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ASSESSMENT OF THE QUALITY OF 'GATE' AREA RAINFALL DATA FROM A NIMBUS-5 RADIOMETER

Final Report Under NASA Grant NAG 5-14

ASSESSMENT OF THE QUALITY OF GATE AREA RAINFALL DATA FROM A NIMBUS-5 RADIOMETER Final Report (Morgan State Univ., Baltimore, Md.) 18 p HC A02/MF A01 CSCL 04B

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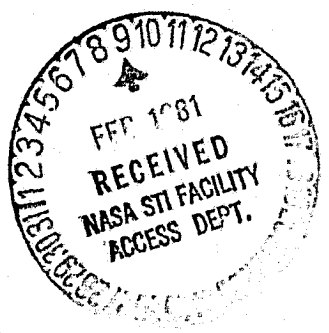

February 1981

INTRODUCTION

The purpose of the present study is to evaluate the quality of rainfall intensity estimates derived from passive microwave measurements by the Electrically Scanned Microwave Radiometer (ESMR-5) aboard the Nimbus-5 satellite. The microwave measurements used are those coincident with the GARP (Global Atmospheric Research Program) Atlantic Tropical Experiment (GATE). ESMR-5 derived rainfall intensity estimates are compared with hourly averaged GATE radar rainfall measurements. Using the radar measurements as ground truth it is determined that with the transfer curves derived herein the ESMR-5 derived data consistently over estimates rainfall by a factor of approximately 1.4.

RESEARCH PLAN

The ESMR-5 data set used herein consists of computer printouts of microwave brightness temperature measurements for seventy-nine (79) Nimbus-5 overpasses coincident with GATE radar rainfall measurements. The following tasks were completed in assessing the quality of these data:

1. Collect and verify computer printouts of ESMR-5 GATE coincident data.
2. Convert ESMR-5 brightness temperatures to rain intensity estimates for the two-degree square of the earth's surface centered at ($23.5^{\bullet}$ W, $8.5^{\bullet}$ N).
3. Compare ESMR-5 derived rain intensity estimates with coincident GATE radar measurements of rainfall.

METHODOLOGY

1. Data Collection and Preparation

The ESMR-5 data are available on computer tape at Goddard Space Flight Center. A search was made of the ESMR-5 data catalogues to locate GATE coincident data. Their references are given in Table 1. Computer printouts of these data were provided by Dr. Paul W. Hwang of Goddard. The printouts indicate brightness temperatures with their latitude-longitude locations and beam positions.

Those data points coincident with the GATE are located and plotted on a grid representing the two degree square centered at (23.5° W, 8.5° N). Beam position, brightness temperature, and scan angle are recorded for each. Then a correction of the brightness temperature is carried out. This correction scheme is given by Wilheit [3, Table 5-3] and is a function of beam position.

GATE radar rainfall data are available on both magnetic tape and microfilm from the GATE World Archives. Also, a GATE Radar Rainfall Atlas [2] is available. Among the data sets contained in the Atlas are tables indicating one hour, three hour, six hour, twelve hour, and twenty-four hour mean area precipitation rate for the fifteen geographic areas shown in Figure 1 [2] . GATE radar derived hourly rainfall intensity estimates for the entire GATE area on a grid of 0.25° x 0.25° were obtained on microfilm from the GATE World Archives. See Figure 4.

Figure 3 indicates the four one-degree square regions into which the two-degree square region centered at (23.5° W, 8.5° N) was divided. Mean ESMR-5 derived rainfall intensity estimates for the entire region and for each of the four subregions were computed for GATE coincident Nimbus-5 overpasses. These means were also computed for corresponding GATE radar rain rate estimates.

2. Conversion of ESMR-5 Brightness Temperatures to Rain Rates

Rain intensity for each data point is determined via an appropriate brightness temperature/rain rate relation. In the present study two such relations are used.

Using ESMR-5 data for September 2, 1974, GMT 12:57-13:04, when Nimbus-5 was directly over the GATE area, arithmetically averaged brightness temperatures for areas 1 through 12 in Figure 1 were determined. A brightness temperature/rain rate relation was determined using a least squares linear fit of these temperatures plotted against hourly precipitation rates for corresponding areas [2]. The resulting relation has the equation

$$R = 0.031T - 4.258.$$

Where R denotes rain rate and T denotes brightness temperature.

