



Supplement of

INFERNO-peat v1.0.0: a representation of northern high-latitude peat fires in the JULES-INFERNO global fire model

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S1 Organic versus mineral soil moisture

In initial runs conducted using mineral soil moisture (JULES standard) we end up having a negative correlation between peat fraction and its combustibility, whereby grid cells with smaller peat fractions are more combustible (figure 1A). This results in large peat burnt areas (Figure 1B), and results in a tendency towards a positive bias in the model compared to GFED5
5 observations. The inflation of peat combustibility is potentially a result of soil moisture, where in general grid cells that have smaller peat fractions tend to have lower moisture content values (Figure 1C). However, it is likely that the peat within this grid cell is significantly wetter than the surrounding mineral soils. Consequently, the moisture content of the peat soil is not being well represented. Therefore, there is a fundamental bias in the model whereby smaller peat fractions are biased towards lower moisture content percentages, consequently inflating combustibility and thus peat burnt area. When the model is run
10 using organic soil moisture, we see a reduction in these biases (figure 2)

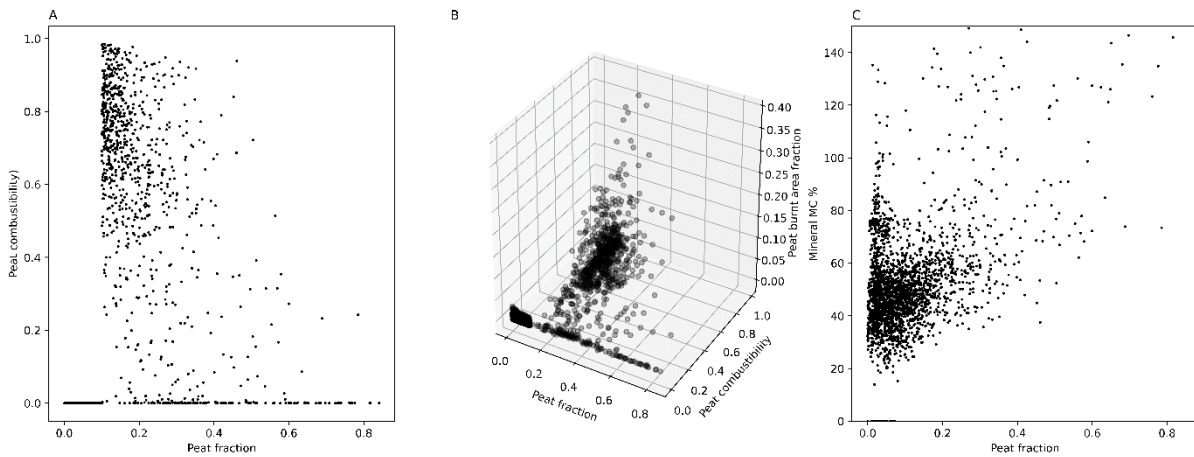


Figure S1: Diagnostic plots from INFERNO-peat using mineral soil moisture, showing the relationship between peat fraction and combustibility (A), combustibility and peat burnt area (B), and mineral moisture content (C).

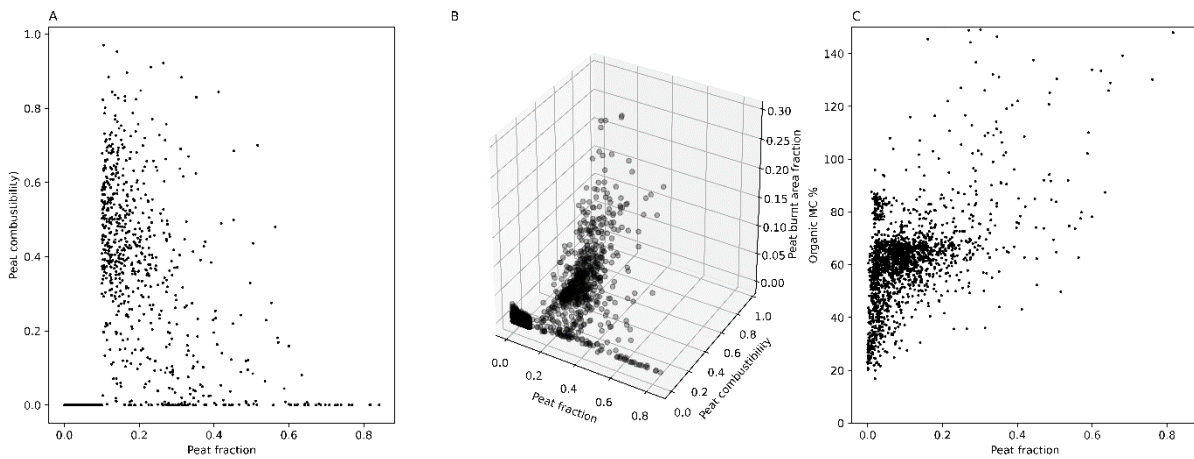


Figure S2: Diagnostic plots from INFERNO-peat using organic soil moisture, showing the relationship between peat fraction and combustibility (A), combustibility and peat burnt area (B), and organic moisture content (C).

S2 Maximum depth of burn and combustion completeness sensitivity analysis

In order to test the optimal model setup for the maximum burn depth and combustion completeness parameters, 16 unique runs using combinations of 4 different maximum depths of burn and 4 different combustion completeness values were carried out.
20 The maximum depths of burn tested were 0.2m, 0.4m, 1m and 3m (entire soil column). Combustion completeness values of 0.4, 0.6, 0.8 and 1.0 were used. To evaluate model performance, RMSE was calculated between each of the runs and GFED500m belowground burning observations. Sensitivity analysis revealed the optimum combination of values to be 0.4m

for maximum depth of burn, and 0.8 for combustion completeness (Figure S3), therefore these values were used in the model runs presented in this paper. Furthermore, to ensure that the maximum depth of burn parameter was not effectively acting as a fixed depth of burn, with the majority of grid cells hitting it, a histogram of average values across the Northern high latitudes between 2010 and 2014 was plotted (Figure S4). It is evident that the burn depth values are rarely reaching 40cm, with the majority of grid cells burning less than the top 4cm.

