MICROCLIMATE ECOLOGY & BIOGEOGRAPHY

ME&B Conference

29 August – 1 September 2022

Antwerp, Belgium

Programme and Abstracts

Day 0: Monday 29 August	
9:00-18:00	Preconference excursion to FORBIO and the National Park Hoge Kempen
18:30-21:00	Icebreaker (at Hof van Liere) + registration (registration is open 18.00-19.30)

Day 1: Tuesday 30 August		
07:45-08:30	Coffee + registration (registration is open 7.45-9.30) + uploading presentations (8.00-8.30)	
08:30-08:45	Opening by Jonas Lembrechts - *Main room: 'Tassiszaal'*	
08:45-09:45	**Keynotes by Rebecca Senior & Silvain Pincebourde** *Main room: 'Tassiszaal'*	
09:45-10:30	**Presentations: Microclimate research in mountain ecosystems** *Main room: 'Tassiszaal'* [Session chair: Jonas Lembrechts] Patrick Saccone Ronja Wedegärtner* Michele Di Misciano*	
10:30-11:00	Coffee break	
11:00-12:30	**Presentations in parallel sessions**	
	Collection and analysis of microclimate data *Main room: 'Tassiszaal'* [Session chair: Koenraad Van Meerbeek] Diego Ellissoto* Fabien Spicher Koenraad Van Meerbeek Eduardo Maeda Roman Plichta Stijn Van de Vondel	**Animal ecology - Impact of microclimate on species performance** Parallel room: '*Prentenkabinet*' [Session chair: Johanna Van Passel] Jamie Weir Jelena Bujan Mathieu Leclerc Loke von Schmalensee* Laura Segura Hernández*
12:30-14:00	Lunch break + registration (registration is open 12.30-13.30)	
14:00-14:30	**Keynote by Florian Zellweger** *Main room: 'Tassiszaal'*	
14:30-15:30	**Presentations: Microclimate research in arctic ecosystems** *Main room: 'Tassiszaal'* [Session chair: Pieter De Frenne] Angelica Casanova Katny* Geerte Fälthammer Jonathan von Oppen	
15:30-16:00	Coffee break	
16:00-17:30	Poster session	

Day 2: Wednesday 31 August		
08:00-08:30	Coffee + registration (registration is open 7.45-9.30) + uploading presentations (8.00-8.30)	
08:30-09:30	**Keynotes by Kassaye Tolassa & Martin Nuñez** *Main room: 'Tassiszaal'*	
09:30-10:30	**Presentations: Drivers of microclimate variability 1** *Main room: 'Tassiszaal'* [Session chair: Pep Serra-Diaz] Jan Wild Joan Díaz Calafat Bence Kovács Yuanyuan Huang	
10:30-11:00	Coffee break	
11:00-12:30	**Presentations in parallel sessions**	
	Microclimate modelling *Main room: 'Tassiszaal'* [Session chair: Stef Haesen] David Klinges Eva Gril Jonas Lembrechts Romain Bertrand* Stef Haesen	**Impact of climate change on plant communities 1** *Parallel room: 'Prentenkabinet'* [Session chair: Pieter De Frenne] Anouch Tamian Cristina Gasperini Eline Lorer Pieter De Frenne
12:30-14:00	Lunch break + registration (registration is open 12.30-13.30)	
14:00-15:00	**Keynotes by Vigdis Vandvik & Anne Bjorkman** *Main room: 'Tassiszaal'*	
15:00-16:00	**Presentations: Drivers of microclimate variability 2** *Main room: 'Tassiszaal'* [Session chair: Emiel De Lombaerde] Alex Sentinella* Caroline Greiser Jeremy Borderieux Rémy Beugnon	
16:00-16:30	Coffee break	
16:30-18:00	**Presentations in parallel sessions**	
	Impact of climate change on plant communities 2 *Main room: 'Tassiszaal'* [Session chair: Pieter Vangansbeke] Brittany Trew* Jofre Carnicer Nathalie Isabelle Chardon* Paul Kardol Ting Shen	**Impact of climate change on ecosystem functioning** *Parallel room: 'Prentenkabinet'* [Session chair: Stijn Van de Vondel] Thomas Vanneste Liesbeth van den Brink Loïc Gillerot Rachel Penczykowksi* Biruk Ayalew Nurihun

Day 3: Thursday 1 September		
08:00-08:30	Coffee + uploading presentations (8.00-8.30)	
08:30-09:30	**Keynotes by Julia Kemppinen & Fernando Maestre*** *Main room: 'Tassiszaal'*	
09:30-10:30	**Presentations: Conservation** *Main room: 'Tassiszaal'* [Session chair: Jonas Lembrechts] Kristoffer Hylander* Lydia Soifer Marie Finocchiaro Xiaqu Zhou	
10:30-11:00	Coffee break	
11:00-12:30	**Presentations in parallel sessions**	
	LiDAR technology to model microclimate *Main room: 'Tassiszaal'* [Session chair: Koenraad Van Meerbeek] Arnaud Callebaut Iris Aalto Josef Brůna Marianne Lasliers Matej Man Mengxi Wang	**Animal ecology - Impact of microclimate on species distributions** *Parallel room: 'Prentenkabinet'* [Session chair: Pieter Vangansbeke] Ly Lindman Maria Vives-Ingla Olivia Bates Pieter Vangansbeke Tim Newbold Runxi Wang*
12:30-14:00	Lunch break + best poster & talk awards	
14:00	Workshops	

*Presentations with an * are virtual*

List of abstracts

TALK ABSTRACTS

POSTER ABSTRACTS

GLORIA: Also a Global network of microclimate monitoring on mountain tops

Patrick Saccone *(patrick.saccone@gmail.com)*

GLORIA is a world-wide network for the monitoring of long-term biodiversity/climate changes in alpine environments. It is based on a shared field design including 3 x 3m permanent plots installed in the 4 cardinal directions 5 m under the top of 4 mountains of different elevations between the tree line and the nival belt in a climatically and geologically consistent region. The four 1x1m quadrats in the corner positions of each plot are dedicated to regular plant community monitoring while the central quadrat shelters temperature sensor buried at 10 cm depth. Considering soil temperature as the best affordable proxy of a microclimate integrative indicator, GLORIA offers a multiscale comparison of the recent microclimate patterns in alpine environments. The fine resolution of the summit aspects is integrated into the elevational gradient at the intermediate regional level itself integrated into a worldwide network of alpine environments. GLORIA is then a unique platform to both correlate biodiversity and climate patterns at different scales, and address the representativeness of climate model outcomes in regard to the reality experienced by biotic communities in the specific context of alpine environments. With a focus on the second question, after a short report of the network status, we will illustrate by regional examples how GLORIA's simple design can improve our ability to model the biodiversity-climate relationship.

Interaction outcomes for seedlings and adult plants along microclimatic gradients in mountain tundra

Ronja Wedegartner *(ronja.e.m.wedegartner@ntnu.no)*

The stress gradient hypothesis (SGH) predicts a greater importance of facilitative interactions between plants in stressful than in benign locations. Vegetation removal experiments are traditionally used to examine biotic interactions between target plants and the surrounding vegetation by minimizing competition and facilitation. Gap size should influence the microclimate that target plans experience within it, and we can expect microclimate to change with distance from the gap edge as wind exposition and shading differ. The ability of plants to interact is spatially limited and the intensity of biotic interactions between resident vegetation around the gap and target plants, should therefore decrease with larger distance to the gap edge.

As gaps may alleviate competition or stressful abiotic conditions depending on the surrounding climate and species characteristics, a species-specific pattern of facilitation and competition with optimal distances to the gap edge for survival, establishment, and growth should result from gradients of competition for light and nutrients, and amelioration of climate. This optimum may differ between life stages. Investigating effects of gap size, within-gap position, and life stage on plant performance will allow for a better understanding and forecasting of effects of disturbance, such as for example trampling along hiking trails, in alpine plant communities.

We established a transplant and seed sowing experiment in gap sizes of 0 to 60 cm along a climatic gradient in the Scandes mountains in Norway, and present effects of gap size, within gap position, and climate, on microclimate, establishment, survival, and above and belowground biomass of transplants and transplants. By calculating the importance of competitive interactions based on the growth rate of seedlings and transplants we can relate our observations to SGH predictions.

Soil Temperature and its related variables shapes species richness dynamic along an altitudinal gradient in the Central Apennines (Italy)

Michele Di Misciano *(michele.dimusciano@univaq.it)*

Plant community assemblage and diversity are not only shaped by average environmental and climatic conditions but also by local micro-abiotic filtering (Ohler et al., 2020). In high mountains, where habitat includes a vertical dimension with significant variation along it, differences in microclimate are expected to be particularly pronounced. In this context microclimatic conditions, specifically soil temperature, can vary noticeably over short distances due to a steep elevational gradient and rugged terrain. Until now, the relationship of heterogenous soil temperature, plant species richness and composition remain understudied (Zellweger et al., 2019). In this work we propose a new approach to test the direct effect of soil temperature variations on plant distribution and communities' structure. The 84 plots of 2x2m were collected in the Velino massif along an altitudinal gradient ranging from 1100 to 2468 m a.s.l. A total of 3 temporal surveys were carried out every five years from 2006 onwards. Soil temperature was measured using 40 iButton datalogger 10 cm below the soil levels. Temperature was registered for one year at a regular interval of one hour. Soil temperature data were than processed to estimate the snow cover length, the number of growing days and growing degrees days. Variation in species richness was estimated trough extrapolating the angular coefficient of the linear model where the explanatory variable is the sampling cycle, and the dependent variable is the species richness. Finally, to investigate the patterns of species richness variation and the soil temperature related variables we used linear mixed models (LMMs). The main result reveals that plot with the longest period of snow cover and with low values of growing degrees days have the highest increase in species richness. These results underscore the importance of soil variables and provide the evidence that cryophilic ecosystems responses to climate change are most closely related to microclimate change.

Ohler, L.-M., Lechleitner, M., Junker, R.R., 2020. Microclimatic effects on alpine plant communities and flower-visitor interactions. Scientific reports 10, 1–9.

Zellweger, F., De Frenne, P., Lenoir, J., Rocchini, D., Coomes, D., 2019. Advances in microclimate ecology arising from remote sensing. Trends in Ecology & Evolution 34, 327–341.

Animal-borne sensors as biologically informed lens on fine-scale climate dynamics

***Diego Ellissoto** (Diego.ellissoto@yale.edu)*

As climate change transforms the biosphere, more comprehensive and biologically relevant measurements of fine-scale climatic conditions are urgently needed. Traditional climate measurements are constrained by geographically static, sparse and biased sampling networks, which constrains both mechanistic understanding and predictive potential for short- and long-term ecological and climate forecasting at fine spatial scales. Satellites complement static sensors with spatially contiguous measurements over large extents, but usually only for surface conditions and with limited spatiotemporal detail. We here illustrate how animal borne instruments (ABI), a rapidly growing suite of on-board sensors deployed alongside animal tracking technologies, can provide a fundamental third data type. ABIs can turn wild animals into complex biological mobile weather sensors that deliver fine-grain, biologically fine-tuned and relevant sampling of climatic conditions in support of ecological forecasting. Billions of fine-scale meteorological observations have already been collected by ABIs across thousands of species, mostly marine. We demonstrate the opportunities these growing data have for the intersection of biodiversity and climate science, including those enabled by a fusion of ABI measurements with in situ station data and remote sensing. Tens or hundreds of thousands of tagged animals worldwide as agile earth observers and environmental sentinels, integrated with other data streams have the potential to deliver a spatially detailed and biologically informed measurements for climate and biological change research.

Of sensors and intercalibrations: The need for standardized protocols and consequences on microclimate studies relying on low-cost temperature sensors

Fabien Spicher *(fabien.spicher@u-picardie.fr)*

The use of temperature sensors in ecology has grown rapidly, due to the increasing accessibility to low-cost and miniaturized versions. We usually rely on a network of sensors to accurately assess temperature variability near the ground at fine spatiotemporal resolutions. As the distance among neighbouring sensors decreases, the observed spatial variation in temperatures gets closer to their measurement uncertainty. This can have important consequences if such differences are instead interpreted as local microclimatic effects. Hence, it is of utmost importance to use relevant metrological and statistical procedures, to account for this potential bias before analysing microclimatic data.

Here, we present a simple and generalizable intercalibration protocol that does not require ultrafine-wire thermocouples of research-grade accuracy for assessing the reference temperature. We applied our protocol on a set of temperature loggers typically used by ecologists: HOBO Pendant, ONSET (n = 376) and TMS, TOMST (n = 122). Each miniature data logger was installed on a regular grid in a climatic chamber, covering a temperature range of 5 to 30°C. The reference temperature in the chamber was assessed by using a spatial analysis based on the position of each data logger inside the grid, in order to account for potential spatial autocorrelation. We then derived an offset (interpolated reference temperature – sensor temperature) for each sensor based on its position on the grid, which provides an estimate of the uncertainty of each temperature sensor. Finally, we used the estimated uncertainty values to assess the effect of this inter-calibration procedure on subsequent in-situ forest microclimate measurements, from the same set of intercalibrated sensors.

Our protocol aims at filling a gap in how ecologists currently handle microclimatic data from low-costs temperature loggers, with a need to account for metrological issues and how this may impact the subsequent analysis of microclimatic data in ecology.

On the measurement of microclimate

Koenraad Van Meerbeek *(koenraad.vanmeerbeek@kuleuven.be)*

Many organisms live in environments in which temperatures differ substantially from those measured by weather stations. The last decade has witnessed an increase in efforts to quantify these differences and to understand their ecological and evolutionary implications. This renewed interest in microclimate ecology has been accompanied by the development of various compact temperature sensors and radiation shields. However, it is clear that there are many pitfalls when measuring temperature using these devices.

Here we address the problem of measuring microclimate temperatures accurately. We first discuss the physics associated with measuring temperature. We then report on the results of experiments in which air temperatures recorded by various commonly-used temperature loggers are compared to those obtained using research-grade instruments and weather stations.

While accurate measurements of surface and ground temperatures and air temperatures at night and in shaded environments can be relatively easily obtained, we show substantial errors are to be expected when measuring air temperatures in sun-exposed environments. Most standard sensors yield large errors, which can reach 25°C due to radiative fluxes operating on the thermometer. This problem cannot be wholly overcome by shielding the thermometer from sunlight, as the shield itself will influence the temperatures being measured and the accuracy of measurement.

Reasonably accurate estimates of air temperature can be obtained with low-cost ultrafine-wire thermocouples that possess low thermal emissivity and a highly reflective surface. As the processes that create microclimatic temperature variation are the same as those that cause errors, other logger types should be used with care, and generally avoided in sun-exposed environments and close to the ground where wind speeds are lower. We urge researchers to pay greater heed to the physics of heat exchange when measuring microclimate temperatures and to understand the trade-offs that exist in doing so.

A new initiative for monitoring the microclimate of Amazonian forests

Eduardo Maeda *(maeda@hku.hk)*

Information on the Amazonian climate is often obtained from sparsely distributed weather stations. Besides resulting in large uncertainties in the characterization of spatial climatic patterns, these data are not suitable for representing the microclimatic experienced by organisms living within the forest canopy. Consequently, our understanding on the impact of forest disturbances and climate change on the Amazonian ecosystem is still largely limited. Filling these knowledge gaps will require substantial efforts in increasing microclimate observations, as well as in understanding the links between macroclimate, the biophysical characteristics of vegetation, and environmental conditions inside the canopy. Here, we present a new initiative aiming at establishing an extensive network of microclimate observations in seven different biogeographic regions in the Amazon basin. Sensors collecting data on soil and air moisture, as well as temperature at four different levels, will be distributed in each study area. One site was established in 2019, currently hosting over 50 sensors, while the remaining sensors will be deployed in 2022. Furthermore, structural and functional characteristics of forests will be obtained using multi-scale remote sensing data. Three-dimensional information on vegetation structural traits will be obtained using terrestrial laser scanning. This information will be complemented and scaled up using a LiDAR sensor on-board an unmanned aerial vehicle platform. Satellite remote sensing will then be used to evaluate forest functioning and structure at a regional scale. We expect that the results of this new initiative will broadly expand our understanding of the climatic conditions hosting the huge diversity of organisms living in the Amazonian forests. Our results will also show how human activities are likely to disrupt current conditions, opening new paths for effective policies that aim to mitigate anthropogenic impact in the Amazonian ecosystem.