The second is a freezing level dependent ralation derived from the Wilheit curves [4] shown in Figure 2. This relation is an interpolation of the 4km and 5 km freezing level curves

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to correspond to a freezing level of 4.7 km which more closely approximates GATE conditions.[+] The formula for the relation is

$$R = \begin{cases} 0 & , \ 0 \leq T \leq 185 \\ 0.101T - 18.643, & 186 \leq T \leq 217 \\ 0.116T - 21.962, & 218 \leq T \leq 247 \\ 0.217T - 46.829, & 248 \leq T \end{cases}$$

where R denotes rain rate and T denotes brightness temperature.

RESULTS AND CONCLUSIONS

The relation (*) $R = 0.031T - 4.258$ was used to calculate rain intensity for each ESMR-5 data point. Of the twelve areas in Figure 1, only area 11 is entirely within the two-degree square centered at (23.5° W, 8.5° N). Thus, in this instance, ESMR-5 rain intensity estimates for area 11, derived using the relation (*) were compared with GATE radar derived hourly mean precipitation rates [2] for this area. Table 3 is a summary of the results and shows that the relation (*) leads to an over estimation of rainfall. However, consistency in the estimations is evident.

Since the relation

$$R = \begin{cases} 0 & , \ 0 \leq T \leq 185 \\ 0.101T - 18.643, & 186 \leq T \leq 217 \\ 0.116T - 21.962, & 218 \leq T \leq 247 \\ 0.217T - 46.829, & 248 \leq T \end{cases}$$

is derived from theoretically sound curves, a more comprehensive

+[1]

analysis was carried out on rain rate estimates derived via this formula. Of the 78 available GATE coincident ESMR-5 sensings only 68 could be matched with coincident GATE radar derived hourly rainfall intensity measurements. Using these data, for each matched overpass, mean rain intensity estimates (ESMR-5 and radar) were computed for each of the five regions (I, II, III, IV, and G) shown in figure 3.

Mean rain rate estimates (ESMR-5 and radar) were computed for the five regions for the entire GATE experiment and for each phase of GATE. For Region I and Region G 14 day and 7 day means were computed. In each instance the ratio ESMR-5 rainfall/radar rainfall was computed. The following is a listing of the results. Rain rates are in mm/hr.

GATE

REGION	ESMR-5	RADAR	RATIO
I	0.73	0.42	1.74
II	0.74	0.41	1.80
III	0.72	0.67	1.07
IV	0.67	0.79	.85
G	0.72	0.54	1.33

Mean ratio 1.36
Standard derivation of ratio 0.41

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PHASE I

REGION	ESMR-5	RADAR	RATIO
I	0.50	0.45	1.11
II	0.36	0.46	0.78
III	0.54	0.61	0.89
IV	0.56	0.54	1.03
G	0.49	0.64	0.77

Mean of ratio 0.91
Standard deviation of ratio 0.15

PHASE II

REGION	ESMR-5	RADAR	RATIO
I	0.87	0.24	3.63
II	0.85	0.12	7.08
III	0.90	0.76	1.18
IV	1.14	1.00	1.14
G	0.94	0.53	1.77

Mean of ratio 2.96
Standard deviation of ratio 2.52

PHASE III

REGION	ESMR-5	RADAR	RATIO
I	0.82	0.52	1.58
II	0.94	0.53	1.77
III	0.75	0.66	1.14
IV	0.52	0.94	0.96
G	0.76	0.56	1.36

Mean of ratio 1.36
Standard deviation of ratio 0.33

FOURTEEN DAY MEANS REGION I

PERIOD	ESMR-5	RADAR	RATIO
1	0.27	0.26	1.04
2	0.78	0.62	1.26
3	1.14	0.28	4.07
4	0.85	0.53	1.60

Mean of ratio 1.99
Standard deviation of ratio 1.40

FOURTEEN DAY MEANS REGION G

PERIOD	ESMR-5	RADAR	RATIO
1	0.47	0.66	0.71
2	0.72	0.59	1.22
3	1.16	0.53	2.18
4	0.68	0.46	1.48

Mean of ratio 1.38
Standard deviation of ratio 0.61

SEVEN DAY MEANS REGION I

PERIOD	ESMR-5	RADAR	RATIO
1	0.07	0.19	0.58
2	0.47	0.40	1.18
3	0.90	0.76	1.18
4	0.66	0.49	1.40
5	1.19	0.02	59.5 *
6	1.09	0.54	2.02
7	1.21	0.35	3.46
8	0.50	0.70	0.71
9	0.39	0.39	1.0

