Severe weather forecast for mountain region by high resolution models COSMO-Ru1 and COSMO-Ru2

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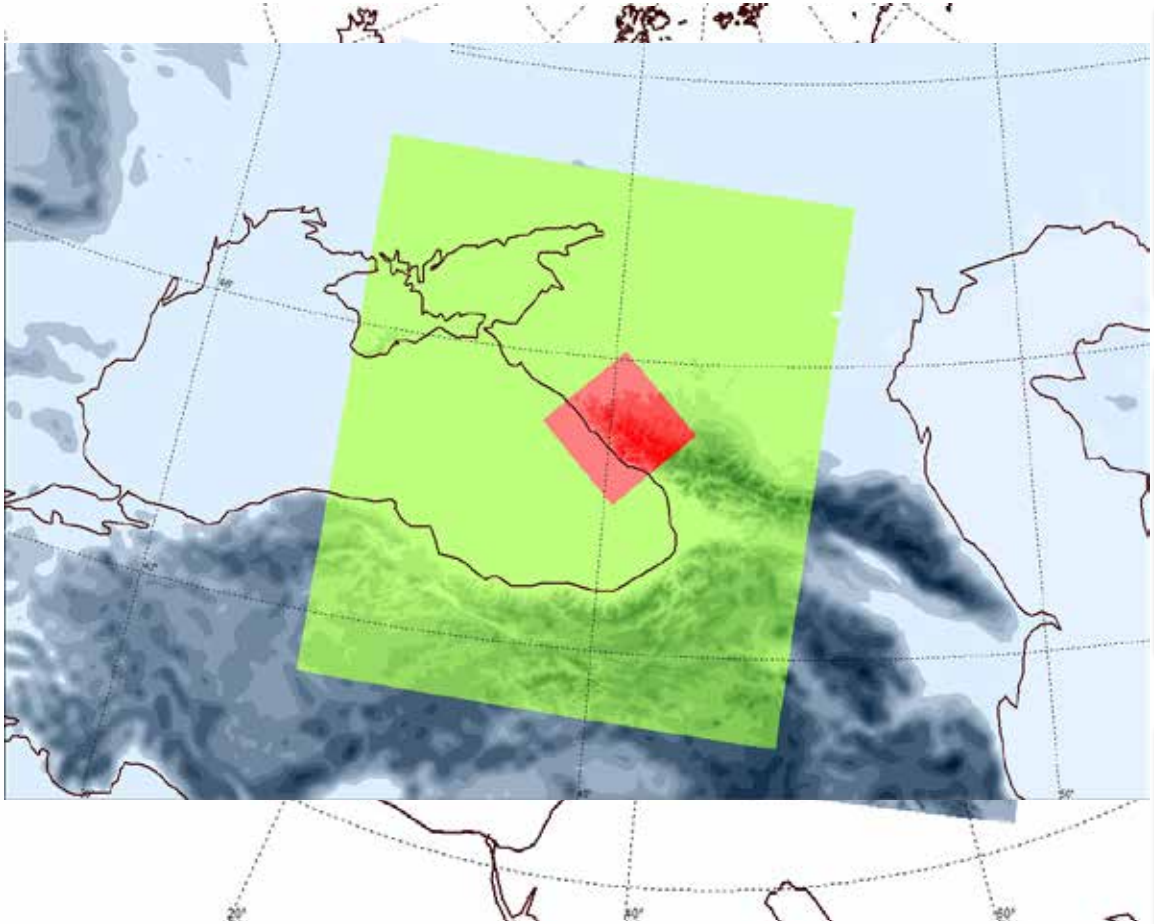
Outlines

- Model overview (domain, setup, orography)
- Observation data (network, tools and types)
- Severe weather case study
- Conclusion
- Future plans

Model overview

Model domain



COSMO-Ru1 runs in operational mode 4 times per day from January, 29, 2014

COSMO-Ru7
Domain: 4900 km x 4340 km
Grid: 700 x 620 x 40
Space step: 7 km
Time step: 40 s
Forecast: 78 h

IC&BC

COSMO-Ru2
Domain: 900 km x 1000 km
Grid: 420 x 470 x 50
Space step: 2.2 km
Time step: 20 s
Forecast: 48 h

IC&BC

COSMO-Ru1
Domain: 209 km x 209 km
Grid: 190 x 190 x 50
Space step: 1.1 km
Time step: 5 s
Forecast: 36 h

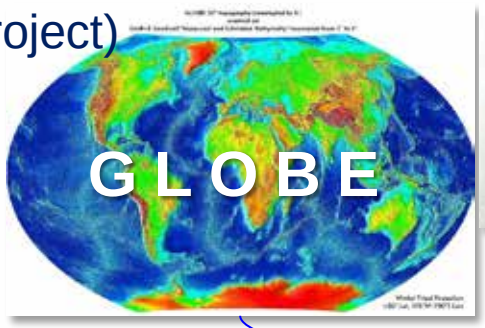
Model overview

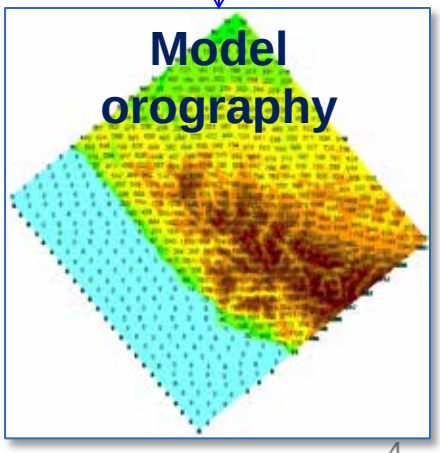
Model orography

Initially model orography was based on the **GLOBE** (The Global Land One-km Base Elevation Project) data (NOAA/NGDC).

Rather large difference between model's grid height and observation points height, and ASTER data also, forced us to correct model orography.

New orography is based on the **ASTER** (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data that has resolution 1" (~ 30 m) (METI/NASA).





With new orography:

- ***T2m and wind forecast* have been improved for the most sites;**
- **slightly improvement of the precipitation forecast was noticed;**
- **there are changes in the precipitation amount, its space and time distribution.**

Observation network

Meteorological stations

Total number	**33**
Roshydromet stations	13
Automatic meteo station (AMS)	20

Most of the AMS are located in the mountain cluster next to the sports facilities.

Variables

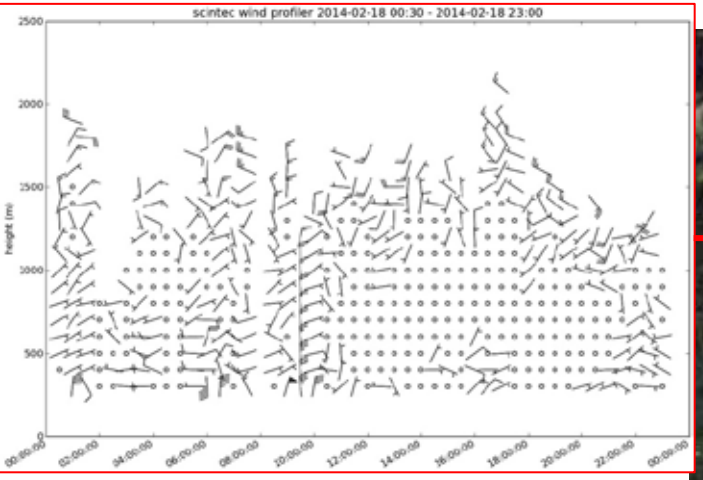
- Pressure
- Air temperature at 2 m,
- Dew point temperature at 2 m
- Relative humidity at 2 m
- Wind speed (mean, min, max) and direction (average period …)
- Wind gust
- Lowest cloud base altitude
- Precipitation rate (average period …)
- Visibility
- Snow depth
- Snow temperature

Radars	4
Profilers	3
Video cameras	3+4x2

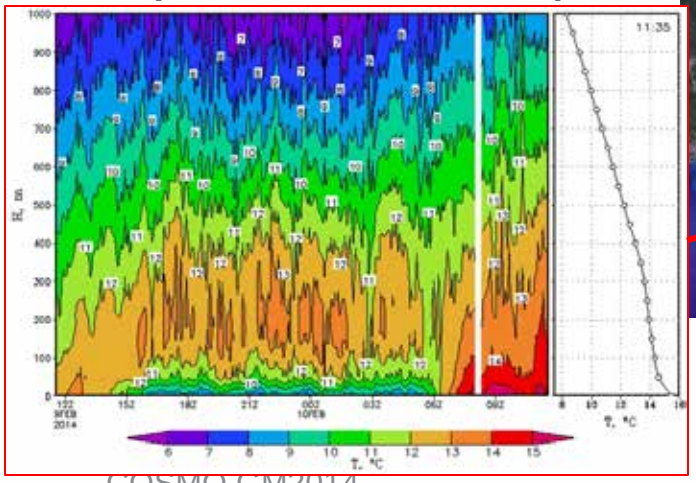
Observation network

Profilers

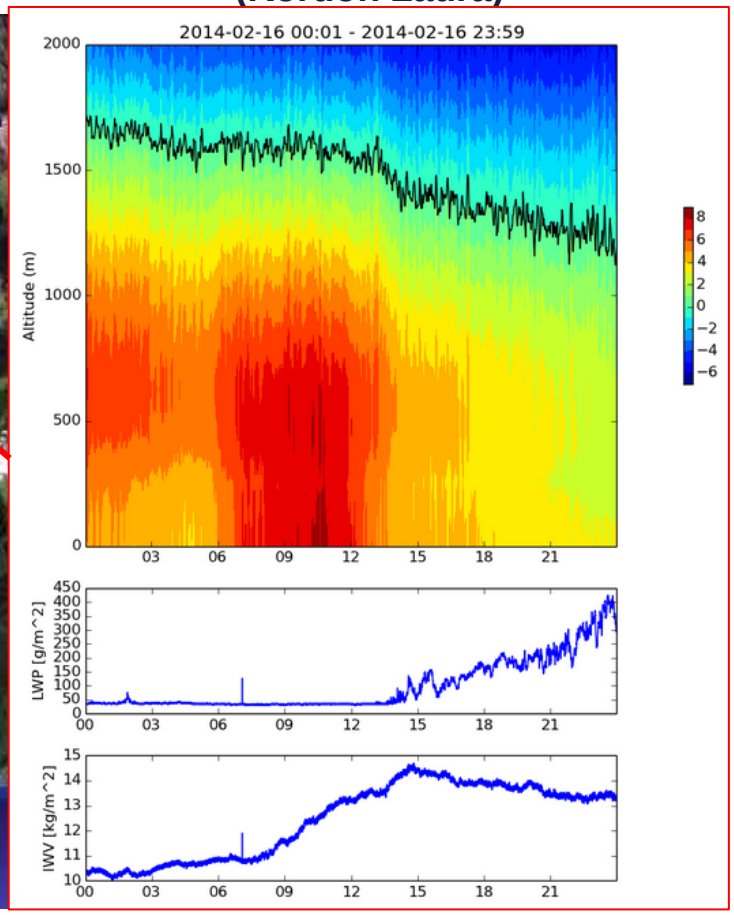
Scintec wind profiler (Kordon Laura)



MTP-5 Temperature Profiler Data (Adler, altitude 6+1.5 m)



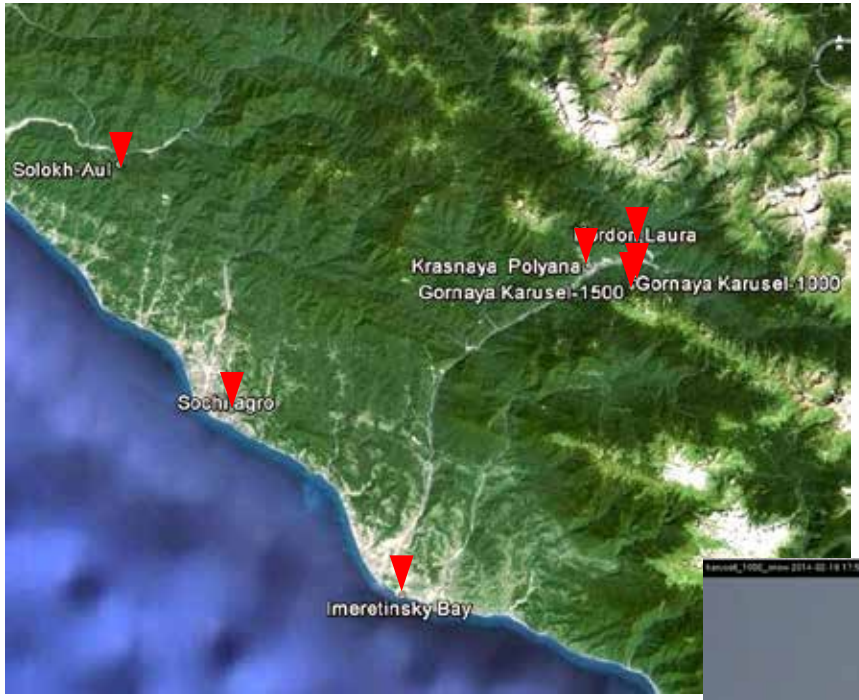
PRG Temperature/Humidity Profiler (Kordon Laura)



Update rate – 20 min for MTP-5 data / 15 min for Scintec

Observation network

Video cameras



Sky conditions and development of the clouds

Surface conditions

fresh snow

Single cam – 3 sites
(2 at the seashore and one at 11 km from the sea)
Paired cam – 4 sites, all within the valley at different altitude (560, 570, 980, 1400 m)

Update rate – 10 min

Case study

Most interesting cases during the Olympics/ Paralympics

N	Date	Meteorological process \ phenomenon	Models' behavior	Impact on competitions
1	February, 07	Foehn	Poor T forecast by most models at Biathlon Stadium	
2	**February, 16**	**Low visibility**		**Postponed competitions at Laura and Extreme Park**
3	**February, 18**	**Cold front**	Good precipitation forecast by most model	
4	February, 22	Foehn	Poor T forecast by most models	
5	**March, 11**	**Cold front & Low visibility**	T_{max} forecast not good by most models	**Postponed skiing competitions at Roza Khutor**
6	March, 13	"Weak" process	Poor precipitation forecast by most models at altitude above 1500 m	
7	March, 17	Cold front	Poor V_{max} forecast by most models at altitude above 1500 m	

List is prepared by T. Dmitrieva

Case study

q On February, 16-18, 2014 in mountain cluster low visibility conditions were observed. The first reason was in high humidity and formation of cloud on the mountain slopes (February, 16-17). The second reason was in heavy snowfall during cold front passing (February, 18).

q Another case of low visibility (March, 11) was connected with cold front.

