Change of the treeline ecotone in Khibiny Mountains, Kola Peninsula, over the last 50 years

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The aim

- tree cover changes in the treeline zone in the Khibiny Mountains during the period 1958 to 2008

Methods

- remote sensing techniques
- ground surveys
- age structure analyses
- statistical analysis

The questions

- To what degree has the treeline ecotone in the Khibiny Mountains changed during the last 50-years?
- What has caused the changes?
- Can specific temporal dynamics be identified?
- Can observed changes and applied methods be used as a predictive tool?

Study Area

Khibiny Mountains

- centre of Kola Peninsula in north-west Russia
- mountain mass of 2500 km^2 and with 900-1100 m.a.s.l. peaks
- January temperature -10.5 °C; July temperature 9.3 °C;

  mean annual temperature is 0.2°C
- Precipitation in April 23mm, in August 63mm;

  mean annual precipitation 488 mm
- snow cover from October to May
- sparse grazing/browsing pressure by moose (Alces alces) and some rodents

Field Sites: the main criteria

- species composition
- gentle topographic slopes
- as little anthropogenic processes as possible

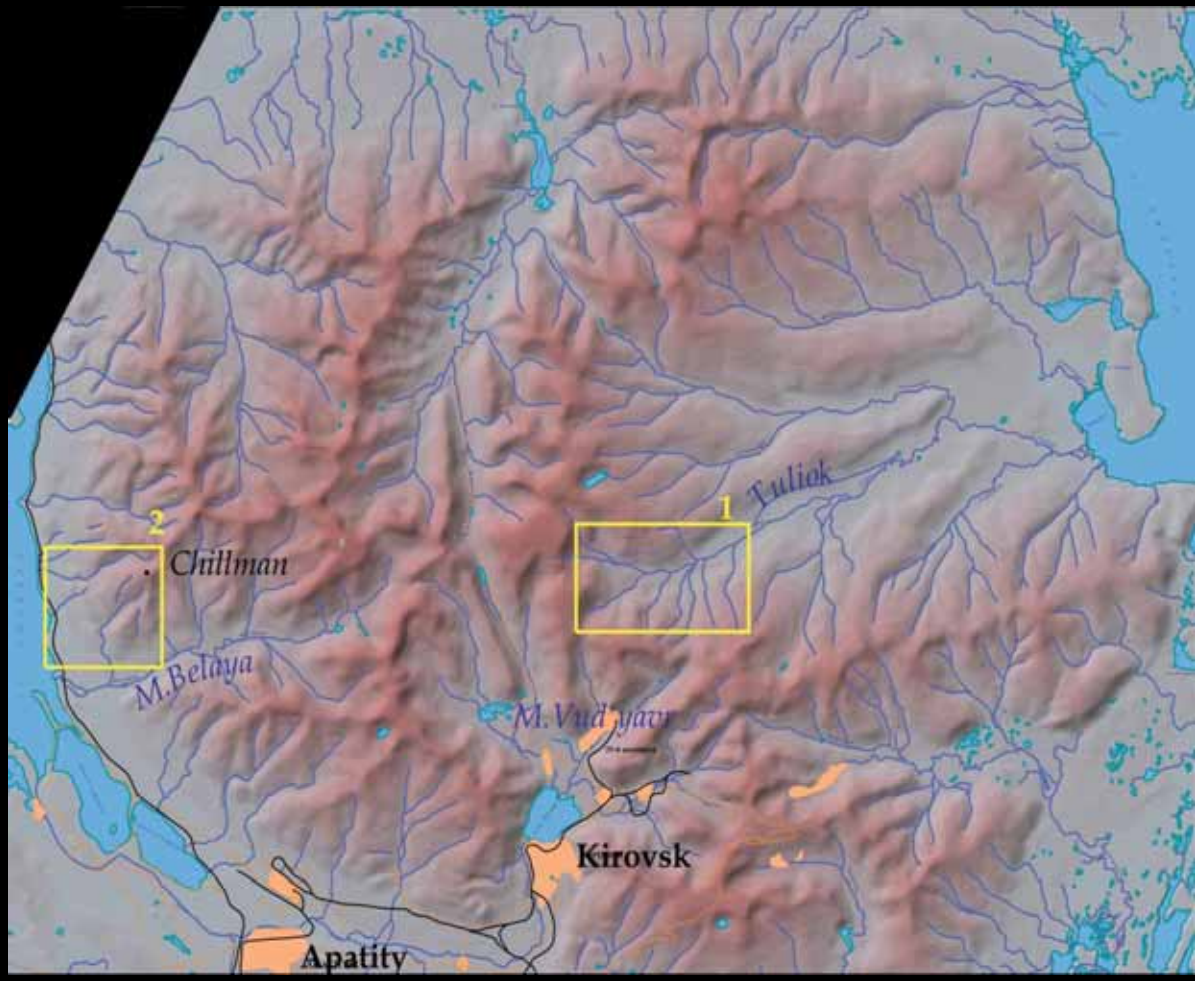
Field Sites

1 – Tuliok site

- north-facing slope
- altitude 500-600 m a.s.l
- forest line at 400 m.a.s.l, tree line at 540 m.a.s.l
- dominant species is *Betula pubencens*

2 – Umechorr site

- south-western facing slope
- altitude 330-470 m a.s.l
- forest line at 360 m.a.s.l, tree line at 400 m.a.s.l
- The dominant species are *Pinus sylvestris, Betula pubencens, Juniperus communis L. with some scattered Populus tremula L.*



Field inventory study

1 – Tuliok site

- 19 birch trees at the tree line
- All birch individuals from:
  - 20 m wide sample band from the treeline to 100 altitudinal metres above the treeline (350 m long)
  - 10 m wide sample band from the treeline to 100 altitudinal metres above the treeline (150 m long)

