ESA Workshop on Cold Regions Hydrology
28-30 April 2010, Innsbruck, Austria

Distributed snow hydrological modeling: The importance of appropriate input data

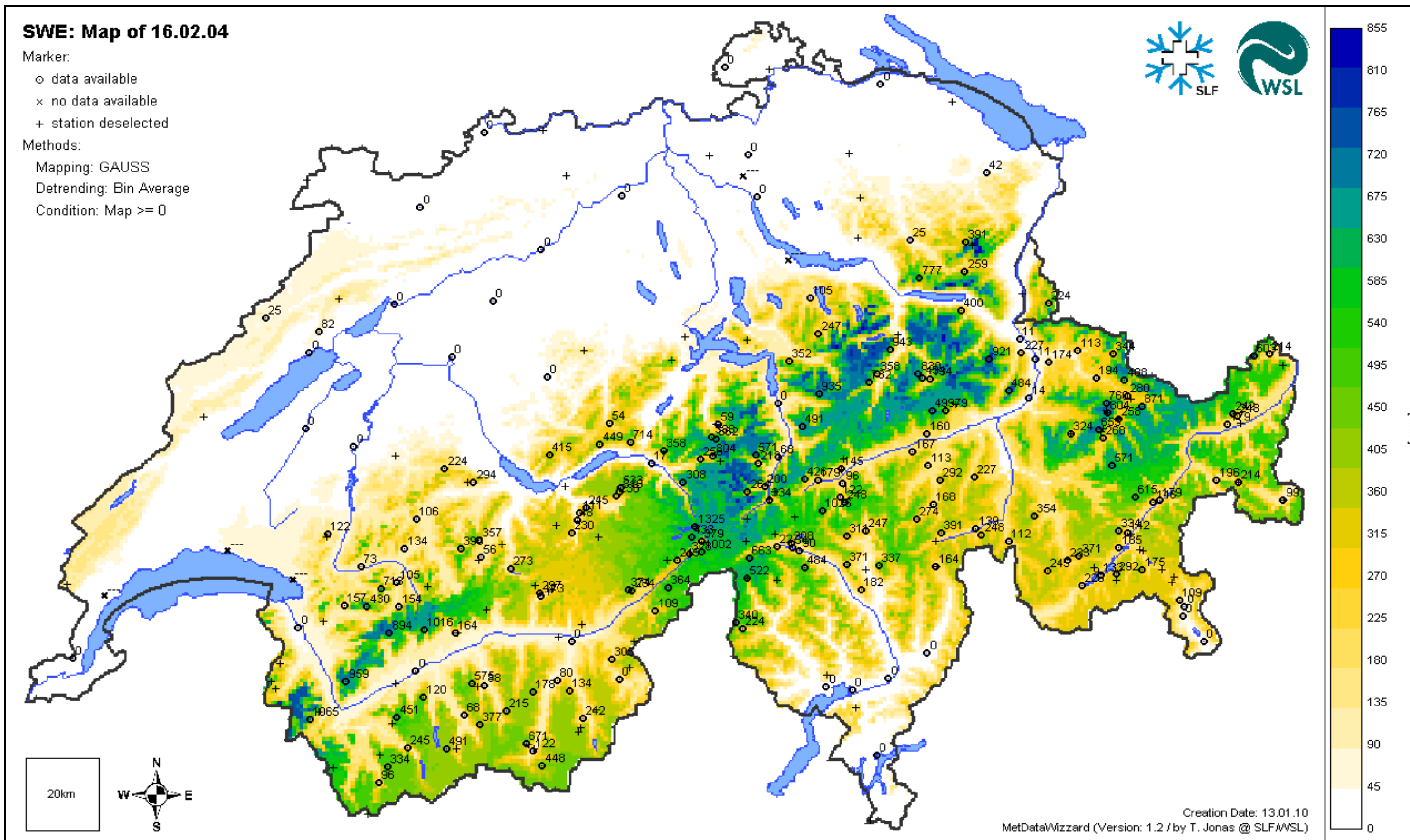
T. Jonas*, A. Bergau*, J. Magnusson*, P. Lang*, M. Bavay*
*WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland

D. Marks[+], A. Winstral[+]
[+]Northwest Watershed Research Center, USDA-ARS, Boise, USA

Background

Distributed snow hydrological models are increasingly being used

- Research: climate change / process understanding
- Operational: mountain water resources / snow melt / hydropower



Background

Today, very sophisticated snow models exist, but …

- spatio-temporal validation remains challenging / is often lacking !
- can we feed these models with appropriate input data ?

