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

COST ES1404, Snow hydrology workshop, Reykjavik, Iceland

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HÁSKÓLINN Í REYKJAVÍK
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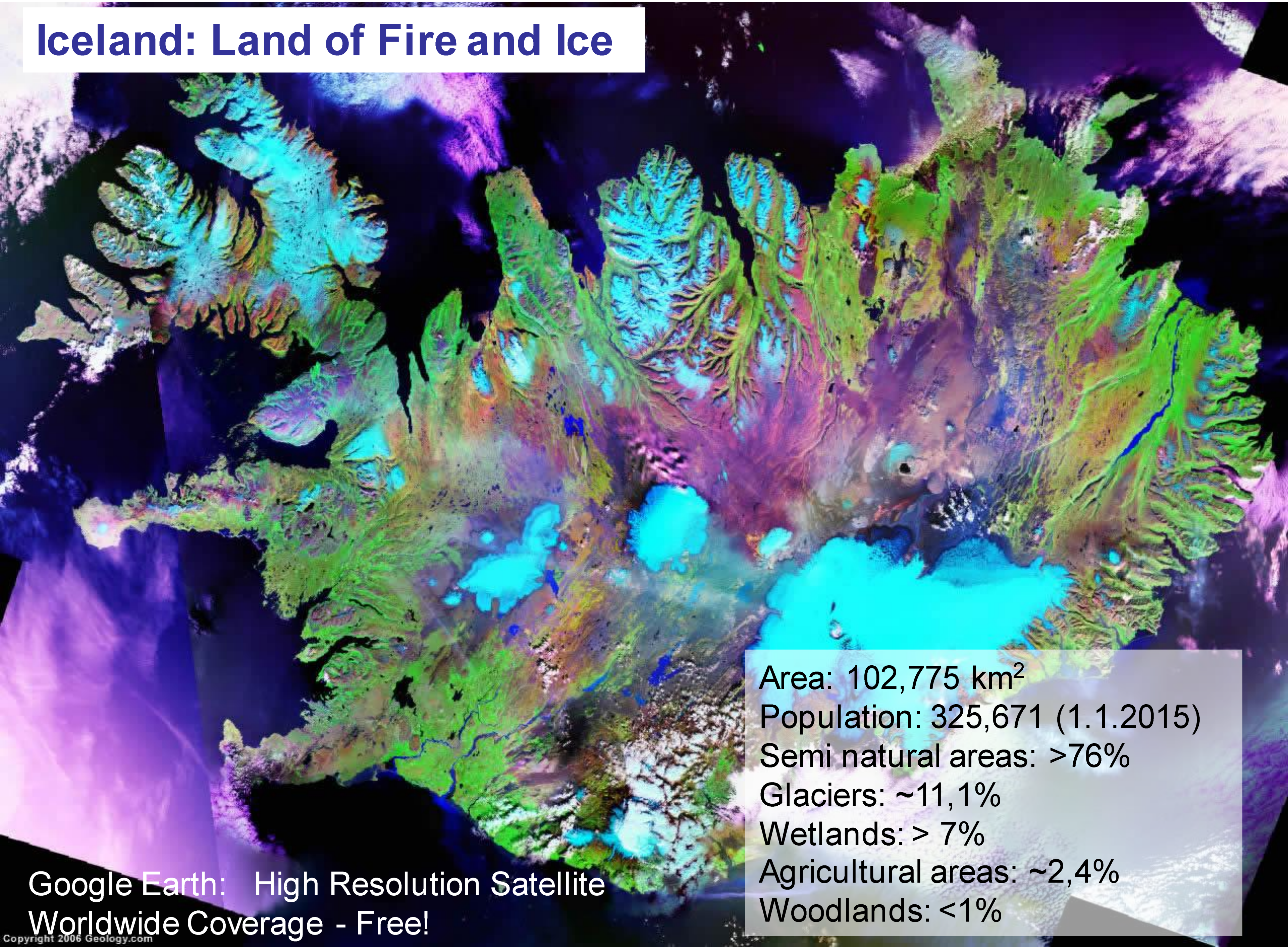
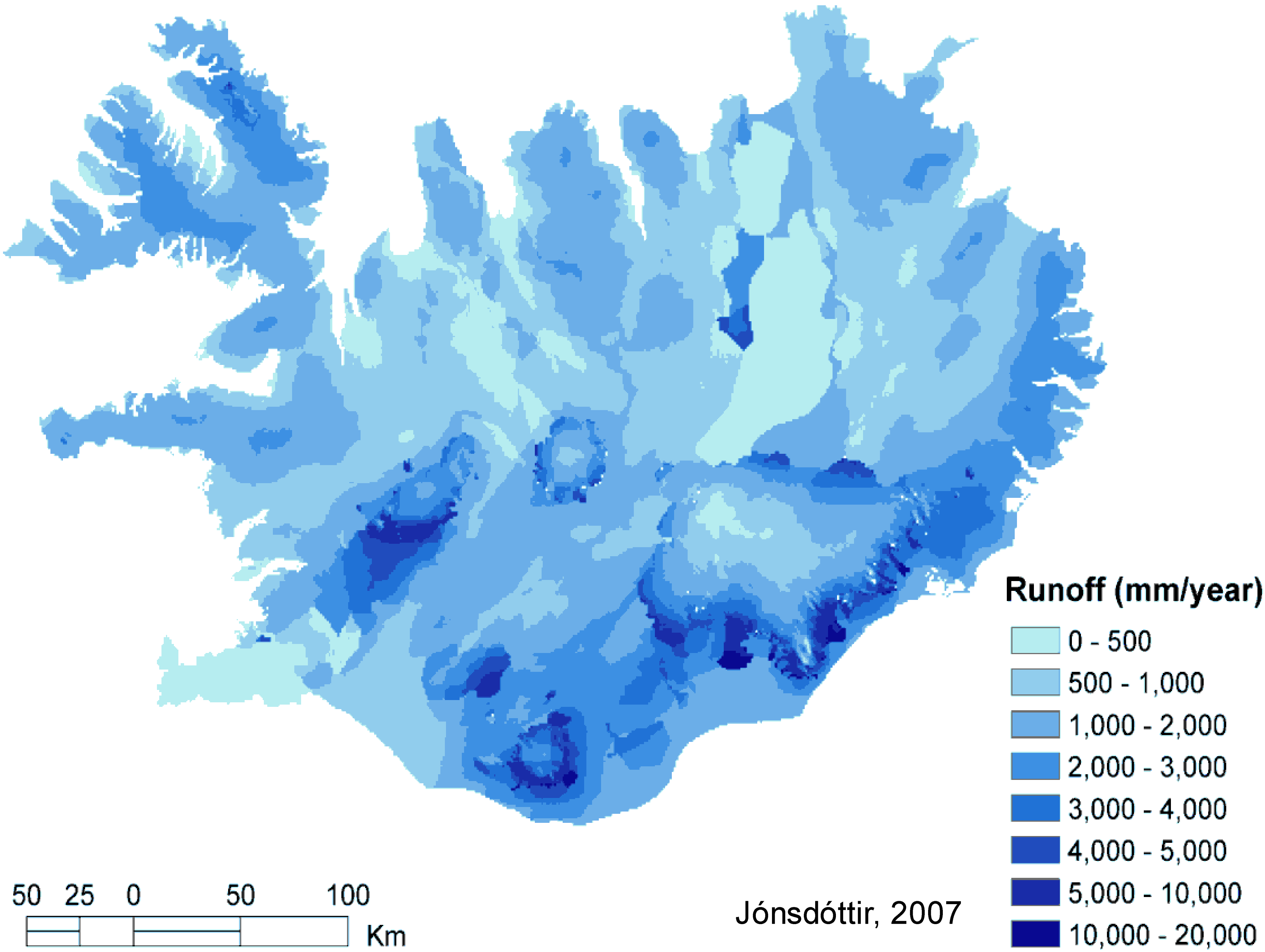
Iceland: Land of Fire and Ice



Google Earth: High Resolution Satellite Worldwide Coverage - Free!

