Capabilities of the COSMO-Ru system to predict low visibility events in Sochi region during winter period

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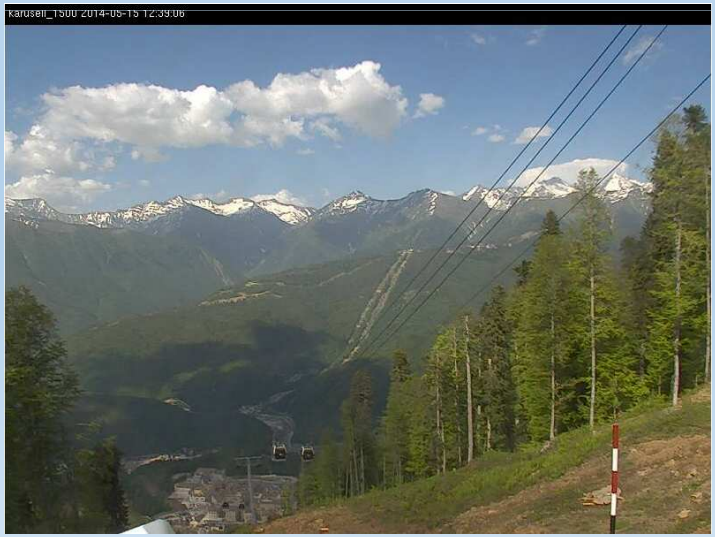


Overview

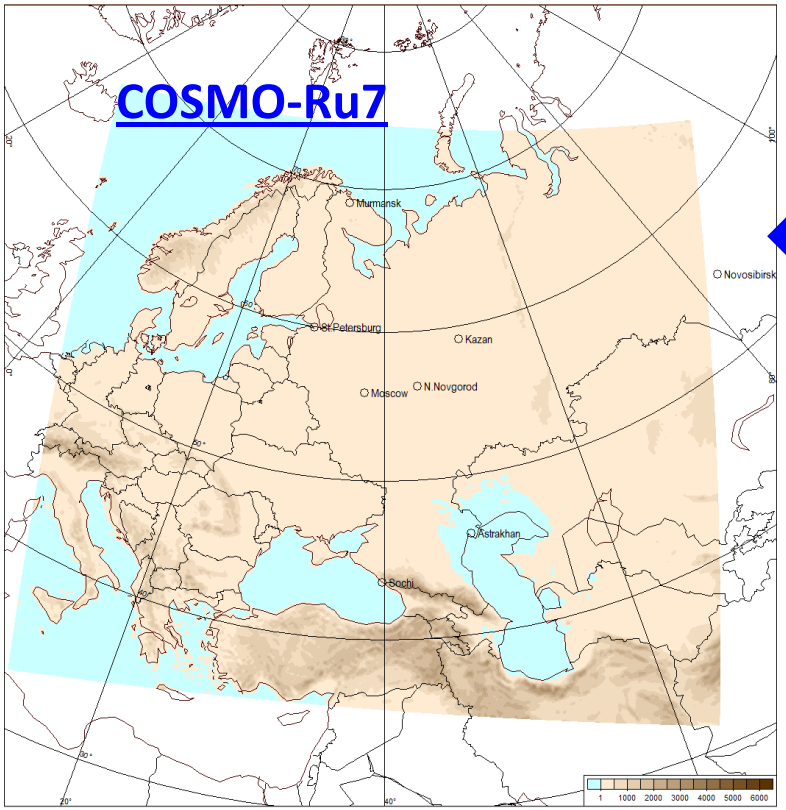
1. COSMO-Ru models used for Sochi-2014 meteosupport
2. Observation network
3. Most Interesting Cases during the Olympics/Paralympics
4. Low Visibility Cases
    - Fog on February 16-17, 2014
    - Heavy snowfall on February 18, 2014
5. The ratio of Relative Humidity and Visibility from observations
    - Observation tools
    - Data availability and selection
    - Searching for the RH/Vis ratio
6. Conclusions and outlook

Motivation

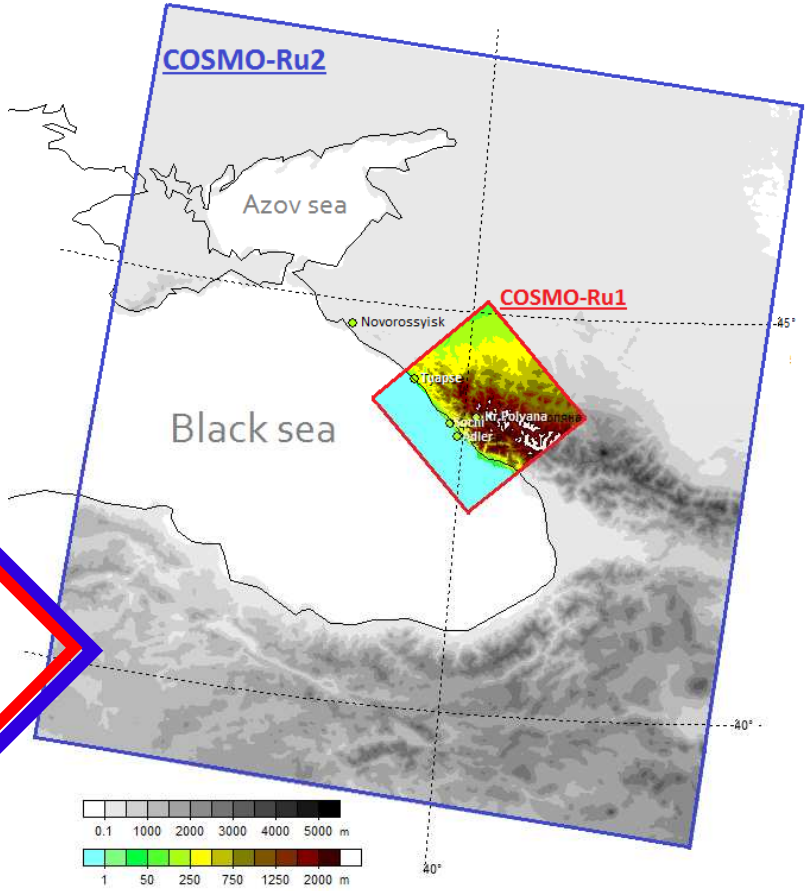
- The prediction of low visibility events (LWE) is one of most important elements of meteosupport of winter competitions (The LWE require to cancel all kinds of competitions in mountains)
- The competition venues in Sochi mountain cluster had just been built before Olympics → no sufficient series of measurements for LWE for prior period to permit to develop , verify and and calibrate
  - the down- scaling statistical postprocessing
  - the very-high resolution systems with (1D, 3D) as operational tool
- The principal kinds of origin of different weather phenomena, incl LWE for trial period were established during trial period (2011-2013)
- COSMO-1 technology was introduced shortly before (Janv 2014) the Games begin for Sochi region
- **The forecasts were based on interpretation of COSMO2.2 & COSMO1.1 direct output**

- Can the direct output of model (step 1-2 km) give to the forecasters the information about the alarms of LWE for 1 day ahead
- Whish are the features of interpretation of this products?

COSMO-Ru models for Sochi-2014



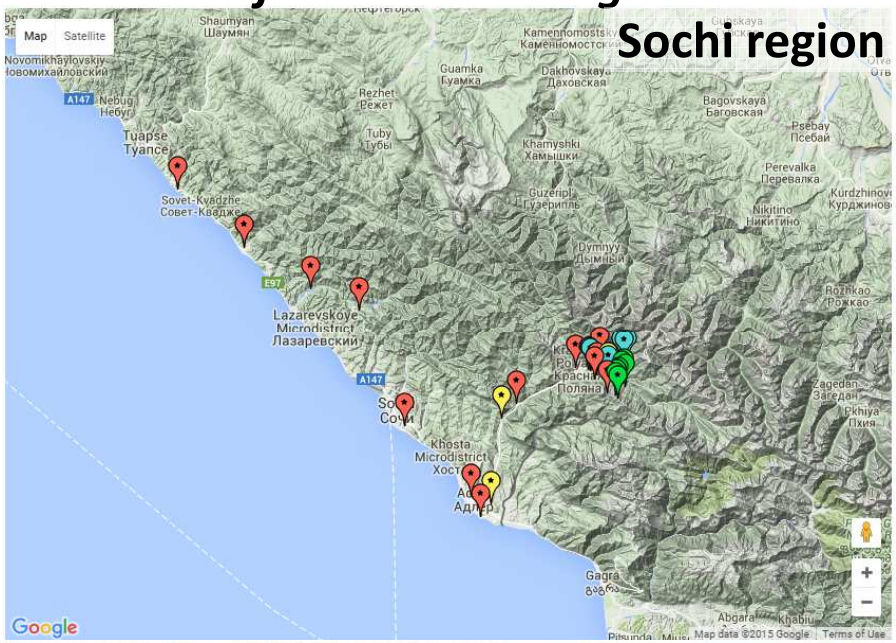
Domain	**700 x 620 grid points**
	4900 x 4340 km
Grid spacing	**7 km**
Time step	**66 s**
Forecast range	**78 h**
IC&BC	**ICON (DWD)**

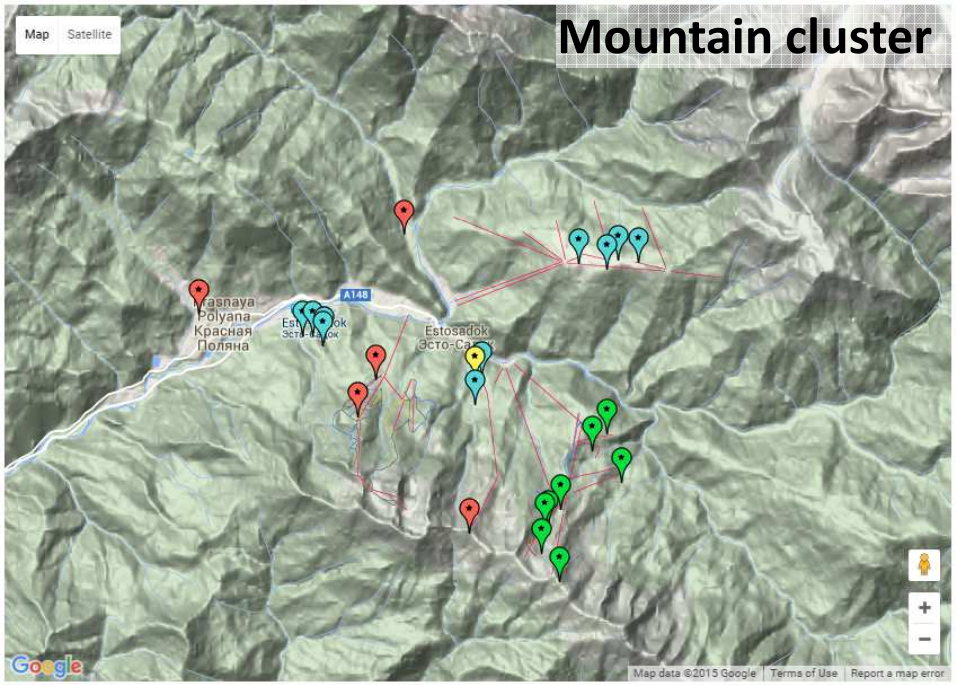


COSMO-Ru2	**COSMO-Ru1**
420 x 470 grid points	**190 x 190 grid points**
900 x 1000 km	**210 x 210 km**
2.2 km	**1.1 km**
15 s	**6 s**
42 h	**36 h**
COSMO-Ru7	**COSMO-Ru2**

Observation Network

Locations of the meteorological stations





Meteorological stations

Total number	**33**
Roshydromet stations	**13**
Automatic meteo station (AMS)	**20**
equipped with PWD	*12*

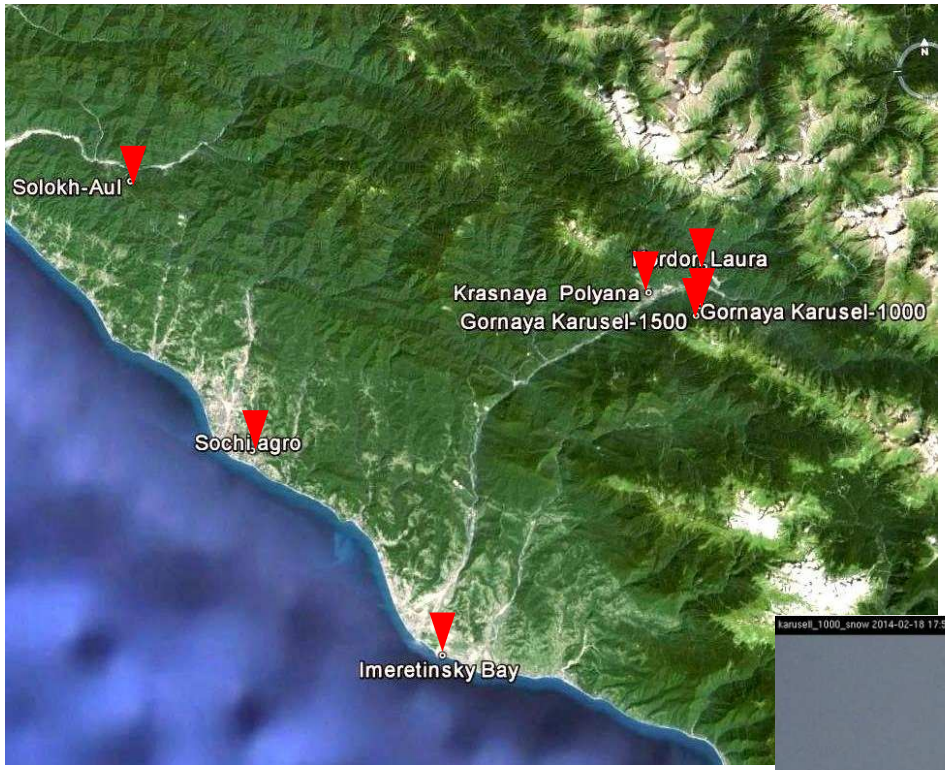
Most of the AMS are located in the mountain cluster next to the sports facilities.

