# Characterizing carbon and water fluxes in the arctic boreal forest using plant hydraulics parameterization in the presence and absence of permafrost: a modelling approach

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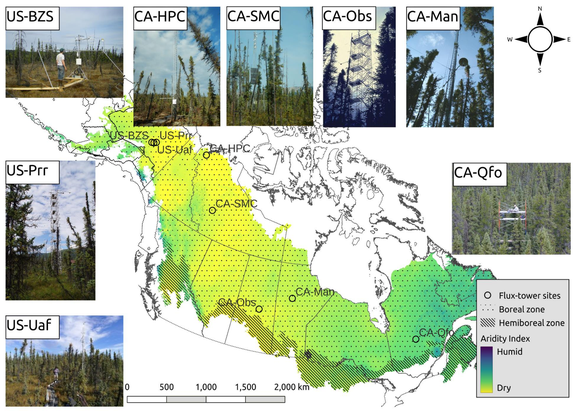
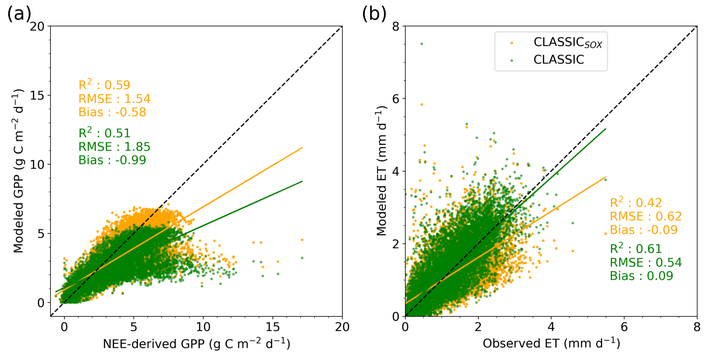
## Introduction

Plant hydraulics parameterizations implemented in various terrestrial biosphere models have been demonstrated to improve simulated carbon and water fluxes and are considered essential to better link soil, plant, and atmosphere in a single continuum. **We implemented a plant hydraulics parameterization (stomatal optimization based on xylem hydraulics - SOX) into the Canadian Land Surface Scheme Including biogeochemical Cycles ($CLASSIC_{SOX}$).** The default version of CLASSIC constrains stomatal conductance by an empirical approach (a soil moisture stress function).

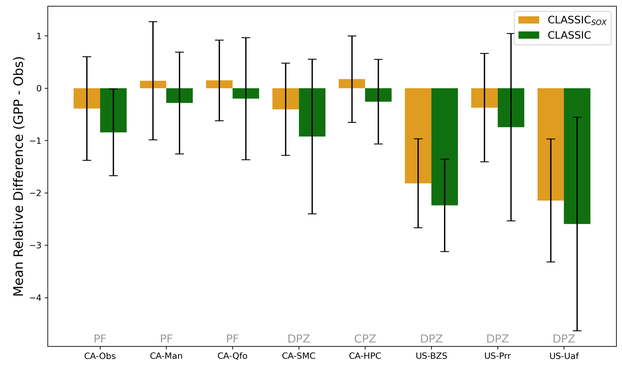



Eight boreal forest eddy covariance (EC) flux tower sites used in this study. Three sites are **permafrost free (PF: CA-Obs, CA-Man, CA-Qfo),** four sites are in **discontinuous permafrost zone (DPZ: CA-SMC, US-BZS, US-Prr, US-Uaf),** and one site is in **continuous permafrost zone (CPZ: CA-HPC).**




Scatter plots for gross primary production (GPP) and evapotranspiration (ET) combined for all sites. The dashed line is 1:1. **$CLASSIC_{SOX}$ improved $R^2$, RMSE, and bias for GPP than the CLASSIC.**

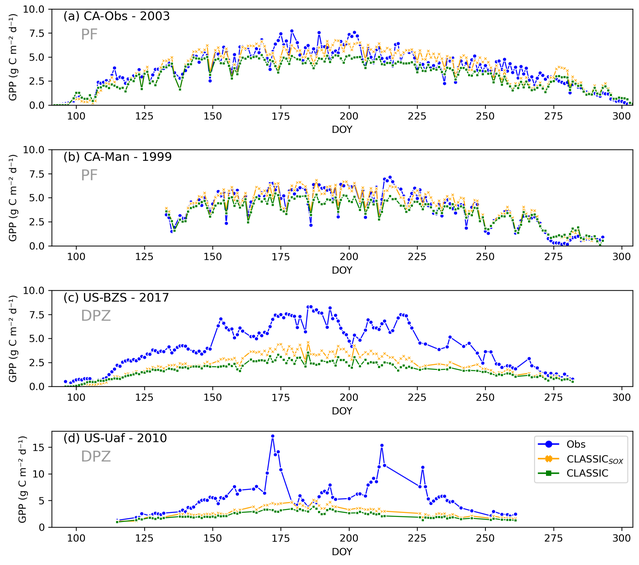
Mean relative difference in GPP - (g C $m^{-2}$ $d^{-1}$) (sim - obs) across all eight study sites **represent improved performance by $CLASSIC_{SOX}$ compared to CLASSIC.** Error bars represent the variability within each site's measurements. **$CLASSIC_{SOX}$ improved GPP in PF, DPZ and in CPZ.**




