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Development of snow parameterization: definition of initial snow density and accounting of fractional snow coverage within a cell

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Methods and data

- model COSMO-Ru 14km resolution, version 4.2
- Integration period – 78h (from 00 UTC)

- Data:
  - station SYNOP measurements (36 stations)
  - decade measurements of snow survey on Roshydromet's stations (33 stations)

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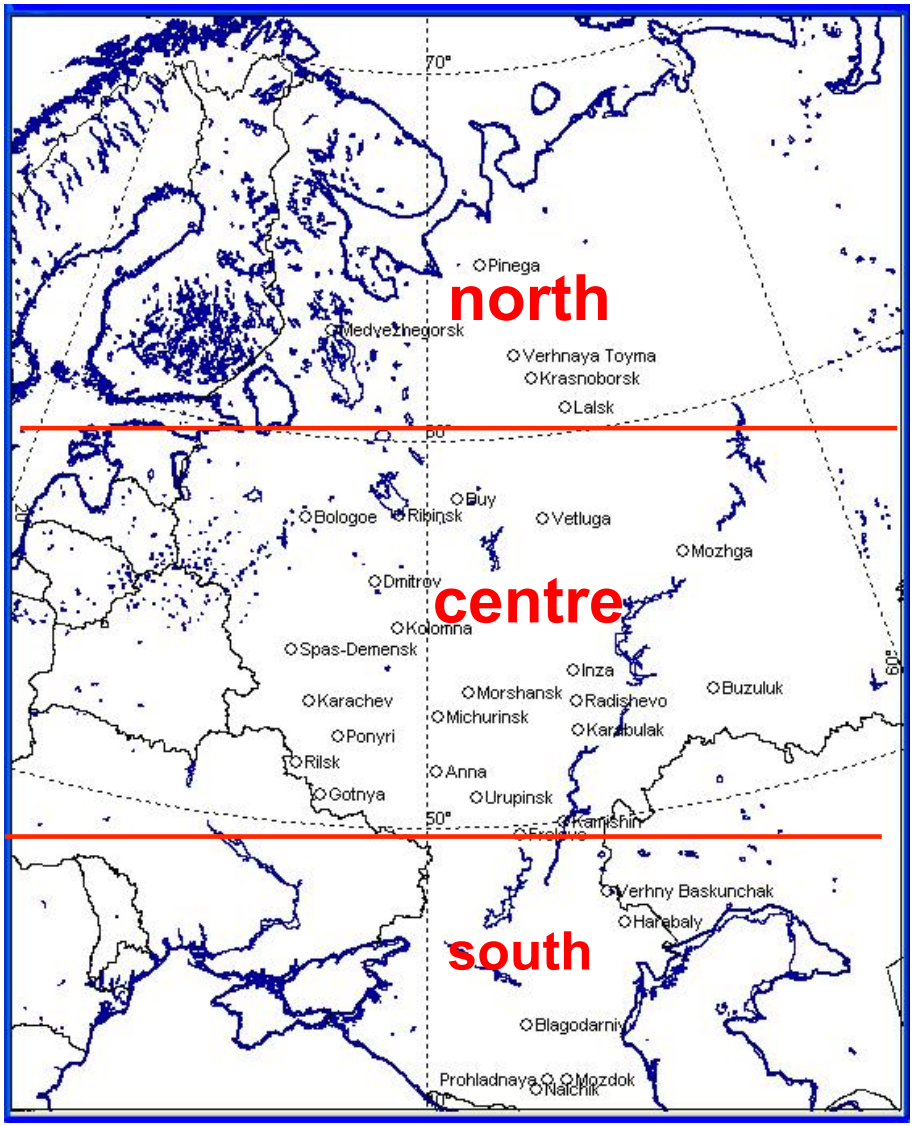
Area of study: European Part of Russia



Problem:

an overestimation (twice as much) of initial snow water equivalent (SWE) from GME (DWD)

→

too much snow mass in the model in comparison with the reality

→

underestimation of T2m forecasts (up to 10ºC) during snowmelt period

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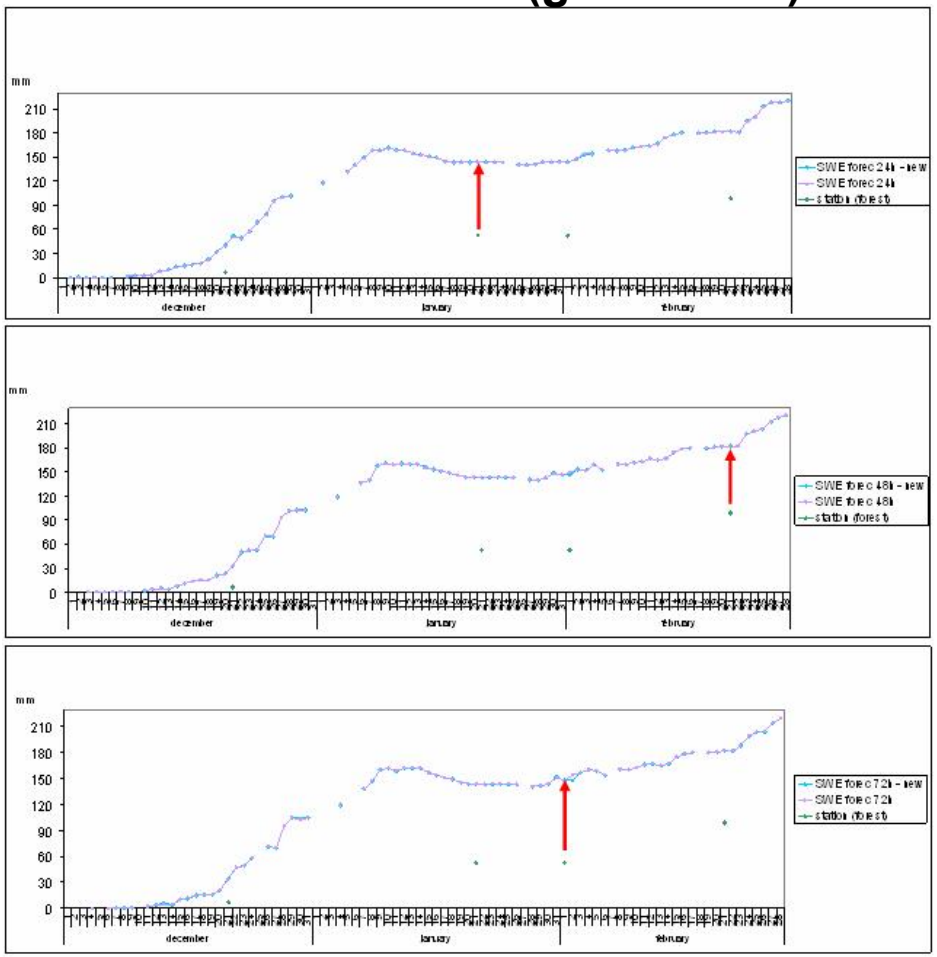
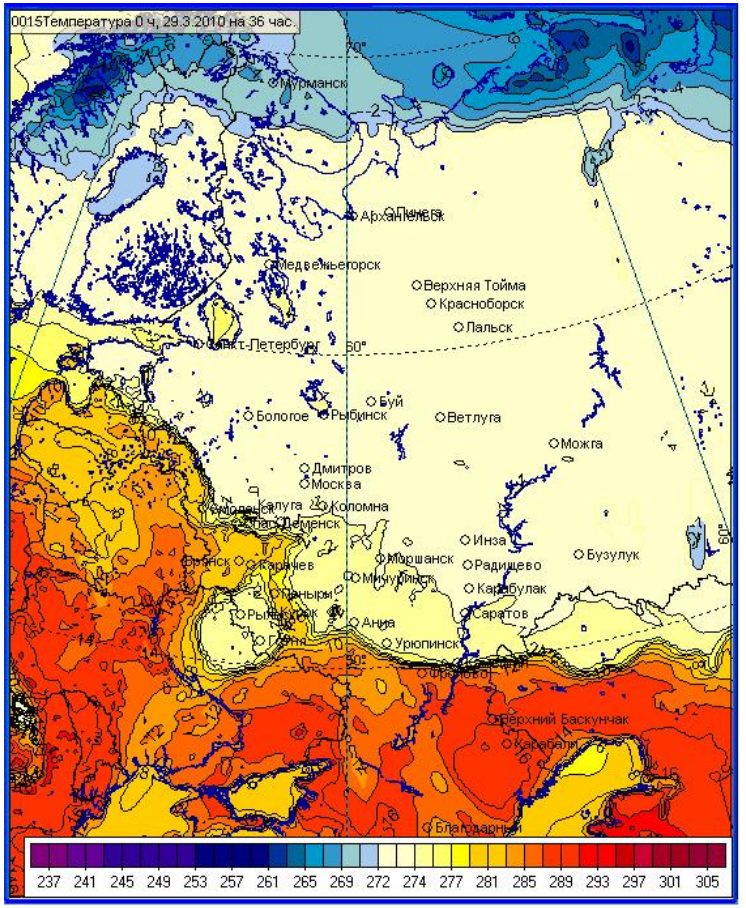
SWE forecasts and station measurements (green dots)