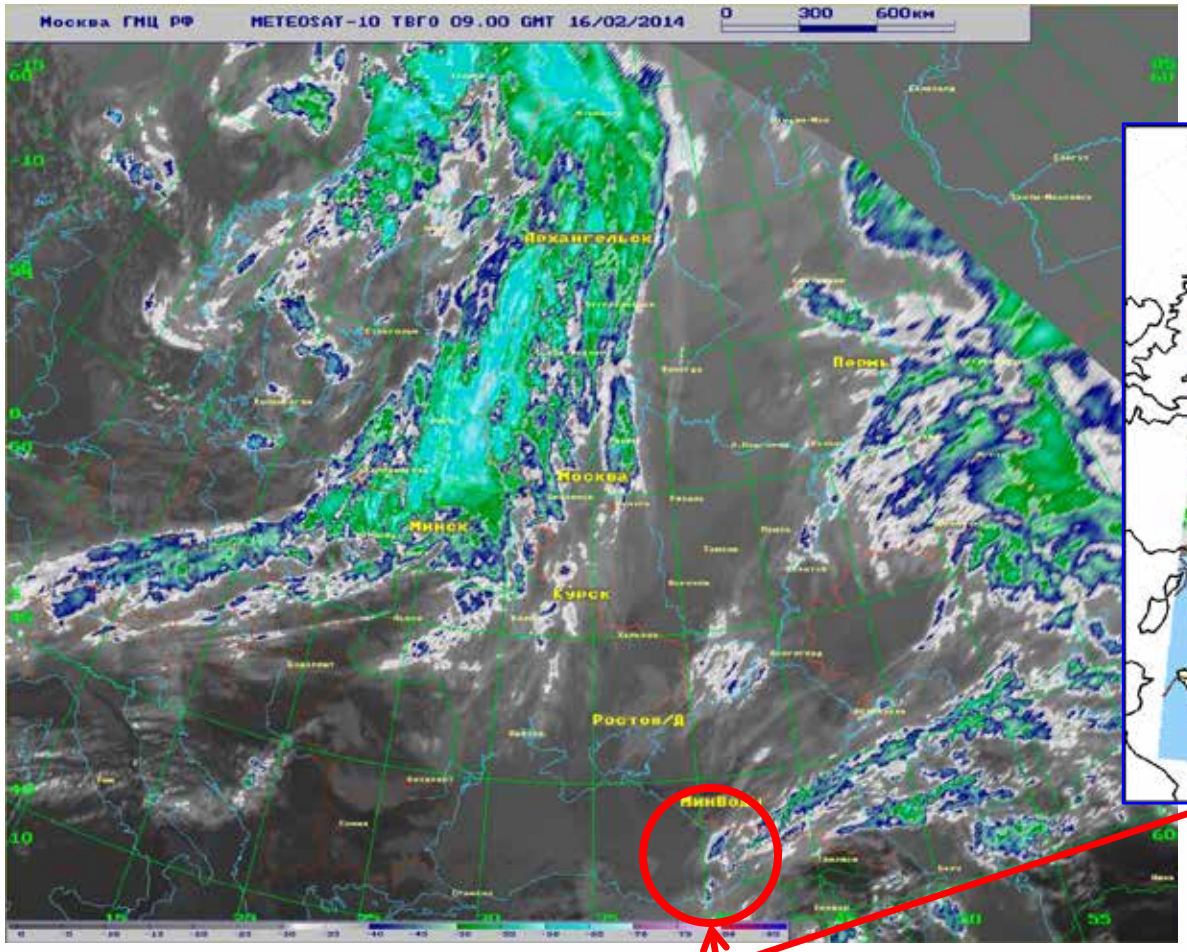
Could we make good forecast of visibility using COSMO-Ru2 or/and COSMO-Ru1 results???

Direction of the study

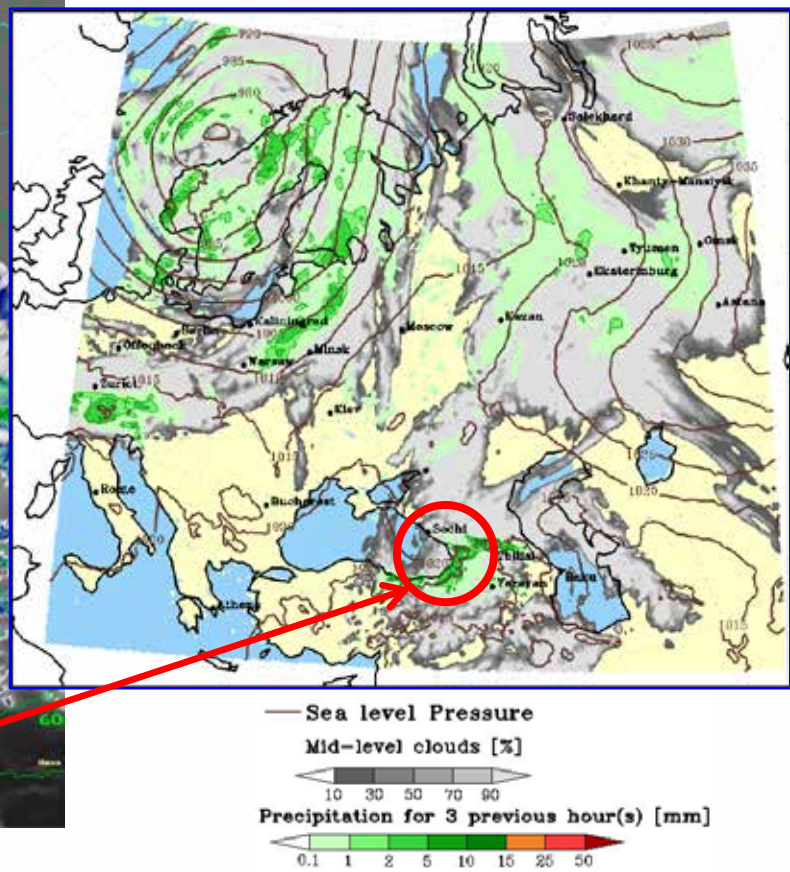
- ü review the synoptic situation
- ü browse observations
- ü investigate models results
- ü make conclusions

Low visibility on February, 16-17, 2014

METEOSAT-10. Cloud top temperature
16.02.2014, 09 UTC



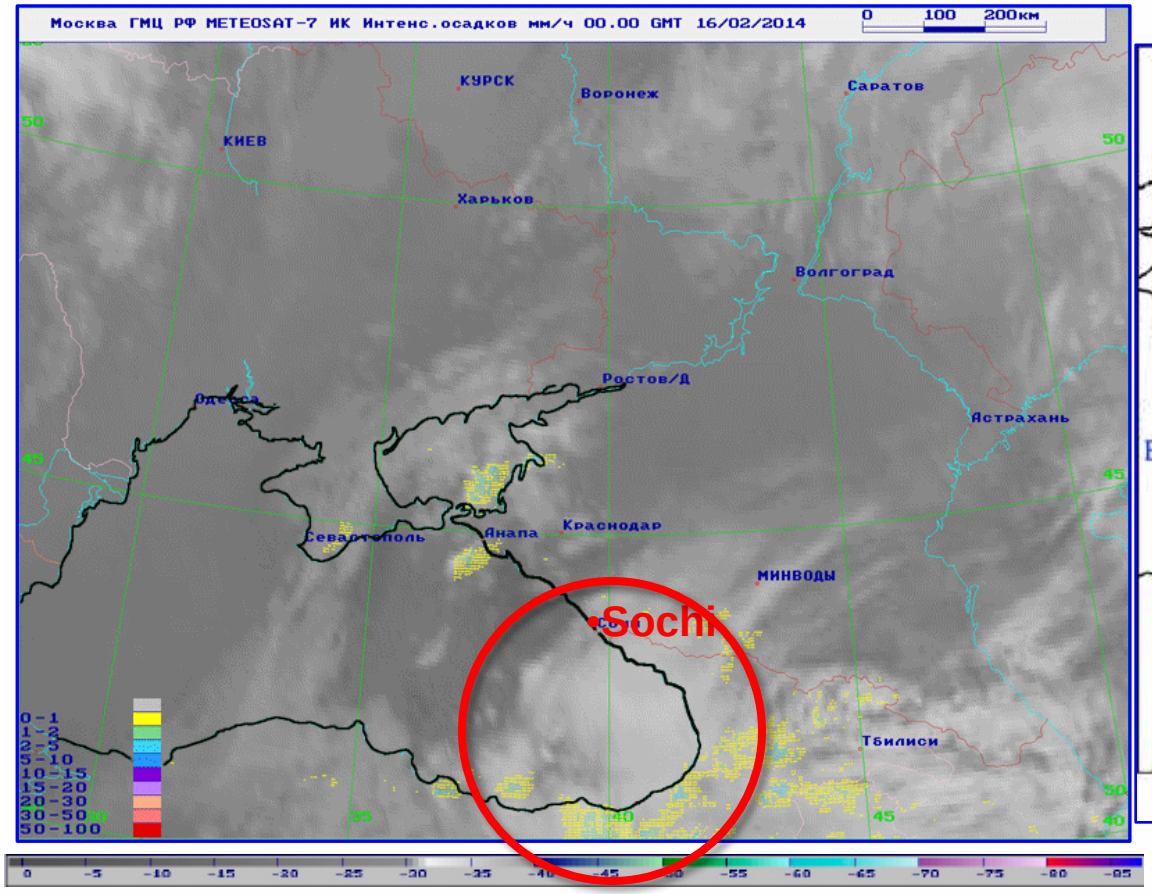
COSMO-Ru7 forecast.
PMSL, Midlevel Cloud & Precipitation
9 h forecast from 16.02.14, 00 UTC



Local cyclone existed during first half the day on February, 16.
Instability zone was observed on satellite images till 15 UTC, 16.02.

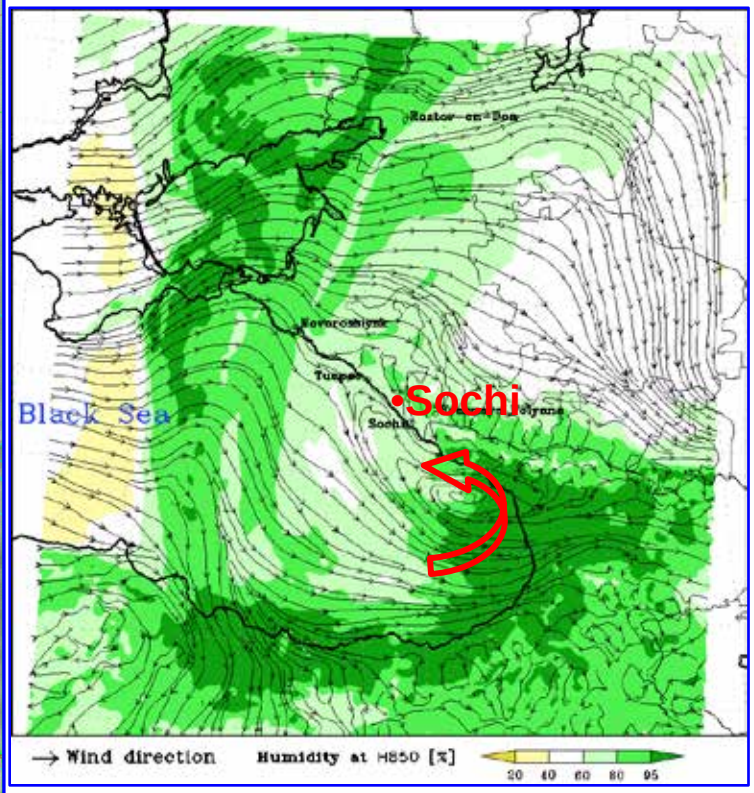
Low visibility on February, 16-17, 2014

METEOSAT-7. Cloudiness and precipitation rate 16.02.2014, 00-22 UTC



COSMO-Ru2 forecast Stream lines and relative humidity at 850 hPa

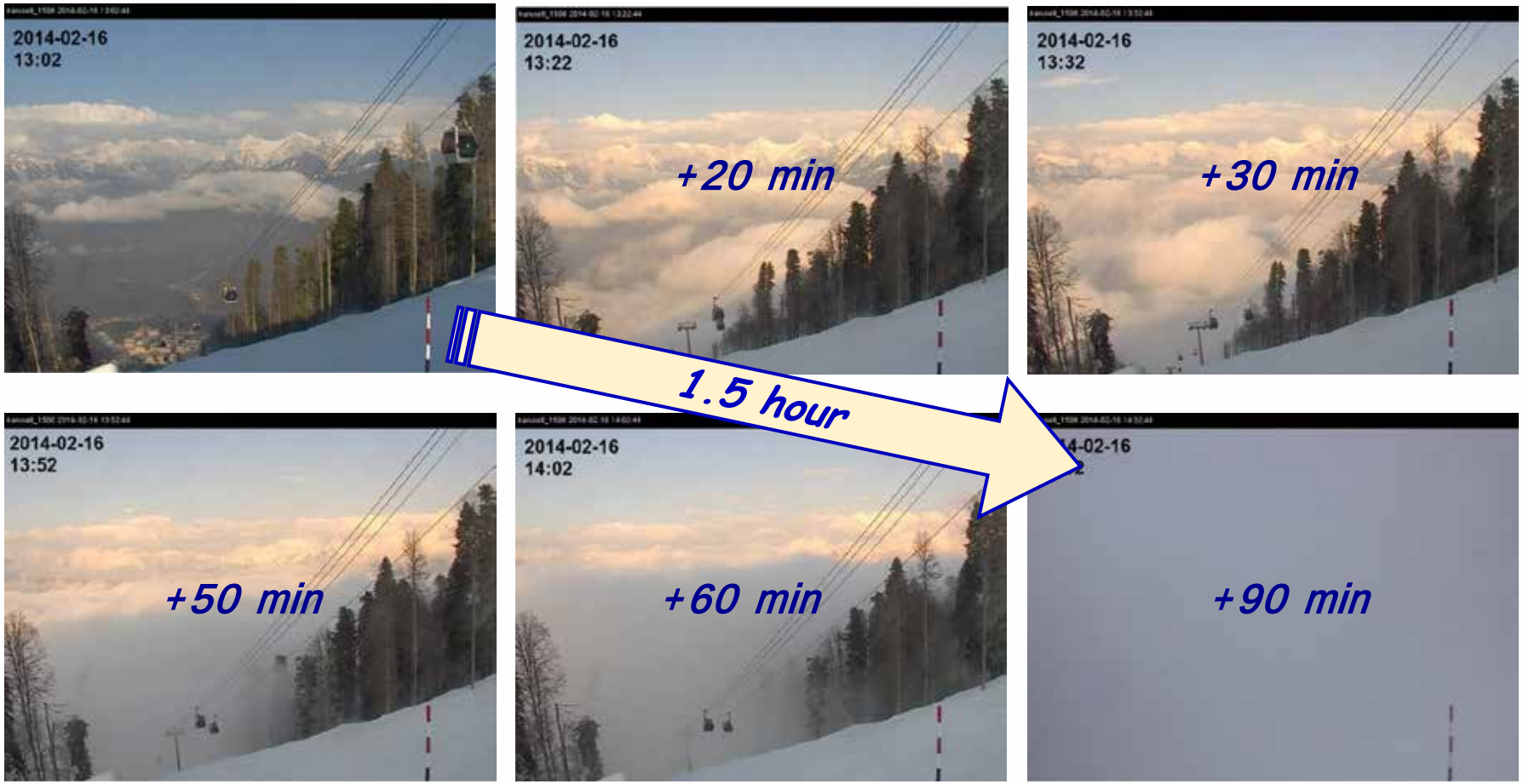
12 h forecast from 16.02.14, 00 UTC



COSMO-Ru2 forecast shows movement of humid air towards Sochi region along the coastline

