Report on climate change projections and changes in climate extremes for POLOG REGION

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Contents

INTRODUCTION

This report will present the preliminary results for the future climate change projections for Polog region, under RCP2.6, RCP4.5 and RCP8.6 scenarios of future concentrations of greenhouse gases defined in the Fifth Intergovernmental Panel on Climate Change (IPCC). The analysis will include changes in essential climate variables: mean daily temperature and daily precipitation. In addition to these results, changes in selected climate indices are presented, as indicators of the possible changes in the intensity and frequency of extreme weather and climate events. All future changes will be presented for the period from 1986 to 2100 and with respect to the reference period 1986-2005, which was used as the reference and in the last Fifth Intergovernmental Panel on Climate Change.

GHG EMISSIONS SCENARIOS

The Fifth Report of the Intergovernmental Panel on Climate Change identifies four so-called Representative Concentration Pathway (RCP) scenarios for future global concentrations of greenhouse gas: RCP8.5, RCP6.0, RCP4.5 and RCP2.6. These scenarios represent possible changes in the concentrations of greenhouse gases in the atmosphere in the period 2006-2100. Scenarios RCP2.6 and RCP4.5 assume that, greenhouse gases concentrations will stabilize in the future, while under RCP8.5 and RCP6.0 scenarios, their concentrations will continue to increase, or follow trends observed in the past (Figure 1). Scenario RCP2.6 even assumes that, in the second half of this century, the concentration of greenhouse gases could even decline, requiring anthropogenic emissions to be zero at one point.

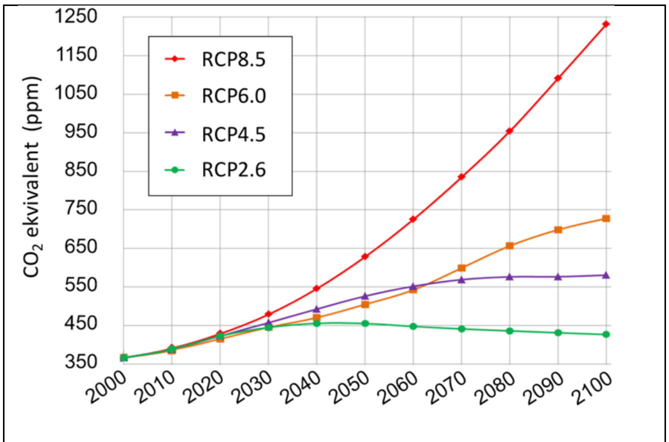

Fig. 1 Future concentrations of greenhouse gases for four different scenarios.

CLIMATE MODELS AND FUTURE PROJECTIONS

For different scenarios of future concentrations of greenhouse gases, with climate models that use these concentrations as input variables, appropriate climate projections can be obtained. For this report regional climate models were used. Regional climate models have significantly better horizontal resolution in comparison to Global Climate Models, usually of the order of 10 km. Based on their results it is possible to estimate the regional spatial changes of the selected variables.

The results of regional climate models are taken from the EURO-CORDEX database, which is the reference database of climate projections for Europe, and which has been the basis of many climate studies in Europe in recent years. Also, this database forms the basis for the European Union's Copernicus Climate Change Service program. The horizontal resolution of the downloaded data is 11 km. Also, the so-called bias-corrected data were taken. Bias-adjusted data are climate projections from which the systematic model errors in the model results are removed. The data from which systematic model error has been removed allow the estimation in future projections of selected climate indices to be more reliable. Seven regional climate models for RCP4.5 and RCP8.5 scenarios were taken from this database: CCLM4-8-17_v1 (r1i1p1 run identifier and CNRM-CM5 global model for boundary conditions), CCLM4-8-17_v1 (r12i1p1 run identifier and EC-EARTH global model for boundary conditions), RACMO22E_v1 (r1i1p1 run identifier and EC-EARTH global model for boundary conditions), RCA4_v1 (r1i1p1 run identifier and IPSL-CM5A global model for boundary conditions), CCLM4-8-17_v1 (r1i1p1 run identifier and MPI-ESM global model for boundary conditions), REMO2009_v1 (r1i1p1 run identifier and MPI-ESM global model for boundary conditions) and REMO2009_v1 (r2i1p1 run identifier and MPI-ESM global model for boundary conditions). For RCP2.6 there were less available models and analysis was done with three different regional climate models: RCA4_v1 (r12i1p1 run identifier and EC-EARTH global model for boundary conditions), REMO2009_v1 (r1i1p1 run identifier and MPI-ESM global model for boundary conditions) and REMO2009_v1 (r2i1p1 run identifier and MPI-ESM global model for boundary conditions). Since that number of models for RCP8.5 and RCP4.5 are different in comparison to the number of models for RCP2.6 comparison between results from them should be taken with care.

