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Supplementary Information for

Separating direct and indirect effects of rising temperatures on biogenic volatile emissions in the Arctic

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This PDF file includes:

> Figures S1 to S8
> Tables S1 to S2
> Legends for Datasets S1 to S3

Other supplementary materials for this manuscript include the following:
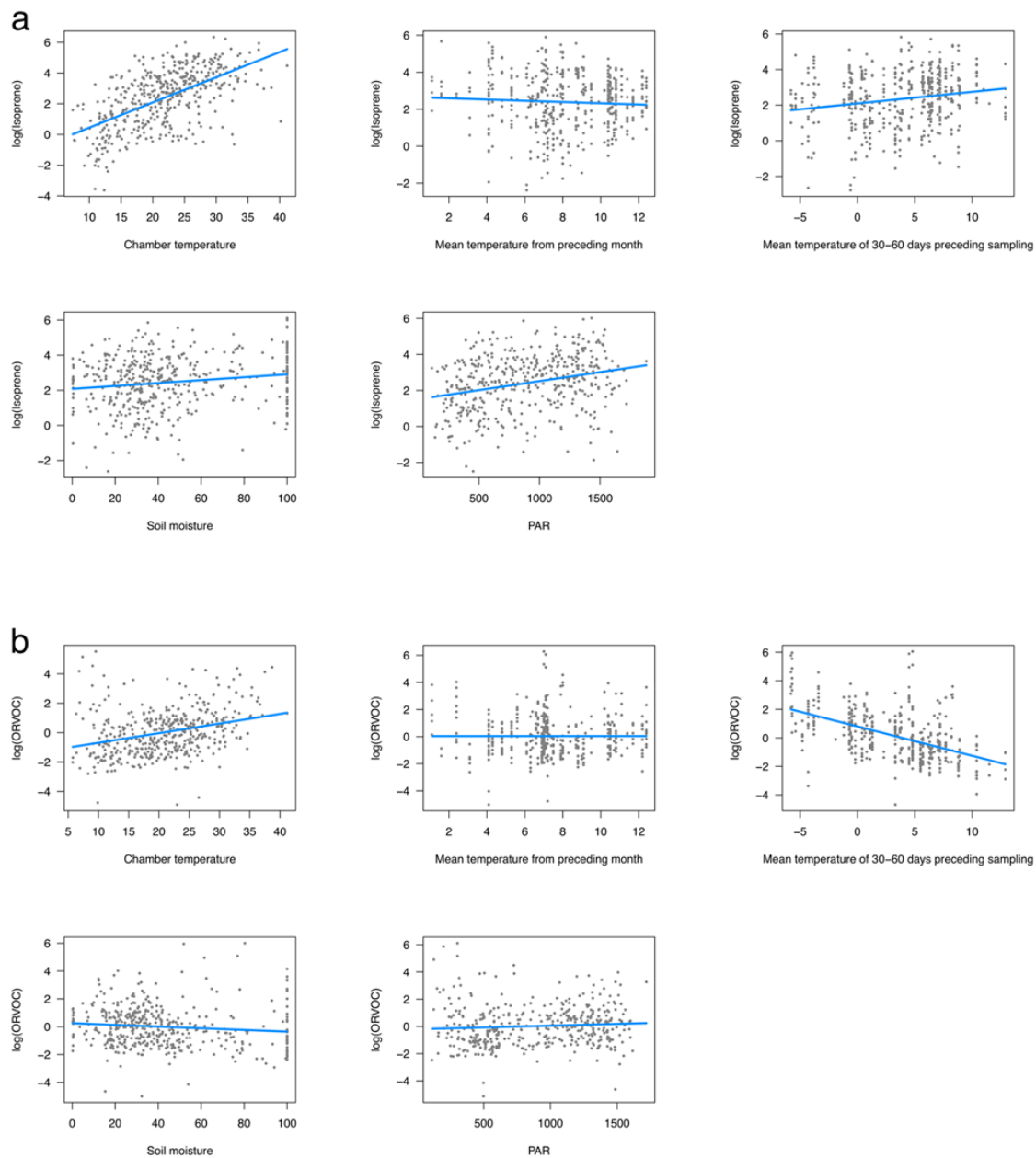
> Datasets S1 to S3

Fig. S1. Correlation plots for (a) Isoprene and (b) ORVOCs. Each panel represents an explanatory variable in the multivariate seasonality model presented in Fig 1. The blue line corresponds to the mean relationship across all measurements.