Low visibility on February, 16-17, 2014

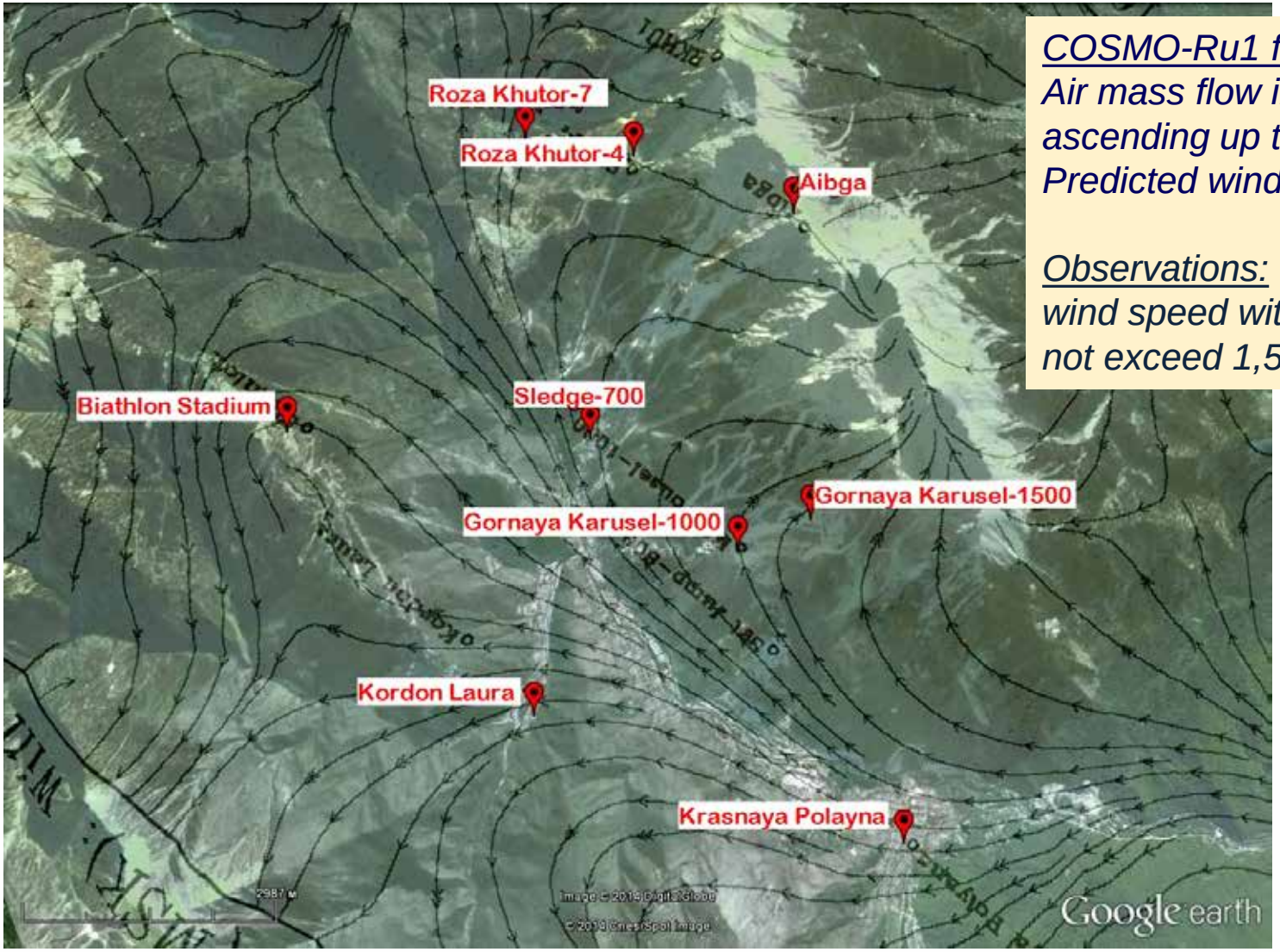
Cloudiness formation due to adiabatic cooling of the moisture air during it rise along the slope of the valley



Camera shots at Gornaya Karusel-1500

Low visibility on February, 16-17, 2014

COSMO-Ru1 wind 13 h forecast from 16.02.2014, 00 UTC for mountain cluster

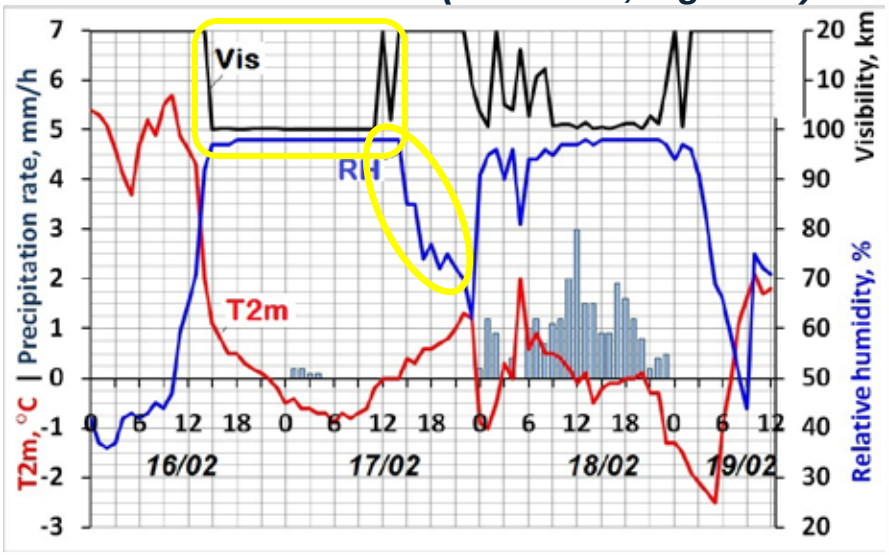


COSMO-Ru1 forecast:
Air mass flow into the valley ascending up the slopes.
Predicted wind speed – 0.5-2 m/s.

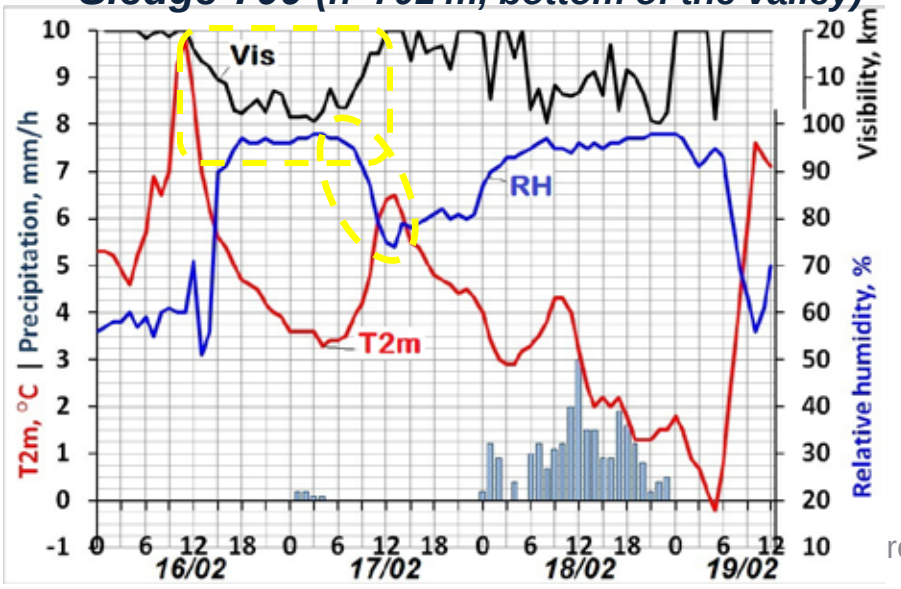
Observations:
wind speed within the valley does not exceed 1,5-2 m/s.

Low visibility on February, 16-17, 2014

***Biathlon Stadium** (h=1455 m, highland)*



***Sledge-700** (h=701 m, bottom of the valley)*



On February, 16-17 there were favorable conditions for the fog (cloudiness) formation and its conservation for a long period of time:

- the presence of snow cover,
- -5°C < T2m < +5 °C,
- wind speed < 1m/s.

At an altitude of 1000 -1500 m low visibility was observed from 14-15 UTC (17-18 h local time) on February, 16 till 12-13 UTC (15-16 h local time) on February, 17.

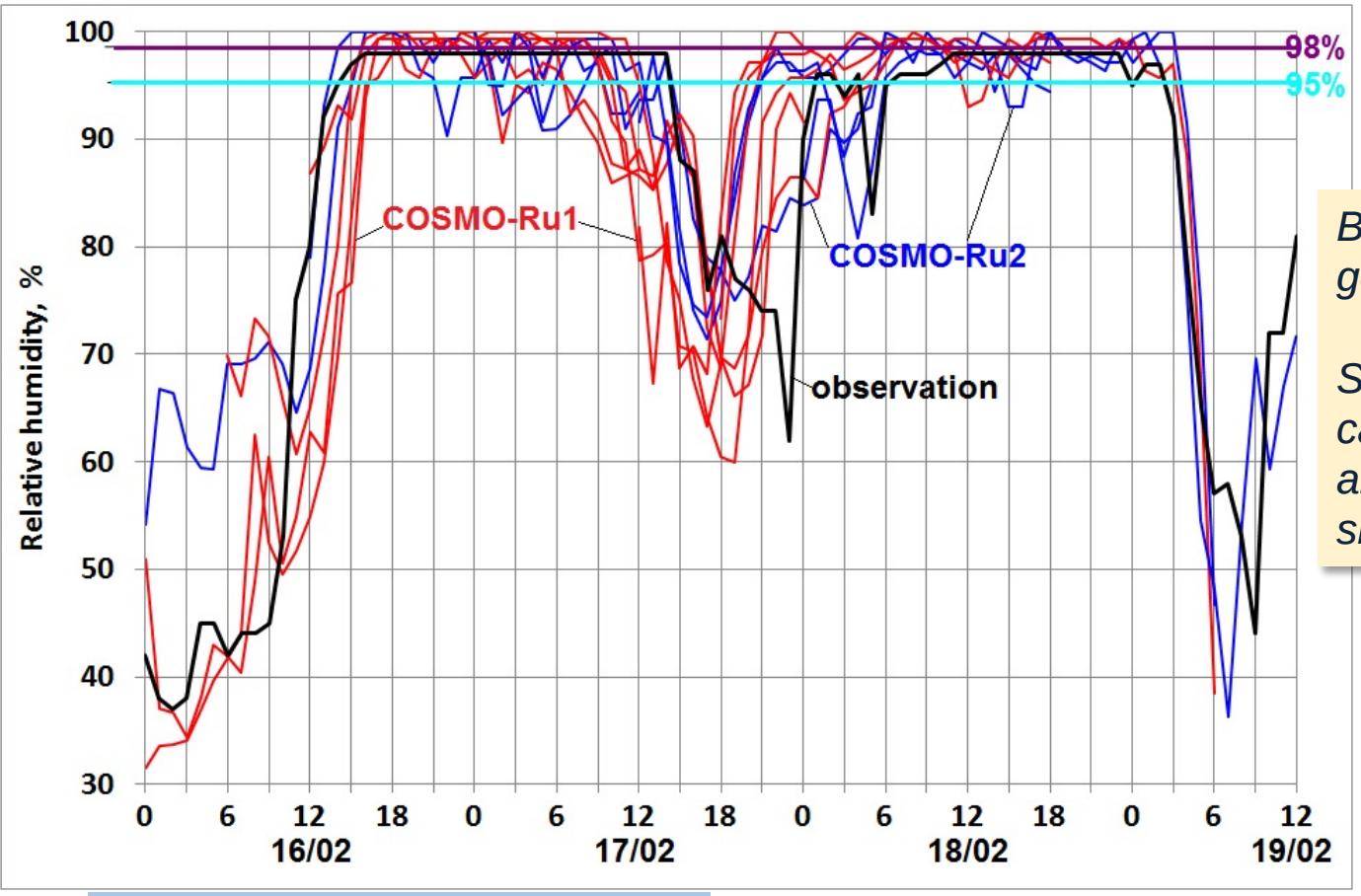
Observed <u>minimum</u> visibility values:

- Roza Khutor 4 (h=1580 m) 44 m
- Biathlon Std. (h=1470 m) 29 m
- G.Carusel 1500 (h=1434 m) 25 m
- Roza Khutor 7 (h= 980 m) 97 m
- G.Carusel 1000 (h= 978 m) 59 m
- *Sledge -700 (h= 701m) 336 m*

Subsequent <u>decrease of the relative humidity</u> and an increase in wind led to the dissipation of the fog (cloudiness).

Low visibility on February, 16-17, 2014

Relative humidity observation, COSMO-Ru1 and COSMP-Ru2 forecasts for Biathlon



Both models gave rather good results.

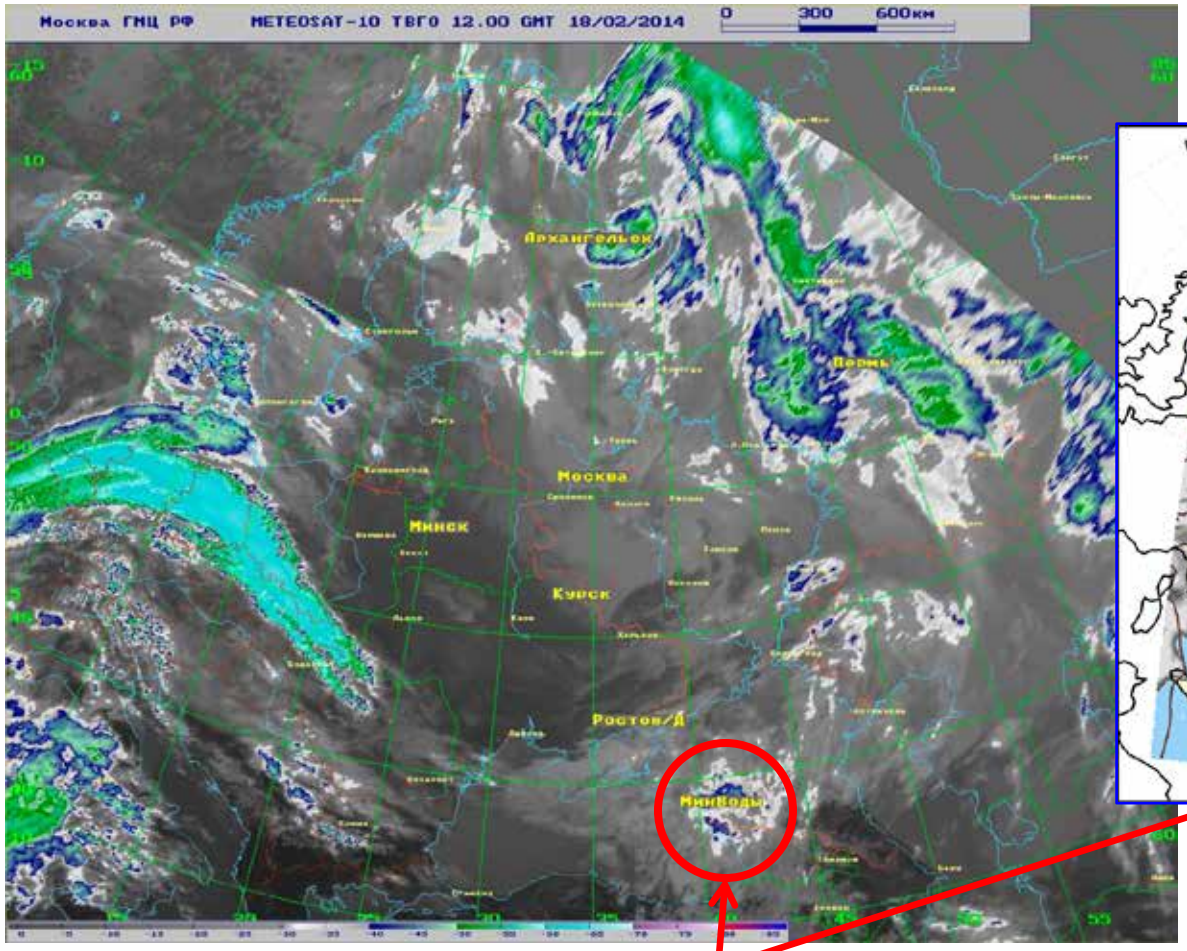
Some discrepancies can be caused by the difference in altitude between observation site and model grid node.

