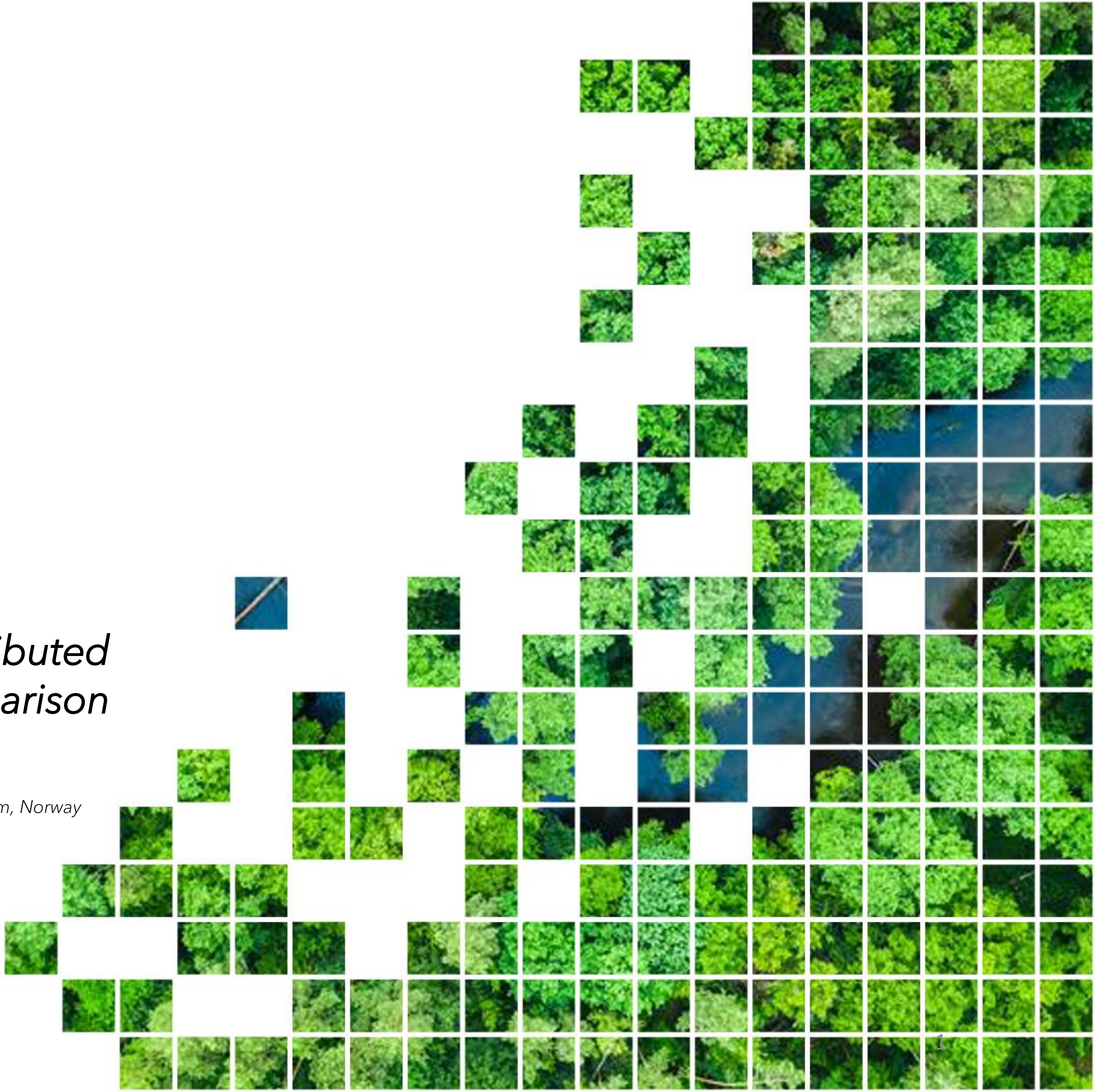
Validation of Kinematic wave model by distributed raster based hydrological modelling in comparison with hydraulic modelling along river section

Mohammadreza Memarzadeh, *Civil and Environmental engineering department at NTNU, Trondheim, Norway*
Oddbjørn Bruland, *Civil and Environmental engineering department at NTNU, Trondheim, Norway*
Ana Adeva Bustos, *SINTEF Energy Research, Department of Energy Research, Trondheim, Norway*
Corine tin Velden, *Department of Catchment and Urban Hydrology, Deltares, Delft, Netherlands*



