Using satellite snow cover images to enhance performance of snow, glacier and rain runoff projections for hydro power usages

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Personal note from the presenter:

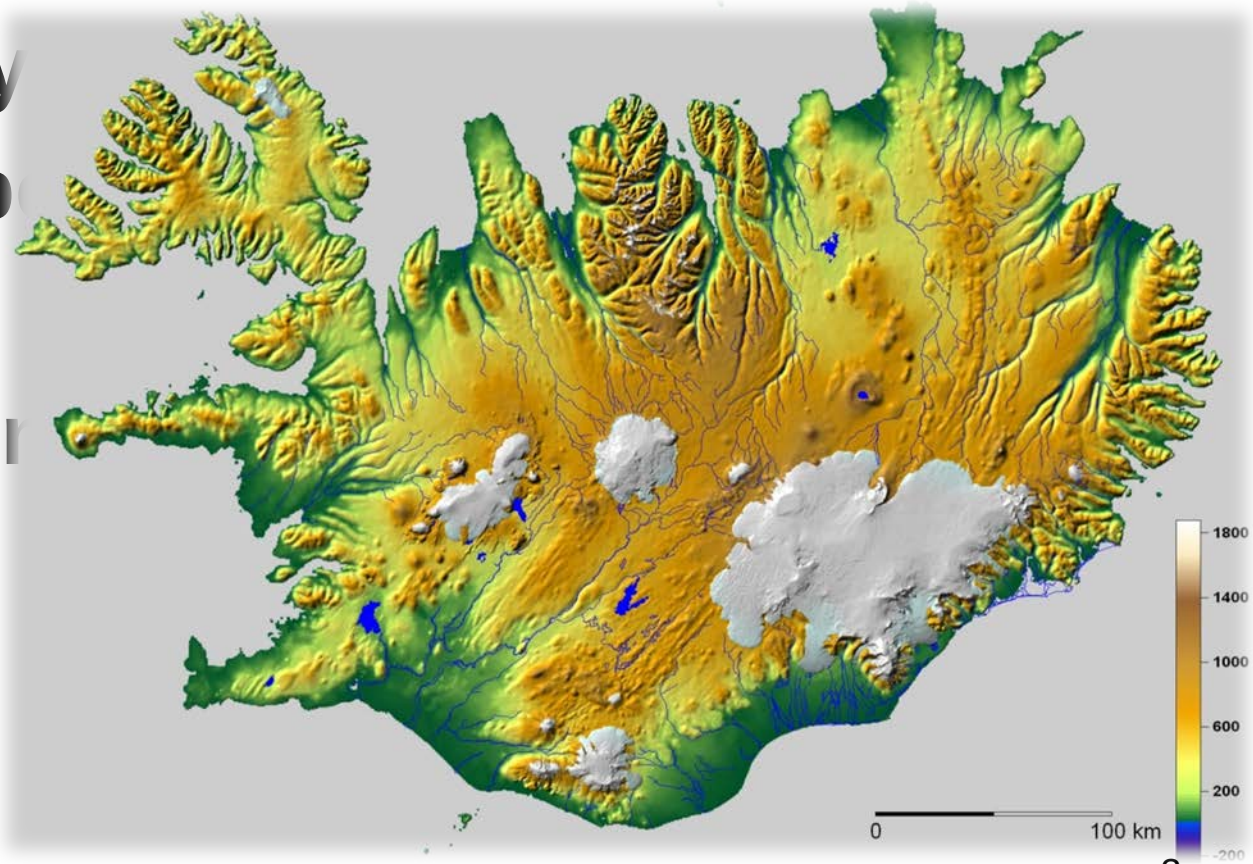
Not many in the audience familiar with hydrology

- "When giving a lecture on scientific matters to other scientists that are not experts in the field, expect no knowledge from your audience, and unlimited intelligence":

… it would be different if I was talking about administrative issues

Hydrology of Iceland
Main influences

- **Location**
- **Meteorology**
- **Bedrock typ**
- **Glaciers**
- **Snow influe**
- **Vegetation**
- **Soils**
- **Land-use**



Runoff maps 1961-1990 vs. 2071-2100

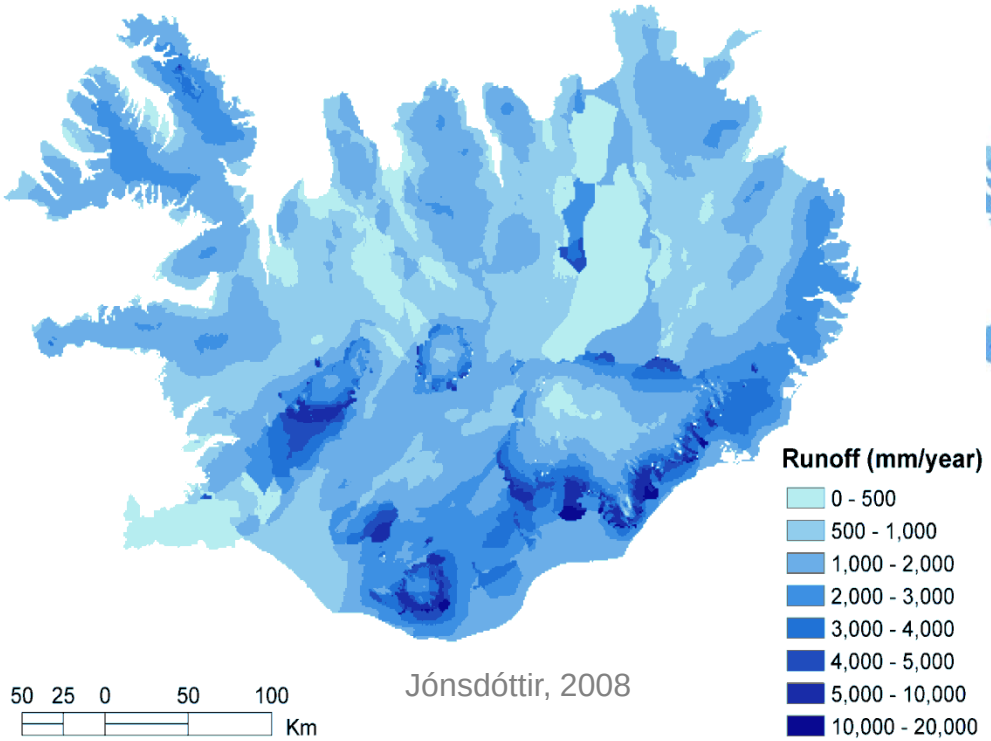
1961-1990

- 1460 mm/year or 4770 m^3/s

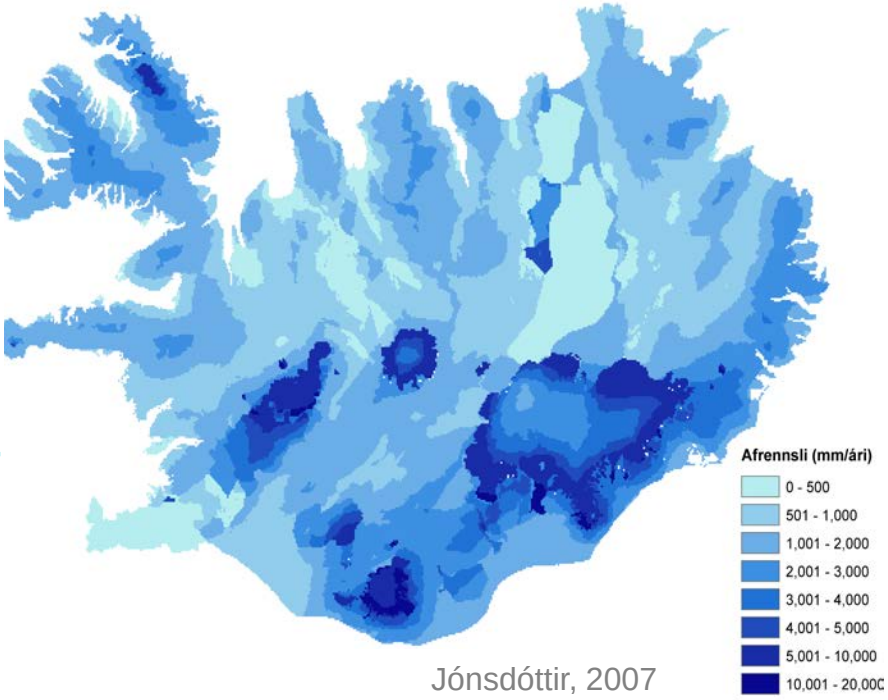
2071-2100

1900 mm/ári eða 5900 m^3/s

25% increase from 1961-1990 to 2071-2100



Jónsdóttir, 2008



Jónsdóttir, 2007

Groundwater of Iceland
Main influences

- **Surface cover**

vegetation, glaciers, frozen earth, etc.