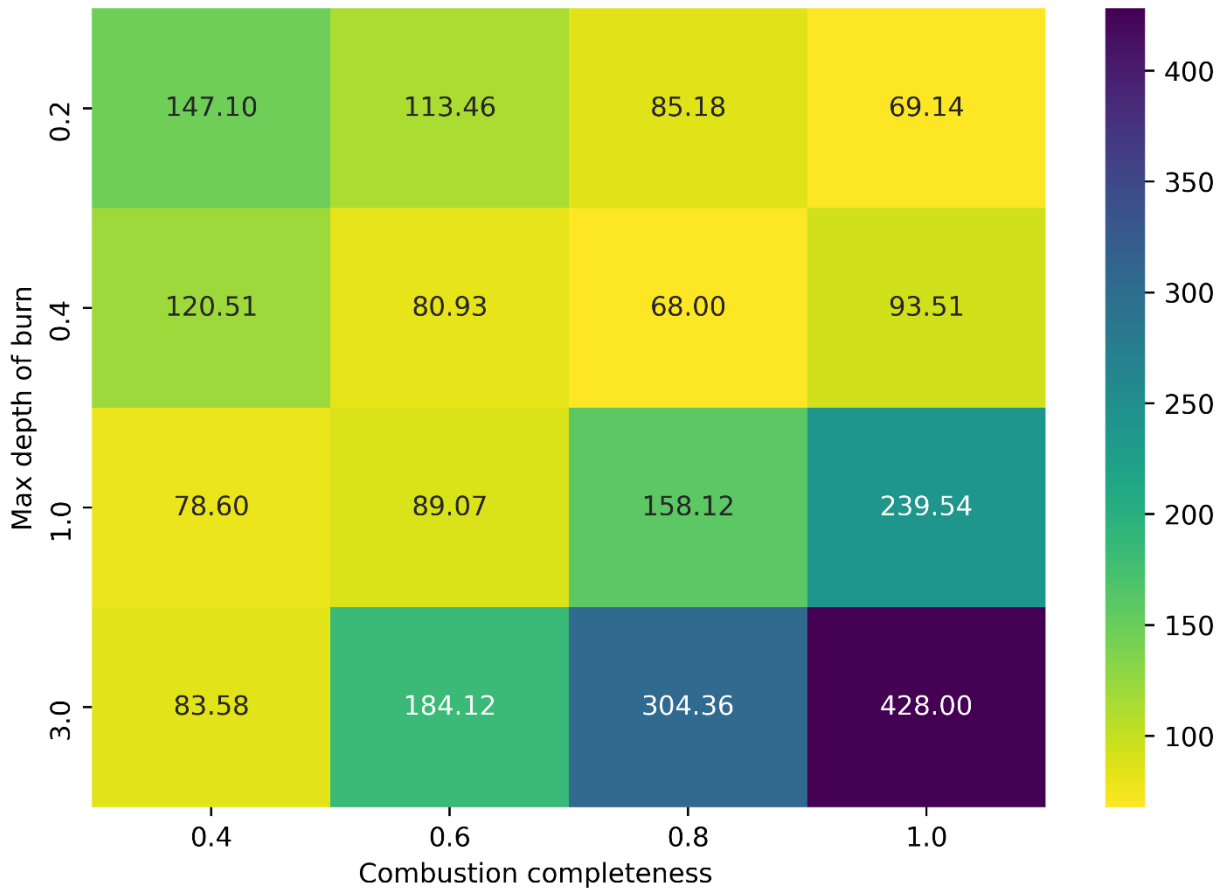


Figure S3: Sensitivity analysis of RMSE across maximum depth of burn and combustion completeness values.

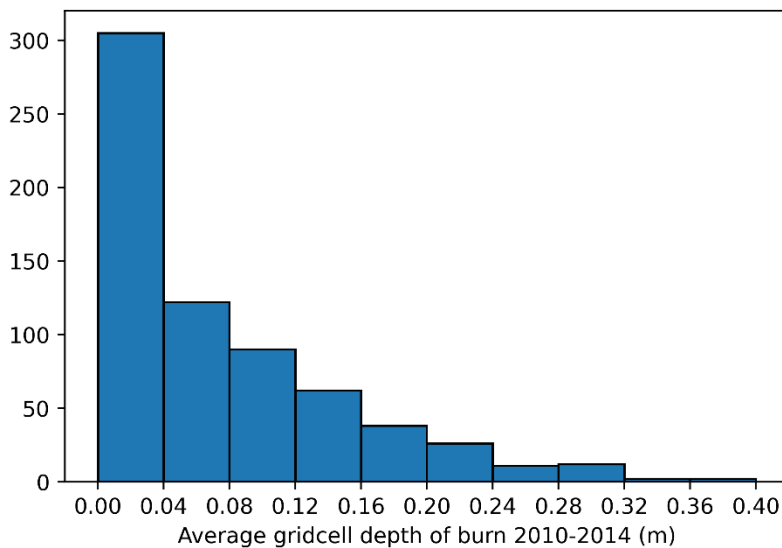


Figure S4: Histogram of the average grid cell depth of burn between 2010 and 2014.

S3 Supplementary maps

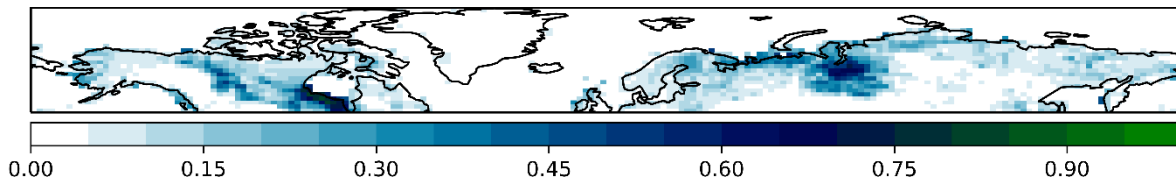


Figure S5: Grid cell peatland fraction plotted from the Northern Peatland Dataset (Hugelius et al., 2020).

