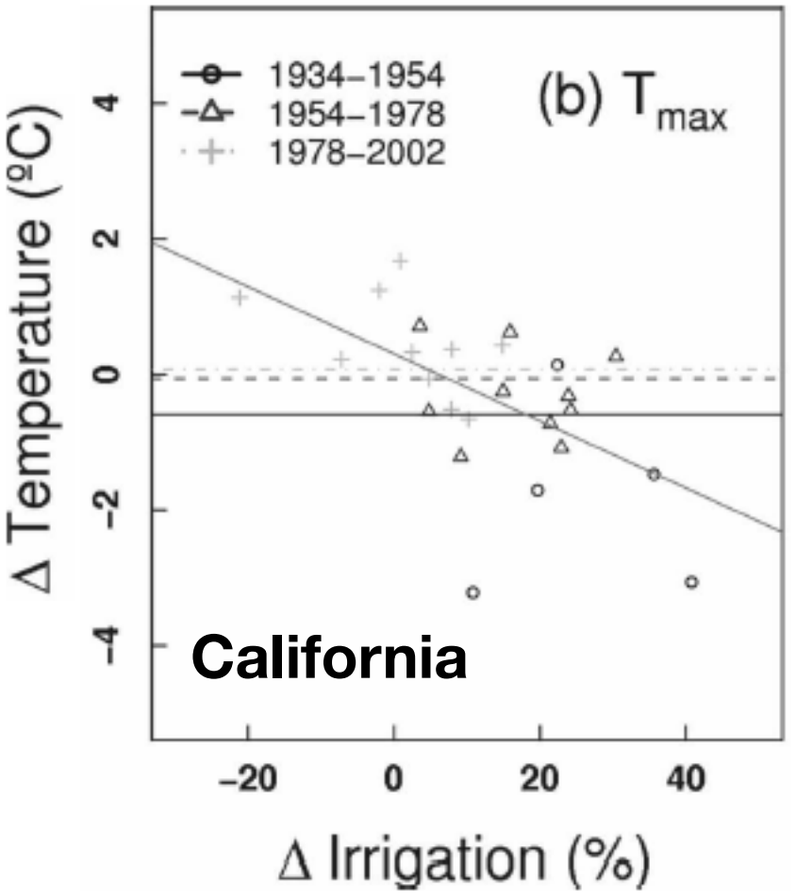
Surface non-radiative effects are strong: RS