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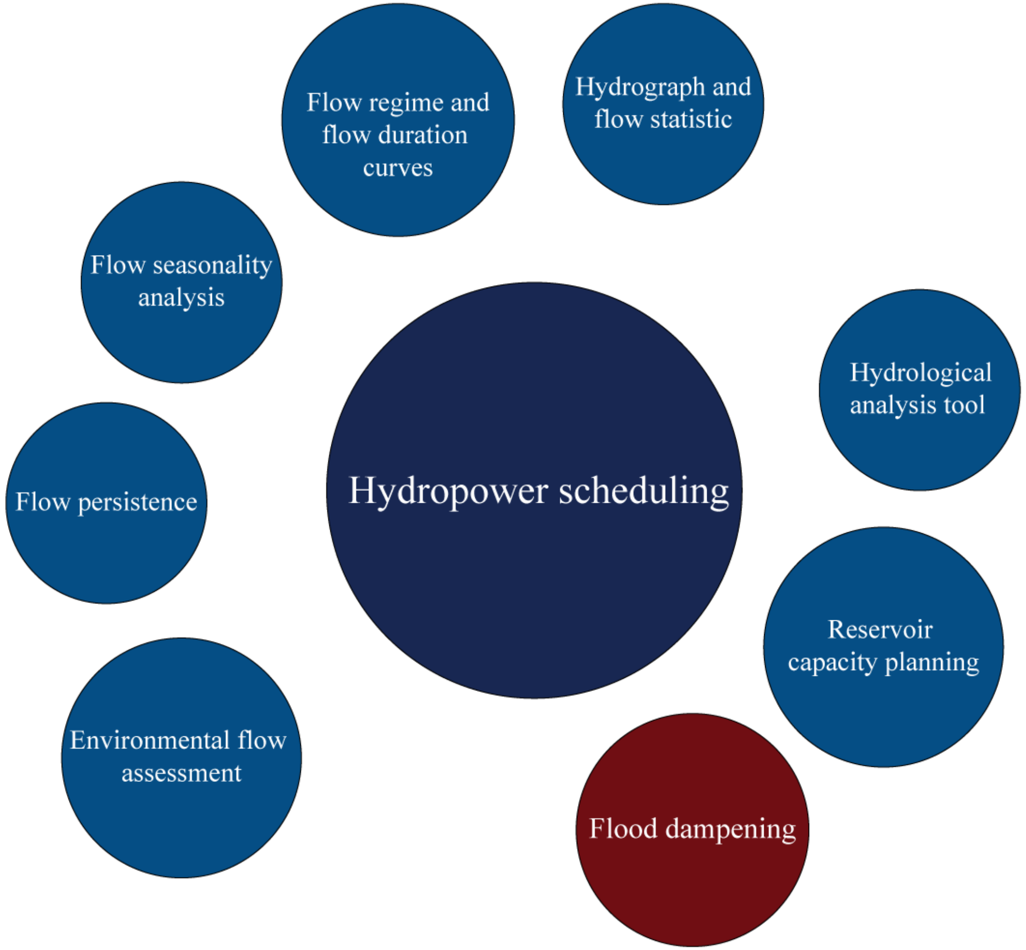
Introduction:

Importance of hydrological in hydropower development:

1- Analyses of historical hydrological data in terms of **flow duration, flow regimes and seasonality** *can provide profound insights on catchments hydrology to help improve hydropower development planning and production scheduling.*

2- Hydropower development/expansion planning and derivation of **reservoirs guide/rule curves based on simulation of hydropower** *systems if adjusted/augmented by routine real-time inflow forecasting to obtain reliable/improved results.*

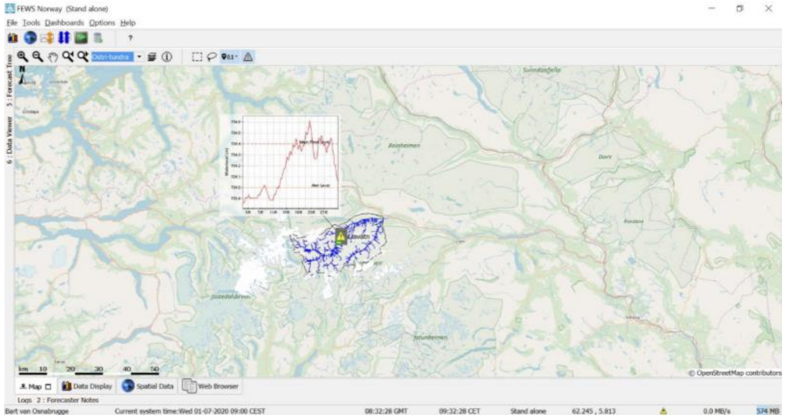
3- the availability of water (i.e. hydrology) is **random/uncertain/stochastic in nature** *(i.e. variable both spatially and temporally due to climatic, topographic, etc. factors) and also challenged by* **anticipated impacts of land use and climate change** *which signify the influential roles of hydrology in the hydropower industry.*

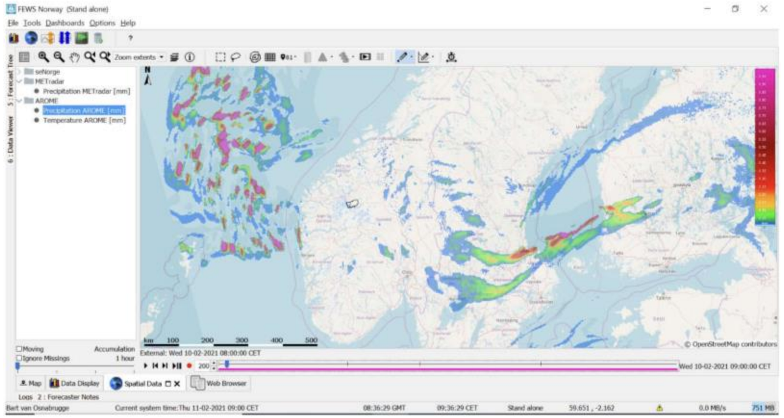


Teklu Hailegeorgis, Knut Alfredsen , Ånund Killingtveit, The influential roles of hydrology for optimal and sustainable planning-management and potential conflict resolution among water uses/users and case studiesfor catchments in Ethiopia and Norway, Department of Hydraulic and Environmental Engineering, Norwegian University of Science and Technology (NTNU), 2016

