Extreme snow loads

a natural hazard

EUMeTrain – SNOW Event Week
February 11, 2021
Michael Winkler, ZAMG Innsbruck (AT)

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Snow on roofs

Snow cover preserves and sums up precipitated mass.

snow load = snow water equivalent *times* gravit. accel.
*SL = SWE*g* [kN/m²]

SWE = snow height *times* bulk density ->
*SWE = HS*ρ*$_b$ = $\sum_i hs_i * \rho_i$

However, snow is a stratified medium.

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However, snow is a stratified medium.

Settling – Densification
Wind drift
Creeping – Gliding
Rain-on-snow
Melting – Refreezing
Melt water damming
Differential stress
…

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Damages by recent extreme snow load events

In Austria and neighboring regions:

- 2006 (Northern Alps, 15 deaths)
- 2008/09 (Southern Alps, roof damages)
- 2014 (Southern Alps, collapses of barns)
- 2012 (Northern Alps, collapses of side buildings)
- 2017 and 2018 (Northern Alps)
- 2021 Southern Alps (many collapses of buildings)

Jan 25, 2021, Tristach (AT)
© P. Fuetsch

yesterday, Sterzing (IT)
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Jan 03, 2021, Matrei (AT)
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Not always roof collapses and fatalities in buildings, but

- deaths and injuries while shoveling
- dead animals
- total losses of roof frameworks
- high expenses (shoveling, renovation)

Jan 2021, Lienz (AT)
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Jan 2021, Kötschach (AT)
© C. Gratzer

Not least, due to wrong or too conservative snow load assessments

- high expenses
- destortion of business competition –
  in favour of e.g. concrete
  to the disfavour of timber construction, superstructures like solar panels…

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However,…

… **extreme snow loads** only rarely are considered as **natural hazards!**

Jan 2021, East Tyrol (AT)
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What is the assessment basis for structures and buildings?

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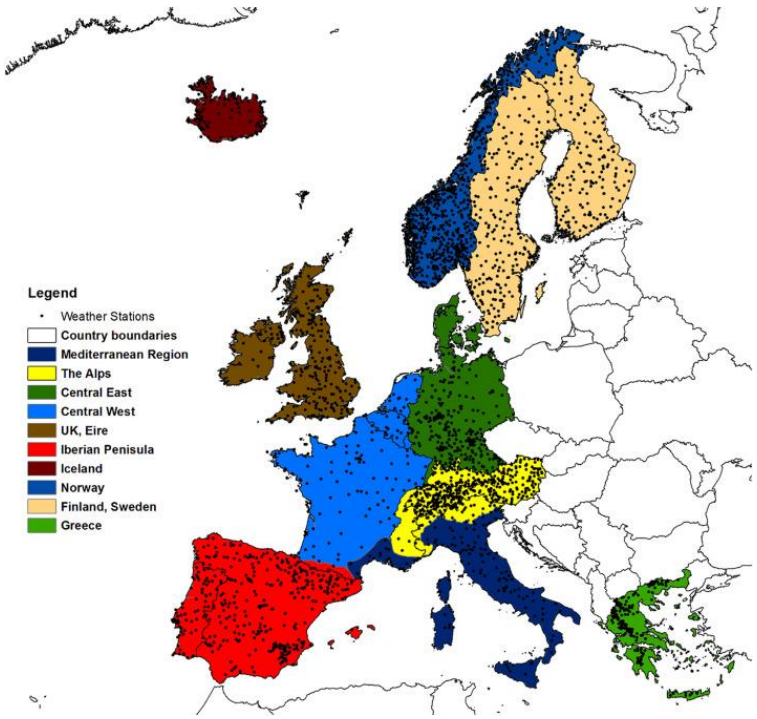
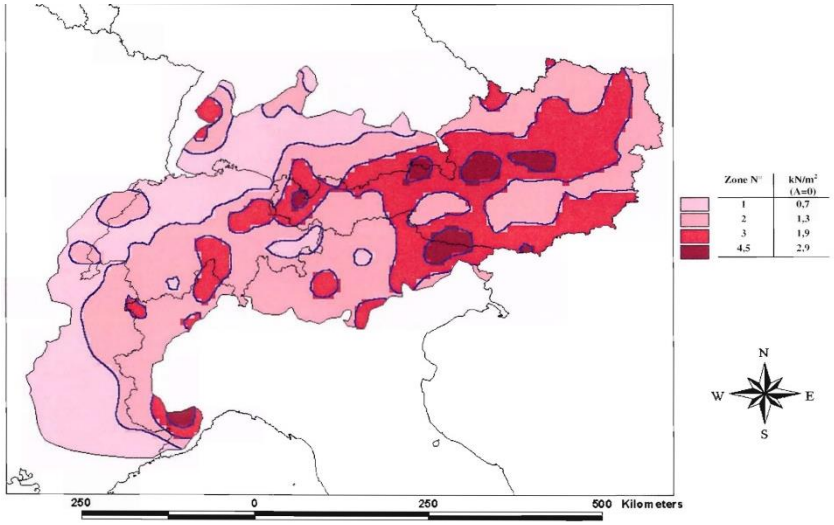
European Standard: Eurocode EN 1991-1-3

„meteorological“ base: **characteristic snow load on the ground s_k [kN/m²]**
s_k from extreme value statistics: **50 year return period** = 2% yearly probability of exeedance

-> „snow load maps“





$$s_k = (0.642 \cdot Z + 0.009) \cdot \left[1 + \left(\frac{A}{728}\right)^2\right]$$