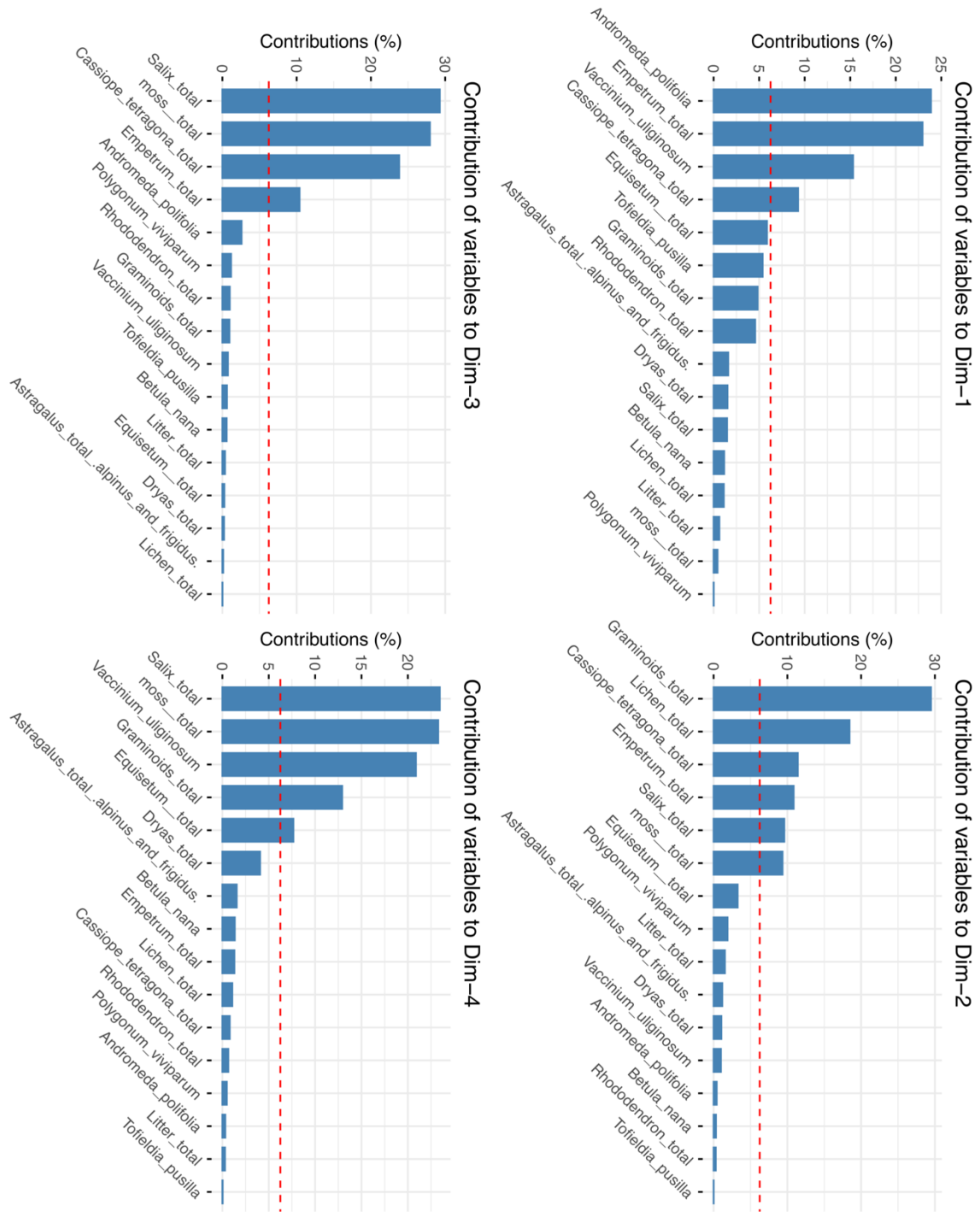
Fig. S2. Contribution of each plant species group on the four principal components (Dim-1-4) describing the vegetation in the tundra plots of the complete dataset.
