VOEIKOV MAIN GEOPHYSICAL OBSERVATORY

Sensitivity of Permafrost and Seasonal Freezing Evolution to Regional Simulation of Snow Cover

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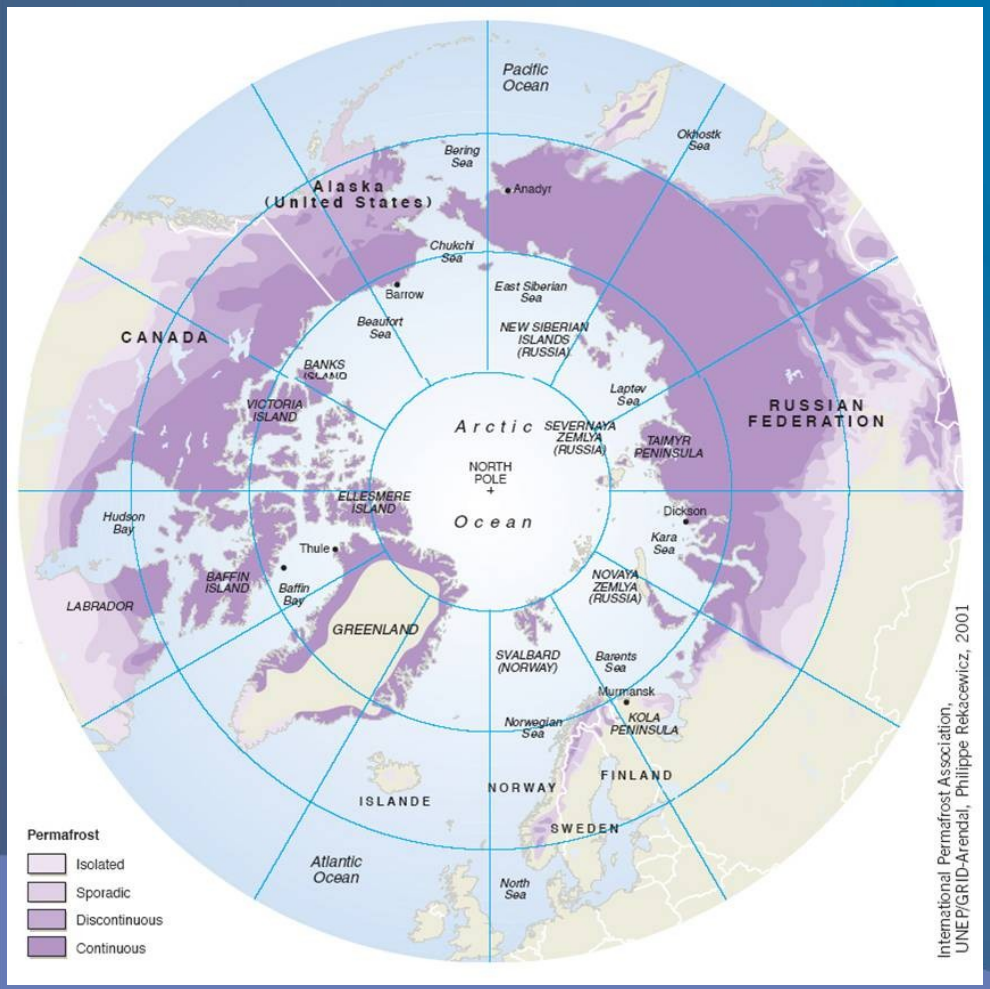
MOTIVATION



Permafrost: 25% of the NH's terrestrial surface and
more than 60% of that of Russia

Anticipated climate warming may seriously affect permafrost: possibility of permafrost degradation

the permafrost properties
are largely constrained by surface air temperature and snow cover.

Our study aims at improving permafrost modelling with regard to snow physics

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OUTLINE

1. MGO RCM
2. Ground heat transfer model
3. Experimental design
4. Results
5. Summary

TOOLS

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1D multilevel ground heat transfer model

forced by MGO RCM output

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MGO Regional Climate Model

(Shkolnik et al., 2000)

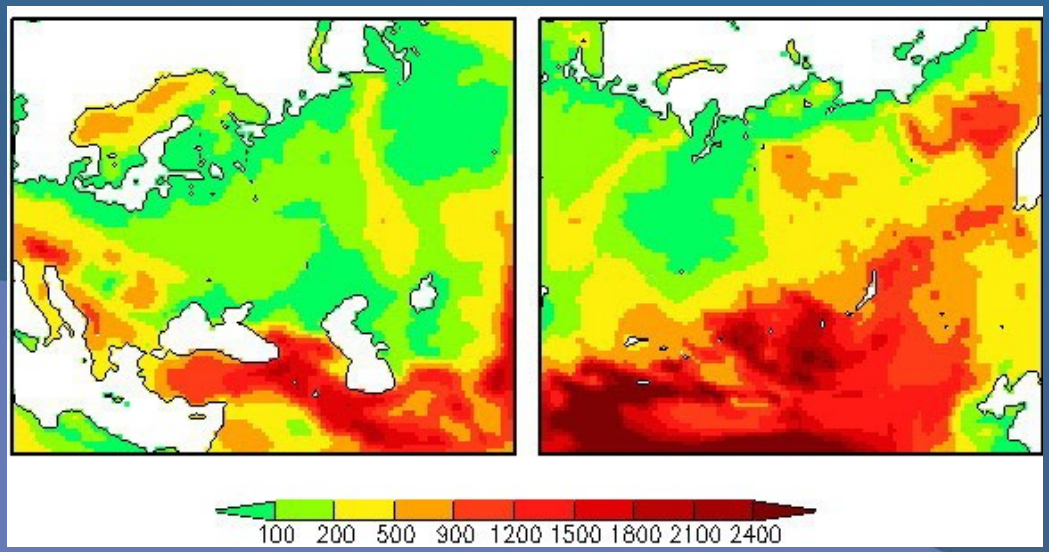
Resolution:

Horizontal → 50 km
Vertical → 14 levels

MGO RCM working domains

Western and central Russia

Siberia



Structure of the ground heat transfer model

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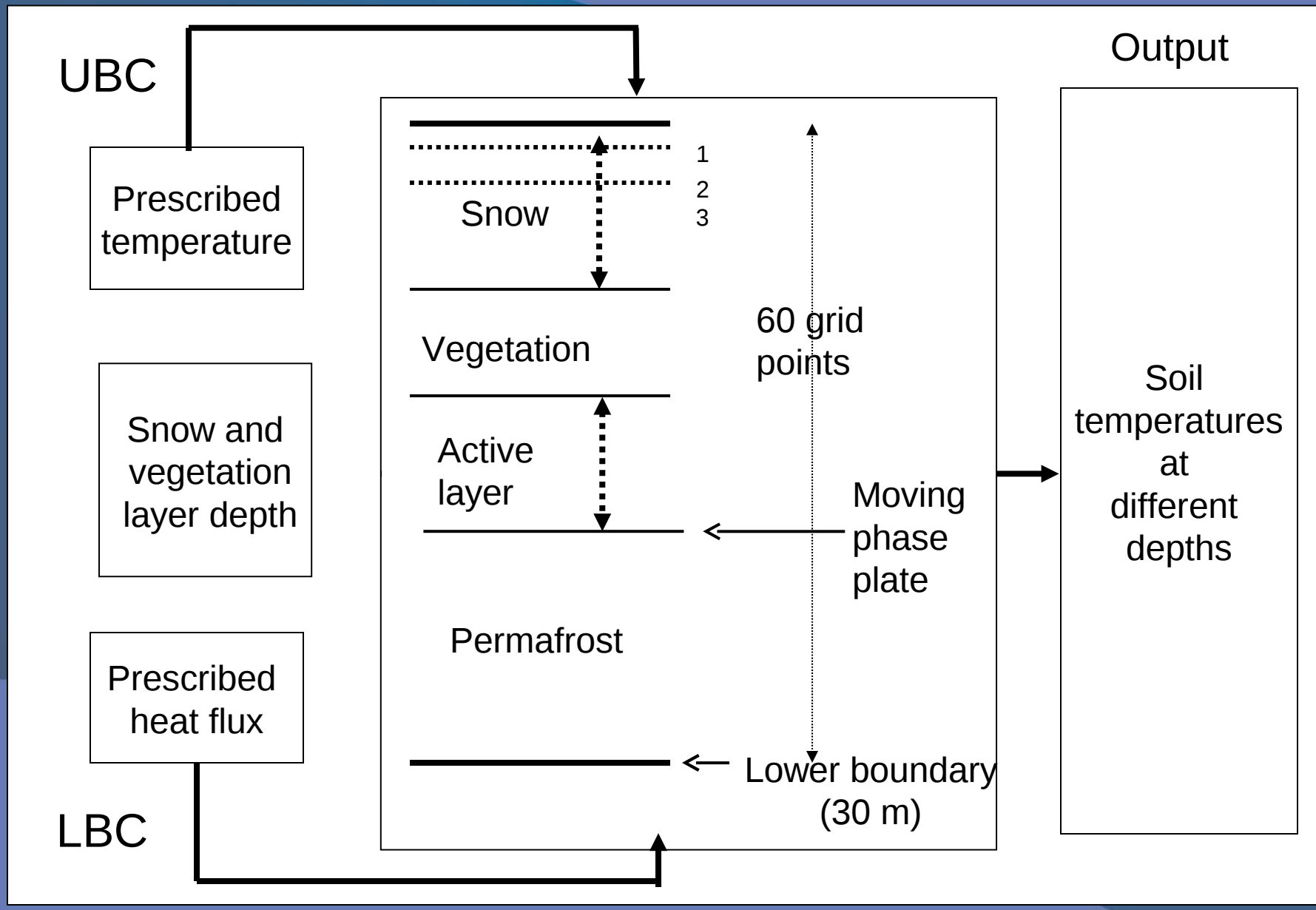

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Upper Boundary Conditions (UBC)

MGO RCM output:

T_s **-** skin temperature

H_s **-** snow water equivalent

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EXPERIMENTAL DESIGN

Previous study:

monthly output from MGO RCM for 1991-2000;

ρ_s= const = 200 kg m^{-3}

Daily output from MGO RCM for 1991-2000

1. Snow density ρ_s= const = 200 kg m^{-3}

2. Snow density ρ_s= *f(t)*

$$\rho_s(t + \Delta t) = [\rho_s(t) - \rho_{s\,max}] \exp(-0.24\Delta t/\tau) + \rho_{s\,max}$$

$$\rho_{s\,min} = 100 \text{ kg m}^{-3}, \qquad \rho_{s\,max} = 300 \text{ kg m}^{-3},$$

$$\Delta t\text{—time step}, \qquad \tau = 86\,400 \text{ s}.$$

[*Mocko and Sud, 2001*]