2 – Umechorr site

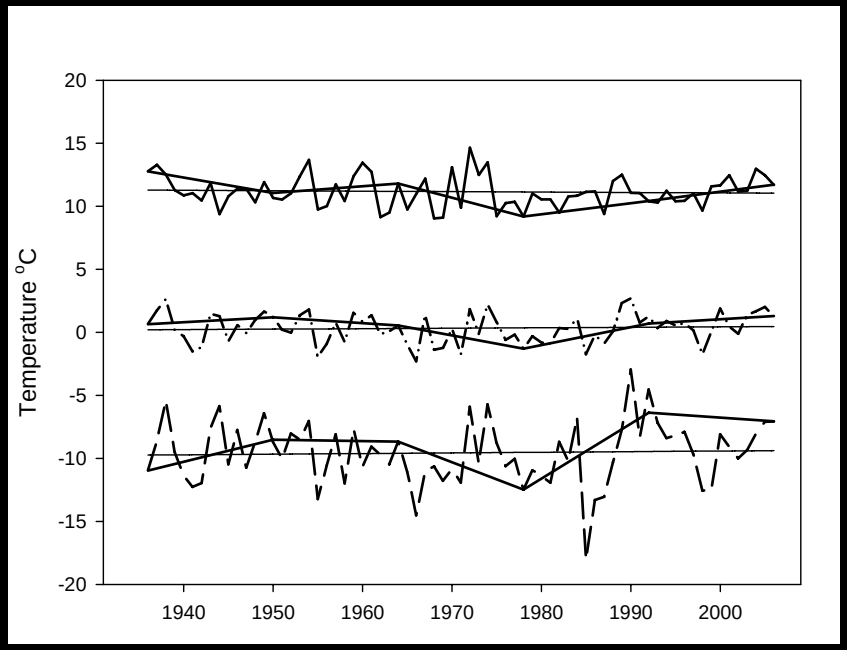
- All pine individuals from:
  - **Treeline:** three 50x50 meter adjacent sample plots
  - **Above the treeline:** eight 50x50 meter adjacent sample plots

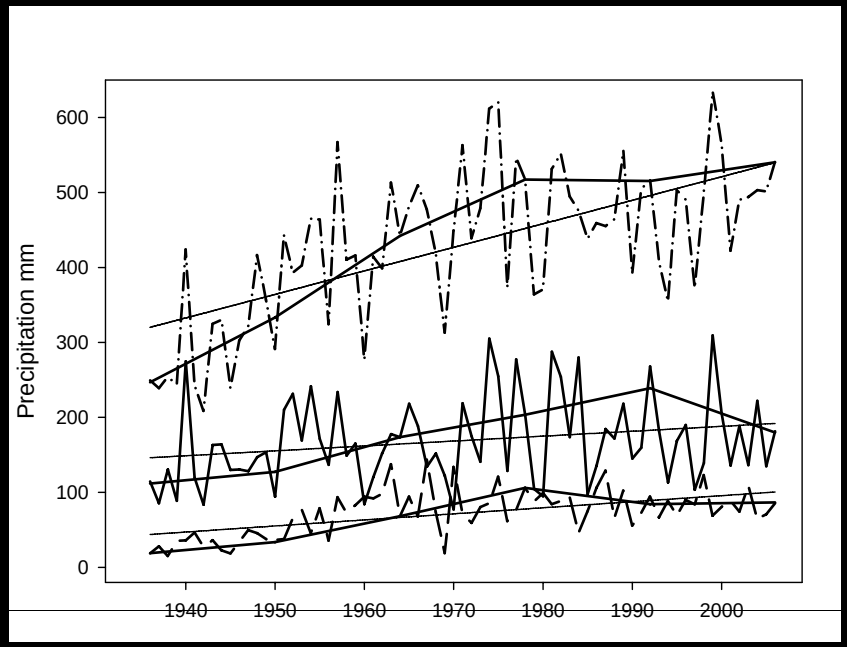
Field data

- age (coring or cutting)
- living height (accuracy 1-25cm)
- the GPS position (horizontal accuracy 10 metres or better, vertical accuracy 30 m).

Climate data

- Murmansk meteorological station 140 km north of the study sites





Airborne & Satellite data

1 – Tuliok site

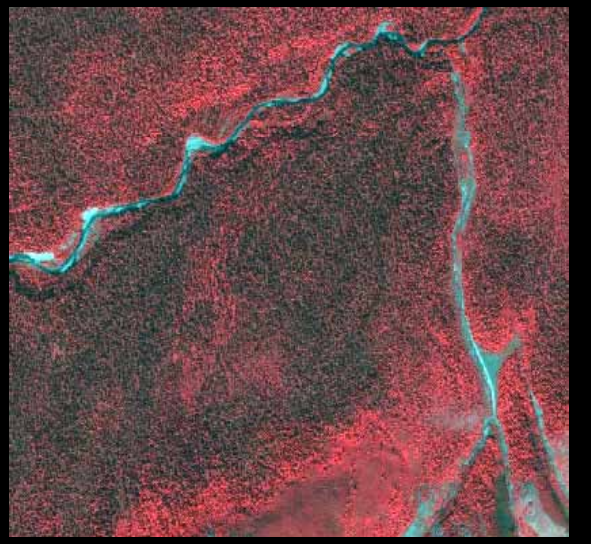
- black and white air photos of 14 August 1958 (spatial resolution is about 1 m)
- multispectral and panchromatic QuickBird satellite image of 28 June 2006 (spatial resolution is 0,6 m)