Mean of ratio 7.89
Standard deviation of ratio 19.37

* When 59.5 is removed we have:
Mean of ratio 1.44
Standard deviation of ratio 0.93

SEVEN DAY MEANS REGION G

PERIOD	ESMR-5	RADAR	RATIO
1	0.33	0.70	0.47
2	0.60	0.63	0.95
3	0.68	0.64	1.06
4	0.76	0.53	1.43
5	1.15	0.43	2.67
6	1.16	0.63	1.84
7	1.00	0.46	2.17
8	0.38	0.46	0.83
9	0.42	0.41	1.02

Mean of ratio 1.38
Standard deviation of ratio 0.71

Observe that the mean of the ratio

ESMR-5 rain rate/radar rain rate

hovers consistently about 1.4. It is known that during Phase II of the GATE, the operation of ESMR-5 was anomalous. For this reason, data from only 15 GATE coincident overpasses were retrievable. The results presented here indicates that these, too, may not be true readings. When the ratio for the Phase II estimates of rain rate are removed from the computations the mean ratio is 1.4 to the nearest hundredth.

These results indicate that oceanic rain rate estimates derived from ESMR-5 data are very consistent when compared to radar estimates.

OTHER PERTINENT QUESTIONS

Several analyses suggested in the grant proposal could not be performed in the allotted time. They are as follows:

1. Compare the quality of ESMR-5 measurements at scan angles less than or equal to 30^{o} with that of angles greater than 30^{o}.

2. Compare the quality of ESMR-5 measurements at scan angles less than or equal to 40^{o} with that of angle greater than 40^{o}.

3. Approximate the fraction of rain during the GATE that was such that ESMR-5 saturation affected rain intensity measurement.

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REFERENCES

[1] Austin, P. and S. Geotis; 1978: 'Evaluation of the Quality of Precipitation Data from a Satellite-Borne Radiometer', Final Report under NASA Grant NSG 5024.

[2] Hudlow, M. D. and V. L. Patterson; 1979: Gate Radar Rainfall Atlas, Center for Environmental Assessment Services, NOAA, Washington, D. C.

[3] Wilheit, T. T.; 1972: 'The Electrically Scanning Microwave Radiometer (ESMR) Experiment', The Nimbus-5 Users Guide, NASA Goddard Space Flight Center, Greenbelt, Maryland.

[4] Wilheit, T. T., A. T. C. Chang, M. S. V. Rao, E. B. Rogers, and J. S. Theon; 1977: 'A Satellite Technique for Quantitatively Mapping Rainfall Rate Over Oceans', Journal of Applied Meteorology, 16, 551-560.

