Photo: Open-top chambers warm up some of the alpine vegetation plots in Låvisdalen, Vestland, 2019 (photo credit: Eva Lieungh)

WELCOME

6th Conference on

Modelling Hydrology, Climate and Land Surface Processes

September 14-16, 2021
Lillehammer, Norway

Organized by:

Norwegian Hydrological Council

Sponsors:

Norwegian Hydrological Council

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Norwegian Meteorological Institute

Norwegian Hydrological Council

6th Conference on Modelling Hydrology, Climate and Land Surface Processes

Scandic Lillehammer hotel, 14.–16. September 2021

Program

Tuesday 14. September 2021		
1030 - 1130	Registration	
1130 - 1230	Lunch	
1240 - 1300	Opening session: Irene Brox Nilsen, chair of organizing committee and Ole Einar Tveito, chair of the Norwegian Hydrological Council	
1300 - 1700	**Session 1: Terrestrial ecology with links to climate and the hydrological cycle**	**Chair: Lena M. Tallaksen Co-chair: Oddbjørn Bruland**
1300 - 1330	**Keynote 1.1** Changes in frequency of extreme precipitation	**Gunnar Myhre, CICERO/MET**
	5 min discussion	
1335 - 1405	**Keynote 1.2** A hierarchical complexity framework for managing the complexity of land surface models	**Rosie Fisher, CNRS France**
	5 min discussion	
1410 - 1430	Explicit representation of sub-grid snow and vegetation heterogeneity in a land surface model	Kjetil Schanke Aas, UiO
1430 - 1450	Sensitivity of evapotranspiration and surface conductance to vapour pressure deficit across high latitude climatic gradients	Astrid Vatne, UiO
1450 - 1520	Coffee break	
1520 - 1540	Probing Fennoscandian snow cover dynamics in the community land model and climate reanalyses during the satellite era	Yeliz Yılmaz,UiO
1540 - 1600	Seasonality of Scandinavian moisture	Mika Lanzky, UiO

	sources, its spatial extent, and physical characteristics	
1600 - 1620	Identifying dominant drivers of Fennoscandian wildfires	Sigrid Jørgensen Bakke, UiO
1620 - 1640	The impact of moss and lichen on hydrological cycle at surface: a study using CLM-FATES	Hui Tang, UiO
1640 - 1700	Modelling the water balance of Norway for 1991 to 2020 with WASMOD gridded precipitation-runoff model	Stein Beldring, NVE
1700 - 1800	Buffer and break	
1800 - 1930	Poster session with drinks. See poster programme on page 6	
1930	Dinner	

Digital/hybrid poster programme

Explanation: Green boxes indicate overview talks, in which all posters are presented in a digital session, 2–4-minute presentations (streamed on Zoom – one Zoom meeting per session). Grey boxes indicate in-depth discussion, in which participants may ask questions and discuss 1–3 posters for up to 30 minutes after the given start time. It will also be possible to present the poster in person, if the poster presenter is attending at Lillehammer. This is denoted as "*author-in-attendance*" below the table.

	Session 1 Zoom room 1 **Moderators:** Ryan Bright (dig) Sigrid Bakke (phys)	**Session 2** Zoom room 2 **Moderators:** Ståle Haaland (dig) Csilla Farkas (phys)	**Session 3** Zoom room 3 **Moderators:** Stein Beldring (dig), Anne Fleig (phys)	**Session 4** Zoom room 4 **Moderators:** Hanne Heiberg (dig) Jostein Blyverket (phys)
1800	2–4-minute presentations of all posters in session 1 Finne Gullvåg Gelati Lambert Narayanappa (Titles below table)		**Extreme rainfall**: Rasmus Benestad Clio Michel	**H2O Project**: Mareile Wolff

1815	**LSM evaluation**: Emiliano Gelati Marius Lambert Devaraju Narayanappa	2–4-minute presentations of all posters in session 2: Kemppinen Farkas Kitterød Farkas et al. (Titles below table)	...continued…	**Data assimilation, snow**: Sjur Kolberg Kristoffer Aalstad
1830	**LSM evaluation:** continued...	**Soil moisture**: Julia Kemppinen Csilla Farkas	2–4-minute presentations of all posters in session 3: Michel Benestad Engeland Le Engeland et al. (Titles below table)	...continued
1845	**Plant mortality, stomatal conduct.**: Eirik Aasmo Finne Rebekka Gullvåg	continued...	**Runoff modelling**: Kolbjørn Engeland Tham Le	2–4-minute presentations of all posters in session 4: Wolf Aalstad Kolberg Mužić Eisner (Titles below table)
1900	**Plant mortality:** continued...	**Modelling soil depth + water regime**: Nils-Otto Kitterød Csilla Farkas et al.	**Runoff modelling continued: ..**.	**Forest changes**: Iris Mužić Eisner and Nilsen
1915	continued...	continued...	**Floods**: Kolbjørn Engeland et al.	continued...
1930	End	End	End	End

Poster presentations

Session 1

Eirik Aasmo Finne, NINA: Effect of winter warming events on vegetation ecophysiology on a low-alpine ridge
Author-in-physical-attendance (in the main meeting room at Lillehammer): 18:15-18:30
Emiliano Gelati, UiO: Community land model v5 runoff evaluation in small near-natural catchments in fennoscandia. *Author-in-physical-attendance: 18:45-19:00*
Rebekka Gullvåg, UiO:Effects of high-latitude light conditions on stomatal conductance and photosynthesis in white clover (trifolium repens)
Author-in-physical-attendance: 18:15-18:30
Marius Lambert, UiO: Causes of plant mortality from extreme winter events: model insights into desiccation processes during frost droughts. *Author-in-physical-attendance: 18:45-19:00*
Devaraju Narayanappa, UiO: Simulated runoff and river discharge in CLM-evaluation over Scandinavia. *Author-in-physical-attendance: 18:45-19:00*

Session 2:

Csilla Farkas, NIBIO: Soil moisture and its role in the water cycle
Digital presentation
Csilla Farkas et al., NIBIO: Modelling the water regime of a drained agricultural field in Norway under present and future conditions. *Digital presentation*
Julia Kemppinen, University of Oulu: Topographic Wetness Index as a proxy for soil moisture: the importance of flow-routing algorithm and grid resolution
Digital presentation, no physical poster.
Nils-Otto Kitterød, NBMU: Is it possible to estimate the soil depth in every point of interest for mainland Norway? *Digital presentation, no physical poster.*

Session 3:

Rasmus Benestad, MET: Testing a simple formula for calculating approximate intensity-duration-frequency curves. *Author-in-physical-attendance: 18:45-19:00*
Kolbjørn Engeland, NVE: Design flood estimation at locations with no data or short records in a Bayesian framework. *Author-in-physical-attendance: 18:00-18:15*
Kolbjørn Engeland, et al., NVE: Estimating long term mean annual runoff by combining outputs from a gridded precipitation runoff model with observations from both short and long records. *Author-in-physical-attendance: 18:15-18:30*
Tham Le, UiO: Calibration and evaluation of hydrological models
Author-in-physical-attendance: 18:00-18:15
Clio Michel, UiB: Characterisation of the atmospheric environment during extreme precipitation events associated with atmospheric rivers in Norway
Digital presentation, no physical poster.

Session 4:

Kristoffer Aalstad, UiO: Leveraging emerging earth observations using data assimilation
Digital presentation, no physical poster.
Eisner and Nilsen: Imprint – the human imprint on land–atmosphere exchange in high latitudes. *Digital presentation, no physical poster.*
Sjur Kolberg, ENKI: Simplified method for satellite snow data assimilation in operational inflow modelling. *Author-in-physical-attendance: 19:00-19:15*
Iris Mužić, CICERO/UiO: Changes in radiative forcing due to clear-cutting in Sweden
Author-in-physical-attendance: 18:00-18:15
Mareile Wolff, MET: Hydrometeorological Observations for Regional Earth System Modelling - Description of the Measurement Program of The Hydrometeorology to Operations (H2O) Project
Author-in-physical-attendance: 19:00-19:15

Wednesday 15. September 2021		
0900 - 1200	**Session 2: Modelling soil water dynamics: from observations to prediction**	**Chair: Csilla Farkas** **Co-chair: Anne Fleig**
0900 - 0930	**Keynote 2.1** Advances in characterizing the structural and functional heterogeneity of soils for hydrological modelling	**Attila Nemes, NIBIO**
	5 min discussion	
0935 - 0955	Evaluation of global soil data for large-scale hydrological modelling in Norway	Shaochun Huang, NVE
0955 - 1015	Modelling and measuring fine-scale soil moisture variation in mountain tundra	Vilna Tyystjärvi, University of Helsinki
1015 - 1035	Assimilation of crowd-sourced observations in SURFEX	Trygve Aspelien, MET
1035 - 1105	Coffee break	
1105 - 1135	**Keynote 2.2** Representing soil dynamics in Earth System Models	**Terje Berntsen, UiO**
	5 min discussion	
1140 - 1200	The role of land surface representation when predicting a convective precipitation event over southern Norway	Åsmund Bakketun, MET
1200 - 1300	Lunch	
1300 - 1615	**Session 3: Improved knowledge-base for decision-making**	**Chair: Hege Hisdal** **Co-chair: Kolbjørn Engeland**
1300 - 1330	**Keynote 3.1** From Climate Information to Hydrological Services: Examples from the Copernicus Programme to Support to the Community of Users	**Christel Prudhomme, ECMWF**

	5 min discussion	
1335 - 1355	Dynamic river networks - Actually believing what we are seeing	Thomas Skaugen, NVE
1355 - 1415	A Bayesian approach to flood-duration-frequency analysis	Danielle Barna, NVE
1415 - 1435	Modeling sensitivity to mesh size and shape a case study at central Himalayan catchment revealing importance of regional model forcing	Olga Silantyeva, UiO
1435 - 1455	Consistent Intensity-Duration-Frequency curves by post-processing of estimated Bayesian posterior quantiles	Thea Roksvåg, NR
1500 - 1530	Coffee break	
1530 - 1550	Towards updated national projections for climate adaptation in Norway	Anita Verpe Dyrrdal, MET and NCCS
1550 - 1610	Revisiting fuzzy and conversional logics in this data-era from environmental modelling perspective	Aynom Teweldebrhan, Hydro
	5 min information	
1615 - 1700	Parallel discussions 1: Hydrological research in Norway, needs and directions. Moderated by Ole Einar Tveito	Parallel discussions 2: Young hydrologists, needs and directions. Moderated by Irene Brox Nilsen
1730 - 1930	Social event: Walk alternatives for smaller cohorts in Lillehammer	
2000 - 2359	Conference dinner	

Social programme, Wednesday 15. September 17:30–19:30

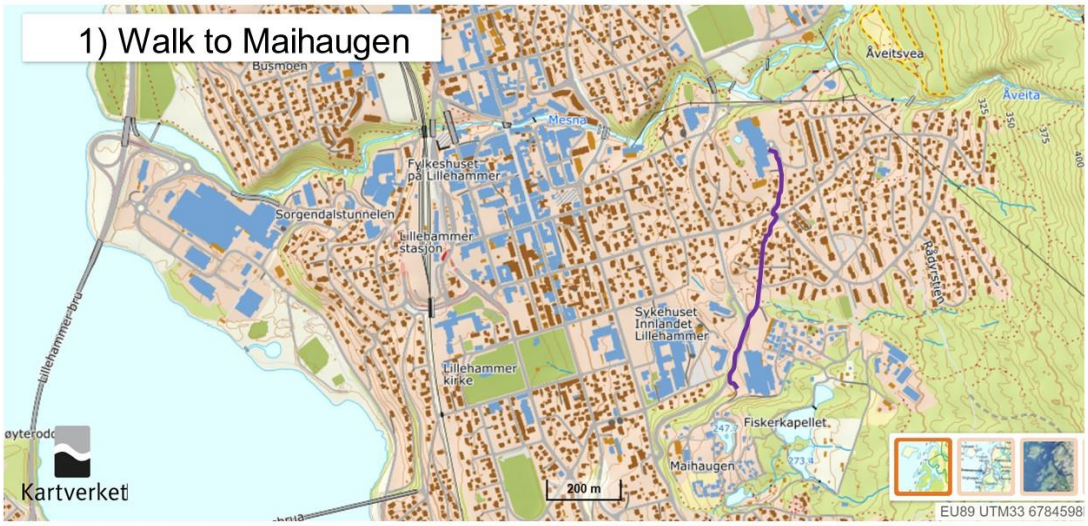
You will choose between four walks for smaller cohorts in Lillehammer. Meet outside the hotel at 17:30, and choose your group:

1) Walk to Maihaugen (led by Oddbjørn Bruland)

2) Short walk to lake Mjøsa (led by Irene Brox Nilsen)

3) Longer walk to lake Mjøsa (led by Ole Einar Tveito)

4) Jogging (led by Hans Christian Udnæs. Note: no map given).




3) Long walk to Mjøsa
Lillehammer
Vingnes
Fylkeshuset på Lillehammer
Sykehuset Innlandet Lillehammer
Fiskerkapellet
Mathiesens gate
Bryggevegen
Vingnesgata
Strandgata
Storgata
Kirkegata
Hamarvegen
Suttestad
Elverhøi
Arettavegen
Dampsagvegen
Messenlivegen
Anders Sandvigs gate
Strandpromenaden
Kvennigutua
Møllevegen
Fossvegen
Hagevegen
Hageslietta
Langsethgutua
Kiævervegen
Smedgutua
213
E6

Thursday 16.September		
0900 - 1200	**Session 4: Integrating observations into earth system modelling, including non-conventional observations**	**Chair: Ole Einar Tveito Co-chair: Hans Christian Udnæs**
0900 - 0930	**Keynote 4.1** Earth observations and their integration in land surface modelling	**Gabriëlle De Lannoy, KU Leuven**
	5 min discussion	
0935 - 0955	Regional Earth System Modelling at MET-Norway. An Overview of The Hydrometeorology to Operations (H2O) Project	Jostein Blyverket, MET
0955 - 1015	Estimation of total water storage changes in catchments using grace satellite gravimetry data	Zoreh Safdari, NTNU
1015 - 1035	Spatial analysis of daily and hourly near-surface atmospheric variables at the Norwegian Meteorological Institute	Cristian Lusanna, MET
1035 - 1105	Coffee break	
1105 - 1135	**Keynote 4.2** Beyond Ecosystem Modeling: A Roadmap to Community Cyberinfrastructure for Ecological Data-Model Integration	**Istem Fer, FMI**
	5 min discussion	
1140 - 1200	Bridging earth system modelling and ecological insights: a model platform for the functionally assembled terrestrial ecosystem simulator with community land model (CLM-FATES)	Sonya Geange, UiB
1200 - 1300	Lunch	
1300 - 1400	Discussion and final remarks.	

