

The value of satellite retrieved snow cover images to assess water resources and the hydropower potential of ungauged mountain areas

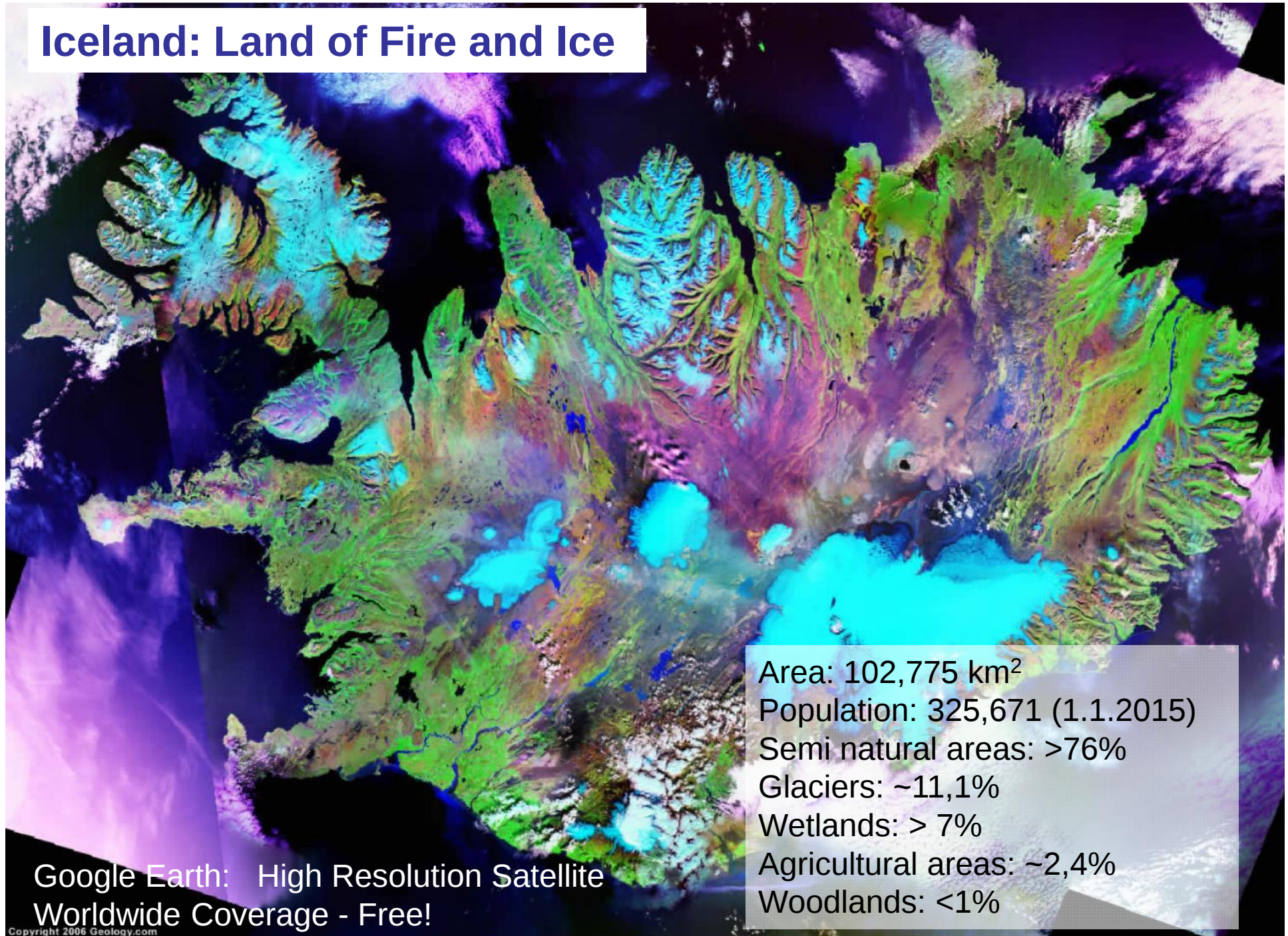
8th EARSeL Workshop Bern 2017

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<http://fingerd.jimdo.com/>



HÁSKÓLINN Í REYKJAVÍK
REYKJAVÍK UNIVERSITY

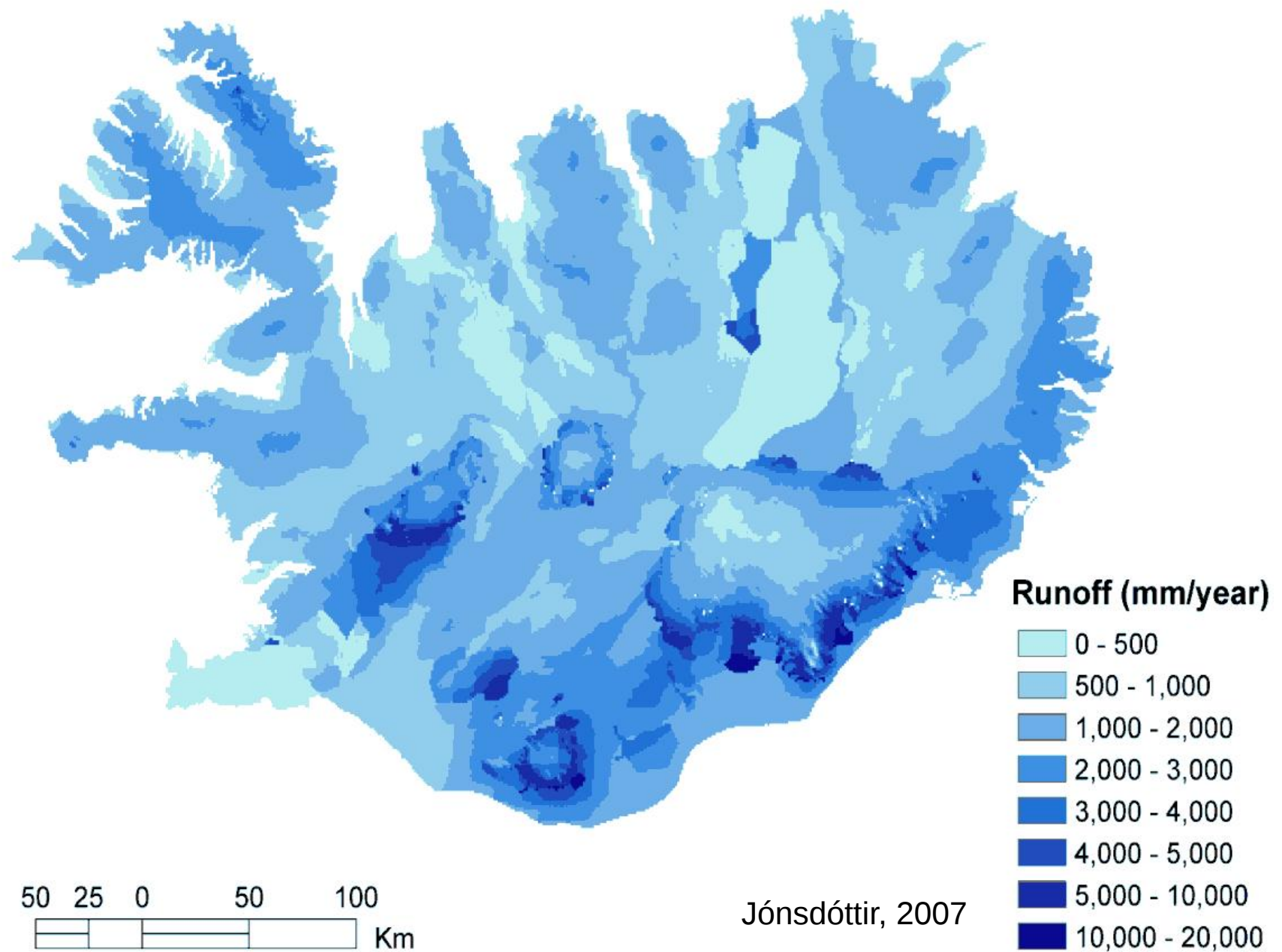
Iceland: Land of Fire and Ice



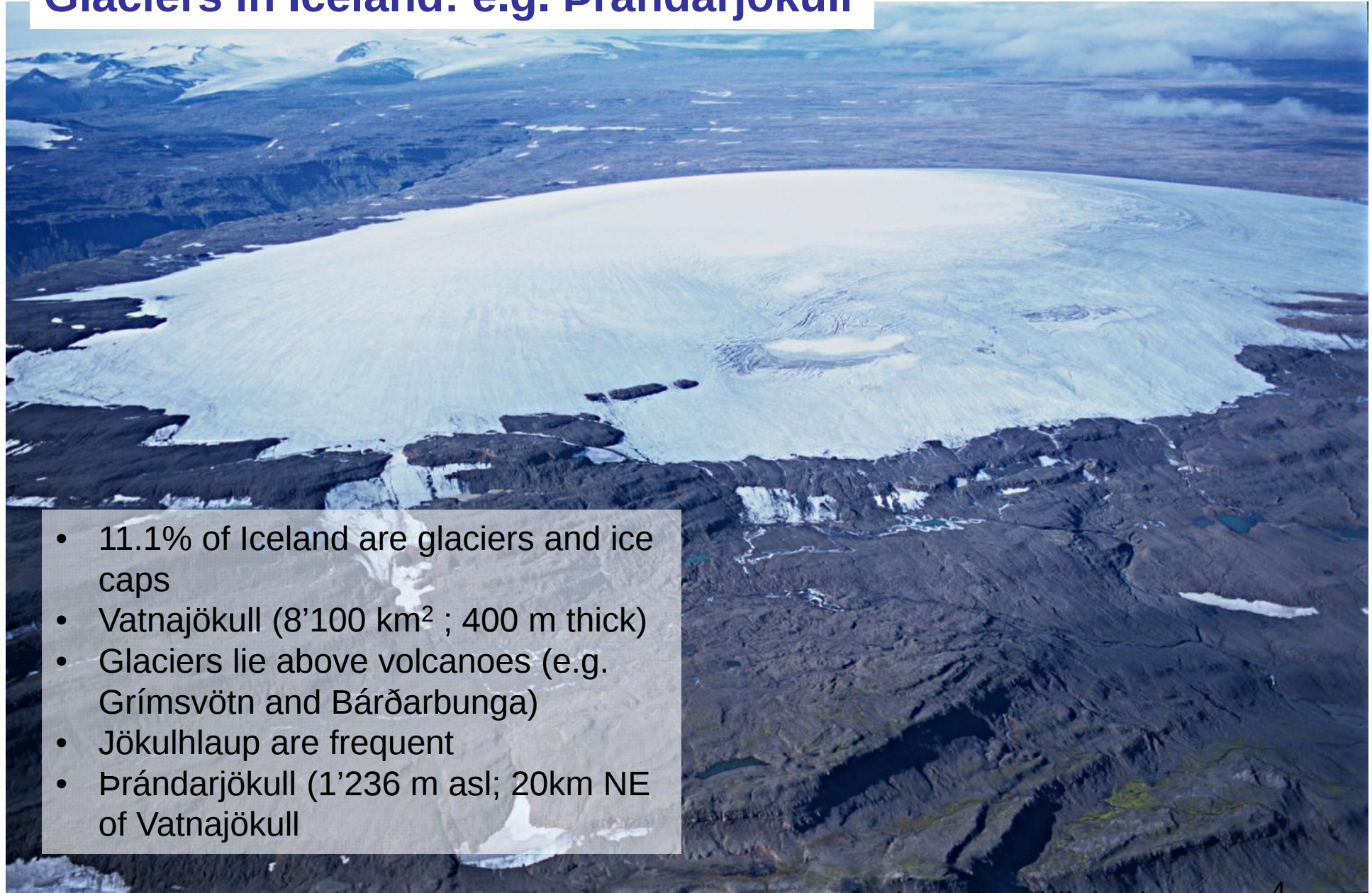
Area: 102,775 km²
Population: 325,671 (1.1.2015)
Semi natural areas: >76%
Glaciers: ~11,1%
Wetlands: > 7%
Agricultural areas: ~2,4%
Woodlands: <1%

Google Earth: High Resolution Satellite
Worldwide Coverage - Free!

