DE GRUYTER
OPEN

Contributions to Geophysics and Geodesy Vol. 44/1, 2014 (79–94)

REVIEW PAPER

History of remote-sensing methods in meteorology, cloud physics and nowcasting in Slovakia over the period 1965–1990

Dušan PODHORSKÝ, Peter GUBA

Geophysical Institute of the Slovak Academy of Sciences
Dúbravská cesta 9, 845 28 Bratislava, Slovak Republic;
e-mail: geofdupo@savba.sk, guba@fmph.uniba.sk

Abstract: A brief overview of building the radar and satellite meteorology in Slovakia over the period 1965–1990 and application of dispatching locators of PAR, SRE and RSR types for studying the evolution of convective cells is given. Further, the conception and implementation of a meteorological radar network in Slovakia, the algorithms for recognition of clouds and phenomena related to the parameters of radioecho are reviewed. The development of a new laser radar (LIDAR) and the application of a prototype meteorological radar with the TESLA RM-3 controlled polarizer are described.

Key words: radar meteorology, satellite meteorology, meteorological radar network, algorithms for cloud phenomena classification, radar climatography, laser radar (LIDAR), digital model of relief

Motto: *Anyone who writes memoirs is inevitably lying... Events that you lived out are just the subjective expressions based on your perceptions and feelings. Others perceive and know these events from their point of view, which is usually different from yours...*

1. Introduction

More than forty years have passed since the opening operation of the Research Meteorological Radar Centre (abbreviation VMRS) of the Slovak Hydrometeorological Institute on the Malý Javorník (584 m above sea level, the ridge of Malé Karpaty in Bratislava, Slovakia. The present contribution is only a subjective memoire of the first author and does not claim to be infallible or entirely exact in his testimony. The aim is to provide a subjective reflection on this period, filled with enthusiasm and desire for scientific knowledge. After all, almost half a century has passed from that time. It was a period filled with difficult compromises and desires.

VMRS was gradually transformed into the National Centre of Radar Meteorology of Czechoslovakia and a Branch of the Slovak Hydrometeorological Institute, with an important Water Resources Computing Centre Division of the Slovak Republic. To this was added in 1984 a Regional Centre for Radar and Satellite Meteorology of the socialist countries, as well as the Activity Centre of the World Meteorological Organization (WMO) for short-term weather forecasts.

In the years 1968–1990 an intensive development of radar technology for meteorology, development of systems for receiving data from meteorological satellites of the Earth, the introduction of computers and information technology, applied research in physics of clouds and related phenomena, and since 1984 the development of very short-term weather forecast (nowcasting) were all held at the Malý Javorník.

2. Radar meteorology in Slovakia

2.1. Period 1965–1968

Origins of building radar meteorology

The second half of the 20th century was marked in meteorology with the technological development of spacing methods of meteorological measurement parameters in the atmosphere. The radio-instrument industry in the USA, England, Japan, Italy and the Soviet Union began to make high-potential meteorological radars which have operated in the wavelength range from 0.8 to 10 cm.

In 1959 the University of Chicago Press published a first textbook on radar meteorology by prof. Louis Joseph Battan (1923–1986), deputy director of the Institute of Atmospheric Physics, University of Arizona, Tucson, entitled *Radar Meteorology.* As described in the Battan's monograph "Radar Observation of the Atmosphere" issued in 1973, the world's first 3 cm Doppler weather radar was put into operation in 1964, measuring the vertical motion and particle sizes in the storm.

Between 1966 and 1972, prof. Col. David Atlas (1924) served as a head of the Department of Meteorology at the University of Chicago. He was a close friend of Prof. Battan. He was a radar meteorologist since the World War II. As a veteran of the U.S. Air Force, he participated in the Korean War, during which under his leadership the meteorological radars were widely applied in the preparation of military operations. In 1964 David Atlas as a researcher at the Air Force Cambridge Research Laboratories, Bedford, Massachusetts gave an outstanding contribution entitled *Achievements of radar meteorology* (*Atlas, 1964*; see aperiodic edition of *Advances in Geophysics*, vol. 10, 1964), which not only treated a radar penetration into the radiolocation atmospheric physics, but also physically justified its future prospects. Atlas is the author of 22 patents and 260 original scientific articles.

