KUVA: ADOBE STOCK

Using Satellite Snow data in hydrological forecasting – SYKE's HUVA project

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Outline

- Project overview and objectives
- Data and Methods
- Results
- Takeaways and conclusion

Project overview and background

The aim of the project was to test the degree of improvements of hydrological model forecasting using EO-based Snow Water Equivalent (SWE) and Snow Cover Area (SCA) products, in a river where the possibility of model calibration and data assimilation is limited due to lack or quality of data.

- Hydrological observations are not always perfect
- There are only few in-situ measurements of snow water equivalent, and they might not represent the SWE of a larger area

➢ EO-Based SWE and SCA products could potentially improve hydrological forecasts

Project objectives

- To improve the calibration performance of the inflow model
- To study the quality and utility of the EO-based SCA and SWE products for hydrological modelling and forecasting
- To improve the snow data assimilation process of the inflow model in hydrological forecasting

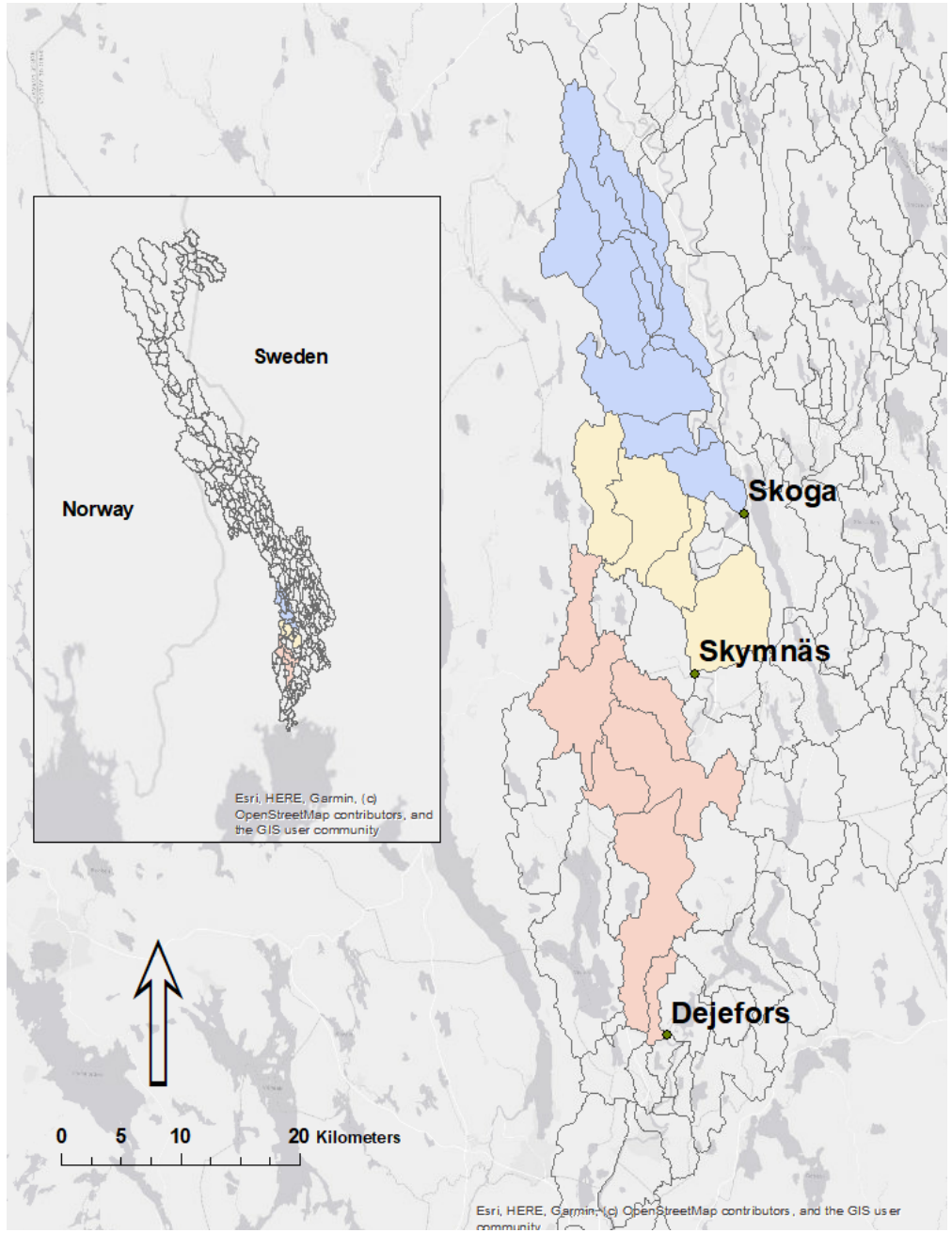
Study areas

3 local areas downstream river Klarälven

Skoga 255 km2
Skymnäs 160 km2

Dejefors 250 km2

Issues with discharge observations, difficulties to achieve realistic snow simulation in this part of river



