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Biogeochemical Cycles in the Earth System

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MAX-PLANCK-GESELLSCHAFT

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Our mission is to investigate the global biogeochemical cycles and how they interact with the climate system.

Biogeochemical Cycles

Biogeochemistry is the study of Earth's metabolism. Elements essential for life, such as carbon, nitrogen, oxygen, and phosphorous, are continuously subject to biological, chemical, and physical transformations as they are exchanged among the Earth's lithosphere, hydrosphere, biosphere, and atmosphere.

"Biogeochemical cycles" are quantitative descriptions of how elements are distributed and exchanged among these component 'spheres' of the Earth System.

As an example, the element carbon can exist as the gases carbon dioxide and methane in the atmosphere, as organic molecules in organisms, soils and sediments, and in dissolved inorganic and organic forms in surface waters and oceans. Processes exchanging carbon between organic and gaseous forms include photosynthesis, respiration, and decomposition, while soluble inorganic forms can exchange with solid carbonate minerals. Biota mediate most of the processes transforming carbon from one form to another and the rates vary with environmental conditions.

Earth System and Climate

Biogeochemical cycles thus interact in complex ways with Earth's climate. They control variations in the atmospheric concentrations of greenhouse gases like carbon dioxide (CO_2), water vapor (H_2O), methane (CH_4), and nitrous oxide (N_2O), which in turn affect the radiative balance of the atmosphere. Large-scale changes in land surface vegetation also influence physical climate through their impact on the surface energy balance.

Our Research

The Max Planck Institute for Biogeochemistry aims to increase our understanding of the role played by land biota in global biogeochemical cycles. We focus on land because it is where humans live and obtain most of their resources, and because the role of land is among the largest uncertainties in global budgets of several of the major elements for life: carbon (C), nitrogen (N), phosphorus (P), and water.

Our Institute also prioritizes observing and understanding current and ongoing changes in the Earth System. Activities associated with increasing human demands for energy, water and food resources have fundamentally altered global biogeochemical cycles and caused rapid increases in atmospheric greenhouse gases, and therefore Earth's climate.

Conversion of large regions of the land surface has affected the diversity and geographic distribution of Earth's biota. Understanding the implications of these changes for the future state of the Earth system is a major scientific challenge, and an urgent one given future demands on ecosystems for resources to sustain increasing human population and living standards.

The study of the Earth System differs from standard reductive methods of science. We have only one Earth, and its properties are inexorably linked to its unique evolutionary history. The changes we are currently imposing on the Earth System provide opportunities to learn how it operates by observing its responses. However, we are conducting unplanned experiments, with many factors changing at the same time and no 'control' – no Earth unaltered by humans for comparison. Further, our ability to observe the complete Earth System in all its aspects is quite limited.

The processes controlling interactions among climate, land surface and biogeochemistry span 18 orders of magnitude in spatial scale: we must understand what factors alter activity of a molecule such as the enzyme RuBisCO responsible for photosynthesis, and how that may help explain global patterns of vegetation productivity visible from space.

Method Diversity

For our research we take advantage of many different methods such as lab and field experiments, measuring instrumentation in ecosystems and on aircraft, satellite measurements, modeling, and data analyses by machine learning, analyzing air, water, and soil samples using biomarkers and stable isotopes.

To handle all the complex interactions and to make large leaps in scale, we rely on conceptual and computational models to test our understanding of the processes determining the state of the Earth System and how it responds to internally or externally driven changes.

There is no Earth unaltered by humans available for comparison nor can we go back in time.