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Considerations for the optimum location of a C-band weather radar in the Athens area

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Abstract. Flood phenomena in Greece in the last 100 years have caused more life loss than any other natural hazards, i.e. earthquakes. Urban areas in Greece, such as Athens, often experience heavy rainfall creating flash floods, as urbanisation was seldom combined with the necessary protective works, such as channel improvements and storm drainage works. In this work, an attempt is made to examine the optimum location in terms of longitude, latitude and elevation of a C-band weather radar in the greater area of Athens and the optimum angle elevation of the beam for rainfall estimation and forecasting. This area has a population of more than four million, that is 40% of the entire population of Greece and is characterized by intense topography. The weather radar is a necessary tool for the area, in order to provide consecutive radar rainfall fields used for rainfall estimation and forecasting and consequently for flood estimation and forecasting. Sensitivity analysis has also been performed using GIS techniques for the optimum location and the optimum angle elevation of the weather radar along with the partial beam filling from the ground, in order to have rainfall estimation, as close as possible to the ground.

1 Introduction

The dominant factor in flood genesis are the intense rainstorms produced by the passage of depressions possibly accompanied by cold fronts, approaching from W, SW or NW. A convectional weather type, characterised by a cold upper air mass that produces dynamic instability, is also responsible for many intense storms, especially in the summer period. In this paper an attempt is made to examine the optimum location of a weather radar in the area of Attika and the optimum angle elevation of the beam for accurate rainfall estimation. This area is the most urbanised area of Greece and has a population of more than four million, that is 40% of the entire population of Greece. The weather radar is a useful

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tool, which can be used for rainfall estimation and forecasting and consequently for flood estimation and forecasting. The area of Attika often experiences heavy rainfall creating flash floods. Thus, the need for optimum placing of a weather radar in the area of Attika aiming to ease the process of rainfall and flood estimation and forecast is straightforward. Rainfall estimation from radar measurements has been a frequent topic in meteorological, hydrological and remote sensing literature within the last 35 years (Mimikou and Baltas, 1996). The power received by the radar antenna from a rainfall target is integrated in space and time to eliminate the characteristic fluctuation of the radar signal. The average received power can be expressed as:

$$P_r = CKZ/r^2 \tag{1}$$

where C is a constant depending on the parameters of the radar system, K is the attenuation constant, r is the range from the antenna to the target and Z is the reflectivity factor.

2 The study area

The region of Attika has an area of 3690 Km². The main parameter for the investigation of the location of a weather radar is the orography of the area. The area of Attika is in many parts mountainous and cannot be easily covered by one radar, making it difficult to locate only one radar. The orography along with the mountains of Attika are shown in Figure 1. In this figure one can see the mountain of Hymettus east of Athens with highest elevation 1026 metres above mean sea level, the mountain of Penteli northeast of Athens with highest elevation 1109 m, the mountain of Parnes North of Athens with highest elevation 1413 m, the mountain of Pastra northwest of Athens with highest elevation 1016 m, the mountain of Kitheronas northwest of Athens with highest elevation 1409 m, the mountain of Pateras west of Athens with highest elevation 1175 m and the mountains of Gerania west of Athens with highest elevation 1351 m.

Athens is highly sensitive to flooding due to climatological, geomorphological and anthropogenic factors. The area



Fig. 2. Visibility of radar with the main elevation angle of radar beam at 1.78 degrees

lies in the eastern part of the country, where the mean annual rainfall may be as low as 400 mm. This is considered to be the dry part of the country, taking into account the fact that the mean annual rainfall exceeds 1800 mm in the mountainous regions of western Greece. However, if one analyses for example the maximum 24-hour rainfall depth for a 50 - year return period for the two parts of the country, it can be seen that the difference is not as big as in the mean annual rainfall. Moreover, this difference is eliminated as one moves to shorter rain durations, such as hourly. The geomorphological factors influencing the occurrence of floods in the Athens area are mainly related to the absence of significant river networks and to the small cross sections of the existing streams. The other reasons for the flood damages are anthropogenic. In the last 50 years, Athens was heavily developed in terms of urbanization. Flood rate was seriously affected by an increase of residential, commercial and industrial areas, while natural parks and farm land diminished. The stream network shrunk and many streams were converted into streets or even were built upon. Flood protection works were not given any priority and the storm drainage network is still primitive.

