Regional and local dimension of climate change: identification of the impact of climate variability and extreme events using the example of heat and drought in Baden-Württemberg

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Abstract

Within the start-up project "Regional and local dimension of climate change: identification of the impact of climate variability and extreme events using the example of heat and drought in Baden-Württemberg" an analysis of the impact of climate change will be conducted. The research is based on simulations of several regional climate models using A1B and B1 scenarios. The investigation area is Baden-Württemberg with focus on heat and drought. Especially the frequency and duration of climate events, short time events like heat waves or droughts, will be analysed. The impact of such climate events can influence sectors (water and energy) and different branches of industry (tourism, health and agriculture). Present research is focused on the identification of heat waves and droughts and on possible affects on viticulture during the 21st century. First results of the project are presented.

1. Introduction

Climate change and its positive and negative effects are a frequently discussed topic in science and in the general public. A worldwide increase of air temperature and a decrease of precipitation in some areas are assumed. According to the research group "Climate alteration and consequences for the water economy" a rising of air temperature as well as more precipitation in winter and less in summer for the period of 2021 to 2050 in Baden-Württemberg are expected (KLIWA, 2006). Their results are mainly based on the "Meteo-Research" MR-Model with a statistical-dynamical downscaling, using the SRES B2. Even more than climate trends, the impact of climate events, like heat waves or droughts, on economic and socio-economic systems can be enormous. The regional and local importance of such events is still not sufficiently investigated for many areas. According to Mehl and Tebaldi (2004) more intense, more frequent, and longer lasting heat waves in the second half of the 21st century in Europe and North America are expected, based on simulations of the "Parallel Climate Model" PCM. With such a development, the importance of heat waves for Baden-Württemberg could increase in the future.

In November 2009 the start-up project "Regional and local dimension of climate change: identification of the impact of climate variability and extreme events using the example of heat and drought in Baden-Württemberg" was initiated at the Meteorological Institute of the Albert-Ludwigs-University of Freiburg. The project's main goal is to research climate impacts based on existent results of regional climate simulations as well as to identify the limits of regional climate models. The results are based on simulations of the "Regional Modell" REMO of the Max-Planck-Institute for Meteorology and the COSMO model in climate mode COSMO-CLM or CLM of the Consortium for Small-scale Modeling. The emission scenarios SRES A1B and B1 were used for the simulation runs.

Hot days, summer days and tropical nights were examined as a first parameter to identify areas with increased heat stress. The impact of high air temperatures on human health can be of importance for health resorts and hospital facilities, which are numerous in Baden-Württemberg. Kovats and Ebi (2006) even proclaimed a requirement for a heat wave warning system because of higher mortality rates connected with heat waves. A first step in the field of agriculture was to investigate the development of viticulture during the 21st century. Viticulture is of great importance for the agriculture of Baden-Württemberg and climate change can influence the quantity and quality of wine (Petgen, 2007). For the investigation a possible expansion of suitable areas for viticulture was determined with the help of the Heliothermal Index (HI). To research the expected decrease of precipitation during summers, as a simple parameter dry days, days with precipitation less than 1 mm, were filtered out of scenario runs.

2. Data

Developed by the Max-Planck-Institute for Meteorology, the three-dimensional hydrostatic regional climate model REMO (Jakob et al., 2007; Jakob and Podzun, 1997) is an atmospheric circulation model, calculating the relevant physical processes dynamically. The simulation runs used are covering mainly the area of Germany in a resolution of 10km x 10km. The simulations were run from 1961 to 2100. Two runs from 2000 to 2100, one based on the SRES A1B and one based on the SRES B1 as well as a simulation for 1961 to 1990 were used. The parameters air temperature 2 meters above ground and total precipitation are both available in a resolution of one hour.
In the same way simulation runs of the model COSMO-CLM were used. The COSMO-CLM (Steppeler et al., 2003; Will et al., 2006) was developed by the "Consortium for Small-scale Modeling" COSMO. It is a non hydrostatic regional model also calculating the relevant physical processes dynamically. The simulation runs used, are in a 0.165° spatial resolution covering mainly the area of Europe. The simulations were run from 1961 to 2100. Two runs from 2000 to 2100, one based on the SRES A1B and one based on the SRES B1 as well as a simulation for 1961 to 1990 were used. The parameters air temperature 2 meters above ground and total precipitation are both available in a resolution of three hours.
The usage of other climate model runs as well as data of climate stations is planned, but not covered in this first report about the ongoing start-up project.

