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Supplement of

Future Retreat of Great Aletsch Glacier and Hintereisferner – application of a full-Stokes model to two valley glaciers in the European Alps

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S1 Figures

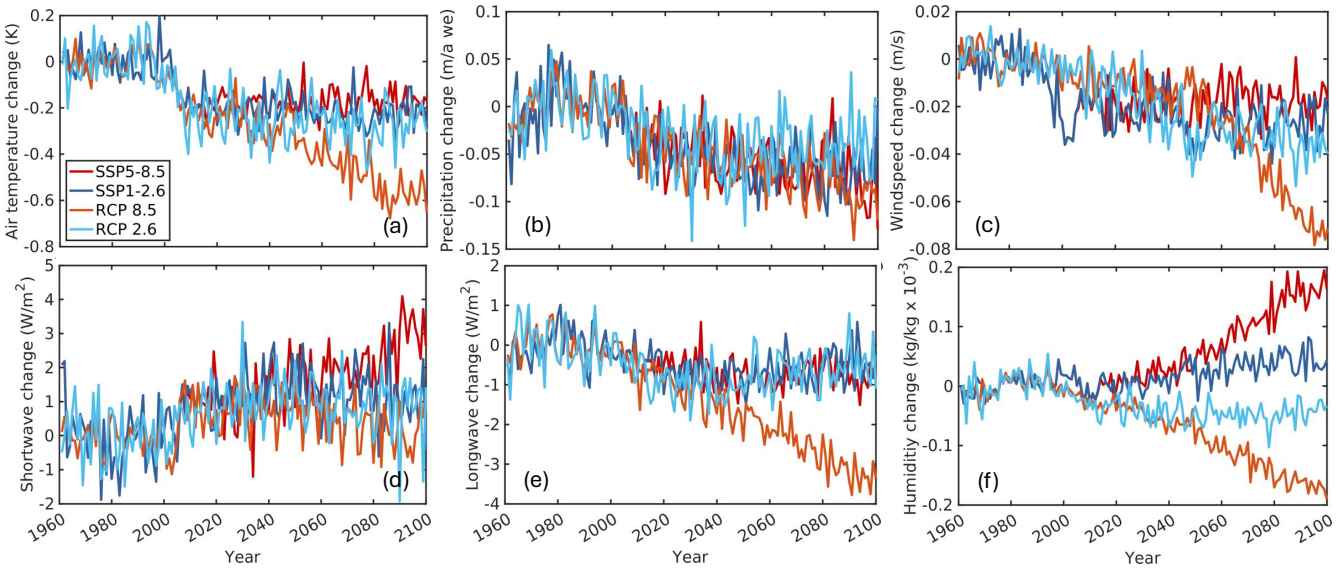

Figure S1. Ensemble mean differences of air temperature (a), precipitation (b), windspeed (c), shortwave radiation (d), longwave radiation (e) and humidity (f) anomalies between GAG and HEF of the downscaled GCM/RCM time series of the EURO-CORDEX (RCP scenarios) and ISIMIP3b ensembles (SSP scenarios).

