SUPPORTING INFORMATION ***(SI Appendix)***

Climate extremes and predicted warming threaten Mediterranean Holocene firs forests refugia

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The purpose of this supplementary material is to provide information that is of less central importance to the paper and that cannot be included in the main body of the text because of space limitations. The Supplementary Information contains 9 tables and 9 figures. The sequence of the supplementary figures and tables follows the citation order in the main text.

Supplementary Tables

Table S1. Main characteristics of sampled sites (codes are as in *SI Appendix*, Fig. S1). Dbh: diameter at breast height. Number of trees and radii per site. Tree-ring width (TRW) was determined from cores taken at 1.3 m. Rbt: is the mean correlation between trees of indexed tree-ring width series; AC: is the first order autocorrelation, and MS: is the mean sensitivity considering the common 1930-2010 period. The EPS (expressed population signal) was > 0.85 for all sites in the 1950-2010 period (61).

Tree species	Site code	Site name	Country	Latitude (N)	Longitude (-W, +E)	Elevation (m a.s.l.)	Aspect	Slope	Dbh (cm)	Nº trees /radii	TRW ± SD (mm)	Rbt	AC	MS	Time span (years)
A. alba	ROSE	Rosello	Italy	42.50	14.57	1086	E	35	89.7	15/32	2.45 ± 0.55	0.30	0.09	0.15	1848–1998
	PESC	Pescopennataro	Italy	42.48	14.50	1370	E	28	67.1	15/35	1.61 ± 0.50	0.42	0.32	0.16	1823–1998
	IANN	Iannace (Pollino)	Italy	40.57	16.35	1400	N-W	20	92.0	14/31	1.38 ± 0.95	0.21	0.13	0.18	1720–1998
	CUGN	Cugno dell'Acero (Pollino)	Italy	40.57	16.37	1350	N-W	25	76.6	16/35	1.29 ± 0.59	0.34	0.08	0.17	1703–1998
	PANT	Pantano (Pollino)	Italy	40.57	16.40	1500	N-E	25	111.8	16/34	1.39 ± 0.80	0.29	0.22	0.14	1697–1998
	GARA	Gariglione	Italy	39.20	17.07	1680	S-E	28	83.4	13/27	1.59 ± 0.82	0.31	0.23	0.15	1719–1999
	GUAR	Guara	Spain	42.30	-0.12	1428	N-NW	47	52.5	23/46	3.11 ± 0.79	0.48	0.09	0.20	1887–2011
	PORH	Peña Oroel-High	Spain	42.52	-0.32	1604	N-NW	36	59.1	12/24	2.57 ± 0.79	0.71	0.78	0.20	1892–2000
	PORL	Peña Oroel-Low	Spain	42.52	-0.32	1587	N	24	46.5	23/46	2.41 ± 0.70	0.67	0.76	0.18	1889–2000
	SJPE	San Juan de la Peña	Spain	42.52	-0.41	1393	N-NE	22	46.0	14/28	2.37 ± 0.49	0.57	0.85	0.23	1855–1999
	BOUM	Boumort	Spain	42.20	1.20	1583	NE	35	64.2	17/40	1.79 ± 1.24	0.36	0.16	0.22	1804–2002
	MONT	Montseny	Spain	41.77	2.43	1550	SW	22	68.0	21/50	1.22 ± 0.78	0.37	0.26	0.17	1587–2010
A. borisii-regis	ABRH	Bredhi i Hotovës High	Albania	40.34	20.38	1361	NW	25	46.3	22/31	2.30 ± 1.03	0.26	0.77	0.22	1900–2010
	ABRM	Bredhi i Hotovës Middle	Albania	40.35	20.39	1144	SE	22	45.4	36/54	2.43 ± 1.26	0.3	0.76	0.26	1874–2010
	ABRL	Bredhi i Hotovës Low	Albania	40.35	20.38	1058	N	19	39.1	18/28	1.83 ± 0.68	0.31	0.72	0.2	1893–2010
	KARP1	Karpenissi (Evrytania)	Greece	38.88	21.86	1120	E	48	47.0	12/23	1.85 ± 0.85	0.61	0.73	0.19	1890–2012
	PERT	Pertouli (Trikala)	Greece	39.55	21.47	1270	E-SE	23	49.0	12/21	2.46 ± 0.34	0.57	0.75	0.19	1880-2013
A. cephalonica	AINO	Ainos Mountain	Greece	38.14	20.67	1450	NE	35	68.4	23/54	1.07 ± 0.66	0.54	0.68	0.23	1769-2007
	KARP2	Karpenissi (Evrytania)	Greece	38.87	21.86	1260	NE	35	45.3	15/25	1.47 ± 0.37	0.44	0.80	0.19	1857–2013
	PARN	Parnitha (Attica)	Greece	38.17	23.74	1223	E	30	44.0	12/19	1.46 ± 0.24	0.49	0.77	0.21	1868–2012
A. cilicica	leb2*	Wadi Balat	Lebanon	34.47	36.23	1175	NW	-	34.3	16/19	1.15 ± 0.33	0.46	0.82	0.25	1722-2001
	syr2*	Bedayat Al Khandak Al Tawil	Syria	35.57	36.20	1450	W	-	23.9	33/35	0.79 ± 0.26	0.52	0.77	0.32	1795-2001
	tu24*	Gazipasa Forest, Antalya	Turkey	36.45	32.52	1770	SW	-	49.1	7/7	1.59 ± 0.41	0.50	0.83	0.22	1797-2003
	DEAC	Derebukak	Turkey	37.32	31.46	1600	SO	-	30.1	6/10	2.48 ± 0.72	0.59	0.79	0.23	1869-2009
	IBAC	Ibradi Civarinda	Turkey	37.21	31.49	1500	SO	-	28.5	5/10	2.28 ± 0.61	0.56	0.62	0.22	1943-2009
A. pinsapo	APSB	Sierra Bermeja	Spain	36.48	-5.21	1300	N	40	37.3	23/26	1.17 ± 0.43	0.57	0.76	0.30	1795-2014
	APSG	Sierra de Grazalema	Spain	36.77	-5.42	1275	N	33	32.1	64/85	2.25 ± 0.59	0.50	0.70	0.26	1764-2015
	APSN	Sierra de las Nieves	Spain	36.72	-5.10	1350	N-NE	27	31.8	69/97	1.65 ± 0.97	0.52	0.81	0.24	1710-2015
A. maroccana	ABMC	Talassemtane	Morocco	35.13	-5.12	1600	NO	27	29.5	14/23	1.45 ± 0.19	0.42	0.73	0.22	1798-2006
A. tazaotana	ABTZ	Tazaot	Morocco	35.23	-5.08	1685	NE	31	45.1	14/18	2.91 ± 0.73	0.48	0.82	0.23	1689-2009

* ITRDB database chronologies (https://www.ncdc.noaa.gov/data-access/paleoclimatology-data)

Table S2. Modelled percentage change in average tree-ring width (TRWi) for projected climate change trends ($TRWi_p$) considering the ensemble IPCC AR5 emission scenarios (RCP 4.5 and RCP 8.5). Values are calculated such as the projected 2011-2049 and 2050-2100 annual mean minus measured 1950–2010 annual mean. Trends (τ, Pearson correlation coefficient) of site mean tree-ring width indices series considering the 2011–2100 period following growth projections based on two IPCC AR5 emission scenarios (see Fig. 4 and *SI Appendix* Fig. S8).

		2011-2049		2050-2100		2011-2100	
		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	Trend (τ Pearson)	
Tree species	Site code	Mean	Mean	Mean	Mean	RCP 4.5	RCP 8.5
A. alba	ROSE	2.4	42.6	-5.2	68.1	-0.15	0.85
	PESC	7.1	37.4	-7.2	61.0	-0.34	0.58
	IANN	-5.6	-7.8	-8.7	-19.3	-0.25	-0.79
	CUGN	-9.1	-13.3	-17.9	-35.6	-0.23	-0.71
	PANT	-2.3	-10.6	-11.2	-13.3	-0.44	-0.63
	GARA	-3.2	-4.9	-6.5	-7.5	0.12	-0.26
	GUAR	-3.9	-5.8	-14.4	-18.7	-0.33	-0.77
	PORH	-18.8	-8.3	-35.2	-42.3	-0.73	-0.93
	PORL	-12.1	-10.4	-18.8	-32.7	-0.50	-0.83
	SJPE	-31.6	-5.8	-68.2	-59.4	-0.81	-0.92
	BOUM	3.7	-2.6	34.4	35.7	0.78	0.85
	MONT	45.9	35.1	65.4	59.8	0.91	0.91
A. borisii-regis	ABRH	18.9	15.2	27.1	30.1	0.62	0.85
	ABRM	-9.3	-8.7	-14.6	-41.8	-0.62	-0.97
	ABRL	-10.9	-6.8	-38.1	-21.6	-0.83	-0.87
	KARP1	-2.5	-3.2	-6.8	-8.7	-0.33	-0.51
	PERT	-9.8	-7.8	-48.3	-58.6	-0.77	-0.92
A. cephalonica	AINO	-1.3	3.2	-10.8	-11.5	-0.27	-0.58
	KARP2	-7.8	-7.5	-24.7	-33.3	-0.69	-0.87
	PARN	13.9	7.4	4.8	5.2	-0.30	0.10
A. cilicica	leb2	-9.3	-11.3	-36.9	-38.2	-0.79	-0.90
	syr2	-7.8	6.3	-16.1	-21.3	-0.29	-0.75
	tu24	12.5	15.1	32.1	35.4	0.55	0.80
	DEAC	30.6	20.4	53.1	49.8	0.79	0.88
	IBAC	4.5	6.8	6.7	6.9	0.11	0.07
A. pinsapo	APSB	15.2	14.5	68.3	47.3	0.68	0.79
	APSG	2.2	15.1	-5.7	-10.6	-0.41	-0.77
	APSN	8.2	14.2	17.3	14.7	0.17	-0.10
A. maroccana	ABMC	-3.6	-1.6	-12.2	-16.5	-0.53	-0.84
A. tazaotana	ABTZ	-9.6	-10.1	-25.7	-30.0	-0.64	-0.86

Table S3. Pearson correlation coefficients calculated between observed site series of tree-ring width indices (TRWi) and VS-Lite indices ($TRWi_{VSL}$) for the calibration period (1950-2010); and for the sub-periods 1950–1980 and 1980–2010 (see *SI Appendix*, Fig. S6), also considering projected site series of tree-ring width indices ($TRWi_p$) and VS-Lite future indices ($TRWi_{p\text{-}VSL}$) for the periods 2010-2050 and 2050-2100 and two IPCC AR5 emission scenarios (RCP 4.5 and RCP 8.5). Correlation values higher than 0.25 are significant at $P < 0.05$.

