Supplement of Biogeosciences, 21, 1301–1321, 2024
https://doi.org/10.5194/bg-21-1301-2024-supplement

Biogeosciences
Open Access

Supplement of

Resolving heterogeneous fluxes from tundra halves the growing season carbon budget

Sarah M. Ludwig et al.

Correspondence to: Sarah M. Ludwig (ludda.ludwig@columbia.edu)

Tables S1 – S3 include prior distribution information following the format used in JAGS. Those reported here include normal distributions 'dnorm' with parameters mean and standard deviation, and uniform distributions 'dunif' with parameters minimum and maximum range.

Table S1. Prior distributions and initial values for CH_4 flux un-mixing. The same values were used for each month of the growing season.

Landcover category	Prior distribution	Chain 1 initial values	Chain 2 initial values	Chain 3 initial values
Lichen tundra	dnorm(0,1e05)	9e-04	1e-03	2e-03
Shrub tundra	dnorm(0,1e05)	9e-04	1e-03	2e-03
Sedge tundra	dnorm(0,1e05)	9e-04	1e-03	2e-03
Edge of degraded permafrost	dunif(0,0.5)	9e-03	0.01	0.02
Degraded permafrost	dunif(0,0.5)	9e-03	0.01	0.02
Wetland	dunif(0,0.5)	9e-03	0.01	0.02
Water	dunif(0,0.5)	9e-03	0.01	0.02

Table S2. Prior distributions and initial values for NEE flux un-mixing for the simple landcover map. The same values were used for each month of the growing season, with the exception of August and September there were no GPP parameters (E0, Pmax) for degraded permafrost.

Landcover category	Parameter	Prior distribution	Chain 1 initial values	Chain 2 initial values	Chain 3 initial values
Tundra	alpha	dnorm(1,1)	0.9	1	1.1
Tundra	beta	dnorm(0.08,2)	0.0255	0.03	0.04
Tundra	E0	dunif(0,0.25)	0.005	0.03038	0.13045
Tundra	Pmax	dunif(0,50)	5.31	14.33	27.5
Degraded permafrost	alpha	dnorm(1,1)	0.9	1	1.1
Degraded permafrost	beta	dnorm(0.08,2)	0.068	0.08	0.16
Degraded permafrost	E0	dunif(0,0.25)	0.005	0.01	0.13045
Degraded permafrost	Pmax	dunif(0,75)	5.90	15	25
Wetland	alpha	dnorm(1,1)	0.9	1	1.1
Wetland	beta	dnorm(0.08,2)	0.085	0.09	0.096
Wetland	E0	dunif(0,0.25)	0.005	0.03038	0.13045
Wetland	Pmax	dunif(0,50)	5.31	14.33	27.5
Water	CO_2 flux	dnorm(0.5,0.01)	0.45	2	5.5

Table S3. Prior distributions and initial values for NEE flux un-mixing for the complex landcover map. The same values were used for each month of the growing season, with the exception of August and September there were no GPP parameters (E0, Pmax) for degraded permafrost.

Landcover category	Parameter	Prior distribution	Chain 1 initial values	Chain 2 initial values	Chain 3 initial values
Lichen tundra	alpha	dnorm(1,1)	0.9	1	1.1
Lichen tundra	beta	dnorm(0.08,2)	0.036	0.04	0.044
Lichen tundra	E0	dunif(0,0.25)	0.00117	0.03038	0.1434
Lichen tundra	Pmax	dunif(0,35)	5.31	14.33	25
Shrub tundra	alpha	dnorm(1,1)	0.9	1	1.1
Shrub tundra	beta	dnorm(0.08,2)	0.072	0.08	0.088
Shrub tundra	E0	dunif(0,0.25)	0.00117	0.03038	0.13038
Shrub tundra	Pmax	dunif(0,35)	5.31	14.33	25
Sedge tundra	alpha	dnorm(1,1)	0.9	1	1.1
Sedge tundra	beta	dnorm(0.08,2)	0.03	0.045	0.01
Sedge tundra	E0	dunif(0,0.25)	0.00117	0.03038	0.1434
Sedge tundra	Pmax	dunif(0,35)	5.31	14.33	25
Edge of degraded	alpha	dnorm(1,1)	0.9	1	1.1
Edge of degraded	beta	dnorm(0.08,2)	0.027	0.03	0.033
Edge of degraded	E0	dunif(0,0.25)	0.00117	0.013045	0.1434
Edge of degraded	Pmax	dunif(0,75)	5.31	14.33	25
Degraded permafrost	alpha	dnorm(1,1)	0.9	1	1.1
Degraded permafrost	beta	dnorm(0.08,2)	0.072	0.08	0.088
Degraded permafrost	E0	dunif(0,0.25)	0.00117	0.013045	0.1
Degraded permafrost	Pmax	dunif(0,75)	5.31	14.33	25
Wetland	alpha	dnorm(1,1)	0.9	1	1.1
Wetland	beta	dnorm(0.08,2)	0.063	0.01	0.055
Wetland	E0	dunif(0,0.25)	0.00117	0.013045	0.1434
Wetland	Pmax	dunif(0,25)	5.31	14.33	25
Water	CO_2 flux	dnorm(0.5,0.01)	1.8	2	2.2

Table S4. Lichen tundra parameter posterior estimations, mean (sd), for carbon fluxes from the complex map.

Footprint model	Parameter	May	June	July	August	September
Hsieh	alpha	0.353 (0.237)	0.774 (0.379)	0.39 (0.271)	0.98 (0.357)	0.287 (0.206)
Hsieh	beta	0.0577 (0.0365)	0.0392 (0.0273)	0.0582 (0.0405)	0.0477 (0.0283)	0.11 (0.0588)
Hsieh	E0	0.0654 (0.0793)	0.0329 (0.0365)	0.0275 (0.0118)	0.0432 (0.029)	0.374 (0.216)
Hsieh	Pmax	6.3 (7.88)	10.1 (5.86)	16.5 (6.15)	11.9 (4.73)	3.2 (2.83)
Hsieh	CH_4 flux	0.00878 (0.0025)	0.00558 (0.0027)	0.00609 (0.00256)	0.0128 (0.00256)	0.00761 (0.00289)
Kljun	alpha	0.276 (0.199)	0.995 (0.398)	0.634 (0.336)	1.33 (0.374)	0.325 (0.227)
Kljun	beta	0.0553 (0.0365)	0.0418 (0.0264)	0.0474 (0.0306)	0.0413 (0.0246)	0.0984 (0.057)
Kljun	E0	0.0314 (0.0593)	0.0314 (0.0253)	0.0339 (0.0127)	0.0485 (0.0267)	0.315 (0.224)
Kljun	Pmax	9.95 (8.15)	11.2 (5.22)	16.2 (5.01)	10.6 (3.69)	3.82 (2.95)
Kljun	CH_4 flux	0.00848 (0.00247)	0.0032 (0.00279)	0.0117 (0.00273)	0.0151 (0.0027)	0.00638 (0.00292)
Kormann & Meixner	alpha	0.302 (0.223)	0.595 (0.35)	0.5 (0.308)	1.17 (0.332)	0.261 (0.201)
Kormann & Meixner	beta	0.0517 (0.0362)	0.0443 (0.0306)	0.0468 (0.0328)	0.0694 (0.0234)	0.0885 (0.0595)
Kormann & Meixner	E0	0.0122 (0.0348)	0.0535 (0.0501)	0.0297 (0.0125)	0.0621 (0.0253)	0.376 (0.21)
Kormann & Meixner	Pmax	12.4 (7.5)	7.03 (4.51)	13 (4.09)	12.6 (2.81)	3.44 (1.33)
Kormann & Meixner	CH_4 flux	0.00666 (0.00223)	0.00592 (0.0026)	0.00852 (0.00252)	0.012 (0.00252)	0.00765 (0.00278)

Table S5. Shrub tundra parameter posterior estimations, mean (sd), for carbon fluxes from the complex map.

