Hydrological extremes in a changing climate - Impacts and Implications for Bavaria

- Florian Willkofer, LMU -
Impact - Climate change in hyd. Bavaria

Temperature

- **Winter**: Spatial mean: 4.2 K
- **Spring**: Spatial mean: 3.6 K
- **Summer**: Spatial mean: 6.3 K
- **Autumn**: Spatial mean: 5.2 K

Precipitation

- **Winter**: Spatial mean: 24.6%
- **Spring**: Spatial mean: 19.5%
- **Summer**: Spatial mean: -23.7%
- **Autumn**: Spatial mean: -3.1%

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Impact - Mean flows

What are the signals for mean flows and mean high flows?

Mean flows

2070-2099 vs. 1981-2010

Median of rel. signal of mean flows (MF) of 50 Ensemble members reference period (1981-2010) vs. future period (2070-2099)

Mean high flows

Median of rel. signal of mean high flows (MHF) of 50 Ensemble members reference period (1981-2010) vs. future period (2070-2099)
Impact - High return periods

Direct benefits from modeling with Single Model Large Ensembles?
Enhancing estimation of extreme return periods, 1:100 year flood, HF100

Robust HF100 estimation for the reference period (1981-2010)
Gauge PEG-Sill-Innsbruck-Reichenau (ID: 30601)

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Impact - High return periods

Will high return periods become more frequent and intense?

Intensity → change in discharge of a reference return period in the future

\[ 250 \text{ m}^3/\text{s} \rightarrow 390 \text{ m}^3/\text{s} \]

100-year → 10-year

Frequency → change in return period from reference to future
Impact - High return periods

Will high return periods become more frequent and intense?

Change in frequency of HF100 in the future period (2070-2099)

Frequency
2070-2099 vs. 1981-2010

HF100 Return Period in FUT [a]
- > 120
- 100 - 120
- 80 - 100
- 60 - 80
- 40 - 60
- 20 - 40
- < 20

increase in frequency
Impact - High return periods

Will high return periods become more frequent and intense?

Change in intensity of HF100 in the future period (2070-2099)

Intensity
2070-2099 vs. 1981-2010

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Impact - Causes for severe flooding

Is there change in the causes for severe flooding?

**What can we see?**

- Heavy precipitation
- Heavy precipitation + continuous rain
- Snowmelt
- COMPOUND EVENTS

**Causes for flood events**

Mean of the 50 ensemble members averaged for all gauges in hydrological Bavaria (1981 - 2099)

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### Impact - Compound events

Which processes might induce extreme high flow events? - compound events

<table>
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<tr>
<th>Spatial</th>
<th>Catchment statistics</th>
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<td>Soil water content</td>
<td>Discharge (dashed line indicates highest record)</td>
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<tr>
<td>Cumulative sum of precipitation</td>
<td>Precipitation</td>
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<td>Soil water content</td>
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**Catchment:** Rott - Ruhstorf
Impact - Compound events

Soil water content root zone

Cumulative sum of precipitation

Compound event - discharge Rott-Ruhstorf

Compound event - precipitation Rott-Ruhstorf

Compound event - soil moisture Rott-Ruhstorf

- Soil water content
- Cumulative sum of precipitation
- Compound event - discharge Rott-Ruhstorf
- Compound event - precipitation Rott-Ruhstorf
- Compound event - soil moisture Rott-Ruhstorf

ClimEx Symposium 2019
Which processes induce extreme high flow events? - compound events

Discharge compound event - Danube

10100 m$^3$/s

Event June 2013
Key messages

Summary of climate change impacts

Regions:
1. Alps
2. Alpine foreland
3. Escarpment (Schichtstufenland)
4. Central highlands

Signal 1981-2010 vs. 2070-2099

<table>
<thead>
<tr>
<th>Region</th>
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<tr>
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<td>Mean High Flow</td>
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<td>Frequency</td>
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Key messages

- Significant decrease in mean flow for most Bavarian river basins
  - Substantial challenge for environmental flow in summer
  - Substantial challenge for power plants (cooling water, discharge of warm water)
  - Decrease in hydropower potential (especially for run-off-the-river plants)
  - Unnavigable waterways for shipping of goods

- Intensity and frequency of severe high flow events (e.g. HF100) are likely to increase
  - Current thresholds applied for design of structural mitigation measures might not be sufficient (e.g. retention basins for decentral flood protection)
  - Adaptation of existing structural mitigation measures might be required

- Severe compound events might impose flood risk to larger areas than currently observed
What are the implications of CC for hydropower generation?
Case study hydropower potential lake Walchensee