Development of land-surface formulizations at Roshydromet

Inna Rozinkina, Ekaterina Kazakova, Alla Yurova, Mikhail Chumakov, Michail Nikitin

Outlook

- Development of modeling of snow cover characteristics in COSMO-Ru:
  - Technology of initialization of Snow fields
  - Calculations of fresh snow depth
  - Application for meteosupport of Sochi-2014
- Other activities:
  - Status of Mire parameterisation
  - Implementation of FLAKE
  - Status of Valday data exchange

Development of modeling of snow cover characteristics in COSMO-Ru:

Technology of initialization of Snow fields

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Motivation

- initial fields of SWE and RHO values came from GME to COSMO-model have errors (the difference between this data and stations observations is up to two-tree times)

- for the detailed modeling (f.e. for resolution 2,2 km) the initial pictures of snow parameters from GME are too much generalized

Snow initial fields from GME-model for COSMO-model





SWE

RHO

Freshsnow

Tsnow

Tsoil

COSMO-algorithms of calculations of initial snow values

- SWE and RHO values were calculated according to developed snow model SMFE, using SYNOP data

- Freshsnow was calculated according to COSMO-formula, using SYNOP values of 12hour precipitation

An ageing function $0 \leq S_{age} \leq 1$ for snow albedo is considered. The snow albedo is calculated by

$$\alpha_s = \alpha_{s,max} S_{age} + \alpha_{s,min}(1 - S_{age})$$

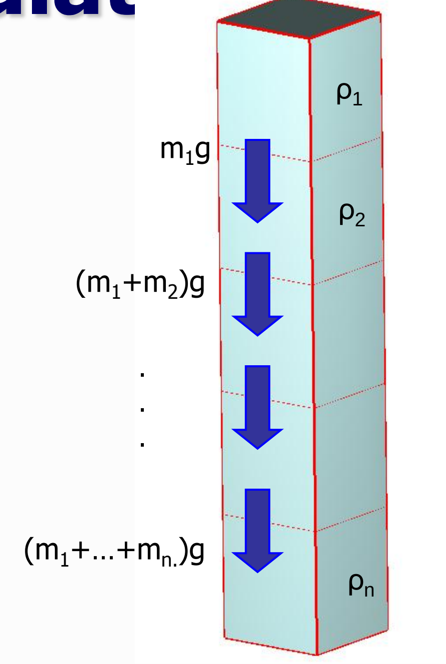
with $\alpha_{s,max} = 0.7$ and $\alpha_{s,min} = 0.4$. The value of S_{age} is 1 for 'fresh' snow and approaches 0 for old snow. The variation of S_{age} with time consists of a constant ageing and a regeneration by falling snow:

$$\Delta S_{age} = S_{age} \left[\frac{P_{snow}}{P_{norm}} - \frac{\Delta t}{\tau_\alpha} \right]$$

P_{snow} is the snowfall rate, $P_{norm} = 5$ mm/24h. The ageing-function is communicated between the snow analysis and the forecast model. If no snow exists, $S_{age} = 1$ is prescribed.

- Tsnow and Tsoil were taken from SYNOP data (CFO) or from COSMO-model (SFO)

The proposed algorithm for calculations of snow values



- Snow column is represented as the set of finite elements, which are in mechanical and thermal interaction with each other. The number of finite elements depends on the height of the snow column. One finite element has height equal to 1 cm

- Yosida and Huzioka is supported that Young's modulus for snow can be calculated by formula:

$$E = (0{,}0167\rho - 1{,}86)\cdot 10^6, -3 < T_a < -1 \qquad E = (0{,}059\rho - 10{,}8)\cdot 10^6, -13 < T_a < -5$$

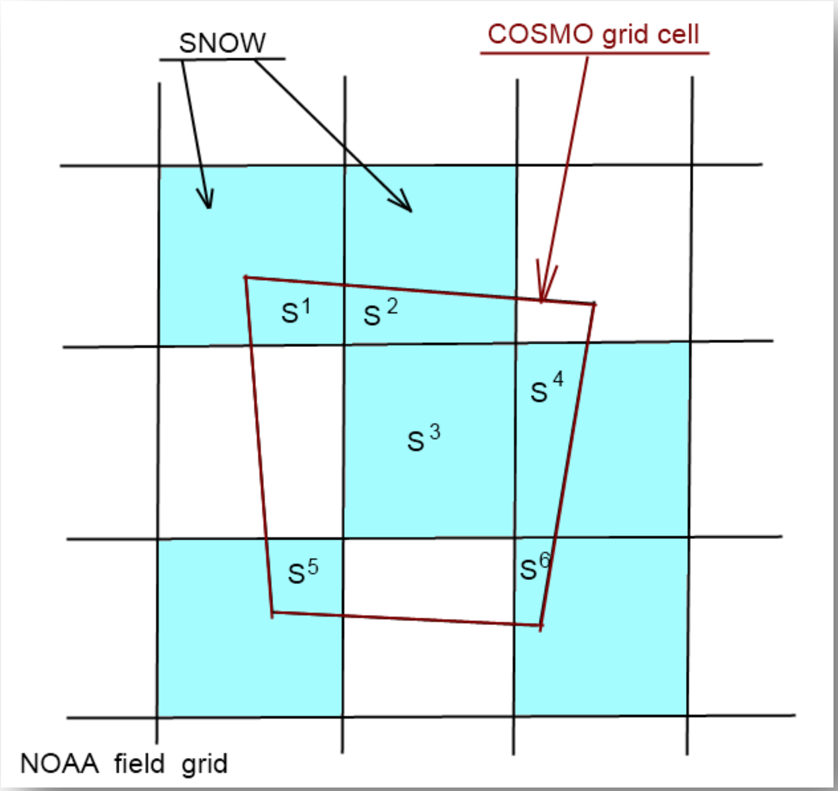
- We suppose that finite elements of the snow column undergo only elastic deformation, so it can be written (example for T_a>-5°C):

$$\rho = \frac{\left(\dfrac{mg}{10^6(1-\sigma_{02})} + 1{,}86\right)}{0{,}0167}, \quad m = (\rho_1 + \rho_2 + \ldots)H, H = 0{,}01m \qquad \frac{l_n}{l_0} = (1-\sigma_{02}) = 1 - 0{,}002$$

Applied methods

- interpolation of station SYNOP values into COSMO-Ru 2.2 grid using Akima spline
- calculation of discrepancies on stations between GME-field and station values, their further interpolation on COSMO-Ru grid and final correction of GME-fields
- for more corrective detection of snow boundary was used NOAA multisensor snow/ice cover product with 4-km spatial resolution or MODIS spectroradiometer data with 250-m spatial resolution
- continuous calculations during whole snow period: forecasts were started at 00 UTC and lasted for 24 (39) hours. Initial station data was taken from the previous day

Snow fraction detection algorithm (authors –Yu.Alferov, V.Kopeykin)



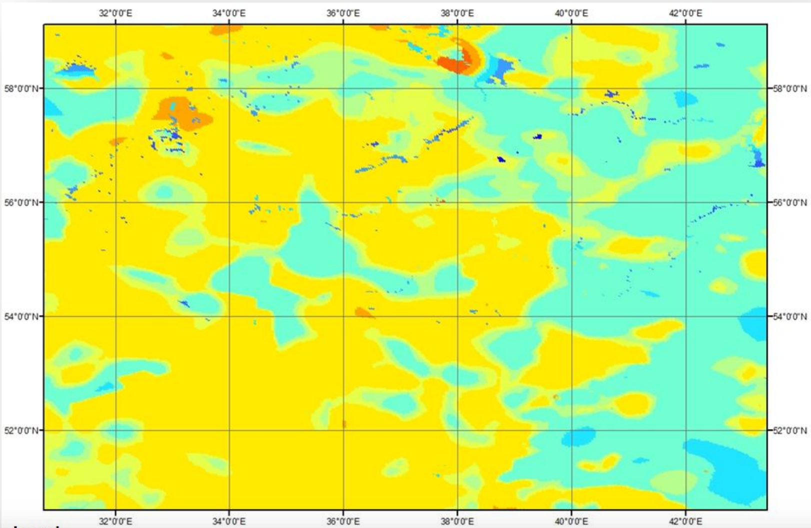
For each cell of COSMO-grid the sum of squares, where the cell crosses the NOAA-field cells, is calculated. Then the received sum is divided on cell square of COSMO-grid according to formula:

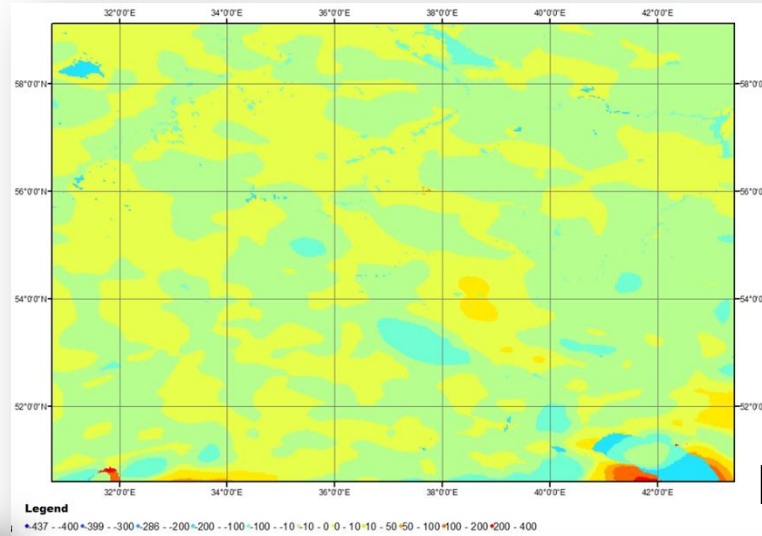
$$F_{snow} = \frac{\sum_i S^i_{snow}}{S_{COSMOcell}}$$

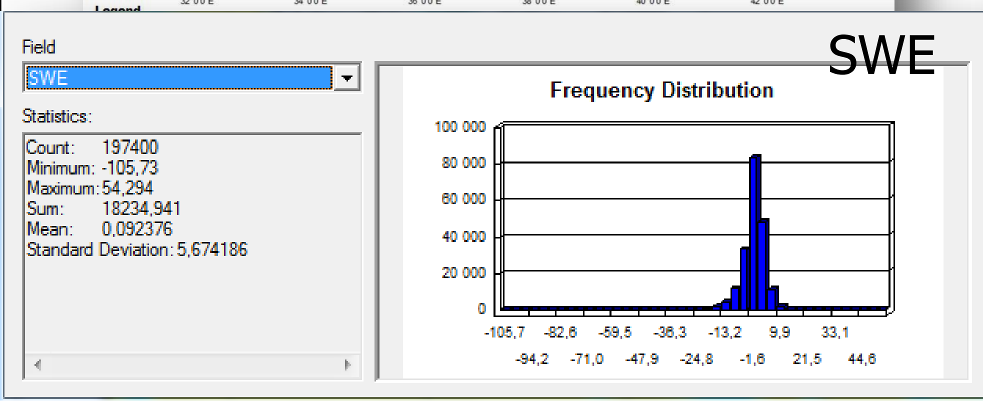
4-km satellite products are available on ftp://140.90.213.161/autosnow/4kmNH/

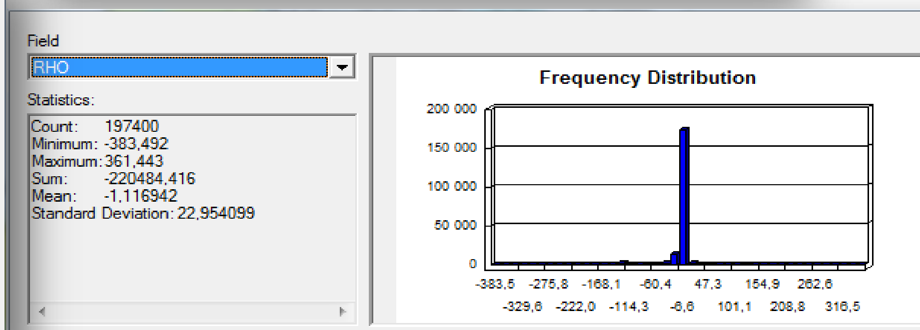
Approbation for European region (CFO)
COSMO-Ru 2.2 domain

Difference between two modified fields: Calculated with use the Akima spine and GME-field, optimized by reciduals calculated on stations, 5 March 2013





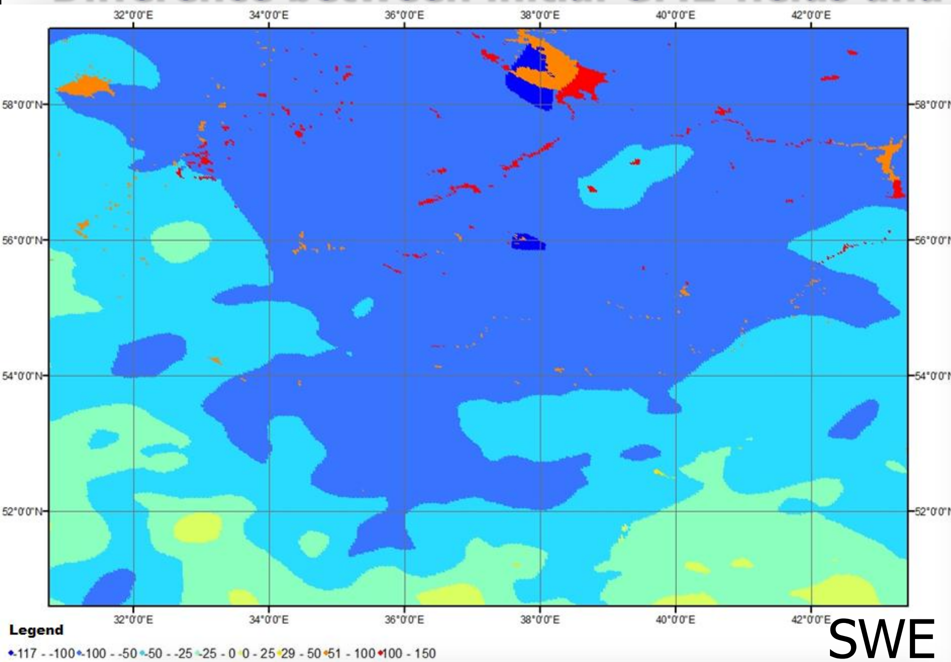


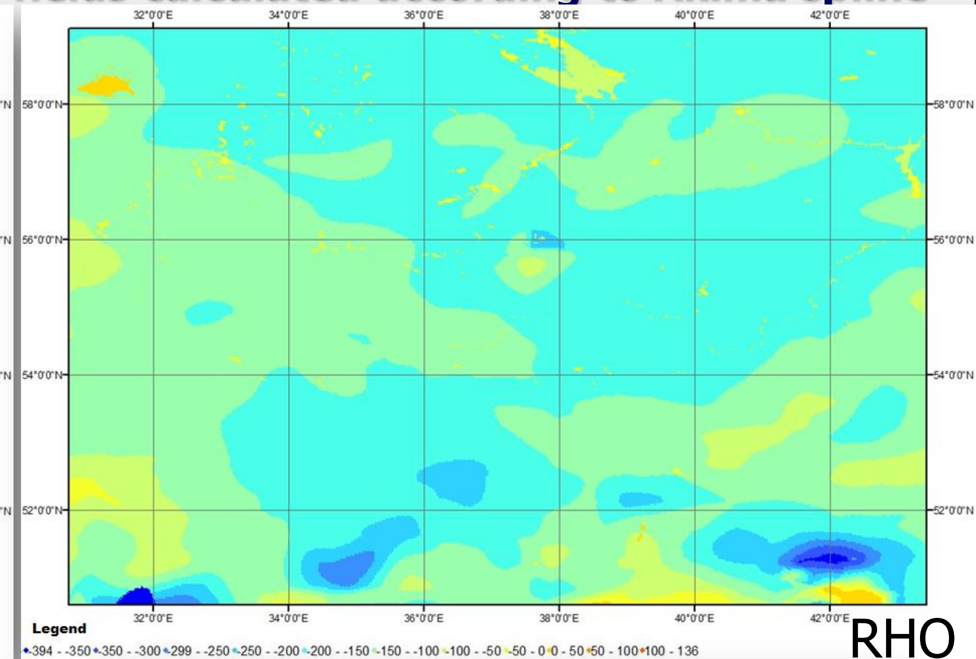


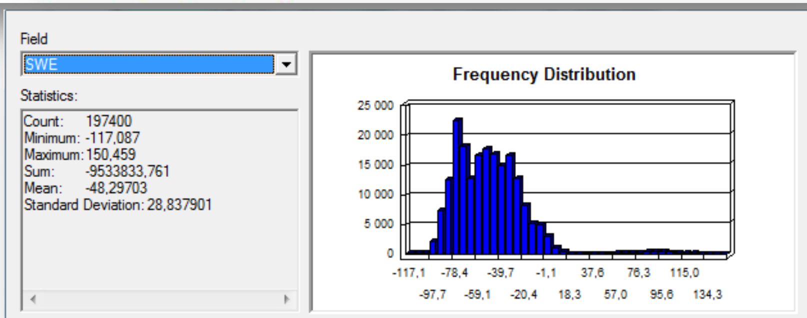
For most of the domain the difference in SWE is not much than 10-20 mm, in RHO – up to 10 kg/m^3, so the calculation of the COSMO-Ru forecast can be executed in both cases

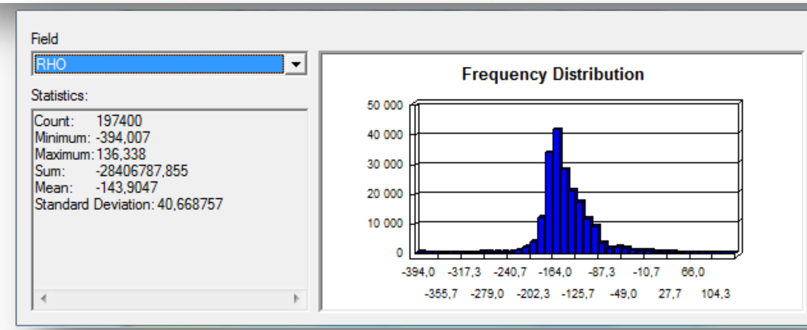
5 March 2013

Difference between initial GME-fields and fields calculated according to Akima spline





