

## Contents

	<b>Preface</b>	XVII
	<b>A Tribute to Dr. Robert Knollenberg</b>	XXI
	<b>List of Contributors</b>	XXIII
<b>1</b>	<b>Introduction to Airborne Measurements of the Earth Atmosphere and Surface</b>	<b>1</b>
	<i>Ulrich Schumann, David W. Fahey, Manfred Wendisch, and Jean-Louis Brenguier</i>	
<b>2</b>	<b>Measurement of Aircraft State and Thermodynamic and Dynamic Variables</b>	<b>7</b>
	<i>Jens Bange, Marco Esposito, Donald H. Lenschow, Philip R. A. Brown, Volker Dreiling, Andreas Giez, Larry Mahrt, Szymon P. Malinowski, Alfred R. Rodi, Raymond A. Shaw, Holger Siebert, Herman Smit, Martin Zöger</i>	
2.1	Introduction	7
2.2	Historical	8
2.3	Aircraft State Variables	10
2.3.1	Barometric Measurement of Aircraft Height	10
2.3.2	Inertial Attitude, Velocity, and Position	12
2.3.2.1	System Concepts	12
2.3.2.2	Attitude Angle Definitions	12
2.3.2.3	Gyroscopes and Accelerometers	14
2.3.2.4	Inertial-Barometric Corrections	15
2.3.3	Satellite Navigation by Global Navigation Satellite Systems	15
2.3.3.1	GNSS Signals	15
2.3.3.2	Differential GNSS	16
2.3.3.3	Position Errors and Accuracy of Satellite Navigation	17
2.3.4	Integrated IMU/GNSS Systems for Position and Attitude Determination	18
2.3.5	Summary, Gaps, Emerging Technologies	18
2.4	Static Air Pressure	18

2.4.1	Position Error	20
2.4.1.1	Tower Flyby	22
2.4.1.2	Trailing Sonde	23
2.4.2	Summary	24
2.5	Static Air Temperature	24
2.5.1	Aeronautic Definitions of Temperatures	25
2.5.2	Challenges of Airborne Temperature Measurements	25
2.5.3	Immersion Probe	27
2.5.4	Reverse-Flow Sensor	29
2.5.5	Radiative Probe	30
2.5.6	Ultrasonic Probe	31
2.5.7	Error Sources	32
2.5.7.1	Sensor	32
2.5.7.2	Dynamic Error Sources	33
2.5.7.3	In-Cloud Measurements	34
2.5.8	Calibration of Temperature Sensors	34
2.5.9	Summary, Gaps, Emerging Technologies	34
2.6	Water Vapor Measurements	35
2.6.1	Importance of Atmospheric Water Vapor	35
2.6.2	Humidity Variables	36
2.6.3	Dew or Frost Point Hygrometer	37
2.6.4	Lyman- $\alpha$ Absorption Hygrometer	39
2.6.5	Lyman- $\alpha$ Fluorescence Hygrometer	40
2.6.6	Infrared Absorption Hygrometer	41
2.6.7	Tunable Laser Absorption Spectroscopy Hygrometer	43
2.6.8	Thin Film Capacitance Hygrometer	44
2.6.9	Total Water Vapor and Isotopic Abundances of $^{18}\text{O}$ and $^2\text{H}$	45
2.6.10	Factors Influencing In-Flight Performance	46
2.6.10.1	Sticking of Water Vapor at Surfaces	46
2.6.10.2	Sampling Systems	47
2.6.11	Humidity Measurements with Dropsondes	47
2.6.12	Calibration and In-Flight Validation	48
2.6.13	Summary and Emerging Technologies	49
2.7	Three-Dimensional Wind Vector	50
2.7.1	Airborne Wind Measurement Using Gust Probes	52
2.7.1.1	True Airspeed (TAS) and Aircraft Attitude	52
2.7.1.2	Wind Vector Determination	53
2.7.1.3	Baseline Instrumentation	54
2.7.1.4	Angles of Attack and Sideslip	55
2.7.2	Errors and Flow Distortion	56
2.7.2.1	Parameterization Errors	56
2.7.2.2	Measurement Errors	56
2.7.2.3	Timing Errors	57
2.7.2.4	Errors due to Incorrect Sensor Configuration	57
2.7.3	In-Flight Calibration	57