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 (averaged) at 10 m, Wind gust at 10 m, Lowest cloud base altitude, Precipitation rate (averaged), Visibility, Snow depth, Snow temperature

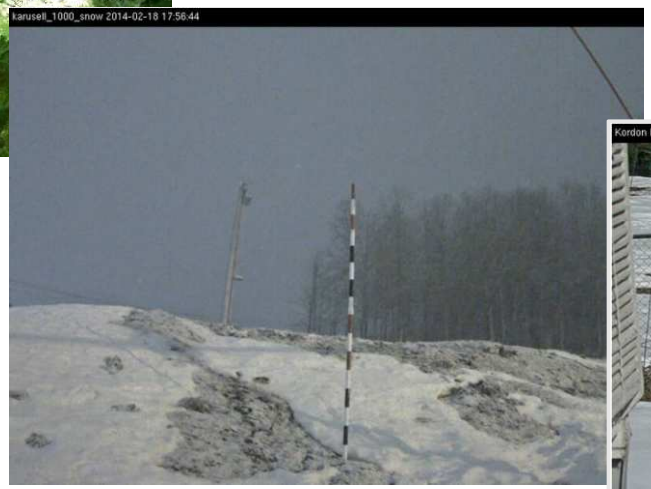
Radars	**4**
Profilers	**3**
Video cameras	**3+4x2**

Observation Network

Video cameras



Sky conditions and development of the clouds



Surface conditions

Single cam – 3 sites
(2 at the seashore – *Imeretinsky Bay* and *Sochi-agro*, and one at 11 km from the sea – *Solokh-Aul*)
Paired cam – 4 sites, all within the valley at different altitude (*Krasnaya Polyana* – 560 m, *Kordon Laura* – 570 m, *Gornaya Karusel-1000* – 980 m, *Gornaya Karusel-1500* - 1400 m)

Update rate – 10 min

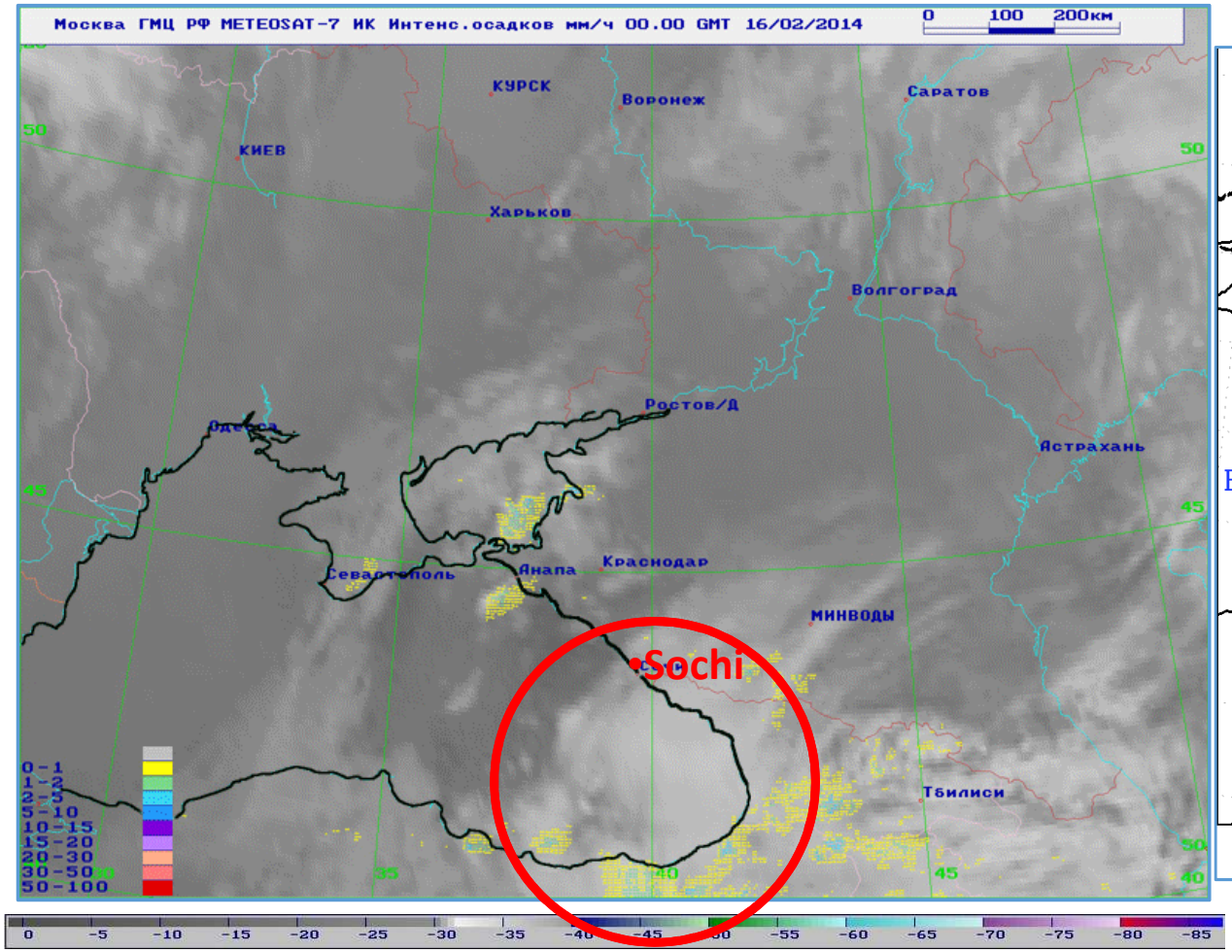
Most Interesting Cases during the Olympics/Paralympics

List is prepared by T. Dmitrieva

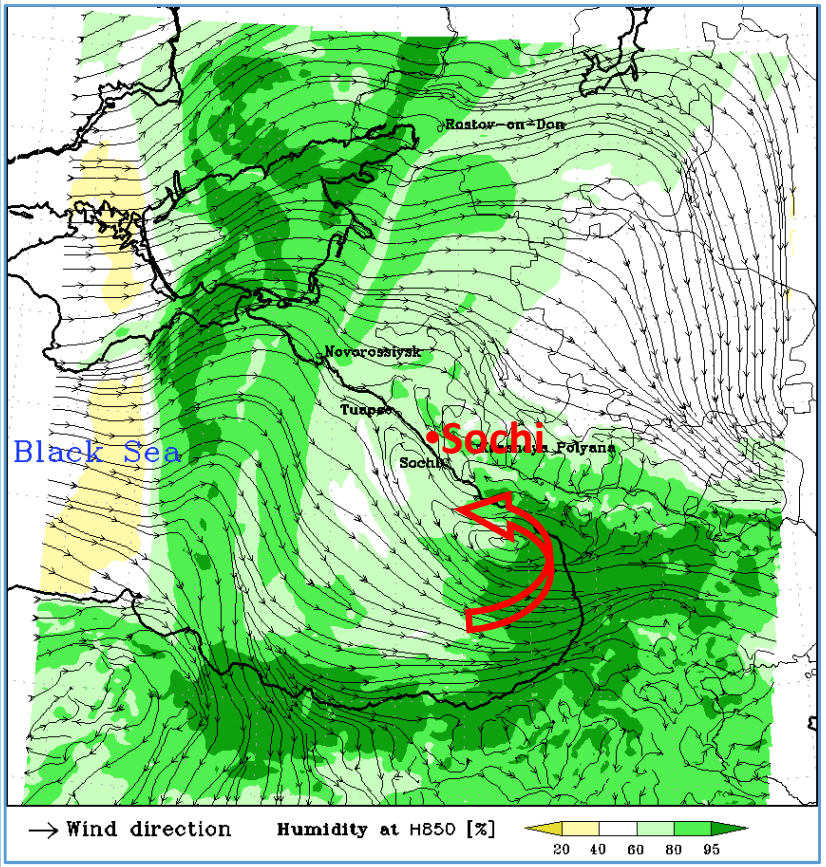
N	Date	Meteorological process \ phenomenon	Models' behavior	Impact on competitions
1	February, 07	Foehn	Poor T forecast by most models at Biathlon Stadium	
2	February, 16	Low visibility		Postponed competitions at Laura and Extreme Park
3	February, 18	Cold front	Good precipitation forecast by most model	
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	

Low Visibility Case on February 16-17, 2014

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



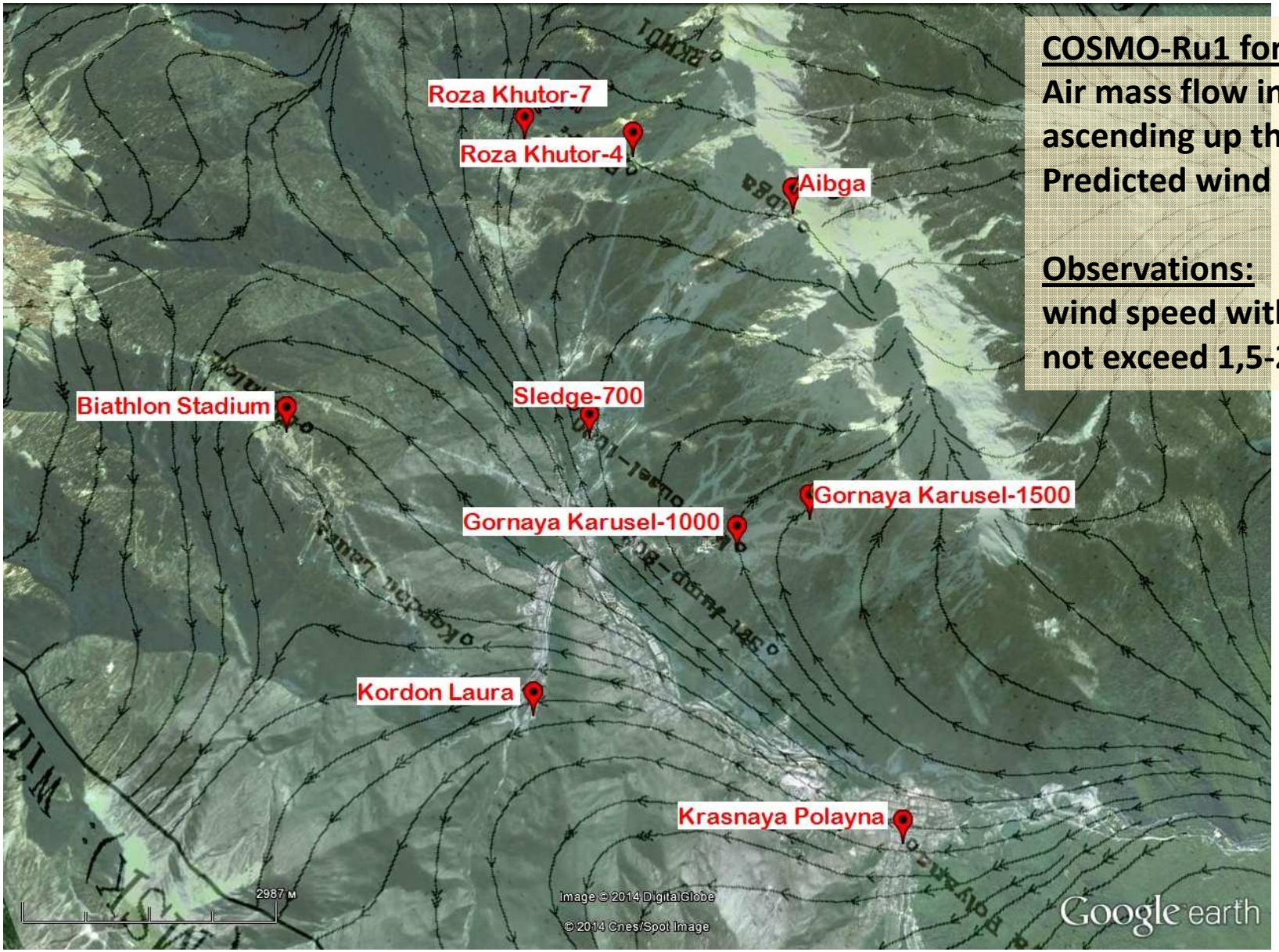
COSMO-Ru2 forecast
Stream lines and relative humidity at 850 hPa
12 h forecast from 16.02.14, 00 UTC



