The Low-Flow Year 2018 in Germany

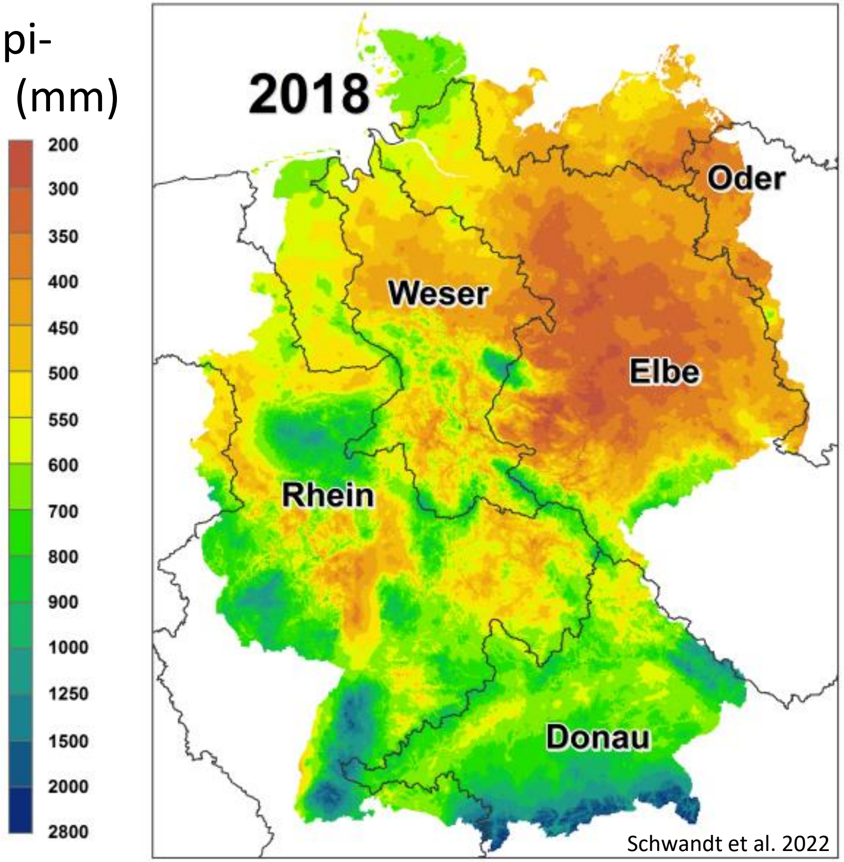
Impact, Hydrological Analysis and Management Approaches

Martin Helms, Axel Keeß, Dennis Meißner and Enno Nilson

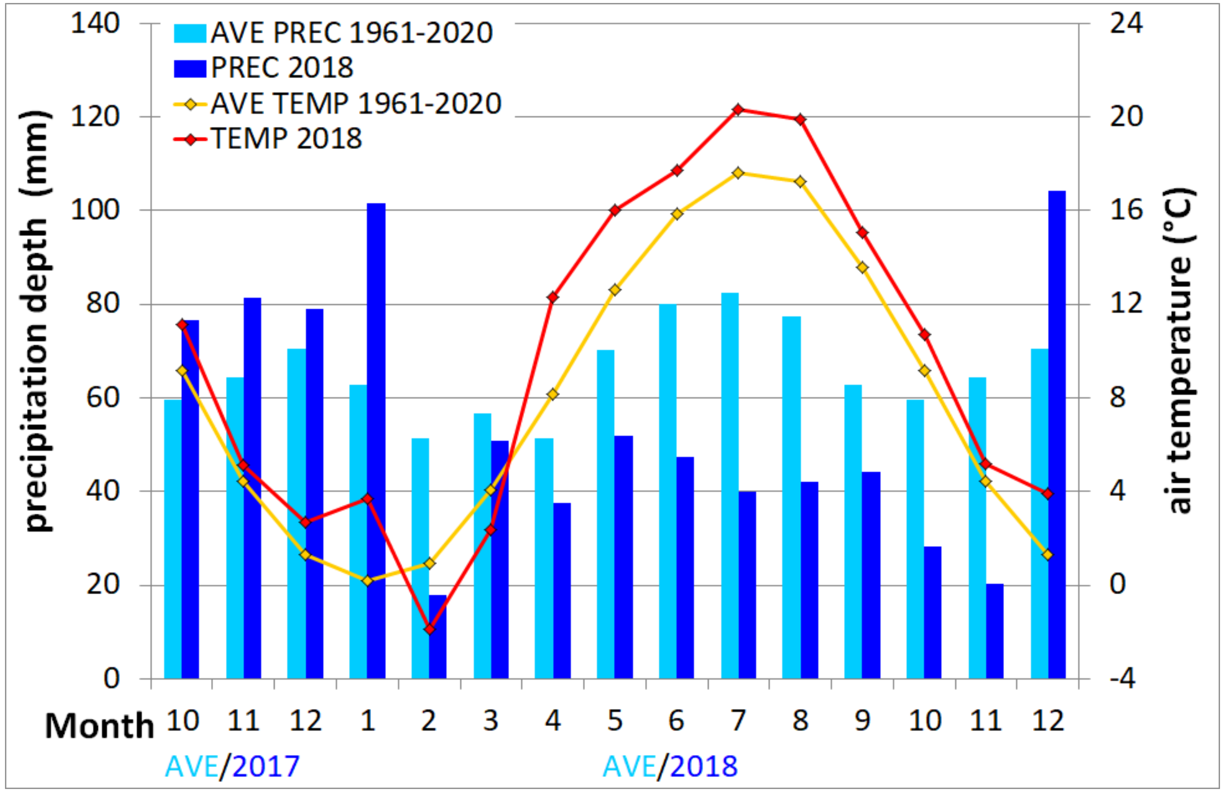
Federal Institute of Hydrology, Germany

The low-flow year 2018 in Germany - meteorology

annual precipi-
tation depth (mm)



Mean monthly precipitation depths and air temp. (Germany)