2.8	Small-Scale Turbulence	58
2.8.1	Hot-Wire/Hot-Film Probes for High-Resolution Flow Measurements	58
2.8.2	Laser Doppler Anemometers	60
2.8.3	Ultrasonic Anemometers/Thermometers	62
2.8.4	Measurements of Atmospheric Temperature Fluctuations with Resistance Wires	64
2.8.5	Calibration of Fast-Response Sensors	66
2.8.6	Summary, Gaps, and Emerging Technologies	67
2.9	Flux Measurements	68
2.9.1	Basics	68
2.9.2	Measurement Errors	69
2.9.3	Flux Sampling Errors	71
2.9.3.1	Systematic Flux Error	71
2.9.3.2	Random Flux Error	72
2.9.4	Area-Averaged Turbulent Flux	73
2.9.5	Preparation for Airborne Flux Measurement	74
<b>3</b>	<b><i>In Situ</i> Trace Gas Measurements</b>	<b>77</b>
	<i>Jim McQuaid, Hans Schlager, Maria Dolores Andrés-Hernández, Stephen Ball, Agnès Borbon, Steve S. Brown, Valery Catoire, Piero Di Carlo, Thomas G. Custer, Marc von Hobe, James Hopkins, Klaus Pfeilsticker, Thomas Röckmann, Anke Roiger, Fred Stroh, Jonathan Williams, and Helmut Ziereis</i>	
3.1	Introduction	77
3.2	Historical and Rationale	81
3.3	Aircraft Inlets for Trace Gases	83
3.4	Examples of Recent Airborne Missions	84
3.5	Optical <i>In Situ</i> Techniques	86
3.5.1	UV Photometry	86
3.5.2	Differential Optical Absorption Spectroscopy	88
3.5.2.1	Measurement Principle	88
3.5.2.2	Examples of Measurement	91
3.5.3	Cavity Ring-Down Spectroscopy	95
3.5.3.1	Measurement Principle	95
3.5.3.2	Aircraft Implementation	98
3.5.3.3	Calibration and Uncertainty	99
3.5.3.4	Broadband Cavity Spectroscopic Methods	101
3.5.4	Gas Filter Correlation Spectroscopy	103
3.5.5	Tunable Laser Absorption Spectroscopy	104
3.5.5.1	Tunable Diode Versus QCLs	105
3.5.5.2	Further Progress	106
3.5.6	Fluorescence Techniques	107
3.5.6.1	Resonance Fluorescence	107
3.5.6.2	LIF Techniques	107

3.5.6.3	Chemical Conversion Resonance Fluorescence Technique	112
3.6	Chemical Ionization Mass Spectrometry	120
3.6.1	Negative-Ion CIMS	120
3.6.1.1	Measurement Principle and Aircraft Implementation	121
3.6.1.2	Calibration and Uncertainties	121
3.6.1.3	Measurement Example	123
3.6.2	The Proton Transfer Reaction Mass Spectrometer	123
3.6.3	Summary and Future Perspectives	129
3.7	Chemical Conversion Techniques	131
3.7.1	Peroxy Radical Chemical Amplification	131
3.7.1.1	Measurement Principles	131
3.7.1.2	Airborne Measurements	132
3.7.1.3	Calibration and Uncertainties	133
3.7.2	Chemiluminescence Techniques	137
3.7.2.1	Measurement Principle	137
3.7.2.2	Measurement of Ozone Using Chemiluminescence	138
3.7.2.3	NO <sub>y</sub> and NO <sub>2</sub> Conversion	139
3.7.2.4	Calibration and Uncertainties	139
3.7.2.5	Measurement Examples	141
3.7.2.6	Summary	142
3.7.3	Liquid Conversion Techniques	143
3.7.3.1	Measurement Principles	143
3.7.3.2	Aircraft Implementation	144
3.7.3.3	Data Processing	145
3.7.3.4	Limitations, Uncertainties, and Error Propagation	146
3.7.3.5	Calibration and Maintenance	146
3.7.3.6	Measurement Examples	146
3.7.3.7	Summary and Emerging Technologies	147
3.8	Whole Air Sampler and Chromatographic Techniques	147
3.8.1	Rationale	147
3.8.2	Whole Air Sampling Systems	148
3.8.2.1	Design of Air Samplers	148
3.8.2.2	The M55-Geophysica Whole Air Sampler	149
3.8.3	Water Vapor Sampling for Isotope Analysis	150
3.8.4	Measurement Examples	150
3.8.5	Off-Line Analysis of VOCs	152
3.8.5.1	Air Mass Ageing	153
3.8.5.2	Using VOC Observations to Probe Radical Chemistry	154
4	<b><i>In Situ Measurements of Aerosol Particles</i></b>	157
	<i>Andreas Petzold, Paola Formenti, Darrel Baumgardner, Ulrich Bundke, Hugh Coe, Joachim Curtius, Paul J. DeMott, Richard C. Flagan, Markus Fiebig, James G. Hudson, Jim McQuaid, Andreas Minikin, Gregory C. Roberts, and Jian Wang</i>	
4.1	Introduction	157

