Assessment of possible change of design flood characteristics in mountainous permafrost basin caused by global warming

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Motivation

- ➢ Sparse hydrometric and meteorological network of Eastern Siberia
- ➢ Hydrologic regime affected by permafrost
- ➢ Changing climate conditions
- ➢ Practical needs of reliable assessment of design flood characteristics for present and future

Goal

- Develop parameterization scheme for modelling runoff formation processes in the Timpton River basin
- Make preliminary assessment of future runoff characteristics at the Kanku hydropower plant gauge by different approaches using the hydrological model Hydrograph
- Compare the results of three approaches: PMF (possible maximum flood), traditional frequency analysis and using climate projections

Approaches

- **Frequency analysis** of observed runoff characteristics (annual mean, maximum, minimum)
- **Probable Maximum Flooding (PMF)** method includes identification of crucial meteorological factors of maximum flooding and assessment of runoff characteristics according to them (in our case, by hydrological modelling)
- Application of **future climate projections** (CMIP5 results) for the 21st century as the inputs to hydrological model

Study object – the Timpton river basin

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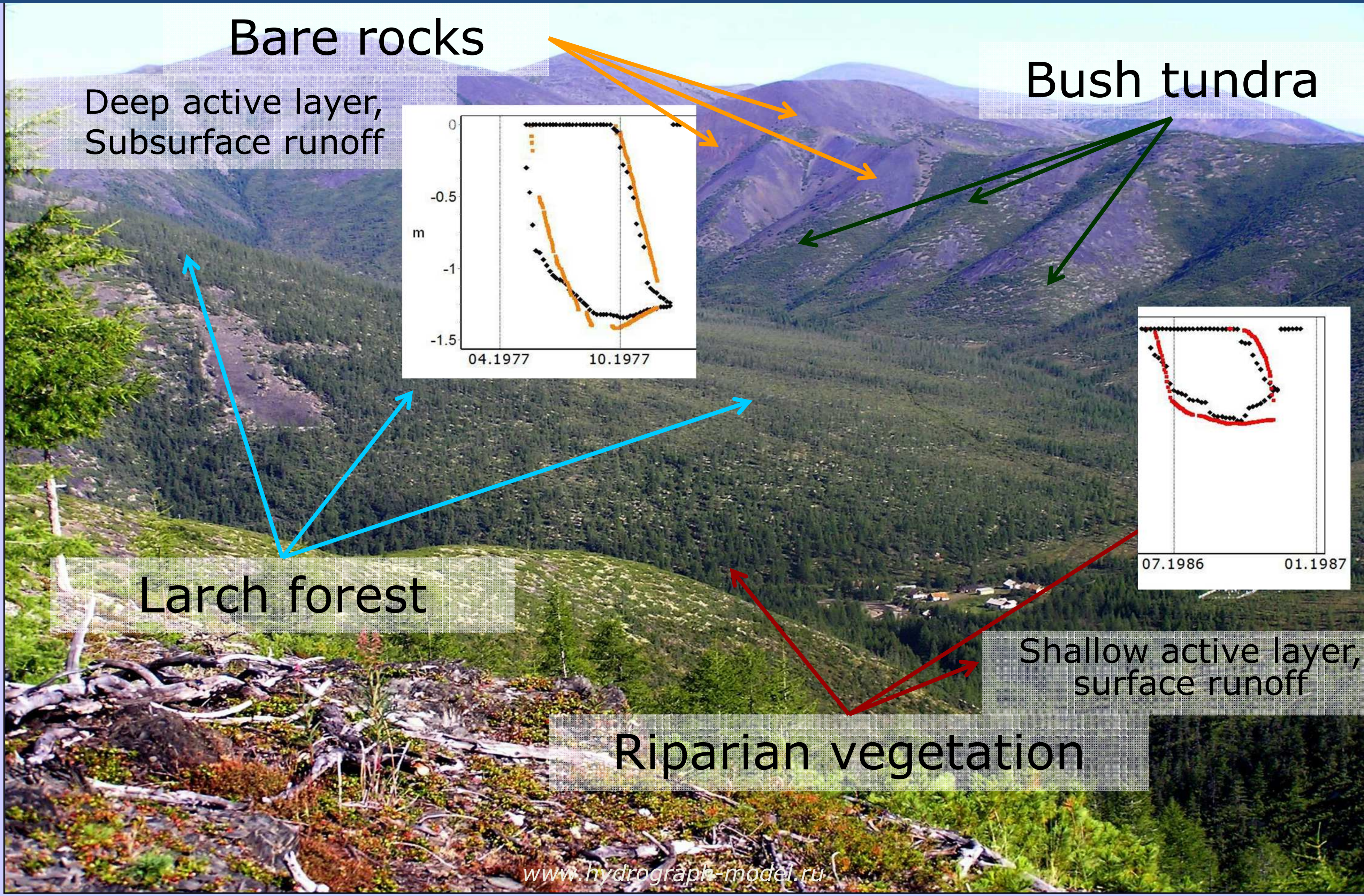
№	Gauge	Distance from river mouth, km	Basin area, km^2	Start of the measurements
1	**Ust'-Baralas**	337	13 300	1954
2	**The Kanku hydropower plant**	201	27 300	-
3	**Ust'-Timpton**	20	43 700	1952