					IPCC emission scenarios			
		Period			RCP 4.5		RCP 8.5	
Tree species	Site code	1950-1980	1980-2010	1950-2010	2010-2050	2050-2100	2010-2050	2050-2100
A. alba	ROSE	0.41	0.33	0.36	0.34	0.52	0.69	0.68
	PESC	0.33	0.22	0.28	0.27	0.36	0.29	0.30
	IANN	0.45	0.51	0.42	0.46	0.38	0.57	0.70
	CUGN	0.47	0.30	0.31	0.35	0.34	0.42	0.44
	PANT	0.35	0.24	0.26	0.24	0.25	0.34	0.54
	GARA	0.41	0.48	0.39	0.38	0.55	0.49	0.34
	GUAR	0.59	0.62	0.67	0.47	0.40	0.50	0.59
	PORH	0.45	0.32	0.34	0.33	0.41	0.53	0.85
	PORL	0.49	0.38	0.44	0.43	0.33	0.55	0.64
	SJPE	0.52	0.38	0.44	0.44	0.50	0.62	0.86
	BOUM	0.41	0.53	0.40	0.65	0.59	0.58	0.65
	MONT	0.55	0.41	0.44	0.82	0.77	0.87	0.90
A. borisii-regis	ABRH	0.40	0.32	0.31	0.41	0.35	0.63	0.69
	ABRM	0.43	0.35	0.41	0.63	0.58	0.61	0.79
	ABRL	0.41	0.34	0.39	0.57	0.41	0.85	0.59
	KARP1	0.36	0.37	0.38	0.29	0.43	0.40	0.45
	PERT	0.33	0.42	0.28	0.45	0.49	0.58	0.89
A. cephalonica	AINO	0.18	0.15	0.26	0.25	0.36	0.34	0.44
	KARP2	0.31	0.32	0.36	0.24	0.56	0.38	0.67
	PARN	0.28	0.38	0.24	0.26	0.24	0.31	0.33
A. cilicica	leb2	0.55	0.47	0.51	0.79	0.39	0.77	0.82
	syr2	0.20	0.15	0.19	0.29	0.29	0.34	0.72
	tu24	0.37	0.27	0.30	0.50	0.40	0.63	0.74
	DEAC	0.48	0.49	0.43	0.74	0.58	0.73	0.34
	IBAC	0.45	0.31	0.36	0.28	0.37	0.34	0.29
A. pinsapo	APSB	0.37	0.37	0.37	0.27	0.25	0.36	0.51
	APSG	0.45	0.47	0.44	0.43	0.24	0.49	0.59
	APSN	0.38	0.52	0.46	0.29	0.26	0.42	0.35
A. maroccana	ABMC	0.49	0.35	0.38	0.35	0.37	0.71	0.82
A. tazaotana	ABTZ	0.47	0.41	0.41	0.64	0.42	0.80	0.81

Table S4. Statistics of the Bayesian estimation of VS-Lite growth response parameters (1950-2010). Statistics of the Bayesian estimation of the site-by-site tuned VS-Lite growth response parameters (T_1, T_2, M_1, and M_2) for the period 1950-2010 and two sub-periods (1950-1980 and 1980-2010).

Tree species	Parameter (unit)	1950-2010				1950-1980				1980-2010			
		Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	SD
Abies alba-Italy	T_1 (ºC)	7.893	6.950	8.323	0.495	8.254	8.032	8.638	0.206	7.294	6.758	8.193	0.575
	T_2 (ºC)	12.839	11.179	13.811	0.995	12.986	11.130	15.292	1.381	12.659	10.453	15.613	2.033
	M_1 (v/v)	0.024	0.001	0.083	0.030	0.025	0.007	0.068	0.022	0.034	0.002	0.064	0.024
	M_2 (v/v)	0.163	0.102	0.319	0.085	0.184	0.150	0.210	0.026	0.127	0.100	0.178	0.030
Abies alba-Spain	T_1 (ºC)	2.573	1.589	5.707	1.564	4.284	2.358	8.246	2.097	3.111	1.696	6.548	1.938
	T_2 (ºC)	13.843	10.840	23.020	4.693	13.443	10.650	18.449	3.187	12.993	10.455	17.033	2.797
	M_1 (v/v)	0.057	0.020	0.090	0.031	0.031	0.001	0.071	0.028	0.040	0.026	0.055	0.011
	M_2 (v/v)	0.375	0.261	0.469	0.091	0.368	0.267	0.482	0.080	0.387	0.260	0.483	0.081
Abies borisii-regis	T_1 (ºC)	3.932	2.911	6.963	1.711	3.378	2.100	5.715	1.371	5.381	3.074	7.891	2.175
	T_2 (ºC)	12.225	10.585	14.023	1.461	12.568	11.007	14.420	1.245	11.697	10.917	12.890	0.814
	M_1 (v/v)	0.036	0.003	0.081	0.034	0.040	0.006	0.088	0.030	0.060	0.025	0.087	0.025
	M_2 (v/v)	0.389	0.177	0.489	0.122	0.395	0.190	0.487	0.119	0.341	0.164	0.470	0.148
Abies cephalonica	T_1 (ºC)	7.340	5.438	8.563	1.669	7.285	5.157	8.570	1.856	8.181	8.058	8.406	0.195
	T_2 (ºC)	13.014	11.238	14.822	1.792	12.300	10.570	15.488	2.764	13.958	11.000	18.012	3.632
	M_1 (v/v)	0.035	0.008	0.079	0.038	0.025	0.005	0.048	0.022	0.054	0.053	0.055	0.001
	M_2 (v/v)	0.135	0.109	0.177	0.037	0.144	0.113	0.199	0.048	0.163	0.106	0.195	0.050

Table S4. continued

Tree species	Parameter (unit)	1950-2010				1950-1980				1980-2010			
		Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	SD
Abies cilicica	T_1 (ºC)	7.183	6.020	8.390	1.068	7.714	5.600	8.600	1.225	6.803	5.600	8.215	1.131
	T_2 (ºC)	13.209	11.079	17.847	2.699	14.790	10.530	18.680	3.551	15.088	10.566	23.404	5.661
	M_1 (v/v)	0.033	0.006	0.053	0.021	0.049	0.002	0.093	0.038	0.041	0.003	0.073	0.030
	M_2 (v/v)	0.296	0.145	0.427	0.121	0.249	0.140	0.356	0.077	0.312	0.102	0.458	0.174
Abies pinsapo	T_1 (ºC)	4.724	3.974	5.868	1.006	6.221	3.002	7.922	2.789	3.411	3.163	3.742	0.299
	T_2 (ºC)	13.136	11.144	14.398	1.746	15.358	12.549	18.562	3.026	13.387	11.525	15.491	1.994
	M_1 (v/v)	0.055	0.002	0.093	0.047	0.038	0.001	0.075	0.037	0.090	0.086	0.092	0.003
	M_2 (v/v)	0.153	0.104	0.227	0.065	0.351	0.263	0.408	0.077	0.121	0.102	0.132	0.017
Abies maroccana	T_1 (ºC)	8.005	-	-	-	4.861	-	-	-	8.666	-	-	-
	T_2 (ºC)	11.506	-	-	-	11.292	-	-	-	17.264	-	-	-
	M_1 (v/v)	0.014	-	-	-	0.077	-	-	-	0.020	-	-	-
	M_2 (v/v)	0.216	-	-	-	0.127	-	-	-	0.454	-	-	-
Abies tazaotana	T_1 (ºC)	7.320	-	-	-	6.104	-	-	-	7.323	-	-	-
	T_2 (ºC)	12.394	-	-	-	13.017	-	-	-	13.123	-	-	-
	M_1 (v/v)	0.007	-	-	-	0.010	-	-	-	0.032	-	-	-
	M_2 (v/v)	0.136	-	-	-	0.205	-	-	-	0.100	-	-	-

Table S5. Climatic characteristics of sampled sites. Climatic characteristics (mean ± SD) and trends (τ, Pearson correlation coefficient) obtained for the studied *Abies* species considering annual and seasonal mean temperatures (T) and total precipitation (P). Data were obtained using the homogenized and quality-checked CRU TS 3.23 meteorological dataset gridded at a 0.5º spatial resolution for the period 1950–2010 (60).

		Mean Annual				Mean winter				Mean spring			
Tree species	Site code	T (ºC)	*Trend* (T)	P (mm)	*Trend* (P)	T (ºC)	*Trend* (T)	P (mm)	*Trend* (P)	T (ºC)	*Trend* (T)	P (mm)	*Trend* (P)
A. alba	ROSE	15.1 ± 0.5	0.48	719 ± 144	-0.11	7.4 ± 0.8	0.10	211 ± 76	-0.18	13.4 ± 0.8	0.36	174 ± 64	0.12
	PESC	13.3 ± 0.5	0.51	754 ± 145	-0.10	5.7 ± 0.8	0.15	212 ± 77	-0.17	11.6 ± 0.7	0.37	173 ± 65	0.11
	IANN	13.9 ± 0.5	0.51	665 ± 140	-0.01	6.6 ± 0.8	0.10	207 ± 66	-0.03	11.9 ± 0.8	0.41	153 ± 54	0.05
	CUGN	13.8 ± 0.5	0.51	665 ± 140	-0.01	6.7 ± 0.7	0.10	207 ± 66	-0.03	11.9 ± 0.7	0.41	153 ± 54	0.05
	PANT	13.8 ± 0.5	0.51	665 ± 140	-0.01	6.7 ± 0.7	0.10	207 ± 66	-0.03	11.9 ± 0.7	0.41	153 ± 54	0.05
	GARA	17.0 ± 0.5	0.57	763 ± 170	0.24	10.3 ± 0.7	0.16	282 ± 101	0.11	14.8 ± 0.7	0.49	157 ± 64	0.24
	GUAR	10.9 ± 0.7	0.68	722 ± 159	-0.18	3.2 ± 1.1	0.37	160 ± 77	-0.06	9.5 ± 0.9	0.41	210 ± 84	-0.04
	PORH	6.6 ± 0.7	0.70	1029 ± 191	-0.19	-0.7 ± 1.1	0.37	247 ± 102	-0.10	4.9 ± 0.9	0.46	292 ± 103	0.01
	PORL	6.6 ± 0.7	0.70	1029 ± 191	-0.19	-0.7 ± 1.1	0.37	247 ± 102	-0.10	4.9 ± 0.9	0.46	292 ± 103	0.01
	SJPE	6.6 ± 0.7	0.70	1029 ± 191	-0.19	-0.7 ± 1.1	0.37	247 ± 102	-0.10	4.9 ± 0.9	0.46	292 ± 103	0.01
	BOUM	9.4 ± 0.6	0.65	832 ± 171	-0.22	2.3 ± 1.0	0.32	166 ± 89	-0.08	7.8 ± 0.8	0.40	233 ± 69	-0.01
	MONT	13.4 ± 0.5	0.53	692 ± 170	-0.19	7.1 ± 0.9	0.24	133 ± 76	0.06	11.4 ± 0.8	0.28	189 ± 81	-0.08
A. borisii-regis	ABRH	10.0 ± 0.5	0.30	1061 ± 182	-0.31	1.7 ± 0.8	-0.02	379 ± 126	-0.32	8.7 ± 0.7	0.33	242 ± 72	-0.14
	ABRM	10.0 ± 0.5	0.30	1061 ± 182	-0.31	1.7 ± 0.8	-0.02	379 ± 126	-0.32	8.7 ± 0.7	0.33	242 ± 72	-0.14
	ABRL	10.0 ± 0.5	0.30	1061 ± 182	-0.31	1.7 ± 0.8	-0.02	379 ± 126	-0.32	8.7 ± 0.7	0.33	242 ± 72	-0.14
	KARP1	12.1 ± 0.5	0.34	770 ± 141	-0.19	4.1 ± 0.7	-0.07	292 ± 96	-0.17	10.4 ± 0.8	0.34	175 ± 53	-0.09
	PERT	10.7 ± 0.5	0.30	871 ± 153	-0.30	2.1 ± 0.9	-0.05	299 ± 102	-0.22	9.4 ± 0.8	0.34	207 ± 59	-0.09
A. cephalonica	AINO	15.9 ± 0.5	-0.12	688 ± 125	-0.10	8.9 ± 0.8	-0.44	283 ± 84	-0.06	13.8 ± 0.7	0.01	143 ± 43	0.02
	KARP2	12.1 ± 0.5	0.34	770 ± 141	-0.19	4.1 ± 0.7	-0.07	292 ± 96	-0.17	10.4 ± 0.8	0.34	175 ± 53	-0.09
	PARN	16.2 ± 0.6	0.40	529 ± 118	-0.05	8.5 ± 0.9	-0.03	224 ± 86	0.01	14.0 ± 0.9	0.36	113 ± 47	-0.07
A. cilicica	leb2	11.8 ± 0.7	0.34	647 ± 171	-0.20	2.9 ± 1.2	0.02	367 ± 123	-0.25	10.3 ± 0.9	0.22	160 ± 65	-0.16
	syr2	17.2 ± 0.6	0.25	712 ± 149	-0.11	8.1 ± 1.2	-0.02	369 ± 114	-0.18	15.7 ± 0.8	0.22	178 ± 72	-0.10
	tu24	13.0 ± 0.6	0.14	681 ± 145	-0.11	4.0 ± 1.0	-0.12	363 ± 126	-0.09	11.4 ± 0.8	0.13	155 ± 61	-0.20
	DEAC	11.5 ± 0.6	0.06	643 ± 139	0.02	2.1 ± 1.2	-0.19	314 ± 111	-0.12	10.1 ± 0.9	0.06	163 ± 58	0.01
	IBAC	11.5 ± 0.6	0.06	643 ± 139	0.02	2.1 ± 1.2	-0.19	314 ± 111	-0.12	10.1 ± 0.9	0.06	163 ± 58	0.01
A. pinsapo	APSB	17.7 ± 0.4	0.43	628 ± 231	0.03	12.6 ± 0.7	0.39	283 ± 163	0.04	15.9 ± 0.7	0.22	157 ± 75	-0.17
	APSG	15.7 ± 0.5	0.56	612 ± 202	-0.04	9.5 ± 0.7	0.41	257 ± 149	-0.12	13.9 ± 0.7	0.34	165 ± 72	-0.29
	APSN	15.7 ± 0.5	0.56	612 ± 202	-0.04	9.5 ± 0.7	0.41	257 ± 149	-0.12	13.9 ± 0.7	0.34	165 ± 72	-0.29
A. maroccana	ABMC	15.1 ± 0.4	0.37	638 ± 204	-0.01	9.5 ± 0.7	0.23	276 ± 142	-0.06	13.1 ± 0.7	0.21	170 ± 76	-0.18
A. tazaotana	ABTZ	15.1 ± 0.4	0.37	638 ± 204	-0.01	9.5 ± 0.7	0.23	276 ± 142	-0.06	13.1 ± 0.7	0.21	170 ± 76	-0.18

