

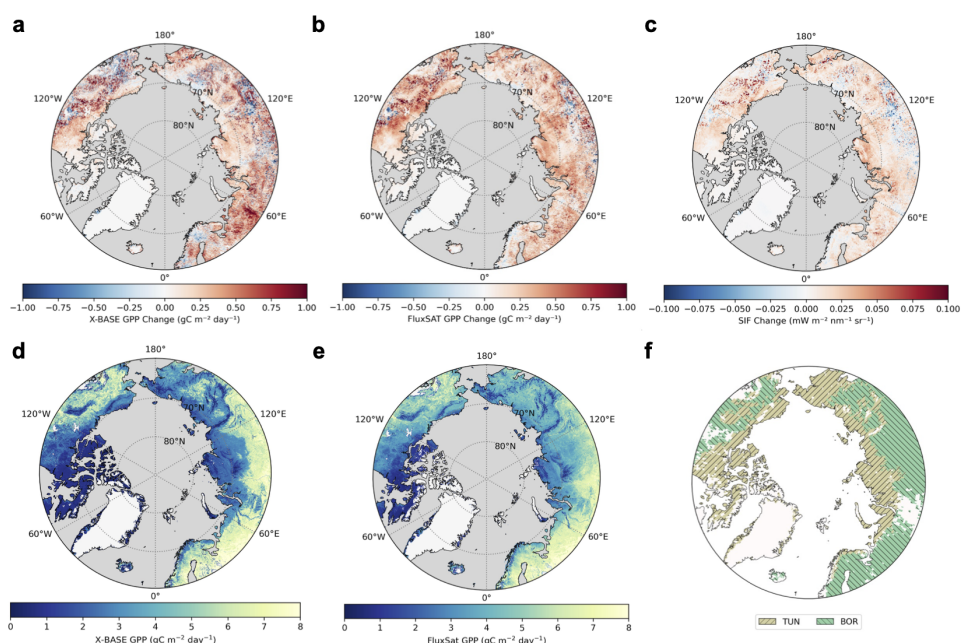


Fig. A1: Spatial Patterns in GPP decadal changes. GPP transition between the second (2011-2020) and first (2001-2010) periods evaluated for the X-BASE and FluxSat datasets in $\text{gC m}^{-2} \text{ day}^{-1}$ (a and b, respectively). SIF transition between the same periods evaluated in $\text{mW m}^{-2} \text{ sr}^{-1} \text{ nm}^{-1}$ (c). Mean climatological GPP values for the entire period of 2001-2020 for X-BASE and FluxSat datasets (d and e, respectively). Tundra and Boreal areas according to the BALWD classification (f)

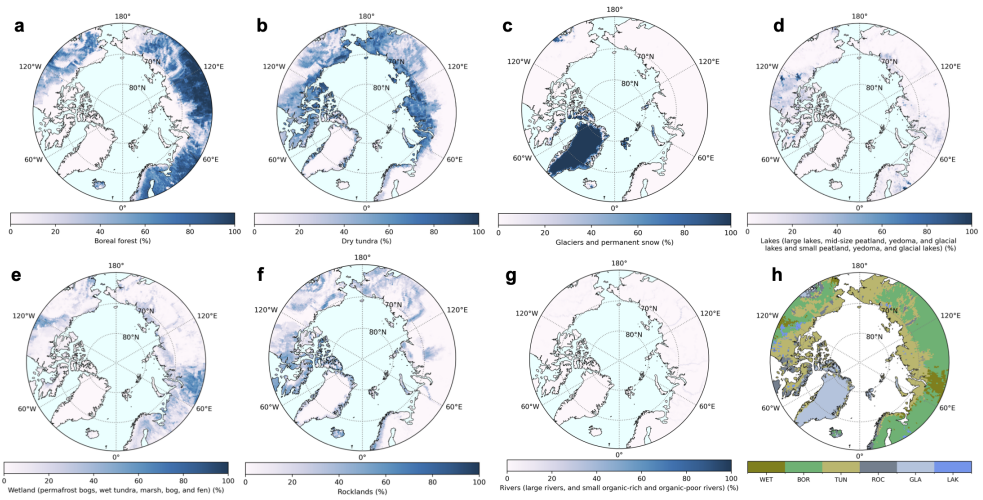


Fig. A2: BAWLD class representation. Percent of the abundance per pixel for the BAWLD classification [47]. Boreal forest (BOR) (a), Dry tundra (TUN) (b), Glaciers and permanent snow (GLA)(c), Lakes (LAK) (d), Wetland (WET) (e), Rocklands (ROC) (f), Rivers (g), BAWLD classification excluding rivers (h).

