Mobile System for Atmosphere Remote Sensing (MS ARS): Results of 24/7 mode of operation during Olympic and Paralympics Games «Sochi- 2014»

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Introduction

The mobile system, composed with three modern remote sensing instruments, was developed and constructed by Research and Production Association «Typhoon» (Roshydromet) specially for instrumental support of short term weather forecasts during Olympic and Paralympics Games "Sochi-2014". The system involves wind radar "Scintec3000", microwave temperature profiler HATPRO and cloud/rain microstructure profiler MRR-2. Wind radar, operating at central frequency 1290MGH, provides wind speed and direction profiles with 100m resolution within height from 600m up to 3500m. Microwave temperature profiler provides temperature profiles from ground level up to 10000m with 50m height resolution. Micro rain radar provides radar reflectivity and Doppler spectra parameters of radio waves scattered by hydro meteors in the vertical beam up to the height 6000m. The detailed description of the system and it internal structure was made at the previous report on TECO 2012 (1)

The presented report aims to share the experience of implementation of modern remote sensing technique to the practice of routine short range forecasts and specially detailed forecasts for different heights in mountain environment. A few most interesting cases of weather events are presented. The benefits and limitations of the technology as well as "Post Olympic" exploitation are discussed on the base of earned experience.

Preliminary inter comparisons of the data

The system, as a completed instrument, was created at the fall 2012. All sensors of the system are from the class of "Remote Sensing", thus the inter comparisons with the standard independent measurements are required. It is clear that for the main set of measured parameters, the radiozond data are applicable as independent measurements. Just MRR-2 data cannot be compared in direct form, but regularly operating weather radar can provide us with the general info to estimate ability of the MRR-2.

The tests and comparisons with radiozondes were made in Dolgoprudny, Moscow Region on fall 2012. The aerological station Dolgoprudny (#27612) has regular launching of MRZ-3A radiozondes two times per day (12:00 UTC and 00:00 UTC). MS ARS was installed within 200 m apart from the radiozondes launching site and performed measurements of temperature profiles up to 10000m each 5 min. Integrated Water Vapor (IWV) and Liquid Water Path (LWP) were measured in parallel with it. Vertical structure of radar reflectivity and first three moments of Doppler spectra were measured by MRR-2 with the time step 1 min. These data were compared with weather radar MRL-5, which is on routine measurements in Moscow City within last 20 years. The distance between Dolgoprudny and this radar is about 15km. The wind speed and direction were not measured during these inter comparisons, because the operation of wind profiling radar was not permitted at the location of Dolgoprudny.

The comparisons were made within about one month. The retrieved temperature profiles were directly compared with the temperature profiles obtained by radiozonde two times a day. The examples of the retrieved profiles compared with radiozondes are presented on the Fig 1 and Fig 2. It was estimated, that average MSD for whole troposphere not exceed 1.5C The IWV was compared with the integral of absolute humidity measured by radiozond. Example of such data is presented on the Fig 3. The data of retrieved IWV during rainy conditions were excluded. It is clear from the plot, the HATPRO overestimate IWV on the value about 1.5kg/m sq. But this overestimate is almost constant every time and not dependant on the absolute value of IWV, hence we can decide it as systematic error caused by calibration of the device. The precipitation type, cloud top and "bright band" (zero isotherm) heights measured by MRL5 and MRR-2 were in good correspondence one to other – difference was not more than tenth of meters

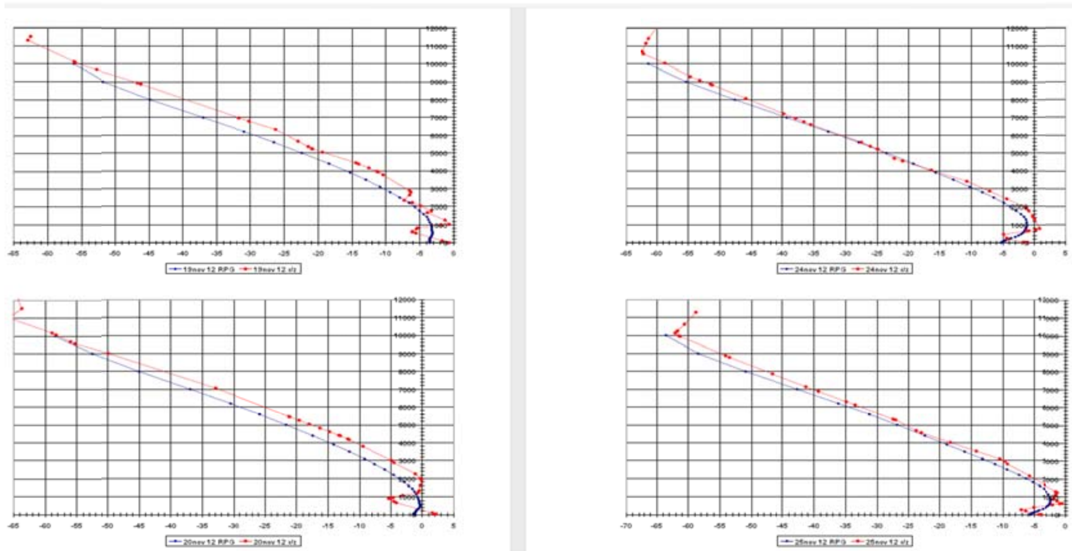

Fig.1 Comparisons of retrieved temperature profiles with measured by radiozondes during the "lifted inversion" cases