- **Type of surface soil**

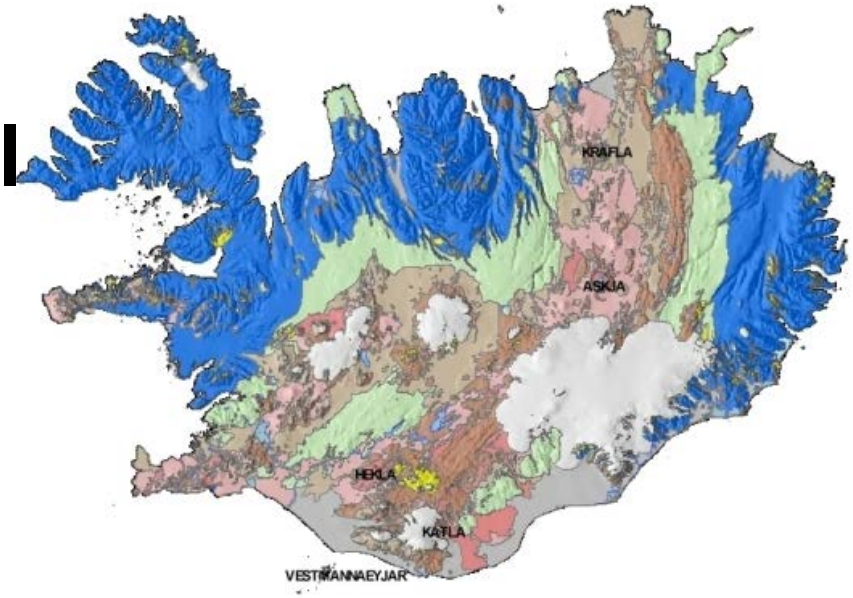
•sand, clay, rock debris

- **Bedrock type**

recent lavas or old bedrock

- **Landscape**

•How easily water flows or infiltrates

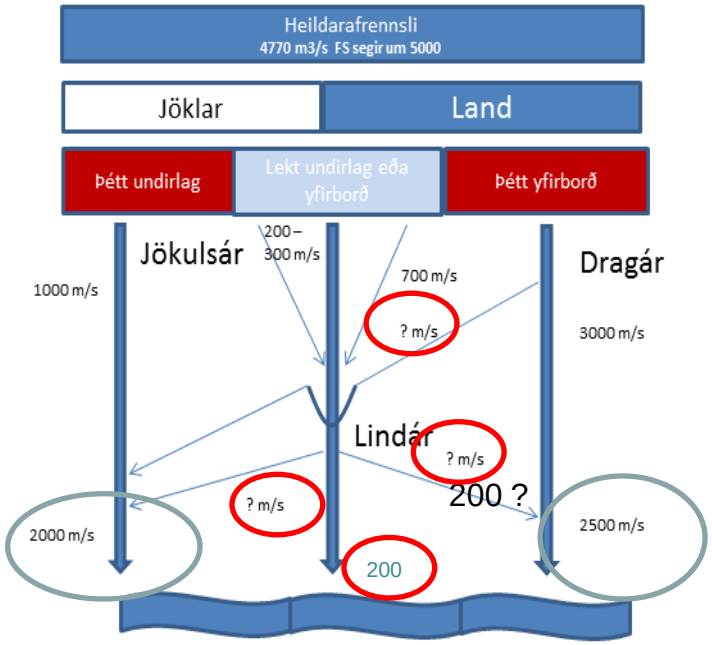


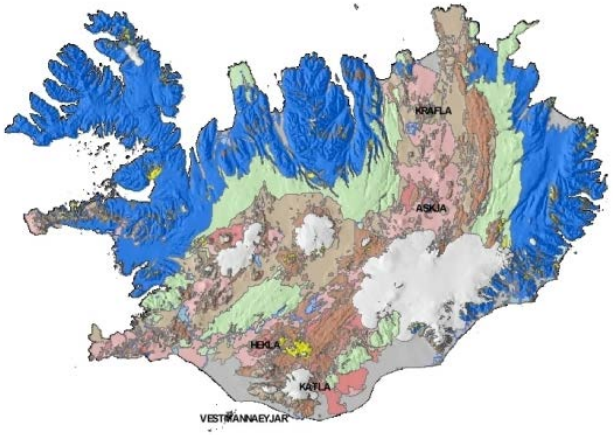
- **Fractures, faults and land forms**

•e.g. long buried moberg ridges or valleys

Distribution of the runoff

Skipting afrennslis eftir FS

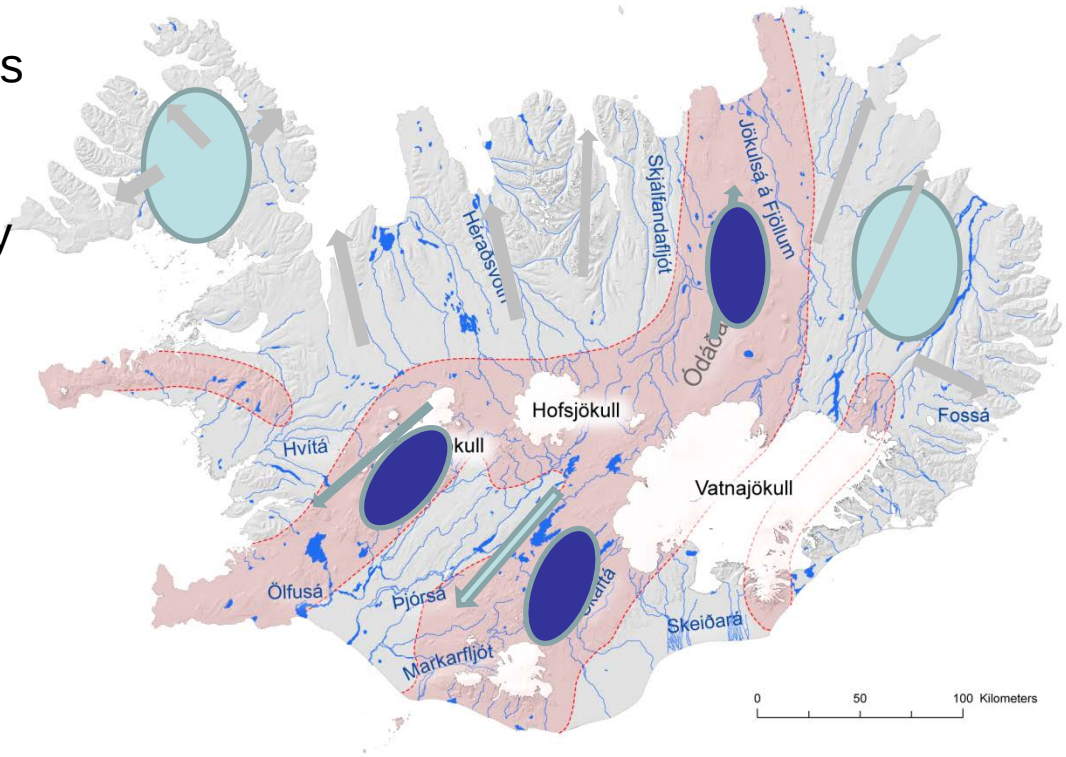




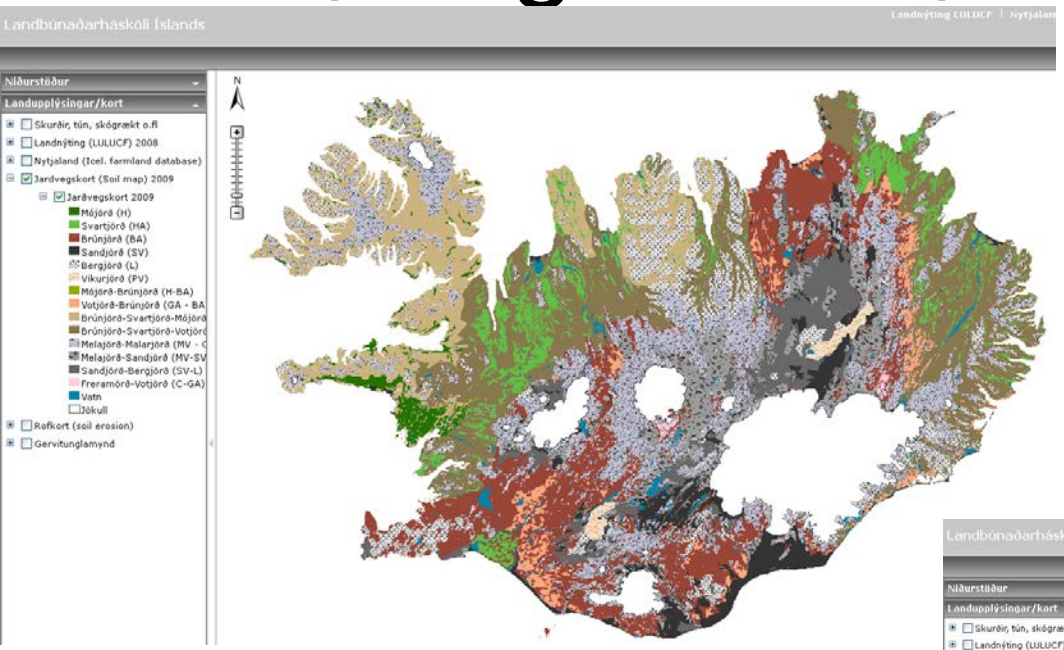
Still work to do

Hydrology of Iceland Geology

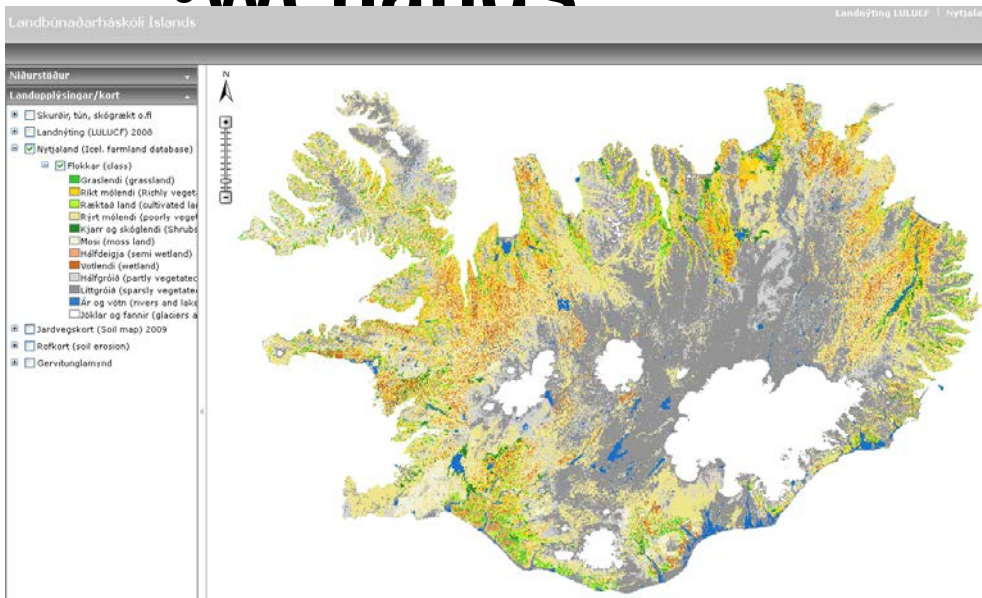
- **Tertiary basalts in the East and West**
  - Little infiltration causes abundant direct runoff rivers
- **Volcanically active zone**
  - Young (postglacial) lava fields with high permeability
  - Limited surface runoff
  - Spring-fed rivers at the boundaries
- **Direction of groundwater and surface flow**
  - Strongly controlled by local tectonics, volcanic formations and glacially scoured landforms



Hydrology of Iceland
Soil, vegetation, land-use



- **Vast areas non- or scarcely vegetated**
- **Wetlands**

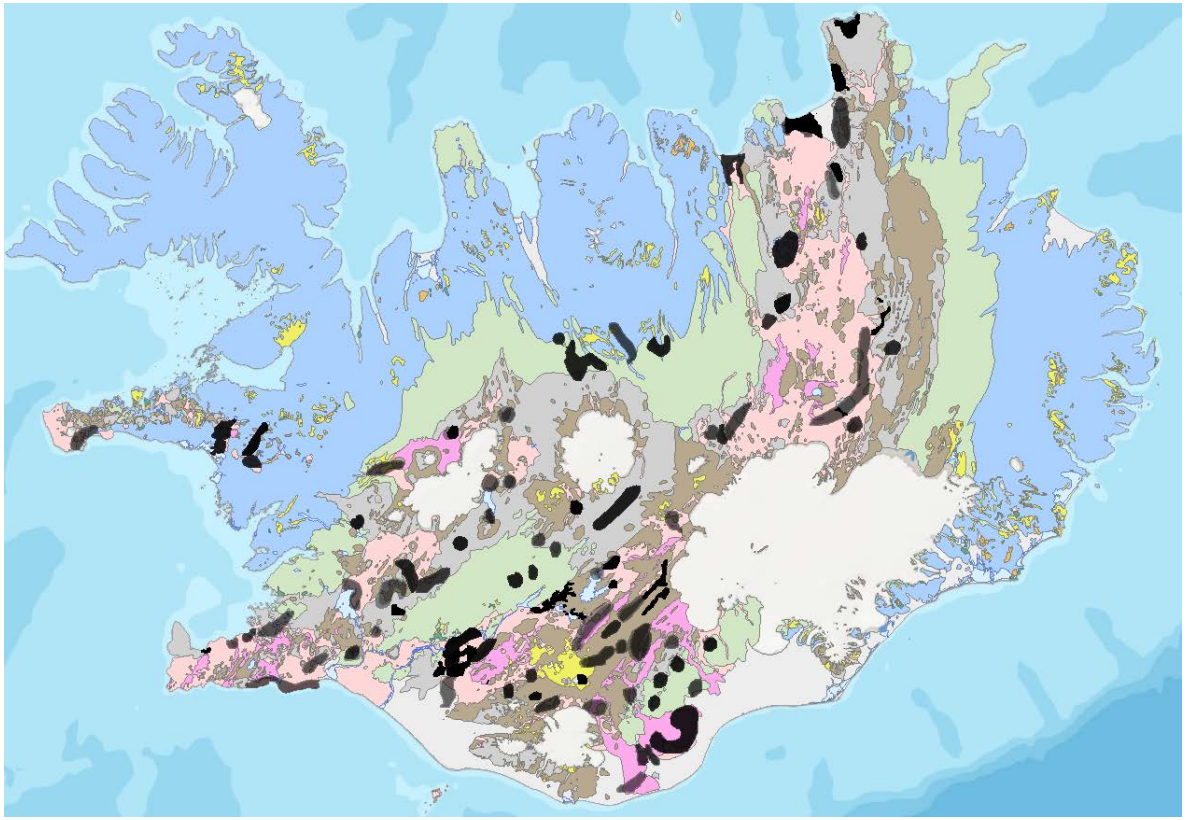


Volcanic soils

- Easily erodable
- Store immense amount of water

Maps from the Agricultural University of Iceland website

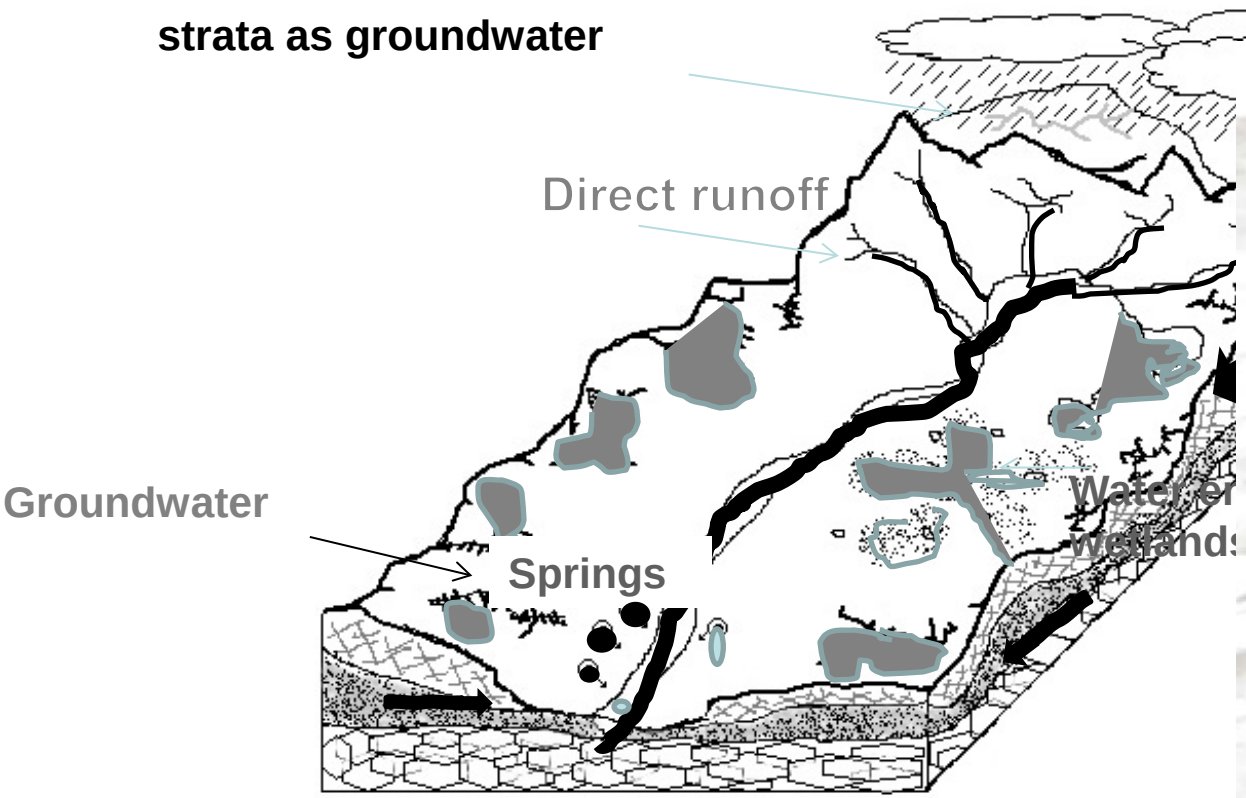
Where are the main spring areas?

