Hydrological extremes in the Elbe catchment and the „Modular Observation Solutions for Earth Systems (MOSES)“ initiative of the Helmholtz-Gemeinschaft

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EXTREMES JUST IN FRONT OF OUR DOOR

Flooding
and:
2006
2010
2013

Low flows
more extreme
2015, and even more extreme
2018

Impact on ecosystem services
(DOC in raw water)

Impacts on ecosystems and services
(Eder Reservoir August 2018)
Why hydrological extremes?

► event chains

- River loads of the Elbe increased by factor 5-50: \( \text{NO}_3^- + \text{NO}_2^- , \text{NH}_4^+ , \text{PO}_4^{3-} , \text{Si} \)
- Considerable part of the annual load of organic and inorganic pollution
- Stratification of the coastal waters
- Unusual algal bloom in summer
- Effects on \( \text{O}_2 \)
Research questions

- Why and how does the filter effect of estuaries change at low retention times at high discharge?
- How do the event-driven matter transport and low discharge/high temperature control the occurrence of (toxic) algal blooms and other ecological long-term changes?
- How and to which extent does the small-scale variability of precipitation orography and soil moisture affect the generation of discharge?
- Why does water quality show different long-term trends at high and low discharge (NW↑; HW↓)?
The Elbe catchment as first test region

Flood May - June 2002

Drought July - August 2003

Elbe catchment
(148.268 km²)
### Modules for hydrological extremes

<table>
<thead>
<tr>
<th>MOSES Module</th>
<th>Consortium</th>
<th>Heat Waves</th>
<th>Hydrologic Extremes</th>
<th>Ocean Eddies</th>
<th>Thaw Events Permafrost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous Vehicles</td>
<td>GEOMAR, HZG</td>
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<tr>
<td>Fixed Point Observatories</td>
<td>AWI, GEOMAR, HZG</td>
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<td>Coastal and Marine Mobile Systems</td>
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<tr>
<td>Permafrost Thaw and Subsidence</td>
<td>AWI, GFZ</td>
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<tr>
<td>Flow and Sediment Dynamics</td>
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<td>Biota</td>
<td>AWI, HMGU, UFZ, KIT, FZJ</td>
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<td>Water Balance</td>
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<td>Soil and Water Quality</td>
<td>HMGU, UFZ</td>
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<tr>
<td>Land-Atmosphere Fluxes</td>
<td>KIT, FZJ, UFZ, GFZ</td>
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<tr>
<td>Atmospheric Dynamics</td>
<td>FZJ, KIT</td>
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<td>X</td>
<td>X</td>
<td>(X)</td>
</tr>
<tr>
<td>Atmospheric Chemistry</td>
<td>FZJ, KIT</td>
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</tbody>
</table>

**DLR: Plane-based TANDEM-L System**
Measurement systems for hydrological extremes

- **Special force Flood events**
- **Interaction atmosphere/land surface/soil moisture**
- **Gravimetry of stored water/generation of discharge**
- **Input pathways, water quality, isotope signatures, ecological processes**
- **Chemodiversity, microbioms, reactivity in plants, soil, water**
- **Water quality estuary**
- **Remote sensing**
- **Underwater observatories, miniaturized chemical sensors**
Innovation: Measurement systems

Balloons for the observation of dynamics and chemistry of the atmosphere
Profiles from surface up to ca. 30 km altitude: temperature, pressure, moisture / water content, horizontal wind, ozone content, clouds / aerosols

Event-based samplers for observation of water quality dynamics
Automatic sampling based on event-driven thresholds:
Water and sediment samples (activ, passiv) coupled with data loggers for temperature, turbidity, conductivity, oxygen and nutrient monitoring
## Planed test campaigns

<table>
<thead>
<tr>
<th>Year</th>
<th>Cuxhaven</th>
<th>Elbe-Ästuar</th>
<th>Müglitztal</th>
<th>Elbe</th>
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</thead>
<tbody>
<tr>
<td>2018</td>
<td>Test of devices</td>
<td>Test of devices</td>
<td>Test campaign</td>
<td>Test campaign</td>
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<td>June 2018</td>
<td>June and October 2018</td>
<td>April – July 2019</td>
<td>2020</td>
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<tr>
<td>2019</td>
<td>Inter-calibration of sensors, adjustment of logistics: water quality parameters</td>
<td>Travel-time based measurement of water quality parameters, transect Geesthacht to Helgoland</td>
<td>Genesis of hydrologically relevant discharge events in small-scale catchments</td>
<td>Dominant processes during dynamic events along an event chain</td>
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</tbody>
</table>
Test campaign Elbe catchment 2020
Conception

- North Sea
- Baltic Sea
- Headwaters, Small/medium catchments
  - Müglitztal
  - Erzgebirge
  - Bode
  - (Ammer)
- Lower Elbe
- Elbe estuary
  - Upstream of Geesthacht
  - Downstream of Geesthacht (Tide-Elbe)

Event measurements
Continuous measurements
Travel-time based measurements
Measurements/experiments in long-term observatories
Elbe catchment

Governmental measurement program Hydrological extremes (HQ, NQ)

Trigger thresholds in Germany

Extension to the complete catchment desirable
What’s new?

Technical innovation
- Novel sensors (automation, miniaturization)
- Sensor networks
- Valuation of digitalization progress

Scientific innovation
- Short- and long-term behaviour of discharge, water storage, water quality, ecosystem status beyond of average trends
- Improved understanding of consequences of climate change and other dynamics
- Event chains in coupled environmental systems (z.B. inland-coast-ocean)

Social relevance
- Hydrological extremes are of regional, national, European and global importance with far reaching consequences for humans and environment
- Climate change/water (extremes) are regarded as No 3 of global risks by the World Economic Forum (after under-/unemployment and failed states/migration)