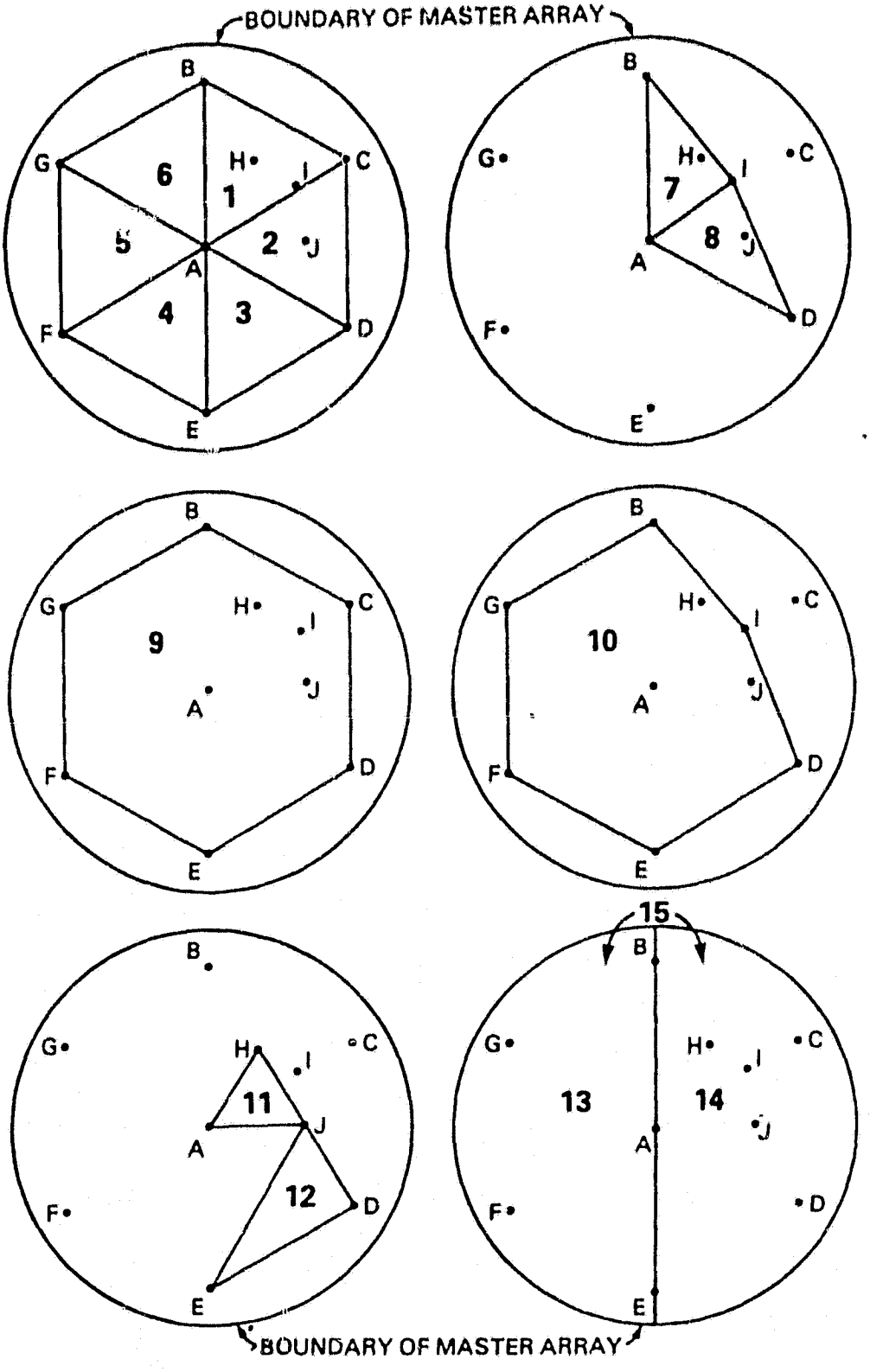

Figure 1. Key giving geometric areas corresponding to the area numbers appearing above the columns of the daily rainfall tabulations. Letters designate ship positions.

Table 1. ESMR-5 GATE DATA

Day	Time Span	Tape-File
179	0107-0117	L9697-17
179	1252-1300	L9679-1
180	1207-1215	L9679-9
181	1309-1315	L9679-17
182	1223-1232	L5308-10
183	0142-0153	L2441-4
183	1325-1332	L5308-18
184	0054-0105	L5308-24
186	0110-0119	L5326-20
186	1256-1304	L5228-3
187	0027-0035	L5228-8
187	1210-1218	L5228-14
188	1313-1319	L5225-4
188	0130-0137	L5228-22
189	1227-1238	L5225-7
190	0145-0157	L5225-13
193	0117-0125	L1599-20
193	1300-1307	L5327-2
194	0033-0040	L5327-14
194	1213-1223	L5327-11
195	1316-1324	L5360-4
196	0048-0055	L5360-11
196	1230-1237	L5360-16
197	0150-0157	L5360-22
197	0005-0012	L5360-23
197	1332-1340	L5359-6
209	0140-0150	L5269-4
209	1325-1332	L5269-10
210	0053-0103	L5269-16
210	1237-1245	L5269-21
211	0008-0017	L5349-6
211	0157-0204	L5349-4
211	1340-1349	L5349-10
212	0110-0119	L5349-16
212	1255-1304	L5349-21
222	0047-0054	L5362-4
222	1230-1237	L5362-15
223	0149-0156	L5362-7
224	1245-1253	L5368-9
225	0021-0026	L5368-17
227	0035-0041	L5381-10
227	1216-1224	L5381-15
242	0143-0150	L5399-11
242	1325-1333	L5399-16
243	0100-0108	L5399-22
243	1241-1248	L6861-4
244	0013-0021	L6861-12
244	0200-0209	L6861-11
244	1154-1202	L6861-17
244	1344-1350	L6861-18
245	1257-1304	L6896-3
246	1210-1219	L6896-16
247	0133-0139	L9661-1
247	1313-1321	L9661-6
248	0043-0053	L9661-18
248	1228-1235	L9661-16
249	0147-0155	L5255-6
249	1330-1337	L5255-4
250	1243-1252	L5255-18
251	0015-0023	L5276-1