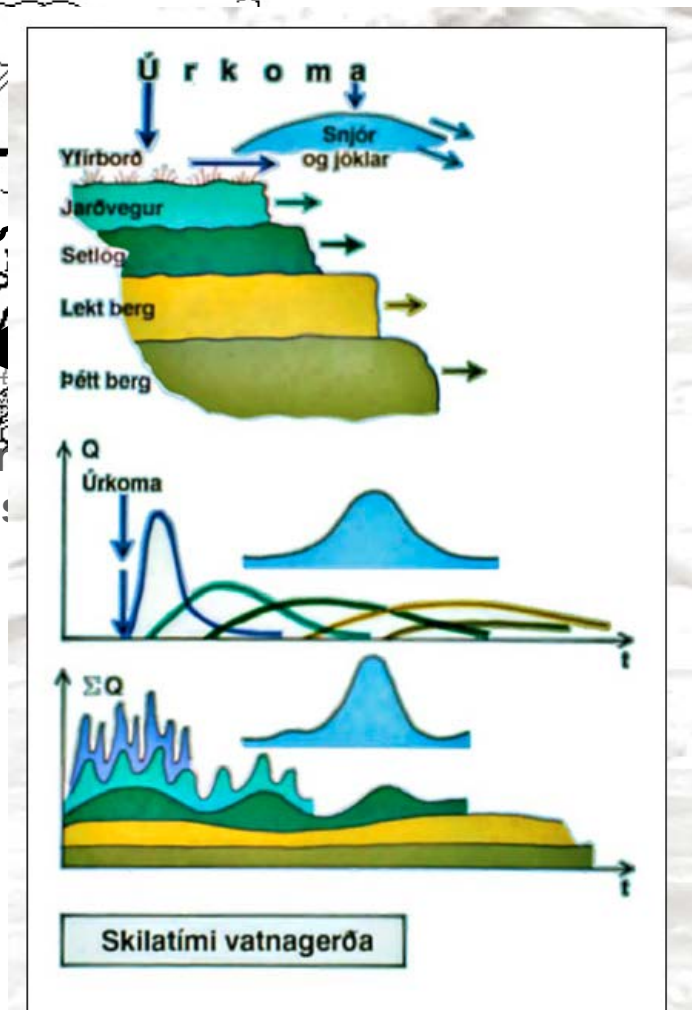


Mainly confined to the Neo-Volcanic Zone and the recent lava flows

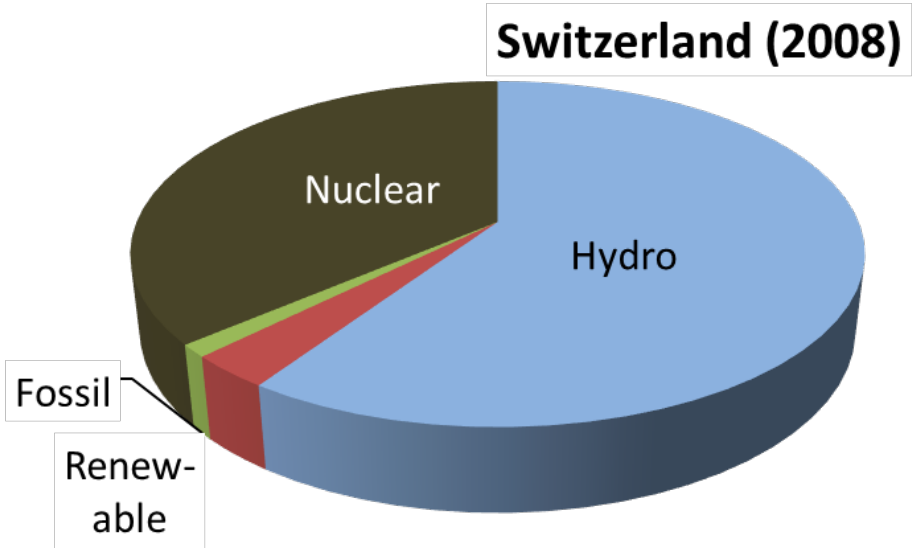
Main features in an hydrograph

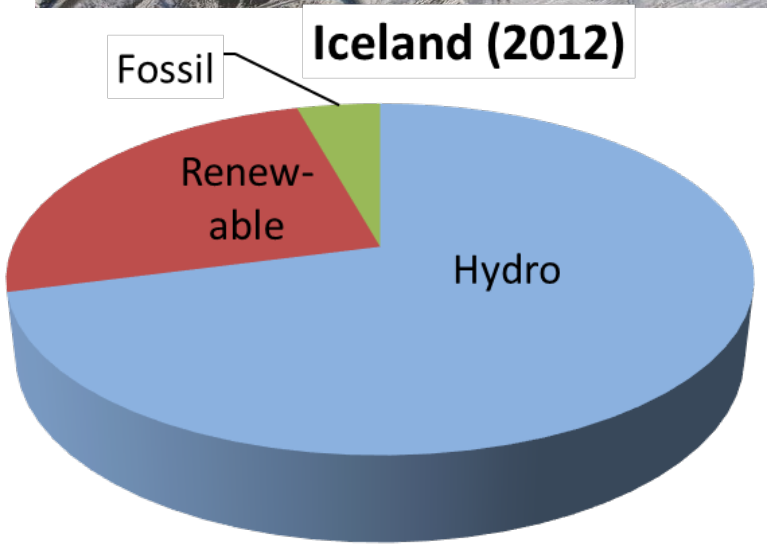
Meltwater and discharge from glaciers can enter as direct runoff or via soil lakes and strata as groundwater





Motivation





Iceland: Kárahnjúkavirkjun (690 MW; 4600 GWh) Base power
Switzerland: Grande Dixence (2068 MW; 2000 GWh) Peak power

Data availability in Iceland

Discharge (Q)

- Over 100 stations all over Iceland

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(Q_{i,\mathrm{obs}} - Q_{i,\mathrm{sim}}\right)^2}{\sum_{i=1}^{n}\left(Q_{i,\mathrm{obs}} - \overline{Q_{i,\mathrm{obs}}}\right)^2}$$

Nash-Sutcliffe

Mass Balances (MB)

- 1930 to present

$$RMSE_{MB} = \sqrt{\sum_{j=1}^{m}\left(MB_{j,\mathrm{obs}} - MB_{j,\mathrm{sim}}\right)^2}$$

MODIS snow cover data (SC)

- Twice a day (TERRA and AQUA)
- 500 m resolution
- Entire world

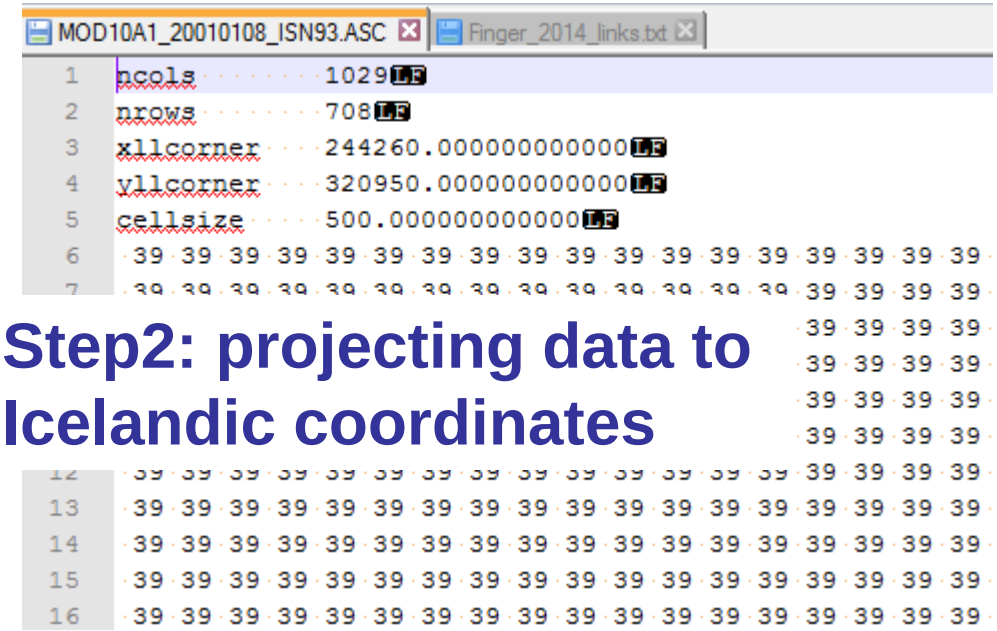
Correctly Predicted Snow Cover

$$CPSC = \frac{c_{\mathrm{corr}}}{c_{\mathrm{tot}} - c_{\mathrm{missing}}}$$

No data due to cloud cover

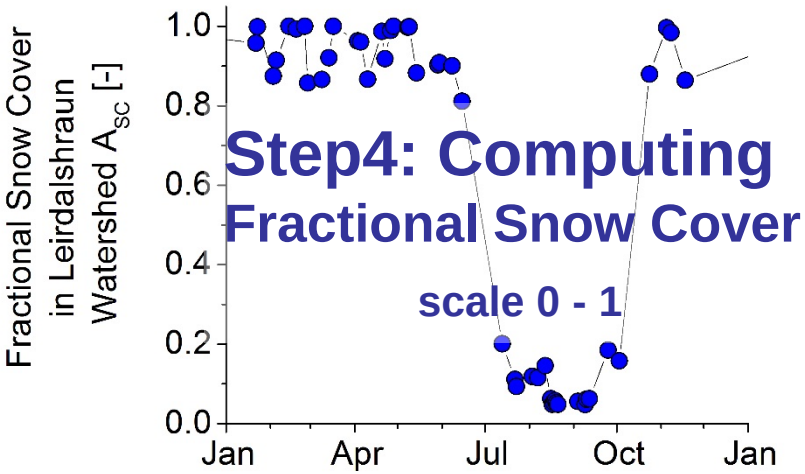
Acquiring snow cover data

Step1: Getting data from NASA web site



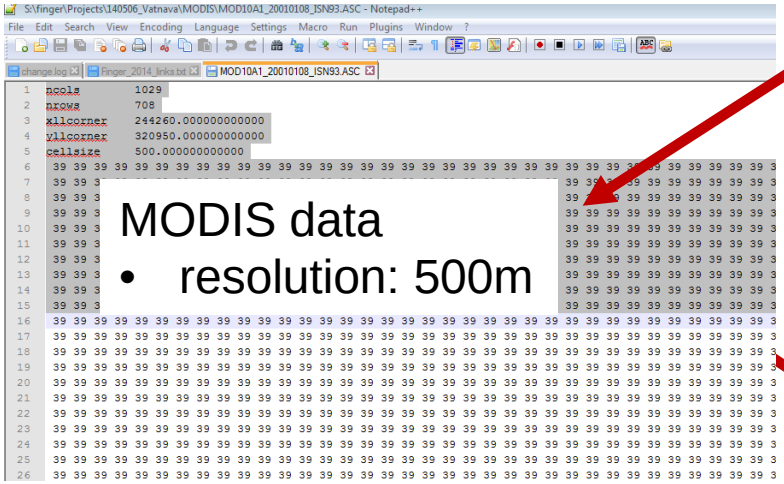
Step2: projecting data to Icelandic coordinates

