Observed and simulated snow profile data

This data set includes information on all observed and simulated snow profiles that were used to train and validate the random forest (RF) model described in Mayer et al. (2022). The data set contains profiles from the region of Davos (DAV subset, 512 profiles) and from all over Switzerland (SWISS subset, 230 profiles). For each observed snow profile, there is a corresponding simulated profile which was obtained using meteorological input data for the numerical snow cover model SNOWPACK (version 3.50). The information on the observed snow profile contains a Rutschblock test result including the depth of the failure interface. As part of the study described in Mayer et al. (2022), each observed snow profile was manually compared to its simulated counterpart and the simulated layer corresponding to the Rutschblock failure layer was identified. Features describing the simulated weak layer and the overlying slab of the profile pairs fulfilling predefined similarity criteria were then used to train a RF model to distinguish between unstable and stable profiles from the DAV subset. The SWISS data set was used for the validation.

Description of content

This data set contains the following files and zipped folders:

– "**properties_observed_and_simulated_DAV.csv**": For each profile pair from the DAV data set, this file contains one row with information on the observed snow stability and all extracted features describing the simulated failure layers. The content of the columns is explained in Table 1. Only those profile pairs which fulfilled the similarity criteria (column "similarity_obs_sim" = 1) and which belonged to the stability classes "stable" and "unstable" (column "stability_class" = 0 or 1) were used to train the RF model. Please note that for each of the two snow profiles with RB score 7 (profile IDs 7228 and 9526), three additional layers were included in this data set to obtain a balanced set of training data (73 unstable and 73 stable profiles).

– "**properties_observed_and_simulated_SWISS.csv**": For each profile pair from the SWISS data set, this file contains one row with information on the observed snow stability and all extracted features describing the simulated failure layers. Please note that only those profile pairs which fulfilled the similarity criteria (column similarity_obs_sim = 1, 121 profiles) were used to validate the RF model. The content of the columns is explained in Table 1.

– "**observed_snow_profiles.zip**: Observed snow stratigraphy in form of one *.csv-file per snow profile from the DAV and SWISS data sets (in respective subfolders). Each file is named after the profile ID which allows identifying the corresponding simulated profile in the "simulated_profiles" folder. One row corresponds to one observed snow layer. The content of the columns is described in Table 2.

– "**simulated_snow_profiles.zip**: Simulated snow stratigraphy in form of one *.csv-file per snow profile from the DAV and SWISS data sets (in respective subfolders). Each file is named after the profile ID which allows identifying the corresponding observed profile in the "observed_profiles" folder. One row corresponds to one simulated snow layer. The content of the columns 1-7 is described in Table 3. The remaining columns (8-31) contain all features that were used in the development of the RF model and are described in Table 1. For the features described in these columns, the respective snow layer is treated as weak layer (wl) and the layers above form the slab (sl).

Related data sets

The observed snow profiles from the DAV data set are a subset of the data set "Field observations of snow instability" (Schweizer et al., 2021).

Acknowlegements

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Table 1. Description of the columns used in the *.csv-files "properties_observed_and_simulated_DAV.csv" and "properties_observed_and_simulated_SWISS.csv" which contain information on observed properties and all features describing weak layer (wl) and slab (sl) properties extracted from the simulated profiles. The "Abbreviation" column refers to the abbreviation used in Mayer et al. (2022). References to relevant literature can be found in Appendix B of Mayer et al. (2022).

Column name	**Abbreviation**	**Feature**	**Formula / remarks**	**Unit**
profID		profile ID from SLF database of observed snow profiles	the profile ID allows identifying the simulated profile that corresponds to an observed profile and vice versa	-
observed properties				
datetime	-	date and time of snow profile observation	"yyyy-MM-dd HH:mm"	-
slopeangle	-	slope angle of observed profile	-	[°]
RB_score	-	Rutschblock score	Rutschblock loading steps as described in Schweizer (2002)	-
RB_releasetype	-	Rutschblock release type	1: whole block, 2: partial, 3: edge only	-
RB_height_obs	-	height of observed Rutschblock failure interface	-	[cm]
RB_class	RB stability class	Rutschblock stability class according to the classification defined in Sect. 3.1.1 of Mayer et al. (2022)	-	-
localNowcast	LN	estimate of local avalanche danger (local nowcast)	-	-
stability_class	-	stability class according to the classification defined in Sect. 3.1.1 of Mayer et al. (2022)	1: unstable, 0: stable, -999: undefined	-
HS_obs	-	observed snow depth	-	[cm]
similarity_obs_sim	-	similarity between observed and simulated profiles as assessed using the criteria in Sect. 3.1.2 of Mayer et al. (2022)	-	-

