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NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

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INTEGRATED ASSESSMENT OF THE IMPACTS OF, AND INTERACTIONS BETWEEN CLIMATE, LAND USE AND THE HYDROLOGICAL CYCLE

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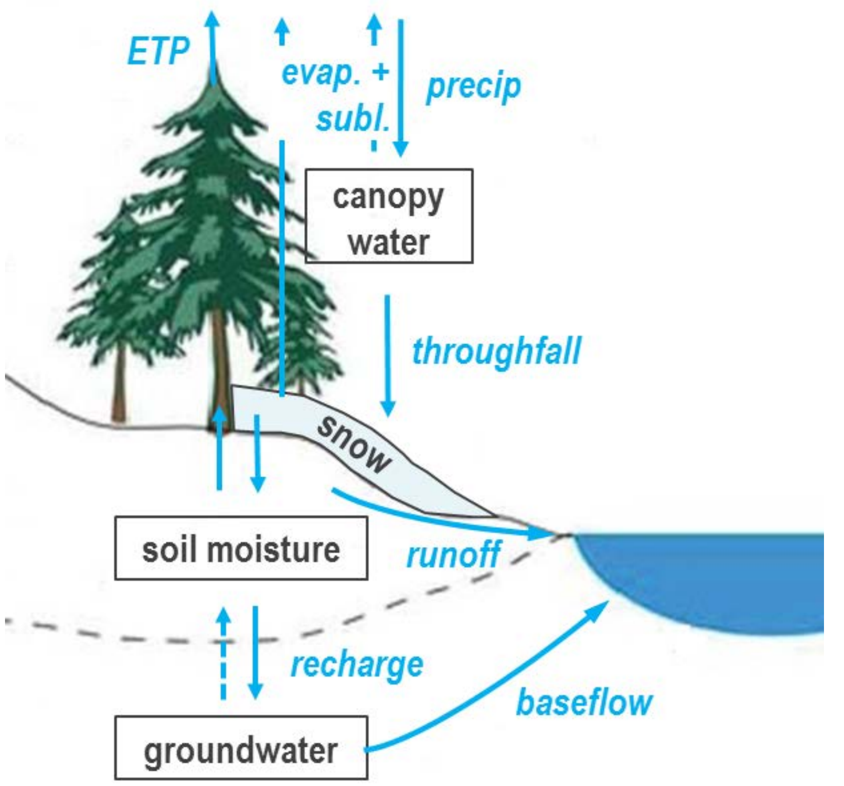
IMPACTS: CLIMATE, ANTHROPOSPHERE AND NATURE (I:CAN) RESEARCH COUNCIL OF NORWAY

- Improve the quantitative assessment of the components of the water cycle in Norway by explicitly including forest changes in the model procedures
- Demonstrate the effects of land use and climate changes on the hydrological cycle
- Investigate local, regional and global hydrological impact assessments

IMPACTS OF FOREST STRUCTURE ON HYDROLOGY

- Forests are recognized for their decisive effect on the landscape water balance
- Forest structure determines energy partitioning and dominant flow paths
- Threefold increase of standing forest volume over the past 100 years
- Spatial and temporal variability in forest structure often poorly represented in (large scale) hydrological modeling frameworks
- Couple the distributed HBV hydrological model with forest structural information from the Norwegian NFI and multi-source remote sensing data
- Forest classification scheme based on forest structure to account for impacts of forest management



CURRENT LAND COVER SCHEME

Open	Bedrock	Glacier	Forest	Alpine	Bog	Heather	Lake

Data-driven, spatially distributed forest characterization that reflects hydrologically relevant differences in land surface parameters:

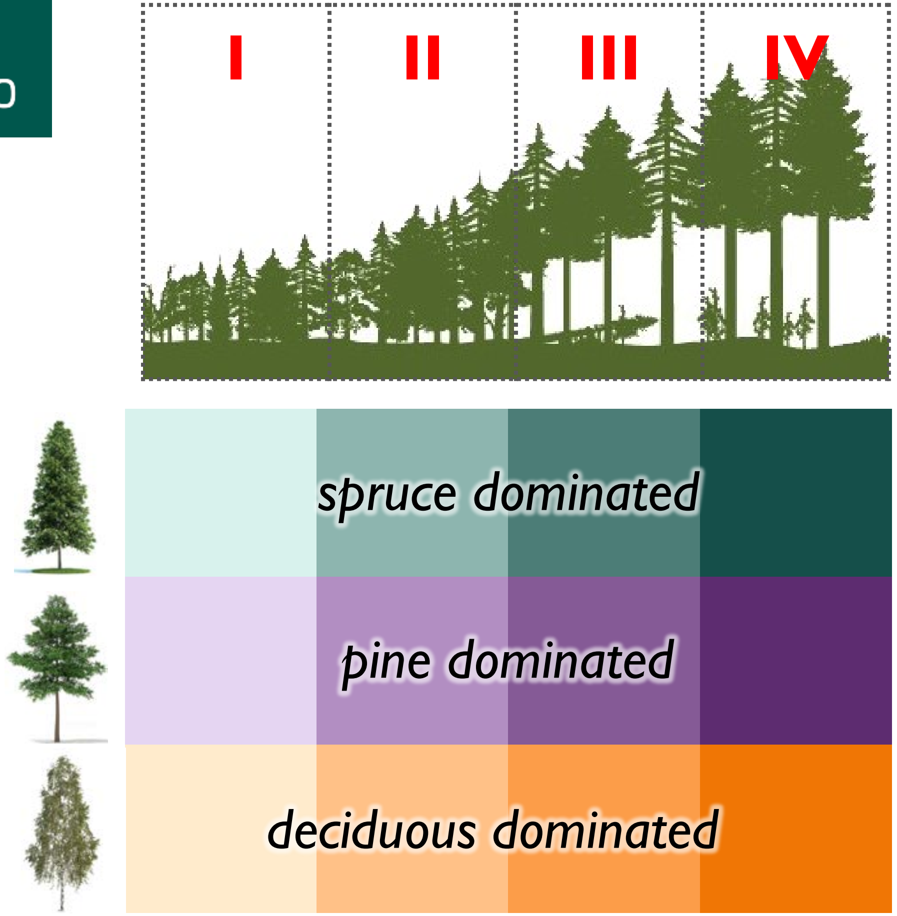
- Albedo
- Canopy height
- Leaf area index
- Deciduous leaf area (share)

