LATE REQUEST FOR A SPECIAL PROJECT 2024–2026

MEMBER STATE: ……………………Denmark…………………………………………………………………

Principal Investigator[1]**:** ………………Jing Tang………………………………………………………………

Affiliation: …Department of Biology, University of Copenhagen (UCPH)………

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Other researchers:
Ida Roos Friis (UCPH)
Daniel Charles Thomas (UCPH)
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Project Title:
Quantifying biosphere-atmosphere interactions: the impacts from vegetation volatile emissions, plant phenology and lake greenhouse gas emissions

To make changes to an existing project please submit an amended version of the original form.)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ………….	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2024	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2024**	**2025**	**2026**
High Performance Computing Facility	[SBU]	45,000,000	60,000,000	80,000,000
Accumulated data storage (total archive volume)[2]	[GB]	100,000	100,000	100,000

EWC resources required for project year:		**2024**	**2025**	**2026**
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

Principal Investigator: *Jing Tang*

Project Title: Investigating plant-atmosphere biochemical and biophysical interactions

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.
[3]The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

Principal Investigator: ………Jing Tang……………………………………………………………

Project Title: … Quantifying biosphere-atmosphere interactions: the impacts from vegetation volatile emissions, plant phenology and lake greenhouse gas emissions………………………………

Extended Abstract

Need for Computer resources:

The computer sources requested will be used to couple the latest dynamic vegetation model LPJ-GUESS into the Earth ecosystem model, EC-Earth, and the main focused features and associated feedback include the extended biogenic volatile organic compounds (BVOCs), new plant phenology in LPJ-GUESS, and newly-coupled lake biogeochemical module. My research group (1) has extended LPJ-GUESS modelled BVOCs from 2 compound groups till a full spectrum of compound species (20 functional groups and approx. 150 compound species), (2) has developed a new temperature-photoperiod coupled vegetation phenology algorithm into the LPJ-GUESS (Chen et al. 2024), and (3) is in the process of coupling the advanced lake biogeochemical model, ALBM (Tan et al. 2015) into the LPJ-GUESS.

To assess the impacts of a range of BVOC species and lake greenhouse emissions on atmospheric composition and climate, we will need to conduct simulations using offline coupled LPJ-GUESS and TM5 (both are part of EC-Earth modules) as well as full-coupled EC-Earth with new features in it. Further, to quantify the regulation of vegetation phenology on ecosystem water and carbon fluxes and assess associated climatic impacts, we will need to run a few sets of EC-Earth assembles to compare the impacts from different phenology modules.

We have good overviews of running offline-coupled LPJ-GUESS with TM5 but very limited experience with running fully coupled EC-Earth on the ATOS system. Therefore, **the values of the requested SBUs are based on our guesses and comparisons with other granted projects.** The offline simulations of LPJ-GUESS will be run on our local supercomputing system, and we will only run offline coupled LPJ-GUESS and TM5 as well as fully-coupled EC-Earth on the ATOS system.

Purpose and aims

The purposes of this project are (1) to assess the impacts of full-spectrum BVOCs on atmospheric composition and the climate, (2) to quantify the regulation of plant phenology on seasonal carbon and water fluxes under changing climate, and (3) to understand the greenhouse effects (CO_2 and CH_4) from lake processes.

The model simulations are part of three ongoing interdisciplinary projects funded by Danish Villum Fonden, Swedish STINT and the University of Copenhagen.

Project description

Below, I will describe the backgrounds and aims for these three projects individually.

Project 1: 5-yr Villum Young Investigator project titled with "**Plant temperature-regulated Arctic responses and feedbacks to the changing climate**" (2023-2028)

Background:

The Arctic experiences warming at twice the global rate, and this amplified warming is expected to largely increase the frequency of heatwaves in this region. In a warmer climate, arctic plants adjust leaf phenological development and adapt photosynthetic rates to influence the fluxes of CO_2 and biogenic volatile organic compounds (BVOCs) to the atmosphere. Under heatwaves, we expect a reduced plant uptake of CO2, but a large burst of stress BVOCs as a plant defence mechanism. Highly reactive BVOCs contribute to lengthening methane lifetime, form aerosols and clouds, and change ozone concentration in the atmosphere, so studying the fluxes of CO_2 and BVOC is highly important for understanding climate changes within and beyond the Arctic. Importantly, all the abovementioned processes are regulated by plant temperature (influenced by plant traits and leaf energy balance) instead of routinely-measured air temperature. The observed differences between plant and air temperatures for arctic plants can be even larger than the projected changes in air temperature by the end of this century. We still tend to use air temperature for understanding plant processes due to its easy availability, which can, however, cause errors in the understood plant responses to changing environments and in estimated impacts of arctic ecosystems on the climate.

Furthermore, to account for the impacts of BVOC on the changing climate, we need to link BVOC emissions with plant physiology, account for stress-induced BVOC emissions and run fully-coupled earth system model, such as EC-Earth. The current limitation in EC-Earth is that plant-emitted BVOCs (simulated LPJ-GUESS) are not coupled with the atmospheric chemistry part in EC-Earth. Instead, a global dataset, disconnected from the dynamic vegetation, was read in to quantify potential impacts from BVOCs, meaning large uncertainties in quantified BVOC impacts on our climate system.