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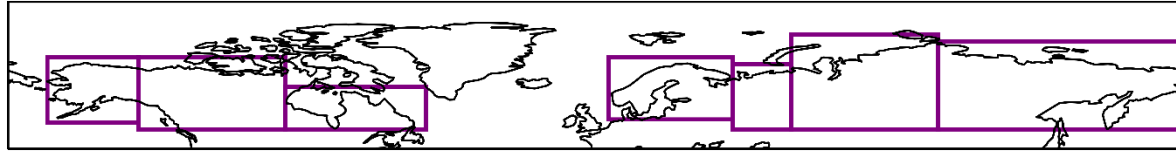


Figure S6: The seven subregions used to analyse INFERNO-peat performance. From L:R, Alaska, Western Canada, Eastern Canada, Fennoscandia, Western Russia, Central Russia, Eastern Russia.

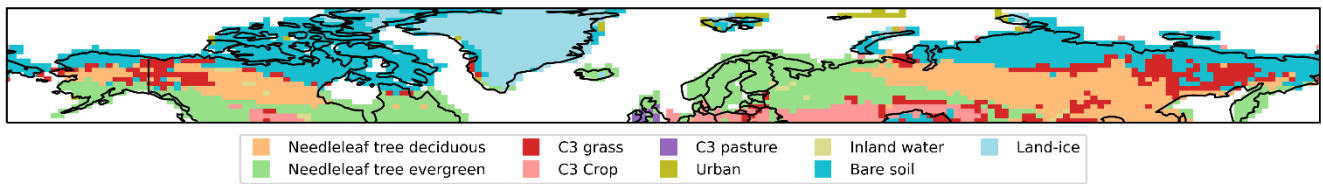


Figure S7: 2010-2014 average dominant land fraction type in each grid cell modelled by JULES

40 S4 Additional burnt area results

Table S1: Temporal correlation coefficients over the 2010 to 2014 period, in INFERNO, and the two INFERNO-peat runs

Model	R (GFED4s)	R (GFED5)	R (fireCCILT11)
INFERNO	0.636	0.937	0.681
INFERNO-peat LIS-OTD	0.312	-0.184	0.241
INFERNO-peat WGLC	0.659	0.302	0.294

Table S2: Burnt area results broken down for each subregion averaged over 2010-2014.

	Average	std	CV	R (Spatial correlation)				RMSE				R (temporal correlation)			
	annual	BA		fireCCI		ABoVE		fireCCI		ABoVE		fireCCI		ABoVE	
	(M km2)			GFED4s	GFED5	LT11	-FED	GFED4s	GFED5	LT11	-FED	GFED4s	GFED5	LT11	-FED
Alaska															
INFERNO	0.007	0.001	0.090	0.202	0.242	0.194	0.682	0.056	0.064	0.056	0.037	0.649	0.703	0.604	0.746
INFERNO-peat LIS-OTD	0.006	0.001	0.105	0.236	0.282	0.216	0.760	0.066	0.071	0.065	0.040	0.646	0.701	0.600	0.744
INFERNO-peat WGLC	0.006	0.001	0.092	0.224	0.272	0.203	0.763	0.066	0.071	0.065	0.040	0.649	0.701	0.603	0.745
GFED4s	0.002	0.002	1.083		0.884	0.959	0.376		0.022	0.007	0.028		0.989	0.989	0.987
GFED5	0.002	0.002	0.798	0.884		0.897	0.430	0.022		0.020	0.047	0.989		0.969	0.995
fireCCILT11	0.001	0.001	0.631	0.959	0.897		0.358	0.007	0.020		0.027	0.989	0.969		0.973
ABoVE-FED	0.002	0.002	0.867	0.376	0.430	0.358		0.028	0.047	0.027		0.987	0.995	0.973	
Western Canada															
INFERNO	0.032	0.002	0.054	0.331	0.384	0.310	0.570	0.074	0.084	0.071	0.048	-0.497	-0.874	-0.905	-0.874
INFERNO-peat LIS-OTD	0.119	0.013	0.114	0.353	0.307	0.379	0.654	0.130	0.135	0.129	0.105	0.458	-0.074	-0.078	-0.120
INFERNO-peat WGLC	0.048	0.006	0.132	0.334	0.322	0.343	0.608	0.087	0.088	0.083	0.059	0.872	0.439	0.385	0.415
GFED4s	0.030	0.016	0.538		0.759	0.948	0.665		0.052	0.020	0.049		0.692	0.640	0.682
GFED5	0.047	0.008	0.243	0.759		0.744	0.482	0.052		0.053	0.077	0.692		0.993	0.998
fireCCILT11	0.025	0.006	0.296	0.948	0.744		0.677	0.020	0.053		0.047	0.640	0.993		0.989
ABoVE-FED	0.023	0.010	0.421	0.665	0.482	0.677		0.049	0.077	0.047		0.682	0.998	0.989	
Eastern Canada															
INFERNO	0.016	0.000	0.031	0.330	0.379	0.295	0.630	0.065	0.079	0.072	0.048	0.074	0.098	0.179	0.134

INFERNO-peat LIS-OTD	0.074	0.004	0.095	0.256	0.285	0.132	0.467	0.148	0.183	0.133	0.118	0.398	0.364	0.292	0.329
INFERNO-peat WGLC	0.027	0.001	0.067	0.309	0.367	0.231	0.562	0.085	0.103	0.086	0.064	0.119	-0.056	-0.061	-0.015
GFED4s	0.004	0.006	1.592		0.608	0.575	0.430		0.046	0.037	0.042		0.965	0.971	0.977
GFED5	0.007	0.006	1.065	0.608		0.909	0.548	0.046		0.024	0.051	0.965		0.996	0.997
fireCCILT11	0.009	0.006	1.223	0.575	0.909		0.566	0.037	0.024		0.042	0.971	0.996		0.999
ABOVE-FED	0.010	0.007	1.136	0.430	0.548	0.566		0.042	0.051	0.042		0.977	0.997	0.999	