2 – Umechorr site

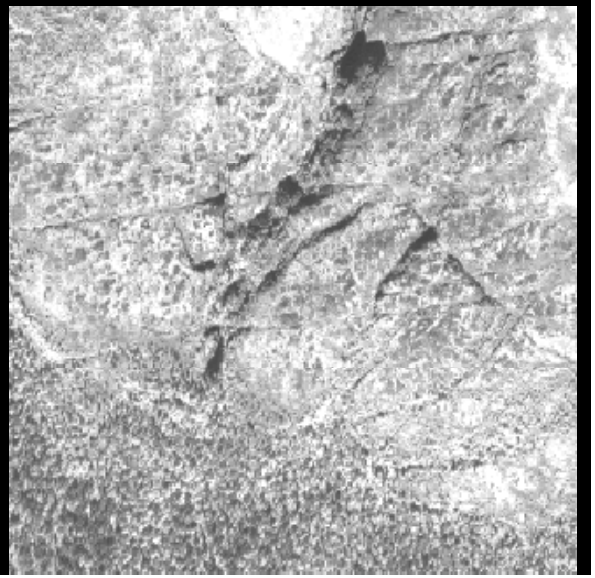
- black and white air photos of 14 August 1958 (spatial resolution is about 1 m)
- black and white WorldView satellite image of 29 July 2008 (spatial resolution is 0,5 m)

Airborne & Satellite data

1 – Tuliok site



2 – Umechorr site

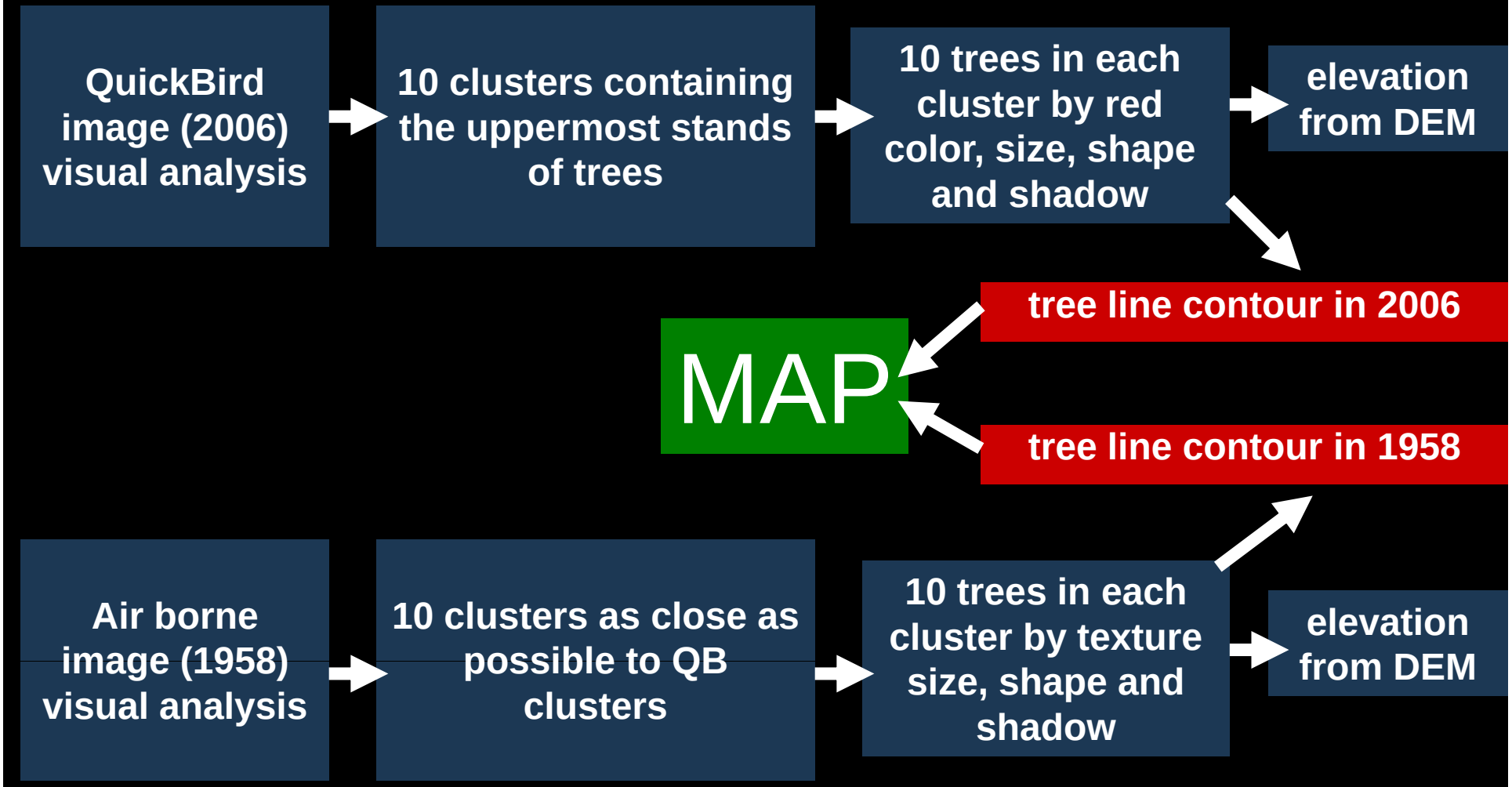


Airborne & Satellite data processing

- creating DEM
  (RMS errors were significant (horizontal error of 20 to 40 m and vertical error of 15-20 m)
- orthorectification of reference airborne images (1:50 000 map was the elevation source)
- 2nd degree polynomial transformation of satellite images
  (positioning accuracy of better than 10 m for the 10 sub-sites of interest)
- visual interpretation of the imagery
  (local adjustments and bring co-registration to individual tree level)

