GC-Carbon Report

Pierre Friedlingstein and Tatiana Ilyina
GC-Carbon

- Endorsed at the JSC-37
- GC SSC
- GC Carbon kick off meeting (Hamburg, November 2016)
- Planned activities for 2017 (and 2018)
- Response to JSC-37 requests
Aim: to understand how biogeochemical cycles and feedbacks control CO$_2$ concentrations and impact on the climate system

Guiding questions:
1. What are the drivers of land and ocean carbon sinks?
2. What is the potential for amplification of climate change over the 21$^{\text{st}}$ century via climate-carbon cycle feedbacks?
3. How do greenhouse gases fluxes from highly vulnerable carbon reservoirs respond to changing climate (including climate extremes and abrupt changes)?
Climate

Climate Impacts

Carbon Dioxide

CO₂ Impacts

Atmospheric depositions

Anthropogenic trace gases emissions

Atmospheric Chemistry

Anthropogenic CO₂ Emissions

Land Use Change

Atm-Ocean C exchange

Ocean BGC Processes

Atm-Land C exchange

Land BGC Processes

GHGs, Aerosols

Land export

Land-ocean exchange
GC-CARBON ORGANISATION
GC-Carbon SSC

Co-chairs: Tatiana Ilyina, Pierre Friedlingstein

SSC:
Ashley Ballantyne (U. Montana, USA)
Laurent Bopp (IPSL, France)
Philippe Ciais (LSCE, France)
Corinne Le Quéré (Tyndall Centre, UK)
Gustaf Hugelius (Stockholm U., Sweden)
Pedro Monteiro (CSIR, South Africa)
Yingping Wang (CSIRO, Australia)
GC-CARBON KICK-OFF MEETING
GC-Carbon kick-off meeting

• Meeting held in Hamburg, 21-22 November 2016
• 35 participants, covering a wide range of expertise such as plant physiology, marine biology, atmospheric inversions, land and ocean biogeochemistry, paleo-climate, Earth system modelling, etc
GC-Carbon kick-off meeting

• Format
  – Intro WCRP GC (David Carlson)
  – Intro GC-Carbon (Tatiana and Pierre)
  – Inspirational talks (Nikki Gruber and Chris Jones)
  – 4 Break-out groups (process understanding on land; process understanding in the ocean; learning from the existing record; and towards improving projections)
  – Report from BG and Synthesis
Report from BGs

- Processes on Land
  - CO₂ fertilisation and role of nutrients
  - Carbon turnover time and response to climate change

- Processes in the ocean
  - Ocean mixing, stratification and carbon uptake
  - Biological pump and carbon export

- Learning from existing records
  - New ocean products for comprehensive spatio-temporal variability
  - Synthesis of surface and satellite measurements as well as manipulative experiments
  - Focus on interannual to decadal variability not just mean

- Improving projections
  - Extended climate-carbon feedback framework
  - Decadal prediction of the carbon cycle
Climate-carbon Feedback framework
Current $\beta/\gamma$ framework is scenario dependent, bases on global temperature only, ignores different time-scales, and regional responses.
A workshop is proposed to develop an extended climate-carbon cycle feedback framework.
This workshop would bring together mathematicians, experts in climate feedbacks, the carbon cycle and Earth System feedbacks
P. Cox (U. Exeter) and T. Froelicher (ETH) will co-organize.
Decadal prediction of the carbon cycle
Growing scientific interest in investigating interannual (land) to decadal (ocean) predictability of the carbon cycle. Potentially highly policy relevant (INDCs pledges)

It is proposed to have initial discussions and a meeting between the global carbon (GC-Carbon, GCP) and the decadal (GC-NTCP, DCPP) communities to explore the feasibility, the scientific and potential societal interests in near term predictions of the carbon cycle.
Ocean physics and biogeochemistry
A workshop is proposed on the ocean boundary layer and its impact on the carbon cycle focusing on mixing parameterizations in models, variation in stratification from data and projected trends with climate change.