Footprint model	Parameter	May	June	July	August	September
Hsieh	alpha	1.25 (0.377)	0.518 (0.309)	0.61 (0.299)	0.592 (0.354)	0.651 (0.349)
Hsieh	beta	0.0548 (0.0232)	0.0877 (0.0433)	0.0911 (0.033)	0.0501 (0.0345)	0.0422 (0.0343)
Hsieh	E0	0.0162 (0.0205)	0.0235 (0.0137)	0.0961 (0.0406)	0.0467 (0.0293)	0.427 (0.209)
Hsieh	Pmax	13.1 (5.93)	15.4 (4.74)	11 (2.24)	10.9 (3.05)	3.93 (2.05)
Hsieh	CH_4 flux	0.00419 (0.00232)	0.0089 (0.00226)	0.00512 (0.00215)	0.00411 (0.00239)	0.00225 (0.0028)
Kljun	alpha	2.06 (0.391)	0.638 (0.366)	0.664 (0.377)	0.383 (0.294)	0.669 (0.366)
Kljun	beta	0.0393 (0.0184)	0.0533 (0.035)	0.0522 (0.035)	0.053 (0.0405)	0.0441 (0.0352)
Kljun	E0	0.0405 (0.0435)	0.0354 (0.0378)	0.0985 (0.0429)	0.0511 (0.0521)	0.442 (0.203)
Kljun	Pmax	8.05 (6.83)	6.38 (5.99)	12.3 (3.01)	10.1 (6.91)	6.04 (2.84)
Kljun	CH_4 flux	0.000657 (0.00301)	0.00269 (0.00285)	-6e-04 (0.00282)	0.00199 (0.00297)	0.000665 (0.00299)
Kormann & Meixner	alpha	1.43 (0.365)	0.765 (0.375)	1.39 (0.374)	2.08 (0.391)	0.635 (0.324)
Kormann & Meixner	beta	0.0539 (0.0222)	0.0551 (0.0328)	0.0644 (0.0229)	0.0516 (0.0201)	0.0381 (0.0318)
Kormann & Meixner	E0	0.00806 (0.00524)	0.0481 (0.0215)	0.0755 (0.0243)	0.0718 (0.0228)	0.45 (0.193)
Kormann & Meixner	Pmax	16 (5.52)	13.7 (3.31)	15.9 (2.79)	16.7 (2.85)	4.18 (1.43)
Kormann & Meixner	CH_4 flux	0.00326 (0.00243)	0.00572 (0.00251)	0.00902 (0.00238)	0.00635 (0.00264)	0.00473 (0.00283)

Table S6. Sedge tundra parameter posterior estimations, mean (sd), for carbon fluxes from the complex map.

Footprint model	Parameter	May	June	July	August	September
Hsieh	alpha	1.81 (0.138)	1.34 (0.274)	1.81 (0.3)	2.45 (0.308)	1.46 (0.279)
Hsieh	beta	0.0234 (0.0121)	0.0705 (0.0156)	0.0475 (0.0142)	0.0452 (0.00819)	0.0354 (0.0199)
Hsieh	E0	0.0174 (0.0063)	0.03 (0.00882)	0.0481 (0.00974)	0.0641 (0.0156)	0.0425 (0.0242)
Hsieh	Pmax	10.2 (2.53)	12.5 (2.26)	12.9 (1.61)	12.2 (1.33)	8.9 (2.46)
Hsieh	CH_4 flux	0.0061 (0.00133)	0.0113 (0.00142)	0.00386 (0.00125)	0.00568 (0.00148)	0.00957 (0.0021)
Kljun	alpha	1.54 (0.136)	1.23 (0.271)	1.99 (0.301)	2.28 (0.328)	2.02 (0.282)
Kljun	beta	0.0322 (0.015)	0.0605 (0.0222)	0.0463 (0.015)	0.0237 (0.015)	0.0205 (0.0132)
Kljun	E0	0.0196 (0.0103)	0.0333 (0.0102)	0.0407 (0.00952)	0.0385 (0.0112)	0.0319 (0.0432)
Kljun	Pmax	13.3 (4.87)	14.9 (2.93)	14.6 (2.02)	12.8 (2.76)	10.9 (6.29)
Kljun	CH_4 flux	0.000888 (0.00245)	0.00467 (0.00197)	0.00701 (0.00178)	0.00902 (0.00223)	0.0016 (0.00268)
Kormann & Meixner	alpha	2.03 (0.135)	1.52 (0.264)	1.7 (0.294)	2.67 (0.32)	1.97 (0.279)
Kormann & Meixner	beta	0.033 (0.0116)	0.0719 (0.0133)	0.0609 (0.00987)	0.0282 (0.0126)	0.018 (0.0122)
Kormann & Meixner	E0	0.0313 (0.0121)	0.0305 (0.00795)	0.0573 (0.0109)	0.0559 (0.0139)	0.026 (0.0133)
Kormann & Meixner	Pmax	10.6 (1.85)	14.9 (2.45)	13.5 (1.41)	11.3 (1.4)	12.6 (4.39)
Kormann & Meixner	CH_4 flux	0.00658 (0.00179)	0.00976 (0.00168)	0.004 (0.0014)	0.00607 (0.00175)	0.00831 (0.00231)

Table S7. Edge of degraded tundra parameter posterior estimations, mean (sd), for carbon fluxes from the complex map.

Footprint model	Parameter	May	June	July	August	September
Hsieh	alpha	1.39 (0.443)	2.3 (0.49)	2.31 (0.522)	2.58 (0.485)	2.36 (0.36)
Hsieh	beta	0.054 (0.0283)	0.0608 (0.0222)	0.0547 (0.0213)	0.0424 (0.021)	0.0446 (0.0193)
Hsieh	E0	0.0347 (0.0169)	0.0739 (0.0167)	0.035 (0.00794)	0.0405 (0.0161)	0.0345 (0.0295)
Hsieh	Pmax	19.7 (4.01)	41.5 (3.13)	54.7 (12.3)	32.5 (12.3)	29.6 (10.4)
Hsieh	CH_4 flux	0.0185 (0.00558)	0.0251 (0.00582)	0.0324 (0.00453)	0.0543 (0.00501)	0.0547 (0.00788)
Kljun	alpha	1.34 (0.521)	2.38 (0.516)	2.2 (0.555)	2.84 (0.5)	1.34 (0.543)
Kljun	beta	0.0496 (0.0253)	0.0774 (0.0197)	0.0537 (0.0218)	0.0717 (0.0167)	0.0647 (0.0389)
Kljun	E0	0.0432 (0.0517)	0.0611 (0.027)	0.0527 (0.023)	0.0936 (0.0336)	0.0541 (0.0373)
Kljun	Pmax	14.1 (6.7)	30.2 (8.33)	18.6 (7.25)	25.1 (6.15)	26.3 (10.7)
Kljun	CH_4 flux	0.0241 (0.00754)	0.0483 (0.00665)	0.0247 (0.00597)	0.0406 (0.00732)	0.0744 (0.00941)
Kormann & Meixner	alpha	1.02 (0.473)	1.95 (0.545)	1.77 (0.565)	1.18 (0.547)	1.46 (0.495)
Kormann & Meixner	beta	0.0527 (0.0306)	0.0614 (0.0258)	0.0322 (0.0202)	0.053 (0.0331)	0.0854 (0.0401)
Kormann & Meixner	E0	0.0425 (0.0593)	0.0529 (0.0185)	0.0211 (0.00689)	0.0193 (0.013)	0.0439 (0.0406)
Kormann & Meixner	Pmax	12.9 (7.14)	35.5 (6.45)	43.8 (15.8)	40.7 (25)	22.8 (11.2)
Kormann & Meixner	CH_4 flux	0.015 (0.00614)	0.036 (0.00692)	0.0265 (0.0062)	0.0554 (0.00752)	0.064 (0.0102)

Table S8. Degraded permafrost parameter posterior estimations, mean (sd), for carbon fluxes from the complex map.

Footprint model	Parameter	May	June	July	August	September
Hsieh	alpha	1.11 (0.529)	0.811 (0.472)	1.57 (0.561)	1.23 (0.533)	0.644 (0.429)
Hsieh	beta	0.0992 (0.0533)	0.0805 (0.0476)	0.0609 (0.0336)	0.0883 (0.0464)	0.104 (0.0714)
Hsieh	E0	0.0749 (0.0427)	0.0478 (0.0553)	0.0652 (0.041)	NA	NA
Hsieh	Pmax	12.9 (7.02)	36.5 (28.2)	11.6 (6.81)	NA	NA
Hsieh	CH_4 flux	0.051 (0.0263)	0.0179 (0.0124)	0.00686 (0.00623)	0.0141 (0.0112)	0.044 (0.025)
Kljun	alpha	1.11 (0.528)	0.997 (0.514)	1.64 (0.55)	0.796 (0.481)	0.879 (0.487)
Kljun	beta	0.0965 (0.0498)	0.0776 (0.0447)	0.0871 (0.0368)	0.0764 (0.0506)	0.117 (0.0678)
Kljun	E0	0.0756 (0.0428)	0.088 (0.0537)	0.0804 (0.0585)	NA	NA
Kljun	Pmax	12.5 (6.97)	52.9 (21.1)	30.4 (17.8)	NA	NA
Kljun	CH_4 flux	0.0578 (0.0319)	0.0117 (0.00991)	0.00922 (0.00832)	0.0153 (0.0131)	0.0329 (0.0242)
Kormann & Meixner	alpha	1.01 (0.526)	0.813 (0.474)	1.21 (0.543)	0.724 (0.452)	0.703 (0.445)
Kormann & Meixner	beta	0.0899 (0.052)	0.0838 (0.0498)	0.0671 (0.0393)	0.095 (0.0577)	0.118 (0.0749)
Kormann & Meixner	E0	0.0813 (0.041)	0.0562 (0.0603)	0.0388 (0.0286)	NA	NA
Kormann & Meixner	Pmax	14.9 (6.74)	35.3 (28)	9.72 (7.13)	NA	NA
Kormann & Meixner	CH_4 flux	0.061 (0.0302)	0.0248 (0.0154)	0.0175 (0.0144)	0.037 (0.024)	0.0634 (0.0364)

Table S9. Wetland parameter posterior estimations, mean (sd), for carbon fluxes from the complex map.

