ROMANIAN NATIONAL METEOROLOGICAL INTEGRATED OBSERVATIONAL SYSTEM – ACHIEVEMENTS AND CURRENT STATUS

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Abstract

The paper briefly describes the architecture of the national meteorological infrastructure, the progresses Romanian National Meteorological Administration did over last few years and provides the current status and modernization perspectives.
Each subsystem (the national radar network, surface observation system, upper-air sounding stations, lightning detection sensors, communication network etc.) is further detailed, presenting data collection philosophy, dissemination and available products.

Key words: SIMIN, modernization, up-grade, weather radar system, ASOS, upper-air sounding, meteorological satellites, lightning detection network, WAN

1. Introduction

Romanian National Meteorological Administration (RNMA) is the national authority in the meteorology field, except aeronautical meteorology (another organization, ROMATSA, being responsible for this activity). Under these circumstances, RNMA plays an important role in almost all activities carried out over Romanian territory, its primary mission being protection of life and goods. RNMA serves all Romanian citizens through Government authorities, but also performs specialized meteorological services for any kind of end-user (like public organizations, private companies etc.). In order to be successful in its missions, RNMA has to develop, up-grade and maintain the national meteorological system (observational infrastructure, communication, processing, displaying and dissemination systems, qualification of the personnel etc.) at high standards. It is important to note that Romania is an Eastern Europe country and the whole process of transition to European Union over the last 15 years highly impacted the meteorological activity. This paper will describe the RNMA achievements in the meteorological infrastructure (sensor networks and communication) domain. The modernization process started in 1998 with the acquisition of an automated message switching system (AMMS), continued in 2000 with the installation of the first two Doppler radar systems, but the biggest contribution was brought by the SIMIN project (implemented during 2000 – 2003 period). The total value of the project was 55 million USD with the primary objective of modernizing and integrating the nations various resources and real-time detection capabilities, and also facilitates the exchange of data at the Local, Regional, and Global levels.
Figure 1 illustrates the geographic distribution of the sensor network and communication and includes all the sensor sites and national and regional meteorological centres.

2. National weather radar network

History:

- Before October 2000, Romanian national radar network included only conventional analogic radar systems (mainly MRL-5 and MRL-2 Russian equipment); the exploitation regime was exclusively manual and consisted in one radar map every hour and one national mosaic map every three hours;
- Modernization – step 1: in October 2000 two new Doppler radar systems are commissioned in Bucharest and Craiova (manufacturer DRS-WS – former EEC, equipment type – DWSR-2500C);
- Modernization – step 2: in 2001 one new Doppler radar system is commissioned in Oradea (manufacturer Gematronik, equipment type – METEOR 500C);

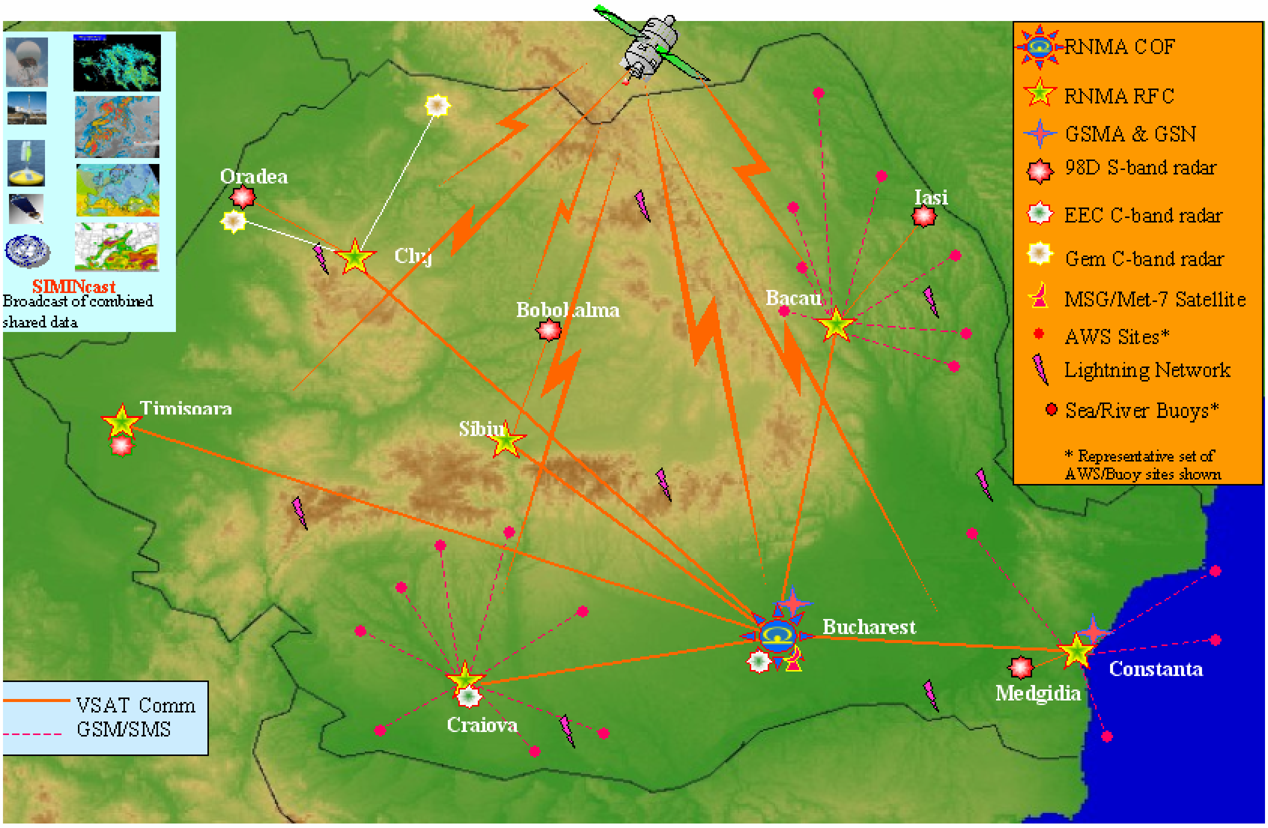

Figure 1 – RNMA sensor networks and communication

- Modernization – step 3: SIMIN project completes the national radar network; during 2002-2003 period, 5 (five) new Doppler S-band radar systems are installed in Barnova, Medgidia, Bobohalma, Timisoara and Oradea (manufacturer Lockheed Martin/Metstar, equipment type – WSR-98D, an upgraded version of the WSR-88D NEXRAD system used by the National Weather Service in US);
- October 2003 – National Integrated Meteorological System (SIMIN) is commissioned by Romanian Meteorological Service; Romanian national radar network consisting in 8 (eight) Doppler radar systems is declared operational;
- First half of 2004 – Romanian Water Authority installed the second Gematronik METEOR 500C in northwestern part of Romania; this system will become soon part of the RNMA weather radar network.

