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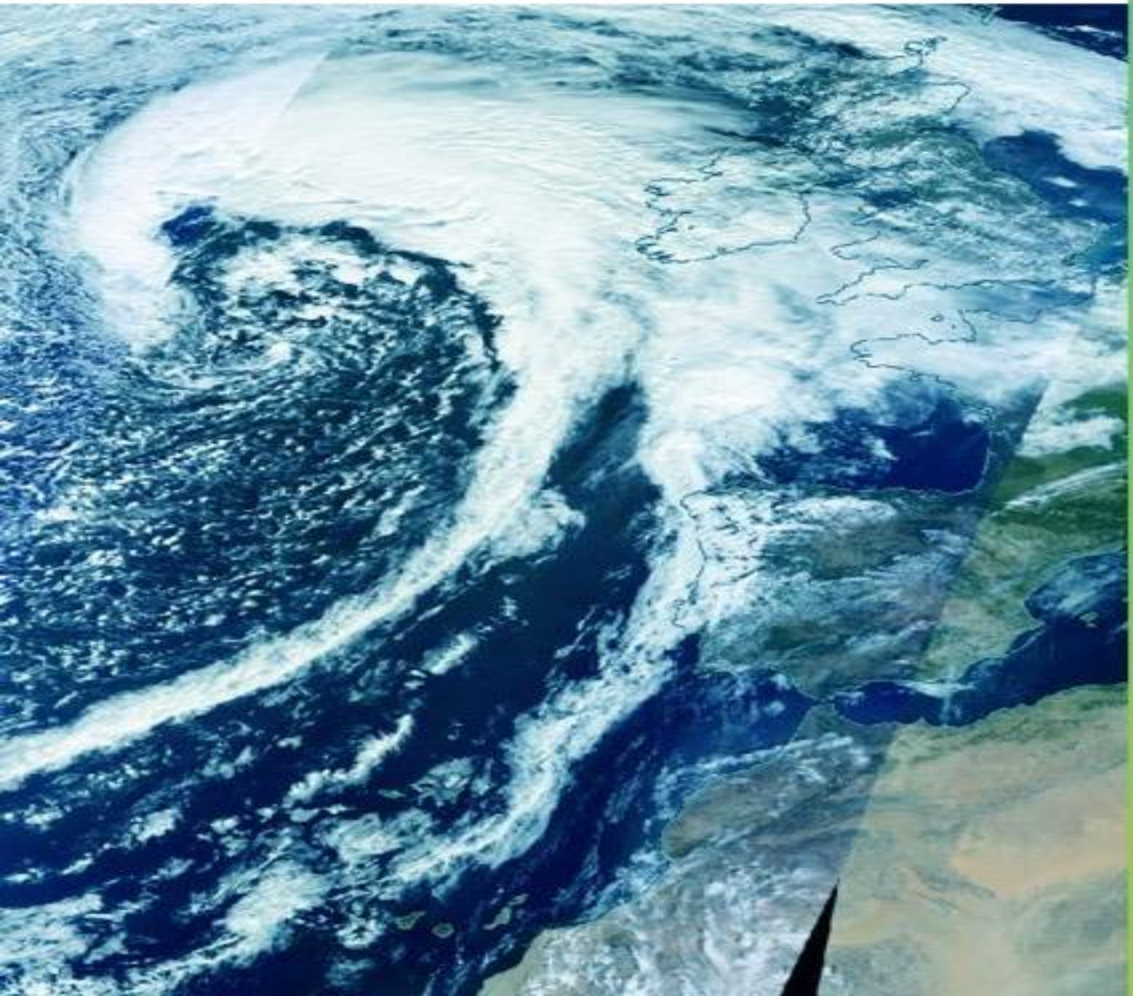

A 20-year reforecast study combining high-resolution hydrological modelling, ensemble forecasting and data assimilation for the 12 largest tributaries of the Rhine

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Deltares

08 May 2020

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Deltares Enabling Delta Life

PhD thesis

Public defense LIVE STREAM:

