Czech University of Life Sciences Prague

Faculty of Forestry and Wood Sciences

Spatiotemporal analysis of growth dynamics under climate change across European unmanaged forests

Appendix

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Dissertation Thesis

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ELECTRONICAL SUPPORTING INFORMATION

This appendix contains the supporting information for each research paper.

Chapter 4.1: CLIMATE-GROWTH RELATIONSHIPS OF NORWAY SPRUCE AND SILVER FIR IN PRIMARY FORESTS OF THE CROATIAN DINARIC MOUNTAINS

Supporting Information S1

Chapter 4.2: LARGE OLD TREES INCREASE GROWTH UNDER SHIFTING CLIMATIC CONSTRAINTS: ALIGNING TREE LONGEVITY AND INDIVIDUAL GROWTH DYNAMICS IN PRIMARY MOUNTAIN SPRUCE FORESTS

Supporting Information S2

Chapter 4.3: SPATIOTEMPORAL CHANGES IN DROUGHT SENSITIVITY CAPTURED BY MULTIPLE TREE-RING PARAMETERS OF CENTRAL EUROPEAN CONIFERS

Supporting Information S3

Chapter 4.4: ECOLOGICAL AND METHODOLOGICAL DRIVERS OF NON-STATIONARITY IN TREE GROWTH RESPONSE TO CLIMATE

Supporting Information S4

4.1. CLIMATE-GROWTH RELATIONSHIPS OF NORWAY SPRUCE AND SILVER FIR IN PRIMARY FORESTS OF THE CROATIAN DINARIC MOUNTAINS – S1

Climate-growth relationships of Norway spruce and silver fir in primary forests of the Croatian Dinaric Mountains by Krešimir Begović, Miloš Rydval, Stjepan Mikac, Stipan Čupić, Kristyna Svobodova, Martin Mikoláš, Daniel Kozak, Ondrei Kameniar, Michal Frankovič, Jakob Pavlin, Thomas Langbehn & Miroslav Svoboda

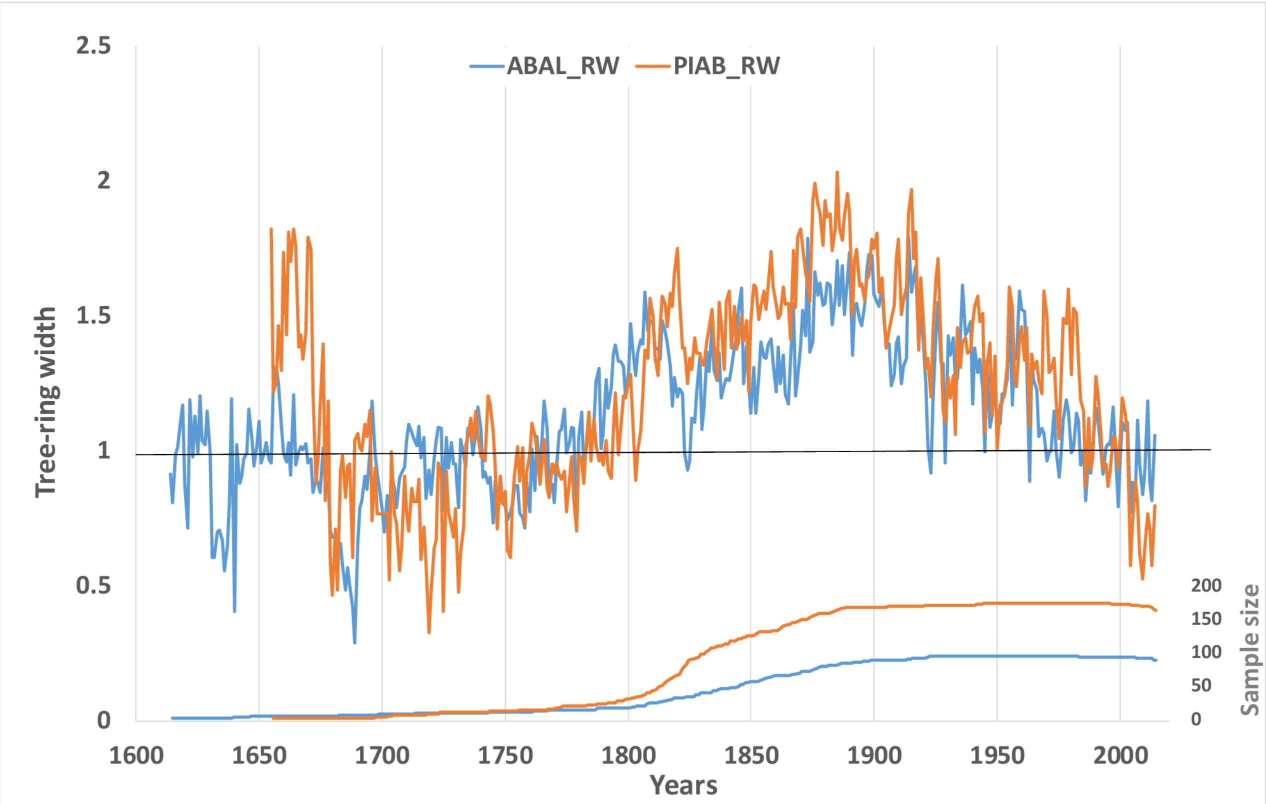

Fig. S1 Silver fir (**blue**) and Norway spruce (**orange**) undetrended 'raw' TRW chronologies with chronology replication.

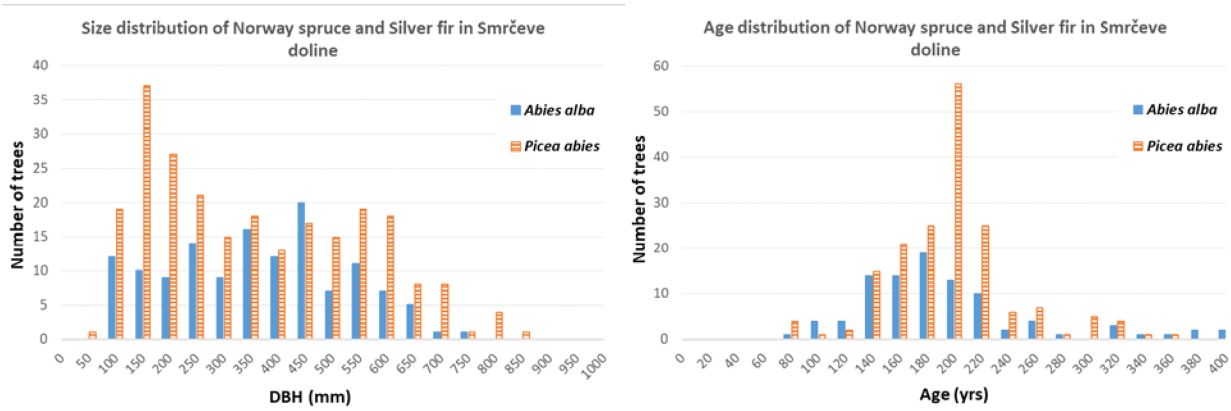

Fig. S2 Size and age distribution of silver fir (filled, **blue** bars) and Norway spruce (vertical dashed, **orange** bars)

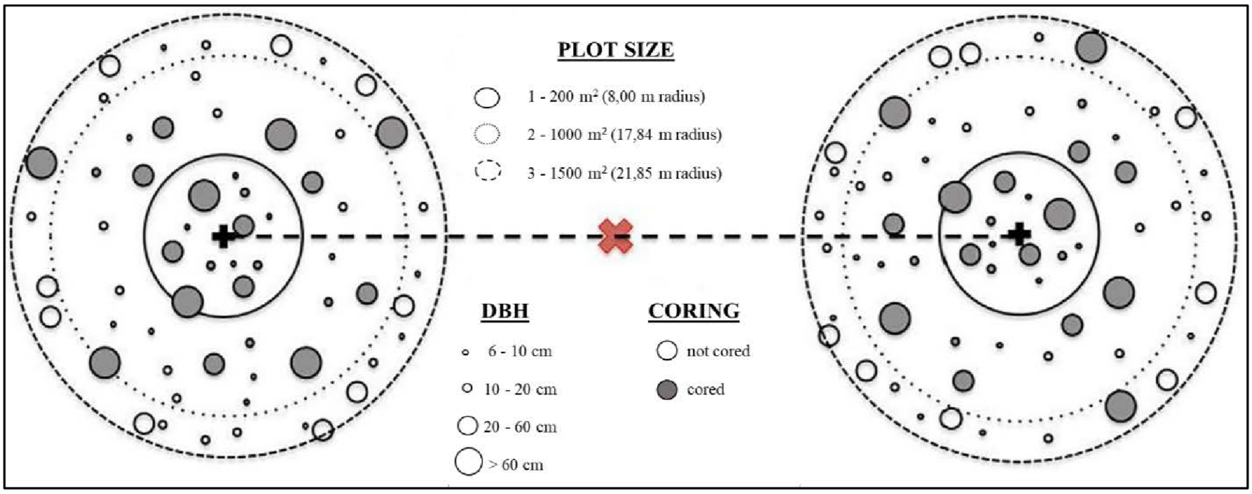

Fig. S3 Plot and sampling design applied in the selection of trees for coring (adapted from Kozák *et al.* 2018). Red cross indicates a randomly generated navigation point used to locate a pair of circular sample plots, while the black dashed line represents 40 m distance between the centres of the neighbouring plots located parallel to the slope contour. Plot centres were limited to the inner 0.25-ha core in each 1-ha cell. In each 1500 m^2 sample plot, all living trees ≥ 6 cm in diameter at breast height (DBH) were labelled and their DBH recorded. Each plot consisted of 3 circles of varying radius (1st circle 8 m, 2nd circle 17,84 m and 3rd circle 21,85 m), which determined the minimal DBH of trees chosen for coring. In the 1st circle, all trees with DBH_{min} > 6 cm were cored, in the 2nd circle trees with DBH between 10 cm and 20 cm, and in the 3rd circle only trees with DBH_{min} > 20 cm were selected. Information on stand and site characteristics were collected from each plot (*i.e.* latitude/longitude of plot centre, aspect, slope, landform, hill form, etc.). Electronic and laser measuring devices linked to a GIS (Field-Map®, Monitoring and Mapping Solutions, Ltd.; www.fieldmap.cz) were used to establish plots, spatially record all trees with a DBH > 6 cm and establish a grid for regeneration surveys.

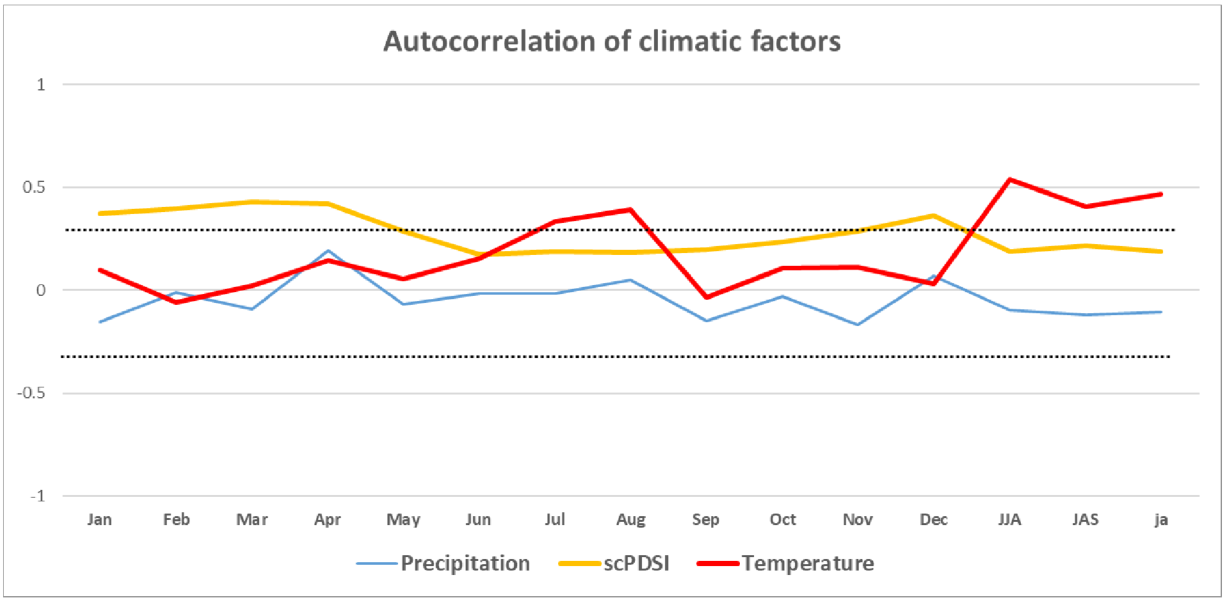

Fig. S4 1st order autocorrelation of climatic variables (precipitation monthly totals, self-calibrating Palmer drought severity index – scPDSI, and average monthly temperature). Black dashed lines indicate significant ($p < 0.05$) correlation limits.

Table S1 Smrčeve doline stand characteristics.

PLOTS	Latitude and longitude		Mean elevation (m a.s.l.)	Total number of surveyed trees	Total number of conifers (*Abies alba* + *Picea abies*)	Stand density (N/ha)	Mean DBH (mm)	Height (m)
CRO_SMR_015	14.9808	44.7886						
	14.9818	44.7885	1530	456	43	1520	192.63	13.06
CRO_SMR_038	14.9760	44.7817						
	14.9755	44.7813	1406	272	84	907	282.47	22.37
CRO_SMR_048	14.9813	44.7800						
	14.9809	44.7799	1482	278	45	927	243.43	20.07
CRO_SMR_049	14.9773	44.7807						
	14.9773	44.7800	1400	236	21	787	303.81	22.47
CRO_SMR_093	14.9765	44.7690						
	14.9755	44.7689	1485	240	52	800	314.01	19.84
CRO_SMR_094	14.9715	44.7693						
	14.9726	44.7690	1418	212	66	707	271.87	19.79
CRO_SMR_095	14.9696	44.7698						
	14.9701	44.7692	1369	273	113	910	288.26	19.89
CRO_SMR_103	14.9798	44.7670						
	14.9801	44.7666	1456	375	131	1250	213.95	16.63
CRO_SMR_104	14.9768	44.7658						
	14.9777	44.7655	1361	246	47	820	278.85	23.3
CRO_SMR_105	14.9718	44.7662						
	14.9710	44.7657	1372	245	56	817	278.33	23.87
CRO_SMR_106	14.9665	44.7662						
	14.9677	44.7662	1411	345	183	1150	268.81	21.3

Table S2 Pearson's correlation coefficients between monthly climate data (precipitation totals, mean monthly temperature and scPDSI) with the standard and residual RW and BI chronologies of Norway spruce and silver fir in the period 1901–2014. Red vertical dashed line separates response of chronologies to climatic variables in the previous and current year relative to the year of tree-ring formation.

STANDARD CHRONOLOGIES RW

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	dec	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JJA	JAS	JA
precip_ABAL_rw_std	0.05	0.06	0.05	0.02	0.00	0.04	0.27	0.22	0.04	-0.01	-0.05	0.21	0.03	-0.03	0.19	-0.18	0.07	-0.03	0.32	-0.05	0.05	0.19	0.00	0.20	0.11	0.14	0.15
precip_PCAB_rw_std	0.01	0.10	0.06	0.07	0.03	0.11	0.28	0.24	0.02	-0.12	-0.04	0.15	0.06	0.06	0.19	-0.04	-0.11	0.07	0.29	0.07	-0.03	0.03	0.00	0.07	0.22	0.14	0.23
PDSI_ABAL_rw_std	0.25	0.26	0.25	0.28	0.26	0.26	0.31	0.34	0.31	0.31	0.26	0.31	0.22	0.19	0.23	0.20	0.16	0.11	0.19	0.16	0.18	0.24	0.21	0.25	0.16	0.18	0.17
PDSI_PCAB_rw_std	0.20	0.26	0.24	0.27	0.30	0.31	0.35	0.37	0.31	0.26	0.21	0.24	0.24	0.25	0.27	0.23	0.19	0.18	0.24	0.25	0.19	0.22	0.20	0.19	0.23	0.24	0.25
temp_ABAL_rw_std	-0.17	-0.06	0.08	-0.05	-0.08	0.07	-0.22	-0.34	-0.15	-0.02	0.13	0.19	0.10	0.17	0.08	0.01	-0.23	0.05	-0.22	-0.14	-0.10	-0.19	-0.03	0.11	-0.14	-0.20	-0.21
temp_PCAB_rw_std	-0.21	0.02	0.02	-0.27	-0.26	-0.33	-0.57	-0.59	-0.28	-0.06	-0.21	-0.06	-0.15	-0.05	-0.08	-0.32	-0.28	-0.22	-0.55	-0.41	-0.16	-0.17	-0.26	0.06	-0.52	-0.49	-0.55

RESIDUAL CHRONOLOGIES RW

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	dec	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JJA	JAS	JA
precip_ABAL_rw_res	0.03	0.10	-0.07	0.12	-0.04	0.06	0.11	0.30	0.01	-0.21	-0.09	0.08	-0.04	0.01	0.14	-0.20	0.09	-0.04	0.32	0.03	0.03	-0.02	-0.09	0.12	0.16	0.17	0.21
precip_PCAB_rw_res	-0.07	0.04	-0.05	0.07	0.13	0.09	0.16	0.25	0.03	-0.20	-0.05	0.14	0.03	0.16	0.19	-0.08	-0.08	0.08	0.40	0.12	0.03	-0.08	0.06	0.11	0.31	0.25	0.33
PDSI_ABAL_rw_res	0.11	0.14	0.11	0.16	0.16	0.19	0.22	0.27	0.22	0.15	0.10	0.13	0.05	0.05	0.10	0.07	0.06	0.03	0.12	0.12	0.14	0.09	0.05	0.08	0.10	0.13	0.12
PDSI_PCAB_rw_res	0.04	0.10	0.07	0.14	0.21	0.23	0.24	0.27	0.23	0.16	0.12	0.15	0.13	0.20	0.24	0.20	0.17	0.16	0.27	0.28	0.25	0.21	0.21	0.21	0.24	0.27	0.27
temp_ABAL_rw_res	-0.21	-0.12	0.06	-0.02	0.09	0.07	-0.09	-0.30	-0.11	0.13	0.17	0.16	0.17	0.32	0.13	0.11	-0.10	0.10	-0.16	-0.15	-0.10	-0.13	0.01	0.16	-0.09	-0.18	-0.18
temp_PCAB_rw_res	-0.21	0.05	0.07	-0.05	-0.07	-0.21	-0.31	-0.42	-0.22	0.06	-0.06	-0.12	-0.09	-0.01	-0.07	-0.12	-0.11	-0.03	-0.40	-0.35	-0.07	-0.05	-0.08	0.10	-0.34	-0.36	-0.43

STANDARD CHRONOLOGIES EWBI

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	dec	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JJA	JAS	JA
precip_ABAL	0.08	0.07	0.17	0.05	-0.03	0.08	0.09	0.01	-0.03	0.13	0.15	0.11	0.08	0.04	0.04	0.01	-0.02	0.16	0.20	0.12	-0.07	0.13	0.07	0.11	0.26	0.10	0.21
precip_PCAB	0.10	0.09	0.10	0.01	-0.06	0.10	0.11	0.07	-0.05	-0.01	0.13	0.05	0.06	0.02	-0.07	0.03	-0.02	0.12	0.19	0.18	-0.09	0.01	-0.03	0.07	0.27	0.12	0.25
PDSI_ABAL	0.27	0.23	0.23	0.26	0.20	0.21	0.22	0.21	0.18	0.28	0.30	0.31	0.29	0.25	0.21	0.24	0.21	0.25	0.28	0.29	0.21	0.28	0.29	0.29	0.28	0.27	0.29
PDSI_PCAB	0.24	0.22	0.21	0.21	0.21	0.23	0.25	0.26	0.17	0.21	0.25	0.22	0.22	0.19	0.12	0.17	0.17	0.19	0.23	0.27	0.14	0.17	0.14	0.13	0.24	0.23	0.25
temp_ABAL	-0.27	-0.17	-0.25	-0.34	-0.36	-0.40	-0.40	-0.45	-0.25	-0.25	-0.28	-0.09	-0.33	-0.15	-0.16	-0.31	-0.33	-0.38	-0.47	-0.52	-0.14	-0.25	-0.19	-0.02	-0.60	-0.50	-0.57
temp_PCAB	-0.25	-0.12	-0.26	-0.37	-0.34	-0.44	-0.46	-0.50	-0.25	-0.15	-0.31	-0.11	-0.29	-0.06	-0.11	-0.36	-0.36	-0.36	-0.48	-0.55	-0.14	-0.21	-0.24	-0.04	-0.62	-0.52	-0.60

RESIDUAL CHRONOLOGIES EWBI

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	dec	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JJA	JAS	JA
precip_ABAL	0.03	0.06	0.22	0.12	-0.08	-0.04	-0.07	0.00	0.05	0.01	0.15	0.09	0.12	0.13	-0.05	0.02	0.03	0.22	0.27	0.40	-0.06	-0.02	0.01	0.04	0.49	0.28	0.46
precip_PCAB	0.08	0.08	0.16	-0.02	-0.13	0.07	0.01	0.02	0.01	-0.07	0.18	0.05	0.04	0.06	-0.19	0.06	0.11	0.11	0.21	0.38	-0.07	-0.12	-0.07	0.06	0.39	0.25	0.41
PDSI_ABAL	0.09	0.09	0.12	0.12	0.07	0.02	0.03	0.03	0.09	0.13	0.18	0.18	0.20	0.22	0.17	0.20	0.22	0.29	0.33	0.39	0.29	0.24	0.21	0.21	0.34	0.35	0.36
PDSI_PCAB	0.14	0.13	0.17	0.11	0.11	0.12	0.13	0.13	0.12	0.15	0.23	0.20	0.20	0.20	0.11	0.18	0.23	0.26	0.29	0.36	0.22	0.17	0.12	0.12	0.31	0.30	0.33
temp_ABAL	-0.12	-0.10	-0.26	-0.22	-0.17	-0.25	-0.16	-0.25	-0.35	-0.16	-0.31	-0.18	-0.28	-0.04	0.03	-0.05	-0.10	-0.24	-0.32	-0.47	-0.01	-0.05	0.01	0.08	-0.46	-0.35	-0.46
temp_PCAB	-0.13	-0.12	-0.27	-0.22	-0.14	-0.31	-0.23	-0.33	-0.28	-0.04	-0.29	-0.21	-0.26	0.04	0.06	-0.11	-0.23	-0.25	-0.33	-0.50	-0.10	-0.03	-0.06	-0.06	-0.48	-0.41	-0.48

STANDARD CHRONOLOGIES LWBI

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	dec	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JJA	JAS	JA
precip_ABAL	0.01	0.12	0.03	0.05	-0.09	0.14	-0.01	-0.03	0.00	-0.09	0.07	0.06	0.00	0.01	-0.10	-0.02	-0.16	-0.06	0.11	-0.07	0.07	0.17	0.07	0.08	-0.02	0.06	0.01
precip_PCAB	-0.17	-0.01	0.08	0.01	0.00	-0.12	-0.10	-0.12	-0.19	-0.03	0.04	0.10	0.21	0.20	0.10	0.01	-0.10	0.06	0.10	-0.02	0.10	0.20	0.15	0.08	0.07	0.10	0.05
PDSI_ABAL	0.01	0.03	0.04	0.06	0.02	0.11	0.07	0.03	0.04	0.04	0.09	0.09	0.11	0.08	0.02	0.05	-0.03	-0.01	0.01	0.02	0.06	0.09	0.09	0.08	0.01	0.03	0.02
PDSI_PCAB	0.11	0.09	0.10	0.15	0.07	0.04	-0.01	-0.06	-0.04	-0.02	0.06	0.09	0.17	0.21	0.21	0.20	0.18	0.17	0.20	0.19	0.22	0.32	0.33	0.31	0.19	0.21	0.20
temp_ABAL	-0.05	-0.16	0.04	0.06	0.05	-0.11	0.03	0.04	0.00	0.03	-0.19	-0.04	0.02	0.15	0.08	0.07	0.00	0.19	-0.10	0.09	0.06	-0.01	0.05	0.12	0.08	0.03	0.00
temp_PCAB	-0.27	-0.24	-0.02	-0.08	-0.11	-0.07	0.05	-0.01	0.07	-0.15	-0.12	-0.04	-0.23	-0.10	-0.15	-0.14	-0.17	-0.10	-0.28	-0.17	-0.18	-0.14	-0.15	-0.10	-0.24	-0.28	-0.26

RESIDUAL CHRONOLOGIES LWBI

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	dec	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JJA	JAS	JA
precip_ABAL	0.04	0.17	0.06	0.08	0.00	0.17	0.05	0.10	0.00	-0.20	0.02	0.05	0.04	0.09	-0.09	-0.01	-0.14	-0.06	0.25	0.07	0.10	0.08	0.06	0.09	0.14	0.21	0.20
precip_PCAB	-0.19	-0.03	0.05	0.00	0.03	-0.15	-0.15	-0.11	-0.19	-0.13	-0.01	0.05	0.22	0.21	0.10	0.00	-0.09	0.02	0.10	-0.01	0.11	0.14	0.12	0.05	0.05	0.11	0.05
PDSI_ABAL	0.02	0.08	0.10	0.12	0.14	0.22	0.19	0.16	0.14	0.10	0.13	0.13	0.17	0.18	0.12	0.14	0.09	0.11	0.17	0.20	0.22	0.19	0.19	0.17	0.16	0.20	0.19
PDSI_PCAB	0.05	0.02	0.04	0.07	0.03	-0.01	-0.06	-0.11	-0.09	-0.11	-0.04	-0.02	0.10	0.15	0.16	0.14	0.14	0.13	0.16	0.15	0.19	0.26	0.27	0.24	0.15	0.18	0.16
temp_ABAL	-0.08	-0.19	0.01	-0.01	-0.04	-0.20	-0.08	-0.17	-0.08	0.07	-0.22	-0.07	-0.03	0.17	0.06	-0.02	-0.12	0.17	-0.31	-0.14	-0.01	0.03	0.03	0.12	-0.12	-0.20	-0.26
temp_PCAB	-0.19	-0.18	0.04	-0.01	-0.05	0.00	0.16	0.08	0.11	-0.10	-0.06	-0.01	-0.16	-0.04	-0.10	-0.10	-0.11	0.00	-0.21	-0.09	-0.16	-0.08	-0.11	-0.12	-0.13	-0.21	-0.17

4.2. LARGE OLD TREES INCREASE GROWTH UNDER SHIFTING CLIMATIC CONDITIONS: ALIGNING TREE LONGEVITY AND INDIVIDUAL GROWTH DYNAMICS IN PRIMARY MOUNTAIN SPRUCE FORESTS – S2

Large old trees increase growth under shifting climatic constraints: aligning tree longevity and individual growth dynamics in primary mountain spruce forests by Krešimir Begović, Jon Schurman, Marek Svitok, Jakob Pavlin, Thomas Langbehn, Kristyna Svobodova, Martin Mikoláš, Pavel Janda, Michal Synek, William Marchand, Lucie Vitkova, Vojtech Čada, Daniel Kozak, Ondrej Vostarek, Radek Bače, and Miroslav Svoboda.

S1: Climatic conditions in the Western Carpathian region

We chose metrics of climatic variability for the analysis of climatic conditions in the region in the period of overlap with the tree ring data (*i.e.* 1901-2018). KNMI Climate Explorer, a web-tool containing monthly and daily values of climatic parameters in the form of Climatic Research Unit gridded Time Series (*i.e.* CRU TS), was used to extrapolate mean values of climatic variables as climate dataset based on interpolated climatic anomalies from a 0.5° x 0.5° grid of extensive network of weather station measurements (Harris *et al.* 2020). Monthly values of average temperature, precipitation sums and the self-calibrating Palmer Drought Severity Index (*i.e.* scPDSI, Wells *et al.* 2004), which integrates available temperature and precipitation data to estimate relative drought, were downloaded and used in the climate-growth relationship analysis between climatic parameters and tree ring widths. We must acknowledge that the gridded-interpolated climate data likely underestimates the local micro-climatic conditions, but for the purpose of our study, the applicability of coarse climatic data was appropriate. Additionally, we plotted the moisture metrics against temperature, to ascertain the overview of temporal climatic variability over the 20th century. While precipitation varied annually across the region, moisture index and temperature have been showing divergent nonlinear trends, especially pronounced since the 1970s (Fig. S1), which is in line with IPCC projections of the global warming trend (IPCC 2018), as is the trend of increasing dryness across temperate and boreal forest zones (Allen *et al.* 2015).

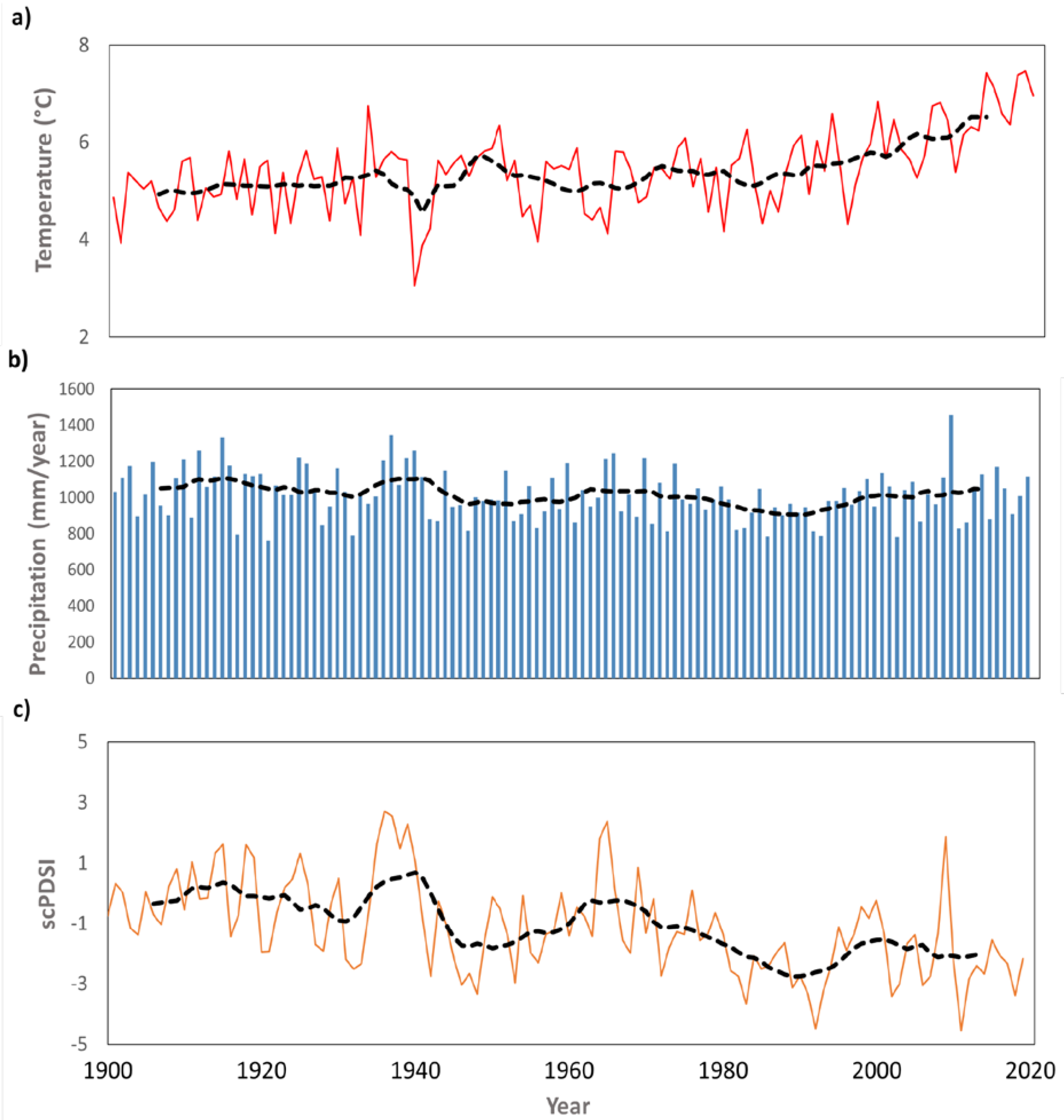

Fig. S1 Climatic conditions for the Western Carpathian region.

Shown are mean annual temperature (**a**), annual precipitation totals (**b**) and mean annual scPDSI (**c**). Dashed black lines represent the decadal trends of each climatic factor smoothed with a moving 10-yr window smoother over the course of the 20th century. Climate data was pooled for the coordinates of the outermost study sites and serves as a rough temporal representation of regional climate.

S2: Tradeoffs between early growth and lifespan

Over time, tree growth follows a range of sigmoid trajectories along the gradients of resource availability, but generally increasing slowly at an early age, becoming exponential during middle age, and plateauing at the onset of senescence (Fig. S2). The difference in phenotypic responses to growing conditions usually entail a cost-benefit effect on tree lifespan (Rose *et al.* 2009). With increasing juvenile growth rates, the adverse effects of rapid tree growth induce both short-term and delayed costs to overall tree development, ultimately resulting in a shorter lifespan. On the other hand, long-lived trees have long-term benefits from increasing their metabolic flexibility at the cost of reduced growth at an early age. By comparing juvenile growth histories of trees across 100-yr age classes, we could clearly discern whether patterns in early life growth histories between young and old trees emerge. The oldest trees exhibited sustained growth rates in the first 50 years of life (*purple colour*), and their abundance progressively decreased with increasing average TRW. Additionally, “early bloomers” (*i.e.* trees with fast early growth) reached larger sizes than their slow-growing counterparts at the same respective age, indicated by steeper slopes of growth trajectories. This figure illustrates the underlying role of slow juvenile growth on age/size trade-offs in closed-canopy forests.

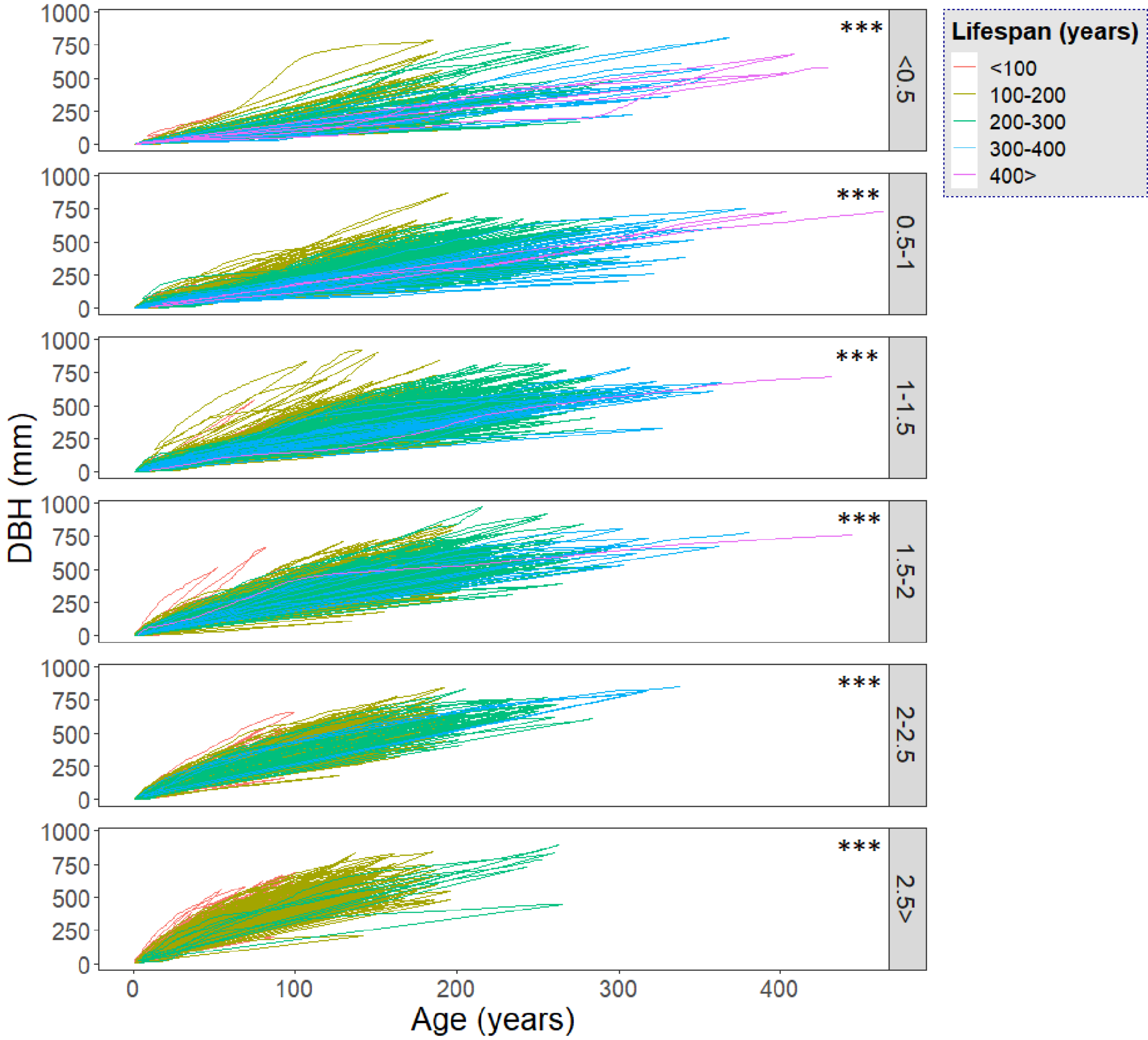

Fig. S2 Development of tree size with age.

