Supporting Information for "Implementing a plant hydraulics parameterization in the Canadian Land Surface Scheme Including biogeochemical Cycles (CLASSIC) v.1.4"

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Text S1. The shape of the leaf water potential (Ψ_l) vulnerability curve parameter (a) can be calculated as a function of the xylem water potential (Ψ_{50}) using empirical relationship from Christoffersen et al. (2016). The relation between the Ψ_{50} and the slope for the linear portion of the vulnerability function is given as:

$$s_x = 65.15(-\Psi_{50})^{-1.25} \tag{1}$$

then a can be calculated as:

$$a = -4\frac{s_x}{100}\Psi_{50} \tag{2}$$

due to the scarcity of observed Ψ_{50} data, we calculated it following the empirical relationship from Christoffersen et al. (2016) using observed wood density (WD, g cm^{-3}) as:

$$\Psi_{50} = -(3.57WD)^{1.73} - 1.09 \tag{3}$$

Text S2. The plant maximum xylem hydraulic conductance (k$_{sl,max}$) was calculated using the same equations as in Eller et al. (2018) followed by Christoffersen et al. (2016) and Savage et al. (2010). It was calculated on a leaf-area basis from the maximum canopy height (h; m), maximum petiole-level hydraulic conductivity ($K_{pet,max}$; mol m^{-1} s^{-1} MPa^{-1}), huber value (H_v) which is calculated as the ratio between active xylem area (sapwood area - A_s; m^2m^{-2}) and the leaf area (A_l; m^2m^{-2}), and a tapering factor (X_{tap}; unitless) which accounts for the changes in conduit diameter as the plant height changes from bottom to the top of the tree.

$$k_{sl,max} = \frac{K_{pet,max}h_v}{h}X_{tap} \tag{4}$$

$K_{pet,max}$ is calculated using maximum branch xylem conductivity ($K_{x,max}$; mol m^{-1} s^{-1} MPa^{-1}) following Christoffersen et al. (2016):

$$K_{pet,max} = \left[\frac{r_{int,pet}}{r_{int,ref}}\right]^2 K_{x,max} \tag{5}$$

where $r_{int,pet}$ is the petiole conduit radius (10 μm) and $r_{int,ref}$ is the conduit radius of the terminal branches (22 μm), to represent conduit tapering from branch to petiole (Friend, 1995). The $K_{x,max}$ can be calculated using an empirical function from Christoffersen et al. (2016) as:

$$K_{x,max} = \frac{0.0021e^{-26.6WD/A_{max}}}{A_lA_s} \tag{6}$$

where WD is the wood density (g cm^{-3}) and A_{max} is the maximum photosynthetic capacity (μmol m^{-2} s^{-1}). The hydraulic tapering factor (X_{tap}) is calculated as:

$$X_{tap} = \frac{X_{tap:notap}(h)}{X_{tap:notap}(1)} \tag{7}$$

where $X_{tap:notap}(h)$ and $X_{tap:notap}(1)$ are factors that represent the ratio of the theoretical whole tree conductance with taper ($K_{max,tap}$) to that without taper ($K_{max,notap}$) at height h and 1 m, respectively. These factors are calculated following the Savage et al. (2010) and Christoffersen et al. (2016).

$$K_{max} = a(n_{ext}^{N/2})^b \tag{8}$$

where a and b are constants set to 7.2×10^{-13} and 1.32, to calculate $K_{max,notap}$ and 6.6×10^{-13} and 1.85 for $K_{max,tap}$ (Christoffersen et al., 2016). The n_{ext} represents the branching patterns in the Savage et al. (2010) model and is set to 2. The N is the total number of branching levels, calculated as a function of h:

$$N = \frac{3ln\left[1 - \frac{h}{L_{pet}}(1 - n_{ext}^{1/3})\right]}{ln(n_{ext})} - 1 \tag{9}$$

where L_{pet} is petiole length set to 0.04 m (Savage et al., 2010).

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Eller, C. B., Rowland, L., Oliveira, R. S., Bittencourt, P. R., Barros, F. V., Da Costa, A. C., ... others (2018). Modelling tropical forest responses to drought and el niño with a stomatal optimization model based on xylem hydraulics. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1760), 20170315.

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Zomer, R. J., Xu, J., & Trabucco, A. (2022). Version 3 of the global aridity index and potential evapotranspiration database. *Scientific Data*, *9*(1), 409.