Interactive time-series data processing and visualisation in R – a new package PLOTeR

Roman Plichta *(roman.plichta@mendelu.cz)*

The ecological research studies are experiencing revolutionary progress with increasing availability of inexpensive environmental sensors. As these sensors are installed in large numbers that produce vast amounts of data in high spatio-temporal resolution, they could provide essential information on the variability of the micro-environment that could be upscaled to relevant macro-scale. However, since most attention is usually paid to data post-processing, the most important first step of incorrect data filtering is often neglected. The data processing and filtering in R language is widely used approach by many of the environmental sensor users, but wrong scripting could lead to production of erroneous data. Moreover, the visual control over the processed data is difficult and time-consuming task in R. For this reason, we are developing an R package PLOTeR based on shiny framework, which combines predefined automatic filters and interactive data management with easy data visualization. The incorporated filters can be also used in a routine command line console of R. Since the package PLOTeR is originally established to manage the widely used point dendrometers and temperature and soil moisture sensors TMS (TOMST, Prague, Czech Republic), it can already automatically manage a number of errors produced by these types of sensors. Nevertheless, the package can be used to manage the time series of any sensors. The standardisation of data processing from different type of sensors and transferring the knowledge between researchers is necessary for production of reproducible environmental data to largescale studies, and the package PLOTeR could be the platform that meets this necessity. The package PLOTeR is currently not publicly available since it is under development, but its trial version is distributed on a request.

Real-time and spatially distributed monitoring of microclimate

Stijn Van de Vondel *(stijn.vandevondel@uantwerpen.be)*

Recently, climate change impacts have become strikingly tangible, with prolonged periods of drought and temperature records being broken. These weather extremes strongly impact soil ecosystem services, with potentially important economic consequences for agriculture, nature conservation, garden maintenance and other sectors. Society increasingly needs to cope with these impacts, thus spurring new economic activities that demand large-scale heat and drought monitoring. In this project, I pioneer cost-effective approaches for large soil microclimate networks that involve 1000s of monitoring locations. These allow to assess the vulnerability of soil ecosystems to extreme weather events, and verify whether implemented adaptation measures are effective (e.g. water infiltration and soil moisture buffering). As a proof of concept, extensive microclimate networks have been deployed in gardens and nature reserves across Flanders, taking advantage of the new TMS-NB sensor, which enables low-cost and real-time measurements of soil temperature and moisture through the Internet of Things. This new data source will allow identifying the drivers of spatiotemporal variability in microclimate along the urban-rural gradient. I will also discuss novel software tools that are being developed for the data streams originating from these sensor networks, thus making the resulting data and insights readily available to relevant societal actors (e.g. farmers, garden maintenance, nature reserve managers).

Phenological and ecological variation in spring-feeding caterpillars could buffer their populations against climate change

Jamie Weir *(Jamie.Weir@ed.ac.uk)*

In spring woodlands, as plants undergo a sudden flush of growth, herbivorous insects dramatically increase in abundance to exploit the availability of the young foliage. For spring-feeding caterpillars, it is very important that they time their appearance so as to match the phenology of this new resource. Hatch too early and they can starve without food, hatch too late and they struggle to feed on tougher, more mature leaves. Climate change is causing widespread phenological changes across taxa. Where the phenological response to these changes differs across species, timed interactions, such as this one, can be disrupted ('phenological mismatch'), with potentially far-reaching detrimental effects. However, these woodland caterpillars inhabit a highly complex physical and ecological environment: host-plant species differ in their nutritional quality, abundance, and leaf-out times—and limited dispersal abilities impede host-plant selection by adult moths. Microclimatic environmental variation combines with genetic variation in plant and caterpillar phenology to create a fine-grained, heterogeneous patchwork of phenological match and mismatch between these two trophic levels. The mechanisms which allow the caterpillars to cope with this uncertainty and variation inherent in their environment could also act to buffer them against future mismatch induced by climate change. I will explore these mechanisms, drawing particular attention to the fact that the importance of microclimate has been underappreciated in this system. Understanding the significance of spatial and temporal scale in modulating the effects of climate (and other environmental) changes is a vital future consideration for ecology.

The effect of microclimatic filtering on ectotherms in Mediterranean islands

Jelena Bujan *(jelena.bujan@unil.ch)*

Small islands are an ideal environment for natural thermal experiments. The size of islands often correlates with the thermal conditions each island experiences, so that seemingly identical habitats experience different microclimatic conditions. Microclimatic heterogeneity between islands is likely to affect the ability of each island community to survive global warming. Generally, ongoing temperature increase is predicted to strongly affect small ectotherms that are unable to thermoregulate. We used ants—cursorial insects whose activity is directly governed by their thermal limits—to test if temperature selects for thermally tolerant species and thereby governs community composition on Mediterranean islands. Additionally, we tested if microclimate drives thermal tolerance within species by promoting thermal plasticity. We recorded community composition, thermal limits, and soil microclimates across 8 Mediterranean islands from the Adriatic Archipelago (island size 2.5-1,600 ha) along with two nearby mainland sites. At two different habitat types: grassland and scrubland, we recorded temperature, relative humidity, and light intensity. Surprisingly, we observed that average soil temperatures varied by as much as 4 °C despite apparently constant macroclimatic conditions observed using WorldClim. We found substantial variation in heat and cold tolerance for 35 ant species from 236 colonies. Heat tolerance ranged from 41 – 49°C and cold tolerance 1 – 7°C. Additionally, we quantified the degree of thermal heterogeneity between a subset of islands using a 3D-analysis of drone thermal imaging. Knowing the extent of microclimatic heterogeneity of islands and the plasticity of the species that inhabit them can give us a better estimate of the experienced thermal stress and availability of thermal relief. Our results suggest that macroclimates currently underestimate heat stress experienced in small island habitats, particularly affecting small ectotherms.

The microclimate temperature inside thermogenic flowers: heterogeneity and impact of environmental conditions

Mathieu Leclerc *(mathieu.leclerc@univ-tours.fr)*

Pollinating insects are crucial for the conservation and sustainability of ecosystems. While the decline of pollinator worldwide is well documented, the mechanisms at play remain unclear. Although the drivers are likely multifactorial, we investigated one aspect that is largely overlooked. During their visit to flowers, pollinators are exposed to temperatures higher than that of the air or flight temperature, forcing them to behaviorally thermoregulate (avoidance). The pollinators of some Araceae, which are thermogenic flowers, are even more exposed to the microclimate temperature of the flower (pollinators are caught 1 day in the flower). However, we found that the heat tolerance of their main pollinator (Psychoda sp.) is low and is close to the temperature of the thermogenic organ of the flower. This suggests a relatively high vulnerability of these flies to environmental warming. We tested under which environmental conditions the flower temperature may surpass the fly's heat tolerance. First, we measured the impact of environmental conditions in a mesocosm setup (water supply, soil temperature and shade level) on the temperature (thermogenesis) and the odor bouquet of the flower of A.italicum. Secondly, we quantified the microclimate temperature heterogeneity within the floral chamber (i.e. place where pollinators are trapped) in a natural population. One of the main results of the mesocosm experiment was an earlier flowering date for warmer soils. We also demonstrate that there is a temperature heterogeneity within a floral chamber of the flower of A.italicum. The hottest part was the stamens (thermogenic organ) while the bottom of the floral chamber and the wall were the coolest areas. This result partly answers the question about the sustainability of the relationship between the Arum flower and one of its pollinators. It also highlights the importance of measuring very finely temperature in relation to the biology of organisms.

The importance of high-resolution microclimate data when predicting insect responses in the field

Loke von Schmalensee *(loke.von.schmalensee@zoologi.su.se)*

Insect thermal reaction norms are often nonlinear and asymmetric, meaning that average temperatures generally poorly represent average thermal performance under variable conditions. This has long been recognized in the field, and a method called rate summation has been developed to largely account for such nonlinearities. Rate summation generates predictions of thermal performance by dividing the thermal regime into sufficiently small time slices before inputting them into the nonlinear response function. However, emphasis on potential inherent differences between variable and constant thermal regimes (e.g. caused by acclimation) has recently increased in the literature. Such differences could render rate summation less useful and potentially misleading when making ecological predictions and projections. Thus, we here test whether the rate summation approach generates accurate predictions of development rate, a key life-history trait in insects, under naturally variable conditions. This was done using a predictive model parameterized through laboratory experiments on the butterfly Pieris napi under constant temperatures. Subsequently, the model was validated through animal transplantations across multiple microhabitats. Last, our findings were expanded to other insect taxa by comparing simulated responses with published data. We show that the rate summation approach can generally yield accurate predictions of insect development times. We also highlight the interplay between fine-scale temporal and spatial variability in temperature, and show that it is crucial to account for this microclimate variation using high-resolution input data in order to achieve a generally high predictive accuracy. For insects, the microclimate matters most! Thankfully, through recent advances in microclimate monitoring and modelling, high-resolution microclimate data is increasingly obtainable, even for biologists.

Effects of microclimate change on the survival of the small ectotherm Dactylochelifer silvestris (Pseudoscorpiones: Cheliferidae)

Laura Segura Hernández *(laura.segura@huskers.unl.edu)*

Arthropods comprise the majority of animal species on our planet and simultaneously comprise the species that might be most vulnerable to global warming. Due to their small size, their inability to internally regulate their temperature, and the potential for extreme environmental variability at the small spatial scales of their microhabitats, it is urgent to understanding how microclimate changes might impact arthropods; animals that play a role in numerous ecosystem services. Pseudoscorpions (Class Arachnida, Order Pseudoscorpiones) are an important, yet understudied, group of arthropod predators whose microhabitats might experience temperatures more extreme than surrounding atmosphere. The pseudoscorpion Dactylochelifer silvestris (Cheliferidae) inhabits the prairies of the Great Plains of the United States. They are found in and under Yucca glauca (Agavaceae) plants at different states of decomposition. In this study, I first recorded microhabitat temperature fluctuations experienced over the course of a single summer for D. silvestris and calculated predicted temperatures under RCP6 scenario of climate change. I then quantified their heat tolerance limit by using respirometry, which showed that this species already inhabits microhabitats with temperatures close to their upper thermal limit. Finally, I exposed D. silvestris to current and projected future temperature fluctuations and assessed survival. I found that differences in survival response across life stages across treatments, with earlier juveniles having lower survival, and females being more resistant to the temperature treatments.

Can Antarctic lichens tolerate high temperatures during passive warming?

Angelica Casanova Katny *(angecasanova@gmail.com)*

Antarctic vegetation forms the so-called polar tundra, where lichens and mosses are the dominant organisms in the terrestrial permanent ice free areas. These tundra species are characterized by their capacity to adapt to low temperatures and freezing. However, due to the global climatic crisis, they are increasingly exposed to warming and, consequently, increased environmental pressure, where they must acclimate to heat but still respond to cold. We wanted to know which are the temperatures of the microenvironment in which mosses and lichens develop, and how they respond to heat stress. We exposed Antarctic lichens to short term high temperature kinetics, comparing responses between species under experimental passive warming with OTC and under control conditions, without OTC. We observed no changes in the primary photochemistry in the exposed species; that is, apparently the examined lichens are acclimated to high temperatures, under conditions of 100% thallus moisture. Further, based on the microclimatic records, we observed that during a day of full sun in Antarctica, soil temperatures can rise above 10-15ºC for a few hours, condition which evidently allows growth of these species, indicating sufficient plasticity to respond to these thermal shocks. Our results and observations suggest that at least certain Antarctic tundra lichens are able to cope with the climate change scenario.

Can we explain heterogeneity in greening and browning trends through microclimatic measurements?

Geerte Fälthammar *(geerte.de.jong@bioenv.gu.se)*

As we observe increasing Arctic warming, we see that the Arctic is not only greening, but also locally browning. The heterogeneity in these processes is recognized but not fully understood. Arctic vegetation change occurs not only heterogeneous spatially, but also temporally, in for instance changes to the growing season length and timing of plant growth. Microclimatic differences have been raised as a potentially important driver to the complexity of Arctic greening. Here we use field and satellite data to investigate the effect of microclimate differences on phenology and Arctic greening/browning. At three Arctic sites in northern Sweden (Latnjajaure), Greenland (Blaesedalen) and Svalbard (Adventdalen) we will set up our experiment for multiple years to monitor both above and belowground microclimate and phenology. We use in-situ logger data, field observations, soil and vegetation samples, and pheno-cams to observe our plots and study micro-climatic variation. Due to the global pandemic we were only able to start our study in northern Sweden in 2020, and the site on Disko in summer 2021. Here we present preliminary results from this project.

Litter decomposition in relationship to canopy traits, plant cover and soil properties across an arctic tundra landscape

Jonathan von Oppen *(jonathan.vonoppen@bio.au.dk)*

The decay of leaf litter represents a fundamental process for nutrient cycling and depends largely on local biotic and abiotic conditions such as canopy structure and microclimate. However, with rapid climate warming severely impacting high-latitude regions, few studies have systematically investigated variation in decomposition across heterogeneous tundra landscapes. In this study, we investigate variation in leaf litter decomposition across a stratified random network of microclimate plots, covering multiple gradients of canopy composition, functional traits of the plant community, and soil abiotic conditions. We incubated standard tea bags following the well-established tea bag index protocol for 14 months. Preliminary results indicate that litter decomposition was largely unresponsive to environmental conditions. This contrasts earlier findings of strong variation in soil temperatures with varying vegetation and snow conditions in the same study system. Based on ongoing analyses, I will discuss potential underlying reasons and implications for nutrient dynamics in a rapidly warming arctic tundra biome.

Ecologically more relevant canopy openness from hemispherical photographs

Jan Wild *(jan.wild@ibot.cas.cz)*

Canopy openness controls species diversity, composition and environmental conditions in the forest understorey. The most commonly used method calculates canopy openness from hemispherical photographs with a 180° angle of view. However, many combinations of cameras and lenses and increasingly popular canopy photographs from smartphones do not provide a 180° angle of view. Therefore, we explored how ecologically relevant is the canopy openness calculated from angles of view < 180°.

Specifically, we explored how canopy openness calculated from progressively smaller angles of view predict plant species diversity and composition, measured in-situ air and soil temperature and photosynthetically active radiation in 115 oak-dominated sites in temperate Europe.

Canopy openness calculated from angles of view < 180°was a better predictor of all measured variables than canopy openness from the whole hemispherical photograph. While openness from 100° - 120° angle of view best explained plant species richness, composition, and in-situ measured air and soil temperatures, openness from 80° best explained the photosynthetically active radiation.

Canopy openness from a complete 180° angle of view is not required for many ecological applications, and smaller angles of view can better predict different ecological variables. These findings suggest that ecologically relevant canopy openness can be calculated from photographs captured not only by specialized cameras and fisheye lenses but also by consumer cameras and lenses and with caution also by widely available smartphones. The standardized and reproducible method of canopy openness calculation is therefore much more accessible and should replace subjective visual estimates often used in ecological studies.

Do the effects of tree canopies on understory temperature vary along gradients of conifer and broadleaved tree mixes, forest structure and macroclimate?

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Forest tree canopies buffer the macroclimate and thus play an important role in determining how climate change may affect biota in forest understories. Despite the importance of the tree layer for understory climates, our knowledge about the effect of forest density, conifer and broadleaved tree mixes, tree species composition, tree distribution, macroclimate, season, and their interactions is still sparse. Aiming to assess how tree canopies interact with macroclimate, we have used five mixed forest stands along a latitudinal gradient ranging from 49° N to 64° N in North-western Europe and covering a ca. 7°C average annual temperature span. Within each of these stands, 40 plots (200 in total) have been established, in which both air and soil temperature have been measured continuously for at least 1 year. These plots cover a gradient from pure deciduous forest to pure evergreen forest. To characterize each plot, all trees within a 10 m radius from each temperature logger have been documented, recording their species, diameter at breast height, distance and azimuth from the logger. Additionally, hemispherical pictures have been taken in summer to calculate canopy cover.

Temperature offsets for air and soil, based on macroclimate data from the ERA5 climatic model, have been calculated for different seasons and used as response variables in statistical models built to illuminate how forest density and deciduous trees interact and whether these effects differ between macroclimates, seasons and plot radii. An ultimate aim of our analyzes is to produce models that can be integrated to forest management decision support systems and thus allow predictions of understory temperatures in scenarios were both forest structure and macroclimate are dynamic.

The combined effects of gap size and gap shape on microclimate and its spatial pattern: first results from a Central European forest ecological experiment

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In Central European broadleaved forests, artificial gaps are the most common tool of continuous cover forestry to ensure timber and regeneration but also to maintain buffered microclimate and biodiversity. However, the concept and details of gap-cutting have to deal with numerous uncertainties.

Our multi-taxon study "Pilis Gap Experiment" was conducted in a 90-year-old sessile oak–hornbeam forest in Hungary. Four treatments with uncut control plots were applied in six blocks within a complete block arrangement in the winter of 2018/2019.

Here we focus on the short-term effects of gap size (150 m2 versus 300 m2) and shape (circular vs. elongated) on the average microclimate conditions (recorded at gap centres) and the within-gap heterogeneity of light and soil moisture (using 41 locations/gap).

