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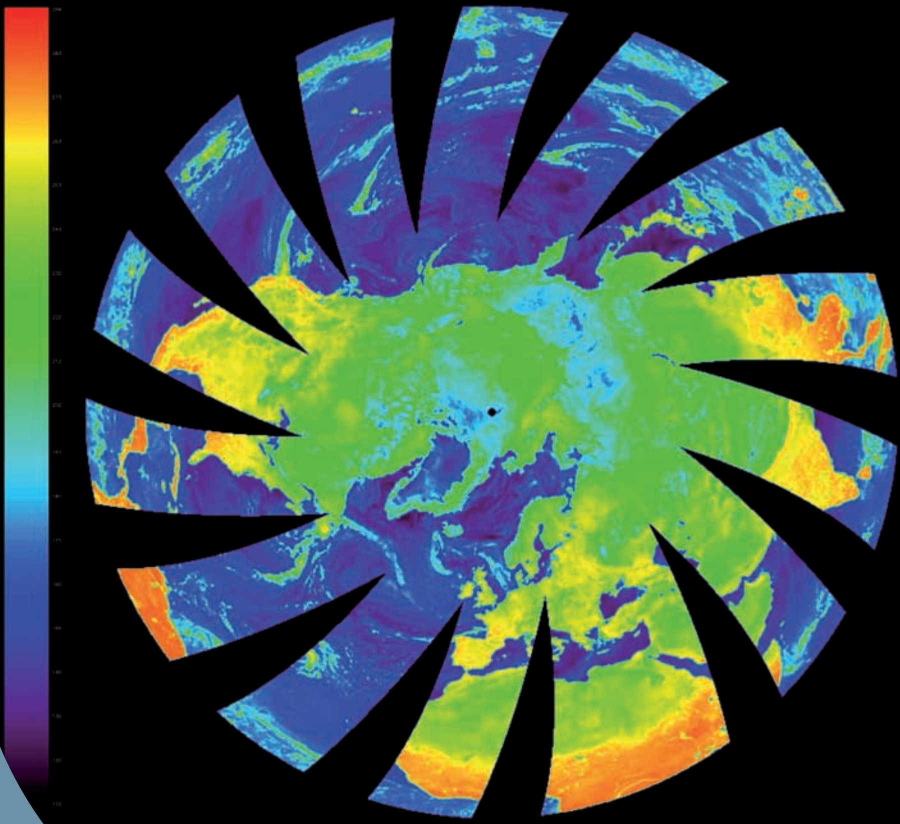

Thermal Microwave Radiation: Applications for Remote Sensing

Edited by C. Mätzler

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Edited by
C. Mätzler

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Contents

Cover images: AMSR-E 36 GHz, horizontally polarized, brightness temperatures, from descending passes, December 31, 2005, gridded to the Northern (Southern) Equal-Area Scalable Earth Grid (EASE-Grid), courtesy of National Snow and Ice Data Center, Boulder, CO, USA.

The brightness temperature ranges from 115 K (violet) to 294 K (red), with intermediate values of 160 K (dark blue) 180 K (bright blue), 225 K (green), 260 K (yellow), 275 K (orange)

Foreword

This book is a result of a wide collaboration between experts in the field of microwave radiometry and its applications. Originally the work began in 1996 by the European Cooperation in Scientific and Technical Research (COST), http:/www.cost.esf.org/. As described in the 'Memorandum of Understanding for the Implementation of a European Concerted Research Action, Designated as COST Action 712 Application of Microwave Radiometry to Atmospheric Research and Monitoring': 'the aims of the action were to improve the application of microwave radiometry to the understanding and monitoring of the hydrological cycle and tropospheric–stratospheric exchange. This includes research for understanding and modelling the atmospheric processes involved in these phenomena. These objectives can be achieved through developments in the following areas:

(1) improved models of the interaction of microwave radiation with the Earth's atmosphere and surface,
(2) improved retrieval, analysis and assimilation techniques, through which atmospheric and surface parameters are estimated from the data,
(3) verification and validation studies, through which the accuracy and characteristics of the data analysis techniques may be assessed,
(4) improved measurement facilities and techniques, including ground-based, aircraft-borne and space-based systems.'

COST Action 712 supported the above activities from 1996 to 2000. Area 1 was addressed as the topic of Project 1 Development of Radiative Transfer Models. Its focus was the development of physical models, fast physical and semi-empirical models and the improvement of critical elements in radiative transfer (e.g. microwave dielectric properties of water, ice, soil, vegetation and of various mixtures). Progress was discussed at several workshops and documented in two reports:

MÄTZLER, C. (ed.): 'Development of radiative transfer models', COST Action 712, Report from Review Workshop 1, held at EUMETSAT, Darmstadt, Germany, April 8 to 10, 1997, revised Oct. (1997).

MÄTZLER, C. (ed.): 'Radiative transfer models for microwave radiometry', COST Action 712 'Application of microwave radiometry to atmospheric research and monitoring', Meteorology, Final Report of Project 1, European Commission, Directorate General for Research, EUR 19543, ISBN 92-828-9842-3 (2000).

The final report, especially, found a wide interest in the scientific community and by students who used it as a supplement to textbooks on the topic of microwave radiometry. Four years later we observed significant advances in radiative transfer and spectroscopy of microwave radiation in natural media. The progress was partly a result of the momentum obtained by the COST 712 Community to perform focused research on identified problem areas. In addition the launch of new satellites, carrying microwave radiometers, also pushed the advancements of microwave radiative transfer. A discussion among members of the former Project 1 of COST 712 led to the proposal in January 2004 to revise, update and widen the report from 2000, and to publish it as a textbook. Many colleagues promised to contribute to this work. We are proud to present the result here.