Aims:
This project will study how plant temperature varies across different arctic ecosystems and improve model accuracy of plant temperature. We then experimentally determine dependences of physiological processes on different temperatures and apply the quantified relationships into models to assess the feedbacks of these modified processes on regional and global climate systems.

This project will also fully couple LPJ-GUESS modelled plant BVOC emissions with atmospheric processes in the upcoming version of EC-Earth 4. More specifically, the major aims are to: (1) extend LPJ-GUESS modelled volatile compounds till full spectrum of compound species (20 functional groups and approx. 150 compound species); (2) develop a flexible framework where the compound species can be easily mapped to different aerosol schemes; (3) assess BVOC impacts modelled aerosol and cloud radiative forcing after explicitly linked to vegetation dynamics and plant photosynthesis.

Project 2: a 3-yr STINT project funded by The Swedish Foundation for International cooperation in Research and Higher Education, and titled "**Assessment of plant phenology impacts on terrestrial carbon and water cycles in northern ecosystems – combing climate change manipulation experiments and LPJ-GUESS modelling**"
Background:
Global warming has profoundly affected the structure and function of terrestrial ecosystems. Vegetation phenology is very sensitive to climate warming and is the most sensitive biological indicator of climate change (Peñuelas et al. 2009) . It was found that climate warming would significantly advance the spring phenology and delay the autumn phenology of vegetation in the middle and high latitudes of the northern Hemisphere, significantly extend the length of the vegetation growing season, and thus affect the carbon and water cycle of terrestrial ecosystems (Keenan et al. 2014; Piao et al. 2020). However, the mechanism by which vegetation phenology responds to climate change remains unclear (Fu et al. 2019; Körner and Basler 2010), resulting in greater uncertainty in the simulation results of phenological models, which in turn leads to inaccuracy in the simulation results of the carbon cycle of global dynamic vegetation models (Richardson et al. 2012; Tang et al. 2015). Therefore, accurate understanding of phenological response mechanisms to climate change, construction of phenological models coupled with global dynamic vegetation models, and identification of future phenological changes under climate change and their impacts on ecosystem carbon and water cycles are urgent research topics in global change ecology.

The interaction of multiple environmental factors should be considered in response to climate change. It was found that the coupling of chilling in winter, growing degree days

(GDDs) and photoperiod in spring determines the spring phenology of vegetation in the middle and high latitudes of the Northern Hemisphere (Fu et al. 2019; Zohner et al. 2016). However, the coupling relationship between the three is still unclear, especially how photoperiod regulates accumulated temperature and cold shock needs further study. Therefore, based on climate change control experiments, it is of great significance to study the difference in response of plant phenology to surface temperature and air temperature, as well as the coupling relationship between photoperiod, cold shock and accumulated temperature, and then build plant phenology models, coupled with global dynamic vegetation models, and study the carbon-water cycle process of terrestrial ecosystems for accurate understanding of ecosystem response to climate change.

Aims:

Following the recent development in the LPJ-GUESS phenology module for the tundra and boreal vegetation functional types (Chen et al. 2024), we will continue building phenology equations for summergreen vegetation types for the rest of the globe. We will further assess the impacts of the new phenology module on carbon and water cycling. To assess the atmospheric impacts, we will couple LPJ-GUESS with new phenology features into the current version of EC-Earth 3 and the upcoming version of EC-Earth 4. The project will provide Earth system models with a set of plant functional type-trained phenology algorithms that can potentially improve the representation of vegetation phenology in different regions.

Project 3: a 3-yr PhD project funded by the University of Copenhagen, 2024-2027, titled with "Warming-induced vegetation growth and permafrost-thaw feedback to lake greenhouse gas production"

Background:

Warming is likely to further accelerate permafrost thawing and enhance plant growth in high latitudes, which can potentially release large amount of organic matter into lake ecosystems. Permafrost thaw can subsequently form thermokarst lakes, increasing lake area in the Arctic. Terrestrial ecosystem models (such as LPJ-GUESS) account for warming-induced vegetation changes and permafrost thaw as well as their impacts on leached carbon and nutrients from soils, but do not simulate the land cover changes caused by thermokarst dynamics. The Arctic Lake Biogeochemistry Model (ALBM), developed by my collaborator (Tan and Zhuang 2015), simulates detailed thermal and biogeochemical cycles in arctic lakes, and accounts for landscape development of thermokarst. The ALBM, however, assumes constant carbon and nutrient discharges from land. These missing spatial connections between land and lake models might result in large uncertainties in estimated regional fluxes of CO_2 and CH_4.

Aims:

Through coupling dynamic vegetation model LPJ-GUESS with arctic-specific lake model, ALBM, this project aims to investigate missing-counted CO_2 and CH_4 emissions from the high latitudes. The coupled model will provide a powerful tool to explicitly quantify the feedbacks from the warming-induced changes in land processes to lake biogeochemical processes. This project will also develop a high-resolution chlorophyll-a dataset across the high latitude lakes based on satellite data (see the retrieving algorithm in my co-authored paper (Guan et al. 2020)) and the dataset will be used for lake model evaluation.

Benefits from the project

In addition to the scientific purposes of these three ongoing projects, the proposed project will provide many new features for the next generation of EC-Earth4, which uses the ECMWF's OpenIFS system. The added new processes and assessed feedback from these new features will be beneficial for many other ecosystem modelling groups.

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