Study areas

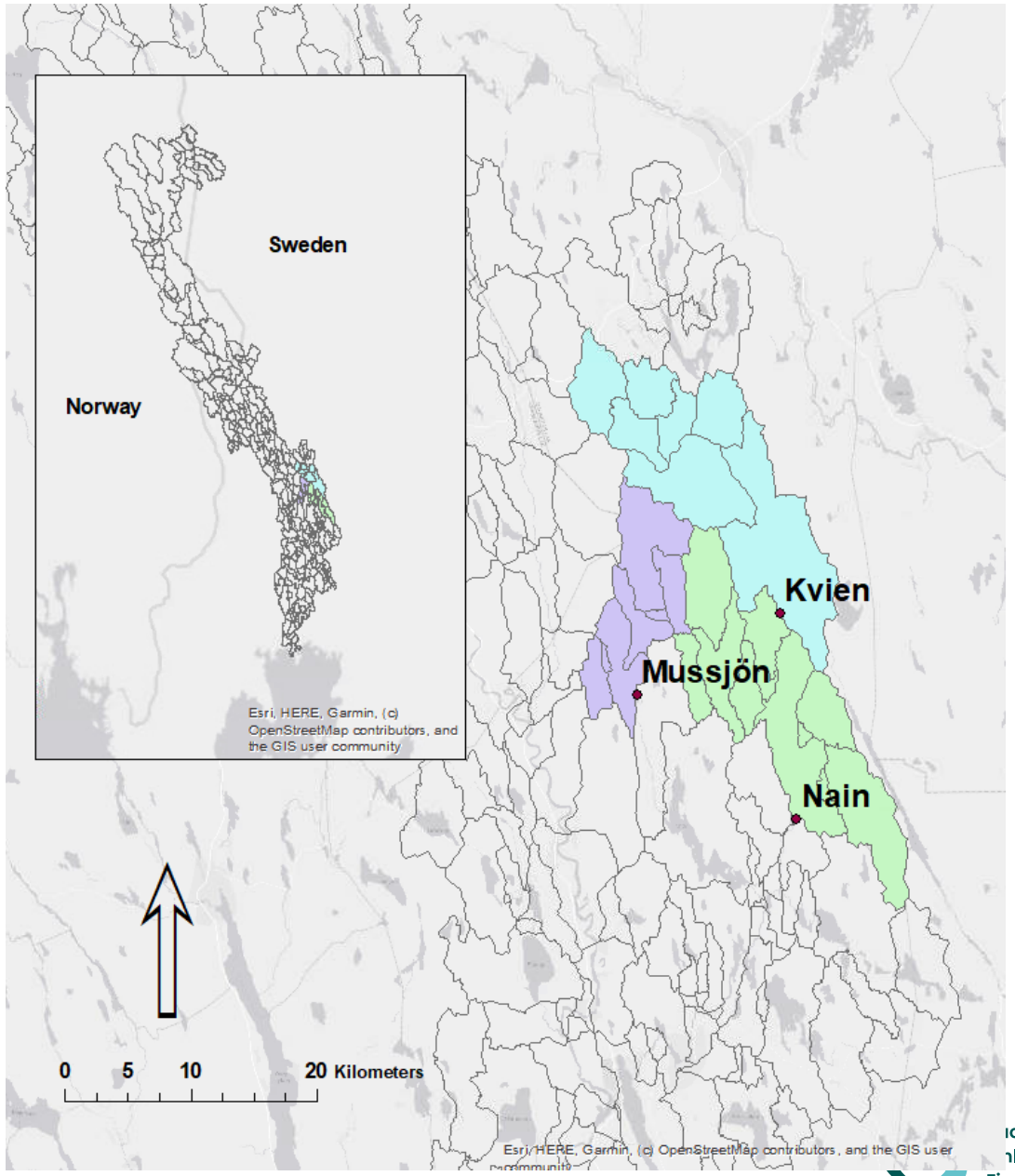
3 local areas along a tributary of the Klarälven River, Uvån

Kvien 216 km2

Mussjön 93 km2

Nain 201 km2

These areas have better quality hydrological observations



Snow Satellite data

Near-real-time data is available, and it covers large areas

Different instruments available to sense the snow layer properties

- passive microwave radiometers for SWE
- optical sensors (visible light or infrared) for SCA

The project used already existing EO-based products with relatively long time series available

EO-based Snow Water Equivalent

GlobSnow-2 SWE product

- daily time resolution
- 25 km spatial resolution
- based on microwave radiometer signal
- fairly accurate for dry snow and <150 mm of swe

Provides data throughout the winter season

Has limitations with deep snow and wet snow conditions due to microwave scattering

Product validated against in-situ snow lines in Russia and former SU

- average root-mean-square-deviation (RMSD) was 32.5 mm and bias 9.8 mm

EO-based Snow Covered Area

based on the CryoLand product

- daily time resolution
- 500 m spatial resolution
- optical sensor

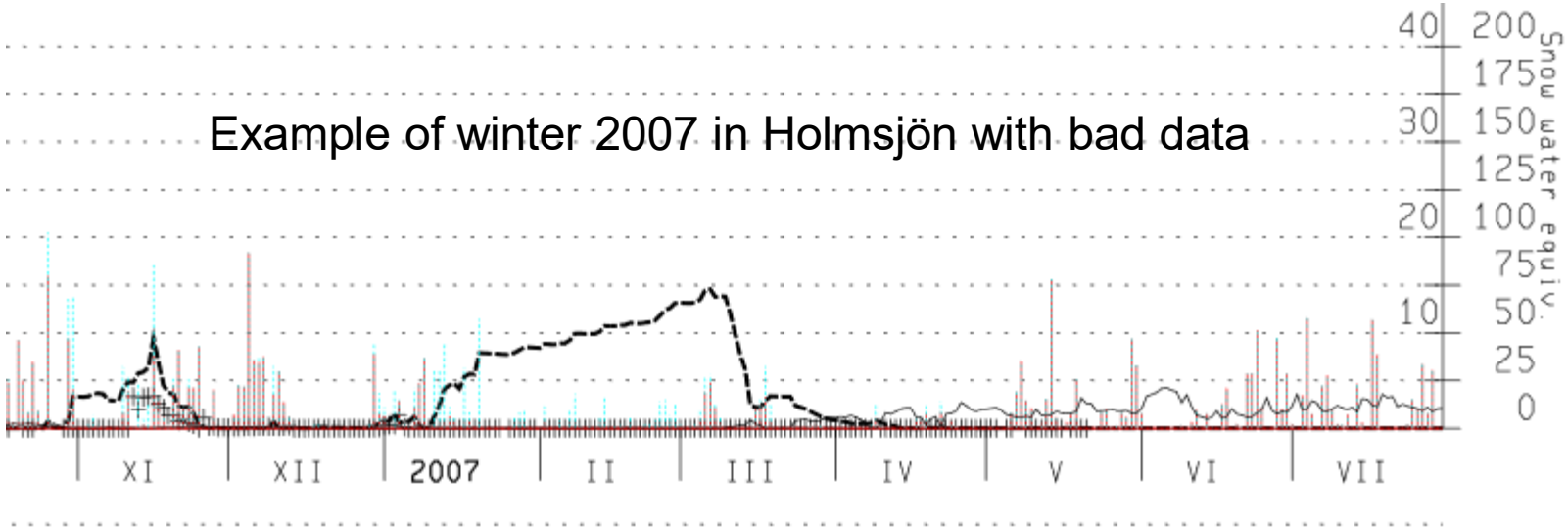
The data is available during spring season with cloudless conditions.

