
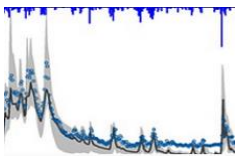
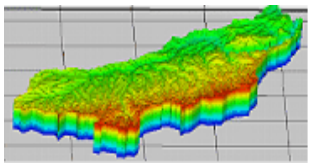
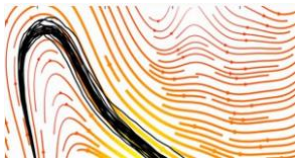

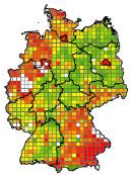

Poster abstracts

ModMonDay 2023

PP5.1 LandTrans

PP Co-Speakers: Sabine Attinger, Hans-Jörg Vogel

1.1 **Long-term dynamics of nitrogen export from European catchments**

Fanny Sarrazin, Tam Van Nguyen, Andreas Musolff, Pia Ebeling, Masooma Batool, Paromita Sarker, Yevheniia Anpilova, Jan Fleckenstein, Sabine Attinger, Rohini Kumar

Anthropogenic activities have severely altered the global nitrogen (N) cycle through the fixation of atmospheric N for the production of N fertilizers, the cultivation of N fixing crops, fossil fuel combustion, and the discharge of human and industrial wastewater into the environment. In this study, we investigate the long-term dynamics of N export from European river basins (Danube and Elbe) over the last 70 years, which is made possible by our recent development of novel gridded datasets of long-term N diffuse sources and point sources across Europe. We apply the mHM hydrological model coupled with the LandTrans mQM model, which accounts for possible N accumulation in the soil (biogeochemical legacy,) as well as in the subsurface (hydrological legacy). We quantify N export accounting for the uncertainties in input data and model parameters. Overall, we find a decreasing contribution of point sources to total N export over the study period, due to improvements in wastewater treatment. However, the use of further data would be needed to reduce the large uncertainties in the simulations. Through learning from the past N export dynamics, our study ultimately contributes to informing the development of future management strategies to reduce N levels below target values.

1.2 **BODIUM - a systemic approach to simulate soil functions in agricultural systems**

Sara König, Ulrich Weller, Julius Diel, Lucas Kangarajah, Thomas Reitz, Judith Rüschhoff, Leonard Franke, Ute Wollschläger, Hans-Jörg Vogel

We present our systemic soil model BODIUM with the aim to understand and predict long-term dynamics of agricultural management and climate change on soil functions. Mainly we are interested in the dynamics of production, water storage & filter, nutrient cycling, carbon storage and biological activity. Our systemic approach integrates various important processes in soil and at the soil-plant interface and their feedbacks, including two special features: (i) microbial processes are simulated explicitly including stoichiometric considerations and ii) soil structure is implemented in a dynamic way allowing to simulate the effects of tillage and interactions with other soil processes.BODIUM is implemented in a modular way such that new components and processes can be easily added, but also as a basis for smooth coupling with other models. BODIUM is developed in the framework of the

BonaRes project, but is also integral part of the LandTrans simulator. Thus, we would also like to discuss possible collaborations within the UFZ such as research ideas involving coupling of BODIUM with another UFZ model or extending BODIUM by other components based on your research.

1.3 **Modelling the effects of global change on soil functions in different land-use types**

Lucas Kanagarajah, Thomas Reitz, Martin Schädler, Franziska Taubert, Hans-Jörg Vogel, Ulrich Weller, Sara König

Global change drivers, including climate change and land-use intensification, pose threats to agricultural ecosystem biodiversity, impacting essential processes and functions. Process-based simulation models have emerged as powerful tools to understand complex microbiota-plant-soil interactions. This study is part of the GLIPMSE consortium, investigating global change impacts on soil functions in diverse land use types. The research focuses on the Global Change Experimental Facility (GCEF), which collects comprehensive data on plant physiology, soil nutrients, microbes, fauna, and structure. GCEF includes conventional/organic cropping, intensive/extensive meadows, and grazed pastures under current and simulated future-climate conditions. The poster presents initial modeling results for organic and conventional land-use systems using the BODIUM model. It also outlines future extensions of BODIUM to enhance predictive capabilities and explore global change effects on soil functions across diverse agricultural systems. The ongoing research contributes to the understanding of global change impacts, offering insights for sustainable land management practices and mitigation strategies in agricultural ecosystems.

1.4 **FINAM -- is not a model**

Stephan Thober, Martin Lange, Sebastian Müller, Thomas Fischer, Sara König, Jeisson Javier Leal Rojas, Matthias Kelbling

FINAM is an open-source, component-based model coupling framework for environmental models. It aims to enable bi-directional online couplings of models for different compartments such as geo-, hydro-, pedo-, and biosphere. Although it has been developed within LandTrans to couple environmental models, but FINAM is not limited to a specific application and can be applied in a wider range of contexts. It is written in the Python programming language, but can be used to couple models of different programming languages.

FINAM enables the integration of different components that handle data in multiple ways. All data exchange is in-memory ensuring efficient run times. It offers functionalities for consistent reading and writing of netCDF files, spatial data regridding, and uniform unit handling, among other features.

The most recent release is FINAM v.0.4, and additional information can be found at finam.pages.ufz.de. Upcoming updates will introduce statistical processing techniques like quantile-quantile mappings and on-the-fly statistics. Currently, FINAM is being used to establish a one-way coupling between high-resolution climate models and the mesoscale Hydrologic Model (mhm-ufz.org) as part of the DestinE initiative, which aims to construct a digital twin of Earth.

1.5 **Spatial Data Infrastructure**

Christian Schulz, Rebekka Lange, Jan Bumberger

Presentation of a system for storing and visualizing geospatial data, including interfaces for interopability and link to a metadata-cataloque.

1.6 **Effects of drought-induced forest dieback and alternative reforestation scenarios on water quality in rivers and reservoirs**

Rico Fischer/Gunnar Dressler, Hans Henniger, Andreas Musolff, Rohini Kumar, Christian Siebert, Oliver Lechtenfeld, Tom Shatwell, Karsten Rinke, Mufeng Chen, Mario Brauns, Karin Frank & Michael Rode

Climate change is a major challenge for forests across Germany. The increased frequency of drought events particularly threatens spruce-dominated forests which become more susceptible to pests such as the bark beetle. The Harz Mountains, which are dominated by spruce, have a particularly high rate of deforestation. This forest dieback harms the multifunctionality of landscapes in several respects by losing habitat for biodiversity, altering water and carbon cycles, and diminishing the retention of nutrients with negative implications for the water quality in adjacent streams and reservoir. Species-rich forests, in contrast, have a higher capacity to cope with the effects of drought and maintain their functions.

We will inform about the work of a cross-RU research initiative which aims to analyse the cascading effects of drought-induced forest dieback on nutrient export and water quality in streams and reservoirs with the Harz region as a case study. Special focus is on the implications of alternative reforestation scenarios which are under discussion among the forest managers. This will be achieved by modelling and investigating the complete effect chain from the forest growth via the transport of water and nutrients in the soil, the nutrient inflow in streams and reservoirs, till the performance of aquatic food webs which partly counteract these inflows by their nutrient uptake. For this purpose, established models of the UFZ will be coupled (forest: FORMIND, hydrology: mHM, water quality: mQM, instream food webs: MASTIFF). This makes the 'Harz forest dieback & water quality' project a promising use case for the application of the modular LandTrans model system.

