Modelling of future changes in seasonal snowpack and impacts on summer low flows in Alpine catchments

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Motivation, research questions, objectives

1) to simulate the effect of changes in selected snow signatures on low flows during the warm seasons

2) to relate drought sensitivity to the simulated snow storage changes in study catchments

January 18, 2013
SWE: normal conditions

January 18, 2014
SWE: 10-30% of normal

Source: NASA Earth Observatory (http://earthobservatory.nasa.gov/NaturalHazards/)
Study area
1. HBV-light model (Seibert and Vis, 2012)

2. Observed data (1971-2012): precipitation, air temperature (Meteoswiss), discharge (BAFU), SWE (SLF)

3. Four objective functions used to calibrate the model; goodness-of-fit assessed against Q and SWE.

4. 100 best parameter sets calibrated which were further used for scenario simulations
• The **Swiss Climate Change Scenarios 2011** data set (CH2011) was used

• The CH2011 data set provides daily changes in air temperature and precipitation (delta-change approach) relative to the reference period 1980-2009 for three scenario periods (2020-2049, 2045-2074 and 2070-2099) and the **A1B emission scenario**.

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**Scenario preparation**
- Daily correction of temperature and precipitation applied to the ref. period

**Scenario simulation**
- 100 model parametrization used to create 100 simulations of each scenario

**Calculation of signatures**
- The specific signature calculated from these 100 model simulations
Climate elasticity

Climate elasticity

- Elasticity $= \frac{\% \text{ change of } Q_{\text{min}}}{\% \text{ change of } SWE_{\text{max}}}$
- Express low flow elasticity to SWE
- The higher the value, the more sensitive is $Q_{\text{min}}$ to changes in $SWE$
Changes in snow signatures

- The largest absolute decrease in $SWE_{\text{max}}$ from 2200 to 2700 m a.s.l.
- Relative decrease in $SWE_{\text{max}}$ up to 80% below 1500 m a.s.l.
- The decrease in $SWE_{\text{max}}$ caused by decrease in snowfall fraction
Changes in snow signatures

• Earlier onset of snowmelt and earlier melt-out (largest changes between 1800-2500 m a.s.l.
• Shortening of the snowmelt period
Influence of snow storage on low flows: decrease in $Q_{\text{min}}$

- $Q_{\text{min}}$ from June to August for scenarios compared to the ref. period.
- Full-colored marks indicate years when $SWE_{\text{max}}$ decreased to less than 50% of respective $SWE_{\text{max}}$ in the ref. period.
- Black: 2020-2049
  Blue: 2045-2074
  Red: 2070-2099

### Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>$Q_{\text{min}}$ (JJA) reference period [mm/d]</th>
<th>$Q_{\text{min}}$ (JJA) scenario period [mm/d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>C9: 776-3242 m a.s.l</td>
<td>2.0-3.0</td>
<td>1.0-3.0</td>
</tr>
<tr>
<td>C14: 518-2169 m a.s.l</td>
<td>2.0-3.0</td>
<td>1.0-3.0</td>
</tr>
</tbody>
</table>
Influence of snow storage on low flows: decrease in snow runoff

• Decrease in snow runoff ($Q_{sf}$) compared to the decrease in $Q_{min}$ (JJA) for scenarios compared to the ref. period
• Marks: mean value; error bars: the inter-annual variability (standard deviation) within individual scenarios.
• Black: 2020-2049
  Blue: 2045-2074
  Red: 2070-2099

C9: 776-3242 m a.s.l

C14: 518-2169 m a.s.l
Influence of snow storage on low flows: elasticity

Elasticity of $Q_{\min}$ to $SWE_{\max}$ for the reference period and scenario periods.
• **Summer low flows will significantly decrease** in the future in snow dominated areas.

• **Decrease in snowfall fraction, snow storage and the shift of snowmelt season** are main causes of the low flow decrease

• **Snow runoff in summer will decrease** by more than 50% (highest elevations) and **almost disappear** (lowest elevations)

• Changes in AET and precipitation both played a minor role and cannot explain the changes in minimum runoff.

• **Higher elevations are more sensitive** to the decrease in snow storage → decrease of water availability in summer
Modeling of Future Changes in Seasonal Snowpack and Impacts on Summer Low Flows in Alpine Catchments

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Abstract It is expected that an increasing proportion of the precipitation will fall as rain in alpine catchments in the future. Consequently, snow storage is expected to decrease, which, together with changes in snowmelt rates and timing, might cause reductions in spring and summer low flows. The objectives of this study were (1) to simulate the effect of changing snow storage on low flows during the warm seasons and (2) to relate drought sensitivity to the simulated snow storage changes at different elevations. The Swiss...