



Impact of land use changes on climate in Europe across spatial and temporal scales

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■ Motivation

- Land use changes (LUC): very important human forcing on climate, especially in relation to forcing by the low emission scenarios
- Biophysical effects of land use changes on climate are often not visible on a global mean scale, but can be large on a regional to local scale
- Direct physical impacts of LUC on the regional climate can exceed those associated with global greenhouse gas forcing (Noblet-Ducoudré et al., 2012)
- Background climate influences the sensitivity of the simulated effects of LUC on regional climate (Pitman et al. 2011)
- Up to now, this important human climate forcing is not sufficiently represented in RCM climate change projections

▶ **FPS LUCAS: Include this important human forcing into RCMs and quantify its biophysical impacts on the regional climate in Europe**

■ FPS LUCAS: Major science questions

- How **sensitive** are the regional climate models to LUC and how is this interrelated to the land-atmosphere coupling strength in different regions and seasons among the suite of models?
- **How large** is the contribution of LUC to detected past and potential future climate trends and variability?
- What is the **effect of spatial resolution** on the magnitude and robustness of LUC-induced climate changes?
- How do **land use practices modulate climate variability**? Can local LUC reduce or amplify extreme climate conditions?



D. Rechid et al., FPS LUCAS
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■ **LUCAS Experiment plan**

Phase 1:

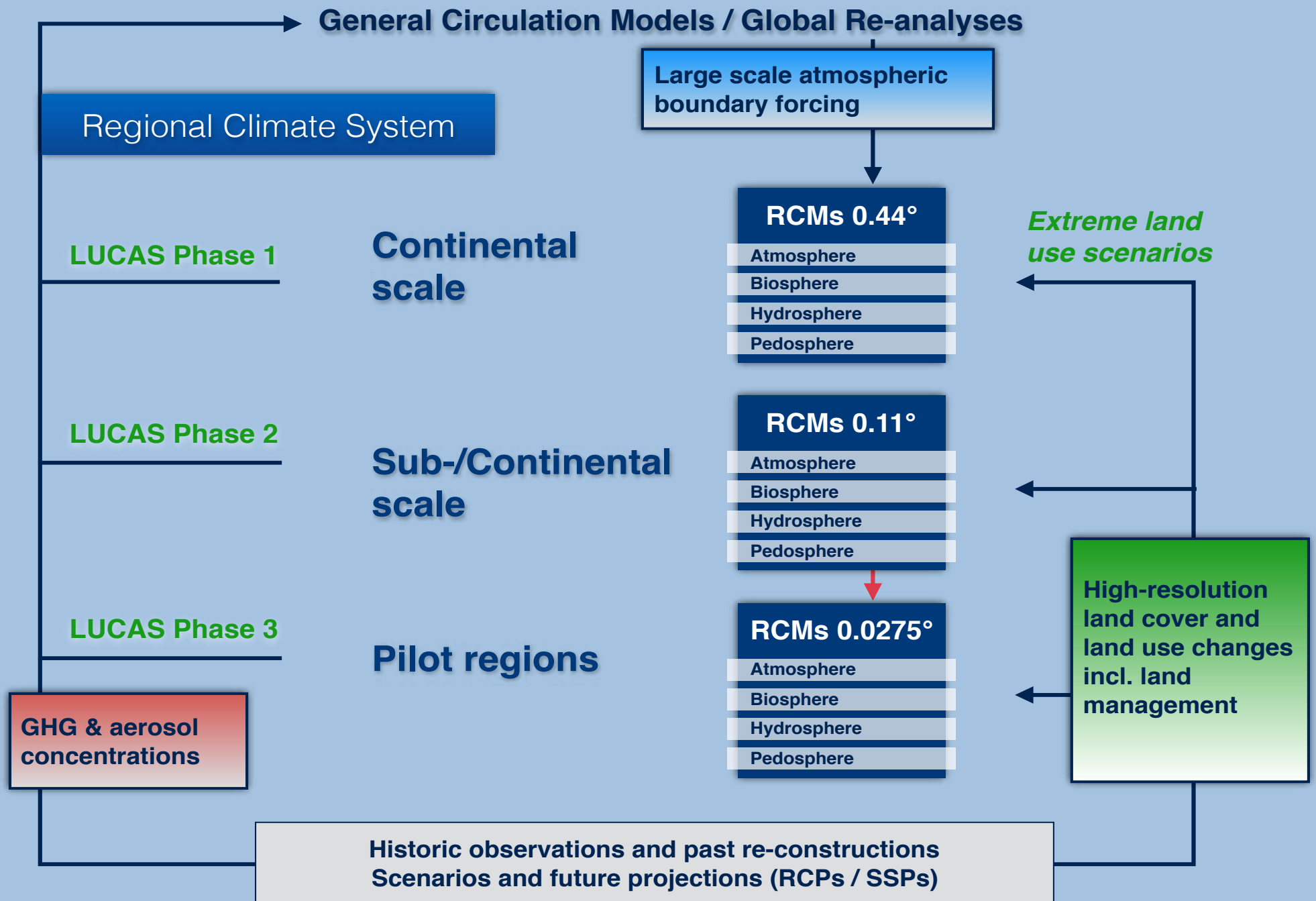
Idealized experiments at continental scale
& reanalysis driven evaluation simulation

