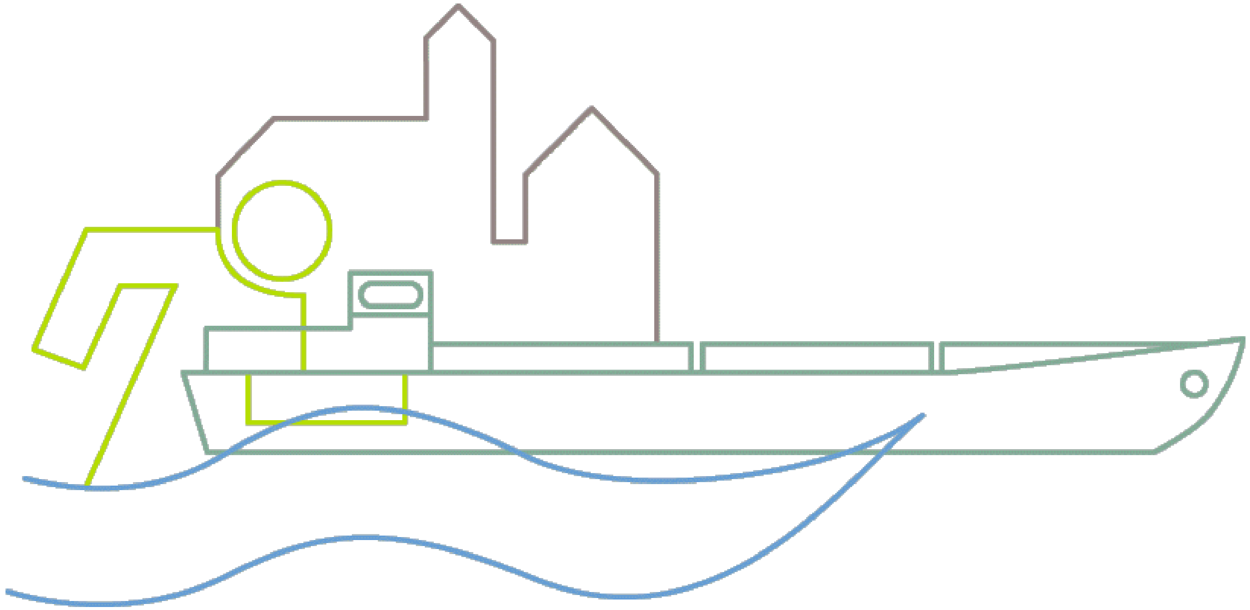

Assimilation of Snow Water Equivalent and Root Zone Soil Moisture Index into HBV-model

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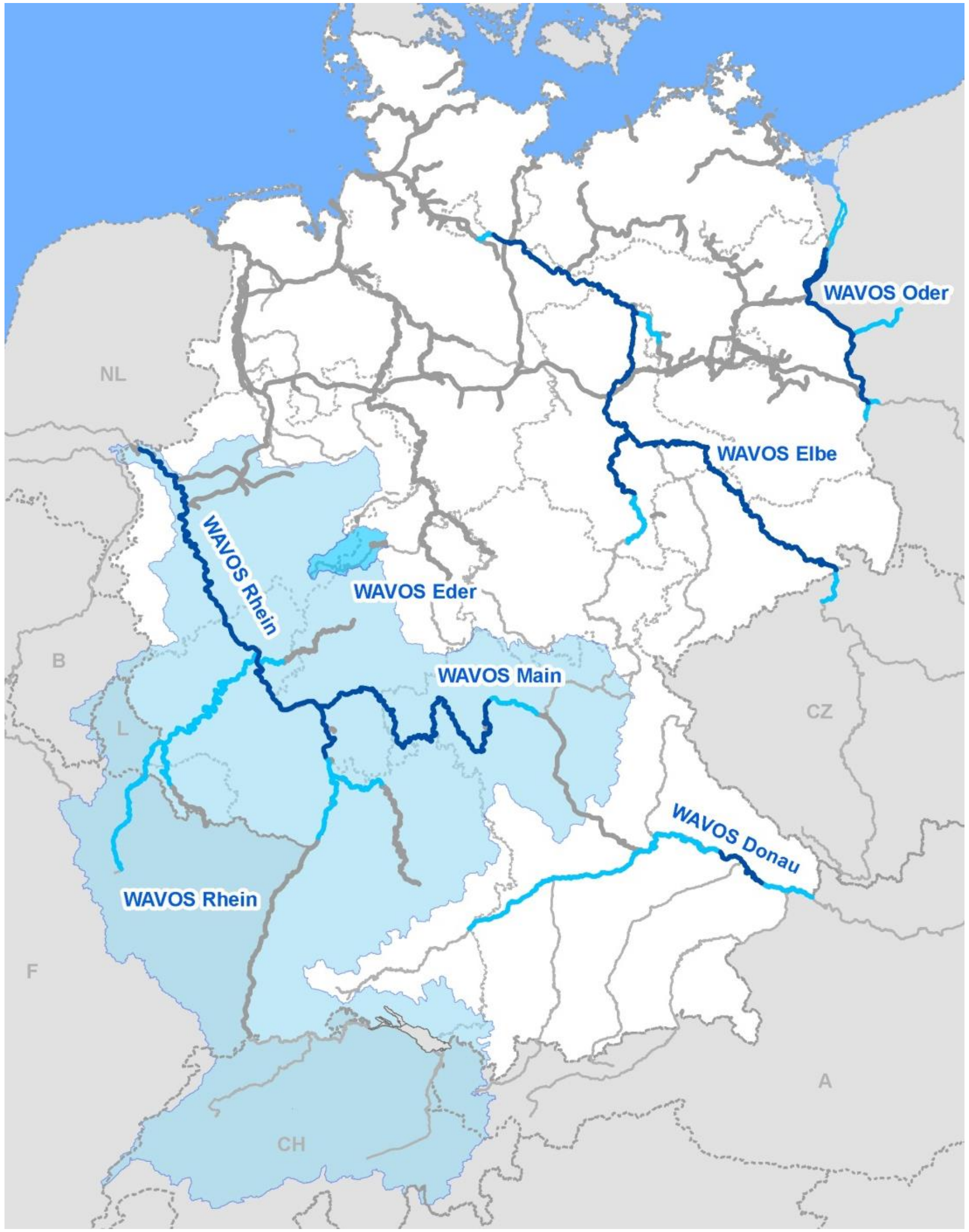
H-SAF and HEPEX workshops on coupled hydrology
Reading, November 5th 2014

Introduction

- Forecasting for federal water ways in Germany
  - Federal Institute of Hydrology responsible for the Rhine
- Rainfall-Runoff Model: HBV
  - → Forecasted discharge
  - covering the whole Rhine catchment (~ 160.000 km²)
  - 134 sub basins (500 – 2000 km²)
  - time-step: 1 hour
- Hydrodynamic Model: SOBEK
  - lateral inputs from HBV-model
  - → Forecasted water level