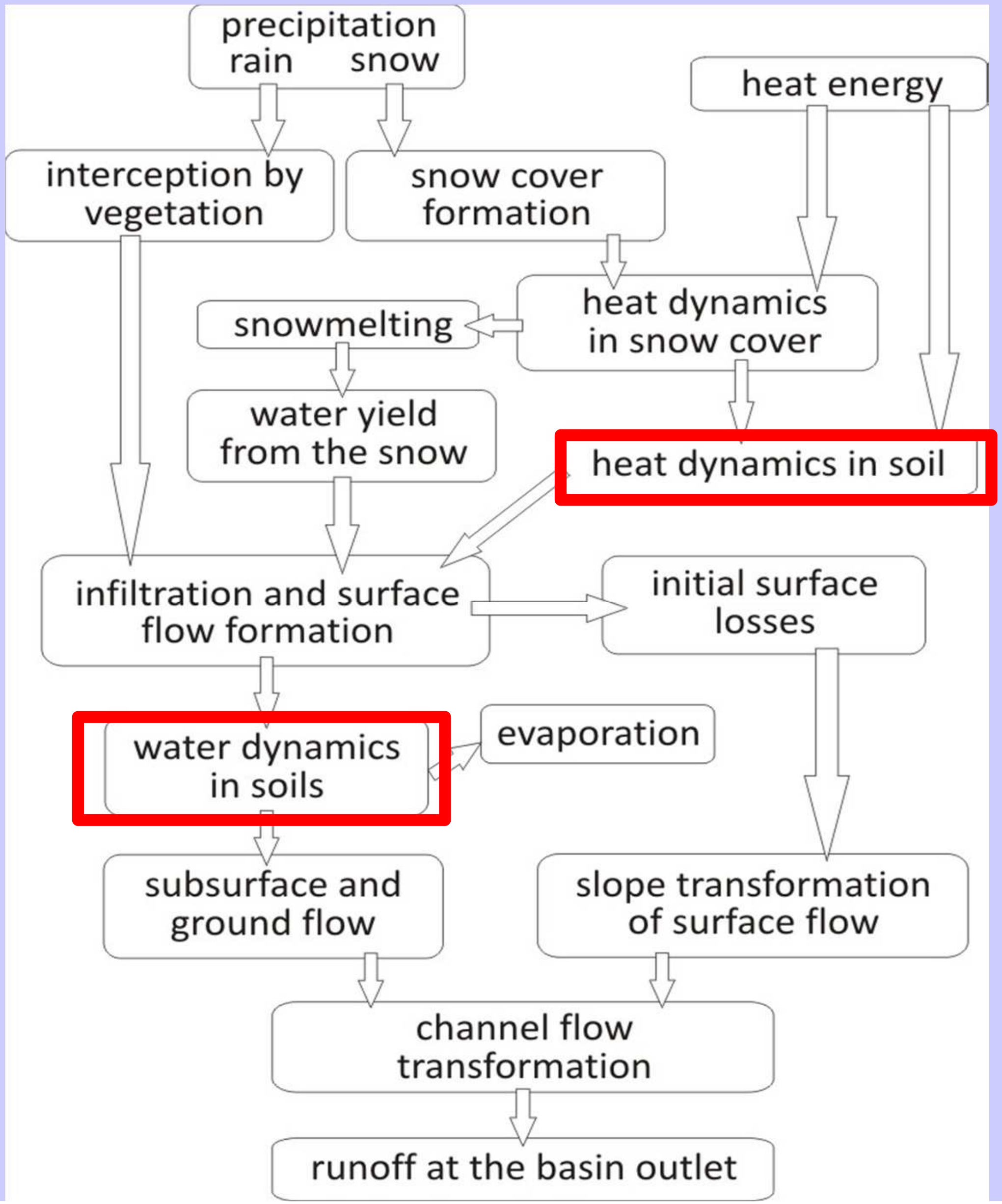
- Altitude varies from 600 to 1700 m
- Continental climate
- Bare rocks, tundra and larch forest
- Zone of discontinuous permafrost