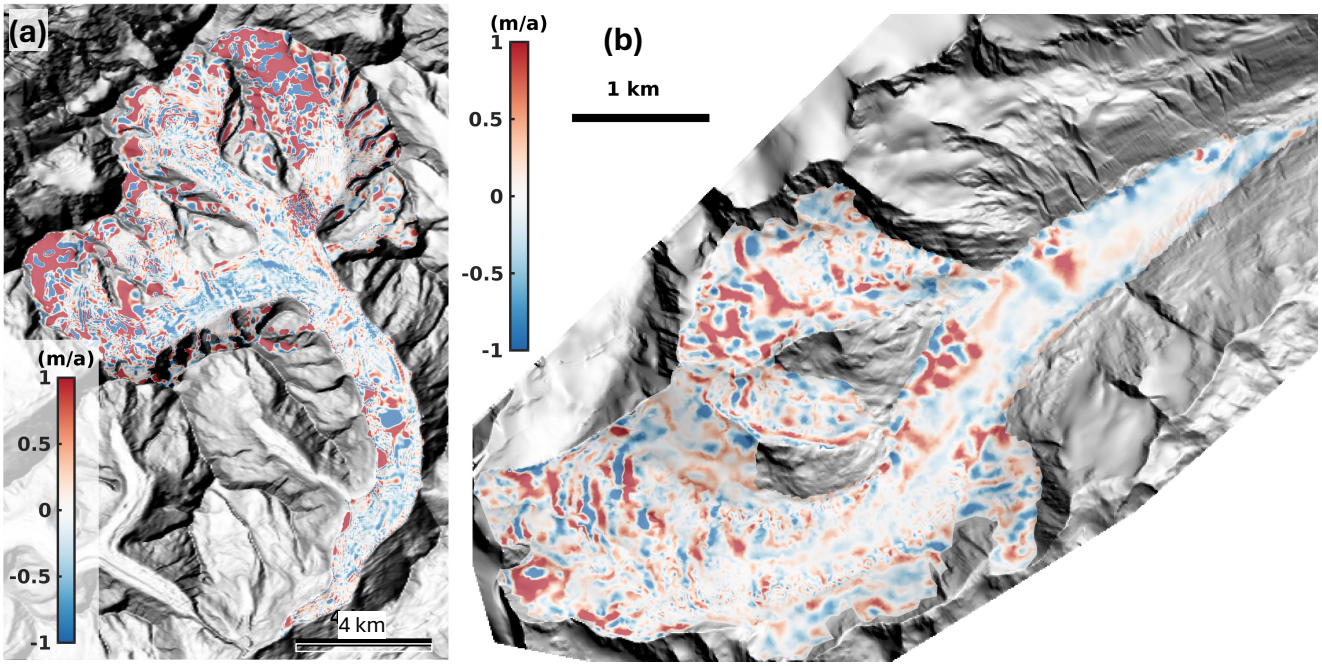

Figure S2. Difference of modelled and observed surface velocity of GAG (a) and HEF (b).

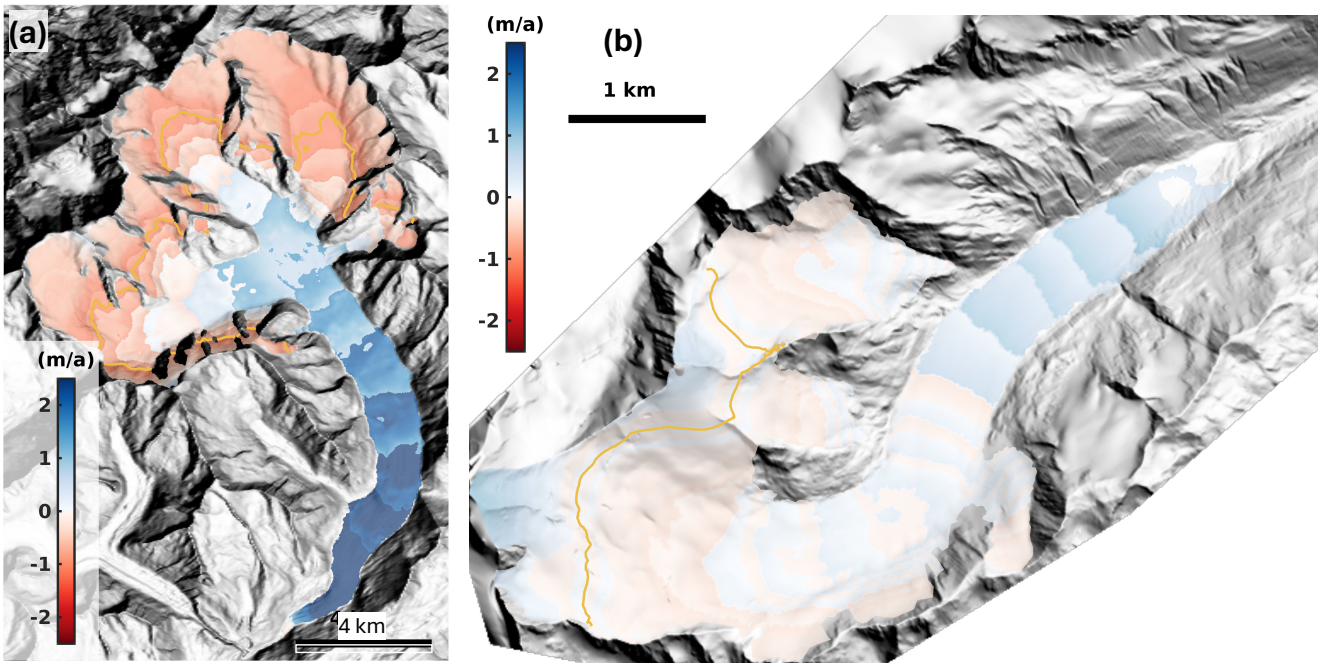

Figure S3. Difference of modelled and observed surface mass balance of GAG (a) and HEF (b). Note that observed SMB are provided in 100 and 50 m elevation bands for GAG and HEF, respectively.