The amount of light increased in all treatments; diffuse light did not differ among gap types; however, increment in the direct component was higher in large ones. Mean air and soil temperatures were higher in all treatment types; at 130 cm, it was mainly influenced by gap size (larger gaps warmed more), but temperatures closer to the ground were driven by shape (warmer conditions in elongated gaps). Offsets in temperature extremes showed similar trends but stronger responses. Soil moisture was mainly influenced by gap shape, it was higher in circular gaps due to cooler soil temperature. All gaps could preserve the air humidity conditions of closed forests. We found a strong North-South gradient in direct light which was more present in large circular gaps, while diffuse light had concentric within-gap pattern. Edge-centre gradients with multiple local maxima in soil moisture were identified.

Our findings help stakeholders to plan harmonized managements in oak-dominated stands since microclimate is essential for biodiversity and regeneration success but are determined by silvicultural decisions.

Plant diversity buffers soil temperature fluctuations in a long-term grassland experiment

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Extreme climate events occur more frequently, and research has shown that plant diversity may help to mitigate climate change through increasing plant productivity and ecosystem stability. However, most studies have focused on aboveground processes. Even though soil temperature is essential for many soil processes that include water and nutrient uptake as well as microbial activities, which are important for ecosystem responses to climate change and extremes, no study has investigated whether plant diversity can buffer fluctuations in soil temperature.

Here we use a unique dataset to investigate the effects of plant diversity on soil temperature stability in a long-term grassland experiment (the Jena Experiment), with a gradient of controlled plant diversity (1, 2, 4, 8, 16, 60 species). We monitored the soil temperature at 5 cm and 15 cm depth in 84 plots for 17 years (2004–2020).

Our results show that, compared to bare soil, vegetated plots can buffer the soil temperature much better (i.e. cooler soil temperature in summer and warmer soil temperature in winter), and that this buffering effect increases with increasing plant diversity. Using structural equation models, we found that plant diversity increases soil temperature stability through increasing both aboveground plant cover and soil microbial carbon. Over the 17 years, macroclimate varied considerably, causing year-to-year variation in the buffering effect of plant diversity. Using the comprehensive time-series dataset, we could further show that the aridity index (temperature/precipitation) enhances the buffering effect of plant diversity. This means that in years with a harsher climate (higher aridity index), the buffering effect of plant diversity is stronger. This research shows that plant diversity plays a crucial role in mitigating belowground microclimate change, which can help to reduce soil carbon release and thus combat global warming.

Scale-dependent microclimate: how representing spatial, temporal, and process resolution improves thermal prediction accuracy for a range of ecological processes

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Temperature and other climate variables are highly scale-dependent. When generating mechanistic or statistical predictions of microclimate as either a spatial grid or time series, the spatial and temporal resolution of both input data and prediction will play a large role in determining the accuracy of predictions when judged against empirical observations. Yet the relative contributions of spatial versus temporal resolution towards prediction performance are not clear. Here, we explore whether increasing spatial or temporal resolution results in larger improvements in predicting microclimate. We describe a method of quickly generating mechanistically-derived, fine-resolution, and large-extent predictions of near-surface and soil microclimate anywhere on earth. This workflow outperforms several commonplace and global climate products– ERA5 and WorldClim– at predicting near-surface and soil temperatures. After validating the workflow using the newly compiled SoilTemp database, we leverage this method to demonstrate that increasing temporal resolution contributes more to improving predicting accuracy than increasing spatial resolution. For instance, an increase in temporal resolution from daily to hourly results in a 21% decrease in root-mean-square error, while an increase in spatial resolution from 1 km2 to 100m2 results in only a 12% decrease in root-mean-square error. These improvements in thermal prediction performance are magnified when temperature predictions are used to drive ecological models: here, using a set of non-linear processes representing plant and animal phenology, species distributions, and soil carbon respiration rates, all validated with empirical data. Again, increasing temporal resolution of temperature predictions results in larger gains in prediction accuracy by ecological models than increasing thermal spatial grain. We thereby demonstrate the importance of spatial, temporal, and process resolution, and argue that for understanding microclimate and its role in ecology, time may be more important than space.

Slope & equilibrium: a parsimonious approach to model microclimate

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Most, if not all models of forest temperature rely on the offset between macro and microclimatic (forest) temperature. However, offsets are far from constant during the day or year. Besides, we need plenty of models, one for each month, and usually one for minimum, mean and maximum temperature. We propose to go down from these 36 models to just two: the slope and the equilibrium point. The slope is derived from the microclimate linear relationship to macroclimate, and the equilibrium point is the temperature at which macroclimate equals microclimate.

We applied this method across 13 forest plots in France. Five HOBO temperature loggers and their white radiation shield were installed at 1-m height in each forest plot (0.5 ha), and one in an open area nearby equipped with a weather station. From a year of hourly temperature data and for each logger, we extracted the monthly equilibrium and the slope, which we considered constant between months. In our mixed-effect models, most forests had a slope estimate smaller than one (acting as “buffer”, with less variability than the macroclimate). Interestingly, the relationship between the weather station temperature and the one measured by the low-cost sensor right beside it can be modelled exactly the same way, but will instead give a slope estimate larger than one (low-cost loggers acting as “accelerators”, with more variability than the weather station).

The monthly equilibrium was highly dependent on a single parameter, mean monthly temperature. The slope depended instead on forest structure variables: height, cover and shade-casting ability of the dominant tree species, with alternative models including stem density and basal area.

This simplified approach is promising to model microclimate, by clearly separating the temporal effect of variation in the macroclimatic temperature (equilibrium) and the spatial buffering effect of local features such as forest cover (slope).

SoilTemp: a global database of microclimate measurements

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While meteorologists do their best to remove what they consider as local “noise” (trees, buildings and topographic features) in weather data, these sources of “noise” are home to many organisms and thus are critical for ecologists. Indeed, it is the local temperatures near the ground or below the vegetation - often tens of degrees different instantaneously from weather station data - that set the bounds of organisms’ range limits and dictate ecosystem processes such as primary production and hydrological, nutrient, and carbon cycles. Without microclimate data, we not only lack information on the current environmental conditions species live in, but also on the true magnitude of microclimatic changes that species are being exposed to as climate warms.

SoilTemp aims to solve this issue: a global database of microclimate measurements, currently hosting data from close to 30.000 sensors, used to improve global bioclimatic products and explore the drivers of microclimate across biomes. The SoilTemp database has allowed major breakthroughs in gridded climate products, amongst others through the launch of global maps of soil temperature and European maps of forest understory temperatures. Now, we are putting our sights on the complex issue of microclimate dynamics. We try to tackle the question of how fast microclimates are changing in recent decades, through incorporating the interaction between macroclimate change and land-use changes, which affect the relation between macro- and microclimate. These new global microclimate data products can then for example be used to improve field-based estimates of species redistributions. Such improved estimates of species’ reactions to climate and land-use change are critically needed to adjust biodiversity management to a rapidly changing world.

µTEMPY: a spatio-temporal microclimate database of air, ground level and water temperature conditions in the Pyrenees

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Microclimate conditions are gaining more and more attention in global change ecology studies as they are the climate conditions actually experienced by plants and animals. They should therefore outperform macroclimate variables for understanding and forecasting the impacts of climate change on biodiversity distribution. However, their monitoring and computation are challenging, time and CPU consuming, which impedes their widespread use in climate change and ecological studies. Here, we present a spatio-temporal microclimate database informing the daily mean, minimum and maximum temperatures (monthly averaged) at 2 meters above the ground, at the ground level, and in rivers between 2003 and 2100 at a 25 m spatial resolution throughout the Pyrenees (including Andorra, France and Spain). Temperatures were inferred from a modeling approach linking temperature measured at 116 sites and a set of explanatory variables capturing mesoclimate conditions as well as microtopography, land uses, vegetation phenology and canopy shading (all extracted from models or fine resolution satellite images). For water temperatures in rivers, streamflow (inferred from the SWAT+ hydrological model) was also considered as an additional driver. Our models have residual mean square errors lower than 1.25°C, which is 2-5 times lower than forecasts from mesoclimate models. We used these models to compute future microclimate conditions expected over the 21st century under climate change and land use change scenarios (i.e. combinations of Shared Socioeconomic Pathways [SSPs] and Representative Concentration Pathways [RCPs]). Land use change scenarios were downscaled at a 25 m spatial resolution through the CLUE-S model. Although our approach may be improved by accounting for further processes driving temperature conditions, our database is unique and will provide insightful information to identify microclimate refugia for the Pyrenean biodiversity, and to assess whether these refugia will help plants and animals to cope with climate change.

ForestTemp – high-resolution bioclimatic temperature variables of European forests

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Traditionally, ecological research makes use of readily-available coarse-gridded climate data with a spatial resolution of 30 arc seconds, - or coarser-, such as WorldClim, CHELSA or TerraClimate. However, these data are derived from standardized meteorological stations at approximately 2 meters height above open vegetations minimizing microclimatic effects. Consequently, these coarse-gridded macroclimatic data represent the average free-air temperature conditions over longer time periods (i.e. 30 years or more) in open ecosystems. Additionally, many organisms experience environmental conditions that differ substantially from those captured by these macroclimatic (i.e. free-air) temperature grids. For instance, it is well-known that forest tree canopies function as a thermal insulator, buffering sub-canopy microclimatic conditions, thereby affecting biological and ecological processes. Using machine learning, we combined more than 1,200 time series of in situ near-surface forest temperatures with topographical, biological and macroclimatic variables. This allowed us to predict monthly offsets in minimum, mean and maximum temperature between sub-canopy temperature at 15 cm above the surface and free-air temperature over the period between 2000 and 2020 at a spatial resolution of 25 m across Europe. These offsets enabled us to calculate relevant bioclimatic variables (BIO1 - BIO11) and, additionally, expose considerable microclimatic variation within landscapes, not captured by the gridded macroclimate products. Finally, we believe that the bioclimatic variables provided in ForestTemp will improve the assessment of climatic conditions and climate change-related impacts on forest biodiversity and ecosystem functioning.

Integrating microclimatic variation in phenological responses to climate change: a 28-year study in a hibernating mammal

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Several species have shown recent phenological (periodic events in biological life cycles) shifts associated with directional changes in climate. However, the extent to which species respond to overall climate change vs. local climate variability is rarely studied. Climate is usually measured over large spatial scales where field heterogeneity can be high (i.e. rugged habitat). Here, we examined the effects of spatio-temporal climate variability and climate change on the phenology of a hibernating mammal species, the Columbian ground squirrel (Urocitellus columbianus). We studied the relationships between microclimatic conditions (estimated using a microclimate model) and emergence from hibernation dates (ED) of adult and juvenile ground squirrels in four neighbouring meadows from 1992 to 2019. Hibernation ED varied with age and sex, among years and meadows, and within meadows some areas emerging earlier than others (up to 10 days difference). Temporal changes in ED differed among meadows, and depended on individual age and sex. Dates of hibernation emergence correlated with local climate variables, both during the preceding winter and summer. Ground squirrels emerged earlier in years when underground winter temperatures were warmer, when snow depth was smaller and melted earlier, and when the previous summer was less windy. Using a microclimate model provided more realistic predictions of phenological responses to climate, highlighting its potential for research on animal responses to abiotic change.

Edge effects on the realised soil seed bank along microclimatic gradients in temperate European forests

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Despite the crucial role of the seed bank in forest conservation and dynamics, the effects of forest edge microclimate and climate warming on germination responses from the forest seed bank are still almost unknown. Here, we investigated edge effects on the realised seed bank and seedling community in two types of European temperate deciduous forest, one in the Oceanic and one in the Mediterranean climatic region. Responses in terms of seedling density, diversity, species composition and functional type of the seed bank at the forest edge and interior were examined along latitudinal, elevational and stand structural gradients by means of soil translocation experiments. Moreover, we translocated soil samples from high to low elevation forests in the two regions, thus performing a warming simulation. Density, species diversity and mortality of the seedlings varied with region and elevation. Seedling density also differed between forest edge and interior position, while seedling cover mainly depended on forest structure. Both the edge and interior forest seed bank contained a high proportion of generalist species. In Belgium, a more homogeneous seed bank was found at the forest edge and interior, while in Italy compositional and ecological differences were larger: at the forest edge, more light and less moisture demanding seedling communities developed, with a higher proportion of generalists compared to the interior. In both regions, the upland-to-lowland translocation experiment revealed effects of warming on forest seed banks with thermophilization of the realised communities. Moreover, edge conditions shifted the seedling composition towards more light-demanding communities. The establishment of more light and warm-adapted species from the seed bank could in the long term alter the aboveground vegetation composition, with communities becoming progressively richer in light-demanding generalists and poorer in forest specialists.

The effects of microclimate change on forest understorey flowering phenology

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Ongoing climate change (CC) has large impacts on the earth's biotic systems. Some of the earliest documented ecological changes associated with CC and in particular warming, have been shifts in phenology. The inability to track CC by changes in phenology can have great consequences for species fitness and demography, and ultimately species in situ persistence. On the other hand, phenology shifts can alter competitive interactions between species competing for similar resources. Forest understorey species experience climate buffering from the overstorey, meaning that their phenology is most likely driven by microclimate, i.e. temperature and light availability at the forest floor, rather than macroclimate. By shaping the overstorey, forest management can play a crucial role in altering the understorey's response to CC, mainly by regulating the microclimate. Following microclimatic changes, species-specific phenology shifts can alter competitive relationships between species, possibly affecting community composition and associated ecosystem functioning. Therefore, understanding how CC and light availability – and their interactions – drive plant phenology and uncovering the ensuing communities' response is crucial to develop strategies to prevent future biodiversity loss and maintain forest functioning.

To assess the impact of microclimate warming and light availability on understorey flowering phenology we monitored flowering of 10 species and collected microclimate data in two mesocosm experiments in the Aelmoeseneie Forest in Gontrode, Belgium from February until October 2021. Preliminary results show that herb layer species' flowering phenology is indeed greatly affected by warming and illumination, but an interspecific variability in these responses is observed. Moreover, we illustrate the significance of gathering microclimate data when studying understorey phenology. We found phenological temperature sensitivities up to more than double the previous reports, relying on macroclimate data. Consequently, predicted changes in community compositions and forest functioning due to phenological shifts in response to CC may have been underestimated.

Unexpected east-west range shifts in forest plants

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Biodiversity redistributions owing to climate change are increasingly documented across terrestrial ecosystems. Such movements theoretically occur from currently warmer to cooler areas, and generally result in south-north tracking of the shifting isotherms. Yet, evidence for species redistributions comes mainly from leading range edges along north-south transects, which can conceal more complex responses across the rest of the range. Here we quantify the multidimensional, long-term, continental-scale shifts of plants by means of their range centroids (abundance-weighted geometric centre of the distributional range) in European forests. We inferred centroid shifts from 2,954 (quasi-)permanent vegetation plots across European broadleaved forests that were surveyed twice, with a mean intercensus interval of four decades. We show that less than a quarter of species are moving northwards (as would be expected in response to ongoing climatic warming) and that range shifts predominantly occur along an east–west axis, in either direction. Range shifts are contingent on species' life-history traits and niche positions, with larger-seeded, wide-ranged species from fertile soils shifting faster. Our findings demonstrate that European forest plants are not migrating in the direction expected from warming temperatures alone, which has important implications for land management and policy making decisions dealing with connectivity and species movements.

Quantifying the spatial heterogeneity of microclimate temperature

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Temperature can vary significantly over spatial scales, with differences sometimes higher over just a few metres, than over kilometres. However, global temperature data is only available at coarse spatial resolution (>1 km^2), often not matching the spatial scale suitable for ecological research. While this heterogeneity in microclimate is beginning to be measured and understood, the magnitude of this heterogeneity has not been quantified at scale. To address this gap, we use data from SoilTemp: a global network of over 14 000 soil temperature time series covering the worlds' biomes. These data have allowed us to quantify and model thermal heterogeneity within 4 km^2 grid cells and identify key drivers in microclimate heterogeneity globally. We also identify a better framework for extending the SoilTemp network, allowing for efficient measurement of microclimate variability in understudied regions. Our data facilitates spatially explicit predictions of thermal heterogeneity and leads to improved ecological forecasting.