Table S5. Continued

Tree species	Site code	Mean summer T (ºC)	Mean summer *Trend* (T)	Mean summer P (mm)	Mean summer *Trend (P)*	Mean autumn T (ºC)	Mean autumn *Trend* (T)	Mean autumn P (mm)	Mean autumn *Trend* (P)
A. alba	ROSE	23.2 ± 0.9	0.43	113 ± 55	-0.01	16.2 ± 0.8	0.22	221 ± 73	-0.10
	PESC	21.4 ± 0.9	0.45	126 ± 61	-0.03	14.5 ± 0.8	0.25	242 ± 86	-0.05
	IANN	21.8 ± 0.9	0.48	82 ± 42	0.04	15.1 ± 0.7	0.23	224 ± 83	-0.01
	CUGN	21.8 ± 0.9	0.48	82 ± 42	0.04	15.7 ± 0.8	0.23	224 ± 83	-0.01
	PANT	21.8 ± 0.9	0.48	82 ± 42	0.04	15.7 ± 0.8	0.23	224 ± 83	-0.01
	GARA	24.5 ± 0.8	0.51	50 ± 34	0.05	18.4 ± 0.7	0.30	274 ± 121	0.13
	GUAR	19.4 ± 1.0	0.66	159 ± 67	-0.28	11.8 ± 0.8	0.47	192 ± 91	0.01
	PORH	14.7 ± 1.1	0.67	227 ± 86	-0.32	7.7 ± 0.8	0.50	263 ± 108	0.03
	PORL	14.7 ± 1.1	0.67	227 ± 86	-0.32	7.7 ± 0.8	0.50	263 ± 108	0.03
	SJPE	14.7 ± 1.1	0.67	227 ± 86	-0.32	7.7 ± 0.8	0.50	263 ± 108	0.03
	BOUM	17.3 ± 1.0	0.57	209 ± 78	-0.34	10.4 ± 0.8	0.46	224 ± 80	0.01
	MONT	20.7 ± 0.9	0.45	161 ± 66	-0.23	14.5 ± 0.7	0.38	209 ± 86	-0.17
A. borisii-regis	ABRH	18.7 ± 0.9	0.30	119 ± 72	0.14	11.0 ± 0.8	0.09	320 ± 96	-0.14
	ABRM	18.7 ± 0.9	0.30	119 ± 72	0.14	11.0 ± 0.8	0.09	320 ± 96	-0.14
	ABRL	18.7 ± 0.9	0.30	119 ± 72	0.14	11.0 ± 0.8	0.09	320 ± 96	-0.14
	KARP1	20.8 ± 0.9	0.43	66 ± 39	0.03	13.2 ± 0.7	0.14	238 ± 81	-0.05
	PERT	19.7 ± 0.9	0.33	106 ± 56	0.05	11.6 ± 0.8	0.10	258 ± 83	-0.22
A. cephalonica	AINO	23.8 ± 0.8	0.35	36 ± 26	0.20	17.3 ± 0.7	-0.26	226 ± 77	-0.14
	KARP2	20.8 ± 0.9	0.43	66 ± 39	0.03	13.2 ± 0.7	0.14	238 ± 81	-0.05
	PARN	24.9 ± 1.0	0.51	30 ± 24	-0.03	17.3 ± 0.9	0.20	172 ± 78	0.01
A. cilicica	leb2	19.8 ± 0.8	0.46	4 ± 8	0.02	14.1 ± 0.8	0.31	117 ± 56	0.09
	syr2	25.5 ± 0.7	0.38	18 ± 22	0.06	19.4 ± 0.9	0.19	147 ± 57	0.14
	tu24	22.2 ± 0.7	0.37	29 ± 24	0.15	14.6 ± 0.9	0.08	133 ± 68	0.01
	DEAC	21.0 ± 0.7	0.37	41 ± 27	0.03	12.9 ± 0.9	0.02	127 ± 63	0.18
	IBAC	21.0 ± 0.7	0.37	41 ± 27	0.03	12.9 ± 0.9	0.02	127 ± 63	0.18
A. pinsapo	APSB	23.2 ± 0.6	0.40	17 ± 16	-0.10	18.9 ± 0.7	0.15	169 ± 95	0.10
	APSG	22.7 ± 0.7	0.53	26 ± 22	-0.19	16.9 ± 0.8	0.24	161 ± 83	0.09
	APSN	22.7 ± 0.7	0.53	26 ± 22	-0.19	16.9 ± 0.8	0.24	161 ± 83	0.09
A. maroccana	ABMC	21.5 ± 0.6	0.35	27 ± 23	-0.04	16.4 ± 0.7	0.11	165 ± 82	0.23
A. tazaotana	ABTZ	21.5 ± 0.6	0.35	27 ± 23	-0.04	16.4 ± 0.7	0.11	165 ± 82	0.23

Table S6. Summary of the Generalized Least Squares regressions model. We used it to forecast site chronologies of tree-ring width indices ($TRWi_p$). Abbreviations: wi, winter; au, autumn; sp, spring; su, summer. Numbers after climate variables indicate months, whereas the subscript "p" indicates the previous year.

Tree species	Site code	R^2 (adj)	Equation
A. alba	ROSE	0.74	$1.29-0.05t_{1}+0.03t_{3}-0.03t_{6}-0.04t_{10p}+0.09p_{wi}+0.04p_{sp}+0.15_{e9}+0.24_{e27}+0.05_{e21p}$
	PESC	0.84	$1.26-0.07t_{1}-0.02t_{10p}-0.15p_{wi}-0.08p_{sp}+0.03p_{sup}+0.04p_{aup}-0.14_{e1}-0.09_{e5}-0.13_{e21}+0.19_{e27}+0.06_{e16p}+0.04_{e24p}$
	IANN	0.70	$0.99-0.05t_{10}+0.07t_{sp}-0.04t_{10p}+0.07p_{5}+0.05p_{su}-0.04_{e17}+0.06_{e25}+0.09_{e24p}$
	CUGN	0.73	$0.95+0.05t_{4}-0.05t_{8}-0.05t_{9p}-0.10p_{1}+0.05p_{5}-0.07_{e5}-0.22_{e8}+0.23_{e22}+0.06_{e24}+0.36_{e9p}+0.21_{e24p}$
	PANT	0.75	$0.97-0.04t_{10}-0.06t_{10p}-0.02p_{2}+0.05p_{sup}-0.08_{e3p}+0.07_{e5p}-0.05_{e15p}+0.10_{e24p}$
	GARA	0.77	$1.00+0.03t_{3}-0.03p_{1}-0.04p_{10}-0.03_{e3}-0.02_{e16}-0.04_{e17}+0.10_{e26}-0.03_{e18p}+0.06_{e20p}$
	GUAR	0.88	$0.94-0.04t_{1}+0.07t_{2}+0.03_{t5}+0.03t_{11p}-0.03p_{9}+0.06_{pau}+0.10_{e8}-0.12_{e16}+0.04_{e18p}+0.05_{e25p}$
	PORH	0.69	$0.92-0.07t_{1}+0.06t_{2}+0.02t_{3}-0.08t_{10}+0.08t_{11p}-0.05t_{aup}+0.06p_{4}+0.03p_{su}-0.11_{e8p}+0.01_{e18p}$
	PORL	0.55	$0.95\ -0.04t_{1}+0.06t_{2}+0.03t_{7}-0.02t_{8}-0.02t_{9p}-0.06t_{aup}+0.04p_{6}-0.09_{e5}+0.04_{e18}+0.01_{e21p}$
	SJPE	0.56	$0.66+0.05t_{2}+0.03t_{5}+0.04t_{11p}-0.06t_{aup}+0.05p_{su}-0.30_{e2}+0.22_{e6}-0.85_{e14}-0.13_{e23}-0.31_{e3p}-0.09_{e8p}$
	BOUM	0.73	$1.09+0.03t_{6}-0.03t_{10}+0.08t_{sp}-0.04t_{9p}+0.02p_{8}+0.01p_{aup}-0.92_{e2}+1.16_{e13}-0.11_{e23}-0.29_{e8p}+0.06_{e17p}$
	MONT	0.64	$1.36+0.04t_{4}-0.02t_{sp}-0.01t_{9p}+0.03t_{12p}+0.06p_{2}-0.03p_{10}+0.03p_{sup}-0.07_{e2}+0.97_{e13}+0.14_{e15}-0.34_{e6p}$
A. borisii-regis	ABRH	0.48	$1.09+0.03t_{4}-0.02t_{9}-0.04t_{su}-0.03t_{9p}+0.02p_{7}+0.17_{e7p}-0.05_{e18p}+0.03_{e21p}$
	ABRM	0.32	$0.91+0.09p_{su}+0.02p_{11p}+0.03p_{sup}-0.13_{e7}$
	ABRL	0.57	$0.97-0.02t_{10}+0.06t_{12p}-0.07t_{aup}+0.04p_{5}+0.04p_{7}-0.02_{e16}-0.05_{e23}+0.17_{e8p}-0.18_{e15p}-0.05_{e18p}+0.07_{e24p}$
	KARP1	0.33	$0.98-0.03p_{4}+0.05p_{6}-0.03_{e19}+0.01_{e25p}$
	PERT	0.76	$0.89+0.03t_{3}-0.04t_{10p}+0.07p_{5}+0.05p_{su}+0.03p_{9p}-0.43_{e9}-0.04_{e16}-0.52_{e2p}-0.08_{e5p}-0.26_{e10p}-0.08_{e23p}$
A. cephalonica	AINO	0.81	$0.98-0.04t_{wi}-0.06p_{3}+0.04p_{6}-0.02p_{sup}-0.05_{e3}+0.03_{e5}-0.14_{e17}+0.18_{e26}-0.07_{e16p}-0.04_{e17p}+0.09_{e23p}+0.11_{e27p}$
	KARP2	0.52	$0.92\ +0.02t_{9}-0.02p_{4}+0.06p_{6}-0.16_{e9}+0.04_{e18}-0.08_{e19}-0.08_{e11p}-0.02_{e15p}+0.04_{e24p}$
	PARN	0.77	$1.06-0.05t_{6}-0.02t_{11p}+0.02p_{2}+0.02p_{6}-0.02p_{12p}-0.47_{e13}-0.09_{e20}+0.05_{e24}+0.08_{e26}+0.42_{e2p}-0.14_{e5p}+0.08_{e24p}$
A. cilicica	leb2	0.85	$0.92-0.02t_{3}+0.04t_{7}-0.06t_{wi}+0.03p_{sp}-0.13p_{11p}+0.10p_{aup}-0.12_{e16}+0.04_{e20}+0.07_{e24}-0.05_{e15p}$
	syr2	0.57	$0.92-0.07p_{10}-0.02p_{12p}+0.18_{e5}-0.55_{e6}+0.01_{e21}+0.04_{e25}+0.10_{e27}-0.27_{e15p}$
	tu24	0.62	$1.10+0.03t_{4}-0.04t_{aup}+0.05p_{8}+0.01p_{au}-0.06p_{11p}-0.18_{e1}-0.07_{e3}-0.07_{e19}-0.09_{e24}+0.13_{e26}+0.17_{e7p}$
	DEAC	0.65	$1.18-0.04t_{9p}+0.08t_{12p}+0.08p_{1}+0.06p_{5}-0.08_{e16}-0.07_{e18}+0.05_{e19}-0.07_{e5p}-0.47_{e14p}-0.11_{e23p}$
	IBAC	0.60	$1.03+0.05t_{4}-0.05t_{9p}+0.06p_{5}+0.04p_{7}+0.08_{e26}+0.16_{e27}-0.24_{e22p}+0.12_{e24p}$
A. pinsapo	APSB	0.54	$1.23-0.04t_{5}-0.06t_{6}+0.06p_{7}-0.05p_{8}+0.06p_{10p}-0.22_{e23}+0.73_{e14p}+0.19_{e18p}-0.11_{e19p}-0.13_{e23p}$
	APSG	0.89	$1.02-0.03t_{5}-0.03t_{8}-0.02t_{11p}+0.03p_{4}+0.04p_{aup}-0.43_{e2}-0.04_{e3}+0.06_{e5}-0.18_{e10}+0.05_{e17}-0.06_{e19}+0.11_{e24}-0.11_{e15p}-0.06_{e16p}$
	APSN	0.77	$1.06-0.04t_{3}-0.03t_{10p}-0.03p_{2}+0.09p_{sp}+0.07p_{9p}-0.61_{e2}+0.17_{e6}-0.23_{e7}-0.10_{e20}-0.08_{e23}+0.13_{e24}+0.48_{e9p}-0.13_{e16p}$
A. maroccana	ABMC	0.58	$0.97-0.05t_{aup}+0.01_{e24}+0.03_{e25}-0.05_{e1p}+0.05_{e19p}-0.08_{e21p}-0.09_{e23p}$
A. tazaotana	ABTZ	0.57	$0.93+0.04t_{2}+0.06t_{4}+0.04t_{7}+0.03p_{4}+0.04p_{su}+0.05p_{10p}+0.03p_{sup}-0.06_{e17}+0.10_{e18}-0.08_{e23p}$