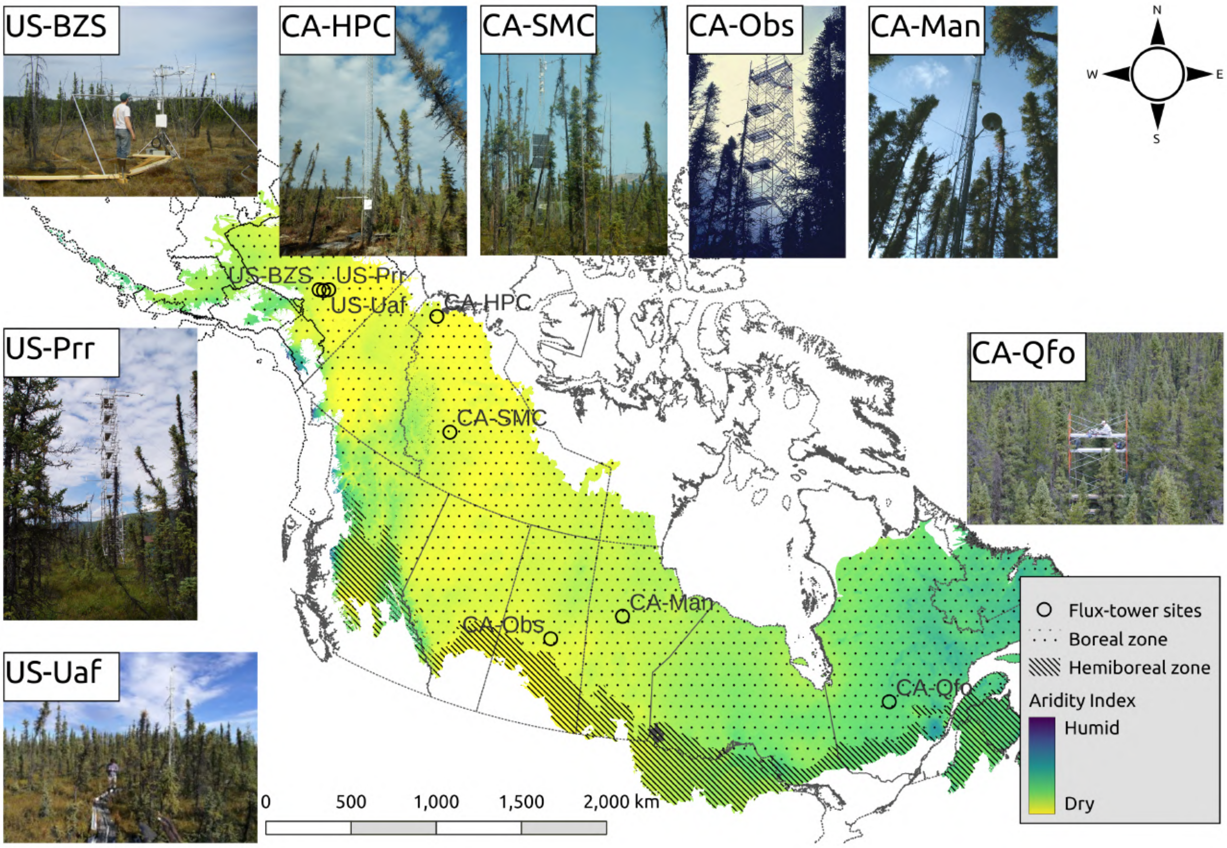

Figure S1. Eight flux tower sites used in the study with aridity index from Zomer et al. (2022)

