SPRINGER BRIEFS IN EARTH SYSTEM SCIENCES

Gerrit Lohmann · Klaus Grosfeld
Dieter Wolf-Gladrow · Vikram Unnithan
Justus Notholt · Anna Wegner *Editors*

Earth System Science: Bridging the Gaps between Disciplines

Perspectives from a Multi-Disciplinary Helmholtz Research School

Springer

SpringerBriefs in Earth System Sciences

For further volumes:
http://www.springer.com/series/10032

Gerrit Lohmann · Klaus Grosfeld
Dieter Wolf-Gladrow · Vikram Unnithan
Justus Notholt · Anna Wegner
Editors

Earth System Science: Bridging the Gaps between Disciplines

Perspectives from a Multi-Disciplinary Helmholtz Research School

Springer

Editors
Prof. Dr. Gerrit Lohmann
Alfred Wegener Institute for Polar and Marine Research
Bremerhaven
Germany

Dr. Klaus Grosfeld
Alfred Wegener Institute for Polar and Marine Research
Bremerhaven
Germany

Prof. Dr. Dieter Wolf-Gladrow
Alfred Wegener Institute for Polar and Marine Research
Bremerhaven
Germany

Prof. Dr. Vikram Unnithan
School of Engineering and Science
Jacobs University Bremen gGmbH
Bremen
Germany

Prof. Dr. Justus Notholt
Institute of Environmental Physics
University of Bremen
Bremen
Germany

Dr. Anna Wegner
Alfred Wegener Institute for Polar and Marine Research
Bremerhaven
Germany

ISSN 2191-589X ISSN 2191-5903 (electronic)
ISBN 978-3-642-32234-1 ISBN 978-3-642-32235-8 (eBook)
DOI 10.1007/978-3-642-32235-8
Springer Heidelberg New York Dordrecht London

Library of Congress Control Number: 2012944976

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Promoting young researchers is a major priority of the Helmholtz Association, Germany's largest scientific research organisation with 18 Research Centres in the fields of science, engineering and biomedicine. In the framework of the Initiative and Networking Fund several promotion instruments were set up with the aim to advance education and to attract excellent young people for science conducted by the Helmholtz Centres. School laboratories, doctoral training programmes, as well as Postdoc programmes support individuals at every stage of their education and career. Helmholtz Research Schools aim to prepare highly skilled doctoral students for a career in science and business. Each research school brings together up to 25 outstanding young doctoral students to conduct research on a specific topic and thus gain valuable experience working together closely in teams—an absolutely essential skill for topnotch research today. In addition, the Helmholtz Association works with distinguished partners such as the Imperial College London, enabling it to provide a curriculum that includes a range of courses that aim to foster professional qualification and personal development and to equip graduates for careers in management positions, both in science and the business world. Since 2006, 21 research schools have been set up at the different Helmholtz Centres. The research schools are complemented by 13 Helmholtz Graduate Schools which provide a roof for a varied number of curricula in different fields, or across disciplines.

At the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, a Helmholtz Research School on Earth System Sciences has been funded since 2008 in collaboration with the University of Bremen and the Jacobs University Bremen. Using the network and collaboration of experts and specialists from the different institutes on observational and paleo-climate data as well as on statistical data analysis and climate modelling, doctoral students from eight countries were trained to understand, decipher and cope with the challenges of global climate change. The Earth System Science Research School (ESSReS) covers all kinds of disciplines, climate science, geosciences and biosciences, and provides a consistent framework for education and qualification of a new generation of expertly trained, internationally competitive doctoral students.

The set-up of a structured doctoral programme like ESSReS combines both, strong scientific cutting-edge research and an interdisciplinary education that bridges the gap between the traditional disciplines. The young students are motivated to learn on an interdisciplinary and trans-institutional basis, guiding their way in modern research. The success and outcome of the first 3 years phase of ESSReS, which also served as precursor for the Graduate School for Polar and Marine Research (POLMAR), established at the Alfred Wegener Institute in 2009, is visible in this book. Both schools provide a new level with binding rules for doctoral education at the Alfred Wegener Institute, satisfying our enduring efforts on the improvement of doctoral education in the Helmholtz Association.

