The role of earth observations and in situ data assimilation in seasonal hydrological forecasting

doi:10.1029/2022WR033655

Jude L. Musuuza[1] Louise Crochemore[2] Ilias Pechlivanidis[1]

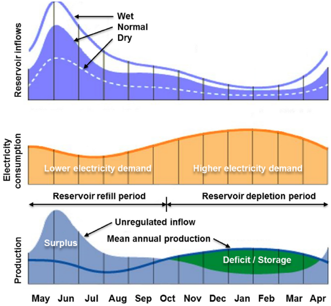
[1]SMHI, Norrköping, Sweden [2]Université Grenoble Alpes, Grenoble, France

HEPEX Workshop, Norrköping, 2023

SMHI

Motivation: Forecast value for hydropower production

- Spring and summer snow melt runoff winter energy demand
- HP producers store snow melt in large reservoirs for next winter production



- 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)

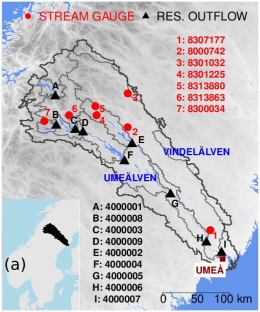
SMHI

Previous data assimilation (DA) studies

Musuuza et a., (2020), Remote Sensing. doi:doi:10.3390/rs12050811

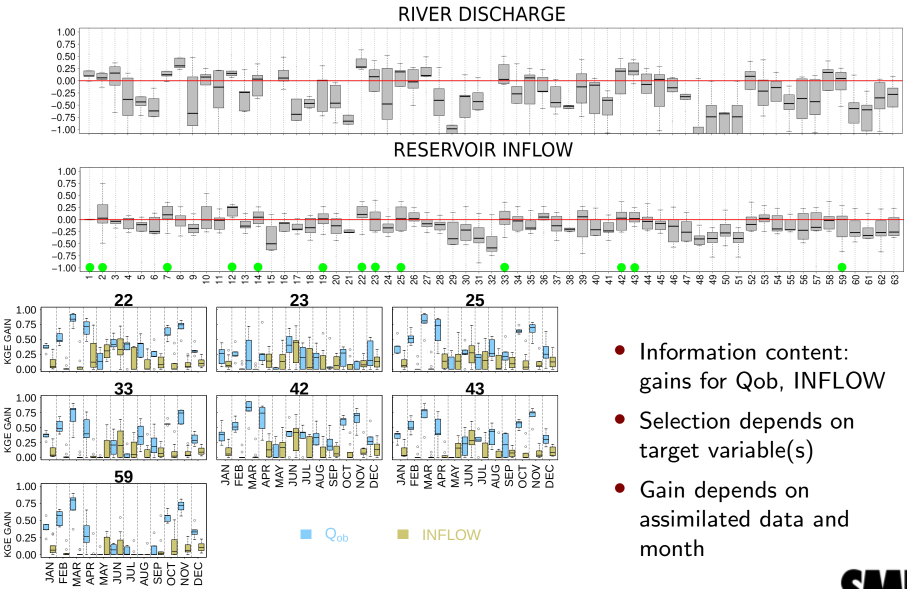
Product	Provider	Coverage	Sp. Res.	Availability	Frequency
Snow Water Equiv.	ESA CCI	Global	12.5 km	1979-2019	Daily
Actual ET	NASA MODIS	Global	500 m	2001-2021	8-day agg.
Potential ET	NASA MODIS	Global	500 m	2001-2021	8-day agg.
Frac. Snow Cover	CRYOLAND	Europe	500 m	2000-2020	Daily
Discharge*	SMHI	Sweden	-	1900-2020	Daily
Reservoir inflows*	VRF	Sweden	-	1961-2019	Daily

* in situ observations



- River Umeälven, Sweden
- Area: 26000 km^2
- Snowmelt-dominated
- Unregulated Vindeälven tributary (4 Q stations)
- Managed lower Umeälven tributary (3 Q stn.)
- Nine reservoir inflow regions

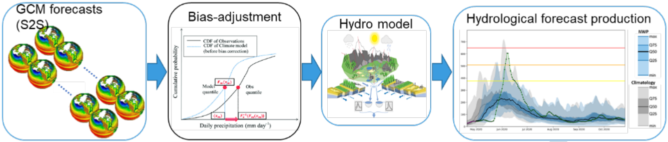
Previous data assimilation (DA) studies Musuuza et al. (2020)

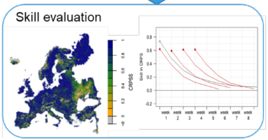


- Information content: gains for Qob, INFLOW
- Selection depends on target variable(s)
- Gain depends on assimilated data and month

Unanswered question: does DA play a role in streamflow forecasts?

