Quantitative evaluation of hydrological modelling approaches in a glacio-nival watershed

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Dammagletscher in central Switzerland

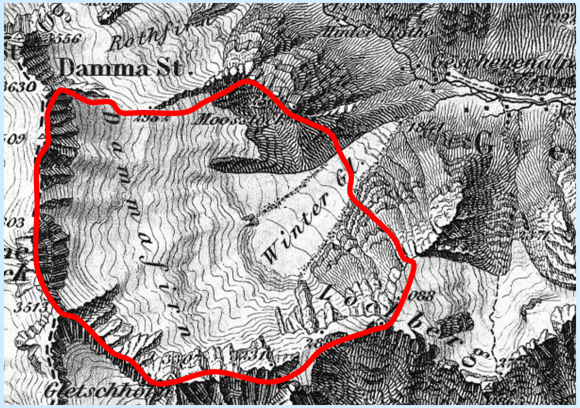
Long-term simulations of hydrological conditions useful for water management, ecosystem-development studies, …

1908

2005

2100

1921



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Quantitative evaluation of hydrological modelling approaches in a glacio-nival watershed

How to predict hydrological conditions in watersheds with both snow and glacier dominated regions?

Dammagletscher in central Switzerland

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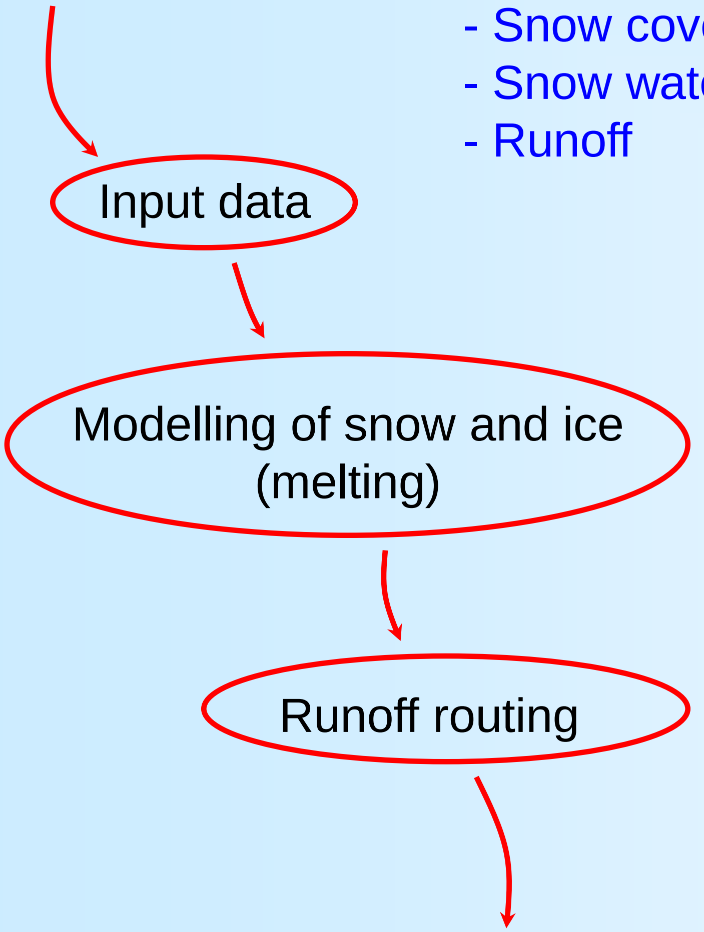
We tried to examine the whole modelling chain

Measurements
- Local meteorology
- Snow covered area
- Snow water equivalents
- Runoff



Input data

Evaluating extrapolated long-term meteorological records to mimic typical data situation for climate change studies

Melt model comparison

1) an energy-balance model primarily designed for snow simulations

2) a temperature-index model developed for glacier mass balance studies

Runoff

Examining different simple models

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Description of energy-balance model

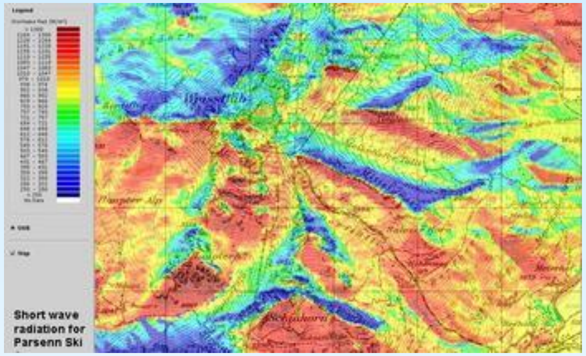
ALPINE3D

Spatially distributed model for simulations of snow-dominated surface processes (Lehning et. al., 2006)

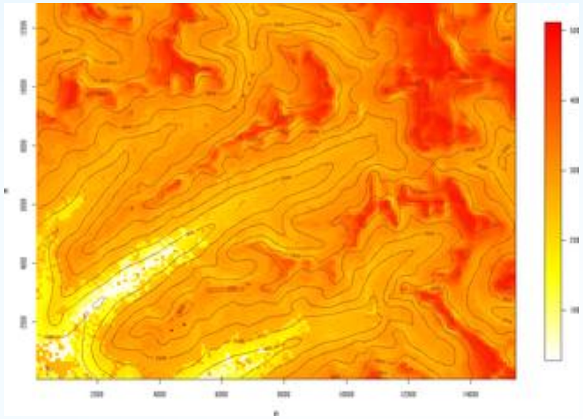
Includes the relevant energy-balance terms for the *snow* and *ice* development

Inputs: Air temperature, relative humidity, wind speed, precipitation and radiation.