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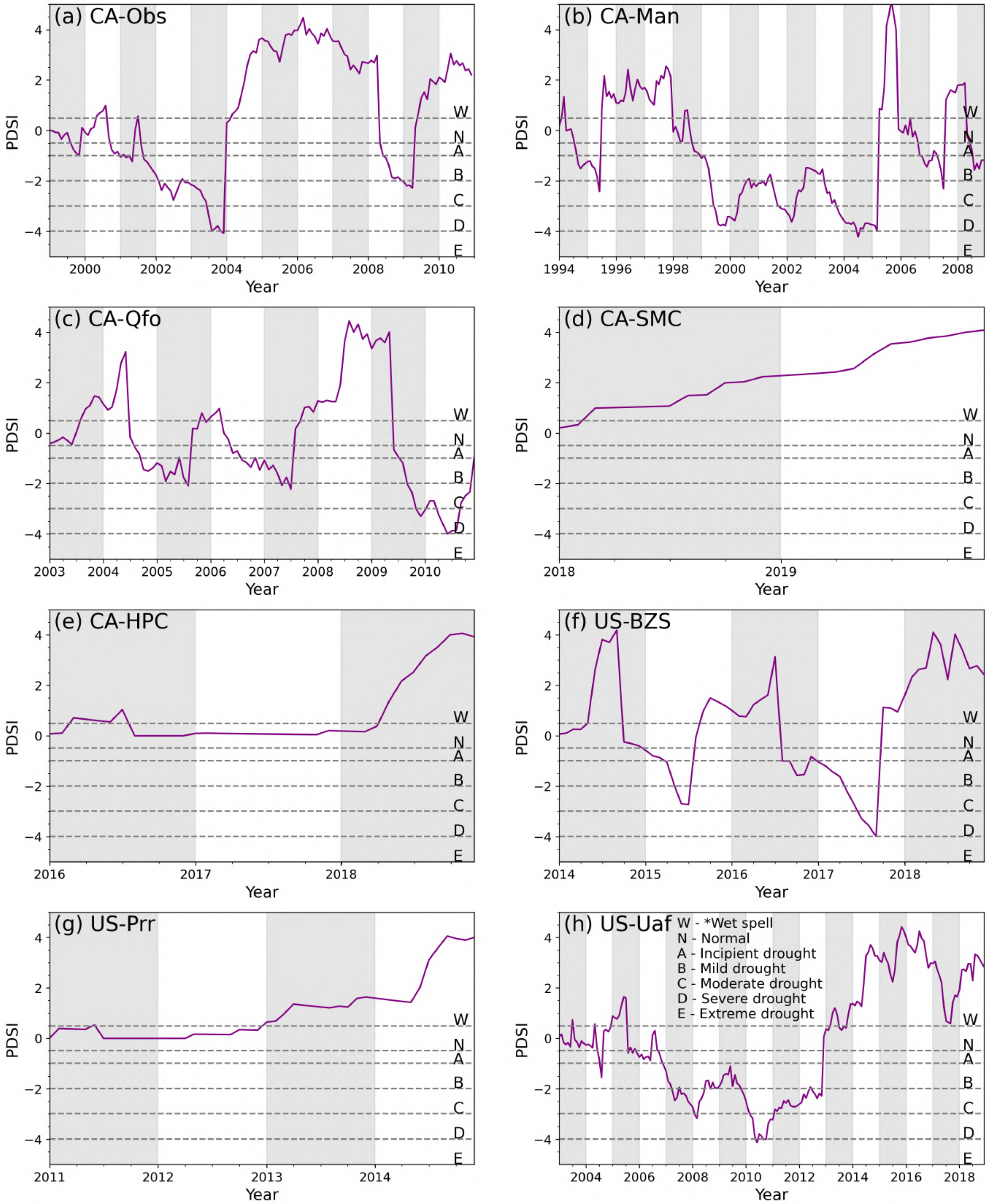

Figure S2. Palmer drought severity index (PDSI) for all sites.*W indicates all the categories under wet conditions. Grey and white bars represent each year.