4.1.1	Historical Overview	157
4.1.2	Typical Mode Structure of Aerosol Particle Size Distribution	159
4.1.3	Quantitative Description of Aerosol Particles	159
4.1.4	Chapter Structure	162
4.2	Aerosol Particle Number Concentration	164
4.2.1	Condensation Particle Counters	164
4.2.2	Calibration of Cut-Off and Low-Pressure Detection Efficiency	166
4.3	Aerosol Particle Size Distribution	168
4.3.1	Single-Particle Optical Spectrometers	168
4.3.1.1	Measurement Principles and Implementation	169
4.3.1.2	Measurement Issues	172
4.3.2	Aerodynamic Separators	174
4.3.3	Electrical Mobility Measurements of Particle Size Distributions	176
4.3.4	Inversion Methods	181
4.4	Chemical Composition of Aerosol Particles	184
4.4.1	Direct Offline Methods	185
4.4.2	Direct Online Methods (Aerosol Mass Spectrometer, Single Particle Mass Spectrometer, and Particle-Into-Liquid Sampler)	191
4.4.2.1	Bulk Aerosol Collection and Analysis	191
4.4.2.2	Mass Spectrometric Methods	193
4.4.2.3	Incandescence Methods	197
4.4.3	Indirect Methods	199
4.5	Aerosol Optical Properties	200
4.5.1	Scattering Due to Aerosol Particles	201
4.5.2	Absorption of Solar Radiation Due to Aerosol Particles	203
4.5.2.1	Filter-Based Methods	204
4.5.2.2	<i>In Situ</i> Methods	205
4.5.2.3	Airborne Application	206
4.5.3	Extinction Due to Aerosol Particles	208
4.5.4	Inversion Methods	209
4.6	CCN and IN	210
4.6.1	CCN Measurements Methods	212
4.6.2	IN Measurement Methods	213
4.6.3	Calibration	217
4.6.3.1	CCN Instrument Calibration	217
4.6.3.2	IN Instrument Calibration	218
4.7	Challenges and Emerging Techniques	219
4.7.1	Particle Number	219
4.7.2	Particle Size	220
4.7.3	Aerosol Optical Properties	221
4.7.4	Chemical Composition of Aerosol Particles	222
4.7.5	CCN Measurements	222
4.7.6	IN Measurements	223

<b>5</b>	<b><i>In Situ</i> Measurements of Cloud and Precipitation Particles</b>	<b>225</b>
	<i>Jean-Louis Brenguier, William Bachalo, Patrick Y. Chuang, Biagio M. Esposito, Jacob Fugal, Timothy Garrett, Jean-Francois Gayet, Hermann Gerber, Andy Heymsfield, Alexander Kokhanovsky, Alexei Korolev, R. Paul Lawson, David C. Rogers, Raymond A. Shaw, Walter Strapp, and Manfred Wendisch</i>	
5.1	Introduction	225
5.1.1	Rationale	225
5.1.2	Characterization of Cloud Microphysical Properties	226
5.1.3	Chapter Outline	227
5.1.4	Statistical Limitations of Airborne Cloud Microphysical Measurements	233
5.2	Impaction and Replication	236
5.2.1	Historical	236
5.2.2	Measurement Principles and Implementation	236
5.2.3	Measurement Issues	238
5.3	Single-Particle Size and Morphology Measurements	239
5.3.1	Retrieval of the PSD	241
5.3.1.1	Correction of Coincidence Effects	242
5.3.1.2	Optimal Estimation of the Particle Concentration	243
5.3.2	Single-Particle Light Scattering	243
5.3.2.1	Measurement Principles and Implementation	243
5.3.2.2	Measurement Issues	252
5.3.2.3	Summary	254
5.3.3	Single-Particle Imaging	254
5.3.3.1	Measurement Principles and Implementation	256
5.3.3.2	Measurement Issues	261
5.3.3.3	Summary	262
5.3.4	Imaging of Particle Ensembles – Holography	263
5.4	Integral Properties of an Ensemble of Particles	266
5.4.1	Thermal Techniques for Cloud LWC and IWC	266
5.4.1.1	Hot-Wire Techniques	266
5.4.1.2	Mass-Sensitive Devices	269
5.4.1.3	Measurement Issues	270
5.4.2	Optical Techniques for the Measurement of Cloud Water	272
5.4.2.1	The PVM	272
5.4.2.2	Angular Optical Cloud Properties	274
5.4.2.3	The PN	276
5.4.2.4	The CIN	280
5.4.2.5	The CEP	283
5.4.2.6	Measurement Issues	285
5.5	Data Analysis	286
5.5.1.1	Adjustment to Adiabaticity	287

