LOMONOSOV MOSCOW STATE UNIVERSITY
Faculty of Geography

Modeling snowpack on avalanche terrain for its stability estimation

Elena Klimenko

Laboratory of Snow Avalanches and Mudflows

Laboratory of Natural Hazard Risk Assessment in Coastal Zone

2011

The objective

- Snow cover modeling
- Defining areas with unstable snow cover

Introduction

Research Area

Description of developed technique

- Meteorological data recalculation
- Snowpack modeling
- Statistical analysis

Discussion
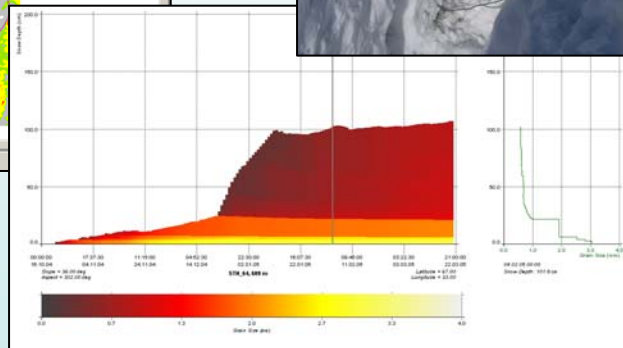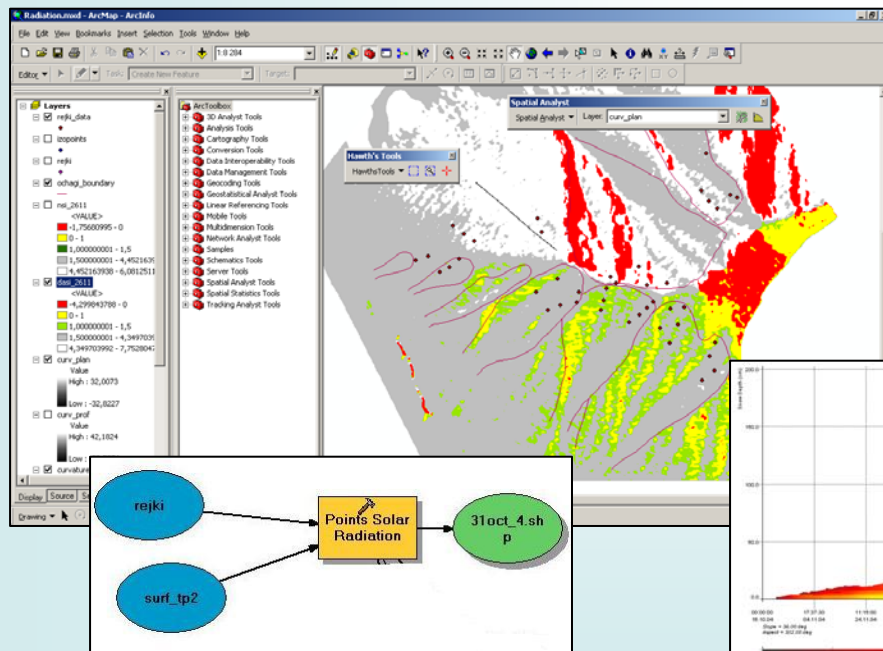
Future development

