Use of Regional Climate Model Output for Modelling the Effects of Future Weather Extremes on Agriculture

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The MODEXTREME Project

The EU FP7 project MODEXTREME has as one of its objectives to investigate how changed climate affects agricultural yields through expected changes in the occurrence of weather extremes. This is addressed through an effort to

- identify and define **indices** of extremes and statistics of climate variability on different time scales relevant for crop/grassland modelling
- to identify and process suitable **climate model output** for input to crop/grassland modelling systems.
- provide **time series** of the key input variables for crop modelling systems (temperature, precipitation, solar radiation, wind speed and relative humidity) for the present day (around 2000) and the future (around 2030 and around 2050) for MODEXTREME study areas based on both RCM-GCM (Regional-Global Climate Models) output and historical weather series.

Bias Correction

In order to make the data useful for agricultural modeling, there is a need for bias correction of the climate model output. As a first step, daily maximum and minimum temperatures as well as precipitation for simulations covering Europe have been corrected towards the ENSEMBLES E-OBS gridded database of observed data. For the MODEXTREME non-European study sites, other observational data have been obtained. Some of these are gridded, some are station time series. In the table, the areas, available model simulations, and observational datasets have been listed; E-OBS is a public gridded observation-based dataset for Europe, GHCN is public and station-based, whereas the remaining areas are covered through data from participants.

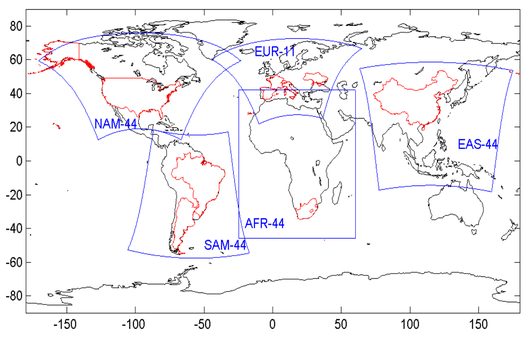
Bias correction has been done with a quantile-based correction, such that simulated present day fields are adjusted to reproduce the point-wise probability density functions of the observations. In short, we sort model values and observed values according to size and correct modelled present-day values to the corresponding observed value. We then do ”the same” for the future scenario. Corrections depend on the time of year, based on 20 years of overlapping observation/simulation, employing a 31-day running calendar window, i.e., 620 values.

MODEXTREME STUDY AREA	CORDEX DOMAIN	OBSERVATIONS
France **Spain** **Italy** **Switzerland** **Ukraine**	Euro-CORDEX 0.11	E-OBS (Tmax, Tmin, precipitation)
South Africa	CORDEX Africa 0.44	Station observations
China	CORDEX East Asia 0.44	GHCN (Tmax, Tmin, precipitation)
Argentina **Brazil**	CORDEX South America 0.44	Station observations (Tmax, Tmin, precipitation)

Regional Climate Model Data Available

A growing number of high-resolution regional climate change simulations are publicly available through the WCRP CORDEX project (http://wcrp-cordex.ipsl.jussieu.fr), particularly for Europe; see e.g. http://cordexesg.dmi.dk.

The so-called Euro-CORDEX simulation domain has a grid distance of around 12 km (0.11 degrees), and a large number of meteorological fields are available on a daily basis for each grid point. Non-European simulation areas typically have 50 km (0.44 degrees) grid distances. Simulations typically go from 1961 to 2100, following global model simulations with future emissions of greenhouse gases compatible with the IPCC pathways RCP4.5 or RCP8.5.



Currently available MODEXTREME-relevant simulations are as follows:

- Europe: 9 simulations
- Africa: 15 simulations
- North America: 6 simulations
- East Asia: 5 simulations
- South America: 1 simulation

These include present-day values as well as future RCP4.5 and RCP8.5 scenarios.

Model Selection: the European Case

Currently, a dozen simulations for each emission pathway are publicly available for Europe. In order to select a sub-set of these simulations for further use, a set of precipitation-based extremes indices has been calculated for south-western Europe. Through a principal-component analysis of models vs. index changes, four simulations have been chosen, one central and three as different as possible.

