CC - MoRe

KARL-FRANZENS-UNIVERSITÄT GRAZ
UNIVERSITY OF GRAZ

UNI GRAZ

Trends/changes of snow pack – how well are these simulated with models?
(with focus on the Alps)

Wolfgang Schöner
University of Graz Austria
based on large team of cooperation partners

Content of talk --> 4 questions

- Which data are available to describe snow pack changes on the decadal/centennial scale in the Alps? How are these measurements affected by inhomogeneities?

- Which trends can be observed for snowpack variables in the Alps?

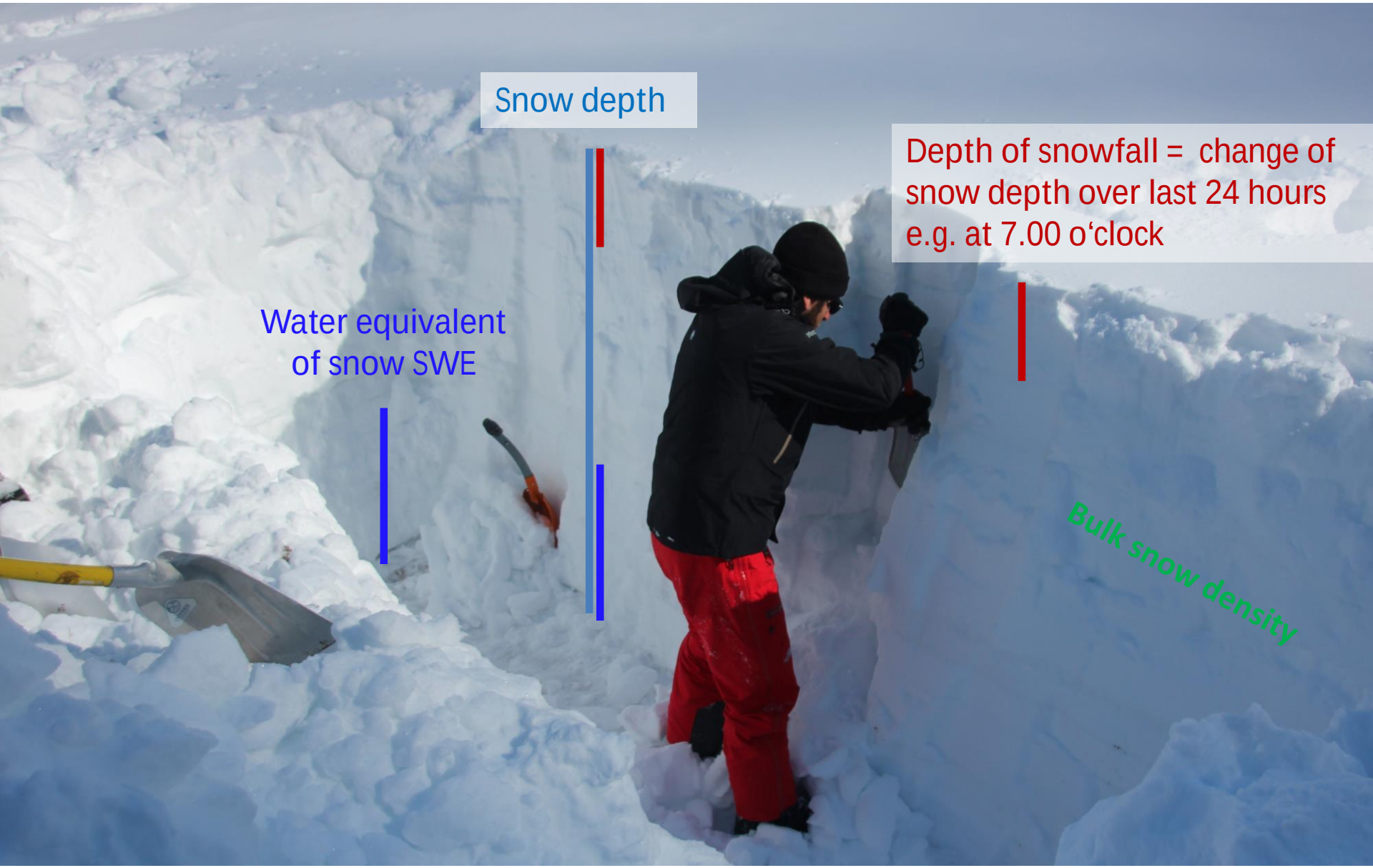
- How well are these changes/trends of snowpack variables are simulated by snow models?
- Are the models good enough to simulate snow melt for runoff simulations?

- What are the main sources of uncertainty in snow melt simulations for studies on runoff in the Alps?

Topic #1

- What data are available to describe snow pack changes on the decadal/centennial scale in the Alps? How are these measurements affected by inhomogeneities?

Measurement of snow pack properties
(on the long-term)

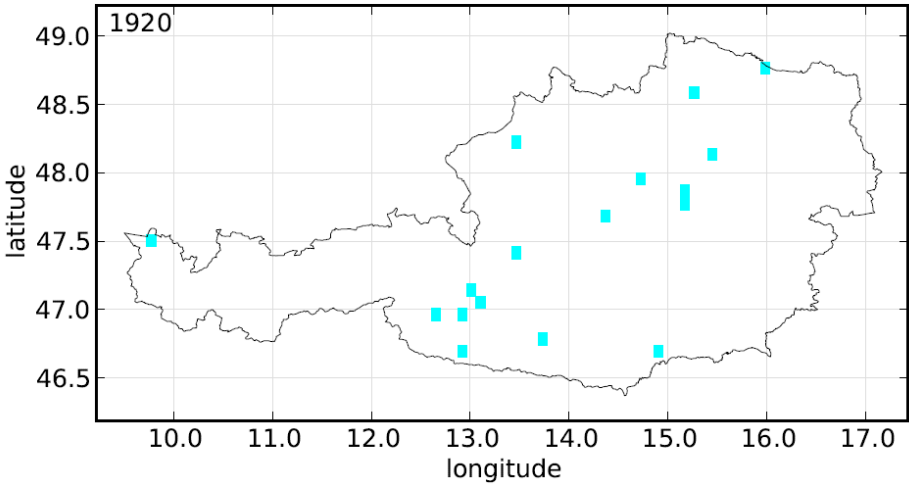


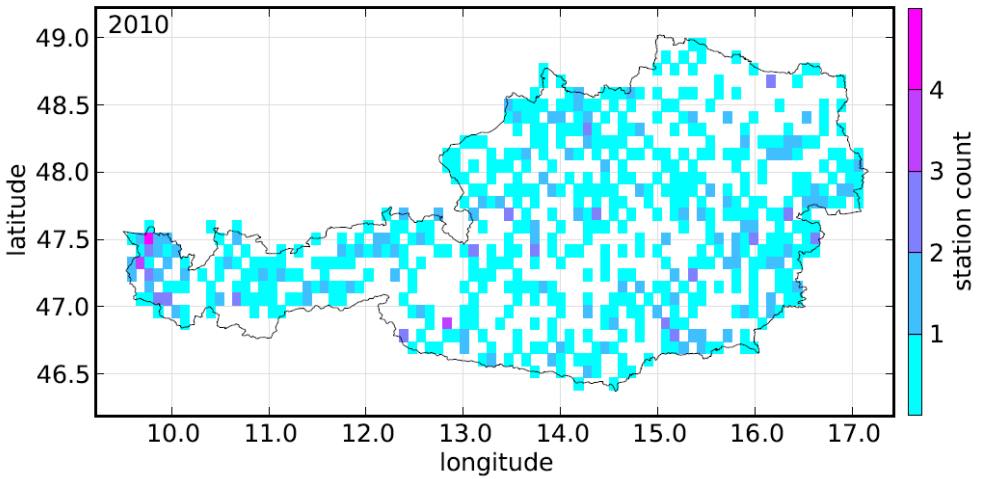
Data availability

Example of Austrian Hydrographic Service

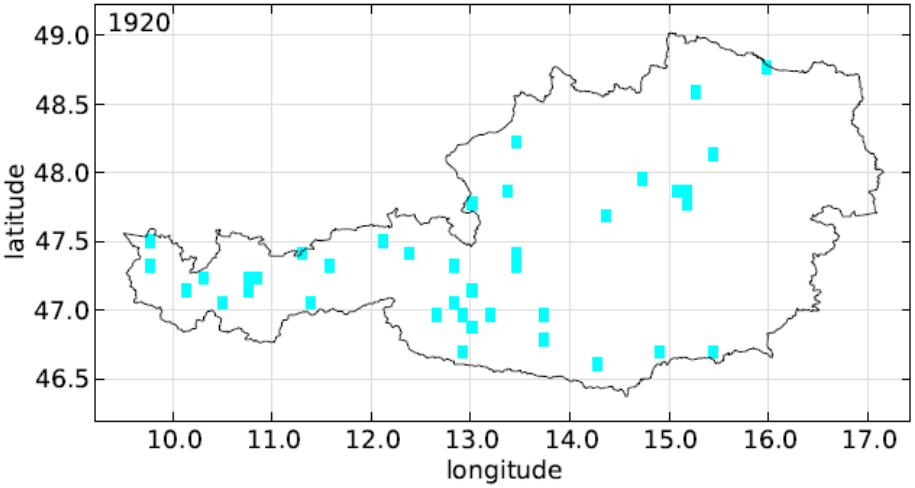
Number of stations per 10x10km², still measuring today

