Poster Presentation
Theme 3.1: Biogeochemical Processes - Processes Understanding and Human Impacts
Keywords: land

Carbon dioxide evasion from boreal lakes: revised estimate, drivers of spatial variability, and future projections

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Carbon dioxide evasion (FCO_2) from lakes (incl. reservoirs) is established as an important component of the global carbon (C) cycle, a significance reflected by the inclusion of this flux in the most recent IPCC assessment report. In the context of lakes, the boreal region is disproportionately important containing both the greatest abundance, and total area of lakes of any biome. In this study, we developed a model driven by globally available environmental geodata, to predict CO_2 partial pressure (pCO_2) in boreal lakes, and to create the first high resolution, circumboreal maps (0.5°) of lake pCO_2 and FCO_2. A multilinear regression was used to derive a prediction equation for lake pCO_2 as a function of lake area, terrestrial net primary productivity (NPP) and precipitation (r^2= 0.56). The map of pCO_2 was combined with lake area from the recently published GLOWABO database and estimates of gas transfer velocity k to produce the resulting map of FCO_2. For the boreal region we estimate an average, lake area weighted, pCO_2 of 966 (678- 1325) µatm and FCO_2 of 189 (74-347) Tg C yr^{-1}, substantially higher than in previous studies based on lower estimates of lake area. Our approach also incorporates a mathematically transparent calculation of uncertainty (5^{th} and 95^{th} percentiles), using a Monte Carlo simulation comprising 10,000 runs. We use our maps along with spatially resolved data of FCO_2 from rivers and estuaries, as well as lateral land-ocean C exports to derive an aquatic carbon budget for the boreal region. Finally, based on spatially resolved projections of terrestrial NPP and precipitation, we use the model to predict changes in lake pCO_2 and FCO_2 over the 21^{st} century.

Poster Session (see poster session schedule)

Poster Presentation
Theme 3.1: Biogeochemical Processes - Processes Understanding and Human Impacts
Keywords: ocean, weathering, biogeochemistry, modeling

Implications of riverine nutrient and carbon fluxes derived from a weathering model on the ocean biogeochemistry

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The coastal ocean is widely viewed as a hotspot for oceanic primary production, partly due to the supply of nutrients by rivers. Furthermore, river loads of C, P, N, Si and alkalinity can be considered as compensation fluxes for any sedimentation processes which occurs within the global ocean. By implementing riverine nutrient and carbon fluxes into the Earth System Model MPI-ESM, we aim to better represent these fluxes from land to the ocean, as well as investigate their effects on the carbon cycle of the coastal ocean, as well as of the global ocean.
We use a first order weathering model (Hartmann et al., 2013) to estimate weathering fluxes of dissolved phosphate, silicate, inorganic carbon as well as alkalinity. We thereby generate a spatial distribution of weathering yields that are dependent on temperature, runoff, lithology and soil properties. Such an approach permits an implementation of dynamical riverine fluxes in the ESM, in a way that they are sensitive to changes in hydrology and climate. The state of art NEWS database (Mayorga et al., 2010) is used to derive the fluxes of organic carbon as well as nitrate, which are from non-weathering sources. The fluxes are routed to the ocean through hydrological catchments from the MPI-ESM.
Our preliminary results show weathering hotspots, more specifically in Southeast Asia, the Amazon, Northern Europe and Siberia. These areas also deliver large fluxes of carbon and nutrients to the coastal ocean. In comparison to a model run without riverine nutrient and carbon fluxes, the total ocean global primary production is only slightly affected by these fluxes, whereas changes in the spatial distribution of the primary production can be observed, as it is enhanced in the proximity of the rivers but is decreased in some areas of the open ocean. The carbon sink of many major coastal regions is thereby enhanced. Other regions in the high latitudes show a source of carbon in comparison to the control run. Furthermore, we make carbon budgets for several well-known coastal shelves, to determine how much of the carbon input from rivers is buried within the shelf, or if it is transported offshore.

Poster Session (see poster session schedule)

Poster Presentation
Theme 3.1: Biogeochemical Processes - Processes Understanding and Human Impacts
Keywords: land, Earth System Modelling, lateral flux, LOAC, future projections, Amazon