We will select up to 4 models for each study area, one central and three to span a set of eight indices based on precipitation:

- **Average precipitation**
- **RX1day**. Highest precipitation amount in one-day period.
- **RX5day**. Highest precipitation amount in five-day period.
- **SDII**. Simple daily intensity index: Mean of precipitation (RR) on days when rain occurred (days when RR ≥ 1mm).
- **R10mm**. Heavy precipitation days: Count of days where RR (daily precipitation amount) ≥ 10 mm.
- **R20mm**. Very heavy precipitation days: Count of days where RR (daily precipitation amount) ≥ 20 mm.
- **CDD**. Consecutive dry days: Maximum length of dry spell (RR < 1 mm).
- **CWD**. Consecutive wet days: Maximum length of wet spell (RR ≥ 1 mm)

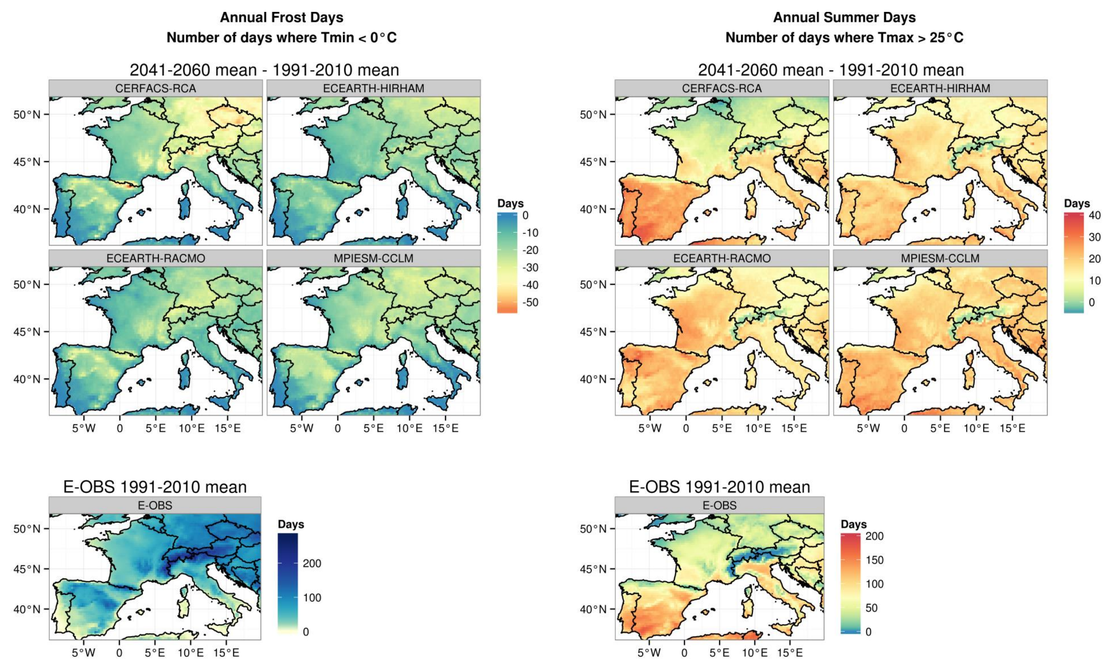
From this analysis, the following simulations for South-west Europe were selected: ECEARTH-HIRHAM (central), CERFACS-RCA, ECEARTH-RACMO, MPIESM-CCLM

Calculated Indices

Indices calculated from the bias-corrected data indicate projected changes in extremes.

Examples for two indices for the RCP4.5 scenario for 2041-2060 are presented here.

Compared to 1991-2010 averages, there is a general indication of reductions in the annual number of frost days and increases summer days with Tmax above 25 °C. The pattern of change is broadly consistent between the four selected RCMs, but the magnitude of changes differs spatially.



Outlook

Bias-corrected daily time series are currently being calculated for all MODEXTREME regions. Based on these, it will be possible to estimate how frequencies of extremes may change due to anthropogenic climate change. Due to the use of several plausible simulations, it will be possible to estimate spans of possible changes. The time series will serve as input to the MODEXTREME yield models, which will be developed and optimized during the project.

It is intended to study how the yield model improvements during MODEXTREME will influence the calculations of possible yield changes caused by changed frequencies of weather extremes.

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