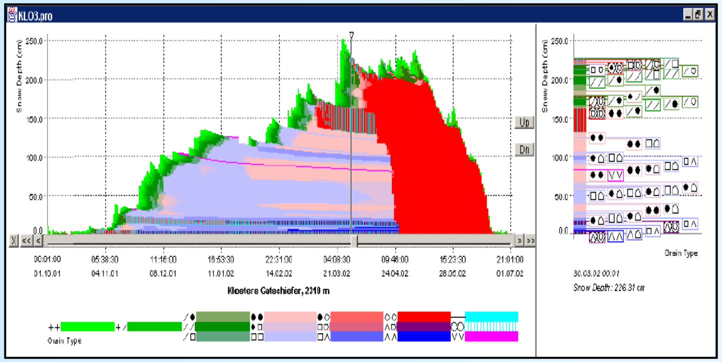
Radiation module



Map of snow water equivalents



SNOWPACK module



Description of temperature-index model

Distributed melt model including radiation effects (Hock, 1999)

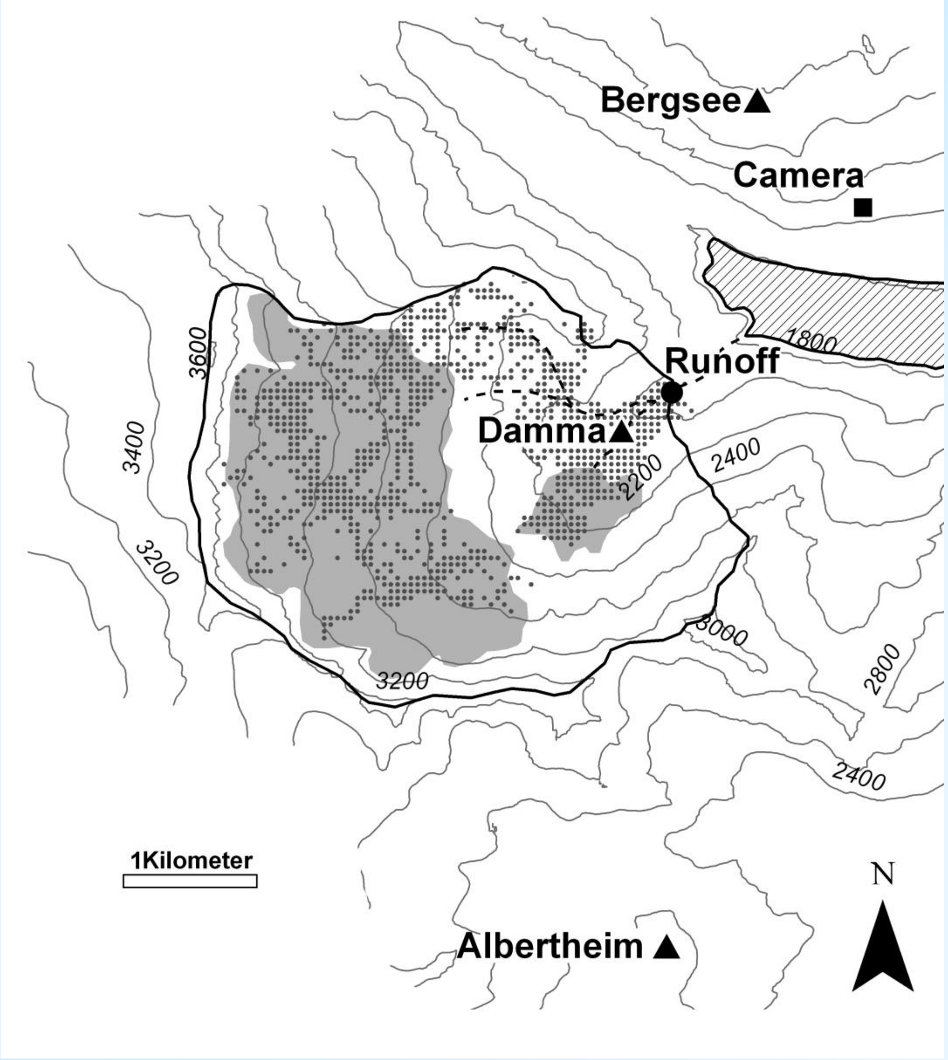
Often used for glacier mass balance studies

$$M = \begin{cases} \left(f_{\mathrm{M}} + r_{\mathrm{snow/ice}} \cdot I_{\mathrm{pot}} \right) \cdot T & \text{if} \quad T > 0^{\circ} C \\ 0 & \text{if} \quad T \leq 0^{\circ} C \end{cases}$$