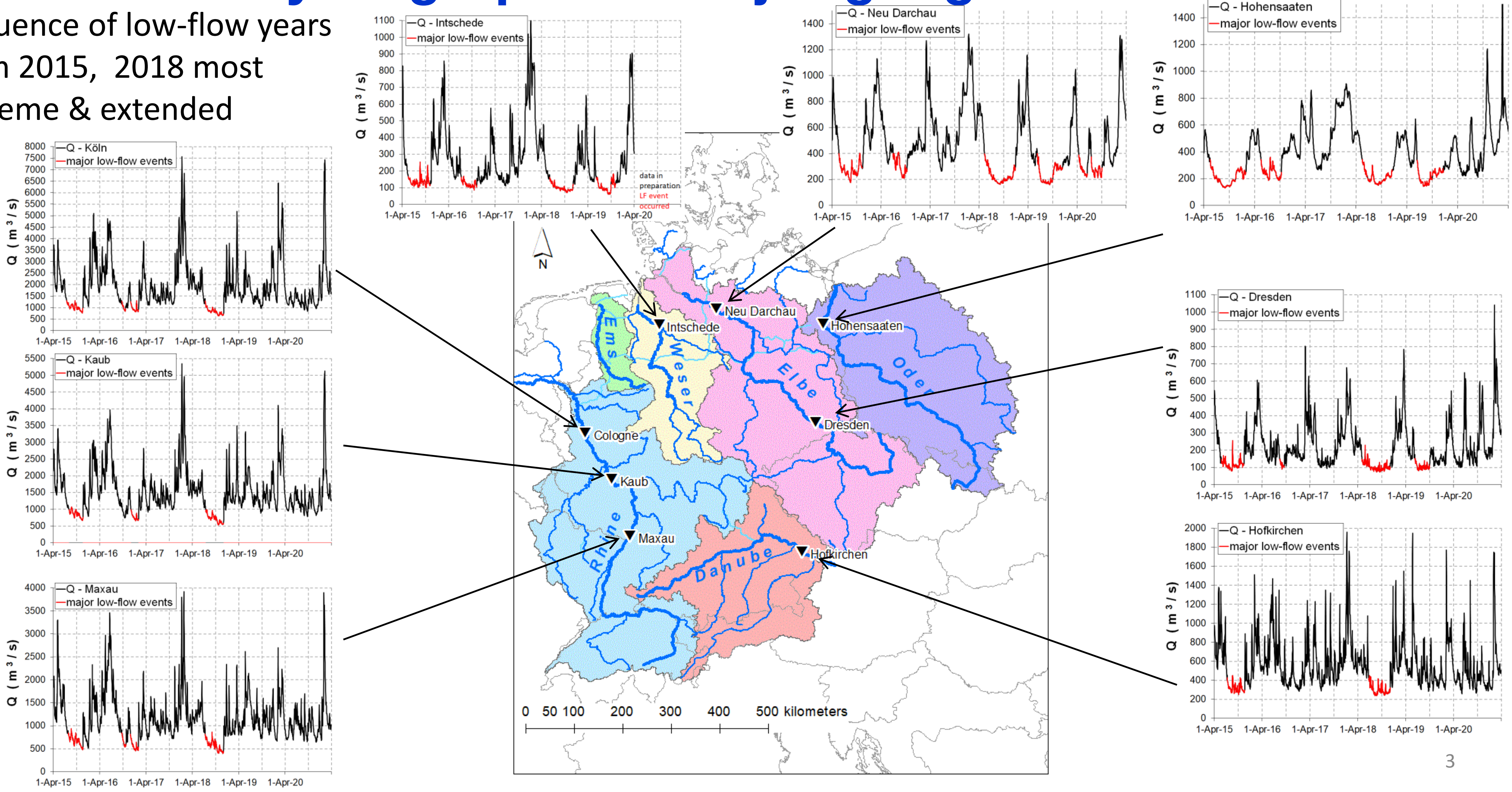


- beginning of the year wet
- Feb. - Nov.: precipitation depths continuously and clearly below average
- Apr. - Dec.: temperatures (partly much) higher than average

