Quantification of peatland-mediated feedbacks to the climate system

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Introduction

Peatlands are one of the biggest carbon reserves on terrestrial ecosystems mostly located in northern latitude areas (45–75° N). They have sequestered approximately 300-550 PgC since the Holocene [1]. The majority of northern peatland areas coincide with low altitude permafrost [2]. The recent changes in climate and land use patterns have disturbed the Earth's climate-carbon cycle equilibrium. These changes trigger some potentially important land-surface feedbacks, which will further modify the Earth's climate[3]. The ongoing changes in peatland carbon balance as a result of climate warming have the potential for strong positive and negative feedbacks to climate, but these impacts are poorly constrained. The main aim of this project is to make a step change in our understanding of peatland-mediated feedbacks and their impacts on climate and the C cycle. This project also seeks to enhance our knowledge about the processes controlling peatland responses to climate change and the effects of land-atmosphere interactions on the overall behaviour of the Earth system.

The specific ***objectives*** of this study are:

a) To integrate a well-benchmarked process-based methane (CH_4) biogeochemical scheme

b) b) To understand the role of peatland-mediated feedbacks on climate

c) c) To perform recent past, present and future simulations in order to capture the impacts of peatland-mediated feedbacks on regional climate

Peatland-Vegetation Model

LPJ-GUESS Peatland

LPJ-GUESS is a modular framework to explicitly model physiological, and biogeochemical processes governing the growth and competition of woody-plant individuals [4]. We combined a dynamic multi-layer approach to peat formation and composition [5] with soil freezing-thawing dynamics [2], plant physiology and competition among plant functional types (PFTs) - shrubs, graminoids and mosses.

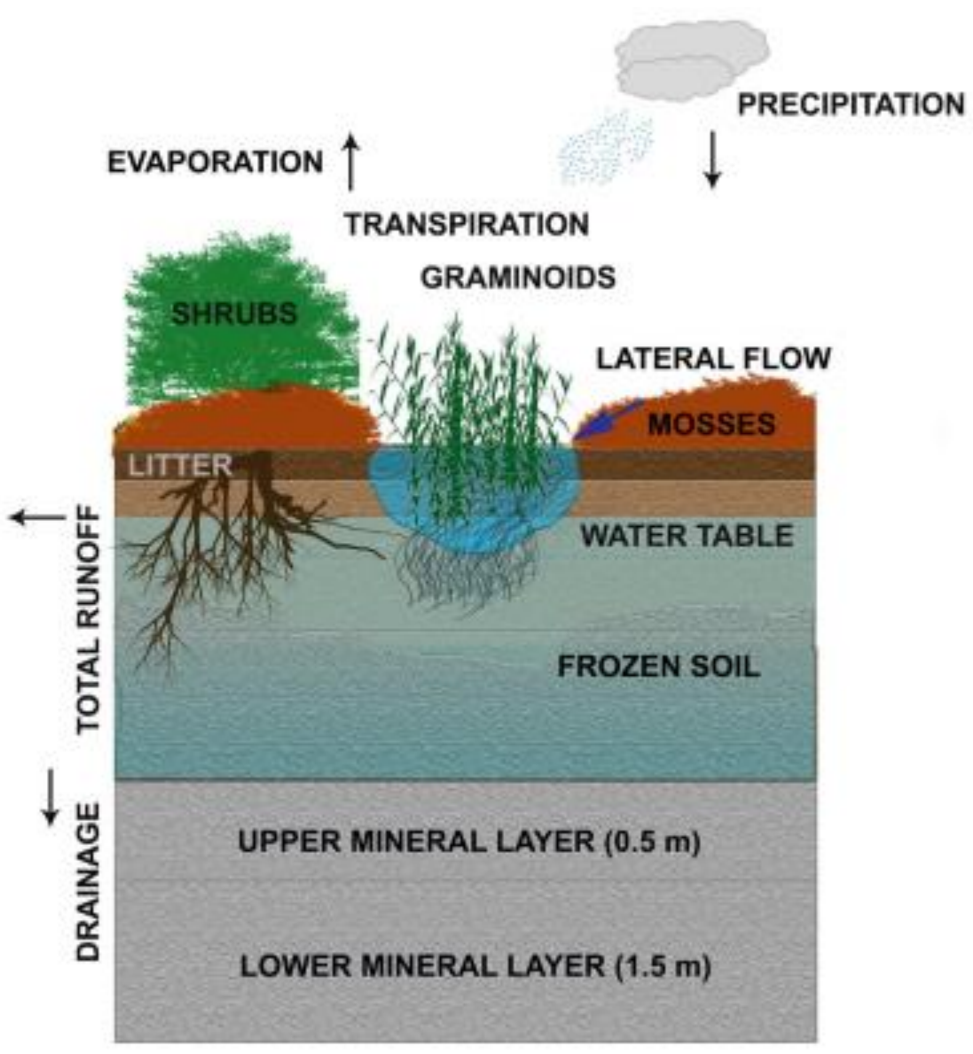

Figure 1. Schematic representation of LPJ-GUESS-Peatland. Dynamic peat layers deposit above the static mineral soil layers (0.5+1.5m). In the shallow peat, plant roots are present in both mineral and peat layers. Once the peat become sufficiently thick (2m), all roots exist in the peat soil.