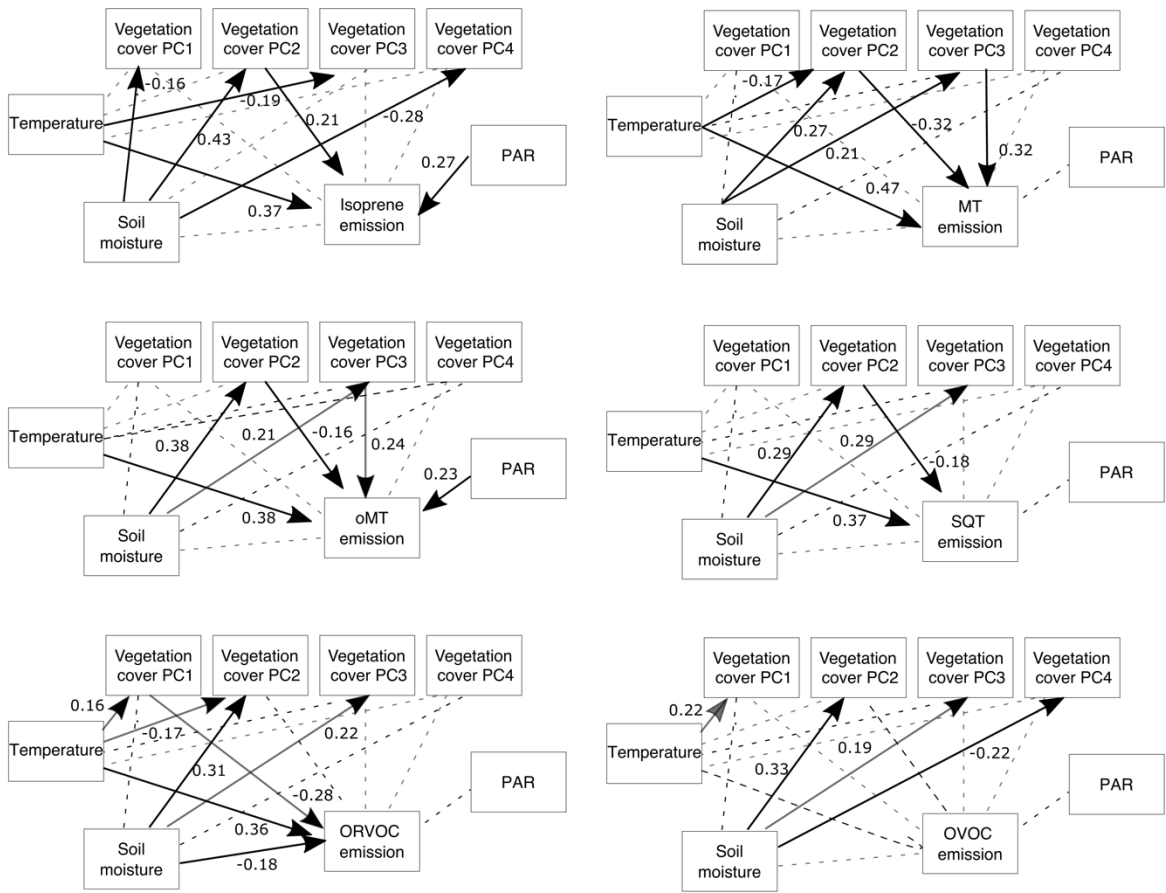
Fig. S3. Structural equation models representing direct and indirect linkages of environmental factors on emission of each BVOC group. Solid arrows represent significant linear paths supported by the model; dashed lines are omitted paths. Values represent standardized effect sizes.
