

H510-0911: Significance of Evaluating Nonlinear Concentration–Discharge Relationships to Understand Reactive Solute Dynamics Across Land Uses

Juan Pesántez^{1*}, Dustin W Kincaid², Alex Webster³, Desneiges Murray¹, Joanna Blaszczak⁴, Hannah M Fazekas⁵, Ariel J Shogren⁶, William H McDowell^{1,7}, William Larsen⁸, Shannon L Speir⁹, and Adam S Wymore¹

*juan.pesantez@unh.edu

(1) University of New Hampshire (2) U.S. Geological Survey (3) University of New Mexico (4) University of Nevada Reno (5) Saginaw Valley State University (6) University of Alabama (7) Florida International University (8) Rice University (9) University of Arkansas

Introduction: C-Q relationships across land uses

- The power-law relationship between C and Q was first used by Hall (1970) to describe simple dilution
- Do more complex equations influence the explanatory power of C-Q relationships?
- What does providing or fitting the "n" parameter mean in terms of the explanation of the C-Q relationship?

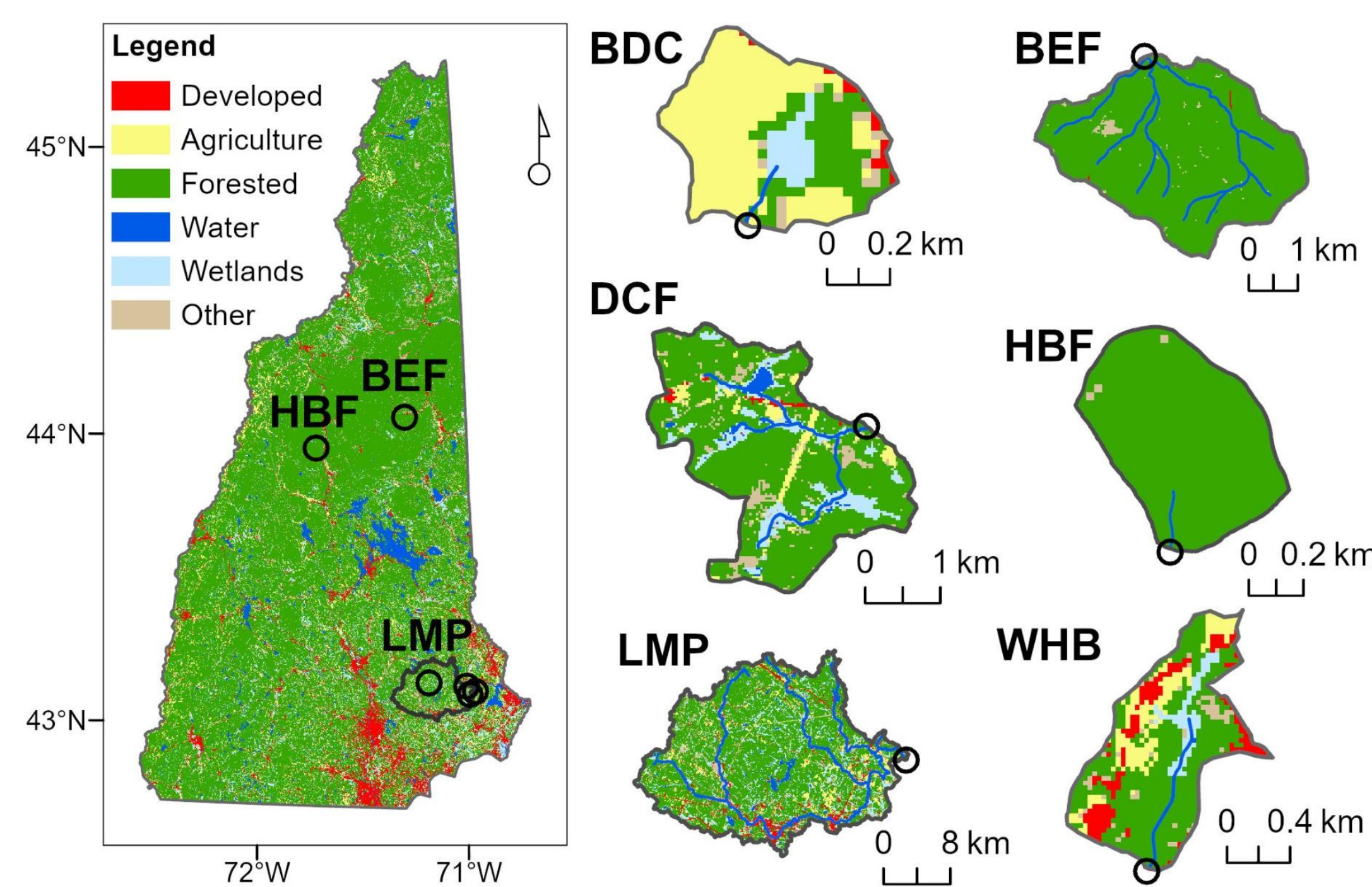


Figure 1. Land cover and location of catchments within New Hampshire. Note the scale differences for catchment sizes.

Theory: C-Q as a function of storage

Model	Equation	Assumptions
0: Log – Log	$\log C = \log Q$	simple log-log equation