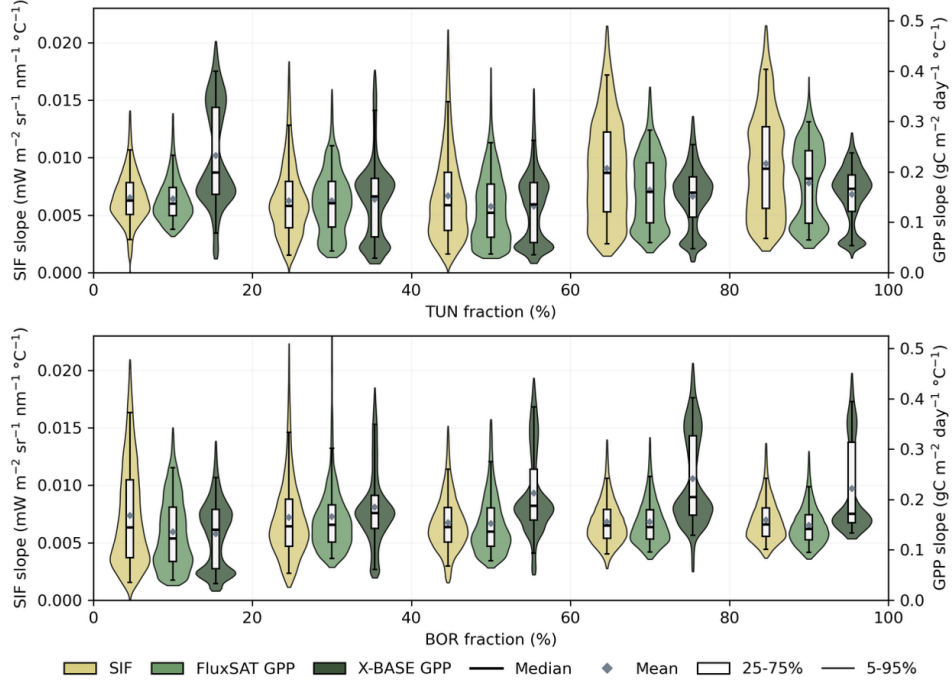


Fig. A3: SIF and GPP FluxSat and X-BASE products sensitivity to air temperature at different tundra and boreal fractions. SIF, GPP_{FluxSat} and GPP_{X-BASE} sensitivity to air temperature assuming a linear regression of the form $f(x) = \alpha x + n$ where $f(x)$ represents either $\delta(SIF, GPP)$ and $x = \delta T_{air}$ with respect to the mean values along 2001-2020 (see Methods). Classification according to tundra (a) and boreal (b) percent representation per pixel (0.05°). Details regarding the statistics are provided in Supplementary Table A5.

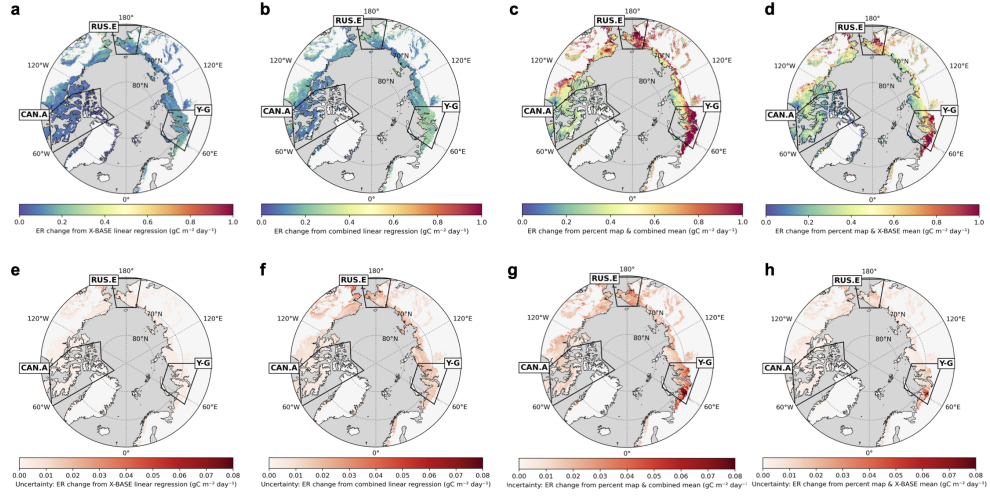


Fig. A4: ER reconstructed maps for 1.4 °C warming-induced response. ER change associated to an increase of 1.4 °C of air temperature modelled as a linear regression using ER_{X-BASE} (a) and ER_{COM} (b). Generated maps of ER change in ($gC\ m^{-2}\ day^{-1}$) using [19] percent maps and the climatological values of ER in the period 2001-2020 from ER_{COM} (c) and ER_{X-BASE} (d). Associated uncertainties in pairs (a-e, b-f, c-g, d-h) to each of the above-defined ER maps.