3. Impact of high air temperature

The expected rise of air temperature during the 21st century may affect human health as well as branches of industry in the form of heat stress or rising cooling costs. Many health resorts and hospital facilities are resident in Baden-Württemberg. For them a financial or image damage caused by changing environmental conditions may be possible. Using common parameters, a first estimation of the simulation runs can be made. The parameters used were: the number of hot days with a maximum air temperature ≥ 30 °C, the number of summer days with a maximum air temperature ≥ 25 °C and the number of tropical nights with a minimum air temperature ≥ 20 °C. More parameters like frost days with a minimum air temperature < 0 °C were examined, too. In figure 1 the increase of the mean annual amount of hot days during the 21st century in Baden-Württemberg is displayed. The periods shown are: 1961 to 1990, 2021 to 2050 and 2071 to 2100. The future periods are based on A1B.

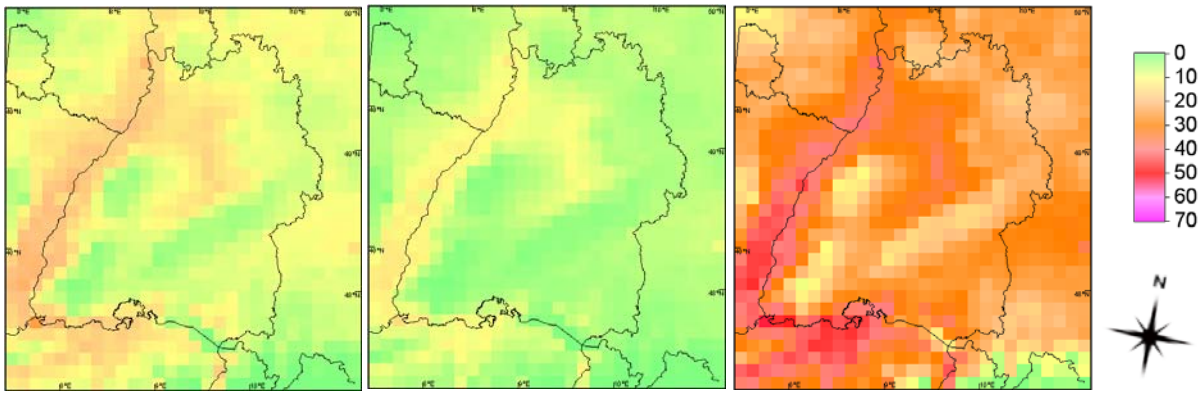

Fig. 1: Mean annual amount of hot days based on REMO with A1B. Periods are from left to right: 1961-1990, 2021-2050 and 2071-2100

An increase of hot days in the future is apparent. In the Upper-Rhine-Areas an increase of hot days from 10 - 20 in 1961 to 1990 to 20 - 30 in 2021 to 2050 is shown. For the period 2071 to 2100 it is simulated that hot days will be common in the whole federal state of Baden-Württemberg even mountainous areas. This kind of development will likely lead to an amplification of heat stress in the future. Simulation runs of the COSMO-EU have shown quite similar results.
Besides extreme temperatures the lack of possibilities to recover can be important as well. Such a problem can occur on days with a tropical night. Nowadays tropical nights are not an important matter for the general public in Germany, because of their rare occurrence. That fact may change in the future, especially in the Upper-Rhine-Areas as one of the warmest regions in Germany.