1: Power-law	$C = A Q^{-\frac{1}{n}}$	single mixing volume, constant load, zero inflow concentration
2: Power-law + C_0	$C = A Q^{-\frac{1}{n}} + C_0$	single mixing volume, constant load, constant inflow concentration
3: Log-linear	$C = F' - E' \log Q$	same as 1 and 2; concentration changes little compared to volume
4: Stretched exponential	$C = H \left(-g' Q^{\frac{1}{n}} \right)$	same as 1; volume changes little compared to concentration
5: Stretched exponential + C_0	$C = H \left(-g' Q^{\frac{1}{n}} \right) + C_0$	same as 2; volume changes little as compared to concentration

Table 1. Models used in this study. n-values were fitted, and supplied by a recession analysis. All other parameters are fitted constants.

Hall, F. R. (1970). Dissolved Solids-Discharge Relationships: 1. Mixing Models. *Water Resources Research*, 6(3), 845–850.
Tashie, A., Pavelsky, T., & Band, L. E. (2020). An Empirical Reevaluation of Streamflow Recession Analysis at the Continental Scale. *Water Resources Research*, 56(1), e2019WR025448.

Methods: long-term dataset to test C-Q models

- ~10 years of 15-minute data: specific conductance, DOC, and discharge
- C-Q models from Hall (1970) are fit using the R nls function
- Some models require C_0 or n-value:
 - Baseflow concentrations used as C_0
 - Recession analysis to determine n