Soil water limits forest temperature buffering

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Forests can buffer understory microclimate and biodiversity against climate warming. Yet, the future buffering of forests against increasingly frequent heat and drought is conditional on stable canopies and sufficient soil water. Buffering of daily maximum temperatures in forests results from a combination of canopy shading and cooling via soil water evaporation and plant transpiration. Dry soils limit evapotranspiration - the most efficient surface cooling mechanism. Up to now, we know too little about the shape of the relationship between soil moisture and temperature buffering as well as about the interaction with canopy cover, topographic setting and general weather conditions. Here, we analysed a number of temperature and soil-moisture time series from the temperate forests in Central Europe region across three years focusing on how fluctuations in soil moisture drive temperature offsets, i.e. the difference between temperatures outside and inside the forest. We modelled daily maximum temperature offsets as a function of soil moisture in interaction with canopy cover, topography and weather. We found that site-specific offsets became more negative (i.e. stronger cooling effect) when soil moisture was higher and that the offsets responded in a non-linear way to soil moisture, as the sensitivity to soil moisture was higher in drier soils compared to more moist soils. This relationship was also contingent on canopy cover, slope exposure and the general dryness of the air above the canopy. In a warmer climate with increasing frequency of drought periods, these soil-water limitations on forest buffering will become more and more important. Therefore, we must urgently adapt forest management practices to not only secure continuous canopy cover but also to keep the water in the soils, for example, by closing drainage ditches or restoring channelized streams.

Landscape forest cover also buffers plant communities from warming

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The ongoing climate warming is expected to reshuffle plant community composition by increasing warm-adapted species at the expense of cold-adapted species, resulting in higher community induced temperatures. To date, observations show that local canopy partly explains the lag between understory community induced temperature and climate warming rates but landscape scale effects have not been consistently reported. Here, we test the hypothesis that the amount of forest in the landscape has a local effect on local community induced temperature.

We performed pairwise comparisons of 4046 nearby French forest inventory plots with contrasting percentage of forest cover in a 1km buffer, while controlling for other environmental factors, such as canopy cover and macroclimate . We computed the difference of community induced temperature between these pairs, and tested the contribution of landscape forest cover and other factors that may explain community differences.

The most forested plot within a pair had, on average, a 0.35° C cooler community induced temperature, this offset represents the buffering capacity of a highly forested landscape. Two thirds of this buffering potential were explained by correlation with other plants traits such as pH preferences, and one third by the difference in forest cover in the landscape per se, interpreted as a microclimate cooling by nearby forest. We further projected the buffering effect on lowland European forest map. The lack of buffering capacity by forested landscapes is mostly apparent in urban and intensive agricultural landscapes due to forest fragmentation being unevenly distributed across Europe.

These results highlight the role of big forest masses for conserving cold adapted species, by adding to the local canopy buffering a cooling effect stemming from nearby forest cover, while diverse landscapes with both small and big forests can host both cold and warm adapted species in a given microclimatic condition.

Tree diversity increases air temperature buffering in forests

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The frequency and intensity of extreme climatic events such as heatwaves and droughts is predicted to increase with intensifying climatic change, threatening ecosystem communities and functions. Forests have been shown to effectively buffer the frequency and the severity of temperature extremes below the canopy and thus protect the ecosystem from large climatic fluctuations. Moreover, tree species richness is expected to promote forest functions like productivity via enhancing complementary canopy space-filling and complementarity in leaf phenology. Therefore, one would expect tree species richness to increase the forest canopy climatic buffering potential by increasing standing tree volume, canopy space-filling and leaf phenological asynchrony. However, the relative importance of these mechanisms for microclimate buffering remains unknown. Here, we tested the effects of tree species richness on air temperature buffering potential in a forest Biodiversity-Ecosystem Functioning experiment (BEF China). Our analyses show that tree species richness increased air temperature buffering by both, preventing temperature extremes. At the yearly scale, we show tree species richness increases forest temperature buffering via increasing tree biomass. At the monthly scale, however, tree diversity increased temperature buffering by increasing leaf cover but reduced temperature buffering by increasing leaf phenological asynchrony. We show that tree diversity controls microclimatic conditions under the canopy by enhancing canopy closure, and therefore, the buffering layer between macro- and microclimate. We suggest that this protection of the below-canopy communities and processes from macroclimatic fluctuations and extremes is one of the key mechanisms enhancing forest ecosystem stability.

Using near-ground temperatures reduces projected climate change impacts in a floristic biodiversity hotspot.

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Species distribution models (SDMs) have been used widely to predict the responses of species to climate change. However, the climate data used to drive these models typically represents ambient air temperatures, derived from measurements taken 1 to 2 metres above the ground. In contrast, most plant species live near the ground where temperatures can differ significantly, owing to the effects of solar radiation and reduced wind speed. Here, we investigate differences in spatio-temporal patterns in near-ground and air temperatures and the implications this has on projected changes in species richness of a suite of Fynbos plant species in South Africa. For each individual plant species (n = 114), we constructed two types of SDMs: one using ambient air temperatures and one using near-ground temperatures. Each of these models was fitted to species occurrence data for a recent time period and projected backwards into the past. Species richness projections for both time periods were then constructed using binarized projections. We found that the adverse impacts of climate change were overestimated by models constructed with ambient air temperatures, especially in more arid locations where temperature profiles in vertical space are more marked due to radiation. At the same time, models constructed using ambient air temperatures are likely to be underestimating the risk to species in mountainous areas where regional weather patterns can influence the level of divergence in geographical space between near-ground and ambient air temperature gradients. We demonstrate that projections by models constructed using ambient air temperatures overestimated the loss of suitable climate space by underestimating the upper limit of a species' thermal niche and assuming a smaller temperature gradient in space. Resultantly, ambient air temperatures should not be considered an effective surrogate for investigating climate change impacts on species living near the ground.

Forest resilience to global warming is strongly modulated by local-scale topographic, microclimatic and biotic conditions

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Resilience of endangered rear edge populations of cold-adapted forests in the Mediterranean basin is increasingly altered by extreme heatwave and drought pressures. It remains unknown, however, whether microclimatic variation in these isolated forests could ultimately result in large intra-population variability in the demographic responses, allowing the coexistence of contrasting declining and resilient trends across small topographic gradients. Here we analysed whether indicators of forest resilience to global warming are strongly modulated by local-scale topographic, microclimatic and biotic conditions. We studied a protected rear edge forest of sessile oak Quercus petraea, applying a suite of 20 indicators of resilience of tree secondary growth, including multidecadal and short-term indices. We also analysed sapling recruitment success, recruit/adult ratios and sapling thermal exposure across topographic gradients. We found large within population variation in secondary growth resilience, in recruitment success and in thermal exposure of tree saplings to heatwaves, and this variability was spatially structured along small-scale topographical gradients. Species-specific associations of trees with microclimatic variability are reported.Biotic factors are key in determining long-term resilience in climatically stressed rear edge forests, with strong limitation of sapling recruitment by increased roe deer and wild boar herbivory. Our findings do not support scenarios predicting spatially homogeneous distributional shifts and limited resilience in rear edge populations, and are more supportive of scenarios including spatially heterogeneous responses, characterised with contrasting intra-population trends of forest resilience. We conclude that forest resilience responses to climate warming are strongly modulated by local-scale microclimatic, topographic and biotic factors. Accurate predictions of forest responses to changes in climate would therefore largely benefit from the integration of local-scale abiotic and biotic factors.

Quantifying potential species distribution shifts with climate change using field experiments

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Climate change-induced shifts in species geographic ranges (i.e. distributions) have been observed in nearly every biome. However, our inability to accurately forecast such species shifts with climate change impedes tailored conservation and land management policies to mitigate ongoing biodiversity loss across the globe. Underlying this problem is the outstanding ecological question of how species will perform beyond their current range. A common, yet untested, assumption in forecasting approaches is that populations will be able to survive and grow in new habitats beyond current ranges that are projected to become climatically suitable, even though differences in microhabitat climate and local population dynamics could alter such responses. It is thus imperative to test whether and how such deviations will impact population response and thereby affect ecological predictions, which we are testing with a multi-year demographic vegetation study in the Washington Cascade Range, USA. We focus on the central question: how do population dynamics respond to microhabitat climate at and beyond current range limits? While surveys along climatic gradients within species' ranges are common, data on how populations respond to microhabitat climate beyond their current range limits are sparse. To address this, we are conducting yearly surveys of 25 focal tree, shrub, forb, and graminoid species transplanted at and beyond their current upper elevational range limits, recording seed germination and seedling survival as well as growth. We are testing how transplants in areas of predicted future habitat suitability (i.e. upward of the range edge) respond to microhabitat environmental conditions (temperature, soil moisture, canopy cover), and present our ongoing work here. We expect that our field experiments will show a strong effect of microhabitat climate on population response, and that this effect is heterogenous between species. Our work will produce the tools and knowledge base necessary to gain a deeper understanding of species response in novel environments to use this information to construct improved range shift projections.

Thresholds and tipping points in ecosystem responses to global warming

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Terrestrial ecosystems are important in providing key services to humankind, but under global warming the provisioning of these services is at risk. There is, however, little consensus on how the functioning of terrestrial ecosystems will change under projected scenarios of global warming, or when we will reach or surpass thresholds and tipping points. This is largely because we have failed to unravel ecosystem responses to warming in terms of the underlying non-linear responses of plants, soil organisms, and their communities. Since plants and their associated soil organisms (i.e., pathogens, mutualists, and decomposers) can vary in their responses to temperature change, global warming may disrupt or decouple interactions among coexisting and co-evolved species. This may have unforeseen consequences for key ecosystem functions, such as carbon cycling. In this presentation, I will introduce our new ERC-funded project THRESHOLD where we aim to advance our knowledge of how non-linear temperature responses transcend levels of ecological organization. We use a global network of forest-tundra and forest-alpine ecotones to assess how responses of ecosystem carbon cycling to increasing temperature will be pushed across thresholds and tipping points. We further perform mesocosm experiments under a range of different temperatures, to estimate how ecosystem process responses to global warming can be predicted from the reordering of plant and soil communities, as well as from the functional traits that they possess and express.

Microclimatic niche partitioning and conservatism in tropical canopy-dwelling bryophytes: a window into their vulnerability to climate change

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Large trees are some of the most iconic biota, but progress in forest canopy science has long been challenged by the limited accessibility of canopies and availability of fine-scale microclimatic data. We took advantage of a tropical canopy crane facility to design microclimate monitoring system and model the spatial variation in light, temperature and humidity and their impact on the taxonomic and phylogenetic structure of epiphytic bryophyte communities. Both taxonomic and phylogenetic turnover were significantly correlated with microclimatic conditions, indicating that community assembly of epiphytic bryophytes is shaped by microclimatic filters, but is also constrained phylogenetically. The correlation between phylogenetic turnover and microclimatic variation evidences microclimatic niche conservatism, suggesting that species may not have the evolutionary potential to shift niches at fine spatial scales. This raises concerns about the ability of tropical epiphyte communities to adapt to climate change, and hence, about the long-term resilience of their role in carbon retention and water storage in tropical forests.

Ecosystem multifunctionality of forests across macro- and microclimatic gradients

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Forests are a key supplier of numerous ecosystem functions, such as food production, carbon storage, pollination, pest control, nutrient cycling, water retention, and climate buffering. The ability of forests to simultaneously provide multiple functions depends on local environmental conditions, stand properties and landscape characteristics, and may vary strongly within forests. Here, we collected data on ecosystem functioning in forests with three levels of density, along a macroclimatic gradient from Italy to Norway. In each of 45 forests, we established five vegetation plots along a south-facing edge-to-interior gradient. For each plot, we calculated a multifunctionality index based on the quantification of the following 12 ecosystem functions: biodiversity (in terms of total plant diversity, specialist diversity, generalist diversity, functional diversity, phylogenetic diversity), aboveground biomass, total carbon storage, edible plants, pollination value, tree regeneration, thermal buffering capacity and nutrient cycling. This multifunctionality index was then related to local soil properties (texture, pH, organic matter content), forest stand characteristics (plant area index, shade-casting ability, maximum summer temperature) and regional drivers (surrounding forest cover, drought index, nitrogen deposition). We found that canopy density and composition were important drivers of the multifunctionality index, indicating that multifunctionality can be optimized through adapted forest management. Our results also stress the negative impact of drought stress on forest multifunctionality. We did not find a clear trend in multifunctionality along the edge-to-interior transect, likely because some drivers of multifunctionality increase with distance-to-edge, while other drivers decrease. Finally, our research stresses the need to consider stakeholder priorities when assessing ecosystem multifunctionality, as different stakeholders will assign different degrees of importance to the functions included in the multifunctionality index.

Space can-not substitute for time – an integrated experimental assessment of climate-change effects on litter decomposition

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Litter decomposition is an important component of the global carbon cycle and strongly determined by climatic conditions. Climate-change effects in decomposition are mainly studied with space-for-time approaches along climate gradients, i.e. correlations of climatic conditions with in situ decomposition. However, these correlations may be confounded with biotic effects (e.g. litter quality) which are likewise affected by climate. Experimental studies that separate these indirect effects from direct climate effects are needed to confirm the validity of the space-for-time approach. To test whether space can substitute for time, we combined the observation of in situ native plant litter along a very pronounced precipitation gradient in Chile (hyper arid to humid temperate), with reciprocally translocated litter and in situ manipulations of precipitation (i.e. rainout shelters). Interestingly, all experimental approaches indicated clear positive effects of soil moisture on decomposition. However, the space-for-time observations showed the opposite, due to indirect climate effects on litter quality, i.e. against theoretical predictions, litter quality decreased gradually from the arid to the temperate site. These results highlight the need for experimental approaches when studying the effect of climate-change on litter decomposition. Resulting data could greatly improve predictions of global models of vegetation, the carbon cycle and climate, which mostly rely on correlative data of decomposition rates.

Forest biodiversity and human thermal comfort

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Thermal comfort and human well-being are closely linked and especially temperature extremes represent potential health threats. From urban planning and health studies on the one hand and ecological research on the other hand, the climate-buffering capacity of vegetation and, especially, forests is well established. However, it is rarely approached from an interdisciplinary angle, leading to incompatible indicators. How ecological forest characteristics such as species diversity and stand structure influence the microclimate experienced by humans remains an open question. To address this, we have conducted studies both on 'objective' and 'subjective' thermal comfort. For the 'objective' study on the one hand, we installed 147 microclimate stations in different forest stands dispersed over eight sites in four European countries. During one year, these continuously logged the four variables that influence thermal perception: air temperature and humidity, mean radiation temperature and wind speed. These were converted to the physiologically equivalent temperature (PET), which is then related to measured ecological forest traits: tree species diversity and composition, basal area, tree height, canopy closure and leaf area index. On the other hand, the 'subjective' study took form of a survey on 225 participants in three urban forests (Austria, Belgium, Germany). Here, a combination of microclimate and ecological data, questionnaires and physiological measures will reveal the role of forest biodiversity on thermal comfort and the effect of individual experiences. As fieldwork was only finished in September 2021, we will present the first results of this PhD project.

Effects of microclimate on plant-pathogen interactions across an urbanization gradient

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More than half the world's human population lives in urban areas, and our establishment and use of urban environments creates gradients in numerous abiotic and biotic factors. One of the most frequently documented of these is increasing temperature with urbanization, due to retention of solar radiation by urban materials and release of heat by vehicles and machinery. Urban-rural temperature gradients can impact the ecology and evolution of diverse organisms. However, the coarse scale of most remotely sensed climatic datasets does not account for microclimate variation that organisms experience within a given habitat. Here, we seek to understand how interactions between herbaceous plants and their fungal pathogens are affected by microclimate differences within populations spanning an urbanization gradient. To characterize microclimates relevant to these organisms, we measured soil temperature (< 5 cm depth) in paired shaded and open microhabitats every 15 minutes for one year in more than 30 sites across an urbanization gradient in St. Louis, Missouri, USA. From July-Oct 2020 we performed monthly surveys of populations of two plant hosts (Plantago spp.) co-occurring in 22 parks and nature areas across the urbanization gradient (with additional intensive surveys along urban and suburban road verges in June-July), and quantified effects of shade on powdery mildew infection status of plants. We found powdery mildew infection was more common in shaded microhabitats, and effects of microclimate varied with month and degree of urbanization. Then, we performed field experiments testing effects of shade on growth of powdery mildew on plants inoculated in July and November 2021. These experiments confirmed the strong effect of shade in promoting mildew growth, but also highlighted seasonal differences in microclimate with changing solar altitude angle. Overall, our work illustrates the importance of accounting for relevant spatial and temporal scales of climatic variation in the study of species interactions.

Impact of climate on coffee berry disease and coffee yield in Arabica coffee’s native range

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Climate change is threatening Arabica coffee production, both due to the direct effects of climate on coffee physiology and berry production, but also through changes in the associated pests and diseases. One of the major threats to coffee production in Africa is coffee berry disease, which is caused by the fungus Colletotrichum kahawae. However, little is known about how temperature, canopy cover and management may affect coffee berry diseases incidence and yield in Arabica coffee’s native range. To investigate the effects of temperature on coffee berry disease and yield in the center of origin of Arabica coffee, we recorded daily minimum and maximum temperature, incidence of coffee berry disease and coffee yield for two consecutive years (2018-2019) in 58 sites along a broad environmental and management gradient in southwestern Ethiopia. Minimum and maximum temperature affected coffee berry disease incidence, for example, incidence of coffee berry disease decreased with increasing minimum temperature during May-June 2018 and increasing with maximum temperature during May-June 2019. Improved coffee cultivars had a marked effect on coffee berry disease incidence, with berry infection rates decreasing with increasing proportion of coffee cultivars. The incidence of coffee berry disease and yield consistently decreased with increasing canopy cover. Coffee yield increased with management intensity, while the coffee berry disease incidence was unaffected by management intensity. Our findings highlight the potential of canopy cover (shade) and improved cultivars in limiting coffee berry disease.