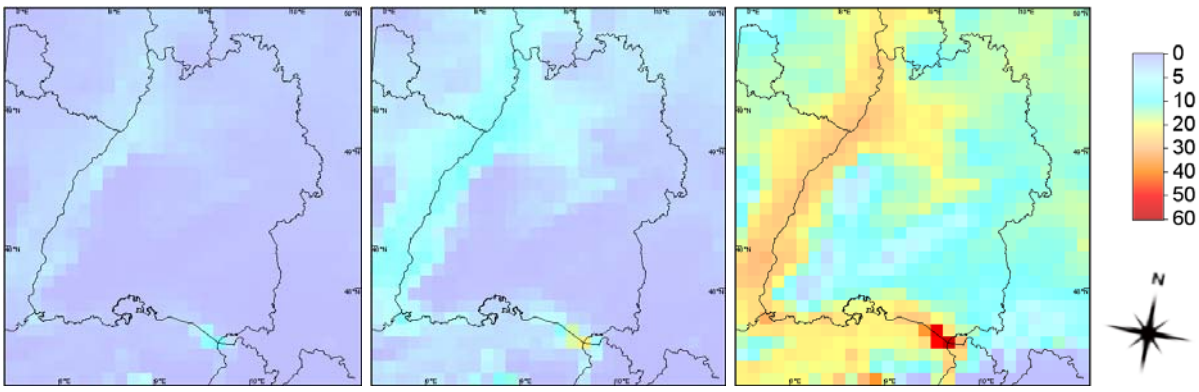

Fig. 2: Mean annual amount of tropical nights based on REMO with A1B. Periods are from left to right: 1961-1990, 2021-2050 and 2071-2100

In figure 2 the rising of the mean annual amount of tropical nights during the 21st century in Baden-Württemberg is displayed. The periods shown are: 1961 to 1990, 2021 to 2050 and 2071 to 2100. The future periods are based on the SRES A1B. A development from very few tropical nights in the Upper-Rhine-Area in 1961 to 1990 to up to 10 events in 2021 to 2050 as well as some in northern Baden-Württemberg is visible. In the period of 2071 to 2100 tropical nights will become a common incidence in the whole federal state of Baden-Württemberg with the exception of the mountainous areas. Simulation runs of the COSMO-EU have shown quite similar results. The development of summer days and frost days will be researched, too.

3. Viticulture

Viticulture is a considerable part of the agriculture in Baden-Württemberg. Changes in air temperature and precipitation are able to change the quantity and quality of a vintage (Mariani, 2009). Some of the negative effects of climate change for viticulture can be an intensified rottenness problem as well as an increase of vermin (Petgen, 2007). A positive aspect is a possible expansion of suitable areas for viticulture (Maracchi et al., 2005; Petgen, 2007). To investigate such a possible expansion the Heliothermal Index or Huglin Index (HI) was used. The HI is an often used index to identify suitable areas for grape-vine, so it was applied by studies of Tonietto and Carbonneau (2004) as well as Petgen (2007). For the HI, daily mean air temperatures T_M and daily maximum air temperature T_X as well as a length of day coefficient d are used for the growing period from April 4th to September 30th each year.

$$HI = \sum_{09.30.}^{04.01.} \frac{\left[(T_M - 10)(T_X - 10)\right]}{2} * d$$

The result can then be ranked in a class system to determine the best suited grape variety for the region. Some examples are given in table 1.

Table 1: Classes of the "Heliothermal Index" and suitable grape varieties (Tonietto and Carbonneau, 2004)

HI	≤1500	>1500 ≤1800	>1800 ≤2100	>2100 ≤2400	>2400 ≤3000	>3000
Class, Example grape varieties	Very cool, no vine or Gewürztraminer	Cool, Riesling	Temperate, Cabernet-Sauvignon	Temperate warm, Grenache	Warm, Nabeul	Very warm, Petrolina

An overview over the different HI values in Baden-Württemberg during the periods of 1961 to 1990, 2021 to 2050 and 2071 to 2100 is shown in figure 3. The future periods are based on the SRES A1B. An expansion of suitable areas for viticulture is visible. The HI is still an index based only on temperature and day length, many areas shown as suitable for viticulture may be unfitting because of different reasons, like thick forest or shadowing effects. Nevertheless, it may be necessary to think about seeding different grape varieties in the future.

