Projected climate change and its effects on mean and extreme runoff in Poland

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Background and objective

- Climate change impacts in Poland understudied until recently
- Lack of process-based distributed hydrological models covering Poland until recently
- The objective was to fill these two research gaps and:
  - To assess impacts of climate change on hydrology of the Vistula and Odra basins
  - To build a multi-purpose, „high-resolution” hydrological model covering most of Poland, with freely available inputs and outputs
Study area (Vistula and Odra basins)

A = 313 000 km²
Data sources for model inputs

<table>
<thead>
<tr>
<th>Data type</th>
<th>Source</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEM PL</td>
<td>ESRI TIN (CODGiK)</td>
<td>TIN interval 10-50 m Vertical 0.8-2 m</td>
</tr>
<tr>
<td>DEM non-PL</td>
<td>SRTM v4.1 (NASA)</td>
<td>Horizontal 90 m; Vertical 16 m</td>
</tr>
<tr>
<td>Rivers and lakes PL</td>
<td>MPHP2010 (IMGW-PIB)</td>
<td>1:50,000</td>
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<tr>
<td>Rivers and lakes non-PL</td>
<td>CCM2 (IES)</td>
<td>1:500,000</td>
</tr>
<tr>
<td>Reservoirs PL</td>
<td>KZGW</td>
<td>128 objects</td>
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<tr>
<td>Land cover EU</td>
<td>CLC2006 (EEA)</td>
<td>100 m</td>
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<tr>
<td>Land cover non-EU</td>
<td>MODIS Landcover</td>
<td>500 m</td>
</tr>
<tr>
<td>Land cover (urban, EU)</td>
<td>Imperviousness 2012 (CLMS)</td>
<td>20 m</td>
</tr>
<tr>
<td>Land cover (crops, PL)</td>
<td>2002 Census data (GUS)</td>
<td>345 districts</td>
</tr>
<tr>
<td>Soil map PL</td>
<td>IUNG-PIB</td>
<td>1:500,000</td>
</tr>
<tr>
<td>Soil map non-PL</td>
<td>HWSD v 1.2</td>
<td>1: 1,000,000</td>
</tr>
<tr>
<td>Channel cross-sections PL</td>
<td>ISOK (KZGW)</td>
<td>20611 cross-sections</td>
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<tr>
<td>Climate PL</td>
<td>IMGW-PIB</td>
<td>687 stations</td>
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<td>Climate DE, CZ</td>
<td>DWD</td>
<td>44 stations</td>
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<td>Climate SK, UA, BY</td>
<td>ECAD, NOAA, NCDC</td>
<td>32 stations</td>
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<tr>
<td>Streamflow PL</td>
<td>IMGW-PIB</td>
<td>76 stations</td>
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<tr>
<td>Streamflow non-PL</td>
<td>GRDC and UA yearbooks</td>
<td>4 stations</td>
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</tbody>
</table>

Note: Water management not considered in the model setup
- calibration of catchments with semi-natural streamflow
- capturing pure climate change effect
- fair spatial comparison of effects
CHASE-PL project: modelling workflow

Current

- CPLFD-GDPT5
- CHASE-PL Forcing
- Data: Gridded Daily Precipitation & Temperature 5 km
  (Berezowski et al., 2015)

Future

- CPLFD-GDPT5
- CHASE-PL Climate Projections: 5-km Gridded Daily Precipitation & Temperature
  (Mezghani et al., 2016)

Climate

Hydrology

SWAT =>

CPL-NH
CHASE-PL—Natural Hydrology (Piniewski et al., 2015)

CPL-FH
CHASE-PL—Future Hydrology (Piniewski et al., 2017)

Talk by I. Kardel
Thurs. session E1 =>

Piniewski et al., 2017, Data
Calibration/validation (spatial)

KGE – Kling-Gupta Efficiency (model performance index after Gupta et al., 2009)