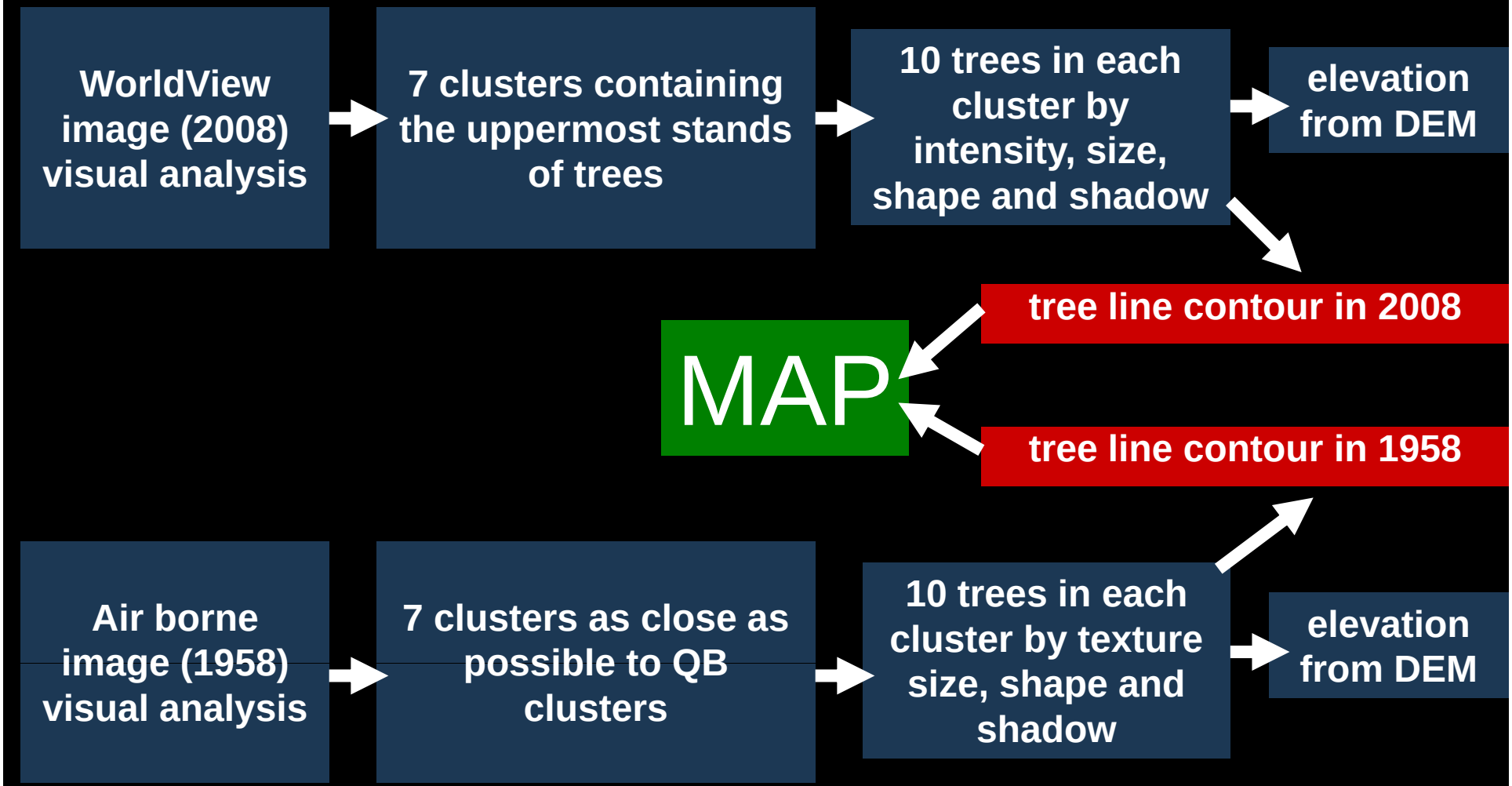
Tree line change detection

1 – Tuliok site



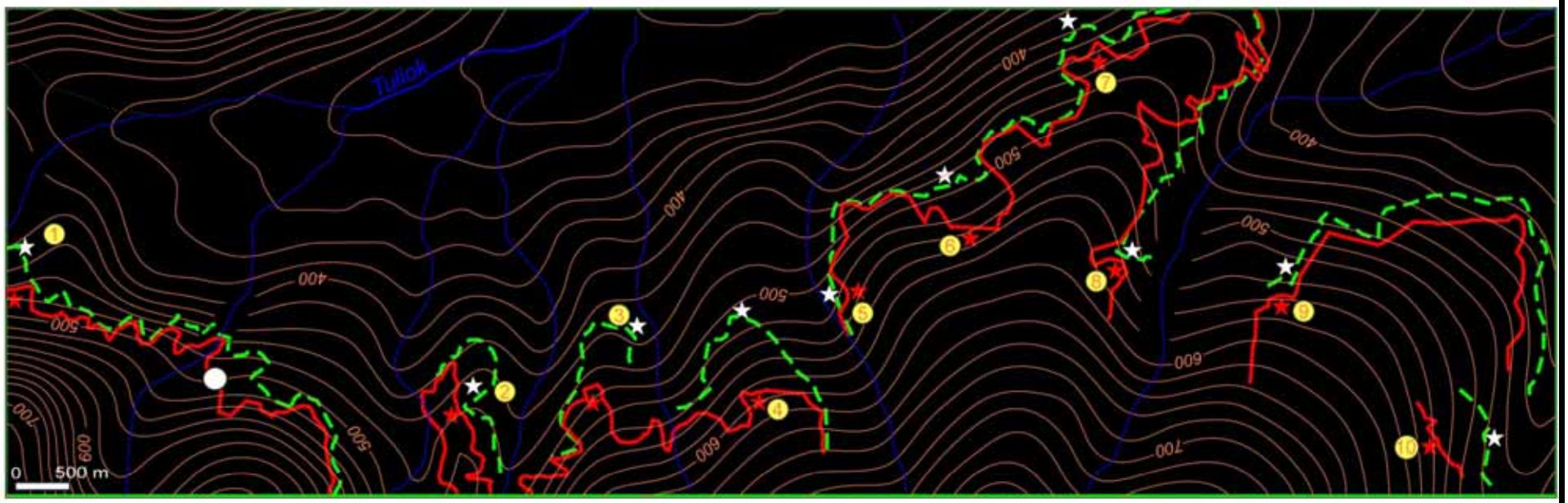
Tree line change detection

2 – Umechorr site



Tree line change map

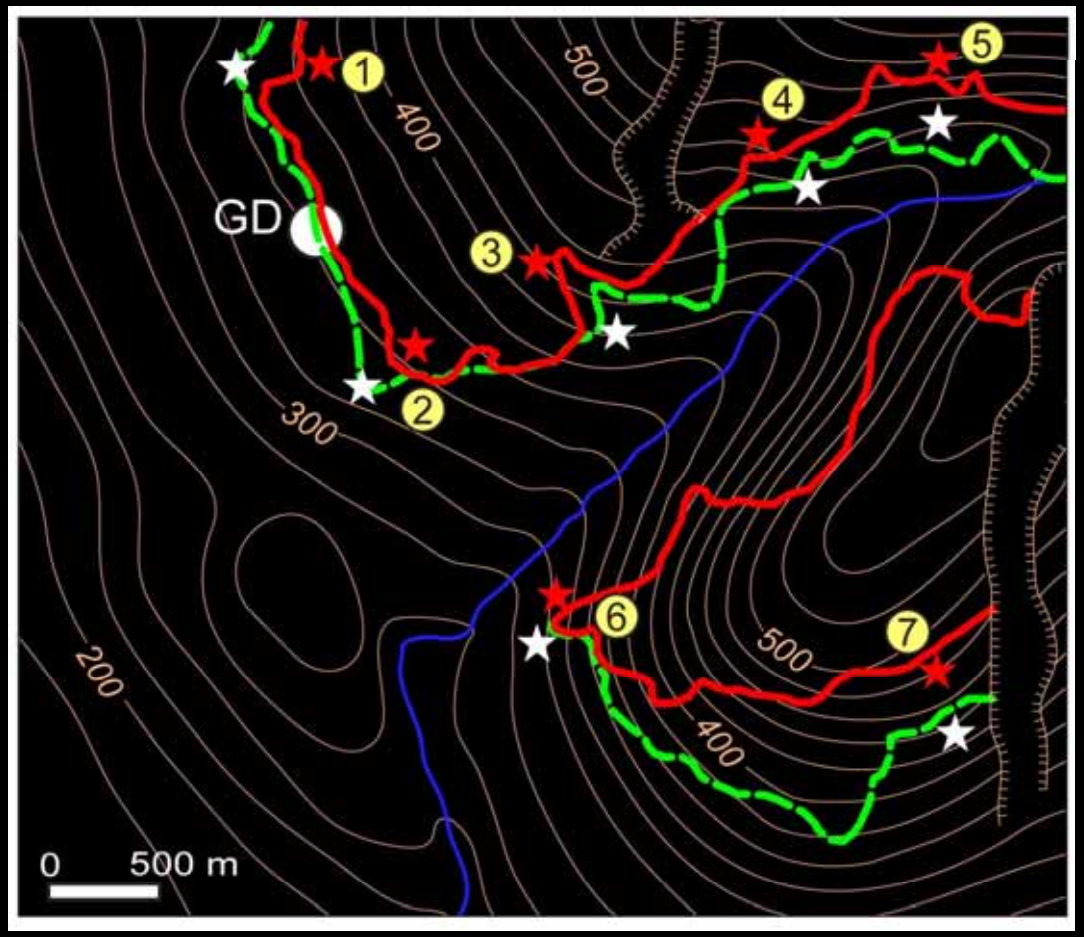
1 – Tuliok site



site	1958	2006/2008	change
