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Probabilistic 6-week-forecasts for the German waterways

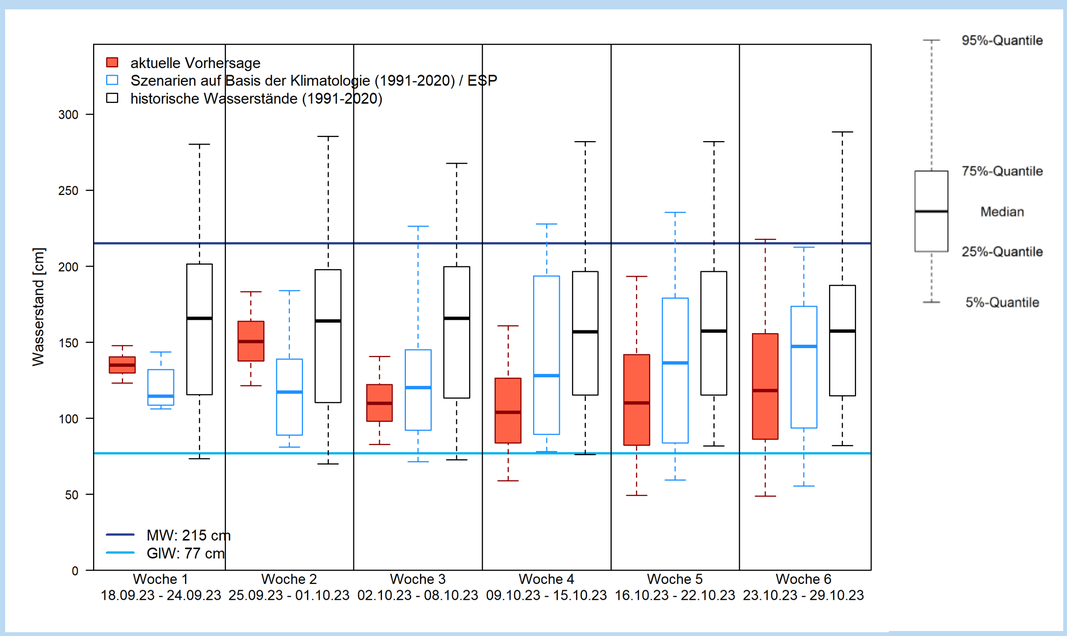
Sub-seasonal forecasting services supporting navigation, logistics and waterway maintenance

Background

As recent years have shown, inland waterways are prone to hydroclimatic impacts: Dry spells, like in 2003, 2015, 2018 or 2022 significantly affected freight transport as well as passenger shipping along Central Europe's major inland waterways, like the River Rhine. Therefore, the need for corresponding forecast information significantly increased to support waterway transport and the corresponding logistical decisions as well as anticipatory waterway management.

Over the past years the Federal Institute of Hydrology (BfG), which is in charge of developing and maintaining the navigation-related forecasting systems for the German inland waterways, has developed medium-range to sub-seasonal hydrological forecast products and related services. In July 2022 the 6-week-forecast for relevant gauges at the major waterways Rhine and Elbe became operational [1]. Extending the 6-week-forecast to further waterways, like Danube and Weser, as well as the development of seasonal forecast products is current work in progress.

At a glance



Forecast gauges
Rhine: Maxau, Kaub, Cologne, Duisburg-Ruhrort
Elbe: Dresden, Barby, Neu Darchau

6-Wochen-Vorhersage

Forecast frequency
Twice a week (Tuesday, Friday)

Forecast products
Probability distribution of weekly mean values presented as box-plots and pie charts for water-level and discharge