Water resources in Iceland



Glaciers in Iceland: e.g. Þrándarjökull



- 11.1% of Iceland are glaciers and ice caps
- Vatnajökull (8'100 km² ; 400 m thick)
- Glaciers lie above volcanoes (e.g. Grímsvötn and Bárðarbunga)
- Jökulhlaup are frequent
- Þrándarjökull (1'236 m asl; 20km NE of Vatnajökull)

Emerging water sources: e.g. Hraunfossar, IS



- Borgarfjörður, western Iceland
- Meltwater from Langjökull flows through a lava field into the Hvítá river ($200 \text{ m}^3 \text{ s}^{-1}$)
- Hydrologic Connectivity is important

Jökulhlaups: e.g. River Skeiðará



- is a 30 km long glacier river
- Its source is the glacier Skeiðarárjökull (part of Vatnajökull)
- during Jökulhlaup discharge is estimated to reach $45,000 \text{ m}^3\text{s}^{-1}$
- 880 m long bridge

Hydropower: e.g. Kárahnjúkavirkjun, IS



Kárahnjúkavirkjun (690 MW; 4600 GWh)
→ Base power

Motivation



Annual Hydropower Production:

EU: ~398 TWh

Norway: ~122 TWh

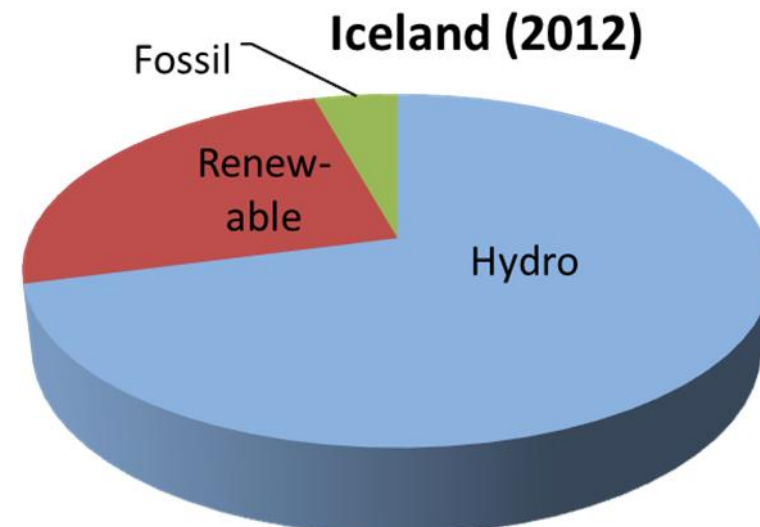
Austria: ~37 TWh

Switzerland: ~35 TWh

Iceland: ~12 TWh

Pot: 220 TWh/yr

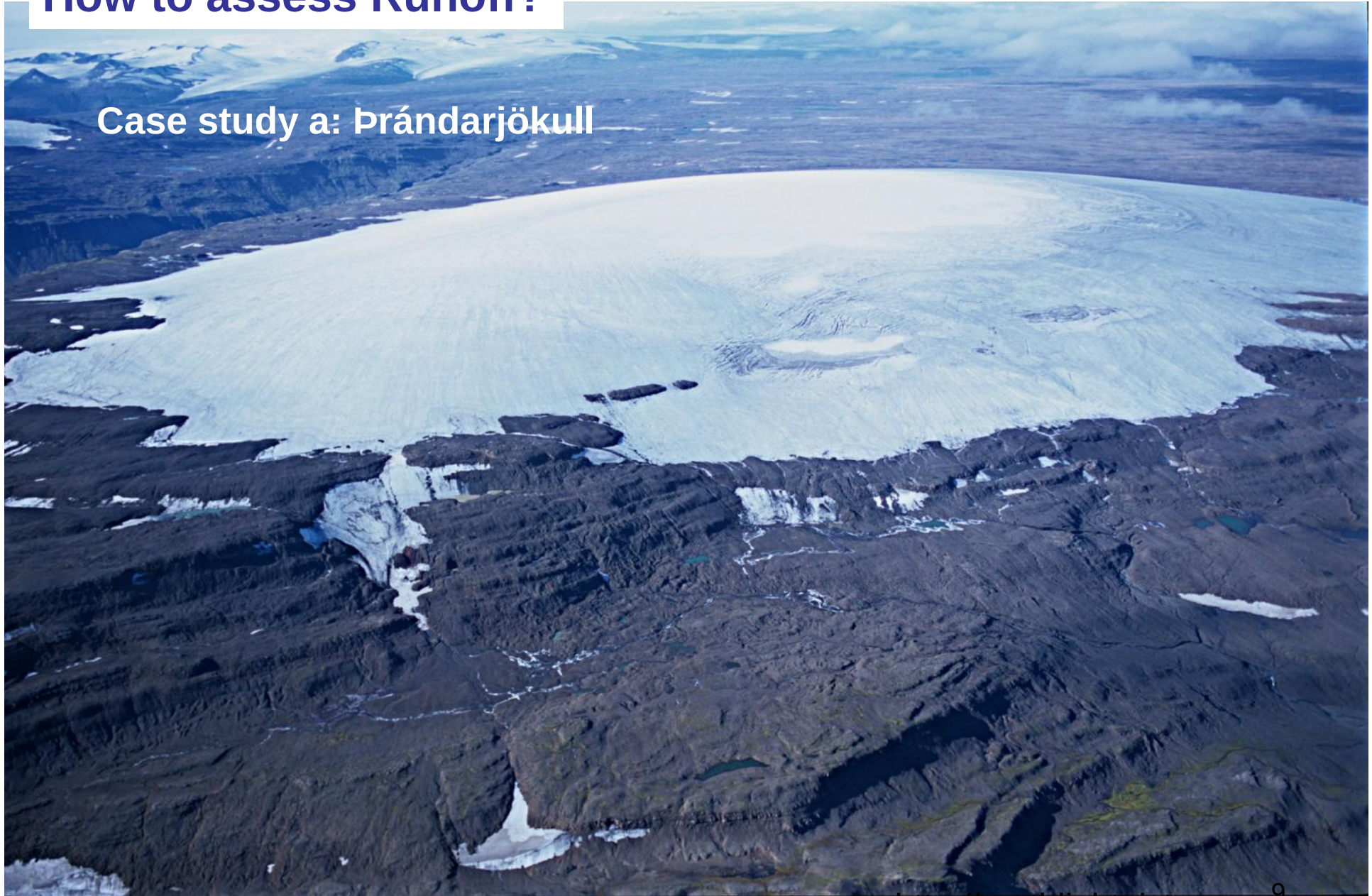
(Data: UN Energy Stat.; NEA, 2014)



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

How to assess Runoff?

Case study a: Þrándarjökull



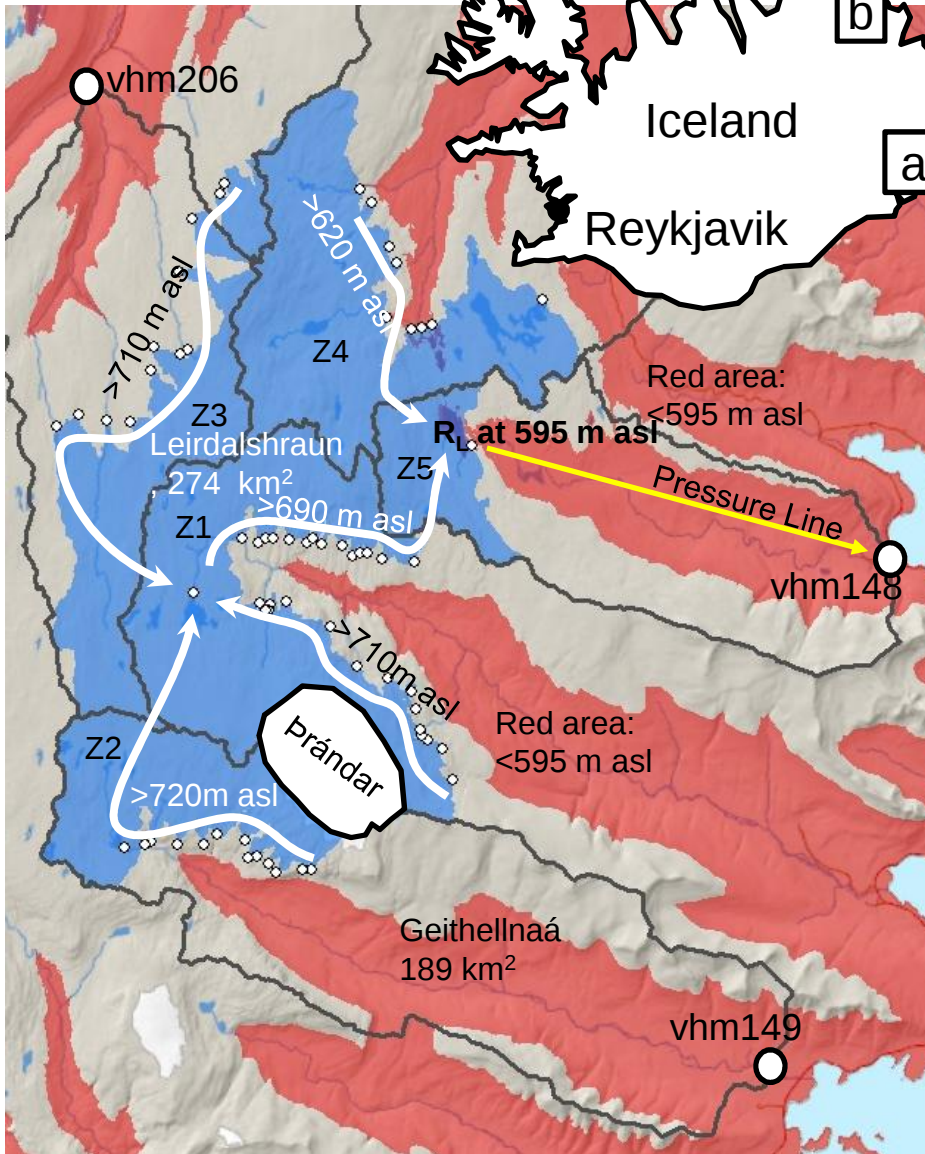
Case study b: River Hafralónsá

- North-east. 700 km from Reykjavik
- Salmon but also arctic char
- catch pr. year: 516 salmon (2007-2011)