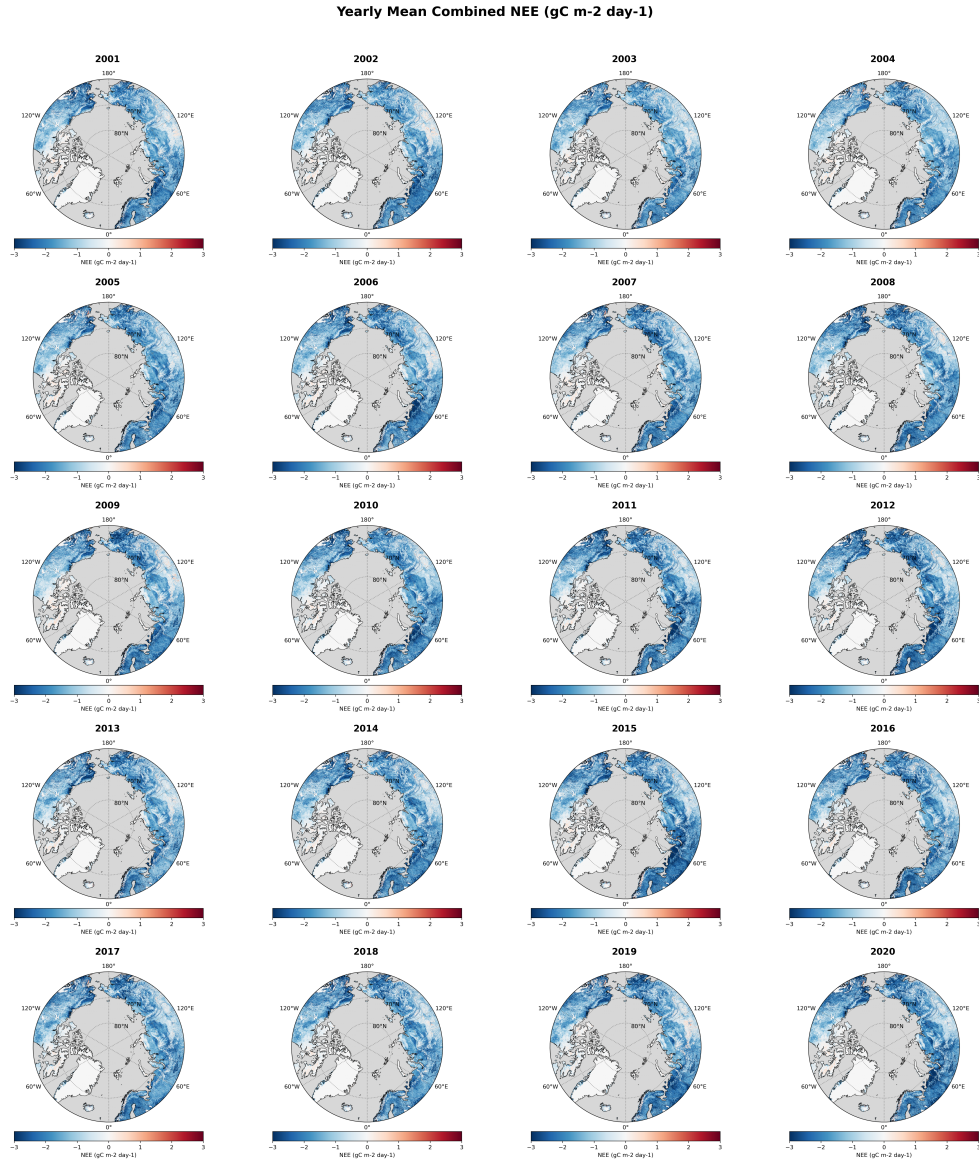


Fig. A5: Yearly Mean NEE_{COM}. Yearly maps for the growing season (JJA) of the NEE combined product NEE_{COM}, using the GPP_{FluxSat} and ER_{X-BASE}, which is built from the relationship of NEE=ER-GPP.

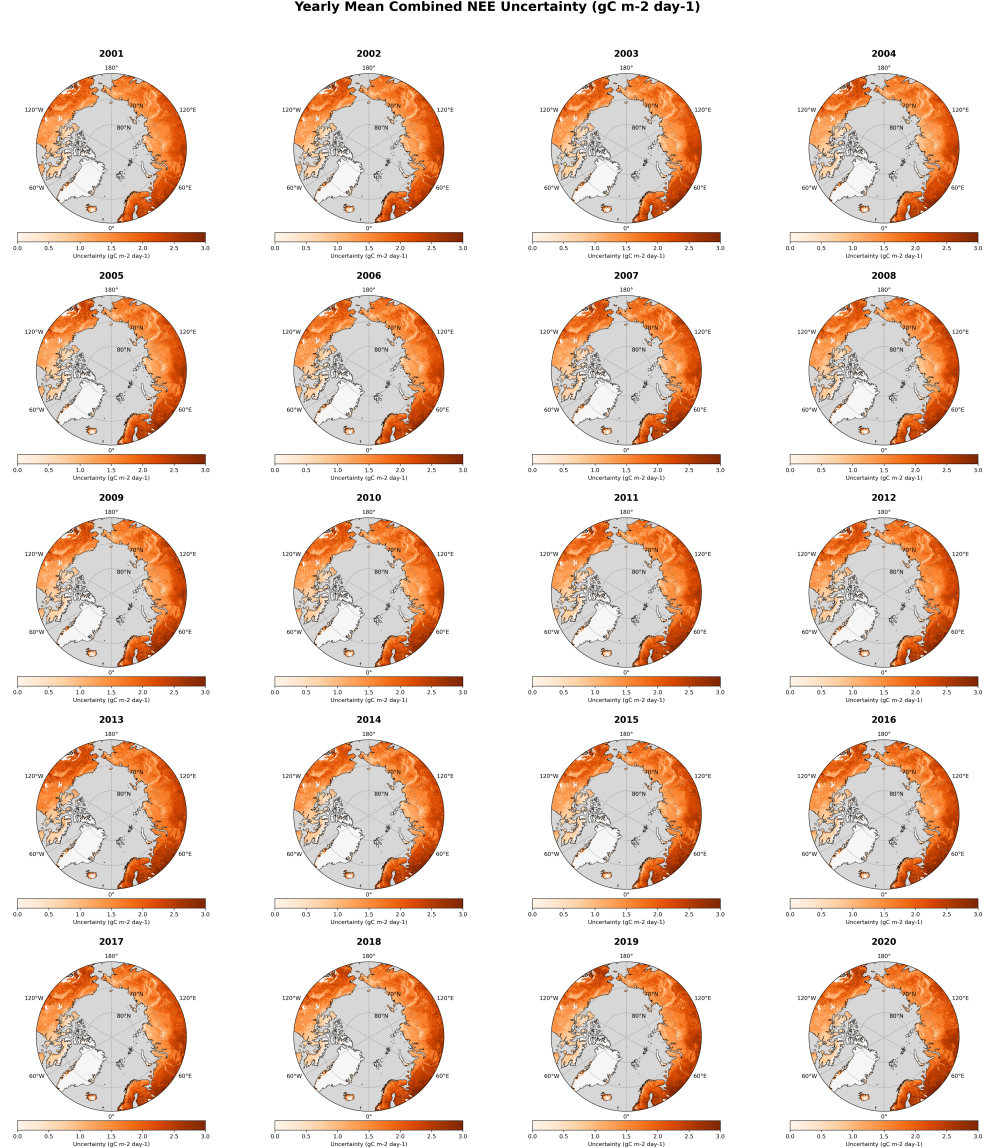


Fig. A6: Uncertainty associated with yearly Mean NEE_{COM} maps. Yearly maps for the growing season (JJA) of the NEE combined product NEE_{COM} mean uncertainty. The mean uncertainty maps represent the mean value computed from all the daily uncertainties covering the JJA period.

