The **ASG**-Project in Relation to Low Flows

**Jörg Uwe BELZ**
Bundesanstalt für Gewässerkunde (BfG)
International Commission of the Hydrology of the Rhine Basin (KHR/CHR)
CHR/KHR: Researching about Flow Regime and Climate Change within the River Rhine Catchment

Impact of climate change on the flow regime (model-simulations)

CHR report I-16
Grabs et al. (1996)

Impact of climate change on hydrological regimes and water resources management in the Rhine basin

Analysis of changes of flow regime in the 20th century

CHR report I-22
Belz et al. (2007)

Das Abflussregime des Rheins und seiner Nebenflüsse im 20. Jahrhundert - Analyse, Veränderungen, Trends

Perspectives of the future development of the discharge

CHR report I-23
Görgen et al. (2010)

Assessment of Climate Change Impacts on Discharge in the Rhine River Basin: Results of the RheinBlick2050 project
ASG-Rhein: Getting Started

...and in the beginning there were headlines...

CLIMATIC CHANGE:
River Rhine is falling dry! (2003)
Climate change... Germany ...another result will be, that

...Rivers like the Rhine „will fall dry from time to time...“

as Hans Joachim Schellnhuber, Director of PIK (Potsdam Institut for Climate Impact Research), stated, being interviewed by the well-respected newspaper „Die Zeit“

(n-tv Wednesday, 21. November 2012)
ASG-Rhein I: Conceptual Items and Tasks
Snow and glacier melt components of streamflow of the river Rhine and its tributaries considering the influence of climate change

1. Gaining knowledge: Identification of the relevant processes, quantification of the amounts and determination of developments of snow and glacier melt runoff within the whole basin, structured in gauge-controlled subcatchments.

2. Setting-up a routing system for discharge, considering the relevant factors and processes (steering of reservoirs, swiss lake regulation etc.) to allow proportional tracking of the discharge fractions.

3. Quantification (in daily resolution) of the fractions of snow and glacier melt runoff for the gauges of the subcatchments and especially for the gauges Basel, Maxau, Worms, Mainz, Kaub, Andernach, Köln und Lobith.
ASG-Rhein: Architecture of the Project

Customer: KHR/CHR
Project lead: BELZ

Scientific personnel:
Freiburg University, chair Prof. Weiler
(WEILER, STAHL, FREUDIGER, FRIELINGSDORF, HOHMANN, KOHN, STEINBRICH)

Hydron GmbH
(GERLINGER, BÖHM)

Zürich university, chair Prof. Seibert
(SEIBERT, FINGER, VIS)

ASG-Steering group:
KHR/CHR
(BELZ, KRAHE, MÜLLER, SCHMOCKER-FACKEL, SPROKKEREFF)

External experts
(BREMICKER/LfU-BW, NACHTNEBEL/BOKU Univ. Wien, NÄF/ETH Zürich, SCHÖNER/ Graz Univ., SPERNA-WEILAND/ Deltares, [JONAS/SLF] )
ASG-Rhein I / Operation (2012-2016): Model chain

- Close analysis of observed data -> climate sensitivity of runoff

- Model-chain:
  downstream of Basel: LARSIM 5x5km
  upstream of Basel: LARSIM 1x1km
  head catchments: HBVlight
ASG-Rhein I: Milestones

- Gridded meteorological dataset 1901-1950 (daily values temperature & precipitation), reconstructed by using a station-related resampling method (analogue conditions of HYRAS-database are transferred to similar days in the earlier period)

- Digital register of glacier areas for early 20th century (based upon „Siegfriedkarten“ 1 : 50 000)

- Detailed empirical data analysis about climate-sensitivity of runoff generation in non-regulated alpine catchments

- Combined model chain, covering the whole Rhine-catchment (HBVlight + LARSIM 1x1km + LARSIM 5x5km), all improved and multi criteria-calibrated

- New development of a model system for proportional discharge routing of different runoff fractions \(Q_{Eis}, Q_{Schnee}, Q_{regen} = Q_{ice}, Q_{snow}, Q_{rain}\) („virtual mixing tanks“)

- Daily values of discharge, period 1901-2006 for the important gauges along river rhine, distinguished for the runoff-fractions \(Q_{ice}, Q_{snow}, Q_{rain}\)
ASG-Rhein I: Results for the Headcatchment Brienzwiler
Daily means of discharge (average values 1901-2006) in absolute and relative numbers

**MQ** = 35 m³/s
**QS(Jahr)** = 55 %
**QE(Jahr)** = 13 %
ASG-Rhein I: Results for the Subcatchments
Runoff fractions, annual means / period 1901-2006

Abflussanteile

- \( Q_E \) Ice
- \( Q_S \) Snow
- \( Q_R \) Rain

Pegel
Gewässer
- Rhein-EZG
- Ländergrenzen
- Gletscher 1900
ASG-Rhein I: Results for the Gauges Basel (CH) und Lobith (NL)
Monthly means (1901-2006) in absolute and relative values

MQ = 1058 m³/s
QS(Jahr) = 39 %
QE(Jahr) = 2 %

MQ = 2224 m³/s
QS(Jahr) = 34 %
QE(Jahr) = 1 %
ASG-Rhein I: Results for the Glacierized Headwater Catchments (MQ(a); Period 1901-2006)

Annual Variability of the streamflow components due to weather conditions
ASG-Rhein I: Results

Modified amounts of the runoff fractions in hot low flow years [%/a]