12 May 2020, 16:00

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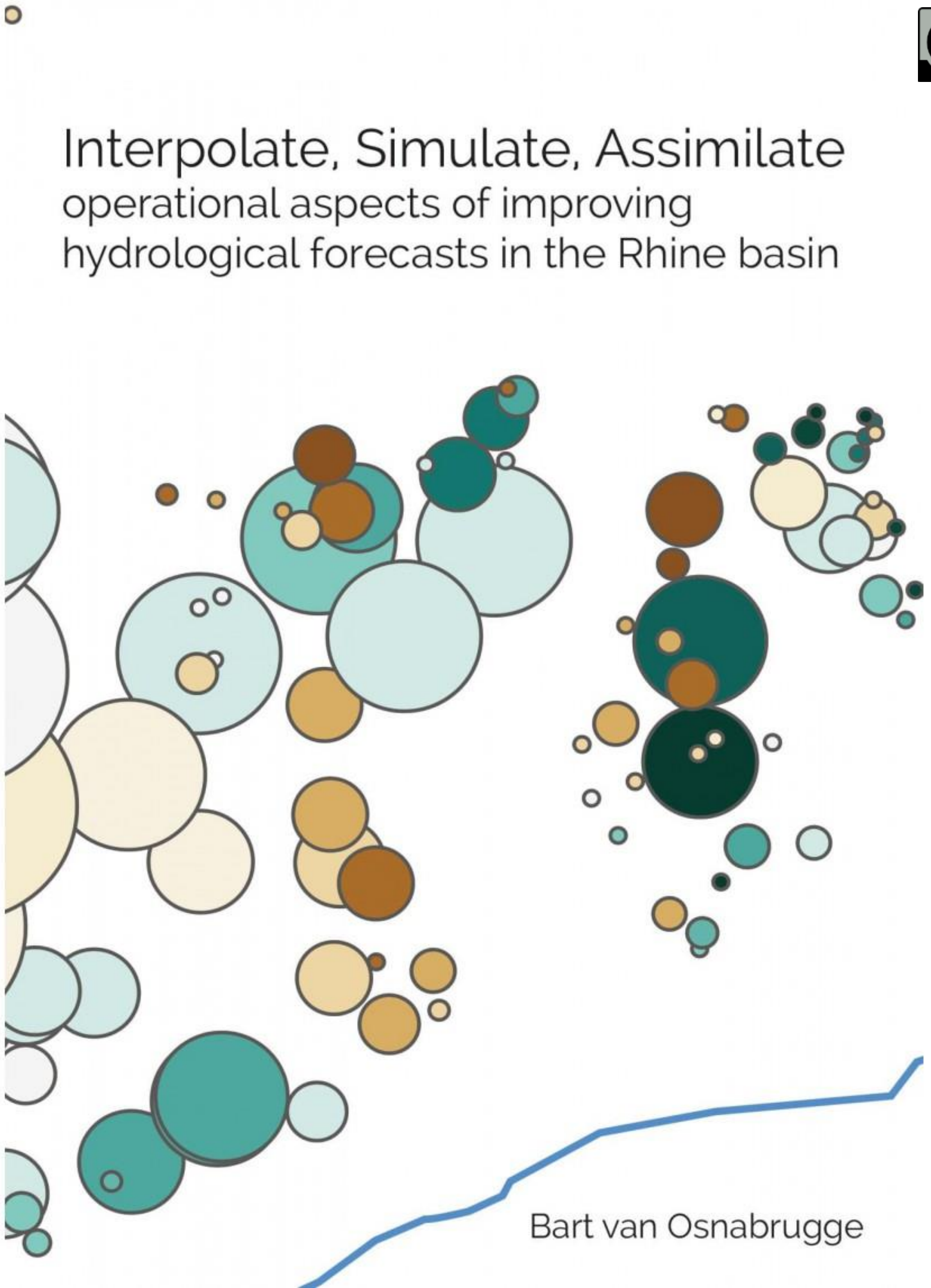
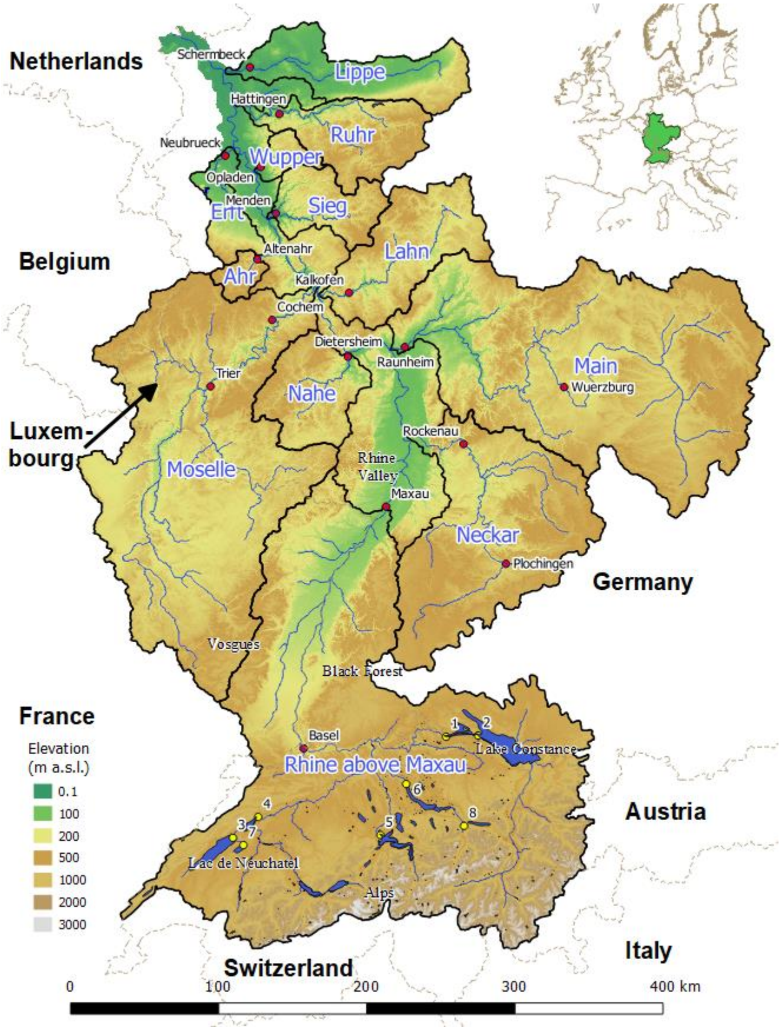
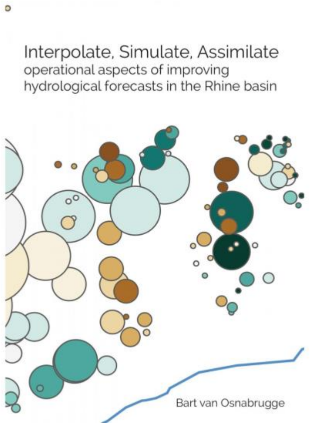


