

CORDEX Flagship Pilot Study "LUCAS - Land Use & Climate Across Scales" - Impact of land use changes on climate in Europe across spatial and temporal scales



Introduction

LUCAS (Land Use and Climate Across Scales) is an initiative on coordinated regional climate model experiments for Europe which includes land use change forcing (Rechid et al., 2017). It was initiated jointly by the European branch of the Coordinated Downscaling Experiments EURO-CORDEX and the global intercomparison study "Land-Use and Climate, Identification of robust impacts" LUCID; and it has been approved by WCRP CORDEX as a Flagship Pilot Study (FPS).

Land use changes (LUC) are an important human forcing on climate, especially at the regional scale and at the seasonal and monthly cycle. The direct effects of LUC on local to regional climate can potentially exceed those associated with (downscaled) global mean warming. Up to now, LUC forcing is not accounted for in RCM climate change projections within CORDEX, while it is at those finer regional scales that they have the strongest impacts. In LUCAS, we step by step include this important human regional climate forcing into RCMs and investigate its direct biophysical effects on the climate in Europe.

The overall objective of LUCAS is to identify robust biophysical impacts of land use changes on climate across regional to local spatial scales and at various time scales from extreme events to seasonal variations and multi-decadal trends. In this context, land use changes (LUC) refer to anthropogenic land cover conversions as well as land management practises. We identified key science questions to be addressed:

- How sensitive are the regional climate models to LUC and how is this interrelated to land-atmosphere coupling in different regions among the suite of models?
- How large is the relative contribution of LUC compared to other forcings in the detection of the past and potential future climate trends ?
- How do land use practices modulate climate variability? Can local LUC reduce or amplify extreme climate conditions?
- What is the effect of spatial resolution on the magnitude and robustness of LUC-induced climate changes?
- What errors do we make on the downscaled climate change if we ignore LUC? This is especially important for subsequent impact studies.

LUCAS overall experiment design

The LUCAS project is designed in three phases: In **LUCAS phase 1**, idealized experiments are performed for the European continent in order to investigate and inter-compare model sensitivities to extreme land use change (LUC) forcing. In the FOREST experiment, we maximize the forest fraction in those model grid cells where trees can realistically grow. In the GRASS experiment, we turn trees into grassland with the ratio of C3 and C4 grasses based on present day distribution. In **LUCAS phase 2**, simulations driven by GCMs and dynamic land use changes are performed for past and future, including LUC forcing based on past re-constructions and future projections. The high resolution experiments in **LUCAS phase 3** shall be conducted over multiple gridded nests to refine the continental simulations down to resolutions below 5 km, in order to investigate feedbacks of local scale land use dynamics on climate.

LUCAS model intercomparison studies and model specific analyses

The LUCAS phase 1 experiments were setup as ERA-Interim driven simulations for 1979/1986 to 2015 on the EURO-CORDEX domain on 0.44° resolution with extreme LUC forcing in 1) FOREST experiment with maximized forest cover, 2) GRASS experiment with only grassland, and 3) and optional EVAL simulation with the individual RCM present-day land cover distribution. The FOREST and GRASS maps were developed and provided by ETH Zurich (Davin et al. 2019). A detailed experiment protocol had been developed by the LUCAS coordination team and is available in the LUCAS wiki: <https://wiki.gerics.de/luc/Experiments>. End of 2018, results of phase 1 experiments were 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.