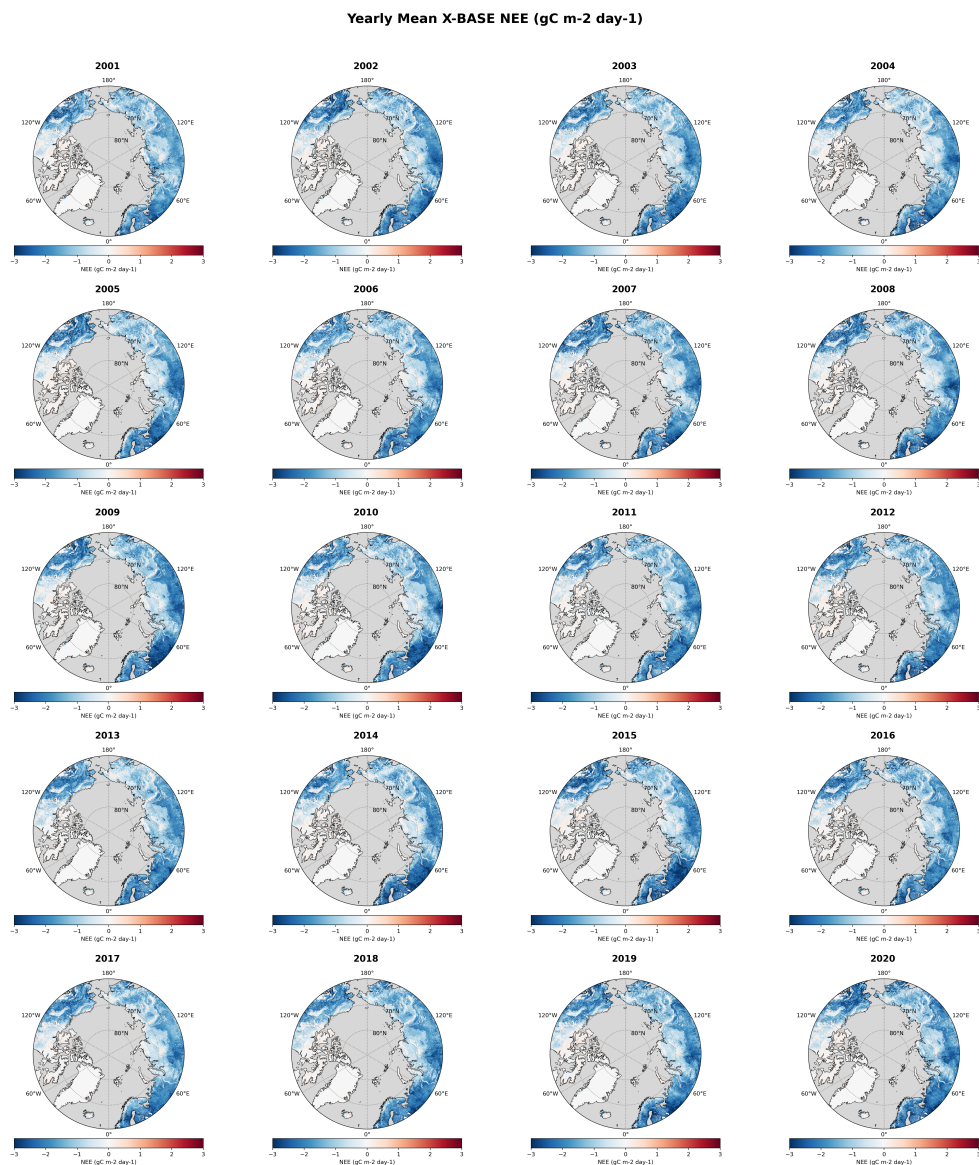


Fig. A7: Yearly Mean NEE_{X-BASE}. Yearly maps for the growing season (JJA) of the NEE combined product NEE_{X-BASE}.

