COSMO/CLM User Seminar, Offenbach, 2013

Snow aspects at Roshydromet

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Motivation

There are large discrepancies in initial SWE values for COSMO model

-SWE is the principal characteristic of snow cover in terms of COSMO-model

- the adaptation of SWE for the atmospheric forcing continue trough full snow period
- SWE values are in fundamental importance for land surface- atmosphere heat in cases of little snow amount or during its melting

How to solve problem of SWE initialization?

Technique	required	model	Approach	Comments
Continuous assimilation cycle, incl. H Snow analysis	**Measurements of H Snow,** **Simple snow parameterization**	GME	Formulae "Aging" (FA)	The FA curves are in highly dependence on the geographical features and thermal and wind condition of snow period. Great errors for long snow periods
Continuous assimilation cycle	Multi-layer snow parameterization	COSMO	Continuous snow modeling, Atmospheric forcing: from COSMO	There are inaccuracies in important factors of forcing – first of all, precipitation. Errors for long snow period
Continuous assimilation cycle, incl. SYNOP data	Measurements of H Snow, T, Td, V Precipitation (add) Multi-layer snow parameterization	COSMO	Continuous snow modeling, Atmospheric forcing: **from measurements**	The inaccuracies can be produced only by algorithms of parameterization

In Roshydromet two 1-d algorithms for snow cover characteristics calculations based only on SYNOP data are developed:

- 1. SMFE – Snow Model based on Finite Element approach with elastic deformation accounting
- 2. FSM –Fresh Snow Module

SMFE – Snow Model based on Finite Element approach

• Model SMFE - a quick and economical 1-d approach for snow characteristics calculation based on

-Physical principles

-SYNOP measurement data

• An opportunity to have values for stations and as a field

• The applied data can be with different time resolution (30 min, 1 hour, 3 hour…)

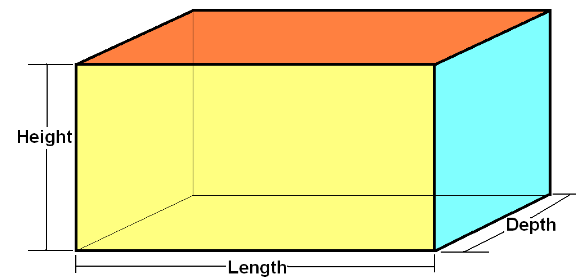
• snow characteristics can be received for the height of user interest (the upper 10cm, 20cm…)

• Ability for different climatic zones

1. Model SMFE

Characteristics of the model

•**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 a cuboid shape with height equal to 1 cm, length and depth equal to 100 cm.**



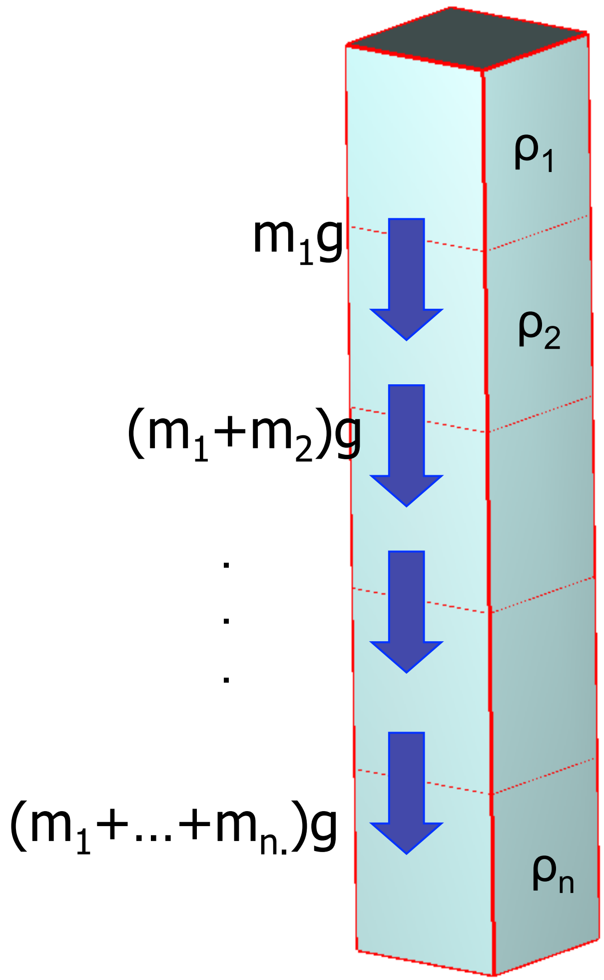
• **Yosida and Huzioka [*Yosida, Z., Huzioka, T.* Some Studies of the Mechanical Properties of Snow. IAHS Red Book Series. Publ. no. 39, Gentbrugge, 1954, pp. 98-105] : Young's modulus for snow can be calculating by formula:**

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

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

$$\rho = \frac{\left(\frac{mg}{10^6(1-\sigma_{02})} + 1{,}86\right)}{0{,}0167}, \quad m = (\rho_1 + \rho_2 + \ldots)H, H = 0{,}001m \qquad \frac{l_n}{l_0} = (1-\sigma_{02}) = 1 - 0{,}002$$

Representation of snow column in the model



Each finite element undergoes the weight of the previous overlying elements and hence its density is defined by ambient temperature and accumulative weight

Characteristics of the model

- **Fresh snow is calculating according to formula from canadian snow scheme CLASS 3.1** [*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]