Simulating C transfers through the terrestrial-aquatic continuum of the Amazon

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Lateral transfer of carbon (C) from terrestrial ecosystems through the in-land water network is an important component of the Global C Cycle, which sustains a large aquatic CO_2 evasion flux fueled by the decomposition of allochthonous C inputs. Globally, estimates of the total C exports through the terrestrial-aquatic interface range from 1.5 to 2.7 Pg C yr^{-1} (Cole et al. 2007; Battin et al. 2009; Tranvik et al. 2009), i.e. in the order of 2-5% of the terrestrial NPP. Earth System Models (ESM) of the climate system ignore these lateral transfers of C, and thus overestimate the terrestrial C sink.
In this study, we present the implementation of fluvial transport of dissolved organic carbon (DOC) and CO_2 into ORCHIDEE, the land surface scheme of the Institut Pierre-Simon Laplace ESM. This new model branch, called ORCHILEAK, represents DOC production from canopy and soils, DOC and CO_2 leaching from soils to streams, DOC decomposition and CO_2 evasion to the atmosphere during its lateral transport in rivers, as well as exchange with the soil carbon and litter stocks in riparian wetlands. We parametrized and validated ORCHILEAK for the Amazon basin, the world's largest river system with regard to discharge and one of the most productive ecosystem of the world. The CO_2 evasion from rivers and wetlands in the Amazon basin has been estimated to 0.5 Pg C yr^{-1} (Richey et al., 2002), i.e. more than one order of magnitude higher than the lateral exports to the ocean. However, it is not easy to compare this value with the terrestrial C budget for the Amazon, as it is not clear in how far this CO_2 evasion is fueled by displaced, terrestrial C or by e.g. wetland plant production (Abril et al., 2014).
With ORCHILEAK, we are able to reproduce observed fluxes of DOC and CO_2, both in terms of spatial patterns and seasonality. In addition, we are able to resolve the spatio-temporal variability in C fluxes along the canopy-soil-aquatic continuum and to decompose the origin of these C fluxes. We simulate that more than 2/3 of Amazon's fluvial DOC export is contributed by the decomposition of submerged litter. Throughfall DOC fluxes from canopy to ground are about as high as total DOC inputs to inland waters. The latter, however, are mainly sustained by decomposition of litter. Decomposition of DOC and submerged plant litter contributes slightly more than half of the CO_2 evasion from the water surface, while the remainder is contributed by soil respiration. Total CO_2 evasion from the water surface equals about 5% of the terrestrial NPP. Finally, we run future simulations to predict how increasing atmospheric CO_2, land use and climate change will affect the C transfers through the terrestrial-aquatic continuum.

Poster Session (see poster session schedule)

Poster Presentation
Theme 3.1: Biogeochemical Processes - Processes Understanding and Human Impacts
Keywords: ocean, Amazon River, carbon uptake, marine biogeochemistry, diazotrophy

The impact of the Amazon River plume on the CO2 sea-air exchange in the Tropical Atlantic Ocean

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The Amazon River delivers large amounts of nutrients to the ocean, enhancing phytoplankton production in the otherwise oligotrophic tropical North Atlantic substantially. Observations suggest a progression of the phytoplankton community composition from the mouth of the river to the open ocean, with diatom-diazotroph assemblages (DDAs) becoming increasingly dominant. These diatom-diazotroph assemblages have been hypothesized to fuel carbon sequestration and to explain the observed anomalously low pCO2 values in the areas influenced by the Amazon plume. Here we aim to better constrain and understand the complex interplay of physical and biogeochemical processes that leads to this unique effect of the Amazon plume on the tropical North Atlantic. To this end, we embedded the Biogeochemical Elemental Cycle model (BEC) within an eddy-resolving configuration of the Regional Oceanic Modeling System (ROMS) and using a novel telescopic grid with a high resolution at the mouth of the river (4 km) while covering nearly the entire Atlantic Ocean. The model reproduces the basin-scale currents structure and the variability of the plume pathways; it also generates phytoplankton blooms that compare well with observational data-sets. In agreement with *in situ* measurements, mesohaline waters (20 – 24 PSU) that are rich in phosphate and silicic acid but poor in nitrate constitute a niche for DDAs associated with high rates of N-fixation. These blooms support important carbon export (net flux between 1.5 and 15 Tg C yr-1) which changes the air-sea pCO2 gradient and turns these waters into a sink of CO2. Our sensitivity analysis shows that the magnitude of the carbon sequestration is highly dependent on the amount and properties of the nutrients supplied by the Amazon River. However, physical components such as advection and residence time of the waters are also crucial as they determine the onset and the length of the blooms, and subsequently the efficiency of the biological pump. Any disturbance of this balance related to climate change or land use changes will affect the CO2 uptake of the Amazon River plume.

Poster Session (see poster session schedule)

Oral Presentation
Theme 3.1: Biogeochemical Processes - Processes Understanding and Human Impacts
Keywords: coupled Earth system, river damming, land-ocean aquatic continuum, organic carbon