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

Water resources in Iceland



Glaciers in Iceland: e.g. Þrándarjökull

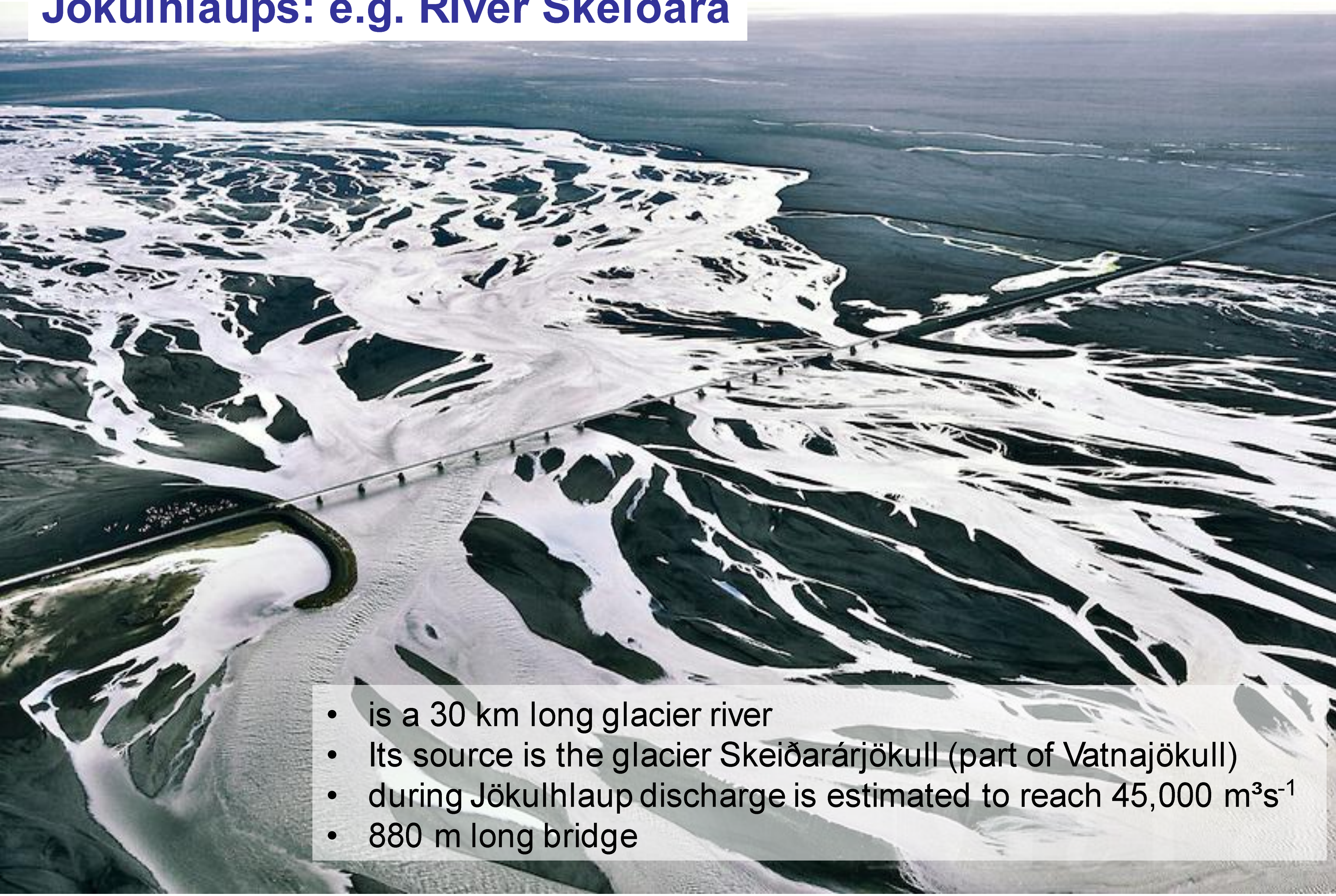
- 11.1% of Iceland are glaciers and ice caps
- Vatnajökull (8’100 km^2 ; 400 m thick)
- Glaciers lie above volcanoes (e.g. Grímsvötn and Bárðarbunga)
- Jökulhlaup are frequent
- Þrándarjökull (1’236 m asl; 20km NE of Vatnajökull

http://northlightpictures.com

Emerging water sources: e.g. Hraunfossar, IS

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

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 m^3s^{-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

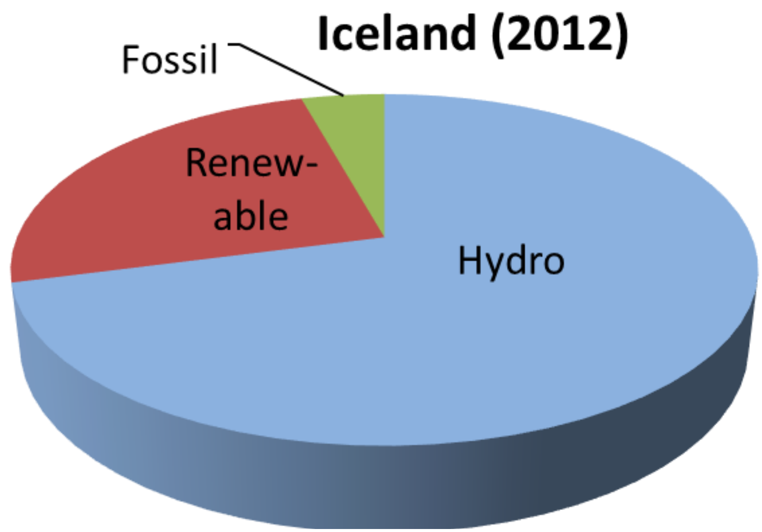
Austria: ~37 TWh

Switzerland: ~35 TWh

Iceland: ~12 TWh

Pot: 220 TWh/yr

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



Iceland: Kárahnjúkavirkjun (690 MW; 4600 GWh) → Base power

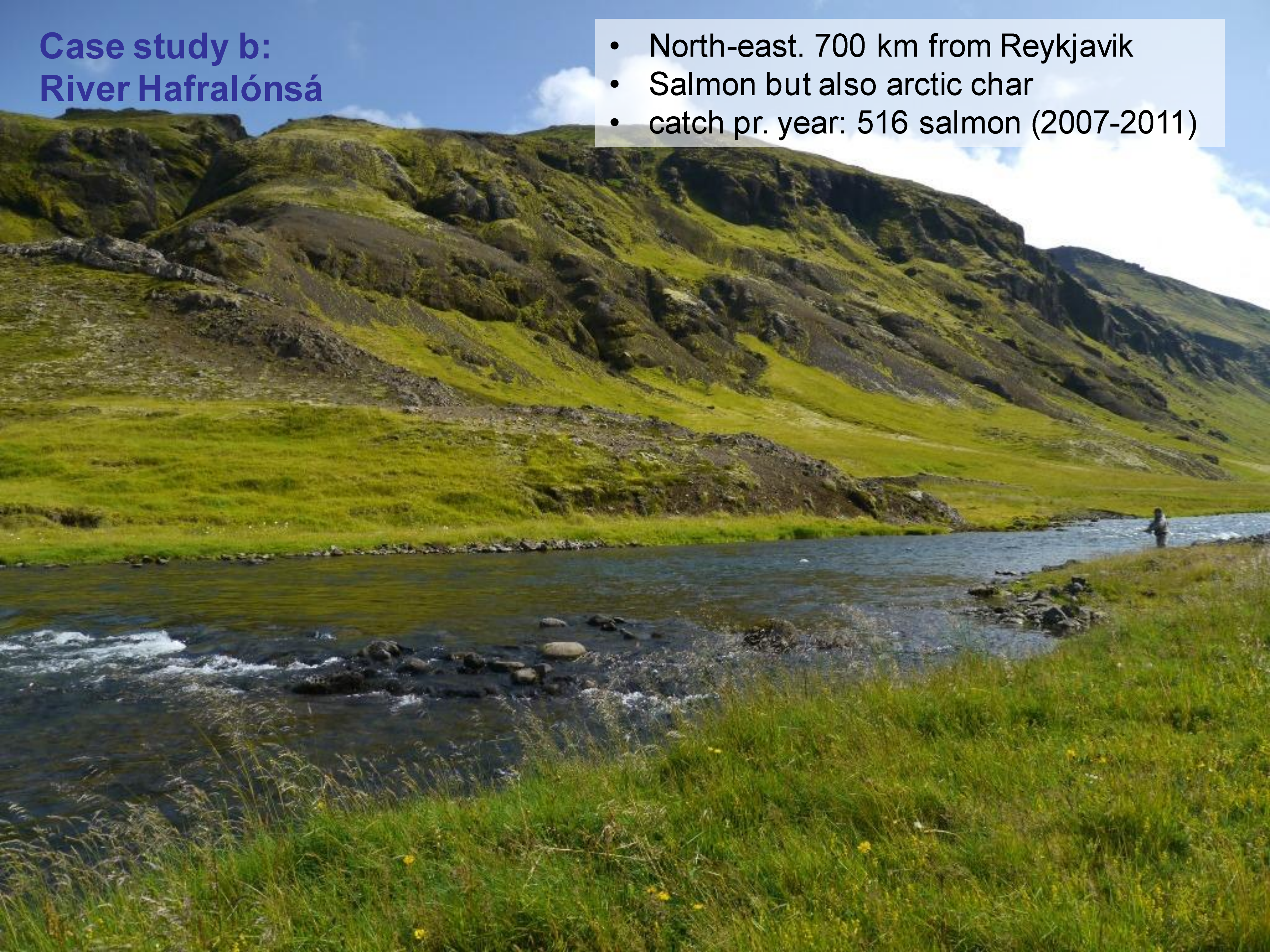
Switzerland: Grande Dixence (2068 MW; 2000 GWh) → Peak power

How to assess Runoff?