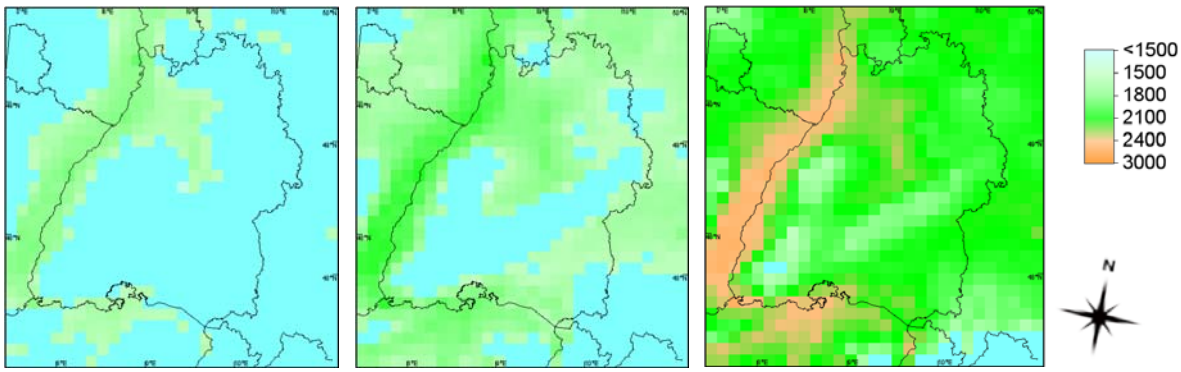

Fig. 3: Mean HI based on REMO with A1B. Periods are from left to right: 1961-1990, 2021-2050 and 2071-2100

4. Aridity and drought

A reduction of summer precipitation together with the presumed rising in air temperature can locally cause problems like droughts. To quantify future aridity, the mean annual amount of dry days, days with less than 1mm precipitation, were filtered out the simulation runs. This step is apparently only a start for research on the subject aridity and drought. Especially for agriculture, droughts in summer are more important than in winter, because of the growing season. For that reason the mean amount of dry days per summer half year from Mai to October is shown in figure 4. The periods are: 1961 to 1990, 2021 to 2050 and 2071 to 2100. The future periods are based on A1B.

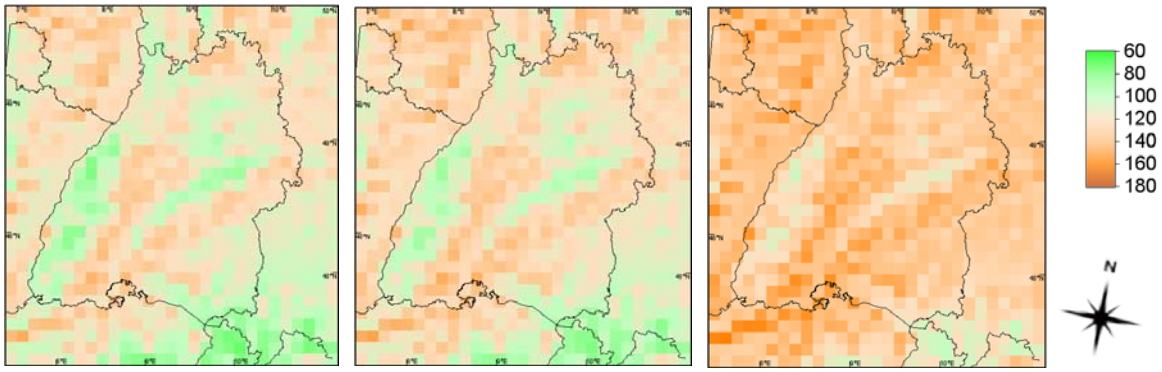

Fig. 4: Mean amount of dry days per summer half-year from Mai to October based on REMO with A1B. Periods from left to right: 1961-1990, 2021-2050 and 2071-2100

From the period 1961 to1990 to the period 2021 to 2050 the increase in dry day seems to be minor in comparison to the future periods where an increase of dry days is clearly visible.

4. Conclusion and Outlook

As a first approach the development of simple parameters during the 21st century was determined. Further steps are: adapting a definition for heat waves and droughts suitable for the region of Baden-Württemberg, finding appropriate indexes to describe changes during the century and evaluate their usefulness for the region. It may be necessary to develop or adjust one or more indexes. For agriculture also Growing Degree Day (GDD) and for health the Physiological Equivalent Temperature (PET) (Matzarakis and Amelung, 2008) will be analysed. With the suitable parameters and indexes, climate trends as well as intensity, duration and frequency of climate events, based on regional climate simulations, are intended to be investigated.

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