Shaping tomorrow's carbon cycle research (side event) - SUMMARY

Place: 9th IPCC Conference, Beijing, China
Time: Thursday June 6, 2013, 18:30-20:00
Panel Members:
Anastasios Kentarchos, European Commission, Brussels, Belgium
Corinne Le Quéré, Tyndall Center, University of East Anglia, Norwich, UK
Galen McKinley, University of Wisconsin at Madison, US carbon cycle coordination WG
Han Dolman, Vrije Universiteit Amsterdam, Netherlands
Hong Liao, IAP and Chinese Academy of Sciences, China
Zhenghui Xie, LASG, IAP, Chinese Academy of Sciences, China
Moderation: Christoph Heinze, University of Bergen, Norway
Minutes: Friederike Hoffmann, University of Bergen, Norway

Auditory: ca. 80 scientists from IPCC conference
Patrizia Zivieri, Universitat Autonoma de Barcelona, Spain, by Webex.

Goal: Provide input for the coming research programmes on carbon cycle research

Agenda:

a. Short introduction by C. Heinze (Univ. of Bergen) and A. Kentarchos (European Commission)
b. Panel members: Brief statements with their views (stimulate discussion)
c. Discussion between audience and panel members (moderation: C. Heinze)

Key questions:

1. What are the **knowledge gaps** in carbon cycle research to be addressed by national & international projects & programmes?
2. How can the **national programmes & projects link** up with the international ones?
3. How to best enhance **international collaboration** for individual researchers & project consortia from the various countries/continents in the carbon cycle community?

Short introduction by C. Heinze (Univ. of Bergen)
- Presents the goal, the key questions and the agenda.
- Many open questions in carbon cycle research – we need to identify them
- Is carbon cycle research really a well-developed research field without further surprises?
- Many key questions seem to be tough to answer and are only "seemingly solved" (e.g. models at times are "right for wrong reasons").
- Society awaits operational systems for carbon cycle quantification and prediction, but are we scientifically there to deliver such mature enough systems?

Short introduction by A. Kentarchos (European Commission)
Carbon cycle research is on a crossroad (purely curiosity driven science vs. policy relevant applications), where does it go from here? Request to research community:
- Suggest how best to integrate disciplines.
- Identify knowledge gaps.
- Come up with a joint strategy.

- Work for planning next IPPC report has started: Agreement on WG1 has to be made. Scientific community needs to reflect upon AR5 input and presentation of results and prepare to engage in discussions/suggestions for AR6 input..
- Horizon 2020 (2014-2020) , the upcoming new EU Framework Program for Research and Innovation. Compared to previous FPs: more integration, more inter- and cross-disciplinary research, more innovation aspects. Carbon cycle community can have strong contribution to the Pillar related to , 'Excellence of Science' and the one on 'Societal Challenges'. - Connect scientific knowledge to policy and communicate science results in the appropriate effective way. Think also about research that can focus on impacts and solutions to meet societal challenges.

Summarized comments (by panel members and audience):

*1. What are the **knowledge gaps** in carbon cycle research to be addressed by national & international projects & programmes?*

Improve measurement technologies:
We need 100x better measurement technologies!
Make measurements cheap, accurate, and good; e.g. use CO_2 sensors or other sensors on smart phones. Also autonomous measurement systems such as oxygen sensors on ARGO floats need to be improved and extended.
Work on development of cheaper and better instrumentation.

More observations needed:
More atmospheric observations needed from all Earth system reservoirs (atmosphere, land, oceans), and especially from highly under-sampled regions, e.g. Africa, Southern Ocean as well as southern Pacific, southern Indian Ocean, southern Atlantic (no seasonal coverage at any location available).
We need more observations and a better focus on observations in research programmes in order to ground truth modelling. Need to maintain long-term observations and make them available to the widest possible community.
Better ways to collect data in an integrated way have to be found, more time series observations are needed.

Integrated approaches:
More integration-efforts are needed: Models-observations, land-ocean-atmosphere, bridging of communities (natural sciences – social/human sciences).
A better quantification of the coupling between land and ocean is needed, also taking account of the coastal areas (and hot spots such as mega-cities close to/at the sea side).
Studies on land-ocean-atmosphere integration should be strengthened including the connection between land carbon, inland waters, coastal ocean, and open ocean.

Better guidelines for interaction of observations and modelling should be created to facilitate collaboration (standardised interfaces).
A special focus has to be placed on properly carrying out data assimilation of carbon cycle observations into models.
Integration, both interdisciplinary and international, will form the background for future research.

Both regional and global perspectives have to be pursued in a connected way.

The link between research on a. greenhouse gases, b. air pollution, c. climate change has to be fostered and extended also through suitable researcher collaboration.

We need more Integrated Assessment Models to link natural sciences to social sciences and policy relevant solution oriented studies
The carbon cycle must be quantified in the context and coupling of/to other biogeochemical cycles (especially to those of oxygen, nitrogen, and phosphorus).
We need to move from pure sink/source quantification to impact assessments C cycle.
Carbon cycling must be addressed within the larger context of climate sensitivity. The carbon cycle research community thus should not only focus on the carbon cycle sensitivity to physical and chemical drivers (how C sources/sinks change with climate and CO2 concentrations). The community should be more active in quantifying climate sensitivity to drives in a holistic way (stronger collaboration with physical climate researchers needed).