Footprint model	Parameter	May	June	July	August	September
Hsieh	alpha	0.44 (0.293)	1.1 (0.528)	2.53 (0.449)	1.8 (0.484)	2.12 (0.437)
Hsieh	beta	0.0715 (0.0446)	0.0415 (0.0294)	0.0688 (0.0123)	0.0483 (0.0249)	0.0362 (0.0214)
Hsieh	E0	0.0376 (0.0435)	0.0662 (0.0582)	0.0539 (0.0532)	0.0441 (0.0553)	0.396 (0.216)
Hsieh	Pmax	12 (6.23)	9.32 (5.73)	10.2 (6.32)	11.5 (7.99)	4.74 (2.77)
Hsieh	CH_4 flux	0.0269 (0.00467)	0.0219 (0.0065)	0.0604 (0.0068)	0.0768 (0.0058)	0.0369 (0.00722)
Kljun	alpha	0.388 (0.297)	1.15 (0.549)	2.34 (0.453)	1.99 (0.513)	1.78 (0.45)
Kljun	beta	0.0585 (0.0398)	0.0361 (0.0246)	0.079 (0.00672)	0.0559 (0.0219)	0.0481 (0.0294)
Kljun	E0	0.046 (0.0537)	0.0945 (0.0626)	0.0593 (0.0347)	0.0521 (0.0396)	0.409 (0.213)
Kljun	Pmax	11.1 (5.78)	7.2 (3.55)	13.8 (4.15)	13.7 (7.26)	5.13 (2.49)
Kljun	CH_4 flux	0.0307 (0.00502)	0.0282 (0.00646)	0.0327 (0.00665)	0.0514 (0.00608)	0.0503 (0.00825)
Kormann & Meixner	alpha	0.374 (0.282)	1.04 (0.529)	2.34 (0.392)	1.38 (0.477)	1.85 (0.435)
Kormann & Meixner	beta	0.0592 (0.0417)	0.0368 (0.027)	0.0758 (0.00868)	0.0509 (0.0274)	0.0436 (0.0269)
Kormann & Meixner	E0	0.0544 (0.0648)	0.0974 (0.0701)	0.0341 (0.0201)	0.035 (0.051)	0.401 (0.209)
Kormann & Meixner	Pmax	8.9 (5.94)	3.91 (2.99)	22.8 (10.4)	15.4 (14)	4.66 (2.01)
Kormann & Meixner	CH_4 flux	0.0241 (0.00437)	0.0152 (0.00595)	0.0461 (0.00653)	0.0635 (0.00563)	0.0283 (0.007)

Table S10. Water parameter posterior estimations, mean (sd), for carbon fluxes from the complex map.

Footprint model	Parameter	May	June	July	August	September
Hsieh	CO_2 flux	1.82 (0.823)	2.52 (0.933)	2.23 (0.915)	2.98 (0.925)	2.02 (0.861)
Hsieh	CH_4 flux	0.0291 (0.0124)	0.0252 (0.0154)	0.122 (0.0219)	0.0619 (0.0186)	0.142 (0.0232)
Kljun	CO_2 flux	2.01 (0.853)	2.74 (0.939)	1.81 (0.863)	4.34 (0.936)	2.67 (0.913)
Kljun	CH_4 flux	0.0414 (0.0124)	0.0258 (0.0147)	0.0651 (0.0195)	0.0543 (0.0183)	0.132 (0.0246)
Kormann & Meixner	CO_2 flux	1.47 (0.735)	2.69 (0.943)	1.97 (0.885)	3.1 (0.914)	2.94 (0.883)
Kormann & Meixner	CH_4 flux	0.0361 (0.0101)	0.0231 (0.0131)	0.102 (0.0191)	0.0504 (0.0169)	0.111 (0.0215)

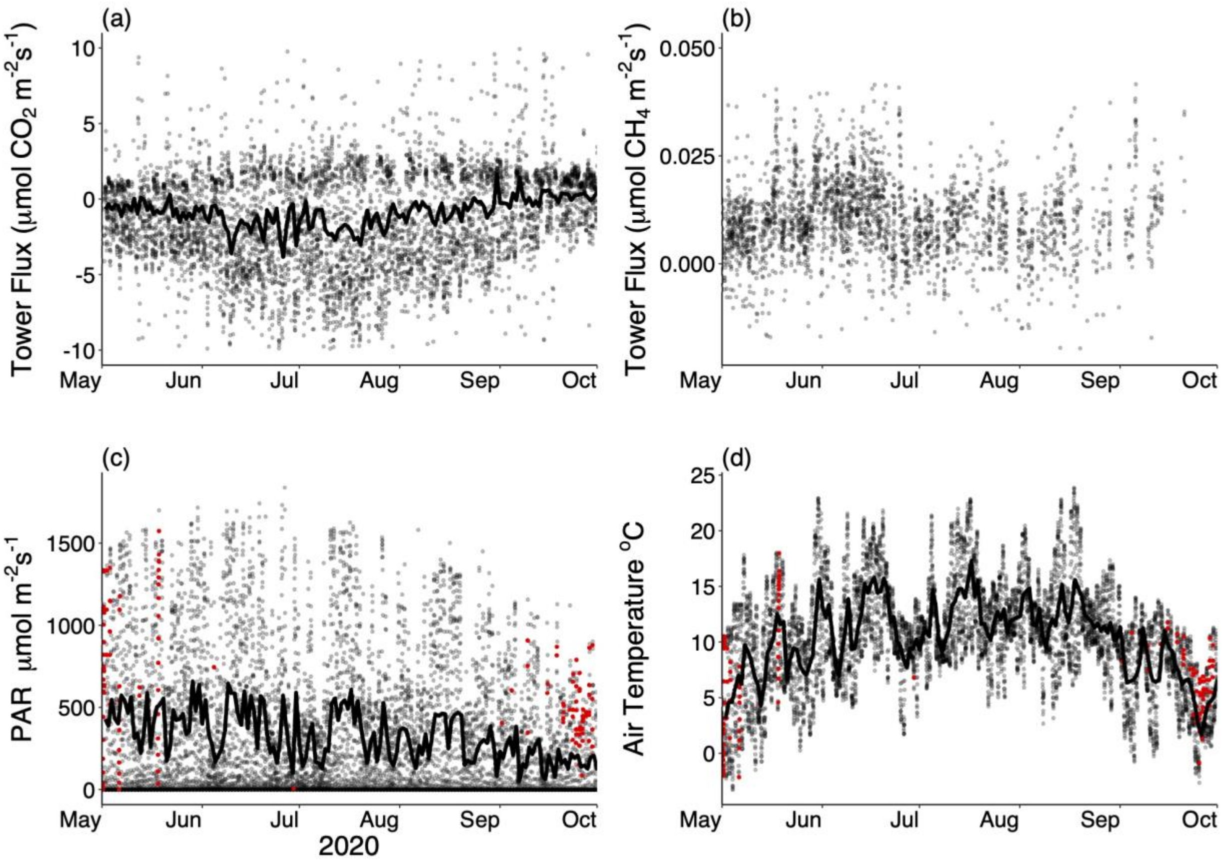

Figure S1. Timeseries of 2020 observations of CO_2 fluxes (a), CH_4 fluxes (b), air temperature (c), and PAR (d). The daily mean values are indicated with a black line. Red points in (c) and (d) are those drivers interpolated for use in monthly budget calculations.

