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THEMATIC MAPPER STUDIES BAND CORRELATION ANALYSIS

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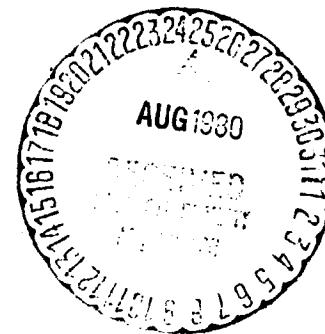
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April 1976



GODDARD SPACE FLIGHT CENTER

NASA Institute for Space Studies

**THEMATIC MAPPER STUDIES
BAND CORRELATION ANALYSIS**

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GISS THEMATIC MAPPER BAND CORRELATION STUDY

Spectral data representative of Thematic Mapper candidate bands 1 and 3-7 were obtained by selecting appropriate combinations of bands from the JSC 24-Channel Multispectral Scanner, as indicated in Table 1. These data represent a rather limited, but nevertheless diversified set of crop conditions as indicated in Table 2. Of all the bands assigned, only candidate bands 4 (.74 μ - .80 μ) and 5 (.80 μ - .91 μ) showed consistently high inter-correlation from region to region and time to time. This extremely high correlation persisted when looking at the composite data set in a multi-temporal, multi-location domain. The GISS investigations lend positive confirmation to the hypothesis advanced by DeGasparis, Tucker and others that TM Bands 4 and 5 are redundant.

JSC 24-Channel MSS data were used to construct simulated TM bands, as indicated in Table 1, for a series of interband correlation studies. Note that TM band 2 was not simulated since the 24-Channel MSS detector most closely corresponding to this wavelength range was malfunctioning. The data used in these studies were acquired along a flight line selected from each of the four dates (two Intensive Test Sites). These data were considered in joint investigations into spatial degradation conducted by LARS, Earth Resources Laboratory (ERL) and GISS. A breakdown of the dates and sites, indicating the number of pixels, amount of area and crop mix is given in Table 2.

Shadowing and look angle effects tend to introduce correlations into the data which are not inherent in the ground scenes. In order

SIMULATION OF THEMATIC MAPPER BANDS WITH JSC 24-CHANNEL MSS

PROPOSED THEMATIC MAPPER		24 CHANNEL MSS
BAND	RANGE (μ)	RANGE USED
1.	.45 - .52	.46 - .50
3.	.63 - .69	.64 - .68
4.	.74 - .80	.76 - .80
5.	.80 - .91	.82 - .87
6.	1.55 - 1.75	1.52 - 1.73
7.	10.4 - 12.5	{ 10.1 - 11.0 11.0 - 12.0

TABLE 1.

CHARACTERISTICS OF SITES STUDIED WITH 24-CHANNEL MSS DATA

<u>DATE/SITES</u>	<u>NO. OF PIXELS</u>	<u>AREA</u>	<u>ESTIMATED CROP MIX OF TEST SITE COVERED</u>
Finney Co., KS 6-9-75 Flight Line # 1	1,544,200	19.39 sq. mi.	Wheat (24%) Alfalfa (18%) Recently Planted (40%) Summer Fallow (12%) Other (6%)
Williams Co., ND 6-22-75 Flight Line # 2	1,384,600	17.38 sq. mil	Wheat (35%) Grass/Pasture (21%) Summer Fallow (32%) Other (11%)
Finney Co., KS 7-6-75 Flight Line # 1	1,764,000	22.15 sq. mi.	Wheat (24%) Alfalfa (18%) Corn (19%) Grain Sorghum (21%) Fallow (12%) Other (6%)
Williams Co., ND 8-15-75 Flight Line # 2	1,314,600*	16.5 sq. mi.	Wheat (35%) Grass/Pasture (21%) Summer Fallow (32%) Other (11%)

*The three segments composing this flight line are populated as follows:

Part	I	438,200 pixels
	II	438,200 pixels
	III	438,200 pixels

TABLE 2

to compensate for this, unit color-vectors were constructed for each pixel by the following formula:

$$N'_i = N_i / \sqrt{\sum_{j=1}^n N_j^2}$$

where N'_i is the normalized count in the i th band.

Correlation studies were conducted using both the raw and normalized (albedo compensated) data. Figures 1 through 4 represent results on a site by site and date by date basis. Note that except for cases of extremely high correlation the unit-vector representation tends to lower interband correlation (and strengthen anti-correlation) by removing some of the systematic variation in apparent albedo due to causes other than changes in ground reflectance (e.g., look angle effects, variation in instrument voltages). The albedo compensated correlations are more indicative of band redundancy than the uncompensated correlations.

The correlation coefficient in these figures was derived in the customary manner assuming linear interband relations:

$$r_{ij} = \frac{n \sum_{k=1}^n N_i^k N_j^k - \sum_{k=1}^n N_i^k \sum_{k=1}^n N_j^k}{\sqrt{n \sum_{k=1}^n (N_i^k)^2 - (\sum_{k=1}^n N_i^k)^2} \sqrt{n \sum_{k=1}^n (N_j^k)^2 - (\sum_{k=1}^n N_j^k)^2}}$$

In order to examine the statistical validity of the derived correlation coefficients, each line was divided into several segments of approximately equal length. Individual segment results are presented for the August 15, Williams County flight line in Figure 5. The relative interband correlations remain completely consistent from segment to segment. This spatial consistency of