$$\rho_{s,f} = 67.92 + 51.25e^{\frac{T_a}{2.59}}, T_a \le 0^0 C$$

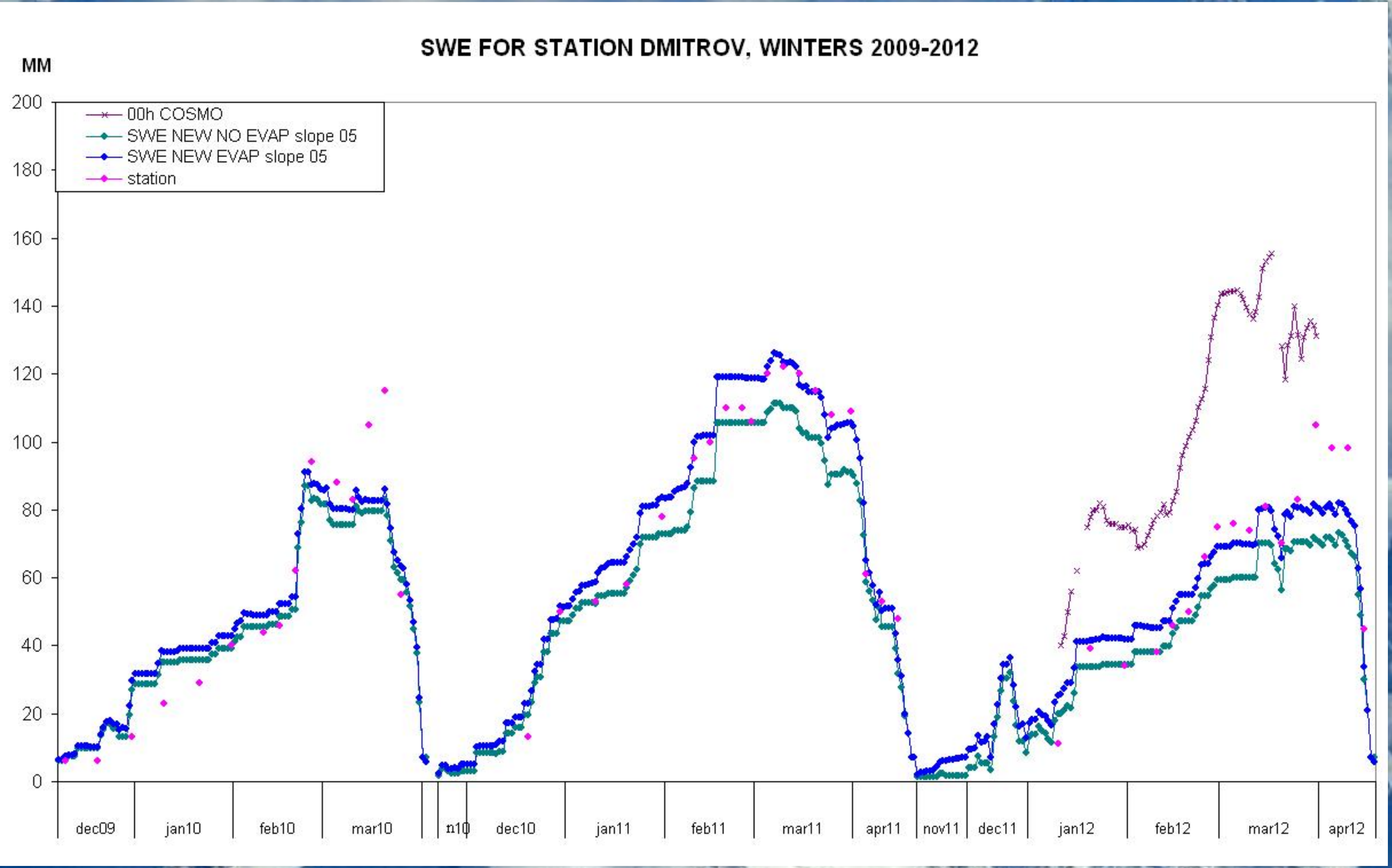
$$\rho_{s,f} = \min(200, 119.2 + 20T_a), T_a > 0^0 C$$

- **Evaporation from snow according to Kuzmin's formula:**

$$F = (0.18 + 0.098u_{10m})(e_{pot} - e_{2m}) \quad mm/day$$

The description of the model is prepared

Central region of the European part of Russia



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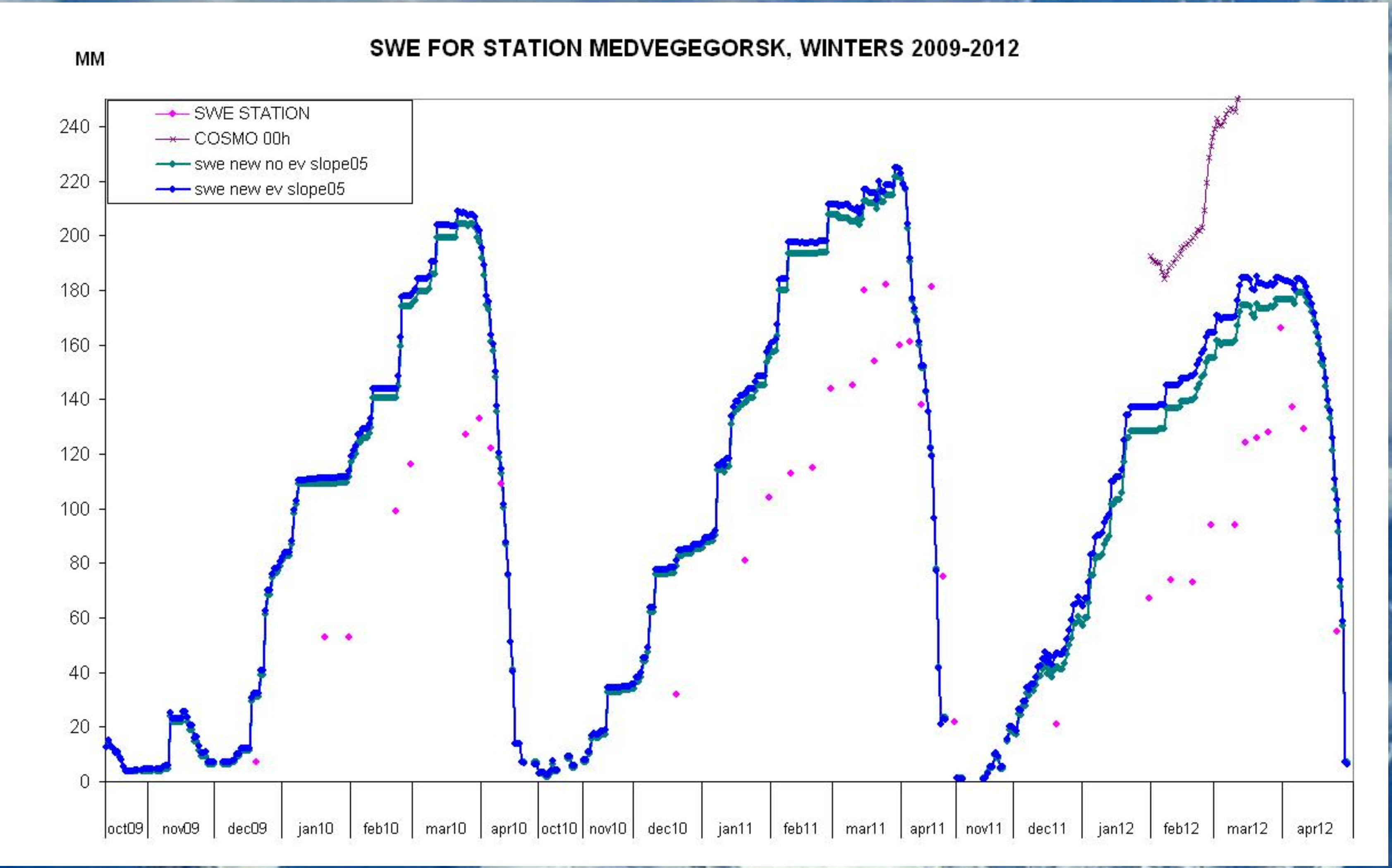
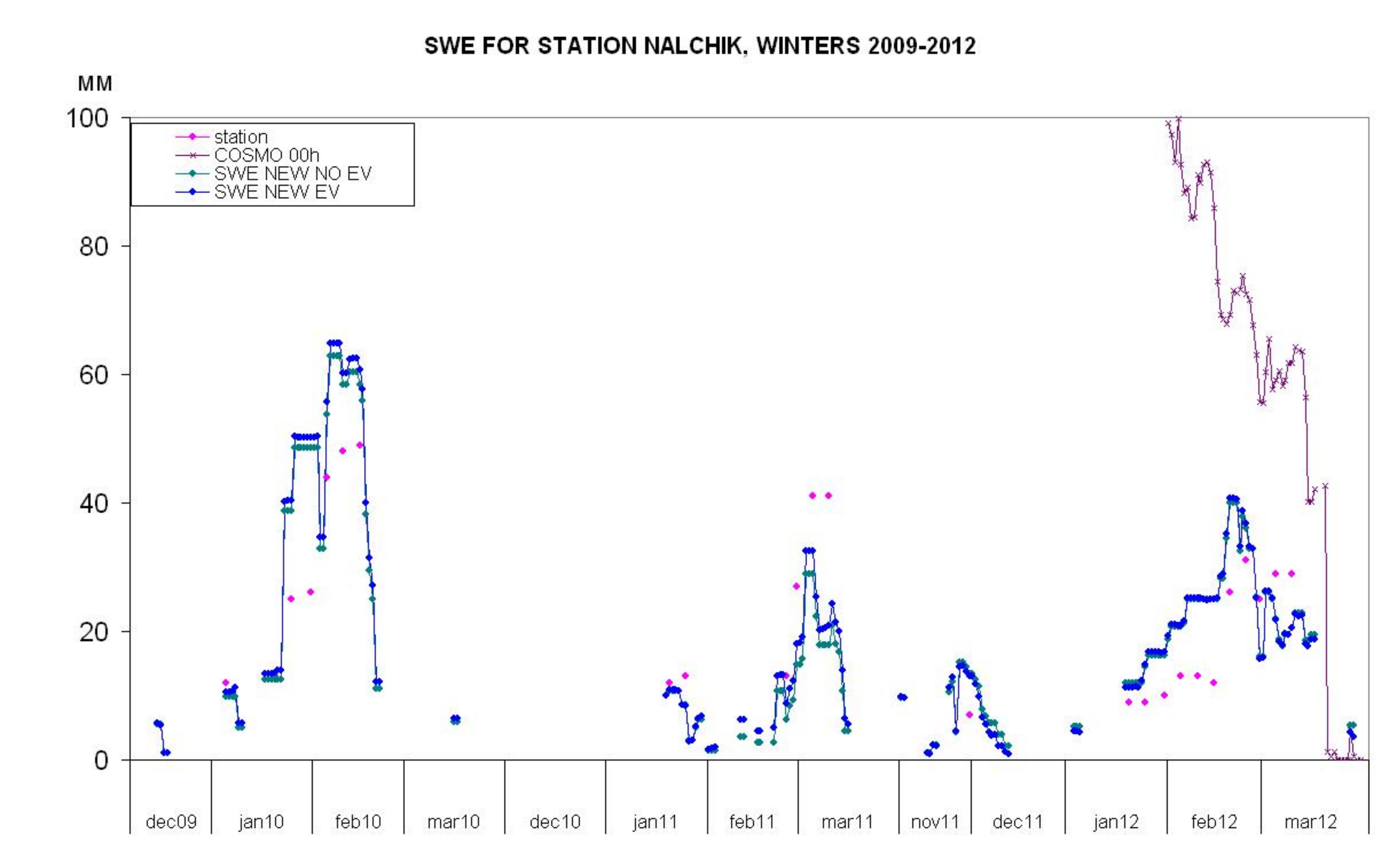
Northern forested region of the European part of Russia