Fennoscandia

INFERNO	0.019	0.002	0.127	0.301	0.341	0.366		0.068	0.128	0.063		-0.230	0.324	0.630	
INFERNO-peat LIS-OTD	0.035	0.005	0.136	0.235	0.216	0.270		0.105	0.150	0.100		-0.355	0.136	0.282	
INFERNO-peat WGLC	0.022	0.006	0.274	0.238	0.266	0.285		0.083	0.141	0.078		-0.057	0.527	0.770	
GFED4s	0.004	0.002	0.979		0.823	0.795			0.114	0.023			0.806	0.502	
GFED5	0.048	0.015	0.532	0.823		0.832		0.114		0.095		0.806		0.816	
fireCCILT11	0.007	0.001	0.273	0.795	0.832			0.023	0.095			0.502	0.816		

Western Russia

INFERNO	0.028	0.004	0.215	0.397	0.324	0.243		0.084	0.108	0.096		0.924	0.859	0.309	
INFERNO-peat LIS-OTD	0.047	0.006	0.163	0.133	0.035	0.040		0.126	0.147	0.133		0.389	0.167	-0.482	
INFERNO-peat WGLC	0.034	0.004	0.173	0.364	0.233	0.202		0.093	0.116	0.104		0.943	0.887	0.227	
GFED4s	0.015	0.003	0.550		0.675	0.685			0.090	0.057			0.972	0.226	
GFED5	0.040	0.020	0.494	0.675		0.894		0.090		0.058		0.972		0.392	
fireCCILT11	0.022	0.006	0.237	0.685	0.894			0.057	0.058			0.226	0.392		

Central Russia

INFERNO	0.052	0.005	0.126	0.489	0.511	0.479		0.069	0.126	0.091		0.869	0.881	0.755	
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INFERNO-peat LIS-OTD	0.151	0.029	0.232	0.274	0.272	0.236	0.127	0.154	0.132	0.225	0.052	0.038
INFERNO-peat WGLC	0.075	0.010	0.181	0.403	0.397	0.362	0.083	0.131	0.101	0.405	0.352	0.200
GFED4s	0.060	0.030	0.632		0.787	0.854		0.102	0.054		0.966	0.975
GFED5	0.187	0.078	0.414	0.787		0.907	0.102		0.066	0.966		0.950
fireCCILT11	0.111	0.047	0.421	0.854	0.907		0.054	0.066		0.975	0.950	
Eastern Russia												
INFERNO	0.049	0.002	0.050	0.480	0.502	0.478	0.068	0.089	0.082	0.283	0.521	-0.138
INFERNO-peat LIS-OTD	0.065	0.003	0.054	0.493	0.531	0.513	0.075	0.089	0.079	0.770	0.606	0.172
INFERNO-peat WGLC	0.055	0.002	0.054	0.495	0.530	0.506	0.070	0.087	0.078	0.374	0.434	-0.209
GFED4s	0.052	0.015	0.324		0.846	0.826		0.056	0.044		0.702	0.669
GFED5	0.094	0.024	0.236	0.846		0.864	0.056		0.044	0.702		0.759
fireCCILT11	0.092	0.020	0.260	0.826	0.864		0.044	0.044		0.669	0.759	

Table S3: Burnt area averages, interannual variability metrics and temporal correlation broken down by each subregion for the 2001 to 2014 period. Results for the WGLC run are only available from 2010 onwards, therefore these runs are excluded from this table. ABoVE-FED correlations are only available for North America subregions.

	Avg	annual std	cv	R			
	BA (M km ²)			GFED4s	GFED5	fireCCILT11	ABoVE-FED
Alaska							
INFERNO	0.007	0.001	0.089	0.059	0.117	0.165	0.143
INFERNO-peat	0.007	0.001	0.097	0.082	0.141	0.180	0.162
LIS-OTD							
GFED4s	0.007	0.012	1.616		0.924	0.858	0.857
GFED5	0.006	0.007	1.261	0.924		0.967	0.980
fireCCILT11	0.004	0.005	1.125	0.858	0.967		0.988
ABoVE-FED	0.006	0.008	1.290	0.857	0.980	0.988	
Western Canada							
INFERNO	0.029	0.002	0.068	-0.022	-0.158	-0.170	-0.166
INFERNO-peat	0.115	0.017	0.145	0.288	0.201	0.130	0.149
LIS-OTD							
GFED4s	0.019	0.015	0.811		0.753	0.808	0.839
GFED5	0.027	0.007	0.261	0.753		0.873	0.845
fireCCILT11	0.015	0.006	0.414	0.808	0.873		0.940
ABoVE-FED	0.017	0.009	0.546	0.839	0.845	0.940	
Eastern Canada							
INFERNO	0.011	0.001	0.090	0.318	0.274	0.258	0.181
INFERNO-peat	0.041	0.007	0.177	0.411	0.360	0.429	0.360
LIS-OTD							
GFED4s	0.004	0.005	1.322		0.925	0.910	0.926
GFED5	0.004	0.004	1.026	0.925		0.970	0.974
fireCCILT11	0.004	0.005	1.118	0.910	0.970		0.985
ABoVE-FED	0.005	0.006	1.190	0.926	0.974	0.985	
Fennoscandia							
INFERNO	0.018	0.003	0.160	0.721	0.759	0.615	
INFERNO-peat							
LIS-OTD	0.035	0.006	0.178	0.691	0.660	0.478	
GFED4s	0.003	0.004	1.160		0.926	0.743	
GFED5	0.040	0.028	0.712	0.926		0.900	
fireCCILT11	0.006	0.003	0.536	0.743	0.900		
Western Russia							
INFERNO	0.016	0.004	0.244	-0.223	-0.349	-0.404	
INFERNO-peat	0.029	0.006	0.217	-0.482	-0.534	-0.727	
LIS-OTD							
GFED4s	0.010	0.005	0.489		0.808	0.640	
GFED5	0.084	0.037	0.436	0.808		0.716	
fireCCILT11	0.034	0.008	0.246	0.640	0.716		