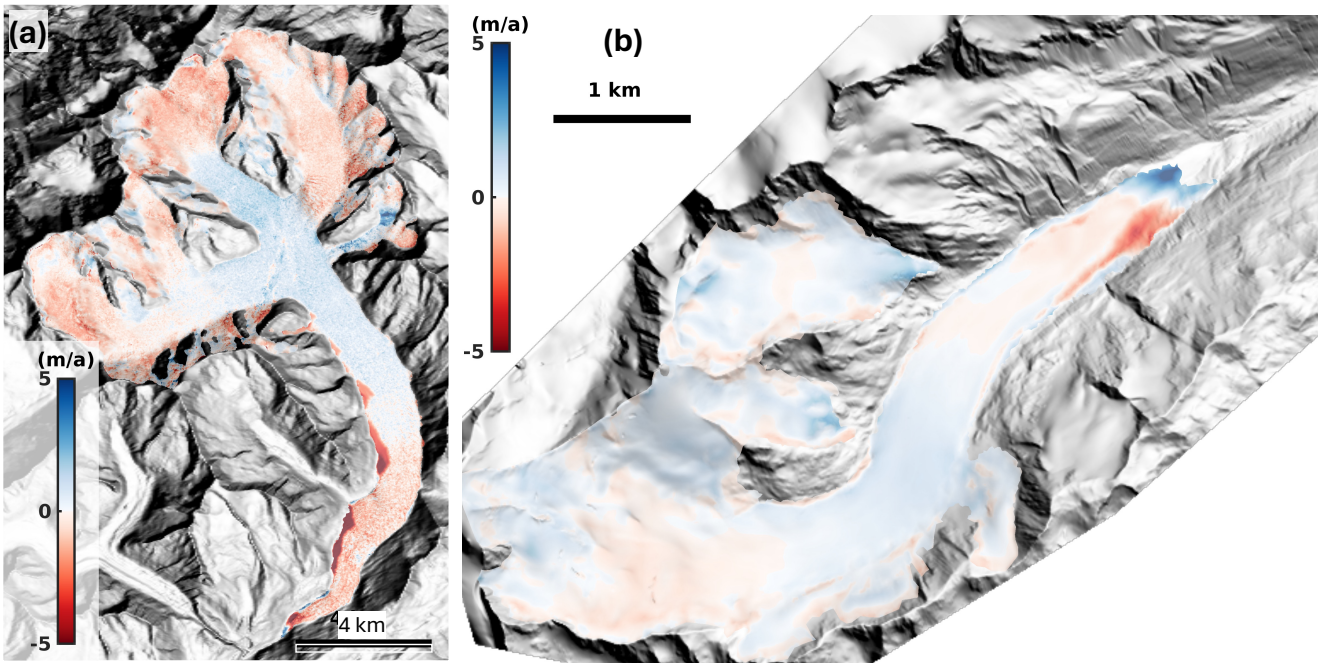

Figure S4. Difference of modelled and observed surface elevation changes of GAG (a) and HEF (b).

S2 Tables

S2.1 Hintereisferner (HEF)

Table S1. Overview of projected year when HEF are gone (i.e. volume drops below 1% of the initial volume) or mostly gone (i.e. volume drops below 10% of the initial volume) of the 22 RCP 26 EURO-CORDEX RCM simulations utilized in this study. If a percentage value is given, the volume has not fallen below the corresponding threshold value in 2100 and the remaining glacier volume is given in comparison to 1997. The simulations marked in red are the ones with a future volume evolution that is closest to the multi-model median.