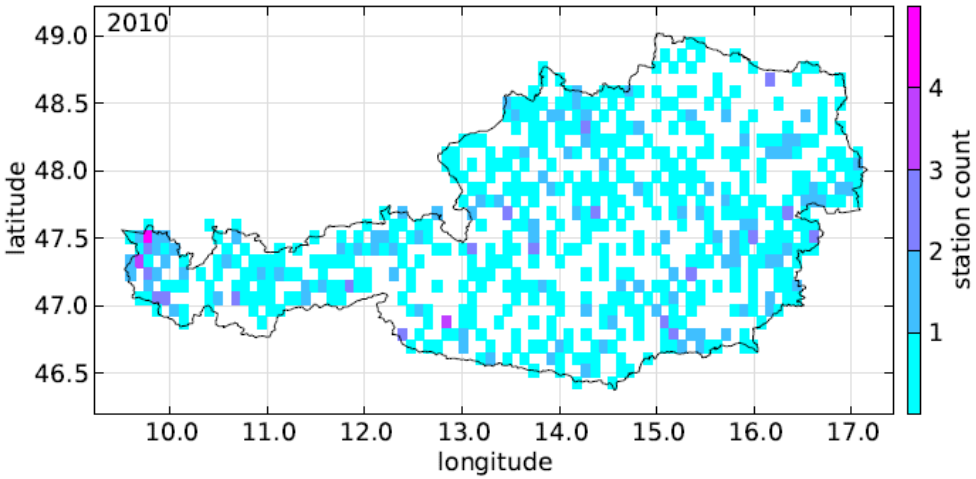
DEPTH OF SNOWFALL





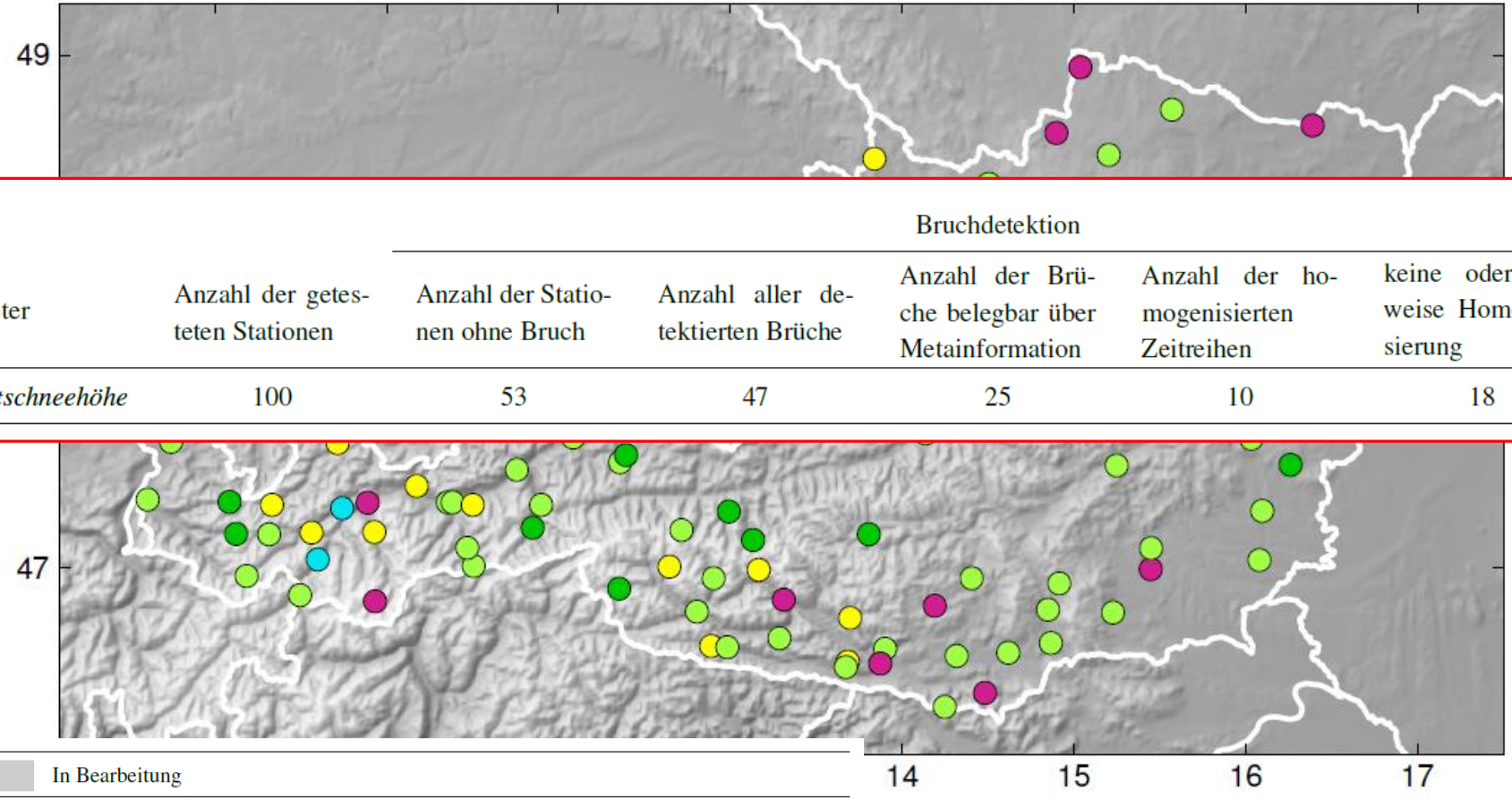
SNOW DEPTH





Homogenization

ZAMG stations

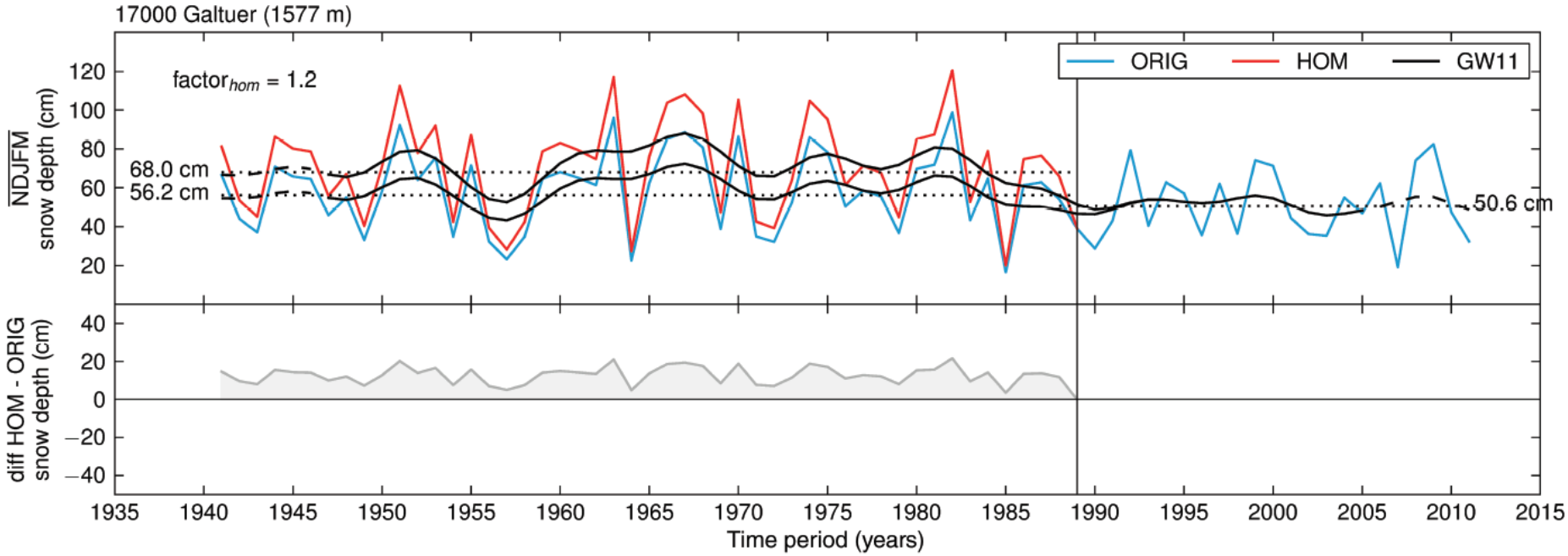


Parameter	Anzahl der getesteten Stationen	Bruchdetektion				
		Anzahl der Stationen ohne Bruch	Anzahl aller detektierten Brüche	Anzahl der Brüche belegbar über Metainformation	Anzahl der homogenisierten Zeitreihen	keine oder teilweise Homogenisierung
Gesamtschneehöhe	100	53	47	25	10	18

	In Bearbeitung
	Keine Brüche detektiert (homogene Reihe)
	Bruch detektiert, Homogenisierung durchgeführt
	keine Homogensierung möglich