List of participants

	Last name	First name	Institution	Type of participation
1	Aalstad	Kristoffer	UiO	digital
2	Aas	Kjetil Schanke	UiO	physical
3	Alsaker Hopland	Agathe	Sweco	digital
4	Aspelien	Trygve	MET	physical
5	Bakke	Sigrid Jørgensen	UiO	physical
6	Bakketun	Åsmund	MET	physical
7	Barna	Daniele	NVE	physical
8	Beldring	Stein	NVE	digital
9	Benestad	Rasmus	MET	physical
10	Berntsen	Terje	UiO	physical
11	Blyverket	Jostein	MET	physical
12	Bright	Ryan	NIBIO	digital
13	Bruland	Oddbjørn	NTNU	physical
14	Etternavn	Fornavn	Institusjon	digital
15	Colleuille	Herve	NVE	digital
16	De Lannoy	Gabrielle	KU Leuven	digital
17	Dyrrdal	Anita Verpe	MET	physical
18	Ehrnsperger	Laura	MET	physical
19	Eisner	Stephanie	NIBIO	digital
20	Engeland	Kolbjørn	NVE	physical
21	Farkas	Csilla	NIBIO	physical
22	Fer	Istem	FMI	digital
23	Finne	Eirik Aasmo	UiO/NINA	physical
24	Fisher	Rosie	CNRS, France	physical
25	Fleig	Anne	NVE	physical
26	Geange	Sonya	UiB	physical
27	Gelati	Emiliano	UiO	physical
28	Glad	Per	NVE	digital
29	Guedj	Stephanie	MET	physical
30	Gullvåg	Rebekka	UiO	physical
31	Haaland	Ståle	NMBU	digital
32	Hegdahl	Trine	NVE	physical
33	Heiberg	Hanne	MET	digital
34	Hisdal	Hege	NVE	physical
35	Huang	Shaochun	NVE	digital
36	Kemppinen	Julia	University of Oulu	digital
37	Kitterød	Nils-Otto	NMBU	digital
38	Kolberg	Sjur	ENKI	physical
39	Kristiansen	Jørn	MET	physical
40	Lambert	marius	UiO	physical
41	Lanzky	Mika	UiO	physical

42	Le	Tham	UiO	physical
43	Li	Lu	NORCE	digital
44	Lussana	Cristian	MET	digital
45	Michel	Clio	UiB	digital
46	Muthanna	Tone	NTNU	digital
47	Mužić	Iris	CICERO	physical
48	Myhre	Gunnar	CICERO	physical
49	Narayanappa	Devaraju	UiO	physical
50	Nemes	Attila	NIBIO	physical
51	Nilsen	Irene Brox	NVE	physical
52	Parmentier	Frans-Jan	UiO	physical
53	Prudhomme	Christel	ECMWF	digital
54	Randriamampianina	Roger	MET	physical
55	Roksvåg	Thea	NR	physical
56	Safdari	Zohreh	NTNU	digital
57	Schultz	Michael	MET	digital
58	Silantyeva	Olga	UiO	digital
59	Skaugen	Thomas	NVE	physical
60	Sodemann	Harald	UiB	digital
61	Stenius	Seija	NVE	digital
62	Tallaksen	Lena M	UiO	physical
63	Tang	Hui	UiO	digital
64	Teweldebrhan	Aynom	Hydro	physical
65	Treichler	Desiree	UiO	digital
66	Trondsen	Elise	NVE	digital
67	Tveito	Ole Einar	MET	physical
68	Tyystjärvi	Vilna	University of Helsinki	digital
69	Udnæs	Hans Christian	HAFSLUND ECO	physical
70	Vatne	Astrid	UiO	physical
71	Vollsnes	Ane	UiO	physical
72	Wolff	Mareile A.	MET and NMBU	physical
73	Yılmaz	Yeliz	UiO	digital

LEVERAGING EMERGING EARTH OBSERVATIONS USING DATA ASSIMILATION

K. Aalstad[1], E. Alonso-González[2], V. Bazilova[1], L. Bertino[2], J. Fiddes[4], N. Pirk[1], S. Westermann[1]
[1]Department of Geosciences, University of Oslo, Oslo, Norway
Email: kristoffer.aalstad@geo.uio.no
[2]Pyrenean Institute of Ecology, Spanish Research Council, Zaragoza, Spain
[3]Nansen Environmental and Remote Sensing Center, Bergen, Norway
[4]WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland

ABSTRACT

The task of mapping from noisy observations to the states that (given a forward model) may have generated them falls under the umbrella of inverse problems. These problems are abundant in Earth system science since our uncertain mechanistic models need to be fully specified while the system is only partially and imperfectly observed. This abundance has, combined with a steadily growing observing system, fueled the development of probabilistic Data Assimilation (DA) schemes that use Bayesian inference to fuse uncertain information from models and observations. Notable operational applications of DA include the production of global atmospheric reanalyses and initializing numerical weather predictions. Perhaps less appreciated is the added value that DA can bring to Earth Observations (EO) as a generalized framework for building retrieval algorithms. In our work we present two completely different inverse problems that show how DA can help us to make the most out of emerging EO.

The first problem is snowpack reconstruction where we constrain snow models using highly informative observations of the dynamics of snow cover depletion retrieved using satellite remote sensing. We provide examples assimilating retrievals from moderate (MODIS) and higher resolution (Landsat, Sentinel-2, PlanetScope cubesats) optical sensors as well as from all-weather radar data (Sentinel-1) in the Californian Sierra Nevada, Svalbard, Finse, the Pyrenees, the Swiss Alps, and Lebanon. This method is being developed to build tailored snow and permafrost reanalysis frameworks that lead to improved global cryospheric mapping capabilities and provide new benchmarks for Earth system models.

The second problem is flux inversion where we seek to infer surface fluxes of carbon, water, and heat using a drone swarm that provides distributed measurements of temperature, gas concentrations, and wind in the atmospheric boundary layer. To achieve this, we assimilate drone data into various boundary layer models, building up complexity from analytical flux-profile relationships based on the widely used Monin-Obukhov Similarity Theory to turbulence resolving large eddy simulations. Through flux inversion with the latter the hope is that we will be able to map fluxes in highly heterogeneous landscapes at the scale of Earth system models (10 km). This is not possible with existing methods like eddy covariance and can thereby shed new light on the role of flux heterogeneities in land-atmosphere coupling.

When solving these problems we test various probabilistic DA schemes including variants of the ensemble Kalman filter, the particle filter, and Markov chain Monte Carlo. These schemes have been adapted to our problems by casting them as smoothers that condition the model on future observations, rather than as sequential filters, which crucially allows information to propagate backwards in time. We also emphasize how we can use DA to move beyond the usual first level of inference where we "fit" our model to data, up to the second level of inference where we can compare different competing model structures and parametrizations using the model evidence framework.

Keywords: Data assimilation; Earth Observation; Snow; Turbulence; Fluxes; Satellites; Drones

EXPLICIT REPRESENTATION OF SUB-GRID SNOW AND VEGETATION HETEROGENEITY IN A LAND SURFACE MODEL

K. S. Aas[1], H. Tang[1]. T. K. Berntzen[1]
[1]Department of Geosciences, University of Oslo,
Postboks 1022, 0315, Oslo – Norway
Email:k.s.aas@geo.uio.no

ABSTRACT

The land surface is heterogeneous on a number of different scales, and across different axes (including vegetation cover, snow cover, soil depth and soil water content). This heterogeneity is greatly simplified in land surface models (LSMs), which typically only represent sub-grid variability in land use and plant functional types explicitly. Previous studies have shown that representing snow variability with "tiles" can improve the representation of land-atmosphere coupling in high-mountain Norway. Here we combine the representation of sub-grid snow and vegetation heterogeneity by assuming covariation between snow accumulation and vegetation types. This is added to the existing sub-grid hierarchy in the Community Land Model (CLM) and tested particularly for alpine and Arctic regions, and compared with existing formulations. This alternative representation could offer a way accounting for uneven snow accumulation, with limited increase in computational cost in LSMs.

Keywords: snow distribution; sub-grid representation; LSMs

ASSIMILATION OF CROWD-SOURCED OBSERVATIONS IN SURFEX

Trygve Aspelien
[1]*MET-Norway*
Henrik Mohns plass 1, 0371, Oslo – Norway
Email: trygveasp@met.no

ABSTRACT

The external surface model SURFEX used in the MET-Norway numerical weather prediction (NWP) setup has a critical dependency for good initial states when predicting the future surface state. This process of blending/ combining model and observation information through data assimilation to improve the NWP initialization has lately evolved in also using amatour weather observations, also called crowd-sourced observations. In this presentation I describe how crowd-sourced observations are used in different model systems at MET-Norway with a focus on hydrological applications and the offline applications planned as a part of the project Hydrometeorology to Operations (H2O).

Keywords: crowd-sourced observations, NWP, SURFEX, model, initial conditions, data assimilation, predictions

IDENTIFYING DOMINANT DRIVERS OF FENNOSCANDIAN WILDFIRES

S.J. Bakke[1], N. Wanders[2], K.V.D. Wiel[3], M. Ionita[4], L.M. Tallaksen[1]
[1]Department of Geosciences, University of Oslo
Sem Sælands vei 1, 0371 Oslo – Norway
Email: s.j.bakke@geo.uio.no
[2]Department of Physical Geography, Utrecht University
[3]Royal Netherlands Meteorological Institute
[4]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research

ABSTRACT

Wildfires are recurrent natural hazards that affect terrestrial ecosystems, the carbon cycle, climate and society. An ignition can lead to a wildfire when there is biomass available for burning, typically in combination with dry and windy conditions. The availability of burnable biomass is itself driven by conditions such as soil moisture, temperature, humidity, precipitation, etc. Wildfires are regarded as compound events, which are extreme impacts that are dependent on multiple statistically dependent variables. Identifying a selection of dominant controls can ultimately improve predictions and projections of wildfires in both current and future climate. In this study, we apply a data-driven bottom-up supervised learning approach (including random forest and generalized additive models) to identify dominant factors determining burned area over Fennoscandia. The work builds on the analysis presented at the conference vEGU21 [1]. A monthly 2001-2019 burned area product derived from satellite observations is used as target variable, and multiple hydrometeorological metrics stemming from the ERA5 reanalysis and observational datasets (e.g. EOBS) are tested as potential predictors. Metrics that are investigated include concurrent temperature, precipitation, wind, humidity, soil moisture, burnable vegetation cover, and meteorological drought indices over various accumulation periods. Because soil moisture and meteorological drought can have a delayed effect on biomass, lagged versions of these metrics are also tested as potential predictors. The derived relationships between wildfires and its compound drivers will further be used to assess the potential changes in such a combination of factors under different climate scenarios using large-ensemble global climate simulations. This new framework will allow us to better quantify the changes in potential wildfire risk in a changing climate using a combination of data driven and physically based models.

[1] Bakke et al. (2021): https://doi.org/10.5194/egusphere-egu21-11524

Keywords: wildfire; compound event; meteorological drought; supervised learning

THE ROLE OF LAND SURFACE REPRESENTATION WHEN PREDICTING A CONVECTIVE PRECIPITATION EVENT OVER SOUTHERN NORWAY

Å. Bakketun[12], J.Blyverket[1], T.Berntsen[2], M.Müller[12]
[1]Meteorologisk institutt
Meteorologisk institutt, Henrik Mohns Plass 1, 0371 Oslo
Email: asmundb@met.no
[2]University of Oslo, Oslo, Norway

ABSTRACT

Over the last decades the intensive effort to understand the current and future climate has led to complex Earth system models, including description of chemical and biological as well as physical and hydrological processes. From a numerical weather prediction (NWP) perspective, higher resolution models, improved input data originating from satellite Earth observation missions, and more computational capacity have made the more realistic, multilayer surface models attractive for operational forecasting systems. In intense convective precipitation events, the land surface can play an important role, either as a triggering mechanism for precipitation or a source for moisture. In this study we use the operational NWP modelling system at Met Norway with a multi-layer surface scheme to study a convective precipitation event in southern Norway. We perform sensitivity studies to understand the relationship between initial conditions and forecasted precipitation, and to evaluate the impact of the multi-layer surface model. The initial soil moisture content is found to be important for the accumulated precipitation amount. Furthermore, the temporal distribution of the precipitation is dependent on the land surface scheme. The results in this study could impact how the surface perturbations of ensemble prediction systems are performed, and possibly lead to more accurate forecasts of convective precipitation and its uncertainty.

Land-atmosphere interactions, soil moisture, NWP, model, initial conditions, precipitation

A BAYESIAN APPROACH TO FLOOD-DURATION-FREQUENCY ANALYSIS

D. Barna[1,3], K. Engeland[1,3], T. Thorarinsdottir[2], C-Y. Xu[3]
[1]Norges vassdrags- og energidirektorat (NVE)
Middelthuns gate 29, 0368 Oslo – Norway
Email: daba@nve.no
[2]Norsk Regnesentral, Oslo, Norway
[3]Department of Geosciences, University of Oslo, Oslo, Norway

ABSTRACT

As floods become increasingly prevalent in Norway under climate change there is a growing need for relevant design flood values. Such values give estimates of flood magnitude within a given return period and are essential to making adaptive decisions around land use planning, infrastructure design, and disaster mitigation. The accuracy of design flood values hinges on their ability to properly characterize the magnitude of a flood; while traditional flood frequency analysis methods consider peak and/or daily average flows when defining magnitude, we seek to implement a more comprehensive method that models flood magnitude as a combination of both peak flow and duration. Such modelling is termed flood-duration-frequency, or QDF, modelling. The QDF modelling approach proposed here establishes a parametric relationship between the quantiles of the distributions from flood events of different durations, allowing for the estimation of design flood values for floods of any duration. We establish an at-site QDF model for select gauging sites in Norway using a Bayesian modelling framework.

Keywords: flood design values; flood frequency analysis; Bayesian modelling; extreme value distribution

MODELLING THE WATER BALANCE OF NORWAY FOR 1991 TO 2020 WITH WASMOD GRIDDED PRECIPITATION-RUNOFF MODEL

Xue Yang, Gusong Ruan, **Stein Beldring**, Kolbjørn Engeland, Erik Holmqvist, Anja Iselin Pedersen

Norwegian Water Resources and Energy Directorate (NVE)
PO Box 5091 Maj., 0301 Oslo, Norway
email: sbe@nve.no

ABSTRACT

A gridded version of the process-based water and snow balance modelling system WASMOD was used for modelling the water balance of Norway and upstream areas in Finland and Sweden at 1 km^2 spatial resolution and monthly time step for the period 1991 to 2020. Input data were gridded temperature and precipitation from seNorge and potential evaporation was estimated by the Penman-Monteith method. Model parameters were assumed to represent the properties of different hydrological response units characterised by their Köppen-Geiger classification, land use and soil type. A regional model calibration procedure was performed by assigning similar parameter values to model elements with identical classification in catchments belonging to three different climatic zones (oceanic, continental and polar tundra) in all regions of Norway. This calibration procedure rests on the hypothesis that model elements with identical characteristics have similar hydrological behaviour and should consequently be assigned the same parameter values. Routing of runoff through the river network is an important component of distributed hydrological models when time series of flows from large drainage basins are considered, but with the monthly time resolution of the model this is not required. All discharge time series available in the national hydrological database were subject to quality control and a total of 171 catchments were used for calibration of WASMOD, while 38 independent catchments were used for evaluation of model performance. It is in general difficult to determine regional parameter sets that can be applied successfully for several catchments. The model simulation results are mostly satisfactory although there are biases compared to the observed data. The gridded simulations from the hydrological model were therefore corrected using a geostatistical model where the runoff estimates from the precipitation-runoff model was used as a covariate and the runoff observations were used as the dependent variable.

