WCRP CORDEX

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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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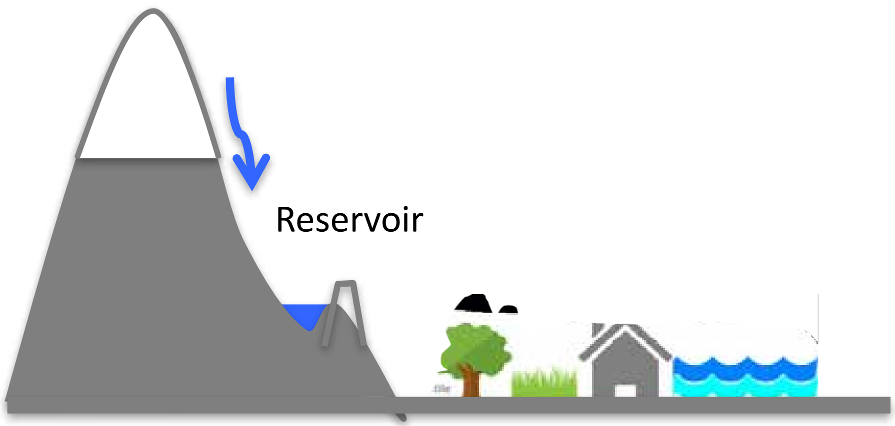
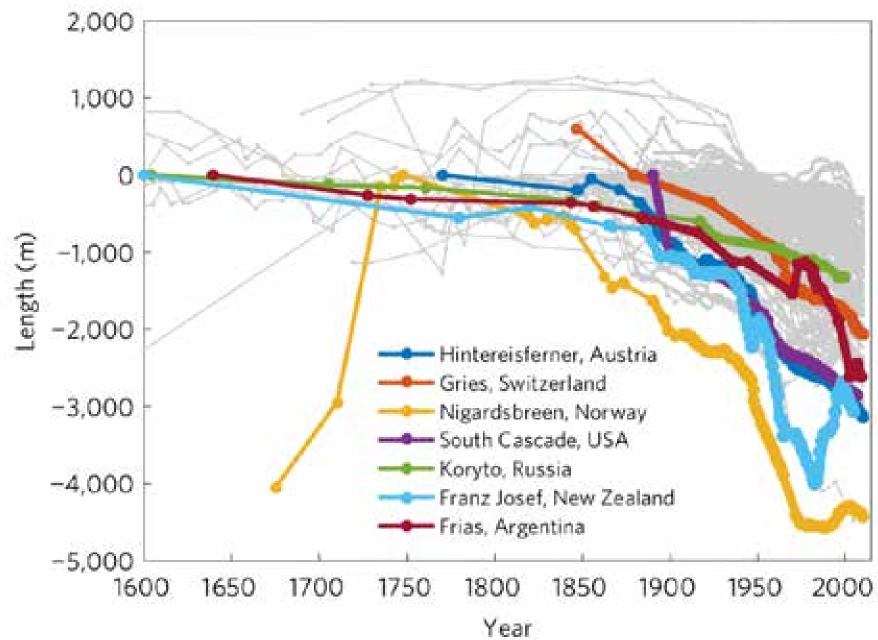
Background



- 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;*

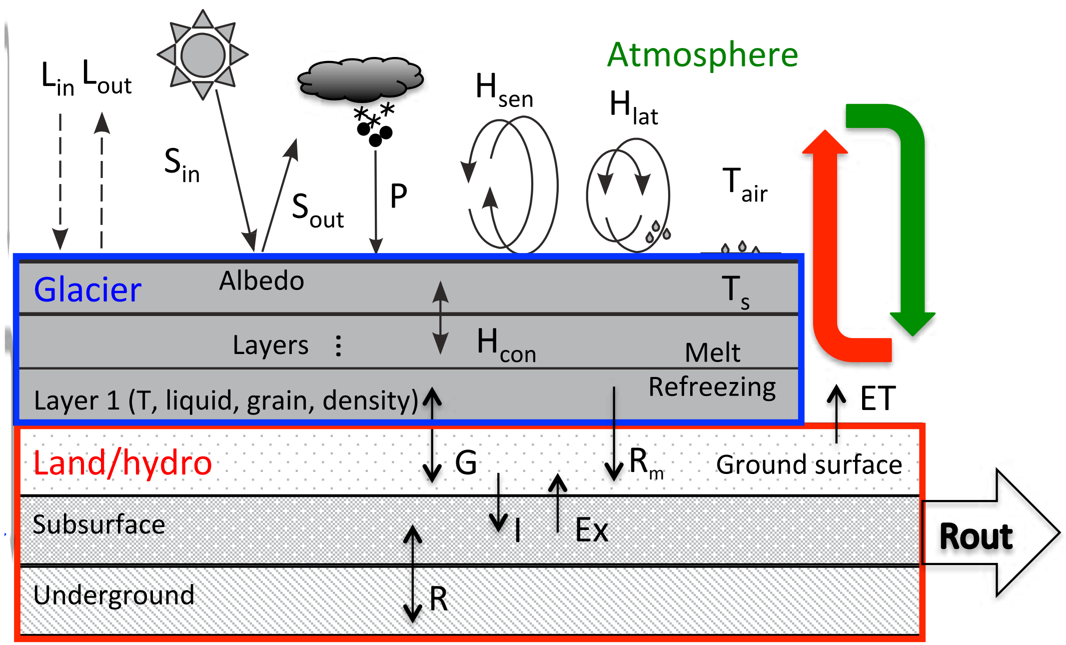


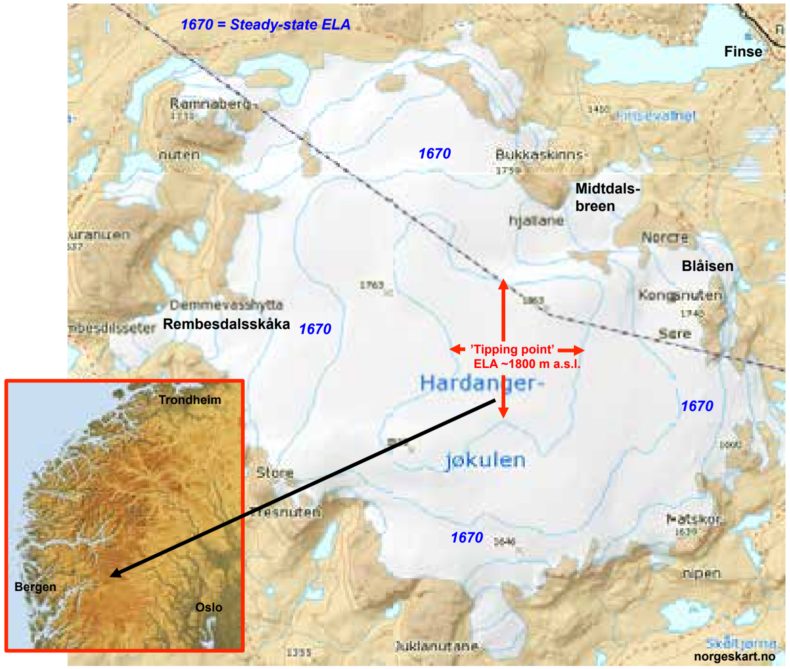
Global glacier lengths (Roe et al., 2016, Nature geosciences)

Main goal

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.