GCM	realization	RCM	version	RCP 26	
				mostly gone	gone
CNRM-CERFACS-CNRM-CM5	r1i1p1	ALADIN63	v2	2054	1.68%
MPI-M-MPI-ESM-LR	r1i1p1	RCA4	v1a	2063	5.01%
NCC-NorESM1-M	r1i1p1	RCA4	v1	2062	3.13%
NCC-NorESM1-M	r1i1p1	RegCM4-6	v1	2064	3.58%
MPI-M-MPI-ESM-LR	r1i1p1	RegCM4-6	v1	2064	4.5%
MOHC-HadGEM2-ES	r1i1p1	RCA4	v1	2047	2100
ICHEC-EC-EARTH	r12i1p1	RCA4	v1	2063	3.49%
MOHC-HadGEM2-ES	r1i1p1	RegCM4-6	v1	2051	1.42%
MOHC-HadGEM2-ES	r1i1p1	RACMO22E	v2	2047	2094
MPI-M-MPI-ESM-LR	r1i1p1	REMO2009	v1	2071	5.09%
MPI-M-MPI-ESM-LR	r2i1p1	REMO2009	v1	2064	3.56%
ICHEC-EC-EARTH	r12i1p1	RACMO22E	v1	2062	4.12%
ICHEC-EC-EARTH	r12i1p1	CCLM4-8-17	v1	2073	5.38%
IPSL-IPSL-CM5A-LR	r1i1p1	REMO2015	v1	2047	2066
NOAA-GFDL-GFDL-ESM2G	r1i1p1	REMO2015	v1	2068	5.34%
ICHEC-EC-EARTH	r3i1p1	HIRHAM5	v2	2077	5.03%
CNRM-CERFACS-CNRM-CM5	r1i1p1	RACMO22E	v2	2066	3.24%
NCC-NorESM1-M	r1i1p1	REMO2015	v1	2056	2.72%
CNRM-CERFACS-CNRM-CM5	r1i1p1	REMO2015	v2	2062	2.01%
MOHC-HadGEM2-ES	r1i1p1	HIRHAM5	v2	2051	1.22%
MPI-M-MPI-ESM-LR	r1i1p1	RACMO22E	v1	2063	4.47%
NCC-NorESM1-M	r1i1p1	RACMO22E	v1	2065	3.34%

Table S2. Overview of projected year when HEF are gone (i.e. volume drops below 1% of the initial volume) or mostly gone (i.e. volume drops below 10% of the initial volume) of the 65 RCP 85 EURO-CORDEX RCM simulations utilized in this study. If a percentage value is given, the volume has not fallen below the corresponding threshold value in 2100 and the remaining glacier volume is given in comparison to 1997. The simulations marked in red are the ones with a future volume evolution that is closest to the multi-model median.

GCM	realization	RCM	version	RCP 85	
				mostly gone	gone
ICHEC-EC-EARTH	r12i1p1	CCLM4-8-17	v1	2062	2083
MOHC-HadGEM2-ES	r1i1p1	CCLM4-8-17	v1	2053	2065
ICHEC-EC-EARTH	r1i1p1	RACMO22E	v1	2053	2075
CNRM-CERFACS-CNRM-CM5	r1i1p1	CCLM4-8-17	v1	2063	2083
MPI-M-MPI-ESM-LR	r1i1p1	CCLM4-8-17	v1	2060	2084
MOHC-HadGEM2-ES	r1i1p1	RACMO22E	v2	2050	2062
MPI-M-MPI-ESM-LR	r2i1p1	REMO2009	v1	2051	2066
MPI-M-MPI-ESM-LR	r1i1p1	REMO2009	v1	2053	2071
ICHEC-EC-EARTH	r12i1p1	RACMO22E	v1	2054	2069
ICHEC-EC-EARTH	r12i1p1	HIRHAM5	v1	2058	2067
CNRM-CERFACS-CNRM-CM5	r1i1p1	RACMO22E	v2	2062	2080
NCC-NorESM1-M	r1i1p1	REMO2015	v1	2047	2068
MPI-M-MPI-ESM-LR	r1i1p1	RACMO22E	v1	2056	2067
MOHC-HadGEM2-ES	r1i1p1	HIRHAM5	v2	2049	2062
ICHEC-EC-EARTH	r3i1p1	HIRHAM5	v2	2062	2078
NCC-NorESM1-M	r1i1p1	HIRHAM5	v3	2054	2070
ICHEC-EC-EARTH	r1i1p1	HIRHAM5	v1	2058	2080
ICHEC-EC-EARTH	r3i1p1	RACMO22E	v1	2055	2074
CNRM-CERFACS-CNRM-CM5	r1i1p1	HIRHAM5	v2	2062	2079
NCC-NorESM1-M	r1i1p1	RACMO22E	v1	2049	2070
MPI-M-MPI-ESM-LR	r3i1p1	REMO2015	v1	2052	2066
NCC-NorESM1-M	r1i1p1	COSMO-crCLIM-v1-1	v1	2054	2070
MPI-M-MPI-ESM-LR	r1i1p1	COSMO-crCLIM-v1-1	v1	2057	2067
MPI-M-MPI-ESM-LR	r1i1p1	HIRHAM5	v1	2057	2073
MPI-M-MPI-ESM-LR	r2i1p1	COSMO-crCLIM-v1-1	v1	2061	2071
MOHC-HadGEM2-ES	r1i1p1	COSMO-crCLIM-v1-1	v1	2052	2064
CNRM-CERFACS-CNRM-CM5	r1i1p1	REMO2015	v2	2055	2066
IPSL-IPSL-CM5A-MR	r1i1p1	REMO2015	v1	2047	2057
MPI-M-MPI-ESM-LR	r3i1p1	COSMO-crCLIM-v1-1	v1	2059	2071
IPSL-IPSL-CM5A-MR	r1i1p1	RACMO22E	v1	2053	2061
ICHEC-EC-EARTH	r12i1p1	COSMO-crCLIM-v1-1	v1	2058	2072