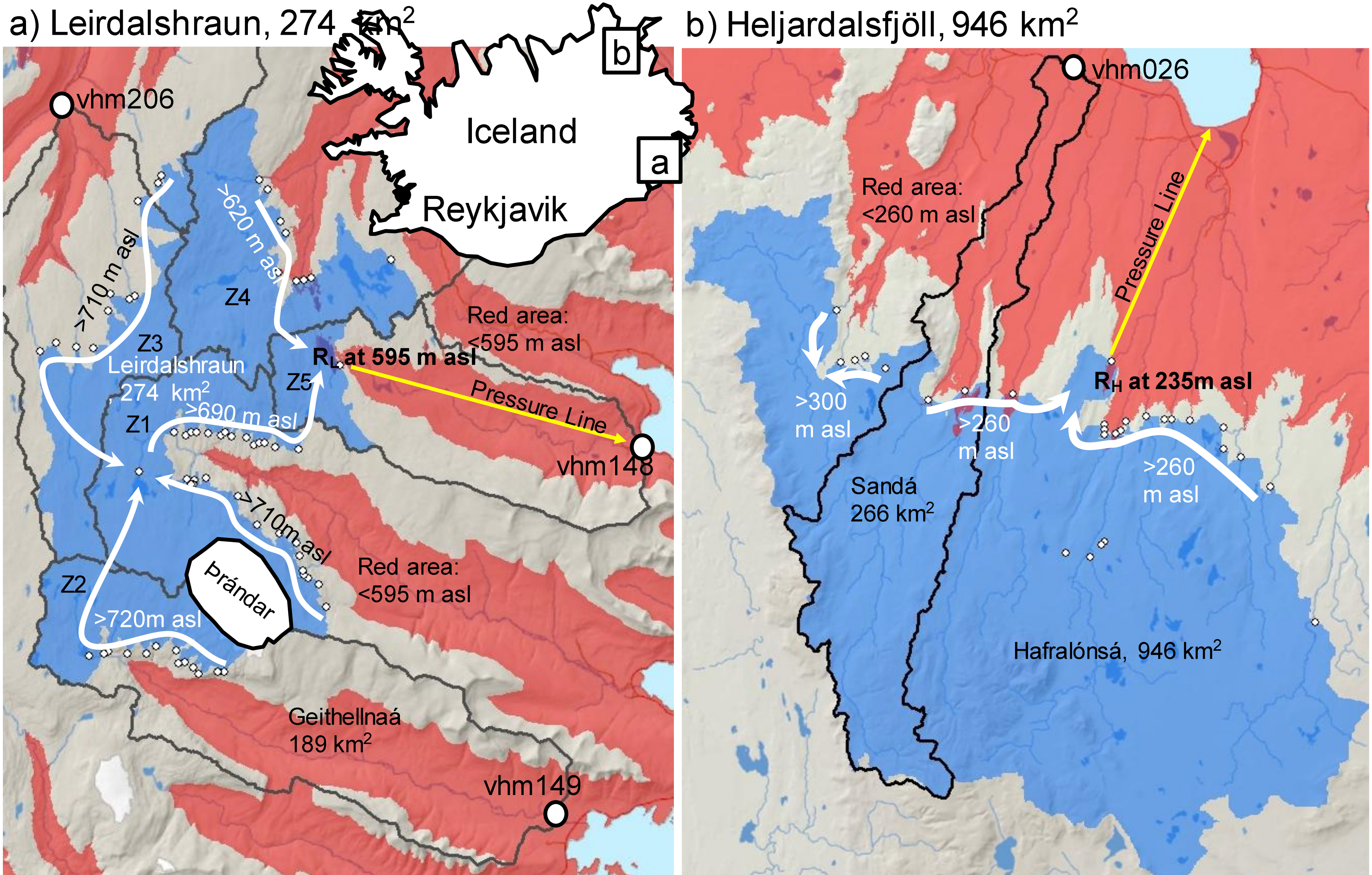
http://northlightpictures.com

Case study b: River Hafralónsá

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

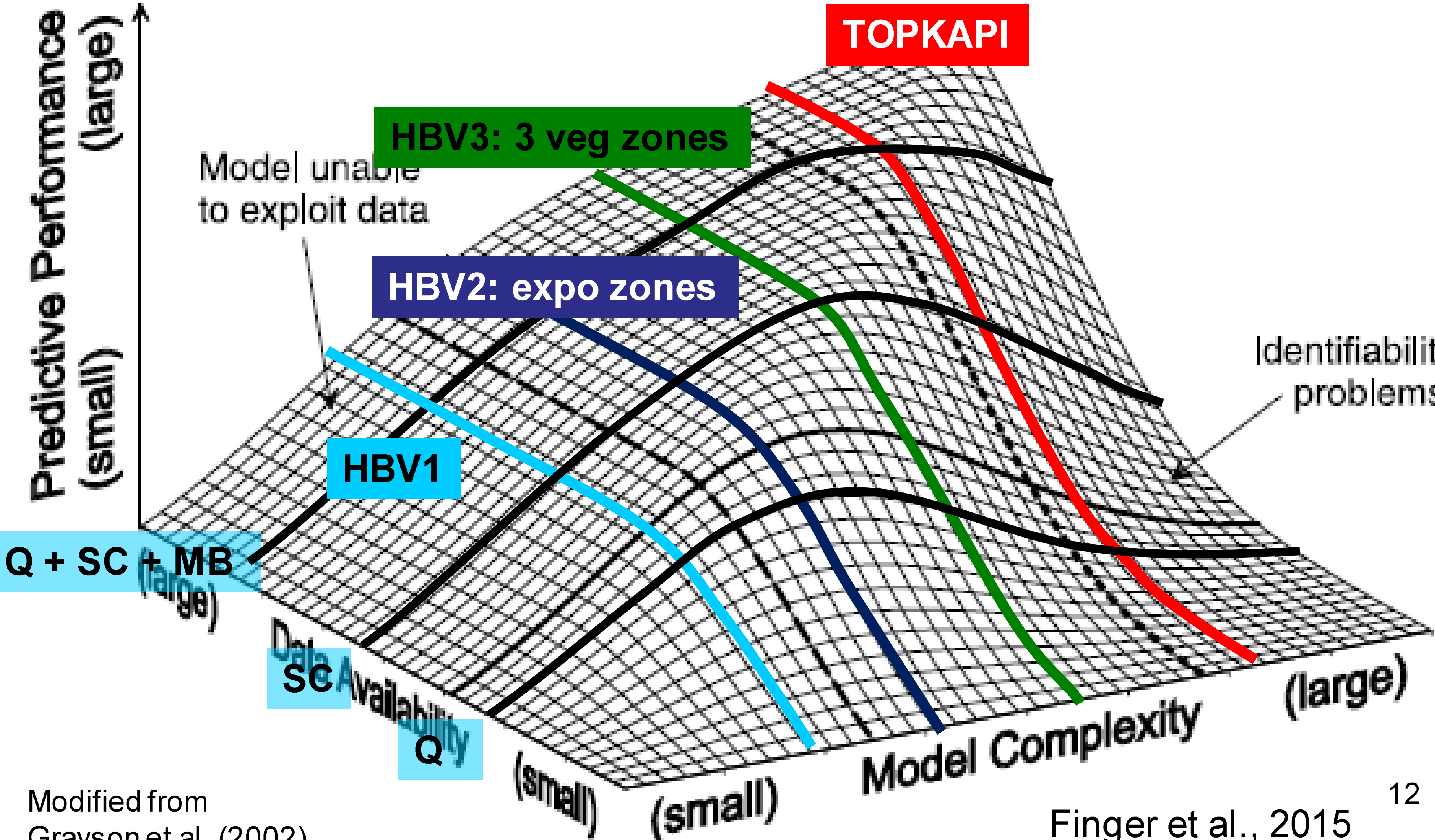


Hydropower potential in Iceland



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

Q: discharge
SC: Snow Cover
MB: Glacier mass balance

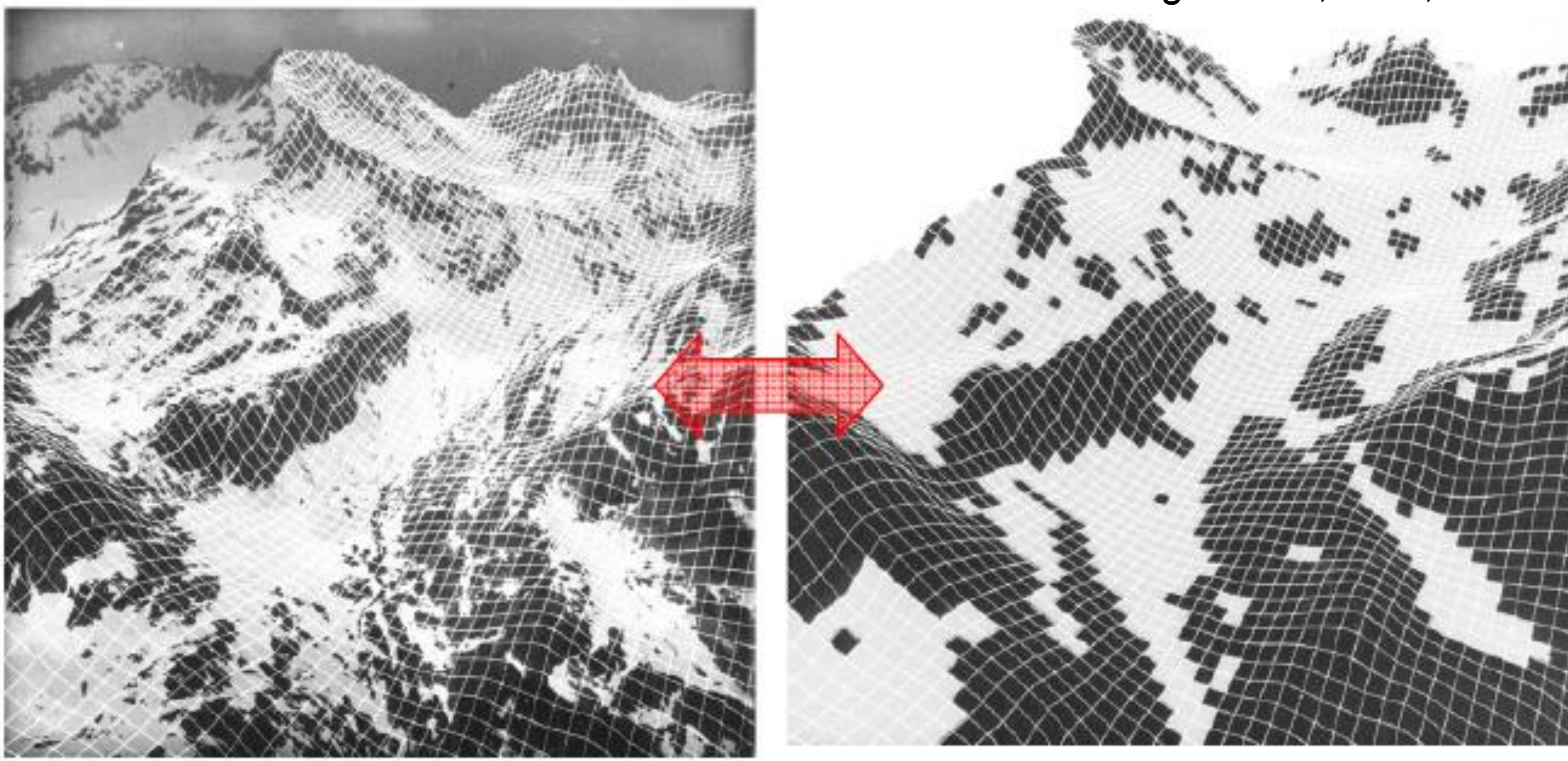


Modified from
Grayson et al. (2002)

Finger et al., 2015

Calibration with MODIS satellite snow cover images

Finger et al., 2011, 2015



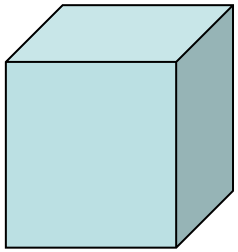
Efficinecy for distributed models (Finger et al. 2011):

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

Efficinecy for lumbed models (Finger et al. 2015):