Snow aspects at Roshydromet

Southern region of the European part of Russia



2. Snow fresh algorithm

Motivation

- Fresh snow density in COSMO:

$$\rho_{snow,fresh} = \rho_{s,f,\min} + (\rho_{s,f,\max} - \rho_{s,f,\min})\frac{T_{low} - T_{\min}}{T_0 - T_{\min}}$$

$$\rho_{s,f,\min} = 50kg/m^3, \rho_{s,f,\max} = 150kg/m^3, T_0 = 273.16^0C, T_{\min} = 258.15^0C$$

- The developed module for fresh snow density:
- uses formula from canadian scheme CLASS
- has a compaction due to gravity according to japan researches
- the number of elements in column depends on the input sum of precipitation value
- as an output we have snow height of newly fallen snow and its density

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Fresh snow density, kg/m^3

T,°C	COSMO	CLASS
3	150,0	179,2
2	150,0	159,2
1	150,0	139,2
0	150,0	119,2
-1	143,3	102,8
-2	136,7	91,6
-3	130,0	84,0
-4	123,3	78,9
-5	116,7	75,4
-6	110,0	73,0
-7	103,3	71,4
-8	96,7	70,3
-9	90,0	69,5
-10	83,3	69,0
-11	76,7	68,7
-12	70,0	68,4
-13	63,3	68,3
-14	56,7	68,2
-15	50,0	68,1
-16	50,0	68,0
-17	50,0	68,0
-18	50,0	68,0
-19	50,0	68,0
-20	50,0	67,9

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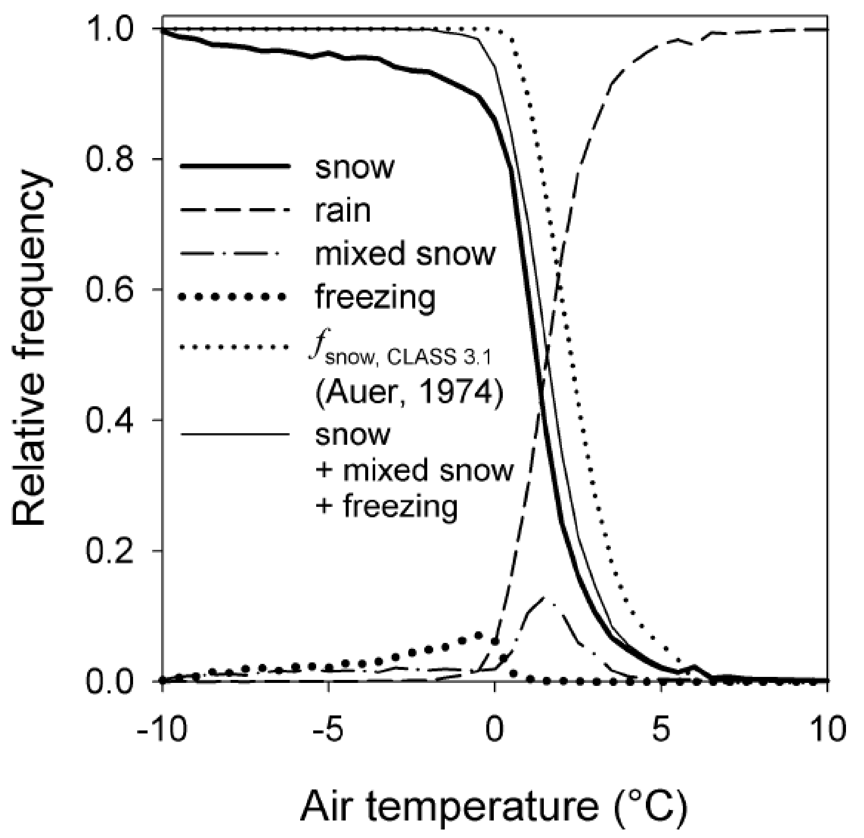

Relative frequency of precipitation types from 10 years of hourly observations at 39 meteorological stations across Canada, compared with the function of Auer (1974) for f_{snow}, the fraction of precipitation that is snow.