FINNEY COUNTY, KANSAS - FLIGHT LINE #1 - 6/9/75

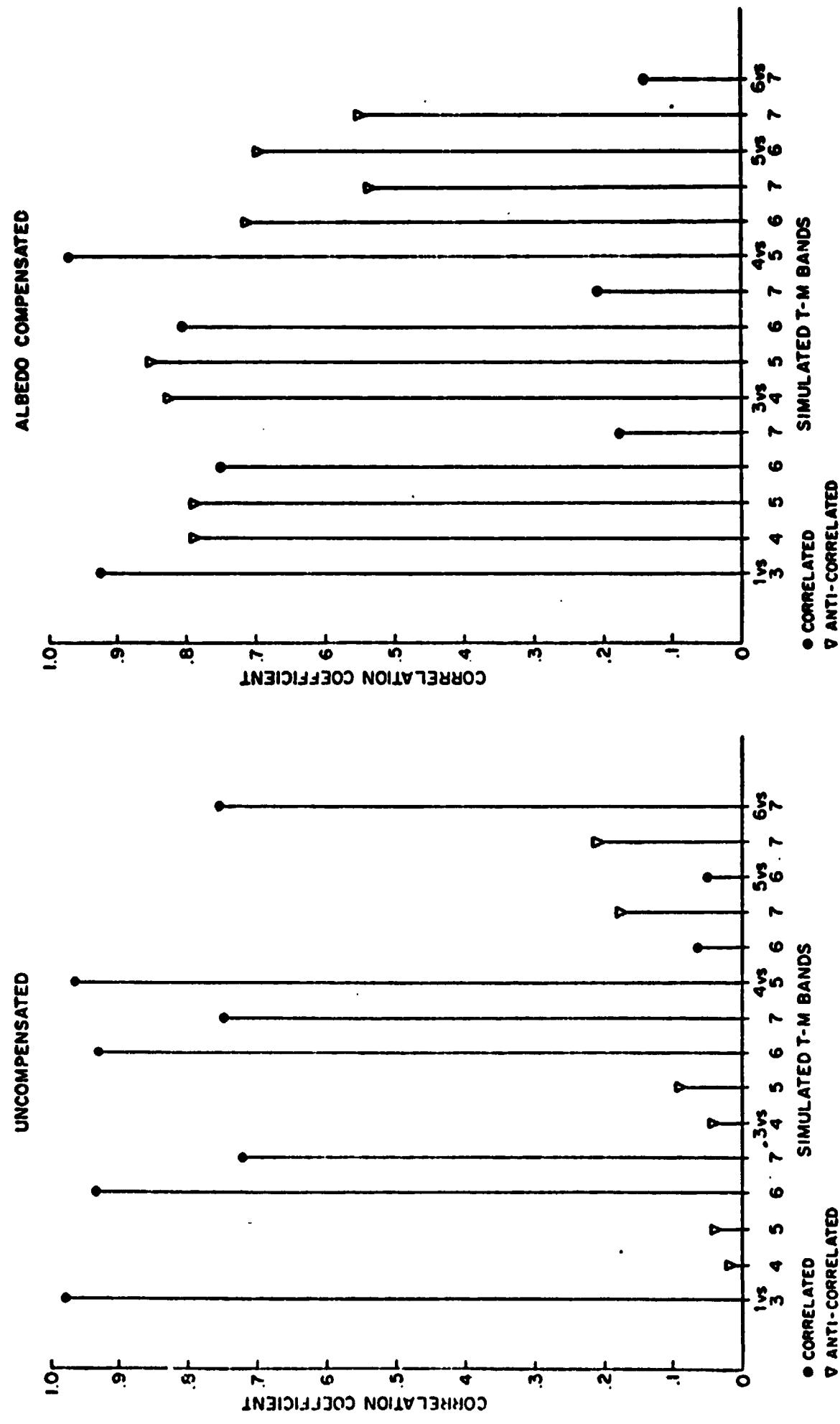


Figure 1

WILLIAMS COUNTY, NORTH DAKOTA - FLIGHT LINE #2-6/22/75