The analyzed indices are given in Table 1.

Table 1. Indices definition.

Index	**Definition**
FD	Number of frost days: Annual count of days when TN (daily minimum temperature) < 0°C.
ID	Number of icing days: Annual count of days when TX (daily maximum temperature) < 0°C.
CSDI	Cold-spell duration index: Annual count of days with at least 6 consecutive days when TN~~G~~ <10th percentile (cold waves).
SU	Number of summer days: Annual count of days when TX (daily maximum temperature) > 25°C.
TR	Number of tropical nights: Annual count of days when TN (daily minimum temperature) > 20°C.
WSDI	Warm spell duration index: Annual count of days with at least 6 consecutive days when TX > 90th percentile (extreme heat waves).
RR40	Annual count of days when daily precipitation ≥ 40mm.
RX1D	Yearly maximum 1-day precipitation.
CDD	Maximum length of dry spell, maximum number of consecutive days with daily precipitation < 1mm.
GSL	Growing season length: Annual (1st Jan to 31st Dec in Northern Hemisphere (NH), 1st July to 30th June in Southern Hemisphere (SH)) count between first span of at least 6 days with daily mean temperature TG>5°C and first span after July 1st (Jan 1st in SH) of 6 days with TG<5°C. (TG – mean daily temperature)

RESULTS

Mean annual temperature and precipitation temporal change for Polog region are given in Figure 2 for scenarios RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*). For all scenarios increase in future temperature is expected. In the first half of the century there is no significant difference for different scenarios and expected temperature increase is between 1 and 1,5 °C, on the other hand for the end of the century increase in temperature is 1 °C, 2,2 °C and 5 °C, for *low*, *mid* and *high* scenarios, respectively, clearly indicating that future evolution in temperature is determined by future concentration of GHGs.

For **precipitation** change, again in the first half of the century, results are similar for all scenarios giving annual precipitation change about -5 %, and according ensemble spread (doted lines) there are some chances that anomaly can be even positive. For the second half precipitation change is clearly negative for *high* scenario up to -20%, and about zero for *mid* and *low* scenario. Ensemble spread indicates that there is a higher chance for *mid* scenario that change will be negative up to -10%.