A typical situation for
distributed snow model
in alpine / complex topography

- Input data from a set of met stations (which may / may not be accurate)
- Interpolation of met data to model grid either externally or by model
- The user is required to take decisions on data preprocessing methodology
- Spatially explicit validation data on SWE is largely unavailable

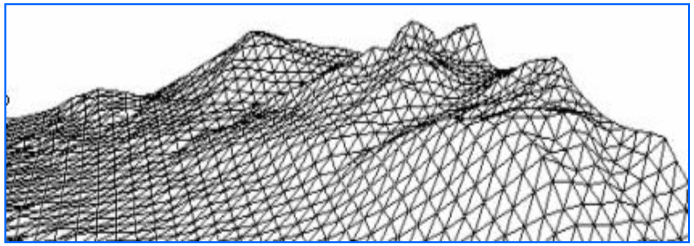
This presentation covers …

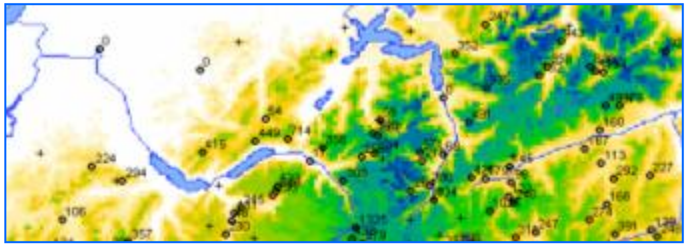
Part 1 - our efforts towards validation of distributed snow models

- spatio-temporal SWE / HS measurements in the area of Davos

Part 2 - analyzing model performance with different input data preprocessing schemes

- using SWE data from periodic validation campaigns
- focusing on different precipitation data correction schemes





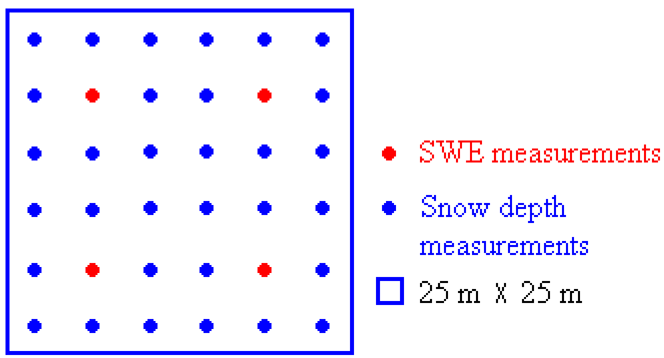
Periodic SWE sampling campaigns

Study area

- Dischma valley Davos
- 43 km^2, 1700–3200 m. asl, mostly unforested + unglaciated

Sampling design

- accounting for within-site variability (site = 1 model grid cell)



- stratified sampling with elevation + sun exposure
- biweekly measuring campaigns since 4 winters
- no revisiting of sites
- so far we got 300 sites, ~ 11000 HS and 1200 SWE data

Constraints

- man power (reaching sites / digging snow pits)
- accessibility of sites (avalanches / weather)

Periodic terrestrial laser scanning campaigns

Study area
- Albertibach catchment Davos
- 1.5 km^2, 2000–2650 m. asl, above treeline
- the basin is stream-gaged
- numerous snow-met stations in the area

Sampling design
- weekly scans during snow depletion since 2 winters
- fix targets installed in areas for geo-referencing

Airborne snow surveys

Study areas

- Albertibach + Dischma catchment

Sampling design

- singular RS campaigns
- accompanied by extensive ground observations

Testing new RS technologies

- 2 weeks ago: airborne Leica ADS80 + TLS + manual snow surveys
- we invite space-borne SWE / HS applications for testing in Davos

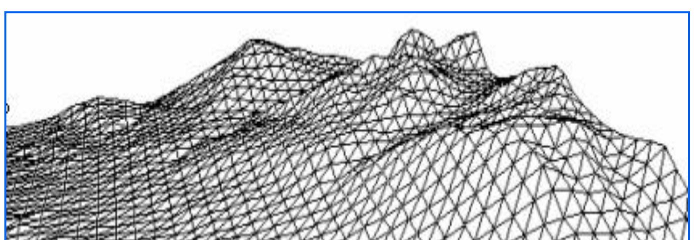
This presentation covers …

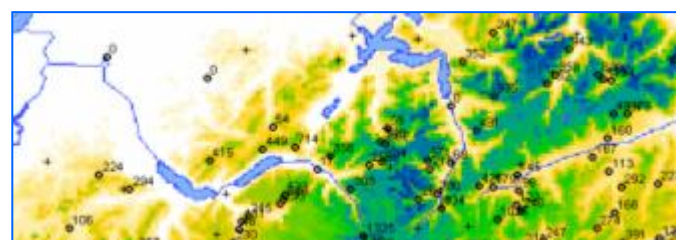
__Part 1__ - our efforts towards validation of distributed snow models