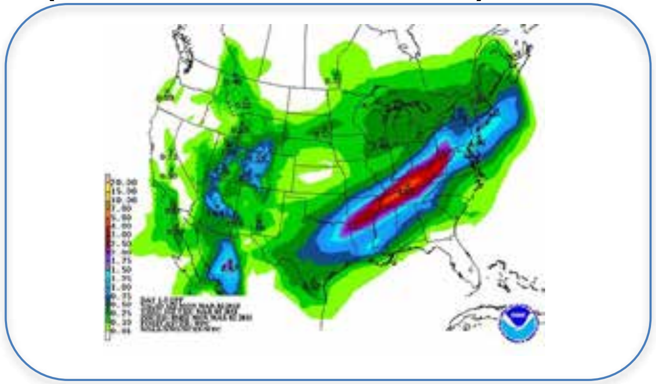


WRF-Hydro System

Model Chain

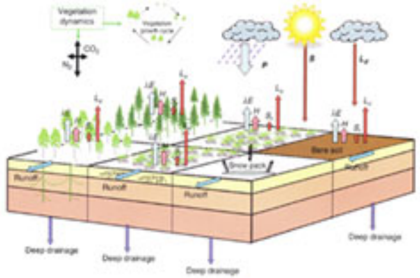
https://www.ral.ucar.edu/projects/wrf_hydro

Meteorological forcing (Observations or model)



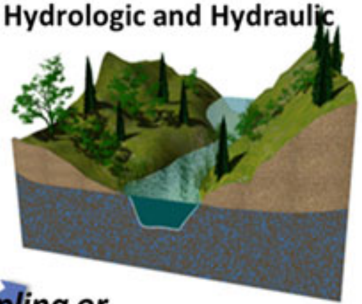
One-way coupling (can be two-way with WRF (Weather Research and Forecasting Model))

Column Land Surface Models:

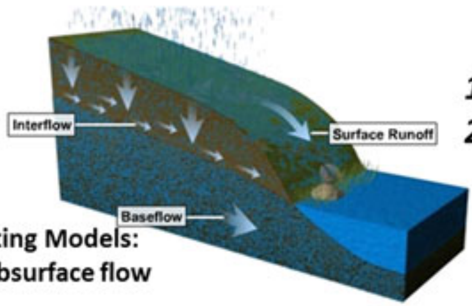


Output Variables:
- Evapotranspiration
- Soil moisture/Soil Ice
- Snowpack/snowmelt
- Runoff
- Radiation Exchange
- Energy Fluxes
- Plant Water Stress

Channel & Reservoir Routing Models: Hydrologic and Hydraulic



2-way coupling



1-way coupling or 2-way coupling

Output Variables:
- Streamflow
- River Stage
- Flow Velocity
- Reservoir Storage & Discharge

Terrain Routing Models: Overland, subsurface flow

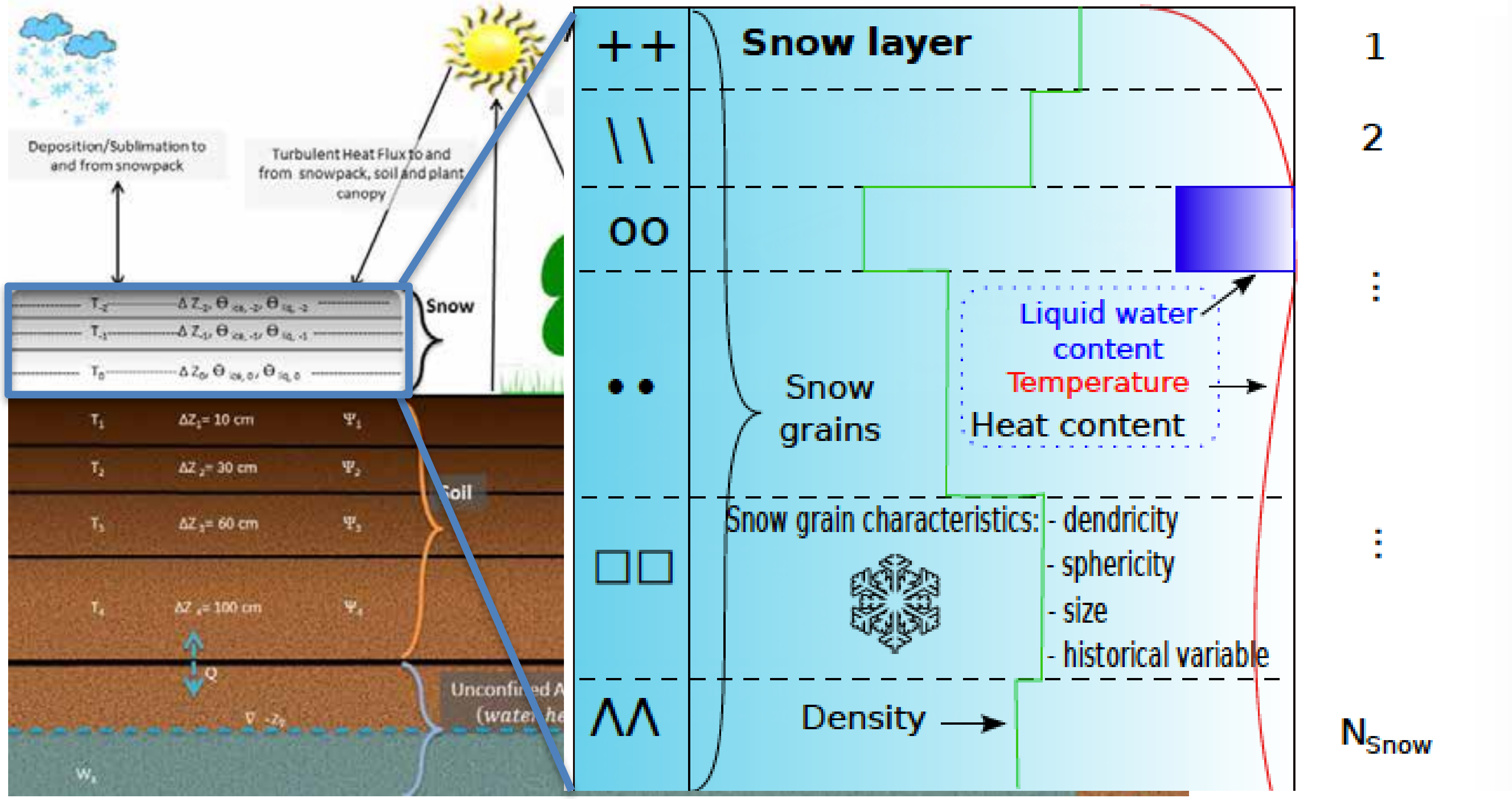
Output Variables:
Stream Inflow, Surface Water Depth, Groundwater Dept

Bjerknes Centre for Climate Research

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.