Variety of landscapes and the issue of calibration



The Hydrograph model

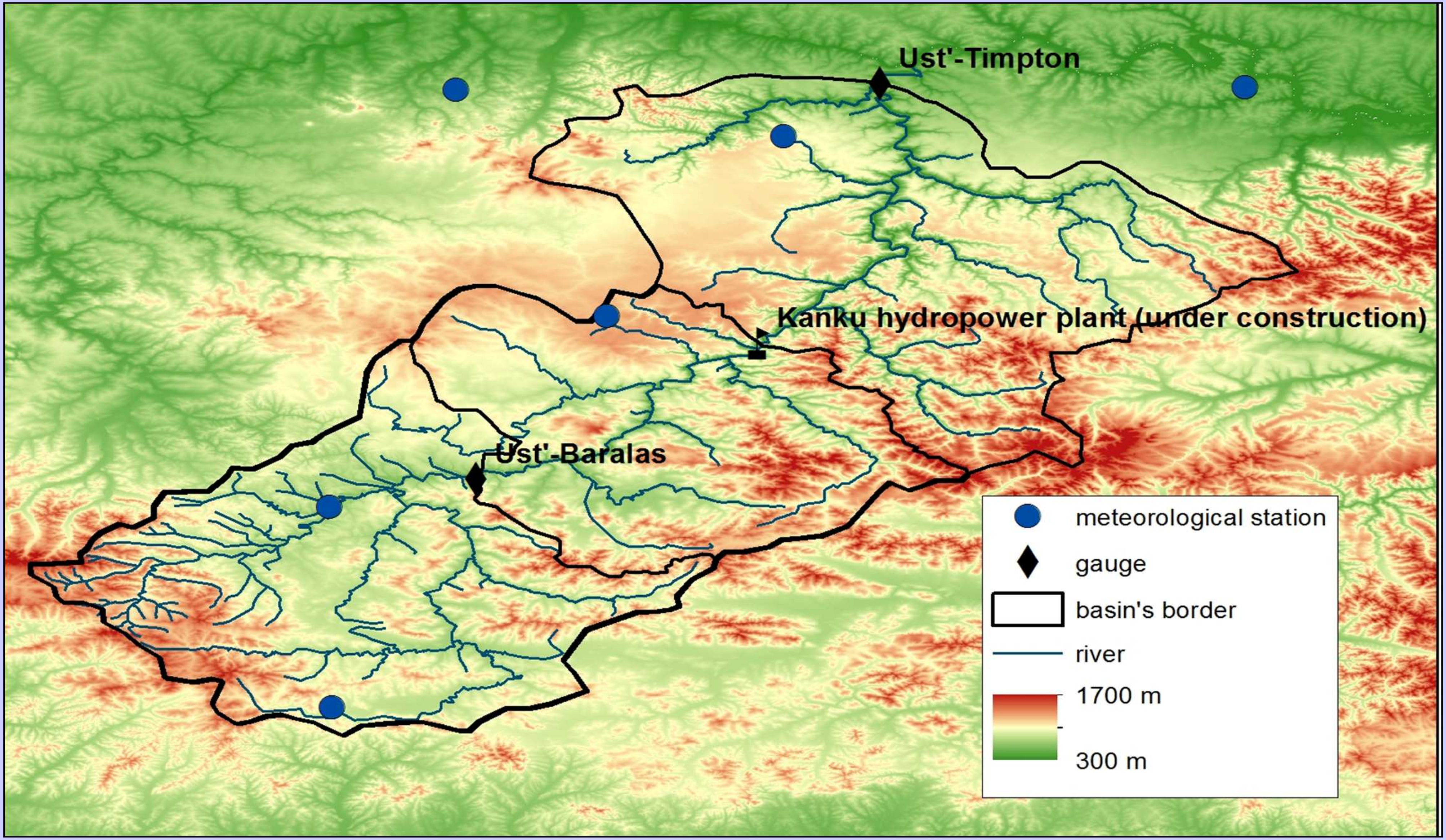


- ✓ Process-based (explicitly includes all processes)
- ✓ Observable parameters, minimum calibration (can be obtained *apriori*)
- ✓ Common input daily data (air temperature and moisture, precipitation)
- ✓ Free of scale problem (from soil column to large basin)

initially developed by Prof. Yury Vinogradov

www.hydrograph-model.ru

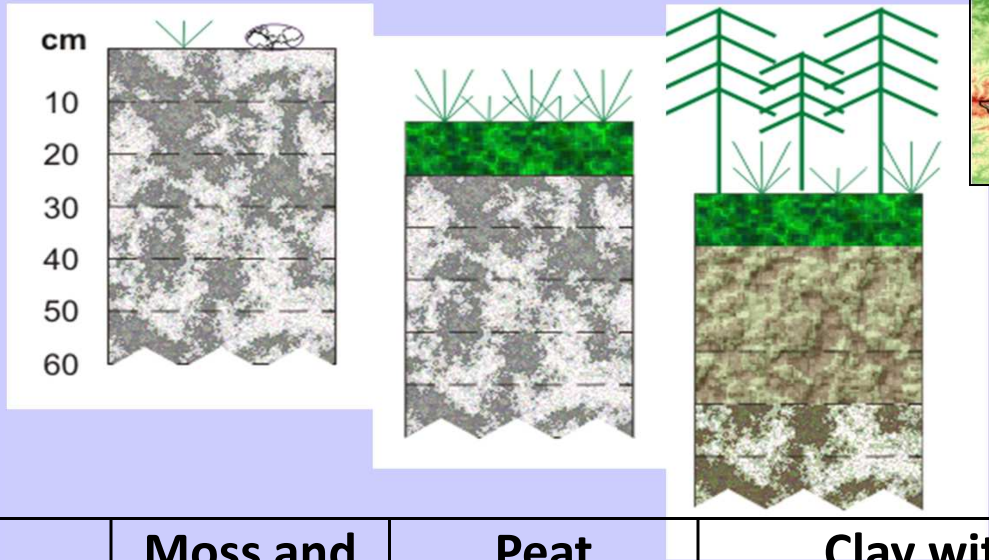
Basin schematization

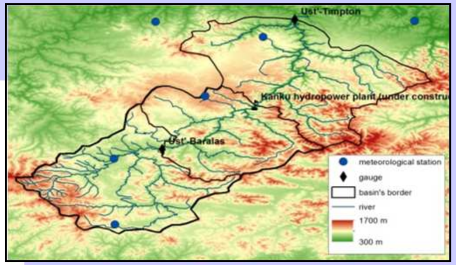


Model parameterization

Basin area was divided into three landcover types:

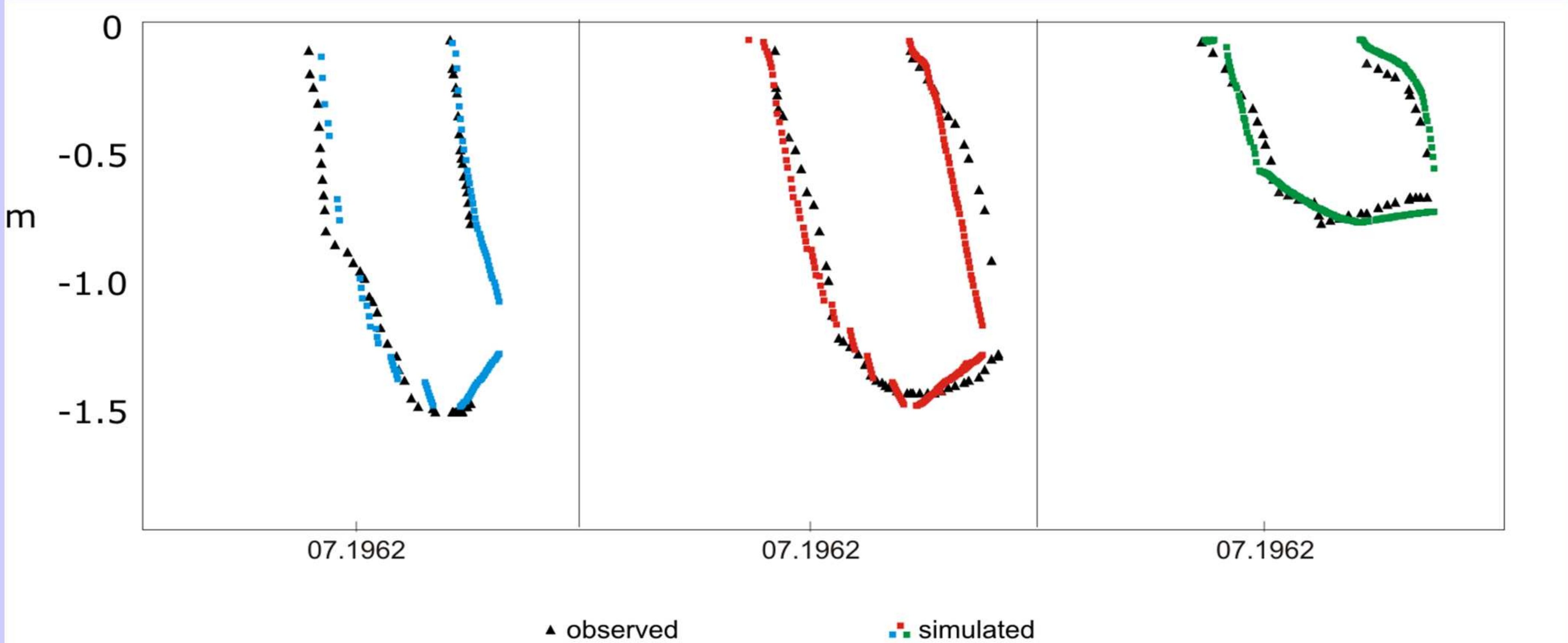
1. Bare rocks
2. Tundra
3. Larch forest





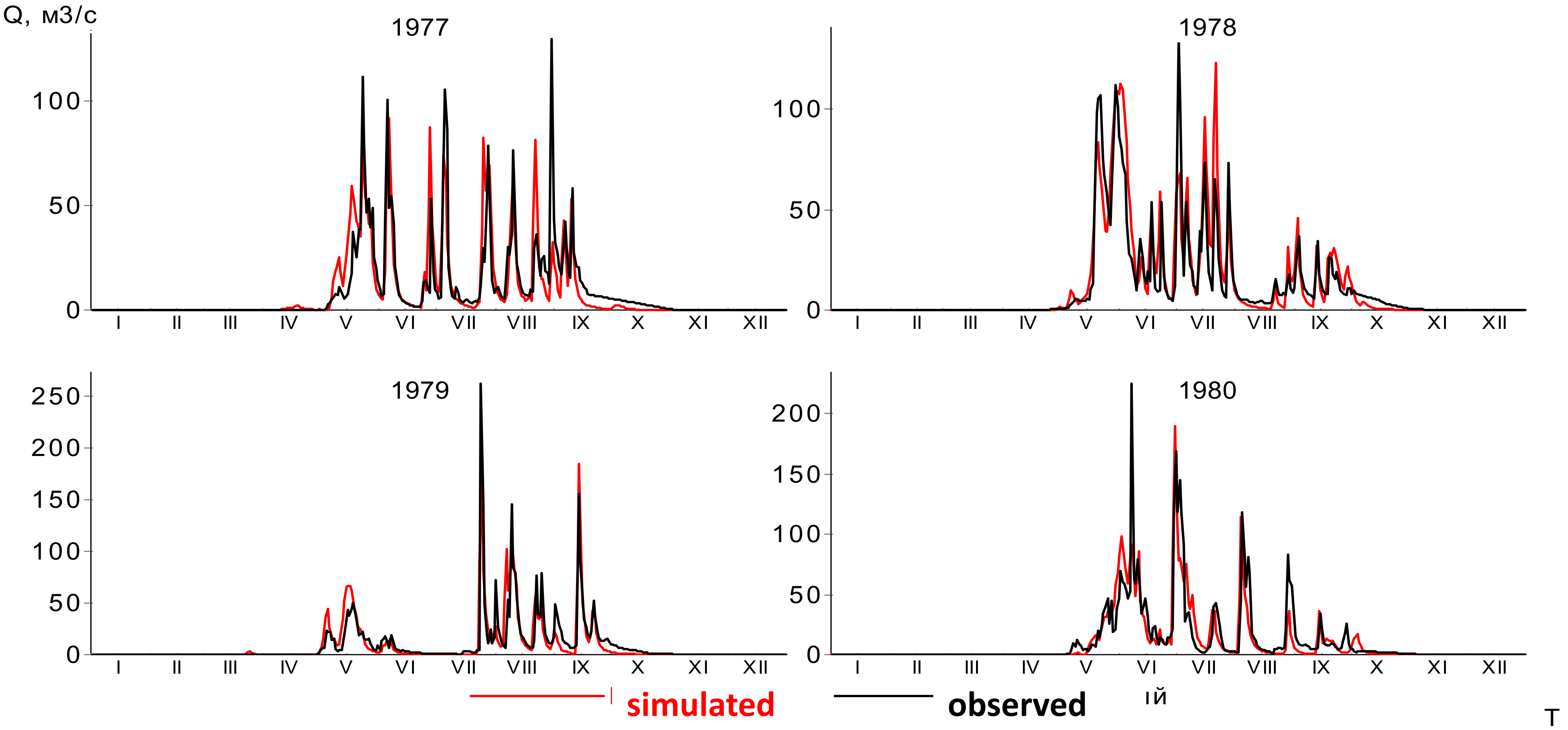
	Moss and lichen	Peat	Clay with inclusion of rocks	Bedrock
Density, kg/m³	500	1720	2610	2610
Porosity, %	90	80	55	35
Water holding capacity, %	60	20-40	13	7
Infiltration coefficient, mm/min	10	0.0005-0.5	0.0005	0.05-1
Heat capacity, J/(kg °C)	1930	1930	840	750
Heat conductivity, W/(m °C)	0.8	0.8	1.2	1.5
Wilting point, %	8	6-8	4	2-3

Analysis and modelling of active layer depth using long-termed observations (bare rocks, tundra and forest)