Table 1. continued

Column name	Abbreviation	Feature	Formula / remarks	Unit
basic SNOWPACK output parameters				
gs_wl	gs_{wl}	grain size of wl	-	[mm]
sph_wl	sph_{wl}	sphericity of wl	-	-
bs_wl	bs_{wl}	bondsize of wl	-	[mm]
dendr_wl	d_{wl}	dendricity of wl	-	-
gt1_wl	gt_{wl}	first grain type of wl	see Table 2, "gt1" for grain type codes	-
rho_wl	ρ_{wl}	density of wl	-	[$kg\ m^{-3}$]
visc_wl	η	viscosity of wl	-	[10^9 Pa s]
age_wl	age_{wl}	age of wl	-	[days]
HS_sim	HS	snow depth	-	[cm]
composed features weak layer				
rho_divby_gs_wl	$\frac{\rho_{wl}}{gs_{wl}}$	-	-	[$10^3\ kg\ m^{-4}$]
rhobs_divby_gs_wl	$\frac{\rho_{wl} \cdot bs_{wl}}{gs_{wl}}$	-	-	[$kg\ m^{-3}$]
composed features slab				
D_sl	D_{sl}	slab thickness	-	[cm]
rho_sl	ρ_{sl}	mean sl density	-	[$kg\ m^{-3}$]
rho_divby_gs_sl	$\langle \frac{\rho}{gs} \rangle_{sl}$	mean of the ratio of density and grain size of all slab layers	$\langle \frac{\rho}{gs} \rangle_{sl} := \frac{1}{N} \sum_{i=1}^{N} \frac{\rho_i}{gs_i}$ with $gs_i =$ grain size of the i^{th} of the N slab layers etc.	[$10^3\ kg\ m^{-4}$]
rhobs_divby_gs_sl	$\langle \frac{\rho \cdot bs}{gs} \rangle_{sl}$	-	$\langle \frac{\rho \cdot bs}{gs} \rangle_{sl} := \frac{1}{N} \sum_{i=1}^{N} \frac{\rho_i \cdot bs_i}{gs_i}$ with $bs_i =$ bond size of the i^{th} of the N slab layers etc.	[$kg\ m^{-3}$]
rho20_sl	ρ_{sl20}	mean density of 20 cm above wl	-	[$kg\ m^{-3}$]
rho10max_sl	ρ_{10max}	maximal mean density of all 10 cm windows above wl	-	[$kg\ m^{-3}$]
penetrationdepth	P_k	skier penetration depth	$P_k = 34.6/\rho_{30}$ with ρ_{30} = mean density uppermost 30 cm	[m]