Tree size is represented by diameter at breast height (DBH); colours indicate the 100-yr age class of Norway spruce trees lifespan. Trees were assigned to classes of early growth (mean ring width over the first 100 years): < 0.5 mm/year, 0.5 – 1 mm/year, 1-1.5 mm/year, 1.5-2 mm/year, 2-2.5 mm/year, and > 2.5 mm/year. Black asterisks indicate significant differences ($p < 0.001$) in age between early growth classes based on Mann-Whitney U-test.

S3: Impact of spatio-temporal variability of disturbance regimes on regional age structure

In high-altitude *Picea abies* forests, mixed-severity disturbance regimes drive the natural variation in forest dynamics, where low and moderate severity disturbances predominantly determine forest development (Meigs *et al.* 2017, Senf & Seidl 2018, Čada *et al.* 2020). Western Carpathian forests span across several mountain ranges and cover an area of about 40 000 ha (Holekša *et al.* 2017). The majority of trees in the region established during peak severe canopy disturbances (*i.e.* between 1840s and 1870s; Fig. S3), indicating a high dependence of the present-day stand structures to spatial/temporal variability of past disturbances. This is further noticeable when distributing trees in classes according to the severity and frequency of plot-level disturbance histories (Fig. S4), which indicates that the majority of currently living trees generally developed under low-to-moderate severity disturbance regimes. The occurrence of LOTs follows the same relationship, as their abundance decreases with higher severity and more recent disturbance events (*i.e.* outliers; Fig. S4). The detected similarities in mean ages across stands and mountain regions (*e.g.* BYS, HLI and KOP) mirror the data on plot-level disturbance histories, demonstrating a synchronizing effect of disturbances on stand development. Other factors, such as topographical characteristics of sites (Senf & Seidl 2018), and the consequent increased exposure to more severe abiotic damages (*e.g.* strong northern winds in Central Tatras) likely add to the observed regional age variability.

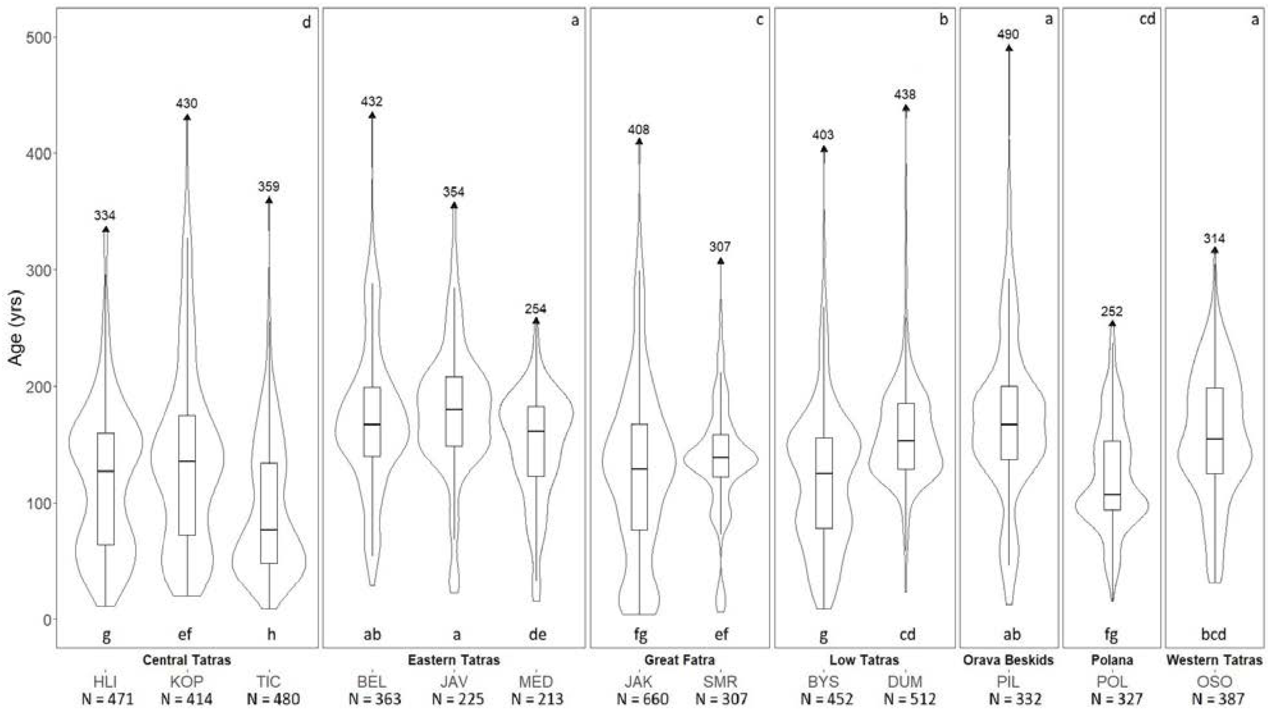

Fig. S3 Age structure across the Western Carpathian region.

Violin and Box-Whisker plots show the age distribution of trees across all stands. Width of violin plots indicates the number of trees, and stands are grouped based on the mountain range. The central bar of the box-plots indicates the median, the margins of each box are the first and third quartile, and the whiskers are at ± 1.57 interquartile range. Plotted numbers indicate the maximum recorded age at each stand. N represents the number of trees. Statistical differences between landscape and stands are indicated by lower case letters and were tested by analysis of variance and post-hoc Tukey HSD test ($p < 0.05$). Short 3-letter abbreviations denote names of stands (see Fig. 1, Table 1).

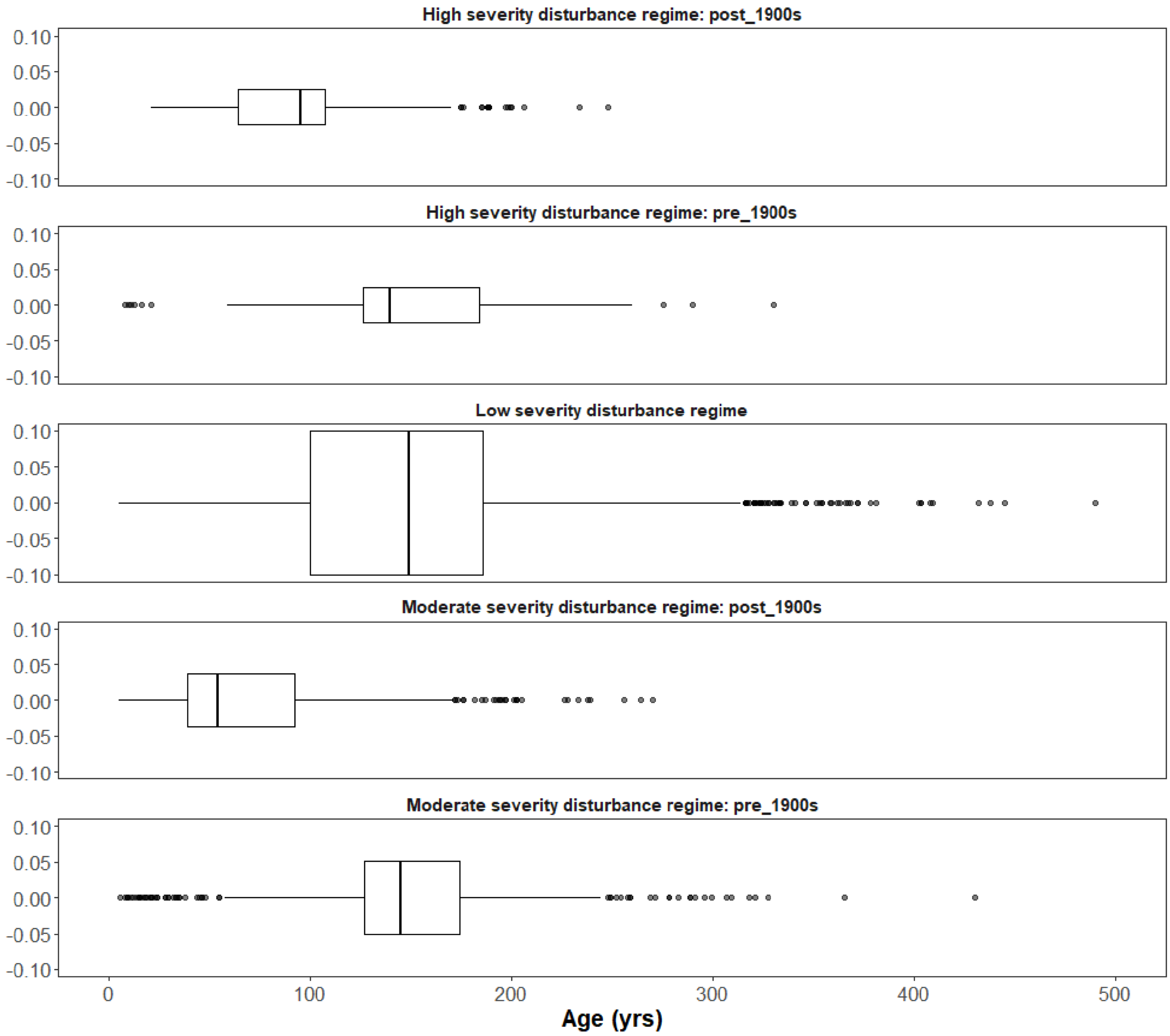

Fig. S4 Age distribution based on differing disturbance histories across the region.

Figure shows the distribution of mean tree ages across stands. Distributions are grouped according to previously determined disturbance groups. Width of the Whisker boxplots indicate tree replication.

S4: Potential study biases

Growth trend studies often derive certain biases related with the methodological approaches to data collection, and/or due to the nature of radial growth time-series (Nehrbass-Alles *et al.* 2014). When coring a set of trees in a population, the earliest growth rates are likely estimated from slow-growing trees, while fast-growers that died in the past are often lacking in the dataset, which may produce an artificial positive growth trend (the so-called "*slow-growing survivor*" bias; Bowman *et al.* 2013). Additionally, using a size-fixed targeted tree sampling threshold (*i.e.* "*big-tree selection bias*"; Brienen *et al.* 2012) and a fixed coring height might cause under-/over- estimation of tree ages and confound the interpretation of growth patterns. Furthermore, using a targeted subset of a population for deriving climate-growth sensitivity analysis can spuriously inflate existing growth trends and introduce additional biases to the interpretation of environmental factors on tree growth.

However, our data collection was not specifically oriented on sampling only large and old living trees, but rather developed as a large population-based random sampling design, containing both living and dead trees with a wide range of tree ages and past growth strategies, thus ensuring a representative tree selection for the regional study. Fitting a relatively flexible standardization curve with adaptive power transformation ensured the retention of high-frequency variability in the regional chronology of LOTs, while removing the centennial-scale biological trend. Furthermore, the observed correspondence between the late 20th century growth trend in BAI found over the whole tree ring dataset (*i.e.* Fig. 6a) and the increase in temperature over the same period strengthens our confidence that the recent growth trend can be attributed to changing environmental factors and not defined as an artefact of demographic biases in the tree ring data.

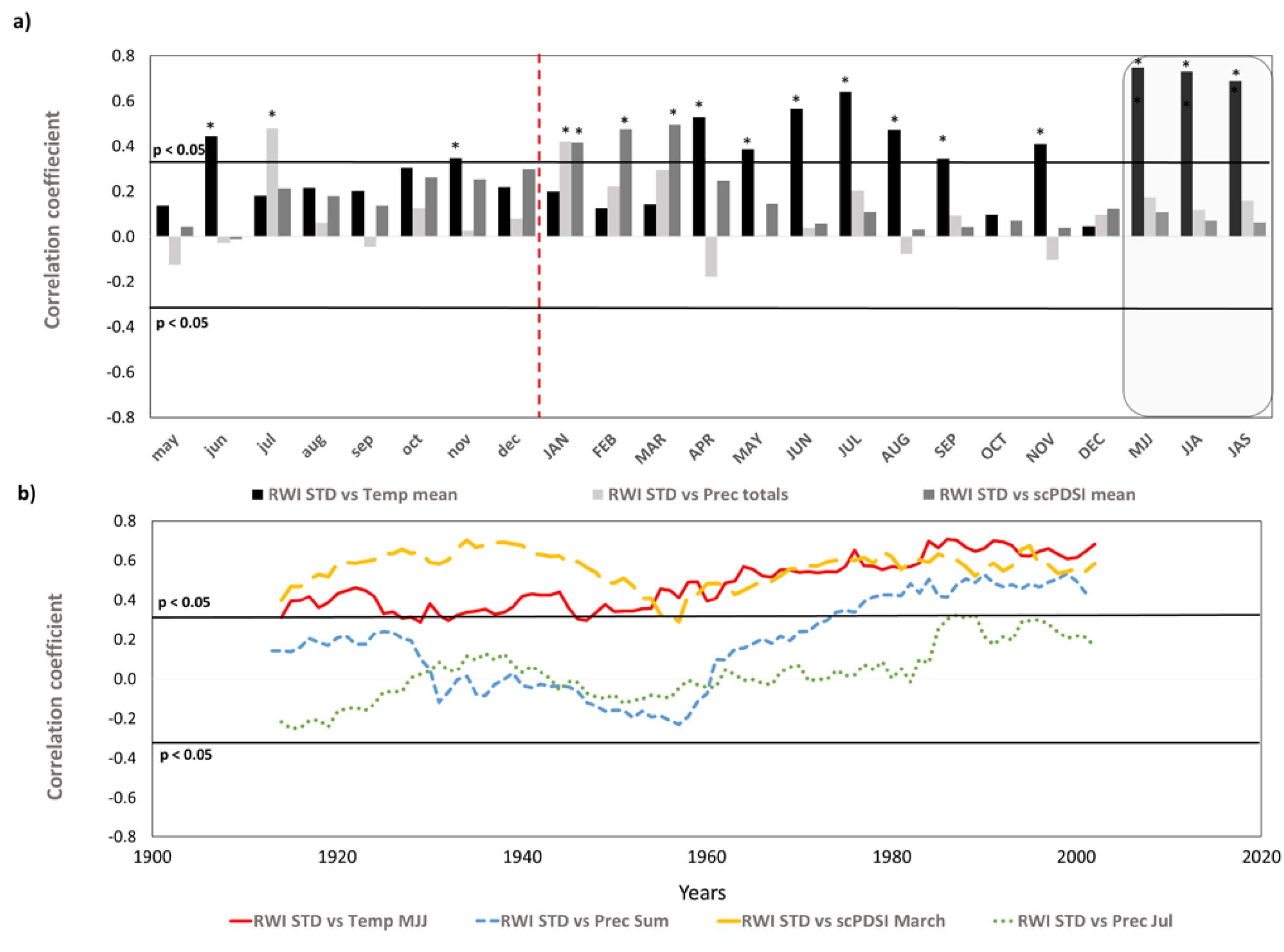

Fig. S5 Correlation response of Norway spruce standard chronology with climate.

(**a**) shows Pearson's correlation between regional standard RWI chronology in relation to monthly climatic variables (mean temperature, precipitation totals and mean scPDSI) for the current and prior year of growth for the period 1980-2018. Relationships with precipitation (light gray stacks), scPDSI (dark gray stacks) and temperature (black stacks) are shown. Black asterisks indicate statistically significant correlations ($p < 0.05$). Red vertical dashed line separates prior and current year of tree-ring formation. Gray rectangle box represents the summer season windows,

(**b**) shows a 31-year moving window Pearson's correlation between regional standard RWI chronology and the most significant climate factors from the climate-growth response analysis over the 20th century. Residual chronology is shown against early summer season temperature (summer window May-July; *red line*), precipitation totals (*blue dashed line*), July precipitation (*green dashed line*) and March scPDSI (*orange dashed line*) values. Black horizontal lines represent the significance threshold ($p < 0.05$).

S5: Model outputs and diagnostics

We used generalized linear mixed-model (GLMM) analyses with site(s) as the random effects to account for the variability between stands and regions, in an overarching effort to discern the effects of tree-level to plot-level factors driving age and growth variability in the Western Carpathians. Although the sites in our analysis were not strictly selected at random, they cover a biogeographical range of natural Norway spruce habitats in the Western Carpathians landscape. GLMMs have the advantage to LMMs in their ability to handle data gathered across multiple individuals from various populations within a single statistical model robustly, as well as handling unbalanced (*i.e.* non-Gaussian) distributions in order to generalize relationships across a populations (Zuur *et al.* 2010). Both models were fitted with their respective fixed effects using restricted maximum likelihood (REML), but different random effect structures, including the null model (*i.e.* no random effect), as REML gives a more robust estimate of the random effects. We used a backward single-term deletion method and resulting changes in AIC and P-values from Chi-square test to evaluate whether significant changes occur by excluding a certain predictor. The final modelS preserved predictors even if their exclusion might somewhat improve the R^2, based on ecological consideration of their biological importance for the relationship with the response variable, instead of focusing on model parsimony metrics (*e.g.* AIC/BIC; Olsson *et al.* 2002, Aho *et al.* 2014).

Longevity model was fit using GLMM with a generalized-Poisson distribution (Fig. S7), in order to account for under-dispersion of residuals, and using log-transformed absolute age as the response variable. Growth model was fit with GLMM with Gaussian distribution (Fig. S8), as BAI values followed normal distribution. We used a simulation-based approach to create easily interpretable scaled (quantile) residuals from the fitted GLMMs („DHARMa“ package in R; Hartig *et al.* 2022), and residual plots and diagnostics were produced in order to test for singularity, heteroscedasticity, zero-inflation and other structural issues that might inflate or cofound the interpretations of the GLMMs. Both models demonstrated no violation with statistical requirements to test the original hypothesis. In Fig. S6, we demonstrate the homogeniety of variance, which uses t-test and ANOVA to demonstrate equal group variances and high explanatory power of significance values, and normal distribution of GLMM residuals using the Shapiro-Wilk test to prove that the model fits the data adequately.

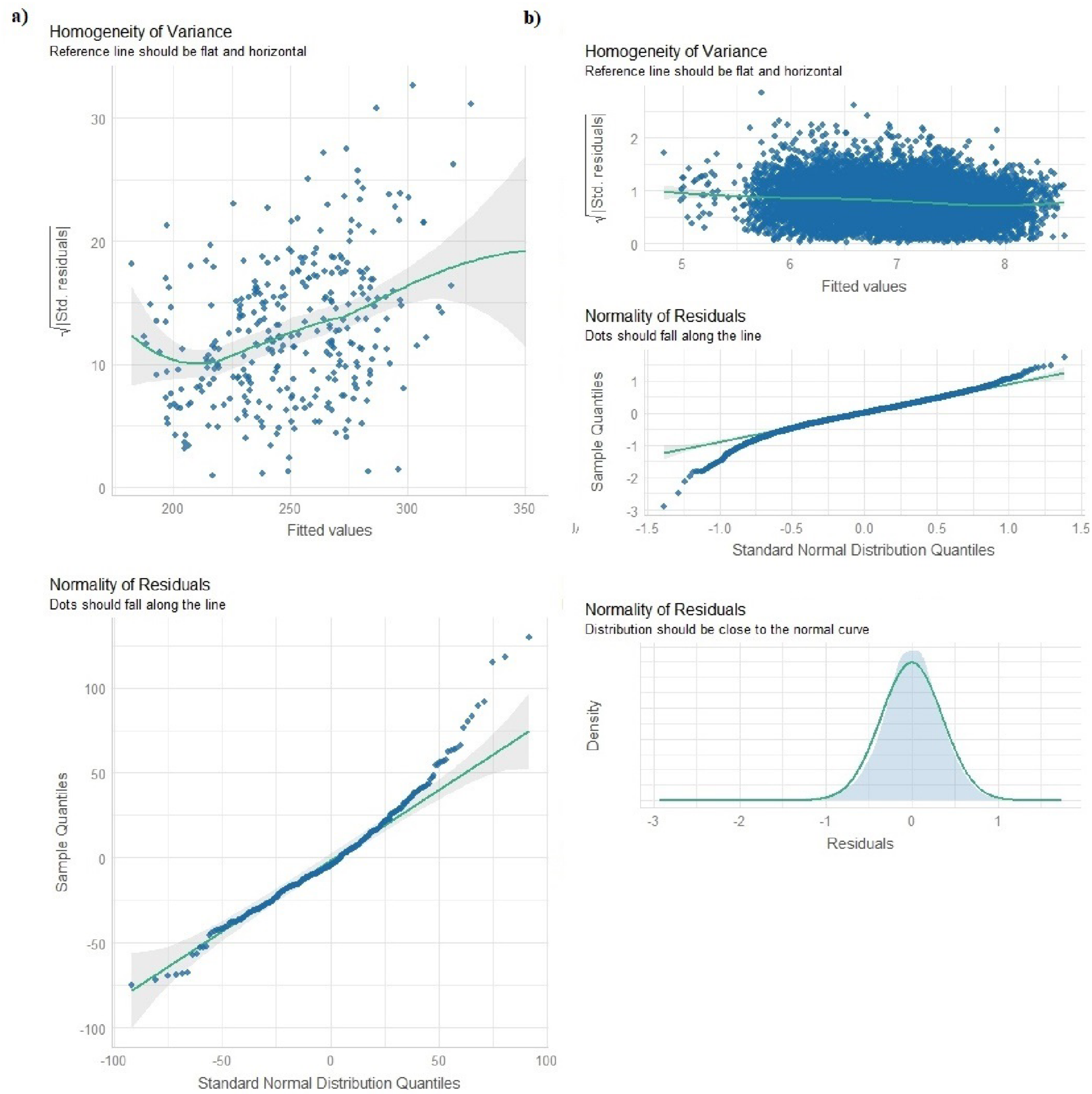

Fig. S6 Longevity and growth model residual diagnostics.

Linear model assumptions of homogeneity of variance, normality and residual distribution through residual analysis for the longevity model (**a**) and the growth model (**b**).

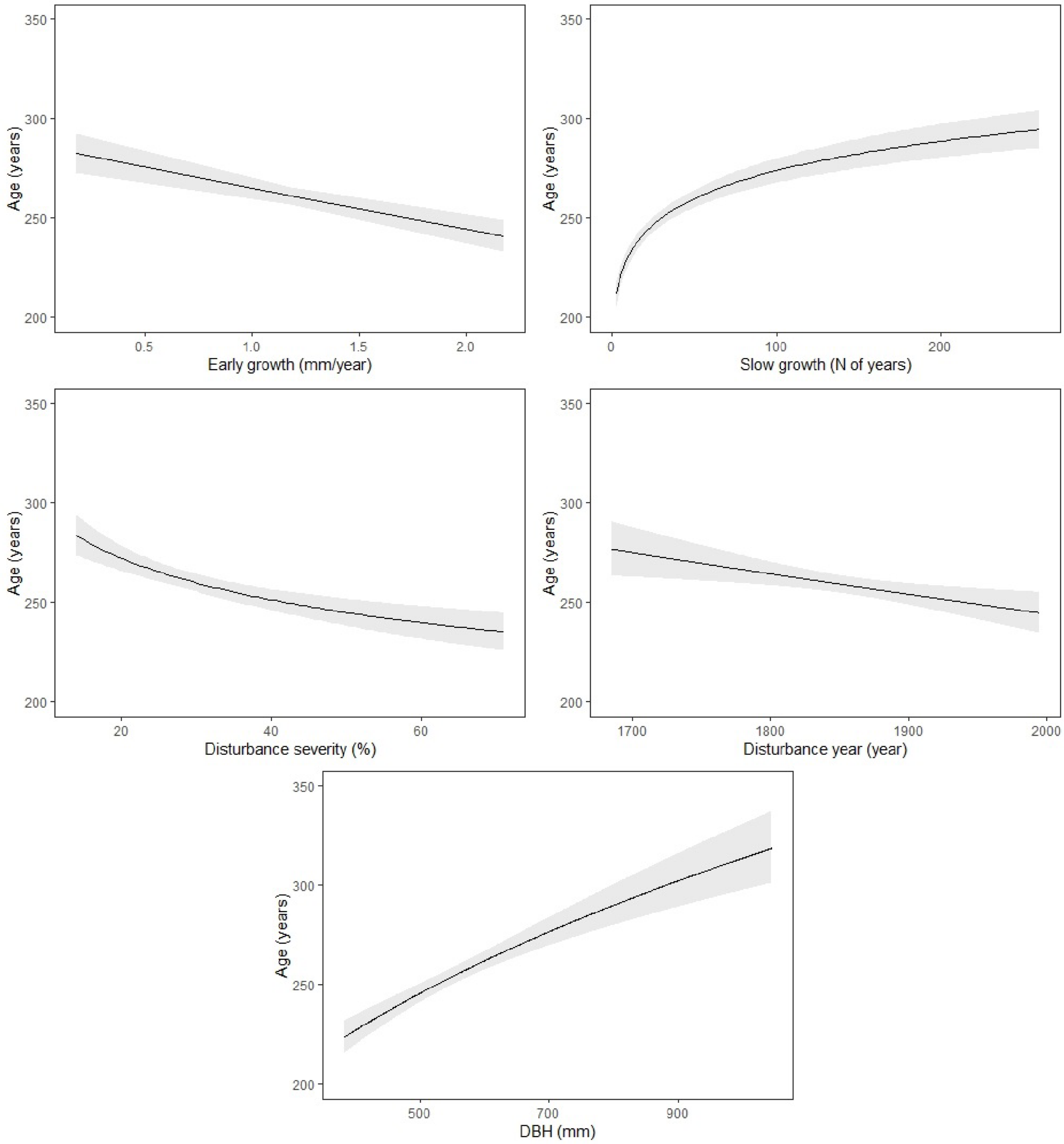

Fig. S7. Modeled effects of the significant predictors from the longevity model.

Predicted age is modeled against the predictors: *early growth* (as average growth in first 50 years of a trees life), *slow growth* (as N of years with 5-yr intervals of mean growth < 0.5 mm/year), *disturbance severity* (as % of canopy disturbed), *disturbance year* (as year of the last most severe disturbance event), and size (as *DBH* in mm). Each curve consists of the mean response (line) and 95% confidence interval (shaded bands).

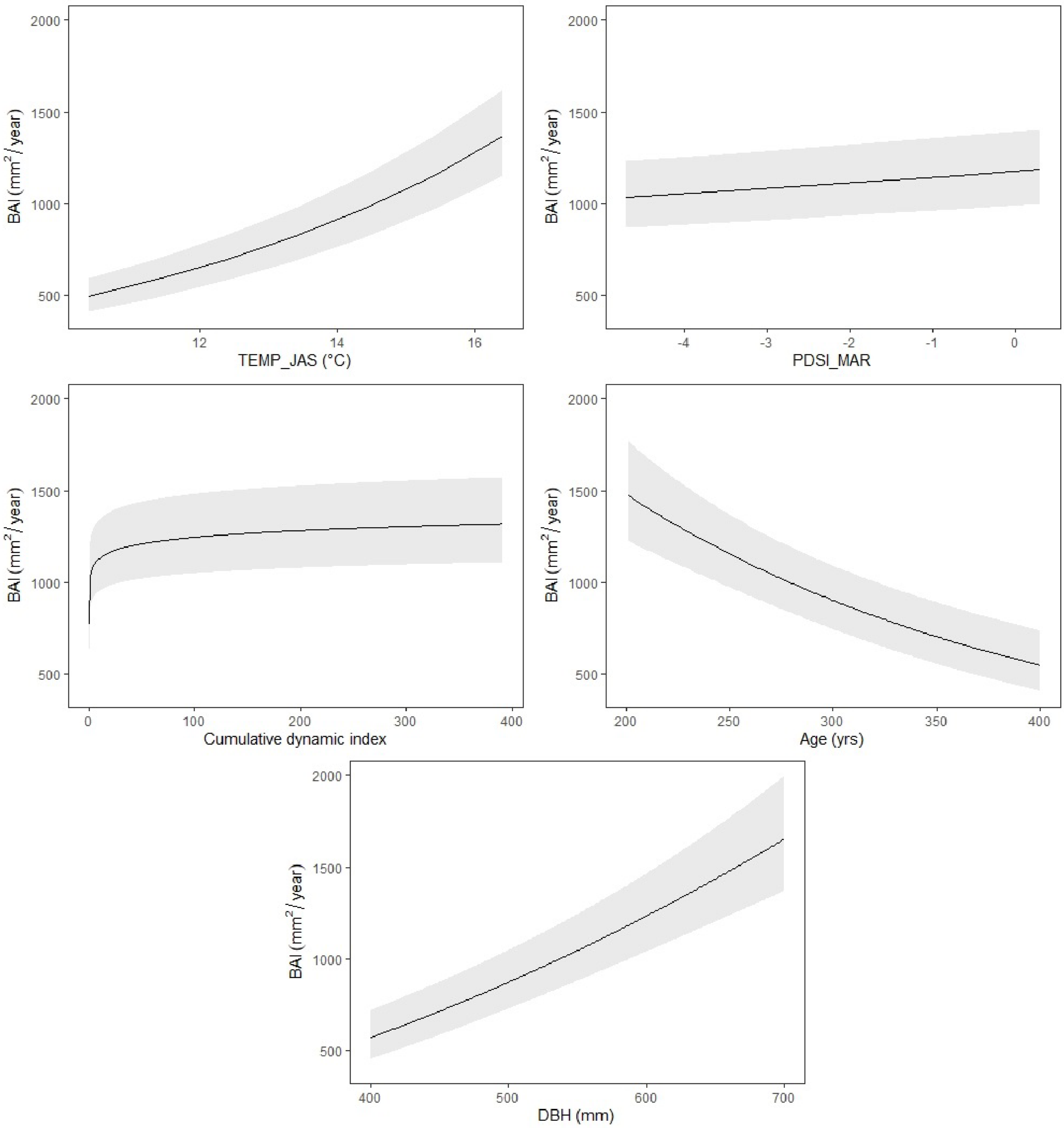

Fig. S8. Modeled effects of the significant predictors from the growth model.

Predicted growth is shown against the main predictors: *TEMP_JAS* (as aggregated mean temperature of months July-August-September), *PDSI_MAR* (as self-calibrated PDSI moisture index for March), *cumulative dynamic index* (as accumulated values from dynamic competition index), *Age* (as tree age) and *DBH* (as diameter at year of coring). Each curve consists of the mean response (line) and 95% confidence interval (shaded bands).

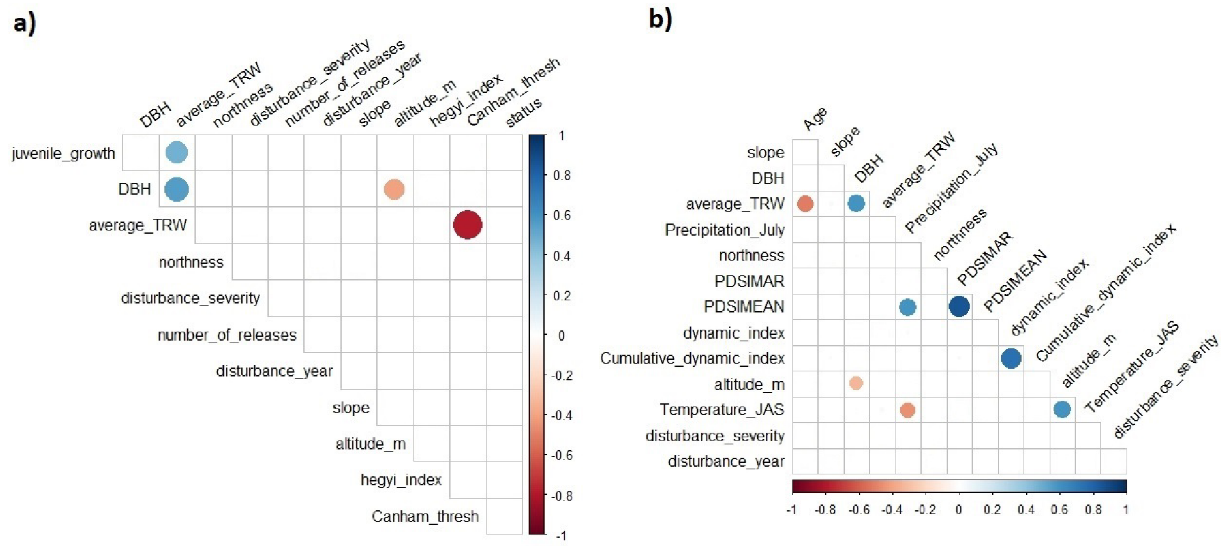

Fig. S9 Correlation matrix of all considered predictor variables.

(**a**) shows the Spearman's correlation matrix between predictors of the full longevity model, while (**b**) shows the Spearman's correlation matrix between the predictors of the full growth model. Significant correlations (r > 0.3, $P < 0.001$) are shown as *circles* of different sizes and colours. Non-significant interactions are omitted from the matrix (blank boxes).

TABLES:

Table S1. List of predictor variables from the GLMMs.

Variable category	Variable name	Variable type	Unit	Min	Max	Mean
Disturbance parameters						
	Disturbance severity	Numerical	%	14	95	36.76
	Disturbance year	Numerical	year	1685	1996	1876
Individual tree-life histories						
	Early growth rate	Numerical	mm/year	0.09	5.63	1.58
	Suppression	Numerical	N of years	0	296	25.31
Tree competition						
	Hegyi index	Numerical	-	0.05	6.04	1.95
	Cumulative dynamic index	Numerical	-	0.28	786.44	66.18
Site attributes						
	Slope	Numerical	°	4	32	26.23
	Aspect	Numerical	°	0	359	204
	Bedrock type	Categorical	-	-	-	-
Climate information						
	Mean temperature July-September	Numerical	°C	12.75	16.44	15.78
	Total precipitation	Numerical	mm/year	595.5	943.6	655.6
	scPDSI March	Numerical	-	-2.71	-0.09	-0.46

Table S2 Summary of linear mixed models testing for the interacting effects of growth decade and tree age class on decadal growth (TRW & BAI) of live and dead trees.

Numerator and denominator degrees of freedom approximated by the Satterthwaite's method (Num/Den DF), test statistics (F) and probabilities (p) are displayed for fixed effects. For random effects, hierarchy of variance components is shown in terms of standard deviations (τ) between stands, between plots and between trees. Likelihood ratio tests statistics (χ^2) and associated probabilities are given for random effect parameters and the whole models. Marginal (R^2_m) and conditional determination coefficients (R^2_c) are also tabulated.