Temperature	Precipitation

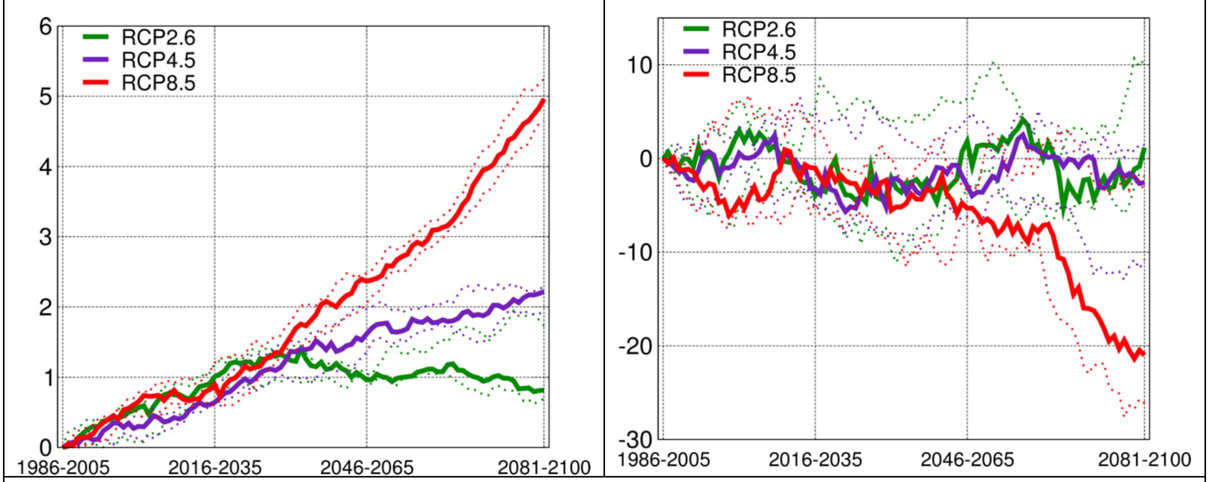

Fig. 2 Change in temperature (in °C) and precipitation (in %) for consecutive 20-year periods starting from 1986-2005 to 2081-2100, with respect to period 1986-2005, for scenarios RCP2.6, RCP4.5 and RCP8.5. Tick lines are mean value of selected multi model ensemble, and doted lines are ensemble range from 25th to 75th percentile.

In Figure 3 change in **frost and ice days** for Polog region are given for scenarios RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*). For all scenarios decrease in future frost and ice days is expected, which is not surprising since that increase in mean annual temperature is expected. In the first half of the century there is no significant difference for different scenarios and expected decrease in frost days is between -10 and -20 days, on the other hand for the end of the century decrease in frost days for *high* scenario is about -55 days. Expected decrease in ice days is about -6 days for all scenarios for the middle of century, and for the end of the century change is about -13 days for *high* scenario and -6 days for *low* and *mid* scenarios.

Frost days | Ice days

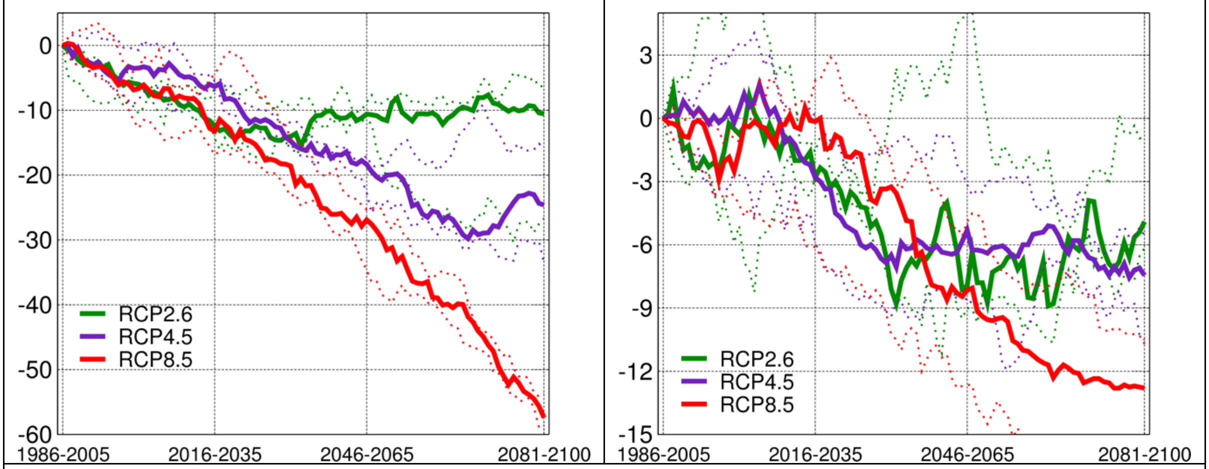

Fig. 3 Change in frost days (in days) and ice days (in days) for consecutive 20-year periods starting from 1986-2005 to 2081-2100, with respect to period 1986-2005, for scenarios RCP2.6, RCP4.5 and RCP8.5. Tick lines are mean value of selected multi model ensemble, and doted lines are ensemble range from 25th to 75th percentile.

In Figure 4 change in **cold waves** for Polog region are given for scenarios RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*). For *mid* and *high* scenarios decrease in future cold waves duration is expected. For the low scenario and whole period change in cold wave index oscillates between +3 and -3 days. In the first half of the century there is no significant difference for different scenarios and expected decrease cold wave duration is about -3 days on average. For the end of the century decrease in cold wave duration is 3 and 6 days for *mid* and *high* scenarios respectively.