→ drought, especially in the North-East, but also in other parts of Germany

The low-flow year 2018 at German rivers – streamflow hydrographs at major gauges

Sequence of low-flow years from 2015, 2018 most extreme & extended

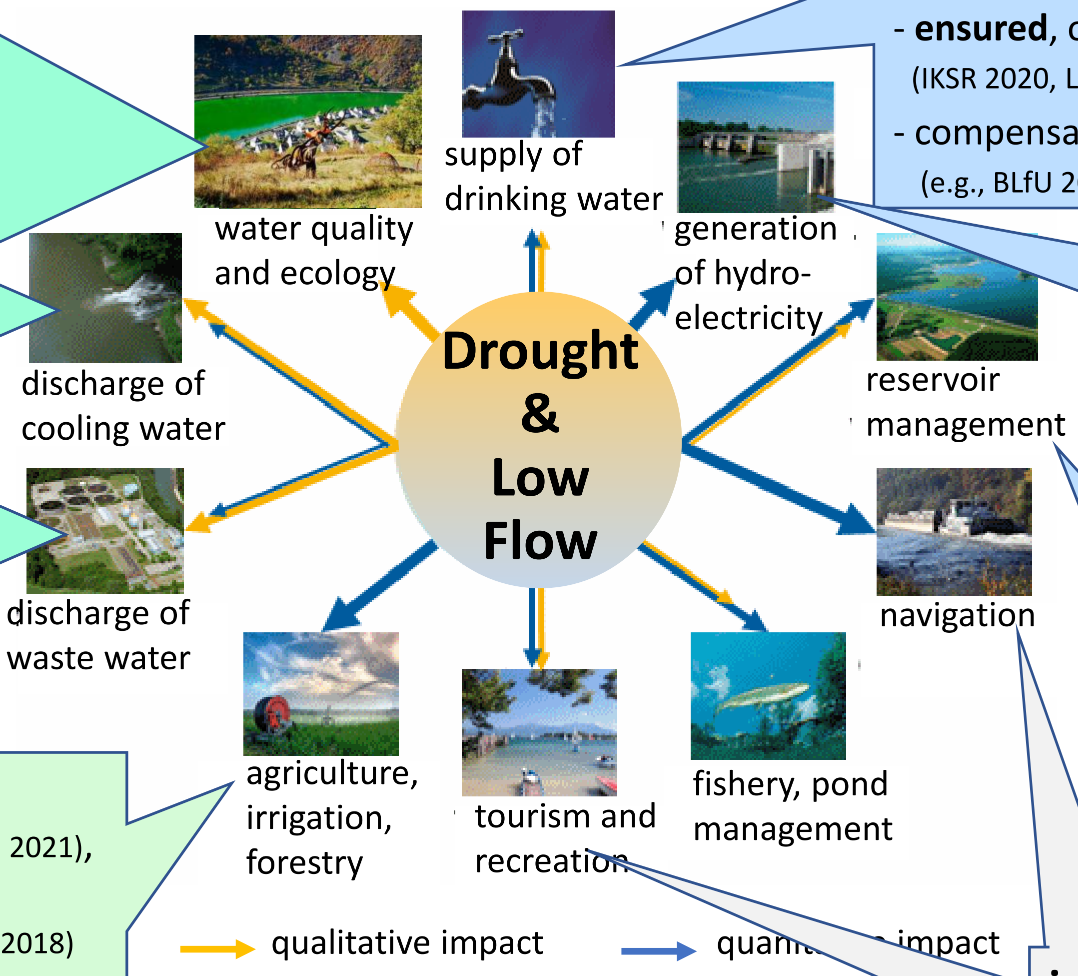


Drought & low-flow 2018 in Germany – impacts

bfg Bundesanstalt für Gewässerkunde

water status, water quality:

- high proportion of **clear water** (BLfU 2020)
- high **subst. concentrations**, esp. on Lower Rhine, Ems, Elbe. In parts, high conc. of heavy metals and drugs (BfG 2021, IKSR 2020).
- widespread and persistent **high water temperature** (>25°C). Middle Rhine: seven weeks continuously (IKSR 2020)
- **reduced oxygen conc.**, mostly not critical, aeration measures at regul. rivers (IKSR 2020)
- **red. performance** of th. power plants and industry (**cool. wat.**) (Riedel et al. ‘21, IKSR ‘20)
- **phytoplankton** developmt. in some rivers, **cyanobacteria** in regulated Mosel until 2d half of Oct. (BfG 2021, IKSR 2020, LfU RP 2019)
- **narrowed habitats** (BLfU 2020, LfU RP 2019)



Source: BLfU - Bayerisches Landesamt für Umwelt 2015

(drinking) water supply:

- **ensured**, only few local shortages in vuln. regions (IKSR 2020, LfU RP 2019, Riedel et al. 2021, BLfU 2020)
- compensations by (remote) supply networks (e.g., BLfU 2020)

hydroelectricity:

- **reduction**, mainly in smaller rivers (maintenance of ecol. continuity) (Riedel et al. 2021, IKSR 2020)

reservoirs, water transfer systems:

- **high usage rate** of storage capacities, partly with adapted operation rules (e.g., BLfU 2020, IKSR 2020);
- **essential functions still fulfilled** (drinking water, ecological minimum flow)

agriculture:

- **yield loss** often 15-20 % (BMEL 2018, Riedel et al. 2021), partly higher, estimated total loss > 3 bn. €, gov. aid program in critical cases (Awater-Esper 2018)

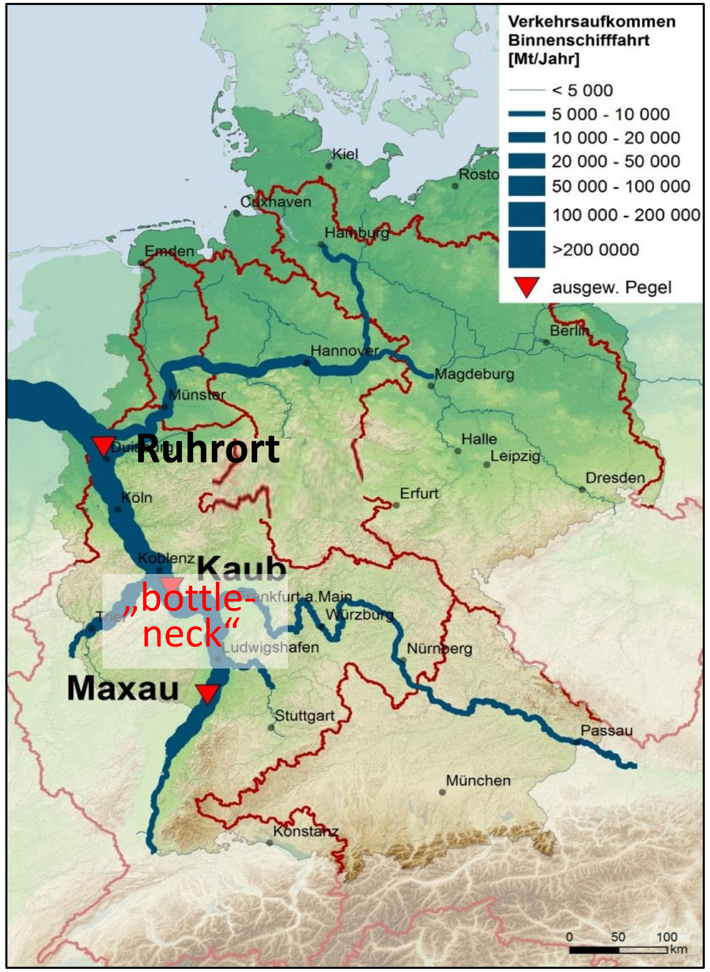
forestry:

- **damage** due to dryness, pest infestation, fire
- 2% of forests to be reafforested after 2018/19 (BMEL 2020, Riedel et al. 2021)

inland navigation:

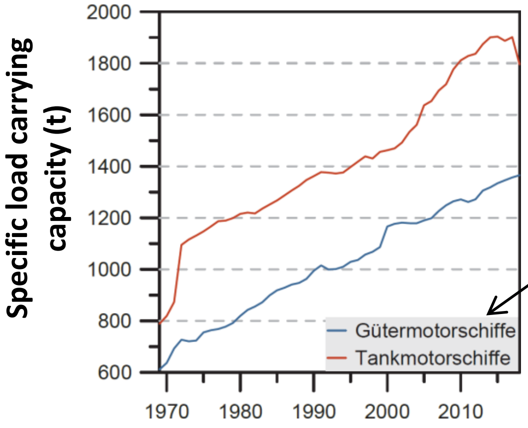
- **early season cancellations** in excursion shipping (e.g., Weser: 2018, ’19 and ’20)
- adverse effects on **transport of goods** …