The applied objectives of the Harz dieback project are 1.) to assess the implications of the forest dieback and following reforestation on the water quality in adjacent streams and the Rappbode reservoir for the coming years (relevant for the reservoir operators and drinking water suppliers); 2.) to investigate which of the reforestation scenarios under discussion facilitate a resilient forest growth by maintaining a high good water quality (relevant for the forest authorities); 3.) to test the transferability of the effect chains to other mountain forest regions in Germany by analyzing the influence of the landscape structural context.

1.7 **Modelling ecological and socio-economic impacts of grasslands**

Franziska Taubert, Sara König, Christian Klassert, Bern Klauer, Birgit Müller, Hans-Jörg Vogel

Almost 30% of Germany's agricultural area is permanent grassland. Its quality is strongly determined by the local environment (soil and weather) and land use of farmers whose decisions may be influenced by policy instruments acting at larger spatial and temporal scales. Here, we aim to develop an interdisciplinary modeling framework within LandTrans by creating a biophysical model system (incl. vegetation-, soil- and hydrological processes), whose output is then integrated with socio-economic / socio-ecological agent-based models that address the impact of policy instruments on farmer decisions.

1.8 **We need to talk! LandTrans: Coupling the modules FORMIND and mQM to help solving a pressing water quality problem**

Andreas Musolff, Franziska Taubert, Rico Fischer

Stakeholders in the Harz area are now facing potentially conflicting interests: Forest managers need a resilient reforestation strategy, reservoir managers need knowledge of future water quality evolution, and federal water agencies need to ensure good longer term chemical and ecological status – a multifunctional landscape problem. How is forest structure and forest state connected to nitrate in receiving surface waters and how will both evolve under a changing climate?
To address this question we aim to combine the strength of our mechanistic modelling approaches on vegetation, water quantity and water quality within the LandTrans framework.

PP5.2 Observation

PP Co-Speakers: Jian Peng, Steffen Zacharias

2.1 **Soil moisture times series and cosmic ray roving at the catchment scale within SwabianMOSES 2023**

Matteo Bauckholt, Peter Dietrich

Soil moisture measurements at different spatial resolutions are important to improve the understanding of soil water dynamics at catchment and landscape scales. Within the hydro-meteorological measurement campaign SwabianMOSES 2023 time-domain transmission soil moisture sensors and temperature sensors with custom-made logger systems will be used to measure time series of these soil state variables. The aim of these investigations is to provide data on physical soil properties used in a cross-disciplinary approach for a better understanding of hydro-meteorological extremes (such as high precipitation events and droughts) and modelling approaches. Each measurement site will consist of sensors at three depths, with two sensors at each depth. Logger systems will be installed at six different observation sites which are distributed across the whole campaign target area in the vicinity of the Swabian Jura in Germany. Decisions on the specific installation depths were made during the installation at the respective sites based on the constitution of the local soil profiles. All sensors will be installed within the upper 50cm below ground.
To monitore changes in root zone soil moisture at the field scale, CRNS measurements are conducted, using a stationary CRNS sensor at the KITcube main site. To obtain soil moisture data at the the catchment scale one cosmic ray detector will be used in a mobile roving mode by installing the sensor in a vehicle and collecting data at tracks around the Lindach catchment. These measurements will be conducted event-driven before and after heavy rain events.

2.2 **Airborne Detection of Sub-Surface Water by Cosmic-Ray Albedo Neutrons at TERENO sites**

Martin Schrön, C. Zengerle, L. Bannehr, S. Oswald, S. Zacharias, P. Dietrich

The method of Cosmic-Ray Neutron Sensing (CRNS) is already well established in the discliplines of near-surface hydrogeophysics. Neutron detectors passively count neutrons in air, which represent the average root-zone soil moisture in an area of several hectares. However, major issues of ground-based neutron sensing (e.g. with mobile detectors in a car: „Rover“) are inaccessible areas and local bias effects from, e.g., dry roads & structures. This work explores the frontiers of hydrogeophysics using airborne CRNS, which allows coverage of larger areas in shorter time. Potential advantages for assessing flood risk on-demand, optimizing spatial irrigation strategies, or estimating trafficability.

2.3 **Regional intensive monitoring of soil moisture in the 456 km² Selke catchment, Harz mountains**

Martin Schrön, Manuel Kreck, Lasse Hertle, Solveig Landmark, Sascha Oswald

The poster presents an ongoing field campaign in the Selke river catchment from June to Oct 2023. In the 456 km² area, observations from sensor 18 CRNS stations, hydrogravimetry, ground water wells, remote sensing are combined to obtain a holistic view on catchment hydrology and optimal samping strategies. It is intended to demonstrate the added value of such a large dataset for hydrological model improvement together with other groups. The data would also facilitate and validate novel upscaling techniques (from field to catchment scales) that are necessary for regional monitoring and modeling.

2.4 **Implementation of Cosmic Ray Neutron Sensing (CRNS) towards soil moisture products on the national scale**

Daniel Altdorff, Martin Schrön, Sascha Oswald, Hendrik Paasche, Steffen Zacharias, Ségolène Dega, Peter Dietrich, Solveig Landmark and Sabine Attinger

There is an increasing demand for root-zone soil moisture products at relevant hydrological scales for regional modeling. Stationary CRNS and mobile CRNS platforms could fill the gap of measurement scales. The poster presentes recent campaigns in the scope of MOSES, FESSTVal, DWD, and PP2, which were conducted on regional and national scales to monitor soil moisture by cars and trains. In combination with computational regionalization approaches, the spatiotemporal data products could be used to improve hydrological modeling in Germany.

2.5 **2-D in situ water screening based on the combination of fluorescence and UV/VIS spectrometry**

Tobias Goblirsch, Helko Borsdorf, Thomas Mayer, Stefanie Penzel

Global climate changes have a significant impact on the health of aquatic systems. Therefore, the protection of water bodies is omnipresent. To handle complex inland waters by data, a comprehensive water information database is necessary. To achieve this, a new type of water sensor system was developed. This innovative sensor system combines a new developed UV-Vis/fluorescence submersible sensor with a flexible data processing platform. The aim of these two features is that a large number of water quality parameters can be measured and processed directly in one sensor system. Using these advantages, the new developed UV-Vis/fluorescence submersible sensor can be used quickly and affordably in a wide range of different inland waters.

2.6 **Gridded Profile Soil Moisture through Artificial Intelligence**

Toni Schmidt, Martin Schrön, Jian Peng

Recent soil moisture products have not yet targeted profile soil moisture estimates derived from cosmic-ray neutron sensors (CRNS) despite their unique footprint. CRNS have a capability to integrate measurements over a volume of ~300 m in radius and ~30 cm in depth, surpassing other in-situ techniques. This extraordinary coverage presents a distinct advantage for gauging plant water availability, which provides valuable information for managing water resources, particularly in farming and land-use planning. To extend the sensor's benefits from station to raster scale, the combination of high-resolution remote sensing data with artificial intelligence models is being pursued. This can offer significant advantages in improving the vertical accuracy of satellite-based soil moisture products.