- spatio-temporal SWE / HS measurements in the area of Davos

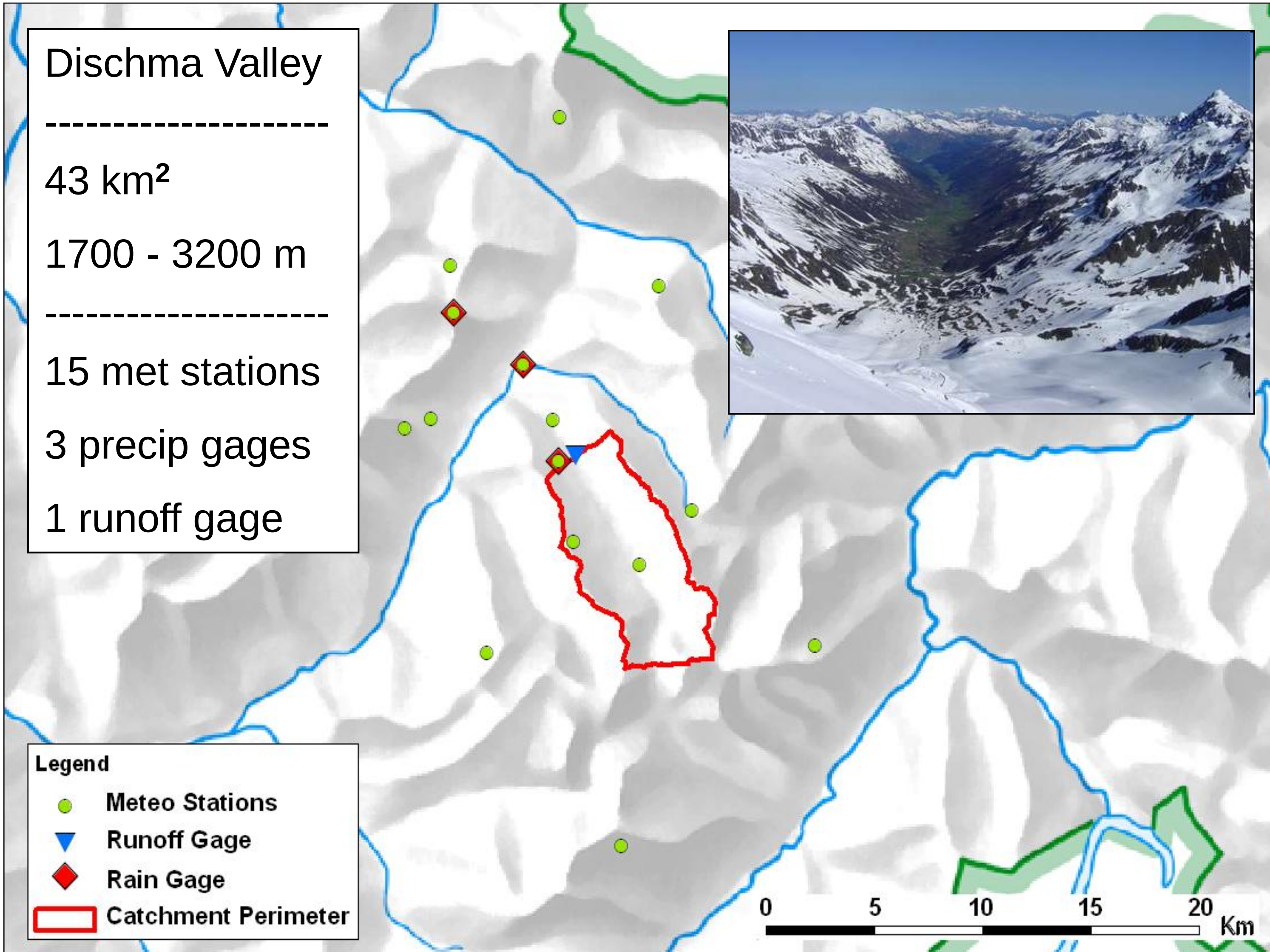
__Part 2__ - analyzing model performance with different input data preprocessing schemes

- using SWE data from periodic validation campaigns
- focusing on different precipitation data correction schemes