Acknowledgements
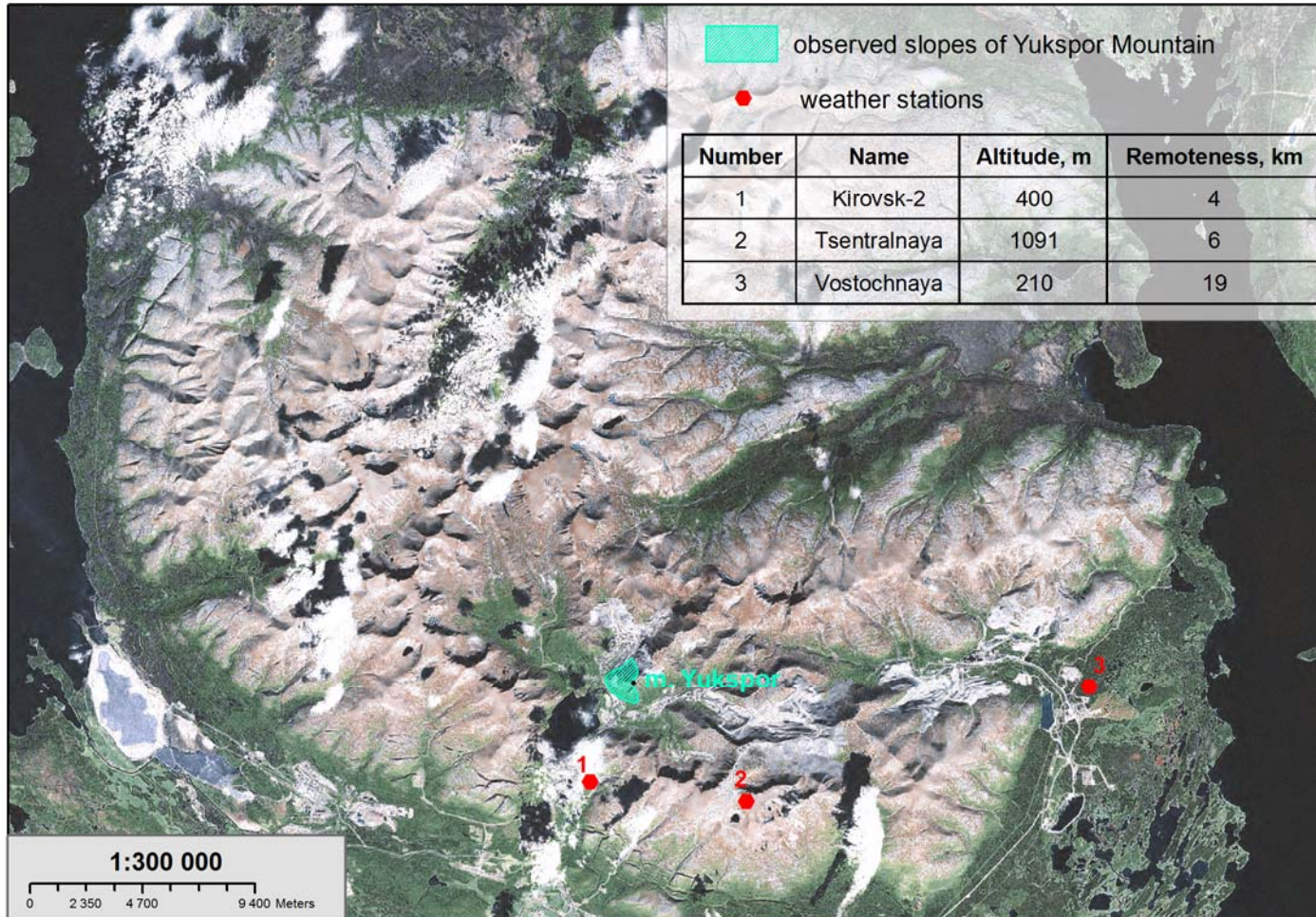
Two blocks

- <u>Snowpack modeling</u> – one-dimensional physically based model **SNOWPACK** (developed by Swiss Federal Institute of Snow and Avalanche Science (SLF))

- <u>Spatial data analysis</u> – GIS tools (**ArcGIS 9.3**)

Introduction

Research Area

North-Westen Russia, Kola Peninsula, The Khibiny Mountain Massif

observed slopes of Yukspor Mountain

● weather stations

Number	Name	Altitude, m	Remoteness, km
1	Kirovsk-2	400	4
2	Tsentralnaya	1091	6
3	Vostochnaya	210	19

1:300 000

0   2 350   4 700   9 400 Meters

- NW and SW slopes of Yukspor Mount

- Winter 2004-2005

- Data from three nearest weather stations with time interval of 3 hours

- Snow-measuring data

First step: Meteorological data recalculation

Most of the meteo parameters were treated with algorithms that consider the physical peculiarities of their spatial spreading

SNOWPACK model was run for **53 points**, located in the avalanche starting zones

Scheme for snow height increment calculation
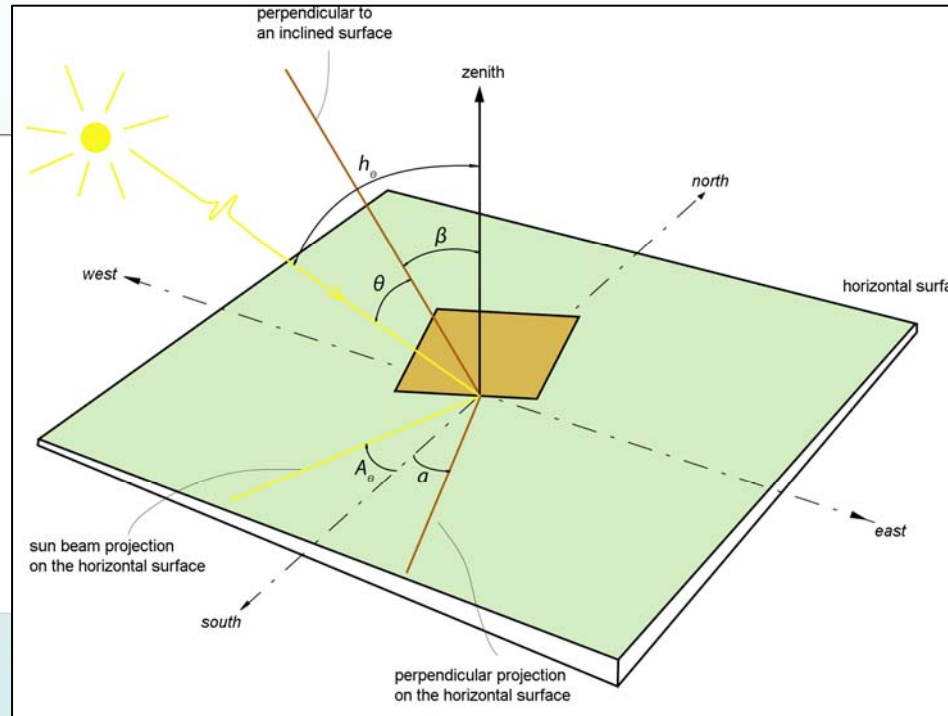
Geometry scheme used for calculation of direct illumination of differently orientated inclined surfaces

Yukspor Mountain slopes: avalanche sites and snow-measuring stakes location

Notation conventions

860
700
500
300

— contours

road
railway
upper timberline
border of analysis zone
avalanche sites borders
17 number of avalanche site
snow-measuring stakes
additional points needed for analysis