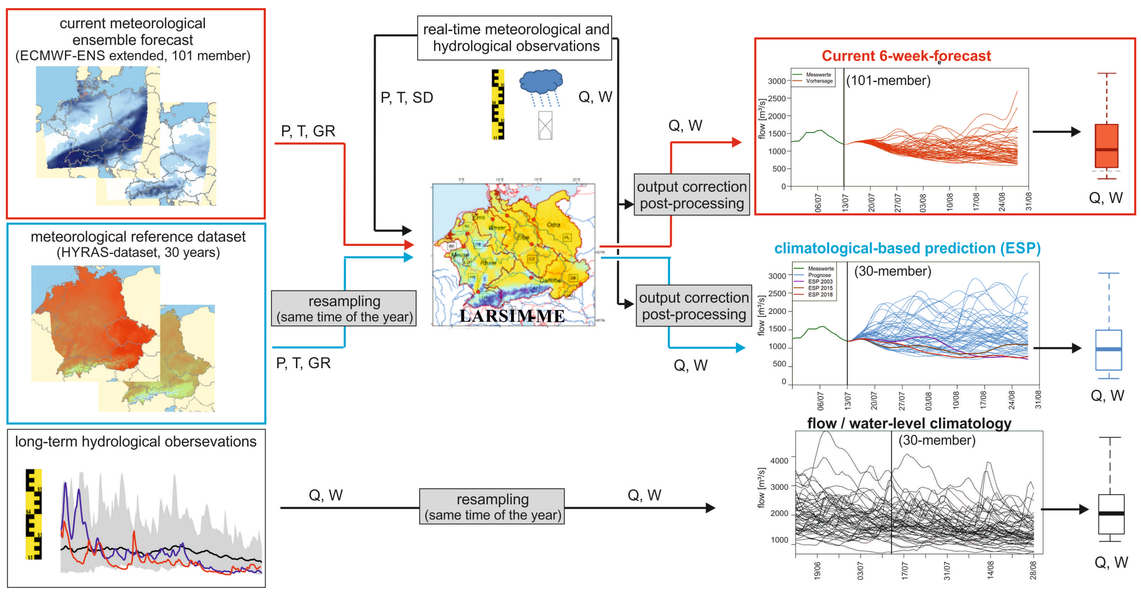
Meteorological forcing
- ECMWF Extended-range forecast
- Resampled climatology based on HYRAS-data from DWD

Forecast access
- Forecast reports: www.elwis.de (River Information Service)
- Web-Application: https://6wochenvorhersage.bafg.de/

6-Wochen-Vorhersage Web-App

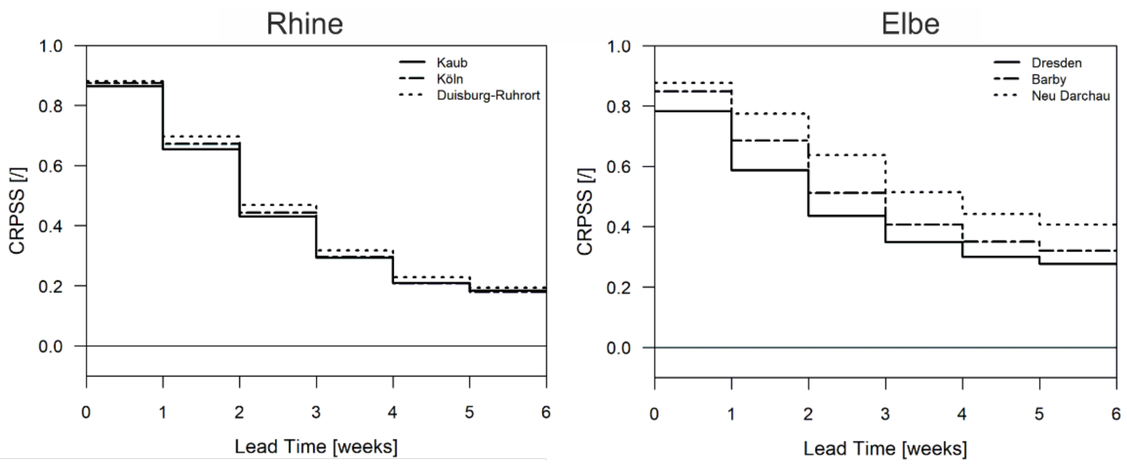
Workflow

In addition to the main forecast workflow using the ECMWF-ENS extended forecasts as input to the water balance model LARSIM-ME (5 x 5 km), two references are generated within the forecast workflow: A forecast based on climatological input following the ESP approach is provided together with a resampling of the historical water levels / discharges at the same time within the reference period (30 years). The whole forecast workflow is implemented in the widely-used Delft-FEWS forecasting framework in a client-server environment [1].



