

## **Perturbations of biogeochemical cycles and climate feedbacks**

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Major perturbations of the natural biogeochemical cycles through human activities such as fossil fuel burning, mining, fertilization in agriculture, as well as industrial production of chemicals have led to direct anthropogenic forcing of climate and to indirect effects on human and ecosystem health through ozone depletion, air pollution, and soil/water contamination world-wide. Air pollution alone is estimated to lead to the premature death of 7 million people a year according to the WHO. In addition, damage to the built environment adds to significant economic costs for society.

Earth-system modelling aims at integrating our knowledge of the processes leading to interactions between biogeochemistry and climate. The field is currently in its infancy, with the modellers facing the challenge of striking the right balance between representing a sufficiently wide range of relevant Earth-system components and a sufficiently detailed description of the complex processes that occur within them. Feedbacks from the Earth system are expected to have both negative and positive forcing effects on climate. Examples range from aerosol-induced radiative cooling with impact on regional climate to changes in air-sea fluxes or wetland and permafrost emissions of long-lived greenhouse gases with a positive climate impact on the global scale. Immediate science questions to address concern interactions between air quality and climate or between the biosphere and climate.

Key questions on air quality-climate interactions:

- How do short-lived climate forcers such as aerosol and ozone affect circulation, weather, and climate on both the regional and global scale?
- How does global climate change affect local air pollution?

Key questions on biosphere-climate interactions:

- How do changes in surface climate affect fluxes of greenhouse gases and other short-lived chemical constituents between the ocean and the atmosphere?
- How do changes in surface climate affect fluxes of greenhouse gases and other short-lived chemical constituents between the terrestrial biosphere (including soils) and the atmosphere?
- How do changes in atmospheric composition including both greenhouse gases and air pollutants affect the terrestrial biosphere?

Quantification of these feedbacks is essential to decision- and policy-making related to the mitigation of and adaptation to climate change. Importantly and perhaps crucially, it will also enable us to more accurately define co-benefits resulting from the simultaneous improvement of air quality and ecosystem health. Co-benefits potentially provide a more compelling argument for climate change action (in the face of competing economic demands) than longer-term mitigation, because the benefits are local and more immediate.