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NEAREST NEIGHBOR, BILINEAR INTERPOLATION AND BICUBIC INTERPOLATION GEOGRAPHIC CORRECTION EFFECTS ON LANDSAT IMAGERY

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16. ABSTRACT

The objectives of this work are to identify effects that are observed in Landsat image data when the image data are geographically corrected using the nearest neighbor, bilinear interpolation and bicubic interpolation registration techniques, and to identify potential impacts of registration on image compression and classification.

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NEAREST NEIGHBOR, BILINEAR INTERPOLATION AND BICUBIC INTERPOLATION GEOGRAPHIC CORRECTION EFFECTS ON LANDSAT IMAGERY

I. INTRODUCTION

There are basically two steps involved in geographically correcting image data. The first step is utilization of a transformation, which tells where to obtain grey scale information from the original data for a particular pixel location on a geographically correct coordinate system image. In a majority of cases, the location for obtaining grey scale information from the original image occurs in between pixels, and this requires that the grey scale value be estimated. The second step, therefore, involves deciding how to assign or estimate the grey scale value. There are three techniques commonly used for determining the proper grey scale value: Nearest Neighbor (NN), Bilinear Interpolation (BL), and Bicubic Interpolation (BC). Figure 1 illustrates how the grey scale values are determined for a location (X) in between pixels (represented by a dot) for the three techniques. For NN there is a direct assignment (indicated by an arrow) of a grey scale value of the pixel that is closest to the location X. For the interpolation techniques, the lines connecting pixels show the pixels used in interpolating to determine a grey scale value at the location represented by deltas. The lines connecting the deltas show another interpolation process required to determine the grey scale value at the desired location X. The BL requires a pair of pixel grey scale values, while the BC requires a set of four pixel grey scale values.

The objectives of the effort are to determine what effects are observed when image data are geographically corrected using the three techniques and to be aware of potential impacts these effects may have on image compression and classification. Effects imply that there will be a deviation between what is observed and what is expected or at least a change will be noticed as a result of the registration (geographic correction) process. In this case, there are only three basic questions that can be asked: what has changed, how much change is there, and where do these changes occur?

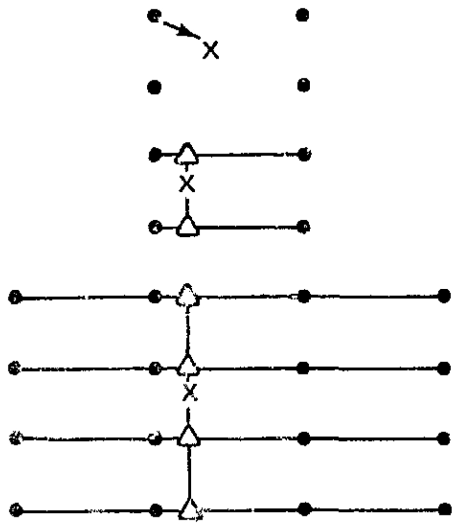

Figure 1. Grey scale determination for NN, BL, and BC at location X.

II. BRIEF DESCRIPTION OF THE IMAGE DATA

The data set consisted of Landsat digital imagery, April 4, 1973, ID Number 1265-15444. The test site extracted from that imagery was 255 pixels wide and 200 scans long, and corresponded to the Bald Knob, Tennessee Quadrangle. The data were geographically corrected to correspond to a digital ground truth map (GTM), supplied by the Tennessee State Planning Office (TSPO) of Nashville, Tennessee, that was 565 pixels wide and 500 scans long. This particular data set has been extensively described, literally and pictorially, as well as extensively classified with various classification techniques that are discussed in a NASA Report.[1] According to the ground truth information, the test site is 0.83 percent urban, 2.53 percent transportation/ communication, 28.68 percent agriculture, 65.93 percent forest, and 2.03 percent water.

1. Jayroe, R., Atkinson, R., Dasarathy, B., Lybanon, M., Ramapriyan, H.: Classification Software Technique Assessment. NASA Technical Note, NASA TN D-8240, May 1976.

III. RESULTS

To determine what had changed and how much change was observed, histograms were computed for the original four bands of data and for the four bands of data that were geographically corrected using NN, BL, and BC. The histograms of the original image had to be normalized so that all of the histograms contain the same number of pixels, because the original image was approximately four times smaller than the geographically correct image. Tables 1 through 4 show this information for the four bands as well as histogram deviations between the original data and the geographically corrected data. Maxima and minima of the histograms are indicated by X and N, respectively, and the mode of the histogram is indicated by XX. The lines separating grey scale values show where each band was density sliced to produce grey scale images. In the columns of deviations, a plus sign indicates that more pixels of a particular grey scale value were requested to be transferred from the original image to the corrected image than were present in the original image. A minus sign indicates that not all of the pixels of a particular grey scale value were requested to be transferred from the original to the corrected image.

One possible interpretation is that the number of pixels with grey scale values that were left over on the original image (indicated by a minus sign) had their grey scale values changed to accommodate a request for more pixels of another grey scale value (indicated by a plus sign). In this sense, the number of grey scale value changes that occurred is shown as absolute value sums under the deviation columns. This number divided by two is the number of pixels which had their grey scale values changed. The numbers under the four columns to the left of the deviation columns show that all of the histograms for the test site contain 211 075 pixels.

Examination of the maxima and minima of the histograms shows that NN most nearly preserves the histogram structure of the original data, while the interpolation methods act as a filter smoothing away most of the structure. This tends to make the procedure of choosing density slices more difficult because all of the natural indications in the data are no longer there. Also, the least amount of grey scale changes occur for NN. Table 5 shows the statistics calculated from the histograms, and indicates that, although the mode of the histogram may change, the mean value appears to be changed very little. However, the variance is reduced quite considerably in some cases. Table 6 is a summary of the number of pixels that had their grey scale values changed and the resulting percent changes in the histograms.