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

Stochastic Calibration: Monte Carlo Simulations



1. Run 10’000 plausible parameter sets

2. Assessment of performance

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

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

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

3. Ranking of parameter sets according to the 3 criteria

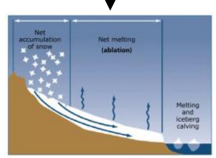
4. Determination of the ranking value

$$P_r^i = \frac{(N+1) - Rank_r^i}{N}$$

5. Overall performance = average of P_r^i

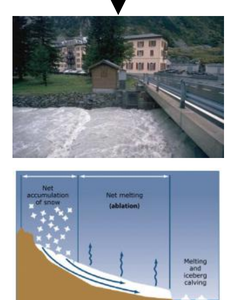
Q

SC

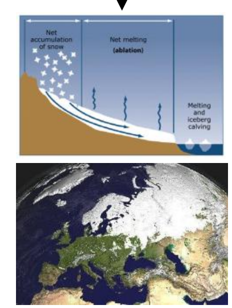


MB

Q + SC



Q + MB

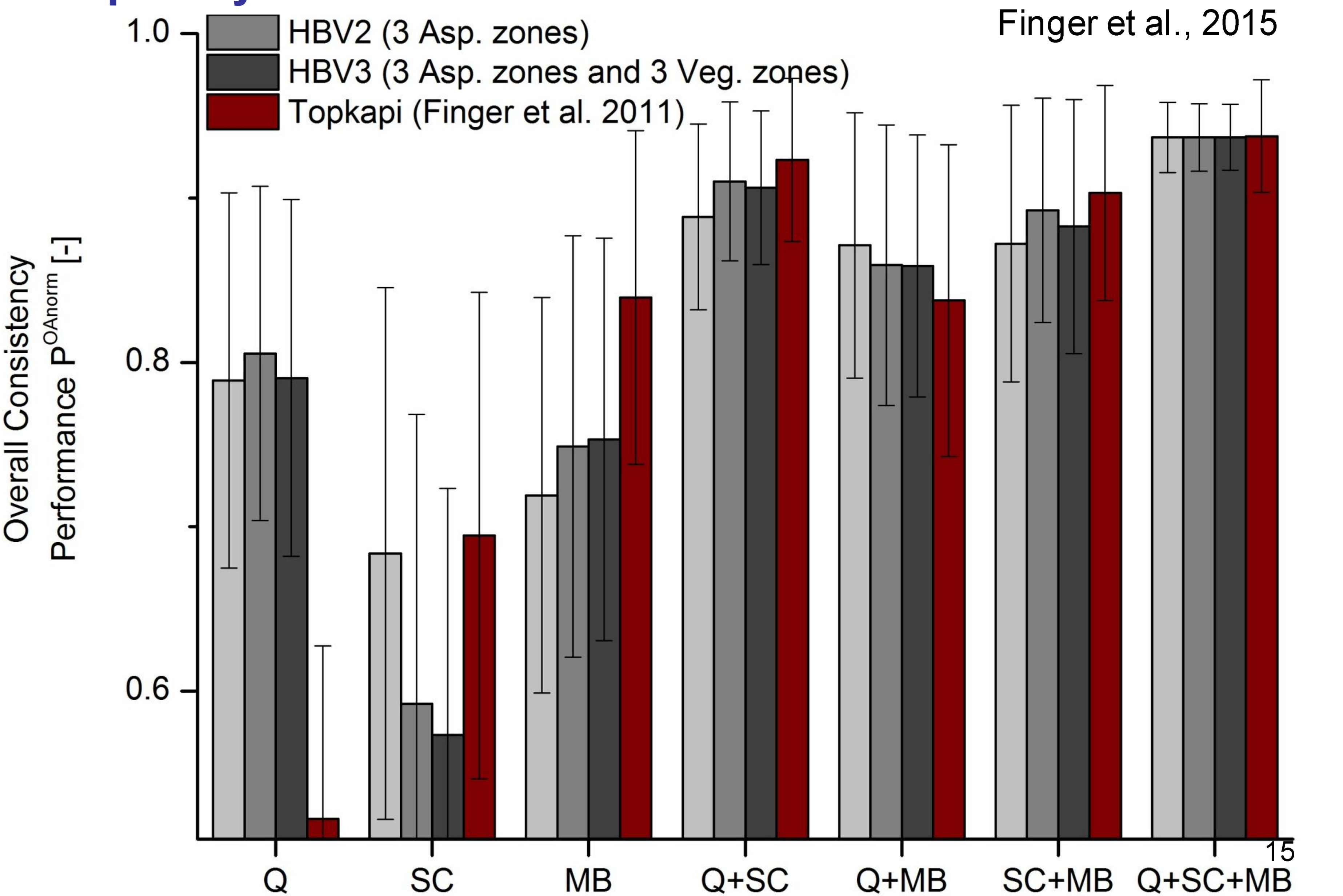


MB + SC

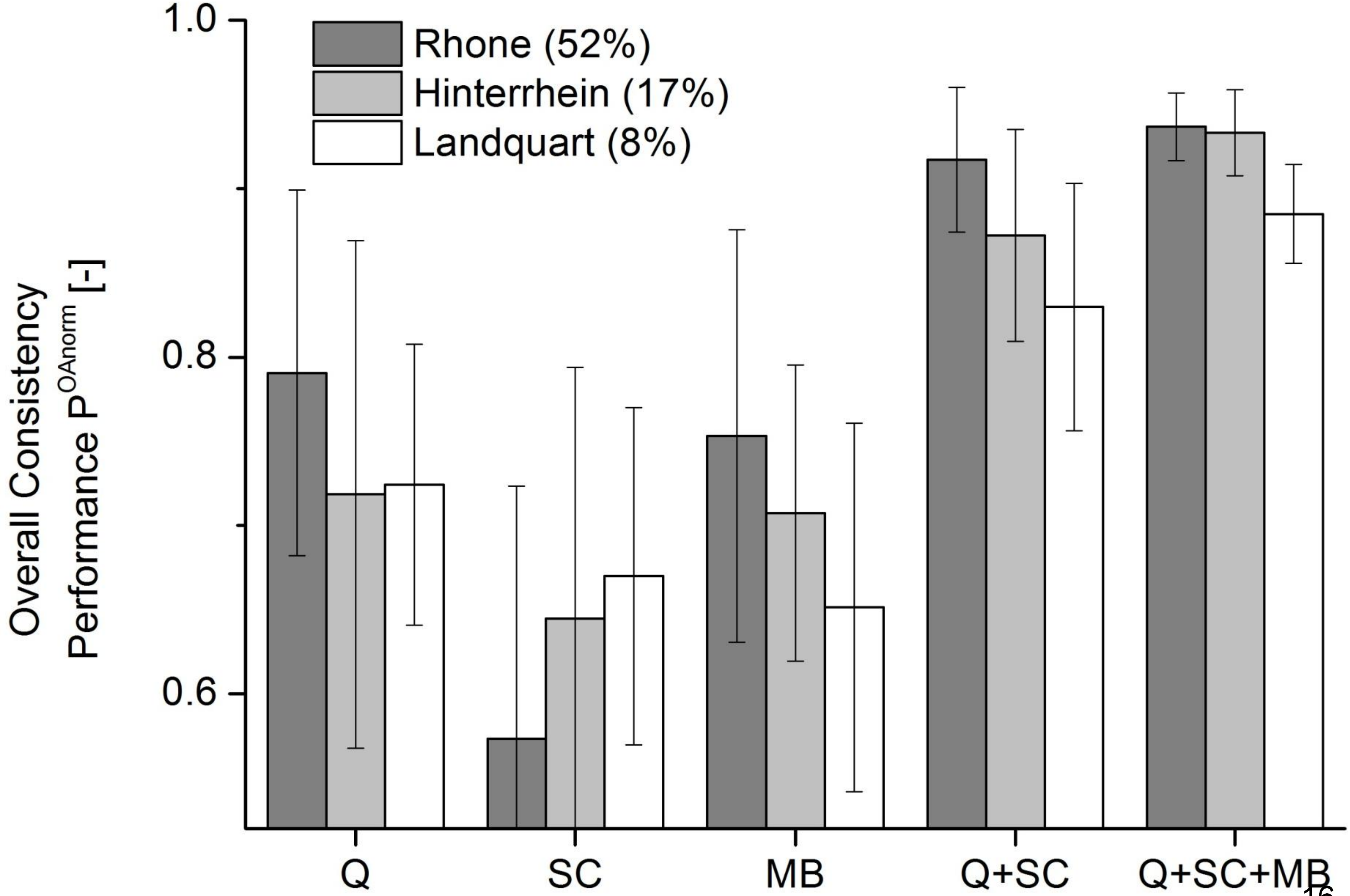