	Detektion von Bruch um angebenes Datum bei vergleichsweise geringen Schneehöhen; keine weiteren Brüche detektiert; Zeitreihe kann als homogen angsehen werden
	Eines der 3 Kriterien CAU, JON oder LEB liefert Division durch Null (Inf); Ursache ist vermutlich eine zu geringe Anzahl von Referenzstationen für die auszuwertende Zeitperioden sowie zuwenig Messwerte, der Kandidatsstation (Beobachtungslücken)

Homogenization of snow depth

Ex: Galtür (Austria)



Sounds less, but:

- Impact on trend
- Snow – no snow

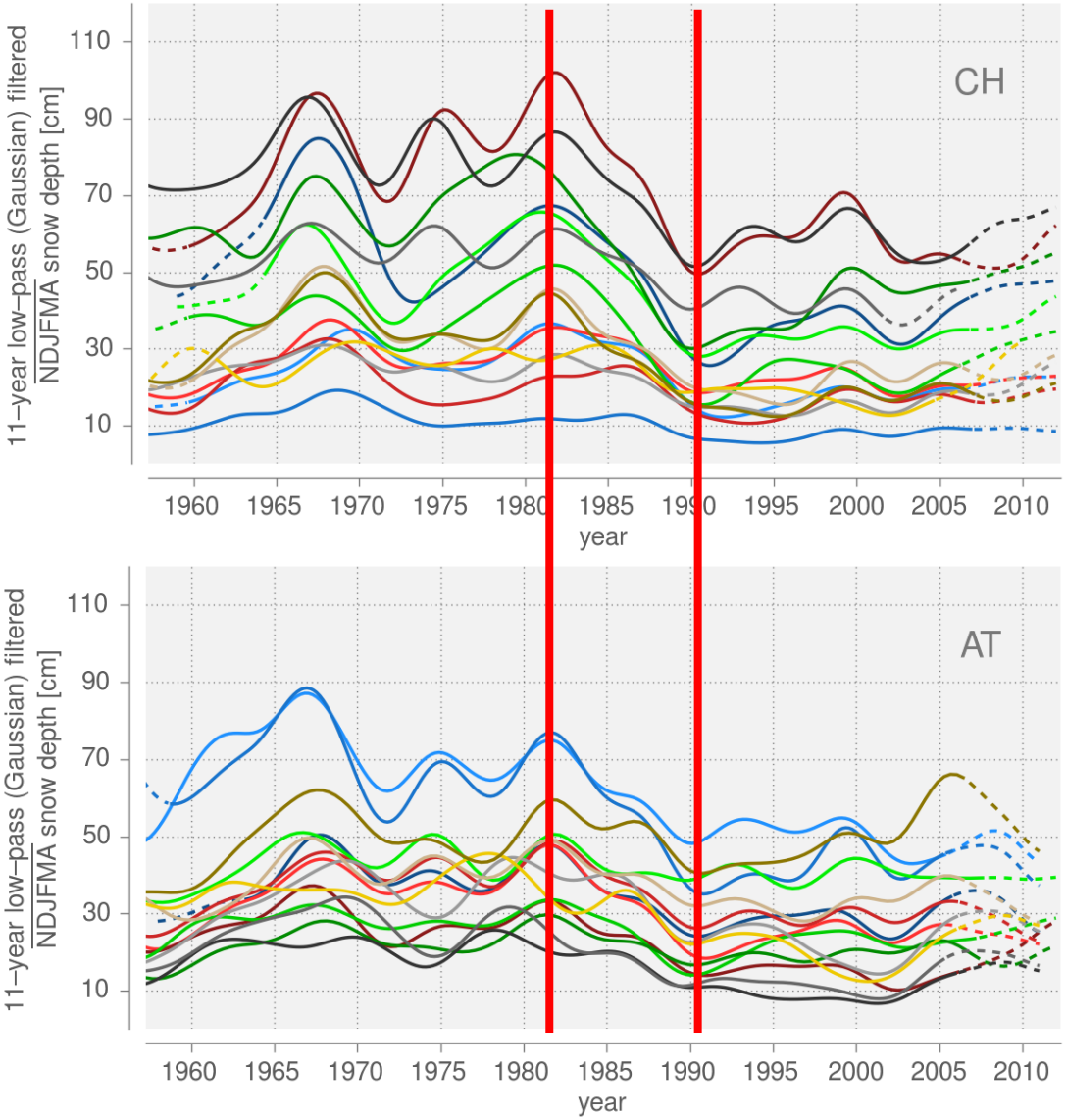
Source: Schöner et al., 2018

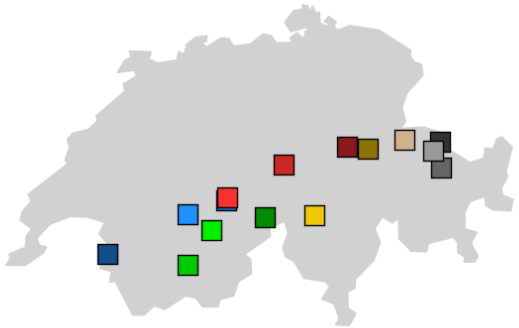
Topic #2

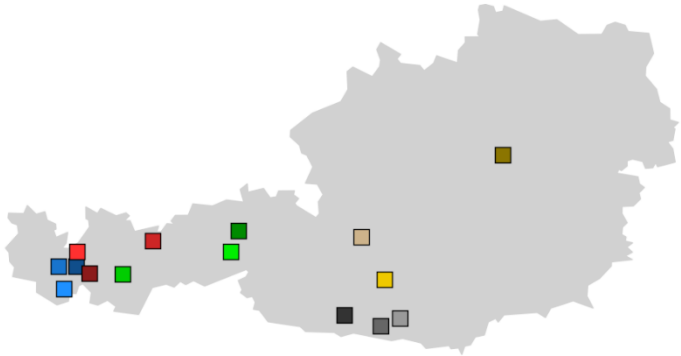
- Which trends can be observed for snowpack variables in the Alps?

