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ESTIMATES OF THE EFFECTS OF TERRAIN BLOCKING ON THE LOS ANGELES WSR-74C WEATHER RADAR

R. G. Pappas, R. Y. Lee, and B. W. Finke

National Weather Service Forecast Office
Los Angeles, California
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This Technical Memorandum has been reviewed and is approved for publication by Scientific Services Division, Western Region.

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Scientific Services Division
Western Region Headquarters
Salt Lake City, Utah

CONTENTS

TABLES AND FIGURE

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I. INTRODUCTION

In the western United States weather radar antennas often must be placed at valley-floor locations bounded on one or more sides by mountainous terrain because of high cost of remoting and difficulty of maintenance. This reduces the effective range of the radar for precipitation detection and its capability to measure intensity to distances less than that limited by earth's curvature alone.

Pappas (1967) derived a simple geometric technique for estimating the height of the base of the radar beam due to the combined effects of the earth's curvature and partial blocking by nearby mountains. A condensed version of his paper is given in the Appendix. This technique was developed for the Sacramento WSR-57 radar to assist users in understanding the radar's limitations and in interpreting observations. This same technique may also be applied to other radar systems and is presented here as an example for development of similar data to assist users in other areas in their evaluation of radar data.

II. APPLICATION TO THE LOS ANGELES RADAR

The Los Angeles WSR-74C radar was installed in early 1978 on top of the Federal Building in west Los Angeles, California. This location is in an area adjacent to mountainous terrain. The Pappas technique was programmed in BASIC by B. W. Finke and run on a microcomputer for application to this radar's site. Table A is the program listing. An example of the output is presented in Table B. Result of plotting the entire output on a map of the area is presented in Figure 1. This provides an easy reference to refer to when determining areas of poor detection or when ascertaining capability of radar to see over particular drainages. Dotted lines represent heights to which storms must reach in order to be detected by the radar.

The map (Figure 1) shows extensive blocking in the west-through-north-through-east sector. (Almost total blocking over a small sector to the east-northeast caused by nearby high buildings is not included in Figure 1.) Less severe blocking occurs to the south and east-southeast. The heavily blocked area over the northern semicircle area will undoubtedly lessen the radar's effectiveness in assessing flash-flood potential over Santa Barbara and northern Ventura Counties, San Gabriel Mountains, northern San Bernardino Mountains, Antelope Valley, and Mojave Desert.

III. REFERENCE

Pappas, R. G., 1967: Derivation of Radar Horizons in Mountainous Terrain. NOAA Technical Memorandum NWS WR-22, National Weather Service, Western Region, Salt Lake City, Utah, 6 p.


```
OK
LIST

0 DIM R(100),HT(100),T(100),HM(100)
10 INPUT"NUMBER OF POINTS ALONG BEARING";N
20 INPUT"BEARING(DEGS)";A
30 FORI=1TON
35 INPUT"RANGE,ELEVATION";R(I),T(I)
40 IF R(I)=<0 THEN 60
50 NEXT
60 PRINT"INPUT TERMINATED":PRINT
65 STOP
100 OUT53,23
110 POKE 1233,53:POKE1241,54:NULL6
120 FOR I=1TO500:Q=15.9*I:NEXT
130 PRINTA
135 PRINTN
140 FORI=1TO100:Q=15.9*I:NEXT
150 FOR I=1TON
160 PRINTR(I)
170 PRINTT(I)
180 NEXT
185 OUT53,55
190 POKE 1233,51:POKE1241,50:NULL0
195 PRINT"TAPED":PRINT
200 SA=SQR(580)
210 S=1
220 FOR I=1TON
230 HT(I)=((R(I)/1.23)-SA)↑2
240 ON S GOTO 250,280
250 IF HT(I)>=T(I) THEN HM(I)=HT(I):GOTO295
260 K=(T(I)-HT(I))/R(I)
270 S=2
280 HM(I)=HT(I)+K*R(I)
290 IF HM(I)<T(I) THEN 260
295 NEXT
300 IF(31ANDINP(255))=0 THEN 320
310 POKE1233,67:POKE1241,66
320 PRINT"RADAR HORIZON FOR ";A;"DEGS":PRINT:PRINT
330 PRINT"RANGE(MIS)","TRRN HGT","ECHO ALT","TRRN MOD ECHO ALT":PRINT
340 FOR I=1TON
350 PRINTR(I),T(I),INT(HT(I)+.5),INT(HM(I)+.5)
360 NEXT
370 POKE1233,51:POKE 1241,50
380 END
OK
```

