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EUCLIPSE Book on Clouds and Climate

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Motivation

An important dissemination task of EUCLIPSE is to train a new generation of scientists on the role of clouds in climate science. Cloud research is a fastly developing branch of climate science and we are convinced that the cloud research community is in urgent need of a book that covers all the new aspects in cloud research in a comprehensive and consistent manner. These applies especially for that part of the community at universities and other reasearch schools that has to teach atmospheric science in the area of clouds and climate. Since EUCLIPSE hosts European top-scientists that are specialists onthe many different aspects of cloud research, this group of people is in an excellent position to collectively write the ultimate book on clouds.

As of today such a book does not exist. There are several books that cover certain aspects of clouds in detail such as cloud microphysics, cloud dynamics or clouds and radiation. We envision a book that integrates all these aspects and relates them to climate processes and climate modeling in the present and future climate. It should be the standard book for any cloud researcher that is in need of the many different aspects of clouds in the climate system.

The Path toward the Book

We, the editors of the book, have started in 2011 a series of telecons on the scope and the topics of the envisioned textbook. The next step was to select authors for the 13 chapters of the book. By mid-2012 we had found an excellent group of 22 authors that agreed to work in pairs on the various chapters of the book entitled"Clouds and Climate". The majority of the writers (15) are partipants of the EUCLIPSE project and are supplemented with 7 cloud experts outside the consortium. As a next step a Book Proposal has been written by the editors and has been submiited in November 2012 to Cambridge Press. This Book Proposal describes the motivation, the summary, list of writers, a description of all the chapters and a discussion on competing and comparable books. The book proposal is attached to the present document. An external review has been conducted by Cambridge Press and the book proposal received excellent reviews in Spring 2013.

The EUCLIPSE Summerschool on "Clouds and Climate" which was held in July 2013, has been the next stepping stone. The lecturers, who were the first authors of the chapters of the envisioned book, prepared first rough versions of their chapters and thier lectures were based and inspired by these drafts. The 55 students who attended the Summerschool were asked to fill in a questionaireon the lectures. These outcomes were reported to to the authors as a further guidance in autumn 2013. With this guidance the authors were asked to write

their chapters and submit these to the editors before the end of the EUCLIPSE project for a further internal review. The submitted 13 chapters are now available and uploaded into the EU-portal which was the desired aim for the end of the EUCLIPSE project.

The Chapters will undergo a thorough review by the publisher after which the revised versions will be copy edited by Cambridge University Press. It is foreseen that the book will be available on the market in early 2016.

Book Proposal: "Clouds and Climate"

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1 Overview

1.1 Title

The title of the book will be *"Clouds and Climate"*. The estimated number of pages is around 420 (including preface, figures, excercises, bibliography and index). The planning of the book has already started and a final draft is expected by the end of 2013.

1.2 Summary

Clouds may never have had a more important meaning to society as they have today. The patterns of clouds are slowly changing, along with increases in global surface temperatures and changes in emissions of anthropogenic aerosols. How clouds respond to these changes, will help determine how our climate as a whole will change. The largest source of uncertainty in future climate model predictions is due to the representation of cloud processes. These include intrinsic cloud processes such as latent heat release due to condensation and evaporation, precipitation and turbulence but also interactions with radiation, soil moisture, and large scale atmospheric dynamics.

The main objective of this book is to provide an up-to-date overview of the scientific knowledge of all the relevant cloud processes and how they are affected in a future climate, from theoretical, observational and modeling perspectives. The book should provide the material necessary to prepare and stimulate a generation of researchers focused on clouds in the climate system.

Chapter 1 provides a overview of the book and a short historical view of clouds. The Basics are treated in Part I in which clouds are discussed from 3 different perspectives: clouds from a radiative perspective (chapter 2), clouds from a dynamical perspective chapter 3) and clouds from a collection of droplets (microphysical) perspective. In Part II (chapter 5-8) of the book various approaches to modeling clouds are reviewed and discussed, approaches ranging from high resolution cloud resolving models to statistical representation used in global climate models. Besides numerical modeling, Part II will also give a comprehensive overview of the theoretical understanding of cloud processes through more conceptual models. Part III (chapter 9-13) discusses the interaction of clouds with other processes in the climate system. Cloud systems in the (extra)-tropics and polar regions and their interaction with the large scale dynamics are treated as well as their interaction with the land surface and aerosols. The last chapter discusses the feedback of cloud processes to changing external forcings in a future climate.