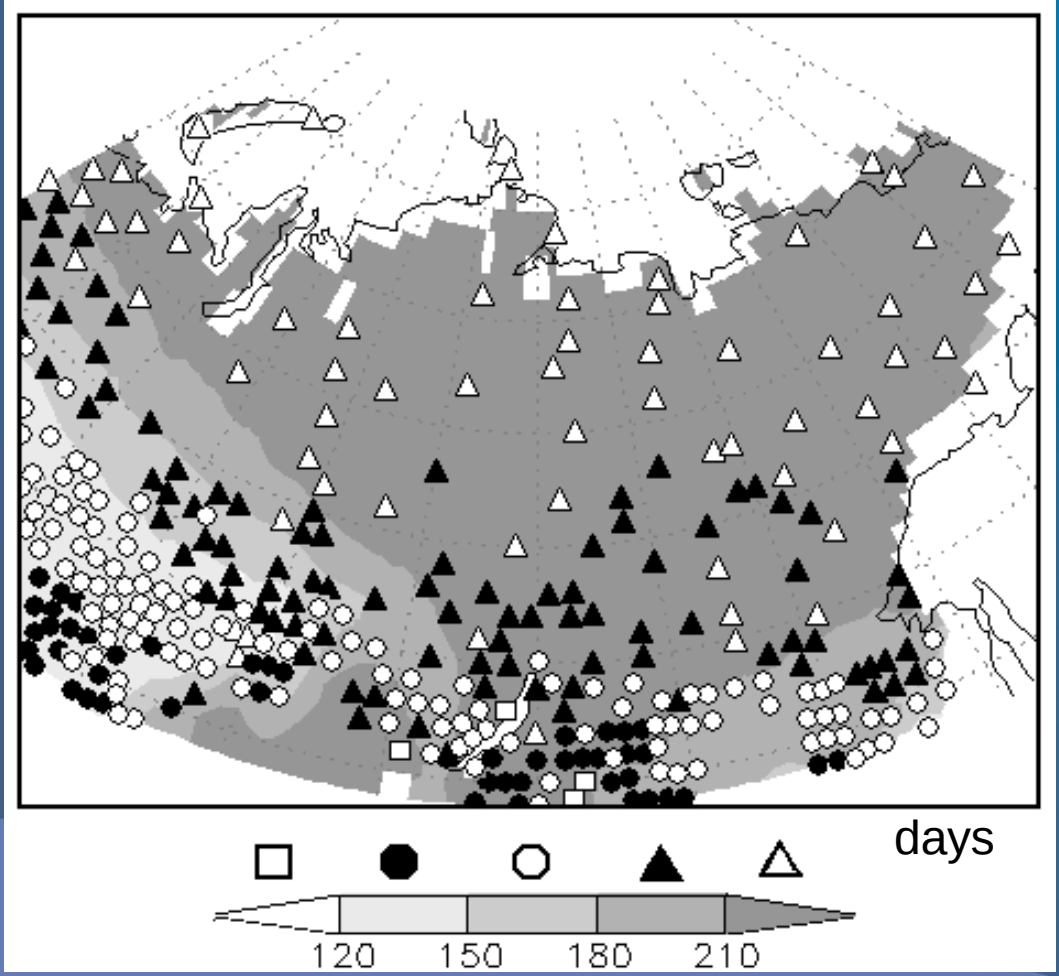
3.Snow heat conductivity λ_s=f(ρ_s)

$$\lambda_s = \lambda_0(\rho_s/\rho_a)^{-1.88}$$

where $\lambda_0 = 2.22 \text{ W m}^{-1} \text{ K}^{-1}$, $\rho_a = 1000 \text{ kg m}^{-1}$.

[*Mocko and Sud, 2001*]

