Measurement and prediction of precipitation using a MMR50 Meteorological Radar

D. Šaur, S. Plšek

Abstract— the article is focused on the use of MMR50 Meteorological Radar for Crisis Management in the Zlin Region of the Czech Republic. Zlin region contributes to project Information, Notification and Warning System project of the Zlin Region (further only, IVVS ZK). The realization of the building of communication and information infrastructure of the region was finished last year and the implementation of some systems has been preformed currently (eg integration of mobile MMR50 meteorological radar to the infrastructure level sensors on rivers, etc.). The goal of implementation MMR50 meteorological radar is to increase the level of monitoring current developments and precipitation forecast over the territory of the Zlin Region. In the article will be described IVVS ZK project in terms of features and the location of the MMR50 Meteorological Radar. The practical part will be compared outcomes radar measurements of MMR50 Meteorological Radar with meteorological radars of CZRAD Radar Network. Outcomes of the measurement will be demonstrated on examples of convective and stratiform precipitation clouds. Following the radar measurements will be compared to the description of predictions TITAN Nowcasting System, which is part of the equipment of MMR50 Meteorological Radar with Nowcasting Systems of Czech Hydrometeorological Institute. In the end success of predictions TITAN Nowcasting System will be discussed in connection with the measured data.

Keywords— Meteorological radars, measurement of precipitation, nowcasting, Crisis Management

I. Introduction

AT the present, the world is facing threats and impacts of global warming, which affects a whole range of processes and phenomena, not only in nature but also in human activities. One of the manifestations of global warming is the increase in the number of extreme events caused by weather. These extreme events include flash flooding accompanied by strong storms with torrential rainfall characteristic, which can cause a local flood in short time.

Another phenomenon is the intensive and prolonged precipitation, which causes long-lasting floods in the winter and summer times. Two typical situations (e.g. radar measurement of convective and stratiform precipitation clouds) were selected for both these phenomena.

In the Czech Republic (in the Zlín Region), there have been eight floods in recent years that have caused loss of life and significant material and economic losses. The Zlín Region as the state-mandated crisis management authority is responsible for managing emergency flood situations. During floods the Zlín Region receives information from Czech Hydrometeorological Institute, but the biggest problems in dealing with floods in terms of crisis management are inadequate and inaccurate information about the current status and future development of weather.

Based on these negative experiences, the Zlín Region decided to implement the IVVS ZK project MMR50 Meteorological Radar in order to refine forecasts and obtain more detailed data on the actual situation in the region. Another important goal of MMR50 Meteorological Radar is to ensure coverage of the territory in the course of the possibility of failure of the CZRAD Radar Network.

In the Czech Republic, the radar measurement of precipitation is in the purview of the Radar Department of the Czech Hydrometeorological Institute. The role of this department is to manage the CZRAD Radar Network. The CZRAD Radar Network uses two meteorological radars (i.e. one located in Brdy in Central Bohemia and the other in Skalky u Protivanov).

The last chapter describes a comparison of outputs radar measurements of CZRAD Radar Network with predictive values TITAN Nowcasting System, which is part of equipment MMR50 Meteorological Radar and Nowcasting Systems of Czech Hydrometeorological Institute. At the end will be consulted suitability integration TITAN Nowcasting System for prediction of heavy rainfall and Crisis Management of the Zlin Region.

The aim of this article is to describe and unify the relevant substantive information on the basis of radar measurements joined with nowcasting of two meteorological situations using the MMR50 Meteorological Radar and the radar based in Skalky in the CZRAD Radar Network. From these radar measurements results, conclusions and knowledge will be drawn. It will be used in the implementation of the MMR50 Meteorological Radar in terms of its location and for setting the parameters for ensuring the efficiency and accuracy of radar measurements of precipitation over the Zlin Region. [11], [14]

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First author (Ing. David Saur) is with the Department of Security Engineering, Faculty of Applied Informatics, and Tomas Bata University in Zlín (corresponding author to provide, mail: saur@fai.utb.cz). Second author (Ing. Stanislav Plsek) is with Department of Automation and Control Engineering, Faculty of Applied Informatics, and Tomas Bata University in Zlín (corresponding author to provide mail: splsek@fai.utb.cz).

II. THE INFORMATION, NOTIFICATION AND WARNING SYSTEM OF THE ZLIN REGION

The overall objective of the Information, Notification and Warning System of the Zlin Region (IVVS ZK) project is to build a robust and secure communications infrastructure to improve public warning system and notifying authorities in the extraordinary event and crisis situations.