Cold waves

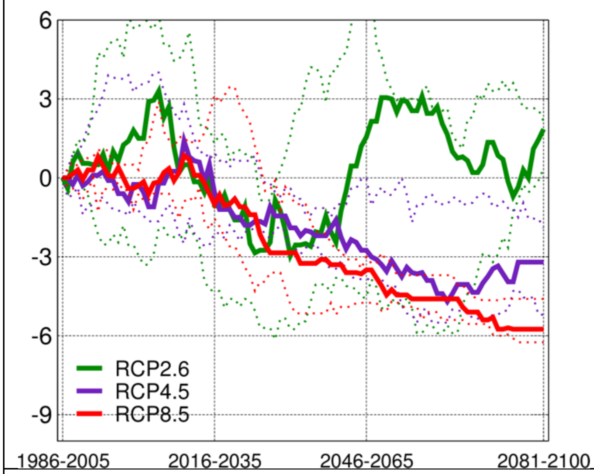

Fig. 4 Change in cold waves duration (in days) for consecutive 20-year periods starting from 1986-2005 to 2081-2100, with respect to period 1986-2005, for scenarios RCP2.6, RCP4.5 and RCP8.5. Tick lines are mean value of selected multi model ensemble, and doted lines are ensemble range from 25th to 75th percentile.

In Figure 5 change in **summer and tropical nights** for Polog region are given for scenarios RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*). For all scenarios increase in future summer days and tropical nights is expected. In the first half of the century there is no significant difference for different scenarios and expected increase in summer days is from 20 to 30 days, on the other hand for the end of the century increase in summer days for *high* scenario is about 65 days. For *low* scenario increase is expected to stay the same, and for *mid* scenario for the end of the century increase is 35 days. Expected increase in tropical nights is 1 to 2 days for all scenarios for the middle of century, and for the end of the century change is 15 days for *high* scenario 3 days for *mid* and no change for *low* scenario.

Summer days | Tropical nights

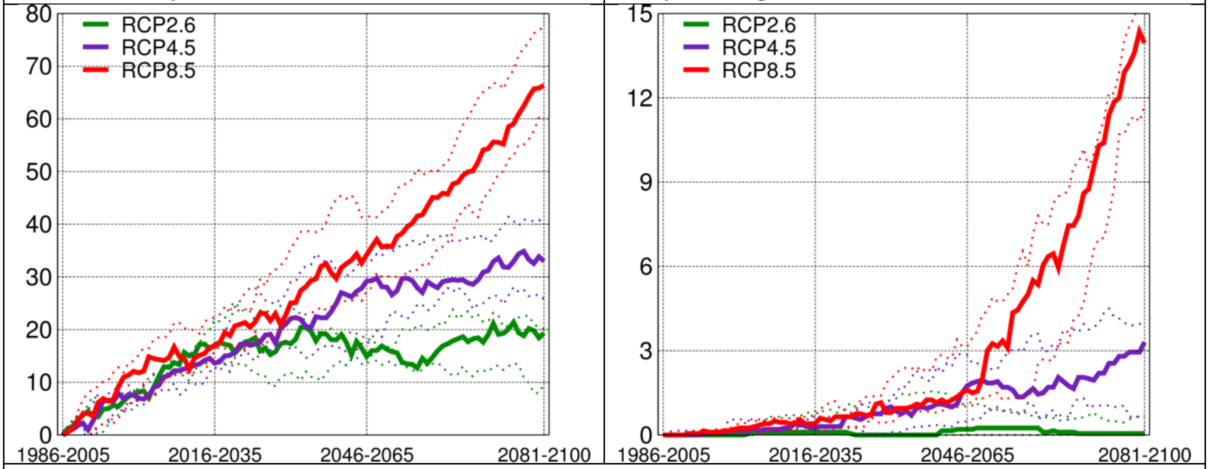

Fig. 5 Change in summer days (in days) and tropical nights (in days) for consecutive 20-year periods starting from 1986-2005 to 2081-2100, with respect to period 1986-2005, for scenarios RCP2.6, RCP4.5 and RCP8.5. Tick lines are mean value of selected multi model ensemble, and doted lines are ensemble range from 25th to 75th percentile.