Global perturbation of organic carbon cycling by river damming

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The damming of rivers represents one of the most far-reaching human modifications of the flows of water and associated matter from land to sea. There is currently an ongoing boom in dam construction, particularly focused in emerging economies, which is expected to double the fragmentation of rivers on Earth. Dam reservoirs are hotspots of sediment accumulation, primary productivity (*P*) and carbon mineralization (*R*) along the river continuum. In this study we developed the first spatially explicit global estimate of organic carbon (OC) burial, photosynthesis and mineralization in dam reservoirs for the years 1970, 2000, 2030 and 2050. We followed a mechanistic modeling approach that overcomes the limitations of relying on data-limited empirical models. Our model includes major in-reservoir fluxes, transformations and OC pools, and distinguishes between allochthonous and autochthonous OC burial and mineralization. The model is fully coupled to an existing reservoir phosphorus model to quantify nutrient-dependent changes in primary productivity (PP). For the period 1970-2030, we show that global carbon mineralization in reservoirs exceeds carbon fixation (P < R); the global P/R ratio, however, varies significantly, from 0.20 to 0.58 because of the changing age distribution of dams. We further estimate that at the start of the 21st Century, in-reservoir burial plus mineralization eliminated 4.0 ± 0.9 Tmol yr^{-1} (48 ± 11 Tg C yr^{-1}) or 13% of total organic carbon (OC) carried by rivers to the oceans. Because of the ongoing boom in dam building, in particular in emerging economies, this value could rise to 6.9 ± 1.5 Tmol yr^{-1} (83 ± 18 Tg C yr^{-1}) or 19% by 2030.

Session:
C2: The Coupled System (part 2)
Thu, 24 August 2017: 11:10 - 12:30

Poster Presentation
Theme 3.1: Biogeochemical Processes - Processes Understanding and Human Impacts
Keywords: ocean, freshwater, carbon cycling, greenhouse gases, fluxes

Spatial and temporal variations of CO2 and CH4 fluxes in the Danube Delta

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In freshwater systems, carbon dioxide (CO_2) and methane (CH_4) are produced during organic matter degradation. Globally, the release of these greenhouse gases from inland waters to the atmosphere is estimated to be of the same order of magnitude as terrestrial carbon fixation. However, large uncertainties on the spatial and temporal dynamics of aquatic CO_2 and CH_4 evasions and the underlying processes persist. As part of the EU Horizon 2020 project C-CASCADES, we investigated the carbon cycling in Europe's second largest river delta, the Danube Delta, to better constrain the spatio-temporal variability of carbon fluxes from temperate deltaic systems. The Danube receives water from 19 European countries and is the major source of freshwater to the Black Sea. Before discharging into the Black Sea, parts of the Danube waters pass an extensive wetland area. While much of the northern Danube Delta has been transformed into agricultural land, the southern delta is still largely pristine and a UNESCO biosphere reserve. The delta is composed of three main river branches and a network of closely connected channels and flow-through lakes between vast reed stands. Hence, it offers an ideal setting to study the seasonal variability of carbon fluxes in different aquatic compartments of a river delta. Throughout the delta, we took monthly measurements of greenhouse gas concentrations and carbon fluxes as well as various physico-chemical parameters at 19 sampling sites over a complete annual cycle. The sampling campaigns were complemented by continuous multi-probe measurements in the upper delta and at the terminus at each of the three main branches. Our time-series study revealed a strong seasonal variability for both CO_2 and CH_4 concentrations and fluxes. We also observed large differences in carbon cycling between the different aquatic compartments (main river branches, channels, lakes) and identified channels in the inner delta as hot spots of greenhouse gas emissions.

Poster Session (see poster session schedule)

Poster Presentation
Theme 3.1: Biogeochemical Processes - Processes Understanding and Human Impacts
Keywords: Dissolved Organic Carbon (DOC), JULES, ORCHIDEE, DOC decomposition and production, DOC leaching

Testing Dissolved Organic Carbon representation in the JULES-DOCM and ORCHIDEE-SOM

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Current global models of the carbon cycle consider only vertical gas exchanges between terrestrial or oceanic reservoirs and the atmosphere, hence not considering lateral transport of carbon from the continent to the oceans. This also means that such models implicitly consider that all the CO2 which is not respired to the atmosphere is stored on land, hence overestimating the land sink of carbon. Moving toward a boundless carbon cycle that is integrating the whole land to ocean continuum and its interactions with the atmosphere is needed in order to better understand Earth's carbon cycle and to make more reliable projection of its future.
Here we are presenting two newly developed land surface models which are capable of representing the production and cycling of dissolved organic carbon (DOC) within soils and the export of DOC from soils to inland waters, JULES-DOCM and ORCHIDE-SOM, and evaluate their performance. Both models represent updated versions of land surface schemes that are routinely used in Earth System simulations. They simulate vegetation growth and litter inputs to the soils as well as soil hydrology and soil temperature that control production, cycling, decomposition and finally leaching of DOC within the soils, thus allowing an integrated, physical based, spatially distributed model approach.
Both models were tested against specific sites (Brasschaat, Hainich and Carlow), for which observations of DOC concentration and leaching are available. Simulation were performed over the same period and by means of the same climate forcing data. Results of both models were compared with each other and with observations. Simulations with JULES-DOCM reproduced observed DOC concentration profiles better than ORCHIDE-SOM, which shows a strong tendency to overestimate DOC concentrations, in particular in the topsoil. Generally, DOC leaching rates simulated by ORCHIDEE-SOM are higher, consistent with higher simulated DOC concentrations. Differences in simulation results between both models are discussed in the light of the different representation of DOC production, decomposition and export.

Poster Session (see poster session schedule)