

ENCYCLOPEDIA OF EARTH SCIENCES SERIES

ENCYCLOPEDIA *of* REMOTE SENSING

edited by

ENI G. NJOKU

*Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
USA*

 Springer Reference

Contents

Contributors	xi		
Preface	xxiii		
Acknowledgments	xxv		
Acoustic Radiation <i>Alain Weill</i>	1	Calibration, Optical/Infrared Passive Sensors <i>Carol Bruegge</i>	47
Acoustic Tomography, Ocean <i>Brian Dushaw</i>	4	Calibration, Synthetic Aperture Radars <i>Anthony Freeman</i>	51
Acoustic Waves, Propagation <i>Alain Weill</i>	11	Calibration, Scatterometers <i>David Long</i>	54
Acoustic Waves, Scattering <i>Alain Weill</i>	13	Climate Data Records <i>Eric F. Wood</i>	58
Aerosols <i>Ralph Kahn</i>	16	Climate Monitoring and Prediction <i>Mathew R. P. Sapiano</i>	58
Agricultural Expansion and Abandonment <i>Jiaguo Qi</i>	20	Cloud Liquid Water <i>Fuzhong Weng</i>	68
Agriculture and Remote Sensing <i>Jerry Hatfield and Susan Moran</i>	22	Cloud Properties <i>Matthew Lebsock and Steve Cooper</i>	70
Air Pollution <i>Annmarie Eldering</i>	32	Coastal Ecosystems <i>Xiaojun Yang</i>	73
Atmospheric General Circulation Models <i>Joao Teixeira, Mark Taylor, Anders Persson and Georgios Matheou</i>	35	Commercial Remote Sensing <i>William Gail</i>	78
Calibration and Validation <i>Andreas Colliander</i>	39	Cosmic-Ray Hydrometeorology <i>Darin Desilets and Marek Zreda</i>	83
Calibration, Microwave Radiometers <i>Christopher Ruf</i>	46	Cost Benefit Assessment <i>Molly Macauley</i>	86
		Crop Stress <i>Susan Moran</i>	88
		Cryosphere and Polar Region Observing System <i>Mark Drinkwater</i>	91

vi	CONTENTS		
Cryosphere, Climate Change Effects <i>Aixue Hu</i>	98	Emerging Technologies, Radiometer <i>Todd Gaier</i>	186
Cryosphere, Climate Change Feedbacks <i>Peter J. Minnett</i>	101	Emerging Technologies, Sensor Web <i>Mahta Moghaddam, Agnelo Silva and Mingyan Liu</i>	190
Cryosphere, Measurements and Applications <i>Roger Barry</i>	104	Environmental Treaties <i>Alexander de Sherbinin</i>	196
Data Access <i>Ron Weaver</i>	119	Fields and Radiation <i>Frank S. Marzano</i>	201
Data Archival and Distribution <i>Mark A. Parsons</i>	121	Fisheries <i>Cara Wilson</i>	202
Data Archives and Repositories <i>Ruth Duerr</i>	127	Forestry <i>Dar Roberts</i>	210
Data Assimilation <i>Dennis McLaughlin</i>	131	Gamma and X-Radiation <i>Enrico Costa and Fabio Muleri</i>	219
Data Policies <i>Ray Harris</i>	134	Geodesy <i>Calvin Klatt</i>	228
Data Processing, SAR Sensors <i>Jakob van Zyl</i>	136	Geological Mapping Using Earth's Magnetic Field <i>Vernon H. Singhroy and Mark Pilkington</i>	232
Decision Fusion, Classification of Multisource Data <i>Björn Waske and Jón Atli Benediktsson</i>	140	Geomorphology <i>David Pieri</i>	237
Earth Radiation Budget, Top-of-Atmosphere Radiation <i>Bing Lin</i>	145	Geophysical Retrieval, Forward Models in Remote Sensing <i>Eugene Ustinov</i>	241
Earth System Models <i>Andrea Donnellan</i>	146	Geophysical Retrieval, Inverse Problems in Remote Sensing <i>Eugene Ustinov</i>	247
Electromagnetic Theory and Wave Propagation <i>Yang Du</i>	150	Geophysical Retrieval, Overview <i>Eugene Ustinov</i>	251
Emerging Applications <i>William Gail</i>	159	Global Climate Observing System <i>Jean-Louis Fellous</i>	254
Emerging Technologies <i>Jason Hyon</i>	162	Global Earth Observation System of Systems (GEOSS) <i>Steffen Fritz</i>	257
Emerging Technologies, Free-Space Optical Communications <i>Hamid Hemmati</i>	163	Global Land Observing System <i>Johannes A. Dolman</i>	261
Emerging Technologies, Lidar <i>David M. Tratt</i>	177	Global Programs, Operational Systems <i>Mary Kicza</i>	263
Emerging Technologies, Radar <i>Alina Moussessian</i>	185	GPS, Occultation Systems <i>Chi O. Ao</i>	264