Table A. Program Listing.

RADAR HORIZON FOR 5 DEGS

RANGE(MIS)	TRRN HGT	ECHO ALT	TRRN MOD ECHO ALT
5	1000	401	1000
10	1100	255	1453
15	800	141	1939
20	3600	61	3600
25	2000	14	4438
30	4200	0	5308
40	4600	71	7149
50	3100	274	9121
60	6100	610	11226
70	6100	1078	13463
80	5600	1678	15833
90	8100	2410	18334
100	6600	3274	20968
110	9600	4270	23734
130	9600	6660	29662
150	11600	9578	36119
170	14384	13025	43105
190	12560	17001	50620

Table B. Program output for azimuth angle of 50°. For each range, the program lists the terrain height (TRRN HGT - input from a suitable topographic map); the radar beam-base height without consideration of terrain (ECHO ALT); and the radar beam-based height modified for terrain blocking (TRRN MOD ECHO ALT). Heights are in feet, range in nautical miles.

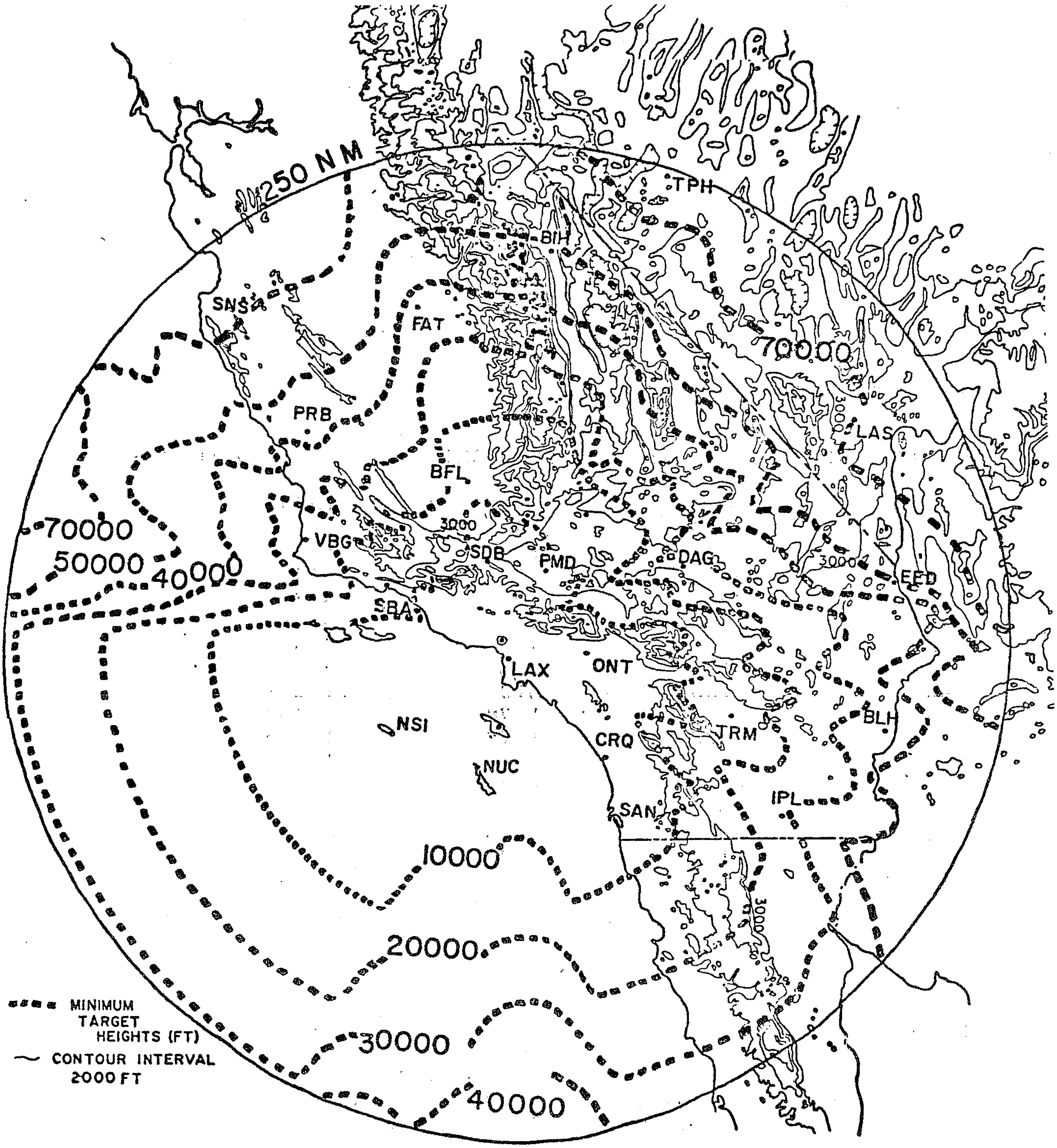

Figure 1. Effects of Terrain Blocking on Los Angeles WSR-74C Radar. Dotted lines represent heights to which storms must reach in order to be detected by the radar.

APPENDIX

Technique for Derivation of Earth's Curvature and Blocking Chart*

Hiser and Freseman (page 83, equation 40) give the maximum possible range between a radar and a target as limited only the radar horizon. This equation assumes standard propagation conditions and radar capability of target detection at this range.

(1) $R_{hmax} = 1.23\ (\sqrt{h_r} + \sqrt{h_t})$ nautical miles where R_{max} is the range to the target, h_r is the height of the radar antenna in feet, and h_t is the height of the target in feet.

By solving for h_t it is possible to determine the minimum target height for interception of the radar beam at a given range:

(2) $h_t = (R_{max}\ /\ 1.23 - \sqrt{h_r})^2$.