Multi-source remote sensing data

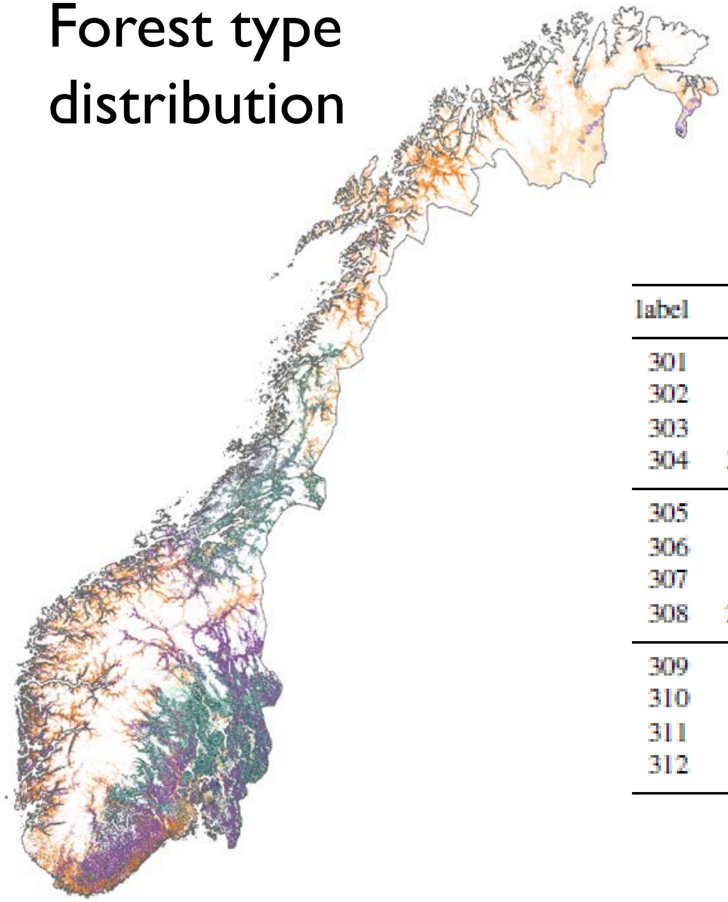
National forest inventory data

Eisner et al. 2018

FOREST CLASSIFICATION SCHEME



Forest type distribution



Parameter look-up table

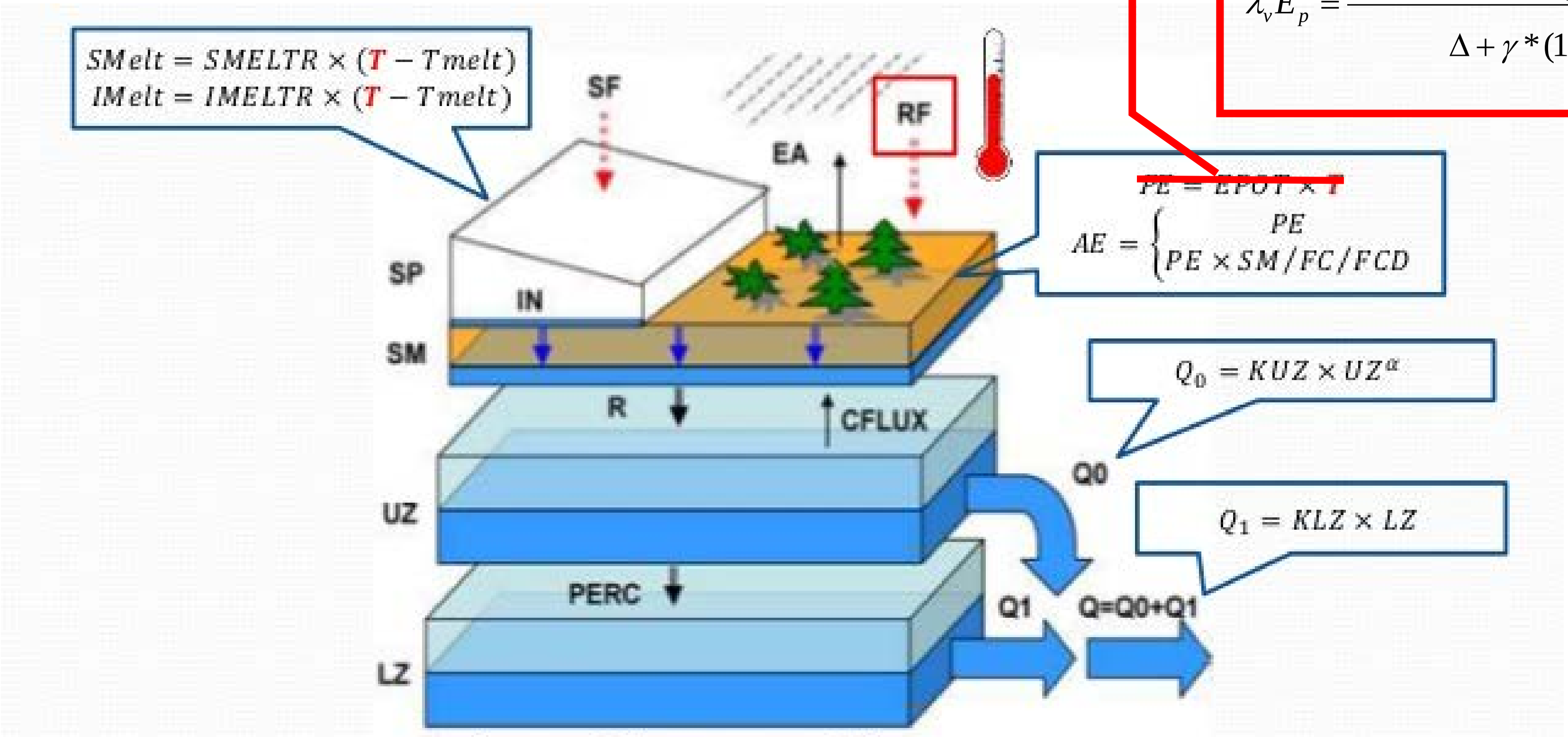
label	V	H	CL	LAI_{max}
301	22 (28.9)	7.5 (3.1)	6.3 (2.8)	1.4 (1.6)
302	92.2 (51.7)	12.3 (2.5)	10.1 (2.2)	4.3 (2.2)
303	201.3 (70.1)	16.8 (3.1)	13.2 (2.6)	6.7 (2.5)
304	373.9 (138.9)	22 (4.5)	15.8 (3.5)	9.1 (3.4)
305	20.8 (23.1)	7.5 (2.8)	4.6 (1.7)	0.9 (1)
306	80 (49.2)	11.6 (2.4)	6.7 (1.4)	2.4 (1.4)
307	129.5 (67.9)	17 (3.9)	9.4 (2)	2.3 (1.2)
308	236.4 (107.1)	17.2 (5)	8.4 (1.6)	4.4 (1.5)
309	7.2 (10.8)	4.9 (1.6)	3.2 (1.1)	0.5 (0.7)
310	36.1 (28.9)	8.4 (2.1)	5.5 (1.3)	1.8 (1.6)
311	97.6 (50.8)	12.2 (3.7)	7.9 (2.5)	3.9 (2.1)
312	227 (111.2)	18.3 (5.5)	10.3 (3.2)	7 (3.2)

Majasalmi et al. (2018): *An enhanced forest classification scheme…*, Biogeosciences 15

HYDROLOGICAL MODEL

- The distributed HBV model with the Penman-Monteith method

$$\lambda_v E_p = \frac{\Delta(R_n - G) + \rho_a c_p (v_s - v_a)/r_a}{\Delta + \gamma * (1 + \frac{r_s}{r_a})}$$



Scheme of the HBV model

Li et al. 2015

Huang et al. 2019

NORWAY (323 781 KM^2), 123 CATCHMENTS (7 – 15450 KM^2)