Keywords: Water balance maps; Mean annual runoff; WASMOD hydrological model

TESTING A SIMPLE FORMULA FOR CALCULATING APPROXIMATE INTENSITY-DURATION-FREQUENCY CURVES

R. Benestad[1], J.Lutz[1], A. Dyrrdal[1], JE. Haugen[1], K. Parding[1], A. Dobler[1]
[1]The Norwegian Meteorological Institute
Henrik Mohns plass 1, 0313, Oslo – Norway
Email: rasmus.benestad@met.no

ABSTRACT

A simple formula for estimating approximate values of return levels for sub-daily rainfall is presented and tested. It was derived from a combination of simple mathematical principles, approximations and fitted to 10 year return levels taken from intensity-duration-frequency (IDF) curves representing 14 sites in Oslo. The formula was subsequently evaluated against IDF curves from independent sites elsewhere in Norway. Since it only needs 24 h rain gauge data as input, it can provide approximate estimates for the IDF curves used to describe sub-daily rainfall return levels. In this respect, it can be considered as a means of downscaling with respect to timescale, given an approximate power-law dependency between temporal scales. One clear benefit with this framework is that observational data is far more abundant for 24 h rain gauge records than for sub-daily measurements. Furthermore, it does not assume stationarity, and is well-suited for projecting IDF curves for a future climate.

Keywords: intensity-duration-frequency; sub-daily rainfall

REPRESENTING SOIL DYNAMICS IN EARTH SYSTEM MODELS

T. Berntsen,
[1]*Department of Geosciences and Center for Biogeochemistry in the Anthroposcene (CBA), University of Oslo*
Sem Seland vei 1, 0371 Oslo, Norway.
Email: t.k.berntsen@geo.uio.no

ABSTRACT

The terrestrial reservoir of carbon, including vegetation and soils, is about three times larger than the amount of carbon in the atmosphere. Modern Earth System Models (ESMs) now include coupled biogeochemistry cycles with different levels of detail. Improving the understanding of terrestrial carbon is important to improve estimates of the terrestrial carbon sink, the potential feedbacks and also how this affects the impacts of climate change. In the recent CMIP6 model inter comparison 11 ESMs contributed to the analysis of biogeochemical feedbacks. The analysis clearly showed that the uncertainties in the carbon-climate feedbacks across the models is as large as the difference imposed across the different future emission scenarios.

Over the last years, it has become more and more evident that the microbial activity in the soil that leads to the degradation of organic matter has to be more explicitly represented in the models. Likewise, the importance of the coupling between the carbon cycle and the cycles of other important nutrients (mainly nitrogen and phosphorous) has to be included in the model.

The talk will describe the current understanding of the soil carbon cycle and how the new model developments can work towards a better representation of this important part of the climate system in the Earth System Models.

Keywords: Soil Carbon, Biogeochemistry

Regional Earth System Modelling at MET-Norway
An Overview of The Hydrometeorology to Operations (H2O) Project

J. Blyverket[1], J. Kristiansen[1], Å. Bakketun[1] , T. Aspelien[1] , H.B. Erlandsen[1] , R. Stappers[1] , M.A Wolff[2,1] ,V. Kristiansen[1]

[1]The Norwegian Meteorological Institute
Henrik Mohns plass 1, 0313, Oslo – Norway
Email: josteinbl@met.no
[2]Norwegian University of Life Science

ABSTRACT

Extreme rainfall, flash floods, drought, snow avalanches and landslides, are all major hazards to lives and property, and may affect business and industrial development negatively. Despite advances in numerical weather prediction (NWP) models and post-processing techniques over the past few decades, prediction of intense, small-scale precipitation remains a challenge. NWP systems are not exploiting fully how the atmosphere influences and interacts with the other components of the Earth system (e.g., soil water content and temperature, terrestrial snow, land biosphere, lake temperature etc.). This is a deficit of our NWP system and it remains a challenge because of the complexity of the Earth system we try to represent with our models. The Hydrometeorology to Operations (H2O) project at the Norwegian Meteorological Institute is guided by the scientific hypotheses that: (**i**) more advanced land surface physics and hydrology in NWP models will improve the short-range forecasts, (**ii**) more accurate initialization of the land surface through the uptake of Earth observations (EOs) benefits both short-range NWP and downstream hydrological forecast accuracy and reliability, and (**iii**) coupled Earth system models need coupled data assimilation (CDA) systems to ensure consistency between the analysis updates in the different domains. In this presentation we give an overview of the H2O project and how the H2O project will address the growing need for accurate and reliable high-resolution, short-range forecasts of hydrometeorological events and extremes.

Keywords: Earth system; Hydrometeorology

TOWARDS UPDATED NATIONAL PROJECTIONS FOR CLIMATE ADAPTATION IN NORWAY

A.V. Dyrrdal[1], H.O. Hygen[1], I.B. Nilsen[2], S. Mayer[3]
[1]Norwegian Meteorological institute
Bok 43 0313 Blindern, Oslo – Norway
Email: anitavd@met.no
[2]Norwegian Water resources and Energy directorate
[3]Norwegian Research Centre

ABSTRACT

In the wake of the 6th assessment report from IPCC due this year, Norwegian Centre for Climate Services has started a project to update their national climate assessment report Climate in Norway 2100. A major part of this update revolves around the selection of a representative model ensemble for a low, medium and high emission scenario, plus bias adjustment of EURO-CORDEX output and statistical downscaling directly from CMIP6 to the national, and subnational, level. The results will form the natural scientific basis for local climate adaptation in Norway, through the computation of expected changes in selected climate indices on a 1 x 1 km grid covering the Norwegian mainland.

The new knowledge will also serve to update the much used climate fact sheets (presented at EMS 2016) for Norwegian counties. We aim to develop a map based webtool for the climate fact sheets, consisting of map layers of several climate indices. The user will be able to get tailored fact sheets for a given point or region, generated from a template that merges information from map layers and predefined texts.

The project is divided into five working groups: 1. Historical climate, 2. Modeling, 2. Future climate, 4. Infrastructure, 5. Outreach. In this presentation we will present the organization and plans for the project, as well as details on the model ensemble selection from EURO-CORDEX, based on both CMIP5 and CMIP6, and the methods for downscaling a bias-adjustment to the national level. The updated report is planned to be issued in 2024.

Keywords: national climate projections, climate adaptation

IMPRINT – THE HUMAN IMPRINT ON LAND–ATMOSPHERE EXCHANGE IN HIGH LATITUDES

S. Eisner[1,2], I. Haddeland[1], I. B. Nilsen[1], R. Bright[2]
[1] Norwegian Water Resources and Energy Directorate
Middelthuns gate 29, 0368 Oslo – Norway
Email: ibni@nve.no
[2] Norwegian Institute of Bioeconomy

ABSTRACT

Human land management contributes to climate change. In Norway, large-scale transitions in forest structure due to forest management have been the most widespread land management impact over the past decades, and forest management will continue to shape landscape and forest structure throughout the 21st century. The project IMPRINT investigates the effects of past and future land and forest management on biogeophysical processes that govern the exchange of energy and water between the land surface and the atmosphere. The project focusses on three intertwined land surface processes that are particularly sensitive to both climatic change and human interference from forest and land management: 1) snow accumulation and melt, 2) land energy balance and 3) soil water dynamics.

The overarching objective of IMPRINT is to improve key process understanding in the interaction between land and forest management, anthropogenic climate change and terrestrial biogeophysical processes that govern surface energy and water fluxes. The study domain is mainland Norway, but links to coordinated global experiments will be established. This is achieved through the following secondary objectives: (1) Advance observationally-constrained modelling to quantify atmosphere–biosphere–hydrosphere interaction processes; (2) Quantify the impact of human activity on land-atmosphere exchange over the past decades; (3) Project the human imprint on surface energy and water fluxes in a coherent scenario framework; and (4) Bridge the gap between fine-scale regional modelling and coordinated global experiments.

IMPRINT will provide an advance over previous assessments in two additional aspects. Firstly, forest and land management scenarios are developed that build on various national data sources, i.e. statistics, forest inventory information, and vegetation surveys. Secondly, the modelling is carried out at fine spatial resolution (1 km^2), i.e. will better reflect spatial heterogeneity in biotic and abiotic factors that govern energy and water fluxes.

Keywords: IMPRINT project, land–atmosphere exchange, forest management

EARTH OBSERVATIONS AND THEIR INTEGRATION IN LAND SURFACE MODELING

De Lannoy, G.[1], M. Bechtold[1], I. Brangers[1], Z. Heyvaert[1], S. Kumar[3], H. Lievens[1], C. Massari[2], S. Modanesi[2], R. Reichle[3]
[1]KU Leuven
Celestijnenlaan 200 E, B-3001 Heverlee – Belgium
Email: gabrielle.delannoy@kuleuven.be
[2]IRPI/CNR
[3]NASA/GSFC

ABSTRACT

The land surface is a crucial part of the Earth system. In this talk, we will review the opportunities and limitations of the increasing number of available satellite data for land surface data assimilation in view of today's needs to limit the harm of natural hazards, to predict energy availability and agricultural production, or to monitor climate variability. Thereafter, we will illustrate how such needs can be addressed via microwave-based data assimilation for soil moisture and snow updating.

Passive and active microwave-based observations from the SMOS, SMAP and Sentinel-1 missions can be used directly in assimilation systems, i.e. as radiances or backscatter values, or they can be converted to geophysical retrievals of land surface properties. The presentation will show recent examples of both pathways to estimate soil moisture and snow depth at different spatial scales and over various regions. More specifically, we will discuss the direct assimilation of (i) SMOS or SMAP microwave radiances to update soil moisture globally, and over peatlands specifically to estimate groundwater, (ii) Sentinel-1 microwave backscatter to correct for soil moisture and irrigation across test regions in Europe, and the retrieval assimilation of (iii) a recent Sentinel-1 snow depth product over the Alps, and (iv) the ESA CCI soil moisture product over Europe.

Keywords: soil moisture; snow; data assimilation

DESIGN FLOOD ESTIMATION AT LOCATIONS WITH NO DATA OR SHORT RECORDS IN A BAYESIAN FRAMEWORK

K. Engeland[1], T. Reitan[3]**,** S.M. Stenius[1]**,** P. Reitan[1]
[1]The Norwegian Water Resources and Energy Directorate (NVE)
Middelthuns gate 29, 0368 Oslo – Norway
Email: koe@nve.no

ABSTRACT

Estimating design floods at location with no measurements or short records is a major challenge for operational hydrology. The aims of this study are to (i) develop a regional flood frequency model that consists of a regression model for the index flood and the parameters in the growth curve; (ii) assess and attribute the uncertainty to the components of the regional flood frequency model, (iii) develop flexible approaches for combining a regional flood frequency model with local data and provide recommendations for how to combine local and regional data. Annual maximum flood data from 529 gauging stations were used for the model development. We re-parametrized the Generalized Extreme Value (GEV) distribution into an index flood component and growth curve component, and we used the median flood as the index flood. The model was estimated using a MCMC algorithm within a Bayesian framework. The Bayesian approach was also used to combine local and regional data. Two approaches were used (i) combining local and regional data to estimate the index flood (ii) combining local and regional data to estimate both the index flood and the growth curve. Simulation experiments were carried out to assess the performance of these approaches. We see that in particular for data records shorter than 10 years, we can benefit from combining the local and the regional model by both approaches. We also constructed a prior for use in local analysis that complied with the distribution of the regional model for three key quantiles. For the index flood, the regression model was successfully estimated and evaluated using a three-step cross validation approach. The most important variables for predicting the index flood were mean annual runoff, river length and lake percentage. The attribution of uncertainty showed that most of the uncertainty was found in the index flood component. This abstract is also presented at the EGU General Assembly 2021 [1].

[1] Engeland, K., Reitan, T., Stenius, S. M., and Glad, P.: Design flood estimation at locations with no data or short records in a Bayesian framework, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-13317, https://doi.org/10.5194/egusphere-egu21-13317, 2021

Keywords: Regional flood frequency analysis; Bayesian estimation; Short records;

ESTIMATING LONG TERM MEAN ANNUAL RUNOFF BY COMBINING OUTPUTS FROM A GRIDDED PRECIPITATION RUNOFF MODEL WITH OBSERVATIONS FROM BOTH SHORT AND LONG RECORDS

T. Roksvåg[2,3], **K. Engeland[1],** I. Steinsland[3]
[1]*The Norwegian Water Resources and Energy Directorate (NVE)*
Middelthuns gate 29, 0368 Oslo – Norway
Email: koe@nve.no
[2]*Norwegian Computing Center, Oslo, Norway (roksvag@nr.no)*
[3]*Norwegian University of Science and Technology, Trondheim, Norway*

ABSTRACT

We present a new framework that combines process-based precipitation-runoff models and geostatistical methods for estimating mean annual runoff for a climatic reference period of 30 years. The approach combines the knowledge implemented in a process-based model with the empirical streamflow observations. The framework consists of two steps. In the first step a precipitation-runoff model is used to simulate the mean annual runoff on a grid covering the whole study area. For such an application, the parameters of the precipitation-runoff model are calibrated globally. Consequently, there are spatially varying biases in the estimated runoff when compared to the observations. Therefore, in the second step, we corrected the gridded simulations using the runoff observations. In this step we applied a Bayesian geostatistical model where the runoff estimates from the precipitation-runoff model was used as a covariate and the runoff observations were used as the dependent variable. The regression coefficient of the covariate was modelled as a spatial field. This allows that the relationship between the covariate (simulations from the process-based model) and the response variable (the observed mean annual runoff) was allowed to vary within the study area. Hence, it is a spatially varying coefficient model. To exploit as much runoff observations as possible, we also used a pre-processing step for including short records (1-29 years) in the modelling of the 30 year mean annual runoff. This approach allowed us to predict runoff in fully gauged, partially gauged (i.e. less than 30 years of observations) and ungauged catchments. We used state of the art statistical methods such as SPDE and INLA to ensure fast Bayesian inference.