Flomrespons, as a joint research project:

Flood Early Warning System (FEWS)

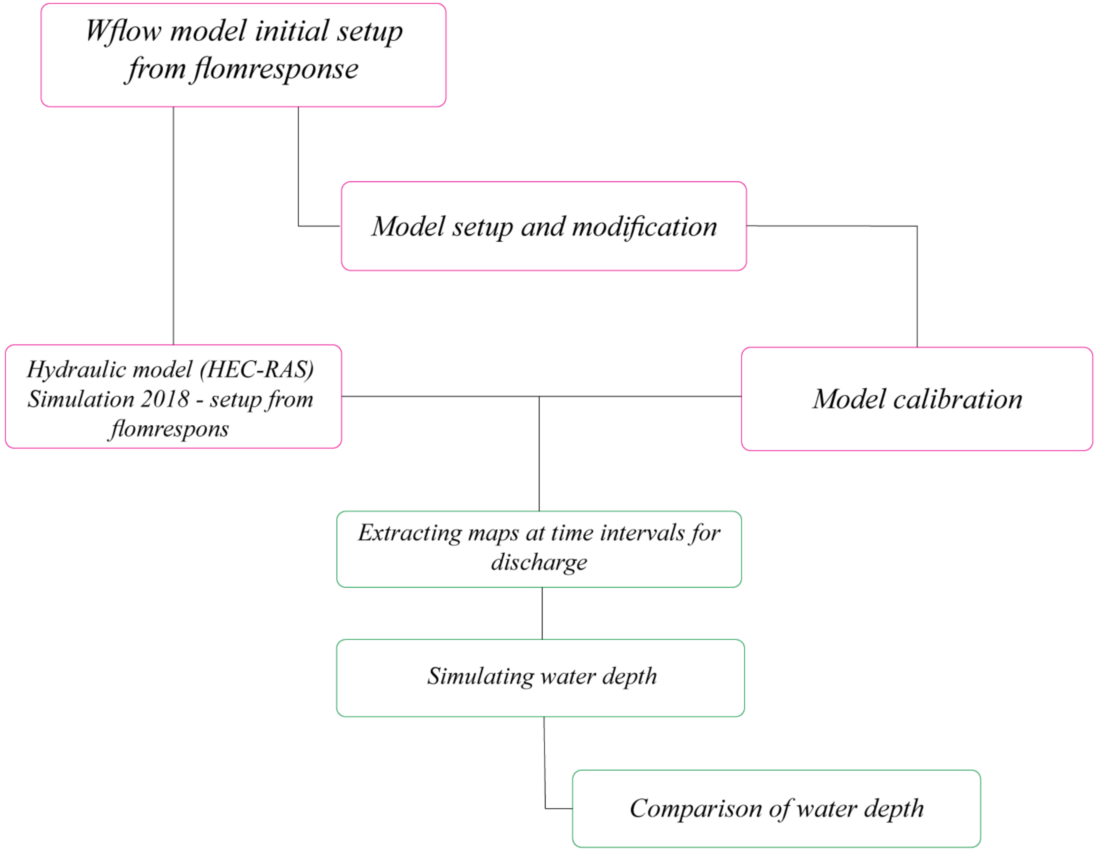




To develop and adapt the Delft-FEWS system for local flood early waning for use in Norwegian municipalities. The system is developed by Deltares and is used for flood forecasting and warning in many areas around the world. During the Flomrespons project, we will implement a version of this tool that is suitable for the needs of the municipalities in Nord-Gudbrandsdal. The innovative aspect in our solution is to develop a new implementation of Delft-FEWS that includes a User Tool in the form of a website/app that can be used by non-expert users in the field.

Target and methodology:

Comparison of water level between hydraulic model (HEC-RAS) and hydrological model (Kinematic wave concept)

