Climate Limited-area Modelling Community

WCRP CORDEX FLAGSHIP PILOT STUDIES

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

CORDEX FPS LUCAS and sensitivity studies

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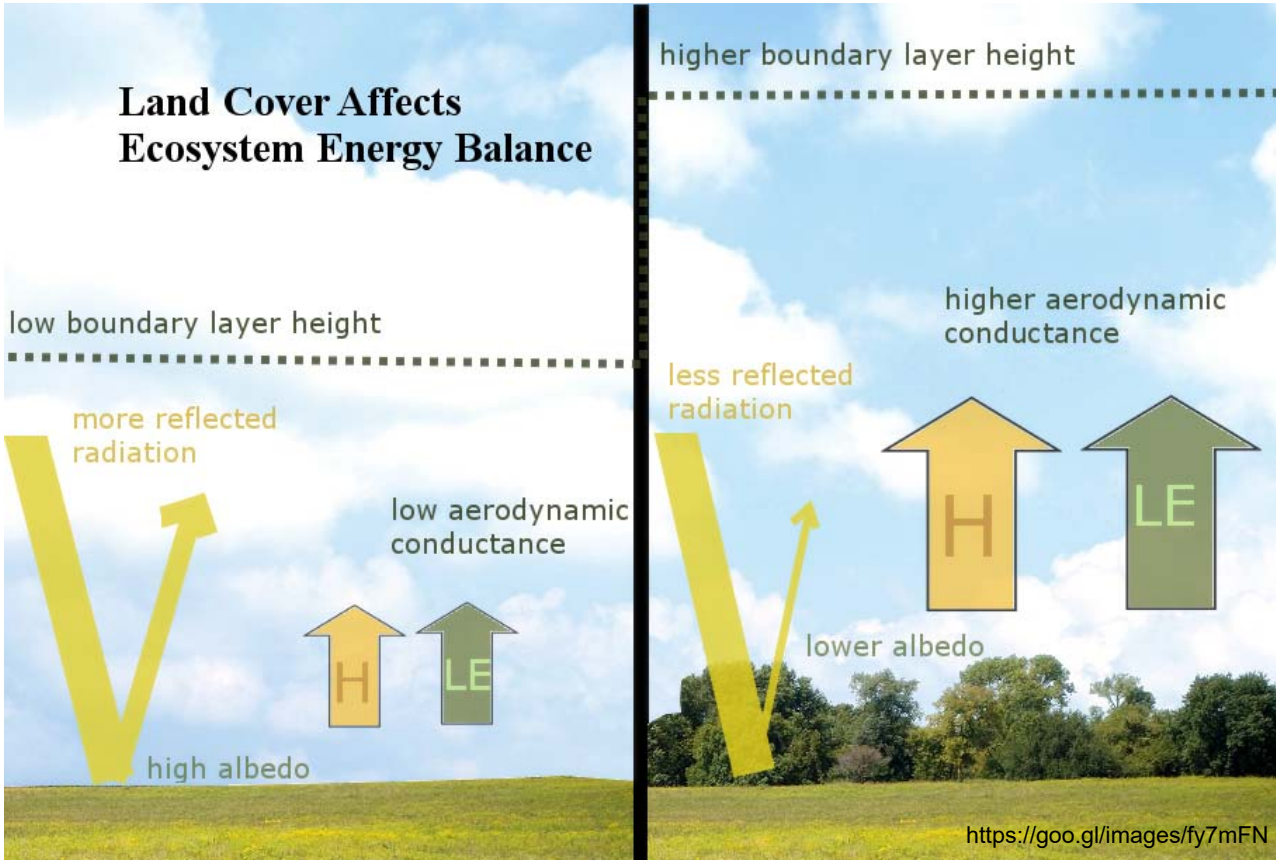
Motivation

- Magnitude, distributional extent, and sign of afforestation on temperature varies between models (Pitman et al. 2009).
- Consensus about the impact of land cover change on climate in winter by the snow-masking effect in high latitudes (Bonan et al. 1992).
- Climatic extent of afforestation depends on the ratio between the increased net shortwave radiation and the increased aerodynamic roughness or evapotranspiration of forest.
- Ratio depends on the used regional climate model and its model uncertainties.



FPS LUCAS (Land Use & Climate Across Scales)

- New era of coordinated RCM – LUC ensemble experiments on high spatial resolutions and consistently implement land use dynamics for the past and future for Europe (Rechid et al. 2017).

- Initiated by EURO-CORDEX and supported by WCRP-CORDEX.

