Abstracts Ginkgo Meeting Frankfurt 2019

Monday, 7.10.2019

13:45 **Martin Claussen**: General introduction to GINKGO network

14:00 **Jens Kattge**: TRY database - Progress since 1st Gingko meeting (2009): data curation, coverage, availability, products

14:30 **João Paulo Darela Filho**

CAETÊ, a new trait-based model: advancing in the understanding of climate-ecosystem-biodiversity relationship

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In the last 10 years ecosystem modeling science is increasingly relying on the so-called trait-based Dynamic Global Vegetation Models, which claim for a better representation of global plant functional diversity. In order to achieve it, this new model generation provide a more detailed and less discretized representation of plant functional traits. Here we present CAETÊ (CArbon and Ecosystem functional Trait Evaluation model), a model that simulates terrestrial vegetation processes based on functional traits of plants and related life-history tradeoffs. Instead of a small group of Plant Functional Types, the model employs thousands of quasi-random combinations of chosen functional plant traits, creating a n-dimensional functional space. Each point inside this space can be understood as a plant prototype, a unique combination of trait values that determines carbon, water, light and nutrients acquisition and/or allocation and ultimately its fitness. We call these combinations Plant Life Strategies - PLS. The environmental filters imposed by climate variables and competition for resources select which PLSs populate each grid cell in the study area. The fitness of each PLS is represented by the potential biomass in the vegetation compartments. Thus, the total potential biomass of each life strategy determines the fraction of the area occupied and its influence on the final mass-based aggregated ecosystem processes. CAETÊ, as other trait-based models allow innovative analysis of model outputs beyond the ordinary exploitation of biogeochemical fluxes and stocks. For example, the inclusion of plant functional traits variability and associated tradeoffs can improve the understanding of biodiversity relationships with ecosystem functioning especially in high diverse plant communities, and thus the detection of the subtle changes that ecosystems may be subject in face of global environmental changes.

14:50 **Bianca Rius**

The role of functional diversity on Amazon forest carbon stock: employing a new trait-based model

Bianca Rius, João Paulo Darela Filho, David Lapola

The effects of climate change on functional diversity and its impacts on ecosystem functioning is still contradictory. This gap of knowledge is especially important in hyperdiverse ecosystems such as Amazon forest, also responsible for a big part of the world's terrestrial carbon sink. This study aimed to understand the role of functional diversity on the response of Amazon forest carbon sink ability in a reduced precipitation scenario (minus 50%) and how functional diversity *per se*responds to this drier condition. For this, we used two versions of the trait-based model named CAETÊ (Carbon and Ecosystem Functional Trait Evaluation model): a low functional diversity (LD) version using five tropical PFTs (plant functional types); and a high functional diversity (HD) version, that employed thousands of plant life strategies (PLSs) that are unique combinations of trait values. Six functional traits were used: allocation and residence time of carbon on leaves, aboveground woody tissues and fine roots. The HD version avoided the loss of 1.6 Pg of carbon in comparison with the LD version. This result was because the former was able to rearrange the community in terms of the strategy dominance and traits abundance with the new climate condition: we observed a decrease on the hyperdominance of some PLSs, what enabled other strategies (including new ones) that coped better with the new environmental condition to stablish and increase their abundance (in agreement with the compensatory dynamics theory). It has lead to a higher and more uniform occupancy of the functional trait space, driving to an expressive increase in functional richness and in functional evenness. Also, the drier condition selected strategies that presented a higher investment in fine roots to the detriment of other compartments, especially to aboveground woody tissues. Thereby, these results indicate that the change on functional diversity can increase the ability of the forest to deal with drier conditions, at least in short term. However, in long term a community with less investment in woody tissues may decrease the ability of forest to store carbon. This type of community rearrengement is not possible to be observed in a PFT modelling scheme. The present study shows the importance of incorporating the diversity of trait values in vegetation models when researching for the effects of climate change in terrestrial ecosystems and the link between functional diversity and ecosystem functioning.