GD	*494*	*530*	*36*
1	419	452	32
2	482	495	13
3	451	520	69
...	...	...	...
average	486	515	29

Tree line change map

2 – Umechorr site

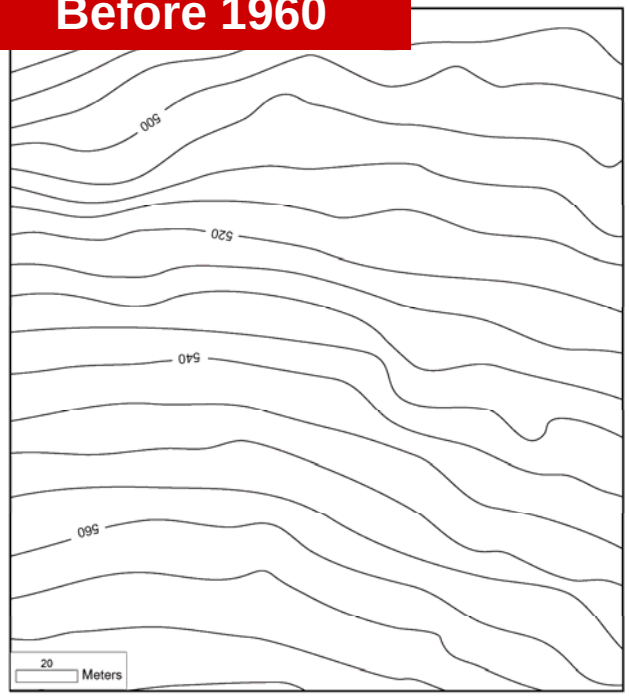


GD	*346*	*348*	*2*
1	364	395	31
2	322	331	9
3	385	407	22
4	498	531	33
5	491	544	53
6	300	301	1
7	444	484	40
average	401	428	27