Low-flow 2018 – impact on inland navigation and industrial production

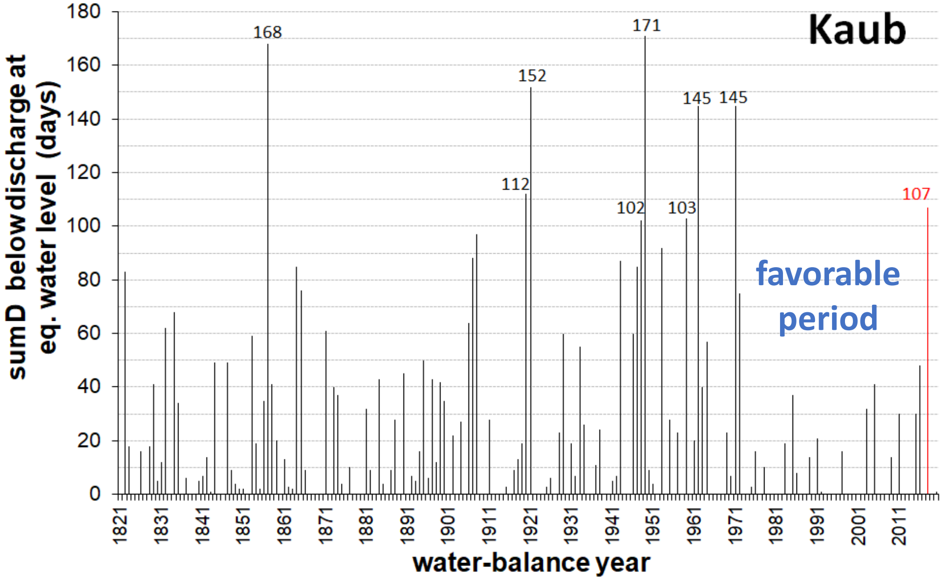


German waterways and freight traffic volumes 2010 (in million tonnes)

- **Inland navigation** with 6 % of freight transport in Germany, for some goods up to 30 % (coal, oil, gas)
- **2018:** reduced loading capacities, high transport costs, transport losses, esp. at the Rhine (80% of German inland water transport)
  → **Rhine & tributaries:**
  - 15 % of freight transport vs. 2017 (Riedel et al. 2021)
- Other transport modes also affected (fuel shortage)
- Concerned **goods at the beginning of production chains**
  → losses in industrial production, at least 2 bn. € (IfW 2018, Destatis 2022)
- In particular, **chem. industry** affected: BASF with 250 m. € loss of revenue due to restrictions in transport and use of cooling water (IKSR 2020)

