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Seminar venue:
Kulttuurikeskus ja kokoushotelli Sofia
Kallvikinniementie 35
00980 Helsinki
https://maps.app.goo.gl/CC73ZJHRCJJwpvfq5

Program of National Modeling Seminar 20.11.2023, Kallahti, Helsinki

The length of the Keynote presentations is 25 min + 5 min for questions
The length of the Session presentations is 12 min + 3 min for questions
The length of the Poster introductions is 1-2 min

09:00 - 09:15 **Coffee and welcoming words**

09:15 - 09:45 **Invited Keynote talk**

Cintia Uvo "Presenting the Digital Waters flagship - DIWA"

09:45 - 10:15 **Invited Keynote talk**

Samuli Junttila "Environmental thresholds for drought- and heat-related tree mortality"

10:15 - 10:30 **Poster introductions**

10:30 - 11:30 **Session 1: Subsurface hydrology**

Jari-Pekka Nousu: Modelling spatiotemporal soil moisture dynamics in a subarctic catchment

Pihla Bergholm: Restoring groundwater levels in an aquifer with the help of groundwater flow modeling

Anna Autio: On the functioning of control tile drainage systems in a mineral agricultural field - lessons learned from simulations and observation; a case study of Tyrnävä

Mika Tähtikarhu: Hydrology from nano- to country-scale: a compilation of studies shows the role of the scales and their links with green transition in agricultural systems

11:30 - 13:15 **Lunch and poster session**

13:15 - 14:15 **Session 2: Tree- to ecosystem fluxes**

Dan Kou: Modeling carbon fluxes from diverse terrestrial and aquatic ecosystems in a boreal landscape (Kaamanen) of Northern Finland

Hui Tang: Implementing frost hardening and mortality through plant hydraulics in CLM5.0-FATES

Teemu Hölttä: Is boreal trees' growth limited by carbon sink activities? -- Implications of coupled semi-mechanistic models of stomata behaviour and cambial growth

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Charlotte Angove: Synchronies between leaf water heavy isotope modelling and ecosystem-level evapotranspiration

14:15 - 14:35 **Seminar questionnaire summary and discussion**

Summary of participants' opinions on models and green transition

14:35 - 14:50 **Coffee break**

14:50 - 15:35 **Session 3: Urban water and carbon**

Emil Nyman: Combining novel methods for comprehensive storm water management, planning and communication

Carla Maria Di Natale: Climate change adaptation using low impact development for stormwater management in a Nordic catchment

Minttu Havu: Modeling CO2 uptake of urban green in a warming Nordic city

15:35 - 16:20 **Session 4: Freshwater**

Erik van Rooijen: Modelling of river bank erosion in cold-climate regions

Marta Fregona: A simple model for predicting ice timing and thickness in lakes

Katri Rankinen: Quantification of the effect of environmental changes on the brownification of Lake Kukkia in southern Finland

16:20 - 16:30 **Final words**

17:30 - 20:00 Dinner at Ravintola Fregatti (at own cost, location: https://maps.app.goo.gl/oApttQwrHrAUSpEP6)

Contact information:

Jari-Pekka Nousu	029 532 2996	firstname.lastname@luke.fi
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Posters:
Parvez Rana: Impact of Hydrological Restoration on Biodiversity in Boreal Peatland Forests
Kersti Leppä: Mechanistic isotope modeling as tool to understand drivers of intraseasonal tree-ring δ18O signals
Vili Virkki: Global water cycle shifts far beyond pre-industrial conditions – planetary boundary for freshwater change transgressed
Marie Korppoo: WSFS-Vemala simulations of quality and quantity of the nutrient loading from Finland to the Baltic Sea
Joy Bhattacharjee: Modeling the suitability of effective Nature-based solutions at the catchment scale
Maarit Raivonen: Water in peatland CH4 model HIMMELI
Hui Tang: Challenges in representing plant hydraulic stress due to drought: A comparison between simple and complex models over a Finnish cropland site

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List of abstracts

Modeling carbon fluxes from diverse terrestrial and aquatic ecosystems in a boreal landscape (Kaamanen) of Northern Finland

