Applying the hydrological model framework HydPy for data assimilation in order to improve operational medium-range forecasts within the Rhine basin

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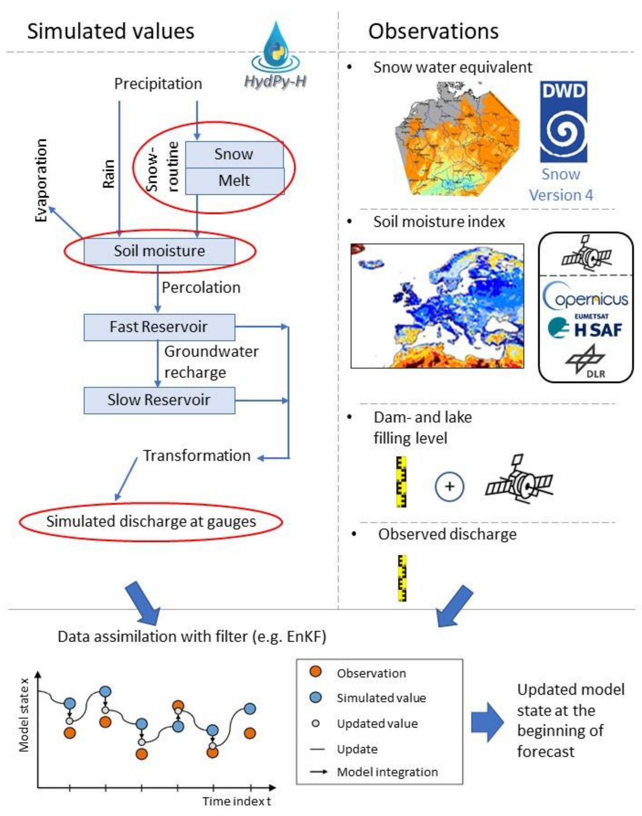
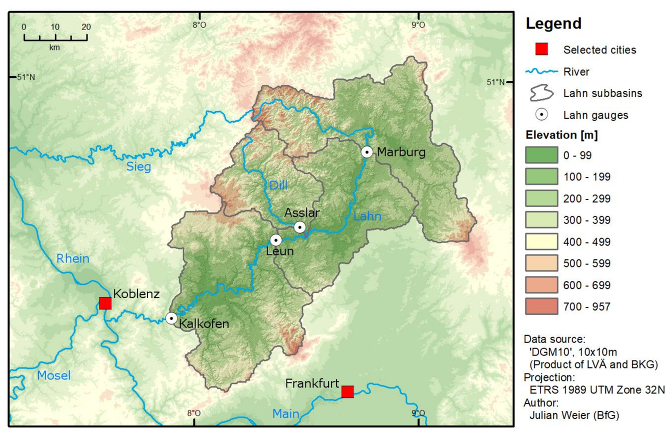
The Federal Institute of Hydrology (BfG) offers in cooperation with the Waterway and Shipping Administration operational hydrological forecasting services for about 3.000 km of Germany's inland waterways. The climatological and hydro-geological characteristics of the river basins vary significantly from alpine regions to the lowland areas next to the North Sea and the Baltic Sea. Therefore, the applied hydrological forecasting models have to account for much heterogeneity and offer much flexibility. Together with different partners, BfG subsequently developed the modelling framework HydPy[3] over the last ten years. This year HydPy will be applied operationally for forecasting tasks in the Rhine basin, in combination with OpenDA[4] and Delft-FEWS[5], for the first time.