Step3: extracting relevant area



Step4: Computing Fractional Snow Cover

Example: satellite snow cover images



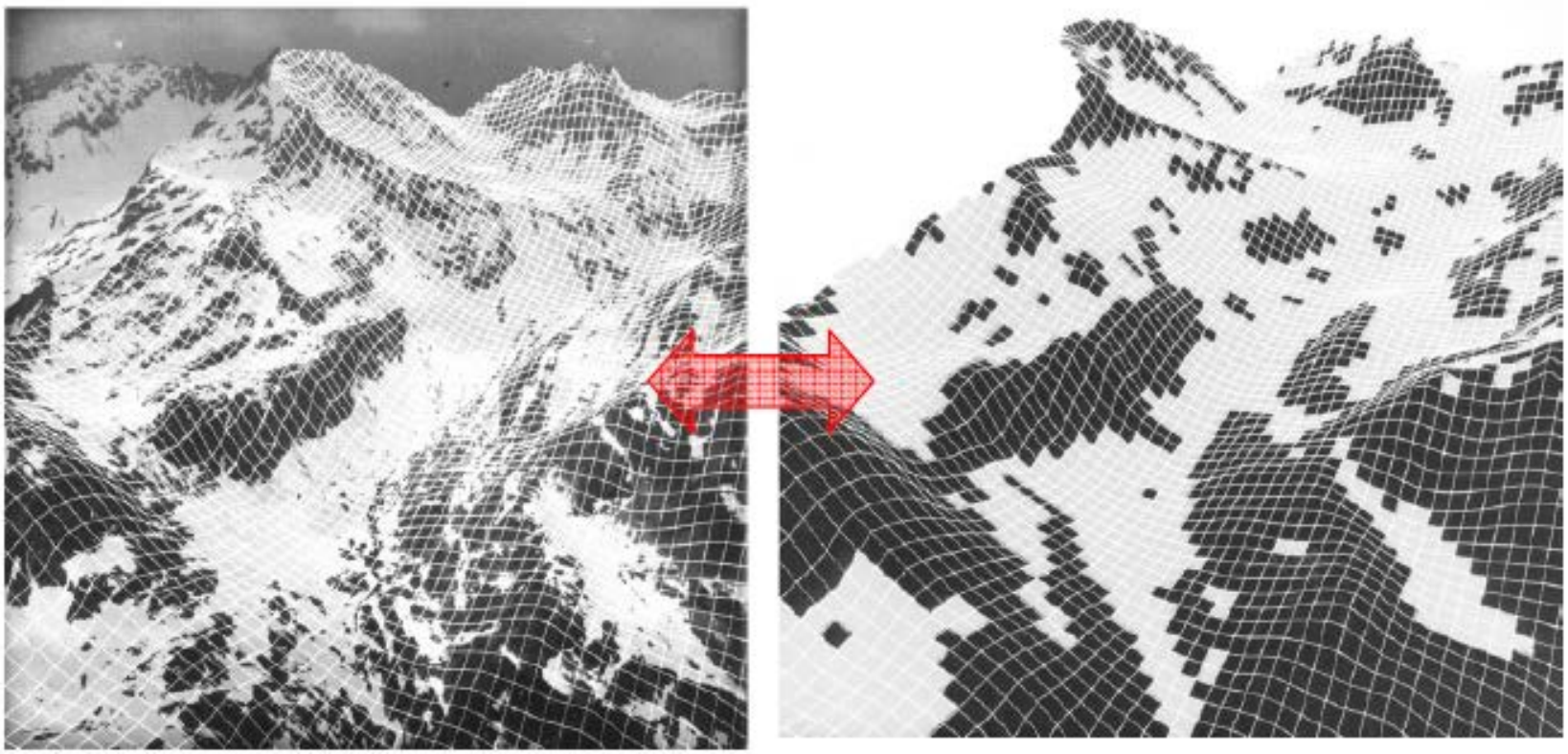
MODIS data

- resolution: 500m

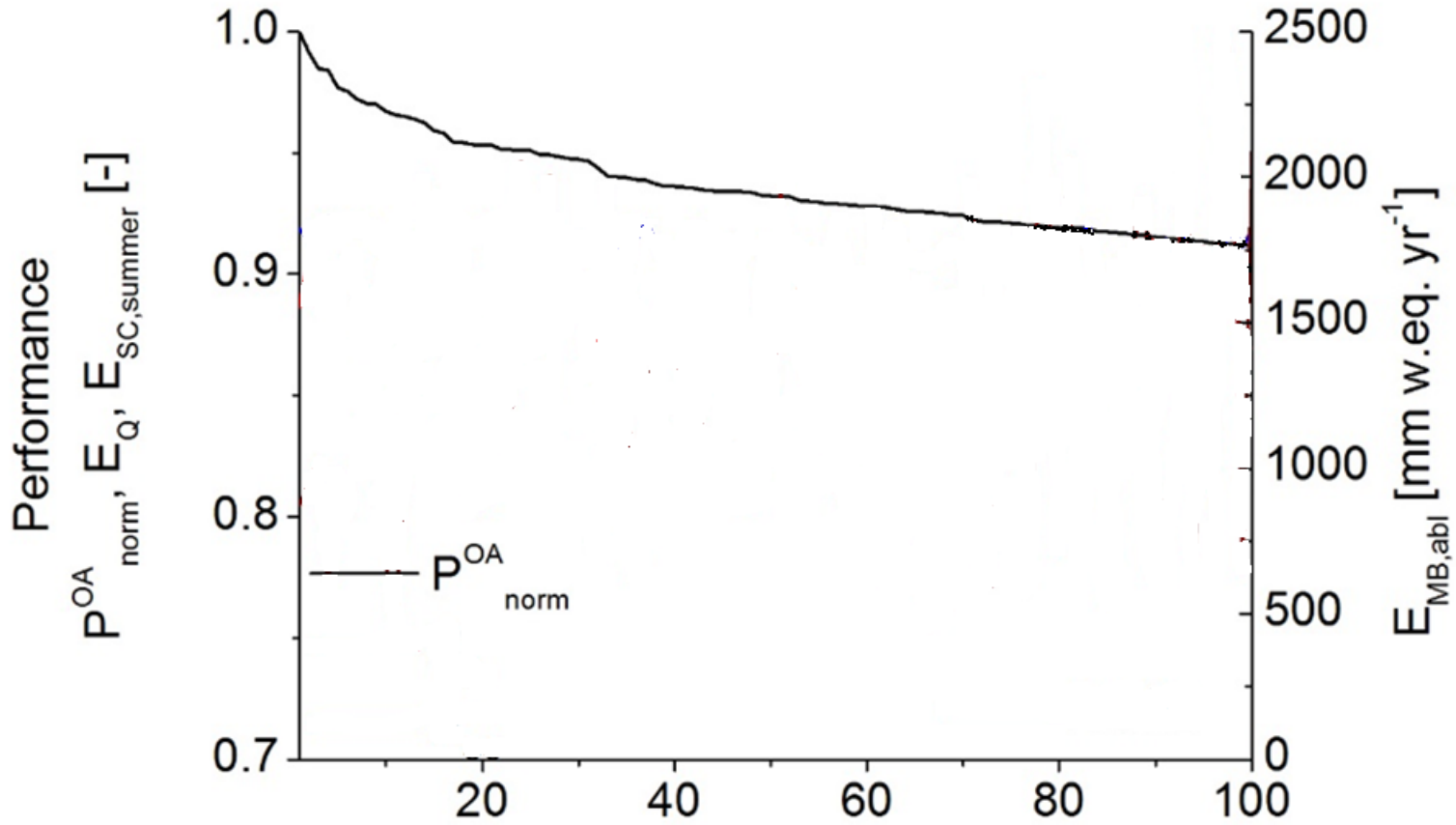
Binary information on snow cover:

- 50 no snow
- 200 snow
- Rest is unknown

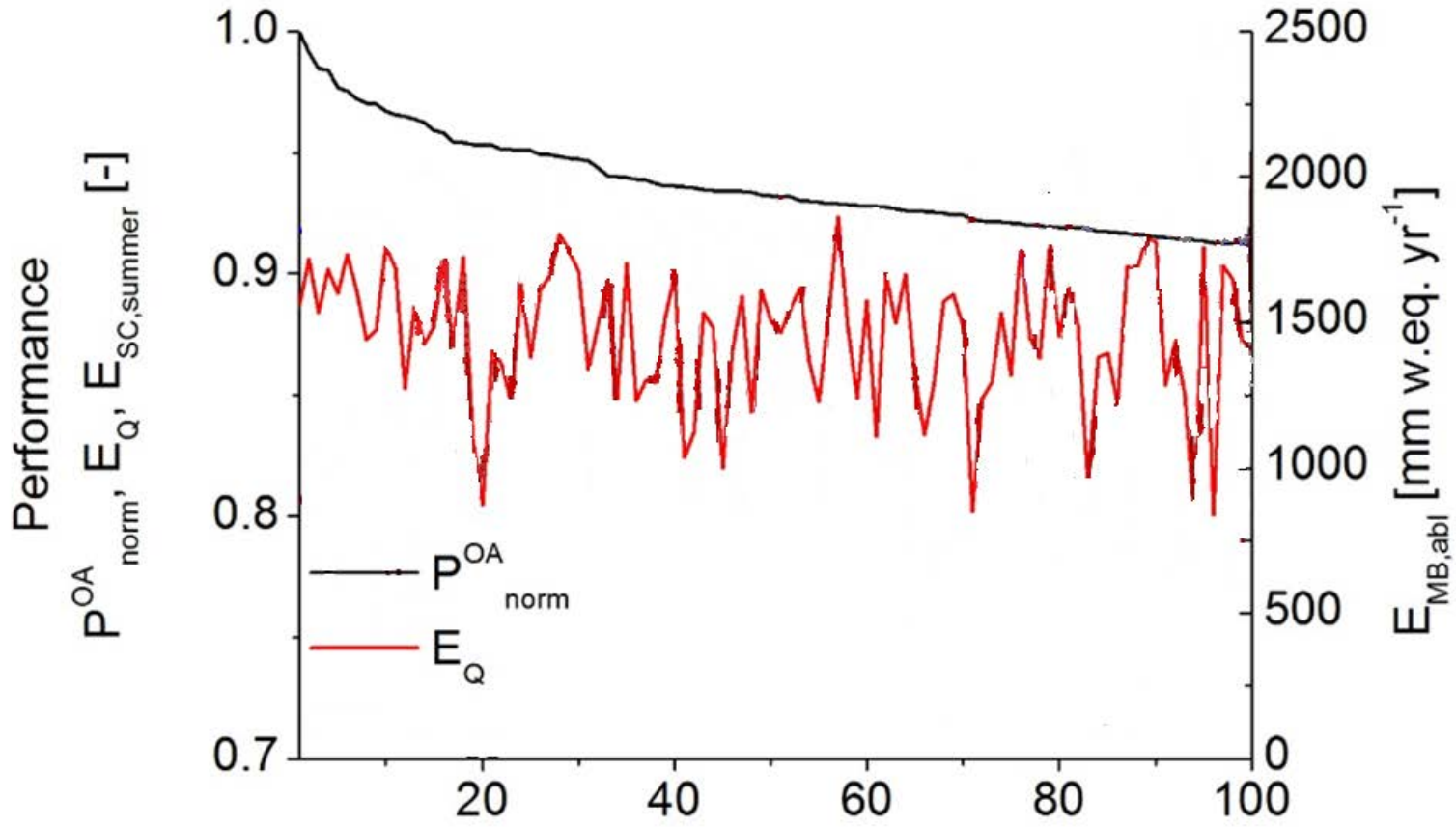
$$CPSC = \frac{c_{corr}}{c_{tot} - c_{missing}}$$