M	- melt rate
T	- air temperature
I_{pot}	- potential solar radiation
f_M	- a melt factor
r_{snow} & r_{ice}	- radiation factors for snow and ice

Calibration: Runoff and snow covered area

Evaluation of meteorological extrapolation schemes



Three supplementary weather stations (Bergsee, Damma, Albertheim)

Precipitation:

• Snow water equivalent measurements (1307 points)

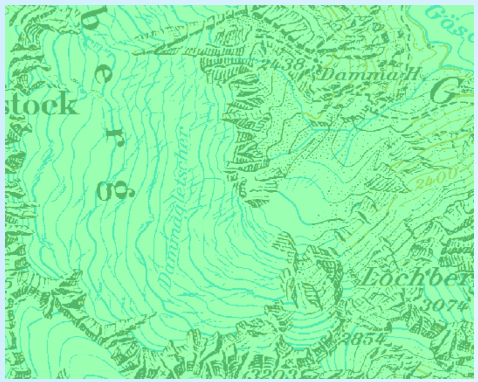
• Snow covered area determined using time-lapse photography (Farinotti, in press)

Different methods to distribute precipitation

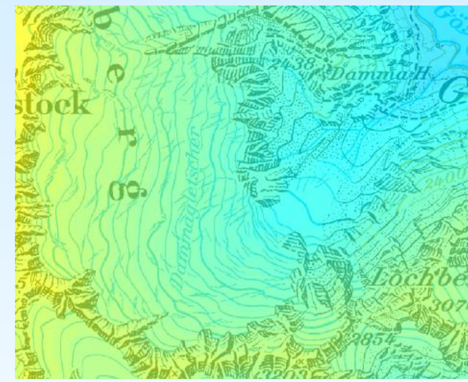
INPUT:

Long-term measurements from a wind sheltered station 3km east of the watershed

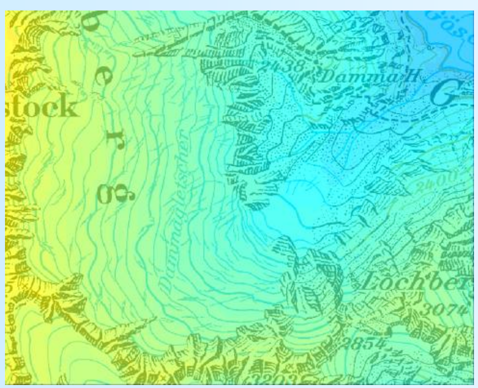
Uniformly distributed



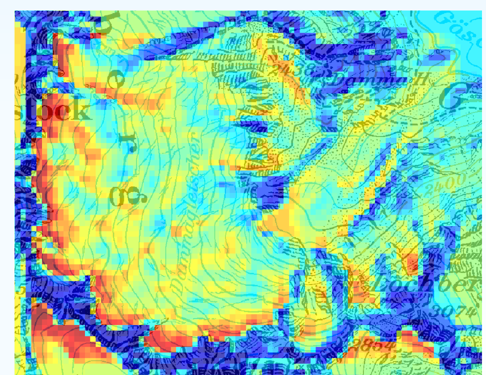
Elevation dependent gradient



Large scale horizontal field (Schwarb, 2001) and elevation dependent gradient



Parametric method handling snow redistribution (Huss et al., 2008)