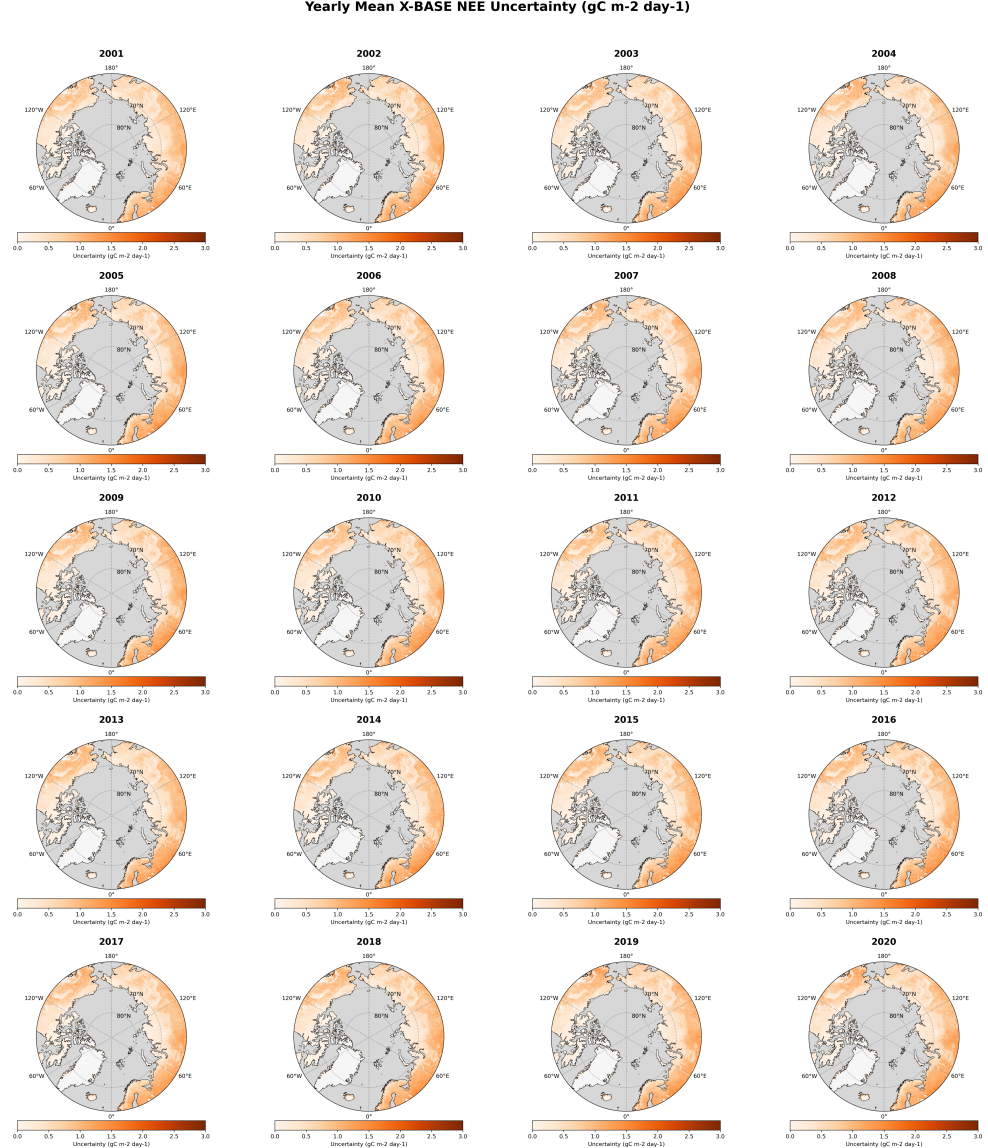


Fig. A8: Uncertainty associated with yearly Mean NEE_{X-BASE} maps. Yearly maps for the growing season (JJA) of the NEE combined product NEE_{COM} mean uncertainty. The mean uncertainty maps represent the mean value computed from all the daily uncertainties covering the JJA period.

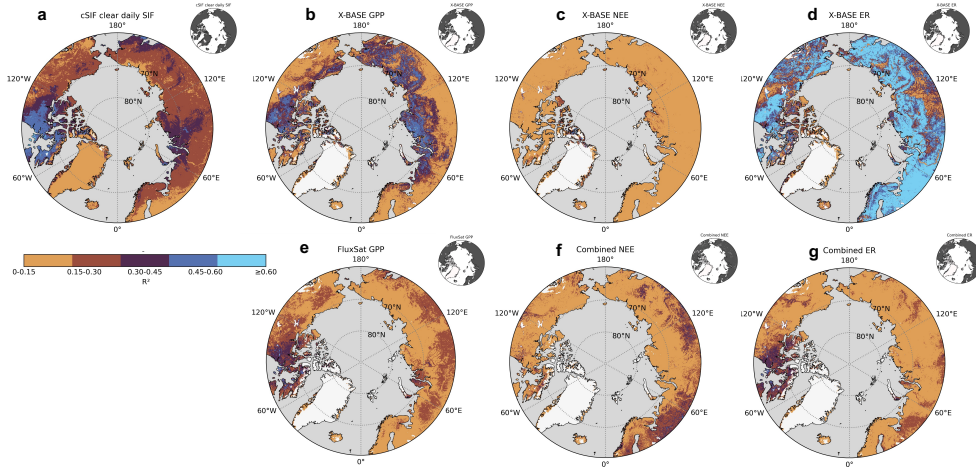


Fig. A9: R^2 and p-value maps for the C flux and SIF sensitivity to air T assuming a linear regression. R^2 and p-value maps for the linear regression C flux and SIF sensitivity to air T. R^2 values associated with SIF (a), X-BASE GPP (b), X-BASE NEE (c), X-BASE ER (d), FluxSat GPP (e), Combined NEE (f), and Combined ER (g). Areas with P-values < 0.05 are shown in a black mask in the upper-left corner of each corresponding panel.

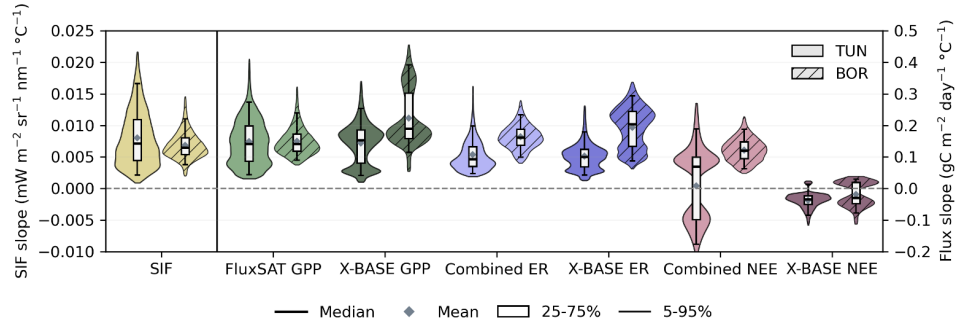


Fig. A10: SIF and C fluxes sensitivity to air temperature. SIF and C fluxes sensitivity to air temperature (α) assuming a linear regression of the form $f(x) = \alpha x + n$ where $f(x)$ represents either $\delta(SIF, GPP, ER, NEE)$ and $x = \delta T_{air}$ with respect to the mean values for the period 2001-2020 (see Methods). Boreal and tundra regions, according to the BAWLD classification (Supplementary Fig. A2), are highlighted as solid or striped patterns. Statistics regarding the linear regression are detailed in Supplementary Table A4.