Long-term mean annual number of days with snow cover



Symbols -the data derived from *[Groisman et al., J.Clim.,2006]*

Shading – simulated by RCM for 1991-2000

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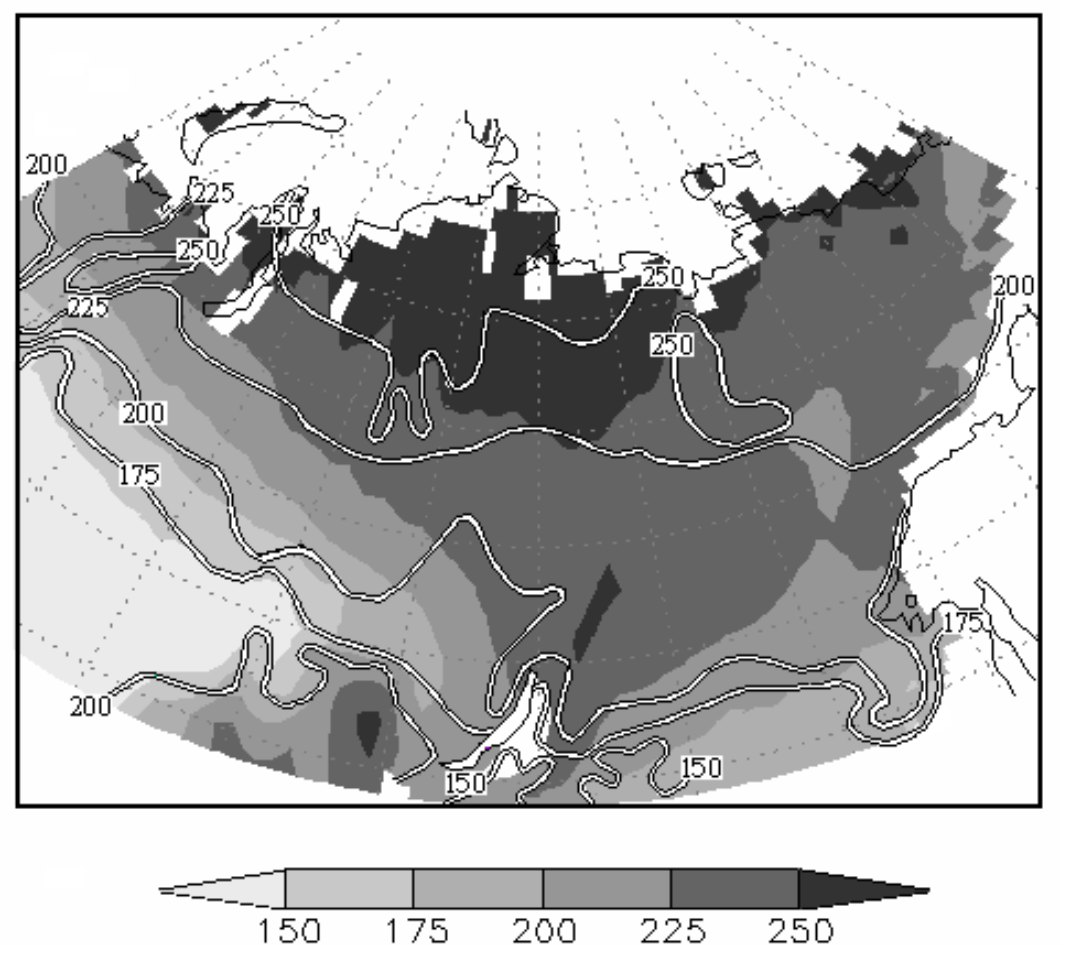
Long-term mean annual number of days with snow cover



Comparison with the data from
[Climate of Russia.,2001]

Lines : observations
Color of shadings : MGO RCM

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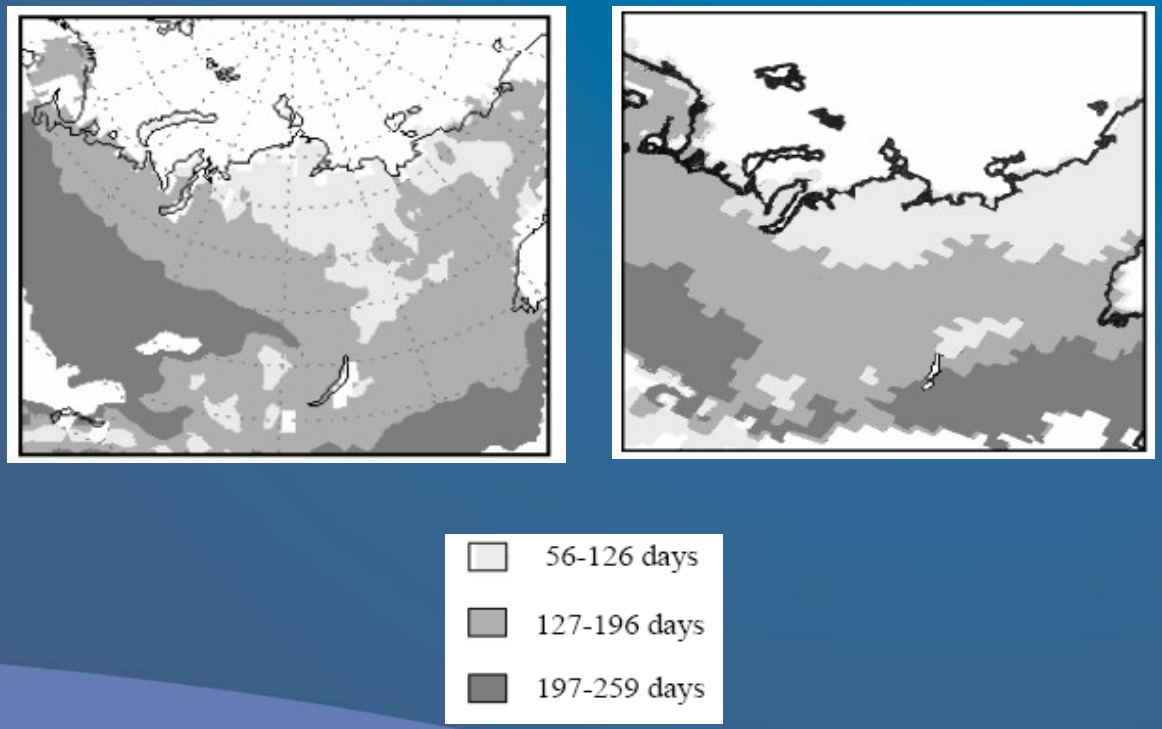
Duration of snow-free period

MGO RCM

Satellite data* [1972-2000]



*[Dye and Tucker, 2003]

Snow cover depth (cm) in the end of February 1991-2000 for various snow density settings