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FPS LUCAS Objectives

- Identify robust biophysical impacts of LUCs on the European climate
  - across local to regional scales and
  - at various time scales from extreme events to multi-decadal trends.

- Three phases:

  I. Idealized experiments over Europe to benchmark the RCM's sensitivity to extreme LULCC (Davin et al. 2019).

  II. Continental scale realistic experiments over Europe for the past and future.

  III. Realistic high resolution experiments over pilot regions in Europe.

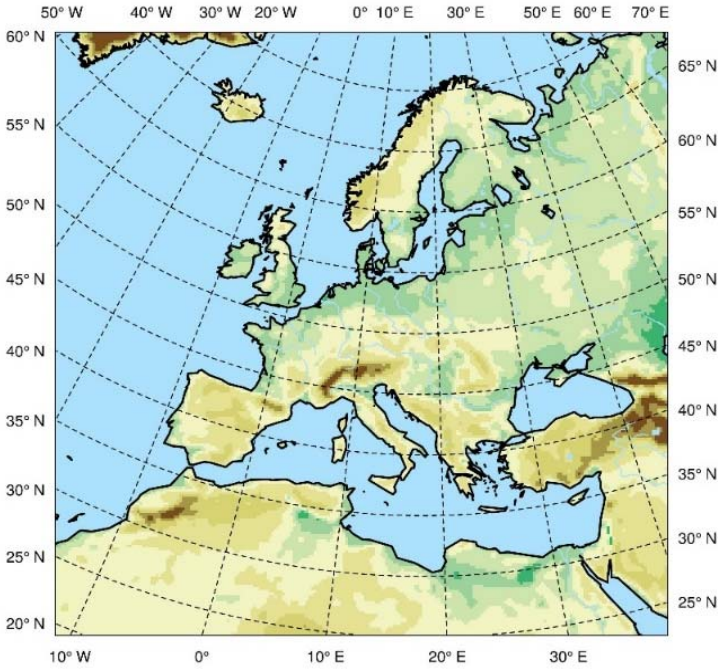
LUCAS experiments phase I

- Performed non-forested (GRASS) and maximally forested (FOREST) experiments with a set of 9 different RCMs.
- FOREST experiment represents a maximally forested Europe.
- In GRASS experiment trees are entirely replaced by grassland.
- Comparing FOREST and GRASS illustrates theoretical effect of a full re/af-forestation over Europe.

Model configuration as for CCLM

	Simulation
Model	COSMO5.0-CLM9
Forcing	ERA-Interim 0.75° (Dee et al. 2011) 6 hr
Time period	1986-2015 with spin-up starting 1979
Land use class	MODIS 0.5° (Lawrence and Chase 2007)
Soiltype	FAO-DSMW 5´ (FAO 2003)
Aerosol	Tanré et al. (1999)
Orography	ASTER 1´´ (NASA 2015)
Soil temperature	CRU 0.5° UEA
Horizontal resolution	0.44° ~ 50 km
Atmos. levels, time step	40, 300 s
Domain	106 x 103 grid points, EURO-CORDEX
Time integration scheme	Runge-Kutta
Convection scheme	Tiedtke scheme
Configuration	EURO-CORDEX (Kotlarski et al. 2014)