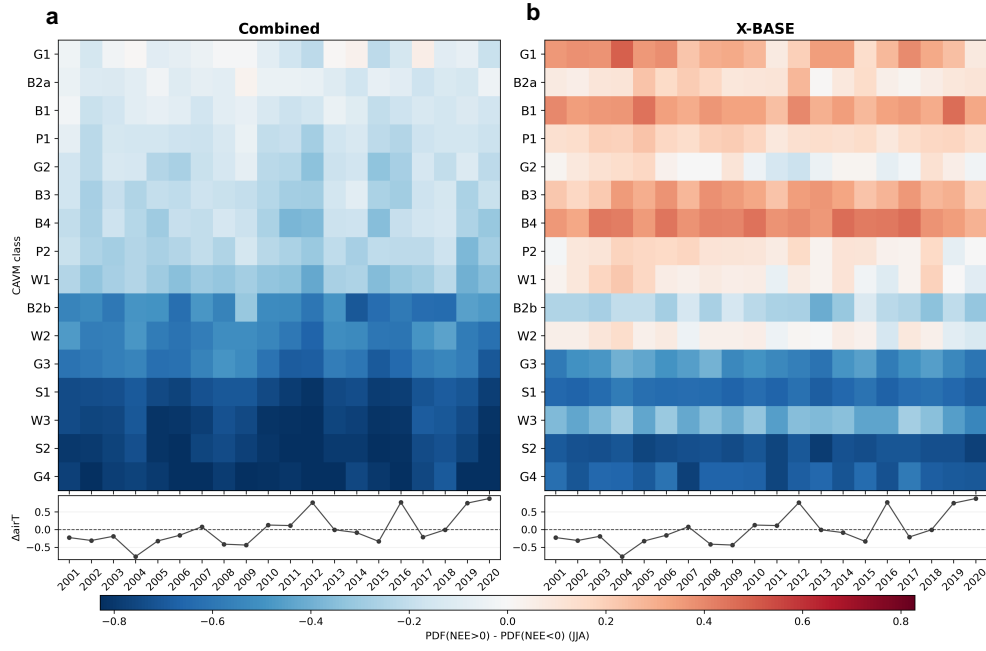


Fig. A11: Net Probability Density function (PDF) of NEE_{X-BASE} and NEE_{COM} annual balance. Heatmap of the net PDF annual balance per CAVM class for the NEE_{COM} (a) and NEE_{X-BASE} datasets (b). Mean air temperature anomaly conditions with respect to the 2000-2020 period for each growing season (JJA) over the CAVM region are marked as black solid lines in the bottom panels.

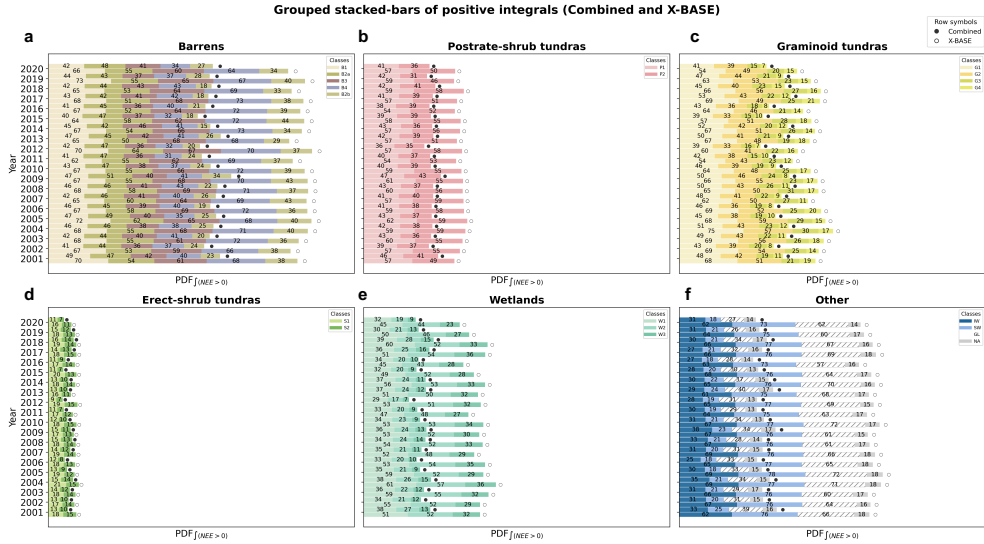


Fig. A12: Normalised contribution of NEE positive values along 2001-2020 per tundra subclass. Integral of the PDF of NEE values positive for the 2001-2020 period grouped by subtypes of tundra class according to the CAVM map. While all the x-axes are equal for all the panels to ease the comparison, the numbers are removed to avoid misleading interpretation, since the stacked bars just include the individual class contribution. Individual contributions per class and year are indicated in the numbers inside each bar.

Dataset name	X-BASE	ER	FluxSat	cSIF
data	NEE, GPP	ER	GPP	SIF
Main source	EC FLUXNET upscaled	Experiments isolated	EC Fluxnet + MODIS BRDF reflectance	SIF satellite estimates
Driven method	XG-Boost	metaregression multifactor model	NN	NN
Uncertainties	no	yes	yes	no
Temp. res.	Hourly (daily average)	N.A.	Daily	4-day
Temp. coverage	2001–2020	Across 2001–2020	2001–2020	2001–2020
Spatial res. (degrees)	0.05	0.05	0.05	0.05

Table A1: Carbon flux and SIF dataset used Collection of the C flux and SIF datasets used and the main features describing their data source, the main products provided and analysed, and the principal method of generation. The references for each dataset are: X-BASE [36], ER [19], FluxSat [42], and cSIF[43]. The acronym NN refers to Neural Networks. Not all the auxiliary data used in the databases’ generation are mentioned in the table.