The Information, Notification and Warning System of the Zlín Region is composed of various elements which are the final output elements of the audiovisual warning systems (e.g. sirens, detectors, speakers), municipal CCTV surveillance systems, measuring sensors (i.e. level meters and rain gauges), the meteorological radar system itself, information boards, hazardous chemical substances detection elements, video-conferencing systems, alternative back-up sources of electric power and other systems.[1], [11]

A. The Functions and Location of the IVVS ZK MMR50 Meteorological Radar

The MMR50 Meteorological Radar from MicroStep-MIS s.r.o is a compact device designed for monitoring the current state of the Earth's atmosphere and for obtaining information on hazardous weather phenomena detectable using the X-band (9.41 GHz) radar frequency within a radius of 200 kilometers from the installation site.

MMR answers the increasing demand for water management tools and hazardous meteorological phenomena detection. Watersheds management, global warming adaptation strategies, flood protection, operative weather forecast, military and civil defense actions or aviation safety are supported by this radar. Combination of its size and low price implies wide use in the water management, tourism, media, transport, military and an civil defense, aviation and agriculture. MMR-50 small weather radar comes with Radar Processor and MMR Software, displaying meteorological spatial data in user-friendly graphic form.

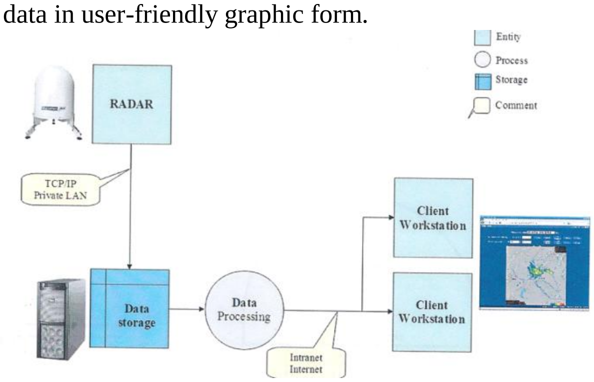

Fig. 1 Scheme of MMR50 Meteorological Radar project [13]

The MMR50 Meteorological Radar consists of an antenna, the elevation and azimuth drive, a radar unit, the controlling computer, heating and cooling systems, the power source, and the structure for mounting the actual radar itself. Part of the control computer is the control software for the fully-automatic, unattended operation of the device. The control software ensures the successful completion of the measurements, in the course of which the settings for the radar and motion control are performed. The MMR50 Meteorological Radar assures the following functions:

- Scan of backscatter from the radar horizon volume,
- data transformation into a spatial matrix,
- input data processing and
- data distribution to customer graphic workstation.

The MMR50 Meteorological Radar will be placed on the roof of the municipal authority in Kroměříž in consultation with experts from MicroStep-MIS, and simulations by Visibility Product software. The advantage of this location is its relatively easy connection to the IVVS ZK information and communication infrastructure. [4], [11], [13]

B. MMR50 Software

The data processing is based on web server architecture and therefore all products are available over the web interface and easily accessible to any user using web browser.

The access to the web interface is secured by encrypted (https) protocol, and protected by password.

The data processing software takes into account the earth curvature and atmospheric refraction. During the data processing, the non-meteorological data, like ground clutters, are removed from observed data. The data processing software offers interpretation of the 3D data in following standard outputs:

- The PPI (Plan Position Indicator) is one radar elevation. Data available from one elevation (one rotation of radar) are lately displayed on the surface of the ground. The particular algorithm is based on the bilinear interpolation for every point of the picture from two nearest shots of the elevation.
- The CAPPI (Constant Altitude Plan Position Indicator) represents horizontal cross section. This product displays horizontal cut in the constant altitude. Every point of the picture is calculated by three linear interpolations like in PPI but there is also one more interpolation from the nearest elevations.
- ColumnMax (Composite Reflectivity) maximas in column. For every point of the picture it displays the highest reflectivity above the particular point on the ground.
- The Range Height Indicator RHI is a vertical cross-section through the atmosphere. The main parameter is the azimuth.
- ECHO TOP calculates the highest altitude above the particular place of the ground with reflectivity of 0.6 dBz (below this altitude higher reflectivity should be detected). The highest layer is chosen from gradually generated PPIs where there is adequate reflectivity.
- VIL – Vertically Integrated Liquid water content, determined on the assumptions of the Marshall-Palmer Distribution; the VIL value is determined by the following equation:

$$VIL = 3{,}44 \times 10^{-6} \int_{h_z}^{h_t} Z^{\frac{4}{7}}\, dh, \quad (1)$$

Where Z [$mm^6.m^{-3}$] is Radar Reflectivity, h_z [m] Height and h_t [m]is the height of cloud tops. In the course of the calculations, each surface element, summation is carried out the various individual levels of PPI is performed. [2],[4], [11], [13], [14], [16]