T2m, 36h forecast. 29 March 2010



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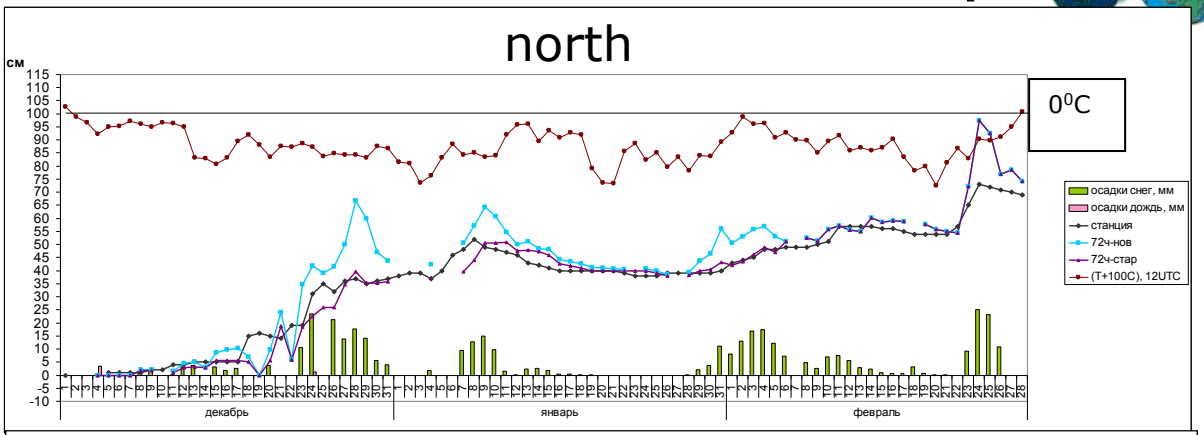
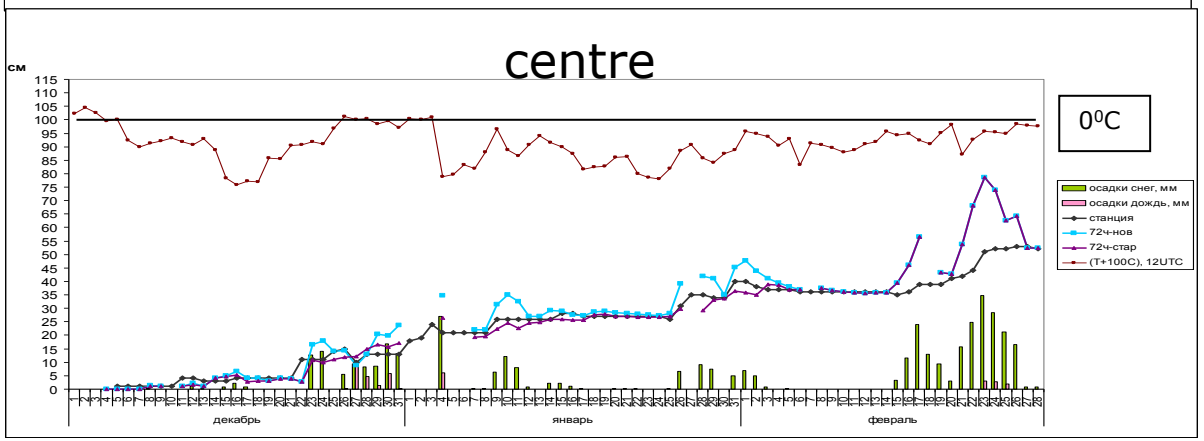
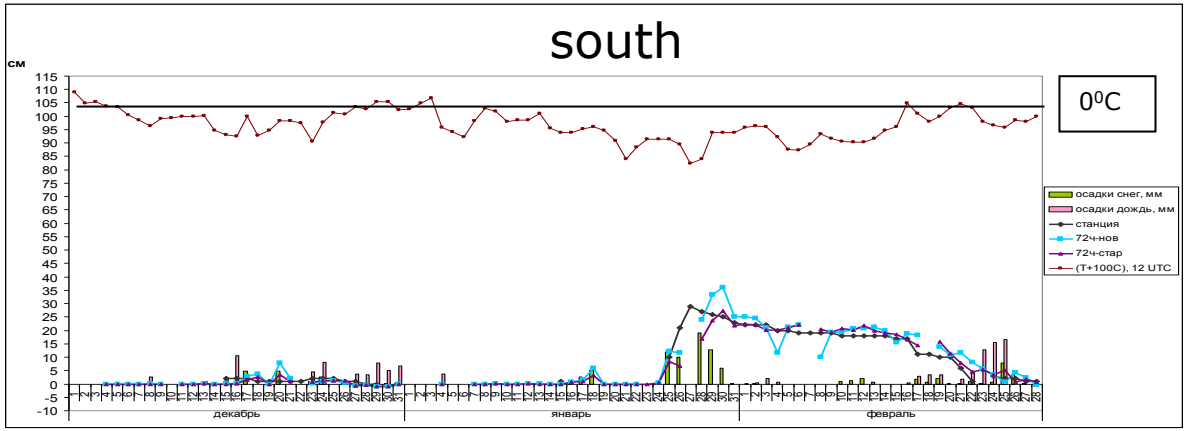
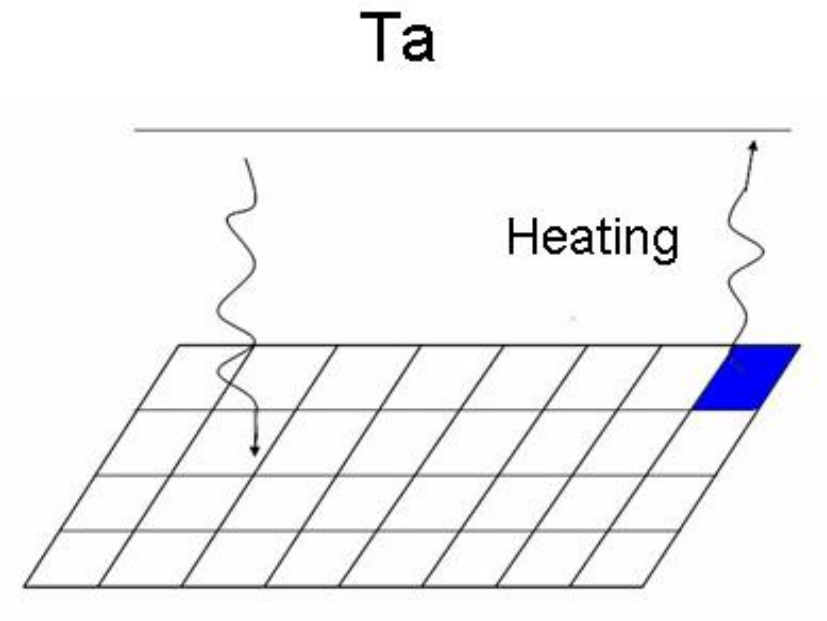
Hsnow

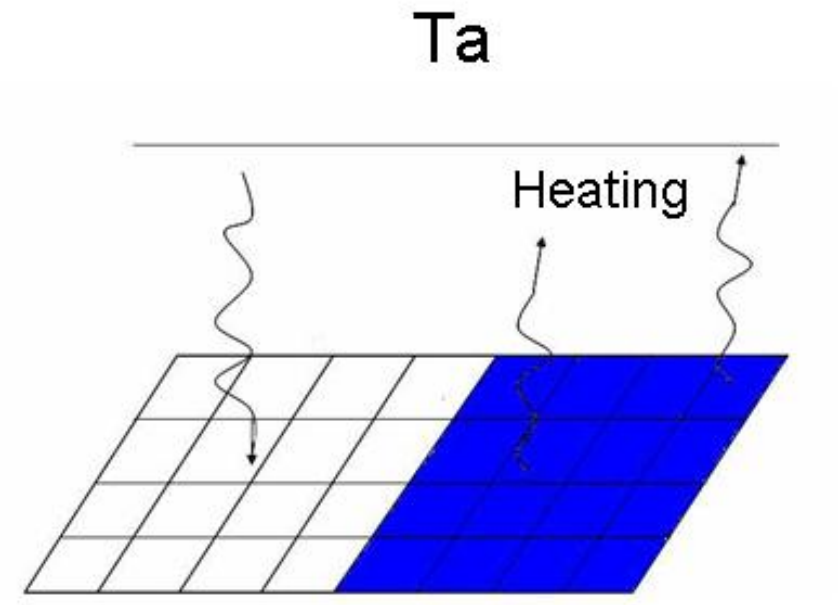






Cell heating





Surface fraction covered by snow (in TERRA within COSMO-Ru)

$$f_{snow} = Max(0.01; Min(1.0, \frac{W_{snow}}{\delta_s}))$$

δ_s = 0.015 parameter

W_{snow} - snow water equivalent (SWE)

Possibilities for improving T2m during snowmelt period:

- To change SWE (there is a feedback in T2m)

Thus it's necessary to define snow density (ρ_{snow}) correctly (since prognostic snow height corresponds to measurements, and $SWE=H_{snow}*\rho_{snow}$)

- To take into account snow fractional covering

Different approaches for determination snow density:

- As constant (for example, 250 kg/m^3)
- Precipitation microphysics
- Laboratorial researches
- “Hydrological-historical” approach: snow density is a function of meteorological parameters during the whole snow period (first of all – temperature)

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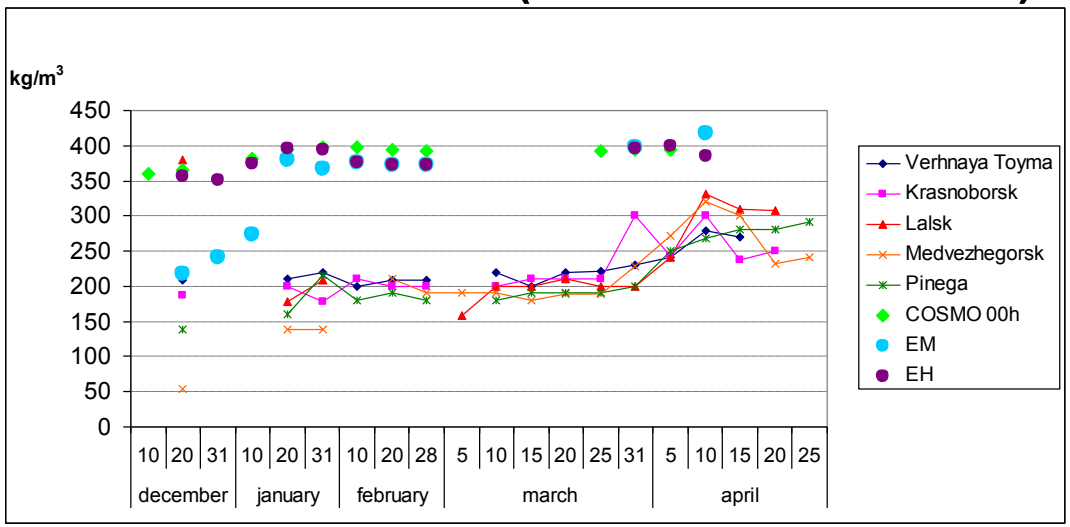
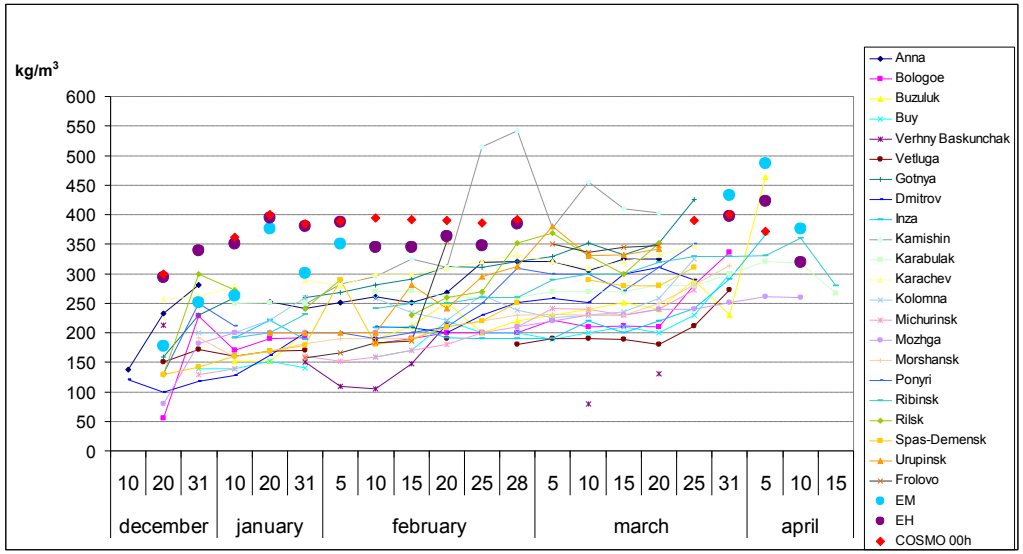
Snow density (kg/m³): initial model values for 00h, 72h forecasts (two snow schemes) and station measurements