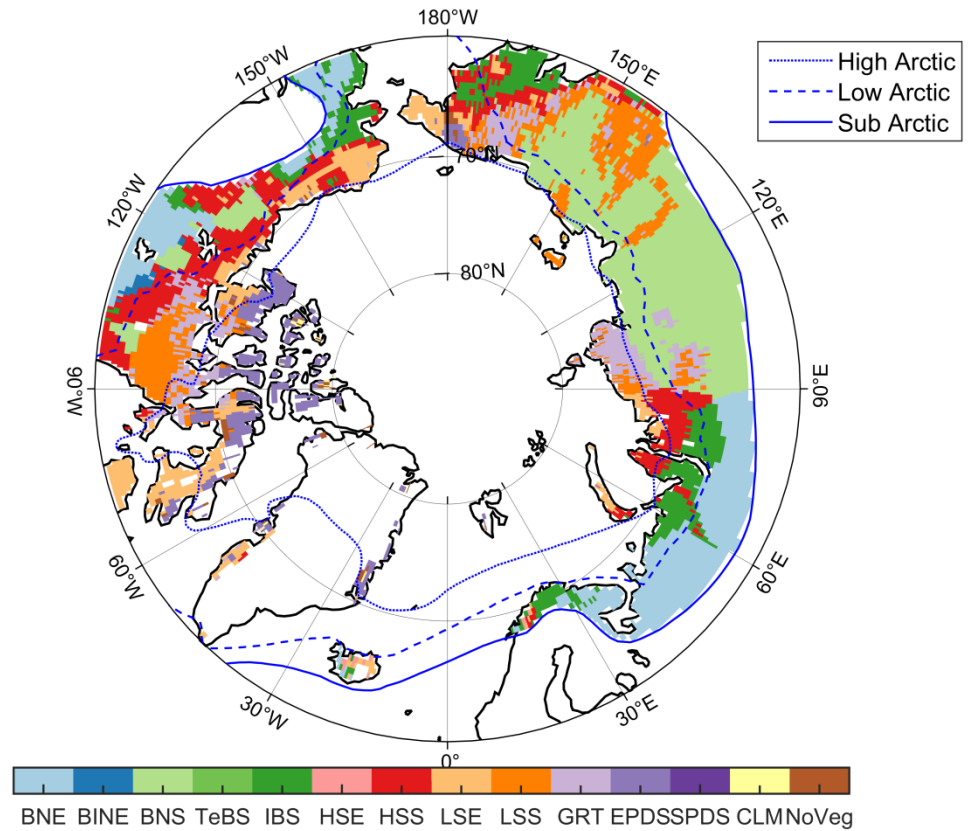
Fig. S4. Dominant plant functional types (PFTs) for 1999-2012 based on the plant biomass in the control run. BNE: boreal needle-leaved evergreen tree; BINE: boreal shade-intolerant needle-leaved evergreen tree; BNS: boreal needle-leaved summergreen tree; TeBS: temperate shade-tolerant broadleaved summergreen tree; IBS: shade-intolerant broad-leaved summergreen tree; HSE: High shrubs evergreen; HSS: high shrubs summergreen; LSE: low shrubs evergreen; LSS: low shrubs summergreen; EPDS: evergreen prostrate dwarf Shrubs; SPDS: summergreen prostrate dwarf shrubs; GRT: graminoid; CLM: cushion forbs, lichens and