Ecosystems turnover time
A focused meeting is proposed in order to provide robust observation-based estimates of vegetation and soil carbon fluxes, pools and turn-over times and to design a $^{14}$C global modelling framework for evaluation of land carbon dynamics.
RESPONSES TO JSC-37 REQUESTS
Change title to clarify its focus

– Done. Title changed from “Biogeochemical cycles and climate change” to “Carbon feedbacks in the climate system”
Explicitly describe partnership with leading carbon community

GC-Carbon SSC
Tatiana Ilyina (C4MIP, SCOR/FeMIP, IOC GO2NE)
Pierre Friedlingstein (GCP annual carbon budget, C4MIP)

Laurent Bopp (IMBER, C4MIP)
Philippe Ciais (GCP, annual carbon budget)
Corinne Le Quéré (GCP, annual carbon budget)
Gustaf Hugelius (Int’l Soil C network, Int’l Permafrost network)
Pedro Monteiro (CLIVAR)
Explicitly describe partnership with leading carbon community

In addition Kick off meeting had representatives from
iLEAPS (A. Arneth)
AIMES (P. Cox, V. Brovkin)
LUMIP (V. Brovkin)
WMO GAW (S. Houweling)
SOCCCOM (N. Gruber)
JSC requests to GC-Carbon

Develop and elaborate a management plan to emphasize policy relevance, and the relevance and future connection/challenge with physical science.

- Policy relevance
  - IPCC AR5 “Cumulative emissions of CO$_2$ largely determine global mean surface warming by the late 21st century and beyond.”. Concept of limited carbon budget is now been used worldwide
Carbon Countdown

How many years of current emissions would use up the IPCC’s carbon budgets for different levels of warming?
Develop and elaborate a management plan to emphasize policy relevance, and the relevance and future connection/challenge with physical science.

- Physical sciences
  - Carbon cycle is controlled by physics both on land and in the ocean. Physical biases impact on the carbon cycle.
  - Carbon cycle controls physics (from local: e.g. vegetation phenology, transpiration; to global: atmospheric CO\textsubscript{2})
  - See KO meeting report. Several big questions are challenges for both carbon and physics.
Projected land photosynthesis constrained by changes in the seasonal cycle of atmospheric CO₂

Sabrina Wohltätig, Peter M. Cox, Volker Eyring & Pierre Friedlingstein

Between 1974 and 2013 the global mean atmospheric CO₂ concentration increased by about 75 p.p.m. by volume (p.p.m.v.) and therefore additional fertilization of the terrestrial carbon sink, considering the full range of responses from an ensemble of complex Earth system simulations for the models, for 1974–2013 for the BRW observations and for 1974–2013 for the CRU observations. Overall, we estimate a GPP increase of 12–14% due to doubling CO₂ concentration (Fig. 1a). The observed range of the CO₂ fertilization effect at BRW allows a determination of the annual cycle and the magnitude of CO₂ fertilization (Fig. 1b). The observed CO₂ fertilization results in a drawdown of CO₂ concentration, which is about 0.16% per p.p.m.v. Our estimates suggest an increase in net primary productivity of about 23% due to doubling CO₂ concentration (Fig. 1c). The models show a wide range of CO₂ fertilization effects at the time of doubling CO₂ concentration (Fig. 1d).

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Accelerating net terrestrial carbon uptake during the warming hiatus due to reduced respiration

Ashley Ballantyne\textsuperscript{1,*}, William Smith\textsuperscript{1}, William Anderegg\textsuperscript{2}, Pekka Kauppi\textsuperscript{3}, Jorge Sarmiento\textsuperscript{3}, Pieter Tans\textsuperscript{4}, Elena Shevliakova\textsuperscript{1}, Yude Pan\textsuperscript{5}, Benjamin Poulter\textsuperscript{6}, Alessandro Anav\textsuperscript{10}, Pierre Friedlingstein\textsuperscript{11}, Richard Houghton\textsuperscript{9} and Steven Running\textsuperscript{1}

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<td>Land temperature anomaly (°C)</td>
<td>-1.00</td>
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<td>0.00</td>
<td>0.50</td>
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<td>Net biome productivity (PgC yr\textsuperscript{-1})</td>
<td>-0.30</td>
<td>-0.10</td>
<td>0.00</td>
<td>0.10</td>
<td>0.30</td>
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<td>Gross primary productivity (PgC yr\textsuperscript{-1})</td>
<td>1.00</td>
<td>1.50</td>
<td>2.00</td>
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<td>3.00</td>
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<td>Total ecosystem respiration (PgC yr\textsuperscript{-1})</td>
<td>4.00</td>
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