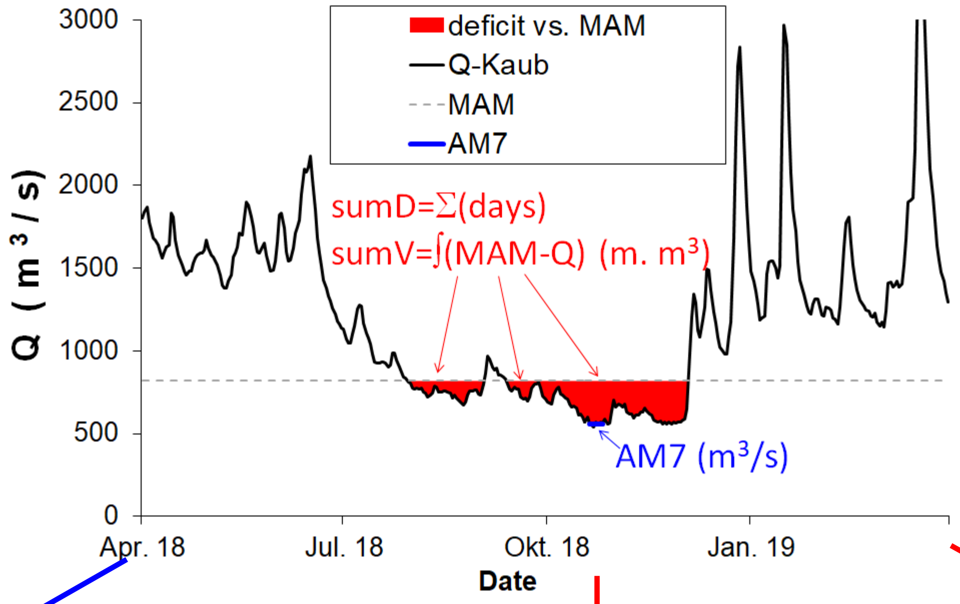


Average sizes of German inland vessels (data: WSV 2019

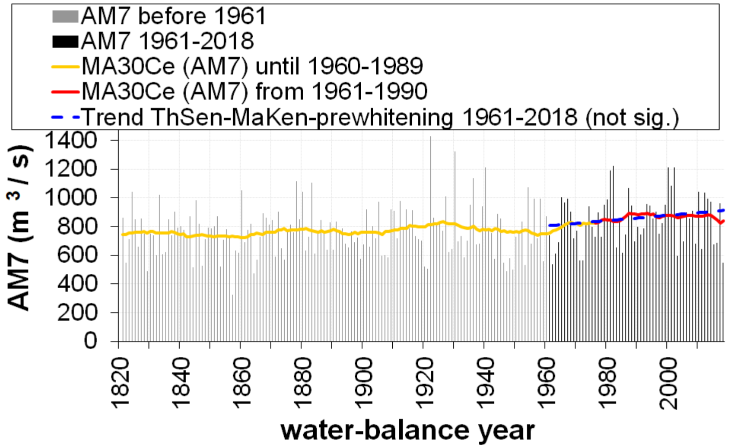


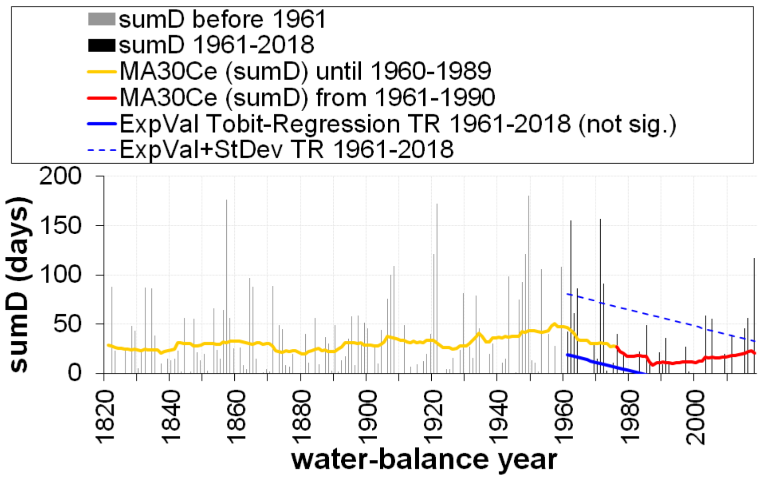
Low-flow indices and longterm series

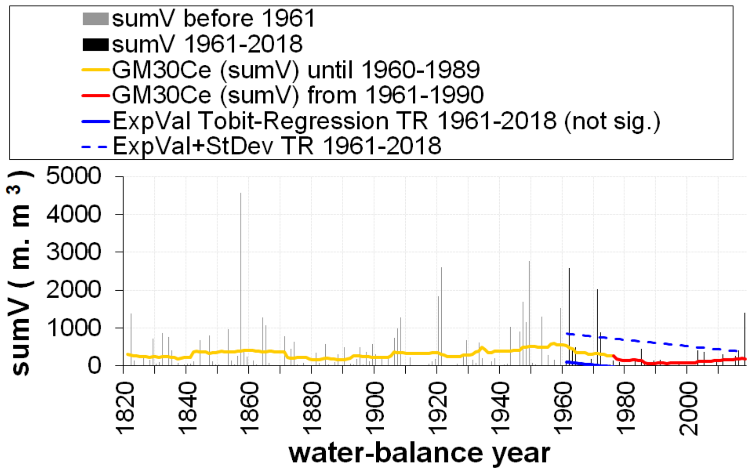
- here: Rhine gauge Kaub
- series1961-2018 for synoptic analysis at various German gauges
- observed overall series from 1821 as reference (including historical extremes)