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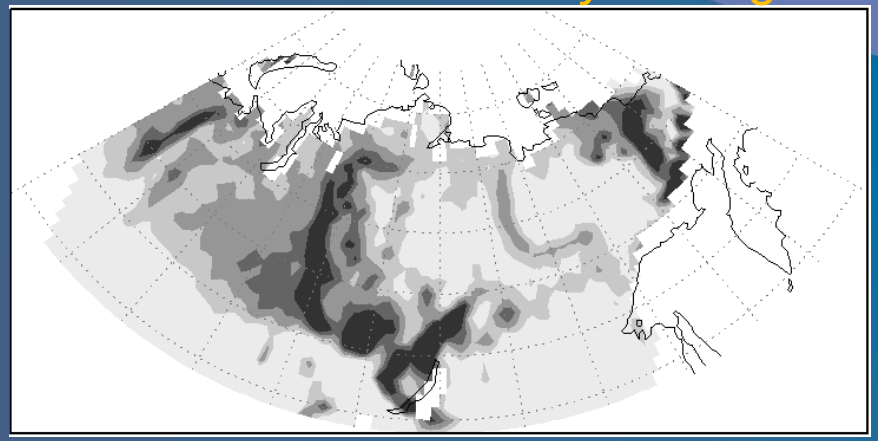
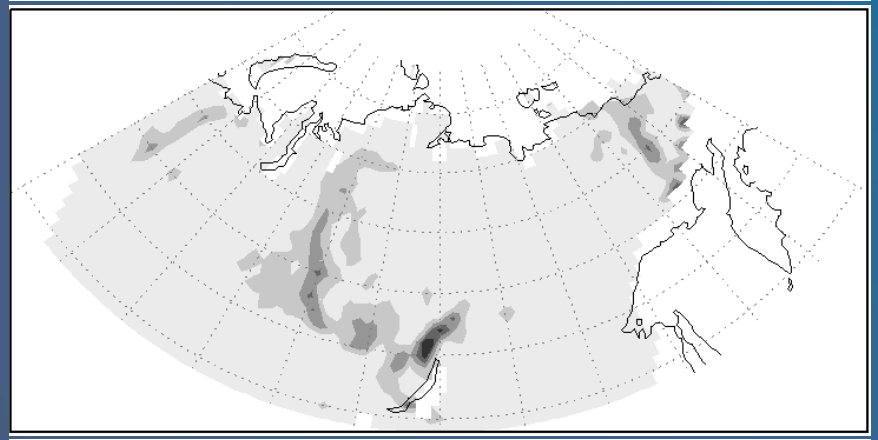
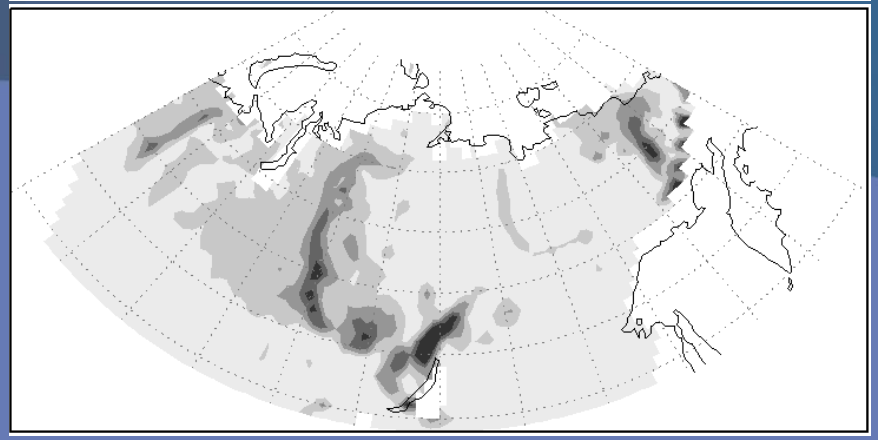


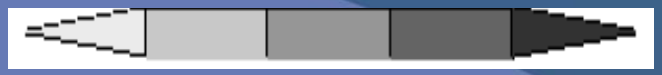
ρ=200 kg m^{-3}



ρ=400 kg m^{-3}



ρ=f(t)



Ground temperature (deg C) at 1.6m depth differences for 1991-2000 due to various snow density settings