Can provide reliable values under boreal forest canopy

Used for detection of snow melt season

Problem points with the satellite data

- In some areas, the satellite data indicates that snow would melt rather early in spring
  Snow melts earlier in SWE product compared to SCA
- In some years, the data is not usable, either it is mostly zeros values or otherwise suspicious
- SWE Data is not usable in mountainous areas due to higher swe and sloped terrain



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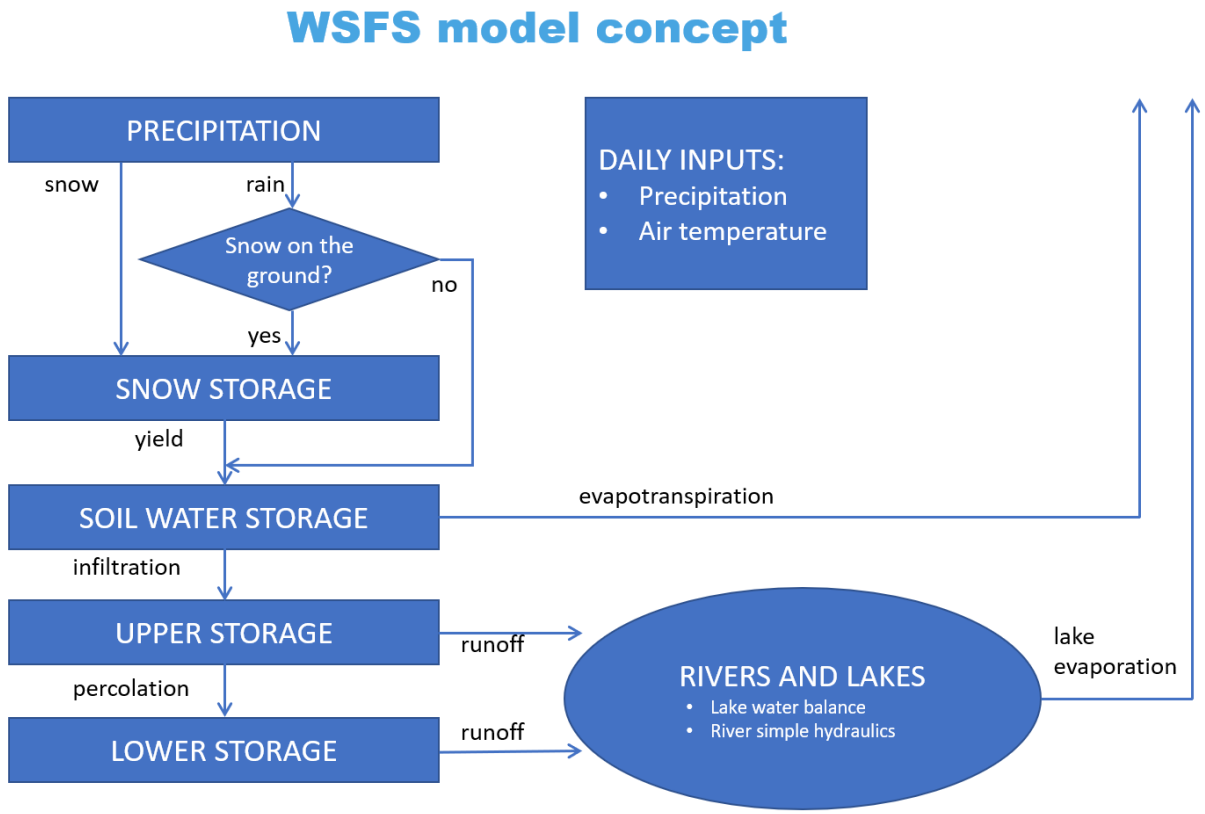
Watershed Simulation and Forecasting System WSFS

The official flood forecasting model covers entire Finland and transboundary watersheds

WSFS forecasting system in operational use also in few other countries

Forecasts are used to

- Evaluate and issue warnings of flood risks
- Hydropower planning
- Monitoring water supply
- Operational lake regulation
- Providing information to media and public



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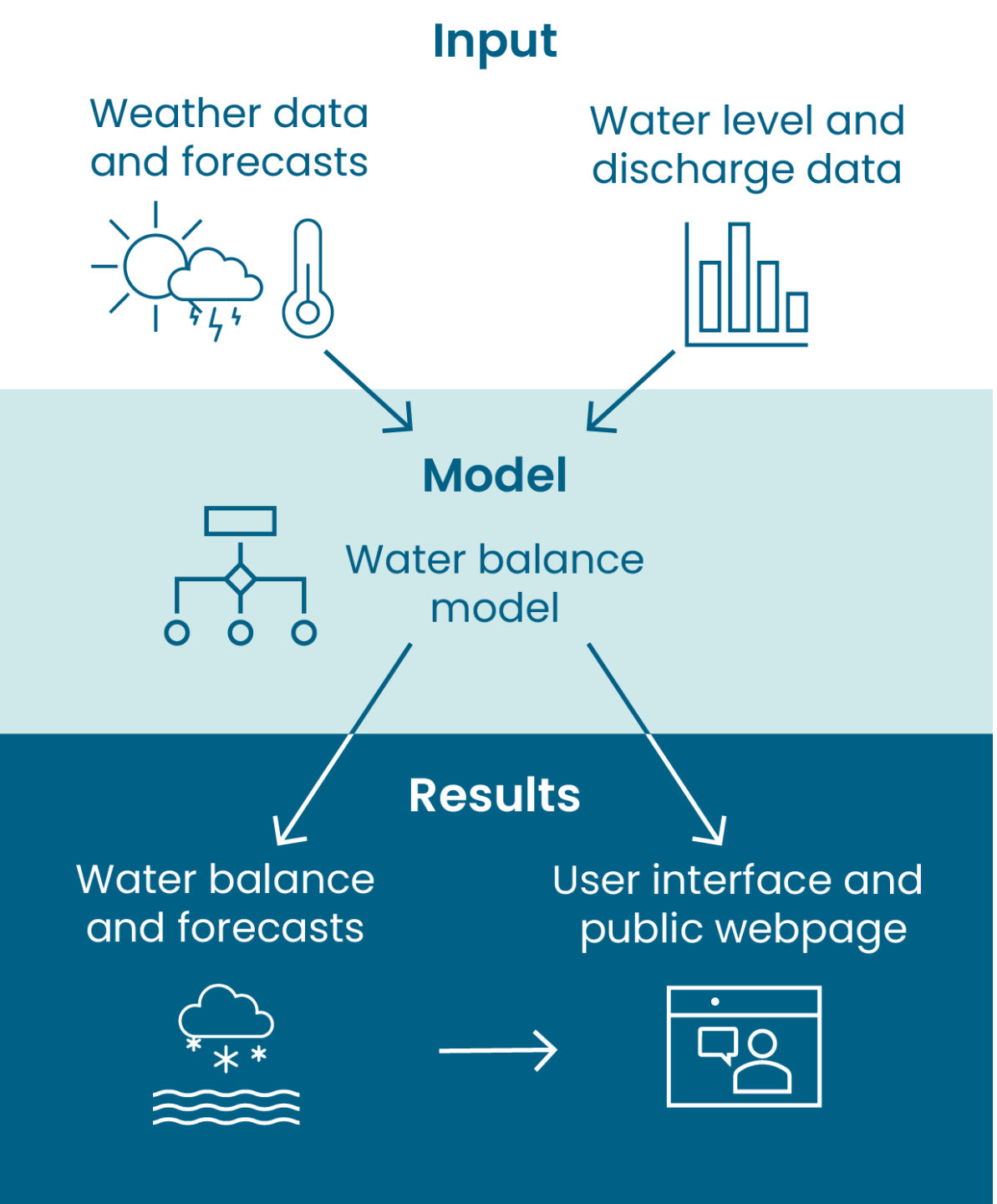


