Impact of satellite and in situ data assimilation on hydrological predictions

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Outline

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   - Added value of data assimilation
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2. Results
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   - Added value of data assimilation
3. Conclusions

Outline

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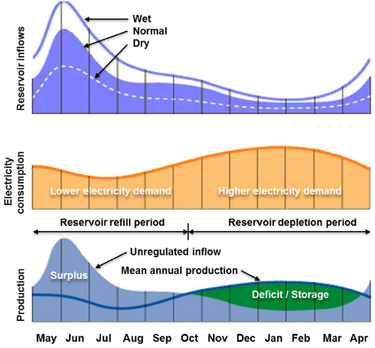
1. More than 2100 hydro power plants
2. Total installed capacity: 16200 MW
3. 200 plants produce 94% of the power
4. Snow-melt fed reservoirs.

Annual reservoir management

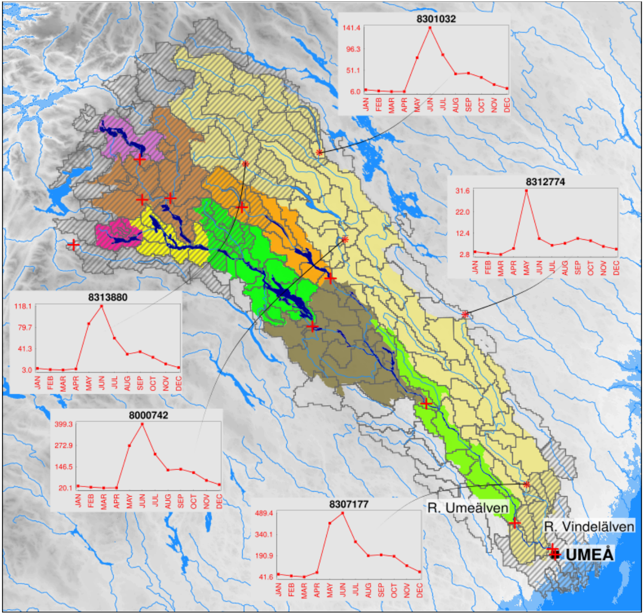


Every day, compare forecasted remaining spring melt runoff to the remaining reservoir volume to fill-up: excess water can be used for production in the current year

1. Information requirements
   - Spring and summer snow melt runoff winter energy demand
   - HP producers store snow melt in large reservoirs for production next winter
2. Use of forecasts
   - Seasonal, short-term runoff forecasts during winter/spring to update production planning
   - Reservoirs must be filled by end of summer!
   - Use as much water as possible for production during the current spring/summer!
   - Avoid release of water from reservoirs that cannot be used for production (spill)

Objectives

1. Provide insights on which satellite products add value to discharge and reservoir inflow predictions
2. Assess economic value of assimilating satellite based snow data and runoff observations in a forecast system



•Northern Sweden •26000km^2 •Snow melt dominated

The assimilation experiment

1. Two in-situ measurements: discharge and reservoir inflow
2. Four satellite products: AET, PET (MODIS), FSC (500×500m), SWE (10×10km) (CRYOLAND)
3. 47 additional unique combinations of the six (53 assimilations in total)
4. Target variables: discharge and reservoir inflow
5. European-scale Hydrological Prediction for the Environment (E-HYPE) model
6. Model performance assessed with the KGE and its three components

$$KGE = 1 - \sqrt{(\rho - 1)^2 + (\beta - 1)^2 + (\alpha - 1)^2}\,.$$

7. Performance gain: $\Lambda = \dfrac{\theta - \theta^\star}{1 - \theta}$

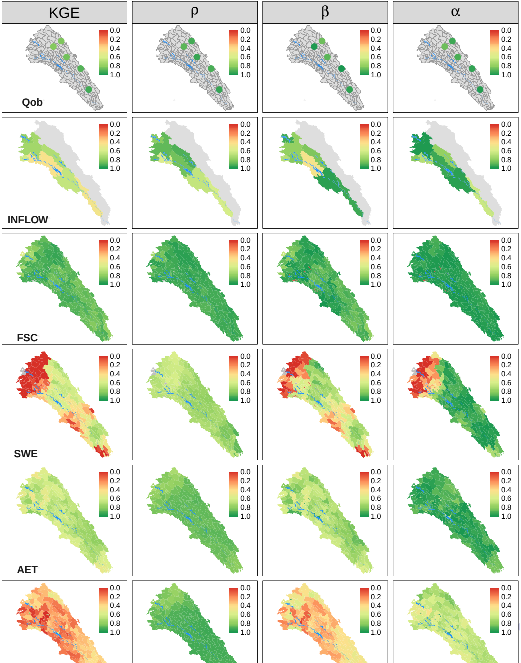
Assessing added value of data assimilation

