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Boreal Forest and Climate Change – From Processes and Transport to Trees, Ecosystems and Atmosphere

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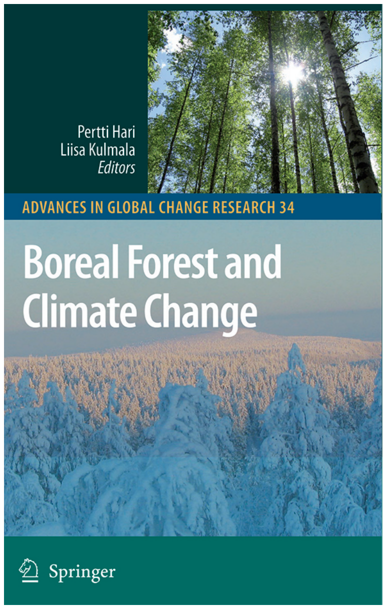

Boreal Forest and Climate Change, edited by Pertti Hari and Liisa Kulmala, synthesizes interdisciplinary research among forest ecologists and physicists in University of Helsinki. The collaborative work commenced in the 1970's and has continued through the Aerosol Physics and Forest Ecology (APFE) group founded by Pertti Hari and Markku Kulmala. Most of the contributors to this book have gained their training as members of APFE or its less formal predecessor. The focus for the authors is the work conducted at the SMEAR (Station for Measuring Ecosystem – Atmosphere Relations) network. Fluxes of energy and matter to and from pine stands have been continuously measured for over a decade in Värriö (SMEAR I) and Hyytiälä (SMEAR II). With few exceptions, the two stations are the only data source for the book. The core of APFE's work is a quantitative, process-based approach to modeling and measuring interactions between forests and their environment. Such an approach allows studying complex, multidimensional problems as climate change and its likely effects on forests.

Boreal Forest and Climate Change combines current biological (physiological, ecological, and microbiological), chemical, and physical (meteorological) knowledge to better understand the interactions between boreal forests and varying climate. The approach and methodologies used – theoretical, dynamic, and statistical modeling – are presented in Chapter 2. Also described are the underlying principles of the most important instruments used in SMEAR I and II. The message of this chapter is unambiguous: For high quality data and their meaningful interpretation, the spatial and temporal domain of the measurements must match the research questions, and all error components must be quantified. Such a careful approach to experimental design and data analysis is, unfortunately, rare in ecological research.

In Chapters 3–6, the description of the systems of interest, atmosphere, vegetation, and soil, are organized under four headings: environmental factors, transport, structure, and processes. This organization highlights the similarities among the systems, covering a range of relevant hierarchical levels within each. It demonstrates that a common language can be used among biologists, chemists, and physicists. The structure of cells, forests, soils, or the atmosphere is the physical framework where processes occur at various hierarchical levels. This structure enables the flow of energy and matter amongst pools.

Chapter 7 is a synthesis of the previous chapters. First, the conservation principles and transport of mass, energy, and momentum are introduced in the context of atmospheric models. The fundamentals of aerosol physics are also presented: sources of aerosols, their transport, reactions in the atmosphere, and role in cloud formation. Based on this knowledge one can predict, for instance, the fate of solar energy in the atmosphere and how the amounts of aerosols and greenhouse gasses affect the energy balance.

The reader is presented with the argument that atmospheric processes cannot be understood unless processes at the forest-atmosphere interface are accounted for. In this book, the exchange of energy, carbon, water, and nitrogen between forest and the atmosphere are quantified using both process-based models and direct measurements. For example, estimating ecosystem carbon exchange begins at the level of a leaf element (the tiny volume of a leaf). The primary metabolic processes of producing sugar from atmospheric carbon and captured solar energy and the release of energy and carbon in respiration, occur at the molecular scale. As does the formation volatile hydrocarbons in secondary metabolism. The rates of these processes depend on internal controls of the plant as well as external factors such as the availability of solar energy and temperature. The net carbon exchange of trees in a forest is the sum of carbon taken up by all leaf elements discounted by the amount of carbon released by all living plant parts. Some of the fixed carbon is stored in new structures formed through growth processes and some is falling on the forest floor as dead organic matter. Some of the carbon in the litter is released back to the atmosphere in decomposition.