Time series of mean snow depth

800 - 1600m.a.s.l. (climate-sensitive elevation zone)

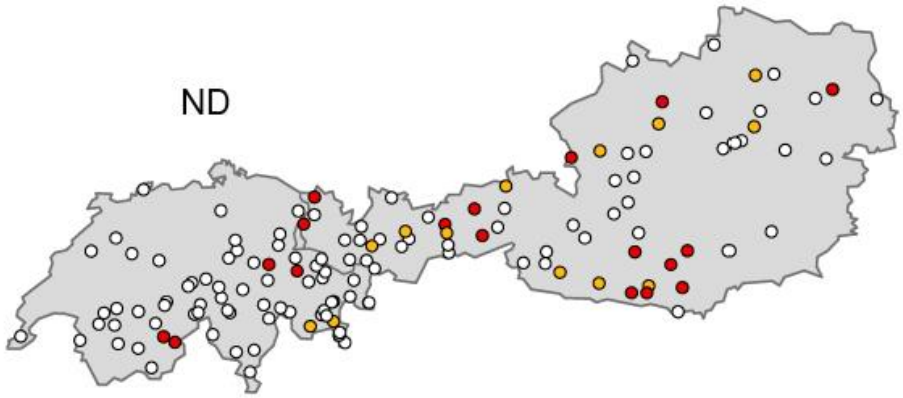


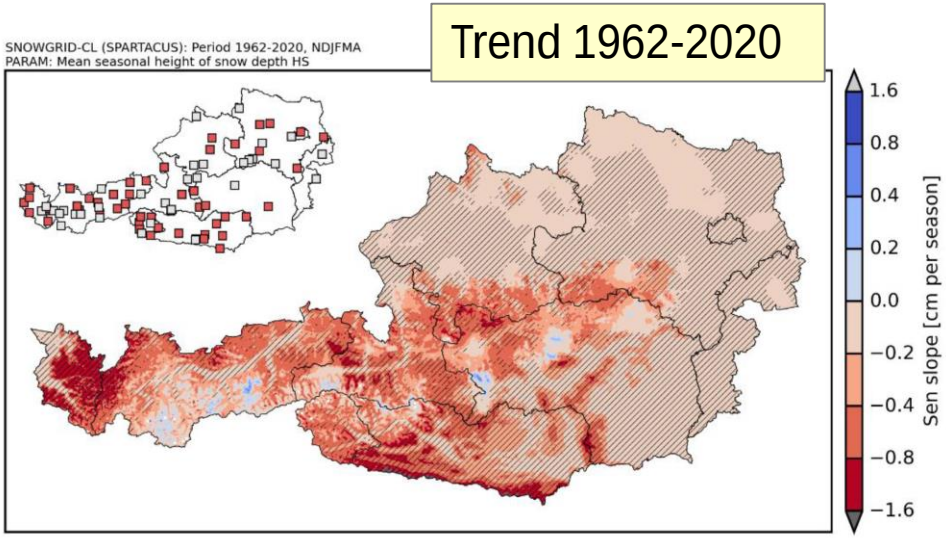


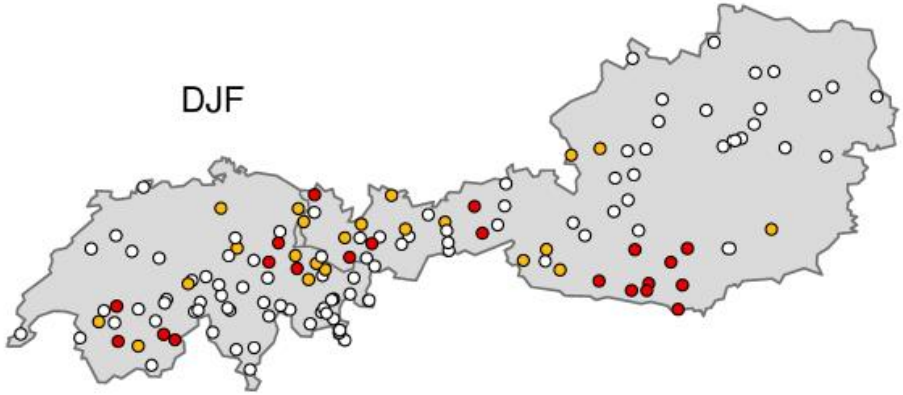


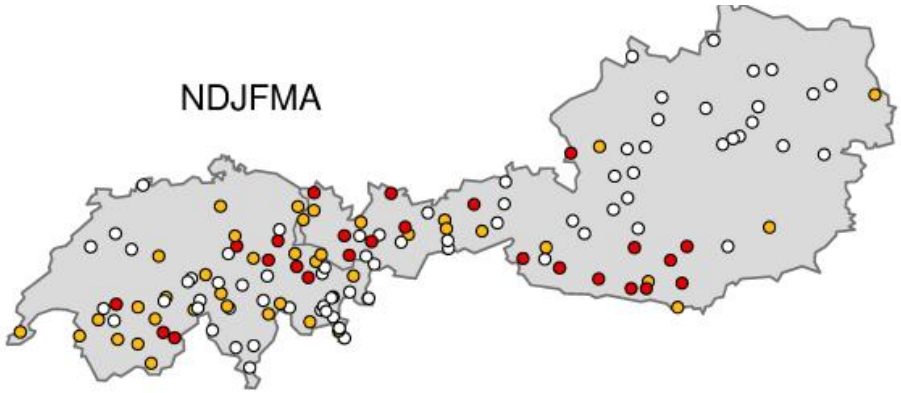
Trend of mean snow depth (diff. seasons)

Trend (Mann-Kendall) 1961-2010









- Sign. Negative 99%
- Sign. Negative 95%
- No trend

Source: Schöner et al., 2018
and Olefs et al., 2021

Topic #3

- How well are these changes/trends of snowpack variables are simulated by snow models?
- Are the models good enough to simulate snow melt for runoff simulations?

The ZAMG SNOWGRID model
Climate mode

SNOWGRID Snowcover model:

<u>Operational forecast mode</u>:

Physically-based and spatially distributed scheme

→ forced by INCA, radiation products, satellite products, …

<u>Climate mode:</u>

Adapted and extended degree-day scheme

→ forced by ZAMG Spartacus gridded air temperature, precipitation and shortwave radiation balance, pot. evapotranspiration