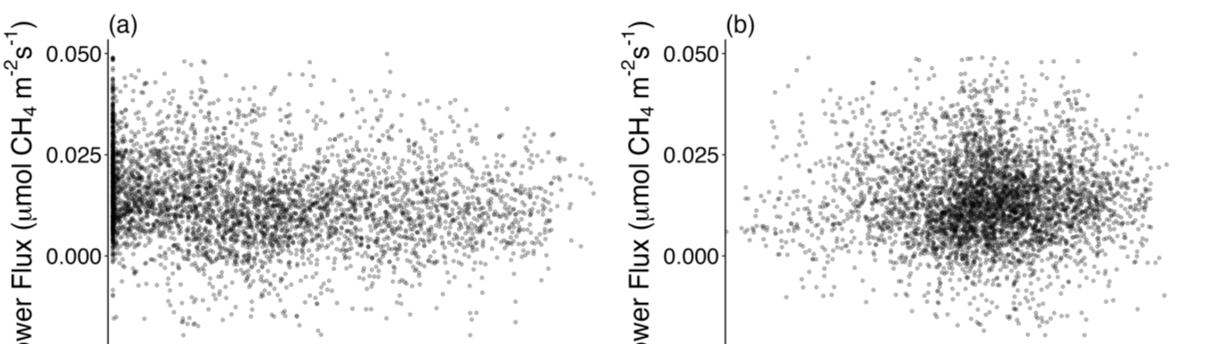

Figure S2. Methane fluxes from the 2020 growing season (May - September) as a function of PAR (a) and air temperature (b).

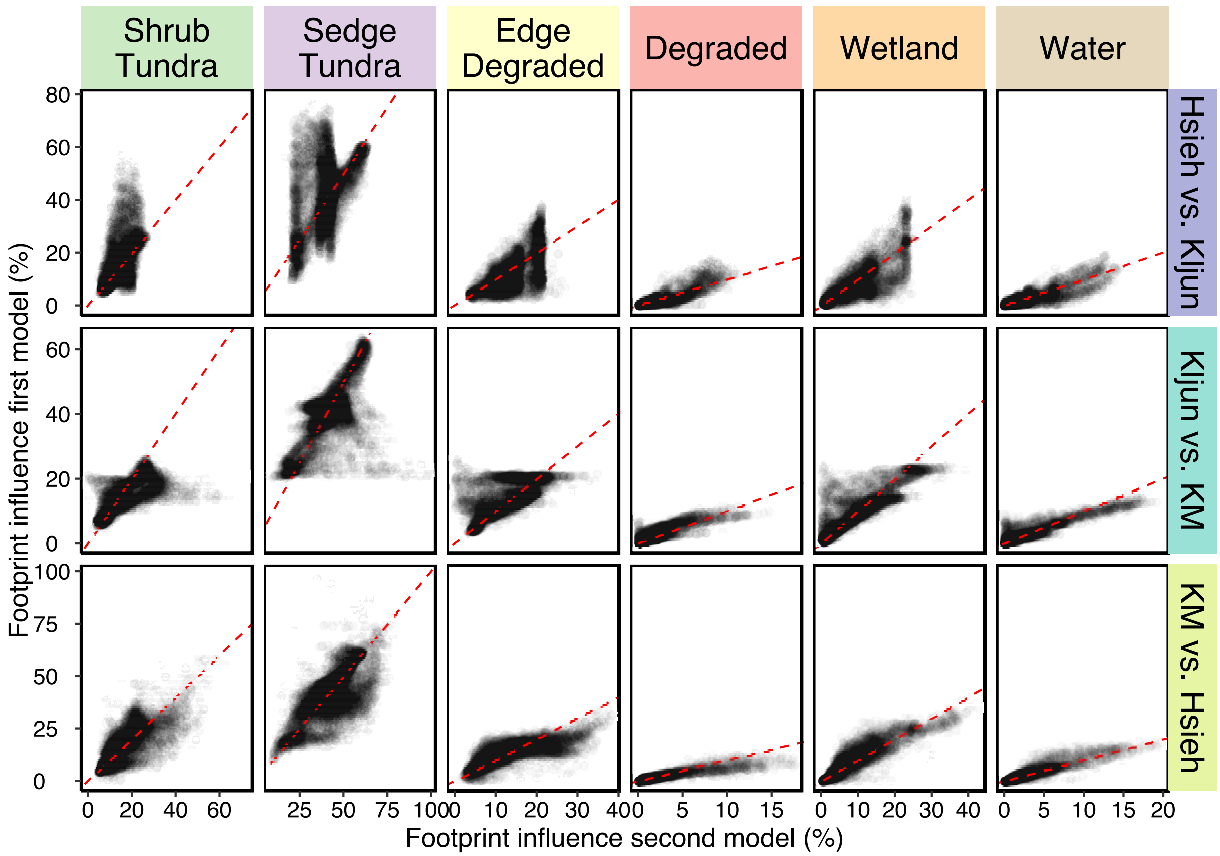

Figure S3. Footprint influences (%) summarized over landcovers for each flux observation. Top row shows Hsieh footprint influence (y-axis) against Kljun footprint influence (x-axis), middle row shows Kljun (y-axis) against Kormann & Meixner (x-axis), and bottom row shows Kormann & Meixner (y-axis) against Hsieh (x-axis). Columns show the summed footprint influence for landcovers from the complex version of the landcover map, which from left to right are; shrub tundra, sedge tundra, edge of degraded permafrost, fen, degraded permafrost, and surface water. Lichen tundra footprint influence comparisons can be found in the main text (Fig 2). The dashed red line indicates the 1:1 line.

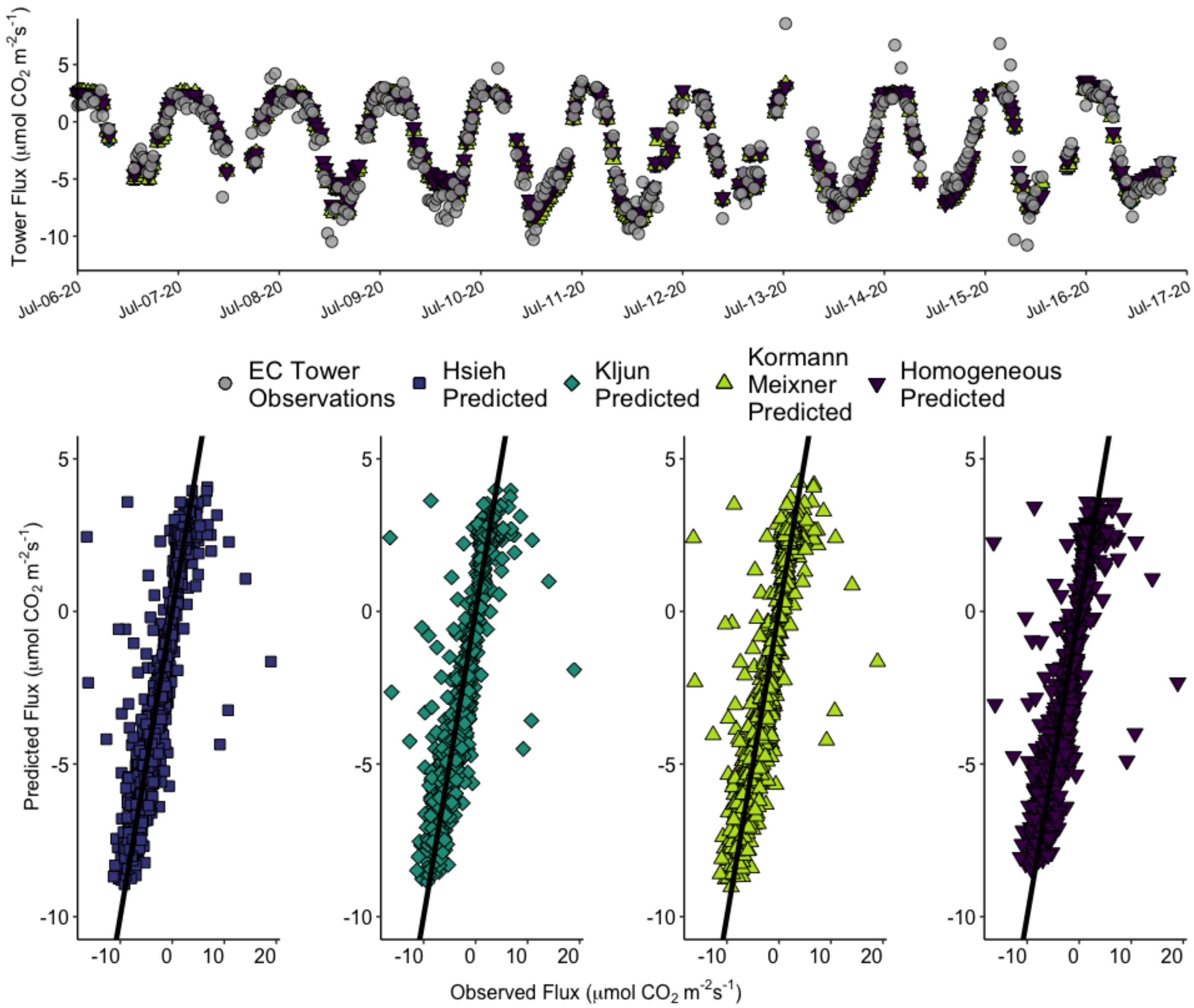

Figure S4. Top: example 10-day timeseries of eddy covariance tower 30-minute fluxes of CO_2 observations and predictions from the homogeneous map and complex landcover map using Hsieh, Kljun, and Kormann and Meixner footprint models. Bottom: the entire month (July 2020) dataset of predicted vs. observed tower fluxes for the same set of models.