Crocus snow model



Land surface of WRF-Hydro model system

WRF-Hydro/Glacier Modelling

WRF 1 km runs as meteorological forcing input

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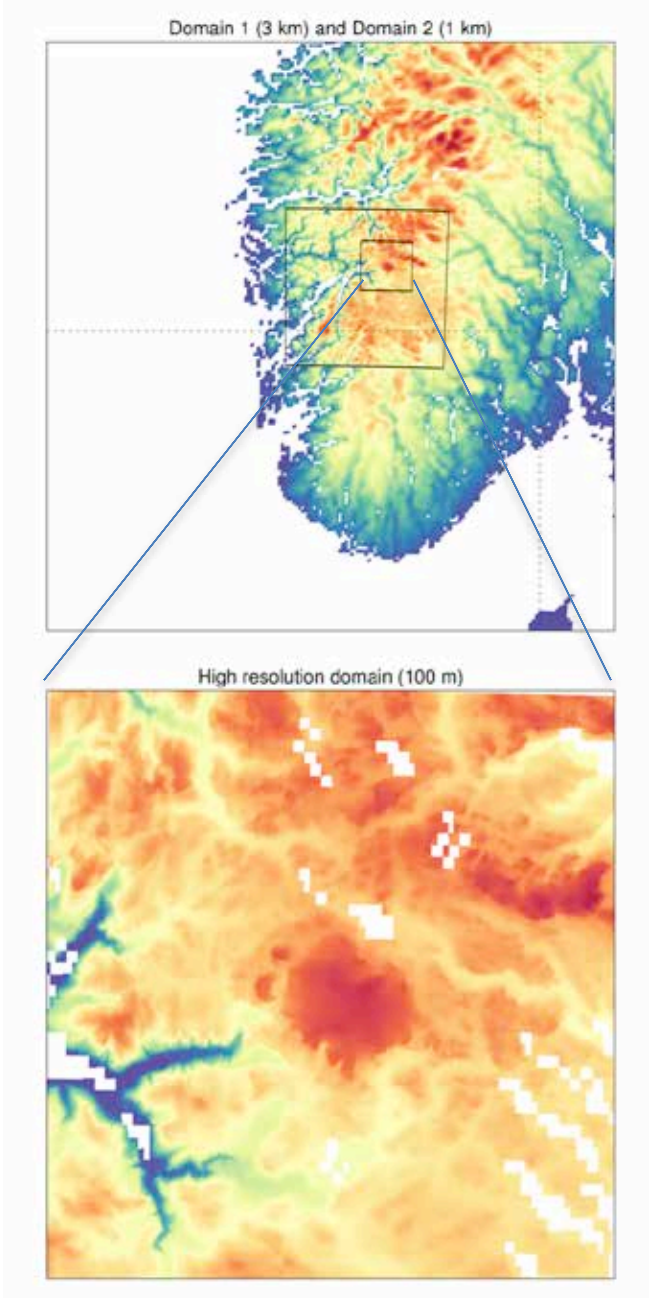
WRF-Hydro/Glacier runs at 100 m grid

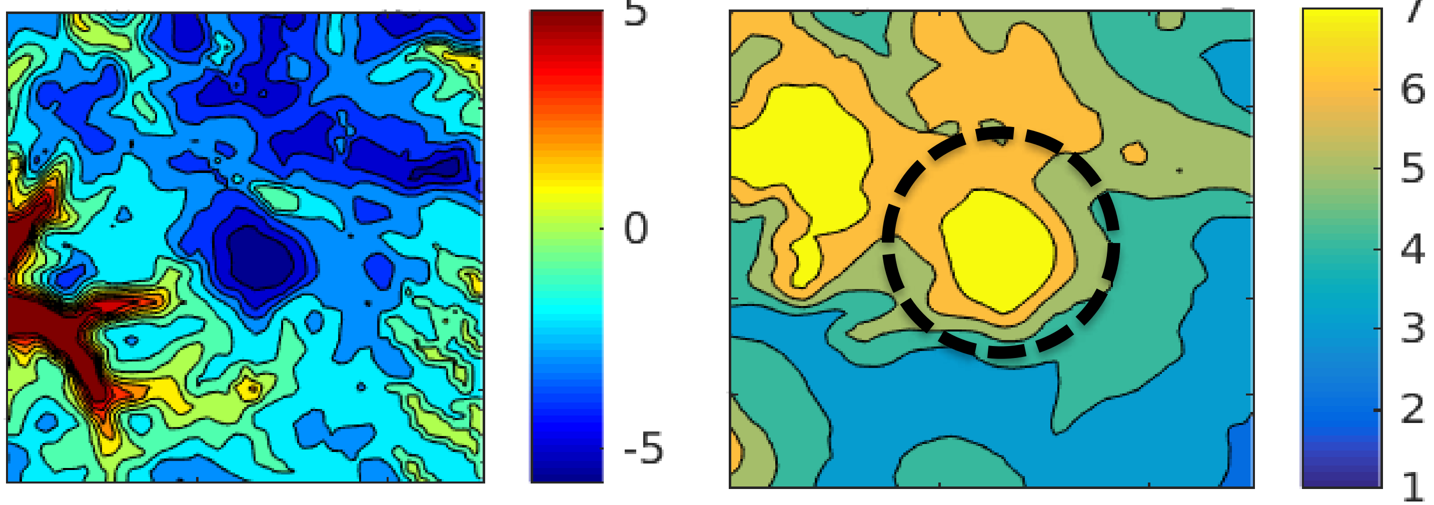
Crocus Snow Model over Glacier grids

- Driven by 6 hourly ERA-Interim

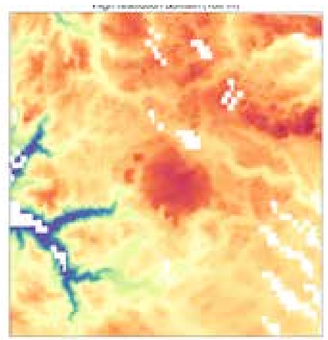


Temperature is accurate (left), details in precipitation (right) are missing in SeNorge2; WRF is more 'true' in a physical sense

