Slab Entrainment and Surge Dynamics of the 2015 Valleé de la Sionne Avalanches

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On 3 February 2015 five avalanches were artificially released at the Valleé de la Sionne test site in the west of Switzerland. The dense parts of the avalanches were tracked by the GEODAR Mark 2 radar system at 111 Hz framerate with 0.75 m down slope resolution.

The data show that these avalanches contain several internal surges and that the avalanche front is repeatedly overtaken by some of these surges. We show that these surges exist on different scales. While the major surges originate from secondary triggered slab releases and occur all over the avalanche, the minor surges are only found in the energetic part of a well developed powder snow avalanche. The mass of the major surges can be as huge as the initial released mass, this has a dramatic effect on the mass distribution inside the avalanche and effects the front velocity and run out. Furthermore, the secondary released snow slabs are an important entrainment mechanism and up to 50 % of the mass entered the avalanche via slab entrainment.

We analyse the dynamics of the leading edge and the minor surges in more detail using a simple one dimensional model with frictional resistance and quadratic velocity dependent drag. These models fit the data well for the start and middle of avalanche but cannot capture the slowing and overtaking of the minor surges. We find much higher friction coefficients are needed to describe the surging. We propose that this data can only be explained by changes in the snow surface. These effects are not included in current models yet, but the data presented here will enable the development and verification of such models.

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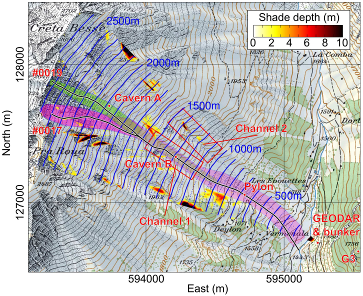
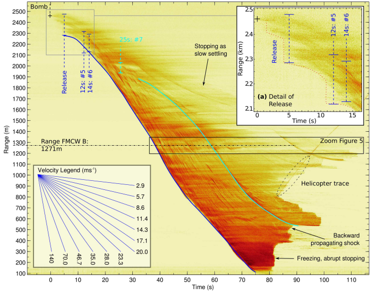
GEODAR (FMCW radar) is installed in the valley bottom and observes the mountain to track the dense flowing core below the powder cloud.

Around 100 radar frames are captured every second with a down-slope resolution of 1 m.

The avalanche front is the change from light to red colors.

The avalanche approaches towards the radar (decreasing range) and the gradient of the line features is the approach velocity.





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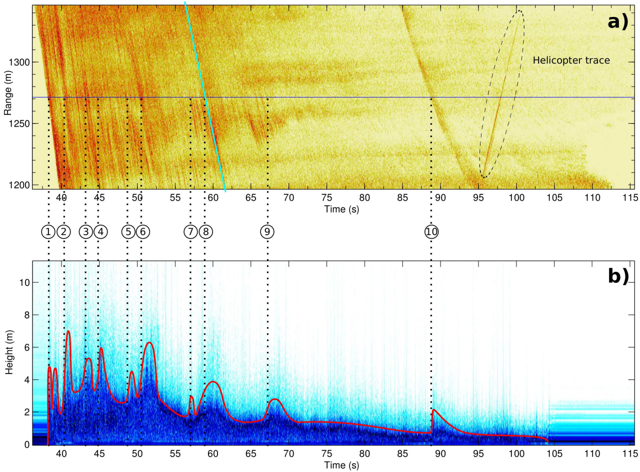

a) GEODAR show many approaching line features

b) Flow-height measured by upward–looking FMCW radar.

⇒ Line features correspond to waves: We call them surges.

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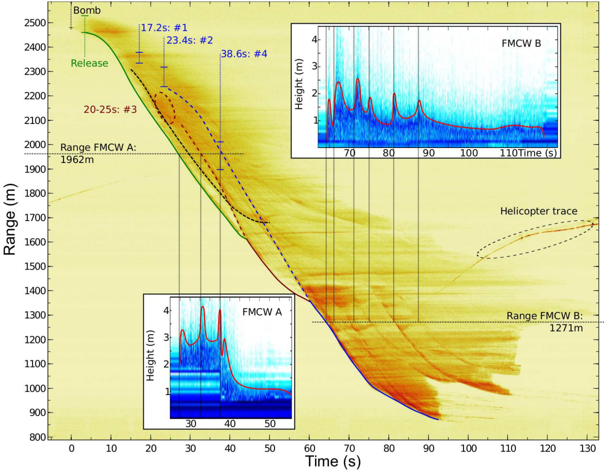

Major surges can exist in the avalanche body and they overrun each other. The origin of the major surges are secondary slab release (colored bars).