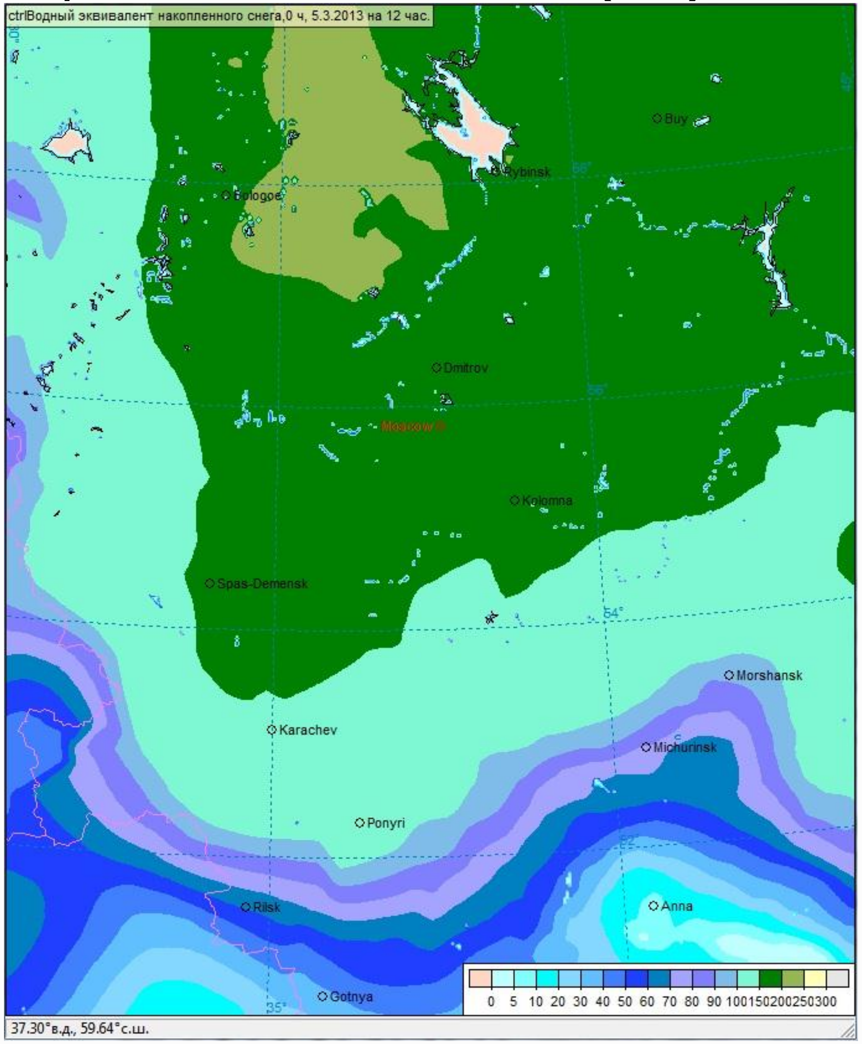




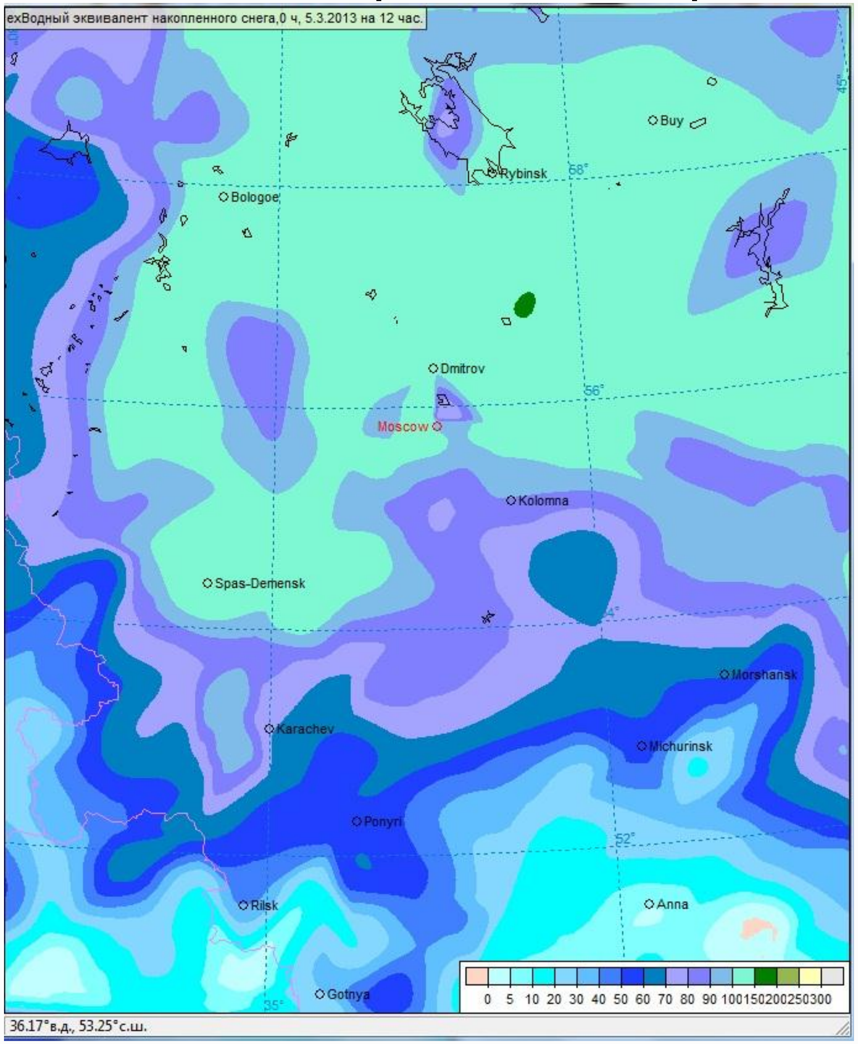
For most of the domain the difference in SWE is up to 100 mm (excluding lakes), in RHO – up to 150-200 kg/m^3

The SWE calculations, example for 5 March 2013

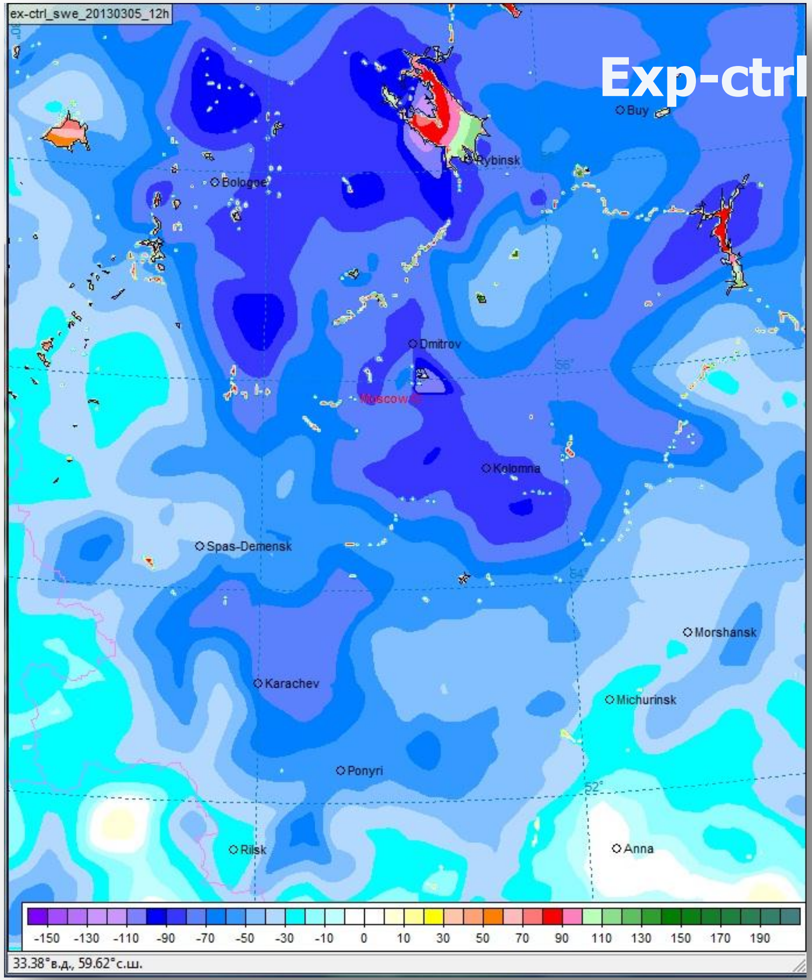
Operational COSMO-RU (ctrl)



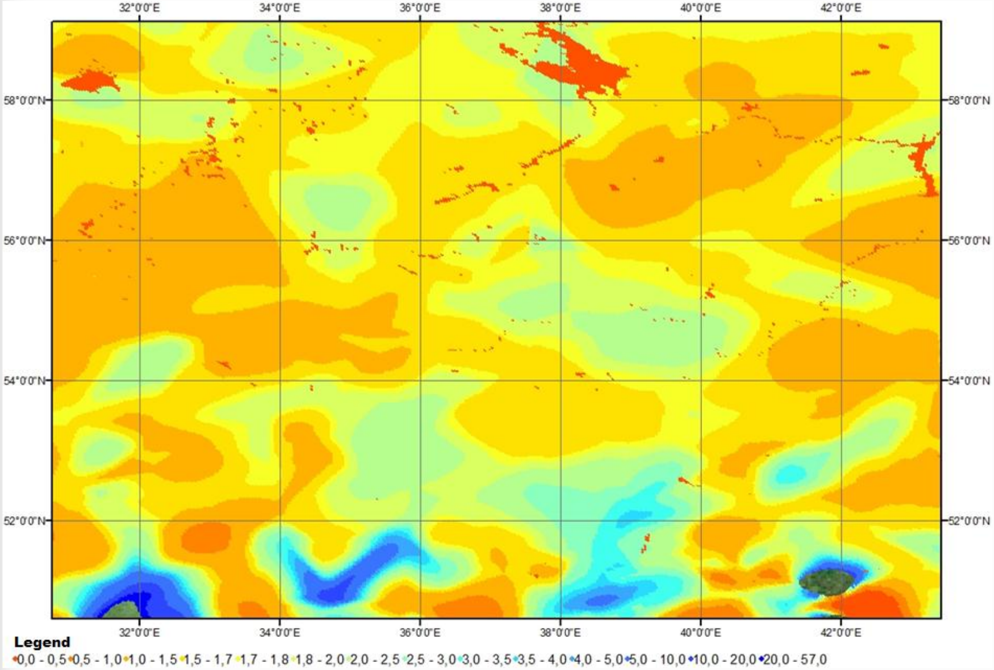
Proposed technique



The SWE calculations, example for 5 March 2013



Exp/ctrl



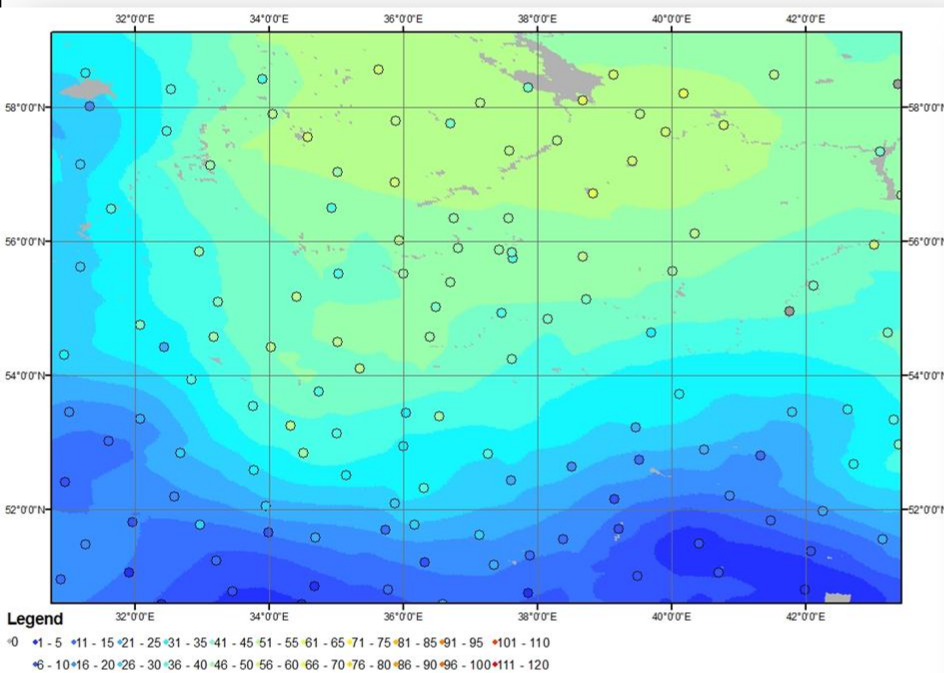
Fields differs in 1,5-2,0 times

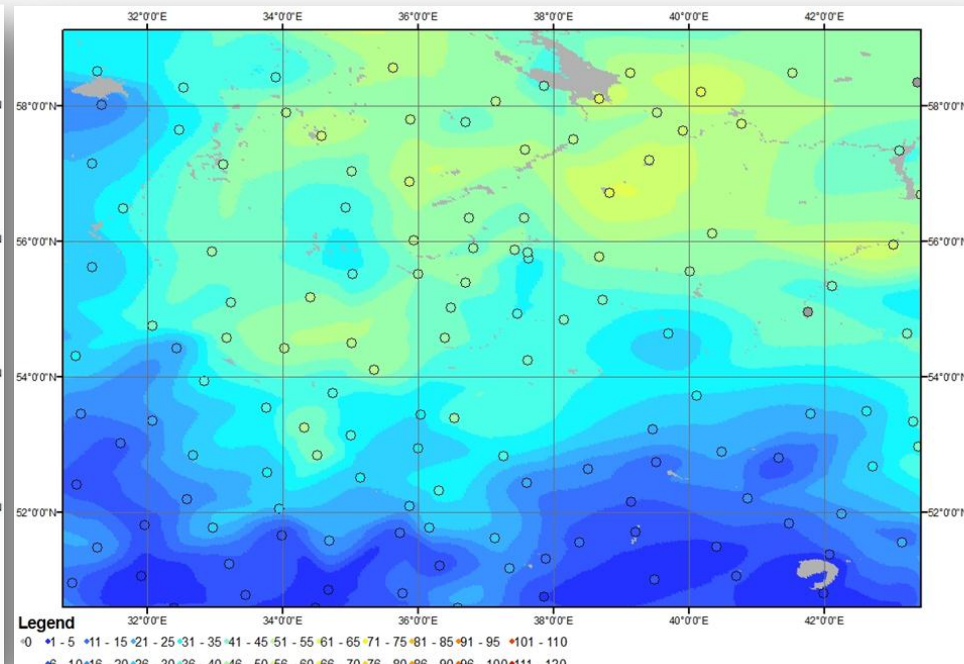
The biggest differences in SWE between Ctrl and Exp fields are observed for territory with maximum SWE and on lakes – in COSMO lakes are not covered with snow

HSNOW, 12h forecast, 5 March 2013

Ctrl

Exp

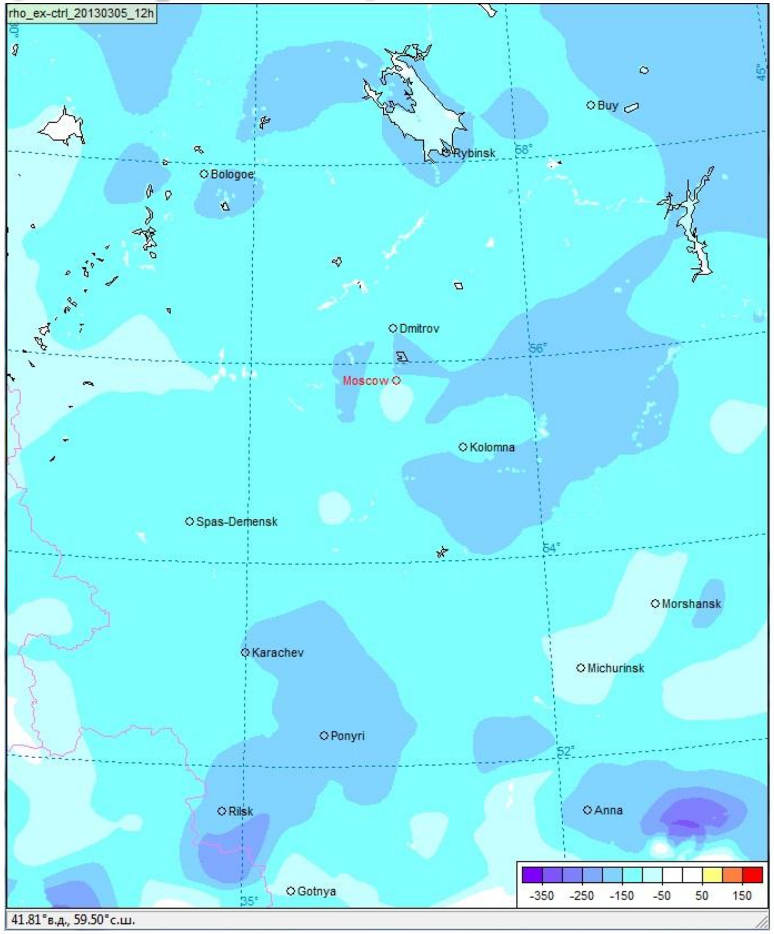




Points - stations

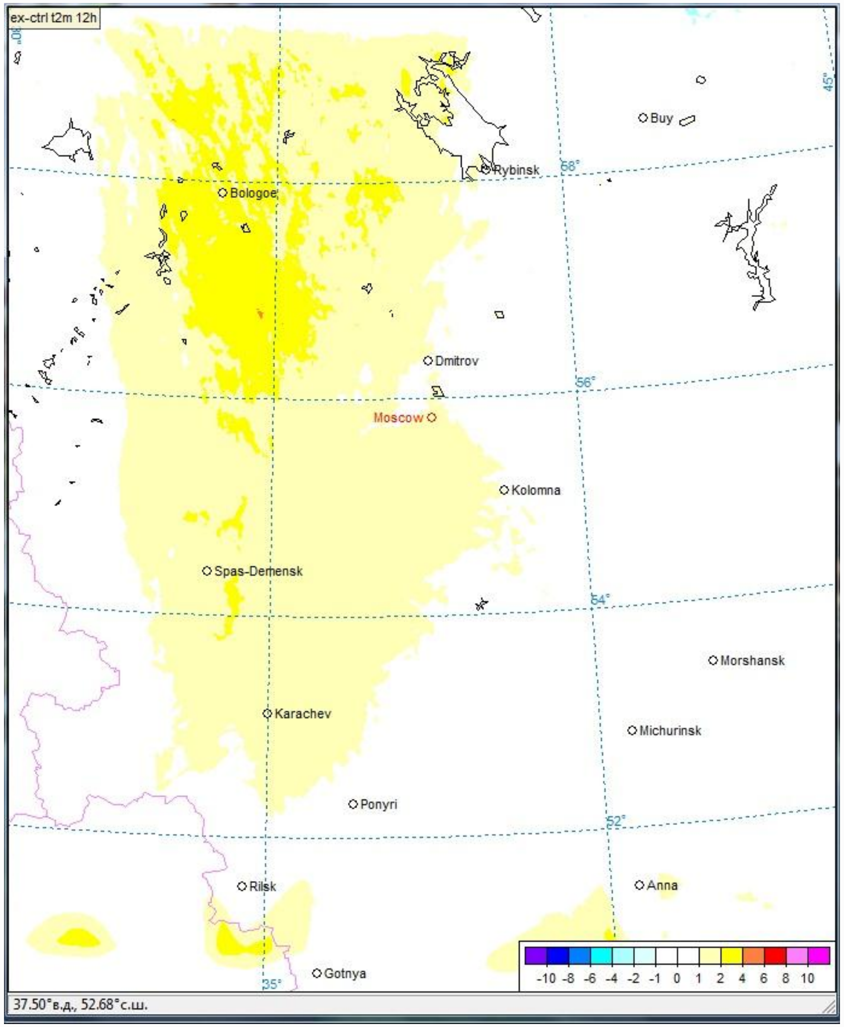
In case of calculating forecast with implemented snow fields, the field of snow depth becomes more realistic.