Before October 2000, the Romanian weather radar network consisted of ageing manually operated radar systems. Specifically the Russian MRL-2 and MRL-5 equipment was used. The disadvantages of such equipment were the obsolete technologies, the manual exploitation of the system, and the large amount of time necessary for processing and distribution. The MRL-2 was designed in 1967 and the MRL-5 in 1972, thus repair and maintenance was always an issue. Manual operation forced the radar operator to sit in front of the radar display and draw the radar echoes on paper by hand. The manual collection also required a large amount of time necessary for acquiring the radar information, putting it on a paper map and disseminating to the end-users. Therefore, radar data was not available in real-time. Every three hours, on the basis of the local information received from the component systems of the network, the National Radar Center at the RNMA headquarters created a national radar mosaic, also in analog paper map format. Figure 2 represents an example of national radar mosaic product used till recently by RNMA.

The first step of the national network modernization was achieved in October 2000 when two modern systems manufactured by Enterprise Electronics Corporation (EEC) were commissioned in the Southern part of Romania. These two systems met the criteria imposed by the EUMETNET GORN and OPERA programs for harmonizing and improving the exchange of the data from operational weather radars in Europe. For the first time, in 2000 Romania had its first regional radar mosaic, with only two systems, and updated every 20 minutes. Figure 3 represents an example of the first stage radar mosaic covering the southern portion of the country.

The second step was early 2001 when Romanian Water Authority (RWA) installed and commissioned another radar system. This equipment is manufactured by Gematronik (METEOR 500C type) and currently is operated also by RNMA.

SIMIN has concluded the transition of the Romanian weather radar network from exclusively manually operated and obsolete systems, to one of the most modern and unique radar networks in the world. SIMIN has installed five (5) new and modern WSR-98D S-band radar systems, to complete the national network. The WSR-98D system, from the Beijing Metstar Radar Co., is based on the technology and meteorological algorithms developed over more than 30 years in the US NEXRAD network. It generates an impressive suite of more than 70 products, including both base and derived products.
The SIMIN added value consists not only in installing the new WSR-98D radar systems, but also in bringing the power of a reliable radar network and integration of the existing digital systems (EEC and Gematronik) into this network. In this respect, Romania is one of very few countries that have fully integrated three types of radar equipment into one integrated network.
Currently, RNMA produces individual site radar products every 6 minutes, depending on the radar and mode of operation. Three types of national radar mosaics are produced every 10 minutes. The available national radar mosaic products include first tilt base reflectivity, echo top and composite reflectivity. The fact that Romania has three radar products at a nationwide scale is another unique feature of the Romanian radar network. Figure 4 illustrates an example of the three current Romanian National Mosaic products.