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

Low Visibility Case on February 16-17, 2014

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

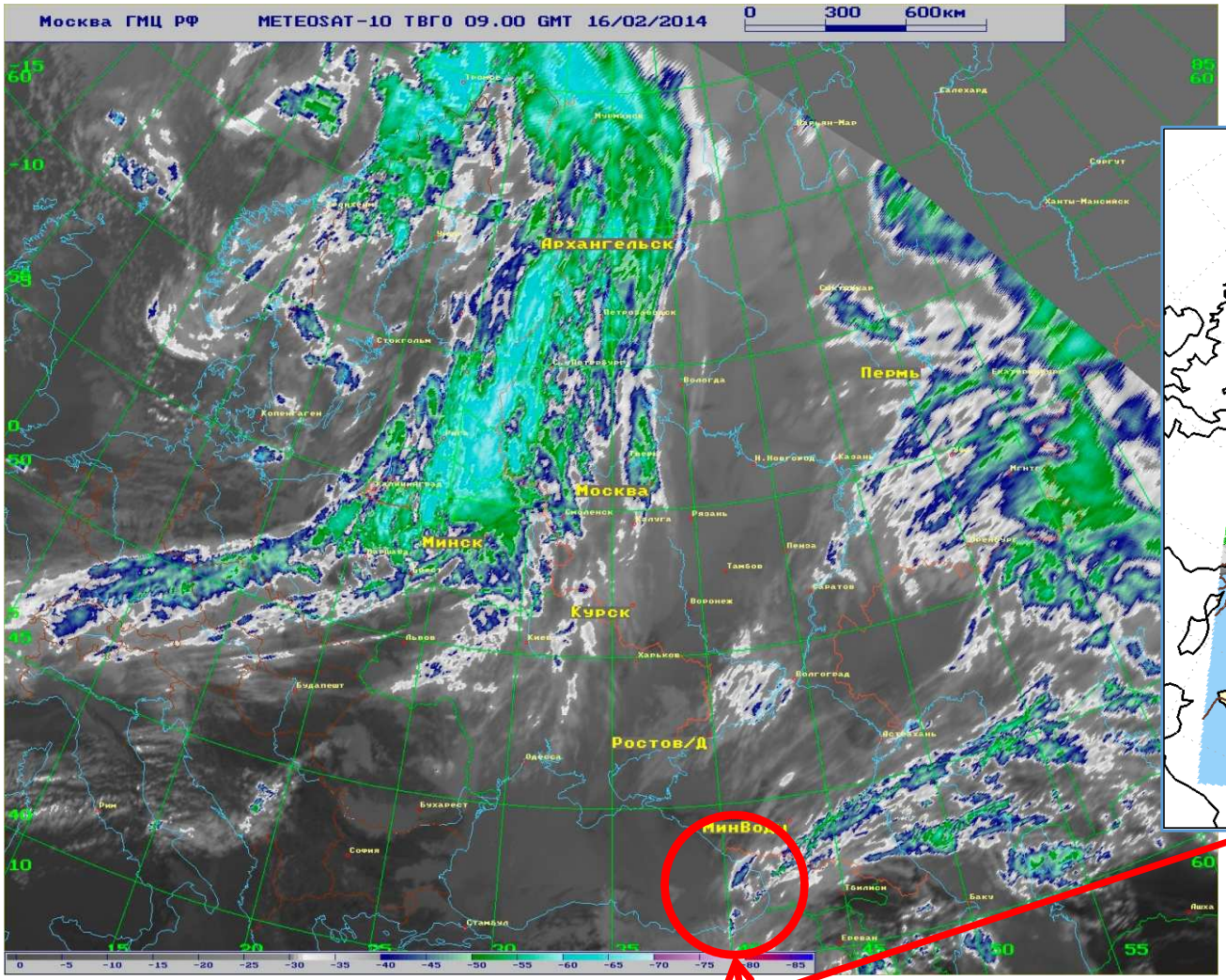


COSMO-Ru1 forecast:
Air mass flow into the valley ascending up the slopes.
Predicted wind speed – 0.5-2 m/s.

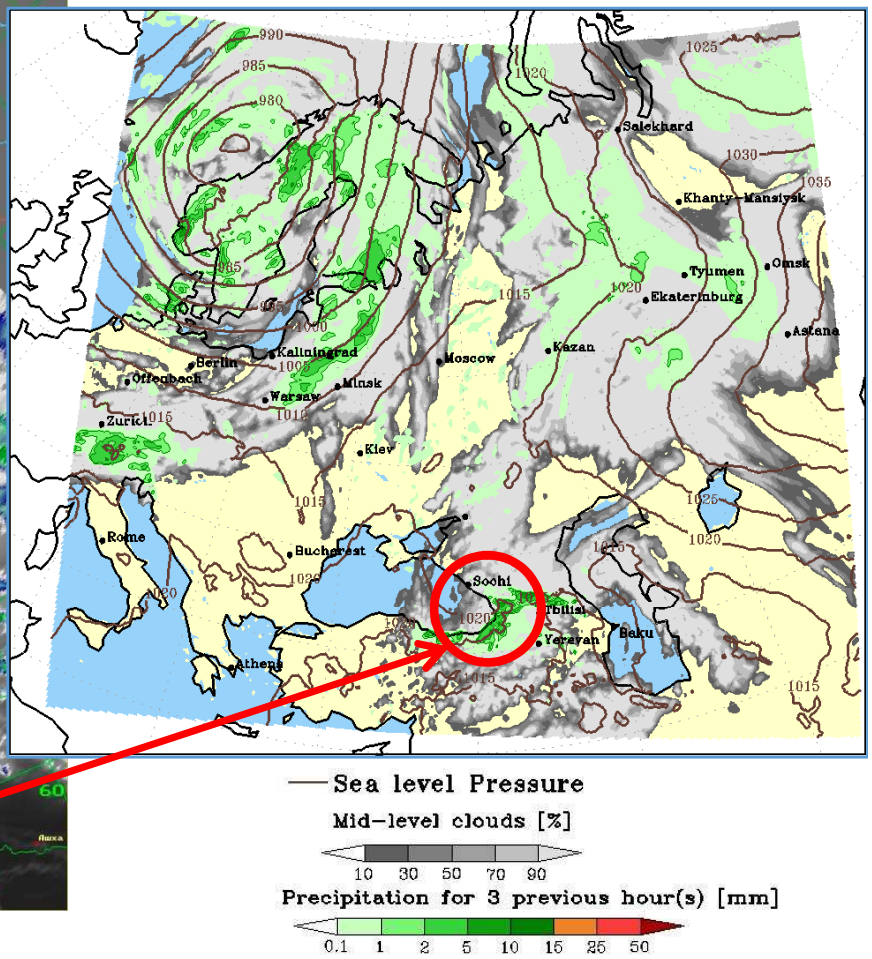
Observations:
wind speed within the valley does not exceed 1,5-2 m/s.

Low Visibility Case on February 16-17, 2014

METEOSAT-10. Cloud top temperature
16.02.2014, 09 UTC



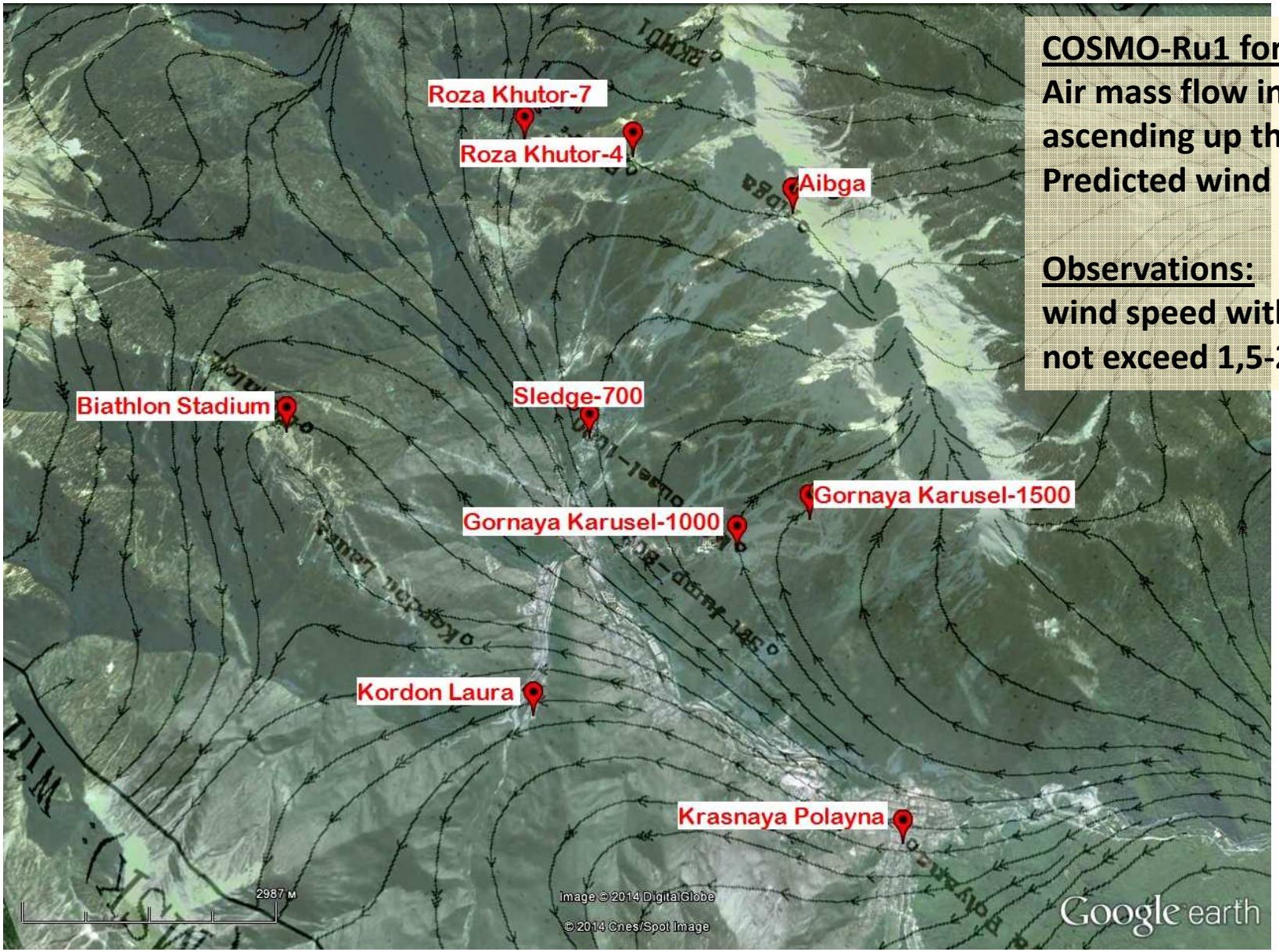
COSMO-Ru7 forecast.
PMSL, Midlevel Cloud & Precipitation
9 h forecast from 16.02.14, 00 UTC



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 Case on February 16-17, 2014

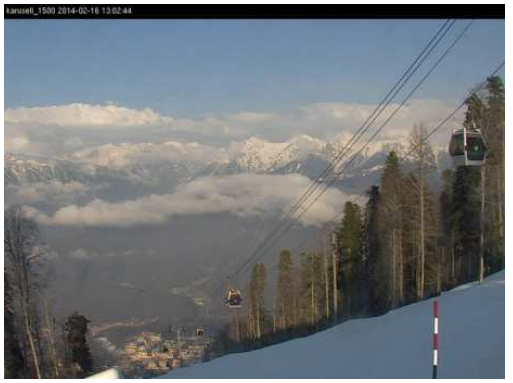
COSMO-Ru1 wind 13 h forecast from 16.02.2014, 00 UTC for mountain cluster



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 Case on February 16-17, 2014

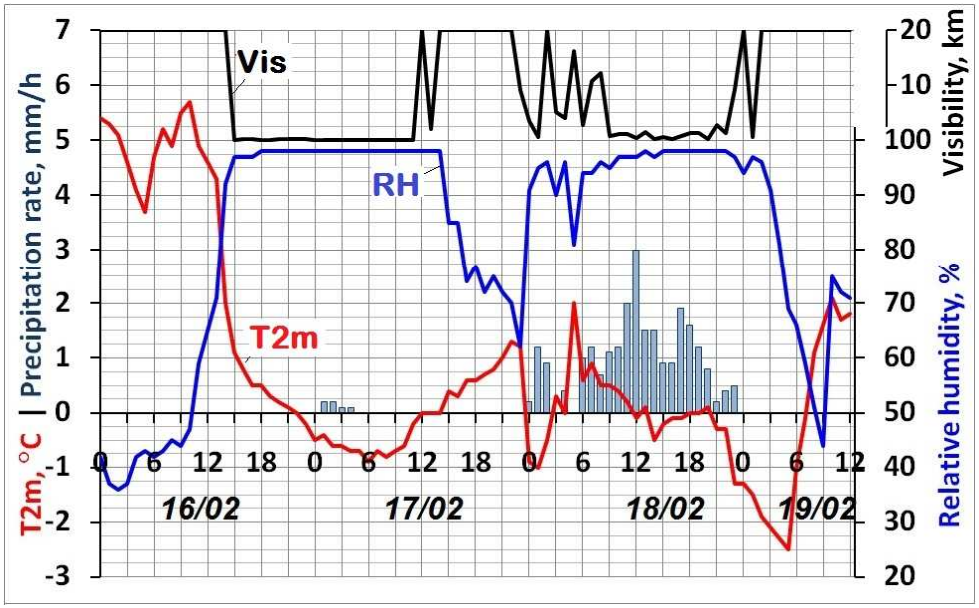
	Solokh-Aul Coastal cluster (11 km from the coast line) H = 441.5 m	**Krasnaya Polyana** Mountain cluster (bottom of the valley) H = 564 m	**Gornaya Karusel-1500** Mountain cluster (northward slope) H = 1432 m
11:05 UTC, 14:05 local time			
13:05 UTC, 16:05 local time			
13:32 UTC, 16:32 local time			

Low Visibility Case on February 16-17, 2014

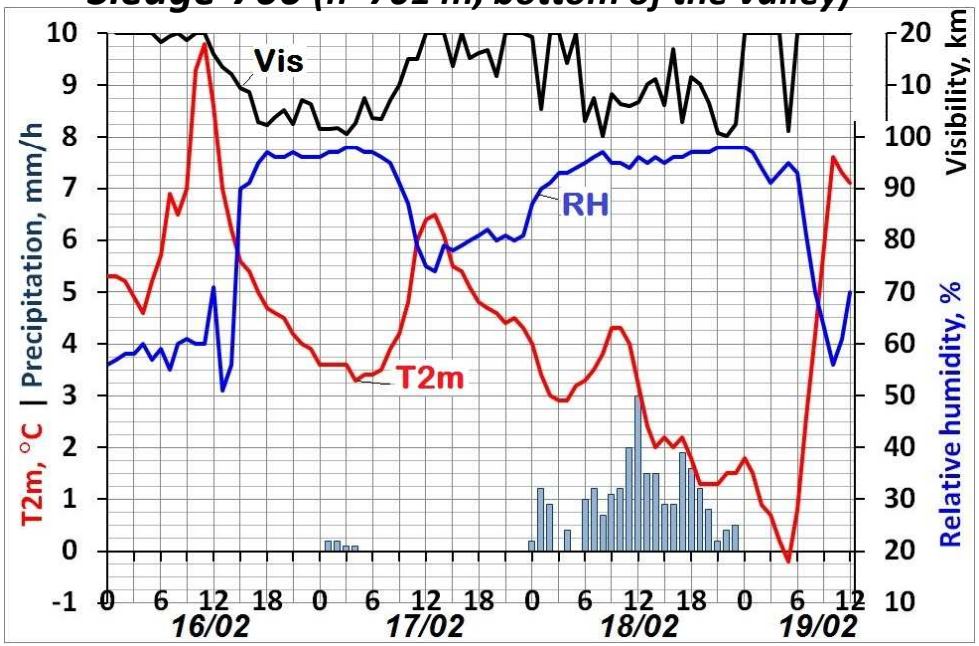
	Solokh-Aul Coastal cluster (11 km from the coast line) H = 441.5 m	**Krasnaya Polyana** Mountain cluster (bottom of the valley) H = 564 m	**Gornaya Karusel-1500** Mountain cluster (northward slope) H = 1432 m
13:52 UTC, 16:52 local time			
14:02 UTC, 17:02 local time			
14:32 UTC, 17:32 local time			

Low Visibility Case 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.