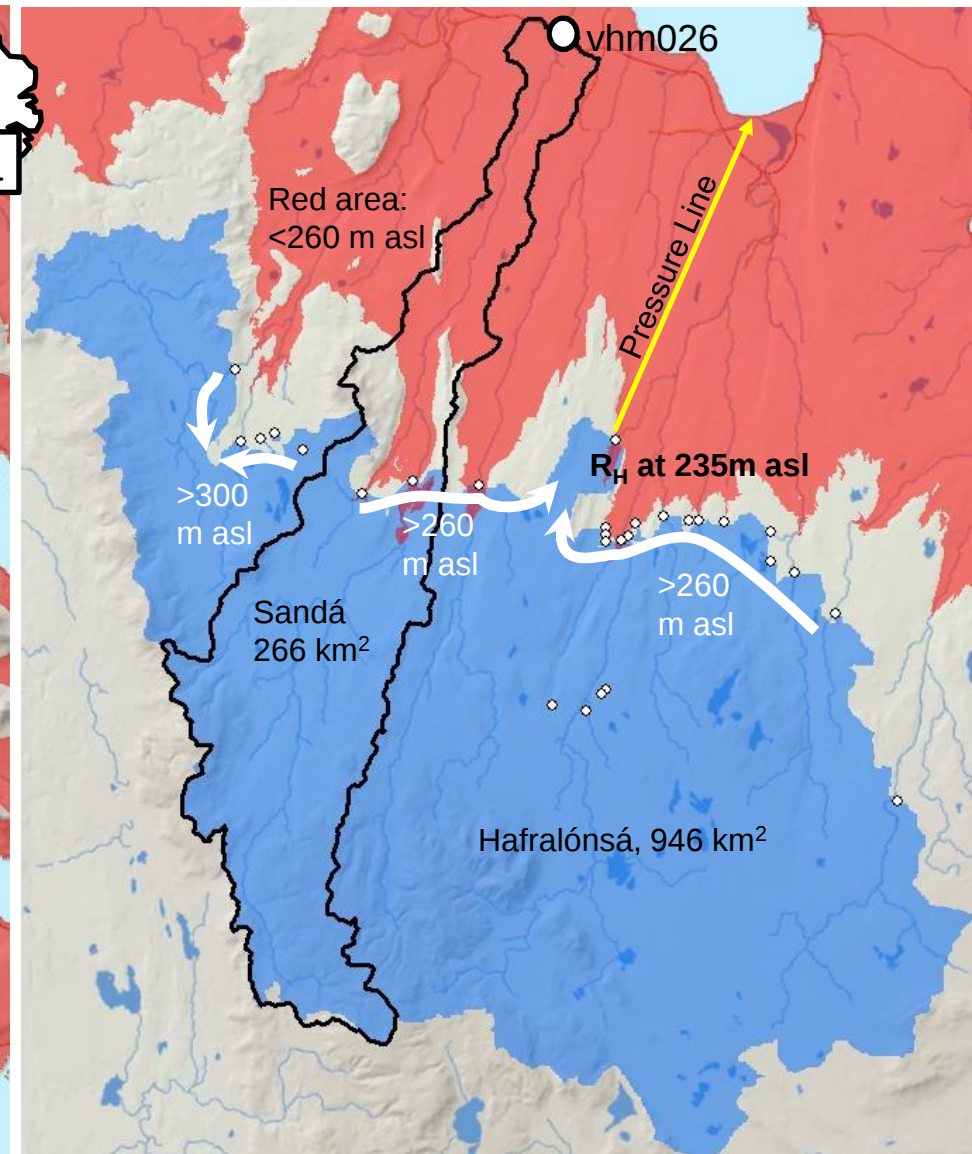


Hydropower potential in Iceland

a) Leirdalshraun, 274 km²



b) Heljardalsfjöll, 946 km²

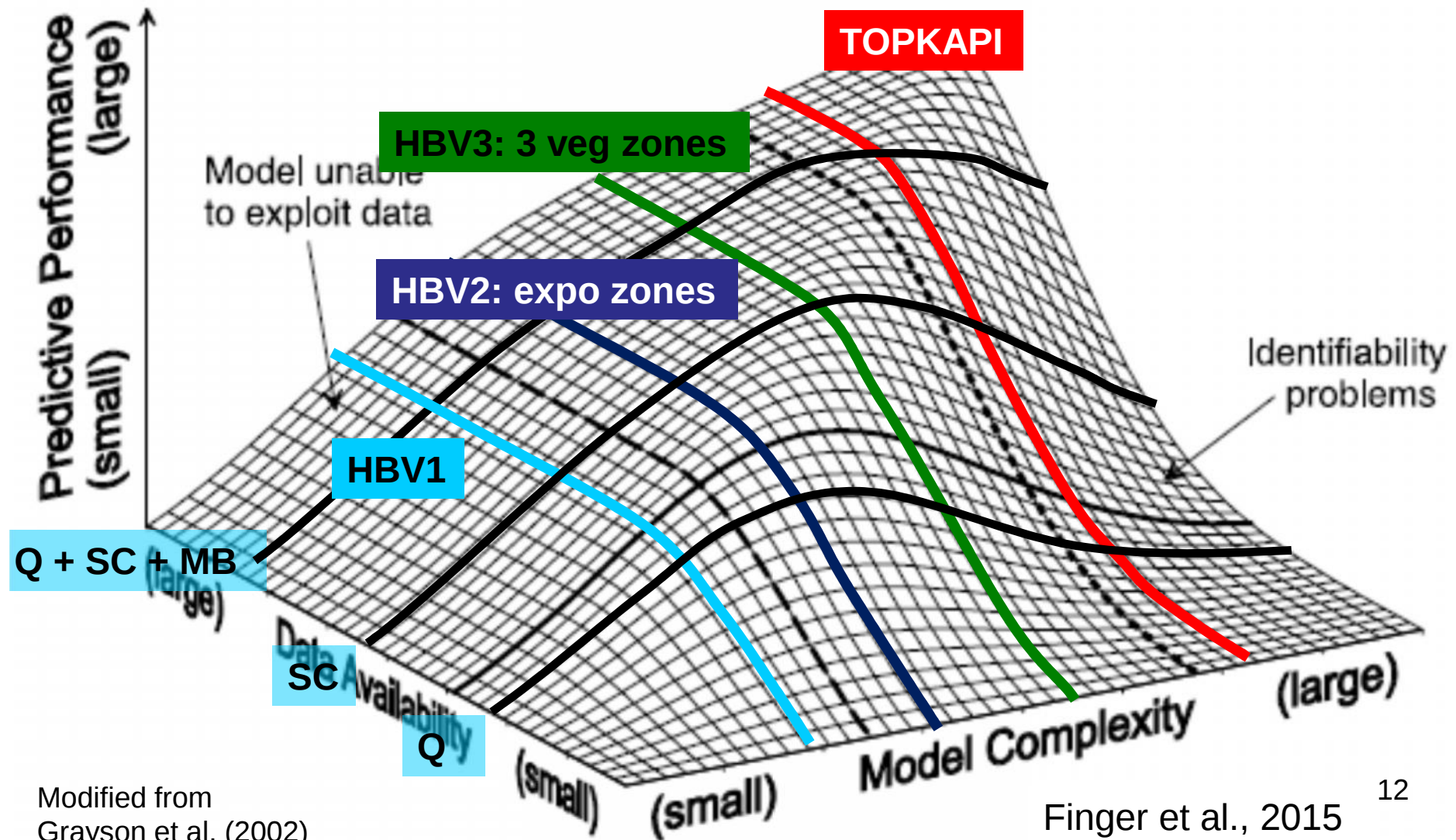


Multi Data Set Calibration method: see Finger et al. 2011, 2015, WRR

Q: discharge

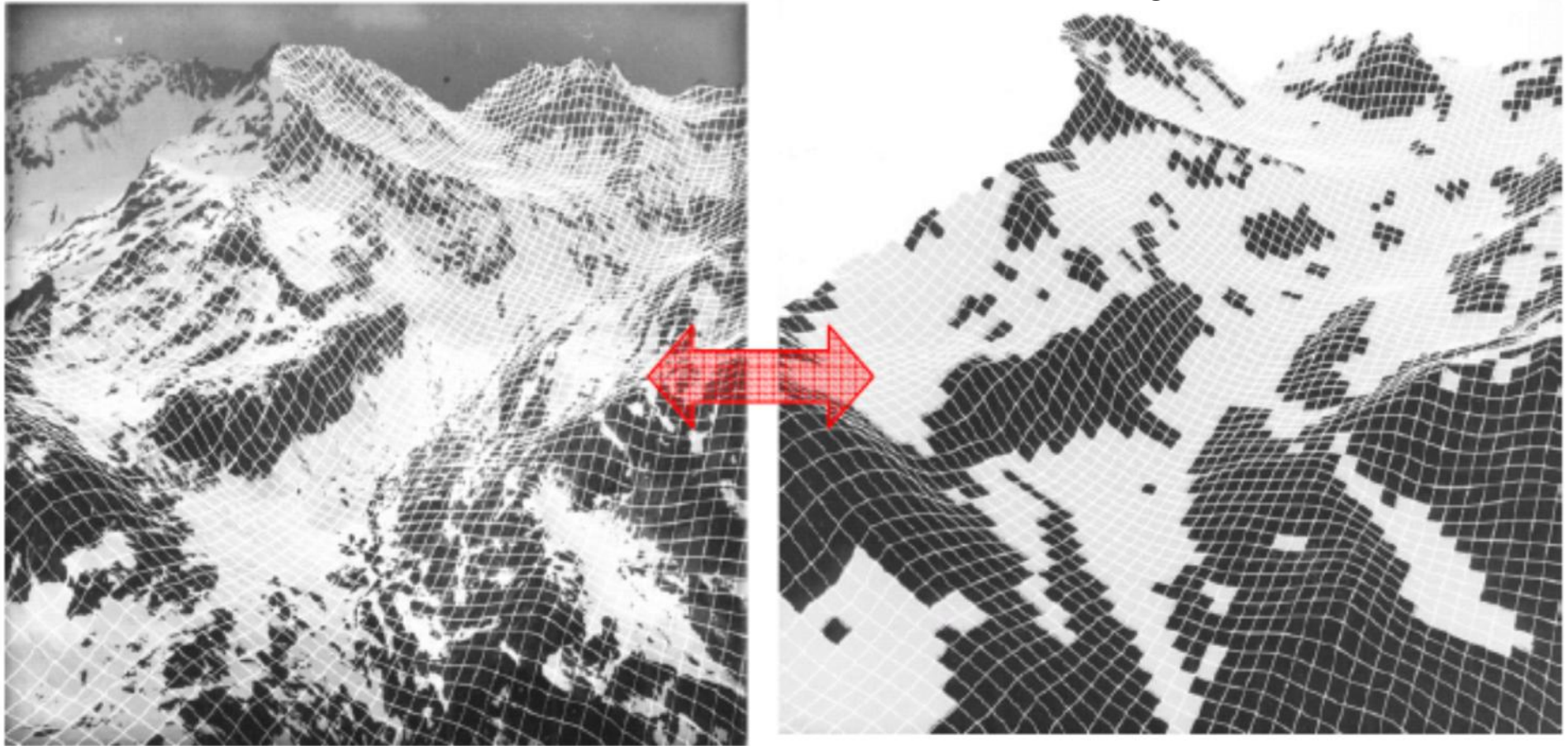
SC: Snow Cover

MB: Glacier mass balance



Calibration with MODIS satellite snow cover images