2.7 **A Sentinel-1 SAR-based global 1 km resolution soil moisture data product: algorithm and preliminary assessment**

Jian Peng, Almudena García-García, Toni Schmidt, Luis Samaniego, Sabine Attinger, Thomas Jagdhuber, Carsten Montzka, etc

High-resolution soil moisture data are essential for studying the complex interactions between the water, energy, and carbon cycles from local to global scales. For agricultural and hydrological applications, a 1 km global-scale soil moisture product is of great interest to the community. In this study, we propose a new dual-polarization algorithm (DPA) for soil moisture retrieval using C-band synthetic aperture radar (SAR) observations. Based on this algorithm, a Sentinel-1-based global-scale

soil moisture dataset with a spatial resolution of 1 km (S1-DPA) was generated. Specifically, using optical data as a proxy of vegetation water content, a semi-empirical forward model from soil moisture to backscattering was constructed and calibrated based on the relationship between Sentinel-1 SAR backscatter and SMAP (Soil Moisture Active and Passive) soil moisture product under different vegetation and soil texture conditions. With the calibrated forward model, soil moisture was estimated using the backscatter coefficients on VV and VH polarizations observed by Sentinel-1 C-band SAR in ascending and descending orbits. The S1- DPA soil moisture data product has the same temporal resolution as Sentinel-1, of 3-6 days for Europe and 6-12 days for other regions. It covers the global land surface and spans the period from 2016 to 2020, utilizing both daily ascending and descending data. The S1-DPA product was validated using ground measurements from the International Soil Moisture Network (ISMN). The results show that the S1-DPA product captures the spatial and temporal characteristics of in-situ soil moisture reasonably, with an overall median Pearson correlation of 0.372, bias of -0.003 m3/m3, RMSD (root mean squared difference with respect to in-situ measurements) of 0.105 m3/m3, and ubRMSD (unbiased root mean squared difference) of 0.076 m3/m3. The generated global 1 km soil moisture product has the potential to promote the application of high-resolution soil moisture data in the fields of hydrology, ecology, and meteorology.

2.8 **Continental heat storage: Current state and preliminary estimates with satellite remote sensing**

Francisco José Cuesta-Valero, Jian Peng

Increases in greenhouse gases alter the energy fluxes at the top of the atmosphere, causing the heating of the climate system that constitutes the greenhouse effect. This additional heat is then distributed among the oceans, the atmosphere, the cryosphere, and the continental surface and subsurface, changing the energy balance between the components of the climate system. Determining the Earth heat inventory provides the best metric to quantify climate change, since heat storage indicates the energy used to alter the behavior of the Earth's climate components.

Changes of heat-dependent processes near the continental surface are particularly relevant, as the vast majority of human activities and many natural services happen in the surface of the planet, such as agriculture or freshwater storage. Despite the importance of quantifying heat storage in the land subsurface, permafrost soils and inland water bodies, there was no comprehensive study analyzing the three components of continental heat storage.

Here, we show some of the results of an international collaboration that has assessed the available evidence of changes in heat content in the land subsurface, permafrost soils, and inland water bodies to quantify the total continental heat storage during the last sixty years. Furthermore, we indicate future research lines to reduce uncertainties and data gaps in order to improve the monitoring of continental heat storage.

2.9 **Geological latent heat storage - Development of a geophysical monitoring concept to map freeze-thaw cycles in aquifers**

Peter Jung, Ulrike Werban, Peter Dietrich

Latent heat storages (LHS) are based on the use of released latent heat during freezing of a storage medium. Frozen storage medium also serves as cold storage for cooling purposes. In the GEWS-project (Geologischer Eis-Wärme-Speicher = geological ice-heat-storage) the LHS-concept is transferred to a shallow aquifer instead of using buried tanks. As a test-plant, heat exchangers are installed in a quaternary aquifer. During several freeze-thaw-cycles, energetic efficiency, deformation, and geochemical and microbiological changes in the aquifer will be investigated.

UFZ's Department of Monitoring and Exploration Technologies focuses on the development of a simple geophysical monitoring concept for GEWS. The monitoring must be able to map the extent of frozen subsurface volume in order to assess the current thermal state. Borehole-GPR is sensitive to the strong change in electromagnetic properties of saturated soil during freezing. For imaging the position of the freeze-thaw boundary, reflection and crosshole measurements are numerically simulated. The ice body appears as reflector in crosshole, and as traveltime and amplitude change in transmission measurements. Field tests show occurring boreholel reflections that can superimpose relevant signals. The accuracy of velocity determination limits positioning accuracy to ~0,1m. Monitoring will begin with the start of operation of the test plant.

2.10 **CityCLIM: Next Generation City Climate Services Using Advanced Weather Models and Emerging Data Sources**

Christine Liang, Uta Koedel, Felix Schmidt, Claudia Schuetze, Peter Dietrich, CityCLIM Consortium

Europe's metropolitan areas are increasingly suffering from the effects of climate change, with urban heat islands and prolonged heat waves threatening the wellbeing of citizens. CityCLIM aims to develop a cloud-based platform that provides various weather and climate services specifically for metropolitan areas. City Climate Services based on advanced weather forecast models will be enhanced with data both from existing but insufficiently used sources, as well as emerging data sources, such as satellite data or data generated by Citizen Science approaches for Urban Climate Monitoring. Approaches will be implemented which will explore the potential of citizen science in terms of current and historical data collecting, data quality assessment, and evaluation of data products. In addition, the approach will also provide strategies for individual climate data use, and the derivation and evaluation of climate change adaptation actions in cities. CityCLIM will significantly contribute to delivering technologically advanced city climate services for citizens and city administrations to cope with urban heat islands. To make the envisaged weather and climate services as application-oriented as possible, the project will be carried out in close cooperation with four pilot cities: Karlsruhe in Germany, the city of Luxembourg, Valencia in Spain, and Thessaloniki in Greece.

2.11 **Reproducible quality control of time series data with SaQC**

David Schäfer, Bert Palm, Peter Lünenschloß, Lennart Schmidt, Jan Bumberger

Environmental sensor networks generate increasingly large volumes of time series data, offering significant potential for enhancing our understanding of complex spatiotemporal environmental processes. However, this growth also presents new challenges. One major challenge is the error-prone nature of sensor data acquisition, which can introduce
disturbances and anomalies into the actual environmental signal. Most applications that utilize such data, whether
for data analysis, input to numerical models, or modern data science approaches, typically require data that meets a certain quality standard.

To achieve high-quality data products, it is crucial to thoroughly assess the quality of a dataset through quality control. A common approach for time series data is to annotate individual observations with quality labels, which convey information
about their reliability. This enables downstream users and applications to make informed decisions about whether the dataset as a whole, or specific parts of it, are suitable for their intended use.

Unfortunately, quality control for time series data is a complex and time-consuming task that is often undervalued,
frequently overlooked and carried out with insufficient rigor. The System for automated Quality Control (SaQC) presented here addresses this challenge. SaQC offers user interfaces tailored to different audiences, catering to both scientific practitioners with limited software development capabilities and trained programmers. It includes a growing collection of generic algorithms for detecting various anomalies and processing data using resampling, aggregation, and data modeling techniques. One unique feature of SaQC is its innovative approach to storing runtime process information, which, when
combined with its flexible quality annotation mechanism, allows for the inclusion of fine-grained provenance information in the quality labels, facilitating full reproducibility of the system's output.

SaQC is currently being successfully utilized in fully automated data flows for large environmental observatories on a daily basis. We highlight a use cases from the TERENO Network, which demonstrates how reproducible automated quality control can be integrated into real-world, large-scale data processing workflows to provide near real-time environmental sensor data to data users, stakeholders, and decision-makers.

2.12 **Research Data Management**

Ronny Gey, RDM Team

The research data management team at UFZ offers services regarding data management, quality, storage, and publication for UFZ scientists.