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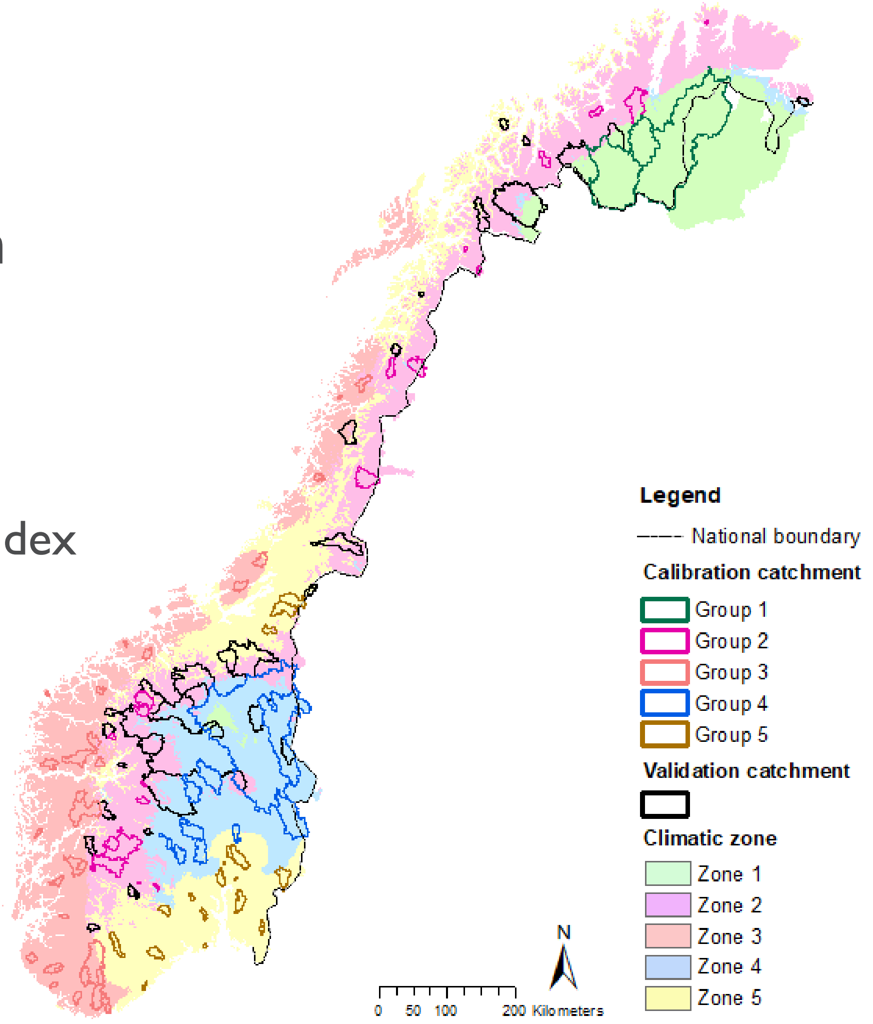
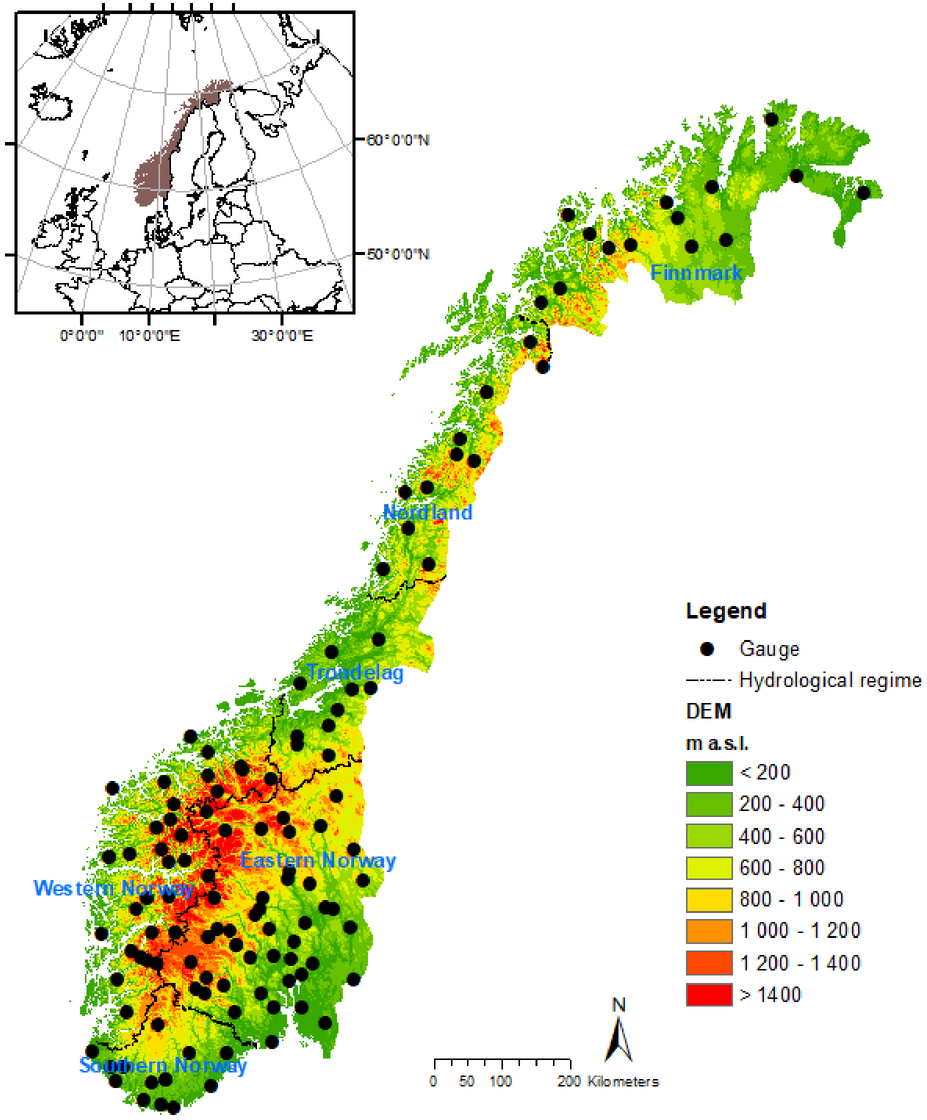
- Regionalized calibration
  - Climate indices
  - Mean annual precipitation
  - Precipitation seasonality index
  - Mean annual temperature
  - Temperature seasonality
  - K-mean clustering





Huang et al. 2019

DATA

- Land surface parameters (20 landscape types)
  - Albedo
  - LAI
  - Vegetation height (m)

    ← National Forest Inventory and remote sensing

  - Bulk resistance (s/m)
  - Roughness parameter (m)

