

R.R. Jensen

J.D. Gatrell

D.D. McLean

Geo-Spatial Technologies in Urban Environments

Ryan R. Jensen
Jay D. Gatrell
Daniel D. McLean

Geo-Spatial Technologies in Urban Environments

with 45 Figures and 14 Tables

 Springer

Dr. Ryan R. Jensen
Dr. Jay D. Gatrell

Indiana State University
Department of Geography,
Geology and Anthropology
Terre Haute, IN 47809
USA

Dr. Daniel D. McLean
Indiana State University
Department of Recreation
and Sport Management
Terre Haute, IN 47809
USA

Library of Congress Control Number: 2004107248

ISBN 3-540-22263-4 Springer Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer-Verlag. Violations are liable to prosecution under the German Copyright Law.

Springer is a part of Springer Science+Business Media
springeronline.com
© Springer-Verlag Berlin Heidelberg 2005
Printed in Germany

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Cover design: E. Kirchner, Heidelberg
Production: Almas Schimmel
Typesetting: camera-ready by the authors
Printing: Mercedes-Druck, Berlin
Binding: Stein + Lehmann, Berlin

Printed on acid-free paper 30/3141/as 5 4 3 2 1 0

Foreword

Using Geospatial Technologies in Urban Environments simultaneously fills two gaping vacuums in the scholarly literature on urban geography. The first is the clear and straightforward application of geospatial technologies to practical urban issues. By using remote sensing and statistical techniques (correlation-regression analysis, the expansion method, factor analysis, and analysis of variance), the authors of these 12 chapters contribute significantly to our understanding of how geospatial methodologies enhance urban studies. For example, the GIS Specialty Group of the Association of American Geographers (AAG) has the largest membership of all the AAG specialty groups, followed by the Urban Geography Specialty Group. Moreover, the Urban Geography Specialty Group has the largest number of cross-memberships with the GIS Specialty Group. This book advances this important geospatial and urban link.

Second, the book fills a wide void in the urban-environment literature. Although the *Annals of the Association of American Geographers* has recently established an editorship devoted to human environmental issues ("Nature and Society"), relatively few of the articles in this section of the journal have focused specifically on urban-environmental topics. Likewise, of the textbooks in urban geography published over the past decade (Knox, 1994; Pacione, 2001; Kaplan, Wheeler, and Holloway, 2004), none has offered a single chapter on urban-environmental questions, and only passing references to such topics as urban heat islands. In the journal, *Urban Geography*, which began publications in 1980, only two articles have been published that can explicitly be considered in the urban-environment context: Gary Talarchek (1990), "The Urban Forest of New Orleans: An Exploratory Analysis of Relationships," and Vibhooti Shukla and Kirit Parikh (1992), "The Environmental Consequences of Urban Growth: Cross-National Perspectives on Economic Development, Air Pollution, and City Size." In addition, Scott Carlin and Jody Emel (1992) published a Progress Report: "A Review of the Literature on the Urban Environment." They concluded (p. 482) that "geographical focus on this subject remains limited."

In addition to helping fill these gaps in the literature, the book impressively offers policy and planning insights and implications for using geospatial technologies to the study of environments, including such topics as green space, environmental justice, urban forests, and quality of life. Thus, the volume is attractive to a variety of readers. Students interested in urban applications of remote sensing and other geospatial methods will find much of significance in these chapters. Those readers concerned with the urban environment will also find much of value here, as will those attracted to policy and planning considerations. The book at once is alluring to academics and nonacademics, such as those employed in government agencies and public and private planning.

This book points urban geographers down a new and largely untrodden lane. Let us hope that many among us will tread the pioneer pathway into this mostly uncultivated place.