Table 1 (continued)

Day	Time Span	Tape-File
25[illegible]	0203-0210	L5276-2
251	1159-1205	L5276-6
252	0116-0125	L5276-14
252	1300-1308	L5276-20
253	0032-0040	L5343-9
253	1215-1223	L5343-3
254	1316-1324	L5343-15
255	1232-1240	L6842-3
256	1333-1340	L6842-14
257	1250-1258	L6872-6
258	1202-1210	L6872-13
259	0123-0129	L6872-21
259	1305-1311	L9649-3
260	0037-0044	L9649-10
260	1219-1228	L9649-15
261	0138-0145	L5268-17
261	1321-1327	L5268-3
262	0053-0100	L5268-9
262	1235-1243	L5268-15

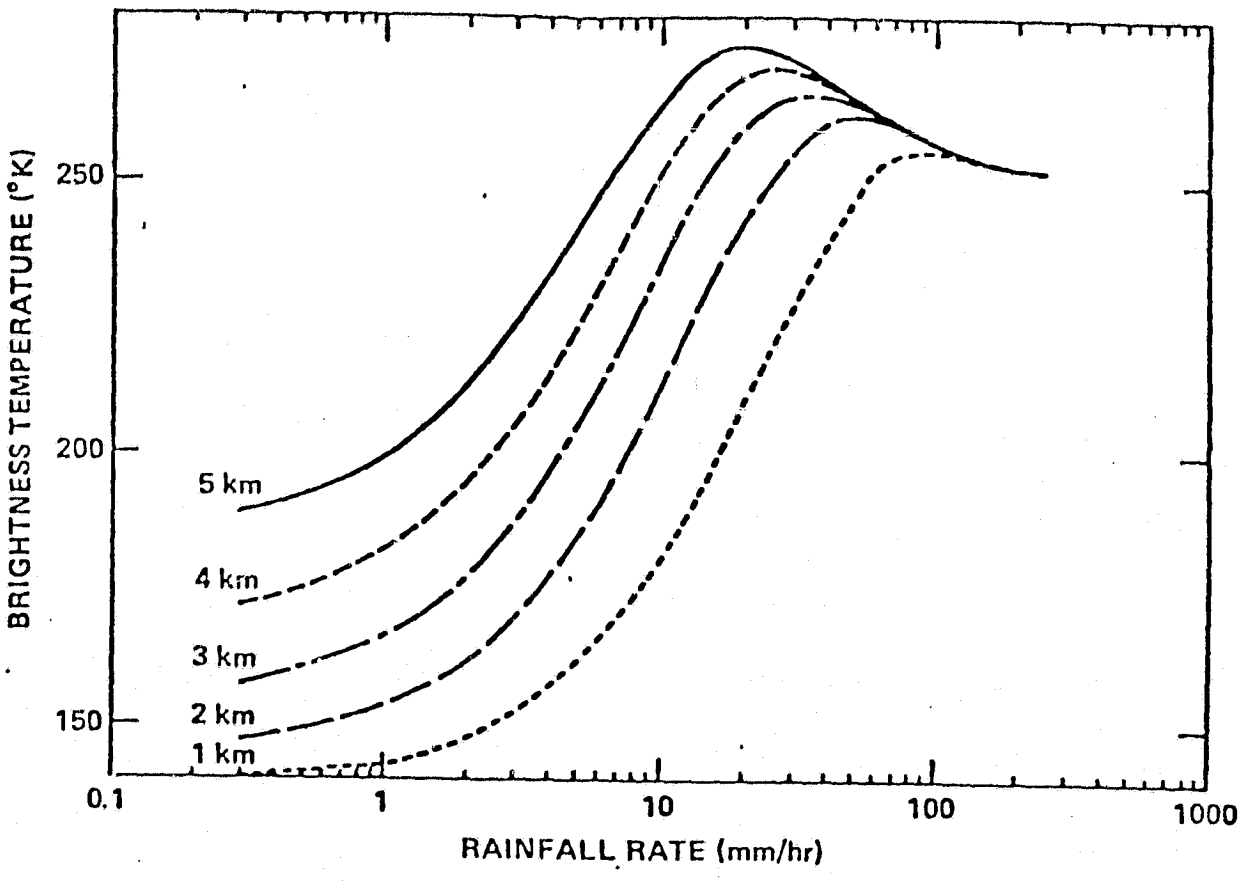

Fig. 2. Calculated brightness temperature at 1.55 cm as a function of rain rate for melting levels of 1, 2, 3, 4 and 5 km (from Wilheit et al, 1977).

TABLE 2: DERIVATION OF THE LINE $R = 0.031\ T_B - 4.258$

T = Brightness Temperature

R = Rain Rate

Region	T	R	R estimate	Residual
1				
1	171	0.64	0.98	-.34
2	175	1.08	1.10	-.02
3	181	1.09	1.28	-.19
4	165	0.43	0.79	-.36
5	172	1.04	1.01	+.03
6	174	1.86	1.07	+.79
7	171	0.82	0.98	-.16
8	175	0.98	1.10	-.12
9	173	1.02	1.04	-.02
10	173	1.05	1.04	+.12
11	172	1.51	1.01	+.5
12	191	1.46	1.59	-.13

Table 3. Comparison of ESMR-5 rain intensity estimates via the relation R = 0.031T - 4.258 with GATE radar derived hourly mean precipitation rates for area 11 of Figure 1.

PHASE I	ESMR	RADAR
June 28 N +	0.59	0.00
28 D #	1.18	1.03
29 D	1.88	m
30 D	1.52	m
July 1 D	1.43	0.01
2 N	1.47	0.03
3 D	2.55	0.08
3 N	0.76	0.00
5 D	0.63	0.03
5 N	0.80	0.32
6 N	1.31	0.03
6 D	1.40	0.00