In Eastern Europe during that period the most intense development of the radiolocation for meteorology was recorded in the Soviet Union, particularly at the Geophysical Institute of A. I. Vojejkov (GGO) in St. Petersburg (E. M. Salman in 1925–1975, G. G. Shchukin in 1937), the A. F. Mozhaysk Military Cosmic–Engineering Academy (MMSA) (V. D. Stepanenko in 1922–2010) and the Central Aerological Observatory (CAO) in Dolgoprudny in Moscow (V. V. Kostarev, A. A. Chernikov, Ju. V. Melnichuk and A. V. Shupiatskii). Development and manufacture of meteorological radar of the MRL type were performed at the Soviet Research Institute for Radio Equipments (VNIIRA) in St. Petersburg (G. F. Shevela).

During the period 1965–1968 at the Research Department of the Synoptic and Aviation Meteorological Service (SALM) at the Hydrometeorological Institute of Slovakia, Bratislava, the photographic and continuous cinematographic records were used to study the evolution of the radioecho of cloud fields (with the three-minute exposure time of the radar screen) using data from the dispatching radars of ATC Czech and Slovak (ATM), especially at the airport Ivanka close to Bratislava and, since 1967, also at Karlovy Vary, Prague-Ruzyne, Brno, Ostrava and Kosice.

In situ observations in real time were performed at the RLP divisions of the Bratislava airport Ivanka, where the three radars were run (*Podhorský, 1967, 1968*):

A. Precision Approach Radar (PAR), wavelength $\lambda = 3.2$ cm, produced by the Tesla Pardubice Company, with the RHI-type indicator with non-linear representation, equipped with a rotator ensuring the creation of circularly-polarized wave and elliptically-polarized wave when operating at 100% power. PAR has been steadily built, had two antenna systems and irradiated the landing area on the tracks 315° and 220° to maximum distance 20 km.

The role of observations on the indicator PAR was the research of the lower cloud boundary dynamics at different polarization high-frequency radiations, further at weak wind conditions the evolutionary characteristics of stalactites were studied (the so-called radioecho outgrowths), which were directed from the bottom of cloud boundary down to the runway and were affecting the inclined visibility during aircraft landings. The relationship between the intensity of rainfall and radioecho attenuation at different signal polarizations has been investigated. Considerable attention was paid to research of the bottom cloud layer of nimbostratus type, particularly to a layer of melting snow flakes in the form of "a clear zone" at the level of zero Celsius degree, clearly displayed at the elliptical radar signal polarization.

B. Airport surveillance radar SRE (Surveillance Radar Element), wavelength $\lambda = 3.2$ cm, produced by the Tesla Pardubice Company, with an indicator of circular horizon PPI and the operating range between 20 and 50 km with a similar RF rotator as in the PAR radar.

C. Provincial surveillance radar RSR (En-Route Surveillance Radar), wavelength $\lambda = 10.3$ cm, produced by the Tesla Pardubice Company, displaying a circular horizon PPI, with the operating ranges 100, 200 and 400 km.

To process and subsequently interpret the radioecho images, a surveillance radar diagrama antenna was used, indicating the ideal integral surface of cloud fields, especially the convective clouds of type Cu cong – Cb, but less ideally for the stratified and rainy clouds of Ns type. At that time, the research was focused on (*Podhorský, 1971*):

1. The determination of the radioecho lifetime for the convective thunderclouds (Cu cong – Cb type) in dependence on its dimensions and at different radar wavelengths. Based on the processing of several hundred photographic and cinematographic records (records taken every three minutes) for separate Cu cong – Cb cells, the rate of formation

and decay of radioecho and the radioecho lifetime were investigated. Particular attention was paid to wavelengths of $\lambda = 3.2$ cm on the SRE and $\lambda = 10.3$ cm on RSR.