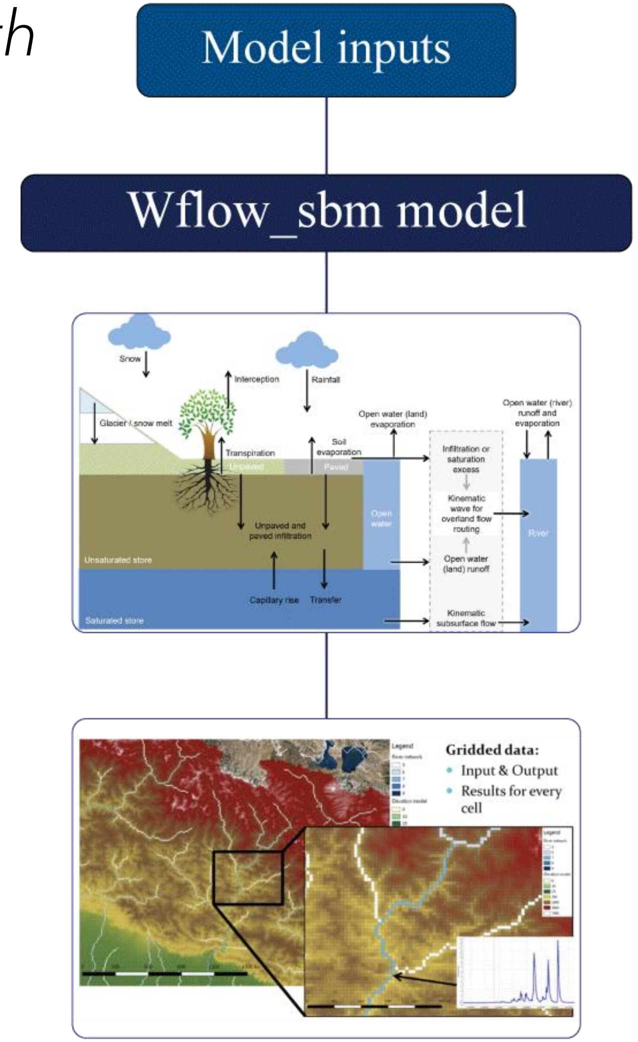


Fully distributed raster-based hydrological modelling with ***Kinematic wave*** *concept:*

1- Adequate results when using a simple base setup with parameters that are derived from landscape attributes that are available globally

2- The processes in the model are ***physically based****, and the model includes modules for relevant processes in the project area, such as* ***glaciers, lakes and reservoirs***

3- ***Gridded nature*** *of the model makes it possible to extract modelled discharges at any point in the model grid*



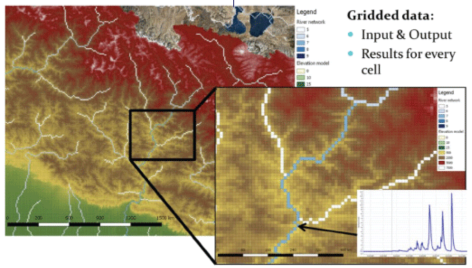
Imhoff, R.O, van Verseveld, W.J., van Osnabrugge, B., Weerts, A.H., 2020. Scaling Point-Scale (Pedo)transfer Functions to Seamless Large-Domain Parameter Estimates for High-Resolution Distributed Hydrologic Modeling: An Example for the Rhine River. Water Resources Research,56,e2019WR026807.

Modelling process in Wflow_sbm:

Model inputs

Precipitation | Po. evapotranspiration | Temperature

Wflow_sbm model



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- **wflow_reservoirareas** map: reservoir IDs [-]
- **wflow_reservoirlocs** map: reservoir IDs at outlet locations [-]
- **ResSimpleArea** map: reservoir area [m2]
- **ResMaxVolume** map: reservoir max volume [m3]
- **ResTargetMinFrac** map: reservoir target min frac [m3/m3]
- **ResTargetFullFrac** map: reservoir target full frac [m3/m3]
- **ResDemand** map: reservoir demand flow [m3/s]
- **ResMaxRelease** map: reservoir max release flow [m3/s]
- **reservoirs** geom: polygon with reservoirs and wflow reservoir parameters