Central Russia						
INFERNO	0.039	0.005	0.130	0.626	0.457	0.448
INFERNO-peat	0.111	0.026	0.234	0.326	0.032	0.214
LIS-OTD						
GFED4s	0.049	0.025	0.498		0.850	0.908
GFED5	0.230	0.074	0.320	0.850		0.753
fireCCILT11	0.109	0.036	0.329	0.908	0.753	
Eastern Russia						
INFERNO	0.041	0.003	0.063	0.534	0.469	0.483
INFERNO-peat	0.054	0.004	0.074	0.587	0.311	0.272
LIS-OTD						
GFED4s	0.043	0.031	0.717		0.810	0.810
GFED5	0.115	0.068	0.592	0.810		0.968
fireCCILT11	0.075	0.039	0.521	0.810	0.968	

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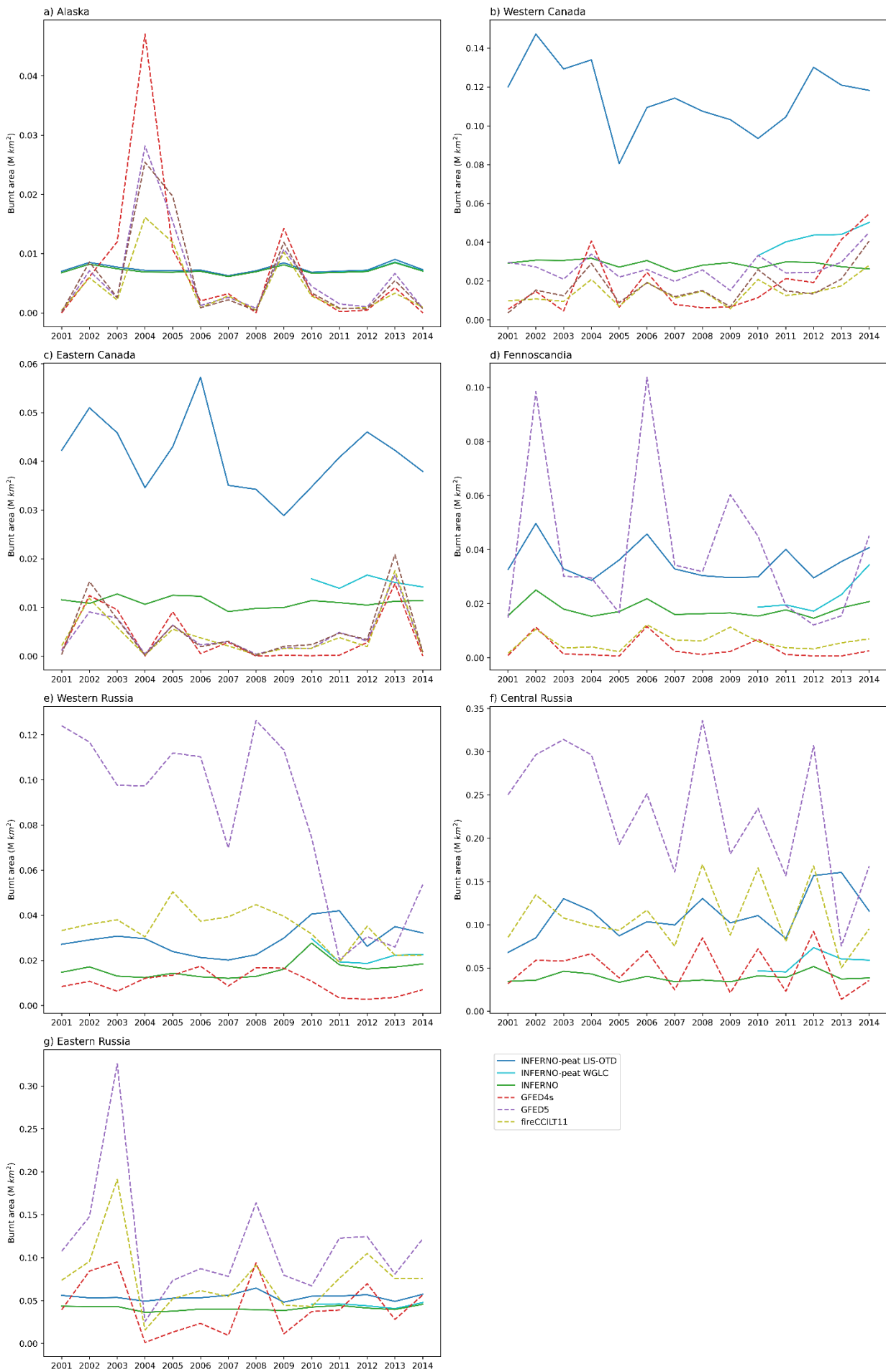


Figure S8: Burnt area timeseries graphs broken down by subregion, from 2001 to 2014. Note that the WGLC INFERNO-peat runs are only for 2010 to 2014. Dashed lines indicate observations and solid lines represent models.

S5 Additional carbon results

55 Table S4: Carbon emission averages, interannual variability and temporal correlations between models and observations over 2003 to 2014, broken down by subregion. Results for the WGLC run are only available from 2010 onwards, therefore these runs are excluded from this table.