Individual cells of radioecho of the local Cong Cu – Cb cells inside the air mass in Middle Europe have an average lifespan of about 25 minutes at $\lambda = 3.2$ cm and at 17 minutes at $\lambda = 10.3$ cm. Average time to reach the maximum diameter of the cells was 11.2 min at $\lambda = 3.2$ cm 8.9 min at $\lambda = 10.3$ cm. The knowledge gained corresponded with similar measurements performed in the USA and the USSR.

The parameters were determined that would help identify hail-content clouds using radioecho with the elliptical poralization, based on the procedure of H. T. Harrison and E. A. Post from Denver who empirically demonstrated that the incidence of hail was associated with the finger-like ejections of $1.6 \div 8$ km length from the convective cells radioecho. In our case, such a phenomenon has been deteced only twice.

2. The effect of Alpine–Carpathian orographic system on the cold fronts movement into the Danube Lowland. A convergence of the cloud mass movement in the valley of the Danube River before its penetration into Devinska Gate was recorded. In some cases cold fronts entered the Danube Lowland a few tens of minutes sooner that its position was observed (and analyzed) from the synoptic maps.

3. Radioecho intensity changes in dependence on the phase of cloud particles and precipitation. Usage of the high-frequency radiation rotator has enabled to obtain empirical evidence on the size of the radar signal attenuation from the liquid and solid phase cloud particles and precipitation.

2.2. Period 1969–1972

The concept of the construction of radar weather stations and its implementation (*Podhorský, 1970*):

In 1969, a Soviet mobile meteorological radar MRL-1 ($\lambda = 0.8$ cm and 3.2 cm) was supplied to the Weather Headquarters of the Czechoslovak Air

Force. The preparation of its entry into service was attended also by the staff of the Research and Development Meteorological Radar Centre (VMRS).

In command of the Hydrometeorological Institute in Prague in 1969, the concept of building a weather radar network in Czechoslovakia was approved. In Slovakia, it was expected to build two radar stations: one at the Malý Javorník in Bratislava (1969–1972) and the other at Kojsovska Hola near Kosice (1986–1990). On the crest of Malé Karpaty with budgetary costs of 1.5 million Slovak crowns were built the access roads to Malý Javorník, high voltage cable connection, source of drinking water and telecommunication cable from Raca near Bratislava. Inauguration of VMRS headquarters at Malý Javorník took place on 26 June 1972, with the participation of representatives of the Czechoslovak state agencies, universities, the Czechoslovak Academy of Sciences and the Slovak Academy of Sciences. Among the participants were the founders of Slovakia meteorology, Prof. Mikulas Koncek and hydrology academic Oto Dub, representatives of meteorological and hydrometeorological services from Hungary, East Germany, Poland, Yugoslavia and the USSR. The advance was made at Strbske Pleso of the International Symposium on Radar Meteorology Prospects.

VMRS at the Malý Javorník from that date began continuous operation of radar measurements using the meteorological radiolocator MRL-2 (USSR, Gorky), which was first exported from the boundaries of the USSR. Measurement methodology was elaborated by the VMRS workers on the basis of GGO publications by A. I. Vojejkov in St. Petersburg (then Leningrad and complemented by the measured radioecho characteristics from the Belarusian radar Brest, Gomel and Minsk) and discussed with workers at the Hydrometeorological Institute in Prague and The Weather Headquarters of the Czechoslovak Air Force in Prague (*Podhorský, 1972*).

Results of the measurements were distributed via facsimile transmitter to the Synoptic and Aviation Meteorological Service of the Hydrometeorological Institute in Prague at the airport in Ivanka, Bratislava.

The studies on the application of laser technology in meteorology were elaborated in close cooperation with the Research Institute of Telecommunication Techniques (VÚST) and the Research Institute for Vacuum Electronics (VÚVET) in Prague, focusing on the spatial measurement of smoke plumes evolution and measuring the vertical profile of As-Cs layered clouds (*Podhorský and Androvič, 1971, 1974*).

