Supplement of

INFERNO-peat: 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

10   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

15   using organic soil moisture, we see a reduction in these biases (figure 2)

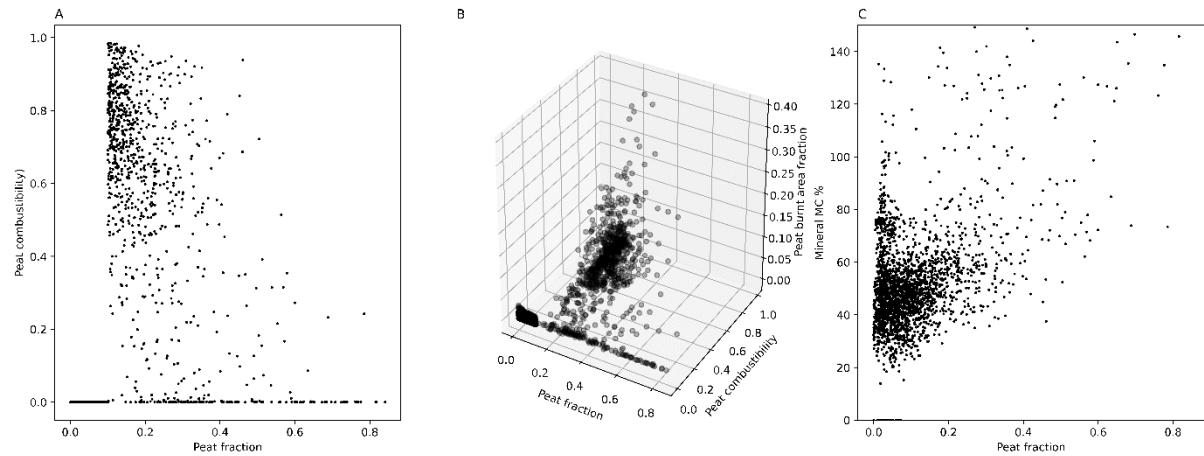
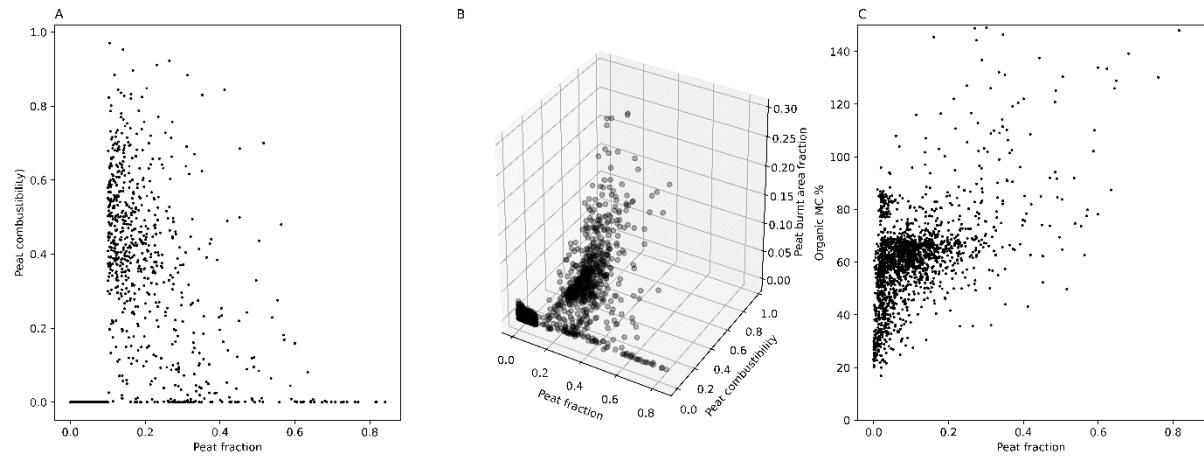



Figure S1: Diagnostic plots from INFERNO-peat using mineral soil moisture, showing the relationship between peat fraction and combustibility (A), combustibility and peat burnt area (B), and mineral moisture content (C).

20   **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 Supplementary maps

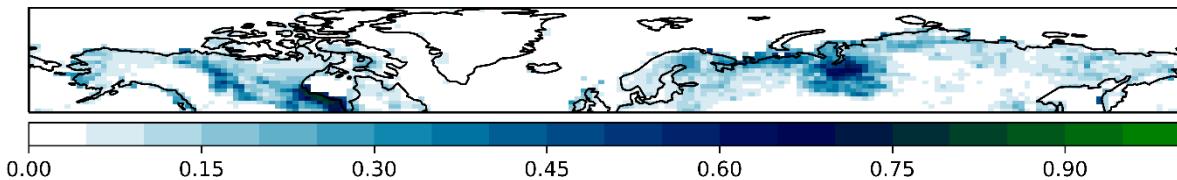



Figure S3: Grid cell peatland fraction plotted from the Northern Peatland Dataset (Hugelius et al., 2020).