	Avg annual C emissions (Tg)	std	cv	R	GFED4s	GFED500m	GFAS
Alaska							
INFERNO	3.735	0.337	0.090	-0.165		-0.286	-0.278
INFERNO-peat	3.766	0.355	0.094	-0.143		-0.264	-0.254
LIS-OTD							
Peat only LIS-OTD	0.031	0.023	0.739				
GFED4s	13.334	21.528	1.614			0.876	0.927
GFED 500m - total	18.657	27.291	1.463	0.876			0.721
GFED 500m - belowground	13.936	20.712	1.486				
GFED 500m - aboveground	4.721	6.614	1.401				
GFAS	9.365	31.298	1.616	0.927		0.721	
Western Canada							
INFERNO	17.612	1.455	0.083	0.015		-0.123	0.066
INFERNO-peat	25.992	7.599	0.292	0.155		0.053	0.311
LIS-OTD							
Peat only LIS-OTD	19.005	7.434	0.391				
GFED4s	45.913	38.696	0.843			0.681	0.930
GFED 500m - total	60.662	33.349	0.550	0.681			0.706
GFED 500m - belowground	43.110	25.925	0.601				
GFED 500m - aboveground	17.553	7.504	0.428				
GFAS	62.659	47.740	0.762	0.930		0.706	
Eastern Canada							
INFERNO	6.987	0.607	0.087	0.513		0.328	0.437
INFERNO-peat	25.992	7.599	0.292	0.155		0.053	0.311
LIS-OTD							
Peat only LIS-OTD	19.005	7.434	0.391				
GFED4s	7.700	10.562	1.372			0.790	0.868
GFED 500m - total	15.387	21.895	1.423	0.790			0.699

GFED 500m -	11.185	16.940	1.515			
belowground						
GFED 500m -	4.202	5.178	1.232			
aboveground						
GFAS	8.350	12.176	1.458	0.868	0.699	
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Fennoscandia						
INFERNO	12.449	1.676	0.135	0.464	0.119	-0.249
INFERNO-peat	22.688	3.482	0.153	0.179	-0.162	-0.452
LIS-OTD						
Peat only LIS-	10.239	2.280	0.223			
OTD						
GFED4s	2.715	3.298	1.215		0.699	0.520
GFED 500m -	2.224	1.659	0.746	0.699		0.691
total						
GFED 500m -	0.006	0.011	1.906			
belowground						
GFED 500m -	2.219	1.656	0.746			
aboveground						
GFAS	8.473	20.215	2.386	0.520	0.691	
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Western Russia						
INFERNO	11.029	3.524	0.320	0.045	0.382	0.361
INFERNO-peat	19.860	5.463	0.275	-0.258	-0.023	0.117
LIS-OTD						
Peat only LIS-	8.832	3.701	0.419			
OTD						
GFED4s	4.135	1.929	0.467		0.829	0.771
GFED 500m -	6.658	3.926	0.590	0.829		0.766
total						
GFED 500m -	0.053	0.125	2.359			
belowground						
GFED 500m -	6.605	3.854	0.583			
aboveground						
GFAS	1.742	1.242	0.713	0.771	0.766	
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Central Russia						
INFERNO	21.271	3.160	0.149	0.848	0.800	0.828
INFERNO-peat	105.394	34.132	0.324	0.448	0.601	0.408
LIS-OTD						
Peat only LIS-	84.124	32.994	0.392			
OTD						
GFED4s	37.573	25.523	0.679		0.918	0.937
GFED 500m -	52.996	46.956	0.886	0.918		0.933
total						

GFED 500m -	27.296	30.240	1.108			
belowground						
GFED 500m -	25.699	18.235	0.710			
aboveground						
GFAS	32.612	26.374	0.809	0.937	0.933	
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Eastern Russia						
<hr/>						
INFERNO	17.476	1.356	0.078	0.666	0.596	0.581
INFERNO-peat	25.266	4.084	0.162	0.166	0.031	0.041
LIS-OTD						
Peat only LIS-	7.790	4.499	0.577			
OTD						
GFED4s	0.607	46.239	0.763		0.914	0.943
GFED 500m -	137.947	107.06	0.776	0.914		0.938
total		9				
GFED 500m -	101.689	84.709	0.833			
belowground						
GFED 500m -	36.258	24.043	0.663			
aboveground						
GFAS	107.550	86.069	0.800	0.943	0.938	

60 **Table S5 Carbon emission averages, interannual variability and temporal correlations between models and observations over 2010 to 2014, broken down by subregion.**

	Avg annual C	std	cv	R		
	emissions (Tg)			GFED4s	GFED500m	GFAS
<hr/>						
Alaska						
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INFERNO	3.849	0.343	0.089	0.648	0.577	0.916
INFERNO-peat	0.374	0.096	0.644	0.572	0.915	0.374
LIS-OTD						
Peat only LIS-	0.031	0.805				0.031
OTD						
INFERNO-peat	0.348	0.090	0.648	0.577	0.916	0.348
WGLC						
Peat only	0.005	0.911				0.005
WGLC						
GFED4s	2.379	2.472	1.039		0.996	0.861
GFED 500m -	4.901	4.358	0.889	0.996		0.811
total						
GFED 500m -	3.384	3.092	0.914			
belowground						
GFED 500m -	1.517	1.290	0.850			
aboveground						
GFAS	2.492	3.247	1.303	0.861	0.811	
<hr/>						
Western Canada						
<hr/>						

INFERNO	17.220	1.254	0.073	-0.255	-0.914	-0.037
INFERNO-peat	83.674	16.411	0.196	0.221	-0.414	0.329
LIS-OTD						
Peat only LIS-	66.455	15.639	0.235			
OTD						
INFERNO-peat	28.956	4.848	0.167	0.824	0.142	0.849
WGLC						
Peat only	11.737	4.834	0.412			
WGLC						
GFED4s	70.783	39.125	0.553		0.444	0.972
GFED 500m -	78.128	27.395	0.351	0.444		0.227
total						
GFED 500m -	56.182	21.700	0.386			
belowground						
GFED 500m -	21.945	5.779	0.263			
aboveground						
GFAS	99.386	39.053	0.393	0.972	0.227	
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Eastern Canada						
INFERNO	7.123	0.232	0.033	0.188	0.297	-0.004
INFERNO-peat	26.517	6.531	0.246	0.111	-0.066	0.344
LIS-OTD						
Peat only LIS-	19.394	6.732	0.347			
OTD						
INFERNO-peat	9.922	1.353	0.136	0.067	-0.091	0.275
WGLC						
Peat only	2.799	1.568	0.560			
WGLC						
GFED4s	7.132	10.618	1.489		0.978	0.969
GFED 500m -	23.005	30.573	1.329	0.978		0.900
total						
GFED 500m -	16.573	23.929	1.444			
belowground						
GFED 500m -	6.432	6.980	1.085			
aboveground						
GFAS	9.243	12.037	1.302	0.969	0.900	
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Fennoscandia						
INFERNO	12.489	1.697	0.136	-0.273	-0.242	-0.420
INFERNO-peat	23.020	4.132	0.180	-0.539	-0.470	-0.673
LIS-OTD						
Peat only LIS-	10.531	3.059	0.291			
OTD						
INFERNO-peat	15.485	4.214	0.272	-0.191	-0.217	-0.363
WGLC						

