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Radar capability of areal precipitation estimation around Oklahoma

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सार — ओकलहोमा राडार छाता के लिए पूरे वर्ष के दौरान वास्तविक काल के आधार पर रेडार जल विज्ञान आंकड़ा संग्रहित कर उनका विश्लेषण किया गया और वर्षामापी द्वारा प्राप्त वर्षा आंकड़ों से इनकी तुलना की गई । वर्षा के रेडार आकलन में मौसमी विचरण पाया गया । जबकि बसन्त और ग्रीष्म की अपेक्षा पतझड़ और शीत में रेडार वर्षा आकलन अपेक्षाकृत सही पाया गया । ग्रीष्मऋतु में क्षेत्रीय वर्षण आकलन के लिए रेडार प्रतिध्वनियों के प्रतिपादन में विस्तृत गैर-वर्षण प्रतिध्वनि की उपस्थिति एक समस्या व्यवधान उत्पन्न करती है ।

ABSTRACT. Radar hydrological data collected on real time basis during a full year for Oklahoma radar umbrella have been analysed and compared with the rainfall realised by raingauges. A seasonal variation in radar-estimate of rainfall is seen. While radar rainfall estimate is generally better in autumn and winter than in spring and summer. Occurrence of widespread non precipitation echo is found to pose a problem in interpretation of radar echoes for areal rainfall estimate in summer.

1. Introduction

The process of quantitative hydrological forecasting consists of acquiring information about the states of the hydrological cycle, assembling this information in an intelligent form and putting the information into models and procedures to predict the future states of a hydrological system. Often the single most important hydrometeorological input to a streamflow prediction model is precipitation which varies widely in space and time. Radar is a potential remote sensing tool to measure precipitation continually in time and space out to distances of approximately 200 km from the radar site. Several successful attempts have been made in UK and USA in this direction. In India this has been experimented for Delhi by Chatterjee and Mathur (1966) and recently by Raghavan and Sivaramakrishnan (1982) and Raghavan *et al.* (1984) at Madras using an S-band radar.

US National Weather Service's Hydrologic Research Laboratory has taken up a hydrological rainfall analysis project (HRAP) with the ultimate aim of operationally merging rainfall data from multiradars and other sources to give more accurate as real analysis. Real time processing of radar data will be possible from the nation's network of next generation weather radar (NEXRAD) (1980). The associated computer system is to process the data in two stages (*i*) on site and (*ii*) off site and finally the output will be available at river forecast centres and to other users (Hudlow *et al.* 1983). The plan of the processing system is shown in Fig. 1.

2. Methodology

An S-band radar situated at Oklahoma has taken observation every ten minutes. Radar reflectivity was converted into rainfall rates using the equation $Z = 200\ R^{1.6}$ where Z is the reflectivity in mm^6/M^3 and R is the rainfall rate in mm/hour. The cumulative rainfall every 24 hours was also computed and stored in the tapes. Same was retrieved and the radar inferred rainfall map was obtained in the coded form. The codes and the corresponding rainfall amounts are shown in Table 1. Radar rainfall map is obtained in the universal grid that is formed by mapping the earth's coordinates on to a polar stereographic map projection which is true at 60 deg. N latitude and oriented such that 105 deg. W longitude is parallel to ordinate of the grid. The grid mesh length is about 4.7 km (Greene and Hudlow 1982).