moss; NoVeg: no vegetation. The arctic PFTs include: HSE, HSS, LSE, LSS, EPDS, SPDS and CLM; while the rest are non-Arctic PFTs. Different temperature response curves have been applied for these two groups of PFTs, see Supplementary Table 3.
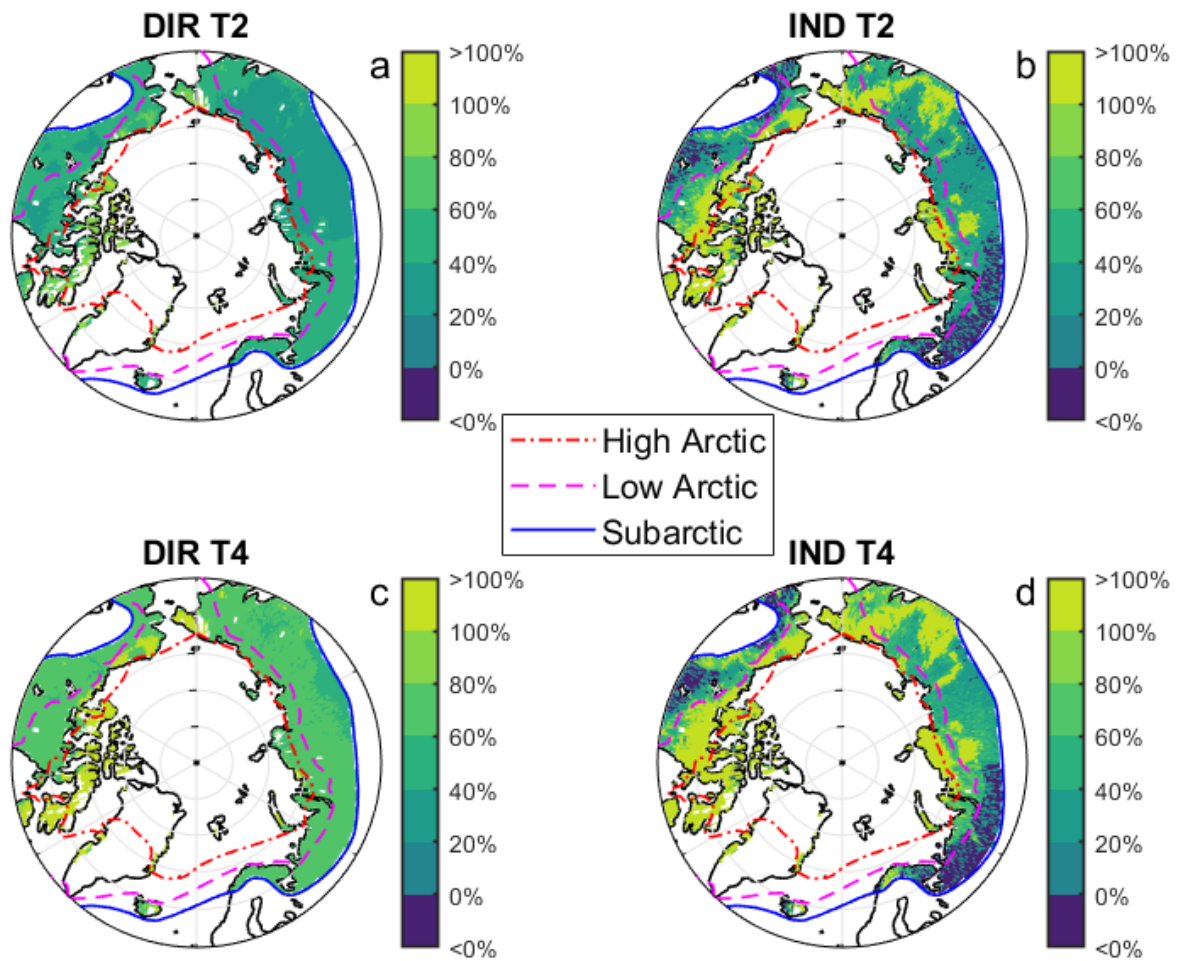
Fig. S5. Relative changes in monoterpene emissions under direct and indirect effects of warming by (a-b) 2 °C and (c-d) 4 °C. (a, c) show the direct warming effects (DIR) on monoterpene production and emission rate, and (b, d) show the indirect warming effects (IND) mainly through changes in vegetation composition and vegetation-related processes averaged for the period 1999-2012.