Modeling snowpack on avalanche terrain for its stability estimation

Elena Klimenko

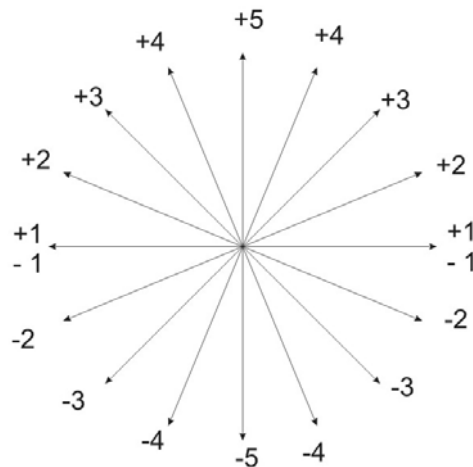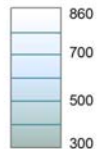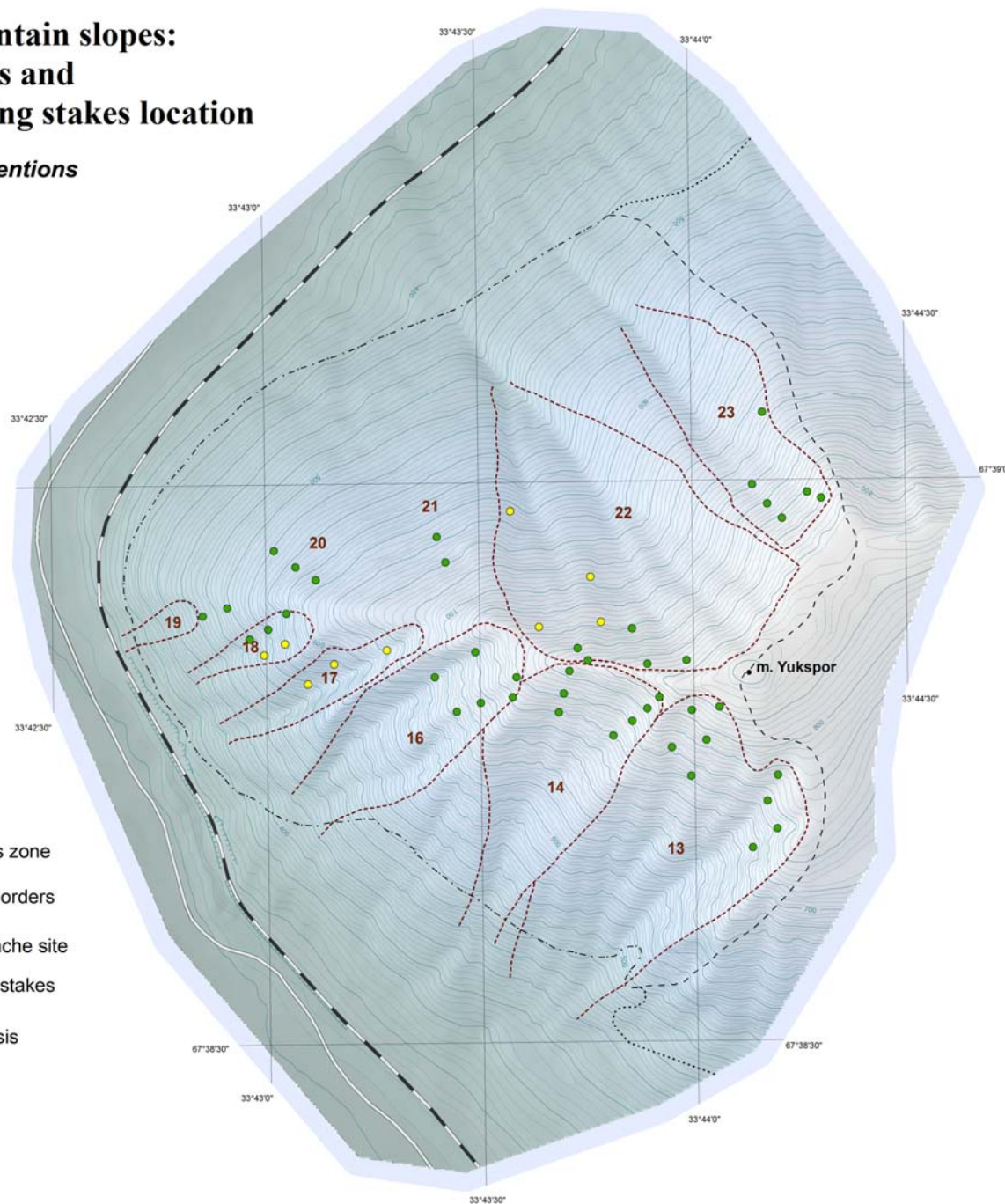Introduction