TABLE 1. CHANNEL 1 HISTOGRAMS AND DEVIATIONS FOR TSPO DATA SET

Grey Scale Value	Original Data	NN	BL	BC	Deviations					
					NN-O	BL-O	BC-O	BL-NN	BC-NN	BC-BL
21	12 X	11 X	0	10	- 1	- 12	- 2	- 11	- 1	+ 10
22	4 N	3 N	8	41	- 1	+ 4	+ 37	+ 5	+ 38	+ 33
23	264	253	72	280	- 11	- 102	+ 16	- 181	+ 27	+ 208
24	1 380	1 342	598	1 446	- 38	- 782	+ 66	- 744	+ 104	+ 848
25	4 562	4 542	3 111	5 400	- 20	-1 451	+ 838	-1 431	+ 858	+2 289
26	13 339	13 346	11 332	13 276	+ 7	-2 006	- 62	-2 013	- 69	+1 944
27	25 476	25 292	23 189	23 728	-184	-2 287	-1 748	-2 103	-1 564	+ 539
28	34 358 X	33 994 X	34 503 XX	31 682 XX	-364	+ 145	-2 676	+ 509	-2 312	-2 821
29	18 566 N	18 413 N	27 999	25 664 N	-153	+9 433	+7 098	+9 586	+7 251	-2 335
30	34 467 XX	31 470 XX	27 208	26 044 X	-297	-7 259	-8 423	-6 962	-8 1[illegible]	-1 164
31	12 206 N	12 367 N	18 096	17 703	+161	+5 890	+5 497	+5 729	+5 336	- 393
32	15 469 X	15 712 X	16 062	15 322	+243	+ 593	- 147	+ 350	- 390	- 740
33	14 584	14 752	15 043	14 222	+168	+ 459	- 362	+ 291	- 530	- 821
34	14 256	14376	12 666	12 355	+120	-1 590	-1 901	-1 710	-2 021	- 311
35	7 826	7 965	8 065	8 146	+139	+ 239	+ 320	+ 100	+ 181	+ 81
36	2 850 N	2 908 N	4 884	5 193	+ 58	+2 034	+2 343	+1 976	+2 285	+ 309
37	5 350 X	5 433 X	3 465	3 839	+ 83	-1 885	-1 511	-1 968	-1 594	+ 374
38	1 843	1 875	1 814	2 389	+ 32	- 29	+ 546	- 61	+ 514	+ 575
39	1 583	1 622	1 082	1 488	+ 39	- 501	- 95	- 540	- 134	+ 406
40	649 N	665 N	630	918	+ 16	- 19	+ 269	- 35	+ 253	+ 288
41	946 X	950 X	393	617	+ 4	- 553	- 329	- 557	- 333	+ 224
42	170	180	222	341	+ 10	+ 52	+ 171	+ 42	+ 161	+ 119
43	130 N	134 N	157	228	+ 4	+ 27	+ 98	+ 23	+ 94	+ 71
44	203 X	205 X	111	169	+ 2	- 92	- 34	- 94	- 36	+ 58
45	170	163	87	136	- 7	- 83	- 34	- 76	- 27	+ 49
46	81	77	66	89	- 4	- 15	+ 8	- 11	+ 12	+ 23
47	20 N	19 N	48	76	- 1	+ 28	+ 56	+ 29	+ 57	+ 28
48	110 X	102 X	34	51	- 8	- 76	- 59	- 68	- 51	+ 17
49	28	27	34	48	- 1	+ 6	+ 20	+ 7	+ 21	+ 14
50	20 N	18 N	28	35 N	- 2	+ 8	+ 15	+ 10	+ 17	+ 7
51	45 X	41	24	37 X	- 4	- 21	- 8	- 17	- 4	+ 13
52	41	44 X	9	28	+ 3	- 32	- 13	- 35	- 16	+ 19
53	28	30	9 N	20	+ 2	- 19	- 8	- 21	- 10	+ 11
54	0	0	10 X	14	0	+ 10	+ 14	+ 10	+ 14	+ 4
55	0 N	0 N	5	9	0	+ 5	+ 9	+ 5	+ 9	+ 4
56	24 X	26 X	5	7	+ 2	- 19	- 17	- 21	- 19	+ 2
57	4	4	4	5	0	0	+ 1	0	+ 1	+ 1
58	0 N	0	1	4 N	0	+ 1	+ 4	+ 1	+ 4	+ 3
59	12 X	15 X	1	9 X	+ 3	- 11	- 3	- 14	- 6	+ 8
60	0	0	0	4	0	0	+ 4	0	+ 4	+ 4
61	0	0	0	2	0	0	+ 2	0	+ 2	+ 2
	211 075	211 075	211 075	211 075	|2192|	|37 889|	|34 864|	|37 346|	|34 486|	|17 170|

TABLE 2. CHANNEL 2 HISTOGRAMS AND DEVIATIONS FOR TSPO DATA SET

Grey Scale Value	Original Data	NN	BL	BC	Deviations					
					NN-O	BL-O	BC-O	BL-NN	BC-NN	BC-BL
12	0	0	0	3	0	0	+ 3	0	+ 3	+ 3
13	0	0	0	16	0	0	+ 16	0	+ 16	+ 16
14	24	28	4	81	+ 4	- 20	+ 57	+ 24	+ 53	+ 77
15	264	271	45	274	+ 7	- 219	+ 10	- 226	+ 3	+ 229
16	625	315	249	556	- 10	- 376	- 69	- 366	- 59	+ 307
17	718	729	577	980	+ 11	- 141	+ 262	152	+ 251	+ 403
18	2 488 X	2 493 X	1 184	1 737	+ 5	-1 304	- 751	-1 309	- 756	+ 553
19	649 N	664 N	1 859	2 563	+ 15	+1 210	+1 914	+1 195	+1 899	+ 704
20	4 997	5 013	3 469	4 870	+ 16	-1 528	- 127	-1 544	- 143	+1 401
21	7 375	7 416	6 683	8 081	+ 41	- 692	+ 706	- 733	+ 665	+1 398
22	14 764	14 898	11 564	12 504	+134	-3 200	-2 260	-3 334	-2 394	+ 940
23	15 303	15 438	15 985	15 514	+135	+ 682	+ 211	+ 547	+ 76	- 471
24	20 528 X	20 560 X	19 598	18 105	+ 32	- 930	-2 423	- 962	-2 455	-1 493
25	14 239 N	14 231 N	21 178	19 679	- 8	+6 939	+5 440	+6 947	+5 448	-1 499
26	21 644	21 633	24 229	21 810	- 11	+2 585	+ 166	+2 596	+ 177	-2 419
27	27 059 XX	27 015 XX	26 232 XX	[illegible]74 XX	- 44	- 827	-2 886	- 783	-2 841	-2 058
28	23 487	23 317	22 797	[illegible]95	-170	- 690	-1 492	- 520	-1 322	- 802
29	18 973	18 639	15 696	1[illegible]80	-334	-3 277	-3 093	-2 943	-2 759	+ 184
30	3 422 N	3 400 N	10 052	9 982	- 22	+6 630	+6 560	+6 652	+6 582	- 70
31	11 605 X	11 537 X	8 340	8 177	- 68	-3 265	-3 428	-3 197	-3 360	- 163
32	5 338	5 407	5 407	5 842	+ 69	+ 69	+ 504	0	+ 435	+ 435
33	3 069 N	3 119 N	3 732	3 989	+ 50	+ 663	+ 920	+ 613	+ 870	+ 257
34	3 759 X	3 792 X	2 966	3 047	+ 33	- 793	- 712	- 826	- 745	+ 81
35	2 423	2 427	1 888	2 253	+ 4	- 535	- 170	- 539	- 174	+ 365
36	1 080 N	1 094 N	1 433	1 574	+ 14	+ 353	+ 494	+ 339	+ 480	+ 141
37	1 676 X	1 691 X	1 104	1 340	+ 15	- 572	- 336	- 587	- 351	+ 236
38	710	733	829	1 011	+ 23	+ 119	+ 301	+ 96	+ 278	+ 182
39	613 N	622 N	718	806	+ 9	+ 105	+ 193	+ 96	+ 184	+ 88
40	844 X	856 X	559	688	+ 12	- 285	- 156	- 297	- 168	+ 129
41	361 N	363 N	459	587	+ 2	+ 98	+ 226	+ 96	+ 224	+ 128
42	601 X	611 X	344	447	+ 10	- 257	- 154	- 267	- 164	+ 103
43	231 N	236 N	323	383	+ 5	+ 92	+ 152	+ 87	+ 147	+ 60
44	264	254	276	312	- 10	+ 12	+ 48	+ 22	+ 58	+ 36
45	447 X	458 X	250	258	+ 11	- 197	- 189	- 208	- 200	+ 8
46	329	335	165	258	+ 6	- 164	- 71	- 170	- 77	+ 93
47	101 N	107 N	133 N	181	+ 6	+ 32	+ 80	+ 26	+ 74	+ 48
48	207 X	213 X	138 X	175	+ 6	- 69	- 32	- 75	- 38	+ 37
49	77	80	78 N	111	+ 3	+ 1	+ 34	- 2	+ 31	+ 33
50	69 N	68 N	87 X	132	- 1	+ 18	+ 63	+ 19	+ 64	+ 45
51	106 X	109 X	79	90	+ 3	- 27	- 16	- 30	- 19	+ 11
52	77	72 N	57 N	86	- 5	- 20	+ 9	- 15	+ 14	+ 29
53	77	81 X	58 X	84	+ 4	- 19	+ 7	- 23	+ 3	+ 26
54	37 N	35 N	28 N	54	- 2	- 9	+ 17	- 7	+ 19	+ 26
55	101 X	100 X	28	50	- 1	- 73	- 51	- 72	- 50	+ 22
56	28 N	25 N	36 X	47	- 3	+ 8	+ 19	+ 11	+ 22	+ 11
57	32 X	31	27	41	- 1	- 5	+ 9	- 4	+ 10	+ 14
58	32	33 X	22	39	- 1	- 10	+ 7	- 11	+ 6	+ 17
59	32	31	18	31	- 1	- 14	- 1	- 13	0	+ 13
60	24 N	27 N	16 N	23	+ 3	- 8	- 1	- 11	- 4	+ 7
61	32	31	27 X	27	- 1	- 5	- 5	- 4	- 4	0
62	49 X	48 X	16	23	- 1	- 33	- 26	- 32	- 25	+ 7
63	16 N	17 N	12	19	+ 1	- 4	+ 3	- 5	+ 2	+ 7
64	41 X	42 X	11	20	+ 1	- 30	- 21	- 31	- 22	+ 9
65	0	0	1 N	18	0	+ 1	+ 18	+ 1	+ 18	+ 17
66	0 N	0 N	4	9	0	+ 4	+ 9	+ 4	+ 9	+ 5
67	16 X	17 X	4 X	14	+ 1	- 12	- 2	- 13	- 3	+ 10
68	4	4	0	4	0	- 4	0	- 4	0	+ 4
69	4	4 N	1	7	0	- 3	+ 3	- 3	+ 3	+ 6
70	4	5 X	0	2	+ 1	- 4	- 2	- 5	- 3	+ 2
71	0	0	0	7	0	0	+ 7	0	+ 7	+ 7
72	0	0	0	1	0	0	+ 1	0	+ 1	+ 1
73	0	0	0	3	0	0	+ 3	0	+ 3	+ 3
74	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0
77	0	0	0	1	0	0	+ 1	[illegible]	+ 1	+ 1
	211 075	211 075	211 075	211 075	|1386|	|39 242|	|36 946|	|38 694|	|36 272|	|17 950|