Table S7. Statistics of the Bayesian estimation of the site-by-site tuned VS-Lite growth response parameters (T_1, T_2, M_1, and M_2) considering two 21st century periods; and the two IPCC AR5 emission scenarios (RCP 4.5 and RCP 8.5). Different letters indicate significant (P < 0.05) differences between periods based on Tukey HSD post-hoc tests.

		IPCC emission scenarios															
		RCP 4.5								RCP 8.5							
Tree species-country	Parameter (unit)	2010-2049				2050-2100				2010-2049				2050-2100			
		Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	SD
Abies alba-Italy	T_1 (ºC)	4.501b	3.261	6.892	1.340	5.896a	3.687	8.581	1.657	4.067b	3.072	5.525	0.873	5.358a	4.632	6.584	0.719
	T_2 (ºC)	10.869b	10.249	12.008	0.625	15.022a	11.294	21.247	4.121	14.957a	10.635	22.833	4.665	13.188b	10.763	21.719	4.374
	M_1 (v/v)	0.058a	0.011	0.086	0.031	0.037b	0.0.2	0.084	0.027	0.052a	0.022	0.085	0.023	0.028b	0.000	0.061	0.026
	M_2 (v/v)	0.214	0.124	0.264	0.047	0.244	0.126	0.371	0.098	0.233a	0.148	0.322	0.076	0.149b	0.103	0.173	0.030
Abies alba-Spain	T_1 (ºC)	3.154b	2.318	4.246	0.176	4.707a	2.881	6.156	1.308	3.407	1.908	6.671	1.940	3.491	2.133	6.868	1.845
	T_2 (ºC)	12.850b	10.388	23.426	5.192	13.703a	10.538	22.481	4.564	13.905b	10.917	22.995	4.569	14.598a	10.209	23.608	4.996
	M_1 (v/v)	0.043b	0.002	0.078	0.033	0.056a	0.017	0.078	0.029	0.057b	0.002	0.082	0.030	0.070a	0.007	0.095	0.032
	M_2 (v/v)	0.279	0.100	0.366	0.126	0.280	0.161	0.357	0.094	0.280	0.107	0.378	0.113	0.230	0.110	0.305	0.091
A. borisii-regis	T_1 (ºC)	6.662	3.148	8.581	2.150	6.843	5.258	8.238	1.257	5.359	2.152	8.626	2.989	5.329	1.628	7.277	2.362
	T_2 (ºC)	14.852a	10.237	23.108	6.067	13.656b	10.236	22.484	4.997	13.704b	10.420	23.419	5.531	12.416a	10.322	18.197	3.336
	M_1 (v/v)	0.042b	0.013	0.075	0.026	0.055a	0.018	0.097	0.039	0.077	0.015	0.094	0.035	0.065	0.017	0.097	0.033
	M_2 (v/v)	0.354a	0.313	0.381	0.030	0.277b	0.190	0.355	0.081	0.331a	0.307	0.363	0.027	0.287b	0.155	0.480	0.138
A. cephalonica	T_1 (ºC)	4.623b	3.353	6.738	1.844	6.031a	3.428	7.403	2.255	5.617a	4.306	7.240	1.492	5.310b	3.511	7.541	2.050
	T_2 (ºC)	11.412	10.965	12.084	0.593	11.261	10.465	12.555	1.131	11.549b	10.440	13.269	1.511	13.177a	10.465	18.022	4.205
	M_1 (v/v)	0.051a	0.028	0.080	0.027	0.030b	0.007	0.074	0.038	0.077a	0.064	0.091	0.013	0.034b	0.001	0.064	0.032
	M_2 (v/v)	0.392a	0.310	0.440	0.072	0.265b	0.214	0.298	0.045	0.225a	0.183	0.305	0.069	0.171b	0.103	0.215	0.060

Table S7. continued.

Tree species	Parameter (unit)	IPCC emission scenarios															
		RCP 4.5								RCP 8.5							
		2010-2049				2050-2100				2010-2049				2050-2100			
		Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	SD
A. cilicica	T_1 (ºC)	5.737b	4.489	6.088	0.699	6.769a	4.633	8.675	1.841	6.058b	4.437	7.277	1.089	6.806a	3.699	8.163	1.770
	T_2 (ºC)	16.134a	11.065	22.237	4.361	15.092b	10.993	19.858	3.315	16.198b	13.159	20.680	2.797	19.652a	12.635	23.109	4.219
	M_1 (v/v)	0.053a	0.005	0.089	0.037	0.030b	0.001	0.077	0.034	0.048a	0.008	0.096	0.038	0.027b	0.001	0.067	0.032
	M_2 (v/v)	0.106b	0.101	0.111	0.004	0.157a	0.102	0.348	0.107	0.119	0.101	0.164	0.026	0.125	0.100	0.175	0.034
A. pinsapo	T_1 (ºC)	6.690	6.223	6.973	0.407	6.720	5.851	7.172	0.753	6.243b	5.531	7.295	0.930	6.965a	6.183	7.885	0.859
	T_2 (ºC)	13.312b	13.279	21.221	4.291	15.878a	12.686	21.894	5.213	18.134b	13.000	20.739	4.446	18.510a	14.007	22.639	4.328
	M_1 (v/v)	0.032	0.003	0.059	0.028	0.038	0.001	0.093	0.049	0.030b	0.004	0.082	0.045	0.058a	0.010	0.093	0.043
	M_2 (v/v)	0.216a	0.104	0.339	0.118	0.110b	0.100	0.121	0.011	0.145a	0.101	0.168	0.038	0.117b	0.106	0.130	0.012
A. maroccana	T_1 (ºC)	7.001a	–	–	–	4.135b	–	–	–	5.303b	–	–	–	5.928a	–	–	–
	T_2 (ºC)	12.865	–	–	–	12.518	–	–	–	11.855b	–	–	–	21.294a	–	–	–
	M_1 (v/v)	0.069a	–	–	–	0.048b	–	–	–	0.095	–	–	–	0.090	–	–	–
	M_2 (v/v)	0.199a	–	–	–	0.100b	–	–	–	0.131	–	–	–	0.111	–	–	–
A. tazaotana	T_1 (ºC)	3.626b	–	–	–	7.099a	–	–	–	7.603a	–	–	–	4.648b	–	–	–
	T_2 (ºC)	11.732b	–	–	–	17.522a	–	–	–	15.472a	–	–	–	12.685b	–	–	–
	M_1 (v/v)	0.004b	–	–	–	0.035a	–	–	–	0.012b	–	–	–	0.090a	–	–	–
	M_2 (v/v)	0.170a	–	–	–	0.128b	–	–	–	0.352a	–	–	–	0.101b	–	–	–

Table S8. Extreme Climate Indices (for details see http://etccdi.pacificclimate.org/list_27_indices.shtml).

Code	ID	Indicator Name	Indicator Definitions	Units
1	FD	Frost days	Annual count when daily minimum temperature <0 °C	days
2	SU	Summer days	Annual count when daily max temperature >25 °C	days
3	ID	Ice days	Annual count when daily maximum temperature <0 °C	days
4	TN	Tropical nights	Annual count when daily minimum temperature > 20 °C	days
5	GSL	Growing season length	Annual (1st Jan to 31st Dec in NH, 1st July to 30th June in SH) count between first span of at least 6 days with TG >5 °C and first span after 1st July (1st January in SH) of 6 days with TG < 5 °C (where TG is daily mean temperature)	days
6	TX_x	Hottest day	Monthly maximum value of daily max temperature	°C
7	TN_x	Warmest night	Monthly maximum value of daily min temperature	°C
8	TX_n	Coldest day	Monthly minimum value of daily max temperature	°C
9	TN_n	Coldest night	Monthly minimum value of daily min temperature	°C
10	TN_{10p}	Cool nights	Percentage of time when daily min temperature < 10^{th} percentile	%
11	TX_{10p}	Cool days	Percentage of time when daily max temperature < 10^{th} percentile	%
12	TN_{90p}	Warm nights	Percentage of time when daily min temperature > 90^{th} percentile	%
13	TX_{90p}	Warm days	Percentage of time when daily max temperature > 90^{th} percentile	%
14	WSDI	Warm spell duration index	Annual count when at least six consecutive days of max temperature >90^{th} percentile	days
15	CSDI	Cold spell duration index	Annual count when at least six consecutive days of min temperature < 10^{th} percentile	days
16	DTR	Diurnal temperature range	Monthly mean difference between daily max and min temperature	°C
17	R_{x1day}	Max 1 day precipitation amount	Monthly maximum 1 day precipitation	mm
18	R_{x5day}	Max 5 day precipitation amount	Monthly maximum consecutive 5 days precipitation	mm
19	SDII	Simple daily intensity index	Ratio of annual total precipitation to the number of wet days (≥ 1 mm)	mm/day
20	R_{10mm}	Number of heavy precipitation days	Annual count when precipitation ≥10 mm	days
21	R_{20mm}	Number of very heavy precipitation days	Annual count when precipitation ≥ 20 mm	days
22	R_{1mm}	Number of precipitation days	Annual count when precipitation ≥ 1 mm	days
23	CDD	Consecutive dry days	Maximum number of consecutive days when precipitation < 1 mm	days
24	CWD	Consecutive wet days	Maximum number of consecutive days when precipitation ≥1mm	days
25	R_{95p}	Very wet days	Annual total precipitation from days > 95^{th} percentile	mm
26	R_{99p}	Extremely wet days	Annual total precipitation from days > 99^{th} percentile	mm
27	PRC_{PTOT}	Annual total wet day precipitation	Annual total precipitation from days ≥ 1 mm	mm

Table S9. Spearman (r_s) correlation coefficients (see color legend) calculated between indexed ring-width chronologies (TRWi) and current (A) and previous (B) annual Extreme Climate Indices (see *SI Appendix*, Table S8 for indices codes) considering the studied Mediterranean fir species (ABAL, *A. alba*; ABBR, *A. borisii-regis*; ABCE, *A. cephalonica*; ABCI, *A. cilicica*; ABPI, *A. pinsapo;* ABMC, *A. maroccana*; ABTZ, *A. tazaotana*). Crosses indicate significant correlations ($P < 0.05$).