    ← VIC vegetation library, Federer et al. 1996 Zhou et al. 2006

  - Crop parameters

    ← Crop database from SWAT model

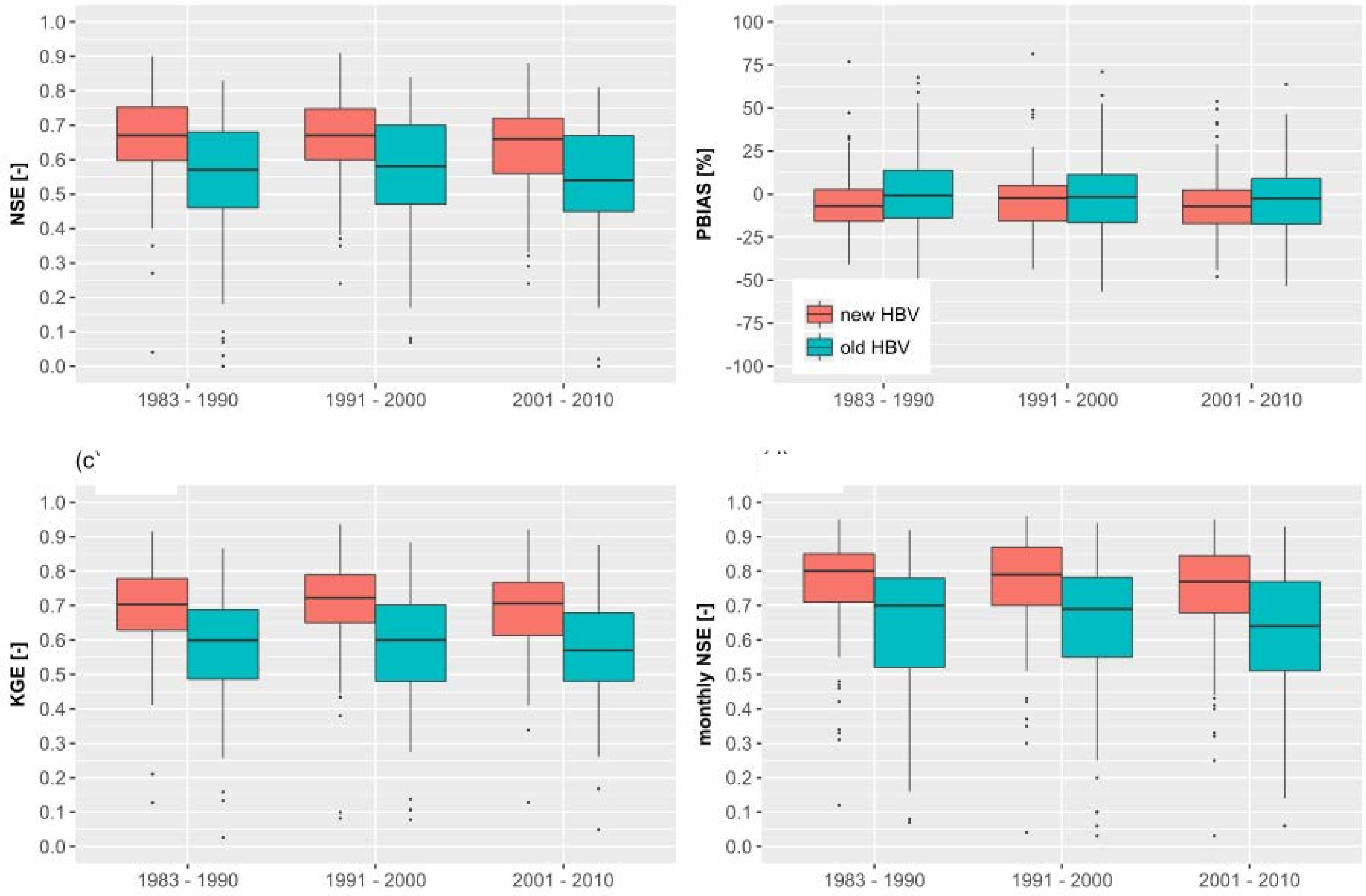
  - Additional biome properties

    ← Mu et al. 2011

Huang et al. 2019

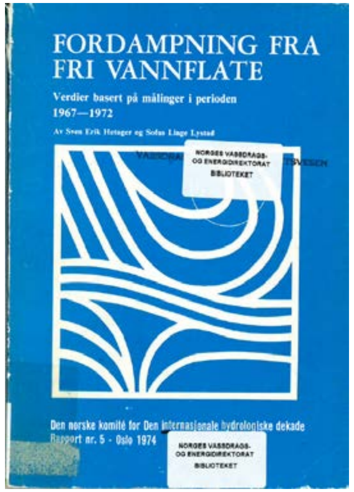
MODEL PERFORMANCE

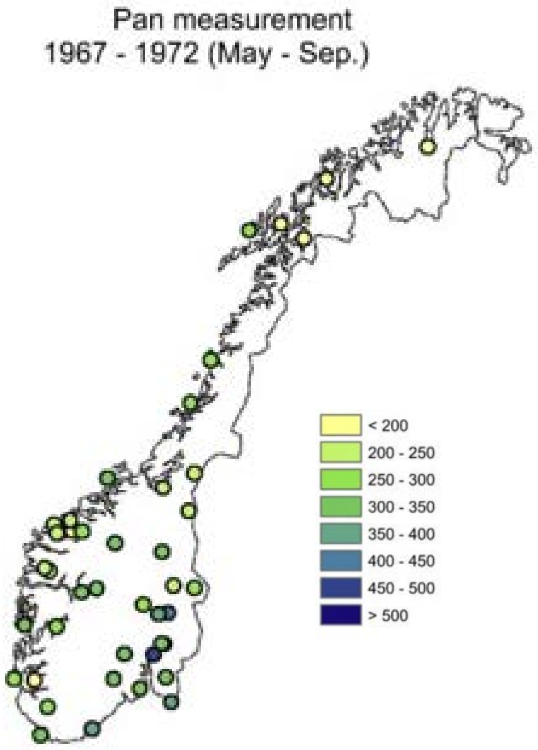
Compare the model performance between the new and old version of the HBV model