Peat only	2.996	2.722	0.909			
WGLC						
GFED4s	2.496	2.853	1.143		0.986	0.980
GFED 500m -	2.219	1.985	0.895	0.986		0.968
total						
GFED 500m -	0.003	0.004	1.218			
belowground						
GFED 500m -	2.216	1.986	0.896			
aboveground						
GFAS	15.987	29.518	1.846	0.980	0.968	
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Western Russia						
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INFERNO	13.982	3.695	0.264	0.986	0.990	0.991
INFERNO-peat	23.993	5.293	0.221	0.598	0.496	0.498
LIS-OTD						
Peat only LIS-	10.011	4.287	0.428			
OTD						
INFERNO-peat	15.689	3.537	0.225	0.993	0.969	0.988
WGLC						
Peat only	1.707	0.810	0.474			
WGLC						
GFED4s	2.865	1.748	0.610		0.972	0.986
GFED 500m -	5.148	5.208	1.012	0.972		0.996
total						
GFED 500m -	0.115	0.175	1.521			
belowground						
GFED 500m -	5.033	5.040	1.001			
aboveground						
GFAS	1.338	1.244	0.930	0.986	0.996	
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Central Russia						
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INFERNO	22.682	3.388	0.149	0.990	0.920	0.959
INFERNO-peat	118.036	40.404	0.342	0.408	0.668	0.501
LIS-OTD						
Peat only LIS-	95.354	39.160	0.411			
OTD						
INFERNO-peat	40.372	11.273	0.279	0.543	0.746	0.659
WGLC						
Peat only	17.690	10.077	0.570			
WGLC						
GFED4s	46.484	34.675	0.746		0.935	0.986
GFED 500m -	77.258	63.823	0.826	0.935		0.969
total						
GFED 500m -	44.059	40.344	0.916			
belowground						

