Supplementary Materials: Environmental and seasonal variability of high latitude methane emissions based on earth observation data and atmospheric inverse modelling

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1. Results for prior methane fluxes

Tables S1, S2, S3 and S4 show results which are calculated as in section 3.2 but with prior methane data.

Table S1. Same as table 3 but for prior methane data: Results using all areas. Methane emission per season in Tg, relative seasonal emission in permille and average flux in nmol m^{-2} s^{-1}. The intensity of the blue or red colour on the flux in the freezing period indicates how close the value is to the winter or the thaw period so that their average would be white.

	thaw			freezing			winter		
	Tg	‰	nmol/m^2/s	Tg	‰	nmol/m^2/s	Tg	‰	nmol/m^2/s
non-permafrost	8.0247	870	2.055	0.5189	56	0.876	0.6821	74	0.380
sporadic	3.3132	883	3.332	0.1287	34	0.909	0.3101	83	0.397
discontinuous	1.5646	892	1.846	0.0615	35	0.442	0.1288	73	0.150
continuous	1.4739	946	0.793	0.0188	12	0.065	0.0660	42	0.025
Db	1.5312	857	1.396	0.1099	61	0.678	0.1466	82	0.344
Dc	11.3001	887	2.763	0.5380	42	0.909	0.9078	71	0.297
Dd	0.3748	943	1.022	0.0053	13	0.122	0.0175	44	0.037
ET	0.1211	967	0.106	-0.0003	-2	-0.001	0.0044	35	0.003
bog	3.4080	881	12.942	0.1892	49	5.527	0.2710	70	1.789
fen	3.5606	888	13.302	0.1768	44	5.404	0.2743	68	1.670
marsh	0.6294	884	13.967	0.0301	42	5.481	0.0526	74	1.720
permafrost bog	2.3819	875	11.410	0.0949	35	3.671	0.2460	90	1.205
tundra wetland	0.9387	884	11.513	0.0300	28	2.512	0.0931	88	0.910
wetland	10.9185	882	12.603	0.5210	42	4.726	0.9370	76	1.436
non-wetland	2.9305	881	0.792	0.1837	55	0.309	0.2135	64	0.071

2. Linear regression in detail

Table S5 shows additional information about the implementation and results of the linear regression model used. The fluxes in the thaw period divided by the wetland fraction and the used flux value limits are shown in Figure S1 and the regression curve for the points in the accepted range are shown in Figure S2 (warm area) and in Figure S3 (cold area). The predicted flux and confidence intervals for the category are on the right side of the figure where the category fraction is 1.

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Table S2. Same as table 4 but for prior methane data: Results using only wetlands. Methane emission per season in Tg, relative seasonal emission in permille and average flux in nmol m^{-2} s^{-1}. The intensity of the blue or red colour on the flux in the freezing period indicates how close the value is to the winter or the thaw period so that their average would be white.

	thaw			freezing			winter		
	Tg	‰	nmol/m^2/s	Tg	‰	nmol/m^2/s	Tg	‰	nmol/m^2/s
non-permafrost	6.2334	877	12.860	0.3651	51	5.561	0.5119	72	1.890
sporadic	2.9101	880	13.949	0.1095	33	4.989	0.2874	87	1.799
discontinuous	1.1584	880	11.980	0.0454	34	3.446	0.1124	85	1.165
continuous	1.0339	934	9.622	0.0171	15	1.245	0.0557	50	0.367
Db	0.7979	866	13.047	0.0551	60	6.685	0.0680	74	2.276
Dc	9.5589	884	13.474	0.4402	41	5.084	0.8185	76	1.597
Dd	0.2413	930	11.909	0.0039	15	1.814	0.0144	55	0.512
ET	0.0748	901	1.945	0.0019	23	0.285	0.0063	76	0.117

Table S3. Same as table 5 but for prior methane data: Results when using temperate wetlands only. Methane emission per season in Tg, relative seasonal emission in permille and average flux in nmol m^{-2} s^{-1}. The intensity of the blue or red colour on the flux in the freezing period indicates how close the value is to the winter or the thaw period so that their average would be white.

	thaw			freezing			winter		
	Tg	‰	nmol/m^2/s	Tg	‰	nmol/m^2/s	Tg	‰	nmol/m^2/s
bog	0.9204	888	14.335	0.0368	35	6.074	0.0796	77	1.695
fen	1.2651	888	14.075	0.0509	36	5.824	0.1094	77	1.618
marsh	0.2907	879	14.404	0.0116	35	5.463	0.0285	86	1.724
permafrost bog	1.8162	862	12.160	0.0826	39	4.624	0.2089	99	1.682
tundra wetland	0.4864	854	15.536	0.0219	38	4.706	0.0610	107	2.029
wetland	4.7789	874	13.463	0.2038	37	5.167	0.4873	89	1.708

Table S4. Same as table A1 but for prior methane data: For warm wetland classes only warm wetland area is used. For cold wetland classes only cold wetland area is used. Methane emission per season in Tg, relative seasonal emission in permille and average flux in nmol m^{-2} s^{-1}. The intensity of the blue or red colour on the flux in the freezing period indicates how close the value is to the winter or the thaw period so that their average would be white.

