Effect of forest stand damage on the hydrophysical properties of snow cover in mountainous spruce forests Zapadne Tatry Mts.

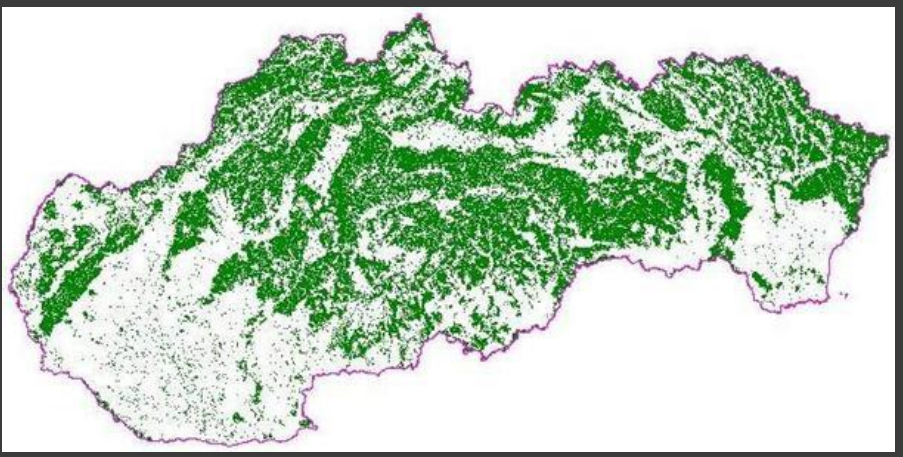
Snow field campaign in Slovakia

Martin Bartík
Roman Sitko
Jaroslav Škvarenina

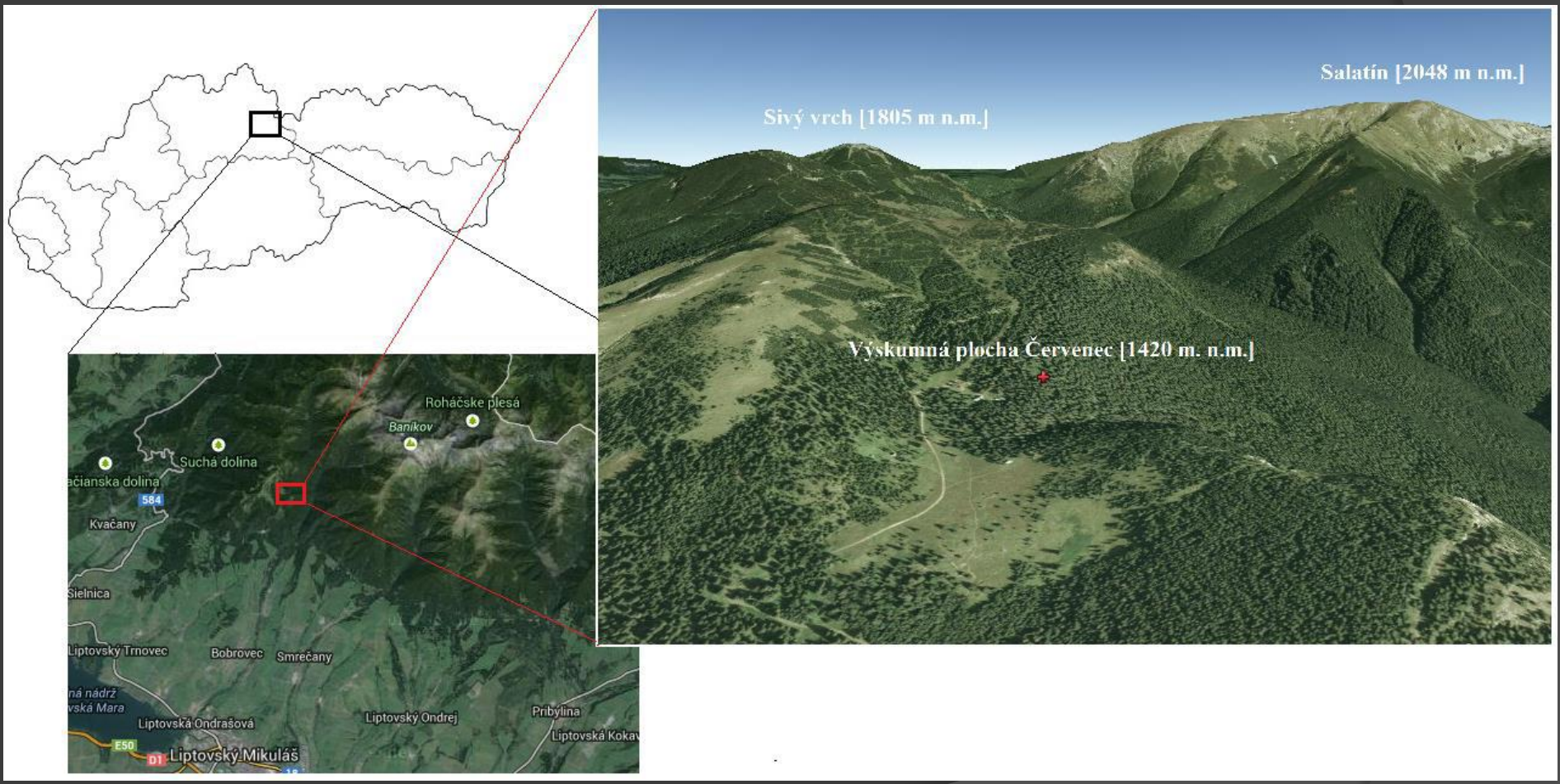
Repište, Demänovska valley **16. February 2016**

Forest and snow

- Forest area 2 012 tsd ha (41% of SR)
- Forest decline

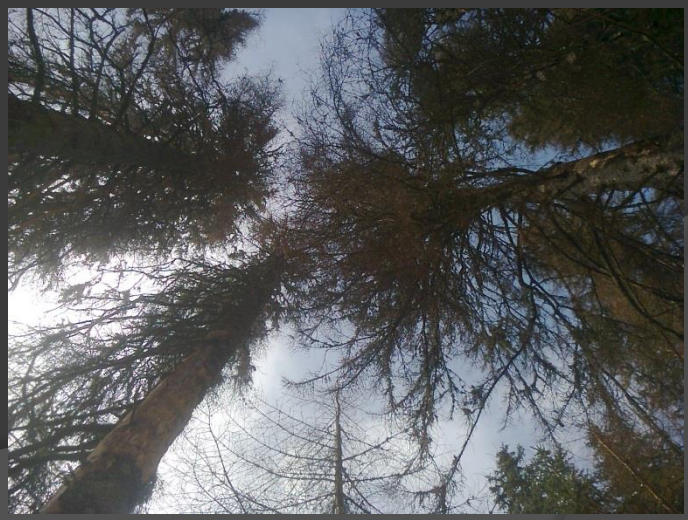


Research area Červenec



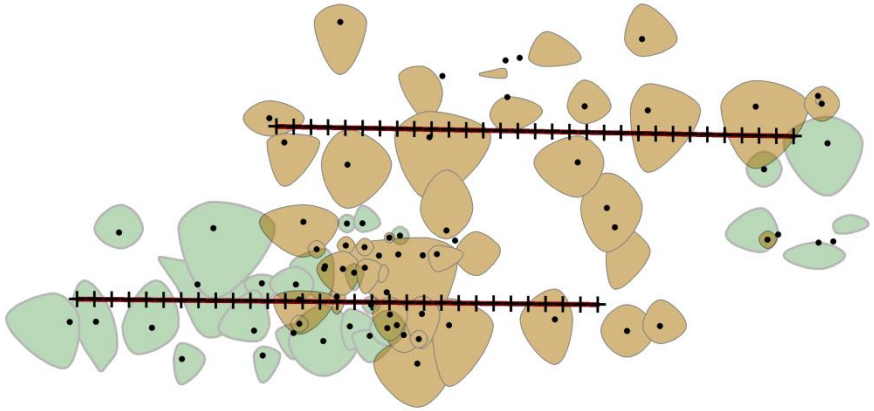
Characteristics of research area

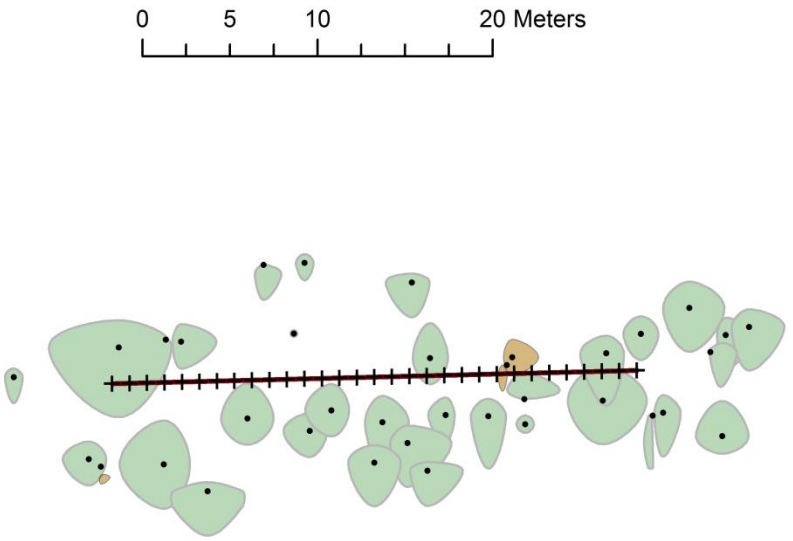
- Border of crystalline and mesozoic rocks with limestone, marlite, claystone and sandstone
- Soils : cambisols, concomitantly rankers and lithosols, cambisolic rendzinas
- Old-growth spruce stand (110 years.) (ρ = 0,6)
- Mean tree height 26,8 m, mean tree diameter 40,5 cm
- July – August 2012 part of research area declined