	Living trees						Dead trees					
	Growth TRW			Growth BAI			Growth TRW			Growth BAI		
Fixed effects	Num/Den DF	F	p	Num/Den DF	F	p	Num/Den DF	F	P	Num/Den DF	F	p
Age class	6/2338	11.9	< 0.0001	6/2345	13.8	< 0.0001	5/444	3.0	0.0112	5/445	5.0	0.0002
Decade	9/20320	30.8	< 0.0001	9/20325	312.6	< 0.0001	9/3891	34.6	< 0.0001	9/3890	113.1	< 0.0001
Age class × decade	54/20333	17.2	< 0.0001	54/20333	16.4	< 0.0001	45/3890	9.9	< 0.0001	45/3890	9.2	< 0.0001
Random effects	τ	χ^2	p	τ	χ^2	p	τ	χ^2	p	τ	χ^2	p
Stand	0.089	83.3	< 0.0001	0.335	80.5	< 0.0001	0.058	6.1	0.0138	0.230	9.7	0.0018
Plot(stand)	0.066	57.3	< 0.0001	0.259	84.6	< 0.0001	0.096	28.5	< 0.0001	0.339	22.9	< 0.0001
Tree(plot(stand))	0.189	7518.8	< 0.0001	0.681	13464.0	< 0.0001	0.159	991.8	< 0.0001	0.607	1810.6	< 0.0001
Whole model	R^2_m/R^2_c	χ^2	p	R^2_m/R^2_c	χ^2	p	R^2_m/R^2_c	χ^2	p	R^2_m/R^2_c	χ^2	p
	0.09/0.56	13455	< 0.0001	0.28/0.77	26453	< 0.0001	0.17/0.59	2798	< 0.0001	0.27/0.74	4612	< 0.0001

Table S3 Summary statistics of RWI chronologies for the common interval 1980–2018.

Shown are stand-level residual chronologies of LOT series and the final regional LOT chronology. The acronyms stand for: number of trees (*N*), mean inter-series correlation (*rbar*), expressed population signal (*EPS*), signal-to-noise ratio (*SNR*) and mean sensitivity (*MS*).

Stand	N of trees	rbar	EPS	SNR	MS
Bielovodska dolina	34	0.322	0.934	14.239	0.247
Bystra	19	0.239	0.848	5.558	0.194
Dumbier	32	0.405	0.95	18.99	0.252
Hlina	19	0.384	0.911	10.205	0.278
Janošikova Kolkaren	52	0.414	0.971	33.654	0.220
Javorova dolina	23	0.365	0.919	11.389	0.243
Koprova dolina	30	0.243	0.893	8.316	0.224
Žadne Medodoly	8	0.368	0.821	4.591	0.185
Osobita	32	0.257	0.904	9.425	0.223
Pilsko	35	0.608	0.981	48.379	0.272
Polana	14	0.205	0.781	3.565	0.202
Smrekovica	13	0.518	0.925	12.301	0.226
Ticha dolina	12	0.348	0.863	6.31	0.254
Regional chronology	323	0.334	0.993	141.95	0.237

Table S4. Likelihood ratio tests and the analysis of deviance of the longevity and the growth models. Final models include the fixed effects of relevant predictors of age and BAI, respectively. Models show results of the analysis of deviance and changes in AIC by a stepwise algorithm that excluded each individual predictor and then refitted the model without that predictor. The full model is determined by ΔAIC value of zero and is given in bold and italics. Additionally, P-values from the Chi-square test were given to indicate the probability of significant change in log-likelihood by including a predictor in the final model.

Longevity model				
Predictor dropped	**AIC**	**ΔAIC**	**LRT**	**Pr > Chi**
none (full model)	***3120***	***0***	-	-
Slope	3114.2	5.8	- 4.0	1
Northness	3113.6	6.4	- 4.6	1
Juvenile growth	3165.7	- 45.7	47.5	< 0.001***
(log) DBH	3137.6	-17.6	19.5	< 0.001***
(log) Supression	3231.2	-111.2	113.1	< 0.001***
(log) disturbance severity	3136.8	-16.8	18.7	< 0.001***
Disturbance year	3118.4	1.6	1.3	0.4*
(log) Hegyi index	3111.2	8.8	- 6.9	1

Growth model				
Predictor dropped	**AIC**	**ΔAIC**	**LRT**	**Pr > Chi**
none (full model)	***9213.5***	***0***	-	-
Slope	9211.6	1.9	0.12	0.7
Northness	9211.8	1.7	0.24	0.6
Bedrock	9207.4	6.1	1.93	0.7
(log) DBH	9282.3	- 68.8	70.79	< 0.001***
Age	9248.1	- 34.6	36.63	< 0.001***
(log) Disturbance severity	9212.0	1.5	0.45	0.5
Disturbance year	9211.5	2.0	0.02	0.9
TEMPJAS	9824.9	- 611.4	613.40	< 0.001***
PDSIMAR	9239.0	- 25.5	27.53	< 0.001***
(log) Cumulative dynamic index	9296.9	- 83.4	85.34	< 0.001***

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4.3. SPATIOTEMPORAL CHANGES IN DROUGHT SENSITIVITY CAPTURED BY MULTIPLE TREE-RING PARAMETRS OF CENTRAL EUROPEAN CONIFERS – S3

Spatiotemporal changes in drought sensitivity captured by multiple tree-ring parameters of Central European conifers by Krešimir Begović, Miloš Rydval, Jan Tumajer, Kristyna Svobodova, Thomas Langbehn, Yumei Jiang, Vojtech Čada, Vaclav Treml, Miroslav Svoboda.

The following Supplementary data are available for this article:

Tables:

Table S1 Descriptive statistics of RWI and BI Norway spruce chronologies for the common interval 1950–2018.

Table S2 Descriptive statistics of RWI and BI Scots pine chronologies for the common interval 1950–2018.

Table S3 Limit thresholds used for the generation of randomized combinations of parameters for the VS-Lite process-based models.

Table S4 Optimal parameters of the VS-Lite model are also given for individual sites.

Table S5 Pearson's correlation coefficients between simulated and observed chronologies during their respective calibration and verification periods. Values exceeding 0.33 are considered as significant with p-value < 0.05.

Figures:

Figure S1 Regional climatic trends in Czechia and Slovakia.

Figure S2 $LWBI_{inv}$ site chronologies.

Figure S3 Running r-bar and EPS of RWI site chronologies.

Figure S4 Running r-bar and EPS of EWBI site chronologies.

Figure S5 Running r-bar and EPS of $LWBI_{inv}$ site chronologies.

Figure S6 Running r-bar and EPS of ΔBI site chronologies.

Figure S7 Biplot of the principal components and the cluster dendrogram of RWI and BI parameters site chronologies.

Figure S8 Correlation response function analysis of individual RWI site chronologies.

Figure S9 Correlation response function analysis of individual EWBI site chronologies.

Figure S10 Correlation response function analysis of individual $LWBI_{inv}$ site chronologies.

Figure S11 Correlation response function analysis of individual ΔBI site chronologies.

Figure S12 Temporal climate signal stability of the RWI site chronologies.

Figure S13 Temporal climate signal stability of the EWBI site chronologies.

Figure S14 Temporal climate signal stability of the $LWBI_{inv}$ site chronologies.

Figure S15 Temporal climate signal stability of the ΔBI site chronologies.

Figure S16 Moving correlation analysis of PCAB and PISY with growing season moisture index.

Figure S17 VS-lite output of modeled and observed chronologies.

Figure S18 Monthly partial RW growth responses to temperature (red line) and soil moisture (blue line) for individual sites.

Table S1 Descriptive statistics of RWI and BI Norway spruce chronologies for the common interval 1950–2018.

Shown are TRW and BI chronologies of each site over the overlapping period. The acronyms stand for: sample depth (*N of trees*), mean RWI (*mean*), median RWI (*median*), standard deviation (*stdev*), skewness of data (*skew*), Gini coefficient of inequality (*Gini*), first order autocorrelation (*AR1*).

	SITE	*TR PARAMETER*	*CHRONO VERSION*	*N OF TREES*	*mean*	*median*	*stdev*	*skew*	*gini*	*ar1*
PIAB LOW ELEVATION SITES	**JEB**	**TRW**	**std**	38	1.054	1.035	0.227	0.256	0.121	0.52
			res		1.001	1.015	0.185	0.005	0.103	-0.113
		EWBI	**std**		1.003	1.003	0.009	-0.834	0.005	0.198
			res		1.002	1.002	0.009	-0.275	0.005	-0.06
		ΔBI	**std**		1.003	1.005	0.043	-0.108	0.024	0.123
			res		1	1.004	0.044	-0.348	0.024	-0.16
	STS	**TRW**	**std**	35	0.963	0.914	0.329	0.432	0.192	0.764
			res		0.992	0.97	0.194	0.584	0.106	-0.047
		EWBI	**std**		1.011	1.01	0.015	0.08	0.008	0.229
			res		1.007	1.006	0.014	-0.111	0.008	-0.062
		ΔBI	**std**		1.009	1.008	0.053	-0.353	0.029	-0.049
			res		1.003	1.008	0.053	-0.539	0.029	-0.338
	RAS	**TRW**	**std**	41	1.074	1.015	0.33	0.569	0.169	0.384
			res		1.02	1.004	0.295	0.281	0.159	-0.045
		EWBI	**std**	36	1.002	1.001	0.015	-0.361	0.008	0.312
			res		1.001	1.001	0.013	-0.133	0.007	0.08
		ΔBI	**std**		1.007	1.02	0.075	-0.604	0.041	-0.072
			res		1.006	1.023	0.075	-0.664	0.041	-0.204
	REJ	**TRW**	**std**	41	0.922	0.931	0.217	0.02	0.131	0.637
			res		0.993	0.989	0.162	-0.426	0.09	-0.063
		EWBI	**std**	30	1.004	1.005	0.017	-1.01	0.009	0.324
			res		1.002	1.004	0.015	-0.54	0.008	0.04
		ΔBI	**std**		1.004	1.02	0.079	-0.805	0.043	0.133
			res		1.002	1.022	0.076	-0.94	0.041	-0.205
	POL	**TRW**	**std**	42	1.063	1.032	0.198	0.673	0.101	0.442
			res		1.004	1.005	0.175	0.119	0.098	-0.205
	HRS	**TRW**	**std**	40	1.001	1.037	0.332	-0.287	0.188	0.813
			res		0.982	0.967	0.175	0.075	0.1	0.08
		EWBI	**std**		1.006	1.009	0.018	-0.964	0.009	0.113
			res		1.003	1.004	0.017	-0.431	0.009	-0.214
		ΔBI	**std**		1.003	1.003	0.06	-0.896	0.032	0.245
			res		1.002	1.004	0.053	-0.752	0.029	-0.185
PIAB HIGH ELEVATION SITES	**OST**	**TRW**	**std**	40	0.979	0.966	0.221	0.258	0.128	0.656
			res		0.991	0.994	0.147	-0.058	0.083	-0.237
		EWBI	**std**		1.004	1.004	0.01	-0.035	0.006	0.231
			res		1.002	1.003	0.01	0.222	0.006	-0.147
		ΔBI	**std**		1.002	1.005	0.064	-0.655	0.035	0.186
			res		1.002	1.017	0.059	-0.824	0.032	-0.235
	DIV	**TRW**	**std**	44	0.915	0.34	0.743	0.183	0.782	0.915
			res		1.025	0.188	-0.329	0.103	0.044	1.025
	SMR	**TRW**	**std**	47	0.949	0.824	0.344	1.102	0.191	0.827
			res		1.003	1.001	0.162	0.712	0.088	0.066
		EWBI	**std**	33	1.007	1.009	0.014	-0.598	0.008	0.398
			res		1.003	1.003	0.012	-0.29	0.007	0.021
		ΔBI	**std**		0.986	0.991	0.101	-0.565	0.056	0.328
			res		0.994	1	0.083	-0.586	0.046	-0.18
	CHO	**TRW**	**std**	43	0.975	0.986	0.138	-0.12	0.08	0.318
			res		0.999	1.009	0.132	-0.161	0.074	-0.189
	JAV	**TRW**	**std**	59	0.916	0.861	0.256	0.764	0.154	0.689
			res		0.994	0.981	0.169	0.252	0.096	-0.091
		EWBI	**std**	43	1.002	1.004	0.015	-0.104	0.009	0.202
			res		1.001	1.001	0.015	-0.242	0.008	-0.151
		ΔBI	**std**		0.999	1.019	0.101	-0.893	0.054	0.044
			res		0.997	1.016	0.093	-0.645	0.051	-0.318

Table S2 Descriptive statistics of RWI and BI Scots pine chronologies for the common interval 1950–2018.

Shown are TRW and BI chronologies of each site over the overlapping period. The acronyms stand for: sample depth (*N of trees*), mean RWI (*mean*), median RWI (*median*), standard deviation (*stdev*), skewness of data (*skew*), Gini coefficient of inequality (*Gini*), first order autocorrelation (*AR1*).

	SITE	*TR PARAMETER*	*CHRONO VERSION*	*N OF TREES*	*mean*	*median*	*stdev*	*skew*	*gini*	*ar1*
PISY LOW ELEVATION SITES	**RAS**	**TRW**	**std**	51	1.024	0.994	0.215	0.32	0.117	0.368
			res		1.005	0.993	0.2	0.133	0.113	-0.102
		EWBI	**std**	21	1.006	1.01	0.021	-0.557	0.011	0.444
			res		1.004	1.008	0.018	-0.533	0.01	0.24
		ΔBI	**std**		1.007	1.018	0.079	-0.762	0.042	0.018
			res		1.006	1.016	0.081	-0.945	0.043	-0.177
	RUZ	**TRW**	**std**	42	0.955	0.925	0.305	0.723	0.176	0.626
			res		0.99	0.972	0.223	0.732	0.123	-0.078
		EWBI	**std**	36	1.014	1.016	0.018	-0.102	0.009	0.48
			res		1.009	1.01	0.015	-0.238	0.008	0.337
		ΔBI	**std**		1.007	1.01	0.112	-0.185	0.063	0.325
			res		1	0.998	0.099	-0.24	0.055	-0.099
	KOS	**TRW**	**std**	49	1.131	1.086	0.364	0.867	0.175	0.557
			res		1.008	1.005	0.283	0.61	0.151	0.064
		EWBI	**std**	27	1.007	1.008	0.014	0.049	0.008	0.563
			res		1.004	1.004	0.011	0.27	0.006	0.196
		ΔBI	**std**		0.998	1.015	0.115	-1.215	0.06	0.425
			res		1	1.011	0.103	-0.761	0.056	0.094
	PRA	**TRW**	**std**	51	0.974	0.946	0.208	0.367	0.12	0.4
			res		0.985	0.966	0.178	0.241	0.1	-0.164
		EWBI	**std**	20	1.01	1.008	0.019	0.271	0.011	0.581
			res		1.004	1.004	0.015	0.072	0.008	0.171
		ΔBI	**std**		1.007	1.024	0.139	-0.661	0.076	0.114
			res		1.007	1.038	0.136	-0.86	0.073	-0.125
	LUB	**TRW**	**std**	43	1.024	1.008	0.235	0.118	0.128	0.668
			res		1.011	1.014	0.15	-0.122	0.082	-0.118
	LET	**TRW**	**std**	58	0.909	0.902	0.2	0.208	0.124	0.2
			res		0.977	1.003	0.193	-0.157	0.112	-0.205
PISY HIGH ELEVATION SITES	**BRE**	**TRW**	**std**	42	0.943	0.94	0.224	0.209	0.132	0.559
			res		0.989	0.981	0.176	0.356	0.098	-0.108
		EWBI	**std**		1.005	1.007	0.019	-0.779	0.01	0.288
			res		1.003	1.003	0.017	-0.947	0.009	-0.105
		ΔBI	**std**		1.001	1.005	0.075	-1.166	0.039	0.316
			res		0.999	1	0.069	-1.051	0.036	-0.064
	SUC	**TRW**	**std**	50	1.062	1.024	0.179	0.401	0.094	0.483
			res		1.012	1.014	0.154	0.161	0.082	-0.176
		EWBI	**std**	33	1.002	1.004	0.016	-0.908	0.009	0.468
			res		1	1	0.012	-0.173	0.007	0.007
		ΔBI	**std**		1.005	1.012	0.077	-0.657	0.042	0.041
			res		1.004	1.006	0.078	-0.749	0.043	-0.216
	TMA	**TRW**	**std**	44	1.083	1.094	0.258	-0.187	0.133	0.43
			res		1.025	1.034	0.225	-0.212	0.119	-0.138
		EWBI	**std**	37	1.011	1.008	0.022	0.048	0.012	0.482
			res		1.005	1.005	0.018	0.002	0.01	0.079
		ΔBI	**std**		1.011	1.016	0.134	-0.742	0.073	0.139
			res		1.007	1.013	0.133	-0.903	0.071	-0.167
	3KP	**TRW**	**std**	52	0.932	0.947	0.17	-0.137	0.102	0.44
			res		0.994	1.013	0.141	-0.39	0.079	-0.185
	PAL	**TRW**	**std**	42	1.044	1.02	0.241	0.561	0.128	0.505
			res		1	1	0.198	0.077	0.109	-0.18
		EWBI	**std**		1.004	1.006	0.018	-0.456	0.01	0.382
			res		1.002	1.002	0.016	-0.497	0.009	0.062
		ΔBI	**std**		1.02	1.026	0.101	-0.199	0.056	0.214
			res		1.006	1.024	0.093	-0.538	0.051	-0.219
	TLO	**TRW**	**std**	47	0.951	0.935	0.228	0.55	0.132	0.6
			res		0.984	0.998	0.171	0.362	0.096	-0.126
		EWBI	**std**	35	1.003	1.005	0.012	-0.983	0.006	0.155
			res		1.002	1.003	0.012	-0.581	0.006	-0.17
		ΔBI	**std**		1.004	1.016	0.073	-0.623	0.04	0.34
			res		1.001	1.015	0.067	-0.52	0.037	-0.094

Table S3 Limit thresholds used for the generation of randomized combinations of parameters for the VS-Lite process-based models.

Model parameter	Description of the model parameter	Minimum	Maximum
T1	Minimum temperature for growth [°C]	1	11
T2	Lower margin of temperature optimum [°C]	max (8; T1)	20
M1	Minimum moisture for growth [-]	0	0.5*mean annual peak soil moisture
M2	Lower margin of moisture optimum [-]	M1	0.5

Table S4 Optimal parameters of the VS-Lite model are also given for individual sites.

Site category	Site	Model parameters			
		T1	T2	M1	M2
PCAB LOW	HRS	9.6	17.7	0.029	0.06
	JEB	1.2	20.4	0.066	0.148
	POL	2.7	21	0.174	0.199
	RAS_PCAB	2.3	10.7	0.048	0.387
	REJ	1	10.4	0.051	0.576
	STS	1.1	16.8	0.109	0.142
PCAB HIGH	DIV	8.9	11	0.046	0.112
	CHO	9	10.1	0.098	0.412
	JAV	1	16.7	0.055	0.08
	OST	9.9	12	0.01	0.048
	SMR	2.2	14	0.033	0.036
PISY LOW	KOS	2.7	12.3	0.064	0.626
	LET	8.8	13.4	0.028	0.269
	LUB	3.4	12.5	0.016	0.159
	PRA	1.8	12.1	0.136	0.644
	RAS_PISY	1.3	20.6	0.048	0.573
	RUZ	1.3	20.9	0.109	0.161
PISY HIGH	BRE	1.4	12.1	0.002	0.006
	PAL	1.9	19.2	0.001	0.512
	SUC	5.8	20.8	0.002	0.649
	TLO	9.6	22.8	0.051	0.144
	3KP	4.3	11.8	0.027	0.603

Table S5 Pearson's correlation coefficients between simulated and observed chronologies during their respective calibration and verification periods. Values exceeding 0.33 are considered as significant with p-value < 0.05.

Site category	Site	Calibration (1940-1979)	Verification (1980-2018)
		r	r
PCAB LOW ELEVATION	HRS	0.56	0.12
	JEB	0.51	0.56
	POL	0.58	0.54
	RAS_PCAB	0.49	0.54
	REJ	0.52	0.54
	STS	0.62	0.64
PCAB HIGH ELEVATION	DIV	0.59	0.52
	CHO	0.47	0.09
	JAV	0.44	0.55
	OST	0.47	0.49
	SMR	0.54	0.58
PISY LOW ELEVATION	KOS	0.28	0.58
	LET	0.61	0.38
	LUB	0.6	-0.18
	PRA	0.39	0.42
	RAS_PISY	0.55	0.27
	RUZ	0.55	0.41
PISY HIGH ELEVATION	BRE	0.35	0.04
	PAL	0.63	-0.05
	SUC	0.28	0
	TLO	0.41	0.24
	3KP	0.7	0.1

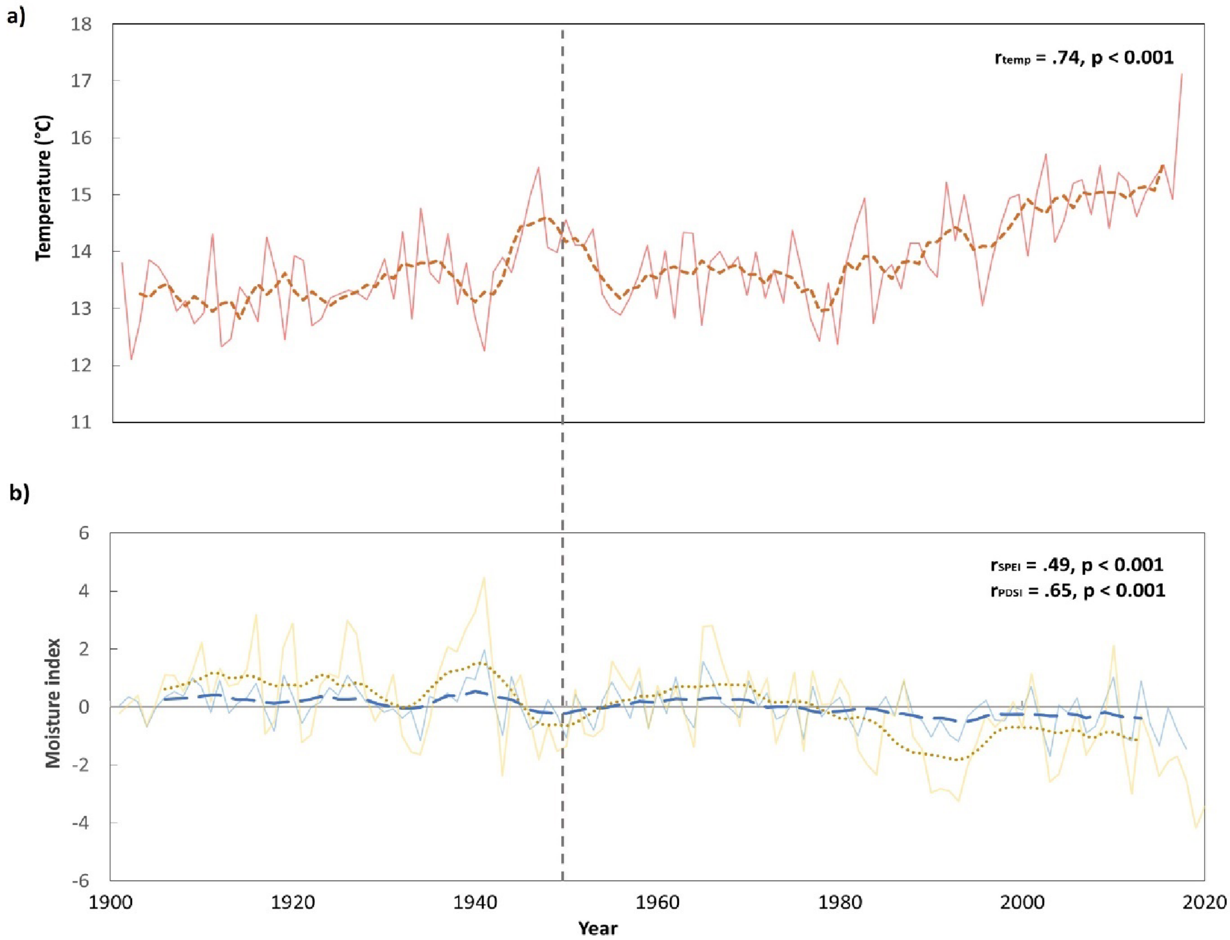

Fig. S1 Regional climatic trends in Czechia and Slovakia.

Shown are mean annual temperature (**a**), scPDSI and SPEI indices (**b**). Dashed vertical black line denotes the starting date of the climate-growth analysis. Trendlines represent the decadal trends of each climatic factor smoothed with a moving 10-yr window smoother over the course of the 20th century. Climate data was pooled for the coordinates of the outermost study sites and serves as a rough temporal representation of regional climate.

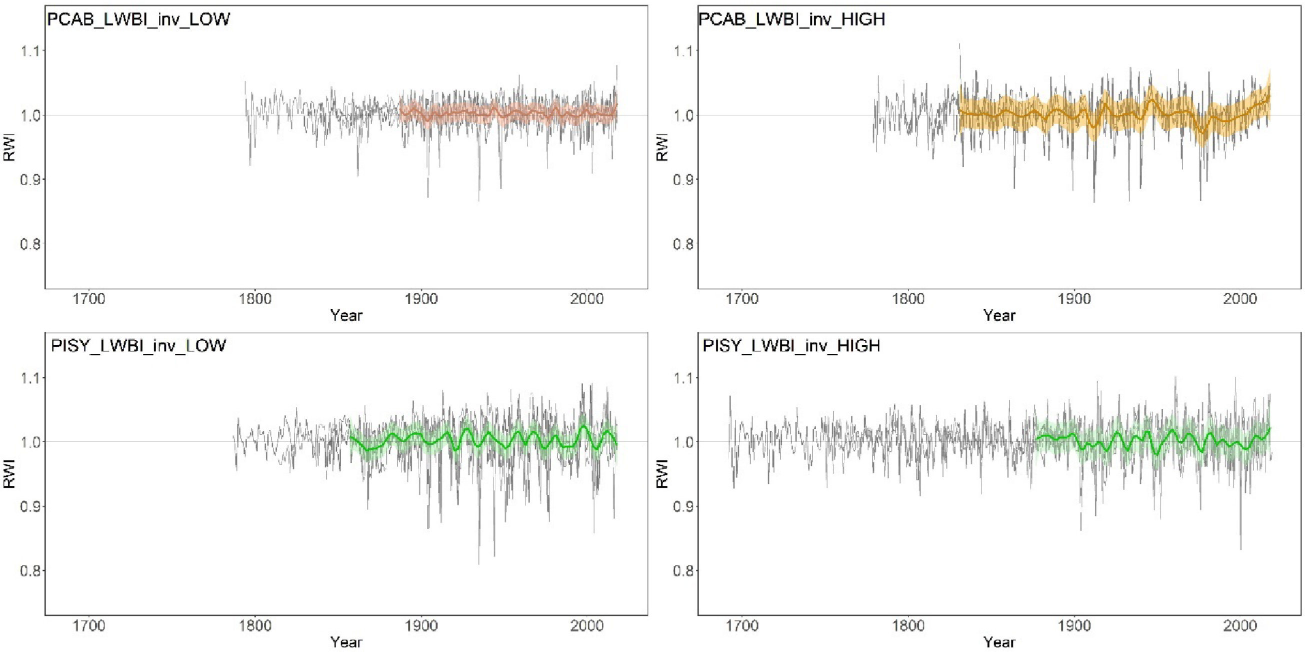

Fig. S2 LWBI$_{inv}$ site chronologies.

Shown are individual residual LWBI$_{inv}$ site chronologies in gray colour and mean chronologies in corresponding colours (see Table 1). Mean chronologies are smoothed based on local regression with minimized sum of squared errors (*loess* function in *ggplot*) and are shown in overlapping years between all site chronologies. Shaded areas represent standard deviation. The individual site chronologies are truncated to the year when the respective minimum replication falls below 5 individual series.

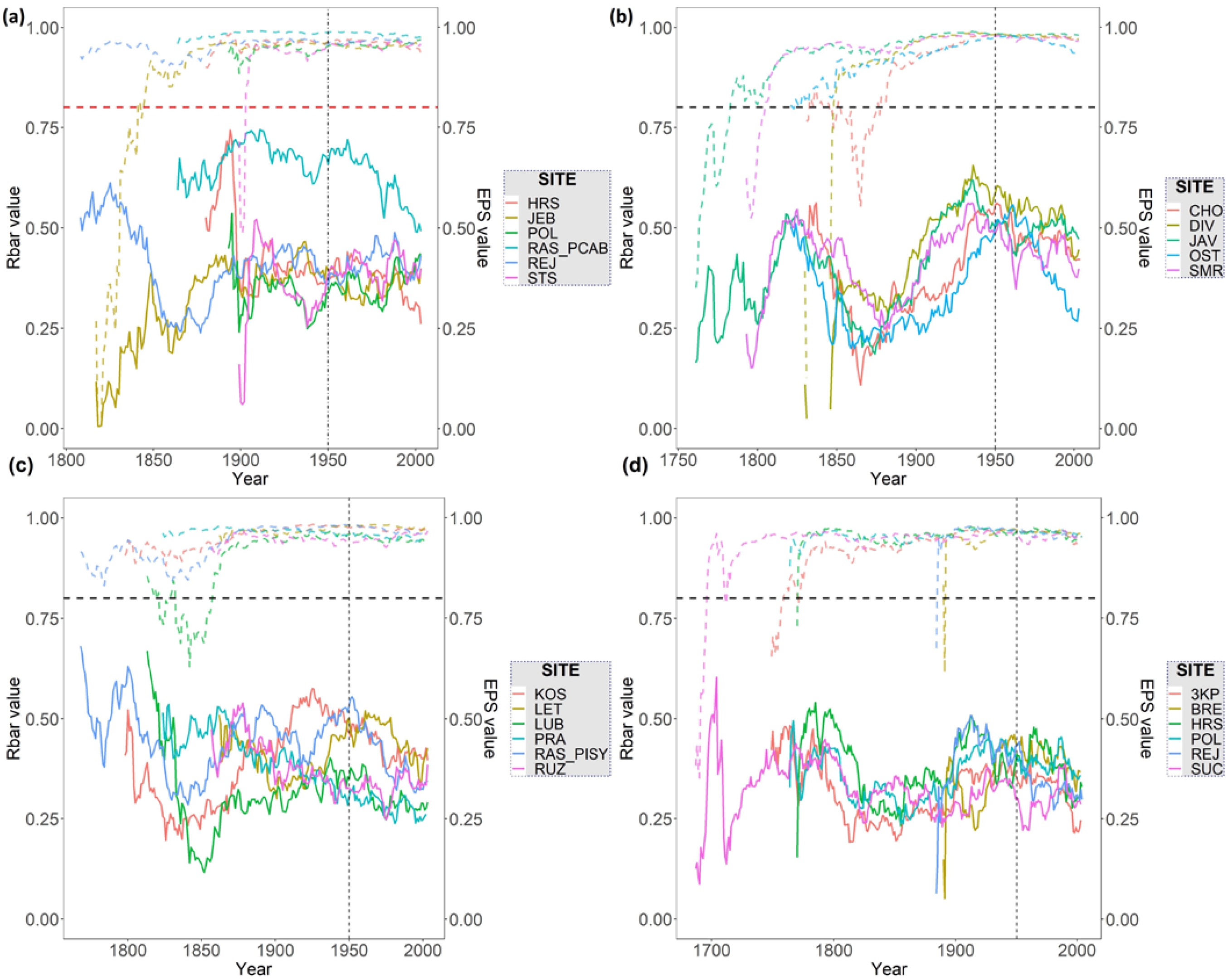

Fig. S3 Running r-bar and EPS of RWI site chronologies in the period 1950-2018.

Shown are EPS (dashed lines) and r-bar (full lines) of PCAB low (**a**), PCAB high (**b**), PISY low (**c**) and PISY high (**d**) residual site chronologies of PCAB low (**a**), PCAB high (**b**), PISY low (**c**) and PISY high (**d**) over the period 1950-2018.

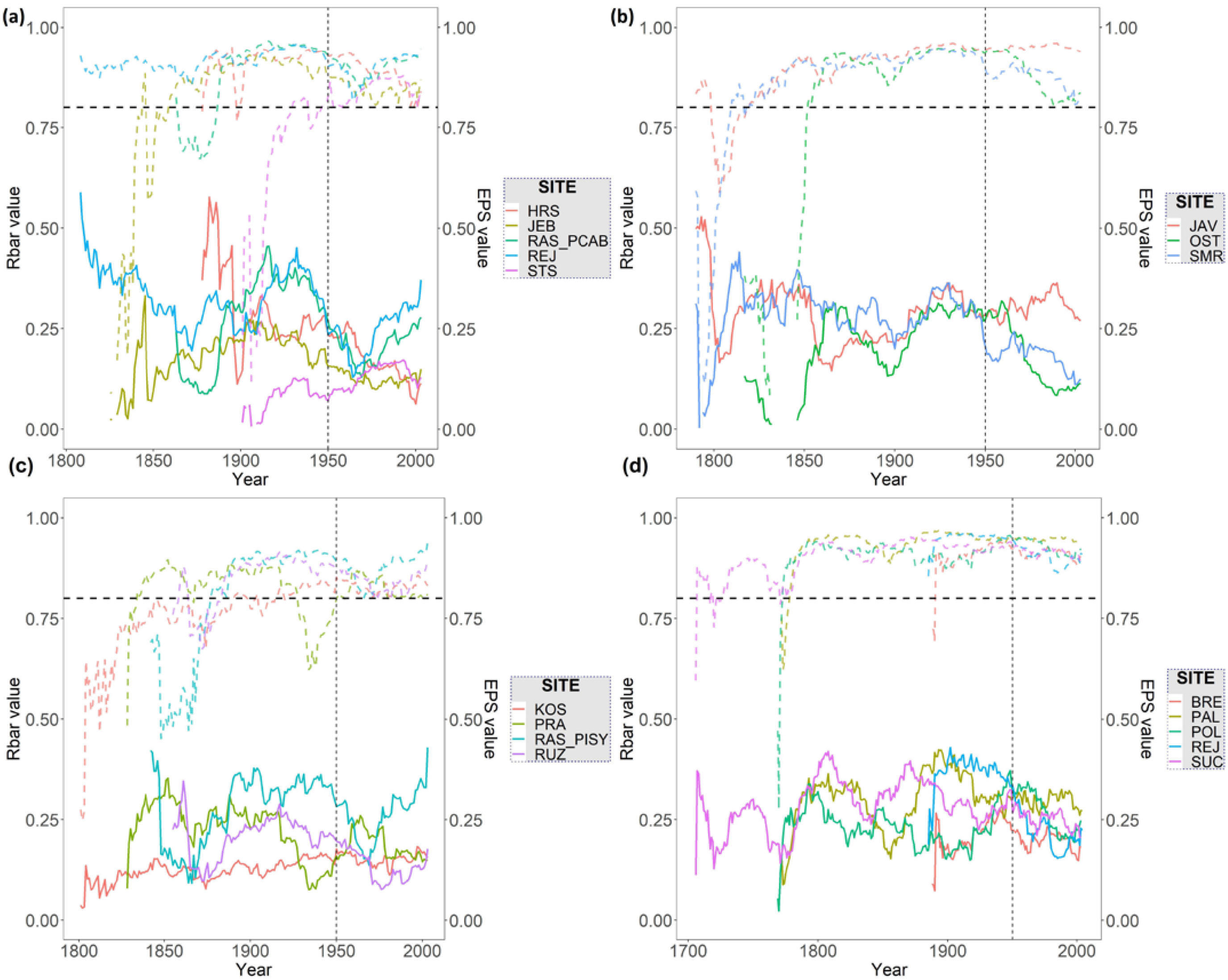

Fig. S4 Running r-bar and EPS of EWBI site chronology in the period 1950-2018.

Shown are EPS (dashed lines) and r-bar (full lines) of PCAB low (**a**), PCAB high (**b**), PISY low (**c**) and PISY high (**d**) residual site chronologies of PCAB low (**a**), PCAB high (**b**), PISY low (**c**) and PISY high (**d**) over the period 1950-2018.