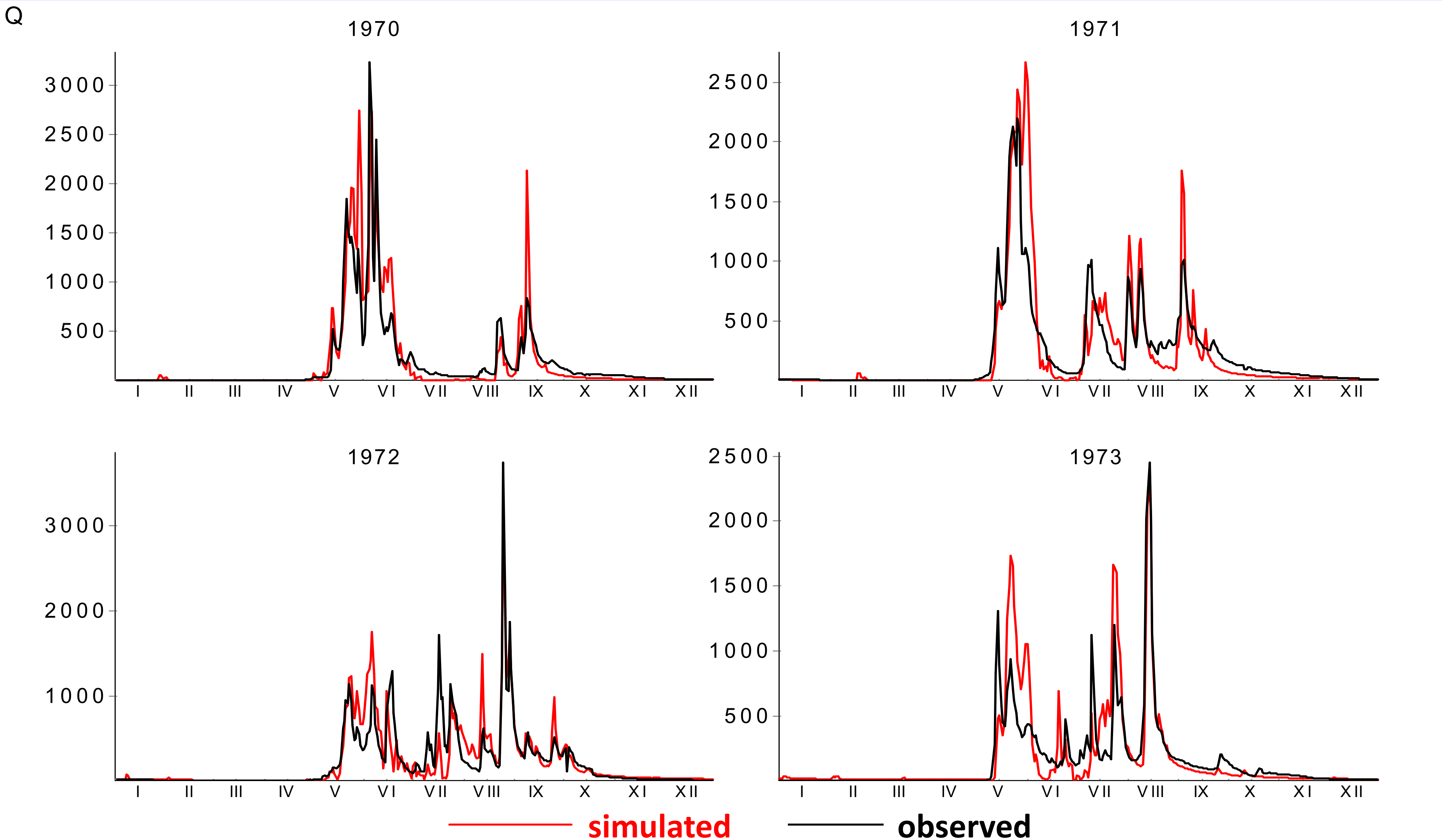
Model validation at different scales

Nagorny (613 km^2), 1966 – 1984, NS = 0.66