The introduction, Chapter 1, starts with a historical overview on radiative transfer and microwave radiometry. Kirchhoff's law of radiation in the form generalised by Planck is then used to relate the scene brightness to the spatial distribution of temperature and absorptivity. Simple examples are used for illustration, based on solutions of the radiative-transfer equation. The final part of Chapter 1 is an introduction to the quantities for describing the polarisation of thermal radiation culminating in the fully polarimetric radiative-transfer equation.

Chapter 2 is concerned with the absorption and emission spectra of atmospheric gases. The emitted energy, measured for example by satellites, can be used to determine atmospheric temperature and moisture or other constituents. Interpretation of surface phenomena, on the other hand, requires consideration of attenuation by the atmosphere. The published literature contains many atmospheric absorption models, so in Chapter 2 emphasis is placed on describing relatively recent developments and on atmospheric measurements that have been done to determine the accuracy of models. The latest versions of the GEISA and HITRAN line-parameter databases are described and some relevant laboratory and theoretical work that may influence future modelling efforts is reviewed. Validation experiments in the atmosphere have the advantage of propagation path lengths much longer than in the laboratory, but to be useful in a decision between alternative absorption models, they require very accurate *in situ* measurement of the atmosphere, which is not easily achieved. The concluding section makes some recommendations for directions of future research.

Chapter 3 concentrates on the interaction of solid and liquid hydrometeors, suspended in the atmosphere, with microwave radiation. Especially in the window regions of the microwave electromagnetic spectrum hydrometeors dominate the signals and make them accessible via remote sensing from the ground and from airborne and satellite platforms. Since scattering by hydrometeors becomes an increasingly important process with increasing frequency, a closer look at the related polarisation effects and the influence of three-dimensional structures in vector radiative transfer will be taken. This chapter reviews first the state of the art in deriving the single scattering properties of atmospheric hydrometeors. Then the links of single scattering parameters derived from available codes with the general properties of the vector radiative-transfer equations and its solution in a heterogeneous emitting and scattering atmosphere is elucidated, followed by a general description of the usually applied solution methods. After describing existing and available exact codes to solve the vector radiative-transfer equation some effort is put on the description of efficient approximations useful for operational remote sensing and data assimilation. The chapter closes with new results on the signatures of clouds and precipitation in passive microwave observations.

Chapter 4 presents recent developments which have been made in the radiative-transfer modelling of the microwave surface emission, including studies made over ocean, bare soil (mainly in arid regions), vegetation-, snow- and ice-covered areas. In most cases, the research activities were carried out in the framework of existing or near future space missions.

Over the ocean, the first contribution reviews recent efforts made on improving ocean emissivity models by handling azimuthal variation and the polarimetric phase signal. These studies were carried out with the objective of retrieving instantaneous wind vectors from existing passive microwave observations (SSM/I and polarimetric Windsat instrument launched in 2002 mainly). The second contribution was written in the framework of future space missions which will attempt to globally monitor sea surface salinity (SSS): the ESA mission SMOS (soil moisture and ocean salinity) that will provide dual-polarisation and multi-angular observations and the NASA mission Aquarius. These missions should be launched, respectively, in 2007 and 2009. This contribution reviews models at L-band and the requirements that should be met to retrieve SSS with sufficient accuracy.

Over the land surfaces modelling the emission from bare soil surfaces is analysed in a specific section that includes (1) a review of recent improvements, (2) a new approach: the air-to-soil transition model and (3) an analysis of the signatures from arid regions as seen from space. All these contributions describe not only recent improvements but also problems to be solved in accounting correctly for the effects of both volume and surface scattering. A specific section is dedicated to the modelling of the influence by vegetation. Most of these studies were carried out in the framework of the near future L-band space missions designed to monitor surface soil moisture (the ESA SMOS and NASA HYDROS missions). Correction of vegetation effects was improved by a better accounting for the vegetation structure of crops and forests. Considering the SMOS configuration system, the dependence of these effects on incidence angle and polarisation is a new challenge in the retrieval process.

Even though most of the contributions in Chapter 4 concern the microwave signature of soil, vegetation and ocean, other sections consider more specific aspects. Recent developments in the modelling of the effects of volume scattering, relief and snow over the land surfaces and of ice over the ocean are considered in specific sections. Improvement in the modelling of these effects, which is rarely addressed in the literature, is a major issue in the understanding of the spatial observations made by current instruments (SSM/I, AMSU, etc.) and by near future instruments operating at L-band (SMOS, HYDROS and Aquarius).

Chapter 5 is devoted to the dielectric properties of important materials found at the terrestrial surface. Since magnetic effects can be ignored for the materials to be discussed the relative dielectric constant is equivalent to the square of the complex refractive index. For homogeneous components, such as ice and water, the main emphasis has been laid on the search for accurate data and on the optimisation of empirical models. The work led to new analytical expressions for the complex dielectric constant of fresh water, saline water, fresh-water ice and slightly saline ice as functions of frequency, temperature and salinity. New measurements of dielectric constants of minerals and rocks were also collected. Natural materials often are a heterogeneous mixture of more basic components. Unfortunately the effective dielectric constant of the mixture is not just a volumetric or mass averaging of the permittivities of its components. In fact mixing rules usually are not strict, but they depend on the shape of the mixing particles. A special section is devoted to present the most relevant mixing models. Dielectric properties of heterogeneous media (clouds, snow, vegetation and soil) are presented and interpreted in the light of these models.

Appendices give complementary information, including original data tables.

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April 2005

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Philip W. Rosenkranz (Coeditor and Coordinator for Chapter 2)
Alessandro Battaglia (Coeditor and Coordinator for Chapter 3)
Jean-Pierre Wigneron (Coeditor and Coordinator for Chapter 4)

Curricula

Editor

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