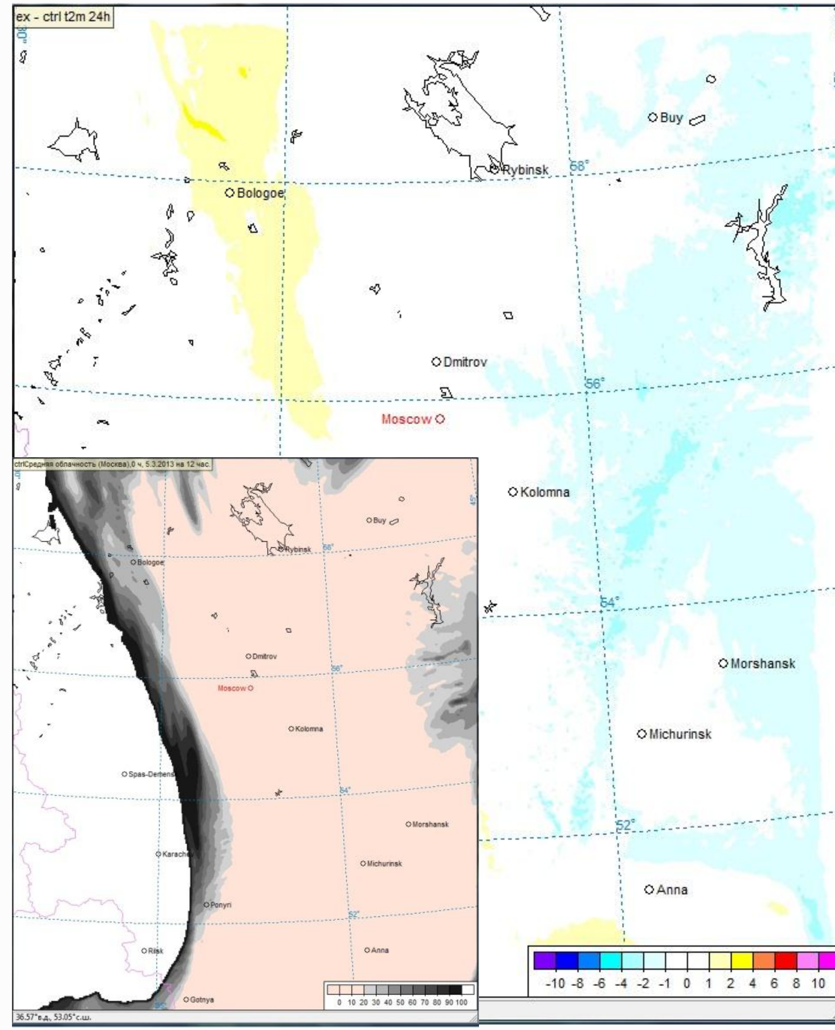
RHO, Exp-Ctrl, 5 March 2013



When calculating snow density in COSMO-model, with no dependence on initial data, snow density evolution is reproduced realistically. Yet values of density changing in time significantly depend on initial snow density values.

T2m, ex-ctrl, 12h (left) and 24h(right) forecast, 5 March 2013

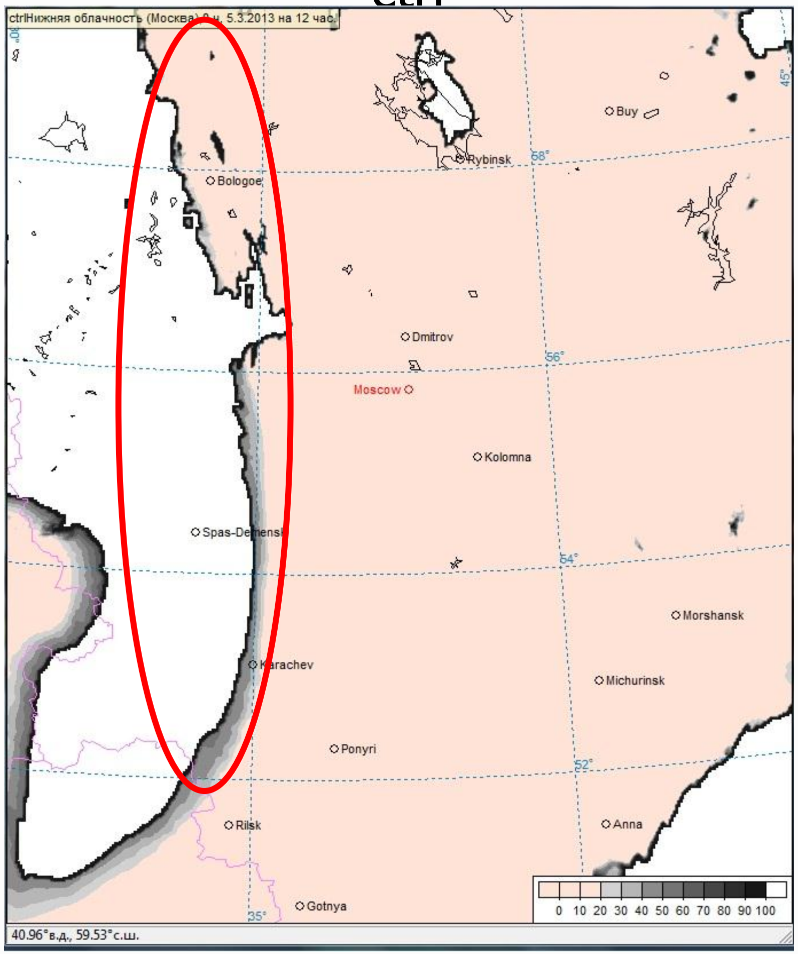




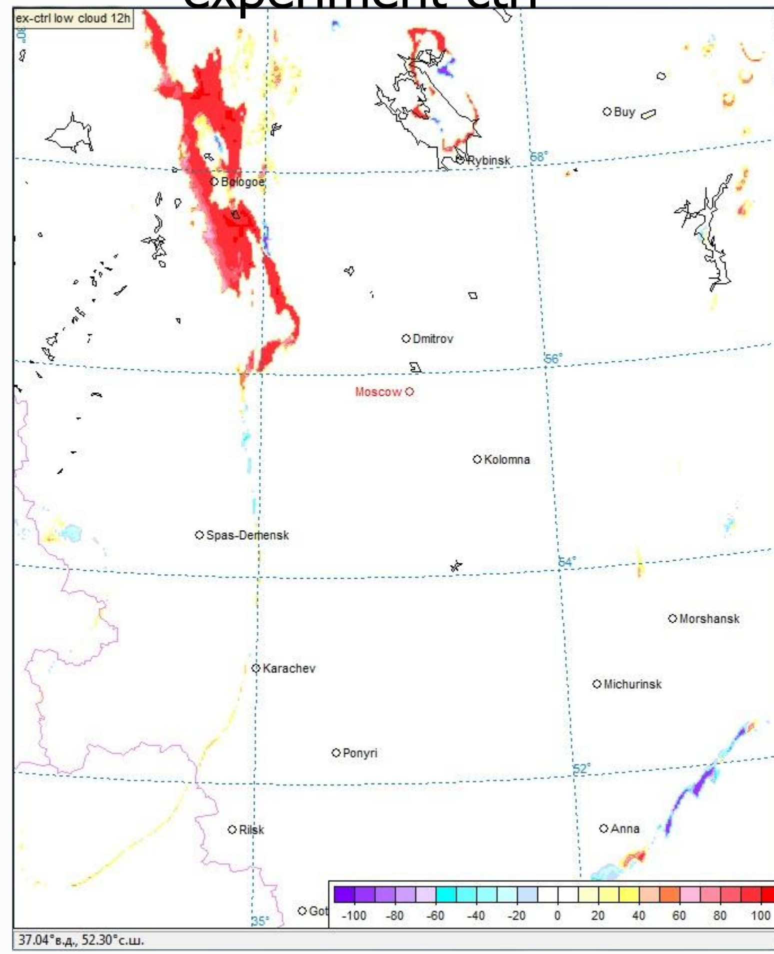
Changes in T2m are regulated by cloudiness and snow density.

Low cloudiness, 12h forecast, 5 March 2013

ctrl



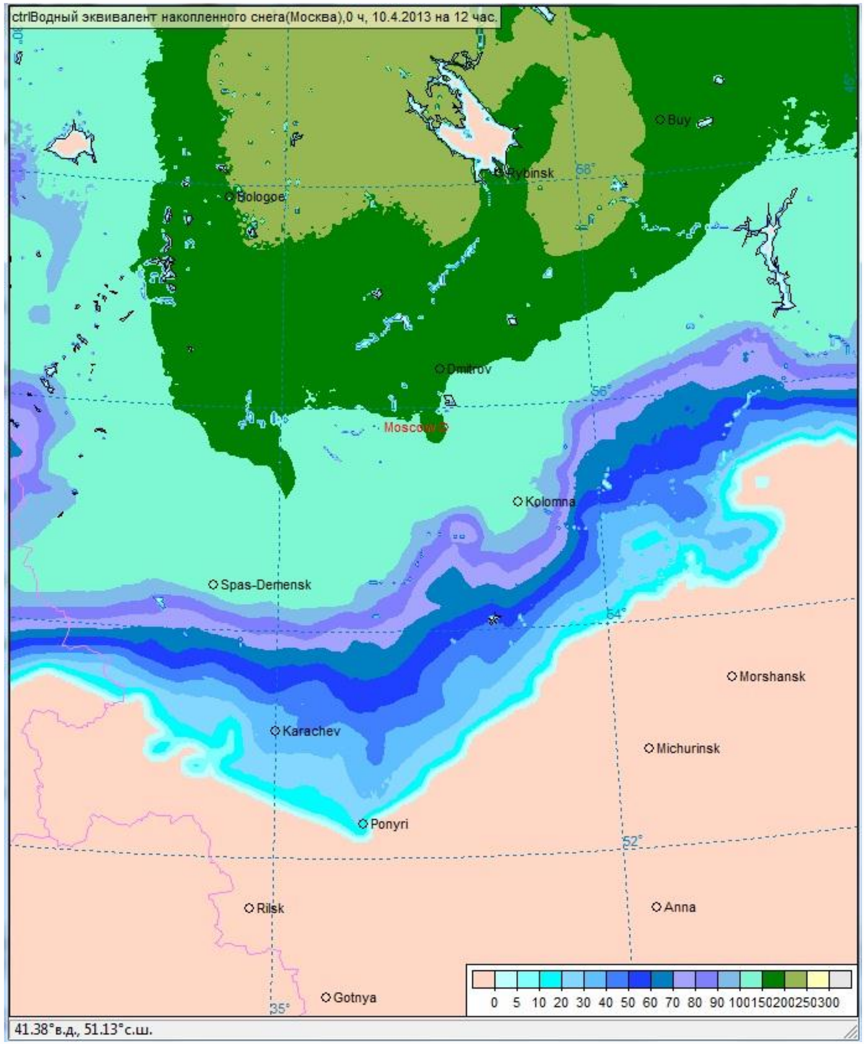
experiment-ctrl



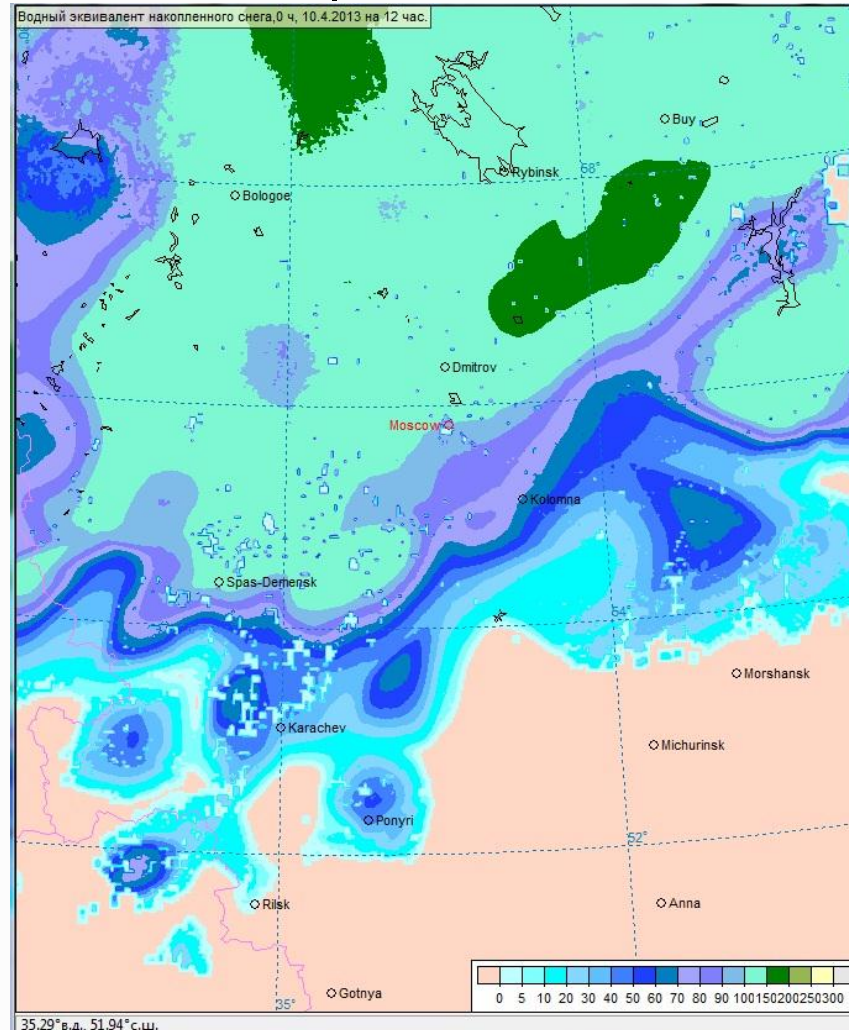
The maximum differences in low cloudiness are observed on the boundary of the cloud in the place, where there are the greatest changes in SWE between ctrl and experiment