GFED 500m -	33.199	24.919	0.751			
aboveground						
GFAS	40.114	38.351	0.956	0.986	0.969	
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Eastern Russia						
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INFERNO	18.371	1.154	0.063	0.421	0.329	0.045
INFERNO-peat	23.498	1.329	0.057	0.807	0.584	0.631
LIS-OTD						
Peat only LIS-	5.127	1.294	0.252			
OTD						
INFERNO-peat	19.189	1.092	0.057	0.650	0.459	0.260
WGLC						
Peat only	0.818	0.437	0.534			
WGLC						
GFED4s	78.207	30.153	0.386		0.893	0.808
GFED 500m -	148.959	48.600	0.326	0.893		0.918
total						
GFED 500m -	107.002	30.833	0.288			
belowground						
GFED 500m -	41.956	17.902	0.427			
aboveground						
GFAS	135.688	66.059	0.487	0.808	0.918	
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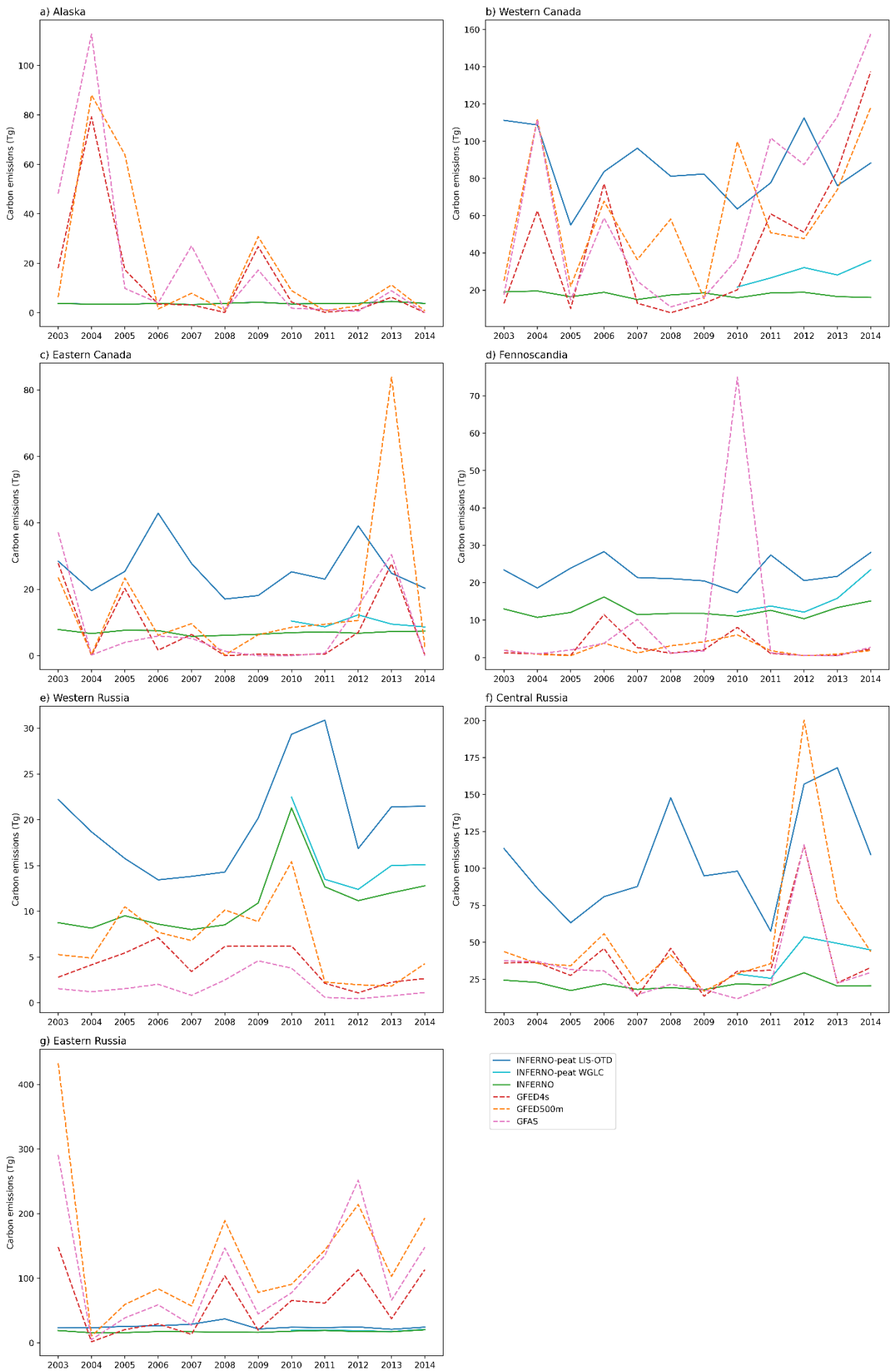
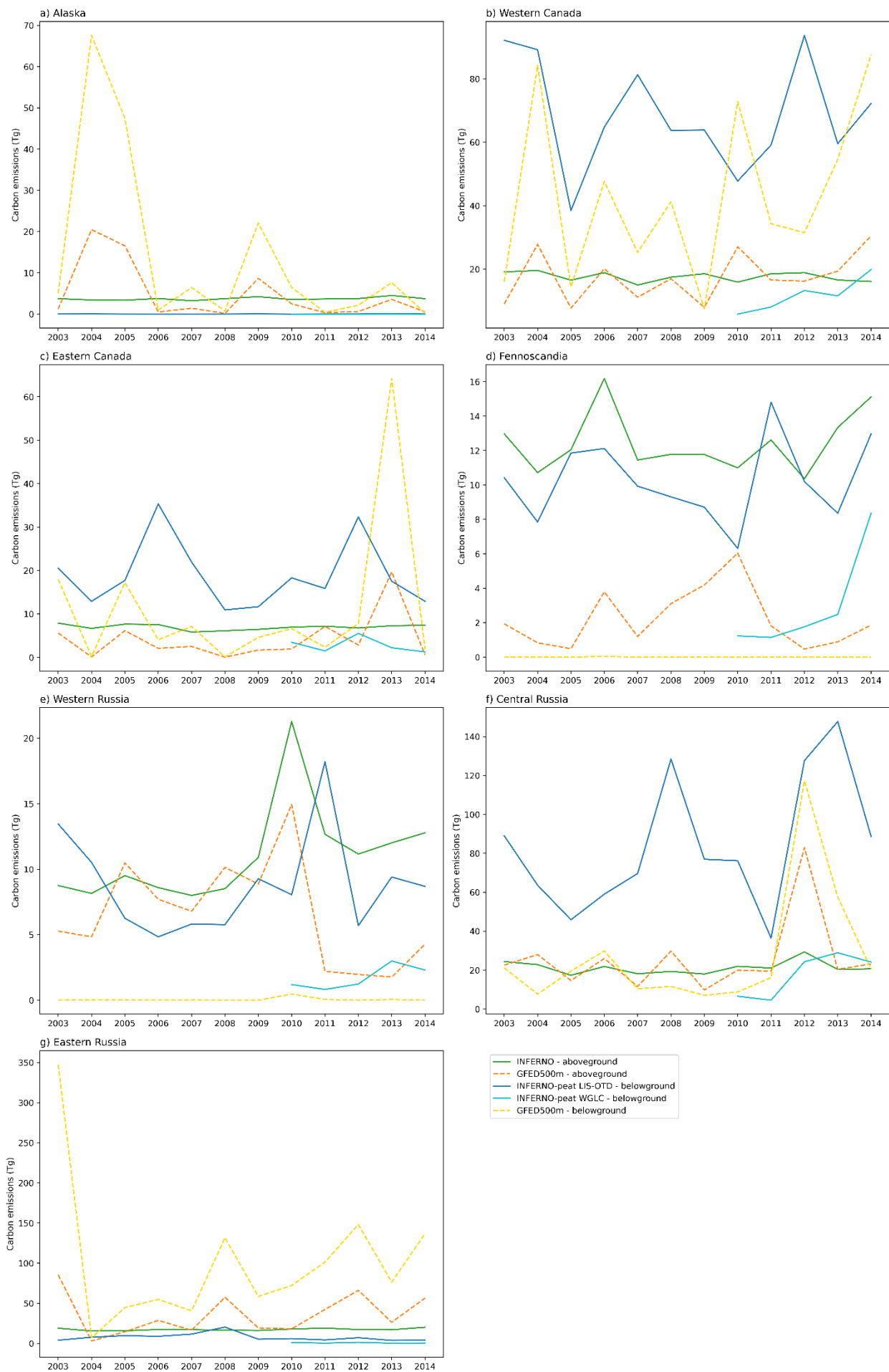


Figure S9: Carbon emissions timeseries graphs broken down by subregion, from 2003 to 2014. Note that the WGLC INFERNO-peat runs are only for 2010 to 2014. Dashed lines indicate observations and solid lines represent models.



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Figure S10: Carbon emissions timeseries graphs comparing aboveground burning from INFERNO and the GFED500m aboveground product, and belowground burning from the peat only INFERNO-peat runs and the GFED500m belowground

product. Results are broken down by subregion, from 2001 to 2014. Note that the WGLC INFERNO-peat runs are only for 2010 to 2014. Dashed lines indicate observations and solid lines represent models.