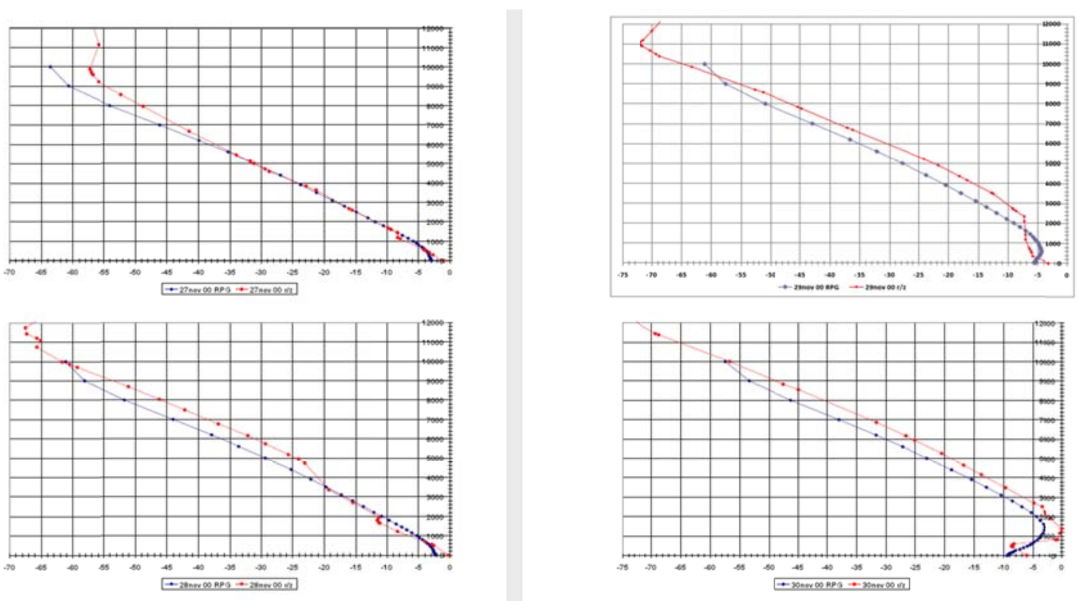

Fig.2 Comparisons of retrieved temperature profiles with measured by radiozondes during the adiabatic and simple inversion cases

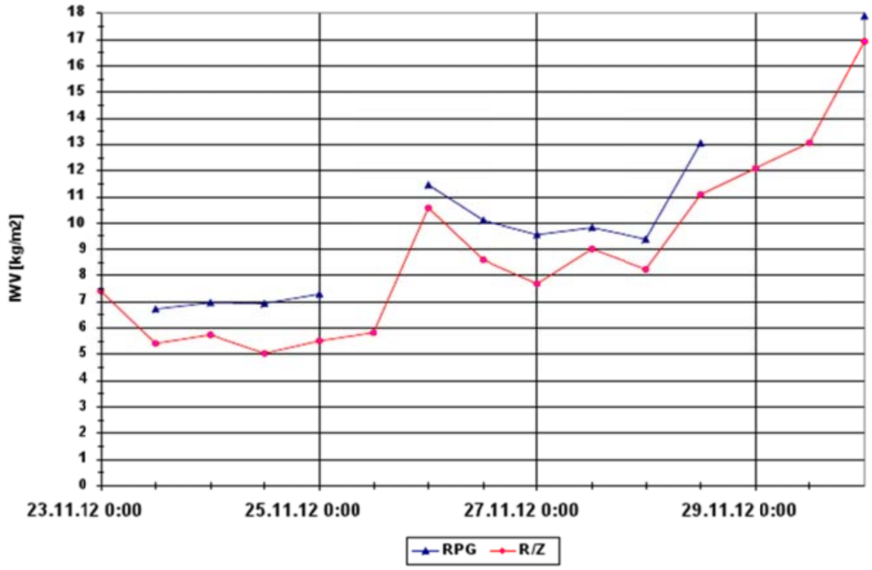

Fig.3 Comparisons of retrieved IWV (RPG) and measured by radiozondes (R/Z)