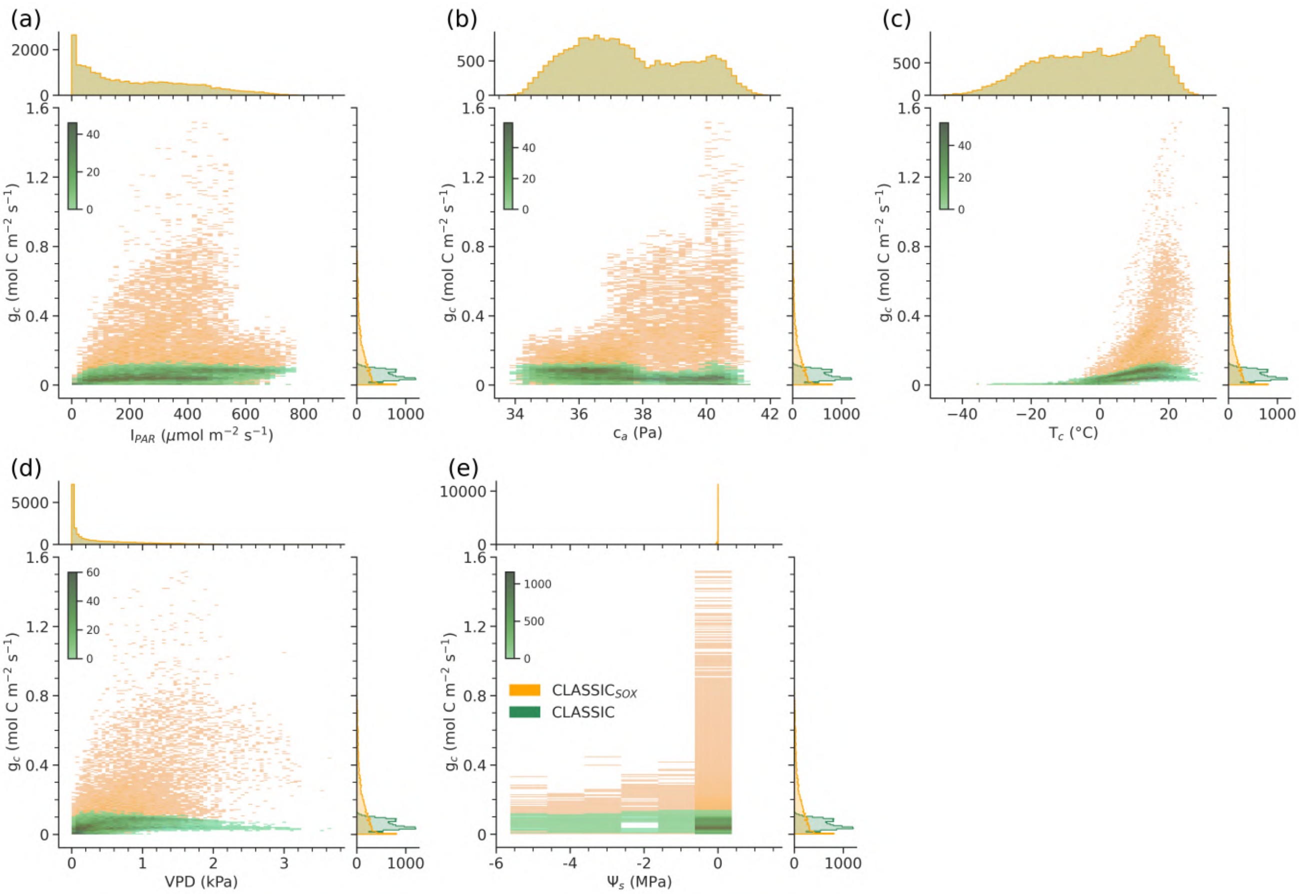

Figure S3. Histograms and kernel density estimates between canopy conductance (g_c) and meteorological variables (incident photosynthetic active radiations (I_{PAR}), canopy temperature (T_c), vapour pressure deficit (VPD)), atmospheric CO_2 concentration (c_a), and soil water potential (Ψ_s).