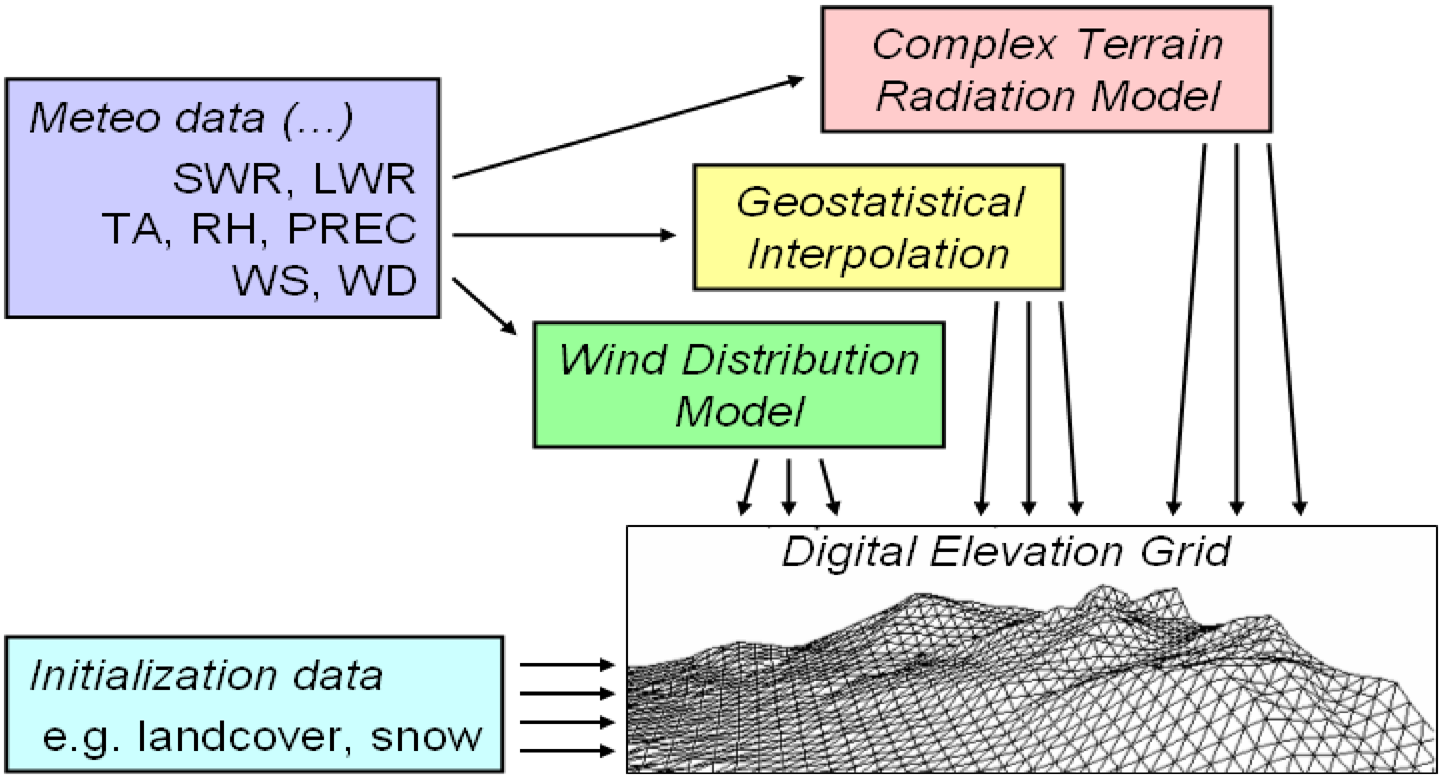
Study area / available hydromet data



SWE distribution modeling

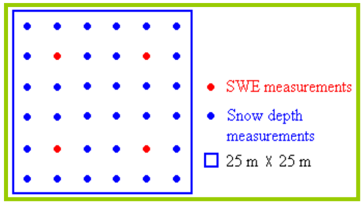
2 snow models

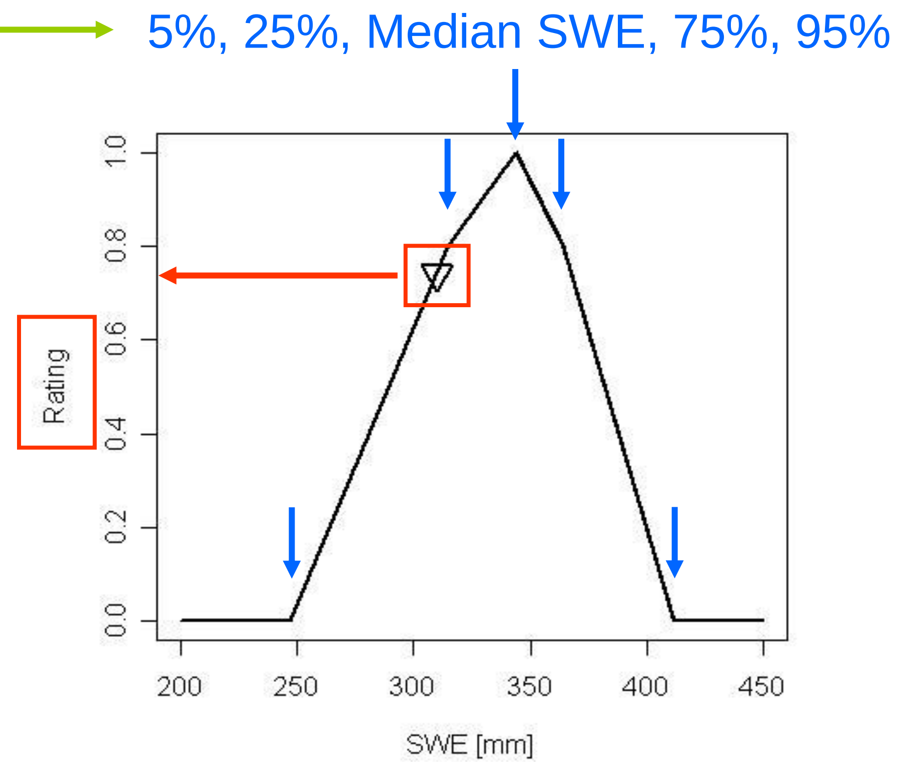
- Alpine3D (M. Lehning et al., 1999)
  mutlilayer model resolving physical processes (e.g. metamorphism)
- ISnoBal (D. Marks et al., 1999)
  2-layer model particularly suited for snow hydrological applications
- both models solve energy / mass balance of snowpack
- both models require distributed met data as input



Spatial validation of models / methods

Comparison grid cell - observations

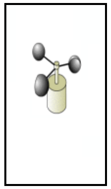




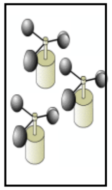
Note

- approach accounts for natural within-site variability of SWE
- rating function allows quantification of model performance
- allows ranking of model runs with different input data preprocessing

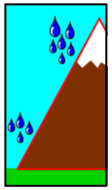
Configuration of model runs (simplified scheme)