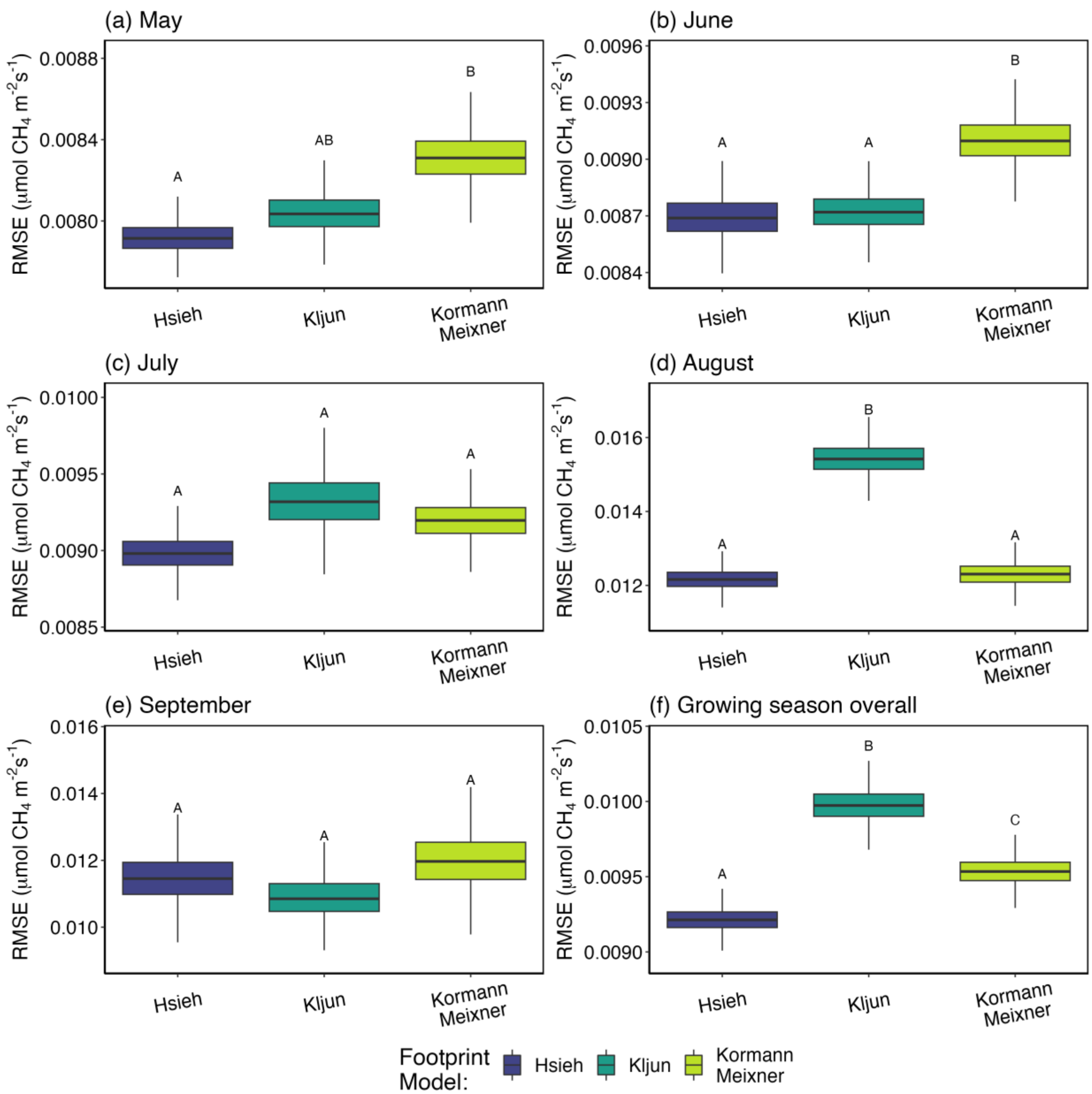

Figure S5. Monthly 2020 (a-e) and growing seasonal 2020 total (f) RMSE from artificial gap-filling CH_4 fluxes. Boxes are the median and interquartile range (IQR), whiskers are 1.5*IQR, for the Bayesian model gap-filling RMSE's. Distributions with non-overlapping Bayesian 89% credible intervals are designated with different letters.

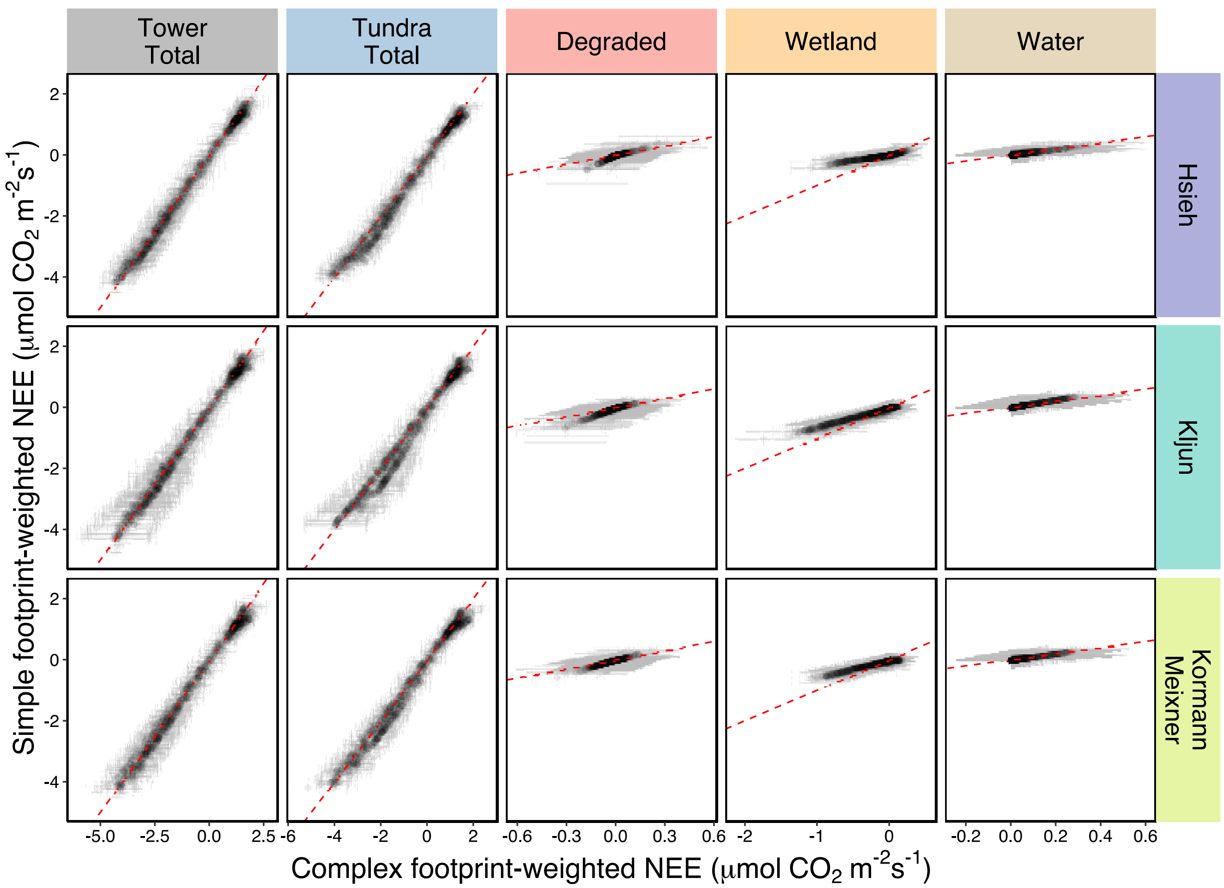

Figure S6. May 2020 median predicted net ecosystem exchange (NEE) for each landcover (simple landcover on the y-axis and complex on the x-axis) weighted by their respective footprint influence. The top row shows NEE predicted with and weighted by footprint influence from Hsieh model, the middle row uses Kljun footprint influence, and the bottom row uses footprint influence from Kormann & Meixner. The leftmost column shows tower total NEE, the linear combination of each predicted NEE weighted by its footprint influence. The next column shows tundra total NEE, the linear combination of lichen tundra, shrub tundra, sedge tundra, and tundra at the edge of degrading permafrost from the complex footprint-weighted NEE on the x-axis, compared to the simple map tundra footprint-weighted NEE on the y-axis. The columns continue with footprint-weighted NEE comparisons for fen, degraded permafrost, and surface water. The error bars show the inter-quartile range on predicted NEE. The dashed red lines indicate the 1:1 line.

