Architecture of HASIS-3D System Designed for Hail Suppression Purposes

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***Abstract* – The main task of hail suppression system is efficient seeding of potentially hail containing clouds. The estimation whether the cloud is potentially hail containing or not is made by tracking the development of cloud systems. Three-dimensional Hail Suppression Information System (HASIS-3D), presented in the paper, provides tracking and measurement of specific parameters of cloud systems. Cloud tracking is enabled by efficient visualization of radar data. The data being used by the system is acquired using meteorological radars and represents cloud reflectivity for electromagnetic waves. Visualization of the data in 2D view is performed using data in polar coordinate system and representing each reflectivity level with appropriate color. Availability of different 2D view modes in HASIS-3D system allows precise analysis of clouds and more adequate estimation of hail probability. Representing clouds with iso-surfaces in 3D view allows early detection of potentially hail containing clouds by inspection of the cloud configuration and size in space. The system, also, provides tools for precise measurement of hail cells that need to be seeded with chemical reagents. The system automatically determines the parameters for launching rockets to efficiently seed the cloud with hail potential. The calculation of parameters uses the 3D iso-surfaces of the cloud that is enclosed by the points with specified reflectivity.**

***Keywords* – Hail suppression, cloud visualization, volume visualization.**

I. Introduction

Many different information systems are involved in meteorology domain, from simple ones that manage meteorological measurements to complex systems that monitor weather conditions [1]. The complex systems use Doppler's radars for data acquisition. The data represents different parameters about the atmosphere and provides various types of analyses.

In this paper, the system for hail suppression - HASIS-3D (Three-dimensional Hail Suppression Information System) is presented, as a specific information system in weather modification domain. It is developed to support hail suppression activities in Hydrometeorological Service of Republic of Serbia (RHMSS). The process of hail suppression is based on seeding the clouds with high probability with chemical reagents. It operates on the infrastructure provided by the RHMSS. HASIS-3D is complete system which uses stationary Gematronik radars for data acquisition. Gematronik radars are delivered with Rainbow 4.0 software for radar data processing [2]. This software controls the radar and provides data visualization using projections on 2D planes. Drawback of the system is lack of support for extraction of cloud area that will be seeded with chemical reagents and calculation of elements for launching rockets on cloud with high probability. Rainbow software neither provides 3D representation of the cloud. The well-known composite hail suppression system TITAN [3], also, has the mentioned shortcomings.

The system HASIS-3D is beeing developed to resolve the emphasized drawbacks and to support the methodology developed for HASIS system [4]. Criteria used in decision-making are combination of measured parameters of clouds and visual impressions that include heuristics similar to criteria presented in [5,6]. HASIS-3D offers two modes for clouds monitoring: two-dimensional (2D) and three-dimensional (3D) view. In 2D view, radar data is represented as colors from chosen color spectra. Analyzing created picture and using zooming option, the operator can detect hail cells. The system provides the possibility to create iso-contour lines in order to improve support for hail cells detection. In 3D view, operator can analyze configuration and dimensions of the clouds represented with several iso-surfaces corresponding to different reflectivity intensity. In 3D view it is possible to detect cloud with high probability in early phase of development and make more accurate decision for seeding the cloud. Using extracted iso-surfaces, the system calculates parameters for launching the rockets to optimally seed the hail cells. Hence, HASIS-3D is a complete system that supports all phases in cloud seeding process, which differentiate it from the other similar solutions in this field.

The paper is organized in four sections. The section 2 describes methodology for cloud seeding that is supported by HASIS-3D system. The architecture of the system is described in section 3. The ending section summarizes the advantages of the proposed system and specifies the interests for further research.

II. HASIS-3D Methodology

The cloud seeding methodology has been defined along with request for HASIS-3D system. HASIS-3D system