COSMO-Ru2 42 h forecasts from:
- 16/02, 00, 12 UTC;
- 17/02, 00, 12 UTC;
- 18/02, 00 UTC

COSMO-Ru1 36 h forecasts from:
- 15/02, 18 UTC
- 16/02, 00, 06, 12, 18 UTC;
- 17/02, 00, 06, 12, 18 UTC;

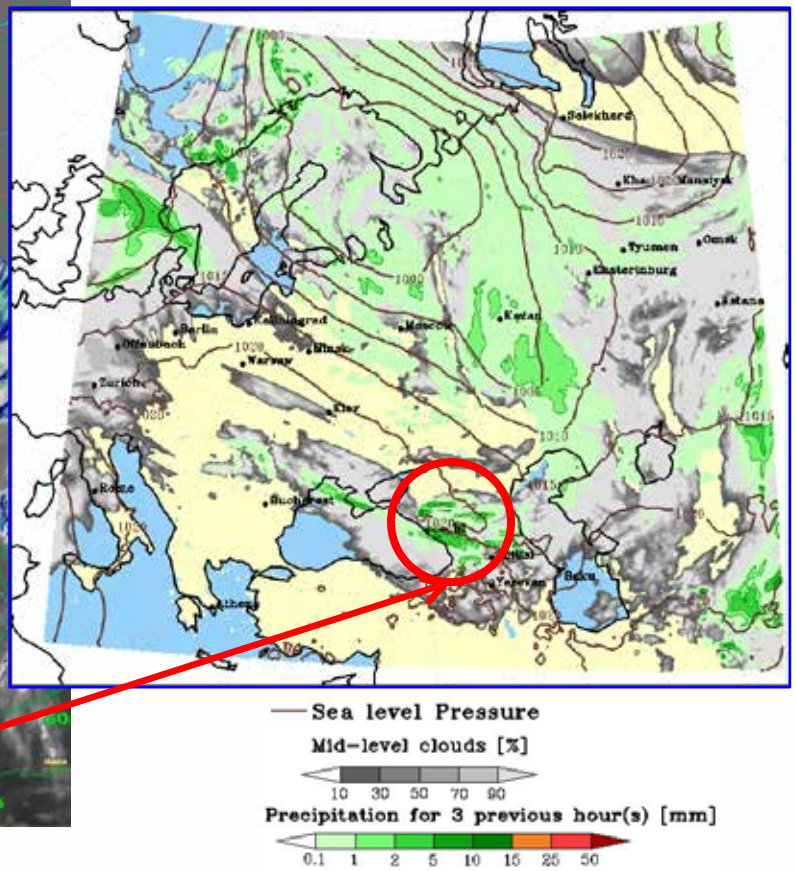
Cold front on February, 18, 2014

METEOSAT-10. Cloud top temperature 18.02.2014, 12 UTC



COSMO-Ru7 forecast. PMSL, Midlevel Cloud & Precipitation

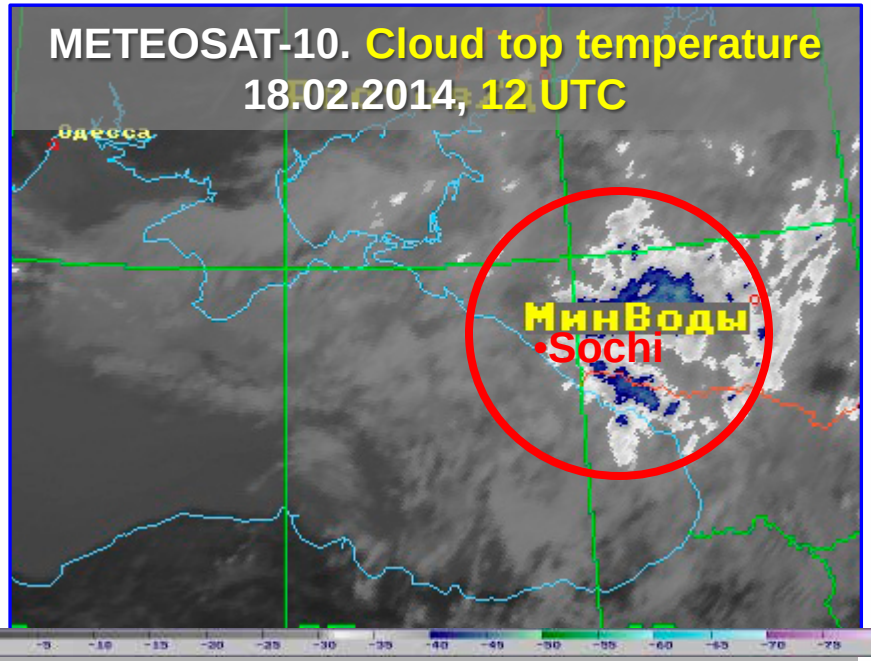
60 h forecast from 16.02.14, 00 UTC



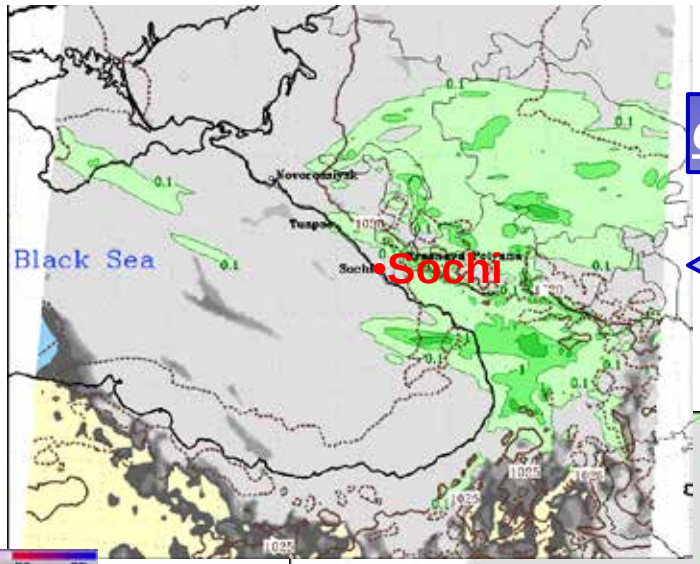
Cold front intensification when faced with mountain ridge