Snow cover monitoring

- February 2009
- winter 2012/13
- SWE
- SD

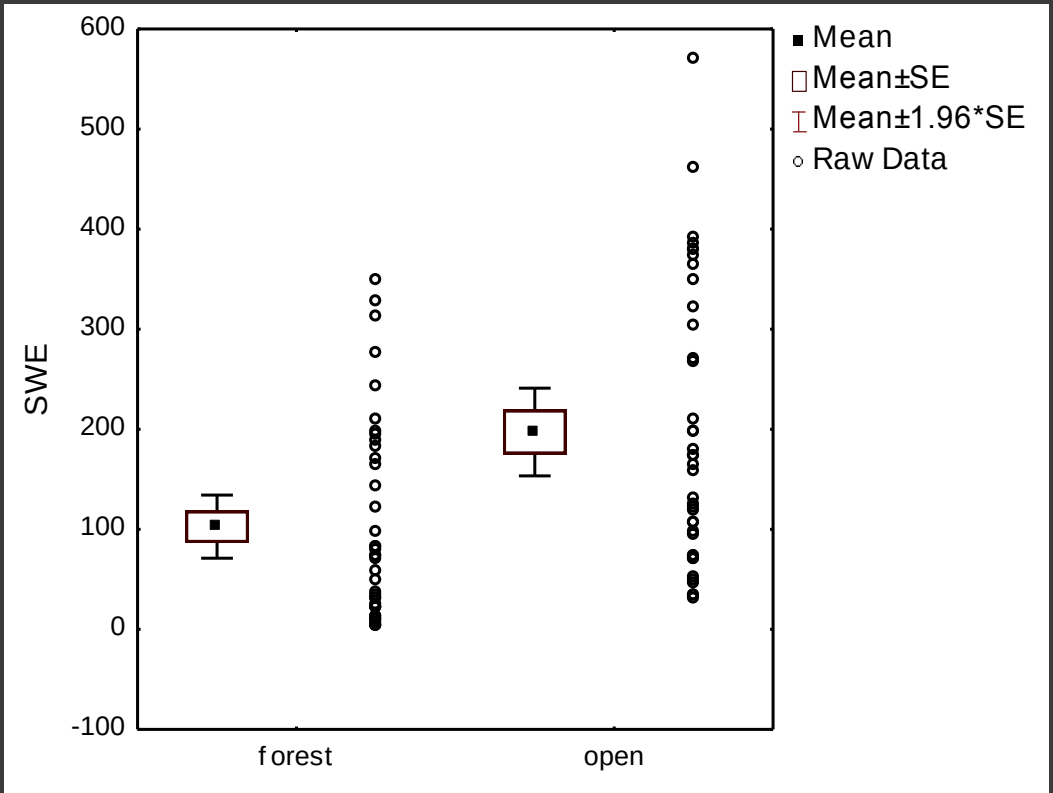




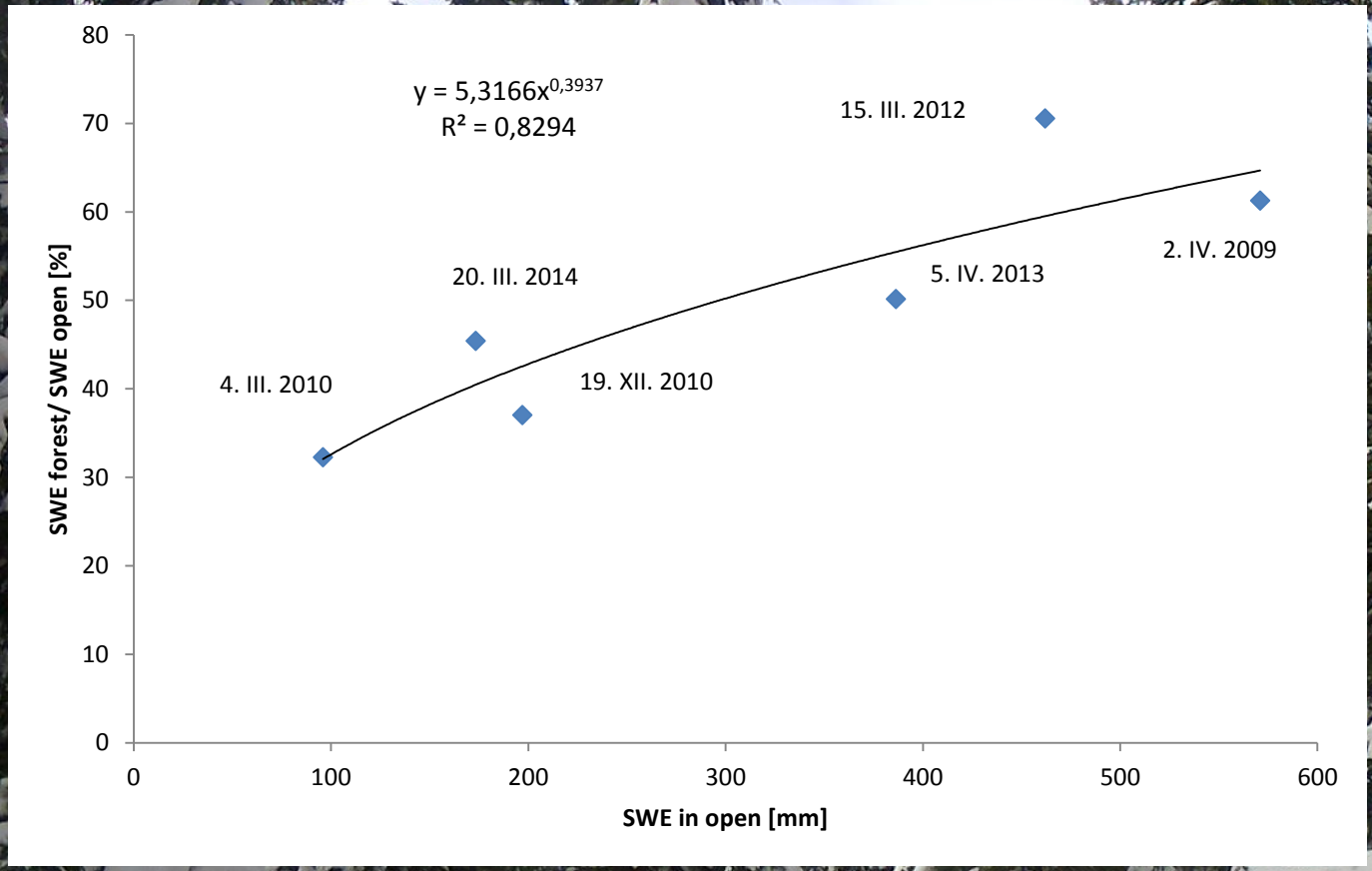
Results

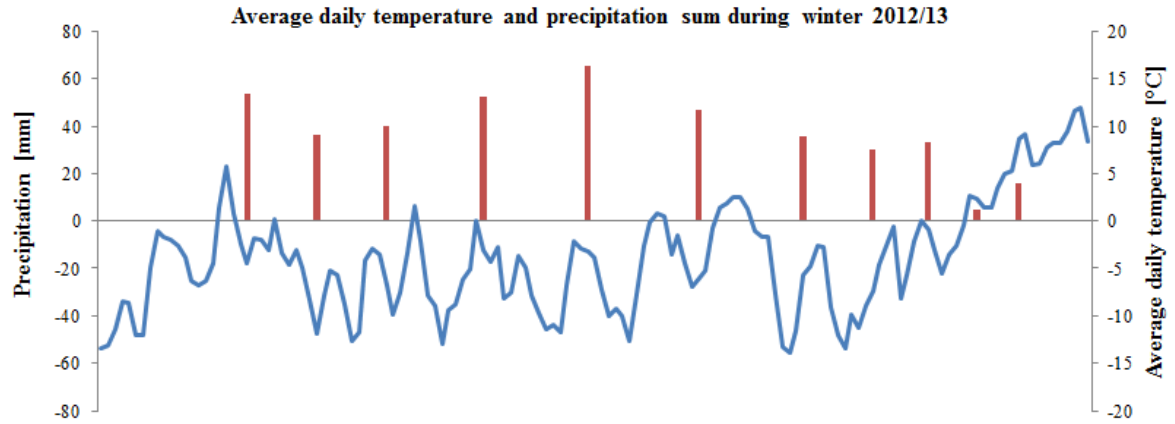
Snow water equivalent [mm] in research area Červenec (1 420 m a.s.l.)

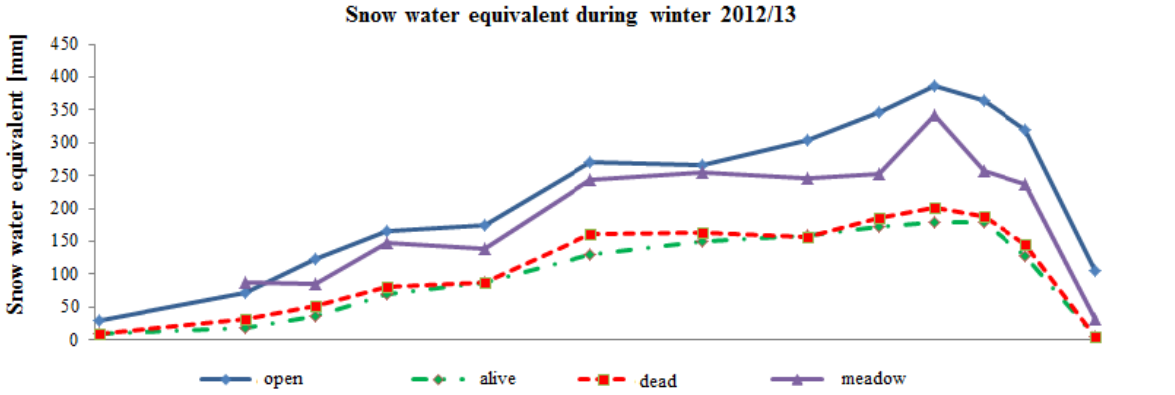
SWE in the forest and in the open space during 2009–2014

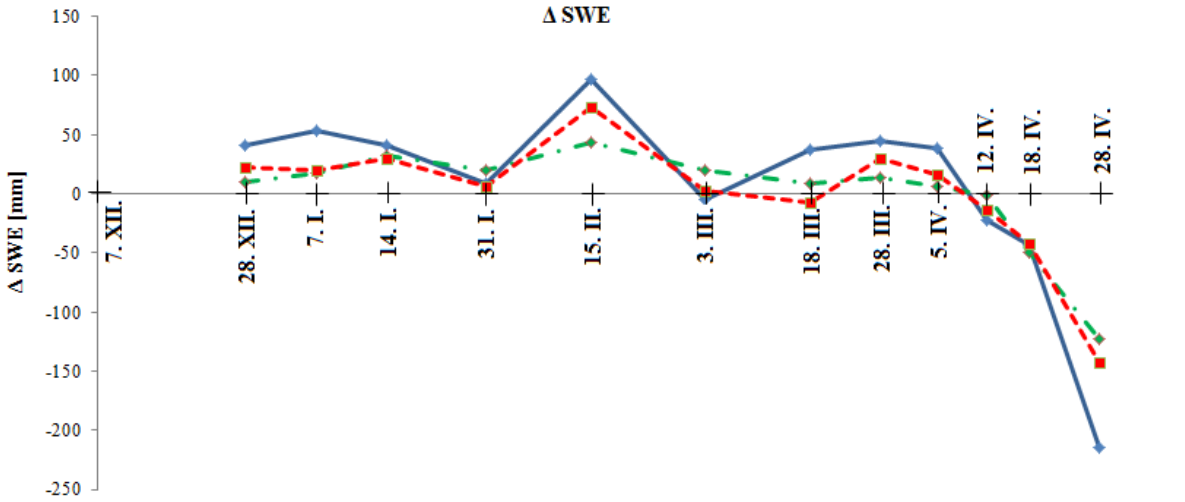


- Ø SWE in the forest 102.7 mm ±32.20 mm (with 95 % confidence level)
- Ø SWE in Open transect197.3 mm ±44.74 mm (with 95 % confidence level)
- SWE in the forest was 48% of SWE in open space

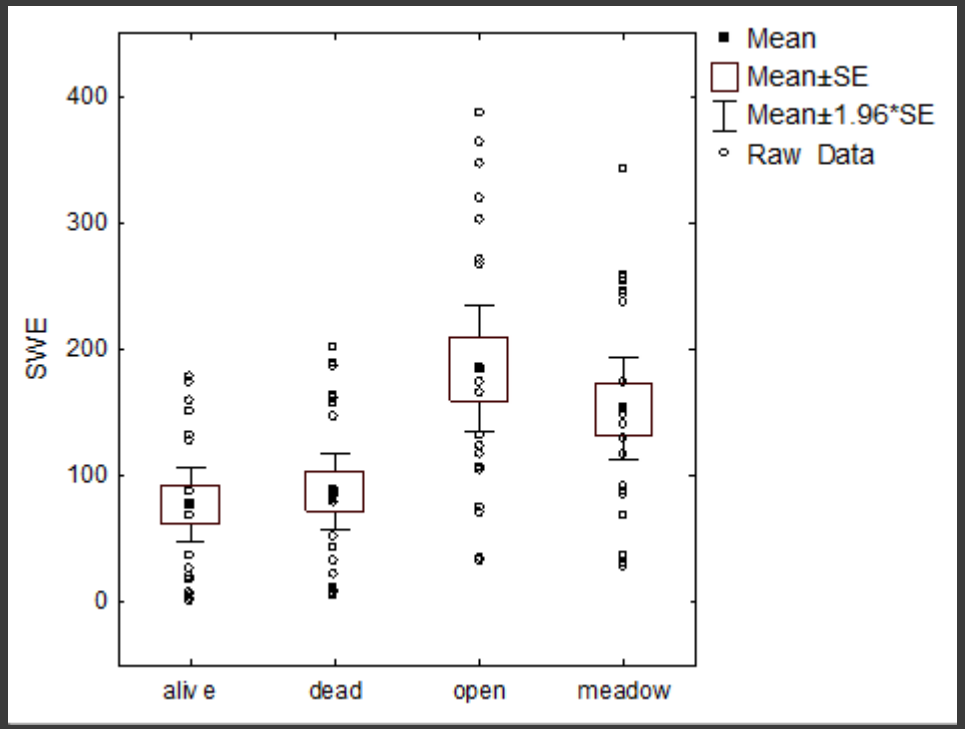

y = 5,3166x^0,3937
R² = 0,8294
15. III. 2012
2. IV. 2009
5. IV. 2013
20. III. 2014
19. XII. 2010
4. III. 2010
SWE forest/ SWE open [%]
SWE in open [mm]
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600


Average daily temperature and precipitation sum during winter 2012/13
Precipitation [mm]
Average daily temperature [°C]
80
60
40
20
0
-20
-40
-60
-80
20
15
10
5
0
-5
-10
-15
-20


Snow water equivalent during winter 2012/13
Snow water equivalent [mm]
450
400
350
300
250
200
150
100
50
0
open
alive
dead
meadow


Δ SWE
Δ SWE [mm]
150
100
50
0
-50
-100
-150
-200
-250
7. XII.
28. XII.
7. I.
14. I.
31. I.
15. II.
3. III.
18. III.
28. III.
5. IV.
12. IV.
18. IV.
28. IV.