Research Area

Description of developed technique

- Meteorological data recalculation
- Snowpack modeling
- Statistical analysis

Discussion

Future development

Acknowledgements

Second step: running SNOWPACK and calculation of snow stability indexes values

Modeling snowpack on avalanche terrain for its stability estimation

Elena Klimenko

Introduction

Research Area

Description of developed technique

• Meteorological data recalculation

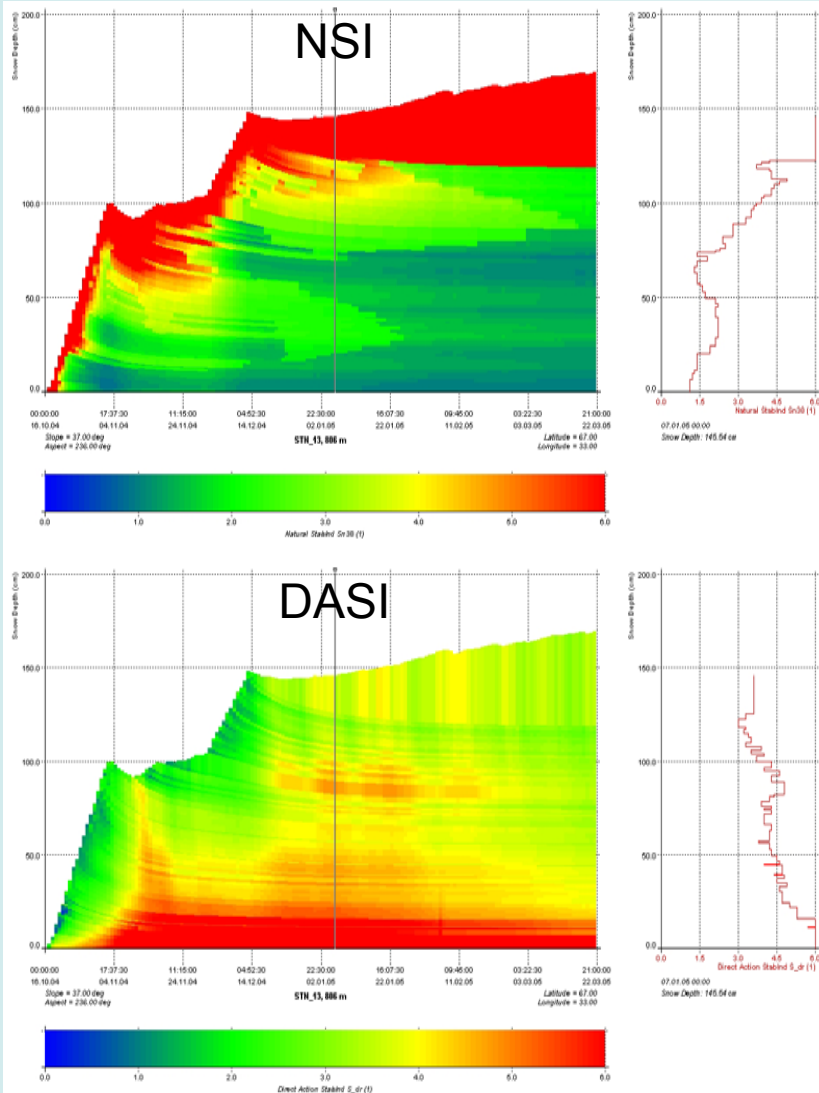• Snowpack modeling

• Statistical analysis

Discussion

Future development

Acknowledgements

NSI

DASI

Results of snowpack modeling in vicinity of 13th stake (avalanche site number 14)

Two indexes (introduced in the SNOWPACK, version 2007) were estimated:

1. **Natural Stability Index** – NSI (relies on static force balance within snowpack, can be used for predicting natural and skier-triggered slab avalanches)

2. **Direct Action Stability Index** – DASI (based on snow deformation rate, is used for predicting wet and fresh-snow avalanches)

NSI, DASI < 1 – unstable snowpack

NSI, DASI > 1,5 – stable snowpack

Third step: Statistical analysis of modeled results

Nine dates were selected from the time interval within which snow was modeled (Five days correspond to avalanche occasions, others were chosen randomly).

Minimum values of snow **stability indexes**, calculated on these days, were taken from graphs constructed in SNOWPACK **for every analyzed point**.

HYPOTHESIS: A significant **correlation** between stability indexes values and morphometric parameters of corresponding slopes **should exist**

Multiple Regression Function was used to deduce empirical equations of indexes values dependence on listed morphometric characteristics:

Independent variables:
- slope
- aspect
- plan curvature
- profile curvature
- altitude
- *snowpack height*

Dependent variables:

- Natural stability index

- Direct action Stability Index

Within-seasonal dynamics links between stability index (NSI) values and morphometric parameters of slopes
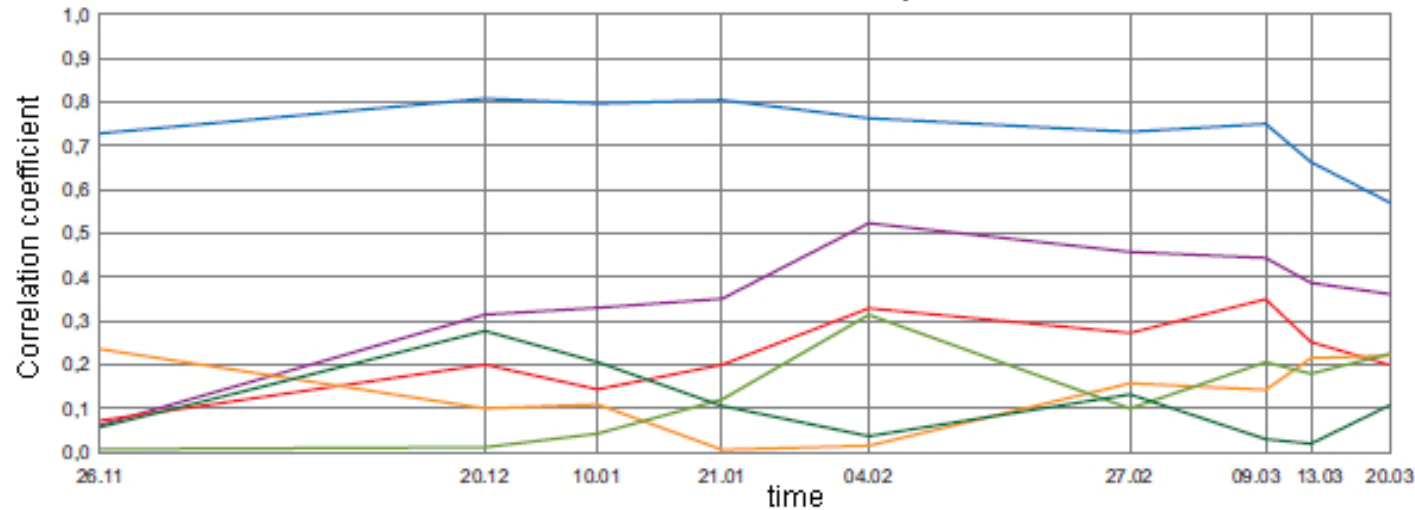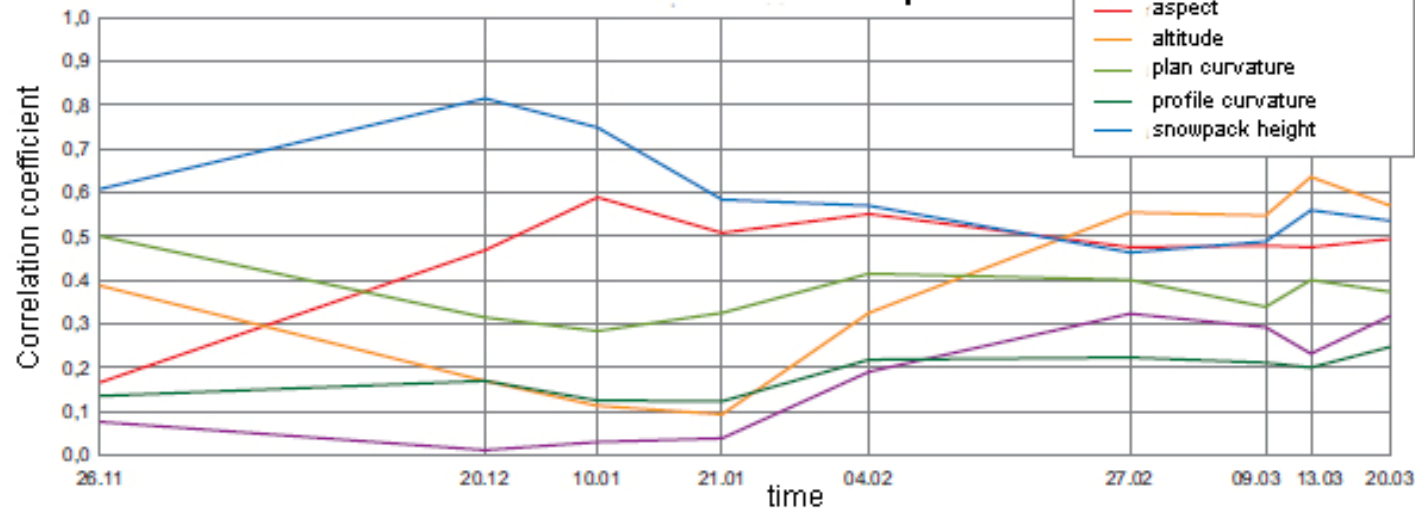
Estimation of snow stability on Yukspor Mountain slopes 27.02.2005

Notation conventions
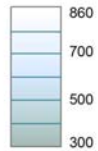
- 860
- 700
- 500
- 300

— contours
— road
— railway
········· upper timberline
– – – – border of analysis zone
- - - - - avalanche sites borders