Longterm variability, no significant trend 1961-2018



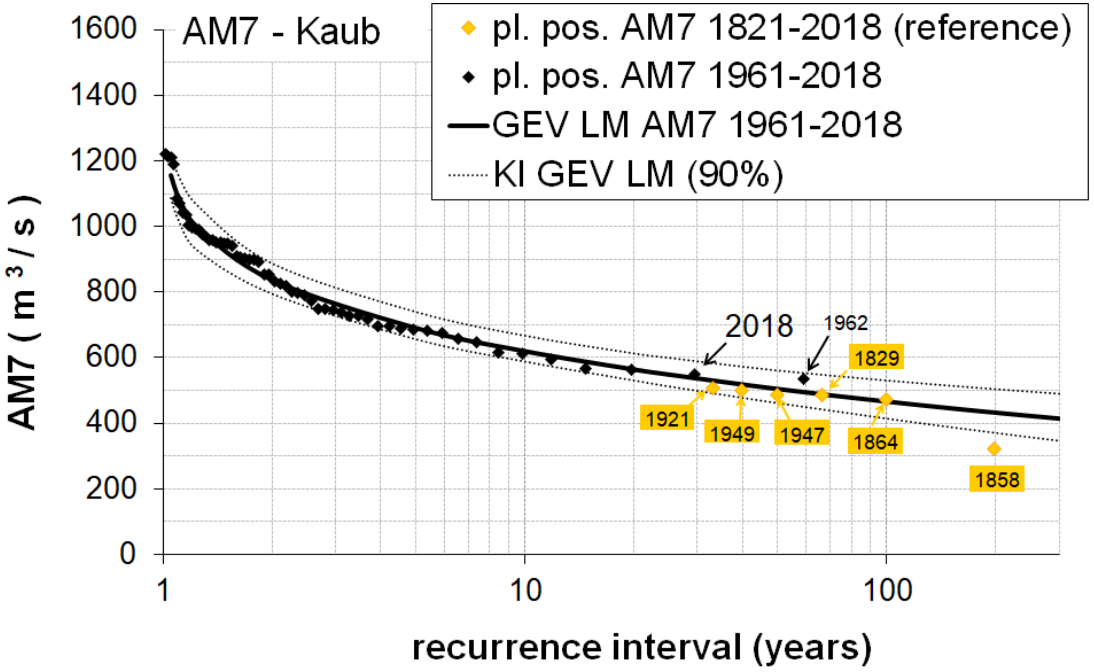


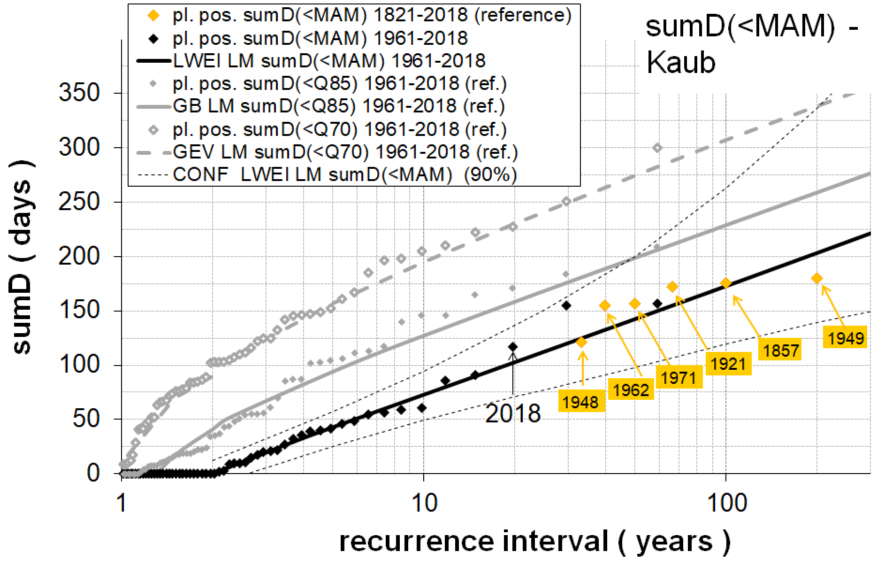


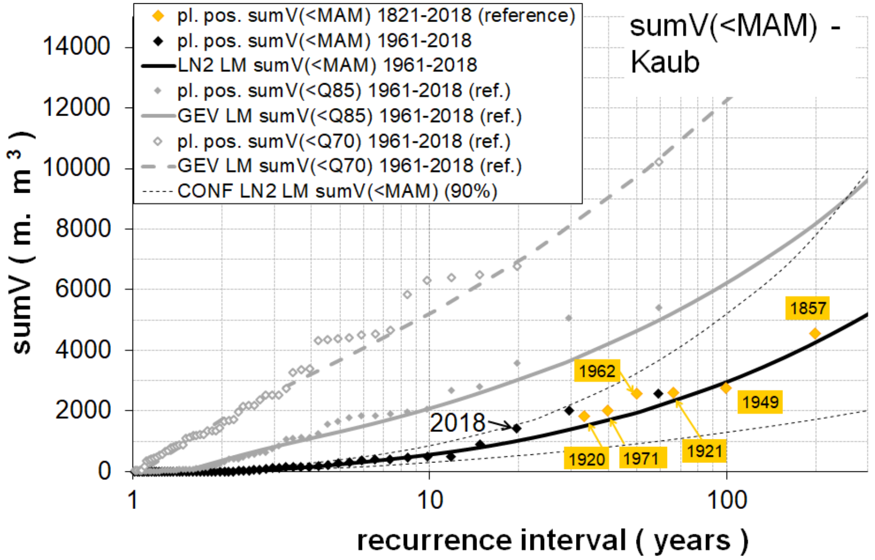
+ sumD- and sumV-series for Q70 and Q85 thresholds (reference)

Extreme-value analyses – fit of cdf's

- Rhine gauge Kaub
- for series 1961-2018: selection, fit & diagnosis of cdf's
- information expansion using reference series and hydrological reasoning to support extrapolation:
  - temporal: including historical extremes
  - causal: graded thresholds (sumD, sumV)







Extr.-val. analyses – quantiles, recurrence intervals

Index		Hohensaaten (Oder)	Intschede (Weser)	Dresden (Elbe)	N. Darchau (Elbe)	Maxau (Rhine)	Kaub (Rhine)	Köln (Rhine)	Hofkirchen (Danube)
AM7 [m³/s]	T=5 J.	196	101	102	226	536	691	831	285
	T=10 J.	170	88,2	92,4	199	479	620	752	264
	T=20 J.	150	78,8	85,5	179	432	564	692	248
	T=25 J.	145	76,3	83,6	174	418	549	674	243
	T=50 J.	130	69,1	78,3	159	379	505	627	231
	T=100 J.	117	63,2	73,8	146	345	466	586	220
	T=200 J.	107	58,0	69,9	135	314	432	550	210
	2018	**154**	**75,9**	**82,8**	**166**	**418**	**548**	**656**	**245**

Index		Hohensaaten (Oder)	Intschede (Weser)	Dresden (Elbe)	N. Darchau (Elbe)	Maxau (Rhine)	Kaub (Rhine)	Köln (Rhine)	Hofkirchen (Danube)
sumD (<MAM) [days]	T=5 J.	84	51	28	59	39	43	42	28
	T=10 J.	123	83	56	101	72	73	71	57
	T=20 J.	157	114	91	140	106	103	101	87
	T=25 J.	167	124	104	151	117	112	110	97
	T=50 J.	197	155	147	184	150	142	142	129
	T=100 J.	225	185	192	213	181	173	174	161
	T=200 J.	251	216	237	237	208	203	208	194
	2018	**185**	**158**	**162**	**193**	**105**	**117**	**126**	**116**

Index		Hohensaaten (Oder)	Intschede (Weser)	Dresden (Elbe)	N. Darchau (Elbe)	Maxau (Rhine)	Kaub (Rhine)	Köln (Rhine)	Hofkirchen (Danube)
sumV (<MAM) [m. m³]	T=5 J.	191	43	20	180	193	246	296	43
	T=10 J.	398	111	51	380	430	566	665	121
	T=20 J.	675	219	98	605	733	1037	1204	258
	T=25 J.	782	262	118	705	847	1228	1421	318
	T=50 J.	1175	424	196	1030	1258	1964	2255	568
	T=100 J.	1675	620	306	1385	1765	2959	3376	938
	T=200 J.	2301	841	456	1780	2384	4273	4849	1466
	2018	**942**	**405**	**271**	**1350**	**974**	**1404**	**2077**	**434**

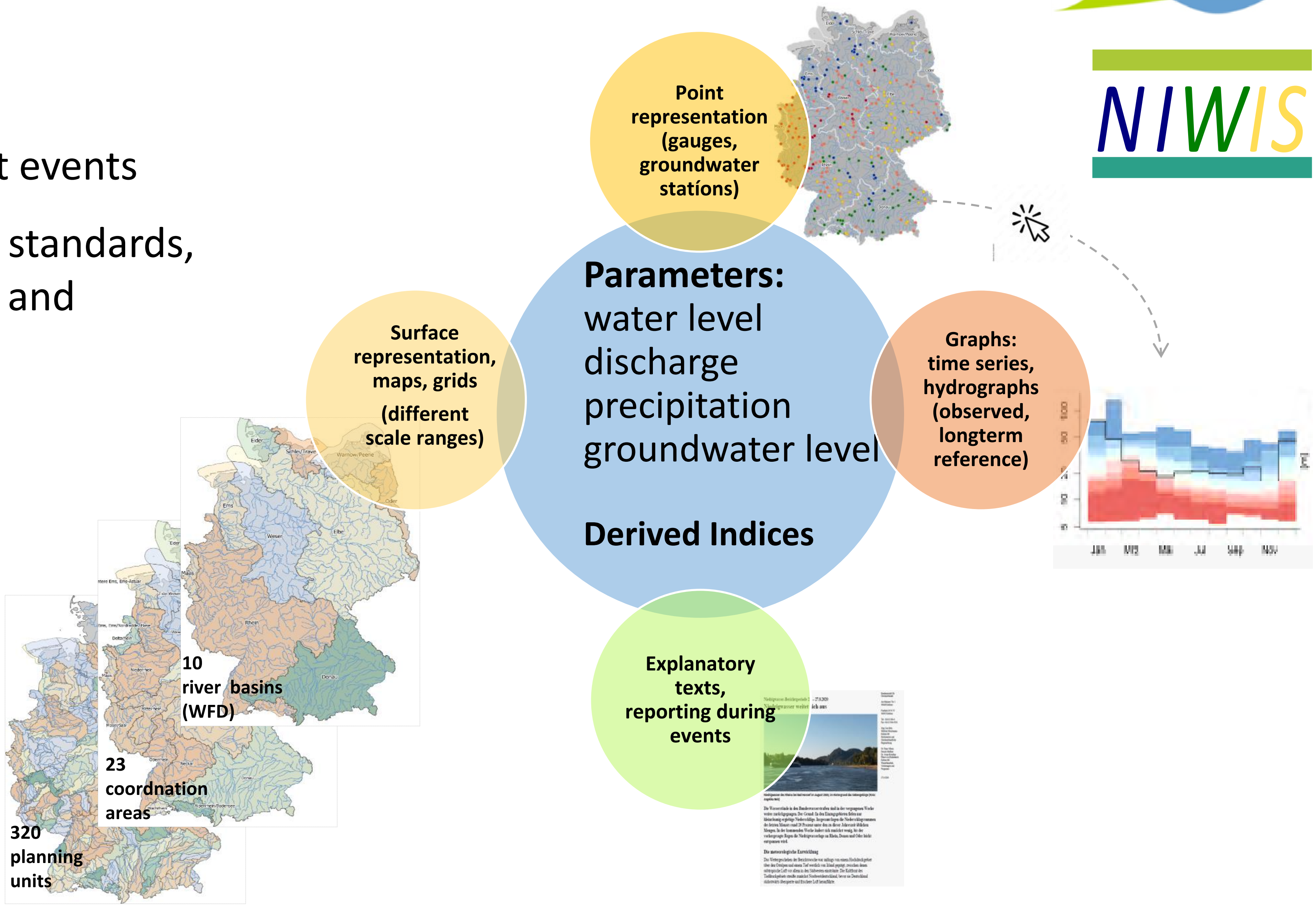
- Low Flow 2018 was a rare event, but has a certain recurrence probability.