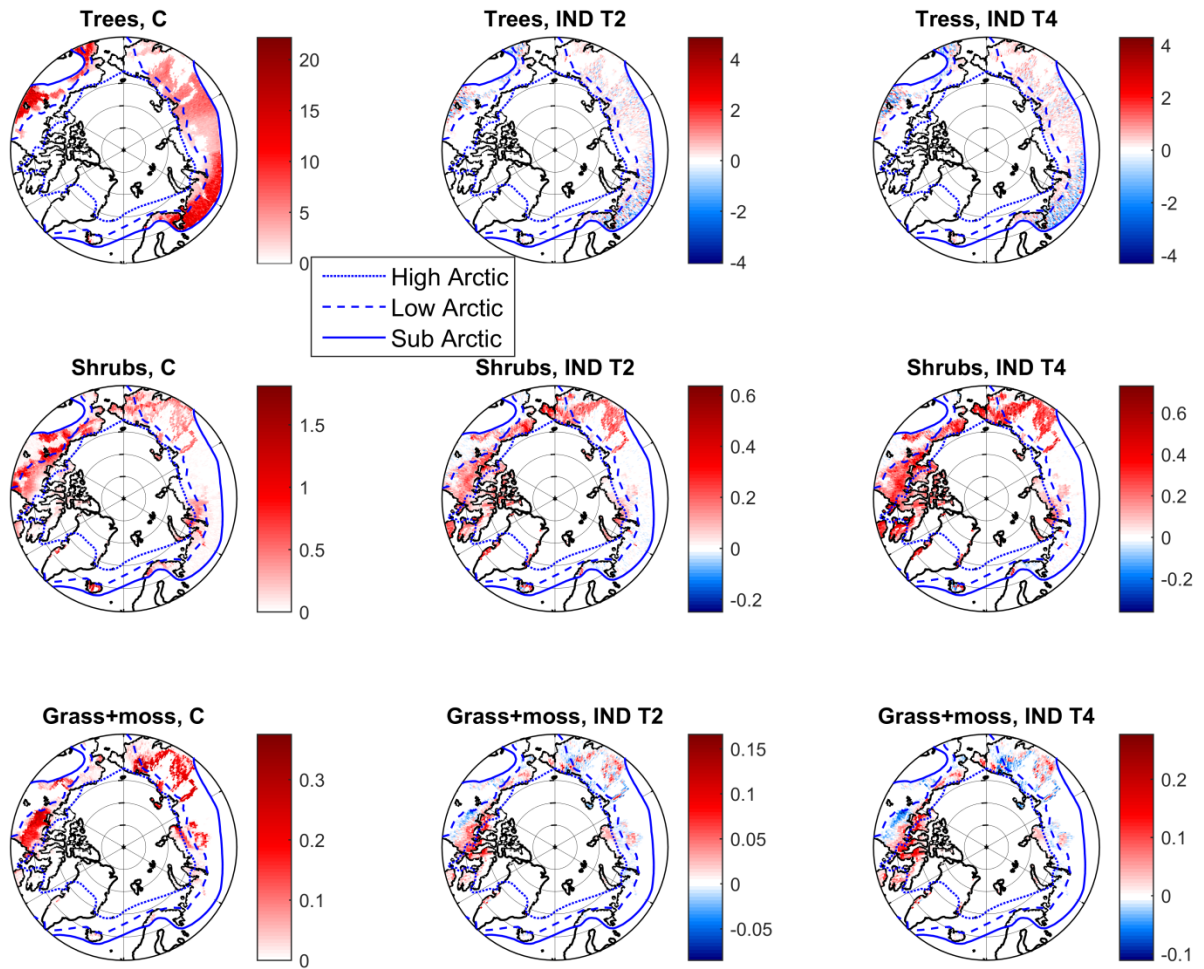
Fig. S6. Modelled tree, shrub, and grass + moss biomass values (kg C m^{-2}) and the associated changes in response to 2 °C and 4 °C warming averaged for the period 1999-2012. The left column shows the absolute biomass values from the control (C) runs, and the middle and right columns showing 2 °C and 4 °C warming-caused changes in vegetation biomass, respectively.

Fig. S7. Absolute changes in isoprene emission (mg C m^{-2} a^{-1}) from direct and indirect warming effects at (a-b) 2°C and (c-d) 4°C, respectively. (a,c) show the direct warming effects (DIR) on BVOC production and emission