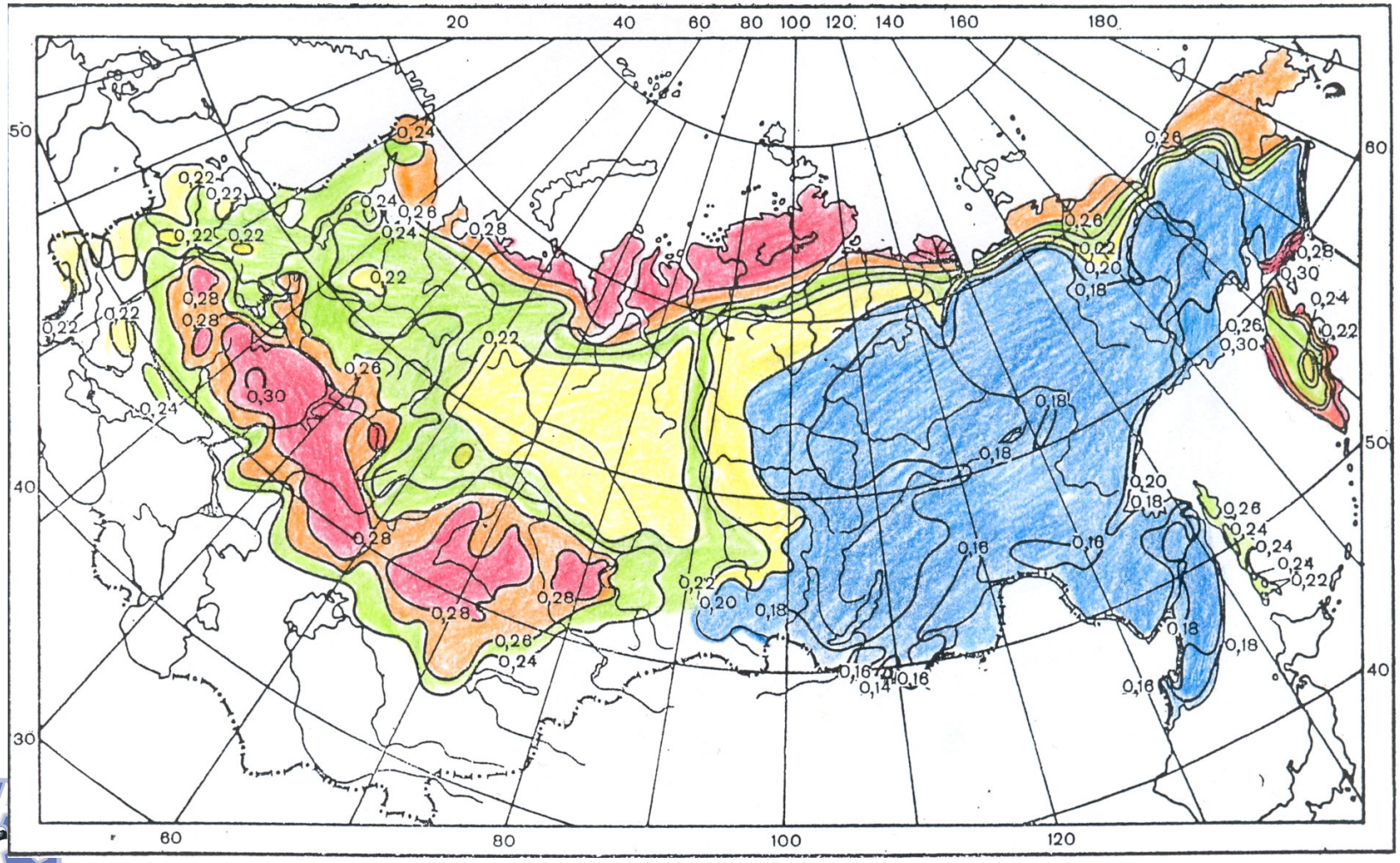
→ **North region**

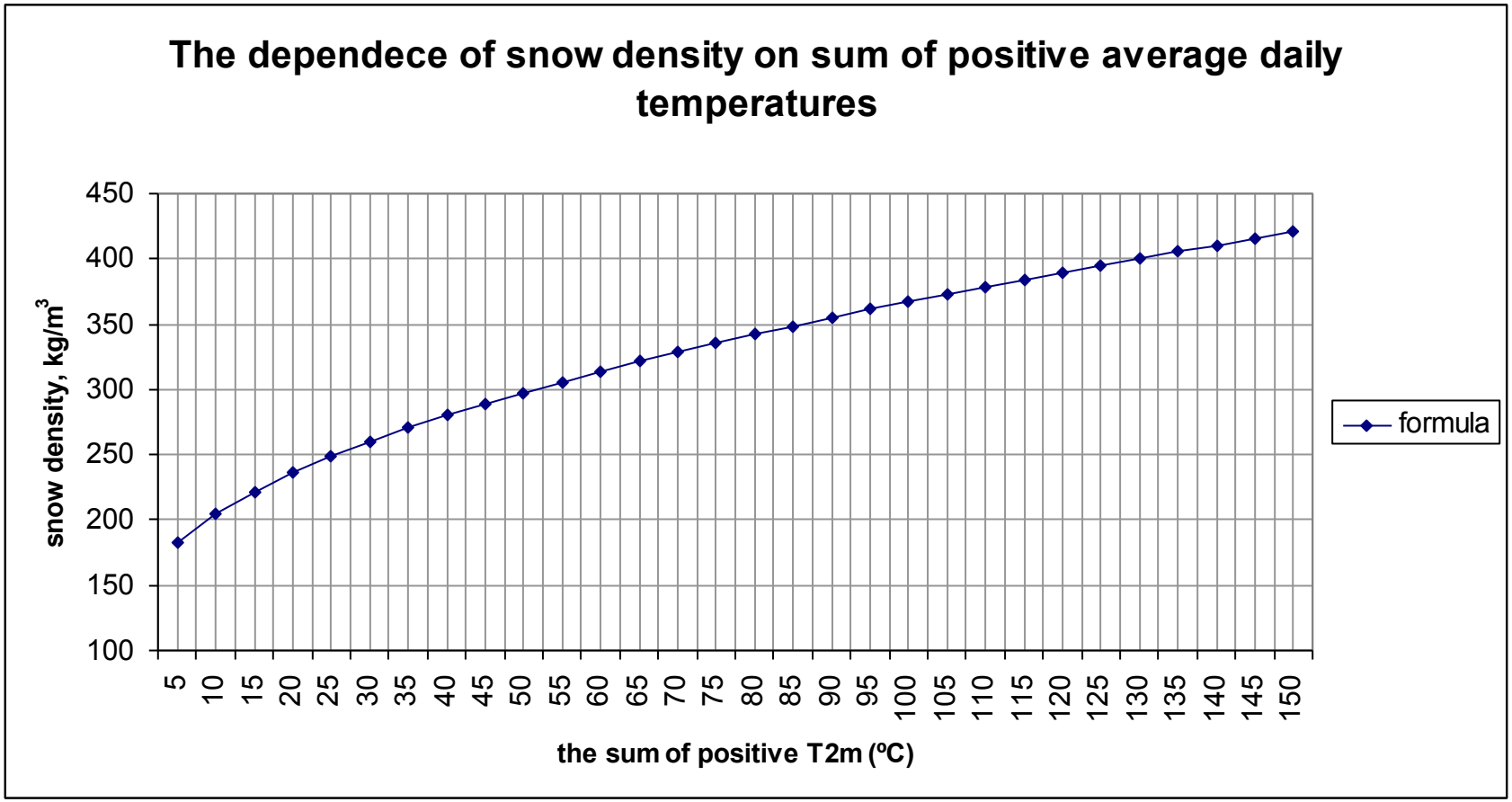
Centre region →



Initial and following snow density overestimation of the model COSMO-Ru

Average snow density (g/cm^3) at maximum snow height





$$\rho = As + 23{,}72 \cdot \sqrt{SumT}$$ ‘temperature’ method

As – empirical coefficient, As=130

See *Dmitrieva N.* Snow density calculation using meteorological data // Meteorology and Hydrology, 1950, №2, pp.39-44

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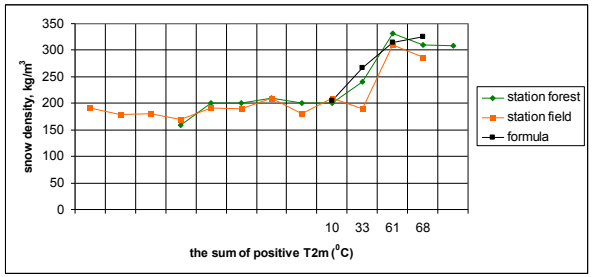
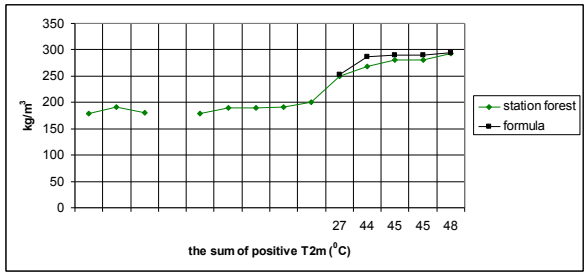
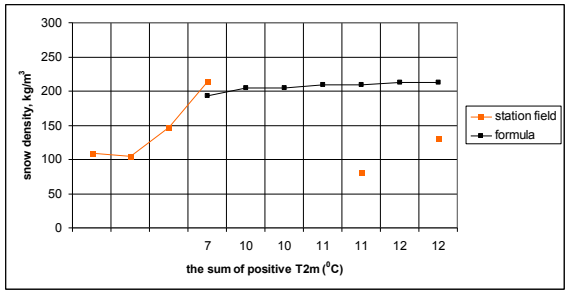
Snow density, kg/m^3:measurement and formula calculations