17 — number of avalanche site

////// sites, where avalanche descent was observed

Natural Stability Index - NSI

- 0 - 0,5
- 0,5 - 1
- 1 - 1,5
- 1,5 - 3
- 3 - 4,5
- 4,5 - 6

• points where NSI>1,5
• points where NSI≤1

Introduction

Research Area

Description of developed technique

- Meteorological data recalculation
- Snowpack modeling
- Statistical analysis

Discussion

Future development

Acknowledgements

Estimation of snow stability on Yukspor Mountain slopes 9.03.2005

Notation conventions

Elevation (m):
- 860
- 700
- 500
- 300
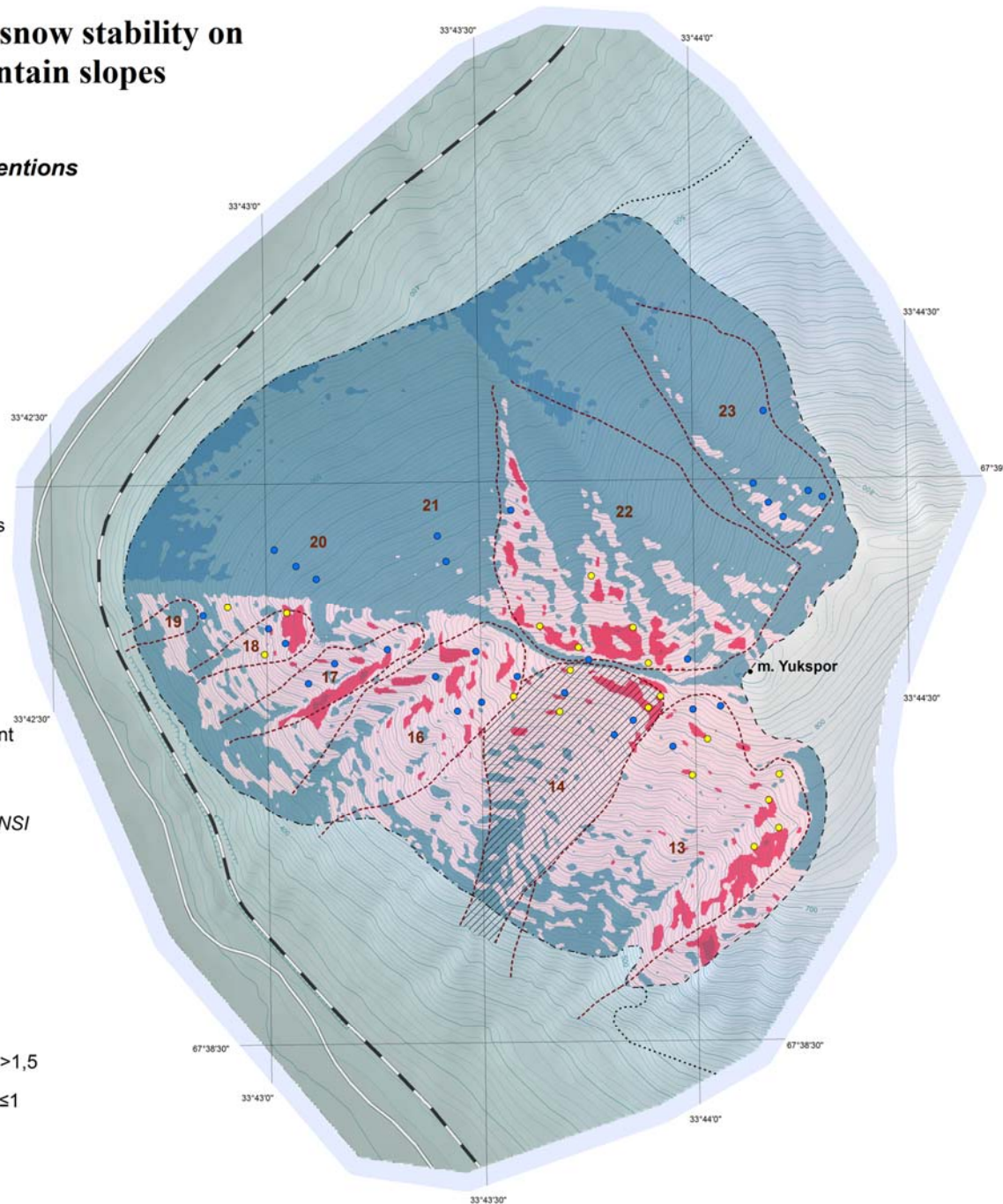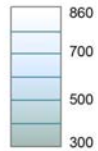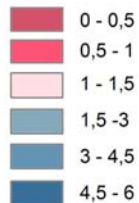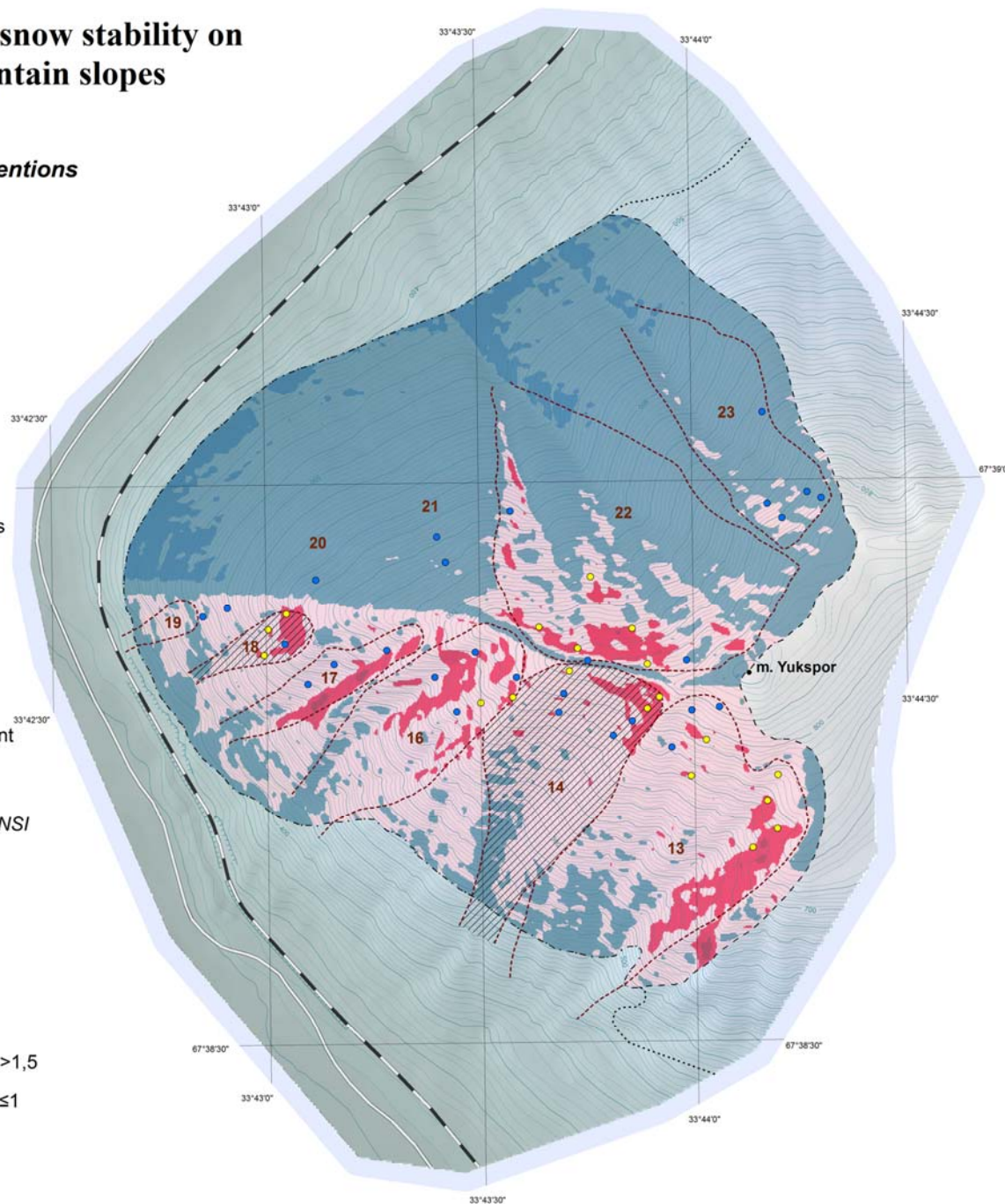
- contours
- road
- railway
- upper timberline
- border of analysis zone
- avalanche sites borders
- 17 number of avalanche site
- sites, where avalanche descent was observed