Methods and materials

Rhine basin

- ~160.000 km2
- Operational forecasting system for water levels and discharge at the Dutch border
- 12 subbasins (Moselle, Main, etc.) from which the discharge is fed into a hydrodynamic model of the Rhine
- The most upstream part (Rhine above Maxau) is characterized by the Alps and natural lakes
- Stations from which data is assimilated are in red dots.
- Assimilation / error correction is done for each subbasin separately





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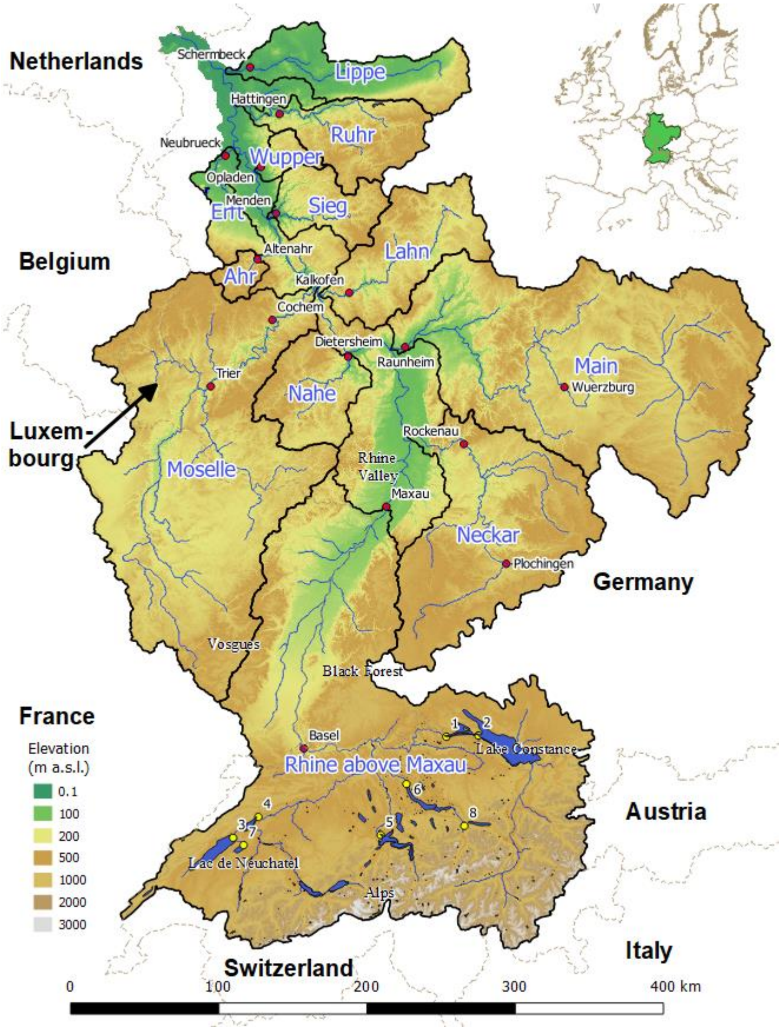
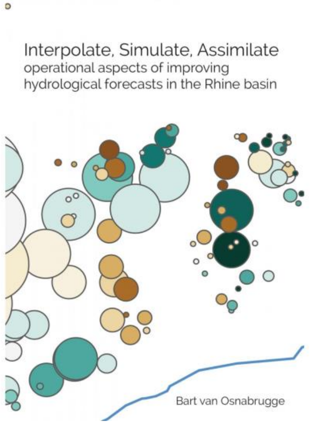
Methods and materials

Why this study?