Results of the 100 best runs from 10’000 MC runs



- **Results of the 100 best runs from 10’000 MC runs**



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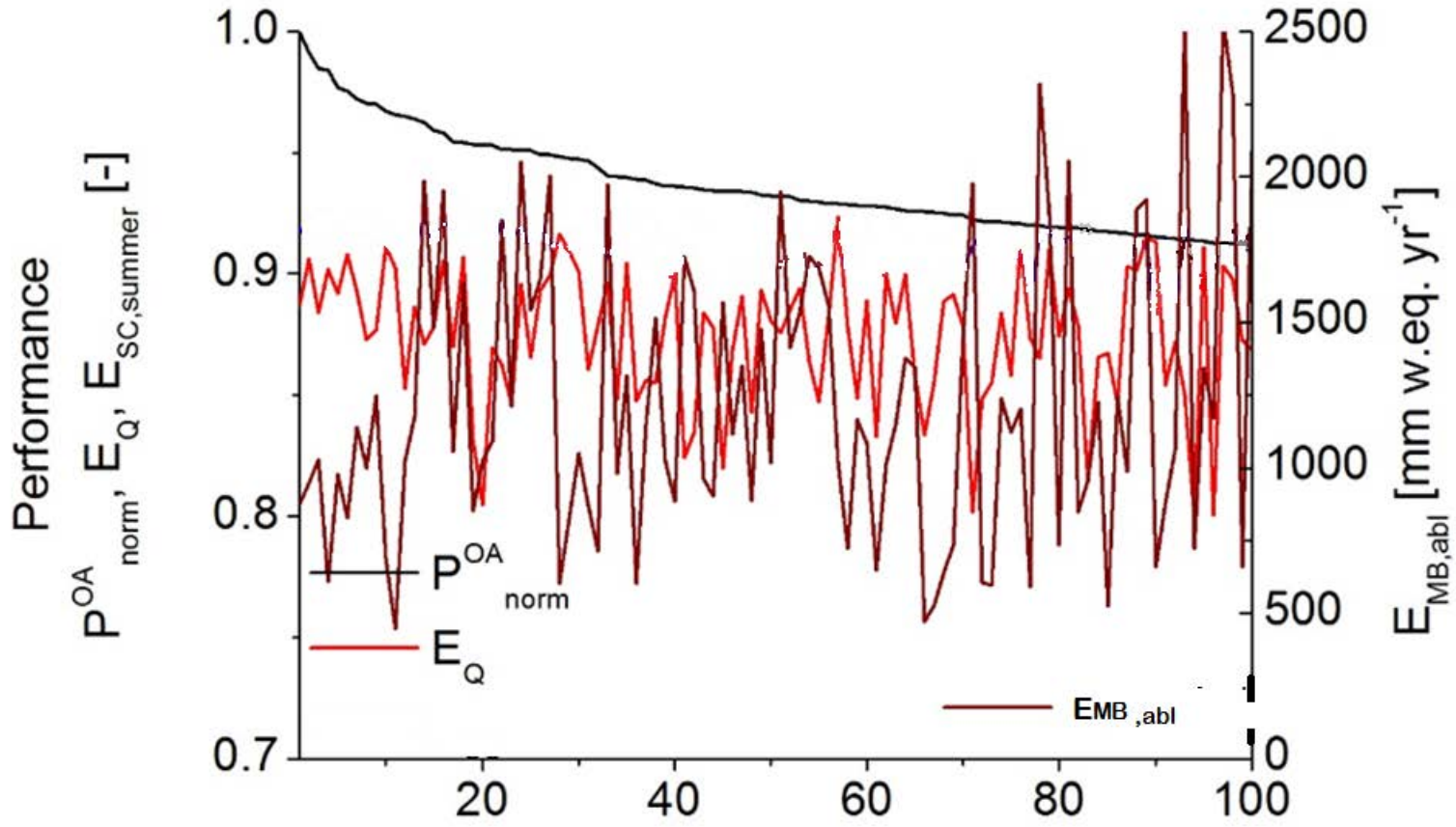
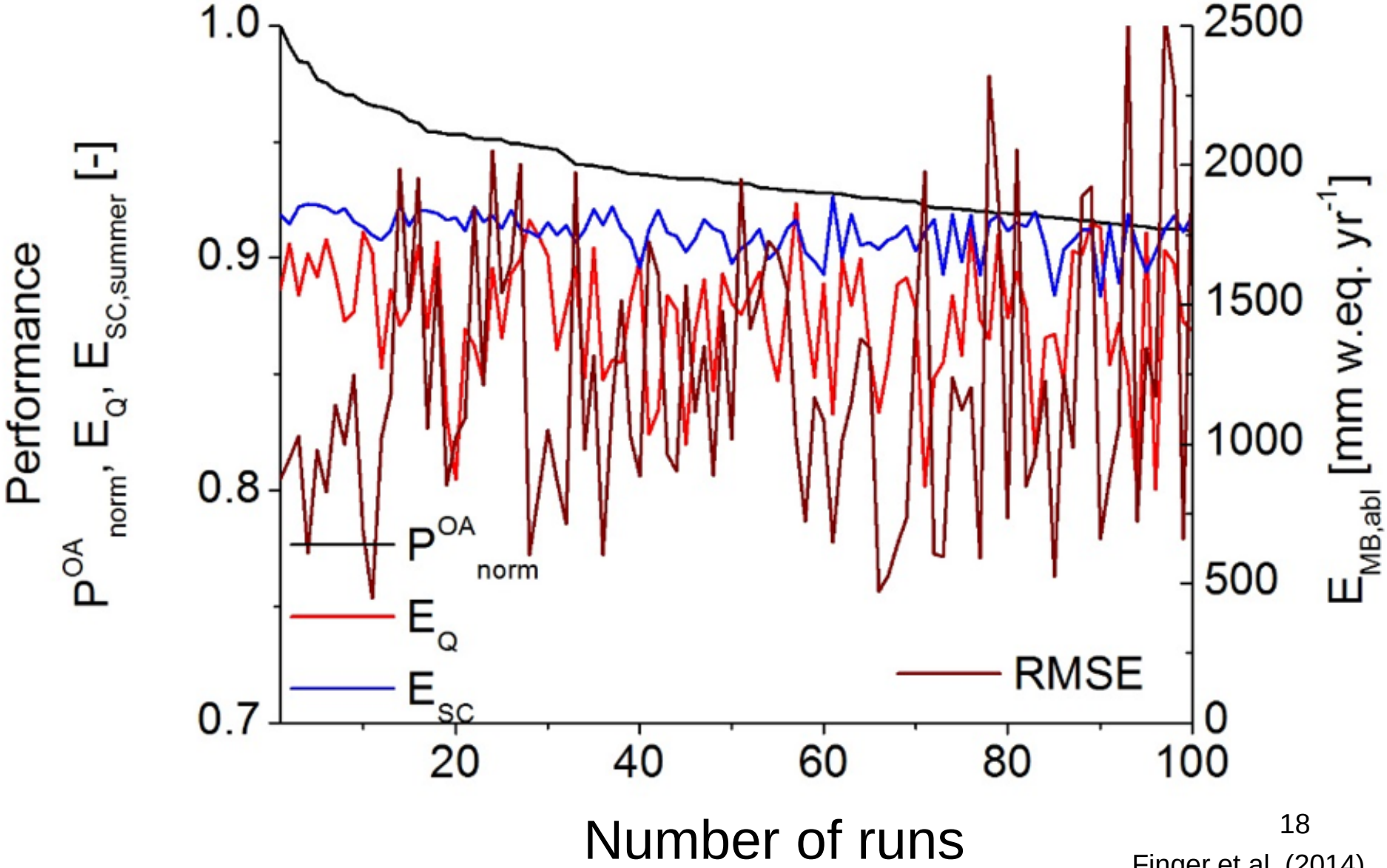
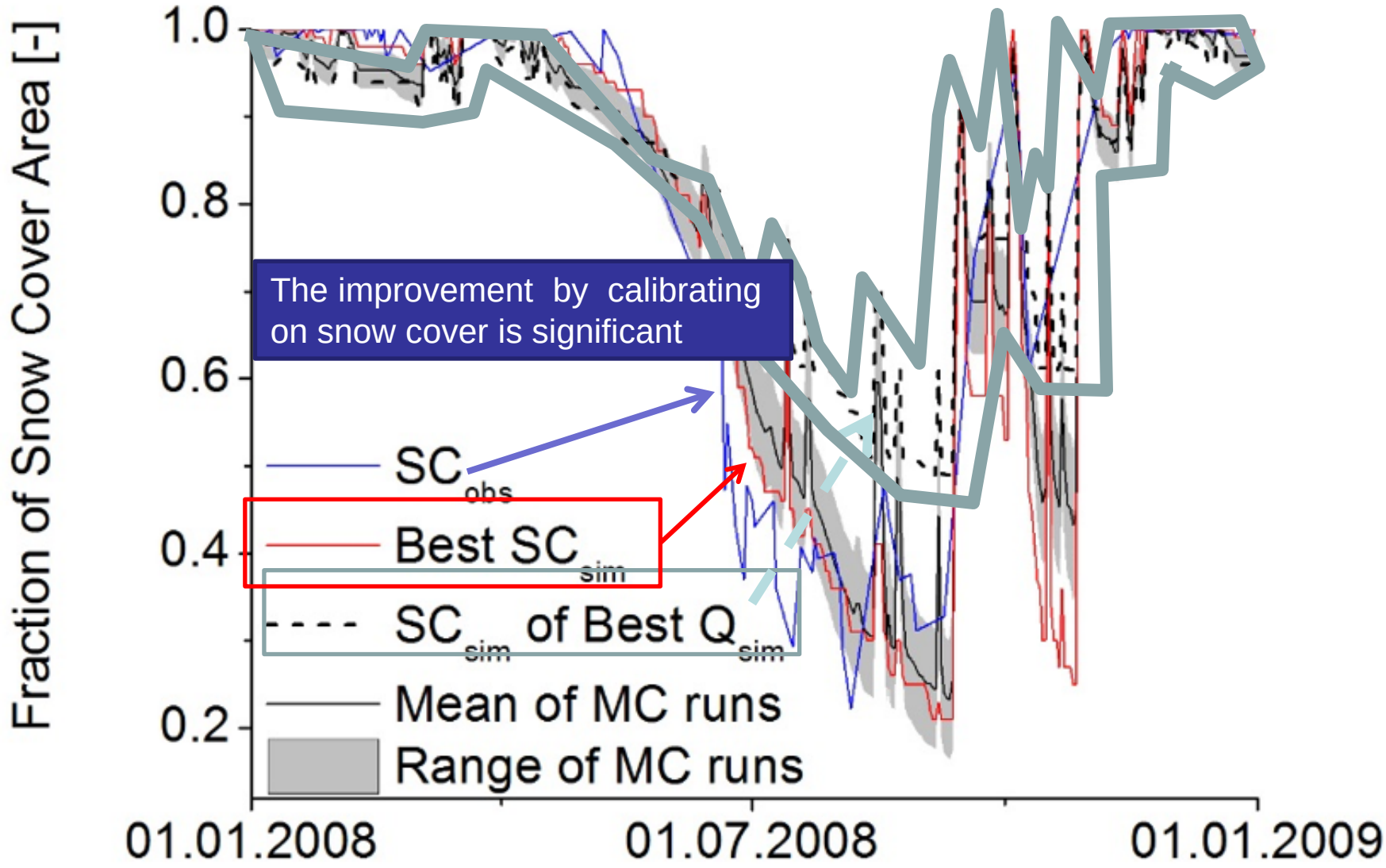


Results of the 100 best runs from 10’000 MC runs



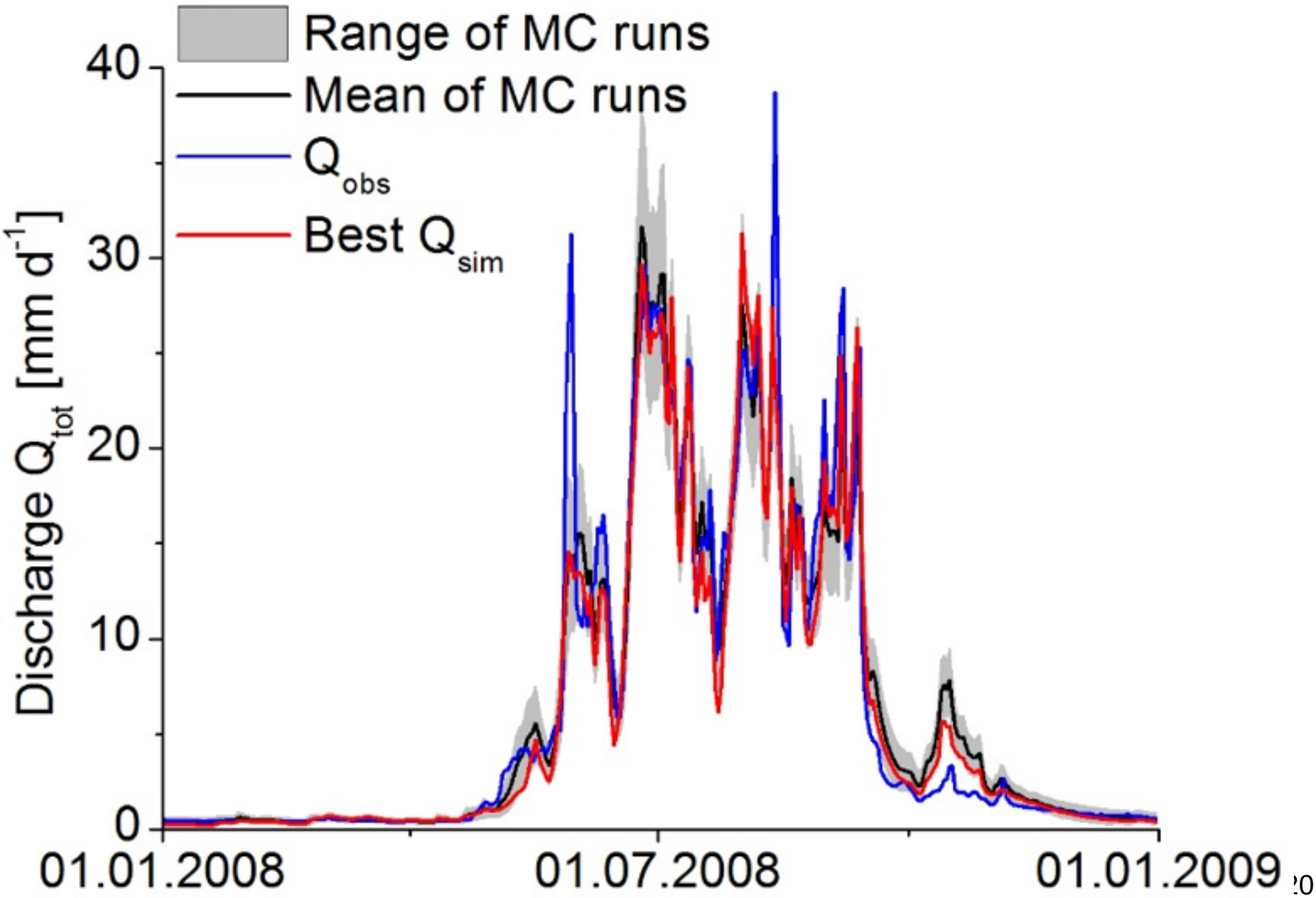
Finger et al. (2014)