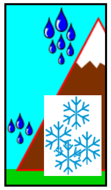
input data from 1 station



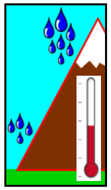
input data from all stations, but precipitation averaged



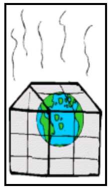
constant lapse rate for precipitation (measured)



constant lapse rate for precipitation (corrected for undercatch)

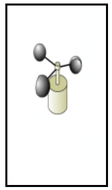


seasonal lapse rate for precipitation (corrected for undercatch)

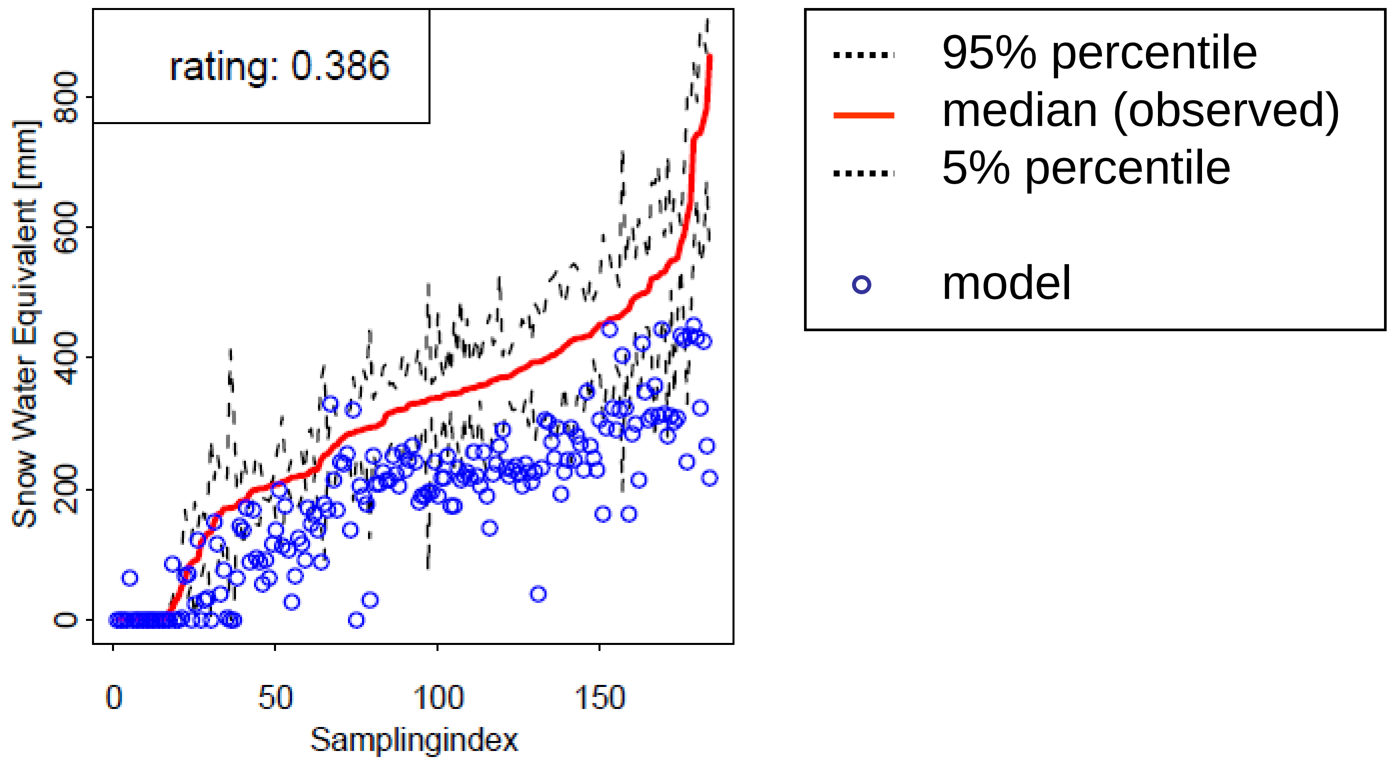


IPCC/OCCC scenarios applied (+20 / +40 yrs)

Model results (single / multiple stations)

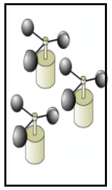


input data from 1 station (@ ~mean elevation)