North region

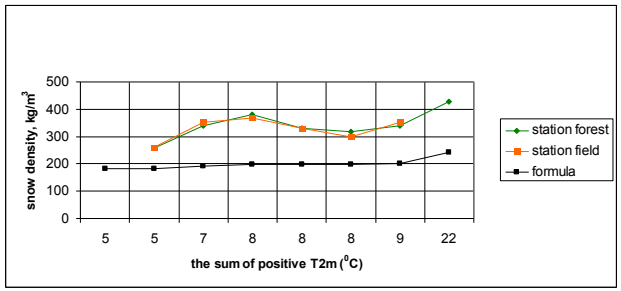


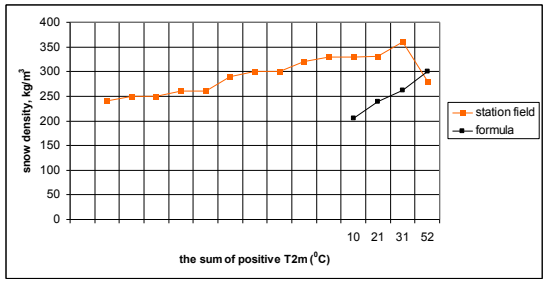


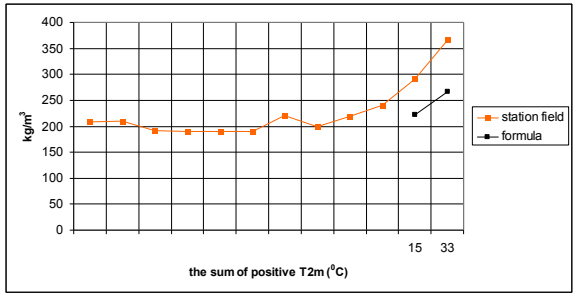
South region

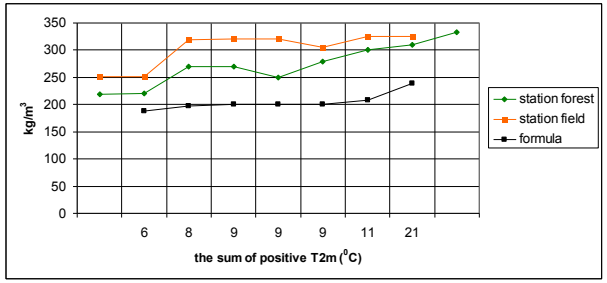


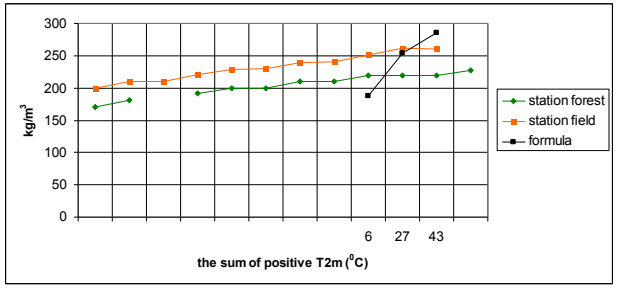
Centre region

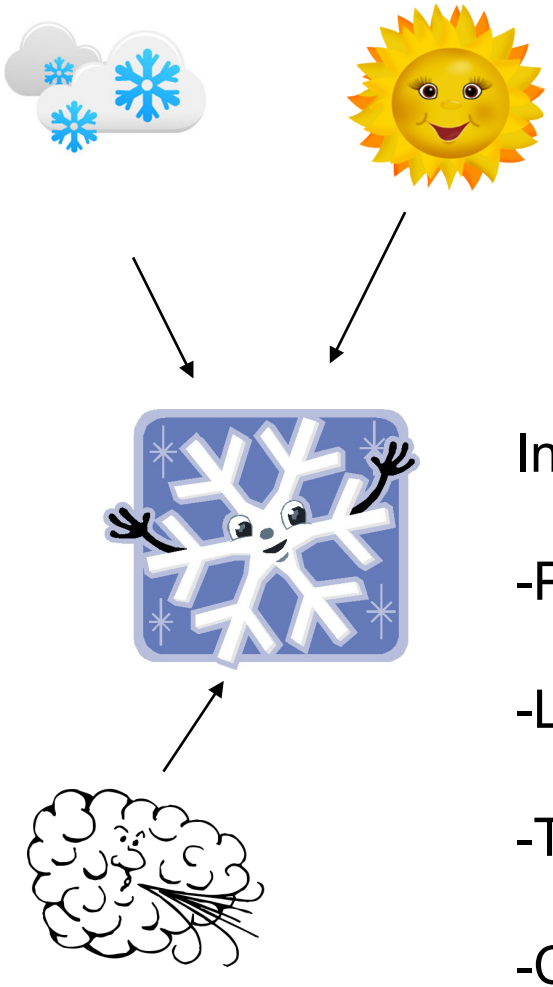


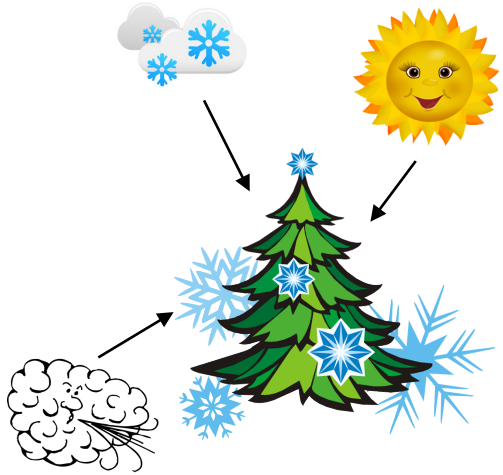


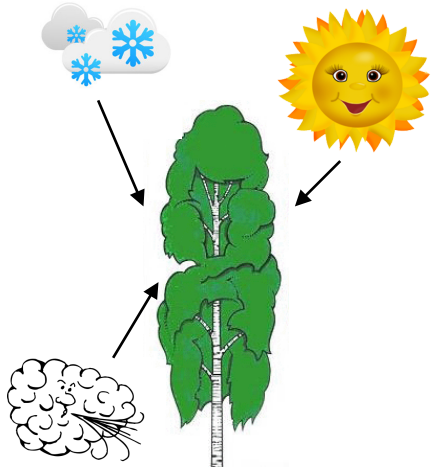












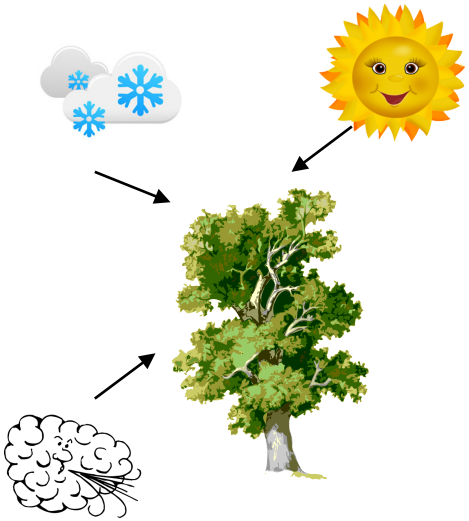
Influencing factors:

-Presence of thaws;

-Length of snow existence;

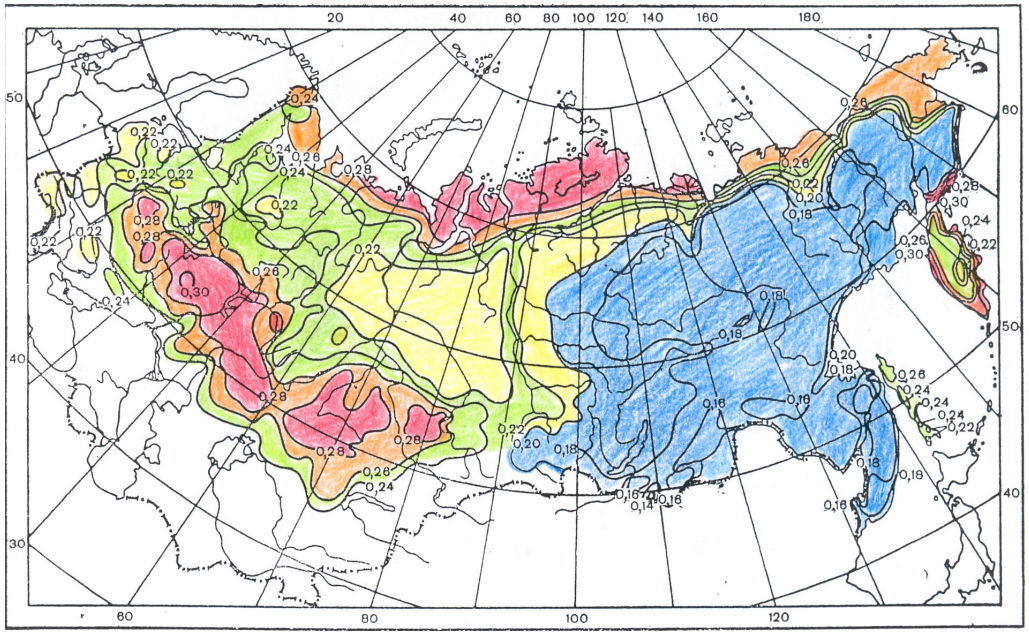
-The amount of precipitation;

-Compaction due to wind



Snow density depends on native zones

Average snow density (g/cm^3)
at maximum ten-day snow height



Types of vegetation

0,28-0,30 tundra, forest-tundra; south - steppe

0,26-0,28 north **-** forest-tundra; steppe and broadleaf forests (with predominance of birch)

0,24-0,26 taiga (spruce; spruce with a touch of oak); south - steppe

0,20-0,22 swamp vegetation, taiga (spruce); west - broadleaf forests (with predominance of oak and hornbeam)

<0.20 taiga (with predominance of larch)