Q + MB + SC

Finger et al., 2011

Overall consistency performance of models with increasing complexity



Overall consistency performance in study sites with decreasing glacierisation



Finger et al., 2015

Trade-off between efficiencies

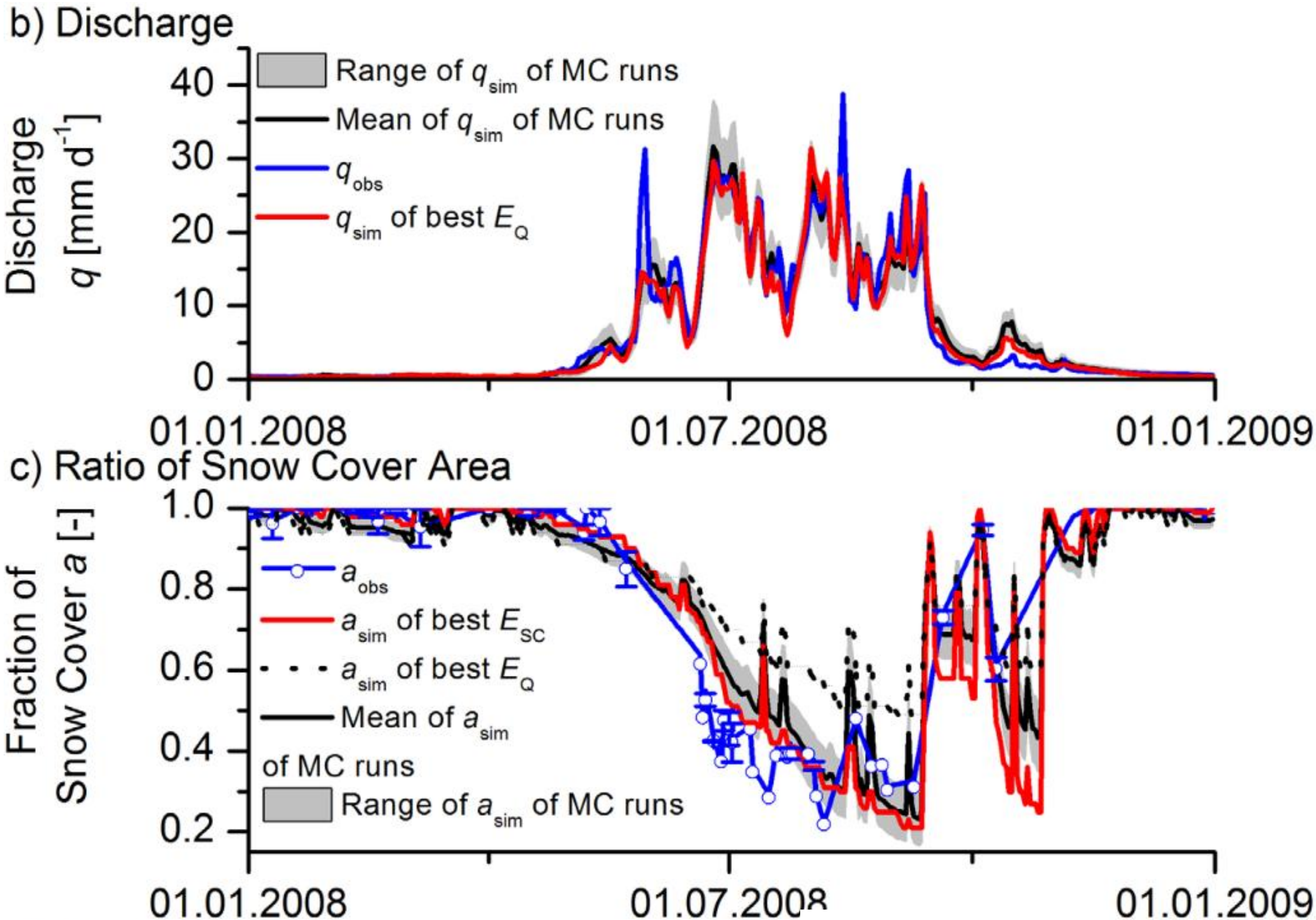
Table 5. Performance of Rhone Regarding Different Selection Criteria of the 100 Best MC-Runs During Calibration

	Performance Criteria							
	Discharge E_Q [-]		Snow Cover $E_{SC,summer}$ [−]		Mass Balances $E_{MB,abl}$ [mm w. eq.]		Consistency Perf. P^{OAnorm} [−]	
[a]Selection Criteria	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

[a]Shaded cells indicate that the data sets relevant for the criterion were used to select the best runs.