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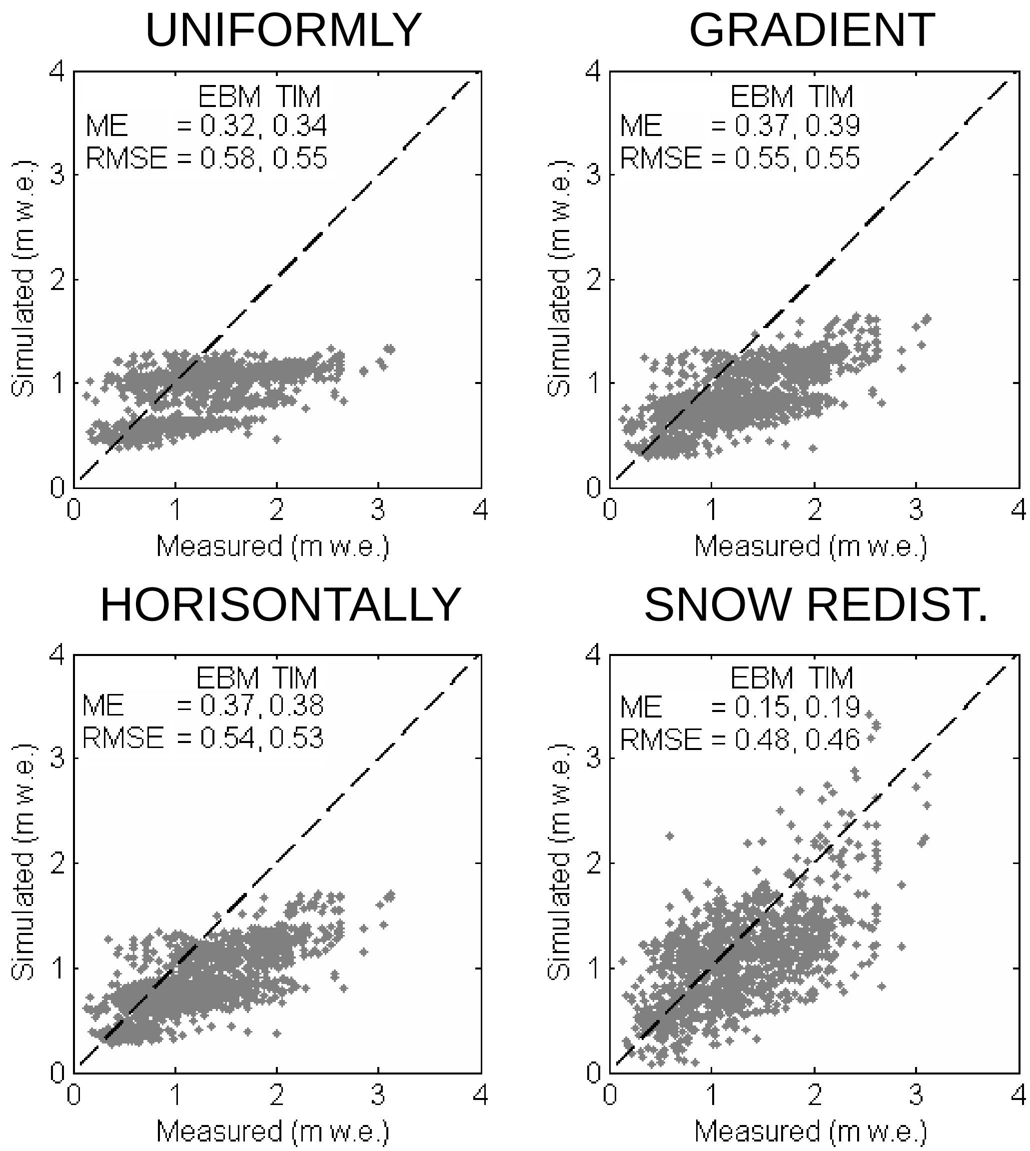
Evaluation of snow simulations