Source: Olefs et al., 2021

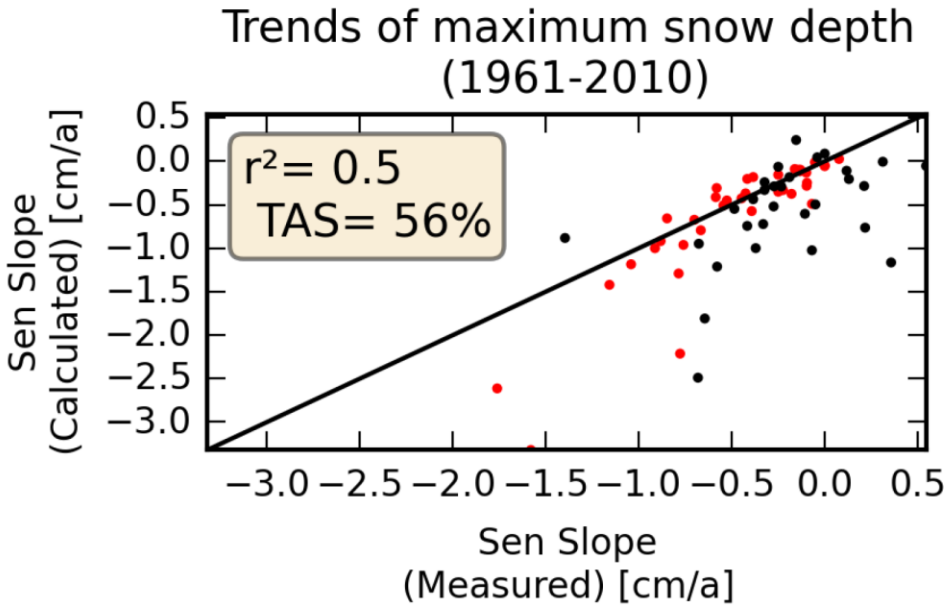
The ZAMG SNOWGRID model

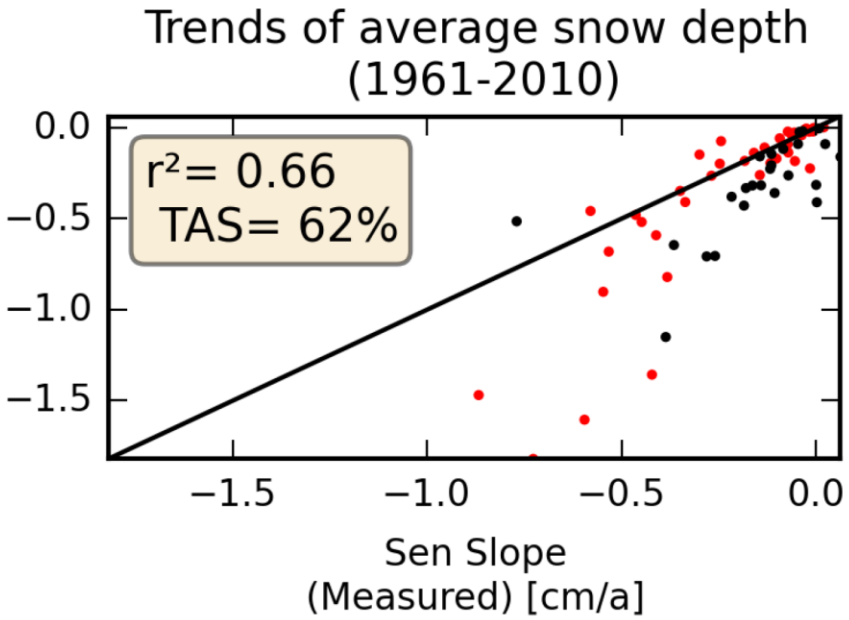
Climate mode, VALIDATION
NDJFMA 1961/62 – 2017/18

Validation Dataset	# of Observations	R^2	RMSE	BIAS	KSS
HS observations (seasonal average NDJFMA) (SNOWPAT), 1962–2018	4884	0.86	10.23 cm	2.86 cm	–
SCD seasonal (# of days with HS ≥ 1 cm; NDJFMA), 1962–2018	4884	0.86	17 days	4 days	–
HS observations (daily, NDJFMA) (TAWES, 2011–2018)	65,552	0.83	14.11 cm	−3.12 cm	–
SWE observations (daily, NDJMA), 1989–2015	6532	0.91	99 kg/m^2	−60 kg/m^2	–
MODIS FSC, 2011–2016	600 scenes	–	–	–	0.69

Source: Olefs et al., 2021

Temporal trend of snow depth
Trend (Mann-Kendall)



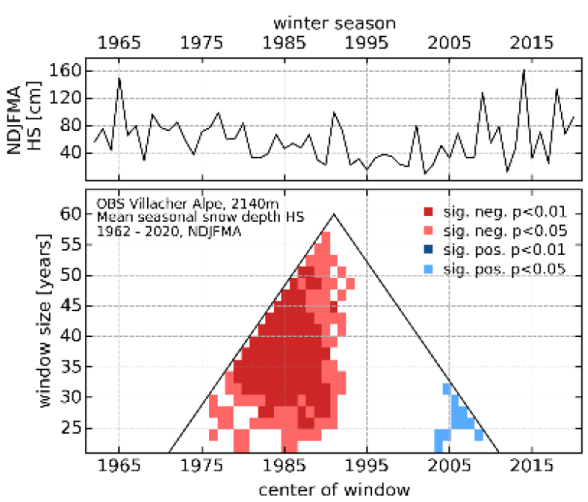


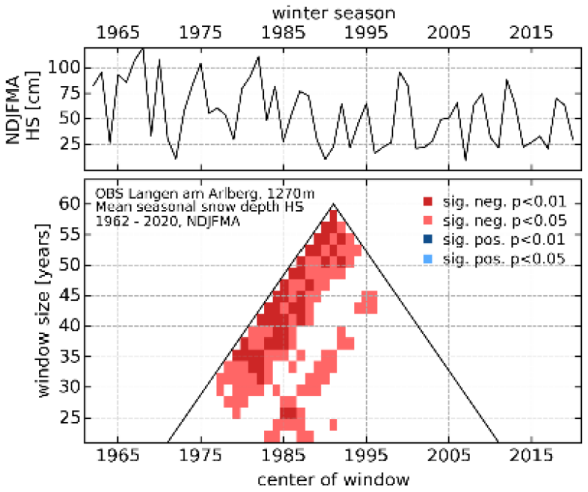
Source: Olefs et al., 2021

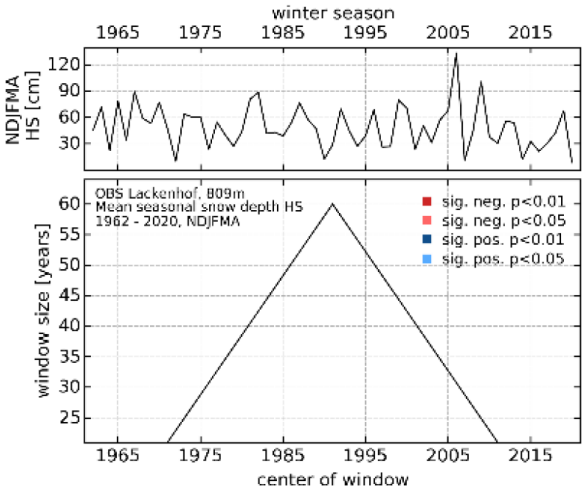
Temporal trend of snow depth

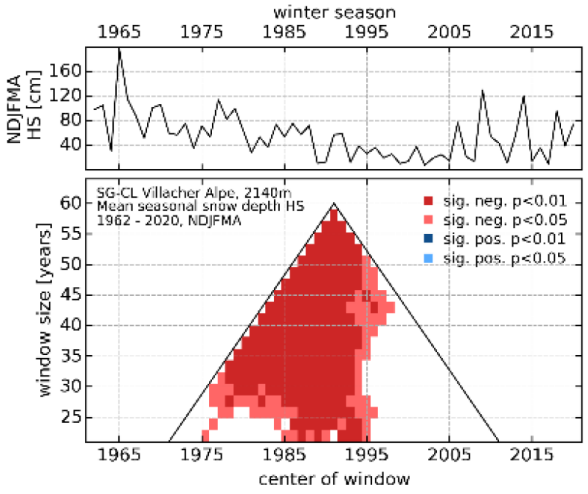
Trend (Mann-Kendall)