In Figure 6 change in **heat wave duration** for Polog region are given for scenarios RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*). The change is very similar up to period 2046-2065, with increased duration of heat waves od about 1 to 2 days. After this period there is significant increase in heat waves duration for *high* scenario, and for the end of the century increase in duration is between 15 and 18 days, for *mid* scenario the increase is about 3 days and for the *low* scenario no change is present.

Heat waves

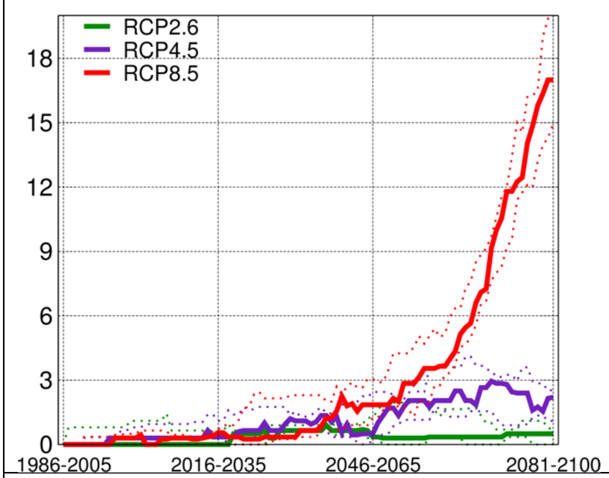

Fig. 6 Change in heat wave duration (in days) for consecutive 20-year periods starting from 1986-2005 to

2081-2100, with respect to period 1986-2005, for scenarios RCP2.6, RCP4.5 and RCP8.5. Tick lines are mean value of selected multi model ensemble, and doted lines are ensemble range from 25th to 75th percentile.

In Figure 7, change in **number of days with precipitation above 40 mm** (RR40) and change in **daily maximum precipitation** (RX1D) for Polog region are given for scenarios RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*). It is clear that internal variability dominates in comparison to potential signal of future change. For number of days with precipitation above 40 mm, overall positive change is present for all scenarios, for majority of future periods. For *high* scenario, upper limit of ensemble spread above 100%, which means that doubling of these days is potentially possible in the future. Similar conclusion can be applied for maximum daily accumulation, for *mid* and *high* scenario ensemble spared is predominantly positive, and for the *low* scenario, spread is evenly distributed on positive and negative change. Maximum of change in terms of upper limit of ensemble spread is between +10% and +15%, for the end of the century, for *mid* and *high* scenario.

Daily precipitation above 40 mm (RR40)	Daily maximum precipitation (RX1D)

