Das Augusthochwasser 2002 im Osterzgebirge und dessen statistische Bewertung

The extreme flood in August 2002 in the eastern part of the Ore Mountains and its statistical assessment

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The extreme flood in August 2002 in the eastern part of the Ore Mountains and its statistical assessment

- The hydrological event
- Statistical evaluation of the flood event
- How realistic is the statistical assessment?
The extraordinary level of the flood 2002 in relationship to flood peaks of the past (since 1771) at an old building in the city of Grimma at the Mulde River in Germany
Meteorological reason for the floods in August 2002 - Vb-Circulation Pattern
Spatial Distribution of the extreme precipitation from August 10 to August 13, 2002 in the German part of the Ore Mountains
## PMP and measured rainfall maxima in August 2002

<table>
<thead>
<tr>
<th>Region</th>
<th>Area in sq.km</th>
<th>Duration 24 hours</th>
<th>Duration 72 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station Zinnwald</td>
<td>1 to 25 km²</td>
<td>350 mm</td>
<td>500 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>312 mm</strong></td>
<td><strong>406 mm</strong></td>
</tr>
<tr>
<td>Region Zinnwald</td>
<td>1,000 km²</td>
<td>300 mm</td>
<td>450 mm</td>
</tr>
<tr>
<td>Part of the Elbe River Basin</td>
<td>5,000 km²</td>
<td>200 mm</td>
<td>275 mm</td>
</tr>
<tr>
<td>Watershed Upper Elbe</td>
<td>12,000 km²</td>
<td>160 mm</td>
<td>250 mm</td>
</tr>
</tbody>
</table>

### Precipitation between August 11 and 13, 2002 in mm

PMP with a duration of 12 hours for watersheds with 500 km² in size in summer (June to August)
Areal precipitation values from August 10 to 13 2002 for watersheds in the Ore Mountains
Temporal distribution of the precipitation from August 11 to 13 for different river basins in Saxonia
Temporal distribution of runoff from August 11 to 14, 2002 for different river basins in Saxonia
Linear regression between direct runoff (in mm) and area precipitation for the flood in August 2002

\[ Q_{\text{sum}} = -58.9 + 0.76 \times P_{\text{sum}} \]

R- (adjusted for d.f.) = 87.8 percent
Polynomial regression between direct runoff (in mm) and area precipitation for the flood in August 2002

\[ Q_{\text{sum}} = 82.68 - 0.436 \times P_{\text{sum}} + 0.002344 \times P_{\text{sum}}^2 \]

\[ R-(\text{adjusted for d.f.}) = 89.4 \text{ percent} \]
Impact of the soil storage capacity $SBE$ in mm and the total sum of precipitation $PSUM$ on the direct runoff

$$Qsum = -24.4309 + 0.741528*Psum - 0.0472646*SBE$$
Runoff coefficients in relationship to sum of precipitation

![Graph showing runoff coefficients vs. sum of precipitation](image)
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Characterisation of the inflow flood peaks in August 2002 in relationship to the assumed 1,000 and 10,000 yrs flood for 7 reservoirs in Saxonia

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Catchment size in km²</th>
<th>Assumed Design Flood 1 HQ(1,000) m³/s</th>
<th>Assumed Design Flood 2 HQ(10,000) m³/s</th>
<th>Max. Inflow in August 2002 m³/s</th>
<th>Max. Release during the flood in August 2002 m³/s</th>
<th>Max. Inflow / 1,000 yrs flood</th>
<th>Max. Inflow / 10,000 yrs flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lehnmühle</td>
<td>60.4</td>
<td>85.4</td>
<td>125</td>
<td>130</td>
<td>120</td>
<td>1.52</td>
<td>1.04</td>
</tr>
<tr>
<td>Klingenberg</td>
<td>90.4</td>
<td>30</td>
<td>200</td>
<td>220</td>
<td>220</td>
<td>1.78</td>
<td>1.07</td>
</tr>
<tr>
<td>Malter</td>
<td>130.5</td>
<td>147</td>
<td>200</td>
<td>220</td>
<td>220</td>
<td>1.50</td>
<td>1.10</td>
</tr>
<tr>
<td>Altenberg</td>
<td>6.8</td>
<td>9.2</td>
<td>11</td>
<td>7</td>
<td>7</td>
<td>0.76</td>
<td>0.64</td>
</tr>
<tr>
<td>Lichtenberg</td>
<td>38.4</td>
<td>39.2</td>
<td>60</td>
<td>60</td>
<td>48</td>
<td>1.53</td>
<td>1.00</td>
</tr>
<tr>
<td>Saidenbach</td>
<td>60.7</td>
<td>39.8</td>
<td>46</td>
<td>63</td>
<td>20</td>
<td>1.58</td>
<td>1.37</td>
</tr>
</tbody>
</table>
Return Period of flood peaks in August 2002, estimated on the basis of time series ending 2001
Uncertainty of statistical assessments of flood risks showing at the example of the flood in August 2002 in Saxonia
Uncertainty of statistical assessments of flood risks showing at the example of the flood in August 2002 in Saxonia
Uncertainty of statistical assessments of flood risks showing at the example of the flood in August 2002 in Saxonia
Modification of the flood statistics at the gauge Hainsberg 1/ Rote Weisseritz

\[ y(T) = -\ln(\ln(1/Pu)) \]