Natural Stability Index - NSI
- 0 - 0,5
- 0,5 - 1
- 1 - 1,5
- 1,5 - 3
- 3 - 4,5
- 4,5 - 6

- points where NSI>1,5
- points where NSI≤1

Modeling snowpack on avalanche terrain for its stability estimation

Elena Klimenko

Introduction

Research Area

Description of developed technique
- Meteorological data recalculation
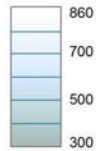- Snowpack modeling
- Statistical analysis

Discussion

Future development

Acknowledgements

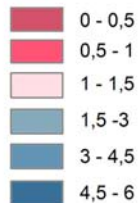Estimation of snow stability on Yukspor Mountain slopes 13.03.2005

Notation conventions

Elevation (m): 860, 700, 500, 300

contours
road
railway
upper timberline
border of analysis zone
avalanche sites borders
17 number of avalanche site
sites, where avalanche descent was observed

Natural Stability Index - NSI
0 - 0,5
0,5 - 1
1 - 1,5
1,5 - 3
3 - 4,5
4,5 - 6

points where NSI>1,5
points where NSI≤1

Modeling snowpack on avalanche terrain for its stability estimation

Elena Klimenko

Introduction

Research Area

Description of developed technique
• Meteorological data recalculation
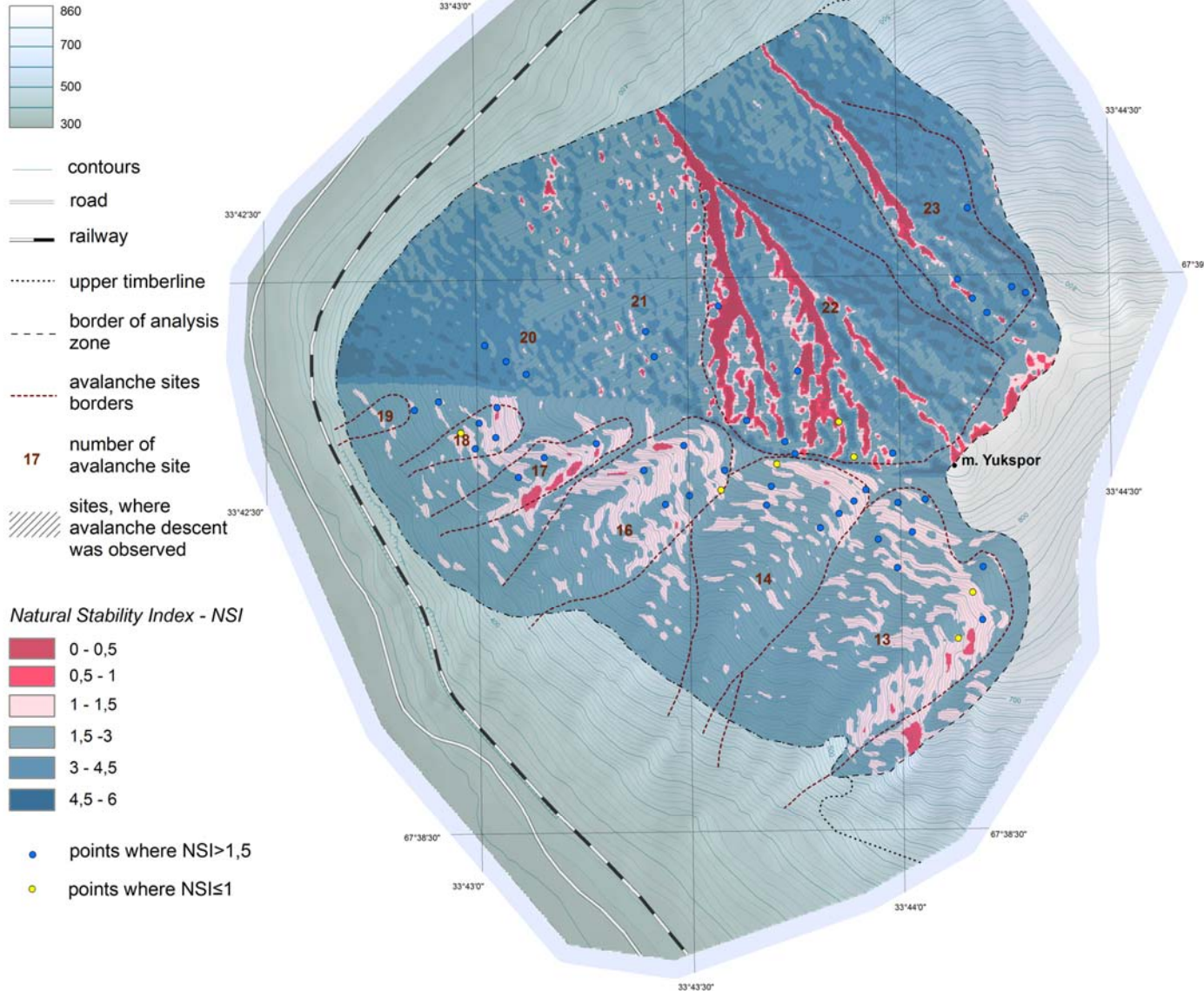• Snowpack modeling
• Statistical analysis