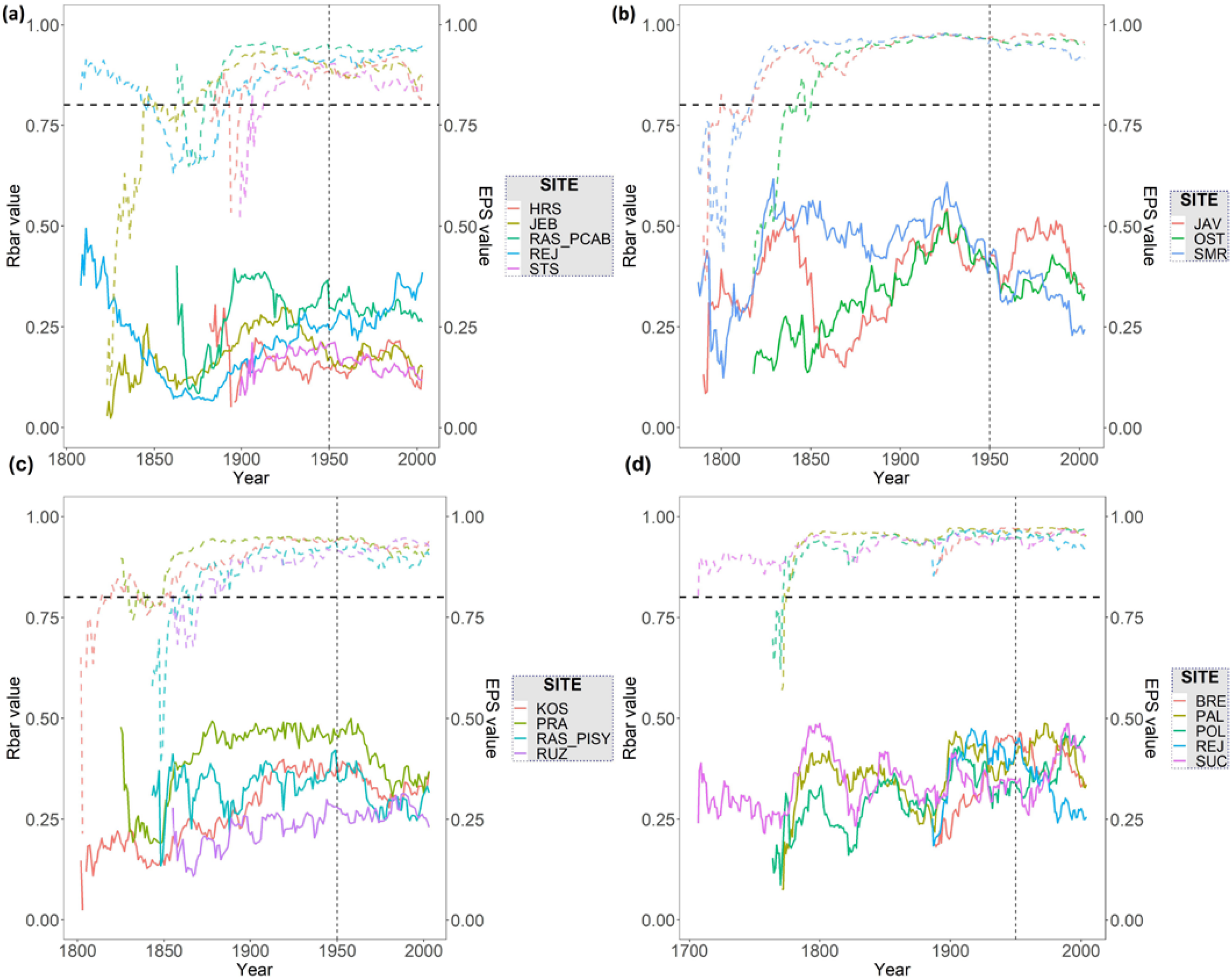

Fig. S5 Running r-bar and EPS of $LWBI_{inv}$ site chronology in the period 1950-2018.

Shown are EPS (dashed lines) and r-bar (full lines) of PCAB low (**a**), PCAB high (**b**), PISY low (**c**) and PISY high (**d**) residual site chronologies of PCAB low (**a**), PCAB high (**b**), PISY low (**c**) and PISY high (**d**) over the period 1950-2018.

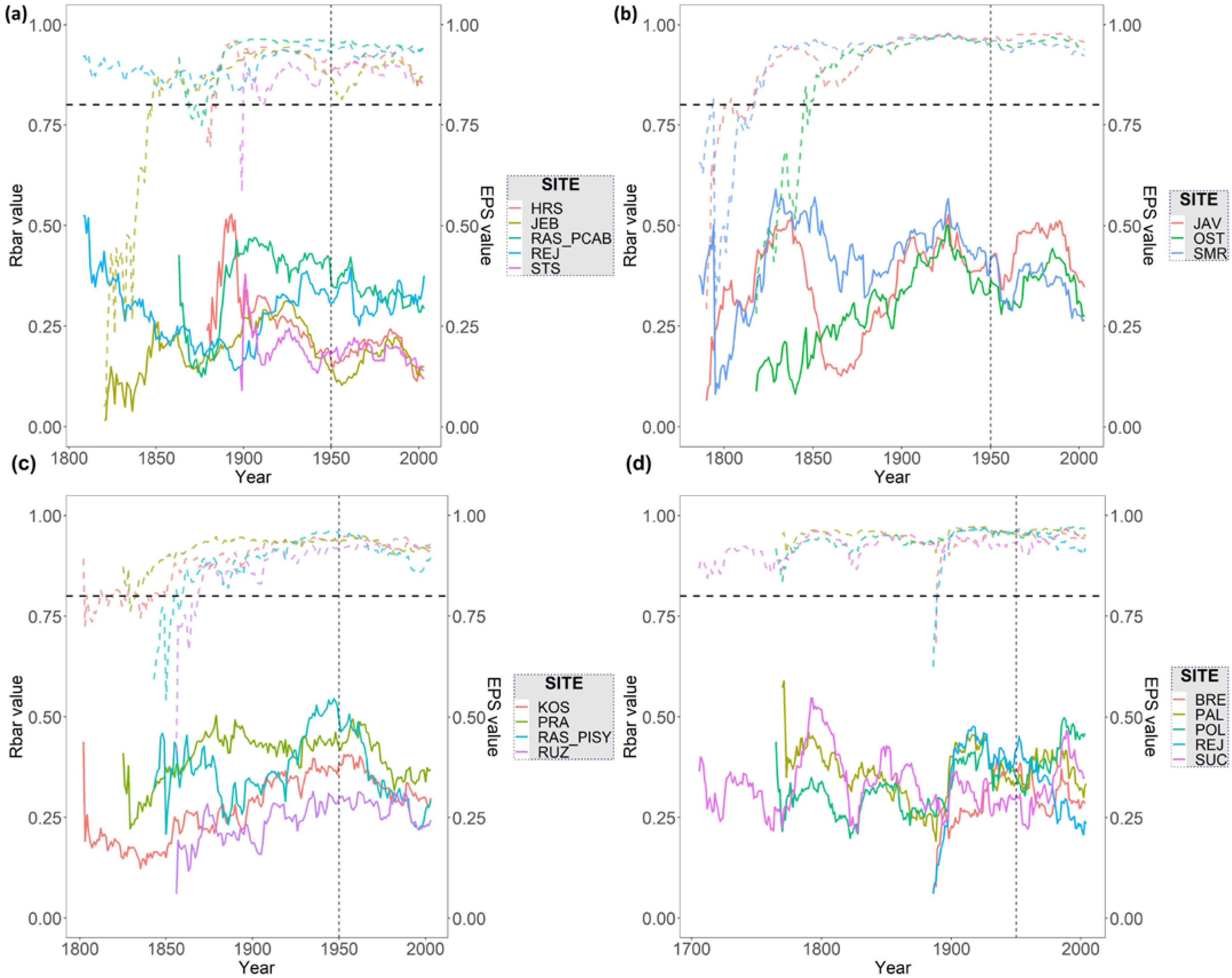

Fig. S6 Running r-bar and EPS of ΔBI site chronology in the period 1950-2018.

Shown are EPS (dashed lines) and r-bar (full lines) of PCAB low (**a**), PCAB high (**b**), PISY low (**c**) and PISY high (**d**) residual site chronologies of PCAB low (**a**), PCAB high (**b**), PISY low (**c**) and PISY high (**d**) over the period 1950-2018.

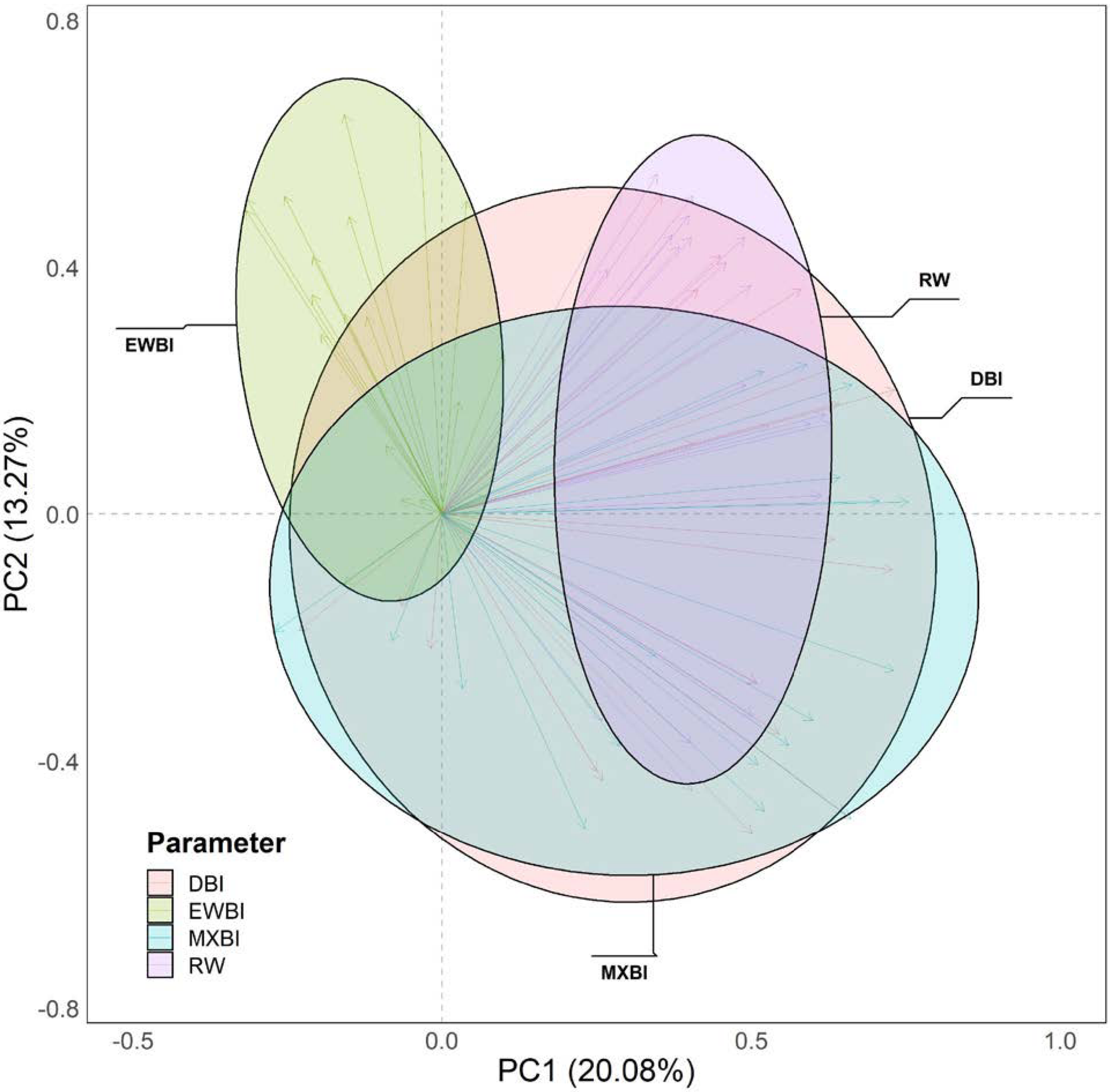

Fig. S7 Biplot of the principal components and the cluster dendrogram of RWI and BI parameters site chronologies.

Shown are the first two principal components of the PCA performed over the common 1950–2018 period. Axis labels in (a) report the percentage of variance explained by the first two components; each arrow corresponds to one of the analysis variables projected onto a two-dimensional plane and proportional to its component loading. The colour of the vectors corresponds to the site categories.

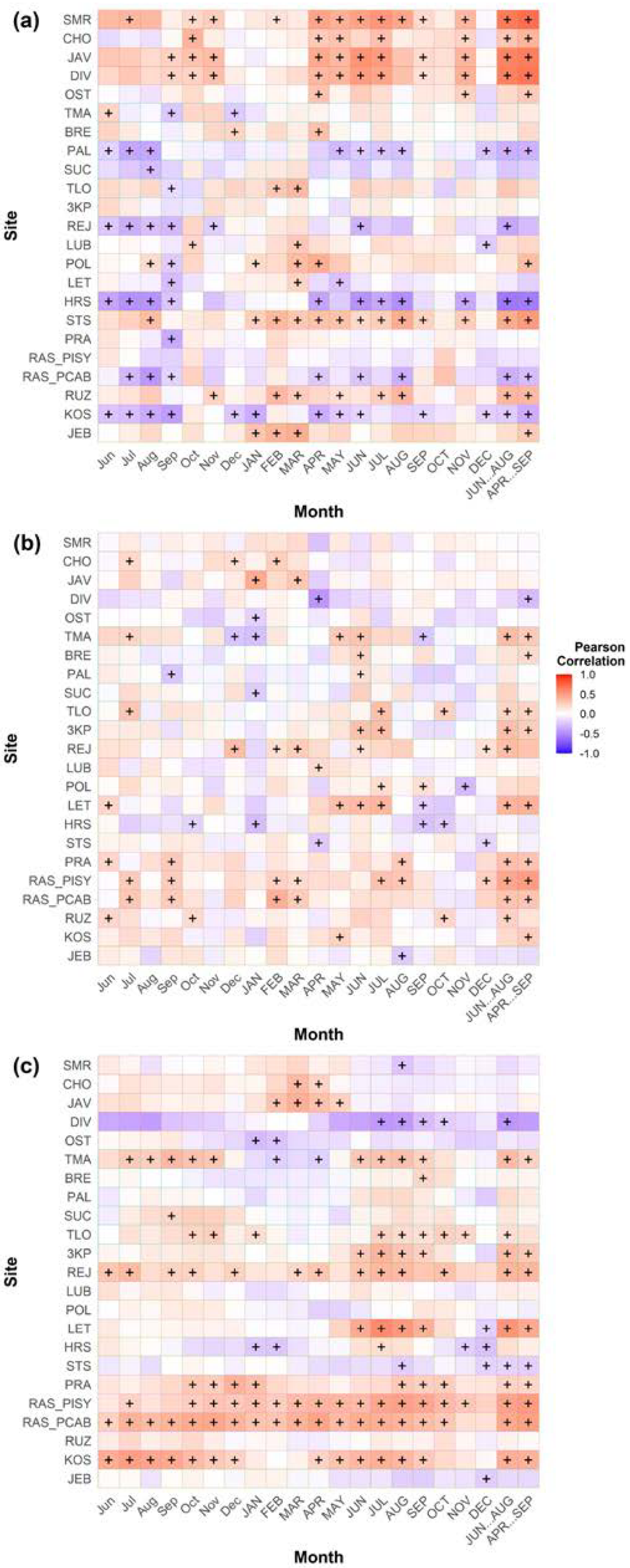

Fig. S8 Correlation response function analysis of individual RWI site chronologies.

Shown are 18-month Pearson's correlation coefficients of residual RWI site chronologies in relation to monthly climatic variables: (**a**) mean temperature, (**b**) precipitation totals and (**c**) mean SPEI-3, for the period 1950-2018. Sites are ordered from the lowest (bottom) to the highest (top) site. Black asterisks indicate statistically significant correlations (p <0.05).

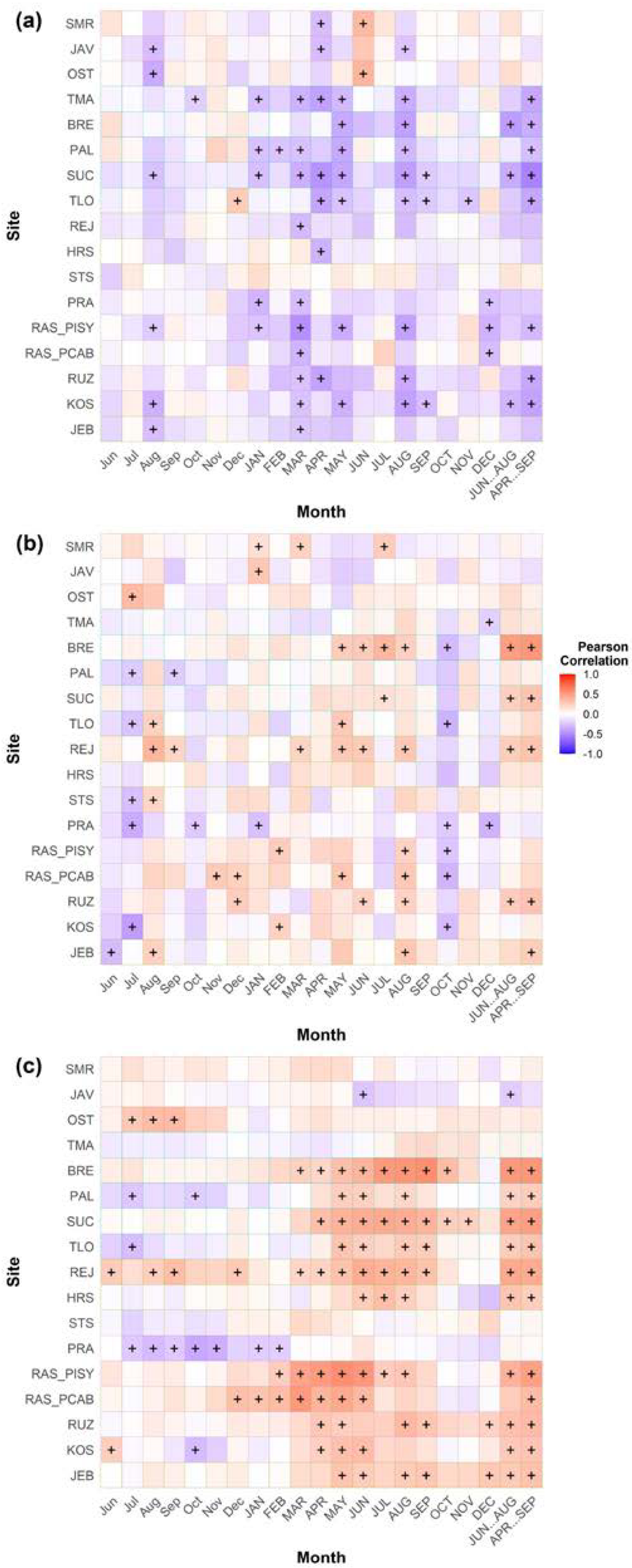

Fig. S9 Correlation response function analysis of individual EWBI site chronologies.

Shown are 18-month Pearson's correlation coefficients of residual EWBI site chronologies in relation to monthly climatic variables: (**a**) mean temperature, (**b**) precipitation totals and (**c**) mean SPEI-3, for the period 1950-2018. Sites are ordered from the lowest (bottom) to the highest (top) site. Black asterisks indicate statistically significant correlations (p <0.05).

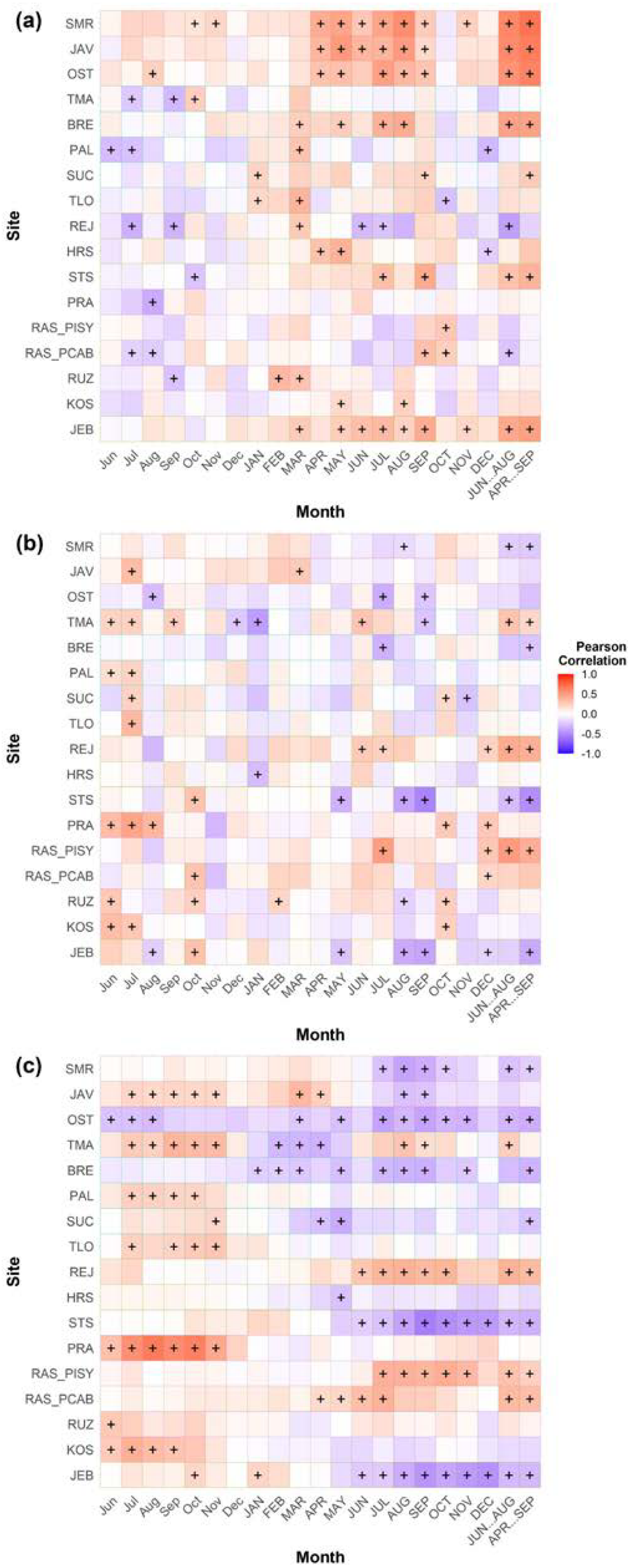

Fig. S10 Correlation response function analysis of individual $LWBI_{inv}$ site chronologies.

Shown are 18-month Pearson's correlation coefficients of residual $LWBI_{inv}$ site chronologies in relation to monthly climatic variables: (**a**) mean temperature, (**b**) precipitation totals and (**c**) mean SPEI-3, for the period 1950-2018. Sites are ordered from the lowest (bottom) to the highest (top) site. Black asterisks indicate statistically significant correlations (p <0.05).

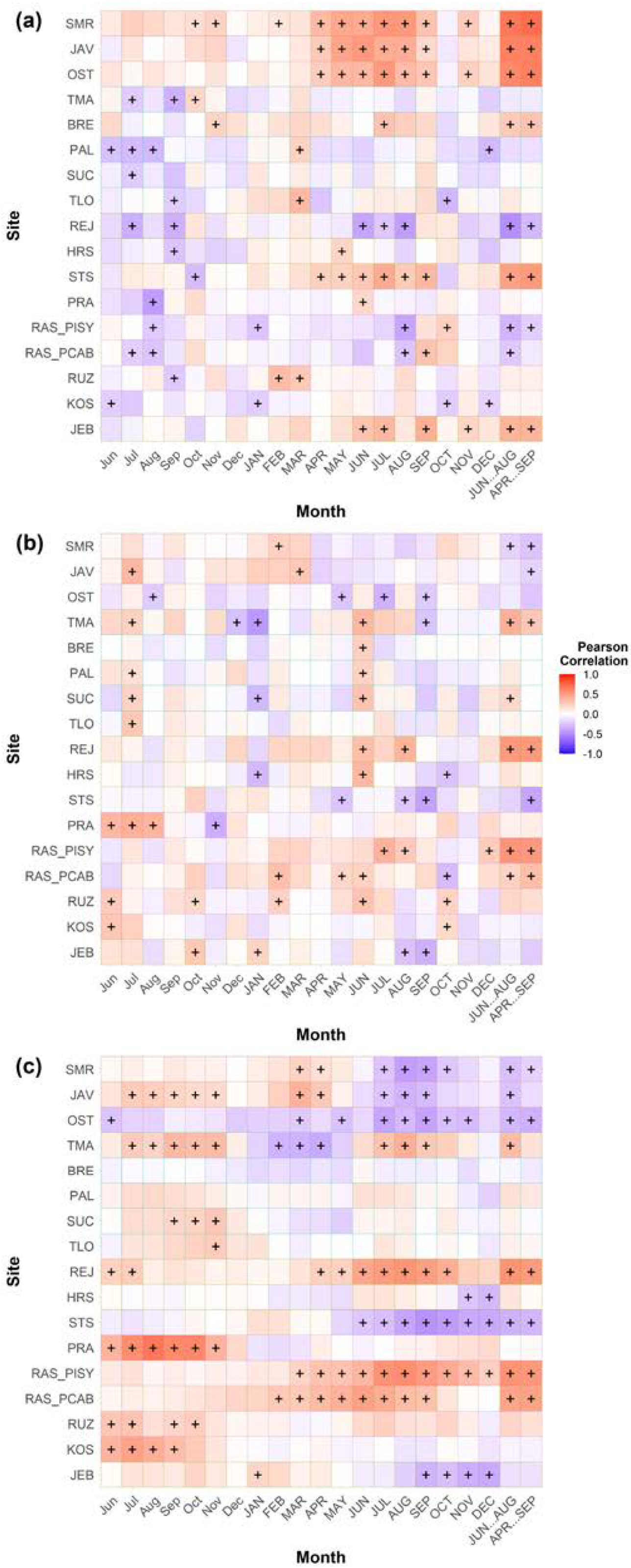

Fig. S11 Correlation response function analysis of individual ΔBI site chronologies.

Shown are 18-month Pearson's correlation coefficients of residual ΔBI site chronologies in relation to monthly climatic variables: (**a**) mean temperature, (**b**) precipitation totals and (**c**) mean SPEI-3, for the period 1950-2018. Sites are ordered from the lowest (bottom) to the highest (top) site. Black asterisks indicate statistically significant correlations (p <0.05).

Fig. S12 Temporal climate signal stability of the RWI site chronologies.

Figure shows a 31-year moving window Pearson's correlation analysis between mean residual RWI site chronologies with summer season temperatures (**a**) and SPEI-3 (**b**) index. Each 31-year window is plotted in the last year of the window span (*e.g.*, 1988 – 2018 plotted in 2018). Black horizontal dashed lines represent the significance threshold ($p < 0.05$).

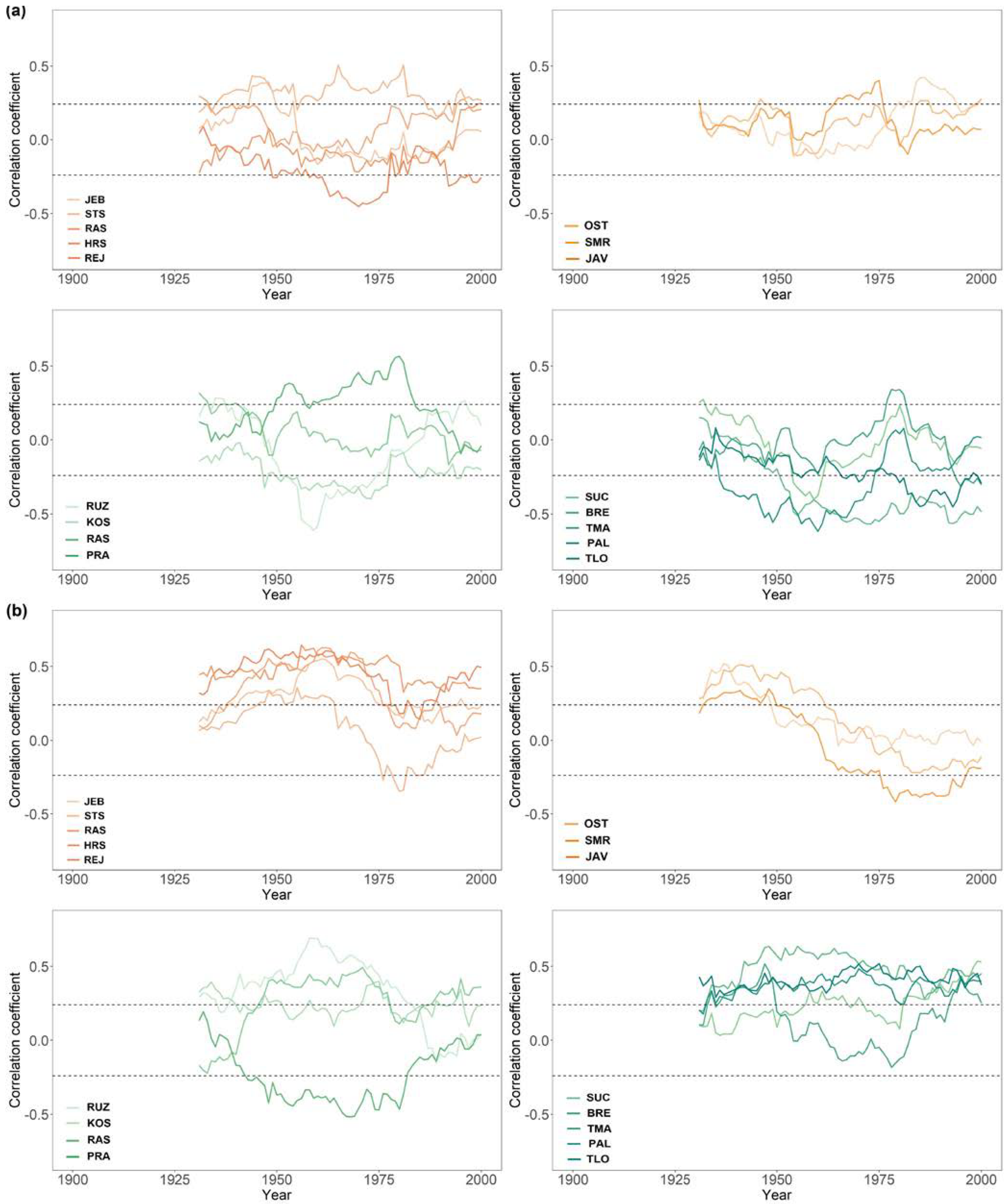

Fig. S13 Temporal climate signal stability of the EWBI site chronologies.

Figure shows a 31-year moving window Pearson's correlation analysis between mean residual EWBI chronologies with summer season temperatures (**a**) and SPEI-3 (**b**) index. Each 31-year window is plotted in the last year of the window span (*e.g.*, 1988 – 2018 plotted in 2018). Black horizontal dashed lines represent the significance threshold ($p < 0.05$).

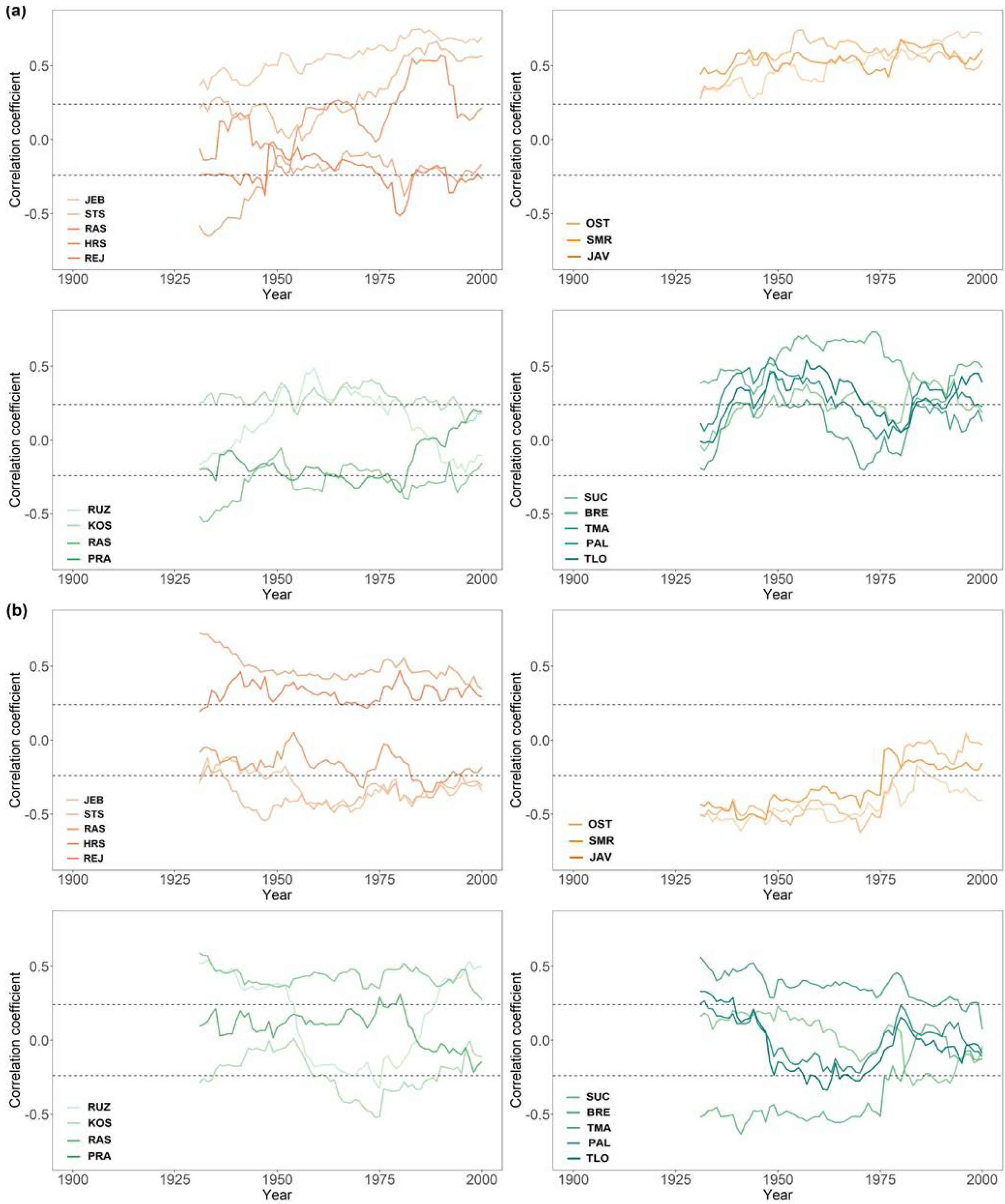

Fig. S14 Temporal climate signal stability of the LWBI_inv site chronologies.

Figure shows a 31-year moving window Pearson's correlation analysis between mean residual LWBI_inv chronologies with summer season temperatures (**a**) and SPEI-3 (**b**) index. Each 31-year window is plotted in the last year of the window span (*e.g.*, 1988 – 2018 plotted in 2018). Black horizontal dashed lines represent the significance threshold ($p < 0.05$).