Snow Cover Results of the 100 best runs Switzerland



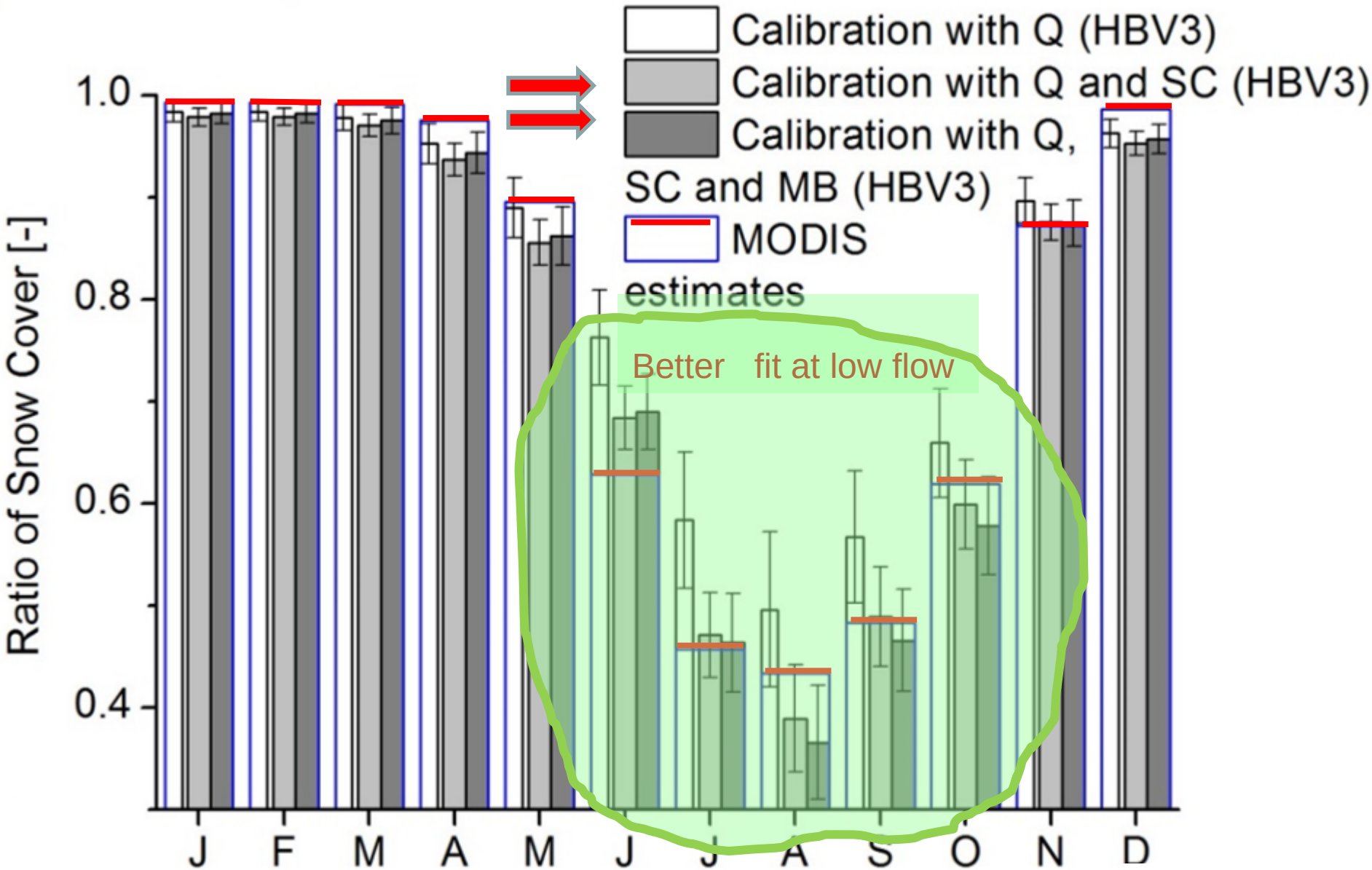
Finger et al. (2014)

Discharge Results of the 100 best



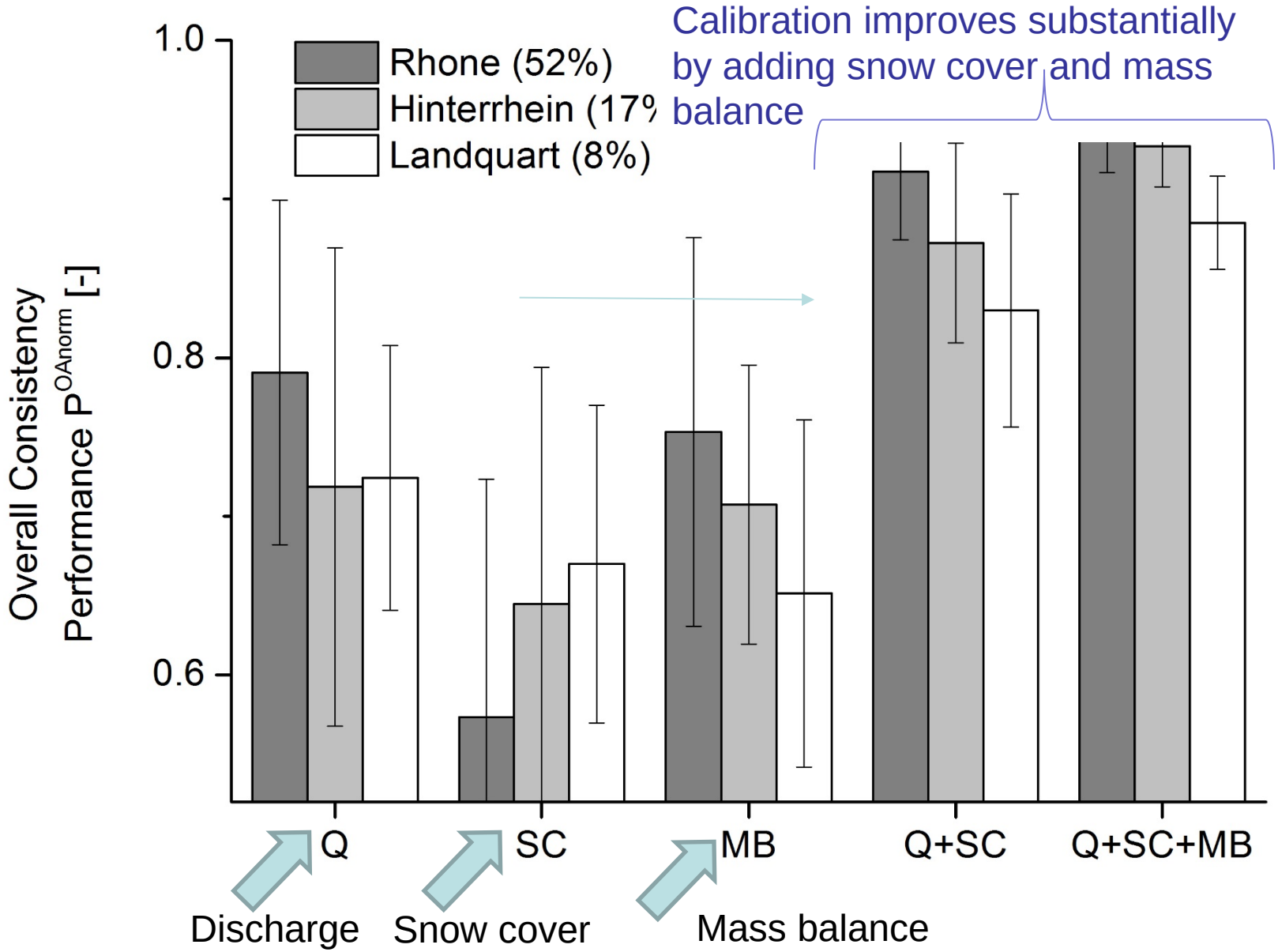
Finger et al. (2014)

When SC is used simulation of Snow Cover become better



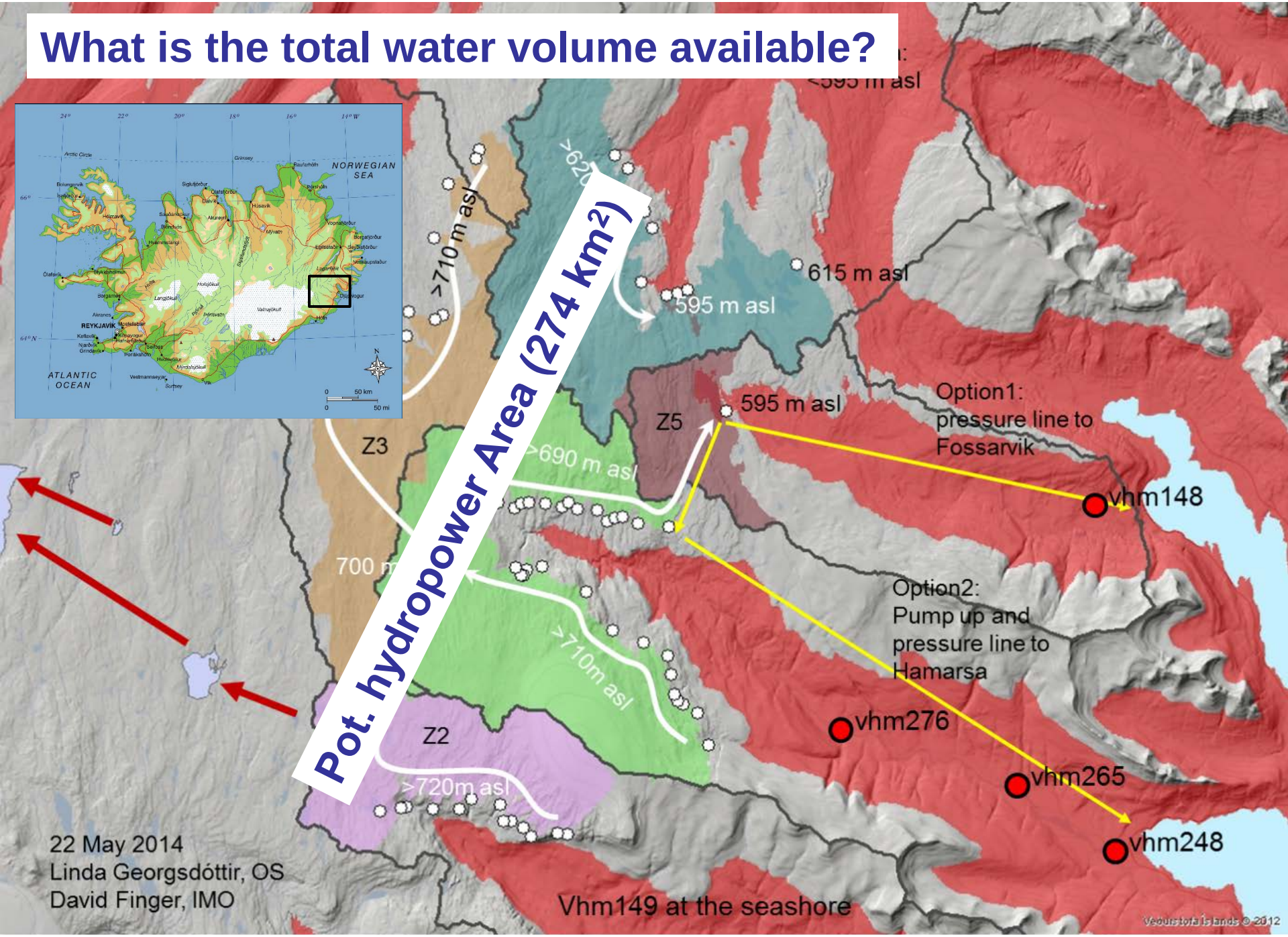
Finger et al. (2014)

The Value of different Datasets for model calibration

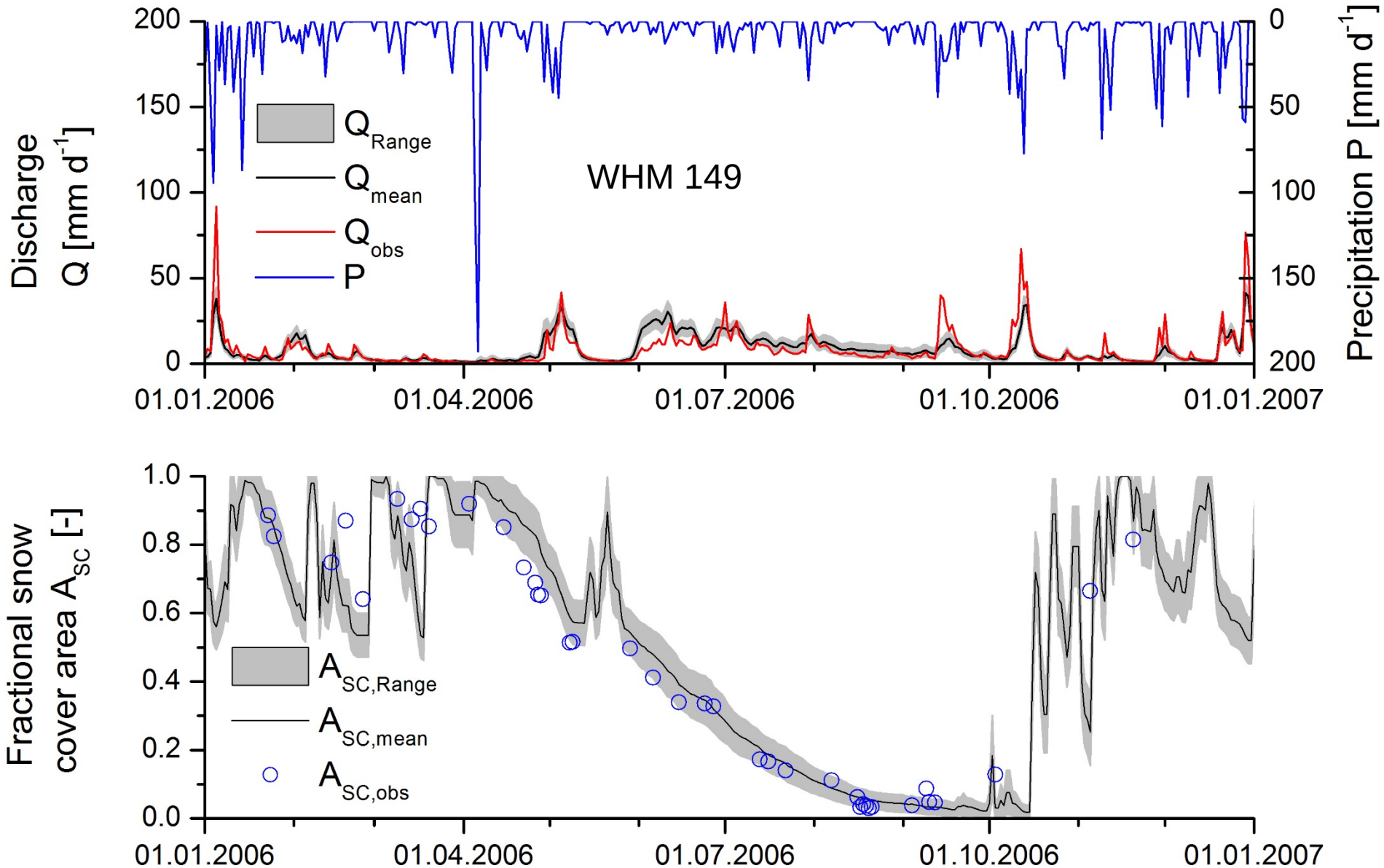


Finger et al. (2014)

What is the total water volume available?

