

Boreal Forest and Climate Change

ADVANCES IN GLOBAL CHANGE RESEARCH

VOLUME 34

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Boreal Forest and Climate Change



Springer

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ISBN 978-1-4020-8717-2

e-ISBN 978-1-4020-8718-9

Library of Congress Control Number: 2008930996

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Printed on acid-free paper

9 8 7 6 5 4 3 2 1

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Preface

The Forest Primary Production Research Group was born in the Department of Silviculture, University of Helsinki in the early 1970s. Intensive field measurements of photosynthesis and growth of forest vegetation and use of dynamic models in the interpretation of the results were characteristic of the research in the group. Electric instrumentation was based on analogue techniques and the analysis of the obtained measurements was based on self-written programs.

Joint research projects with the Research Group of Environmental Physics at the Department of Physics, lead by Taisto Raunemaa (1939–2006) started in the late 1970s. The two research groups shared the same quantitative methodology, which made the co-operation fruitful.

Since 1980 until the collapse of the Soviet Union the Academy of Finland and the Soviet Academy of Sciences had a co-operation program which included our team. The research groups in Tartu, Estonia, lead by Juhan Ross (1925–2002) and in Petrozawodsk, lead by Leo Kaipainen (1932–2004) were involved on the Soviet side. We had annual field measuring campaigns in Finland and in Soviet Union and research seminars. The main emphasis was on developing forest growth models.

The research of Chernobyl fallout started a new era in the co-operation between forest ecologists and physicists in Helsinki. The importance of material fluxes was realized and introduced explicitly in the theoretical thinking and measurements.

The measuring techniques developed slowly during the 1970s and 1980s. The system was computerized, but the utilization of the new possibilities was rather limited. SMEAR I measuring station (station for measuring ecosystem-atmosphere relations) was a clear step forward in utilizing the possibilities of the digital techniques. In addition, the measuring system was planned and constructed to fulfill the research needs of forest ecologists and physicists. Markku Kulmala was leading the physicists in their research of environmental physics, especially the behavior of aerosols.

SMEAR II was planned and constructed to measure all relevant mass and energy fluxes and processes generating the fluxes in a forest ecosystem in southern Finland. The new fully digitalized and automatic measurements opened a new comprehensive source of information for research. A large number of papers dealing with

the gas exchange of trees, soil behavior, gas and energy fluxes between ecosystem and atmosphere, and aerosol formation and growth has been published in scientific journals indicating the benefits of the interaction between forest ecologists and physicists.

Our book is a comprehensive summary of the research done within the long lasting co-operation between forest ecologists and physicists at Helsinki University. Several generations of researchers and students have contributed to the work presented here. Despite the fact that the number of contributors is large, a great number of people who contributed to our book remain unnamed. We want to thank them for their contribution.

John Grace from Edinburgh, U.K. read our manuscript and made a large number of constructive and clarifying comments that clearly improved the book. We acknowledge John Grace for his advice and support.

Helsinki
June 3 2008

Pertti Hari and Liisa Kulmala

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Definitions

ABL – Atmospheric boundary layer, also known as the planetary boundary layer. The lower part of the troposphere, where friction on the Earth's surface influences the air flow.

Absolute humidity – Water vapour concentration in the air.

Absorptivity – A property of a material, the ratio of the absorbed radiation to the incident one; in equilibrium absorptivity and emissivity are the same.

Acclimations – Changes in the biochemical regulations system, in functional substances and in fine structure matching vegetation with irregular changes in the environment.

Accuracy – Magnitude of systematic error in measurements.

Adaptation – Results of evolution to a specific environment.

Adhesion – The tendency of certain dissimilar molecules to cling together due to attractive forces.

Aerosol – The combination of solid or liquid aerosol particles and the gaseous medium they are suspended in.

Air seeding – Gas can be sucked from embolised conduits to water conducting ones through pores in the membranes separating the conduits when water tension rises through increasing transpiration demand.

Albedo – The fraction of solar radiation reflected by a surface of an object, often expressed as a percentage.

Allocation to something – The share of available resources used to the growth of the specified component.

Anemometer – Device for measuring wind speed.

Annual cycle of environmental factors – Exact annual cycle in all environmental factors caused by globes orbiting around the sun, seasonality.

Annual cycle of metabolism – Changes in the biochemical regulations system, in functional substances and in fine structure matching vegetation with the annual cycle of environment.

Aquaporins – Integral membrane proteins enabling selective penetration of water molecules across the membrane.

ATP – Adenosine-5'-triphosphate transports chemical energy within cells for metabolism.

Attenuation of light – Reduction of light due to absorption.

Base saturation – The proportion of cation exchange sites occupied by the so-called basic cations (Na^+ , K^+ , Mg^{2+} , Ca^{2+}) rather than acidic cations (H^+ , Al^{3+}).

Biochemical regulation system – Formed by substances that control the functional substances.

Biome – A biotic community of plants and animals.

Black body – A perfectly efficient emitter and absorber of radiation.

Boreal forest – Set of coniferous forest ecosystems that can survive in northern, specifically subarctic, regions.

Boreal zone – Terrestrial division consisting of the northern coniferous parts.

Bulk flow – Ordinary flow of fluid, but “bulk” stresses the contrast to molecular motion.

BVOC – Biogenic volatile organic compounds; a diverse group of volatile compounds evaporating from plant tissues; e.g. isoprenoids, acetone, methanol.

Cambium – Lateral meristem tissue which gives rise to secondary thickness growth; vascular cambium forms phloem and xylem tissues, and cork cambium forms cork tissues.

Carbon balance – Carbon fixed in photosynthesis during time unit is used to the maintenance and growth.