Phase 2:

GCM-driven experiments at continental scale

Phase 3:

High-resolution experiments in spatially refined pilot regions (< 5 km resolution)



LUCAS Modeling Framework

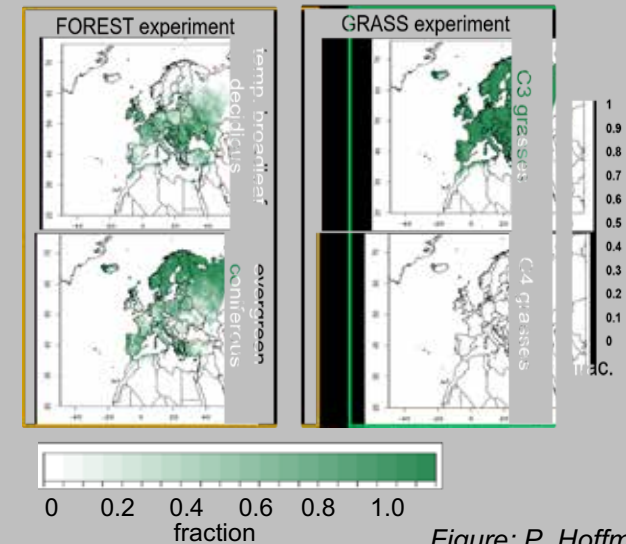
FPS LUCAS „Land Use & Climate Across Scales“

■ LUCAS phase 1: Idealized experiments on continental scale

How **sensitive** are the regional climate models to LUC and how is this interrelated to the land-atmosphere coupling in different regions and seasons?

Experiment setup:

- EURO-CORDEX domain on 0.44°
- Reanalysis-driven 1979/1986-2015
- „FOREST“ and „GRASS“ Experiments (+ „EVAL“)
- LUC-forcing: land cover maps with
- 1) maximized forest vs. 2) only grassland