16:10 **Andreas Huth**

Linking vegetation modelling and remote sensing
- the dynamics of the Amazon forests and the role of forest structure (FORMIND) -

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Precise descriptions of forest productivity, biomass, and structure are essential for understanding ecosystem responses to climatic and anthropogenic changes. However, relations between these components are rarely investigated, in particular for tropical forests.
We developed an approach to simulate forest dynamics of around 410 billion individual trees within 7.8 Mio km² of Amazon rainforest (using the FORMIND forest model). We then integrated remote sensing observations from Lidar (forest height map) in order to detect different forest states and structures caused by small-scale to large-scale natural and anthropogenic disturbances.
Under current conditions, we identified the Amazon rainforest as a carbon sink, gaining 0.56 Gt C per year. We also estimated other ecosystem functions like gross primary production (GPP) and woody aboveground net primary production(wANPP), aboveground biomass, basal area and stem density.
We found that successional states play an important role for the relations between productivity and biomass. Forests in early to intermediate successional states are the most productive and carbon use efficiencies are non-linear. Simulated values can be compared to observed values at various spatial resolutions (local to Amazon-wide, multiscale approach). Notably, we found that our results match different observed patterns (e.g., MODIS GPP).
We conclude that forest structure has a substantial impact on productivity and biomass.
It is an essential factor that should be taken into account when estimating current carbon budgets or analyzing climate change scenarios for the Amazon rainforest.

16:30 **Franziska Taubert**

The role of species traits for grassland productivity

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Abstract

The relation between species diversity and ecosystem functioning is one of the most frequently discussed topics in ecology. Experiments often revealed an increase of productivity in species-rich ecosystems. But large variations in these relationships still challenge our understanding of the role of species and their interactions in ecosystems. In this study, we explored the role of species traits for ecosystem functioning. We used an individual-based mechanistic grassland model which captures intra- and interspecific competition between plants for light and soil resources. We explored how the dynamics and productivity of grasslands are influenced by species traits and analyzed in a simulation study two grass species which behave similar but differ only in particular traits. Our focus was on traits that determine how species can cope with resource limitations, for which we identified their relative importance for (i) individual plant growth, (ii) monoculture dynamics and (iii) species mixture dynamics. We observed diverse relationships between species traits and different vegetation attributes for the three ecosystem levels. Most traits showed positive but saturating trends of increasing trait values but the variability in these relations increased in monocultures with intraspecific plant interactions and even more pronounced in mixtures with interspecific interactions. Using a process-based grassland model we were able to simulate overyielding even though it was not correlated with trait values or trait differences between both species. Correlations were also not found in terms of stability. In contrast, for some traits already small differences supported the dominance of a species in the mixture in which species dynamics generally followed trade-offs. The here presented simulation study demonstrates the use of process-based models for analyzing diversity-productivity relationships in grasslands. Such models can complement previous approaches in empirical and theoretical biodiversity research and can help to move closer to understanding the mechanisms governing grassland dynamics.

16:50 **Porada Philipp**

Simulating physiological diversity of non-vascular vegetation in a global process-based model

Lichens, mosses, terrestrial algae and cyanobacteria (non-vascular vegetation) are seldom considered in global dynamic vegetation models. However, it has been recently shown that these organisms play a crucial role for biogeochemical processes at the global scale. They have been suggested to carry out around half of the biotic nitrogen fixation in natural terrestrial ecosystems, for instance. Moreover, they contribute substantially to productivity and carbon content of high-latitude regions and they affect the global hydrological cycle through interception of rainfall.

Incorporating non-vascular vegetation in global modeling approaches, however, is complicated by the fact that biogeochemical functioning usually depends strongly on species-specific physiological properties of the organisms. Interception of rainfall, for instance, depends on water storage capacity of the organisms, which varies by almost two orders of magnitude between species. At high latitudes, the impact of lichens and mosses on permafrost soil temperature depends crucially on the growth height and porosity of the organisms.

In the last years I have developed a stand-alone dynamic global non-vascular vegetation model, which also explicitly represents physiological diversity of the organisms. The model randomly samples the possible ranges of certain physiological properties to generate a large number of distinct functional types. Subsequently, differences in the performance of these functional types are used to determine their relative abundance and, therefore, global patterns of non-vascular physiological properties. Additionally to current effects, this flexible modeling approach also allows for predicting future changes in species composition of non-vascular vegetation and the associated consequences for biogeochemical functioning. Furthermore, impacts of early non-vascular vegetation on global climate in the geological past can be estimated. I will present an overview of my modeling approach and the biogeochemical effects of non-vascular organisms at the global scale.

17:10 **Pin-hsin Hu**

Using the Jena Diversity (JeDi) approach to represent plant functional diversity in the ICON-Earth System Model and its' potential application in Eocene

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In Earth System Models (ESMs), global vegetation is commonly categorized into only a few discrete plant functional types (PFTs) using phenological, physiological and bioclimatic differences. The PFT-approach crudely captures the average behavior of different plant types. However, growing evidence from the ecology community indicates that plant trait variation within a PFT is sometimes larger than between PFTs (Kattge et al. 2011). In simulations, it is found that the local climate is sensitive to the qualitative combination of the PFTs (Groner et al 2018). Accordingly, a less parameter-dependent approach with results being more robust to the empirical selection of parameters is necessary to address vegetation-climate interaction in climate models.