1. Seasonal forecasts of runoff as well as electricity demand (and price) may be rather uncertain.
2. Before onset of snowmelt, and in early phase of spring flood period, hydropower companies may still have high flexibility to adapt production planning as the conditions unfold.
3. Later in snow melt period, when the annual reservoir storages are closer to the maximum filing level, the flexibility is smaller, and forecasts becomes more important
4. Still, seasonal forecast before and early in the season are still used to make long-term production planning

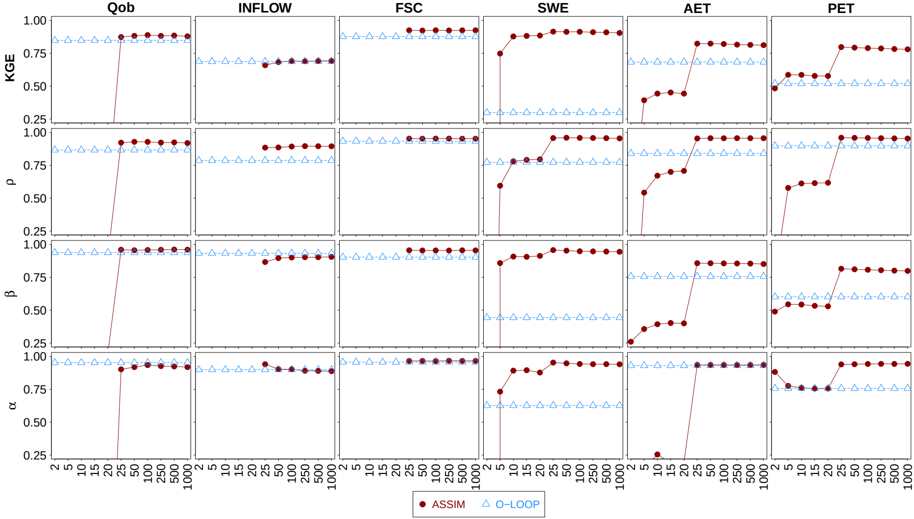
Economic model

1. Production volume = (inflow forecast – reservoir demand) (until 31July)
2. Production value = Production volume * MWh/volume * MSEK/MWh
3. Forecast gain = |value(obs) – value(benchmark)| − |value(obs) - value(forecast)|

Benchmark

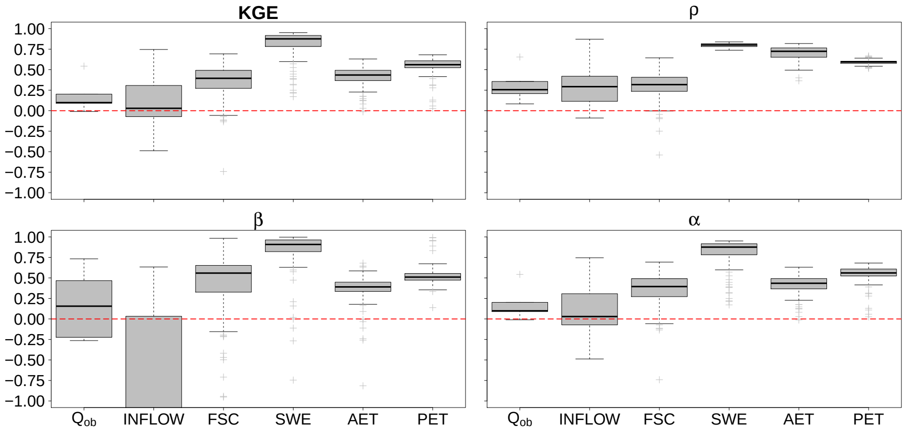


Sensitivity to the ensemble size



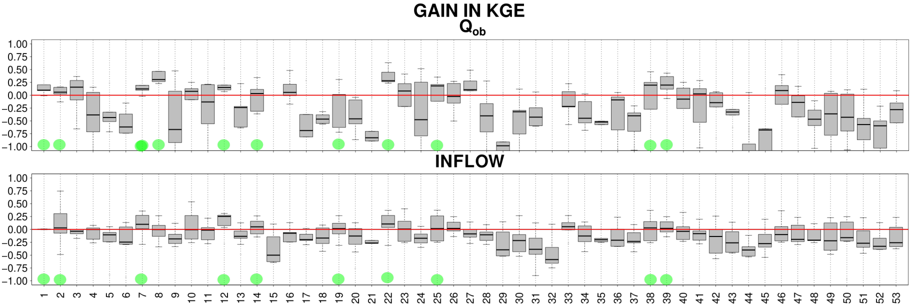
- Most assimilation stabilised with 25 members
- INFLOW KGE and β needed 100 members.