EUR44 Domain



LUCAS results phase I T_2M

Summer FOREST - GRASS

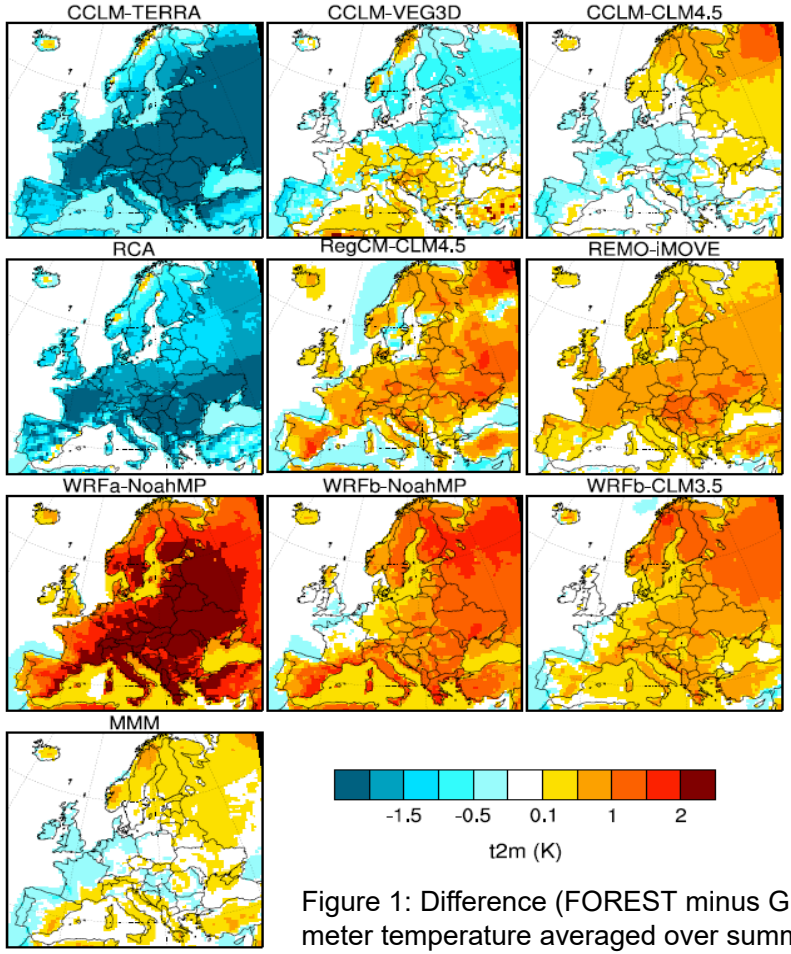


Figure 1: Difference (FOREST minus GRASS) of 2 meter temperature averaged over summer (JJA) for 9 different regional climate models and the multi-model mean (MMM, source: Davin et al. 2019).

- Large inter-model spread in the simulated climate response to re/af-forestation for temperature changes in summer.
- Inter-model disagreement in T_2M.

LUCAS energy balance components

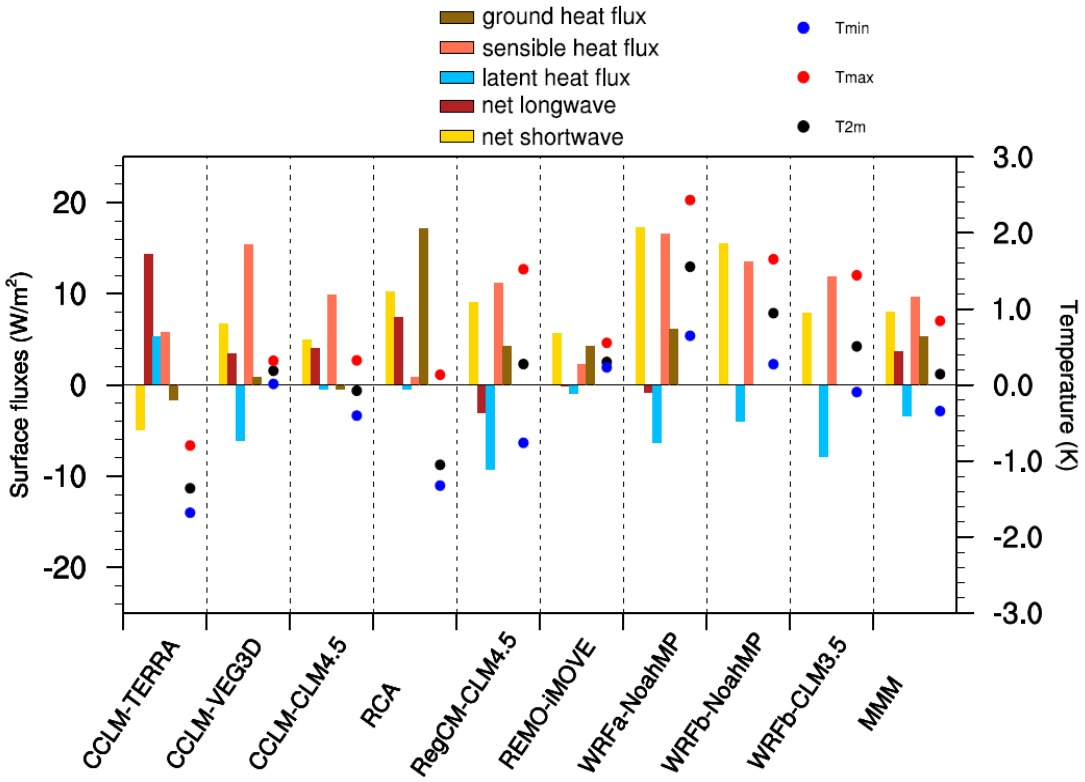


Figure 2: Changes (FOREST minus GRASS) in temperature and surface energy balance components averaged over summer (JJA) for 9 different regional climate models and the multi-model mean (MMM) over the Mediterranean region only (source Davin et al. 2019).