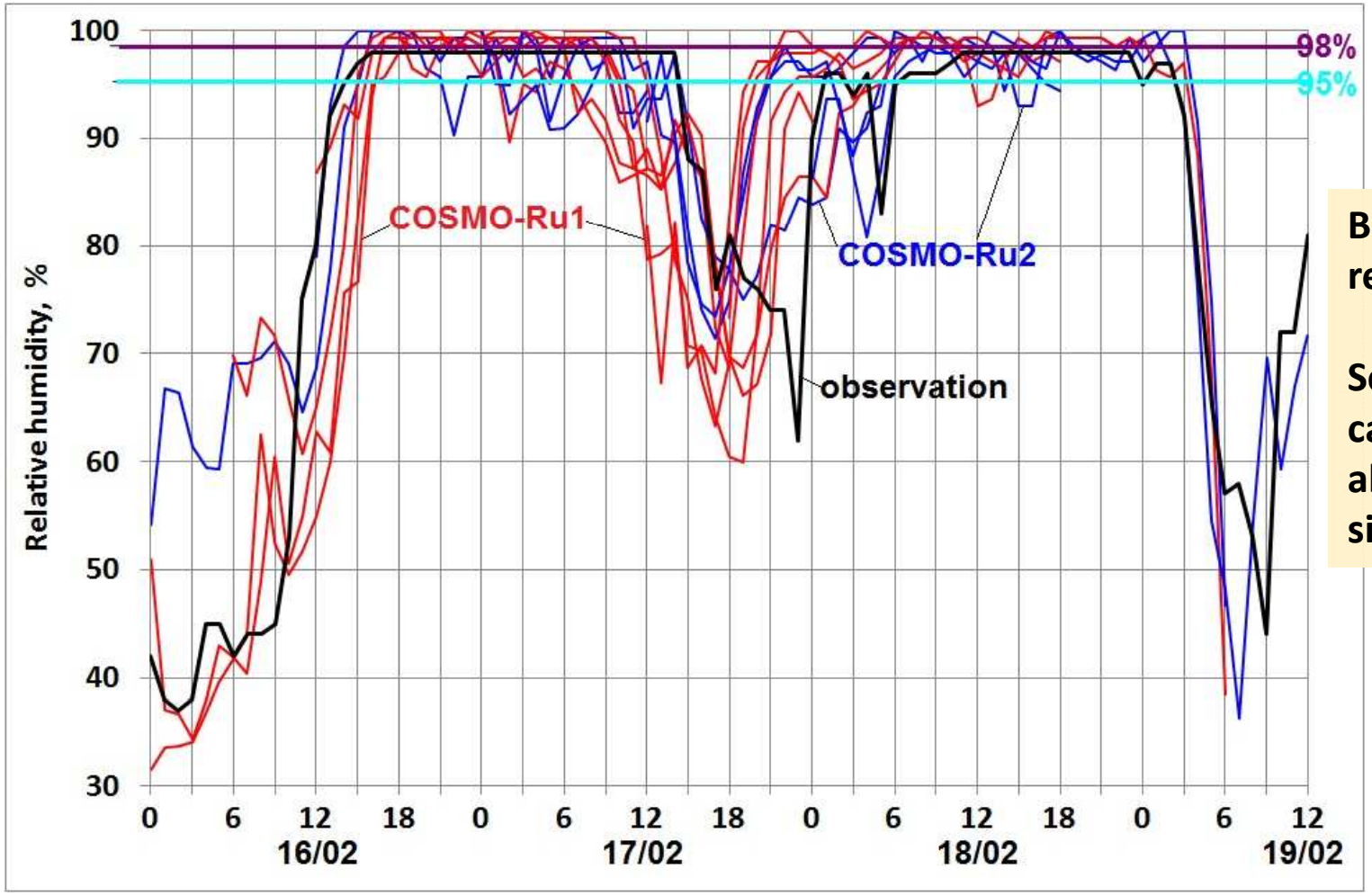
Observed minimum visibility values:

- **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 decrease of the relative humidity and an increase in wind led to the dissipation of the fog (cloudiness).

Low Visibility Case 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:

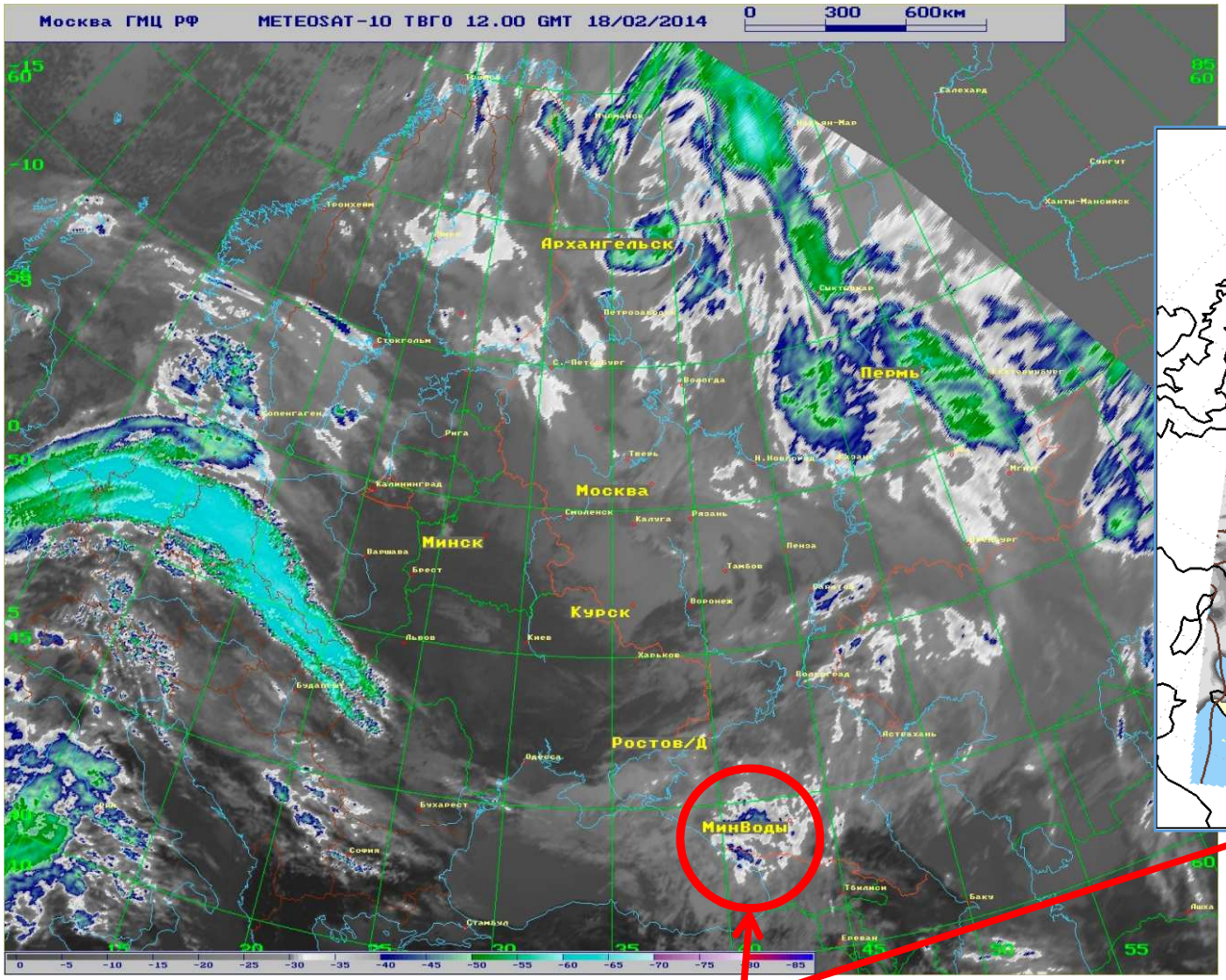
- 16/02, 00, 12 UTC;
- 17/02, 00, 12 UTC;
- 18/02, 00 UTC

COSMO-Ru1 36 h forecasts from:

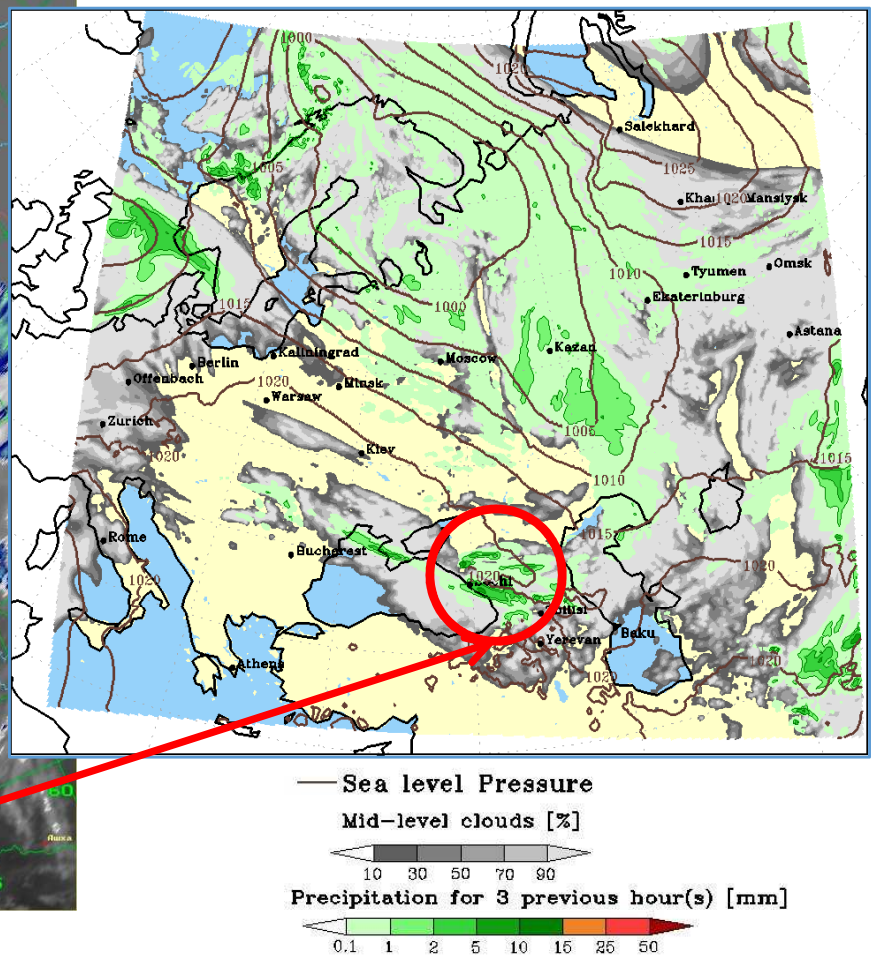
- 15/02, 18 UTC
- 16/02, 00, 06, 12, 18 UTC;
- 17/02, 00, 06, 12, 18 UTC;