Daily operation of WSFS

Model is run few times a day

Observations and weather forecasts as input

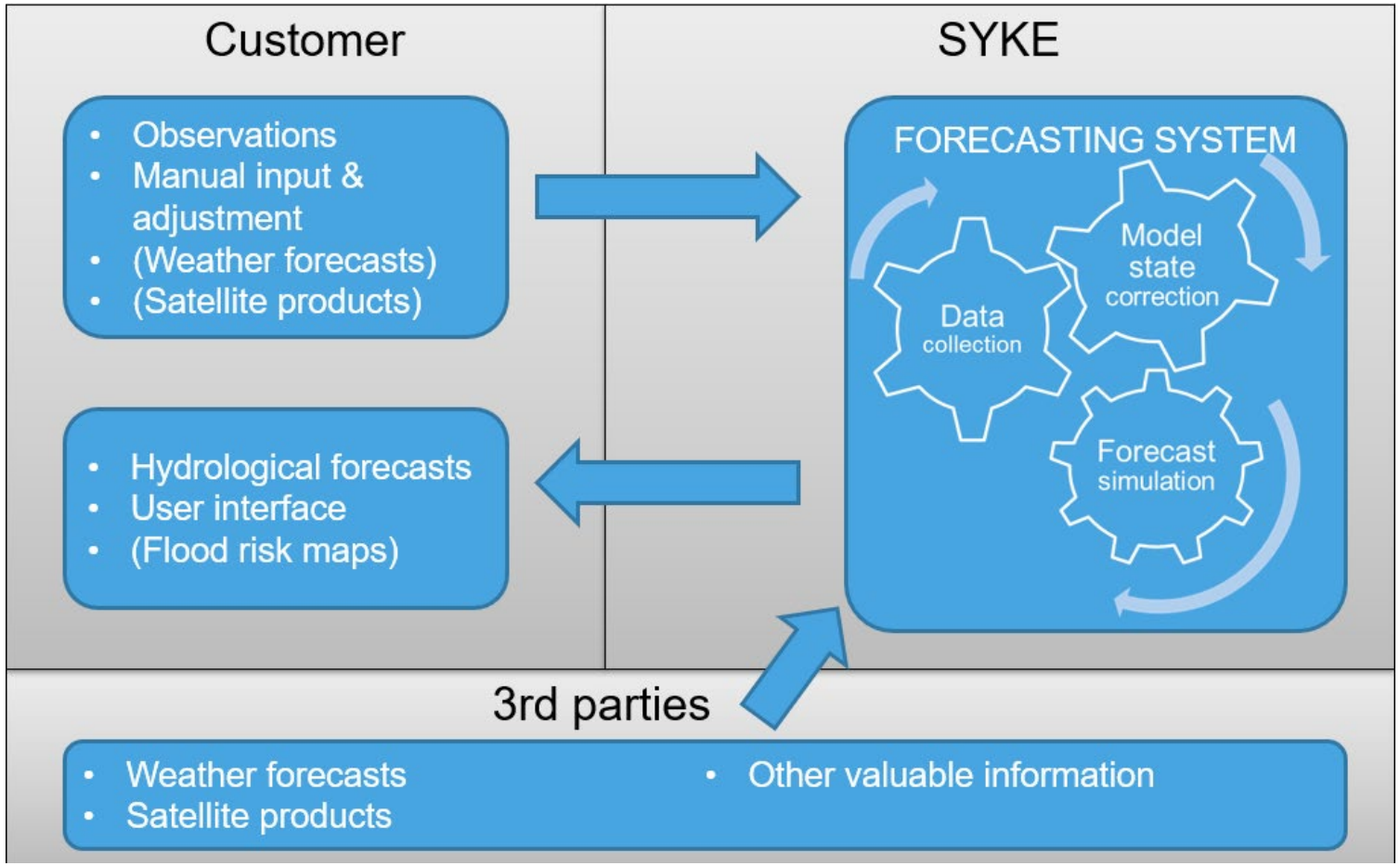
Model data assimilation and updating

Results into figures and maps

Water level Forecasts are reliable for up to 3-5 days, in large rivers and lakes even longer

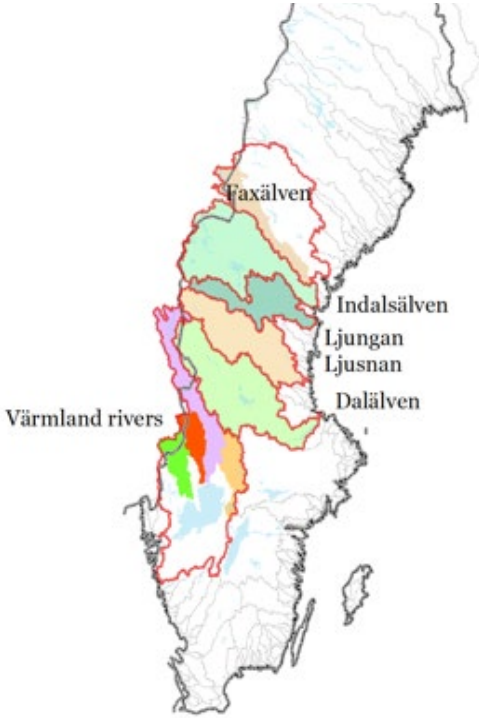
- Limiting factor is weather forecast
- Uncertainty in long-term forecasts (several weeks or even months) is managed using probability forecasts, based on ECMWF ensemble forecasts and historical weather data.