Carbon reactions (dark reactions, Calvin cycle) – Join a carbon atom to five-carbon sugar in chloroplast stroma utilising energy released from ATP and NADPH.

Carbon sequestration – Amount of carbon fixed in vegetation and soil organic matter during a year.

CBL – Convective planetary boundary layer, planetary boundary layer where heating and evapotranspiration at the surface creates thermal instability and thus generates turbulence. The CBL is typical in summer hemisphere during daytime, when turbulence tends to mix air properties and quantities such as conservative concentrations and potential temperature are close to constant.

Cell – Basic structural and functional unit in all living organisms.

Coagulation (aerosol dynamic process) – The process where two particles collide and coalesce, forming a new larger particle.

Cohesion – A physical property of a substance. Cohesion is caused by the intermolecular attraction between similar molecules within a body or substance that acts to unite them. Water, for example, is strongly cohesive.

Cohesion theory – The hypothesis that water is pulled upward along a pressure gradient during transpiration by the electric forces between water molecules. According to this theory, the evaporation of water at the leaf surfaces pulls a continuous water column against a gravitational gradient through a continuous pathway of xylem conduits reaching all the way down to the roots.

Condensation – The phase transition where a vapour is changing to liquid; it is accompanied by the release of (latent) heat.

Conduction – Molecular transport mechanism of energy (heat) arising from random motion of molecules.

Convection – Bulk flow of the fluid. Flowing gas or liquid carries mass, heat and momentum associated to it. In meteorology, convection refers to the vertical bulk flow of air.

Decomposition of soil organic matter – A process where organic macromolecules are disassembled by soil micro-organisms, leads to release of nutrients and CO_2 .

Denitrification – The respiratory bacterial reduction of nitrate (NO_3^-) or nitrite (NO_2^-) to nitrogen oxides or molecular nitrogen.

Density of mass – Amount of plant material in a volume element divided with the volume of the element.

Deposition – (aerosol dynamic process) – The process of aerosol particles being transported and deposited onto existing surfaces and thus away from the airborne phase.

Dermal tissues – The outermost layer of cells facing the atmosphere or soil.

Diffusion – Transport of atoms and molecules by random thermal movement.

Dormancy – Period in an organism's annual cycle when growth, development, and possible physical activity is temporarily suspended.

Dynamic model – Mathematical model having time in a central role.

Ecosystem – A spatial unit composed of interacting biotic (animals, plants, micro-organisms) and abiotic (non-living physical and chemical) factors.

Eddy – Flow pattern in the turbulent flow with some coherent structure.

Eddy covariance – Meteorological technique to measure exchange of mass, energy and momentum between the surface and the atmosphere, based on the direct determination of the turbulent transport.

Embolism – Introduction of air bubbles into the water transporting xylem tissue, as individual water-conducting vessels are filled by water vapor or air, and they become embolised. Cause the water column to break.

Emergent property – Feature that cannot be directly derived from lower level phenomena.

Emission scenario – A plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g., greenhouse gases, aerosols), based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their key relationships. In general, climate model simulations use some of the so-called SRES scenarios (Nakicenovic and Swart, 2000).

Emissivity – A property of a material, the ratio of the emitted radiation by the material to that of a black body (perfectly efficient) radiator.

Enthalpy – A thermodynamic property of a system related to the internal energy of the system, its pressure and its volume; enthalpy difference between vapour and liquid phases corresponds to the latent heat released in condensation or consumed in evaporation.

Environmental factor – Such feature in the environment that effects on some process.

Enzymes – Large protein molecules acting as biological catalysts in all metabolic processes that occur in living tissue.

Evaporation – The phase transition where liquid is changing to vapour; it is accompanied by the consumption of (latent) heat.

Evapotranspiration – The sum of evaporation and transpiration.

Evolution – New metabolic processes, structures and biochemical regulations and improvements in the existing ones emerge and these novel features are tested against the existing ones in the process of Natural Selection. If the novel feature contributes to the success of the species, then it has the tendency to become more common. This process results in slow evolution of the species as it becomes adapted to the environment of its location.

Extra cellular enzyme – Enzyme emitted by microbes outside the cell to split macromolecules.

FAD⁺ – Flavin adenine dinucleotide.

Flux density – Amount of flow of material or energy through a plane element during time element divided with the product of the area and the length of the duration of the time element.

Forced convection – Convection (bulk flow) arising from any other reasons excluding density (temperature) deviations in the fluid, especially flow arising from pressure difference.

Free convection – Natural convection; convection (bulk flow) arising from density deviations in the fluid, especially flow arising from temperature differences.

Freezing tolerance – Ability to survive freezing temperatures.

Functional balance – The uptake of carbon and nitrogen are balanced with each other.

Functional substance – Enable metabolic processes in living organisms. Enzymes, membrane pumps and pigments are examples of functional substances.

GCM – General Circulation Models or General Climatic Models.

Global radiation – The total of direct solar radiation and diffuse sky radiation received by a unit horizontal surface.

GPP – Gross primary production of an ecosystem, i.e., photosynthesis of the ecosystem.

Greenhouse effect – Greenhouse gases absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. As a result of this, only a small part of the thermal radiation emitted by the Earth's surface and the lowest atmospheric layers escapes directly to space. Although greenhouse gases by themselves emit thermal radiation to all directions, the upward emitted radiation that finally escapes to space originates from air layers that are much colder than the surface, and the intensity of this radiation is therefore smaller. Therefore, the Earth's surface can maintain an average temperature of about +14°C, which is 33°C warmer than the temperature (−19°C) that would be observed without the greenhouse effect. As the concentrations of greenhouse gases in the atmosphere are increasing, the greenhouse effect is becoming stronger and this is expected to lead to an increase in the Earth's surface temperature.