C. Technical Specification

Dimensions	
• height	125 cm
• width	92 cm x 92 cm
Weight	90 kg
Antenna	Parabolic, 55 cm
Antenna Elevation - Angle Span	- 1 to + 90°
Antenna Scanning Speed	0 to 60 rpm
Transmitter Tube	Magnetron
Receiver Sensitivity	- 111 dBm
Modulator Type	Solid-state
Dynamic Range	65 dB
Operating Frequency Range	9410 MHz (X-band)
Half Power Beam Width	3.5°
Polarization	Linear, horizontal
Antena Gain, typical	32 dB
Transmitter Power Peak	50 kW
Raw Data Resolution	32 bit
RF Pulse Width	2 μs
Pulse Repetition Frequency	500 Hz
Maximum Range	50 km - 100 km - 200 km
Radial Resolution	300 m
Consumption	250 W
Data Update Rate	3D full scan in 2 minutes

Fig. 2: Technical specification of MMR50 Meteorological Radar [13]

Low pulse capacity enables to monitor important dangerous radar meteorological objects up to distance of 200 km.
Radar meteorological objects with lower intensity can be monitored only up to distance of 50 km. The device thus complies with standards for operation in settled areas (towns, airports, highways, yachts, etc.).
MMR can complete “white spots” in existing large radar network or a complete network of MMRs can be established in ares with no radar coverage. Small size and low weight enables easy installation and operation. [13]

III. RADAR MEASUREMENT

Two main types of precipitation clouds are commonly encountered in the Czech Republic; i.e. convective and stratiform precipitation clouds. This chapter presents the results of varying radar measurements of the Skalky Meteorological Radar in the CZRAD Radar Network and that of the MMR-50 Meteorological Radar. The outputs of measurements by the MMR-50 Meteorological Radar match the outputs from the Skalky Meteorological Radar measurements. For Tables I and III, the value of radar reflectivity *Z* in dBZ is shown at first, and in the next column, the recalculated value *I* of rainfall in mm / hr according to the following equation:

$$I = 10^{\frac{[(Z-10\log(a)]}{10b}}, \qquad (2)$$

Where the values of (a) and (b) are experimentally-determined constants (a = 16, b = 200). Precipitation is shown in fifteen-minute intervals and amount of precipitation is given in mm. [15], [16]

A. Measurement of Convective Precipitation

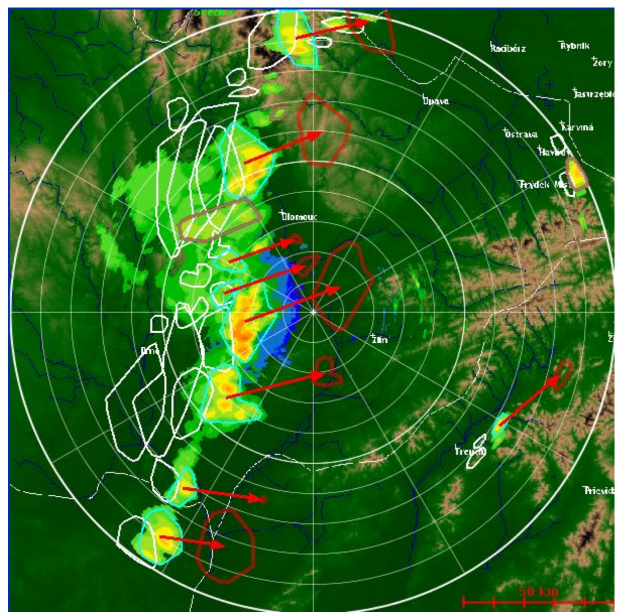

Fig. 3 Radar Image from the MMR50 Meteorological Radar of June 15,2013

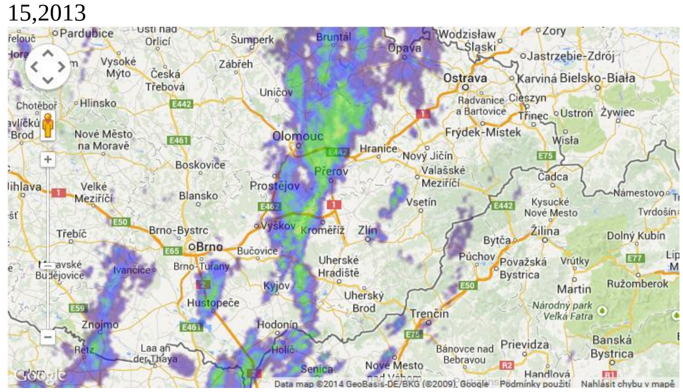

Fig. 4 Radar image from the Skalky Meteorological Radar from the CZRAD Radar Network of June 15, 2013 [8], [11]

In the context of this chapter, precipitation measurements were taken for two types of precipitation clouds. In Figs. 2 and 3, we can contrast and compare the distribution of precipitation from the MMR50 Meteorological Radar measurements (Fig. 3) and those of the Skalky Meteorological Radar (Fig. 4). In the first case (Table I), these were of convective precipitation clouds on a cold front from the west - typical for the summer, dating from 15.6.2013. Tables I and III, show the relatively great difference between the measured intensity of precipitation and data from the meteorological stations in the Zlín Region. This, however, has to do with a humidity rate of 80% of water in the atmosphere, which does not fall on the earth´s surface. The resultant amount of rainfall from meteorological stations makes up a very small percentage of the total volume of water (humidity) in the atmosphere. X-band meteorological radars are therefore eminently suitable for the detection of this type of cloud with its characteristic high radar reflectivity (above 40 dBZ) even at great distances.