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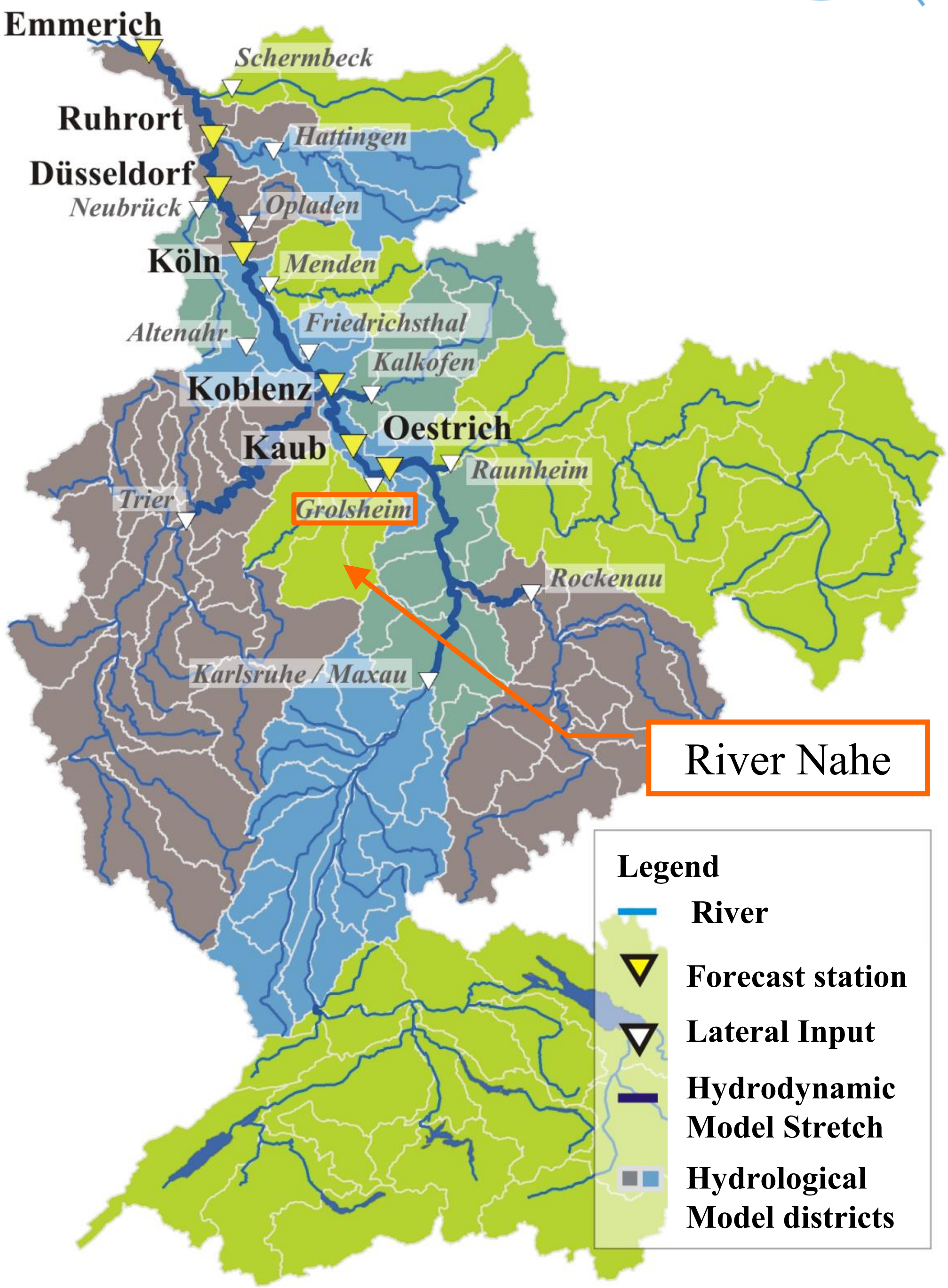
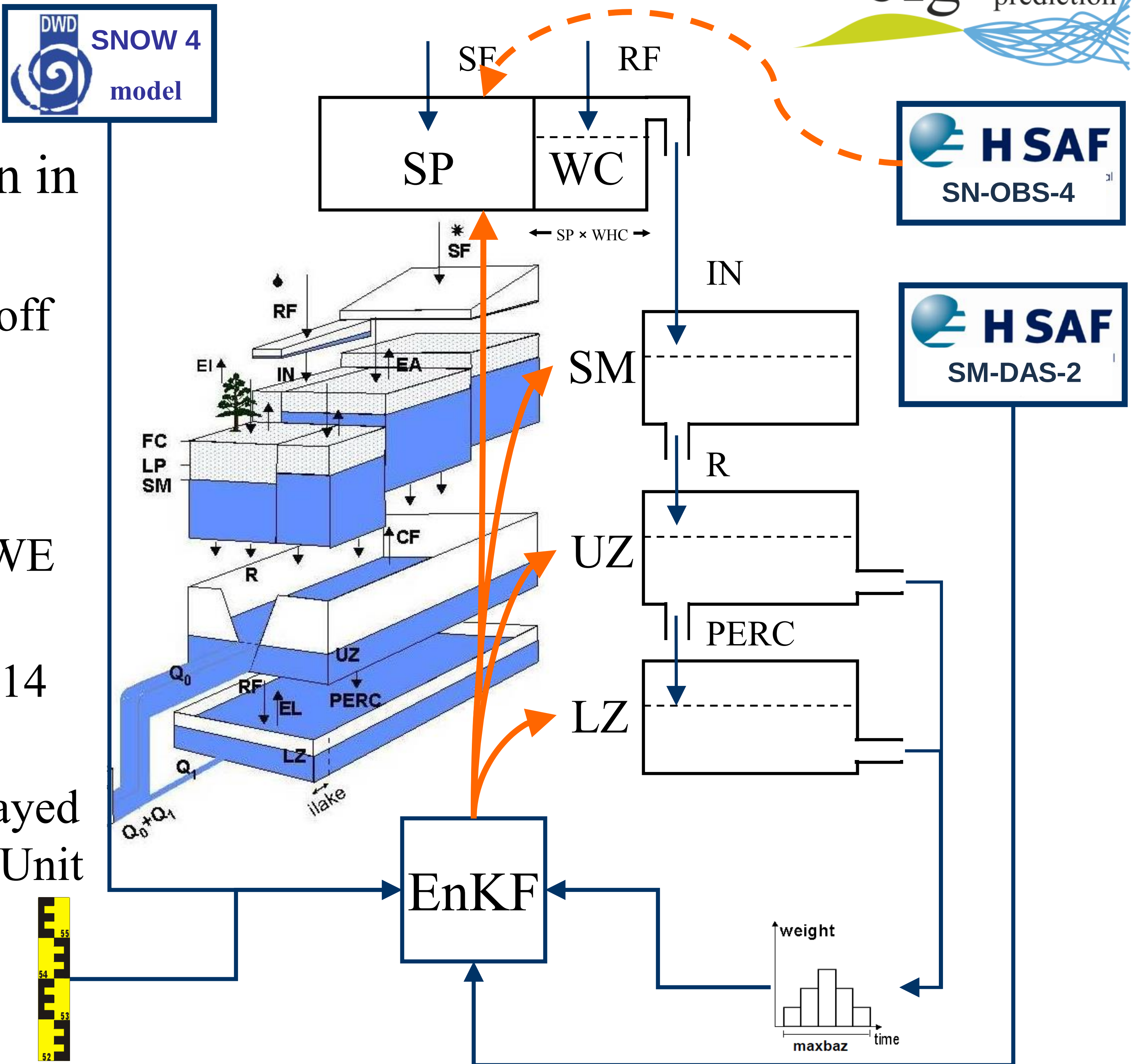


Introduction

- Data Assimilation in HBV:
  - Updating of runoff storages with observed runoff
  - Updating snow storages with SWE
  - Updating of soil moisture with H14 product
  - Account for delayed response due to Unit Hydrograph