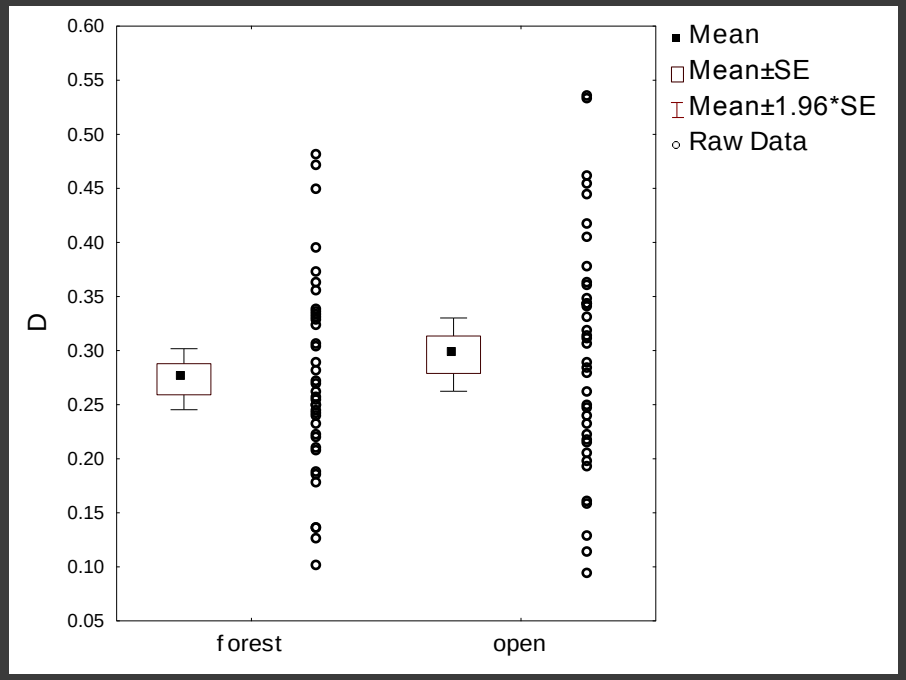
Statistical analysis of SWE during winter 2012/13 and 2013/14



Tested Samples	N	Diff. [mm]	Std. Err. [mm]	t	p
Alive vs. Open	20	**-107.2**	±12.55	-8.54	0.0000
Dead vs. Open	20	**-97.0**	±11.89	-8.16	0.0000
Dead vs. Alive	20	**10.2**	±1.90	5.33	0.0000
Open vs. Meadow	20	**31.6**	±7.84	4.03	0.0007

Ø SWE alive 77,3 mm, dead 87,4 mm, meadow 152,8 mm and in open 184,5 mm

Statistical analysis of snow density in the open space and in the forest during period 2009-2014



Open transect 0.296 g.cm^{-3}, Forest transect 0.274 g.cm^{-3}

Tested Samples	N	Diff. [mm]	Std. Err. [mm]	t	p
Forest vs. Open	39	**- 0.023**	± 0.0097	-2.33	0.0249

Statistical analysis of snow density during winter seasons 2012/13 and 2013/14

- Ø SD open 0.285 g.cm^{-3} , meadow 0.303 g.cm^{-3}, alive 0.257 g.cm^{-3} and dead 0.250 g.cm^{-3}

Tested Samples	N	Diff.	Std. Err.	t	p
Alive vs. Open	20	**-0.028**	±0.0119	-2.34	0.0305
Dead vs. Open	20	**-0.035**	±0.0092	-3.84	0.0011
Dead vs. Alive	20	-0.008	±0.0101	-0.75	0.4606
Open vs. Meadow	20	-0.018	±0.0087	-2.02	0.0573

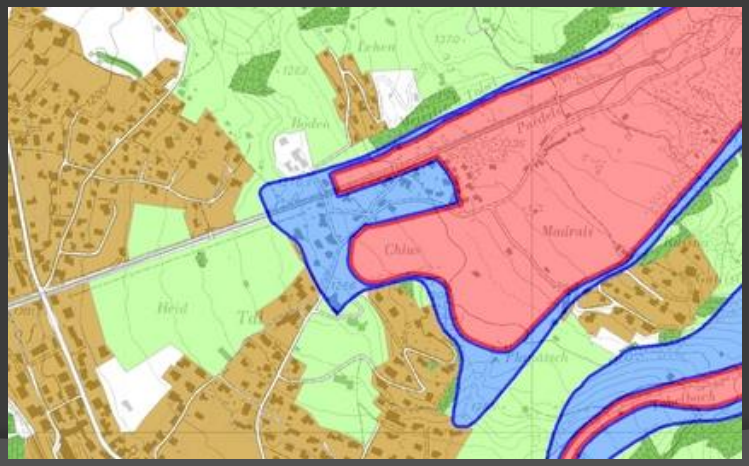
CONCLUSIONS

- The most snow-abundant winter during the monitored period (2009 – today) was in 2008/09 (max. SWE was 571 mm in the open space, and 350 mm in the forest)
- The ratio of snow accumulation at the open space to snow accumulation in the forest increases in snow-poor winter seasons due to the interception
- The average SWE in the living forest, dead forest, and meadow was 42 %, 47% and 83% of the SWE at the open space, respectively.
- The differences between SWE at the open space and SWE on meadow, dead forest, living forest, as well as the differences between the living and dead forest were significant.
- The comparison of snow accumulation and melting in the living and dead forest revealed that the snow cover was more stable in the living forest

Avalanche modeling

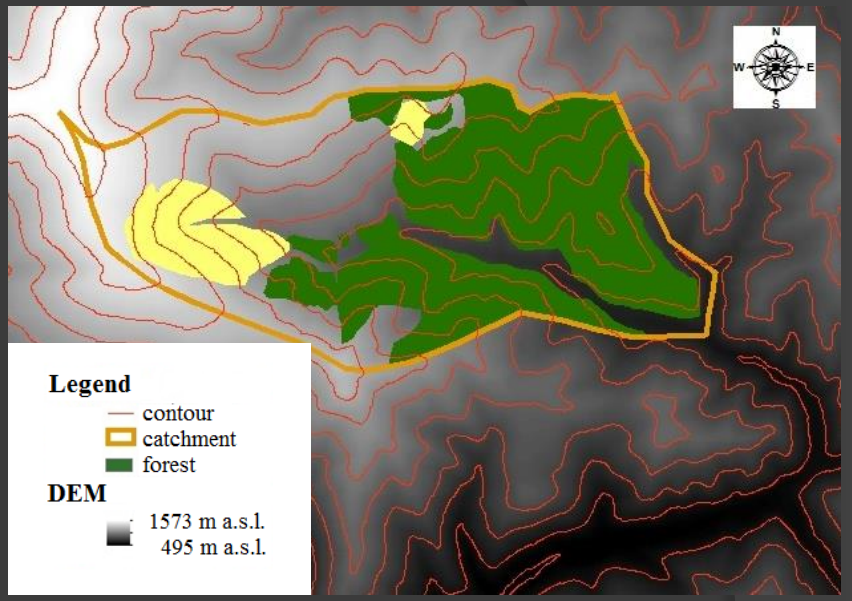
Software applications

- Avalanche simulations
- Results : length, velocity, pressure
- Utilization: dimensioning avalanche structure, land-use restrictions, planning of hazard-zone
- RAMMS, Samos AT, ELBA+, AVAL 1D

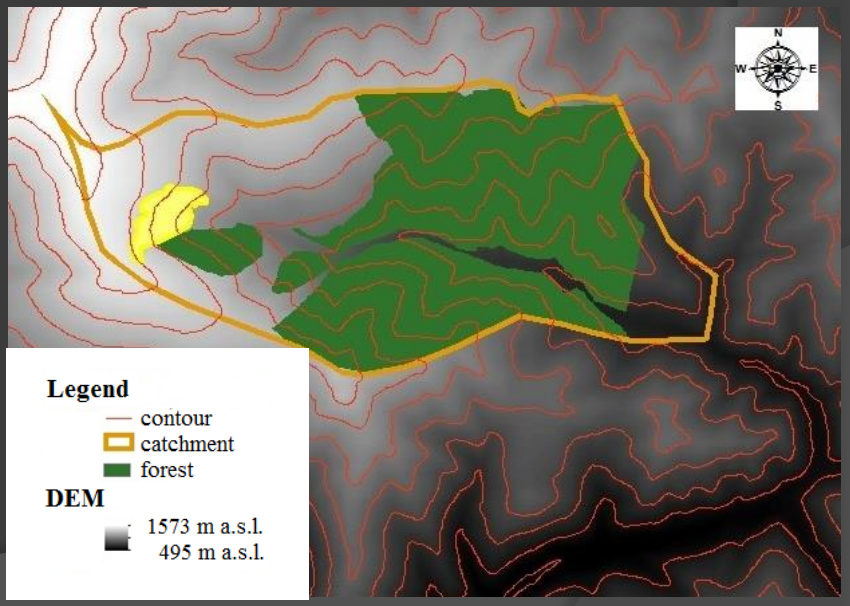


ELBA +

Input data:
- release zone
- catchment
- DEM
- forest area
- profiles
- snow cover characteristic

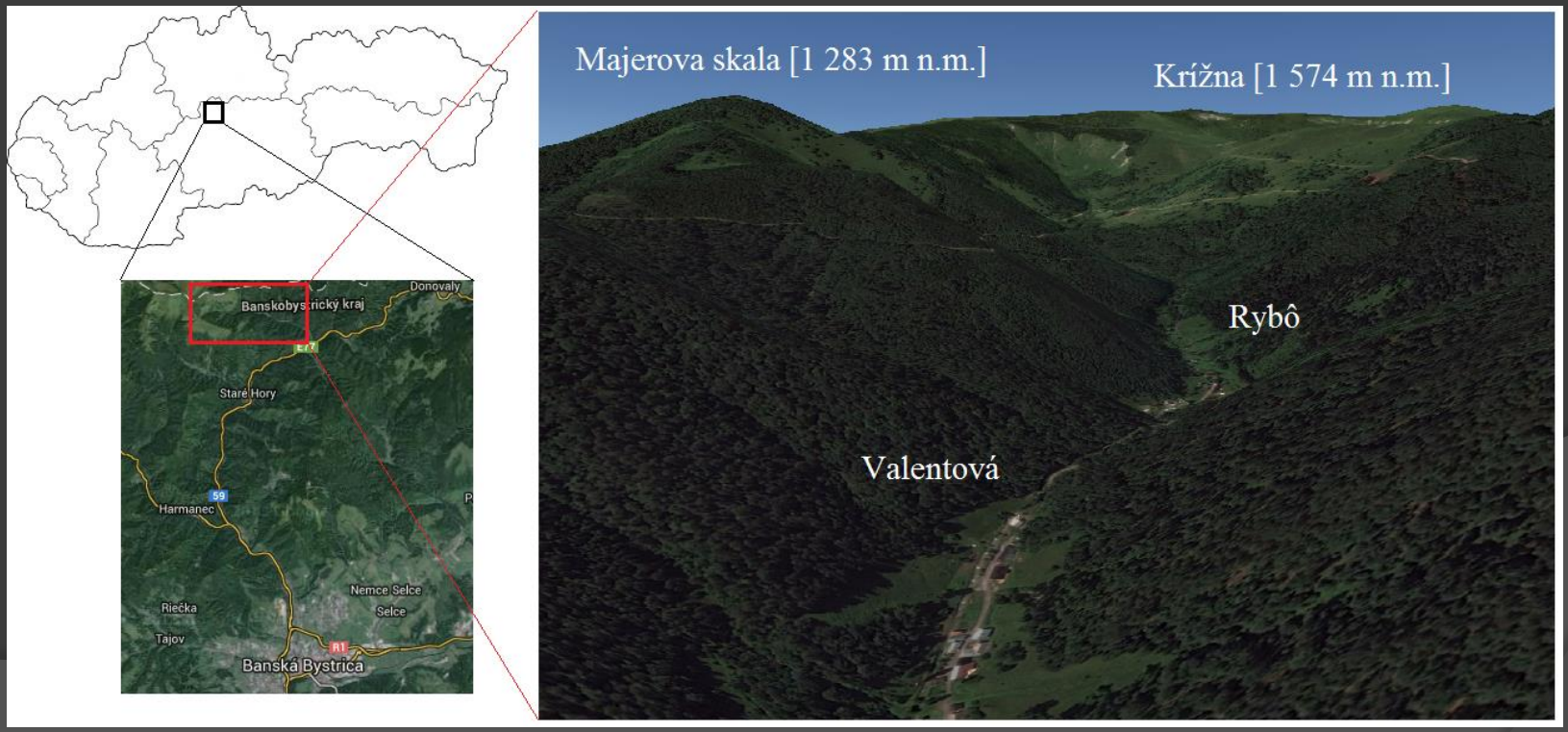


Results:
- avalanche length
- velocity
- maximal pressure
- maximal flow height
- deposit