Tailored watershed modeling solutions available internationally



in Sweden

6 catchments modelled



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Use of EO-based SWE and SCA data in WSFS

Values for each sub-basin were calculated as an average of relevant grid values

Implemented new criteria for SWE data reliability to avoid the usage in wet snow conditions

- Temperature criteria
  - last 5 days mean less than zero degree
- Snow cover area criteria with satellite SCA data to identify the snow melt
  - Cases when SCA less than 80%

Additional error criteria for SCA data in case of no snow detection

- SCA being 0 % marks end of the snowmelt season
- ➢ Improves the timing of the flood forecasts

WSFS Model calibration

For Skoga, Skymnäs and Dejefors only snow parameters were calibrated against the EO-based snow data

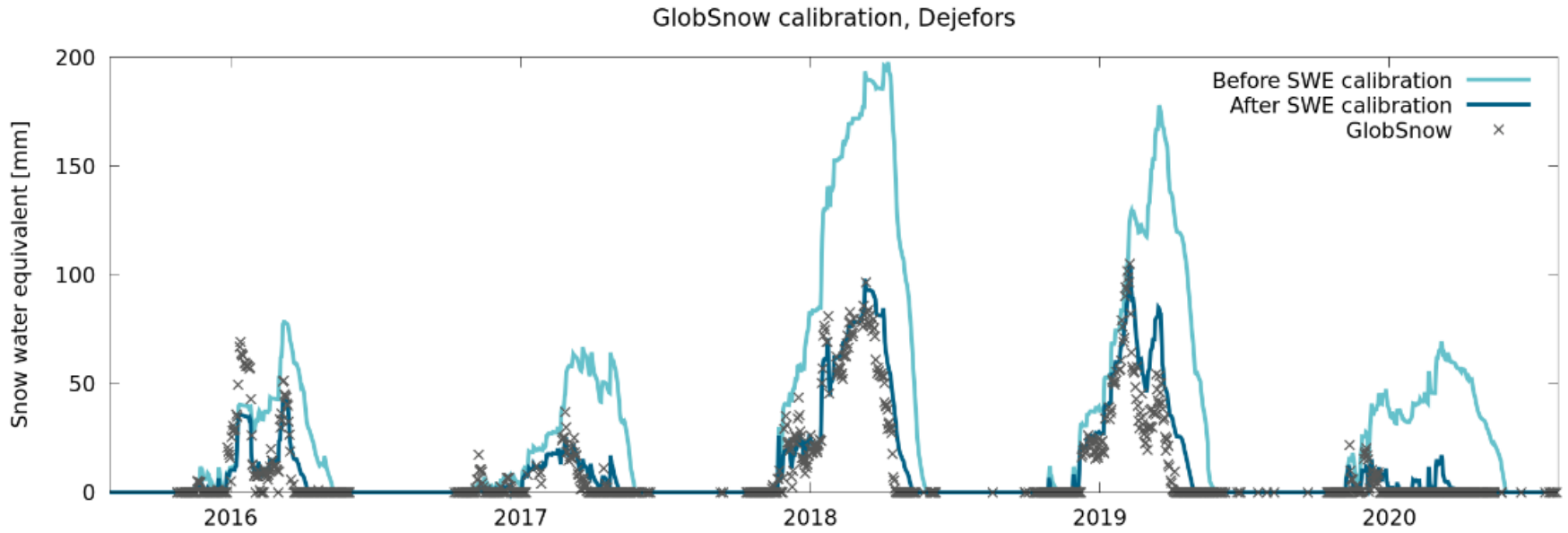
For Kvien Mussjön and Nain, the full parameter set was calibrated against hydrological observations and the EO-based snow data

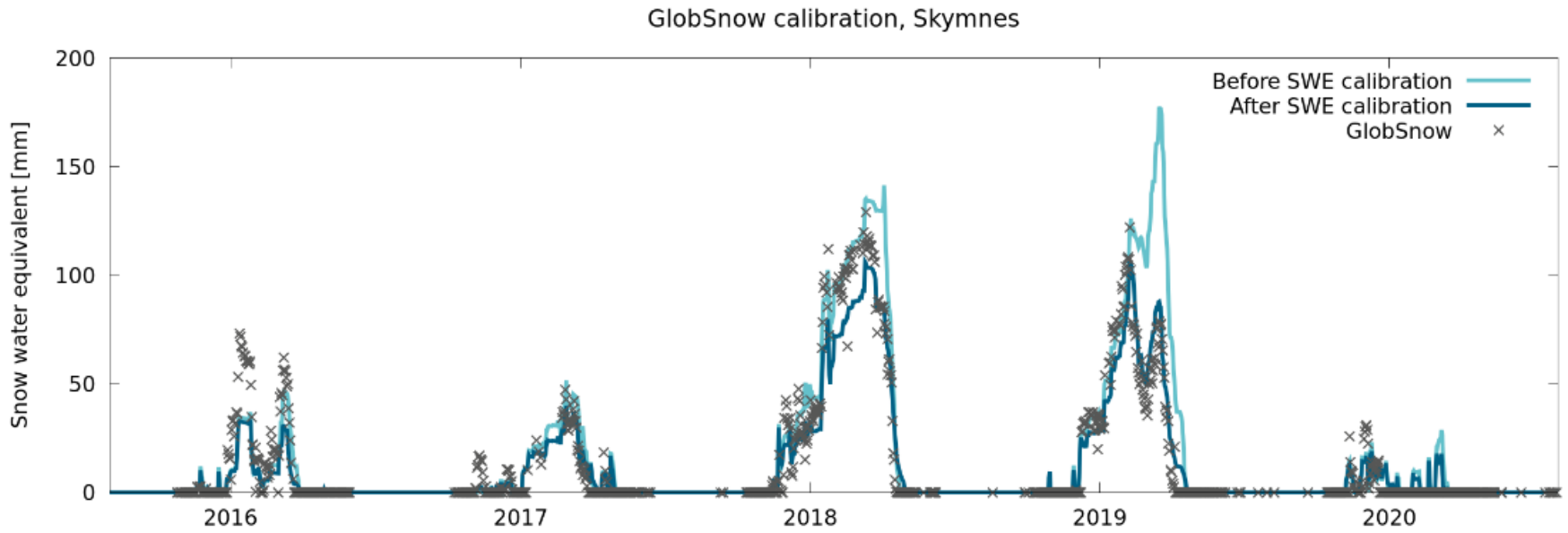
Calibration period 2011-2020

WSFS uses The Hooke-Jeeves algorithm to minimise the difference between reference data and the simulation