	thaw			freezing			winter		
	Tg	‰	nmol/m^2/s	Tg	‰	nmol/m^2/s	Tg	‰	nmol/m^2/s
bog	2.4876	879	12.493	0.1524	54	5.409	0.1914	68	1.832
fen	2.2954	888	12.912	0.1259	49	5.251	0.1649	64	1.707
marsh	0.3386	888	13.612	0.0185	49	5.493	0.0242	63	1.715
permafrost bog	0.5657	920	9.526	0.0123	20	1.540	0.0371	60	0.465
tundra wetland	0.4523	918	9.005	0.0082	17	1.118	0.0321	65	0.444
wetland	6.1397	889	12.006	0.3172	46	4.480	0.4497	65	1.224

Table S5. Additional information on parameters and results of regression models used to separate fluxes on wetland categories. Obtained average flux is the mean of predicted fluxes on each class weighted by the area of each class. Target average flux is the mean of regression model input flux values weighted by grid cell area.

	thaw		freezing		winter	
	warm	cold	warm	cold	warm	cold
upper flux limit	30	52	7	23	3	59
lower flux limit	3	-6	3	-4	0	-0
accepted proportion	0.7143	0.9402	0.3675	0.9830	0.4813	1.0000
$\frac{\text{obtained}}{\text{target}}$ average flux	0.9980	0.9930	0.9330	1.0950	1.0870	1.2570
R^2	0.0017	0.0229	0.0221	0.0313	0.0181	0.0003

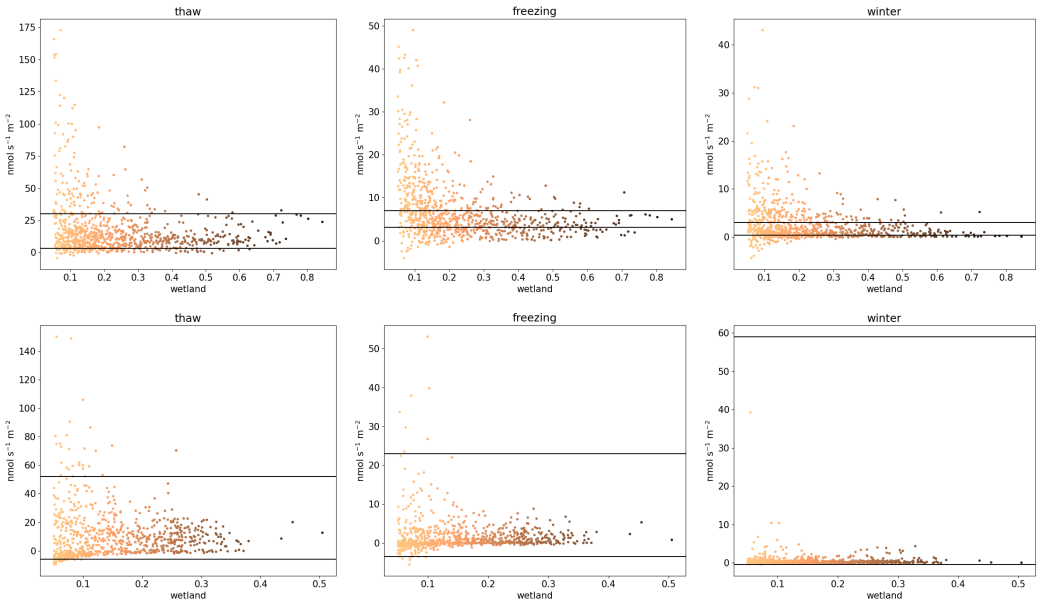


Figure S1. Top: warm wetland area. Bottom: cold wetland area. Methane flux divided by wetland fraction as function of wetland fraction. Horizontal lines show selected flux bounds for the regression model in that area and season. Each point is the average flux in a grid cell. The colors of the points are used to help link this figure to figures S2 and S3. Grid cell sizes are not visible in the figures, but they were taken into account in the linear regression.