Table S2. Continuation of Tab. **??**

GCM	realization	RCM	version	RCP 85	
				mostly gone	gone
IPSL-IPSL-CM5A-MR	r1i1p1	HIRHAM5	v1	2054	2063
ICHEC-EC-EARTH	r1i1p1	COSMO-crCLIM-v1-1	v1	2059	2081
ICHEC-EC-EARTH	r3i1p1	COSMO-crCLIM-v1-1	v1	2058	2070
CNRM-CERFACS-CNRM-CM5	r1i1p1	COSMO-crCLIM-v1-1	v1	2068	2092
ICHEC-EC-EARTH	r12i1p1	HadREM3-GA7-05	v1	2051	2063
CNRM-CERFACS-CNRM-CM5	r1i1p1	HadREM3-GA7-05	v2	2050	2063
MOHC-HadGEM2-ES	r1i1p1	HadREM3-GA7-05	v1	2044	2053
MPI-M-MPI-ESM-LR	r1i1p1	HadREM3-GA7-05	v1	2047	2063
NCC-NorESM1-M	r1i1p1	HadREM3-GA7-05	v1	2045	2066
MOHC-HadGEM2-ES	r1i1p1	ALADIN63	v1	2049	2065
CNRM-CERFACS-CNRM-CM5	r1i1p1	WRF381P	v2	2057	2070
MOHC-HadGEM2-ES	r1i1p1	WRF381P	v1	2052	2065
NCC-NorESM1-M	r1i1p1	WRF381P	v1	2052	2071
IPSL-IPSL-CM5A-MR	r1i1p1	WRF381P	v1	2058	2073
MPI-M-MPI-ESM-LR	r1i1p1	ALADIN63	v1	2052	2069
ICHEC-EC-EARTH	r12i1p1	WRF381P	v1	2057	2078
CNRM-CERFACS-CNRM-CM5	r1i1p1	ALADIN63	v2	2054	2071
MPI-M-MPI-ESM-LR	r1i1p1	WRF381P	v1	2059	2077
NCC-NorESM1-M	r1i1p1	ALADIN63	v1	2048	2068
MPI-M-MPI-ESM-LR	r2i1p1	RCA4	v1	2053	2068
NCC-NorESM1-M	r1i1p1	RCA4	v1	2047	2067
ICHEC-EC-EARTH	r3i1p1	RCA4	v1	2054	2075
ICHEC-EC-EARTH	r1i1p1	RCA4	v1	2050	2069
CNRM-CERFACS-CNRM-CM5	r1i1p1	RegCM4-6	v2	2057	2078
MPI-M-MPI-ESM-LR	r3i1p1	RCA4	v1	2054	2069
MPI-M-MPI-ESM-LR	r1i1p1	RCA4	v1a	2053	2069
MOHC-HadGEM2-ES	r1i1p1	RCA4	v1	2044	2055
IPSL-IPSL-CM5A-MR	r1i1p1	RCA4	v1	2051	2061
ICHEC-EC-EARTH	r12i1p1	RCA4	v1	2055	2070
CNRM-CERFACS-CNRM-CM5	r1i1p1	RCA4	v1	2057	2078
ICHEC-EC-EARTH	r12i1p1	RegCM4-6	v1	2058	2081
NCC-NorESM1-M	r1i1p1	RegCM4-6	v1	2052	2075
MPI-M-MPI-ESM-LR	r1i1p1	RegCM4-6	v1	2054	2071
MOHC-HadGEM2-ES	r1i1p1	RegCM4-6	v1	2049	2061