Temperature **rainfall**

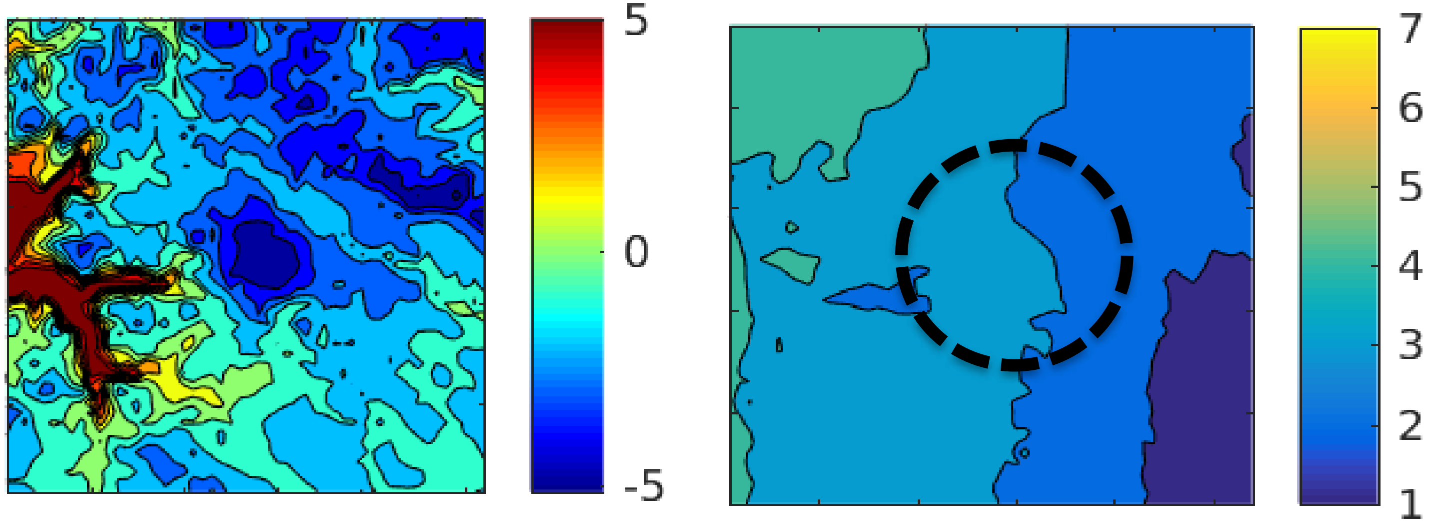


WRF



Topography

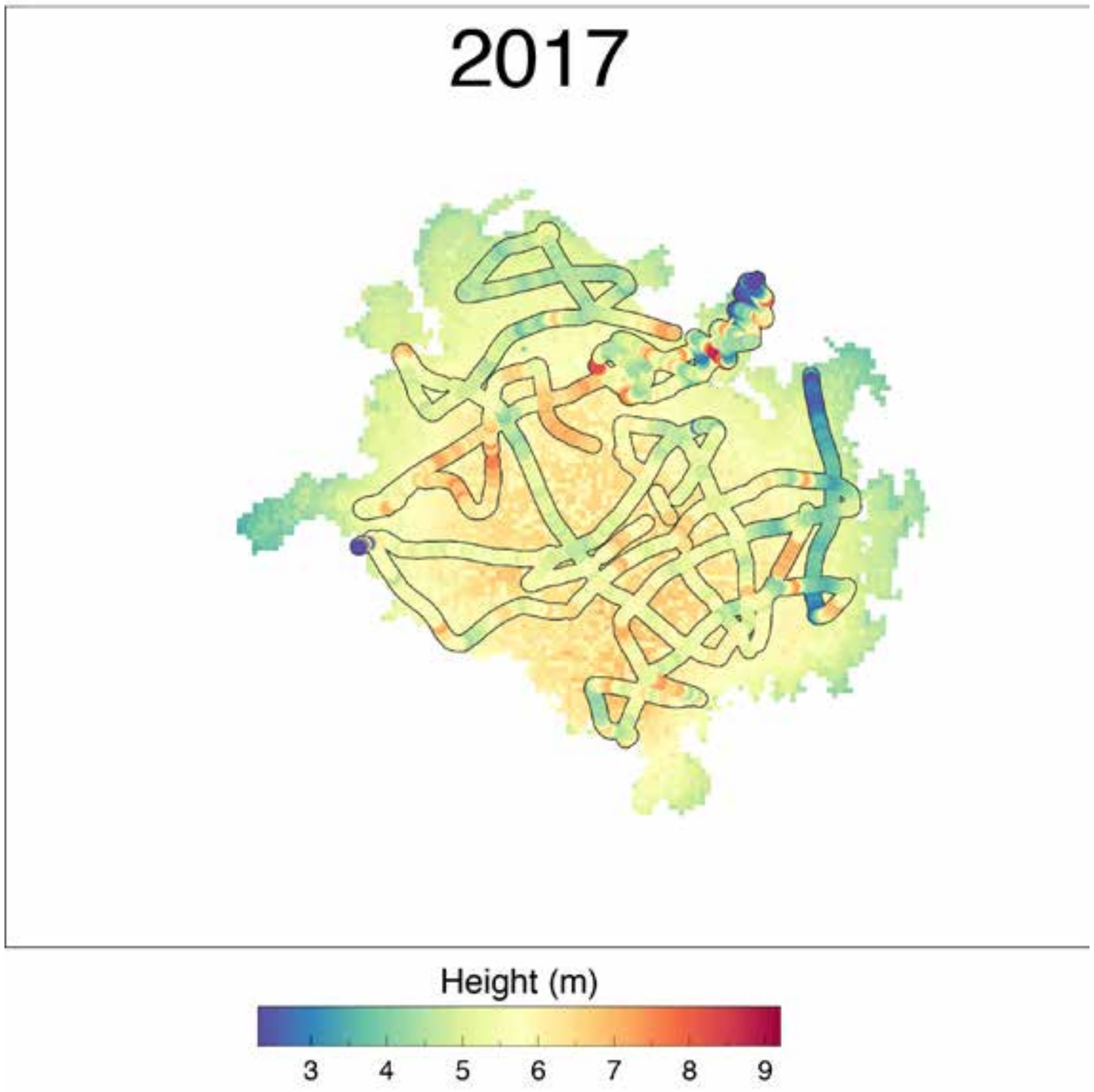
Mean daily (1995)

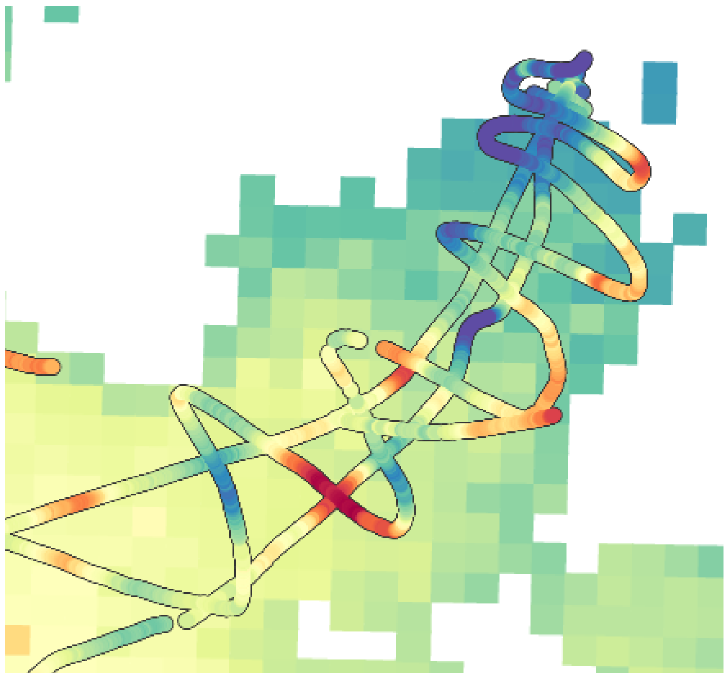


Observation (SeNorge2)