Cold front on February, 18, 2014

METEOSAT-10. Cloud top temperature
18.02.2014, 12 UTC

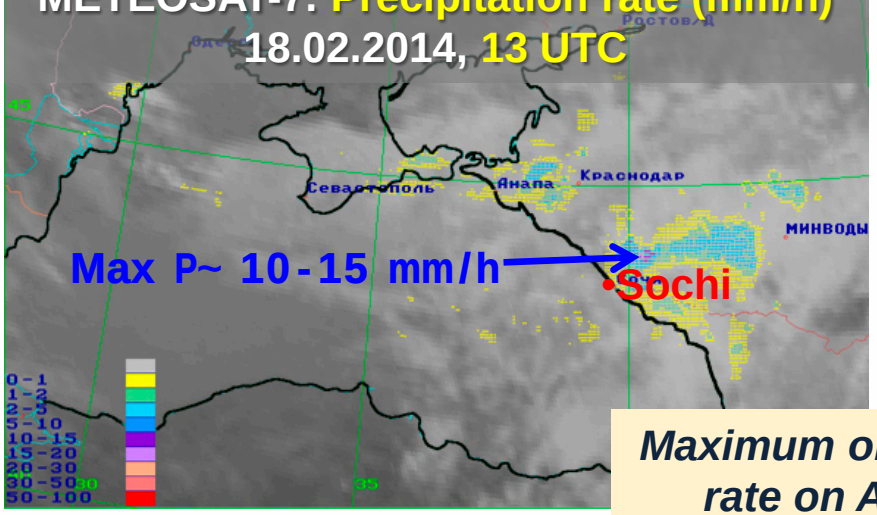


PMSL, Midlevel Cloud & 1h Precipitation
24 h forecast from 17.02.14, 12 UTC

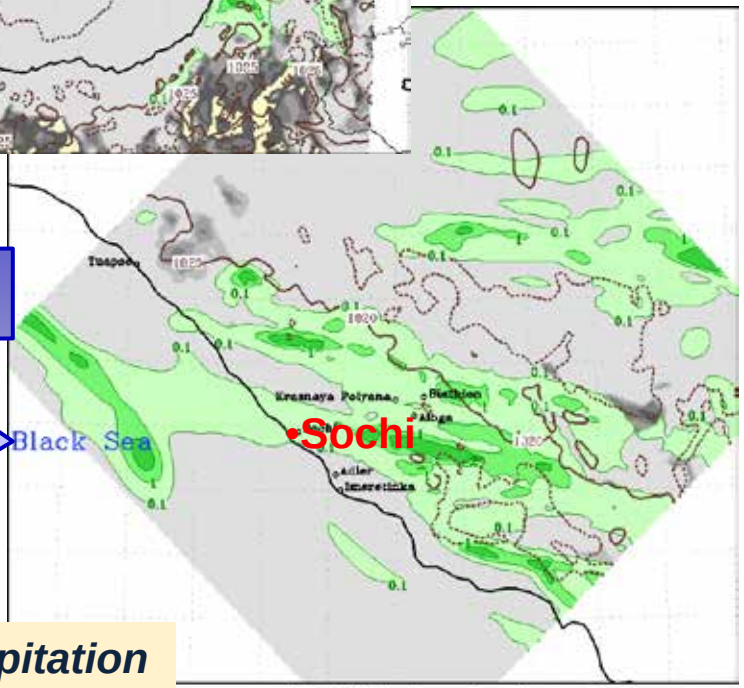


COSMO-Ru2

METEOSAT-7. Precipitation rate (mm/h)
18.02.2014, 13 UTC

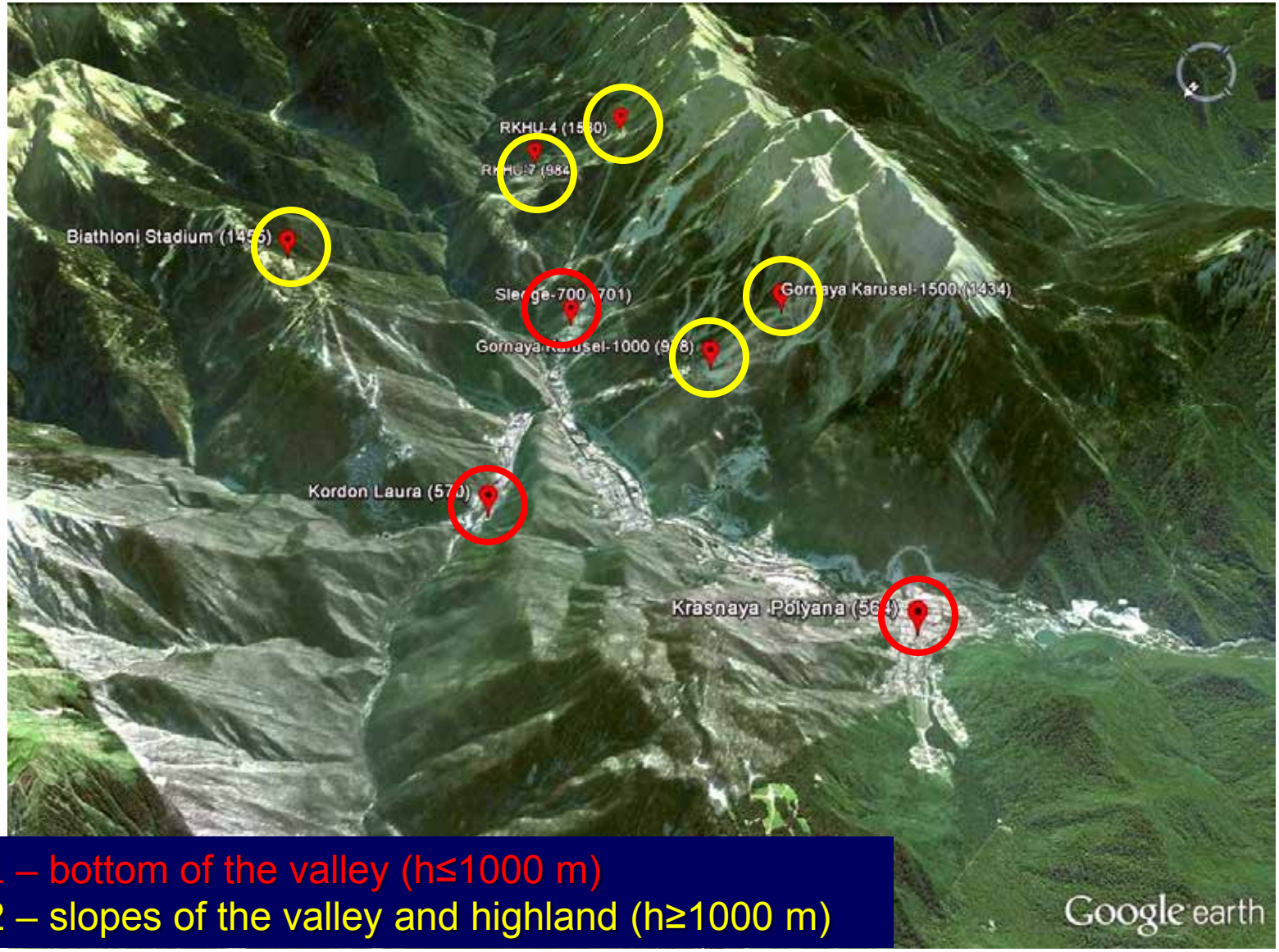


COSMO-Ru1



Maximum observed precipitation rate on AMS was 3.9 mm/h

Cold front on February, 18, 2014



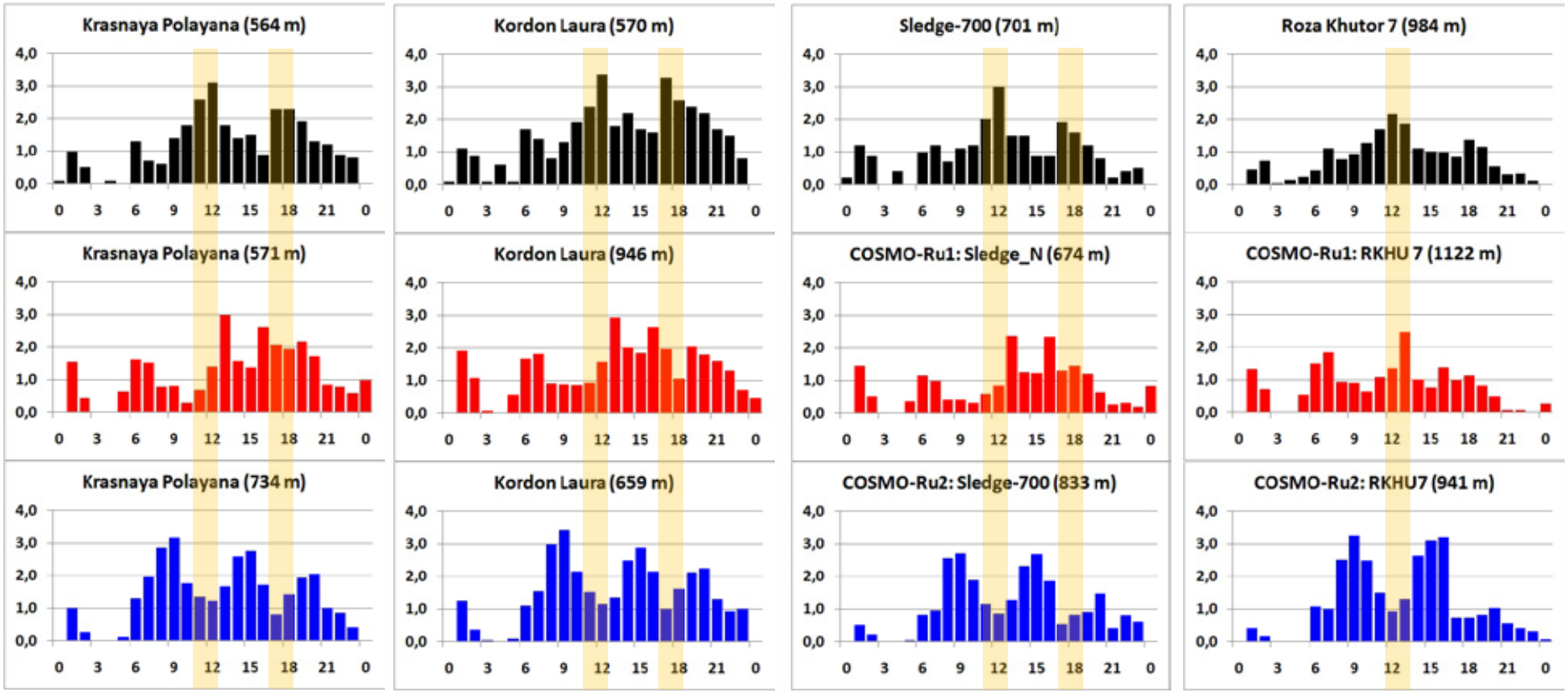
Set 1 – bottom of the valley (h≤1000 m)
Set 2 – slopes of the valley and highland (h≥1000 m)

Cold front on February, 18, 2014

Precipitation rate (mm/h). Observation, COSMO-Ru1 and COSMO-Ru2 forecasts

Sites located in the bottom of the valley

Site locates on the slope



Total precipitation, mean and maximum precipitation rate (mm/h)

Observations	29.5	1.2	3.1
COSMO-Ru1	29.3	1.2	3.0
COSMO-Ru2	32.3	1.3	3.2

Observations	37.6	1.5	3.4
COSMO-Ru1	32.6	1.3	2.9
COSMO-Ru2	34.8	1.4	3.4

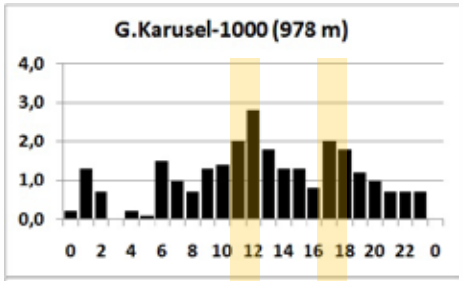
Observations	24.3	1.4	3.0
COSMO-Ru1	20.4	0.8	2.4
COSMO-Ru2	25.5	1.0	2.7

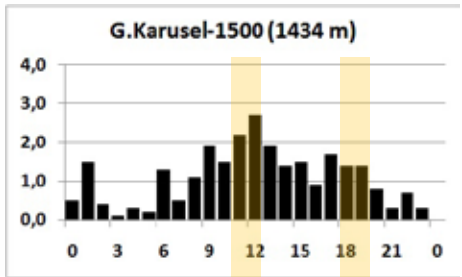
Observations	19.7	0.8	2.2
COSMO-Ru1	20.3	0.9	2.7
COSMO-Ru2	28.3	1.1	3.3

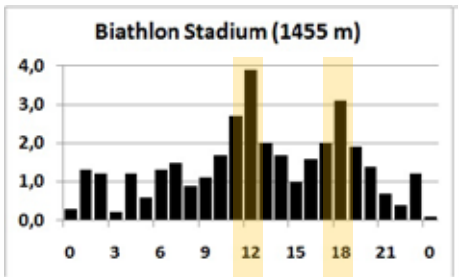
Cold front on February, 18, 2014

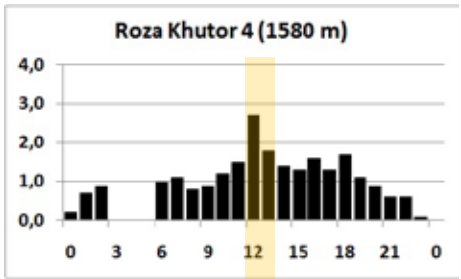
Precipitation rate (mm/h). Observation, COSMO-Ru1 and COSMO-Ru2 forecasts

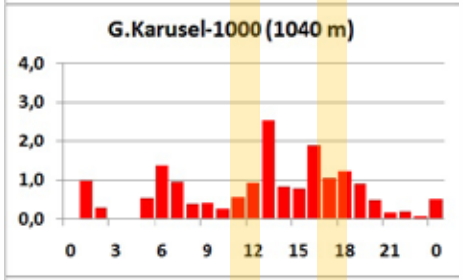
Sites located on the slopes of the valley and in the highland

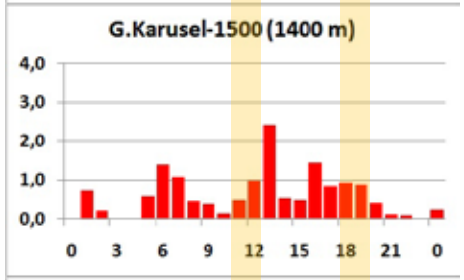


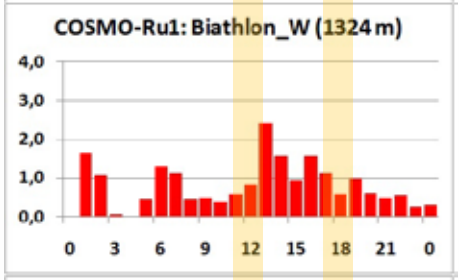


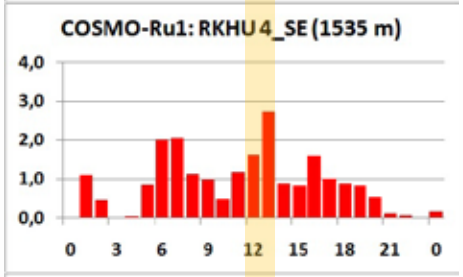


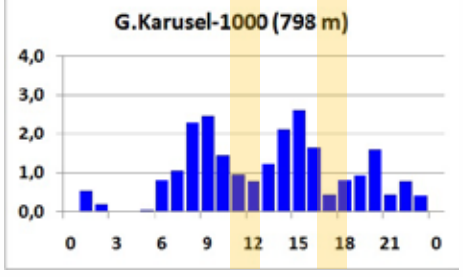


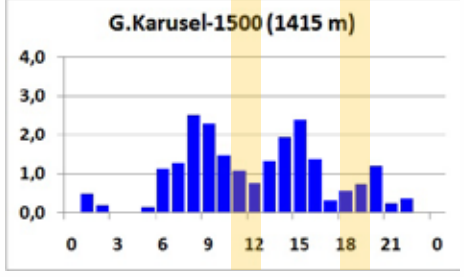


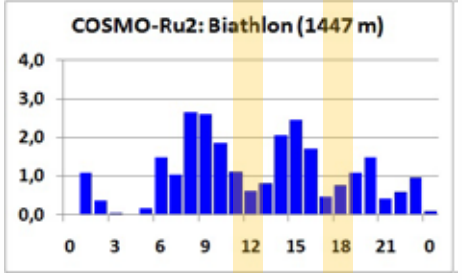


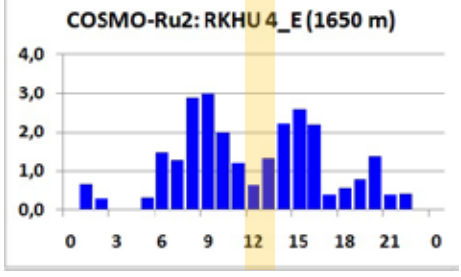












Total precipitation, mean and maximum precipitation rate (mm/h)

Observations	26.5	1.1	2.8
COSMO-Ru1	17.3	0.7	2.5
COSMO-Ru2	23.6	0.9	2.6

Observations	26.5	1.1	2.7
COSMO-Ru1	14.9	0.6	2.4
COSMO-Ru2	21.7	0.9	2.5

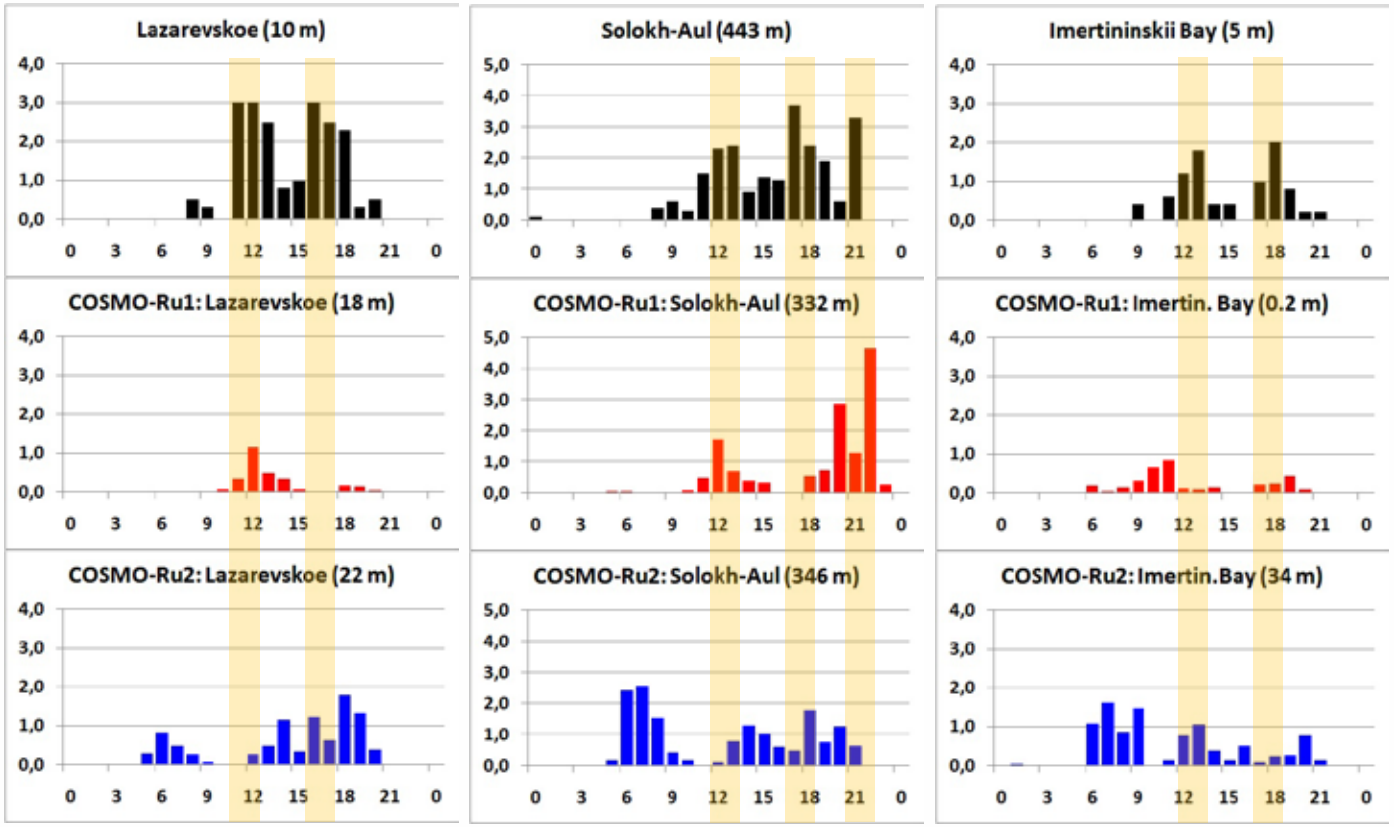
Observations	35.0	1.4	3.0
COSMO-Ru1	19.8	0.8	2.4
COSMO-Ru2	25.9	1.0	2.6

Observations	23.4	0.9	2.7
COSMO-Ru1	21.6	0.9	2.7
COSMO-Ru2	26.0	1.0	3.0

Cold front on February, 18, 2014

Precipitation rate (mm/h). Observation, COSMO-Ru1 and COSMO-Ru2 forecasts

Sites located in coastal cluster



Total precipitation, mean and maximum precipitation rate (mm/h)