(A)

		Extreme Climate Indices*																										
	Site	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11	e12	e13	e14	e15	e16	e17	e18	e19	e20	e21	e22	e23	e24	e25	e26	e27
ABAL	ROSE			X	X																						X	X
	PESC																							X			X	
	IANN																											
	CUGN						X									X			X				X					
	PANT																		X									
	GARA			X		X												X	X			X				X	X	X
	GUAR						X								X		X											X
	PORH						X	X	X	X						X												
	PORL					X	X	X	X	X	X					X												
	SJPE	X							X	X						X												
	BOUM								X							X												
	MONT															X									X			
ABBR	ABRH																											
	ABRM				X																							
	ABRL				X																							
	KARP1																			X					X		X	
	PERT																	X		X								
ABCE	AINO						X																		X		X	X
	KARP2																			X								
	PARN																										X	
ABCI	leb2		X			X						X		X			X						X					X
	syr2			X		X																						
	tu24																X		X	X	X							X
	DEAC																		X					X				
	IBAC			X																				X				
ABPI	APSB							X										X				X		X	X			X
	APSG					X		X										X						X	X			X
	APSN					X														X	X		X		X			X
ABMC	ABMC			X														X		X	X		X		X	X	X	X
ABTZ	ABTZ								X									X							X			

Legend
$r_s > 0.4$
$0.3 < r_s < 0.4$
$0.2 < r_s < 0.3$
$0.1 < r_s < 0.2$
$0 < r_s < 0.1$
0
$0 < r_s < -0.1$
$-0.1 < r_s < -0.2$
$-0.2 < r_s < -0.3$
$-0.3 < r_s < -0.4$
$r_s < -0.4$

(B)

	Site	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11	e12	e13	e14	e15	e16	e17	e18	e19	e20	e21	e22	e23	e24	e25	e26	e27
		Extreme Climate Indices*																										
ABAL	ROSE																					X				X	X	
	PESC																					X						
	IANN											X			X									X	X			
	CUGN											X												X	X			
	PANT																								X			X
	GARA																							X				
	GUAR			X																				X	X			X
	PORH			X	X												X											
	PORL	X		X													X							X				X
	SJPE	X	X	X		X											X	X						X				X
	BOUM		X		X	X			X	X														X				
	MONT			X		X												X	X									
ABBR	ABRH																		X									
	ABRM																		X									
	ABRL																	X	X									
	KARP1																	X										
	PERT					X																			X			
ABCE	AINO																							X				
	KARP2																							X				
	PARN					X															X			-X	X			X
ABCI	leb2	X																						X	X			X
	syr2	X						X		X	X	X				X												
	tu24									X														X				
	DEAC					X																		X				X
	IBAC																								X			X
ABPI	APSB	X							X															X	X			X
	APSG	X	X	X		X			X	X												X		X	X			X
	APSN	X	X	X					X	X							X							X	X			X
ABMC	ABMC	X							X													X		X				
ABTZ	ABTZ				X	X			X	X							X					-X		X	X			

Legend

$r_s > 0.4$	
$0.3 < r_s <$	
$0.2 < r_s <$	
$0.1 < r_s <$	
$0 < r_s <$	
0	
$0 < r_s < -$	
$-0.1 < r_s <$	
$-0.2 < r_s <$	
$-0.3 < r_s <$	
$r_s < -0.4$	

*e1: *FD*; e2: *SU*; e3:*ID*; e4: *TR*; e5: *GLS*;e6: TX_x; e7: TN_x, e8: TX_n; e9: TN_n; e10: TN_{10p}; e11: TX_{10p}; e12: TN_{90p}; e13: TX_{90p}; e14: *WSDI*; e15: *CSDI*; e16: *DTR*; e17: R_{x1day}; e18: R_{x5day};e19: *SDII*; e20: R_{10mm}; e21: R_{20mm}; e22: R_{1mm}; e23: *CDD*; e24: *CWD*; e25: R_{95pTOT}; e26: R_{99pTOT}; e27: PRC_{PTOT}

Supplementary Figures

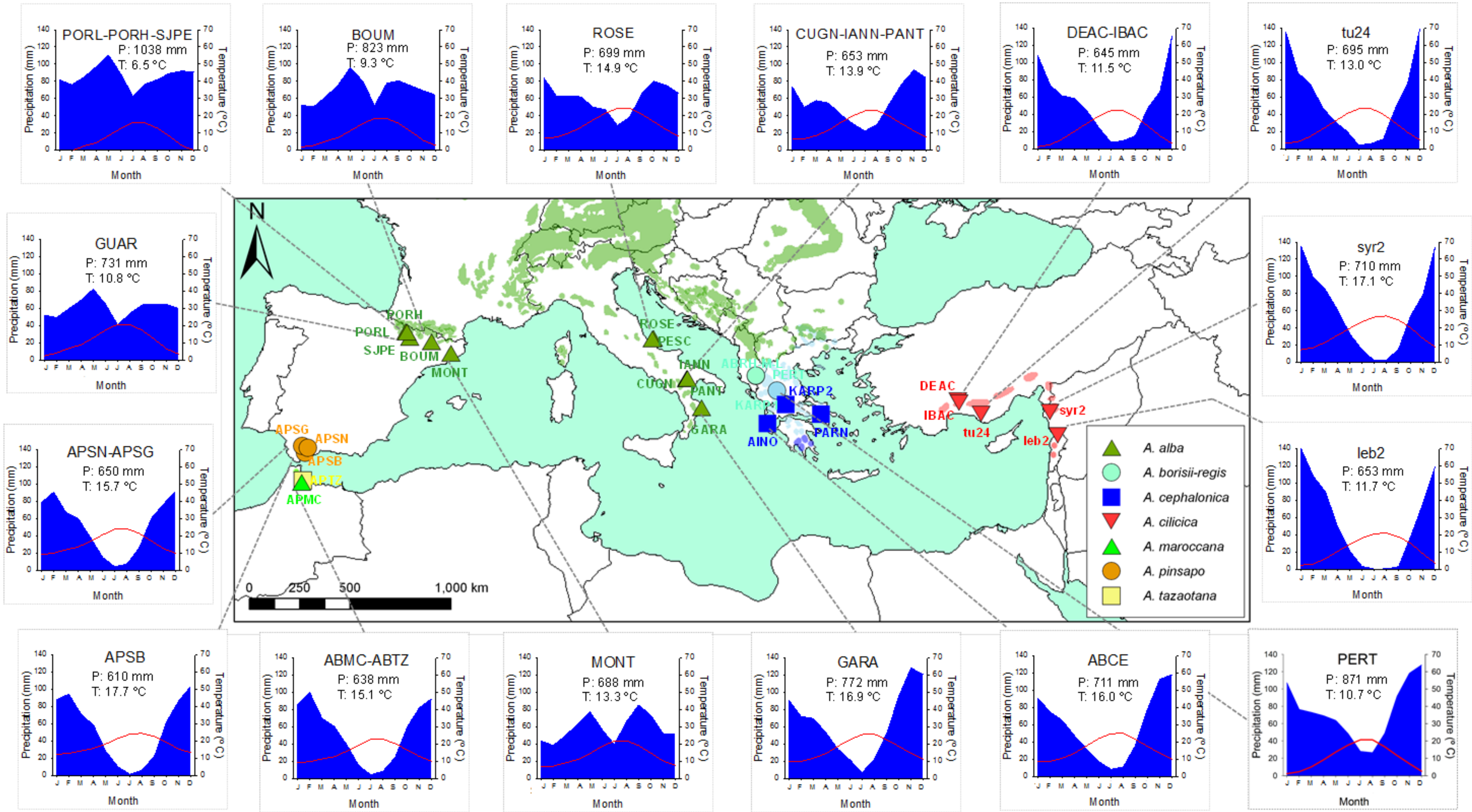

Fig. S1. Distribution of the sampled Mediterranean fir forests and climatic diagram for each study site. Total monthly precipitation (P) and mean monthly temperature (T) corresponding to the 1950-2010 period (see site codes in *SI Appendix*, Table S1).

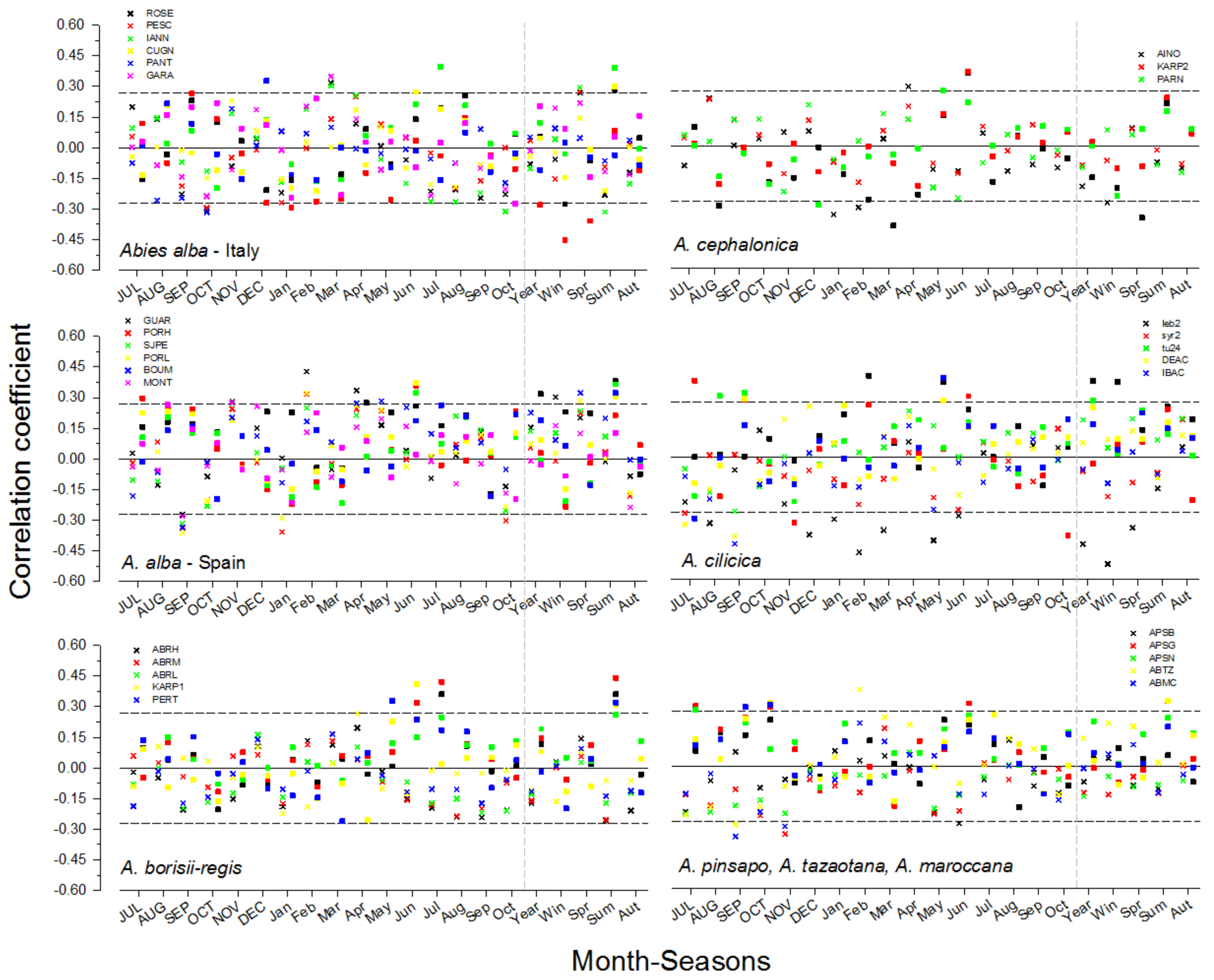

Fig. S2. Pearson correlation coefficients calculated between TRWi and climate variables. Pearson correlation coefficients calculated between site chronologies of tree-ring width indices (TRWi) and mean temperature (cross symbols) and total precipitation (square symbols) for the studied *Abies* species in the common period 1950-2010. The analyzed temporal window spans from previous (capital letter) July to current October and seasonal periods. The values located outside the dashed lines indicate significant ($P < 0.05$) correlation coefficients.