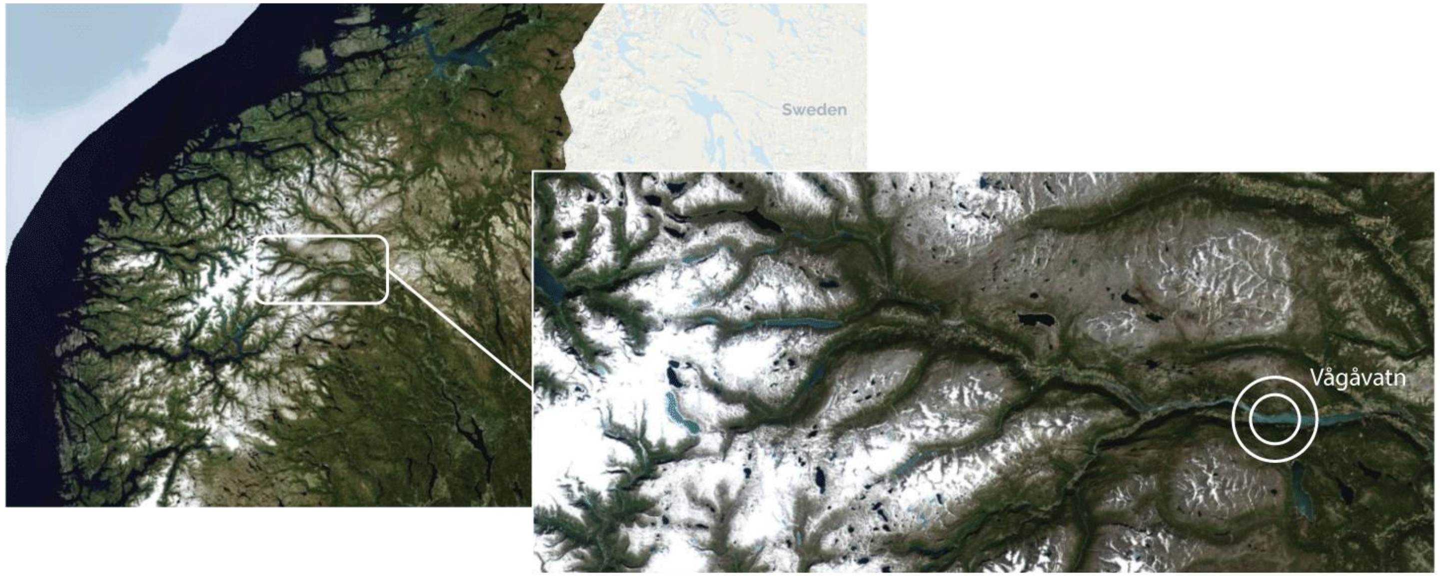
Model parameter	Data resources
Elevation, drainage network, rivers, catchment delineation	HydroMERIT[1]
Reservoirs	GRAND[2]
Lakes	GlobCover[3]
Glaciers	Randolph Glacier Inventory[4]
Land-use based parameters	GlobCover
Leaf area index	MODIS LAI[5]
Soil-based parameters	ISRIC SoilGrids i.c.w. Brakensiek pedotransfer function[6]
Gridded daily historical observations dataset of precipitation and temperature	SeNorge[7]
Deterministic meteorological forecast	AROME[8]

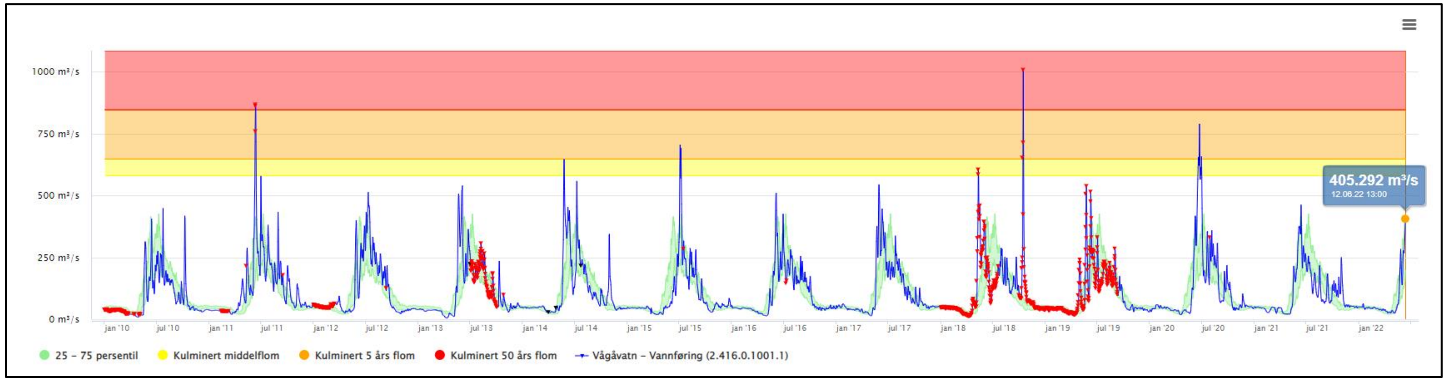
1 Global hydrography datasets, developed based on the MERIT DEM and multiple inland water maps.
2 Global Reservoir and Dam Database (GRanD)
3 Global composites and land cover maps using as input observations from the 300m MERIS sensor on board the ENVISAT satellite mission.
4 Globally complete collection of digital outlines of glaciers, excluding the ice sheets
5 MODIS Leaf Area Index/FPAR Overview LAI.
6 Global soil data product generated at ISRIC — World Soil Information.
7 Daily updated maps of snow, weather and water conditions and climate in Norwayn.
8 Numerical prediction model, operational at Meteo-France.

*1- **Interception**: based on the modified Rutter model*
*2- **Snow and glaciers**: based on a degree day factor method (similar to HBV)*
*3- **Soil:** largely based on the Topog-SBM model*
*4- **Kinematic wave routing for rivers**, overland and lateral subsurface flow*
*5- **Lakes and reservoirs***

Nord-gudbransdalen:

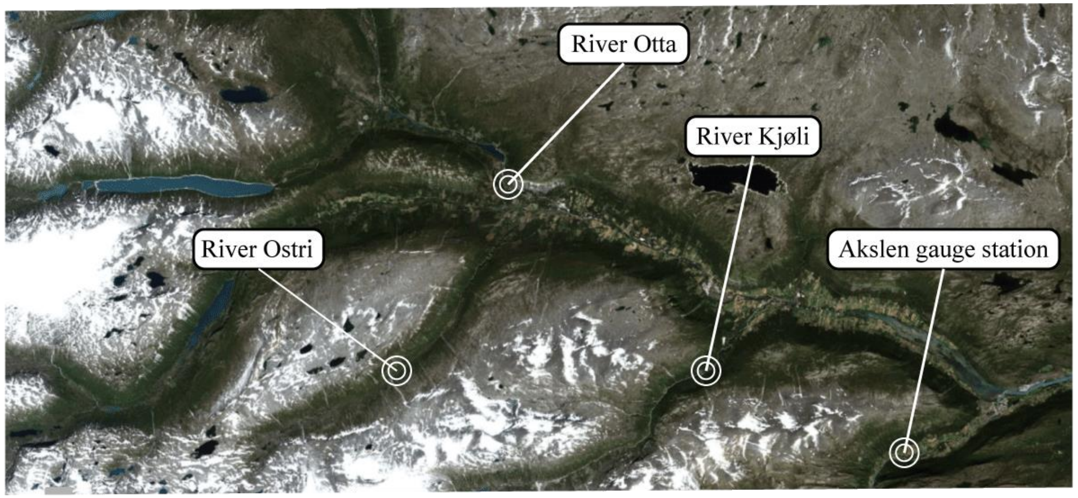
Nord-Fron commune (LARS ERIK SKREFSRUD / NRK)





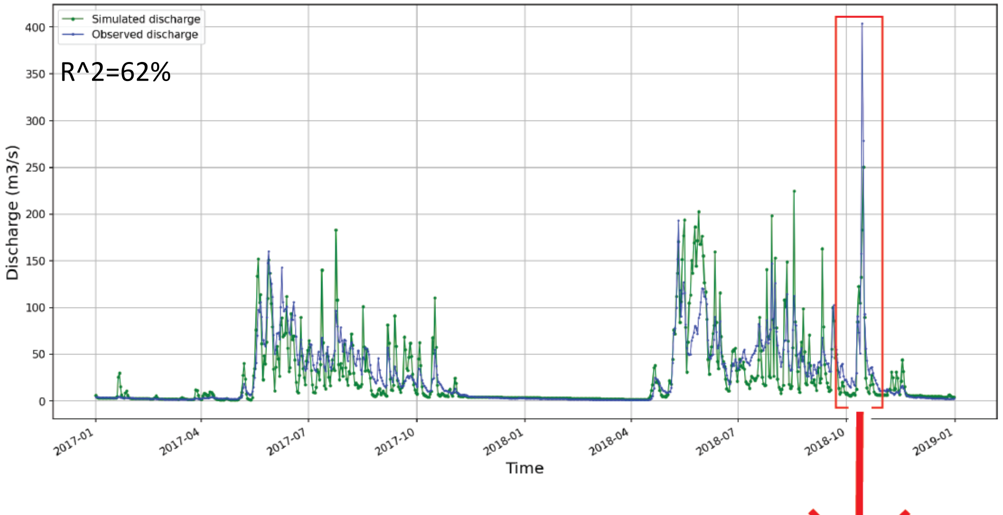
Discharge at Vågåvatn gauge station between 2010 and 2022 (SeNorge.no)

Model calibration:

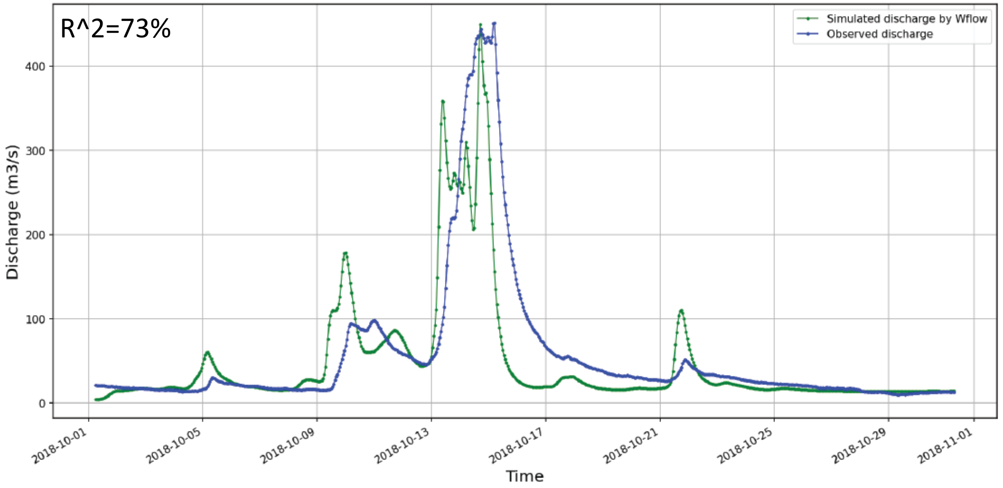


Otta, Kjøli, Ostri boundary and Akslen gauge station (SeNorge.no)