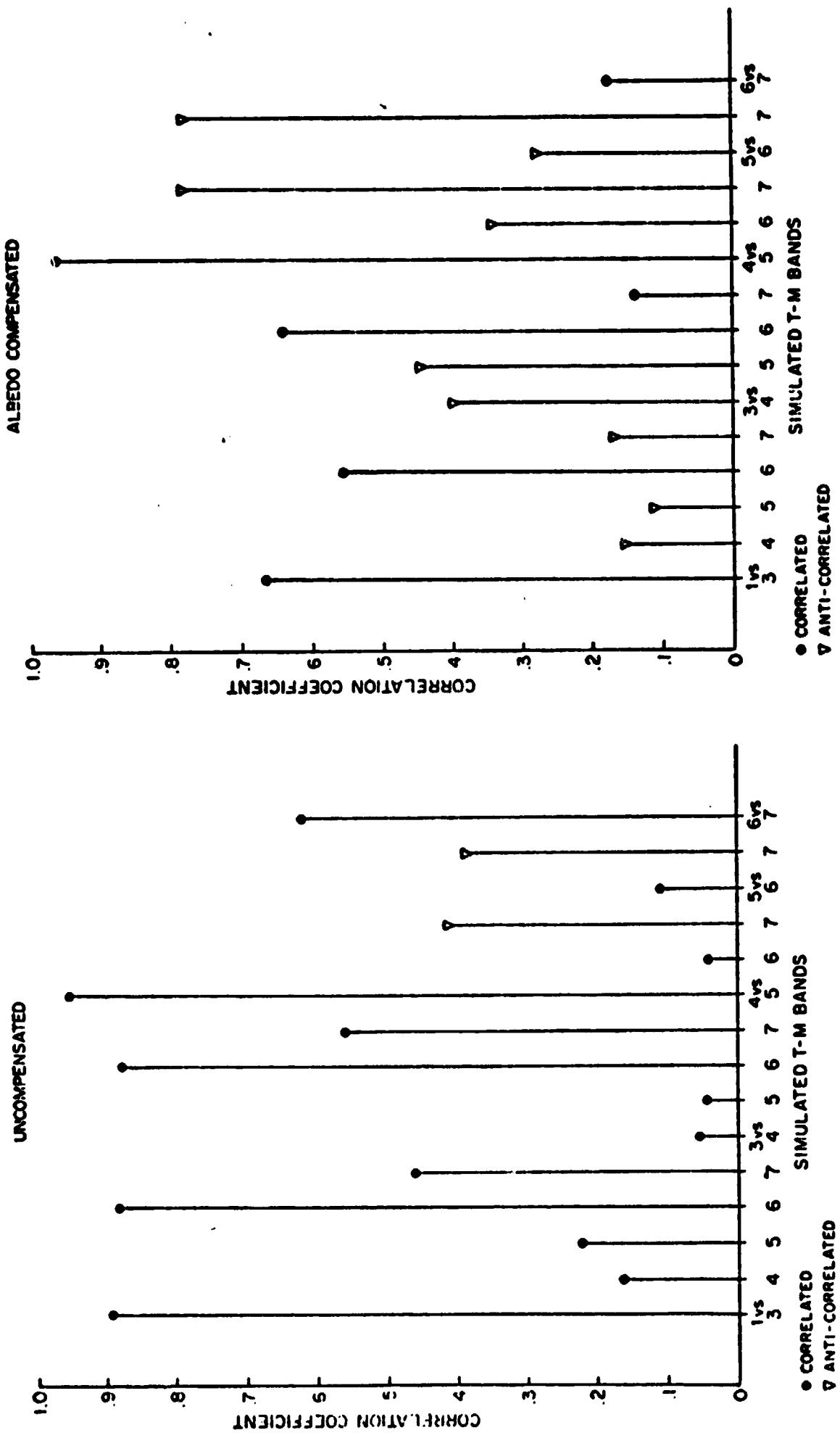


Figure 2

FINNEY COUNTY, KANSAS - FLIGHT LINE #1 - 7/6/75

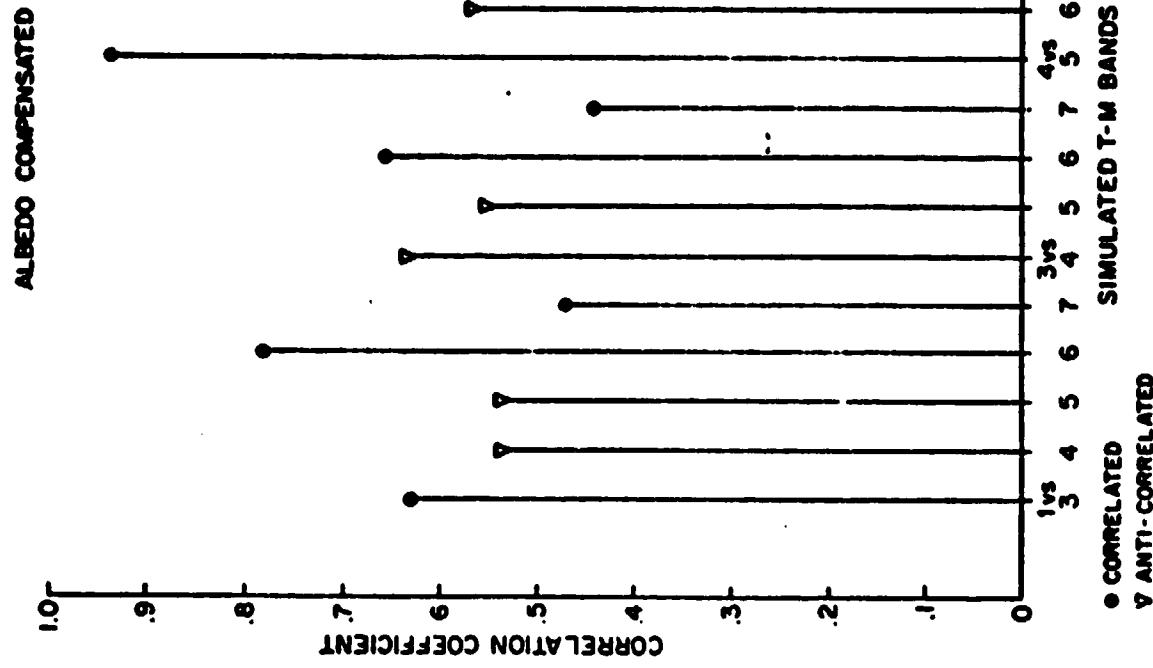
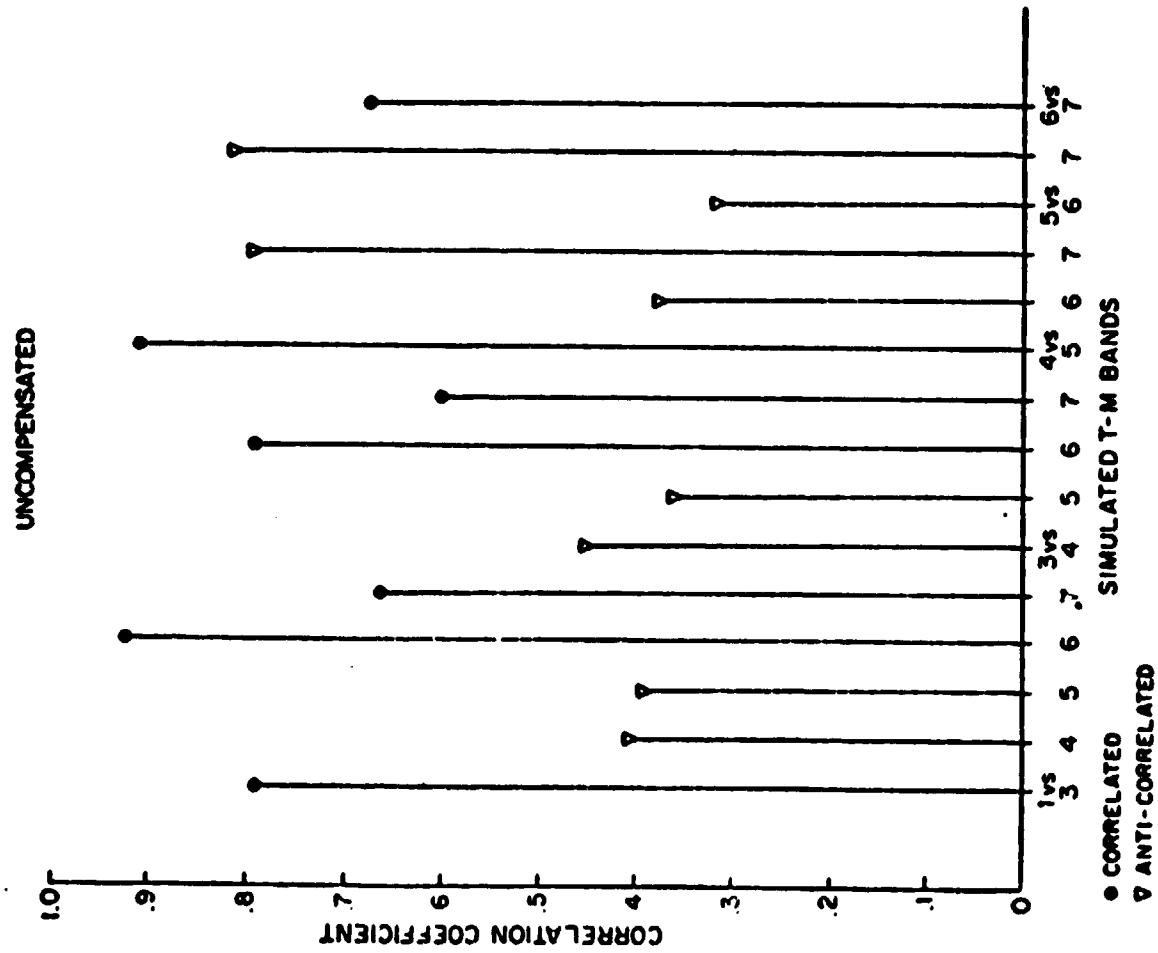