Low Visibility Case on February 18, 2014

METEOSAT-10. Cloud top temperature
18.02.2014, 12 UTC

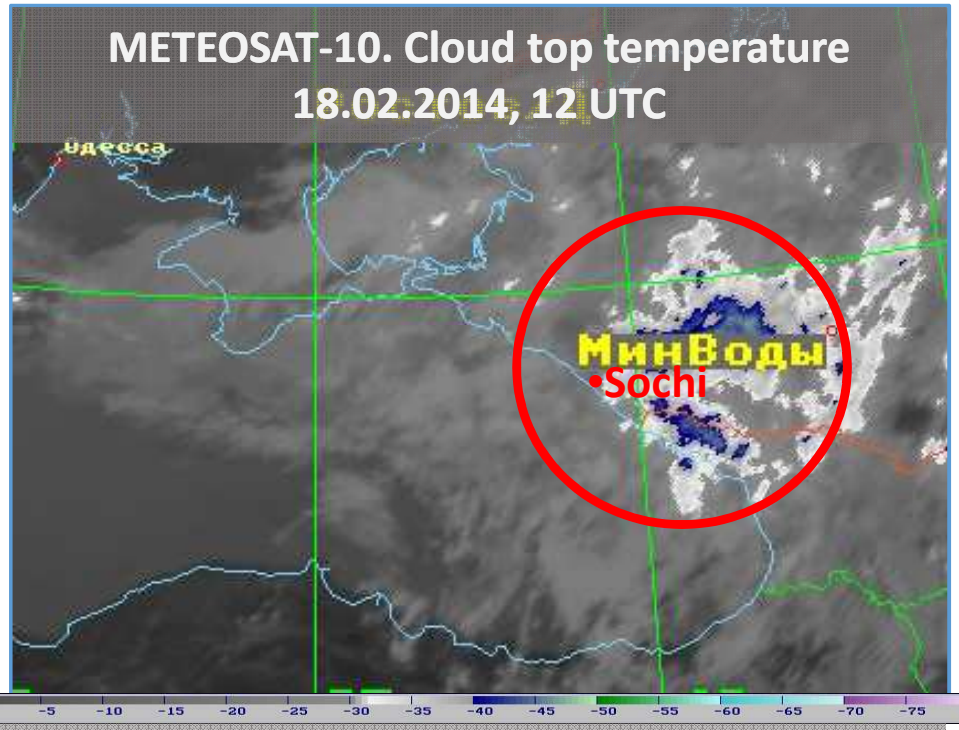


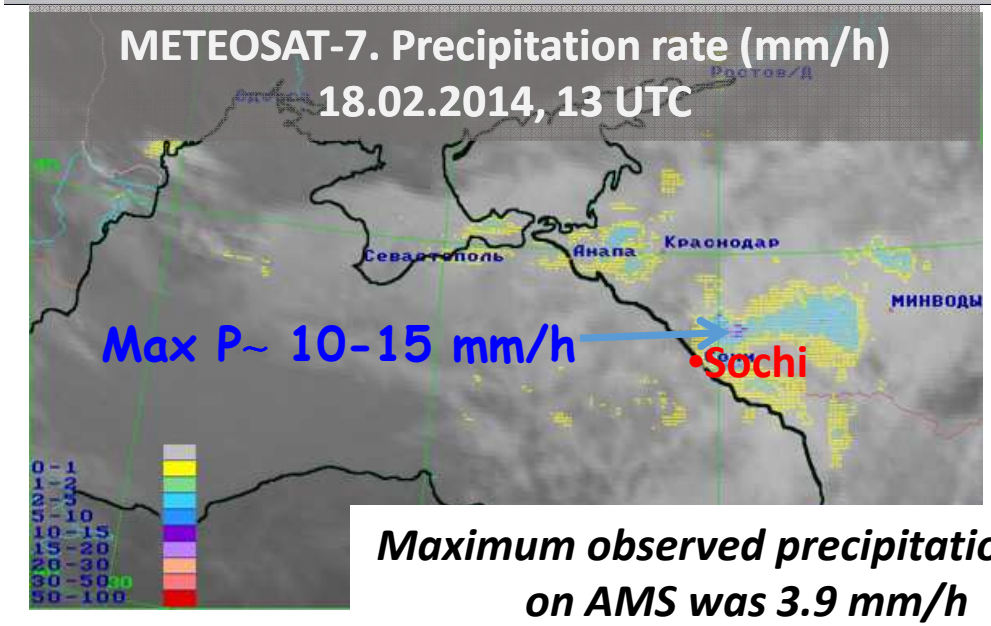
COSMO-Ru7 forecast
PMSL, Midlevel Cloud & Precipitation
60 h forecast from 16.02.14, 00 UTC



Cold front intensification when faced with mountain ridge

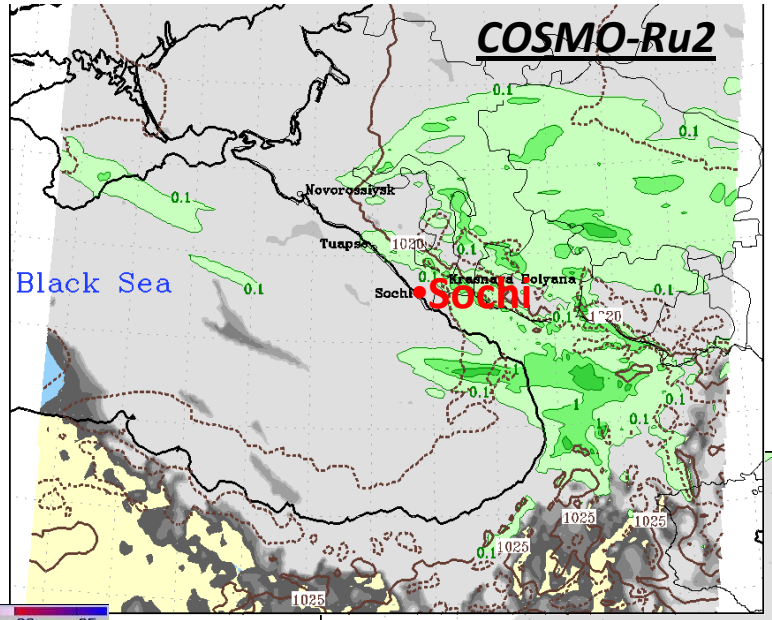
Low Visibility Case on February 18, 2014

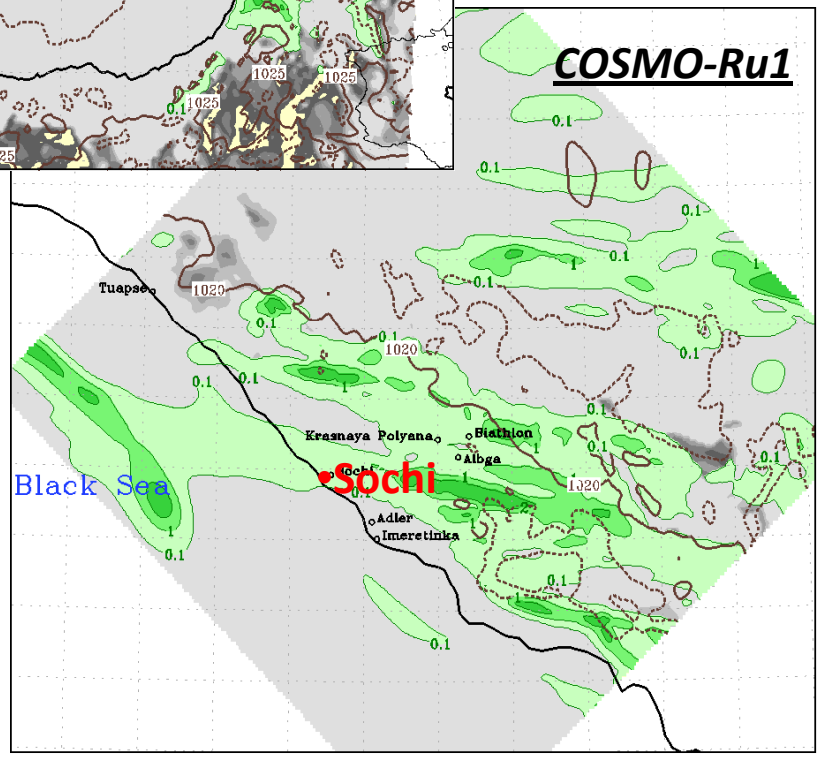




Maximum observed precipitation rate on AMS was 3.9 mm/h

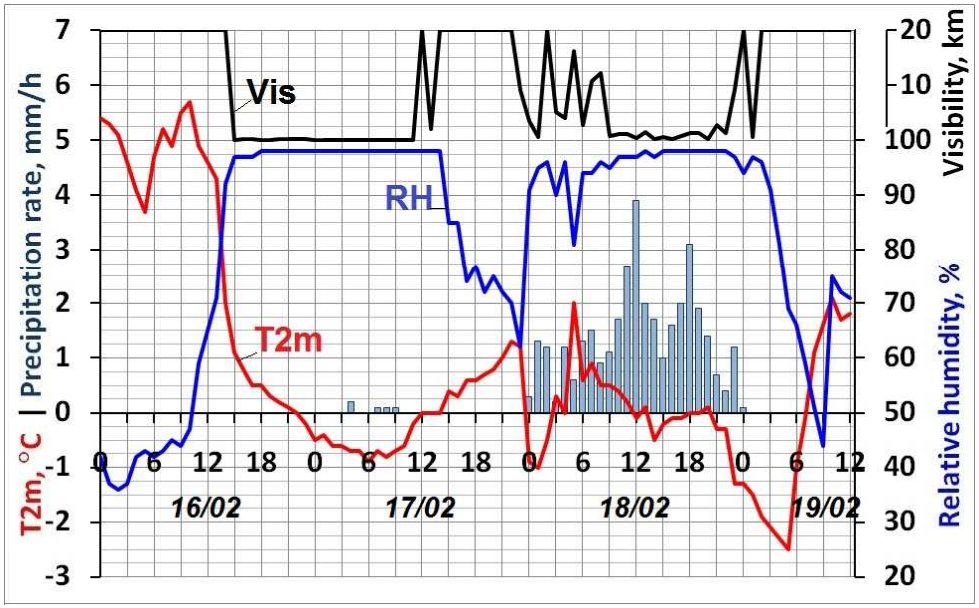
PMSL, Midlevel Cloud & 1h Precipitation
24 h forecast from 17.02.14, 12 UTC



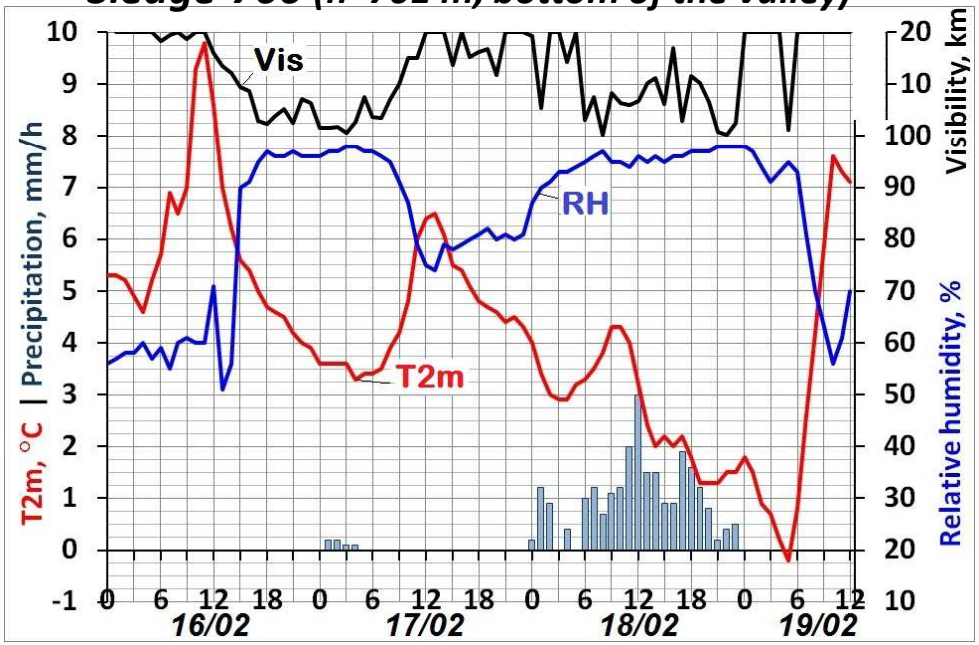


Low Visibility Case on February 18, 2014

***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 precipitation rate 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**

Snow or mix phase

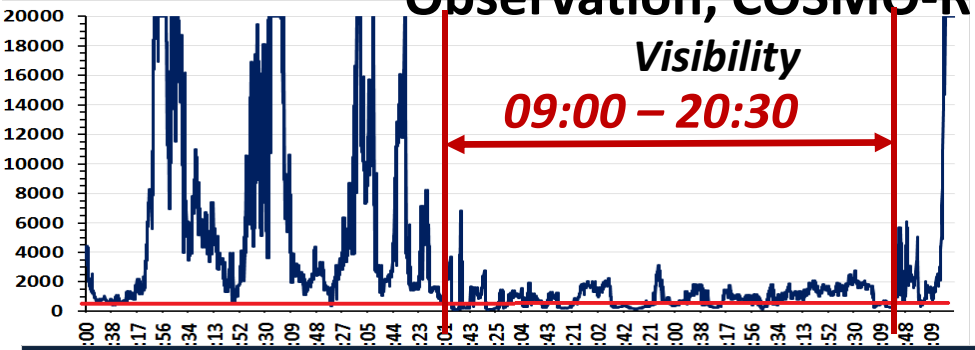
G.Carusel 1000	(h= 980 m)	1.1 mm/h	**2.8 mm/h**
Roza Khutor 7	(h= 970 m)	0.8 mm/h	**2.2 mm/h**
Sledge -700	(h= 701m)	1.0 mm/h	**3.0 mm/h**
Kordon Laura	(h= 570m)	1.5 mm/h	**3.4 mm/h**
Krasnaya Polyana	(h= 564 m)	1.2 mm/h	**3.1 mm/h**

Rain?

