Oslo, 30 December 2023

LATICE – Annual letter 2023

Dear all,

Yet another year is coming to its end and it is time to thank you all for your contribution to making it another interesting and motivating LATICE year - our nineth year! The high level of activity and the many achievements are due, not only to LATICE, but also to the many projects and people that are closely associated with it.

Significant time has been devoted to three main LATICE activities, all with important contributions from associated projects (see below for further details); i) the continuing collection and analysis of data from LATICE Flux and associated sites, encompassing various infrastructure and field investigations, ii) the finalisation and publication of a common modelling platform for CLM/FATES (the NorESM Land Sites Platform), and iii) the LATICE Model Intercomparison Project's two key activities (LATICE-MIP Snow and Evaporation). New observations are vital for improved process understanding and support novel parametrisation of high latitude processes in land surface and hydrological models as demonstrated by these activities.

The LATICE 2023 annual meeting was held on 29-30 March in Drøbak. The main scientific topics were the role of snow and vegetation within land-atmosphere interactions and exchange, and ample time was allocated to discussions. We were very happy that our advisory board members, Eleanor Blyth (CEH) and Roy Rasmussen (NCAR) both were able to join in person, as was our invited speaker, Walter Immerzeel (Utrecht University). He provided valuable input to the meeting, including an update on snow research in High Mountain Asia. The agenda and list of participants are available on the LATICE webpage, under "Annual meetings".

LATICE co-leader Norbert Pirk was awarded the highly competitive European Research Council (ERC) Starting Grant[1] for his project 'Actively learning experimental design in terrestrial climate science (ACTIVATE)'. More details are provided under 'New Associated Projects and Initiatives'. ACTIVATE will run for the next five years and builds on the expertise and infrastructure we have developed within LATICE. We are very proud to have Norbert on our team!

Eva Lieungh defended her thesis 'Changing alpine vegetation dynamics: insight from complementary modelling and observation approaches' for the degree of Philosophiae doctor, 29 September at the Natural History Museum (NHM). Although not a LATICE funded PhD, she has been an active participant in LATICE and contributed important knowledge of high relevance for the project as also acknowledged in her thesis.

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[1] *LATICE co-lead Norbert Pirk is awarded the prestigious ERC StG - Department of Geosciences (uio.no)*

Some further highlights and details of activities in 2023 are presented below.

Infrastructure and Observations

Our flux measurement sites operated well during the last year. Apart from a few days with data logging issues, most sensors at the Finse site reported useful measurements throughout 2023. A paper (led by Norbert Pirk) that investigates snow-vegetation-atmosphere interactions at Finse was published in the journal Biogeosciences. We decided to keep the mobile flux tower running at Iškoras to provide continuous baseline estimates for carbon and energy exchange, as well as for meteorological and soil conditions. The BioGov project, associated with the Centre for Biogeochemistry in the Anthropocene (CBA), among others, uses Iškoras as a key research site for which the flux tower delivers invaluable data. At the Hedmark (Hisåsen) twin sites, where one of the drained mires was restored during the autumn of 2021, we have been able to document the carbon, energy and water balance in the second year after restoration. Preliminary analyses show that the increased methane emissions due to the re-wetting persisted in 2023, while CO_2 fluxes almost returned to their pre-restoration levels this year. A manuscript describing the carbon balance of the restauration experiment is in preparation, led by Postdoc Michael Bekken (Fulbright Grantee) and Astrid Vatne (LATICE PhD) in collaboration with our Danish partners.

A number of related activities benefit from the data collected and experience gained through the establishment of the LATICE Flux sites. This includes Postdocs, PhD and master students, as well as interns, both from UiO and abroad. A study co-led by LATICE researcher Simon Filhol on innovative meteorological measurements on polar glaciers, has been published and highlighted on Titan.uio.no[2]. We maintained our collaboration with NIBIO (PI Holger Lange), NMBU (PI Mareile A. Wolff) and MetNo (PI Laura Ehrnsperger), responsible for the ICOS-Norway site at Hurdal (NIBIO) and a grassland flux site at Ås (NMBU and MetNo), respectively.

The LATICE cold climate container is steadily being developed into a key laboratory for our projects. A snowmaker is now up and running in the lab, providing the backbone for experiments planned in the SnowSub project led by Olga Silantyeva (see 'New Associated Projects and Initiatives'). We are excited to see the upcoming results and insights on the critical snow-atmosphere interface.