Microclimate knowledge helps to select tools for climate adaptation of biodiversity conservation in managed forests

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In this talk we will summarize the message from a newly published paper in Conservation Biology aiming at providing hands-on tools for adaptation of biodiversity conservation in a changing climate. These tools complement already existing tools but add a climate lens through which policy makers and managers could look. Frameworks for adaptation of biodiversity conservation to climate change generally include two major strategies: the 'resistance strategy' (actions to increase the capacity of species and communities to resist the changes) and the 'transformation strategy' (actions that ease the transformation of communities to the novel environmental conditions by allowing a changed species composition). We review the literature and list five tools under the 'resistance strategy', of which several utilize the knowledge of microclimate buffering of forests in combination with the topoclimate, e.g. to identify and protect refugia for cold-favoured species. Under the 'transformation strategy' we list three tools including: to enhance conditions for forest species favored by the new climate (but currently disfavored by forest management). We suggest that it is important to apply a combination of tools from both strategies to maintain a rich biodiversity in future forest ecosystems. Good knowledge about the microclimate experienced by both cold- and warm-adapted species is crucial to make the adaptation tools effective in real landscapes.

Three-dimensional distribution modelling of epiphytic bromeliads in Trinidad

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Microclimates are critical to determining species' distribution, particularly in forested habitats where microclimate varies along vertical gradients from the ground to the forest canopy and along horizontal gradients across topographically heterogeneous land surfaces. A suite of mechanistic modelling packages in R have recently become available to produce meso- and micro-climate grids by downscaling macroclimate data based on the effects of topography and vegetation. However, these models have yet to be widely incorporated into species distribution models (SDMs). In the current study, we are working to model the distribution of four epiphytic tank bromeliads (Genus Aechmea) in Trinidad at fine spatial scales and in three dimensions. We focus on epiphytic bromeliads because they occupy unique canopy environments not characterised by large scale models and many are likely threatened by climate change if forest structure cannot provide adequate microrefugia. Specifically, we are 1) mechanistically modelling canopy microclimates based on topography and vegetative derived from airborne LiDAR; 2) producing fine-scale, three-dimensional SDMs for epiphytic bromeliads by modelling distribution at a relevant height and then projecting these models to microclimates across vertical canopy strata; 3) evaluating the relative extents of habited predicted to be suitable by micro- and macro-climate models to determine whether incorporating microclimates into SDMs may help identify microrefugia. By providing fine-scale estimates of distribution, this research could inform conservation management strategies for epiphytic bromeliads and could be extended to future climate scenarios to estimate potential vertical and horizontal range shifts over time.

Existing microrefugia in the Mediterranean region : a microclimatic approach

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Microrefugia are small areas with favorable environmental conditions enabling the survival of population outside their species range. In the context of global warming, a clear understanding of current microrefugia is crucial. However, there is a lack of knowledge to conclude whether, and to what extent, the climate encountered within existing microrefuges differed from the surrounding climate.

We use the most abyssal and southernmost disconnected populations of the circumboreal herbaceous specie Oxalis acetosella in Southern France to study if populations matching the definition of current "microrefugia" benefit from particularly cold climatic conditions compared to neighboring sites (50-100m). Air and soil temperature were recorded every 15 minutes in microrefuges and their neighborhoods during approximately 2 years to quantify their thermal contrasts. Botanical inventories were performed to test if biological communities reflect microclimatic contrasts, based on Pignatti species-indicator values.

We found systematic temperature variations with cooler conditions within microrefugia compared to nearby sites. This pattern was stronger for air temperature and verified throughout seasons, especially pronounced in summer. Abyssal populations showed stronger contrasts compared to neighboring sites than the southernmost populations occurring at high altitude. Community composition systematically differed, with species more adapted to cooler and moister conditions in microrefugia compared to nearby sites.

Current microclimatic dynamics are genuinely at stake within abyssal sites, enabling the persistence of cold-adapted species into constrained limited surfaces. Microrefugium climate is cooler than its immediate surrounding landscape, and biological communities in place already translate strong spatial climatic variability, even at such microscale approach.

Mapping climate microrefugia in European forests using climate-based approaches

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Recently, research suggested that microrefugia could mitigate the loss of species in response to climate change. Microrefugia are safe islands of establishment with a microclimate that supports populations of a species beyond the large-scale boundaries of its climatic limits. In this study, we used a recently-developed high-resolution microclimate temperature map of Europe to identify potential climate microrefugia in European forests. Different approaches were used to map microrefugia: First, we quantified the climate offset values (i.e. the difference between macroclimate and forest microclimate), which are related to potential to buffer macroclimate warming and second, we calculated climate change exposure, quantified by the magnitude of predicted future warming at a certain location and by the predicted climate change velocity. Areas with higher buffering capacity, lower magnitudes of predicted warming and lower climate change velocity were identified as potential microrefugia. The generated continental maps provide guidance for the prioritization of conservation efforts.

Using airborne laser scanning to model light conditions in the forest understory

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The development of LiDAR technologies in forestry and their widespread implementation in more and more forests around the world, especially in Europe, calls for new methods for reading and processing raw point clouds in order to extract ecologically meaningful information. For instance, LiDAR data can help us better understand the impact of canopy shading on different aspects of forest microclimates, notably through the quantification of light filtered through the canopy. Another key component of the forest microclimates is sub-canopy temperature which highly relates to light conditions in the forest understory. Temperature has a major impact on many ecosystem processes in the forest understory such as tree regeneration, among others, and it is a real challenge to model sub-canopy temperature. Here, we propose to use airborne LiDAR data to model the amount of direct radiation emitted by the sun and reaching the forest floor. By simulating the course of the sun throughout the year and over the raw point cloud of airborne LiDAR data acquired across the Compiègne Forest in France (144 km2), we developed a luminosity index reaching the forest understory and generated luminosity maps at very high temporal resolution and across the entire forest. For several sites across the entire Compiègne forest (n = 150), we also recorded in-situ temperature condition at 1-m height above the ground surface and at very high temporal resolution (hourly). Finally, we overlaid our luminosity maps with the 150 sites where we monitored sub-canopy temperatures to assess the explanatory power of the luminosity index on sub-canopy temperature conditions. The fields of application are important for our understanding of the underlying drivers of forest-dwelling species distribution.

Structural metrics driving microclimatic variability of managed boreal forests assessed using terrestrial laser scanning

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Forest management in Finland has traditionally been based on even-aged forestry practices including the regeneration naturally or artificially, thinning, and the final cutting. However, recently, uneven-aged forest management has become an alternative management approach. Uneven-aged forestry is based on selection felling and natural regeneration. The different age compositions of the differently managed forests produce vegetation structures characteristic to the management types. These structures are expected to influence microclimates by intercepting incoming and outgoing radiation, and by affecting evapotranspiration and aerodynamic resistance. In this study, we quantified the structural characteristics of total 20 study plots in even-aged and uneven-aged forest stands in the Vesijako-Kailankulma Research Forest by Natural Resources Institute Finland. Using terrestrial laser scanning, we derived and compared the structural metrics canopy ratio (CR), relative height (RH), foliage height diversity (FHD) and plant area index (PAI), that describe the vertical layering and amount of tree material. We found that the total PAI did not differ between the management types. However, we observed significant structural differences within different vertical strata. The PAI in 0–5 m was highest in young even-aged plots, while in the layers above 15 m the PAI was highest in mature even-aged plots. In the intermediate layers, the PAI was highest in the uneven-aged stands. Similar layered structure was also visible in CR, RH and FHD. The next step in this study is to evaluate how the structural characteristics of different management regimes contribute to regulating microclimate. Temperatures and humidity in our plots are being monitored since March 2021 using 40 TOMST TMS4 and 20 HOBO Pro V2 sensors. We expect that our results will clarify how forest management can contribute to improving such forest structural characteristics that may lead to more stable microclimates and resilient forest ecosystems.

Microclimatic grids of the Bohemian Forest: linking temperature measurements, land-surface topography and forest structure through spatial GAMs

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Accurate microclimate variables are the key for effective forest management, ecosystem modelling and biodiversity conservation. However, existing climatic layers do not capture microclimatic variability at the biologically relevant scales. Moreover, existing climatic layers do not capture microclimate under the tree canopy, because they are based on weather stations operating outside forests.

To provide spatially-continuous, high-resolution microclimate data for the National Park Šumava (Czech Republic) and NP Bavarian Forest (Germany), we established microclimate measurement network across 923 km2 using TMS loggers. We measured air, near-surface and soil temperatures every 15 minutes at 288 microclimatic stations in all types of forests in the area. We have used stratified random points to cover gradients in altitude, solar radiation, topographic wetness and canopy cover. We used data from October 2019 to October 2020 to derive first generation of high-resolution grids.

From high-density LiDAR point cloud, we calculated land-surface parameters and forest structural attributes and combined those using spatial GAMs to model microclimate variables at 5 m resolution for the whole territory of both National Parks. Beside internal cross-validation, we used also data from independent stations to validate the accuracy of the modelled microclimatic maps. These maps should provide more realistic climate variables for research and management.

Opportunities and challenges in using airborne LiDAR data to model microclimate in temperate deciduous forests

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We know canopy cover influences microclimate dynamics, from a cooling effect on summer days to a warming effect on winter nights. Hitherto, the spatiotemporal resolution used in most models falls short at capturing both the vertical structure and the seasonal variability of canopy cover in temperate deciduous forests. Here, we wish to discuss the potential of airborne light detection and ranging (LiDAR) data to fill this gap in modelling forest microclimate dynamics. Airborne laser scanning is a very promising technology as it allows to capture, in a spatially contiguous manner, the vertical structure of canopy cover at unprecedented details. However, it usually fails at capturing temporal changes in canopy cover as it would require repeated flights over time, at least during the leaf-on and leaf-off periods. This obvious limitation suggests to be really cautious when linking forest microclimate data recorded at hourly intervals, and the whole year round, to a single snapshot of airborne LiDAR data acquisition. Is it relevant to use airborne LiDAR data acquired during the leaf-on period to interpolate sub-canopy temperature measurements recorded during the winter season? Another challenge in using airborne LiDAR data to model forest microclimate is the amount of data generated by this technology which can be overwhelming. There is an infinite possibility of LiDAR-derived variables to describe the vertical complexity of canopy cover (maximum canopy height, point density per height category, plant area density, plant area index, etc.). Yet, which one of these descriptors are most relevant to model in-situ temperature conditions below treetops? At which spatial resolution shall we generate such metrics? To illustrate these challenges, we will combine airborne LiDAR data acquired during the leaf-on or leaf-off period with in-situ temperature measurements below treetops across four temperate deciduous forests in France, from north to south: Mormal; Compiègne; Blois; and Aigoual.

Topography or canopy structure could not substitute in-situ measured microclimate while study bryophytes in temperate coniferous forests

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Increasingly available high-resolution digital elevation models (DEMs) facilitate the use of fine-scale microclimatic proxies derived from DEMs. Topographic proxies are thus often used instead of in situ measured microclimatic variables in ecological research and conservation applications. However, the accuracy of such a strategy needs to be evaluated against in situ microclimatic records and species responses. At 220 forest sampling sites we measured microclimate continuously for two years (every 30 minutes from 1 May 2010 to 30 April 2012) using TMS ground loggers. To characterize topographic variability, we derived eleven topographic indices from a LiDAR-based DEM with a 1 m resolution. We recorded bryophyte species composition and forest vegetation characteristics. We calculated eleven microclimatic variables from TMS temperature and soil moisture records. Hemispheric photography and canopy height models were used to derive eleven variables describing vegetation structure. To evaluate the substitutability of the measured microclimate with topographic and canopy variables, we partitioned the variation in bryophyte species composition and richness. We found that canopy structure nor fine grain terrain topographic variables cannot fully substitute for the in situ measured microclimate while explaining bryophyte assemblages in temperate coniferous forests.

Monitoring the effect of tree species composition on forest structural diversity using terrestrial laser scanning

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Forest structural diversity is a key feature for biodiversity assessments because a diversified structure is likely to host more species and more available resources and make the forest microclimates contrast strongly with the climate outside forests. Species composition is a very important biodiversity feature in forests, but there is limited study on how tree species composition affects forest structural diversity. To monitor the effect of tree species composition on forest structural diversity, we collected data from three FORBIO experimental forests (Gedinne, Zedelgem, and Hechtel-Eksel). These sites total 126 plots and the biodiversity experiment is designed using a fixed species pool of five functionally different tree species for each site. Each plot is planted with a different species mix from this pool (1-4 tree species). Lidar is particularly useful in monitoring forest structure by providing detailed 3D data of the canopy, and we collected terrestrial laser scanning (TLS) measurements in all 126 plots using RIEGL VZ-400 in July and August 2021. Each plot was scanned at four different locations. From these 3D laser scanning data, the structural diversity is described through vertical plant profiles (gap fraction, plant area index, and plant area volume density) to accurately describe the 3D structure of each plot. In the meanwhile, microclimate stations are recording humidity, temperature, wind speed. Here, we will show the effect of tree diversity on vertical plant profile, and those related microclimate conditions.

Microclimate in deadwood and how it affects inhabiting beetle species, Tragosoma depsarium

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While climate change has increased interest in the influence of microclimate on many organisms, species inhabiting deadwood have rarely been studied. We explored the relationships between characteristics of forest stands, deadwood and microclimate, and analysed how the microclimate inside deadwood affects the occurrence of wood-living organisms, exemplified by the red-listed beetle Tragosoma depsarium.

In our study area in south-eastern Sweden we included 23 sites with 98 dead pinewood items for which we (i) counted new and old exit-holes of T. depsarium, (ii) measured deadwood and forest characteristics, which previously have been described as important for T. depsarium or suggested to influence microclimate, (iii) placed data-loggers inside each deadwood item for recording hourly temperature and humidity, and left them there for a whole year.

We found that some of the measured deadwood and forest variables explain much of the variation in temperature, but little of humidity aspects of the microclimate within deadwood. Several variables known to influence habitat quality for deadwood-dependent species were found to correlate with microclimate viz.: warmer conditions in standing deadwood and open canopy than in downed logs and under a closed canopy; higher humidity and more stable daily temperatures in shaded habitats and in downed and large-diameter wood, than in sun-exposed locations and standing, small-diameter wood.

Microclimatic variables added explanation to the patterns of T. depsarium in comparison to the deadwood and forest characteristics. T. depsarium occupancy and abundance were negatively correlated with daily temperature fluctuations, and positively related to spring and summer temperature and humidity. This can explain why the species occurred more frequently in deadwood items with characteristics associated with these microclimatic conditions, i.e. downed large-diameter logs occurring in open conditions.

Interspecific differences in microhabitat use expose insects to contrasting thermal mortality

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Narrow ecotones that link open and forested habitats generate multiple microhabitats with varying vegetal structure and microclimatic regimes. Ecotones host many insect species whose development is intimately linked to the microclimatic conditions experienced at fine scales (e.g. the leaves of their host plants). Yet microclimatic heterogeneity at fine scales and its effects on insects remain poorly quantified for most species. Here we studied how interspecific differences in the use of microhabitats across ecotones lead to contrasting thermal exposure and survival costs between two closely-related butterflies (Pieris napi and P. rapae). We first assessed whether they selected different microhabitats to oviposit and quantified the thermal conditions where their offspring develop at the microhabitat and foliar scales. We also predicted the associated thermal mortality of the larvae in the field based on the experimental quantification of larval time of death under different temperatures (TDT curves). Finally, we assessed concurrent changes in the quality and availability of host plants. Vegetation cover determined the microclimatic processes that operated in the different microhabitats, which also influenced host plants. Leaves in open microhabitats were subject to thermal amplification mechanisms that could lead temperatures 5–10 ºC warmer than the surrounding air and the leaves from other microhabitats. More closed microhabitats presented more buffered temperatures and a more homogenous microclimatic mosaic, instead. Interspecific differences in microhabitat use matched the TDT curves and the thermal mortality in the field. Open microhabitats posed acute thermal challenges that were better withstood by P. rapae, where the species mainly laid their eggs. Although P. napi eluded higher thermal mortalities and drier host plants by avoiding open microhabitats, its offspring faced a period of host-plant scarcity. Our results show how the interaction of small organisms with microclimatic variation emerging at fine scales expose populations to contrasting challenges, potentially mediating local responses to broader-scale stressors.

