Future scenarios of forest microclimates using a Land Surface Model

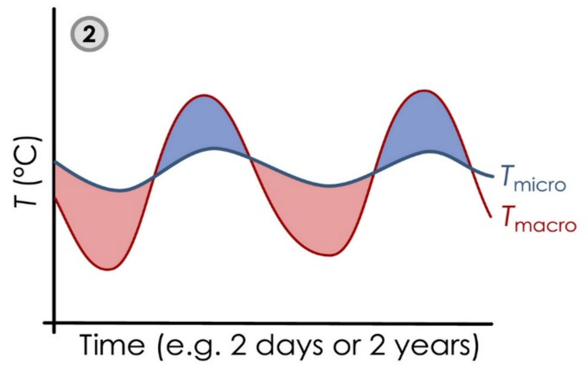
Gabriel Hes[1], Inne Vanderkelen[2,3,4], Rosie Fisher[5], Jérôme Chave[1], Jérôme Ogée[6], Edouard L Davin[2,3,4]

gabriel.hes@univ-tlse3.fr

Full article on ERL

MOTIVATION

- Forest canopies dampen understory temperatures i.e. the **buffering effect**, thereby generating a forest microclimate
- This buffering effect allows the development of a **diversity of life** in the forest understory
- However, **global warming** could impact the **capacity** of forests to ensure comparable temperature buffering in the future

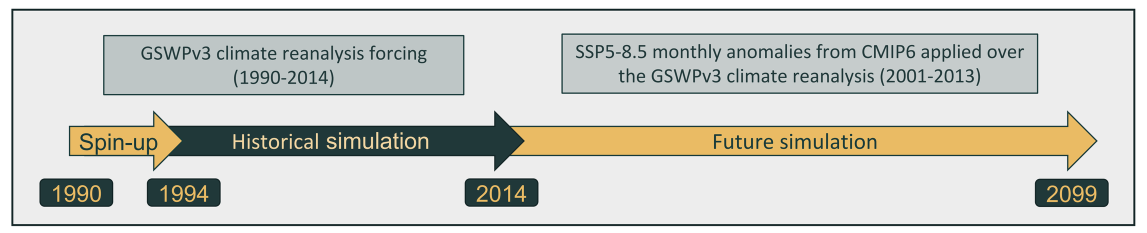


- To date, future global forest microclimate have been estimated through **statistical modeling[1] only**

How stable is the temperature decoupling in forests (in-side vs. outside) under global climate warming?

APPROACH

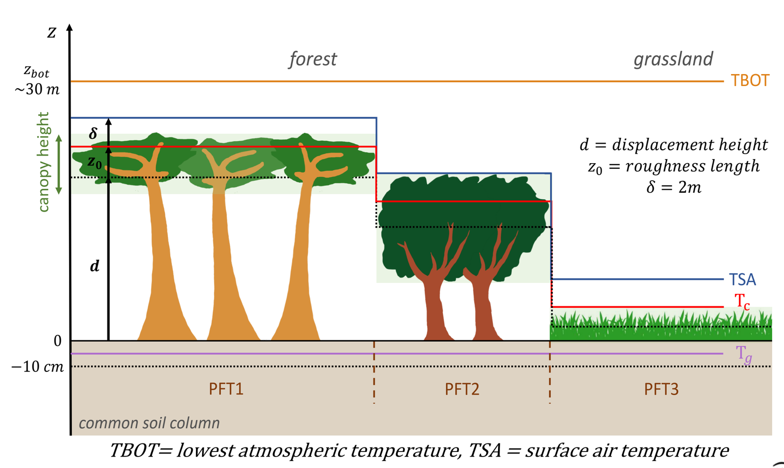
- **Model**: We use **CLM5.1** (0.5°x0.5°) land surface model including **biomass heat storage** (BHS) and a **revised roughness parametrisation[3]**