The new framework was evaluated by predicting mean annual runoff for 1981-2010 for 127 catchments in Norway based on streamflow observations from 411 catchments. Simulations from the HBV model on a 1 km x 1 km grid for the whole country were used as covariate. On average this new approach outperformed a purely process-based approach (HBV) when predicting runoff for ungauged and partially gauged catchments. The RMSE was reduced by 20 % in ungauged catchments and 58 % in partially gauged catchments compared to using the HBV model only. In ungauged catchments the proposed framework reduces the RMSE by 10 % when compared to a geostatistical method. For partially gauged catchments however, purely geostatistical methods performed equally well or slightly better than the proposed two step procedure.

This method will be used to estimate the new runoff map for Norway for the new normal period 1991-2020. Then the precipitation-runoff model WASMOD operating on a monthly time scale will be used.

Keywords: Runoff map; Mean annual runoff; Short records; Geostatistical methods.

MODELLING THE WATER REGIME OF A DRAINED AGRICULTURAL FIELD IN NORWAY UNDER PRESENT AND FUTURE CONDITIONS

Cs. Farkas, S.H. Kværnø and J. Deelstra
Division of Environment and Natural Resources, Norwegian Institute of Bioeconomy Research (NIBIO)
Oluf Thesens vei 43, 1433 Ås – Norway
Email: csilla.farkas@nibio.no

ABSTRACT

A large proportion of the soils in Norway require artificial drainage to improve the conditions for crop growth and field operations, but also to reduce the risk of soil compaction, surface runoff and erosion. The need for artificial drainage depends on climate, topography, soil type, groundwater conditions, and also the crop. At present, about 60-70 % of the agricultural land in Norway is artificially drained.

Future climate change is expected to lead to higher temperatures, more precipitation and more frequent extreme events in Norway. This poses a challenge with respect to the drainage systems as more intensive drainage than present today may be required in some areas, although it is unclear whether this will be an efficient solution. In this study we aimed to evaluate the possible future changes in subsurface runoff and water balance elements at the Kvithamar experimental site.

We set up the and calibrated the DrainMod model for the experimental data from poorly and optimally drained experimental fields. The calibrated model was further used to evaluate changes in subsurface runoff and the water cycle as a whole under changing conditions. We tested the effect of different drainage system designs (drain depth and spacing) on water regime under present and future climate conditions.

It was quite difficult to calibrate the DrainMod model for surface runoff and drain flow measured from the Kvithamar lysimeter plots and to find a parameter set that could give a reasonable partitioning of the water. We concluded that due to the complexity of the hydrological regime of a drained field the effect of drains can be masked by other factors, like land use and spatio-temporal variability of soil properties. Our simulation results indicate that drainage system design has a big effect on surface and subsurface runoff as well as on evapotranspiration. Concerning future changes in the hydrological regime, the results varied depending on the future climate scenarios selected.

Keywords: tile drainage; water regime; DrainMod model; drainage design

SOIL MOISTURE AND ITS ROLE IN THE WATER CYCLE

Cs. Farkas
Division of Environment and Natural Resources, Norwegian Institute of Bioeconomy Research (NIBIO)
Oluf Thesens vei 43, 1433 Ås – Norway
Email: csilla.farkas@nibio.no

ABSTRACT

Soil moisture is an important but often undervalued element of the water cycle. Compared to other components, the volume of soil moisture is small; nonetheless, it is of fundamental importance to many hydrological, biological and biogeochemical processes. Through processes like evaporation and plant transpiration, soil moisture is a key variable in controlling the water and energy exchange between the land surface and the atmosphere, hence, it plays an important role in the development of weather patterns and the precipitation formation. It also strongly effects surface and subsurface runoff, soil erosion, food production, greenhouse gas emission, the buffer capacity of the soil, the soil biota and many other processes and sectors. It is deducible today that short-sighted mismanagement of soil or soil water strongly contributed to the collapse of large, powerful historic civilizations.

Soil degradation is a global problem that is of strong concern for European countries as well. Yet, while much focus is given to open surface water recourses - the EU Water Framework Directive is in place since 2000 - the Soil Framework Directive is still to be adopted. It is important to improve the global understanding of the importance of soil as a natural resource, and its hydraulic functioning, including its global change context. The presentation aims at taking a deeper insight into the "butterfly effect" of soil status and moisture dynamics by highlighting how small-scale management decisions and processes might influences large-scale processes and our life.

Keywords: soil water; soil quality; water balance elements

A NEW ERA OF DATA-MODEL INTEGRATION WITH COMMUNITY CYBERINFRASTRUCTURE TOOLS

I. Fer[1], PEcAn Team[2]
[1]*Finnish Meteorological Institute*
Erik Palmenin aukio, 00560, Helsinki – Finland
*Email: i*stem.fer@fmi.*fi*
[2]*Predictive Ecosystem Analyzer, pecanproject.org*

ABSTRACT

A more predictive global change science needs to be based on Earth System Models (ESMs) that are informed by data to have their uncertainties reduced and process representations improved. However, the rates at which new information has been integrated into ESMs have been lagging behind the pace of Earth Observation (EO) data generation significantly. To constrain ESMs efficiently with the ever-increasing volume, speed, and diversity of EO data and push them to new limits, a community-driven model-data integration strategy that invests in accessible, scalable, and transparent cyberinfrastructure tools is proposed. These community tools bring the computational and organizational structures needed for operational and systematical integration of EO data into ESMs by reducing the bottlenecks in the associated model-data activities. Within a community cyberinfrastructure, the challenge of developing advanced model-data integration workflows can be faced by the experts. In return, not only our ability to confront models with data will be accelerated by allowing a wider audience to adopt these methods, but also progress on developing novel and more advanced techniques will be fostered by utilizing experts' time more efficiently. Here, we give examples of model-data integration activities using a state-of-the art community cyberinfrastructure tool, Predictive Ecosystem Analyzer (PEcAn). These activities include but are not limited to emulator-based (hierarchical) Bayesian calibration of models, Bayesian calibration of models using remotely sensed surface reflectance data, state data assimilation using a novel algorithm that generalizes the Ensemble Kalman Filter and operationalized near-term iterative ecological forecasting. This community-driven effort in developing shared model-data integration tools presents a key opportunity to inform and test new process representations and scaling approaches in the next generation of ESMs.

Keywords: community cyberinfrastructure; model-data integration; data assimilation; Earth System Models; ecological informatics

EFFECT OF WINTER WARMING EVENTS ON VEGETATION ECOPHYSIOLOGY ON A LOW-ALPINE RIDGE

E. A. Finne[1,2], L. M. Tallaksen[1], F. Stordal[1], J. W. Bjerke[2]
[1]Department of Geosciences, University of Oslo,
PO Box 1047, Blindern, NO-0316 Oslo, Norway
Email: e.a.finne@geo.uio.no
[2] Norwegian Institute for Nature Research (NINA), Framsenteret
PO Box 6606, Langnes, NO-9296 Tromsø, Norway

ABSTRACT

Extreme weather events can both influence carbon cycling and sequestration and lead to pervasive changes in ecosystem structure and function. At high latitudes and in alpine bioclimatic zones, the effect of winter warming can be particularly important for vegetation dynamics, even leading to vegetation browning. Under future climate change, the frequency and severity of these events are expected to increase. Midwinter snow melt that leads to full exposure of vegetation is a strong stressor to some, but not all, vegetation types. Vascular plants break hibernation during such events and become photosynthetically active. Both factors lead to reduced protection against freezing damage. Thus, returning to freezing conditions typically result in freeze damage. Together with snow meltwater, rain-on-snow events can lead to excessive ground-icing causing anoxic conditions for active cells. Hence, plant leaves are killed by the side products of anaerobic metabolism. If such events occur in late winter with much sunlight, but still frost in the soil, plants tend to dry out in response to the leaf activity and the lack of water supply from the roots, and hence, shoots die from what is referred to as a frost drought. In some cases, freeze damage, anoxic conditions and frost drought can all occur in the same area during the same winter. While the impacts of changing winter climate on plants that rely on an insulating snow-cover in winter have been well explored during the last ten years, the effects on bryophytes and lichens are much less known. In March 2021, six experimental plots at a lichen and bryophyte-dominated ridge on Finse (1200 m a.s.l., N 60.59°, E 7.53°) were heated by infrared lamps. In six additional plots, a 10 cm layer of ice was experimentally developed. During the summer of 2021, ecophysiological measurements from dominant lichen, bryophyte and vascular plants species will be collected, and contrasted with control plots. This treatment will be repeated during the winter of 2022. Preliminary results of this field experiment will be presented at the conference and discussed in relation to biochemical fluxes and spectral properties of vegetation.

Keywords: Lichen; Bryophytes; Carbon cycle; Snowmelt; Rain on Snow

A HIERARCHICAL COMPLEXITY FRAMEWORK FOR MANAGING THE COMPEXITY OF LAND SURFACE MODELS

Rosie Fisher[1], Charles Koven[2]. Ryan Knox[2], Greogory Lemieux[2], Hui Tang[3]
[1]Évolution and Diversité Biologique, University of Toulouse Paul Sabatier. Toulouse, France.
Email: rosieafisher@gmail.com
[2]Lawrence Berkeley National Lab, Berkeley, California, USA.
[3]Department of Geosciences, University of Oslo, Oslo, Norway.

ABSTRACT

Modern land surface models are designed to simulate both the present and future biophysical and biogeochemical feedbacks between climate change and the terrestrial biosphere, as well as, increasingly, the impacts of climate change on numerous land surface processes and conditions (drought, floods, fires, forest productivity). This immense scope means that they encapsulate process representations from numerous overlapping scientific disciplines, that they are exceptionally complex, and subject to extraordinary structural and parametric uncertainty. At the present time, few tractable strategies exist to assist with this substantial barrier to progress, despite the increasing value that society places in predictions both of the trajectories and impacts of climate change.

We propose that one way of 'managing' this complexity is to design models in such a way that sets of processes relevant to particular questions can be 'decoupled'. In this system, critical variables can either be dynamically predicted, or prescribed to the model as inputs. Thus, individual elements can be tested under known conditions without being subject to complex and potentially biased feedbacks from other components.

Here we present this capability in the FATES demographic vegetation model. We illustrate how model calibration and uncertainty analysis can be facilitated by first assessing performance in 'satellite phenology' mode, with fixed LAI, followed by biogeochemical processes in 'fixed biogeography' mode, thus allowing a more tractable analysis of the highest complexity fully prognostic dynamic vegetation mode.

Keywords: land surface model; demography; complexity; uncertainty.

BRIDGING EARTH SYSTEM MODELLING AND ECOLOGICAL INSIGHTS: A MODEL PLATFORM FOR THE FUNCTIONALLY ASSEMBLED TERRESTRIAL ECOSYSTEM SIMULATOR WITH COMMUNITY LAND MODEL (CLM-FATES)

S. Geange[1], EMERALD project members
[1]*Department of Biological Sciences, University of Bergen, Norway*
Thormøhlensgt, 53 A, 5020, Bergen, Norway
Email: Sonya.Geange@uib.no

ABSTRACT

High latitude ecosystems are rapidly being impacted by climate change, with changes in precipitation and temperature dynamics, CO_2 and methane emissions and subsequently wide-ranging shifts in vegetation composition and function. However, currently these critical ecosystems are relatively poorly represented within earth system models (ESMs). In particular, ensuring we capture dynamic vegetation processes is key to developing accurate, reliable and trustworthy insights into the role of vegetation in moderating global atmospheric, soil and hydrological cycles. Developing such insights requires a broad, interdisciplinary approach, drawing together earth system modelers, climate scientists, and ecologists. However, cross-disciplinary integration can be hampered by the 'black-box' nature of ESMs, technical and terminology-based barriers, and also potential spatial and temporal mis-matches between climate change projections and the ecological and environmental variables needed to accurately estimate ecosystem change.

Here, we introduce a co-designed effort to build a model platform (https://github.com/NorESMhub/NorESM_LandSites_Platform) for a demographic vegetation model FATES (Functionally Assembled Terrestrial Ecosystem Simulator) within the Community Land Model (CLM). We highlight how the model platform can be useful from several different perspectives, from experienced model developers through to a training device for early career ecologists and geoscientists.

One key element of the model platform is the capacity to enable users to explore the role of ecosystem function through developing localised, single-site simulations, where model runs can a) explicitly integrate in-situ vegetation characteristics, and impacts on energy, carbon and hydraulic fluxes and b) updated models can be validated against in-situ measures of ecosystem function. In developing these single-site simulations, we recognize challenges faced when integrating diverse local ecological and environmental datasets, and therefore are developing decision support tools, data-import pathways and recommended workflows to streamline this process. For example, decision support tools explore the myriad of ways in which we source data, from default values within the model itself, to data collection from trait repositories, published literature or the online repositories run by research groups. In developing these elements, and recognising the increased role of reproducible and Open Science practices, the model platform endeavors to provide workflow management tools which facilitate model running, documentation of input sources, parameterizations and model outputs, with minimal need for technical assistance. Through developing structured reproducible workflows, the model platform promotes rapid sharing of insights between modelers, but also enables increased use by ecologists. Bottom-up engagement with ESMs, from across the disciplines facilitates informed, rapid development of model performance. Here, in addition to a script-based work environment, the model platform is also integrated into an online cloud computing platform GALAXY which provides a GUI interface enabling ecological researchers to develop 'virtual laboratories' to explore ecosystem processes and parameterization. This online GUI workflow is paired with tutorials, facilitating not only researcher engagement but also providing educational opportunities.

We see the model platform as an opportunity to encourage, facilitate and lead the development of sustainable, transparent and mutually beneficial collaborative workflows to bridge the gap between insights held by ecological and environmental researchers and those within the earth system modelling community.

Keywords: Cross-disciplinary; Reproducible workflows

COMMUNITY LAND MODEL V5 RUNOFF EVALUATION IN SMALL NEAR-NATURAL CATCHMENTS IN FENNOSCANDIA

E. Gelati[1], Y. Yilmaz[1], S. Jørgensen Bakke[1], L. M. Tallaksen[1]
[1]University of Oslo, Department of Geosciences
P.O. Box 1047 Blindern, 0316, Oslo, Norway
Email: emiliano.gelati@geo.uio.no

ABSTRACT

Validating model representations of land surface processes is crucial for reducing the uncertainty of future projections, especially at high latitudes where climate change is amplified. As part of a regional assessment of the latest version of the Community Land Model (CLM5) in cold environments, we compare simulated grid-scale runoff with discharge measurements in small near-natural catchments in Fennoscandia. CLM5 is the land component of the Norwegian Earth System Model. Evaluating land surface models involves a large set of state and flux variables, for many of which direct measurements are either not available or not representative at the typical modelling spatial scales (10^0–10^2 km). In this context, discharge measurements provide valuable information that can be used to assess how well models are able to reproduce the downstream outcome of catchment hydrologic processes. We compare two 2001-2014 CLM5 simulations at 0.25° spatial resolution over Fennoscandia: one forced with the default 3-hourly 0.5° GSWP3v1 product and another with the hourly 0.25° ERA5 near-surface atmospheric data. To characterise forcing uncertainty, precipitation and temperature forcing data are compared to the 2 km resolution daily observational Nordic Gridded Climate Dataset (Norwegian Meteorological Institute). Daily discharge and catchment information are obtained from the Norwegian Water Resources and Energy Directorate, the Swedish Meteorological and Hydrological Institute, and the Finnish Environment Institute. To avoid uncertainties due to human alterations and model representation of large-scale river routing, we select time series of unregulated catchments whose areas are smaller than 10^3 km^2 and thus are compatible with single model grid-cells. Accordingly, we evaluate CLM5 daily total runoff, which is the sum of subsurface and surface runoff prior to channel routing, against observed discharge. We analyse the hydrological regime (i.e. seasonal cycle of average monthly runoff), to assess how well the prevailing regional streamflow regimes are simulated in small headwater catchments. We also derive the overall bias, variance error and correlation between simulated monthly runoff and observed discharge, to evaluate the reproduction of water balance as well as hydrograph amplitude and shape. Further, we investigate whether spatio-temporal patterns of agreement/ discrepancy between modelled and measured runoff correlate with atmospheric forcing uncertainties, land surface properties, or climatology. In particular, we try to detect model runoff errors occurring in specific environmental conditions. This study builds on work presented at vEGU21 [1] and aims to inform future regional CLM5 experiments that will test atmospheric forcing corrections and alternate parametrisations of hydrologic processes, in the framework of the Land-ATmosphere Interactions in Cold Environments (LATICE) research initiative.