Can local climate data better predict the spread of introduced species?

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Biological invasions are among the greatest environmental threats worldwide and ever accelerating trade and human movement continues to contribute to the spread of several thousand species globally. Predicting where such detrimental species may spread based on their climatic niche is important to protect ecosystems. However, it has been suggested that invasive species may frequently establish in climates outside their native niche, experiencing 'niche shifts'. Yet, research on niche shifts is typically done on macroclimatic scales, and observed niche shifts may be an artefact of climate data that does not represent the species' niche well. Indeed, a niche shift observed on the macroclimatic scale could in fact be conservatism on the microclimatic scale. Using 100 species of introduced ant species (Formicidae), we investigated the effect of different resolutions of climate data on the frequency of niche shifts of introduced species, and the ability of SDMs to predict their spread. We quantified niche shifts based on local climate and macroclimate data, using two distinct methods, ordination of environmental variables and correlative species distribution models (SDMs). We found that the majority of species have experienced less expansion into novel climate when soil-level datasets were used. Furthermore, soil-level data also predicted the introduced range of the majority of species better than comparative macroclimatic. As global-level fine-scale microclimate data is currently hard to obtain for species with an introduced range spread over multiple continents, data which have coarse grid cells but better represent the microhabitat type (i.e. soil temperature) is a useful compromise to better predicting species occurrences. This dataset overall reveals higher levels niche conservatism between ranges, thus highlighting its usefulness in predicting invertebrate soil-dwelling species range movements in the future. Overall our study demonstrates the future potential of emerging datasets for correlative prediction models of invasive ants.

Negative effects of fragmentation and forest management on moth communities due to reduced microclimate buffering

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Temperate forests are biodiversity hotspots in densely populated regions and face the coinciding pressure of fragmentation, intensive forest management and climate change. Moths (Lepidoptera) are a species-rich group that play a key functional role in temperate forests as pollinators, herbivores, but also as an important food source for other taxa. Currently however, the effect of forest fragmentation and forest management on moth communities remains largely unknown. Throughout the summer of 2020 we sampled moths with light traps in plots along edge-to-core transects in dense and open forests in four Western European regions. We also determined important measures of plant diversity, microclimate, forest structure and surrounding land use for every plot. We found a higher activity-density and species richness in moth communities in dense forests and in forest cores. These patterns appeared to be mainly driven by microclimatic temperature, forest structure (foliage height diversity) and by the amount of forest in the surrounding landscape. Finally, we also use differences in phylogeny, species' thermal niches and functional traits related to mobility to explain species specific patterns. Our findings have important implications for the conservation of moths and associated species, indicating that large, unfragmented and dense forest with a strongly buffered microclimate are beneficial to sustain abundant and diverse moth communities.

Demonstrating the impact of land-use-driven microclimate changes on the structure of ecological assemblages

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Changes in land use are associated with changes in local climatic conditions, with human-disturbed land uses often experiencing increases in temperature extremes, and decreases in moisture availability. These local climatic changes are expected to lead to predictable changes in the ecological communities present within human-disturbed areas, favouring species that can tolerate the more extreme local climatic conditions created. I will present recent work, on both vertebrates and insects, quantifying how species with different climatic requirements respond to land use. To do so, we use a global database of spatial comparisons of biodiversity under different land-use conditions: the PREDICTS database. We often find that human land uses favour species able to tolerate more extreme temperature conditions. Nevertheless, results were less clear for species' precipitation tolerance, and were not consistent across all groups of species, highlighting the complex nature of local climatic changes following land-use change, and the resulting changes in the structure of ecological assemblages.

Microclimate and biotic competition drive the diel community dynamics of ants

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The majority of terrestrial animals are ectotherms and forage in a complex and dynamic thermal landscape of microhabitats. How their activities and distributions track the temperature fluctuation remains unclear due to a lack of assessment of the thermal conditions they directly experienced, i.e., microclimate. Among terrestrial arthropods, ants represent a great model organism for investigating community dynamics: they are diverse, ecologically dominant, have sessile to semi-sessile colonies, sensitive to changes in abiotic environments and forage both day and night. Using fine-scale continuous field observations and sampling of subtropical ground foraging ant communities over 24 hours' period, we asked how their diversity and composition respond to the diel temperature fluctuation in different seasons (wet and dry) and habitats (open and closed). We integrated high resolution thermal photographs (over 300,000 samples per 0.3 m2) and in situ near-ground surface temperature recordings (~0.5 million records per year) to obtain the intensive assessment of spatial and temporal thermal heterogeneity of microhabitats. In addition, we also measured the critical thermal tolerance (maximum and minimum) of ants to quantify their thermoregulation limit. Our results show that if interactions with seasonality and habitat structure exist, the dominant factors shaping ant temporal community changes are microclimatic conditions in open habitats (e.g., grassland) and species competition in closed habitats (i.e., forest). The fine scale spatial and temporal niche partitioning of ants driven by environmental filtering and competition are also observed. These results reveal the assembly processes underlying diel community changes of ants and also highlight the importance of high-resolution temperature measurements in understanding activities, distribution and community composition of terrestrial ectotherms.

Poster 1

The impact of forest management on the understory microclimate

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Forest canopies buffer climate extremes in the understory. In particular, near-ground air temperatures inside the forest are often cooler during the day and in the summer, and warmer at night and in the winter than outside the forest. This buffering capacity of climate extremes is key to explain understory biodiversity and forest regeneration, and thus the resilience of forests to further climate change. Forest management practices can potentially impact this understory microclimate by modifying forest structure and composition (through changes in tree density, cutting regimes, tree species composition, understory control, forest fragmentation, etc.). Yet currently, forest managers have no tools to quantify the impact of their practices on microclimate.

To improve our understanding of how silviculture and forest management alter understory microclimate, we used two existing biophysical models [MuSICA (Ogée et al., 2003) and Microclimc (Maclean & Klinges, 2021)] that we evaluated against microclimate datasets from forest ecosystems with different and co-located management practices. Complementary field measurements to characterize forest structure (e.g. leaf area, basal area and tree height distribution, species composition) were used to parameterize the models and identify the main forest structural factors influencing the understory microclimate, with reference to climate extremes. Here we present the steps carried out so far to identify these factors and their influence on understory air temperature and moisture during targeted climate extreme events.

Poster 2

Mapping microclimate variations using near-surface temperature modelling: validation of the Microclima R package on the scale of the Compiègne forest and its surroundings

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Climate conditions matter for soil biodiversity in agroecosystems. However, the microclimatic temperatures perceived near the soil surface by species are different from ambient-air temperatures (cf. macroclimate) as measured by weather stations. To predict microclimate temperatures, Maclean et al. (2019) developed a mechanistic model relying on microclimatic processes that govern fine-scale variation of soil surface temperature. Here, we aim implement the Maclean et al. (2019) model by integrating data on temporal changes in vegetation height, before verifying the validity of the model outputs in closed and open environments using microclimatic temperature data, as collected in 2018-2019 by 50 sensors installed in the Compiegne Forest and its surroundings. We generated hourly maps of soil surface temperature between February 2018 and October 2019. Our results show a strong correlation between predicted and observed temperatures (R^2 = 0.945). We analyzed the relationships between the R^2 and the environmental parameters, which allows us to know under which environmental conditions the strongest correlations between predicted and observed temperatures are observed. In summer, the relationship between R^2 and canopy density is non-linear, with R^2 being lowest on habitats without canopy and under the highest canopy densities. Our study thus allows us to better optimize the modeling of predicted temperatures and highlights the need to validate predictions with observed temperature data in both forest and open habitats. Based on our findings, we conclude that the model can be extended to other territories that do not have in-situ microclimate measurements data to predict soil surface temperature variations. In the context of climate change, this work and future research would allow us to determine which agroecosystem states maintain a favorable soil surface temperature for species living near the soil surface.

Poster 3

Could the soil microclimatic conditions affect recruitment and fitness in Epipactis tremolsii?

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The otherwise barren heavy metal polluted tailing dump of Barraxiutta (South-Western Sardinia, Italy) hosts an Epipactis tremolsii Pau (Orchidaceae) population. In this framework the soil microclimatic condition could play a relevant role in directing seed traits, production, and the recruitment success of the metallicolous orchid population. The scarce plant coverage rate together with the soil properties could indeed result in extremes values and strong oscillations in the superficial soil temperature right where germination events take place, so we hypothesized for the metallicolous orchid population a thermal stress beside the heavy metal one. In the metallicolous population site a temperature logger (HOBO Pendant Temp Logger, Onset Computer Corporation) was then buried at 5 cm in depth in order to record the soil temperature at 90 min intervals. An in-situ germination experiment was consequently carried out by means of the packets of seeds technique. A near (less than one km as the crow flies) E. tremolsii population growing in pristine environment featured by dense forest canopy and mature soil was used as a control reference to compare with tailing dump population recruitment potential and soil temperatures data. When compared with the control site, tailing dump soil microclimate presented poorer thermal inertia leading to more marked day/night fluctuations and extreme values of temperatures. Regarding the metallicolous population recruitment (intended as the number of seeds presenting significant evidence of incipient development), it resulted lower with respect to the control population one.

The initial hypothesis was confirmed, since underground thermal extremes were registered in the tailing dump while poor recruitment potential featured the metallicolous orchid population. Future studies are needed to weigh how thermal and heavy metal stress interacts and to which extent each one of them contributes to the low recruitment potential of the metallicolous orchid population.

Poster 4

Drought resilience in native versus planted species: studying microclimates using a field rain exclusion platform in the ATLANTIS project

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Current knowledge gaps on the vulnerability of forests to climate change and management pressures limit the ability to maintain forest sustainable productivity under increasing anthropic and natural disturbances. The ATLANTIS project is funded by the Spanish Ministry of Science and Innovation and aims to develop soil-smart forestry practices and early tree vulnerability diagnosis tools to improve soil conservation and long-term forest stability. With these purposes in mind, ATLANTIS has been designed to get a clear picture of tree vulnerability by studying the eco-physiological of representative broadleaf native species (Quercus sp.) and planted conifer tree species of high economical value (e.g. Pinus sp). Two drought simulation facilities were installed near Vitoria-Gasteiz at the beginning of the growing season (April 2022), one for Quercus faginea and the other one for Pinus sylvestris. Long-term soil and plant responses to drought will be continuously monitored and controlled by a weather monitoring station for a total of 16 trees. Briefly, the rain exclusion is based on a shelter around each tree, using outdoor waterproof tarpaulins held to the trunk. Under the tarpaulins, drainage gutters were installed and covered with griscolene waterproofing sheet. To monitor plant responses to drought, a range of automated sensors was installed on each experimental tree and in the soil. These sensors will record soil moisture and temperature at 15-min intervals at different depths (10, 40 cm). To quantify stem growth and water fluxes, point dendrometers and sap flow sensors are used. Canopy changes are continuously monitored by ground digital camera installation. Finally, soil health indicators and tree health will be analysed (by leaf metabolomics) to identify threshold points of "no return" that, once passed, lead to tree decline and mortality. Our system will help provide data on the impacts of extreme drought on large trees of native versus planted species.

Poster 5

Effect of microclimate on deadwood organisms in Sweden

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It has been hypothesized that certain wood-dependent organisms are decreasing due to increased competition from species favored by forestry or warming climate. If so, species assemblages on clear-cuts in the north are becoming more similar to managed forests in the south, while species favored by clear-cuts may spread also to other forests and compete with northern species. In this research project we test for the first time hypotheses related to this. We expect that i) in north, southern species increase with increased level of light and this is less pronounced for northern species, and ii) in south, northern species decrease with increased level of light and this is less pronounced for southern species. In 2021, we installed 450 eclector traps along a 1200 km long latitudinal gradient in Sweden. These traps consisted of 1.5 m long spruce logs and sampled all emerging beetles from April until September. They were set up under three different light levels and their under-bark temperature was measured each hour. We will analyze collected data this winter, and at the conference we will be ready to present our newly acquired knowledge on how wood-dependent species composition is related to microclimate.

Poster 6

Temperature and the speed of (a butterfly) life

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Temperature influences the rate of most biological processes. A thermal performance curve describes how such a process, e.g. development rate, changes with temperature – generally increasing up to an optimum, beyond which it rapidly declines. This typical non-linear response to temperature complicates intuitive predictions on how individual organisms and populations respond to naturally fluctuating temperatures, and by extension, to climate warming. We quantified the effects of extreme small-scale temperature variation on the important biological traits phenology, eclosion synchrony and voltinism (i.e. the number of generations produced during one growing season) in a butterfly population. In a novel way, we simulated development of individual green-veined white butterflies (Pieris napi) across a real microclimate landscape of ca. 26 ha by combining hourly data from 110 temperature loggers with empirically-derived thermal performance curves for each life stage. We demonstrate that microclimate variation has large effects on the rate of development and synchrony of neighboring butterfly individuals that eclose only a couple of meters apart. Yet, we also show, that across an entire growing season, these effects can partly cancel each other out resulting in no net-effect on voltinism, as all sites consistently, to our surprise, produced two generations. The results were robust across three years and three different egg-laying starting dates. Interestingly, optimal sites for developmental speed were not stationary across the season, i.e. ”fast” sites could become ”slow” sites as season progressed. Also, the fast sites were not the warmest sites in the study area, stressing the necessity – whenever possible - to incorporate species- and life-stage-specific non-linear response to temperature when studying the effects of natural temperature variation and climate change on organisms.

Poster 7

How stable is the temperature decoupling in forests (interior vs. outerior) under global warming? Perspectives from CLM5 simulations

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Forest microclimates feature dampened temperature extremes thereby allowing the development of a diversity of life in understory environments. However, there is much uncertainty on the capacity of forests to ensure comparable temperature buffering under increasing global warming. Therefore, providing reliable projections of future forest microclimates is crucial to determine conservation and land use strategies. A recent study based on a statistical approach shows that global warming results in an increasing difference between maximum temperatures inside and outside forests. Yet, the evolution of forest microclimates is seldom assessed in dynamical global vegetation models (DGVMs). Thus, we propose to investigate the stability of temperature decoupling in forests (interior VS exterior) under global warming with a mechanistic approach. Using atmospheric anomalies to force the Community Land Model (CLM5) including a Biomass Heat Storage (BHS) scheme, we compute below canopy microclimate projections for RCP2.6 and 8.5 warming scenarios. A present-day control run is evaluated against the global soil temperature database (SoilTemp) and both future simulations are compared to recent estimates of future forest microclimates. Our research illustrates the potentials and limitations of DGVMs to simulate forest microclimates and calls for further collaborations between Earth system modelers and ecologists to jointly question climate and biosphere dynamics.

Poster 8

Using a thermal unmanned aerial vehicle for the identification of microrefugia for biodiversity in the Spanish Pyrenees

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The loss of biodiversity is one of the most important consequences of the current global warming scenario. A first step for its conservation is to identify climatic microrefugia: thermally stable areas where certain organisms can withstand climatic changes. In this project, we used thermal sensors attached in an unmanned aerial vehicle (UAV) recording in RGB and thermal infrared (TIR) for the identification of microrefugia at centimetric scales across six areas of the Spanish Pyrenees. The UAV-TIR data allowed us to estimate land surface temperatures (LST) at two contrasted moments of the day in 4 flight campaigns in 2020-2021. For each centimetric pixel we estimated the thermal range it experienced in each season in order to identify the most thermally stable pixels for each site. UAV-LST data were validated with miniaturized thermal sensors (iButtons) in the same areas. Furthermore, UAV-RGB data allowed us to generate geo-environmental variables (slope, aspect, curvature, SWI) and strucutural metrics from vegetation which facilitated us to know their effects on thermal stability.

Measurements of temperatures from UAV and iButtons correlated rather well (R2: 0.7973). Thermal stability was modelled using GLMs as a function of geo-environmental variables and strucutral metrics, all of them having a significant effect on it. The results showed that the most stable sites were forest patches regardless of the aspect, and north-faced cliffs. On the contrary, the less stable areas were grasslands in south-faced slopes, rocky surfaces and few screes sectors. This is the first study to date that have used a UAV in complex areas to produce thermal landscapes and identify climatic microrefugia. The potential of this method is highly promising not only because of the extraordinary fine resolution UAVs provide, but also because it allows to work in remote or inaccessible areas.

Poster 9

Open source database solution for microclimate data

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Managing and maintaining microclimatic data is an important task. Data from a small number of sensors can be maintained in csv files. However, with increasing amounts of data, their management becomes complex. Here we explore the use of the open-source database TubeDB for microclimate data management.

The main features of TubeDB are on-demand time-series processing including quality control, interpolation, and interactive visualization. TubeDB is a web service that can be easily installed locally on your own computer or run as a server solution for the entire team. The data are hierarchically divided into projects and individual project can be divided into groups of stations. The station includes loggers and the logger contains sensors, which can be defined by the user. Moreover, sensors can be physical or virtual based on the aggregation of other sensors.