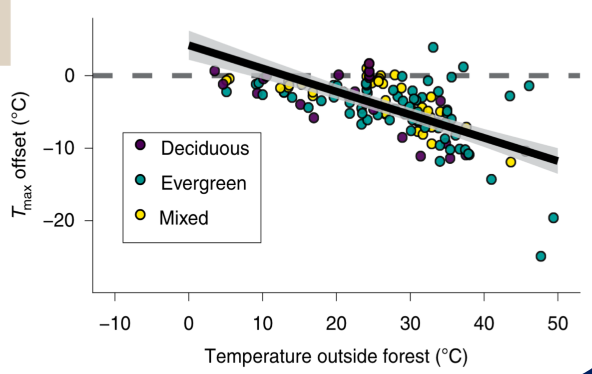
- **Assumptions**:
  - **No vegetation dynamics** (pft distribution prescribed from satellite phenology)
  - **No land-use change** scenario

allows to test for the **biophysical response** of **present-day forest cover** in future climates

TEMPERATURE OFFSET



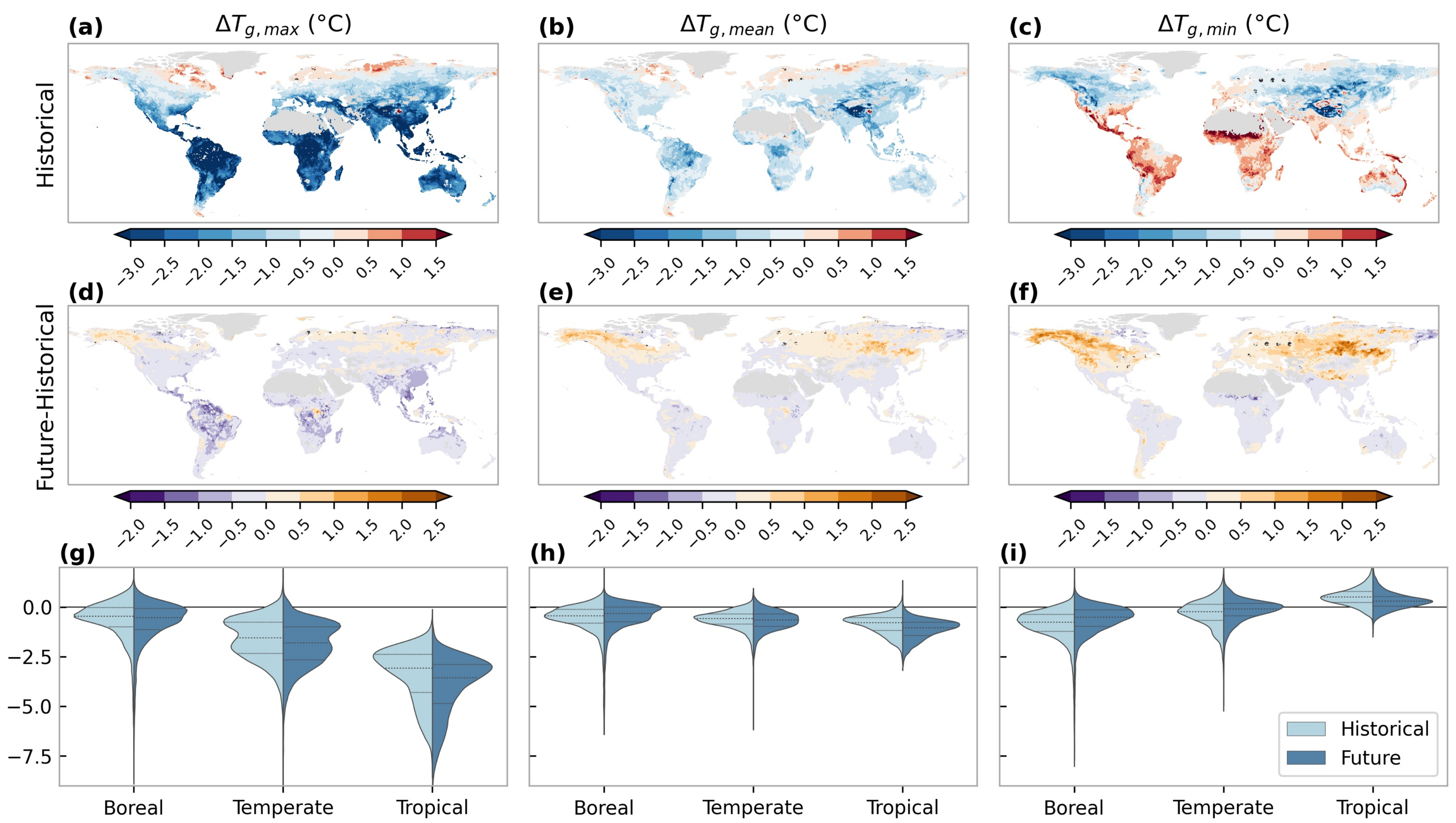
- Temperature offset: $\Delta T = T_{forest} - T_{grass}$
- We compute the **monthly** maximum, mean and minimum of 6-hourly **soil temperature Tg** and **canopy air temperature Tc**