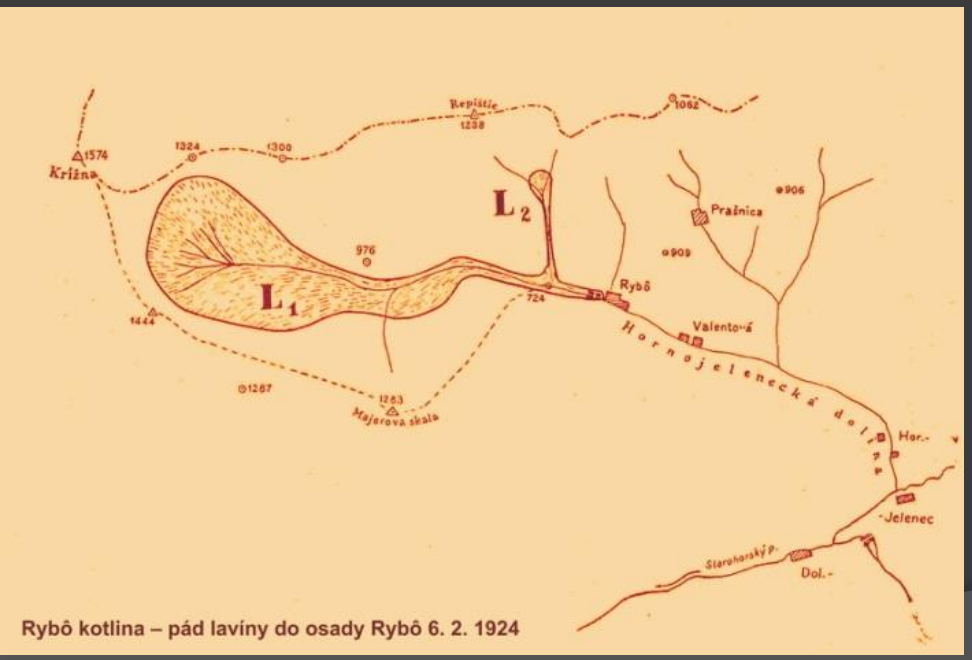
Rybô

- 6th February 1924 10:00 PM
- 18 victims
- 3 houses destroyed and 2 damaged
- Avalanche length 2,5 km
- Avalanche front height 35 m

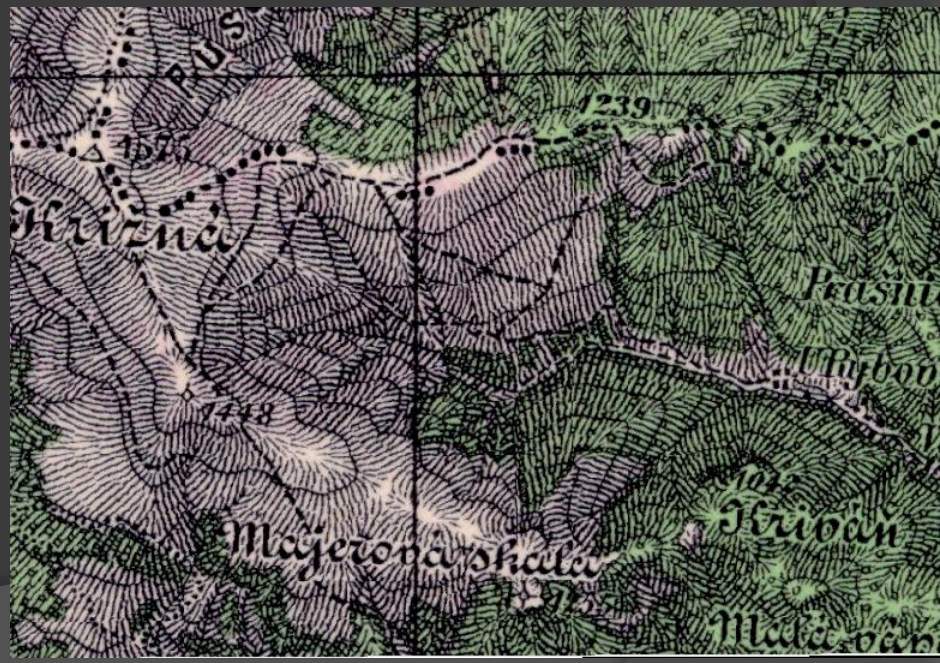


Material and Methods

- Reconstruction of historical avalanche from year 1924
- Simulation of avalanche without retarding effect of other avalanche, which fell a few days before from site slope „Rizničky“
- Avalanche simulation in present conditions

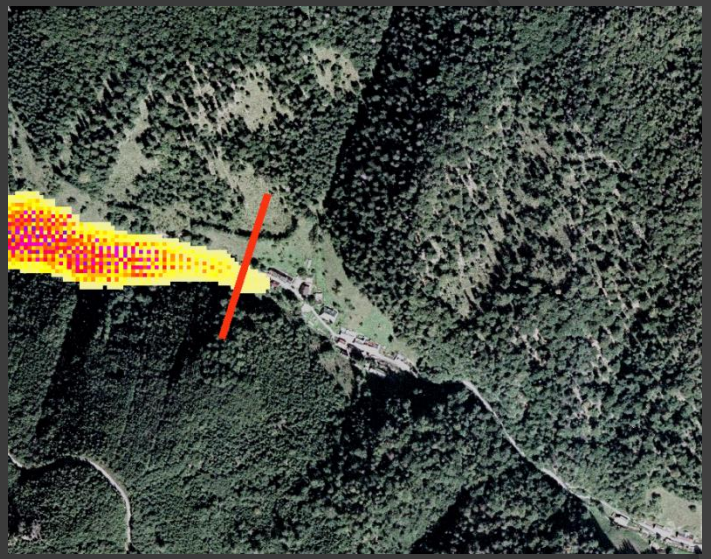


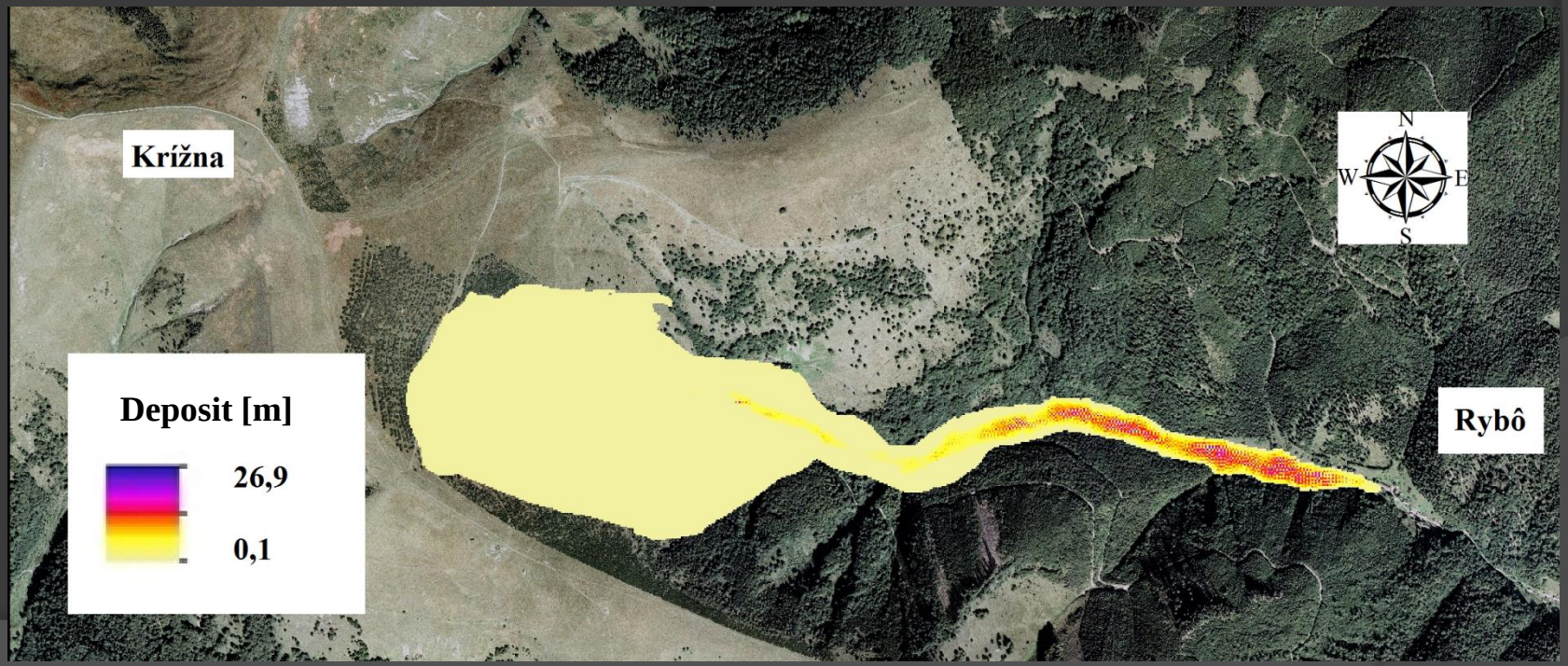
Rybô kotlina – pád lavíny do osady Rybô 6. 2. 1924