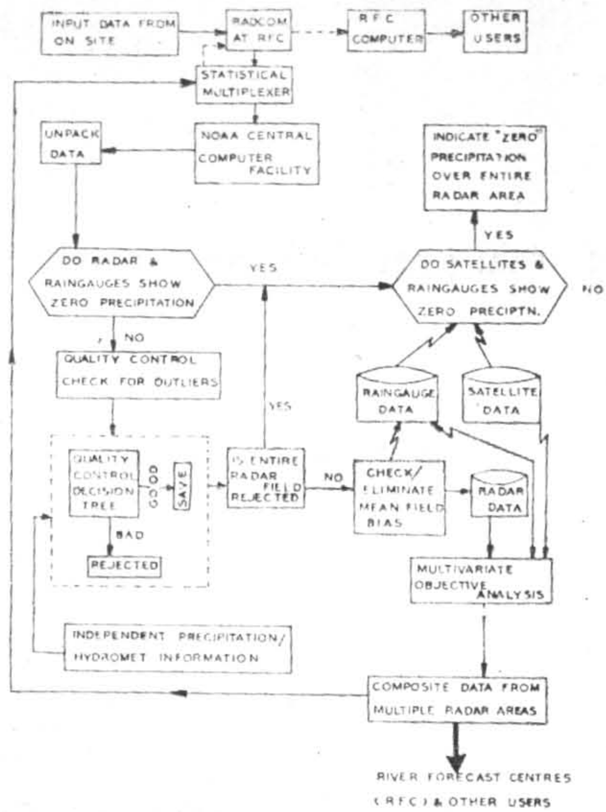


Fig. 1. Block diagram giving the plan of NEXRAD offsite processing system

There are about 200 raingauges giving 24 hourly rainfall in Oklahoma radar umbrella. These are well distributed in the area. Gauge rainfall map was also obtained to the same size as radar rainfall map so that the radar and gauge rainfall maps could be superposed for comparison. Isohyetal analysis was done for both the maps. The analysed maps were superposed and the agreement was examined. Seasonwise analysis was made and the results are presented.

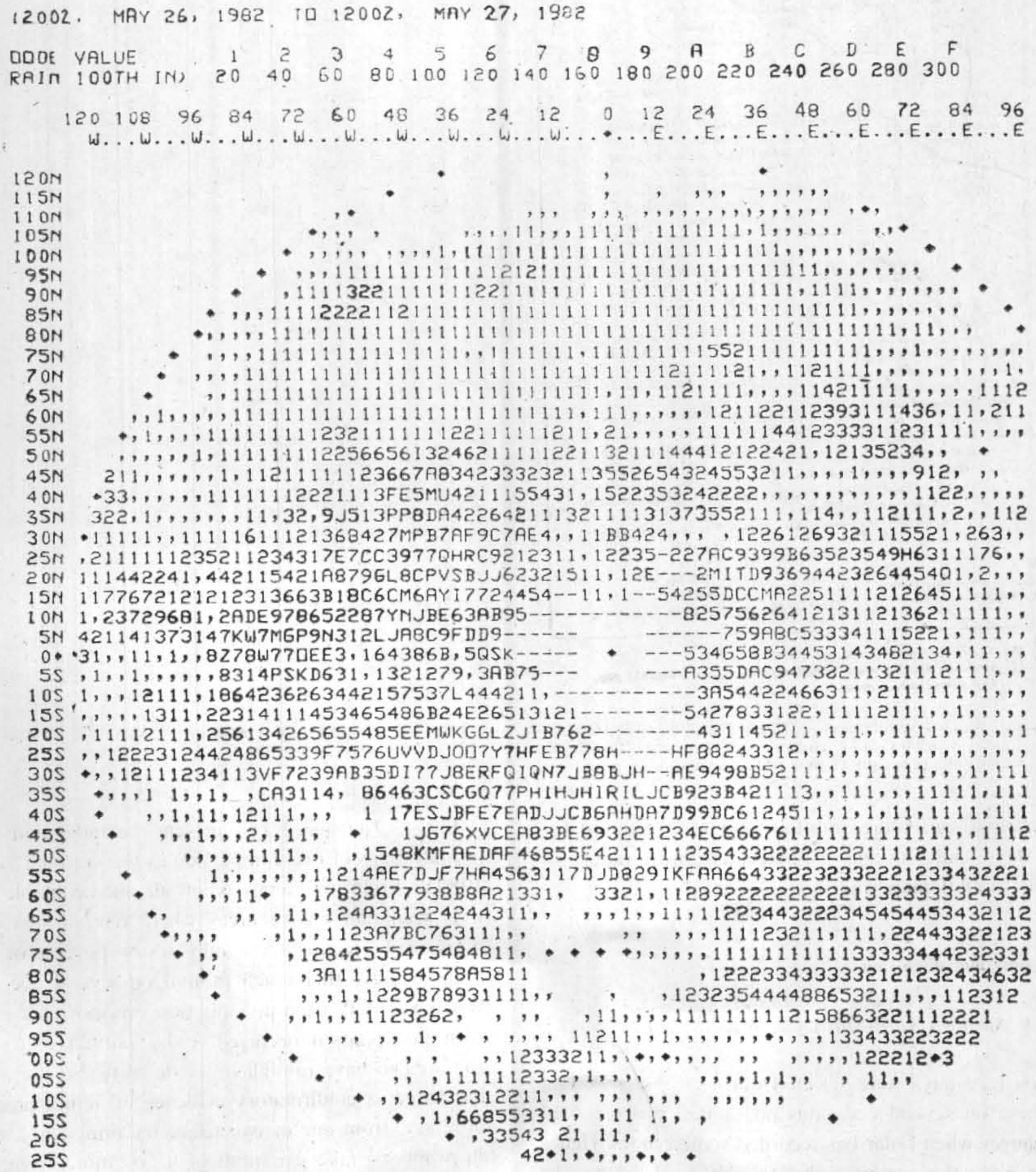
On certain days there were some missing data. On a preliminary scrutiny it was seen that whenever missing data period was small, say, 2 hours or less, the rainfall estimate is not very much affected ($<10\%$). Hence the days when the data missing period was 2 hours or more were not considered for analysis.