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

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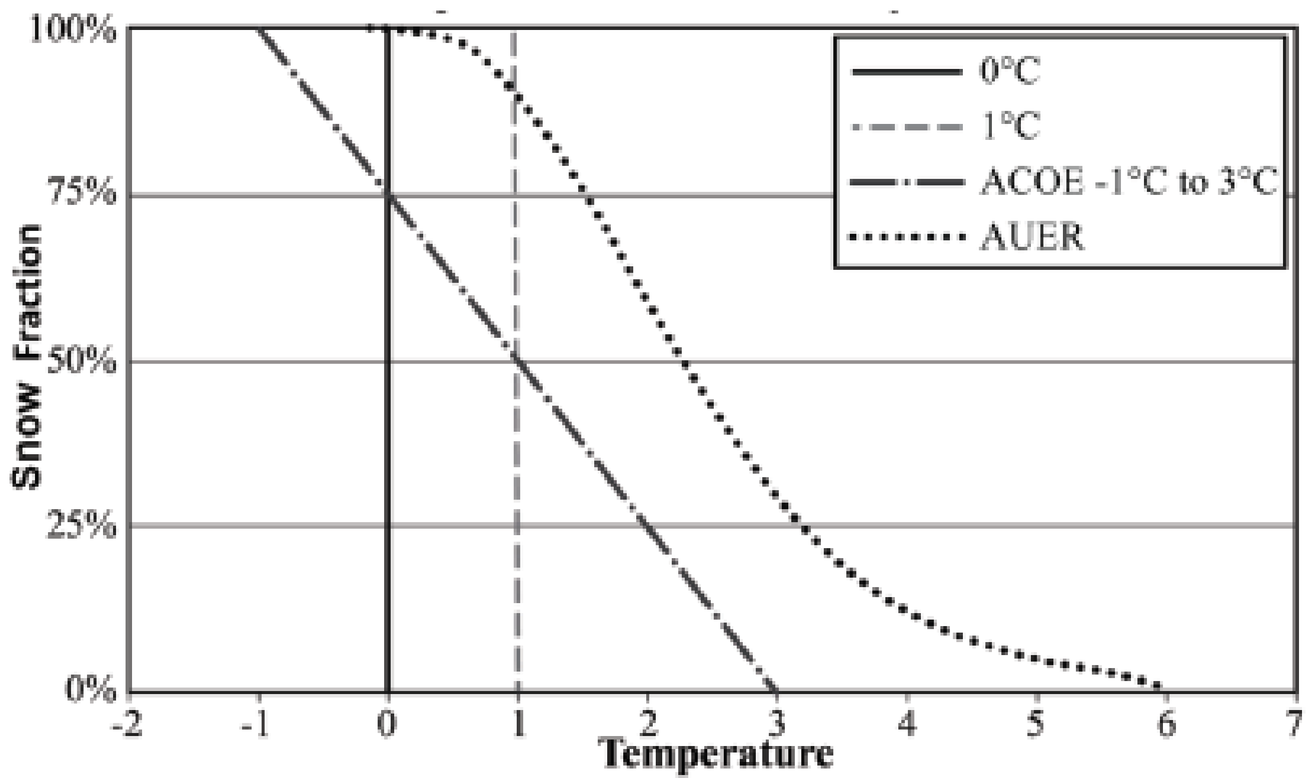
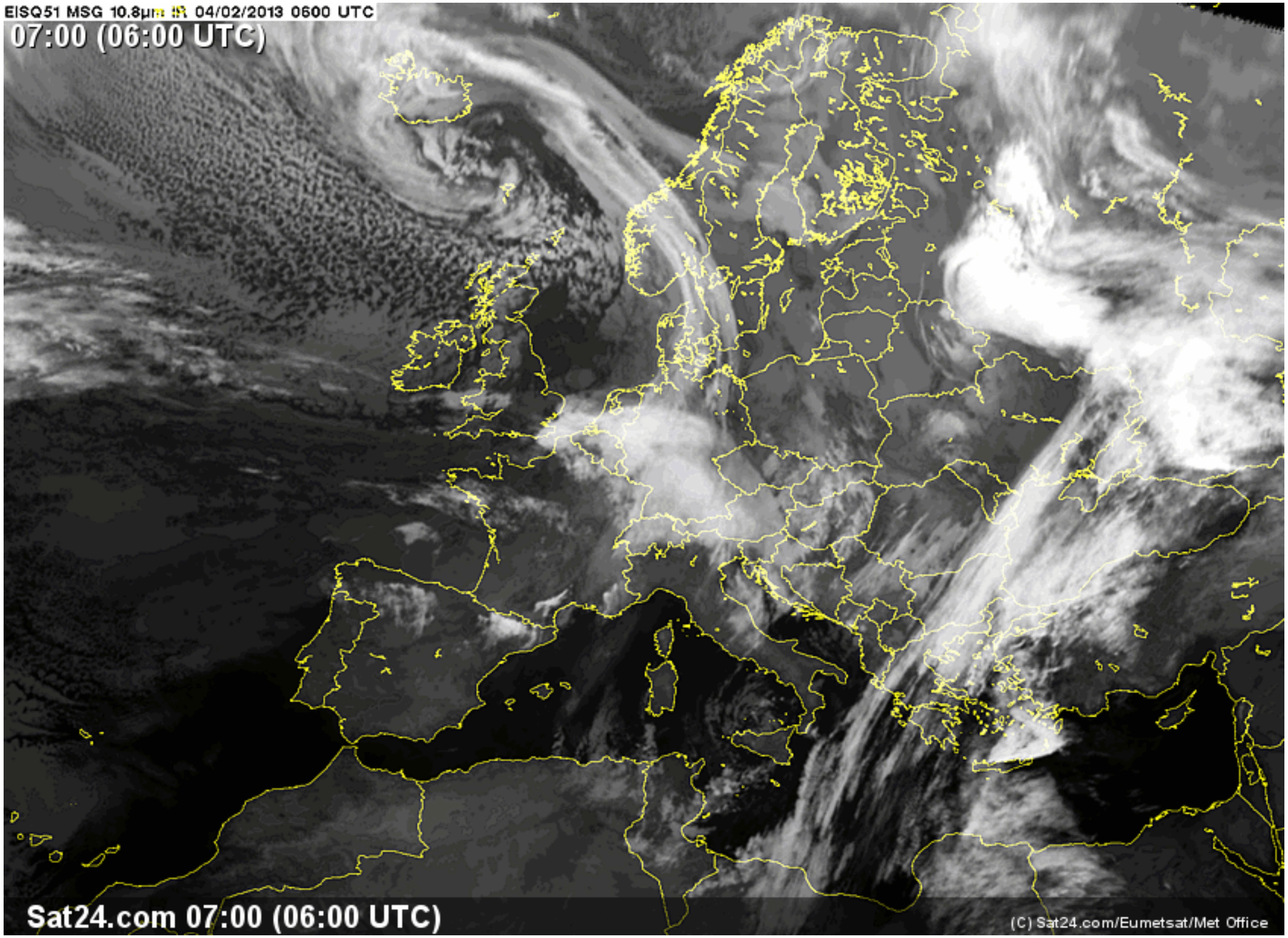