Recent Findings

Carbon accumulation rates

In our recent study[8] using our peatland-vegetation model, we found that areas where peat production was initially hampered by permafrost and low productivity would accumulate more carbon because of the initial warming, moisture rich environment due to permafrost thaw, higher precipitation and elevated CO_2 levels. On the other hand, areas which experience reduced precipitation rates and without permafrost will lose more carbon in the near future, particularly, peatlands located in the European region and between 45–55° N latitude.

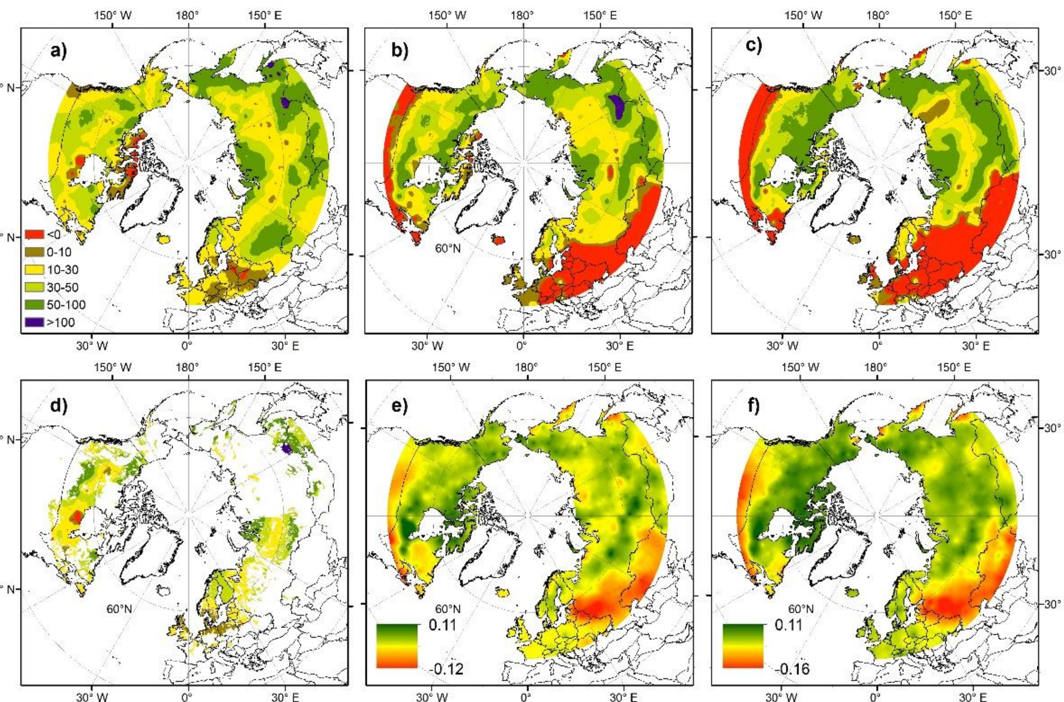

Figure 2. a) Carbon accumulation rates (average 1990–2000), b) under RCP2.6 scenario (average 2091–2100), c) under RCP8.5 scenario (average 2091–2100), d) clipped carbon accumulation rates (average 1990–2000) according to the most up-to-date observed map, e) difference between images B and A; and f) difference between images C and A

Bio-geophysical feedbacks

Feedbacks are important interactions in the Earth system which can accentuate or dampen the effects of climate forcings and play an important role in determining the future climate state. Changes in the land surface properties such as albedo, surface roughness, soil moisture, leaf area and rooting depth directly modify the surface energy, momentum and moisture fluxes which in turn trigger biogeophysical feedbacks[6]. These feedbacks are critical for regional climate and can be captured using regional ESMs. By studying these feedbacks, the relevant information related to the direction, strength, and magnitude of these triggers can be extracted. To accurately quantify and predict the effects of these feedbacks, state-of-the-art regional ESMs need to be employed. However, due to the absence of any comprehensive ESMs with the representation of detailed peatland and cryospheric processes, our understanding of the peatland-mediated feedbacks at regional and global scales is limited. My individual– and patch– based peatland-vegetation model (LPJ-GUESS) can capture the C accumulation rates and permafrost dynamics at different spatial and temporal scales and will be further improved to account for these changes.

