RADAR OBSERVATIONS IN METEOROLOGY

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The article deals with the basic conceptual definition of radar meteorology, briefly describes meteorological radars. It discusses the principles of measurements by radars and sources of error in these measurements. It analyses the outputs of meteorological radars and discusses interpretations of radar observations. In conclusion, in the article the current state of aeronautical meteorological radars in the SR is analysed and proposals to improve the current weather radar network in terms of the location of these radars and also their performance parameters are proposed.

K e y w o r d s: weather radar, radar observations, radar characteristics

1 INTRODUCTION

Radars complement the ground stations and satellite observation for the synoptic and aviation meteorology due to its coverage and data resolution within the time and space. They provide us with an up to time overview in the precipitation gesture and the structure systems. They are focused on a short term forecast (from several minutes up to few hours in advance), noticing about an injurious actions which are shortly connected to the convective cloudiness mode (thunderstorms, hail). Some of the modern radars can measure the radial particle velocity (in the beam routing) and the turbulence intensity (Doppler effect) or some of the energy backscattered polarization (determining the design and the phase of precipitation). When researching a structure of precipitation systems and processes included, we use reactance radars measurements.

2 WEATHER RADARS

The operational use of weather radars in many fields calls for automated forecast tools.

Potential users are all who are interested in short-term forecasts of precipitation (rain, snow, hail) for a specific location or a specific region, e. g: weather services, media (radio, TV...), air services, road services, police, agriculture, construction companies (buildings, roads...), water management services (municipalities, sewers, electricity...), sports and private users [1].

Weather detection by radars is focused on:

- Precipitation measurements
- Severe storm detection and tracking
- Snow detection
- Cloud detection
- Weather modification programs
- Wind measurements

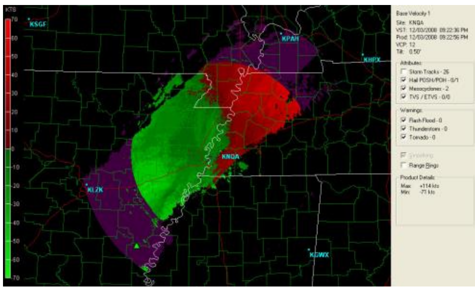

Fig. 1 Radar images [2]

2.1 Types of metrological radars and radar block scheme

In general radars measure the location of a target – its range, azimuth and height. The major distinction between meteorological radar and other kinds of radars lies in the nature of the targets. Meteorological targets are distributed in space and occupy a large fraction of the spatial resolution cells observed by the radar. Weather radars are pulsed radars with Doppler capability. So we can call them as Pulsed Doppler Weather Radars. Weather radars can operate in different frequency bands. So a classification can be made based on the frequency band as follows:

- L band radars
- S band radars
- C band radars
- X band radars
- K band radars

2.2 Radar block scheme

Radar systems, as well as other electronic systems compose of several subsystems and individual circuits [2]. Although modern radar systems are quite complex, their operation can be easily understood by primary radar scheme.

- **The main timer / Computer**: creates all the necessary signals and send them to the appropriate constituents radar.
- **Transmitter**: generates a high frequency signal that spreads outward into the atmosphere radar antenna. The transmitter generates powerful pulses of electromagnetic energy at precise intervals.
- **Modulator**: The purpose of the manipulator is to enable and disable the transmitter ON and OFF and to provide for the proper waveforms transmitted pulse.
- **Leadership wave** (waveguide) shows that linking the transmitter to the antenna means for guiding waves. Usually there is a hollow metal conductor inside dimensions depend on the wavelength according to the realized signal.
- **Antenna**: Antennas are devices that emit radar signals into the atmosphere.
- **Receiver**: It is designed to detect amplification of very weak signals received by an antenna.

- **Display**: There are many different types of radar displays. The simplest and oldest way radar is to put everything on the oscilloscope.
- **Duplexer** (duplex): Duplex, also called a receiver / transmitter is a special switch added to the radar receiver to protect against high power transmitter.