(Courtesy: Bhuwan Bhatt)

Snow depth: Model vs. Radar survey





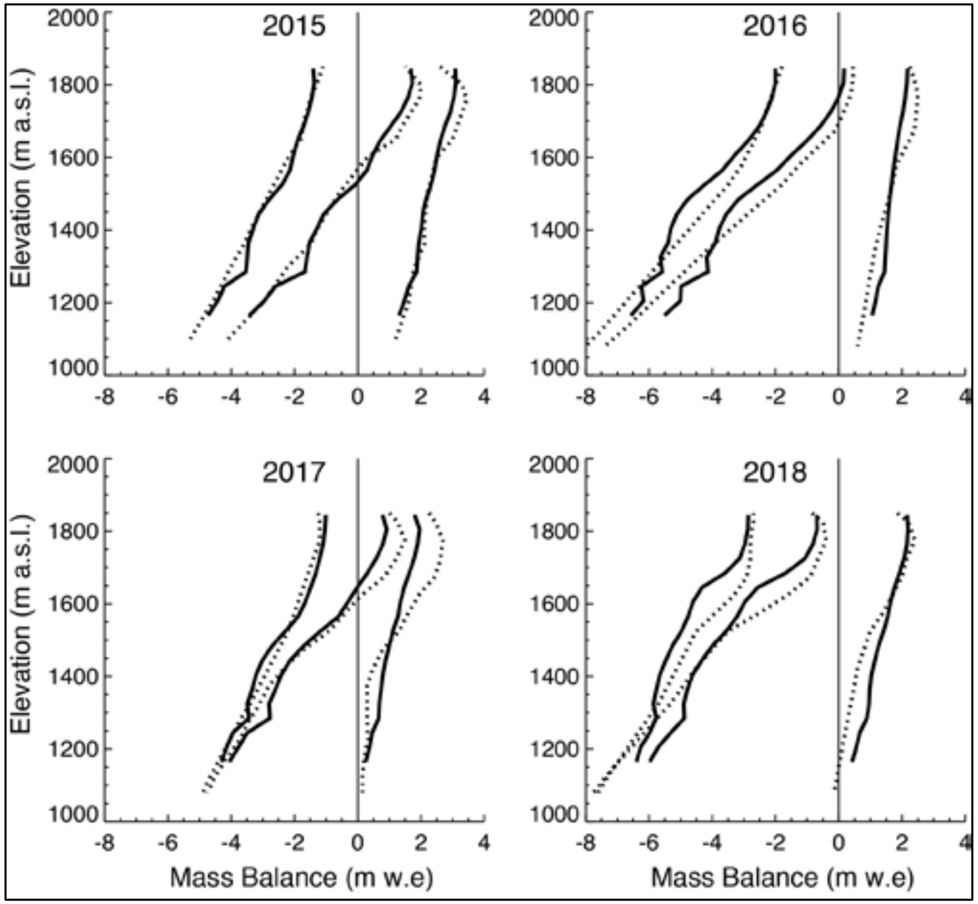
General pattern in agreement, although some issues with absolute values.

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

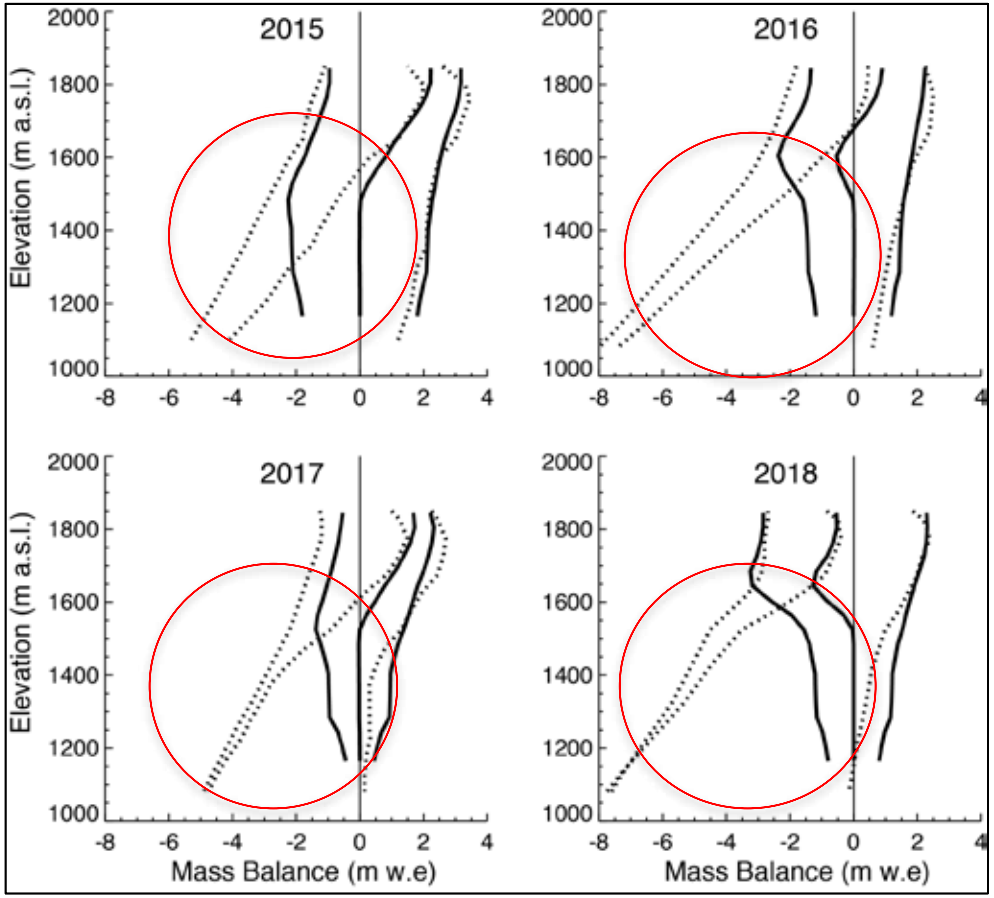
(Courtesy: Adam)