rate, and (b,d) show the indirect warming affects (IND) mainly through vegetation changes averaged for the period 1999-2012.
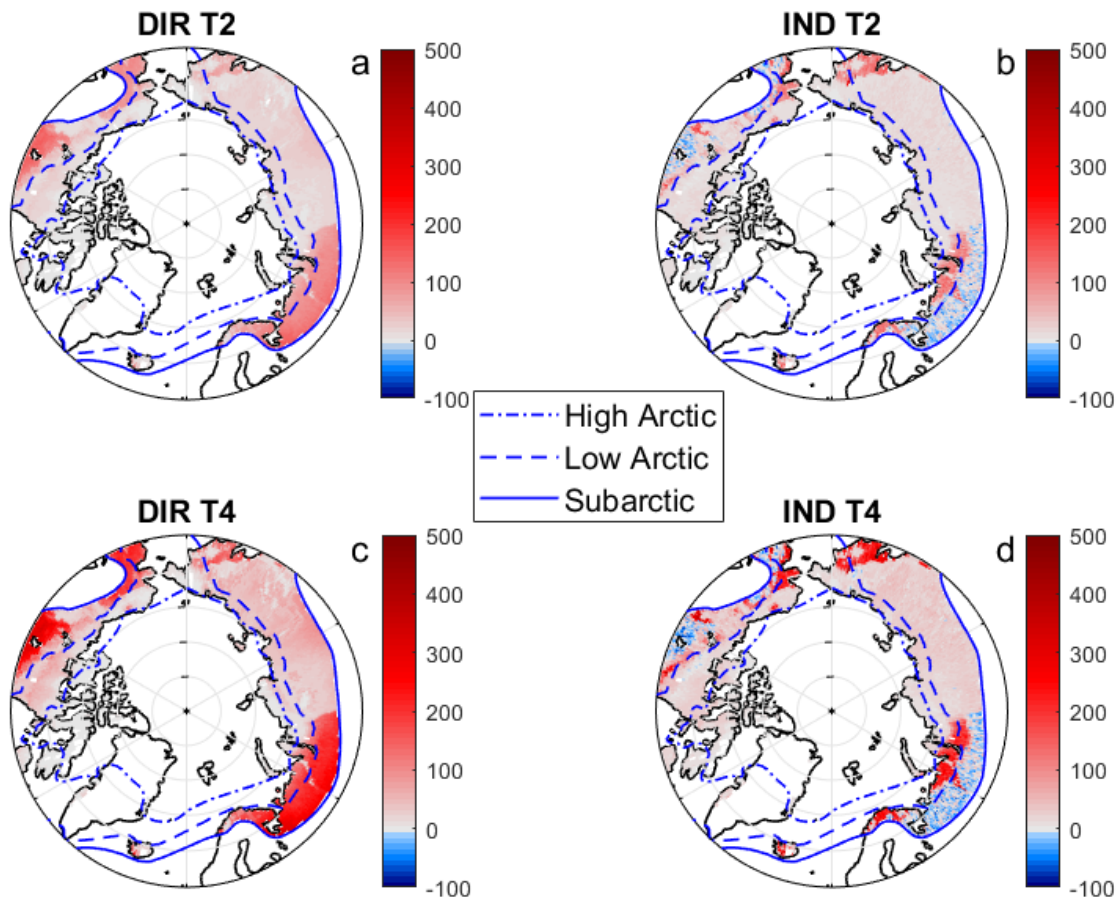
Fig. S8. Absolute changes in monoterpene emission (mg C m^{-2} a^{-1}) from direct and indirect warming effects at (a-b) 2°C and (c-d) 4°C, respectively. (a,c) show the direct warming effects (DIR) on BVOC production and emission rate, and (b,d) show the indirect warming affects (IND) mainly through vegetation changes averaged for the period 1999-2012.
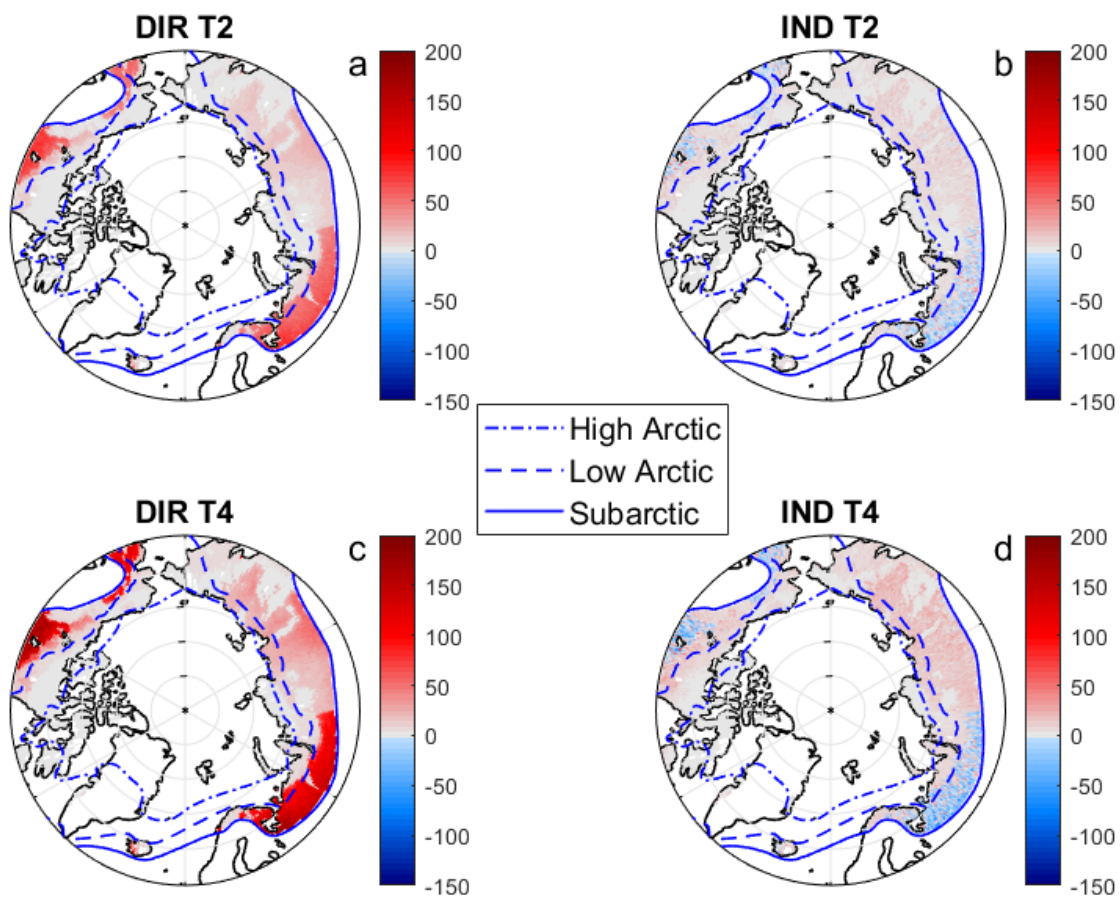
Table S1. Mean estimates and 95% confidence intervals for the parameters displayed in Fig.1.

