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Strategic plan for the BECC research theme *Carbon Cycle and Climate Change*

We have entered the Anthropocene, the age in Earth history in which human activities dominate over natural processes in forming the Earth System. Climate is changing fast and the biogeochemical cycles of key elements for life are highly disturbed as a result of human activity.

Climate change is both a symptom and cause of a disturbed carbon cycle. The carbon cycle dynamically couples the biosphere, oceans and atmosphere, and links societal and biophysical dimensions of the Earth system. The disturbances in it can be assessed at different scales, from molecular to global, and by their effects on the atmosphere and ultimately on natural systems including the development of human societies. The carbon cycle is also tightly coupled to biogeochemical cycles of other elements such as P and N, and direct and indirect feedback mechanisms may enhance or dampen climate change.

The *Climate* Theme within BECC

This strategic plan aims to identify the scope of the BECC research theme *Carbon Cycle and Climate Change* – hereafter abbreviated to *Climate* – for the second BECC period 2017-2020.

The BECC *Climate* theme is a hub for interdisciplinary research and connections to stakeholders interested in questions of climate change. It provides a platform to initiate and support novel research activities within our scope. It especially supports interdisciplinary projects during their establishment phase, which will likely result in synergies and insights that could not have been achieved without the collaboration.

The BECC *Climate* theme welcomes and encourages all BECC researchers to join the theme or selected *Climate* theme meetings. It has a mailing list of its own that is updated regularly. Information on meetings, workshops or other activity is always announced first to the entire BECC community.

Climate Theme Vision for 2017-2020 and beyond

The *Climate* theme aims to improve understanding of the carbon cycle to better predict and mitigate climate change. The theme aims to foster carbon cycle and climate change-related research, especially interdisciplinary collaborations, such as empirical research to modeling activities, or to connect natural sciences, social sciences and humanities. It also especially encourages interactions between the Universities of Lund and Gothenburg.

BECC *Climate* has a strong research profile in biogeochemistry, soil carbon dynamics, microbial ecology, ecological modeling, global climate projections, mitigation scenarios, social implications of climate change, as well as climate

policy and environmental regulation. Successful interdisciplinary projects have already been established e.g. within microbial biogeochemistry, microbial process modeling, coupled ecological and economical assessments, mapping research needs globally, interactions between animals and terrestrial systems. However, important challenges remains to be tackled.

Our most important *grand challenge* is to reduce wide uncertainty in the components of the carbon cycle, its responses to anthropogenic and biophysical drivers, and the legacy effects of slow-responding processes of vegetation and soils. To address this challenge, it is necessary to combine empirical ecology and modeling, informed by studies of the past, and accounting for links across scales from the local to the global. Accurately quantifying and projecting changes in the carbon balance, regionally and globally, across compartments and sectors, and accounting for links to other biogeochemical cycles (e.g. N and P), is central to understanding and predicting climate change and its impacts on ecosystems and biodiversity. This in turn provides a sound basis for the design of effective mitigation strategies to sequester greenhouse gases from the atmosphere through land use and management interventions.

Identified knowledge gaps and opportunities

Despite important achieved accomplishments, BECC *Climate* identified core knowledge gaps in the science frontiers that can be tackled by bringing together different competences within the BECC PI team. It further identified competences gaps in BECC Climate's present composition of PIs.
The most important, but not limited to, are the following:

- *How correct are soil carbon stock estimates, and where is the highest need for improvement of monitoring?* Soil C stock estimates, and projected changes in those, are a crucial base for earth ecosystem models and policy arguments. However, these estimates are often crude, and sometimes manifold wrong. Especially in the Arctic and boreal regions, where we predict largest changes in C stocks, and impact on global climate, current estimates are very uncertain. Permafrost soils and their fate and feedback loops to climate change are of special importance. BECC *Climate* actively works towards a strategy to improve assessment, monitoring and dissemination of soil C estimates in those regions.

- *Uncertainty in chemical process rates within degradation of recalcitrant soil organic matter.*
  Plants and soil organisms are the main sources for input of organic matter into soils. The gross of the material will be recycled back to CO_2 within short time periods, but parts will remain in the soils for years to decades or millennia. We do not well understand what drives increased or decreased recalcitrance of organic matter, and how to upscale this. BECC already has ongoing collaborations addressing empirical estimates in combination with modeling on molecular processes in organic matter degradation, including priming effects, and BECC *Climate* will support and encourage to expand those.

- *How spatial soil structures and dynamics at micro- to molecular scale influence microbial driving of the C cycle, and how soil treatment techniques can alter these.* An important but rudimentary understood way of soil C stabilization is by physical protection, i.e. spatially disrupting decomposers from access to organic matter substrates.
  We have BECC PI competence in researching soil structure effects on microbial processes at bulk scale, investigating into mechanisms at microscale (amongst others via synchrotron analyses), experimentally manipulating soil structure at microscale, and microbial modeling for upscaling of empirically confirmed processes. BECC *Climate* will actively work to foster ongoing and initial new collaborations within the topic.

- *Constraining long-term (decadal to centennial-scale) variations in soil and biosphere carbon storage.* Earth system models lack a confident data base to model the so-far uncertain and slow response rates; thus, a correct assessment and projections of theses are of high importance for recommendations to policy-makers.
  Archives in tree rings and isotope signatures in geological deposits could help to provide such constraints to tune models. Among BECC researchers we have experts in tree ring analysis and other proxy data, which could together with the ecosystem modelers design experiments to constrain the slow carbon processes in the models. BECC Climate aims to bring together the involved scientists and encourage them to tackle this question.

- *Linkages and feedbacks between nutrient and carbon cycles.*
  We expect complex feedback interactions between nutrient- and carbon cycle especially through the biosphere. However, mechanisms are not sufficiently understood and predictions are therefore uncertain. Too little is known on e.g. the effect of CO2 fertilization in combination with nutrient deposition, and how decomposition rates may be affected by shifts in mineral nutrient limitations. BECC *Climate* aims to work on the basis of the Global Carbon Project on these questions, and to initiate a joint experimental climate manipulation facility (see below).

- *C cycle and climate change in Sweden embedded in global processes*
  Sweden and its policies are not uncoupled from the rest of the world, and all recommendations and incentives regarding climate change mitigation needs to be seen in a global context. Further, we can learn from other ecosystems around the globe, or policies in other countries and use their experiences to improve Swedish society. BECC *Climate* actively encourages studies of topics outside of the Nordic countries when they can be used as a model for future Swedish problems.

- *How to make climate scenarios realistic and relevant for society*?
  Climate scenarios are an important tool for influencing societal development via policy making. The choice and combination of scenarios may be crucial for what politicians will consider as realistic. BECC has an expert team on researching into narratives of climate scenarios and their impact on notion and perception in

society. BECC Climate will actively bring together them with modelers to improve model scenario choices.