The first model intercomparison study has recently been submitted to *Earth System Dynamics* by Davin et al. (2019): Biogeophysical impacts of forestation in Europe: First results from the LUCAS Regional Climate Model intercomparison. The intercomparison analysis of the impact of surface roughness on the diurnal cycle by Breil et al. will be presented at the EGU2019. Further joint analyses are done with respect to "Comparison of LUCAS-EVAL summer results with E-OBS" as presented by Warrach et al. at the LUCAS annual meeting 2018. Sofiadis et al., presented the poster "Quantifying the summer temperature response to extreme deforestation in Europe" in the MedClivar Conference 2018 in Serbia (best poster award). The "seasonal response of LUCAS RCMs to extreme land use changes under wet and dry conditions" by Hoffmann, Rechid et al. was also presented at the LUCAS meeting 2018. A further RCM specific study based on the LUCAS experiment set up has recently been published by Tölle et al. (2018) "Sensitivity of European Temperature to Albedo Parameterization in the Regional Climate Model COSMO-CLM Linked to Extreme Land Use Changes" in *Frontiers in Environmental Science*, 6, 123. Strandberg et al. presented the analysis of "Changes in cyclone activity in afforestation and deforestation simulations" at the LUCAS annual meeting. Jach et al.

developed a "Framework to assess the influence of land-use and land-cover changes on precipitation" as important metrics for detecting robust impacts for LUC. Reinhart et al. presented a concept for "Mapping of high resolution land use dynamics in Europe for the past and the future", and Sofiadis et al. presented an investigation of "Land cover changes over Europe in the last 25 years: Analysis of various land use data products for Europe" at the LUCAS annual meeting, both studies provide important knowledge basis for the next LUCAS phases experiments.

LUCAS meetings in 2018

In 2018, GERICS organised a LUCAS meeting back to back with the EURO-CORDEX General Assembly in January in Hamburg, where preliminary results of phase 1 experiments were presented and joint intercomparison analyses had been defined. The big annual LUCAS meeting was organised by AUT 1-2 October 2018 in Thessaloniki, which was kindly sponsored by WCRP CORDEX. Regional climate modellers from 10 different European institutions presented their results of LUCAS phase 1 experiment, which helped to understand the response of RCMs to extreme land use changes. The design of new experiments for the subsequent LUCAS phases was further developed. The conference also provided a great opportunity for PhD students to present their newly developed PhD projects related to LUCAS and to exchange their ideas and experiences.



CORDEX FPS LUCAS Annual meeting 2018 in Thessaloniki

Outlook 2019

LUCAS phase 1 simulations will be performed and finalized by recently joined modelling groups. There will be further efforts in joint analyses of phase 1 and we will finalise the experiment protocol for LUCAS phase 2. The annual FPS LUCAS meeting will be planned in Sep/Oct 2019 very likely again in Thessaloniki.

FPS LUCAS Team

Around 20 European institutions are currently involved in LUCAS. It is coordinated jointly by Diana Rechid from Climate Service Center Germany (GERICS) at Helmholtz Zentrum Geesthacht; Nathalie de Noblet-Ducoudré from Laboratoire des Sciences du Climat et de l'Environnement, Institute Pierre Simon Laplace, France; Edouard Davin from Eidgenössische Technische Hochschule Zurich, Switzerland; and Eleni Katragkou from Department of Meteorology and Climatology, School of Geology, Aristotle University of Thessaloniki, Greece. If you are interested in this initiative, please contact diana.rechid@hzg.de

See also our new website: https://www.hzg.de/ms/cordex_fps_lucas

LUCAS publications

Davin E, Rechid D, et al. (2019) Biogeophysical impacts of forestation in Europe: First results from the LUCAS Regional Climate Model intercomparison. *submitted to Earth System Dynamics*

Tölle M, 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

Rechid, D., E. Davin, N. de Noblet-Ducoudré, E. Katragkou, and LUCAS Team (2017) CORDEX Flagship Pilot Study LUCAS - Land Use & Climate Across Scales - a new initiative on coordinated regional land use change and climate experiments for Europe. 19th EGU General Assembly, EGU2017, proceedings from the conference held 23-28 April, 2017 in Vienna, Austria., p.13172, Vol. 19 of, 13172.

Rechid D, Noblet-Ducoudré N, et al. (2016) EURO-CORDEX-LUC: A new initiative on coordinated regional land use change experiments (2016) International Conference on Regional Climate- ICRC-CORDEX May 2016, Stockholm, Sweden