James O. Wheeler
University of Georgia
Athens, GA
January 31, 2004

Dedications

To my wife and children – RRJ

To my favorite editor, s., and our children, f. and m. –JDG

To my many students who challenged, nourished, and strengthened me as an educator – DDM

Contents

1 Applying Geospatial Technologies in Urban Environments..... 1
 Ryan R. Jensen, Jay D. Gatrell, and Daniel D. McLean
 1.1 About this book 1
 1.2 Chapters..... 2
 References 4

2 Remote Sensing of Impervious Surfaces and Building Infrastructure..... 5
 John R. Jensen, Michael E. Hodgson, Jason A. Tullis, and George T. Raber
 2.1 Introduction 5
 2.2 Conventional Methods..... 6
 2.3 Remote Sensing Process..... 6
 2.3.1 Analog and Digital Aerial Photography 7
 2.3.2 Satellite Imagery..... 7
 2.3.3 Light Detection and Ranging (Lidar) 9
 2.3.4 Case Study 1 – Extraction of Impervious Surfaces 10
 2.3.5 Case Study 2 – Extraction of Building Infrastructure 15
 2.4 Conclusion..... 20
 References 20

3 Policy Implications of Remote Sensing in Understanding Urban Environments: Developing a Wetlands Inventory for Community Decision-Making in Lucas County, Ohio..... 23
 Patrick L. Lawrence, Kevin Czajowski, and Nathan Torbick
 3.1 Wetlands 24
 3.2 Study Area 25
 3.3 Background..... 27
 3.4 Analysis 30
 3.4.1 Data Preprocessing 30
 3.4.2 Classification 31
 3.4.3 Results 32
 3.5 Conclusions 34
 3.6 Acknowledgements 35
 References 35

4 Making Spatial Data Usable to the General Public: a Case Study in Tax Mapping 37
 Daniel R. Morgan, Ryan R. Jensen, and Daniel D. McLean

4.1 Background.....	37
4.2 GIS and Public Access to Tax Data.....	39
4.3 Organizing GIS Data Layers	39
4.4 Creation of the Tax Map Public Access Website	40
4.5 Implementation of the Website.....	43
4.6 Discussion.....	44
4.7 Conclusion.....	44
References	46
 5 Modeling Human-Environment Interactions with the Expansion Method	47
<i>Jay D. Gatrell</i>	
5.1 The Expansion Method.....	47
5.2 Making Sense of the Local: The Use of the Expansion Method to Assess and Explore Contingency	48
5.3 Human & Physical Applications: Combination	50
5.4 Rationale for Adopting Casetti to Model Human-Environment Interaction.....	51
5.5 Conclusion.....	51
References	53
 6 The Relationship Between Urban Leaf Area and Summertime Household Energy Usage	55
<i>Ryan R. Jensen, James R. Boulton, and Bruce T. Harper</i>	
6.1 Introduction	55
6.2 Methods	56
6.2.1 Study Area.....	56
6.2.2 LAI Field Measurements.....	56
6.2.3 Satellite Imagery.....	58
6.2.3 LAI Model.....	58
6.3.4 Household Energy	59
6.3 Results	59
6.4 Discussion.....	60
Acknowledgement.....	61
Bibliography	61
 7 The Urban Environment, Socioeconomic Conditions, and Quality of Life: An Alternative Framework for Understanding and Assessing Environmental Justice	63
<i>Ryan R. Jensen, Jay D. Gatrell, James R. Boulton, and Bruce T. Harper</i>	
7.1 Introduction	63
7.1.1 Urban Forestry.....	64

7.1.2 Environmental Justice	65
7.2 Methods	66
7.2.1 Study Area	66
7.2.2 Socioeconomic Variables	67
7.2.3 Leaf Area Index	67
7.2.4 The models	68
7.3 Results	69
7.4 Discussion	70
References	70
8 Image Homogeneity and Urban Demographics: An Integrated Approach to Geo-Techniques	73
<i>Ryan R. Jensen and Jay D. Gatrell</i>	
8.1 Image Texture	73
8.2 Methods	74
8.2.1 Study Area	74
8.2.2 Remote Sensing Data	74
8.2.3 Census Block Groups	75
8.2.4 Gray Level Co-Occurrence Matrix	75
8.3 Results	76
8.4 Discussion	78
References	79
9 Local Government Perceptions of Urban Forestry	81
<i>Daniel D. McLean, Ryan R. Jensen, Paul M. Hightower, Sister Alma M. Anderson</i>	
9.1 Composition and Size of the Urban Forest	83
9.2 Policy Learning	83
9.3 The Political Leader's View of the Urban Forest	84
9.4 Knowledge, the Relationship Model, Understanding and Closing the Gap in Local Government Perceptions of the Urban Forest	89
References	89
10 Satellite Remote Sensing of Urban Heat Islands: Current Practice and Prospects	91
<i>Qihao Weng and Robert Larson</i>	
10.1 Current Practice in Remote Sensing of UHIs	92
10.2 Basic Theory of Thermal Remote Sensing of LST	93
10.2.1 Retrieval of LST	93
10.2.2 Emissivity	94
10.2.3 Fractional Vegetation Cover	95
10.2.4 Thermal Properties and Moisture Content of the Soil	95