with A…altitude and Z…zone number

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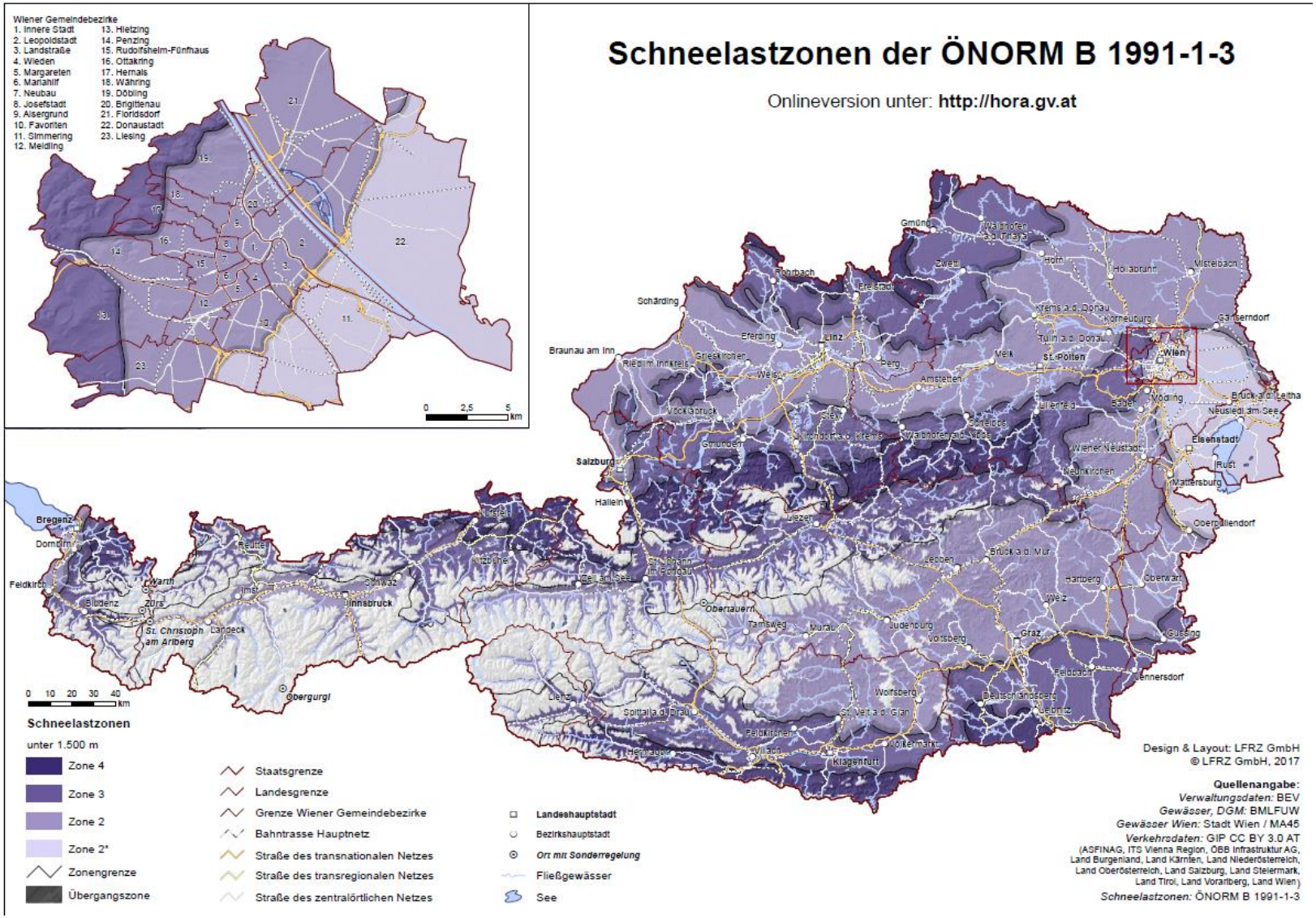
Actual Austrian snow load map



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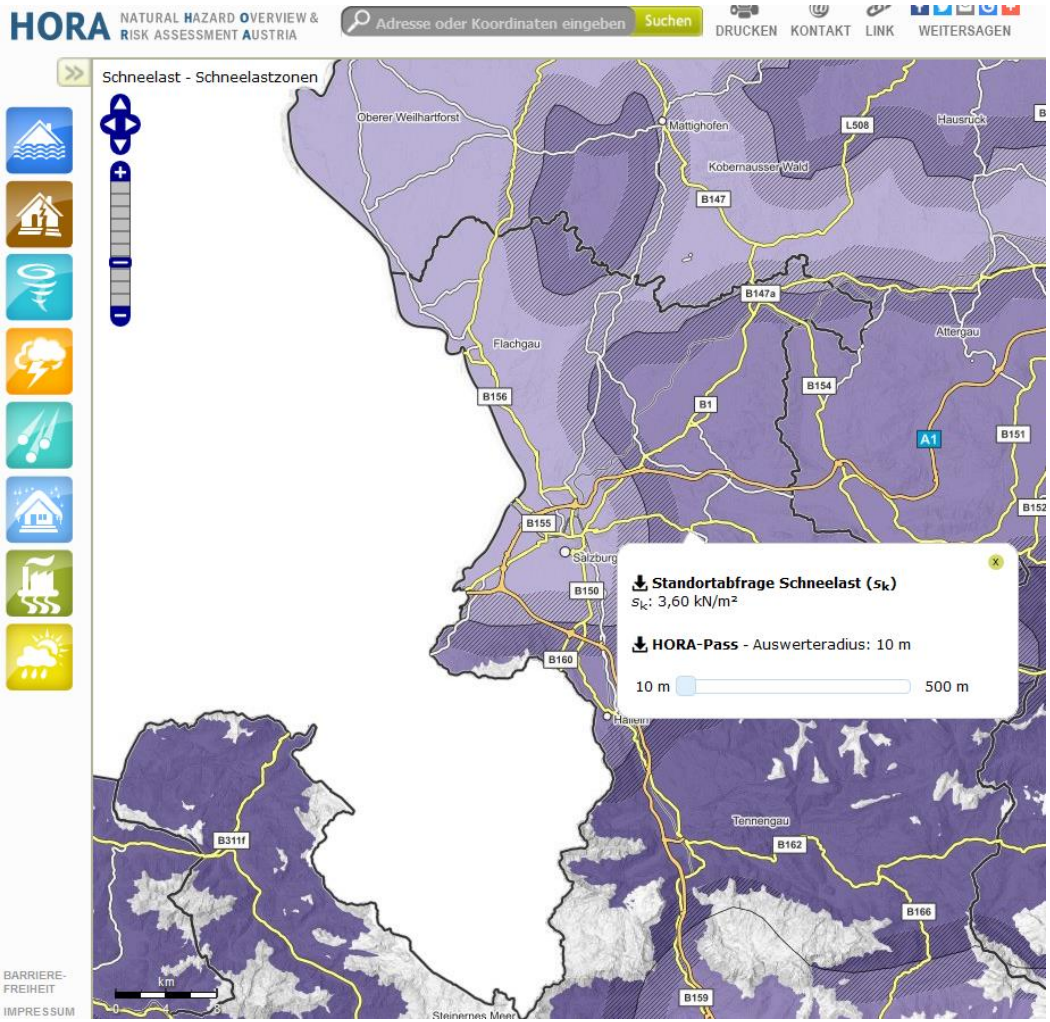
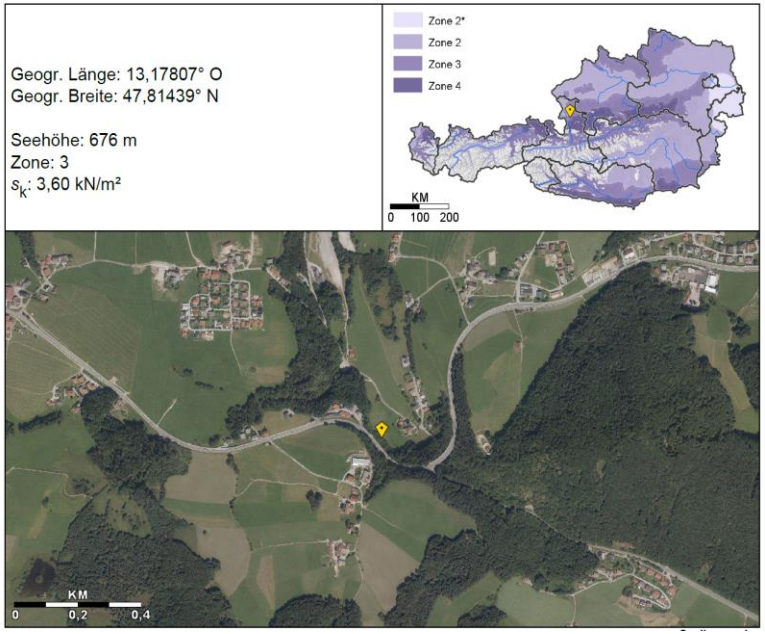
Online at https://hora.gv.at