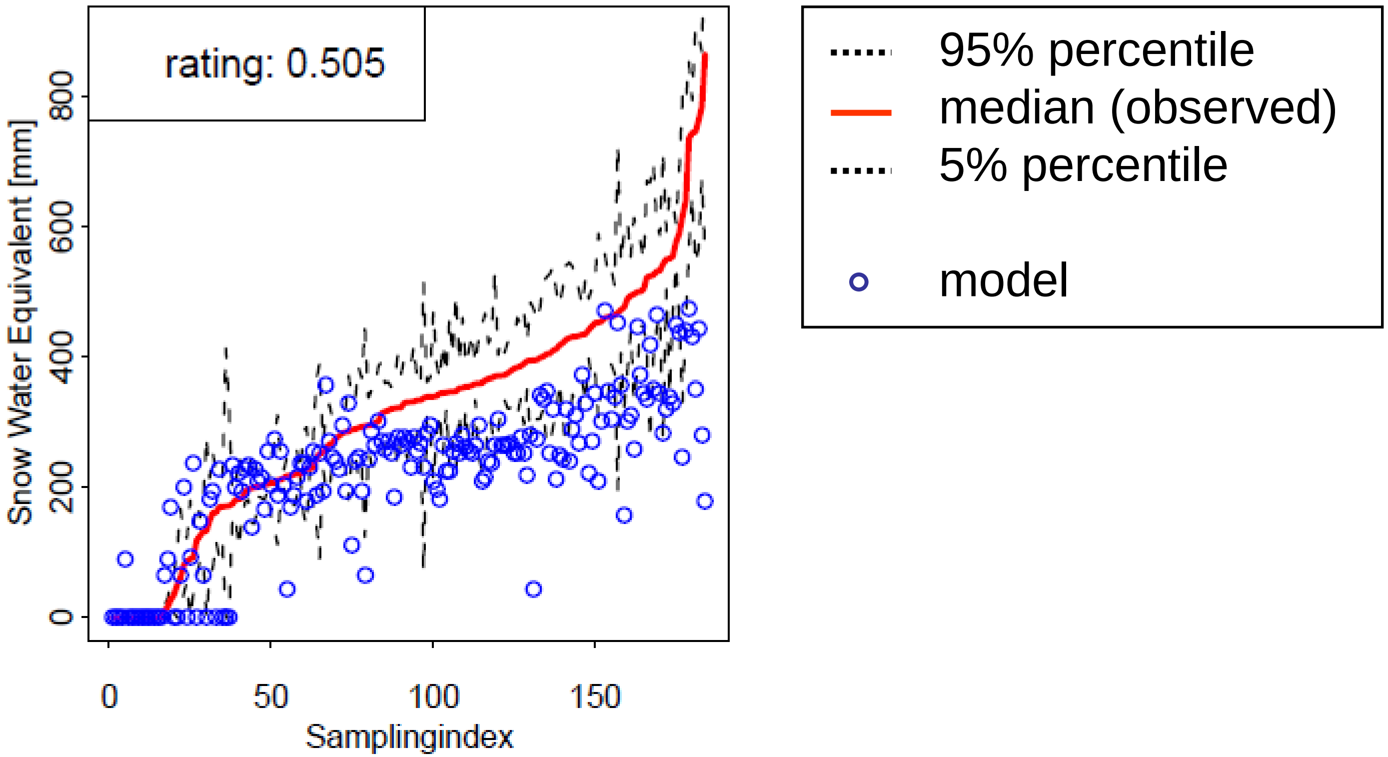


Consistently too little SWE in model estimates
Rating rather off-putting
(Precipitation input not representative)

Model results (single / multiple stations)

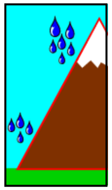


input data from 15 stations (PREC averaged)