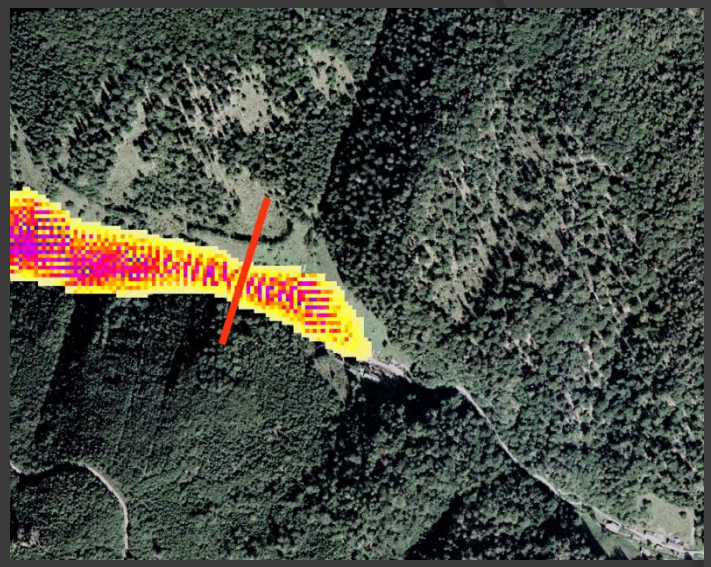
Results

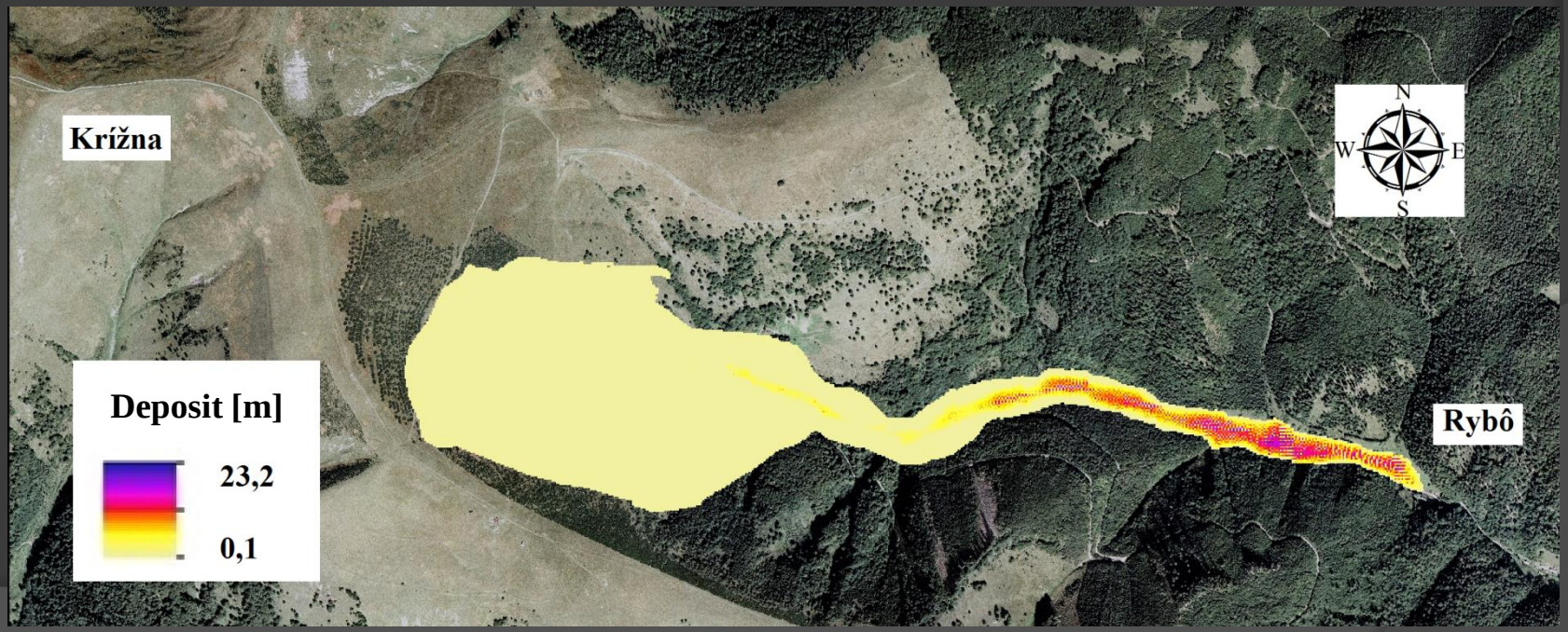
- Avalanche reconstruction



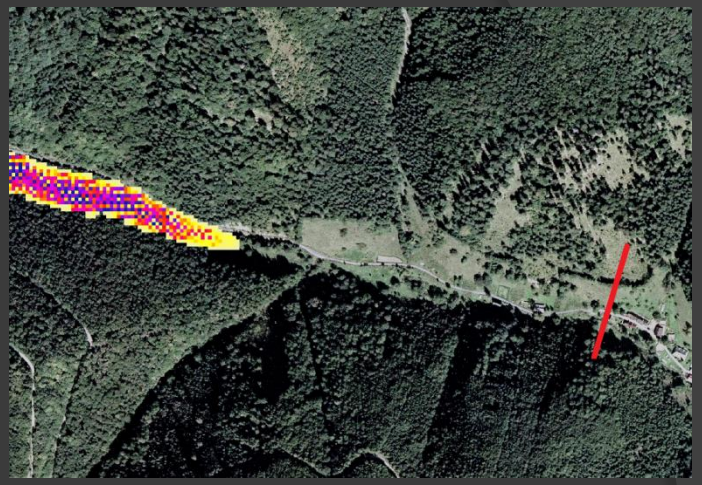


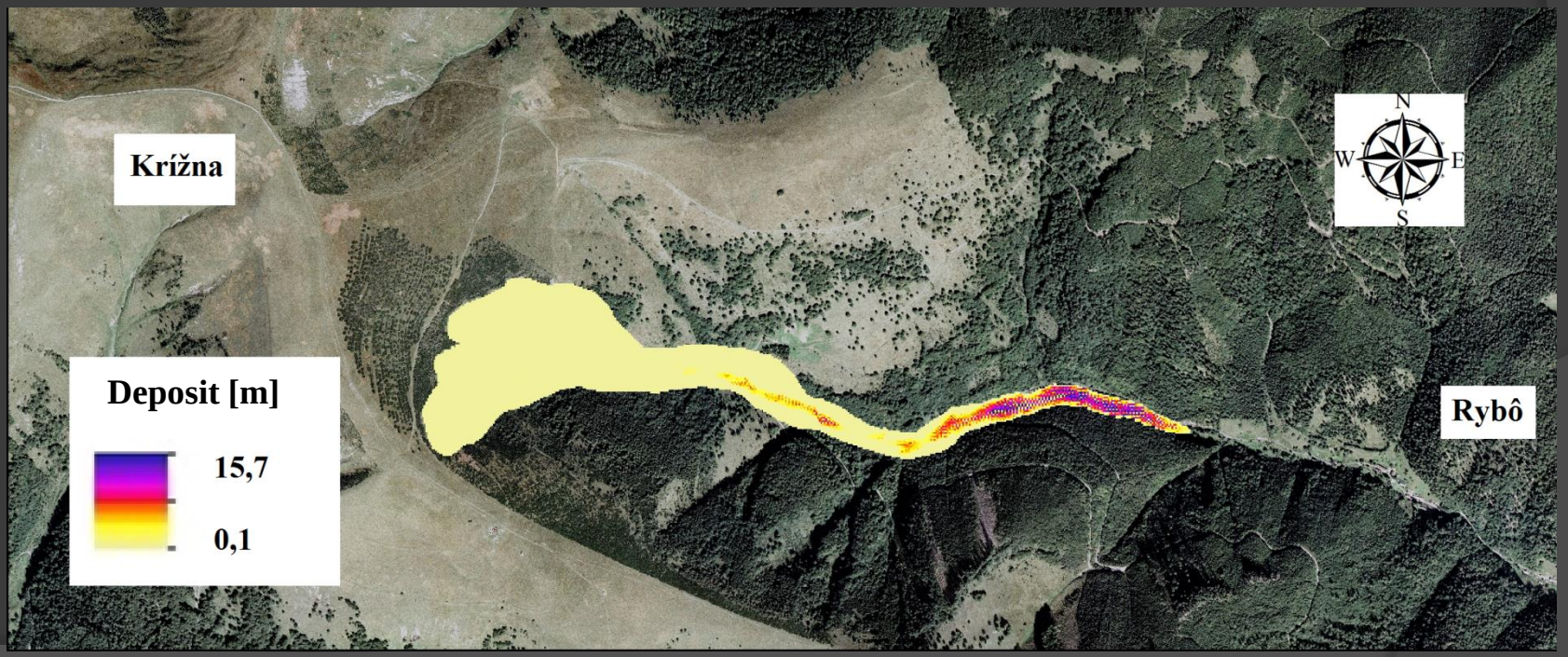
- Avalanche simulation without retarding effect of other avalanche





- Avalanche simulation in present state of release zones



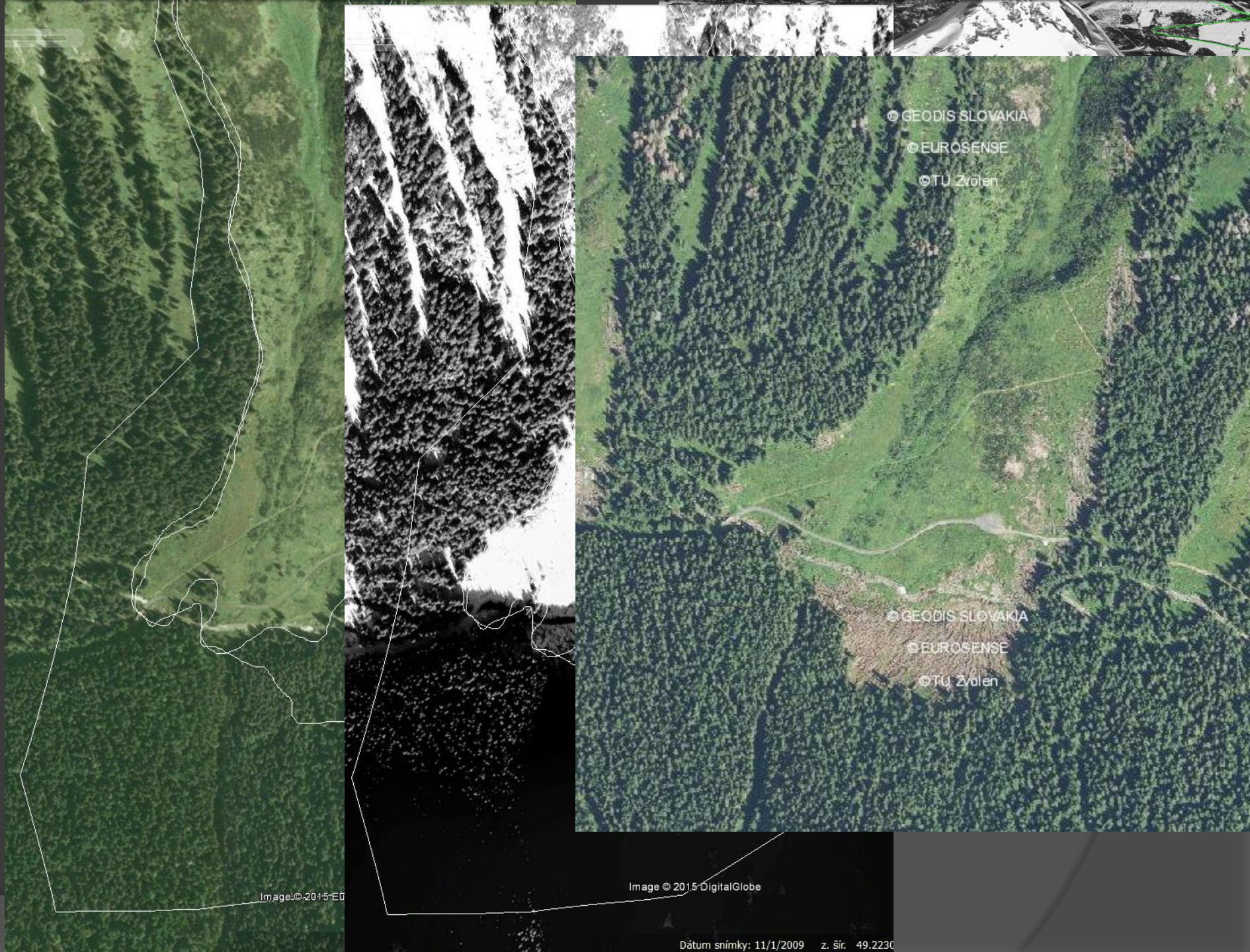


Conclusions

- Evaluation of reconstruction accuracy is in this case very complicated because we feel the lack of exact data (schematic sketch, snow cover characteristics, size release zone)
- Differences between our results and really data are not significantly: avalanche path 2,5 km (our result 2,55 km), deposit height 35 m (27 m) and deposit volume 580 00 m^3 (800 000 m^3)
- Avalanche simulation without retarding effect shows extensive damage and settlement would be destroyed from major part.
- Avalanche simulation at present conditions in release zones assumes, that reduction of release zone from 51 ha to potential 15 ha, should be avalanche length ca. 500 m shorter
- Finally we remind, that ELBA + is only model, which accordance with reality depend on input data quality

RAMMS EXTENDED

- Winter 2008/09 (March, April)
- 26 avalanches (9 wet, 17 powder)
- 22 avalanches with forest damages


© GEODIS SLOVAKIA
© EUROSENSE
© TU Zvolen
© GEODIS SLOVAKIA
© EUROSENSE
© TU Zvolen
Image © 2015 DigitalGlobe
Dátum snímky: 11/1/2009

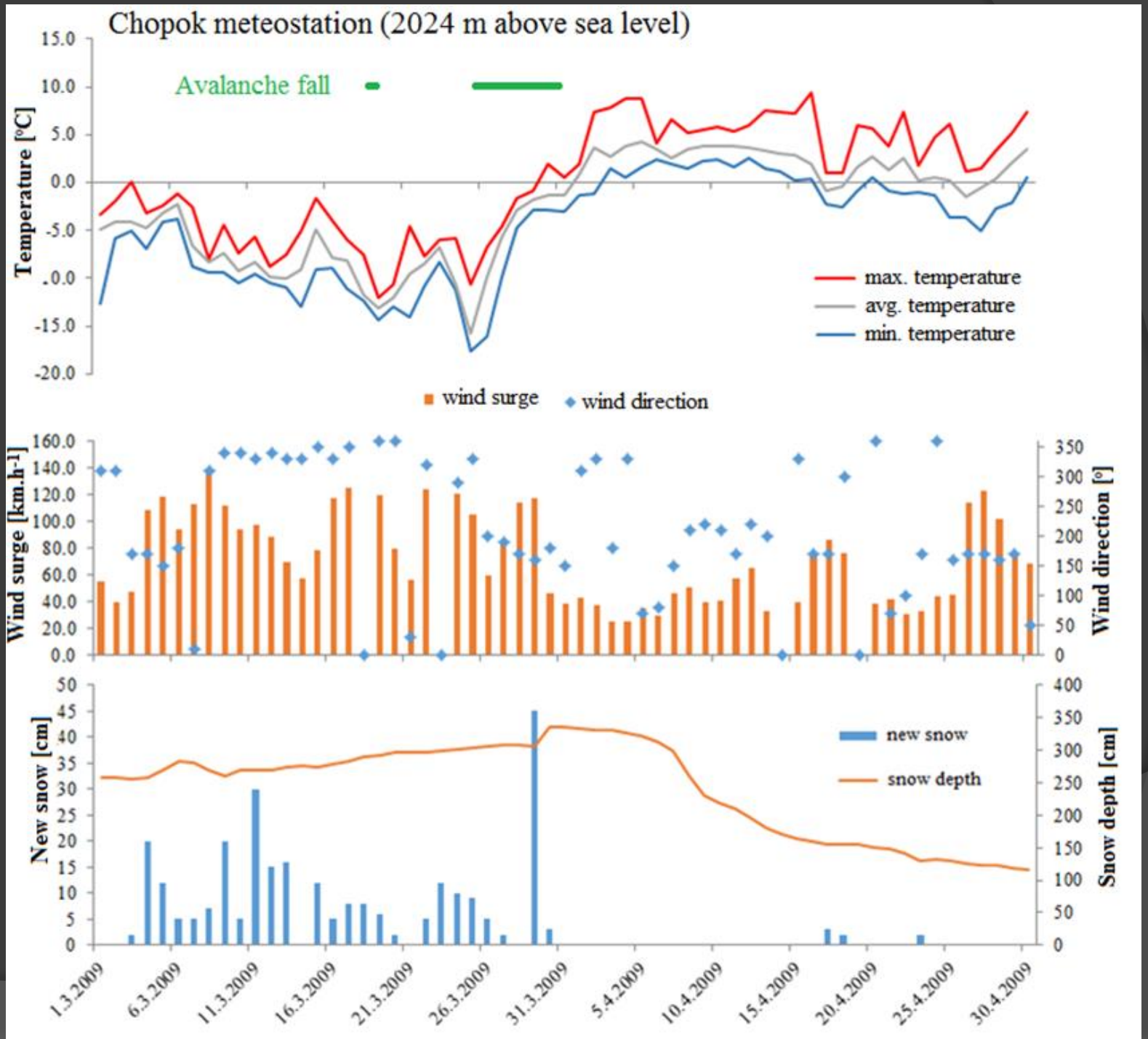

Chopok meteostation (2024 m above sea level)
Avalanche fall
Temperature [°C]
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
max. temperature
avg. temperature
min. temperature
wind surge
wind direction
Wind surge [km.h-1]
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Wind direction [°]
350
300
250
200
150
100
50
0
New snow [cm]
50
45
40
35
30
25
20
15
10
5
0
Snow depth [cm]
400
350
300
250
200
150
100
50
0
new snow
snow depth
1.3.2009
6.3.2009
11.3.2009
16.3.2009
21.3.2009
26.3.2009
31.3.2009
5.4.2009
10.4.2009
15.4.2009
20.4.2009
25.4.2009
30.4.2009


Image © 2015 Eurosense/Geodis Slovakia
Image © 2015 DigitalGlobe
Dátum snímky: 4/2/2009 z. šír. 49.243148° z. dĺž.