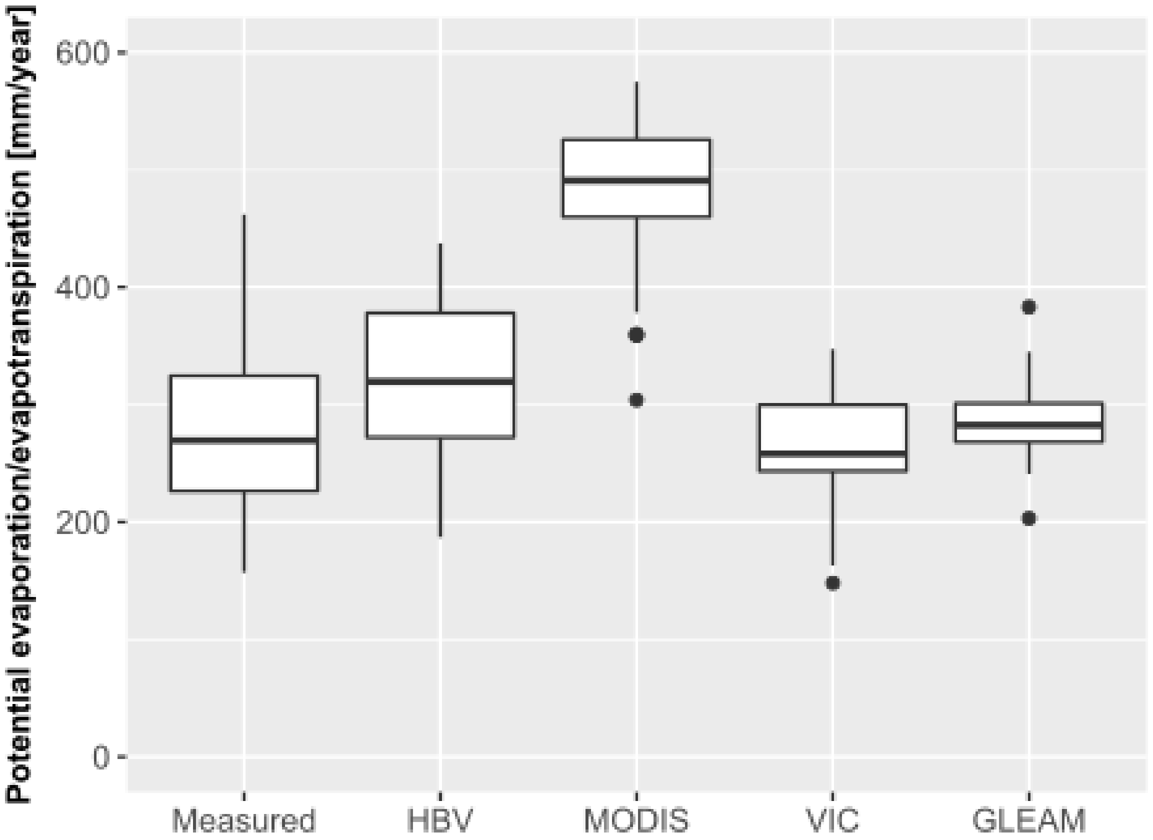


Huang et al. 2019

POTENTIAL EVAPOTRANSPIRATION



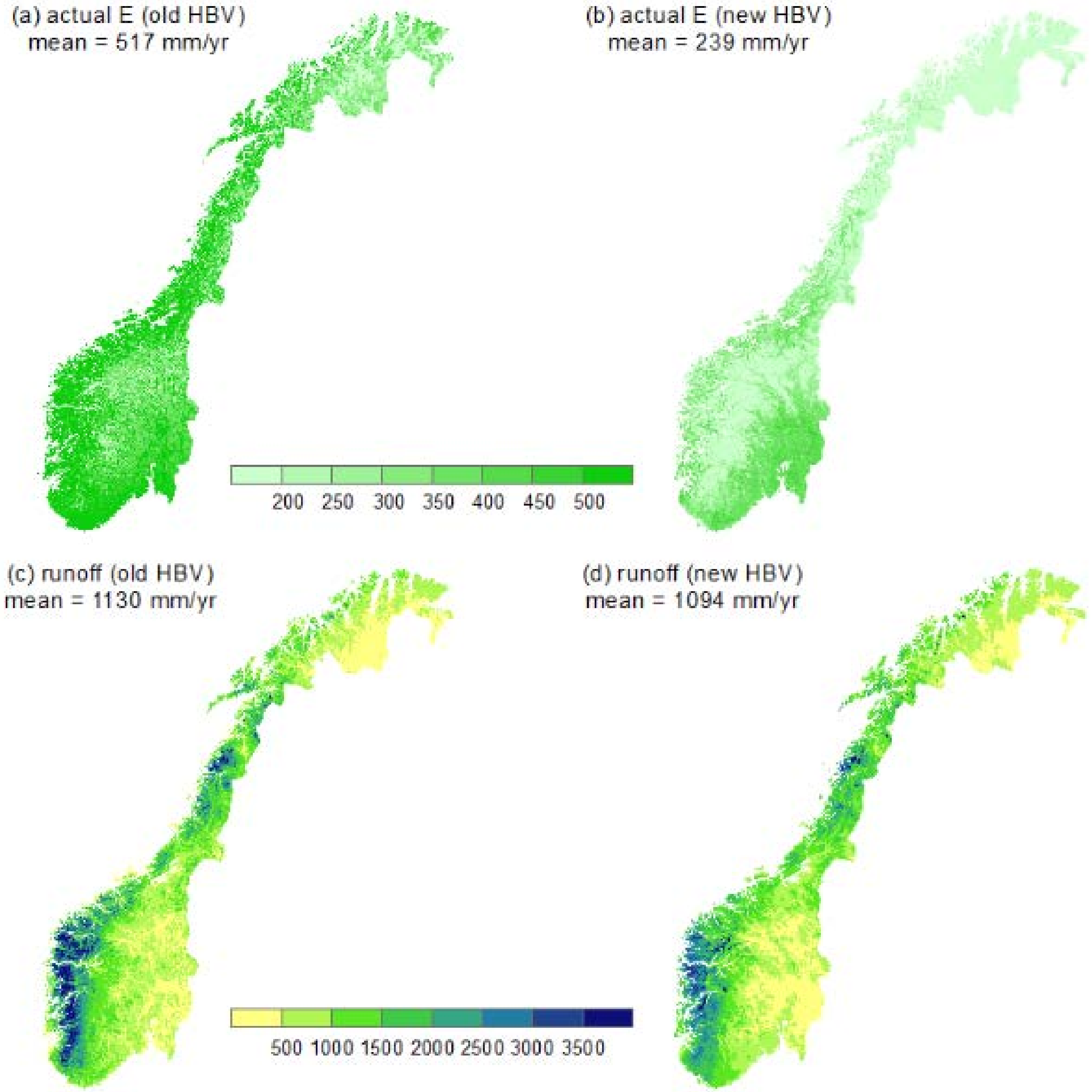




Huang et al. 2019

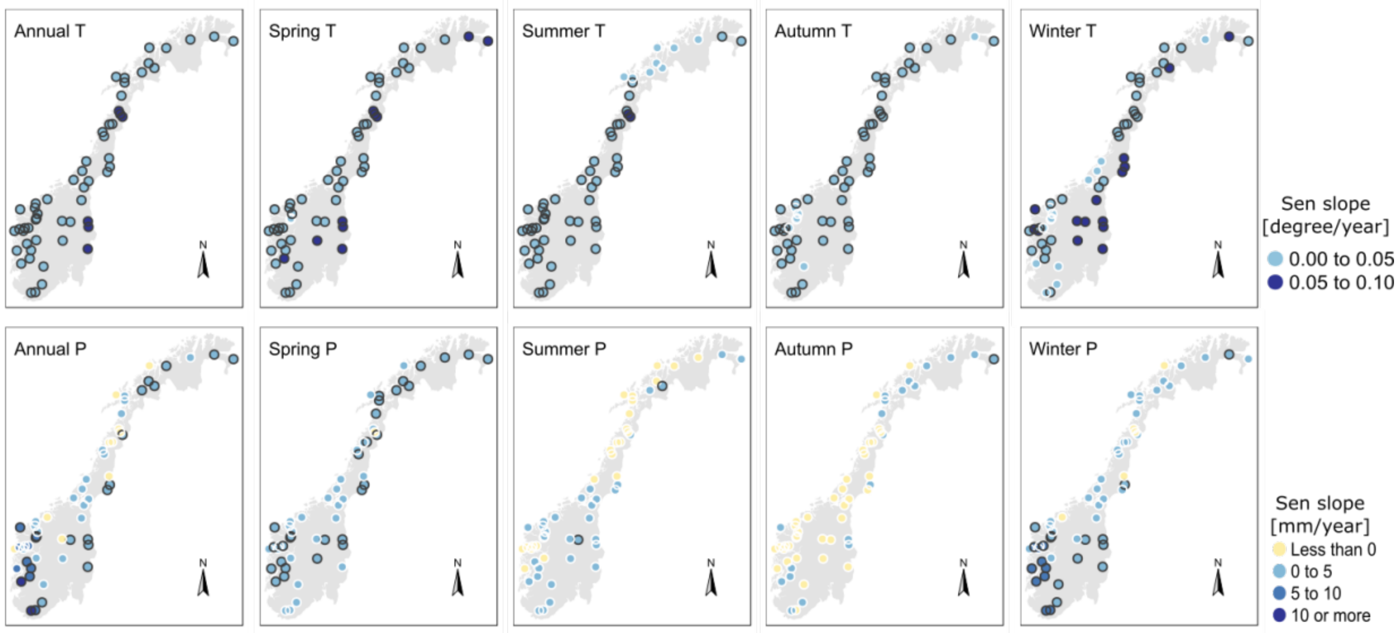
RESULTS

Average annual actual evapotranspiration (E) and runoff in 1983 – 2012

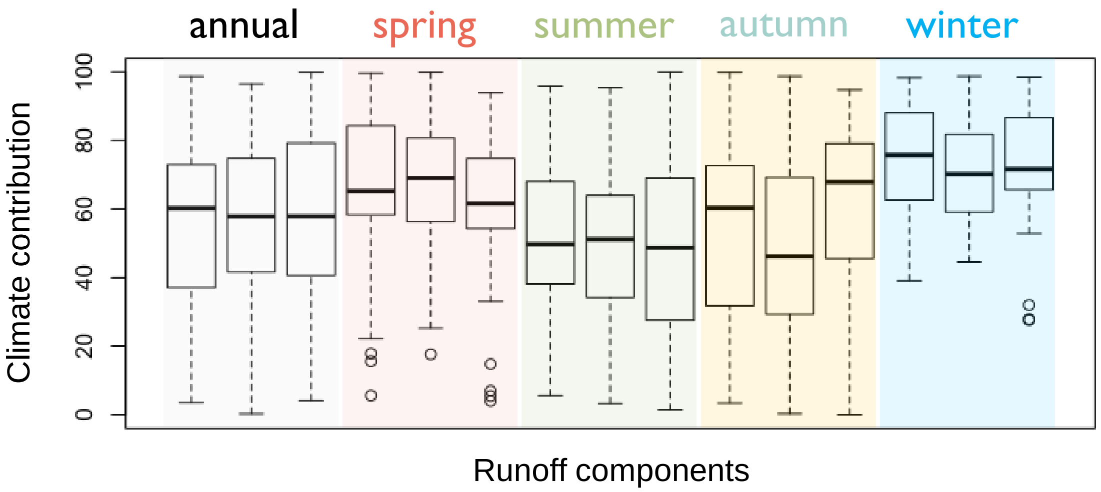


Huang et al. 2019