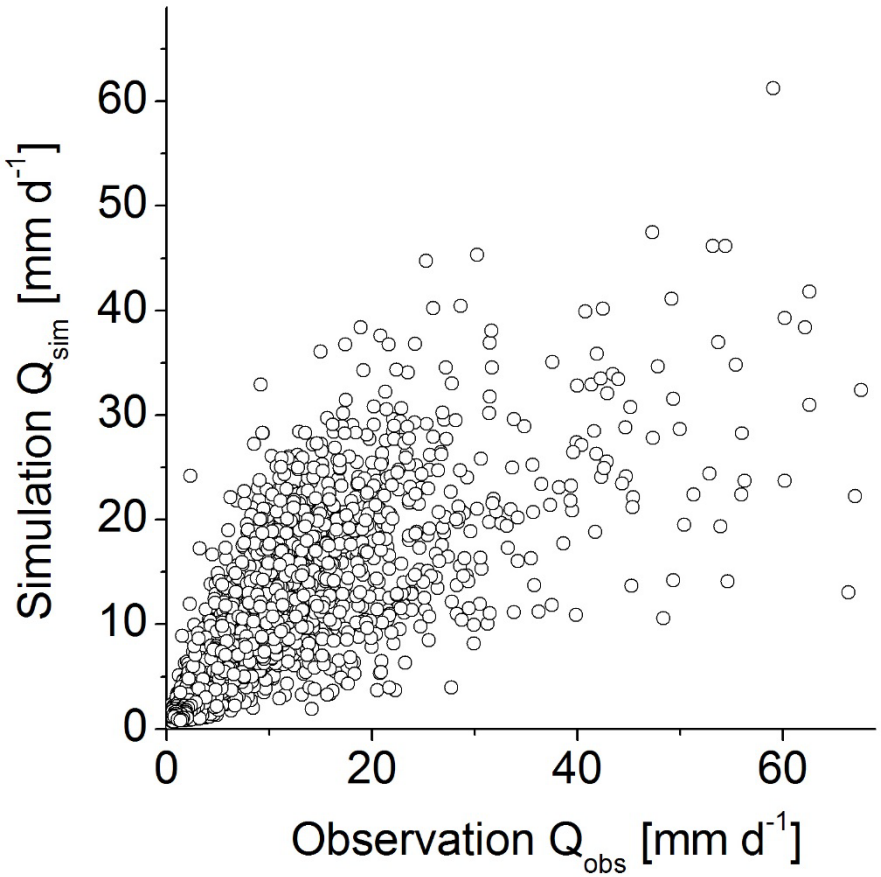


Calibration runs on gauged sub-catchment in eastern Iceland

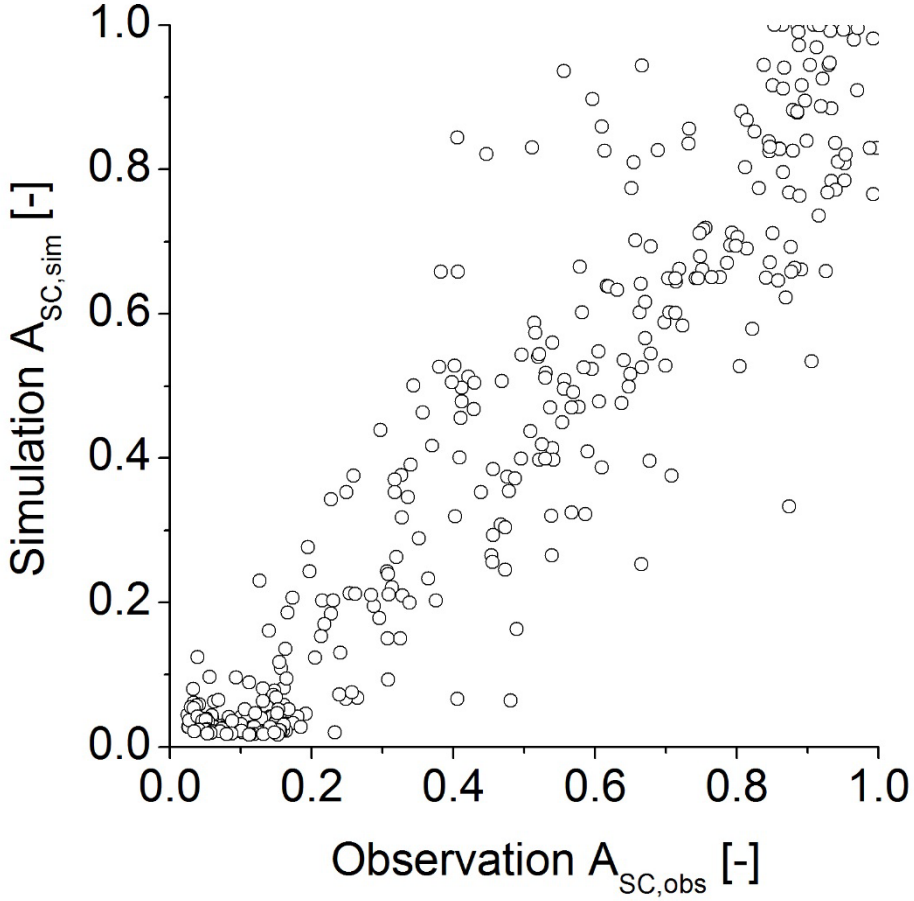


Long-term Validation of gauged sub-catchment (vhm149) in eastern Iceland

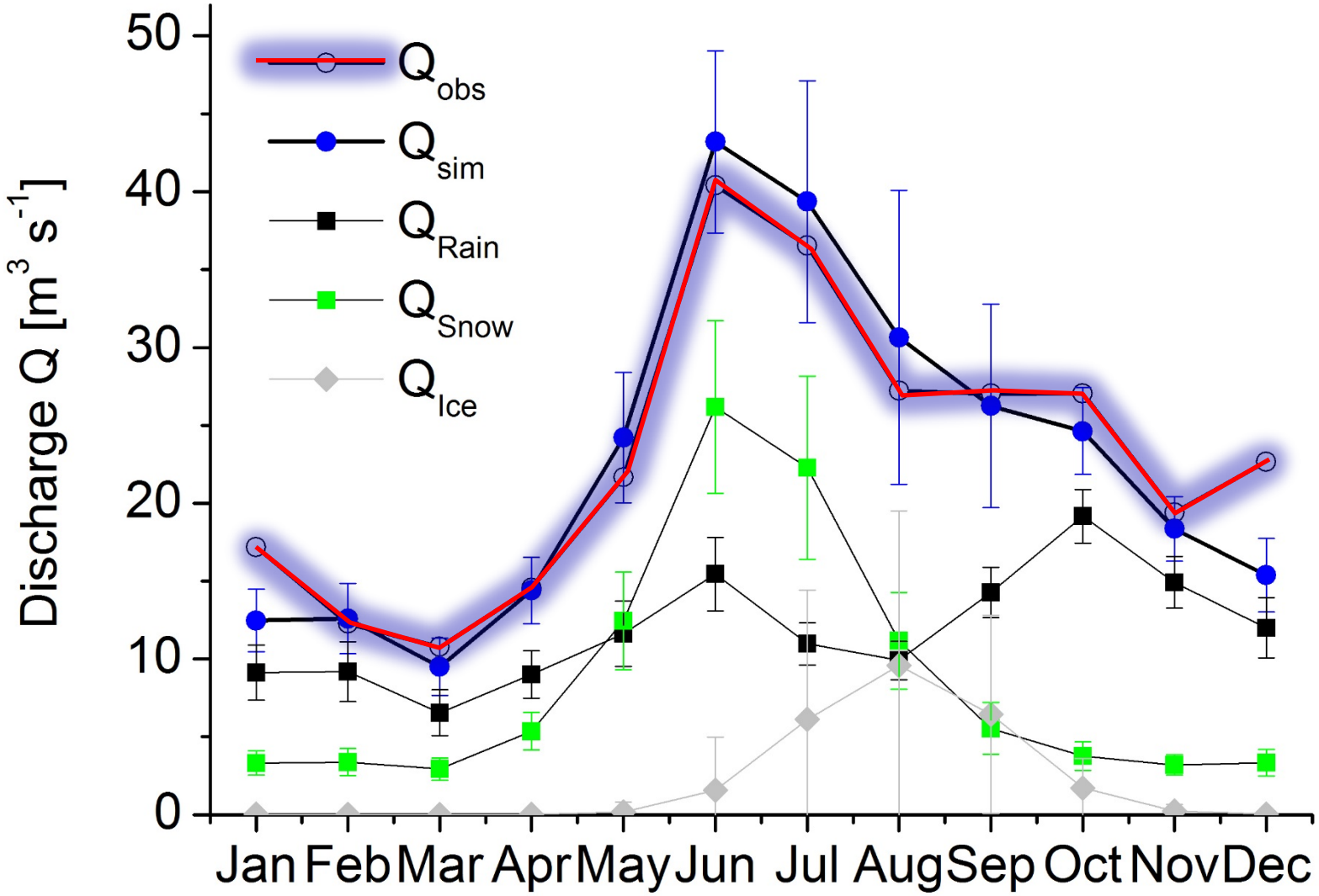
Discharge (1991 -2010)



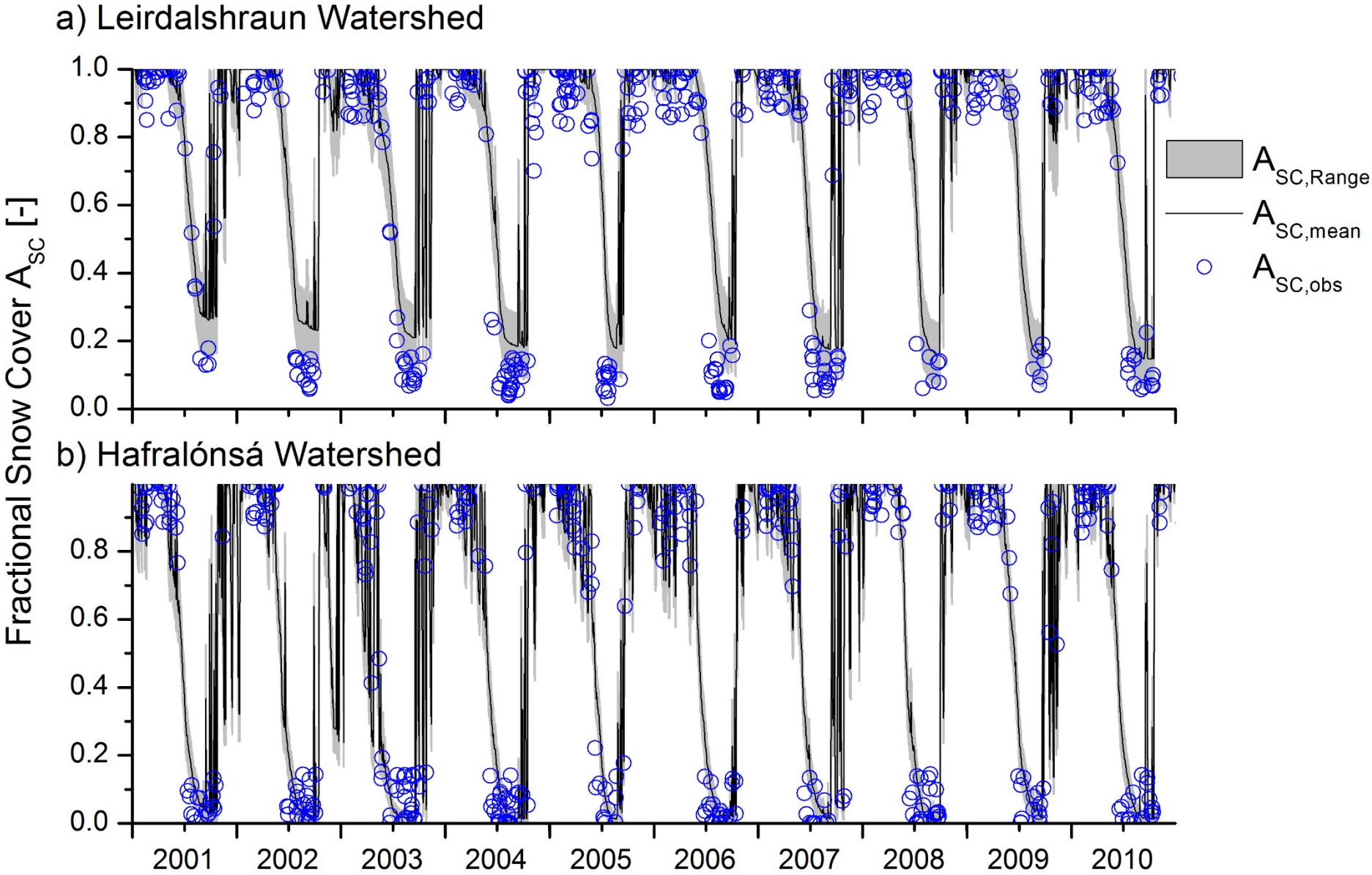
Snow Cover (2001 -2010)