BVOC	Variable (scaled to Z-scores)	Parameter estimate	Lower 95% limit	Upper 95% limit	Conditional R^2
Isoprene	PAR	0.42	0.16	0.67	0.82
Isoprene	Soil moisture	0.24	0.03	0.44	
Isoprene	Chamber temperature	1.09	0.83	1.35	
Isoprene	Mean temperature from preceding month	-0.09	-0.60	0.46	
Isoprene	Mean temperature of 30-60 days preceding sampling	0.28	-0.34	0.92	
MT	PAR	-0.26	-0.56	0.03	0.52
MT	Soil moisture	-0.32	-0.52	-0.12	
MT	Chamber temperature	1.23	0.94	1.52	
MT	Mean temperature from preceding month	0.37	-0.18	0.93	
MT	Mean temperature of 30-60 days preceding sampling	0.39	-0.31	1.07	
oMT	PAR	-0.02	-0.26	0.22	0.69
oMT	Soil moisture	-0.29	-0.45	-0.10	
oMT	Chamber temperature	0.98	0.71	1.23	
oMT	Mean temperature from preceding month	0.49	-0.08	1.08	
oMT	Mean temperature of 30-60 days preceding sampling	0.30	-0.36	0.87	
SQT	PAR	-0.18	-0.44	0.09	0.52
SQT	Soil moisture	-0.12	-0.34	0.07	
SQT	Chamber temperature	0.99	0.71	1.27	
SQT	Mean temperature from preceding month	0.35	-0.16	0.88	
SQT	Mean temperature of 30-60 days preceding sampling	1.08	0.52	1.64	
ORVOC	PAR	0.11	-0.16	0.37	0.77
ORVOC	Soil moisture	-0.16	-0.35	0.03	
ORVOC	Chamber temperature	0.47	0.21	0.75	
ORVOC	Mean temperature from preceding month	0.00	-0.53	0.56	
ORVOC	Mean temperature of 30-60 days preceding sampling	-0.87	-1.54	-0.18	
OVOC	PAR	0.02	-0.22	0.26	0.77
OVOC	Soil moisture	-0.16	-0.35	0.01	
OVOC	Chamber temperature	-0.02	-0.28	0.22	
OVOC	Mean temperature from preceding month	0.33	-0.11	0.77	
OVOC	Mean temperature of 30-60 days preceding sampling	-0.71	-1.25	-0.20	0.29

Table S2. Model evaluation of the final structural equation models via Fishers C statistic. P values > 0.05 indicate a significant fit between model and data. R^2 values are conditional R^2 estimates of the BVOC component in each SEM.

BVOC group	Fisher C statistic	df	P value	R^2
Isoprene	41.64	32	0.12	0.77
MT	1.17	6	0.94	0.67
oMT	5.88	12	0.92	0.71
SQT	12.67	10	0.24	0.49
ORVOC	9.76	14	0.78	0.82
OVOC	14.07	18	0.73	na

Dataset S1. Summary of the dataset used in statistical modelling.

Dataset S2. Detailed description of the plant functional type parameters for the Pan-Arctic simulations using LPJ-GUESS.

Dataset S3. Summary statistics and parameter estimates for the SEM models.