Snow fractional covering: experiments

$$f_{snow} = Max(0.01; Min(1.0, \frac{W_{snow}}{\delta_s}))$$

δ_s = 0.015 parameter

W_{snow} - snow water equivalent

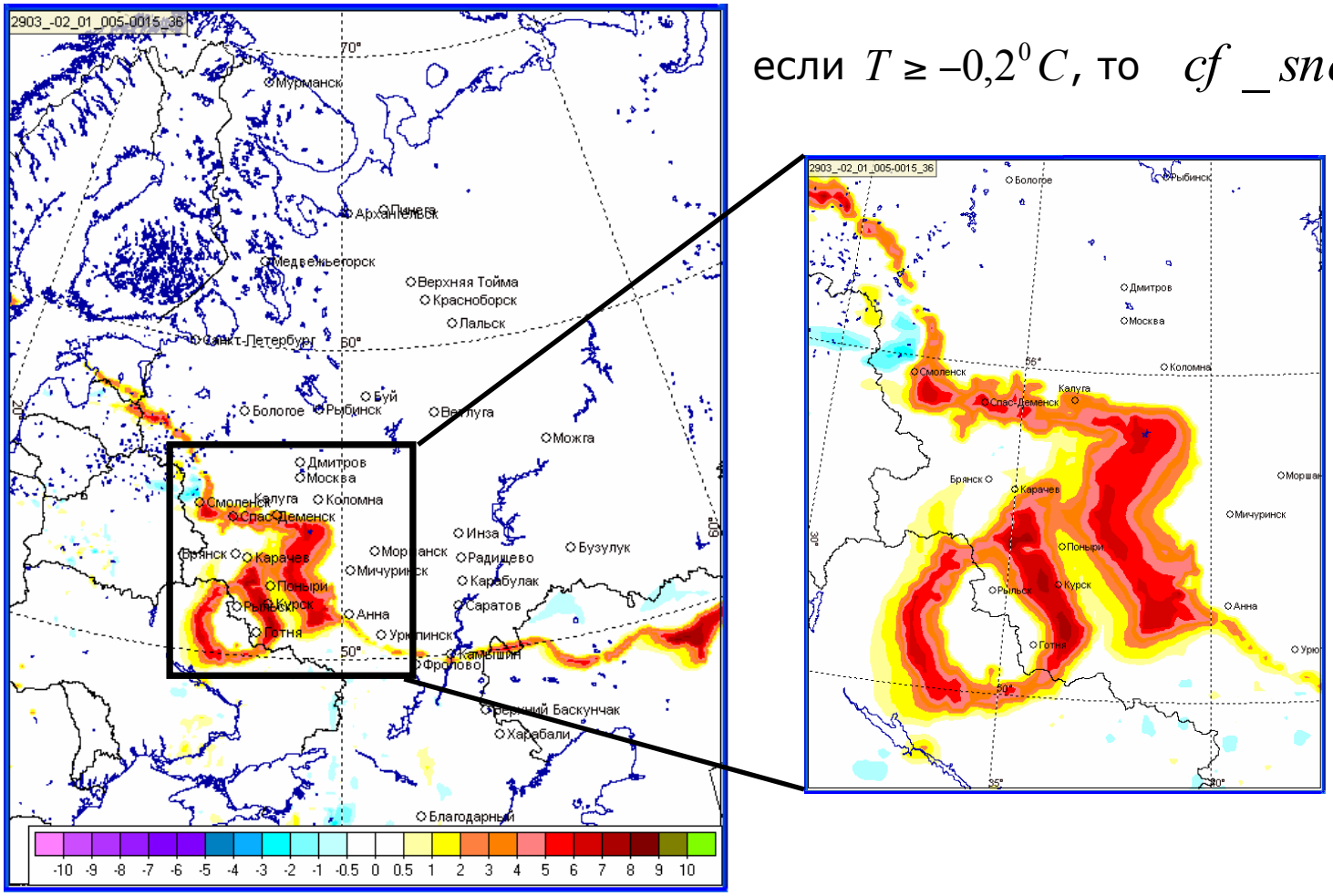
$$f_{snow} = Max(0.01; Min(1.0, 0.2))$$

$$f_{snow} = Max(0.01; Min(1.0, 0.5))$$

ΔT2m (29.03.10)

$$cf\_snow = 0.05м$$

если $T \geq -0{,}2^0 C$, то $cf\_snow = 0.1м$



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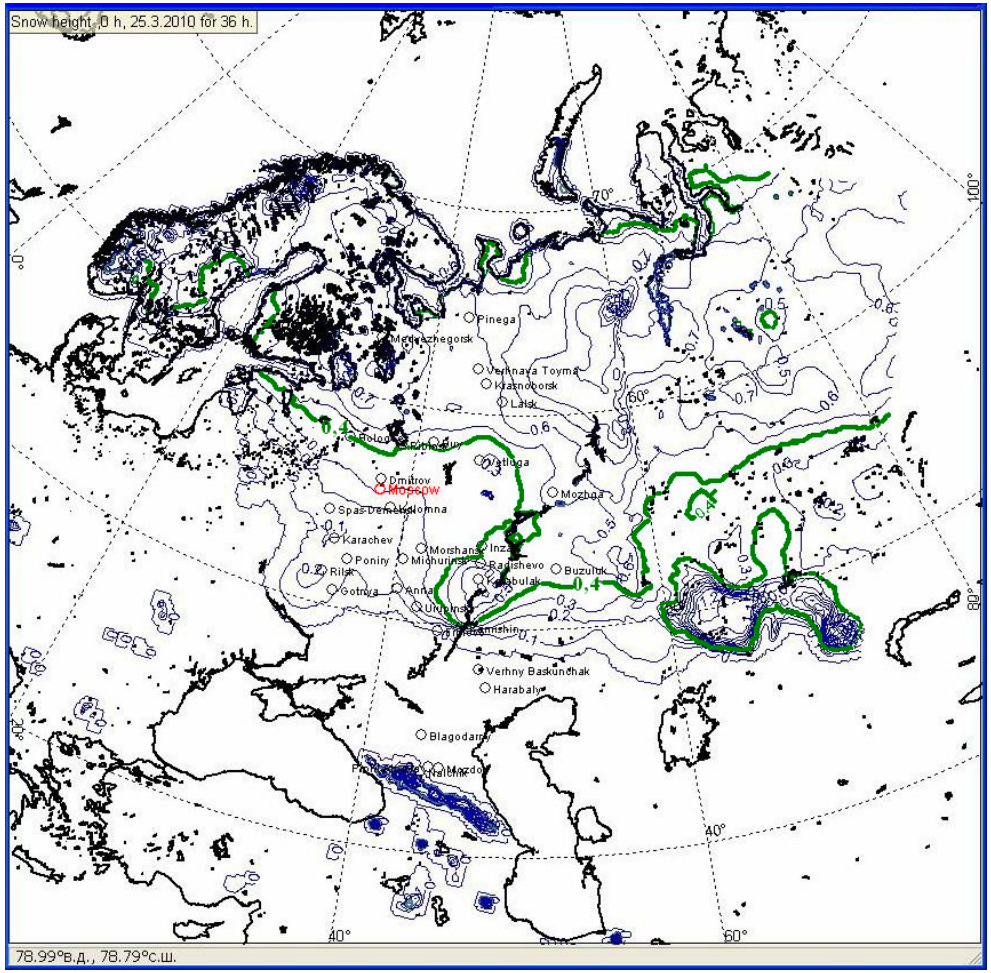
Snow height (m), 36h forecast



According to model 36h forecast of snow height (see fig.), 40-cm snow exists on a wide territory in model as well as in the reality. However model snow mass is more big then according to observations (due to overestimated initial model SWE) and measured T2m is above 0ºC

It was decided to change longwave radiation and total forcing at snow surface as they gave the main effect on the instability in calculating a forecast. So, only in these terms fractional cover was calculated as usual :

$$f_{snow} = Max(0.01; Min(1.0, \frac{W_{snow}}{\delta_s}))$$

δ_s **=0.015**

For the rest of terms (net radiation, latent and sensible heat fluxes for snow and soil as well as evaporation and evapotranspiration) fractional cover was:

$$f_{snow} = Max(0.01; Min(1.0, \frac{H_{snow}}{b_s}))$$

b_s=0.4

Total forcing at snow surface

$$G_{snow} = f_{snow}(c_p H_{snow} + LE_{snow} + Q_{rad,net} + G_p)$$

G_{snow} total forcing at snow surface

$c_p H_{snow}$ LE_{snow} sensible and latent heat fluxes at snow surface

$Q_{rad,net}$ net radiation at snow surface

$G_p = L \cdot P_r$ freezing rain

or $G_p = -L \cdot P_{snow}$ melting snowfall

$$f_{snow} = Max(0.01; Min(1.0, \frac{W_{snow}}{\delta_s}))$$

surface fraction covered by snow

Longwave radiation

$$Q_{lw} = \sigma(1-\alpha)\cdot((1-f_{snow})\cdot T_s + f_{snow}\cdot T_{snow})^4 + Q_{gr}$$

Q_{lw} downward longwave radiation

σ Boltzmann-constant

α thermal albedo (of all soil types)

$$f_{snow} = Max(0.01; Min(1.0, \frac{W_{snow}}{\delta_s}))$$ surface fraction covered by snow