- Temperature extremes are **buffered** if **ΔTmax<0** or **ΔTmin>0**
- Hypothesis: **negative correlation** of **ΔTmax** with the macroclimate

1 De Lombaerde et al 2022, Maintaining forest cover to enhance temperature buffering under future climate change
2 De Frenne et al 2021, Forest microclimates and climate change: Importance, drivers and future research agenda
3 Meier et al 2021, Impacts of a revised surface roughness parameterization in the Community Land Model 5.1
4 De Frenne et al 2019, Global buffering of temperatures under forest canopies
5 Lembrechts et al 2022, Global maps of soil temperature

RESULTS: GLOBAL $\Delta T_{g,max}$ PATTERNS



Historical period (1994-2014)

- Strong **latitudinal gradient**
- Strong buffering of both extremes in the Tropics
- T_{max} is slightly **amplified** in the **boreal region**

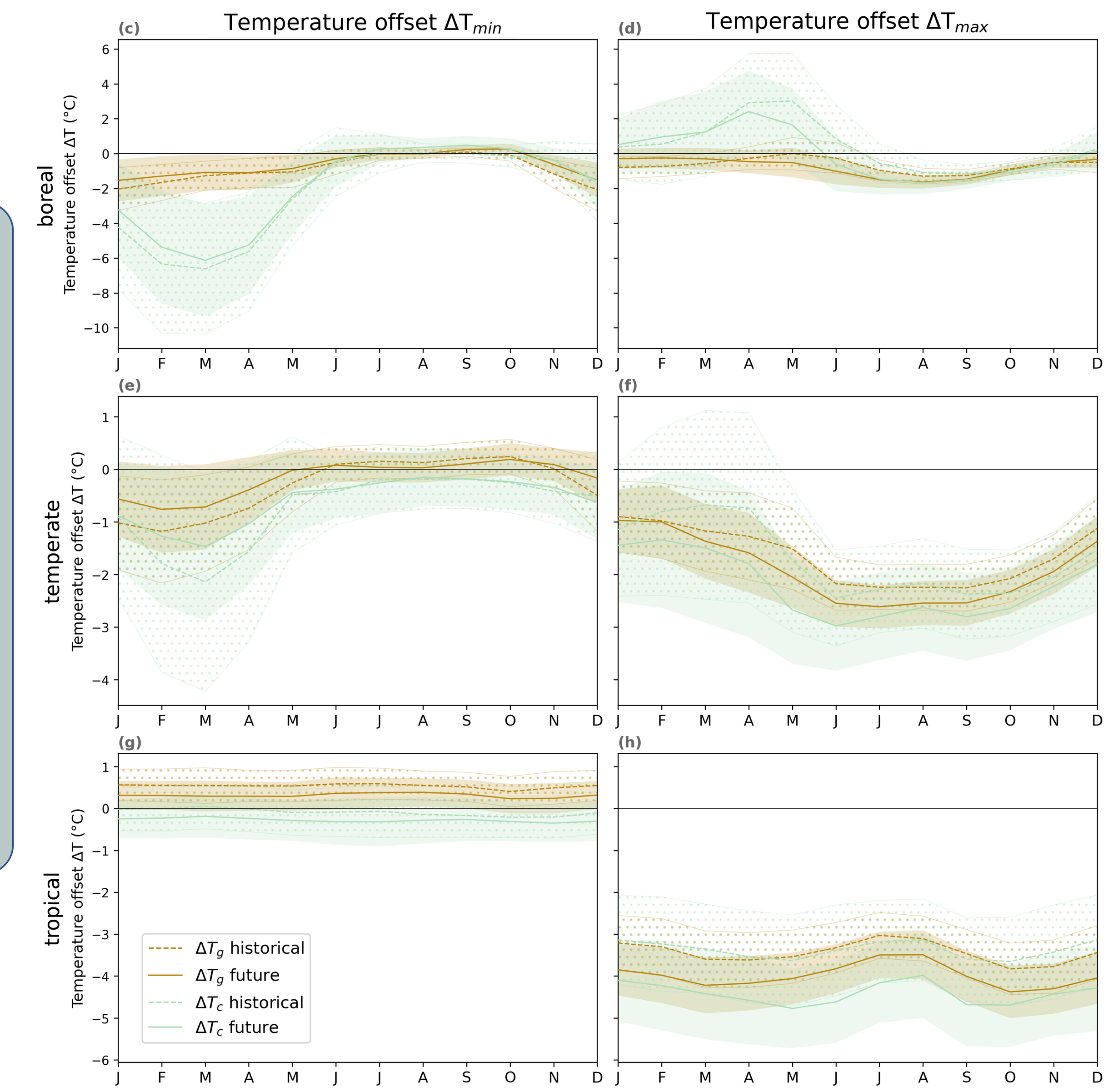
Future period (2080–2099)

- Strong **increase of tropical T_{max} buffering**
- Boreal ΔT_{min} distribution tends towards zero

RESULTS: SEASONAL ΔT_g AND ΔT_c PATTERNS

Historical period

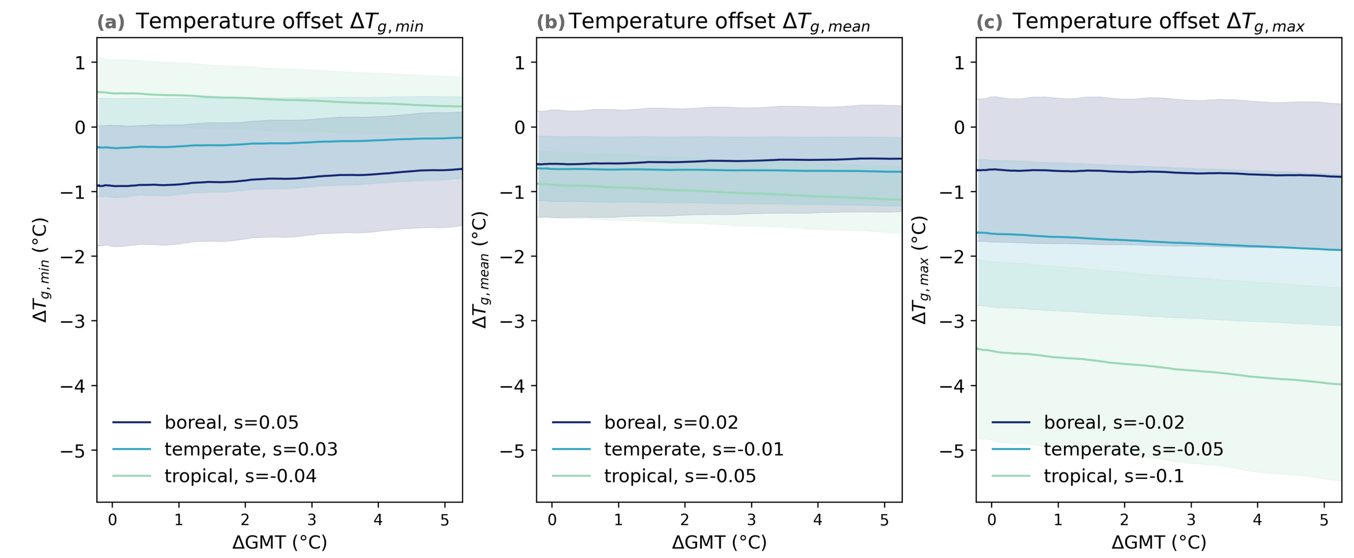
- Boreal: strong **seasonality** with **wintertime amplification** of T_c and little variation of T_g
- Temperate: **increase** of $T_{g,max}$ & $T_{c,max}$ **buffering** during growing season
- Tropical: continuous **buffering** of $T_{g,max}$ & $T_{c,max}$