Finger et al., 2011, 2015



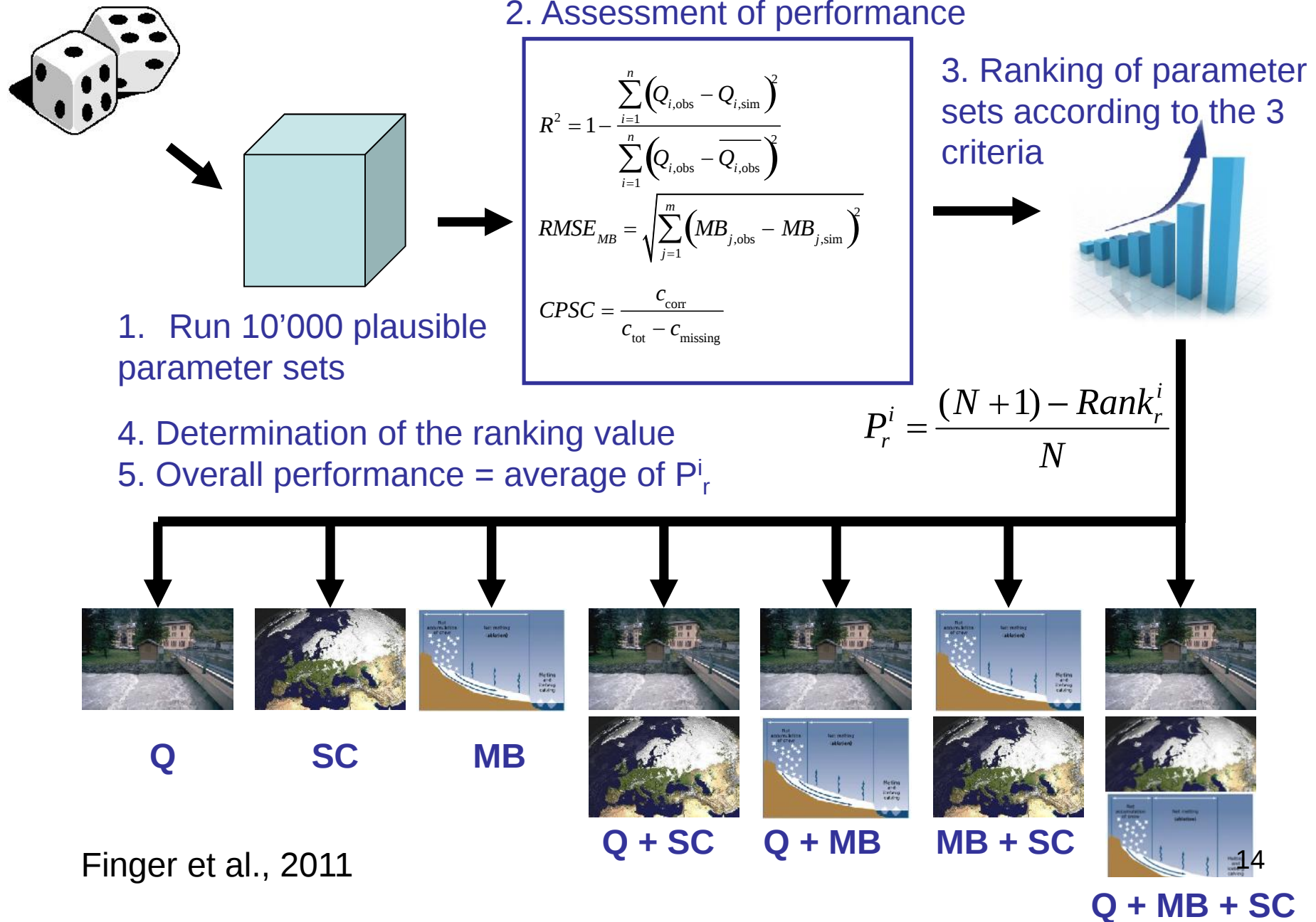
Efficacy for distributed models
(Finger et al. 2011):

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

Efficacy for lumped models (Finger et al. 2015):

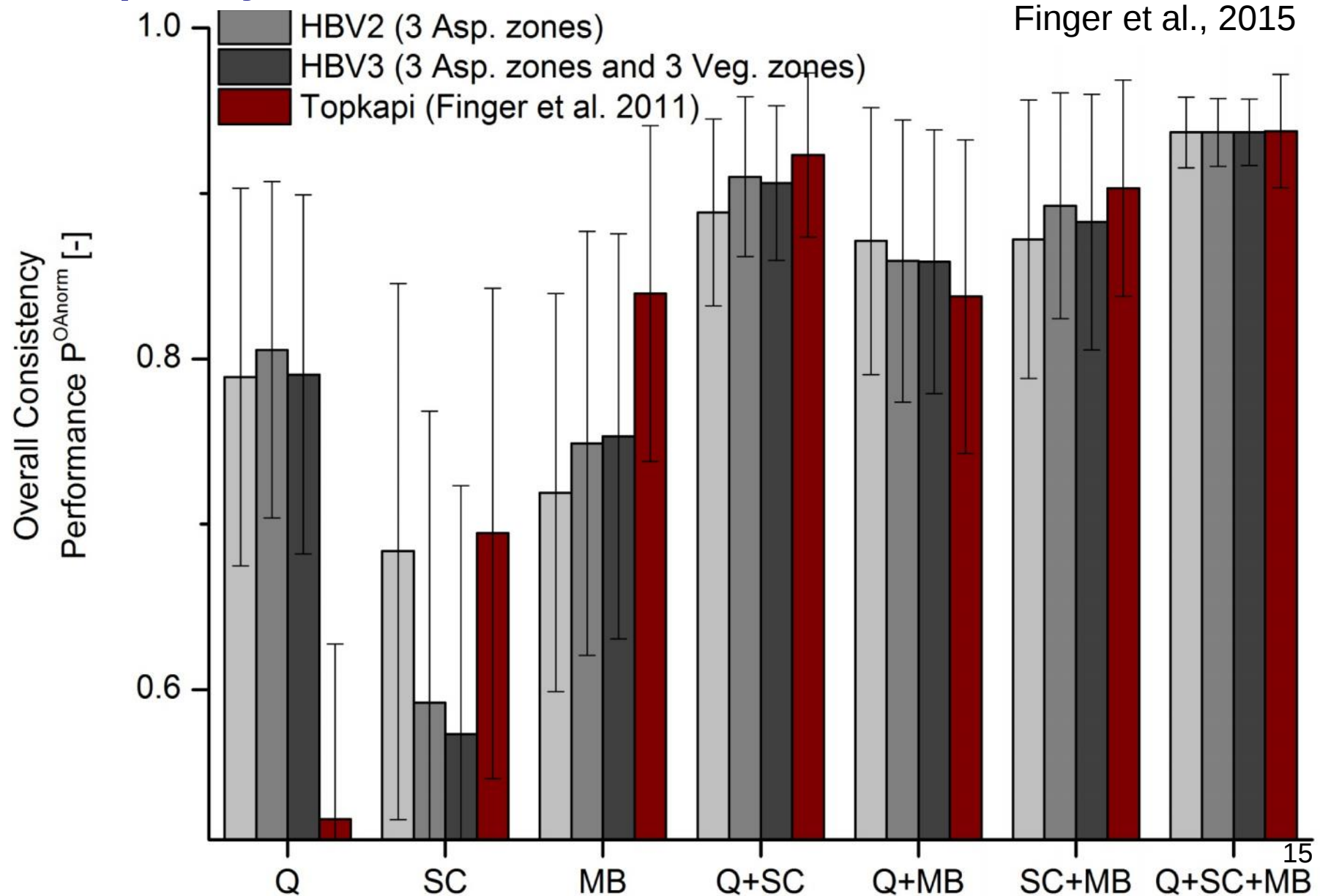
$$E_{SC} = \frac{1}{n} \sum_{i=1}^n \left(1 - |a_{sim,i} - a_{obs,i}| \right) \quad 13$$