Dan Kou, Tarmo Virtanen, Claire C. Treat, Juha-Pekka Tuovinen, Aleksi Räsänen, Sari Juutinen, Juha Mikola, Mika Aurela, Lauri Heiskanen, Maija Heikkilä, Jan Weckström, Teemu Juselius, Sanna R. Piilo, Jia Deng, Yu Zhang, Nitin Chaudhary, Conghong Huang, Minna Väliranta, Christina Biasi, Xiangyu Liu, Mingyang Guo, Qianlai Zhuang, Ate Korhola, Narasinha Shurpali

Peatlands, with high spatial variability in ecotypes and microforms, constitute a significant part of the boreal landscape and play an important role in the global carbon (C) cycle. However, the effects of this peatland heterogeneity within the boreal landscape are rarely quantified. Here, we use field-based measurements, high-resolution land cover classification, and biogeochemical and atmospheric models to estimate the atmosphere-ecosystem C fluxes and the corresponding radiative effect (RE) for a boreal landscape (Kaamanen) in northern Finland. Our result shows that the Kaamanen catchment currently functioned as a sink of carbon dioxide (CO_2) and a source of methane (CH_4). Peatlands (26% of the area) contributed 22% of the total CO_2 uptake and 89% of CH_4 emissions; forests (61%) accounted for 78% of CO_2 uptake and offset 6% of CH_4 emissions; water bodies (13%) offset 7% of CO_2 uptake and contributed 11% of CH_4 emissions. The heterogeneity of peatlands accounted for 11%, 88%, and 75% of the area-weighted variability (deviation from the area-weighted mean among different land cover types (LCTs) within the catchment) in CO_2 flux, CH_4 flux, and the combined RE of CO_2 and CH_4 exchanges over the 25-year time horizon, respectively. Aggregating peatland LCTs or misclassifying them as nonpeatland LCTs can significantly ($p < 0.05$) bias the regional CH_4 exchange and RE estimates, while differentiating between drier noninundated and weter inundated peatlands can effectively reduce the bias. Current land cover products lack such details in peatland heterogeneity, which would be needed to beter constrain boreal C budgets and global C-climate feedbacks.

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Climate change adaptation using low impact development for stormwater management in a Nordic catchment.

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Climate change is raising a need to adapt stormwater management systems to altered conditions. Low Impact Development (LID) controls are regarded as a promising solution for adaptation in urban areas. The main objective was to demonstrate how LID controls function in climate change adaptation. The analysis used air temperature and precipitation from the regional climate model HCLIM, with RCP8.5 emission scenario, as input to the Storm Water Management Model (SWMM). Urban runoff and snow dynamics were simulated in historical, mid- and far-future periods. With the increase in mean air temperature, snow water equivalent reduces, which alters the seasonal runoff behavior in the future. To alleviate the climate change impacts, subcatchments generating high total runoff volumes were determined for LID implementation. Bioretention cells, permeable pavements and green roofs achieved runoff volume reduction in summer, while also having some impact on other seasons. Permeable pavements and bioretention cells behaved similarly throughout the year, but green roofs had a negligible runoff volume reduction in winter. This study suggests a transparent methodology to adapt the current urban stormwater management systems by using LID solutions. It also highlights that LID adaptation design for summer flow events does not behave similarly in other seasons.

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Modelling of river bank erosion in cold-climate regions

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Rivers continuously change and affect landscapes, biological communities and societies. All these effects that rivers can have, are influenced directly or indirectly by the amount of sediments transported by the river. Even though a significant percentage of the sediments in rivers originate from banks and are delivered to the river via bank erosion, how and when exactly river bank erosion occurs is still unknown, especially in Northern rivers. The goal of this work is to provide a river bank erosion model that can be used to gain more insight into river bank erosion processes and their interactions, including the often-overlooked cold-climate processes. We have already obtained field data using an automatic real-time bank erosion monitoring system, which is analyzed to gain more insight into the bank erosion processes and which will be used to calibrate and validate the model that will be built. We will develop a process-based model for bank erosion, with different submodels that interact and can be individually turned on or off. The following processes will be considered: soil moisture flow, heat transfer, ice formation, mass wasting and seepage erosion. It is planned that the bank erosion model can be linked to a hydrodynamic model which will allow fluvial erosion to be considered. Furthermore, the bank erosion model can influence the hydrodynamic model by updating the topography and sediment supply in the hydrodynamic model. This will allow predictions to be made regarding the effect of changing conditions on bank erosion and the effect of this changing bank erosion on river systems as a whole.