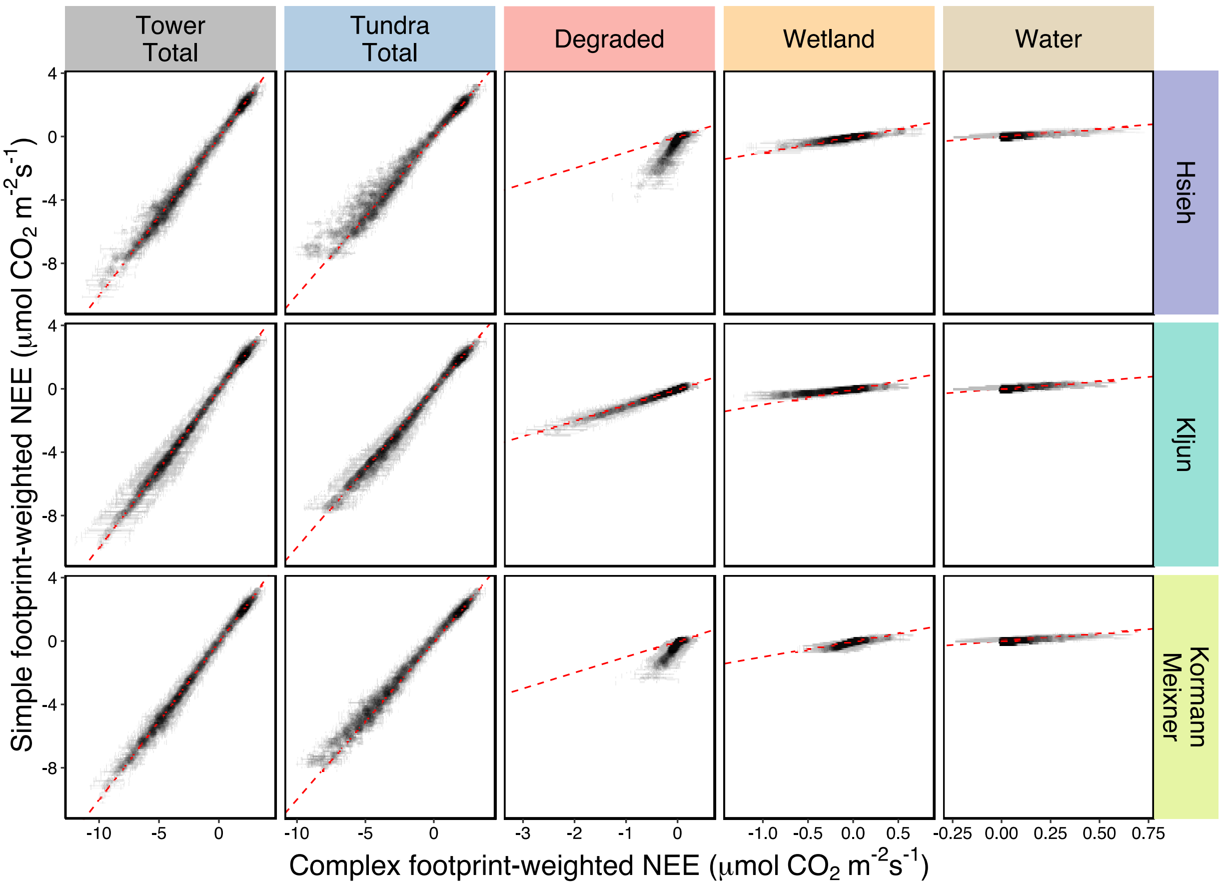

Figure S7. June 2020 median predicted net ecosystem exchange (NEE) for each landcover (simple landcover on the y-axis and complex on the x-axis) weighted by their respective footprint influence. The top row shows NEE predicted with and weighted by footprint influence from Hsieh model, the middle row uses Kljun footprint influence, and the bottom row uses footprint influence from Kormann & Meixner. The leftmost column shows tower total NEE, the linear combination of each predicted NEE weighted by its footprint influence. The next column shows tundra total NEE, the linear combination of lichen tundra, shrub tundra, sedge tundra, and tundra at the edge of degrading permafrost from the complex footprint-weighted NEE on the x-axis, compared to the simple map tundra footprint-weighted NEE on the y-axis. The columns continue with footprint-weighted NEE comparisons for fen, degraded permafrost, and surface water. The error bars show the inter-quartile range on predicted NEE. The dashed red lines indicate the 1:1 line.

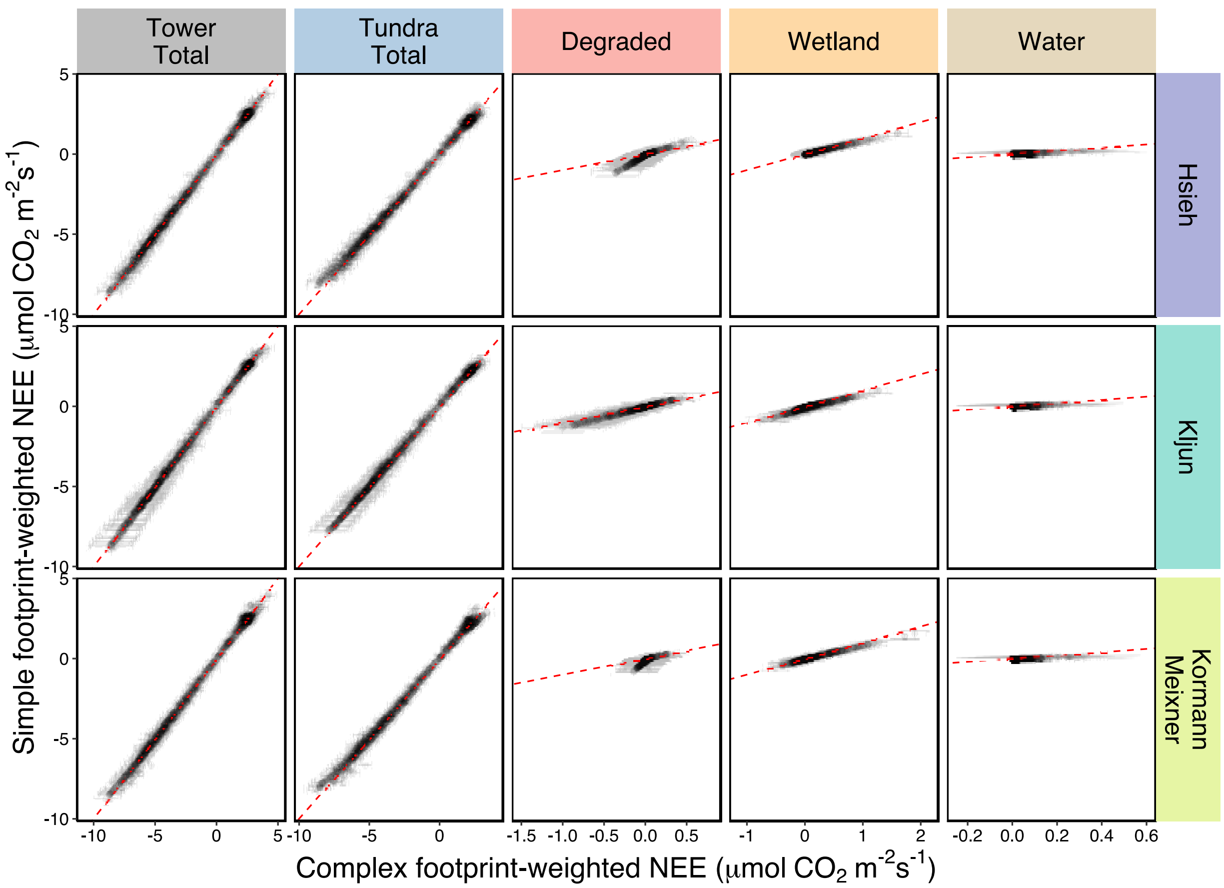

Figure S8. July 2020 median predicted net ecosystem exchange (NEE) for each landcover (simple landcover on the y-axis and complex on the x-axis) weighted by their respective footprint influence. The top row shows NEE predicted with and weighted by footprint influence from Hsieh model, the middle row uses Kljun footprint influence, and the bottom row uses footprint influence from Kormann & Meixner. The leftmost column shows tower total NEE, the linear combination of each predicted NEE weighted by its footprint influence. The next column shows tundra total NEE, the linear combination of lichen tundra, shrub tundra, sedge tundra, and tundra at the edge of degrading permafrost from the complex footprint-weighted NEE on the x-axis, compared to the simple map tundra footprint-weighted NEE on the y-axis. The columns continue with footprint-weighted NEE comparisons for fen, degraded permafrost, and surface water. The error bars show the inter-quartile range on predicted NEE. The dashed red lines indicate the 1:1 line.