- Ongoing movement towards spatially distributed models on (very) high spatial and temporal resolutions
- Ongoing movement to implement ensemble forecasts
- Ongoing development to combine ensemble forecasts with state-updating data assimilation

- But only few studies that combine all three…
- And even less so over long time periods





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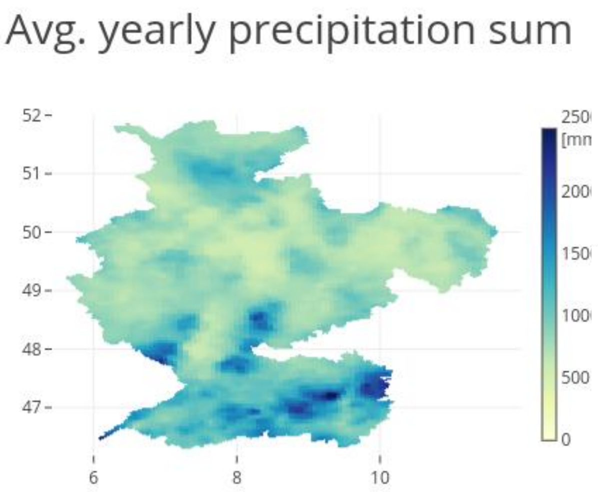
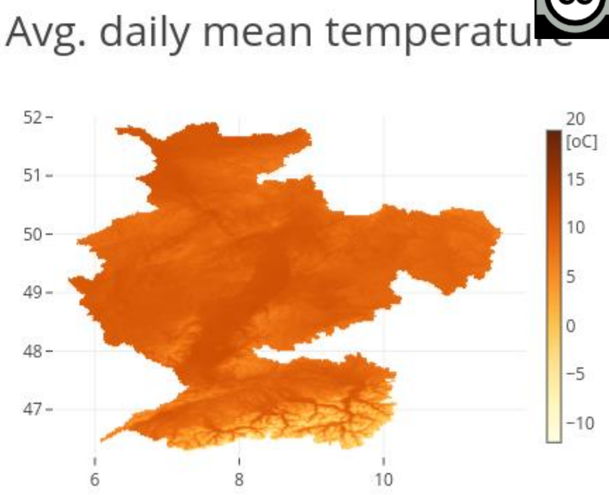
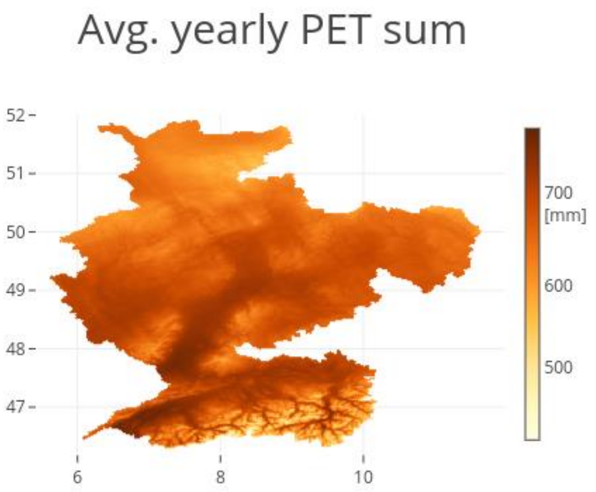
Methods and materials

Data

- Hourly 1.2x1.2 km forcing data set (1998-2016)
- ECMWF hindcast data set for 20 years of forecasts every 3-4 days.







van Osnabrugge, B. (Bart) (2017) Gridded precipitation dataset for the Rhine basin made with the genRE interpolation method. Deltares. Dataset. https://doi.org/10.4121/uuid:c875b385-ef6d-45a5-a6d3-d5fe5e3f525d

