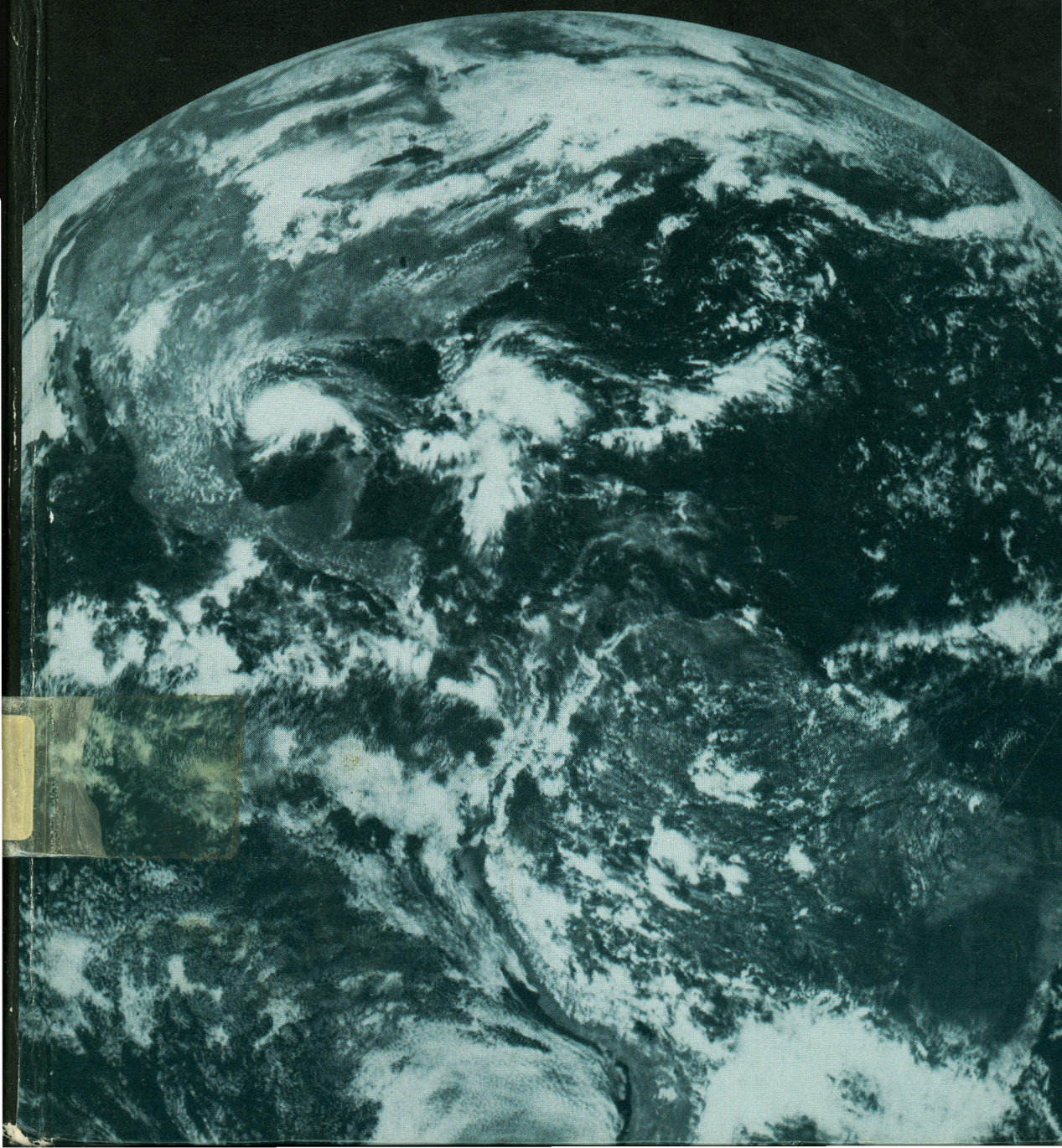


REMOTE SENSING AND IMAGE INTERPRETATION

LILLESAND/KIEFER



1171 2454 INSTITUT
FÜR METEOROLOGIE U. KLIMATOLOGIE
UNIVERSITÄT HANNOVER
HERRENHAUSER STR. 2 • 3000 HANNOVER 21

REMOTE SENSING AND IMAGE INTERPRETATION

THOMAS M. LILLESAND

University of Minnesota

RALPH W. KIEFER

University of Wisconsin—Madison

John Wiley & Sons

New York Chichester

Brisbane Toronto

CONTENTS

1	CONCEPTS AND FOUNDATIONS OF REMOTE SENSING	1
1.1	Introduction	1
1.2	Energy Sources and Radiation Principles	2
1.3	Energy Interactions in the Atmosphere	9
1.4	Energy Interactions With Earth Surface Features	12
1.5	Data Acquisition and Interpretation	22
1.6	Reference Data	23
1.7	An Ideal Remote Sensing System	26
1.8	Characteristics of Real Remote Sensing Systems	27
1.9	The Status of Remote Sensing	29
1.10	Organization of This Book	32
	Selected Bibliography	34
2	ELEMENTS OF PHOTOGRAPHIC SYSTEMS	35
2.1	Introduction	35
2.2	Early History of Aerial Photography	36
2.3	The Simple Camera	39
2.4	Basic Negative-to-Positive Photographic Sequence	42
2.5	Processing Black and White Films	45
2.6	Spectral Sensitivity of Black and White Films	46
2.7	Color Film	48
2.8	Processing Color Films	53
2.9	Color Infrared Film	54
2.10	Filters	58
2.11	Aerial Cameras	64
2.12	Types of Aerial Photographs	77
2.13	Taking Vertical Aerial Photographs	77
2.14	Scale of Aerial Photographs	79
2.15	Ground Coverage of Aerial Photographs	85
2.16	Photographic Resolution	89
	Selected Bibliography	93