System location during Olympic and Paralympics Games

The results of inter comparisons were accepted as positive and the system was transported to Krasnaya Polyana- Mountain Cluster of “Sochi-2014” .It was in test operation since February 2013. But this test operation was made without usage of wind profiling radar. The problem was that wind profiling radar has required official permission for radiation, which, due to Law, can be provided only for specific installation site. From the other hand, the microwave temperature profiler can operate properly in mountain environment just when it has enough free space in horizontal direction (5 km in our case), and the horizontal beam use to be parallel to the nearest mountain slope. Otherwise the assumption about “layer-uniform” atmosphere will not be applicable, and retrieving of temperature profiles from the scanning microwave measurements will be not valid. And third limitation for the system location was created by the geography of the Olympic competition sites and by the location of the ground based weather stations on these sites.

Taking into account these three critical parameters, we have investigated all Mountain Cluster during the winter 2012-2013. As a result, we have applied to State Committee of Russian Federation for Radio Communications for three specific sites within the area of Krasnaya Polyana in March 2013. After 6 month we have finally received the permission for the all three sites. So, this gives us a favor to make the final choice by ourselves and we have decided to install the system for Olympic Games in the Caucuses National Park at the place “Kordon Laura”. The satellite picture of the territory is presented on the Fig 4. Installation site is marked with the red dot, and the direction of scanning by microwave radiometer is presented by the green arrow. On the up-right corner of the picture can be seen the biathlon and running ski stadium, and on the bottom-left corner can be seen the Olympic village Esto-Sadok.

The location at “Kordon Laura” was preferable with respect to all other, because it is at the approximately equal distance (7-8 km) from the ground based meteorological stations installed on different Olympic objects at different heights. This circumstance allows us to make regular inter comparisons of retrieved temperature profile with “in-situ” temperature measurements. Although, the temperature sensors were installed at 2m above the ground, and maximum horizontal distances between sensors at the same height were approximately 8km also, we still had the chance to average the data for each height to compare it with microwave radiometer profile. The validity of such inter comparisons can be explained by the space integration of the signal received by microwave radiometer. As far this integrated over 10 km signal is used for retrieving of the temperature profile, then, this retrieved profile, should be compatible with averaged data for about the same area. Such logic is absolutely clear for the flat area, and is not so obvious for the mountain environment. We will demonstrate below, how two opposite direction of sounding within the same valley could led to the very different results in temperature profile retrieving. But if the direction of sounding corresponds to the valley with the same micro climate, then the logic for flat area is applicable.

Fig 4. Map of the MS ARS installation. Red dot is location of the system at “Kordon Laura”. Green arrow is direction of sounding for scanning microwave radiometer.

Measurements configuration

Detailed technical spec of all instruments of the system was reported at the previous TECO-2012 Conference in Brussels (1). In difference to the system configuration described over there, the micro rain radar “MRR-2” was detached from the system and installed separately to meet the recommendation of International Working group of the Project “FROST-2014” (2)

The general view of the system at the location “Kordon Laura” is presented on the Fig 5. The microwave radiometer was installed on the roof of the operator cabin instead of standard it’s place on the wall behind the wind radar. To avoid any problem for microwave radiometer caused by snow accumulation on the roof, we have installed it on a special frame about 1m tall. This frame allows us to rotate radiometer independent to the whole trailer. The trailer was oriented from south to north, which corresponds to the orientation of the wind radar, because it was firmly connected to the trailer. The flat phase array antenna of the wind radar was surrounded by the side lobe reflectors. The side lobe reflectors (red sheets on the Fig 5) are made from the very light plastic material covered by the aluminum folia from inside. Such construction was very convenient for fast assembling/disassembling as for transportation, as for removing of snow from the wind radar antenna during the snow storms.

According to the requirements of the Main meteorologist of the Olympic Games, the system was specially configured for measurements and data transmission on the parameters as presented in the Tab. 1:

Parameter	Wind Radar	Microwave Radiometer
Vertical range (m)	Up to 3500	Up to 10000
Vertical resolution (m)	100	50
Rate of measurements (min)	5	5
Integration time (min)	30	-
Data transfer rate (min)	30	15

Tab. 1 System configuration


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Fig. 5 Common view of the MS ARS system at the "Kordon Laura"

Organization of 24/7 duty measurements and data transfer

Starting from 20 January and up to 17 March 2014 the system was in 24/7 duty operational mode without any interrupt despite of harsh weather and troubles in power supply and communication infra structure. The date for start of duty mode operation as well as finishing of this work was clearly corresponded to the official requirements of the International Olympic Committee. According to the official requirements, Roshydromet has an obligations to release the operative forecasts for the coming 24 hours with 1 hour temporal step separately and specifically for all heights of sport objects in mountain cluster. For this reason, the absence of any instrumental data within more than ½ hours was decided as non acceptable case.