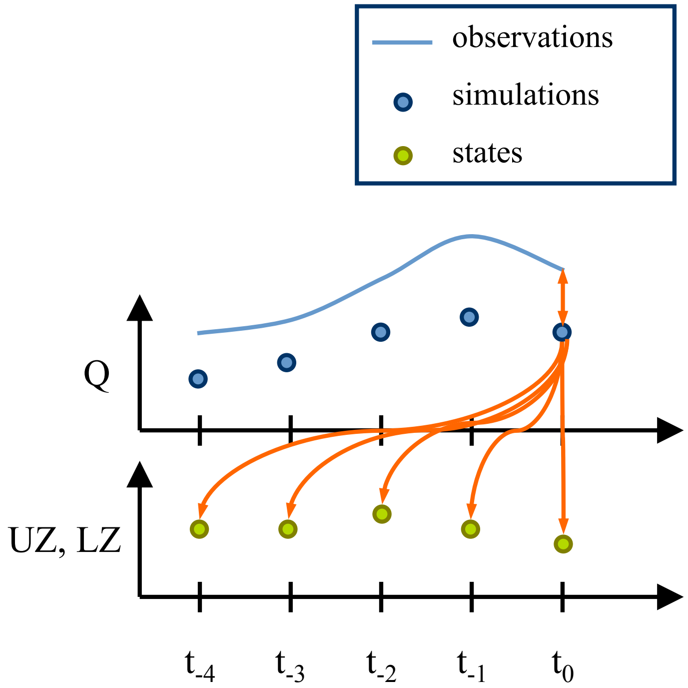


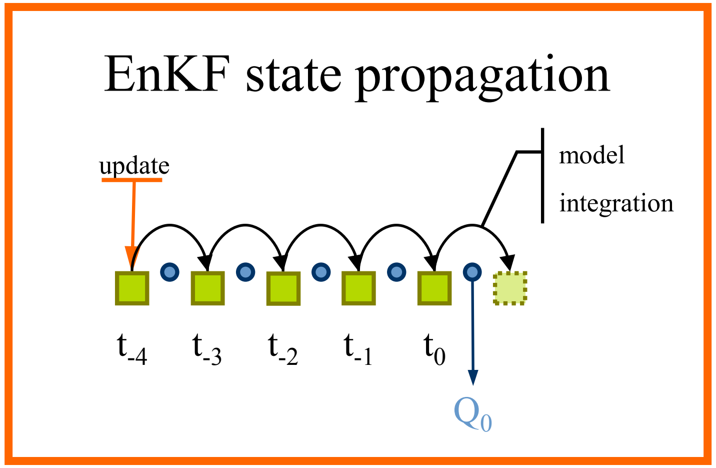
Data Assimilation Approach

- Runoff Storage Updating (UZ and LZ) with Ensemble Kalman Filter

$$x_t^+ = x_t^- + K\left(y_t - Hx_t^-\right)$$

  - Mitigate erroneous melt water generation and input uncertainty at start of forecast
    > particularly effective in no-snow conditions
  - Account for runoff delay (Transformation Function)
    > Updating states a number of time-steps before observation





Data Assimilation Approach

- Snow Water Equivalent Updating (SP and WC)
  Soil Moisture Storage Updating (SM)
  with Ensemble Kalman Filter

$$x_t^+ = x_t^- + K\left(y_t - Hx_t^-\right)$$

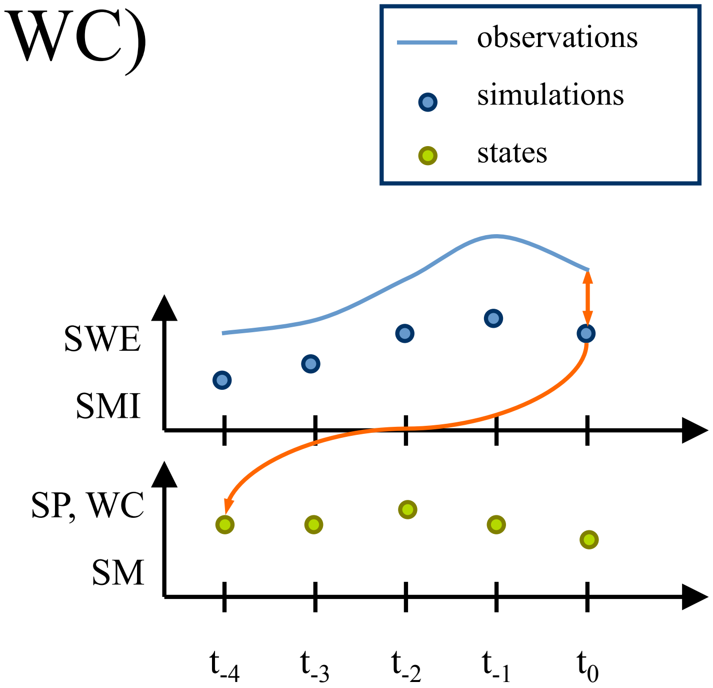
  - Limit available melt water for forecast

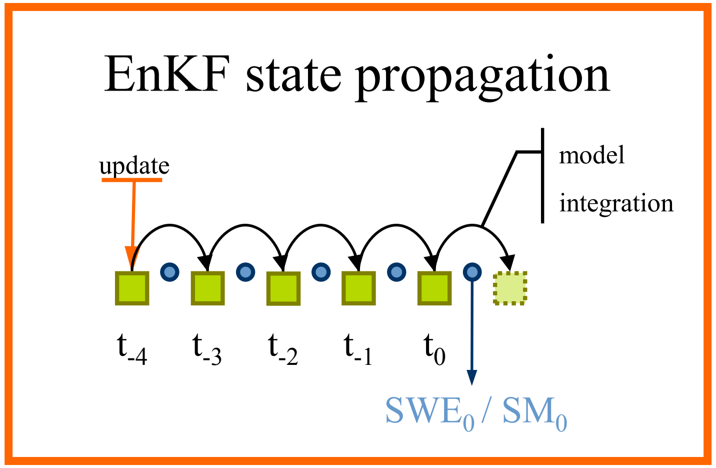
$$SWE = SP + WC$$

  - Control effect of soil moisture on runoff generation

$$SMI = \frac{SM}{FC}$$

  - Perturb model SWE / SM at same time-step as runoff storages
  - Propagate to observation time step





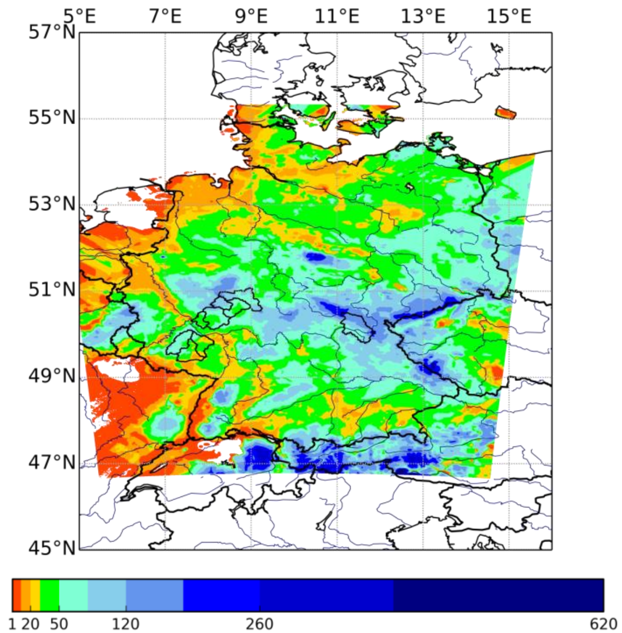
Data Assimilation Approach

- Snow Storage Updating with SNOW4-model (German Weather Service)

  - Simulation of past snow cover evolution
  - Assimilation of satellite snow mask and snow observations
  - Outputs: Snow Water Equivalent, Precipitation Supply