Bremerhaven, September 2012

Prof. Dr. Karin Lochte
Prof. Dr. Jürgen Mlynek

Acknowledgments

Funding by the Helmholtz Association and continuous support of the Earth System Science Research School (ESSReS) of the Alfred Wegener Institute for Polar and Marine Research, the University of Bremen and the Jacobs University of Bremen is gratefully acknowledged. The editors wish to thank Dr. Peter Köhler, Dr. Martin Werner, Dr. Gregor Knorr, Andrea Bleyer, Renate Kuchta, and Stefanie Klebe (all AWI) for their kind support during the planning and implementation phases of ESSReS and the review and editing processes of this book.

Contents

Chapter 1
Introduction

1.1 General Aspects of Earth System Science

Gerrit Lohmann[1] (✉), Klaus Grosfeld[1], Dieter Wolf-Gladrow[1], Vikram Unnithan[3], Justus Notholt[2] and Anna Wegner[1]

[1]Alfred Wegener Institute for Polar and Marine Research Bremerhaven, Germany
e-mail: Gerrit.Lohmann@awi.de
[2]Institute of Environmental Physics, University of Bremen, Germany
[3]Jacobs University, Bremen, Germany

To properly address the pressing question of climate change and its natural and anthropogenic causes, intimate knowledge on amplitude and rapidness in the natural variations of temperature or other temperature-related environmental properties in the ocean, over the continents, and in the cryosphere is required.

The best way to gain this knowledge is the inspection of historical time series of direct temperature measurements or documentation of such environmental observations. Unfortunately, historical records of direct temperature measurements which would allow consideration of changing climate on a global scale are too short and fall already within the period of strong human impact on natural conditions. Information on earlier times can be obtained either from proxies that record past climate and environmental conditions, or by simulating climate using comprehensive models of the climate system under appropriate external forcing.

One of the greatest challenges is getting reliable assertions regarding future global climate and environmental change. The longer the time scale the more components of the Earth system are involved, e.g. weather prediction models can take the ocean as constant in order to estimate the next days; interannual to decadal variations can be described in the coupled atmosphere–ocean-sea ice system, whereas longer variations like glacial-interglacial transitions incorporate the full carbon cycle as well the ice sheets and associated feedbacks (Fig. 1.1). In order to

G. Lohmann et al. (eds.), *Earth System Science: Bridging the Gaps between Disciplines*, SpringerBriefs in Earth System Sciences,
DOI: 10.1007/978-3-642-32235-8_1,

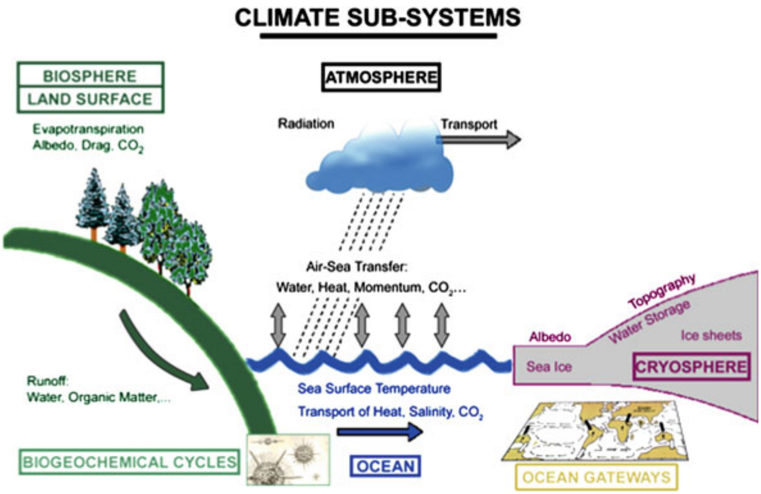

Fig. 1.1 The complex climate system requires a multi-disciplinary approach. The figure shows the interactions between different components. The biogeochemical cycles (including foraminifera) are a key element for the carbon cycle in the oceans and on land, feeding back to the atmosphere through the CO_2 effect on long wave radiation. The position and extent of the big ice sheets are important for the global climate system. The long-term climate cooling is also related to the carbon cycle and ocean gateway configurations, known as tectonic-sedimentary puzzle

get a systematic view of the Earth System, one has to consider the climate components with its specific time scales.