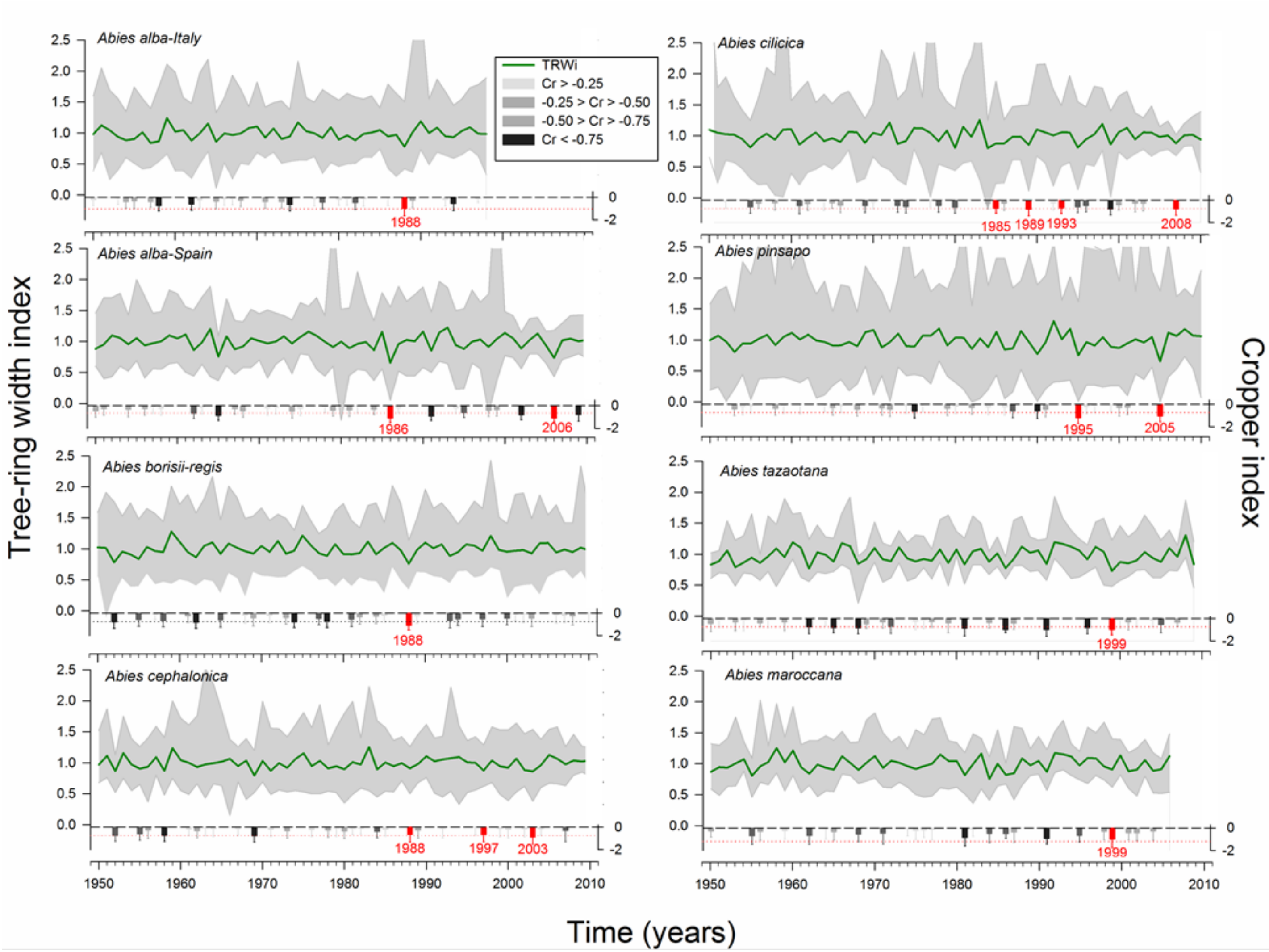

Fig. S3. Tree-ring width indices (TRWi) calculated for each fir species and extreme growth years (Cropper index, right *y* axis). Means are shown as dark green lines and grey areas represent the maximum and minimum TRWi values considering all studied sites per species. The lower plots show negative pointer years (bars) expressed as Cropper indices. The red bars and numbers indicate selected climatically extreme years causing a sharp growth reduction. Horizontal lines frame extreme Cropper values.

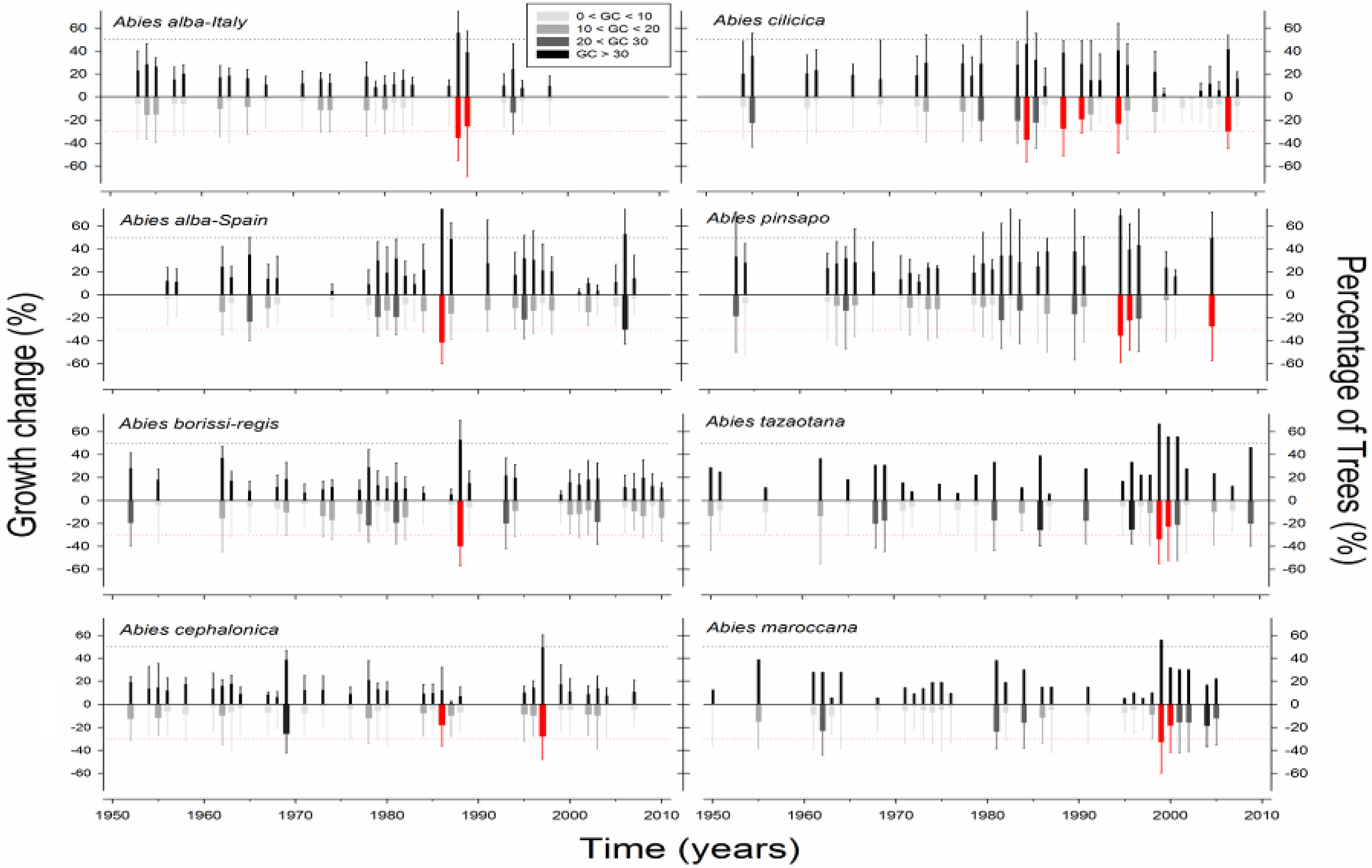

Fig. S4. Percentage of Growth Change (%) to the observed extreme negative years. Percentage of Growth Change (%) to the extreme negative years and percentages of trees showing drought- or heat-induced pointer years during the period 1950-2010 for each of the studied *Abies* species.