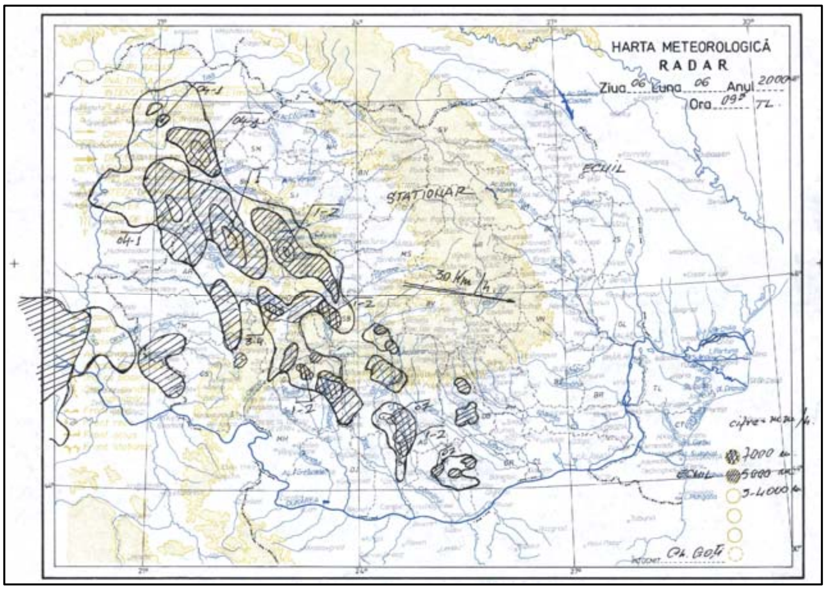

Figure 2 - Manual National Radar Mosaic

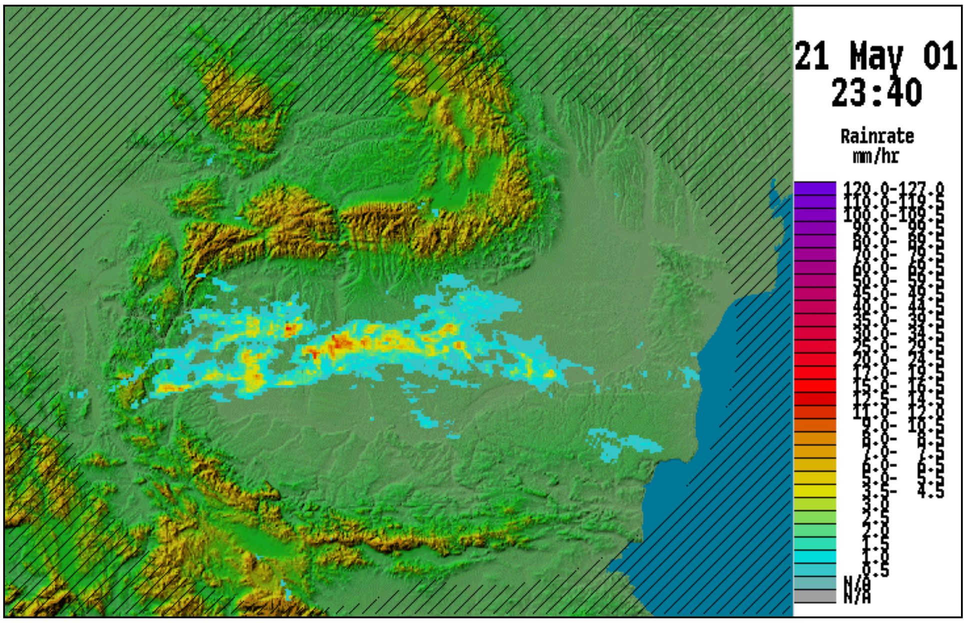

Figure 3 - Initial Regional Mosaic with 2 Radars

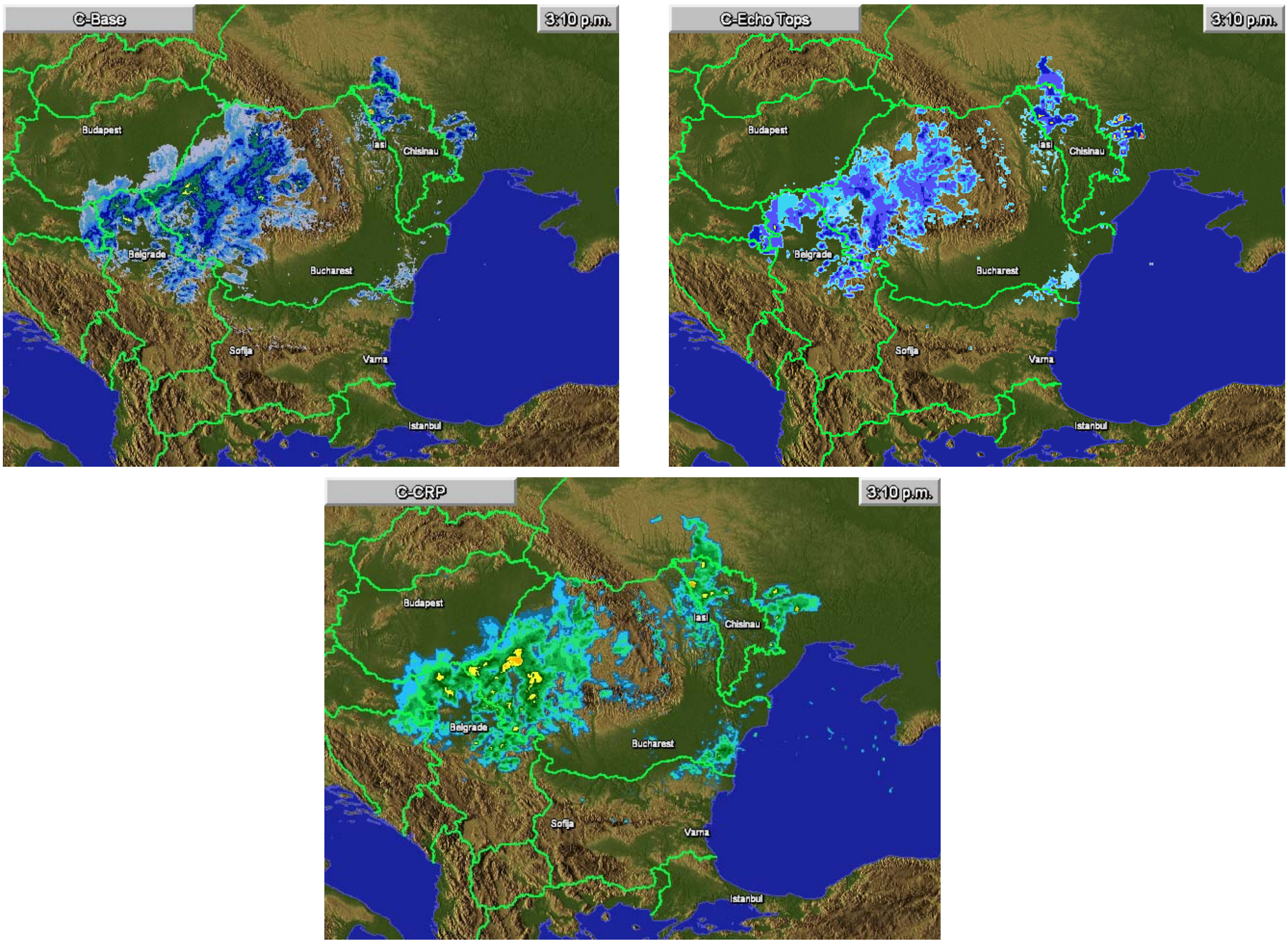

Figure 4 – The three types of National Radar Mosaic with 8 contributing radars

3. Romanian surface observation network

The surface observation network (the meteorological stations) is a very important component of the RNMA observational system. The data provided by this network is used directly by the forecasters (they receive hourly reports from all meteorological stations), is used in climatological studies, serves as input for NWP and part of this data is introduced in the international meteorological data flow (GTS).
The network consists in approximately 135 meteorological stations that perform various types of observations (synoptic, climatologic, agro meteorological etc.). Data coming from 23 out of these 135 stations is representing the RNMA contribution to the international data flow.
Figure 5 illustrates the geographical distribution of the RNMA surface observation network. It is important to note the fact that the number and the locations for the meteorological stations are slightly varying from one year to another depending on various conditions (new needs for meteorological information in a specific area, degradation, from meteorological standpoints, of some locations, administrative problems -like RNMA is not the owner of the station land / building, budget cuttings etc.
At the beginning of 90s, all the meteorological stations were using classic instruments for measuring the various parameters. Starting with 1995, RNMA acquired the first automatic surface observation stations (ASOS), but, due to the fact that these ASOS were very few, it can not be considered the start for the modernization of the network. This modernization happened only in 2000 when a number of 10 ASOS were installed in 10 important locations (mostly county capitals locations). The modernization continued with the SIMIN project – 60 new ASOS were installed all over Romania. In the present, the national network contains a number of 73 fixed location ASOS and another 2 mobile ASOS. In the first half of 2005 another 15 ASOS will be installed, and other infrastructure modernization projects are in progress (like agro meteorological projects, INTEROPERATE project etc.).