During this period, at McGill University, at the J. S. Marshall Radar Observatory in Montreal and at the CAO in Dolgoprudny in Moscow, the research was conducted on the attenuation of radio waves by cloud particles of differing phases (solid, liquid and mixed) and shapes (e.g. spherical or elliptical). By studying these sources, the requirements for the development of a prototype experimental radar TESLA RM-3 regulated polarizer were identified, which was then developed at the Technical University in Prague.

2.3. Period 1973–1976

Radioecho recognition

During continuous operation, the parameters were identified which could be used in the algorithms for recognition of the types of radioecho. For the convective clouds, it was an algorithm Y (Cu cong, Cb, Cb with showers and the hail) and for the layered rain clouds of Ns-type it was an algorithm X. The details of these algorithms are to be described in the paper under preparation (*Podhorský, 1976*).

Radar Climatography

For the period of 1973–1976, the measured radar parameters of radioecho from the continuous operation of MRL- 2 have been archived and subsequently analyzed in terms of radar climatographic maps of Central Europe with the structure of Ns, Cb with showers, Cb with hail and Cb with penetration into the stratosphere. Climatographic maps of convective cloud radioecho were constructed in relation to orography maps of Central Europe, and specifically to air routes maps of a region considered. To verify primary radioecho data, 153 weather stations (aviation, synoptic and climatological) as well as data on the vertical profile of the atmosphere from aerological stations in Czechoslovakia, Yugoslavia, Hungary, Poland and Austria were used. For complex processing of these raw data, database system MARS III and the operating system CDC MASTER 3.0 on a powerful computer CDC 3300 were used. The computer was installed at the Research Computing Centre – The United Nations Programme (VVS/UNO) in Bratislava (*Podhorský 1974, 1976*).

Development of laser radar – LIDAR

Research teams in VÚST and VÚVET from Prague under the meteorological auspices of VMRS, developed and implemented two prototypes of laser radar – LIDAR: one for stationary operation (at the airports) and the other for mobile operation in the field. Czechoslovak LIDARs had the following specifications (*Podhorský and Androvič, 1971, 1974*):

A. Transmitter: ruby laser, $\lambda = 6943 \times 10^{-10}$ m, peak pulse power 20 to 50 MW (i.e. up to one joule), pulse length 20 to 50 ns, frequency 20 pulses per minute, refractor (optics , antenna) diameter 105 mm, the angle of diffraction 1 μrad.

B. Receiver: FEU TESLA VÚVET indicator, type 65 EA 413 S, optics (antenna) – Newtonian telescope – reflector, diameter 248 mm, field view at an angle of diffraction of 1 μrad of $7,85 \times 10^{-7}$ sr (steradians), interference filter width around 30×10^{-10} m, logarithmic amplifier with a range of 60 db, signal correction for the distance, indicator RHI (distance–height) with a Polaroid camera, an indicator of type A with a Polaroid camera, a digital readout of angular coordinates with distance radar control, angular resolution of 0.2°, digital distance readout with an accuracy of 5 m.

Within the numerous experimental measurements on at Malý Javorník, around the power plant in Novaky (with 300 m chimney as the third tallest building in the SR serving also as a calibration target), around the power plants Tisova in the Sokolov Basin etc. the following results have been obtained:

– determination of the base cloud boundary and its spatial and temporal dynamics
– geometrical and optical thickness of the cloud type Ci, Cc and particularly Cs
– the determination of the top cloud boundary away from the LIDAR station
– rainfall intensity based on the volume scattering coefficient
– spatial and temporal characteristics of smoke plumes, especially at night.

Official launch of the stationary LIDAR into operation took place on 29 March 1973 during the first historic visit of Prof. D. A. Davies in Bratislava and Malý Javorník (the General Secretary of the World Meteorological Organization, in 1956-1979 in office).