Error weights were set with trial and error to each local area and data type

Results - Changes in snow simulation





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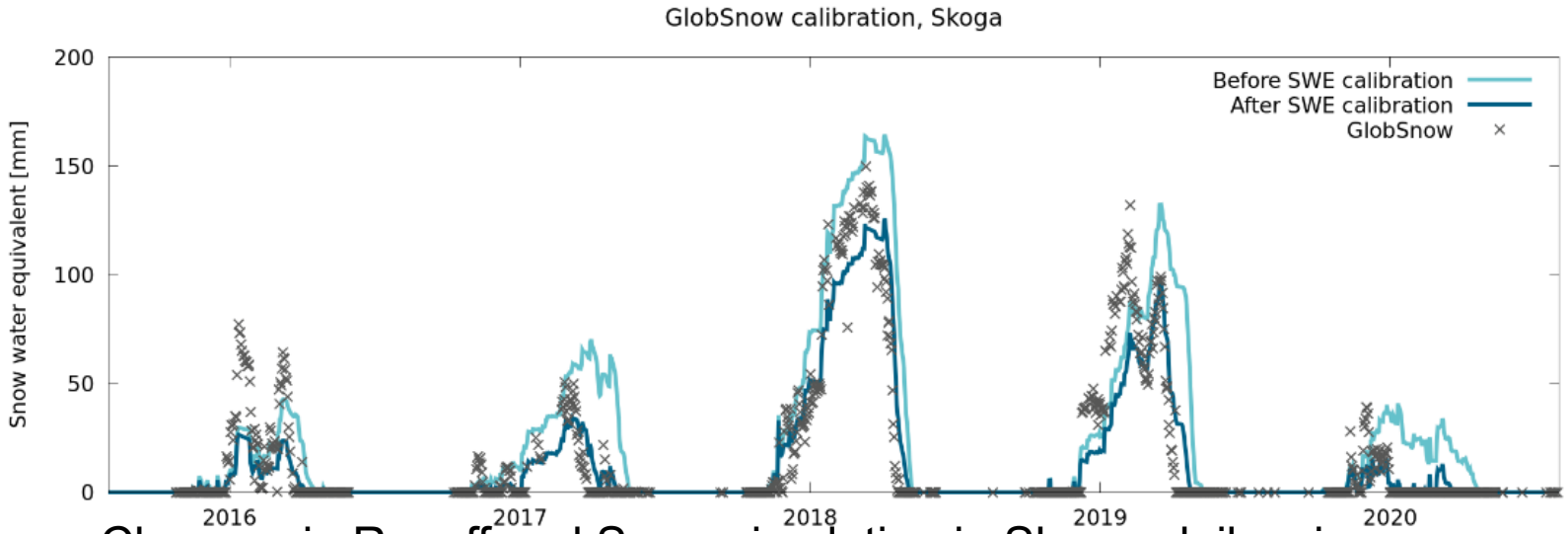
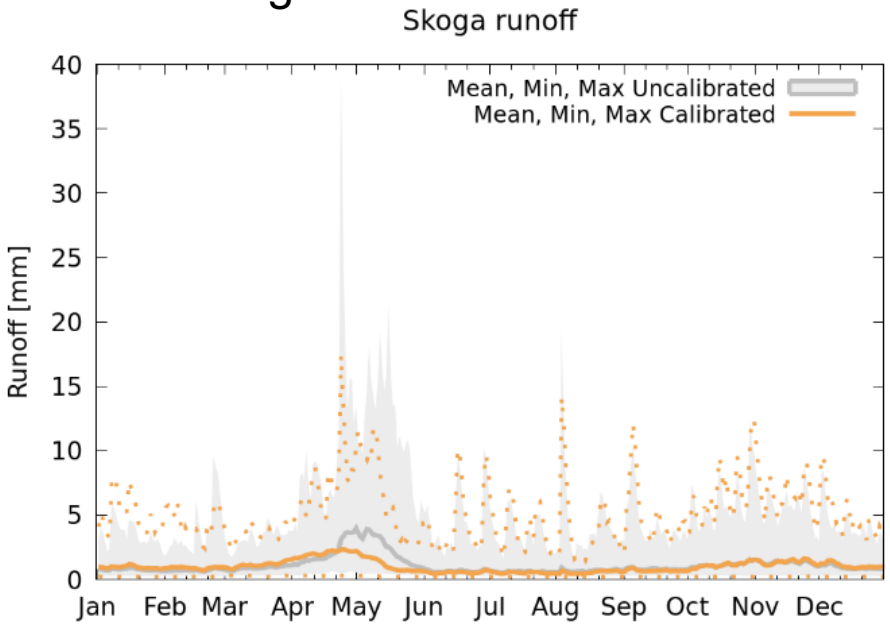
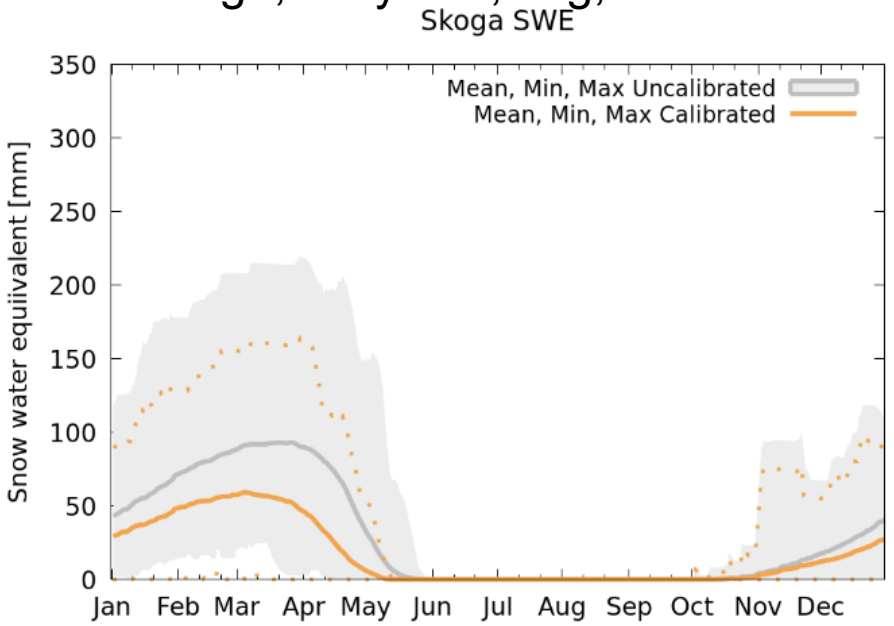
Results - Changes in snow simulation