    > hourly time step on grid with 1km² resolution

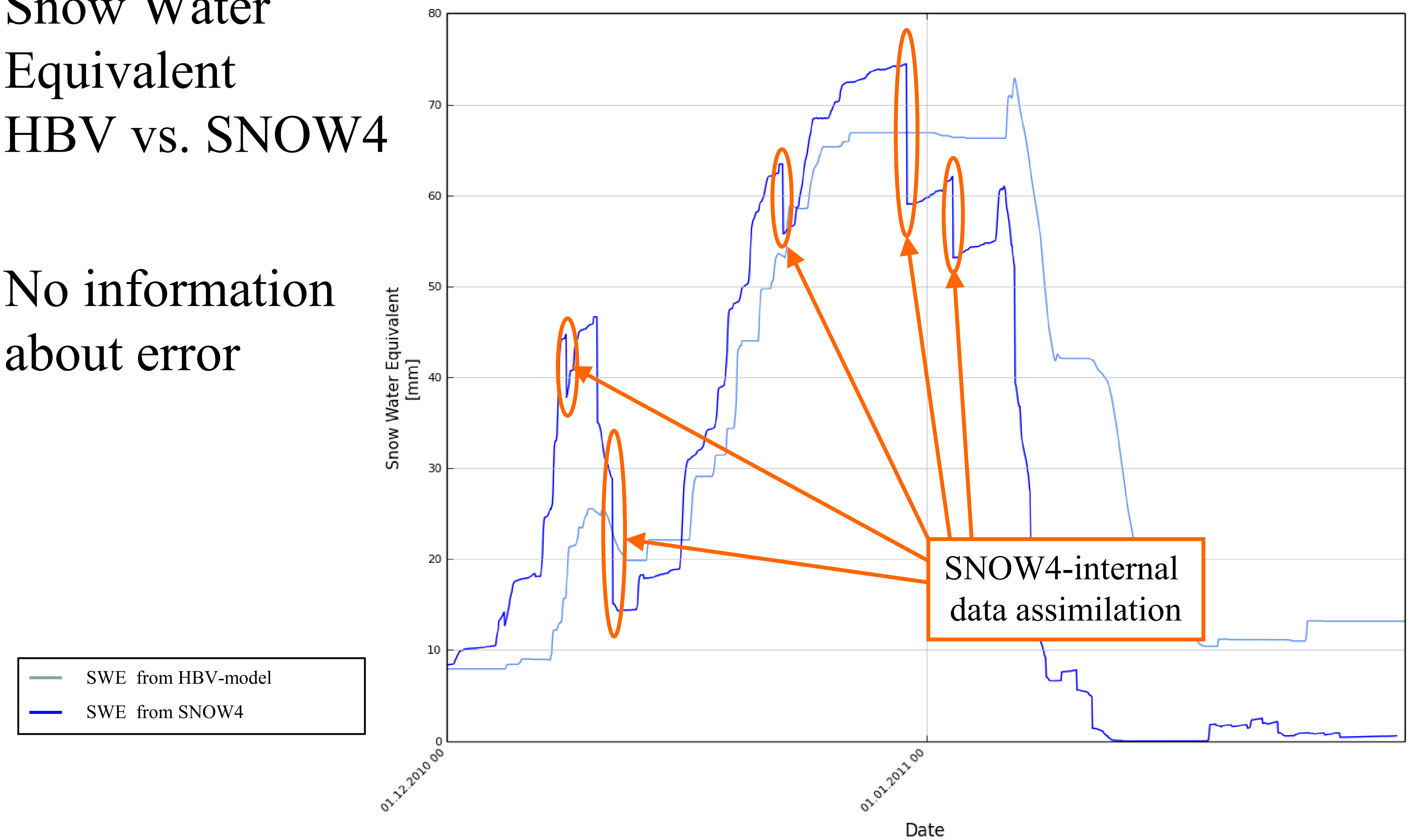
  - Pro: - high spatial and temporal resolution
  - Contra: - overestimates snow accumulation
    - internal DA leads to jumps in time series



Snow Water Equivalent from SNOW4-model on 2011-01-06

Data Assimilation Approach

- Snow Water Equivalent HBV vs. SNOW4
- No information about error

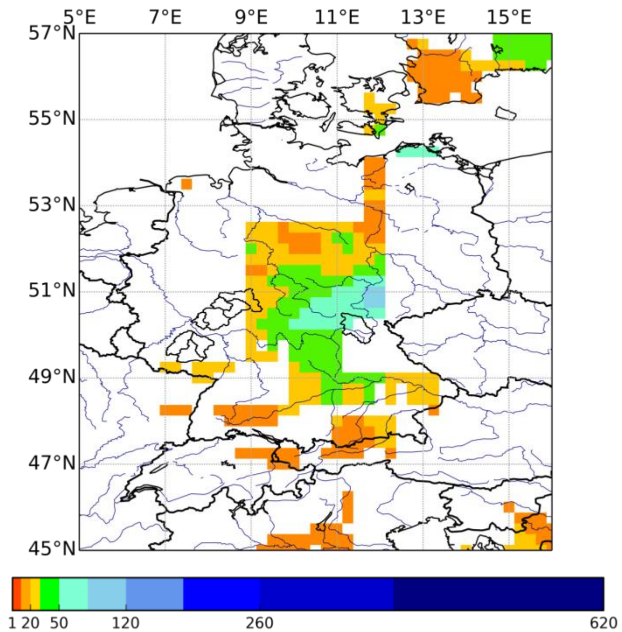


Data Assimilation Approach

- Snow Storage Updating with H-SAF H13

  - Pro: - potentially consistent due to assimilation of brightness temperature into regionalization of observed snow density
    - quality information available

  - Contra: - coverage



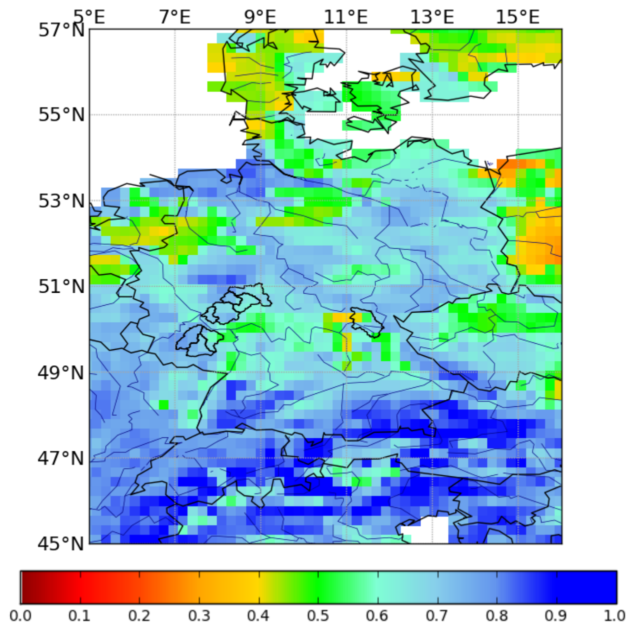
Snow Water Equivalent from H-SAF H13 product
on 2011-01-06

Data Assimilation Approach

- Soil Moisture Updating with H-SAF H14 Soil Moisture Index (3 layers, 0-100 cm)