[1] Gelati, E., Yilmaz, Y., Jørgensen Bakke, S., and Tallaksen, L. M.: Community Land Model v5 runoff evaluation in small near-natural catchments in Fennoscandia, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-10248, https://doi.org/10.5194/egusphere-egu21-10248, 2021.

Keywords: Runoff; Land surface modelling; Fennoscandia

EFFECTS OF HIGH-LATITUDE LIGHT CONDITIONS ON STOMATAL CONDUCTANCE AND PHOTOSYNTHESIS IN WHITE CLOVER (*Trifolium repens)*

R. Gullvåg[1], A. V. Vollsnes[1], A. Bryn[2], A. K. Brysting[1], A. Vatne[3]
[1]University of Oslo/Department of Biosciences
P.O. Box 1066 Blindern, 0316, Oslo – Norway
Email: rebekkgu@student.ibv.uio.no
[2]University of Oslo/Natural History Museum
[3]University of Oslo/Department of Geosciences

ABSTRACT

Terrestrial plants play an important role in the climate system, largely due to photosynthesis and transpiration. In this study we will investigate how these two processes may be influenced by the bright summer nights at high latitudes. Photosynthesis and transpiration are both regulated by stomata, microscopic pores on the surface of leaves and stems. Land plants are covered by a water-impermeable waxy layer (cuticle) that protects against desiccation. However, while hindering water-loss, it also inhibits diffusion of CO_2 into the leaves. As a result, up to 98% of gas exchange in vascular plants occurs through stomata, although they typically make up less than 3% of the leaf surface (Lawson & Blatt, 2014). In other words: Stomata are the gateways that connect the interior of plants with their surrounding atmosphere.

Opening and closure of stomata is actively regulated, enabling plants to balance the trade-off between water-saving and uptake of CO_2 for photosynthesis. Stomatal aperture is determined by guard cells (specialised epidermal cells flanking the stomatal pore), which undergo turgor (hydrostatic pressure) changes in response to a range of internal and environmental signals. Because of this, transpiration responds differently to environmental factors than evaporation from soil and other surfaces does. Light is a key regulator of stomatal movements, generally promoting opening. The stomatal response to light is two-fold: There is an indirect effect of photosynthesis, driven mainly by red and blue light (photosynthetic active radiation); and a specific response to blue light. The specific blue-light response is sensitive to irradiances too low to drive photosynthesis. Moreover, blue light is up to 20 times more efficient than red light in opening stomata (Willmer & Fricker, 1996). At twilight, the sun is below the horizon and only diffuse light, having a higher proportion of blue light, reaches the ground. At high latitudes, the twilight period is extended and can last from sunset until sunrise. As stomatal regulation is especially sensitive to blue light, this could potentially affect stomatal movements throughout the diurnal cycle - and thus patterns of transpiration and photosynthesis - in vegetation at high latitudes.

To investigate how an extended twilight period may affect plant activity, we will conduct experiments in controlled growth conditions on white clover varieties originating from different latitudes. Plants of selected varieties will be grown in a room mimicking high-latitude light conditions and compared to clones grown in a control room, with light conditions corresponding to a lower latitude. Gas exchange will be measured throughout the diurnal cycle and used to calculate stomatal conductance and rates of transpiration and photosynthesis. If the different light conditions should produce a significant difference in these parameters, it could indicate a similar effect in nature - with implications for land-atmosphere interactions at high latitudes. If so, assumptions concerning stomatal responses in lower latitudes may not be valid for vegetation at high latitudes. Our results will therefore be relevant for Earth System Models regarding high latitudes. This work contributes to the LATICE (Land-ATmosphere Interactions in Cold Environments) project at the University of Oslo.

Keywords: Vegetation-atmosphere interaction; plant physiology; stomata; terrestrial vegetation; ESMs; high latitudes; light; carbon capture; transpiration

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EVALUATION OF GLOBAL SOIL DATA FOR LARGE-SCALE HYDROLOGICAL MODELLING IN NORWAY

Shaochun Huang[1], Stephanie Eisner[2], Ingjerd Haddeland[1], Zelalem Tadege Mengistu[1]
[1]Norwegian Water Resources and Energy Directorate (NVE)
Middelthuns gate 29, 0368 Oslo – Norway
Email: shh@nve.no
[2]Norwegian Institute of Bioeconomy Research (NIBIO), Ås, Norway

ABSTRACT

Soil moisture is widely considered as a key mediator that modulates energy and water exchanges at the land and atmosphere interface. However, soil moisture dynamics in Norway are rarely studied and the simulated results are seldom compared with ground measured or satellite-based data, especially at large scale. Until now, no soil map of Norway includes detailed soil properties, so global soil databases can be an alternative input data for large-scale hydrological modelling in Norway. The major objectives of this study are 1) to evaluate the most updated global soil data and their impacts on simulated discharge and soil moisture for three large river basins in Norway and 2) to suggest the most appropriate global soil database for large-scale hydrological modelling in Norway. Three global databases, which were published after 2014 and used different methods to derive soil property maps, were evaluated in this study: the Global Soil Dataset for Earth System Model (GSDE), the harmonized dataset of derived soil properties for the world at a nominal resolution of 30 by 30 arc sec (WISE30sec), and the SoilGrids system. The global soil data were used as input data for the Soil and Water Integrated Model (SWIM) and the Variable Infiltration Capacity (VIC) model to simulate river discharge and soil moisture. A three-step evaluation has been conducted: 1) the global soil data were compared directly with the Norwegian forest soil database; 2) the simulated discharge was compared with measured discharges and 3) the simulated soil moisture was compared with the European Space Agency's Climate Change Initiative Soil Moisture (ESA CCI SM) data (version 5.2). The first-step evaluation showed that the GSDE has the largest errors among the three databases while the SoilGrids in general has the best agreement with the Norwegian forest soil samples. However, the WISE30sec estimated slightly better soil textures in deep soil layers for some soil types. Despite the different estimates between the SoilGrid and WISE30sec, the very preliminary hydrological modelling results were similar regarding both discharges and soil moisture.

Keywords: soil moisture, Norwegian forest soil database, satellite soil moisture data

TOPOGRAPHIC WETNESS INDEX AS A PROXY FOR SOIL MOISTURE: THE IMPORTANCE OF FLOW-ROUTING ALGORITHM AND GRID RESOLUTION

H. Riihimäki[1*], J. Kemppinen[2*], M. Kopecký[3,4] and M. Luoto[1]
[1]Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland.
[2]Geography Research Unit, University of Oulu, Oulu, Finland
[3]Institute of Botany of the Czech Academy of Sciences, Průhonice, Czech Republic
[4]Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Prague, Czech Republic

Email: julia.kemppinen@oulu.fi
**Shared first-authorship*

ABSTRACT

The Topographic Wetness Index (TWI) is a commonly used proxy for soil moisture. The predictive capability of TWI is influenced by the flow-routing algorithm and the resolution of the Digital Elevation Model (DEM) that TWI is derived from. Here, we examine the predictive capability of TWI using 11 flow-routing algorithms at DEM resolutions 1 - 30 m. We analyze the relationship between TWI and field-quantified soil moisture using statistical modelling methods and 5200 study plots with over 46 000 soil moisture measurements. In addition, we test the sensitivity of the flow-routing algorithms against vertical height errors in DEM at different resolutions. The results reveal that the overall predictive capability of TWI was modest. The highest R2 (23.7%) was reached using a multiple-flow-direction algorithm at 2 m resolution. In addition, the test of sensitivity against height errors revealed that the multiple-flow-direction algorithms were also more robust against DEM errors than single-flow-direction algorithms. The results provide field-evidence indicating that at its best TWI is a modest proxy for soil moisture and its predictive capability is influenced by the flow-routing algorithm and DEM resolution. Thus, we encourage careful evaluation of algorithms and resolutions when using TWI as a proxy for soil moisture.

Keywords: Soil moisture; Topographic Wetness Index; Digital Elevation Model; Light Detection and Ranging; Flow-routing algorithms; Grid resolution

IS IT POSSIBLE TO ESTIMATE THE SOIL DEPTH IN EVERY POINT OF INTEREST FOR MAINLAND NORWAY?

Nils-Otto Kitterød
Norwegian University of Life Sciences
P.O. Box 5003, N-1432 Ås – Norway
Email: nils-otto.kitterod@nmbu.no

ABSTRACT

The physical relation between soil physics, water storage and fluid flow has been studied since the advent of hydrology, and the importance of soil for hydrology are beyond any reasonable discussion. Still, there is a great challenge to fill in the gap between the water flux at the catchment scale and soil physical properties at the hill slope scale. One problem that remains to be solved is the question of soil structure and spatial connectivity of hydraulic properties. Such information is in principle available from geological maps, borehole information, test drilling and geophysical surveys, but this kind of information is usually not readily available as input for meteorological or hydrological purposes. In this study we explored different approaches to model the soil depth as a continuous stochastic function in space where we include geological mapping of bedrock outcrops, digital terrain models and point information of soil depth (Kitterød, 2018; Kitterød and Leblois, 2021). The goal was to describe the bedrock topography and the soil depth with high spatial resolution (25 x 25 m), and at the same time minimize the estimation uncertainty. To achieve this goal, it is necessary to include practical procedures for estimating the spatial trend in soil depth. Here, in this presentation, we show results from a procedure where bedrock outcrops were used as boundary conditions in Poisson's equation. By inverse modelling of the constant parameter in Poisson's equation, we obtained a parabolic function which mimic the trend in soil depth. Conditional estimates of soil depth were obtained by ordinary kriging of the deficits between the trend function and the point information. After these initial results, we suggest initiating projects to estimate soil depth (or sediment thickness) in every point of interest for mainland Norway. Combined with digital terrain models, such estimates yield also information on the bedrock topography, which is of interest in many different contexts.

Keywords: Soil depth; Soil structure; Hydraulic connectivity; Bedrock topography

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A SIMPLIFIED METHOD FOR SATELLITE SNOW DATA ASSIMILATION IN OPERATIONAL INFLOW MODELLING

S. Kolberg
Enki hydrologi
Blåklokkeveien 10, 7050 Trondheim - Norway
Email: Sjur.Kolberg@enki-hydrologi.no

ABSTRACT

Experiments with satellite-based re-estimation of snow storage during spring have shown improved results when auxiliary discharge measurements are also taken into account. Combining the two information sources enable water managers to perform spatial distributed updates of snow cover fraction, snow storage and the main moisture storage, despite only snow cover and the catchment-integrated runoff being directly observed.

A major key to the value of this combination is that the discharge data are highly informative on aspects for which the satellite data are weak, and vice versa. A sequence of snow cover images does not distinguish well between rapid melting from a large snowpack and slower melting from a more moderate starting point; a difference easily detected by observed meltwater volumes. Similarly, observed discharge provides little information on snow covered area or melt intensity separately, but is strongly informative regarding the product of the two. Further, images have high detail in space, river gauges in time.

A Bayesian sampling scheme was published in 2010 which did utilise both data sources, although focused on the satellite data. However, its MCMC methodology required too long computation time and extensive manual monitoring and adjustment to be operationally practical. A simplified algorithm is therefore formulated and implemented, in which heavier reliance on the complementarity between the two mentioned data sources compensates for a less rigid algorithm. The method uses only time-aggregated discharge, allowing full utilisation of naturalised inflow data computed from reservoir levels. Such data are notoriously noisy in the hourly resolution typically used in inflow models, but reliable for longer integration periods, and are often the only data available in regulated basins.

At the time of abstract submission, evaluation of the simplified methodology is work in progress. Results will be shown for more than 20 catchments in a mountainous region in mid-Norway.

Keywords: Data assimilation; snow; hydropower

CAUSES OF PLANT MORTALITY FROM EXTREME WINTER EVENTS: MODEL INSIGHTS INTO DESICCATION PROCESSES DURING FROST DROUGHTS

Marius Lambert[1], Hui Tang[2,3], Kjetil S. Aas[2], Frode Stordal[2], Jarle W. Bjerke[4], Frans-Jan W. Parmentier[1,5]

[1]Centre for Biogeochemistry in the Anthropocene, Department of Geosciences, University of Oslo, 0315 Oslo, Norway

Email: marius.lambert@geo.uio.no

[2]Department of Geosciences, University of Oslo, 0315 Oslo, Norway

[3]Geo-Ecology Research Group, Natural History Museum, University of Oslo, 0562 Oslo, Norway

[4]Norwegian Institute for Nature Research, High North Research Centre for Climate and the Environment, 9296 Tromsø, Norway

[5]Department of Physical Geography and Ecosystem Science, Lund University, 223 62 Lund, Sweden

ABSTRACT

Frost droughts are suggested to occur when sudden warm events trigger leaf transpiration combined with deeply frozen soils preventing root water uptake. The recent incorporation of a detailed plant hydraulic module based on tissue (root, stem, leaf) level traits in terrestrial biosphere models, opens up the possibility to investigate how frost droughts experienced by plants impact land-atmosphere interactions.

In this study, we use CLM5.0-FATES-Hydro (a cohort model of vegetation coexistence and competition) driven by high-resolution atmospheric forcing (ERA5-land), to evaluate how frost droughts impacted vegetation mortality in northern Norway during the unusual (cold and dry) winter 2017-2018.

We establish a clear link between the insulation effect of snow, drought types (chronic winter and acute frost desiccation) and their intensity, demonstrate the ability of the model to simulate root water exudation as soil freezes, show that acute frost desiccation can be represented in cases where a sudden atmospheric temperature increase triggers excessive stomatal transpiration, and highlight the dependence of a drought's severity to the state of dryness of vegetation.