3	INTRODUCTION TO AIRPHOTO INTERPRETATION	94
3.1	Introduction	94
3.2	Fundamentals of Airphoto Interpretation	95
3.3	Basic Photo Interpretation Equipment	99
3.4	Geologic and Soil Mapping	112
3.5	Land Use/Land Cover Mapping	119
3.6	Agricultural Applications	127
3.7	Forestry Applications	131
3.8	Water Resources Applications	141
3.9	Urban and Regional Planning Applications	155
3.10	Wetland Mapping	156
3.11	Wildlife Ecology Applications	159
3.12	Archeological Applications	166
3.13	Environmental Impact Assessment	169
3.14	Land Information Systems	170
	Selected Bibliography	184
4	AIRPHOTO INTERPRETATION FOR TERRAIN EVALUATION	188
4.1	Introduction	188
4.2	Soil Characteristics	188
4.3	Land Use Suitability Evaluation	192
4.4	Elements of Airphoto Interpretation for Terrain Evaluation	193
4.5	The Airphoto Interpretation Process	200
4.6	Sedimentary Rocks	201
4.7	Igneous Rocks	218
4.8	Metamorphic Rocks	232
4.9	Aeolian Deposits	234
4.10	Glacial Landforms	243
4.11	Fluvial Landforms	266
4.12	Organic Soils	275
	Selected Bibliography	281
5	PHOTOGRAMMETRY	283
5.1	Introduction	283
5.2	Geometric Elements of a Vertical Photograph	286
5.3	Determining Horizontal Ground Lengths, Directions, and Angles From Photocoordinates	290
5.4	Relief Displacements of Vertical Features	294
5.5	Image Parallax	300
5.6	Parallax Measurement	305
5.7	Ground Control for Aerial Photography	312
5.8	Use of Ground Control in Determining the Flying Height and Airbase of Aerial Photographs	313
5.9	Stereoscopic Plotting Instruments	316

5.10	Orthophotos	321
5.11	Flight Planning	329
5.12	Analytic Photogrammetry	334
	Selected Bibliography	334
6	RADIOMETRIC CHARACTERISTICS OF AERIAL PHOTOGRAPHS	335
6.1	Introduction	335
6.2	Film Exposure and Density	336
6.3	Film Characteristic Curves	338
6.4	Preparing Characteristic Curves	344
6.5	Densitometers	345
6.6	Selected Examples of Densitometric Analysis	350
6.7	Geometric Factors Influencing Film Exposure	359
6.8	Atmospheric Effects	368
6.9	Determining Comparative Reflectances of Objects From Exposure Measurements	374
6.10	Spectral Ratioing	376
6.11	Conclusion	379
	Selected Bibliography	380
7	AERIAL THERMOGRAPHY	382
7.1	Introduction	382
7.2	Blackbody Radiation	383
7.3	Radiation From Real Materials	386
7.4	Atmospheric Effects	388
7.5	Interaction of Thermal Radiation With Terrain Elements	390
7.6	Thermal Energy Detectors	393
7.7	Thermal Radiometers	394
7.8	Thermal Scanners	398
7.9	Interpreting Thermal Scanner Imagery	402
7.10	Geometric Characteristics of Thermal Scanner Imagery	414
7.11	Radiometric Calibration of Thermal Scanners	425
7.12	Temperature Mapping With Thermal Scanner Data	433
7.13	Conclusion	440
	Selected Bibliography	441
8	MULTISPECTRAL SCANNING AND SPECTRAL PATTERN RECOGNITION	442
8.1	Introduction	442
8.2	Multispectral Scanners	443
8.3	MSS Operation and Design Considerations	454
8.4	Spectral Pattern Recognition	457
8.5	The Classification Stage	461
8.6	The Training Stage	470
8.7	Unsupervised Classification	477

8.8	The Output Stage	481
8.9	Temporal and Spatial Pattern Recognition	482
8.10	Conclusion	485
	Selected Bibliography	486
9	MICROWAVE SENSING	488
9.1	Introduction	488
9.2	Radar Development	489
9.3	SLAR System Operation	492
9.4	Spatial Resolution of SLAR Systems	494
9.5	Transmission Characteristics of Radar Signals	502
9.6	Terrain Characteristics Influencing Radar Returns	503
9.7	Interpretation of SLAR Imagery	506
9.8	Geometric Characteristics of SLAR Imagery	512
9.9	Future Prospects of Radar Remote Sensing	520
9.10	Elements of Passive Microwave Sensing	521
9.11	Passive Microwave Sensors	523
9.12	Applications of Passive Microwave Sensing	526
	Selected Bibliography	527
10	REMOTE SENSING FROM SPACE	528
10.1	Introduction	528
10.2	Early History of Space Imaging	528
10.3	Landsat Satellite Characteristics	531
10.4	Landsat Data Reception, Processing, and Distribution	540
10.5	Landsat Image Interpretation	543
10.6	Analysis of Digital Landsat MSS Data	553
10.7	Corrections Applied To Landsat Data	557
10.8	Digital Enhancement Techniques	561
10.9	Computer Classification of Landsat Data	578
10.10	Landsat-D	579
10.11	Other Earth Resources Platforms and Systems	583
10.12	Meteorological Satellites	590
10.13	Conclusion	597
	Selected Bibliography	597
	APPENDIX—Image Sources	600
	INDEX	603