Nine Class Reference Utility Mask of Landsat-5 TM Scene of Chugach, Alaska at 28.5 m and 500 m (MODIS) Resolution

Daniel Knowles Jr.

March 19, 1993

A means was required for establishing the integrity of MODIS Utility Masks developed by the MODIS Calibration Support Team (MCST). The solution was to utilize EASI/PACE remote sensing software packages for the generation of a reference utility mask at the Thematic Mapper (TM) resolution of 28.5 meters and 500 meters. A 1Aug1985 Landsat-5 TM digital image of Chugach, Alaska was used to produce this reference mask due to the region's diversity of classes.

Methodology

Using EASI/PACE software packages, nine spectrally unique class sites were trained for the 82 x 82Km subscene of Chugach, Alaska. These training sites, (water, land, mountainous land, ice, snow, cumulus cloud, cirrus cloud, snow shadow, land shadow), were stored as bitmap segments. Classification signature segments were developed from each bitmap segment applying a guassian threshold of four standard deviations with no class biasses. A theme map was then produced by running Maximum Likelihood Classification (MLC) using the nine signature segments with the allowance of a null (unclassified) class. Only TM bands 2, 3, 4, 5 and 6 were used in the classification due to saturation levels in bands 1 and 7. About 50% of the pixels were classified with substantial groupings of unclassified pixels, so it was necessary to add some of these unclassified pixels to their respective training sites.

On the second iteration, MLC was run with about 90% of the pixels classified. The unclassified pixels were scattered with no groupings, so it was decided that each of these pixels must be mixtures of two or more classes, namely mixels. MLC was run a third time, with each pixel forced to its nearest spectral class. A Pseudo-Color Table segment was formed from the theme map output of the final run of MLC, with 'Earth' colors assigned to the respective classes, creating an apparent 'true color' mask.

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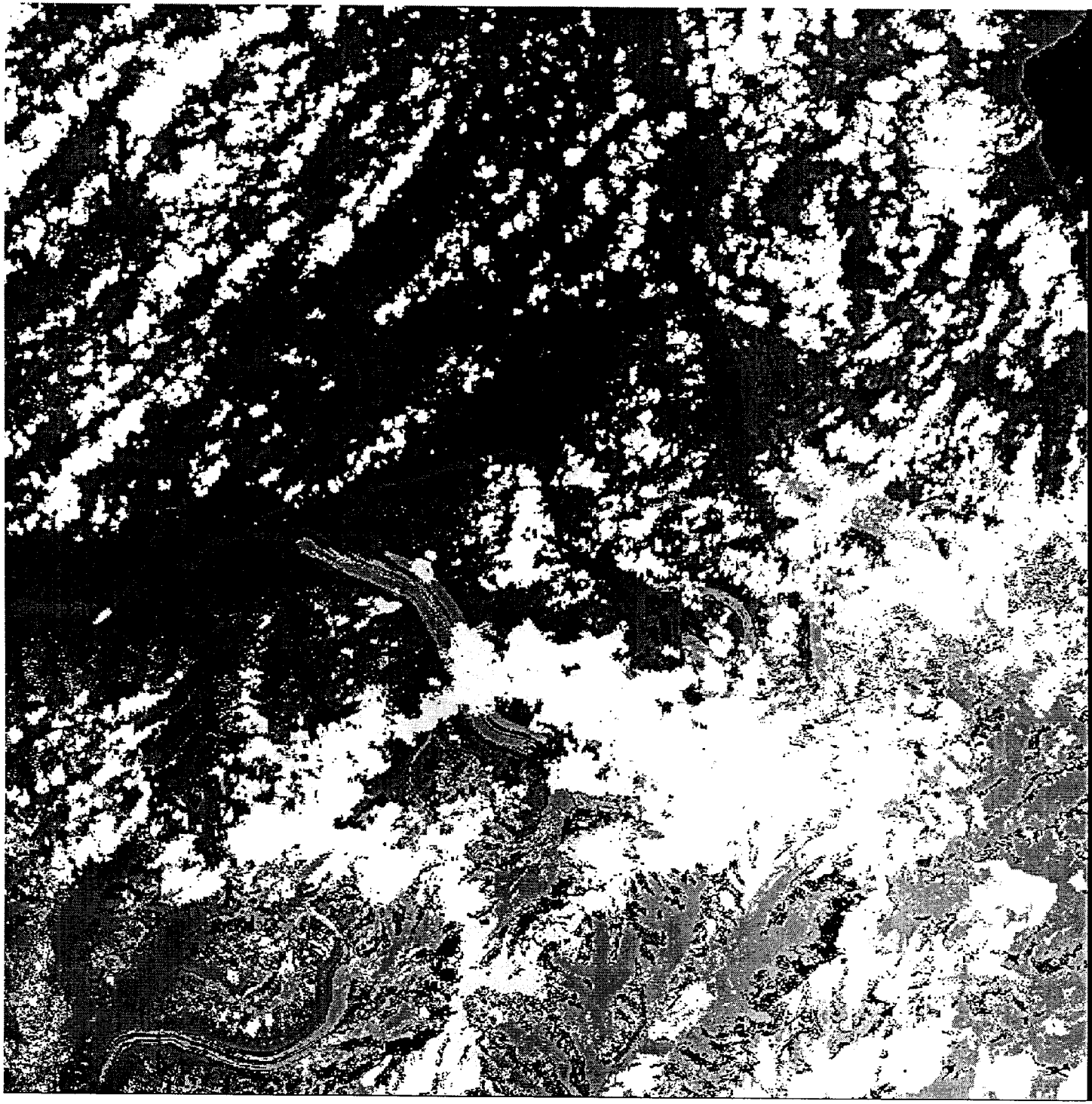
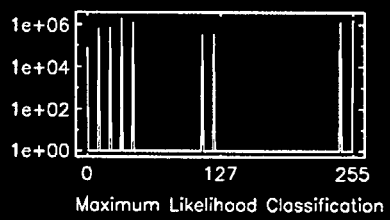