In light wind condition visibility can be less than 500 m when snowfall rate is more then 1.2 mm/h. Visibility is more then 3 km if rain rate is less than 7-8 mm/h. (A.Zverev "Synoptic meteorology", 1977; I.Gultepe, J.Milbrandt, 2007)

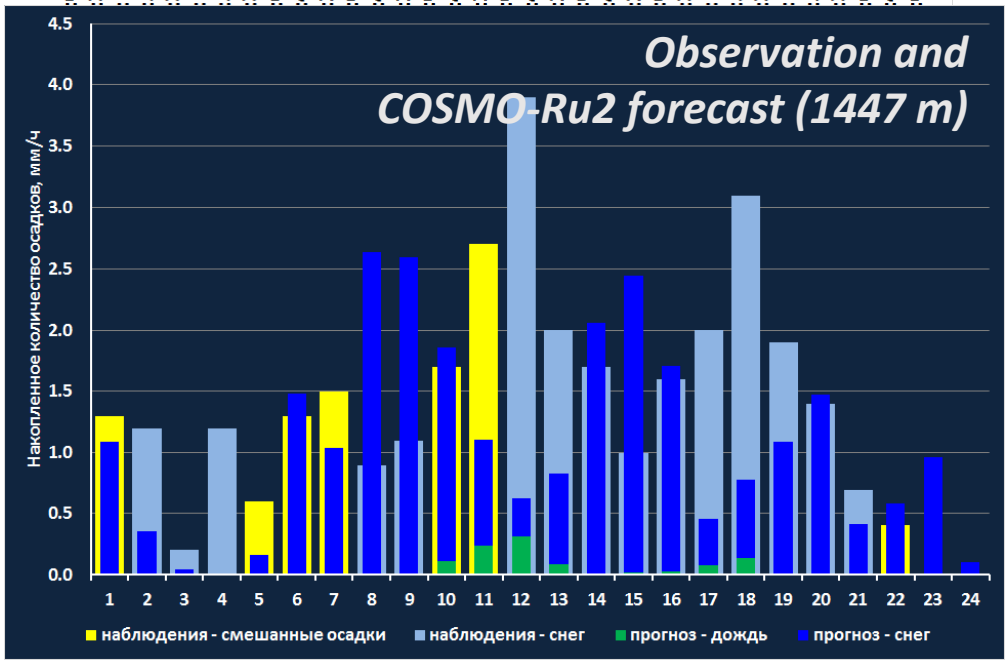
Low Visibility Case on February 18, 2014

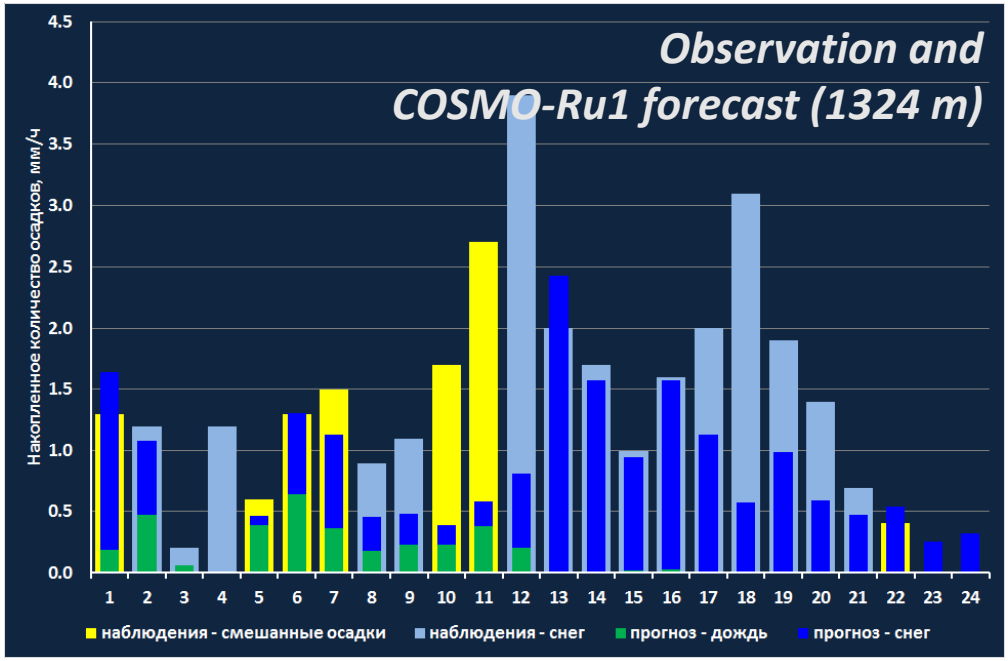
Precipitation phase and rate
Observation, COSMO-Ru1 and COSMO-Ru2 forecasts



Biathlon-Stadium (1455 m)

(precipitation rate and visibility – AMS data, precipitation phase – PWD data)





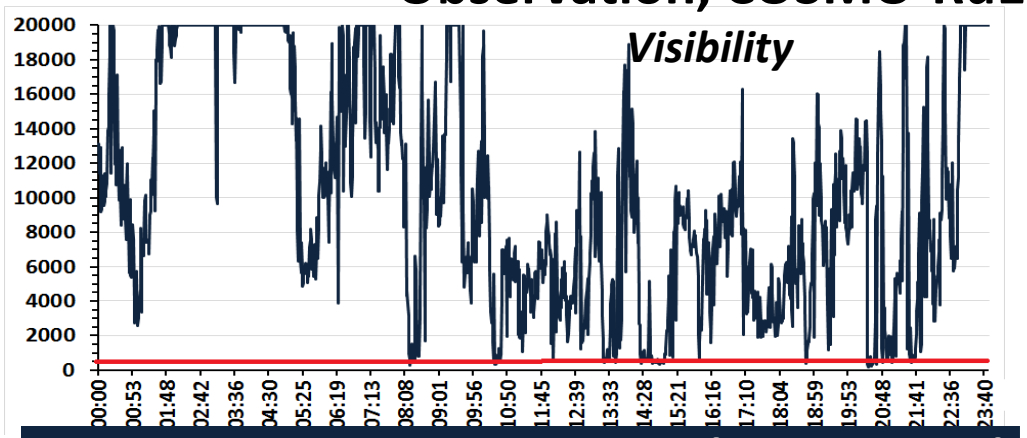
Observations (at the background) : **light green** – rain, **yellow** – mixed, **light blue** – snow
Forecast (at the foreground): **green** – rain, **blue** - snow

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.

Low Visibility Case on February 18, 2014

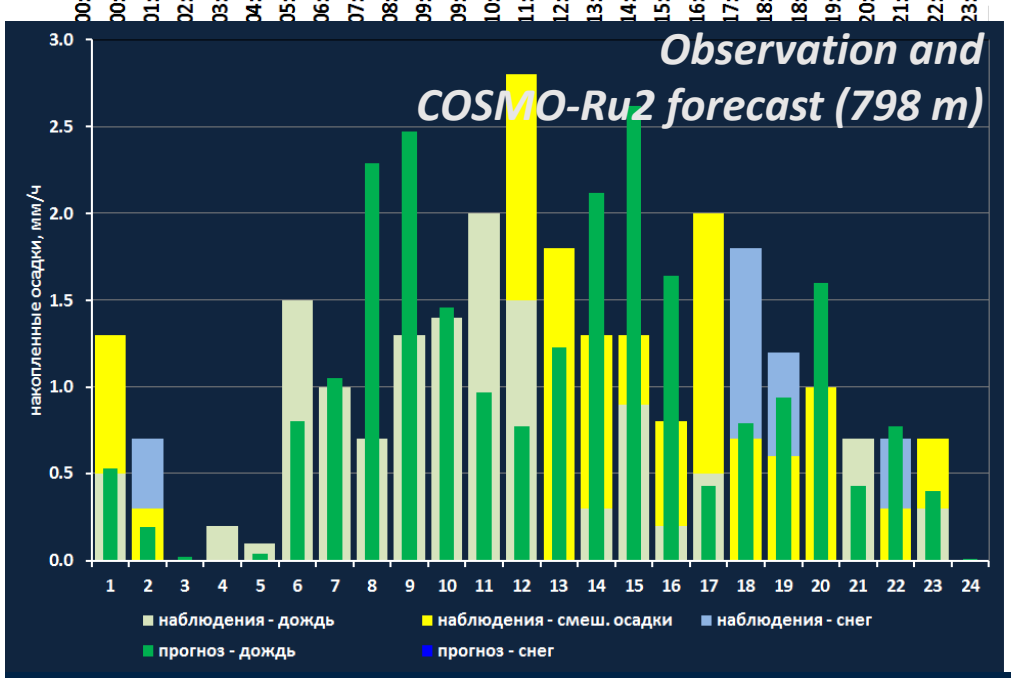
Precipitation phase and rate

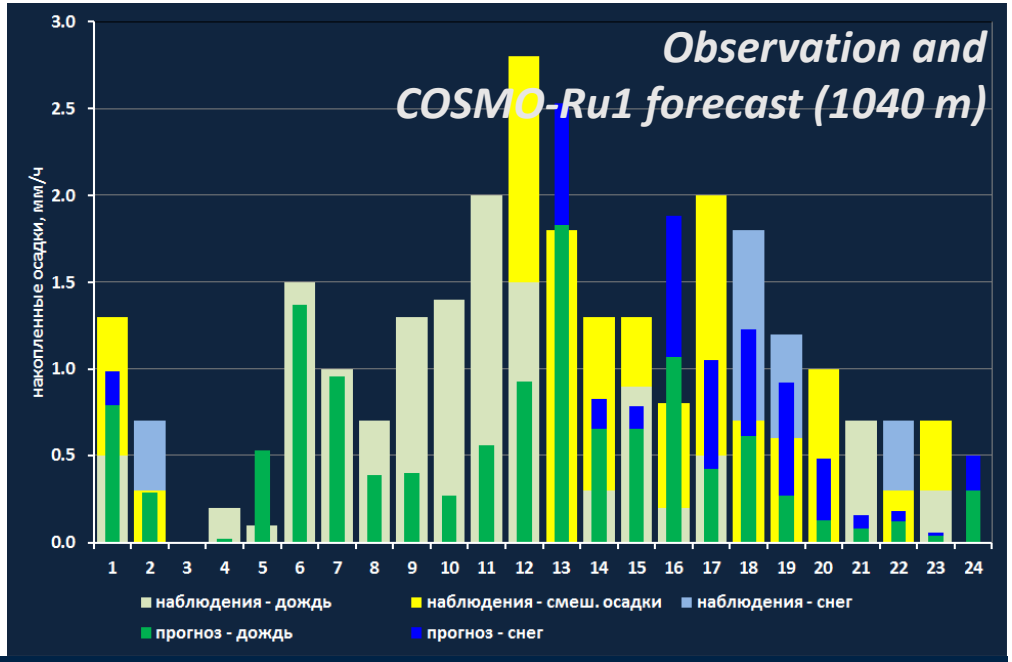
Observation, COSMO-Ru1 and COSMO-Ru2 forecasts



Gornaya Karusel-1000 (978 m)

(precipitation rate and visibility – AMS data, precipitation phase – PWD data)





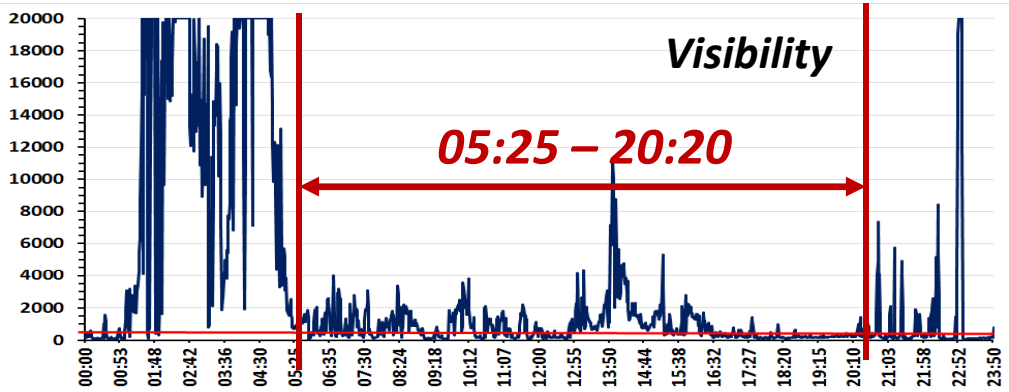
Observations (at the background) : **light green** – rain, **yellow** – mixed, **light blue** – snow
Forecast (at the foreground): **green** – rain, **blue** - snow

Precipitation phase and temporal distribution were better predicted by COSMO-Ru1, but precipitation sum forecast was better for COSMO-Ru2.

Low Visibility Case on February 18, 2014

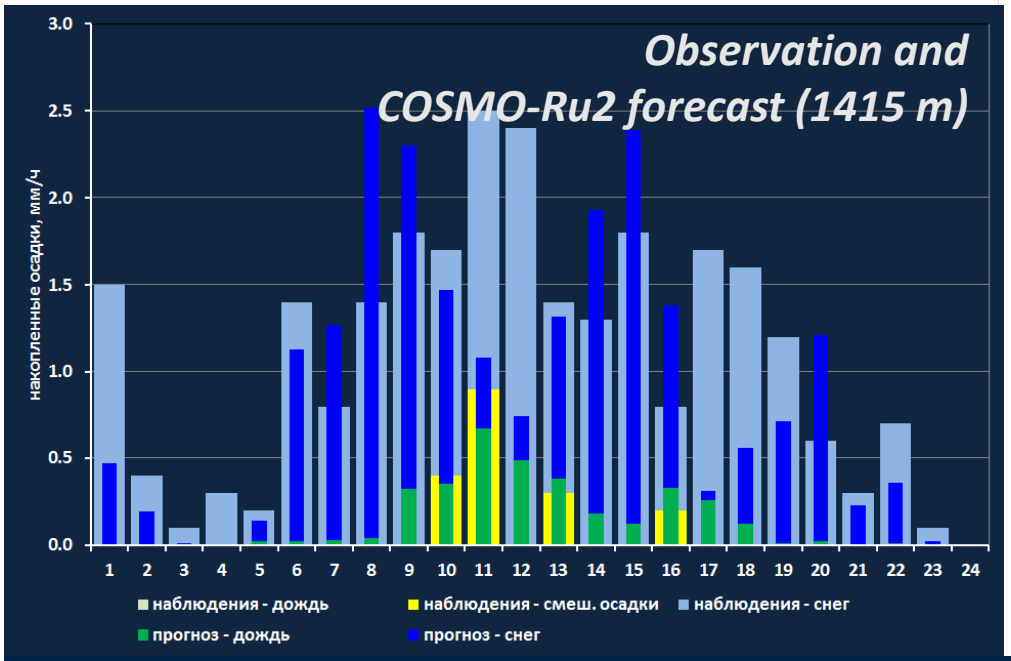
Precipitation phase and rate

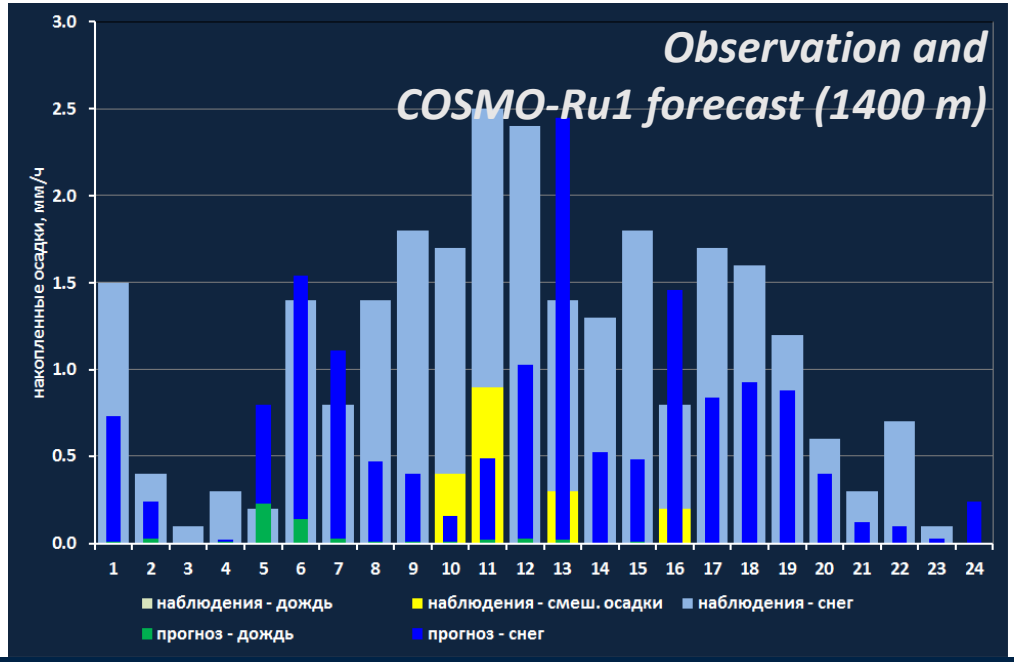
Observation, COSMO-Ru1 and COSMO-Ru2 forecasts



Gornaya Karusel-1500 (1432 m)

(precipitation rate and visibility – AMS data, precipitation phase – PWD data)





Observations (at the background) : **light green** – rain, **yellow** – mixed, **light blue** – snow
Forecast (at the foreground): **green** – rain, **blue** - snow

Precipitation phase and temporal distribution were better predicted by COSMO-Ru2, by there are errors in temporal distribution.