Our results, for the first time connect hydraulic redistribution to plant damage from extreme winter events by linking root water efflux, tissue dehydration, and chronic winter desiccation. We are now expanding our research to the whole northern Norwegian area to see if this is still observed at larger scales, and to identify id some regions have been strongly hit by droughts over the period 2012-2020.

Keywords: Tissue dehydration; Frost drought; Land surface model

SEASONALITY OF SCANDINAVIAN MOISTURE SOURCES, ITS SPATIAL EXTENT, AND PHYSICAL CHARACTERISTICS

M. Lanzky[1], J. F. Burkhart[1] and H. Sodemann[2]
[1] Department of Geosciences, University of Oslo
Sem Sælands vei 1, 0371 Oslo, Norway
Email: mika.lanzky@geo.uio.no
[2] Geophysical Institute, University of Bergen, and
Bjerknes Centre for Climate Research, Bergen, Norway

ABSTRACT

Snow is an important factor for hydropower production, leisure activities, and potential for flooding in Norway. The moisture sources of precipitation arriving in Norway is controlled by the atmospheric weather patterns, which themselves are governed by the overall climate.

As the climate is warming, this could potentially influence the weather patterns of the future thus affecting the distribution of snow in Norway. However, in order to assess possible impacts of future moisture sources on snow catchments for hydropower, we lack a systematic, contextual overview of the current sources of precipitation.

To determine the moisture sources for Scandinavia over the previous 40 years, we utilize meteorological information from ERA-Interim coupled with Lagrangian particle trajectories from FLEXPART to characterize the precipitation in terms of source location as well as environmental meteorological state variables.

We found that Scandinavian precipitation is comprised of a blend of nearby and remote moisture sources, transported by south-westerlies. Different ocean and land sectors' exhibit varying behaviour during the year like in the timing of their minimum and maximum relative moisture contribution to Scandinavia. Seasonal differences are also seen by the movement of the maximum source location from ocean to land, with terrestrial, recycled contributions showing a clear seasonal maximum in summer.

In the analyzed region, we observe a gradient in different moisture properties related to the Scandinavian mountain chain. Compared to the European Alps, which Sodemann & Zubler (2009) founds acts as a topographic barrier of moisture, the effect seem less strong. Comparison of deuterium excess, a source humidity proxy, with stable water isotope observations from a field campaign in Finse serves as validation for the moisture source analysis method.

By characterizing the broader Scandinavian precipitation sources, we set the background for further focused studies of the potential impacts of a changing climate on the catchment-scale seasonal snowpack which represents the prime resource for the hydropower industry.

Keywords: Lagrangian moisture sources

CALIBRATION AND EVALUATION OF HYDROLOGICAL MODELS

T. Le[1], K. Engeland[1,2], E. Langsholt[2], L.M. Tallaksen[1]
[1]Department of Geosciences, University of Oslo (UiO)
Sem Sælands vei 1, 0371 Oslo – Norway
[2]The Norwegian Water Resources and Energy Directorate (NVE)
Email: tttle@student.geo.uio.no

ABSTRACT

Hydrological precipitation-runoff models are important tools for computing streamflow forecasts. The flood warning service in The Norwegian Water Resources and Energy Directorate (NVE) uses such streamflow forecasts as a guidance when assessing flood risk for the coming days. An opportunity to improve the flood forecast models is to use different strategies to calibrate them, so that they are robust in regard to making good flood forecasts for different seasons and weather situations. One way to do this is to adapt the models for situations with high streamflow by emphasizing high streamflow more than low streamflow in the calibration. A total of six different calibration experiments were performed where (i) the 50% highest streamflow, (ii) the 90% highest streamflow, (iii) flood events during the snow melting season, (iv) flood events during the rain flood season, (v) a linear weighting where the weight increases by the magnitude of the water flows and finally, (iv) a reference calibration where all the observed streamflow were given equal weights in the calibration of the model, which is also the most common way of calibrating the models. The model used in this study was the hydrological precipitation-runoff model HBV together with the calibration tool PEST. Time series of 40 years with observed streamflow in daily time resolution from 12 flood stations distributed around Norway were used to calibrate the model. These 12 gauging stations were classified into three flood regimes, (i) dominant snowmelt floods (ii) dominant rain floods and (iii) combination regime. The calibrated model runs show us that there is no link between gauging stations that have flood regimes with dominant snowmelt floods and rain floods, respectively with calibration of flood events in snowmelt season and rain flood season. The model runs show that it is consistent that the calibration of all stream flows, the reference calibration, makes the best of the six experiments. But the calibration experiment where water flows above 50% are emphasized also gives good, simulated stream flows.

Keywords: HBV model; flood forecasting; modeling; calibration; evaluation

SPATIAL ANALYSIS OF DAILY AND HOURLY NEAR-SURFACE ATMOSPHERIC VARIABLES AT THE NORWEGIAN METEOROLOGICAL INSTITUTE

Cristian Lussana, Thomas N. Nipen, Ivar A. Seierstad, Frederik De Roo, Christoffer A. Elo, and Line Båserud
Norwegian Meteorological Institute
Henrik Mohns Plass 1, 0371, Oslo – Norway
Email: cristianl@met.*no*

ABSTRACT

Daily and hourly near-surface variables, such as two-metre temperature, ten-metre wind or precipitation amounts, are used as forcing variables for hydrological and snow- modeling.

The Norwegian Meteorological Institute (MET Norway) produces several datasets of near-surface atmospheric variables. Among them are the two families of datasets: (1) seNorge and (2) MET Nordic analysis. The gridded data are provided on a regular grid with 1 km spacing and they are updated regularly and on a real-time basis.

seNorge is a collection of datasets for daily aggregated temperature and precipitation variables over the Norwegian mainland, spanning from 1957 to today. Additionally, seNorge input data for precipitation are adjusted for the wind-induced undercatch of the rain gauges, which means that daily wind fields are also available. seNorge has several versions and the historical archive is updated every year.

MET Nordic analysis is a dataset for hourly aggregated variables covering Fennoscandia and spanning the time period from 2013 to the current hour. It includes temperature, precipitation, wind, relative humidity, sea level pressure, short-wave incoming radiation and cloud area fraction. Some variables, such as temperature and precipitation, are obtained from a combination of observations and model data, while others are downscaled from numerical model output. MET Nordic analysis is closely connected with MET Nordic forecast. In this sense, MET Nordic aims to provide a seamless transition between analysis and forecast of atmospheric variables.

Together, seNorge and MET Nordic provide a large amount of data that can be used for hydrological and snow- simulations. The presentation will illustrate the main characteristics of the datasets and will try to highlight their complementary aspects.

Keywords: atmospheric variables; observations; gridded datasets

CHARACTERISATION OF THE ATMOSPHERIC ENVIRONMENT DURING EXTREME PRECIPITATION EVENTS ASSOCIATED WITH ATMOSPHERIC RIVERS IN NORWAY

C. Michel[1], A. Sorteberg[1], S. Eckhardt[2], C. Weijenborg[3], A. Stohl[4], and M. Cassiani[2]
[1]University of Bergen and Bjerknes Centre for Climate Research
Allégaten 70, 5007 Bergen, Norway
Email: Clio.Michel@uib.no
[2]Norwegian Institute for Air Research, Kjeller, Norway
[3]Meteorology and Air Quality Group, Wageningen University, Wageningen, The Netherlands
[4]Faculty of Earth Sciences, Geography and Astronomy, University of Vienna, Austria

ABSTRACT

By combining ERA-Interim and daily precipitation observations, we study the large-scale atmospheric state and moisture sources during extreme precipitation events that are associated with atmospheric rivers during the period 1979-2018 in Norway. We find that most of those events occur in fall and winter along the Norwegian west coast and in summer in the more inland regions. The atmospheric rivers are most of the time associated with cyclones that can still slightly deepen through baroclinic intensification. Cyclonic Rossby wave breaking is most frequent when extreme precipitation occurs over Southern Norway, whereas anticyclonic wave breaking is most frequent for the extreme precipitation events occurring more north along the west coast. Finally, using a Lagrangian air parcel tracking algorithm, we show that moisture sources are more continental than oceanic for extreme events occurring in summer, whereas it is the opposite for extremes in winter. Our analysis allows generalising results from previous studies, as we use a long period (40 years) and the whole year instead of particular seasons or regions of Norway.

Keywords: extreme precipitation; atmospheric rivers; moisture sources

CHANGES IN RADIATIVE FORCING DUE TO CLEAR-CUTTING IN SWEDEN

I. Mužić [1,2], P. Vestin[3], A. Lindroth[3], M. Mölder[3], T. Biermann[3,4], M. Heliasz[3,4], J. Rinne[3]
[1]CICERO Center for International Climate Research, Norway
Email: iris.muzic@cicero.oslo.no
[2]Department of Geosciences, University of Oslo, Norway
[3]Department of Physical Geography and Ecosystem Science, Lund University, Sweden
[4]Centre for Environmental and Climate Research, Lund University, Sweden

ABSTRACT

Land cover conversion affects climate by imposing perturbations in the surface properties and greenhouse gas fluxes. Forest management systems often disregard that modification in surface albedo influences the exchange of energy and greenhouse gases. In this study, we examine the net climatic effect of clear-cutting in high-latitude regions by comparing the importance of biogeophysical (albedo) and biogeochemical (carbon dioxide release) changes in Sweden. The hypothesis is that the albedo effect of high-latitude clear-cutting can reduce climate warming.

Data on incoming and reflected shortwave radiation was obtained from four-component net radiometers installed in the forest and neighbouring clear-cut sites, in southern (56°N), central (60°N) and northern (64°N) Sweden. The study site pairs along a latitudinal gradient were chosen to account for different climatic conditions. Data at these station pairs covered a continuous period of three (2016-2018), five (2014-2018) and one year (2014), respectively. Due to lack of clear-cut measurement stations in close vicinity to the northernmost forest site, the shortwave radiation data was retrieved from an open mire, where albedo and its temporal dynamics are similar to a clear-cut. All the forest stations and the mire station are part of ICOS Sweden network. Data on carbon dioxide release from clear-cutting was estimated as a difference in the aboveground carbon stock of the standing biomass between forest and clear-cut sites. The estimated carbon dioxide release was translated into an equivalent change in absorbed shortwave radiation and compared to the radiative forcing by albedo difference between forest and clear-cut sites.

Our results underline results from previous studies showing that the magnitude of the net radiative forcing by clear-cutting varies considerably depending on the latitudinal position of the examined sites. Based on available data, clear-cutting in southern and central Sweden had a warming effect on the climate while in northern Sweden clear-cutting had a net cooling effect. However, large inter-annual variability (central Sweden) and lack of available continuous data (northern Sweden) resulted in high uncertainty of the climatic effects of changes in net radiative forcing due to clear-cutting. This study indicates that the albedo effect has an essential role in the estimation of the climatic effect of clear-cutting and should thus be incorporated in future forest management strategies.

Keywords: land-cover change; albedo; carbon dioxide

CHANGES IN FREQUENCY OF EXTREME PRECIPITATION

G. Myhre[1, 2]
[1]CICERO Center for International Climate Research, Norway
[2]Norwegian Meteorological institute, Oslo, Norway

ABSTRACT

The intensity of the heaviest extreme precipitation events is known to increase with global warming. How often such events occur in a warmer world is however less well established, and the combined effect of changes in frequency and intensity on the total amount of rain falling as extreme precipitation is much less explored, in spite of potentially large societal impacts. We employ observations and climate model simulations to document strong increases in the frequencies of extreme precipitation events occurring on decadal timescales. Based on observations we find that the total precipitation from these intense events almost doubles per degree of warming, mainly due to changes in frequency, while the intensity changes are relatively weak, in accordance to previous studies. This shift towards stronger total precipitation from extreme events is seen in observations and climate models, and increases with the strength – and hence the rareness – of the event. Based on these results, we project that if historical trends continue, the most intense precipitation events observed today are likely to almost double in occurrence for each degree of further global warming. Changes to extreme precipitation of this magnitude are dramatically stronger than the more widely communicated changes to global mean precipitation.

Keywords: precipitation

SIMULATED RUNOFF AND RIVER DISCHARGE IN COMMUNITY LAND MODEL-EVALUATION OVER SCANDINAVIA

Narayanappa, Devaraju, Terje Koren Berntsen, and Frode Stordal

University of Oslo
Sem Sælands vei 1, 0371, Oslo – Norway
Email: devaraju.narayanappa@mn.uio.no

ABSTRACT

Reliable representation of terrestrial water and energy balance in global climate models is crucial to better understand the response of the hydrological cycle to climate change. Though the current generation of global climate models have improved substantially, they still fail to represent all terrestrial processes adequately. Specifically simulating runoff and river discharge are important for many applications such as water resources management and future water availability projections. In this study, we use the land surface model component of the Norwegian Earth System Model which is Community Land Model version 5 (CLM5) to evaluate against observation-based estimates of runoff and river discharge data of selected catchments data. For the latest three decades (1985-2015), we compare the CLM5 simulated grid-scale runoff with observation-based gridded runoff estimates (E-RUN version 1.1) and with data from the Global Runoff Data Centre (GRDC). CLM5 is also capable of simulating river discharge to the oceans through the Model for Scale Adaptive River Transport (MOSART) and is applicable across local, regional, and global scales. The 3-hourly 0.5º meteorological forcing for CLM5 was provided by the Global Soil Wetness Project version 3v1, an international land surface modeling project. We also compare the simulated river discharge data with selected station discharge data in Norway and Sweden. I will present the detailed evaluation results at the conference. Briefly, the evaluation analysis suggests the further calibration to hydrologic parameters is needed to improve simulations of runoff and river discharge, especially subsurface runoff.