Potential change in annual surface temperature due to afforestation

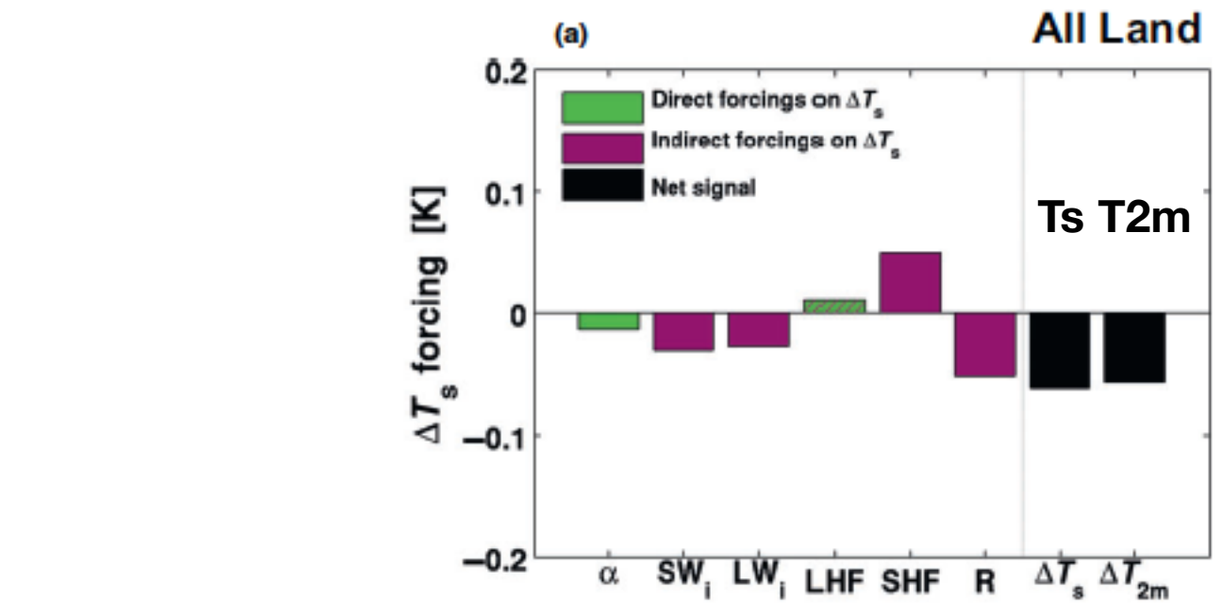
Bright et al., 2017

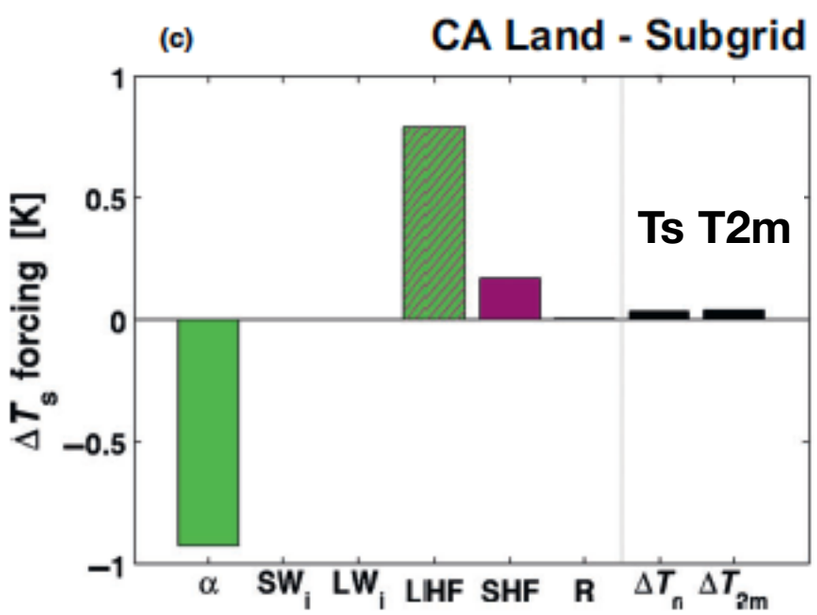
Agricultural management effects

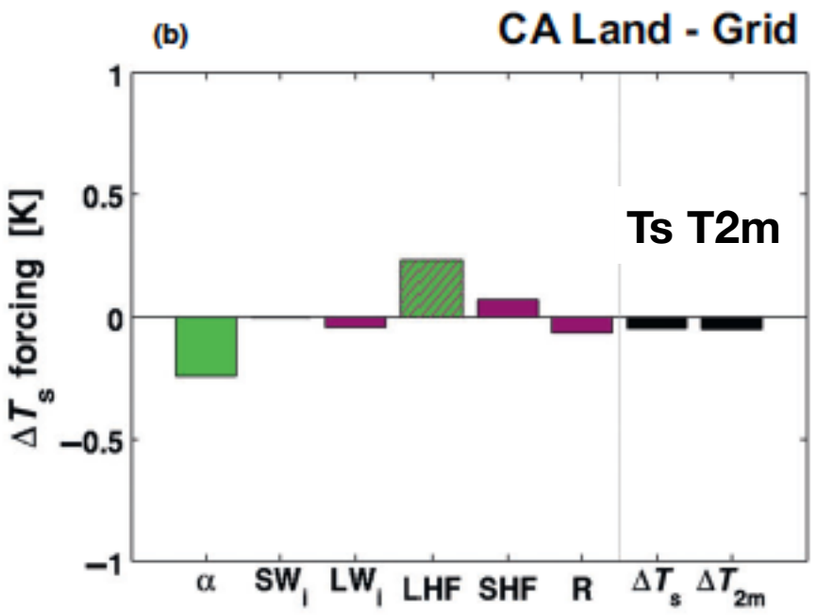


Lobell and Bonfils, 2008