HQ in m³/s

<table>
<thead>
<tr>
<th>T</th>
<th>bis 2001</th>
<th>mit 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>12.74</td>
<td>11.91</td>
</tr>
<tr>
<td>5</td>
<td>21.53</td>
<td>23.01</td>
</tr>
<tr>
<td>10</td>
<td>28.11</td>
<td>34.46</td>
</tr>
<tr>
<td>20</td>
<td>35.07</td>
<td>50.06</td>
</tr>
<tr>
<td>25</td>
<td>37.41</td>
<td>56.25</td>
</tr>
<tr>
<td>50</td>
<td>45.1</td>
<td>80.15</td>
</tr>
<tr>
<td>100</td>
<td>53.47</td>
<td>113.33</td>
</tr>
<tr>
<td>200</td>
<td>62.62</td>
<td>159.46</td>
</tr>
<tr>
<td>300</td>
<td>68.36</td>
<td>194.43</td>
</tr>
<tr>
<td>500</td>
<td>76.03</td>
<td>249.31</td>
</tr>
<tr>
<td>1000</td>
<td>87.31</td>
<td>348.8</td>
</tr>
</tbody>
</table>

Reihe 1928-2001
Reihe 1928-2002
T=2 a
T=5 a
T=10 a
T=20 a
T=25 a
T=50 a
T=100 a
T=200 a
T=500 a
T=1000 a
The extreme flood in August 2002 in the eastern part of the Ore Mountains and its statistical assessment

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- How realistic is the statistical assessment?
Yearly flood values at the gauge Dohna/ Mueglitz River

<table>
<thead>
<tr>
<th>Return Period T</th>
<th>Risk of 3 events in 106 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1:5600</td>
</tr>
<tr>
<td>500</td>
<td>1:780</td>
</tr>
<tr>
<td>200</td>
<td>1:571</td>
</tr>
</tbody>
</table>

Jahr
HQ
Return Period T
Risk of 3 events in 106 years
1000 1:5600
500 1:780
200 1:571
Evidence of „record-breaking floods“
(Vogel et al. 2001)

Yearly flood observations \(X_1, X_2, \ldots, X_i\)

Counting of the highest flood peaks from the begin of observation with a yearly extension of the series

\[ Y_i = \begin{cases} 1 & \text{max}(X_1, X_2, \ldots, X_i)\text{ records an event}\vspace{1mm} \\ 0 & \text{otherwise} \end{cases} \]

Number of record breaking floods in a series of \(n\) years

\[ R = \sum_{i=1}^{n} Y_i \]

Probability of \(r\) record-breaking floods in a series of \(n\) years

\[
P[R = r] = \frac{S^r_n}{(n)!} \text{ with S- Stirling's number} \]

\[
S^r_n = \sum_{k=0}^{n-r} (-1)^k \binom{n-k+r}{n-r+k} (2n-r-k)! \left[ \sum_{j=0}^{k} \frac{1}{k!} \sum_{j=0}^{k} (-1)^{k-j} \binom{k}{j} j^{n-r+k} \right]
\]

Approximation for \(n > 20\) yrs

\[
P[R = r] = \frac{[\ln(n)]^{r-1}}{n \cdot (r-1)!}
\]

\[
\mu_R = \sum_{i=1}^{n} \frac{1}{i}, \sigma_R^2 = \sum_{i=1}^{n} \frac{1}{i} - \sum_{i=1}^{n} \frac{1}{i^2}
\]
Number of „record breaking floods“ dependent on the starting point of the series in the Mulde River basin
Effect of random samples on flood statistics, Dependency of the 1000 yrs- flood from the starting point of the flood series
Effect of random samples on flood statistics, Dependency of the 1000 yrs-flood from the ending point of flood series
Flood Levels since 1771 at an old building in the city of Grimma at the Mulde River in Germany, differentiated between winter and summer flood events.
Seasonal Distribution of Catastrophic Floods in the history of the City of Zwickau between 1291 and 1835