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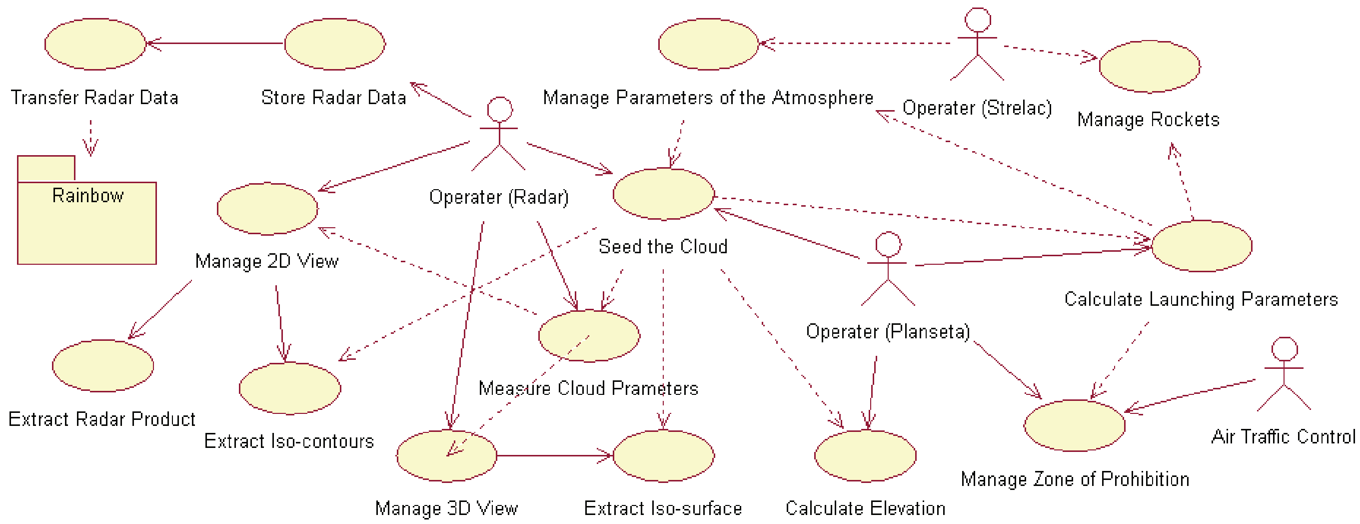

Fig. 1. Global use case diagram of HASIS-3D system

consists of the three subsystems: Main workstation, GIS workstation and Database workstation. The configuration is defined to support hail suppression methodology defined by meteorologist from RHMSS and approved in previously conducted researches [4]. Figure 1 depicts functionalities provided by HASIS-3D system.

System HASIS-3D is developed to function at the radar centers equipped with Gematronik 400S and 500S radars. The radar control is provided by the Rainbow system. It gathers the radar data and creates files with different products. The first task of HASIS-3D Main station is to acquire the product with cloud reflectivity as it is created. The next step is to reference data in coordinate system of the corresponding geographic area. After that, radar data is prepared for visualization and analysis. The analyses can be performed in 2D and 3D view. In 2D view, the cloud reflectivity is represented using the color spectra projected on the horizontal and vertical planes. To improve the cloud analysis, operator can zoom and the created radar data picture is stretched to cover corresponding geographical area. In this way, operator can more precisely detect hail cells and determine the parameters of the cells. If the cloud is estimated as potentially dangerous, operator measures the parameters either in 2D or 3D view. The system can automatically extract the iso-contour from 2D view to help operator measure cloud parameters more precisely. Even better monitoring perspective is provided in 3D view. In 3D view, operator can analyze configuration and dimensions of the clouds represented with several iso-surfaces corresponding to different reflectivity intensity (using rotation and flying through the scene). This view can help the operator to estimate the hail cells dimensions and to make decision whether to seed the cloud or no. The extraction of iso-surfaces is done automatically by the system and iso-surfaces are transferred to the GIS workstation.

The GIS workstation accepts the forwarded iso-contour or iso-surface, georeferences it and visualizes it on the geographical map in the 2D view. This workstation also provides 3D view of extracted cloud iso-surface with the terrain that is underneath the cloud. The 2D and 3D view provide information about position of rocket launching stations. The main task of this workstation is to calculate ballistic parameters for launching the rockets with chemical reagent, to optimally seed extracted iso-contour or iso-surface. The calculation is performed automatically, according to geographic location of the launching station, ballistic elements of the rockets and regions of space that are allowed for seeding. The user can adjust parameters for calculation to improve the efficiency. The only task that is not done automatically is requesting and obtaining the permission from Air-traffic control for the regions to seed. The ballistic parameters are forwarded to Database station.

The Database station stores data about meteorological situation in the atmosphere at that day and the results of seeding process. These include data about ballistic parameters of rockets, location and availability of the launching station and the rockets that they possess. Operator on this system issue the commands to each launching station using voice radio according to the ballistic parameters calculated earlier on GIS workstation.

III. HASIS-3D Architecture

This section describes architecture of the HASIS-3D system that implements the methodology described in previous section. The subsystem RADAR and PLANSETA are designed and implemented as one integral part, and during installation of the system user can chose witch of two set of functionalities to activate. The subsystem consists of six components: Observer, Processor, Extractor, Viewer, Seeder and Manager (Fig. 2).

Rainbow software that controls Gematronik radar works on *Solaris* operating system which is installed on *Sun* workstation. This workstation is delivered as bundle with the Gematronik 400S radar. Rainbow software provides visualization of basic radar canvas created from row radar data. HASIS-3D system uses only product that contains cloud reflectivity gathered by radar. HASIS-3D system works on MS Windows operating system. The optimal solution to transfer data from Solaris to Windows workstation is to use file transfer protocol. For that purpose FTP server is set up on *Sun* workstation and Rainbow software is configured to store files with reflectivity of the atmosphere and be accessible through FTP. This solution provides independence of two systems. During scanning process radar files with products are periodically created and stored on FTP server. Product creation period depend on scanning parameters that can be defined using Rainbow software. Aside HASIS-3D system, component **Observer** is designed according to *Observer* design pattern. The basic task of the component is to detect appearance of new product on FTP server and transfer the file to RADAR workstation. Component **Observer** is developed to memorize snapshot of the contents of the FTP server after starting the system and begin transfer when new reflectivity radar product file is detected on the server.