Table S3. Overview of projected year when HEF are gone (i.e. volume drops below 1% of the initial volume) or mostly gone (i.e. volume drops below 10% of the initial volume) of the 10 SSP 585 and SSP 126 ISIMIP3b GCM simulations utilized in this study. If a percentage value is given, the volume has not fallen below the corresponding threshold value in 2100 and the remaining glacier volume is given in comparison to 1997. The simulations marked in red are the ones with a future volume evolution that is closest to the multi-model median.

GCM	SSP 585		SSP 126	
	mostly gone	gone	mostly gone	gone
CANESM5	2040	2048	2039	2052
CNRM-CM6	2045	2053	2048	2073
CNRM-ESM2	2047	2064	2044	2086
EC-EARTH3	2032	2040	2036	2046
GFDL-ESM4	2051	2064	2047	1.85%
IPSL-CM6A	2044	2052	2047	2075
MIROC6	2043	2051	2037	2058
MPI-ESM1-2	2051	2061	2051	3.24%
MRI-ESM2-0	2036	2043	2041	2059
UKESM1	2033	2041	2035	2042

S2.2 Great Aletsch Glacier (GAG)

Table S4. Overview of projected year when GAG are gone (i.e. volume drops below 1% of the initial volume) or mostly gone (i.e. volume drops below 10% of the initial volume) of the 22 RCP 26 EURO-CORDEX RCM simulations utilized in this study. If a percentage value is given, the volume has not fallen below the corresponding threshold value in 2100 and the remaining glacier volume is given in comparison to 2011. The simulations marked in red are the ones with a future volume evolution that is closest to the multi-model median.

GCM	realization	RCM	version	RCP 26	
				mostly gone	gone
CNRM-CERFACS-CNRM-CM5	r1i1p1	ALADIN63	v2	26.18%	26.18%
MPI-M-MPI-ESM-LR	r1i1p1	RCA4	v1a	40.84%	40.84%
NCC-NorESM1-M	r1i1p1	RCA4	v1	31.3%	31.3%
NCC-NorESM1-M	r1i1p1	RegCM4-6	v1	32.92%	32.92%
MPI-M-MPI-ESM-LR	r1i1p1	RegCM4-6	v1	38.06%	38.06%
MOHC-HadGEM2-ES	r1i1p1	RCA4	v1	21.68%	21.68%
ICHEC-EC-EARTH	r12i1p1	RCA4	v1	35.18%	35.18%
MOHC-HadGEM2-ES	r1i1p1	RegCM4-6	v1	23.15%	23.15%
MOHC-HadGEM2-ES	r1i1p1	RACMO22E	v2	19.62%	19.62%
MPI-M-MPI-ESM-LR	r1i1p1	REMO2009	v1	36.83%	36.83%
MPI-M-MPI-ESM-LR	r2i1p1	REMO2009	v1	34.61%	34.61%
ICHEC-EC-EARTH	r12i1p1	RACMO22E	v1	37.05%	37.05%
ICHEC-EC-EARTH	r12i1p1	CCLM4-8-17	v1	43.41%	43.41%
IPSL-IPSL-CM5A-LR	r1i1p1	REMO2015	v1	16.21%	16.21%
NOAA-GFDL-GFDL-ESM2G	r1i1p1	REMO2015	v1	39.62%	39.62%
ICHEC-EC-EARTH	r3i1p1	HIRHAM5	v2	34.69%	34.69%
CNRM-CERFACS-CNRM-CM5	r1i1p1	RACMO22E	v2	30.2%	30.2%
NCC-NorESM1-M	r1i1p1	REMO2015	v1	26.4%	26.4%
CNRM-CERFACS-CNRM-CM5	r1i1p1	REMO2015	v2	24.03%	24.03%
MOHC-HadGEM2-ES	r1i1p1	HIRHAM5	v2	22.21%	22.21%
MPI-M-MPI-ESM-LR	r1i1p1	RACMO22E	v1	36.74%	36.74%
NCC-NorESM1-M	r1i1p1	RACMO22E	v1	31.74%	31.74%

Table S5. Overview of projected year when GAG are gone (i.e. volume drops below 1% of the initial volume) or mostly gone (i.e. volume drops below 10% of the initial volume) of the 65 RCP 85 EURO-CORDEX RCM simulations utilized in this study. If a percentage value is given, the volume has not fallen below the corresponding threshold value in 2100 and the remaining glacier volume is given in comparison to 2011. The simulations marked in red are the ones with a future volume evolution that is closest to the multi-model median.