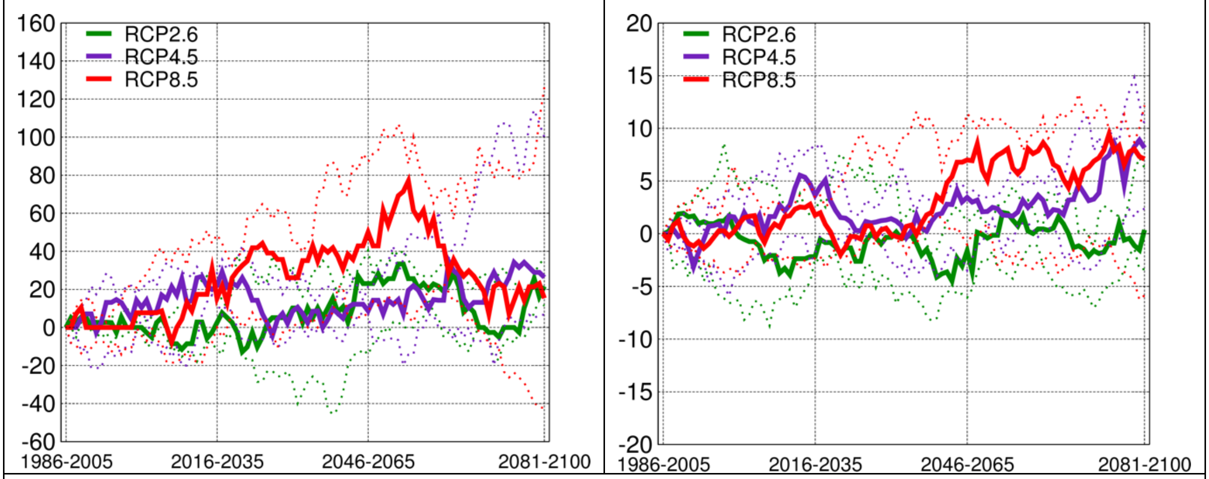

Fig. 7 Change number of days with precipitation above 40 mm (in %) and maximum daily precipitation (in %) for consecutive 20-year periods starting from 1986-2005 to 2081-2100, with respect to period 1986-2005, for scenarios RCP2.6, RCP4.5 and RCP8.5. Tick lines are mean value of selected multi model ensemble, and doted lines are ensemble range from 25th to 75th percentile.

In Figure 8 change in **consecutive dray days** for Polog region are given for scenarios RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*). For *low* and *mid* scenario, the increase is between -3 and 3 days, for most of the analyzed future period. For the *high* scenario significant increase is present for the end of the century with change of 9 days, indicating higher risk for drought in case of this scenario.

Consecutive dry days

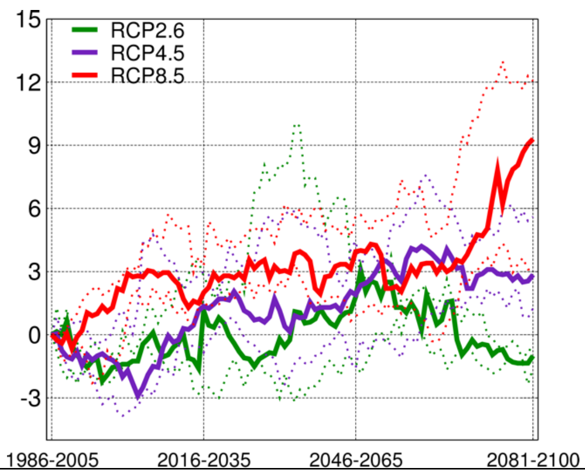

Fig. 8 Change in consecutive dry days (in days) for consecutive 20-year periods starting from 1986-2005 to 2081-2100, with respect to period 1986-2005, for scenarios RCP2.6, RCP4.5 and RCP8.5. Tick lines are mean value of selected multi model ensemble, and doted lines are ensemble range from 25th to 75th percentile.

In Figure 9 change in **growing season length** for Polog region are given for scenarios RCP2.6 (*low*), RCP4.5 (*mid*) and RCP8.5 (*high*). For all scenarios increase in growing season length is present. In the middle of the century the expected increase is 20 days. For the end of the century, for low and mid scenarios, change is 20 and 30 days respectively, but for high scenario increase is about 70 days.

Growing season length

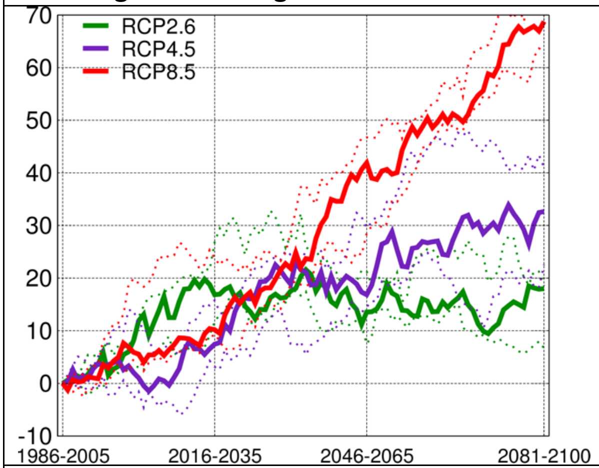

Fig. 9 Change in growing season length (in days) for consecutive 20-year periods starting from 1986-2005 to 2081-2100, with respect to period 1986-2005, for scenarios RCP2.6, RCP4.5 and RCP8.5. Tick lines are mean value of selected multi model ensemble, and doted lines are ensemble range from 25th to 75th percentile.