Discussion

Future development
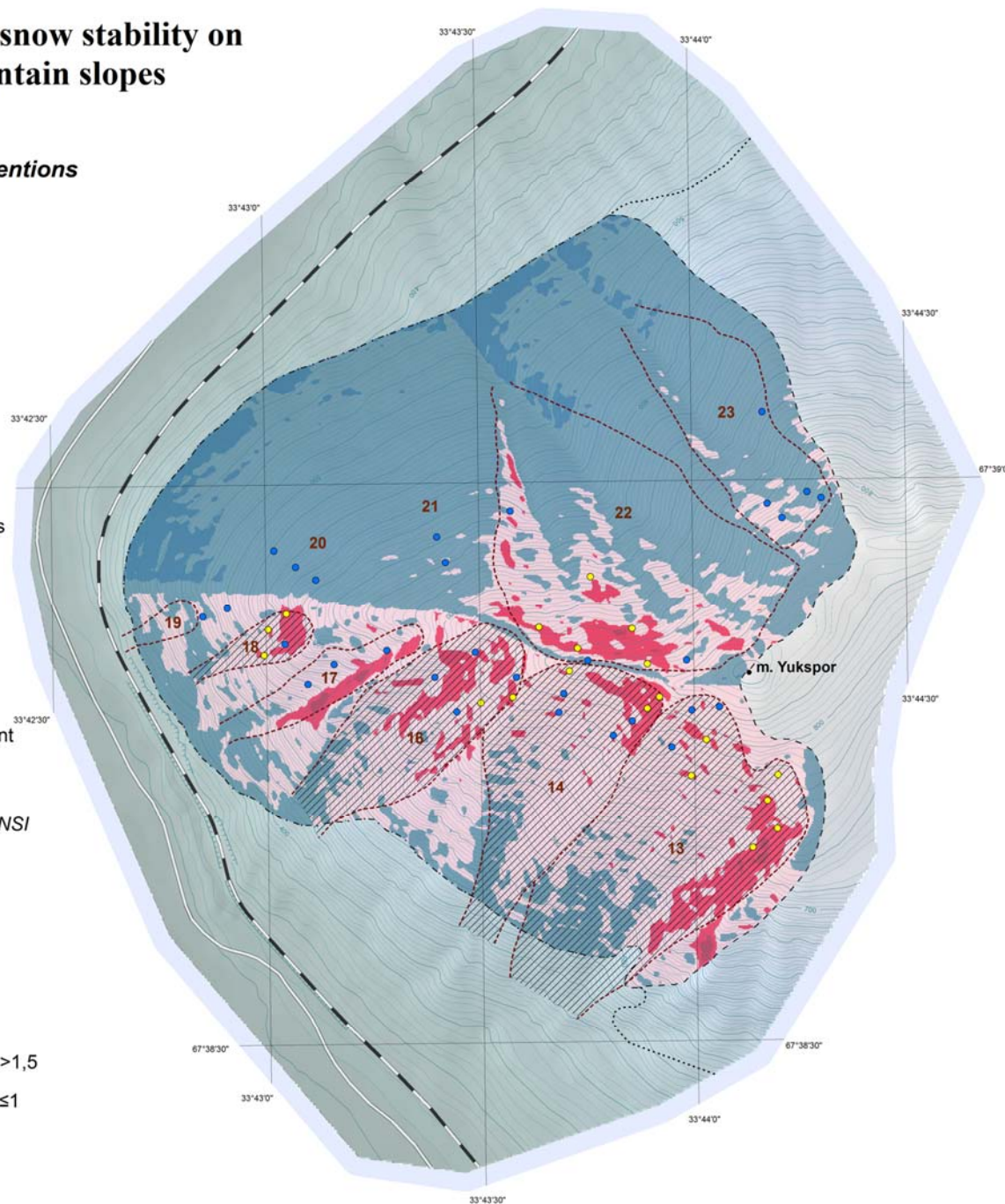
Acknowledgements

Revealed problems

1. Smoothing of extreme values of parameters

2. Lack of data + overwhelming influence of one or two morphometric factors = unrealistic pattern of unstable zones spreading in mid-winter

Estimation of snow stability on Yukspor Mountain slopes 21.01.2005

Notation conventions

860
700
500
300

contours
road
railway
upper timberline
border of analysis zone
avalanche sites borders
17 number of avalanche site
sites, where avalanche descent was observed

Natural Stability Index - NSI
0 - 0,5
0,5 - 1
1 - 1,5
1,5 - 3
3 - 4,5
4,5 - 6

points where NSI>1,5
points where NSI≤1

Total algorithm

- DEM analysis

- Meteorological data recalculation for points at avalanche sites

- Running SNOWPACK at these points

- Statistical analysis of modeled data, spatial spreading of stability indexes values

- Marking the spatial zones of possible avalanche formation

Future development

- Additional more accurate algorithms of meteorological data recalculation will be put into operation

- More profound use of statistical analysis

- Automation of calculation processes

- Method's approbation in different geographical conditions

Thank you for your attention!

<u>Acknowledgements</u>