## Key Results

- Accumulated GPP for $CLASSIC_{SOX}$ improved by ~15 % (across 65 site years / 8 sites). % improvement = [($CLASSIC_{SOX}$-CLASSIC)/Observation].
- $CLASSIC_{SOX}$ improved $R^2$ (from 0.51 to 0.59), reduced RMSE (from 1.85 to 1.54 g C $m^{-2}$ $d^{-1}$), and bias (from -0.99 to -0.58 g C $m^{-2}$ $d^{-1}$) for GPP, combined for all sites.
- $CLASSIC_{SOX}$ degraded ET because the model evaporation is tuned to the CLASSIC transpiration-parameterization and now requires retuning.
- Drought and non-drought categories were defined using the Palmer drought severity index at all sites. $CLASSIC_{SOX}$ improved GPP and ET during drought conditions.

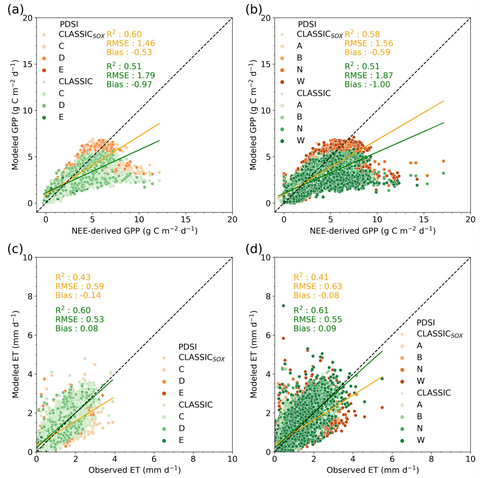
Daily GPP (g C $m^{-2}$ $d^{-1}$) time Series for a drought year (CA-Obs - 2003, CA-Man - 1999, US-BZS - 2017, US-Uaf - 2010) where PDSI < -2.0. **$CLASSIC_{SOX}$ improved GPP during all four drought years.** Two sites (CA-Obs and CA-Man) are PF and two sites (US-BZS, US-Uaf) are in DPZ.



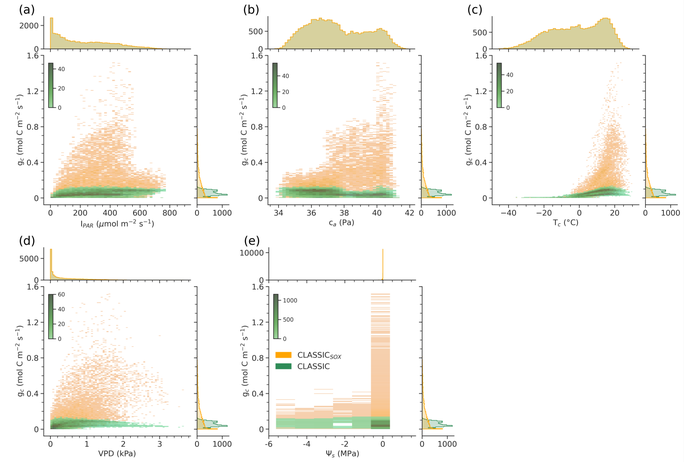

**Palmer drought severity Index (PDSI) categories:**

Drought categories:
C: Moderate drought
(PDSI = -2.0 to -2.99)
D: Severe drought
(PDSI = -3.0 to -3.99)
E: Extreme drought
(PDSI >= -4.0)

Non-drought categories:
W: Wet spells
(PDSI >=0.50)
N: Normal conditions
(PDSI = 0.49 to -0.49)
A: Incipient drought
(PDSI = -0.50 to -0.99)
B: Mild drought
(PDSI = -1.0 to -1.99)




Scatter plots between modelled and observed GPP and ET under drought and non-drought categories. **$CLASSIC_{SOX}$ improved $R^2$, RMSE, and bias for drought categories.**




**Higher canopy conductance for $CLASSIC_{SOX}$** with a) Incident photosynthetically active radiation ($I_{PAR}$), b) atmospheric $CO_2$ concentration ($c_a$), c) canopy temperature ($T_c$), d) vapor pressure deficit (VPD), and e) soil water potential ($\Psi_s$) **compared to CLASSIC due to more realistic plant hydraulics parameterization by using plant hydraulic conductance parameters.**

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**References**
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