The computation of the minimum target height is complicated by the introduction of a mountain barrier or "block" in the radar beam. This is illustrated in Figure I. In Figure I the location of the radar is at Point R. Point H is where the radar beam is tangential to the earth, i.e., the horizon of the radar. A mountain or blocking barrier is introduced at Point E, with a height CE. It is desired to determine the height of the beam's case, C'E', over Point E' after partial beam blocking by the mountain at E.

It can be seen that B is the point at which the base of the beam is intercepted by the mountain and BB' represents the extension of the beam's base if no blocking had occurred. Further, the stippled area represents the region below the radar horizon, and the hatched area the additional region blocked by the mountain at E. HBB' is the locus of h_t.

Since RCB and RC'B' are triangles which are approximately similar,

$\frac{CB}{RHB} \approx \frac{C'B'}{RHBB'}$, where CB = CE - BE, or the difference

between the elevation of the mountain and h_t computed for range to E. RHB is essentially the range to E, and RHBB' is the given range to E'. Hence, C'B' is easily evaluated, and when added to B'E' (the value of h_t at Point E') gives the value of C'B'E', the minimum target height for penetration of the radar beam.

In cases where higher terrain is down range from the blocking mountain at, say, Point E', it is necessary to test whether or not it is higher than C'B'E'. It it is higher, a new proportionality must be set up based on the amount of further blocking caused by the peak at Point E'. If not,

*Pappas, 1967: Derivation of Radar Horizons in Mountainous Terrain, NOAA Technical Memorandum NWS WR-22.

APPENDIX (Continued)

the computations continue down range at intervals of 10 to 20 nautical miles.