CONTRIBUTION OF CLIMATE AND LAND COVER IMPACTS ON STREAMFLOW



Reference period: 1961 – 1988
Changing period: 1989 – 2015

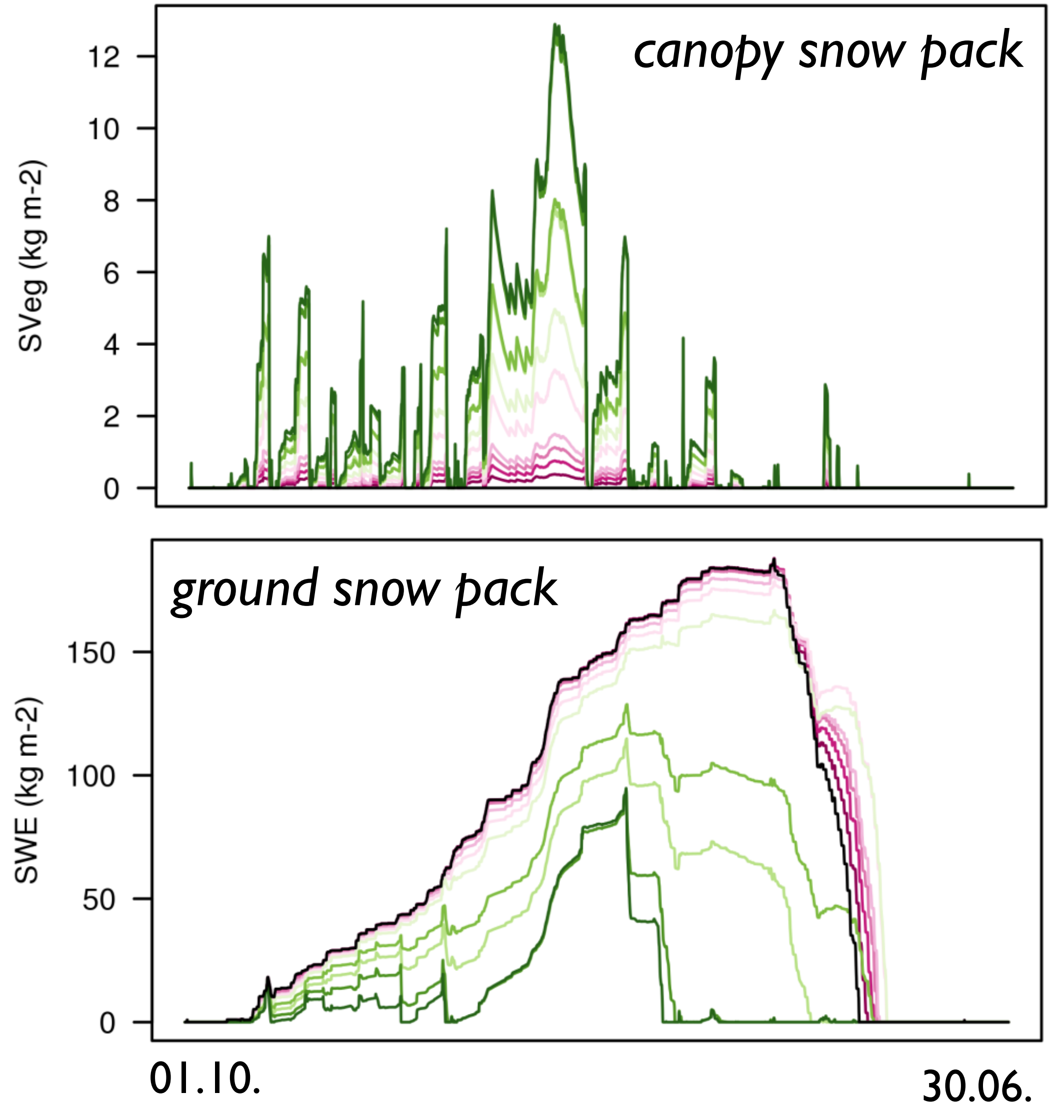


Huang et al. 2017

EFFECT OF FOREST TYPE ON SNOW PACK DYNAMICS

- Site-based sensitivity analysis of snow dynamics under different forest structures (LAI & canopy height)

accumulated precipitation & runoff



[low LAI] [high LAI]