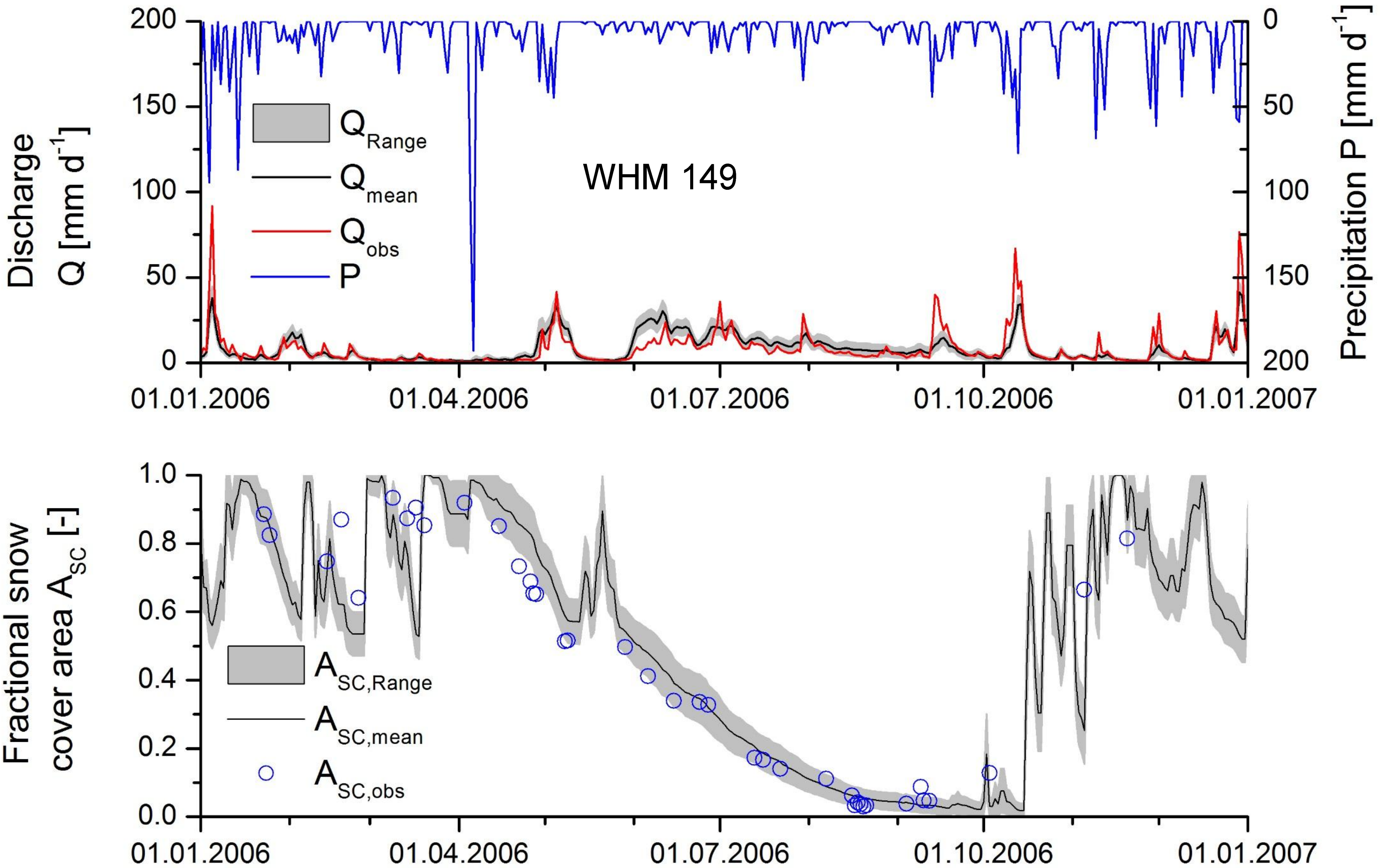
Finger et al., 2015

Calibration using only Q and using SC and Q combined

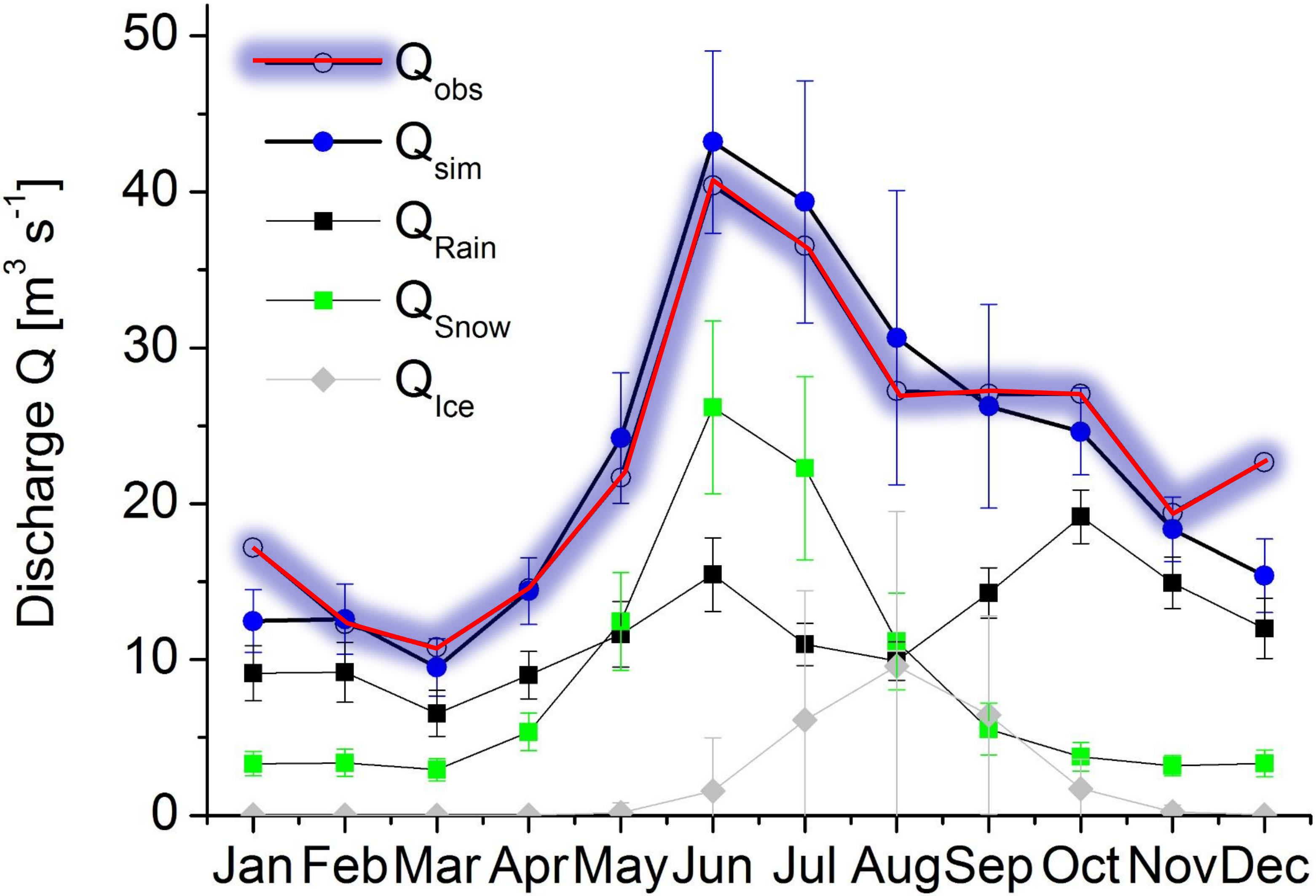


Finger et al., 2015

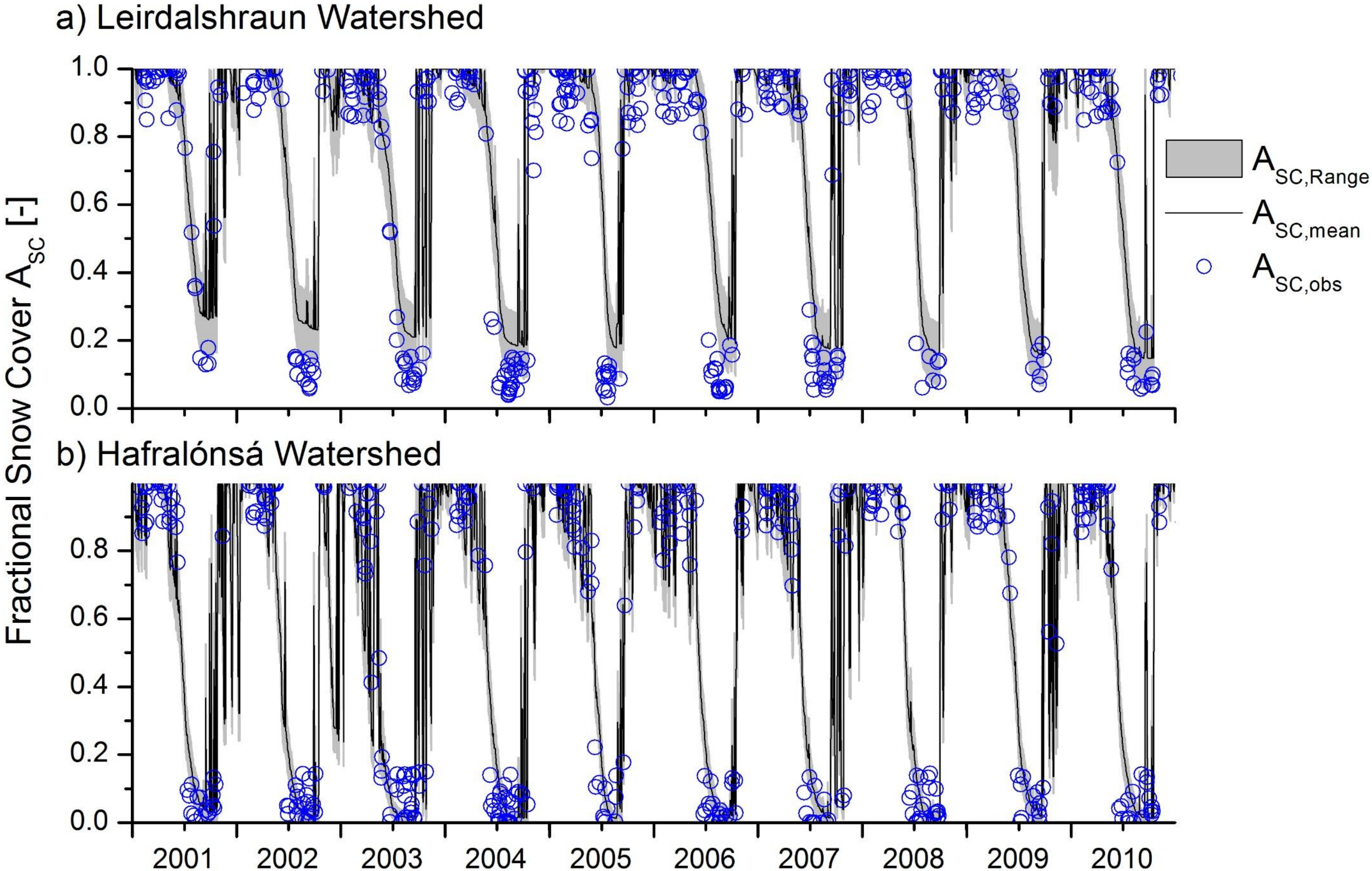
Calibration runs for gauged sub-catchment in Iceland