Charakteristische Schneelast am Boden s_k



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Snow load map: Status quo and problems (in Austria)

- snow load map was renewed **15 years** ago (ÖNORM B 1991-1-3:2006)
- still **one of the most detailed** snow load maps
- **4 main zones** with 5km transition zones in between
  (to make zonings are internationally common)
- valid up to **1500m** asl.
  (also internationally common)

Problems -> motivation for new approaches:

1. **data base** mostly ends in the **1980s**
2. It‘s snow depth data. **How about snow density?**
3. **drawing of the zones** is meteorologically sound, but **subjective and not reproducible**
4. zonings force **„jumps“**
5. **>1500m?**
6. „jumps“ at **national borders**

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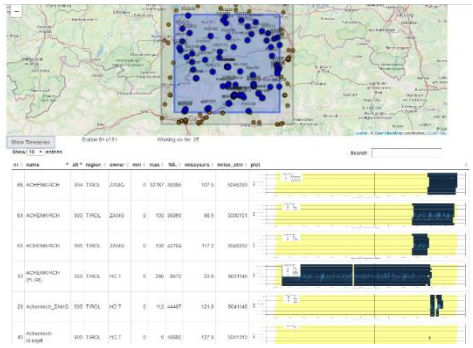
Project **Schneelast.Reform - Methods**

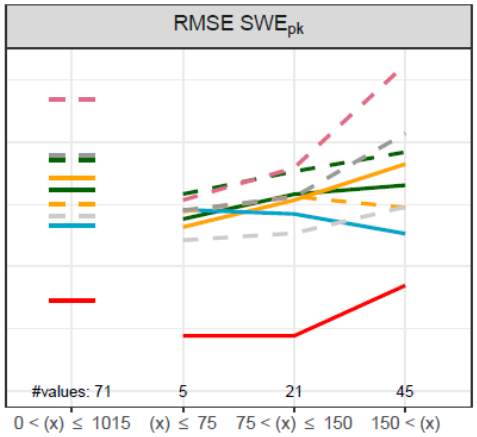
Data

- Longterm (>30 years), daily snow depths records from A, D, CH, IT, SLO
- Quality checks
- Corrections
- Gap filling



snow model

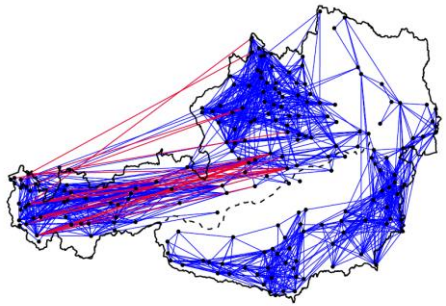
to get snow loads (SWE) from snow depth data