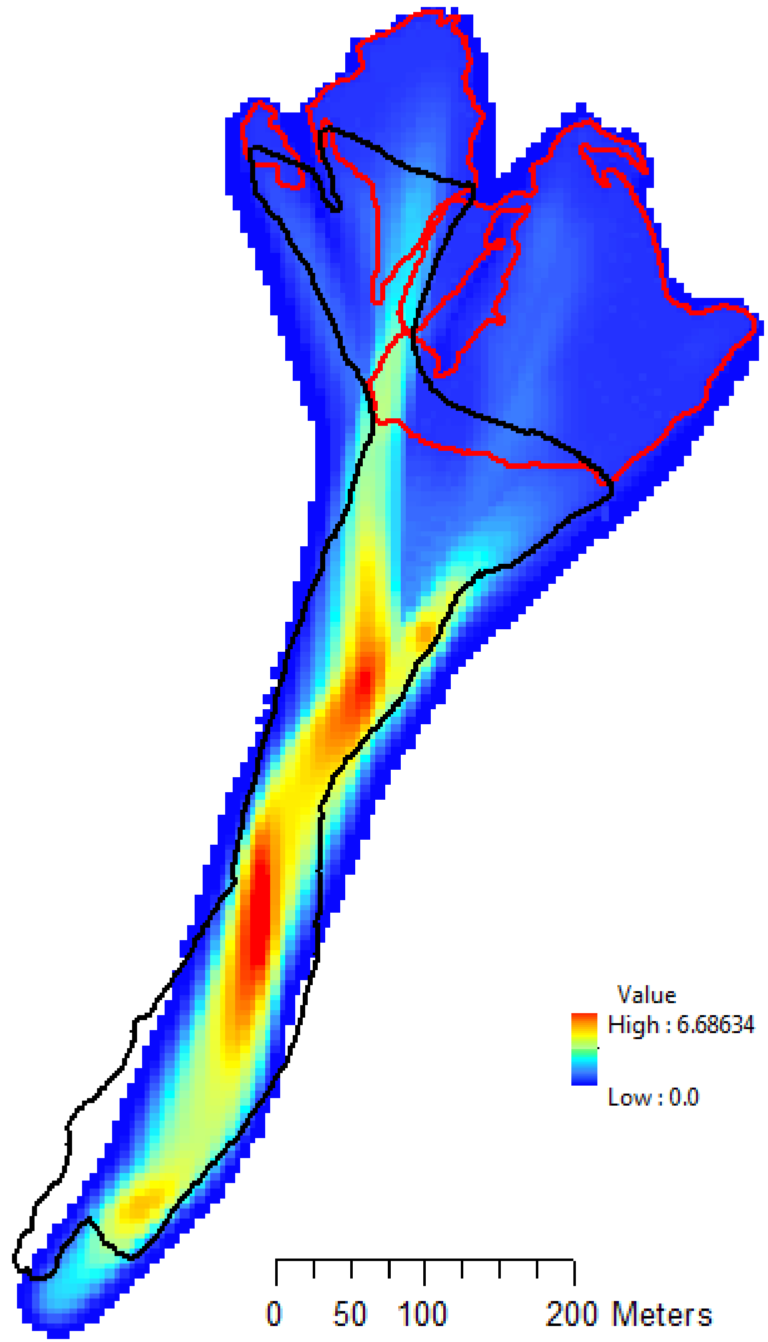
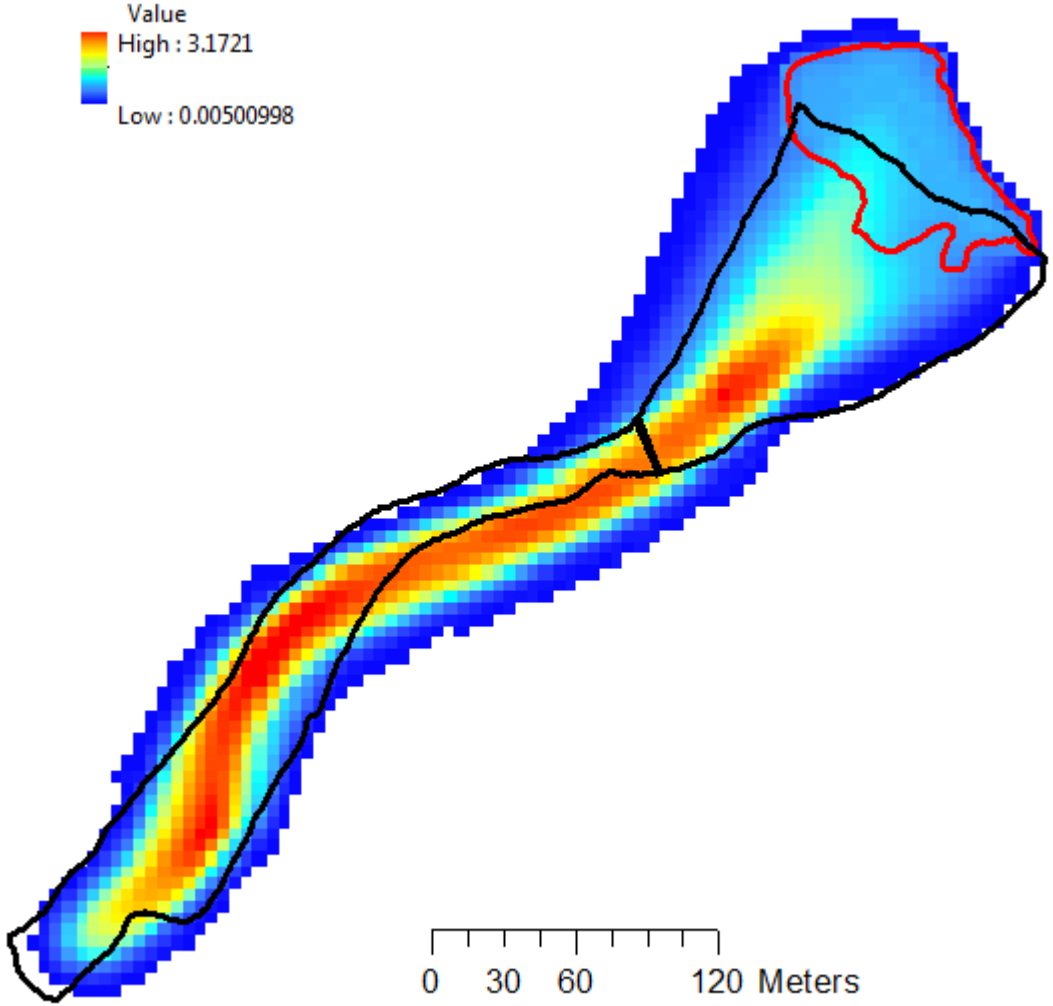
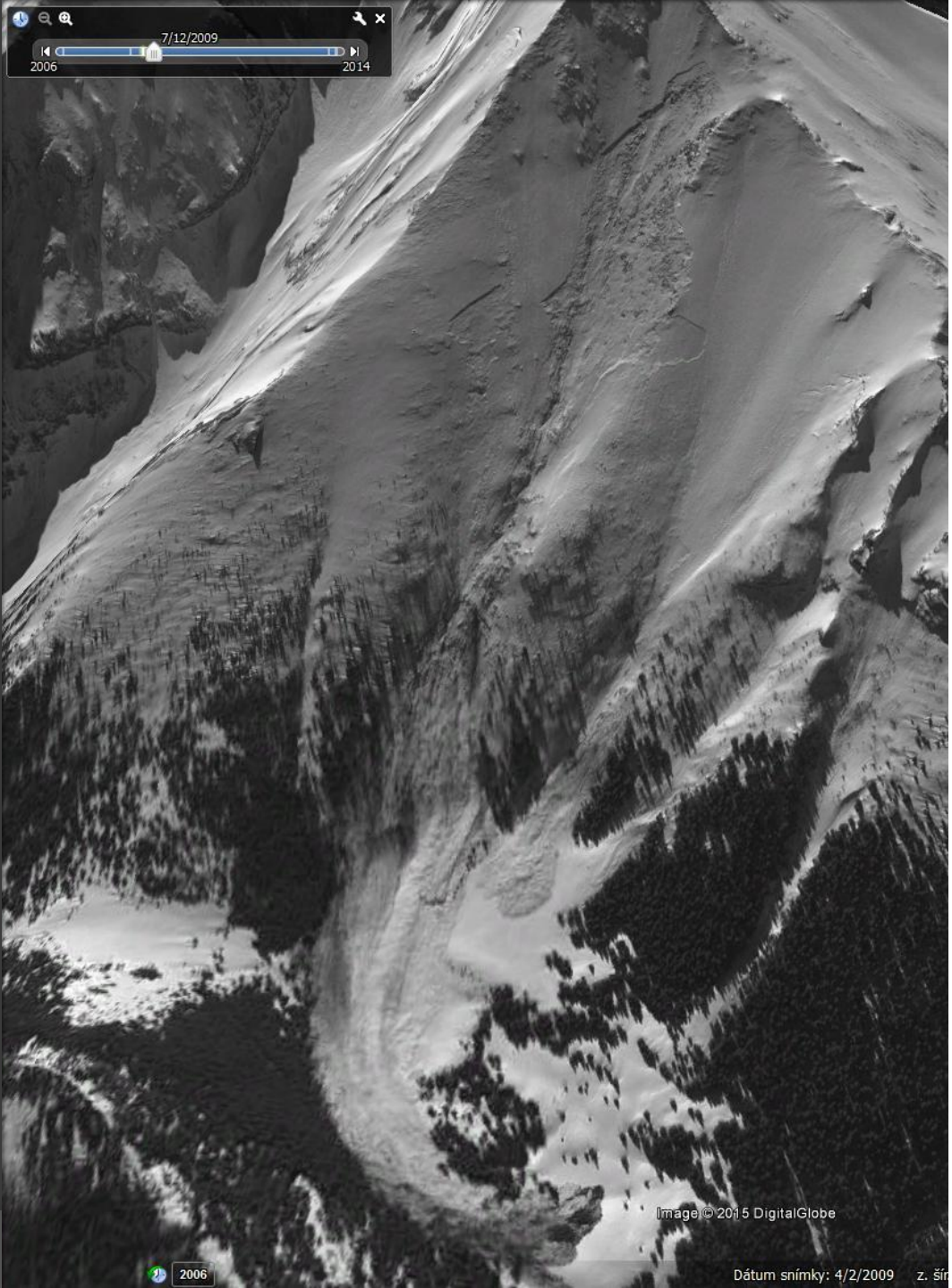
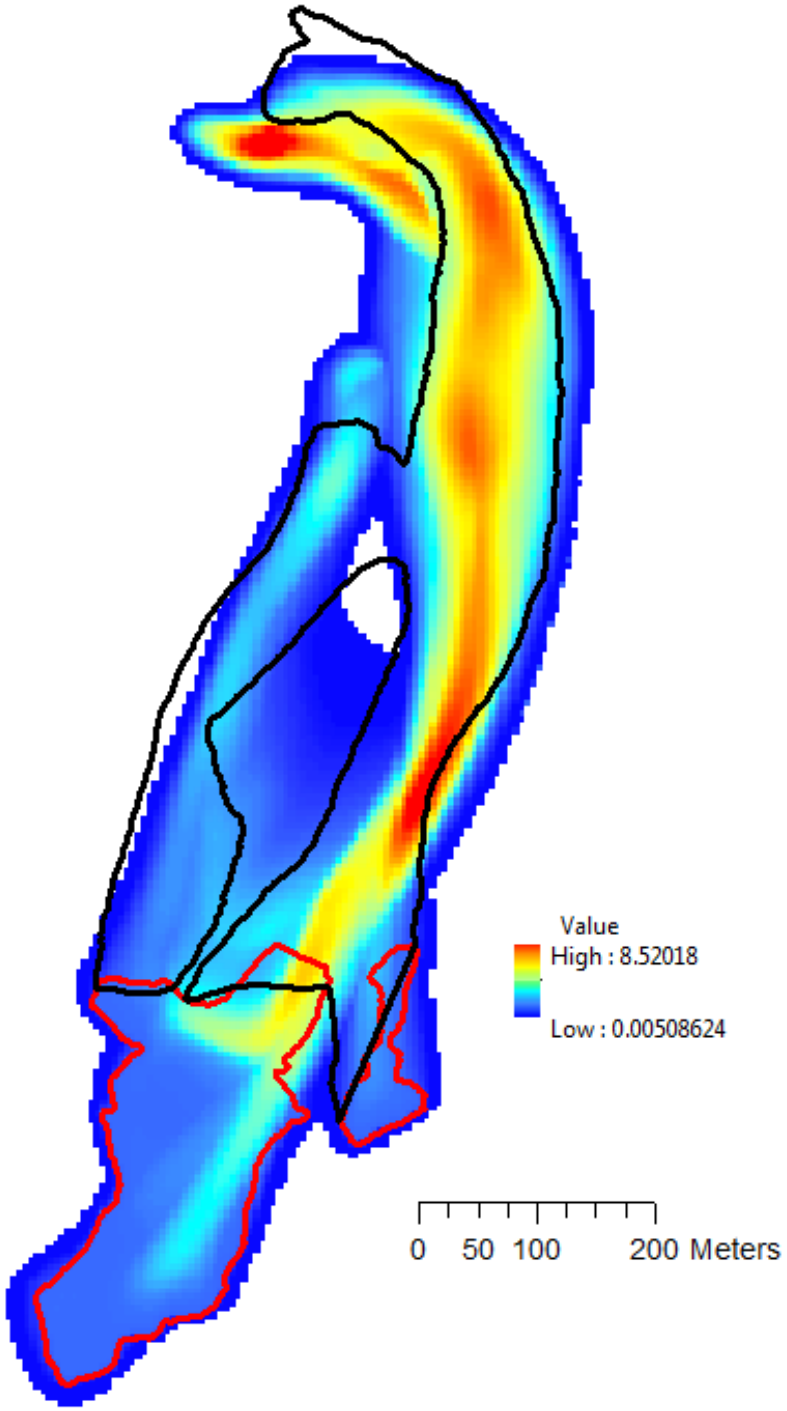