PP5.3 SMART Methodology – Modeling, Data, Data Science

PP Co-Speakers: Thorsten Wiegand, Jakob Zscheischler

3.1 **Reproducing alpine treeline ecotones in an agent-based model: the STEM**

Lukas Flinspach, Thorsten Wiegand, Maaike Bader (Universität Marburg)

Alpine treeline ecotones are characteristic and widespread vegetation boundaries. Due to their global correlation to temperature, they are an interesting target for climate change research.
At a local scale, characteristic spatial patterns can be observed at the ecotones that serve to distinguish different treeline forms. These patterns include transitions of tree height, density, and clustering. They are likely related to the most limiting processes at the site, as different treeline forms respond differently to climate change. A better understanding of these relationships would help us predict future treeline dynamics.
We have developed an agent-based model, the Spatial Treeline Ecotone Model (STEM), to investigate these relationships. STEM simulates a tree population under the influence of elevation-dependent gradients in demographic processes.
Additionally, we have developed analytical approaches to quantify the spatial patterns in both simulated and field-sampled treeline data, and classify them into treeline forms.
In the future development of the model, we will incorporate more environment-driven demographic rates. STEM may also serve other researchers as a tool to test hypotheses on pattern formation at alpine treelines world-wide.

3.2 **Linking multiple stressor research with SMART ecological modelling**

Karin Frank, Sabine Attinger, Volker Grimm, Martin Schrön, Peter Dietrich, Steffen Zacharias, Olaf Kolditz, Susanne Dunker, Markus Weitere & Mechthild Schmitt-Jansen

Landscapes are under increasing pressure from multiple stressors associated with e.g. the ongoing climate change or land management activities. For identifying sustainable development paths which sustain the multifunctionality of landscapes, a new generation of terrestrial environmental models. On the one hand, these models have to be SMART, i.e. Scalable, Mechanistically sound, of Adjusted complexity, Robustly predictive, and regionally Transferable. On the other hand, they have to adequately incorporate the effects of the multitude of relevant stressors which usually affect the environmental system via specific processes on specific levels of organization such that cross-scale combined effects can emerge. In connection with ecological systems, this comes along with a particular challenge, as these systems do not respond linearly to external changes, but have a certain coping capacity. These systems can withstand external changes to a certain extent, but collapse if these changes occur too often or at a too large spatial scale, last too long, or are too intensive. Accordingly, there is an intensive literature debate on what factors have to be incorporated for causally sound predictions of multiple stressor effects on ecological systems.

We will present a methodology for linking multiple stressor research with SMART ecological modelling by combining different fields of special expertise existing in RU ModMon: (i) knowledge of the key importance of (spatial and organizational) transfer functions for SMART modeling, (ii) benefits from next-generation individual-based ecological models which relate all individual-level processes to general (and, thus, regionally transferable) physiological principles, and (iii) knowledge of a checklist

of individual-level processes influencing the coping capacity of ecological systems to external environmental stressors. This it the outcome of two collaborative initiatives: a within-ModMon working group on the SMART modeling strategy and a cross-RU working group on “multiple stressor research”.

3.3 **Non-parametric upscaling of agent-based models**

Thorsten Wiegand

The problem of scaling up from tractable, small-scale observations and experiments to prediction of large-scale patterns is one of the central problems in ecology. I present a general non-parametric framework to upscale spatially-explicit simulation models to predict landscape scale dynamics. The idea is to design a state space, defined by the important state variables of a small-scale model, and to divide it into a finite number of discrete states. Similarly, the external drivers are divided into a finite number of discrete conditions. For a given time interval, transition probabilities between states are then tallied by monitoring extensive simulation runs of the small-scale model. If the space of external drivers is not too high, the original small-scale model can be replaced by the transition probability matrices. The resulting transition matrices can be analysed with Markov chain and network analysis to gain insights into the dynamics of the underlying detailed model. The approach is illustrated by an individual-based model simulating the dynamics of semiarid grass steppes in Patagonia under alternative grazing management, to identify pathways of degradation and rehabilitation, as well as critical grazing thresholds and early-warning vegetation states to guide sustainable grazing management in these steppes.

3.4 **Mapping Amazon Forest Productivity by Fusing GEDI Lidar Waveforms with an Individual-Based Forest Model**

Luise Bauer, Nikolai Knapp, Andreas Huth, Rico Fischer

The Amazon rainforest plays an important role in the global carbon cycle. However, due to its structural complexity, current estimates of its carbon dynamics are very imprecise. The aim of this study was to determine the forest productivity and carbon balance of the Amazon, particularly considering the role of canopy height complexity. Recent satellite missions have measured canopy height variability in great detail over large areas. Forest models are able to transform these measurements into carbon dynamics. For this purpose, about 110 million lidar waveforms from NASA’s GEDI mission (footprint diameters of ~25 m each) were analyzed over the entire Amazon ecoregion and then integrated into the forest model FORMIND. With this model–data fusion, we found that the total gross primary productivity (GPP) of the Amazon rainforest was 11.4 Pg C a−1 (average: 21.1 Mg C ha−1 a−1) with lowest values in the Arc of Deforestation region. For old-growth forests, the GPP varied between 15 and 45 Mg C ha−1 a−1. At the same time, we found a correlation between the canopy height complexity and GPP of old-growth forests. Forest productivity was found to be higher (between 25 and 45 Mg C ha−1 a−1) when canopy height complexity was low and lower (10–25 Mg C ha−1 a−1) when canopy height complexity was high. Furthermore, the net ecosystem exchange (NEE) of the Amazon rainforest was determined. The total carbon balance of the Amazon ecoregion was found to be −0.1 Pg C a−1, with the highest values in the Amazon Basin between both the Rio Negro and Solimões rivers. This model–data fusion reassessed the carbon uptake of the Amazon rainforest based on the latest canopy structure measurements provided by the GEDI mission in combination with a forest model and found a neutral carbon balance. This knowledge may be critical for the determination of global carbon emission limits to mitigate global warming.

3.5 **Utilising the coupled approach of GRASSMIND and PROSAIL models to simulate remote sensing signals from variably managed grasslands**

Maksim Iakunin, Daniel Doktor, Franziska Taubert, Reimund Goss, Severin Sasso, Hannes Feilhauer, Sylvia Haider, Christiane Roscherx

Cost-effective, thorough data-gathering techniques can enhance our understanding of grassland biodiversity. The integration of the grassland model GRASSMIND and the radiative transfer model PROSAIL is proposed. This combination captures variations in grassland traits under different management practices and enables remote sensing detections.

GRASSMIND adjusts influences on grassland dynamics, including cutting events, fertilization, weather data, and soil qualities. PROSAIL predicts canopy reflectance based on leaf biochemical properties and community structure.

This approach enables large-scale data gathering on important grassland attributes, improving our knowledge of biodiversity, management practices, remote sensing signals, and environmental factors.

Extensive plant trait sampling results were paired with remote sensing measurements in diverse grassland communities. Data on plant height, leaf area index, weight, pigment concentrations, and hyperspectral observations were collected from grasslands at three different sites.

We can better understand ecological processes and management impacts by combining terrestrial and satellite data. Details on integrating GRASSMIND and PROSAIL models and their parameterization and validation are discussed.

3.6 **Deep learning integrated scale conversion and pedo-transfer function estimation to avoid potential errors in cross-scale parameter transfer**

Peijun Li, Yuanyuan Zha, Yonggen Zhang, Chak-Hau Michael Tso, Luis Samaniego, Jian Peng

Pedo-transfer functions (PTFs) relate soil basic properties to a wide range of parameters that are essential to model soil hydrological processes, for example soil hydraulic parameters. Combining PTFs and physical models is a powerful strategy allowing the use of soil basic properties for the generalization of large-scale modeling. However, since the spatial scales of soil hydraulic parameters and soil basic properties are often not identical, cross-scale parameter transfer is required, which can be a significant source of errors. Here we develop an approach that avoids the potential errors in cross-scale parameter transfer. The approach uses the convolutional neural network as a cross-scale parameter transfer to directly map soil basic properties to soil hydraulic parameters at target spatial scales. To estimate the CNN-based cross-scale parameter transfer, the CNN and soil-water model are integrated, and the performance of the two different estimation frameworks are investigated. Both synthetical and real-world results around the conterminous United States (CONUS) indicate that in general the one framework is preferred. The CNN-based integrated model successfully reduces potential errors in cross-scale parameter transfer and can be applied to other areas lacking information on parameters or observations. Besides, discrepancies remain between publicly available soil hydraulic parameter datasets and model-adapted ones inverted from the observations. The proposed method can be extended to improve parameter estimation in Earth system models and enhance our understanding of key hydrological processes.