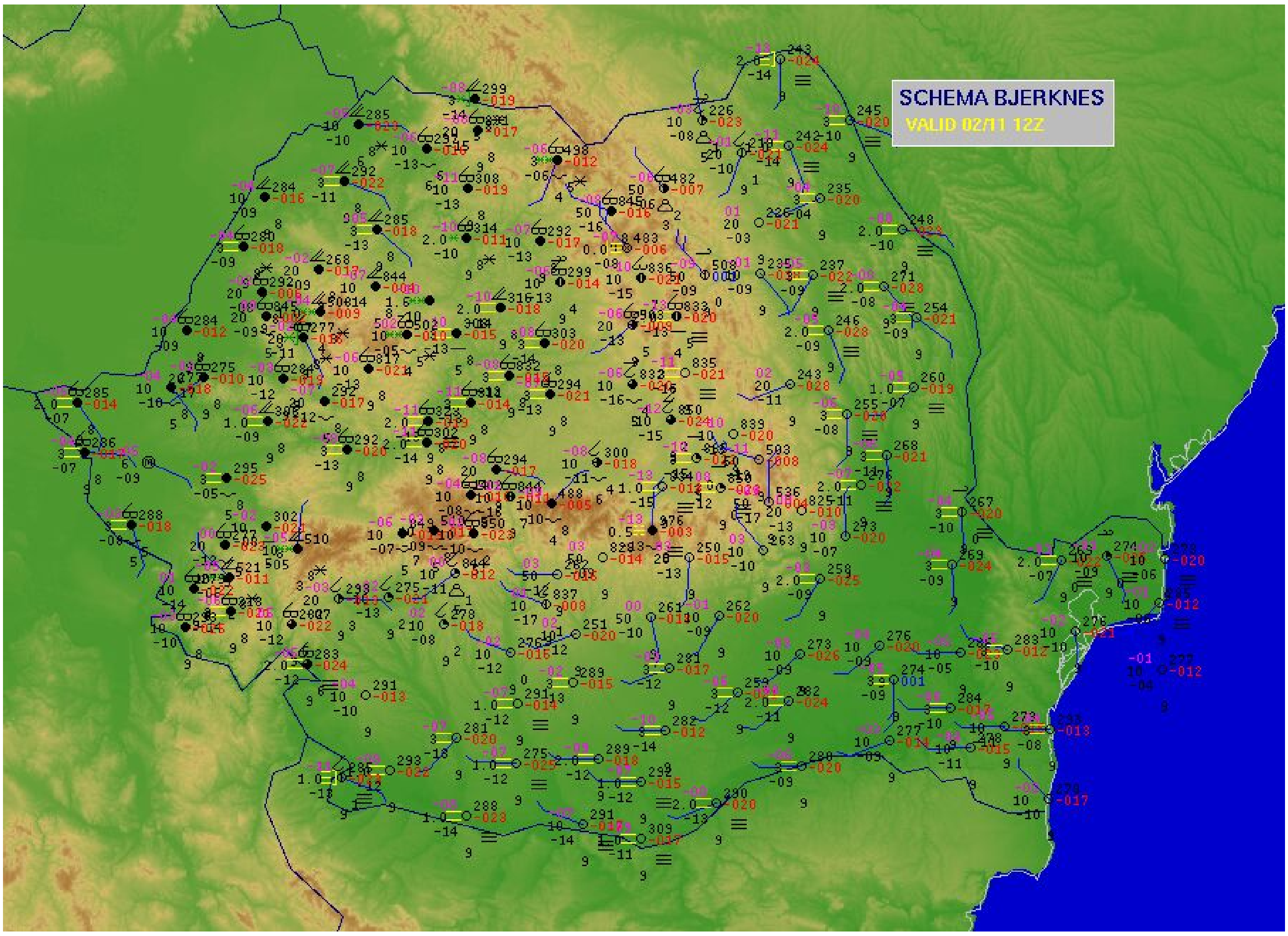

Figure 5 – RNMA surface observation network

The table below summarizes the type, locations, manufacturers and the year of acquisition for all the automatic surface observation stations included in the RNMA network. When the ASOS locations were selected, several criteria were considered: county capitals are important from synoptic and climatological standpoint, other representative locations are important for their geographical areas, special needs (like mountain and marine meteorology, special projects for different areas etc.).

Number / Location	Manufacturer	Type	Year of installation	Acquisition procedure
10 / county capitals	Vaisala/Finlanda	MAWS301	**2000**	RNMA funds, international bidding
1 / Mangalia (mobile)	Vaisala/Finlanda	MAWS201	**1998**	RNMA funds
1 / RNMA HQ (mobile)	Vaisala/Finlanda	MAWS201	**1998**	RNMA funds; special measurements (like 1999 eclipse, Baia Mare project)
1 / Bucuresti – Afumati	Thies/Germania	AWS7800	**1997**	PHARE funds
1 / Constanta	Vitel/SUA	VX1004	**1996**	Offered free of charge, in the frame of a WMO programme
1 / Bucuresti – Banesa	Thies/Germania	DL15	**1995**	RNMA funds
60 / county capitals and other representative locations	Vaisala/Finlanda	MAWS301	**2001 - 2003**	SIMIN project

Another aspect of the network modernization is the data collection method. Before 1998 the collection and validation of the data was done manually, using phones and radio communication devices. In 1998 another communication concept was introduced: GSM SMS (short message system). All the stations were provided with cell phones and all the observers were reporting to the collecting centre using SMS service. Later on, in the frame of SIMIN project, a complex application for data collection, transmission and validation was implemented. This application has three components, one for each level of collection and validation: local (station site), regional and national.

4. Upper-air observations

Romanian upper-air network consists of three operational upper-air sounding stations located in Bucharest, Cluj and Constanta. All three stations are equipped with Vaisala DigiCORA systems upgraded to Loran C in 2004 in order to use RS-92 KL sondes and, alternatively, Vaisala GPS sondes RS-92 SGP.
The upper-air measurements program consists of two soundings per day at the synoptic hours of 00 and 12 GMT in Bucharest and Cluj stations. The Loran C wind finding system and RS-92 KL radiosondes are used. Currently the measurements program in Constanta is temporary interrupted for the hydrogen building reconstruction and it is estimated that during 2005 the activity will be resumed.
Meteorological variables measured in upper-air programs include pressure, temperature, humidity, and wind direction and wind speed. The obtained data are examined using quality control procedures, coded in TEMP bulletins and disseminated in national and international data flow at the a.m. synoptic hours.
Upper-air meteorological measurements used daily as input for numerical weather forecast models are therewith the main support for nowcasting activity, especially to analyse and predict severe weather and the evolution of the local meteorological phenomena. For this purpose the upper-air data are daily processed to derive the thermodynamic parameters and other atmospheric variables such as: potential and equipotential temperatures, main isotherm levels, height and strength of inversions, onset and dissipation of fog, convective condensation level, precipitable water content, vertical stability (convective instability indices, thunderstorms, hail, turbulence), mixing level, etc. Two types of aerological diagrams are automatically performed for visualization and graphical analyze of physical processes: thermodynamic diagram and daily variations of the main upper-air parameters for the last seven days.
The upper-air data are recorded on temporary files in order to perform CLIMAT-TEMP bulletins and update database at every end of month. At the same time the main upper-air climatological parameters are computed assuring hereby the input data for climatological studies of the atmosphere.

5. Satellite data acquisition and processing

Since 1970, in the frame of Satellite Meteorology Department there are sustained preoccupation concerning the use of digital information provided by the geostationary and polar-orbital meteorological satellites for specific activities.
The main purpose of the RNMA Satellite Department is to provide satellite images, derived products for operational meteorology purposes, and integration of the satellite derived parameters in NWP models.
Meteorological products and geophysical parameters are derived and made available to the operational services like the National and Regional Forecasting Centres. Taking into account all these aspects, a NOAA AVHRR / HRPT system was installed in 1998 – 1999 by SMARTECH company. The software for the acquisition and pre-processing (SMARTrack and SMARTVue) was also delivered by SMARTECH. The development of new algorithms is done using ERDAS IMAGINE and ENVI software. Also the RNMA - Satellite Department benefits by the direct reception of digital High Resolution Imagery Transmissions data from METEOSAT and High Rate Information Transmission and Low Rate Information Transmission data from MSG (Meteosat Second Generation). These two receiving stations have been manufactured by VCS-Engineering and were provided in the frame of SIMIN project. The systems actually receive, store and process all the HRI data dissemination formats (A-format, B-format and X-formats for foreign satellites) and HRIT and LRIT data from MSG.
The products derived from MSG data are listed below and are used to support the nowcasting and very short range forecast:
Cloud Mask (CMa)
This product shall provide information on the possible occurrence of clouds within each pixel. The central aim is to delineate all absolutely cloud-free pixels in a satellite scene with a high degree of confidence.
Cloud Type (CT)
The main objective of this product is to support detailed cloud analysis. It may be used as input to an objective meso-scale analysis or as an image product for display at the forecaster's bench.
Cloud Top Temperature and Height (CTTH)
The CTTH product shall contain information on the cloud top temperature and height for all pixels identified as cloudy in the satellite scene with the highest possible spatial and temporal resolution. The main use of this product is in the analysis and early warning of thunderstorm development.
Precipitating Clouds (PC)

The Precipitating Clouds product provides information on the probability of weak, moderate and strong precipitation.