Ice Sheets and Ice Volume <i>Robert Thomas</i>	269	Microwave Dielectric Properties of Materials <i>Martti Hallikainen</i>	364
Icebergs <i>Donald L. Murphy</i>	281	Microwave Horn Antennas <i>Yahya Rahmat-Samii</i>	375
International Collaboration <i>Lisa Robock Shaffer</i>	284	Microwave Radiometers <i>Niels Skou</i>	382
Ionospheric Effects on the Propagation of Electromagnetic Waves <i>Attila Komjathy</i>	286	Microwave Radiometers, Conventional <i>Niels Skou</i>	386
Irrigation Management <i>Steven R. Evett, Paul D. Colaizzi, Susan A. O'Shaughnessy, Douglas J. Hunsaker and Robert G. Evans</i>	291	Microwave Radiometers, Correlation <i>Christopher Ruf</i>	389
Land Surface Emissivity <i>Alan Gillespie</i>	303	Microwave Radiometers, Interferometers <i>Manuel Martin-Neira</i>	390
Land Surface Roughness <i>Thomas Farr</i>	311	Microwave Radiometers, Polarimeters <i>David Kunkee</i>	395
Land Surface Temperature <i>Alan Gillespie</i>	314	Microwave Subsurface Propagation and Scattering <i>Alexander Yarovoy</i>	398
Land Surface Topography <i>G. Bryan Bailey</i>	320	Microwave Surface Scattering and Emission <i>David R. Lyzenga</i>	403
Land-Atmosphere Interactions, Evapotranspiration <i>Joshua B. Fisher</i>	325	Mission Costs of Earth-Observing Satellites <i>Randall Friedl and Stacey Boland</i>	405
Landslides <i>Vernon H. Singhroy</i>	328	Mission Operations, Science Applications/Requirements <i>David L. Glackin</i>	407
Law of Remote Sensing <i>Joanne Irene Gabrynowicz</i>	332	Observational Platforms, Aircraft, and UAVs <i>Jeffrey Myers</i>	409
Lidar Systems <i>Robert Menzies</i>	334	Observational Systems, Satellite <i>David L. Glackin</i>	412
Lightning <i>Rachel I. Albrecht, Daniel J. Cecil and Steven J. Goodman</i>	339	Ocean Applications of Interferometric SAR <i>Roland Romeiser</i>	426
Limb Sounding, Atmospheric <i>Nathaniel Livesey</i>	344	Ocean Data Telemetry <i>Michael R. Prior-Jones</i>	429
Madden-Julian Oscillation (MJO) <i>Baijun Tian and Duane Waliser</i>	349	Ocean Internal Waves <i>Werner Alpers</i>	433
Magnetic Field <i>Nils Olsen</i>	358	Ocean Measurements and Applications, Ocean Color <i>Samantha Lavender</i>	437
Media, Electromagnetic Characteristics <i>Yang Du</i>	362	Ocean Modeling and Data Assimilation <i>Detlef Stammer</i>	446
		Ocean Surface Topography <i>Lee-Lueng Fu</i>	455

Cover figure:

Cloud formati
Islands, taken |
US Geologic
Observation an

viii	CONTENTS	
Ocean Surface Velocity <i>Bertrand Chapron, Johnny Johannessen and Fabrice Collard</i>	461	Radiation (Natural) Within the Earth's Environment <i>Anthony England</i> 558
Ocean, Measurements and Applications <i>Ian Robinson</i>	469	Radiation Sources (Natural) and Characteristics <i>Anthony England</i> 574
Ocean-Atmosphere Water Flux and Evaporation <i>W. Timothy Liu and Xiaosu Xie</i>	480	Radiation, Electromagnetic <i>Frank S. Marzano</i> 576
Operational Transition <i>Richard Anthes</i>	489	Radiation, Galactic, and Cosmic Background <i>David M. Le Vine</i> 581
Optical/Infrared, Atmospheric Absorption/ Transmission, and Media Spectral Properties <i>Gian Luigi Liberti</i>	492	Radiation, Multiple Scattering <i>Frank S. Marzano</i> 585
Optical/Infrared, Radiative Transfer <i>Knut Stamnes</i>	495	Radiation, Polarization, and Coherence <i>Yang Du</i> 588
Optical/Infrared, Scattering by Aerosols and Hydrometeors <i>Gian Luigi Liberti</i>	498	Radiation, Solar and Lunar <i>David M. Le Vine</i> 591
Pattern Recognition and Classification <i>Björn Waske and Jón Atli Benediktsson</i>	503	Radiation, Volume Scattering <i>Leung Tsang and Kung-Hau Ding</i> 595
Polar Ice Dynamics <i>James Maslanik</i>	509	Radiative Transfer, Solution Techniques <i>Rodolfo Guzzi</i> 606
Polar Ocean Navigation <i>Lawson Brigham</i>	512	Radiative Transfer, Theory <i>Frank S. Marzano</i> 624
Policies and Economics <i>Roberta Balstad</i>	515	Radio-Frequency Interference (RFI) in Passive Microwave Sensing <i>David Kunkee</i> 634
Precision Agriculture <i>Kelly Thorp</i>	515	Rainfall <i>Ralph Ferraro</i> 640
Processing Levels <i>Ron Weaver</i>	517	Rangelands and Grazing <i>Hunt E. Raymond, Jr.</i> 653
Public-Private Partnerships <i>William Gail</i>	520	Reflected Solar Radiation Sensors, Multiangle Imaging <i>David J. Diner</i> 658
Radar, Altimeters <i>Keith Raney</i>	525	Reflected Solar Radiation Sensors, Polarimetric <i>David J. Diner</i> 663
Radar, Scatterometers <i>David Long</i>	532	Reflector Antennas <i>Yahya Rahmat-Samii</i> 668
Radar, Synthetic Aperture <i>Keith Raney</i>	536	Remote Sensing and Geologic Structure <i>Vernon H. Singhroy and Paul Lowman</i> 681
Radars <i>Keith Raney</i>	547	Remote Sensing, Historical Perspective <i>Vincent V. Salomonson</i> 684

Remote Sensing, Physics and Techniques <i>David L. Glackin</i>	691	Terrestrial Snow <i>Son V. Nghiem, Dorothy K. Hall, James L. Foster and Gregory Neumann</i>	821
Resource Exploration <i>Fred A. Kruse and Sandra L. Perry</i>	702	Thermal Radiation Sensors (Emitted) <i>Simon Hook</i>	830
SAR-Based Bathymetry <i>Han Wensink and Werner Alpers</i>	719	Trace Gases, Stratosphere, and Mesosphere <i>Nathaniel Livesey</i>	834
Sea Ice Albedo <i>Donald Perovich</i>	722	Trace Gases, Troposphere - Detection from Space <i>Pieter F. Levelt, J. P. Veefkind and K. F. Boersma</i>	838
Sea Ice Concentration and Extent <i>Josefino C. Comiso</i>	727	Trafficability of Desert Terrains <i>Charles Hibbitts</i>	846
Sea Level Rise <i>Josh Willis</i>	743	Tropospheric Winds <i>Chris Velden</i>	849
Sea Surface Salinity <i>Gary Lagerloef</i>	747	Ultraviolet Remote Sensing <i>Arlin Krueger</i>	853
Sea Surface Temperature <i>Peter J. Minnett</i>	754	Ultraviolet Sensors <i>Arlin Krueger</i>	860
Sea Surface Wind/Stress Vector <i>W. Timothy Liu and Xiaosu Xie</i>	759	Urban Environments, Beijing Case Study <i>Son V. Nghiem, Alessandro Sorichetta, Christopher D. Elvidge, Christopher Small, Deborah Balk, Uwe Deichmann and Gregory Neumann</i>	869
Severe Storms <i>Charles A. III Doswell</i>	767	Urban Heat Island <i>Lela Prashad</i>	878
Snowfall <i>Ralf Bennartz</i>	780	Vegetation Indices <i>Alfredo Huete</i>	883
Soil Moisture <i>Yann Kerr</i>	783	Vegetation Phenology <i>John Kimball</i>	886
Soil Properties <i>Alfredo Huete</i>	788	Volcanism <i>Michael J. Abrams</i>	890
Solid Earth Mass Transport <i>Erik Ivins</i>	791	Water and Energy Cycles <i>Taikan Oki and Pat J.-F. Yeh</i>	895
Stratospheric Ozone <i>Michelle Santee</i>	796	Water Resources <i>Taikan Oki and Pat J.-F. Yeh</i>	903
Subsidence <i>Stuart Marsh and Martin Culshaw</i>	800	Water Vapor <i>Eric Fetzer</i>	909
Surface Radiative Fluxes <i>Rachel T. Pinker</i>	806	Weather Prediction <i>Peter Bauer</i>	912
Surface Truth <i>Christopher Ruf</i>	815	Wetlands <i>John Melack</i>	921
Surface Water <i>Michael Durand</i>	816	Author Index	923
		Subject Index	925