Model validation at different scales

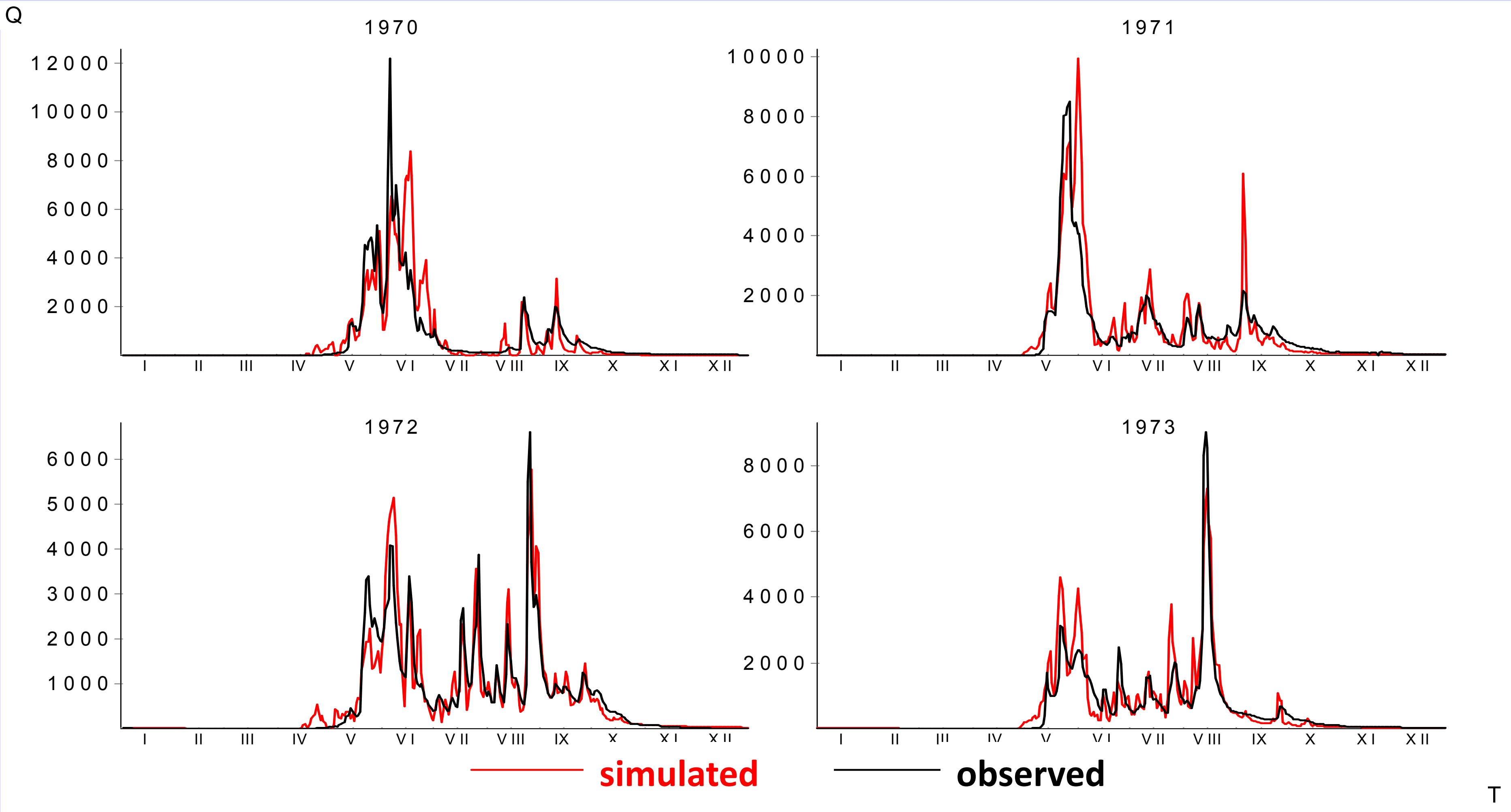
Ust’-Baralas (13300 km^2), 1966 – 1984, NS = 0.61