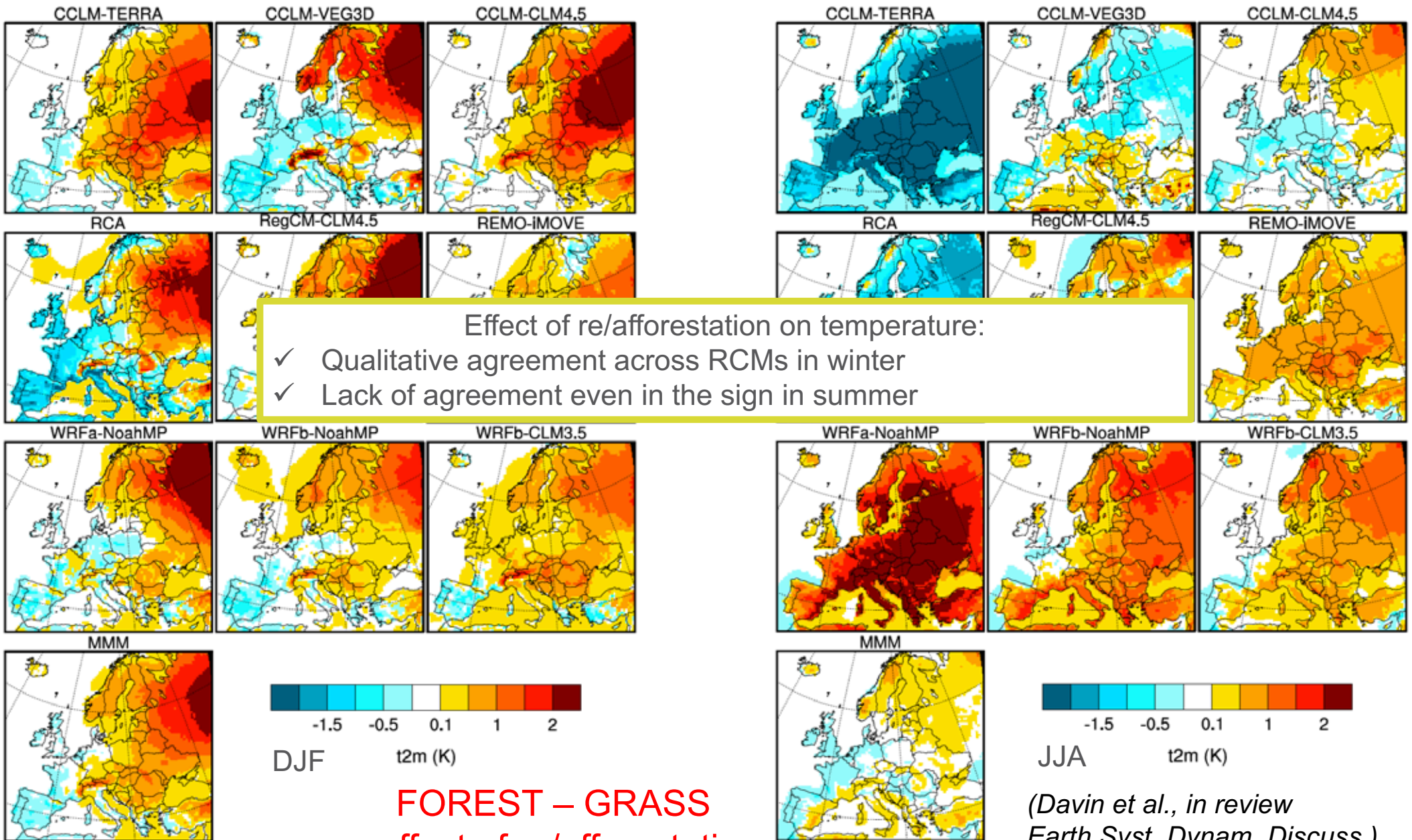


Status of LUCAS phase 1:

- available from 9 different RCM-LSM models: CCLM-TERRA, CCLM-VEG3D, CCLM, CLM4.5, RCA, RegCM-CLM4.5, REMO-iMOVE, WRFa-Noah, WRFb Noah, WRFb-CLM3.5
- WRF V3.8.1.-Noah (diff PBL scheme) - running

(B1 talk on Wednesday; Jach et al.)