Keywords: land surface model; runoff and river discharge; catchments

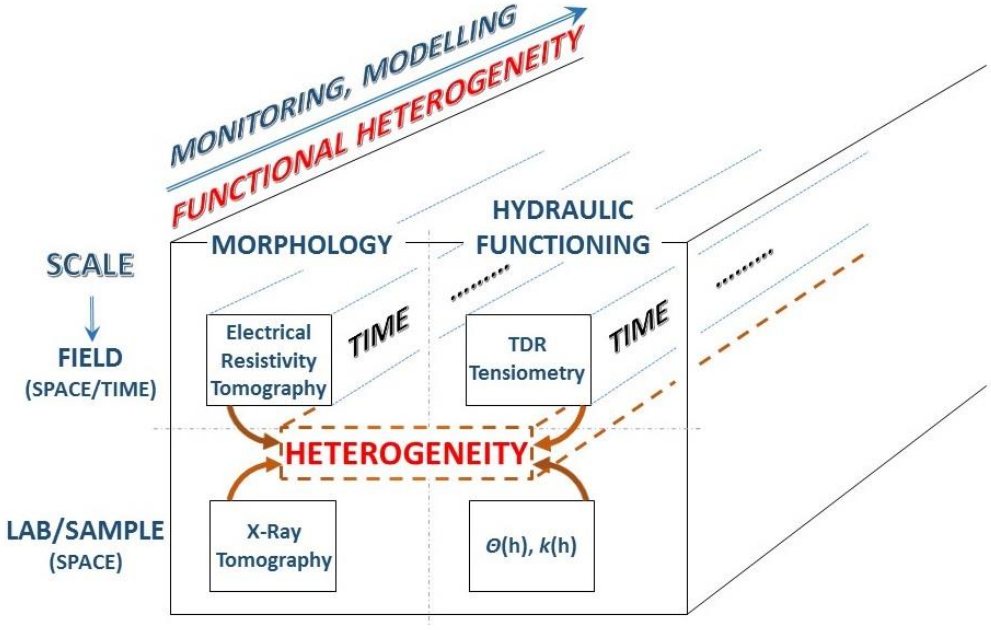
ADVANCES IN CHARACTERIZING THE STRUCTURAL AND FUNCTIONAL HETEROGENEITY OF SOILS FOR HYDROLOGICAL MODELLING

A. Nemes[1], M. Qin[2], M. Patterson[2], Cs. Farkas[1], D. Krzeminska[1], D. Giménez[2]

[1]Norwegian Institute of Bioeconomy Research
P.O. Box 115, NO-1431 Ås - Norway
Email: attila.nemes@nibio.no
[2]Rutgers University, Department of Environmental Sciences
14 College Farm Rd., New Brunswick, NJ 08901-8551 - USA

ABSTRACT

Soil is a non-renewable resource at the scale of human life-span that according to new and growing evidence is adapting to shifts in climate occurring at that time scale. Hence, there is urgency in approaching soils as temporally variable, 'living' media with a dynamic physical structure that effects the soil's inherent hydraulic functioning. Quantifying and representing the spatio-temporal variability of soil in hydrological and land-surface models poses a significant, mostly unresolved challenge. Apart from their heterogeneity, the task is further complicated by the fact that both the underlying processes and our observations are scale dependent, and there is often a lack of unified quantitative metrics to describe our observations. This presentation will cover selected aspects of scale-dependent observations, as well as the estimation and upscaling of soil hydraulic behavior for the purpose of hydrological modelling. Experience and findings from multiple projects will be discussed, including the NFR Soilspace project that coupled advanced techniques to augment the relevance of laboratory-based soil hydraulic measurements for environmental modelling.



Keywords: saturated hydraulic conductivity; X-ray computed tomography; electrical resistivity tomography; HYDRUS-3D; infiltration

FROM CLIMATE INFORMATION TO HYDROLOGICAL SERVICES: EXAMPLES FROM THE COPERNICUS PROGRAMME TO SUPPORT TO THE COMMUNITY OF USERS

C. Prudhomme[1,2,3]
[1]*European Centre for Medium-range Weather Forecast*
Reading, UK
[2]*Loughborough University, Loughborough, UK*
[3]*UK Centre for Ecology and Hydrology, Wallingford, UK*
E-mail: christel.prudhomme@ecmwf.int

ABSTRACT

Abstract text

With the development and easy access to large computing and archiving facilities, huge volumes of climate-related data are now freely available to anyone. However, the translation of such data into relevant and actionable information is a pre-requisite for a climate service to be effective, and cannot be done without the contribution of the community of users. This is even more important for downstream application, such as hydrology, that requires further processing from the outputs of traditional Numerical Weather Prediction Systems and Regional or Global Climate Models. This talk describes some of the processes put in place to build and deliver hydrological services for the Copernicus programme through examples from the operational European and Global Flood Awareness Systems (EFAS and GloFAS) of the Copernicus Emergency Management Service and from the data and facilities of the Copernicus Climate Change Service. This includes the development of robust modelling chains and archiving facilities -from data cataloguing, acquisition and processing through to the simulation of Essential Climate Variable and associated uncertainty – and engagement and co-creation activities with the community of users, critical to help with understanding user needs, achieving effective product design and developing effective information and dissemination mechanisms.

Keywords: Hydrological service; Copernicus; Forecasting; Hydrological extremes

CONSISTENT INTENSITY-DURATION-FREQUENCY CURVES BY POST-PROCESSING OF ESTIMATED BAYESIAN POSTERIOR QUANTILES

T. Roksvåg[1], J. Lutz[2], L. Grinde[2], A.V. Dyrrdal[2], T.L. Thorarinsdottir[1]

[1]Norwegian Computing Center (NR)
P.O. Box 114 Blindern, NO-0314 Oslo, Norway
Email: roksvag@nr.no
[2]Norwegian Meteorological Institute

ABSTRACT

The importance of accurate rainfall statistics is increasing as a warming climate leads to intensified and more frequent heavy rainfall. Rainfall statistics are often presented as intensity-duration-frequency (IDF) curves. These show the rainfall intensity (return level) we can expect at a location as a function of duration (in minutes or hours), and how often the intensity is expected to occur (frequency or return period). A common way to create IDF curves is to fit generalized extreme value (GEV) distributions to observed annual maximum precipitation data for some durations of interest. Typically, one GEV distribution is fitted for each target duration, independently of other durations. However, the independence assumption may result in IDF curves that are inconsistent across durations and return periods.

In this work, we propose a method that can be used to post-process a set of estimated IDF curves such that they become consistent. The post-processing method is a quantile selection algorithm that can be used in conjunction with any Bayesian inference approach for estimating IDF curves. It searches through the posterior quantiles of the Bayesian return level estimates until it finds a consistent curve set or until a non-convergence criterion is met.

The post-processing method was evaluated by using simulated precipitation data and by using observed Norwegian precipitation data from 83 pluviometers from all over the country. We produced IDF curves consisting of design values for 16 durations, ranging from 1 minute to 24 hours, and for return levels between 2 and 200 years. The results showed that the post-processing method yields consistent return level estimates that are more accurate than unadjusted Bayesian estimates. The suggested approach also outperformed d-GEV, a reference method that ensures consistent IDF curves by simultaneous estimation across durations. The post-processing algorithm will be used for future IDF calculations at the Norwegian Meteorological Institute, and an R implementation of the quantile selection algorithm is available at https://github.com/ClimDesign/fixIDF.

Keywords: IDF curves; precipitation extremes; Bayesian statistics; Design rainfall

ESTIMATION OF TOTAL WATER STORAGE CHANGES IN CATCHMENTS USING GRACE SATELLITE GRAVIMETRY DATA

Z. Safdari[1], H. Nahavandchi[1], G. Joodaki[2]
[1]Department of civil and transport engineering/Norwegian University of Science and Technology (NTNU)
Høgskoleringen 3, Gløshaugen, 7030, Trondheim – Norway
Email: hossein.nahavandchi@ntnu.no, zohreh.safdari@ntnu.no
[2] Faculty of Science and Technology, Norwegian University of Life Sciences (NMBU)
Universitetsunet 3, 1430, ÅS – Norway
Email: gholamreza.joodaki@nmbu.no

ABSTRACT

Total water storage (TWS) is a key state variable of the regional and global hydrologic cycles. Nowadays, satellite observations from Gvity Recovery and Climate Experiment (GRACE) mission and GRACE Follow On (GRACE FO) mission, the successor of the erstwhile GRACE mission, present a new and valuable tool to estimate TWS at regional scale. In this study, we have developed a method named Least square Mascon (mass concentrated) Solution (LMS) to GRACE data to estimate TWS at catchment scale. The case study is Iran's main water basins. Iran has six main water basins: Caspian Sea basin, the Persian Gulf and Oman Sea basin, the Lake Uremia basin, the Central Plateau basin, the Eastern Boundary basin, and the Ghareghom basin. This method is based on adjusting mascon's shapes at the same shapes and sizes of main hydrological basins in Iran and reduces satellite measurement error, leakage error, and striping error.

We have used 163 months of CSR GRACE level 2 release 6 data during 2002 to 2017, and 15 months GRACE FO data from 2018 to 2019 to estimate TWS in the catchments. Before applying LMS to the GRACE data, degree 1 coefficients of the data are included as described by Swenson et al. 2008 and its degree 2 coefficient (C_{20}) is replaced by estimates from SLR (Satellite Laser Ranging). The effects of Glacial Isostatic Adjustment (GIA) are removed by subtracting the GIA Stokes coefficients computed by A et al. 2013. The Spherical Harmonic coefficients are smoothed using a Gaussian smoothing function with a 100 km radius. TWS is synthesized on a 0.5° spatial grid over Iran. The Caspian Sea, Persian Gulf and Oman Sea signals are removed following Swenson and Wahr 2007. Urmieh Lake storage contributions are removed using altimeter lake level observations following Swenson and Wahr 2007.

The results based on the GRACE data show that TWS trends are: -7.0 ± 4 GT/yr for central plateau basin, -7.82 ± 4 GT/yr for Caspian Sea catchment, -4.44 ± 1 GT/yr for Persian Gulf and Oman Sea basin, -1.0 ± 1 GT/yr for Urmiah Lake basin, 0.80 ±2 GT/yr for Eatern Boundary basin, and -0.23 ± 1 GT/yr for Gharaghom basin. Observation wells data in these main basins have been used to validate the results.The TWS trends based on observation well data are: -11.55 GT/yr for Central Plateau basin, -3.60 GT/yr for Caspian Sea catchment, 3.0 GT/yr for Persian Gulf and Oman Sea, -0.53 GT/yr for Urmiah Lake basin, -0.57 GT/yr for Eatern Boundary basin, and -0.83 GT/yr for Gharaghom basin. The results show GRACE TWS trends in good agreement with the well results.

Keywords: GRACE; Hydrology; Total water Storage Changes

MODELING SENSITIVITY TO MESH SIZE AND SHAPE: A CASE STUDY AT CENTRAL HIMALAYAN CATCHMENT REVEALING IMPORTANCE OF REGIONAL MODEL FORCING

O. Silantyeva[1], B. C. Bhattarai[2], L. M. Tallaksen[1], J. F. Burkhart[1], O. Skavhaug[3], S. Helset[4]
[1]University of Oslo
1072 Blindern, Oslo – Norway
Email: olga.silantyeva@geo.uio.no
[2]Meteorologisk Institutt
[3]Expert Analytics AS
[4]Statkraft AS

ABSTRACT

The complex terrain, high seasonal variability, complexity in precipitation patterns and cold region hydrology at Budhi-Gandaki catchment in central Himalaya, Nepal, presents a challenge for hydrological modeling. Regional or local forcing data, especially with high spatial resolution is preferred over coarser global dataset. However, such data is not always available. The Budhi-Gandaki catchment is subject to significant hydropower development, so accurate discharge simulation is important. Shyft is a novel hydrologic modeling software for streamflow forecasting targeted for use in hydropower production environments and research (Burkhart et al, 2021). It allows easy manipulation with configurations, which is a great tool in decision-making processes in the power production chain. The latest functionality of the Shyft.hydrology package allows one to capture detailed terrain topography using triangular irregular networks (tin) and "on the fly" slope and aspect correction of radiation forcing. We compare discharge simulations using two different forcing datasets: WFDEI global dataset ($0.5^o x 0.5^o$) and the HI-AWARE regional dataset (5x5 km precipitation and temperature) in both a grid and tin-based configurations. Simulated discharge is compared to observed discharge for a ten-year period (2000-2010) using two performance measures, Nash-Sutcliffe efficiency (NSE) and Kling-Gupta efficiency (KGE). We show that the regional dataset combined with a tin configuration performs better than using a rectangular grid resolution, both in terms of NSE and KGE. Furthermore, correcting radiation for slope and aspect at each cell improves the target metrics NSE and KGE further. Ironically, the global dataset with tin-based configuration performs worse than a simple grid. This appears to be partly attributed to the complexity of the precipitation distribution over the catchment area. One WFDEI grid cell covers the whole catchment, so it is only represented by one precipitation value, which does not allow the interpolation routines in the Shyft.hydrology to separate between windward and leeward areas. However, for less complex terrain and precipitation patterns, like those found in the Marsyangdi catchment, studied previously (Bhattarai et all, 2020), good results are obtained even with the coarse resolution of the WFDEI dataset. Introducing a tin configuration improved agreement between simulated and observed discharge as compared to using a rectangular grid in this case. Generally, we conclude that using a tin-based configurations for water planning in hydropower production in the region is advantageous. This work contributes to LATICE (Land Atmosphere Interactions in Cold Environments) project at the University of Oslo.

Keywords: Central Himalaya; Budhi-Gandaki; Hi-AWARE; Shyft; TIN; Discharge simulation

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DYNAMIC RIVER NETWORKS- ACTUALLY BELIEVING WHAT WE ARE SEEING

T. Skaugen[1], R. Ortega[1], K. Møen[1], I. Peerebom[1], D. Lawrence[1] and E. Langsholt[1]
[1]Norwegian Water Resources and Energy Directorate, Department of Hydrology
P.O.Box 5091, Maj. 0301 Oslo, Norway
Email: ths@nve.no

ABSTRACT

River networks are perceived to be an important factor for the dynamics of runoff. The configuration of the river network within a catchment, as expressed by the distribution of distances between points in the catchment and the closest river reach, is one of the basic principles controlling the runoff dynamics in the Distance Distribution Dynamics (DDD) model. River networks derived by terrain analysis using GIS are an alternative to digitizing river networks from aerial photography, which can be uncertain due to the catchment's unknown degree of saturation or the poor visibility of rivers that are obscured by vegetation. A problem with GIS-derived river networks, however, is that the GIS analyst must specify a minimum contributing area (CA) in order to identify a 'start point' for the channel. A large body of previous literature has investigated this problem, "where does the channel start?", and factors such as climate forcing, catchment steepness, water velocity, soil types and their erodibility are discussed. In this study we have derived the river network using different CAs (10 m^2- 120 km^2) for several catchments and calculated DDD model parameters, such as mean and maximum distance from a point in the catchment to the closest river reach (*dm* and *dmax*) and the mean, standard deviation and maximum distance in the river network to the outlet. The DDD model was thereafter calibrated with the initial objective to find the optimal CA. For, so far, 6 catchments, ranging in size from 0.0075-432 km^2, the performance of the DDD model was completely independent of the CA used. All river networks gave, more or less, identical skill scores (KGE, ranging from 0.87-0.93 over the 6 catchments). Furthermore, the changes in river network (represented by the distance parameters) were compensated in full by changes in subsurface velocities, and a very high degree of linearity was found between *dm* and the calibrated mean subsurface water velocity. The implications of this finding are both of a practical and perhaps of a theoretical nature. First, recall that that the DDD model uses a distribution of subsurface velocities and the degree of saturation determines the velocity of subsurface flow. For practical purposes this finding shows that the search for the optimal, true river network is futile, and a river network derived using any CA will do if one is primarily interested in discharge at the outlet of the catchment. Furthermore, if one has a strong and well-founded opinion of what the mean subsurface velocity is, a corresponding river network can be derived. For the more theoretical-conceptual considerations, perhaps a more realistic concept is to hold the subsurface velocity constant, in accordance with the Dupuit-Forscheimer assumption, and let the degree of saturation determine the density of the river network instead of subsurface velocities. The dynamic response of the catchment in terms of the extension and contraction of the river network can then be directly related to the catchment soil moisture status.

