Supplementary Information for “Past and future changes in avalanche problems in northern Norway estimated with machine-learning models”

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Table S1. Linear trends in d a^{-1} of historical (NORA3) avalanche day frequency (ADF) for all avalanche problems (APs). Statistically significant trends (p < 0.05) are shown in bold type. The full season encompasses December through May, winter is December through February, and spring March through May.

	wind slab			PWL slab			wet			general		
	full	winter	spring	full	winter	spring	full	winter	spring	full	winter	spring
Nord-Troms	-0.12	**-0.28**	0.18	0.08	0.01	0.11	0.25	0.16	0.22	0.06	-0.13	0.23
Lyngen	-0.03	-0.20	0.22	-0.01	-0.12	0.09	0.15	0.16	0.10	0.10	-0.16	**0.33**
Tromsø	-0.17	**-0.35**	0.21	0.25	0.02	0.36	0.06	-0.15	0.15	-0.02	-0.23	0.24
Sør-Troms	-0.12	-0.21	0.12	0.04	-0.12	0.16	0.07	0.04	0.06	0.02	-0.14	0.22
Indre Troms	-0.03	-0.17	0.19	-0.02	-0.02	0.00	0.17	0.05	0.17	0.15	-0.07	0.28

Table S2. Correlation (Pearson R) of winter (Dec-Feb) avalanche day frequency (ADF) with Arctic Oscillation (AO) index. Statistically significant correlations (p < 0.05) are shown in bold type.

	wind slab		PWL slab		wet		general	
	1-yr	7-yr	1-yr	7-yr	1-yr	7-yr	1-yr	7-yr
Nord-Troms	**0.36**	**0.44**	0.02	**-0.37**	**0.46**	**0.72**	**0.44**	**0.60**
Lyngen	**0.34**	**0.43**	-0.05	-0.22	**0.58**	**0.76**	**0.46**	**0.60**
Tromsø	0.21	0.03	-0.04	**-0.51**	**0.44**	**0.56**	**0.45**	**0.50**
Sør-Troms	0.24	0.04	-0.16	**-0.66**	**0.61**	**0.80**	**0.44**	**0.56**
Indre Troms	**0.52**	**0.66**	-0.15	**-0.72**	**0.51**	**0.78**	**0.49**	**0.72**

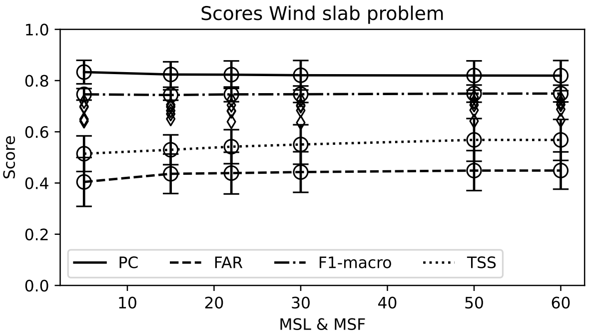

Figure S1. Dependence of the machine-learning model performance scores for the wind slab avalanche problem. The scores comprise the percentage correct (PC), the false alarm rate (FAR), the F1-macro score, and the true skill score (TSS). See Appendix C for the definitions of these metrics.

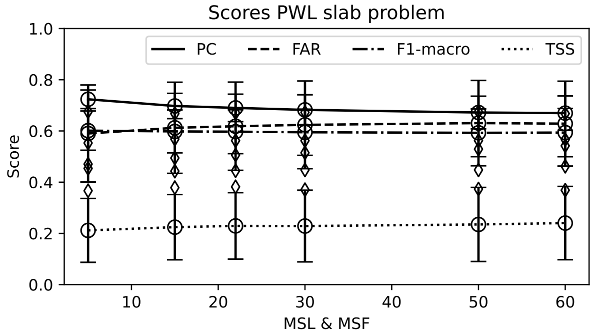

Figure S2. Same as S1 but for the persistent weak layer (PWL) slab avalanche problem.

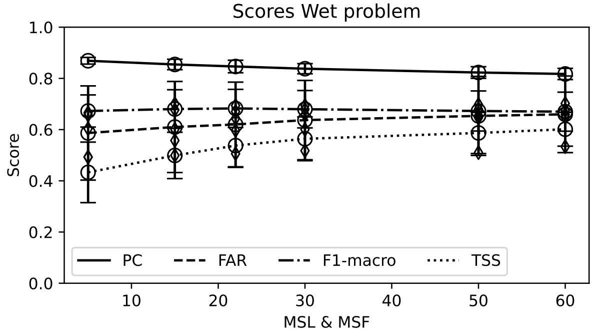

Figure S3. Same as S1 but for the wet avalanche problem.