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TABLE 3. CHANNEL 3 HISTOGRAMS AND DEVIATIONS FOR TSPO DATA SET

Grey Scale Value	Original Data	NN	BL	BC	Deviations					
					NN-O	BL-O	BC-O	BL-NN	BC-NN	BC-BL
7	0	0	0	2	0	0	+ 2	0	+ 2	+ 2
8	0	0	0	6	0	0	+ 6	0	+ 6	+ 6
9	4 X	4 X	0	15	0	- 4	+ 11	- 4	+ 11	+ 15
10	0 N	0 N	0	32	0	0	+ 32	0	+ 32	+ 32
11	45	47	1	74	+ 2	- 44	+ 29	- 46	+ 27	+ 73
12	66	66	6	95	- 1	- 60	+ 30	- 60	+ 29	+ 89
13	223 X	221 X	32	153	- 2	- 191	- 70	- 189	- 68	+ 121
14	176	174 N	79	171	- 1	- 96	- 4	- 95	- 3	+ 92
15	166	176 X	108	169	+ 10	- 58	+ 3	- 68	- 7	+ 61
16	89 N	44 N	140	140	+ 5	+ 51	+ 60	+ 46	+ 58	+ 0
17	207 X	201 X	160 X	137	- 6	- 27	- 70	- 21	- 64	- 42
18	195	194	180	156	- 1	- 15	- 39	- 14	- 38	- 24
19	179	185 N	162 N	165	+ 6	- 17	- 14	- 23	- 20	+ 3
20	170	186 X	173	183	+ 16	+ 3	+ 13	- 13	- 3	+ 10
21	142 N	145 N	218	223	+ 3	+ 76	+ 81	+ 73	+ 78	+ 5
22	276	274	220	284	- 2	56	+ 8	- 54	+ 10	+ 64
23	402	403	300	463	+ 1	- 102	+ 61	- 103	+ 60	+ 163
24	544	567	499	783	+ 23	- 45	- 239	- 68	+ 216	+ 284
25	1 514	1 533	915	1 333	+ 19	- 599	- 181	- 618	- 200	+ 418
26	1 660	1 694	1 489	2 195	+ 34	- 171	+ 535	- 205	+ 504	+ 709
27	4 083	4 111	2 890	3 628	+ 28	-1 193	- 455	-1 221	- 483	+ 738
28	4 181	4 155	4 832	5 635	- 26	+ 651	+1 454	+ 677	+1 480	+ 803
29	9 362	9 279	9 013	9 776	- 83	- 349	+ 414	- 266	+ 497	+ 763
30	13 679	13 615	12 000	12 208	- 64	-1 679	-1 471	-1 615	-1 407	+ 208
31	14 800	14 666	14 894	14 332	-134	+ 94	- 468	+ 228	- 334	- 562
32	17 170 X	17 093 X	15 770 XX	14 693 XX	- 77	-1 400	-2 477	-1 323	-2 400	-1 077
33	8 320 N	8 293 N	14 830	13 687 N	- 26	+6 510	+5 358	+6 540	+5 394	-1 152
34	20 760 XX	20 284 XX	14 586	13 694 X	-476	-6 174	-7 066	-5 698	-6 590	- 891
35	4 855 N	4 739 N	11 974	11 450	-116	+7 119	+6 594	+7 235	+6 700	- 525
36	17 687 X	17 358 X	11 269	10 921	-329	-6 418	-6 766	-6 089	-6 437	- 348
37	4 060 N	4 041 N	8 213	8 060	- 18	+4 154	+4 001	+4 172	+4 019	153
38	9 969 X	9 955 X	6 557	6 777	- 14	-3 412	-3 192	-3 398	-3 178	+ 220
39	1 409 N	1 413 N	4 577	4 591	+ 4	+3 168	+3 182	+3 164	+3 178	+ 14
40	6 263 X	6 314 X	3 923	4 022	+ 51	-2 340	-2 241	-2 391	-2 292	+ 99
41	483 N	493 N	3 076 N	3 153	+ 10	+2 593	+2 670	+2 583	+2 660	+ 77
42	4 493 X	4 535 X	3 086 X	2 992	+ 42	-1 407	-1 501	-1 449	-1 543	- 94
43	2 606	2 668	3 004	2 849	+ 62	+ 398	+ 243	+ 336	+ 181	- 155
44	2 054 N	2 055	2 870 N	2 807 N	+ 1	+ 816	+ 753	+ 815	+ 752	- 63
45	4 851 X	4 873 X	3 182 X	2 897 X	+ 22	-1 669	-1 954	-1 691	-1 976	- 285
46	1 242 N	1 276 N	3 088 N	2 894 N	+ 34	+1 846	+1 652	+1 812	+1 618	- 194
47	3 576 X	3 653 X	3 273	3 091 X	+ 77	- 303	- 485	- 380	- 562	- 182
48	2 164 N	2 221 N	3 309	3 075 N	+ 57	+1 145	+ 911	+1 088	+ 854	- 234
49	4 286 X	4 341 X	3 610	3 257	+ 55	- 676	-1 029	- 731	-1 084	- 353
50	2 902 N	2 922 N	3 659	3 498	+ 20	+ 757	+ 596	+ 737	+ 576	- 161
51	3 653	3 708	3 866	3 574	+ 55	+ 213	- 79	+ 158	- 134	- 292
52	4 372 X	4 477 X	3 970	3 804	+105	- 402	- 568	- 507	- 673	- 166
53	3 706 N	3 797 N	4 064	3 827	+ 91	+ 358	+ 121	+ 267	+ 30	- 237
54	3 937 X	3 996 X	4 109 X	3 861 X	+ 59	+ 172	- 76	+ 113	- 135	- 248
55	2 850 N	2 919 N	3 997	3 754	+ 69	+1 147	+ 904	+1 078	+ 835	- 243
56	4 680 X	4 720 X	3 697	3 657	+ 40	- 983	-1 023	-1 023	-1 063	- 40
57	2 769	2 836	3 392	3 365	+ 40	+ 603	+ 599	+ 557	+ 536	- 4
58	1 969 N	2 011 N	2 882	3 023	+ 42	+ 913	+1 054	+ 871	+1 012	+ 141
59	4 128 X	4 226 X	2 640	2 818	+ 98	-1 488	-1 310	-1 586	-1 408	+ 178
60	1 961 N	2 013 N	2 161	2 360	+ 52	+ 200	+ 399	+ 148	+ 347	+ 199
61	2 245 X	2 295 X	1 658	2 007	+ 50	- 587	- 238	- 637	- 288	+ 349
62	1 266	1 330	1 083	1 509	+ 64	- 183	+ 243	- 247	+ 179	+ 426
63	544 N	549 N	755	1 149	+ 5	+ 211	+ 605	+ 206	+ 600	+ 394
64	1 043 X	1 046 X	596	788	+ 5	- 447	- 255	- 450	- 258	+ 192
65	595	601	382	578	+ 6	- 203	- 7	- 209	- 13	+ 196
66	290 N	300 N	264	398	+ 10	- 26	+ 108	- 36	+ 98	+ 134
67	373 X	377 X	158	303	+ 4	- 215	- 70	- 219	- 71	+ 145
68	81 N	75 N	86	188	- 6	+ 5	+ 107	+ 11	+ 113	+ 102
69	134 X	131 X	38	118	- 3	- 96	- 16	- 93	- 13	+ 80
70	57	62	31	70	+ 5	- 26	+ 13	- 31	+ 8	+ 39
71	20 N	21 N	24	58	+ 1	+ 4	+ 38	+ 3	+ 37	+ 34
72	28 X	31 X	11	36	+ 3	- 17	+ 8	- 20	+ 5	+ 25
73	28	28	6	18	0	- 22	- 10	- 22	- 10	+ 12
74	0	0	6	16	0	+ 6	+ 16	+ 6	+ 16	+ 10
75	0	0	2 N	7	0	+ 2	+ 7	+ 2	+ 7	+ 5
76	20 X	21 X	6 X	3	+ 1	- 14	- 17	- 15	- 18	- 3
77	0	0	3	2 N	0	+ 3	+ 2	+ 3	+ 2	- 1
78	0	0	0	3	0	0	+ 3	0	+ 3	+ 3
79	4	4	1	6 X	0	- 3	+ 2	- 3	+ 2	+ 5
80	0	0	2	2	0	+ 2	+ 2	+ 2	+ 2	0
81	0	0	0	2	0	0	+ 2	0	+ 2	+ 2
82	4	5	0	1	+ 1	- 4	- 3	- 5	- 4	+ 1
	211 075	211 075	211 075	211 075	|2756|	|66 [illegible]86|	|66 058|	|65 874|	|65 560|	|15 480|