→ need of preparedness to mitigate low-flow risks

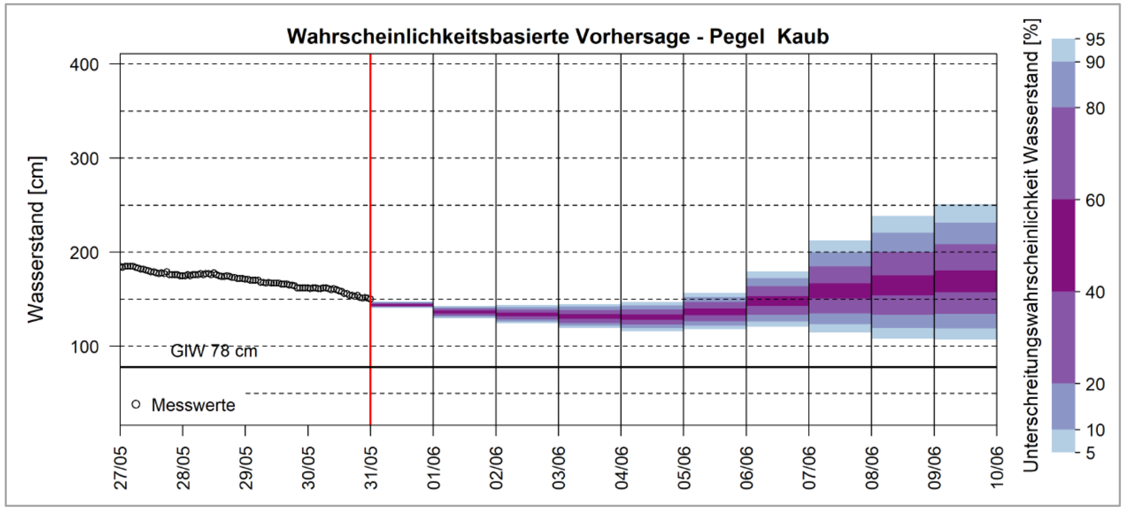
→ intensified research and development of low-flow related products.

Development of a low water information system

- synoptic representation of current hydrological state, in particular during drought events
- Interregionally comparable standards, harmonized among federal and state authorities (common classification schemes).
- Currently in development, implementation planned for 2025.

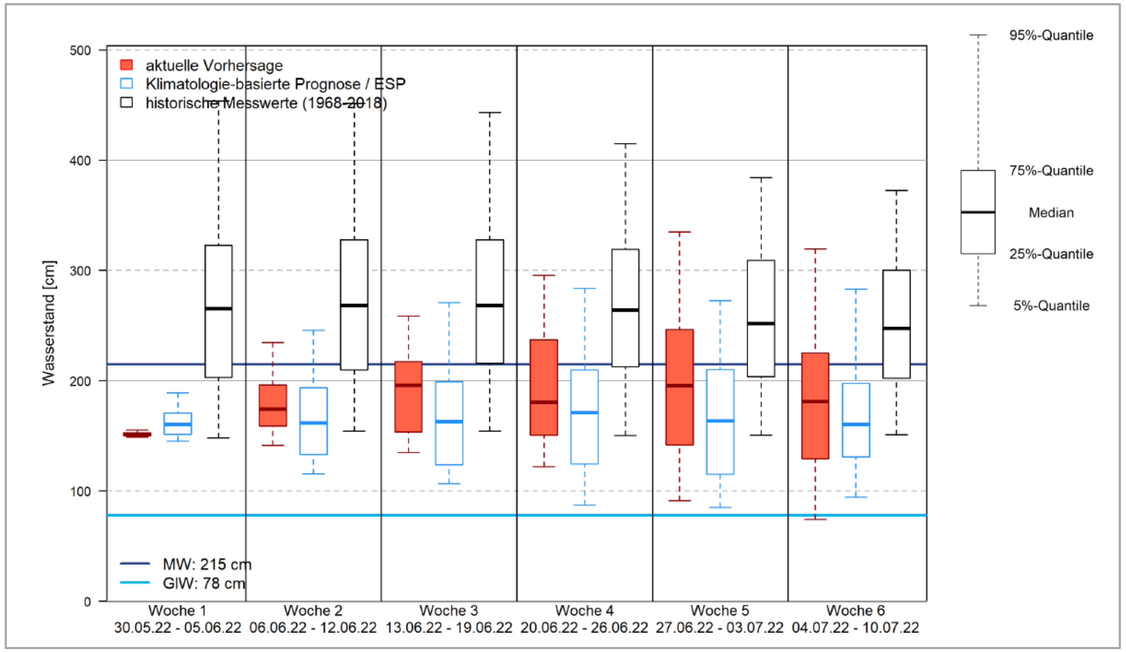


Forecast tools with increased lead time (BfG, ELWIS)