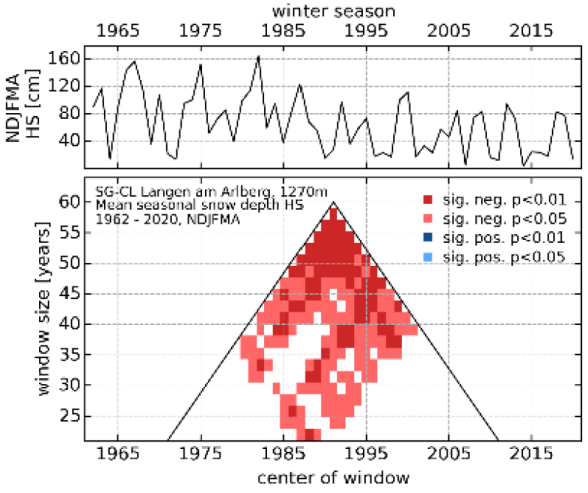
OBSERVATION

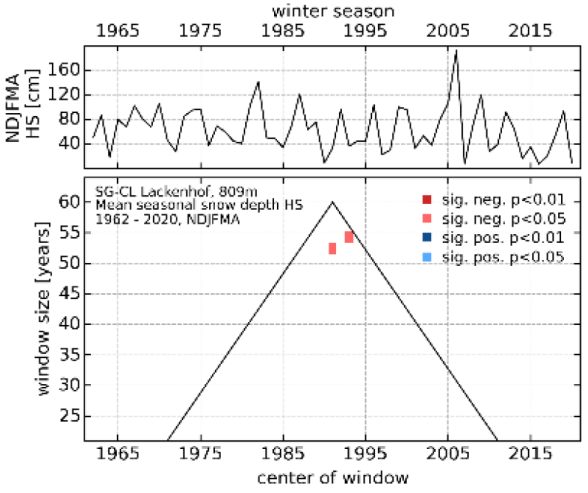












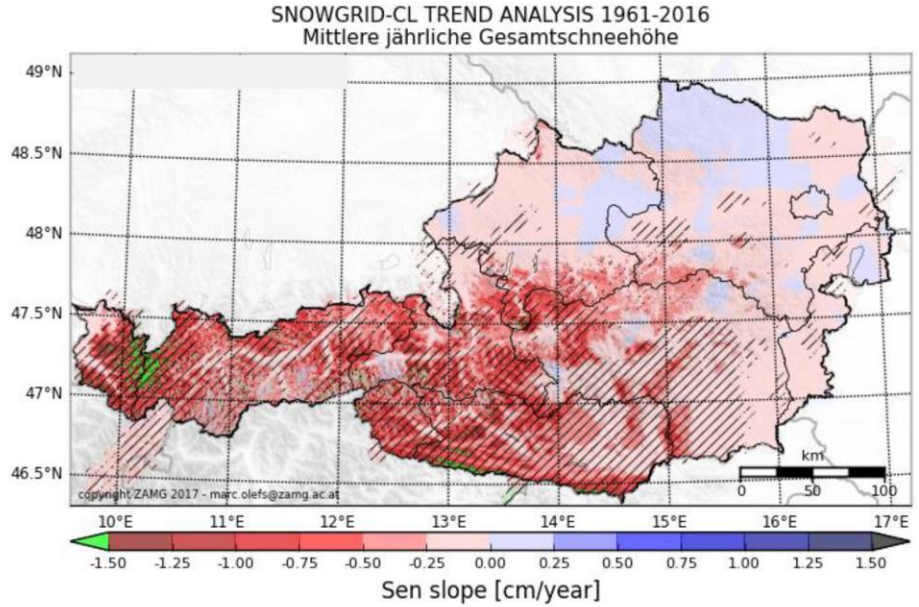
MODEL

Source: Olefs et al., 2021

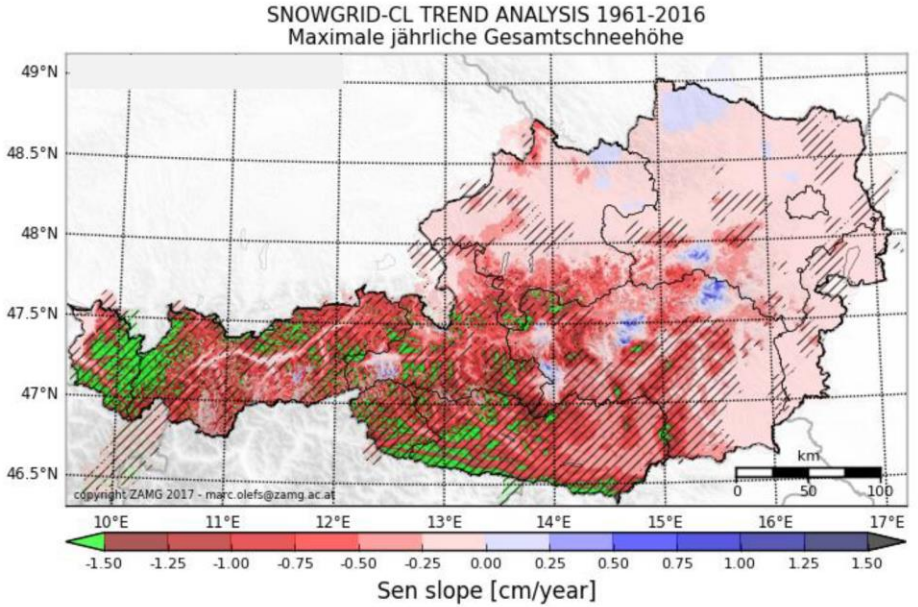
Temporal trend of snow depth

Trend (Mann-Kendall)

Benefit of snow model



Trend: -2.7cm/decade
1961-2015: 15cm
Climate mean (1981-2010): 34cm

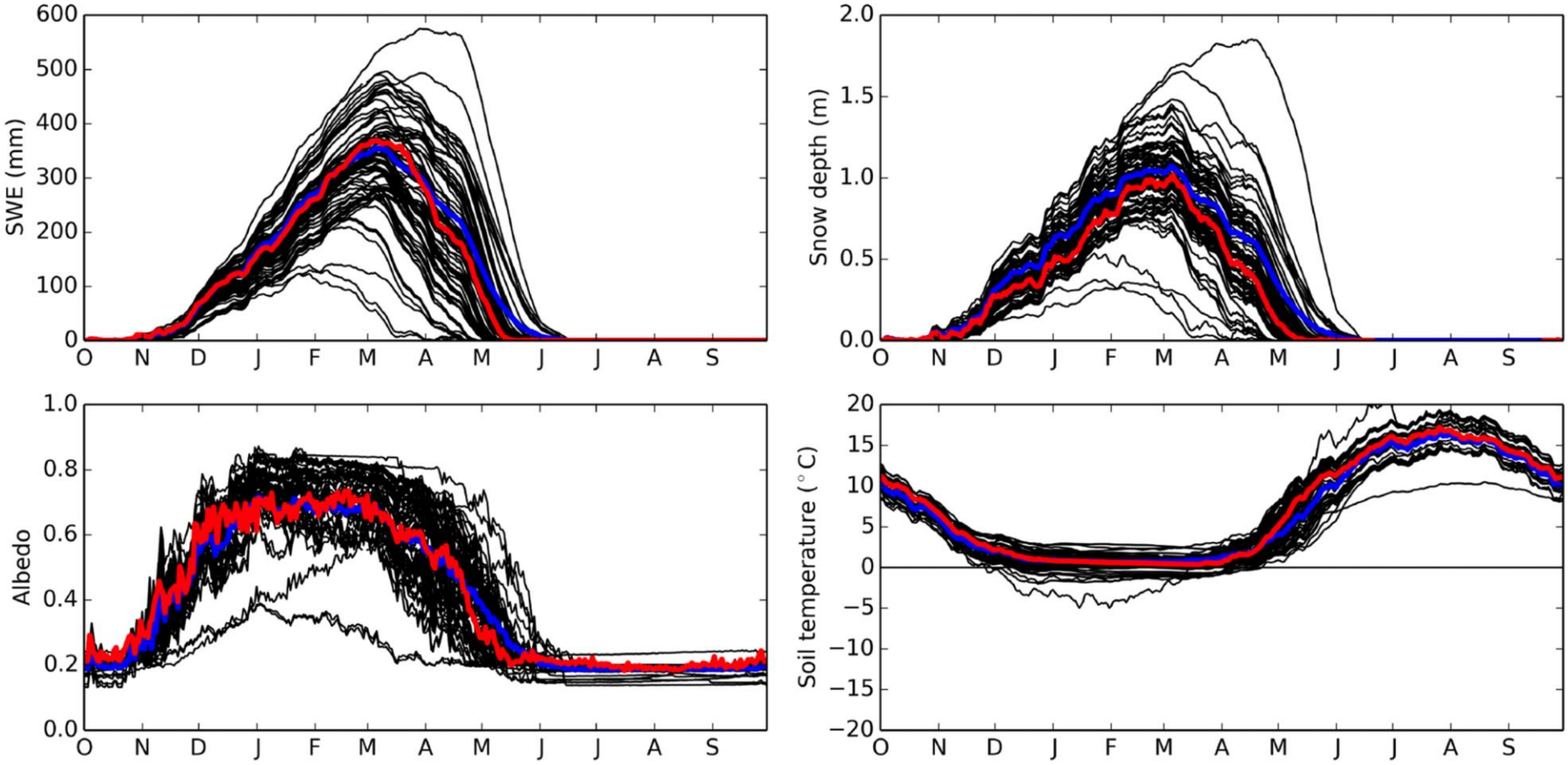


Trend: -5cm/decade
1961-2015: 28cm
Climate mean (1981-2010): 73cm

Source: Olefs et al., 2021

Snow-MIP

Snow model intercomparison experiment
>30 (physical based) models incl. land surface schemes of climate models
Col de Porte (France)