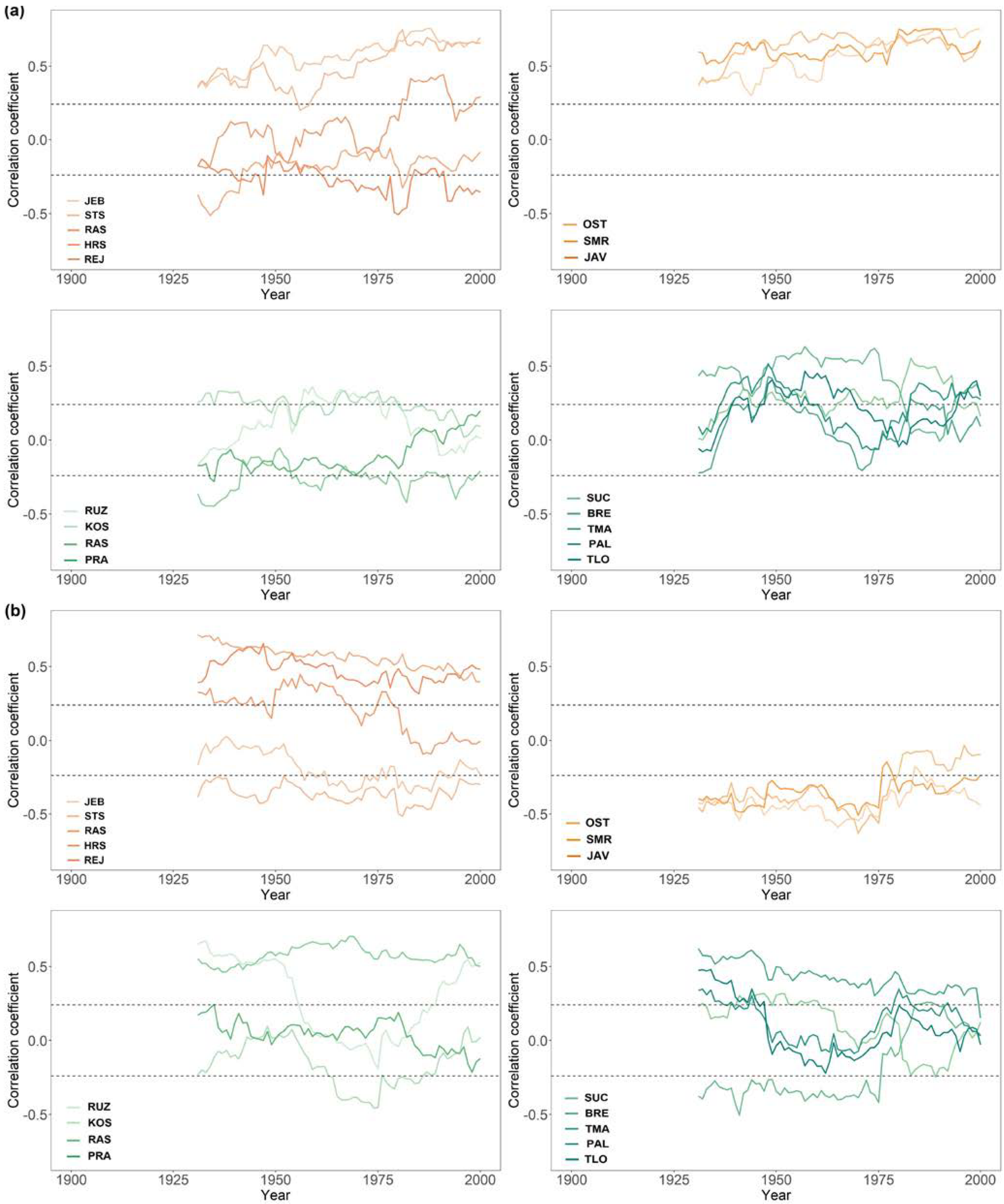

Fig. S15 Temporal climate signal stability of the ΔBI site chronologies.

Figure shows a 31-year moving window Pearson's correlation analysis between mean residual ΔBI chronologies with summer season temperatures (**a**) and SPEI-3 (**b**) index. Each 31-year window is plotted in the last year of the window span (*e.g.*, 1988 – 2018 plotted in 2018). Black horizontal dashed lines represent the significance threshold ($p < 0.05$).

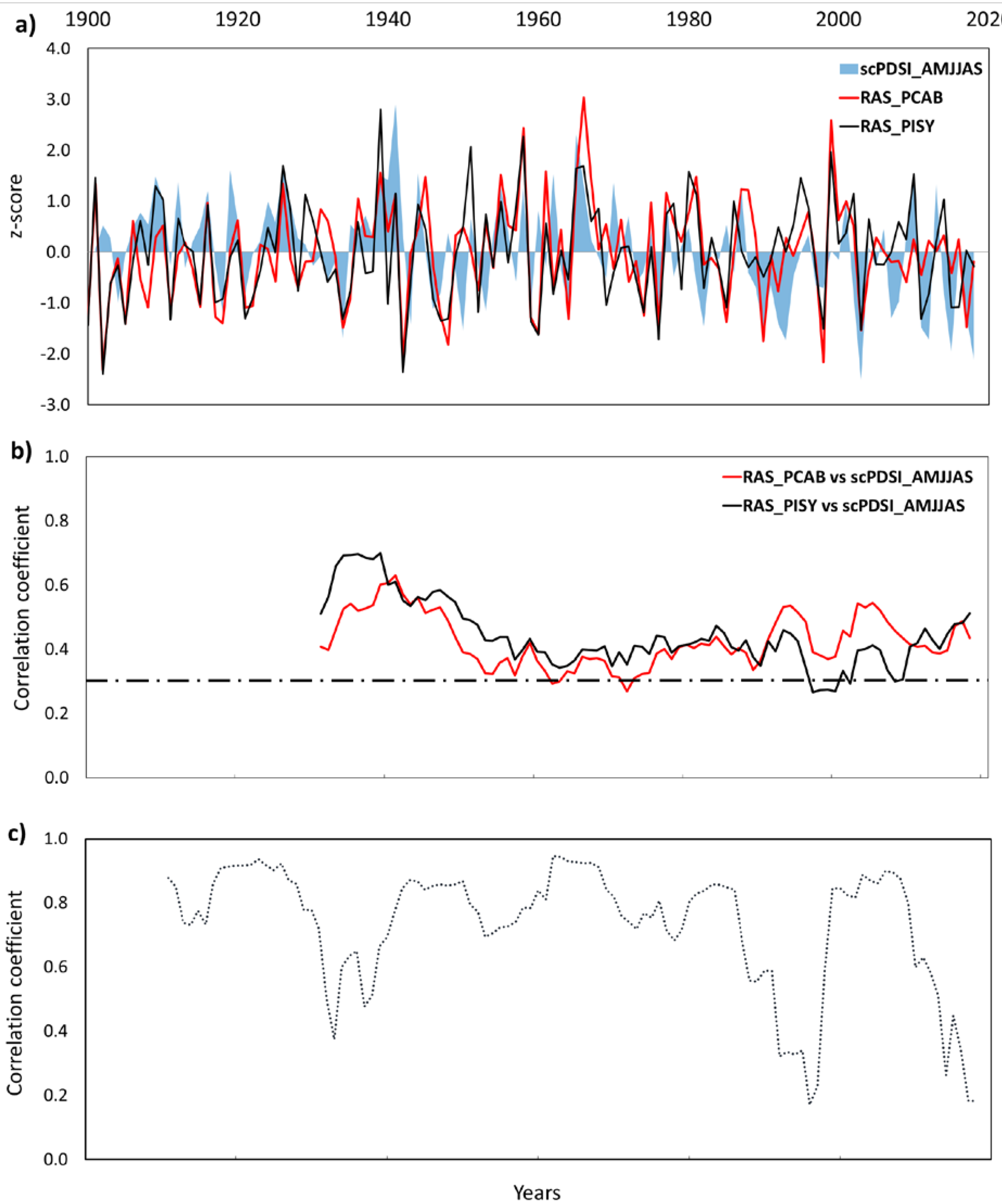

Fig. S16 Moving correlation analysis of PCAB and PISY with moisture index.

Shown are (**a**) residual PCAB (**red**) and PISY (**black**) site chronologies with growing season scPDSI (**blue area**), (**b**) 31-year running window correlations of both residual chronologies with growing season scPDSI, and (**c**) 11-year running correlations between residual PCAB and PISY site chronologies. Dashed black line in (b) presents significance threshold ($p < 0.05$). All series are expressed as z-scores relative to the 1901-2018 period.

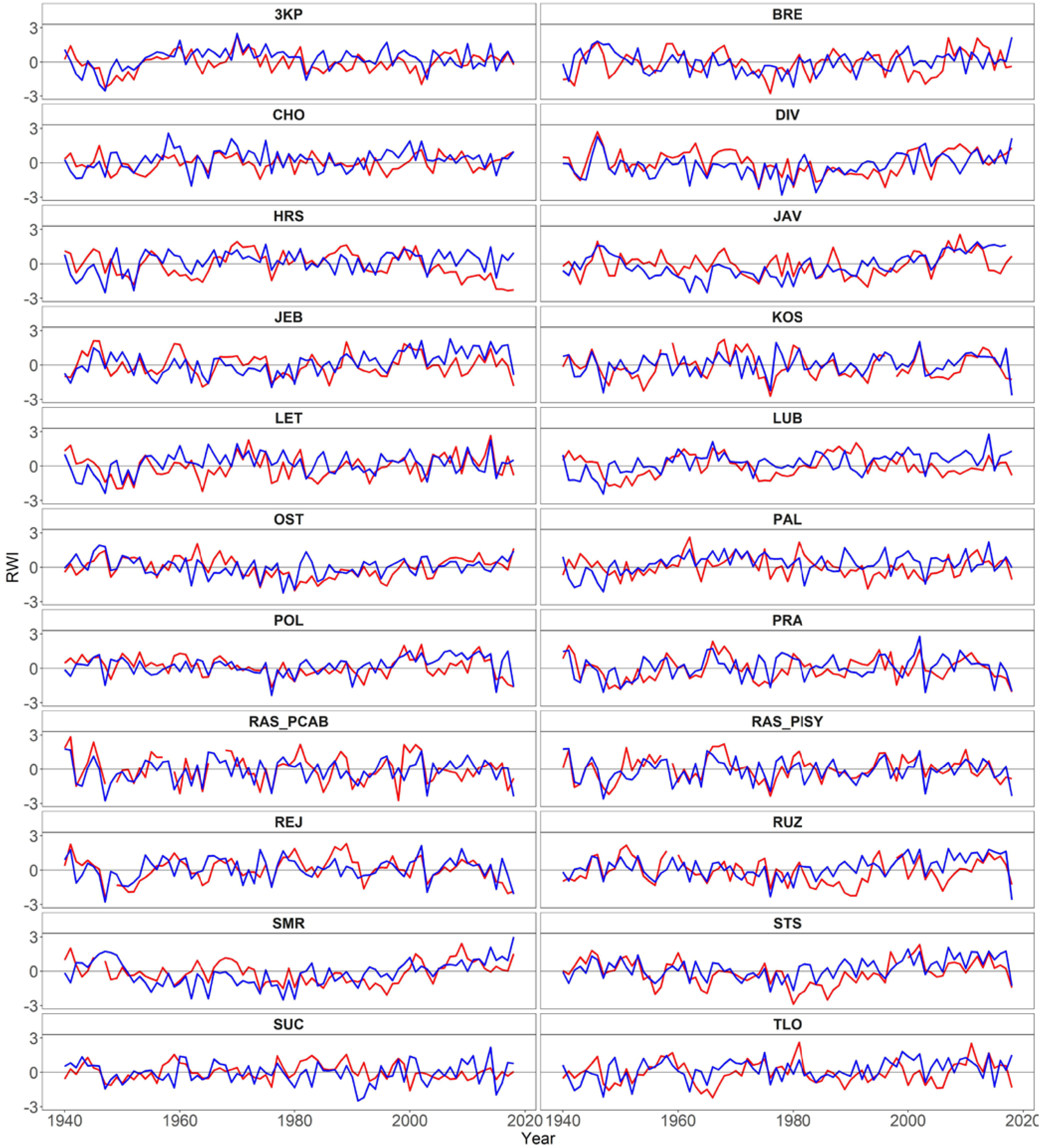

Fig. S17 VS-lite output of modeled and observed chronologies.

Shown is the overlap between the simulated (**blue**) and observed residual (**red**) RWI site chronologies (z-scored) over the period 1940-2018.

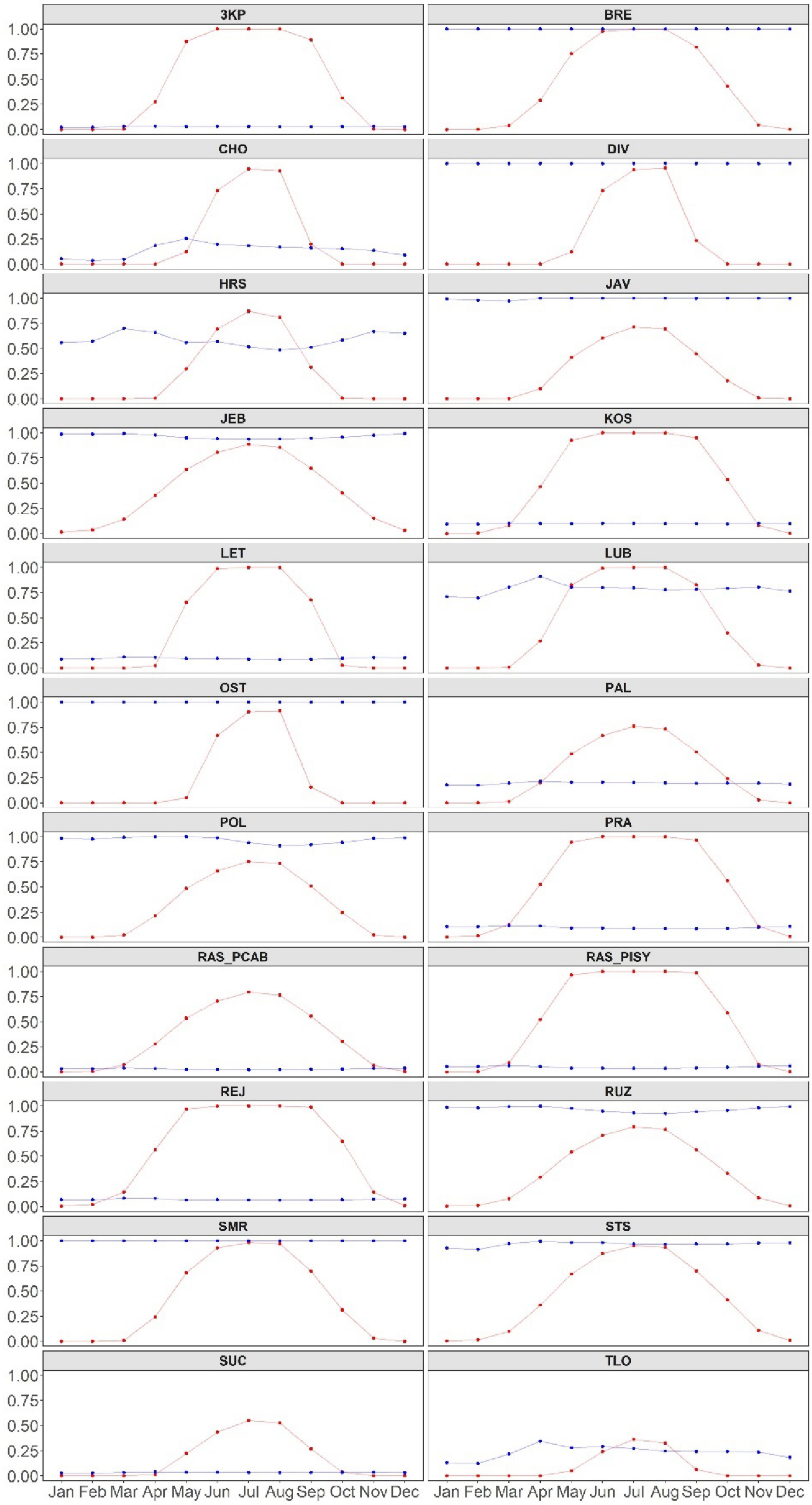

Fig. S18 Monthly partial RW growth responses to temperature (red line) and soil moisture (blue line) for individual sites.

4.4 ECOLOGICAL AND METHODOLOGICAL DRIVERS OF NON-STATIONARITY IN TREE GROWTH RESPONSE TO CLIMATE – S4

Ecological and methodological drivers of non-stationarity in tree growth response to climate by Jan Tumajer, Krešimir Begović, Vojtěch Čada, Michal Jenicek, Jelena Lange, Jiří Mašek, Ryszard J. Kaczka, Miloš Rydval, Miroslav Svoboda, Lukáš Vlček, Václav Treml

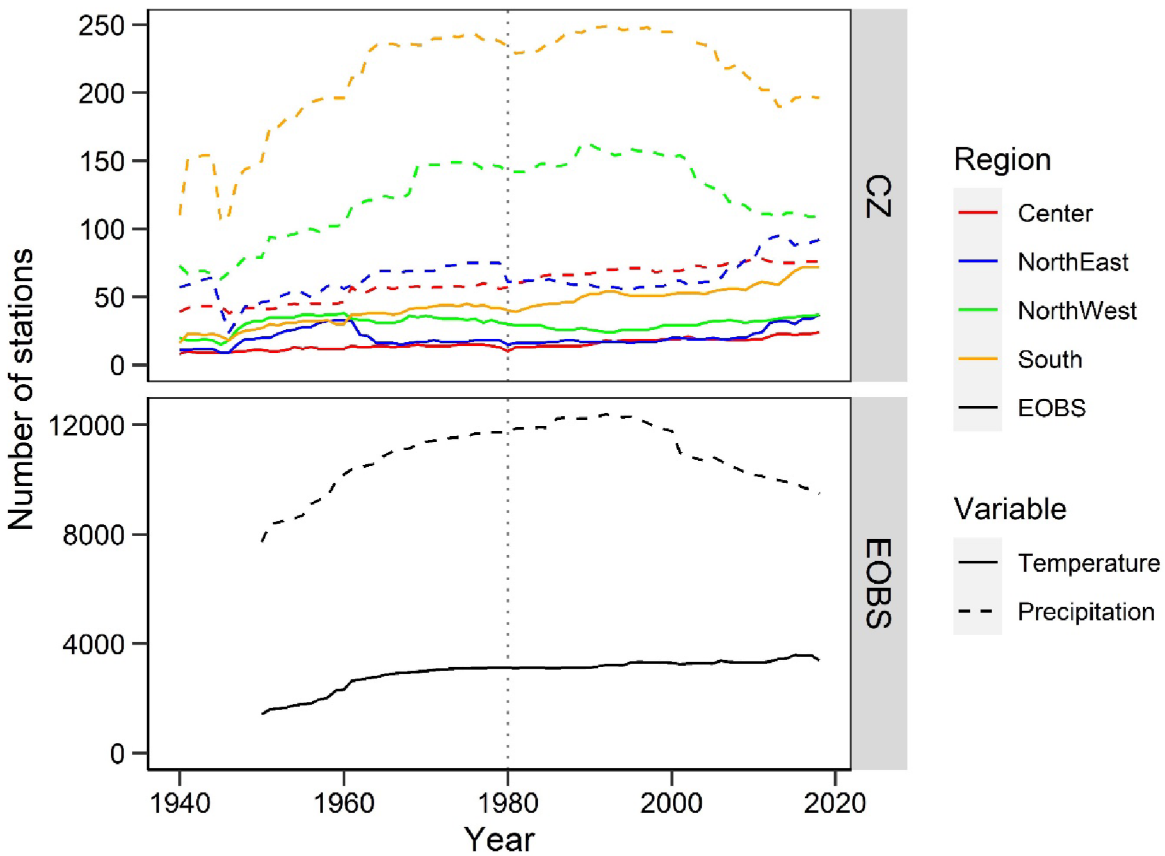

Figure S1: Temporal evolution of the number of climatic stations used to interpolate mean daily temperature (solid line) and precipitation totals (dashed line) for climatic datasets employed in this study. For the Czech Republic, the interpolation was performed in four regional areas delimited by buffers around the sampled forest stands (Center, NE, NW South) and the number of stations per each region is indicated by different colours. For the EOBS dataset, only sites between 41-71°N and 6-45°E are shown, because this region agrees with the distribution of tree-ring width chronologies (**Figure 1**).

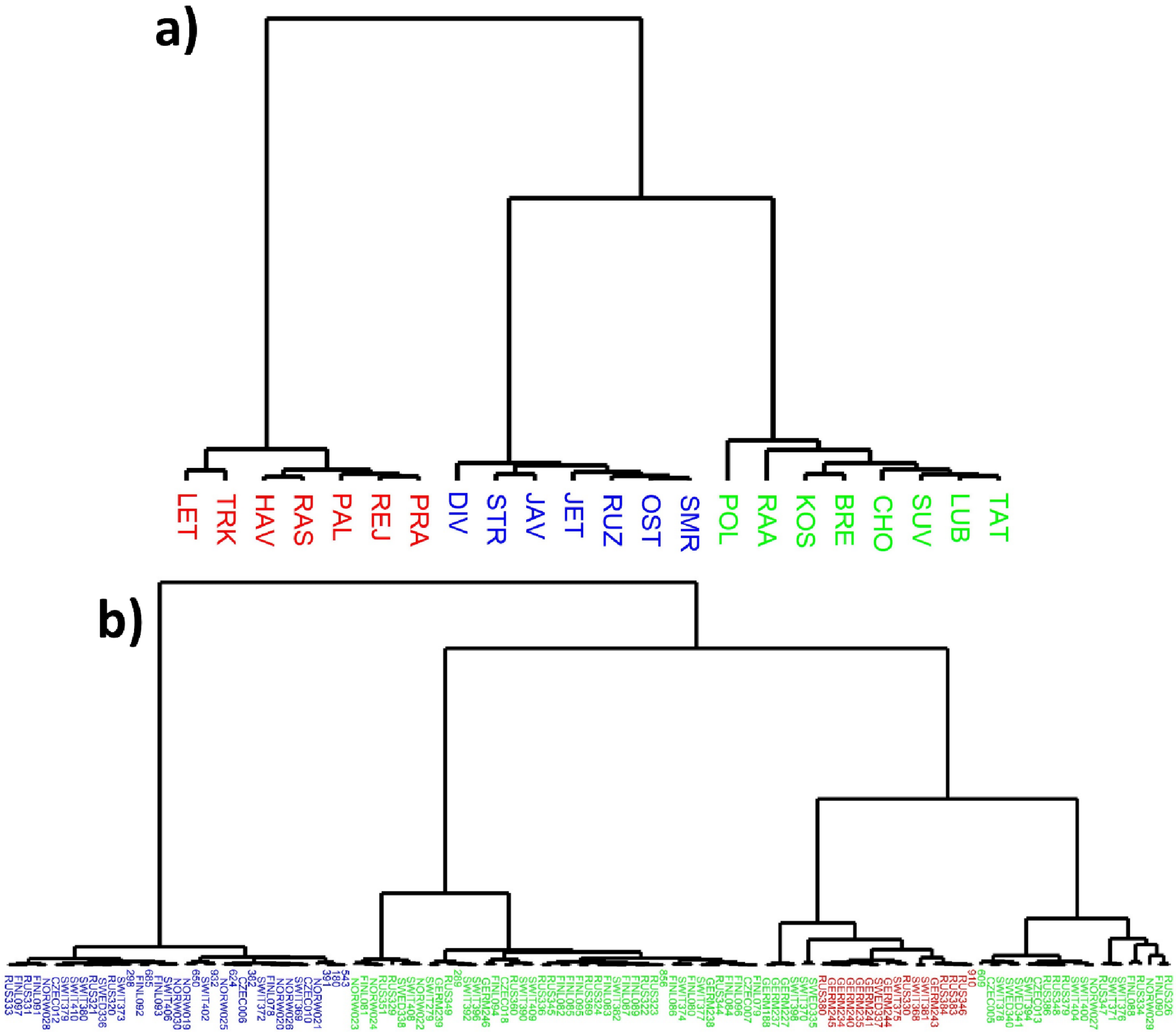

Figure S2: Clustering of sites from the (a) CZSK database and (b) ITRDB database based on peak season correlation coefficients of site chronologies with temperature and precipitation/soil moisture during the 1940/50-1979 calibration period. Correlation coefficients obtained using both monthly and daily linear models were used for clustering. The dendrograms were produced by the hierarchical clustering approach employing Ward distance to identify node positions (Rokach & Maimon, 2005). The colours of labels refer to our clustering approach employed in the main body of the manuscript (blue = cold dendroclimatic cluster, red = dry dendroclimatic cluster, green = mixed dendroclimatic cluster).

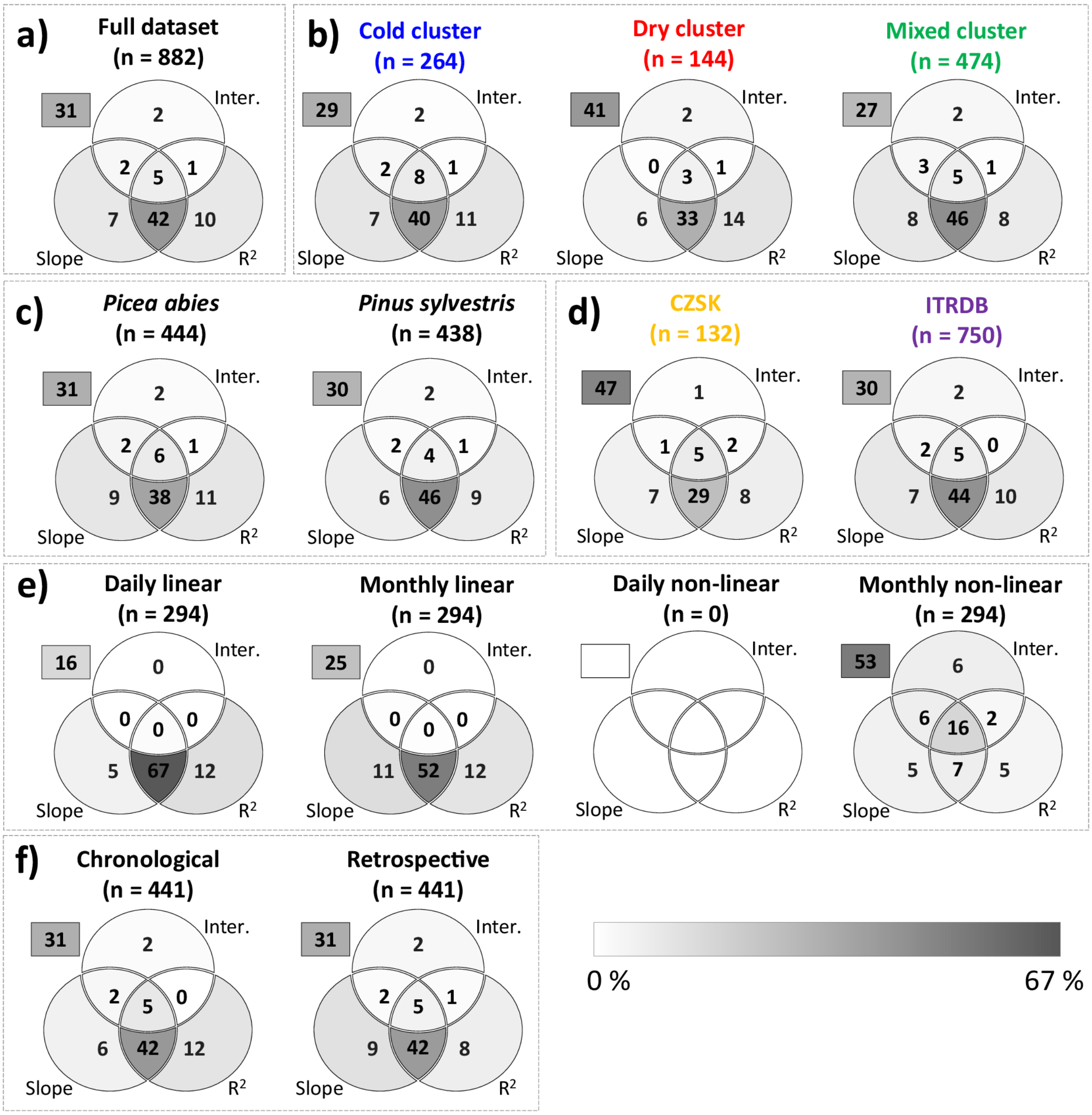

Figure S3: Same as **Figure 3,** but excluding all models simulated by VS-Orig (daily-resolved non-linear model of climate-growth interaction). This figure was produced to enable a comparison of the ITRDB and CZSK databases and other evaluated categories not biased by the choice of different models applied for sites of each database.

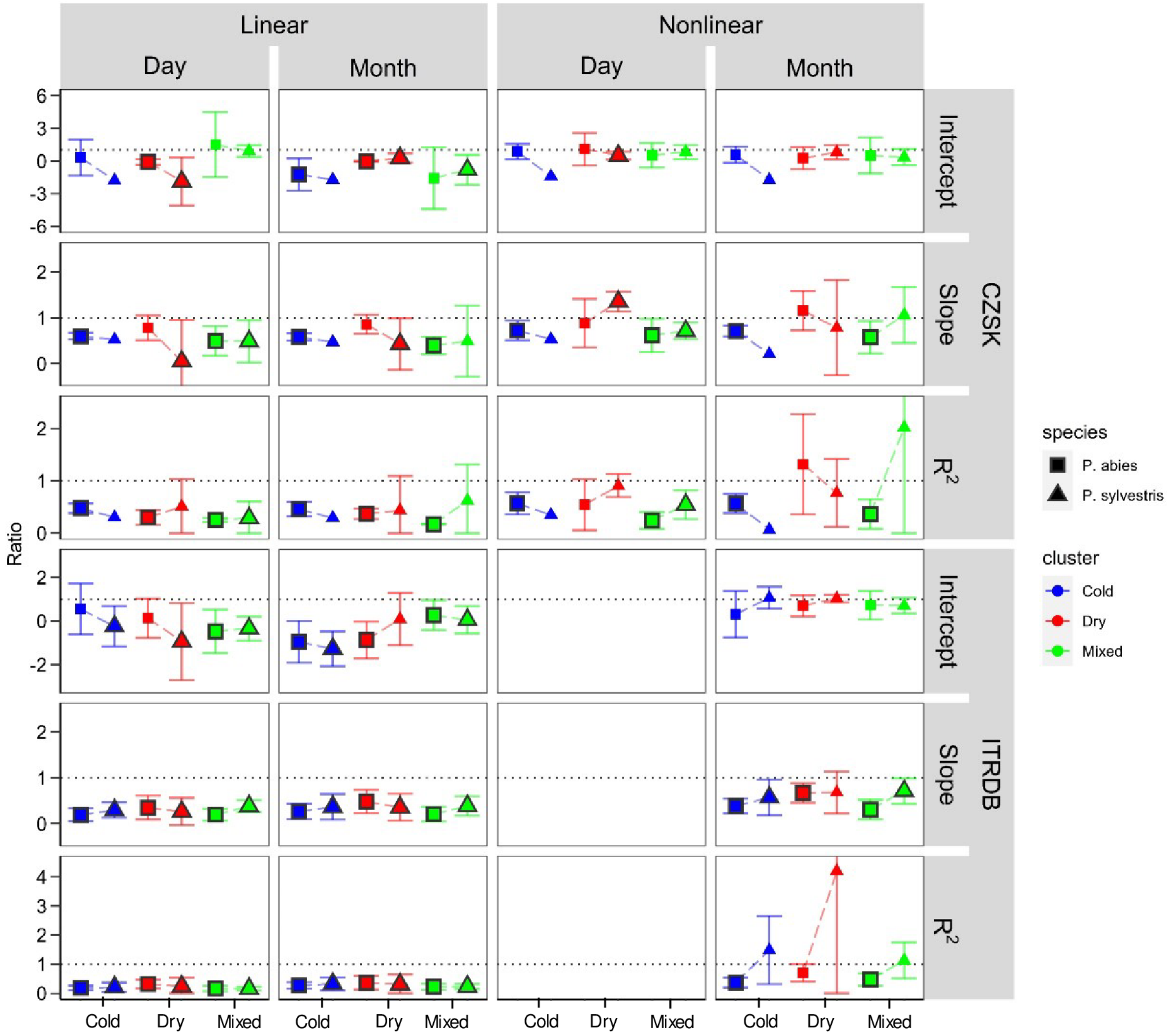

Figure S4: Mean values (squares and triangles) and confidence intervals (95%, error bars) of non-stationarity metrics of different dendroclimatic clusters and species obtained by climate-growth models in the retrospective calibration mode. Symbol colour refers to the site dendroclimatic cluster (blue = cold, red = dry, green = mixed) and symbol shape refers to species (square = *Picea abies*, triangle = *Pinus sylvestris*). Symbols with a grey outline highlight metrics with significant deviation from 1.0 (p-value < 0.05). Note, that in the CZSK dataset there was only one *P. sylvestris* site in the cold dendroclimatic cluster, and, therefore, an assessment of statistical significance was not performed in this case. Note that charts might have different y-axes scales to aid visual comparison between clusters and species.

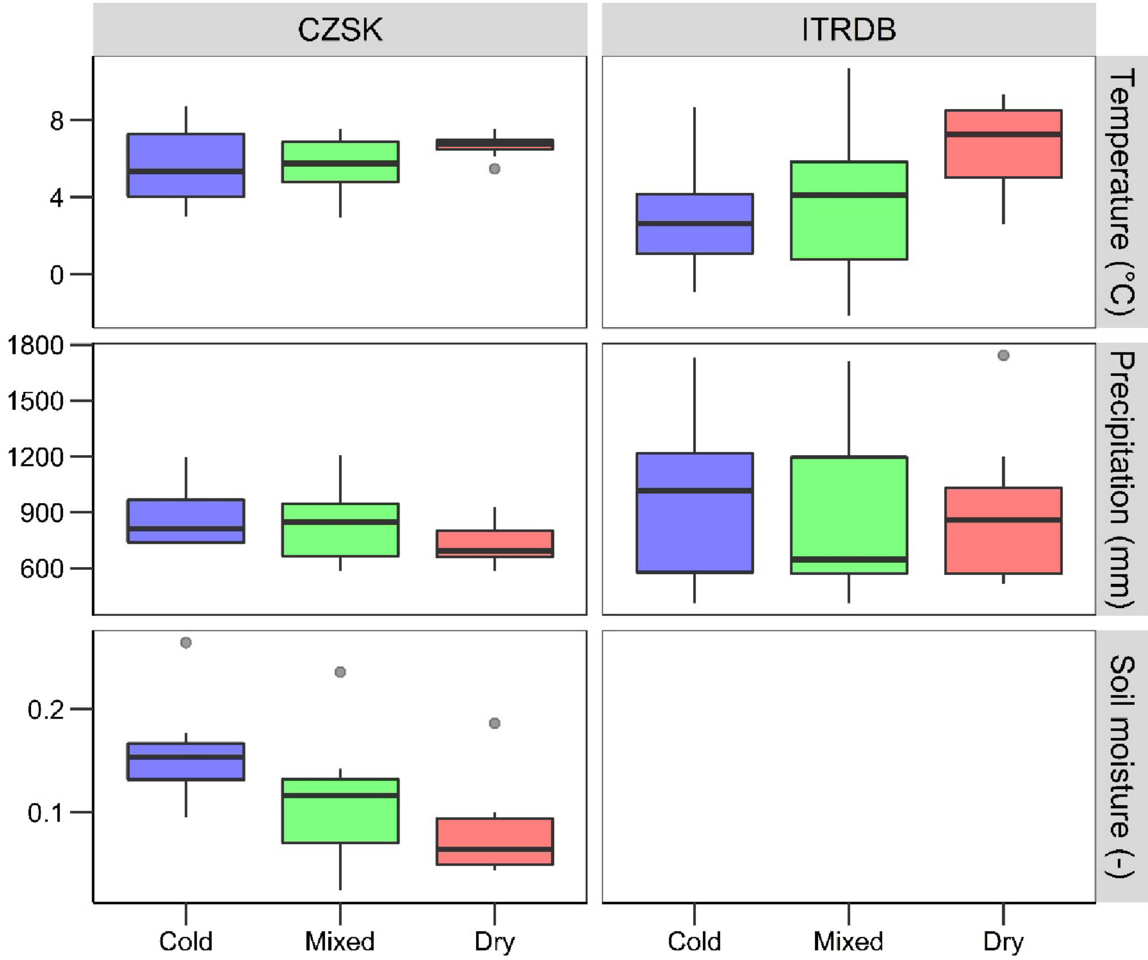

Figure S5: Mean values of annual climatic variables for sites of the three dendroclimatic clusters over the period 1st January 1950 – 31st December 2018. Note that the soil moisture model was applied only to sites from the CZSK database.