3.7 **POLAR MOSES - Developing cross-compartment strategies investigating the dynamic behaviour of greenhouse gas emissions and influencing factors in arctic environments**

Claudia Schütze, Peter Dietrich, Uta Ködel, Martin Schrön, Philipp Fischer (AWI)

The dynamics of greenhouse gas (GHG) emissions in Arctic regions are strongly influenced by global change. There is still a knowledge gap concerning the spatial and temporal variability of GHG emissions and influencing factors in arctic environments. Especially the development of adapted monitoring methods that link point scale measurements with remote sensing products on the landscape level is still required. It is required that cross-compartment monitoring approaches are being tested, evaluated and applied within the framework of the Helmholtz cross-center research infrastructure MOSES – Modular Observation Solutions for Earth Systems. With the hierarchical approach the main research questions are addressed: (1) What are the contributions of each compartment to the landscape-level GHG fluxes? (2) Do the GHG fluxes of the different compartments show similar responses to varying meteorological and near-surface conditions? (3) What are the main controlling factors for landscape-level GHG fluxes? For the qualitative characterization of the spatial heterogeneity of GHG emissions, the focus is on mobile OP-FTIR systems. Geophysical methods are used to investigate near-surface structures and processes that influence the dynamics of the emissions. The long-term installation of a CRNS (Cosmic Ray Neutron Sensing) monitoring system will contribute to the evaluation and validation of satellite-based soil moisture measurements.

3.8 **Enhancing environmental sensor data quality control with graph neural networks**

Timo Houben, Elżbieta Lasota, Timo Houben, Julius Polz, Christian Chwala, Lennart Schmidt, David Schäfer, and Jan Bumberger

Time series quality control (QC) from multiple spatial, irregularly distributed sensors is a challenging task, as it requires the simultaneous integration and analysis of observations from sparse neighboring sensors and consecutive time steps. Manual QC is often time- and labour- expensive and requires expert knowledge, which introduces subjectivity and limits reproducibility. Therefore, automatic, accurate, and robust QC solutions are in high demand.
In this study, we present a novel approach for the quality control of time series data from multiple spatial, irregularly distributed sensors using graph neural networks (GNNs). Although we applied our method to commercial microwave link attenuation data collected from a network in Germany, our solution aims to be generic with respect to the number and type of sensors. The proposed approach involves the use of an GNN architecture combined with an LSTM, where the GNN is used to model the spatial relationships between the sensors.
While our model shows promising results in initial tests, further research is needed to fully evaluate its effectiveness and to demonstrate its potential in a wider range of environmental applications. Eventually, our solution will allow us to further foster the observational basis of our understanding of the natural environment.

3.9 **OpenWorkFlow – Contribution to Open Science**

Olaf Kolditz

The OpenWorkFlow concept (OWF) was developed for the implementation of the different requirements for near and far models of deep geological repositories and especially their combinations. The generic workflow concept consists of ensuring continuous data and model flows starting with data integration from different sources for model building, the availability of suitable

simulation tools with subsequent data analysis (including support of virtual reality methods). The goals of the analysis are, for example, improved process understanding, system optimisation, experimental and monitoring design as well as support for planning tasks. An important element of the workflows in knowledge transfer via open source codes and interfaces to ensure transparency and independent further development - hence the concept is called OpenWorkFlow.

PP5.4 TiM4Land

PP Co-Speakers: Franziska Taubert, Daniel Doktor

4.1 **Developing a grassland dynamics metamodel: impact of management strategies and climate extremes.**

Johanna Eichler, Franziska Taubert

4.2 **Grassland Biodiversity Dynamics**

Thomas Banitz, Franziska Taubert

The poster presents the state of our work on a prototype digital twin of grassland biodiversity dynamics within the EU-funded project BioDT (https://biodt.eu/). While productivity is typically the focus of grassland site management, biodiversity does not necessarily coincide with high productivity. However, both are important for long-term feed and bioenergy supply, food security, and the diversity of other trophic levels (e.g. pollinators). We therefore investigate how different climate change scenarios, soil conditions and management regimes affect grassland biodiversity and productivity. To this end, we use GRASSMIND, an individual-based, mechanistic ecological model. For a given grassland site, GRASSMIND explicitly simulates the processes that let biodiversity dynamics emerge: individual plants can establish, grow and die. Starting with long-term grassland observations from the GCEF site, we are developing the model further and embedding it in a digital twin architecture. The latter includes high-performance computing, regular updates of input or observation data, and user-specific predictions for various climate and management scenarios.

4.3 **Honey bee performance in Germany - towards a Digital Twin prototype**

Jürgen Groeneveld, Tuomas Rossi, Tomas Martinovic, Volker Grimm

Honey bees (Apis mellifera) provide important services by producing honey and pollinating commercial crops but also a wide range of wild flowers. Therefore, honey bees contribute to diversity but also rely to some extent on diverse landscapes, since bees depend on the continuous provision of nectar and pollen in particular in times when the mass flowering crops (e.g. oil seed rape) are not available. Honey bees face multiple stressors such as intensive agriculture, diseases and temporal limitation in nectar and pollen supply. Digital Twin applications can help to assess the quality of a given landscape for honey bee performance and honey production. Such a Digital Twin is presented in this presentation. Freely accessible land use data, weather data and beekeeping regimes drive the open source simulation model BEEHAVE which can be calibrated by stock weight data. Using a HPC facility we can run the model for thousands of locations. Doing so we are producing performance maps for honey bees for Germany. We have established a workflow and have produced prototype maps. In the next step we need to calibrte the BEEHAVE model using a monitoring network.

4.4 **Detecting tree species-specific forest health anomalies**

Maximilian Lange, Sebastian Preidl, Anne Reichmuth, Daniel Doktor

Large areas of Europe have been repeatedly afflicted by severe droughts that heavily increased stress to forests. Stressed trees were not only suffering from direct drought impacts such as water stress or heat, but were also more susceptible to other stress agents and calamities. Monitoring vulnerable forests is crucial to support forest management in early forest stress detection. However, most remote

sensing studies dealing with forest condition are either not species-specific, not accounting for morphological and climatic conditions across different regions or not considering natural variations in phenology. Here, we extract species-specific reflectance time series separately for seven natural regions covering Germany for 2016-2022, representing the range of variation in reflectances of the dominant tree species in German forests. Their distribution across temporal and spectral dimension is used as reference to detect forest condition anomalies: We calculated a similarity metric, further called forest condition anomaly index (FCA), between each observation and the respective measurements within the reference time series, also considering natural temporal deviations caused by phenology. The FCA shows patterns related to fires, storms and insect infestations. Consequently, it can be used to detect forest disturbances or linked with vegetation models to assess e.g. forest biomass or carbon flux.