To prevent the system to instantaneously replace the radar product that operator analyzes at the moment the component **Observer** stores up to 10 last products in circular bafer. To keep operator informed that new data are available system will visually notify him. Operator can carry on with ongoing analysis or begin analysis of new data. Except providing contiguity in analysis process, circular buffer offer operator possibility to examine the history of performed scanning. Last 10 products cover the time from 30 to 100 minute. All products are stored locally on RADAR workstation and can be loaded in the circular bafer for further analysis.

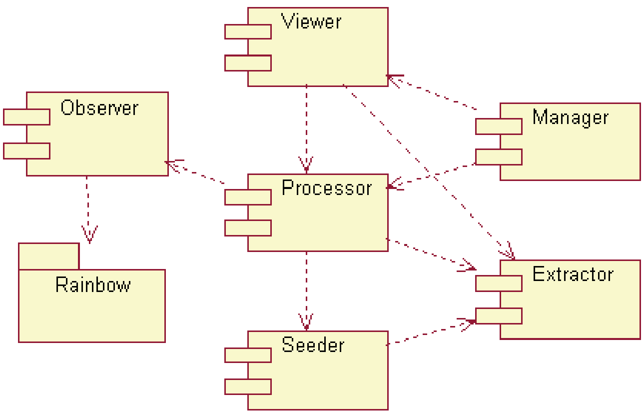

Fig. 2. Component model of RADAR and PLANSETA subsystem

The processing of converted radar data is performed by component **Processor**. This component is specific for RADAR subsystem. The first task of this part of the system is to create products of radar canvas for visualization in 2D view. Basic product that can be created are CAPPI (*Constant Altitude Plan Position Indicator*), RHI (*Range Height Indicator*), MAX and AB. Every radar canvas product represent the cross section of atmosphere reflectivity in the planes parallel to horizontal and vertical. This component processes data in polar coordinate system to extract product of radar canvas [7]. The extraction process uses algorithms from computer graphics to achieve requested efficiency and precission. To provide better precision in visualization three-linear interpolation is used in creating products. The next task of this component is to determine parameters of the cloud. It provides, also, storage of radar product canvas, after its loading and analysis. **Processor** is the heart of the system and it distributes data to all other parts of subsystem RADAR.

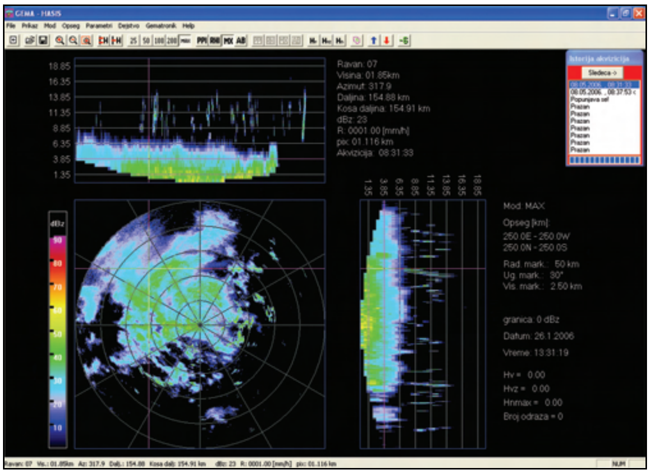

Fig. 3. 2D visualization of radar canvas in HASIS-3D system

The **Extractor** component has two mayor tasks in automatic analysis of clouds, extraction of iso-contours and iso-surfaces. Based on the extracted iso-contours and iso-surfaces it is possible to calculate cloud's parameters that help make more precise estimation of potential hail risk. **Extractor** extracts iso-contours for the specified reflectivity value in either horizontal or vertical 2D cross section using flood fill algorithm, first, and then vectorizes it [4]. The **Extractor** uses marching cubes algorithm for iso-surface extraction [8,9]. Basic idea of this algorithm is to analyze reflectivity in 3D matrix vertices. The algorithm uses data in Descarte coordinate system, therefore system must convert row radar data from polar coordinate system. Transformation is performed in two steps. The first step is conversion from polar to cylindrical, and then from cylindrical to rectangular. The conversion uses interpolation by virtue of two nearest points. Efficiency conversion is critical condition for this component of the system because it is the most time consuming operation in the system. The major advantage of marching cubes volume visualization algorithm is high level of optimization. Therefore, algorithm use less time than other algorithms and quality is suitable for hail suppression purposes.