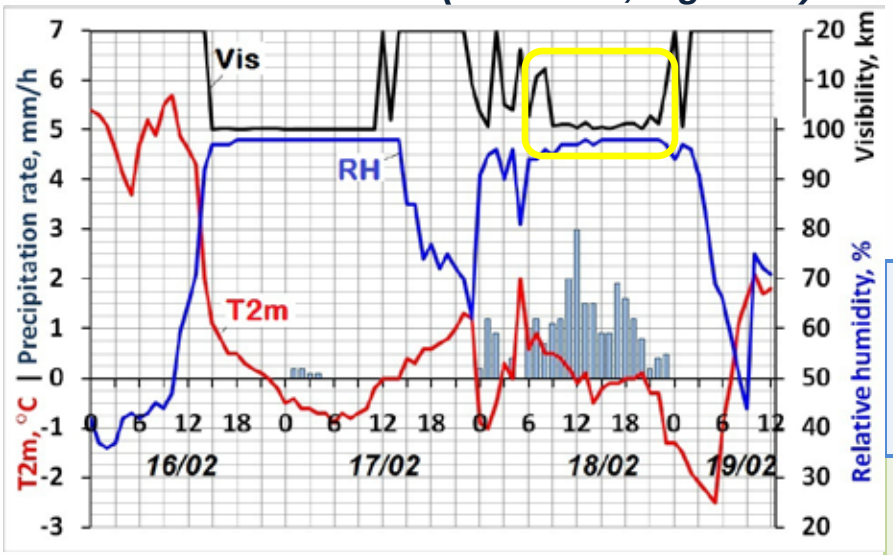
Observations	19.7	0.8	3.0
COSMO-Ru1	2.9	0.1	1.2
COSMO-Ru2	9.6	0.4	1.8

Observations	23.1	0.9	3.7
COSMO-Ru1	14.2	0.6	4.7
COSMO-Ru2	16.0	0.6	2.6

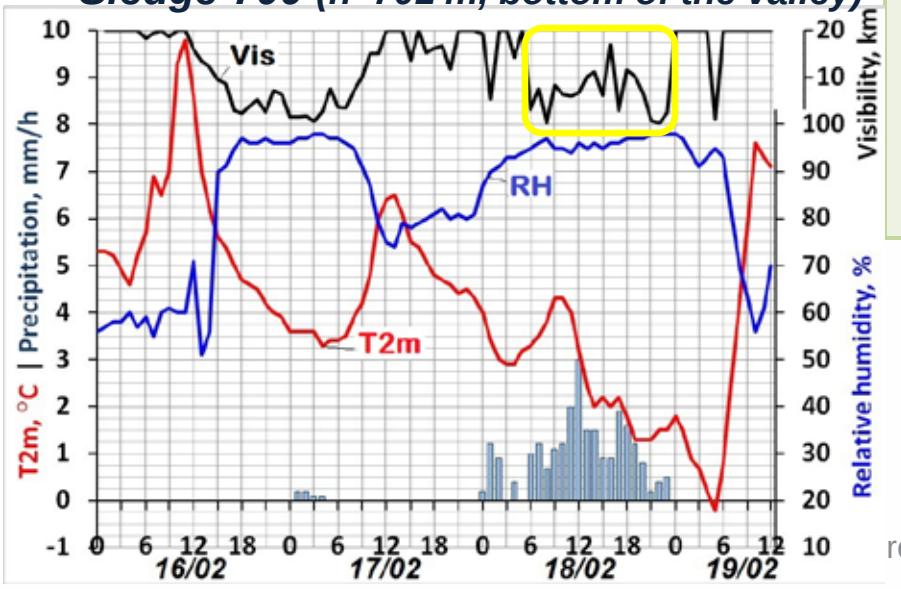
Observations	9.0	0.4	2.0
COSMO-Ru1	3.5	0.1	0.9
COSMO-Ru2	9.7	0.4	1.6

Cold front on February, 18, 2014

***Biathlon Stadium** (h=1455 m, highland)*



***Sledge-700** (h=701 m, bottom of the valley)*



Next low visibility period was connected with ***heavy snowfall*** on February, 18.

In light wind condition <u>precipitation rate</u> was

		mean	max
Roza Khutor 4	(h=1580 m)	0.9 mm/h	2.7 mm/h
Biathlon Std.	(h=1470 m)	1.4 mm/h	3.9 mm/h
G.Carusel 1500	(h=1434 m)	1.1 mm/h	2.7 mm/h
G.Carusel 1000	(h= 980 m)	1.1 mm/h	2.8 mm/h
Roza Khutor 7	(h= 978 m)	0.8 mm/h	2.2 mm/h
Sledge -700	(h= 701m)	1.0 mm/h	3.0 mm/h
Kordon Laura	(h= 570m)	1.5 mm/h	3.4 mm/h
Krasnaya Polayna	(h= 564 m)	1.2 mm/h	3.1 mm/h

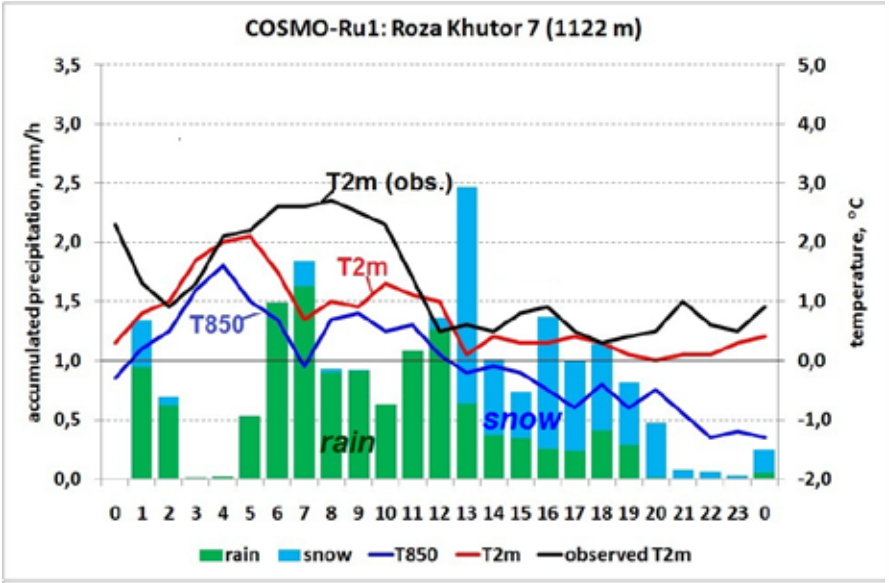
Snow or mix phase

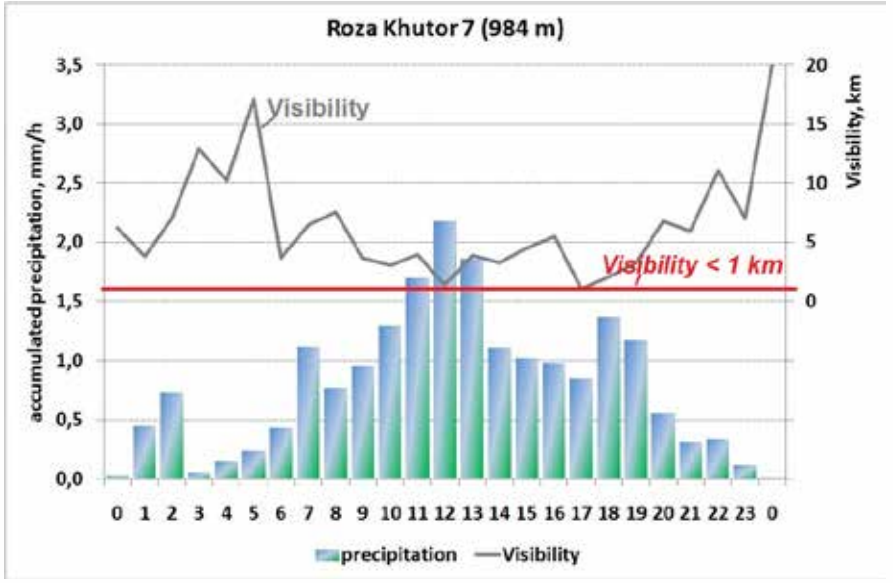
Rain?

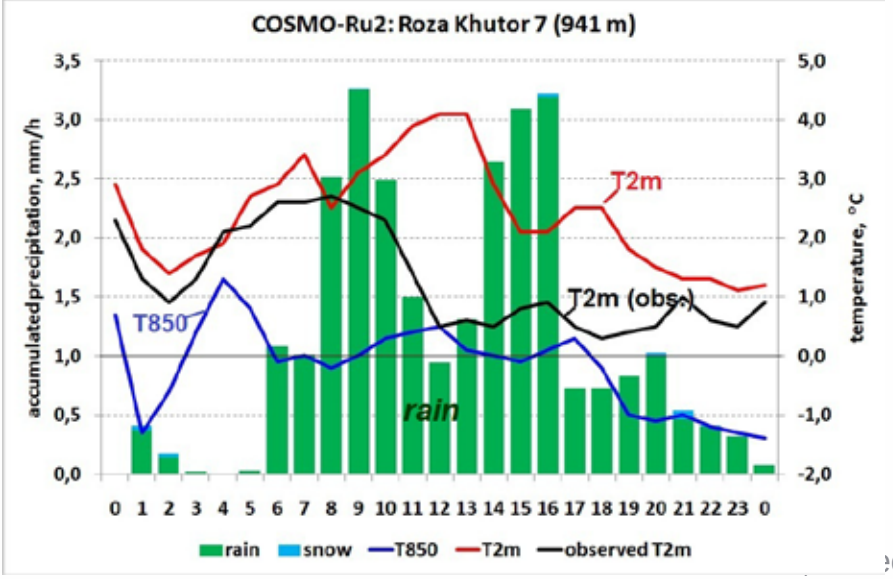
In light wind condition visibility can be less than 500 m when <u>snowfall rate is more then 1.2 mm/h</u>. Visibility is more then 3 km if rain rate is less than 7 mm/h. (A.Zverev "Synoptic meteorology", 1977)

Cold front on February, 18, 2014

Precipitation and its phase, T2m and T850. Observation, COSMO-Ru1 and COSMO-Ru2 forecasts





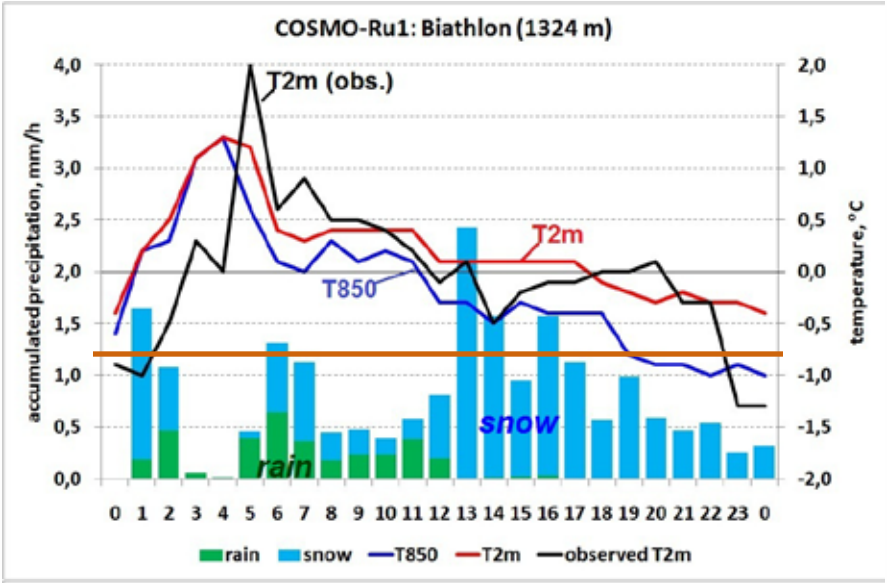


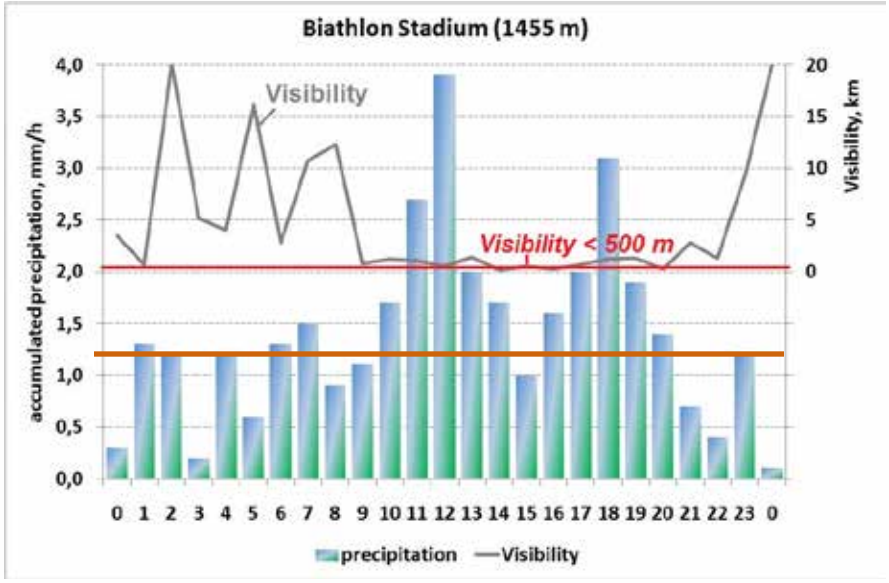
This example shows possibility to predict visibility using COSMO-Ru1 forecast for precipitation amount and phase.

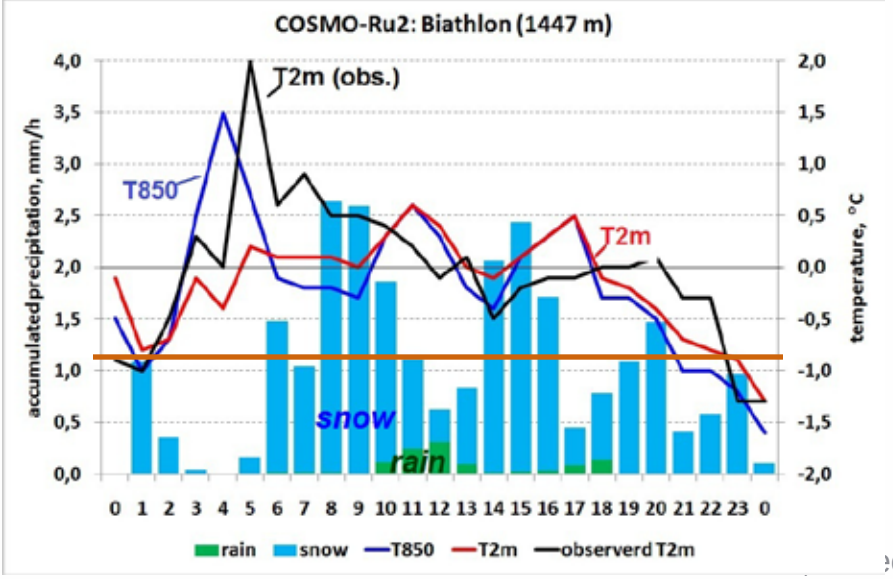
Visibility forecast would be false if we used COSMO-Ru2 results because of erroneous forecast for temperature and thus for the precipitation phase, and also for precipitation temporal distribution.

Cold front on February, 18, 2014

Precipitation and its phase, T2m and T850. Observation, COSMO-Ru1 and COSMO-Ru2 forecasts







COSMO-Ru1 and COSMO-Ru2 forecasted snow with intensity more than **1.2 mm/h** that could cause significant reduction in visibility.