10.2.5 Relations of NDVI with LST and Vegetation Abundance	96
10.3 Recent Trends	97
10.3.1 Effect of Urban Morphology	97
10.3.2 Landscape Ecology Approach	97
10.3.3 Fractal Analysis	98
10.4 Urban Heat Island vs. Urban Heat Sink: Case Studies	98
10.4.1 The Urban Heat Island Phenomenon of Indianapolis	99
10.4.2 The Urban Heat Sink Phenomenon of Indianapolis	102
10.5 Discussion and Conclusions	105
References	107
11 Remote Sensing as a Program Assessment Device: The case of Urban Forestry and the Competition for Local Investment	113
<i>Jay D. Gatrell and Ryan R. Jensen</i>	
11.1 The Politics of Local Economic Development	114
11.2 From Grassroots to Public Policy: Environmentalism	115
11.2.1 Urban Forestry	116
11.3 Urban Forestry Assessment Case Studies	123
11.4 Urban Forestry Policies Up Close	126
11.5 Methods	130
11.6 Discussion	132
Acknowledgement	132
References	132
12 Urban Sprawl Detection Using Satellite Imagery and Geographically Weighted Regression	137
<i>Robert Hanham and J. Scott Spiker</i>	
12.1 Introduction	137
12.2 From Change Detection Techniques	140
12.3 Geographically Weighted Regression	141
12.4 Data and Methods	142
12.5 Results	144
12.6 Conclusion	150
Acknowledgement	150
References	150
13 Satellites, Census, and the Quality of Life	153
<i>Valerie A. Muller and Frank Gossette</i>	
13.1 Study Area	153
13.2 Census Data	154
13.3 Factor Analysis	155
13.4 Observed Values	157

13.5 Structural Variables from Landsat Imagery	162
13.6 NDVI from Multispectral Imagery	162
13.7 Predicted Values	162
13.8 Regression	166
13.9 Summary and Conclusion.....	169
References	169
 14 Urban Environmental Approaches: Policy, Application & Method	 171
<i>Jay D. Gatrell, Ryan R. Jensen, and Daniel D. McLean</i>	
14.1 Case Studies.....	171
14.1.1 Policy	172
14.1.2 Application	172
14.1.3 Method.....	173
14.2 Conclusion.....	173
References	174
 Index	 175

About the Contributors

Sister Alma Mary Anderson (M.F.A., Rochester Institute of Technology) is Professor of Graphic Design at Indiana State University.

James R. Boulton (M.A., Indiana State University) is a mining consultant with research interests in environmental change, GIS, quality of life, and urban forestry.

Kevin Czajkowski (Ph.D. University of Michigan) is Associate Professor of Geography and Planning. At the University of Toledo he teaches Weather and Climate and Remote Sensing courses. Dr. Czajkowski is the University of Toledo's representative to the OhioView remote sensing consortium - a consortium of 11 universities in Ohio whose goal is to spread remote sensing.

Frank Gossette (Ph.D., University of California, Los Angeles) is a Professor of Geography at CSU-Long Beach and with expertise in geo-techniques and interests in urban-economic change and East Asia.

Robert Q. Hanham (Ph.D. Ohio State University) is associate professor of geography at West Virginia University. His research interest is in the political economy of uneven development.

Bruce T. Harper (M.A. candidate, Indiana State University) is a graduate student interested in remote sensing and GIS. Bruce has research interests in urban forestry and urban change.

Paul M. Hightower (Ph.D., University of Iowa) is Professor of Journalism at Indiana State University and has research interests in multi-media and the potential intersections between geo-techniques and emerging technologies. As a journalist, Paul is also interested in how media influence public perceptions and issue salience.