  - Pro: - Soil Moisture Index for 4 soil layers
    - continuous coverage

  - Contra: - relation to HBV-soil moisture not clear

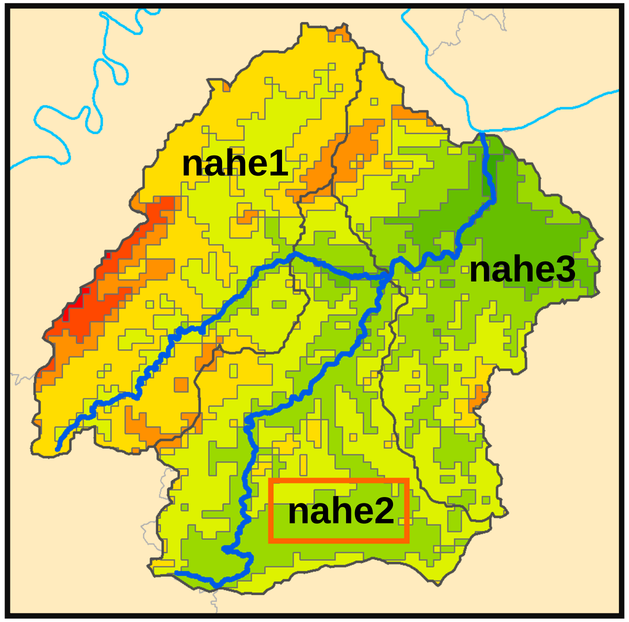


Soil Moisture Index from H-SAF H14 product on 2012-06-01

Data Assimilation Approach

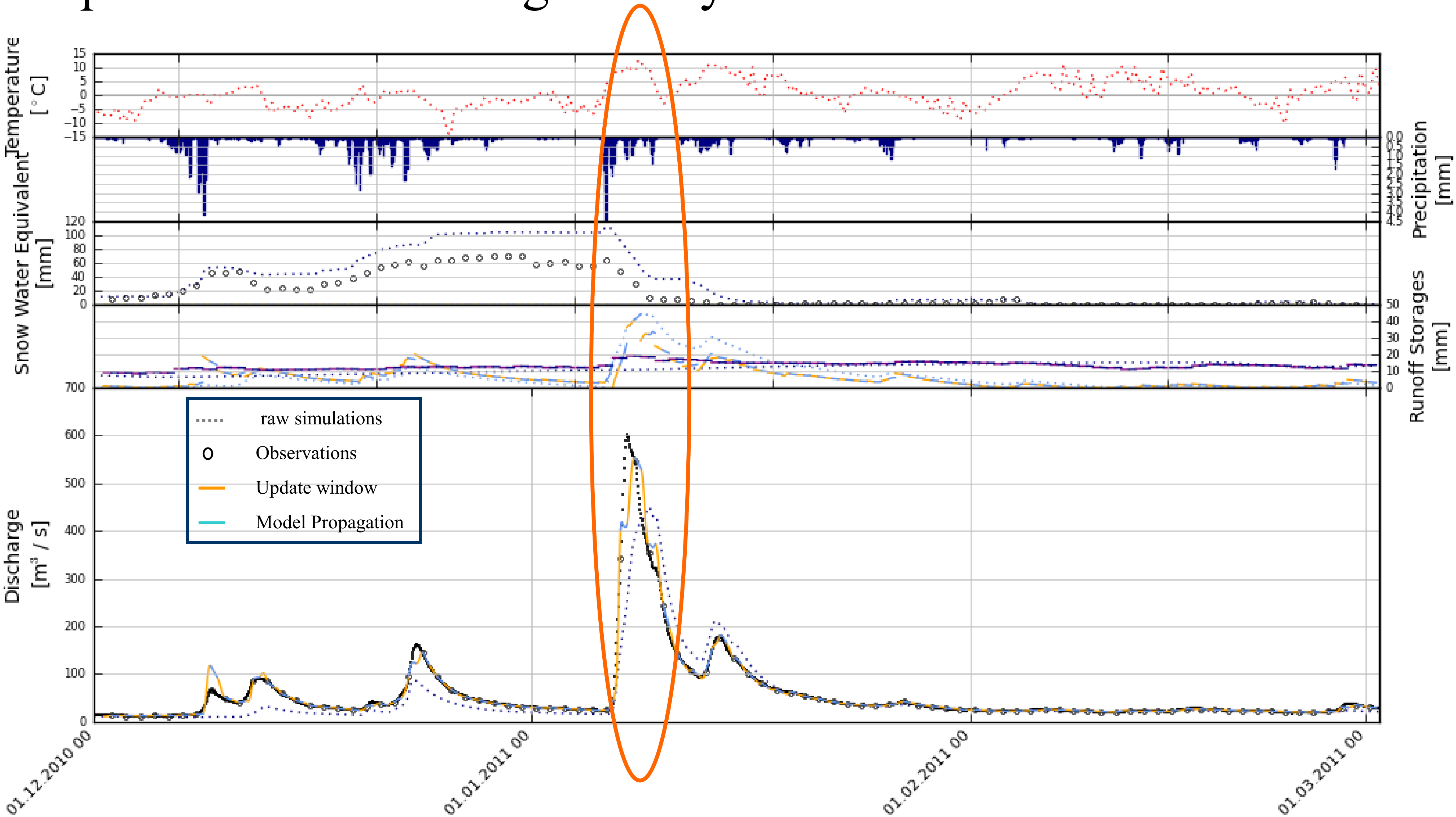
- Methodology

1. Read / decode data for observation time-step
2. Map grid points to sub basins
3. Perform regionalization
4. Apply EnKF to snow storages
and runoff storages
   - Perturb SWE / SMI some time-steps before observation and find updated storage that results in observed storage value at observation time-step.
   - Find optimal UZ and LZ that result in observed discharge at observation time-step.



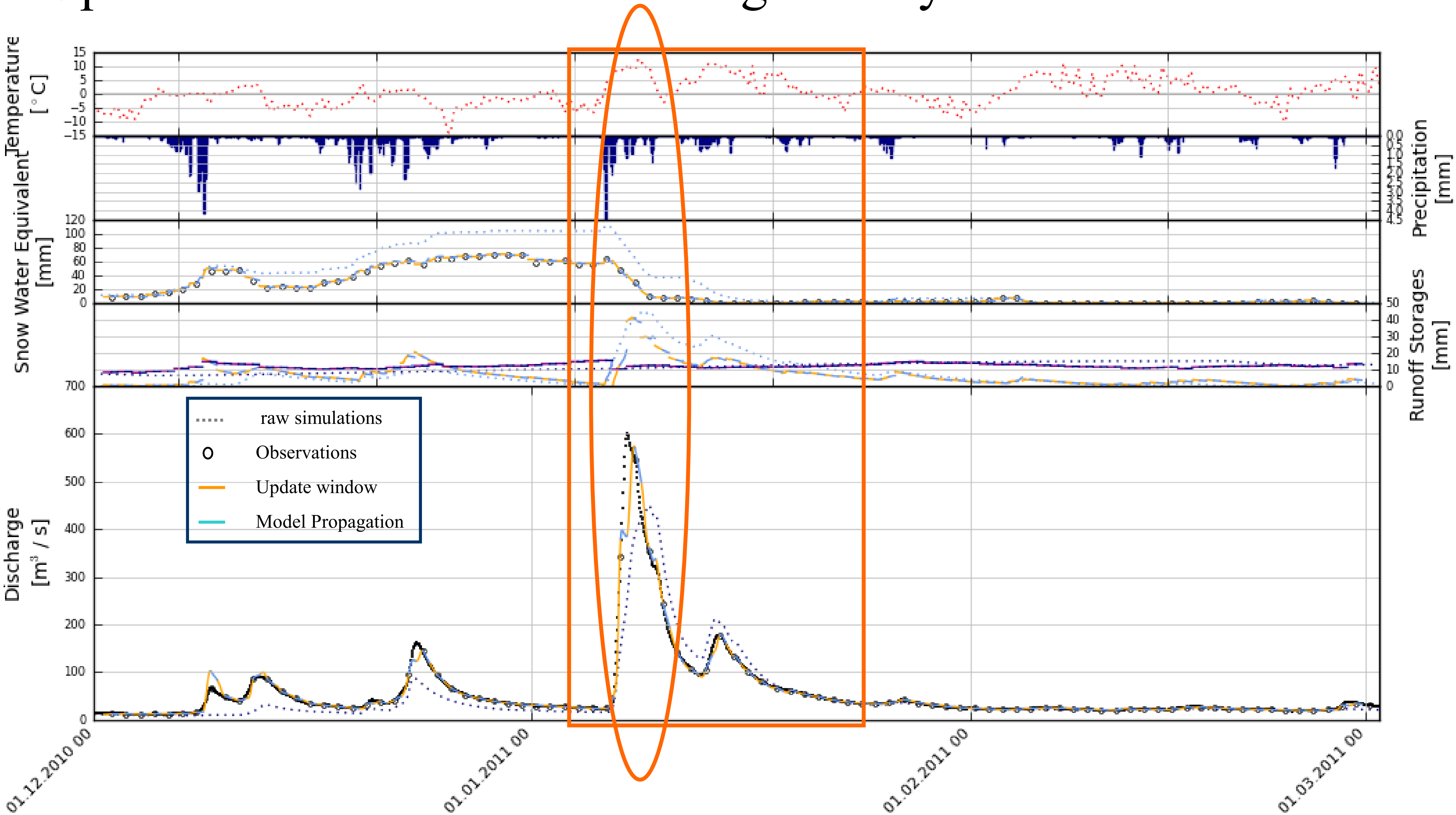
Results (Winter)