Selected results from LUCAS ensemble studies



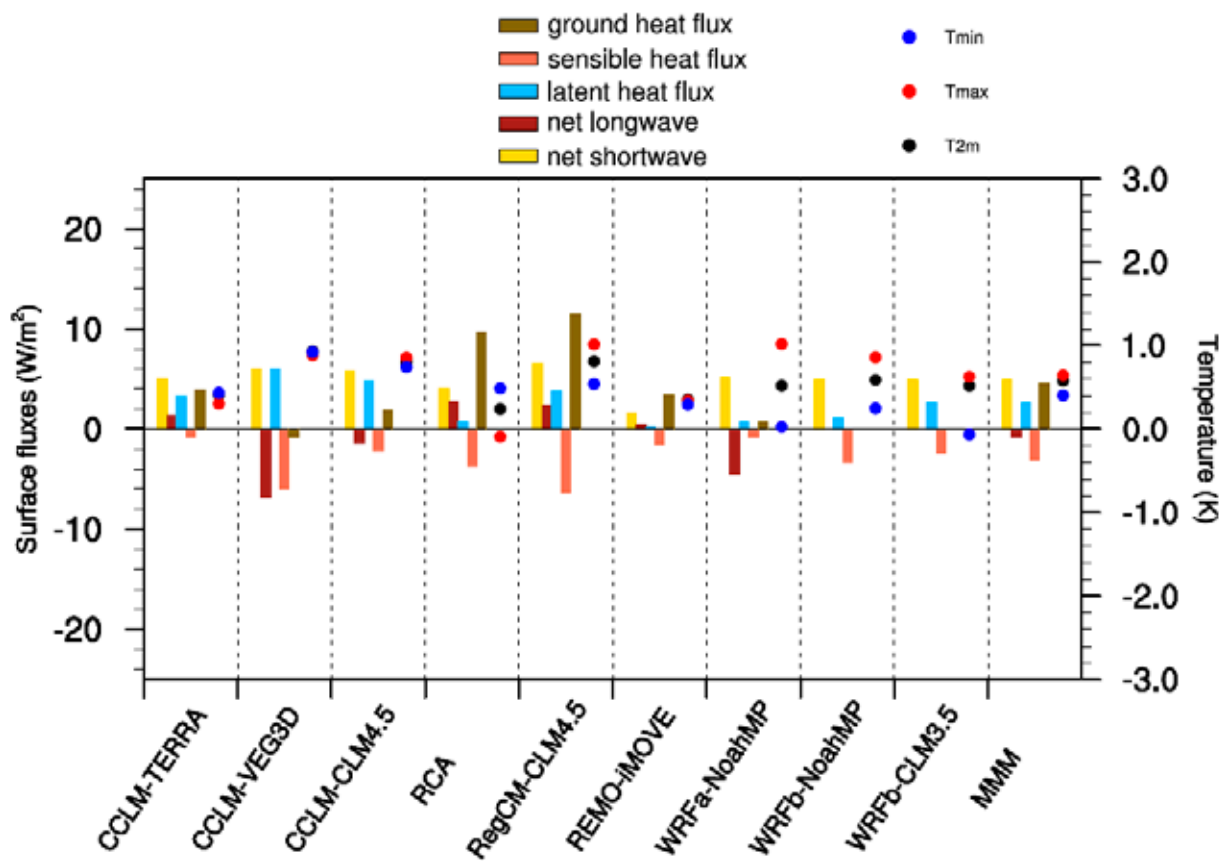
FOREST – GRASS
= effect of re/afforestation

(Davin et al., in review
Earth Syst. Dynam. Discuss.)

Selected results from LUCAS ensemble studies

Surface energy balance

DJF; Scandinavia



✓ Winter response is dominated by the radiative effect of forest (albedo decrease) which is consistent across RCMs

FOREST – GRASS
= effect of re/afforestation

(Davin et al., in review
Earth Syst. Dynam. Discuss.)