extreme value model

PhD Thesis of H. Schellander

ON THE SPATIAL MODELING OF METEOROLOGICAL EXTREME VALUES



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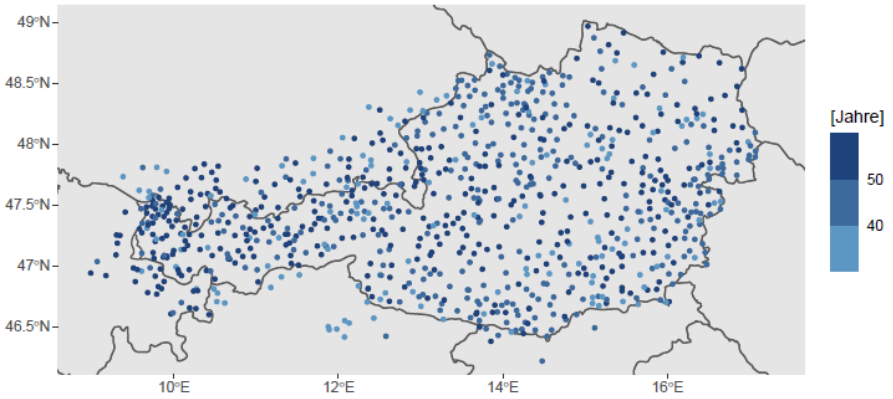
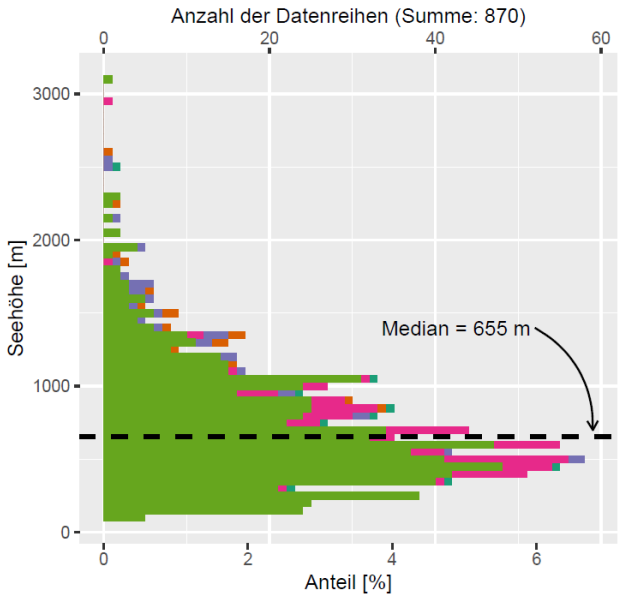
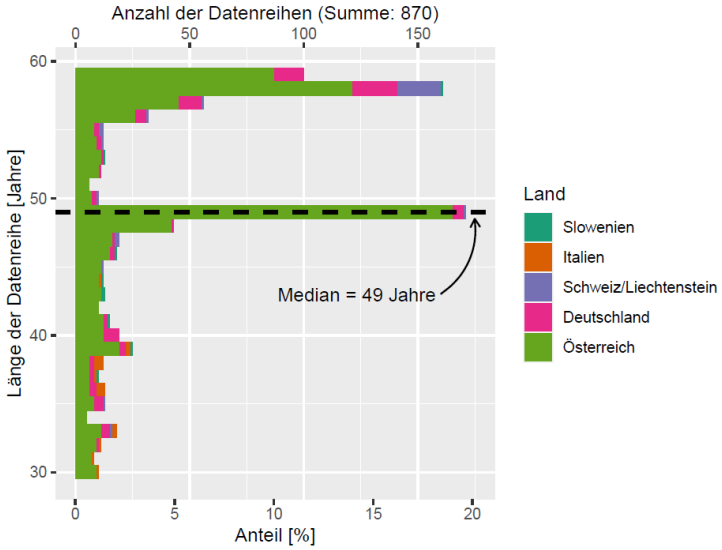
Project **Schneelast.Reform** - Results: **Data**

- gapless, daily snow depths
- from 870 stations
- evenly distributed (horizontal)
- between 118m and 3109m altitude
- each record covers at least 30 winters
- between 1960 and 2019
- median record length is 49 years







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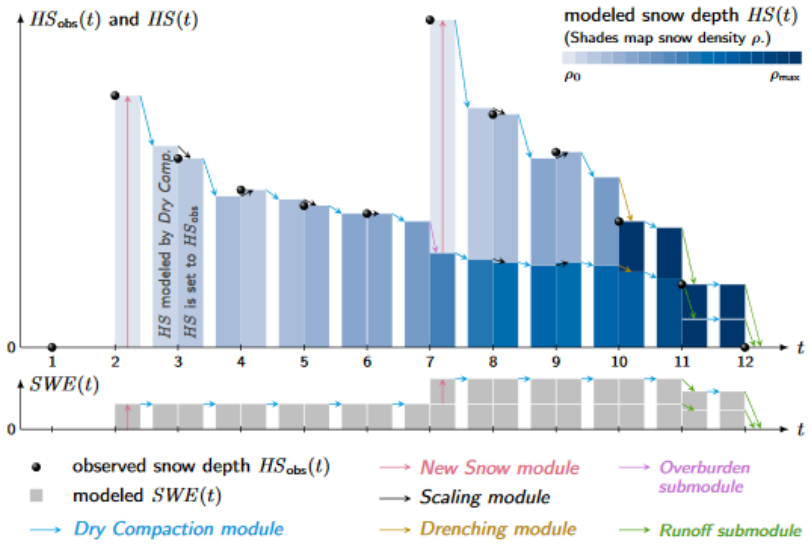
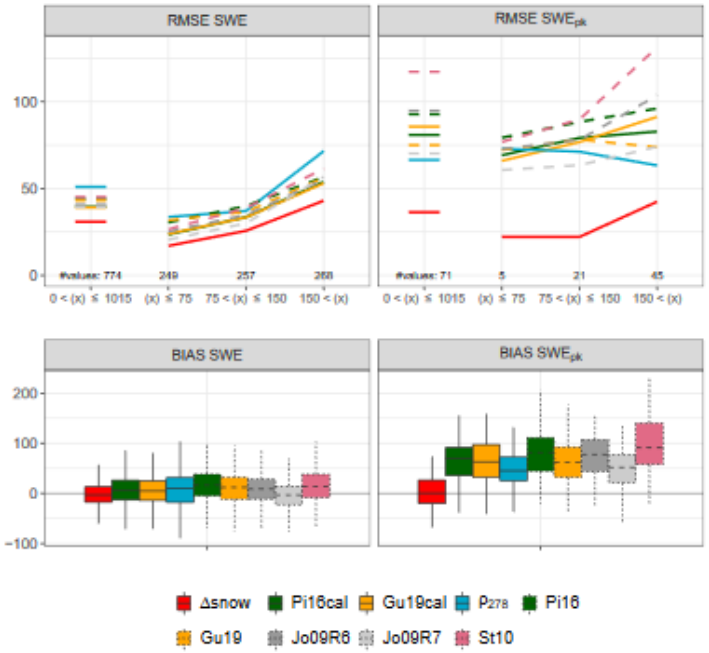
Project **Schneelast.Reform** - Results: **snow model**

Development of new snow model
ΔSNOW

- semi-empirical, layer-resolving
- only input: regular snow depths





Winkler et al., in press, HESS

Snow water equivalents exclusively from snow depths and their temporal changes: The ΔSNOW model