Development of a prototype meteorological radar TESLA RM-3 with regulated polarizer (*Podhorský, 1976; Podhorský and Tekušová, 1981*):

At VMRS Malý Javorník the upper limits of radioecho, associated with intense storm activity, were measured in summer 1973–1976, which under the action of tropopause penetrated into the lower layers of the stratosphere. These case studies were summarized in the form of a written report for the radar conference held in Moscow in 1974. Frequency of these events as well as the values for upper limits of radioecho of around 15–16 km gave the present radar experts mistrust as to the precision of angle and distance readouts on the radar MRL-2 at the Malý Javorník. An advice was given to check the basic operational rada parameters by a dedicated technician from the manufacturing plant in Russia. At the same time, the "Javorník" hypothesis concerning the frequency of penetration Cb into the stratosphere over Central Europe has been rejected. Also, it was doubted that in the next period the penetration will increase as a result of global warming of the troposphere by increasing its energy potential (*Podhorský, 1976*).

At that time (1971–1976), development of a prototype meteorological radar TESLA RM-3 with regulated polarimeter has been conducted at the Institute for Radio Research of the TESLA Company in Opocinek, Pardubice. The originally-planned location for the radar TESLA RM-3 was the Malý Javorník (within the projected seven-story building), but the "Moscow" doubts caused the transfer of RM-3 to about 80 to 100 km distance eastwards from the Malý Javorník to the Danube Lowland (*Podhorský et al., 1975*).

After a thorough field reconnaissance the location was fixed to Károly brickworks at Šurany, where in a relatively short time the polygon VMRS was built, for radar measurements based on RM-3 and for laser experiments with own mobile LIDAR, in cooperation with the Department of Physical Electronics, Faculty of Nuclear and Physical Engineering of the Czech Technical University in Prague and a ruby laser for monitoring atmospheric pollution using Raman scattering.

The prototype TESLA RM-3 has a regulated polarimeter, with a distance control of the parameters of RF radiated waves developed by the Faculty of Electrical Engineering of the Czech Technical University in Prague. At that time, there were meteorological radars with polarimeters in operation only at the CAO in Dolgoprudny and at the radar J. S. Marshall Observatory of the McGill University in Montreal. RM-3 radar worked on a wavelength $\lambda = 3.0$ cm, transmitter power at 1 μs or 0.5 μs pulses was 150 kW. Broadband calibrated attenuation of polarimeter had a value of 6 dB.

Based on experimental measurements from the RM-3, the phase state of the cloud particles and precipitation were determined from the values of the circular depolarization coefficient of the radioecho for the Ns-type clouds, with the following four phase states identified: (*a*) a drop – liquid phase, (*b*) a mixed phase with the prevailing liquid phase, (*c*) a mixed phase with the prevailing crystalline phase and (*d*) a crystal phase. Furthermore, the theory of L. G. Kacurin of spontaneous crystallization in layered clouds was verified, and physical conditions necessary for the formation of precipitation were determined. Synchronized measurements of identical radioecho caps on the MRL-2 and RM-3 clearly confirmed the penetration of Cb into the stratosphere through a radio link between Malý Javorník and Šurany (*Podhorský et al., 1975; Podhorský and Tekušová, 1981*).

Regional Centre of Radar Meteorology of the socialist countries (RCRM)

In 1974 in Bratislava, the meeting of directors of hydrometeorological and meteorological services of socialist countries was held. Based on the work done in the VMRS at Malý Javorník, this assembly granted to this workplace the status of the Regional Centre for Radar Meteorology of the socialist countries (*Podhorský, 1981*).

Satellite meteorology

Since 1972, the reception of analog images from meteorological satellites with a polar trajectory of the TIROS Operational System (USA) and later METEOR (USSR) was secured. Receiving device has been developed by redesigning the radioteodolite Malachite (USSR). After 1975, we began to merge the radar maps from Prague (Libuš), Malý Javorník and Surany. Gradually, using the television cameras, the radar maps were combined with satellite photographs of cloud systems over central Europe, and have been experimentally transmitted using the radio-relay device RTL-4 to Bratislava Airport at Ivanka (*Podhorský and Pavlík, 1979*).