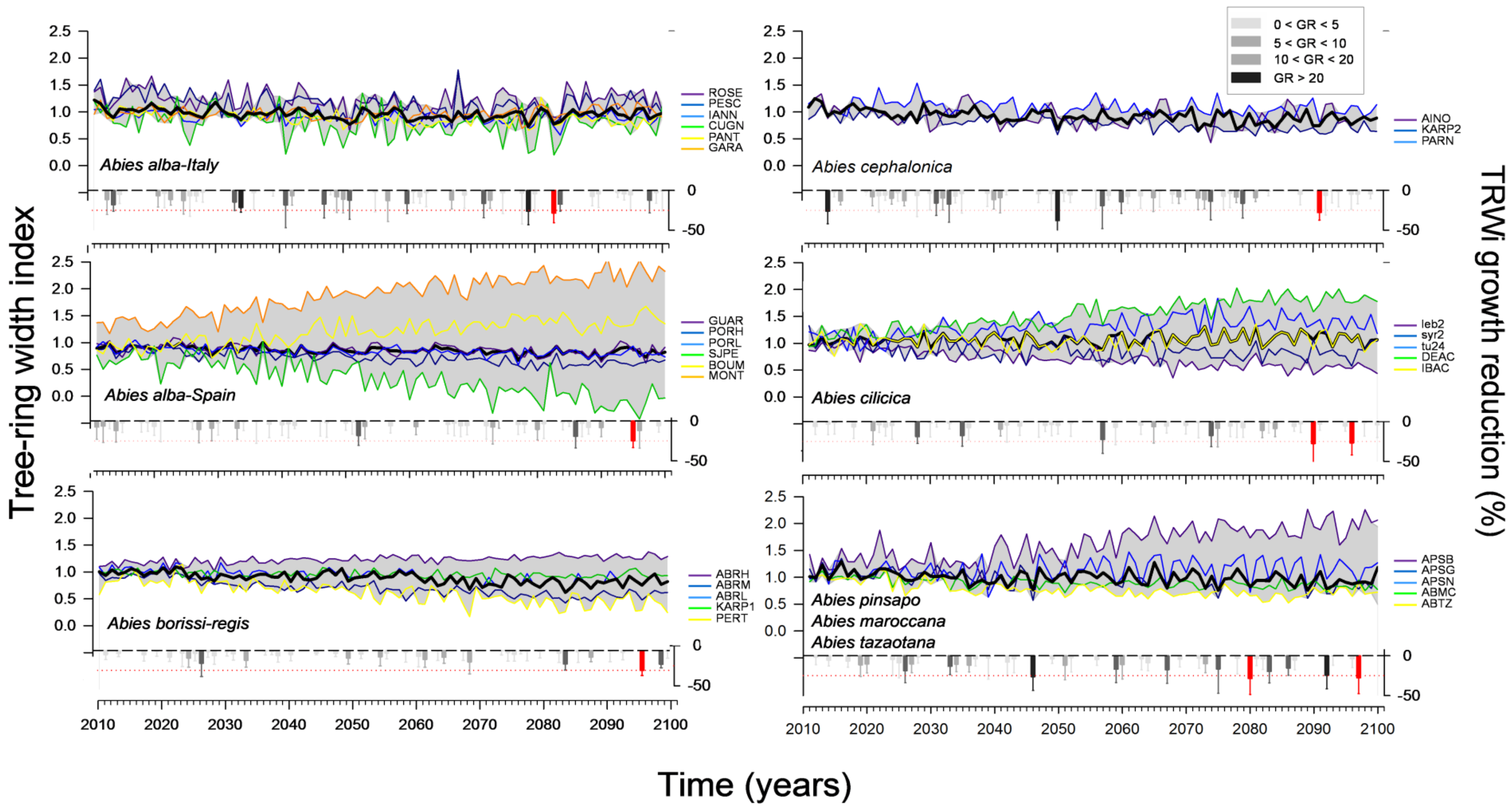

Fig. S5. Growth projections according to RCP 4.5 emission scenarios (2). Projected tree-ring width indices ($TRWi_p$) for each *Abies* species site considering the emission scenario RCP 4.5. Species means are shown as black lines and grey polygons represent the $TRWi_p$ maximum and minimum values considering all sites per species. The graph below shows the projected change in TRWi reduction (GR) computed considering the 5-year moving average values from 2011 to 2100 period. The red bars and numbers indicate selected climatically extreme years causing reduced growth in each species during the 21st century. Bold lines frame extreme values (GR > 25%).

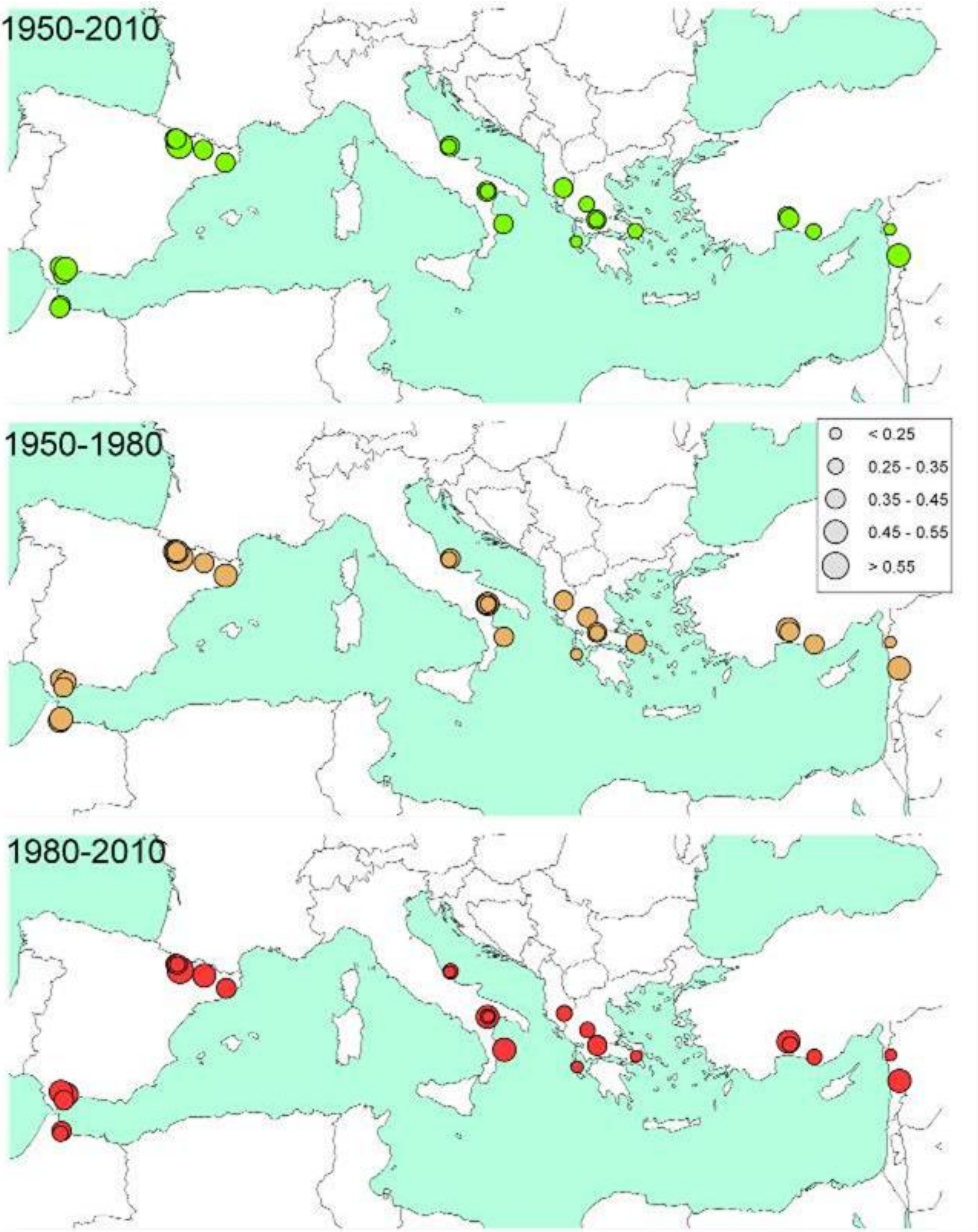

Fig. S6. Maps displaying Pearson correlation coefficients calculated at site level between observed (TRWi) and VS-Lite model projected ($TRWi_{VSL}$) tree-ring indices for *Abies* species. Plots show the entire period of analyses (1950–2010, green symbols) and two sub-periods (1950–1980, orange symbols; and 1980–2010, red symbols). Correlation values higher than 0.25 are significant at $P < 0.05$.

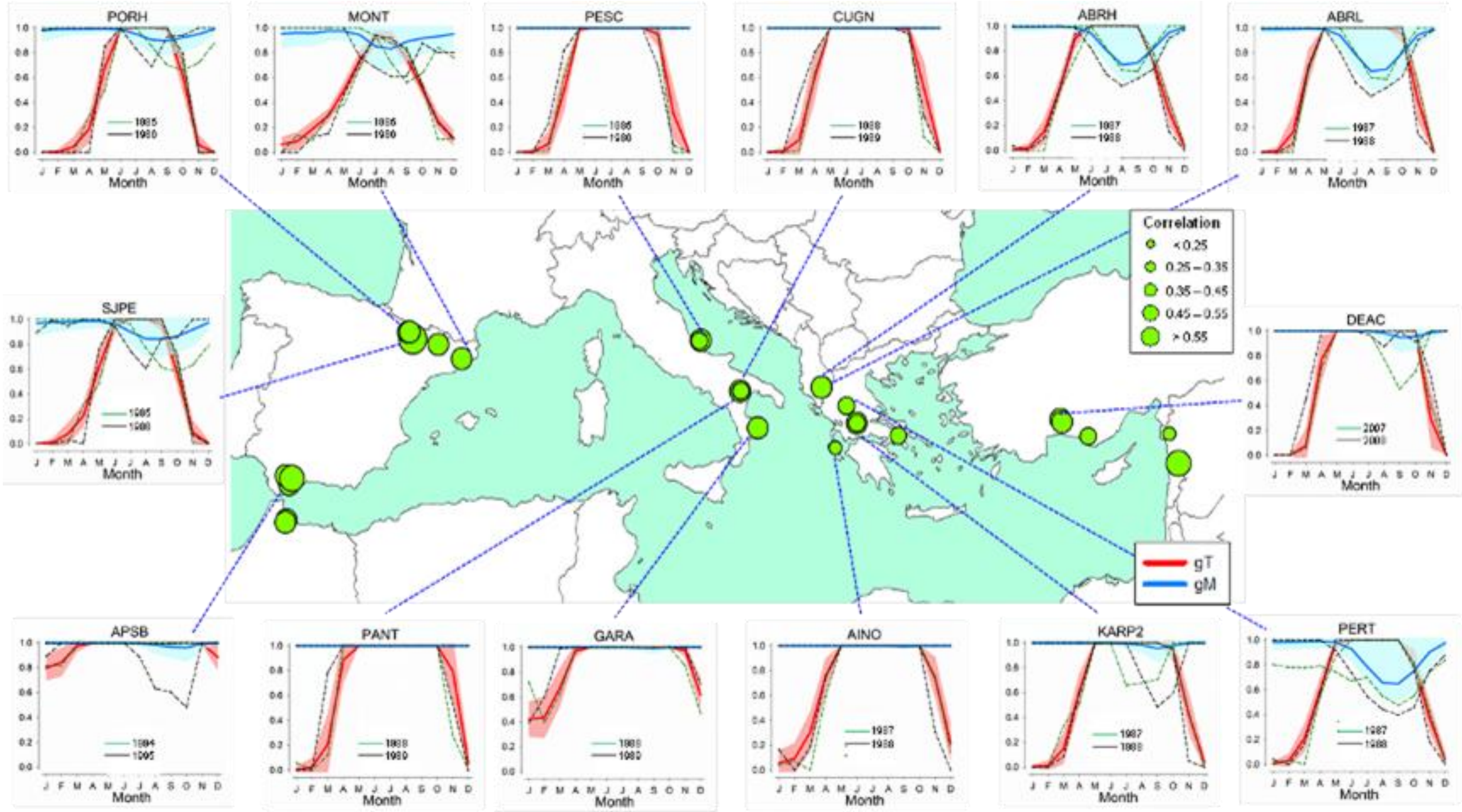

Fig. S7. Simulated monthly growth response curves (*gT*, *gM*) for the period 1950-2010. Simulated (VS-Lite, period 1950-2010) monthly growth response curves considering temperature (*gT*, red lines-mean and areas-SD) and soil moisture limitations (*gM*, blue lines-mean and areas-SD) for each species. Selected extreme events are indicated in different colors (see Figs. 2 and 3). See *SI Appendix*, Table S1 for site codes.