First radar inferred rainfall map was inspected and if there were considerable echoes, that day was selected

TABLE 1

Codes & rainfall amounts

Code	Rainfall (inches)	Code	Rainfall (inches)	Code	Rainfall (inches)
1	0.2	C	2.4	N	4.6
2	0.4	D	2.6	O	4.8
3	0.6	E	2.8	P	5.0
4	0.8	F	3.0	Q	5.2
5	1.0	G	3.2	R	5.4
6	1.2	H	3.4	S	5.6
7	1.4	I	3.6	T	5.8
8	1.6	J	3.8	U	6.0
9	1.8	K	4.0	V	6.2
A	2.0	L	4.2	W	6.4
B	2.2	M	4.4	X	6.6


12002, MAY 26, 1982 TO 1200Z, MAY 27, 1982
CODE VALUE 1 2 3 4 5 6 7 8 9 A B C D E F
RAIN 100TH IN) 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
120 108 96 84 72 60 48 36 24 12 0 12 24 36 48 60 72 84 96
120N
115N
110N
105N
100N
95N
90N
85N
80N
75N
70N
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
0
5S
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55S
60S
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05S
10S
15S
20S
25S

Fig. 2

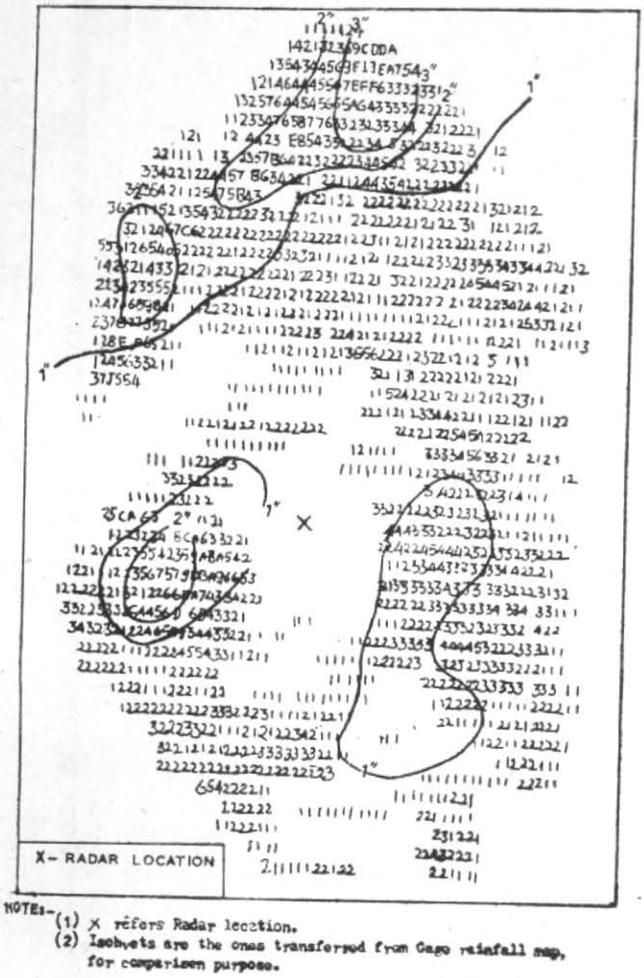

Fig. 3(a). Radar rainfall map for 31 May 1982 (30th, 1200 GMT — 31st, 1200 GMT). Isohyets are the ones transferred from gauge rainfall map for comparison purpose

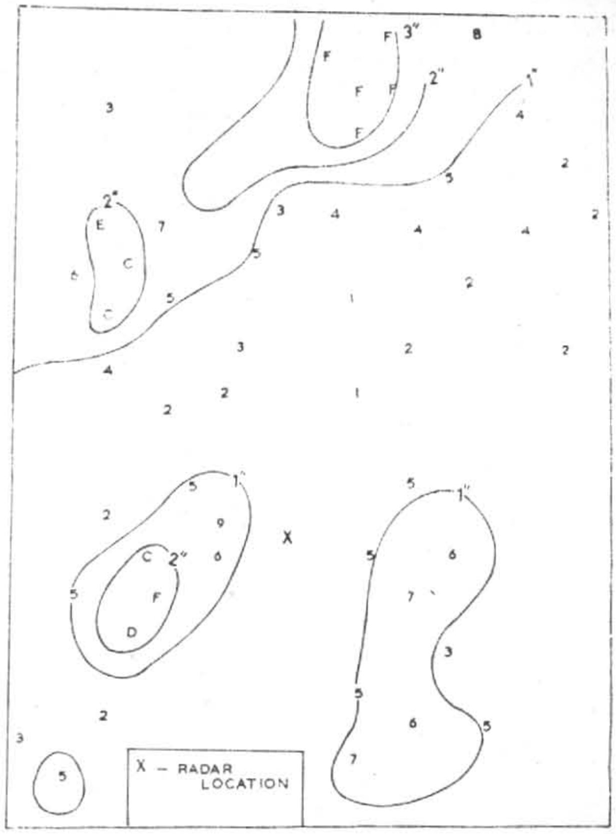

Fig. 3(b). Gauge rainfall map for 31 May 1982 (X refers to radar location)

for comparison. Gauge rainfall map was retrieved for that day, analysed and its agreement with radar inferred rainfall map was seen.

3. Results and discussion

3.1. *Spring (April-May)*

Fourteen days were selected during the season. Out of these on several occasions no rainfall was recorded by gauges when radar has recorded some echoes. Hence these were the non-precipitation echoes. This may be due to what is called 'anomalous propagation' of radio waves. For example, Fig. 2 presents the radar print out of 27 May 1982. Though a lot of echoes is seen including rainamounts of 4″ (code K), from the gauge map it was observed that not even a single gauge recorded any rainfall on that day.

Figs. 3 (a) and 3 (b) present the radar and gauge rainfall maps of one comparison in the season (31 May 1982). From the analysis of all the available days it is seen that out of areas where rainfall was 3″ or more, radar could show only lesser portion of these areas to have that much rainfall on several occasions. Whenever A.P. (non-precipitation echoes) inter mixing with precipitation occurred, radar rainfall map shows the area to have rainfall of 4″ or more. So the analyst has to get a confirmatory evidence of actual precipitation, say, from one or two telemetry rainguages, before he wants to take a rainfall of 4″ or more from radar map as such in this season.