Chugach Q2 TM MLC

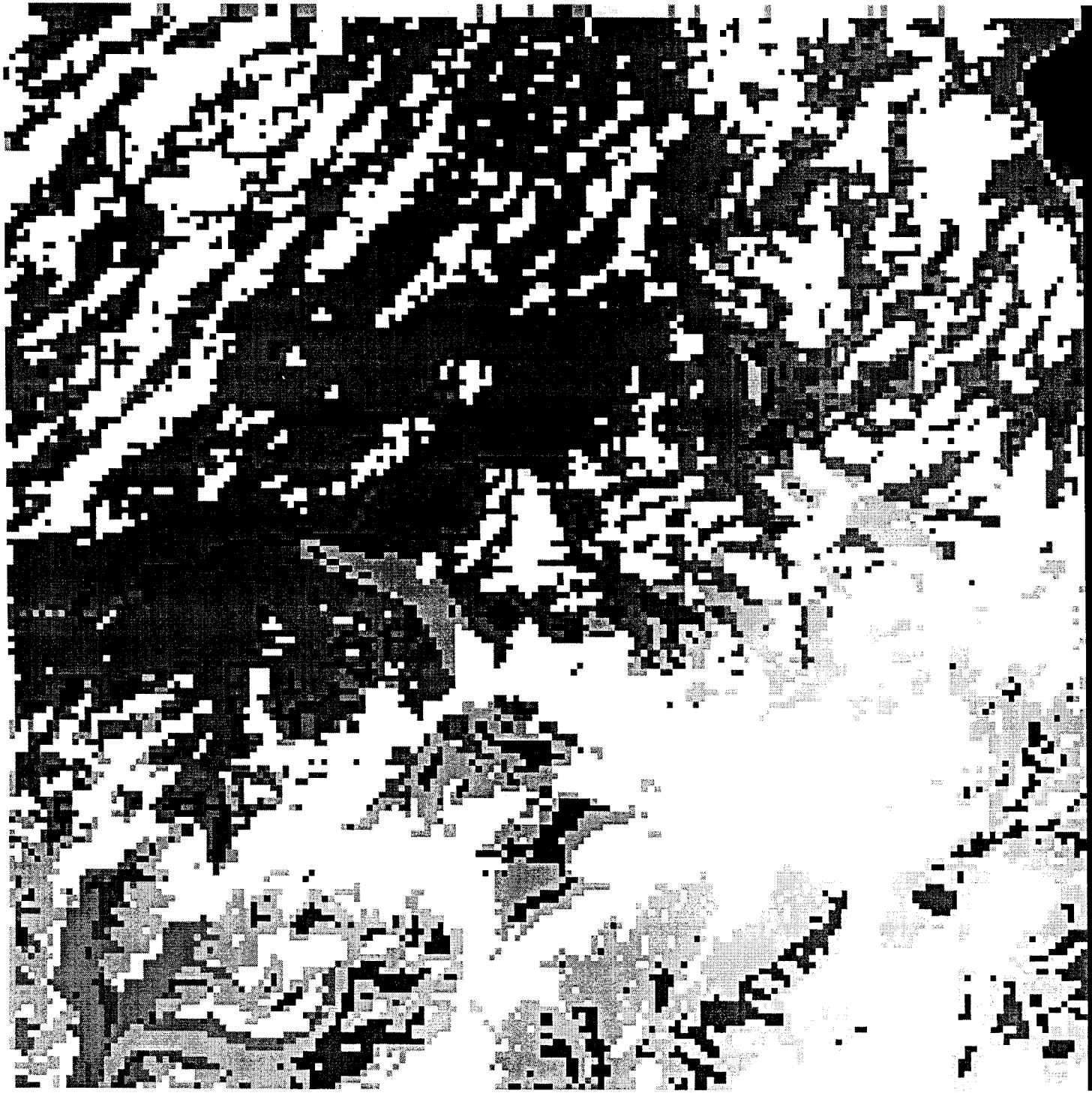
Location: Chugach Mtns, AK
Center Lat/Lon: N61-29/W148-34

Path/Row: 68/17
NASA ID: 50518-20372
Satellite: Landsat-5
Instrument: Thematic Mapper (TM)
Acq. Date: 1AUG85
Sun EL: 43 AZ: 152
Resampled Pixel Size: 28.5 m
Image Size: 2904.0 x 2904.0 pixels
Scene Size: 82.8 x 82.8 km



- Water
- Shadowed Snow
- Shadowed Land
- Land
- Mountainous Land
- Snow
- Ice
- Cirrus Cloud
- Cumullus Cloud

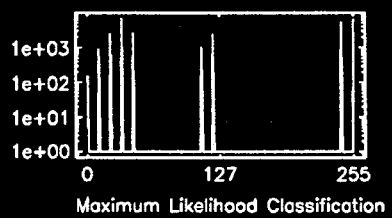
JLBarker/JWBurelbach/DKnowles
NASA/GSFC/MCST Code 925
Fri Mar 19 14:42:55 1993



Chugach Q2 MODIS MLC

Location: Chugach Mtns, AK
Center Lat/Lon: N61–29/W148–34

Path/Row: 68/17
NASA ID: 50518–20372
Satellite: Simulated EOS
Instrument: Simulated MODIS
Acq. Date: 1AUG85
Sun EL: 43 AZ: 152
Resampled Pixel Size: 500.0 m
Image Size: 168.0 x 168.0 pixels
Scene Size: 84.0 x 84.0 km



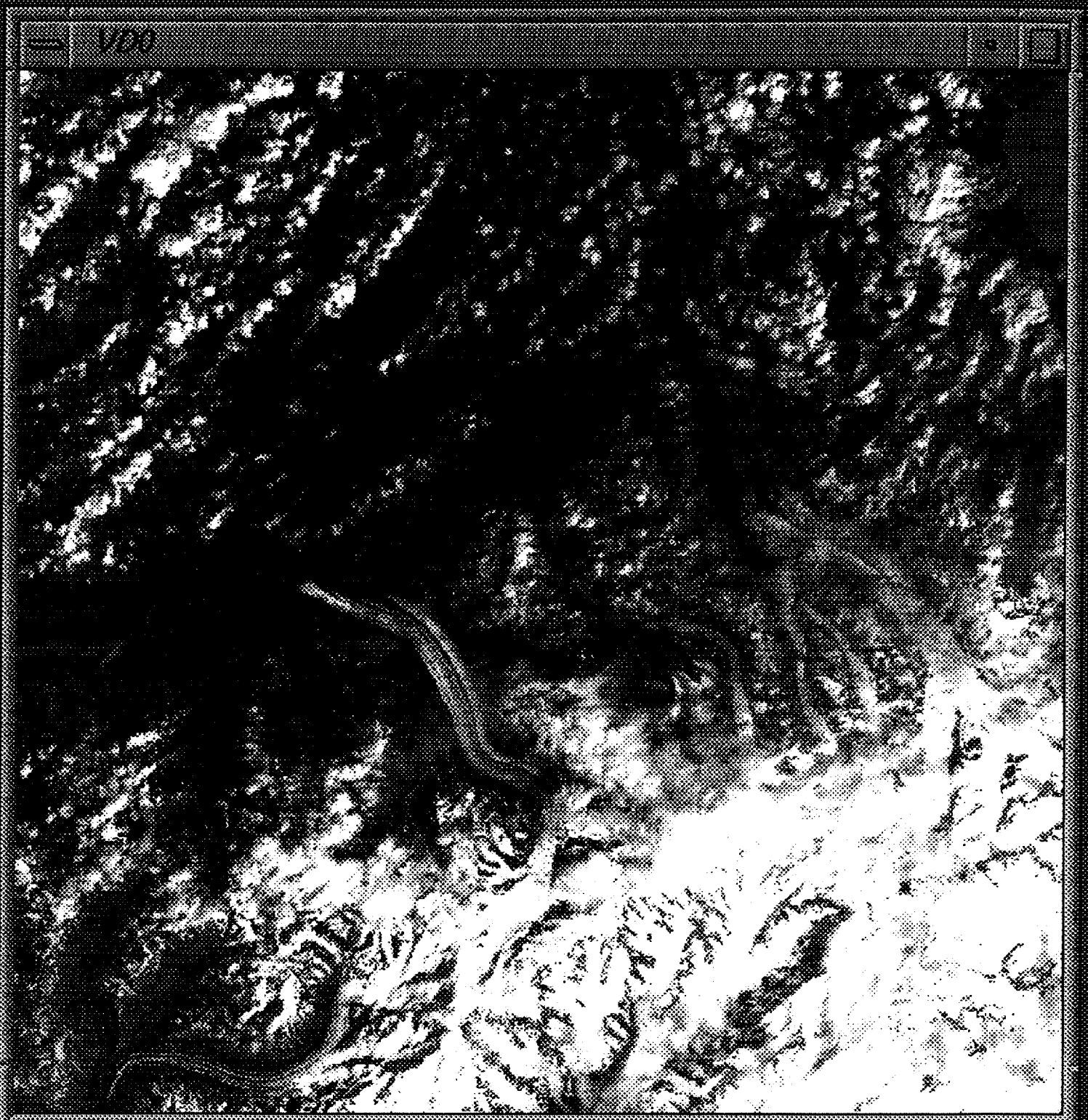
- Water
- Shadowed Snow
- Shadowed Land
- Land
- Mountainous Land
- Snow
- Ice
- Cirrus Cloud
- Cumullus Cloud