2 Motivation

Cloud research is a fastly developing branch of climate science as it is increasingly appreciated that our understanding and representation of clouds is the Achilles heel in climate modeling. Therefore, establishing the extent to which clouds will undergo changes in respons to warming can be thought of as the Higgs Boson of the theory of climate, and climate change. It is also a topic with many new opportunities due to a number of developments. New satellite observations from space with active instruments

such as lidar and radar allow for the first time to construct a three-dimensional cloud climatology. In addition, cloud resolving models that serve as a virtual atmospheric laboratory have provided many new insights in cloud dynamics. This knowledge is used in the development and the evaluation of cloud processes in climate models as well as for the understanding of how clouds respond to a perturbed climate. This also requires a close collaboration of different research communities (i.e. satellite observations, cloud process studies, climate model developing and evaluation), something that is starting to happen now.

We are convinced that the cloud research community is in urgent need of a book that covers all the above aspects in cloud research in a comprehensive and consistent manner. These applies especially for that part of the community at universities and other reasearch schools that has to teach atmospheric science in the area of clouds and climate.

As of today such a book does not exist. There are several books that cover certain aspects of clouds in detail such as cloud microphysics, cloud dynamics or clouds and radiation. We envision a book that integrates all these aspects and relates them to climate processes and climate modeling in the present and future climate. It should be the standard book for any cloud researcher that is in need of the many different aspects of clouds in the climate system.

"We" are a group of leading European scientists that are working together in a funded EU project: EU Cloud Intercomparison, Process Study and Evaluation Project (EUCLIPSE), that aims to understand and reduce the uncertainty due to cloud processes in future climate model predictions. On key aspect of this project is that it hosts European top-scientists from all the different aspects of cloud research mentioned above. This group of people is therefore in an excellent position to collectively write the ultimate book on clouds. As part of the EUCLIPSE project the various chapters will form the material for a Summerschool to be held in summer 2013.

3 Contents

Since the writing of this book will be a challenging multi-author effort we describe in the next section an outline of how we will organise the writing process. Subsequently we will provide an extended table of contents, describing the scope and depth of material to be covered by the book.

3.1 Organisation of the writing and the editing

We would like to ensure uniformity across the book both in layout but also in style and content. This will be challenging and ambitious given the large number of authors. It is not the idea that the book will consist of a collection of chapters with the preferred topics of the authors but rather a coherent and consistent textbook. The editors will play a key role here. Besides the fact that they will write 4 of the 13 chapters, the remaining 9 chapters will each be adopted by 2 of the 4 editors, who will monitor and advise the writing teams on especially the issues of uniformity and consistency. We will provide the authors with instructions on the layering of the chapters (writing style and uniformity on the figures). We also plan to have an internal review of the chapters.

3.2 description of the chapters

Below we outline the book by providing the titles and themes of each of the 13 chapters. if requested we can also provide more detailed information on the content of each of the chapters.

Chapter 1 Introduction and Overview
(Louise Nuijens and Christian Jakob)

- Overview of the book
- Historical view of clouds, including surface climatologies
- Present issues

Part I: Cloud Basics

Chapter 2 Clouds and Radiation
(Helene Chepfer and Robert Pincus)

- Basic description of how clouds interact with radiation
- Cloud properties and climatologies as derived by satellite remote sensing.

Chapter 3 Cloud Dynamics
(Bjorn Stevens and A. Pier Siebesma)

- Clouds as a multi-phase flow.
- Thermodynamic Concepts.
- Turbulence Concepts

Chapter 4 Cloud Microphysics
(Hanna Pawlowska and Ben Shipway)

- Basic description of cloud microphysical dtructures and processes.
- Key insights from in-situ measurements.
- Relevant and emergent microphysical climatologies.