In Table 1 some of the most severe floods causing loss of human lives in Attika are referenced. 179 lives were lost during the last 100 years, out of which 96 during the last 35

Table 1. Floods causing loss of human lives in Attika (adapted fromNicolaidou and Hadjichristou, $1995)^{\dagger}$

| Date | Lives lost |
|--------------------|------------|
| 14 November 1896 | 61 |
| 23 November 1925 | 8 |
| 26 October 1930 | 2 |
| 17 October 1933 | 1 |
| 2 December 1933 | 2 |
| 22 November 1934 | 6 |
| 5 November 1936 | 2 |
| 29 October 1938 | 1 |
| 5-6 November 1961 | 40 |
| 2 November 1977 | 38 |
| 27 October 1980 | 1 |
| 5 October 1989 | 7 |
| 15 January 1991 | 1 |
| 21-22 October 1994 | 9 |

[†] Missing data may be in the periods 1885-95, 1897-20, 1950-60 and 1962-72.

years. These figures are higher than any other part of Greece. Also the number of lives lost due to floods in Athens, are greater than those lost due to any other natural hazards.

3 Description of software – selection of weather radar type

For the optimum placing of a weather radar in the area of Attika the software ArcView of ESRI was used. ArcView gives you the ability to visualize, explore, query, and analyze data geographically. With this software one can work with data, understand geographic relationships, gain insights, solve problems and achieve results for a variety of projects. For the needs of this work, two different scripts were developed. The first script named "radar cone" gives the cone of radar beam. The second script named "radar coverage" gives the radar beam coverage in the project area. The programming language Avenue supported by the ArcView software, was used to develop these scripts (GIS by ESRI, 1996). The radar type selection is a very important decision for the optimum operation and development of the weather radar (Collier, 1989). The radar type selection depends among other parameters on the orography and the region of the study area, as well as, on the type of precipitation under study. The area of Attika has many orographic problems and its region is relatively small. For these reasons, a C-band radar is suggested. In Table 2, one can see the technical characteristics of a Cband radar.

Table 2. Technical characteristics of a C - band radar

| Operating Frequency | 5.42 – 5.82 GHz |
|----------------------|-----------------------|
| Pulse Length | 0.4 - 10 microseconds |
| Receiver | Logarithmic |
| Azimuth angle span | 0 deg – 360 deg |
| Elevation angle span | -3 deg -+183 deg |
| Reflector Diameter | 6.1 m |
| Beam width | 2 deg (maximum) |
| Max Velocity az/el | 36 deg/s |
| | |



Fig. 3. Coverage of Attika in relation with the percentage of radar beam



Fig. 4. Distance between hydrometeors and land

4 Optimum placing of the weather radar in the area of Attika

A number of different locations for the installation of a Cband weather radar have been examined. The criteria which were chosen for the optimum placing of the weather radar in the area of Attika were the radar beam coverage in the study area and the distance between hydrometeors and land. After thorough investigation with the use of ArcView, it has been found that the optimum location is at the east of the Bathi village in the island of Aegina. The location of a weather radar



Fig. 5. Distance between hydrometeors and land in relation with the region they cover

and the radar beam coverage are shown in Fig. 2. The radar covers the largest part of the study area with the main elevation angle of the radar beam at 1.78 degrees. The meaning of this is that the 50% of the radar beam covers the entire area. The coverage region by the radar beam in relation with the percentage of the radar beam is shown in Fig. 3.

In Fig. 4, one can observe the distance between hydrometeors and land with the main elevation angle at 1.78 degrees for the located weather radar. The smaller altitudes of hydrometeors means better rainfall estimation for rainfall and flood forecasting. Figure 5 shows that for the same location and main elevation angle of radar beam, the distance between hydrometeors and land is close to the ground and therefore can give satisfactory results. The largest part of hydrometeors, is in an altitude from 500 to 1500 metres.

5 Conclusions

As far as the optimum placing of the weather radar in the area of Attika is concerned, it can be said that the optimum location is at the east of the Bathi village in the Aegina island. In this area the weather radar gives the best coverage in the study area and the lowest distance between hydrometeors and land. However, the installation of a radar in this site brings up economical and technical problems due to the difficult proximity from Athens (the only way to reach the region is by ship). The location in Aegina is suggested because it is the only place, where the weather radar can give reliable measurements for all the Attika area. The rejection of this location will impose the need to place at least two weather radars in the study area with direct implications to the cost of the installation.

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