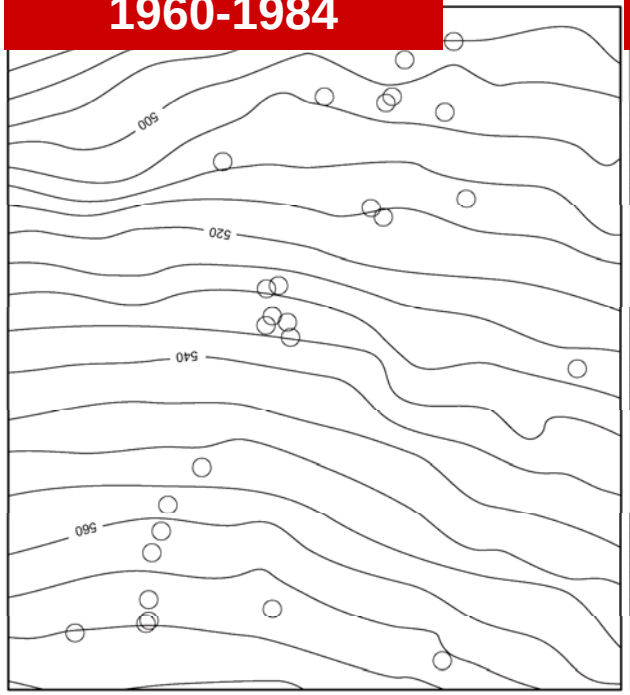
Ground data

1 – Tuliok site

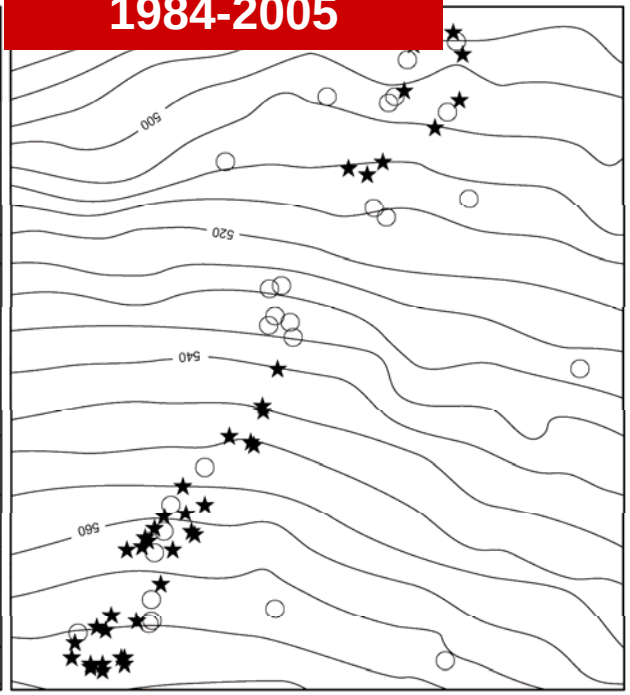
Before 1960



1960-1984



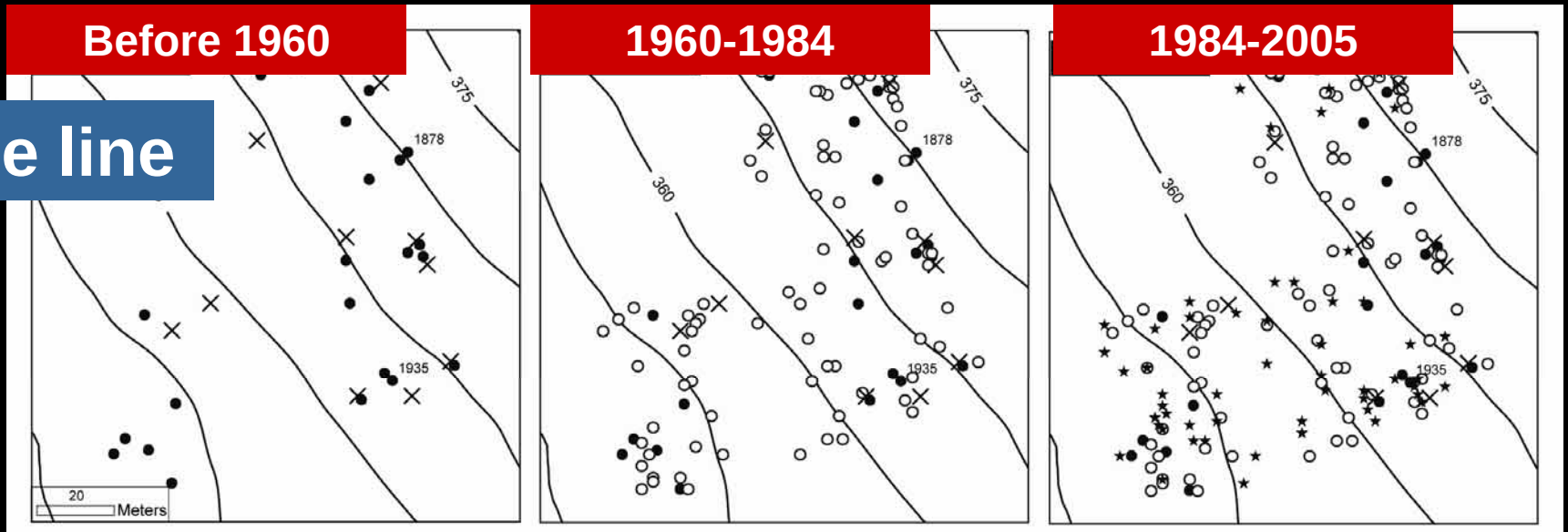
1984-2005



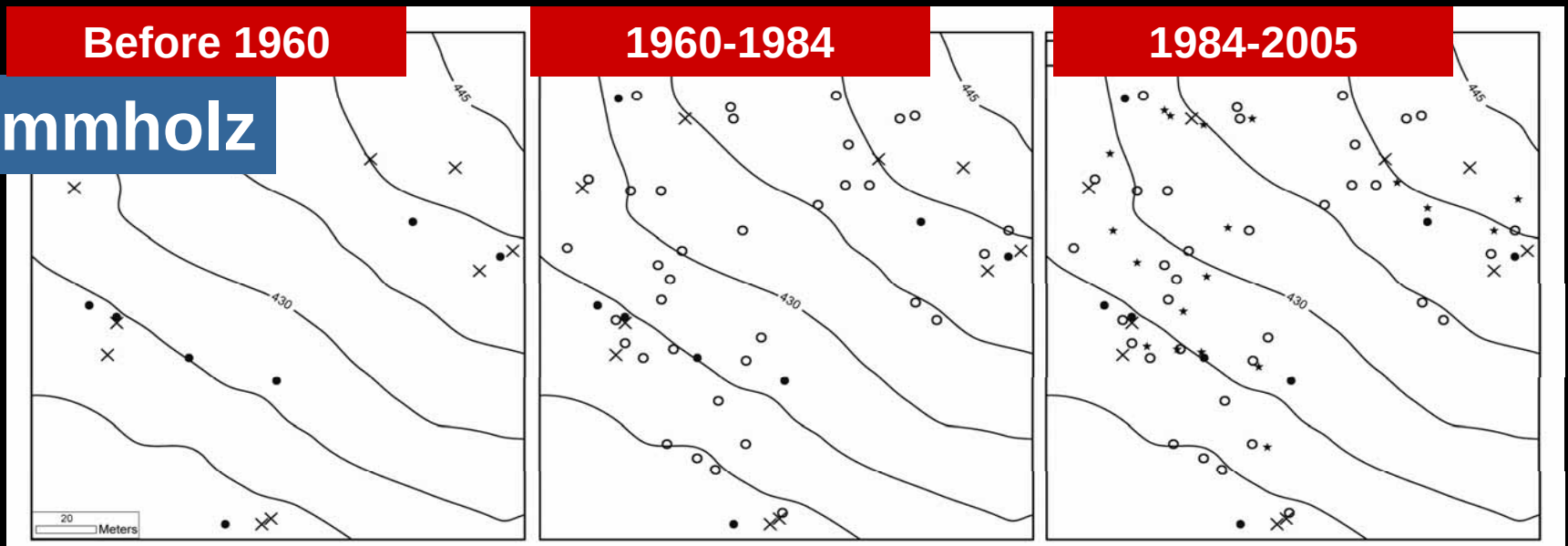
Ground data