Figure 3

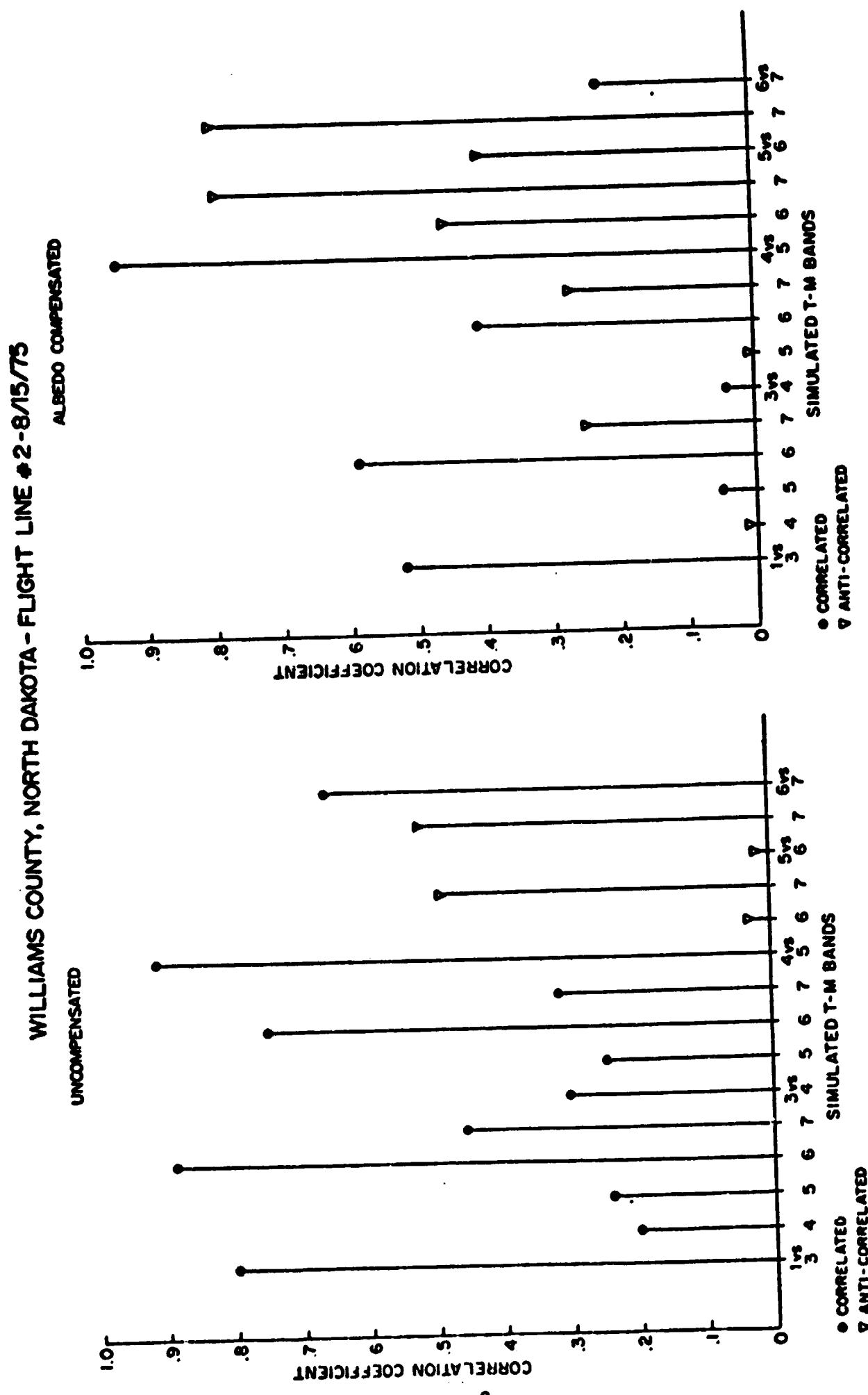


Figure 4

WILLIAMS COUNTY, N.D.-FLIGHT LINE #2-8/12/73

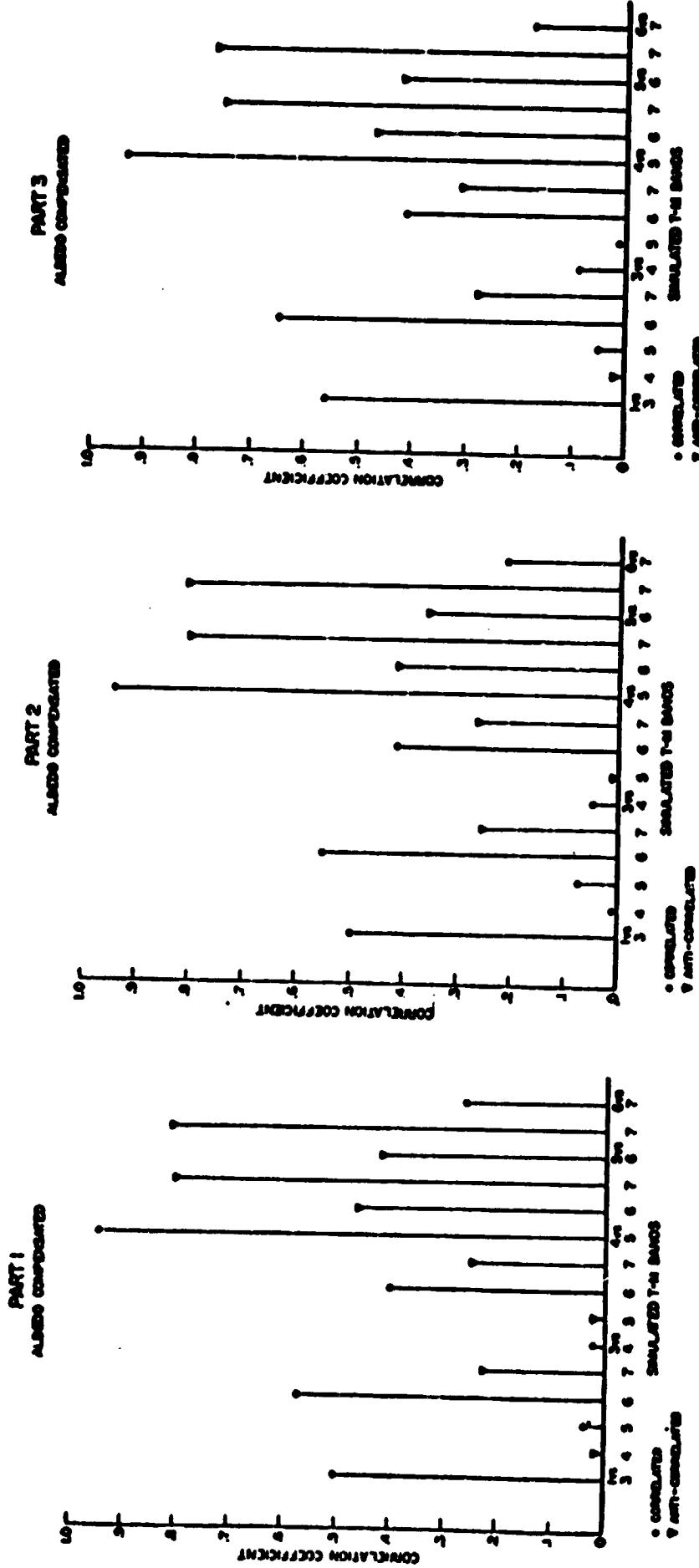


Figure 5

results was also present among the four segments of the July, Finney County flight line. However, the June 9, Finney County flight line and the June 22, Williams County flight line each displayed one anomalous segment. In both instances the segments contained appreciable cloud cover as compared to the uniformly cloud free condition for all other areas considered in this study.

The effect of cloud cover and shadow on interband correlation will be the subject of a future report.

Figure 6 represents the multi-geographic, multi-temporal data set formed by the union of all 4 data sets in the study. This data set is composed of some six million pixels representing crops such as spring and winter wheat, corn, grain sorghum, alfalfa and pasture at up to five stages of maturity.

Conclusions:

Arguments appearing in a GSFC report dated December, 1975 issued by J. Harnage through ERPO conclude that Thematic Mapper Bands 4 and 5 are highly redundant. These findings are based on laboratory and field spectra obtained under a highly restrictive set of conditions. Although these arguments are convincing when taken in context, they constitute a hypothesis when extrapolated to a multi-spectral scanner such as Thematic Mapper. Investigations by GISS using real MSS data under a variety of conditions may be considered an independent test of this hypothesis. Although the MSS data used represent a rather limited mix of cropping practices, the agricultural situations represented are precisely the