Free code: Schellander and Winkler, R-package *niXmass,* cran.r-project.org

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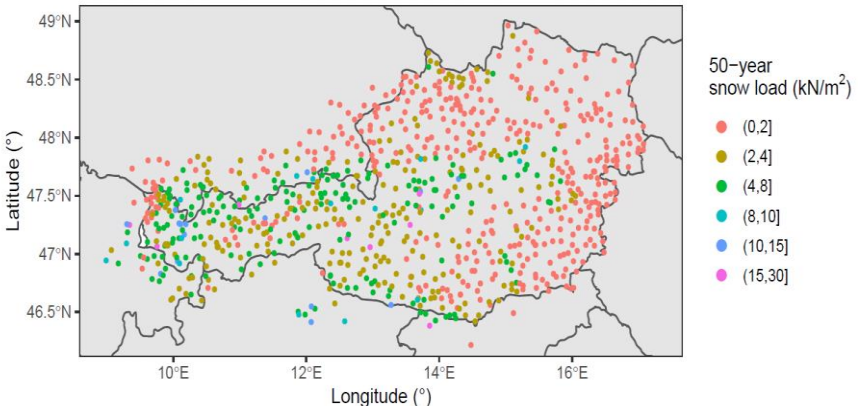
Project **Schneelast.Reform** - Results: **spatial extreme value model**

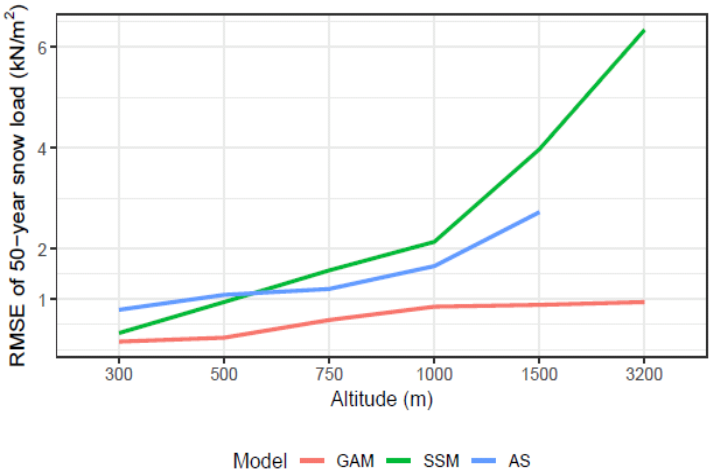
Generalized additive model (GAM) was used to spatially model the parameters of the generalized extreme value (GEV) distribution.

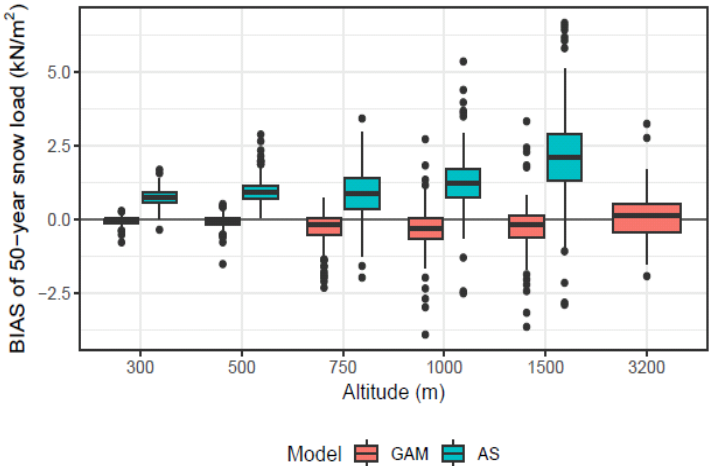
(Schellander et al. *Towards a reproducible snow load map – an example for Austria*, Adv. Sci. Res., submitted)



Model	RMSE	BIAS
	kN/m^2	kN/m^2
GAM	0.66	-0.21
AS	1.61	1.16

AS … actual Austrian standard





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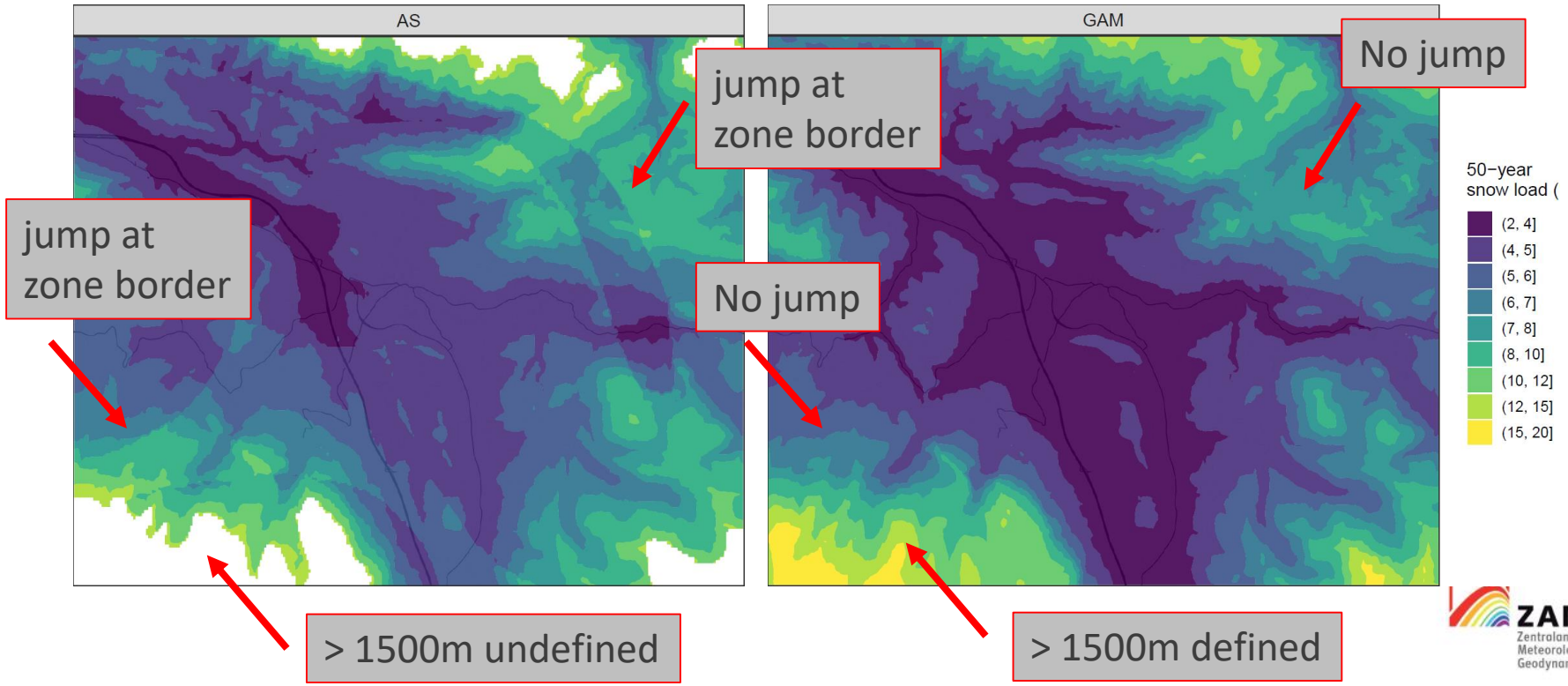
suggestion for a novel snow load map