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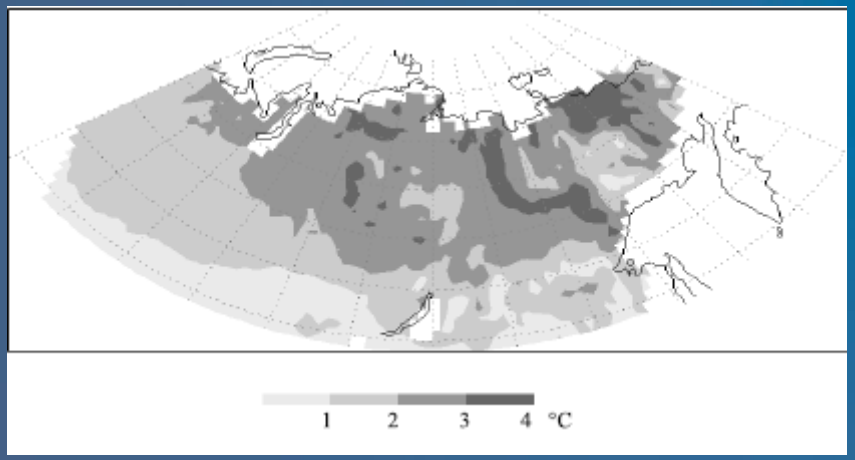
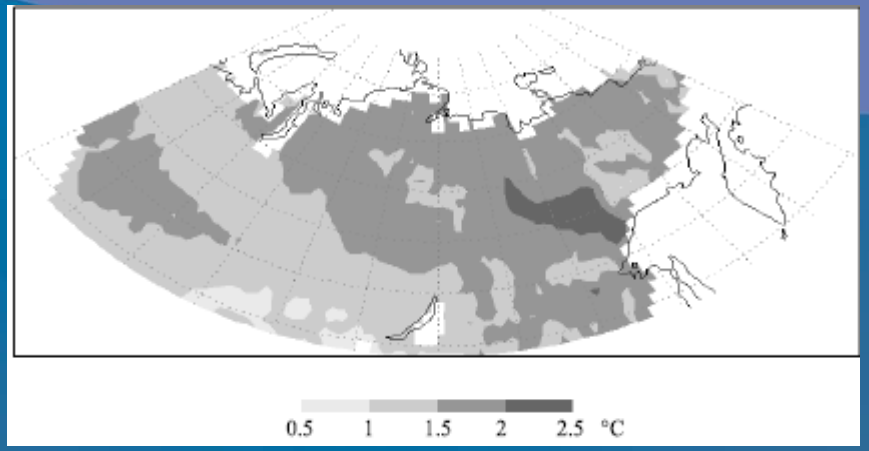
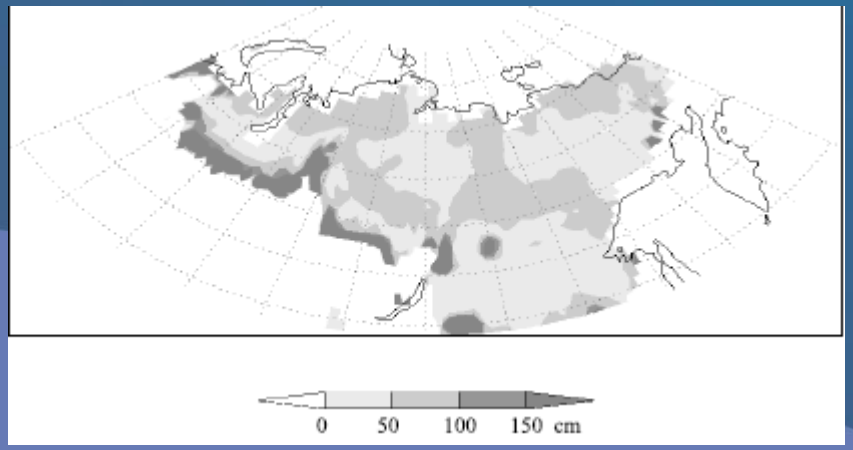