Red ... Observations
Blue ... Mean of all models

Source: Krinner et al., 2018

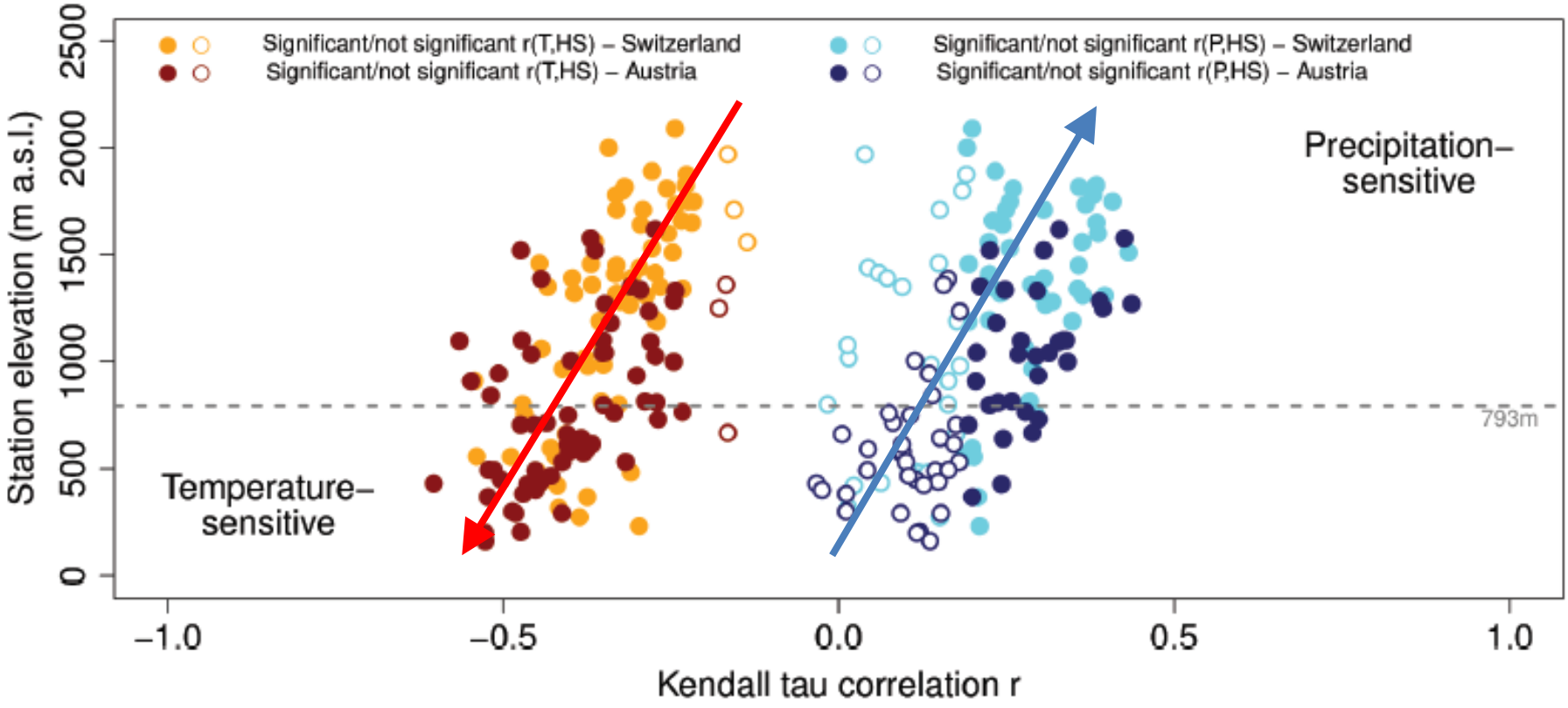
Topic #4

- What are the main sources of uncertainty in snow melt simulations for runoff studies in the Alps?