Convective Rainfall Rate (CRR)

The CRR product provides the maximum level of information on convective rainfall from the SEVIRI channels. The main use of this product is the monitoring of convective systems and their rain intensity.

Total Precipitable Water (TPW)

The TPW gives information on the total atmospheric water vapour contained in a vertical column of unit cross-sectional area extending from the Earth's surface to the "top" of the atmosphere. This product can be used for objective quantitative studies giving a diagnosis of the total water vapour content in pre-convective areas and therefore helps to classify the air mass in terms of severe weather air masses. Also it gives some information on the intensity of the phenomena to be expected and localisation where severe convection is likely to occur.

Layer Precipitable Water (LPW)

The LPW product provides, in absence of clouds, information on the atmospheric water vapour contained in a vertical column of unit cross-sectional area in three layers in the troposphere. The special interest of this product is the detection of dry-over-moist configurations and of horizontal moisture gradients, as these factors contribute to severe storm formation.

Stability Analysis Imagery (SAI)

The SAI product gives an index summarising the information content in the SEVIRI channels on the vertical thermodynamic structure of the cloud-free atmosphere. In particular, information on the stability of the troposphere is given by SAI with the scope of delineating unstable and stable areas.

High Resolution Wind Vectors on HRV (HRW)

The HRW provides information on mesoscale wind vectors at two different horizontal resolutions: a basic wind product at a scale of approximately 20-25 km, a fine-scale product with a resolution of 10 km. Both products use data from the HRVIS channel and are thus solely extracted during daytime.

Automated Satellite Interpretation Imagery (ASII)

This product provides an automatic interpretation of features seen on satellite images. Hence, the product identifies fronts, wave structures, areas of intensification at fronts by jet streak crossing, position of the jet axis, comma clouds, enhanced convection areas, etc. The result of the automatic interpretation will be given in the form of text and object attributes, which can be overlaid on the satellite IR image.

Rapid Development Thunderstorms (RDT)

The RDT provides information about significant convective systems from meso-alpha scale down to smaller scales, and possible isolated storms (meso-gamma scale). The objectives are twofold: identification, monitoring and tracking of intense convective systems and detection of rapidly developing convective cells.

Air Mass Analysis (AMA)

The goal of the AMA product is to evaluate basic quantities that describe air masses (upper and middle level humidity, mean temperature, atmospheric stability, cloud pattern, etc) and to combine them into one integrated classification of the air mass. The main use is to monitor air masses and air mass boundaries for an early recognition of unstable weather situations.

6. Lightning detection network (LDN)

This type of network represents something new for Romania, therefore we can not speak about modernization but about a new type of information. The network was installed in 2002 in the frame of SIMIN project. The purpose was gathering precise information on the electric activity of the atmosphere. The manufacturer of the network is Vaisala company. The system provides information on its own display, but the data is also integrated into RNMA data flow and can be displayed on other integrated platforms / applications. Below is a brief description of the system, with main specifications and few considerations on localization accuracy.

The LDN consists of:

1. Detection Network of 8 SAFIR 3000 Total Lightning Automatic Detection Stations, located on RNMA sites;
2. Spare parts set;
3. Transmissions from the detection stations to the Network Centre, using the RNMA communication means (leased lines, wireless 64 kbps);

4. A network centre situated at RNMA HQ comprising:
    - Central Processing System (CPS) performing the acquisition and processing of detection network data (SCM), the technical control of the detection network (DCM) and data storage into Oracle database.
    - Main User Terminal performing the real-time mapping of Total Lightning localizations and thunderstorm nowcasting processing & display (PDM or BPDM), and post processing on archived data (DAM & EPM).

The Detection Stations are made of a VHF Interferometric sensor designed to perform the accurate angular localization of total thunderstorm electrical activity (intra-cloud and cloud to ground lightning), complemented by a wide band LF electric field sensor for the characterization of lightning strikes to ground. Detection stations are connected via telecommunication means to the central processing system.
The Central Processing System (CPS) acquires the data transmitted by the detection stations and computes the locations of lightning discharges by triangulation technique. The CPS processes and displays the technical status of the detection stations and communication links, and can be remotely accessed from VAISALA technical centre for diagnostics and maintenance. The CPS stores the processed data to the Oracle data base.
The Main User Terminal receives the data from the CPS and depending on the selected processing modules perform the advanced real-time processing and display of lightning and storm nowcasting information, as well as post processing of archived data, such as:

- Localization of Total lightning activity;
- Discrimination of lightning type;
- Total lightning activity density mapping;
- Automatic thunderstorm cells identification and tracking (direction and velocity);
- Automatic thunderstorm cells nowcasting;
- Automatic storm warning functions.

Detection performance

- Type of lightning discharges: Total lightning activity, (intra-cloud + cloud to ground lightning);
- Detection efficiency: 90 % (see simulation map hereafter);
- Localization accuracy: minimum < 1 km (mean error, see simulation map hereafter);
- Coverage: (see simulation maps)

Processed data provided by the CPS

- Localization of total lightning activity (date, time, lat., long, intensity);
- Discrimination of lightning type, and characterisation of CG return stroke parameters:
    - Polarity
    - Peak current
    - Rise time
    - Decay time

Processing on display terminal

- Total lightning activity density mapping;
- Automatic thunderstorm cells identification and tracking;
- Automatic thunderstorm cells nowcasting;
- Automatic warning functions for user defined sites and areas.

The simulation of localization accuracy for 8 stations are presented hereafter using the final station locations selected and agreed by RNMA:

- Station 1: Tarcu Peak
- Station 2: Rosia Montana
- Station 3: Grivita
- Station 4: Pauleni
- Station 5: Poiana Nord
- Station 6: Furculesti
- Station 7: Rociu