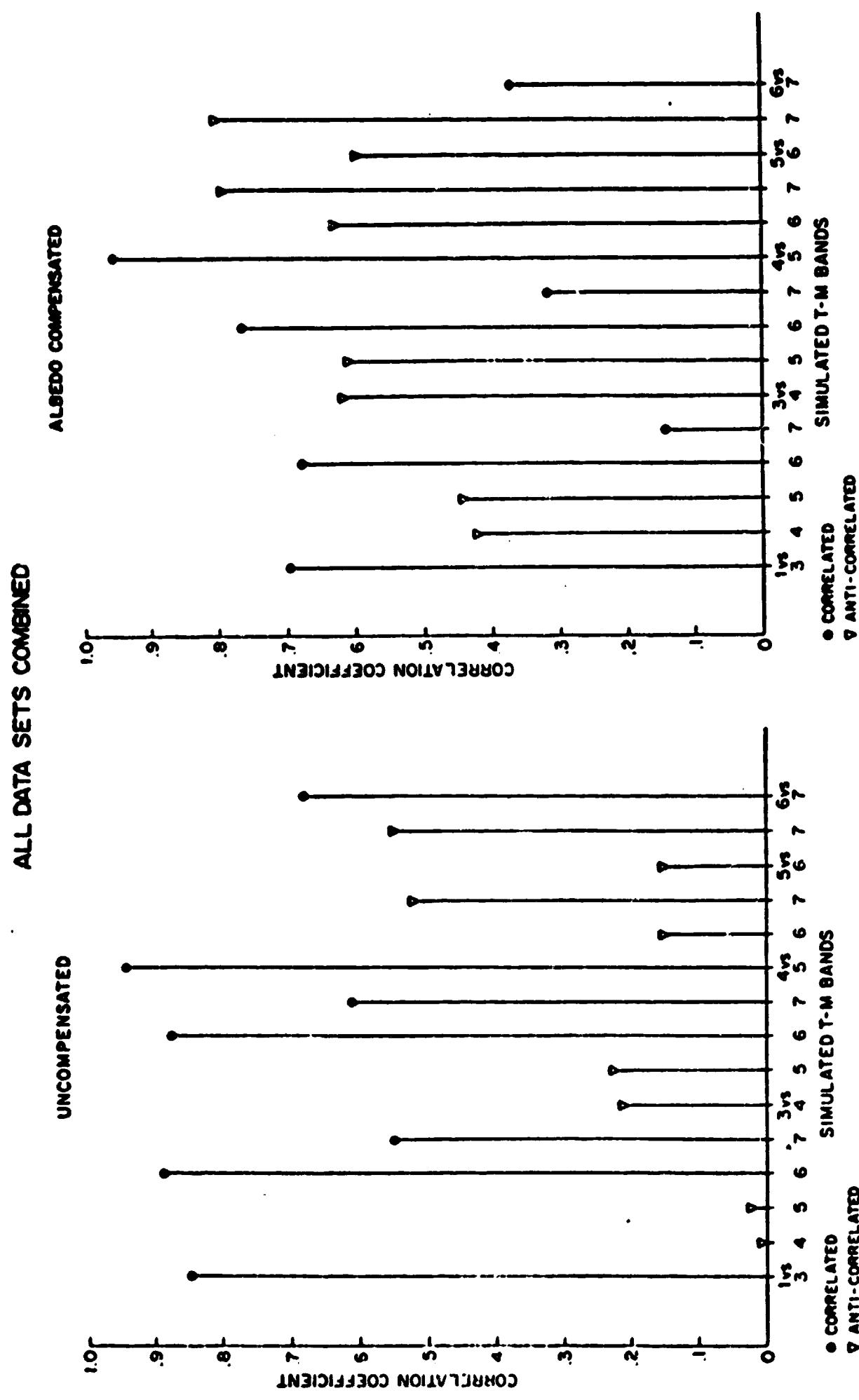


Figure 6

ones which have been heavily emphasized for consideration of Thematic Mapper design. The GISS findings are significant, and supportive of the contention that TM Bands 4 and 5 are highly redundant.

Appendix

Linear Correlation Coefficients 24 Channel MSS Data

TABLE A1: FINNEY COUNTY, KANSAS, JUNE 9, 1975. FLIGHT LINE #1.
 LINEAR CORRELATION COEFFICIENTS, UNCOMPENSATED DATA.
 COMPARE WITH FIGURE 1 IN TEXT.