First round calibration



Second round calibration



Observed (SeNorge.no) and Simulated discharge by Wflow

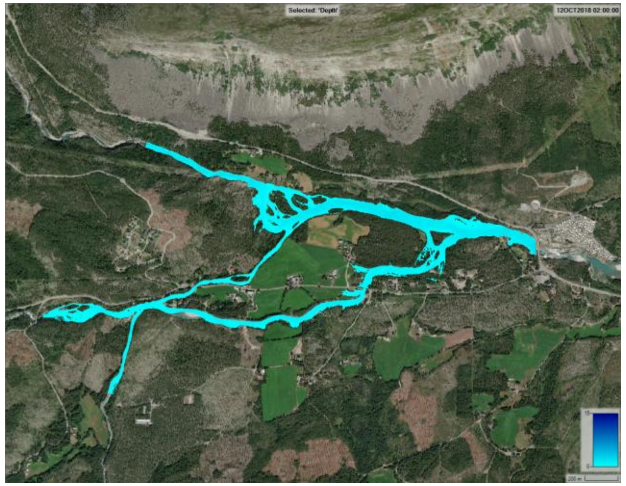
Hydraulic modelling:

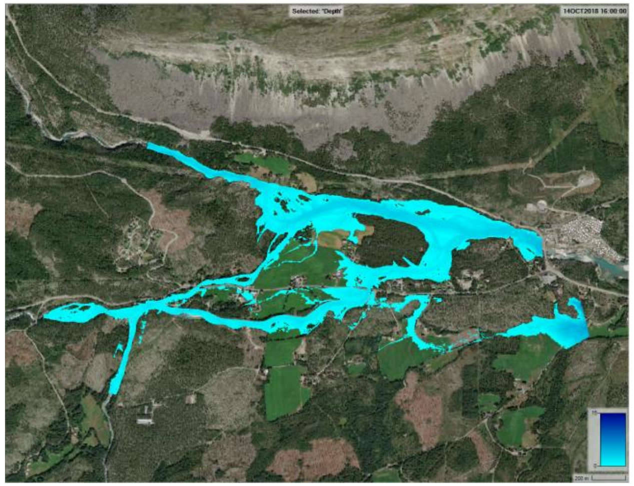
Kjøli:

Software	HEC-RAS
Process modelled	2D overland flow
Modelling concept	2D solution of Saint-Venant equations
Modelling area	1.79 km^2
Input data (scenario)	Discharge in October 2018
Output data	Water level and water depth, flood extent, velocity
Initial conditions	Dry
Spatial resolution	5m * 5m cells (71,284 cells)
Temporal resolution and simulation period	44 hours for quasi-unsteady simulations for the flood zone maps; 118 hours for the flood event

Otta:

Software	HEC-RAS
Process modelled	2D overland flow
Modelling concept	2D solution of Saint-Venant equations
Modelling area	1.89 km^2
Input data (scenario)	Discharge in October 2018
Output data	Water level and water depth, flood extent, velocity
Initial conditions	Dry
Spatial resolution	2m * 2m cells (472,362 cells)
Temporal resolution and simulation period	44 hours for quasi-unsteady simulations for the flood zone maps; 118 hours for the flood event





Model outputs:

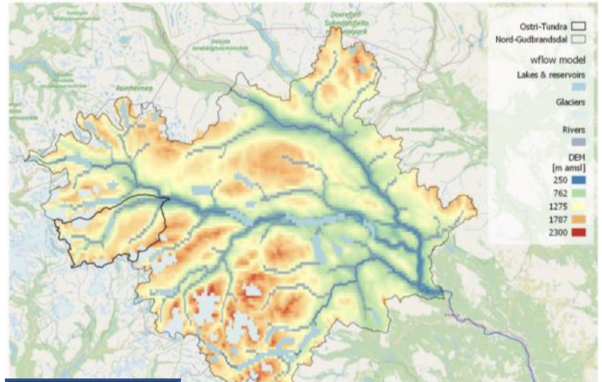


Fig (1)

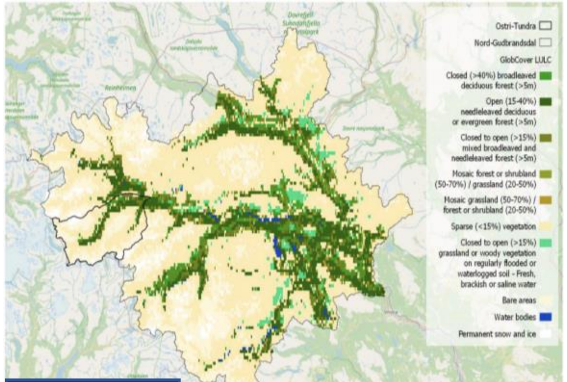


Fig (2)

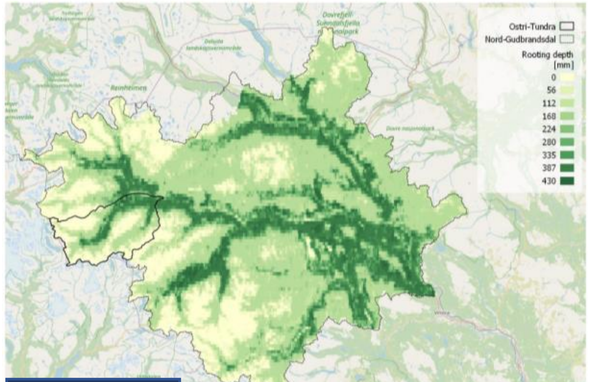


Fig (3)