Skill

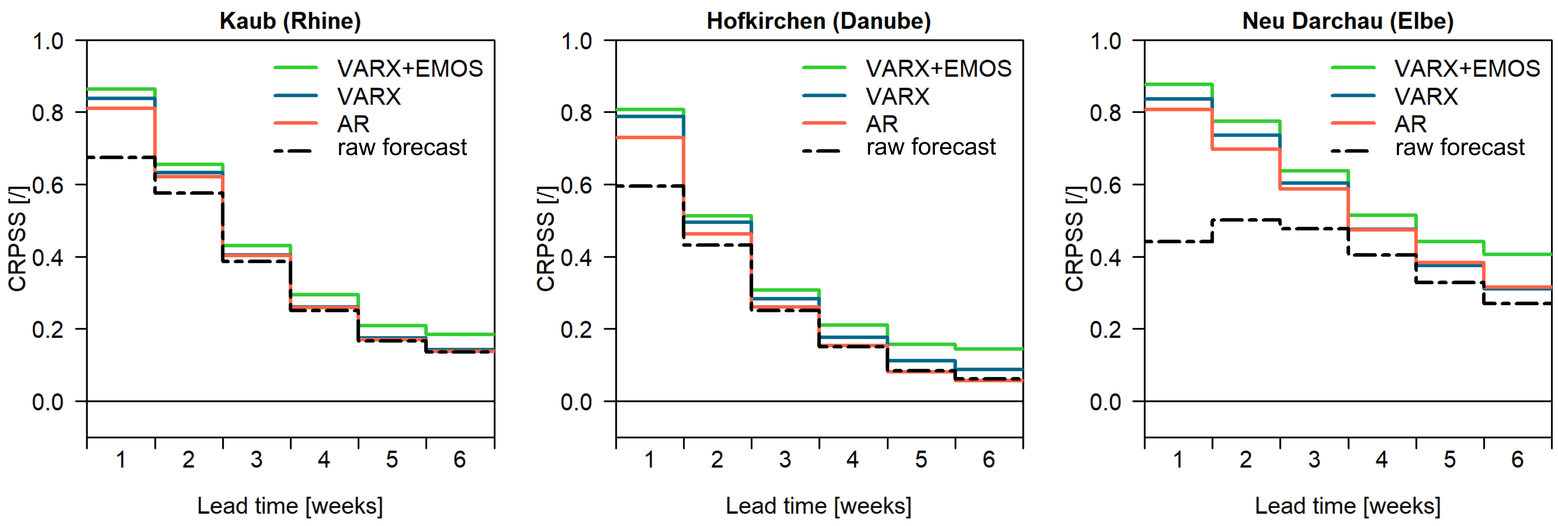
Although the hydro-meteorological predictability is limited compared to other parts of the world, the hydrological 6-week-forecast provides skillful forecasts at all gauges at Rhine and Elbe being relevant for navigation. Overall, the forecast skill for the Elbe has turned out to be higher than that for the River Rhine as the latter is much more dominated by relatively fast-reacting tributaries compared to the Elbe. At the Elbe, the forecast performance significantly increases in the downstream direction. At both rivers forecast skill shows moderate seasonal effects, like snow accumulation or snow melt in early winter and spring / early summer respectively [1, 2].



CRPSS: Continous ranked probability skill score using climatology as reference forecast

Validation period: March 2016 to March 2022 (two forecasts per week)

Improvements by post-processing



Validation period: March 2016 to March 2022 (two forecasts per week)

Proper postprocessing proved to be a key element to generate skill- and useful sub-seasonal forecasts for the German waterways. Hindcast analysis proved that the hydrological forecasts for Rhine, Elbe and Danube on a weekly-mean basis already have an overall skill compared the climatology at least for the first three weeks without using statistical postprocessing or data assimilation [2].

Besides an autoregressive output correction (AR) a wavelet-based approach (VARX-Wavelet) as well as the postprocessing method EMOS [3, 4, 5] have been implemented to further increase the predictive skill. The intercomparison based on hindcasts show significant improvements compared to the raw forecasts, as well as differences depending on the selected catchment and forecast season. Overall, the VARX-Wavelet correction in combination with EMOS leads to the best forecast skill along the whole forecast horizon. A post-processing of the meteorological forecast based on hindcasts is an option to be investigated in future.

BfG Bundesanstalt für Gewässerkunde

Literature:

[1] Meißner, D., Klein, B., Frielingsdorf, B. (2022): Implementing Hydrological Forecasting Services Supporting Waterway Management and Transportation Logistics Relating to Hydroclimatic Impacts. Atmosphere 2022, 13, 1606. https://doi.org/10.3390/atmos13101606
[2] BfG (2022): Entwicklung längerfristiger hydrologischer Vorhersageprodukte im Rahmen der Forschungs- und Entwicklungsprojekte Seamless Prediction II und IMPREX. BfG-Bericht 2026. http://doi.bafg.de/BfG/2020/BfG-2026.pdf
[3] Bogner, K. & Pappenberger, F. (2011): Multiscale error analysis, correction, and predictive uncertainty estimation in a flood forecasting system. WATER RESOURCES RESEARCH, VOL. 47, W07524, doi:10.1029/2010WR009137
[4] Gneiting, T., Raftery, A.E., Westveld, A.H., Goldman, T. (2005): Calibrated probabilistic forecasting using ensemble model output statistics and minimum CRPS estimation. Monthly Weather Review 133(5). 1098-1118.
[5] Hemri, S. & B. Klein (2017): Analog-Based Postprocessing of Navigation-Related Hydrological Ensemble Forecasts. Water Resources Research 53(11), 9059-9077 https://dx.doi.org/10.1002/2017WR020684