5.5.1.2	Instrument Intercalibration	288
5.5.1.3	Instrument Spatial Resolution	289
5.5.1.4	Integrating Measurements from Scattering and Imaging Probes	291
5.5.1.5	Integrating Cloud Microphysical and Optical Properties	292
5.5.1.6	Evaluation of OAP Images	293
5.6	Emerging Technologies	295
5.6.1	Interferometric Laser Imaging for Droplet Sizing	296
5.6.2	The Backscatter Cloud Probe	298
5.6.3	The Cloud Particle Spectrometer with Depolarization	299
5.6.4	Hawkeye Composite Cloud Particle Probe	301
	Acknowledgments	301
<b>6</b>	<b>Aerosol and Cloud Particle Sampling</b>	<b>303</b>
	<i>Martina Krämer, Cynthia Twohy, Markus Hermann, Armin Afchine, Suresh Dhaniyala, and Alexei Korolev</i>	
6.1	Introduction	303
6.2	Aircraft Influence	305
6.2.1	Flow Perturbation	306
6.2.2	Particle Trajectories	308
6.2.3	Measurement Artifacts	310
6.3	Aerosol Particle Sampling	311
6.3.1	Particle Loss Processes	311
6.3.2	Sampling Efficiency	313
6.3.2.1	Inlet Efficiency	313
6.3.2.2	Transport Efficiency Inside the Sampling Line	315
6.3.3	Inlet Types	315
6.3.3.1	Solid Diffuser-Type Inlet	316
6.3.3.2	Isokinetic Diffuser-Type Inlet	316
6.3.3.3	Low-Turbulence Inlet	317
6.3.3.4	Nested Diffuser-Type Inlet	319
6.3.4	Size Segregated Aerosol Sampling	319
6.3.5	Sampling Artifacts	322
6.4	Cloud Particle Sampling	324
6.4.1	Cloud Sampling Issues	325
6.4.1.1	Effect of Mounting Location	325
6.4.1.2	Effect of Probe Housings	325
6.4.1.3	Droplet Splashing and Breakup	327
6.4.1.4	Ice Particle Bouncing and Shattering	328
6.4.2	Bulk Cloud Sampling	335
6.4.2.1	Cloud Water Content – Inlet-Based Evaporating Systems	336
6.4.2.2	Chemical Composition of Cloud Water – Bulk Sampling Systems	338
6.5	Summary and Guidelines	340