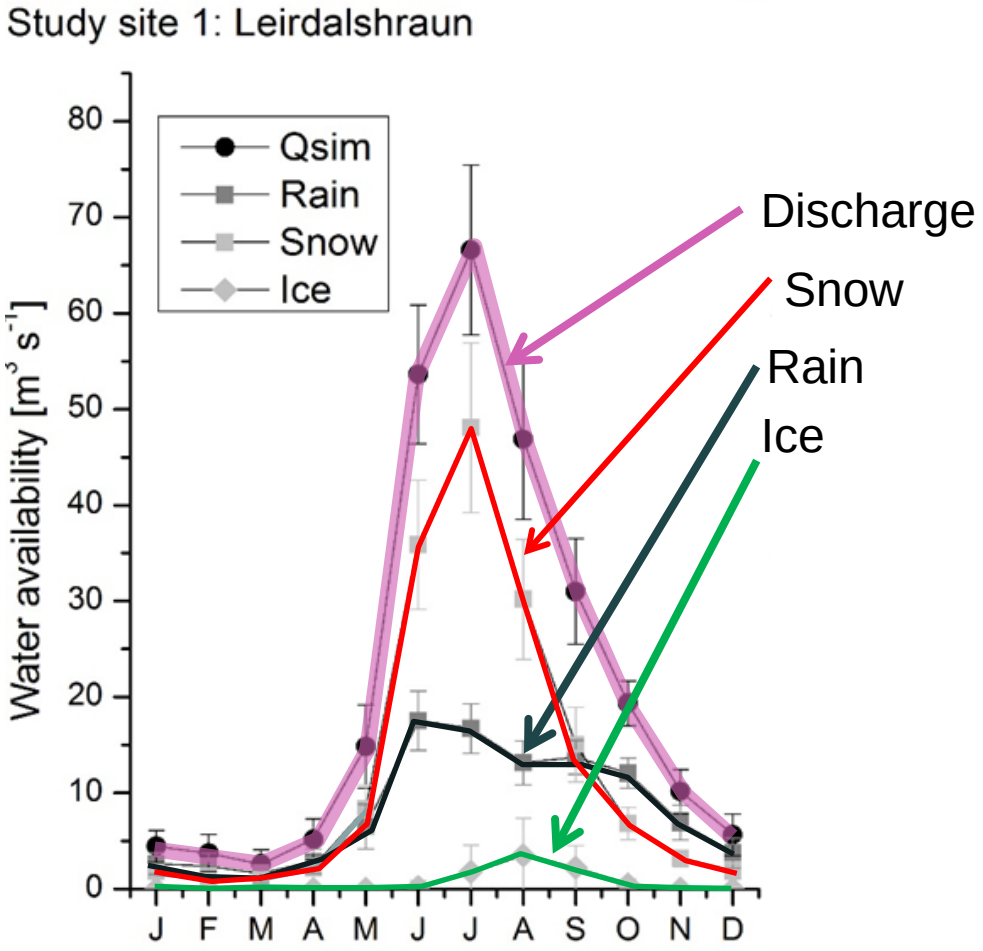
Validation runs on gauged sub-catchment (vhm149) in eastern Iceland



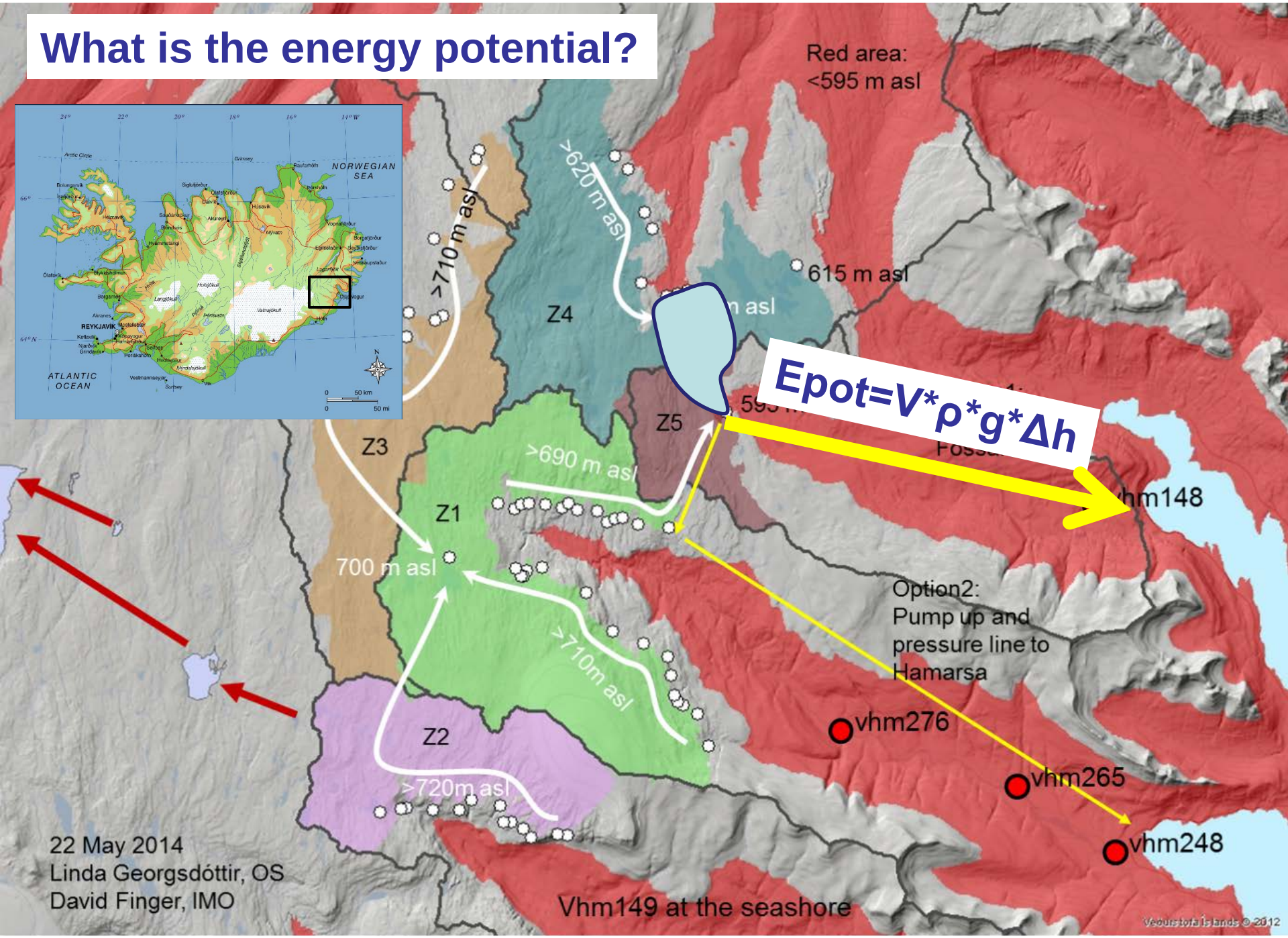
Validation of snow cover for entire ungauged catchments



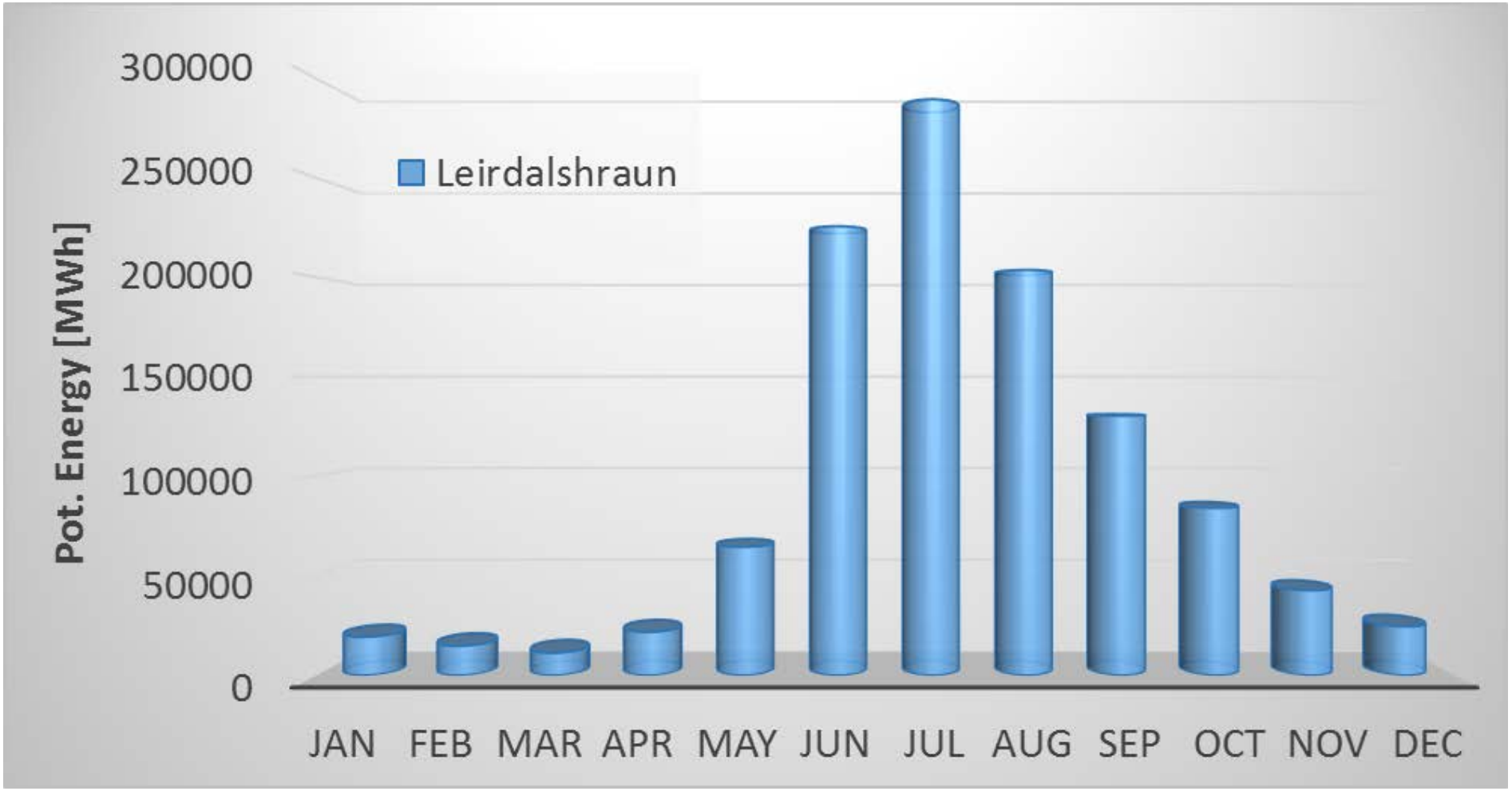
Potential of water amount available for hydropower production



What is the energy potential?



Estimations of the potential Energy available in the study Site (274 km²) in eastern Iceland



Conclusions

- In modelling it is essential to constrain model results to different datasets
- Satellite snow cover images make hydrological modelling more robust and accurate
- Satellite snow cover images are in particular useful in ungauged areas where no discharge observations are available
- Satellite snow cover images make climate change projections into the future more reliable

Thanks for your attention

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References:

Finger, D., Huss, M., Vis, M., and Seibert, J. (2014): Assessing the hydropower potential of two prospective sites in north eastern Iceland using hydrological modeling, IMO Internal report.

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Crochet, P (2013). Sensitivity of Icelandic river basins to recent climate variations. Jökull, 71-90, No. 63.

°Special thanks to Philippe Crochet to provide information on weather data in Iceland

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