SWE, 12h forecast, 10 April 2013

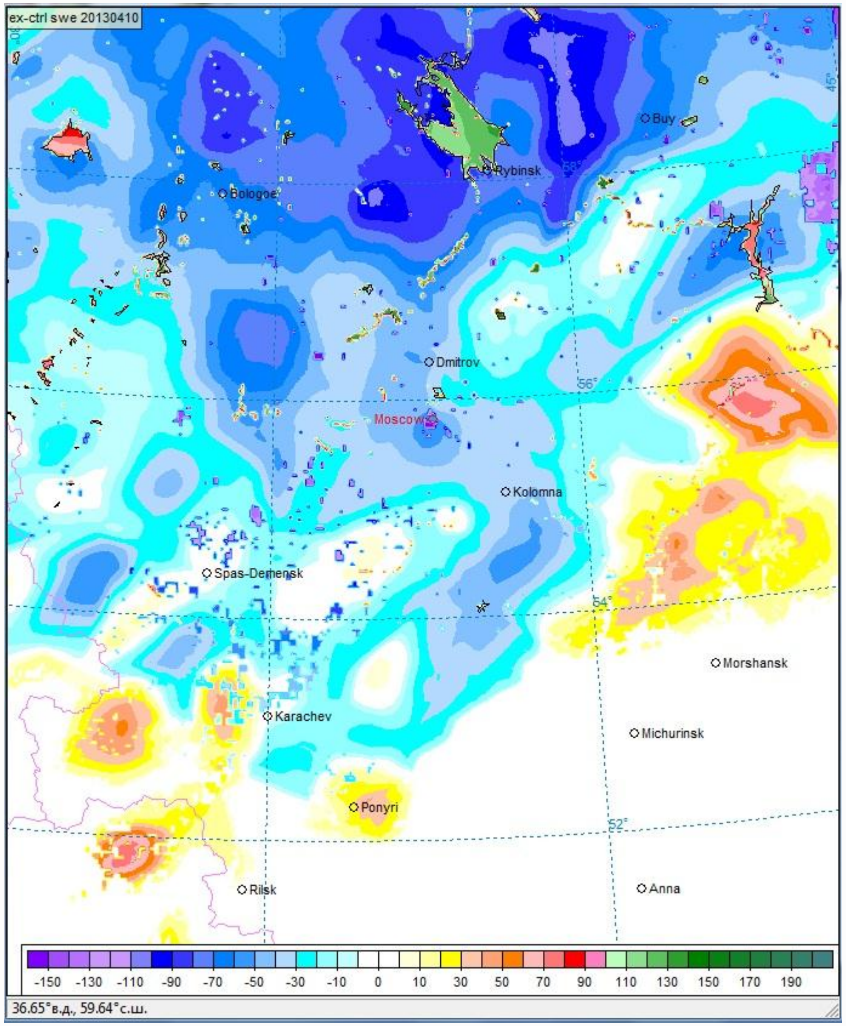
Ctrl



Exp

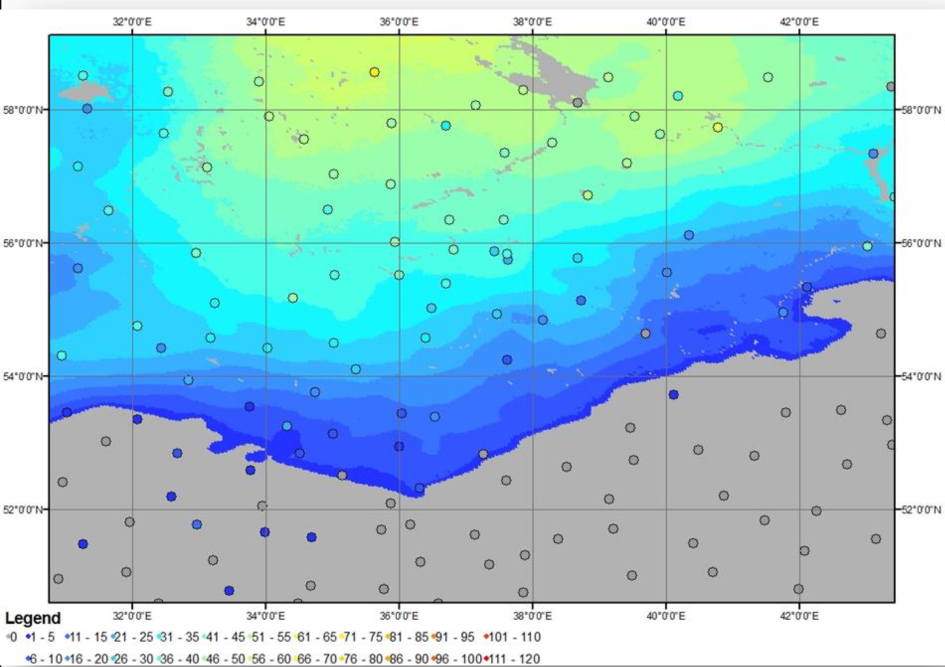


SWE, exp-ctrl, 12h forecast, 10 April 2013

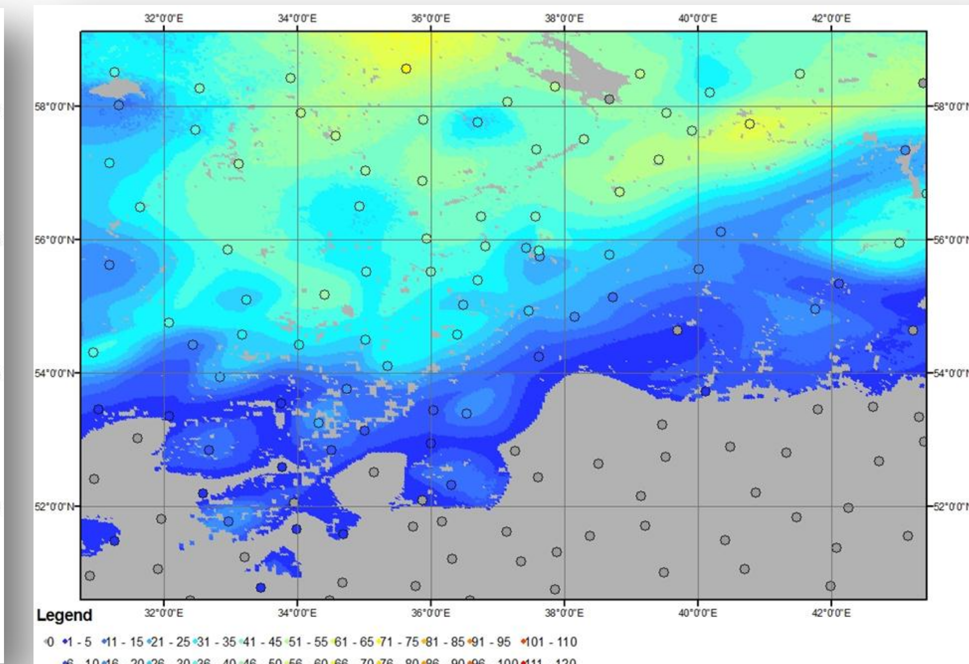


SNOW DPT, 10 April 2013

ctrl



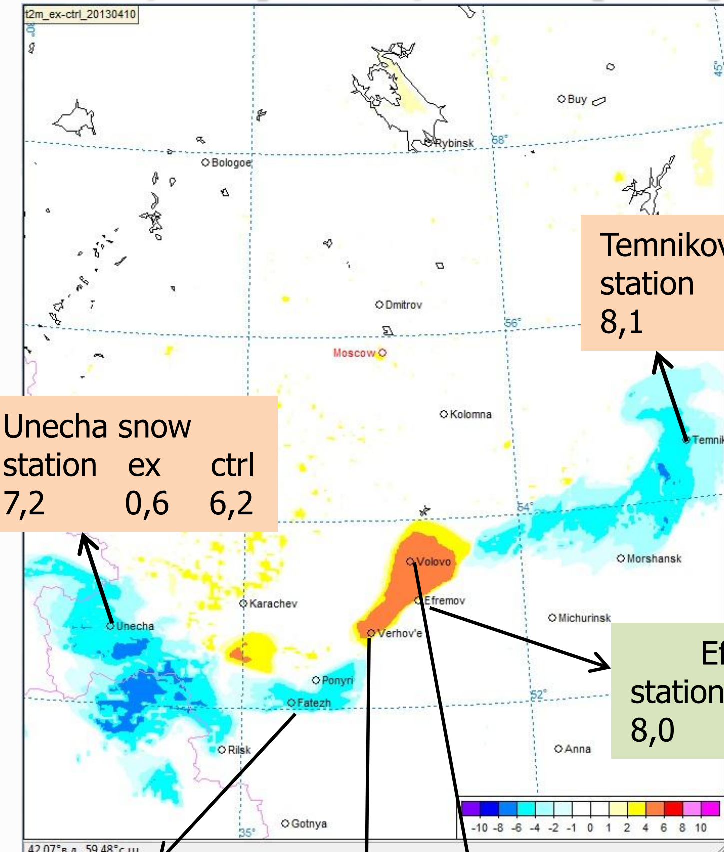
exp

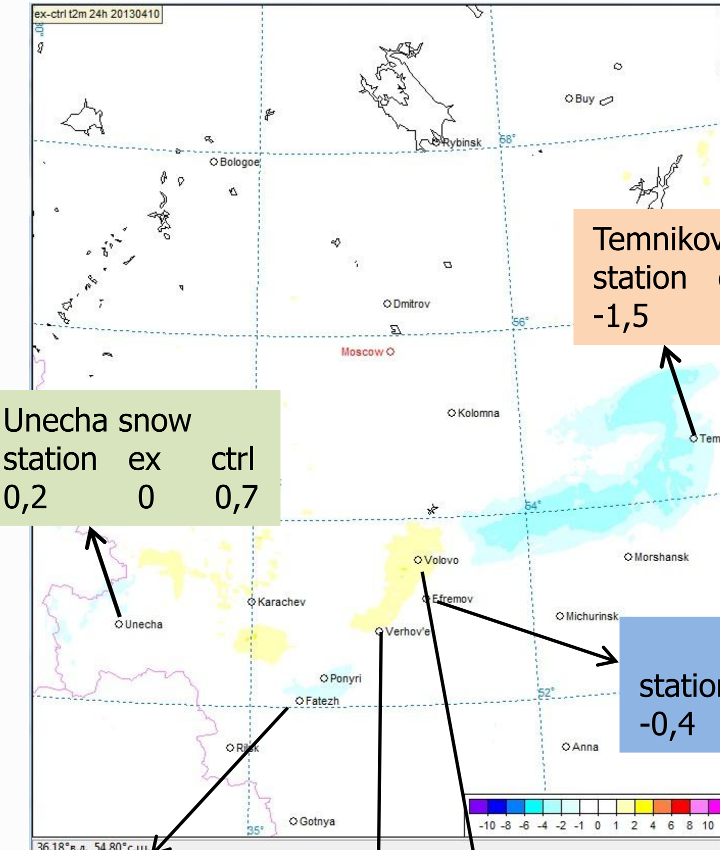


Points - stations

In case of calculating forecast with implemented snow fields, the field of snow depth becomes more realistic. Satellite information specified snow boundary.

T2m, exp-ctrl, 12h (left) and 24h(right) forecast, 10 April 2013





12h (left):

Temnikov snow

station	ex	ctrl
8,1	1,1	5,6

Unecha snow

station	ex	ctrl
7,2	0,6	6,2

Efremov

station	ex	ctrl
8,0	6,6	4,3

Fatezh snow 9 Apr

station	ex	ctrl
7,1	1,3	6,6

Volovo

station	ex	ctrl
6,9	5,7	0,6

Verhov'e

station	ex	ctrl
7,0	6,0	1,2

24h (right):

Temnikov snow

station	ex	ctrl
-1,5	-4,9	-3,0

Unecha snow

station	ex	ctrl
0,2	0	0,7

Efremov

station	ex	ctrl
-0,4	-0,9	-0,5

Fatezh snow 9 Apr

station	ex	ctrl
1,0	-0,3	0,4

Volovo

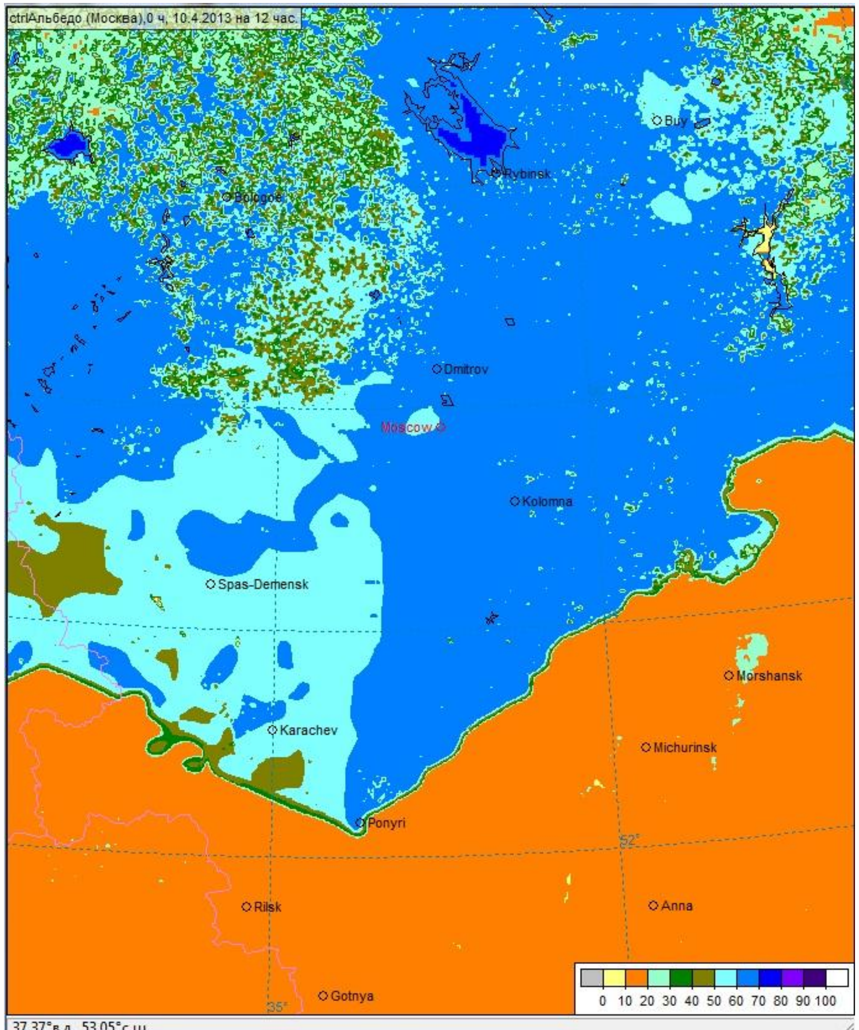
station	ex	ctrl
-1,1	-2,1	-3,6

Verhov'e

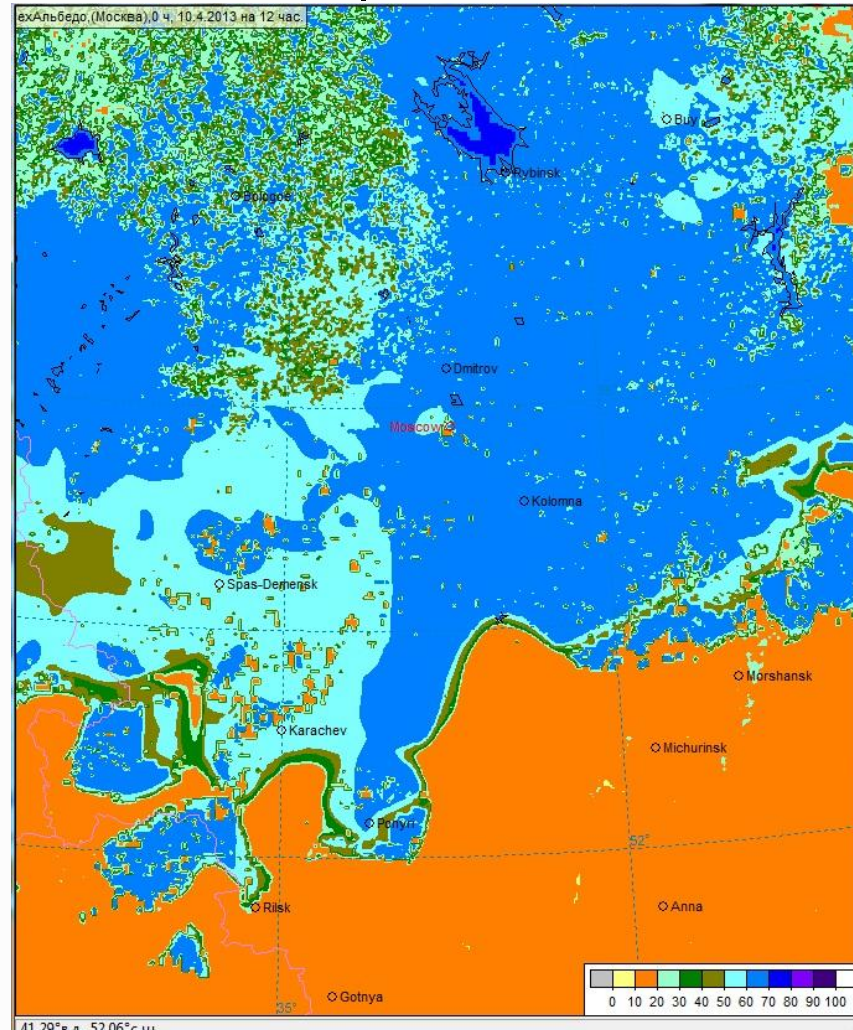
station	ex	ctrl
0,8	-0,2	-1,2

ALBEDO, 12h forecast, 10 April 2013

ctrl



exp



Conclusions

•Propozed method for initialization of snow parameters is realizated and tested for the COSMO-Ru02 (Center of European part of Russia)

• 2 variants of approaches of interpolations are realized – Akima spline interpolation of SMFE (or measurement data for Snow depth) and with the use of COSMO-Ru2 FG fields normalized by residuals before interpolation

• the method allows to obtain initial realistic SWE and RHO values and hence, to make more correct initial fields and forecasts

• feedback of improvements is obtained for some meteoparameters in boundary layer

Conclusions

• The SWE initial values are important parameter for detection of boundary of Snow cover

•The boundary of Snow cover is the most sensitive area for all changes

•The more accurate snow boundary leads to improvements in T2m in places, where snow has already melted. In regions, where snow is present according to station and satellite information, T2m forecast will be close to 0ºC during day in comparison with positive values of T2m measurements (but this is a discrepancy of the model algorithm)

-there are changes in albedo as well

-wind changes are mostly during day, at night the difference between ctrl and experiment up to 0.5 m/s

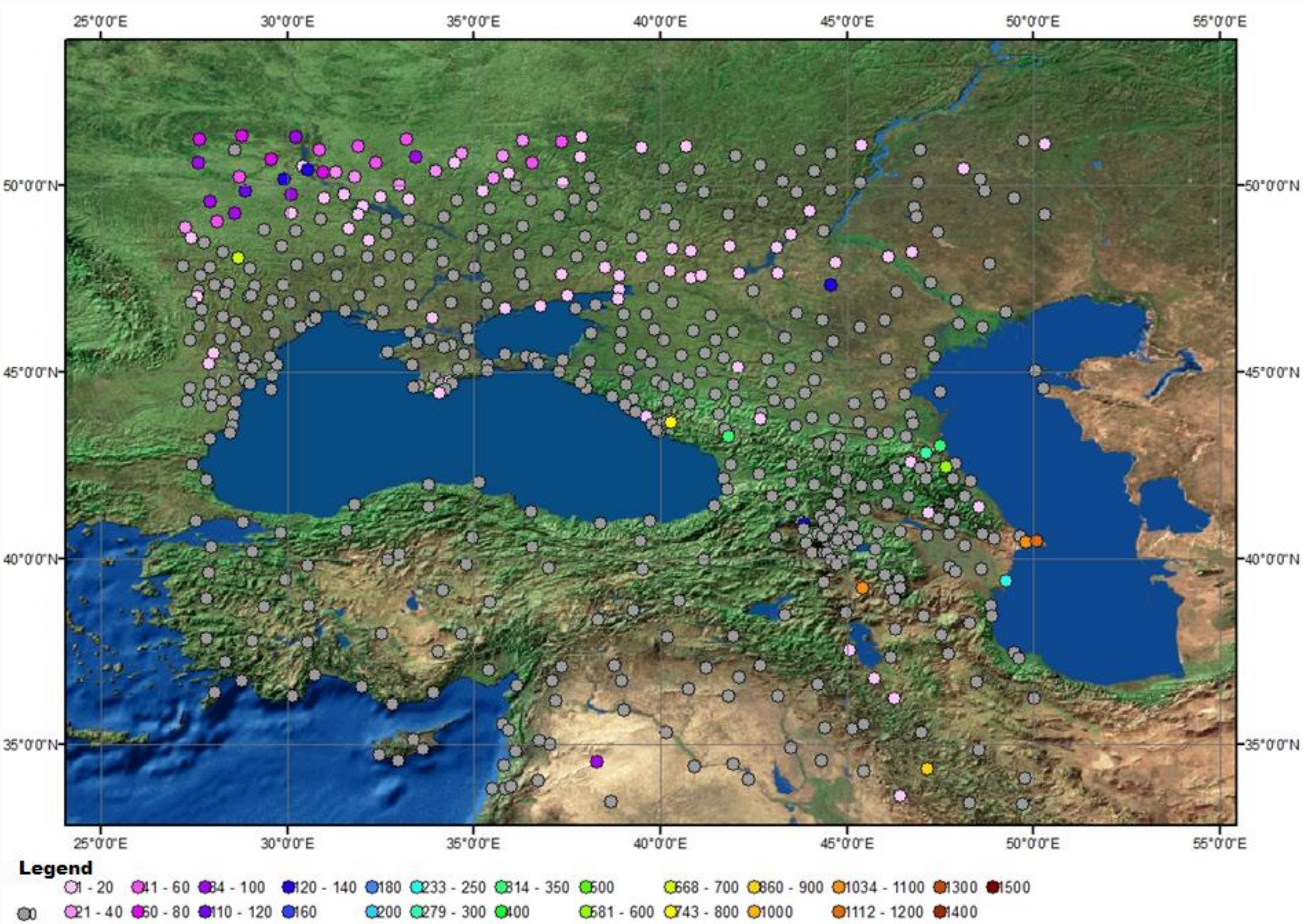
• Low cloudiness is experienced changes on sharp and narrow boundaries, especially in places where there are the biggest differences between ctrl and experiment values. In such places there will be T2m increase

• In case of absence of clouds reducing RHO (less thermal conductivity) and SWE leads to surface cooling and hence - some air cooling (mostly at night)

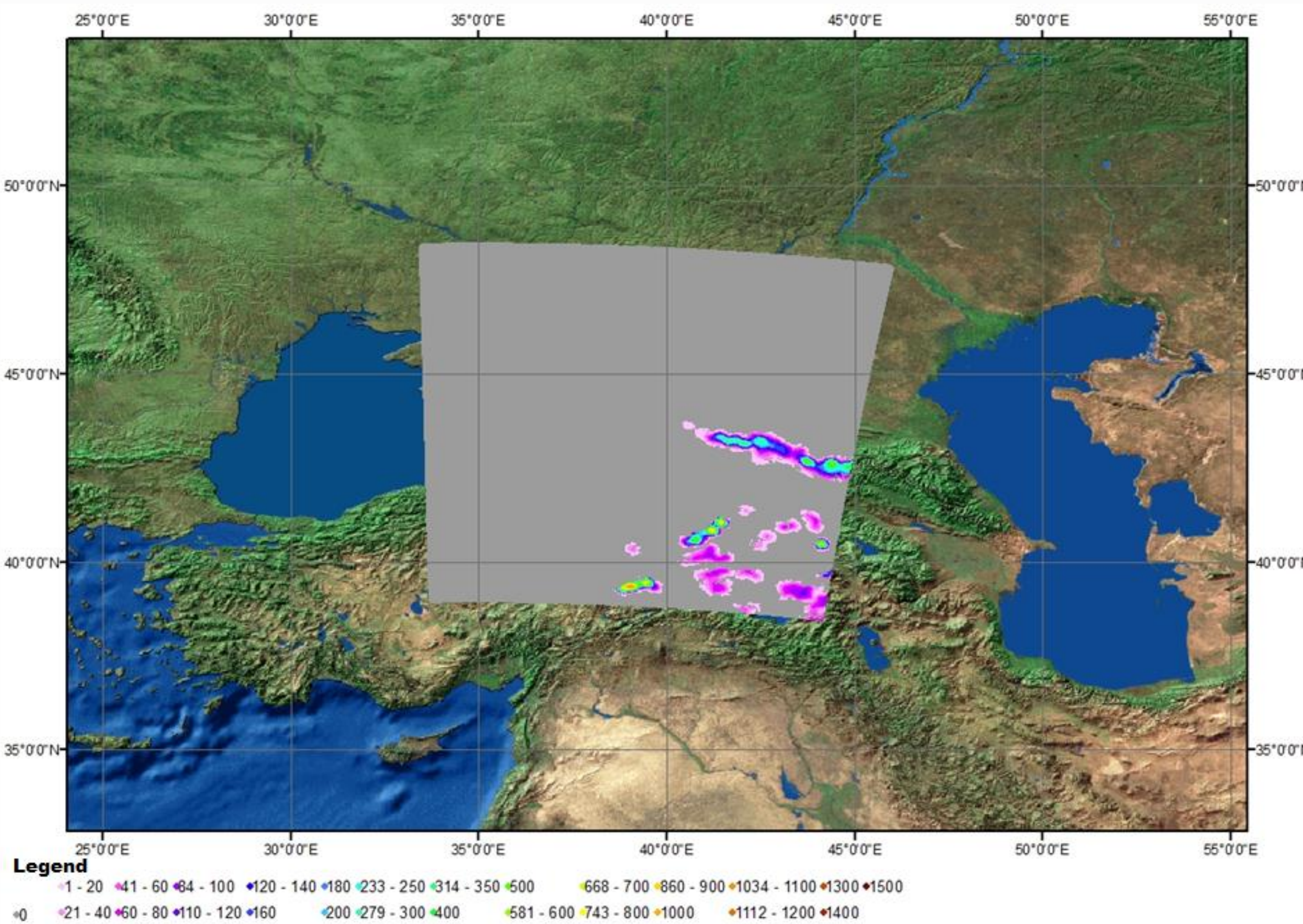
Development of modeling of snow cover characteristics in COSMO-Ru:

Applications for Sochi-2014

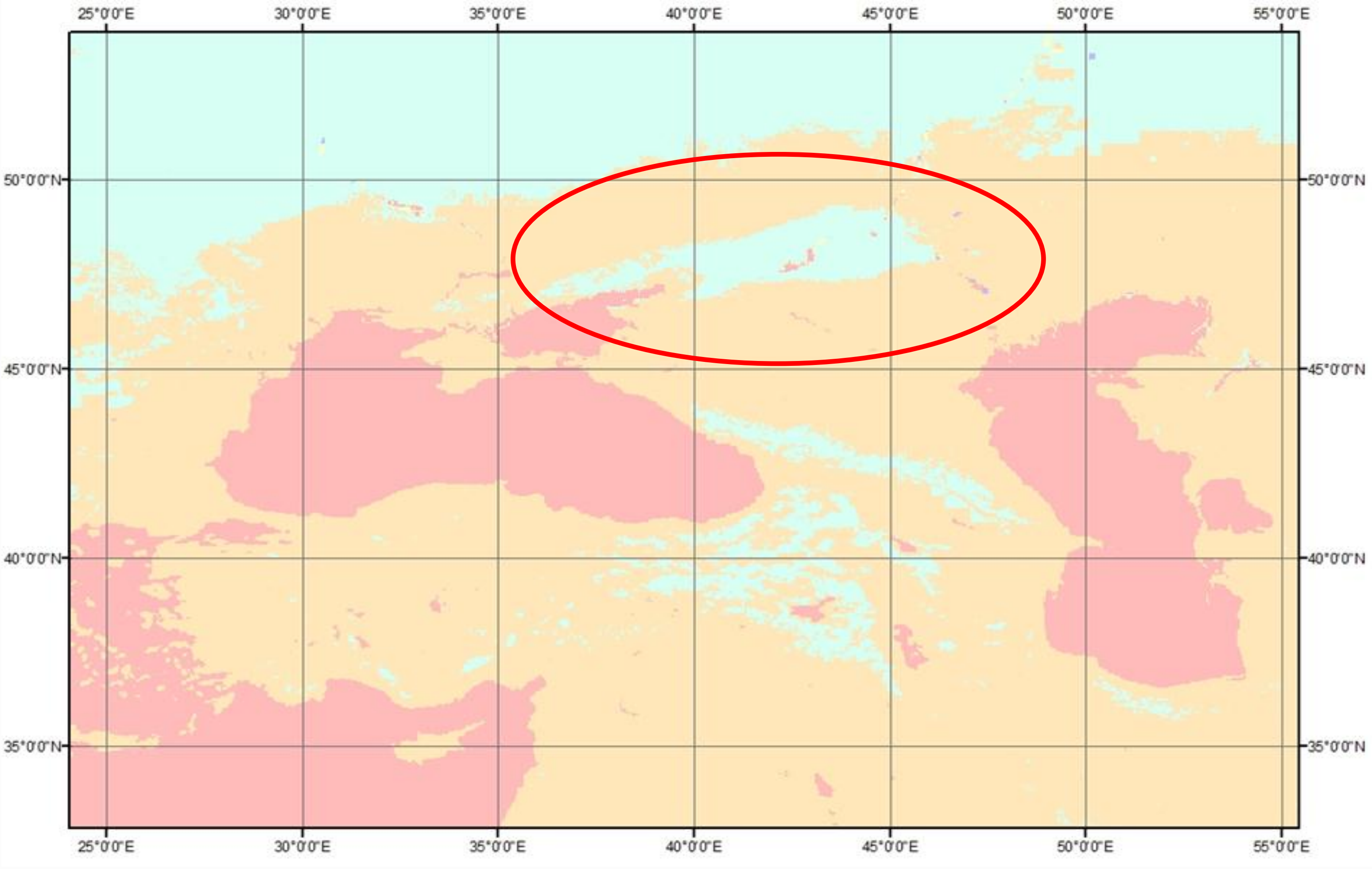
SWE,measurenments, 30 March 2013



SWE, COSMO-Ru 2.2, 31 March 2013

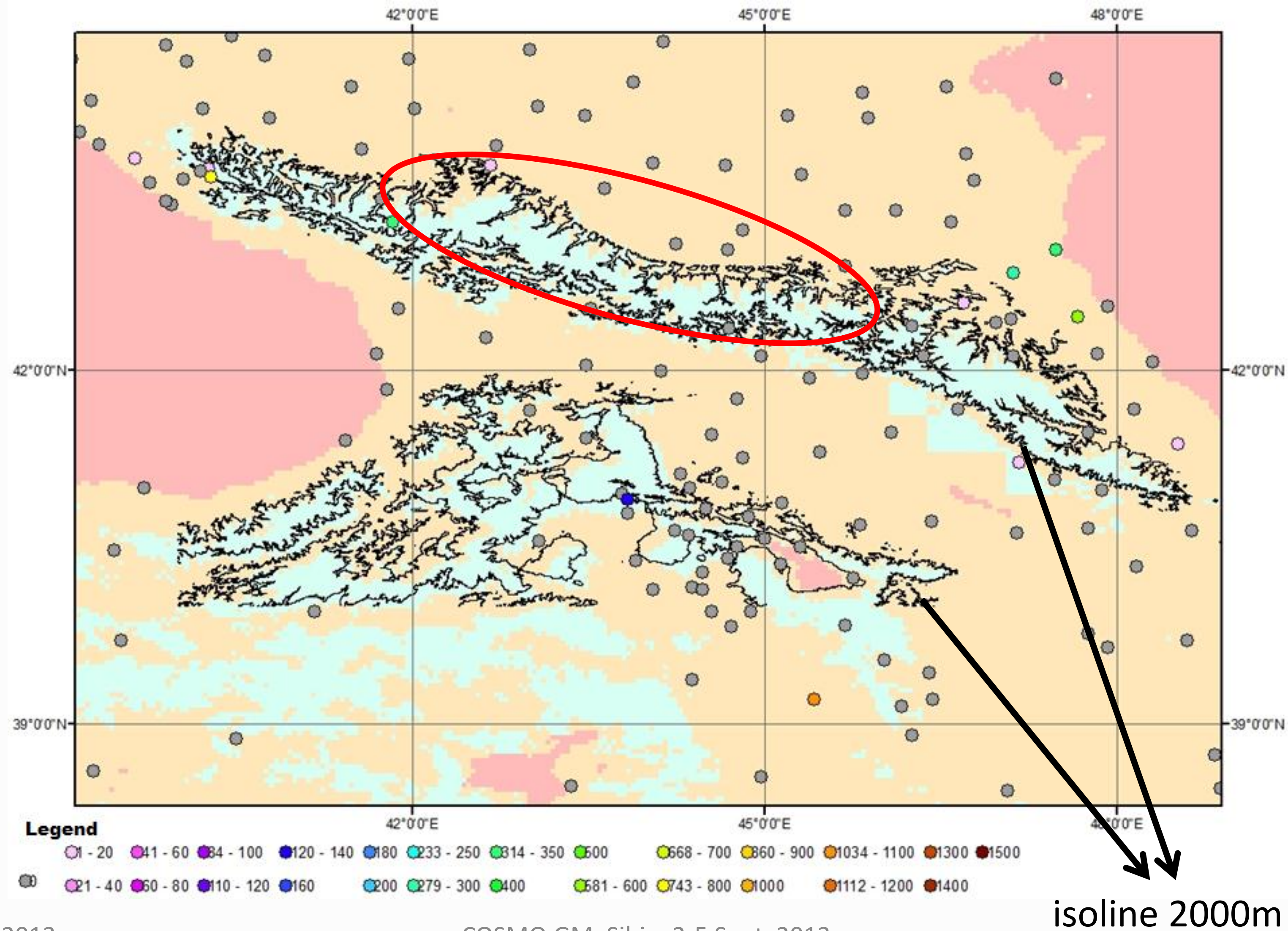


Satellite data, 4km, snow (blue), 30 March 2013



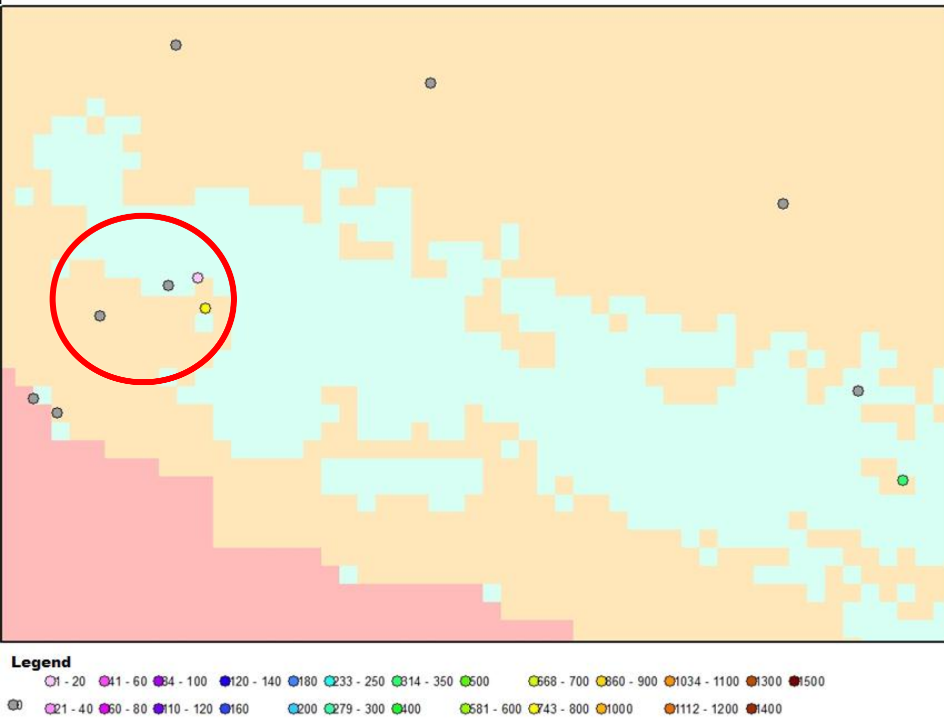
Satellite products are available on ftp://140.90.213.161/autosnow/4kmNH/

Satellite, 4km, snow (blue) 30 March 2013



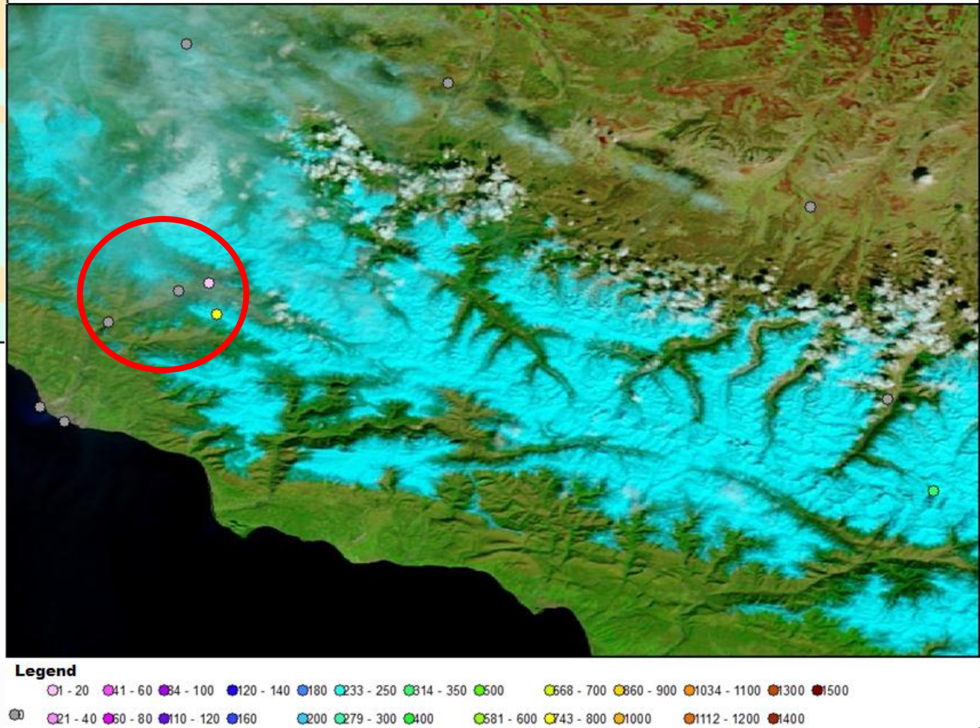
30 March 2013

Satellite, 4km, snow (blue)



MODIS 250m

http://earthdata.nasa.gov/data/near-real-time-data/rapid-response/modis-subsets



High spatial resolution satellite data is needed for correct snow cover representation in model

MODIS snow data interpretation in mountain region
case 1: 31 March 2013

- Dependence on relief height and SMFE station data

>2200 m SWE=700 mm, RHO=200 kg/m^3

1800-2200 m SWE=400 mm, RHO=200 kg/m^3

1200-1800 m SWE=300 mm, RHO=200 kg/m^3

<1200 m SWE=50 mm, RHO=200 kg/m^3

- Tsoil=-0.5°C, Freshsnow=1.0
- Tsnow is taken from COSMO initial field or according to formula:

$$T_{snow} = T_{2\mathcal{M}} - \frac{1}{\mathcal{K}}\sqrt{\frac{\tau_0}{\rho}} ln \frac{z}{z_0}$$

where $\mathcal{K} = 0.4$ - constant von Karman, τ_0 - shear stress, $\rho = 1.293 kg/\mathcal{M}^3$ - air density, $z = 2\mathcal{M}$ - the height for standard observations at meteorological station, $z_0 = 0.001\mathcal{M}$ - aerodynamic roughness for snow.

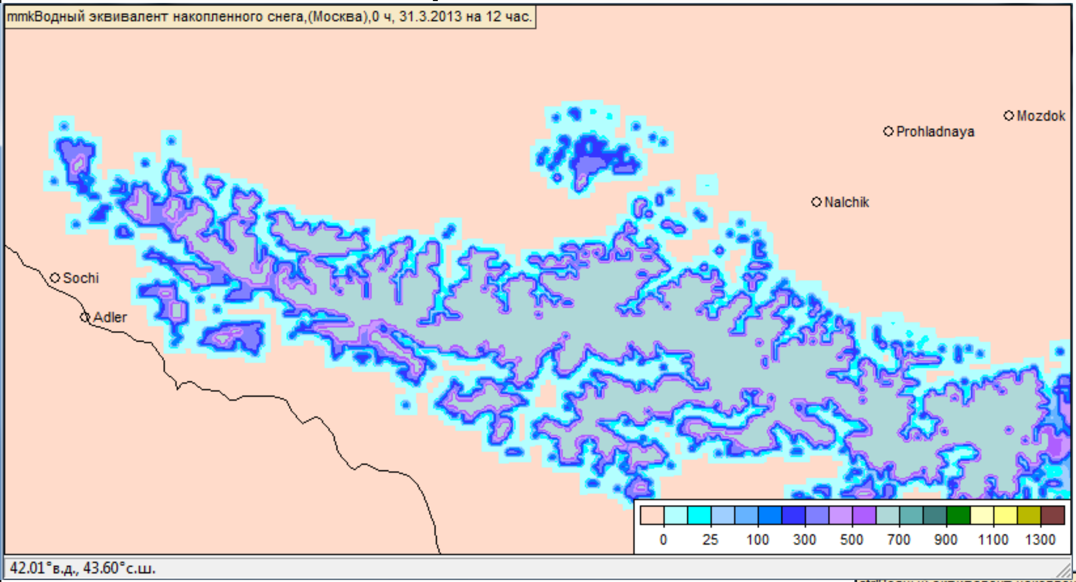
The formula for wind shear stress τ_0 mostly used in practice of engineering calculations looks as:

$$\tau_0 = \rho c |u_{10\mathcal{M}}| u_{10\mathcal{M}}$$

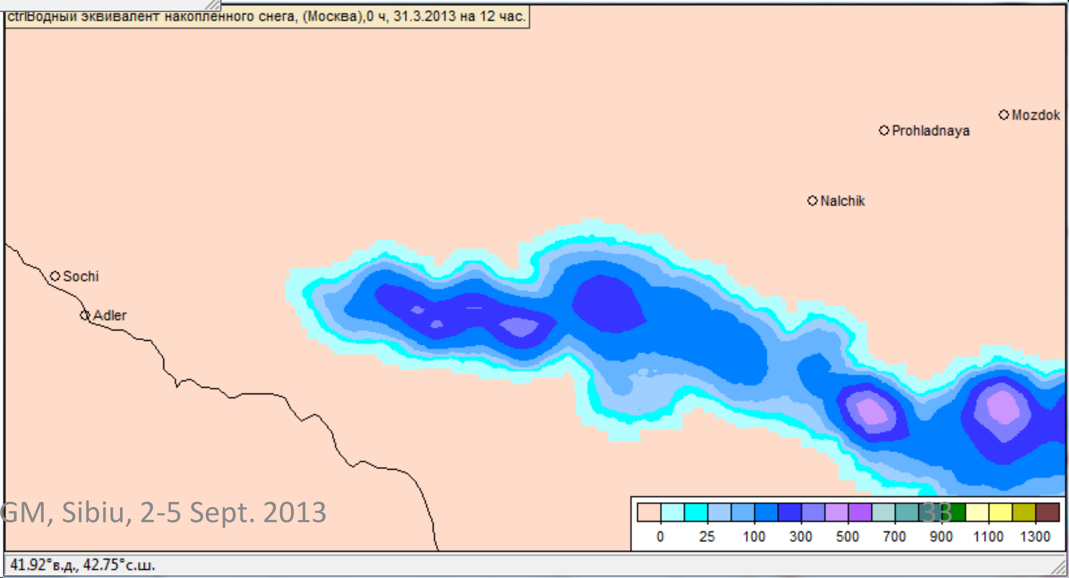
where $c = 0.003$ - a typical value of friction coefficient