Changes in Runoff and Snow simulation in Skoga, daily min, avg, max 1961- 2011





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Results - Changes after snow calibration in metrics

Study Area	Snow RMSD		Snow bias	
	before calibration	after calibration	before calibration	after calibration
Skymnäs	49.9	15.9	34.9	-0.6
Skoga	37.5	29.1	21.9	12.5
Dejefors	54.9	19.6	43.5	9.6

Results - Model calibration including snow criteria

Study area	Snow RMSD		Snow bias		Qin R^2	
	before calibration	after calibration	before calibration	after calibration	before calibration	after calibration
Kvien	26.1	16.4	7.7	-3.2	0.80	0.79
Nain	47.1	20.2	-35.6	-13.4	0.36	0.38
Mussjön	34.6	24.1	19.5	8.9	0.82	0.79

Using SWE and SCA data in model updating for spring flood forecasting

SWE and SCA error criteria were added to automated model update routine

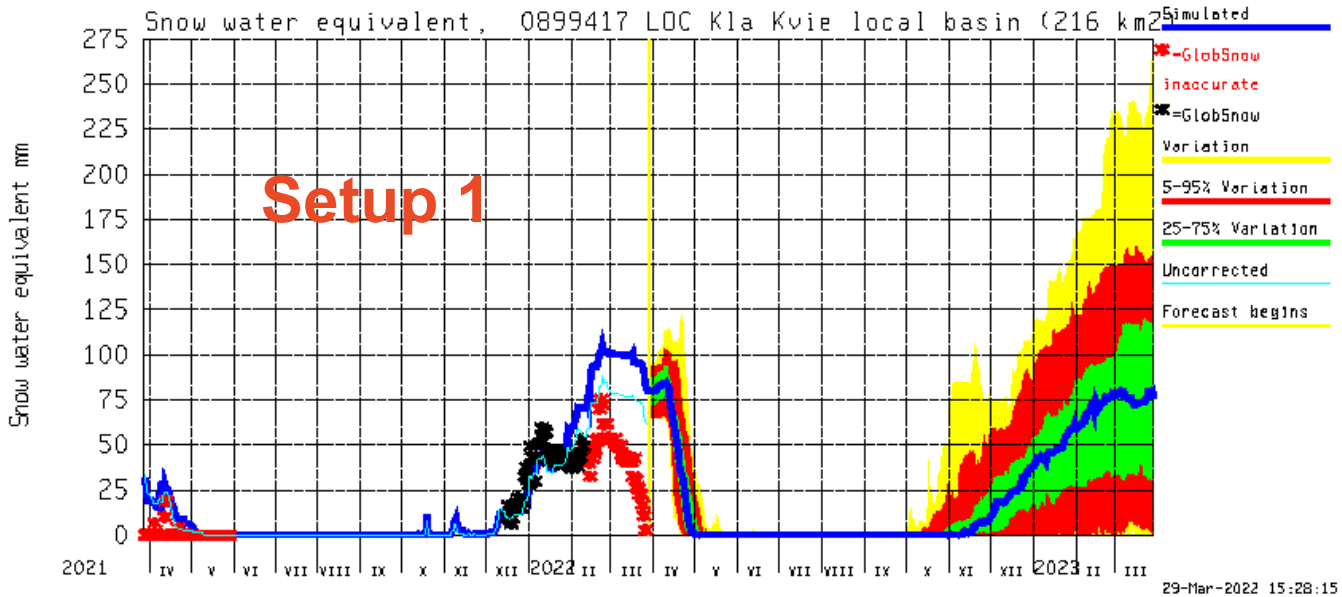
- Normally model inputs (temperature and precipitation) are corrected only against water level and inflow observations

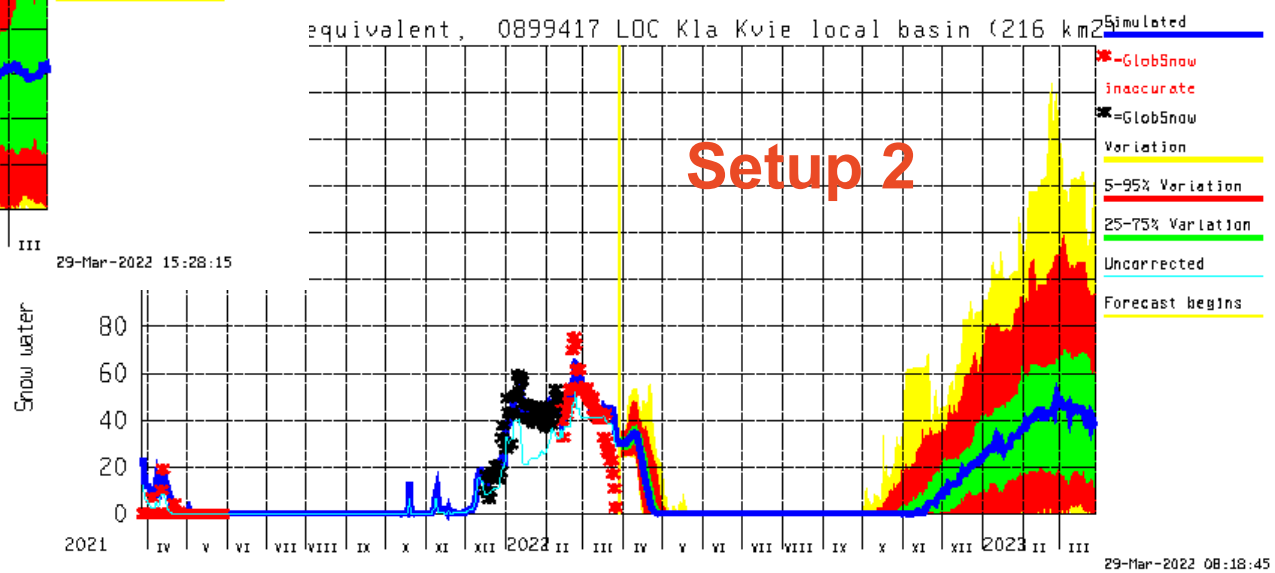
Effectiveness of model updating was tested during latter half of winter 2021-2022