JLBarker/JWBurelbach/DKnowles
NASA/GSFC/MCST Code 925
Fri Mar 19 14:39:40 1993

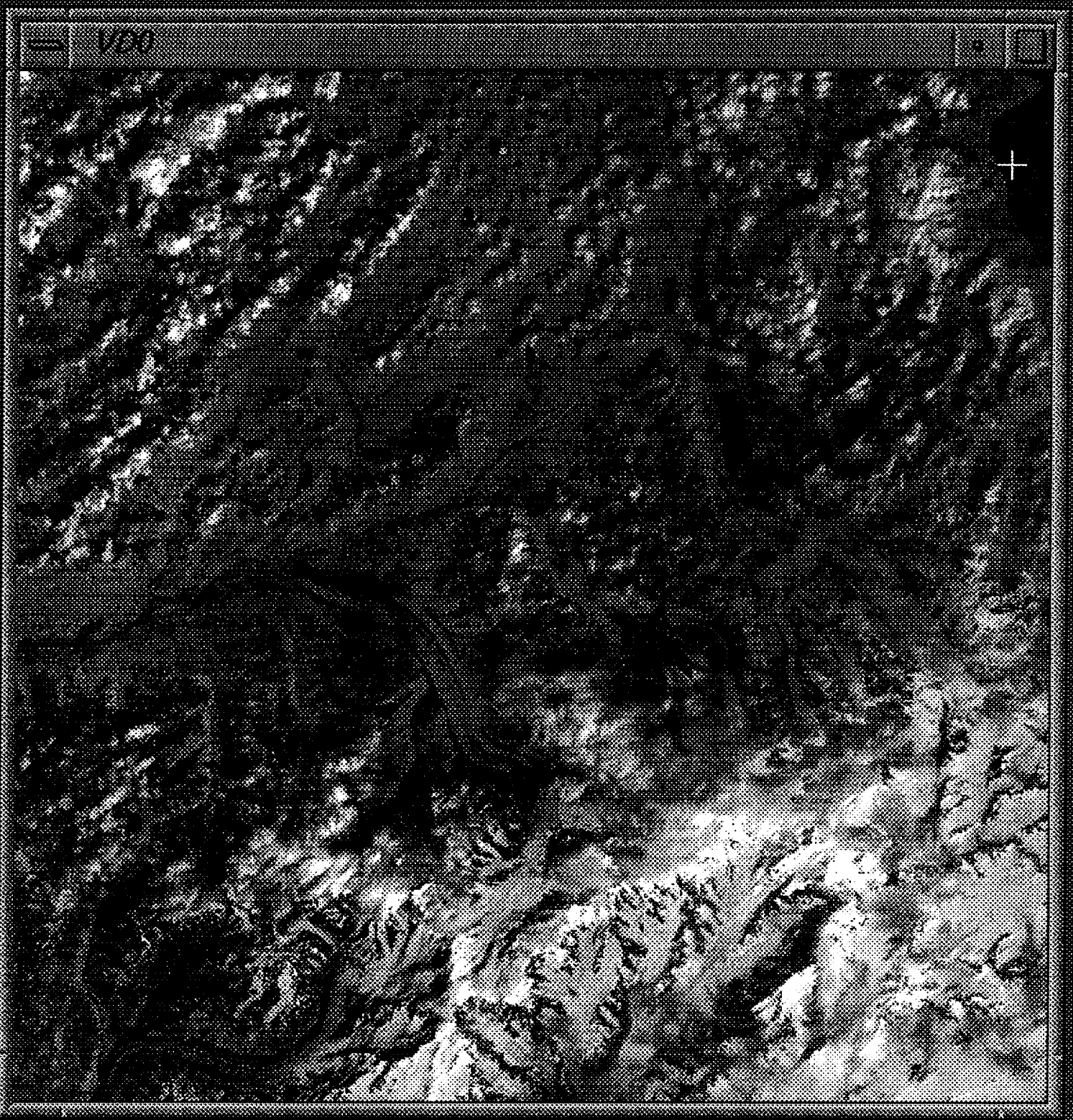
TM1

TM 2 .56 μm

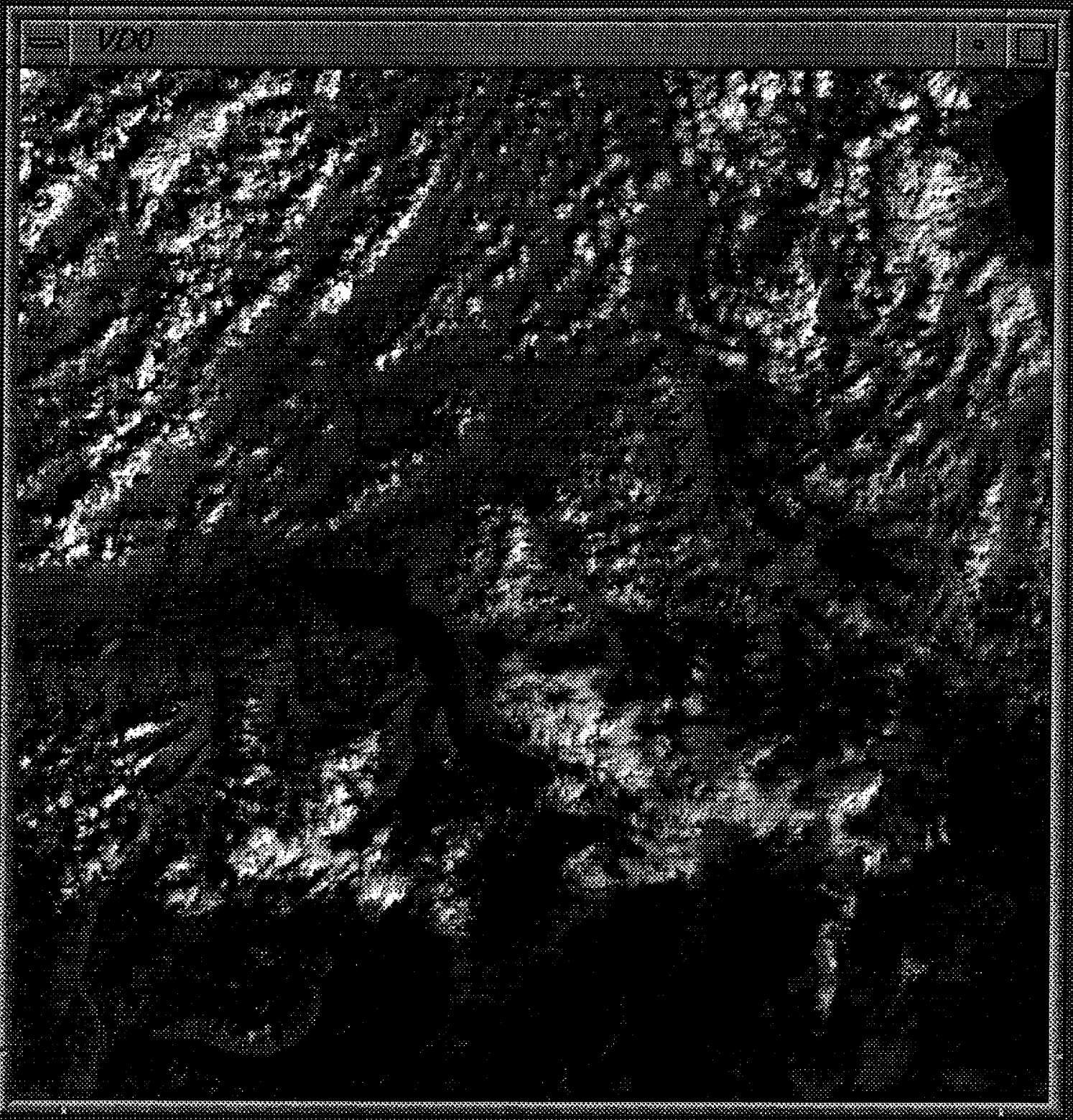
TM3 .66μm



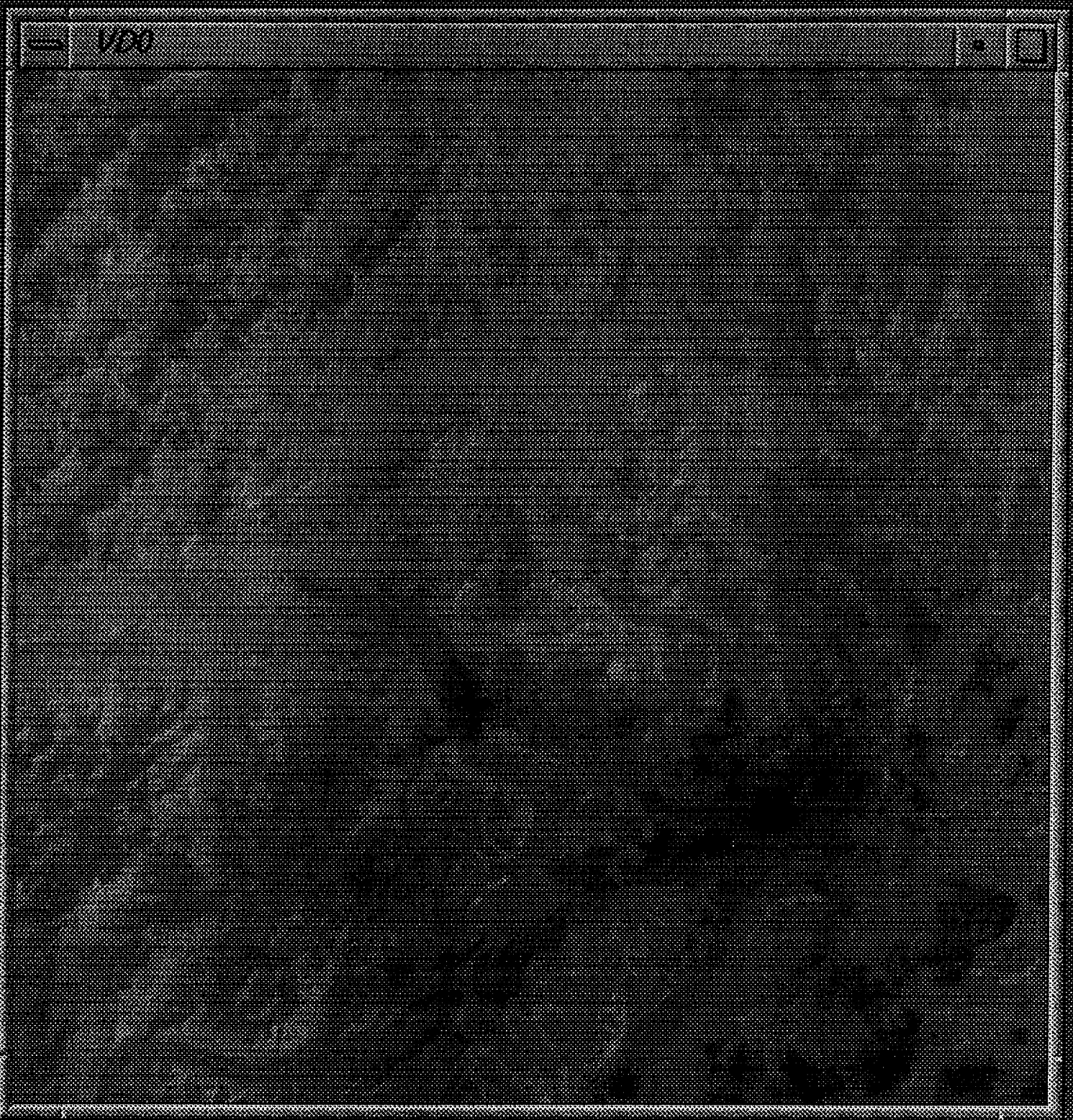
TM4 .83 μm

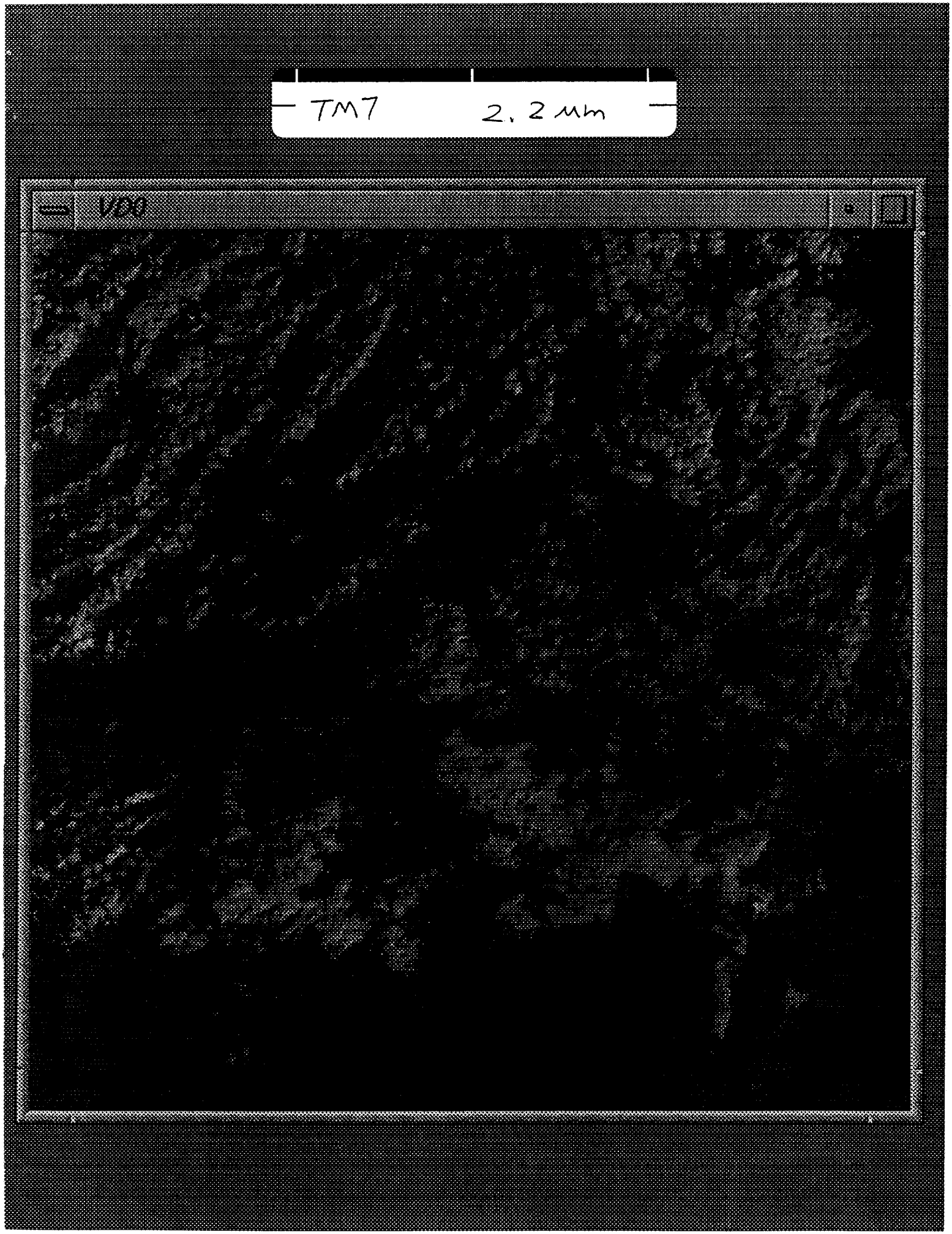


TM5 1.65 μm



TM6 11.45μm




TM7
2.2 μm
VDU

Full Maximum Likelihood Classification with all pixels classified

Classification Date:24Feb93
File: /barker/jb/images/chugach/chugach.q2.pix
Channel: 10

Signatures used in Classification

```
47:Water      Type:121 [Signatures
   Contents: Water Training Site
48:Land       Type:121 [Signatures
   Contents: Land Training Site
49:Cloud      Type:121 [Signatures
   Contents: Cloud Training Site
50:TCloud     Type:121 [Signatures
   Contents: Transparent Cloud Training Site
51:Mountain   Type:121 [Signatures
   Contents: Mountain Training Site
52:LShadow    Type:121 [Signatures
   Contents: Shadow over Land Training Site
53:SShadow    Type:121 [Signatures
   Contents: Shadow over Snow Training Site
54:Snow       Type:121 [Signatures
   Contents: Snow Training Site
55:Glacier    Type:121 [Signatures
   Contents: Glacier Training Site
```

Classification Results

Seg	Name	Code	Pixels	%Image	Thres	Bias
47	Water	20	77839	0.92	4.00	1.00
48	Land	50	2024384	24.00	4.00	1.00
49	Cloud	250	1685965	19.99	4.00	1.00
50	TCloud	240	1360512	16.13	4.00	1.00
51	Mountain	60	1198945	14.22	4.00	1.00
52	LShadow	40	713270	8.46	4.00	1.00
53	SShadow	30	681573	8.08	4.00	1.00
54	Snow	120	338079	4.01	4.00	1.00
55	Glacier	130	352649	4.18	4.00	1.00
	NULL	0	0	0.00		
	OVERLAP	255	0	0.00		
	Total		8433216	100.00		

Full Maximum Likelihood Classification with Null Class