Based on the Jena Diversity (JeDi) approach (Pavlick et al. 2013), we introduce the new plant functional diversity model JeDi-BACH into the ICON-Earth System Model. Rather than diagnostically parameterizing vegetation, JeDi-BACH 'grows' plants based on the principle of 'environmental filtering'. First, JeDi-BACH randomly generates numerous growth strategies. Each strategy is determined by several trade-off relationships. Next, the environmental conditions will sieve out unsuccessful strategies. In this way, JeDi-BACH obtains a more continuous spectrum of plants compared to the discrete PFT-approach.

As part of the ICON-ESM, JeDi-BACH can couple with the atmospheric model. This advancement of JeDi-BACH allows us to investigate the interaction of plant functional diversity and climate. One potential period for applications of the coupled JeDi-BACH is the Eocene. Previous modelling studies on Eocene relied on the modern-day PFTs and failed to capture reconstructed Eocene vegetation types. JeDi-BACH has the advantage to 'grow' diverse plants that are adapted to the Eocene climate by environmental filtering. Hence, we aim to investigate the role of functionally diverse vegetation in shaping the Eocene climate.

Keywords: plant functional diversity, trade-offs, Eocene vegetation

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Pavlick, R., Drewry, D. T., Bohn, K., Reu, B., and Kleidon, A. (2013). The jena diversity-dynamic global vegetation model (JeDi-DGVM): a diverse approach to representing terrestrial biogeography and biogeochemistry based on plant functional trade-offs. Biogeosciences, 10:4137–4177.

Tuesday, 8.10.2019

9:00 **Boris Sakschewski**

Variable rooting strategies stabilize biome productivity

Tree water access via roots is crucial for forest functioning and therefore a vast variety of rooting strategies have evolved in the global forest systems. Especially, the distribution of roots within the soil column is important for buffering temporal shortages of precipitation. However, dynamic global vegetation models (DGVMs) often condense this variety into biome scale averages, potentially overestimating the dependence of forest functioning on short term precipitation. Here we present first results of implementing variable root systems into a DGVM (LPJmL 4.0) applied to Central- and South-America. We show how variable root systems constrained by soil & sediment thickness enable a better reproduction of state variables like forest cover or biomass pattern as well as intra-annual variability of e.g. evapotranspiration. We find that trade-offs between water accessibility and below ground carbon investment explain local diversity and co-existence of rooting strategies. We present mean rooting depth maps and below ground carbon investment maps based on our modelling results. Conclusively, we propose a stabilizing effect of realized rooting depth on ecosystem productivity.

Authors list:

Boris Sakschewski, Werner von Bloh, Sarah Bereswill , Anna Sorensson, Romina Ruscica, Markus Drüke, Fanny Langerwisch, Maik Billing, Rafael Oliveira, Marina Hirota, Sibyll Schaphoff, Kirsten Thonicke

9:20 **Mirjam Pfeiffer**

Plant traits, functional diversity, and vegetation patterns – how trait-based dynamic vegetation modeling can contribute to questions in biogeography

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Keywords: plant traits, aDGVM2, dynamic vegetation modeling, environmental filtering, biome shifts

Abstract

Plant traits shape vegetation patterns and ecosystem functions on a global scale. They determine plant community assembly, adaptation to environmental conditions, and success in plant competition. Nonetheless, most global-scale dynamic vegetation models do not account for plant trait variability. With aDGVM and aDGVM2, we simulate plants as individuals characterized by unique combinations of trait values that determine plant performance, survival, and community assembly. Environmental filtering eliminates non-viable trait combinations while fostering those that provide fitness benefits. Implemented trait trade-offs ensure avoidance of Darwinian demons. Emerging successful trait combinations are passed on to offspring and may be altered through mutation and crossover. This approach allows simulated plant communities to react and adapt dynamically to changes in environmental forcing. Model applications allow addressing a wide range of scientific questions regarding vegetation dynamics, biogeographic patterns, and changes in ecosystem function. We show that i) southern Africa will experience critical biome shifts under future climate change; ii) fire and soil depth explain savanna-forest boundaries in Amazonia; iii) grazing and aridity determine grass-layer composition in agreement with observations; iv) biomes in South Asia occupy distinct regions in the trait space; v) shrub distribution in Africa is linked to fire and water availability. Model results can be used to inform, e.g., conservation management with regard to mitigation and adaptation strategies under future environmental change.