A. Calibration

B. Temporal validation

C. Spatial validation

KGE

- <0.1
- 0.1-0.2
- 0.2-0.3
- 0.3-0.4
- 0.4-0.5
- 0.5-0.6
- 0.6-0.7
- 0.7-0.8
- 0.8-0.9

Main rivers
VOB
Benchmark catchments

Piniewski et al., 2017, HSJ
Validation (hydrographs) – 3 examples

1. R. Narewka

2. R. Olza

3. R. Vistula (mouth)

Piniewski et al., 2017, HSJ
Climate change scenarios

- Bias-corrected RCM climate projections
  - Quantile mapping method
  - 9 climate model simulations
  - 2 RCPs: 4.5 and 8.5
  - Reference period 1971-2000, 2 future horizons 2021-2050 (near future, NF), 2071-2100 (far future, FF)

<table>
<thead>
<tr>
<th>N</th>
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<th>Model</th>
<th>Run</th>
<th>Regional Climate Model Institute</th>
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<td>CCLM4-8-17</td>
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<td>KNMI</td>
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<td>r1i1p1</td>
<td>SMHI</td>
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<td>MPI-ESM-LR</td>
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</tbody>
</table>
Projected changes in temperature and precipitation – ensemble range

\[ T_{\text{min}}, T_{\text{max}} \]

Precipitation

Piniewski et al., 2017, Met. Z.
Projected changes in mean annual runoff (ensemble mean)

- Maps convey information about robustness (method used in IPCC AR5)
- Robustness of climate projections: a combination of an agreement between models and statistical significance of change


Projections of monthly discharge to the Baltic Sea

The River Odra - near future

The River Vistula - near future

The River Odra - far future

The River Vistula - far future

- Historical
- RCP 4.5
- RCP 8.5
Projected changes in snow melt

RCP 4.5

RCP 8.5

Snow melt [mm]

Month

Historical
Near Future
Far Future
Projections of runoff components

- GWQ: baseflow
- LATQ: lateral flow
- SURQ: surface runoff
Runoff change vs. T and P change

- Each point represents one of 36 climate scenarios.
- Symbol size represents the magnitude of mean runoff increase.

Changes in low flow indicator (daily Q90)

RCP 4.5

NF

O: 22.0%
V: 19.1%

Mean +25.8%

RCP 8.5

FF

O: 28.2%
V: 25.0%

Mean +34.1%

O: 34.3%
V: 34.9%

Mean +44.9%

O: 52.6%
V: 55.9%

Mean +70.1%

Piniewski et al., 2017, Hydrol Proc.
Changes in high flow indicator (daily Q10)
Comparison with large scale studies (mean flows)

Hydrological model: JULES LSM
Climate models: EURO-CORDEX
Ensemble: 5 members (5 GCM-RCMs and RCP8.5)
Bias-correction: YES
Future horizon: „+4 degrees”
Indicator: average runoff

Papadimitriou et al., 2016, HESS
Comparison with large scale studies (low flows)

Hydrological models: Lisflood and E-HYPE
Climate models: EURO-CORDEX
Ensemble: 11 members (5 GCM-RCMs and 3 RCPs)
Bias-correction: YES
Future horizon: “+2 degrees”
Indicator: magnitude of low flow with 10-year return period

Roudier et al., 2016, Clim. Chan.
Comparison with large scale studies (high flows)

Hydrological models: Lisflood
Climate models: EURO-CORDEX
Ensemble: 7 members (7 GCM-RCMs and RCP8.5)
Bias-correction: NO
Future horizon: 2080s
Indicator: 100-year daily peak flow
Summary

- Uncertainty (as usual) high, but some signals emerge
- Runoff and streamflow increasing on annual and seasonal basis (although not everywhere)
- Relative changes in low flows higher than for high flows
- The later, the wetter + the higher RCP, the wetter
- Timing of maximum flow advanced by 1-2 months
- Precipitation (and snow melt) change as the main driver of runoff change
- Results consistent with large-scale EURO-CORDEX-driven models for Europe
- **Model inputs and outputs freely available in open repositories and geoportal**
Further reading


Acknowledgements

Thank you for your attention!