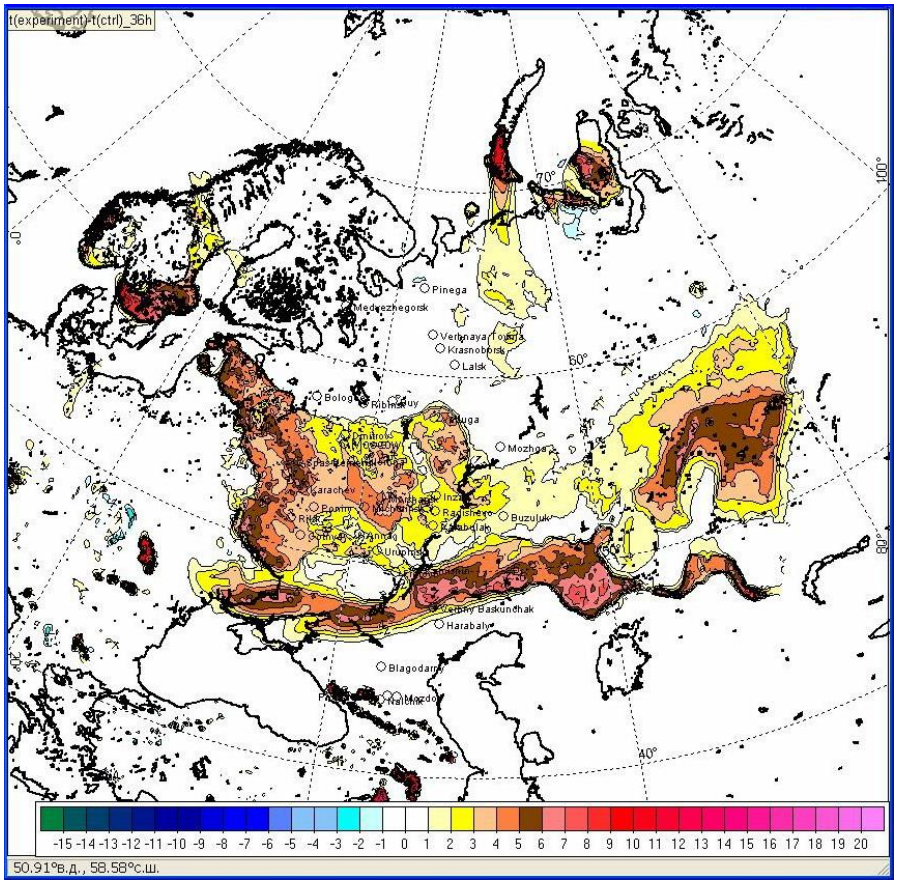
T_s soil surface temperature

T_{snow} snow surface temperaure

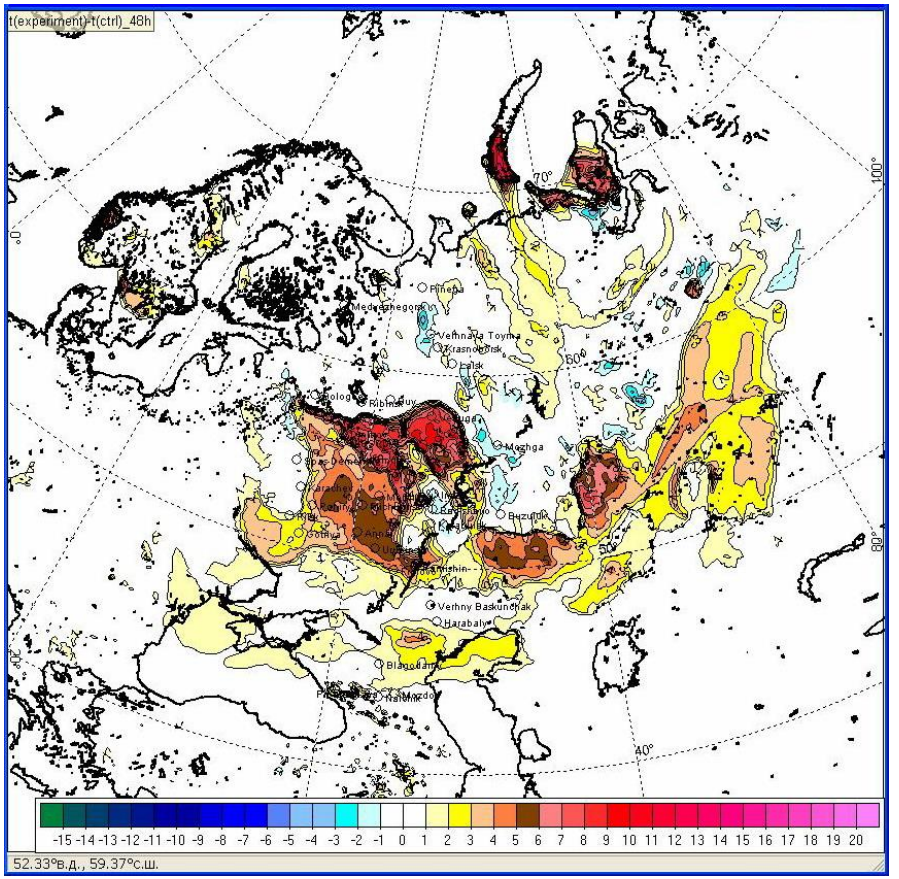
Q_{gr} thermal radiation at the ground

T2m(experiment)-T2m(ctrl)

36h forecast



48h forecast



T2m temperature raised up to 10ºC on the territory where according to model data snow cover was below 40 cm

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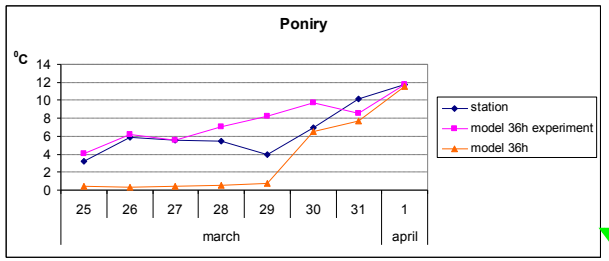
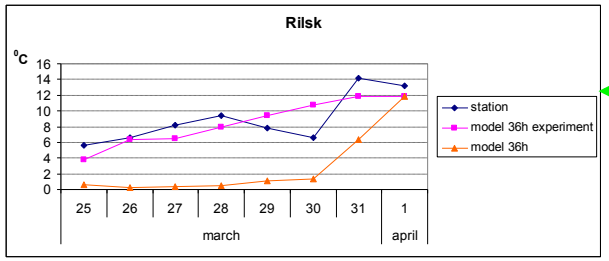
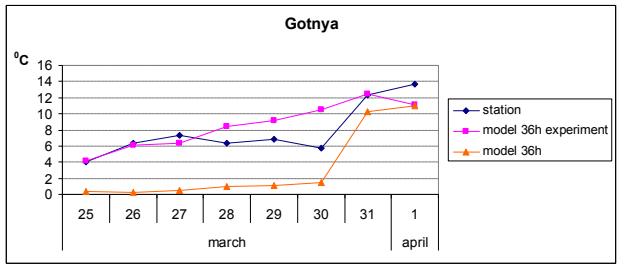
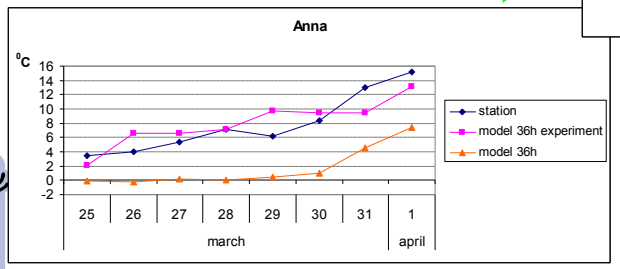
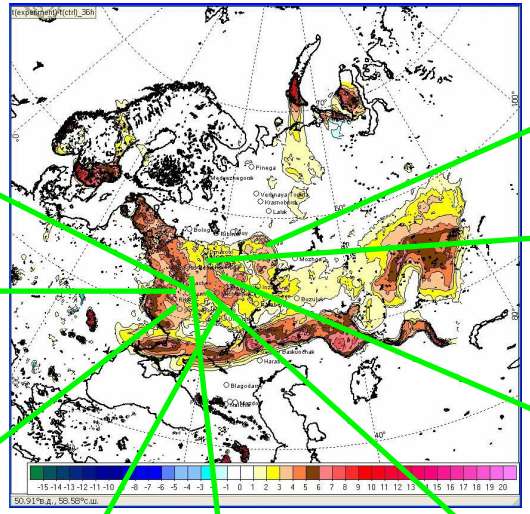
Day T2m temperature (ºC): measurements (blue), 36h forecasts – experiment (pink), ctrl model (orange)