Model validation at different scales

Ust'-Timpton (43700 km^2), 1966 – 1984, NS=0.69

(NS=0.81 – calibration without permafrost)

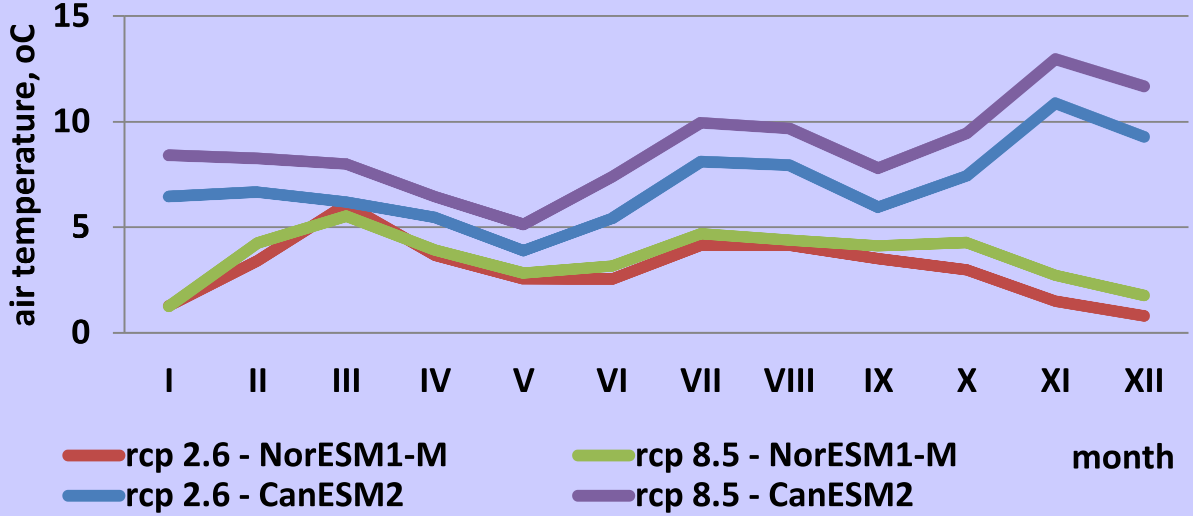


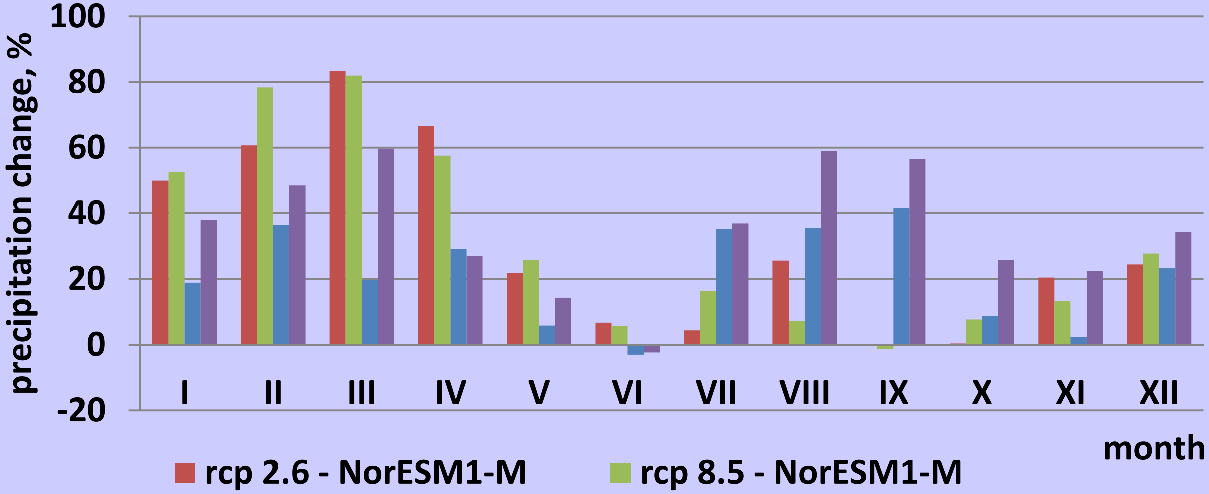
Projected changes in air temperature (left) and precipitation (right) by 2100

Model	Institution
CanESM2	Canadian Centre for Climate Modelling and Analysis
NorESM1-M	Norwegian Climate Centre

Air temperature change, ^{0}C

Reference period – 1966-1984





Precipitation change, %

<u>Spatial resolution of GCMs</u>:
T63 – 140x210 km grid spacing depending on latitude