- Large part of this spread is attributed to the representation of land processes.
- Models sharing the same Land Surface Model (LSM) exhibit more similarity in their response compared to models sharing the same atmospheric model but different LSMs.
- Inter-model disagreement can be partly linked to evapotranspiration changes, which in the case of COSMO-CLM depends on the albedo parameterization in the model.

Albedo sensitivity tests of forest simulations in CCLM

- CONTROL
  considers the standard operational albedo parameterization, where the albedo depends on the soil type and soil moisture, and is further modified by plant and snow fraction. A constant value of 0.15 is applied for the vegetation albedo with no distinction between different vegetation types.

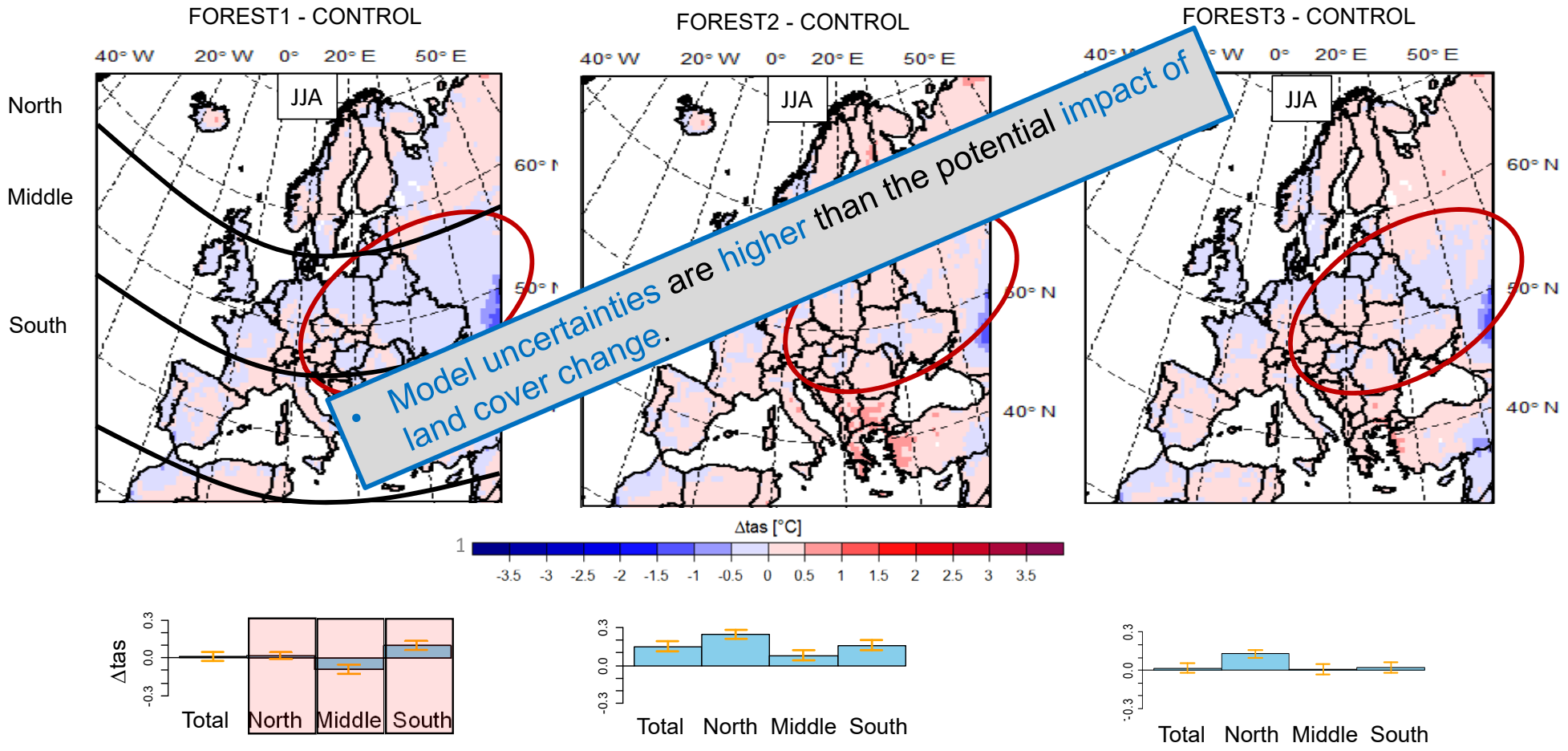
- FOREST1
  considers the standard operational albedo parameterization.