Date	Convective precipitation cloud	MMR50 Radar		Skalky Radar	
15. 6. 2013	Measurement time	Z[dBZ]	I[mm/h]	Z[dBZ]	I[mm/h]
	0:45	44	20,5	42	15,4
	1:00	41	13,3	38	8,6
	1:15	45	23,7	40	11,5
	1:30	42	15,4	42	15,4
	1:45	46	27,3	44	20,5
	2:00	44	20,5	42	15,4
	2:15	39	10,0	40	11,5
	2:30	36	6,5	38	8,6

Table I Comparison of the MMR-50 and Skalky Meteorological Radar Output Measurements of June 15, 2013

Date					
15. 6. 2013	Meteorological stations	1:00-1:30	1:30-2:00	2:00-2:30	Amount of precipitation
	Holešov	2,2	0,3	0	2,5
	Kroměříž	3,2	0,1	0	3,3
	Staré město	2,2	0	0	2,2
	Luhačovice	0,1	1,6	0,1	1,8
	Štítná nad Vláří	0	0,1	0,4	0,5
	Vizovice	0,2	0,9	0	1,1
	Vsetin	1,5	1,6	0,3	3,4
	Valašské Meziříčí	0,6	1,1	0,1	1,8

Table II Precipitation Totals in the Zlín Region June 15, 2013 [9], [11]

Figs. 5 and 6 illustrate the dynamics in developments of convective precipitation over time. From Tables I and II, it is clear that the intensity of convective precipitation changes very rapidly over time. For this very reason, it is essential to respond quickly to these meteorological situations from the Crisis Management perspective when dealing with floods caused by heavy torrential rainfall.

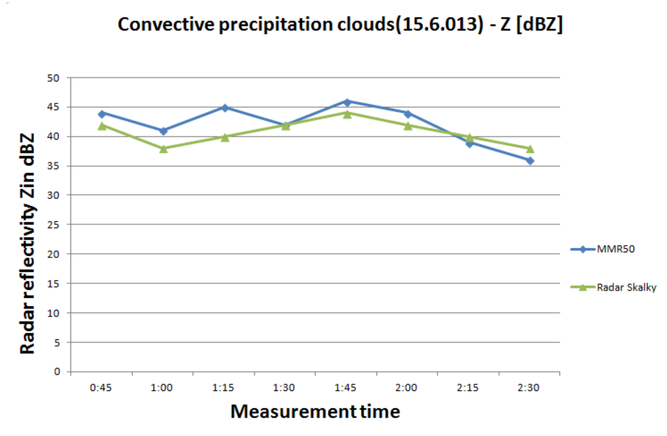

Fig. 5 A Comparison of the Radar Reflectivity Z [dBZ] Parameters of the MMR50 Meteorological Radar and Skalky Meteorological Radar for Convective Precipitation Clouds Formations of June 15, 2013

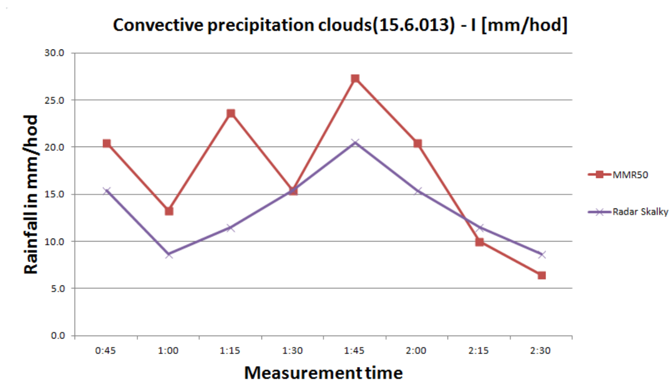

Fig. 6 A Comparison of the Rainfall Parameters I [mm / h] Parameters of the MMR50 Meteorological Radar and Skalky Meteorological Radar for Convective Precipitation Clouds Formations of June 15, 2013