Figure 1: Examples of commonly used surface air temperature based precipitation phase determination schemes.

Case of snowfall in Moscow 3-4 Feb 2013



Case of snowfall in Moscow 3-4 Feb 2013

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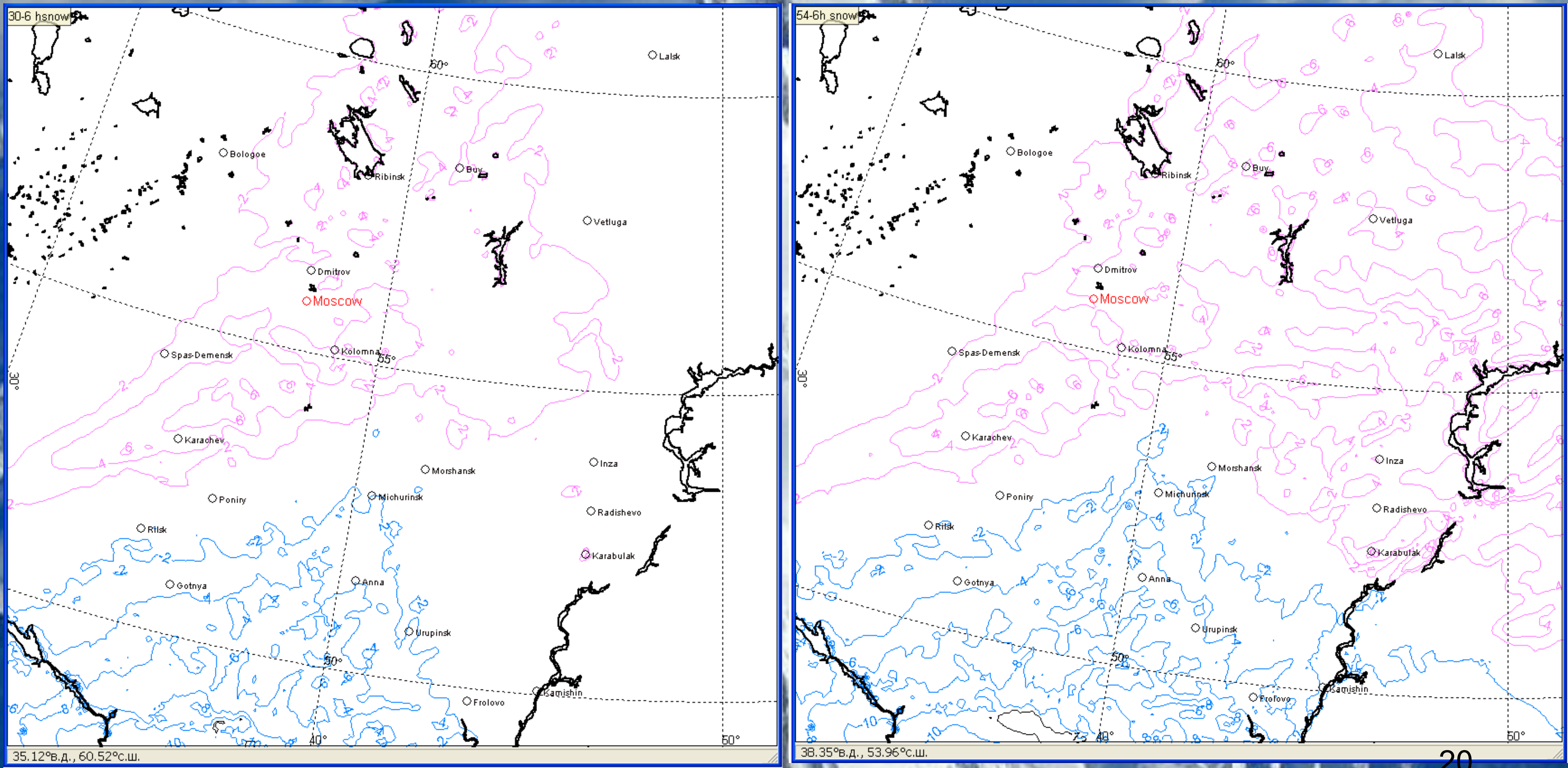
Case of snowfall in Moscow 3-4 Feb 2013