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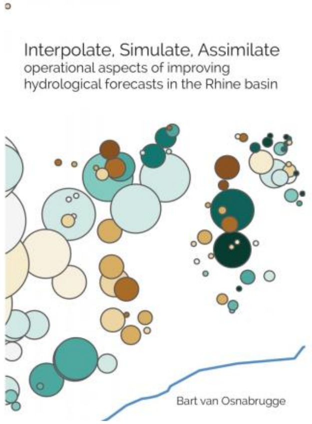
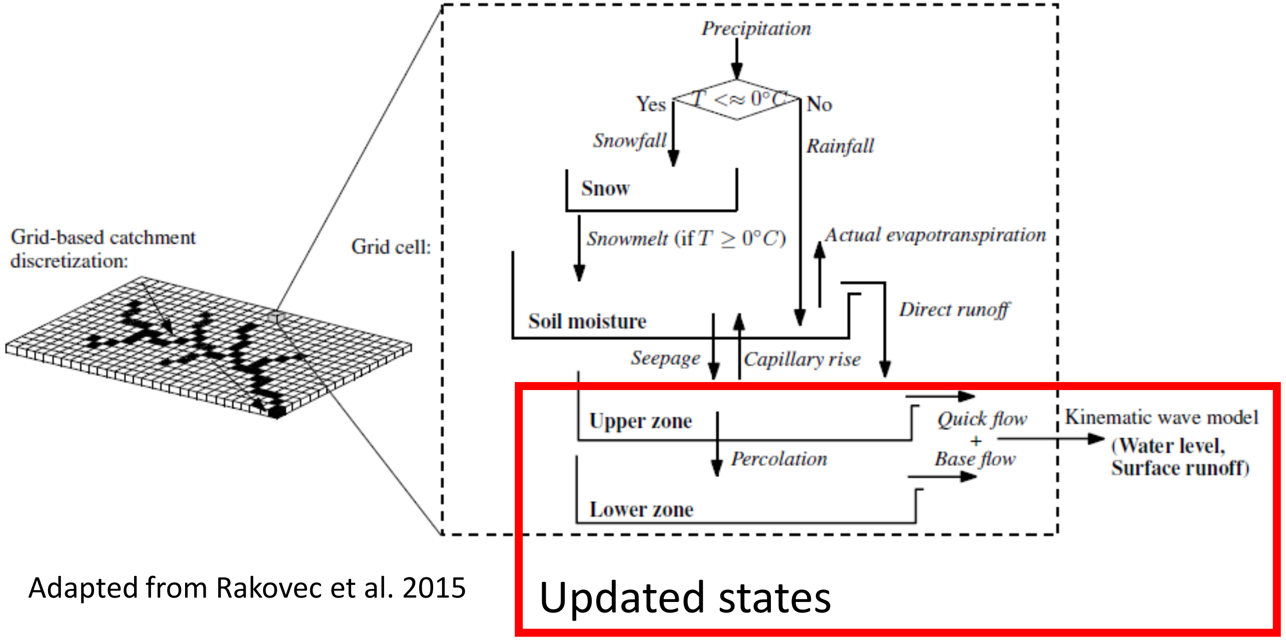
Methods and materials

Model: wflow_hbv

- Based on the well known HBV concept
- Discretisized for each grid cell
- Flows are routed with kinematic wave
- Hourly time step
- 1.2x1.2 km
- Upper zone and Lower zone states are updated as well as the water level





Adapted from Rakovec et al. 2015

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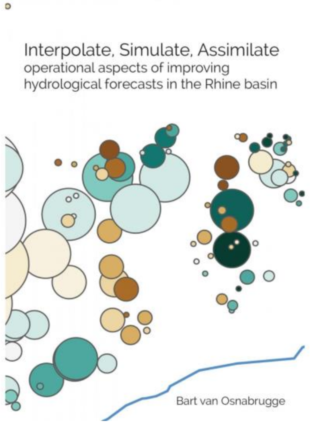
Methods and materials
Data assimilation and Auto Regression

Asynchronous EnKF

- AEnKF in OpenDA (Ridler et al., 2014, see also Rakovec et al. 2015)



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AR

- ARMASA algorithm in Delft-FEWS (Broersen and Weerts, 2005)
- $X_t = c + e_t + \sum_{i=1}^{p} \varphi_i X_{t-i} + \sum_{i=1}^{q} \theta_i e_{t-i}$