TABLE 4. CHANNEL 4 HISTOGRAMS AND DEVIATIONS FOR TSPO DATA SET

Grey Scale Value	Original Data	NN	BL	BC	Deviations NN-O	BL-O	BC-O	BL-NN	BC-NN	BC-BL
1	0	0	0	8	0	0	+ 8	0	+ 8	+ 8
2	4	5	0	58	+ 1	- 4	+ 54	- 5	+ 53	+ 58
3	73	72	8	115	- 1	- 65	+ 42	- 64	+ 43	+ 107
4	231	233	36	207	+ 2	- 195	- 24	- 197	- 26	+ 171
5	204 X	207 X	125	202	+ 3	- 139	- 62	- 142	- 65	+ 77
6	223	226	177	184	+ 3	- 46	- 39	- 49	- 42	+ 7
7	207 N	209 N	219	210	+ 2	+ 12	+ 3	+ 10	+ 1	- 9
8	248 X	260 X	240	260	+ 12	- 8	+ 12	- 20	0	+ 20
9	211 N	218 N	230	267	+ 7	+ 19	+ 56	+ 12	+ 49	+ 37
10	333	320	291	279	- 13	- 42	- 54	- 29	- 41	- 12
11	373	383	371	400	+ 10	- 2	+ 27	- 12	+ 17	+ 29
12	467	482	455	632	+ 15	- 12	+ 165	- 27	+150	+ 177
13	1 031	1 047	805	1 188	+ 16	- 226	+ 157	- 242	+141	+ 383
14	2 529	2 585	1 999	2 797	+ 56	- 530	+ 268	- 586	+212	+ 798
15	6 058	6 041	4 872	5 964	- 17	- 186	+ 906	- 169	+923	+1 092
16	12 579	12 626	11 330	12 246	+ 47	-1 249	+ 333	-1 296	-380	+ 916
17	18 376	18 295	18 378	18 240	- 81	+ 2	- 136	+ 83	- 55	- 138
18	22 734	[illegible]	23 367	22 029	- 45	+ 633	- 705	+ 878	-400	-1 338
19	24 201 XX	[illegible] XX	25 085	23 774	-30[illegible]	+ 884	- 427	+1 189	-122	-1 311
20	22 126	21 [illegible]	21 884	21 024	-426	- 242	-1102	+ 184	-676	- 860
21	17 008	16 715	16 606	16 375	-298	- 402	- 633	- 104	-335	- 231
22	10 692	10 679	10 369	10 742	- 13	- 323	+ 50	- 310	+ 63	+ 373
23	5 991	6 013	6 600	6 748	+ 22	+ 609	+ 757	+ 587	+735	+ 148
24	5 853	5 955	5 492	5 382	+102	- 361	- 471	- 463	-573	- 110
25	4 477 N	4 540 N	5 129	4 875	+ 63	+ 652	+ 398	+ 589	+335	- 254
26	4 599 X	4 654 X	5 205	4 783	+ 55	+ 606	+ 184	+ 551	+129	- 422
27	4 579 N	4 646 N	5 130	4 819	+ 67	+ 551	+ 240	+ 484	+173	- 311
28	5 115	5 243	5 295	5 050	+128	+ 180	- 65	+ 52	-193	- 245
29	5 261	5 348	5 668	5 200	+ 87	+ 407	- 61	+ 320	-148	- 468
30	5 330 X	5 429 X	5 561	5 148	+ 99	+ 231	- 182	+ 132	-281	- 413
31	4 611 N	4 701 N	5 397	5 129	+ 90	+ 786	+ 518	+ 696	+428	- 268
32	5 366 X	5 451 X	5 324	4 991	+ 85	- 42	- 375	- 127	-460	- 333
33	4 445	4 509	4 512	4 585	+ 64	+ 67	+ 140	+ 3	+ 76	+ 73
34	3 657	3 708	3 563	3 888	+ 51	- 94	+ 231	- 145	+180	+ 325
35	2 971	3 019	2 868	3 095	+ 48	- 103	+ 124	- 151	+ 76	+ 227
36	2 565	2 642	2 290	2 484	+ 77	- 275	- 81	- 352	-158	+ 194
37	1 957	2 027	1 840	1 968	+ 70	- 117	+ 11	- 187	- 59	+ 128
38	1 510	1 524	1 350	1 631	+ 14	- 160	+ 121	- 174	+107	+ 281
39	1 165	1 193	1 044	1 266	+ 28	- 121	+ 101	- 149	+ 73	+ 222
40	1 015	1 056	738	965	+ 41	- 277	- 50	- 318	- 91	+ 227
41	572	593	494	671	+ 21	- 78	+ 99	- 99	+ 78	+ 177
42	406	397	291	421	- 9	- 115	+ 15	- 106	+ 24	+ 130
43	244	264	217	279	+ 20	- 27	+ 35	- 47	+ 15	+ 62
44	223	229	136	216	+ 6	- 87	- 7	- 93	- 13	+ 80
45	130	127	68	140	- 3	- 62	+ 10	- 59	+ 13	+ 72
46	49	48	12	81	- 1	- 37	+ 32	- 36	+ 33	+ 69
47	12	12	4	36	0	- 8	+ 24	- 8	+ 24	+ 32
48	4	4	0	18	0	- 4	+ 14	- 4	+ 14	+ 18
49	0	0	0	5	0	0	+ 5	0	+ 5	+ 5
	211 075	211 075	211 075	211 075	|2824|	|11 278|	|9614|	|11 540|	|8356|	|13 446|