Sensitivity of mean snow depth changes

to air temperature and precipitation

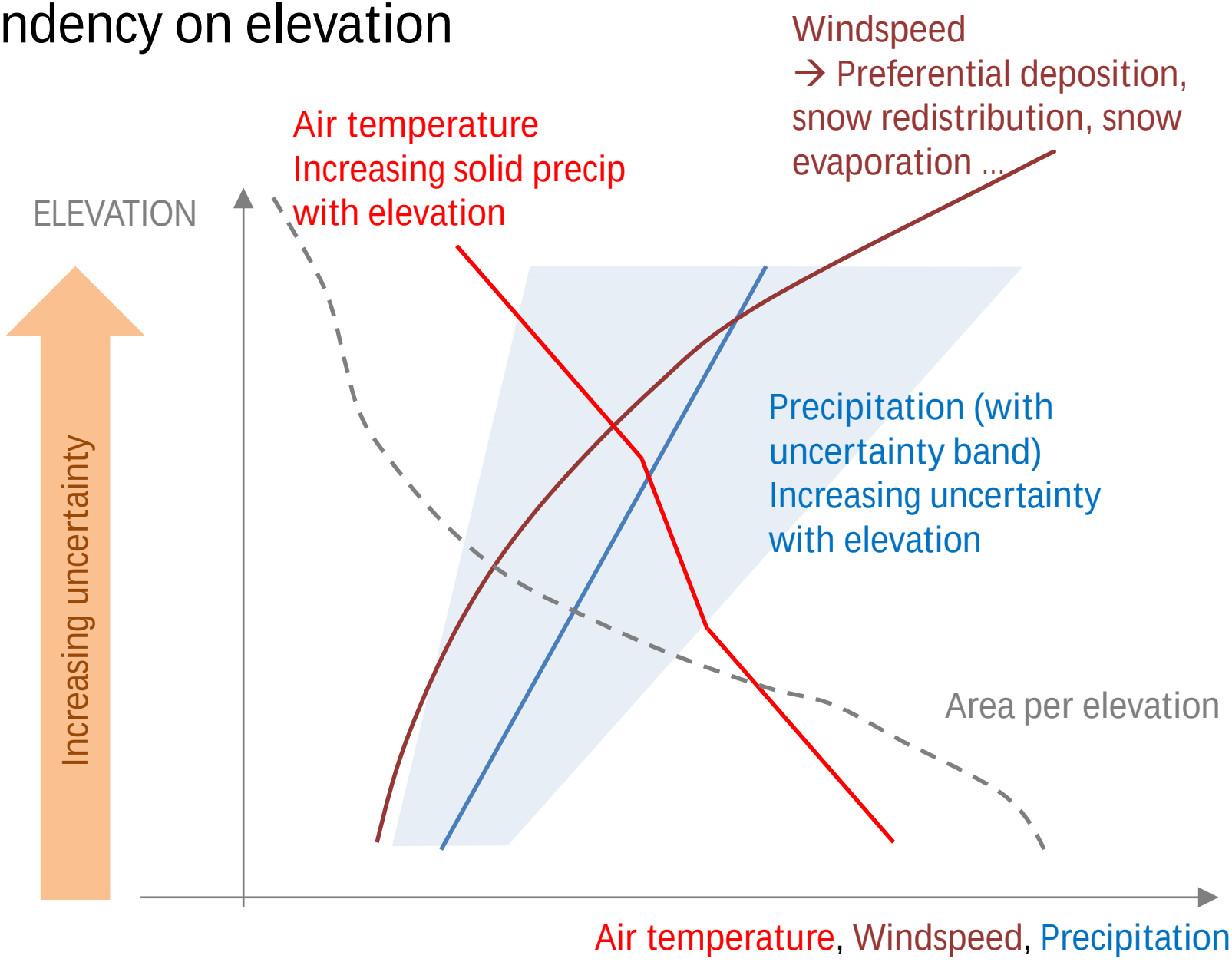
Switzerland and Austria



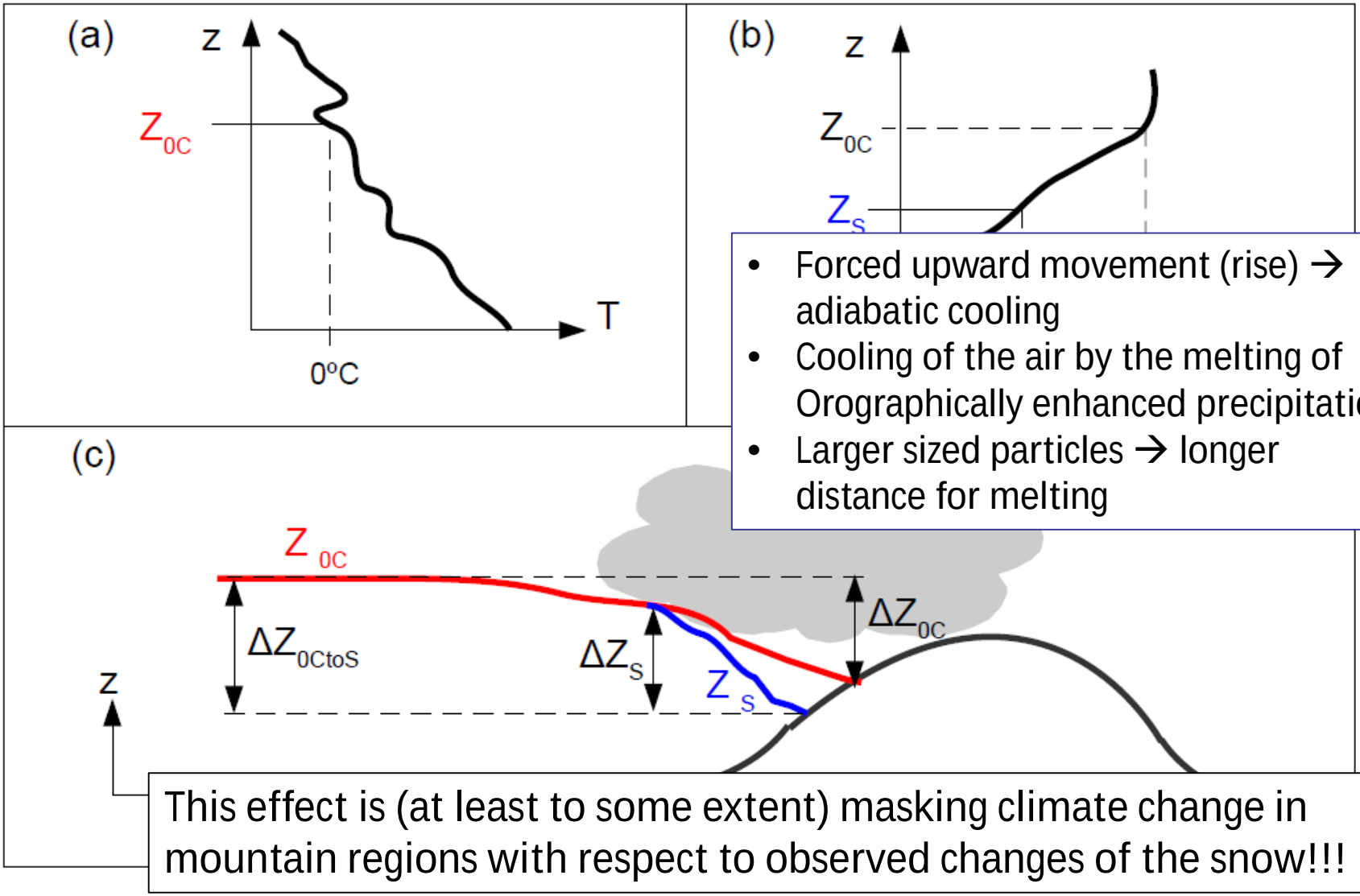
Source: Schöner et al., 2018

Uncertainty in snow modelling

dependency on elevation



Altitude of 0° line vs. Snowfall line



- Forced upward movement (rise) → adiabatic cooling
- Cooling of the air by the melting of Orographically enhanced precipitation
- Larger sized particles → longer distance for melting

This effect is (at least to some extent) masking climate change in mountain regions with respect to observed changes of the snow!!!

Source: Minder et al., 2010

Take home:

- Decadal/century-long changes of snow pack properties in the Alps can be described by snow depth and depth of snowfall (SWE, snow density) measurements. Homogeneity of snow series is an issue to be tackled.
- Snow models are generally able to simulate snow depth/SWE well. Performance decrease for extreme values and for higher temporal resolution (e.g. daily snow depth compared to monthly mean snow depth). Simulation performance for snow depth/SWE also decrease with elevation.
- Main uncertainty of snow model simulations comes from accumulation processes (and generally increases with elevation).
- *(i) Many mountain regions worldwide are strongly undersampled for snow properties (and changes are not really known). (ii) We mainly look at quantity not quality of water stored in snow pack (we should improve in the future).*

Joint Body SMSC: Status of the Mountain Snow Cover

Highlight the relevance of the mountain snow cover in general. The main objectives are:

Robust information on mountain snow cover changes at a global scale in the past few decades *based on compiling and standardizing existing data (sources) at sufficiently high resolution.* (including surface observations, remote sensing products, downscaled reanalysis data and snow model simulations).

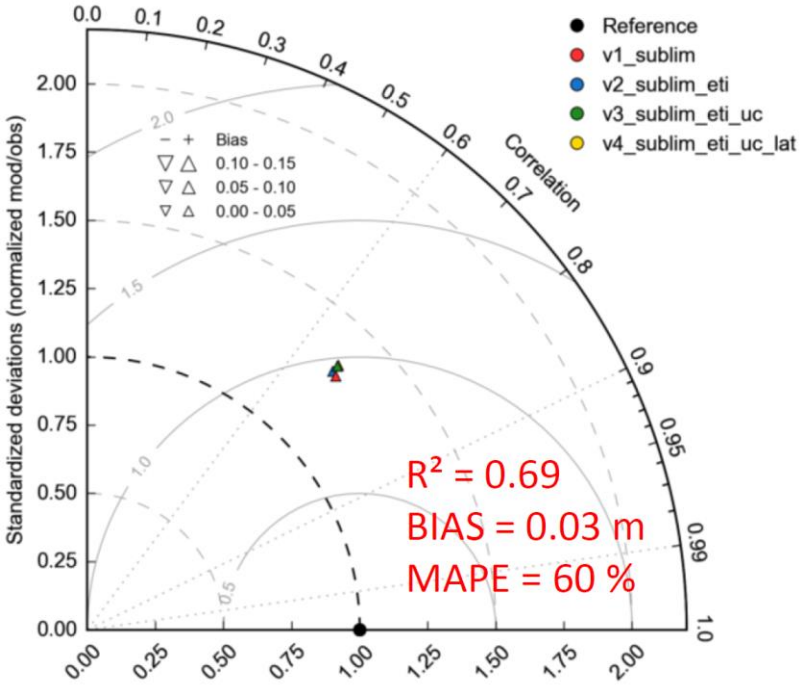
Better understanding of processes of accumulation and ablation based on existing modelling and observational studies;

Open access to the snow data for the research community, and to contribute to the operational capacity building in terms of understanding mountain snow cover changes and its impacts on and responses to climate, water and environment.

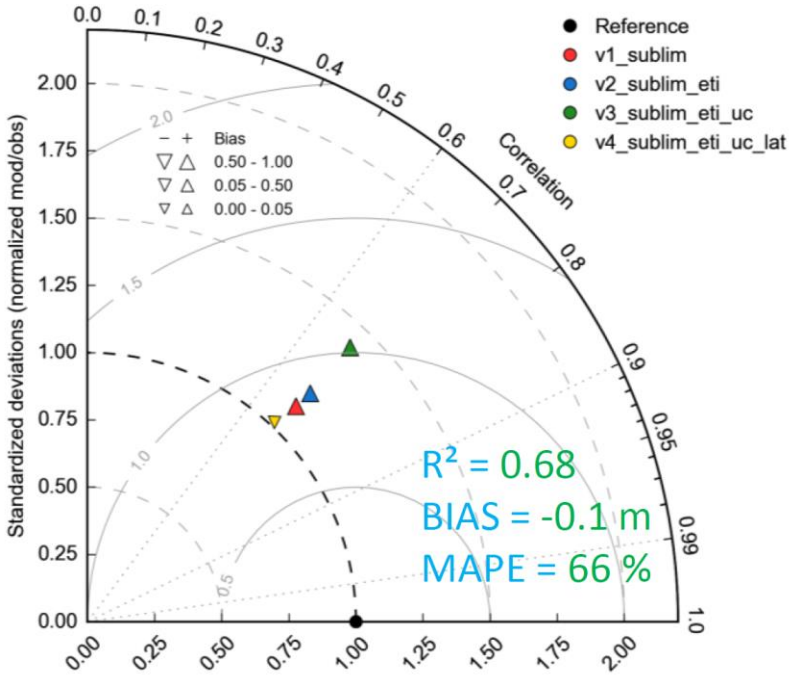
Thank you!

The ZAMG SNOWGRID model
Climate mode, VALIDATION

SNOWPAT 1961-2010



TAWES 2011-2016 & LWD 2011-2016



Source: Olefs et al., 2021