7 D	1.92	1.33
7 N	1.19	0.12
8 D	2.08	1.04
9 N	1.24	m
12 N	1.12	0.00
12 D	0.71	0.00
13 N	1.75	0.10
13 D	2.01	0.77
14 D	2.01	1.36
15 N	1.87	2.65
15 D	1.24	0.10
16 N	1.17	0.00
16 D	1.54	0.00

PHASE II	ESMR	RADAR
July 28 N	1.28	1.38
28 D	1.75	0.00
29 N	0.71	1.20
29 D	1.14	0.69
∫ 00:00 30 N	2.23	0.27
30 D	1.96	0.07
02:01 30 N	1.39	0.00
31 N	1.05	m
Aug. 1 D	0.81	m
10 N	2.54	4.95
10 D	2.39	0.14
11 N	1.23	0.00
13 N	2.57	0.00
15 N	1.06	0.00
15 D	1.25	0.00

PHASE III	ESMR	RADAR
Aug. 30 N	2.67	2.16
30 D	1.60	0.11
31 N	0.70	0.01
31 D	0.75	0.00
Sept.		
00:22 1 N	2.16	0.06
02:10 1 N	1.40	0.04
12:03 1 D	2.03	0.42
13:51 1 D	2.01	0.47
2 D	1.05	1.51
3 D	1.72	0.03
4 N	1.26	0.00
4 D	1.13	0.01
5 N	1.88	0.84
5 D	1.97	2.53
6 N	1.29	m
6 D	2.39	1.17
7 D	0.72	0.09
8 N	2.22	0.36
9 N	1.37	0.10
9 D	1.27	3.49
10 N	1.52	0.18
10 D	1.39	0.02
11 D	1.30	0.00
12 D	2.50	3.00
13 D	2.32	m
14 D	1.34	2.83
15 D	1.67	0.10
16 N	1.52	0.33
13:05 16 D	1.77	3.21
00:37 17 N	1.66	0.64
17 D	2.05	0.54
18 N	1.43	0.03
18 D	1.53	0.02
19 N	0.95	0.22
19 D	1.80	1.61

PHASE I	AVERAGE:	ESMR - 1.41,	RADAR - 0.41;	RATIO - 3.44
PHASE II	AVERAGE:	ESMR - 1.56,	RADAR - 0.67;	RATIO - 2.33
PHASE III	AVERAGE:	ESMR - 1.61,	RADAR - 0.79;	RATIO - 2.08
GATE	AVERAGE:	ESMR - 1.53,	RADAR - 0.64;	RATIO - 2.40

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Figure 3. Subdivisions of the two-degree square region centered at (23.5° W, 8.5° N). The letter G denotes the entire region.