A separate study was attempted to see the radio refractive index (RRI) gradient on days of getting a lot of anomalous propagation echoes from the upper air sounding data of Oklahoma. It was noticed that the sounding of 12 GMT can serve as a hint in this

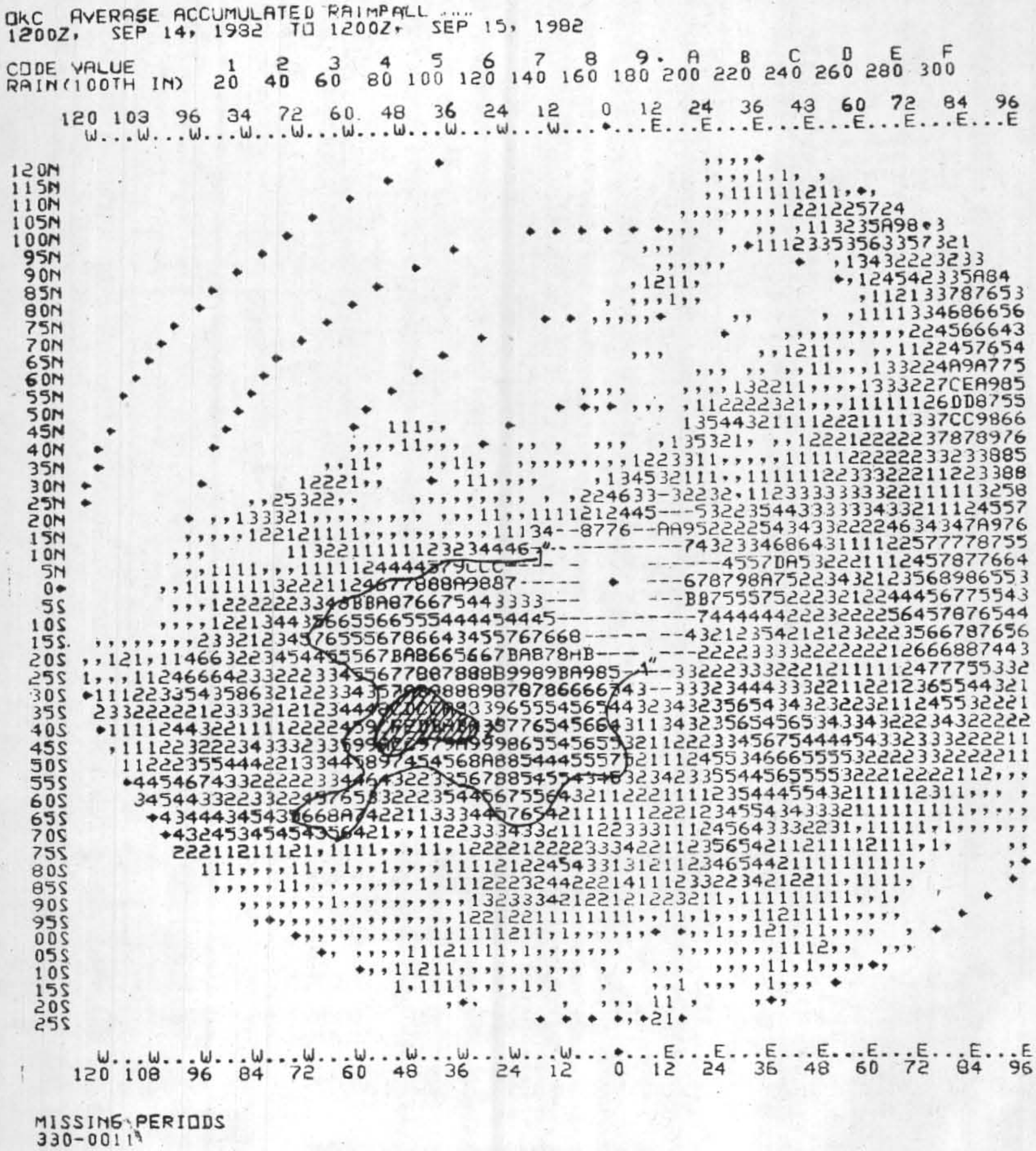

Fig. 4(a)