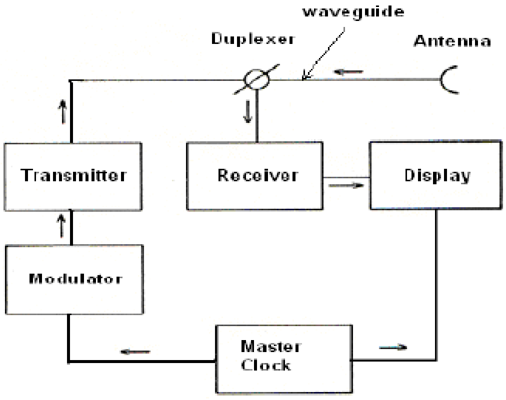

Fig. 2 Block scheme

2.2 Radar parameters

The basic radar parameters are:

- **Reflectivity** (Z) - Some degree of transmitted energy (power) is likely to be returned to the radar antenna (receiver) as a result of backscattering. Reflectivity is simply a measure of how much power was scattered back to the radar from any targets. Stronger targets have higher levels of reflectivity and return more energy. Thus, stronger targets have higher reflectivity values; that is, higher dBZ levels. dBZ is also related to the number of drops per unit volume and the sixth power of their diameter (and also it can be related to rainfall rate through an empirical relationship called the Z-R relationship).
- **Rain fall rate** (R) - One of the earliest quantitative uses of meteorological radar data was for the measurement of rainfall. Radar’s ability to scan rain showers and thunderstorms over large areas very quickly made it obvious to the early users that much could be learned about rainfall through the use of radar. Weather radars are not able to measure precipitation directly. We saw earlier that the reflectivity factor (z) is related to the size of precipitation particles in the radar echo. If we assume that our radar echo has known distribution of precipitation particles (i.e. number of drops of different size categories), we can relate the reflectivity factor (z).
- **Velocity** (W) - Until now, we have only considered power measurements with radar. Most modern radars now easily measure velocities of targets. These are Doppler radars. Doppler is a means to measure motion. Doppler radars not only detect and measure the power received from a target.
- **Spectrum width data** is a measure of dispersion of velocities within the radar sample volume. In other words, it is the distribution of velocities within a single radar pixel. One pixel on radar represents a volume within which there can be literally millions of individual hydrometeors. Each individual hydrometeor will have its own speed and direction of movement. The radar averages the individual radial velocities with a volume sample to produce a single average radial velocity that is displayed for that pixel.
- **Differential reflectivity** parameter is a kind of data produced by polarimetric radars. In general, weather radars send and receive microwaves at one polarization, usually horizontal, because raindrops are usually oblate. By transmitting and/or receiving radar waves at more than one polarization, additional information can be obtained on the nature of the targets. Differential reflectivity is a ratio of the reflected horizontal and vertical power returns.

Sources of error in meteorological observations include various problems such as: surrounding terrain, dead band attenuation, hydrometeor classification, Doppler dilemma, range folding, false echoes, anomalous spread, fold the radar beam [4-8].

2.3 Signal processing and radar product generation

The processing of radar data generally involves two distinct steps [6-9]. The first step, called signal processing, is the extraction of raw radar parameters like echo strength (reflectivity) or Doppler velocity from the radar signals coming out of the receiver. The second step, called data processing or product generation, is the further processing of raw radar parameters in order to obtain information that is useful for meteorological or hydrological purposes. In general, these two steps are done by different computers, signal processing being done at the radar site, while product generation can be done everywhere the data are sent to.

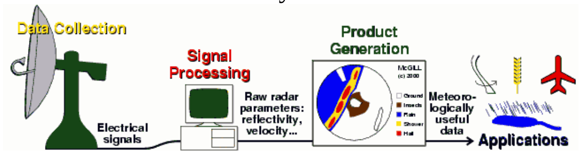

Fig. 3 Signal processing and evaluation of results [10]

Analysis of results

For meteorological purposes, we can divide the objects observed on radar: meteorological targets, one can distinguish targets convective and layered character, other targets, usually disturbing, most important of which are ground targets (reflections from the ground). Weather objectives are divided into the following kinds and extent usually larger than individual pixels, more compact shape, spatial changes in reflectivity are continuous, time-reflectance changes are small (outside the convective core), the animation seems obvious move, appear and disappear gradually.

There are two aspects of image analysis directly related to radar – the amount of energy dissipated between the target and the radar (estimate stormy intensity and amount of precipitation) and target velocity towards the radar (motion estimation and air circulation in the clouds).

Rainfall Rate

One of the earliest quantitative uses of meteorological radar data was for the measurement of rainfall. Radar's ability to scan rain showers and thunderstorms over large areas very quickly made it obvious to the early users that much could be learned about rainfall through the use of radar.

Base reflectivity - any particles in the atmosphere, which may reflect microwave energy to cause echoes that appear on the radar. Many times, these reflections are not deductions, but are naturally weather. If the base reflectivity shows reflections that are not naturally weather, the echoes of which we call the anomalous spread. They are usually to the boundary between warm, moist air and cold air and dry air caused by wave reflection. This threshold will be displayed as a very thin line of light reflectance. This figure may represent a warm or cold front, line dry air or outer limit of the storm.