SWE, 12h forecast, 31 March 2013

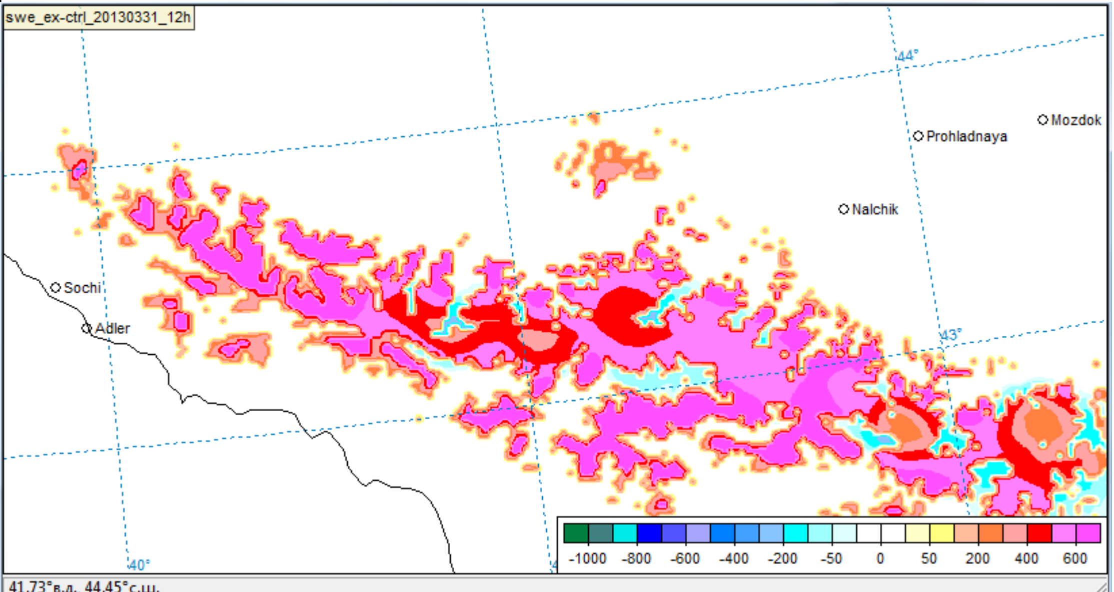
experiment



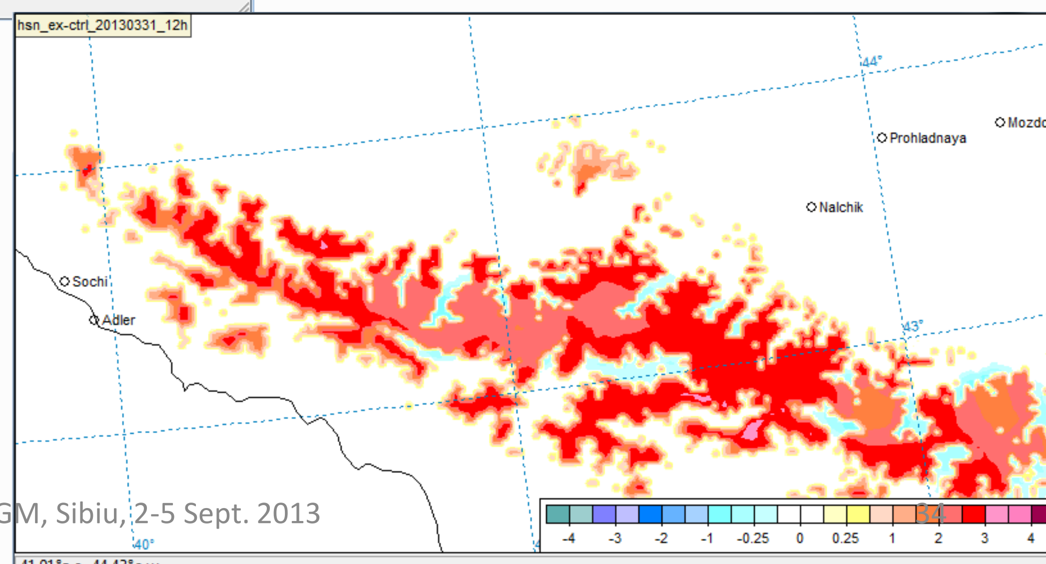
ctrl



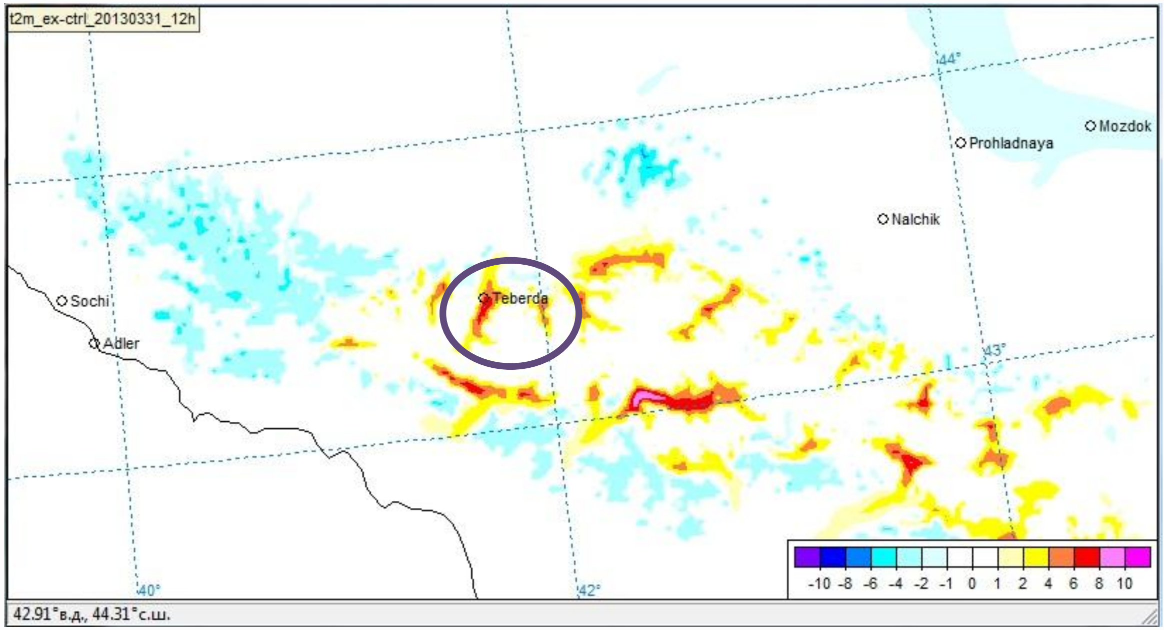
SWE (left), HSNOW (right) ex-ctrl, 12h forecast, 31 March 2013



The positive difference in SWE and HSNOW is observed in mountains and negative – in vallies.



T2m, ex-ctrl, 12h forecast, 31 March 2013



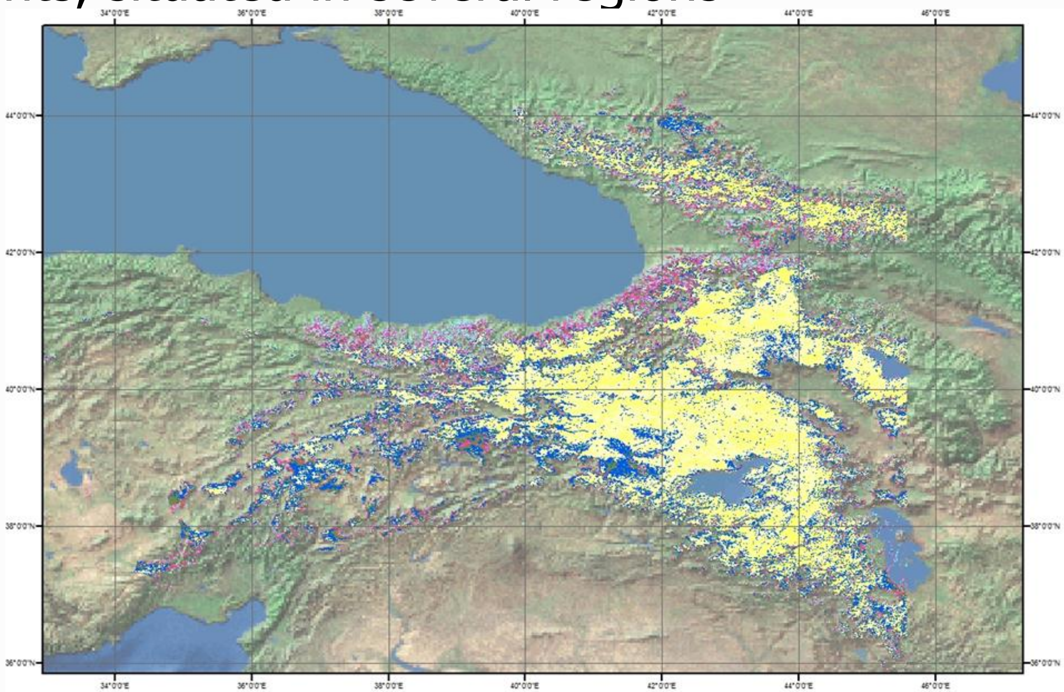
Teberda

h	station	ex	ctrl
3	3,8	2,8	2,3
6	11,0	5,9	3,2
9	17,0	10,5	4,0
12	16,5	12,6	6,3
15	11,3	8,8	5,2
18	6,9	5,5	4,1
21	6,1	5,1	4,5
0	5,1	5,7	5,3

Station is situated on 1325 m, in river Teberda valley. In winter 2012-2013 snow cover was observed in December-January.

MODIS snow data interpretation in mountain region
case 2: 8 March 2013

• Dependence on color (emissivity), values for classes are based on available SYNOP measurements, situated in several regions

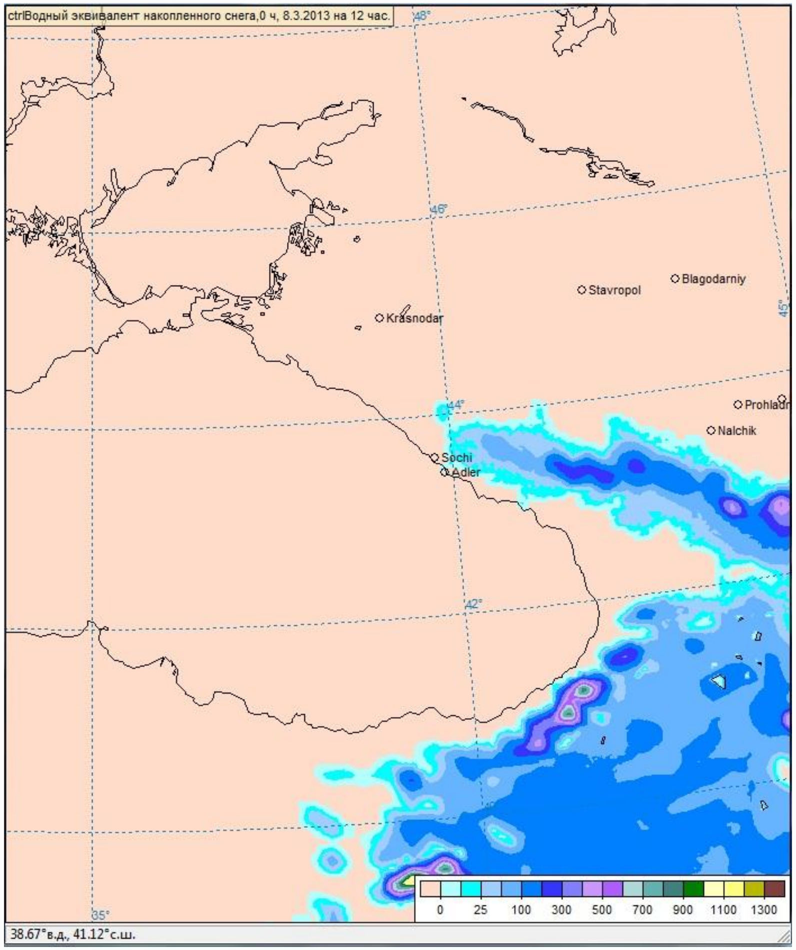


• Tsoil=-0.5°C, Freshsnow=1.0

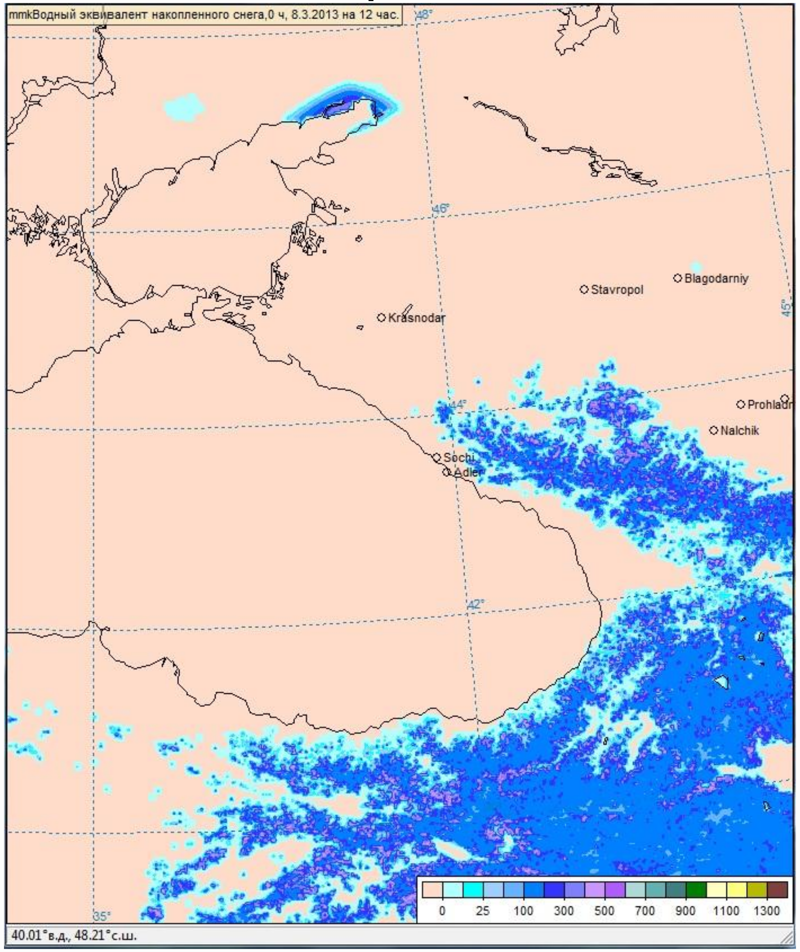
• Tsnow is taken from COSMO initial field or according to formula used in case1

SWE, 12h forecast, 08 March 2013

ctrl



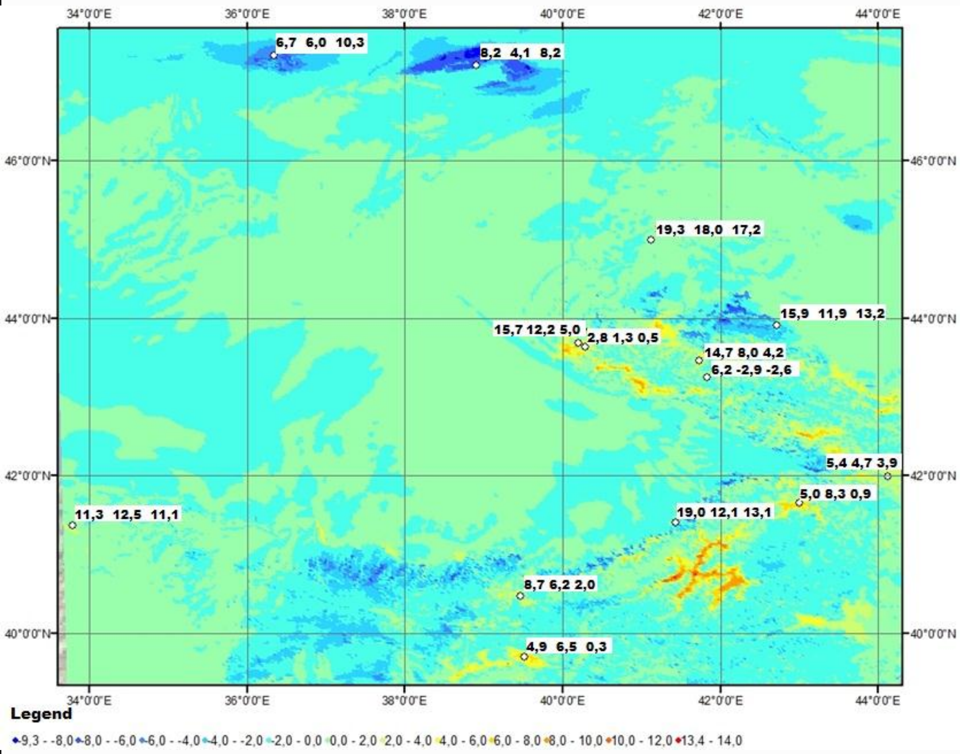
experiment



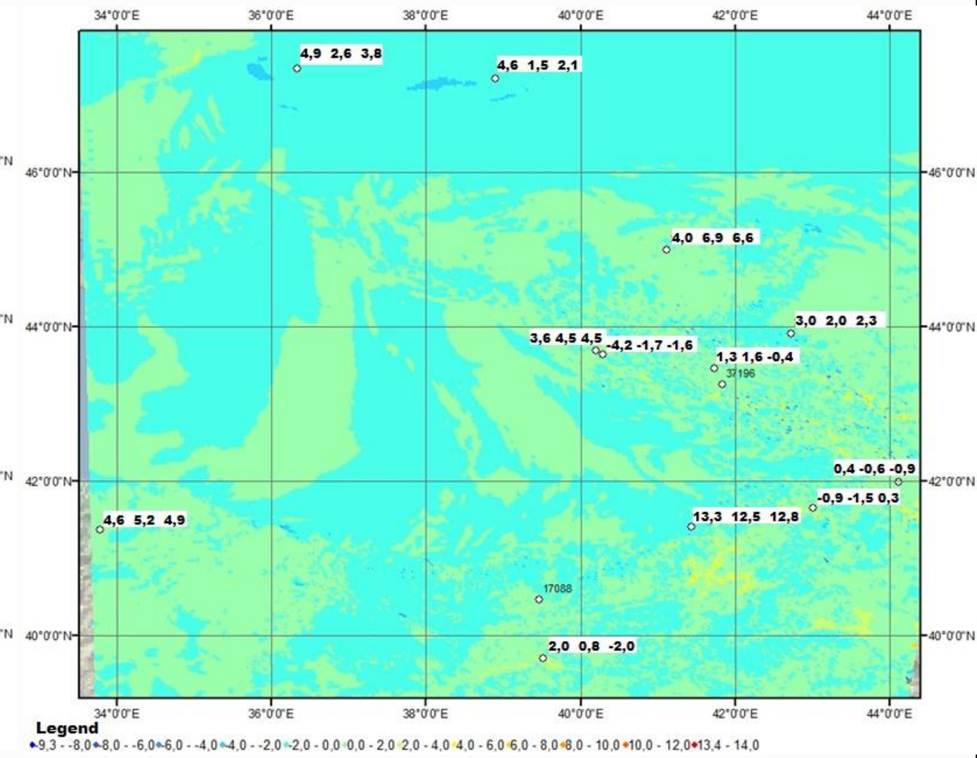
In experiment snow cover is more realistic. Besides, additional snow areas are present.

T2m, ex-ctrl, 12h (left) and 24h(right) forecast, 08 March 2013

ctrl

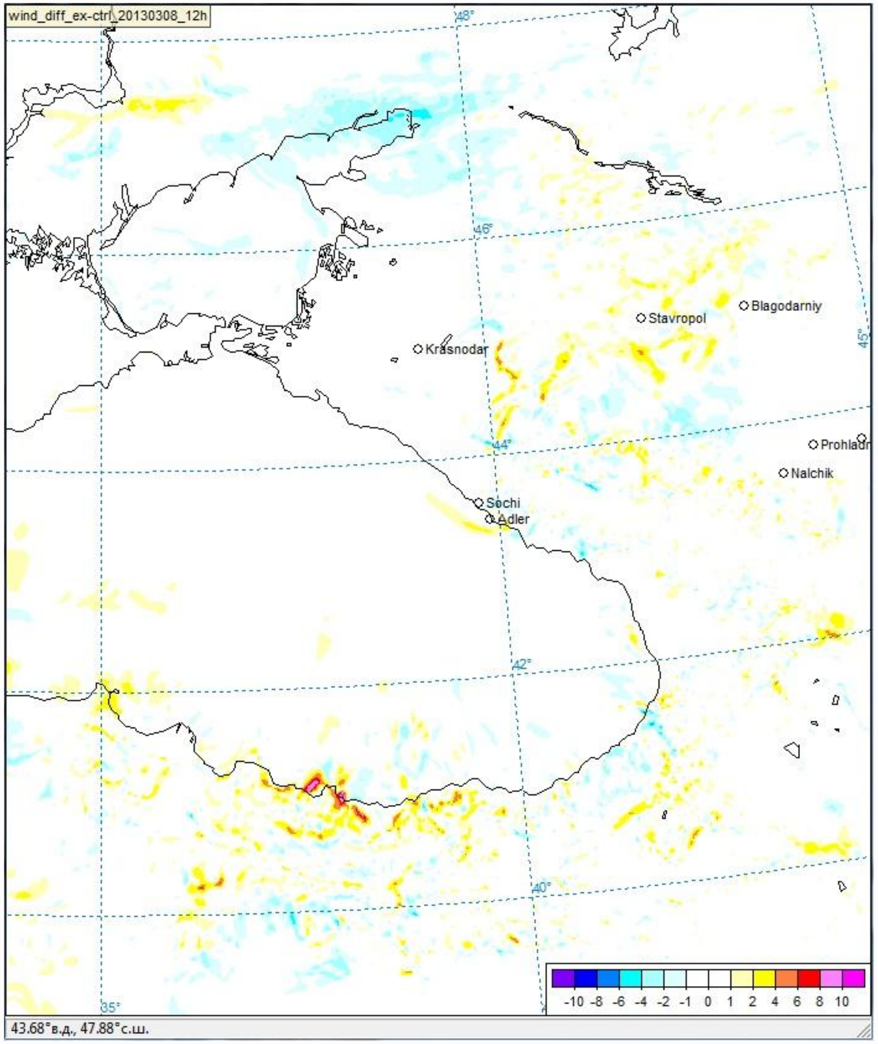


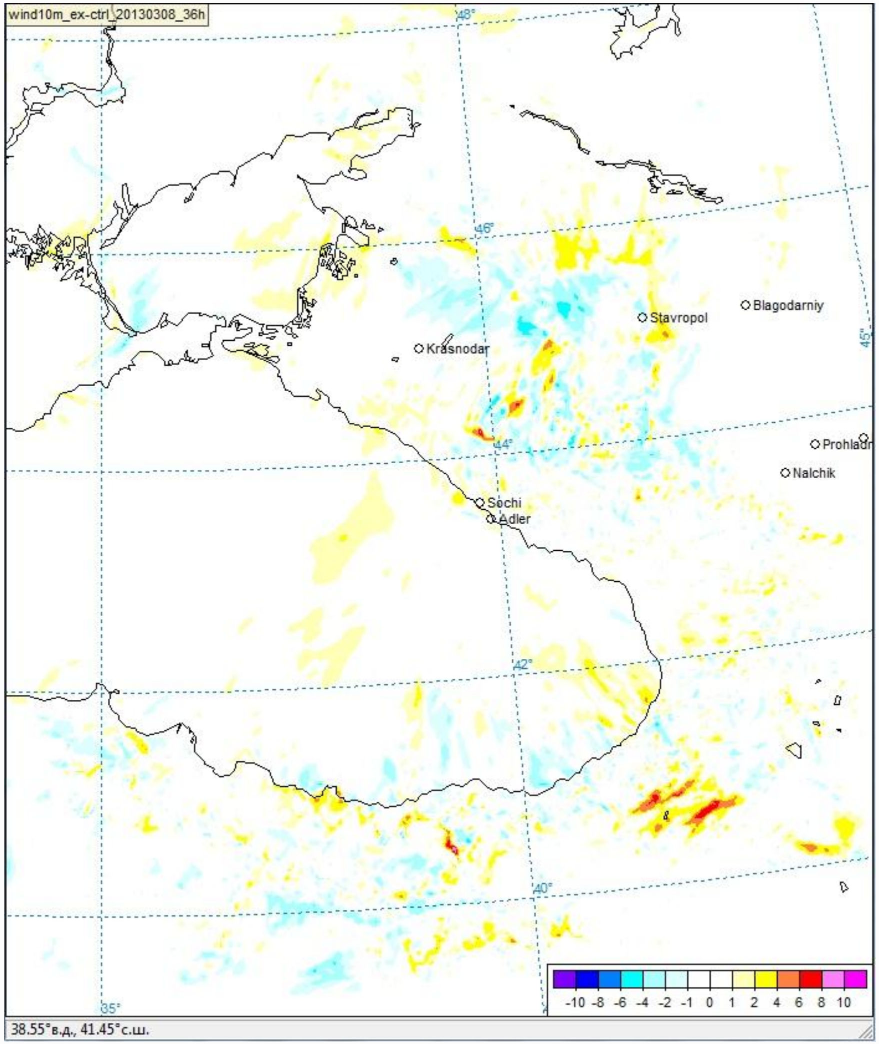
experiment



Snow cover changes mountain-valley circulation (cloudless conditions). The main differences are observed during day.