Earth System Science is traditionally split into various disciplines (Geology, Physics, Meteorology, Oceanography, Biology etc.) and several sub-disciplines. Overall, the diversity of expertise provides a solid base for interdisciplinary research. However, gaining holistic insights of the Earth System requires the integration of observations, paleo-climate data, analysis tools and modelling. These different approaches of Earth System Science are rooted in different disciplines that cut across a broad range of timescales. It is, therefore, necessary to link these disciplines at a relatively early stage in PhD programs. The linking of 'data and modelling', as a special emphasis in our graduate school, enables graduate students from a variety of disciplines to cooperate and exchange views on the common theme of Earth System Science, which leads to a better understanding of processes within a global context.

A conceptual unification among the sciences of the Earth has never developed in the German education system. Disciplinary specialization has played a large role instead of integration. Already Humboldt proposed an integration of several disciplines, establishing international cooperative networks of meteorological and geomagnetic measurement stations. Humboldt's general physics of the Earth envisioned climate as a major control of Earth-surface phenomena.

The modern view takes the Earth's land surface, oceans, atmosphere, and inhabitants as an integrated whole, with linkages among the various components (Fig. 1.1). This effort is often referred to as Earth System Science. It provides a challenge for theory, observations, reconstructions and modelling, to describe past, present and future changes in the Earth system. Global environmental change is probably one of the greatest challenges faced by human societies ever since. As a logical step, scientists need to understand the interactions and feedbacks among the components of the Earth system, encompassing the lithosphere, atmosphere, hydrosphere, cryosphere, and biosphere.

Basic knowledge in the other disciplines in Earth System Science enables graduate students from a variety of disciplines to cooperate and exchange views on the common theme of global environmental change. In our approach, we tried to cover a wide spectrum of Earth System Science: Remote sensing, data exploration, process understanding, modelling, and informatics. Informatics is also relevant since a large amount of data is retrieved through models, satellites and high-resolution geosciences data. Examples of how to link the different disciplines as a key concept of future PhD education in Earth System Science are shown in the chapters of the book. The different research projects are clustered in respect to their common research field, such as remote sensing and modelling of atmospheric chemistry, Earth system modelling and data analysis, geo-tectonics, climate archives, ecosystems and climate change, geo-informatics and geo-engineering.

1.2 The Structural and Educational Concept in an Interdisciplinary Research School for Earth System Science

Klaus Grosfeld[1] (✉), Gerrit Lohmann[1], Dieter Wolf-Gladrow[1], Annette Ladstätter-Weißenmayer[2], Justus Notholt[2], Vikram Unnithan[3] and Anna Wegner[1]

[1]Alfred Wegener Institute for Polar and Marine Sciences Bremerhaven, Germany
e-mail: Klaus.Grosfeld@awi.de
[2]Institute of Environmental Physics, University of Bremen, Germany
[3]Jacobs University, Bremen, Germany

Today, Earth System Sciences are based on highly interdisciplinary research, demanding a broad basic knowledge of the different research aspects, their feedbacks and interconnections. A major difficulty in cross-disciplinary science is, therefore, to find a proper common language/level, where people from different disciplines can explain their research question and contribute to solution strategies. Consequently, the major goal of the Earth System Science Research School (ESSReS) is bridging theses gaps by providing a scientific education and basic and expert knowledge on Earth System Science, which has not been given within the master or diploma studies of the applicants that are specialized on their research fields. By these efforts, the PhD students obtain systematic insights into the different disciplines in order to be able to