Restoring groundwater levels in an aquifer with the help of groundwater flow modeling

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Groundwater levels have declined several meters widely in an aquifer in Satakunta region in Western Finland during the past 50 years and there are indicators that the decline has started even earlier, at least at the beginning of the 20th century. Studies have shown that a possible cause for the decline is the agricultural and forestry drainage in the area. The drainage has spread closer to the aquifer over the past century and the groundwater flows towards these drained areas.

The area's three municipalities and industry are dependent on the groundwater in the area. The decline also threatens the recreational use of the area's lakes as their water levels are impacted by the groundwater levels. Thus, there is an ongoing project in the area where the possibilities for stopping the decline of the groundwater levels by restoring agricultural or forestry drainage in the area are studied to ensure sustainable use of the area's water resources.

Groundwater flow modeling plays a crucial role in the project. The area of the aquifer is over 41 km^2. Thus, modeling is the most cost-effective tool for identifying the potential areas for the drainage restoration, predicting the impacts of the restoration, and assessing the magnitude of the restoration measures needed. Additionally, the model helps in assessing the disadvantages of the drainage restoration, and the impacts of other phenomena, such as climate change, to minimize the harms and maximize the benefits of the restoration.

After identifying the potential places and restoration measures with the model, further studies have been launched on the areas identified, and later as more detailed information is gathered, the model can be updated and used for making more detailed predictions. Thus, groundwater flow models can be used in comprehensive and iterative manner for supporting the sustainable use of water resources.

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Combining novel methods for comprehensive storm water management, planning and communication

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Holistic urban stormwater management is complicated by the changing climate, urban densification, and disconnections between different actors. Holistic stormwater management requires a systemic analysis of water resources on scales ranging from catchments to individual development sites. The ISMO project at Turku UAS aims to combine various monitoring and modeling approaches to provide new tools to support holistic stormwater management. We combine comprehensive catchment-wide monitoring, 1-2D established models and novel high-fidelity site-specific CFD models, and visualization tools to incentivize efficient stormwater management on all scales. A cost-efficient city-wide near-real time IoT LoRaWAN monitoring network is built to provide comprehensive data for validation and calibration of hydrologic and hydraulic models. The data are further used to force local site-specific high-fidelity CFD models, for example for stormwater management solutions, to analyze multiphase (air and water) flows in porous media. The CFD-model results can be used to optimize stormwater management solution design. Further, the models are designed such that they can be operated by non-CFD experts through the adaptation of easily modifiable digital twins. These models are an advancement from the state-of-art stormwater models (e.g., SWMM) as they can simulate 2-3D hydrological processes within individual stormwater management solutions such as bioretention cells and may be used for design optimization studies. Further, field measurements of soil moisture, infiltration rates and runoff from homogenous drainage areas, such as roof-tops or parking lots are integrated in the approach to be able to validate model abstractions. To incentivize uptake and implementation of urban stormwater management solutions on block and building scales, a novel workflow has been developed. The workflow describes the use of photogrammetric methods in analyzing design alternatives and testing the design alternatives through simulations using game engines. The proposed workflow allows the analysis of architectural quality and quantitative assessments of stormwater management solutions on local scales.

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On the functioning of control tile drainage systems in a mineral agricultural field - lessons learned from simulations and observation; a case study of Tyrnävä

Autio, A.[1*], Ala-Aho, P.[1], Ghag, K, [1], Pylvänäinen, M. [2], Torvela, J. [2], Liedes, T[2], Haghighi, A.T[1]. Klöve, B.[1]

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The use of controlled drainage systems in agriculture has recently received much attention in Finland and other Nordic areas. This water management method is believed to improve field moisture conditions, decrease agricultural nutrient load to surface water bodies, and slow down the carbon matter degradation in soil with high organic matter content. Furthermore, the systems might be converted to subsurface irrigation systems, making them potential tools for drought mitigation. There is, however, little knowledge of how this system functions in real agricultural settings.

Through field observations and simulations conducted with the fully-integrated physically based model HydroGeoSphere, we evaluate the functioning of the control drainage system, pinpoint the pitfalls and show the opportunities for agricultural water management with controlled drainage for Northern Finland. Our study site is an industrial potato mineral soil field in the Tyrnävä region, Northern Ostrobothnia. In contrast to typical research fields, the farmer schedules and conducts the system regulation and agricultural activities; field condition monitoring was done by the scientific community and included soil moisture, soil matric potential and water table observations.

