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Climate change impacts on streamflow in Norway

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1. Introduction:

About 99 % of the electricity production in Norway is based on hydropower. Climate change can lead to changes in the amount and seasonality of streamflow in Norwegian rivers, and thus affect the hydropower production. The Norwegian Meteorological Institute and the Norwegian Water Resources and Energy Directorate have developed scenarios of streamflow in Norway as basis for scenarios of the future electricity production.

2. Climate scenarios:

The streamflow scenarios were based on scenarios from two Atmospheric-Ocean General Circulation Models, the ECHAM4/OPYC3 model based on the emission scenario IS92a and the HadleyAm3 model based on the emission scenarios A2 and B2. The simulated series for the control period and the scenario period were downscaled using the Regional Climate Model HIRHAM. Daily temperature and rainfall series for the control and the scenario periods were interpolated to 80 climate stations and adjusted to be representative locally based on statistical techniques.

3. Hydrological modelling:

The streamflow have been calculated using the Gridded Water Balance Model, a gridded version of the HBV-model with a grid size of 1 x 1 km^2. Each grid cell were characterised by their altitude and land use. Series of daily temperatures and precipitation were assigned to each grid cell based on the three nearest climate stations. The model has components for accumulation, sub-grid scale distribution and ablation of snow, interception storage, sub-grid scale distribution of soil moisture storage, evapotranspiration, groundwater storage and runoff response, lake evaporation and glacier

mass balance. Potential evapotranspiration is a function of air temperature, however, the effects of seasonally varying vegetation characteristics are considered. The model is spatially distributed since every model element has unique characteristics that determine its parameters, input data are distributed, water balance computations are performed separately for each model element, and finally, only those parts of the model structure which are necessary are used for each element. When watershed boundaries are defined, runoff from the individual model grid cells is sent to the respective catchment outlets without delay.

A regionally applicable set of parameters was determined by calibrating the model with the restriction that the same parameter values are used for all computational elements of the model that fall into the same class for land surface properties. This calibration procedure rests on the hypothesis that model elements with identical landscape characteristics have similar hydrological behaviour, and should consequently be assigned the same parameter values.

4. Changes in the annual and seasonal streamflow:

Series of daily streamflow were calculated for 21 catchments in Norway representing important hydropower production for the control and the scenario period. The ECHAM4/OPYC3 model uses the period 1980-1999 as control period and 2030-2049 as scenario period, while the HadleyAm3 control period is 1961-1990 and the scenario period 2071-70. Annual and seasonal streamflow statistics were calculated for each basin. The percentage changes will be shown per decade since the two models differs in their control and scenario periods.

5. Conclusions:

The annual streamflow will increase in most of Norway according to the ECHAM4/OPYC3 scenario.

The HadleyAM3 indicates a moderate increase in most of the basin for the B2-scenario, while the A2-scenario indicates a lower increase in some basins and a decrease in others. More significant is the changes of the seasonality. The winter streamflow will generally increase, most in the HadleyAm3 scenarios. The spring streamflow will increase substantially in basins draining high mountain areas, and decrease marginally in coastal and lowland basins. The summer streamflow will decrease substantially, most in the HadleyAm3 scenarios. The autumn differs in the two scenarios, with a moderate increase in the ECHAM4-scenario and a moderate decrease in South Norway in the Hadley-scenarios. The two models agree in North Norway. The interannual variability of the annual and seasonal values does not change much through the series, indicating that dry years can occur even in region with a general increasing

streamflow.