The drone-based flux mapping technique developed within the Research Council of Norway (RCN) Spot-On project is further being developed and tested. The approach combines meteorological measurements on drones with turbulence-resolving large eddy simulations using data assimilation to infer surface fluxes. Our dScience PhD student Alouette van Hove is further refining the technique by adding functionality to find optimal sampling strategies for the drones. Her latest paper entitled "Guiding drones by information gain" will be presented at the Northern Lights Deep

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[2] *LATICE co-led study on innovative meteorological measurement stations on polar glaciers is on Titan - Department of Geosciences (uio.no)*

Learning Conference in Tromsø in January 2024. These developments also contributed to the successful application for an ERC Starting Grant this year to Norbert Pirk.

Land surface and Hydrological model developments

The CLM/FATES group at the Department of Geosciences has been less active the last year as key members have left the department. Still, we have benefitted from their engagement in follow-up activities, notable related to model development and joint research proposals (unfortunately not funded in 2023). Notable, new PFTs for moss and lichen have been further refined and evaluated as part of the EMERALD project, and a paper is in preparation (led by Hui Tang). We appreciate their continuing support to LATICE, joint papers and sharing of knowledge and competence. The loss of modelling competence makes us even more pleased that Yeliz Yilmaz, also in our original CLM core group, has obtained a 'long'-term engagement at the department.

A paper summarising the experience gained in the development of the NorESM Land Sites platform (NorESM-LSP) was published in June this year. The platform allows users to run the CLM-FATES model over prescribed sites, facilitating validation of ecological and environmental processes and parameterisations against observed local estimates of ecosystem productivity and performance. The first release supports customisable simulations for 20 geo-ecological observation sites in Norway, including LATICE sites. First authorship is shared between Eva Lieungh, who defended her PhD (NHM funded) in 2023 and Lasse Keetz, who will soon submit his PhD thesis (LATICE funded), with several LATICE participants as co-authors. The release of the platform was also presented on Titan.uio.no through an interview with Eva and Lasse[3]. Detailed information about the platform, including links to technical documentation and paper can be found at GitHub[4].

In addition to the published platform, other CLM developments funded by LATICE associated projects have taken place this year. The second PhD paper of Marius S.A. Lambert was published. In his previous paper, his hardening scheme (i.e., ecosystems increasing tolerance to freezing) was used to improve hydraulic processes in cold-tolerant plants. In the 2023 paper, he expanded upon this hardening scheme by implementing hardiness-dependent frost mortality into CLM5.0-FATES to study the impacts of frost on vegetation in temperate and boreal sites. Work led by Hui Tang to include a new PFT for moss and lichen has been further developed and systematically evaluated against observations. The parameters for describing the hydraulic traits of moss have been improved based on recent observation and modelling studies. Adjustable soil layer structures due to the presence of moss have also been implemented in the model, allowing moss to be represented by a vegetation layer only or a mixed soil and vegetation layer. A manuscript describing the implementation of a moss PFT is in preparation. Further, a new scheme for explicit representation of soil organic matter decomposition (PhD work of Elin Aas) has been developed and is tested against soil inventories from Norway. The scheme includes explicit representation of soil microbes, mycorrhiza (fungi living in symbiosis with the plants) and nutrient cycling (so far only nitrogen).

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[3] https://www.titan.uio.no/energi-og-miljo/2023/na-er-det-lettere-a-bli-klimaforsker.html
[4] *NorESM Land Sites Platform technical documentation (noresmhub.github.io)*

Iris Mužić (PhD at CICERO, previously LATICE intern) continues her PhD research by using the coupled climate model WRF-CTSM as the main tool for analysing land-atmosphere interactions over the Nordic region. After her research visit to NCAR in 2022 summer, she has been able to run this model with its recently developed Hillslope Hydrology feature which allows to explore the role of topography and hydrology on the soil moisture and snowpack variability. She presented her preliminary results at the EGU23 General Assembly, and a manuscript is currently in preparation. Terje Berntsen and Yeliz Yilmaz are co-supervisors, strengthening the links between CICERO and LATICE partners.