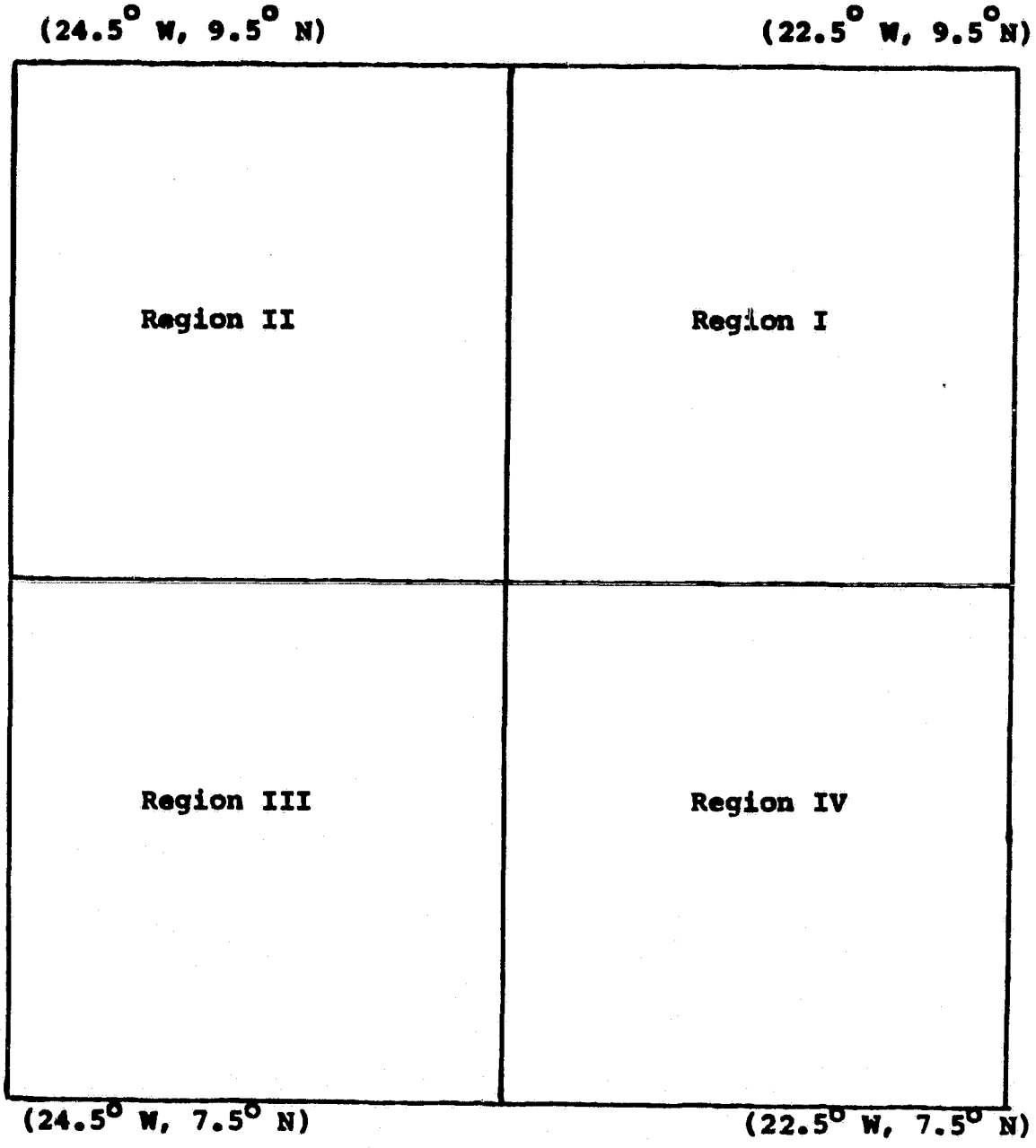

Figure 4 The GATE Area