Motivation: Forecasting service chain





Bias-adjustment
Distribution-based scaling (quantile mapping)

Hydrological model
E-HYPE pan-European model
~215 km^2 catchment resolution

Skill evaluation
Continuous Ranked Probability Skill Score (CRPSS)

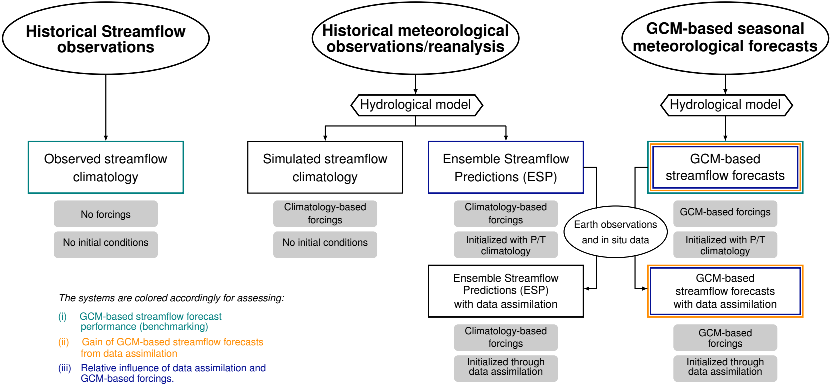
Forecast	**Time horizons**
Weather	0-14 days
Subseasonal	1-12 weeks
Seasonal	**1-12 months**
Interannual	1-10 years
Climate	decades-centuries

- Main skill sources: Initial Hydrological Conditions (IHC), Meteorological Forcing (MF)
- Skill generally falls with lead time
- Skill depends on choice of benchmark

SMHI

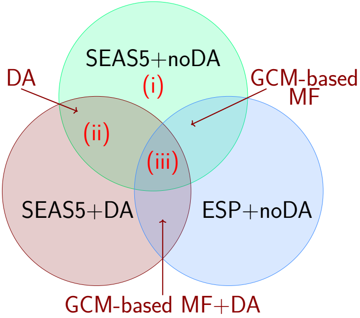
The diagnostic framework to detect sources of skill

Published in Musuuza et al. (2023), WRR. doi:10.1029/2022WR033655



The experiment: questions (Musuuza et al. (2023))

1. Seasonal Forecast (SF) quality in relation to lead time
2. Value and persistence of Data Assimilation (DA) in seasonal streamflow forecasts
3. Relative importance of DA and Meteorological Forcing (MF) in SF

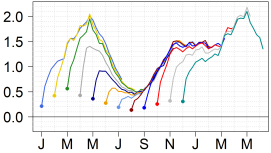


SMHI

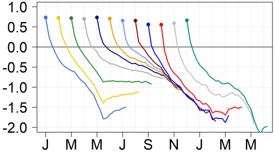
The experiment: methodology (Musuuza et al. (2023))

1. Reference meteorological forcing: HydroGFD v2
2. Dynamic seasonal forecasting: ECMWF SEAS5 (bias-adjusted), ESP
3. Model initialization: 1st of every month, weekly aggregations
4. Forecast horizon: 7 months ahead
5. Performance metric: Continuous Ranked Probability Score (CRPS)
6. Skill metric: Continuous Ranked Probability Skill Score (CRPSS)