Wind10m, ex-ctrl, 12h (left) and 36h(right) forecast, 08 March 2013





The new formulae in COSMO postprocessing tools for calculation of new snow depth and tables of results were proposed for practical forecasters

The proposed module for fresh snow density:

- **represents the amount of newly fallen snow as a column with elements**

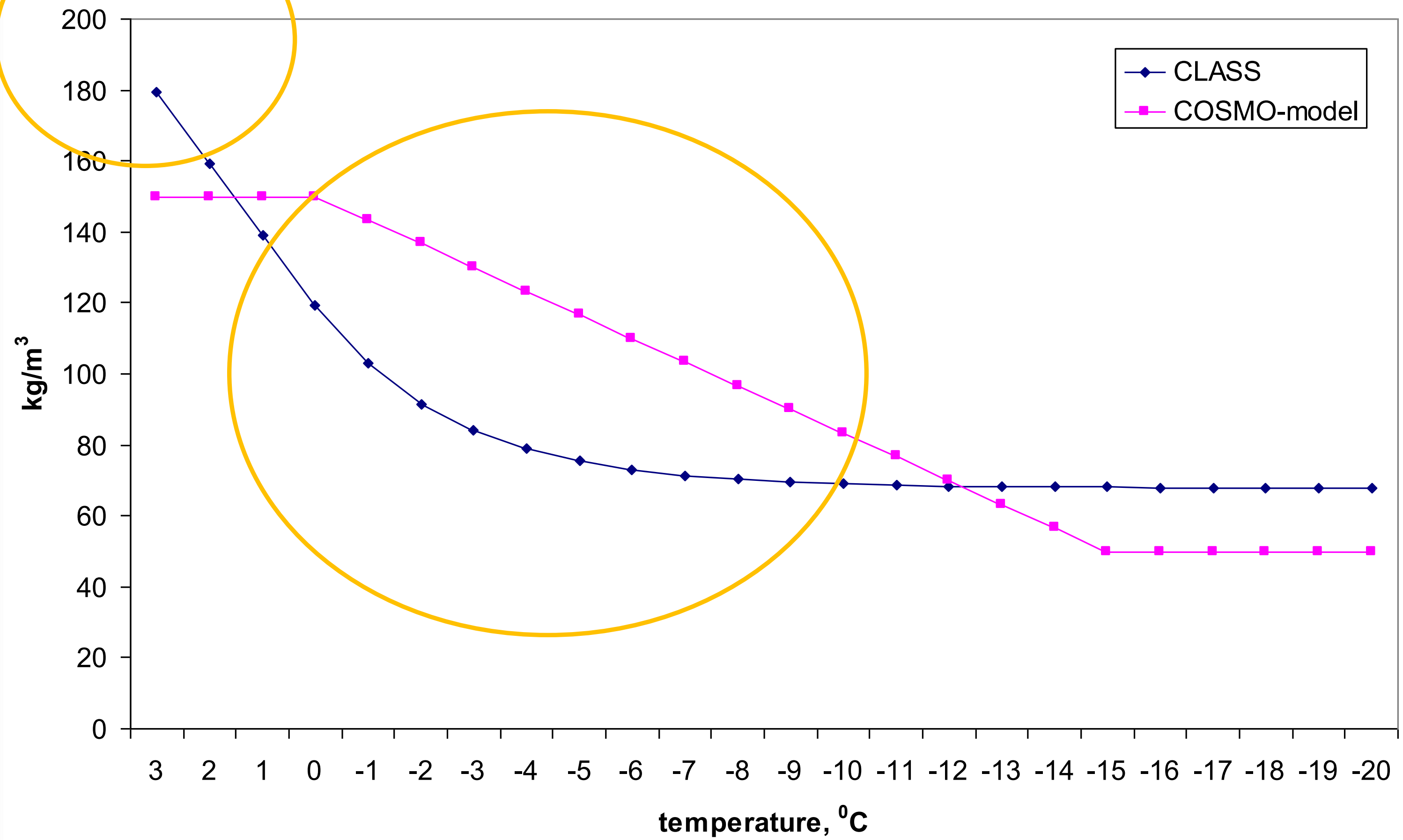
- **uses formula for density calculation from scheme CLASS** [*Barlett P.A, MacKay M.D. and Verseghy D.L.* Modified Snow Algorithms in the Canadian Land Surface Scheme: Model Runs and Sensitivity Analysis at Three Boreal Forest Stands // Canadian Meteorological and Oceanographic Society, ATMOSPHERE-OCEAN 43 (3), 2006, pp.207–222]

- **the number of levels depends on the input sum of precipitation value**

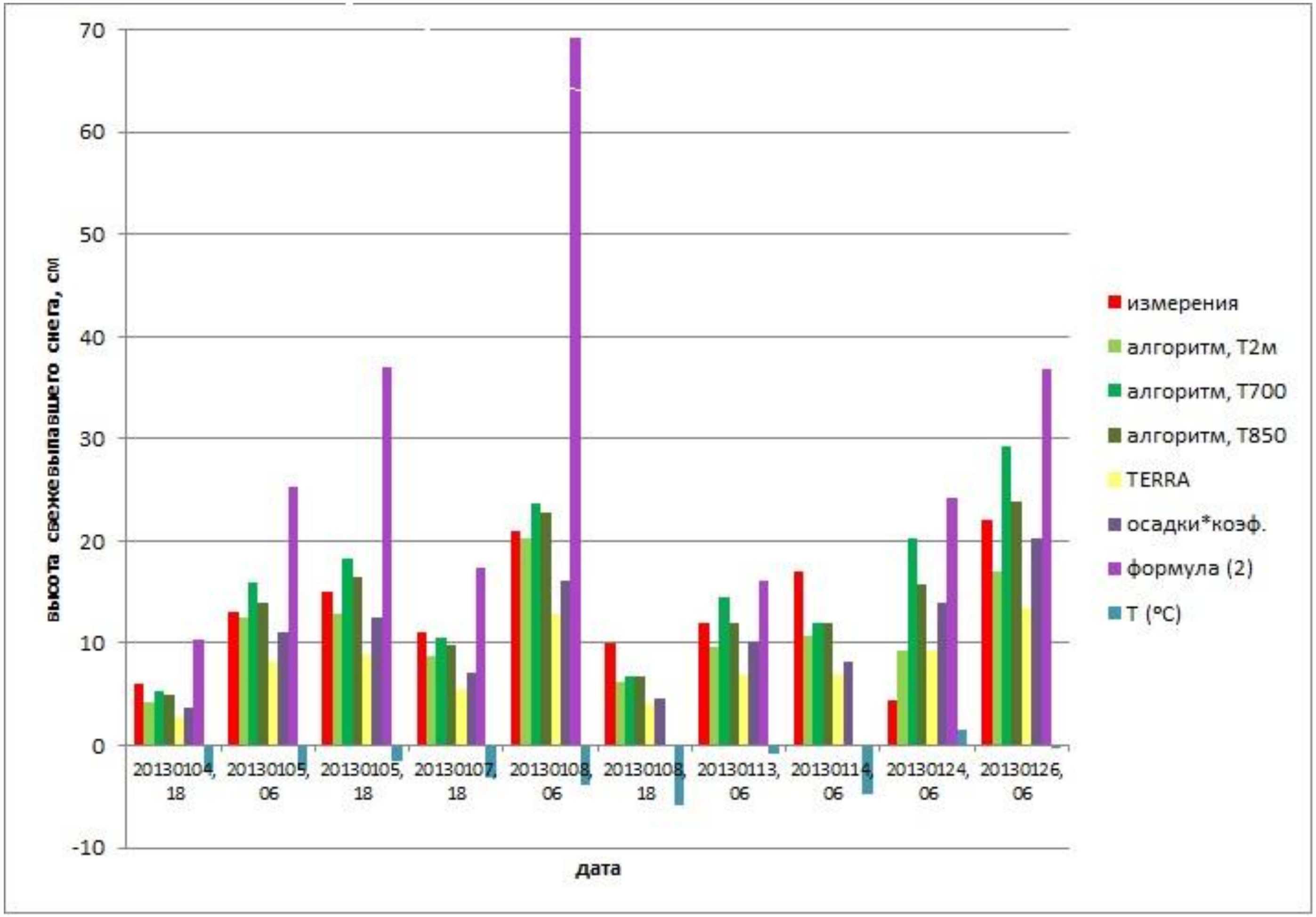
- **as an output we have snow depth of newly fallen snow and its density**

- **It's usefiul to add the algorithm for fresh snow depth calculations into FIELDEXTRA**

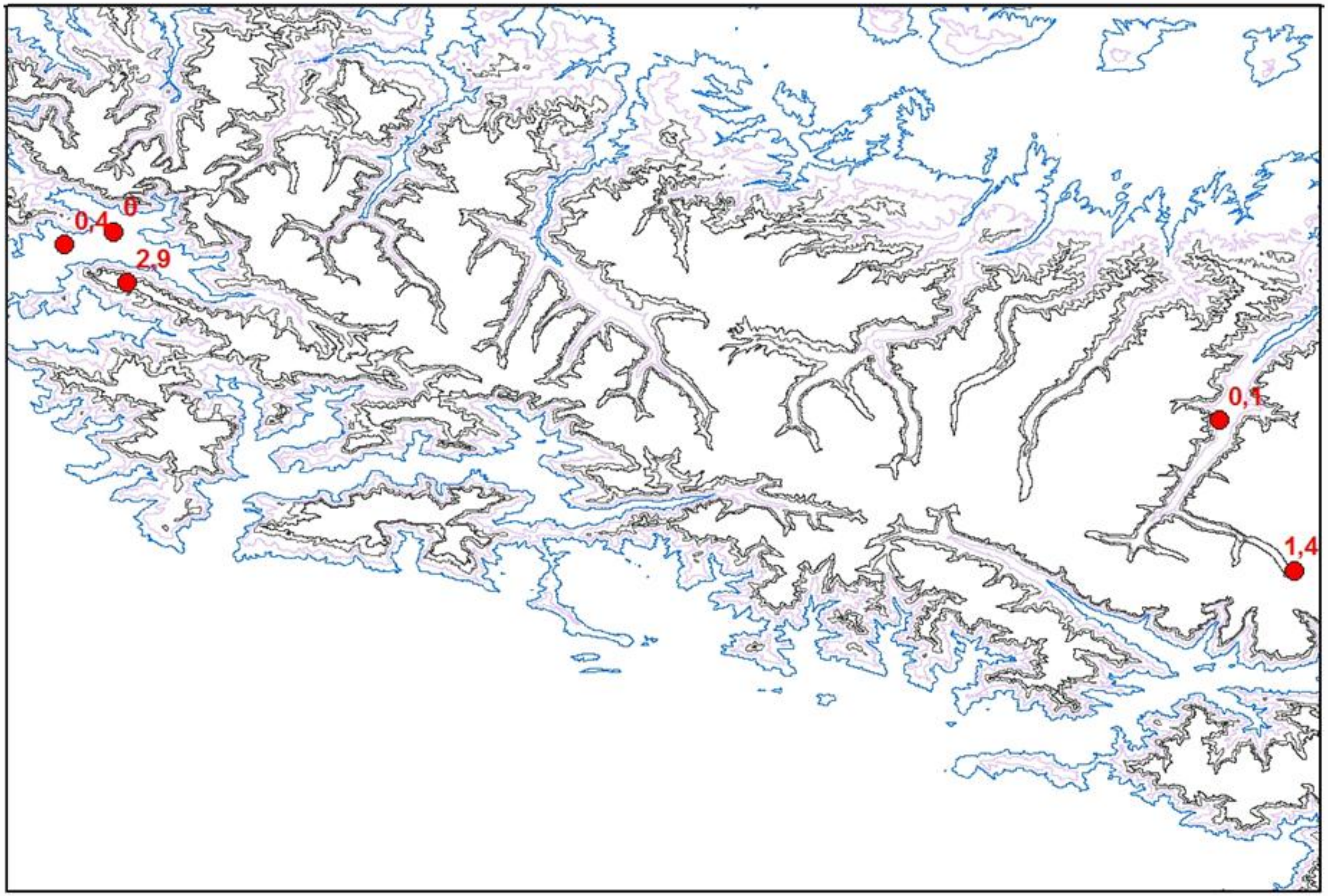
Fresh snow density values according to temperature dependence in TERRA (COSMO-model) parameterization and module CLASS



The calculations of fresh snow depth with use the different algorithms for (ст. (Gornaya Karusel, janv. 2013)



Map of fresh snow depth, 5 March 2013, 3 UTC



Conclusions

- It is necessary to use satellite data with high spatial resolution for detection of Snow boundary for a complex mountain region

- The main changes in calculations are observed on the area of valleys and places with tiny snow cover

- There are some changes in wind field, additional research is needed

Land- surface techniques : Other activities

1. Implementation of mire parameterization

(Alla Yurova)

- **The the mire parameterization was implemented into TERRA in COSMO-RUSib**
- **The little improvement for T2m forecasts for area of northern western Siberia area was obtained. The tests for close areas with mire domination are in progress**
- **Code (modified TERRA) with documented additional lines available on request from alla.yurova@gmail.com**
- **Parameterization description submitted to WRR special issue**
- **Standing water version under development to implement rice paddies**

As plans:

- To continue the testing for close area with mire dominated
- To analyze the influence on the convective instability. Case studies

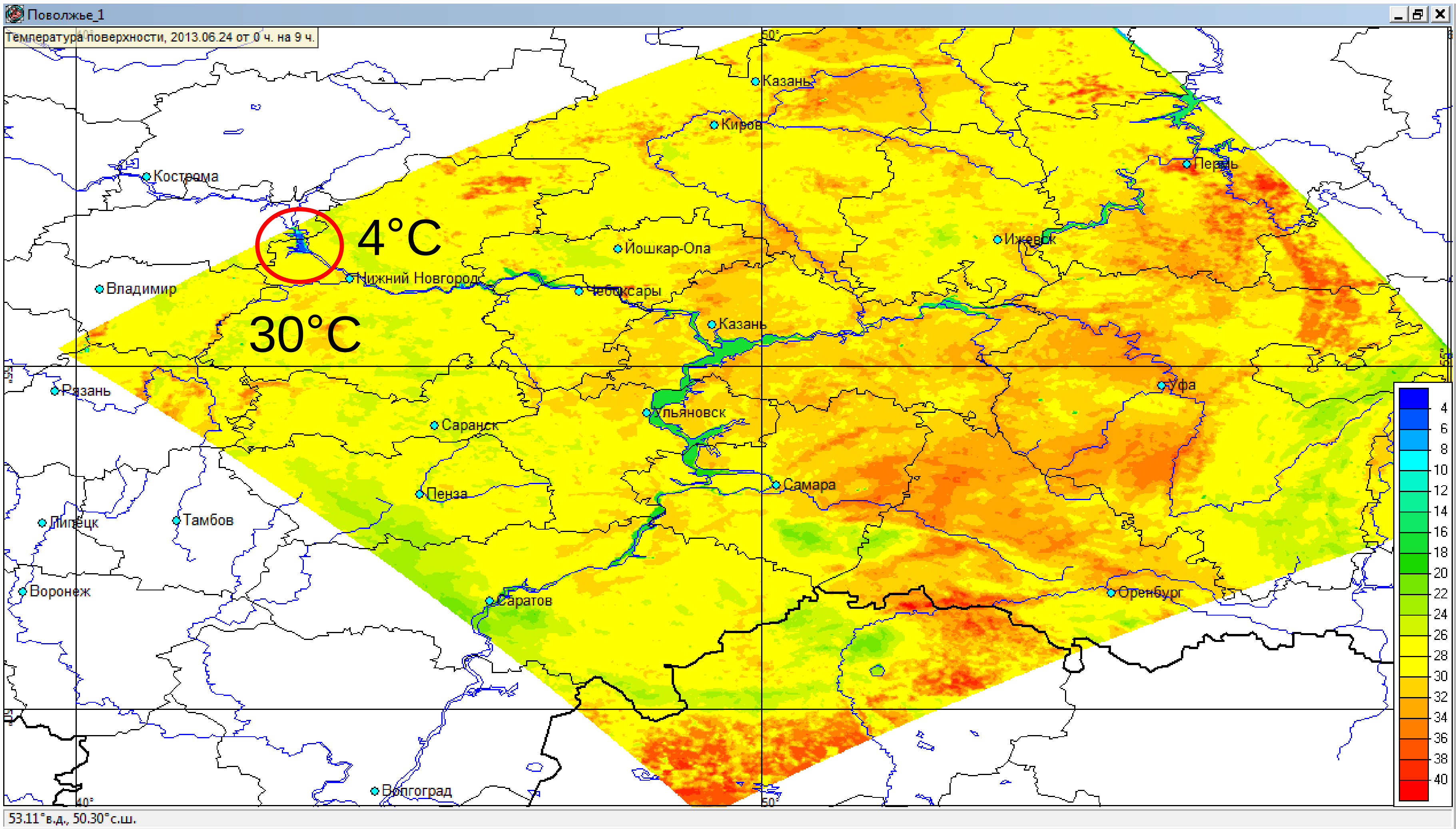
No the correct and detailed geographical mires information?