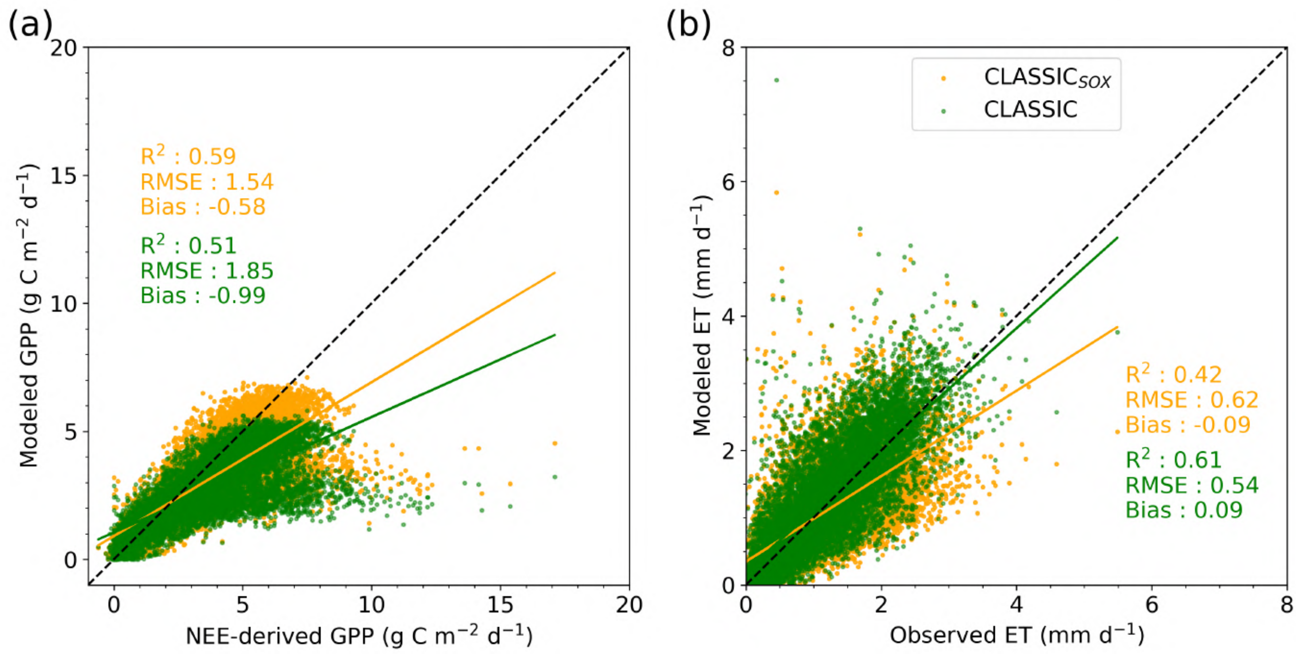

Figure S4. Combined scatter plots of GPP and ET for all sites. The black dotted line is the 1:1 line between modelled and observed data.

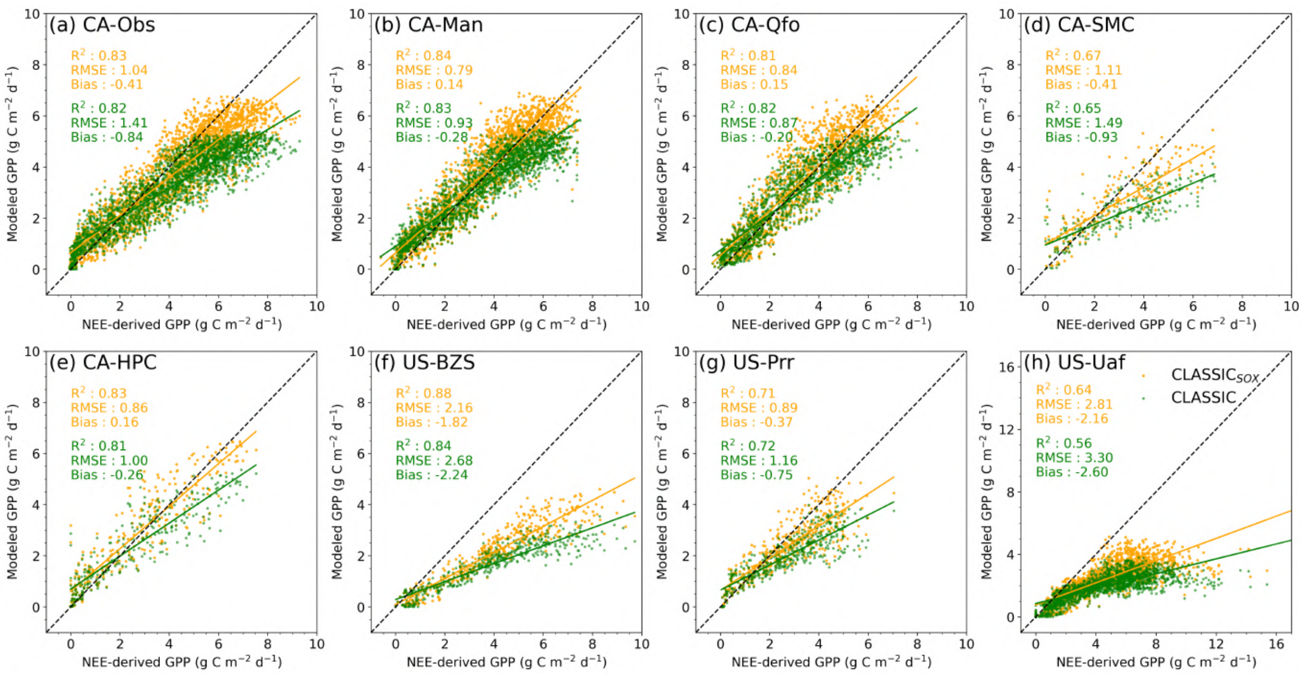

Figure S5. Scatter plots of NEE-derived GPP with CLASSIC and CLASSIC$_{SOX}$ simulations for all sites. The black dotted line is the 1:1 line between modelled and NEE-derived GPP.