TubeDB also has rich options for data visualisation, including an interactive map of stations and time-series visualisation, and an interactive application for data exploration.

TubeDB also allows to control access to individual projects based on username and password and contains API functionality to query data. Users can also o query data directly from the R, using the rTubeDB package.

At the Institute of Botany of the Czech Academy of Sciences, we run a TubeDB database in a Docker container. Our solution includes scripts that update data semi-automatically and we are working on a fully automated solution linked to GitLab. Our database currently contains 34 projects, more than 1700 TMS loggers and time-series longer than 10 years. Despite that, the application is still fast. Therefore, we would like to introduce this useful tool to the microclimatic community.

Poster 10

Using mechanistic microclimate modelling to reveal high thermal variability of boreal forests

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Local climates greatly affect the local forest types in addition to the local fauna. These in turn help create local microclimates, causing variations in for example temperature and relative humidity values. These variations can affect things such as species distribution and drought risks. Due to the coarse spatial resolution of climate model data, this knowledge has been difficult to factor in the many types of models, such as forest fire risk index and species distribution models, both of which rely heavily on climate data. However, the most recent advancements in mechanistical microclimate modelling now allow us to better understand and visualize the local microclimate in boreal forest environments. Here we aim to use such a model to reveal the temperature variability of boreal forest environments. Using the open source mechanistical microclimate model Microclimf, we modeled the hourly microclimatic temperature variability of summer 2020 at three sites in different boreal forest environments in Finland, two sites in the Southern Finland and one in the North. Temperatures were modelled for 0.15 m and 1.5 m heights. The results were then validated using local microclimate data from a set of ~50 microclimate loggers located at each of these sites. Compared to the 10 km2 resolution climate data used for the temperature modelling to the resulting 5 m2 resolution temperature values show the effects of local vegetation and topography on the local temperatures, resulting in greater variability and temperature ranges in the area. Validation results for the three sites showed a mean root mean square error of 2.47-2.9 degrees centigrade when comparing hourly values of the model and collected microclimate data. These results help understand the variability of temperature values in boreal forests and shows the additional value that this increased spatial resolution can give to different kinds of models.

Poster 11

Impacts of local light and temperature conditions on understory herbaceous plants and bryophytes in temperate deciduous forests

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In forest ecosystems, local light and temperature conditions experienced by understory species are altered by dynamic changes in stand characteristics, acting mostly through forest management practices and natural disturbances. However, disentangling the respective impacts of light and local temperature conditions on understory communities remains a challenging task. Here, we studied the response of herbaceous plants and bryophytes to both light—using visual estimates of vegetation cover, a densiometer and hemispherical photos—and temperature—using HOBO temperature sensors at one meter above ground and buried eight centimeters into the soil—along a forestry gradient ranging from young to mature forest stands. A total of 180 plots were sampled in three temperate deciduous forests in France, with floristic surveys of terricolous and saxicolous plants and bryophytes. We used generalized linear models, including covariates to account for potential cofounding effects, to test the effect of light and temperature on species richness and mean community indices, calculated from Ellenberg indicator values. Light and temperature conditions were clearly influenced by forest management practices. Among covariates, the number of tree species, the dominant tree species and the proportion of in-situ management disturbances were found to be strong explanatory variables of total species richness. Light community indices responded to estimates of vegetation cover as expected, but temperature community indices were driven by large-scale macroclimate, not microclimate. In the face of climate change, the distribution of species is likely to change. The concept of thermophilization in understory flora relies on community indices such as Ellenberg values, and this may call for caution in their interpretation. Understanding the responses of the forest flora to the dynamic fluctuations of its microclimatic environment could enable foresters to adapt their management practices to these new challenges.

Poster 12

Investigating near-surface microclimatic conditions in a Norway spruce stand in the Hildburghausen municipal forest and the effects of small-scale deadwood enrichment

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Forests have moved into the focus of climate change research in environmental sciences. Especially the understanding of microclimate dynamics within forest stands is of increasing interest for decisions on forest management strategies to convert and stabilize forests at the local level. Moreover, precise measurement, interpretation and understanding of microclimate conditions in forests helps to understand mutual interdependencies with larger scale climatic and environmental changes. However, microclimatic characteristics of the air layer immediately above the forest floor, particularly in terms of wind, are often neglected and only few studies investigate potential microclimatic effects of deadwood. This study aims to fill these gaps by exemplarily applying a dense near-surface microclimate measurement grid and a deadwood-manipulation experiment in the municipal forest of Hildburghausen (Germany).

Within this managed forest, a mature, even-aged Norway spruce dominated stand (7.1 ha) is investigated. To enhance ecosystem resilience, it is undergoing forest conversion through direct seeding of Silver fir. During the 2022 vegetation period 12 monitoring stations log wind speed, humidity, and air temperature in 10 s intervals at 0.15 m and 1.90 m above the forest floor. A nearby meteorological station collects reference data in a clear-cut site. After two months, six of the stations are treated with deadwood from tree cuttings. Observations are contextualized with the stand's structural attributes including, tree and ground vegetation type, their spatial distribution and degree of coverage. Results will capture the microclimatic characteristics of the understudied near-surface air layer that serves as microclimate for seedlings and quantify the effects of deadwood this specific microclimate. The study further aims to assess whether deadwood accumulations might serve as a forest management practice to bolster the forest's buffering of adverse macroclimatic conditions and improve forest resilience.

Poster 13

MICROMED - Conservation of flora in the face of global warming: describing and assessing the role of microrefugia in the French Mediterranean region

Eric Meineri *(eric.meineri@imbe.fr)*

Microrefugia are as small patches with favorable local climate for the persistence of species into regions with unsuitable macroclimate. While studies dealing with forest ecosystems into temperate regions accumulates, the Mediterranean ecosystem have been less studied. The project MICROMED aims to better understand the drivers enabling the persistence of marginal populations, assimilated as putative microrefugia, and to use this novel knowledge to model potential future microrefugia for species threatened by climate change into French Mediterranean region.

It is still unclear whether marginal populations of species persist because of favorable microclimate. To bridge this gap, WP1 ask if putative current microrefugia of an alpine and a circum-boreal species, Arabis alpina and Oxalis acetosella, respectively, experience cooler and moister microclimate compared to their surrounding (50-100m distance). The first results demonstrate systematic cooler microclimate into putative microrefugia (~0.7°C) compared to their closed surrounding, also indicated by the ecological requirements of dominating plant species.

WP2 aims to use marginal populations of A.alpina and O.acetosella to quantify buffering and decoupling effects on microclimate according to topographic and biotic forcing factors. Preliminary results suggest that stronger thermal contrasts between putative microrefugia and their surrounding (buffering effects) occur when marginal populations are located into convex landscape, near streams. Forest characteristics do not seem to play a major role. Decoupling effects have not been studied yet.

WP3 aims to use the results of WP2 to model potential microrefugia for species threatened by climate change. Threatened species will be identified using bioclimatic envelope models. Quantification of buffering and decoupling effects on microclimate will then be used to search for potential microrefugia for these threatened species. The preliminary results identified that 15 species (out 2800 species modeled) would have no remaining suitable habitats by 2070-2100. The modelling of potential microrefugia will now focus on these potentially threatened species.

Poster 14

Microclimate of plant origin, drought and early shading affect intra-individual variability in Galium odoratum

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Climate change is leading to prolonged droughts and warmer temperatures, but also earlier tree leaf-out in spring and, thus, earlier shading of the forest floor. Forest understorey herbs may respond to drought and shading by adjusting functional traits either plastically or genetically. Whereas individual mean trait values are generally investigated to understand population responses, preliminary studies have suggested that intra-individual variability (IIV) is an important source of phenotypic variation, with a contribution to total phenotypic variation often exceeding inter-individual variation. This suggests that IIV may be important in plant responses to environmental conditions. Our study species Galium odoratum is a primarily clonal species, allowing us to measure IIV in leaf length and width, and plant height at different hierarchical levels of organisation: intra-genet, intra-clone, intra-ramet. We sampled genet from 21 populations across three regions in Germany, along a microclimatic gradient determined by forest mangement, and transplanted them in a common garden, allowing us to investigate the genetic basis of IIV. We applied early shading and drought treatments to investigate plastic responses in IIV. We found significant variation in IIV among populations of origin, indicating that IIV has a genetic basis and suggesting adaptation to local conditions. When correlating IIV with several microclimatic variables of sites of origin, we found that annual mean soil temperature correlated negatively with IIV in our common garden, indicating that individuals originating from colder sites show increased IIV. Furthermore, we observed that earlier shading leads to increased IIV and that the relationship between trait means and IIV seems to be drought-dependent. Concluding, patterns in genetic and plastic variation in IIV suggest a role for IIV in adaptation to past microclimatic conditions. However, the mechanisms of how IIV confers fitness advantages remain elusive.

Poster 15

Landscape scale assessment of the microclimatic buffering capacity of hedgerows in agricultural landscapes of Ontario, Canada

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Within agricultural landscapes, hedgerows represent important natural habitats for many species but their microclimate properties are less well known. Hedgerow vegetation varies in vegetation structural attributes and composition, from remnant forests to a combination of forbs and woody shrubs, and may provide important thermal refugia for species due to their ability to buffer against temperature extremes. We evaluated how different local hedgerow features and landscape features, such as the proportion of forest cover in a landscape, influence the availability of microclimates and the buffering capacity of hedgerows in agricultural landscapes. To quantify microclimate variability in agricultural landscapes, we deployed a network of 180 temperature loggers in 30 crop fields and paired hedgerows across 20 1-km2 landscapes in eastern Ontario, Canada. Landscapes were selected to reflect variation in the proportion of natural land cover to assess the role of landscape scale forest cover on microclimate heterogeneity. The microclimatic buffering capacity of hedgerows as compared to loggers deployed in crop fields was mostly explained by hedgerow characteristics whereby tree dominated vegetation resulted in significant cooling. At the landscape scale, we found a positive effect of the proportion of natural areas on the daily mean buffering capacity. Across the summer season, mean and maximum daily temperatures were on average 1.56 and 5.57 higher in crop fields than in treed hedgerows, which reflect temperature increases within the range of expected future climate change. Weather station seasonal mean and maximum temperatures were consistently lower than field and hedgerow temperatures, suggesting the use of weather station data underestimates temperatures experienced by organisms in these landscapes. Our results underscore the importance of both landscape scale and local hedgerow forest cover as climate change adaptation strategies due to their capacity to buffer against warming temperatures, which is of particular importance to organisms living in agroecosystems, such as pollinators.

Poster 16

Logistic regression modelling the Spatio-temporal distribution of Mauritius Thorn (Caesalpinia decapetala) and River Red Gum (Eucalyptus camaldulensis) in the Soutpansberg Mountains of the Vhembe Biosphere Reserve

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Biomes in the Global South are under increasing pressure due to multiple stressors associated with global change. Continuous monitoring using modelling, GIS, and remote sensing are fundamental tools for informing invasion and management strategies. Here, we examine how environmental, habitat, and phenological parameters affect the establishment and distribution of Invasive alien plant species in Vhembe biosphere reserve (VBR), Limpopo Province, South Africa. Twenty-one predictor variables split into environmental, GIS and Remote sensing data were collected across two seasons (hot-dry, cool-dry) from seventy-four (39 presences and 33 absence sites) for river red gum (Eucalyptus camaldulensis) and seventy-eight (32 presences and 46 absence sites) Mauritius thorn (Caesalpinia decapetala) from fourteen belt transects and forty quadrants measuring 200 x 200m within the VBR. The stepwise logistic regression analysis for Mauritius thorn and River red gum using Environmental, GIS and Remote Sensing variables produced a significantly high Akaike information criterion (AIC) and an area under the curve (AUC) values. The stepwise logistic regression analysis shows an AIC of 84.28 and an AUC of 0.79. Therefore, these variables accounted for significant levels of variation in the distribution of Mauritius thorn and River red gum. The model increases suitable habitat from west to east along the Soutpansberg mountain and riparian areas. Further studies are required to assess the importance of environmental factors and climatic influencing the distribution of other invasive alien plant species under growing anthropogenic pressures.

Poster 17

Microclimatic imprints on community characteristics across space and time

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The climate of high-latitude areas is expected to change faster than that of any other region of the globe. This will make their biota particularly vulnerable to changing climatic conditions, and may affect both plant and insect communities in terms of abundances, diversity and, ultimately, community stability and functioning. However, little is known on the link between microclimate and community characteristics. To evaluate the extent to which plant and insect communities are consistently structured by environmental imprints across time and space, we sampled plant and arthropod communities in two sub-arctic landscapes (Kilpisjärvi and Varanger) during two consecutive summers. To sample primary producers (plants), we used field-based inventories and to sample arthropods we used malaise traps. Microclimatic conditions were characterized by soil moisture, temperature and habitat related characteristics such as altitude and snow depth. With the aim of investigating whether microclimatic and habitat structure shaped insect and plant communities equally, we implemented a piecewise structural equation modelling (pSEM) framework of direct and indirect imprints on species richness across regions and years. Both regions were characterized by similar microclimatic conditions. However, only half of the arthropod species pool was shared between regions, with about one-quarter unique to Kilpisjärvi and one-quarter to Varanger. Similarity among trophic level richness was reflected by differential imprints of altitude and soil moisture and temperature depending on the region. Preliminary pSEMs revealed plant and air-borne arthropod richness to be primarily affected by altitude in Varanger whereas soil moisture and temperature appear to be the main forces driving the similarity between the two trophic levels in Kilpisjarvi.The differences uncovered suggest that different components of the interacting species communities respond differently to environmental drivers depending on theregion, with potential impacts on community structure along contemporary environmental gradients. Similar imprints may then affect differently community structure with ingoing climate change.

Poster 18

The plant-water conundrum: response of mature temperate deciduous future forests to elevated CO2.

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Extreme anthropogenic global change, such as increasing atmospheric CO2, can challenge long-lived organisms including trees. At Birmingham Institute of Forest Research (BIFoR) Free-Air CO2 Enrichment (FACE), we investigate soil-plant-atmosphere flows, monitoring root-xylem-stomatal response to ambient and elevated (+150ppmv) CO2 in a c170-year-old mixed deciduous temperate forest. Measurements include root soil water inputs, xylem sap flux, and leaf stomata transpiration outputs, from dominant Q. robur/ oak and understorey tree species. Xylem sap flux data is collected half-hourly from eighteen Q. robur and smaller numbers of subdominants in nine experimental patches: 3 patches with elevated CO2 infrastructure; 3 with infrastructure but ambient CO2; and 3 'ghost' (without infrastructure or elevated CO2). Transpiration data is derived from in-situ and cut twig stomatal conductance porometry. Early results show the expected strong seasonal cycles in soil water and sap flow, and diurnal cycles in leaf transpiration. From studying leaf level assimilation elevated atmospheric CO2 would be expected to reduce daytime plant water usage, but this response is confounded by the complexity of canopy and stem growth. Shallow and profile soil moisture demonstrate substantial heterogeneity due to the complexity of demands on this resource, including soil respiration and ground evapotranspiration. This complicates interpretation of belowground root-water processes. Similarly aboveground processes pose confounding questions concerning water storage versus water usage in photosynthesis. Early preliminary results concerning quantitative plant-water responses to the CO2 treatment are presented for 2017-2019. We find that between-individual within-species variability of summer tree water usage in oak is linearly proportional to tree stem radius (ca. 3.3 litres per millimetre radius). Between-treatment results season-to-season, location-to-location, and between species variability are being further explored within the complexity of through-canopy variation in microclimatic conditions. The results will provide valuable input to improve vegetation, soil and landscape models and increase understanding of trees in mature future-forest environments.

Poster 19

Vegetation diversity buffers soil microclimatic extremes: phenomenon and mechanisms

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The frequency and intensity of extreme climatic events, such as heatwaves and droughts, are increasing with climate change, threatening humanity and other life on Earth. Especially, belowground communities and functions are known to be highly sensitive to changes in microclimatic conditions (e.g., temperature and humidity). Yet, vegetation was shown its potential to buffer macroclimatic fluctuations by providing a critical buffering layer between macro- and microclimatic conditions. Moreover, higher vegetation diversity increased primary productivity. Therefore, we would expect vegetation diversity to increase the macroclimate buffering effect, and thus protect belowground communities and functions from microclimatic extremes. Here, we tested the effect of vegetation diversity on macroclimatic buffering across ecosystems at the European scale using the SoilTemp database. Our results show that increasing vegetation diversity increases the buffering of extreme macroclimate temperature events by increasing low temperatures and reducing high temperatures. Therefore, our results suggest that the plant diversity-induced stabilization of ecosystem functions could be mediated by the stabilization of microclimatic conditions.