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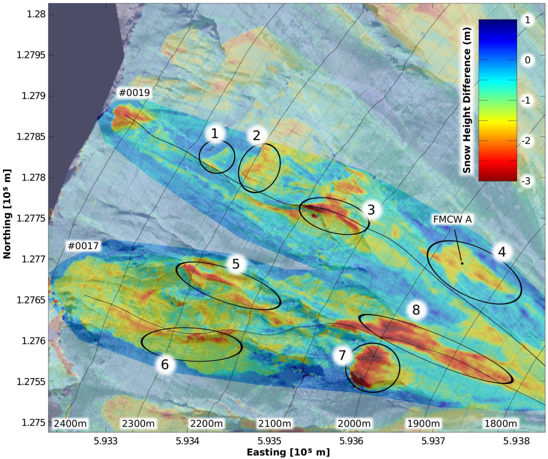
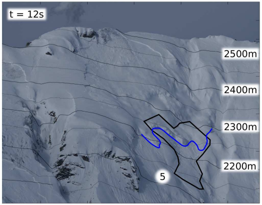
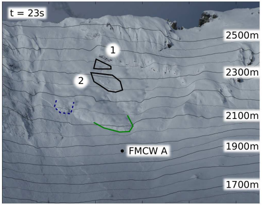


Avalanche #0017



Avalanche #0019



Video and laserscan data reveal the occurrence of slab releases.
Around 50 % of the total entrained volume entered the flow via slabs.
The slabs can be as large as the initial released slab. more . . .

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Slabs enter at random locations into the flowing avalanche and their mass is not concentrated at the front.

⇒ Spreading the mass over the flow alters the runout.

	Time [s]	Volume [m³]	Range [m]	Length [m]	Area [m²]	Depth [m]
Avalanche #0019		V_t=29500			40411	0.73
initial release	3.4	V_0= 2188	2506	62	1400	1.56
slab #1	17.2	V_1= 521	2356	39	701	0.74
slab #2	23.4	V_2= 3503	2284	83	2753	1.28
slab #3	20–25*	V_3= 3345	2150	99	1880	1.78
slab #4	38.7	V_4= 4276	1945	153	3657	1.17
Avalanche #0017		V_t=78500			82632	0.95
initial release	5.2	V_0=15233	2402	191	12974	1.17
slab #5	12.2	V_5= 7620	2219	202	6043	1.26
slab #6	14.1	V_6= 5868	2215	166	5851	1.01
slab #7	25.6	V_7= 6307	1982	95	3320	1.90
slab #8	15–25*	V_8=10663	1947	253	5037	2.12

Table: Release time, Volume, Location and size parameters of all identified slabs.

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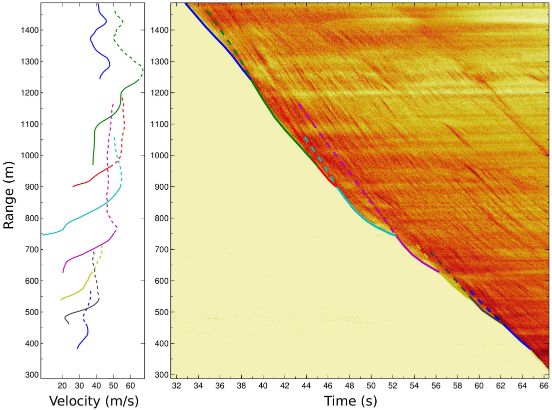

Minor surges are only found in the head of large powder avalanches.

They are flow features (roll waves) in the energetic frontal region.

Their speed is high and constant when behind the front, but dramatically decelerate as soon as they overtake the leading edge.

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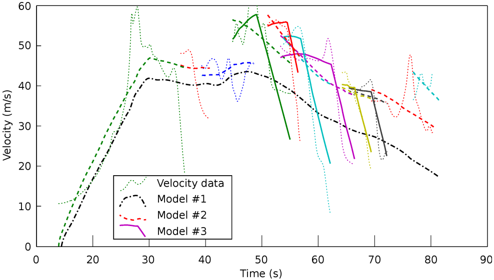

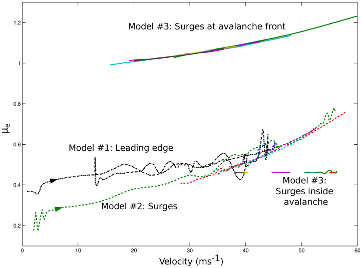

Minor surges were simulated with a 1D Voellmy–like model.
Model #1 describes the front, thats what usual models do.
Model #2 tries to follow every surge individually, but no deceleration.
Model #3 explains minor surges with 2 sets of friction parameters

⇒ The effective friction changes dramatically as soon as the surge reaches the front

⇒ The avalanche body experiences different flow conditions as the front.

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- GEODAR radar is able to track internal surges (flow height waves) below the powder cloud of snow avalanches. Two types of surges exist: *Major* and *Minor surges* are differentiated by their length.
- Major surges can occur at random location in the flow and influence the mass distribution of the avalanche. Minor surges are ubiquitous feature of the fast–flowing energetic part in the frontal region of large powder avalanches.
- The effective friction between the front and the avalanche body differs. This must be explained with changes in the snow surface like smoothing and entrainment of the soft, upper snow layers. Numerical models not yet account for this.

Köhler, A., J. N. McElwaine, B. Sovilla, M. Ash, P. Brennan (in Review), Surge dynamics of the 3 February 2015 avalanches in Valleé de la Sionne, *J. Geophys. Res.*