Keywords: River networks; hydrologic model concepts

THE IMPACT OF MOSS AND LICHEN ON HYDROLOGICAL CYCLE AT SURFACE: A STUDY USING CLM-FATES

Hui Tang[1,5], Kjetil Aas[1], Eirik. Aasmo Finne[1,2], Inge Althuizen[3], Rosie Fisher[6,7], Hans Tømmervik[2], Ane Victoria Vollsnes[4], Anders Bryn[5], Sonya Rita Geange[1], Sunniva Indrehus[1], Vigdis Vandvik[3], Jarle Werner Bjerke[2], Terje Berntsen[1], Frode Stordal[1]

[1]*Department of Geosciences, University of Oslo, 0315 Oslo, Norway*
[2]*Norwegian Institute for Nature Research, High North Centre for Climate and the Environment, 9296 Tromsø, Norway*
[3]*Department of Biological Sciences, University of Bergen, 5008 Bergen, Norway*
[4]*Department of Biosciences, University of Oslo, 0316 Oslo, Norway*
[5]*Natural History Museum, University of Oslo, 0318 Oslo, Norway*
[6]*CERFACS, Toulouse, France*
[7]*National Center for Atmospheric Research, Boulder, CO, USA*

Email:hui.tang@geo.uio.no

ABSTRACT

Moss and lichen are important components of the Arctic terrestrial ecosystem, but have not been well represented in the land surface models. Moss and lichen are particularly distinct from vascular plants in their hydraulic traits as they do not have stomatal control over the water exchange between plant and air. Instead, moss and lichen have relatively large water holding capacity and obtain water mainly from the interception of precipitation rather than from soil through root. In this study, we will employ the newly developed moss and lichen module in the Community Land Model coupled with Functionally Assembled Terrestrial Ecosystem Simulator (i.e., CLM-FATES) to explore the impacts of the unique hydraulic traits of moss and lichen on the hydrological cycle at surface in different ecosystems, including open tundra, and forest. We will particularly focus on how latent heat flux, soil moisture and surface runoff of moss and lichen covered surface differ from those covered by shrub and grass. In addition, the hydrological process of moss and lichen covered surface during the extreme events, e.g., flood and drought, will also be examined to demonstrate the importance of including moss and lichen in the land surface model to better capture the hydrological cycle in the boreal and Arctic region.

Keywords: moss; lichen; soil moisture; latent heat flux; runoff; CLM-FATES; drought

REVISITING FUZZY AND CONVERSIONAL LOGICS IN THIS DATA-ERA FROM ENVIRONMENTAL MODELLING PERSPECTIVE

Aynom Teweldebrhan[1], Thomas Schuler[2], Chong-Yu Xu[2]
[1]Hydro-Energi, Hydro
Drammensveien 264, 0283, Oslo – Norway
Email: aynom.teweldebrhan@hydro.com
[2]Department of Geosciences, University of Oslo

ABSTRACT

In this era of big data, the amount of data produced from multiple sources is growing rapidly. These myriads of datasets pose both challenges and opportunities depending on how we use them in our modelling work. In some sectors (e.g. financial services) significant advancements have been made during this data era through improvements on their analysis tools. However, in environmental modelling many of the old methodologies are still applied without much adaptation to the evolving developments such as the emergence of new datasets (e.g. from satellite scenes). In this study, new fuzzy-logic based data assimilation (FL-DA) schemes were introduced and were applied in a case-study focused on the assimilation of MODIS fractional snow cover area into a hydrological model. The FL-DA schemes take into account the information content of the assimilated dataset and main goal of this case-study was to get an improved estimate of the spatiotemporal distribution of snow water equivalent (SWE) through reanalysis using these schemes.

Timing of the more informative period varies both spatially and temporally in response to various climatic and physiographic factors. Here we use an automatic detection approach to locate the critical points in the time axis where the mean snow cover changes and where the melt-out period starts. The assimilation period was partitioned into three timing windows based on these critical points. A fuzzy coefficient was introduced in two ensemble-based DA schemes to take into account for the variability in informational value of fSCA observations with time. One of the DA schemes used in this study was the particle batch smoother (Pbs). The main challenge in Pbs and other Bayesian-based DA schemes is, that most of the weights are carried by few ensemble members. Thus, we also considered an alternative DA scheme based on the limits of acceptability concept (LoA) and certain hydrologic signatures and it has yielded an encouraging result. An improved estimate of SWE was also obtained in most of the analysis years as a result of using the FL-DA schemes. The most significant improvement was obtained in the correlation coefficient between the predicted and observed SWE values (site-averaged); with an increase by 8% and 16% when using the FL-DA versions of Pbs and LoA, respectively. The results from this study suggest the need for improvements in the conventional-logic based reanalysis tools in order to handle the spatio-temporal variability in information content of the prevailing datasets and thereby minimize the uncertainties emanating from these additional datasets.

Keywords: Data assimilation; Uncertainty reduction; Information content; Environmental modelling

MODELLING AND MEASURING FINE-SCALE SOIL MOISTURE VARIATION IN MOUNTAIN TUNDRA

V. Tyystjärvi[1,2], J. Kemppinen[3], M. Luoto[1,] T. Aalto[2], T. Markkanen[2], S. Launiainen[4], A.-J. Kieloaho[4] & J. Aalto[1,2]

[1]Department of Geosciences and Geography, University of Helsinki, P.O. Box 64, 00014 University of Helsinki, Finland

Email: vilna.tyystjarvi@helsinki.fi

[2] Finnish Meteorological Institute, P.O. Box 503, 00101 Helsinki, Finland

[3] Geography Research Unit, University of Oulu, P.O. Box 3000, 90014 Oulu, Finland

[4] Nature Resources Institute Finland, Latokartanonkaari 9, 00790 Helsinki, Finland

ABSTRACT

Soil moisture is an important part of the hydrological cycle, influencing ecosystem functionality as well as the interactions between land surface and atmosphere. In Arctic environments, particularly mountain tundra, it is inherently linked with complex environmental heterogeneity – varying topography, fine-scale vegetation and soil patterns all contribute to creating considerable spatio-temporal variation in soil moisture. Here, we quantify this fine-scale variation using extensive field measurements in a study area located in northwestern Finland. To understand how this is interpreted in hydrological models, we simulate the soil moisture conditions in the study area using two mechanistic models – SpaFHy, a cathcment-scale, semi-distributed model and JSBACH, a global land surface model.

We distinguished three moisture regimes in the study area – very dry conditions with little vegetation cover and thin mineral soils covered most of the study area. On the opposite end, nearly water-logged tundra mires with thick organic soils were found in parts of the study area. Additionally, mesic moisture conditions with varying depths of organic soil layers were found particularly near streams and in the low-lying areas. The spatial variation in moisture conditions was clearly linked to soil properties, particularly soil organic matter in both models and measurements. However, variation within these regimes was more pronounced in the measurements while nearly non-existent in the models. This is partly linked to insufficient input data on the spatial variation of soil properties but might also partly be explained by the influence of fine-scale topographical variation. Our findings suggest that more effort should be made in considering local processes that influence soil moisture variation and how these are described in hydrological models.

Keywords: soil moisture; tundra; mechanistic modelling

SENSITIVITY OF EVAPOTRANSPIRATION AND SURFACE CONDUCTANCE TO VAPOUR PRESSURE DEFICIT ACROSS HIGH LATITUDE CLIMATIC GRADIENTS

A. Vatne[1], L. M. Tallaksen[1], N. Pirk[1], A. V. Vollsnes[2], K. Engeland[1,3], P. Larsen[4] , A. Ibrom[5]

[1]University of Oslo/Department of Geosciences
Sem Sælands vei 1, 0371, Oslo – Norway
Email: astrid.vatne@geo.uio.no
[2]University of Oslo/Department of Biosciences
[3]Norwegian Water Resources and Energy Directorate
[4]Dansk Miljørådgivning, DMR
[5]Technical University of Denmark/Department of Environmental Engineering

ABSTRACT

While the evapotranspiration in high latitude wetlands is largely controlled by available energy, the surface also exerts a non-negligible control. The surface control on evapotranspiration, often represented by the surface conductance, is sensitive to environmental variables such as vapour pressure deficit (VPD). Previous studies have shown that higher surface conductance leads to higher evapotranspiration from boreal wetlands than from boreal forests during periods of high VDP. However, it is unclear how the surface conductance-VPD relation varies across climatic gradients. Furthermore, studies have shown that choices made in processing of the observations used to estimate surface conductance affect the resulting surface conductance-VPD relation. In particular, the choice of method for spectral correction of turbulent fluxes is important. Few studies have explored this effect in high latitude environments. To study the sensitivity of surface conductance to increasing values of VPD, we use data from three recently established eddy covariance sites in Norway, situated along high latitude climatic gradients. The sites included are Hisåsen (680 m.a.s.l., N 61.11°, E 12.24°), Finse (1200 m.a.s.l., N 60.59°, E 7.53°) and Iškoras (360 m.a.s.l, N 69.34°, E 25.29°). We first estimate surface conductance from the eddy covariance data, by inverting the Penman-Monteith equation. We then apply a boundary line analysis to assess the sensitivity of the surface conductance to VPD. Additionally we test how robust the results are to different methods of processing eddy covariance data, and different filtering of data. Our preliminary results suggest that variation between sites in the sensitivity of the surface conductance to VPD is small, but that both processing of observations and filtering of data have a large effect on the resulting surface conductance-VPD relation. The results emphasize the importance of scrutinizing observations before using them to study ecosystem dynamics. This work is a further development of work presented at the EGU General Assembly 2021 [1], and is a contribution to the Strategic Research Initiative 'Land Atmosphere Interaction in Cold Environments' (LATICE) of the University of Oslo.

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Keywords: Land-Atmosphere Interactions; Evaporation; Evapotranspiration; Ecosystem Surface Conductance; Observations; Vegetation Dynamics

Hydrometeorological Observations for Regional Earth System Modelling - Description of the Measurement Program of The Hydrometeorology to Operations (H2O) Project

M.A. Wolff[1,2], L. Ehrnsperger[1], V. Kristiansen[1], J. Blyverket[1], Å. Bakketun[1], H.B. Erlandsen[1], J. Kristiansen[1]
[1]Norwegian Meteorological Institute
Henrik Mohns plass 1, 0313, Oslo – Norway
Email: mareile.astrid.wolff@nmbu.no
[2]Norwegian University of Life Science, Ås - Norway

ABSTRACT

Checking the weather forecast is at most people's fingertips today. Private users and companies, as well as the public sector, infrastructure, and rescue operations alike, are all relying on the information about temperature and precipitation during the next hours or days. And while numerical weather prediction (NWP) has seen tremendous improvements over the past, small scale local rainfall events, which may be of severe intensity remain a challenge as the complexity of the interactions between the different components of the Earth system are not fully resolved in the NWP system.

The H2O project at the Norwegian Meteorological Institute is seeking a better representation of the land surface physics and hydrology NWP, thus improving both short-range weather forecasts as well as downstream hydrological forecast accuracy and reliability. A higher grade of coupling of the different domains in Earth system models and data assimilation including a wider range of data products are planned. Those efforts will also rely on tailored observations from across all domains. Therefore, an extended observation program is part of the H2O project to support the modelling and data assimilation activities.

We plan to combine, compare and analyse operational observations from existing meteorological, agricultural and hydrological ground-based networks for atmospheric and hydrological parameters and related satellite data, i.e. soil moisture and snow depth. Additionally detailed local studies will be performed at Ås, Norway, where the Norwegian Meteorological Institute, the Norwegian University of Life Sciences, the Norwegian Institute of Bioeconomy Research and the Norwegian Water Resources and Energy Directorate already operate a wide range of hydrometeorological observations, including run-off, potential evaporation, radiation, soil fluxes, air- and soil temperatures and precipitation. The existing infrastructure at Ås will be complemented by soil moisture measurements, both of high-end professional sensors and a mini network of low-cost sensors, an eddy covariance system for the high-resolution measurement of atmospheric fluxes and radiosonde measurements. Two dedicated measurements campaigns will be performed to study the land-atmosphere interaction during convective precipitation events during two consecutive summers.

In this presentation, we'll describe the observations program, technical aspects of the instrumentation on site, present data and some preliminary results of the test period and the first summer campaign in 2021.

Keywords: Earth system; Hydrometeorology; Land-atmosphere-interaction; Extreme precipitation events

PROBING FENNOSCANDIAN SNOW COVER DYNAMICS IN THE COMMUNITY LAND MODEL AND CLIMATE REANALYSES DURING THE SATELLITE ERA

Y. A. Yılmaz[1], K. Aalstad[1], S. Filhol[1], S. Gascoin[2], F. Stordal[1], L. M. Tallaksen[1]
[1]Department of Geosciences, University of Oslo, Oslo, Norway
Email: yeliz.yilmaz@geo.uio.no
[2]CESBIO, Université de Toulouse, CNES/CNRS/INRA/IRD/UPS, Toulouse, France

ABSTRACT

Snow is an essential climate variable in cold regions due to its effect on the terrestrial exchange of energy, water, and carbon. Accurately simulating snow processes is therefore important in capturing various climate feedbacks in Earth system models. The representation of snow properties and processes are major sources of uncertainty in the land surface schemes of these models. Using multiple data sources helps to probe these uncertainties and evaluate overall model performance. Unlike in-situ observations, satellite remote sensing products provide unique representative information at the scale of Earth system models. For instance, the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor onboard the Aqua and Terra satellites provide a continuous long-term climate data record for the last two decades. This record can be complemented with more recently launched satellites, such as Sentinel-2 and Landsat 8, which can provide even higher resolution imagery.

In this study, two daily snow cover data sets from MODIS (MOD10A1 and MYD10A1) were used to retrieve fractional snow-covered area (fSCA) and other snow cover metrics over Fennoscandia for the 2001-2020 water years. We use these retrievals to evaluate the fSCA outputs from multiple reanalyses (ERA5-Land, ERA5, and MERRA-2) and the latest version of the Community Land Model (CLM5) which is the terrestrial component of the Community Earth System Model (CESM) and the Norwegian Earth System Model (NorESM). To disentangle the effect of different atmospheric forcing, we conducted two offline CLM5 simulations forced with the default data set (GSWP3) and ERA5 reanalysis, respectively. In order to evaluate the accuracy of the MODIS data, we employed Sentinel-2 and Landsat 8 satellite retrievals as well as local-scale measurements around the Finse Eco-Hydrological Observatory (Finse EcHO), a low-alpine site in central Norway. Our work shows a path towards integrating Earth observations into Earth system modeling in cold regions to help identify and constrain sources of uncertainty.

Keywords: snow cover; MODIS; CLM5; ERA5; model evaluation; Sentinel-2; Landsat 8