Stochastic Calibration: Monte Carlo Simulations

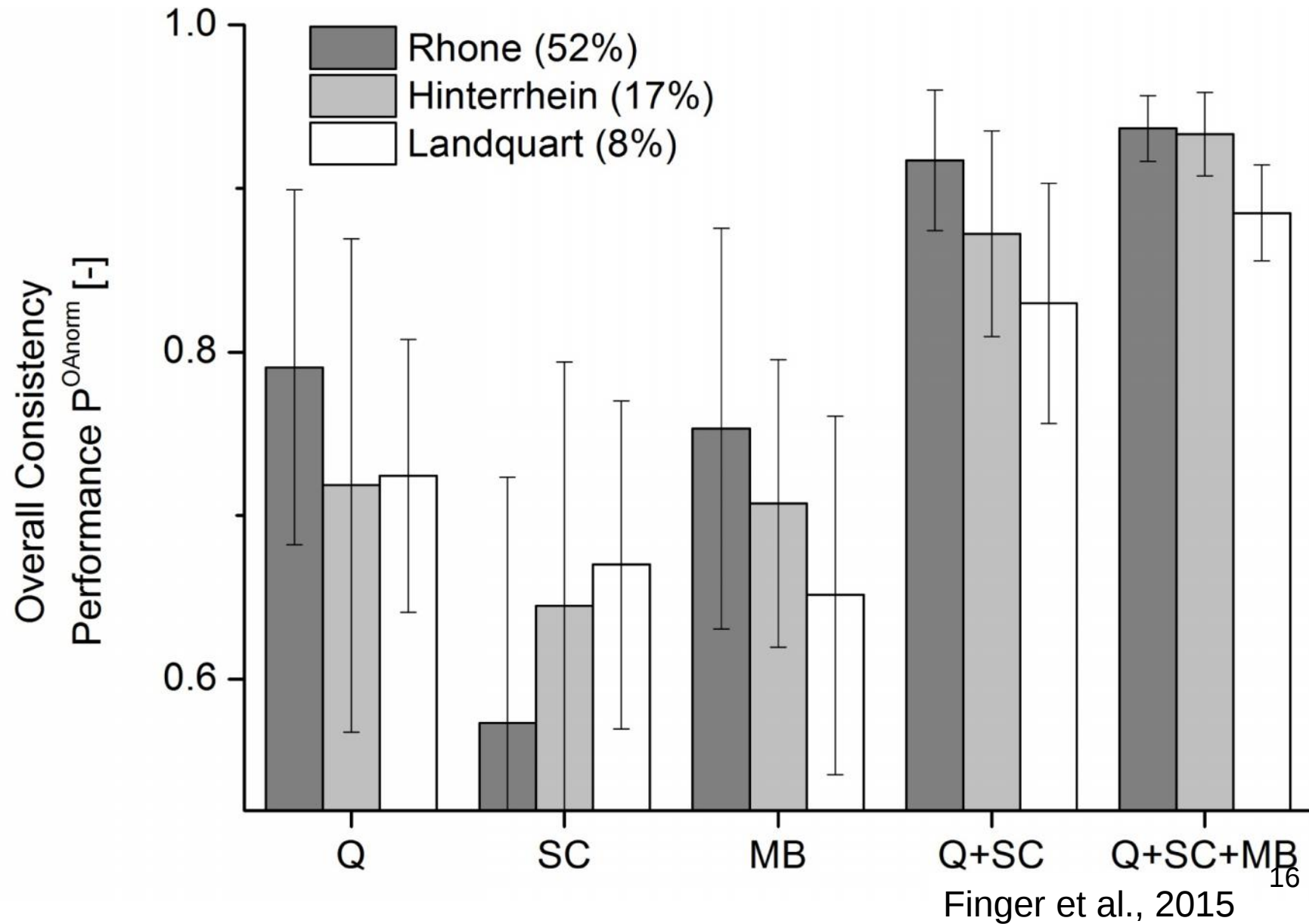


Finger et al., 2011

Overall consistency performance of models with increasing complexity



Overall consistency performance in study sites with decreasing glacierisation



Trade-off between efficiencies

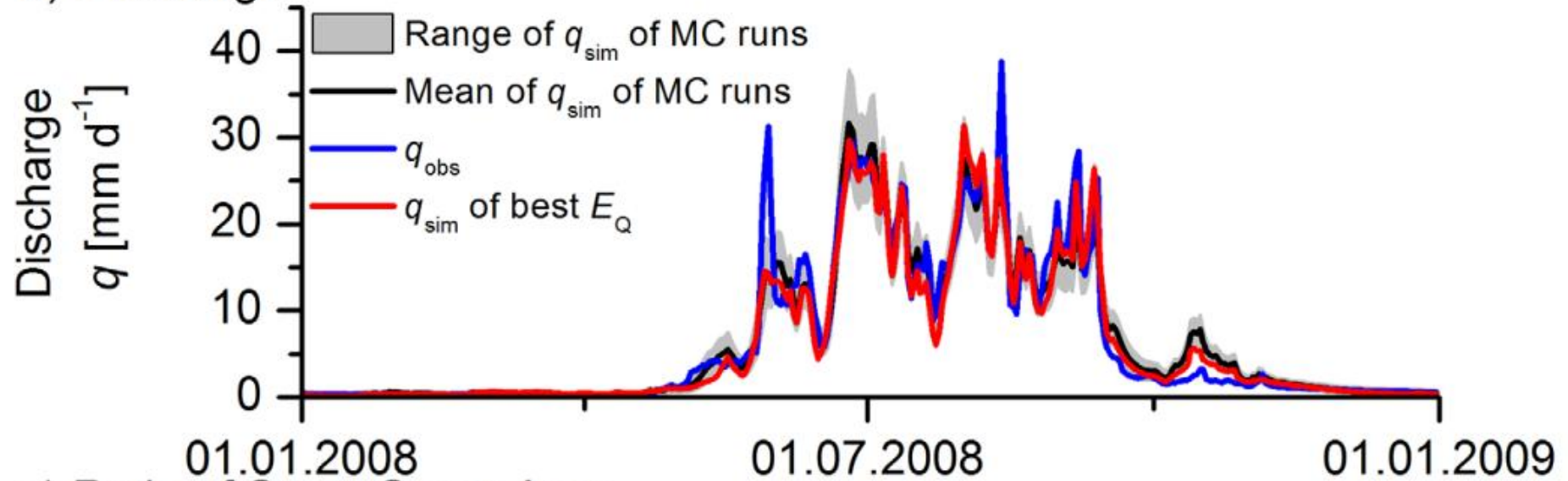
Table 5. Performance of Rhone Regarding Different Selection Criteria of the 100 Best MC-Runs During Calibration

^a Selection Criteria	Performance Criteria							
	Discharge E_Q [-]		Snow Cover $E_{SC,summer}$ [-]		Mass Balances $E_{MB,abl}$ [mm w. eq.]		Consistency Perf. p^{OAnorm} [-]	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Q	0.912	0.006	0.879	0.026	1907.227	1007.419	0.791	0.109
SC	1.961	3.223	0.925	0.001	10002.875	6122.284	0.573	0.150
MB	0.782	0.087	0.873	0.033	486.965	115.472	0.753	0.122
Q+SC	0.889	0.019	0.915	0.005	1842.336	1021.465	0.906	0.047
Q+MB	0.895	0.015	0.890	0.020	893.392	215.205	0.859	0.080
MB+SC	0.807	0.122	0.916	0.005	950.524	287.872	0.883	0.077
Q+SC+MB	0.875	0.028	0.911	0.009	1225.856	498.622	0.937	0.020

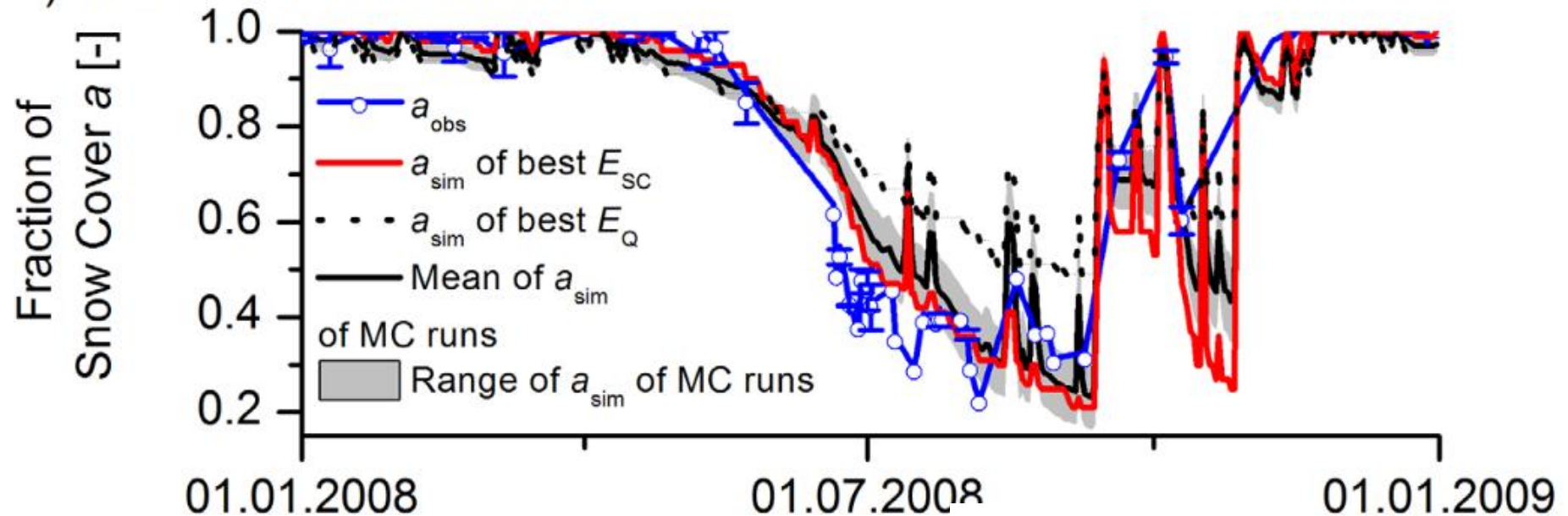
^aShaded cells indicate that the data sets relevant for the criterion were used to select the best runs.