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TABLE 5. HISTOGRAM STATISTICS FOR TSPO DATA SET

	Channel 1				Channel 2			
	Original	NN	BL	BC	Original	NN	BL	BC
Mode	30.00	30.00	28.00	28.00	27.00	27.00	27.00	27.00
Mean	30.24	30.27	30.27	30.27	26.80	26.80	26.80	26.79
Mean Square	926.15	924.33	922.41	924.38	738.67	737.25	733.53	737.68
Variance	11.70	8.21	6.46	8.31	20.49	19.24	15.52	19.82
rms	3.42	2.86	2.54	2.88	4.53	4.37	3.94	4.45
	Channel 3				**Channel 4**			
	Original	NN	BL	BC	Original	NN	BL	BC
Mode	34.00	34.00	32.00	32.00	19.00	19.00	19.00	19.00
Mean	39.14	39.24	39.24	39.24	22.37	22.43	22.43	22.42
Mean Square	1637.11	1611.92	1603.90	1612.01	541.83	541.89	538.47	542.27
Variance	105.49	72.08	63.99	72.50	41.54	38.84	35.52	39.53
rms	10.27	8.49	8.00	8.52	6.44	6.24	5.96	6.29

TABLE 6. HISTOGRAM DEVIATION STATISTICS FOR TSPO DATA SET

		NN-O	BL-O	BC-O	BL-NN	BC-NN	BC-BL
Channel 1	# Changes	1096	18 940	17 432	18 673	17 243	8585
	% Change	0.52	8.97	8.26	8.85	8.17	4.07
Channel 2	# Changes	693	19 621	18 473	19 347	18 136	8975
	% Change	0.33	9.30	8.75	9.17	8.59	4.25
Channel 3	# Changes	1393	33 243	33 004	32 937	32 780	7740
	% Change	0.66	15.75	15.64	15.60	15.53	3.67
Channel 4	# Changes	1412	5 639	4 807	5 770	4 178	6723
	% Change	0.67	2.67	2.28	2.73	1.98	3.19

#Changes is the number of pixels that had to have their grey scale values reassigned. The transformation/ registration algorithm either:

1. Did not select all the pixels from a particular grey scale, some were left over; or

2. Selected more pixels than were available from a particular grey, hence the pixels that were left over had to be relabeled.

Figures 2 through 5 present black and white representations of color coded joint histograms between channels 2 and 3 for the original data and for the three geographically corrected sets of data. In the figures white represents no simultaneous occurrence of pixel values in channels 2 and 3 except for the portion that appears in all the figures near the bottom of the joint histograms. In this case, white shows where a majority of the data occur and these data belong mostly to the forest category. Again, NN preserves most of the structure of the original joint histogram and the filtering or smoothing effect of the interpolation techniques is visible in Figures 4 and 5.

Figures 6 and 7 show the result of density slicing the original data and the BC corrected data, respectively, for channel 1 using the slices indicated in Table 1. In Figures 6 and 7, the lighter areas represent forest and the darker areas represent agriculture. The curvilinear feature at the left (west) center edge of the image is a portion of a river, which continues across the center of the image. The curvilinear feature starting at the middle of the bottom (south) edge of the image and continuing towards the top left corner is a highway. If Figure 6 is viewed from an east-west direction, the linear pattern of banding is evident. However, if Figure 7 is viewed from an east-west direction the banding is considerably less evident. BL and BC tend to reduce the banding problem, whereas NN does not.

To determine where the deviations occur, absolute value difference histograms and images were computed for the three geographic correction techniques. The images obtained from using NN, BL, and BC can only be compared with themselves and not with the original image, which has a different coordinate system. The first column in Table 7 is the absolute value grey scale differences that can occur when the geographically corrected images are absolute value differenced. The next four columns are the number of pixels in each channel that have a particular absolute value grey scale difference for comparing NN and BL. The remaining eight columns are interpreted in a similar manner. Table 8 shows the accumulative percentages for the absolute value differences. For example, when NN is being compared with BL using channel 1, 55.02 percent of both images are identical, 89.3 percent differ by ±1 or less, and 96.28 percent of both images differ by ±2 or less. Figure 8 shows an absolute value image difference of BL and BC for channel 3. The areas where the is no disagreement occur where there is no symbol, and the larger and darker symbols indicate larger absolute value differences. The largest differences appear to occur at transitions between features, such as agriculture and forest, because these features are rather clearly outlined.

Figure 2. Joint histogram of channels 2 and 3 for the original data.

Figure 3. Joint histogram of channels 2 and 3 for NN corrected data.

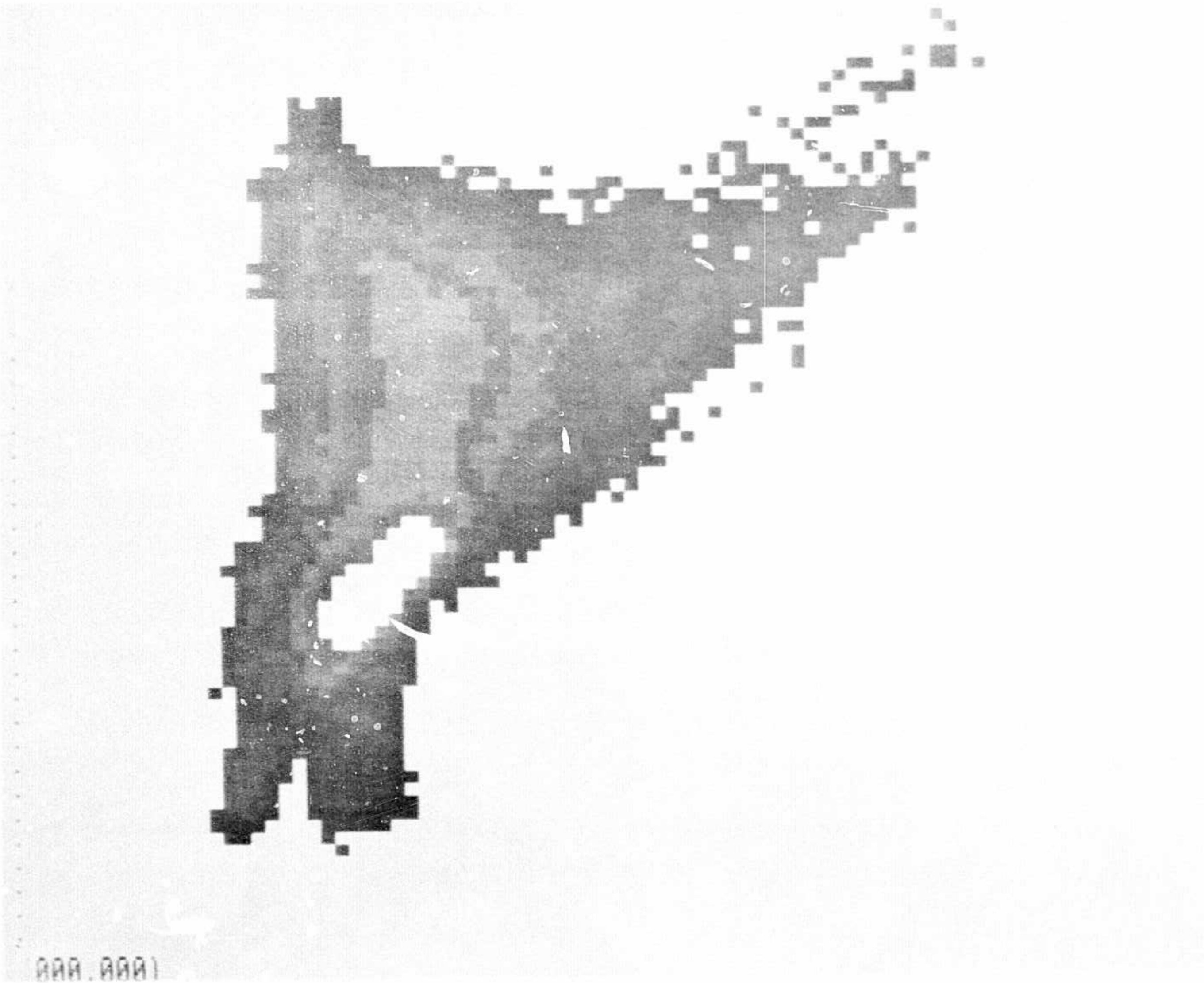

Figure 4. Joint histogram of channels 2 and 3 for BL corrected data.