March



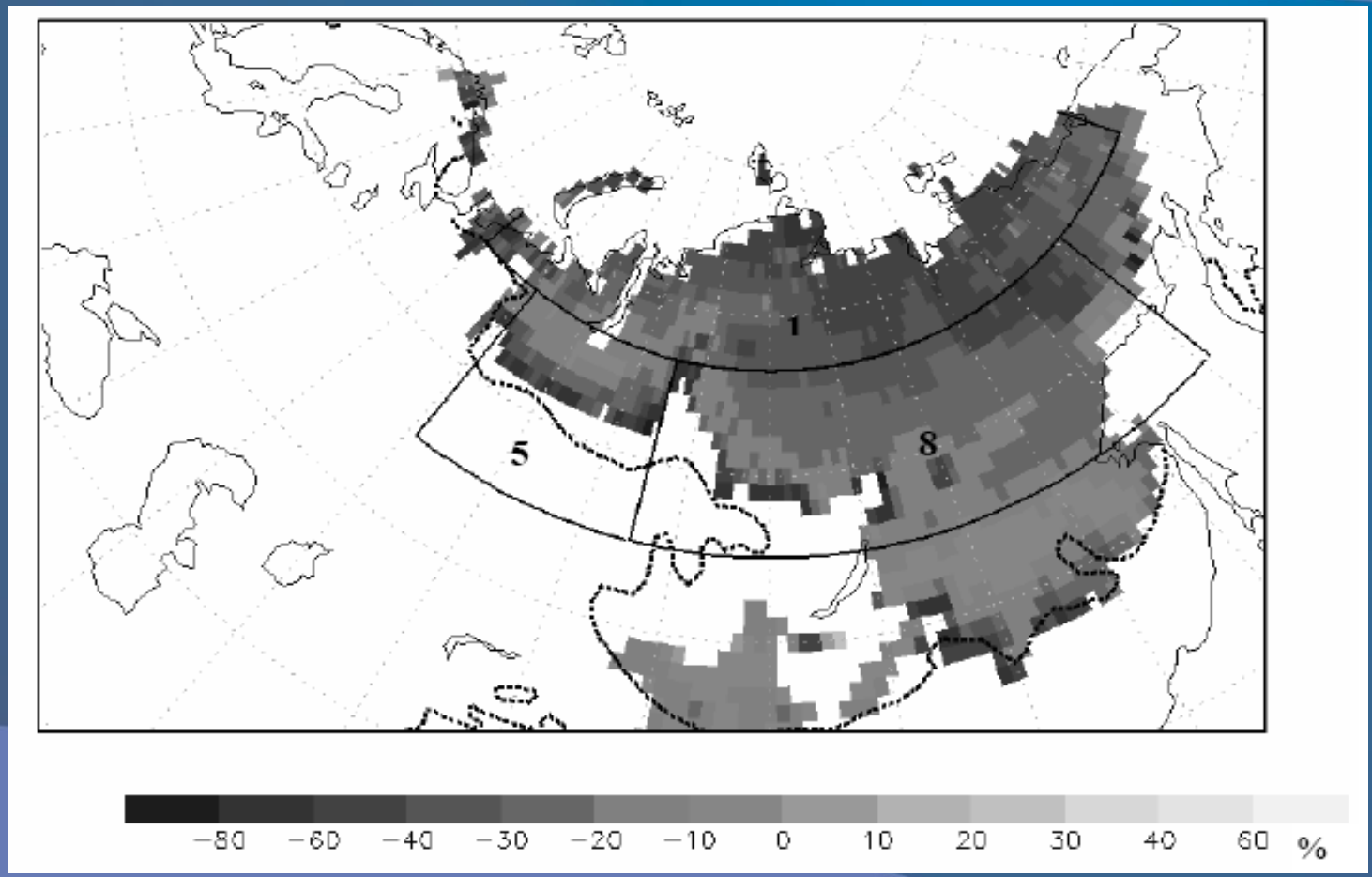
October

Active layer depth (cm) differences due to various snow density settings



August

The differences between the active layer depths simulated by ρ_s=const and ρ_s=f(t) for 1991-2000



dashed line – observed permafrost zone boundary

1, 5, 8 – climatic regions [*Groisman et al., 2006*]

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Inter-annual variability of the snow depth (h_s) and snow duration for various climatic regions (1, 5, 8) and for various settings of the snow density (ρ_s) in comparison with summer temperature sums evolution.

years	h_s in February (cm)						Summer air temperature sums			years	Number of days with snow		
	$\rho_s \neq$ const			ρ_s =200 kg· m $^{-3}$									
	Region			Region			Region				Region		
	1	5	8	1	5	8	1	5	8		1	5	8
1991	37	39	39	54	58	58	40.4	47.5	52.9	1991-92	263	203	233
1992	40	32	32	59	48	47	34.9	40.6	53.3	1992-93	267	200	226
1993	32	52	40	48	78	61	37.5	52.4	52.3	1993-94	269	193	232
1994	39	35	33	51	52	49	36.8	44.7	53.4	1994-95	268	200	233
1995	38	41	39	51	62	59	35.1	39.1	50.9	1995-96	268	196	236
1996	41	42	42	54	63	61	37.1	43.2	53.5	1996-97	266	192	235
1997	40	41	38	53	61	56	40.7	47.9	55.9	1997-98	266	195	230
1998	39	4	37	56	65	54	40.3	49.6	58.0	1998-99	262	190	227
1999	39	36	35	55	54	51	40.4	50.7	53.4	1999-2000	264	197	230
2000	33	42	32	47	63	47	39.0	45.5	54.4				
mean	38	40	37	53	60	54	38.2	45.9	53.8	ave.mod	266	196	231
										ave.obs	245	186	204

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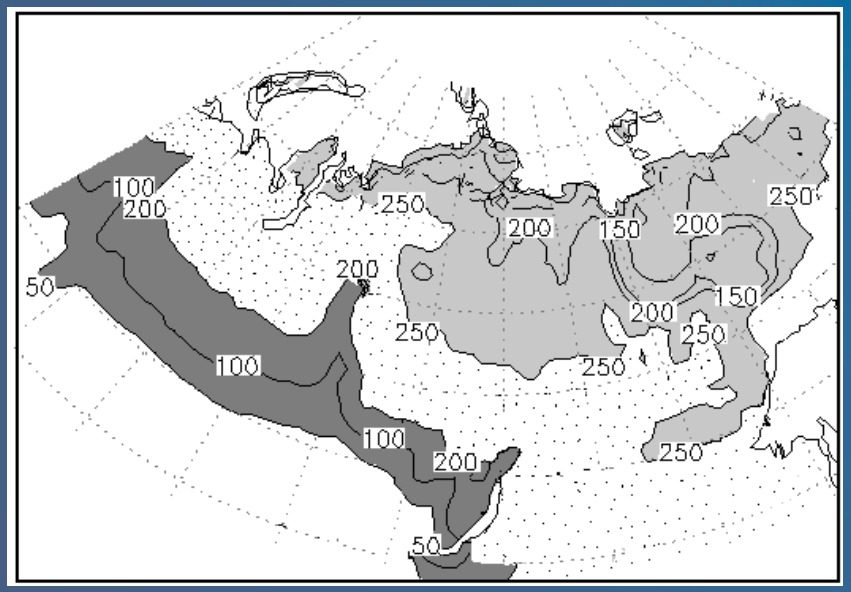
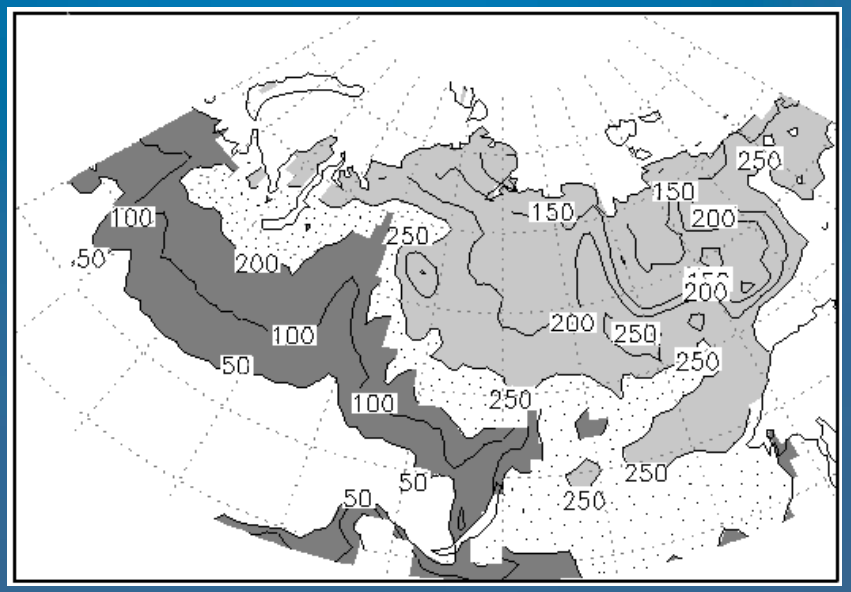
Seasonal thawing/freezing depths (cm) as projected by the end of 21st century (2091-2100) relative to the late 20th century



