The investigation future evolution of glacier and hydrological impacts by an integrated atmosphere-glacier-hydrological modelling system: case study of a Norwegian glacier

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Background

- Glaciers cover ~10% of the Earth’s land surface;
- Water supply for domestic and industrial consumption, irrigation and hydropower;
- Glaciers are shrinking rapidly, leading to cascading impacts on downstream system.

We still don’t fully understand these changes and how they will pan out in the future.

✓ Observations scarcity;
✓ Topographic complexity;
✓ Too coarse atmospheric models;
✓ Regional ‘atmosphere-only’ models;

Global glacier lengths (Roe et al., 2016, Nature geosciences)
Hypothesis: missing feedbacks and resolution dependent processes result in an underestimate of the rates of glacier change and attendant hydrological impacts.

An integrated coupled-modelling approach is needed in order to fully assess the effects of a warming climate on glaciers and their hydrological impacts.
WRF-Hydro System
Model Chain

Meteorological forcing (Observations or model)

https://www.ral.ucar.edu/projects/wrf_hydro

One-way coupling (can be two-way with WRF (Weather Research and Forecasting Model))
Coupling of Crocus snow model in WRF-Hydro model system (WRF-Hydro/Glacier)

- One-dimensional multilayer snow scheme;
- Variable snow layers (up to 50);
- Detailed physical description of snow properties.

Land surface of WRF-Hydro model system
WRF-Hydro/Glacier Modelling

WRF 1 km runs as meteorological forcing input

WRF-Hydro/Glacier runs at 100 m grid

- Driven by 6 hourly ERA-Interim

Crocus Snow Model over Glacier grids
Temperature is accurate (left), details in precipitation (right) are missing in SeNorge2; WRF is more ‘true’ in a physical sense.

Temperature

Mean daily (1995)

WRF

Observation (SeNorge2)

(Courtesy: Bhuwan Bhatt)
General pattern in agreement, although some issues with absolute values.

More faith in GPR depths over the thin snow, more faith in the model over thicker snow.

(Courtesy: Adam)
Mass balance Rembesdalskåka: CROCUS vs. NoahMP

(Courtesy: Trude)
Glacier (ice thickness) initialization

- Glacier will be retreating in Hardangerjøkulen during 2005 – 2055 taken from (Åkesson, 2018)
- Future simulation by PGW method.
Future mass balance changes of Rembesdalskåka

The results show a change ~ -2 m/yr of glacier mass balance in the future (2055-2065) compared with the historical period (1995-2005).

NVE-Obs Ba: -0.58
Hindcast Ba: 0.04
Future Ba: -1.98

(mass balance observation from NVE)
Future change of runoff


- Future runoff are projected to increase in Spring and Autumn;
- Summer runoff will increase in the heavily glacierized and decrease in the non- /little-glacierized basins.
Summary

• Model precipitation showed a more reasonable result than gridded observation data;
• The integrated model with CROCUS improves the mass balance results comparing with NoahMP;
• In Hardangerjøkulen, future warming climate (2055-2065, RCP8.5) will conduct a change ~ -2 m/yr mass balance comparing with historical period (1995-2005), which will result in runoff increase in both Spring and Autumn, while more mixed changes in summer, i.e., runoff decrease in the little /no glacierized basin while increase in the heavily glacierized (60%) basin.

Forward:

• Compare the outputs from WRF-Hydro/Glacier simulations and HBV model with glacier parameterization.
• Model can be applied to other glaciers in Norway and beyond (i.e., Himalaya, TP).
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Catchments

- 10 catchments
- DEM 10 m topography
- Discharge data most missed after 1980th.
Investigate convective-scale events, related processes and their changes

Provide a collective multi-model ensemble assessment and intercomparison

Shape a coherent and robust assessment of the consequences of climate change on convective phenomena impacts at local to regional scales

The FPS Convection launched Fall 2016 (31 participating institutes), Fall 2019 first future change ensembles completed

By Stefan Sobolowski, Erika Coppola and The FPS Convection team

(Courtesy: Stefan Sobolowski)