9:40 **Higgins Steven**: aDGVM-BT. Developing a tool for exploring consumer control in the Earth system

Dynamic global vegetation model (DGVM) is a term used to describe a class of dynamic vegetation models that aim to predict how the dynamics and distribution of vegetation formations are influenced by climate and soils. DGVMs however fail to correctly simulate the net primary productivity trends inferred from the satellite record and they have difficulty in reproducing vegetation distribution patterns in some regions. There is no shortage of authors offering suggestions for how to remedy these failures. The aDGVM family of models is one attempt to improve DGVMs. The aDGVM is being developed as a collaboration between different research projects. Each project develops its own novel branch of the model. Here I introduce the aDGVM-BT branch. aDGVM-BT includes several innovations some of which can be interpreted as responses to criticisms of how DGVMs model growth and allocation, whereas others are motivated by the desire to better understand the influence of consumer control in the Earth system. The major change is that aDGVM-BT uses the Thornley Transport Resistance (TTR) model to coordinate assimilation, growth and allocation processes in simulated plants. The TTR model separates growth processes from assimilation processes and considers multiple substrate pools (C, N, H_2O) and how transport gradients drive the flow of these substrates between organs. Using the TTR to manage allocation and growth has a domino effect, which made some aDGVM sub-models redundant and necessitated the redesign of other sub-models. For example, using the TTR makes the need for a refined soil C-N model acute. The aDGVM-BT therefore uses the Allison soil organic carbon model, which has been shown in other studies to dramatically improve our ability to simulate global patterns of soil organic carbon. To link to soil N dynamics, the aDGVM-BT considers the nitrogen and carbon stoichiometry of microbial biomass as proposed by the nitrogen immobilisation and carbon overflow hypotheses. The Fixation and Uptake of Nitrogen (FUN) model is used to describe nitrogen assimilation by plants. Uptake pathways considered by the FUN model include mass flow, active root uptake and symbiotic uptake via ectomycorrhizal, arbuscular mycorrhizal and biological nitrogen fixation. The aim of this presentation is to provide an overview of the aDGVM-BT and illustrate how aDGVM-BT individuals grow.

10:00 **Thomas Hickler** LPJ-GUESS-Humboldt

10:20 **Matthew Forrest**

DGVMTools: R tools for processing, analysing and plotting output from DGVMs

DGVMTools is a high-level framework for analysing DGVM data output. The framework enables a complete DGVM analysis workflow, taking raw model output through comprehensive analysis and evaluation to publication-quality figures. It also easily interfaces with both the raster package and base R functionality. Functionality includes:

- Read raw output from supported DGVMs, currently LPJ-GUESS, aDGVM (and the FireMIP output with the companion FireMIPTools package).
- Read pre-prepared benchmarking data sets at commonly used spatial resolutions (contact matthew.forrest@senckenberg.de for access to data files).
- Crop and aggregate the data space and time (and sub-annual dimensions).
- Convenient and flexible potting of data in time and space (also seasonal cycles). Plots further customisable with ggplot2.
- Easy aggregation across layers PFTs, to calculate for example, total tree biomass, grass productivity or evergreen tree cover.
- Compare models and data and calculate benchmarking metrics.
- Perform biomisations.
- Export data as R rasters or data.frames, also save data to disk in portable format with convenient netCDF writing functionality.
- Thorough tracking of metadata.

Posters

Camille Gaillard

African shrub distribution emerges via a trade-off between height and sapwood conductivity

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Keywords: plant life-form, aDGVM2, savanna, shrubs, trait trade-off

Abstract

Aim: Shrubs are a successful growth form in many ecosystems globally. However, they are, in contrast to trees, often understudied both in empirical and modelling studies. We define shrub andtree strategies by a trade-off between water uptake capacity and height growth and aim to explore ifthis trade-off allows us to explain shrub distribution.

Methods: We improve a dynamic vegetation model, the adaptive Dynamic Global Vegetation Model version 2 (aDGVM2), to simulate shrubs as multistemmed woody plants, based on a trade-off between rapid height growth in single-stemmed trees and efficient water uptake in multistemmed shrubs.

Results: We show that, in aDGVM2, (a) the implemented trade-off allows a multi-stemmed shrub strategy to emerge and is sufficient to simulate the broad distribution of shrubs in African savannas; (b) fire and aridity promote shrubs at the expense of trees and grasses; and (c) the presence of shrubs influences competitive interactions between grasses and woody vegetation.

Conclusions: We provide a novel approach to simulate shrubs in a dynamic vegetation model, which enhances our understanding of shrubs distribution. Further work is required for arid and Mediterranean shrublands. Introducing fundamental trade-offs between growth forms intovegetation models can improve vegetation representation.