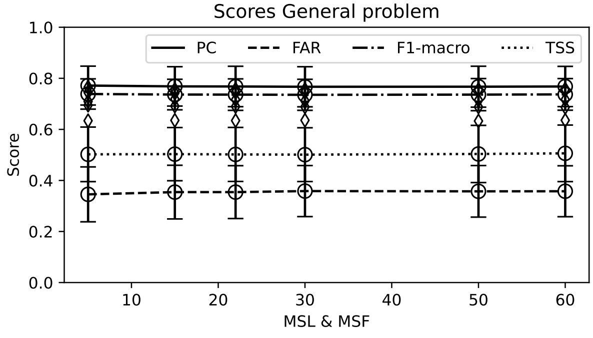

Figure S4. Same as S1 but for the general avalanche problem.

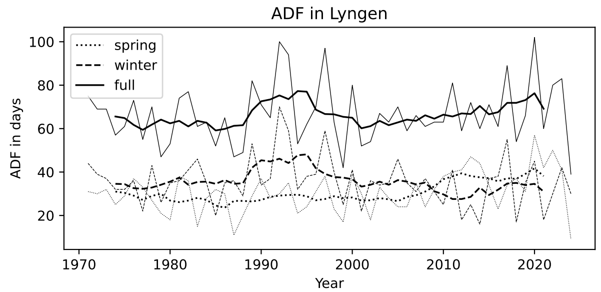

Figure S5. Historical (1970–2024) avalanche day frequency (ADF) in Lyngen for winter (dashed), spring (dotted), and full (solid) season. Thin and bold lines represent annual and 7 y rolling mean values, respectively.

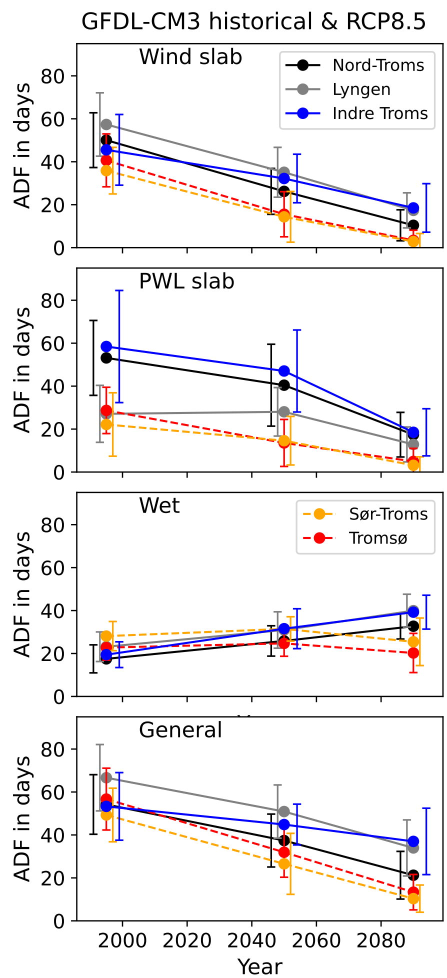

Figure S6. As Fig. 9 but for the GFDL-CM3, but only for the RCP8.5 since RCP4.5 is not available for GFDL-CM3.