- Updated Runoff-Storages every 24 hours



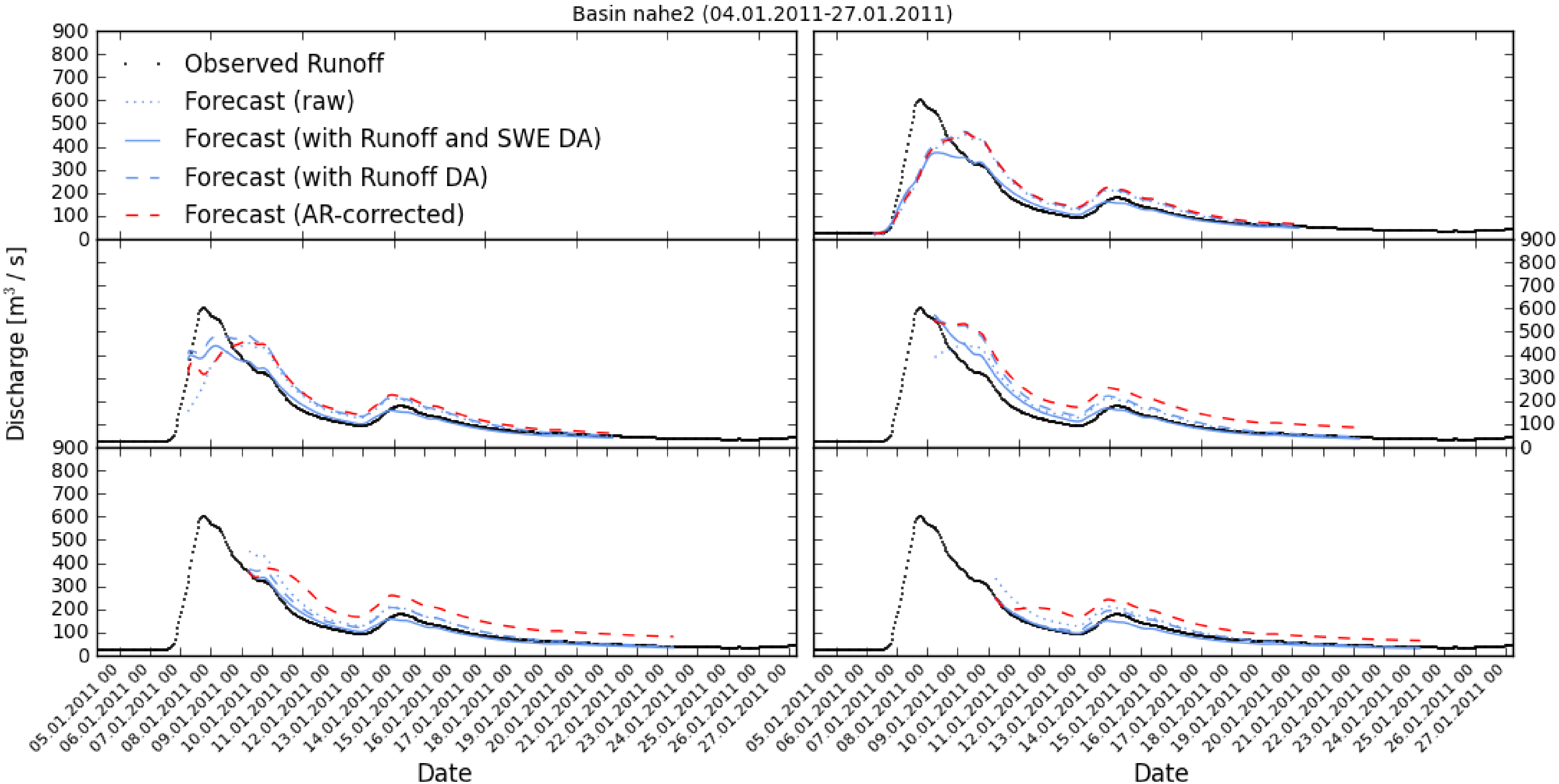
Results (Winter)

- Updated SWE and Runoff-Storages every 24 hours



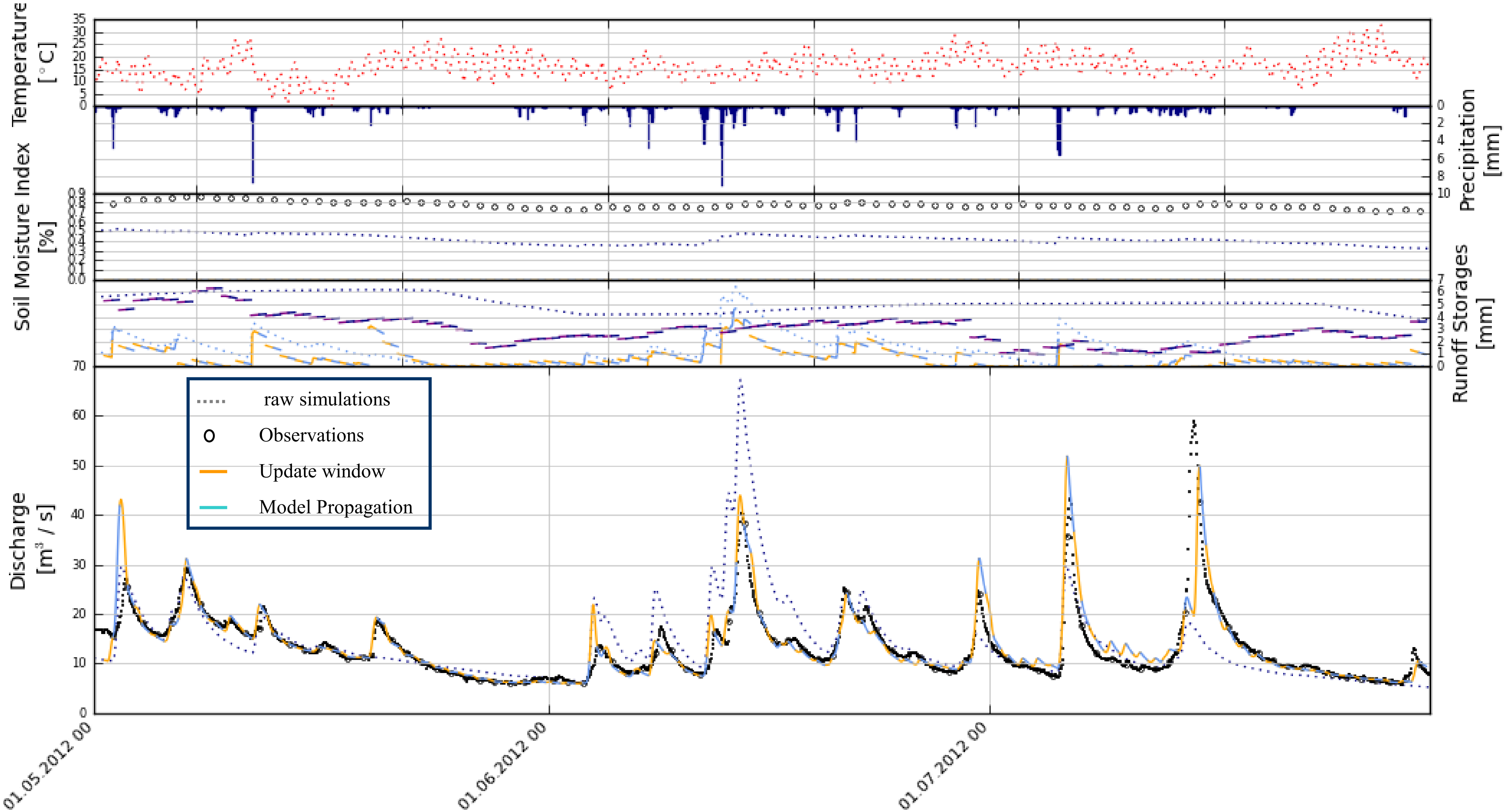
Results (Winter)

- Perfect Forecasts (14 days leadtime)