LATICE-MIP Snow group (led by Yeliz Yilmaz, UiO) presented the results from the initial phase at two events, with focus on the comparisons between snow observations derived from long-term satellite observations (MODIS) and newer high-resolution satellite observations (Sentinel-2), and the CLM model over the Scandinavian region. Both events were coincidentally held at the same day on 25 May 2023, namely 'NVE faglunsj seminar' and 'Precipitation trends in Nordic Regions'. Kristoffer Aalstad was granted the Climate Change Initiative Research Fellowship from European Space Agency for his project called PATCHES (Probabilistic reAnalysis of the Terrestrial Cryosphere by History-matching using Evidence from Satellites). The PATCHES project brings the worlds of terrestrial cryosphere modelling and Earth Observations (EO) together using ensemble-based data assimilation techniques to produce the first global multi-decadal kilometre-scale snow reanalysis. The project will generate daily estimates of snow water equivalent and fractional snow-covered area for 1 km pixels covering the entire Earth's seasonally snow-covered areas. Kristoffer and Esteban (visited GeoHyd last year) published a paper on spatio-temporal information propagation (Hydrology and Earth System Sciences journal, HESS). Another LATICE contribution is the TopoPyScale package in Python (led by Simon Filhol), which facilitates the downscaling pf climate reanalysis data at the hillslope scale (published in the Journal of Open Source Software, JOSS).

The LATICE-MIP Evaporation group (led by Kolbjørn Engeland, NVE) focuses on evaporation as a component of the water cycle and is motivated by the large uncertainties in simulated annual water balance in Norway. It involves researchers from several organisations in the Oslo region (MetNo, NIBIO, NVE and UiO) with expertise on different types of models. Three hydrologic models (HBV, Shyft and LISFLOOD) and two land surface models (CLM and SURFEX) are compared at three spatial scales: the point scale (site level) encompassing several flux sites (Finse, Hedmark, Hurdal, Iškoras and Ås), the catchment scale including more than 100 near-natural catchments in Norway, and the regional scale covering all of mainland Norway. During 2023, test simulations were performed for all sites and models and initial results were presented at EGU2023. At the catchment scale, a model intercomparison protocol has been established and model calibration experiments are planned for early 2024. Expanding on this research aspect, a successful proposal (led by Terje Berntsen) was funded by the faculty call for PhDs within 'Sustainability' (TREX-Hydro; see 'New Associated Projects and Initiatives').

The hydrologic and water resources model LISFLOOD, which is developed by the European Commission's Joint Research Centre (JRC) and the European Centre for Medium-Range Weather

Forecasts (ECMWF), has been applied to the heavily regulated Drammen catchment. Preliminary results from this study were presented by LATICE postdoc Emiliano Gelati at the 7th Conference on Modelling Hydrology, Climate and Land Surface Processes (Lillehammer, 19-21 September). This initiative has led to collaborations with NVE, the EU-funded STARS4Water research project and JRC. Moreover, as LISFLOOD can simulate the effects of reservoirs and water abstractions, it can be used to study catchment-scale hydrologic processes in areas affected by human interventions.

New associated projects and initiatives

SnowSub – 'Assessing impact of snow sublimation for hydropower production in Norway is funded by RCN as a Collaborative and Knowledge-building project. It had its kick-off meeting in Oslo in October. The project is led by Olga Silantyeva (original LATICE Innovation PD) and collaborates with partners from Statkraft, Skagerak Energi, MetNo, NVE, and University of Oulu, including several LATICE members. The project aims to answer an important question for hydropower production: how much snow is 'lost' as a result of sublimation processes?

TREX-Hydro – 'The impact of tree-line expansion – A threat to hydropower resources?' is a faculty funded PhD position. The project addresses how treeline changes in Norway may affect the water balance through increased evaporation. A reduction in streamflow in the mountain areas will lead to reduced potential for hydroelectric power production. The project will use the CLM coupled to the atmospheric model WRF.

PATCHES – 'Probabilistic reAnalysis of the Terrestrial Cryosphere by History-matching using Evidence from Satellites' is funded by European Space Agency The project is led by Kristoffer Aalstad and collaborates with partners from the University of Bern (Switzerland), CESBIO (France), and SLF (Switzerland). The project aims to produce the first global multi-decadal kilometre-scale snow reanalysis.

ACTIVATE - 'Actively learning experimental design in terrestrial climate science' is an ERC funded Starting grant awarded to Norbert Pirk. It will run for five years (2024-2028). The project combines an observing system consisting of a swarm of drones carrying meteorological sensors and gas analysers, mobile and stationary flux towers, as well as satellites, and fuses their observations with different land-atmosphere models using data assimilation methods.