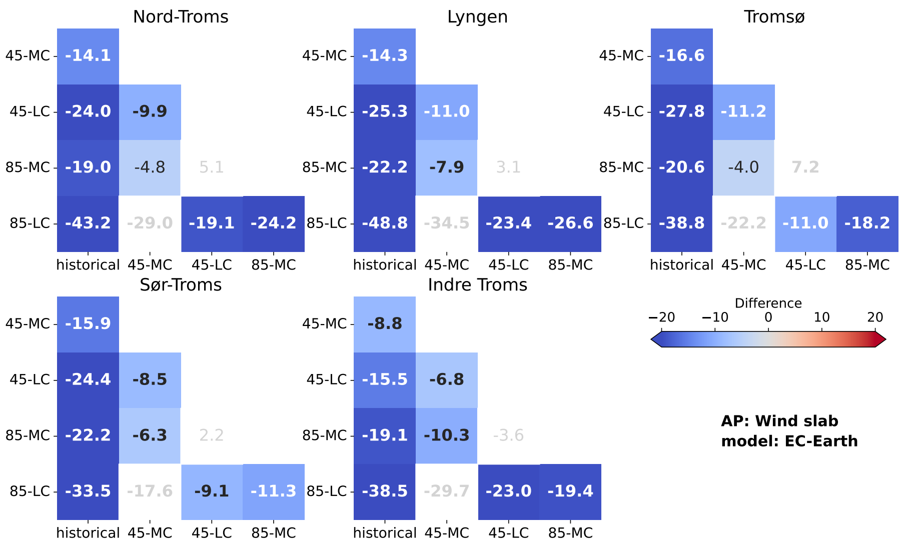

Figure S7. Changes of the wind slab avalanche day frequency (ADF) in the EC-Earth RCP4.5 and RCP8.5 simulations. Bold values indicate significance on the $p < 0.05$ level based on a Monte-Carlo simulation with 100,000 permutations. Changes are calculated as scenario on the y axis minus scenario on the x axis.

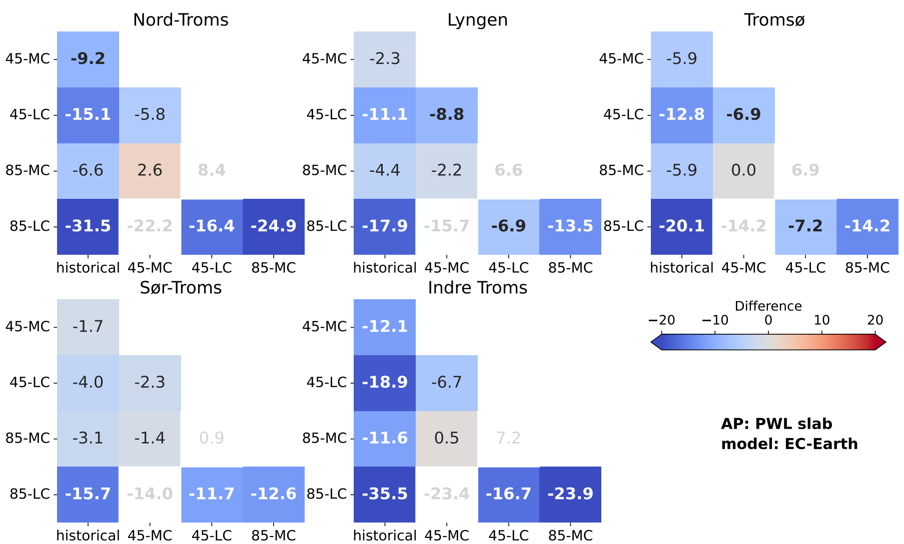

Figure S8. Same as Fig. S7 but for the PWL slab problem.

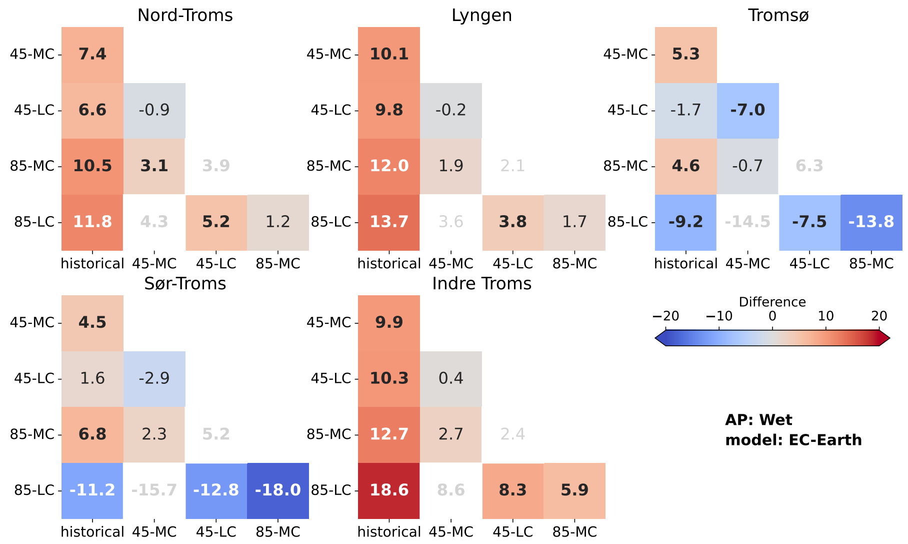

Figure S9. Same as Fig. S7 but for the wet problem.