Changes due to conservation agriculture (CA) evaluated at different scales

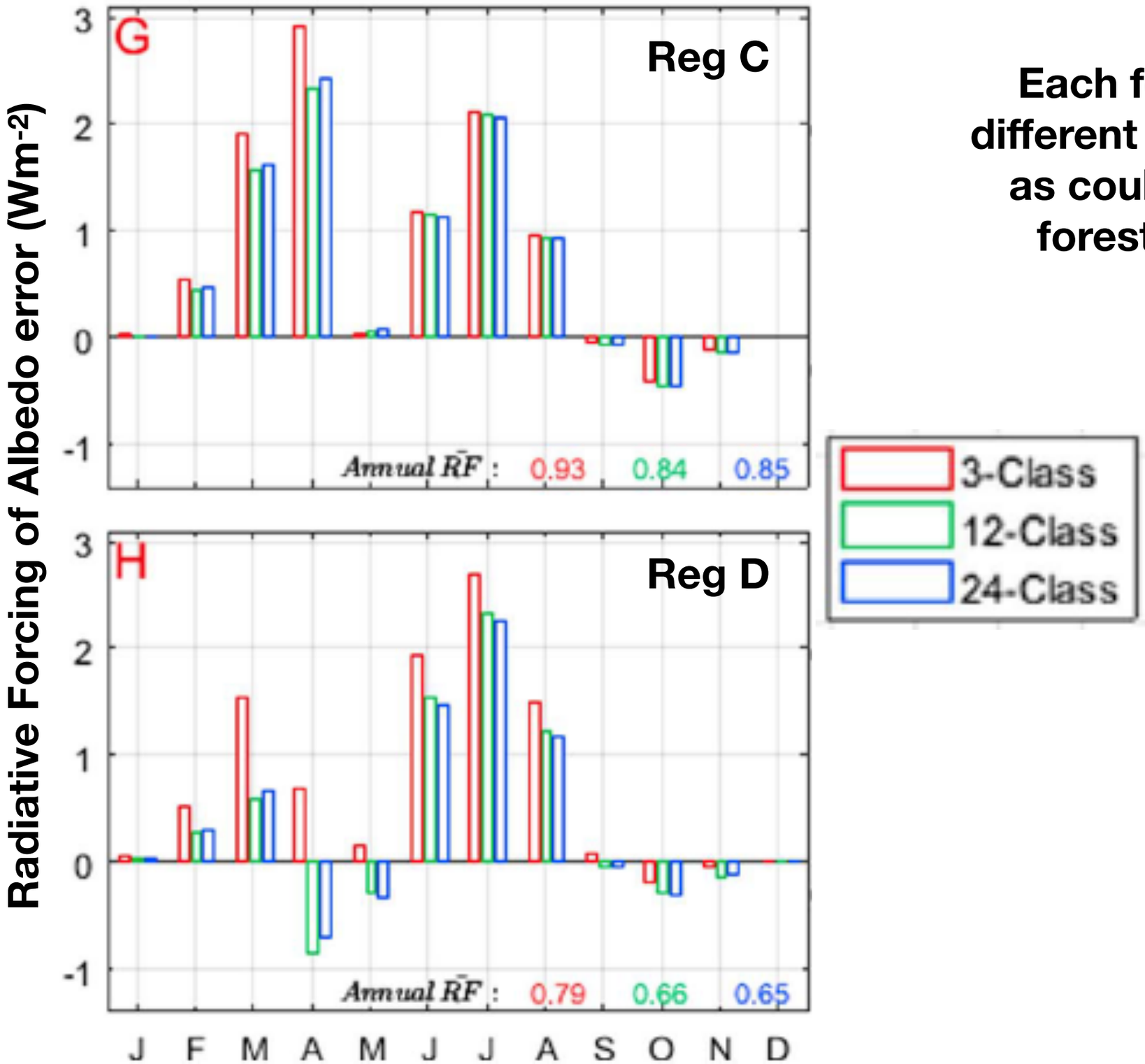






Hirsch et al., 2018

Potential effects of forest management



Each forest class has different structure/albedo, as could be caused by forest management

Bright et al., 2018