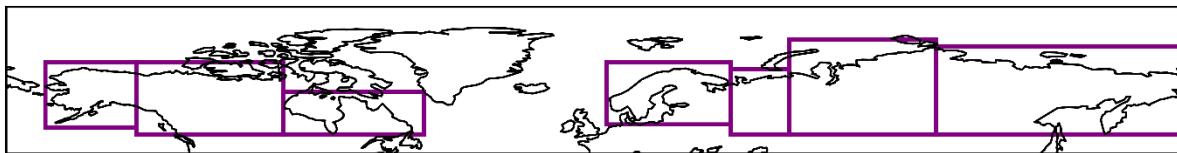



Figure S4: The seven subregions used to analyse INFERNO-peat performance. From L:R, Alaska, Western Canada, Eastern Canada, Fennoscandia, Western Russia, Central Russia, Eastern Russia.

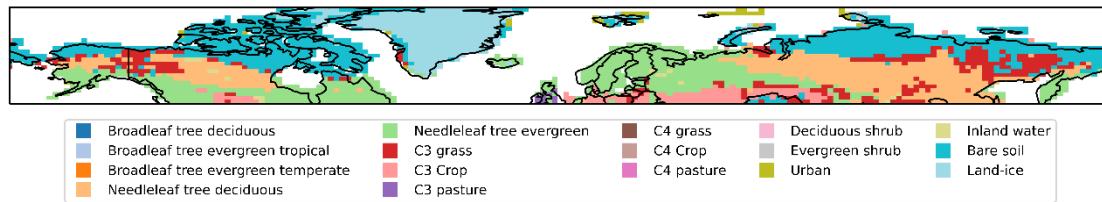



Figure S5: 2010-2014 average dominant land fraction type in each grid cell modelled by JULES

S3 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 annual BA (M km2)	std	CV	R (Spatial correlation)				RMSE				R (temporal correlation)			
				GFED4s	GFED5	fireCCI LT11	ABoVE -FED	GFED4s	GFED5	fireCCI LT11	ABoVE -FED	GFED4s	GFED5	fireCCI LT11	ABoVE -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	

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	

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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 BA (M km2)	std	cv	R 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	

55 **S4 Additional carbon results**

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	3.802	0.372	0.098	-0.119	-0.240	-0.226
LIS-OTD						
Peat only LIS-OTD	0.067	0.045	0.676			
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	87.390	15.455	0.177	0.169	0.112	0.241
LIS-OTD						
Peat only LIS-OTD	69.778	14.735	0.211			
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 LIS-OTD	34.084	8.547	0.251	0.204	0.099	0.369
Peat only LIS-OTD	27.097	8.293	0.306			
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 - belowground	11.185	16.940	1.515			
GFED 500m - aboveground	4.202	5.178	1.232			
GFAS	8.350	12.176	1.458	0.868	0.699	
Fennoscandia						
INFERNO	12.449	1.676	0.135	0.464	0.119	-0.249
INFERNO-peat LIS-OTD	25.116	4.109	0.164	0.431	-0.036	-0.266
Peat only LIS-OTD	12.668	2.725	0.215			
GFED4s	2.715	3.298	1.215		0.699	0.520
GFED 500m - total	2.224	1.659	0.746	0.699		0.691
GFED 500m - belowground	0.006	0.011	1.906			
GFED 500m - aboveground	2.219	1.656	0.746			
GFAS	8.473	20.215	2.386	0.520	0.691	
Western Russia						
INFERNO	11.029	3.524	0.320	0.045	0.382	0.361
INFERNO-peat LIS-OTD	22.452	6.058	0.270	-0.289	-0.120	0.084
Peat only LIS-OTD	11.423	4.604	0.403			
GFED4s	4.135	1.929	0.467		0.829	0.771

	Avg annual C emissions (Tg)	std	cv	R GFED4s	GFED500m	GFAS
GFED 500m - total	6.658	3.926	0.590	0.829		0.766
GFED 500m - belowground	0.053	0.125	2.359			
GFED 500m - aboveground	6.605	3.854	0.583			
GFAS	1.742	1.242	0.713	0.771	0.766	
Central Russia						
INFERNO	21.271	3.160	0.149	0.848	0.800	0.828
INFERNO-peat LIS-OTD	107.365	28.676	0.267	0.486	0.643	0.458
Peat only LIS-OTD	86.094	27.333	0.317			
GFED4s	37.573	25.523	0.679		0.918	0.937
GFED 500m - total	52.996	46.956	0.886	0.918		0.933
GFED 500m - belowground	27.296	30.240	1.108			
GFED 500m - aboveground	25.699	18.235	0.710			
GFAS	32.612	26.374	0.809	0.937	0.933	
Eastern Russia						
INFERNO	17.476	1.356	0.078	0.666	0.596	0.581
INFERNO-peat LIS-OTD	26.365	3.395	0.129	0.359	0.192	0.207
Peat only LIS-OTD	8.889	3.617	0.407			
GFED4s	0.607	46.239	0.763		0.914	0.943
GFED 500m - total	137.947	107.069	0.776	0.914		0.938
GFED 500m - belowground	101.689	84.709	0.833			
GFED 500m - aboveground	36.258	24.043	0.663			
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 emissions (Tg)	std	cv	R GFED4s	GFED500m	GFAS
Alaska						
INFERNO	3.849	0.343	0.089	0.648	0.577	0.916