Performance of single variables



- High improvements in SWE, AET and PET
- Lower in Q_{ob} and INFLOW: high open-loop performance

Performance of product combinations

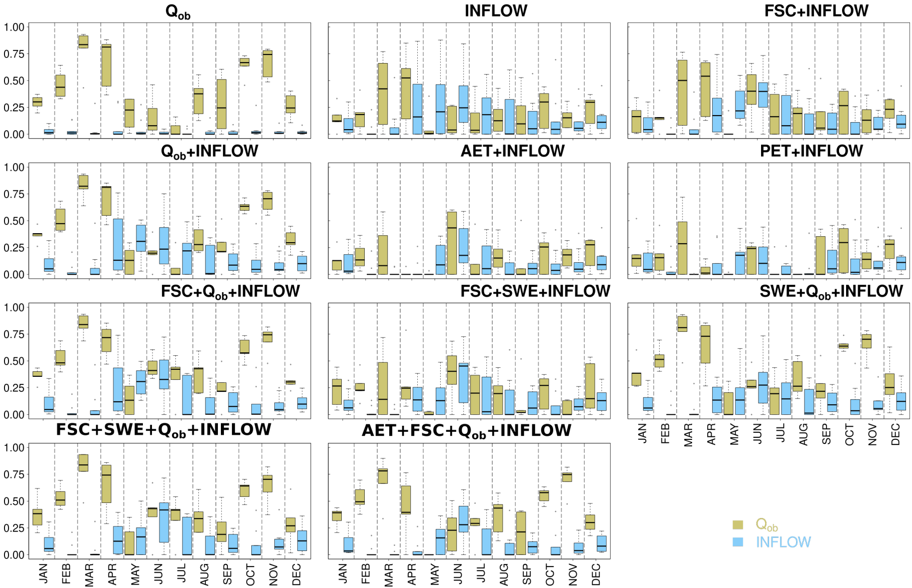


- Informativeness: assimilation with positive gains for Q_{ob} and INFLOW

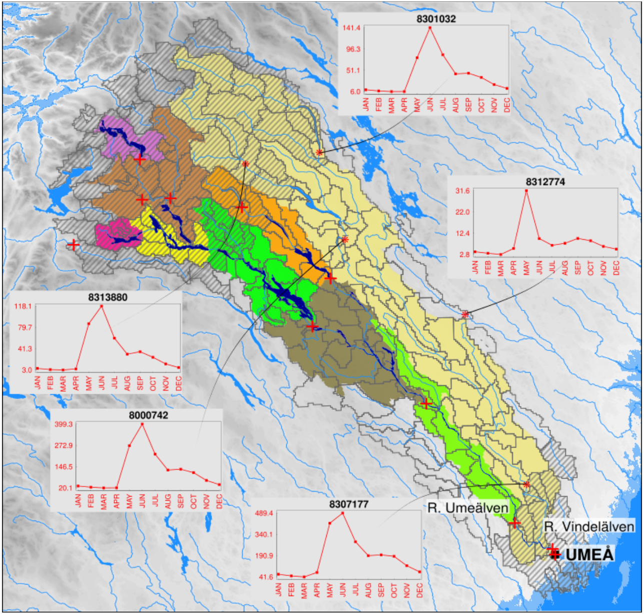
The informative assimilations

Assim.	Q_{ob}	SWE	FSC	INFLOW	AET	PET
1	•					
2				•		
3			•	•		
4	•			•		
5				•	•	
6				•		•
7	•		•	•		
8		•	•	•		
9	•	•		•		
10	•	•	•	•		
11	•		•	•	•	

Predictions during different months

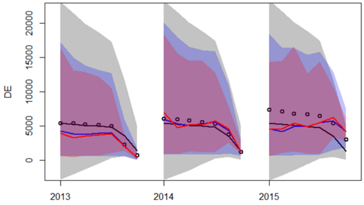


Gain from assimilation: Överuman reservoir (R+FSC)



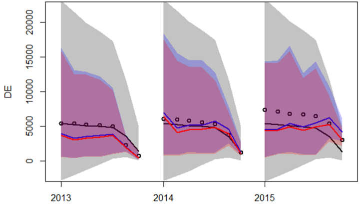
Gain from assimilation: Överuman reservoir (R+FSC)

CLIMATOLOGY
EPS, NO ASSIM
SF4 NO ASSIM



EPS and SF4 improves mainly late in spring (June and July) – especially the snow rich year 2015
SF4 reduces ensemble spread more than EPS, but not mean value

CLIMATOLOGY
SF4, NO ASSIM
SF4 ASSIM



Assimilation of inflow and snow data mainly improved compared to EPS and SF4 in 2015 – and in general also in late part of melt period

Conclusions

1. 100 members are needed for the optimum performance of the ensemble Kalman filter with the E-HYPE model
2. Certain combinations of datasets improve prediction of stream flow and reservoir inflows when assimilated together
3. The ET products especially PET not generally add value to the assimilations
4. The informative assimilations improved reservoir inflow predictions during the critical snow-melt months
5. Assimilation of reservoir inflow and FSC data results into a forecast gain of SEK 20M (economic model, part of ongoing research) for a single event in 2015.