Poster 20

Local snow and fluvial conditions drive taxonomic, functional, and phylogenetic plant diversity in tundra

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Ecosystems are globally facing drastic changes due to altering climatic conditions and on-going biodiversity crisis. Cold ecosystems are especially under threat as high-latitude and mountain regions suitable for sensitive tundra vegetation are constantly shrinking. To understand, how the diversity and functioning of tundra might respond to altering environmental conditions, studies close to plant scale are needed as local conditions may buffer the effects of large-scale changes. Here, we combine microclimatic measurements and other high-resolution environmental data with global plant trait and phylogeny data to investigate the effect of local habitat conditions on the diversity of tundra vegetation. Specifically, we examine the effect of growing season length, soil moisture, snow persistence, soil pH, and fluvial conditions on taxonomic, functional, and phylogenetic vascular plant diversity. Using state-of-the-art modelling methods, we investigate the relationship between several diversity metrics and presented environmental factors at 561 plots in Rastigaisa mountain region in northern Norway. According to the first results, local snow persistence and fluvial conditions (i.e. distance from streams and rivers) drive variation both in taxonomic, functional and phylogenetic diversity, whereas the importance of commonly used temperature and moisture variables was notably lower. Therefore, our study demonstrates that addressing variables that may represent both resources as well as disturbances for vegetation should be addressed to better characterize and predict local diversity in arctic-alpine landscapes.

Poster 21

Effects of plant area index derived from Terrestrial Laser Scanning on microclimate temperature along a selective logging gradient in Borneo forest

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Changes in the structural characteristics of vegetation caused by selective logging have direct impacts on the energy exchange and functional attributes of forests, resulting in altered microclimates. In this study, we investigated how logging-induced changes in total plant surface area affected microclimate temperatures in tropical forest. We used Terrestrial Laser Scanner (TLS) to derive structural metrics over 16 forest plots (25 x 25 m) with a gradient in logging intensity. The plots are located in Sabah – Malaysian Borneo, in the Stability of Altered Forest Ecosystems (SAFE) Project. The TLS point clouds were used to calculate the Plant Area Index (PAI), which represents the amount of plant material allocated per ground unity for every plot. We monitored the air temperature at 15 cm above ground, every 15 minutes for a total period of 365 days, using microclimate probes located in the middle of each plot. Finally, we tested whether PAI derived from TLS point clouds could explain the variability of microclimate metrics such as mean, maximum, and minimum air temperature. We found that forests with high PAI have consistently lower average temperature and intra-daily variability, in comparison with forests with low PAI. In average, mean daily temperature decreased by 0.9 °C for each PAI unit. Nonetheless, PAI alone could capture 21% of the microclimate variability between plots, indicating that structural metrics accounting for the vertical distribution of vegetation are key for a comprehensive understanding on how logging disturbances affect energy dissipation within tropical forests.

Poster 22

Measurement network of soil temperature and moisture in urban parks – a case study from the city of Warsaw (CLIMPARK project)

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Vegetation regulates the urban climate in three ways: by intercepting incoming solar radiation (shading), through the process of evapotranspiration and by altering air movement and heat exchange. Therefore parks are treated as oasis of cold and moisture and their role in creating and mitigating climate grow during vegetation season.

The CLIMPARK project - The role of urban parks in modifying city climate and bioclimate today and in the future will be carried out in the years 2022-2024 in Warsaw, Poland. The main aims of CLIMPARK are to measure and precisely evaluate the impact of parks of different size, structure, age etc. on mitigating climate/bioclimate in their surroundings, but also to study the diversity of local climate and perceptible conditions inside the parks, due to different species composition and spatial arrangement. We will also focus on the reduction in exposure to thermal stress among park visitors and people living next to the parks.

We plan to create a network of meteorological measurements in six urban parks of different sizes (from 3.5 ha to c. 76 ha) in Warsaw. Measurements of standard meteorological elements (solar radiation, air temperature and humidity, wind speed and direction) as well as soil temperature and moisture will be carried out continuously for 24 months. Measurements will be also taken outside the parks, in built-up areas of different intensity. In the parks we intend to record in-situ in soil temperature (0-5 cm) depending on the type of vegetation (exposed lawns, lawns shaded by trees, thickets, areas close to water reservoirs) in the dominant topographic configurations. We will also analyze maps of land surface temperature (LST) calculated from satellite images, and the ground measurements will be used to validate them. We will perform these analyzes for the seasons and different soil moisture conditions.

Poster 23

Effects of growing season microclimate in broadleaved seedlings growth in Sweden

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Microclimatic gradients affect the individual vital rates and growth and, limit tree species distributions. Thus, to understand the influence of climate change on forest biodiversity in a broad sense, an important starting point is to get a good understanding of the effects of microclimate on trees distributions. Here, we investigated the effects of microclimate during the 2021 growing season on seedling's growth of the tree species Acer platanoides and Quercus robur. Using species distribution models, we modeled both realized and potential distribution of each species and life stages. For the transplant experiment, we selected 60 sites along the gradients of suitability that, according to the juvenile oaks distributions, were predicted to be: (i) suitable according to the potential distribution but unsuitable for realized distribution; (ii) suitable and, (iii) unsuitable in both models. The transplantation was carried out in May 2021, and at each site, we transplanted 18 seedlings, installed data loggers to record the temperature every 1 h, and recorded size. In September 2021, we measured stem length and, collected the logger's data. Using univariate analyses, we examined the differences of suitable sites microclimates and the relation between seedling's growth with microclimates variables. The monthly temperature averages are distinct between the different suitability sites. Sites that are suitable according to both models present higher temperatures than unsuitable sites. We found no difference between growth and different suitability sites for both species, however, the effects of microclimatic conditions on growth differed among species. For A. platanoides we did not find a clear pattern between growth and microclimate. On the other hand, for Q. robur, the growth is related to the maximum, minimum, and daily range temperatures. Our preliminary results suggest that, during the growing season, Q. robur has an optimum temperature for seedling's growth between 10 and 30oC.

Poster 24

Causal Inference of soil temperature dynamics as affected by plant diversity in a long-term grassland experiment

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Plant diversity is often suggested as an effective tool to stabilize ecosystems. While the relation between plant diversity and stability is well supported throughout the literature, the underlying mechanisms are still under discussion. A possible mechanism that we hypothesize to explain a big part of the observed stability increases is the effects of plant diversity on the soil temperature and the soil temperature dynamics. Since soil temperature drives many ecosystem processes, changes to its dynamic could provide an underlying mechanism for many other observed phenomena.

To gain further understanding of this dynamic, we aim to explore how temperature propagates through the system of different soil layers and how this dynamic is affected by plant diversity. Based on a multi-depth temperature data set collected at the Jena Experiment, a large grassland field site in the east of Germany, we analyze the heat flow of temperature above and below ground. With 18 years of high-resolution continuous data, we leverage Causal Inference methods to unravel underlying patterns. This set of methods aims to find causal directions in data, which we find essential to extract the truthful relations from our data, possibly veiled by correlation.

Poster 25

Fine-resolution snow model to simulate winter surface temperatures

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Winter surface temperatures can have important influences on ecosystem functioning, particularly influencing vegetation dynamics such as phenology and productivity. This is especially true in cold environments where seasonal snow cover controls a large part of spatial and temporal variation of surface temperatures. However, lack of in-situ measurements in cold regions and difficulties in simulating snow cover accurately have hindered broad-scale descriptions of winter surface temperatures. While recent modelling advances allow for detailed simulations of snowpack properties, these models are often heavy to run which makes their use challenging in microclimatic studies. Here, we present a microclimatic snow model which simulates spatial and temporal variation of snow cover at high spatial and temporal resolution and can further be coupled with a microclimatic model to quantify thermal conditions in winter. The model consists of a point-scale energy-balance model which simulates snow accumulation and melting throughout the winter. Point-scale estimates are then spatially distributed based on local topography and canopy characteristics. We compare the model simulations to field measurements of snow depth and snow water equivalent in several study areas in Finland to show the model performance in both tundra and boreal forest landscapes. Based on preliminary results, the model captures general temporal and spatial variations well although it does not simulate more detailed processes within the snowpack. We also combine the snow model with a microclimate model microclimf to simulate winter surface temperatures with unprecedented detail. These simulations are also compared to in-situ measurements of surface temperatures in boreal and tundra ecosystems. As these regions are experiencing rapid changes in winter climates and the cryosphere, this model provides new tools in helping us understand how the changes affect microclimates and the functioning of boreal and tundra ecosystems as a whole.

<u>Poster 26</u>

CurieuzeNeuzen in de Tuin

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For several years in a row, heat and drought records have tumbled one after the other. Our summers are getting hotter and drier, and we are increasingly affected by these extreme weather events. You've probably noticed it in your garden: dry patches appear in the lawn, or trees lose their leaves prematurely during a heat wave. But farmers and managers of nature reserves are also increasingly seeing the direct consequences of heat and drought.

'CurieuzeNeuzen in de Tuin' (or Curious Noses in the Garden) explores how we can better deal with the effects of increasingly hot and dry summers. How do we ensure that our garden remains cool during a heat wave? And how do we better arm our gardens, as well as our parks, fields and natural areas, against drought?

Answering these questions will require detailed mapping of heat and drought all over Flanders, but collecting so much data presents a challenge. For this reason, CurieuzeNeuzen has appealed to 5,000 citizen scientists for assistance.

'CurieuzeNeuzen in de Tuin' will yield an internationally unique dataset that will provide scientists with a much better understanding of how drought-prone our gardens, parks, natural and agricultural areas really are. The project is part of the international SoilTemp project, for which the CurieuzeNeuzen project will provide a considerable data injection into the SoilTemp database.

Here, results of the 2021 measurement campaign are presented, showing the strength of the sheer number of measuring points. This "big data" provides great statistical power, allowing us to more easily identify the factors responsible for heat and drought.

Poster 27

To thin or not to thin: that's the question!

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Climate change influences the way our forests are functioning, and may thereby threaten the provisioning of ecosystem services that are vital to our society. Increased tree mortality and decreasing growth trends due to climate change-related droughts have already been observed. Importantly, droughts are expected to increase in frequency, duration, and intensity in the future, thereby posing one of the largest threats to forest ecosystems in temperate Europe. Climate-smart forest management has been proposed as a drought alleviation strategy, with thinning as one of its main tools. Thinning decreases competition for nutrients and water, of which the latter is especially important during drought events. However, increasing thinning intensity will open up the tree canopy, which can alter temperature and soil moisture near the forest floor. This possible drawback of increased thinning on the forest microclimate is often overlooked in research, even though the microclimate is an ecosystem feature underlying forest biodiversity and many other forest ecosystem processes. Therefore, this research aims at understanding the relationship between climate-smart forest management and the drought response of trees, while also investigating the negative feedback of management on the microclimate. The focus is placed on the tree species pedunculate oak (Quercus robur) and beech (Fagus sylvatica), which are economically important for Flanders, and could potentially suffer from future drought stress. The study is being executed at two spatial scales, (i) a forest stand scale (Meerdaal and Sonian forest) and (ii) a regional scale (Flanders). Information on the forest microclimate at stand level is currently being gathered through in situ measurements by TMS-4 loggers, which measure temperature and soil moisture, and pitfall traps, which collect invertebrates such as woodlice whose distribution is affected by the taxon’s desiccation sensitivity.

Poster 28

Microclimate measurements as a baseline for a global study of plant invasions in cold environments

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Biodiversity of cold regions, both in high latitudes and altitudes, is increasingly threatened by anthropogenic factors such as climate change and biological invasions. In the presented study, we combine experimental and observational approaches to study the synergistic effects of both processes on species redistributions. We aim at predicting biological invasions under the conditions of future climatic and land-use changes to develop sound mitigation and management measures in these areas. This will be achieved by studying distributional shifts of selected alien and native expansive plant species along altitudinal and latitudinal gradients, their tolerance limits and ecological niches.

The study is performed in cold environments worldwide, using 50 selected study sites in polar (Arctic, Antarctic, and Subantarctic Islands) and alpine regions (tundra; Oceanic, Hemiboreal, Continental, and Subtropical climatic groups). To explore the effect of climate on species movements from lowland to mountains, within each site plots were established at three altitudes along one road or hiking trail leading across the elevation gradient. In addition, to study the effect of land use and human pressure, each latitudinal site contains one pair of permanent plots located at the roadside and in the undisturbed vegetation further from the road, giving six plots per site in total.

We study the patterns in soil temperatures and humidity over years and soil nutrient availability over vegetation season in connection with vegetation composition. A subset of most frequent alien and native expansive vascular plants are used as model species in chamber experiments to study their plasticity and reaction to different temperature regimes.

The project is part of the ongoing global project ASICS (ASsessing and mitigating the effects of climate change and biological Invasions on the spatial redistribution of biodiversity in Cold environmentS; https://www.coldregioninvasives.com/) supported within BiodivERsA in 2021-2024.

Poster 29

Distributions and management of the invasive Black wattle (Acacia mearnsii) under variable microclimates in the Eastern Cape Province, South Africa

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The black wattle's invasive expansion is a threat, with persistent drawdown of ground water and reducing biodiversity emerging as some of its adverse impacts in South Africa. Although the major instigators of its expansion are well known, with climate change-driven CO2 fertilisation and inappropriate human resource use practices emerging as some of the causes of its expansion, proper management of this phenomenon is undermined by lack informed intervention strategies. This lack is premised on its short-term's benefits by providing wide-ranging goods and services. These benefits are outweighed by adverse effects associated with its expansion. This study seeks to address the challenges and adverse impacts associated with the expansion of this species. We do this by using a case study-based investigative approach to (1) temporally spatialize its expansion and, (2) ascertain the adverse impacts of its expansion on the livelihoods of local communities in Hogsback and Matatiele in the Eastern Cape Province, South Africa and (3) providing recommendations on how this phenomenon can be managed. The method we used comprises an improvisation that includes a GIS-based mapping of this species' expansion and, the solicitation of information from key informants and relevantly selected stakeholders through focus group discussions. The results of this study point to periodic expansion of this species in tandem with cyclical variations in local climate and, policy-directed land use practices. The take home message from this study is that there is urgent need to adopt climate-friendly resource use practices that are guided by sound management strategies. Examples of how this can be accomplished include practical implementation of resource partitioning and appreciation of how problems can be turned into opportunities.

Poster 30

Climate change and macadamia production in Malawi

Emmanuel Zuza *(emmanuel.zuza@open.ac.uk)*

Climate change is predicted to profoundly affect crop production due to rising temperatures and altered precipitation regimes. We used an ensemble model approach for the first time in Malawi to determine the current and future suitability for macadamia (Macadamia integrifolia) production areas across the country in relationship to climate. The precipitation of the driest month and isothermality were the climatic variables that strongly influenced macadamia's suitability in Malawi. We found that these climatic requirements were fulfilled across many regions in Malawi under the current conditions. Our model suggests a decline in land suitable for macadamia production by −18% (17,015 km2) and −21.6% (20,414 km2) based on RCP 4.5 and RCP 8.5, respectively, with much of the suitability shifting to higher elevations and northwards. This means that some currently productive areas will become unproductive in the future, while current unproductive areas will become productive. Notably, suitable areas in Malawi will increase in the central and northern regions while the sourthen region is projected to lose most of its suitable areas (100%). Our study provides critical evidence about the potential negative impacts of climate change on the suitability of macadamia production in the country. We recommend developing area-specific adaptation strategies to build resilience in the macadamia sector in Malawi under climate change.

Poster 31

The influence of the weather patterns on the microclimatic conditions at the peatland - forest edge

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In the young glacial areas, peatlands are often habitat islands in the forest landscape. Their sizes vary, from vast areas to small kettleholes located in terrain depressions. Relatively few in-situ microclimatic studies have been carried out on peatlands, and its microclimatic impact on the surrounding areas is also poor understand. However, forest edges are characterized by different climate conditions, as shown by the numerous works carried out at the transition zones between clearcuts and forest interior.

The study site was a mid-forest small Sphagnum mire (ca. 6.0 ha) situated in the terrain depression at the border between a moraine hill and a sandur with a system of dunes. The mire is located in Poland, in a transitional temperate climate and is the only place in polish lowlands where glacial relict Betula nana occurs.

We have conducted transect microclimatic measurements (air temperature and humidity) across peatland and forest edges in the summer period, but under different weather patterns, i.e. radiation and rainy weather. We showed that the mire had a particular impact on the thermal conditions of the air in the zones directly adjacent to it, however, depending on the weather conditions, the strength and distance of these impacts were different. During rainy weather, the microclimate diversity was determined more by the species composition of the forest than by the distance from the mire.

More in-situ microclimatic research is needed to understand biotic-abiotic feedbacks in ecotone zones between peatlands and forests especially in the context of modeling processes in the forest edges.