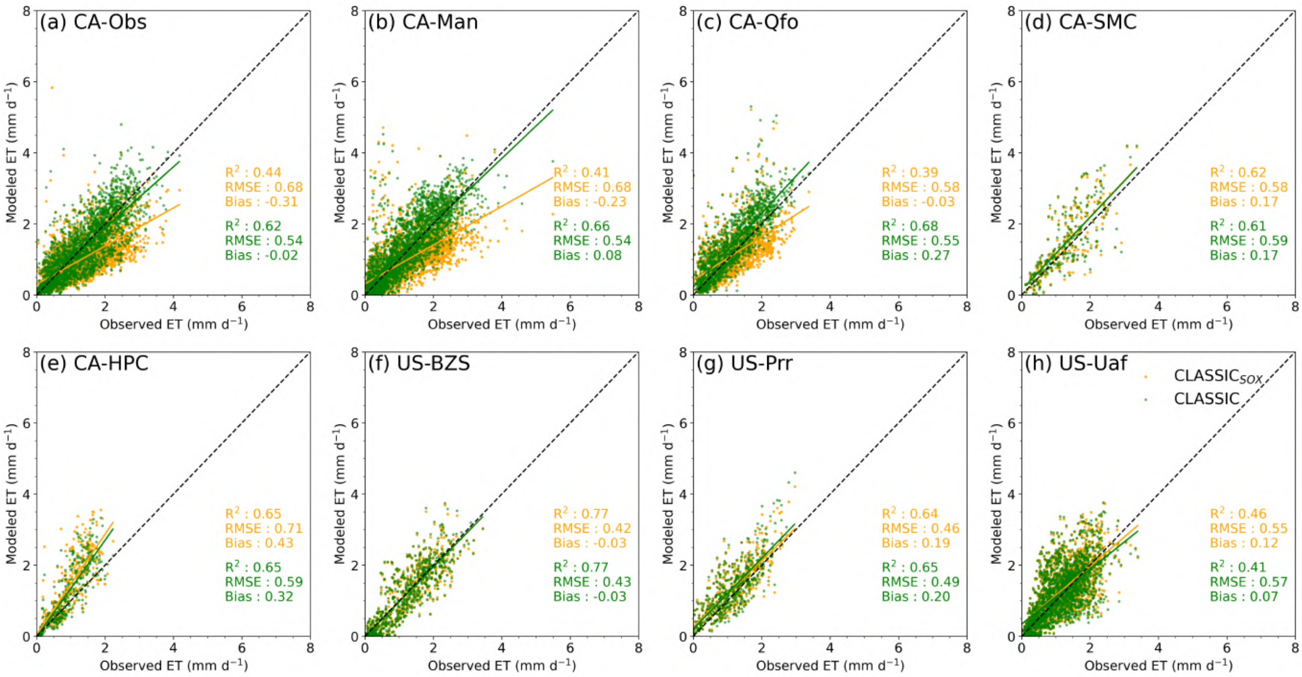

Figure S6. Scatter plots of observed ET with CLASSIC and CLASSIC$_{SOX}$ simulations for all sites. The black dotted line is the 1:1 line between modelled and observed ET.