Our observations suggest that by springtime flooding, soil macropore development and unintended leaching of drainage system make accurate field simulations challenging. Preliminary simulations indicate that the timing of opening/closing the control structure, especially with respect to spring snowmelt, is a critical factor in regulating groundwater table elevation and soil moisture conditions.

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Hydrology from nano- to country-scale: a compilation of studies shows the role of the scales and their links with green transition in agricultural systems

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Hydrology links with the green transition in multiple length scales. From pore- to country scale there are interlinks between food production, carbon processes and water flow in soils. While the scales are often studied separately, the aim of this presentation is to demonstrate the connections between scales and their relevance regarding hydrology and the green transition. The demonstration is conducted by showcasing several of our recently published and yet unpublished studies from nano- to country scale and beyond. Furthermore, the related knowledge gaps and research needs are discussed.

Our pore scale 3D image analyses and computations, helium microscopy images and conventional lab analyses show how water retention and flow in pore scale are affected by changes in their carbon content. Moreover, we demonstrate the challenges and opportunities of different organic amendments (biochar and forest industry side streams) in changing the hydraulic properties. Type, dose and structure of the amendment have controls on their hydraulic impacts.

While the pore scale processes largely control water flow and retention in soils, farm-level water management is also related to larger scale structures, namely drainage systems, farming practices and catchment characteristics. Our simulations and data show how controlled drainage systems can affect field-scale hydrology in different peat soils. The water level changes can have consequences on the greenhouse gas emissions. Moreover, we show how the hydrology of peat fields is connected to the larger hydrological systems surrounding the field area, with practical implications.

Our work regarding the larger hydrological systems is demonstrated in catchment and country scale erosion and sediment connectivity modeling studies. The studies show the benefits and challenges of producing spatially explicit data with models.

Process-based studies in different scales together with computational analyses which combine the knowledge with different data sources can pave a way to advance hydrological knowledge and water management.

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Modeling CO_2 uptake of urban green in a warming Nordic city

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Many cities are striving to reduce greenhouse gas emissions and improve local climate conditions through climate initiatives. Urban green areas have the dual benefit of acting as carbon sinks and mitigating heat through transpirative cooling and shade. In this research, we used the urban land surface model SUEWS (Surface Urban Energy and Water Balance Scheme) to assess the local 2- m air temperature and net CO_2 uptake in Helsinki in present and future climates. We focused on the relationship between net CO_2 uptake and transpiration, both influenced by local air temperatures and the urban water balance. Furthermore, we investigated how both temperature and CO_2 uptake were affected by various urban land use types as described using Local Climate Zones (LCZs). Two simulations were considered: years 2014-2019, and in the 2050s following the climate scenario RCP8.5.

Urban green areas exhibited an annual CO_2 uptake of 36.3 kt C. A 2.1°C variation in mean annual temperatures was detected between different LCZs within the city. While urban forests emerged as the most robust carbon sinks (0.3 kg C m^{-2} $year^{-1}$), urban neighborhoods were responsible for a substantial 47% of Helsinki's net CO_2 uptake. With the climate scenario, local temperatures increased on average 1.3°C within the city, while the net CO_2 uptake increased 11%. This modest increase was attributed to elevated temperatures influencing the timing of leaf-on and leaf-off, while extended dry periods led to drier soil conditions in summer. Urban neighbourhoods could mitigate dryness through irrigation, demonstrating adaptability to the future climate, while urban forests were susceptible to dryness.

This research highlights how climate change may impact the capacity of urban vegetation to mitigate CO_2 emissions and shape local climate conditions, emphasizing the significance of considering the interplay between CO_2 uptake, air temperature and water balance.