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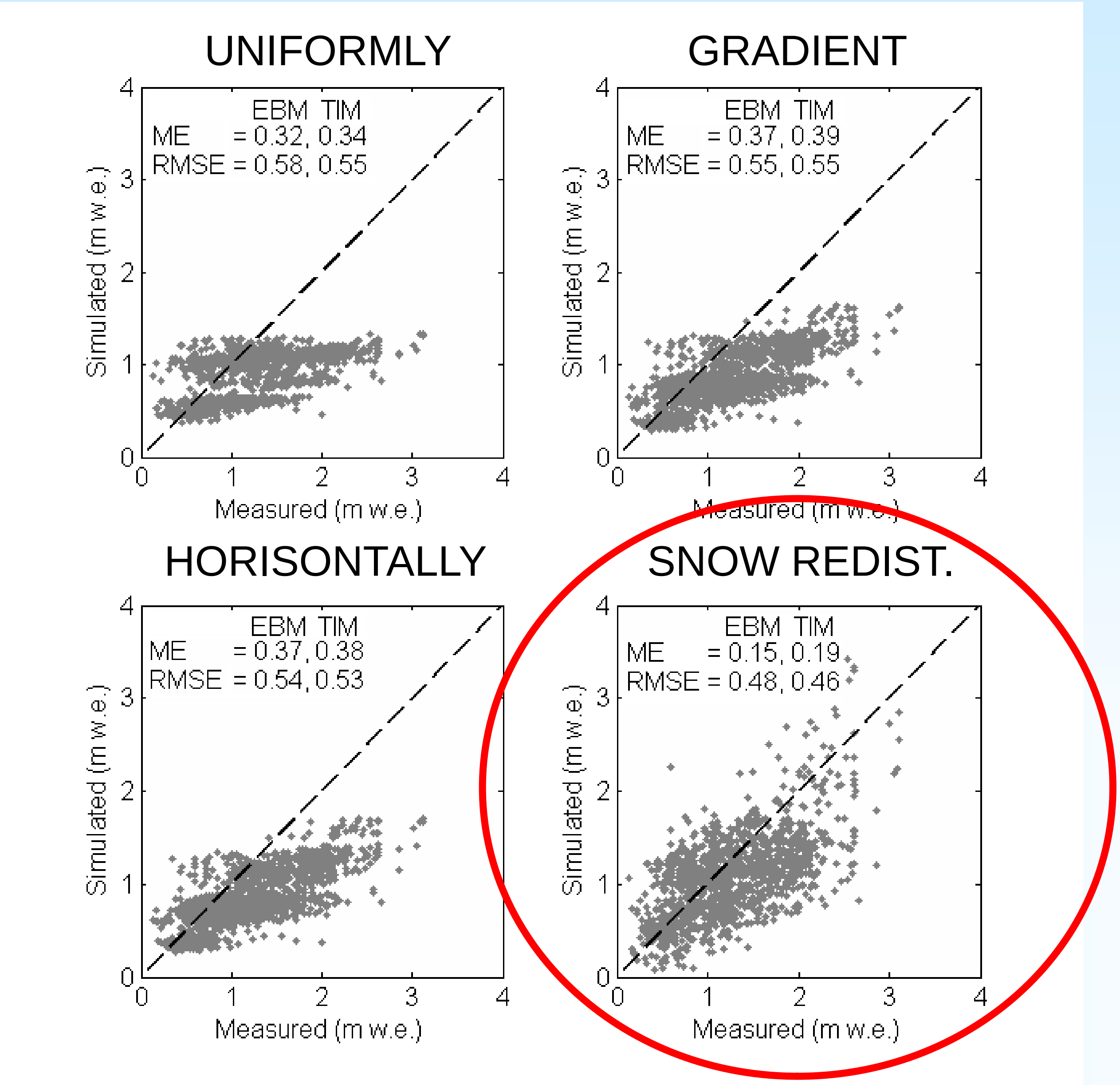
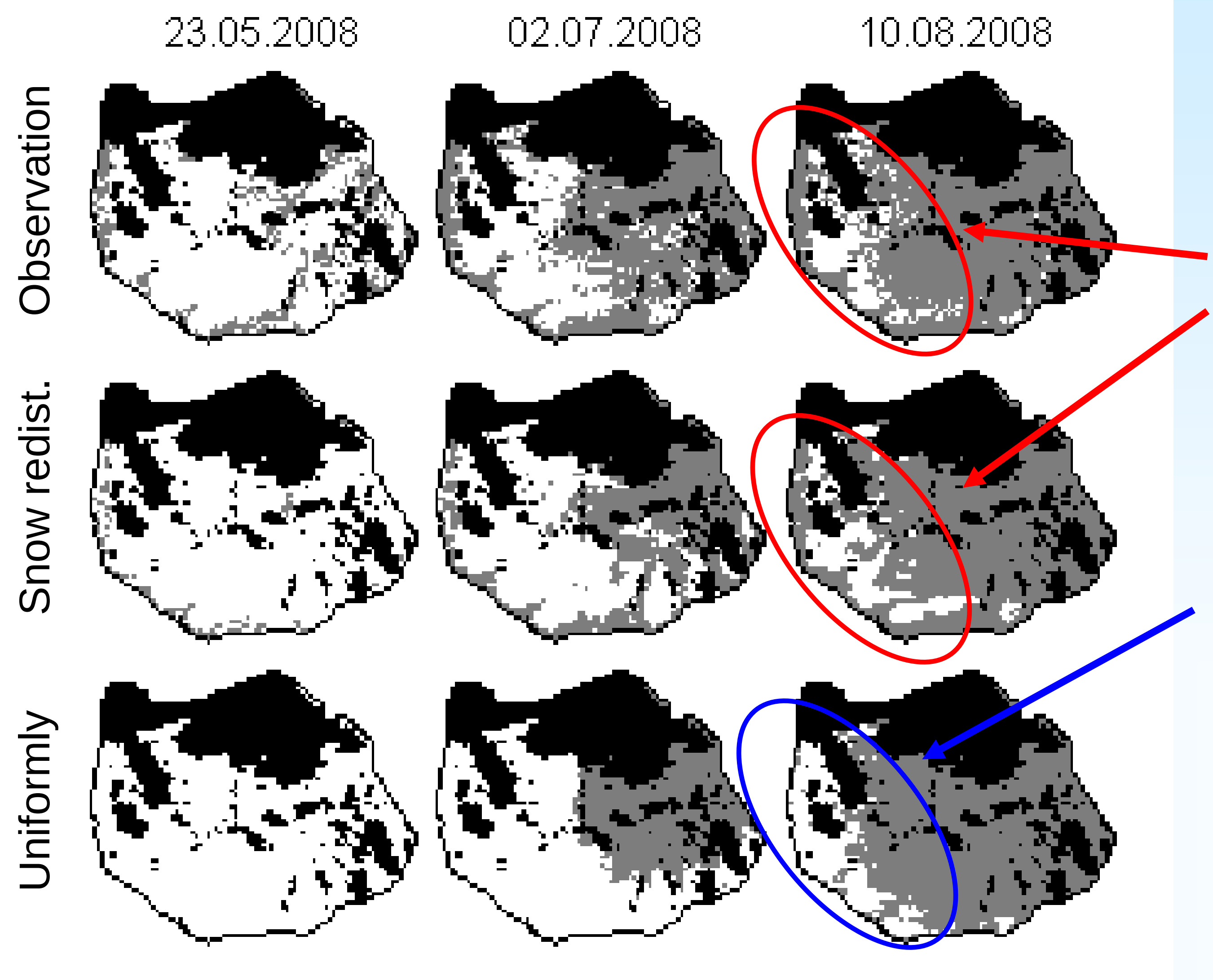
Evaluation of snow simulations