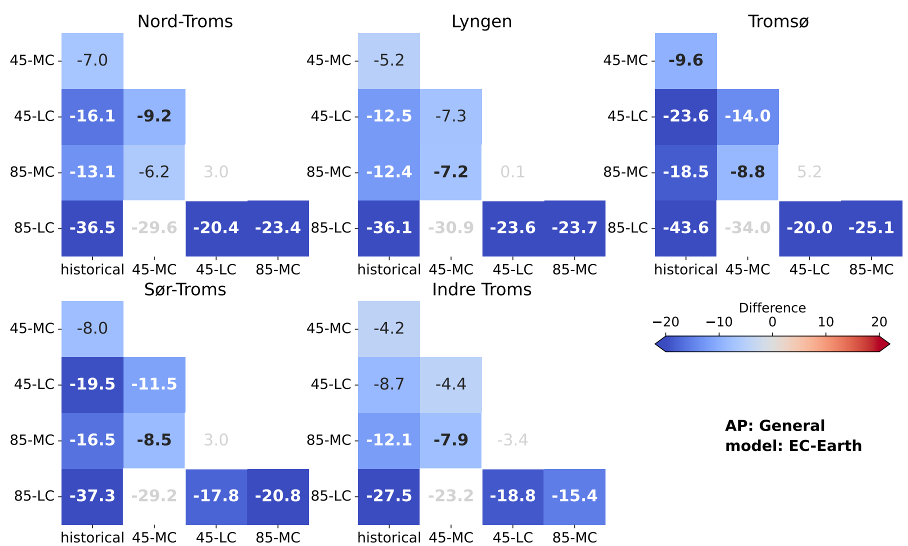

Figure S10. Same as Fig. S7 but for the general problem.

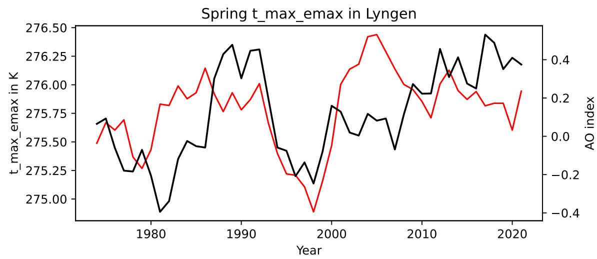

Figure S11. Historical (1970–2024) t_max_emax (red) and Arctic Oscillation (AO) index (black) in Lyngen for spring.