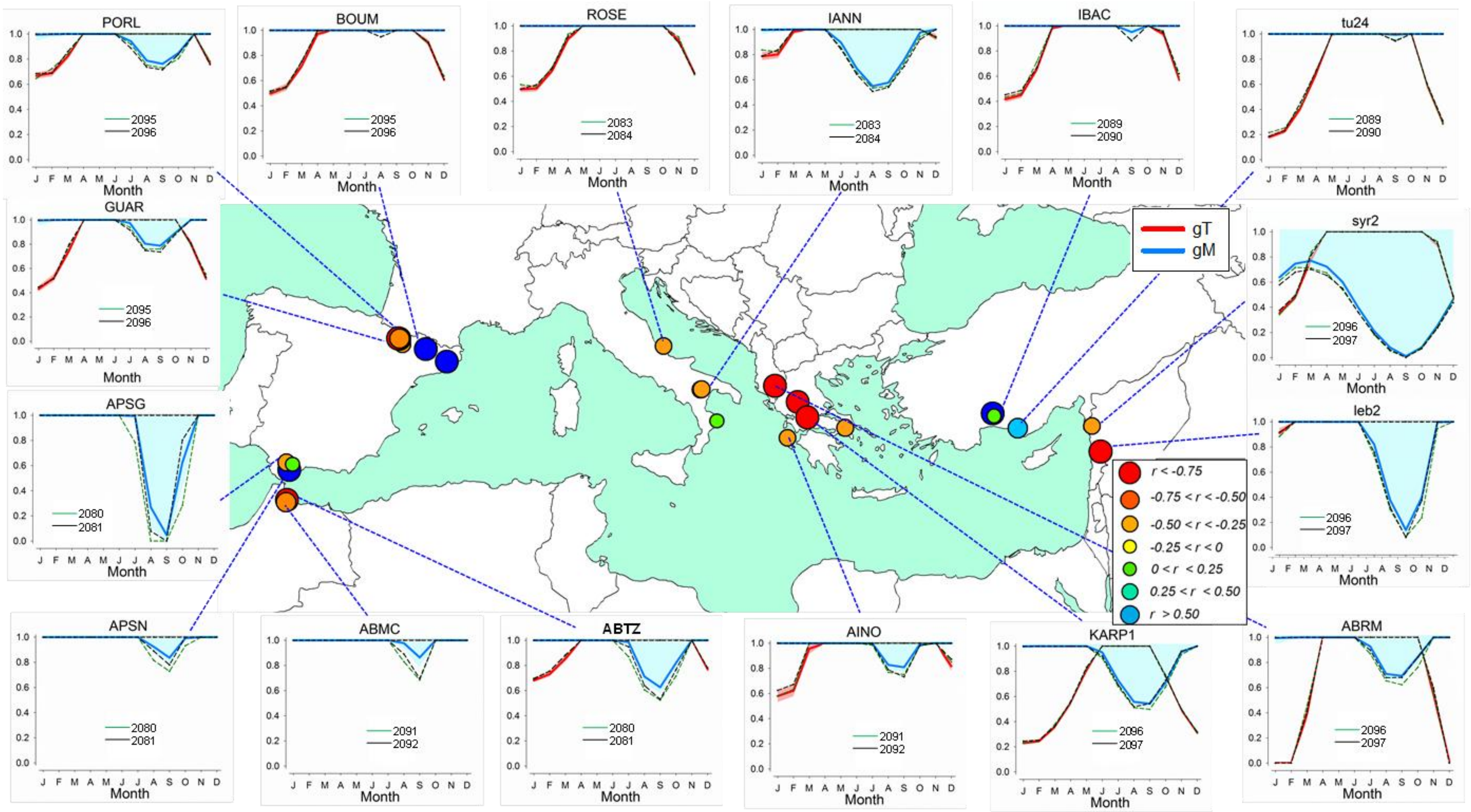

Fig. S8. Projected monthly growth response curves (*gT*, *gM*) for the period 2050-2100 for RCP 4.5 and RCP 8.5 emission scenarios. Projected monthly growth response curves corresponding to the RCP4.5 (upper map) and RCP 8.5 emission scenarios (below map) with VS-Lite for the period 2050-2100 considering temperature (*gT*, red lines-mean and areas-SD) and soil moisture limitations (*gM*, blue lines-mean and areas-SD) for each selected site. Selected extreme events are indicated in different colors (see Figs. 4 and 5). Map displaying projected growth trends (Pearson correlation coefficients of site mean tree-ring width indices series) considering the 2011–2100 period following growth projections based on respective emission scenarios. Values higher than 0.25 and lower than 0.25 are significant at $P < 0.05$. See *SI Appendix* Table S1 for site codes.

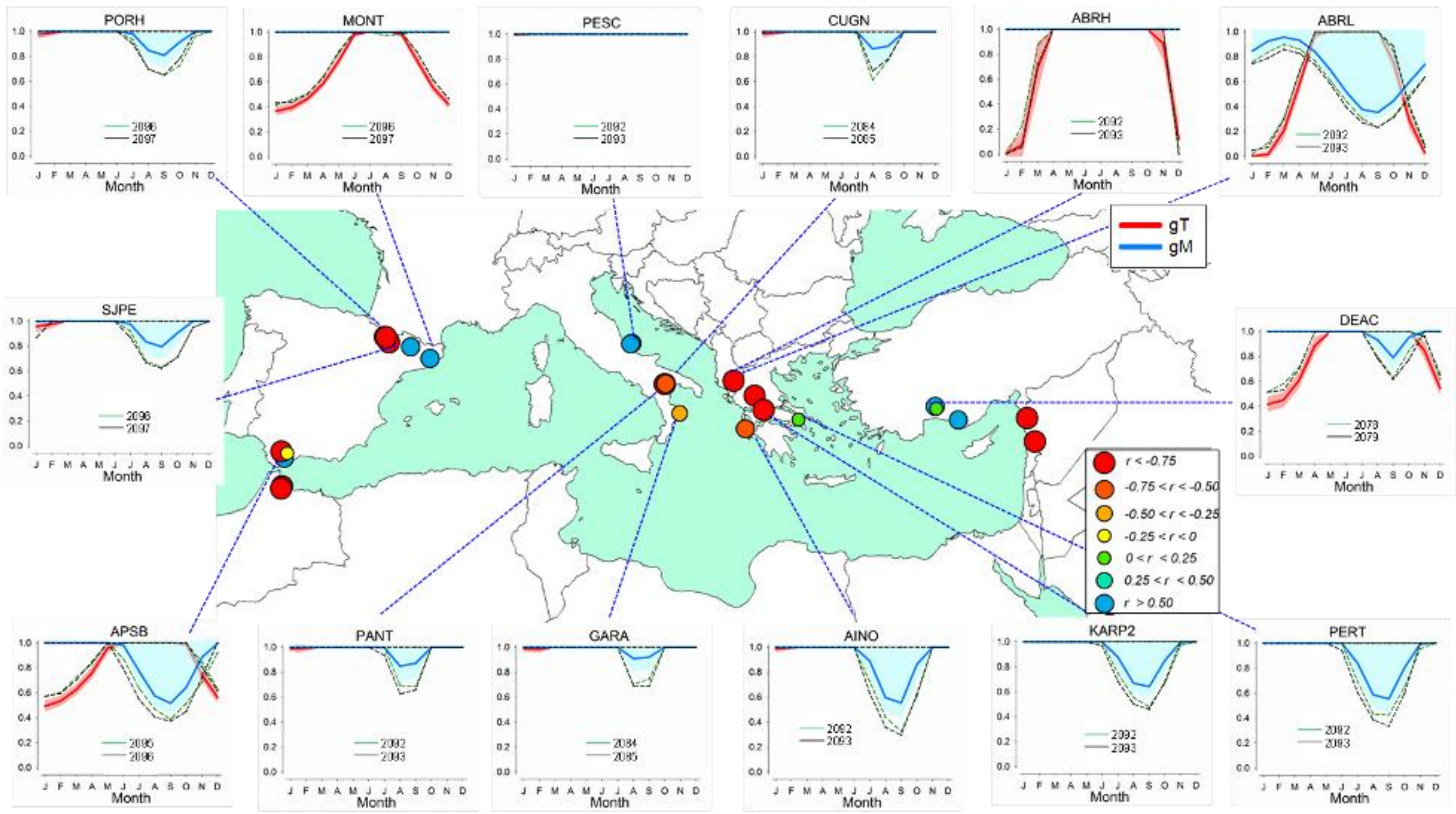

Fig. S8. Continued.

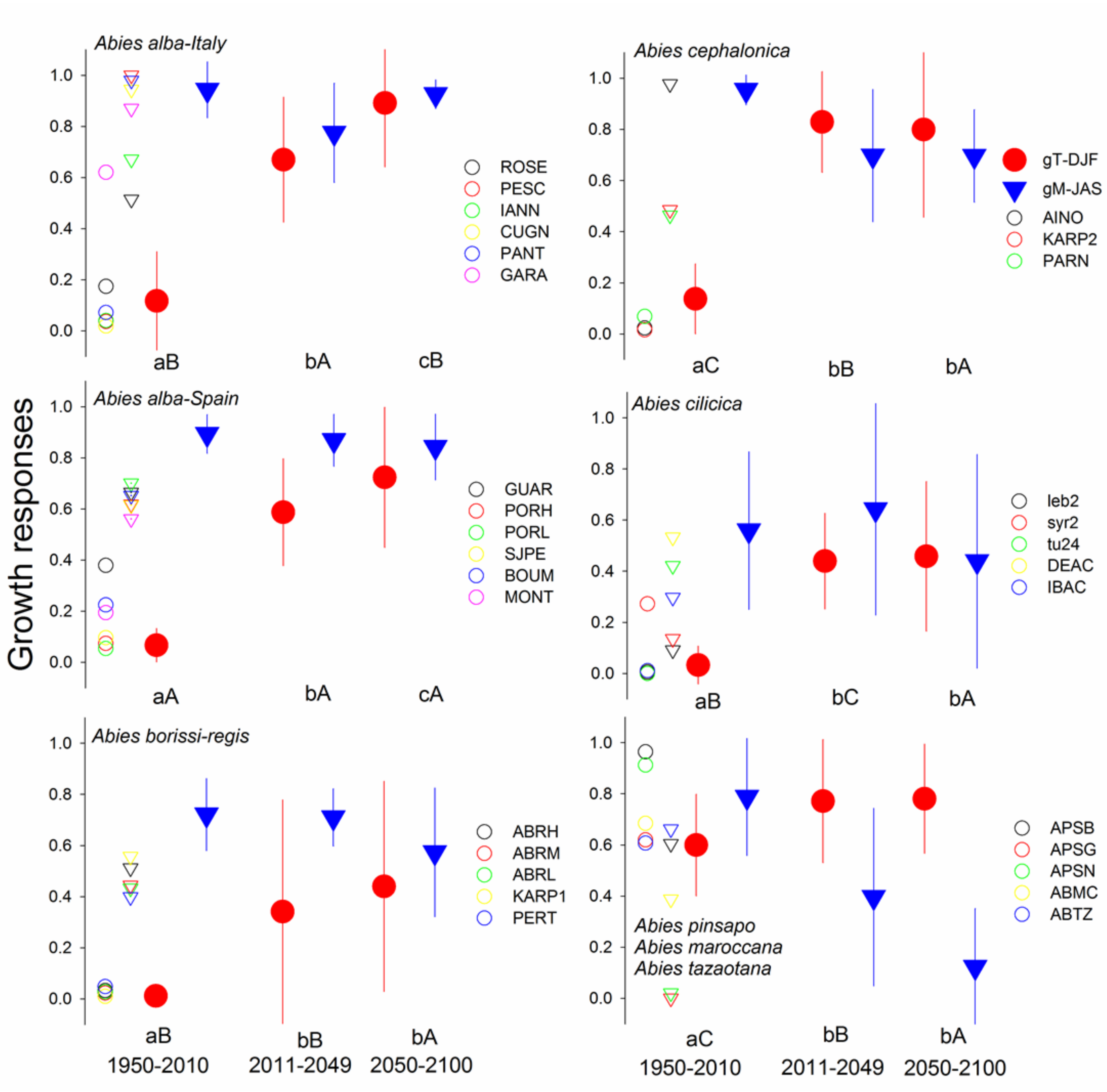

Fig. S9. Simulated winter (*gT*) and summer (*gM*) growth responses for the observed and forecasted periods**.** Simulated (VS-Lite) mean growth response representing winter (DJF) temperature (*gT*, red circles-mean and SD) and late summer (JAS) soil moisture limitations (*gM*, blue triangles-mean and SD) for each *Abies* species. Values were fitted for one observed 1950-2010 period and two 21st century (2011-2049 and 2050-2100) periods based on RCP 8.5 emission scenario. Selected observed growth responses during extreme events (1950-2010 period, see Figs. 2 and 5) with extreme low growth rates are indicated in different colors on the left. These values defined the thresholds of vulnerability for each climate refugia under forecasted growth response for RCP 8.5 climate scenario. Different letters indicate significant ($P < 0.05$) differences between observed and projected periods based on Tukey's HSD post-hoc tests (lowercase and uppercase letters correspond to the 2011–2049 and 2050–2100 periods, respectively).