Value
High : 6.68634
Low : 0.0
0 50 100 200 Meters

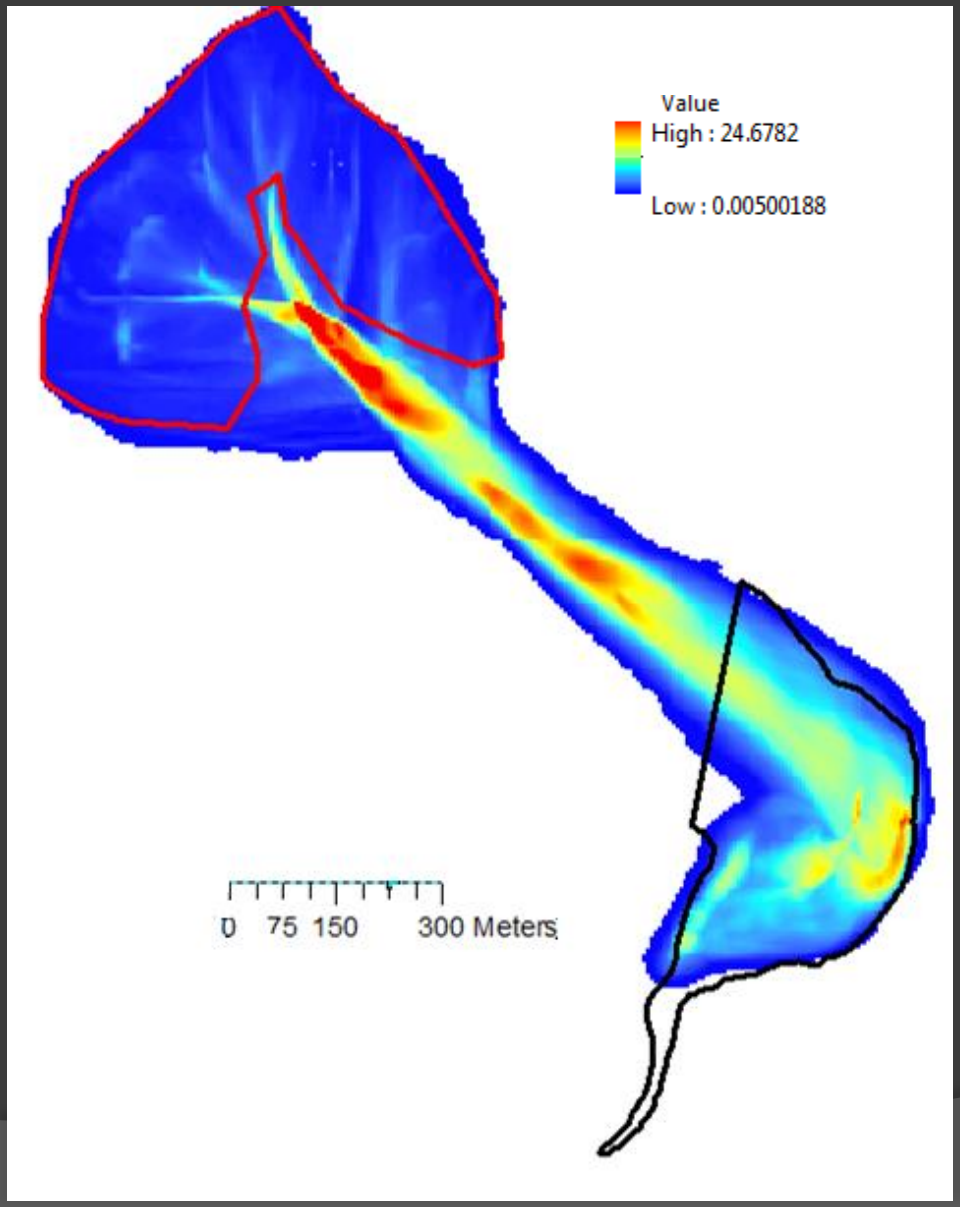

Image © 2015 Eurosense/Geodis Slovakia
Image © 2015 DigitalGlobe
Dátum snímky: 4/2/2009 z. šír. 49.233637° z. dĺž. 20.2