Due to this, we organized 24 hours work for operator at site in parallel with 24 hours monitoring of the data remotely with the use of "Tem Viewer TM" software. The operator at site was responsible for controlling of the power supply, GPRS data transfer, preliminary quality control of the data transmitted to the Main Information Center (MIC), cleaning of the working antenna area of the wind profiler and microwave radiometer, checking of the visual situation and so on. It was established the set of action, what use to be done by duty operator in case of different possible troubles could happen. On top of that the supervisor on the remote site has controlled the system from time to time, and if he has found any uncertainties, he has requested by phone some actions from the duty operator.

The data from all sensors in simplest form were transferred to the MIC every 30 minutes. The examples of such data are presented on the Fig. 6 and Fig. 7 These data were immediately analyzed by the duty synoptic and in case of any suspicions, the synoptic has verified by phone with the system supervisor the current status of the system. So, at the end, the system has operated under the three organizing steps and three qualification level of quality and operation control.

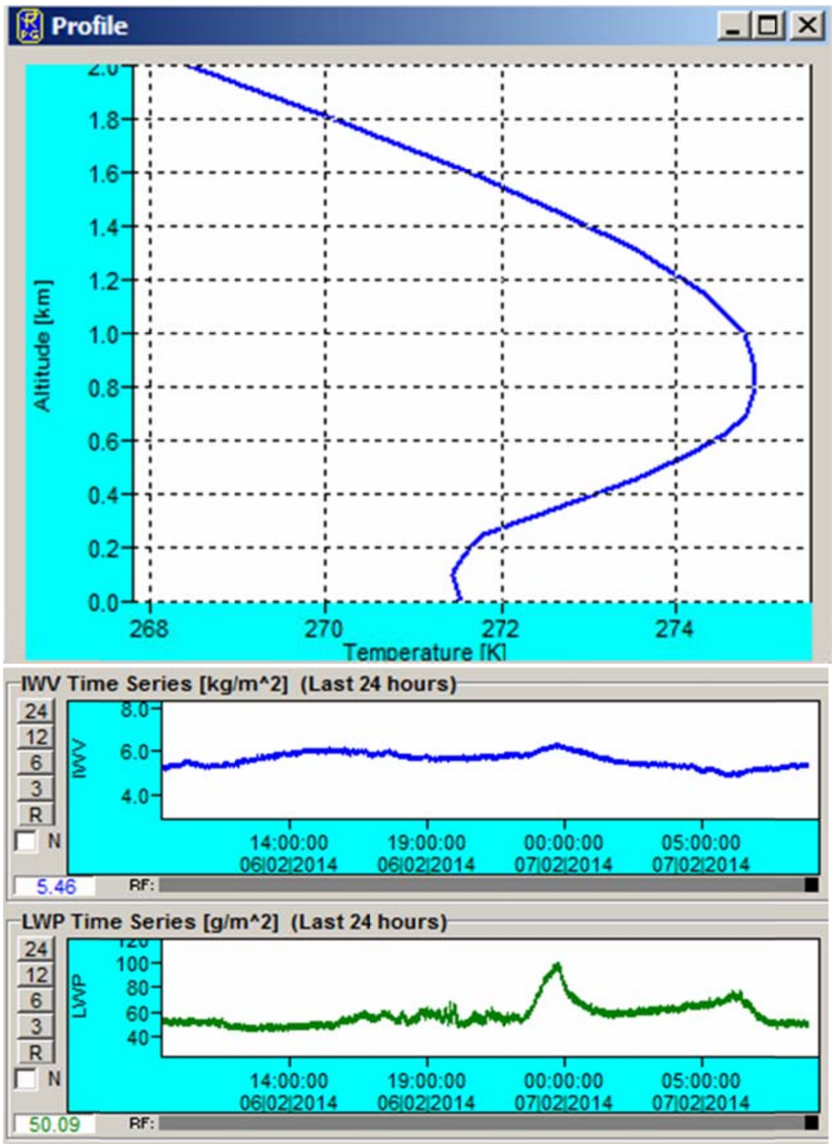

Fig 6. Exampel of transferred data: top pannel- temperature profile up to the height 2000m; middle pannel- time series of the IWV; bottom pannel – time series of the LWP.