Differences between COSMO forecasts: snow height. Start 3 Feb 2013, 00 UTC

30h – 6h 54h – 6h



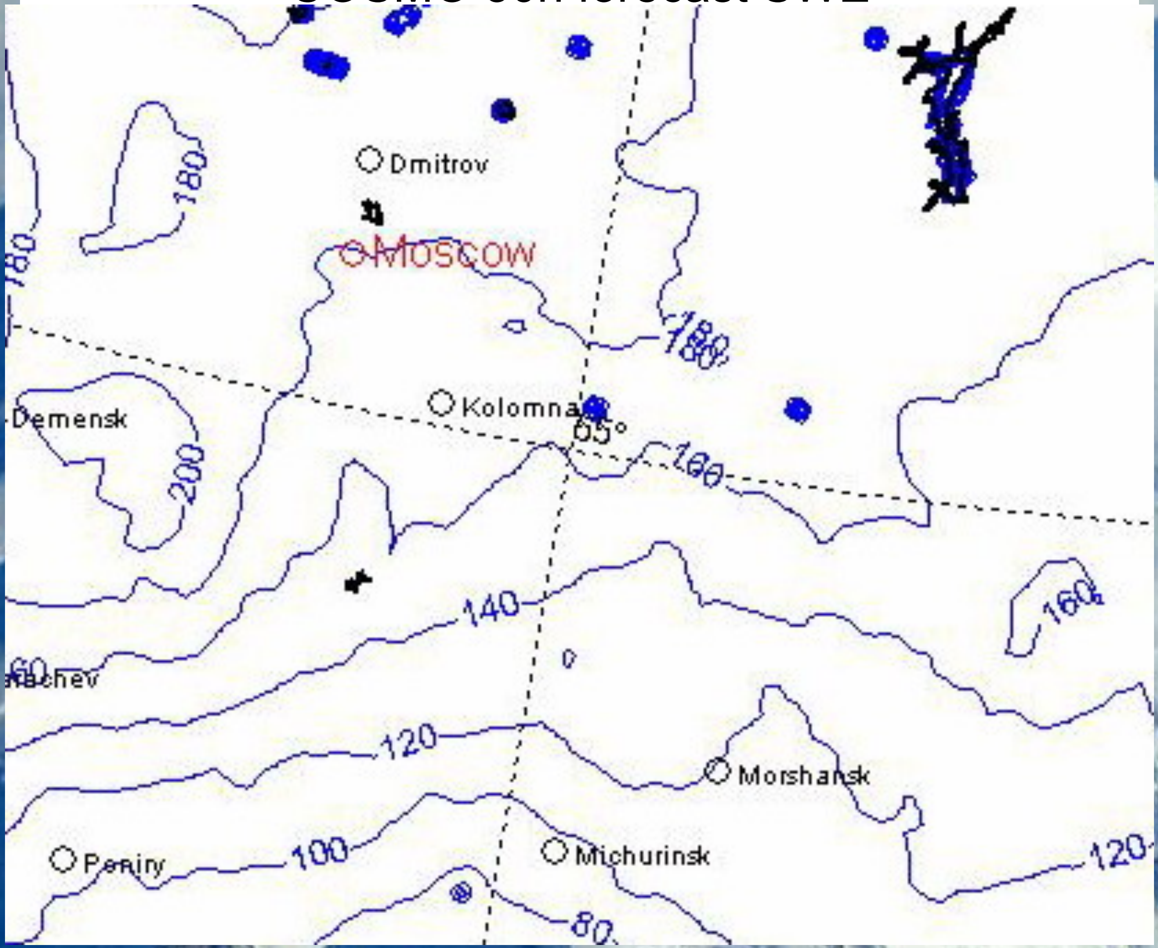
Case of snowfall in Moscow 3-4 Feb 2013

date	T2m obs (°C)	prec obs (mm)	H snow FSM (cm)	rho FSM (kg/m^3)	rho COSMO (kg/m3)	prec COSMO (mm)	T2m COSMO (°C)
2013020306	0,2	0,8	0,649	123,2	147,333	1,07	-0,4
2013020318	1	5	3,592	139,201	150,000	6,09	0,3
2013020406	0,3	2	1,597	125,2	149,333	13,6	-0,1
2013020418	-3,4	16	19,58	81,715	117,333	19,62	-4,9
2013020506	-7,1	2	2,808	71,225	102,000	19,93	-7,2
		25,8	28,226			18,86	

date	rho FSM (kg/m^3)
2013020318	125,201
2013020406	117,231
2013020418	75,649
2013020506	71,1

Case of snowfall in Moscow 3-4 Feb 2013

COSMO 30h forecast SWE

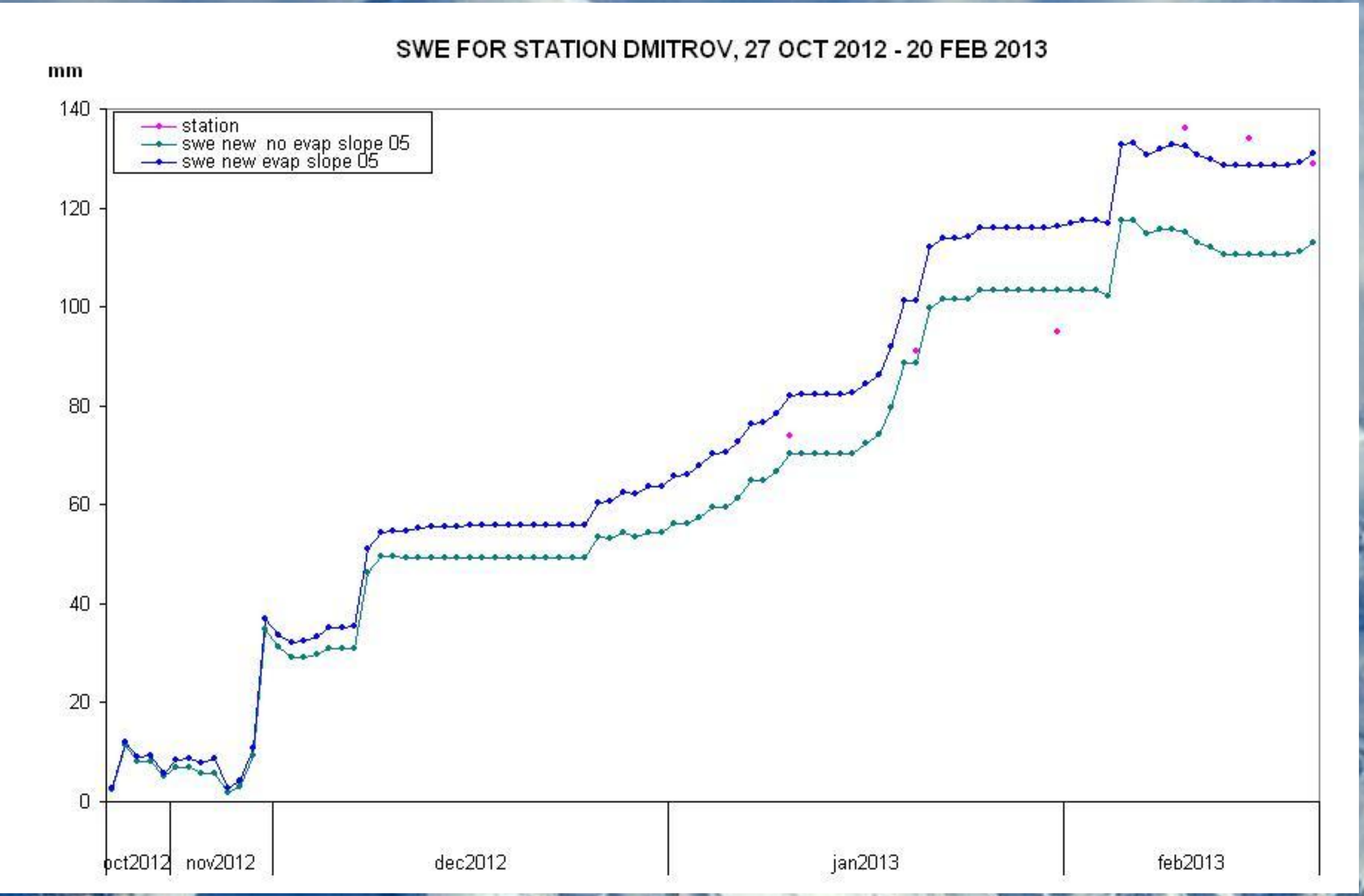


Model SMFE:
From 31 Jan to 10 Feb
102-133 mm

Hydrological measurements of SWE in Moscow region:

31 Jan 2013	95 mm
10 Feb 2013	136 mm

Case of snowfall in Moscow 3-4 Feb 2013



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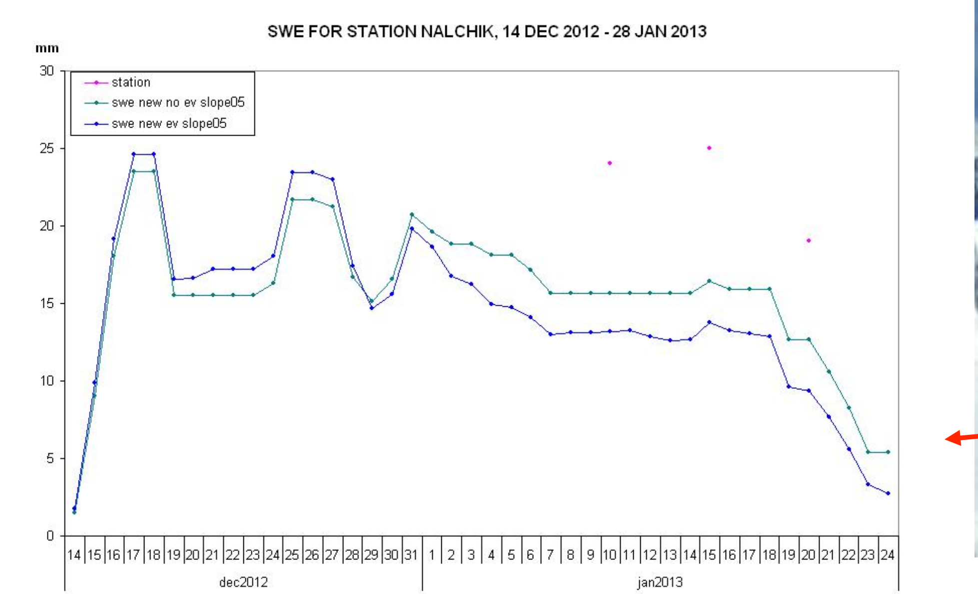