But **start time and duration** of event would be predicted erroneously:

- early (start at 6 h), with possible improvement in visibility at 12-14 h and 17-18 h for COSMO-Ru2;
- later (start at 13 h), improvement after 18 h for COSMO-Ru1

Conclusions

- High resolution model (the higher the better) has a potential for visibility forecast having most of the necessary predictors as a simulation results (e.g. temperature, humidity and wind speed at different level, precipitation intensity and phase).

  But! It is necessary to have high vertical resolution within near surface layer.

  And not forget about high precision of the prescribed model orography, especially for mountain regions!

- Meteorological support for sporting events should have high temporal resolution forecasts. It's important to know time of the beginning and ending of events, the timing of the maximum (e.g. heavy precipitation, low visibility, etc).

  Today error in determining the beginning of the event is about 1-2 hours.

Conclusions

Common conclusions (were presented on CUS2014)

- COSMO-Ru1 run in operational mode during SOCHI-2014 Olympic Games
- COSMO-Ru1 forecast were used by forecasters along with COSMO-Ru2
- Experiments demonstrated the capability of COSMO-based system with space resolution 1,1 km to produce satisfactory forecast with lead-time till 36 hours. It made possible to create operational forecast technology meets the requirements of forecasters.
- Using new orography data from EXTPAR based on ASTER GDEM2 has a positive effect on the temperature, wind and precipitation forecast.
- Verification by VERSUS show good quality of the COSMO-Ru1 forecasts.

Future plans

• Subtask within the PT CORSO-A: the guidance of the optimal domain's size selection for 1.1 km resolution of nested COSMO models for the regions with complex mountain relief.

Motivation: *During the CORSO PP were obtained results shown the strong dependence of the predicted precipitation amount and spatial distribution on the model's domain size. This problem need the more attentive examination, because the runs of COSMO1 as part of nested technologies are very expensive in point of view of computing time.*

• To perform case study for all cases mentioned by forecasters (see Table).

Acknowledgement

We would like to thank

our **colleagues from MeteoSwiss G. de Morsier, M. Arpagaus, P. Steiner** for support our first steps in working with 1-km resolution COSMO model,

colleagues from DWD and personally **D. Majewski, J. Helmert** for advices and support, especially for providing external parameters for numerous COSMO-Ru1 domains J,

Anastasia Bundel (HMC, Russia) and **Alexandr Kirsanov** (HMC, Russia) for help and discussion of model verification results,

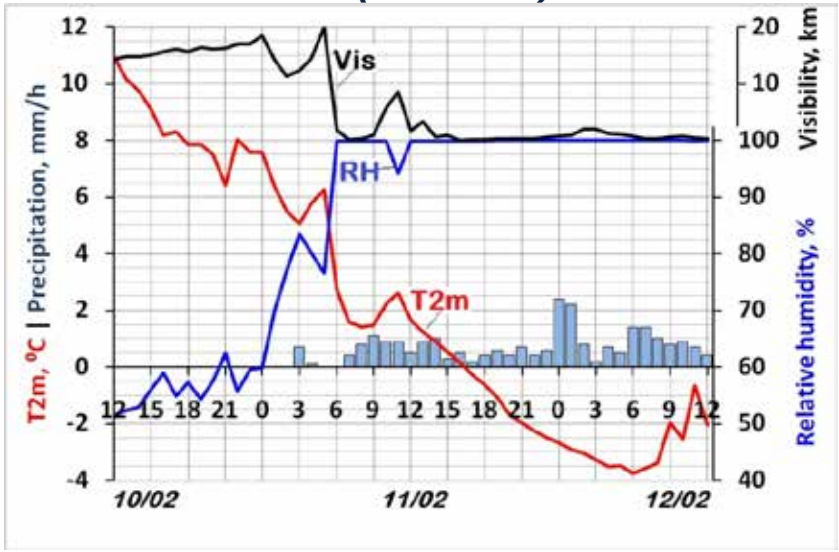
Russian **FROST team** for providing observation data,

Irina Gorlach (HMC, Russia) for providing satellite images and consultation.

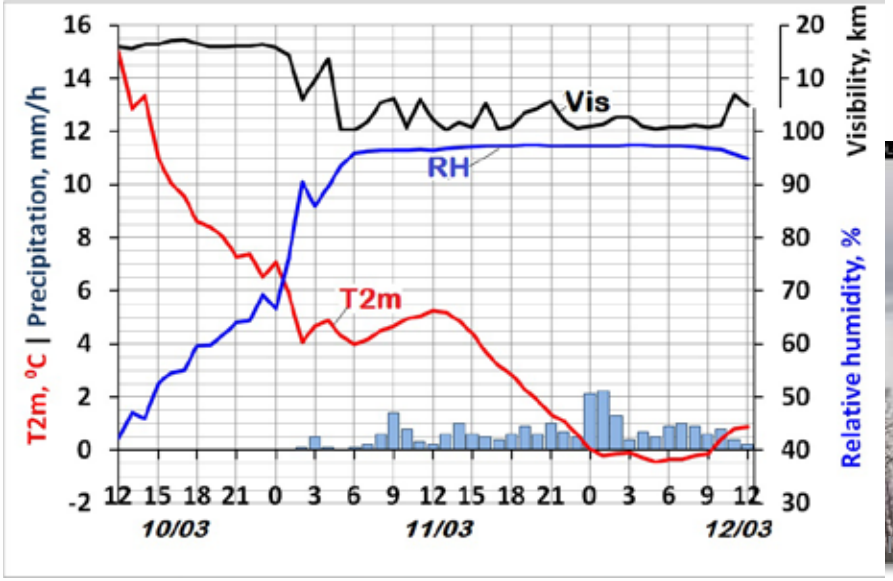
Thank you for your attention!

Cold front on March, 11, 2014

Roza Khutor 4 (h=1580 m)



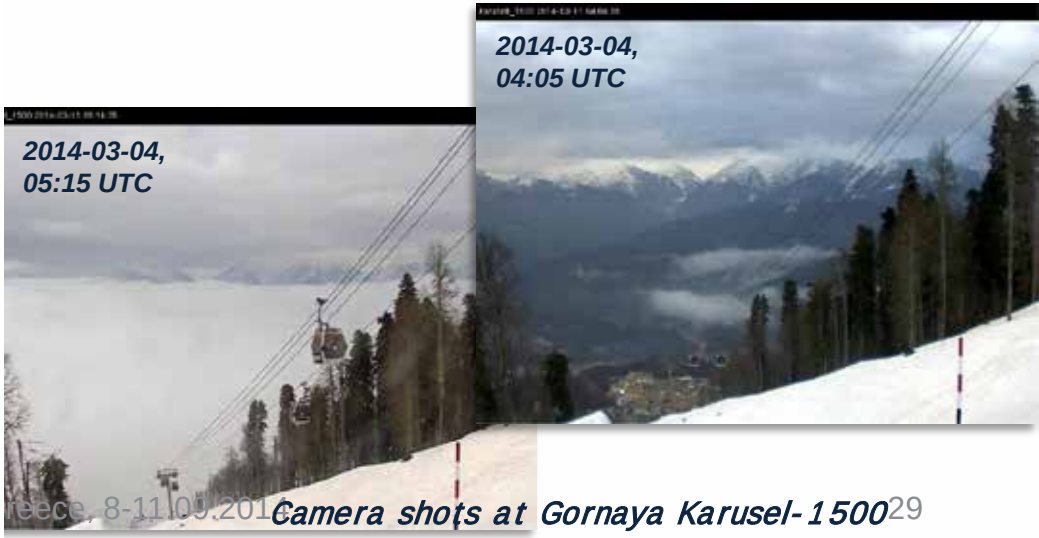
Roza Khutor 7 (h=984 m)



On March, 11 as a result of the passage of a cold front increasing of relative humidity and concomitant reduction in visibility took place on the most sites in mountain cluster.

Observed minimum visibility values:

- Roza Khutor 4 (h=1580 m) 71 m
- Biathlon Std. (h=1470 m) 40 m
- G.Carusel 1500 (h=1434 m) 36 m
- Snowboard (h=1025 m) 53 m
- Roza Khutor 7 (h= 980 m) 128 m
- G.Carusel 1000 (h= 978 m) 65 m
- Sledge -700 (h= 701 m) 163 m
- Krasnaya Polyana (h= 564 m) 290 m