c: constant

e: white noise error

φ: auto regressive parameters

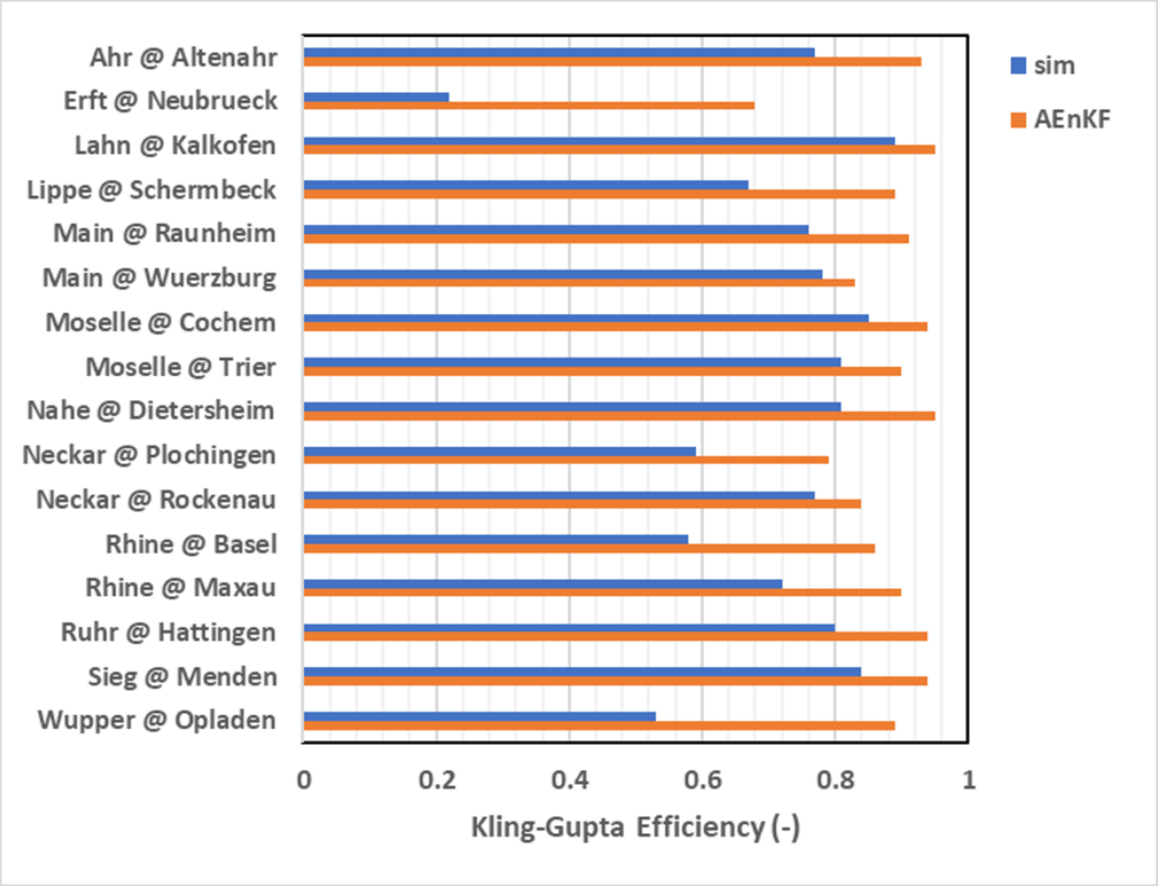
θ: moving average parameters

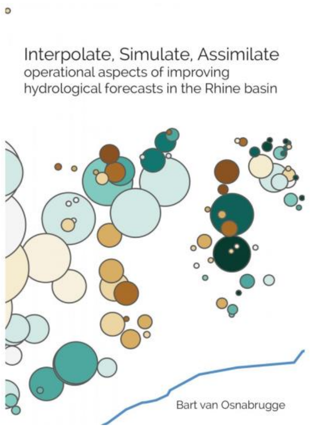
Here: only AR part is used with maximum order 3

Results

Historic state estimation

- KGE of modelled discharge as proxy for correct state
- KGE improves greatly for each basin with AEnKF state updating
- Especially when initial model results were very poor
- Calculated over a 20 year simulation period on a daily time step





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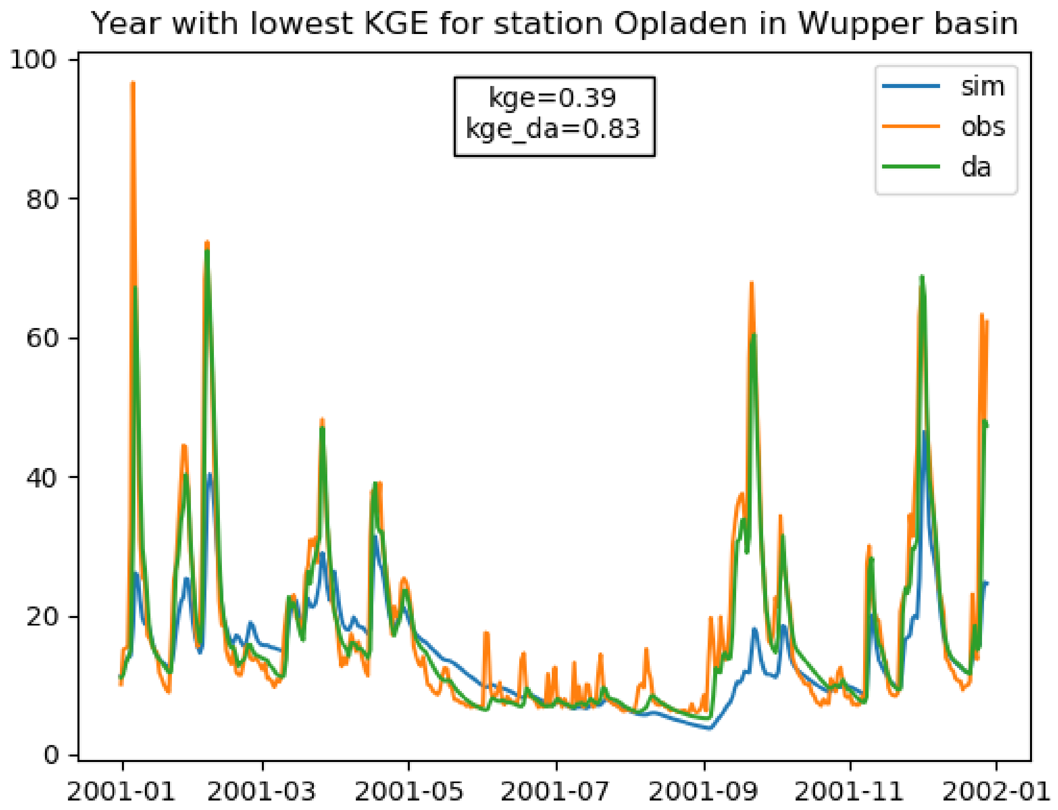
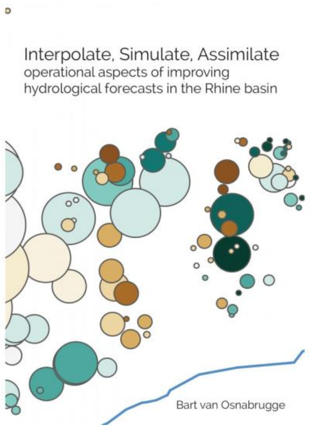
Results

