Projections of future flood and drought conditions in Germany by combining RCMs and a regional hydrological model

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Regional impacts and strategies
Research Domain II - Climate Impacts & Vulnerabilities

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Isar Flood, 2005, Phillip Oertel
www.nowpublic.com/isar_flood_munich_germany

Neisse river flood on August 8, 2010. 
AFP PHOTO / ROBERT MICHAEL

Dry river bed in Dresden in 2007. 
(Source: Reuters)

in the future?
Introduction – Water problems in Germany

• More often and more intensive floods and pronounced droughts under climate change

• Uncertainty of the climate projections and hence of the impacts on both
Introduction - Study area
Introduction - Model system

Climate change

ECHAM5
Global climate

Regional climate model
Wettreg, CCLM, REMO

SWIM
Daily discharge

Projected floods and drought condition

Uncertainty from the climate scenarios
Method - Regional Climate models (RCMs)

<table>
<thead>
<tr>
<th>RCMs</th>
<th>Model type</th>
<th>Simulation period</th>
<th>GCM based</th>
<th>Emission scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCLM</td>
<td>Dynamic</td>
<td>1960-2100</td>
<td>ECHAM5</td>
<td>A1B, B1</td>
</tr>
<tr>
<td>REMO</td>
<td>Dynamic</td>
<td>1951-2100</td>
<td>ECHAM5</td>
<td>A1B, A2, B1</td>
</tr>
<tr>
<td>Wettreg</td>
<td>Statistical-empirical</td>
<td>1961-2100</td>
<td>ECHAM5</td>
<td>A1B, A2, B1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Realization per scenario</th>
<th>Spatial resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCLM</td>
<td>2</td>
<td>0.2°</td>
</tr>
<tr>
<td>REMO</td>
<td>1</td>
<td>0.088°</td>
</tr>
<tr>
<td>Wettreg</td>
<td>20</td>
<td>1965 stations in Germany</td>
</tr>
</tbody>
</table>

CCLM

REMO

Wettreg
The Model SWIM (Soil and Water Integrated Model)

**Climate:** Global radiation, temperature, precipitation

- **Hydrological cycle**
  - Soil profile
  - Upper ground water
  - Lower ground water

- **Vegetation/Crop growth**
  - LAI
  - Biomass
  - Roots

- **Nitrogen cycle**
  - N\(_{\text{NO}_3}\)
  - N\(_{\text{ac}}\)
  - N\(_{\text{st}}\)
  - N\(_{\text{res}}\)

- **Phosphorus cycle**
  - P\(_{\text{lab}}\)
  - P\(_{\text{m-ac}}\)
  - P\(_{\text{m-st}}\)
  - P\(_{\text{org}}\)
  - P\(_{\text{res}}\)

**Land use pattern & land management**

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**SWIM** was developed in PIK, Potsdam based on SWAT-93 and MATSALU for climate and land use change impact studies (Krysanova et al., 1998)
Methods - flood and low flow indices

✓ Generalized Extreme Value (GEV) distribution (Coles, 2001) for fitting annual maximum discharges and annual minimum 7-day mean flows:

\[ G(z) = \exp \left\{ -\left[ 1 + \xi \left( \frac{z - \mu}{\sigma} \right) \right] \right\} \]

shape parameter $\xi$, location parameter $\mu$ and scale parameter $\sigma$ (>0)

Relative change in %

\[ \frac{Q1 - Q0}{Q0} \times 100 \]

Annual maxima return level plot

- Scenario
- Reference

Q0
Q1
50

Return period (Year)

Discharge (m³/s)
Calibration results – two examples

(a) Intschede (Weser)

Calibration period
Efficiency: 0.90
Deviation: 1%

(b) Hofkirchen (Danube)

Calibration period
Efficiency: 0.87
Deviation: 0%
Results - calibration and validation

Distribution of the statistical results obtained from all 29 gauges in the control period (1961 - 2000)

Havel: lowland + mining activity
Fulda: reservoir

Result – calibration and validation

50-year flood level

50-year low flow level

Simulated discharge vs. Observed discharge graphs for 50-year flood and low flow levels.
Results – changes in 50-year flood level

(2061 – 2100) vs (1961 – 2000)

REMO

A1B

A2

B1

Relative change in %

< -25
-25 - -10
-10 - 0
1 - 10
11 - 25
> 25

River

Germany

Subbasin

CCLM

A1B, real. 1

A1B, real. 2

B1, real. 1

B1, real. 2
Results – changes in 50-year flood level

Large uncertainty in flood projection due to:

- RCM structures
- Different emission scenarios
- Different realizations by CCLM.
Results - changes in 50-year low flow level

REMO

CCLM
Results - changes in 50-year low flow level

- Smaller uncertainty in low flow projections.
- Critical regions: German Danube and river Rhine.
Conclusion and outlook

• Flood: large uncertainty, no distinct pattern

• Low flow: smaller uncertainty with decreasing trend in German Danube and river Rhine

• Future strategies:
  – reduce the large uncertainty in flood projections
  – Apply other GCM driven scenarios
Thank you for your attention!

Dry river bed in Dresden in 2007
(Source: Reuters)
(a) Intschede (Weser)

- Efficiency: 0.90
- Deviation: 1%

(b) Hofkirchen (Danube)

- Efficiency: 0.87
- Deviation: 0%
Observed

Simulated with observed climate

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Result – calibration and validation: one example

Generalized Extreme Value (GEV) plots for the annual maxima of daily discharge and the annual minimum 7-day (AM7) mean flow observed and simulated during control period 1961 - 2000 at the gauge Neu Darchau (Elbe)
Results – flood/low flow generation over time

Intschede (Weser) Flood

Hofkirchen (Danube) Low flow

30-year flood/low flow level estimated
95% confidence level

30-year flood/low flow level for 1961 -1990
95% confidence level for 1961 -1990
Annual maxima return level plot

- GEV fitting
- 95% confidence level

Discharge (m³/s)

Return period (Year)