Probable Maximum Flooding approach

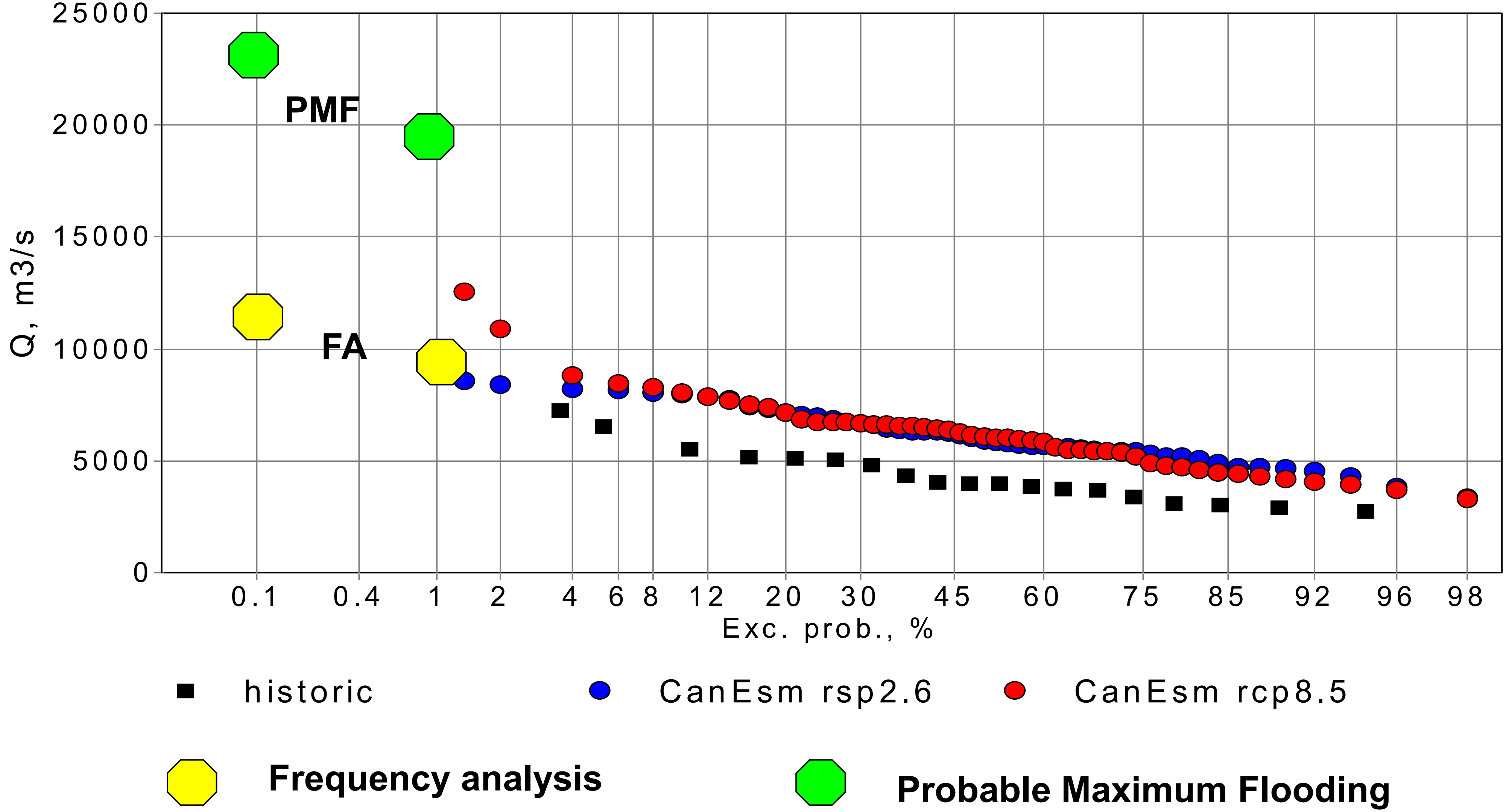
1. Main factors of maximum flooding:

- ***Pre-melt snow depth***
- ***Liquid precipitation during snowmelt***
- *Intensity of warming during snowmelt*
- *Date of the temperature transition from positive to negative values in autumn antecedent year*
- *Precipitation of the last warm month of antecedent year*

2. The values of 1, 0.1, and 0.01% probability of chosen factors were used to generate artificial meteorological series

3. Generated meteorological data were used as the forcings for the Hydrograph model to simulate the probable maximum flood

Comparison of the results for the Kanku hydropower gauge



Conclusions

1. Three different approaches to estimate maximum flood characteristics for the mountainous permafrost basin were implemented, with two of them based on modelling.
2. The results have shown significant variability: PMF maximum discharge was estimated two times higher than by standard frequency analysis technique used in the Russian engineering practice.
3. Soil processes of thaw/freeze control runoff formation and should be explicitly included in modelling algorithms. It means that only relevant process-based models with observable parameters are valid to be used in such tasks.
4. Uncertain character of future climate projections can not be avoided but “more truthful” hydrological projections can be obtained by right choice of applied models. We doubt the potential of flexible model structure ideology in that form which has been recently widely propagated (as a matter of fact – calibration not only models’ parameters but even models’ structures). Truthfulness of hydrological projections is reversely proportional to the extent of calibration application.
5. Right choice of models may be supported only by their tests at different scales.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Thank you for attention!