Michael E. Hodgson (Ph.D., University of South Carolina) is an Associate Professor of Geography in the South Carolina Department of Geography. Michael's research interests include GIS/RS integration and the capacity for these technologies to monitor, detect, and assess geographic change and hazards.

John R. Jensen (Ph.D., University of California, Los Angeles) is Carolina Distinguished Research Professor of Geography at the University of South Carolina. Dr. Jensen's research interests are in remote sensing image processing, GIS, and biogeography.

Robert Larson (Ph.D., Indiana University) is an Associate Professor of Geography with primary interests in urban and economic geography. Bob has specific expertise in modeling both socio-economic change and the urban heat island effect in urban systems.

Patrick Lawrence (Ph.D. Waterloo) is an Assistant Professor in the Department of Geography and Planning at the University of Toledo. His areas of research interest include environmental planning, community decision-making, watershed management, wetlands, land use change analysis, and the Great Lakes.

Daniel R. Morgan (M.S. Utah State University) is GIS manager in Beaufort County, South Carolina. Dan continues to develop new ways to serve geographic information to county residents.

Valerie A. Muller (M.A., California State University, Long Beach) is a geotechniques specialist at a regional planning and development office in southern California.

George T. Raber (Ph.D., University of South Carolina) is an Assistant Professor of Geography at the University of Southern Mississippi and specializes in remote sensing of the environment and the assessment of environmental change.

J. Scott Spiker (Ph.D. Candidate, West Virginia University) has primary research interests in remote sensing and spatial analysis. In particular, Scott investigates spatial autocorrelation issues and the design and implementation of alternative methodologies in remote sensing.

Nathan Torbick (M.A. candidate, University of Toledo) is a graduate student with research interests in wetlands ecology and use remote sensing and GIS technology.

Jason A. Tullis (Ph.D. candidate, University of South Carolina) is a remote sensing specialist with interests in urban change and environment assessment.

Qihao Weng (Ph.D., University of Georgia) is an Assistant Professor of Geography in the Department of Geography, Geology, & Anthropology. Dr. Weng's research interests include remote sensing of urban environments and modeling urban environmental change. Specifically, Qihao's research emphasizes the development remote sensing techniques to detect land surface temperature and the assessment of urban heat islands.

1 Applying Geospatial Technologies in Urban Environments

Ryan R. Jensen, Department of Geography, Geology & Anthropology, Indiana State University, Terre Haute, IN

Jay D. Gatrell, Department of Geography, Geology & Anthropology, Indiana State University, Terre Haute, IN

Daniel D. McLean, Department of Recreation and Sport Management, Indiana State University, Terre Haute, IN

Cities have been around since the 3rd millennium B.C. and as long as they have existed, people have been drawn to them for what they offer. As recently as 1800, however, only 2 per cent of the world's population lived in urban areas. Today, with 6 billion people on earth, slightly less than one-half live in cities and towns; by 2007 one half of them will. In the century ahead, urban centres are expected to expand to sizes never before seen.

United Nations, Istanbul + 5, 2001, p. 1

1.1 About this book

As the epigraph suggest, cities are to become one of the chief policy concerns of the 21st century. Moreover, cities are unique policy realms in that urbanization is an issue and process that resides at the nexus of human and physical systems and unites the research and policy interests of natural and social scientists alike. This is true as urbanization as a process unites often-disparate social and physical systems to create entirely new policy challenges such as environmental degradation, the development and maintenance of physical and social infrastructures, the challenge of expanding economic opportunities, designing effective service delivery regimes that promote the overall sustainability of urban areas, and assessing the policy outcomes. Consequently, researchers and policy makers are concerned with identifying and overcoming the full range of challenges associated with urban systems. Unfortunately, the ability of researchers and planners to assess and investigate complex urban systems has been somewhat frustrated by a lack effective and accessible research and decision making tools. Over the past fifteen years, remote sensing and geographic information systems (GIS) have been shown to provide an excellent way to investigate urban areas. However, the availability, “usability”, and range of potential applications of these technologies had until recently been limited to a community of specialists and scientist. Today remote

sensing and GIS technologies provide an accessible and increasingly user friendly suite of data and data analyses that facilitate the integrated investigation of spatial information. Further, the ability of GIS to integrate tabular data with spatial data allows for detailed investigations with socioeconomic data. .