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Is boreal trees' growth limited by carbon sink activities? -- Implications of coupled semi-mechanistic models of stomata behaviour and cambial growth

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A crucial question for predicting forest growth's response to the changing climate is whether environmental factors control forest growth mainly through photosynthesis (carbon source pathway) or directly on cambial/meristematic activities (sink pathway). Lately, photosynthesis-centred models have been questioned by observations emphasizing the importance of the sink pathway. To clarify this issue in boreal forests featuring harsh conditions for both source and sink activities, we coupled mechanistic models of stomata optimality and cambial enzymatic activation via hydraulic dynamics, and extended it to include an empirical description of cambial phenology. The coupled model was parameterized using an adaptive Monte Carlo Markov chain (MCMC) algorithm and tested against observations from wooded peatland and mineral-soil forest sites in Finland. The model performance on transpiration and stem radial dimension (SRD) was good, but without the expression of phenology it failed to capture the seasonal pattern of SRD. Statistical analyses of parameters showed significant correlations between phenology (growth onset and duration) and assimilation for Picea abies in peatland but not Pinus sylvestris in mineral soils. Sensitivity analysis of growth and assimilation rates to temperature and soil water content (SWC) showed that both species' growth was more sensitive than assimilation to these environmental factors. We conclude that 1) sink pathway of environmental control of growth, including instantaneous and seasonal-scale effects, is critical for boreal trees and thus should be incorporated into tree growth models, and 2) seasonal-scale control in the sink pathway represented by phenology is correlated with carbon gain under favourable temperature and water conditions.

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Synchronies between leaf water heavy isotope modelling and ecosystem-level evapotranspiration

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Climate change threatens boreal forests, for example by drought and increased wildfires. The water cycle in a boreal forest is pivotal for boreal forest response to climate change. Evapotranspiration is a major component of water loss from boreal forests. Leaf water heavy isotope (LWI) values are intrinsically related to evapotranspiration, for example they are strongly affected by transpiration, as well as by evaporation from the soil and the source of water vapor. While LWI modelling is commonly used for the interpretations of longer-term bioindicators such as isotope variability of tree rings and *n*-alkanes, we have not yet explored the potential for LWI modelling to support the investigation of water loss from boreal forests via evapotranspiration. In this study, we explored the synchronies between LWI modelling and ecosystem-level evapotranspiration, to find if LWI modelling can be used as an indicator of ecosystem-level evapotranspiration in boreal forests. We found that LWI can be more strongly correlated to evapotranspiration than other factors conventionally correlated to LWI, such as atmospheric relative humidity, and we untangled this relationship between LWI and evapotranspiration using sensitivity tests on LWI modelling, alongside sap flow and transpiration rate measurements.

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Implementing frost hardening and mortality through plant hydraulics in CLM5.0-FATES

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Vegetation of temperate and boreal ecosystems can increase its tolerance to freezing temperatures in the winter seasons. This process, known as hardening, encompasses a set of physiological changes at the molecular level that initiate modifications of cell membrane composition and the synthesis of anti-freeze proteins, which reduces plant water potentials and xylem conductivity. In this study, we implement a scheme that represents frost hardening and mortality into a land surface model CLM5.0 coupled with an ecological demographic model FATES (CLM5.0-FATES). It is found that the introduction of changes in plant water potentials and conductivities in the plant hydraulic module of FATES (FATES-hydro) due to hardening is essential for modeling realistic impacts from frost droughts on vegetation growth and photosynthesis, leading to more reliable projections of how northern ecosystems respond to winter climate changes. The implementation of hardiness-dependent frost mortality into CLM5.0-FATES yields a high autumn and spring frost mortality, especially at colder sites, and increasing mid-winter frost mortality due to global warming, especially at warmer sites. These developments form a major step forward in including a level of frost tolerance that is responding to the environment with cost (implicitly) and benefit of frost tolerance both being explicitly represented in the model.

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A simple model for predicting ice timing and thickness in lakes

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In lakes that freeze in winter, the ice cover plays an important role for human activities and lake ecology and can be used as informative indicator of climate change. Being able to accurately predict ice-on and ice-off dates and ice thickness is therefore a relevant task, which becomes particularly intriguing when simple ice models can be used with relatively good predictive capabilities. Here we present an extension of the existing *air2water* model, originally developed to predict lake surface water temperature (LSWT) and epilimnion thickness, adding the possibility to simulate ice cover growth and decay. The new ice module preserves: i) the simplicity of the original *air2water* model (air temperature being the only forcing variable), ii) its parsimony (from 8 to 10 model's parameters) and iii) the physically based derivation of the equations (one for ice growth and the other for ice melting). The extended version of the *air2water* model is tested using long time series of observed LSWT and ice thickness (1960-2021) for 29 Finnish lakes with different climate and lake type conditions. Relative to the validation period, the RMSE for daily LSWT is 1.37±0.35 °C and that for ice thickness is 10±3 cm, while the mean error for ice-on and ice-off dates is -9±7 and -3±4 days, respectively. Similar performances are obtained when calibrating the model using both LSWT and ice thickness observations or only LSWT observations, thus allowing the application of the model to lakes without available ice observations. Overall, the results suggests that the proposed model is competitive with other more complex lake ice models available in the literature in terms of accuracy despite requiring air temperature as the only input variable.