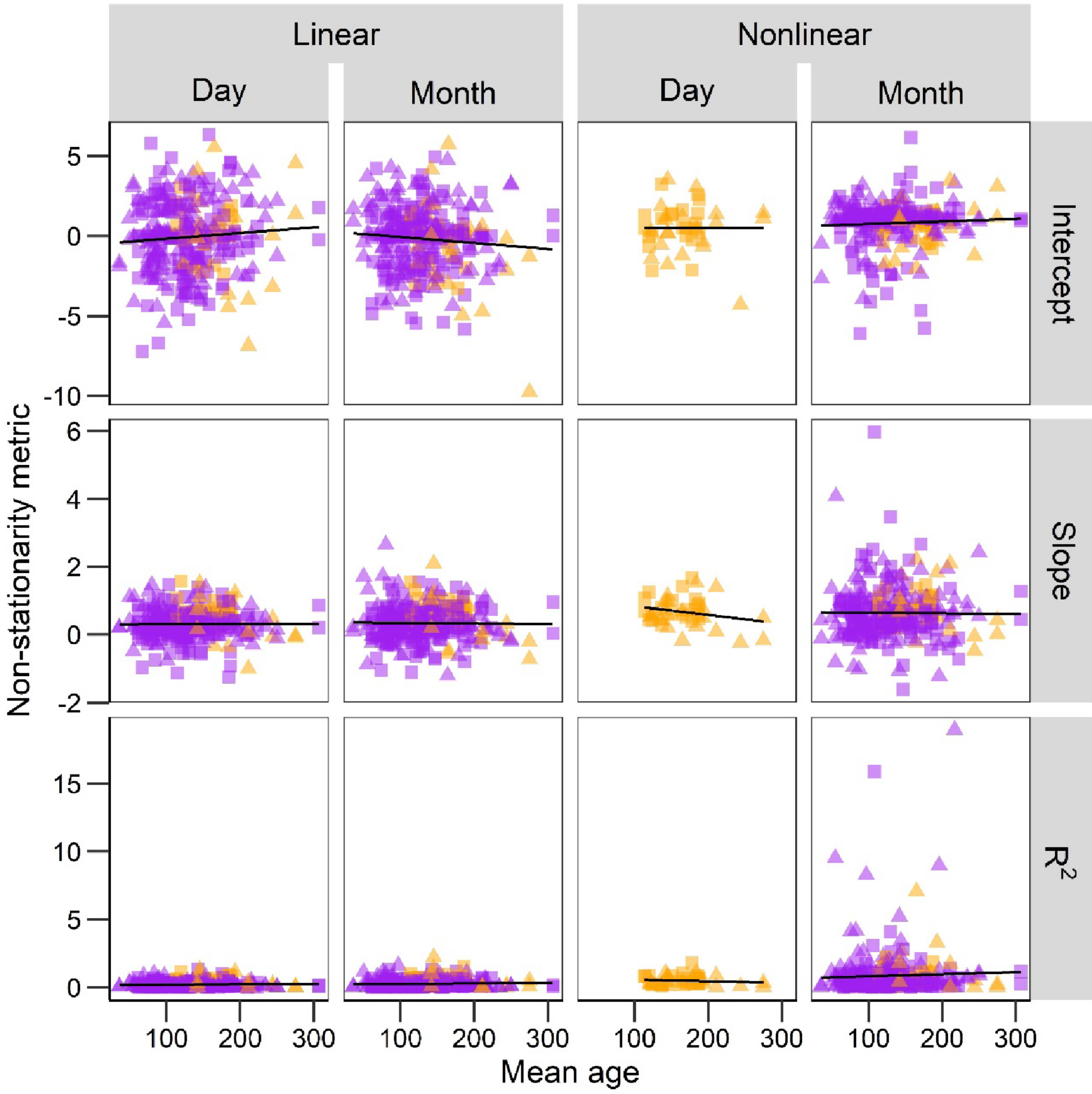

Figure S6: Scatterplots of non-stationarity metrics against mean tree age of each stand. Symbols indicate species (square = *Picea abies*, triangle = *Pinus sylvestris*), colours refer to the database (orange = CZSK database, purple = ITRDB database). Solid lines represent linear fits. Mean tree age was approximated as the mean number of tree-rings measured per core without a pith-offset correction (*i.e.*, the real age of the stand might be underestimated).

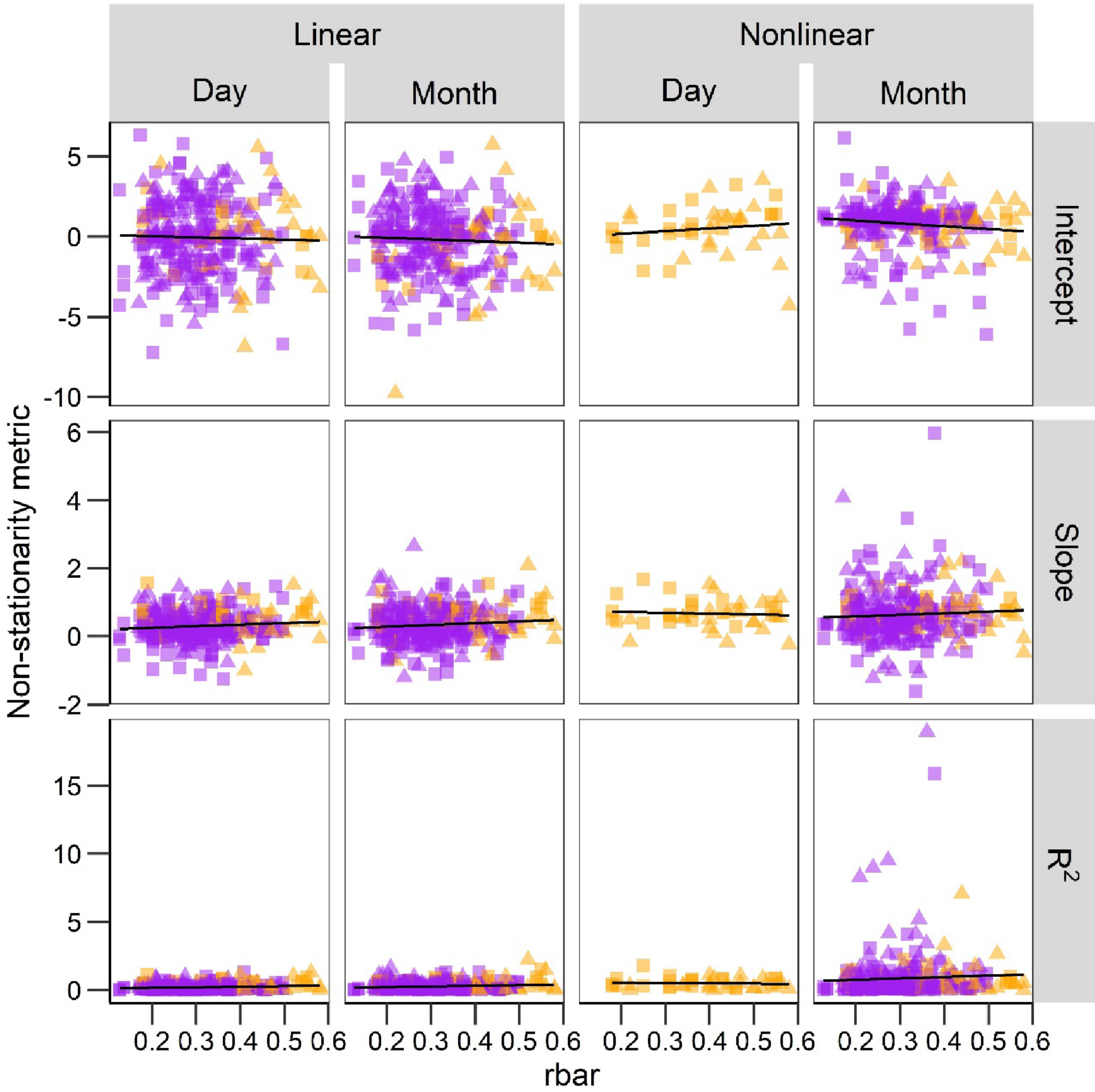

Figure S7: Scatterplots of non-stationarity metrics against mean inter-series correlation of each stand (rbar). Symbols indicate species (square = *Picea abies*, triangle = *Pinus sylvestris*), colours refer to the database (orange = CZSK database, purple = ITRDB database). Solid lines represent linear fits.

Table S1: Site coordinates and basic statistics of dendrochronological data for each site.

Database	Site	Species	Latitude (°N)	Longitude (°E)	Elevation (m a.s.l.)	Number of trees	rbar	Mean age (year)	Last ring
CZSK	JET	*P. abies*	50.85	14.36	200	38	0.18	170	2018
	RAS	*P. abies*	50.04	13.30	460	49	0.31	165	2018
	STR	*P. abies*	50.89	14.26	470	35	0.43	114	2018
	HAV	*P. abies*	48.95	20.43	540	42	0.31	124	2018
	POL	*P. abies*	49.79	15.75	580	42	0.19	120	2018
	REJ	*P. abies*	49.14	13.50	650	40	0.55	186	2018
	OST	*P. abies*	49.20	13.11	1200	40	0.25	178	2018
	DIV	*P. abies*	50.08	17.21	1300	44	0.54	151	2018
	JAV	*P. abies*	49.22	20.16	1400	60	0.36	188	2018
	CHO	*P. abies*	48.93	19.61	1450	43	0.46	137	2018
	SMR	*P. abies*	48.99	19.22	1450	48	0.36	183	2018
	KOS	*P. sylvestris*	50.57	14.46	400	38	0.40	193	2018
	RUZ	*P. sylvestris*	50.89	14.41	425	47	0.34	123	2018
	RAA	*P. sylvestris*	50.04	13.30	460	41	0.52	145	2018
	PRA	*P. sylvestris*	49.32	13.68	470	43	0.40	184	2018
	LET	*P. sylvestris*	48.95	20.44	550	58	0.56	145	2018
	LUB	*P. sylvestris*	49.12	19.16	620	43	0.44	165	2018
	TAT	*P. sylvestris*	49.15	20.26	910	44	0.47	142	2018
	TRK	*P. sylvestris*	48.94	20.31	910	52	0.41	211	2018
	SUV	*P. sylvestris*	50.16	17.35	940	50	0.22	275	2018
	PAL	*P. sylvestris*	49.23	20.32	950	42	0.58	244	2018
	BRE	*P. sylvestris*	49.15	13.41	1000	42	0.50	136	2018
ITRDB	GERM188	*P. sylvestris*	50.6	6.48	415	13	0.46	150	2011
	SWIT279	*P. abies*	46.59	7.98	1850	27	0.362	185	2011
	CZEC005	*P. abies*	48.67	14.7	785	100	0.203	223	2010
	SWIT368	*P. abies*	47.23	8.93	472	27	0.331	126	2016
	SWIT369	*P. abies*	47.29	8.95	1106	24	0.237	93	2016
	SWIT370	*P. abies*	47.25	8.94	618	26	0.232	106	2016
	SWIT371	*P. abies*	47.17	8.72	829	31	0.31	115	2016

	SWIT372	*P. abies*	47.04	8.74	1506	19	0.252	211	2015
	SWIT373	*P. abies*	46.92	9.17	1180	25	0.32	105	2015
	SWIT374	*P. abies*	47.06	8.76	1198	15	0.451	127	2015
	SWIT375	*P. abies*	47	9.1	1022	23	0.379	108	2016
	SWIT376	*P. abies*	47.03	9.06	627	30	0.317	130	2014
	SWIT377	*P. abies*	47.07	8.82	1000	30	0.274	82	2016
	SWIT378	*P. abies*	47	9.1	845	30	0.456	155	2016
	SWIT379	*P. abies*	46.93	9.21	1723	32	0.313	160	2015
	SWIT380	*P. abies*	47.25	9.04	856	30	0.202	67	2016
	SWIT381	*P. abies*	47.24	8.57	646	30	0.237	97	2014
	SWIT382	*P. abies*	46.9	8.94	1707	29	0.373	185	2015
	GERM227	*P. abies*	51.08	8.04	550	92	0.336	74	2011
	GERM234	*P. abies*	50.05	8.01	540	91	0.398	77	2012
	GERM235	*P. abies*	50.29	7.01	519	96	0.343	61	2012
	GERM237	*P. abies*	50.06	7.51	450	74	0.37	90	2010
	GERM238	*P. abies*	49.34	8.12	490	80	0.303	81	2011
	GERM239	*P. sylvestris*	49.34	8.34	106	70	0.186	36	2011
	GERM240	*P. abies*	49.3	7.32	340	40	0.375	62	2010
	GERM241	*P. abies*	50.44	7.76	420	50	0.2	63	2010
	GERM243	*P. abies*	50.44	7.76	420	80	0.363	105	2010
	GERM244	*P. abies*	50.81	7.97	440	90	0.335	82	2010
	GERM245	*P. abies*	50.69	8.16	530	93	0.334	85	2012
	GERM246	*P. abies*	50.7	8.23	334	110	0.409	143	2012
	SWED335	*P. sylvestris*	60.23	14.97	190	61	0.24	164	2012
	SWED336	*P. sylvestris*	60.15	14.47	350	96	0.343	142	2011
	SWED337	*P. sylvestris*	60.89	17.13	40	33	0.361	217	2011
	SWED338	*P. sylvestris*	59.57	15.58	65	19	0.239	196	2010
	CZEC006	*P. abies*	50.75	15.66	1350	143	0.48	103	2019
	SWIT390	*P. abies*	47.18	9.18	1380	12	0.24	140	2011
	SWIT392	*P. abies*	47.01	8.74	1435	15	0.182	178	2011
	SWIT394	*P. abies*	47.07	8.68	1275	15	0.285	193	2011
	SWIT396	*P. abies*	46.73	8.9	1435	14	0.289	125	2011
	SWIT398	*P. abies*	46.65	8.99	1450	14	0.233	130	2011
	SWIT400	*P. abies*	46.57	9.42	1300	15	0.336	147	2011
	SWIT402	*P. abies*	46.56	9.36	1480	14	0.203	121	2011
	SWIT404	*P. abies*	46.66	9.59	1010	15	0.278	131	2011
	SWIT406	*P. abies*	46.64	9.72	1280	15	0.201	128	2011
	SWIT408	*P. abies*	46.56	9.61	1750	72	0.215	118	2016
	SWIT409	*P. abies*	46.66	8.77	1640	26	0.127	158	2015
	SWIT410	*P. abies*	46.77	9.88	1830	67	0.23	177	2016

	CZEC007	*P. abies*	50.73	15.67	1270	43	0.496	89	2018
	CZEC010	*P. abies*	50.72	15.7	1270	28	0.46	107	2018
	FINL078	*P. sylvestris*	69.52	28.57	120	110	0.322	111	2011
	FINL079	*P. sylvestris*	69.52	28.57	120	80	0.438	172	2011
	FINL080	*P. sylvestris*	65.49	29.4	229	99	0.296	97	2011
	FINL081	*P. sylvestris*	65.49	29.4	229	101	0.391	120	2011
	FINL082	*P. sylvestris*	69.26	27.4	200	144	0.271	95	2011
	FINL083	*P. sylvestris*	69.26	27.4	200	170	0.302	136	2011
	FINL084	*P. sylvestris*	62.73	31.01	147	86	0.275	83	2011
	FINL085	*P. sylvestris*	62.73	31.01	147	125	0.216	62	2011
	FINL086	*P. sylvestris*	68.45	27.36	302	88	0.273	55	2011
	FINL087	*P. sylvestris*	68.45	27.36	302	87	0.183	50	2011
	FINL088	*P. sylvestris*	68.83	27.31	258	126	0.339	215	2011
	FINL089	*P. sylvestris*	68.83	27.31	258	74	0.279	142	2011
	FINL090	*P. sylvestris*	60.73	24.06	120	93	0.262	80	2011
	FINL091	*P. sylvestris*	60.73	24.06	120	116	0.284	87	2011
	FINL092	*P. sylvestris*	61.81	29.31	78	84	0.432	80	2011
	FINL093	*P. sylvestris*	61.81	29.31	78	102	0.371	101	2011
	FINL094	*P. sylvestris*	64.12	28.34	148	98	0.171	56	2011
	FINL095	*P. sylvestris*	64.12	28.34	148	93	0.274	93	2011
	FINL096	*P. sylvestris*	68.77	27.15	170	73	0.423	136	2015
	FINL097	*P. sylvestris*	68.77	27.15	170	80	0.479	144	2015
	NORW019	*P. sylvestris*	68.86	19.59	320	77	0.258	74	2013
	NORW020	*P. sylvestris*	68.86	19.59	320	105	0.23	86	2013

	NORW021	*P. sylvestris*	69.06	19.34	151	67	0.209	97	2014
	NORW022	*P. sylvestris*	69.06	19.34	151	72	0.275	83	2014
	NORW023	*P. sylvestris*	69.36	18.73	90	63	0.28	74	2014
	NORW024	*P. sylvestris*	69.36	18.73	90	69	0.336	76	2014
	NORW025	*P. sylvestris*	68.57	16.06	345	93	0.208	69	2013
	NORW026	*P. sylvestris*	68.57	16.06	345	71	0.211	90	2013
	NORW027	*P. sylvestris*	69.35	20.32	72	98	0.191	76	2013
	NORW028	*P. sylvestris*	69.35	20.32	72	104	0.288	92	2013
	NORW029	*P. sylvestris*	69.92	23.11	73	73	0.268	95	2015
	NORW030	*P. sylvestris*	69.92	23.11	73	93	0.314	128	2015
	SWED340	*P. sylvestris*	66.65	20.11	302	86	0.266	102	2013
	SWED341	*P. sylvestris*	66.65	20.11	302	126	0.417	87	2013
	CZEC012	*P. abies*	48.87	13.79	950	36	0.19	153	2017
	CZEC013	*P. sylvestris*	48.89	14.35	480	34	0.309	124	2019
	CZEC018	*P. sylvestris*	50.06	12.78	760	41	0.33	119	2018
	RUS320	*P. abies*	65.09	35.67	20	42	0.415	127	2016
	RUS321	*P. abies*	65.04	35.64	9	30	0.298	117	2016
	RUS322	*P. sylvestris*	65.04	35.64	9	42	0.269	88	2016
	RUS323	*P. abies*	43.4	41.31	1714	28	0.302	307	2011
	RUS324	*P. sylvestris*	43.24	42.51	2470	18	0.18	207	2011
	RUS326	*P. sylvestris*	42.85	43.71	2015	36	0.31	250	2014
	RUS329	*P. sylvestris*	54.66	34.14	195	19	0.311	110	2014
	RUS330	*P. abies*	53.96	35.81	166	25	0.27	79	2014
	RUS331	*P. sylvestris*	64.56	43.16	90	17	0.341	149	2012
	RUS333	*P. sylvestris*	58.87	44.23	141	21	0.218	135	2012

	RUS334	*P. sylvestris*	54.53	36.2	183	34	0.204	190	2013
	RUS336	*P. sylvestris*	43.43	41.71	2285	69	0.208	179	2010
	RUS344	*P. sylvestris*	57.35	36.62	155	24	0.36	144	2014
	RUS345	*P. abies*	56.46	32.96	244	38	0.363	112	2014
	RUS346	*P. sylvestris*	55.24	40.04	125	30	0.235	126	2014
	RUS347	*P. sylvestris*	55.73	36.84	167	35	0.209	171	2014
	RUS348	*P. abies*	55.7	36.73	199	35	0.37	102	2013
	RUS349	*P. sylvestris*	54.91	37.66	181	40	0.316	147	2014
	RUS351	*P. sylvestris*	54.05	35.83	154	22	0.25	234	2010
	RUS360	*P. sylvestris*	51.2	40.2	94	36	0.3	196	2014
	RUS369	*P. sylvestris*	52.36	42.6	128	27	0.419	135	2015
	RUS379	*P. sylvestris*	50.62	35.94	148	33	0.333	102	2014
	RUS380	*P. sylvestris*	50.68	37.8	100	22	0.372	153	2014
	RUS383	*P. sylvestris*	56.54	44.8	108	33	0.334	128	2014
	RUS384	*P. sylvestris*	56.54	44.8	108	23	0.273	144	2014
	RUS386	*P. sylvestris*	54.77	43.4	180	39	0.282	116	2014
ITRDB (REMOTE Forest)	180	*P. abies*	51.8	10.63	1044	27	0.240	152	2014
	289	*P. abies*	45.64	24.8	1598	29	0.227	209	2012
	298	*P. abies*	45.62	24.97	1605	31	0.263	187	2013
	382	*P. abies*	45.55	24.43	1643	34	0.136	123	2013
	391	*P. abies*	45.57	24.62	1713	30	0.208	91	2013
	543	*P. abies*	48.95	19.67	1535	28	0.323	176	2013
	609	*P. abies*	49.02	19.21	1386	31	0.291	131	2013
	624	*P. abies*	49.17	19.98	1501	29	0.174	158	2014
	650	*P. abies*	49.23	20.2	1521	30	0.327	125	2013
	685	*P. abies*	49.52	19.33	1398	23	0.390	171	2013
	856	*P. abies*	48.59	23.93	1415	25	0.260	158	2012
	910	*P. abies*	48.56	24.09	1482	27	0.181	143	2012
	932	*P. abies*	48.54	24.16	1425	25	0.253	133	2012

rbar is mean inter-series correlation; Mean age was approximated as the mean number of tree-rings per core (i.e., the actual mean tree age is higher due to missing rings near the pith).

Table S2: Volume errors and Spearman's ρ showing the agreement of simulated and observed soil moisture for the six sites of the CZSK network with direct measurement of the volumetric soil moisture.

Site	Volume error	Spearman's *ρ*
RUZ	1.00	0.39
RAB	1.00	0.71
KOS	0.99	0.19
JET	1.00	0.83
DIV	0.99	0.62
SUV	0.98	0.57

Table S3: Intervals of values set as limits during the generation of random combinations of parameters for the original Vaganov-Shashkin and VS-Lite process-based models. The random values of parameters were estimated from the top rows of this table to the bottom rows. This means that values estimated for the first parameters were later used to determine margins of later parameters (*e.g.*, estimated value of T1 was used to define the lower margin of interval for T2, estimated value of T2 served as lower margin of interval for T3, etc.).

Par.	Meaning	Vaganov-Shashkin		VS-Lite	
		Minimum	Maximum	Minimum	Maximum
T1	Minimum temperature for growth [°C]	1	11	1	10
T2	Lower margin of temperature optimum [°C]	max(8; T1)	20	10	24
T3	Upper margin of temperature optimum [°C]	T2	30	NA	
T4	Maximum temperature for growth [°C]	T3	35	NA	
M1	Minimum moisture for growth [-]	0	0.5*mean annual peak soil moisture	0	0.75*mean monthly soil moisture
M2	Lower margin of moisture optimum [-]	M1	0.5	M1	0.65
M3	Upper margin of moisture optimum [-]	M2	0.8	NA	
M4	Maximum moisture for growth [-]	M3	0.9	NA	
Tbeg	Cumulative temperature to determine growth onset/cessation [°C]	35	160	NA	
tbeg	Period of cumulative temperature to determine growth onset/cessation [°C]	5	17	NA	
Vcr	Smoothing factor of growth cessation [-]	0.02	0.25	NA	

NA = parameters not applicable in the VS-Lite model

Table S4: Correlation coefficients between simulated and observed chronologies during their respective calibration and verification periods. Values exceeding 0.33 are considered as significant with p-value < 0.05.

Database	Site	Chronological (calibration 1940/50-1979)				Retrospective (calibration 1980-2010/18)				Chronological (verification 1980-201/18)				Retrospective (verification 1940/50-1979)			
		Linear Month	Linear Day	Non-linear Month	Non-linear Day	Linear Month	Linear Day	Non-linear Month	Non-linear Day	Linear Month	Linear Day	Non-linear Month	Non-linear Day	Linear Month	Linear Day	Non-linear Month	Non-linear Day
CZSK	HAV	0.53	0.62	0.56	0.56	0.65	0.71	0.23	0.56	0.46	0.36	0.12	0.23	0.36	0.31	0.38	0.32
	JET	0.52	0.54	0.51	0.52	0.54	0.55	0.59	0.64	0.39	0.38	0.56	0.33	0.33	0.37	0.42	0.46
	POL	0.41	0.51	0.58	0.6	0.65	0.69	0.67	0.61	0.34	0.55	0.54	0.47	0.27	0.33	0.49	0.41
	RAS	0.6	0.65	0.49	0.52	0.71	0.71	0.56	0.52	0.6	0.55	0.54	0.47	0.41	0.4	0.48	0.5
	REJ	0.49	0.56	0.52	0.4	0.65	0.66	0.62	0.62	0.62	0.53	0.54	0.45	0.43	0.41	0.39	0.32
	STR	0.52	0.58	0.62	0.7	0.59	0.65	0.69	0.7	0.53	0.48	0.64	0.66	0.48	0.49	0.62	0.62
	DIV	0.71	0.76	0.59	0.67	0.74	0.75	0.71	0.69	0.68	0.61	0.52	0.48	0.59	0.59	0.47	0.49
	CHO	0.53	0.59	0.47	0.51	0.5	0.56	0.42	0.44	0.13	0.13	0.09	0.17	0.19	0.27	0.28	0.15
	JAV	0.6	0.68	0.44	0.55	0.64	0.72	0.62	0.62	0.43	0.6	0.55	0.43	0.4	0.54	0.39	0.36
	OST	0.5	0.56	0.47	0.51	0.67	0.67	0.62	0.64	0.44	0.46	0.49	0.6	0.41	0.4	0.48	0.45
	SMR	0.59	0.64	0.54	0.62	0.7	0.71	0.67	0.65	0.55	0.63	0.58	0.55	0.45	0.42	0.48	0.54
	KOS	0.37	0.45	0.28	0.43	0.59	0.65	0.59	0.44	0.29	0.49	0.58	0.2	0.29	0.3	0.25	0.26
	LET	0.74	0.77	0.61	0.67	0.46	0.5	0.53	0.53	0.33	0.32	0.38	0.41	0.59	0.59	0.37	0.52
	LUB	0.61	0.61	0.6	0.69	0.45	0.49	0.08	0.39	-0.33	-0.23	-0.18	-0.18	-0.11	0.13	0.36	0.19
	PRA	0.65	0.63	0.39	0.54	0.55	0.62	0.52	0.32	0.29	0.26	0.42	0.16	0.18	-0.22	0.36	0.45
	RAA	0.72	0.76	0.55	0.7	0.41	0.49	0.33	0.39	0.35	0.31	0.27	0.2	0.63	0.52	0.47	0.45
	RUZ	0.51	0.55	0.55	0.63	0.61	0.63	0.58	0.59	0.16	0.22	0.41	0.31	0.34	0.37	0.04	0.28
	BRE	0.38	0.44	0.35	0.48	0.43	0.46	0.4	0.38	0.06	0.06	0.04	0.19	-0.02	0	0.25	0.22
	PAL	0.57	0.61	0.63	0.59	0.34	0.4	0.21	0.23	-0.04	-0.05	-0.05	-0.16	0.1	0.15	-0.18	-0.32

	SUV	0.51	0.61	0.28	0.55	0.44	0.49	0.28	0.3	-0.37	-0.06	0	-0.07	-0.05	0.01	0.19	0.18
	TAT	0.55	0.55	0.41	0.53	0.45	0.5	0.26	0.38	0.11	0.1	0.24	0.34	0.46	0.23	0.38	0.43
	TRK	0.85	0.87	0.7	0.74	0.34	0.41	0.28	0.37	0.06	0.06	0.1	0.07	0.08	-0.26	0.39	0.42
ITRDB	GERM188	0.46	0.64	0.5	NA	0.67	0.71	0.55	NA	0.01	0.25	0.18	NA	0.05	0.19	0.32	NA
	SWIT279	0.33	0.53	0.27	NA	0.45	0.53	0.36	NA	0	-0.34	-0.1	NA	0.11	0.12	0.14	NA
	CZEC005	0.54	0.67	0.3	NA	0.35	0.49	0.23	NA	0.1	0.11	-0.26	NA	0.29	0.3	-0.03	NA
	SWIT368	0.49	0.58	0.38	NA	0.64	0.7	0.29	NA	0.32	0.4	0.19	NA	0.22	0.41	0.19	NA
	SWIT369	0.57	0.64	0.49	NA	0.43	0.58	0.32	NA	0.01	0.06	0.08	NA	-0.18	-0.18	-0.16	NA
	SWIT370	0.53	0.62	0.35	NA	0.62	0.66	0.63	NA	0.32	0.36	0.63	NA	0.21	0.19	0.32	NA
	SWIT371	0.47	0.56	0.19	NA	0.47	0.52	0.42	NA	-0.33	-0.32	0.18	NA	-0.19	-0.17	-0.14	NA
	SWIT372	0.51	0.63	0.42	NA	0.5	0.59	0.3	NA	0.46	0.39	-0.11	NA	0.41	0.02	0.35	NA
	SWIT373	0.48	0.53	0.46	NA	0.56	0.61	0.61	NA	-0.17	-0.14	-0.06	NA	0.03	0.07	-0.03	NA
	SWIT374	0.63	0.69	0.57	NA	0.43	0.5	0.44	NA	-0.08	-0.11	0.21	NA	-0.16	-0.03	-0.1	NA
	SWIT375	0.67	0.71	0.13	NA	0.54	0.65	0.51	NA	0.27	0.34	0.49	NA	0.03	0.21	0.01	NA
	SWIT376	0.57	0.65	0.17	NA	0.53	0.66	0.32	NA	0.02	0.16	0.33	NA	-0.02	0.14	0.15	NA
	SWIT377	0.51	0.62	0.36	NA	0.39	0.52	0.31	NA	0.07	0.04	0.24	NA	-0.16	-0.02	0.32	NA
	SWIT378	0.61	0.73	0.37	NA	0.64	0.6	0.67	NA	-0.04	0.1	0.46	NA	0.01	0.15	0.23	NA
	SWIT379	0.49	0.62	0.47	NA	0.53	0.59	0.45	NA	0.32	0.2	0.14	NA	0.4	0.25	0.32	NA
	SWIT380	0.54	0.63	0.48	NA	0.54	0.61	0.49	NA	-0.19	-0.31	0.06	NA	-0.07	-0.08	0.04	NA
	SWIT381	0.5	0.59	0.27	NA	0.46	0.57	0.45	NA	0.14	0.36	0.36	NA	0.08	0.16	0.12	NA
	SWIT382	0.56	0.61	0.43	NA	0.63	0.65	0.53	NA	0.44	0.41	0.19	NA	0.37	0.36	0.37	NA
	GERM227	0.56	0.61	0.51	NA	0.56	0.68	0.27	NA	-0.38	0.08	0	NA	-0.13	-0.29	-0.05	NA
	GERM234	0.72	0.73	0.66	NA	0.6	0.72	0.56	NA	0.27	0.26	0.34	NA	0.38	0.48	0.53	NA
	GERM235	0.68	0.75	0.73	NA	0.58	0.72	0.64	NA	0.21	0.32	0.55	NA	0.48	0.63	0.64	NA
	GERM237	0.51	0.63	0.53	NA	0.77	0.71	0.71	NA	-0.14	0.15	0.52	NA	0.12	0.09	0.39	NA
	GERM238	0.53	0.67	0.45	NA	0.56	0.65	0.42	NA	-0.27	-0.17	0.15	NA	0.12	0.04	0.34	NA
	GERM239	0.4	0.5	0.43	NA	0.58	0.67	0.28	NA	0.05	0.12	-0.08	NA	0.11	0.16	0.1	NA
	GERM240	0.68	0.74	0.6	NA	0.64	0.69	0.66	NA	-0.07	-0.1	0.41	NA	-0.01	0.01	0.44	NA
	GERM241	0.65	0.67	0.56	NA	0.47	0.61	0.58	NA	0.25	0.21	0.48	NA	0.21	0.36	0.53	NA

	GERM243	0.57	0.57	0.52	NA	0.6	0.64	0.57	NA	0.26	0.34	-0.07	NA	0.22	0.14	0.4	NA
	GERM244	0.75	0.8	0.68	NA	0.63	0.76	0.55	NA	0.55	0.47	0.31	NA	0.59	0.62	0.52	NA
	GERM245	0.69	0.76	0.74	NA	0.33	0.53	0.48	NA	0.08	0.12	0.28	NA	0.38	-0.37	0.63	NA
	GERM246	0.75	0.84	0.8	NA	0.63	0.64	0.74	NA	0.57	0.43	0.59	NA	0.72	0.73	0.75	NA
	SWED335	0.55	0.65	0.36	NA	0.45	0.57	0.18	NA	0.14	-0.04	-0.11	NA	-0.33	0.04	0.13	NA
	SWED336	0.48	0.57	0.1	NA	0.48	0.61	0.01	NA	0.08	0.03	-0.18	NA	0.09	0.14	-0.23	NA
	SWED337	0.64	0.66	0.51	NA	0.58	0.72	0.02	NA	0.07	-0.23	-0.1	NA	0.07	-0.01	0.3	NA
	SWED338	0.55	0.69	0.37	NA	0.5	0.55	-0.02	NA	-0.08	-0.13	-0.13	NA	-0.12	0.04	0.31	NA
	CZEC006	0.6	0.64	0.49	NA	0.56	0.62	0.7	NA	0.26	0.33	0.49	NA	0.44	0.45	0.38	NA
	SWIT390	0.62	0.64	0.62	NA	0.58	0.62	0.38	NA	0.36	0.31	0.17	NA	0.36	0.29	0.5	NA
	SWIT392	0.48	0.58	0.46	NA	0.52	0.57	0.45	NA	0.31	0.21	0.02	NA	0.25	0.11	0.28	NA
	SWIT394	0.51	0.66	0.34	NA	0.43	0.52	0.15	NA	0.21	0.29	-0.07	NA	0.11	0.14	0.03	NA
	SWIT396	0.44	0.62	0.41	NA	0.48	0.63	0.36	NA	0.02	-0.07	0.1	NA	0.08	-0.02	0.16	NA
	SWIT398	0.51	0.69	0.43	NA	0.38	0.52	0.13	NA	-0.21	-0.34	-0.03	NA	0.24	0.18	0.12	NA
	SWIT400	0.65	0.65	0.27	NA	0.59	0.64	0.22	NA	-0.42	-0.35	-0.3	NA	-0.41	-0.37	-0.39	NA
	SWIT402	0.66	0.7	0.55	NA	0.55	0.68	0.4	NA	-0.09	-0.14	0.08	NA	-0.32	-0.24	0.3	NA
	SWIT404	0.59	0.7	0.35	NA	0.68	0.7	0.53	NA	-0.14	-0.1	0.41	NA	0.07	0.16	0.23	NA
	SWIT406	0.43	0.63	0.36	NA	0.49	0.59	0.58	NA	0.23	0.14	0.4	NA	0.14	-0.04	0.16	NA
	SWIT408	0.61	0.67	0.55	NA	0.49	0.56	0.37	NA	0.22	0.21	0.16	NA	-0.17	-0.04	0.15	NA
	SWIT409	0.62	0.67	0.39	NA	0.61	0.72	0.59	NA	0.03	0	0.18	NA	0.17	-0.1	-0.05	NA
	SWIT410	0.49	0.61	0.43	NA	0.65	0.74	0.45	NA	0.4	0.53	0.27	NA	0.22	0.28	0.37	NA
	CZEC007	0.62	0.69	0.58	NA	0.62	0.73	0.69	NA	0.47	0.5	0.64	NA	0.48	0.25	0.5	NA
	CZEC010	0.59	0.67	0.56	NA	0.54	0.67	0.6	NA	0.21	0.11	0.27	NA	0.45	0.4	0.16	NA
	FINL078	0.65	0.72	0.43	NA	0.7	0.76	0.46	NA	0.42	0.13	0.41	NA	0.36	0.34	0.33	NA
	FINL079	0.64	0.67	0.42	NA	0.66	0.67	0.36	NA	0.45	0.49	0.33	NA	0.07	0.07	0.32	NA
	FINL080	0.66	0.71	0.5	NA	0.63	0.73	0.55	NA	0.05	0.04	0.32	NA	0.02	0.01	0.18	NA
	FINL081	0.64	0.67	0.26	NA	0.66	0.7	0.56	NA	0.02	-0.04	0.4	NA	-0.14	-0.1	0.13	NA
	FINL082	0.74	0.73	0.49	NA	0.66	0.68	0.63	NA	0.36	0.3	0.48	NA	0.44	0.42	0.42	NA
	FINL083	0.63	0.68	0.25	NA	0.61	0.64	0.4	NA	0.14	0.11	-0.16	NA	0.47	0.47	0.26	NA