Classification Date: 23Feb93
File: /barker/jb/images/chugach/chugach.q2.pix
Channel: 9

Signatures used in Classification

```
47:Water      Type:121 [Signatures
   Contents: Water Training Site
48:Land       Type:121 [Signatures
   Contents: Land Training Site
49:Cloud      Type:121 [Signatures
   Contents: Cloud Training Site
50:TCloud     Type:121 [Signatures
   Contents: Transparent Cloud Training Site
51:Mountain   Type:121 [Signatures
   Contents: Mountain Training Site
52:LShadow    Type:121 [Signatures
   Contents: Shadow over Land Training Site
53:SShadow    Type:121 [Signatures
   Contents: Shadow over Snow Training Site
54:Snow       Type:121 [Signatures
   Contents: Snow Training Site
55:Glacier    Type:121 [Signatures
   Contents: Glacier Training Site
```

Classification Results

Seg	Name	Code	Pixels	%Image	Thres	Bias
47	Water	20	54623	0.65	4.00	1.00
48	Land	50	2024384	24.00	4.00	1.00
49	Cloud	250	1558267	18.48	4.00	1.00
50	TCloud	240	1106525	13.12	4.00	1.00
51	Mountain	60	957905	11.36	4.00	1.00
52	LShadow	40	713270	8.46	4.00	1.00
53	SShadow	30	300492	3.56	4.00	1.00
54	Snow	120	338079	4.01	4.00	1.00
55	Glacier	130	352649	4.18	4.00	1.00
	NULL	0	1027022	12.18		
	OVERLAP	255	0	0.00		
	Total		8433216	100.00		

Classification Signature for Water

47:Water Type:121 [Signatures
Contents: Water Training Site
Sample size: 38645 Encoding: 20

Channel	Mean	Deviation
2	56.675041	6.360469
3	55.833149	6.400200
4	16.741261	2.574434
5	7.154250	2.456987
6	93.813194	9.922579

Class Correlation Matrix:

	2	3	4	5	6
2	1.00000000				
3	0.98000008	1.00000000			
4	0.75655228	0.78525019	1.00000000		
5	0.34882310	0.38806051	0.74130666	1.00000000	