New team members

The LATICE-funded group consisted in 2023 of two PhDs (Lasse Keetz and Astrid Vatne) and one Postdocs (Emiliano Gelati) funded by the faculty. Lasse Keetz will submit his thesis early next year, whereas Astrid Vatne is currently in maternity leave (since October). In addition, several other researchers, Postdocs and PhDs associated with LATICE contributed through collaborative projects, many of them with important fieldwork at Finse and other high latitude sites in Norway.

Malin Ahlbäck started in fall as a PhD in the SnowSub project. The overall aim of her research is to quantify and analyse the importance of sublimation for improved water balance and streamflow

prediction. She will use data from LATICE Flux and associated sites and field observations from Norway (and Finland) together with model parameterisation and evaluation.

Gunnar Liahjell started in fall as a PhD in the TREX-Hydro project. The overall aim of his research to quantify the impacts on the hydrological cycle and hydropower potential due to changes in vegetation, in particular the rise of tree- and shrub-lines in Norway. He will use a coupled land-atmosphere model and perform field studies using eddy-covariance and drones.

We are pleased to have you all as part of the LATICE team.

Interdisciplinary teaching and training

GEO9915/5915 - Ecological Climatology, led by Anders Bryn and Frode Stordal, taught for the fifth time in spring 2022, was not given in 2023. It will be taught again in 2024. GEO3032 - Climate Change and Impacts - was given for the third time in spring 2022, whereas GEO4990/9990 – The Earth System - is a new course given for the first time in fall 2023 (both courses are coordinated by MetOs). LATICE members contribute with several lectures to these three interdisciplinary courses.

Dissemination and Communication

The group has been active in dissemination and communicating the LATICE project and our research at various national and international conferences and events, such as the EGU23 conference in Vienna in April. The LATICE leader, Lena M Tallaksen, gave an invited talk at the VII Convective Permitting Climate Modelling workshop (CPCM2023[5]) in Bergen in August, presenting key achievements of the LATICE and EMERALD projects. A total of 127 scientists from 33 countries from all continents participated in the event. Tallaksen further contributed as member of the organisation committee of the 7th Conference on Modelling Hydrology, Climate and Land Surface Processes at Lillehammer in September arranged by the Norwegian Hydrological Council. Contributions from LATICE scientists at these events are provided at our LATICE website, including presentations given at EGU23 (see 'News').

On 17 October 2023, the EMERALD Open Science Day (OSD) was organised in the Climate House at the Natural History Museum. This open day gathered altogether 46 researchers in the field of ecological climatology, many of them LATICE participants or affiliated. The Climate House is a special venue for LATICE scientists since they contributed to the opening of the house with a temporary climate exhibition in 2019.

Three LATICE seminars were arranged in 2023 (also attendance on Zoom), providing a discussion forum for new research initiatives, funding applications, interaction with related projects, and regular updates on field and modelling activities. A complete list can be found on the LATICE website under 'Events'.

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[5] *VII CPCM 2023, 29-31 August, Bergen, Norway - (uib.no)*

Three LATICE researchers presented their work (on Zoom) at the 2023 CESM Land Model & Biogeochemistry Working Group Meeting organised by NCAR in Boulder, on 7-8 February 2023. This annual meeting is regularly held to provide a venue for CLM developers and users to meet and share experiences.

The exhibition "Natur i endring" (A changing nature) remained at the Norwegian Mountain Centre in Lom throughout the year, acknowledging among others the LATICE project. Visitors learn how climate scientists measure the amount of snow and the soil temperature in alpine areas, and how studies of plant communities are executed. It is based on an exhibition originally made for the Climate House at the Natural History Museum (NHM), but largely expanded and with new activities especially aimed at a younger audience.

We have a CRiStin project page for LATICE where all are encouraged to link their LATICE-relevant publications: https://app.cristin.no/projects/show.jsf?id=2492739. Check out our website[6] for recently published highlighted articles.

Thanks to you all, we are able to maintain a high level of activities in the field, lab as well as within the modelling groups, endorsing LATICE's position as a natural hub for research within the field of land-atmosphere interactions at high latitudes. We look forward to continuing our joint effort in in the year to come with exciting research results emerging. In particular, we aim to engage in the discussion of the future of LATICE, now that we are entering what is formally its last year in terms of funding. The friendly and open atmosphere that characterises LATICE makes it a motivating and great project to endorse and engage in, so thanks to you all for making it so.

With our best wishes for the New Year - Godt Nyttår!

Lena, Frode, Norbert, Yeliz, and Emiliano

LATICE coordination team

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[6] *Land-ATmosphere Interactions in Cold Environments – LATICE - Department of Geosciences (uio.no)*