4.5 **Early detection of forest-damaging insects based on their species-specific volatiles**

Robby Rynek, Thomas Mayer, Helko Borsdorf

Forest-damaging insects such as the European spruce bark beetle (Ips typographus) can have severe negative impacts on forest ecosystems, ranging from the infestation of individual weakened trees to the destruction of entire forest areas. Until now, monitoring of this pest has relied on trapping with attractants and visual inspection for bore dust at the base of trees. These labor-intensive and time-consuming methods often miss individual infested trees, which can lead to rapidly spreading infestations, resulting in economic and environmental damage.
The aim of this project is to develop an analytical tool to detect species-specific volatiles of forest pests directly in the field using ion mobility spectrometry. Experiments will be carried out to identify the species-specific volatiles at different stages of development and finally to detect and quantify them in the complex matrix of forest air. Ultimately, the analytical tool developed should enable foresters to identify infested areas at an early stage and take appropriate action. The early detection of infested trees or areas can consequently reduce the amount of damaged wood, leading to the reduction in CO2 release and ensure CO2 fixation in the healthy forest stand.

4.6 **Assessing impacts of agricultural practices on instream food webs and water quality through innovatively linking remote sensing and hydro-ecological modelling**

Karin Frank, Laura Meier, Devanshi Pathak, Ulrike Scharfenberger, Olaf Büttner, Mechthild Schmitt-Jansen, Rohini Kumar, Andreas Musolff, Dietrich Borchardt, Volker Grimm, Markus Weitere & Mario Brauns

Running waters such as small rivers and streams are facing increasing pressure from multiple stressors from various sources, e.g. climate change or land management activities in the catchment. Of particular relevance are agricultural practices which can affect the running waters through changes in the riparian vegetation or pollution with agrochemicals (esp. fertilizers, pesticides). This does not only change the water chemistry, but also the functioning of the instream food webs which markedly contribute to water quality by up-taking nutrients or controlling the growth of biofilms and thus eutrophication.
Understanding and predicting multiple stressor effects on instream food webs and their water quality control come along with challenges: (i) there is an ongoing literature debate on ecological factors to be considered for improving the forecast, (ii) river streams are exposed to integral pressures from agrochemicals in the entire catchment because of their transport which are applied in a crop-specific way, and (iii) timing and frequency of stressor occurrence strongly influence their ecological effect.

We inform about two cross-RU (RU5, RU2, RU3) research initiatives which jointly allow to tackle these challenges. The first initiative is OperaSOS aiming at the development of a 'Land Use Intensity Index for Streams' (LUIS-index) for determining the integral pressure from agrochemicals on a river reach. This index results from innovatively linking land use classification maps from remote sensing with crop-specific standard application regimes of agrochemicals (esp. pesticides), catchment data and connectivity modeling. The second initiative aims at linking this information to the hydro-ecological model MASTIFF which allows cross-scale analyses of multiple stressor effect on the functioning of instream food webs.

4.7 **Can extensive grassland management pay off for farmers? A sensitivity analysis of grassland systems under climate change**

Julia Kunkel, Jürgen Groeneveld, Birgit Müller

Climate change is expected to increase the frequency and severity of droughts in central Europe, affecting the quantity and quality of grassland yields and thus farmers' incomes. This may lead to an adaptation of farmers' management behaviour towards less intensive farming in order to increase their resilience to drought. Understanding these dynamics is crucial for designing appropriate policy instruments to conserve grasslands without unintended side effects. Social-ecological models are an appropriate tool to study this. However, there is a lack of long-term grassland data to disentangle climate and management effects on yield quantity and quality, which hinders the parameterisation of such a model.

To this end, we have built a semi-empirical grassland model, combined with sensitivity analysis tools, to show under what circumstances extensive grassland management pays off from a farmer's point of view. The results will help us to identify our data needs and to discuss them with experts in order to further develop our social-ecological model, which can then be used to identify appropriate policy instruments, such as payments for ecosystem services or support for drought insurance, that can support the transformation processes needed under climate change, even with limited empirical data.

4.8 **Risk or opportunity: How does financial and natural insurance interact to tackle weather-related damages in agriculture**

Leonore Jungandreas, Martin Quaas, Jian Peng

Agriculture is significantly exposed to risk due to climate change. Especially extreme weather events such as drought, heat, and extreme precipitation threaten yields and increase yield variability (IPCC Special Report on climate change and land).

The economic consequences for farmers of increasing adverse weather events can be tackled by financial insurance. However, land management practices themselves influence climate and weather conditions, especially on a local or regional scale. Therefore, by choosing specific land management practices, farmers can actively (maybe positively) influence the probability and/or the extent of extreme weather events such as droughts, heat waves, or extreme precipitation events. Hence, such "natural or self-insurance" can potentially reduce farmers' risk of yield loss and variability while simultaneously conserving and improving the ecosystem services of farmlands.

But how do financial and self-insuring systems interact? How can we close this feedback loop?

4.9 **Prediction of microbial activity and pesticide degradation in soils using remote and proximal sensing technologies**

Ulrike Werban, Marie Uksa, Lukas Y Wick, Anja Miltner

Can we use digital field observation data to predict soil microbial activities and the fate of pesticides on the field scale?
Using machine learning, potential alkaline phosphomonoesterase activities in soil can be similarly well predicted either by soil properties or remote and proximal sensing data.

4.10 **Natura 2000 areas under climate change: Effects of tree species distribution shifts**

Anne Reichmuth, Ingolf Kühn, Andreas Schmidt, Daniel Doktor

The climate crisis leads to a change in forest tree species distributions, favouring most likely heat and drought tolerant species. As a consequence, many forest sites across Europe will become unsuitable for drought sensitive species. The combination of climate change and conservation goals of Natura2000 forest habitat types will lead to severe conflicts in conservation and forestry. The concept of “no deterioration” in article 6 of the Habitats Directive supports a static conservation of the prevalent flora and fauna. In those areas forestry is oriented towards conservation of natural forest habitat types. Especially areas with reduced silvicultural activities or strict silvicultural requirements, such as Natura 2000 sites, are prone to a long forest conversion process towards more suitable tree species. As forestry is based on long-term life cycles, this development will impact forest condition, forest cover, silviculture and conservation negatively. The Natura2000 legislation is under pressure.

This study aims at analysing (1) the changes of future tree species ranges in Europe, (2) how severe changes will impact current natural forest habitat types of Natura 2000 sites and (3) which new tree species might be present in future climate scenarios. We selected a combination of generalised additive models, generalised linear models and boosted regression trees for the modelling process. As model input serve four preselected bio-climatic variables from a total of 26 bio-climatic variables, derived from EURO-CORDEX CMIP5 climate simulations for 1971-2098 for IPCC’s representative concentration pathways 2.6, 4.5 and 8.5. JRC soil characteristics and JRC European tree species data serve as additional input variables. Potential tree species ranges with 1km spatial resolution as model outcome is compared to current definition of natural forest habitat types of Natura 2000 sites. This allows conclusions about their potential future occurrence and endangered static protection state. Most tree species reveals a severe decline of suitable ranges in all RCP scenarios and range shift towards polwards regions and higher elevations. As a consequence protection goals of forest Natura 2000 areas are at stake.