	FINL084	0.58	0.64	0.73	NA	0.49	0.6	0.4	NA	0.22	0.26	0.12	NA	0.12	0.16	0.32	NA
	FINL085	0.62	0.73	0.62	NA	0.48	0.57	0.3	NA	-0.03	0.1	-0.04	NA	-0.12	0.1	0.35	NA
	FINL086	0.66	0.69	0.43	NA	0.46	0.5	-0.01	NA	0.08	0.16	-0.05	NA	-0.28	-0.14	0.31	NA
	FINL087	0.63	0.67	0.39	NA	0.51	0.55	0.27	NA	0.31	0.42	0.24	NA	0.54	0.29	0.31	NA
	FINL088	0.71	0.78	0.6	NA	0.64	0.72	0.52	NA	0.33	0.35	0.43	NA	0.51	0.51	0.34	NA
	FINL089	0.65	0.74	0.4	NA	0.57	0.66	0.25	NA	0.37	0.31	0.19	NA	0.41	0.46	0.2	NA
	FINL090	0.45	0.59	0.16	NA	0.54	0.66	0.38	NA	0.44	-0.05	-0.06	NA	0.36	0.27	-0.19	NA
	FINL091	0.65	0.66	0.17	NA	0.59	0.6	0.25	NA	-0.26	-0.23	-0.02	NA	-0.12	-0.14	-0.15	NA
	FINL092	0.59	0.6	0.35	NA	0.53	0.57	0.51	NA	0.15	0.18	0.2	NA	-0.17	0.04	-0.04	NA
	FINL093	0.49	0.52	0.19	NA	0.58	0.62	0.58	NA	-0.2	-0.21	0.26	NA	0.06	0.09	0.01	NA
	FINL094	0.73	0.78	0.75	NA	0.67	0.78	0.48	NA	0.24	0.27	0.33	NA	0.49	0.46	0.41	NA
	FINL095	0.58	0.66	0.31	NA	0.67	0.79	0.58	NA	0.27	0.14	0.5	NA	0.15	0.24	0.09	NA
	FINL096	0.62	0.7	0.45	NA	0.64	0.68	0.49	NA	0.55	0.46	0.48	NA	0.23	0.18	0.3	NA
	FINL097	0.6	0.7	0.34	NA	0.6	0.68	0.44	NA	0.17	0.08	0.44	NA	0.18	0.13	0.34	NA
	NORW019	0.68	0.76	0.54	NA	0.64	0.61	0.32	NA	0.19	0.16	0.25	NA	0.29	0.11	0.41	NA
	NORW020	0.57	0.66	0.44	NA	0.66	0.62	0.24	NA	0.28	0.13	0.18	NA	-0.13	0.05	0.39	NA
	NORW021	0.81	0.82	0.71	NA	0.36	0.5	0.21	NA	0.11	0.1	0.13	NA	0.46	0.46	0.6	NA
	NORW022	0.64	0.77	0.56	NA	0.37	0.49	0.2	NA	0.14	0.28	0.13	NA	0.16	0.5	0.4	NA
	NORW023	0.7	0.77	0.74	NA	0.5	0.58	0.1	NA	0.01	0.12	0.02	NA	-0.07	0.01	0	NA
	NORW024	0.57	0.63	0.57	NA	0.45	0.51	0.21	NA	0.21	0.23	0.21	NA	0.08	0.07	0.43	NA
	NORW025	0.65	0.73	0.59	NA	0.52	0.57	0.5	NA	0.2	0.19	0.46	NA	0.46	0.52	0.53	NA
	NORW026	0.63	0.66	0.55	NA	0.49	0.48	0.48	NA	0.25	0.26	0.3	NA	0.42	0.38	0.45	NA

	NORW027	0.62	0.69	0.19	NA	0.47	0.59	0.35	NA	0.45	0.38	0.23	NA	0.51	0.37	0.05	NA
	NORW028	0.6	0.61	0.42	NA	0.65	0.71	0.51	NA	0.14	0.11	0.24	NA	0.39	0.21	-0.05	NA
	NORW029	0.43	0.49	0.47	NA	0.38	0.61	0.34	NA	-0.05	0.11	0.06	NA	0.16	0.06	0.06	NA
	NORW030	0.39	0.5	0.51	NA	0.48	0.56	0.32	NA	-0.02	-0.09	0.21	NA	0.08	-0.02	0.18	NA
	SWED340	0.42	0.47	0.22	NA	0.49	0.66	0.23	NA	0.28	0.2	-0.24	NA	0.18	0.13	0.05	NA
	SWED341	0.51	0.57	0.22	NA	0.45	0.56	0.26	NA	0.06	0.2	0.07	NA	0.2	0.08	-0.13	NA
	CZEC012	0.47	0.59	0.4	NA	0.54	0.57	0.5	NA	-0.05	0.01	0.41	NA	0.26	0.21	0.23	NA
	CZEC013	0.5	0.6	0.64	NA	0.59	0.68	0.47	NA	0.1	-0.08	0.41	NA	0.29	0.06	0.64	NA
	CZEC018	0.6	0.67	0.65	NA	0.53	0.63	0.42	NA	-0.06	0.1	0.3	NA	0.2	0.29	0.55	NA
	RUS320	0.64	0.59	0.4	NA	0.51	0.63	0.28	NA	0.1	0.26	0.08	NA	0.16	0.14	0.3	NA
	RUS321	0.56	0.65	0.39	NA	0.48	0.55	0.29	NA	0.34	0.02	0.08	NA	0.03	0.06	0.29	NA
	RUS322	0.63	0.71	0.55	NA	0.6	0.73	0.48	NA	0.31	0.39	0.41	NA	0.36	0.55	0.47	NA
	RUS323	0.61	0.66	0.46	NA	0.49	0.6	0.56	NA	0.27	0.26	0.5	NA	0.03	0.18	0.3	NA
	RUS324	0.6	0.68	0.47	NA	0.43	0.63	0.36	NA	-0.11	-0.04	0.24	NA	0.16	0.04	0.38	NA
	RUS326	0.48	0.56	0.22	NA	0.56	0.53	0.25	NA	-0.14	-0.06	0.22	NA	-0.16	0.05	0.23	NA
	RUS329	0.39	0.49	0.44	NA	0.55	0.66	0.53	NA	0.09	0.26	0.34	NA	0.19	0.22	0.21	NA
	RUS330	0.57	0.7	0.61	NA	0.56	0.67	0.51	NA	-0.01	-0.08	0.28	NA	-0.02	0.04	0.17	NA
	RUS331	0.61	0.6	0.42	NA	0.64	0.71	0.66	NA	-0.01	-0.17	0.23	NA	0.28	0.13	0.22	NA
	RUS333	0.58	0.64	0.69	NA	0.41	0.57	0.4	NA	0.05	0.02	0.25	NA	-0.15	0.2	0.26	NA
	RUS334	0.5	0.55	0.65	NA	0.74	0.76	0.59	NA	0.52	0.34	0.41	NA	0.1	0.14	0.49	NA
	RUS336	0.63	0.72	0.55	NA	0.43	0.44	0.44	NA	0.04	0.04	0.35	NA	-0.2	0.19	0.39	NA
	RUS344	0.54	0.66	0.3	NA	0.51	0.6	0.6	NA	0.14	0.37	0.57	NA	0.17	0.02	0.31	NA
	RUS345	0.63	0.7	0.55	NA	0.67	0.69	0.5	NA	0.1	0.12	0.33	NA	0.38	0.33	0.33	NA
	RUS346	0.53	0.6	0.59	NA	0.38	0.45	0.45	NA	0.2	0.31	0.38	NA	0.18	0.14	0.51	NA
	RUS347	0.44	0.53	0.36	NA	0.74	0.78	0.65	NA	0.12	-0.01	0.45	NA	0.01	0.15	0.14	NA

	RUS348	0.61	0.62	0.3	NA	0.5	0.58	0.35	NA	0.26	0.26	0.32	NA	0.01	-0.03	0.18	NA
	RUS349	0.59	0.57	0.58	NA	0.74	0.78	0.73	NA	0.39	0.19	0.31	NA	0.15	0.19	0.4	NA
	RUS351	0.62	0.59	0.62	NA	0.62	0.63	0.62	NA	-0.02	0.22	0.49	NA	0.06	0.14	0.53	NA
	RUS360	0.57	0.59	0.52	NA	0.7	0.77	0.67	NA	0.11	0.15	0.57	NA	0.16	0.16	0.5	NA
	RUS369	0.62	0.73	0.63	NA	0.86	0.88	0.78	NA	0.35	0.43	0.69	NA	0.27	0.25	0.49	NA
	RUS379	0.52	0.6	0.27	NA	0.71	0.67	0.49	NA	-0.09	-0.02	0.21	NA	-0.1	-0.14	0.04	NA
	RUS380	0.7	0.71	0.59	NA	0.58	0.64	0.37	NA	0.42	0.48	0.28	NA	0.58	0.58	0.27	NA
	RUS383	0.51	0.5	0.32	NA	0.64	0.65	0.64	NA	0.25	0.34	0.47	NA	0.31	0.3	0.15	NA
	RUS384	0.48	0.56	0.37	NA	0.62	0.71	0.43	NA	0.09	0.24	0.11	NA	-0.09	-0.14	0.1	NA
	RUS386	0.52	0.6	0.24	NA	0.63	0.57	0.38	NA	0.31	0.21	0.11	NA	0.16	0.17	0.02	NA
ITRDB (REMOTE Forest)	180	0.63	0.68	0.77	NA	0.7	0.74	0.69	NA	0.45	0.55	0.67	NA	0.57	0.56	0.59	NA
	289	0.44	0.55	0.28	NA	0.56	0.67	0.31	NA	0.28	0.2	0.13	NA	-0.15	-0.02	-0.1	NA
	298	0.57	0.64	0.37	NA	0.59	0.61	0.32	NA	-0.38	-0.39	0.09	NA	-0.18	-0.28	0.17	NA
	382	0.58	0.62	0.58	NA	0.61	0.79	0.66	NA	-0.21	-0.25	0.1	NA	0.13	0.31	0.23	NA
	391	0.66	0.71	0.64	NA	0.71	0.74	0.74	NA	0.24	0.11	0.35	NA	0.2	0.27	0.23	NA
	543	0.64	0.69	0.62	NA	0.71	0.79	0.72	NA	0.69	0.69	0.48	NA	0.49	0.56	0.25	NA
	609	0.65	0.71	0.43	NA	0.72	0.78	0.73	NA	-0.18	-0.21	0.72	NA	0.32	0.46	0.38	NA
	624	0.63	0.68	0.26	NA	0.71	0.73	0.71	NA	0.3	0.36	0.06	NA	0.11	0.16	0.06	NA
	650	0.74	0.82	0.55	NA	0.8	0.87	0.79	NA	0.63	0.58	0.72	NA	0.63	0.6	0.07	NA
	685	0.53	0.59	0.39	NA	0.73	0.81	0.75	NA	0.24	0.01	0.57	NA	0.22	0.3	0.28	NA
	856	0.67	0.69	0.65	NA	0.71	0.87	0.65	NA	0.31	0.24	0.33	NA	0.2	0.52	0.34	NA
	910	0.46	0.56	0.58	NA	0.63	0.68	0.48	NA	0.33	0.4	0.32	NA	0.44	0.44	0.58	NA
	932	0.75	0.79	0.39	NA	0.58	0.63	0.57	NA	0.16	0.23	0.3	NA	0.11	0.04	0.25	NA

Table S5: Peak-season linear correlations for individual sites. COR indicates a value of a Pearson correlation coefficient, PER indicates a period of peak correlations.

Database	Site	DAY CHRON TEMP		DAY CHRON PREC/SM		MONTH CHRON TEMP		MONTH CHRON PREC/SM		DAY RETRO TEMP		DAY RETRO PREC/SM		MONTH RETRO TEMP		MONTH RETRO PREC/SM		Cluster
		COR	PER	COR	PER	COR	PER	COR	PER	COR	PER	COR	PER	COR	PER	COR	PER	
CZSK	HAV	-0.33	Jun 14 - Jul 23	0.623	Jun 21 - Jul 20	-0.3	Apr	0.523	Jun - Jul	-0.69	Jul 14 - Sep 17	0.454	Jun 05 - Jul 18	-0.63	Jun - Aug	0.414	Mar - Jul	Dry
	JET	0.474	Feb 13 - May 22	-0.32	Sep 01 - Sep 30	0.442	Feb - May	-0.31	Sep	0.544	Feb 18 - Mar 22	0.247	Feb 15 - Mar 16	0.542	Jan - Mar	-0.16	May - Jun	Cold
	POL	0.446	Feb 19 - Apr 29	0.274	Jul 11 - Aug 09	0.383	Mar - Apr	-0.23	Dec	0.46	Feb 24 - May 12	0.389	Jul 04 - Nov 15	0.366	Mar - May	0.384	Jul - Oct	Mixed
	RAS	-0.37	Jul 17 - Sep 20	0.641	Feb 14 - Jul 13	-0.33	Apr - May	0.599	Mar - Jul	-0.6	Dec 02 - Jan 01	0.597	Mar 01 - Jul 28	-0.59	Dec	0.597	Mar - Jul	Dry
	REJ	-0.46	Mar 29 - May 11	0.491	Apr 06 - Sep 02	-0.42	Apr - Aug	0.49	Apr - Aug	-0.63	May 26 - Aug 31	0.581	Apr 05 - Aug 31	-0.6	Jun - Aug	0.576	Apr - Aug	Dry
	STR	0.512	Feb 09 - May 30	-0.56	Mar 28 - Apr 26	0.483	Feb - May	-0.48	Apr	0.625	Feb 12 - May 11	0.515	Feb 13 - Mar 14	0.586	Feb - May	-0.42	Apr - May	Cold
	DIV	0.76	Apr 16 - Jul 26	-0.43	May 10 - Jul 27	0.709	Apr - Jul	-0.4	May - Jul	0.701	Mar 28 - Jul 17	0.582	Mar 31 - Apr 29	0.666	Apr - Jul	0.573	Apr	Cold
	CHO	0.561	Oct 07 - Nov 28	0.34	Apr 18 - May 17	0.526	Oct - Nov	0.26	Nov	0.491	Jun 24 - Aug 03	0.426	Apr 07 - May 06	0.434	Jul	0.402	Apr	Mixed
	JAV	0.657	Jun 07 - Jul 07	-0.52	Jun 03 - Jul 09	0.514	Jun - Oct	-0.48	Jun - Jul	0.699	Jun 07 - Jul 18	-0.42	May 02 - May 31	0.636	May - Jul	-0.42	May	Cold
	OST	0.555	Jun 04 - Aug 06	-0.39	May 12 - Aug 05	0.495	Jun - Jul	-0.35	May - Aug	0.666	Mar 28 - Jul 29	-0.39	May 01 - May 30	0.653	Apr - Jul	-0.39	May	Cold
	SMR	0.606	Apr 07 - Aug 07	-0.4	Feb 15 - Jul 14	0.527	Apr - Jun	-0.37	Feb - Jun	0.693	Mar 28 - Jul 24	-0.47	Apr 28 - May 27	0.674	Apr - Jul	-0.44	May	Cold
	KOS	0.302	Feb 03 - Mar 08	0.35	Apr 17 - Jun 01	0.306	Feb	0.32	Feb - May	-0.44	Mar 20 - May 07	0.618	Apr 14 - Aug 01	-0.4	Apr - May	0.57	Apr - Jul	Mixed
	LET	-0.42	Apr 14 - Jul 06	0.763	Apr 14 - Jul 20	-0.32	Jun	0.738	May - Jul	0.385	Feb 13 - Apr 10	0.399	Apr 18 - Aug 27	0.301	Feb - Mar	0.368	May - Aug	Dry
	LUB	0.52	Oct 05 - Nov 10	0.431	Mar 07 - Aug 03	0.487	Oct - Nov	0.427	Mar - Jul	-0.49	May 17 - Jun 25	-0.18	Jan 15 - Feb 13	-0.42	May - Jun	-0.15	Jul	Mixed
	PRA	-0.38	Jan 01 - Jan 30	0.508	Feb 11 - Jul 09	-0.36	Jan	0.495	Feb - Jun	-0.58	Sep 15 - Nov 11	0.42	Feb 12 - Mar 13	-0.43	Aug - Oct	0.381	Jan - May	Dry

	RAA	0.409	Sep 21 - Oct 22	0.716	Feb 11 - Jul 10	0.306	Oct	0.701	Feb - Jun	-0.39	Jul 16 - Aug 14	0.37	Feb 04 - Jun 09	-0.25	Aug	0.36	Feb - May	Mixed
	RUZ	0.523	Feb 09 - May 22	-0.47	Mar 25 - Apr 23	0.508	Jan - May	-0.38	Apr	0.413	Feb 12 - Mar 13	0.486	Jun 12 - Jul 29	0.343	Feb - Mar	0.472	Jun - Jul	Cold
	BRE	0.437	Jan 15 - Jun 07	0.308	Feb 04 - Mar 05	0.372	Feb - May	0.287	Feb	-0.33	Aug 09 - Nov 08	0.399	May 29 - Jul 29	-0.27	Aug - Oct	0.392	Jun - Jul	Mixed
	PAL	-0.46	May 25 - Jul 06	0.61	May 10 - Jun 13	-0.4	Jun - Jul	0.562	May - Jul	0.399	Mar 01 - Apr 09	-0.24	Apr 02 - May 01	0.329	Mar	-0.23	Apr	Dry
	SUV	0.5	Oct 06 - Nov 04	0.43	Feb 15 - Mar 16	0.431	Oct - Nov	0.331	Feb - Mar	-0.43	Oct 29 - Dec 14	0.428	Jun 05 - Jul 04	-0.37	Nov	0.37	Jun	Mixed
	TAT	0.449	Jan 02 - Jan 31	0.488	Jan 01 - Apr 02	0.448	Jan	0.477	Jan - Mar	0.431	Feb 05 - Apr 09	0.391	Oct 08 - Nov 06	0.364	Feb - Mar	0.355	Jul	Mixed
	TRK	-0.52	Jun 01 - Oct 17	0.867	Apr 07 - Jul 31	-0.47	Jun - Sep	0.854	Apr - Jul	0.368	Jun 24 - Aug 09	-0.25	Mar 20 - Apr 18	-0.33	May	0.128	Jul - Nov	Dry
ITRDB	GERM188	0.385	Apr 15 - May 15	0.477	Feb 15 - Jul 08	-0.28	Jun	0.432	May - Aug	0.661	Jan 30 - Apr 06	0.434	Jun 07 - Jul 14	0.634	Feb - Mar	0.362	Jul	Mixed
	SWIT279	0.355	Aug 10 - Sep 08	0.452	Oct 14 - Nov 14	0.253	Jun - Aug	0.251	Feb	0.468	Jul 03 - Aug 01	-0.44	May 30 - Jul 12	0.438	Jul	-0.34	Jun - Jul	Mixed
	CZEC005	-0.51	Apr 17 - Sep 13	-0.45	Jan 09 - Feb 17	-0.5	Apr - Aug	-0.38	Nov	0.435	Mar 06 - Apr 12	-0.39	May 08 - Jun 26	0.305	Mar	-0.29	Mar - Jun	Mixed
	SWIT368	-0.55	Aug 05 - Sep 04	0.361	Jul 17 - Aug 30	-0.46	Aug	0.25	Mar	-0.64	Jun 05 - Sep 16	0.454	Jul 16 - Aug 17	-0.6	Jun - Oct	0.358	Dec	Dry
	SWIT369	0.575	Apr 08 - Jun 07	-0.52	Jun 28 - Jul 27	0.474	Apr - May	-0.45	Jul	-0.44	Aug 26 - Oct 05	-0.4	Jan 06 - Feb 04	-0.37	Sep	0.338	Aug - Dec	Cold
	SWIT370	-0.51	May 06 - Sep 16	0.416	Mar 15 - Apr 13	-0.48	May - Aug	-0.3	Sep - Dec	-0.59	Jun 03 - Sep 24	0.56	May 21 - Sep 23	-0.56	Jun - Sep	0.513	Jun - Sep	Mixed
	SWIT371	-0.44	Jan 01 - Feb 17	-0.41	Nov 30 - Dec 30	0.378	Jul	-0.39	Dec	-0.4	Jul 08 - Sep 21	0.364	Oct 28 - Dec 30	-0.36	Jul - Sep	0.351	Nov - Dec	Mixed
	SWIT372	0.603	Jun 27 - Aug 20	-0.53	Jun 27 - Aug 12	0.507	Jul	-0.34	Jul - Sep	0.478	Jun 21 - Aug 01	-0.55	May 25 - Jul 13	0.454	Jul	-0.45	Jul	Cold
	SWIT373	0.422	Apr 07 - May 06	-0.47	Aug 22 - Oct 01	0.331	Sep - Nov	-0.43	Sep	0.44	Jan 01 - Feb 09	0.549	Feb 21 - Mar 22	0.393	Jan	0.442	Mar - Apr	Cold
	SWIT374	0.604	Apr 09 - May 14	0.401	Apr 28 - Jun 26	0.551	Apr - Jul	0.265	May - Jun	0.383	Jan 03 - Apr 12	0.404	Feb 05 - Mar 26	0.316	Jan - Mar	0.356	Nov - Dec	Mixed
	SWIT375	-0.54	Aug 03 - Sep 01	0.535	Mar 07 - Apr 18	-0.52	Aug	0.473	Mar	-0.54	Jun 07 - Oct 12	0.424	Feb 21 - Mar 22	-0.47	Jun - Sep	0.366	Aug - Dec	Dry
	SWIT376	-0.49	Jun 16 - Oct 13	-0.46	Nov 29 - Dec 28	0.438	Mar	-0.41	Dec	-0.53	Jun 18 - Aug 24	0.496	Oct 09 - Nov 07	-0.42	Jun - Aug	0.3	Oct - Dec	Mixed
	SWIT377	0.504	Apr 08 - May 15	0.465	May 25 - Jun 26	0.406	Apr - May	0.373	May - Jun	0.361	Oct 03 - Nov 14	-0.33	May 13 - Jun 17	0.282	Oct	0.251	Aug - Dec	Mixed
	SWIT378	-0.52	Aug 13 - Dec 03	-0.39	Nov 16 - Dec 29	-0.45	Oct - Nov	-0.34	Nov - Dec	-0.49	Jul 10 - Oct 15	0.553	Jun 05 - Oct 31	0.398	Jan - Mar	0.544	Jun - Oct	Mixed
	SWIT379	0.53	Apr 10 - May 15	-0.5	Jun 27 - Aug 11	0.46	Jul	-0.35	Jul	0.541	May 14 - Aug 02	-0.41	Jun 12 - Jul 13	0.507	May - Jul	-0.33	Jun - Jul	Cold

	SWIT380	0.48	Apr 18 - May 29	-0.51	Jul 27 - Dec 21	0.423	Apr - May	-0.42	Aug - Dec	-0.58	Jun 10 - Aug 23	0.398	Jun 02 - Oct 16	-0.5	Jun - Aug	0.324	Jun - Oct	Cold
	SWIT381	-0.53	Jun 13 - Oct 06	0.348	Jun 12 - Jul 13	-0.44	Aug - Sep	0.232	Feb - Mar	-0.44	Jun 05 - Aug 08	0.441	May 07 - Sep 15	-0.35	Jun - Jul	0.374	Apr - Jul	Dry
	SWIT382	0.538	May 24 - Jul 24	0.509	Oct 21 - Nov 19	0.495	Jun - Jul	0.456	Nov	0.587	May 12 - Aug 02	0.457	Jul 31 - Sep 23	0.579	May - Jul	0.358	Aug - Sep	Mixed
	GERM227	0.434	Oct 09 - Nov 07	0.541	Feb 14 - Mar 31	-0.32	Jan - May	0.48	Aug - Sep	0.469	May 11 - Jun 09	-0.49	Aug 12 - Sep 11	-0.36	Oct - Nov	0.446	Apr	Mixed
	GERM234	-0.41	May 18 - Jul 21	0.725	May 06 - Aug 20	-0.38	Jun	0.704	May - Aug	0.501	Feb 16 - Mar 17	0.663	Jun 05 - Jul 14	-0.38	Jun - Jul	0.596	Jun - Jul	Dry
	GERM235	-0.34	Jun 13 - Aug 17	0.74	Mar 22 - Jul 19	-0.26	Jun - Aug	0.672	Apr - Aug	0.444	May 09 - Jun 07	0.575	Feb 18 - Jul 14	0.318	Jan - Mar	0.469	Mar - Jul	Dry
	GERM237	0.355	Apr 15 - May 15	0.494	May 25 - Jun 25	-0.31	Jan	0.399	May - Sep	0.665	Jan 18 - May 29	0.575	Feb 09 - Mar 12	0.647	Mar - May	0.462	Feb - Mar	Mixed
	GERM238	0.498	Sep 20 - Oct 19	0.526	Jul 28 - Aug 26	0.41	Oct	0.396	Aug	-0.51	Jul 25 - Nov 20	0.591	May 17 - Jun 23	-0.44	Sep - Nov	0.4	May - Jun	Mixed
	GERM239	0.329	Apr 08 - May 15	0.424	Oct 15 - Nov 13	0.2	Jul - Oct	0.311	Jun - Oct	0.496	Feb 22 - Mar 23	0.467	May 29 - Jun 27	-0.42	Sep - Oct	0.443	Jun	Mixed
	GERM240	-0.46	May 16 - Jun 30	0.699	May 09 - Sep 15	-0.37	Jun	0.658	Apr - Aug	0.628	Feb 03 - Jun 18	0.584	Feb 07 - Mar 12	0.607	Feb - Jun	0.389	Jul - Aug	Dry
	GERM241	-0.42	Jun 13 - Jul 18	0.668	Mar 29 - Jul 07	-0.3	Jun	0.639	Apr - Jun	0.454	Aug 14 - Sep 12	0.532	Apr 06 - May 22	0.31	Mar - May	0.356	Apr	Dry
	GERM243	-0.44	Jun 13 - Jul 17	0.555	Mar 29 - Jun 28	-0.27	Jan	0.528	Apr - Jun	-0.49	Apr 07 - May 06	0.589	Apr 04 - May 06	-0.33	Oct - Nov	0.507	Apr	Dry
	GERM244	-0.63	Jun 10 - Jul 21	0.734	Feb 14 - Jul 06	-0.56	Jun - Jul	0.692	Apr - Jun	0.445	May 10 - Jun 08	0.655	Apr 05 - Jul 23	0.238	Mar - May	0.598	Apr - Jul	Dry
	GERM245	-0.48	May 16 - Aug 07	0.754	May 06 - Aug 14	-0.41	Jun - Jul	0.686	May - Aug	0.391	May 12 - Jun 10	-0.41	Aug 25 - Sep 26	-0.29	Oct - Nov	0.265	Jun - Jul	Dry
	GERM246	0.484	Sep 03 - Oct 19	0.789	May 05 - Jul 16	0.436	Sep - Oct	0.732	May - Jul	0.257	Mar 26 - Apr 28	0.634	Apr 28 - Aug 02	0.221	Jun	0.596	May - Jul	Mixed
	SWED335	-0.47	May 31 - Jun 29	0.586	Apr 30 - Jun 24	-0.46	Jun	-0.48	Nov	-0.48	Apr 14 - May 14	-0.38	Nov 14 - Dec 13	-0.41	Apr	-0.23	Dec	Mixed
	SWED336	0.459	Jun 28 - Jul 27	-0.46	Oct 24 - Nov 27	0.394	Jul	-0.38	Oct - Nov	-0.47	Sep 04 - Oct 03	-0.43	Jan 14 - Feb 13	-0.4	Sep	-0.3	May - Aug	Cold
	SWED337	-0.4	Jun 18 - Jul 17	0.657	Aug 16 - Oct 11	-0.36	Jun - Aug	0.625	May - Sep	-0.38	Apr 28 - Jun 05	0.71	May 05 - Jun 04	-0.3	May - Jul	-0.51	Jan	Dry
	SWED338	0.483	Jan 09 - Mar 15	0.573	May 10 - Jun 09	0.453	Jan - Mar	-0.41	Nov	-0.52	Apr 04 - May 14	0.43	Mar 21 - May 01	-0.48	Apr	0.356	Apr	Mixed
	CZEC006	0.548	Apr 13 - Aug 28	-0.56	Nov 17 - Dec 30	0.5	Apr - Aug	-0.47	Nov - Dec	0.572	Apr 27 - Jul 22	0.396	Jan 18 - Mar 01	0.541	May - Jul	0.377	Jan - Mar	Cold
	SWIT390	0.467	Jul 18 - Nov 29	0.562	Feb 24 - Jun 29	0.421	Jul - Nov	0.525	Mar - Jun	0.562	Jun 08 - Nov 04	0.36	Jan 13 - Mar 13	0.554	Jun - Oct	0.227	Jan - May	Mixed
	SWIT392	0.442	Apr 23 - Aug 15	0.455	May 25 - Jun 26	0.379	Jul	0.297	Jun	0.527	Jul 02 - Aug 02	-0.49	Jun 15 - Jul 14	0.499	Jul	-0.41	Jun - Jul	Mixed

	SWIT394	-0.51	Nov 23 - Dec 22	-0.49	Jul 01 - Aug 13	-0.38	Dec	-0.4	Jul	-0.41	May 22 - Jun 20	0.476	Feb 26 - Apr 18	-0.36	Apr	0.349	Feb - Apr	Mixed
	SWIT396	0.488	Apr 09 - May 15	0.435	May 05 - Jun 09	0.4	Apr - Jul	0.26	Nov - Dec	0.36	Oct 06 - Nov 04	0.63	Feb 12 - Apr 18	0.31	Oct	0.466	Feb - Apr	Mixed
	SWIT398	0.4	Apr 07 - May 06	0.617	Apr 20 - Jun 25	-0.29	Feb	0.466	May - Jun	0.33	Sep 19 - Nov 03	0.51	Feb 19 - Apr 14	0.263	Oct	0.343	Mar	Mixed
	SWIT400	-0.46	Jan 01 - Feb 20	-0.57	Apr 05 - Jun 06	-0.44	Jan	-0.54	Mar - Jun	-0.5	May 23 - Jul 01	0.574	Feb 24 - Apr 09	-0.47	Jun	0.471	Feb - May	Mixed
	SWIT402	0.524	Apr 25 - Jun 21	-0.64	Apr 04 - Jun 17	0.461	May - Jul	-0.6	Mar - May	0.291	Sep 29 - Nov 04	0.677	Jan 29 - Mar 18	0.277	Oct	0.543	Feb - Mar	Cold
	SWIT404	-0.38	Jun 09 - Jul 16	-0.67	Nov 16 - Dec 21	-0.33	Jun	-0.59	Nov - Dec	-0.45	Nov 04 - Dec 14	0.675	Feb 21 - Jul 04	0.383	Jan - Mar	0.624	Feb - Jun	Mixed
	SWIT406	0.429	Apr 24 - Jun 08	-0.47	Nov 16 - Dec 19	0.321	Apr - May	-0.33	Aug - Sep	0.451	Feb 03 - Apr 12	0.519	Feb 20 - Mar 26	0.41	Feb - May	0.325	Feb - Mar	Cold
	SWIT408	0.615	Apr 24 - Jul 29	0.509	Oct 17 - Nov 15	0.587	May - Jul	-0.41	Mar - Jul	0.417	Feb 25 - Mar 26	0.432	Feb 13 - Mar 27	0.355	Mar	0.31	Aug - Sep	Mixed
	SWIT409	0.428	Sep 29 - Nov 24	0.659	Mar 06 - Jul 29	0.363	Oct	0.61	Mar - Jul	0.696	Jun 12 - Jul 11	-0.33	May 18 - Jul 11	0.598	Jun - Oct	-0.22	Oct	Mixed
	SWIT410	0.482	Jun 05 - Aug 02	-0.49	Jun 26 - Jul 25	0.464	Jun - Jul	-0.37	Mar - Jul	0.702	Jun 17 - Jul 29	-0.51	Sep 26 - Oct 27	0.542	May - Jul	-0.34	Oct	Cold
	CZEC007	0.577	Apr 07 - Aug 14	0.458	Mar 11 - May 06	0.521	Jul - Nov	0.415	Feb - Jun	0.671	Jun 05 - Jul 09	0.39	Aug 30 - Dec 30	0.615	Apr - Aug	0.352	Jan - Mar	Mixed
	CZEC010	0.595	Jul 16 - Aug 14	-0.52	Nov 23 - Dec 30	0.511	Jul - Nov	-0.41	Dec	0.595	Jun 06 - Jul 07	0.458	Jan 05 - Jun 03	0.457	Jun - Jul	0.435	Jan - May	Cold
	FINL078	0.585	Mar 06 - Apr 04	-0.49	Jul 07 - Aug 15	0.548	Mar - Jul	-0.41	Jul	0.596	Jul 12 - Sep 25	0.641	Jan 09 - Mar 20	0.532	Jul - Sep	0.591	Jan - Feb	Cold
	FINL079	0.561	Mar 07 - Jul 30	0.468	May 04 - Jun 04	0.528	Mar - Jul	0.4	May	0.56	Dec 01 - Dec 30	0.553	Dec 01 - Dec 30	0.572	Dec	0.534	Dec	Mixed
	FINL080	0.658	Feb 16 - May 26	0.353	May 07 - Jun 14	0.598	Mar - May	0.325	Mar - Jun	0.625	Jul 23 - Oct 22	0.496	Apr 05 - May 27	0.612	Jul - Oct	0.423	May	Mixed
	FINL081	0.651	Feb 24 - May 26	0.343	Mar 01 - Apr 13	0.604	Mar - May	-0.29	Jan - Feb	0.669	Jul 01 - Oct 25	0.44	May 03 - Jun 01	0.651	Jul - Oct	0.385	May	Mixed
	FINL082	0.644	Mar 07 - Jul 30	0.51	May 04 - Jun 13	0.614	Mar - Jul	0.48	May	0.573	Jun 02 - Aug 30	0.531	Nov 26 - Dec 27	0.565	Jun - Aug	0.5	Dec	Mixed
	FINL083	0.569	Mar 06 - Apr 04	0.526	May 04 - Jun 12	0.478	Mar - May	0.475	May	0.587	Jul 11 - Aug 24	-0.49	Jun 24 - Nov 12	0.469	Jul - Aug	-0.46	Jul - Nov	Mixed
	FINL084	0.506	Apr 30 - May 29	0.443	May 06 - Jul 01	0.47	May	0.396	May - Jun	0.488	Jun 25 - Nov 20	-0.49	Feb 06 - Mar 14	0.464	Jul - Nov	-0.35	Feb - Mar	Mixed
	FINL085	0.693	Oct 22 - Nov 20	0.512	Jun 05 - Nov 01	0.54	Nov	0.498	Jun - Oct	0.498	Mar 20 - May 13	-0.35	Sep 22 - Oct 21	0.391	Apr	-0.26	Oct	Mixed
	FINL086	0.65	Mar 07 - May 26	0.466	May 13 - Jun 16	0.604	Mar - Jul	0.343	May - Jun	-0.31	Jan 04 - Feb 26	-0.44	Jan 26 - Feb 25	-0.29	Jan - Mar	-0.37	Feb	Mixed
	FINL087	0.543	Mar 24 - Jul 30	0.509	May 12 - Jun 22	0.518	Jul	0.478	May - Jun	0.49	Apr 24 - May 23	-0.49	Oct 22 - Dec 01	0.367	Jul	-0.37	Feb	Mixed