Relative Humidity / Visibility Ratio

Observation Tools (Technical Data)

Parameter	Sensor	Measurement range	Accuracy, Range
Temperature	Vaisala HMP155	-80 … +60°C	±(0.12 … 0.45)°C
Relative Humidity	Vaisala HMP155	0 … 100%	±(1 …1.8)%, -20 … +40°C
Visibility	Vaisala PWD22	10 … 20 000 m	±10%, 10 … 10 000 m
Precipitation type	Vaisala PWD22		
Precipitation amount	OTT Pluvio2	0.1 … 500 mm	5%

PWD22 (Present Weather Detector) identifies 7 different type if precipitation (rain, freezing rain, drizzle frizzing drizzle, mixed rain/snow, snow, ice pellets), fog, mist, haze or clear.

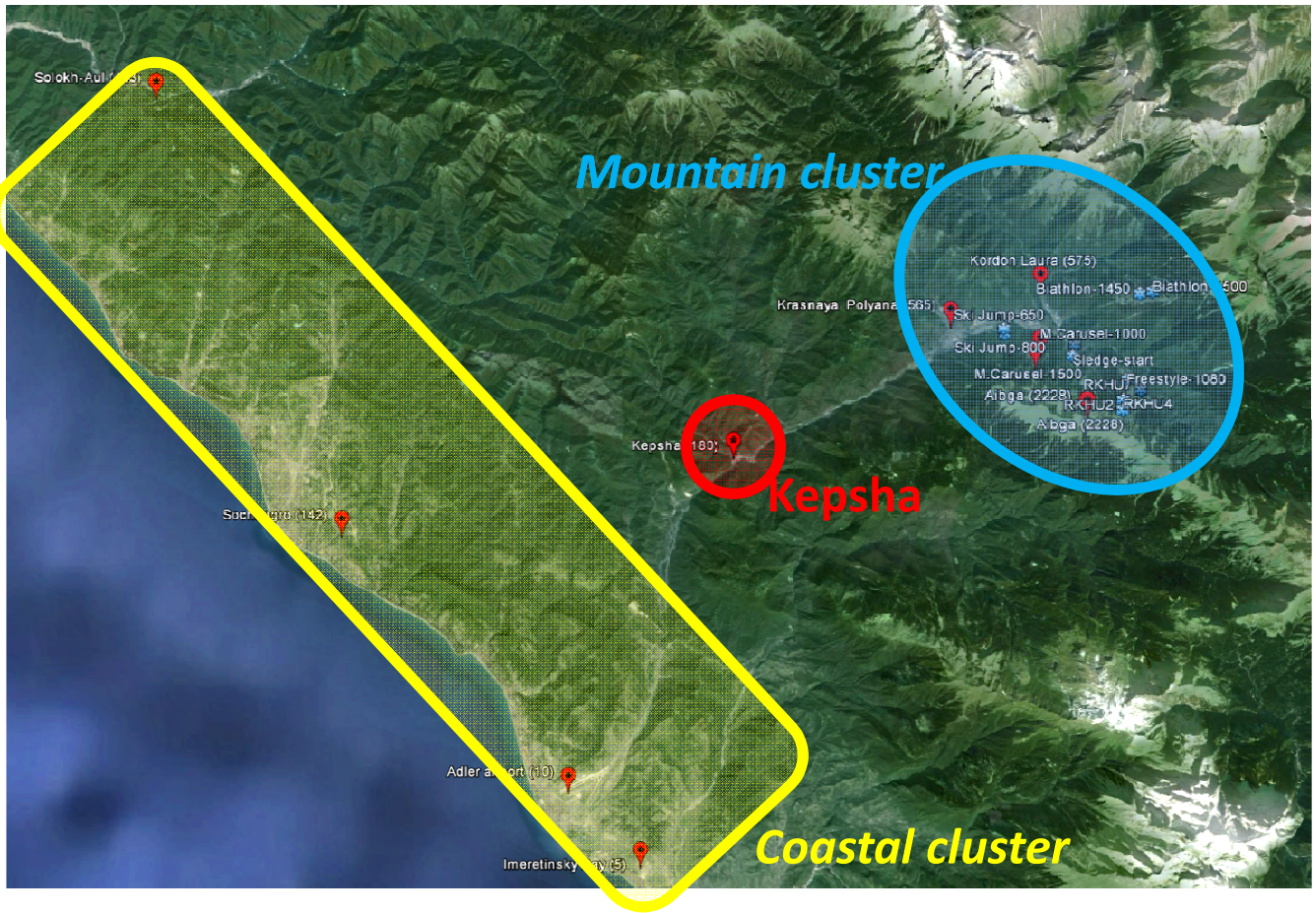
In further research 10 min averaged data were used.

Relative Humidity / Visibility Ratio

Data availability

Simultaneous monitoring data of Relative Humidity and Visibility can be obtained for **21 stations** for the study period (January 1, 2014 – March 31, 2014) without significant gaps in observations.

4 stations located in coastal cluster,
16 stations – in mountain cluster,
and **one** – somewhere between.



Relative Humidity / Visibility Ratio

Data selection

1. Non precipitation cases – Precipitation cases
2. January & February – March
3. Coastal cluster – Mountain cluster
4. Altitude (for the sites within the valley)

Mountain cluster, altitude distribution

- H > 2 000 m: 2 stations, No Data or few Data
- H = 1500 … 2000 m: 2 stations, a large spread of data – not good for analysis
- H = 1000 … 1500 m: 6 stations , Data can be regarded as satisfactory (for analysis) for 2 stations only
- H = 500 … 1000 m: 6 stations, Data distribution similar to the one for H = 1000-1500 m

Coastal cluster + Kepsha

- RH / Vis ratio looks the similar for all stations

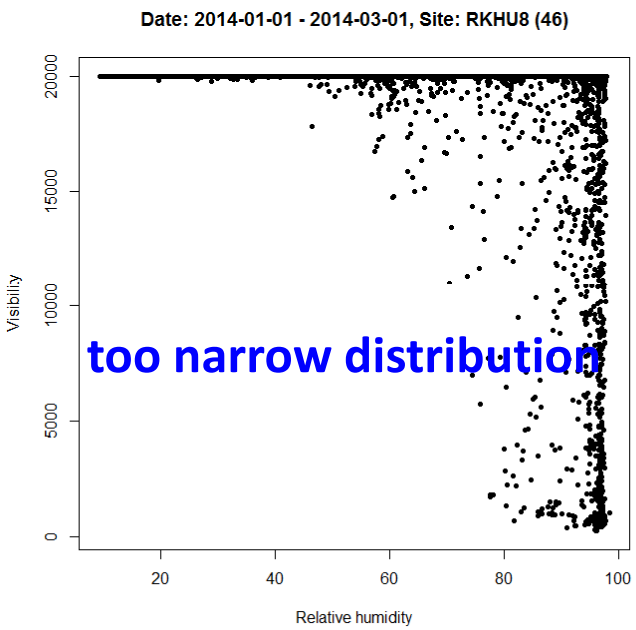
Problems:

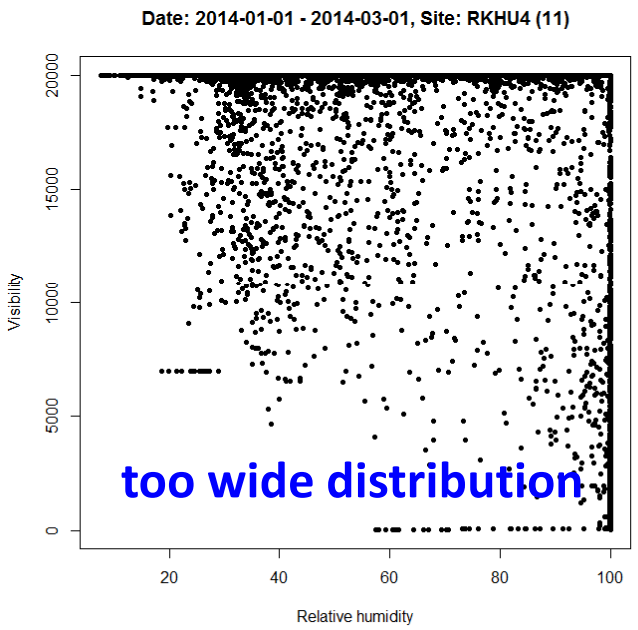
- In Data Base for some stations RH values were rounded to the whole number!!! (mainly for precipitation cases)
  Instead observed RH we use T2m and DPT to calculate RH
- There are some "suspected" visibility observations that were excluded from data sets.