PP5.5 TiM4Water

PP Co-Speakers: Thomas Kalbacher, Luis Samaniego

5.1 **A new satellite-based product for studying land-atmosphere interactions**

Almudena García-García, Jian Peng

Improving our understanding of the energy and water exchanges between the land surface and the lower atmosphere (i.e. land-atmosphere interactions), and how climate change may affect them, is crucial to analyze changes in temperature and precipitation extremes. Observations of energy and water fluxes at the land surface are typically retrieved from the eddy covariance method, which presents limitations related to spatial and temporal gaps, and the non-closure of the energy and water balances. Here, we aim to improve the spatial coverage of land-atmosphere interactions data ensuring the energy and water balance closure by exploring the combination of remote sensing data and a physical-based model. The High resOlution Land Atmosphere Parameters from Space (HOLAPS) framework is a one dimensional modelling framework that solves the energy and water balance at the land surface using remote sensing data and reanalysis products as forcings. We used HOLAPS to produce hourly estimates of energy and water fluxes over Europe at 5km resolution. Preliminary results from the evaluation of HOLAPS outputs show a moderate improvement in HOLAPS latent heat flux estimates against energy-balance corrected eddy covariance measurements in comparison with other products that solve the energy and water balance equations, such as the ERA5Land product. These estimates can have several applications for water and agricultural management.

5.2 **Transpiration in forest ecosystems based on deep learning and sap flow observations**

Marco Hannemann, Almudena García-García, Jian Peng

Transpiration (T), the component of evaporation (E) controlled by vegetation, dominates terrestrial Evaporation, but measurements are highly uncertain. In the light of the importance of evaporation for studying the terrestrial water cycle, hydro-climatic extremes such as droughts and heatwaves and land-atmospheric interactions, there is a strong demand on novel approaches to reliably estimate T. Currently available approaches to estimate T mostly rely on its relationship with photosynthesis, but parameterizing this relationship is difficult and estimates of T strongly disagree among each other in terms of magnitude. Moreover, in-situ measurements are scarce and and evaporation cannot be measured directly from space. We developed a hybrid Priestley-Taylor (PT) model using Deep Learning to learn the relationship between T and state variables such as soil moisture, vapor pressure deficit and the fraction of photosynthetic active radiation for different plant functional types (PFTs). We use globally available variables from reanalysis and remote sensing data as forcing to train an artificial neural network on the PT-coefficient α obtained by inverting the PT model on sap flow based ecosystem T. In this way, we can predict Transpiration at local scales independently from hard-to-obtain fluxes like E or vegetation parameters such as stomatal conductance. We evaluate our algorithm against T estimates from flux partitioning methods based on water use efficiency at eddy covariance sites for different PFTs and regions. Also, we compare our estimates with other available products of transpiration like GLEAM, PML-V2 and ERA5-Land. Preliminary results of this research showed that the developed model can learn the relationship between T and few influencing variables, without incorporating variables such as net radiation or GPP. Our findings contribute to dissolving the scarcity of T estimates in forest ecosystems based on actual observations. Future work is needed to apply our method to the larger scale for studying spatial patterns of T, e.g. across the European continent.

5.3 **MOSES ELBE CAMPAIGN 2023: Fate of Environmental Chemicals, Microplastic and Nutrients**

Ute Weber, Werner Brack, Annika Jahnke, Norbert Kamjunke

Germany's watercourses, such as the Elbe, are polluted by external inputs from industry, agriculture and wastewater treatment plants. This pollution can fluctuate over the course of the river - also because the input substances are subject to degradation processes. In a joint measurement campaign, researchers from several Helmholtz centers analyze how environmental chemicals, nano- and microplastic particles and nutrients enter the Elbe and then the sea, and how they are degraded and changed along the way. This year's Elbe cruise as part of the MOSES research initiative begins in the Czech Republic at the end of June and ends in the German Bight in mid-September. Prof. Werner Brack is responsible for the studies on environmental chemicals, which comprise more than 600 substances, including pharmaceutical residues, endocrine disruptors, preservatives, PFAS, pesticides, industrial chemicals and surfactants. Prof. Annika Jahnke focuses on the transport and distribution of nano- and microplastics and chemicals associated with them, such as plasticizers or UV stabilizers. A team coordinated by Nobert Kamjunke measures the concentrations of nutrients such as nitrate, phosphate, ammonium or silicon as well as organic compounds and determines the nutrient uptake by algae. With this poster we would like to invite discussion on how this Elbe-focused research can be integrated more strongly into the catchment area in the future. Current activities are e.g., the "Zero Pollution Initiative".

5.4 **KONATES - Design and pilot plant test operation for the use of ATES plants in contaminated aquifers - component for a future de-carbonized campus**

Diana Altendorf, Maximilian Dörnbrack, Haibing Shao, Holger Weiß

Within the KONATES project, an Aquifer Thermal Energy Storage (ATES) system is planned in the scientific park of Leipzig, where the groundwater is contaminated with chlorinated volatile organic compounds (Cl-VOCs). Operating cyclically with a two-well system, the planned ATES system will inject heated water up to 80 °C. Compared to ATES systems operating at lower temperatures, this has a more significant influence on the chemical composition of the groundwater. Therefore, the study examines the hydrochemical and biological interactions that occur in the extraction and injection wells, as well as in the aboveground system. Thus, in the aboveground treatment of groundwater, the Cl-VOCs will be removed by using an on-site regenerable zeolite absorber (Fe-zeolite). To satisfy the regulatory requirements and facilitate the understanding of the environmental impacts of these kind of operation, a 3D numerical model has been constructed, simulating both hydraulic and heat transport processes in the aquifer. The model is capable of predicting the propagation of the thermal plume in response to different design of injection temperature and flow rate. By optimizing a remediation benefit through ATES operation, it is possible to enhance urban energy management's carbon footprint.

5.5 **Balancing Local Water Demand in Apple Production and Mesoscale Water Availability: Bridging Research and Practice**

Thomas Ohnemus, Simon Paasch, Hannes Mollenhauer

Subtitle: "Enhancing Water Consumption Modelling for Sustainable Apple Agriculture and Assessing Regional Water Supply"

This work aims to juxtapose water requirements in apple production at the local level with mesoscale water availability. Thus, the key aspects are the optimization of water management in apple orchards and the assessment of regional water supply. For apple agriculture, field instrumentation and

meteorological sensors are employed in apple cultivation areas in Central Germany (Saxony, Saxony-Anhalt, Thuringia). The collected data drives water consumption modeling, incorporating a detailed radiation model specifically tailored for apple cultivation. This novel approach fills a gap in available models and provides practical insights for efficient irrigation strategies in the apple industry. Simultaneously, the research addresses regional water supply by conducting an extensive review of mesoscale water balance models. Collaborating with water supply companies, suitable models are selected to meet practical requirements, improving planning certainty. This crucial step facilitates the transfer of research outcomes into practical applications, benefiting both apple production and regional water supply management. By integrating advanced modeling techniques and practical collaboration, this study bridges the gap between theoretical research and real-world implementation. The findings contribute to optimized water management in apple production, enhancing sustainability and resilience amidst anticipated future water scarcity and changing climatic conditions. Moreover, the research supports regional water supply assessment, enabling a comprehensive understanding of the interplay between water management in apple production and mesoscale water availability.

5.6 **Developing tools for sustainable irrigation management in Mediterranean crops – PRIMA project HANDYWATER**

Felix Thomas, Ulrike Werban, Marco Pohle, Luis Bonet Pérez de León, Amparo Martínez-Gimeno, Juan Miguel Ramírez Cuesta, Daniela Vanella, Simona Consoli, Juan Gabriel Pérez Pérez

Mediterranean agriculture needs to face a transition in food production in the interplay of population growth, protection of the environment, resource efficiency and ensuring resilience to future climatic change. Smallholders act as crucial part of Mediterranean agricultural community and the Mediterranean region could save 35% of water by implementing more efficient irrigation and conveyance systems. To achieve a water-efficient agricultural sector, new irrigation technologies and best practices need to be adopted. PRIMA project HANDYWATER is focused on gaining new knowledge and offering low-cost and lean solutions for enhancing the adoption of efficient irrigation innovations by small farmers. We aim to increase the environmental and economic sustainability of two crop productions models, both highly water demanding and widely cultivated in the Mediterranean area: citrus (as intensive system) and olive (as rainfed system).