The purpose of this book was to assemble a collection of studies that investigate and develop alternate methodological approaches to understanding the urban environment. In particular, it seeks to bring together studies that use remote sensing technologies and geographic information systems to explore issues often ignored by the mainstream community of geo-technical specialists, such as environmental justice, the meaning of data, and the everyday lives of urban residents. This book is meant to bridge the gap between the geography / planning / public administration communities and others that use geospatial technologies. Urban resource professionals need new management practices, skills, and tools to address the new and changing urban environment, and research is needed to place the best scientific data into the hands of decision makers (Hermansen and Macie, 2002).

This book seeks to expand the current frame of reference of remote sensing and geographic information specialists to include an array of socio-economic and related planning issues. Using remotely sensed data, the project explores the efficacy and policy implications of new approaches toward analyzing data (i.e., homogeneity indices), integrates approaches from human geography (i.e., Expansion Method), and explores the utility of employing geo-technologies to further the politics of local growth and smart growth coalitions (i.e., green space). Indeed, this book seeks to build upon Longley's (2002) call for better urban geography by integrating these technologies into the urban environment.

1.2 Chapters

There are many ways to classify the 12 main chapters of this book including the techniques used, the context of the analysis, the data sets used, the spatial resolution or scale of the data and so on. Because of this breadth, it made classifying the chapters into specific groups very difficult. This book not only gives many research examples of geospatial technologies in urban areas, but it also provides the basics of these technologies in several introductory chapters. These chapters are meant to provide a foundation of these technologies to readers that are not as familiar with them. For example, those readers lacking a basic understanding of the principles of urban remote sensing should read chapter 2. Those seeking to understand more of the Casetti expansion method and its role in this book and in spatial data processing should read chapter 5. Chapter 3 describes policy implications of remote sensing through a case study. Many chapters demonstrate the potential role of geospatial technologies in examining and solving urban problems. Specifically, two chapters examine urban quality of life and environmental justice (Chapters 7 & 8). Another chapter details how local community leaders perceive the

costs and benefits of the urban forest to their community (Chapter 9) and how a healthy urban forest can actually spur economic development (Chapter 11), while another chapter details the economic impact of urban forestry on summertime electrical energy usage (Chapter 6). Chapter 10 reviews much of the remote sensing urban heat island literature and provides an urban heat island case study. Those readers seeking an example of how to provide spatial data to the public should read chapter 4. Chapter 12 describes how remote sensing can be used to estimate urban sprawl, and chapter 13 details the links between satellite and census data.

Table 1. Summary of substantive chapters in this book

	Author(s)	Subject
2	J. Jensen et al.	Urban remote sensing
3	Lawrence et al.	Policy implications of remote sensing detection of an urban wetland
4	Morgan et al.	Making spatial and tabular data available to the public – the case of Internet tax mapping
5	Gatrell	Assessing socio-spatial interactions with the expansion method
6	R. Jensen et al.	Relationship between urban leaf area and energy consumption
7	R. Jensen et al.	Using remote sensing technologies to study urban environmental justice
8	R. Jensen and Gatrell	Using texture to assess urban quality of life
9	McLean et al.	Local government leaders perceptions of the urban forest
10	Weng and Larson	Remote sensing of urban heat islands
11	Gatrell and Jensen	Remote sensing and urban assessment – using remote sensing and urban forestry to compete for local investment
12	Hanham and Spiker	Urban sprawl detection using remote sensing
13	Muller and Gossette	The relationship between urban structural variables and socioeconomic conditions

The authors and editors hope that this book will be used by planners, landscape architects, urban foresters, GIS and remote sensing specialists, and many others to improve quality of life in the urban environment. People will continue to migrate to urban areas. Our ability to examine and mitigate the potential negative impacts of this migration is very important today and will be even more important tomorrow. As such, this book and the studies contained within it should be used as a point of reference of sorts for those who might imagine and re-imagine the range of potential geo-technical applications to assist urban decision making and promote the overall sustainability of social and physical systems.