respect. Whenever RRI gradient was 35 N units/km or more between surface and 850 mb level at 12 GMT, A.P. echoes were found to be detected by this radar. This may serve at least as a thumb rule in interpretation of radar data by the hydrologist.

Another feature noticed was that radar estimate of rainfall is comparatively better in northern sector than in southern sector, though the reason is not understood.

3.2. *Summer (June-August)*

The first point to be observed was that the occurrence of non-precipitation echoes probably due to A.P. is very much. Out of 20 days selected for analysis there were 10 days when only non precipitation echoes were present in radar map and no rainfall has occurred. On four more days A.P. was found to intermix with rain echoes. Thus on 70% of occasions, the

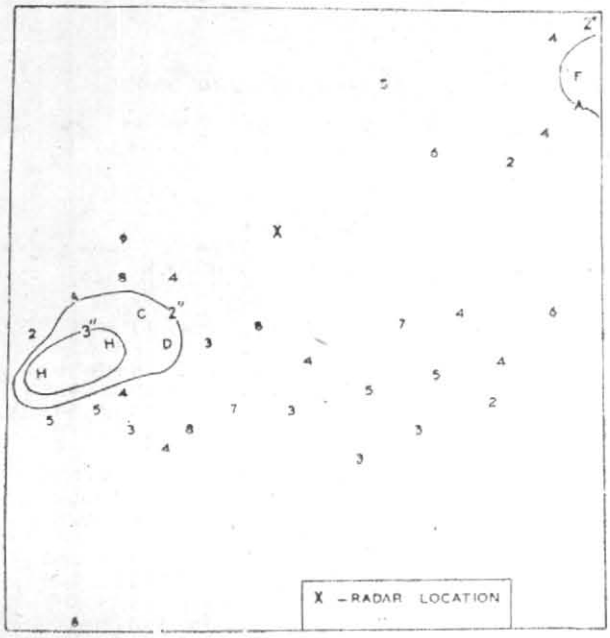

Fig. 4(b). Gauge rainfall map for 15 September 1982 (Autumn)

analyst is likely to err. Hence the method as such is not found to be usable in summer for radar hydrology.

This suggests the imminent need for devising a method suitable for real time filtering of anomalous propagation echoes. From the experience of working with the data to be collected in one or two more years, there may be a possibility for the evolution of such a method.

3.3. *Autumn* (*Sept-Nov*)

As gauge data could not be retrieved on certain days, selected days available for analysis were fourteen. Radar generally detects all the rainfall echoes during this season. Whenever we find a grouping of rain-levels of code 4 (0.8″) or above at a place in radar map, one is sure to get a rainfall regime there or closeby to that region. Radar estimate of rain is found to be on lower side of actual (given by gauges). A sample day printout (15 Sep) of radar and gauge map is given in Figs. 4 (a) and 4 (b).

3.4. *Winter* (*Dec-Feb*)

As during autumn, radar does detect the rainfall regions in this season also. In fact the estimate is even better quantitatively. But a point to remember here is that during this season, the rainfall rarely exceeds code No. 6 (**1.2″**).

4. Conclusions

(1) The interpretation or confidence of radar estimated rainfall is not uniform throughout the year and varies with seasons around Oklahoma.

(2) Interpretation of radar echo for areal rainfall is difficult in summer due to occurrence of widespread non-precipitation echoes.

(3) Any rainfall shown to be 4″ or more in spring has to be taken only after confirmation of absence of A.P.

(4) Radar estimate of rain is generally better in autumn and winter. No rainfall regime is missed by radar in these two seasons.

Acknowledgement

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