Spectrum width data is a measure of dispersion of velocities within the radar sample volume. In other words, it is the distribution of velocities within a single radar pixel. One pixel on radar represents a volume within which there can be literally millions of individual hydrometeors.

Types of precipitation

For moderate to heavy rain drops, freezing rain, ice pellets, hail and snow identification strong of echoes in horizontal polarization are determining.

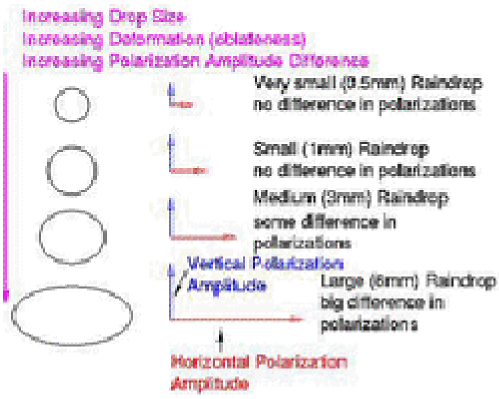

Fig. 4 Diagram raindrops [4]

Wind

The base rate is the ability that radar shows an average wind speed of particles detected by the radar. Radar can determine the speed using the Doppler effect, in which the frequency changes when the waves are reflected by moving particles in the atmosphere, and then returns to a fixed point (ie radar). Since the radar sends pulses of energy in one direction to one pulse, the measured wind speed is important for determining the speed and direction of the beam

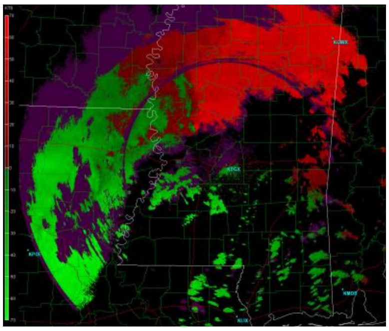

Fig. 5 Wind speed and air

Wind Shear

Wind shear in the atmosphere can be detected by Doppler radars. Wind shear product is used for microburst and gust front detection. An important point that mountain radars are not able to observe to sufficiently low altitudes immediately above the airports to reliably detect microburst.

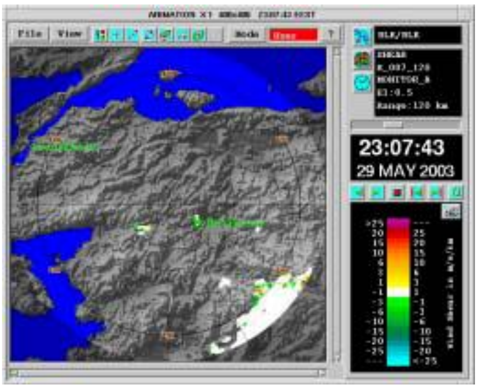

Fig. 6 Results of wind shear

3 WEATHER RADAR FOR THE SLOVAK REPUBLIC

Currently in Slovakia there are two meteorological radars operating at a wavelength of 5 cm (C band) and both are equipped with Doppler mode (odometry). In 1997 was introduced into operational service DSWR92C Doppler radar – Weather Surveillance Radar manufactured by Enterprise Electronics Corporation (EEC) located in the Malé Karpaty 6 km from Bratislava to Little Javorník (584 m). This is the type of one wave radar with linear polarization, which is equipped to measure the Doppler mode = radial wind speed. The radar is equipped with Doppler Enterprise Software Graphics Environment for displaying meteorological data and control system.

Fig. 8 Malý Javorník

In 2005 in Slovakia polarimetric radar RDR250-GC Doppler Weather Radar manufacturered by Radtec and Gamik has been put into the operational service, which is located in Volovské vrchy in eastern Slovakia, 38 km from Košice. This radar is located on Kojšovská hoľa (1260 m). This department has been established and has been in operation since 1989. Its main tasks are to schedule cloud radar measurements over Slovakia and synoptic automatic measurement of selected variables. The workplace is equipped with modern radar antenna set, which uses the Doppler effect for the processing of reflected signals. Measured data are processed continuously during the measurement itself, so the results are available within a very short time.

Fig. 9 Kojšovská hoľa

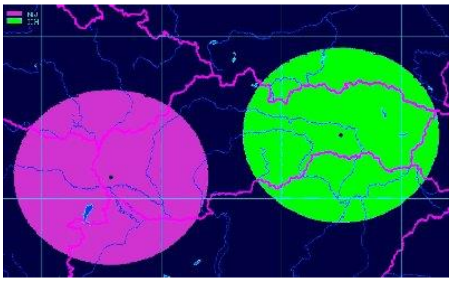

Fig. 10 Range 100 km.