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Quantification of the effect of environmental changes on the brownification of Lake Kukkia in southern Finland

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The browning of surface waters due to the increased terrestrial loading of dissolved organic carbon is observed across the northern hemisphere. Brownification is often explained by changes in large-scale anthropogenic pressures (including acidification, and climate and land-use changes). We quantified the effect of environmental changes on the brownification of an important lake for birds, Kukkia in southern Finland. We studied the past trends of organic carbon loading from catchments based on observations taken since the 1990s. We created hindcasting scenarios for deposition, climate and land-use change in order to simulate their quantitative effect on brownification by using process-based models. Changes in forest cuttings were shown to be the primary reason for the brownification. According to the simulations, a decrease in deposition has resulted in a slightly lower leaching of total organic carbon (TOC). In addition, runoff and TOC leaching from terrestrial areas to the lake was smaller than it would have been without the observed increasing trend in temperature by two degrees Celsius in 25 years

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Exploring spatiotemporal dynamics of soil moisture: three model conceptualizations in a subarctic catchment

Jari-Pekka Nousu[1,2], Kersti Leppä[2], Hannu Marttila[1], Pertti Ala-aho[1], Mika Aurela[3], Annalea Lohila[3,4], Samuli Launiainen[2]

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Surface soil moisture has a key role in regulating energy, water and carbon exchanges between the land and the atmosphere. In this study, we test the impact of different groundwater model conceptualizations developed in Spatial Forest Hydrology model (SpaFHy) on simulations of soil moisture. We model the Pallas catchment in Northern Finland, covered by coniferous forests and peatlands. The model conceptualizations differ in how the groundwater flow is treated, which is shown to have a clear impact on the spatiotemporal soil moisture dynamics within the catchment. The conceptualizations range from i) neglecting groundwater storage, to ii) TOPMODEL approach, and to iii) lateral groundwater flow model. By comparing these scenarios, we can assess when and where solving the lateral flow is prerequisite for accurate predictions of soil moisture, and in which conditions soil moisture variability is driven more by vertical water movement and evapotranspiration. The model results are compared against continuous point-scale measurements, distributed in-situ measurements and SAR-based spatiotemporal soil moisture estimates. We demonstrate the added value of spatiotemporal SAR-data to evaluate the performance of spatiotemporal model simulations.

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Impact of Hydrological Restoration on Biodiversity in Boreal Peatland Forests

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Peatlands serve as vital ecosystems for biodiversity, offering a range of ecosystem services. To manage peatlands sustainably, it is crucial to identify and understand the impacts of different management approaches. In this study, we investigated the effects of peatland management on biodiversity and financial performance, the latter measured as Net Present Value (NPV). We chose 33 red-listed plant species as proxies to offer broader insights into how restoration aids in the recovery of peatland biodiversity. The research was conducted across three different landscapes in Finland, and we examined four distinct peatland management scenarios: no management activity (NOMANAGE), hydrological restoration (REST), wood harvesting for bioenergy (BIOENERGY), and timber production (TIMBER). Our findings reveal notable differences in potential habitat areas across the various scenarios. The REST scenario yielded the most extensive potential habitat areas, followed by BIOENERGY, NOMANAGE, and TIMBER. Notably, TIMBER yielded the highest financial performance under conditions of low interest rates. In conclusion, our study indicates that hydrological restoration can significantly enhance potential habitat areas while also yielding financial benefits, especially under higher interest rate scenarios. The findings underscore the importance of aligning ecological conservation with economic viability in peatland management strategies.