B. Measurement of Stratiform Precipitation

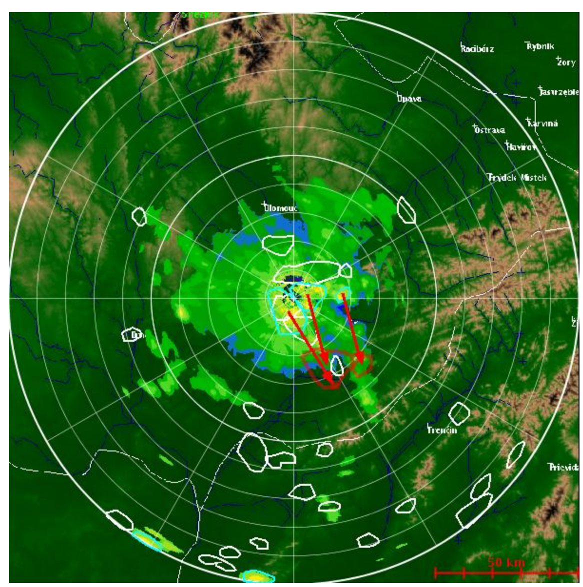

Fig. 7 Radar Image from the MMR50 Meteorological Radar of November 7, 2013

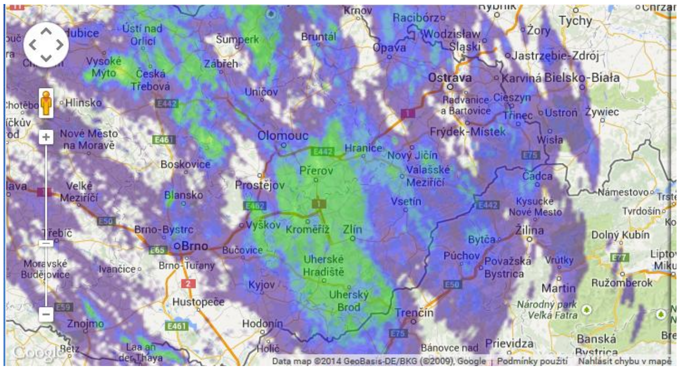

Fig. 8 Radar image from the Skalky Meteorological Radar from the CZRAD Radar Network of November 7, 2013 [8], [11]

In the second case (Table III and IV), this involved stratified precipitation clouds on a warm front from the southwest, measured on 7.11. 2013. Stratified precipitation cloud formations are characteristic for the winter period in mild, temperate climes. Unlike convective precipitation clouds, there is not such a noticeable difference between radar reflectivity, rainfall intensity and the data from the ground-based meteorological stations. This type of precipitation in the course of the passage of at front mostly falls directly onto the earth's surface. The disadvantage for mobile meteorological radars is their low impulse power with which these radars cannot detect weak rainfall (usually less than 1 mm / hr) at a great distance. This deficiency can mean big problems - especially in wintertime, in predicting icy weather.

Date	Stratiform precipitation cloud	MMR-50 Radar		Skalky Radar	
7.11.2013	Measurement time	Z[dBZ]	I[mm/h]	Z[dBZ]	I[mm/h]
	0:15	26	1,5	28	2,1
	0:30	32	3,6	32	3,6
	0:45	28	2,1	29	2,4
	1:00	26	1,5	27	1,8
	1:15	24	1,2	23	1,0
	1:30	24	1,2	22	0,9
	1:45	22	0,9	22	0,9
	2:00	22	0,9	20	0,6

Table III Comparison of the MMR-50 and Skalky Meteorological Radar Output Measurements of November 7, 2013

Date						
7.11.2013	Meteorological stations	0:00-0:30	0:30-1:00	1:00-1:30	1:30-2:00	Amount of precipitation
	Holešov	0,3	0,5	0,5	0,3	1,6
	Kroměříž	0,4	0,3	0,4	0,4	1,5
	Staré město	0,3	0,5	0,4	0,3	1,5
	Luhačovice	0,4	0,6	0,4	0,5	1,8
	Štítná nad Vláří	0	0	0	0	0
	Vizovice	0,1	0,3	0,3	0,3	1,0
	Vsetín	0,7	0,6	0,6	0,5	2,4
	Valašské Meziříčí	0,4	0,3	0,3	0,2	1,2

Table IV Precipitation Totals in the Zlín Region 7 November 2013 [9], [11]

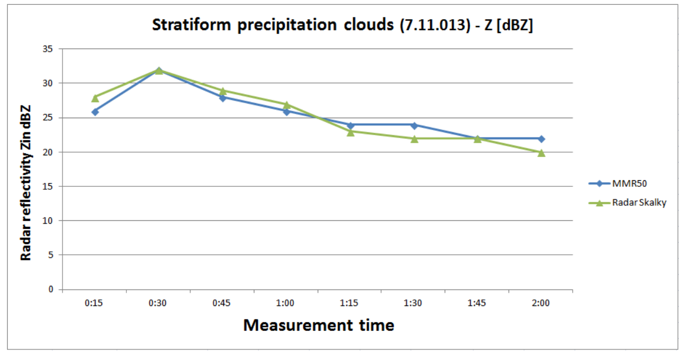

Fig. 9 A Comparison of the Radar Reflectivity Z [dBZ] Parameters of the MMR50 Meteorological Radar and Skalky Meteorological Radar for Convective Precipitation Clouds Formations of November 7, 2013