- Station 8: Movileni

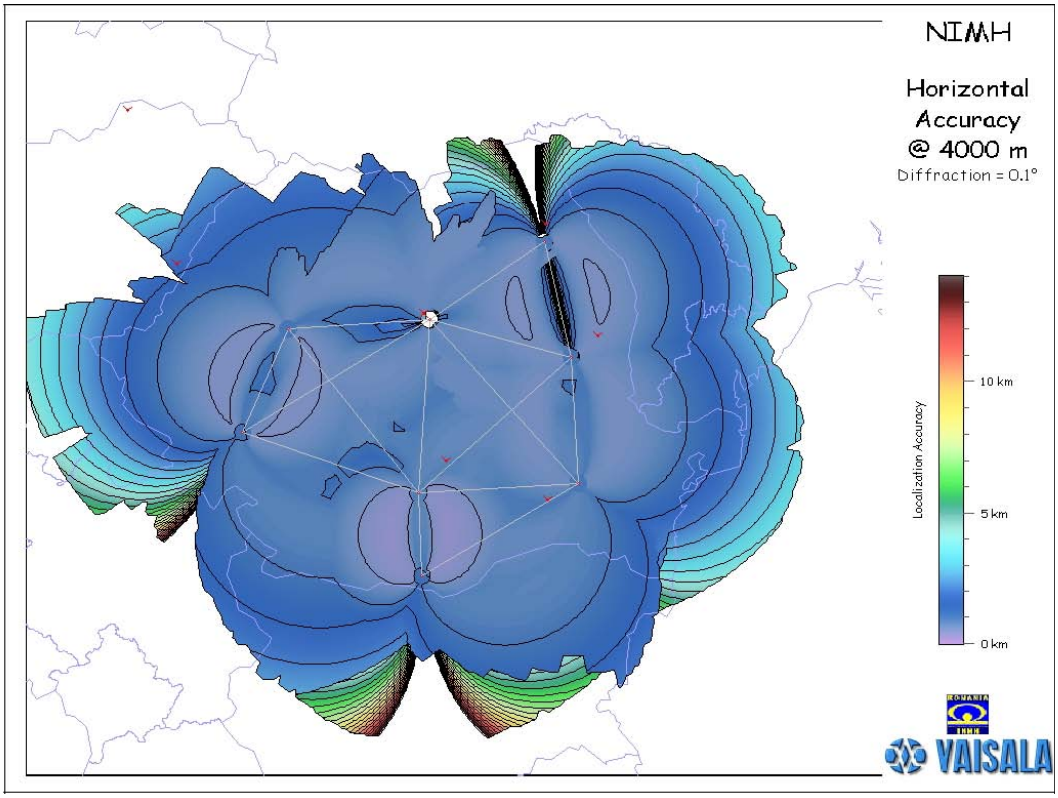

Figure 6 - Simulation of coverage and accuracy at an altitude of 4000m, with 8 HR SAFIR 3000 stations

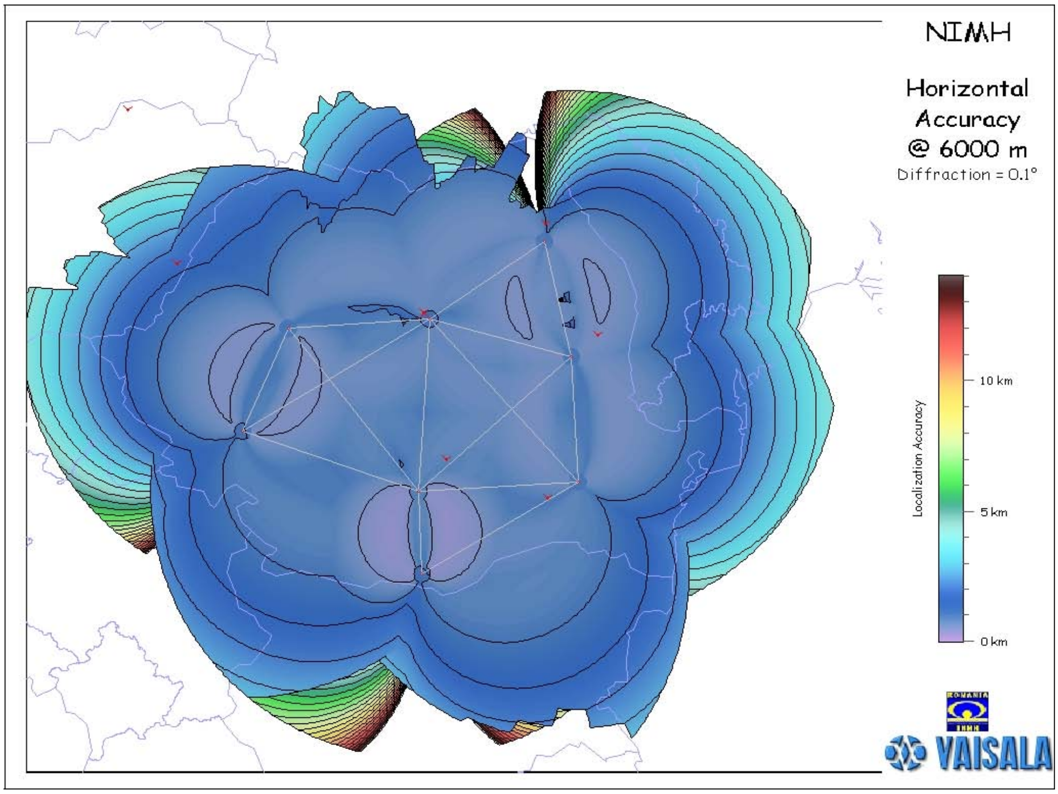

Figure 7 - Simulation of coverage and accuracy at an altitude of 6000m, with 8 HR SAFIR 3000 stations

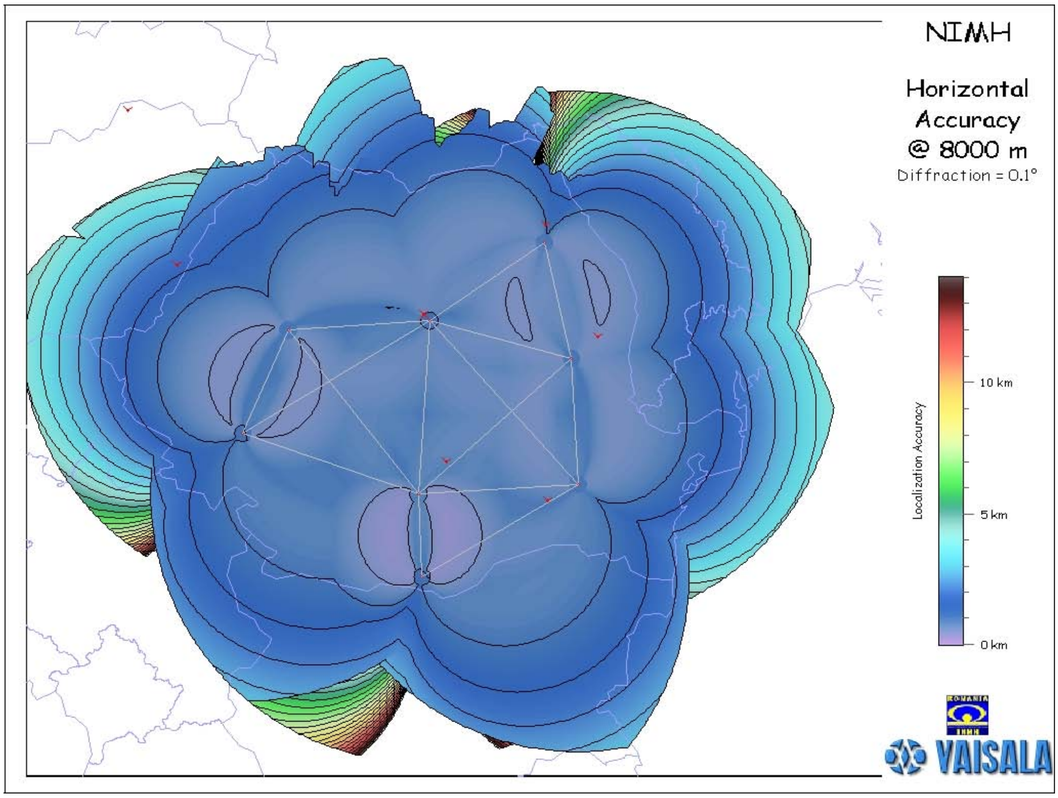

Figure 8 - Simulation of coverage and accuracy at an altitude of 8000m, with 8 HR SAFIR 3000 stations