- FOREST2
  further distinguishes between deciduous and evergreen forest and grass albedos.

- FOREST 3
  As of FOREST2 except that the soil albedo does not depend on soil moisture.

- Δ = Experiment - CONTROL

Changes in summer temperature



- Model uncertainties are higher than the potential impact of land cover change.

Summer diurnal temperature cycle of CCLM-VEG3D

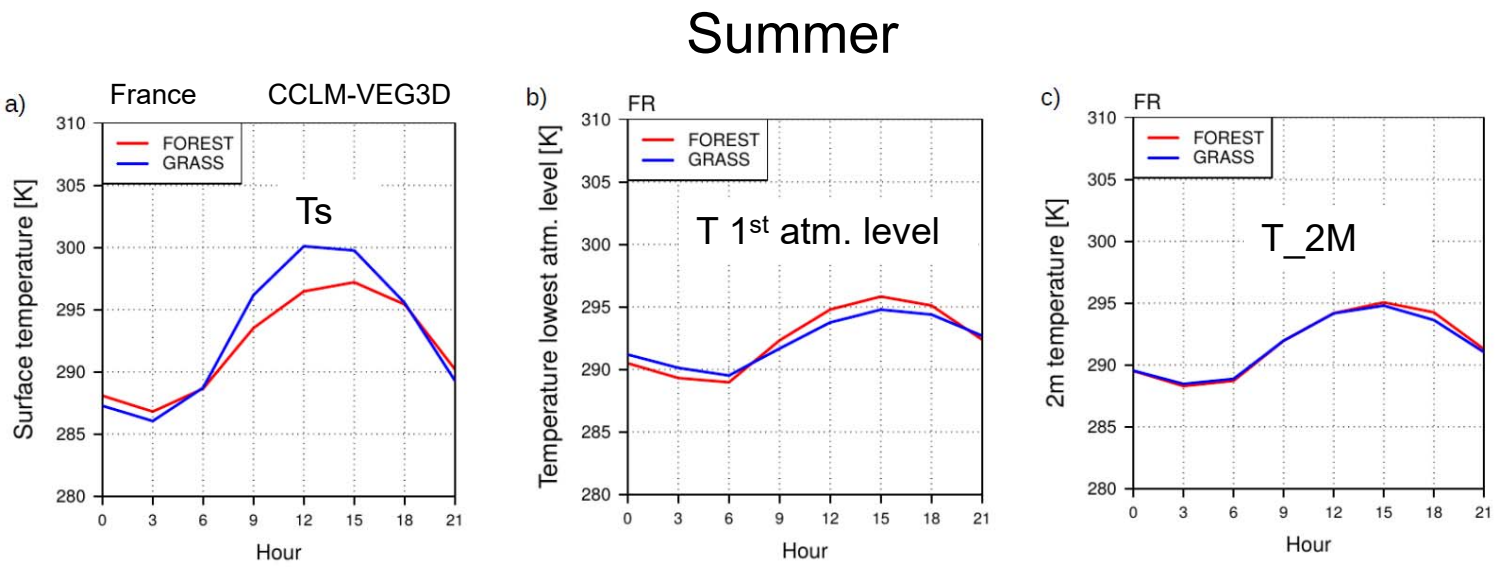


Figure 3: CCLM-VEG3D simulation results for the mean seasonal diurnal temperature cycle in summer at the surface, the lowest atmospheric model level, and in 2m height for France (source Breil et al. 2019).

- Opposing diurnal temperature cycles for surface and atmosphere. Dampened at the surface and amplified in the lower atmosphere for afforestation.
- Opposing temperature response with afforestation is caused by the higher surface roughness of forest.
- Therefore, diagnostic T_2M, which depends on both quantities, can be misleading.