INFERNO-peat LIS-OTD	3.929	0.402	0.102	0.642	0.570	0.916
Peat only LIS-OTD	0.080	0.060	0.747			
INFERNO-peat WGLC	3.861	0.353	0.091	0.649	0.577	0.916
Peat only WGLC	0.012	0.010	0.839			
GFED4s	2.379	2.472	1.039		0.996	0.861
GFED 500m - total	4.901	4.358	0.889	0.996		0.811
GFED 500m - belowground	3.384	3.092	0.914			
GFED 500m - aboveground	1.517	1.290	0.850			
GFAS	2.492	3.247	1.303	0.861	0.811	
Western Canada						
INFERNO	17.220	1.254	0.073	-0.255	-0.914	-0.037
INFERNO-peat LIS-OTD	84.574	15.494	0.183	0.246	-0.276	0.329
Peat only LIS-OTD	67.355	14.808	0.220			
INFERNO-peat WGLC	28.918	4.743	0.164	0.834	0.192	0.851
Peat only WGLC	11.699	4.767	0.407			
GFED4s	70.783	39.125	0.553		0.444	0.972
GFED 500m - total	78.128	27.395	0.351	0.444		0.227
GFED 500m - belowground	56.182	21.700	0.386			
GFED 500m - aboveground	21.945	5.779	0.263			
GFAS	99.386	39.053	0.393	0.972	0.227	
Eastern Canada						
INFERNO	7.123	0.232	0.033	0.188	0.297	-0.004
INFERNO-peat LIS-OTD	34.238	5.627	0.164	0.271	0.076	0.497
Peat only LIS-OTD	27.114	5.771	0.213			
INFERNO-peat WGLC	10.753	1.291	0.120	0.176	-0.013	0.401

Peat only WGLC	3.630	1.483	0.409			
GFED4s	7.132	10.618	1.489		0.978	0.969
GFED 500m - total	23.005	30.573	1.329	0.978		0.900
GFED 500m - belowground	16.573	23.929	1.444			
GFED 500m - aboveground	6.432	6.980	1.085			
GFAS	9.243	12.037	1.302	0.969	0.900	
Fennoscandia						
INFERNO	12.489	1.697	0.136	-0.273	-0.242	-0.420
INFERNO-peat LIS-OTD	25.534	3.784	0.148	-0.436	-0.342	-0.562
Peat only LIS-OTD	13.045	2.492	0.191			
INFERNO-peat WGLC	16.223	4.650	0.287	-0.152	-0.180	-0.322
Peat only WGLC	3.734	3.142	0.841			
GFED4s	2.496	2.853	1.143		0.986	0.980
GFED 500m - total	2.219	1.985	0.895	0.986		0.968
GFED 500m - belowground	0.003	0.004	1.218			
GFED 500m - aboveground	2.216	1.986	0.896			
GFAS	15.987	29.518	1.846	0.980	0.968	
Western Russia						
INFERNO	13.982	3.695	0.264	0.986	0.990	0.991
INFERNO-peat LIS-OTD	26.713	5.498	0.206	0.551	0.389	0.425
Peat only LIS-OTD	12.731	4.815	0.378			
INFERNO-peat WGLC	16.410	3.559	0.217	0.949	0.896	0.933
Peat only WGLC	2.428	1.539	0.634			
GFED4s	2.865	1.748	0.610		0.972	0.986
GFED 500m - total	5.148	5.208	1.012	0.972		0.996
GFED 500m - belowground	0.115	0.175	1.521			

GFED 500m - aboveground	5.033	5.040	1.001			
GFAS	1.338	1.244	0.930	0.986	0.996	

Central Russia

INFERNO	22.682	3.388	0.149	0.990	0.920	0.959
INFERNO-peat LIS-OTD	118.011	35.040	0.297	0.429	0.691	0.523
Peat only LIS-OTD	95.329	33.738	0.354			
INFERNO-peat WGLC	40.312	10.752	0.267	0.633	0.814	0.741
Peat only WGLC	17.630	9.238	0.524			
GFED4s	46.484	34.675	0.746		0.935	0.986
GFED 500m - total	77.258	63.823	0.826	0.935		0.969
GFED 500m - belowground	44.059	40.344	0.916			
GFED 500m - aboveground	33.199	24.919	0.751			
GFAS	40.114	38.351	0.956	0.986	0.969	

Eastern Russia

INFERNO	18.371	1.154	0.063	0.421	0.329	0.045
INFERNO-peat LIS-OTD	25.354	1.724	0.068	0.853	0.637	0.558
Peat only LIS-OTD	6.983	1.250	0.179			
INFERNO-peat WGLC	19.722	1.230	0.062	0.606	0.381	0.214
Peat only WGLC	1.351	0.545	0.404			
GFED4s	78.207	30.153	0.386		0.893	0.808
GFED 500m - total	148.959	48.600	0.326	0.893		0.918
GFED 500m - belowground	107.002	30.833	0.288			
GFED 500m - aboveground	41.956	17.902	0.427			
GFAS	135.688	66.059	0.487	0.808	0.918	