- 50x50m resolution
- up to 2000m
- No zonings, no jumps
- Reproducible, transparent, usable across borders
- Only input: snow depth records

actual Austrian standard

Suggestion based on ΔSNOW and GAM



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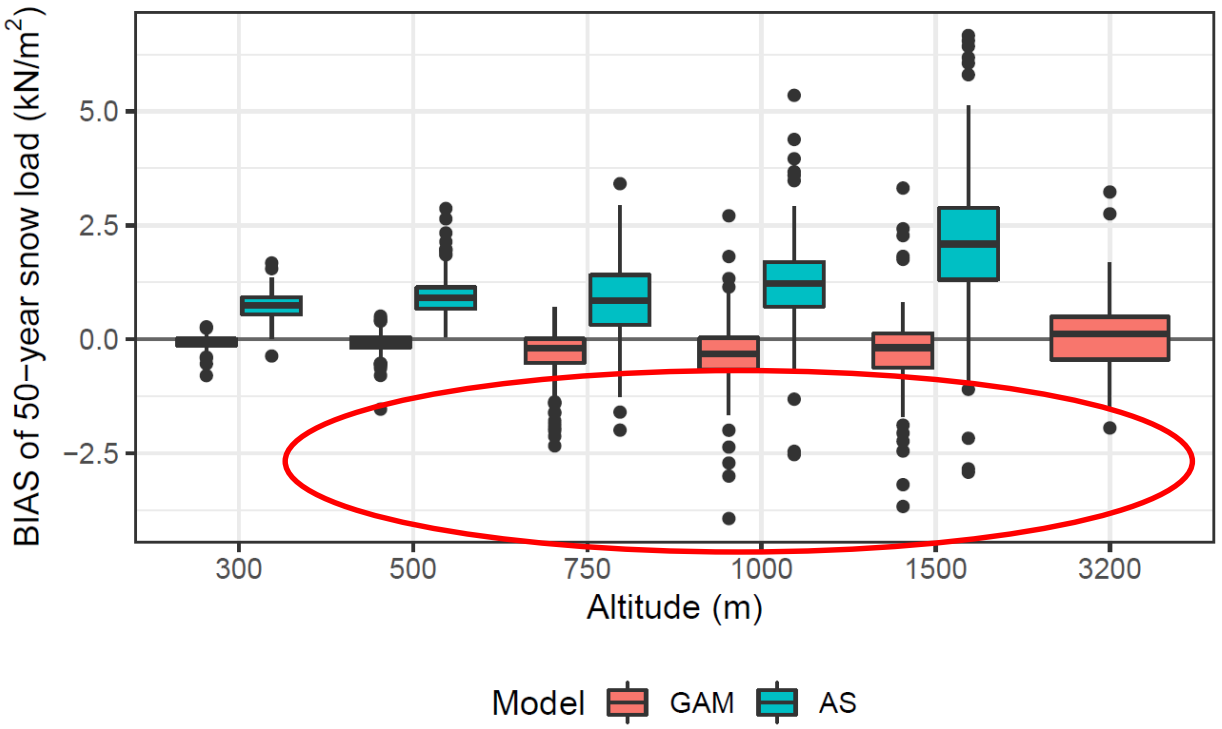
Ongoing…

- reduce outliers
- develop uncertainty measures
- other return periods (temporary buildings)
- Contact to other countries (Germany, Slovenia, …to be continued…)



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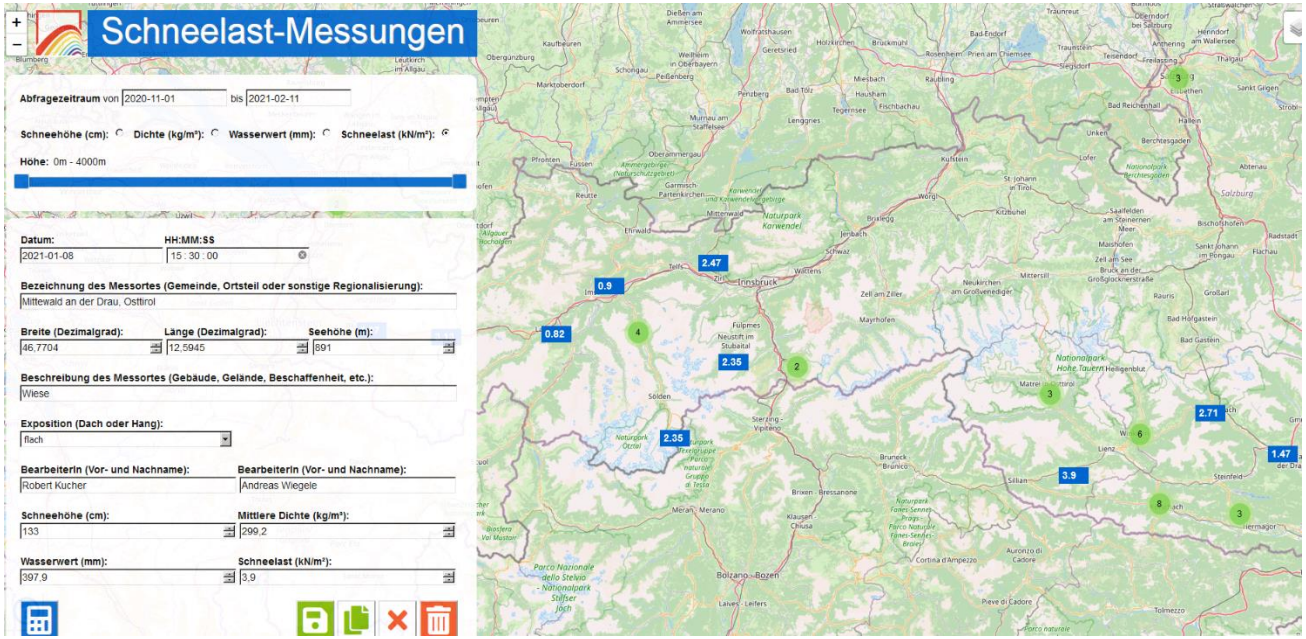
Snow load monitoring