Mass balance Rembesdalskåka: CROCUS vs. NoahMP

CROCUS



NoahMP

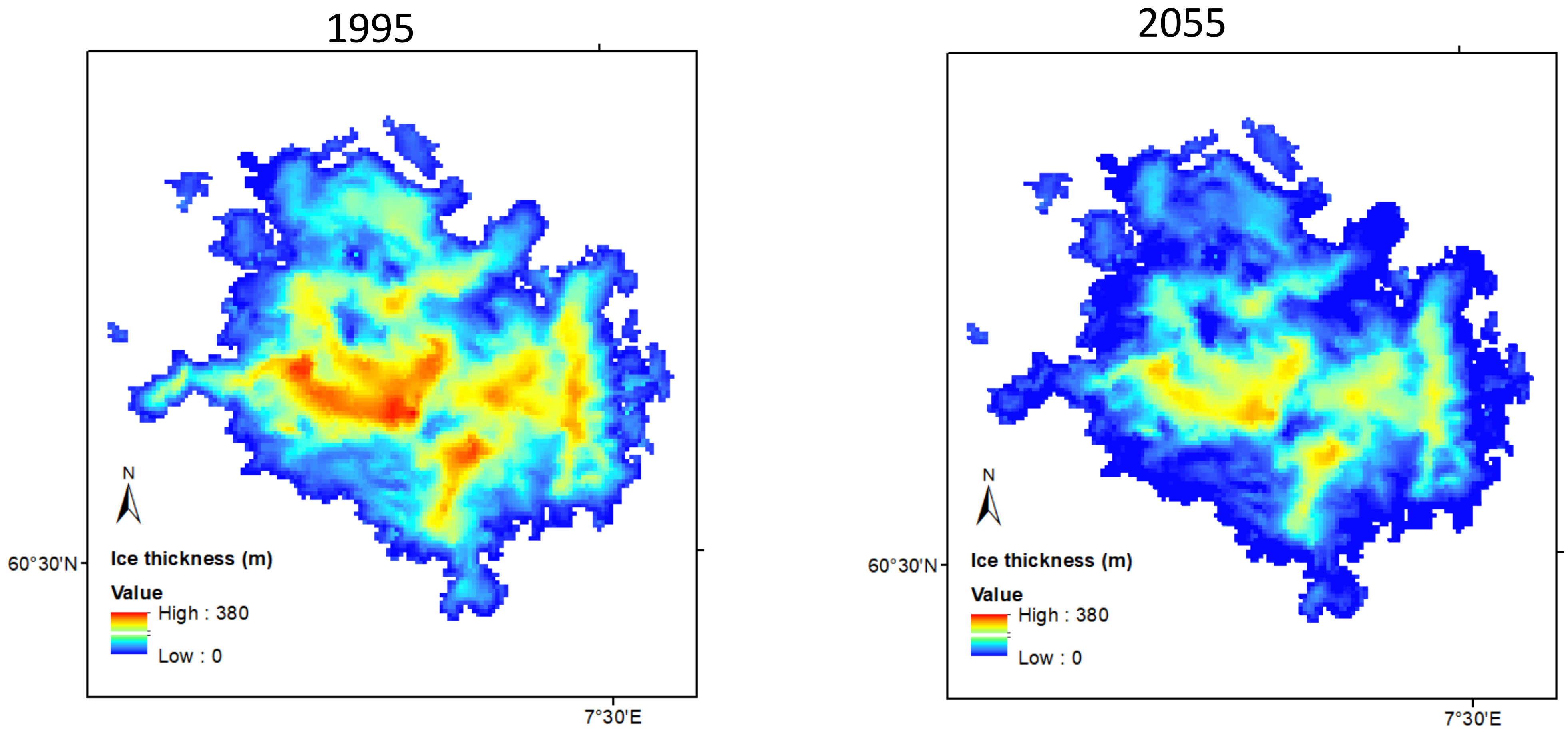


Model

Observations

(Courtesy: Trude)