Change in diurnal temperature cycle

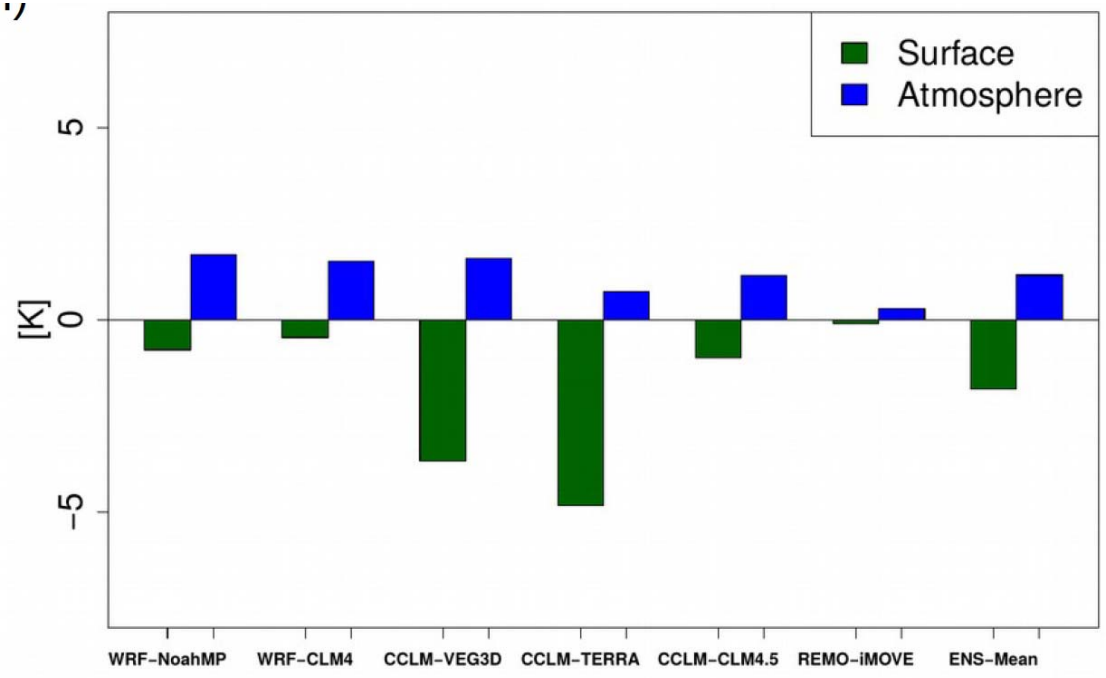


Figure 4: Change in diurnal temperature cycle for surface temperature (green) and lowest atmosphere temperature (blue) for FOREST minus GRASS in summer for France (source Breil et al. 2019).

- Consistent model response to afforestation in the diurnal temperature cycle at the surface and in the lowest atmospheric model level between all models.

LUCAS Phase 1

Phase 1: Continental scale, idealised experiments

- 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?

Publications:

Rechid D, Davin E, de Noblet-Ducoudré N, Katragkou E, and the LUCAS Team, CORDEX Flagship Pilot Study "LUCAS - Land Use & Climate Across Scales" - a new initiative on coordinated regional land use change and climate experiments for Europe. Solicited presentation. Geophysical Research Abstracts, Vol. 19, EGU2017-13172, 2017, EGU General Assembly 2017

Davin, E. L., D. Rechid, M. Breil, R. M. Cardoso, E. Coppola, P. Hoffman, L. L. Jach, E. Katragkou, N. de Noblet-Ducoudré, K. Radtke, M. Raffa, P. M. M. Soares, G. Sofiadis, S. Strada, G. Strandberg, M. H. Tölle, K. Warrach-Sagi, V. Wulfmeyer, 2019: Biophysical impacts of forestation in Europe: First results from the LUCAS Regional Climate Model intercomparison, Earth System Dynamics, DOI: 10.5194/esd-2019-4

Tölle, M. H., M. Breil, K. Radtke, H.-J. Panitz, 2018: Sensitivity of European temperature to albedo parameterization in the regional climate model COSMO-CLM linked to extreme land use changes, Frontiers Environmental Science, DOI: 10.3389/fenvs.2018.00123

Breil, M., D. Rechid, E. L. Davin, N. de Noblet-Ducoudré, E. Katragkou, R. M. Cardoso, P. Hoffmann, L. L. Jach, P. M. M. Soares, G. Sofiadis, S. Strada, G. Strandberg, M. H. Tölle, K. Warrach-Sagi, 2019: The opposing effects of
afforestation on the diurnal temperature cycle at the surface and in the atmospheric surface layer in the European summer, (In Review)

LUCAS Experiment plan

Phase 2: Continental scale, realistic experiments

- How large is the contribution of LUC to detected past and potential future climate trends in Europe?

Ongoing…

Phase 3: Pilot regions, high resolution experiments

- 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?

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Thank you for your attention!

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