Dushyant Kumar

How does climate change shift the grassland-savanna-forest biome boundaries in South Asia? A dynamic vegetation modelling approach

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Keywords: Asian savanna, climate change, woody-encroachment

Abstract

South Asian vegetation is a complex mixture of forest, savanna and grassland. Studies have documented a long history of C4 plant communities. Yet, savannas in South Asia have often been misinterpreted as degraded dry tropical forests which are threatened by land-use changes, including conversion to agriculture and governmental afforestation initiatives. South Asia is likely to experience drastic climatic changes in the future, but the consequences for vegetation patterns and diversity are highly uncertain. Therefore, the distribution and diversity of forest-savanna-grassland systems under different climate scenarios need to be explored.

We used the dynamic vegetation model aDGVM2 to simulate the future vegetation state of South Asia. Simulations show a general trend of woody encroachment that can be explained by increasing atmospheric CO_2 concentrations and CO_2 fertilization of woody vegetation. Changes in woody cover translate into biome shift towards forest. Yet, our results indicate that misclassification of Asian savannas as degraded dry forest under-predicts critical biome shifts and that classifying biomes correctly is important for our understanding of potential climate change impacts on vegetation. Therefore, we argue that there is an urgent need to recognize and correctly classify ecosystem states and accordingly prioritize the conservation measures and strategies.

Nils Weitzel

Estimating climate and vegetation variability during the last Glacial from pollen records

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Abstract:
Climate variability inuences the probability of extreme events and is therefore of great importance for risk management. Nevertheless, the changes of climate variability over time are far less studied than changes in the mean state of the climate system, especially for hydroclimate. Proxy records can be used to estimate the dependency of climate variability on the state and timescale, but their climate signal is perturbed by non-climatic processes and dating uncertainties. Studies show that temperature variability during the last Glacial was much larger than in the Holocene and that the changes in variability depend on latitude. We estimate vegetation and climate variability on millennial to orbital time scales during the last Glacial from pollen records. Our work complements previous estimates from ice cores and marine sediments.
We draw on a global network of published pollen records and compare these estimates with climate and vegetation variability in climate simulations that include dynamical vegetation. This gives new insight on the mismatch between climate simulations and proxy-based reconstructions. We discuss the regional consistency of estimates and compare glacial and interglacial variability.
We plan statistical climate reconstructions from the pollen data and subsequent estimates of climate variability. Reconstruction uncertainties should include contributions from the pollen-climate relation and age uncertainty. As CO_2 concentrations during the last Glacial were lower than today, analytic corrections of the modern calibration need to be incorporated. Our new estimates will facilitate the comparison of climate and vegetation variability, and of reconstructed and simulated climate variability.

Alexander Winkler

Almost four decades of satellite observations reveal widespread changes of the terrestrial vegetation across the globe. These greening and browning trends reflect persistent changes in the abundance of green leaves, and thus, the rate of photosynthesis. Agriculturally dominated landscapes are mostly greening due to human land management which has a negligible long-term effect on the carbon cycle. On the contrary, the observed persistent increases or decreases of leaf area in various natural biomes indicate regional sinks or sources of carbon. The underlying drivers are hypothesized as being CO2 fertilization, climate change, and episodic disturbances; however, an attribution on a biome level integrated into the global picture is lacking.

Here, we analyze the longest satellite-based record of global leaf area observations (1981–2017). We detect and identify clusters of significant rates of increase and decrease of leaf area index (LAI) on a biome level. Based on process-based model simulations (fully-coupled Max Planck Institute Earth system model and 16 standalone land surface models driven with observed climate), we disentangle the effects of rising CO2 on LAI. Through the use of Causal Counterfactual Theory, we attribute changes on the biome level to the key drivers in a probabilistic setting.

Our analysis unveils a slowing down of greening and a strengthening of browning trends, particularly in the last two decades (2000–2017). Decreases in LAI primarily occur in regions of high LAI (i.e. tropical forests), whereas increases in LAI are generally confined to low LAI regions (i.e. northern and arid non-forested lands). We find that many biomes bear the signature of climatic changes (long-term drying, warming or droughts). CO2 fertilization is the main driver in the temperate forests and biomes in cold and/or arid climatic zones. These results question the previously suggested global prevalence of CO2 fertilization.

The observed persistent leaf area loss in the most productive ecosystems could be an early indicator of a slow-down in the global terrestrial carbon sink. However, models fail to reproduce vegetation browning, particularly in the tropics, where they suggest compensatory effects of rising CO2 on LAI: Climatic changes induce browning, which is outbalanced by greening due to a strong CO2 fertilization effect. Models need to better account for this effect on natural vegetation for plausible Earth system projections of the 21st century.