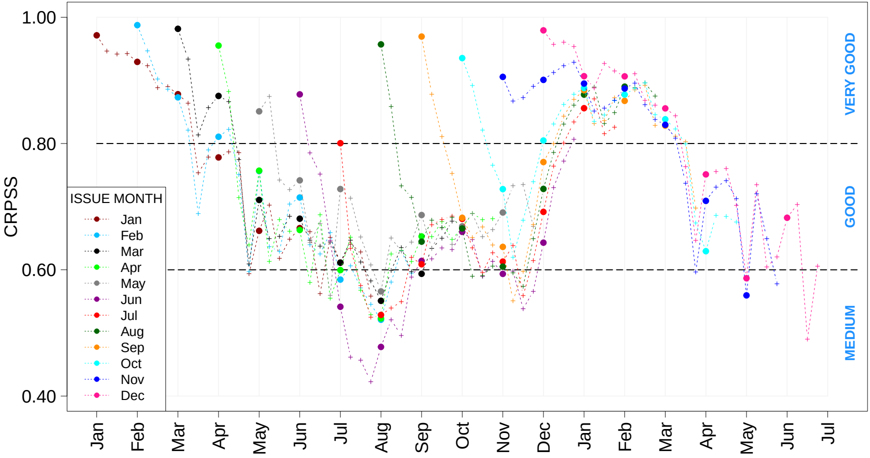
CRPS: optimum 0



CRPSS: optimum 1



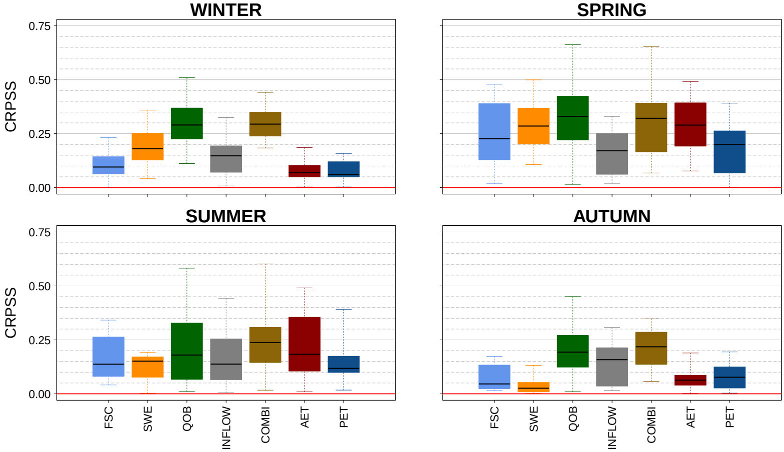
Results 1: The quality of seasonal forecasts



Forecast sys: SEAS5+noDA, BM: observed climatology
Generally high skill for all initialization months
May-Jul initialization skills lower large Q measurement errors? model process representation?

SMHI

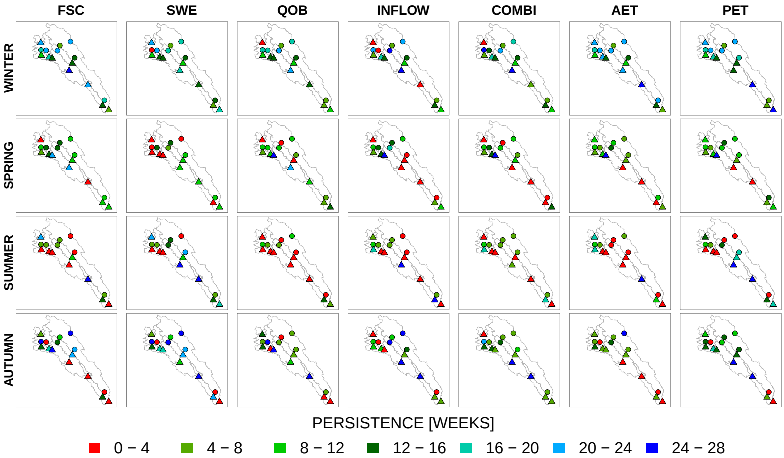
Results 2a: The value of data assimilation



Forecast sys: SEAS5+DA; BM: SEAS5+noDA
Highest skill in Winter and Spring
Large spreads in spring and summer values: Q flood measurement errors?

SMHI

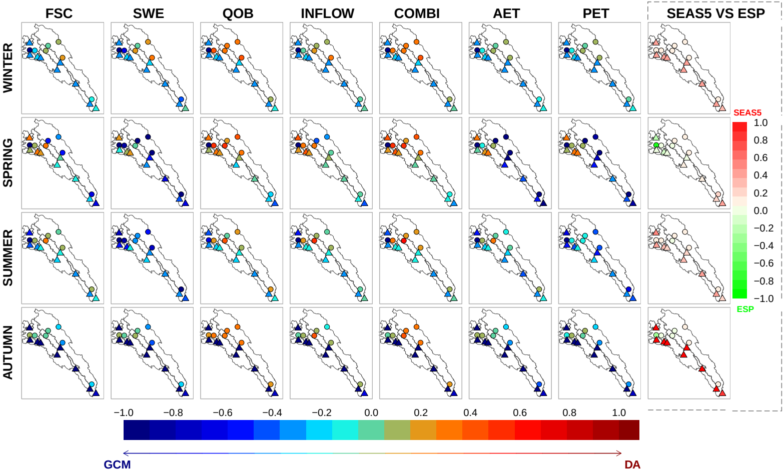
Results 2b: The persistence of data assimilation



Different between assimilations and seasons
Persistence longest in winter and shortest in summer
Short summer values: snow depletion, Q errors?

SMHI

Results 3: Relative importance of DA



DA: winter and spring; MF: autumn and summer
SEAS5 MF superior to ESP except in spring and autumn

Conclusions

1. The assimilation of EO datasets generally improves the initial hydrological conditions and hence the forecasts at short lead times (lead-week 0). However, the added value from EO assimilation depends on the assimilated variable and the season.
2. The impact of data assimilation (in terms of persistence) varies between the variables and seasons. In particular, FSC, AET and reservoir inflow have the longest persistence during spring
3. Overall, the data assimilation (hence the improvements in initial hydrological conditions) have higher impact on seasonal streamflow forecasts than the meteorological forcing.

References

1. Musuuza, J.L.; Gustafsson, D.; Pimentel, R.; Crochemore, L.; Pechlivanidis, I. Impact of Satellite and In Situ Data Assimilation on Hydrological Predictions. Remote Sens. 2020, 12, 811. doi:10.3390/rs12050811
2. Musuuza,J.L.; Crochemore, L.; Pechlivanidis, I. Evaluation of Earth Observations and In Situ Data Assimilation for Seasonal Hydrological Forecasting, Water Resour. Res. 2023. doi:10.1029/2022WR033655

SMHI