References

- Hermansen, L.A. and E. A. Macie. 2002. "Introduction." In *Human Influences on Forest Ecosystems*. United States Department of Agriculture, Forest Service General Technical Report SRS-55
- Longley, P.A. 2002. "Geographical information systems: will developments in urban remote sensing and GIS lead to 'better' urban geography?" *Progress in Human Geography* 26:231-239.
- United Nations Centre for Human Settlements (HABITAT). 2001. BROCHURE: Istanbul + 5: The United Nations Special Session of the General Assembly for an Overall Review and Appraisal of the Implementation of the Habitat Agenda. New York: United Nations, Department of Public Information, 8 pages with figures.

2 Remote Sensing of Impervious Surfaces and Building Infrastructure

John R. Jensen, Department of Geography, University of South Carolina, Columbia, SC

Michael E. Hodgson, Department of Geography, University of South Carolina, Columbia, SC

Jason A. Tullis, Department of Geography, University of South Carolina, Columbia, SC

George T. Raber, Department of Geography, University of Southern Mississippi, Hattiesburg, MS

2.1 Introduction

The rapidly expanding urban surfaces of today are generally impervious to water and are a key environmental indicator (Arnold and Gibbons 1996) that can be measured with remote sensing. Roads, sidewalks, parking lots, and rooftops are usually constructed of materials that repel almost all incident precipitation. In some cases, precipitation events can result in flash flooding that is similar to the flash floods occurring in rock canyons. The ability to detect, monitor, and analyze changes in the extent of impervious surfaces is important for many other aspects in the quality of environment, such as urban heat islands and pollution. This capability is in high demand for water quality engineering purposes (Zug et al. 1999) and for the assessment of stormwater taxes (Kienegger 1992).

There is also significant value in the ability to detect, monitor, and analyze changes in building infrastructure over large areas (hundreds to thousands of km²). Individual dwelling units, for example, are an important surrogate for population estimates (Jensen 2000). Even though a census is routinely collected (e.g. every ten years in the United States), remote sensing of individual dwellings can provide annual (instead of just decennial) estimates of population status. The changing building landscape is important and relevant to the economy, the environment, and quality of life. Disorganized growth can lead to unintended consequences such as insufficient open space, traffic congestion, and overcrowded schools. Many public and private leaders are investigating new urban growth models that will mitigate these problems (O'Neill et al. 2000).

This chapter gives case studies of remote sensing of impervious surfaces and building infrastructure using a variety of remote sensor data sources, including aerial photography, digital aerial imagery, satellite imagery, and lidar.

2.2 Conventional Methods

In situ GPS surveying and digitization of hardcopy maps (e.g. engineering drawings) can provide urban infrastructural information suitable for analysis using GIS. These techniques can be expensive and difficult to implement on a systematic basis. Much effort has been expended to improve and simplify these methods. One popular technique for inventorying roads and paved surfaces is the use of GPS enabled vehicles, sometimes equipped with additional survey equipment. In another example, Great Britain is implementing methods for individual postal workers to identify commercial and dwelling locations nationwide (Ordnance Survey 2000). Digitization of hardcopy maps has progressed from the use of digitizing tablets to the use of a variety of scanners and feature extraction algorithms.

2.3 Remote Sensing Process

Remote sensing offers an alternative to *in situ* and/or hardcopy digitization methods which may or may not be sufficient (or efficient) for obtaining the desired urban information. However, remote sensing techniques also have their strengths and weaknesses that should be considered. Even if a remote sensing method is judged to be superior, it will likely require field verification. The scope and nature of the urban analysis problem must be carefully considered when deciding on a particular technique, or combination of techniques.

Remote sensing in the urban environment requires special considerations regarding data sources and utilization. Often these considerations are based on fundamental resolution requirements (i.e. suitable spatial, spectral, temporal, and radiometric resolutions). Many urban applications, including impervious surface and building infrastructure mapping, require a high to moderate temporal resolution of from 1 to 5 years. These types of applications also utilize high spatial resolution, often at or below 1×1 m, in order to capture the detail and complexity of the urban landscape (Jensen and Cowen 1999).

In traditional urban applications, which are primary based on manual image interpretation, most image analysts would agree that when extracting information from remotely sensed data it is more important to have high spatial resolution than to have high spectral or radiometric resolution (Jensen 2000). However, when using automated computer processing methods such as those presented in this chapter, subtle changes in spectral and radiometric response can prove to be of equal im-