<b>7</b>	<b>Atmospheric Radiation Measurements</b>	<b>343</b>
	<i>Manfred Wendisch, Peter Pilewski, Birger Bohn, Anthony Bucholtz, Susanne Crewell, Chawn Harlow, Evelyn Jäkel, K. Sebastian Schmidt, Rick Shetter, Jonathan Taylor, David D. Turner, and Martin Zöger</i>	
7.1	Motivation	343
7.2	Fundamentals	344
7.2.1	Spectrum of Atmospheric Radiation	344
7.2.2	Geometric Definitions	345
7.2.3	Vertical Coordinate: Optical Depth	346
7.2.4	Quantitative Description of Atmospheric Radiation Field	347
7.2.5	Basic Radiation Laws	349
7.2.5.1	Lambert – Bouguer Law	349
7.2.5.2	Planck Law	350
7.2.5.3	Kirchhoff's Law	351
7.2.5.4	Brightness Temperature	351
7.2.5.5	Stefan – Boltzmann Law	352
7.3	Airborne Instruments for Solar Radiation	352
7.3.1	Broadband Solar Irradiance Radiometers	353
7.3.1.1	Background	353
7.3.1.2	Instruments	355
7.3.1.3	Calibration	358
7.3.1.4	Application	361
7.3.1.5	Challenges	362
7.3.2	Solar Spectral Radiometers for Irradiance and Radiance	363
7.3.2.1	Instruments	363
7.3.2.2	Calibration	365
7.3.2.3	Application	367
7.3.3	Spectral Actinic Flux Density Measurements	369
7.3.3.1	Background	369
7.3.3.2	Instruments	369
7.3.3.3	Calibrations	370
7.3.3.4	Application	372
7.3.4	Directly Transmitted Solar Spectral Irradiance	373
7.3.4.1	Background	373
7.3.4.2	Instruments	374
7.3.4.3	Calibration	377
7.3.4.4	Application	378
7.3.5	Solar Radiometer Attitude Issues	379
7.3.5.1	Background	379
7.3.5.2	After-Flight Software Corrections for Fixed Instruments	381
7.3.5.3	Stabilized Platforms	383
7.3.5.4	Challenges	385
7.4	Terrestrial Radiation Measurements from Aircraft	385
7.4.1	Broadband TIR Irradiance Measurement with Pyrgeometers	386
7.4.1.1	Instruments	386

7.4.1.2	Calibration	388
7.4.2	TIR Spectral Radiance	388
7.4.2.1	Instruments	388
7.4.2.2	Calibration	389
7.4.2.3	Application	390
7.4.3	TIR Interferometry	390
7.4.3.1	Background	390
7.4.3.2	Instruments	391
7.4.3.3	Calibration	393
7.4.3.4	Principal Component Noise Filtering	395
7.4.3.5	Application	398
7.4.4	Microwave Radiometers	400
7.4.4.1	Background	400
7.4.4.2	Instruments	405
7.4.4.3	Application	408
7.4.4.4	Challenges	411
<b>8</b>	<b>Hyperspectral Remote Sensing</b>	<b>413</b>
	<i>Eyal Ben-Dor, Daniel Schläpfer, Antonio J. Plaza, Tim Malthus</i>	
8.1	Introduction	413
8.2	Definition	414
8.3	History	416
8.4	Sensor Principles	417
8.5	HRS Sensors	419
8.5.1	General	419
8.5.2	Current HRS Sensors in Europe	422
8.5.3	Satellite HRS Sensors	425
8.6	Potential and Applications	428
8.7	Planning of an HRS Mission	430
8.8	Spectrally Based Information	432
8.9	Data Analysis	439
8.9.1	General	439
8.9.2	Atmospheric Correction	440
8.9.2.1	Empirical Reflectance Normalization	441
8.9.2.2	At-Sensor Radiance Description	442
8.9.2.3	Radiative-Transfer-Based Atmospheric Correction	443
8.9.3	Process of Complete Atmospheric Correction	444
8.9.3.1	Atmospheric Parameter Retrieval	445
8.9.3.2	Adjacency Correction	445
8.9.3.3	Shadow Correction	445
8.9.3.4	BRDF Correction	445
8.9.4	Retrieval of Atmospheric Parameters	446
8.9.5	Mapping Methods and Approaches	447
8.10	Sensor Calibration	451
8.10.1	General	451