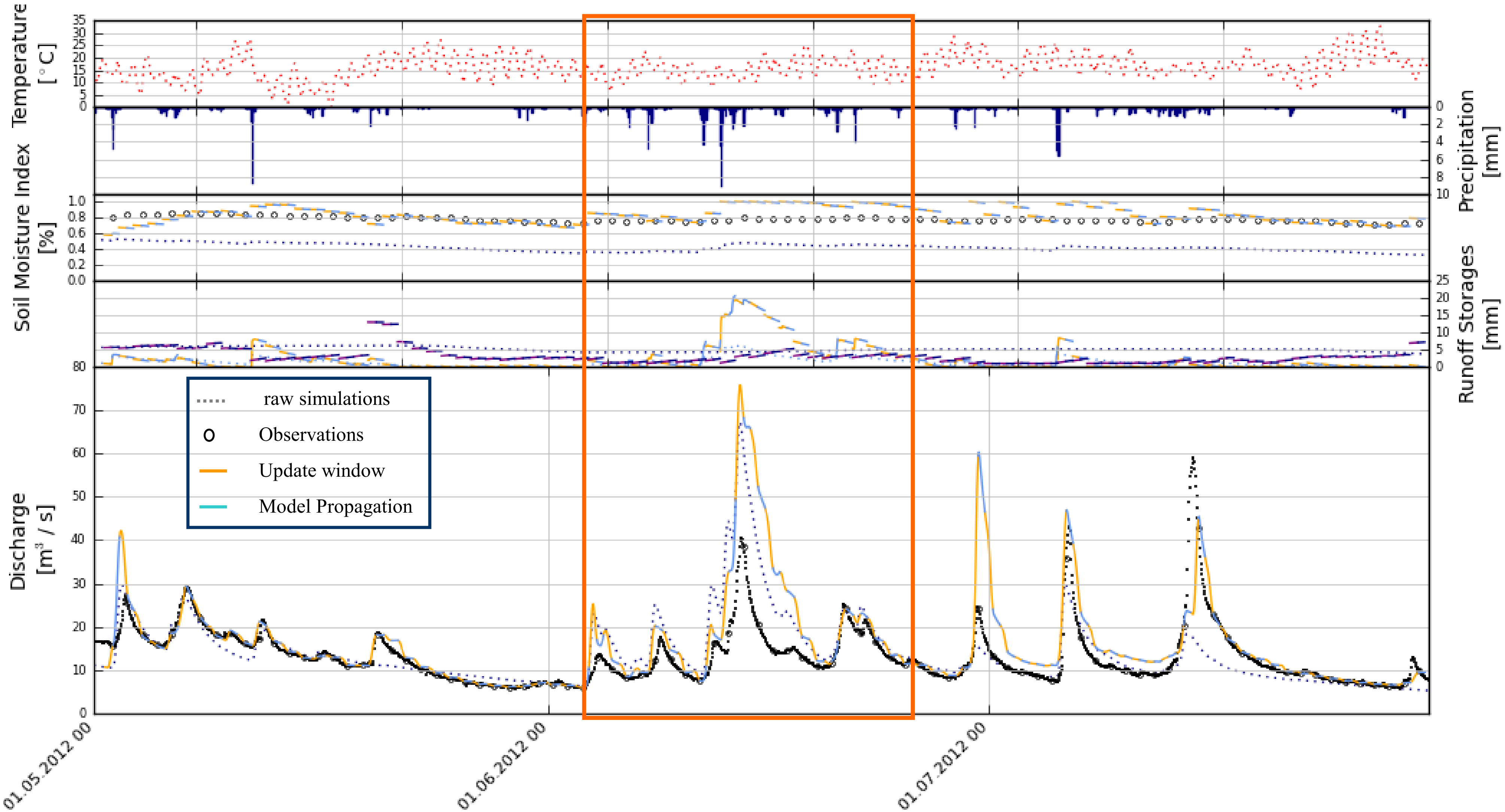
Results (Summer)

- Updated Runoff-Storages every 24 hours



Results (Summer)

- Updated SMI and Runoff-Storages every 24 hours



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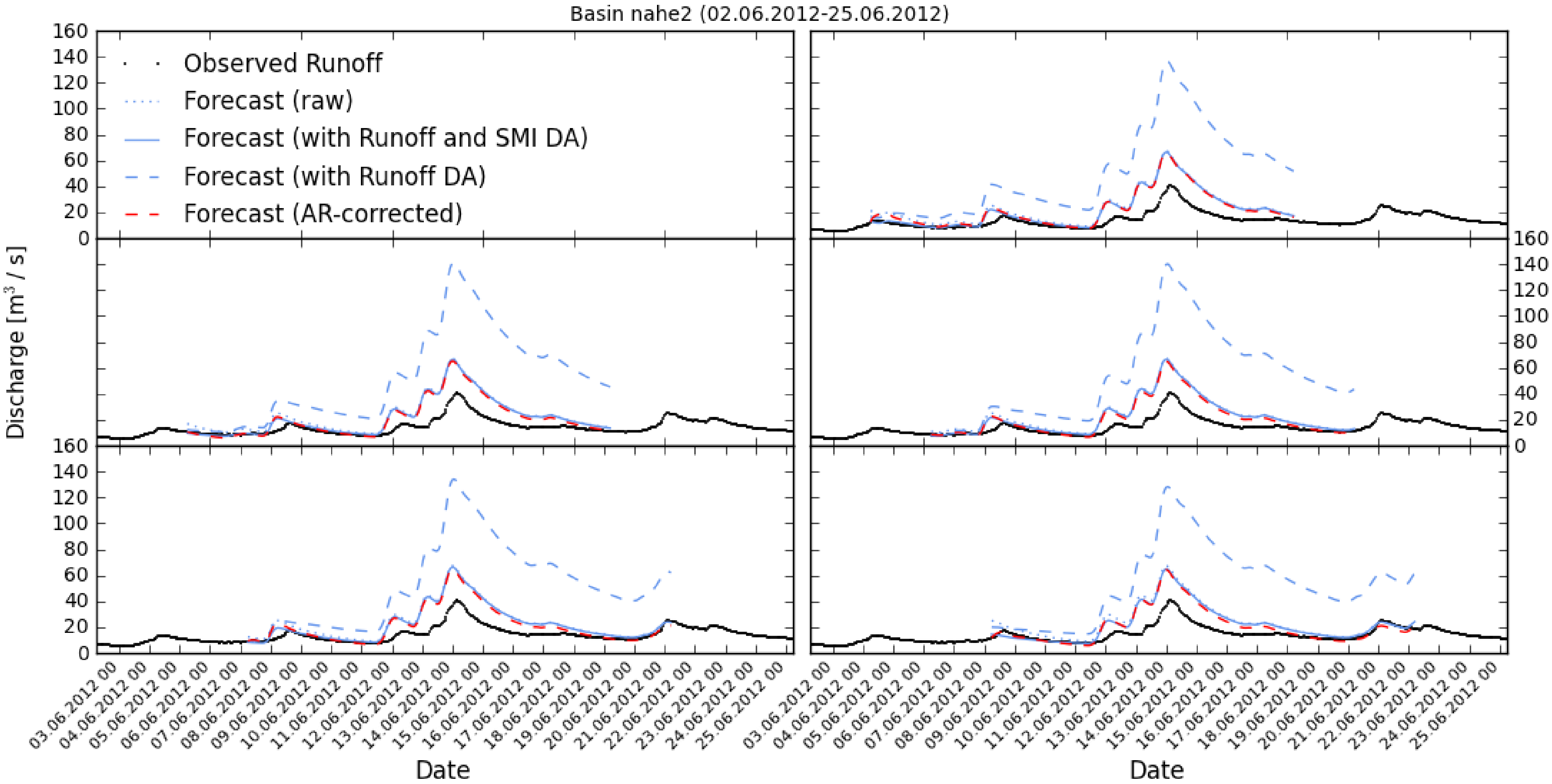
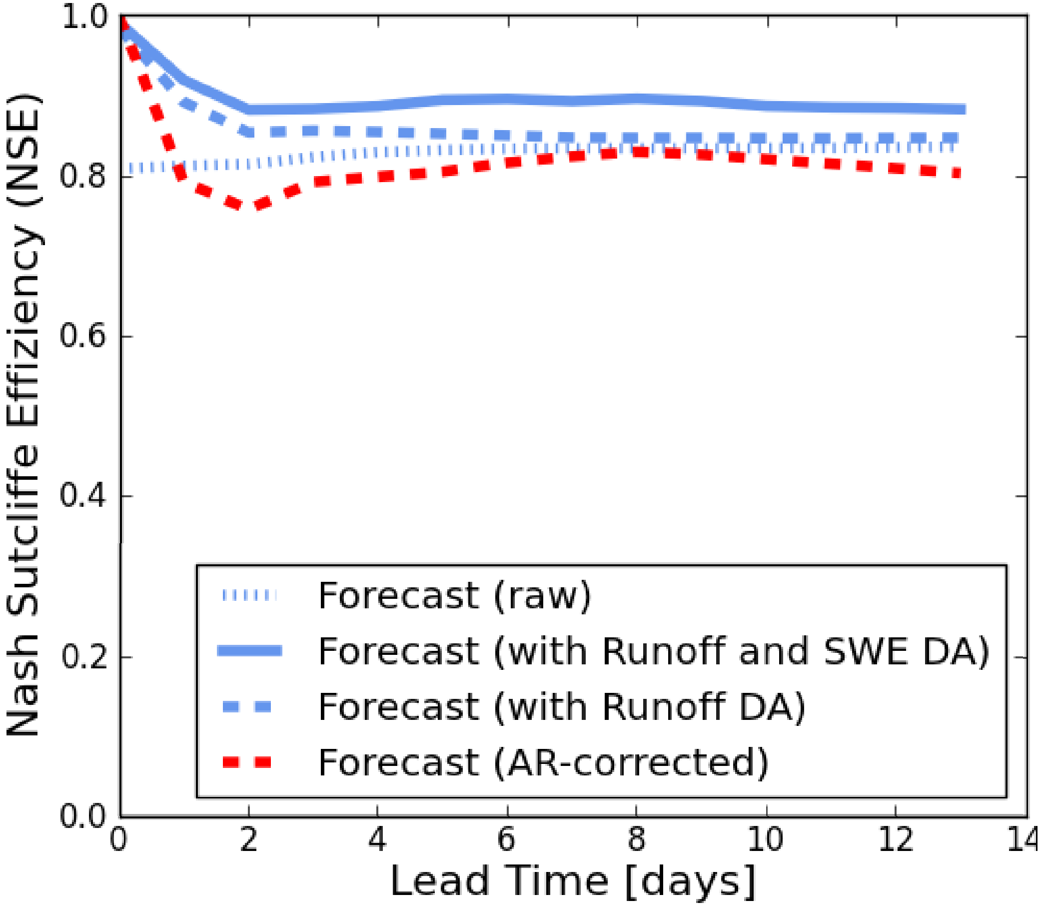