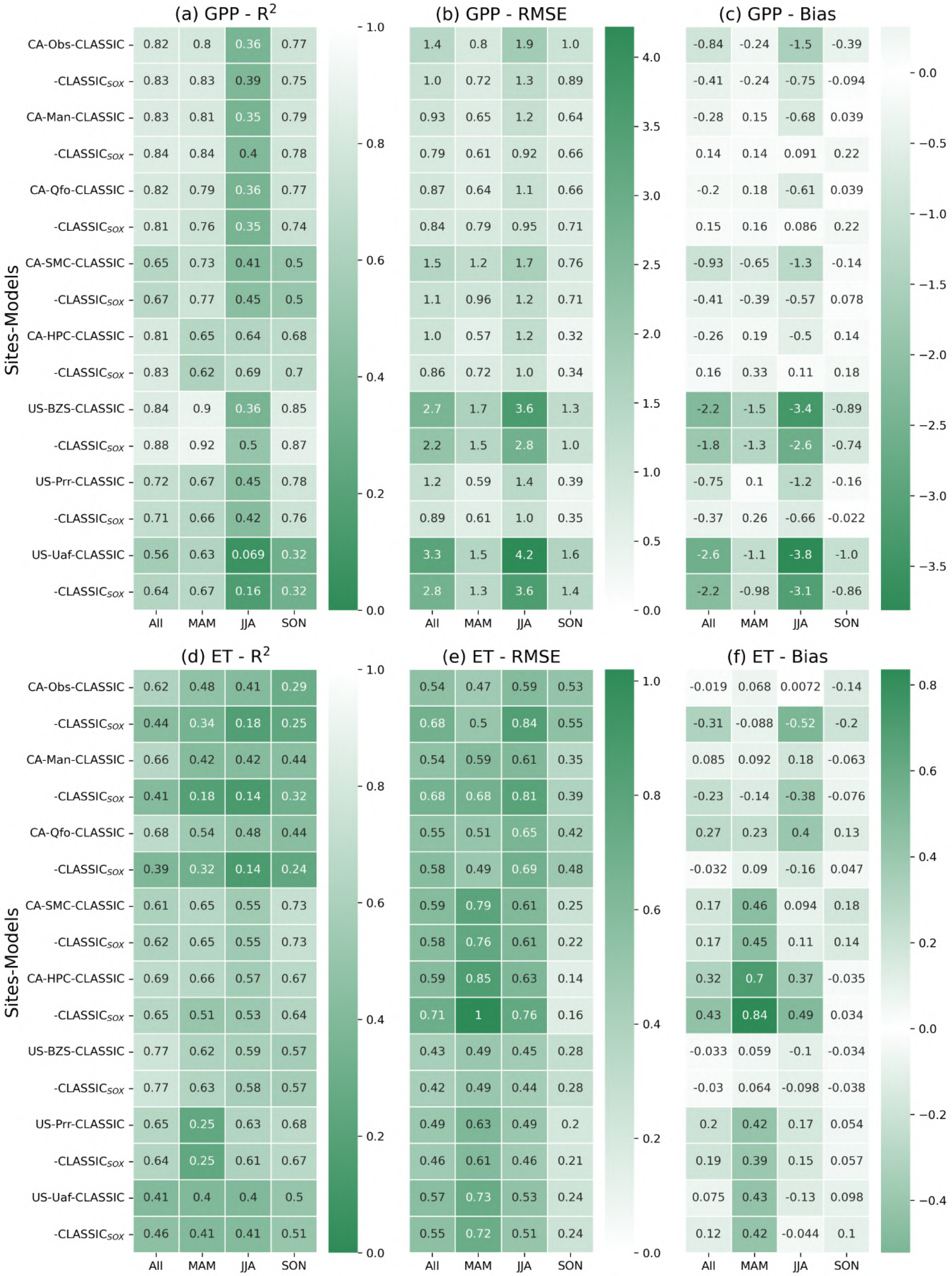

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Figure S7. R^2, RMSE, and bias of GPP and ET for March-April-May (MAM), June-July-August (JJA), September-October-November (SON), and all seasons combined (All) for all sites.

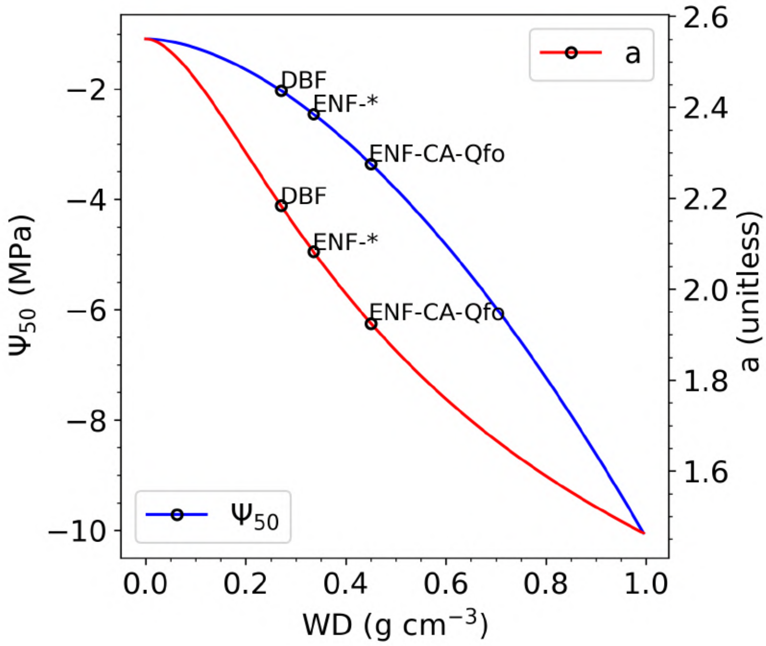

Figure S8. Water potential at 50 % loss of maximum hydraulic conductance (Ψ_{50}) and vulnerability curve parameter (a) are calculated using wood density following empirical relationship from (Christoffersen et al., 2016).