Component **Viewer** provides realistic representation of radar canvas. It works in three modes, Radar 2D view, Planseta 2D view and 3D view. Radar 2D view consists of three rectangular cross sections according to the selected radar canvas product (Fig. 3). The cross section data are created by **Processor**. It uses color palette defined by operator to visualize reflectivity of point in the product. The reflectivity of the atmosphere is raster layer in 2D view. Besides raster data, 2D view visualizes vector data too. The vector layers are extracted iso-contours, regions of responsibility of radar center, lakes, rivers, cities etc. Planseta 2D view visualizes two raster and three vector layers. Raster layers are georeferenced map of terrain and horizontal cross section. Vector layers are iso-contours, locations of rocket launching stations and prohibited zones. Prohibited zones are square regions that represent units of space defined by Air-traffic control for witch permition from the Air Traffic Controll must be obtained before launching rockets for seeding. 3D view visualizes part of 3D space selected in 2D view using iso-surfaces created by **Extractor** (Fig. 4). 3D view provides also visualization of horizontal and vertical cross section selected by operator. This view includes also terrain representation extracted from real data elevation model.

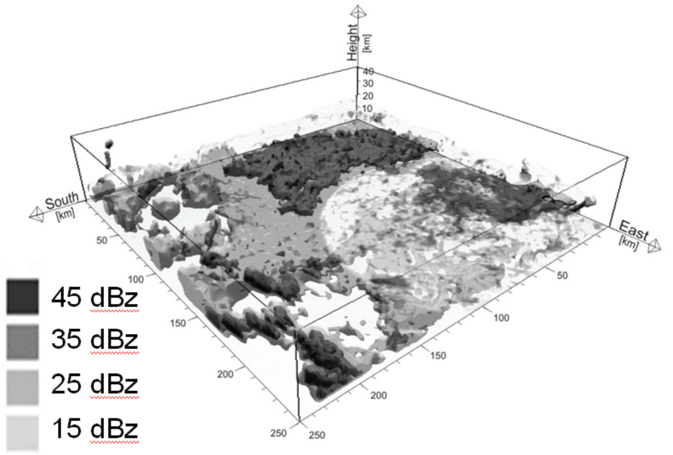

Fig. 4. 3D visualization of clouds in HASIS-3D system using iso-surfaces specified reflectivity values (15dBz, 25dBz, 35dBz, 45dBz)

Component **Seeder** is specific component for subsystem PLANSETA. It performs automatically two major tasks in cloud seeding process. The first is calculation of span of elevations for launching rockets which is effective for current parameters measured in the atmosphere. The second is to automatically determine distribution of rocket trajectories to achieve near optimal seeding of the cloud with hail potential. The result of this phase is sequence of azimuths and elevations for rocket launching stations that can seed the cloud and it is stored on subsystem STRELAC.

Component **Manger** is connection between system and operator. This component manages and synchronies work of all other components. **Manager** forwards the extracted iso-contours and iso-surfaces in subsystem RADAR and receives it in subsystem PLANSETA. The communication with database is done by this part of the system.

IV. Conclusion

HASIS-3D is a complete information system supporting tracking of cloud systems and estimating probability of hail. HASIS methodology was successfully enhanced and adapted and at the same time retained all techniques from the legacy system. HASIS-3D successfully fulfills following tasks:

1. Viewing and tracking cloud systems. System fulfills this task by providing precise and efficient visualization of radar data in two types of displays, 2D and 3D. Data in 2D display is available by creation of different types of cross-sections representing reflectivity levels of cloud system in real space. Iso-surfaces created from preset levels of reflectivity provide adequate representation of the cloud in 3D view.

2. Early detection of clouds posing hail threat. Quick conversion of data acquired from the radar and their efficient visualization shortens the time required for decision-making wheather to engage hail-threatening cloud or not. Viewing reflectivity of cloud systems at various 2D cross-sections and, more efficiently, their 3D representation based on their size, shape and cloud transformation enables recognition of clouds with high hail probability in early phases of their forming.

3. Automatization of the seeding process. Impact of operator error on the seeding process is minimized. Using iso-surfaces to calculate the parameters for launching rocket improves precision of identifying zones within cloud that need to be seeded and improve the effect of seeding the cloud.

The next step in further HASIS-3D development will be realization of virtual environment that will provide animation of three-dimensional clouds motion and rockets trajectories visualization, as well as parallelization of used algorithms to improve efficiency of the seeding process.

Acknowledgement

Research presented in this paper is partially funded by Serbian Ministry of Science and Environment Protection and Republic Hydrometeorological Service of Serbia as part of the project “Development of virtual environment for three-dimensional cloud visualization and three-dimensional cloud seeding”, ref. no. TR-6213A.

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