Monthly mean climate forcing
ρ_s= const



Daily mean climate forcing
ρ_s= f(t)

Seasonal thawing area

Seasonal freezing area

Transition thawing/freezing area

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MGO Regional Climate Model

(Shkolnik et al., 2000)

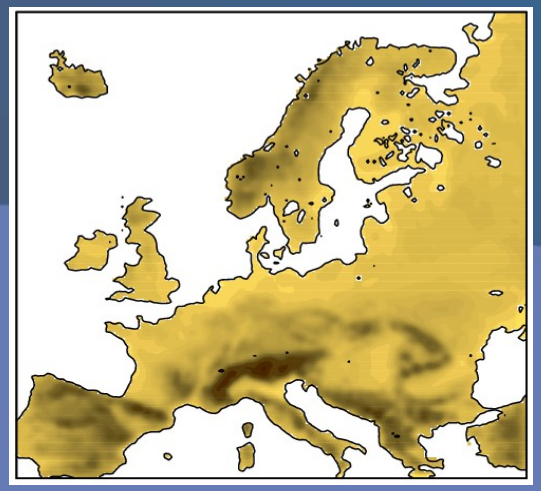
Resolution:

Horizontal → 25 km
Vertical → 25 levels
Temporal → 3 h

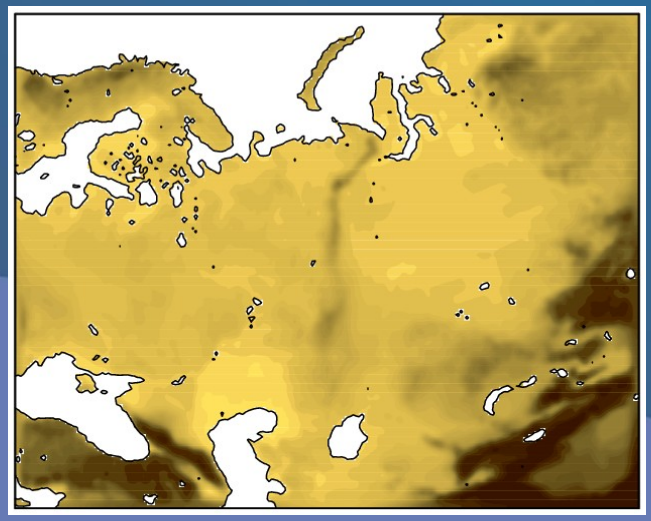
ENSEMBLES

Three MGO RCM working domains (25 km resolution)

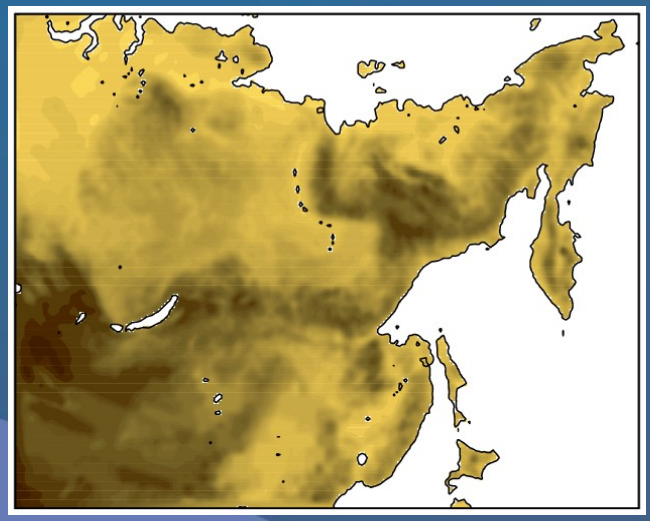
Europe



Western and central Russia



Siberia



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Summary

The scenario of changes by the end of 21st century in permafrost and thawing/freezing depths largely depends on snow density parameterization.

Further research is needed in order to address changes in the cryosphere within the context of RCM ensemble simulations for permafrost regions;

Coordination of RCM + Permafrost Model efforts over the northern Eurasia is appreciated under umbrella of large projects/programs (CORDEX, CAPER, NEESPI)