Thus, Chapter 7 provides the reader with the component processes necessary to consider, e.g., in ecosystem carbon accounting. If one is more interested in the flow of water and sugars within a tree, tools for such assessments can also be found. So are analyses of the production and consumption in forest soil of two greenhouse gases, methane and nitrous oxide. Chapter 7 is the weightiest section of the book and is especially challenging for a reader with no experience in mathematical modeling. Nevertheless, even without the background necessary to follow the chapter in its entirety, any reader could benefit from the rate information presented at the end of the chapter. There one finds estimates of the sizes of carbon, water and nitrogen pools in the pine forest of SMEAR II and their annual fluxes between the forest and the atmosphere.

Chapter 8 is important for understanding the principles in forest growth modeling. The reader learns that tree growth cannot be described simply based on its net carbon gain over time. Rules for the partitioning of carbon for growth of various plant parts are needed. It can be assumed, as in this book, that tree structure is trained by selection pressures through evolution and has become balanced and efficient in resource acquisition. For example, increases in the transpiring and photosynthesizing leaf area of an individual tree must be balanced with increases in woody structures that transport water and nutrients and fine roots that uptake these resources. These emergent structural regularities in trees are readily measurable and their expected variation with resource availability testable, and therefore can be directly implemented in stand growth models. In Chapter 9, such a model (MicroForest) is introduced. In MicroForest, in addition to trees, carbon and nitrogen compounds are cycling through ground vegetation and soil.

MicroForest is the tool used for making predictions on the effects on climate change on boreal forests and the effects of forests on the progression of climate change. These predictions are discussed in Chapter 10. The dynamics of the carbon and nitrogen pools in boreal forests is simulated over a period of three hundred years, from 1800 to 2100. Three responses may dominate future interactions between boreal forests and the atmosphere. According to the simulations, the leaf mass in boreal forests increases under future climate. This will reduce surface albedo representing a positive feedback to climate change. At the same time, carbon sequestration in woody biomass will increase. This will slow down the rate at which atmospheric carbon dioxide concentration increases. Also, the biogenic aerosol formation is projected to increase, enhancing the atmospheric reflectance of solar radiation. Combined, the latter two negative feedbacks outweigh the positive one and the boreal forest is expected to slow climate change a little.

The reader is reminded of the uncertainty around predictions made for the entire biome and over several hundreds of years. The uncertainties originate from lack of mechanistic understanding of a number of important processes. For instance, the effect of increasing atmospheric carbon dioxide concentration on photosynthesis remains uncertain. Also, projections of the amount of atmospheric aerosols are difficult to make. Furthermore, the forest growth simulations rely on greatly simplifying assumptions. For example, MicroForest does not distinguish among forest types in the boreal region and the future climate scenarios do not allow for potential changes in the water cycle.

The scope of Boreal Forest and Climate Change is exceptionally broad; the book accomplishes this by cutting across several disciplines. Its areas of emphasis reflect APFE's long traditions in the field of forest production ecology and related field measurements as well as its groundbreaking research in atmospheric and, especially, aerosol physics. From this perspective the book is unique.

However, the breadth of the book has drawbacks. In addition to the Editors, the book has 65 named contributors representing many disciplines. This results in inconsistent style and level of detail. Some inconsistency is clearly discipline related; for instance, soil scientists have different writing traditions than meteorologists. In addition, the effect of the organization of the book on the book as a whole is twofold. While the organization is insightful and compelling for its symmetry across disciplines, it causes discontinuity among chapters and sections. It creates the need for extensive within-book referencing, requiring non-expert readers to search back and forth while attempting to formulate a picture of any component (atmosphere, vegetation, soil).

Nevertheless, the flow of the book is logical and each chapter applies information presented in previous sections. In my opinion, the use of consistent flow diagrams throughout the book considerably increases the accessibility of the text. Moreover, a particular strength of the book is that it provides enough detail and explicitly lists the assumptions used in each analysis. Based on such information, the reader can readily agree or disagree with any of the conclusions.

The potential audience of this Boreal Forest and Climate Change is at least as broad as the expertise of its contributors. For example, it is a handbook of environmental physics for ecologists and of forest ecology for environmental physicists. It can be an excellent textbook for teaching graduate students and motivated undergraduate students in both disciplines, and in related fields.