TM	CHAN	MSS CHAN
1	3	
3	6	
4	8	
5	9	
6	12	
7	20	21
1	17	18
2	19	20
3	21	22
4	23	24
5	25	26
6	27	28
7	29	30
8	31	32
9	33	34
10	35	36
11	37	38
12	39	40
13	41	42
14	43	44
15	45	46
16	47	48
17	49	50
18	51	52
19	53	54
20	55	56
21	57	58
22	59	60
23	61	62
24	63	64
25	65	66
26	67	68
27	69	70
28	71	72
29	73	74
30	75	76
31	77	78
32	79	80
33	81	82
34	83	84
35	85	86
36	87	88
37	89	90
38	91	92
39	93	94
40	95	96
41	97	98
42	99	100
43	101	102
44	103	104
45	105	106
46	107	108
47	109	110
48	111	112
49	113	114
50	115	116
51	117	118
52	119	120
53	121	122
54	123	124
55	125	126
56	127	128
57	129	130
58	131	132
59	133	134
60	135	136
61	137	138
62	139	140
63	141	142
64	143	144
65	145	146
66	147	148
67	149	150
68	151	152
69	153	154
70	155	156
71	157	158
72	159	160
73	161	162
74	163	164
75	165	166
76	167	168
77	169	170
78	171	172
79	173	174
80	175	176
81	177	178
82	179	180
83	181	182
84	183	184
85	185	186
86	187	188
87	189	190
88	191	192
89	193	194
90	195	196
91	197	198
92	199	200
93	201	202
94	203	204
95	205	206
96	207	208
97	209	210
98	211	212
99	213	214
100	215	216
101	217	218
102	219	220
103	221	222
104	223	224
105	225	226
106	227	228
107	229	230
108	231	232
109	233	234
110	235	236
111	237	238
112	239	240
113	241	242
114	243	244
115	245	246
116	247	248
117	249	250
118	251	252
119	253	254
120	255	256
121	257	258
122	259	260
123	261	262
124	263	264
125	265	266
126	267	268
127	269	270
128	271	272
129	273	274
130	275	276
131	277	278
132	279	280
133	281	282
134	283	284
135	285	286
136	287	288
137	289	290
138	291	292
139	293	294
140	295	296
141	297	298
142	299	300
143	301	302
144	303	304
145	305	306
146	307	308
147	309	310
148	311	312
149	313	314
150	315	316
151	317	318
152	319	320
153	321	322
154	323	324
155	325	326
156	327	328
157	329	330
158	331	332
159	333	334
160	335	336
161	337	338
162	339	340
163	341	342
164	343	344
165	345	346
166	347	348
167	349	350
168	351	352
169	353	354
170	355	356
171	357	358
172	359	360
173	361	362
174	363	364
175	365	366
176	367	368
177	369	370
178	371	372
179	373	374
180	375	376
181	377	378
182	379	380
183	381	382
184	383	384
185	385	386
186	387	388
187	389	390
188	391	392
189	393	394
190	395	396
191	397	398
192	399	400
193	401	402
194	403	404
195	405	406
196	407	408
197	409	410
198	411	412
199	413	414
200	415	416
201	417	418
202	419	420
203	421	422
204	423	424
205	425	426
206	427	428
207	429	430
208	431	432
209	433	434
210	435	436
211	437	438
212	439	440
213	441	442
214	443	444
215	445	446
216	447	448
217	449	450
218	451	452
219	453	454
220	455	456
221	457	458
222	459	460
223	461	462
224	463	464
225	465	466
226	467	468
227	469	470
228	471	472
229	473	474
230	475	476
231	477	478
232	479	480
233	481	482
234	483	484
235	485	486
236	487	488
237	489	490
238	491	492
239	493	494
240	495	496
241	497	498
242	499	500
243	501	502
244	503	504
245	505	506
246	507	508
247	509	510
248	511	512
249	513	514
250	515	516
251	517	518
252	519	520
253	521	522
254	523	524
255	525	526
256	527	528
257	529	530
258	531	532
259	533	534
260	535	536
261	537	538
262	539	540
263	541	542
264	543	544
265	545	546
266	547	548
267	549	550
268	551	552
269	553	554
270	555	556
271	557	558
272	559	560
273	561	562
274	563	564
275	565	566
276	567	568
277	569	570
278	571	572
279	573	574
280	575	576
281	577	578
282	579	580
283	581	582
284	583	584
285	585	586
286	587	588
287	589	590
288	591	592
289	593	594
290	595	596
291	597	598
292	599	600
293	601	602
294	603	604
295	605	606
296	607	608
297	609	610
298	611	612
299	613	614
300	615	616
301	617	618
302	619	620
303	621	622
304	623	624
305	625	626
306	627	628
307	629	630
308	631	632
309	633	634
310	635	636
311	637	638
312	639	640
313	641	642
314	643	644
315	645	646
316	647	648
317	649	650
318	651	652
319	653	654
320	655	656
321	657	658
322	659	660
323	661	662
324	663	664
325	665	666
326	667	668
327	669	670
328	671	672
329	673	674
330	675	676
331	677	678
332	679	680
333	681	682
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350	715	716
351	717	718
352	719	720
353	721	722
354	723	724
355	725	726
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358	731	732
359	733	734
360	735	736
361	737	738
362	739	740
363	741	742
364	743	744
365	745	746
366	747	748
367	749	750
368	751	752
369	753	754
370	755	756
371	757	758
372	759	760
373	761	762
374	763	764
375	765	766
376	767	768
377	769	770
378	771	772
379	773	774
380	775	776
381	777	778
382	779	780
383	781	782
384	783	784
385	78	

TABLE A1 (CONTINUED): FINNEY COUNTY, KANSAS. JUNE 9, 1975. FLIGHT LINE #1. LINEAR CORRELATION COEFFICIENTS, ALBEDO COMPENSATED DATA.

COMPARE WITH FIGURE 1 IN TEXT.

20 6 21

MSS	CHAN
TH	CHAN
1	3
3	6
4	8
5	9

TABLE A2: WILLIAMS COUNTY, NORTH DAKOTA. JUNE 22, 1975. FLIGHT LINE #2. LINEAR CORRELATION COEFFICIENTS, UNCOMPENSATED DATA.
COMPARE WITH FIGURE 2 IN TEXT.

TM	CHAN	MSS CHAN
1	3	1
3	6	12
4	8	112
5	9	117
6	12	114
7	20	20

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TABLE A2 (CONTINUED): WILLIAMS COUNTY, NORTH DAKOTA. JUNE 22, 1975.
 FLIGHT LINE #2. LINEAR CORRELATION COEFFICIENTS,
ALBEDO COMPENSATED DATA.
 COMPARE WITH FIGURE 2 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 6 21
8	112
9	113
10	115
11	117
12	118
13	119
14	120
15	121
16	122
17	123
18	124
19	125
20	126
21	127
22	128
23	129
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365	471
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393	499
394	500
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397	503
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399	505
400	506
401	507
402	508
403	509
404	510
405	511
406	512
407	513
408	514
409	515
410	516
411	517
412	518
413	519
414	520
415	521
416	522
417	523
418	524
419	525
420	526
421	527
422	528
423	529
424	530
425	531
426	532
427	533
428	534
429	535
430	536
431	537
432	538
433	539
434	540
435	541
436	542
437	543
438	544
439	545
440	546
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443	549
444	550
445	551
446	552
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459	565
460	566
461	567
462	568
463	569
464	570
465	571
466	572
467	573
468	574
469	575
470	576
471	577
472	578
473	579
474	580
475	581
476	582
477	583
478	584
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503	609
504	610
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507	613
508	614
509	615
510	616
511	617
512	618
513	619
514	620
515	621
516	622
517	623
518	624
519	625
520	626
521	627
522	628
523	629
524	630
525	631
526	632
527	633
528	634
529	635
530	636
531	637
532	638
533	639
534	640
535	641
536	642
537	643
538	644
539	645
540	646

TABLE A3: FINNEY COUNTY, KANSAS. JULY 6, 1975. FLIGHT LINE #1.
LINEAR CORRELATION COEFFICIENTS, UNCOMPENSATED DATA.
COMPARE WITH FIGURE 3 IN TEXT.