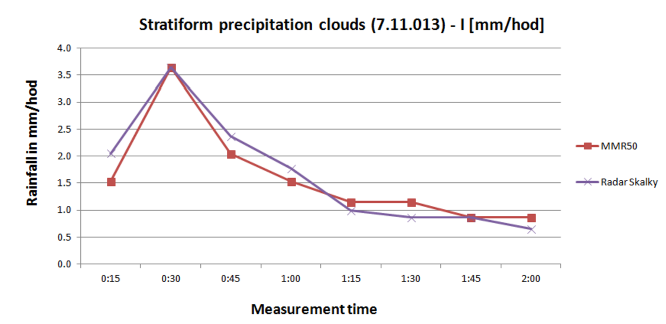

Fig. 10 A Comparison of the Rainfall Parameters I [mm / h] Parameters of the MMR50 Meteorological Radar and Skalky Meteorological Radar for Convective Precipitation Clouds Formations of 7.11.2013

For stratiform precipitation cloud formations, the reflectivity and intensity of precipitation does not change dramatically in terms of their dynamics. The intensity of the rainfall remains constant. When dealing with flood situations caused by prolonged rainfall, it is not a problem to detect these collisions in terms of their intensity, but the problem is to determine their duration. Not only weather prediction model, but even experienced meteorologists have problems with estimating duration. [2], [3], [4], [10], [11]

IV. COMPARISON OF OUTCOMES MEASUREMENT NOWCASTING SYSTEMS

Nowcasting systems utilize input data from two radar networks in Czech Republic:

- INCA_CZ, COTREC_CZ and MERGE_CZ Nowcasting Systems of CZRAD Radar Network operated by the Czech Hydrometeorological Institute (CHMI).
- TITAN Nowcasting System of MMR50 Meteorological Radar, which is part of Information, Notification and Warning System project of the Zlín Region.

Czech Hydrometeorological Institute Nowcasting Systems INCA_CZ, COTREC_CZ and MERGE_CZ are included with nowcasting webportal Czech Hydrometeorological Institute. The application displays the measured data (radar reflections, lightning, station measurements), analyzes and forecasts derived through the three nowcasting systems. INCA_CZ Nowcasting System is designed for precise temperature field and wind field computed ALADIN numerical model based on the effect of topography and current measurements from ground weather stations. COTREC_CZ Nowcasting System operates with the analysis of the radar echoes and creates a collision prediction motion fields at 30-60 minutes in advance. MERGE_CZ Nowcasting System works with a combination of radar precipitation estimates and rain gauge stations. For radar measurements of precipitation radar network is used CZRAD composed of two meteorological radar in Brdy near Prague and Skalka u Protivanov. The output of the combined radar images, which are updated after 5 minutes (on site 15 minute interval).

TITAN Nowcasting System of MMR50 Meteorological Radar is the nowcasting system, which implemented in a user interface of MMR50 Meteorological Radar. This nowcasting system evaluates characteristic hazardous atmospheric phenomena based on the selected limits. Precipitation field is marked in red, together with arrows indicating the direction of movement for approximately 60 minutes in advance.

The same two meteorological situations were selected for nowcasting of precipitation of as the radar measurements. The aim of this chapter is to compare predicted as reported nowcasting systems with state of the measured meteorological radars. The values measured in units of dBZ (radar reflectivity) have been converted to values rainfall. Results from individual predicted and measured states are shown in the graphs. [12]

A. *Prediction of convective precipitation clouds*

Outputs from radar measurements and nowcasting systems were selected for western cyclonic situation when a cold front from west to east across the Czech Republic. Measured values relate to the territory of the Zlin Region. This type of precipitation cloud is most rainfall in summer, when the cold fronts occur thunderstorms with heavy rainfall. The largest amount and intensity of rainfall was recorded for the city Kromeriz a Wallachian Mezirici.