Two independent inflow forecast setups were used in daily forecast production, one without snow error criteria (setup1) and one with it (setup2)

Results - Using SWE and SCA data in model updating for spring flood forecasting

SWE in Kvien at end of March, setup 1 vs setup 2

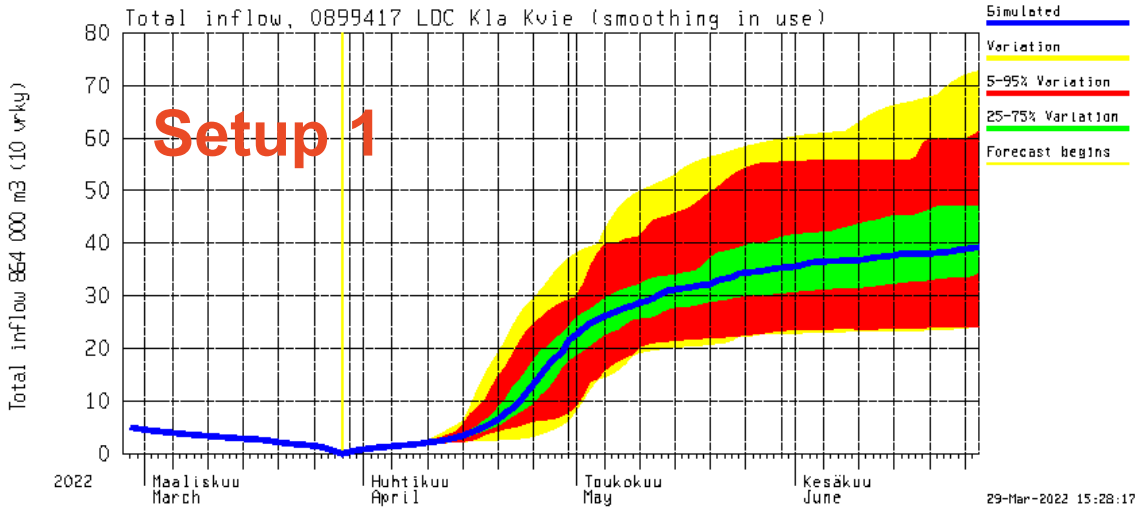




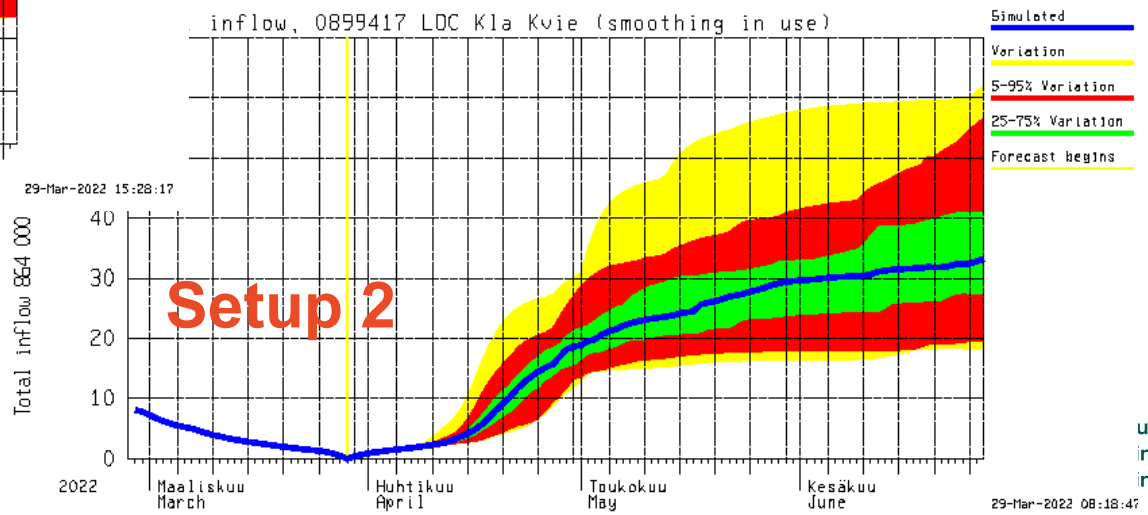
Results - Using SWE and SCA data in model updating for spring flood forecasting

Forecasted total inflow for Kvien at end of March, setup 1 vs setup 2

The median inflow volume sum until 18 May was estimated to be roughly 300 day units for setup 1 and 240 day units for setup 2. The actual inflow sum was about 320 day units



1 day unit = 86400 m^3



Median of forecasted precipitation sum was fairly close to observed in this case

Findings and considerations for future

It is important to be able to identify possible reliability challenges of a particular satellite snow product (wet snow conditions with swe data)

More extensive forecast testing would be needed over several years or use of other methods like reanalysis data

There are promising novel EO-based snow products that could improve the usage further

Conclusions

Benefits of SWE and SCA data used in calibration

- Can improve snow simulation
- Areal variation of snow can be more uniform
- SWE data may improve the simulation of snow accumulation and maximum SWE
- SCA data improves the timing of the snowmelt

Water level and discharge observations are most important observations for calibration and model updating

We will continue testing SWE and SCA data with other forecast basins, also outside Klarälven

SnowIce

A joint project between Finnish Meteorological institute and Syke for 2024-2028

Aims to pursue for new ways to improve the accuracy of Northern Hemisphere and basin scale snow mass estimates

Evaluation of the performance improvements of hydrological models with the obtained new cryosphere information

“The model is only as good as the data it is fed”

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