- currently active for regions East Tyrol and Carinthia
- „prototype“ was established 2012 at ZAMG
- manual measurements in snow pits
- still at developmental stage



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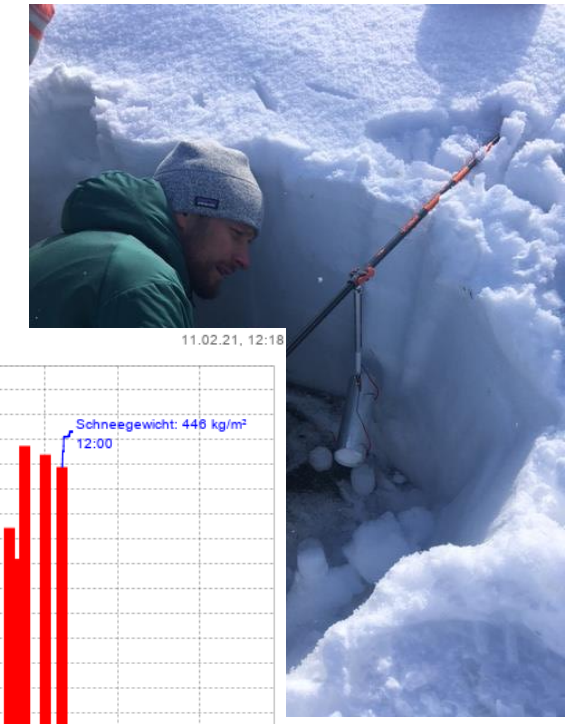