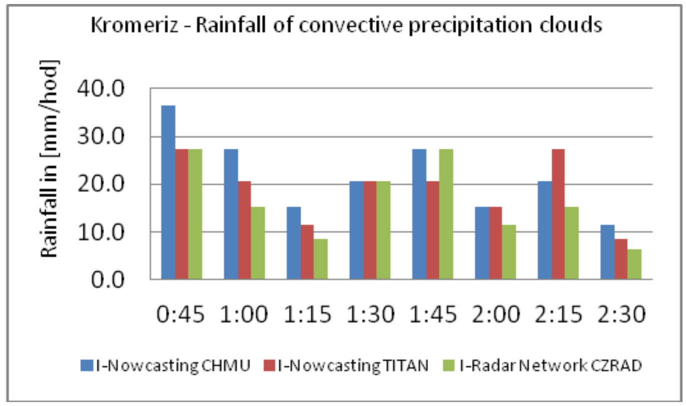

Fig.9: Predicted and measured rainfall convective precipitation cloud over the town Kromeriz, on 15 June 2013 in time 0:45 to 2:00

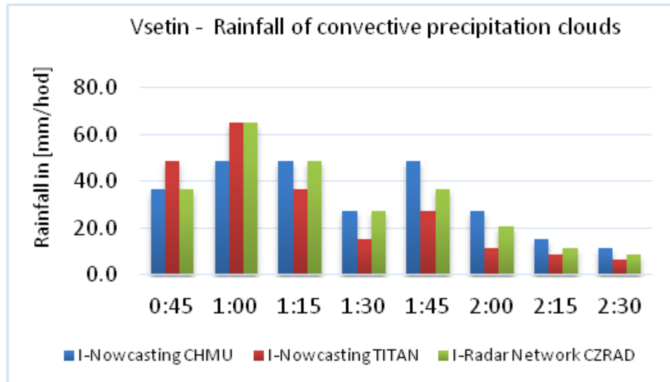

Fig.10: Predicted and measured rainfall convective precipitation cloud over the town Vsetin, on 15 June 2013 in time 0:45 to 2:00

The rainfall of convective cloud precipitation was highly variable in time. From the graphs we can see a comparison of predicted values of precipitation rainfalls CHMI a TITAN nowcasting systems with the measured values of CZRAD Radar Network. The most intense rainfalls were recorded in the first half of the period measured by the CZRAD Radar Network. Stronger precipitation occurred over the city Vsetín due to the influence of topography terrain than over the town Kromeriz. CHMI nowcasting systems predicted rainfall intensity for the city Kromeriz and Vsetin overvalued compared TITAN nowcasting system and radar measurements CZRAD Radar Network. On the contrary TITAN nowcasting system forecast slightly underestimated for town Vsetin. Prediction of convective precipitation clouds for the first 60 minutes of moderate deviations quite reliable; longer period percentage decreases significantly due to the dynamics of development of this type precipitation.

B. *Prediction of stratiform precipitation clouds*

Outputs from radar measurements and nowcasting systems for stratiform precipitation clouds were selected for a warm front from the southwest on November 7, 2013. The largest and most intense rainfall totals occurred over towns Luhacovice and Vsetin.

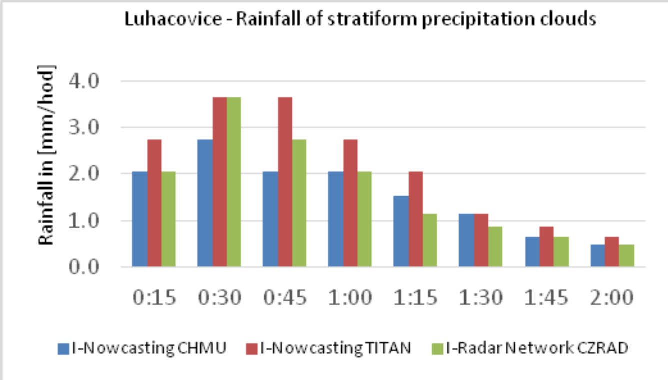

Fig.11: Predicted and measured rainfall stratiform precipitation cloud over the town Luhacovice, on 7 November 2013 in time 0:45 to 2:00

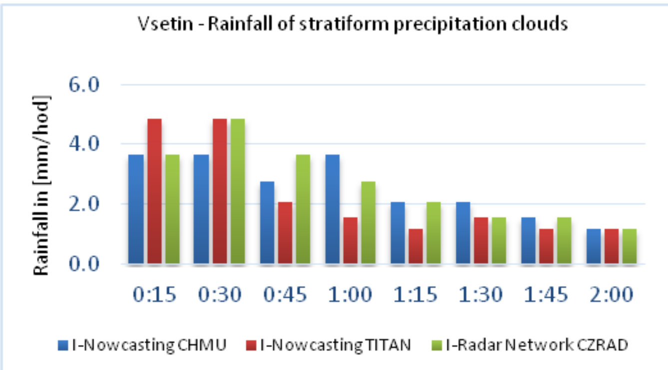

Fig. 12: Predicted and measured rainfall stratiform precipitation cloud over the town Vsetin, on 7 November 2013 in time 0:45 to 2:00

CHMI and TITAN Nowcasting Systems predicted a similar trend of the rainfall of precipitation as CZRAD Radar Network. Moderate rainfall field were predicted and measured from 0:15 to 1:15, which is manifested most warm front. In the second half of the rainfall intensity gradually weakened. Stratiform precipitation clouds can predict with a higher success rate for longer periods of time than convective precipitation clouds due to the constant development of the precipitation field. This type of precipitation clouds with most occurring in autumn and winter. Most dangerous element in this precipitation cloud is forecast rain or drizzle, which may on cold earth's surface damaged by frosts.