Future period

- Boreal: **Lag effect** i.e. ΔT changes occur earlier
- Temperate: Stronger **buffering** of $T_{g,max}$ & $T_{c,max}$ **+ Lag effect**
- Tropical: Stronger **buffering** of $T_{g,max}$ & $T_{c,max}$

RESULTS: LINEAR TREND



- ΔT varies **linearly** with Global Mean Warming (GMT)
- Strongest buffering increase for tropical forests: $\Delta T_{g,max}$ trend = **−0.1 °C/°C**

DISCUSSION

Forest Temperature changes

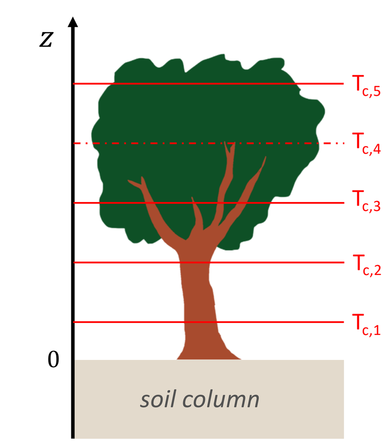
- Historical ΔT_g & ΔT_c is overall **consistent with observations[1,5]**
- Future changes in ΔT_{max} over the Tropics are consistent with our hypothesis
- Future changes of $\Delta T_{g,min}$ & $\Delta T_{c,min}$ are driven by changes in **snow dynamics** (shorter snow cover duration, smaller fraction of snow-covered ground)

Implication for understory biodiversity

- **Tropical forests** could become a **key refugia** for understory species
- Tropical species might accumulate a **higher climatic debt** than their temperate forest counterparts

Perspectives for future studies

- Rerun the simulation with **evolving phenology** and **physiology**
- Overcome the limited representation of forest understory variables in CLM5.1
  => move to a **multilayered canopy model**



TAKE HOME

- Strong **buffering** of maximum soil and canopy air temperatures in **tropical forests**.
- This buffering effect **increases** with **global warming**
- We need complementary simulations to test **sensitivity to forest dynamics**, **canopy structure** and **land use change**
- Importance to discuss the **level of complexity** needed for microclimate models

[1] Centre de Recherche sur la Biodiversité et l'Environnement (CRBE), Université de Toulouse, Toulouse, France
[2] Wyss Academy for Nature, University of Bern, Bern, Switzerland
[3] Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland
[4] Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
[5] CICERO Center for International Climate Research, Oslo, Norway
[6] Atmosphere Plant Soil Interactions Research Unit (UMR ISPA), INRAE, Villenave d'Ornon, France