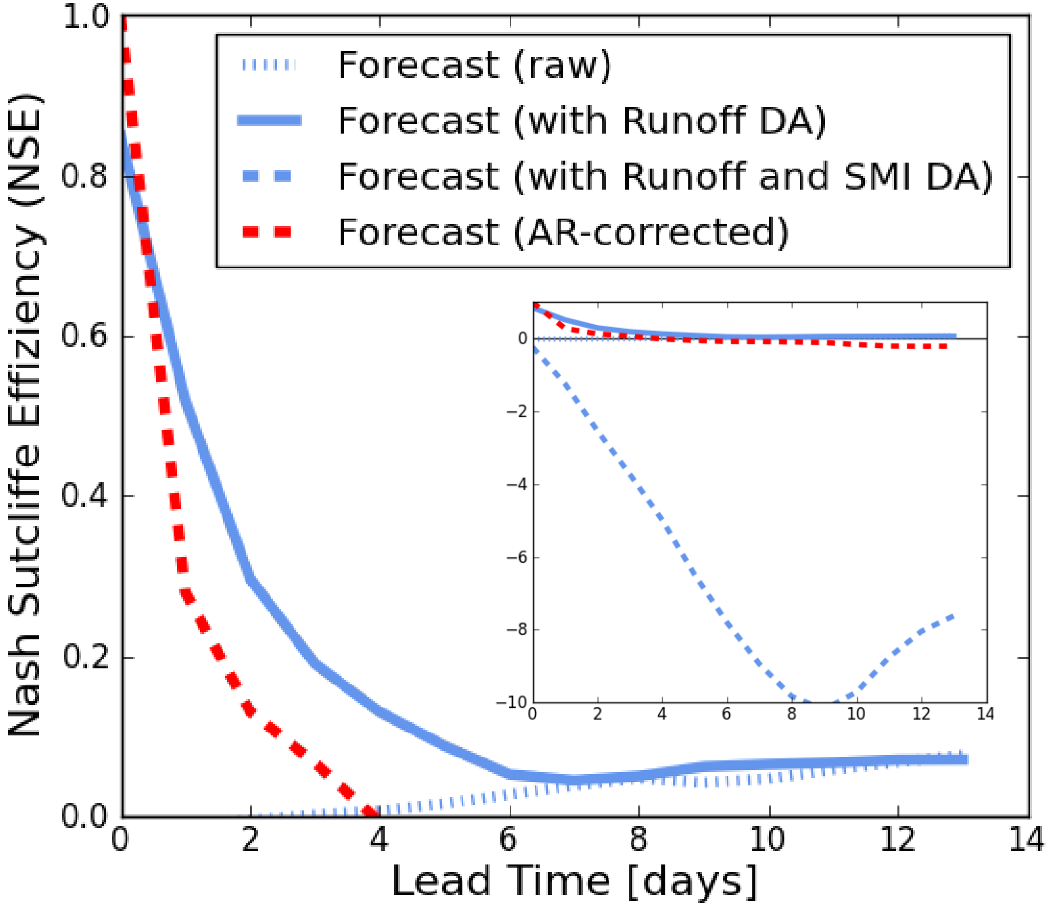
Results

- Leadtime performance (Perfect Forecasts)

Winter 2010, 2011, and 2012

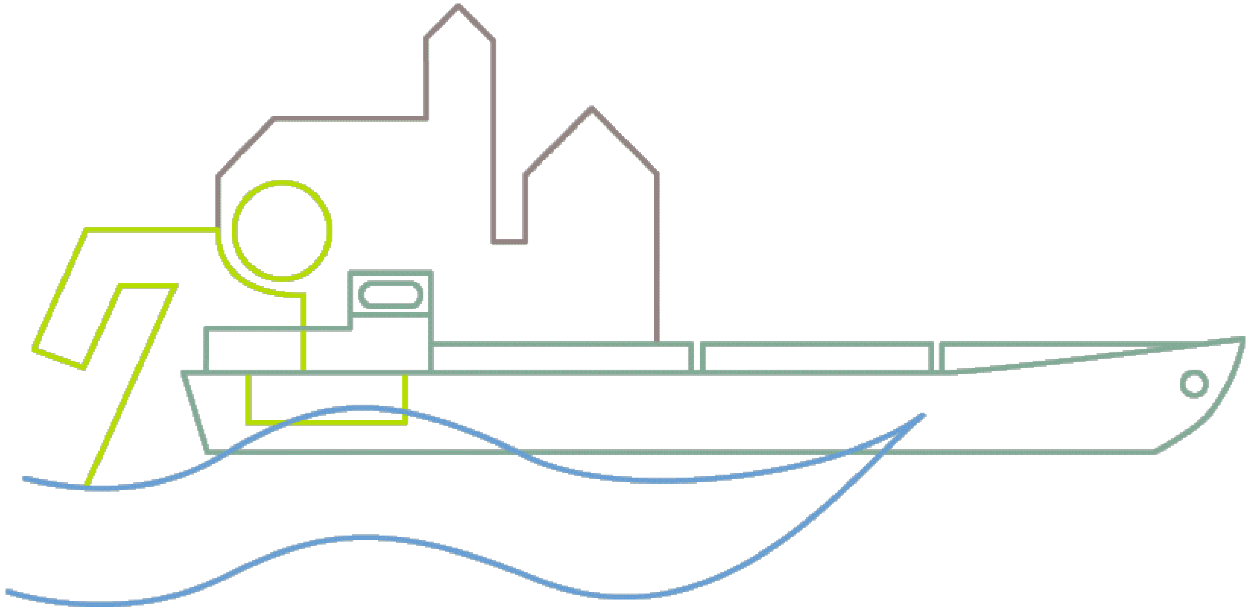


Summer 2012 and 2013



Conclusions

- Updating HBV runoff storages gives optimal runoff at forecast start.
  - Persistence dependent on hydrological situation.
- Updating HBV snow storage helps to limit available melt water for forecasts.
  - Yields a slight improvement for greater lead-times.
  - Equivalent improvement assumed for H13 SWE.
- Updating Soil Moisture Storage with H14 SMI degrades simulation results.
  - Benefit of rescaling SMI to be assessed.



Thank you for your attention!

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RUB

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