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Mechanistic isotope modeling as tool to understand drivers of intraseasonal tree-ring $\delta^{18}O$ signals

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The oxygen isotope ($\delta^{18}O$) compositions in tree rings provide a powerful tool to evaluate environmental conditions for tree growth and tree physiological responses. The main processes defining the tree-ring $\delta^{18}O$ signature are evaporative enrichment at leaf level and variations in source water $\delta^{18}O$, but gaps remain in the mechanical understanding on how the final signal is formed. With technological developments in isotope analysis, intraseasonal $\delta^{18}O$ series have become more accessible but their interpretation is still limited. This is because the typically observed dominant effect of relative humidity in leaf level $\delta^{18}O$ (1) becomes dampened due to the relatively long and poorly understood formation times of tree-ring sections and (2) mixed with the potentially opposing signal of source water $\delta^{18}O$ during cellulose synthesis. Dynamic mechanistic models present valuable tools to investigate the processes modifying the signal down-stem from leaves to tree rings as well as the potential causes for present and/or lacking environmental signals at various timescales. In this study, we investigate 10-year-long intraseasonal signals dominating tree ring $\delta^{18}O$ in a Scots pine stand in Hyytiälä, Southern Finland. The statistical data analysis is complemented by mechanistic modeling to better understand the underlying processes and key uncertainties. Our preliminary model results suggest that at the study site, the variation of source water $\delta^{18}O$ does not interfere with the dominating relative humidity signal. While the data shows similar trends, the correlations are much weaker. This was partly attributed to varying behavior between the five sampled trees but may also be caused by (1) uncertainties in wood formation periods corresponding to tree-ring subsections or (2) a non-constant mixing ratio (p_{ex}) between leaf and source water signals during cellulose synthesis. These potential causes will be addressed with further modeling and results will be presented at the seminar.

Luonnonvarakeskus

Global water cycle shifts far beyond pre-industrial conditions – planetary boundary for freshwater change transgressed

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Human actions compromise the many life-supporting functions provided by the freshwater cycle, such as ecosystem provision and local and regional climate regulation. Yet, scientific understanding of anthropogenic freshwater change and its long-term evolution is limited. Using a multi-model ensemble of global hydrological models, we estimate how, over a 145-year industrial period (1861–2005), streamflow and soil moisture have deviated from pre-industrial baseline conditions (defined by 5th–95th percentiles, at 0.5° grid level and monthly timestep over 1661–1860). We find an increased frequency of local deviations on approximately 45% of land area, mainly in regions under heavy direct or indirect human pressures. To estimate humanity's aggregate impact on the freshwater cycle, we present the evolution of deviation occurrence at regional to global scales. Currently, local streamflow and soil moisture deviations occur on 18.2% and 15.8% of global land area, respectively, which is 8.0 and 4.7 percentage points beyond the ~3 percentage point wide pre-industrial variability envelope. Streamflow and soil moisture deviations have often exceeded their pre-industrial variability envelope already by the 1960s–1970s in many regions with extensive human activities. Our results signify a substantial shift from pre-industrial streamflow and soil moisture reference conditions to persistently increasing change. This indicates a transgression of the new planetary boundary for freshwater change, which is defined and quantified using our approach. Urgent actions – such as ambitious climate action, halting deforestation, and respecting environmental flows – are thus needed to reduce human disturbance of the freshwater cycle.

Luonnonvarakeskus

WSFS-Vemala simulations of quality and quantity of the nutrient loading from Finland to the Baltic Sea

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The operational, national-scale nutrient loading model, WSFS-Vemala (Vemala), was developed to simulate past, present, and future nutrient loading from Finnish watersheds to the Baltic Sea. It simulates leaching and transport of nutrients on land, as well as in rivers and lakes. The hydrological simulation is based on the WSFS system, which simulates the hydrological cycle on a one-day time step using standard meteorological data. A field scale model is applied for phosphorus and nitrogen terrestrial leaching from agricultural areas. The model includes point loads, urban runoff, atmospheric deposition, and load from settlements. Estimated values are used for natural background leaching and loading from forestry. Since 2013, the Vemala v3 version has been developed to include a biogeochemical model to provide quantity and quality of the nutrient loading reaching the Baltic Sea. Vemala v3 simulates total and bioavailable nutrient species such as nitrate, ammonium, organic nitrogen, phosphate, particulate inorganic phosphorus, organic phosphorus, phytoplankton, suspended sediments, and total organic carbon in the aquatic ecosystem. It predicts the co impact of dissolved inorganic nitrogen and phosphate on algal growth and, therefore, on eutrophication. The quality of loading to various sea basins in Finland varies depending on factors such as land use, soil type, and season. For instance, the northern part of Finland is characterized by a higher proportion of organic nutrients in both the nutrient loading to the freshwater ecosystem and the output loading to the Bothnian Bay. In contrast, southern catchments show a higher proportion of inorganic nitrogen (up to 50% of the total nitrogen loading in the Archipelago Sea). Additionally, the quality of nitrogen loading fluctuates over time, with nitrate representing an average of 66% of the annual total nitrogen load, ranging from 29% in the summer to 88% in the winter over the period 2010-2020.