2 – Umechorr site

tree line



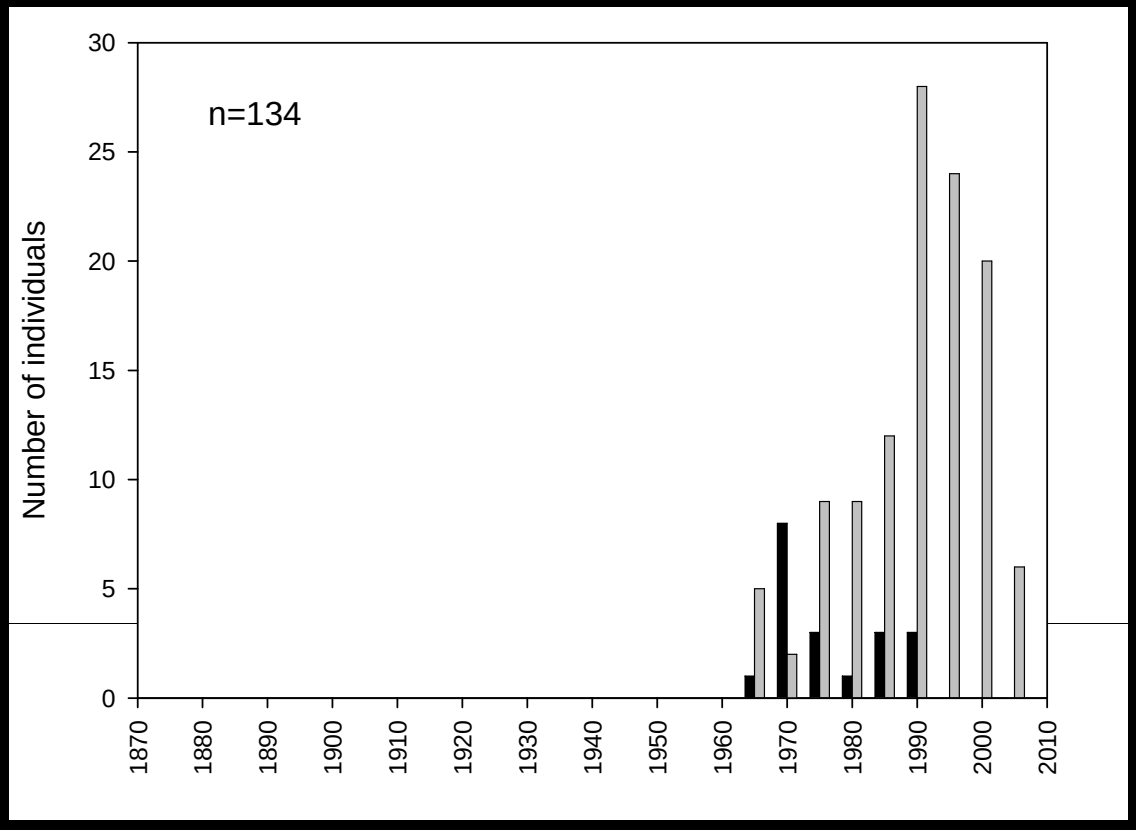
krummholz



Age distribution

1 – Tuliok site

- most of the colonization has been confined after the 1960's with establishment peaks from the middle of the 80's