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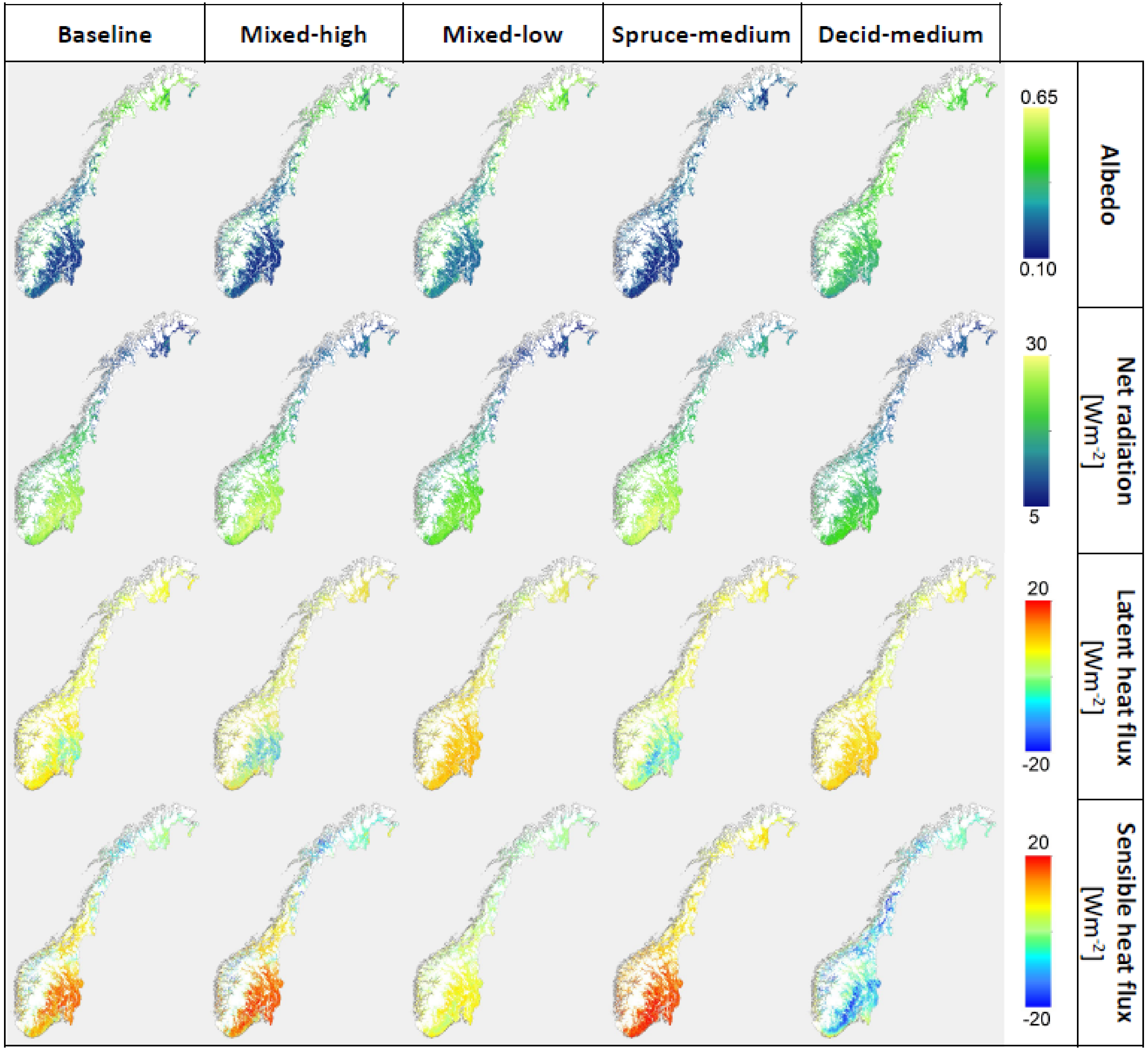
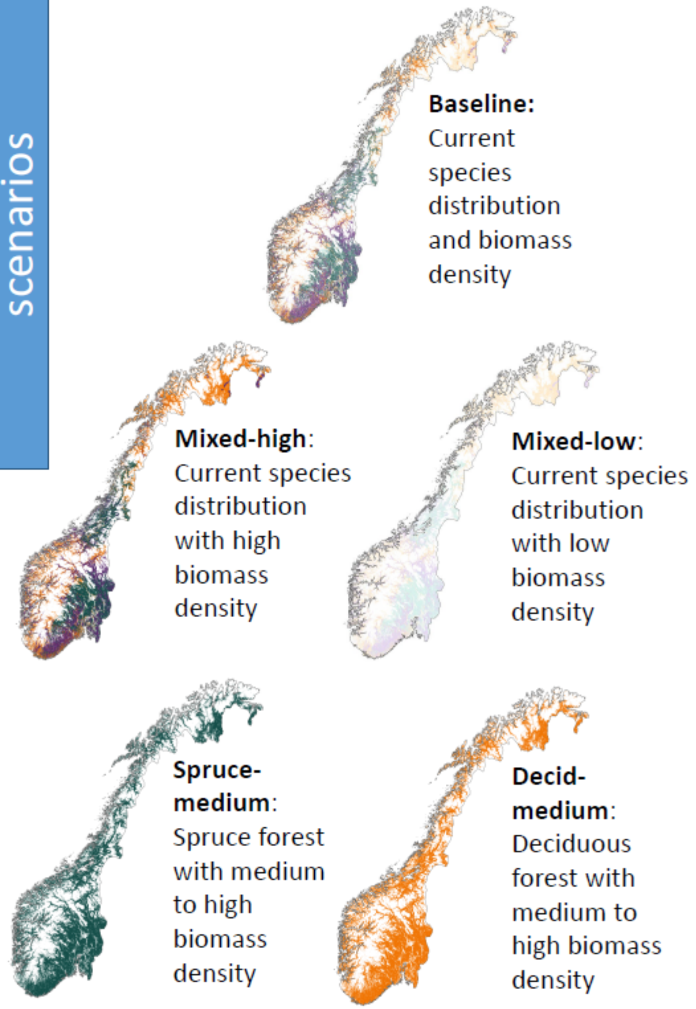
Factorial Snowpack Model, Essery 2015 Eisner et al. 2018