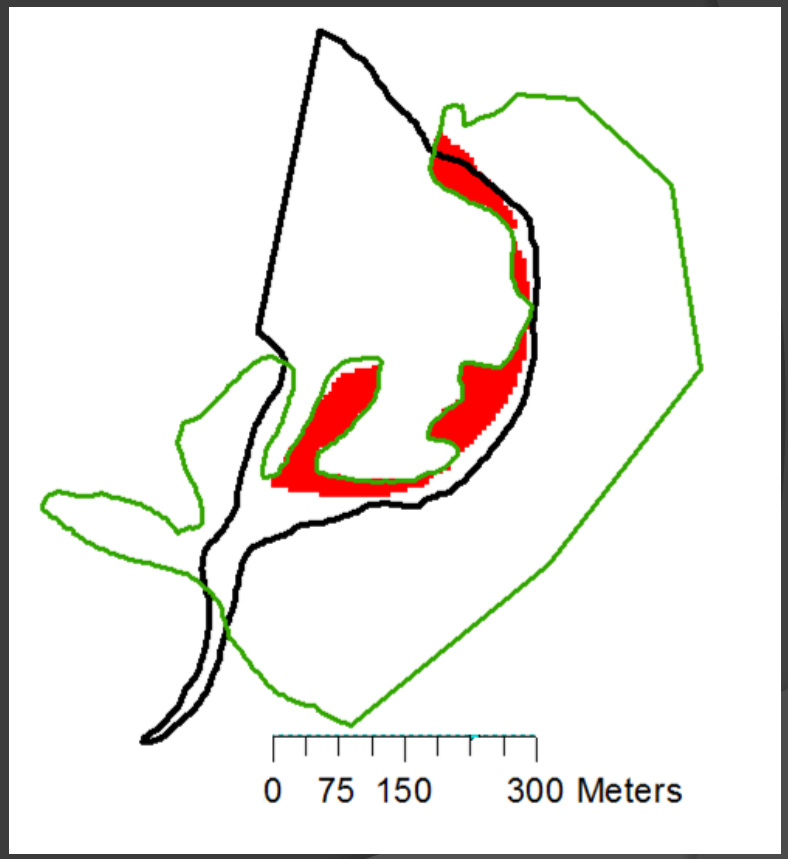

Value
High : 3.1721
Low : 0.00500998
0 30 60 120 Meters

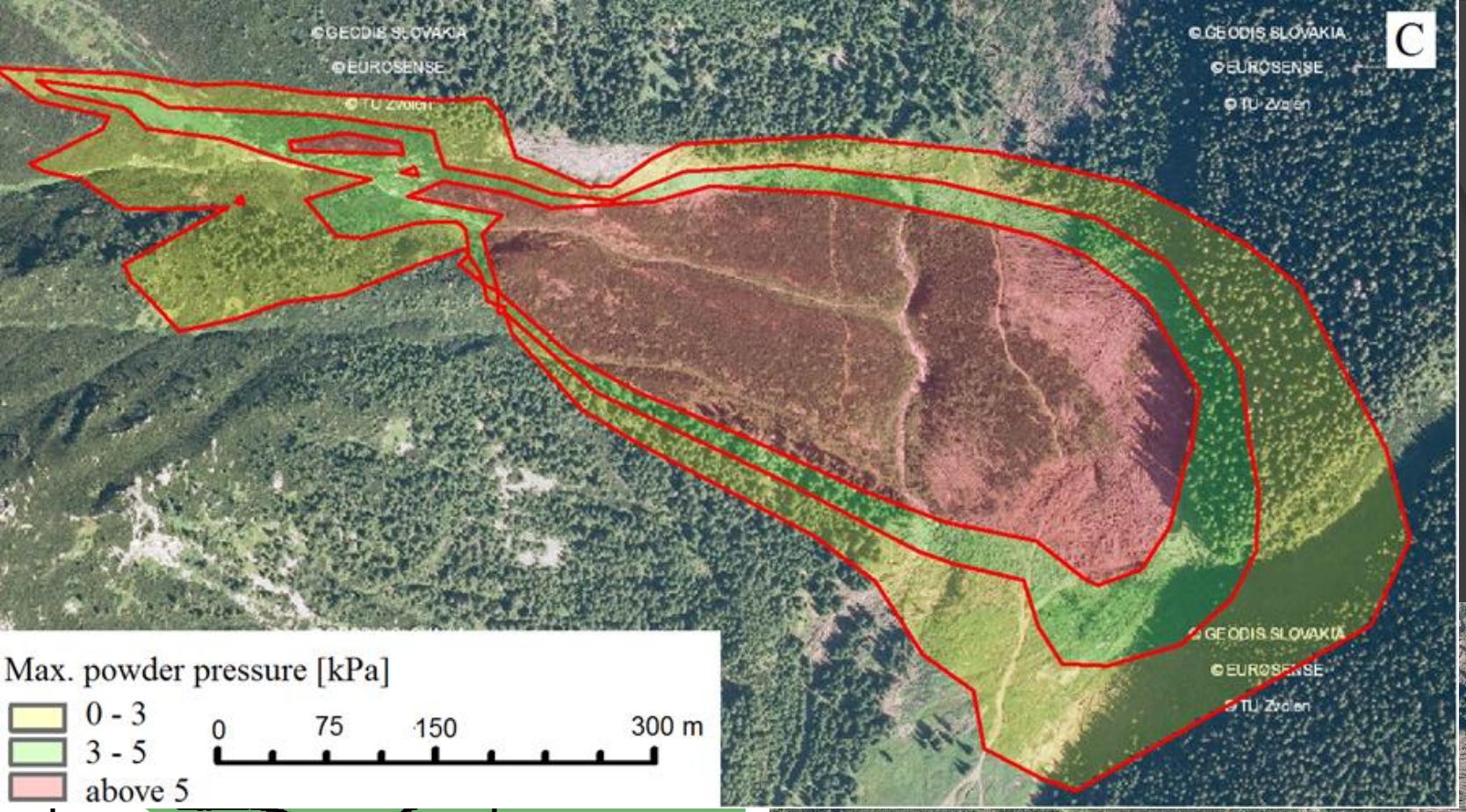

7/12/2009
2006
2014
Image © 2015 DigitalGlobe
2006
Dátum snímky: 4/2/2009

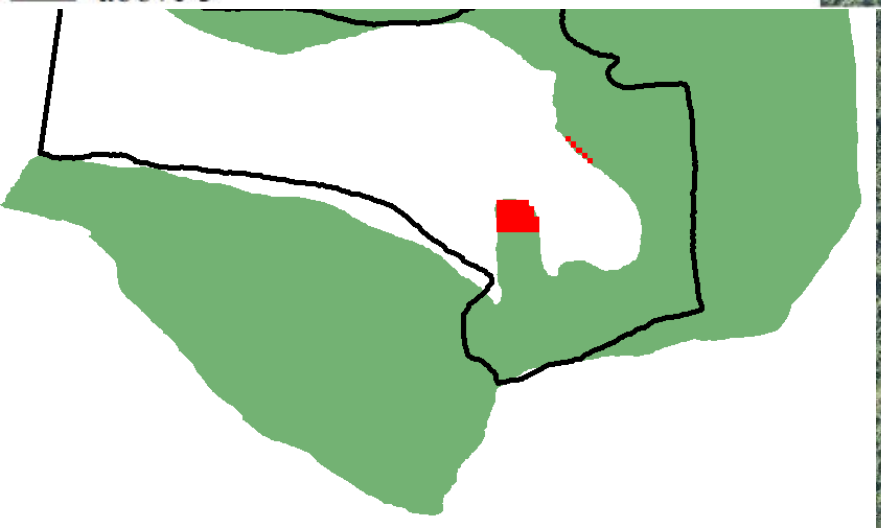

Value
High : 8.52018
Low : 0.00508624
0 50 100 200 Meters

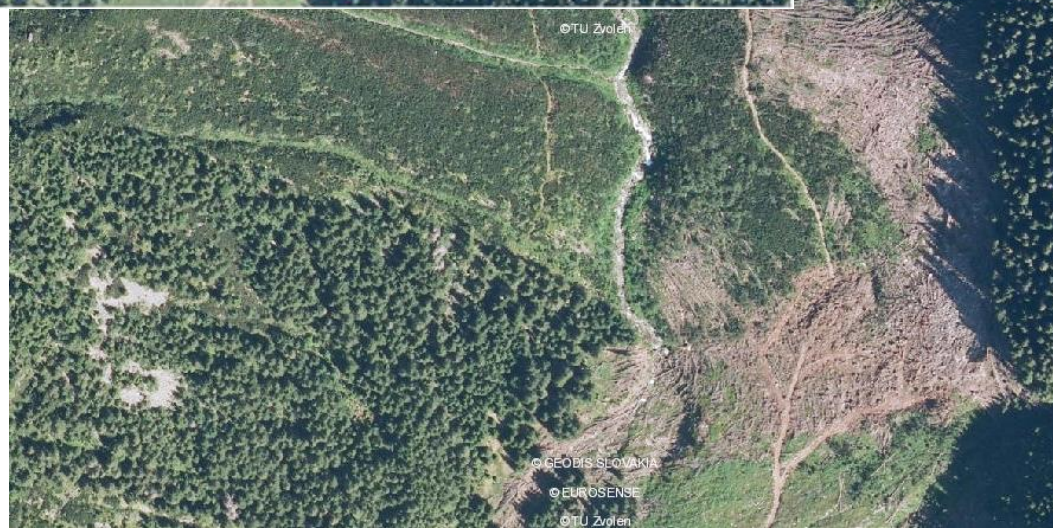
Powder avalanches

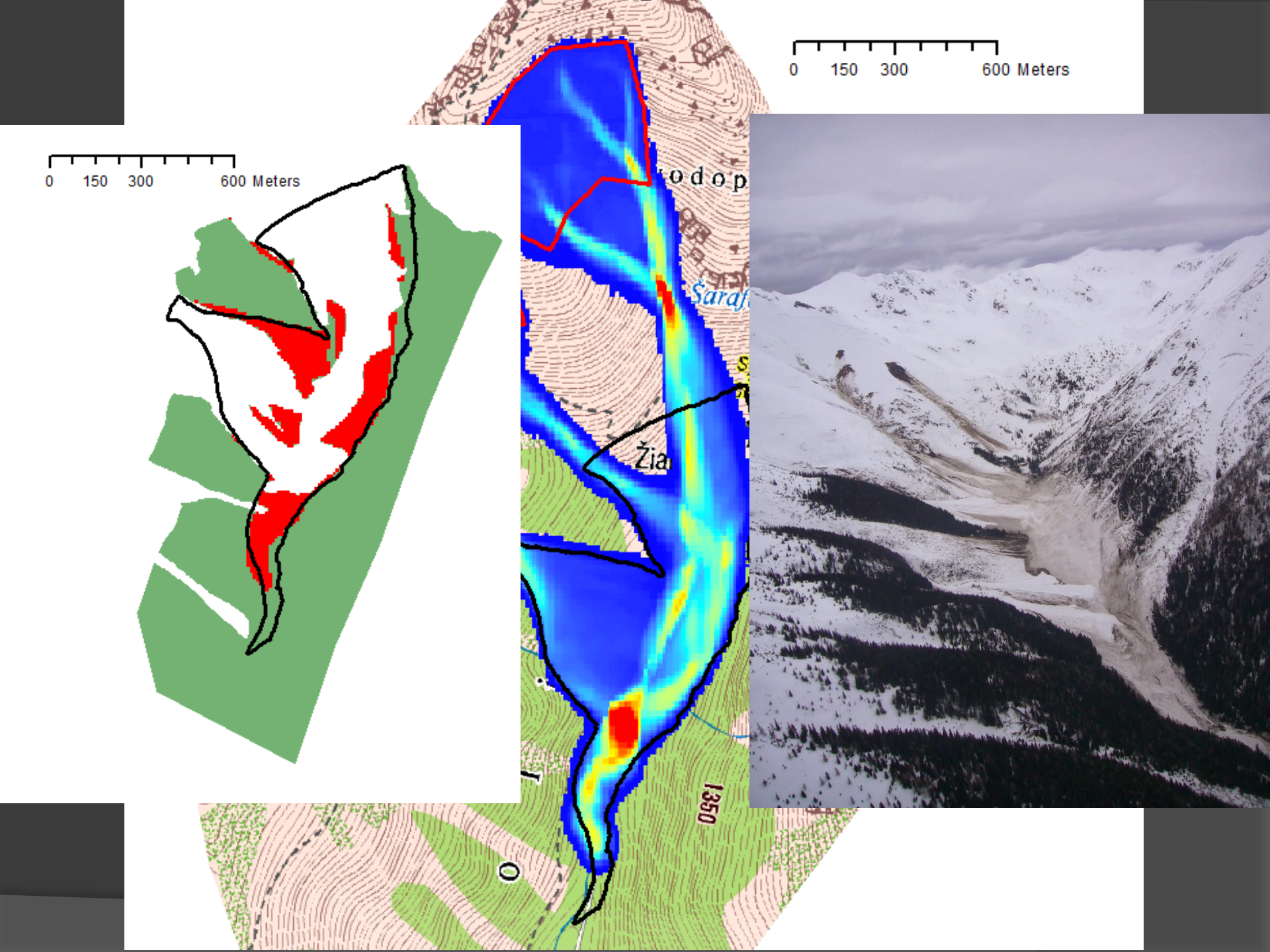




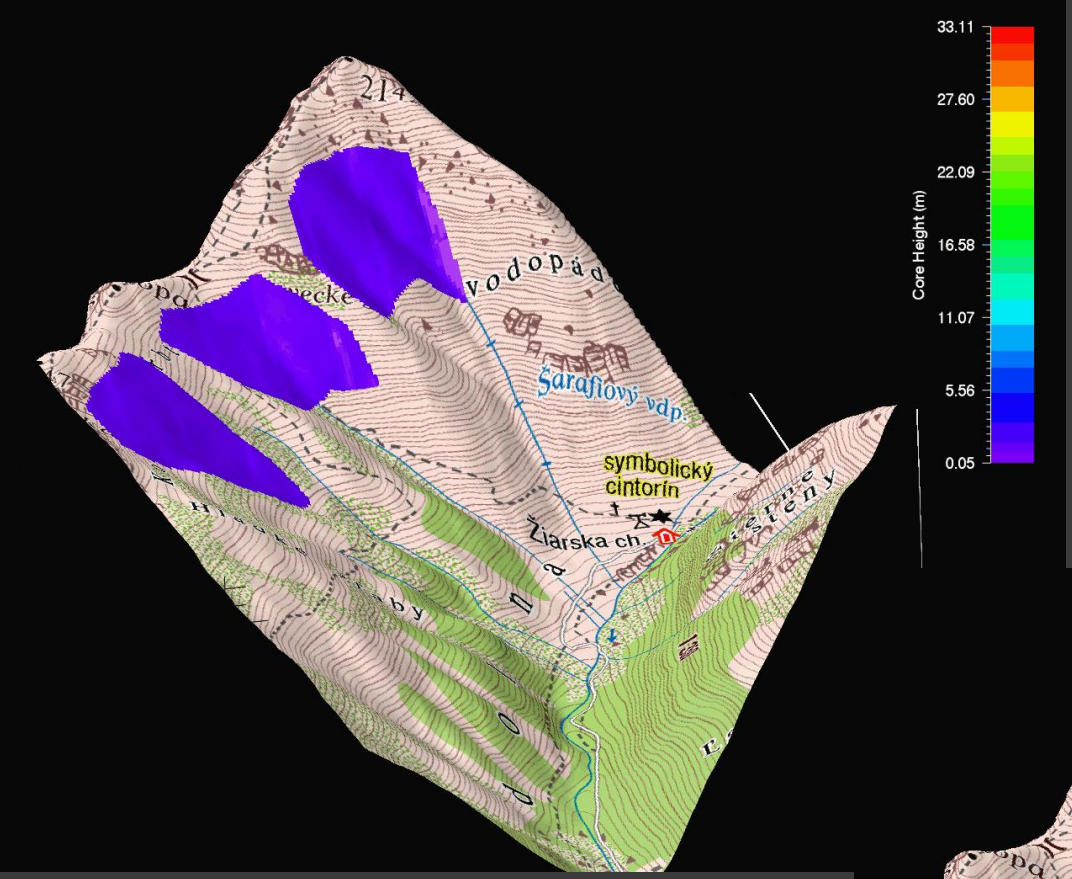

© GEODIS SLOVAKIA
© EUROSENSE
© TU Zvolen
C
Max. powder pressure [kPa]
0 - 3
3 - 5
above 5
0
75
150
300 m

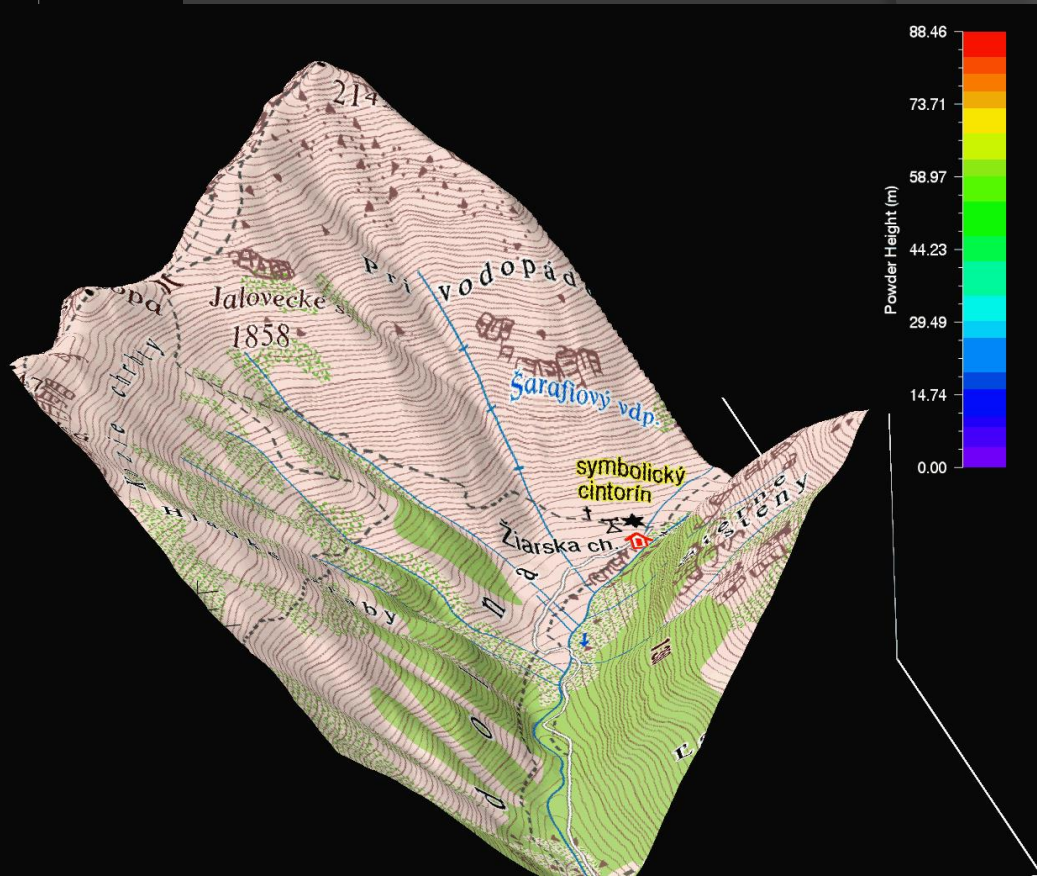



©TU Zvolen
© GEODIS SLOVAKIA
© EUROSENSE
©TU Zvolen


0 150 300 600 Meters
0 150 300 600 Meters
Žia
1350

conclusions





- Very good correspondence with reality
- Good opportunity for different simulation scenarios (dry or wet conditions)
- Good correspondence with forest damage (damage underestimated in the last meters)


Thanks for your attention