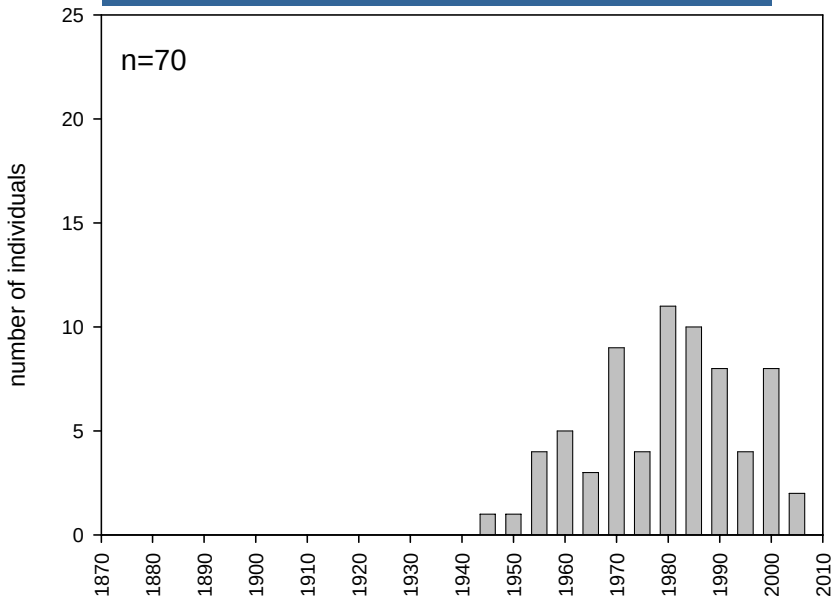


Age distribution

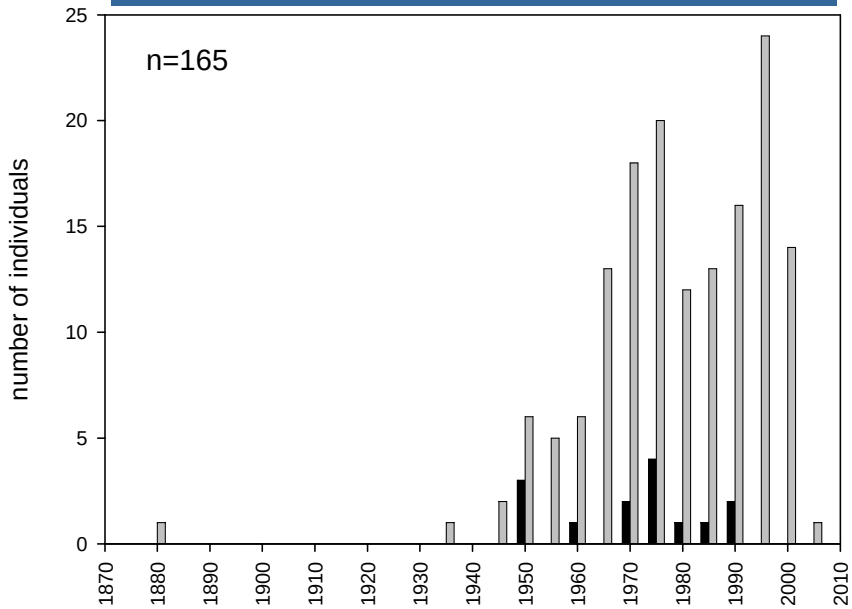
2 – Umechorr site

- most of the colonization has been confined to the second half of the 20th century and particularly in the 70’s and 90’s

krummholz



tree line



Statistical analysis

		Tuliok	Umechorr	both sites
	sample size	39	57	59
Temperature	January	0,201	-0,15	-0,046
	February	0,218	-0,049	0,046
	March	0,29	0,035	0,25
	April	0,186	0,214	0,145
	May	0,261	-0,015	0,038
	June	0,184	-0,035	0,028
	July	-0,089	-0,1	-0,051
	August	0,031	-0,154	-0,169
	September	0,123	-0,087	-0,039
	October	0,057	-0,048	-0,03
	November	-0,124	0,037	-0,13
	December	0,009	-0,015	-0,091
	Annual	0,200	-0,021	0,020
	Winter	0,171	-0,051	-0,016
	Summer	0,058	-0,126	-0,072

		Tuliok	Umechorr	both sites
	sample size	39	57	59
Precipitation	January	0,197	0.309*	0.401**
	February	0,125	0.277*	0.394**
	March	-0,243	0,165	0,127
	April	0,127	0,196	0,253
	May	0,06	0,117	0,157
	June	0,006	0.289*	0.267*
	July	0,103	0,01	0,071
	August	0,049	-0,098	0,048
	September	-0,24	-0,073	-0,119
	October	-0,003	0,072	0,129
	November	0,042	0,106	0,134
	December	-0,105	0,171	0,149
	Annual	0,035	0,242	0.358**
	Winter	0,114	0.302*	0.398**
	Summer	0,081	0,097	0,2

Statistical analysis

1 – Tuliok site

- No significant correlation values between
  - number of established individuals in each year
  - monthly, seasonal and annual average temperature
  - monthly, seasonal and annual total precipitation.

2 – Umechorr site

- No correlation between year of establishment and average temperatures.
- Number of individuals established in the respective years correlated with January and February precipitation (p=0.0193 and p=0.0353)
- The seasonal total precipitation of winter (December, January and February) had a p=0.021 correlation with number established.
- When the number of established plants in each year was added from both study sites, number of established individuals correlated with January- (p=0.0018) and February-precipitation (p=0.002), again the winter precipitation is significant at the p=0.001 level.

Conclusion

- advance of the treeline by about 30 m over 50-year period in two sites in Khibiny Mountains
- remote sensing analysis has been successful despite technical difficulties with source data, as validated by the ground age structure data
- the age structure at both sites (with many young individuals) is indicative of advancing treeline and in favourable conditions the advance can continue.

Discussion

- The increase in treeline between 1958 and today can be probably explained by the increase in precipitation levels during winter.
- No trend in temperature levels the last 70 years - lack of response to temperature in the two study sites
- The tree line change between today and 1958 might be less than the 29 and 27 meters found here (difficult to recognize small trees on the air borne image)

Thank you!