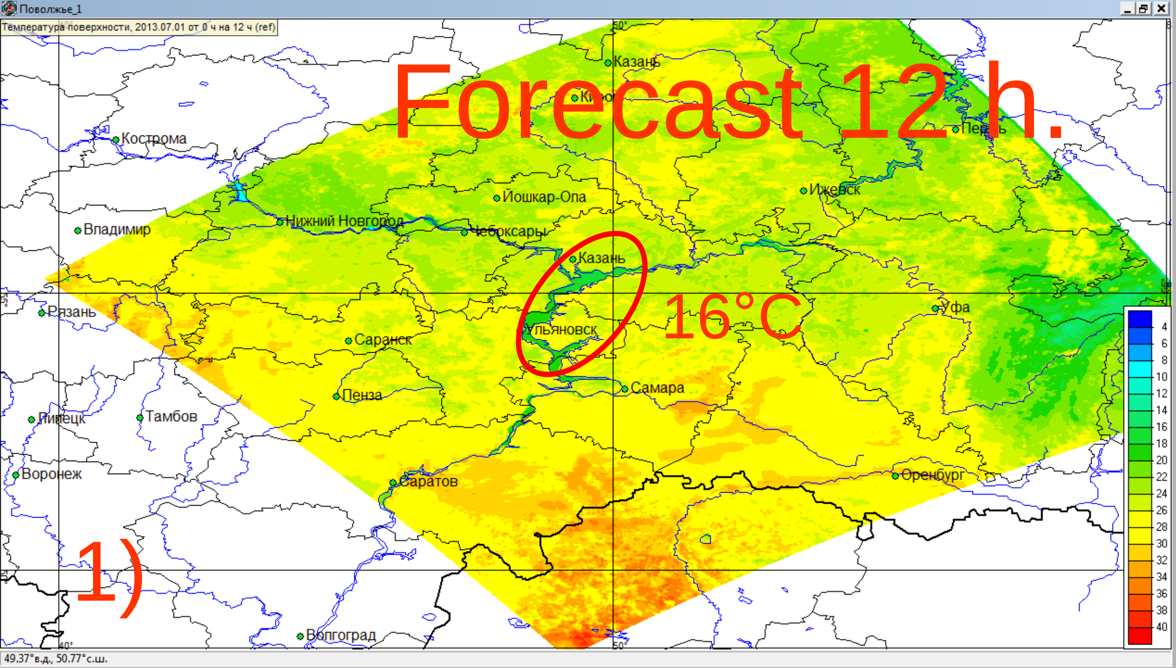
2. Flake implementation in COSMO-RU

(M.Nikitin, D.Blinov, I.Rozinkina)

Motivation

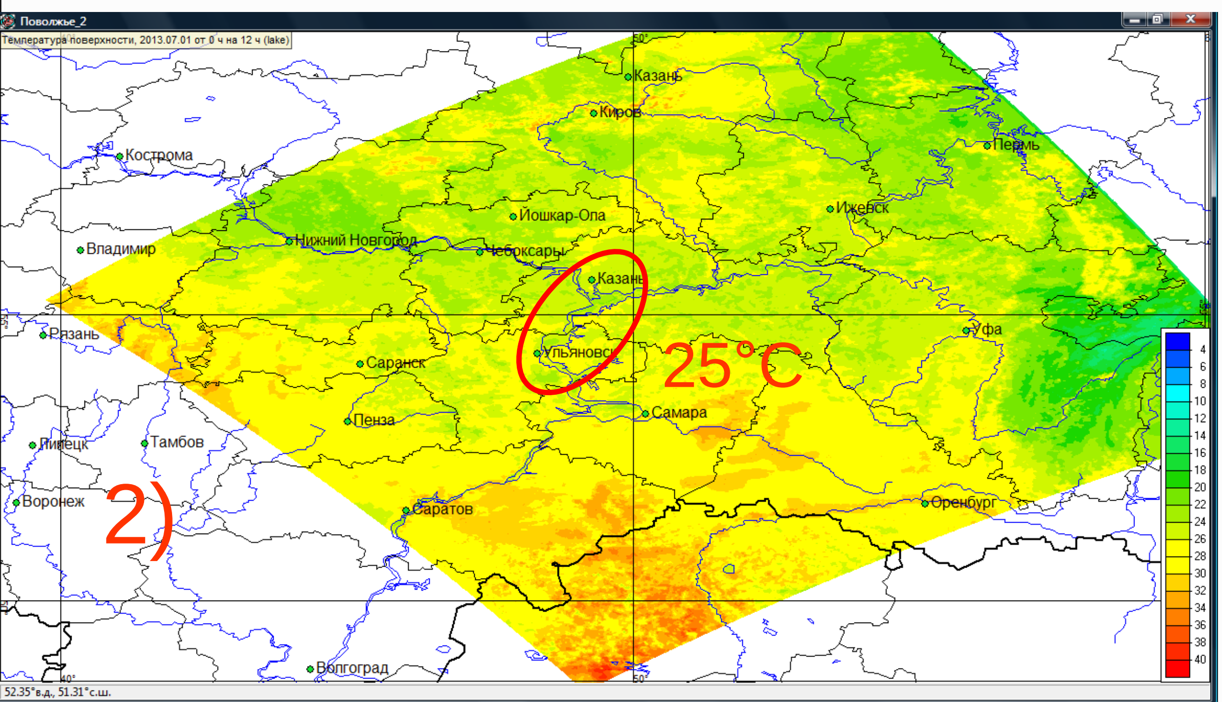
TG, 2013.06.24, forecast without Flake from 00 UTC on 09 h.





1) Surface temperature (TG), reference experiment, 2013.07.01 from 0 UTC, forecast for 12 h.

2) Surface temperature (TG), Flake experiment, 2013.07.01 from 0 UTC, forecast for 12 h.



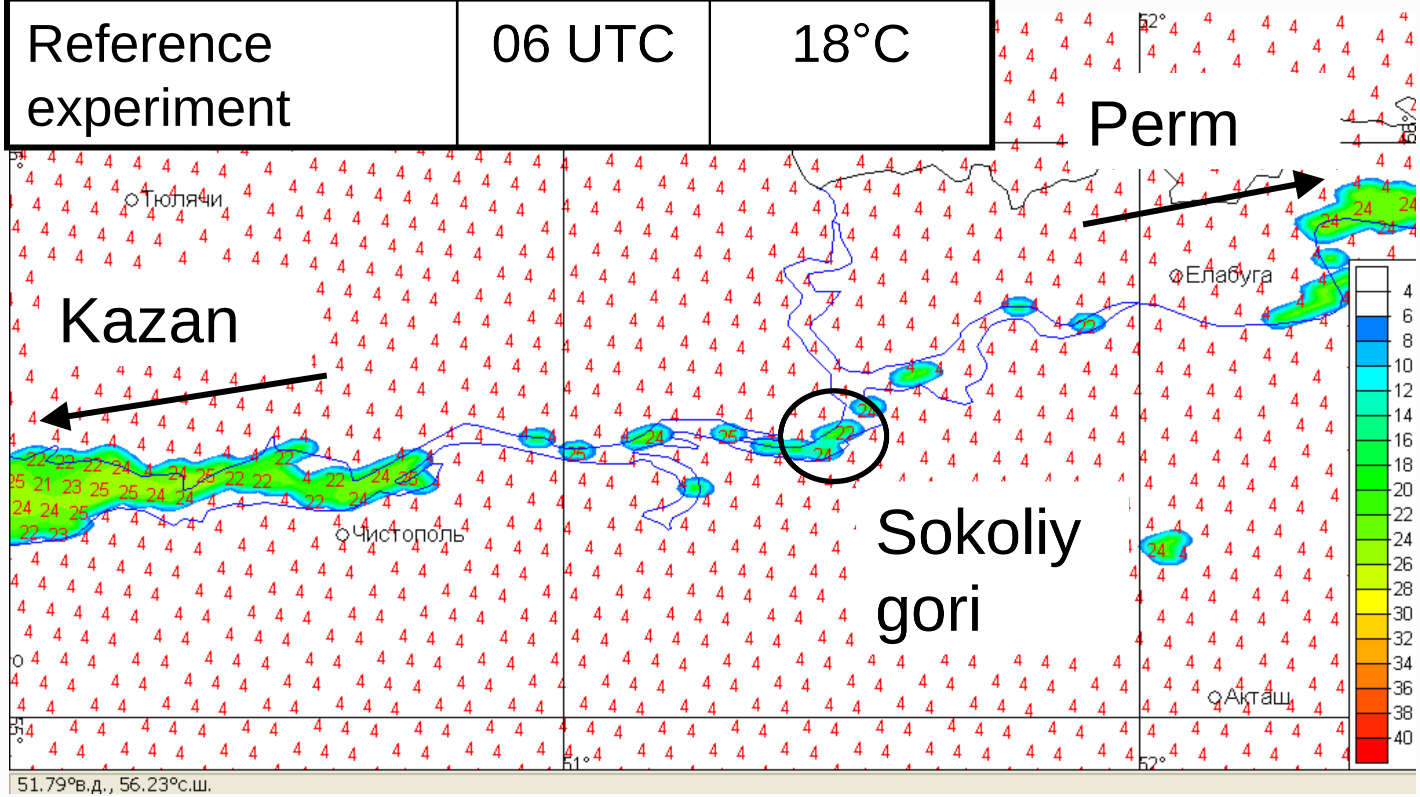
At the day hours this difference reaches 8-12°C!

But difference in air temperature on 2 meters (T2m) is not such high.

Testing of water surface temperature from hydrological data

Data from hydrological station “Sokolyi gori”, Kama area of Kuybyshev reservoir, 1 of July, 2013. Experiments stat at 00 UTC (04 local time)

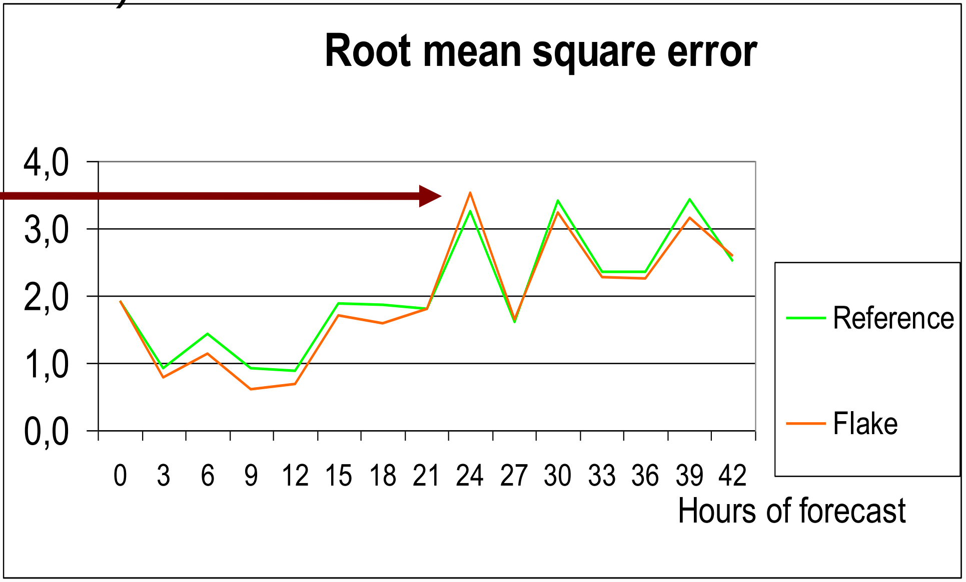
	Hour	Data
Measure	04 UTC	22°C
Flake experiment	06 UTC	22°C
Reference experiment	06 UTC	18°C

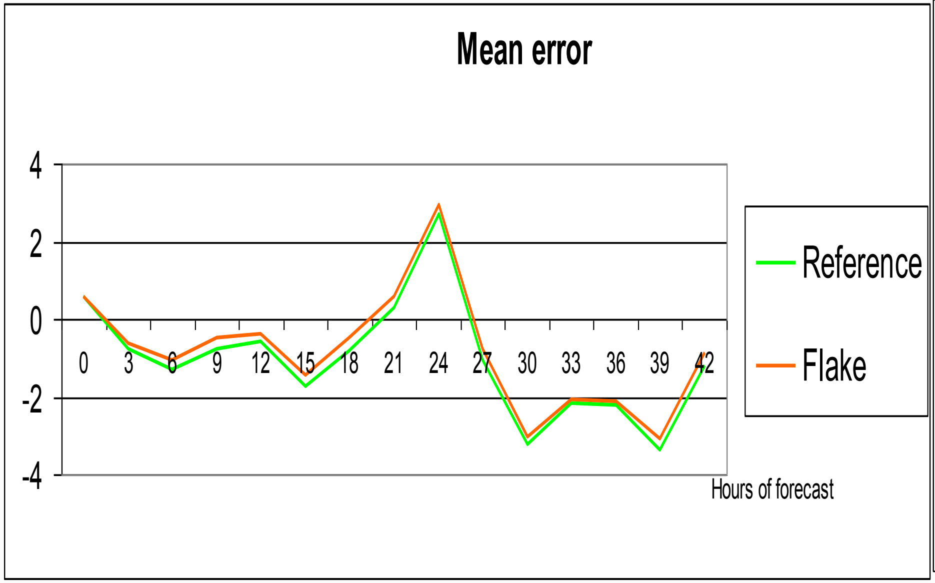


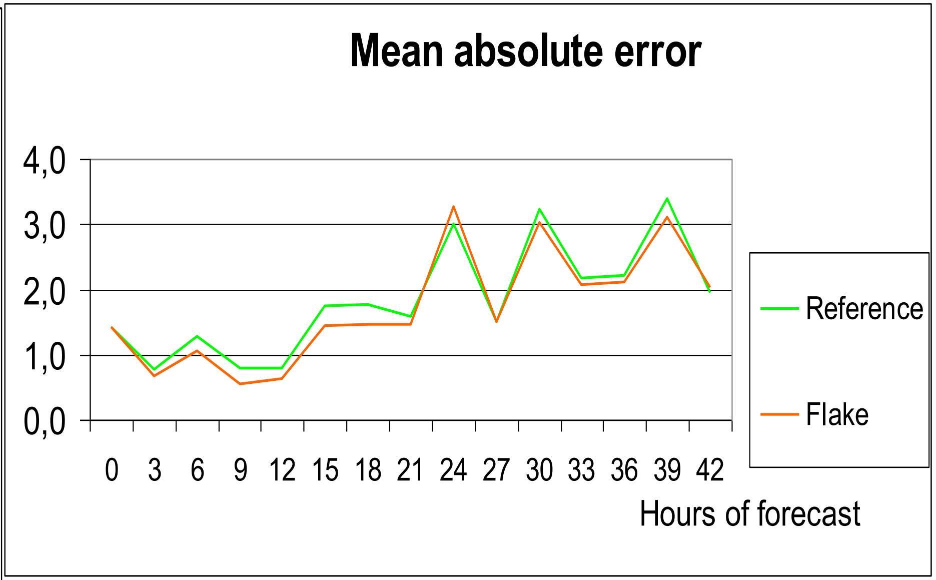
Forecast for the 1 of july 2013 from 00 UTC (typical situation)

Error decreases all the time, except night hours.

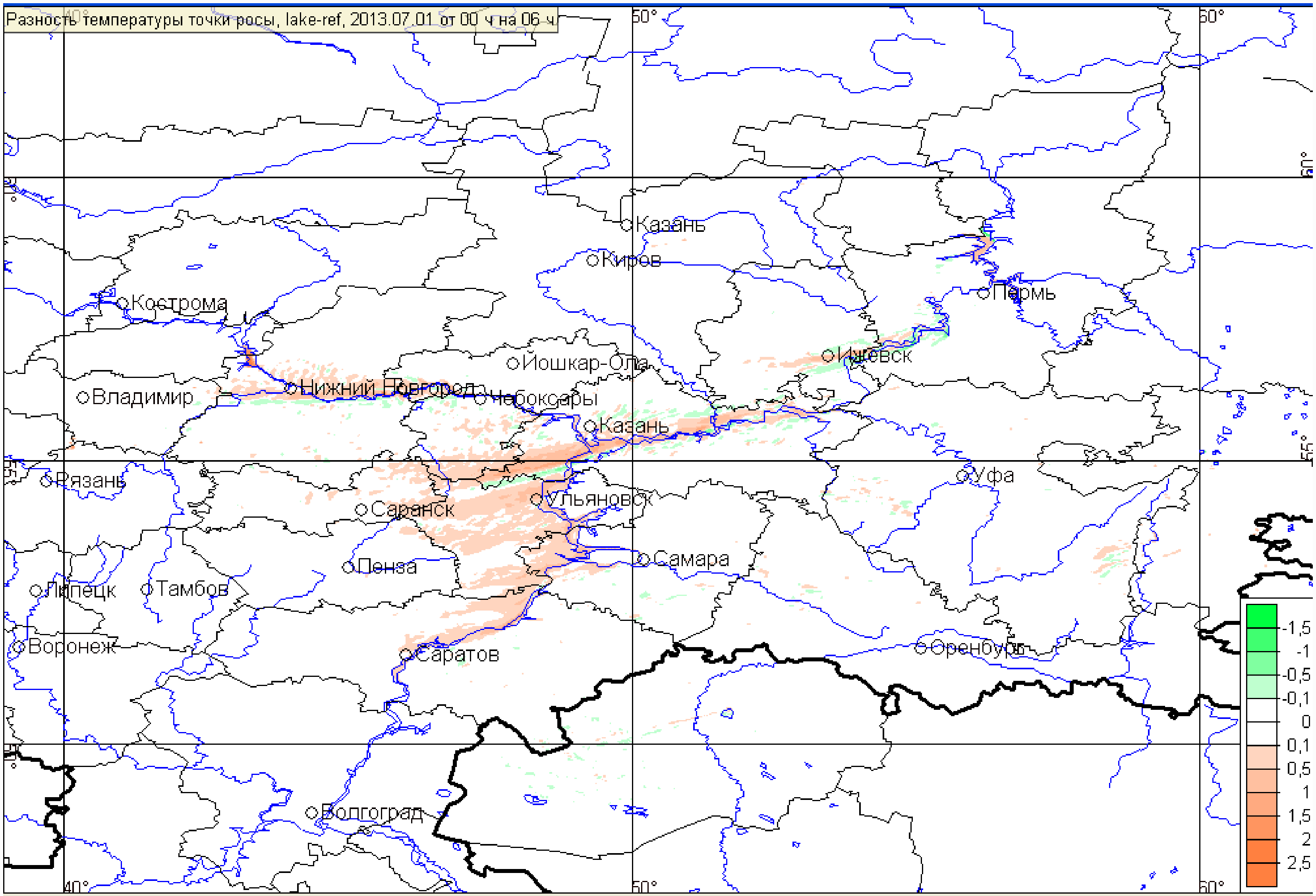
Difference between reference and flake experiments is about 0, 3°C







Deference in dew point temperature between Flake and reference experiments, 2013.07.01 from 0 UTC on 06 h



Results and plans

1) The FLAKE was inplemented into COSMO-Ru technology (continuous calculations, “Cold start”)
2) The time of acceleration – about 1-2 months
3) COSMO RU 2,2 with flake parametrization more correctly reproduces temperature in the daytime. But at night time it overestimates air temperature.- the additional tuning of scheme FLAKE is useful
4) The COSMO technology for initialization of initial fields of surface temperature with FLAKE need to improvement (is received from global model, not from flake block. In some areas difference between surface and water mixed layer temperature can reach 10°C). An error of output in GRIB format of cold start (Flake) In COSMO was corrected but it is present in basic version
5) Further plans – use flake parameterization for the winter season with negative temperature. Estimate vertically profiles of water temperature using data from Valday station.
6) Case-study and fed-back from the boundary-level parameters

Status of Valday data exchange

Were obtained and available:

- The measurement data of water T profiles for 3 points of observations in Valday flake chains (1 for 10 days, 2011-2012 years)
- The rows for daily values of T of water surface for summer 2011-2012

Thank you for your attention!