Relative Humidity / Visibility Ratio

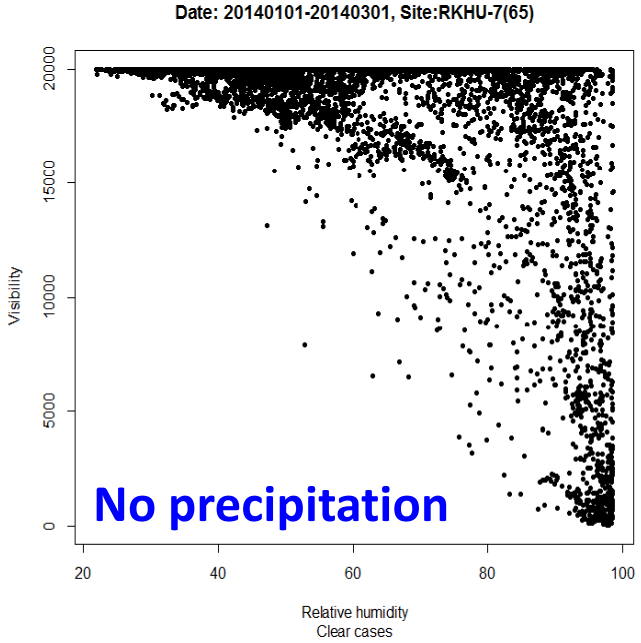
Mountain cluster

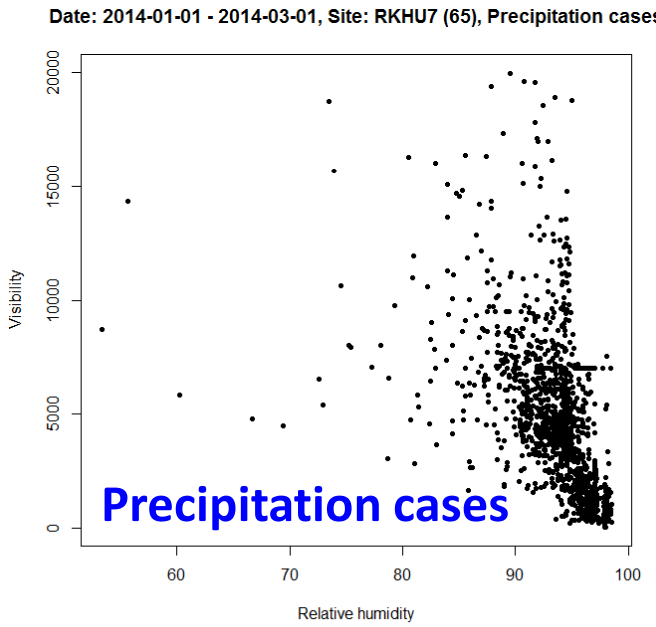
H = 1500 … 2000 m





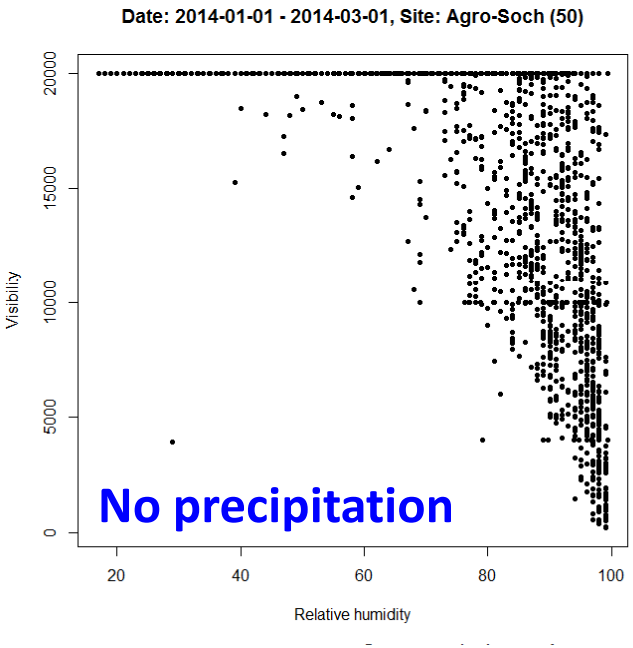
H = 1000 … 1500 m

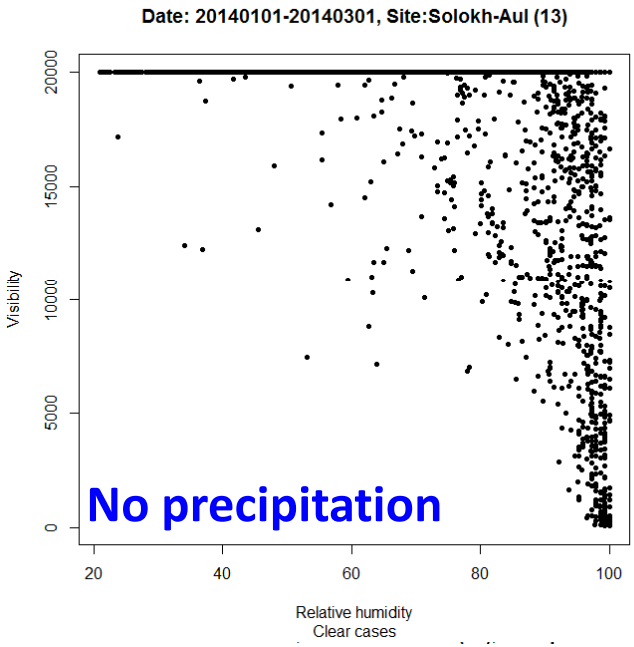


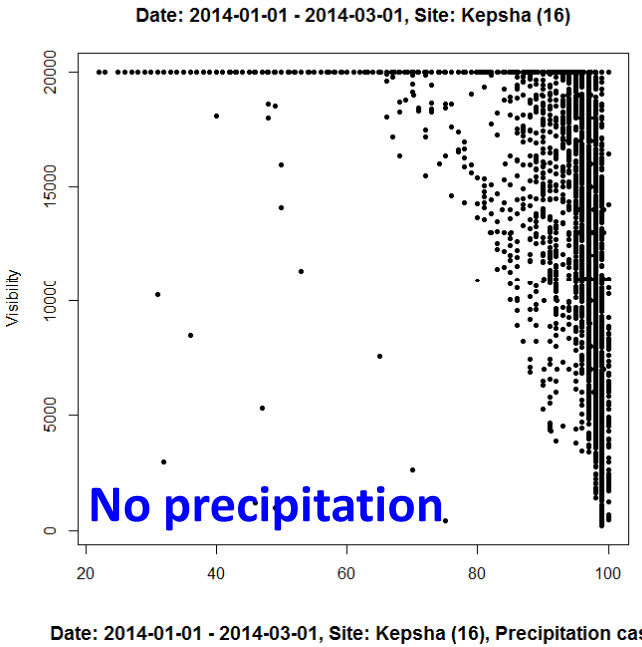


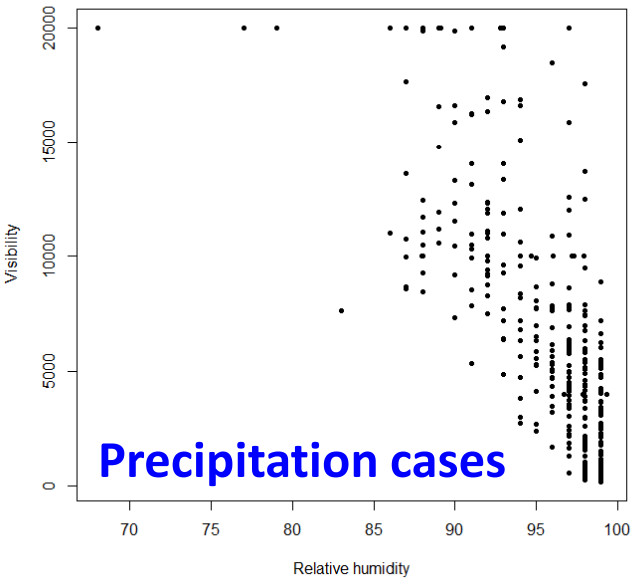
Relative Humidity / Visibility Ratio

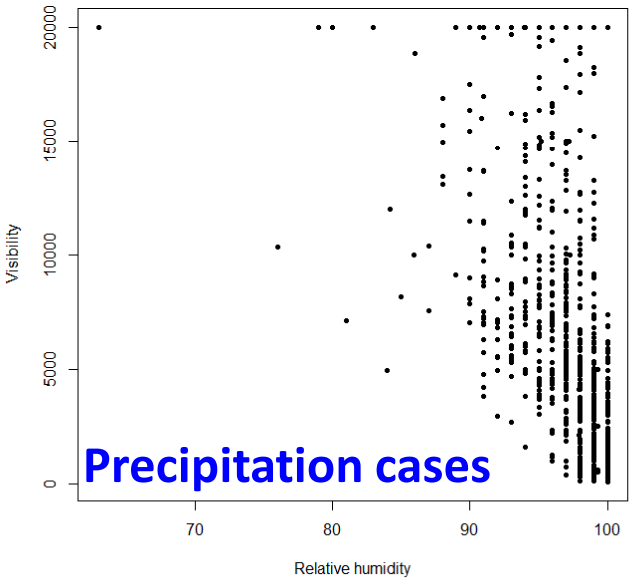
Coastal cluster

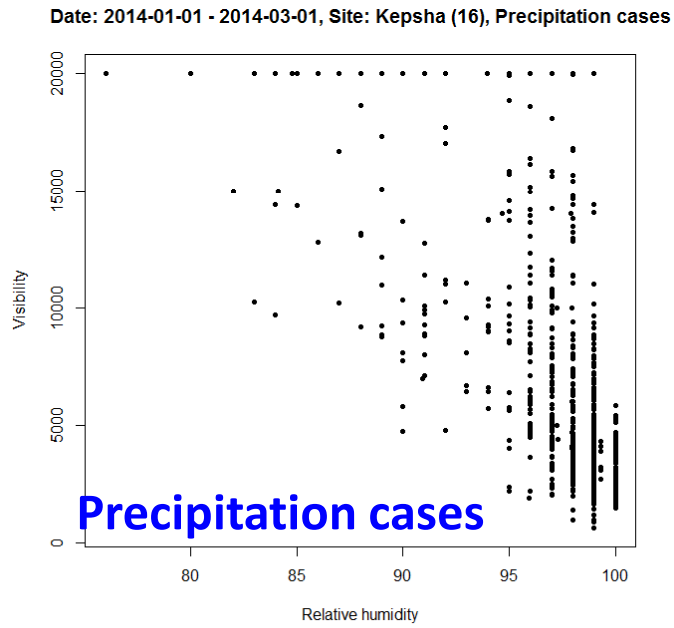








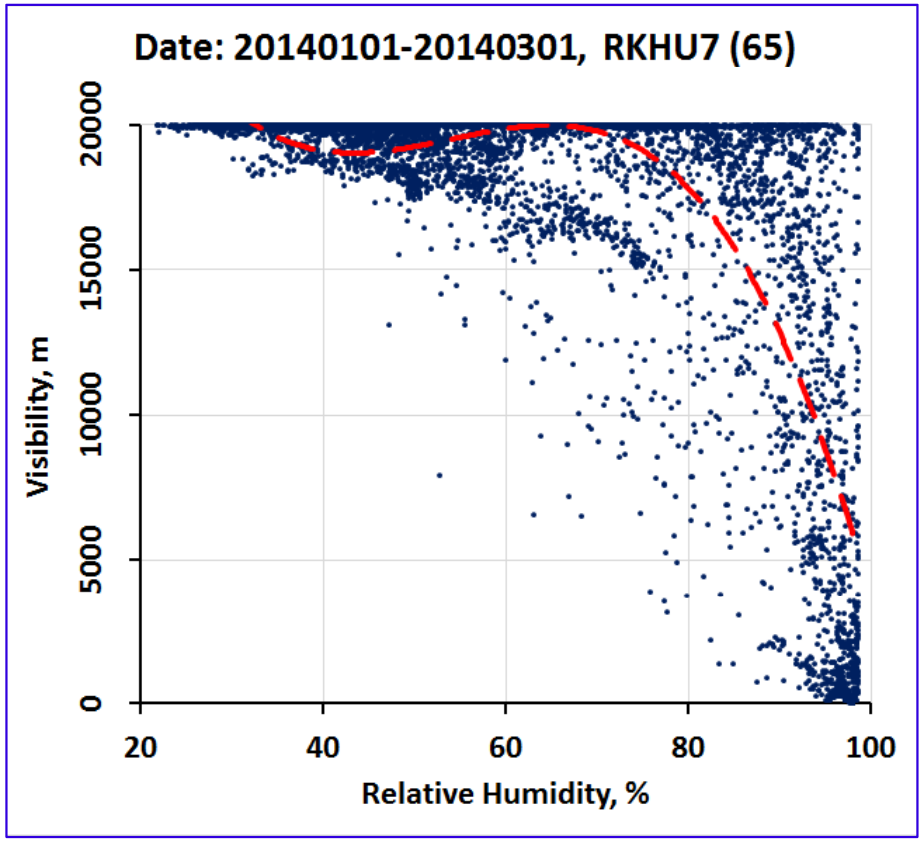




Relative Humidity / Visibility Ratio

Mountain cluster, Roza Khutor-7

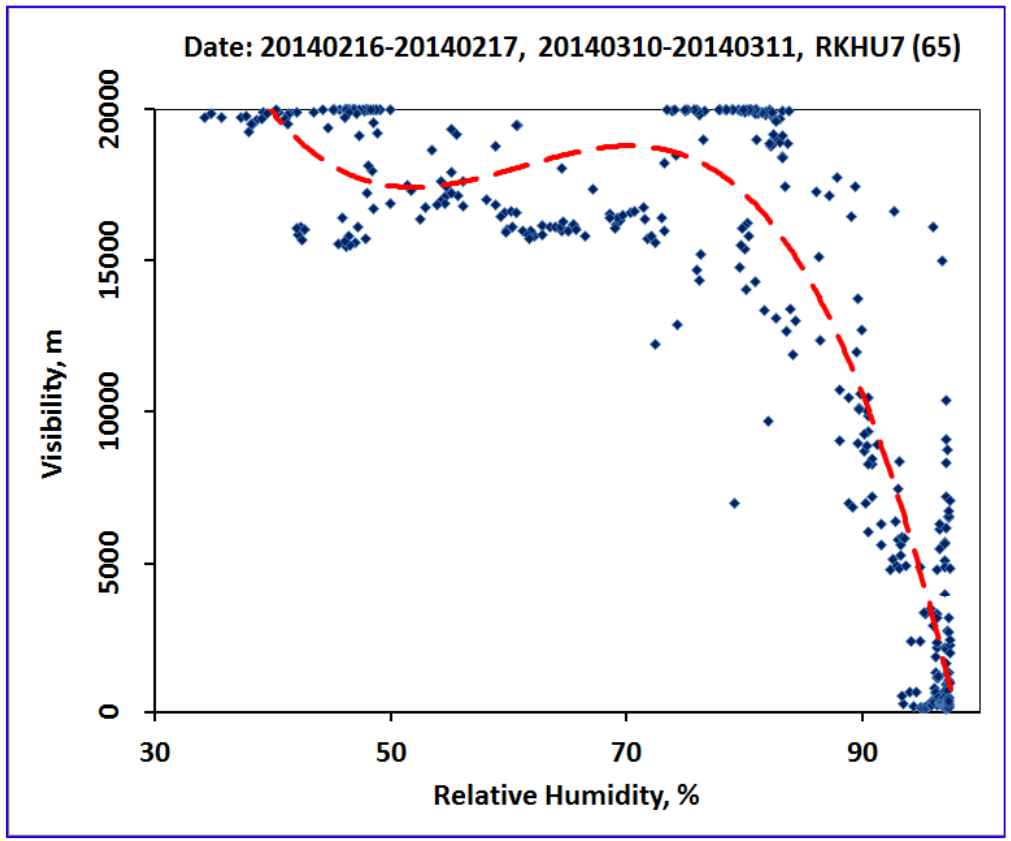
All data for non precipitation cases during January 1, 2014 – March 1, 2014



$y=-0.1955x^3+31.7x^2-1646.3x+46750$

$R^2 = 0.62$

Data for low visibility cases (due to cloud formation on the slope) February 16-17 and March 10-11



$y=-0.444x^3+81.37x^2-4858.4x+112477$

$R^2 = 0.87$

Conclusions and outlook (1)

1. It was shown that COSMO-Ru models with grid spacing 2.2 and 1.1 km produced good forecasts of relative humidity and wind for the region of complex terrain.
2. COSMO-Ru1 model has some advantages because of better model orography based on high resolution ASTER data in contrast to GLOBE data that is used for COSMO-Ru2 model orography. That leads to better wind forecast and no need to do any height correction of temperature.
3. Forecasters could predict accurately visibility changes during Sochi Olympics / Paralympics using COSMO-Ru model output (e.g. forecast chars of relative humidity + stream lines at different levels).
4. Comparison with PWD data on precipitation type showed good agreement between predicted and observed phase composition of the precipitation.

Conclusions and outlook (2)

5. **Analysis of the Observation Data Base for Sochi-2014 region showed:**

- **Visibility and Relative Humidity observations should be checked jointly;**
- **Another predictor (instead of RH) may be used – e.g. Dew Point Deficit;**
- **Only low visibility cases should be investigated in order to find RH / Vis ratio (or DPD / Vis ratio)**
- **…**

Thank you for your attention!