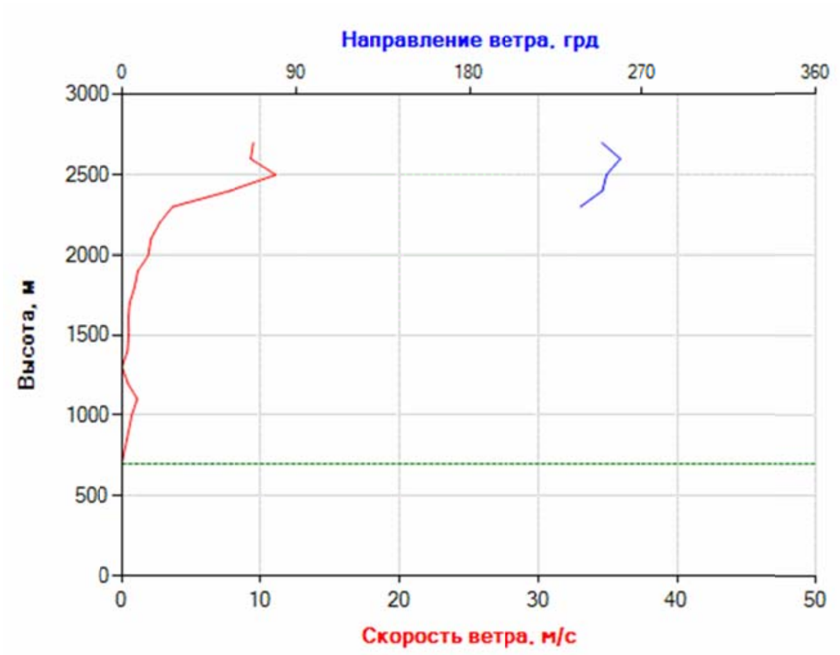

Fig.7 Example of transferred data: wind sped profile in red and wind direction in blue (just for wind more then 4m/sec

Operative data analysis and information exchange

The data obtained by the system were much richer and informative then those transferred to the duty synoptic as described above. The idea of these simple forms was only in supporting of the current instrumental data flow without analyzing of the details. Duty synoptic simply does not have a time for such analysis.

The operative data about trends in development of meteorological parameters were analyzed by the supervisor on the remote site. For the analysis of the temperature trends at different heights were used the 24 hours temperature fields for 2000m height range (Fig. 8) and 24 hours temperature fields for 10000m (Fig. 9). From the 10000m temperature field it was deducted the height of friction (physical boundary layer at given situation) and temperature waves on the troposphere top. From the 2000m temperature field it was deducted the character and shape of isotherm within the boundary layer.

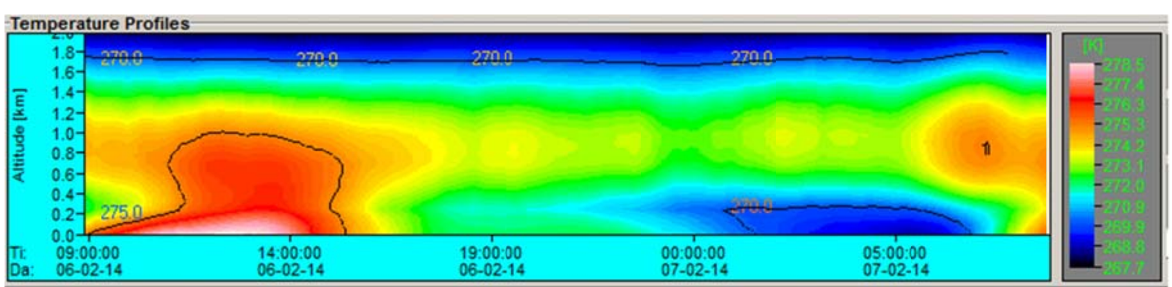

Fig. 8 Example of 24 hours temperature field for 2000m height.

The data from the wind profiler were used to construct the same time\height field, where the color corresponds to the different wind speed (Fig. 10) or wind direction (Fig.11). It was observed from the very beginning of wind measurements at “Kordon Laura” site, that air mass within the valley are very conservative, and there is no any disturbance in it while the weather is stable. As a result, the wind profiler is normally measure weak wind at low height level: no turbulence- no reflection. But as soon the weather change is expected from the NWP models, thus wind profiler start to feel turbulence up to the height

3500m and up. This specific behavior was really surprising for NWP models validation and for next forecast approaches