- Only the precipitation field accounting for snow redistribution bare any relation to the observations

- However, still some room for improvement of the parametric approach …

Evaluation of snow simulations



- The precipitation field accounting for snow redistribution reproduces the glacier accumulation area

- The remaining precipitation fields accumulate snow on the steep slopes on high altitudes instead

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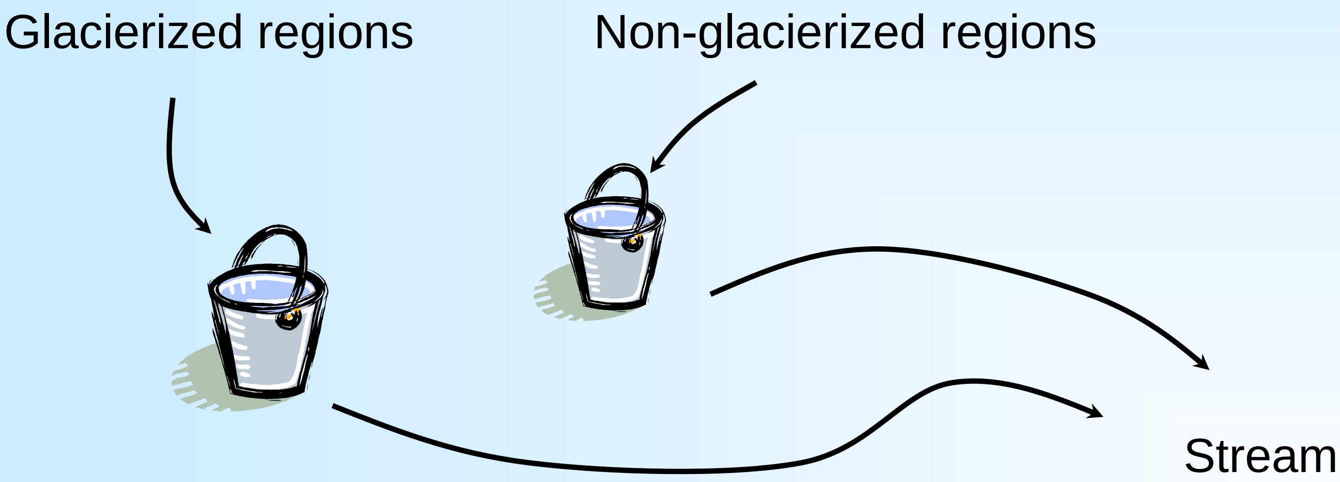
Description of runoff routing scheme

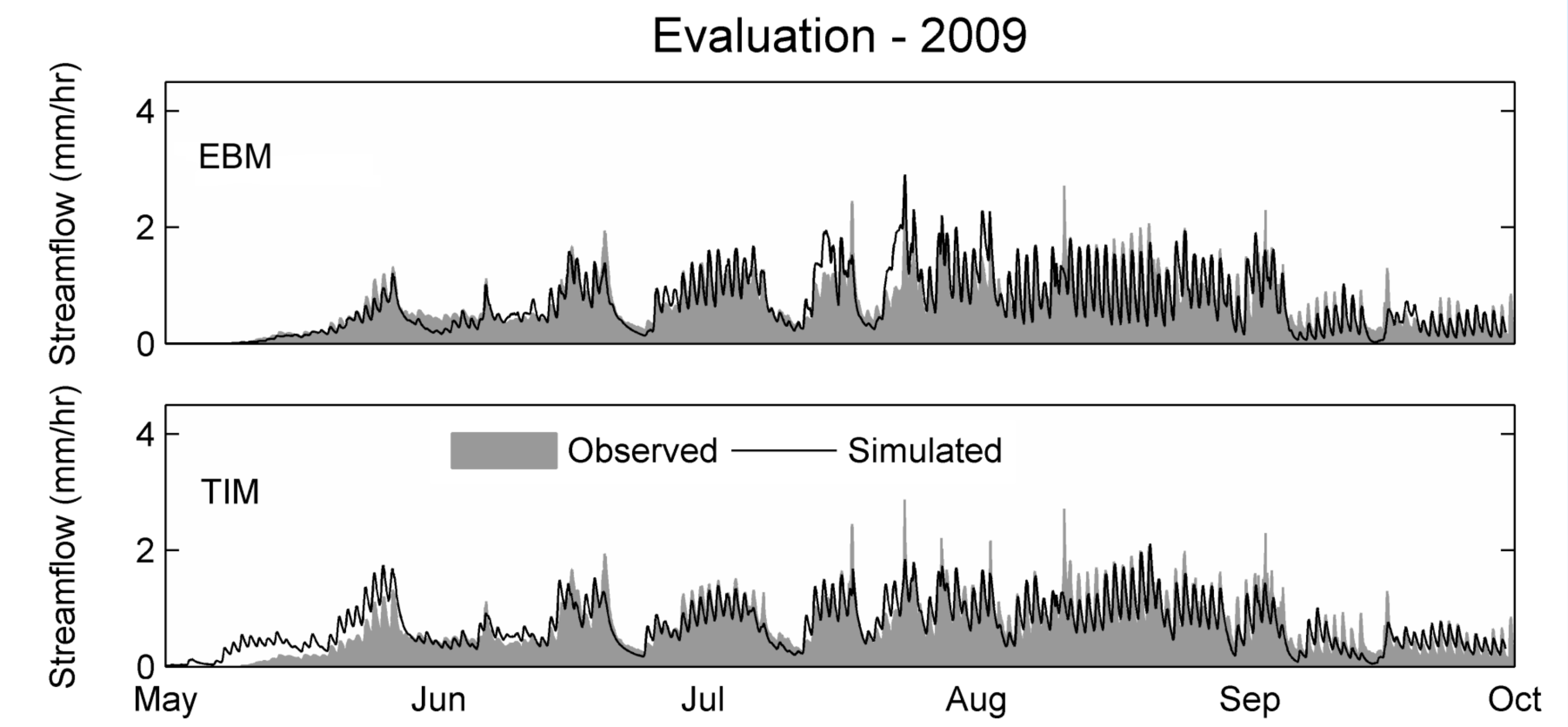
Simple: A two bucket linear reservoir model