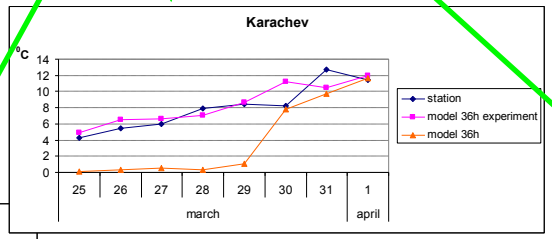


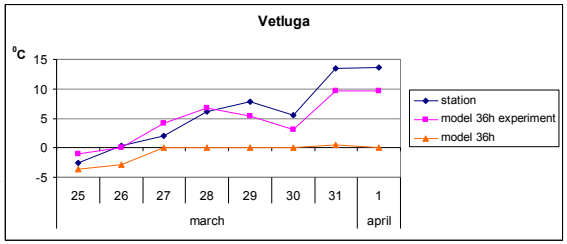


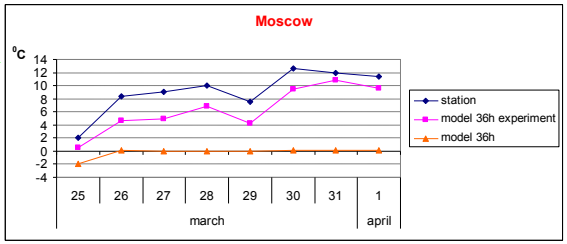


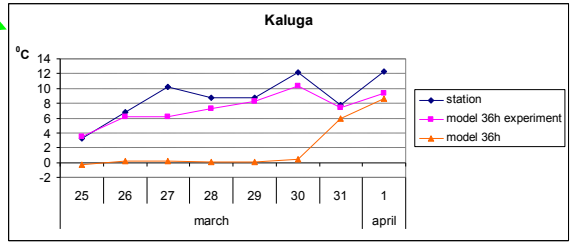


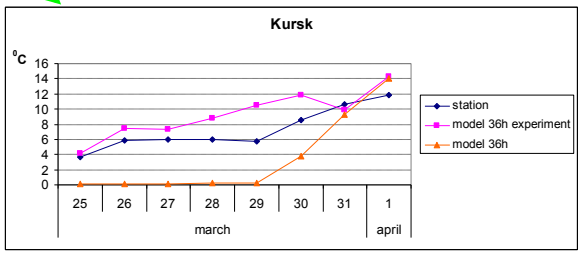




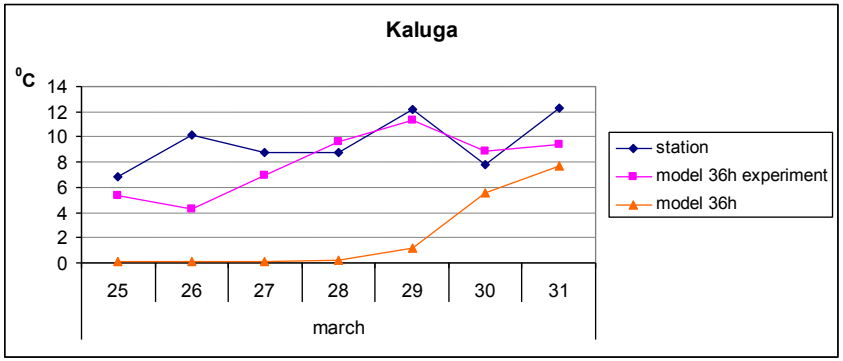


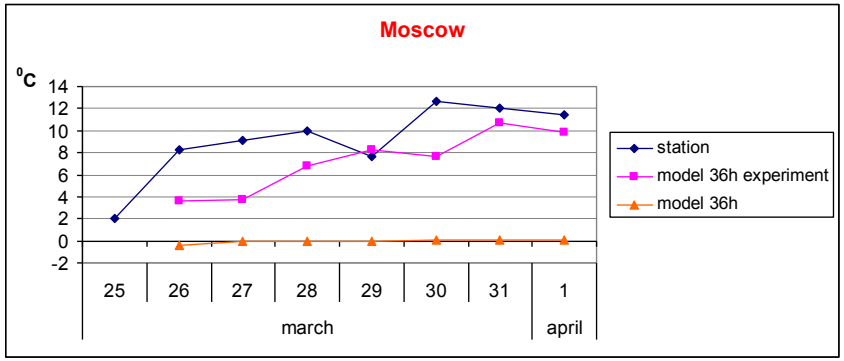


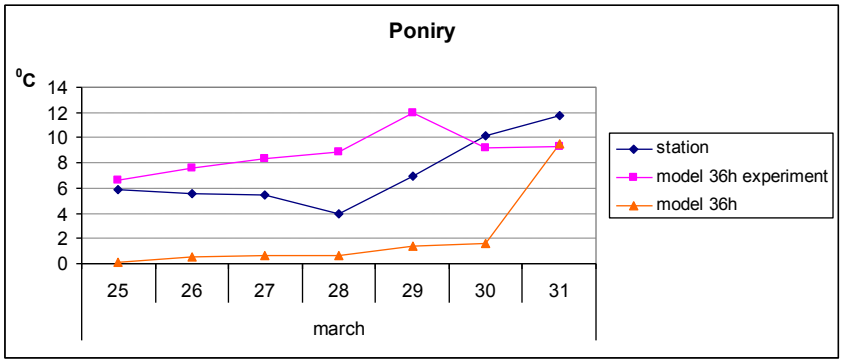




For 60h forecast the tendency remains as for 36h



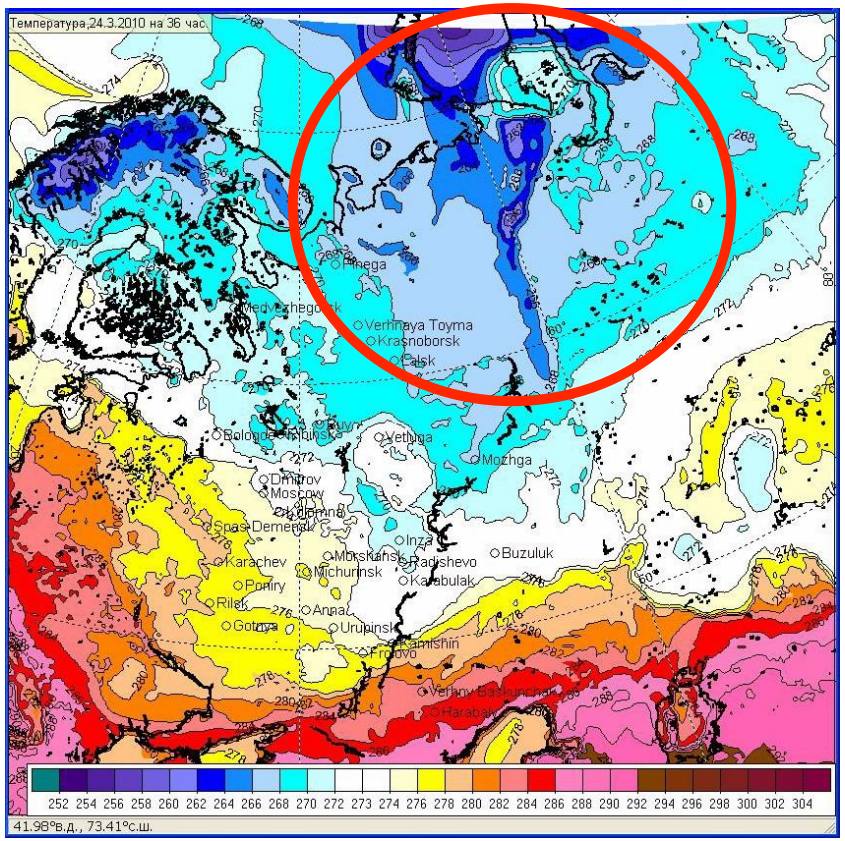




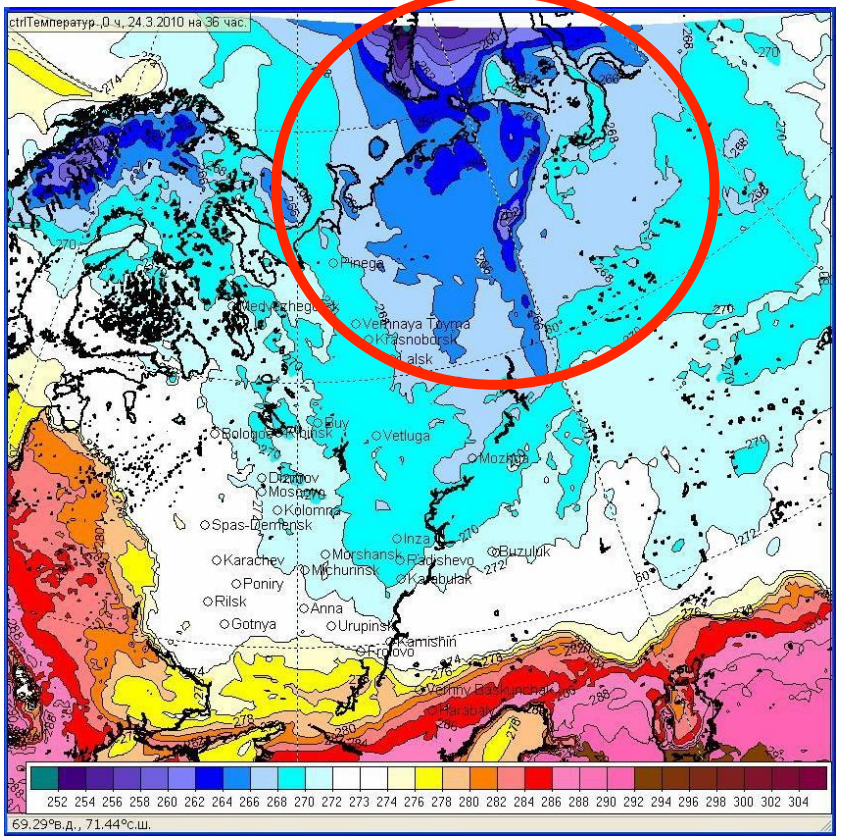
	AE experiment	AE ctrl model
Vetluga	-1,1	-6,5
Moscow	-2,7	-9,3
Kaluga	-1,5	-6,9
Karachev	0,4	-4,1
Rilsk	-0,4	-6,2
Anna	0,2	-6,2

T2m (K), 36h forecast

experiment



Ctrl model



Changes also occured to northern regions, where snow height was more then 40 cm: areas with extreme T2m were reduced

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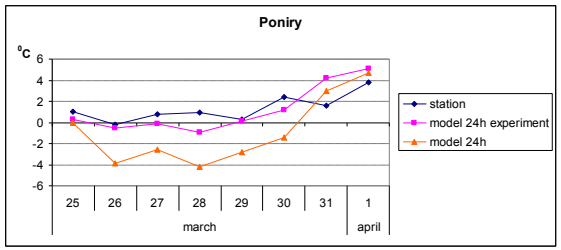
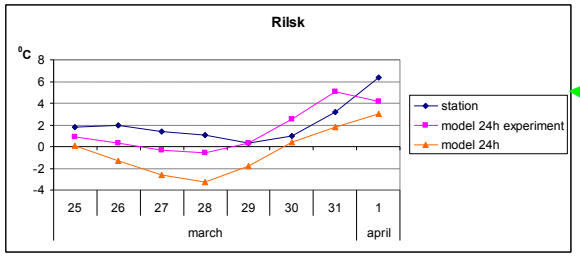
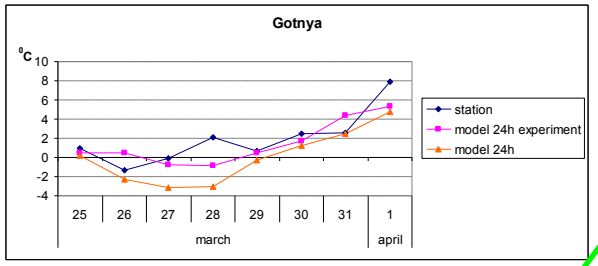
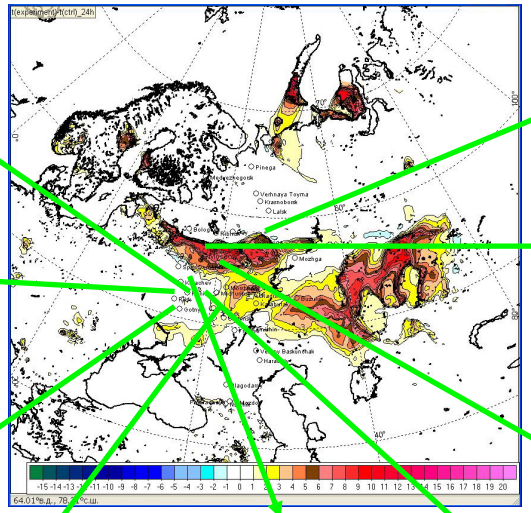
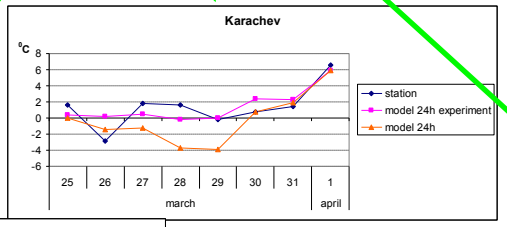
Night T2m temperature (ºC): measurements (blue), 24h forecasts – experiment (pink), ctrl model (orange)