8.10.2	Calibration for HSR Sensor	453
8.10.2.1	Preflight Calibration	453
8.10.2.2	In-Flight/In-Orbit Calibration	454
8.10.2.3	Vicarious Calibration	454
8.11	Summary and Conclusion	456
<b>9</b>	<b>LIDAR and RADAR Observations</b>	<b>457</b>
	<i>Jacques Pelon, Gabor Vali, Gérard Ancellet, Gerhard Ehret, Pierre H. Flamant, Samuel Haimov, Gerald Heymsfield, David Leon, James B. Mead, Andrew L. Pazmany Alain Protat, Zhien Wang, and Mengistu Wolde</i>	
9.1	Historical	457
9.2	Introduction	457
9.3	Principles of LIDAR and RADAR Remote Sensing	458
9.3.1	LIDAR and RADAR Equations	458
9.3.2	Dependence on Atmospheric Spectral Scattering/Absorption Properties	460
9.3.3	Basic Instrument Types and Measurement Methods	462
9.3.3.1	Backscatter and Reflectivity	462
9.3.3.2	Doppler	463
9.3.3.3	Differential – Absorption	465
9.3.4	LIDAR and RADAR Types and Configurations	467
9.3.4.1	Different Types of LIDAR Systems	468
9.3.4.2	Different Types of RADAR Systems	469
9.4	LIDAR Atmospheric Observations and Related Systems	472
9.4.1	Aerosol and Clouds	472
9.4.1.1	Structure	472
9.4.1.2	Optical Parameters	472
9.4.1.3	Cloud Phase, Effective Diameter of Cloud Droplets and Ice Crystals	473
9.4.2	Winds in Cloud-Free Areas	475
9.4.2.1	Wind from Scattering by Particles	476
9.4.2.2	Wind from Scattering by Molecules	476
9.4.3	Water Vapor	478
9.4.3.1	Airborne H <sub>2</sub> O– DIAL Instruments	480
9.4.3.2	Measurement Examples	482
9.4.4	Other Gases	483
9.4.4.1	Ozone	483
9.4.4.2	Carbon Dioxide	484
9.4.4.3	Methane	486
9.4.5	Water Vapor Flux Measurements	486
9.4.6	Calibration: Precision and Accuracy	489
9.4.6.1	Calibration on Molecular Scattering	489
9.4.6.2	Calibration Using a Hard Target	490
9.4.6.3	Calibration Using Sea Surface Reflectance	490

- 9.5 Cloud and Precipitation Observations with RADAR 491
- 9.5.1 Reflectivity from Cloud Droplets, Rain and Ice Crystals 491
- 9.5.2 Attenuation 497
- 9.5.3 Doppler RADAR Measurements 501
- 9.5.4 Polarization Measurements 504
- 9.5.5 Calibration: Precision and Accuracy 509
- 9.5.5.1 Calibration using Retroreflectors 511
- 9.5.5.2 Calibration Using Sea Surface Reflectance 516
- 9.6 Results of Airborne RADAR Observations – Some Examples 517
- 9.7 Parameters Derived from Combined Use of LIDAR and RADAR 518
- 9.7.1 Ice Cloud Microphysical Properties Retrieval with Airborne LIDAR and RADAR 518
- 9.7.2 Water Cloud Microphysical Properties Retrievals with Airborne Multi-Sensor Measurements 521
- 9.7.3 Mixed-Phase Cloud Microphysical Properties Retrievals with Airborne Multi-Sensor Measurements 524
- 9.8 Conclusion and Perspectives 525
- Acknowledgments 526

## **Appendix A: Supplementary Online Material**

**[www.wiley-vch.de](http://www.wiley-vch.de)**

- A.1 Measuring the Three-Dimensional Wind Vector Using a Five-Hole Probe
  - A.1.1 Rosemount Method
  - A.1.2 Five-Difference Method and Calibration
  - A.1.3 In-Flight Calibration
    - A.1.3.1 The Lenschow Maneuvers
    - A.1.3.2 Reverse Heading Maneuver
    - A.1.3.3 Speed Variation Maneuver
    - A.1.3.4 Pitch Maneuver
    - A.1.3.5 Yaw Maneuver
    - A.1.3.6 Rodi Maneuvers
  - A.2 Small-Scale Turbulence
    - A.2.1 Sampling and Sensor Resolution
- A.3 Laser Doppler Velocimetry: Double Doppler Shift and Beats
- A.4 Scattering and Extinction of Electromagnetic Radiation by Particles
  - A.4.1 Approximate Solutions of Light Scattering Problems as Used in the Processing Software of Modern-Size Spectrometers
  - A.4.2 Light Scattering Theory for Specific Spectrometers
  - A.4.3 Imaging Theory
  - A.4.4 Holography Theory
- A.5 LIDAR and RADAR Observations
  - A.5.1 Overview of Airborne RADAR Systems
  - A.5.2 Results of Airborne RADAR Observations – Some Examples

A.6	Processing Toolbox
A.6.1	Installation and Use

**Color Plates** 527

**List of Abbreviations** 539

**Constants** 549

**References** 551

**Index** 641