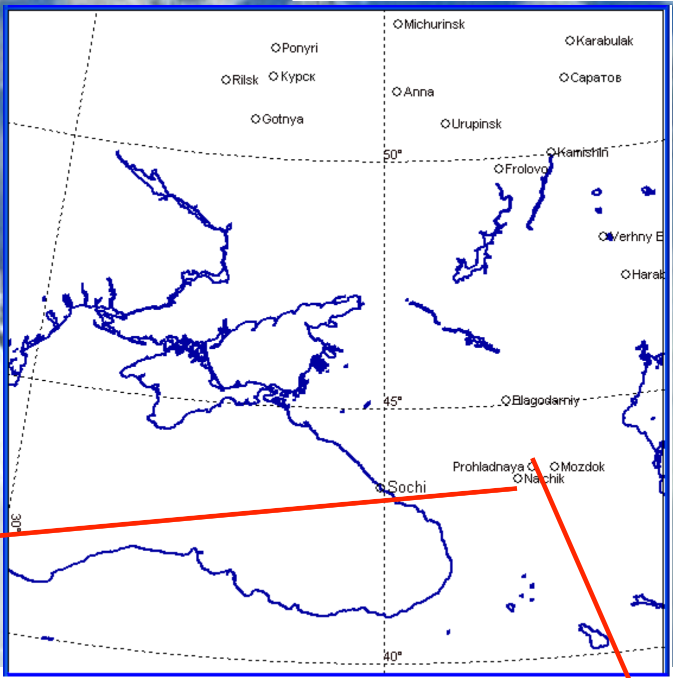

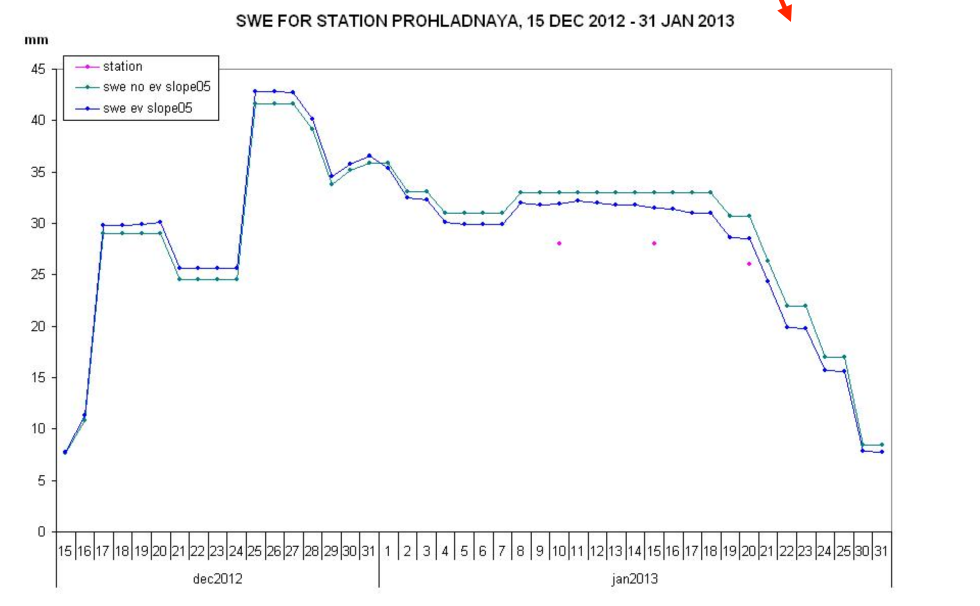

Results of SMFE-model

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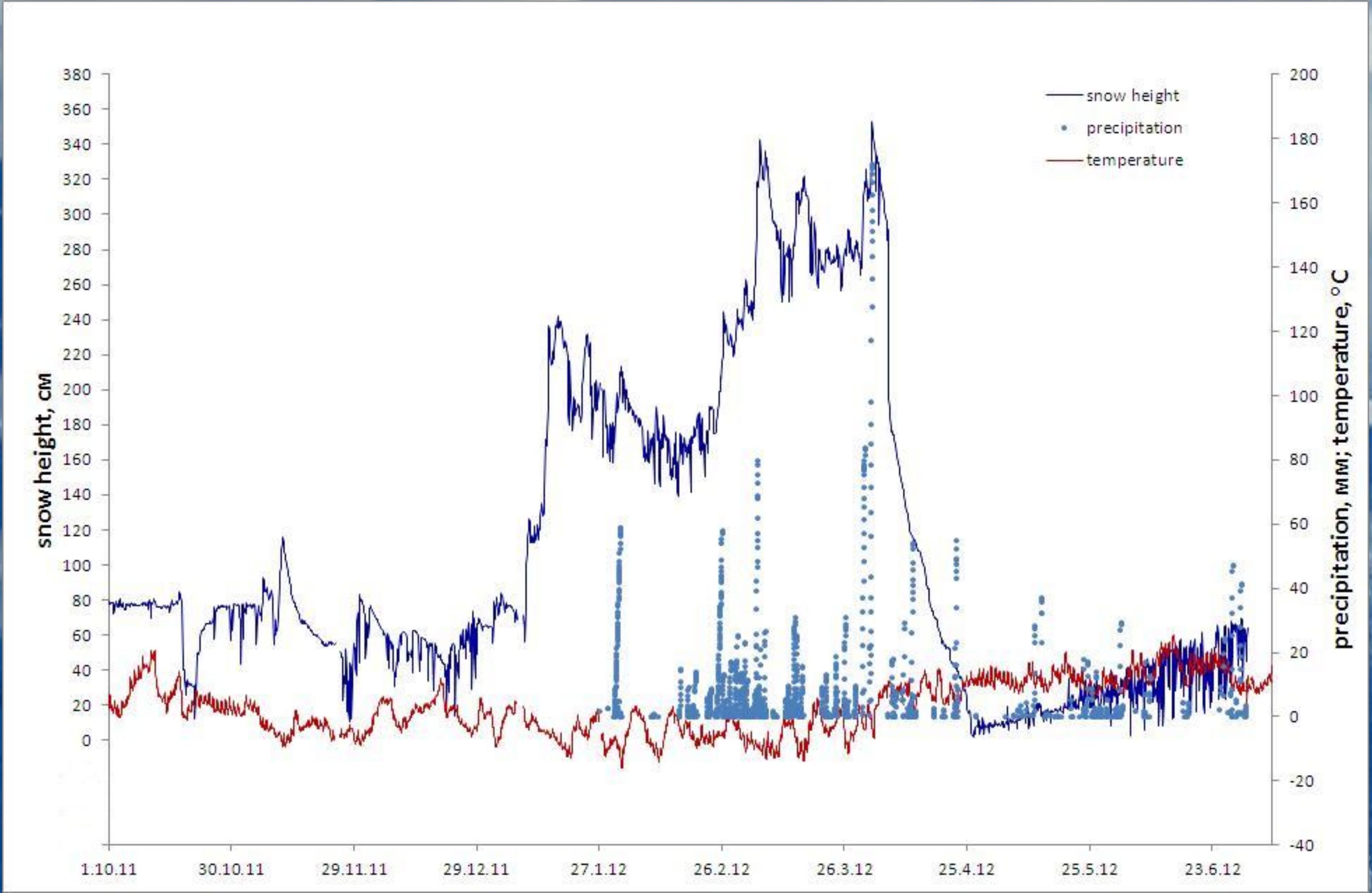
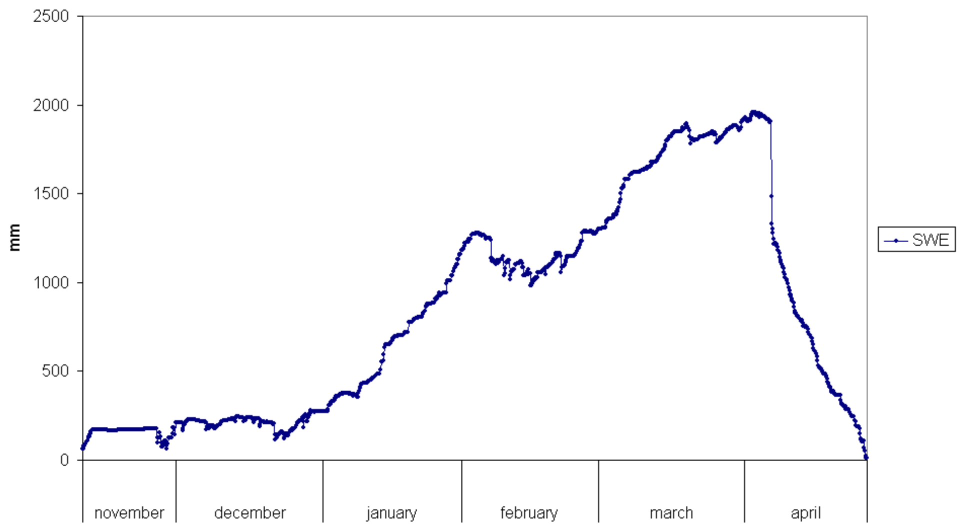
The representation of measured values of snow height, T2m and precipitation for the period 1 October 2011 – 1 August 2012 for station 11 in the Sochi region

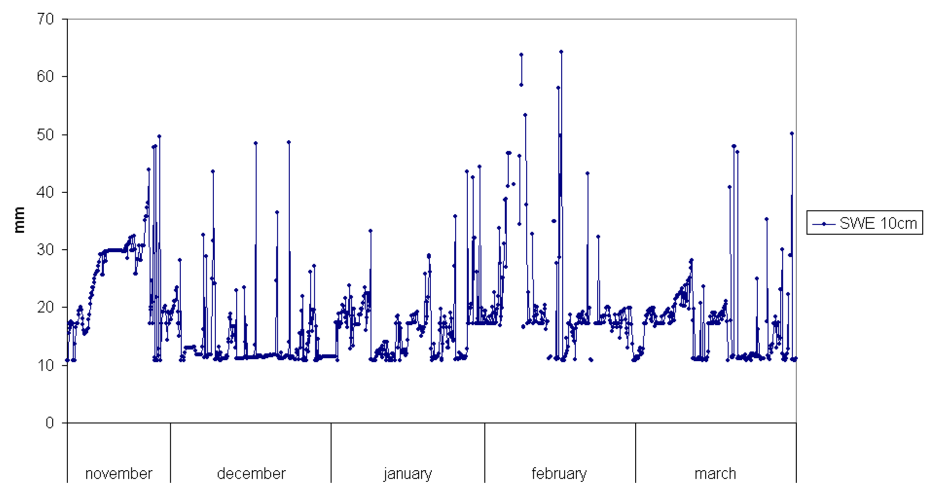


Snow aspects at Roshydromet

SWE for station 11 (height 1580 m) in November 2011 - April 2012



SWE for station 11 (height 1580 m) in November 2011 - March 2012. The upper 10 cm of snow



Results of SMFE-model

Comparison of FSM with observations on meteorological post Gornaya Karusel (H=1500 m)

date	precip, mm	type	add snow, cm	T2m, °C	rho snow, kg/m^3	add snow FSM, cm	rho snow FSM, kg/m^3
20130104	3,7	snow	6	-2,5	120-140	3,5-4,5	84-92
20130108	4,6	snow	4,6	-5,5	80-130	5,5-6,5	72-75
20130124	14	snow	3	3	230-300	7-10	120-200
20130130	8,2	snow	6	-0,5	110-120	7-8	102-120

Thank you for your attention!