Part II: Models and their Evaluation

Chapter 5 Conceptual and Theoretical Models
(Stephan de Roode and Roel Neggers)

- Mixed layer and Bulk Models
- Equilibrium Solutions, Regimes

Chapter 6 Cloud Resolving Models
(Francoise Guichard and Fleur Couvreux)

- What are they (broad view including large eddy simulations)
- How are they used and what have we learned fron them?
- Outstanding issues and future

Chapter 7 Representation of cloud processes in large-scale models
(A. Pier Siebesma and Axel Seifert)

- The parameterization problem
- Types of parameterization for clouds and convective transport
- Outstanding issues: unification of schemes, scale-adaptive parameterizations, stochastic parameterizations.

Chapter 8 Evaluation of clouds in large-scale models
(Christian Jakob and Jean-Louis Dufresne)

- Intercomparison Studies
- Process based evaluation
- Evaluation as part of the parameterization development process

Part III: Clouds and Climate Processes

Chapter 9 Tropical and Subtropical Cloud Systems
(Gilles Bellon and Sandrine Bony)

- Patterns, variability and classification
- Coupling to dynamical processes through precipitation and radiation

Chapter 10 Extratropical and Polar Cloud Systems
(Gunilla Svensson and George Tselioudis)

- Patterns, variability and classification
- Coupling to dynamical processes through precipitation and radiation

Chapter 11 Clouds and Land Surface Interaction
(Cathy Hohenhegger and Christoph Schär)

- Soil Moisture Cloud-Precipitation feedbacks
- Heterogeneity
- Impact on Extremes

Chapter 12 Clouds and Aerosols
(Ulrike Lohmann and Johannes Quaas)

- Role of aerosols in determining the cloud micophysical structure
- Interplay between couds and aerosol processes
- Cloud mediated aerosol effects on climate

Chapter 13 Clouds and Climate Sensitivity
(Sandrine Bony and Bjorn Stevens)

- Measuring the response of clouds to external forcing
- Slow and fast response mechanisms
- Roleof clouds in other feedbacks (water vapor, carbon cycle)

4 Readership and Level

The audience of the book will be advanced graduate students, or PhD candidates with a background in one of the disciplinary areas the book covers (for instance radiative transfer and remote sensing, turbulence, cloud microphysics, or geophysical fluid mechanics). The book will be intermediate between a textbook and a research expository and each chapter provides material for two 90 minute lectures so the book itself could be covered in two semesters. Each chapter will end with excercises and will extend and complement the material presented in the body of the chapter. The ultimate goal will be to provide the material necessary to prepare and stimulate a generation of researchers focused on cloud processes in the climate system.

5 Competing and Comparable books

Most standard existing textbooks treat clouds from one specific perspective such as "Radiation and Cloud Processes in the Atmosphere" by K.N. Liou (Oxford University Press, 1992), "Microphysics of Clouds and Precipitation" by H.R. Pruppacher and J.D Klett (Springer 1996) or "Cloud Dynamics" by R.A. Houze (Academic Press 1993). The book we envision treats clouds from all these different perspectives and moreover will put it into the context of climate. Another distinghuishing feature of "Clouds and

Climate" is that part II is largely dedicated to the representation of cloud processes in numerical models ranging from cloud resolving models to physical paramerizations in state of the art global climate models.

The recent published book "Atmosphere, Clouds and Climate" by D.A. Randall (Princeton Primer in Climate 2012) bears some similarity with the book we envisopn but is meant to be a primer at a more introductory, and hence more descriptive level, aiming for undergraduate students while our book aims to be a textbook for advanced graduate students and PhD candidates.

6 Credentials

Recent cv's of the editors (A. Pier Siebesma, Sandrine Bony, Christian Jakob and Bjorn Stevens) are attached as an appendix as well as the names, expertise and affiliations of the rest of the writer's team.

7 Appendix: List of the Writers

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