Selected results and conclusions from LUCAS ensemble studies*

- Agreement in winter warming - with consistently simulated albedo change
- No agreement on the sign of temperature response in summer - with disagreement in evaporative fraction
- Summer temperature response dominantly driven by land processes; atmospheric processes more important for winter response
- Opposing effects of the diurnal temperature range (DTR) at the surface and in the overlying atmospheric surface layer
 - Most RCMs simulate colder summer surface temperatures during the day and warmer summer surface temperatures during the night - in line with observation based studies
 - In contrast, the DTR in the overlying atmospheric surface layer is increased – due to higher surface roughness which increases turbulent heat fluxes
- Limited usefulness of 2m temperature as diagnostic quantity to assess effects of LUC on European summer climate - use of temperature at surface and in lowest atmospheric level is recommended.
- The results show the importance and the challenges to consider LUC forcing in RCM simulations.
- Fundamental uncertainties remain, with the need for model evaluation

*Davin et al. (in review, Earth Syst. Dynam. Discuss.); Breil et al. (in review, J. Climate)

■ Outlook: LUCAS experiments phase 2

Phase 2: GCM-driven experiments at continental scale

Experiment setup:

- EURO-CORDEX domain on 0.11°
- driven by GCM CMIP6 simulation 1950-2015/2016-2100
- for low and high emission scenario, e.g. RCP2.6 (or RCP1.9) / SSP1 and RCP8.5 / SSP5
- with dynamic LUC forcing based on LUH2
- reference simulation: static present day land cover map

Status of LUCAS phase 2:

- LUC forcing: Dynamic long-term PFT timeseries and LUC TRANSLATOR for use in RCMs are currently developed, based on e.g. GlobCover 2009 (300 m) & LUH2

(B1 talk on Wednesday; Hoffmann et al.)

■ **Thank you for your attention!**

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■ LUCAS phase 1 model intercomparison studies

Paper in review:

Davin, E. L., Rechid, D., Breil, M., Cardoso, R. M., Coppola, E., Hoffmann, P., Jach, L. L., Katragkou, E., de Noblet-Ducoudré, N., Radtke, K., Raffa, M., Soares, P. M. M., Sofiadis, G., Strada, S., Strandberg, G., Tölle, M. H., Warrach-Sagi, K., and Wulfmeyer, V. (2019) **Biogeophysical impacts of forestation in Europe: First results from the LUCAS Regional Climate Model intercomparison**, *Earth Syst. Dynam. Discuss.*, <https://doi.org/10.5194/esd-2019-4>, discussion paper preprint, 2019.

Paper submitted:

Breil M.; Rechid D; Davin E; de Noblet-Ducoudré N.; Katragou E; Cardoso R; Hoffmann P; Jach L; Soares P; Sofiadis G; Strada S; Strandberg G; Toelle M; Warrach-Sag K (2019) **The opposing effects of afforestation on the diurnal temperature cycle at the surface and in the atmospheric surface layer in the European summer.** submitted to *Journal of Climate*.

Related studies:

Tölle et al. (2018) **Sensitivity of European Temperature to Albedo Parameterization in the Regional Climate Model COSMO-CLM Linked to Extreme Land Use Changes.** *Frontiers in Environmental Science*, 6, 123,

■ PhD projects related to LUCAS

Giannis Sofiadis, Aristotle University of Thessaloniki

Investigating the impact of land cover changes on European climate with regional climate model simulations

Lisa Jach, University Hohenheim

Framework to assess the influence of land-use and land-cover changes on precipitation

Vanessa Reinhart, GERICS and University Hamburg

Mapping of high resolution land use dynamics in Europe for the past and the future

Ronny Meier, ETH Zurich

Assessing past and future impacts of forest management with a regional climate model

Mingyue Zhang, JLU:

Time-varying land surface data set for the regional climate model COSMO-CLM at 1 km horizontal resolution

Eva Nowatzki, JLU

Implementing a dynamical phenology scheme into COSMO-CLM

Christina Asmus, GERICS and University Hamburg

Investigating effects and feedbacks of land management practises on regional climate