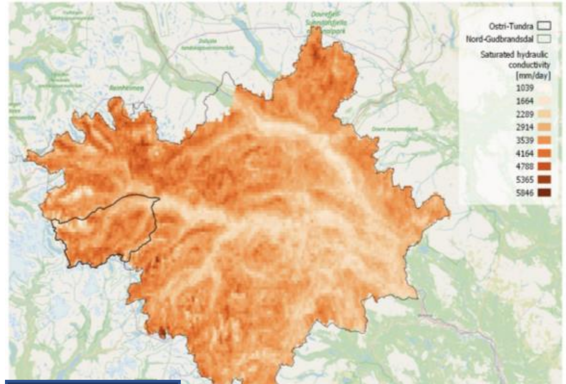
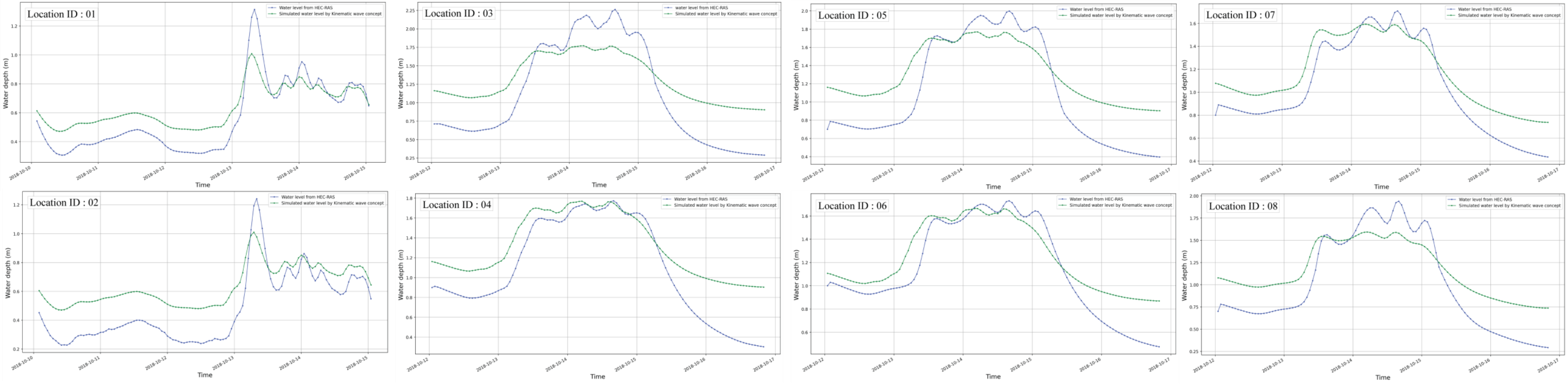


Fig (4)

1- Extent of the Wflow model for the Nord-Gudbrandsdal domain, showing the elevation, rivers, lakes, reservoirs and glaciers. The black line indicates the Ostri-Tundra basin
2- Map showing the land use / land cover for the model domain, based on GlobCover
3- Map showing the rooting depth parameter for the model domain
4- Map showing the saturated hydraulic conductivity parameter for the model domain

Comparison results:



	Location ID	River	Coordination (x,y)	Max. water depth in HEC-RAS	Max. water depth in KVM	R square value
Unregulated	01	Kjøli	8.29730 , 61.86920	1.315	1.008	0.913
	02	kjøli	8.28775 , 61.86226	1.242	1.009	0.817
Regulated	03	Otta	8.08760 , 61.92067	2.263	1.771	0.789
	04	Otta	8.07914 , 61.92067	1.773	1.769	0.885
	05	Otta	8.07123 , 61.92073	1.998	1.768	0.831
	06	Otta	8.06264 , 61.92080	1.730	1.664	0.948
	07	Otta	8.05445 , 61.92073	1.708	1.593	0.946
	08	Otta	8.04570 , 61.92050	1.939	1.592	0.851

[1]; Leopold & Maddock (1953). The hydraulic geometry of stream channels and some physiographic implications (No. 252; Professional Paper). U.S. Government Printing Office.
[2]; Andreadis et al. (2013). A simple global river bankfull width and depth database. Water Resources Research, 49(10), 7164–7168.

Conclusion:

1. Providing fast simulation time (<3 mins for the whole Nord Gudbransdal)
2. Straightforward Implementation of local data sets (e.g. lake/reservoir characteristics)
3. Linking to forecasting tools and providing discharge time series
4. Validation of modelling by several parameters (e.g. precipitation, glaciers, snow water etc.)
5. Manual calibration over tens of parameters
6. Uncertainty over river geometry and river bathymetry
7. Actual changes in river characteristics (e.g. erosion and sediment process)

Further steps:

1. *Model sensitivity analysis*
2. *Direct model application in hydropower scheduling*
3. *Adding new measurements and estimate the added value*
4. *Exploring one or more forecast improvements*

Thank you for your attention

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