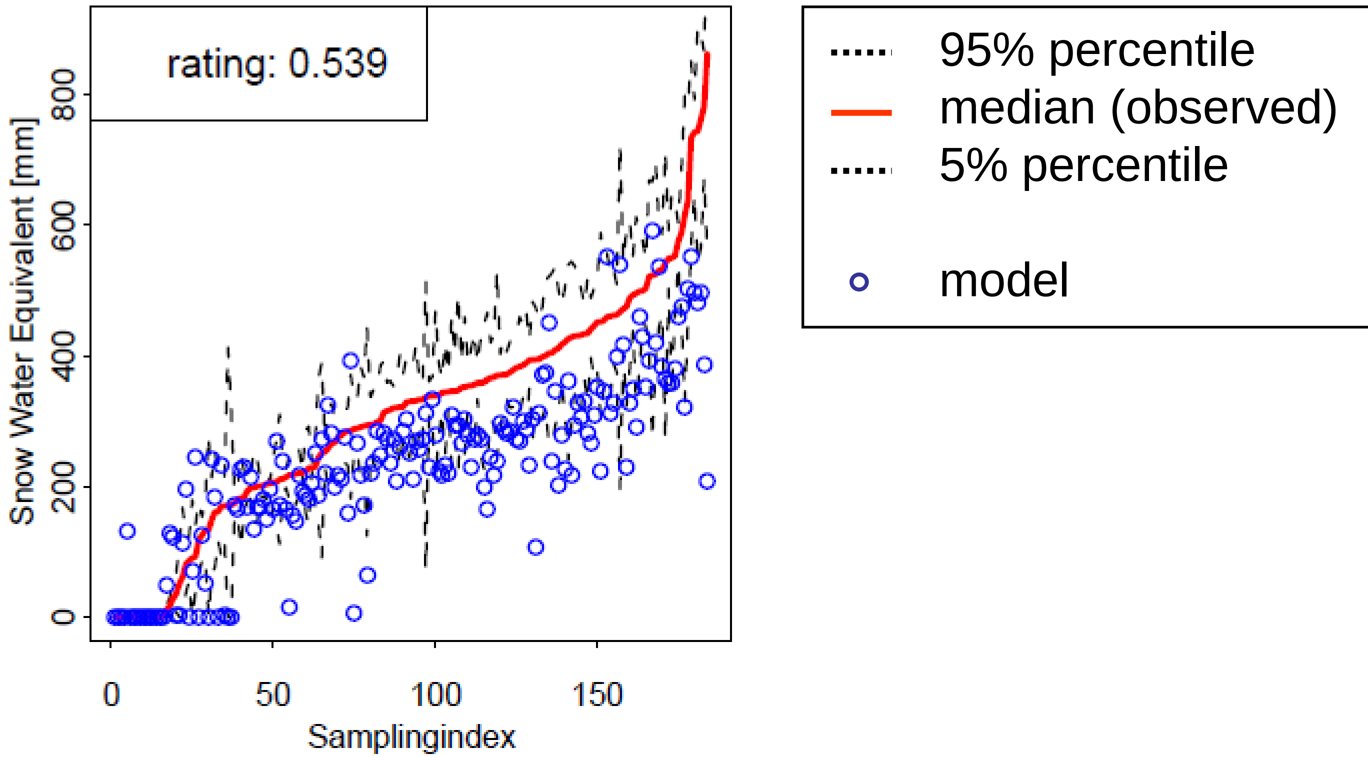


Observed range of SWE >> modeled range
Rating better though
(Still precipitation input not representative)

Model results (precip pre-processing methods)

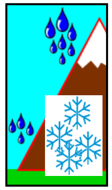


constant lapse rate for precipitation (as measured)

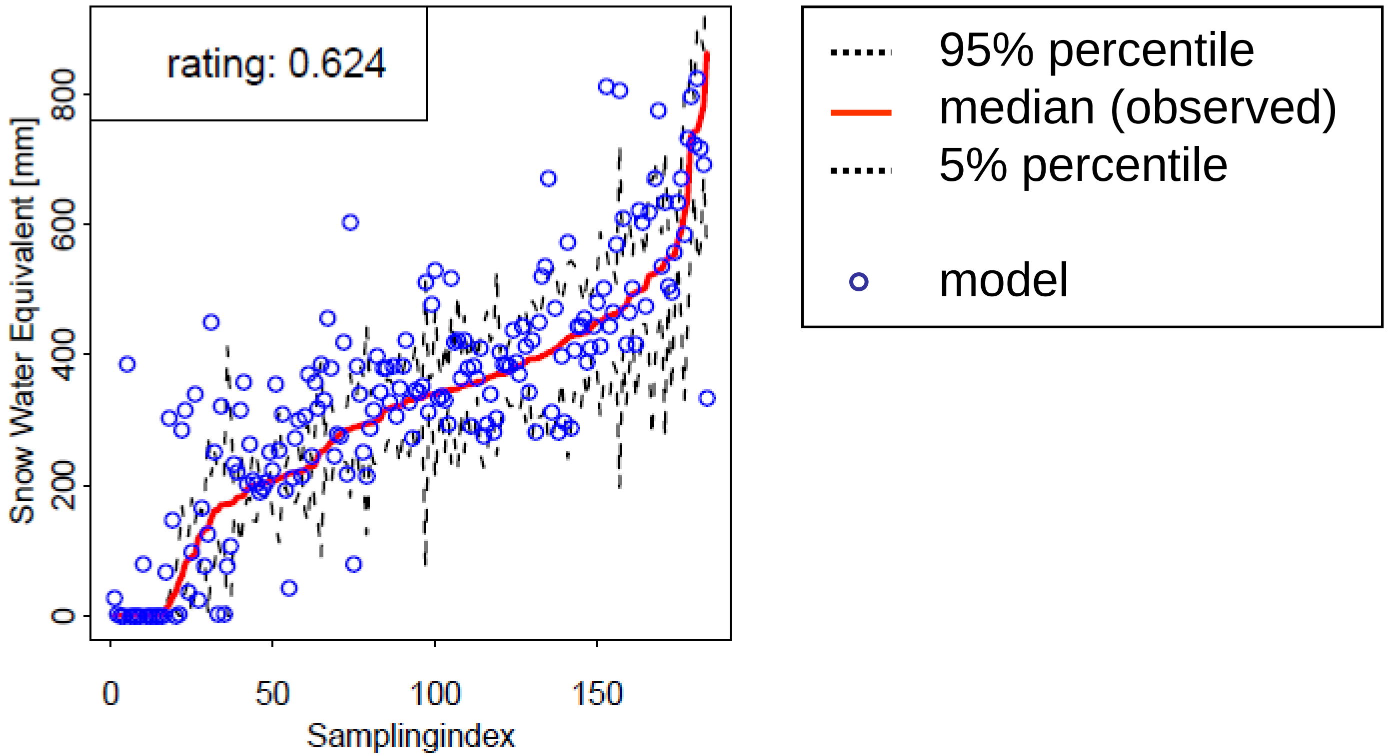


Modeled range of SWE enhanced now,
but still not matching observations
Rating better

Model results (precip pre-processing methods)



constant lapse rate for precipitation (corrected f. undercatch)