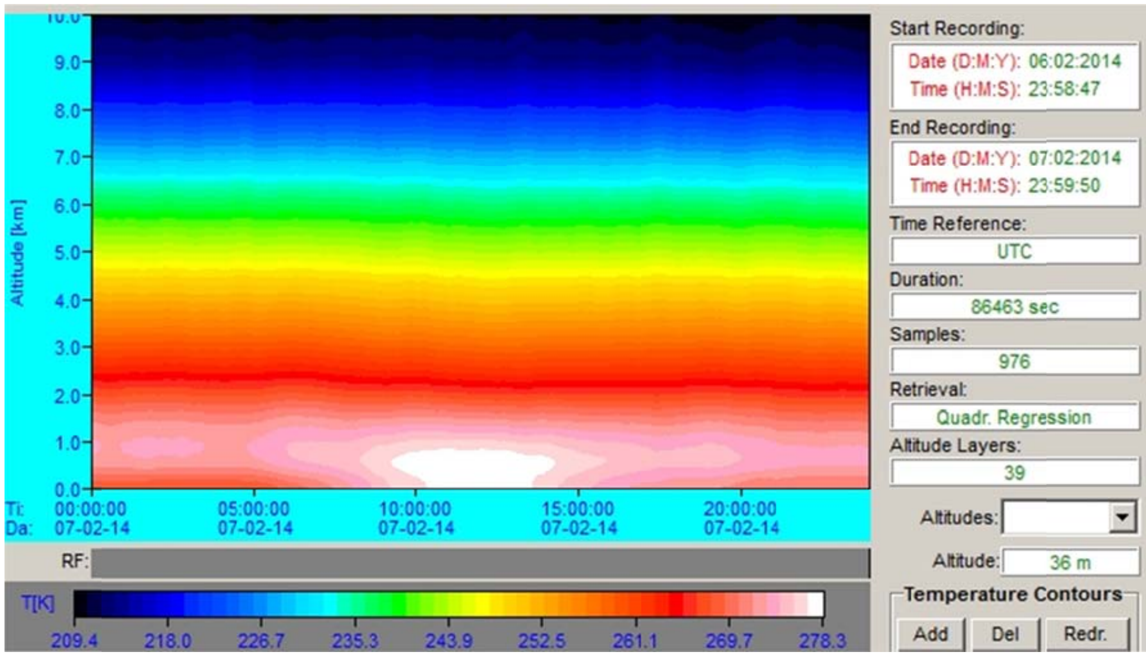

Fig.9 Example of 24 hours temperature field for 10000m height.

The information retrieved from the analysis of the temperature and wind fields as well as from 24 hours trends in Integrated Water Vapor and LWP (if applicable)) were reported to Main Meteorologist of the Olympic Games 7 days a week at 5 A.M. local time without any excuse. Then Main Meteorologist has compared forecast for all heights with the MS ARS data, and if it is in a good agreement, then the report is decided as accepted. If there is any discrepancy in the data versus meteorological station data or NWP model output, then the situation was discussed between MS ARS supervisor and Main Meteorologist verbally by phone. Anyway, the negotiated vision of the situation was released as official forecast every day to 6:30 AM

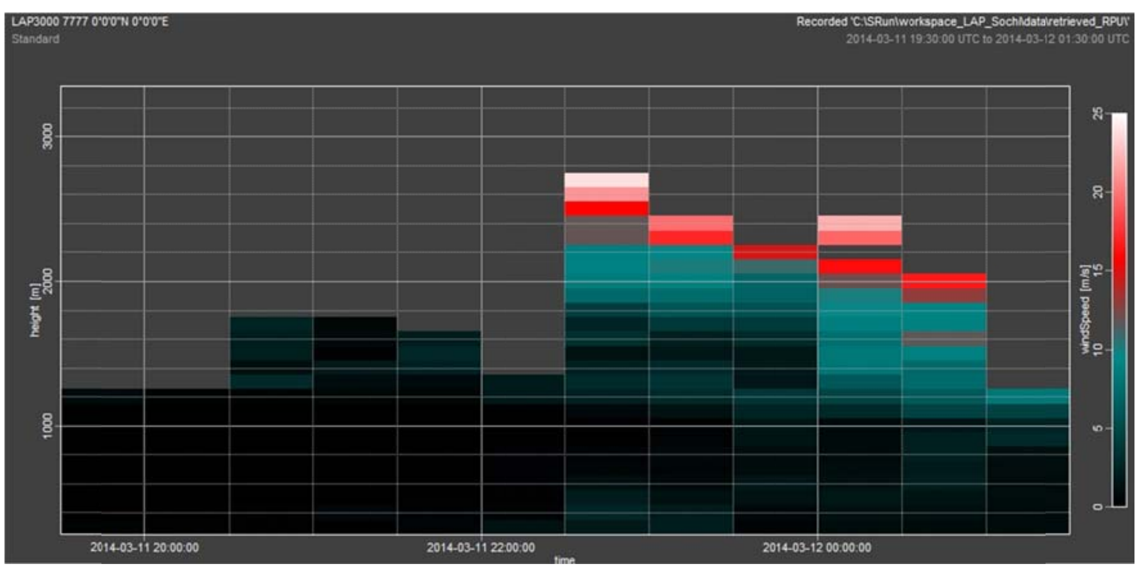

Fig. 10 Example of 24 hours wind speed field (height is above the installation level=650m)

Data verification: lessons and findings.