6	0.90199405	0.87384659	0.55590880	0.14723276	1.00000000

Class Covariance Matrix:

	2	3	4	5	6
2	40.456				
3	39.894	40.963			
4	12.388	12.938	6.628		
5	5.451	6.102	4.689	6.037	
6	56.927	55.495	14.201	3.589	98.458

Determinant of Covariance Matrix: 0.49656948E+04

Inverse Covariance Matrix:

	2	3	4	5	6
2	0.81950480				
3	-0.61620665	0.69673425			
4	-0.12508856	-0.19933878	1.00015676		
5	0.04551970	0.01179507	-0.49722067	0.48633862	
6	-0.11012407	-0.00810544	0.05855335	0.02101735	0.06918605

Triangular Inv-Covar. Matrix:

	2	3	4	5	6
2	0.90526503				
3	-0.68069285	0.48310608			
4	-0.13817798	-0.60731250	0.78245455		
5	0.05028317	0.09526397	-0.55264258	0.41148657	
6	-0.12164811	-0.18817972	-0.09270769	-0.01500235	0.10077891

Classification Signature for Land

48:Land Type:121 [Signatures
Contents: Land Training Site
Sample size: 135935 Encoding: 50

Channel	Mean	Deviation
2	27.548586	7.820440
3	26.191084	10.592919
4	77.285759	20.921360
5	59.656433	19.328409
6	114.722565	7.169202

Class Correlation Matrix:

	2	3	4	5	6
2	1.00000000				
3	0.82692033	1.00000000			
4	0.27148694	0.15062012	1.00000000		
5	0.71377462	0.65351564	0.65163052	1.00000000	
6	-0.44426435	-0.40931344	0.01676767	-0.07433538	1.00000000

Class Covariance Matrix:

	2	3	4	5	6
2	61.159				
3	68.503	112.210			
4	44.419	33.380	437.703		
5	107.892	133.804	263.504	373.587	
6	-24.908	-31.084	2.515	-10.301	51.397

Determinant of Covariance Matrix: 0.24321029E+10

Inverse Covariance Matrix:

	2	3	4	5	6
2	0.07294843				
3	-0.02350278	0.03447660			
4	0.00277839	0.00510562	0.00544466		
5	-0.01410831	-0.00895720	-0.00639173	0.01421693	
6	0.01817478	0.00741604	0.00288688	-0.00909237	0.03078573

Triangular Inv-Covar. Matrix:

	2	3	4	5	6
2	0.27008969				
3	-0.08701844	0.16402557			
4	0.01028690	0.03658436	0.06324893		
5	-0.05223565	-0.08232049	-0.04494537	0.05188083	
6	0.06729163	0.08091211	-0.01210241	0.01039747	0.13948554

Classification Signature for Cloud

```
49:Cloud      Type:121 [Signatures
   Contents: Cloud Training Site
   Sample size: 141399    Encoding: 250
```

Channel	Mean	Deviation
2	194.313248	51.169304
3	225.133377	45.707779
4	181.319275	45.421314
5	179.312180	47.890484
6	67.711578	11.911871

Class Correlation Matrix:

	2	3	4	5	6
2	1.00000000				
3	0.88702404	1.00000000			
4	0.89495045	0.86383963	1.00000000		
5	0.48871839	0.55096215	0.66130441	1.00000000	
6	-0.51965296	-0.46857893	-0.31579223	0.08417658	1.00000000

Class Covariance Matrix:

	2	3	4	5	6
2	2618.298				
3	2074.603	2089.201			
4	2080.023	1793.424	2063.096		
5	1197.615	1206.038	1438.502	2293.499	
6	-316.740	-255.125	-170.860	48.020	141.893

Determinant of Covariance Matrix: 0.36793806E+14

Inverse Covariance Matrix:

	2	3	4	5	6
2	0.00332267				
3	-0.00116339	0.00271779			
4	-0.00234985	-0.00086093	0.00403278		
5	0.00030046	-0.00031011	-0.00081484	0.00097837	
6	0.00239399	0.00135791	-0.00166158	-0.00119917	0.01323815

Triangular Inv-Covar. Matrix:

	2	3	4	5	6
2	0.05764263				
3	-0.02018279	0.04806713			
4	-0.04076583	-0.03502803	0.03382250		
5	0.00521251	-0.00426288	-0.02222397	0.02095534	
6	0.04153159	0.04568897	0.04824857	-0.00709173	0.08394985

Classification Signature for Transparent Cloud

```
50:TCloud    Type:121 [Signatures
   Contents: Transparent Cloud Training Site
   Sample size:  42242    Encoding: 240
```

Channel	Mean	Deviation
2	176.227966	84.041580
3	186.565048	78.500320
4	145.740356	66.388687
5	64.553314	16.655600
6	54.734673	16.499475

Class Correlation Matrix:

	2	3	4	5	6
2	1.00000000				
3	0.98000002	1.00000000			
4	0.95438612	0.94765949	1.00000000		
5	-0.03621332	-0.03609511	0.08488967	1.00000000	
6	-0.68123335	-0.72321719	-0.58406413	0.10007002	1.00000000

Class Covariance Matrix:

	2	3	4	5	6
2	7062.987				
3	6465.345	6162.300			
4	5324.912	4938.759	4407.458		
5	-50.690	-47.193	93.866	277.409	
6	-944.627	-936.721	-639.771	27.500	272.233

Determinant of Covariance Matrix: 0.15204109E+14

Inverse Covariance Matrix:

	2	3	4	5	6
2	0.00442115				
3	-0.00332341	0.00562634			
4	-0.00163801	-0.00178284	0.00386677		
5	0.00079917	0.00059851	-0.00165685	0.00436390	
6	-0.00002463	0.00357731	-0.00256369	0.00049790	0.00982177

Triangular Inv-Covar. Matrix:

	2	3	4	5	6
2	0.06649171				
3	-0.04998236	0.05592947			
4	-0.02463481	-0.05389189	0.01885628		
5	0.01201908	0.02144231	-0.01088225	0.06034277	
6	-0.00037045	0.06363003	0.04541333	-0.00609564	0.06060793

Classification Signature for Mountain Slopes

```
51:Mountain  Type:121 [Signatures
   Contents: Mountain Training Site
   Sample size:  31420    Encoding:  60
```

Channel	Mean	Deviation
2	46.588352	7.618810
3	51.914833	11.286090
4	65.336502	30.740858
5	56.313145	17.159449
6	103.176384	13.481862

Class Correlation Matrix:

	2	3	4	5	6
2	1.00000000				
3	0.49841180	1.00000000			
4	-0.11517709	-0.32737905	1.00000000		
5	0.07720201	0.03649365	0.61953831	1.00000000	
6	0.47290632	0.44753829	-0.19841442	0.05960088	1.00000000

Class Covariance Matrix:

	2	3	4	5	6
2	58.046				
3	42.857	127.376			
4	-26.975	-113.582	945.000		
5	10.093	7.067	326.804	294.447	
6	48.575	68.096	-82.232	13.788	181.761

Determinant of Covariance Matrix: 0.96784876E+11

Inverse Covariance Matrix:

	2	3	4	5	6
2	0.02575547				
3	-0.00661119	0.01303046			
4	-0.00046324	0.00193593	0.00218730		
5	0.00000616	-0.00213756	-0.00248526	0.00624307	
6	-0.00461624	-0.00207702	0.00057661	-0.00079878	0.00783503

Triangular Inv-Covar. Matrix:

	2	3	4	5	6
2	0.16048512				
3	-0.04119502	0.10645859			
4	-0.00288648	0.01706788	0.04344714		
5	0.00003835	-0.02006397	-0.04931728	0.05838072	
6	-0.02876429	-0.03064070	0.02339740	-0.00442869	0.07417373

Classification Signature for Shadow over Land

52:LShadow Type:121 [Signatures
Contents: Shadow over Land Training Site
Sample size: 18626 Encoding: 40

Channel	Mean	Deviation
2	24.096155	8.757340
3	23.555836	11.728048
4	25.853807	11.594797
5	20.965908	12.384901
6	100.557983	10.540193

Class Correlation Matrix:

	2	3	4	5	6
2	1.00000000				
3	0.93049967	1.00000000			
4	0.72765392	0.67968827	1.00000000		
5	0.86964977	0.83737552	0.86887985	1.00000000	
6	-0.72902852	-0.72856194	-0.26938719	-0.46588609	1.00000000

Class Covariance Matrix:

	2	3	4	5	6
2	76.691				
3	95.568	137.547			
4	73.886	92.427	134.439		
5	94.321	121.629	124.772	153.386	
6	-67.292	-90.062	-32.922	-60.816	111.096

Determinant of Covariance Matrix: 0.52113748E+08

Inverse Covariance Matrix:

	2	3	4	5	6
2	0.15947719				
3	-0.04773742	0.06212136			
4	-0.01292385	0.00154518	0.03472226		
5	-0.03609704	-0.01593674	-0.02560856	0.05796611	
6	0.03430820	0.01317838	-0.01030464	-0.01064078	0.03158684

Triangular Inv-Covar. Matrix:

	2	3	4	5	6
2	0.39934596				
3	-0.11953896	0.21870482			
4	-0.03236257	-0.01062338	0.18319954		
5	-0.09039039	-0.12227406	-0.16284311	0.09125163	
6	0.08591100	0.10721335	-0.03485475	0.04995326	0.09487496

Classification Signature for Shadow over Snow

```
53:SShadow   Type:121 [Signatures
   Contents: Shadow over Snow Training Site
   Sample size:   1312    Encoding:  30
```

Channel	Mean	Deviation
2	72.685974	37.245483
3	60.986282	33.064396
4	33.835365	26.184099
5	9.730183	5.893781
6	81.207314	9.346546

Class Correlation Matrix:

	2	3	4	5	6
2	1.00000000				
3	0.26273146	1.00000000			
4	0.25599417	0.95546979	1.00000000		
5	0.06294952	0.21465582	0.25011688	1.00000000	
6	-0.05993397	0.07762518	0.14436518	0.65609664	1.00000000