10-day-forecast for the Rhine

- operational since December 2019
- first probabilistic product for German waterways
- for daily water-levels with graded confidence intervals (representing a forecast ensemble)
- extension to 14 days lead time in July 2022

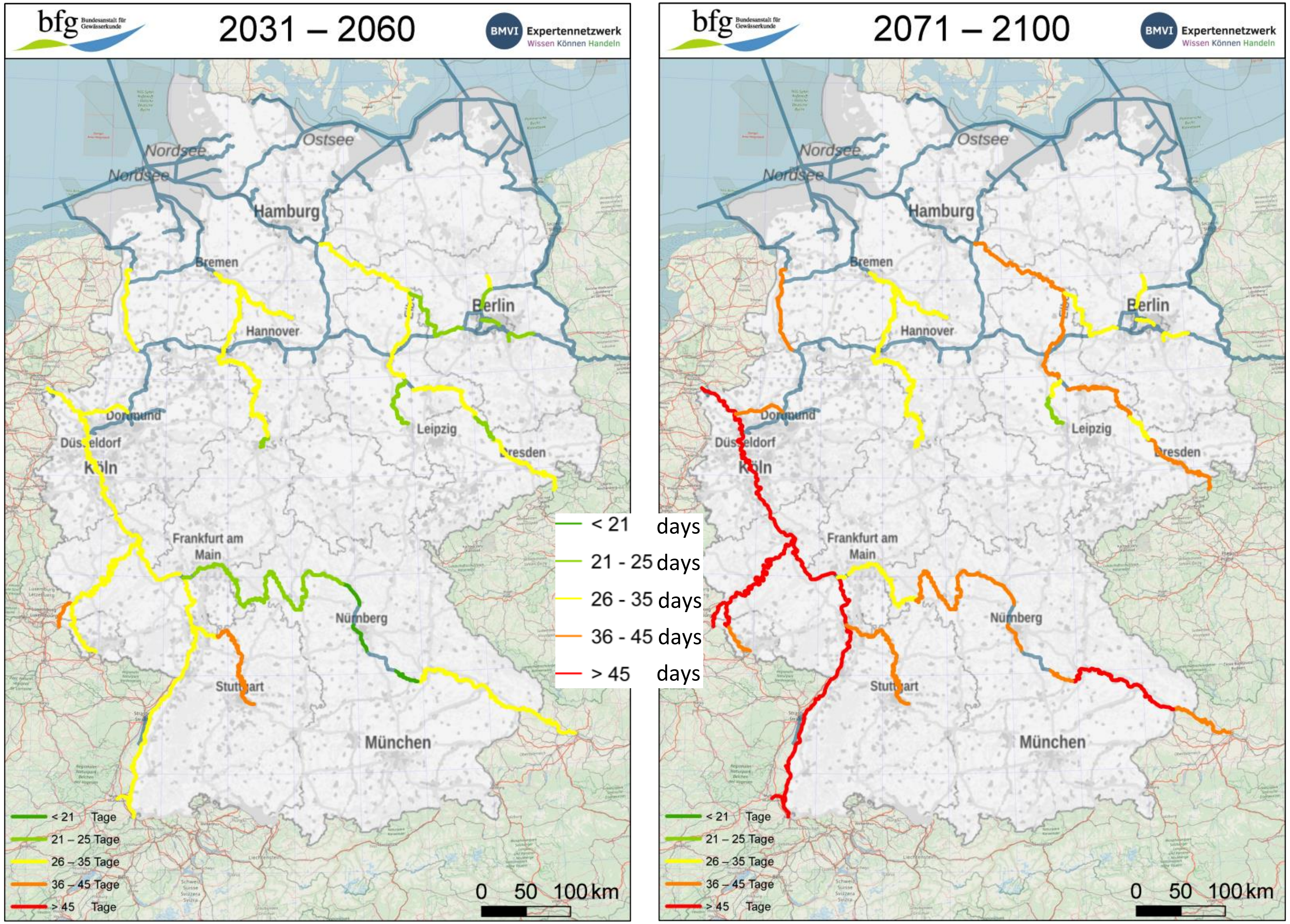


6-week-forecast for Rhine and Elbe

- pre-operational, becoming operational in July 2022
- for weekly mean values (discharge + water level) in box plots (forecast ensemble)
- current forecast (red) & seasonal reference ensembles based on historical meteorol. observations and hydrological simulation (blue) and historical gauge series (black)

Future projection for German rivers / fed. waterways

- annual sumD (<$Q_{20d/a,\ 1971\text{-}2000}$)
- high emission scenario RCP 8.5
- ensemble of 16 simulations (GCMs & RCMs & LARSIM ME)
- high estimates (85% quantiles) of mean sumD in the ensemble's individual simulation runs for:
- middle of 21st century: mostly moderate increase vs. ref. period
- end of 21st century: sig. increased sumD vs. ref. period, especially at Rhine and Danube.
- 85% qtl.: rather pessimistic case, but certain probability



Conclusion

- extreme drought & low flow 2018 were part of a sequence of drought years 2015-2019
- decades before less concerned by extreme low flow (“favorable period”)
- multiple adverse impacts on water resources and ecology, severe economic losses esp. in 2018, e.g., with regard to inland waterway transport (esp. Rhine) and dependent production chains
- BfG intensified low-flow related activities to quantify low-flow hazards and to mitigate potential risks by:
    - statistical analysis and classification (to be continued …)
    - developing an information system (NIWIS, to be implemented in 2025)
    - provision of forecasts, scenarios and future projections

    …
    - integration in comprehensive risk mitigation and adaptation concepts, e.g., FMDT-“Action Plan Low Water Rhine” including further measures of
        - information provision,
        - optimizations in transport, logistics and infrastructure,
        - investigation of options in hydraulic eng. and wat. res. management,
        - stakeholder dialogue.

Further information: UBA 26/2021: Climate Impact and Risk Assessment 2021 for Germany
https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/cc_27-2021_climate_impact_and_risk_assessment_2021_for_germany_english_summary_bf.pdf

UBA 174/2021: Riedel, Th. et al. (2021): Niedrigwasser, Dürre und Grundwasserneubildung …
https://www.umweltbundesamt.de/publikationen/niedrigwasser-duerre-grundwasserneubildung