More buckets: Did not improve the final model results

Evaluation of runoff simulations

Both models worked almost equally well when snow redistribution was included



NS = 0.64
R^2 = 0.75
ΔQ = + 3%

NS = 0.66
R^2 = 0.69
ΔQ = + 8%

Similar model performance to comparable studies
(Michlmayr et al. (2008), Zappa et. al. (2003),…)

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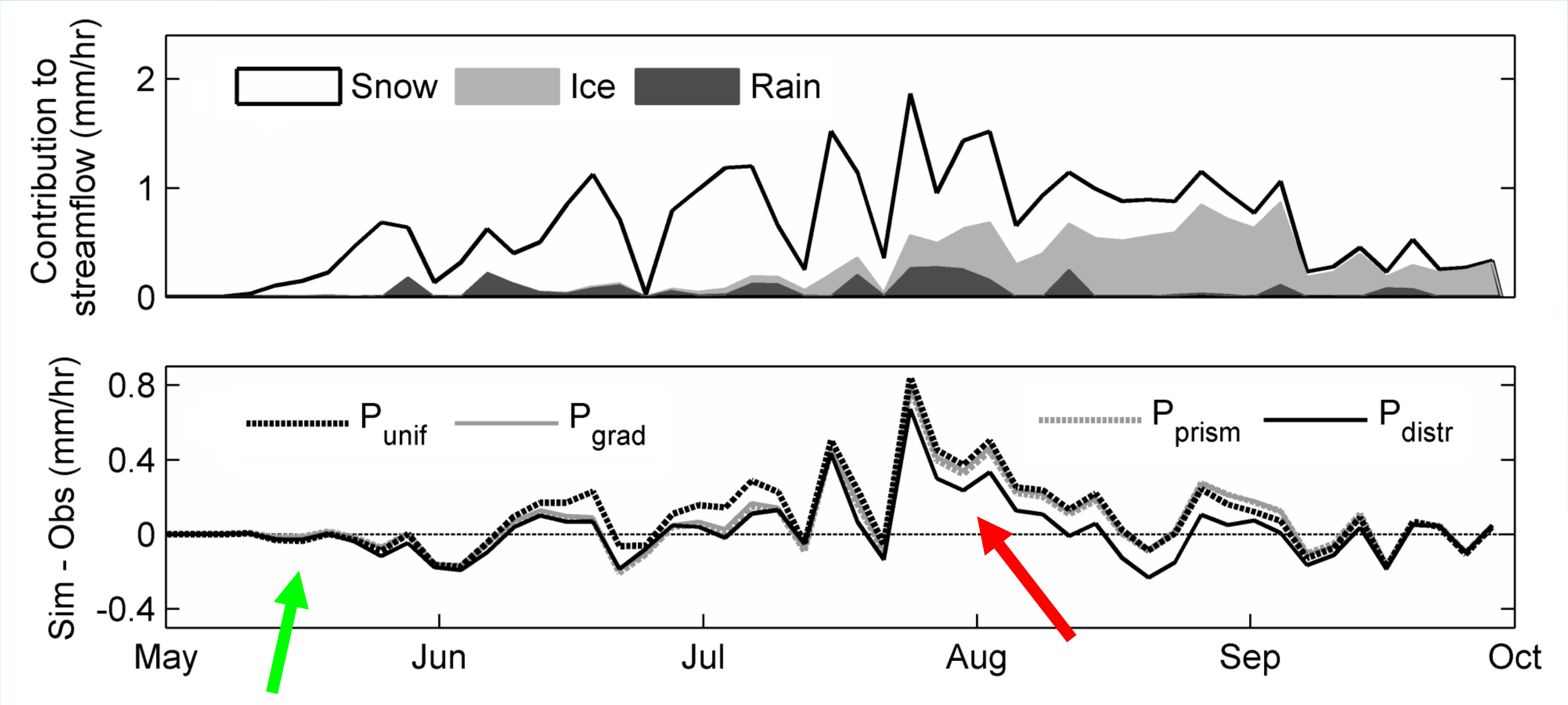
Energy-balance model