V. Conclusion

The aim of this article was to summarize current knowledge and experience acquired from measurements from the Czech Hydrometeorological Institute´s Meteorological Radars and the MMR50 Meteorological Radar within the context of the implementation of the Information, Notification and Warning System project of the Zlín Region. The acquired knowledge can be used to improve accuracy of measurements made by the MMR50 Meteorological Radar and find better ways of measuring these phenomena.

Although radar is a beneficial instrument, bear in mind its limitations while interpreting images. Some limitations come out from radar´s technical structure; some have their origin in physics of atmosphere and objects themselves.

The MMR50 Meteorological Radar has a lot of limitations, for example one of the biggest problems is lower transmitter power weak related with radar attenuation of signal by heavy rainfall. This problem is joined with great attenuation of signal by media which signal is passing through. Shorter wavelengths used by X-band radars (MMR50) are useful for smaller particles, but the signal is more quickly attenuated. The physical limitation in X-band may cause "blindness" of the radar (i.e. reduce the sensitivity in the case of precipitation more than 50 dBZ above the radar). This can cause the problem that the radar cannot "see" a cloud precipitation formation following just behind the first cloud precipitation formation detected. Major attenuation also occurs in the detection of snowfall and rainfall occurring directly above the radar. This drawback can be minimized radar images by merging MMR50 with images from the CZRAD Radar Network to reliably cover the whole area which is being monitored. The MMR50 Meteorological Radar has great difficulty in detecting very difficult a lower radar reflectivity (15 dBZ below) and only up to a distance of 40 km from the antenna.

One more limitations are associated with pulse repetition frequency (PRF). The radar transmits a pulse of energy and then waits for an echo. When a target lies beyond the maximum range of the radar, e.g. 100 km, the echo returns after the time of receiving in time of next pulse transmission. But at 1 500 Hz of PRF for MMR50 the echoes up to distance 350 km do not be considered and the echoes beyond 350 km are very weak to be displayed, while the CZRAD Radar Network´s range is up to 250 km at 600 Hz of PRF.

All of the previous issues are related to the location of the MMR50 Meteorological Radar. In the course of detection of precipitation, this can lead to disruptive reflections in the town as well as the windward side of the nearby hills. Due to its low altitude (200 m) there is a reduction in the coverage area of the Beskids Mountains area in the northeast of the Zlin Region. If after a year of trial operations, the MMR50 Meteorological Radar does not prove successful in this location, it will be moved to a place with a higher altitude. This problem will be solved operatively through the merging of the MMR50 Meteorological radar images with those of the CZRAD Radar Network.

Apart from mentioned restrictions, there are limitations on resolution of range which depends on pulse length, azimuthal and vertical resolution depending on beam width, measuring step, or distortion effects caused by diffraction of electromagnetic waves, false returns caused by solar radiation. Radar is an electromagnetic device and may interfere with electromagnetic equipment. It causes noise on the radar picture products.

The last chapter described compares very short-term forecasting (nowcasting) with radar measurements of convective and stratiform precipitation clouds. With nowcasting predictions were additionally compared the results of measurements nowcasting systems operated by CHMI and TITAN Nowcasting System, which is part of a software accessory MMR50 Meteorological Radar. The measured results showed that convective precipitation clouds can be predicted with a higher percentage (approximately over 70%) in a relatively short period of time, about 30-60 minutes than stratiform precipitation cloud. We can predict for 90 minutes or longer (depending on stability of precipitation development field) with stratiform precipitation cloud. The results of measurements of convective precipitation clouds also showed that TITAN Nowcasting System more undervalued the development of precipitation in hilly terrain compared to predictions of CHMI Nowcasting Systems. But it was a slight variation in the measurements, which was not important for predictions. However, for nowcasting of precipitation is important to remove all deficiencies related to radar measurements due to distortion predictions. These shortcomings are mainly echoes from the Earth's surface and interference from Internet service providers. In the end we can confirm on the basis made radar measurements that TITAN Nowcasting System can be a good predictions system of heavy rainfall destined for crisis management and civil protection.

The MMR50 Meteorological Radar is particularly suitable for the detection of convective cloud precipitation, which it can detect up to the limits of its maximum range (about 100 km). Thereby, this device fulfills its purpose - the detection and prediction of heavy rainfall. Although the study found a number of shortcomings with the MMR50 Meteorological Radar, the device can still be used for Crisis Management purposes in the IVVS ZK project. [11]

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