Starting up the computer VIDEOTON 1010 EC and experimental operation of Digigrafu 1006 (Nový Bor) opened in 1974 the possibility of not only the existence of the National Centre for Radar Meteorology (NCRM) in Czechoslovakia, but also for RCRM.

2.4. Period 1977–1985

Radioecho recognition

Over this period, the methodology of radar measurements and data acquisition from the meteorological satellites was enhanced. Also, work began to develop a comprehensive prospective data bank system for the NCRM. Every year, the nationwide consultations on radar meteorology (Czech Hydrometeorological Institute, Slovak Hydrometeorological Institute and Ministry of Defense) and the meetings of the Working Group for Synoptic and Aviation Meteorology of Socialistic Countries (RGSAM) took place. Since 1979, the headquarters at Malý Javorník were elected to the position of the National Correspondent for Radar Meteorology of the Regional Association of WMO VI in Europe. This mission allowed to present a unique Slovak project with a vision to establish a Meteorological Radar Network in Europe, regardless of the political subdivisions of European countries, at various internationally-recognized conferences and symposiums organized by WMO, IAHS, COST, ESA, FAO etc.

During this period there was a significant qualitative progress in terms of renting the longwave transmitter of the Radiocommunication Council (the power of up to 100 kW), which allowed continuous facsimile distribution of merged radar weather forecast maps, together with the processed aerological outputs from Prague, Poprad and Vienna to the whole of Central and Eastern Europe.

At the request of the Ministry of Agriculture and the Ministry of Forestry and Water Management, the division of SHMÚ at the Malý Javorník organized the harvest management in the district of Levice from 1979 to 1989, and later in the district of Nitra and Bratislava–countryside. In these works was also involved an experimental mobile radar TESLA RR (based on river radar), with 3 m parabolic antena, with wavelength of 3.2 cm, with a range of 80 km, located on the vehicle AVIA, in order to perform the radar measurement of rainfall intensities. An integral part of this mobile system was also the laser radar – LIDAR.

Efforts of the 22-member research team at the Malý Javorník, in close cooperation with the Department of Physical Geography of the Faculty of Natural Sciences in Bratislava, culminated in participation in the state research project entitled *Interaction of atmosphere and the hydrosphere in terms of a general balance*, solving a partial task of *Remote Sensing Detection of Precipitation and Dynamic Model of Natural Environment* in 1981–1985. For reasons of brevity we list only the key activities related to this project (*Krcho and Podhorský, 1981; Podhorský and Vítek, 1981*):

- remote detection of precipitation and dynamic model of the natural environment in terms of its impact on the concept of geo-hydrometeorological system METEOSYS,
- application of dual-wave radar MRL- 5 for the determination of rainfall intensities,
- use of multispectral space information with high resolution for the determination of thespatial and surface characteristics of precipitation,
- comprehensive digital elevation model,
- creating a Unified Cartographic System for radar and satellite data,
- numerical processing methods of radar data of precipiation,
- operative information on precipitation for synoptic analysis.

During this period, new buildings were built at the Malý Javorník for placement of another radar MRL-5 for the receipt and processing of primary digital data with a high resolution from the polar geostationary meteorological satellites WIRPS by DORNIER (Germany), for computers SM 4-20 (ZVT SR) and large-capacity EC 1040 (ROBOTRON, GDR). Created METEOSYS database system, based on IDMS (Integrated Database Management System, IBM), have gradually become the basis for the processing of individual products of SHMÚ Bratislava. The benefit was a Single Cartographic System (JKS), which allowed pooling of data from meteorological radar network and data from meteorological satellites METEOSAT and NOAA. The entire data mining system included the identification of signals from each channel, channel calibration and geometric image transformations to JKS.