Class Covariance Matrix:

	2	3	4	5	6
2	1387.226				
3	323.554	1093.254			
4	249.656	827.209	685.607		
5	13.818	41.831	38.599	34.737	
6	-20.864	23.989	35.331	36.142	87.358

Determinant of Covariance Matrix: 0.12811806E+12

Inverse Covariance Matrix:

	2	3	4	5	6
2	0.00078624				
3	-0.00011347	0.01103557			
4	-0.00014504	-0.01334165	0.01778812		
5	-0.00053340	-0.00149606	0.00011854	0.05342071	
6	0.00049828	0.00295724	-0.00361411	-0.02186594	0.02126222

Triangular Inv-Covar. Matrix:

	2	3	4	5	6
2	0.02803995				
3	-0.00404671	0.10497237			
4	-0.00517269	-0.12729622	0.03945924		
5	-0.01902281	-0.01498523	-0.04783211	0.22482522	
6	0.01777035	0.02885665	0.00383058	-0.09301557	0.10699140

Classification Signature for Snow

```
54:Snow       Type:121 [Signatures
   Contents: Snow Training Site
   Sample size:  33160    Encoding: 120
```

Channel	Mean	Deviation
2	253.874664	5.013159
3	254.936646	1.004902
4	194.452957	19.003628
5	17.483807	3.119239
6	72.603767	2.212388

Class Correlation Matrix:

	2	3	4	5	6
2	1.00000000				
3	0.25967896	1.00000000			
4	0.30872229	0.20009290	1.00000000		
5	0.08176117	0.01845736	0.12841351	1.00000000	
6	0.11795735	0.03558648	0.23836836	-0.54705220	1.00000000

Class Covariance Matrix:

	2	3	4	5	6
2	25.132				
3	1.308	1.010			
4	29.411	3.821	361.138		
5	1.279	0.058	7.612	9.730	
6	1.308	0.079	10.022	-3.775	4.895

Determinant of Covariance Matrix: 0.21223103E+06

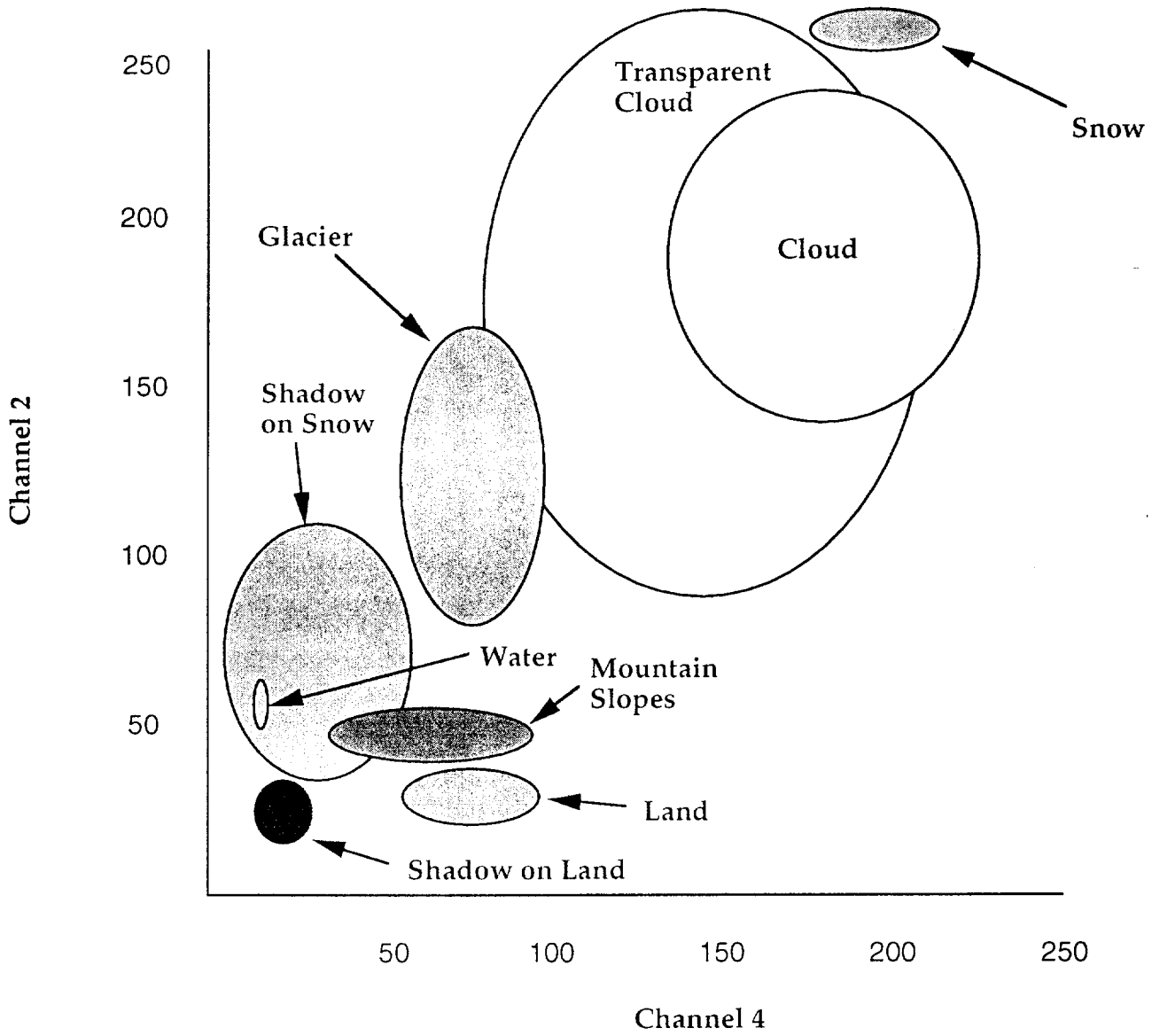
Inverse Covariance Matrix:

	2	3	4	5	6
2	0.04663366				
3	-0.04851525	1.08257568			
4	-0.00275094	-0.00857408	0.00355594		
5	-0.00861066	0.01669564	-0.00692907	0.16486256	
6	-0.01268904	0.02590128	-0.01175121	0.14337532	0.34192139