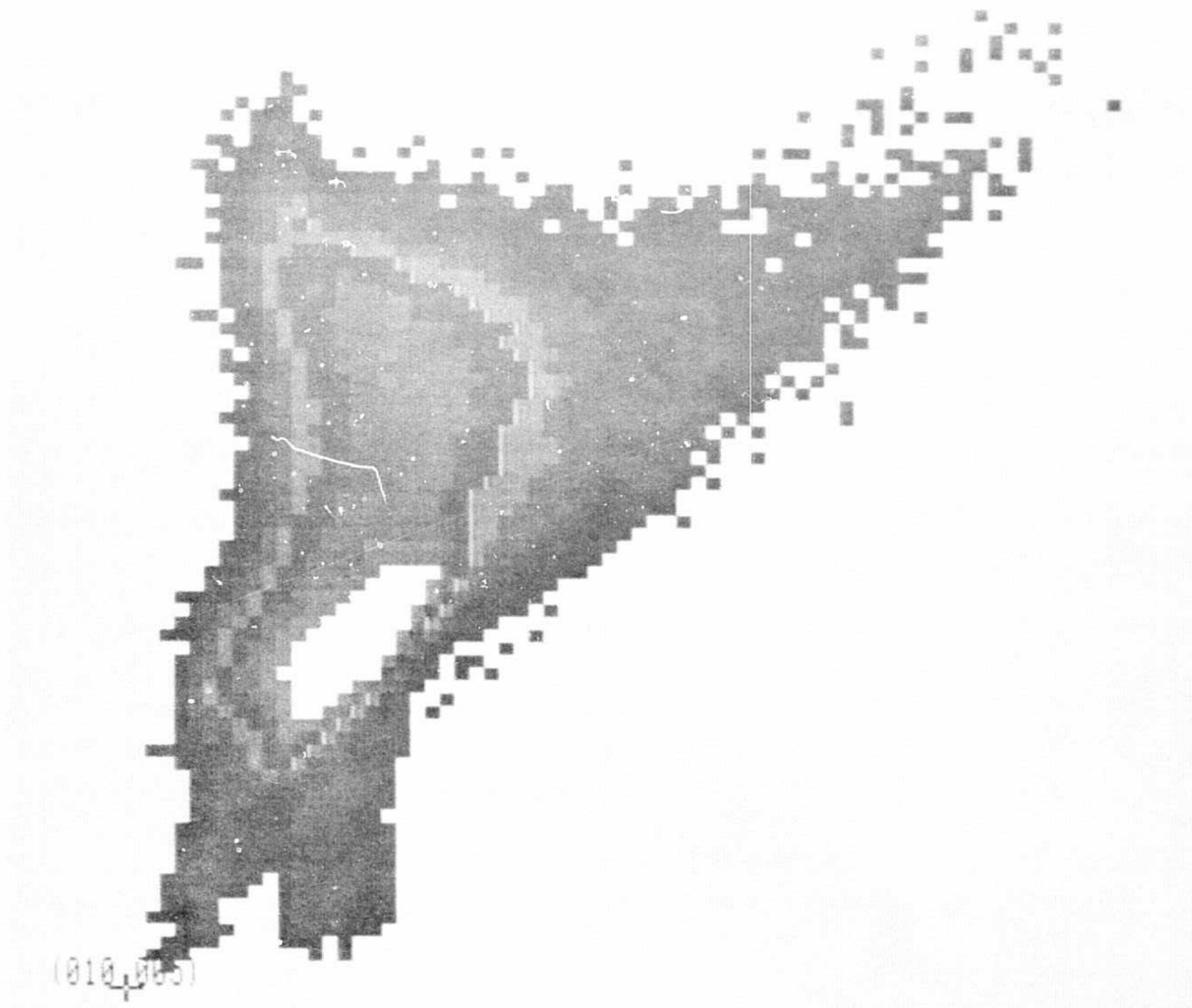

Figure 5. Joint histogram of channels 2 and 3 for BC corrected data.

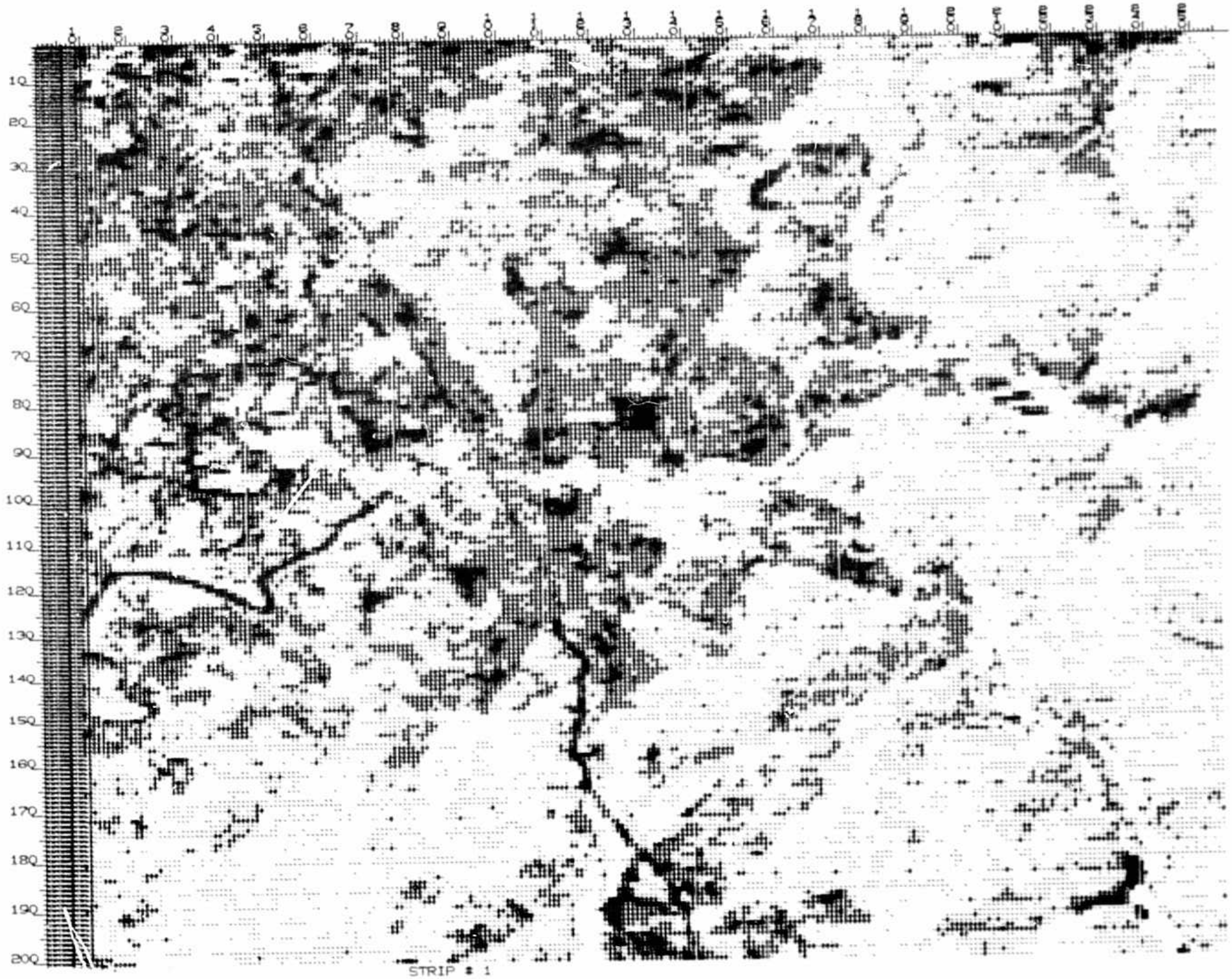

Figure 6. Density slice image of channel 1 for the original data.