Brienzwiler / Aare

Basel / Rhein

Lobith / Rhein

Snowmelt

Icemelt
ASG-Rhein I: Results for the Low flow Extreme 2003

Hydrographs of the runoff fractions at gauges along river rhine downstream mouth of river
ASG-Rhein I: Results for the Low-Flow Extreme 2003

Lowest simulated (total) discharge, highest amount of $Q_{Ice}$ (absolute values) and highest amount of $Q_{Ice}$ of total discharge (relative values)

<table>
<thead>
<tr>
<th>Pegel</th>
<th>Minimum $Q_{sim}$ (m³/s)</th>
<th>$Q_{gem}$ (m³/s)</th>
<th>$Q_{E}$ (%)</th>
<th>Max. absoluter $Q_E$-Anteil</th>
<th>Tag</th>
<th>$Q_E$ (m³/s)</th>
<th>$Q_{E}/Q_{gem}$ (%)</th>
<th>Max. relativer $Q_E$-Anteil</th>
<th>Tag</th>
<th>$Q_E$ (%)</th>
<th>$Q_{E}/Q_{gem}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worms</td>
<td>22. Sep 610</td>
<td>511</td>
<td>14</td>
<td>02. Sep 166</td>
<td>18</td>
<td>20</td>
<td></td>
<td>27. Aug 21</td>
<td>149</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Mainz</td>
<td>22. Sep 660</td>
<td>619</td>
<td>13</td>
<td>03. Sep 165</td>
<td>18</td>
<td>19</td>
<td></td>
<td>27. Aug 20</td>
<td>150</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Kaub</td>
<td>23. Sep 668</td>
<td>621</td>
<td>13</td>
<td>03. Sep 164</td>
<td>17</td>
<td>18</td>
<td></td>
<td>27. Aug 20</td>
<td>151</td>
<td>21</td>
<td></td>
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</tbody>
</table>

28.08.2003, gauge Lobith (NL): ~17% of the whole daily discharge of River Rhine was glacier-melt fraction
ASG-Rhein I: Results for the Low-Flow Extreme 2003

Lowest simulated (total) discharge, highest amount of $Q_{Ice}$ (absolute values) and highest amount of $Q_{Ice}$ of total discharge (relative values)

Main message:
- In average neglectable importance of icemelt for most of the rivers in the Rhine basin
- In hot low flow years, glaciermelt enriches the total discharge of river Rhine in an essential amount

<table>
<thead>
<tr>
<th>Pegel</th>
<th>Minimum $Q_{sim}$ (NQ 2003)</th>
<th>Max. absoluter $Q_{E}$-Anteil</th>
<th>Max. relaterer $Q_{E}$-Anteil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$Q_{sim}$</td>
<td>$Q_{gem}$</td>
<td>$Q_{E}$</td>
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<tr>
<td></td>
<td>(m³/s)</td>
<td>(m³/s)</td>
<td>(m³/s)</td>
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<tr>
<td>Bryenzwiler</td>
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<td>Basel</td>
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<td>Maxau</td>
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<td>Worms</td>
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<td>Mainz</td>
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<td>Kaub</td>
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<td>Andernach</td>
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<td>Köln</td>
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28.08.2003, gauge Lobith (NL): ~17% of the whole daily discharge of River Rhine was glacier-melt fraction
ASG-Rhein I: Conclusions for navigation

GIW(Rhine) without icemelt

GIW (= *equivalent waterlevel*): For every gauge along River Rhine, the GIW marks the waterlevel, which is not exceeded for 20 d/a in average during the period 1911-2010.

GIW is important for purposes of navigation and river maintenance (reference value for the depth of the fairway).

<table>
<thead>
<tr>
<th>Name</th>
<th>Position [Rhein-km]</th>
<th>GIW 2012 (obs.) Reference period 100 years (IV/1911-III/2011)</th>
<th>Example: GIW (Qsim-oe) Reference period 95 years (IV/1911 - III/2006)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxau</td>
<td>362,3</td>
<td>369</td>
<td>354 [cm] -15</td>
</tr>
<tr>
<td>Kaub</td>
<td>546,2</td>
<td>78</td>
<td>67 [cm] -11</td>
</tr>
<tr>
<td>Düsseldorf</td>
<td>744,2</td>
<td>97</td>
<td>79 [cm] -18</td>
</tr>
</tbody>
</table>
### ASG-Rhein I: Conclusions for navigation

**GIW(Rhine): Undercutting the threshold with and without icemelt**

<table>
<thead>
<tr>
<th>Gauge</th>
<th>Number of days falling below $Q(GIW)$ / 15-year periods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Qsim [d]</td>
</tr>
<tr>
<td>Maxau</td>
<td>184</td>
</tr>
<tr>
<td>Kaub</td>
<td>342</td>
</tr>
<tr>
<td>Düsseldorf</td>
<td>405</td>
</tr>
</tbody>
</table>
ASG-Rhein I: Conclusions for navigation

GlW(Rhine) / observed data: gauge Kaub 2003
ASG-Rhein I: Conclusions for navigation

GIW(Rhine) / Discharge without icemelt: gauge Kaub 2003

57 vs. 23 days of dropping below Q(GIW)
Compensation of decreasing volume of glaciers by intensifying icemelt-dynamics throughout 20th century because of rising of temperatures induced by climate change (?)
THANKS TO THE LARGE TEAM OF SCIENTISTS FOR THEIR QUALIFIED WORK AND THANKS TO YOU FOR YOUR ATTENTION!

Jörg Uwe BELZ
Bundesanstalt für Gewässerkunde (BfG)

Report available via http://www.chr-khr.org
- Complete version (german language only)
- Synthesis (bilingual German + English)