There were a few interesting lessons, which we have learned during the work with MS ARS within January-March 2014. First of all we had a special interest to the verification of the remote sensed data outcomes with the same outcomes from the ground based stations located at various heights on the different sport objects. It is clear; that the data measured at the ground surface (2m for temperature and 9m for wind) will not correspond directly to those in the free atmosphere. But we had not any intention to make quantities comparisons with the aim to estimate accuracy. We have intended just to verify the type of profiles and their main characteristics as the height of specific points like max\min, inversion and so on.

For this purposes all the " in situ" data" from about 23 ground based automatic meteorological stations were collected in MIC and processed once per 24 hours to create approximately the same temperature or wind field as it was constructed by MS ARS. The example of such temperature field is presented n the Fig. 11. The "in situ" temperatures measured at the same (within 50m range) height were simply averaged to get one temperature for one height with the step 50m. It is easy to see, that the MS ARS data for the same period are very similar (Fig 12), but has much more details in the structure.

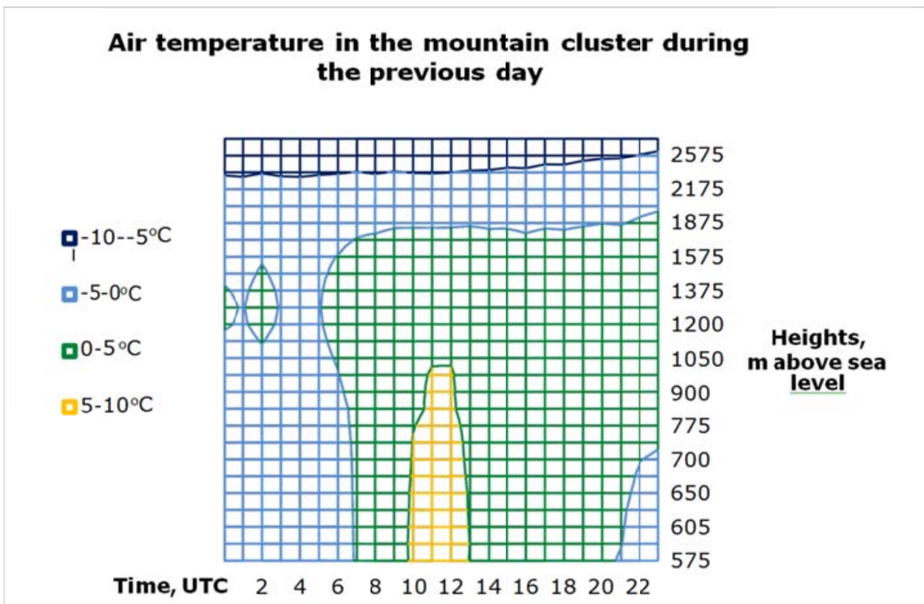

Fig. 11 Example of 24 hours temperature field constructed on the basis of "in situ" data

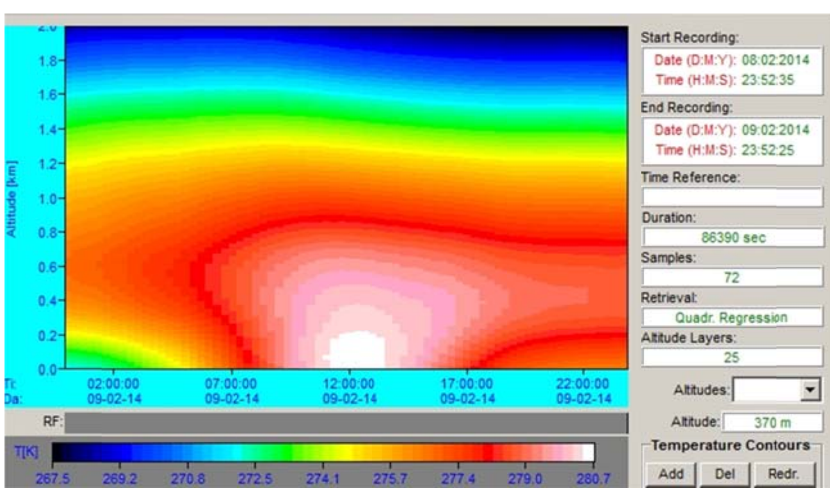

Fig. 12 RPG data about temperature field for the same date as on Fig 11

However, such qualities agreement were achieved after some curious case: when we have compared the immediate temperature profiles from RPG with the same from “in situ” sensors at the beginning of February (prior the Olympic games), we have found, that the type of temperature profile is close one to other, but the height of inversion is shifted at about 200m. It was look like all the profile from MS ARS was parallel lifted on this height. At this time the direction of scanning was exactly opposite to those shown on the Fig. 4 Then we have simply rotated microwave radiometer on 180 degree in azimuth, and the picture for boundary layer temperature field was changed immediately, which corresponds to 09:00 UTC on Fig 13. The picture for the upper troposphere was not changed a lot that can be seen even on boundary layer at 1800m and up.