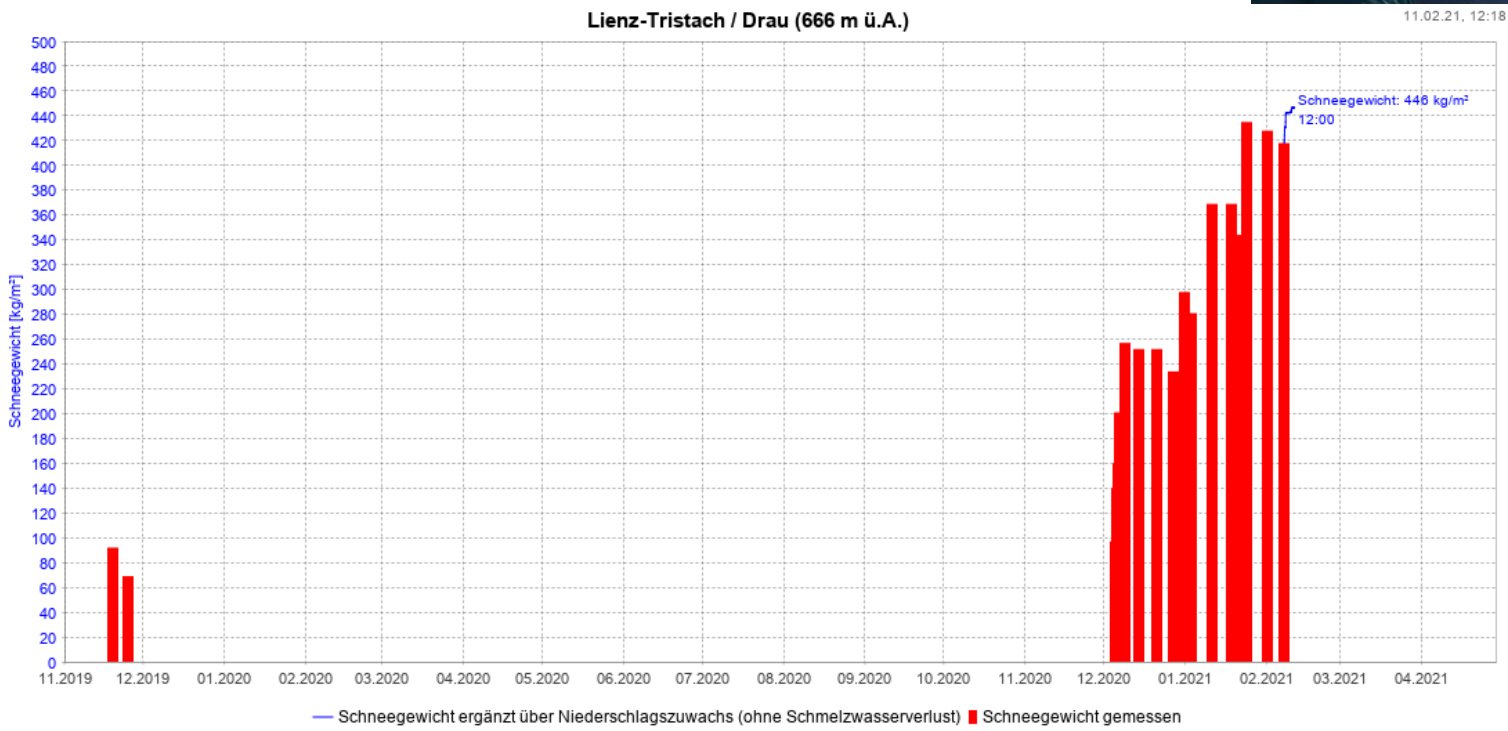

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		Datum	Seehöhe	Schneehöhe	Schneelast	SWE	Dichte	ÖNORM B 1991-1-3 (gültig ab 2006)				ÖNORM B 4013 (gültig: 1983-2005)				ÖNORM B 4000 (gültig: 1960-1983)		
		der Messung	in Meter															
				cm	kN/m²	kg/m²	kg/m³	Zonen-Rechenwert	Wert / (kN/m²)	Differenz [kg/m²]	%	Zone (Seehöhe lt. Tab.)	Wert / (kN/m²)	Differenz [kg/m²]	%	Wert / (kN/m²)	Differenz [kg/m²]	%
OT	Matrei i.O. (ZAMG)	09.01.2021	933	120	3,50	357	298	2,00	3,42	-8	102	A	2,68	-84	131			
NT	Gnadenwald (HD)	20.01.2021	875		0,98	100		2,00	3,16	223	31	A	2,42	147	40			
OT	Lienz Tristach (HD)	25.01.2021	666	105	4,26	435	414	3,00	3,55	-72	120	B/C	2,60	-170	164			
OT	Obertilliach (HD)	25.01.2021	1400	190	5,41	552	291	3,75	11,35	606	48	C	8,75	341	62			
OT	Anras (HD)	25.01.2021	1300		3,46	353		3,00	8,11	474	43	B	5,68	227	61			
OT	Innervillgraten (HD)	25.01.2021	1400		4,26	435		3,00	9,09	493	47	B	6,51	229	65			
OT	St.Jakob Def. (HD)	25.01.2021	1381	140	3,04	310	221	2,00	5,95	297	51	A	5,22	222	58			
OT	Prägraten (HD)	25.01.2021	1340		3,38	345		2,00	5,67	234	60	A	4,94	159	68			
NT	Ginzling (HD)	01.02.2021	987	40	1,47	150	375	2,00	3,67	224	40	A	2,93	149	50			
NT	Gnadenwald (HD)	01.02.2021	875		0,64	65		2,00	3,16	258	20	A	2,42	182	26			
NT	Hochfilzen (HD)	01.02.2021	961	40	1,18	120	300	4,50	7,95	691	15	C	4,64	354	25			
OT	Obertilliach (HD)	08.02.2021	1400	165	5,68	580	352	3,75	11,35	578	50	C	8,75	313	65			
OT	Anras (HD)	08.02.2021	1300		3,77	385		3,00	8,11	442	47	B	5,68	195	66			
OT	Innervillgraten (HD)	08.02.2021	1400		4,26	435		3,00	9,09	493	47	B	6,51	229	65			
OT	St.Jakob Def. (HD)	08.02.2021	1381	140	3,19	325	232	2,00	5,95	282	54	A	5,22	207	61			
OT	Prägraten (HD)	08.02.2021	1340		4,02	410		2,00	5,67	169	71	A	4,94	94	81			
OT	Felbertauern Süd (HD)	08.02.2021	1637		5,19	530		2,00	7,83	269	66	A	7,13	198	73			
OT	Lienz Tristach (HD)	08.02.2021	666	105	4,21	430	410	3,00	3,55	-67	119	B/C	2,60	-165	162			
NT	Plangeroß (HD)	08.02.2021	1605		3,00	306		2,00	7,58	467	40	D	5,55	260	54			
NT	Obernberg (HD)	14.12.2020	1360		1,86	190		2,00	5,81	402	32	A	5,07	328	37			
NT	Leutasch (HD)	08.02.2021	1135	70	2,52	257	367	2,50	5,54	308	45	C	6,04	360	42			
NT	Seefeld (ZAMG)	09.02.2021	1182	69	2,47	252	365	2,50	5,87	347	42	B	4,80	238	51			
NT	Vergötschen (HD)	09.02.2021	1269		2,16	220		2,00	5,22	313	41	D	3,35	122	64			

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Snow load monitoring

In case of exceedances of standards:

warning/information distributed to

- local authorities (communities, regions)
- civil defense agencies
- Press

intensified observations

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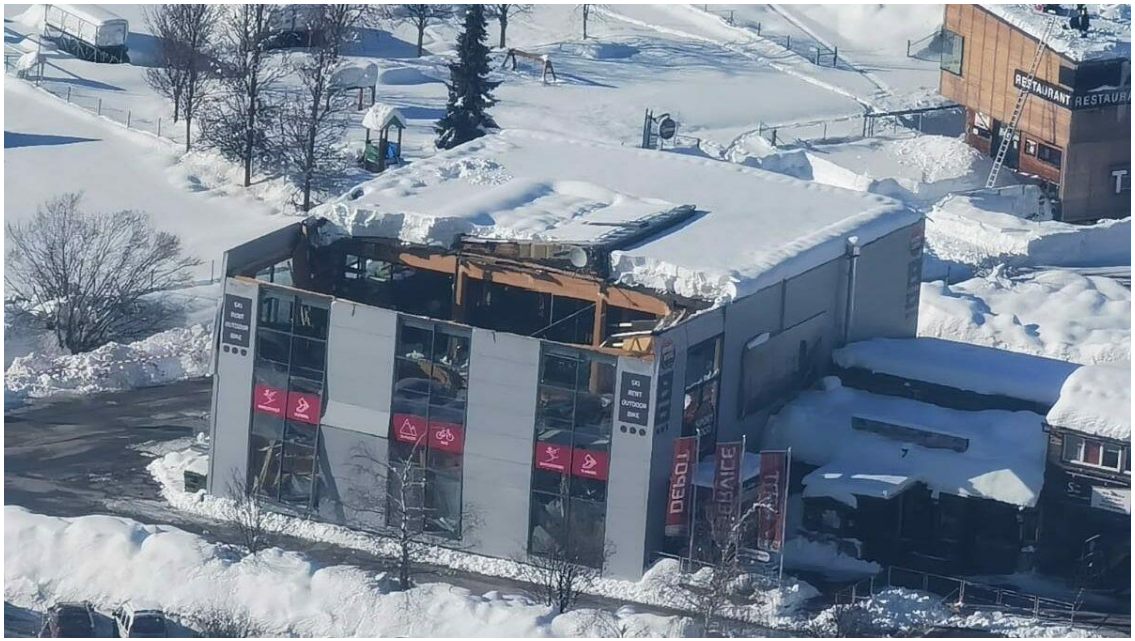
Snow load monitoring - Outlook

- more systematic SWE observations in Austria
- platform to collect available measurements (citizen science)
- automated measurements
- powerful tools to compare current situtations with standards
- exchange across borders
- not least: **Manifest extreme snow loads as a natural hazard!**



Jan 3rd, 2021. Matrei (AT). ©krone.at

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Extreme snow loads: a natural hazard

Thank you!

Jan 2021, Lienz (AT)
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contact: **michael.winkler@zamg.ac.at**

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