3. 1 Comparison of radar and radar in Slovakia in neighboring countries

Radars in Slovakia

DWSR-92C radar operates at a frequency range of 5.5 – 5.65 DHZ. Radar sends pulses with an output of 250 kW with a length of 2 microseconds. Parabolic antenna with a diameter of 4.25 sends a beam wide and 1° with gain of 45 dB. The maximum radar range is 240 km, but we consider only data relay valve of 150 km.

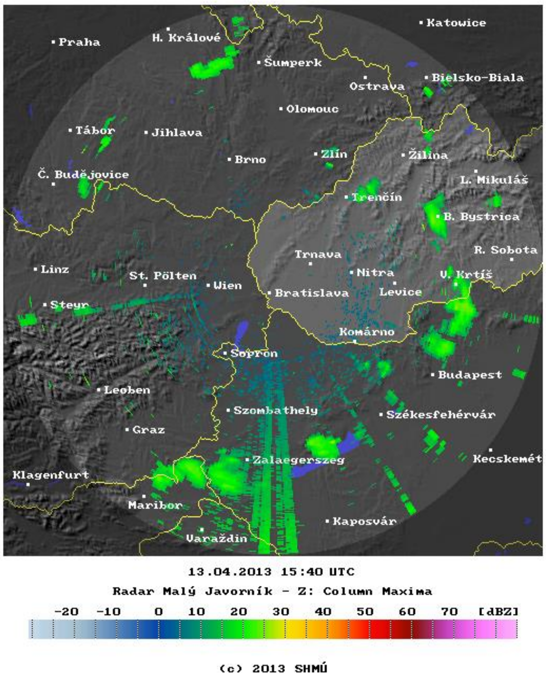

Fig. 11 Radar Malý Javorník DWSR - 92C [10]

Radar RDR-250 is the most advanced radar and has been in operation since 2005 and has the following basic parameters: PRF adjustable from 250 to 2400; optional pulse width 0.4, 0.8 or 2.0 sections; the digital receiver / signal processor; maximum sensitivity 9.6 dBZ at 200 km and 4.3 m high antenna source.

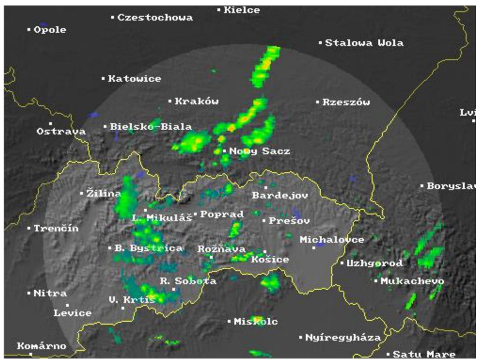

Fig. 12Radar Kojšovská hoľa RDR – 250 [10]

Radar in the Czech Republic

The weather radar in the Czech Republic is operated by the Czech Hydrometeorological Institute. There are placed two radars. The first is located near the Prague in Brdy and the other one on top of the Cliffs at Protivanova in Drahanská vrchovina. Maximum range of the radar used in the Czech Republic is about 250 km (data will then have the curvature of the earth surface with this type of radar can not receive). Both radars have undergone modernization in 2007.

Radars in Hungary

Budapest radar is one of the three radars located in Hungary. This DWSR 2500C radar was introduced into service in 1999. The antenna is located at a height 22 m above the ground. Its basic parameters are adjustable PRF 0.8 us 600 Hz, optional pulse width 1.0. It includes the digital receiver / signal processor and its maximum sensitivity is 25 dBZ and has a 4.2 m high antenna source.

5 PROPOSED IMPROVEMENTS

5.1 Methods of site selection

Only very little scientific papers deal with location of radars and issues relating to the location of the radar [11–13]. There are also missing legislative standards that would protect the meteorological radar in term of the long-term reliable measurement. Only military meteorological radars, or companies dealing with traffic control points have in most cases the protection radar secured, but it is an indirect way. This means that the general rules are applicable for the provision of military goods, the company's operating management of air traffic, but there are no special restrictions for weather radars.

To achieve a clear sky for the location of the radar it is necessary to focus the efforts on the preparation of the selected points. By using digital, high-resolution terrain models and selected areas with a combination of simulated beam propagation in GIS program, or other specific programs (EUROCONTROL SACC, Radio Mobile or custom-developed scheduler) can be used to find the optimal distribution of radar.