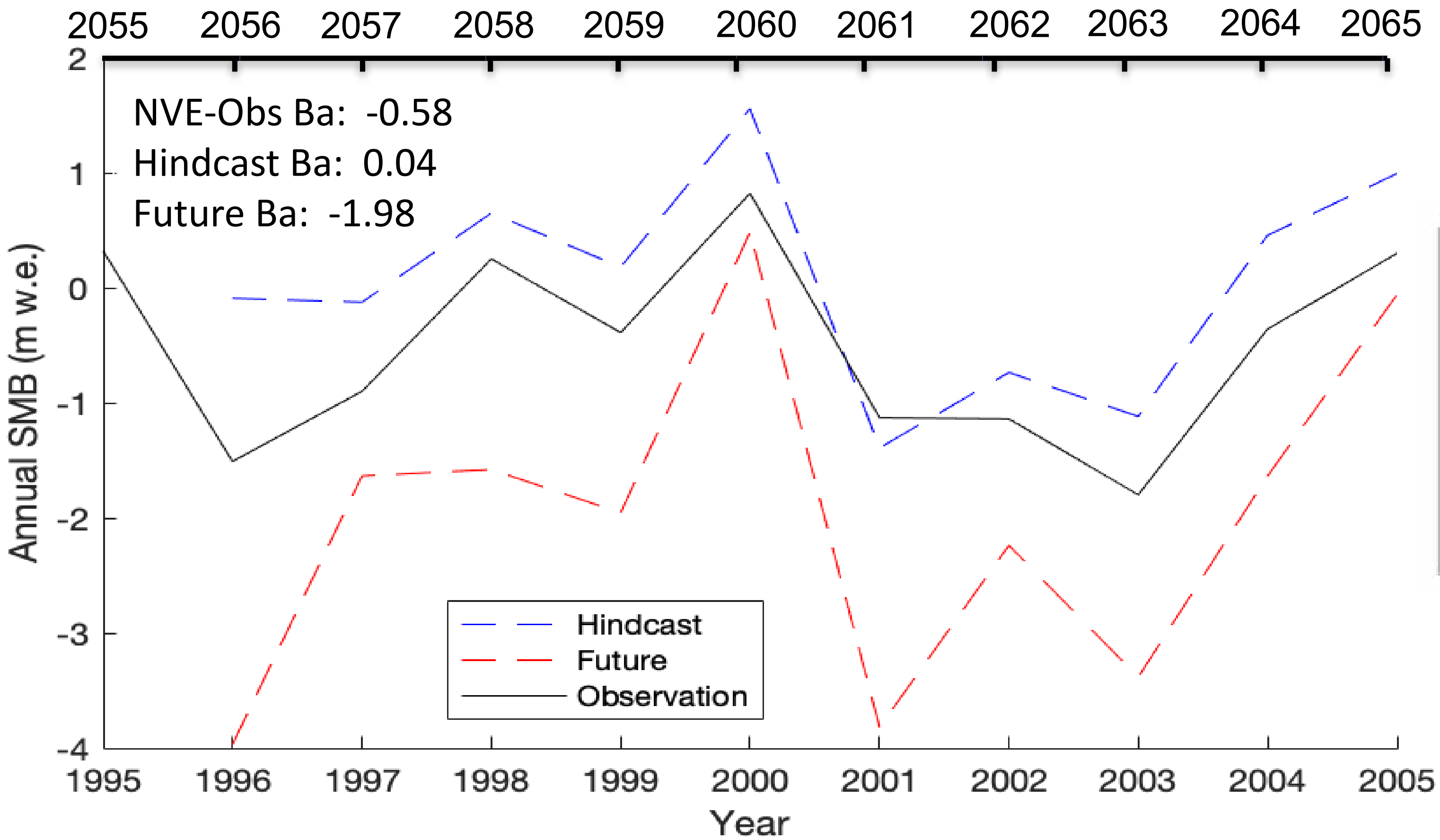
Glacier (ice thickness) initialization

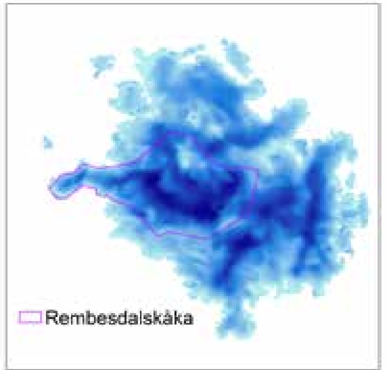


- Glacier will be retreating in Hardangerjøkulen during 2005 – 2055 taken from (Åkesson, 2018)
- Hindcast: 1995-2005 and Future: 2055-2065
- Future simulation by PGW method.

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).

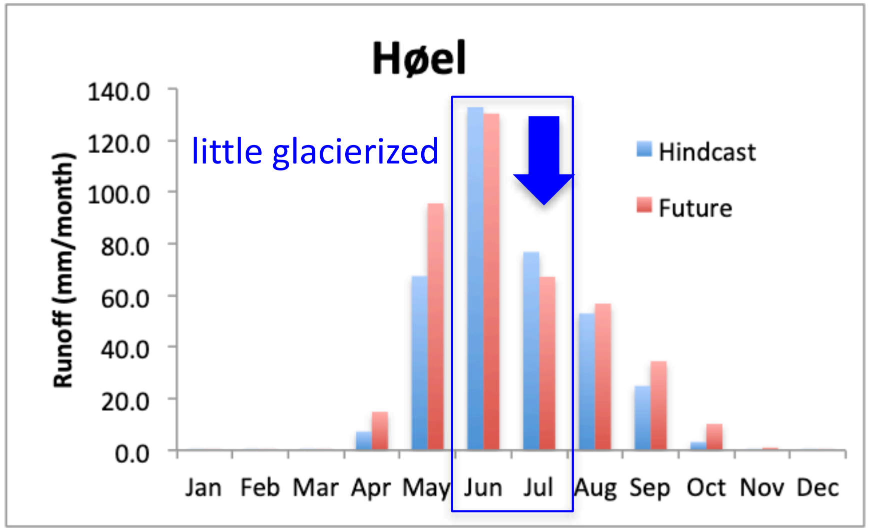


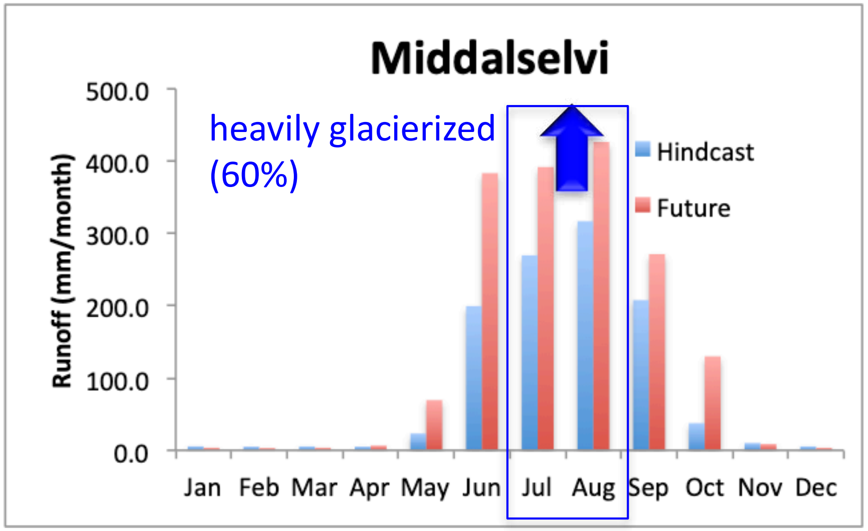


(mass balance observation from NVE)

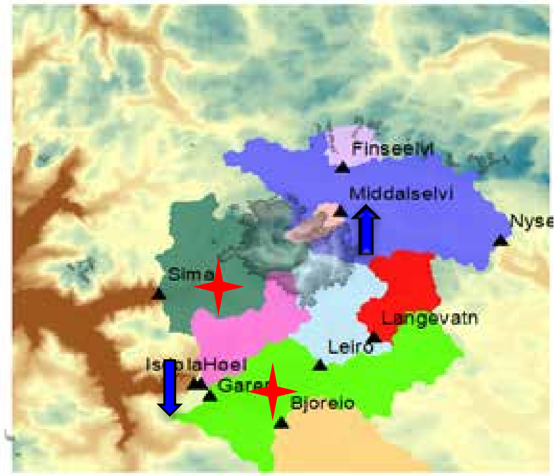
Future change of runoff

Future (2055-2065) vs. Hindcast (1995-2005)





- 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).

Acknowledgements to the whole EvoGlac team and supports from LATICE group, NVE and HiddenCost project!