In 1985, an Automated Radar Observation System (ARMS) was put into experimental operation, which provided a complete microprocessor automation of the two-channel measurements performed by the meteorological radar MRL-5 with the control computer SM 4-20 (ZVT Námestovo); see *Podhorský and Vlčák (1981).*

Since 1984, the continued animation of satellite images for cloud weather forecast was secured with the equipment WIRPS. The forecast was broadcast by the Slovak and Czech TVs, and later for the needs of the Austrian, Bulgarian and East German televisions. For ensuring hydrometeorological service, the satellite animation was broadcast also to meteorological offices in Bratislava (Airport Ivanka, SHMÚ Koliba), Prague (Airport Ruzyn) and the Main Weather Headquarters of CSLA in Prague.

Based on the decisions of WMO in 1984, the RCRM Malý Javorník become an activity center of WMO (WMO AC) for very short-term weather forecasts, while the center was in charge of the Steering Group of the WMO for very short-term weather forecasts with the participation of experts from the U.S., Sweden, Japan and Canada (1984–1990).

2.5. Period 1986–1990

The main attention was focused on the activities of AC WMO to address the avant-project targets of the Council for Mutual Economic Assistance (RVHP): A comprehensive automated meteorological safeguarding of aviation and other sectors of the national economy (KAS METEO). Work on the Malý Javorník addressed the following tasks: use of 32-bit computers SM 52-12 (ZVT Banská Bystrica) and fast 16-bit computers SM 52-11 (ZVT Námestovo); address reliability and faultless measurement by ARMS provide remote control of ARMS and present the processed outputs in real-time on the color graphic screen video equipments; apply the X.25 format in KAS METEO information transmission through the telecommunication and computer networks. A secondary aim of solving these tasks was preparing to build a prospective center for processing radar observations in the European network (RA VI. WMO) to AC WMO Malý Javorník.

In May 1987, at a meeting of KAS METEO experts held Pardubice, Czech Republic, the real-time, fully-automated remote control of ARMS at Malý Javorník was performed, via publicly available telephone lines, along with graphic color output of processed radar observations of clouds in Pardubice. At the International Engineering Fair in Brno in September 1988, the ARMS system was awarded a Gold Medal.

Particular attention was paid to the processing of primary digital information from the geostationary satellites Meteosat 2 to ensure the needs of pattern recognition for modeling cloud nowcasting and the associated phenomena, with the working title METEOTREND (*Podhorský, 1985*).

3. Conclusions

Listed quarter of a century has been extremely successful thanks to enthusiasm of the first team of 'musketeers' on the crest of Malé Karpaty, which since 1977 has been gradually enriched in qualified programmers, electrical engineers and IT specialists, making a total of 112 members. Close cooperation between RCRM and several universities in the Czech Republic and Slovakia resulted in a number of master and doctoral theses led by the staff at Malý Javorník. These were years filled with numerous professional internships for students and professionals, supported financially by the World Meteorological Organisation, FAO, IAHS, ESA, CMEA, COSPAR and INTERKOSMOS.

References

Atlas D., 1964: Advances in Radar Meteorology. Advances in Geophysics, **10**, 317-478.

Krcho J., Podhorský D., 1981: Dynamic landscape relief model and remote detection of natural environment (Dynamický model reliéfu krajiny a diaľková detekcia prírodného prostredia). Meteorologické zprávy, Praha, **34**, 2, p. 45–48 (in Slovak).

Podhorský D., 1967: Airborne radars utilization for meteorological purposes (Využitie leteckých radarov pre meteorologické účely). Meteorologické zprávy, **20**, 1, p. 913 (in Slovak).

Podhorský D., 1968: Application of radar meteorology for study of lower troposphere dynamics (Použitie rádiometeorológie pri štúdiu dynamiky spodnej troposféry), rigorous thesis, Comenius University, Faculty of Natural Sciences, AGM department, Bratislava, p. 52 (in Slovak).

Podhorský D., 1970: Radar meteorology in Czechoslovakia (Rádiolokačná meteorológia v Československu). Meteorologické zprávy, Praha, **23**, 6, 84–87 (in Slovak).

Podhorský D., 1971: Cold fronts investigation by means of ground-based air surveillance radars (Studium der Kaltfronten mit Hilfe von Bodenradaranlagen für den Flugverkehr). Acta Facultatis Rerum Naturalium Universitatis Comenianae, Meteorologia, **IV**, 49–73 (in German).