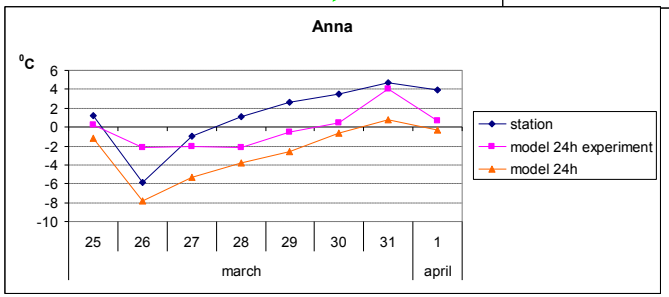


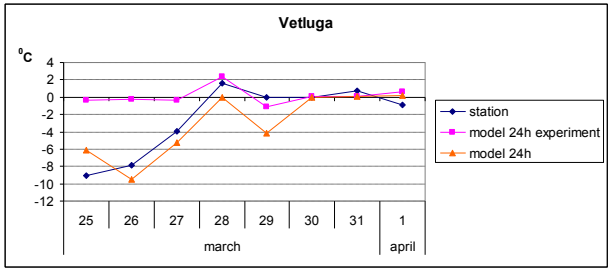


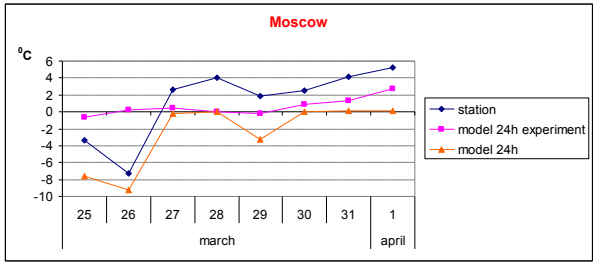


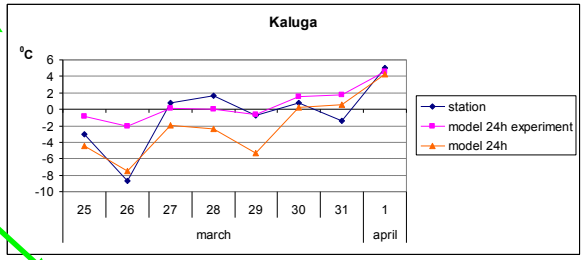


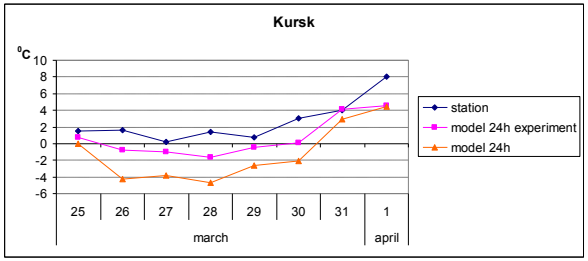






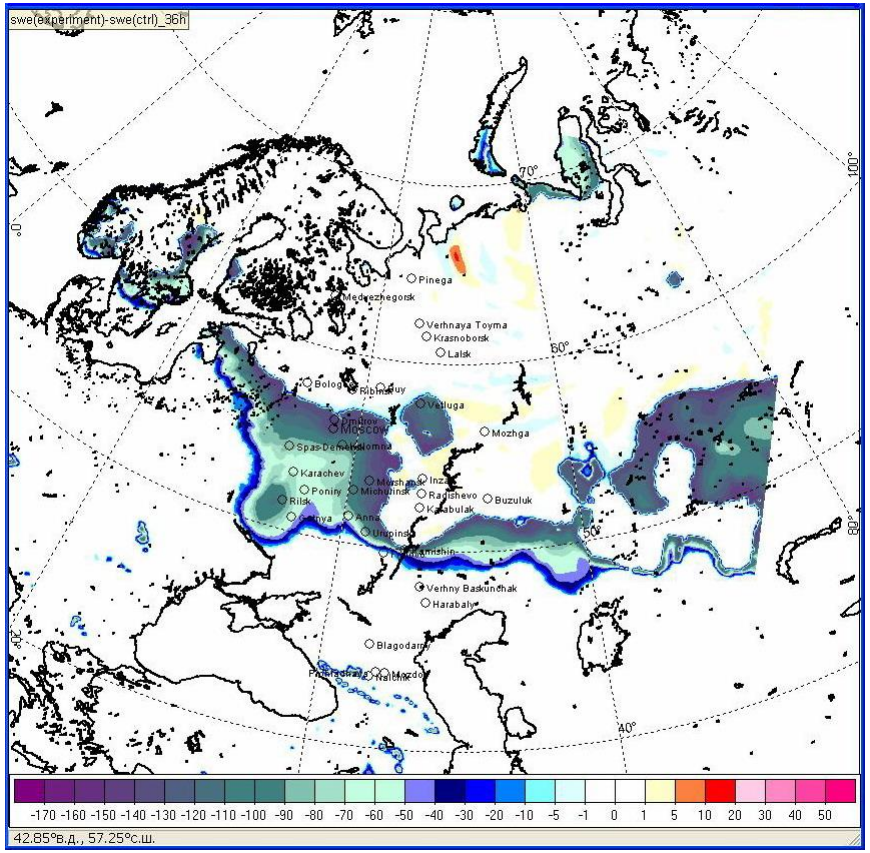




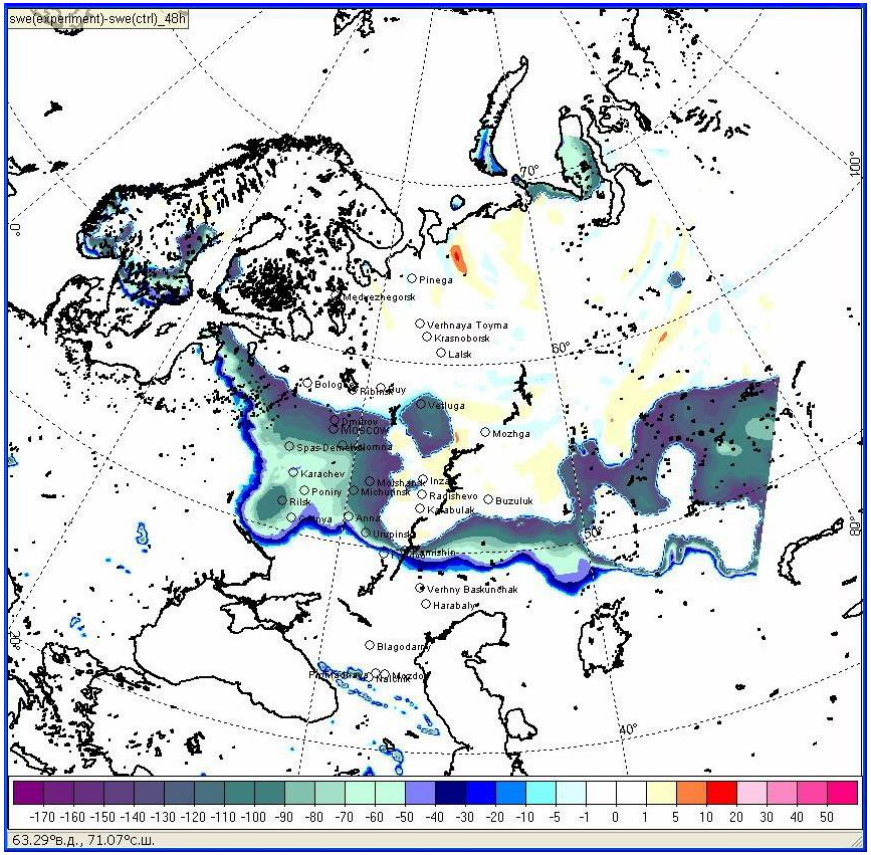


SWE(experiment)-SWE(ctrl), mm

36h forecast

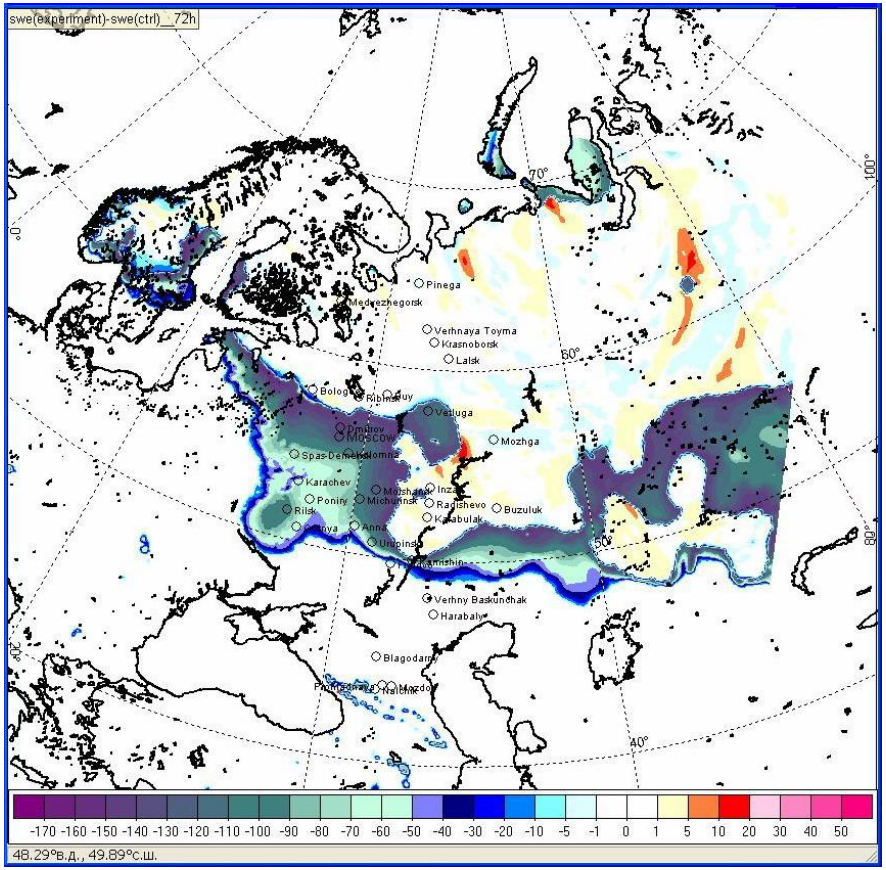


48h forecast

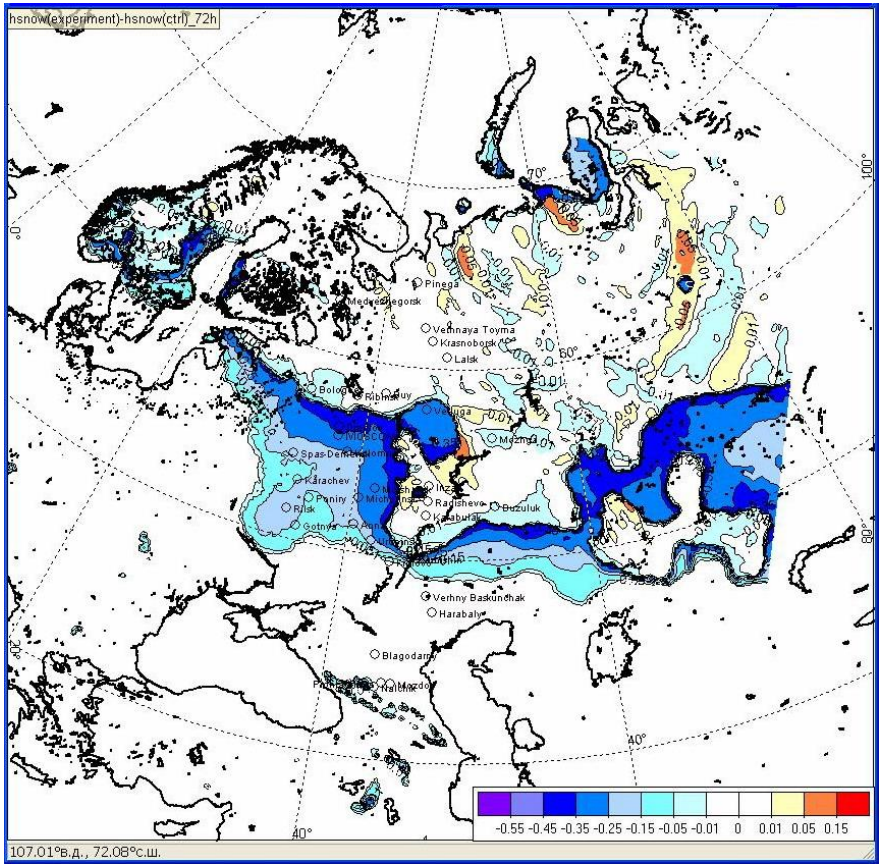


72h forecast

SWE(experiment)-SWE(ctrl), mm



Hsnow(experiment)-Hsnow(ctrl), m



Conclusions

- SWE used as initial condition for COSMO-Ru run is overestimated, correspondingly, snow density is significantly overestimated as well
- It impacts the predicted near surface air temperature (T2m) during snowmelt period caused by the excessive snow mass, which prevents air to get warmer
- The more realistic algorithm of snow density calculation considers meteorological conditions during the period of snow presence (“temperature” method)
- Constants are in the empirical dependence of “temperature” method, and have geographical distribution close to configuration of vegetation-native zones
- Changes in algorithm of fractional snow coverage (SWE→Hsnow) lead to possibility to simulate air warming more realistically (COSMO-Ru, version 4.2)

It is necessary further investigations of fractional snow coverage impact in the new COSMO-versions (4.13, 4.17)

Thank you for your attention!