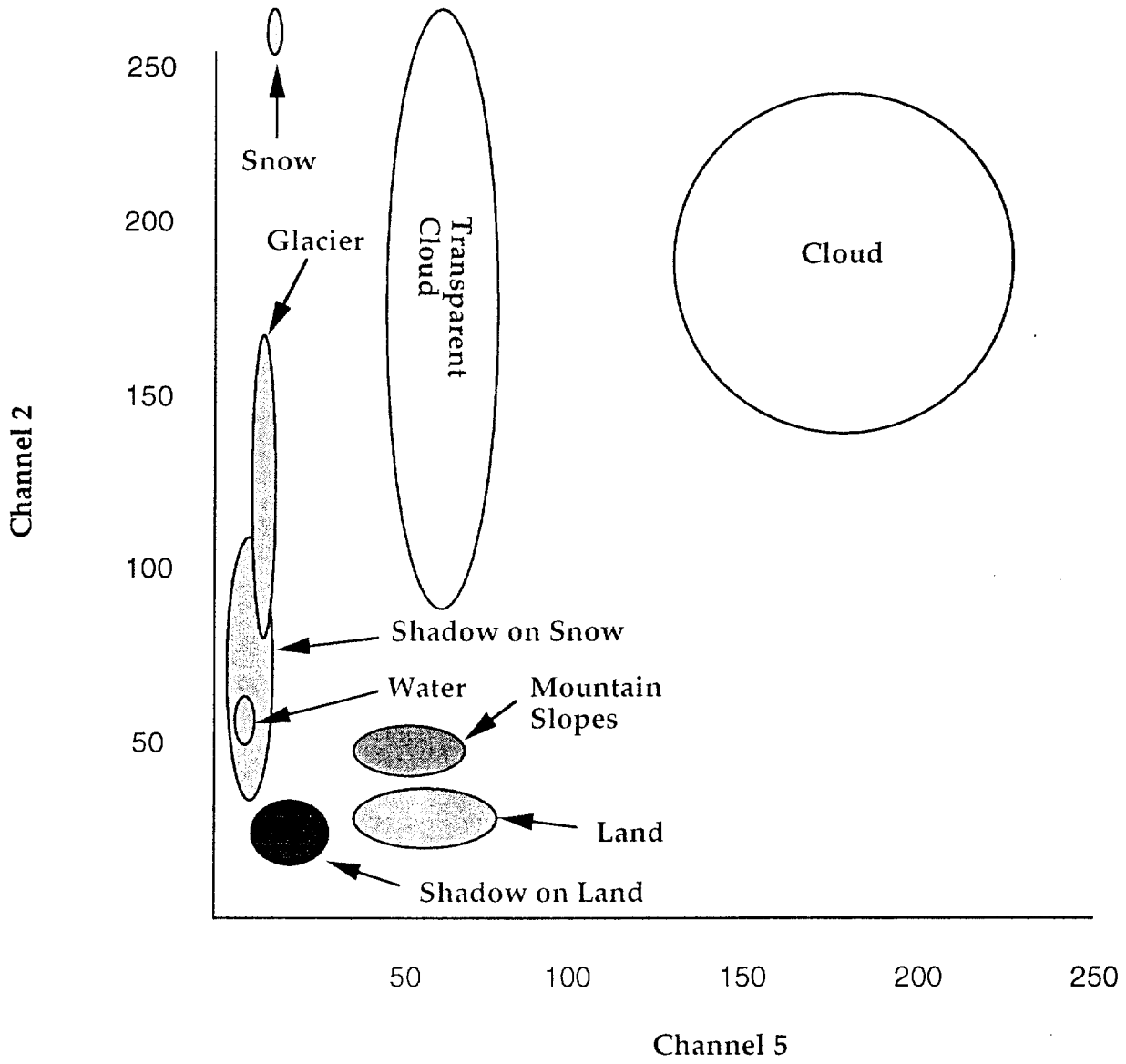
Triangular Inv-Covar. Matrix:

	2	3	4	5	6
2	0.21594827				
3	-0.22466145	1.01592469			
4	-0.01273887	-0.01125675	0.05715719		
5	-0.03987370	0.00761627	-0.12861523	0.38297880	
6	-0.05875964	0.01250118	-0.21622862	0.29538673	0.45200029

Channel 2 vs Channel 4 with one standard deviation



Channel 2 vs Channel 5 with one standard deviation



Channel 4 vs Channel 5 with one standard deviation

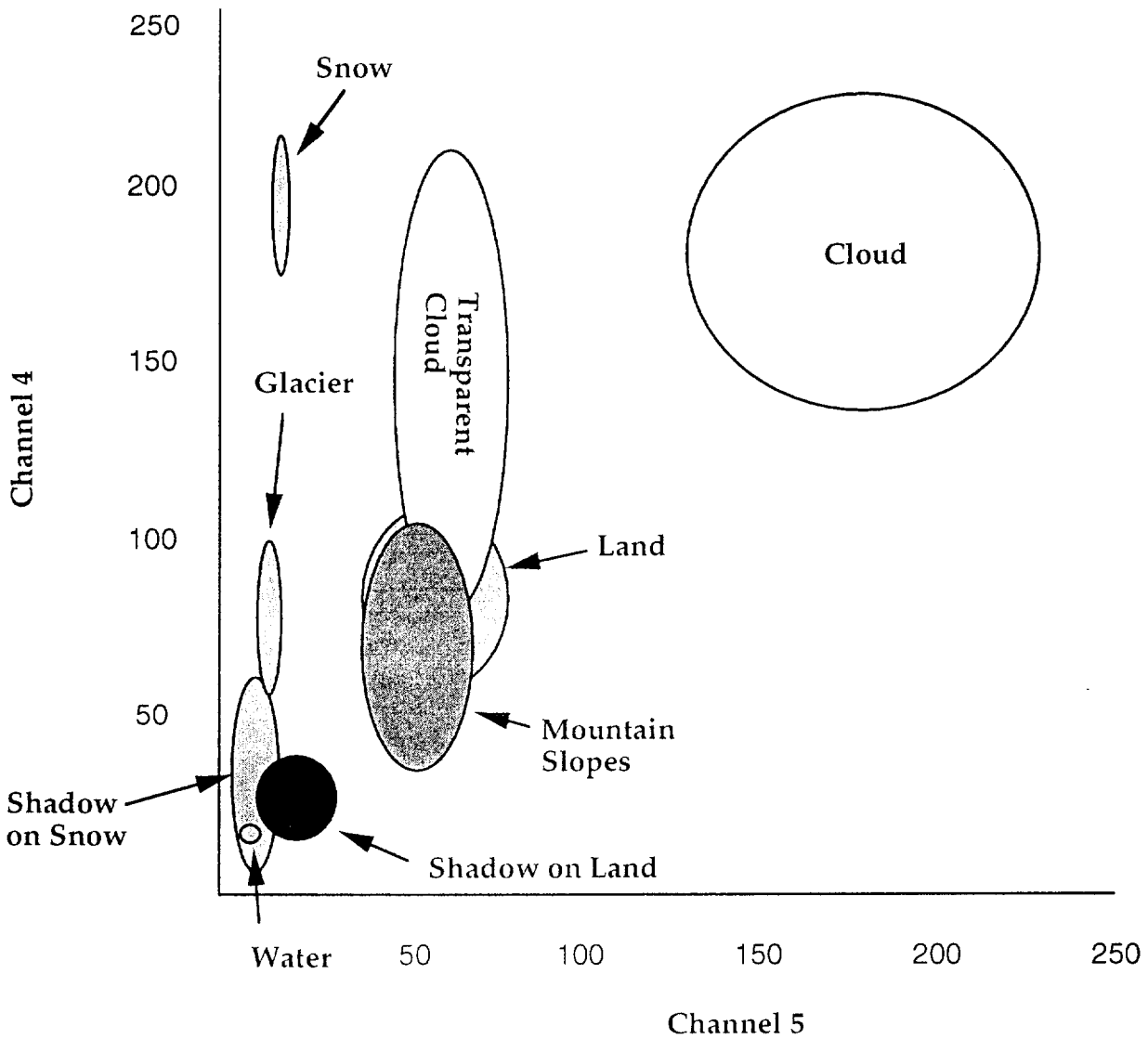


Table 1. Center wavelengths and spatial resolutions for TM and MODIS spectral bands for the observation of land and cloud properties. (MODIS specifications from Hughes SBRC, April 1992.)

TM Band	MODIS Band	Center Wavelength (μm)		Spatial Resolution (m)	
		TM	MODIS	TM	MODIS
3	1	.66	.659	30	250
4	2	.83	.865	30	250
2	4	.56	.555	30	500
5	6	1.65	1.640	30	500
7	7	2.22	2.130	30	500
6	31	11.45	11.030	120	1000