	TM CHAN	MSS CHAN
1	3	
2	6	
3	6	
4	8	
5	9	
6	12	
7	20	
8	19	
9	18	
10	17	
11	16	
12	15	
13	14	
14	13	
15	12	
16	11	
17	10	
18	9	
19	8	
20	7	
21	6	
22	5	
23	4	
24	3	
25	2	
26	1	
27	0	
28	-1	
29	-2	
30	-3	
31	-4	
32	-5	
33	-6	
34	-7	
35	-8	
36	-9	
37	-10	
38	-11	
39	-12	
40	-13	
41	-14	
42	-15	
43	-16	
44	-17	
45	-18	
46	-19	
47	-20	
48	-21	
49	-22	
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51	-24	
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69	-42	
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453	-426	
454	-427	
455	-428	
456	-429	

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TABLE A3 (CONTINUED): FINNEY COUNTY, KANSAS. JULY 6, 1975. FLIGHT LINE #1. LINEAR CORRELATION COEFFICIENTS,
ALBEDO COMPENSATED DATA.
COMPARE WITH FIGURE 3 IN TEXT.

20 6 21

0	23	32	32	2
0	66	99	04	08
0	00	00	45	97
0	00	00	00	54
0	-	-	-	-
1	2	3	4	5
1	6	7	8	9
0	0	1	2	3
0	4	5	6	7
0	8	9	0	1
0	2	3	4	5
0	7	8	9	0
0	1	2	3	4

—N—N—N—N—N—N—N—N—N—N—

21

SS PAN 3 6 8 9 2 4

ML
CH 10

2

2

TM
HAN | 1 3 4 5 6 7

1

TABLE A4: WILLIAMS COUNTY, NORTH DAKOTA. AUGUST 15, 1975. FLIGHT LINE #2. LINEAR CORRELATION COEFFICIENTS, UNCOMPENSATED DATA.
COMPARE WITH FIGURE 4 IN TEXT.

20	6	21
0.0	2.25042	
0.0	4.54157	
0.0	3.01185	
0.0	3.16135	
0.0	3.28150	
0.0	4.87595	
0.0	5.15405	
0.0	4.12657	
0.0	6.54663	
0.0	6.64591	
0.0	8.29190	
0.0	8.07132	
0.0	9.50276	
0.0	9.77185	
0.0	9.63103	
0.0	9.92535	
0.0	9.92481	
0.0	8.00643	
0.0	8.04186	
0.0	7.89086	

TABLE A4 (CONTINUED): WILLIAMS COUNTY, NORTH DAKOTA. AUGUST 15,
 1975. FLIGHT LINE #2. LINEAR CORRELATION COEFFICIENTS,
ALBEDO COMPENSATED DATA.

TABLE A5 (PART ONE): WILLIAMS COUNTY, NORTH DAKOTA. AUGUST 15, 1975. FLIGHT LINE #2, PART ONE. LINEAR CORRELATION COEFFICIENT, ALBEDO COMPENSATED DATA.

CHAN	CHAN
1	3
3	6
4	8
5	9
6	12
7	20 6 21

TABLE A5 (PART TWO): WILLIAMS COUNTY, NORTH DAKOTA. AUGUST 15, 1975. FLIGHT LINE #2, PART TWO. LINEAR CORRELATION COEFFICIENT, ALBEDO COMPENSATED DATA.

MSS	CHAN	
TM	CHAN	
1	3	
3	6	
4	8	
5	9	
6	12	
7	20	6 21

TABLE A5 (PART THREE): WILLIAMS COUNTY, NORTH DAKOTA, AUGUST 15, 1975. FLIGHT LINE #2, PART THREE. LINEAR CORRELATION.

COFFEE EFFICIENT

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COMPARE WITH FIGURE 3 IN TEXT.

20 6 21

MSS CHAN	TW CHAN	3	6	8	9	12	21
	1						
	3						
	4						
	5						
	6						
	7						

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TABLE A6: ALL SITES COMBINED. JUNE 9, JUNE 22, JULY 6, AUGUST 15, 1975. LINEAR CORRELATION COEFFICIENTS, UNCOMPENSATED DATA.
COMPARE WITH FIGURE 6 IN TEXT.

MSS CHAN	TH CHAN	
1	3	
3	6	
4	8	
5	9	
6	12	
7	20	4 21

	TM	MSS CHAN	CHAN	1	3	5	9	12	14	16	18	20	21	23	24
1	0.7200251	-0.243434	0.001364	-0.250197	-0.375767	0.236803	0.248858	0.240680	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
2	0.7409612	-0.2220203	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
3	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
4	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
5	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
6	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
7	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
8	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
9	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
10	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
11	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
12	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
13	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
14	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
15	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
16	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
17	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
18	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
19	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
20	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
21	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
22	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
23	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709
24	0.7434345	-0.224734	0.113362	0.092477	-0.026292	-0.675784	0.168649	0.168649	0.396229	0.494714	0.414128	-0.424707	-0.423709	-0.423709	-0.423709

TABLE A6 (CONTINUED): ALL SITES COMBINED. JUNE 9, JUNE 22, JULY 6,
AUGUST 15, 1975. LINEAR CORRELATION COEFFICIENTS,
ALBEDO COMPENSATED DATA.

TM	MSS CHAN	CHAN	1	3	5	9	12	14	16	18	20	21	23	24
4	8	8	1	3	5	9	12	14	16	18	20	21	23	24
5	9	9	1	3	5	9	12	14	16	18	20	21	23	24
6	12	12	1	3	5	9	12	14	16	18	20	21	23	24
7	20	21	1	3	5	9	12	14	16	18	20	21	23	24