Table S1. Site details include location, time period, PFT (overstory and understory), ground cover, species, mean annual temperature (MAT), and mean annual precipitation (MAP).

Site ID	Site Name	Latitude	Longitude	Years	PFT [Overstory] [Understory]	Ground Cover	Species	MAT (°C)	MAP (mm)
CA-Obs	Saskatchewan-Western Boreal, Mature Black Spruce / Saskatchewan, Canada	53.99°N	105.12°W	1999-2010	[90% ENF] [10% DNF]	10% Sphagnum, 70% Feathermoss, 10% Lichen	90% Black spruce, 10% Tamarack	0.8	406
CA-Man	Manitoba-Northern Old Black Spruce / Manitoba, Canada	55.88°N	98.48°W	1994-2008	[90% ENF] [5% EBS, 5% DBS]	17% Brown moss, 34% Sphagnum, 53% Feathermoss	90% Black spruce	-3.2	520
CA-Qfo	Quebec-Eastern Boreal, Mature Black Spruce / Quebec, Canada	49.69°N	74.34°W	2003-2010	[90% ENF] [10% DBS]	13% Sphagnum, 46% Feathermoss, 6% Lichen	90% Black spruce	-0.4	962
CA-SMC	Smith Creek / Northwest Territories, Canada	63.15°N	123.25°W	2018-2019	[22% ENF] [34% EBS, 12% DBS, 15% SDG, 4% FORB]	36% Sphagnum, 25% Feathermoss, 15% Lichen	22% Black spruce	-2.8	388
CA-HPC	Havikpak Creek / Northwest Territories, Canada	68.33°N	133.5°W	2016-2018	[15% ENF] [58% EBS, 5% DBS, 4% C3G, 3% FORB]	4% brown moss, 9% Sphagnum, 18% feather moss, 42% lichen	15% Black spruce	-8.2	241
US-BZS	Bonanza Creek Black Spruce / Fairbanks, Alaska	64.70°N	148.32°W	2014-2018	[21% ENF] [75% EBS, 22% DBS, 39% SDG, 13% FORB]	6% Sphagnum, 73% Feathermoss, 10% Lichen	21% Black spruce	-2.4	274
US-Prr	Poker Flat Research Range Black Spruce Forest / Fairbanks, Alaska	65.12°N	147.49°W	2011-2014	[20% ENF] [14% EBS, 13% DBS, 24% SDG]	14% Sphagnum, 13% Feathermoss, 13% Lichen	20% Black spruce	-2.0	275
US-Uaf	University of Alaska, Fairbanks / Fairbanks, Alaska	64.87°N	147.86°W	2003-2018	[20% ENF] [45% EBS, 10% DBS, 25% SDG]	76% Sphagnum, 14% Feathermoss, 10% Lichen	20% Black spruce	-2.9	263

Table S2. Input variables and parameters used in the stomatal response curves for SMS function of CLASSIC and SOX standalone simulations, which are shown in figure 2 and discussed in Section 3.1.

Variables/Parameters	Name	Value
input variables	incident photosynthetic radiation (I_{PAR})	2000 μmol m^{-2} s^{-1}
	atmospheric CO_2 concentration (c_a)	40 Pa
	canopy temperature (T_c)	20°C
	vapour pressure deficit (VPD)	0.5 kPa
	soil water potential (Ψ_s)	- 0.1 MPa
	atmospheric pressure (P_{atm})	0.1 MPa
	air O_2 concentration (O_a)	0.2 mol mol^{-1}
input parameters	maximum rubisco carboxylation at 25°C (V_{max})	5 x 10^{-4} mol m^{-2} s^{-1}
	leaf scatter coefficient (v)	0.15
	high temperature photosynthesis limit (T_{high})	40°C
	low temperature photosynthesis limit (T_{low})	10°C
	quantum efficiency (ϵ)	0.1 mol mol^{-1}
	plant height (h)	20 m
	maximum soil-to-leaf hydraulic conductance ($k_{sl,max}$)	0.01 mol m^{-2} s^{-1} MPa^{-1}
	photosynthesis canopy conductance coupling parameter (m)	9.0
	photosynthesis canopy conductance coupling parameter (b)	0.01
	photosynthesis canopy conductance coupling parameter (V_o)	2000 Pa
	PFT specific sensitivity to soil moisture stress (ϱ)	2.0