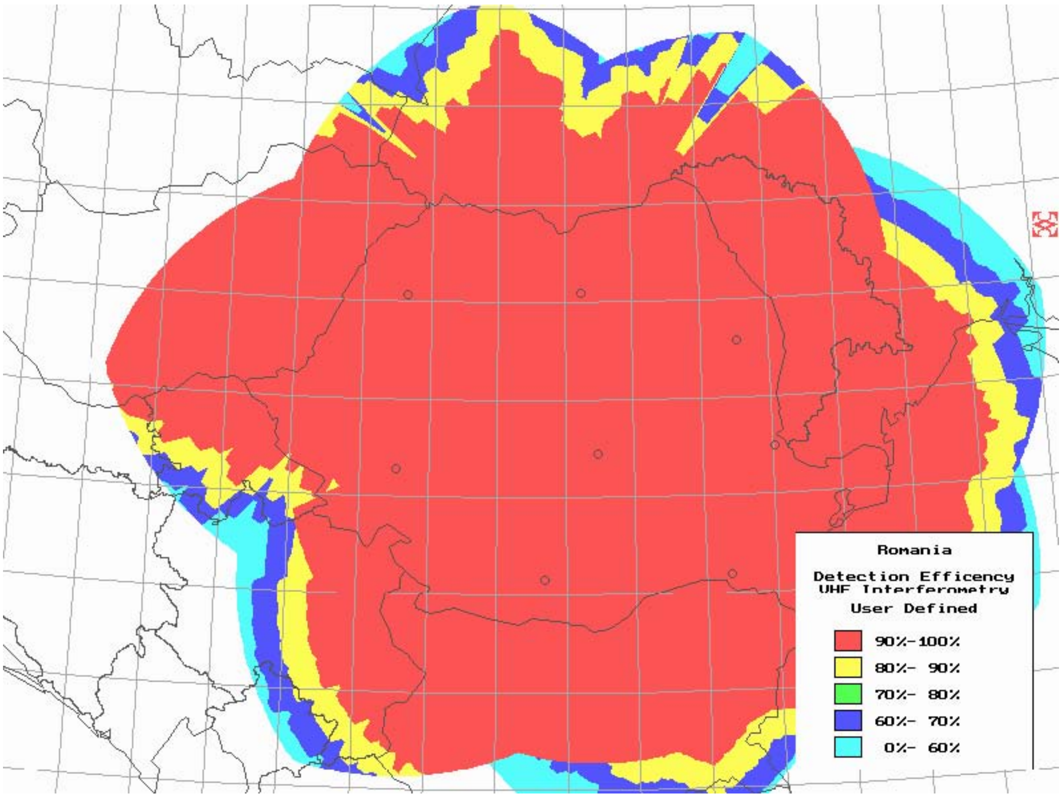

Figure 9 - Simulation of Total Lightning Detection Efficiency (Cloud to Ground and Intra Cloud lightning) with 8 SAFIR detection stations over Romania

7. Communication network

In order to be able to perform data collection and transmission and to preserve the timeliness of the data, any meteorological system needs a communication network specially designed in accord to the volume of the data transported, number of sites, other types of traffic involved in the network (like voice / IP, e-mail, internet, administration etc.).
In the frame of SIMIN project a WAN was designed and implemented taking into account the above mentioned criteria. The support of the WAN is a mesh VSAT network, with 12 terminals: 2 at RNMA HQ (for redundancy reason), 6 at the RFCs and 4 at the S-band radar sites. This network sustains both operational data traffic and voice traffic necessary for administration. The routing and switching equipment is provided by CISCO. The figures below provide the topologies of the WAN and LAN at the RNMA HQ.