The aim is always to find the optimum area that would meet various criteria. First of all a place with the best radar coverage area has to be chosen. For the methods of site selection can also be used topographic maps (GTOPO30/SRTM30) as a kind of an initial step for calculating surface by radar hits. One of the specific tools and applications of GIS is to assist in site selection. An important issue when choosing a place to which we should not forget the safety distance of the maximum permissible exposure with regard to Directive 2004/40/EC. During the study of the beam spread the lowest achievable level maps using digital terrain models and / or calculations of radio horizon through digital surface model and standard refractive transmitter are usually used. Local infrastructure (owners, land access, electricity, communication lines...) and possible conflicts (environment, compatibility transmitters, obstacles...) also have to be taken into consideration. Visiting the site and assess local barriers visual observation / theodolite (trees, buildings...) and equipment is the next step followed by consultations with local authorities, clarifying property rights, specification of authorization son on. Consultation with national authorities due to the permission to EMI and striping is also necessary. Then the safety distance using the maximum permissible radiation exposure has to be calculated. Preparing of documents for final decision is the last step.

Considering all these requirements and coverage of the existing radar network in SR adding of smaller radar seems to be the best solution.

The distance between the two existing radars is 288 km. As far as the distance is higher, the radar cannot provide us always with correct information, because the precision of the radar information is dependent on the distance between the radar position and the monitored area. As a suitable position for the third radar can be near Poprad, because the Poprad Airport is placed 72 km from the Kojšovská hoľa and 221 km from Malý Javorník. Placement of the radar would lead to the improvement of the Slovak weather radar network and would be profitable mainly for the middle of the Slovakia.

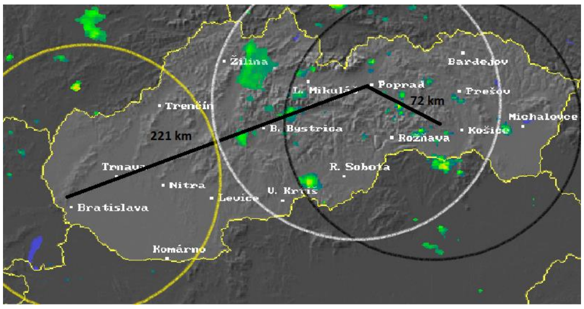

Fig. 13 Draft radar location near Poprad

5.2 Radar choosing

Important basic parameters of currently used radar in the world and in our country are parameters such as CAPPI, PPI, ETOPS, CMAX. In Slovakia these parameters fulfil both of our radars performing volumetric measurements every 10 minutes. These measurements allows the software to create a variety of products such as CAPPI Z 2 km - radar reflectivity at a constant rate or ETOPS - the upper limit of radio echo and CMAX - Maximum radar reflectivity.

It should also be noted that the radar located on Little Javorník has been in operation for 16 years and in the near future will require the reconstruction due to the modernization and improvement of meteorological data.

As a supplemental radar placed near Poprad can be used Skyscanner that is a small stationary meteorological surveillance radar (MSPMR), which carries the trade name Skyscanner, is pulsed radar providing weather forecasts up to a distance of 160 km.

Fig. 14 SkySCANner

It works on the principle of direct transmission pulses of microwave radiation and reception of pulses reflected back from particles in the atmosphere. Their subsequent evaluation and determines the amount of rainfall and other meteorological phenomena in the scanning area. The result is the prognosis of meteorological phenomena, their intensity and speed of the procedure below, or warning depending on the particular observation. Forecast is valid in the range of one to three hours depending on the type of installation. Radar can be used either as a solitaire or may BYR incorporated in radar network.

Properties of the device and its main advantages is that it combines the advantages of small and large radar systems is small, lightweight, easily transportable, low-power, has a large operating temperature and humidity Simple installation and maintenance, simple to use and friendly user interface, can be used alone or in a network consisting of several radars. Data can be displayed in the original unprocessed form, or processed using filters and other tools, the software allows you to view collected data, graphical output with meteorological forecasts (for 1 hours for self-functioning radar, 3 hours for network consisting of multiple cameras, it can be controlled remotely by web server through a network, has a favourable price / performance ratio. It provides horizontal distribution of cloud and its intensity at any rate, shows the structure of clouds in the vertical cross section, and information about the current state of cloud and detection of dangerous meteorological phenomena.

6 CONCLUSION

The article defines and easily describes weather radar fundamentals and its usage. The next part deals with analysis of weather radar outputs because the correct result understanding is one of the critical issues when observing the weather conditions by weather radars.

The third part is dedicated to the description of currently used weather radars in Slovak republic and a comparison with the meteorological radars used in Czech republic and in Hungary was performed.

According to the principles of the meteorological radar site selection a placement of the third meteorological radar near Poprad was proposed. For this location Skyscanner radar with its characteristics seems to be the most convenient radar for this area.

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