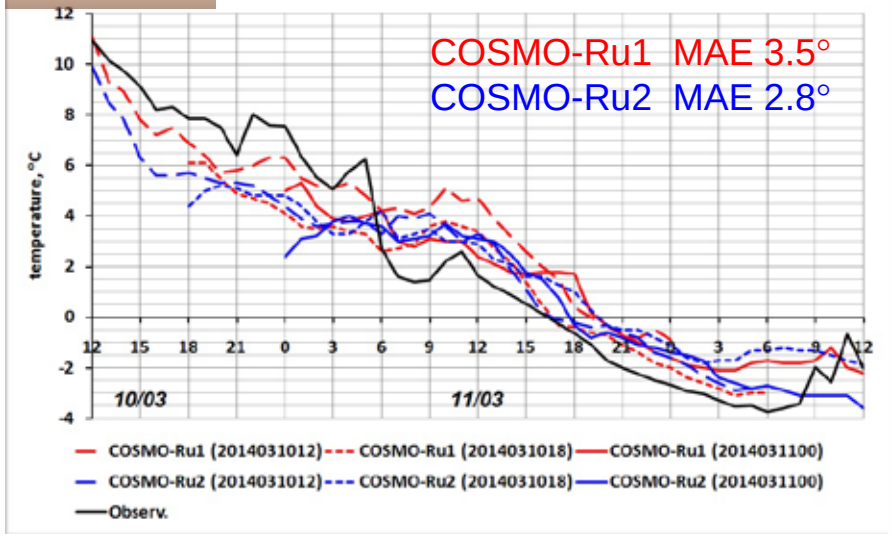


Camera shots at Gornaya Karusel-1500

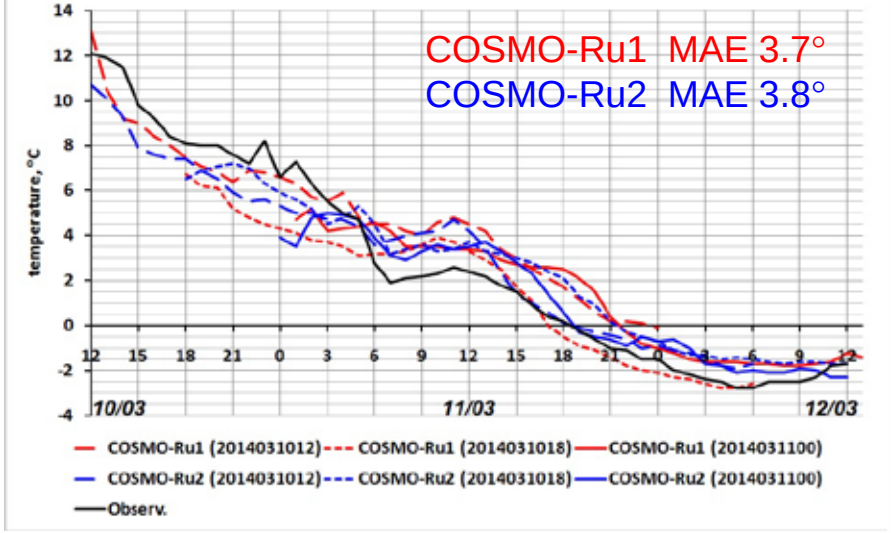
Cold front on March, 11, 2014

T2m. Observation, COSMO-Ru1 and COSMO-Ru2 forecasts

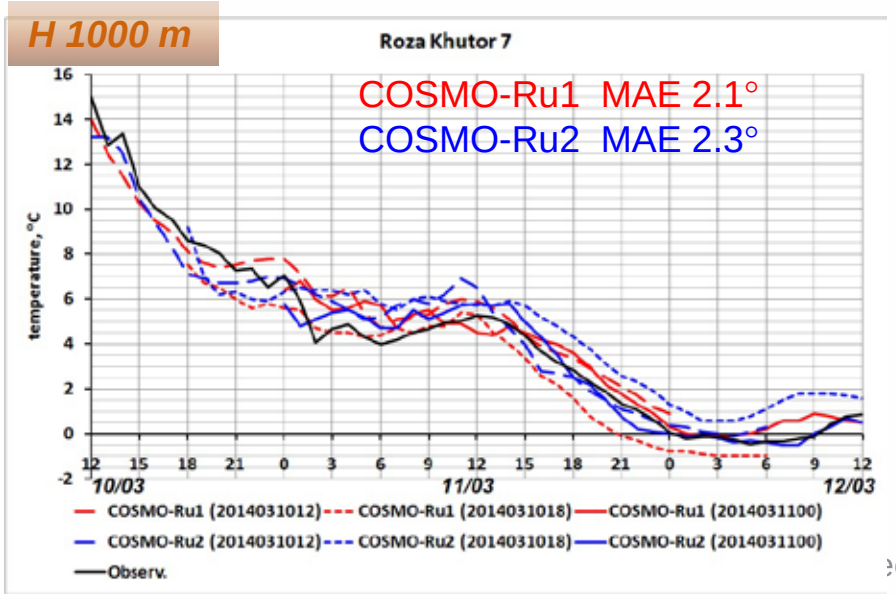
H 1600 m



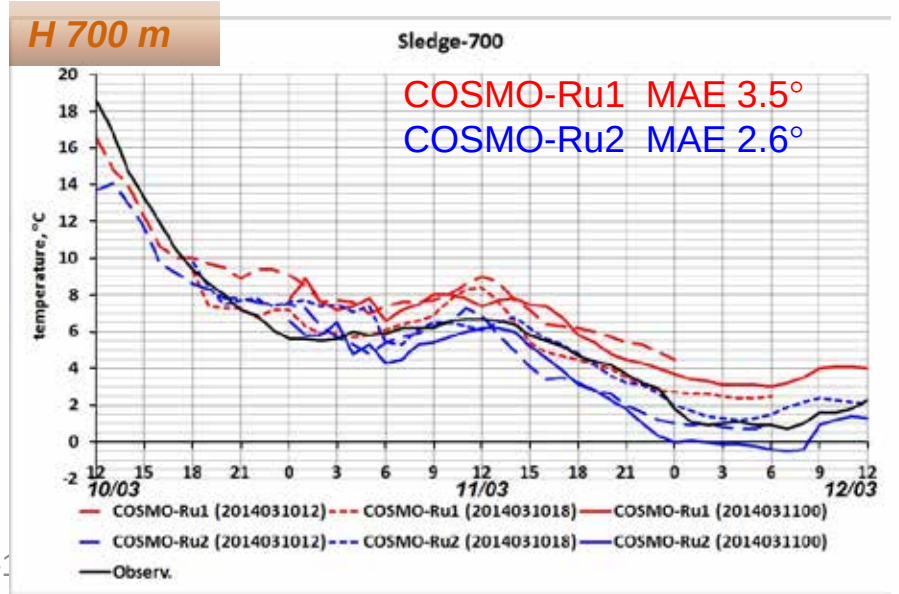
H 1400 m



H 1000 m



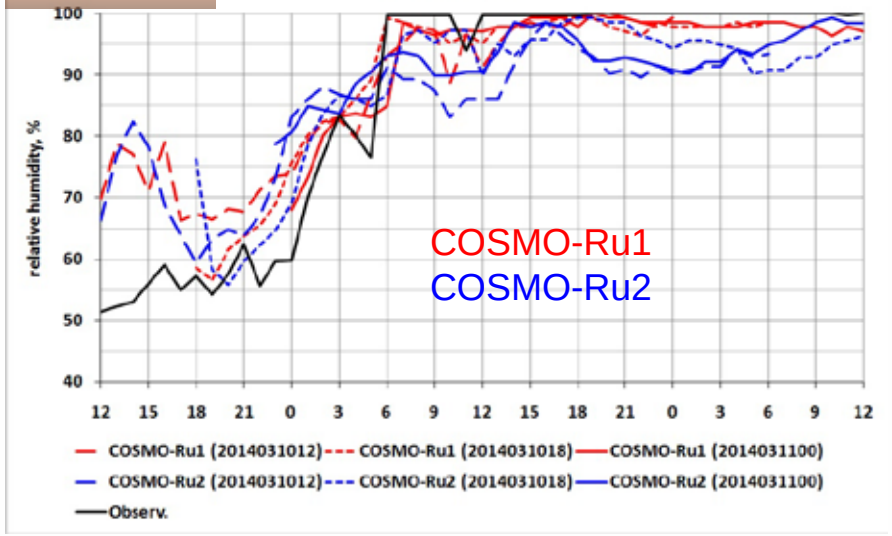
H 700 m



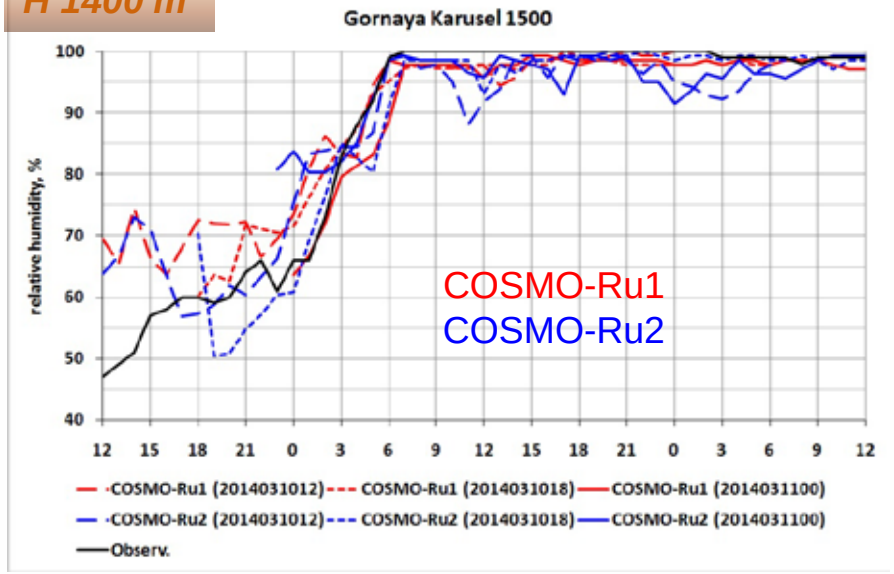
Cold front on March, 11, 2014

RH. Observation, COSMO-Ru1 and COSMO-Ru2 forecasts

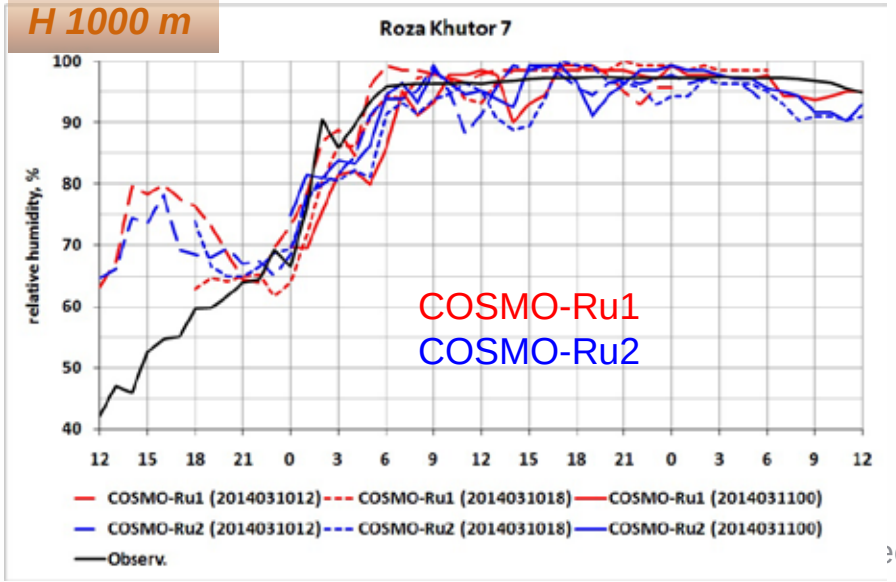
H 1600 m



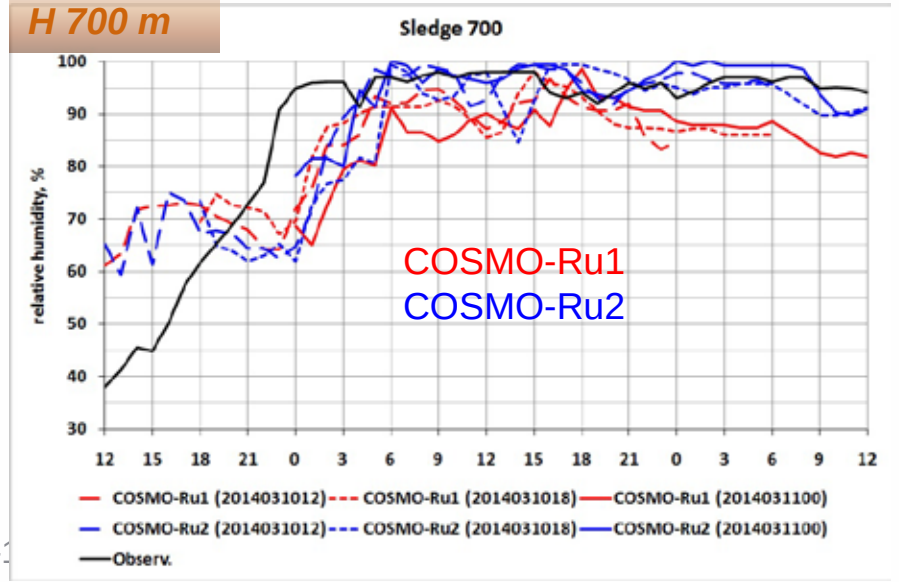
H 1400 m



H 1000 m

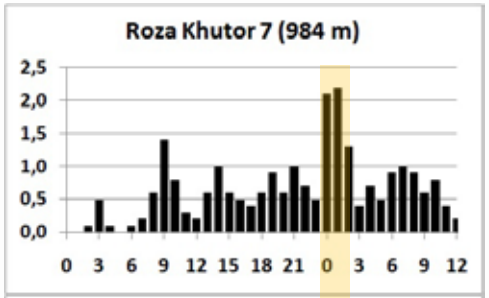


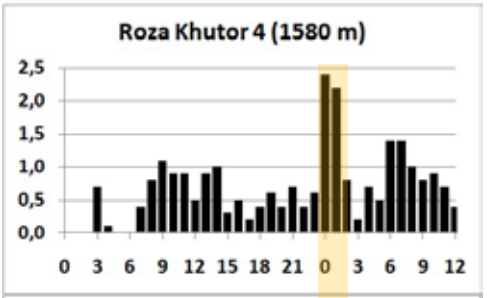
H 700 m

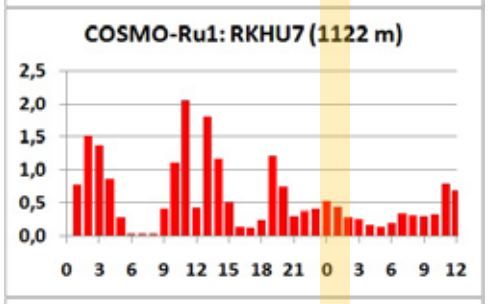


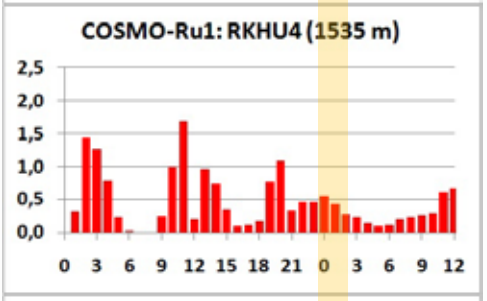
Cold front on March, 11, 2014

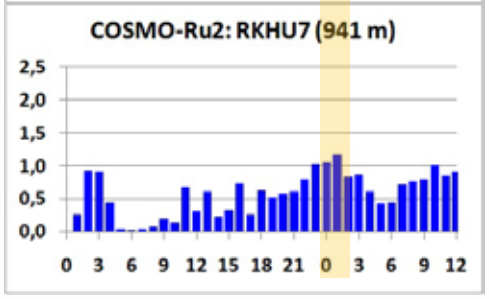
Precipitation. Observation, COSMO-Ru1 and COSMO-Ru2 forecasts

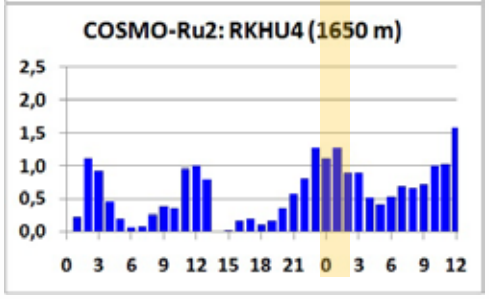












Total precipitation, mean and maximum precipitation rate (mm/h)

Observations	23.7	0.7	2.2
COSMO-Ru1	20.6	0.6	2.1
COSMO-Ru2	21.0	0.6	1.2

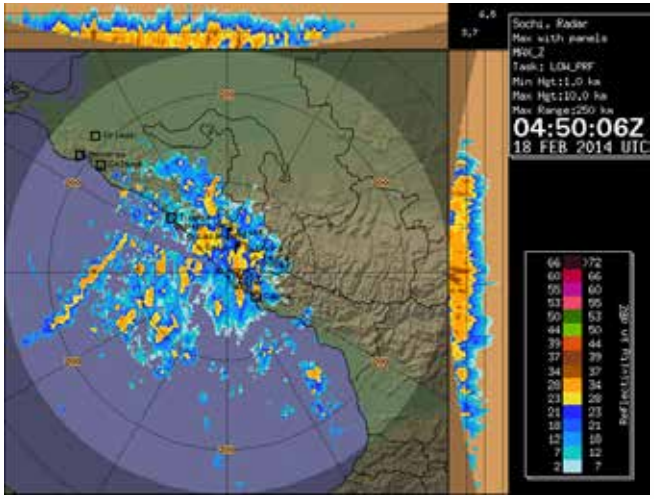
Observations	24.8	0.7	2.4
COSMO-Ru1	16.9	0.5	1.7
COSMO-Ru2	22.0	0.6	1.6

Observation network

Radar

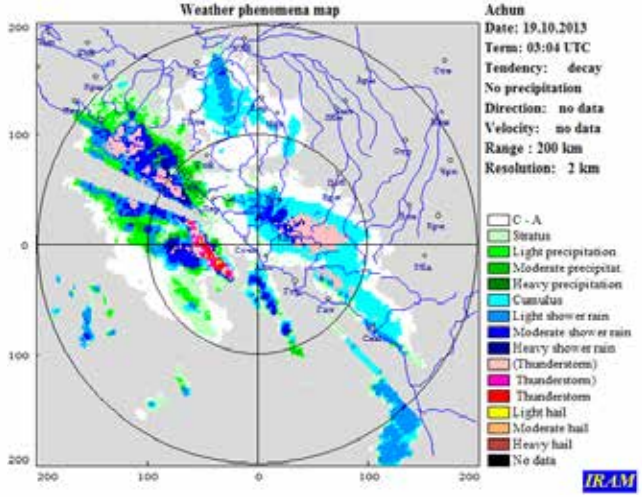
Max Reflictivity (Akhun Radar)

Product of Central Aerological Observatory



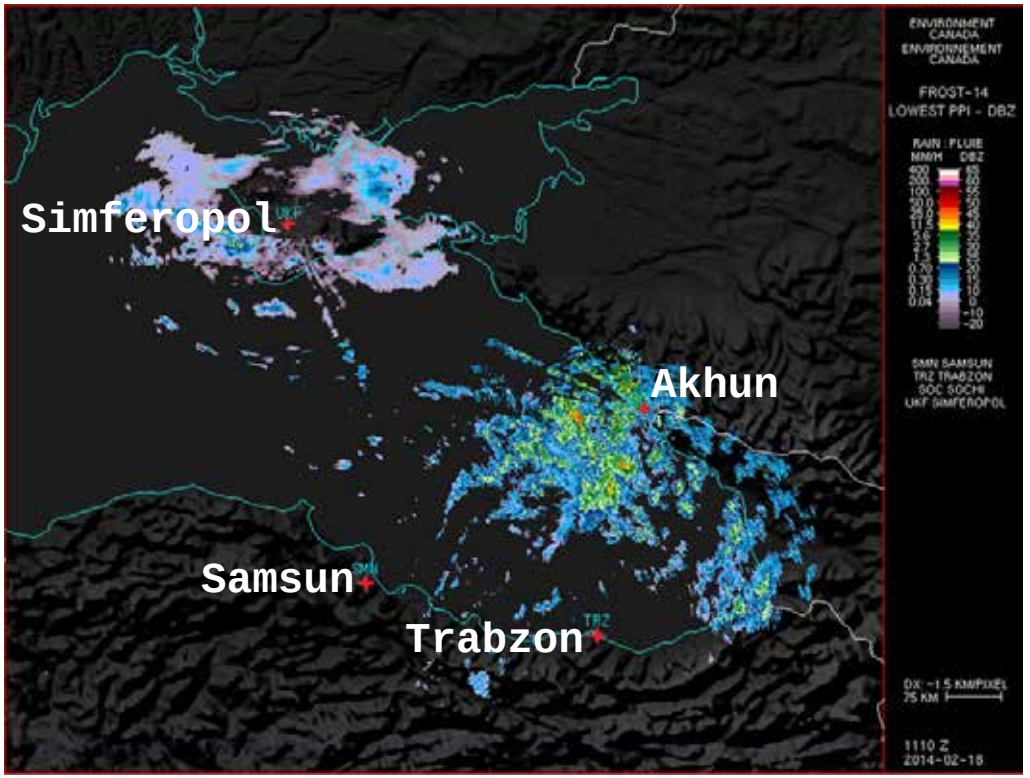
Weather phenomena map (Akhun Radar)

Product of IRAM



Black Sea Composite map (Akhun+Simferopol+Samsun+Trabzon)
Rain Intensity (mm/h) / Reflectivity (DBZ)

Product of Envaronment Canada



Update rate – 10 min