Calibration using only Q and using SC and Q combined

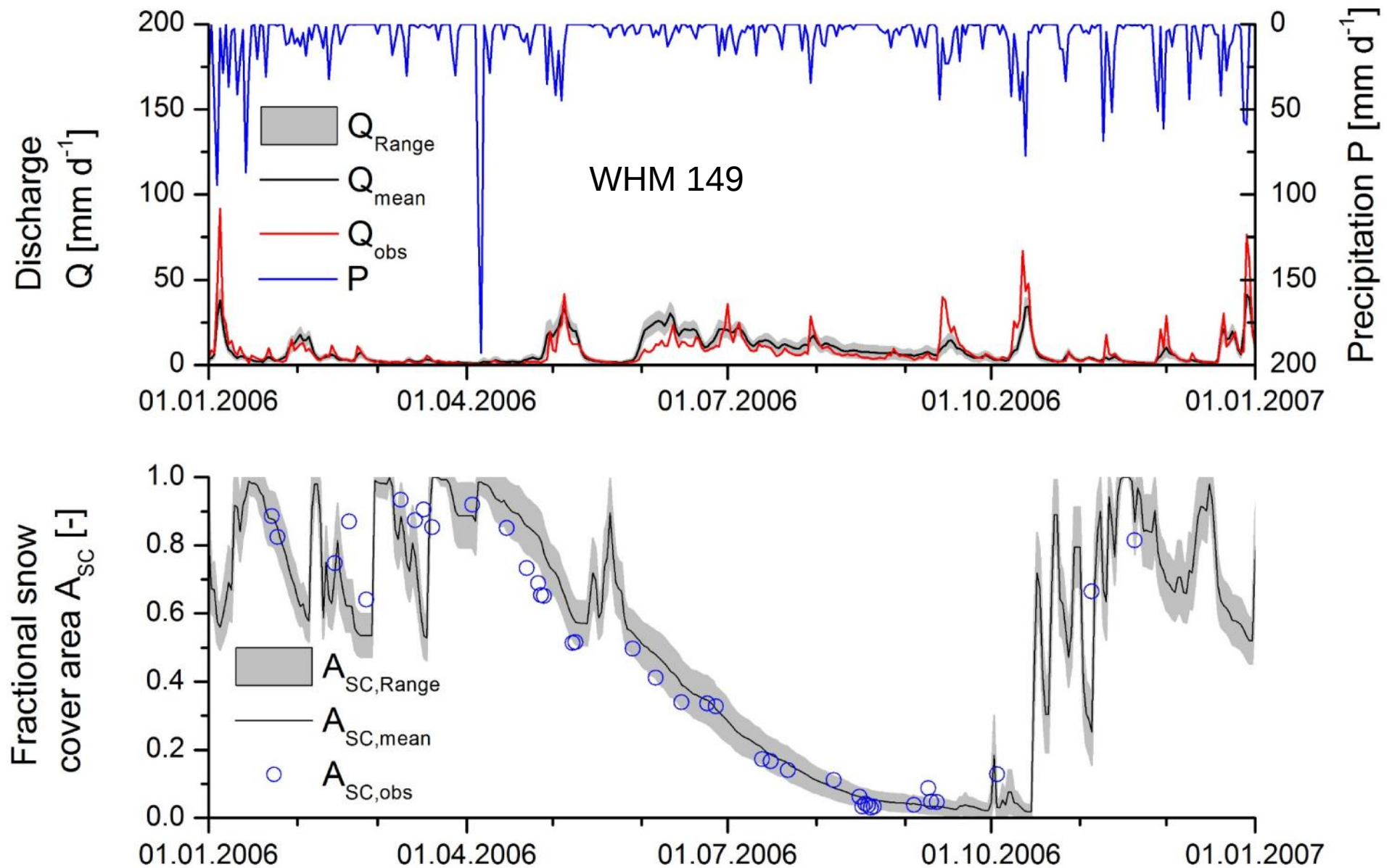
b) Discharge



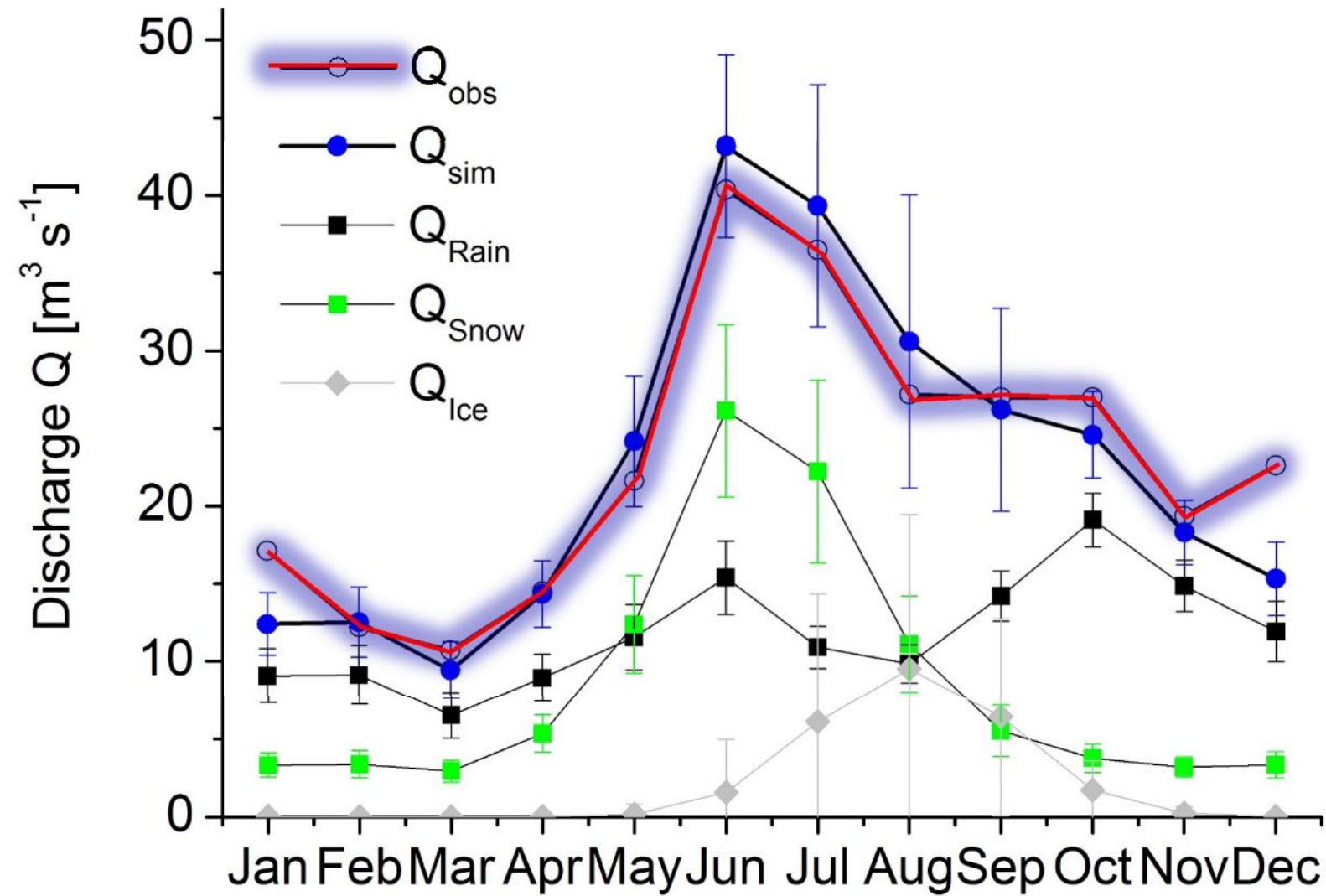
c) Ratio of Snow Cover Area



Calibration runs for gauged sub-catchment in Iceland

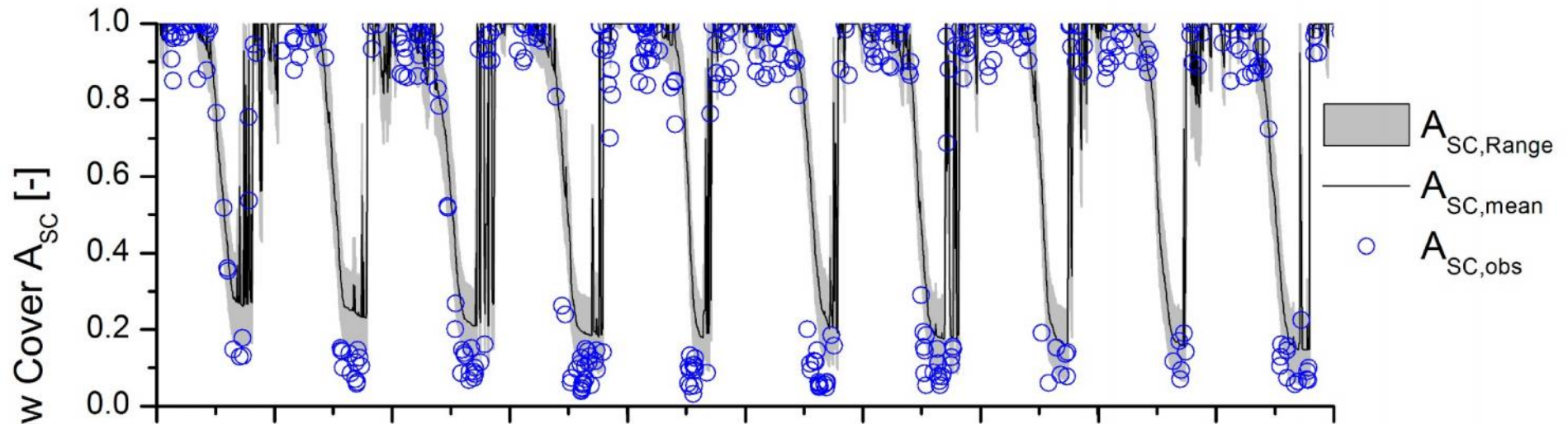


Validation runs for gauged sub-catchment (vhm149) in eastern Iceland

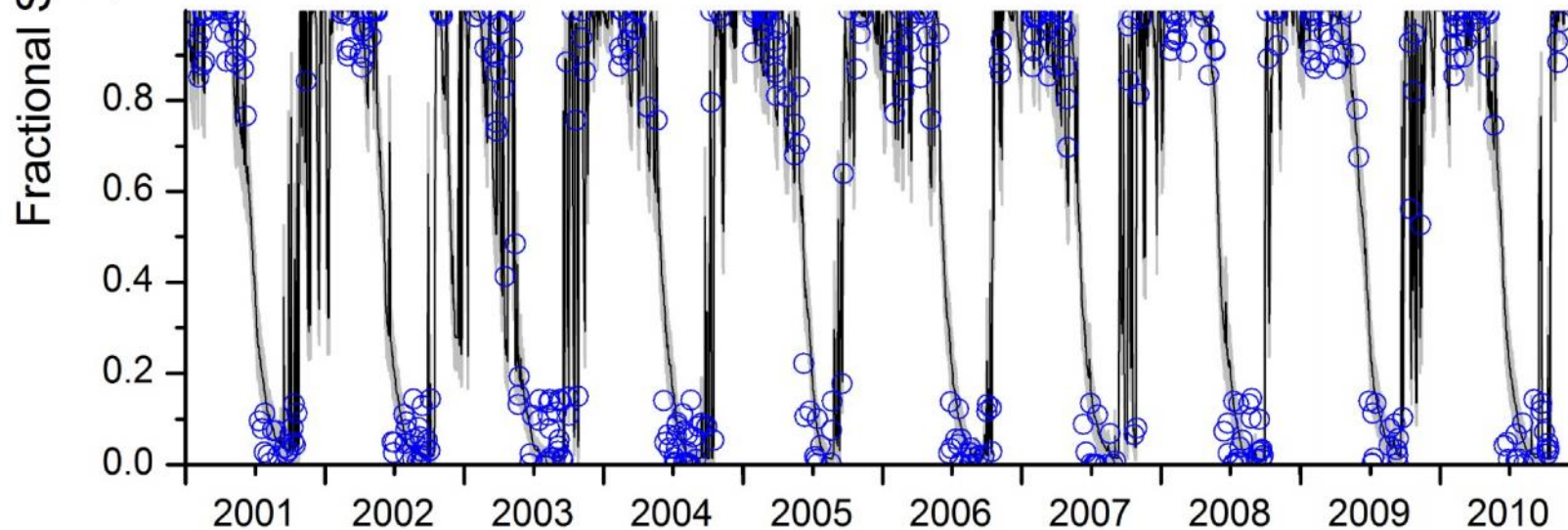


Validation of snow cover for entire ungauged catchments

a) Leirdalshraun Watershed

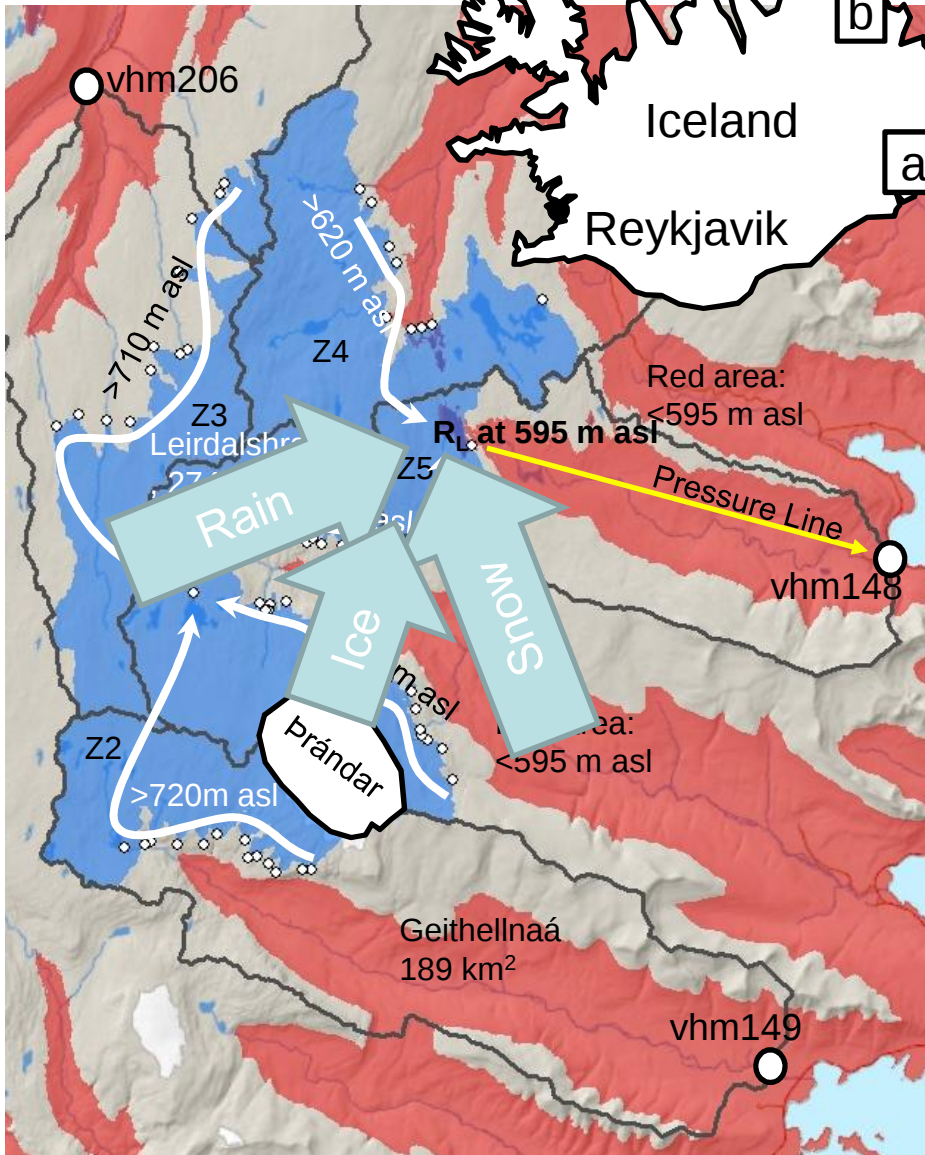


b) Hafrolónsá Watershed

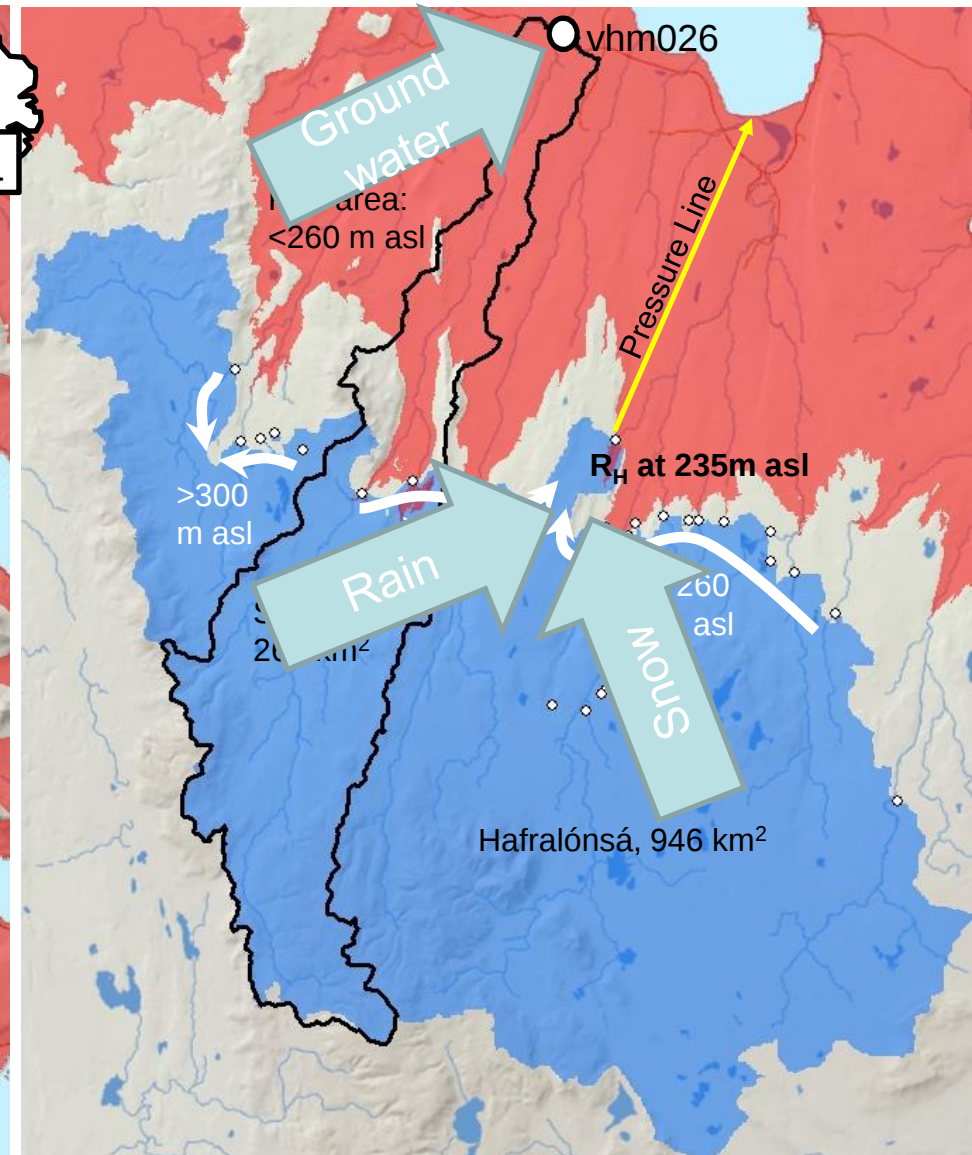