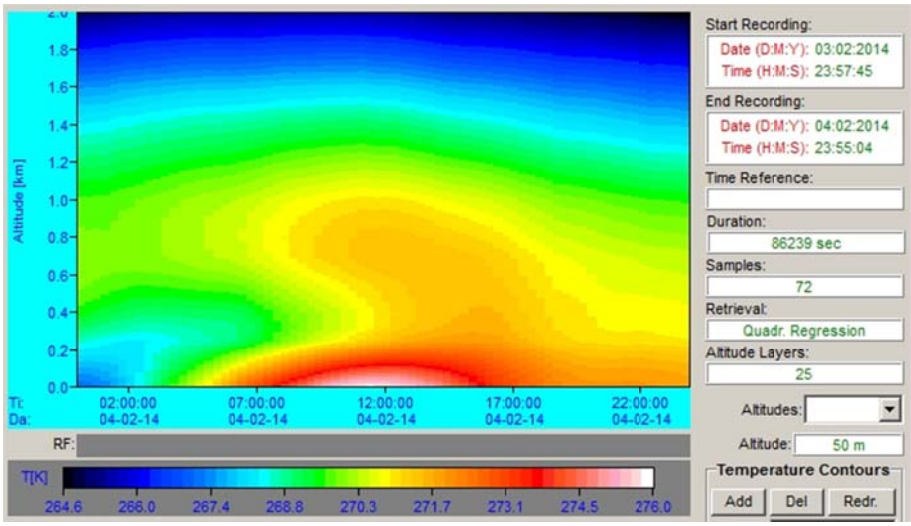

Fig. 13 Example of azimuth non homogeneity of the temperature field of boundary layer in valley

The wind fields measured at the ground based stations were not corresponding in general to the wind measured by MS ARS. Just extreme max data were more or less close one to other. But the wind data from radiozonds released in Sochi were close to the MS ARS data when it can feel the signal from the height above 2000m over sea level (1350 above installation site).

The integrated water vapor has very serious meaning for forecasts of cloudy conditions. The absolute value of IWV increased in 3-4 times during the potentially perceptible clouds with respect of non cloudy. It is very interesting, that the increase and decrease of ILW is close to symmetric shape during passing the cloudy fronts over the area. The cloudy conditions have a special interest for mountain cluster. As we know the height of condensation, we could easy predict decrees in visibility caused by low clouds.

The Liquid Water Path time series demonstrates very good ability to diagnose the originations of clouds. If the shape of LWP time series is very smooth with very long time wave structure, it corresponds to orographic clouds, which generated by the up flow in the nearest mountains and are quays stable. If the shape of LWP has short time big variation, thus it is frontal clouds.

Unfortunately all microwave radiometer data were not available during snow storm and rain on the ground. The system of precipitation protection delivered by RPG is not suitable for mountain conditions, where the precipitation has very heavy character.

The development of wind during the air mass change has absolutely different structure then ILW and LWP. It looks like the wind field more close to the temperature field: both of them has very sharp change while the air mass change and then very slow drop of the values with time at each individual height (See for example the Fig. 10 above). In general: radar wind profiler looks like most critical instrument from the point of view of correct data interpretation. For instance during the weak wind it can measure direction of wind randomly within the range 0-360. This point is very confusing for routine meteorologists. Thus we have excluded the wind direction data for the wind less then 4m/sec. Helicopters launching site, which was jut in a two hundred meters from us creates a lot of artificial signals – we have filtered it manually. And finally, the operation of the emergency service for initiation of artificial avalanche during the deep night caused the extreme wind also, but it was very short and sharp, and not connected anyhow with the weather.

If to summarize the experience of exploitation of MS ARS at mountain cluster during the Olympic and Paralympics Games "Sochi-2014", we should say, that it was very productive. The proper knowledge about limitation of each individual technology allows escaping miss interpreting of the data. But the main period of time (>80%) the remote sensing sensors of MS ARS provides reliable and very useful data. So at the end of Olympic season it was decided by Roshydromet authority, that the system will be moved to Moscow region for the servicing of Hydrometcenter of Russian Federation for evaluation of the new NWP models with very high time and space resolution.

References

1.TECO 2012 , Brussels, Belgium, October 2012: WMO IOM-109 "**Mobile System for Remote Sensing of Wind, Humidity, Temperature and Precipitation Microstructure Profiles during Special Events and Sport Competitions"** by Alexander Gusev, Viktor Ignatov, Arkadiy Koldaev, Sergey Sarychev

2.FROST 2014: https://www.wmo.int/pages/mediacentre/news_members/documents/FromtheOlympicGamesSochi.pdf