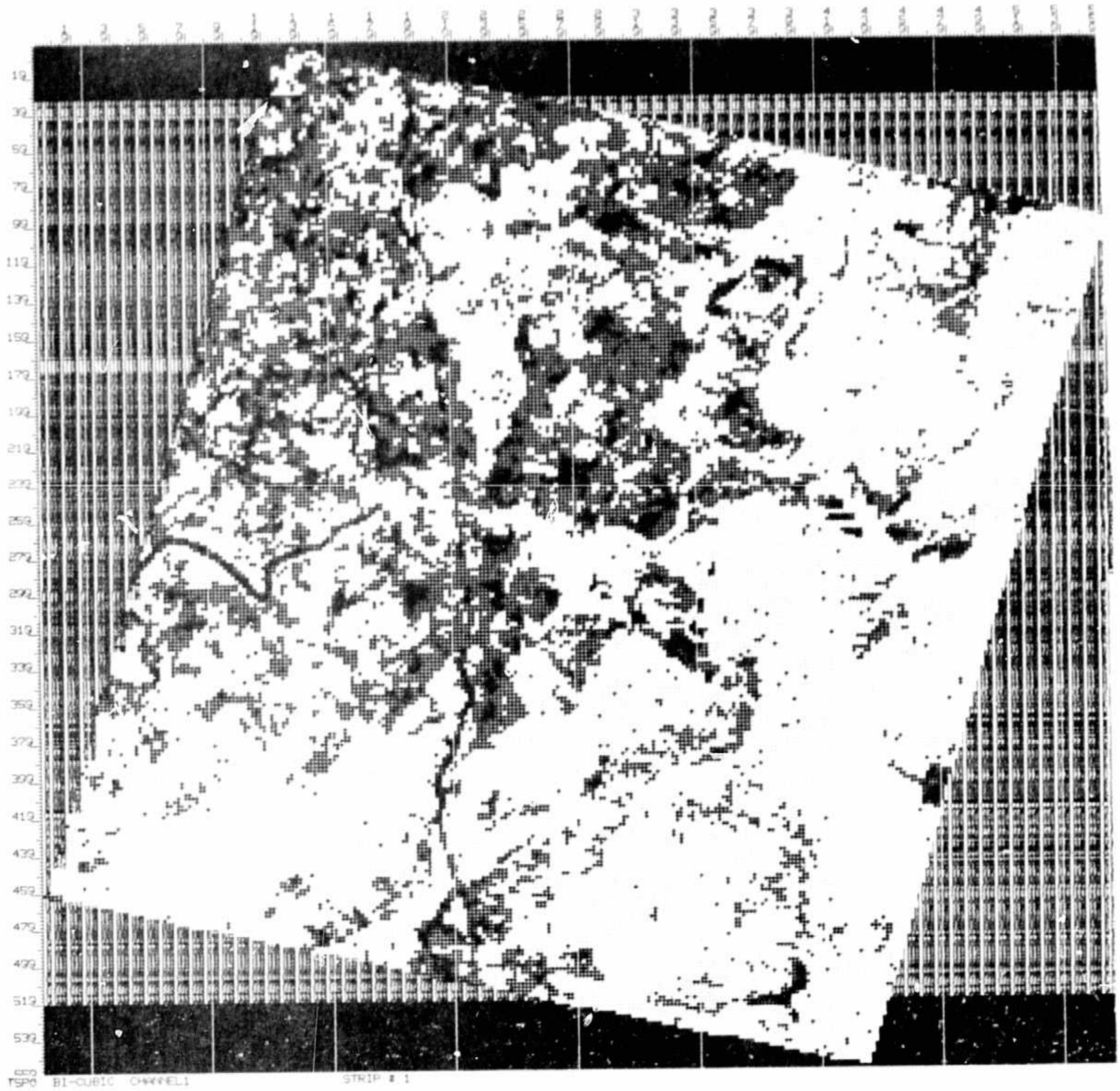

Figure 7. Density slice image of channel 1
for the BC corrected data.

TABLE 7. ABSOLUTE VALUE DIFFERENCE HISTOGRAM FOR NN, BL, AND BC OVERLAYS

	NN/BL				NN/BC				BL/BC			
	CH1	CH2	CH3	CH4	CH1	CH2	CH3	CH4	CH1	CH2	CH3	CH4
0	116 133	93 818	72 993	[illegible] 919	106 025	83 599	65 810	96 748	138 270	116 192	95 125	124 790
1	72 354	78 089	76 151	68 862	77 884	80 574	73 353	72 401	66 809	79 002	81 156	70 571
2	16 852	24 260	29 734	19 229	19 190	27 559	32 703	22 665	5 175	11 824	22 283	12 316
3	3 969	8 260	13 913	8 201	5 222	10 305	15 853	9 805	623	2 624	8 016	2 655
4	1 091	3 222	7 402	3 747	1 642	4 270	8 881	4 682	132	847	2 925	589
5	405	1 484	4 364	1 742	619	2 015	5 345	2 434	44	324	1 017	105
6	141	807	2 659	775	251	1 116	3 294	1 160	13	138	332	27
7	71	442	1 608	326	128	632	2 204	594	4	61	140	7
8	32	257	944	155	55	352	1 408	278		35	38	5
9	18	177	578	61	29	214	851	157	2	10	15	4
10	6	84	303	29	17	150	500	71	2	8	10	4
11	1	68	172	12	5	89	325	30	1	2	9	
12	1	43	109	13	3	75	201	23		3	1	1
13	1	22	69	2	2	33	126	10		1	1	1
14		19	26	1	2	28	85	10		2		
15		9	22			24	41	3			2	
16		4	14	1		16	31	3			2	
17		4	6		1	8	22	1			2	
18		5	3			4	18			1		
19			2			4	10			1		
20			2			4	2					
21						2	6					
22		1	1				2				1	
23							3					
24						1	1					
25												
26												
27												
28												
29												
30						1						

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TABLE 8. ACCUMULATIVE PERCENTAGES FOR ABSOLUTE VALUE DIFFERENCES OF NN, BL, AND BC OVERLAYS

	NN/BL				NN/BC				BL/BC			
	CH1	CH2	CH3	CH4	CH1	CH2	CH3	CH4	CH1	CH2	CH3	CH4
0	55.02	44.44	34.58	51.12	50.23	39.60	31.17	45.83	65.50	55.04	45.06	59.12
1	89.30	81.43	70.65	83.74	87.12	77.77	65.92	81.13	97.15	92.46	83.50	92.55
2	96.28	92.92	84.73	92.85	96.21	90.82	81.41	91.86			94.05	
3			91.32			95.70	88.92	96.50				
4							93.12					