GCM	realization	RCM	version	RCP 85	
				mostly gone	gone
ICHEC-EC-EARTH	r12i1p1	CCLM4-8-17	v1	2096	7.45%
MOHC-HadGEM2-ES	r1i1p1	CCLM4-8-17	v1	2080	2100
ICHEC-EC-EARTH	r1i1p1	RACMO22E	v1	2100	9.63%
CNRM-CERFACS-CNRM-CM5	r1i1p1	CCLM4-8-17	v1	2099	9.31%
MPI-M-MPI-ESM-LR	r1i1p1	CCLM4-8-17	v1	2096	7.75%
MOHC-HadGEM2-ES	r1i1p1	RACMO22E	v2	2089	4.43%
MPI-M-MPI-ESM-LR	r2i1p1	REMO2009	v1	2084	2.02%
MPI-M-MPI-ESM-LR	r1i1p1	REMO2009	v1	2088	3.25%
ICHEC-EC-EARTH	r12i1p1	RACMO22E	v1	2096	8.13%
ICHEC-EC-EARTH	r12i1p1	HIRHAM5	v1	13.08%	13.08%
CNRM-CERFACS-CNRM-CM5	r1i1p1	RACMO22E	v2	13.79%	13.79%
NCC-NorESM1-M	r1i1p1	REMO2015	v1	2084	2.14%
MPI-M-MPI-ESM-LR	r1i1p1	RACMO22E	v1	2099	9.64%
MOHC-HadGEM2-ES	r1i1p1	HIRHAM5	v2	10.02%	10.02%
ICHEC-EC-EARTH	r3i1p1	HIRHAM5	v2	12.99%	12.99%
NCC-NorESM1-M	r1i1p1	HIRHAM5	v3	11.46%	11.46%
ICHEC-EC-EARTH	r1i1p1	HIRHAM5	v1	14.21%	14.21%
ICHEC-EC-EARTH	r3i1p1	RACMO22E	v1	2097	8.59%
CNRM-CERFACS-CNRM-CM5	r1i1p1	HIRHAM5	v2	14.9%	14.9%
NCC-NorESM1-M	r1i1p1	RACMO22E	v1	14.9%	14.9%
MPI-M-MPI-ESM-LR	r3i1p1	REMO2015	v1	2087	3.05%
NCC-NorESM1-M	r1i1p1	COSMO-crCLIM-v1-1	v1	2089	4.54%
MPI-M-MPI-ESM-LR	r1i1p1	COSMO-crCLIM-v1-1	v1	2095	7.4%
MPI-M-MPI-ESM-LR	r1i1p1	HIRHAM5	v1	14.48%	14.48%
MPI-M-MPI-ESM-LR	r2i1p1	COSMO-crCLIM-v1-1	v1	2098	8.4%
MOHC-HadGEM2-ES	r1i1p1	COSMO-crCLIM-v1-1	v1	2083	1.49%
CNRM-CERFACS-CNRM-CM5	r1i1p1	REMO2015	v2	2090	4.42%
IPSL-IPSL-CM5A-MR	r1i1p1	REMO2015	v1	2076	2096
MPI-M-MPI-ESM-LR	r3i1p1	COSMO-crCLIM-v1-1	v1	2095	6.61%
IPSL-IPSL-CM5A-MR	r1i1p1	RACMO22E	v1	2089	4.31%
ICHEC-EC-EARTH	r12i1p1	COSMO-crCLIM-v1-1	v1	2093	6.02%