Data assimilation



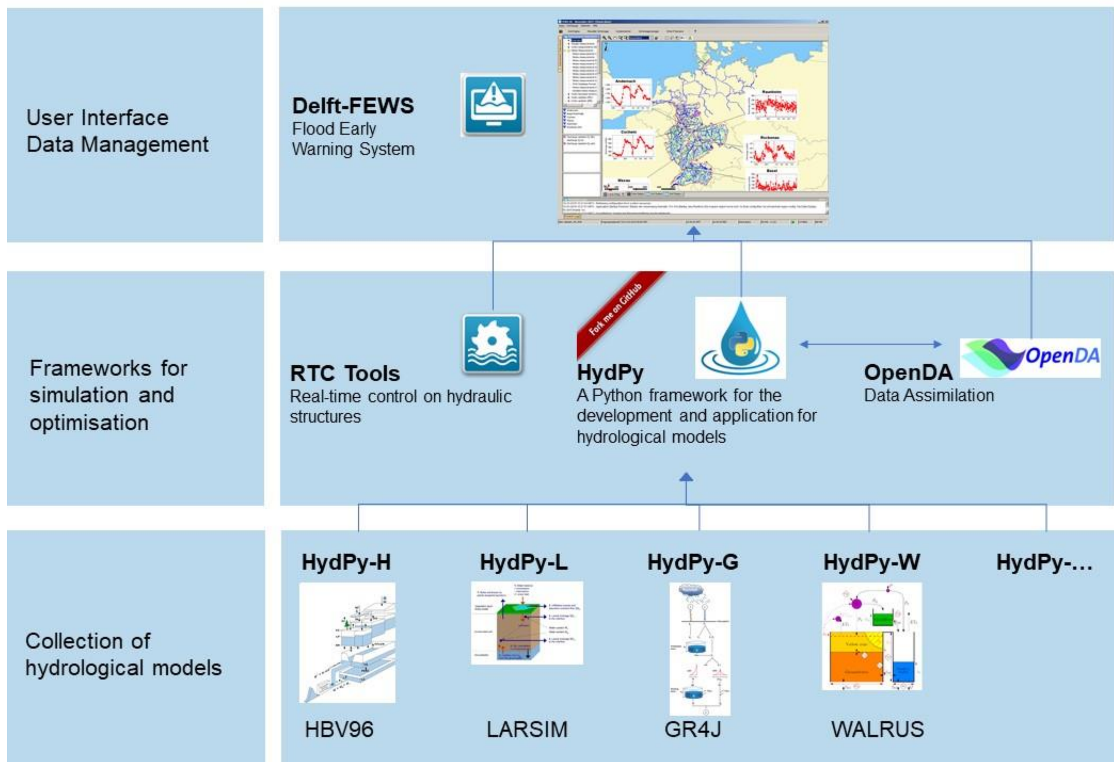
Planned assimilation workflow with a schematical HBV-model including the states to be updated (left top) and respective observations (right top)



Study area: Lahn basin (Characteristics (Kalkhofen): basin size: 5304 km², MQ: 45,9 m³/s)

We demonstrate the effect of applying data assimilation techniques in combination with the HydPy framework. In this study, we focus on the Lahn subbasin of the Rhine catchment representing a low mountain range on an intermediate scale. So far, observed discharge is used as the input dataset in the assimilation process to update the fast and slow reservoir of the HydPy-HBV model. The inclusion of the SNOW4 product produced by the German Meteorological Service (DWD) is currently done. Furthermore, we have scheduled to assimilate measured lake water levels and remotely sensed soil moisture data provided via Copernicus service as well as via EUMETSAT H-SAF. To facilitate the assimilation, we use the (Asymmetric) Ensemble Kalman Filter.