Luonnonvarakeskus

Modeling the suitability of effective Nature-based solutions at the catchment scale

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Nature-based solutions (NBS) can be defined as the ways that are inspired and powered by nature, can address societal challenges and provide several benefits, and can be highly effective and economically efficient. Even though landscape-level processes dominate the development and sustainability of NBS, the functioning varies a lot based on the regional scale. Thus, it is needed to analyze the impact of regional future projections of NBS (wetland, peatland restoration) on different land system management attributes (changes in landuses, biomass volume) at a catchment scale. The Oulanka catchment (1981 km^2) in northern Finland has been considered in this study to apply the SWAT+ hydrological model to understand the effectiveness of NBS, where forests dominate the catchment. The SWAT+ model offers a useful way to focus and set goals for different NBS in a spatially explicit way. Multiple NBS (i.e., implementing wetlands) have been integrated with the baseline model of SWAT+ to explore the future consequences of forest management practices for different NBS scenarios. We have also included climate-imposing emission scenarios into the model to analyze longer perceptions of climate change (CC). The outcomes of the proposed scenarios (NBS and/or CC) will portray the probable impacts on each land system management attribute and water quality parameter in the catchment, to guide future water resources management.

Luonnonvarakeskus

Water in peatland CH_4 model HIMMELI

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HIMMELI, HelsinkI Model of MEthane buiLd-up and emIssion, is a model for simulating CH_4 (and CO_2) emissions from peatland soils. It is not a complete peatland carbon cycle model but it was designed to be used e.g. as a module within a larger ecosystem model. It needs the source of CH_4, i.e., rate of anoxic soil respiration, as well as leaf area index (LAI) of aerenchymatous plants, from outside. Other inputs are soil water table (WT) depth, air temperature, and soil temperature profile. HIMMELI describes a layered peat column of given thickness and simulates microbial processes and transport mechanisms that control CH_4, CO_2 and O_2 concentrations in the soil, and fluxes between peat and the atmosphere. As the model tracks development of gas concentrations (dissolved and gas-phase) in the soil layers, the effect of moving WT on them needs to be simulated. In HIMMELI, the peat above WT is considered completely air-filled and below it, completely water-filled. This is a simplification as there is water in the peat pores also above the WT. In this poster, we present some work related to treatment of water in HIMMELI. We have tested different ways to handle the concentrations when WT moves and the impact of adding water also above WT.

Luonnonvarakeskus

Challenges in representing plant hydraulic stress due to drought: A comparison between simple and complex models over a Finnish cropland site

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Drought events are projected to become more frequent and severe in northern Europe due to future global warming. The impact of these trends on the yield and carbon sequestration potential of northern croplands remain largely unknown. Process-based crop models are valuable tools for predicting future changes in agriculture systems and understanding the underlying mechanisms. These models, however, have been mostly developed and tuned to represent average conditions. How well they can depict the response of crops to extreme conditions still needs to be investigated. We compared process-based models with different complexity in parameterizing plant water stress and its impacts and assessed their capability of describing the response of crops to drought. Our simplest model assumes a simple soil water stress function for photosynthetic capacity and stomatal conductance (Sellers et al. 1996), a common approach in many crop models. In comparison, our complex model explicitly simulates water storage and potential in different plant parts (root, stem and leaf) (Christoffersen et al. 2016), and water stress emerges from changes in water conductances of the whole plant, not only leaf stomata. Additionally, our newly developed model assumes plants optimize their response to water stress (i.e., maximizing its water use efficiency) by coordinating photosynthetic capacity and stomatal conductance (Joshi et al. 2022). We evaluated these different models against observations from Field Observatory (www.fieldobservatory.org, Nevalainen et al. 2022) over Finnish cropland sites to explore which model complexity is suitable for representing plant water stress effects and predicting future changes in crop yield and carbon sequestration potential over Finland.