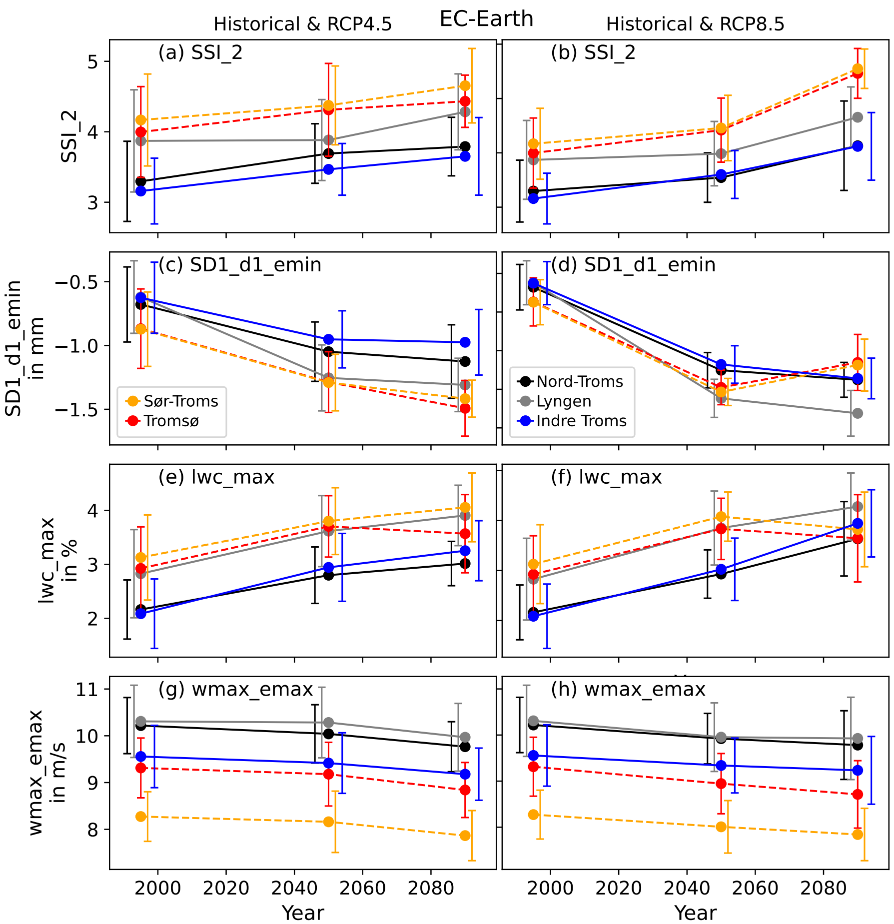

Figure S12. As Fig. 11 but for different features.

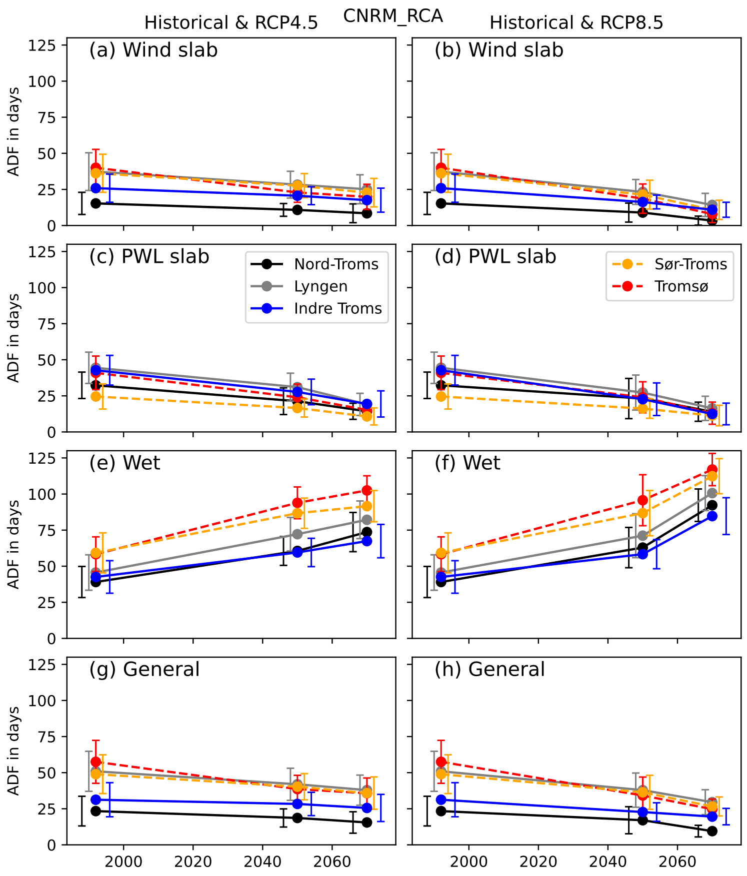

Figure S13. As Fig. 9 but for the statistically downscaled CNRM-RCA model from EURO-CORDEX. Note that for the statistically downscaled EURO-CORDEX data show a stronger warming response than the NorCP data. Interestingly, the latter show a cold bias in near-surface temperatures (Lind et al., 2020), while the former have been bias-corrected to exhibit higher temperatures (Wong et al., 2016).