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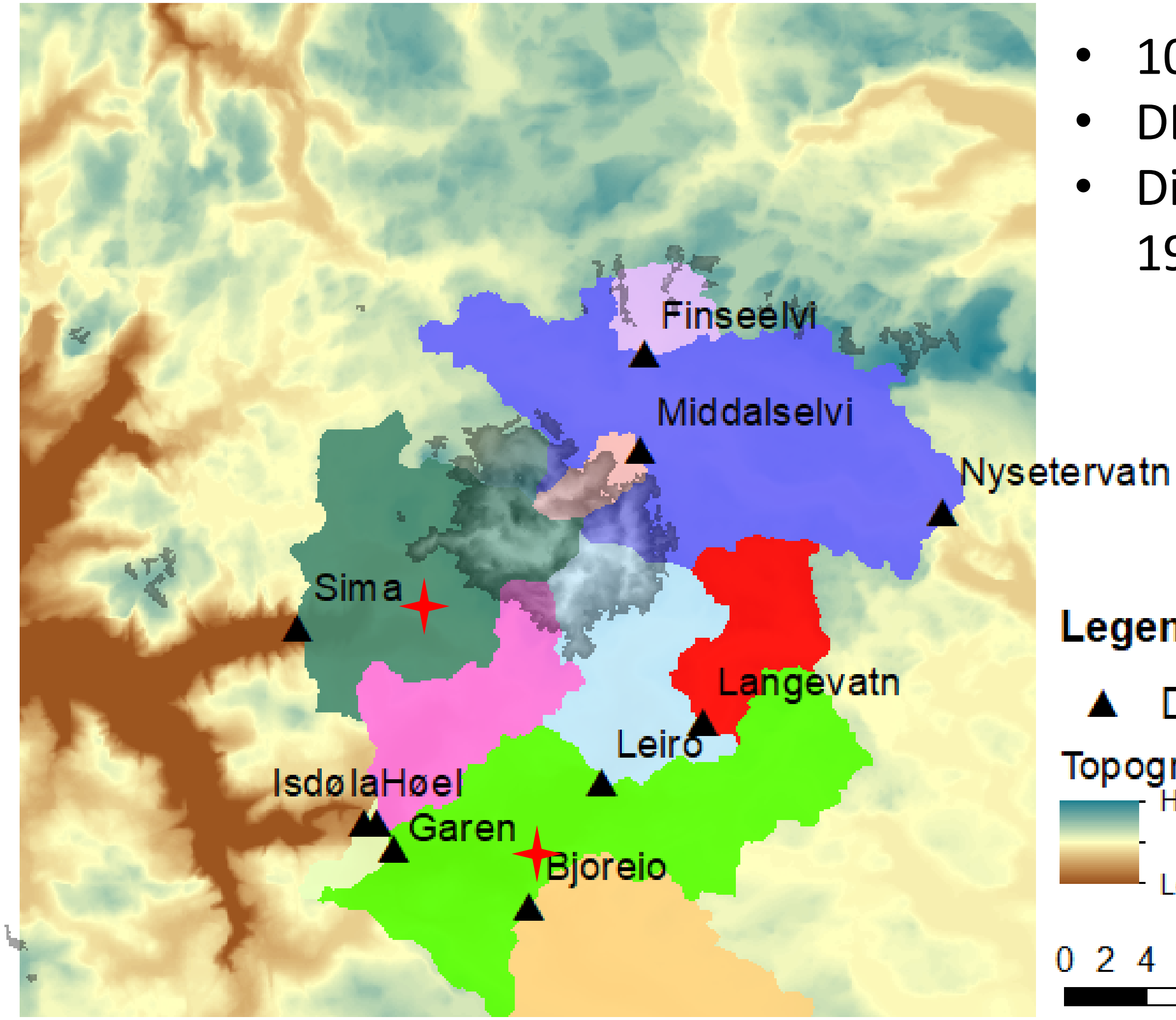
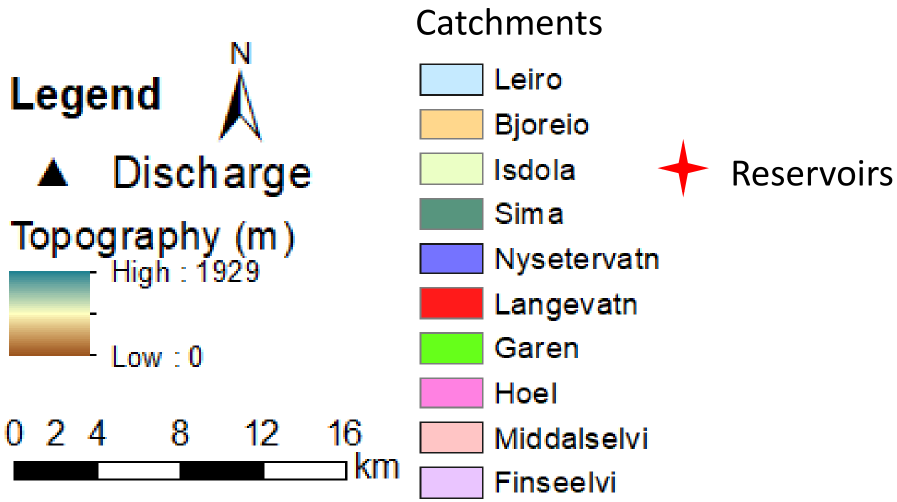
Catchments



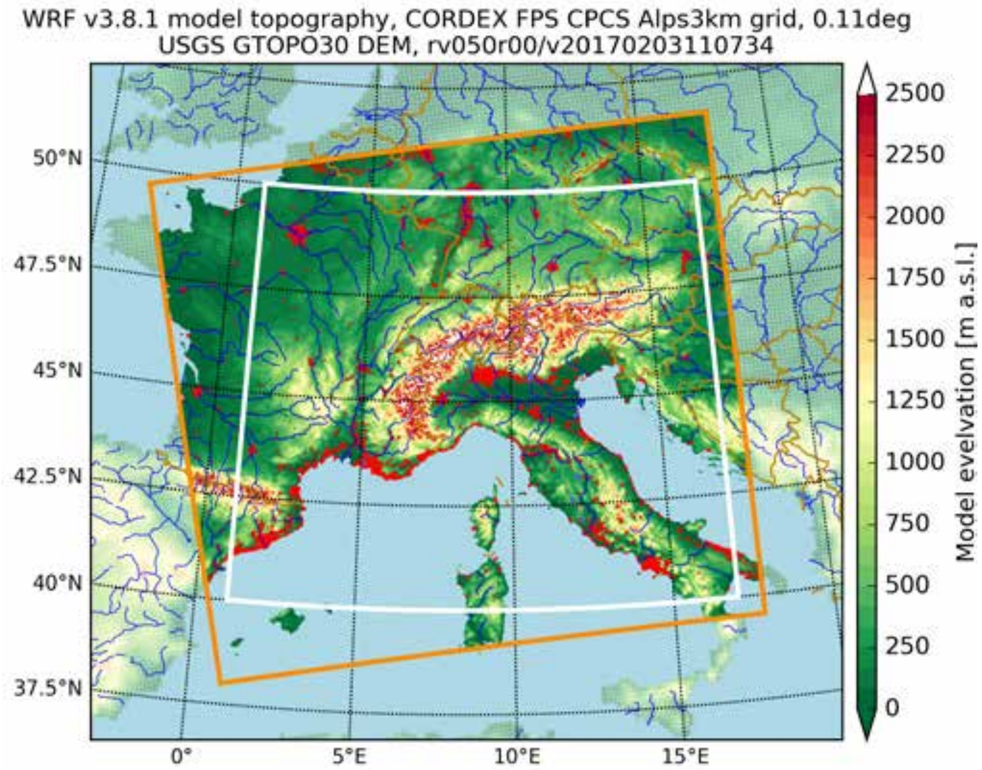
- 10 catchments
- DEM 10 m topography
- Discharge data most missed after 1980th.



WCRP-CORDEX Flagship Pilot Study on Convection

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

- **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**



By Stefan Sobolowski, Erika Coppola and The FPS Convection team

(Courtesy: Stefan Sobolowski)