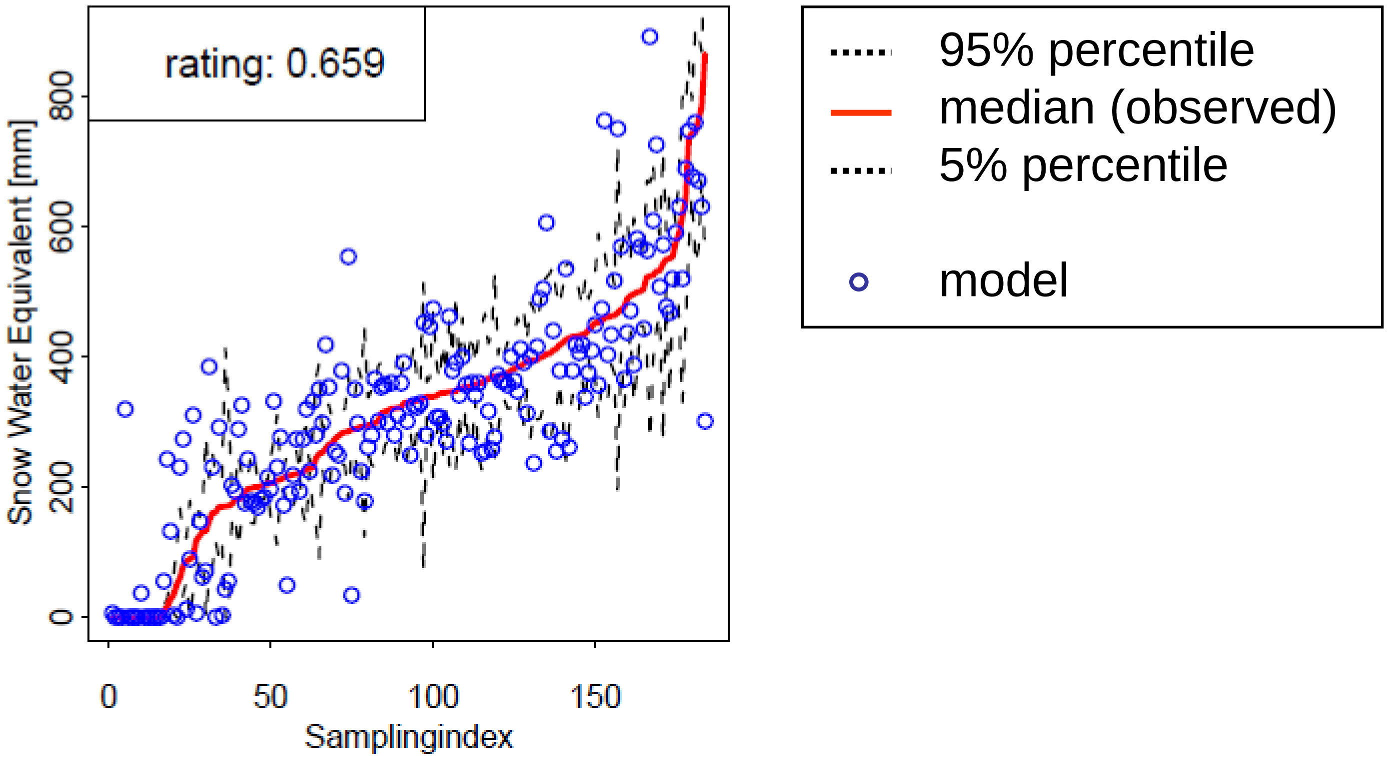


Modeled SWE matches observations much better,
Now SWE partly overestimated (& too much rain in summer)
Rating better

Note: Correction for undercatch according to observations

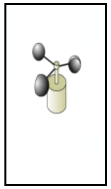
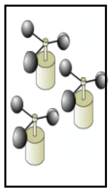
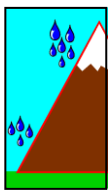
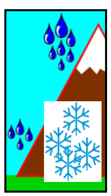
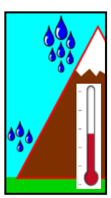
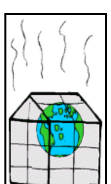
Model results (precip pre-processing methods)

seasonal lapse rate for precipitation (corrected f. undercatch)



Modeled SWE matches observations even better,
Water balance now ok (Σprecip vs. Σrunoff)
Best rating

Model results – summary (Alpine3D only)

	Rating	% within 25%-75%	% within 5%-95%	Δ SWE$_{tot}$
	0.386	0.293	0.620	-46%
	0.505	0.402	0.723	-33%
	0.539	0.435	0.755	-24%
	0.624	0.582	0.788	+9%
	0.659	0.608	0.821	used as reference
		---	---	20yrs: -5% 40yrs: -10%

Summary & take-home message

Part 2: effect of different input data preprocessing schemes

- SWE data / approach allowed quantification of model performance
- model results for several input data preprocessing schemes tested
- in this example seasonal precipitation lapse rates, based on measured data and corrected for undercatch yielded best results
- the choice of preprocessing schemes had huge impact on mod. SWE modeled CC effects on total SWE were comparably small

Sound input data preprocessing and model validation are a key towards accurate snow hydrological model applications

Part 1: validation

- major effort to collect SWE/HS data for validation purposes
- observational techniques, expertise in distr. snow modeling, and available hydromet data make Davos a suitable environment for high-resolution RS validation studies