region	variable	lon_min	lon_max	lat_min	lat_max	n	mean	median	std	q25	q75	min	max
CAN.A S (1)	X-BASE GPP rel (%)	-75.0	-60.0	62.0	70.0	24147	0.01	0.34	16.6	-5.42	4.64	-551.47	180.42
CAN.A S (1)	FluxSat GPP rel (%)	-75.0	-60.0	62.0	70.0	20663	0.95	0.95	6.22	-2.38	4.35	-147.86	200.0
CAN.A S (1)	X-BASE NEE rel (%)	-75.0	-60.0	62.0	70.0	24147	57.82	5.33	6153.15	-10.85	22.72	-52201.63	940657.72
CAN.A S (1)	Combined NEE rel (%)	-75.0	-60.0	62.0	70.0	19691	-45.78	1.58	966.84	-18.93	15.49	-55472.7	42990.62
CAN.A S (1)	SIF rel (%)	-75.0	-60.0	62.0	70.0	20785	-1.15	1.31	665.47	-4.56	7.05	-76438.07	13932.07
CAN E (2)	X-BASE GPP rel (%)	-118.0	-90.0	60.0	70.0	97334	10.48	9.99	13.26	5.23	15.95	-133.36	132.43
CAN E (2)	FluxSat GPP rel (%)	-118.0	-90.0	60.0	70.0	96409	9.0	9.57	8.97	5.72	13.39	-116.49	97.49
CAN E (2)	X-BASE NEE rel (%)	-118.0	-90.0	60.0	70.0	97334	-169.28	-13.28	20756.33	-45.39	2.84	-5550018.13	774187.05
CAN E (2)	Combined NEE rel (%)	-118.0	-90.0	60.0	70.0	94917	-25.77	-11.07	1962.38	-23.4	0.24	-147480.36	524352.33
CAN E (2)	SIF rel (%)	-118.0	-90.0	60.0	70.0	94357	9.42	10.41	197.11	5.52	15.15	-47400.86	11735.69
AK (3)	X-BASE GPP rel (%)	-170.0	-140.0	60.0	70.0	93490	4.47	3.19	12.63	-1.49	9.27	-113.62	414.76
AK (3)	FluxSat GPP rel (%)	-170.0	-140.0	60.0	70.0	92670	6.32	5.9	6.87	2.96	9.12	-80.81	177.54
AK (3)	X-BASE NEE rel (%)	-170.0	-140.0	60.0	70.0	93490	-0.5	0.83	393.97	-9.41	8.62	-74838.14	43533.95
AK (3)	Combined NEE rel (%)	-170.0	-140.0	60.0	70.0	91523	-0.56	-6.13	963.69	-15.2	2.22	-48636.7	217102.46
AK (3)	SIF rel (%)	-170.0	-140.0	60.0	70.0	91782	7.78	5.61	48.68	1.2	11.01	-6478.24	5938.46
RUS (4)	X-BASE GPP rel (%)	80.0	118.0	70.0	79.0	84890	14.01	12.64	9.29	8.19	18.59	-63.29	104.31
RUS (4)	FluxSat GPP rel (%)	80.0	118.0	70.0	79.0	80602	14.13	13.22	6.17	9.85	17.42	-47.25	57.88
RUS (4)	X-BASE NEE rel (%)	80.0	118.0	70.0	79.0	84890	-91.06	-19.07	3655.53	-37.02	-7.48	-942233.32	17443.54
RUS (4)	Combined NEE rel (%)	80.0	118.0	70.0	79.0	79880	-43.32	-16.47	757.55	-26.75	-9.68	-133418.68	37005.61
RUS (4)	SIF rel (%)	80.0	118.0	70.0	79.0	82096	24.78	17.36	381.7	11.09	24.93	-15096.63	64494.19
FEN (5)	X-BASE GPP rel (%)	14.0	35.0	65.0	70.0	38005	1.98	1.94	8.1	-2.22	5.95	-74.59	67.92
FEN (5)	FluxSat GPP rel (%)	14.0	35.0	65.0	70.0	38310	1.02	1.45	4.82	-1.22	3.89	-49.48	40.06
FEN (5)	X-BASE NEE rel (%)	14.0	35.0	65.0	70.0	38005	-27.81	-2.73	1829.79	-10.79	3.54	-315432.0	33292.7
FEN (5)	Combined NEE rel (%)	14.0	35.0	65.0	70.0	37697	13.37	-1.67	1339.23	-9.29	6.2	-48497.61	244358.81
FEN (5)	SIF rel (%)	14.0	35.0	65.0	70.0	36294	-0.14	1.23	65.68	-2.11	4.27	-11526.39	241.83
WHOLE	X-BASE GPP rel (%)					1268351	7.12	5.56	181.67	0.66	11.6	-1954.14	130393.11
WHOLE	FluxSat GPP rel (%)					1142620	5.94	5.61	7.43	2.25	9.81	-126.58	181.01
WHOLE	X-BASE NEE rel (%)					1268351	208.74	-5.68	300288.8	-20.12	4.21	-9766836.35	337879006.35
WHOLE	Combined NEE rel (%)					1142620	-22.48	-6.58	5792.08	-17.95	3.71	-4395231.09	853546.04
WHOLE	SIF rel (%)					1218253	7.51	6.5	1360.15	1.29	12.29	-1202353.85	663438.52
TUN	X-BASE GPP rel (%)					556617	8.58	7.34	195.12	1.69	13.62	-223.21	112329.54
TUN	FluxSat GPP rel (%)					503018	7.57	7.46	6.96	3.46	11.65	-200.0	151.16
TUN	X-BASE NEE rel (%)					556617	522.42	-10.1	453211.17	-27.71	2.25	-9766836.35	337879006.35
TUN	Combined NEE rel (%)					500965	-31.4	-8.91	6471.52	-19.1	-0.3	-4395231.09	524352.33
TUN	SIF rel (%)					548017	8.66	9.1	1747.36	3.73	14.95	-1202353.85	171619.42
BOR	X-BASE GPP rel (%)					475589	4.47	3.98	11.86	0.02	8.24	-129.4	149.79
BOR	FluxSat GPP rel (%)					475777	4.57	4.35	7.57	1.72	7.58	-101.32	177.54
BOR	X-BASE NEE rel (%)					475589	-19.81	-2.72	8671.64	-11.38	4.81	-5550018.13	774187.05
BOR	Combined NEE rel (%)					475208	-15.44	-4.39	5620.85	-16.69	7.11	-3499325.24	853546.04
BOR	SIF rel (%)					475040	4.52	4.13	24.25	-0.05	8.54	-3227.73	9411.37