Shown as hydrograph

- Effect of updating is shown in the hydrograph
- Correction is applied for whole biased periods





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Results

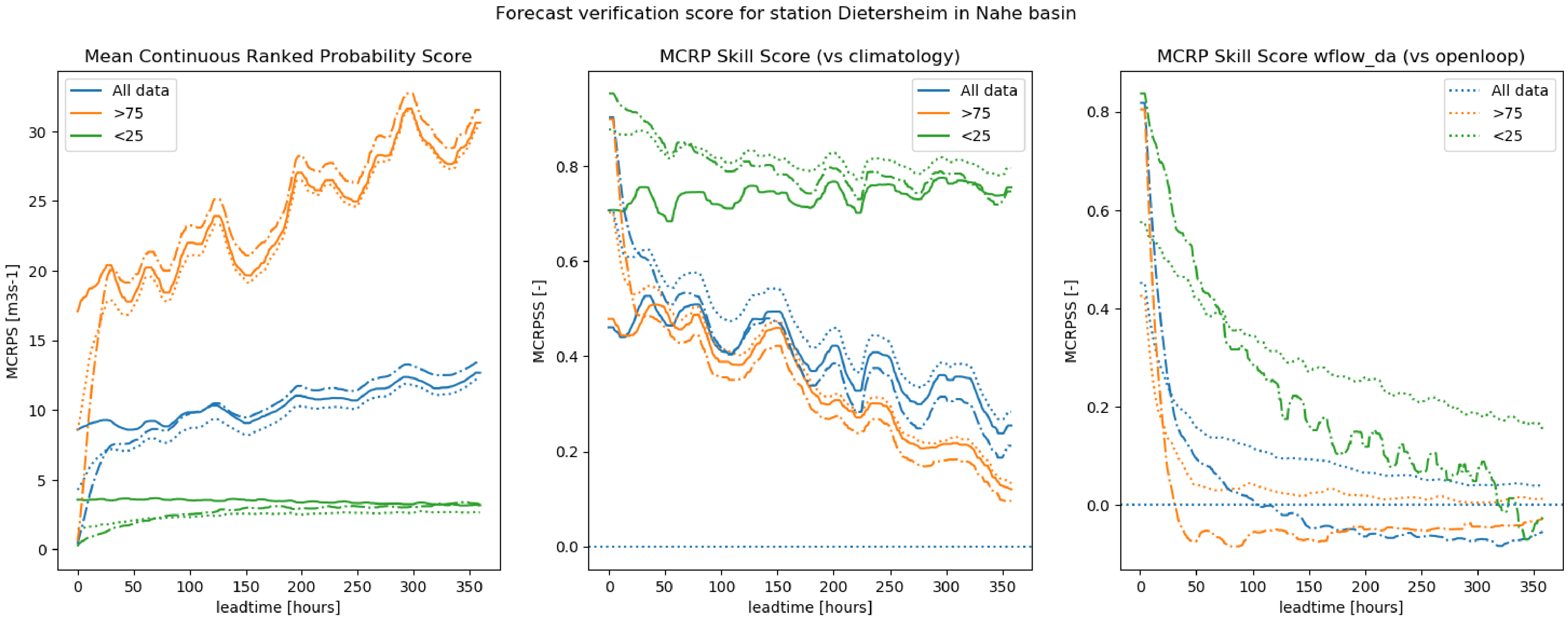
Results in forecast mode

Forecast verification scores. MCRPS (left) and MCRP **Skill Score** against climatology (middle) or the open loop simulation (right)