Contribution to runoff can be constrained using SC

a) Leirdalshraun, 274 km²

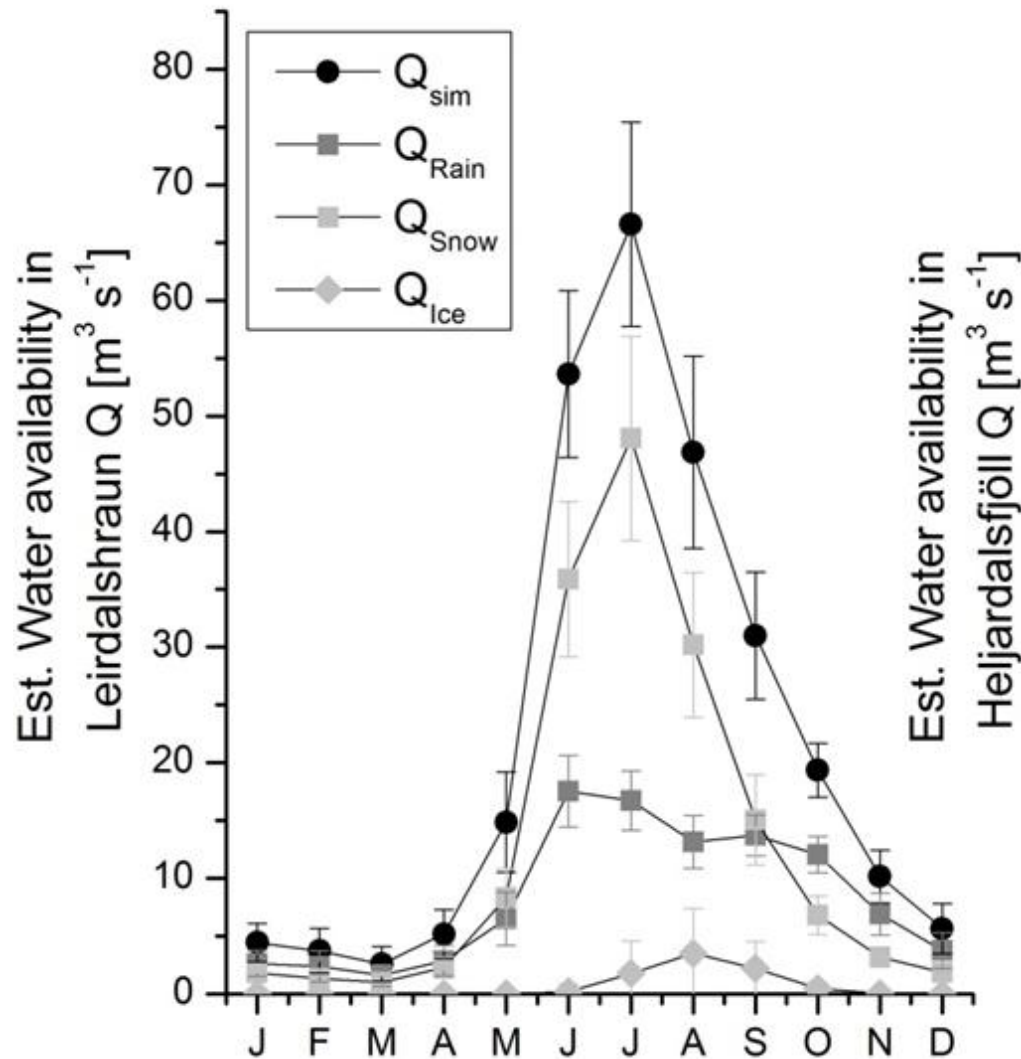


b) Heljardalsfjöll, 946 km²

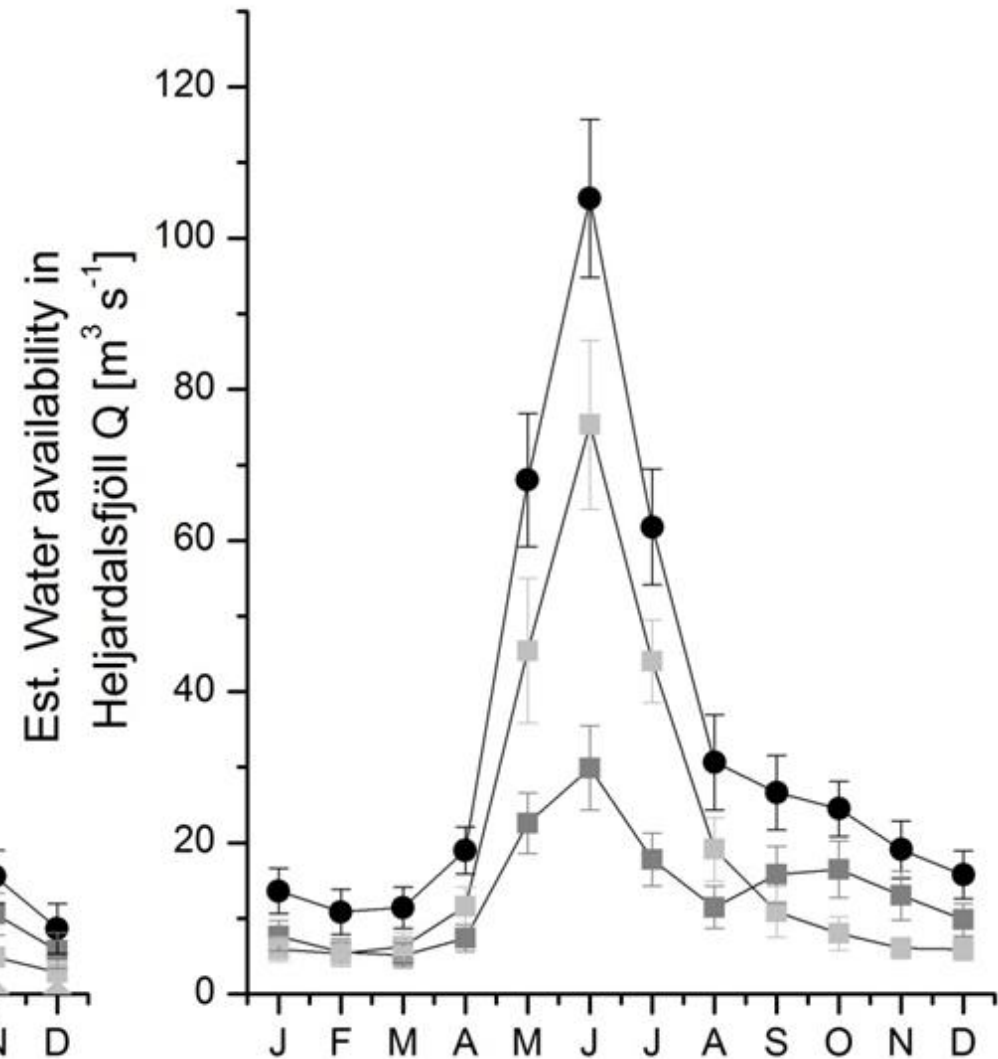


Estimated water runoff in the ungauged areas

a) Leirdalshraun



b) Heljardalsfjöll



Leirdalshraun: 274 km²; 595 m asl; 5.7 % glacierized

Heljardalsfjöll: 946 km²; 235 m asl;

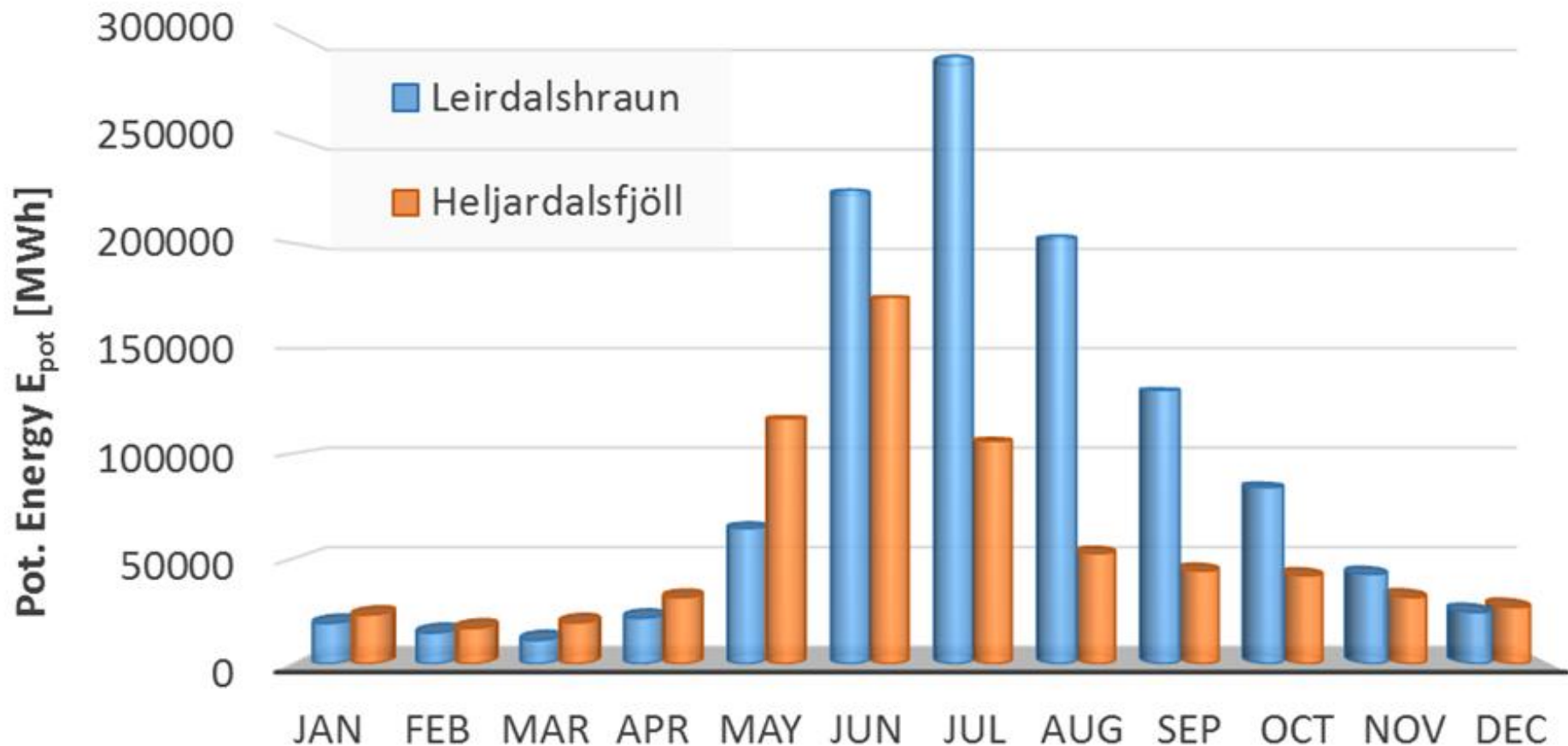
→ 792 GWh a⁻¹

→ 480 GWh a⁻¹

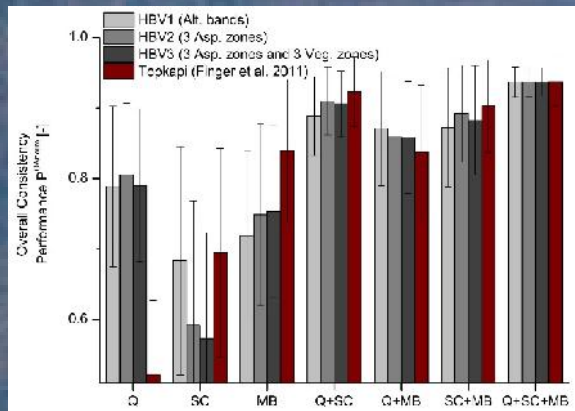
Estimated hydropower potential in the ungauged areas

Leirdalshraun: 274 km²; 595 m asl; 5.7 % glacierized