Table S5. Continuation of Tab. **??**

GCM	realization	RCM	version	RCP 85	
				mostly gone	gone
IPSL-IPSL-CM5A-MR	r1i1p1	HIRHAM5	v1	2099	9.19%
ICHEC-EC-EARTH	r1i1p1	COSMO-crCLIM-v1-1	v1	10.19%	10.19%
ICHEC-EC-EARTH	r3i1p1	COSMO-crCLIM-v1-1	v1	2094	6.34%
CNRM-CERFACS-CNRM-CM5	r1i1p1	COSMO-crCLIM-v1-1	v1	17.21%	17.21%
ICHEC-EC-EARTH	r12i1p1	HadREM3-GA7-05	v1	2086	2.39%
CNRM-CERFACS-CNRM-CM5	r1i1p1	HadREM3-GA7-05	v2	2083	2.2%
MOHC-HadGEM2-ES	r1i1p1	HadREM3-GA7-05	v1	2075	2095
MPI-M-MPI-ESM-LR	r1i1p1	HadREM3-GA7-05	v1	2084	1.93%
NCC-NorESM1-M	r1i1p1	HadREM3-GA7-05	v1	2081	1.46%
MOHC-HadGEM2-ES	r1i1p1	ALADIN63	v1	2084	1.97%
CNRM-CERFACS-CNRM-CM5	r1i1p1	WRF381P	v2	10.18%	10.18%
MOHC-HadGEM2-ES	r1i1p1	WRF381P	v1	2093	5.6%
NCC-NorESM1-M	r1i1p1	WRF381P	v1	2095	7.17%
IPSL-IPSL-CM5A-MR	r1i1p1	WRF381P	v1	12.13%	12.13%
MPI-M-MPI-ESM-LR	r1i1p1	ALADIN63	v1	2092	6.14%
ICHEC-EC-EARTH	r12i1p1	WRF381P	v1	2096	7.77%
CNRM-CERFACS-CNRM-CM5	r1i1p1	ALADIN63	v2	2095	6.89%
MPI-M-MPI-ESM-LR	r1i1p1	WRF381P	v1	2100	9.95%
NCC-NorESM1-M	r1i1p1	ALADIN63	v1	2087	3.33%
MPI-M-MPI-ESM-LR	r2i1p1	RCA4	v1	10.03%	10.03%
NCC-NorESM1-M	r1i1p1	RCA4	v1	11.12%	11.12%
ICHEC-EC-EARTH	r3i1p1	RCA4	v1	14.1%	14.1%
ICHEC-EC-EARTH	r1i1p1	RCA4	v1	15.71%	15.71%
CNRM-CERFACS-CNRM-CM5	r1i1p1	RegCM4-6	v2	2095	7.15%
MPI-M-MPI-ESM-LR	r3i1p1	RCA4	v1	11.18%	11.18%
MPI-M-MPI-ESM-LR	r1i1p1	RCA4	v1a	2099	9.09%
MOHC-HadGEM2-ES	r1i1p1	RCA4	v1	2089	3.59%
IPSL-IPSL-CM5A-MR	r1i1p1	RCA4	v1	2095	7.11%
ICHEC-EC-EARTH	r12i1p1	RCA4	v1	12.74%	12.74%
CNRM-CERFACS-CNRM-CM5	r1i1p1	RCA4	v1	17.04%	17.04%
ICHEC-EC-EARTH	r12i1p1	RegCM4-6	v1	2092	5.88%
NCC-NorESM1-M	r1i1p1	RegCM4-6	v1	2090	4.66%
MPI-M-MPI-ESM-LR	r1i1p1	RegCM4-6	v1	2092	6.1%
MOHC-HadGEM2-ES	r1i1p1	RegCM4-6	v1	2078	2097

Table S6. Overview of projected year when GAG are gone (i.e. volume drops below 1% of the initial volume) or mostly gone (i.e. volume drops below 10% of the initial volume) of the 10 SSP 585 and SSP 126 ISIMIP3b GCM simulations utilized in this study. If a percentage value is given, the volume has not fallen below the corresponding threshold value in 2100 and the remaining glacier volume is given in comparison to 2011. The simulations marked in red are the ones with a future volume evolution that is closest to the multi-model median.

GCM	SSP 585		SSP 126	
	mostly gone	gone	mostly gone	gone
CANESM5	2069	2084	10.28%	10.28%
CNRM-CM6	2077	2095	12%	12%
CNRM-ESM2	2080	2098	12.97%	12.97%
EC-EARTH3	2069	2086	12.62%	12.62%
GFDL-ESM4	2091	5.23%	25.9%	25.9%
IPSL-CM6A	2073	2089	14.68%	14.68%
MIROC6	2078	2096	15.41%	15.41%
MPI-ESM1-2	2092	4.31%	34.7%	34.7%
MRI-ESM2-0	2073	2096	14.33%	14.33%
UKESM1	2060	2075	2070	1.57%