Solid line: open loop simulation

Dotted line: AEnKF

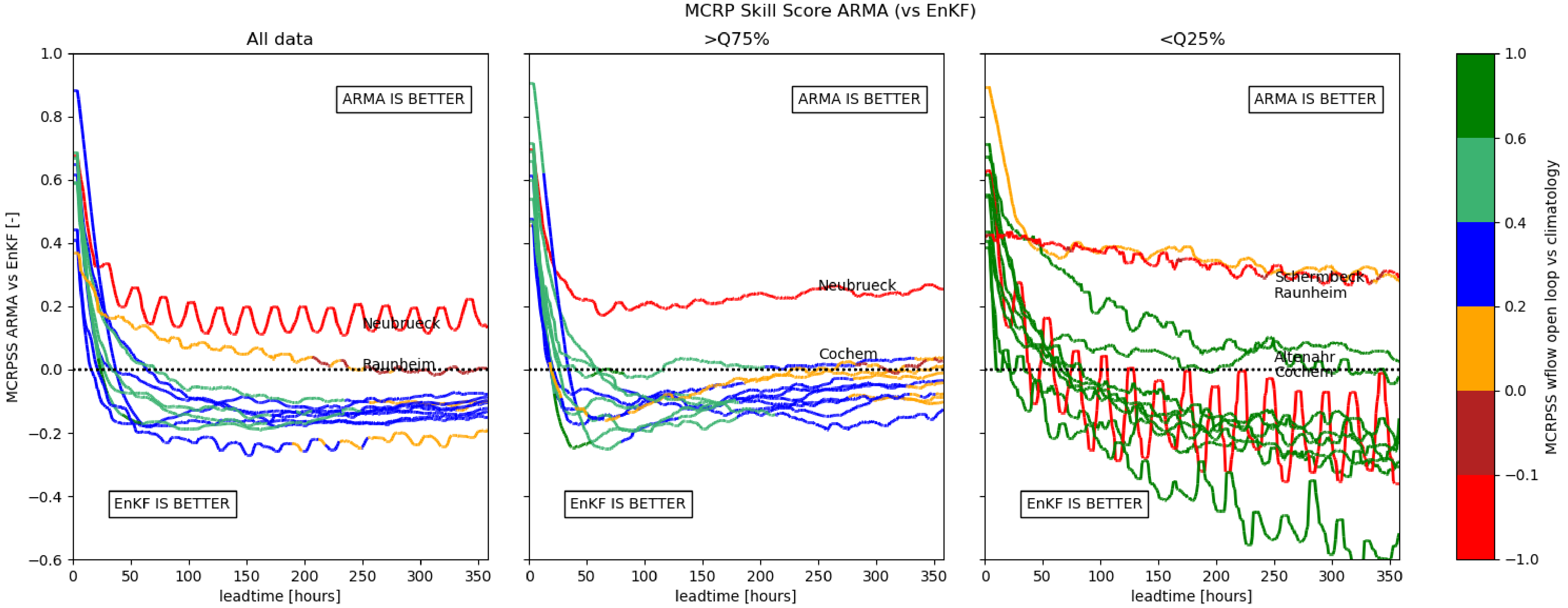
Stripe-dot: AR correction



Results

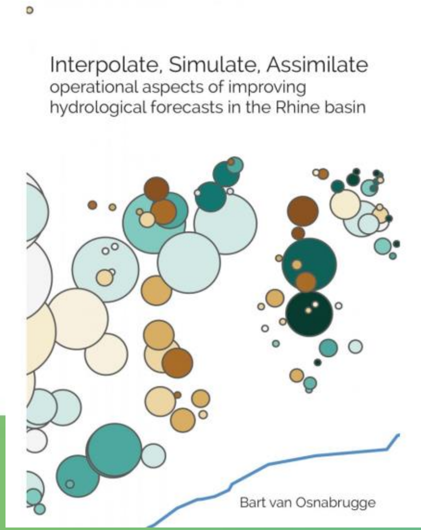
Comparison AR and AEnKF

- Below zero line: EnKF has better results than AR
- Colors indicate the quality of the original (open loop) simulation (colorbar on the right)
- AR outperforms EnKF for the first ~2 days, EnKF outperforms for longer forecasts
- Exceptions are poorly modelled basins



Conclusions

- Large scale data assimilation experiment combining current trends in hydrological forecasting: high resolution spatial and temporal model, with ensembles and state-updating but for a long continuous time period
- AR correction strong for 2 day period
- AEnKF improves longer forecasts
- AR can give ‘odd’ results, while AEnKF results are always consistent with the model



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