	FINL088	0.672	Apr 16 - Aug 25	-0.49	Jul 07 - Aug 20	0.635	Mar - Jul	0.395	May	0.588	Jun 10 - Jul 24	0.576	Dec 01 - Dec 30	0.497	Jun - Aug	0.558	Dec	Mixed
	FINL089	0.576	Mar 18 - May 28	0.56	Apr 15 - Jun 03	0.52	Mar - May	0.461	May	0.624	Apr 14 - May 13	-0.45	Oct 19 - Nov 24	0.437	Mar - May	0.478	Dec	Mixed
	FINL090	-0.51	Apr 18 - Jun 18	-0.41	Jun 18 - Jul 17	-0.4	May	0.325	Feb - Mar	0.423	Jan 20 - May 05	0.653	Feb 04 - Apr 07	0.412	Jan - Apr	0.526	Feb - Mar	Mixed
	FINL091	0.497	Mar 01 - Apr 14	-0.54	Jan 01 - Jan 31	0.446	Mar	-0.54	Jan	-0.43	Mar 02 - Mar 31	0.554	Aug 30 - Dec 30	-0.42	Mar	0.544	Sep - Dec	Cold
	FINL092	0.527	Jun 17 - Sep 14	-0.39	Jan 01 - Jan 30	0.484	Jul - Aug	-0.38	Jan	0.501	Mar 25 - May 11	-0.39	Mar 31 - Apr 30	0.442	Apr - May	-0.32	Apr	Cold
	FINL093	0.428	Feb 25 - Apr 06	-0.37	Jan 01 - Feb 01	0.369	Mar	-0.36	Jan	0.56	Mar 30 - May 31	-0.37	Mar 31 - May 01	0.535	Apr - May	-0.26	Apr	Cold
	FINL094	0.599	Jan 17 - May 29	0.712	Mar 23 - Jul 12	0.554	Feb - May	0.682	Apr - Aug	0.495	Jun 26 - Nov 21	0.76	May 08 - Jun 10	0.484	Jul - Nov	0.617	May	Mixed
	FINL095	0.484	Sep 04 - Nov 15	0.614	May 11 - Jul 10	0.46	Sep - Dec	0.422	May - Jun	0.649	Jun 12 - Nov 08	0.516	Jan 16 - Feb 14	0.614	Apr - Aug	-0.39	Oct	Mixed
	FINL096	0.554	Apr 16 - Aug 26	0.45	Apr 15 - Jun 03	0.497	Apr - Aug	0.399	May	0.572	Jul 01 - Sep 24	0.528	Sep 04 - Oct 09	0.54	Jul - Sep	0.45	Sep	Mixed
	FINL097	0.455	Jul 13 - Aug 25	-0.54	Jul 07 - Nov 11	0.396	Apr - Aug	-0.49	Jul - Nov	0.544	Jul 01 - Sep 24	0.555	Sep 08 - Oct 09	0.514	Jul - Sep	0.41	Sep	Cold
	NORW019	0.71	Jul 11 - Aug 15	-0.6	Sep 17 - Dec 09	0.596	Jul - Aug	-0.51	Sep - Dec	0.423	Apr 11 - May 20	0.572	Apr 30 - Jun 02	0.322	May - Jul	0.542	May	Cold
	NORW020	0.608	Jul 12 - Aug 30	-0.48	Jan 29 - Mar 02	0.524	Jul - Aug	-0.43	Jan - Feb	0.369	Apr 11 - May 20	0.614	May 02 - Jun 03	-0.25	Jan - Feb	0.57	May	Cold
	NORW021	0.8	Jul 03 - Aug 01	-0.54	Sep 15 - Dec 15	0.794	Jul	-0.44	Sep - Dec	0.318	Jun 13 - Jul 13	-0.41	Jun 27 - Aug 04	0.165	Jun - Jul	-0.35	Jul	Cold
	NORW022	0.595	Jul 06 - Aug 18	0.612	Apr 16 - Jun 06	0.54	Jul - Aug	-0.52	Jul - Nov	0.351	Jun 11 - Jul 14	-0.38	Jun 27 - Aug 07	-0.25	Feb	-0.3	Jul	Mixed
	NORW023	0.732	Jun 27 - Aug 06	0.422	May 11 - Jun 14	0.689	Jul - Aug	-0.29	Apr	-0.39	Aug 04 - Nov 17	0.436	Aug 04 - Sep 05	-0.33	Aug - Oct	0.363	Aug	Mixed
	NORW024	0.582	Jun 16 - Aug 10	0.361	May 11 - Jun 14	0.549	Jun - Aug	-0.28	Apr - May	0.353	Jul 11 - Aug 30	-0.5	May 19 - Jul 31	0.278	Jul - Aug	-0.43	Jul	Mixed
	NORW025	0.599	Jun 11 - Sep 19	-0.59	Jan 25 - Feb 25	0.538	Jun - Sep	-0.49	Jan - Feb	0.532	Jun 10 - Aug 17	-0.48	Jun 10 - Jul 09	0.507	Jun - Jul	-0.35	Jun - Jul	Cold
	NORW026	0.58	May 29 - Sep 19	-0.48	Jan 03 - Mar 02	0.536	Jun - Sep	-0.45	Jan - Feb	0.417	May 29 - Aug 17	-0.41	Jun 05 - Jul 06	0.356	Jun - Aug	0.339	Oct	Cold

	NORW027	-0.48	Jan 09 - Feb 28	-0.59	Nov 23 - Dec 30	-0.44	Jan - Feb	-0.55	Dec	-0.57	Jan 14 - Feb 17	-0.38	Jan 20 - Feb 20	-0.4	Jan - Mar	-0.37	Dec	Mixed
	NORW028	0.513	Jul 06 - Aug 26	-0.5	Sep 17 - Dec 30	0.447	Jul	-0.49	Nov - Dec	0.56	Apr 11 - Jul 17	0.45	May 10 - Jun 26	0.501	Apr - Aug	0.373	May - Jun	Cold
	NORW029	0.336	Mar 05 - Apr 08	-0.44	Mar 21 - Apr 19	-0.28	Oct	0.29	Aug	0.426	Jun 07 - Aug 17	0.398	Apr 22 - May 21	0.348	Jun - Jul	0.233	Jan	Mixed
	NORW030	0.412	Jul 06 - Aug 04	-0.42	Mar 15 - Apr 14	0.363	Jul	-0.25	Mar - Apr	0.492	Apr 12 - May 18	0.412	Feb 28 - Apr 02	0.379	Apr - Jul	0.395	Mar	Cold
	SWED340	-0.39	Sep 04 - Oct 24	-0.33	Jun 12 - Jul 12	-0.37	Sep - Oct	-0.16	Feb - Mar	0.523	Apr 05 - May 16	-0.44	Apr 28 - Jul 08	0.434	Mar - Jun	-0.33	May - Jul	Mixed
	SWED341	-0.45	Sep 03 - Nov 02	-0.32	Apr 11 - Jul 08	-0.44	Sep - Oct	-0.27	Feb	0.502	Apr 05 - May 16	-0.33	Apr 14 - May 27	0.407	Apr - May	-0.21	May	Mixed
	CZEC012	0.488	Jul 23 - Nov 05	-0.51	Nov 10 - Dec 15	0.428	Oct - Nov	-0.31	Nov	0.47	Mar 12 - May 23	0.406	Jul 04 - Sep 28	0.411	Mar - May	0.381	Jul - Sep	Cold
	CZEC013	-0.41	Jun 04 - Sep 14	-0.54	Oct 21 - Dec 03	-0.35	Apr - Jun	-0.46	Nov	-0.44	Sep 13 - Oct 16	0.566	May 31 - Aug 01	0.246	Feb	0.545	Jun - Jul	Mixed
	CZEC018	0.354	Oct 10 - Nov 23	0.593	Feb 17 - May 04	0.342	Sep - Dec	0.493	Apr	-0.4	Jul 29 - Nov 11	0.565	Mar 13 - Jul 23	-0.34	Aug - Oct	0.436	Mar - Jul	Mixed
	RUS320	0.488	Jun 11 - Jul 17	-0.45	Nov 14 - Dec 13	0.405	Jun - Aug	-0.43	Jan	-0.47	Feb 07 - Mar 27	-0.37	Nov 28 - Dec 27	-0.45	Feb - Mar	0.292	Sep - Oct	Cold
	RUS321	0.52	Jun 10 - Jul 18	-0.49	Mar 16 - Apr 27	0.428	Jun - Jul	-0.41	Nov - Dec	-0.46	Oct 30 - Dec 30	-0.43	Nov 25 - Dec 24	-0.46	Nov - Dec	-0.29	Nov - Dec	Cold
	RUS322	0.552	Jul 14 - Nov 22	0.536	Feb 15 - Jul 14	0.518	Jul - Nov	0.454	Feb - Jun	0.456	Jul 05 - Aug 15	0.54	May 28 - Jul 17	0.415	Jul	0.407	Jun	Mixed
	RUS323	0.602	Jan 01 - Feb 06	0.51	Dec 01 - Dec 30	0.548	Jan	0.485	Dec	0.581	May 31 - Jul 11	0.388	Feb 06 - Mar 15	0.483	Jun	0.268	Feb - Mar	Mixed
	RUS324	0.562	Mar 26 - May 08	0.47	Oct 02 - Dec 29	0.469	Apr	0.459	Oct - Dec	-0.36	May 16 - Jun 14	-0.41	Jan 04 - Feb 03	0.301	Jul - Aug	-0.36	Jan	Mixed
	RUS326	-0.39	May 23 - Jun 28	-0.43	Feb 23 - Apr 12	-0.35	May - Jun	0.39	Dec	0.407	Jun 20 - Aug 01	-0.46	Jan 12 - Feb 16	-0.33	Jan	-0.35	Jan - Feb	Mixed
	RUS329	0.353	Mar 06 - May 07	0.366	Apr 11 - May 16	0.322	Aug - Nov	-0.26	Dec	-0.42	May 08 - Jun 14	0.566	Jan 19 - Apr 27	0.383	Oct	0.499	Jan - Apr	Mixed
	RUS330	-0.48	Apr 20 - Jun 30	0.665	Jun 05 - Jul 05	-0.44	May - Jun	0.549	Jun	0.473	Mar 31 - Apr 29	0.61	Jan 17 - Jun 07	0.443	Apr	0.467	Jan - May	Dry
	RUS331	0.452	Jan 12 - Feb 11	-0.55	Oct 30 - Nov 29	0.369	Oct - Dec	-0.53	Nov	0.639	May 26 - Aug 02	0.474	Oct 05 - Nov 14	0.595	Jun - Jul	0.353	Jul	Cold
	RUS333	0.41	Aug 13 - Oct 27	-0.58	Nov 03 - Dec 02	0.374	Aug - Oct	-0.51	Nov	0.5	Oct 13 - Nov 11	0.368	Feb 09 - Apr 09	0.313	Apr - May	-0.32	Jan	Cold
	RUS334	0.457	Sep 02 - Nov 11	-0.39	Nov 20 - Dec 21	0.425	Sep - Oct	0.281	Mar	0.464	Feb 10 - Apr 30	0.726	Jan 19 - May 13	0.438	Jan - Apr	0.7	Jan - May	Mixed

	RUS336	0.579	Mar 25 - Apr 26	0.625	Jun 21 - Jul 20	0.521	Mar - Apr	0.505	May - Jul	0.377	Oct 17 - Dec 12	0.388	Sep 10 - Oct 17	-0.37	Apr - May	0.268	Jun - Oct	Mixed
	RUS344	0.514	Nov 09 - Dec 08	0.487	May 23 - Jul 25	0.388	Apr	0.417	Jun - Jul	0.384	Sep 12 - Oct 27	0.536	Feb 27 - Jul 14	-0.38	Feb - Jun	0.443	Mar - Jul	Mixed
	RUS345	0.615	Mar 17 - May 07	0.612	Mar 23 - May 01	0.524	Mar - Apr	0.57	Apr	0.621	Jul 15 - Dec 10	0.6	Nov 07 - Dec 29	0.609	Jul - Nov	0.558	Nov - Dec	Mixed
	RUS346	-0.39	Nov 24 - Dec 23	0.49	May 08 - Jul 26	-0.38	Dec	0.436	May - Jul	-0.43	Jul 23 - Sep 16	0.409	May 25 - Oct 19	-0.32	Jul - Aug	0.357	Jun - Oct	Dry
	RUS347	-0.37	May 06 - Jun 18	-0.42	Nov 20 - Dec 21	0.304	Aug - Sep	-0.35	Dec	0.431	Aug 18 - Nov 05	0.752	Jan 19 - Mar 26	0.38	Aug - Oct	0.724	Jan - May	Mixed
	RUS348	-0.42	May 06 - Jul 08	-0.49	Mar 29 - Apr 27	-0.37	May - Jun	-0.44	Apr	0.504	Mar 08 - Apr 16	0.491	Jan 21 - Feb 28	0.409	Mar - Apr	0.462	Jan - Feb	Mixed
	RUS349	0.347	Sep 01 - Sep 30	0.43	Jul 07 - Aug 08	0.371	Sep	0.331	May - Sep	-0.48	May 02 - Jun 09	0.73	Feb 25 - Jun 08	-0.43	May	0.663	Mar - May	Mixed
	RUS351	0.555	Oct 01 - Nov 29	0.387	Oct 24 - Nov 23	0.565	Oct - Nov	-0.31	May	0.411	Sep 08 - Nov 01	0.616	Jan 01 - May 29	0.321	Sep - Oct	0.615	Jan - May	Mixed
	RUS360	0.35	Mar 01 - Mar 30	0.57	Jan 01 - Feb 16	0.339	Mar	0.509	Jan	-0.69	Apr 28 - Jun 13	0.582	Apr 04 - Jun 14	-0.65	May - Jun	0.543	Apr - Jul	Mixed
	RUS369	0.512	Feb 28 - Mar 29	0.594	Feb 13 - May 20	0.498	Mar	0.441	Jan - May	-0.82	May 02 - Jun 23	0.746	Apr 04 - Jun 17	-0.8	May - Jun	0.678	Apr - May	Mixed
	RUS379	-0.46	May 09 - Jun 16	-0.49	Mar 30 - May 01	-0.41	May	-0.45	Apr	0.448	Jan 14 - Mar 17	0.652	Jan 27 - Apr 24	0.381	Jan - Feb	0.63	Mar - Jul	Mixed
	RUS380	-0.54	Apr 20 - Jun 22	0.682	May 02 - May 31	-0.43	Apr - May	0.688	May	-0.59	Apr 30 - Jun 14	0.509	Apr 15 - Jun 01	-0.54	May	0.44	Apr - May	Dry
	RUS383	-0.34	Apr 03 - Jul 05	0.484	Jun 20 - Jul 20	-0.33	Feb - Jun	0.461	May - Sep	-0.5	May 01 - Sep 02	0.602	Feb 20 - Jul 17	-0.49	May - Aug	0.59	Mar - Jul	Dry
	RUS384	-0.43	Nov 09 - Dec 08	0.456	Jan 01 - Jan 30	-0.28	Nov	0.445	Jan	-0.61	Aug 11 - Sep 27	0.505	May 30 - Aug 27	-0.56	Aug - Sep	0.425	Jun - Aug	Dry
	RUS386	-0.42	Nov 07 - Dec 30	-0.51	Oct 08 - Dec 02	-0.43	Nov - Dec	-0.41	Nov	-0.47	Aug 15 - Sep 13	0.474	Jul 02 - Jul 31	0.432	Jan - Apr	0.477	Jul	Mixed
ITRDB (REMOTE Forest)	180	0.667	Jun 04 - Aug 05	-0.46	Nov 17 - Dec 16	0.626	Jun - Oct	-0.38	Dec	0.724	Apr 27 - Jul 29	-0.43	Jun 08 - Jul 07	0.697	May - Jul	-0.41	Jun	Cold
	289	0.506	Jan 09 - Feb 15	0.4	Mar 05 - May 15	0.38	Jan	0.311	Mar - Apr	-0.53	Mar 16 - May 13	0.524	Oct 24 - Dec 26	-0.43	Apr	0.488	Dec	Mixed
	298	0.429	May 22 - Jun 24	-0.54	Oct 20 - Dec 29	0.398	Sep	-0.41	Nov - Dec	0.481	Feb 03 - Mar 04	0.541	Aug 25 - Dec 29	0.46	Jan - Feb	0.497	Sep - Dec	Cold
	382	0.547	Jul 27 - Sep 08	-0.53	Aug 07 - Dec 29	0.522	Aug	-0.49	Aug - Dec	0.409	May 21 - Jun 19	0.674	May 29 - Jul 07	0.212	Jun	0.597	Feb - Jun	Cold
	391	0.694	May 04 - Jun 24	-0.5	May 20 - Jun 18	0.658	May - Jun	-0.34	May - Jul	0.508	Jul 14 - Aug 18	0.691	Feb 11 - Mar 27	0.435	Jun	0.643	Feb - Jun	Cold
	543	0.684	Jun 05 - Aug 13	-0.5	Apr 24 - Jun 28	0.629	Jun - Jul	-0.39	May - Jun	0.771	Jun 11 - Jul 18	-0.44	Jun 05 - Jul 04	0.692	Jul	0.34	Jan - Mar	Cold
	609	-0.66	Jan 03 - Feb 01	-0.37	May 21 - Jun 19	-0.64	Jan	-0.24	Apr - Jun	0.715	Jun 10 - Aug 27	0.527	Feb 10 - Mar 24	0.702	Apr - Aug	0.482	Jan - Mar	Mixed

	624	0.53	Oct 10 - Nov 30	-0.51	Aug 23 - Oct 01	0.503	Oct - Nov	-0.46	Sep	0.687	May 01 - Jul 24	-0.49	Mar 27 - May 10	0.684	May - Jul	-0.41	Apr - Jun	Cold
	650	0.748	Jun 14 - Jul 13	-0.68	Apr 23 - Jul 03	0.611	Jun - Jul	-0.65	May - Jun	0.804	Jun 06 - Aug 03	0.503	Feb 18 - Mar 24	0.776	Jun - Jul	0.402	Jan - Mar	Cold
	685	0.507	Oct 07 - Nov 06	-0.36	Nov 26 - Dec 30	0.477	Oct - Nov	-0.31	Sep - Dec	0.779	Jun 10 - Aug 27	0.447	Feb 11 - Mar 24	0.728	Apr - Aug	0.423	Jan - Mar	Cold
	856	0.598	Apr 06 - May 19	0.536	Feb 21 - Apr 13	0.535	Apr - May	0.452	Mar	0.759	Jun 10 - Jul 31	0.639	Feb 11 - Mar 21	0.703	Jul	-0.45	Jun - Jul	Mixed
	910	-0.39	Nov 23 - Dec 22	0.485	Feb 20 - Apr 19	-0.33	Dec	0.406	Mar - Apr	0.509	Mar 01 - Apr 12	0.522	Jan 02 - Mar 27	0.439	Mar	0.429	Jan - Mar	Dry
	932	0.621	Jun 09 - Jul 08	-0.75	Oct 13 - Dec 29	0.432	Jun - Oct	-0.71	Oct - Dec	0.516	Jun 26 - Aug 03	0.547	Feb 08 - Mar 21	0.449	Jul	0.41	Jan - Mar	Cold

Table S6: Optimal parameters of the VS-Lite model for individual sites. For the meaning of parameter abbreviations, please refer to Table S3.

Database	Site	Chronological				Retrospective			
		T1	T2	M1	M2	T1	T2	M1	M2
CZSK	HAV	9.6	17.7	0.029	0.06	2.5	11.8	0.027	0.589
	JET	1.2	20.4	0.066	0.148	2.6	14.7	0.081	0.129
	POL	2.7	21	0.174	0.199	1.1	23.7	0.071	0.321
	RAS	2.3	10.7	0.048	0.387	1.9	10.5	0.048	0.514
	REJ	1	10.4	0.051	0.576	2.5	10.7	0.051	0.546
	STR	1.1	16.8	0.109	0.142	1	23.1	0.084	0.17
	DIV	8.9	11	0.046	0.112	9.9	14.2	0.167	0.354
	CHO	9	10.1	0.098	0.412	3.8	10.1	0.003	0.096
	JAV	1	16.7	0.055	0.08	7.2	22.7	0.038	0.185
	OST	9.9	12	0.01	0.048	1.6	13.4	0.01	0.047
	SMR	2.2	14	0.033	0.036	4.8	16.6	0.075	0.128
	KOS	2.7	12.3	0.064	0.626	2.8	10.7	0.079	0.552
	LET	8.8	13.4	0.028	0.269	6.8	14.5	0.006	0.384
	LUB	3.4	12.5	0.016	0.159	1.1	11.7	0.003	0.6
	PRA	1.8	12.1	0.136	0.644	1.1	10.6	0.024	0.572
	RAA	1.3	20.6	0.048	0.573	2.9	10.1	0.027	0.607
	RUZ	1.3	20.9	0.109	0.161	10	14	0.063	0.371
	BRE	1.4	12.1	0.002	0.006	8.1	10.3	0.08	0.554
	PAL	1.9	19.2	0.001	0.512	10	10	0.031	0.054
	SUV	5.8	20.8	0.002	0.649	8.9	13.7	0.012	0.446
	TAT	9.6	22.8	0.051	0.144	9.8	10.2	0.05	0.32
	TRK	4.3	11.8	0.027	0.603	6.5	10.6	0	0.613
ITRDB	GERM188	5.3	12.5	0.196	0.638	2.3	20.9	0.003	0.503
	SWIT279	3.1	22.3	0.47	0.503	5.5	22.6	0.433	0.438
	CZEC005	9.9	21.5	0.395	0.547	10	11.7	0.041	0.315
	SWIT368	5.8	11.8	0.477	0.484	8.6	11.2	0.371	0.474
	SWIT369	3.7	15.8	0.07	0.157	2.2	11.7	0.466	0.478
	SWIT370	1.9	10.4	0.419	0.491	1.2	10.6	0.34	0.482
	SWIT371	6.5	11.5	0.234	0.412	8.2	15.6	0.524	0.524
	SWIT372	5.1	15.8	0.474	0.474	10	19.4	0.382	0.49
	SWIT373	9.3	10.1	0.291	0.524	3.4	12.3	0.556	0.563
	SWIT374	9.2	21.4	0.493	0.493	4.1	10.7	0.502	0.573
	SWIT375	1.3	10.1	0.582	0.586	1.2	21.3	0.57	0.6
	SWIT376	1.6	10.5	0.519	0.523	1.6	10.2	0.444	0.528
	SWIT377	1.1	10.2	0.429	0.518	1.8	10.2	0.436	0.47
	SWIT378	9.9	10.1	0.561	0.57	1.3	12.5	0.516	0.565
	SWIT379	1.1	14.6	0.507	0.513	3.8	17.8	0.485	0.49

	SWIT380	4.8	10.4	0.081	0.389	1.6	12.1	0.431	0.519
	SWIT381	2.2	10.7	0.194	0.546	4.4	15.2	0.432	0.441
	SWIT382	1.1	23	0.509	0.529	4.1	23.1	0.478	0.481
	GERM227	6.7	23.2	0.38	0.38	10	19.3	0.15	0.515
	GERM234	9.7	14.8	0.09	0.555	1.2	10.1	0.169	0.298
	GERM235	9.9	14	0.171	0.528	9.6	13.9	0.331	0.342
	GERM237	4.7	18.7	0.219	0.241	1.3	23.9	0.013	0.528
	GERM238	8.2	13.4	0.056	0.29	6.9	12.3	0.267	0.486
	GERM239	9	18.6	0.166	0.175	6	10.1	0.069	0.106
	GERM240	6.9	13.8	0.147	0.384	4.1	17.9	0.024	0.363
	GERM241	8.7	13	0.198	0.419	8.7	22.9	0.18	0.576
	GERM243	6.8	13.4	0.215	0.227	9.9	23	0.354	0.54
	GERM244	9.2	12.9	0.359	0.36	10	11.9	0.036	0.552
	GERM245	3.6	19.5	0.262	0.557	8.8	13.3	0.39	0.39
	GERM246	7	15.2	0.294	0.647	5.8	19.2	0.364	0.383
	SWED335	8.9	15.5	0.297	0.335	5.6	10.5	0.345	0.351
	SWED336	9.8	21.5	0.086	0.377	7	18.1	0.395	0.404
	SWED337	5.4	10.1	0.004	0.489	9.4	13.1	0.23	0.241
	SWED338	9.8	22.8	0.282	0.29	8.7	16.2	0.089	0.138
	CZEC006	1.2	20.3	0.115	0.24	7.9	14.7	0.226	0.634
	SWIT390	2.9	22.7	0.463	0.488	5.5	20.2	0.426	0.447
	SWIT392	7	21.3	0.498	0.503	9.5	21.3	0.453	0.475
	SWIT394	6.7	11.5	0.427	0.466	2.6	13	0.547	0.547
	SWIT396	5.9	10.6	0.504	0.514	9.3	10.3	0.336	0.583
	SWIT398	2	18.3	0.523	0.53	7	10.1	0.498	0.631
	SWIT400	4.7	16.7	0.482	0.487	1.1	18.7	0.573	0.634
	SWIT402	4.9	14.9	0.486	0.498	8.2	10	0.449	0.592
	SWIT404	6.6	16.2	0.44	0.646	1.8	10.2	0.45	0.574
	SWIT406	2.6	10.5	0.056	0.633	9.2	10.6	0.417	0.648
	SWIT408	2.9	16	0.295	0.361	8.4	11.6	0.46	0.608
	SWIT409	1.2	11.8	0.429	0.642	5.9	10	0.197	0.219
	SWIT410	3.2	18	0.416	0.418	1	18.3	0.352	0.38
	CZEC007	9.9	20.1	0.432	0.472	8.2	13.8	0.208	0.516
	CZEC010	1	12	0.201	0.357	9.7	18.1	0.466	0.488
	FINL078	1	19.5	0.004	0.064	4.9	16.4	0.082	0.144
	FINL079	1.1	21.8	0.027	0.142	7.3	22.4	0.13	0.161
	FINL080	3	10.6	0.023	0.57	1.9	23.7	0.017	0.341
	FINL081	1.9	10.6	0.054	0.134	2.5	23	0.069	0.286
	FINL082	1	19.5	0.034	0.153	9.7	18.6	0.037	0.145
	FINL083	1.4	11.1	0.014	0.644	9.9	19.5	0.037	0.187
	FINL084	7.1	10.2	0.069	0.618	4.5	16.2	0.011	0.194
	FINL085	6.9	10.3	0.004	0.619	1.1	20.3	0.002	0.339
	FINL086	1	21.4	0.082	0.113	9.2	13.9	0.029	0.104
	FINL087	1	22.3	0.014	0.169	9.8	15	0.006	0.172
	FINL088	1.2	18.7	0.01	0.038	8.3	19.6	0.143	0.17
	FINL089	2.3	10.2	0.008	0.016	1.5	13.8	0.131	0.141

	FINL090	2.2	11.6	0.308	0.547	1.1	17.3	0.216	0.221
	FINL091	10	19.6	0.011	0.233	1.5	13.3	0.189	0.212
	FINL092	8.9	23.6	0.052	0.183	1.3	11	0.113	0.147
	FINL093	8.6	21.1	0.193	0.218	2	10.1	0.146	0.149
	FINL094	6.1	10.5	0.134	0.633	1.1	10.8	0.336	0.491
	FINL095	1.1	10.1	0.006	0.189	1	24	0.065	0.069
	FINL096	1	22.5	0.034	0.142	2.9	21.4	0.138	0.159
	FINL097	1	22.4	0.026	0.038	1.1	22.4	0.011	0.176
	NORW019	9.3	18.3	0.042	0.092	9.4	11.6	0.008	0.222
	NORW020	9.3	20	0.027	0.041	9.7	11.3	0.019	0.02
	NORW021	10	20.7	0.011	0.151	8.6	14.3	0.036	0.043
	NORW022	9.9	18.4	0.067	0.22	5.1	14.2	0.04	0.094
	NORW023	9.9	19.4	0.049	0.194	2	23.8	0.423	0.456
	NORW024	9.9	14.7	0.038	0.231	9.8	15	0.202	0.269
	NORW025	9.1	10.6	0.316	0.332	8.6	12.3	0.319	0.371
	NORW026	6.3	23.5	0.312	0.377	8.5	14	0.353	0.377
	NORW027	9.9	16.9	0.108	0.198	8.4	11.3	0.042	0.107
	NORW028	9.9	20.3	0.015	0.063	2.8	20.4	0	0.526
	NORW029	3.7	20.4	0.172	0.173	5	14.3	0.007	0.114
	NORW030	3.3	23.2	0.16	0.209	1.7	14.7	0.024	0.144
	SWED340	1.9	10.2	0.262	0.532	1.1	11.6	0.088	0.094
	SWED341	4.1	10.5	0.255	0.64	2.9	23	0.213	0.231
	CZEC012	1.1	10.8	0.026	0.05	1.3	15.8	0.217	0.441
	CZEC013	5.5	21.7	0.293	0.315	9.8	22.5	0.284	0.362
	CZEC018	8.6	15.1	0.176	0.399	8.1	10.3	0.167	0.425
	RUS320	7.1	15.4	0.075	0.173	7.1	11.1	0.036	0.185
	RUS321	7.2	23.8	0.101	0.156	7.8	11.5	0.043	0.13
	RUS322	7.5	10.3	0.085	0.503	1.1	20.6	0.137	0.299
	RUS323	9.9	10.8	0.323	0.599	9.6	11.5	0.471	0.632
	RUS324	6.6	13.3	0.492	0.497	8.2	10.2	0.41	0.498
	RUS326	6.4	10.1	0.285	0.52	7.3	12.6	0.3	0.489
	RUS329	5.6	10.3	0.068	0.225	8.7	10.3	0.008	0.35
	RUS330	1.1	12.1	0.239	0.389	5.2	10.8	0.092	0.233
	RUS331	9.5	10.2	0.057	0.359	7	23.5	0.085	0.417

	RUS333	4	10.1	0.07	0.289	2.2	11	0.064	0.181
	RUS334	4.9	12.3	0.176	0.187	7	10.2	0.013	0.264
	RUS336	10	19.7	0.401	0.552	8.8	14.4	0.383	0.516
	RUS344	6.7	20.8	0.274	0.395	1.6	14	0.314	0.33
	RUS345	1.9	15.1	0.137	0.209	6.8	10.2	0.044	0.046
	RUS346	1.1	10.1	0.267	0.414	6.1	11.3	0.123	0.633
	RUS347	5.6	11.3	0.16	0.196	7.2	10	0.089	0.263
	RUS348	4	10.1	0.052	0.22	3.3	10.1	0.335	0.347
	RUS349	6.7	10.5	0.027	0.211	8.1	12	0.204	0.634
	RUS351	7.9	23.7	0.002	0.626	6.1	22.4	0.13	0.345
	RUS360	5.2	10.7	0.053	0.641	9.9	19.5	0.203	0.474
	RUS369	1.7	14.4	0.223	0.252	1.7	10	0.233	0.575
	RUS379	9.6	11.9	0.061	0.207	6	10.5	0.081	0.601
	RUS380	1.7	15.4	0.256	0.62	9.8	11.2	0.236	0.244
	RUS383	8.7	10.9	0.207	0.3	1.9	15.8	0.302	0.367
	RUS384	8.7	20.1	0.209	0.231	6	10.1	0.216	0.643
	RUS386	8.3	10.3	0.089	0.148	4.8	10	0.001	0.64
ITRDB (REMOTE Forest)	180	6.9	19.9	0.173	0.616	4.2	15.2	0.11	0.187
	289	1.7	17.4	0.425	0.536	3.9	11.7	0.346	0.414
	298	6.2	23.2	0.175	0.25	9.9	16.8	0.307	0.317
	382	9.4	22.3	0.233	0.332	7.7	17.8	0.369	0.627
	391	7.7	15	0.176	0.202	8.7	10.6	0.337	0.636
	543	8.4	11.3	0.089	0.181	4.2	19.9	0.317	0.525
	609	2.9	20.8	0.025	0.578	6.9	18.7	0.047	0.533
	624	9.5	10.1	0.37	0.563	4.3	13.9	0.096	0.135
	650	7.9	13.3	0.007	0.288	4.3	16	0.303	0.541
	685	2.3	13.2	0.007	0.431	9.6	17.5	0.386	0.404
	856	1.5	10.2	0.172	0.303	5.5	21.4	0.227	0.505
	910	2.2	10.2	0.099	0.419	6.8	10.2	0.061	0.453
	932	9.9	14.1	0.245	0.325	5.9	16.3	0.292	0.378

Table S7: Optimal parameters of the Vaganov-Shashkin model for individual sites of the CZSK database. For the meaning of parameter abbreviations, please refer to Table S3.

Database	Site	Chronological mode											Retrospective mode										
		T1	T2	T3	T4	M1	M2	M3	M4	Tbeg	tbeg	Vcr	T1	T2	T3	T4	M1	M2	M3	M4	Tbeg	tbeg	Vcr
CZSK	HAV	10.3	15.3	18.5	19.5	0.008	0.433	0.729	0.980	6	72	0.042	1.8	11.1	18.0	18.6	0.006	0.030	0.684	0.860	16	78	0.208
	JET	1.5	19.4	29.6	33.8	0.000	0.147	0.157	0.981	7	81	0.169	3.0	14.0	21.2	28.3	0.096	0.128	0.139	0.534	16	74	0.024
	POL	4.0	16.1	26.0	30.5	0.045	0.084	0.103	0.484	13	103	0.113	1.8	8.6	18.3	28.9	0.013	0.087	0.298	0.670	8	44	0.130
	RAS	2.5	11.7	21.3	33.8	0.045	0.308	0.853	0.909	6	36	0.168	2.0	14.9	16.4	20.3	0.034	0.377	0.485	0.534	5	37	0.164
	REJ	9.1	14.5	17.1	17.2	0.062	0.107	0.891	0.983	16	77	0.097	2.5	13.6	16.6	17.6	0.044	0.334	0.789	0.879	10	53	0.054
	STR	2.9	18.9	28.8	31.9	0.088	0.161	0.494	0.856	5	56	0.205	2.8	18.8	24.2	33.1	0.102	0.145	0.271	0.280	7	58	0.124
	DIV	1.8	19.6	26.8	28.5	0.176	0.204	0.290	0.996	10	119	0.139	10.6	16.5	17.1	25.5	0.107	0.360	0.835	0.898	9	108	0.182
	CHO	2.4	19.7	20.1	31.6	0.019	0.488	0.769	0.999	6	39	0.163	10.2	16.6	17.1	21.9	0.089	0.121	0.444	0.961	6	35	0.153
	JAV	1.1	9.2	28.5	31.8	0.028	0.083	0.837	0.848	6	40	0.052	2.7	20.0	20.3	23.4	0.022	0.131	0.895	0.917	8	95	0.077
	OST	1.6	14.4	22.3	24.6	0.003	0.068	0.602	0.698	14	63	0.052	1.3	9.7	23.3	32.6	0.003	0.013	0.434	0.725	11	47	0.106
	SMR	1.1	18.0	18.8	32.8	0.020	0.147	0.751	0.974	8	72	0.143	1.6	19.6	22.5	26.3	0.003	0.088	0.663	0.667	12	53	0.174
	KOS	10.2	11.0	29.5	32.3	0.078	0.123	0.217	0.747	14	51	0.225	1.0	14.5	28.4	33.2	0.081	0.347	0.419	0.632	5	36	0.132
	LET	1.6	10.7	25.0	33.0	0.018	0.314	0.462	0.532	9	94	0.078	2.2	17.6	25.5	26.3	0.006	0.172	0.407	0.653	7	50	0.222
	LUB	1.4	17.6	25.8	34.3	0.012	0.224	0.854	0.879	9	82	0.090	9.5	13.6	14.9	15.6	0.034	0.064	0.662	0.980	7	65	0.098
	PRA	9.9	10.1	29.2	30.3	0.108	0.206	0.340	0.918	16	62	0.190	2.0	17.9	19.3	20.5	0.083	0.340	0.747	0.931	9	50	0.037
	RAA	5.5	17.9	24.4	26.8	0.045	0.489	0.573	0.909	14	155	0.132	4.6	15.3	16.7	19.9	0.033	0.054	0.059	0.281	6	40	0.101
	RUZ	1.1	19.9	26.7	30.4	0.022	0.182	0.553	0.932	14	109	0.040	10.7	13.4	29.2	34.2	0.080	0.319	0.630	0.856	12	143	0.187
	BRE	1.3	18.3	20.2	34.2	0.019	0.154	0.780	0.892	14	67	0.181	1.7	10.8	20.0	24.3	0.061	0.392	0.445	0.793	15	57	0.148
	PAL	1.9	10.6	17.3	28.3	0.020	0.430	0.539	0.885	11	91	0.182	10.7	12.2	29.9	32.3	0.022	0.025	0.034	0.059	11	124	0.237
	SUV	10.6	16.1	17.9	27.9	0.021	0.436	0.649	0.996	7	43	0.244	10.2	11.2	12.9	13.2	0.009	0.056	0.783	0.978	10	82	0.039
	TAT	10.7	13.2	21.6	27.9	0.059	0.39	0.801	0.876	16	72	0.240	10.5	16.1	22.8	26.4	0.052	0.246	0.419	0.442	14	143	0.027
	TRK	10.9	13.4	26.8	30.9	0.038	0.284	0.472	0.522	10	105	0.245	5.6	13.9	27.8	31.5	0.031	0.032	0.352	0.895	5	53	0.149