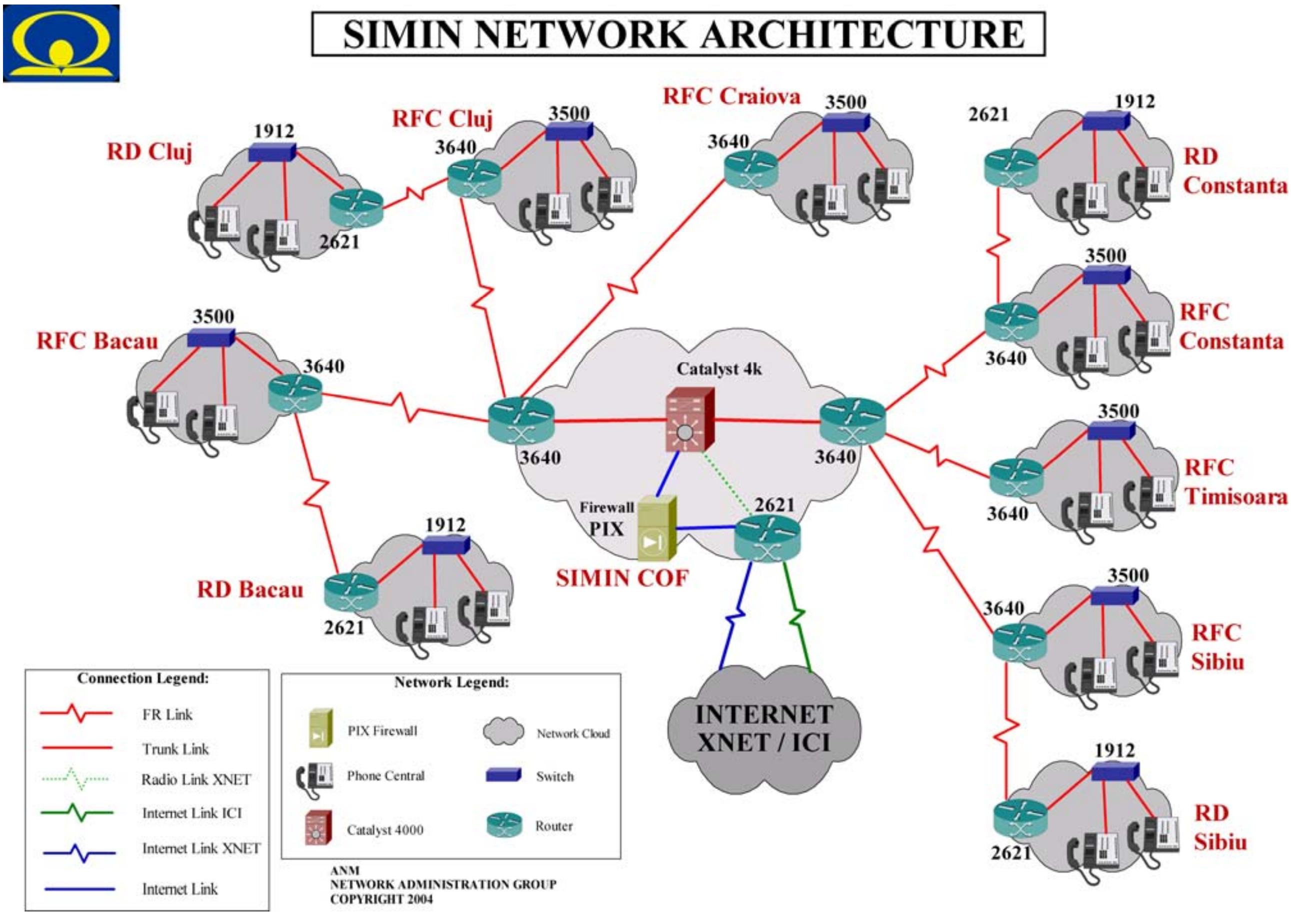

Figure 10 – RNMA WAN topology

Considering the importance of the communication network for a meteorological system, during 2004 RNMA implemented a back-up solution for the VSAT network. The back-up is in fact a VPN that includes all site locations and few others. When the VSAT network is functioning normal, the VPN is used for off-line and administrative traffic (like e-mail, Internet etc.), but in case a PVC is going down, the back-up correspondent connection comes up automatically and drops all non-operational traffic.

During the last couple of years, a special attention was paid in developing the IT&C domain: acquisition of new switching equipment (CISCO), renewing the computer fleet, performing security audits in order to better protect the WAN/LAN against inside and outside threats, etc.

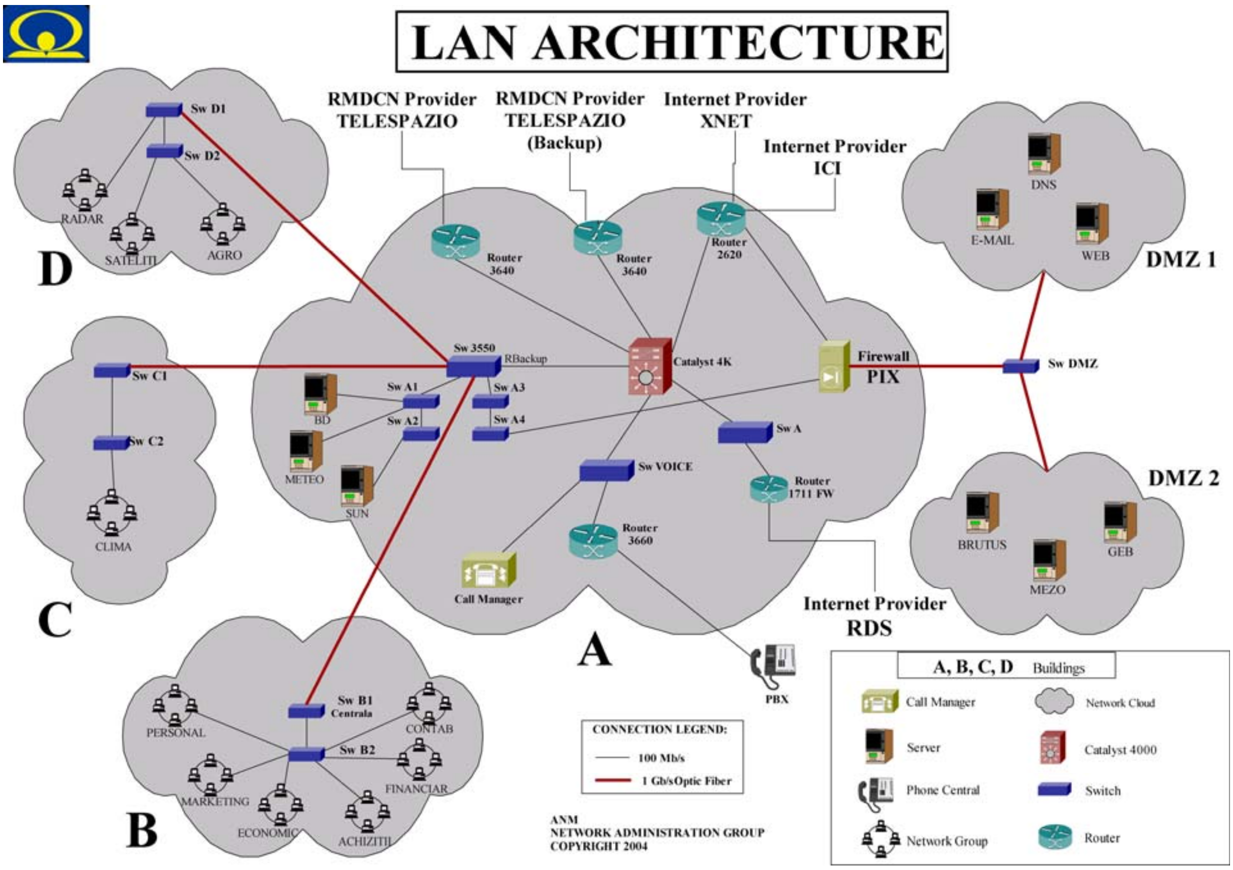

Figure 11 – RNMA HQ LAN topology

8. Conclusion and up-grade perspectives

As presented in this paper, RNMA made a lot of efforts since 1998 to continuously develop and modernize its observational system. In some domains (like radar and lightning detection) the progresses are spectacular and in others (like upper-air or ASOS) the progress is visible but it takes more time to be completed.
Below is synthesized the RNMA strategy for each domain included in this paper:

- Radar network. Some of the radar equipments are becoming obsolete (due to the analog receiver used and because dual-polarization feature is absent). The plan for the oldest systems (those installed in 2000) is to be up-graded to dual-polarization and digital receivers. Eventually, in the next 5 years, dual-polarization will become a standard for any operational radar equipment. Another directions that RNMA will pursuit in the future are integration of the radar data in NWP models and increasing the accuracy of the precipitation data measured by the weather radar;
- For the surface observation network, it is obvious that, over the next couple of years, the automatization of the surface observations will become a priority for all meteorological services. This is the case also for RNMA, but this process takes time and money. Another direction of modernization is to up-grade the existing ASOS with new sensors or to up-date the existing sensors;
- The upper-air sounding domain is evolving a little bit slower. The priorities in this domain would be increasing the number of sounding stations and soundings performed at each station, keeping the sounding equipment up to date and evaluation and implementation of the new techniques (for example using the upper-air data provided by the commercial aircrafts);
- In the meteorological satellites domain, RNMA plans include implementation of all MSG products in the operational activity, using data supplied by other satellites for meteorological applications, integration of the data into NWP models;
- About lightning detection network, RNMA plans to keep the hardware up to date and to obtain more products from the LDN data, both for internal use and for other customers;
- For the IT&C domain, RNMA will try to keep as close as possible to the international evolution of this domain.