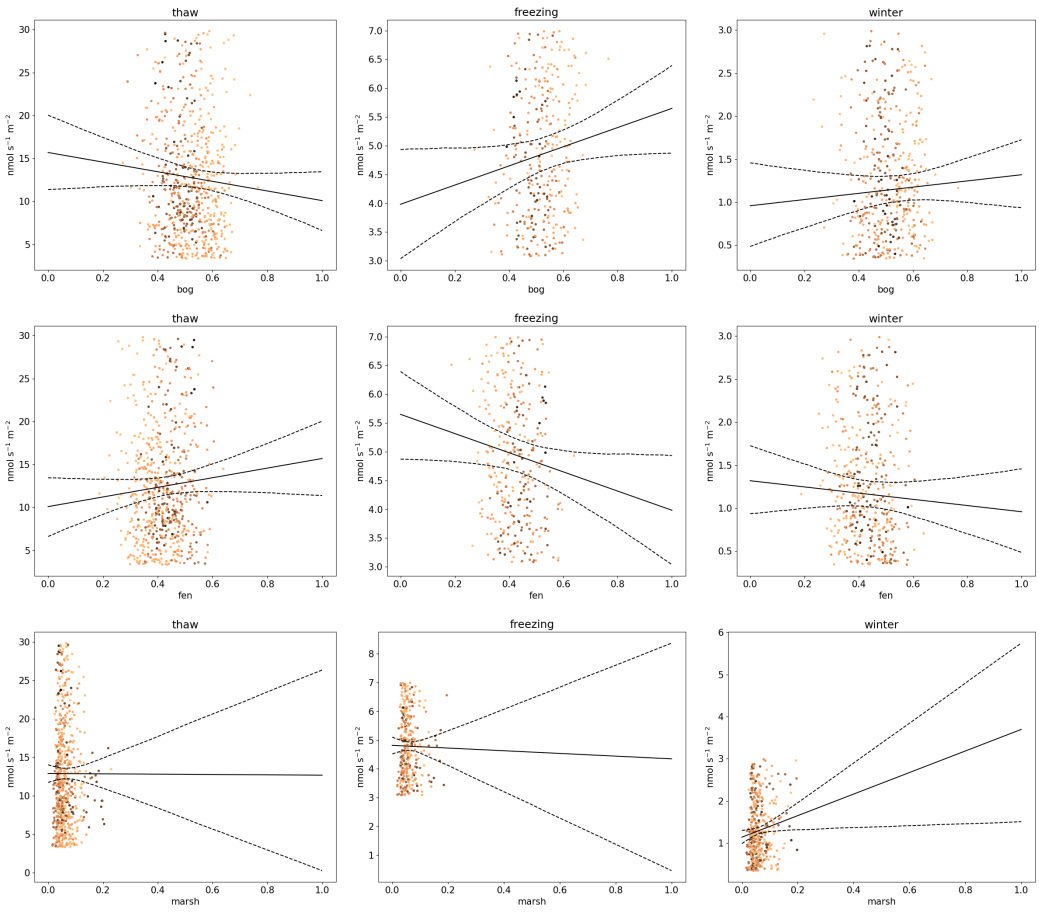


Figure S2. Regression line, confidence intervals and fluxes for warm wetlands. The dots are flux data divided by wetland fraction (the same dots as at the top of Fig. S1) and the x-axis is category proportion of total wetland. All bog, fen and marsh are explanatory variables in the regression, but only one of them is visible in a figure. For fen, the drawn regression line is $y = \text{coef(fen)}x + \text{coef(bog)}(1 - x)$ and vice versa for bog. For marsh the regression line is $y = \text{coef(marsh)}x + 0.5(\text{coef(bog)} + \text{coef(fen)})(1 - x)$. Dashed lines show two-sided 95 % confidence intervals.

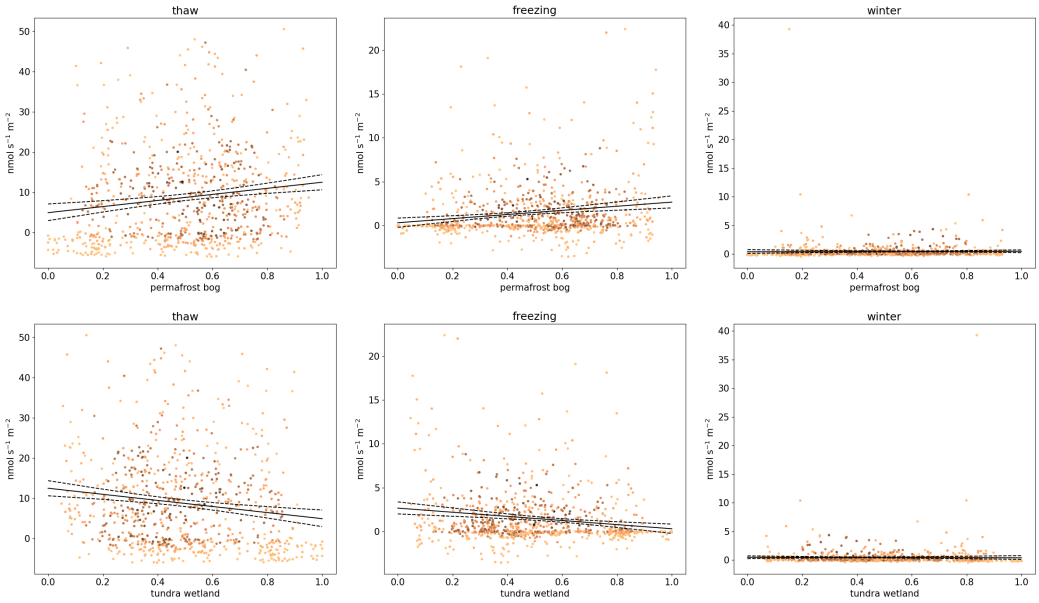


Figure S3. Regression line, confidence intervals and fluxes for cold wetlands. The dots are flux data divided by wetland fraction (the same dots as at the bottom of Fig. S1) and the x-axis is category proportion of total wetland. The drawn regression line is $y = \text{coef}(\text{this class})x + \text{coef}(\text{the other class})(1 - x)$ Dashed lines show two-sided 95 % confidence intervals.