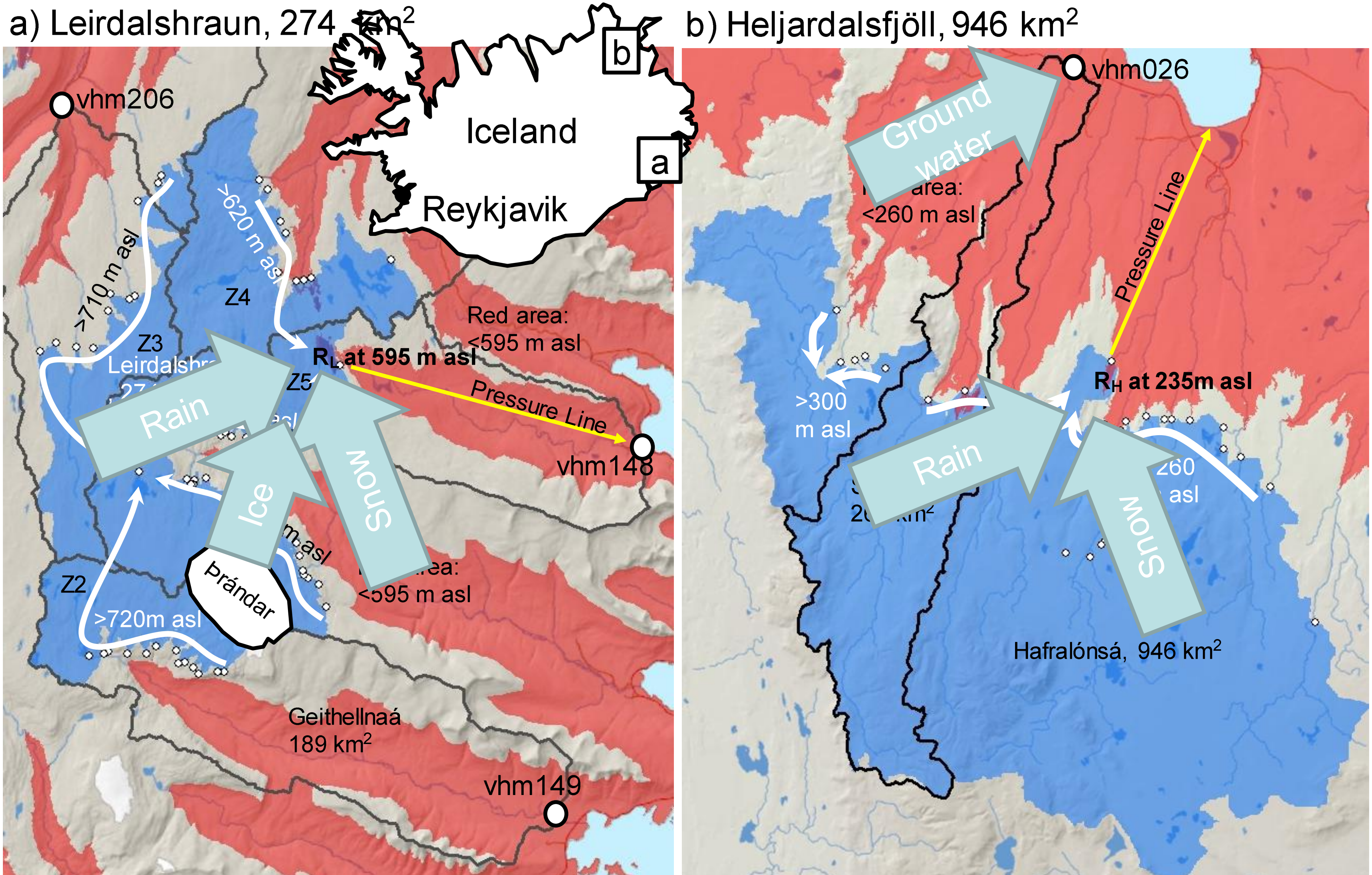
Validation runs for gauged sub-catchment (vhm149) in eastern Iceland



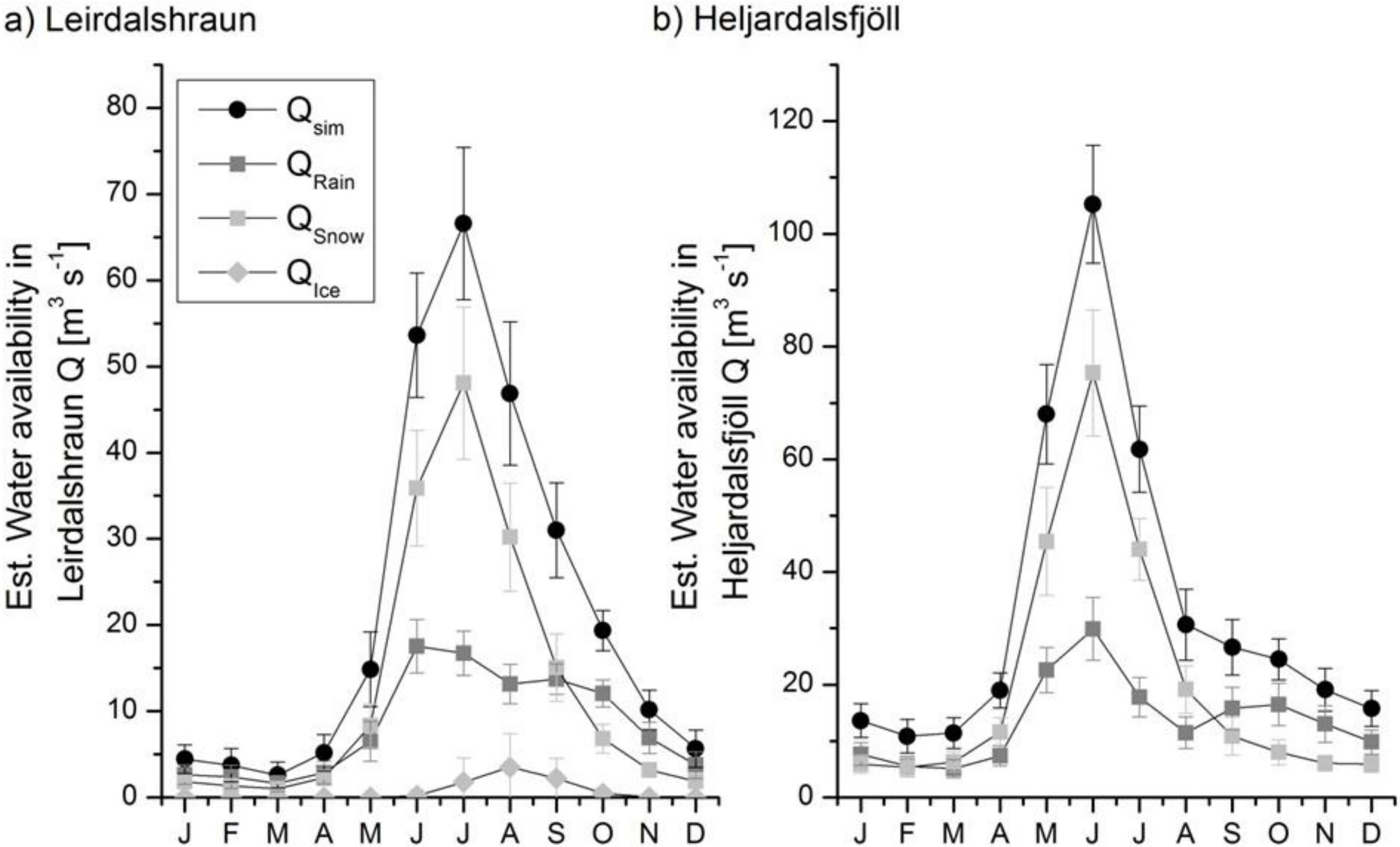
Validation of snow cover for entire ungauged catchments