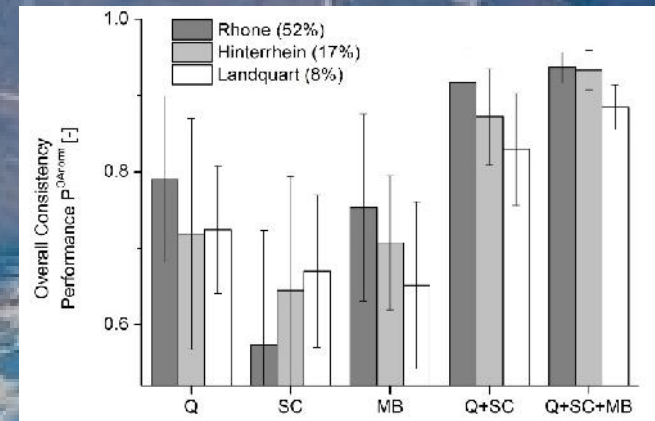
Heljardalsfjöll: 946 km²; 235 m asl;



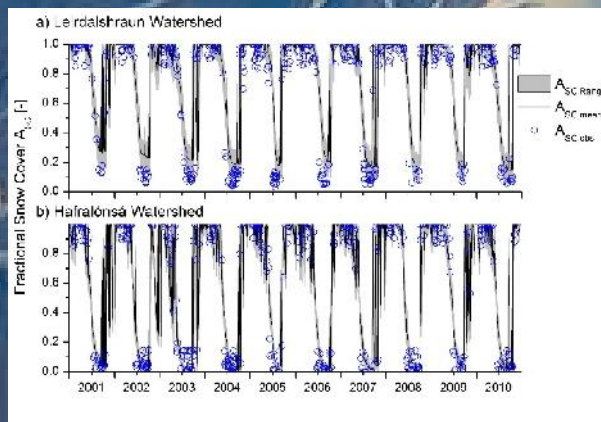
Take home messages: MODIS snow cover data...



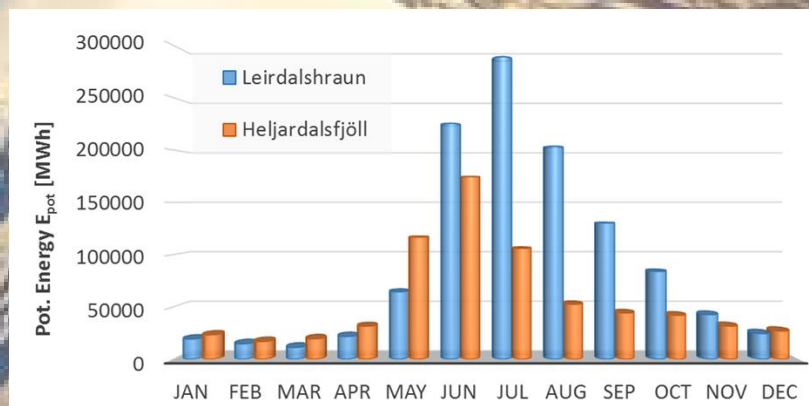
... improve hydrological simulations regardless of model complexity.



... has a bigger effect in areas with low glacierisation.



... allow validation of ungauged areas.



... allow an estimation of the hydropower potential.

Þakkir fyrir athygli þína

Sjáumst á Íslandi
Summer school
registration open now!!!

<https://fingerd.jimdo.com/teaching/>

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