5.7 **Long-term Trajectories of Soil Nitrogen Surplus Across Europe (1850-2019)**

Masooma Batool, Fanny Sarrazin, Sabine Attinger & Rohini Kumar

Worldwide surface waters suffer from the presence of nitrogen (N) compounds causing eutrophication and deterioration of the water quality. Despite many Europe-wide legislations, we still observe high N levels across many water bodies in Europe. Information on long-term annual soil N surplus is needed to better understand these N levels and inform future management strategies. Here, we reconstructed and analyzed the annual long-term N surplus for both agricultural and non-agricultural soils across Europe at a 5 arcmin (~10 km at the equator) spatial resolution for more than a century (1850-2019). The dataset consists of 16 N surplus estimates that account for the uncertainties resulting from input data sources and methodological choices in major components of the N surplus. We documented the consistency and plausibility of our estimates by comparing them with previous studies and discussed about possible avenues for further improvements. Importantly, our dataset offers the flexibility of aggregating the N surplus at any spatial scale of relevance to support water and land management strategies.

5.8 **Linking Environmental Data into European Scale Research Infrastructures**

Joost Hemmen, Martin Abbrent, Florian Gransee, Tobias Kuhnert, Luca Johannes Nendel, Bert Palm, Karsten Rinke, David Schäfer, Maximilian Schaldach, Christian Schulz, Thomas Schnicke and Jan Bumberger

We present the work on a NFDI4Earth pilot project that aims to establish a standardized interface for environmental time series data at the Helmholtz-Centre for Environmental Research to the European Open Science Cloud. The chosen interface is the emerging SensorThingsAPI, which will be facilitated through the Fraunhofer FROST-Server.

The implementation of this interface is a collaborative effort by the Time Series Management (TSM) group from the Research Data Management (RDM) team. Existing solutions like the System for automated Quality Control (SaQC) and the Sensor Management System (SMS) for sensor metadata provide valuable building blocks for integrating the FROST-Server.

To demonstrate the practical application of this project, we utilize the TERENO observatory Rappbode Reservoir as a real-world use case. This observatory will provide near real-time observational data and sensor metadata, both of which will be made accessible through the SensorThingsAPI.

5.9 **Incorporating reservoirs for improved simulations in hydrological models**

Pallav Kumar Shrestha, Luis Samaniego, Oldrich Rakovec, Rohini Kumar, Chenxi Mi, Karsten Rinke, Stephan Thober

Accurate simulation of reservoirs has been a challenge for global hydrological models due to highly discontinuous water management, uncertainties in reservoir shape representation and scalability issues of reservoirs across modeling resolutions. We augment the mesoscale Hydrological Model (mHM) with a newly developed lake module that incorporates an existing reservoir regulation scheme with non-consumptive demand predictions from random forest. Subgrid catchment conservation (SCC) routing scheme is employed that preserves reservoir catchment across scales to achieve scalable reservoir simulations. We also evaluate the sensitivity of reservoir shape on surface area and evaporation for three shape approximations of varying complexities.

We tested the lake module at the Rappbode reservoir of Germany. Streamflow simulations with reservoirs and model calibration show a KGE improvement of +0.47 (calibration) and +0.61 (validation) when compared against model simulations without reservoir and default parameter set. We find reservoir evaporation highly sensitive to reservoir shape with half-pyramid approximation resulting in best fit at Rappbode reservoir with surveyed bathymetry. In contrast, the linear approximation (or rectangular prism assumption) and a global bathymetry dataset produced large evaporation biases. Further work is necessary for testing the regulation approach in reservoirs with consumptive water usage.

5.10 **Water security transformations across the food-water-energy nexus: Insights from three coupled human-natural systems models**

Christian Klassert, Mansi Nagpal, Jasmin Heilemann, Simon Werner, Yuanzao Zhu, Heinrich Zozmann, Raphael Karutz, Bernd Klauer, Erik Gawel

Adapting to dwindling freshwater resources under climate change will require societal sustainability transformations involving multiple food-water-energy (FWE) nexus sectors. Human agency and institutions are paramount determinants of the success of this endeavor, yet their representation in water security projections has traditionally been overly simplistic.
Here, we present insights from coupled human-natural systems modeling efforts to assess water security transformations in three case studies (Jordan – completed; Pune, India – ongoing; Thuringia – starting). We find future water security critically depends (1) on implementing solutions that span the FWE nexus, (2) on the performance of formal and informal institutions allocating water, and (3) on enhancing urban water access equality.

5.11 **A Baseflow Analysis Framework with OGS using mHM data products**

Thomas Kalbacher, Thomas Fischer, Mariaines Di Dato, Timo Houben Christian Siebert, Sabine Attinger

The baseflow of a river is the portion of the water flow that is maintained by groundwater discharge. and depends on several factors, including among others, precipitation, hydrogeologic conditions (e.g., hydraulic pressure gradients, permeability, storage capacity, etc.), soil composition, vegetation, land cover, and topography. However, baseflow is also influenced by human activities. For example, pumping of groundwater, diverting surface water, and land use change can still significantly affect groundwater inflow even over long distances. River ecosystems in particular rely on baseflow to maintain water quality, support aquatic life, and maintain overall ecological balance. As climate change leads to altered precipitation patterns, the need for analytical tools is great.

The Baseflow Analysis framework presented in the poster is being developed to help water resource managers and planners allocate water resources in an environmentally sound manner, particularly during drought periods, to assess the potential impacts of water withdrawals on river ecosystems, and to assist in infrastructure planning, particularly for projects related to hydropower, irrigation, and water supply systems.

Technically, the modeling environment builds on the OGS software and mHM data products. Embedded in a workflow management system (Snakemake), the data can be completely pre-processed and maintained in QGIS before being automatically prepared for modeling and processed in the simulation. Also part of the overall workflow is the analysis of the model results. This holistic approach makes it possible to perform different system and scenario analyses for large catchments, such as the German Danube catchment, as well as for smaller subcatchments, such as the Ammer, Iller or Günz, using the same database.

5.12 **A PhD topic introduction: Implementing an interactive interface between soil and groundwater hydrology for regional water resource management**

Afid Nur Kholis, Mariaines Di Dato, Thomas Kalbacher, Luis Samaniego, Chrisitan Siebert, Ulrike Werban

Climate change and land use pressures are expected to alter the dynamics of multifunctional surface and groundwater systems, and thus the regional hydrologic cycle. However, the specific impacts are uncertain because there are numerous feedbacks between the surface and shallow aquifers. Within this hydrologic compartment, groundwater recharge and soil moisture are key variables in the water balance, and their alteration not only directly affects the hydrologic cycle, but also has significant implications for the carbon and nutrient cycles. Therefore, it is important to understand where and how the interplay between groundwater levels and soil moisture distribution is changing due to climate change and land use, and the implications of changing distribution and dynamics for water availability to humans and nature. Scenario analyses using the interconnected models that simulate parts of the hydrologic cycle (e.g., OGS, mHM) are needed to investigate this. Within this study we will develop a smart OGS-mHM interface that will enable a goal-oriented two-way coupling between OGS and mHM, which can be used to study the interaction of changing groundwater levels with soil moisture and groundwater recharge. Equipped with digital workflows it shall extend decision support for cross-scale planning of the quantitative management of groundwater as well as its influence on the adjacent surface waters.