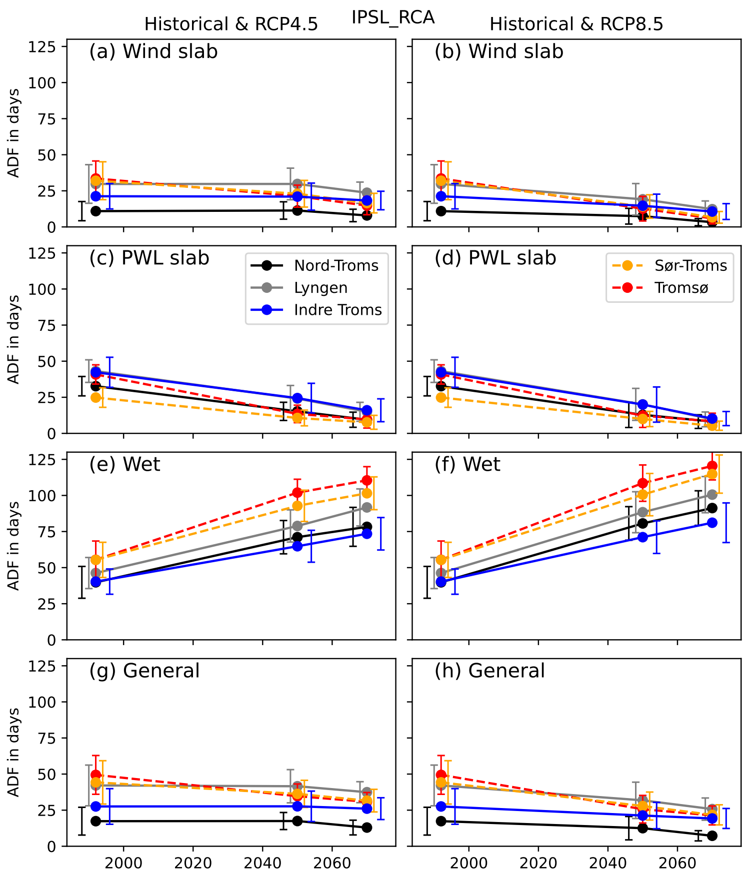

Figure S14. As Fig. 9 but for the statistically downscaled IPSL-RCA model from EURO-CORDEX.

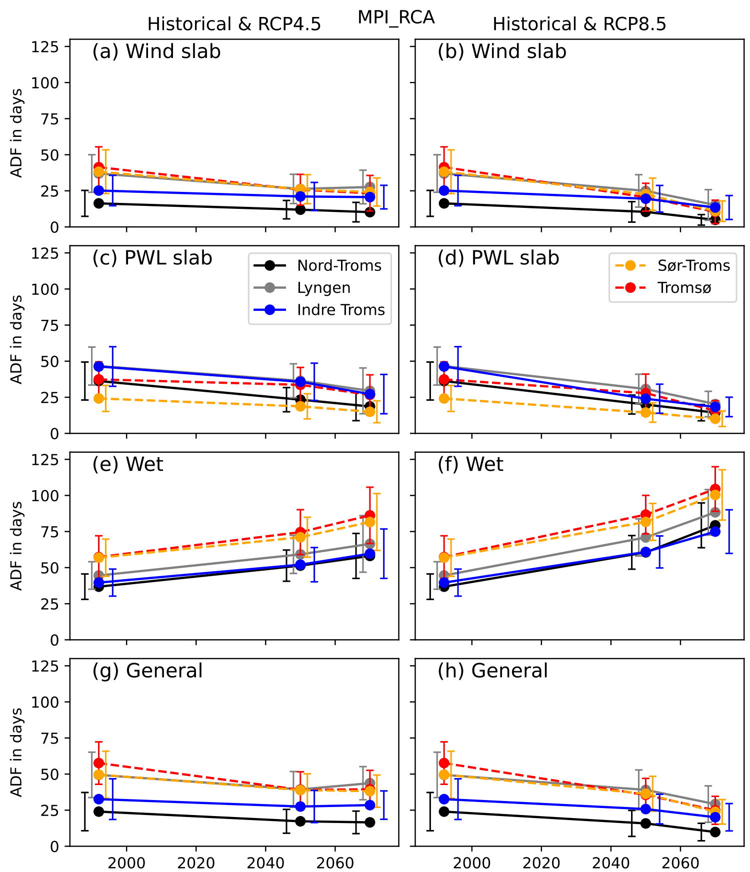

Figure S15. As Fig. 9 but for the statistically downscaled MPI-RCA model from EURO-CORDEX.

References

Lind, P., Belušić, D., Christensen, O. B., Dobler, A., Kjellström, E., Landgren, O., Lindstedt, D., Matte, D., Pedersen, R. A., Toivonen, E., and Wang, F.: Benefits and added value of convection-permitting climate modeling over Fenno-Scandinavia, Climate Dyn., 55, 1893–1912, https://doi.org/10.1007/s00382-020-05359-3, 2020.

Wong, W. K., Haddeland, I., Lawrence, D., and Beldring, S.: Gridded 1 × 1 km Climate and Hydrological Projections for Norway, NVE Report 59–2016, Norwegian Water Resources and Energy Directorate, https://nve.brage.unit.no/nve-xmlui/handle/11250/2500569, 2016.