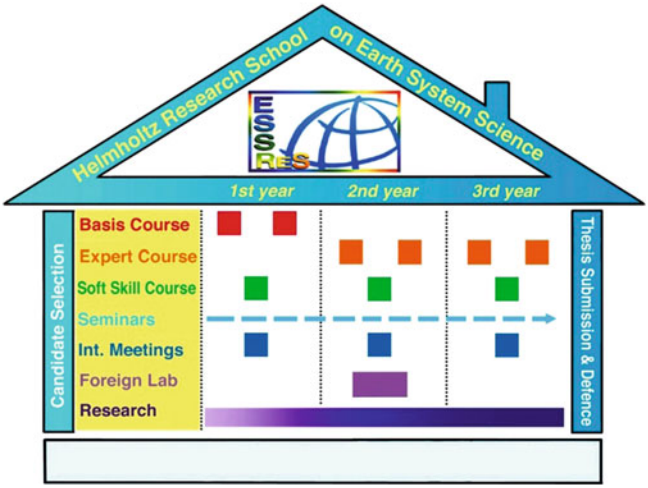

Fig. 1.2 ESSReS curriculum during the 3-years PhD education. Basic courses provide a common frame and scientific language. Transferable skills courses are related to social competence, management skills, oral and poster presentation techniques and scientific writing, as well as career planning

discuss common research questions on a solid fundament and to identify cooperation and collaboration across disciplines.

Hence, a structured educational PhD programme has been developed, which consists of basic and expert courses in the field of Earth System Science, gaining knowledge and tools, all the way to brand new developments and scientific topics (Fig. 1.2).

ESSReS is designed as a class of up to 25 PhD students from all around the globe starting the educational programme together at a certain date and following the programme as a cohort. We preferred this concept for our research school against the more common ones, where new PhDs are recruited continuously and where the research school provides a framework for different graduation stages. The advantage of our concept is that from the beginning, the PhD students build a close scientific and social network.

In total, two weeks of lectures during the introductory phase and one week of lectures per semester during the expert phase are taught. The lectures are complemented by monthly PhD seminars that are organized by the PhD students themselves and hosted in turns at the different institutes (Fig. 1.3).

Once a year, the PhD students present their results with oral and poster presentations at a common retreat to their colleagues and the supervisor assembly, giving room to extensive discussion and interdisciplinary exchange. For expert courses external lecturers are invited for an extended research stay at one of the collaborating institutes, to teach challenging new topics relevant for the research school and to be available during their research stay for intensive discussions and collaborations with

Fig. 1.3 Monthly ESSReS seminar with self-organized presentations and discussion about the different research topics and planning of common activities

the PhD students. An overview on the curriculum and course programme can be found on our research School web page www.earth-system-science.org. Additional courses, interesting for the PhD students and provided by our cooperation graduate schools at the Alfred Wegener Institute (www.polmar.awi.de), at the Bremen University (www.glomar.de) or at the Max Planck Institute Research School for Marine Microbiology (www.marmic.mpg.de) are accepted within the curriculum.

The scientific education is complemented by a three-stage training in transferable skills. Besides the scientific work, the PhD students join each year a residential course organized by the Helmholtz Association and performed by tutors from the Imperial College London, where "Research Skill Development", "Presentation and Communication Skills", and "Career Planning and Leadership Skills" are trained. The courses are run together with participants from other Helmholtz research Schools to foster further interdisciplinary experience and networking within the young researchers' community of the Helmholtz Association. In addition to the transferrable skills training, a special coaching programme for scientific writing is offered to the PhD students through the foreign language institute at the University of Bremen, to support the writing of their first scientific papers directly from the beginning. Deficiencies in scientific writing have shown to be a great obstacle in the time planning, because the first paper takes empirically much longer than expected.

During the programme, students will be required to directly apply their soft skills. Fellows may wish to receive financial assistance for activities beyond what is generally covered by the research school, *e.g.* for additional travel to conferences, summer schools or lab support. To this end, the research school provides a certain budget for each PhD student. To access these funds, fellows are required to write short proposals that are evaluated by the Academic Council. In writing these proposals and reports, the PhD students undergo basic training in fundraising and fund management which is an important part of professional research right from the beginning. Furthermore, this represents a good exercise for applicants who