HydPy-Framework

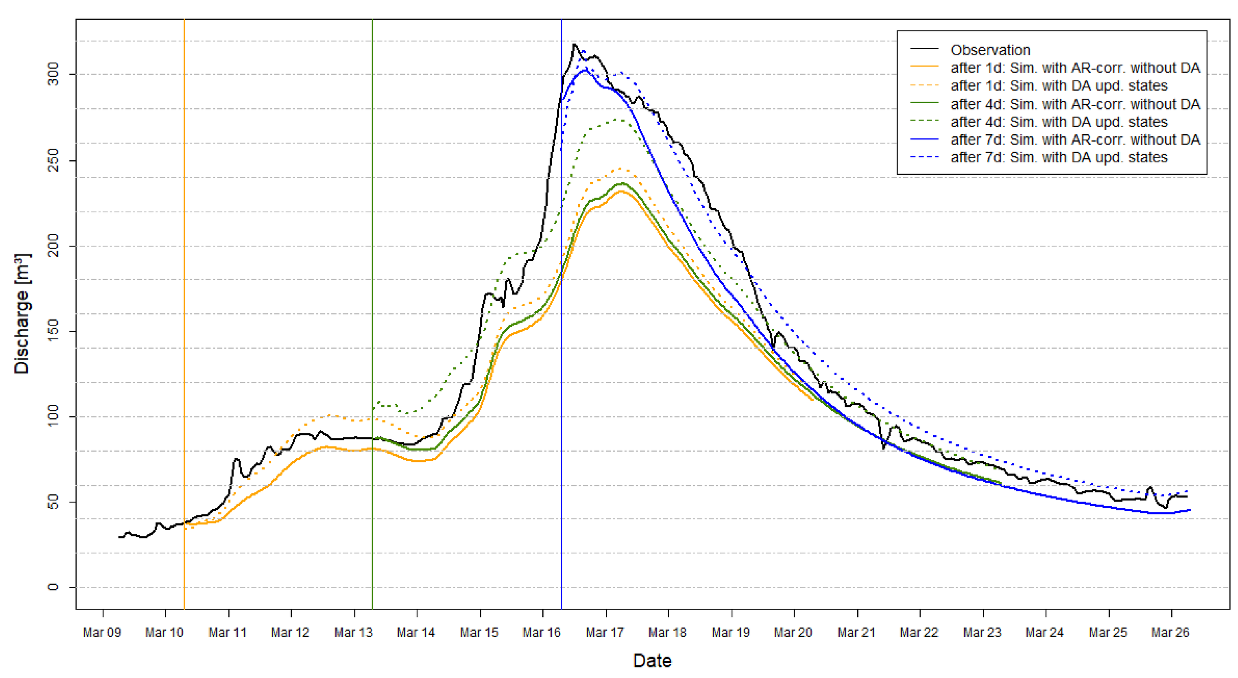


HydPy as a unifying interface for the seamless integration of multiple hydrological models in forecasting workflows.

HydPy is an interactive modelling framework developed in Python. Its main goal is the programmatic unification of conceptionally different hydrological models. All models implemented into the HydPy framework follow the same programming standards and subject to similar and rigorous testing. The unified design allows a single interface to connect one external methodology with multiple hydrological models. One example of such an interface is the OpenDA-HydPy wrapper. We use it to apply the data assimilation approaches implemented in the OpenDA software (e.g. the Ensemble Kalman Filter) on HydPy-H and HydPy-L, which are functionally similar to HBV96 and LARSIM, respectively. HydPy provides direct runtime access to all model states and fluxes, allowing for efficient and straightforward online coupling with data assimilation techniques.

Results

In this example, the time to peak of the flood hydrograph of all three forecast dates is hit better than without data assimilation, even by applying an autoregressive error correction. Particularly the decline of the hydrograph is more realistic with data assimilation. This example shows the clear advantage of "process-based" data assimilation of the storages of the hydrological model against statistical error correction methods estimated on the hydrological model error of the past. However, updating merely the linear storages of the hydrological model is not always sufficient during winter and spring. To take into account snow and its related processes, we are currently working on additionally updating the snow storage using the gridded SNOW4 product (DWD) for subbasins being located in low mountain ranges as well as in alpine areas.



Data assimilation example: Initiation of 10-day-prediction at three points of time with updates states (dotted lines) and without update but with autoregressive correction (continuous lines)

Flow hydrograph in March 2019 at gauge Kalkhofen Neu (Lahn)

Subfigures taken from

HBV96: Lindström et al., 1997
LARSIM: Ludwig and Bremicker, 2006
GR4J: https://wiki.ewater.org.au/display/SD41/GR4J+-+SRG
WALRUS: Brauer et al., 2014

Links

[3] https://github.com/hydpy-dev
[4] https://gitlab.com/deltares/rtc-tools
[5] https://oss.deltares.nl/web/delft-fews

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