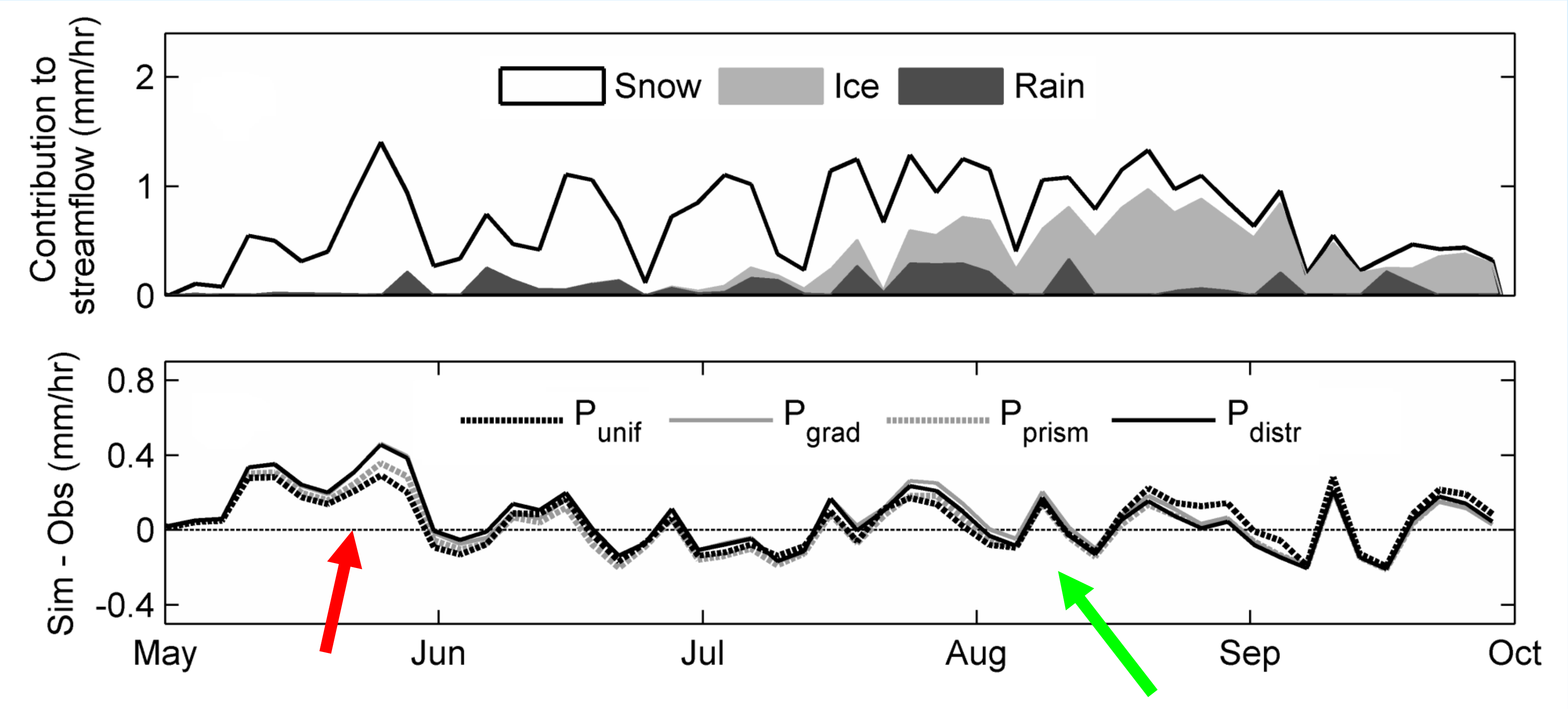
Sensitive to precipitation distribution (ΔQ = <1% to 15%)
Sensitive to atmospheric stability (ΔQ = -18% to 35%)



Captures the snow melt accurately but not the glacier ablation

Temperature-index model

Robust to the different precipitation distributions



Reproduces the glacier ablation well but not initial snow melt

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Conclusions

The energy-balance model was sensitive to the precipitation distributions whereas the temperature-index model showed compensating mechanism

To improve the energy-balance model results:

Examine the input data and turbulent heat fluxes on the glacier

To improve the temperature-index results:

Include refreezing and percolation of melt water through the snowpack

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Conclusions

• **Both models reproduced the observed discharge (snow redistribution) despite:**

- Rare long-term measurements
- Both snow and ice dominated regions
- Large spatial variations (meteorology, snow cover, …)

The simple parametric approach to distribute precipitation improved the snow simulations:

- Affects for example the glacier albedo

- Prerequisite for correctly constraining melt parameters