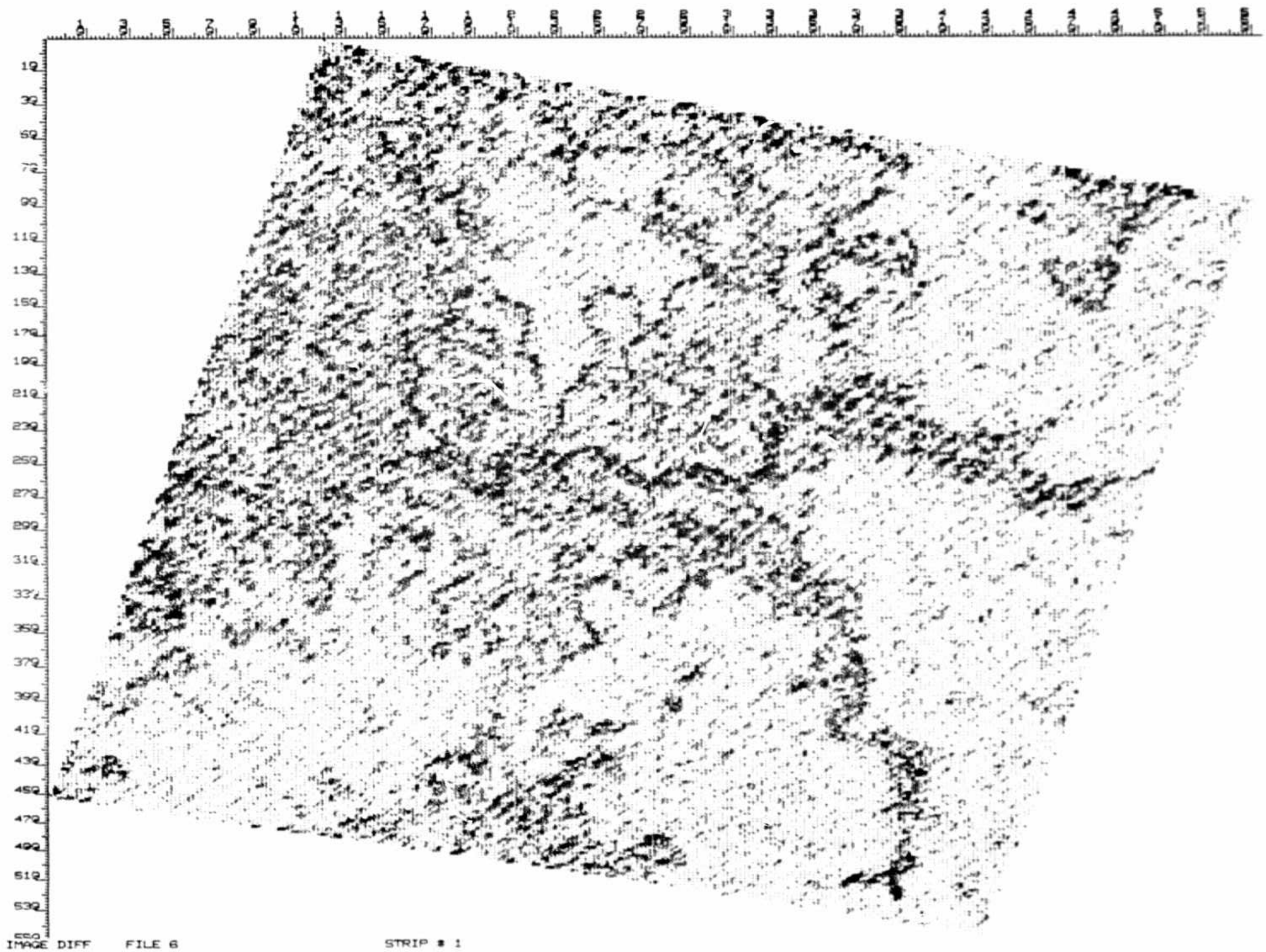

Figure 8. Absolute value image difference of BL and BC for channel 3.

A linear pattern of agreements and disagreements can be seen in the direction from the lower left corner to the upper right corner of Figure 8. The light linear patterns correspond to data taken from locations very close to pixels on the original image, and the dark linear patterns correspond to data taken from locations in between pixels on the original image. This linear pattern occurs in all the image differences with each pair of geographic correction techniques and, therefore, must be present to some degree in all of the geographically corrected data.

IV. SUMMARY OF OBSERVATIONS

Based upon the results obtained from comparing the original image data and the geographically corrected image data and from comparing the corrected data using NN, BL, and BC, the following observations were made:

a) The histograms provided information on whether or not the same number of pixels were selected from each grey scale category and transferred from the original to the geographically correct image. The histograms provide no information on where the pixel grey scale values are placed in the geographically correct image.

b) The absolute value image differences provide information on where the disagreement occurs between the correction techniques and on the consistency of the techniques, but do not indicate which technique is best.

c) In all channels, the NN histogram is most like the original data histogram in that it preserves the maxima/minima structure of the original histogram and does not create any new grey scale values.

d) The interpolation methods act as a filter smoothing out most of the original histogram maxima/minima structure and may create new great scale values that were not present in the original histogram data.

e) The following is a ranking for channels 1, 2, and 3 according to histogram similarities:

1) NN is most like O

2) BC is most like BL

3) BC is most like NN

4) BC is most like O

5) BL is most like NN

6) BL is most like O.

There was very little difference observed between categories 4) and 5) in channels 1 and 2, but were switched in channel 3.

f) The ranking for channel 4 was:

1) NN is most like O

2) BC is most like NN

3) BC is most like O

4) BL is most like O

5) BL is most like NN

6) BC is most like BL.

Comparing with the original histogram only, NN, BC, and BL, respectively, were most like O for all channels.

g) The correction techniques appear to have little effect on the image mean value, although the mode may change, but the variance of the image was reduced. In all channels, BC reduced the variance the least, then NN and BL, respectively.

h) Very little difference could be seen between the original and the geographically corrected images when density slicing was used. However, the interpolation methods appeared to partially remove some of the banding.

i) Comparisons of the geographically corrected images indicate that 30 to 65 percent of the pixels were in exact agreement, and that 65 to 97 percent of the pixels differed by ±1 or less.

j) In comparing the registration methods, the most agreements occurred in channel 1, then 4, 2 and 3.

k) The greatest disagreements appeared at transitions between two or more features, and the majority of disagreements appeared evenly spread over the image difference. The greatest disagreements appeared to show up more readily in the infrared channels than in the visible channels.

l) A regular linear pattern of agreement and disagreement appears in all of the geographically corrected image differences, which is a direct result of the geographic transformation.

n) The CPU time for the NN, BL, and BC was 34.8, 59.6, and 135.5 s, respectively.

As a result of these observations, there are some potential problems that are worth exploration and commentary. First, if the image contained a few large homogeneous areas, then it probably would not matter which geographic correction technique was used to correct the image, at least in the large homogeneous areas. The problem areas are the transitions between two or more features. The results presented in the reference (footnote) also show that the majority of misclassifications occur at transitions between two or more features. Thus, there is a question of whether the image data should be registered (geographically corrected) and then classified or classified and then registered. If the image data are classified first, then the choice of registration techniques is limited to the NN. This procedure needs to be explored to determine the order and combination of registration and classification techniques that minimize classification errors.

Secondly, preliminary results using transform compression techniques indicate that the greatest deviations between the compressed/reconstructed image and the original image also occur at transition regions. Hence, the order of importance of compression and registration need to be explored as well as their combined impact on various classification techniques.

Thirdly, the transform compression techniques and the interpolation geographic correction methods act as filters on the image data, smoothing out most of the natural discrimination present in the original image data. These two effects, plus the fact that the transformation injects linear patterns into the image data, need to be explored for impact on change detection and multitemporal classification.

APPROVAL

NEAREST NEIGHBOR, BILINEAR INTERPOLATION AND BICUBIC INTERPOLATION GEOGRAPHIC CORRECTION EFFECTS ON LANDSAT IMAGERY

By Robert R. Jayroe, Jr.

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

for J. T. POWELL
Director, Data Systems Laboratory

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