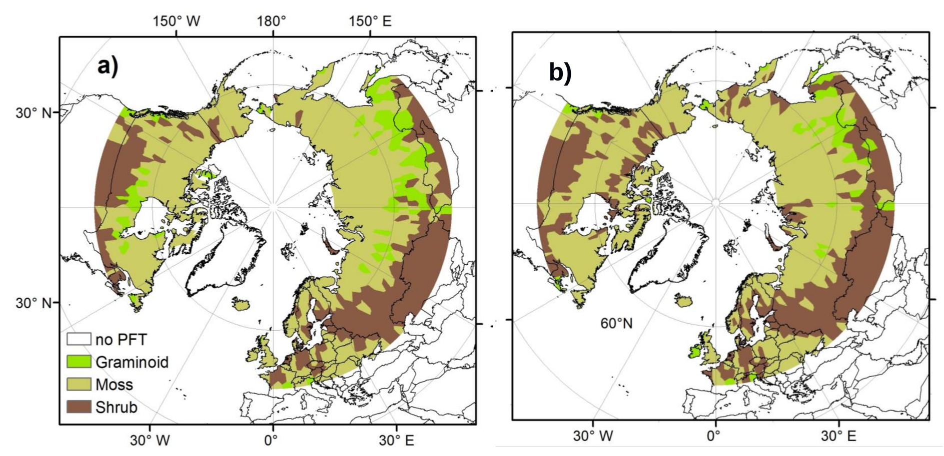

Figure 3. Probable changes in dominant vegetation cover in the northern latitude region - a) 2000 and b) 2100 (RCP8.5)

Integrating peatland dynamics in Regional ESM – RCA-GUES

This research project focuses on further development and evaluation of an established peatland version of the LPJ-GUESS, a dynamic global vegetation model[4]. The improved and adapted peatland-vegetation model will be coupled with the regional ESM, RCA-GUESS, a regional Earth System Model (ESM) [7].

RCA-GUESS is one of the comprehensive regional ESMs which uses an interactive coupling between LPJ-GUESS and the Land Surface Scheme of RCA (see Fig. 4). The model comprises two sub-models: a vegetation sub-model based on LPJ-GUESS and the physical sub-model RCA. The vegetation sub-model simulates vegetation dynamics and leaf phenology while the physical sub-model simulates regional climate conditions.

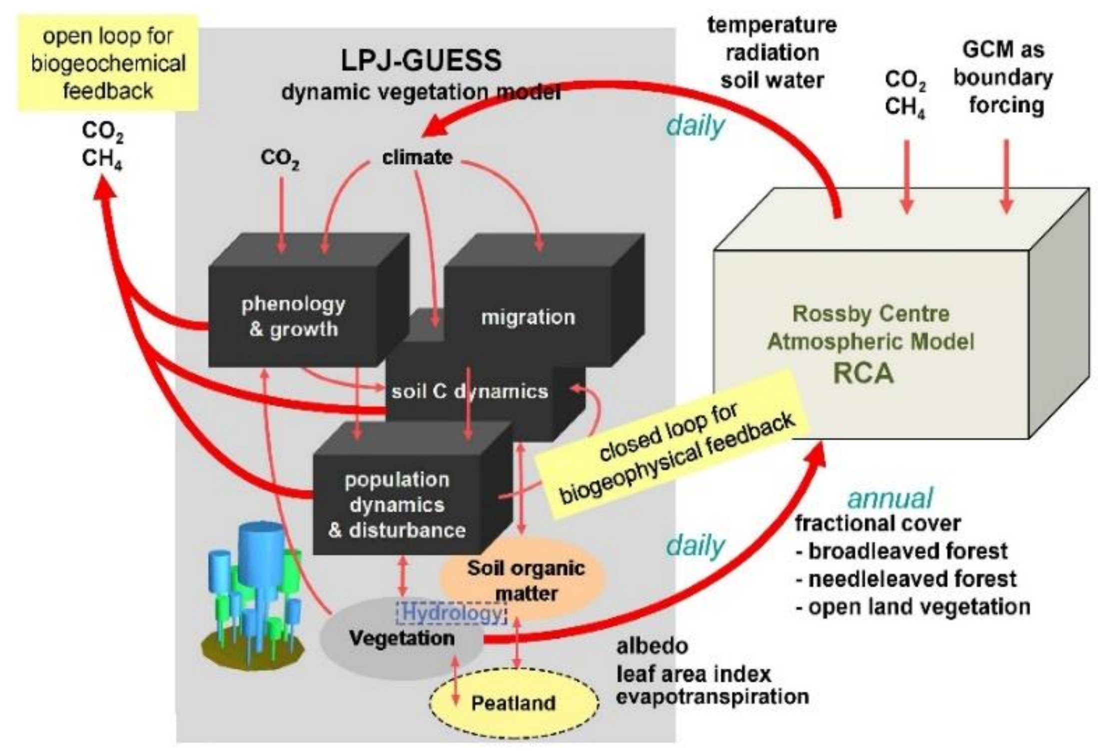

Figure 4. A proposed schematic representation of regional Earth system model, RCA-GUESS

Expected Results

1) This study will provide a better understanding of the role of peatland-mediated feedbacks and peatland processes at regional and global scales by including their representations in regional and global ESMs.

2) The study results can be used to predict the most probable demarcation of peatland and permafrost extent for the coming century and to reduce current uncertainties regarding CH_4 emissions from the peatlands.

3) The study will help in identifying the 'hotspots' in the pan-Arctic region and other geographical areas that are vulnerable to high C emissions and permafrost degradation and will evaluate their direct consequences to plant ecology and hydrology.

References

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