Ingredients of Runoff Events: Regional Differences between Small and Large Floods

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Motivation

**Objective:** investigate transformation of processes from small runoff events to large floods at catchment scale

**Tool:** a framework for causative classification of runoff events
Proposed framework

Novelty

• **Space-time dynamics** of rainfall and snowmelt events and spatial patterns of antecedent soil moisture as indicators

![Maps showing precipitation and soil moisture over time](image)

• **Dimensionless indicators** (cv, covariance and ratios)
• **Adaptive and hierarchical structure**
• **All runoff events of various sizes**
• **Runoff-free classification**

Study area and events

- **Study period:** 1951-2013
- **Study area:** 185 German mesoscale catchments
- **Daily observation datasets:** discharge, gridded precipitation (1 km), gridded temperature (4 km)
- **Daily modelled gridded datasets (4 km):** snow water equivalent, soil moisture

Rainfall-runoff event separation

1. Base flow separation
2. Rainfall attribution
3. Refinement of multiple-peak events:
   - Distribution equality test
   - Iteration

220,000 events of various sizes

Tarasova, L., Basso S., Zink M., and R. Merz 2018. Time-series-based event separation and temporal dynamics of event runoff response in Germany. WRR
Samaniego, L., Kumar, R., Attinger, S., 2010. Multiscale parameter regionalization of a grid-based hydrologic model at the mesoscale. WRR
# Proposed framework

## Indicators and thresholds

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Thresholds</th>
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</thead>
<tbody>
<tr>
<td>Ratio of snowmelt/rainfall and precipitation volume</td>
<td><strong>Covariance:</strong> 1</td>
</tr>
<tr>
<td>Spatial covariance of snow cover and rainfall</td>
<td><strong>Temporal cv:</strong> 1</td>
</tr>
<tr>
<td>Spatial covariance of pre-event level of soil freezing and rainfall</td>
<td><strong>Spatial cv:</strong> $Q_2$</td>
</tr>
<tr>
<td>Temporal cv of precipitation rate</td>
<td>Ratio (rainfall, snowmelt): 0.95</td>
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<tr>
<td>Ratio of intensity and volume</td>
<td>Ratio (volume, intensity): 0.5</td>
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<tr>
<td>Spatial cv of precipitation volume</td>
<td><strong>Soil moisture:</strong> max curvature of fitted non-linear function of pre-</td>
</tr>
<tr>
<td>Mean spatial covariance of precipitation rates between consecutive time</td>
<td>event soil moisture and event runoff coefficients</td>
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<tr>
<td>steps</td>
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<tr>
<td>Catchment-averaged antecedent soil moisture</td>
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<tr>
<td>Spatial covariance of precipitation volume and antecedent soil moisture</td>
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</tbody>
</table>
Layer-wise process characterization

Runoff event

- Rainfall, Rain-on-ice, Rain-on-snow, Mixture of rainfall and snowmelt, Snowmelt
- Intensity, Volume
- Local Steady, Local Unsteady, Extensive Steady, Extensive Unsteady
- Wet, Dry
- No Overlap, Overlap
Transformation of processes from small to large events

Inducing event: frequency of occurrence

- Rainfall
- Rain-on-ice
- Rain-on-snow
- Mixture
- Snowmelt

All events

MAF

HQ30
Transformation of processes from small to large events

Intensity | Volume | Extensive Unsteady | Extensive Steady | Local Unsteady | Local Steady
---|---|---|---|---|---
All events

MAF

HQ30

Temporal organization | Space-time organization | Wetness state

frequency of occurrence

Wetness state
Hierarchical classification

Runoff event

Classification Tree

Event type: a combination of ingredients (e.g., Rain.Dry.Intensity.Local.Steady)
Event type frequency

Regional clustering

- Study period: 1979-2002
- Study area: 392 catchments
- 196,000 events

Event type frequency within each cluster:

- All events
- Events $Q_{\text{peak}} > Q_{75}$
Runoff characteristics of event types

*The values are rescaled to mean=0 for all catchments
Summary

- Changing relevance of *rain-on-snow* from ordinary to larger events
- Variable importance of *intensity-dominated* events for higher return periods among different regions
- Emergence of *regional pattern* of event type frequency
  - regionalization
- Distinct differences of *runoff characteristics* of classified event types
  - flood-type specific design hydrographs
Thank you for your attention!

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