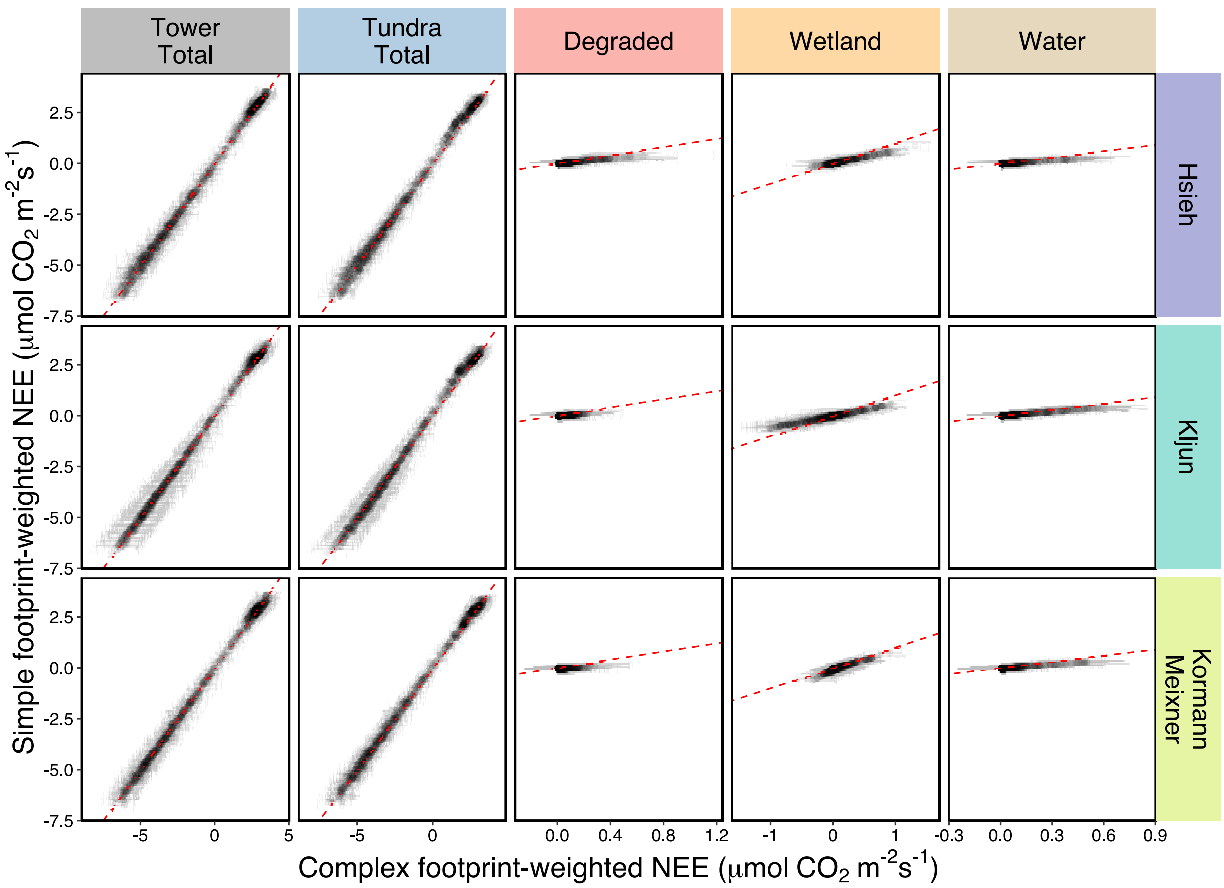

Figure S9. August 2020 median predicted net ecosystem exchange (NEE) for each landcover (simple landcover on the y-axis and complex on the x-axis) weighted by their respective footprint influence. The top row shows NEE predicted with and weighted by footprint influence from Hsieh model, the middle row uses Kljun footprint influence, and the bottom row uses footprint influence from Kormann & Meixner. The leftmost column shows tower total NEE, the linear combination of each predicted NEE weighted by its footprint influence. The next column shows tundra total NEE, the linear combination of lichen tundra, shrub tundra, sedge tundra, and tundra at the edge of degrading permafrost from the complex footprint-weighted NEE on the x-axis, compared to the simple map tundra footprint-weighted NEE on the y-axis. The columns continue with footprint-weighted NEE comparisons for fen, degraded permafrost, and surface water. The error bars show the inter-quartile range on predicted NEE. The dashed red lines indicate the 1:1 line.

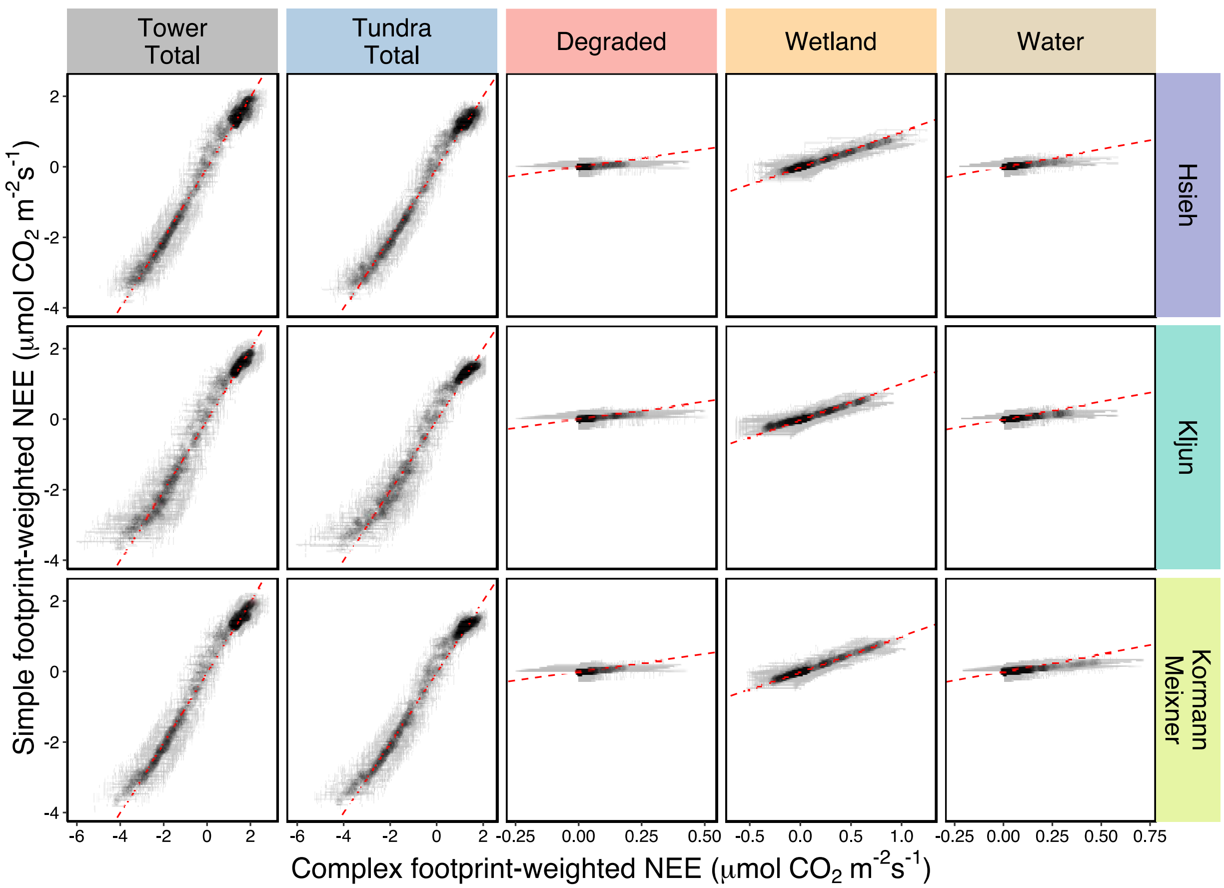

Figure S10. September 2020 median predicted net ecosystem exchange (NEE) for each landcover (simple landcover on the y-axis and complex on the x-axis) weighted by their respective footprint influence. The top row shows NEE predicted with and weighted by footprint influence from Hsieh model, the middle row uses Kljun footprint influence, and the bottom row uses footprint influence from Kormann & Meixner. The leftmost column shows tower total NEE, the linear combination of each predicted NEE weighted by its footprint influence. The next column shows tundra total NEE, the linear combination of lichen tundra, shrub tundra, sedge tundra, and tundra at the edge of degrading permafrost from the complex footprint-weighted NEE on the x-axis, compared to the simple map tundra footprint-weighted NEE on the y-axis. The columns continue with footprint-weighted NEE comparisons for fen, degraded permafrost, and surface water. The error bars show the inter-quartile range on predicted NEE. The dashed red lines indicate the 1:1 line.