Table 1. continued

Column name	Abbreviation	Feature	Formula / remarks	Unit
composed features weak layer & slab				
delta_gs	$\triangle$gs	difference in grain size between wl and layer above wl	-	[mm]
delta_hh	$\triangle$h	difference in hand hardness between wl and layer above wl	-	[index steps]
frac_rhogs	$\left[\frac{\rho}{\mathrm{gs}}\right]_{\mathrm{wl}/(\mathrm{wl}+1)}$	-	$\left[\frac{\rho}{\mathrm{gs}}\right]_{\mathrm{wl}/(\mathrm{wl}+1)} = \frac{\rho_{\mathrm{wl}}\mathrm{gs}_{\mathrm{wl}+1}}{\mathrm{gs}_{\mathrm{wl}}\rho_{\mathrm{wl}+1}}$ with $(\mathrm{wl}+1)$: layer above wl	-
rts	rts	relative threshold sum	-	-
snow mechanical features				
shear_strength_wl	τ_p	shear strength of wl	-	[10^3 Pa]
normalstress	σ_n	normal stress exerted on wl by sl	-	[10^3 Pa]
skier_stress	$\triangle\tau$	skier shear stress on wl	calculated for slope angle = 38°	[10^3 Pa]
skier_stress_monti	$\triangle\tau^*$	refined skier shear stress on wl	calculated for slope angle = 38°	[10^3 Pa]
sk38	SK_{38}	skier stability index	$\mathrm{SK}_{38} = \frac{\tau_p}{\tau_{sl38}+\triangle\tau}$, with τ_{sl38} = shear stress on wl by overlying sl	-
sk38_monti	SK^*_{38}	skier stability index, refined version	$\mathrm{SK}^*_{38} = \frac{\tau_p}{\tau_{sl38}+\triangle\tau^*}$	-
S_skier	S_{skier}	failure initiation criterion	$\frac{\tau_p}{\triangle\tau}$	-
rc	r_c	critical cut length (flat field)	$r_c = \sqrt{\frac{2\tau_p}{\sigma_n}}\sqrt{E'D_{sl}F_{wl}}$	[m]
			with E' = plain strain elastic modulus of sl and F_{wl} a function of $\rho_{wl} \cdot gs_{wl}$	[m]
neck_stress	σ_{ns}	wl neck stress	-	[Pa]
neck_strain_rate	$\dot{\epsilon}_n$	wl neck strain rate	-	[$10^{-10}\mathrm{s}^{-1}$]
viscdefrate	$\dot{\epsilon}_v$	viscous deformation rate	$\dot{\epsilon}_v = \frac{\sigma_n}{\eta}$	[$10^{-6}\mathrm{s}^{-1}$]
defrateindex	S_{dr}	deformation rate index	$S_{\mathrm{dr}} = \frac{\sigma_c}{\sigma_{ns}}$	-
		with σ_c = critical neck stress	-	

Table 2. Description of columns used in the *.csv files of the observed profiles.

Column name	Feature	Formula / remarks	Unit
layer_top	height of upper boundary of snow layer	-	[cm]
layer_bottom	height of lower boundary of snow layer	-	[cm]
hardness	hand hardness	1: fist - very soft, 2: four fingers - soft, 3: one finger - medium, 4: pen - hard, 5: knife blade - very hard, 6: ice	-
gt1	first grain type	1: precipitation particles, 2: fragmented particles, 3: rounded grains, 4: faceted crystals, 5: depth hoar, 6: surface hoar, 7: melt forms, 8: ice layer, 9: rounding faceted crystal, 0: graupel	-
gt2	second grain type	see remarks gt1	-
gs1	first grain size	-	[mm]
gs2	second grain size	-	[mm]
crust	melt-freeze crust?	if crust = 1, the layer is a melt-freeze crust	-

Table 3. Description of columns used in the *.csv files of the simulated profiles. Description of columns not described in this table can be found in Table 1.

Column name	Feature	Formula / remarks	Unit
layer_top	height of upper boundary of snow layer	-	[cm]
layer_bottom	height of lower boundary of snow layer	-	[cm]
hardness	hand hardness	see remarks on "hardness", Table 2	-
gt1	first grain type	see remarks on "gt1", Table 2	-
gt2	second grain type	see remarks on "gt1", Table 2	-
crust	melt-freeze crust?	if crust = 1, the layer is a melt-freeze crust	-
failure_layer	is this layer the manually determined failure layer?	the manually determined failure layer corresponding to the Rutschblock failure layer is indicated by failure_layer=1 (else failure_layer=0)	-

References

Mayer, S., van Herwijnen, A., Techel, F., and Schweizer, J.: A random forest model to assess snow instability from simulated snow stratigraphy, The Cryosphere, zz, xxx–yyy, https://doi.org/10.5194/tc-2022-34, 2022.

Schweizer, J.: The Rutschblock test - Procedure and application in Switzerland, The Avalanche Review, 20, 1,14–15, 2002.

Schweizer, J., Mitterer, C., Reuter, B., and Techel, F.: Field observations of snow instabilities, EnviDat [data set], https://doi.org/10.16904/envidat.222, 2021.