Table A2: Statistics on the relative percentage change between the two decades, 2011-2020 and 2001-2010. Columns indicate the region and variable analysed, the spatial extent of the corresponding domain (minimum and maximum longitude and latitude), the sample size (n), and distribution statistics, including the mean, median, standard deviation (std), interquartile range limits (q25 and q75), and the minimum (min) and maximum (max) values. Statistics computed for GPP and NEE products from X-BASE and FluxSat and SIF from cSIF clear. The Combined NEE product is defined in Methods and uses X-BASE derived ER and FluxSat GPP. The relative percent is computed as the difference between two decades divided by the climatological mean of the corresponding variable for the whole period of 2001-2020.

region	variable	n	mean	median	std	q25	q75	min	max
WHOLE	X-BASE GPP mean (2001-2020)	1268351	3.38	2.82	2.43	1.2	5.6	-0.06	10.93
TUN	X-BASE GPP mean (2001-2020)	556617	2.12	2.12	1.4	0.92	2.82	-0.06	9.4
BOR	X-BASE GPP mean (2001-2020)	475589	5.51	5.94	1.93	3.88	6.92	0.08	10.93
WHOLE	FluxSat GPP mean (2001-2020)	1162304	3.95	3.91	1.89	2.62	5.27	0.0	10.09
TUN	FluxSat GPP mean (2001-2020)	503018	2.91	3.0	1.3	1.88	3.82	0.03	9.14
BOR	FluxSat GPP mean (2001-2020)	475777	5.35	5.28	1.43	4.27	6.42	0.03	10.09

Table A3: Statistics on the mean values, here referred to as climatological, for the full period of 2001-2020 during the growing season between June–August (JJA). Columns report the region and variable analysed, the sample size (n), and distribution statistics, including the mean, median, standard deviation (std), interquartile range limits (q25 and q75), and the minimum (min) and maximum (max) values. Statistics are computed for GPP from X-BASE and FluxSat for the entire (WHOLE) region (60-90)°N and for those regions overlapping the dominant BAWLD classes, dry tundra (TUN) and boreal (BOR) zones masked in Fig1.f.

Dataset	Dominant BAWLD class	Passing pixels (%)	Passing pixels (N)
SIF	TUN	80.3	461 073
	BOR	69	328 789
FluxSat GPP	TUN	21.6	123 884
	BOR	24.2	115 140
X-BASE GPP	TUN	50.3	288 506
	BOR	19.3	91 797
Combined ER	TUN	13.6	78 217
	BOR	10.1	47 970
X-BASE ER	TUN	63.2	362 898
	BOR	73.8	351 530
Combined NEE	TUN	2.1	12 182
	BOR	25.7	122 339
X-BASE NEE	TUN	4	23 027
	BOR	0.1	713

Table A4: Number and percentage of pixels passing the p-value and R^2 masks for each dataset within dominant BAWLD classes, dry tundra (TUN) and boreal (BOR). Data are masked using $p < 0.05$ and $R^2 > 0.15$.

BAWLD class	Bin	Dataset	Passing pixels (%)	Passing pixels (N)
TUN	0–20%	SIF	44	309 093
		FluxSat GPP	17	119 631
		X-BASE GPP	10.1	70 654
	20–40%	SIF	62.9	147 003
		FluxSat GPP	18.5	43 253
		X-BASE GPP	31.9	74 602
	40–60%	SIF	76.9	235 710
		FluxSat GPP	26.1	80 034
		X-BASE GPP	43.3	132 870
	60–80%	SIF	82	167 050
		FluxSat GPP	17.4	35 444
		X-BASE GPP	54.3	110 554
BOR	0–20%	SIF	85.9	62 181
		FluxSat GPP	10.6	7 669
		X-BASE GPP	60.8	44 020
	20–40%	SIF	53.5	482 779
		FluxSat GPP	16.2	146 337
		X-BASE GPP	32	288 383
	40–60%	SIF	78.5	109 196
		FluxSat GPP	19.3	26 780
		X-BASE GPP	37	51 414
	60–80%	SIF	73	100 177
		FluxSat GPP	17.6	24 137
		X-BASE GPP	28.5	39 200
	80–100%	SIF	61.9	97 002
		FluxSat GPP	17.3	27 140
		X-BASE GPP	20.7	32 479
	80–100%	SIF	71.9	131 883
		FluxSat GPP	33.9	61 637
		X-BASE GPP	11.6	21 224

Table A5: Percentage and number of pixels passing the p-value and R^2 masks across BAWLD fractional bins (0–100%) for dry tundra (TUN) and boreal (BOR) classes. Data are masked using $p < 0.05$ and $R^2 > 0.15$.

Region	R2	Adj.R2	RMSE	Obs.	pValue	tStat	SE	β_1	Conf. Int
None	0.12	0.12	0.52	2713048	0.00	604	2.50E-04	0.15	0.15 - 0.15
Low	0.20	0.20	0.41	5847944	0.00	1220	1.40E-04	0.17	0.17 - 0.17
Moderate	0.19	0.19	0.42	2705380	0.00	806	1.90E-04	0.16	0.16 - 0.16
High	0.21	0.21	0.44	1855456	0.00	698	2.40E-04	0.17	0.17 - 0.17
Very High	0.26	0.26	0.45	2633216	0.00	971	1.90E-04	0.19	0.19 - 0.19

Table A6: Summary Table of GPP Statistics by thermokarst classification region defined in [52]. In the original classification by Olefeldt et al., coverage is classified as ‘Very High’ (60–100% regional coverage), ‘High’ (30–60%), ‘Moderate’ (10–30%), ‘Low’ (1–10%) and ‘None’ (0–1%) and differentiated between wetland, lake and hillslope thermokarst landscapes. For this paper, the classification takes into account the higher percent regardless of its origin: wetland, lake, or hillslope. The p-value, t-stat, standard error (SE), and confidence interval values are associated with the β_1 parameter of the OLS method in $y = \beta_1 x + \beta_0$.