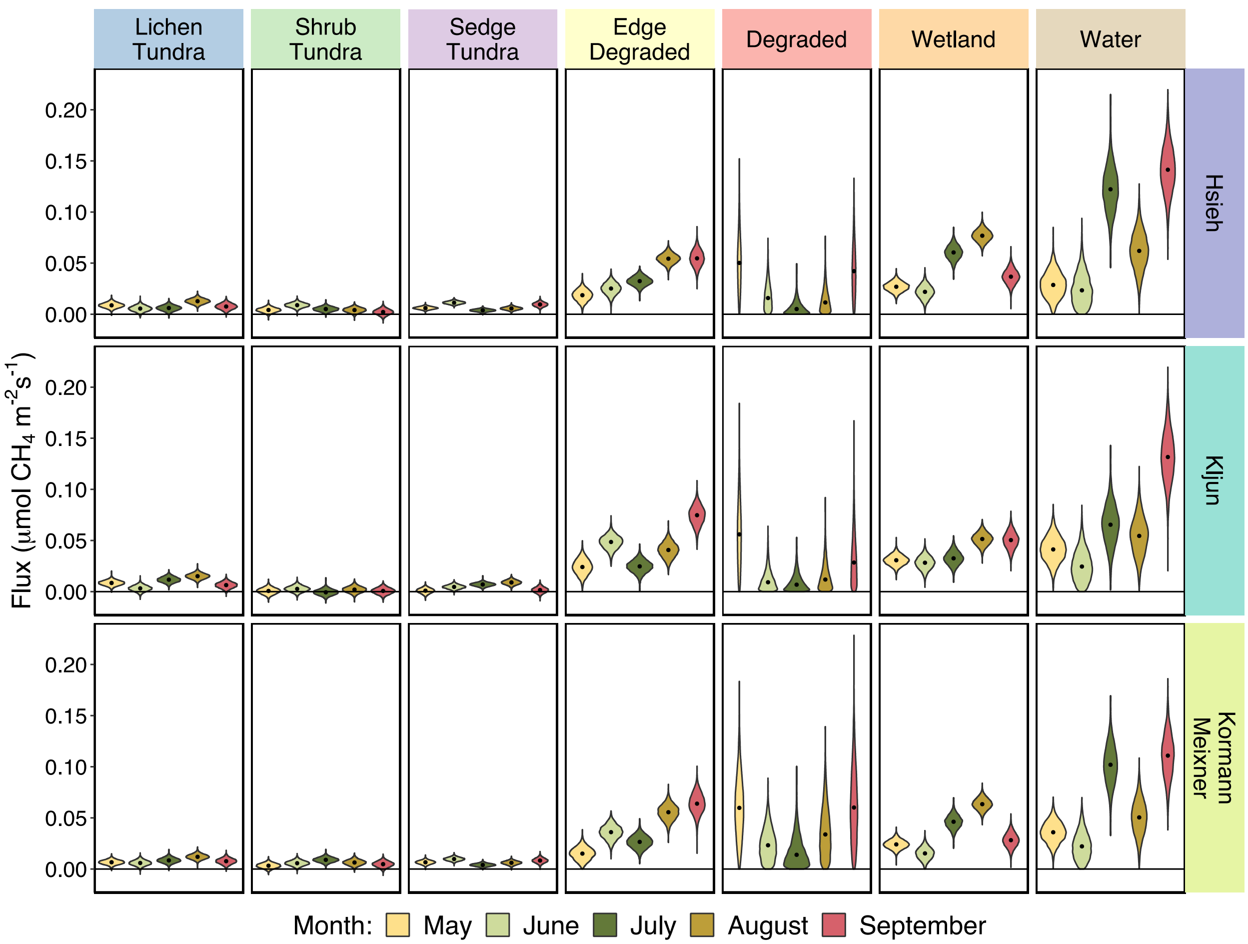

Figure S11. Monthly 2020 violin plots of CH_4 fluxes by landcovers (columns) for each footprint model (rows). Distributions for violin plots are derived from posterior distributions of predicted CH_4. Black dots indicate medians.

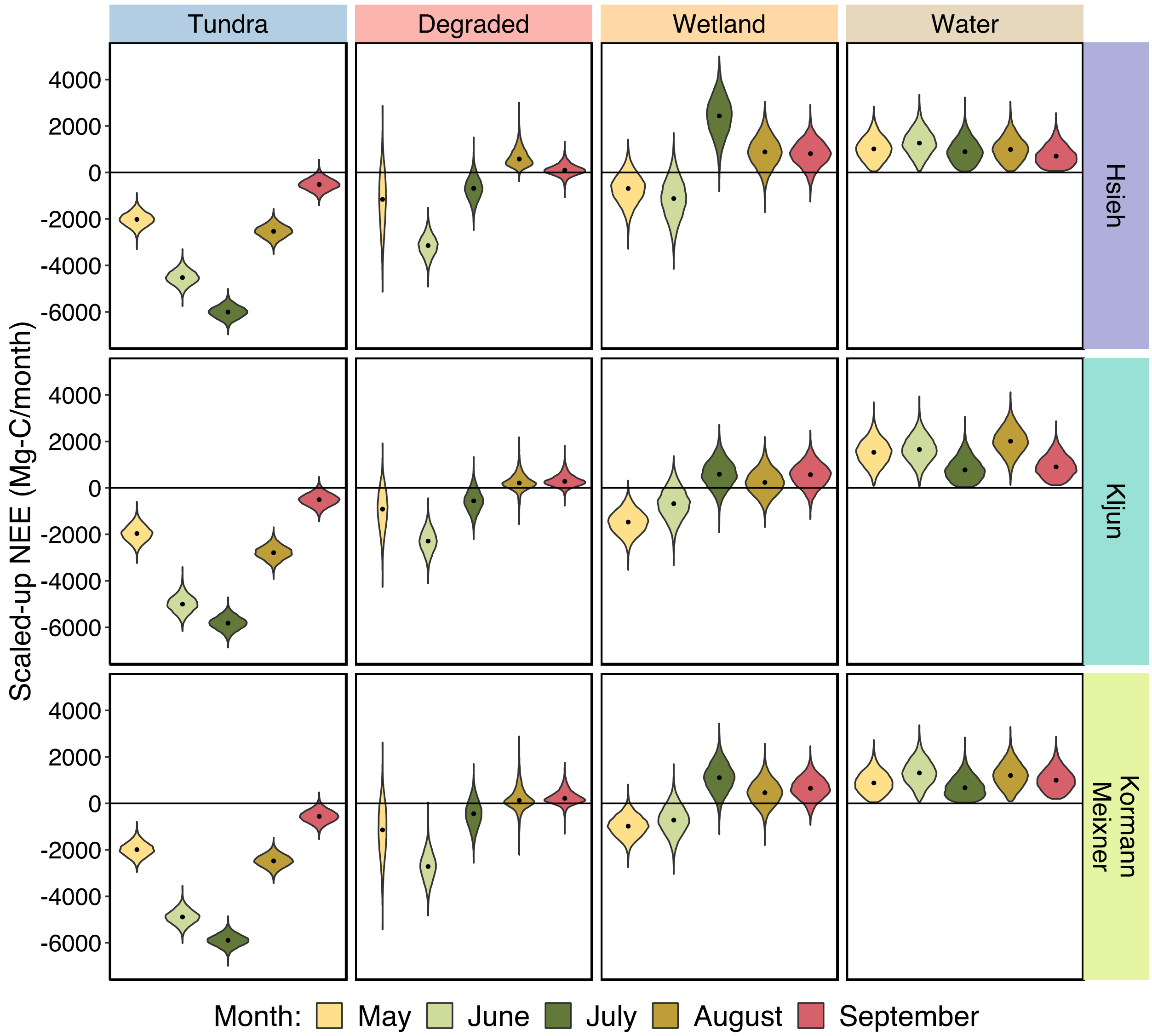

Figure S12. Monthly violin plots of 2020 growing season NEE carbon budgets by landcovers (columns) in the simple map for each footprint model (rows). Distributions for violin plots are derived from posterior distributions of predicted NEE fluxes scaled by their landcover areas in figure 1. Black dots indicate medians. Monthly scaled-up carbon budgets for landcovers using the complex map can be found in the main text (Fig 5).