Podhorský D., Androvič A., 1971: Application of meteorologic lidar for atmospheric pollution investigation (Využitie meteorologického lidaru pri štúdiu znečistenia atmosféry), Hydrometeorological Institute Bratislava, Meteorológia a životné prostredie, 92–104 (in Slovak).

Podhorský D., 1972: Recent and future objectives of radar meteorology (Problémy rádiolokačnej meteorológie v súčasnosti a v budúcnosti). Hydrometeorological Institute Bratislava, 30–46 (in Slovak).

Podhorský D., 1974: Comprehensive processing of meteorological data for rainfall intensity assessment (Komplexné využitie meteorologických údajov pre stanovenie intenzity zrážok), Práce a štúdie, **10**, Hydrometeorological Institute Bratislava (in Slovak).

Podhorský D., Androvič A., 1974: Development of meteorological lidar in Czechoslovakia (Vývoj meteorologického lidaru v ČSSR). Proceedings of Hydrometeorological Institute, **7**, Bratislava (in Slovak).

Podhorský D., Fabková M., Kovár S., Pánik V., 1975: Some possibilities of utilization of radio waves polarization and inorganic reagents for weather modification (Niektoré možnosti využitia polarizácie rádiovĺn a anorganických reagentov pri ovplyvňovaní počasia). Hydrometeorological Institute Bratislava, III. seminár slov.-maď. meteor. spol., Nitra (in Slovak).

Podhorský D., 1976: Justification of scientific and operational observation radar system for location of dangerous phenomena in Czechoslovakia (Obosnovanije radiolokacijonnoj sistemy naučnych i operativnych nabljudenij za opasnymi meteorologičeskimi javlenijami v ČSSR). thesis, LGMI, Leningrad, p. 214 (in Russian).

Podhorský D., Pavlík J., 1979: Utilization of weather satellites in particular research areas of Hydrometeorological Institute (Možnosti využívania meteorologických družíc v jednotlivých smeroch činnosti Hydrometeorologického ústavu). Sborník referátú vědecko-technické konference, Praha, 28–32 (in Slovak).

Podhorský D., 1979: Current status, possibilities and perspectives of radar meteorology utilization in term of national economy (Stav, možnosti a perspektívy využívania rádiolokačnej meteorológie pri zabezpečovaní potrieb národného hospodárstva). Sborník referátú vědecko-technické konference, Praha, 33–39 (in Slovak).

Podhorský D., 1981: Space and radar meteorology in the hydrometeorological service in Czechoslovakia (Kozmická a rádiolokačná meteorológia v hydrometeorologickej službe ČSSR). Meteorologické zprávy, Praha, **34**, 1, 1–3 (in Slovak).

Podhorský D., Tekušová M., 1981: Clouds phase and rainfall status determination by means of depolarization selection of high-frequency radiation (Určovanie fázového stavu oblakov a zrážok pomocou depolarizačnej selekcie vysokofrekvenčného žiarenia). Meteorologické zprávy, Praha, **34**, 1, 8–10 (in Slovak).

Podhorský D., Vlčák Ľ., 1981: Particular algorithms of comprehensive weather satellites data processing for ASRLP (Niektoré algoritmy komplexného spracovania digitálnych údajov z meteorologických družíc pre účely ASRLP). Meteorologické zprávy, Praha, **34**, 1, 22–24 (in Slovak).

Podhorský D., Vítek Z., 1981: Operative data bank generation for national and regional radar meteorology centre (Tvorba operatívnej banky údajov pre účely národného a regionálneho centra pre rádiolokačnú meteorológiu). Meteorologické zprávy, Praha, **34**, 2, 58–60 (in Slovak).

Podhorský D., 1985: Utilization of remote detection methods for hydrology purposes (Problém využitia metód diaľkovej detekcie pre potreby hydrológie a vodného hospodárstva). Meteorologické zprávy, Praha, **38**, 5, 134–137 (in Slovak).