SEASONAL AVERAGE SEPTEMBER - JUNE



Forest management scenarios



Factorial Snowpack Model, Essery 2015

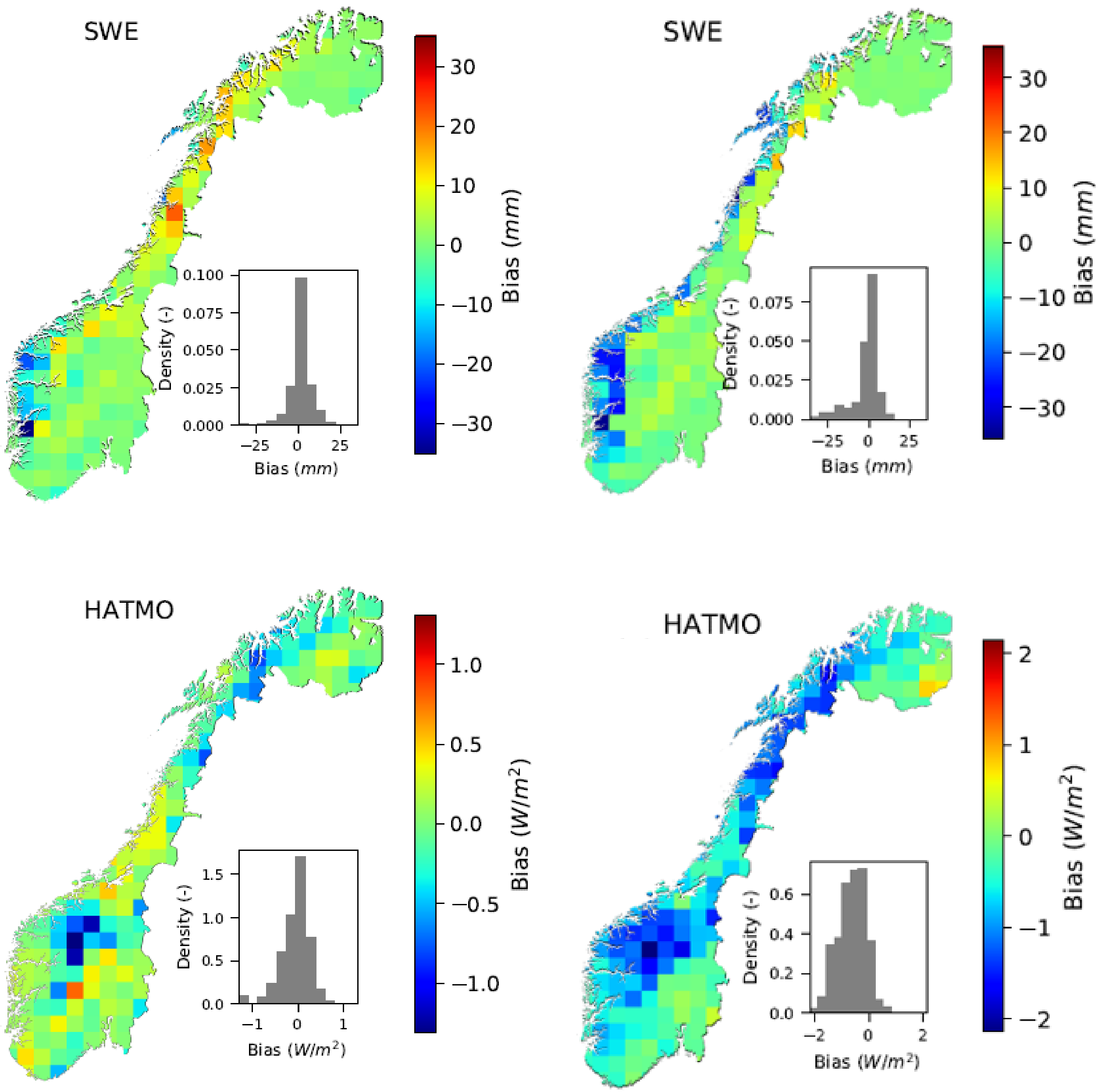
Eisner et al. 2019

FACTORIAL SNOWPACK MODEL

Bias between the coarse (50 km) and fine (1 km) scale simulations for snow water equivalent (top), and sensible heat fluxes (bottom).

Left figures: all process parameterisations are set to option 1, also for turbulent heat exchanges (atmospheric stability correction scheme).

Right figures: all process parameterisations are set to option 1, except for turbulent heat exchanges that was set to 0 (assuming neutral atmospheric conditions).



Factorial Snowpack Model, Essery 2015 Magnusson et al. 2019

CONCLUSIONS

- The Penman-Monteith method was successfully implemented in the HBV model and showed reasonable estimation of potential evapotranspiration for Norway
- The calibration and validation results show a significant improvement on the simulated discharge as well as hydrological components compared to previous simulation results
- Further improvement may be obtained by substituting a physically based snow model for Norway for the parametric snow module in HBV
- Forest structure impacts on albedo, energy balance and water balance
- Model simulations show that scale errors depends on model structure and process parameterization

I:CAN PUBLICATIONS

1. Huang, S., S. Eisner, J. Magnusson, C. Lussana, X. Yang, S. Beldring. 2019. Improvements of the spatially distributed hydrological modelling using the HBV model at 1 km resolution for Norway. *Journal of Hydrology, 557:123585, https://doi.org/10.1016/j.jhydrol.2019.03.051*
2. Magnusson, J., S. Eisner, S. Huang, C. Lussana, G. Mazzotti, R. Essery, T. Saloranta, S. Beldring. 2019. Influence of spatial resolution on snow cover dynamics for a coastal and mountainous region at high latitudes (Norway). *Water Resources Research. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019WR024925*
3. Bright, R. et al. (incl. R. Astrup and S. Eisner) 2018. Inferring surface albedo prediction error linked to forest structure at high latitudes. *Journal of Geophysical Research: Atmospheres, 123:4910-4925, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JD028293*
4. Majasalmi, T. et al. (incl. R. Astrup and S. Eisner) 2018. An enhanced forest classification scheme for modeling vegetation–climate interactions based on national forest inventory data 2018. *Biogeosciences, 15:399–412, https://doi.org/10.5194/bg-15-399-2018*
5. Zaherpour, Z. et al. (incl. I. Haddeland and S. Eisner) 2018. Worldwide evaluation of mean and extreme runoff from six global-scale hydrological models that account for human impacts. *Environmental Research Letters 13:065015, https://iopscience.iop.org/article/10.1088/1748-9326/aac547*
6. Gosling. S.N. et al. (incl. I. Haddeland). 2017. A comparison of changes in river runoff from multiple global and catchment-scale hydrological models under global warming scenarios of 1°C, 2°C and 3°C. *Climatic Change, 141: 577-595. https://link.springer.com/article/10.1007/s10584-016-1773-3*
7. Zhou, T., I. Haddeland, B., Nijssen, D.P. Lettenmaier. 2016. Human induced changes in the global water cycle. *Terrestrial Water Cycle and Climate Change: Natural and Human-Induced Impacts (Eds. Tang, Q., T. Oki). American Geophysical Union Geophysical Monograph Series. https://agupubs.onlinelibrary.wiley.com/doi/10.1002/9781118971772.ch4*

Thank you