The construction of the blocking charts was accomplished by tabulating terrain height data along azimuth radials from the radar at five-degree increments. Using an aeronautical chart showing 1000-foot contours, the crossing of each contour on the radials is noted with regard to its range. In the case of mountain peaks, the exact elevation is recorded. Starting with the first contour of elevation that is higher than the h_t value at that range, the "blocking" computation is begun and carried down range as explained above (with, of course, testing for additional down-range blocking by higher terrain and setting up new proportionalities if necessary). Values for CBE, C'B'E', C"B"E", etc., (or h_t if there is no terrain blocking) along each five degrees of azimuth are then plotted and isopleths drawn to obtain the final chart. The procedure is rather time-consuming and tedious, but certainly worth the effort. Once the computations get beyond about 100 nautical miles, they become fewer since blocking from terrain rarely occurs at those extended ranges. It should be pointed out that this technique could easily be programmed for a computer.

Reference:

Hiser and Freseman, 1959: Radar Meteorology, The Marine Laboratory University of Miami, Coral Gables, Florida, p. 83.

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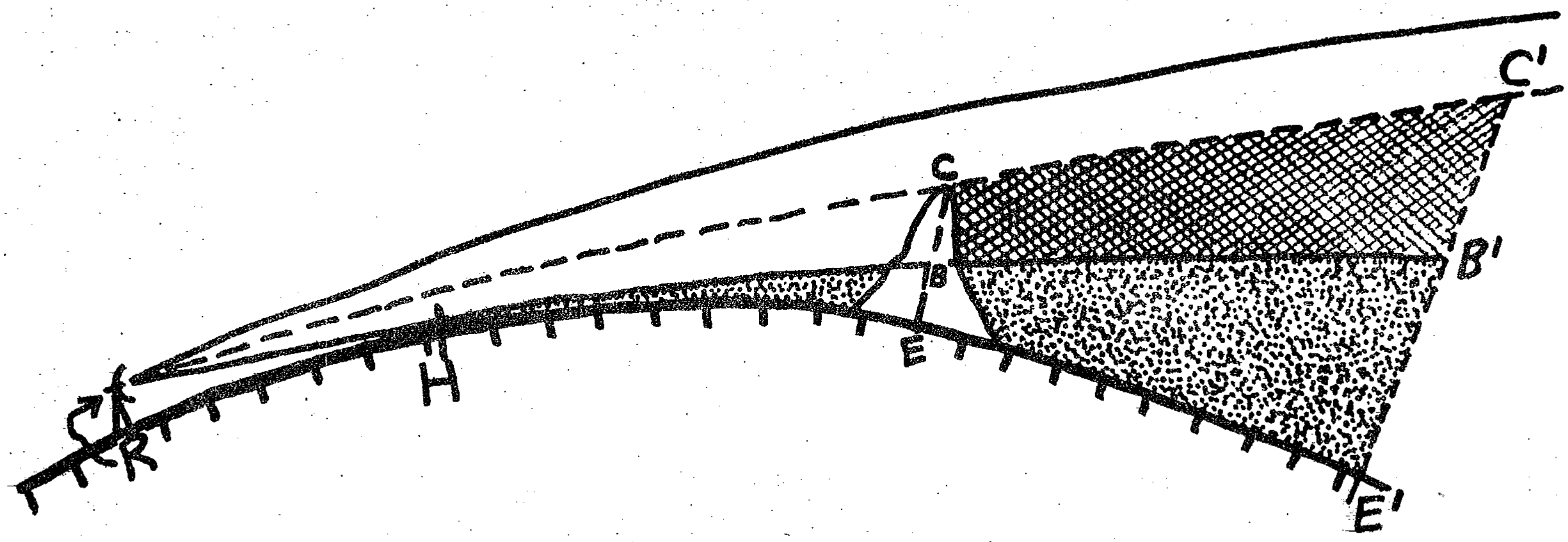

Figure 1. Beam Blocking Diagram.

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