Zwickau - Häufigkeitsauswertung historischer Hochwasser der Zwickauer Mulde gemäß Angaben aus der Stadtchronik (Zeitfenster: 1291 bis 1835)

Anzahl der Hochwasser

- Altstadt überflutet
- Häuser beschädigt
- Brücken beschädigt
- ohne Bauwerksschäden

Anzahl der Hochwasser

Monate

Jan Feb Mär Apr Mai Jun Jul Aug Sep Okt Nov Dez
Example for a seasonal flood statistics
Gauge Lichtenwalde/ Zschopau

Pegel Lichtenwalde/ Zschopau

- Jahres-HQ- Werte bis 2001
- Sommer-HQ unkorrigiert
- Winter-HQ unkorrigiert
Example for a seasonal flood statistics
Gauge Lichtenwalde/ Zschopau

Pegel Lichtenwalde / Zschopau

- Jahres-HQ Werte bis 2001
- Sommer-HQ korrigiert
- Winter-HQ korrigiert
Example for a seasonal flood statistics
Gauge Lichtenwalde/ Zschopau

Pegel Lichtenwalde / Zschopau

- Jahres-HQ- Werte bis 2001
- Sommer-HQ korrigiert
- Winter-HQ korrigiert
- AEV- Winter
- AEV Sommer
Example for a seasonal flood statistics
Gauge Lichtenwalde/ Zschopau
Differences of statistical assessments of a flood peak of 30 times of the mean annual discharge utilizing a combined seasonal based distribution or the distribution of annual flood

<table>
<thead>
<tr>
<th>Pegel</th>
<th>Watershed in km²</th>
<th>Discharge (30 times MQ) in m³/s</th>
<th>Annual maxima Based on winter and summer maxima</th>
<th>D.F. of summer maxima</th>
<th>D.F. of winter maxima</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golzern1/ Vereinigte Mulde</td>
<td>5442</td>
<td>1842</td>
<td>353</td>
<td>150</td>
<td>189</td>
</tr>
<tr>
<td>Niederschlema/ZwickauerMulde</td>
<td>759.4</td>
<td>375</td>
<td>53</td>
<td>55</td>
<td>89</td>
</tr>
<tr>
<td>Wechselburg/ ZwickauerMulde</td>
<td>2106.8</td>
<td>777</td>
<td>133</td>
<td>104</td>
<td>147</td>
</tr>
<tr>
<td>Aue1/ Schwarzwasser</td>
<td>362.5</td>
<td>187.2</td>
<td>42</td>
<td>40</td>
<td>67</td>
</tr>
<tr>
<td>Goeritzhain/ Chemnitz</td>
<td>532.3</td>
<td>186.9</td>
<td>97</td>
<td>67</td>
<td>91</td>
</tr>
<tr>
<td>Lichtenwalde/ Zschopau</td>
<td>1574.6</td>
<td>648</td>
<td>111</td>
<td>71</td>
<td>157</td>
</tr>
<tr>
<td>Streckewalde/ Preßnitz</td>
<td>205.9</td>
<td>90</td>
<td>165</td>
<td>114</td>
<td>137</td>
</tr>
<tr>
<td>Pockau1/ Flöha</td>
<td>384.6</td>
<td>177.6</td>
<td>89</td>
<td>52</td>
<td>114</td>
</tr>
<tr>
<td>Rothenthal/ Natzschung</td>
<td>75</td>
<td>41.4</td>
<td>89</td>
<td>57</td>
<td>90</td>
</tr>
<tr>
<td>Zoeblitz/ SchwarzePockau</td>
<td>129.2</td>
<td>69.3</td>
<td>279</td>
<td>126</td>
<td>131</td>
</tr>
<tr>
<td>Berthelsdorf/ Freiberger Mulde</td>
<td>244.4</td>
<td>105.9</td>
<td>86</td>
<td>81</td>
<td>86</td>
</tr>
<tr>
<td>Nossen1/ Freiberger Mulde</td>
<td>585.2</td>
<td>202.8</td>
<td>283</td>
<td>99</td>
<td>108</td>
</tr>
<tr>
<td>Wolfsgrund/ Chemnitzbach</td>
<td>37.2</td>
<td>19.83</td>
<td>1102</td>
<td>280</td>
<td>436</td>
</tr>
<tr>
<td>Niederstrieg/ Stregis</td>
<td>283</td>
<td>80.1</td>
<td>179</td>
<td>87</td>
<td>90</td>
</tr>
</tbody>
</table>
Return Period of flood peaks in August 2002, estimated on the basis of time series ending 2002
Thank you very much for your attention!

Vielen Dank für Ihre Aufmerksamkeit!