Contribution to runoff can be constrained using SC



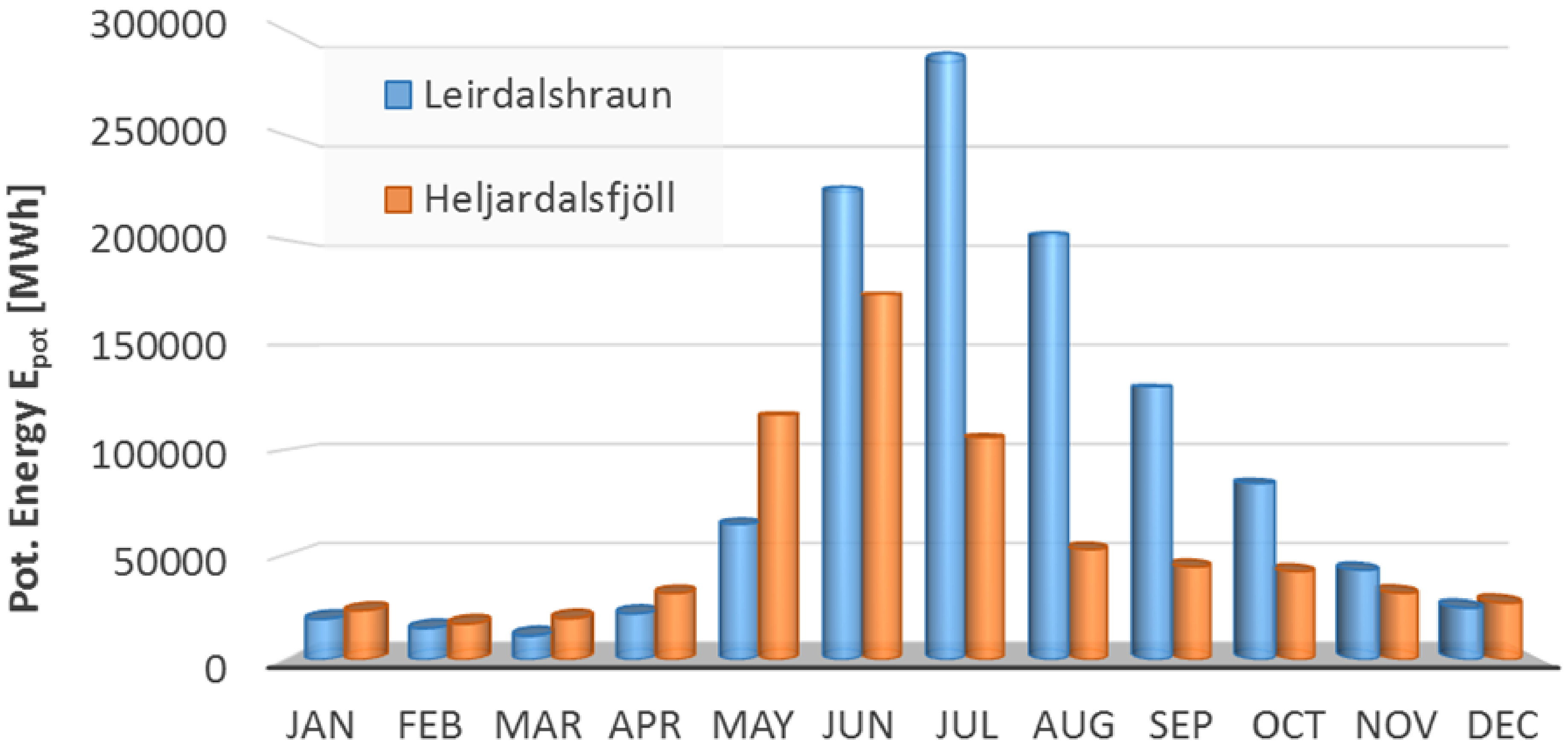
Estimated water runoff in the ungauged areas



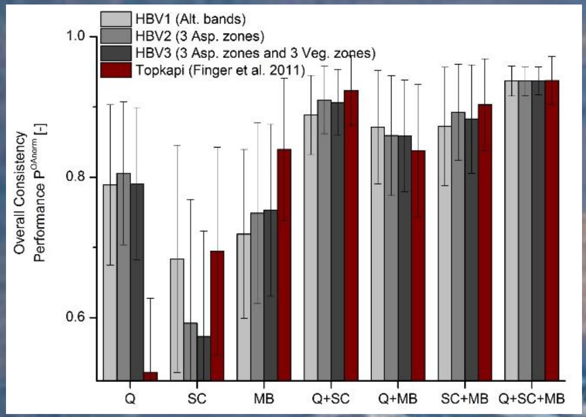
Leirdalshraun: 274 km2; 595 m asl; 5.7 % glacierized → 792 GWh a^{-1}
Heljardalsfjöll: 946 km2; 235 m asl; → 480 GWh a^{-1}

Estimated hydropower potential in the ungauged areas

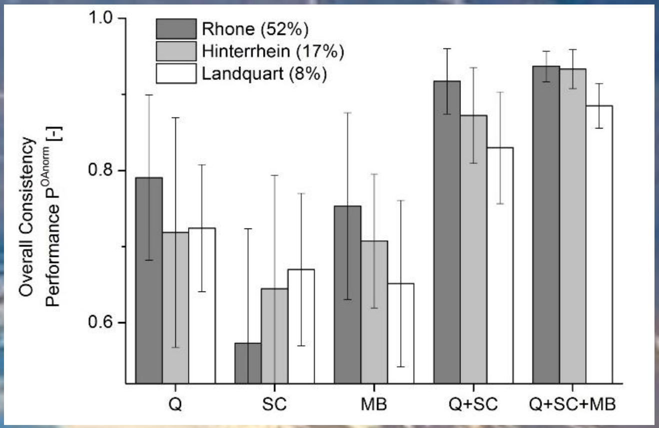
Leirdalshraun: 274 km2; 595 m asl; 5.7 % glacierized
Heljardalsfjöll: 946 km2; 235 m asl;



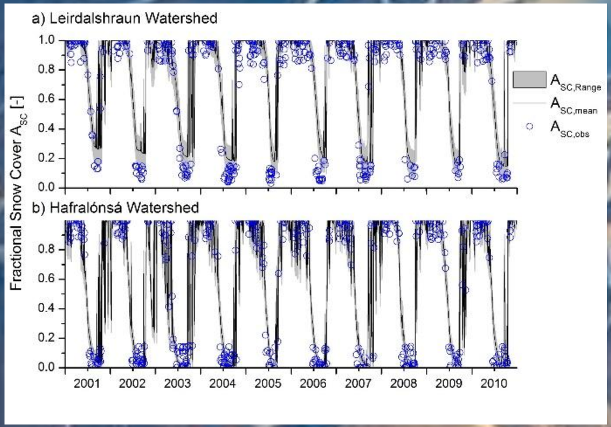
Take home messages: MODIS snow cover data…



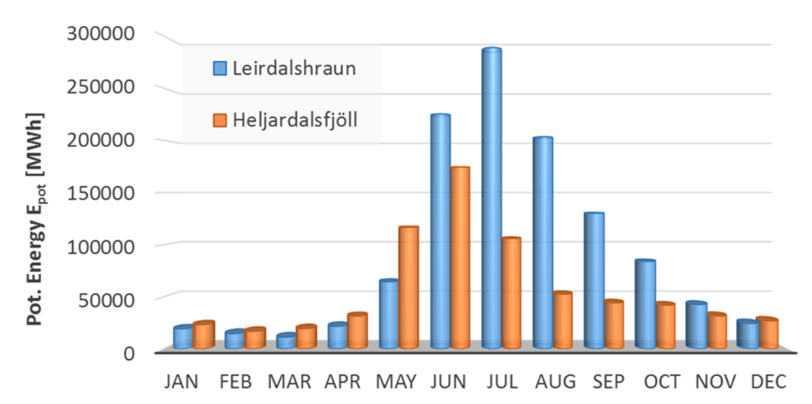
… improve hydrological simulations regardless of model complexity.



… 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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