Understand long time scales:
Understand carbon cycle dynamics on multidecadal/centennial scales, especially also over the past 1000-2000 years; paleo studies can help to understand such natural variations which is also useful for quantifying the contemporary C cycle. Some drivers might be different on different scales. It is relevant to understand the patterns to make predictions. More interaction between paleo and recent timescales is needed.
Process understanding over long time scales is needed, as some processes have impacts on very long time scales.
The glacial-interglacial carbon cycle variations are not yet explained...

Land:
The land modules in current climate models still produce results with a high level of uncertainty. The land carbon uptake is not yet explained/simulated in a sufficient way: Why does the land take up 2.5-3 PgC/year? Can anybody really answer this question today? The terrestrial carbon cycle is in a long-standing disequilibrium with the other reservoirs – what is the legacy of this situation and what account has been taken from this for future quantifications?

Soil organic carbon, which is key for quantification of C cycle but not yet adequately quantifiable, strong source/sink of GHG (CO_2, N_2O, CH_4), but cannot be adequately quantified in its stock and dynamics as yet. Long-term records based on observations are needed. Process understanding is lacking.

Integration of the land carbon cycle and water cycle is needed.
Inland waters and their role in carbon cycling need to be included in future research studies. E.g. lakes are important and not yet well quantified in the terms of C sources and sinks (but their overall impact of changing carbon budgets due to anthropogenic changes may be small). In any case a better integration of aquatic systems in terrestrial carbon cycle research would be good.

Atmosphere:
For atmospheric research, ozone, VOCs, and other relevant trace gases need to be measured and modelled at the same time.
We are still far away from emissions control through present observing systems. Remote sensing may help here.
More in-situ measurements are needed (including isotope measurements such as ^{13}C, ^{14}C, and other compounds in order to identify greenhouse gas sources).

Ocean:
The open ocean is the ultimate carbon sink. Model runs and observations over longer time scales are needed.

The **Southern Ocean** needs to receive more attention for observations (vastly undersampled) and modelling (difficult to simulate because of complex process interaction) as it is the key source and sink area for CO_2 from the atmosphere (future as well as glacial times).
The coastal ocean and shelf seas have to be interlinked with open ocean studies. A specific difficulty is the heterogeneity of near continent seas (similar difficulty as in the heterogeneous terrestrial systems).

Climate/ecosystem modelling and management:
We have to better identify interactions between climate management and carbon cycle research, both for land and ocean. One has to distinguish between natural variations and impacts and anthropogenic signals.
Scientists also should look at implications of their research for environmental services, and realise the values for those services that they can offer.

Better collaboration between carbon cycle researchers and people working in ecosystem management is necessary: Current models used in land use change and forest management may lack the latest scientific data.
In general, the link between ecosystem research/ecosystem modelling and carbon cycle research has to be fostered and extended.

We need more Integrated Assessment Models to link natural sciences to social sciences and policy relevant solution oriented studies also in view of expected climate change impacts.

More detailed regional studies and specifically ecosystem impact studies are necessary, e.g. in view of ocean acidification and multi-stressor combined action.

Detection and attribution methodologies

Cities, urbanisation, climate-smart development:
High emission societies such as China, USA/Canada, Europe, and India need to find a pathway to “climate-smart development” within the current rapid urbanisation process. International collaboration and support are needed.

Uncertainties in greenhouse gas budgets for cities need more attention and consideration, as urban areas are hot spots for carbon emissions and are so far not adequately included in upscaling approaches for carbon sources/sinks. Because of its importance, the urban

environment needs to be integrated in carbon cycle quantifications in view of many already existing and further growing urbanisation/mega-cities.

Accurate determination of fossil fuel emissions is still difficult to do. What approaches are needed to achieve such quantification and how can they become implemented?

US priorities in carbon cycle research currently are:
-Natural processes and climate change
-Policy and decisions
-Ecosystem impact by GHG
-Effects of mitigation actions

Chinese priorities in carbon cycle research currently are:
- Improvements of Earth system models including the carbon cycle
- Better tools to measure air quality
- Reduce greenhouse gas emissions also in order to improve air quality within the context of climate change

*2. How can the **national programmes & projects link** up with the international ones?*

Timely information on upcoming events and programmes/opportunities should be provided and optimal communication pathways have to be found.

Mechanisms for global funding need to be created and made more transparent.

Some good international tools/approaches already can be used as good examples (Global Carbon Budget, RECCAP)
ICOS is an excellent possibility. 15 countries are active now in this infrastructure mechanism. Hopefully more countries will have the possibility join in.
The GCP would be a natural candidate to take responsibility for further international collaboration and coordination. One should make optimal use of the already established frameworks.

National bi-lateral/multi-lateral possibilities for funding on national/international level should be harmonised and interlinked more easily (some good initiatives exist already).

*3. How to best enhance **international collaboration** for individual researchers & project consortia from the various countries/continents in the carbon cycle community?*

Data sharing and providing an operationally functioning technical framework for data exchange is important.
Models should be made easily available to other people (“open source code approach” including model documentation). Journals, such as the EGU journal *Geoscientific Model Development* are good tools to help here. An effort to provide an improved web-based space

for science communication would be good to make knowledge easily available and accessible in a harmonised/standardised way (formats, protocols, etc.) which are easy to use by everybody). Scientific results should be made available for all so that these results can be put to use. Easy access to data through usage of established databases should be created. Data policies should encourage/facilitate data and model code sharing including proper acknowledgement of the originators.