Results: recession analysis

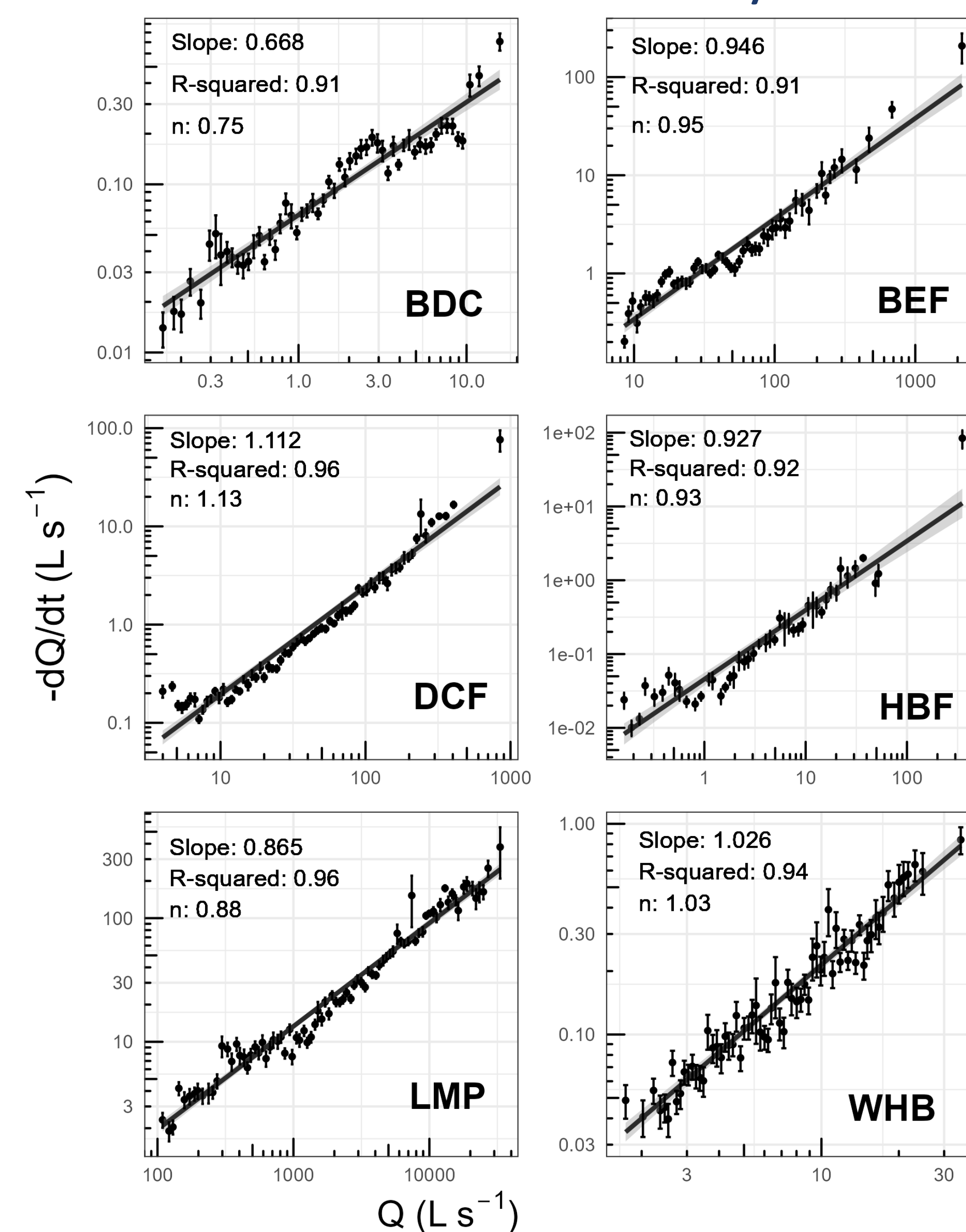


Figure 2. Recession analysis for all catchments with their respective slope and n-value (Kirchner, J. W. (2009). Catchments as simple dynamical systems: Catchment characterization, rainfall-runoff modeling, and doing hydrology backward. *Water Resources Research*, 45(2), 2008WR006912).

Site	n recession analysis	n fitted from Hall's equations for DOC				n fitted from Hall's equations for SPC			
		eq1	eq2	eq4	eq5	eq1	eq2	eq4	eq5
BDC	0.75	2.5E7	3.16	6.61	0.3	6.1	1.9	1	-3.4
BEF	0.95	1.6E6	1.4E5	3.57	-2	5.4	6.4E5	-4.5	24.8
DCF	1.13	19.9	2.5E5	11	16.4	7.83	6.1E7	40.7	23.4
HBF	0.93	2.3E7	1.4E7	3.7	-6.22	9.4	1.3E7	43	37.6
LMP	0.88	4.6E5	7.4E5	65.2	37.7	8.0	-3.86	14.2	12.1
WHB	1.03	1.4E3	8.5E6	10.6	10.3	12.1	0.7	-3.2	9.16

Table 2. The n-values obtained from the recession analysis and the fitted n-values within Hall's equations for SPC and DOC.

Results: C-Q models and performance

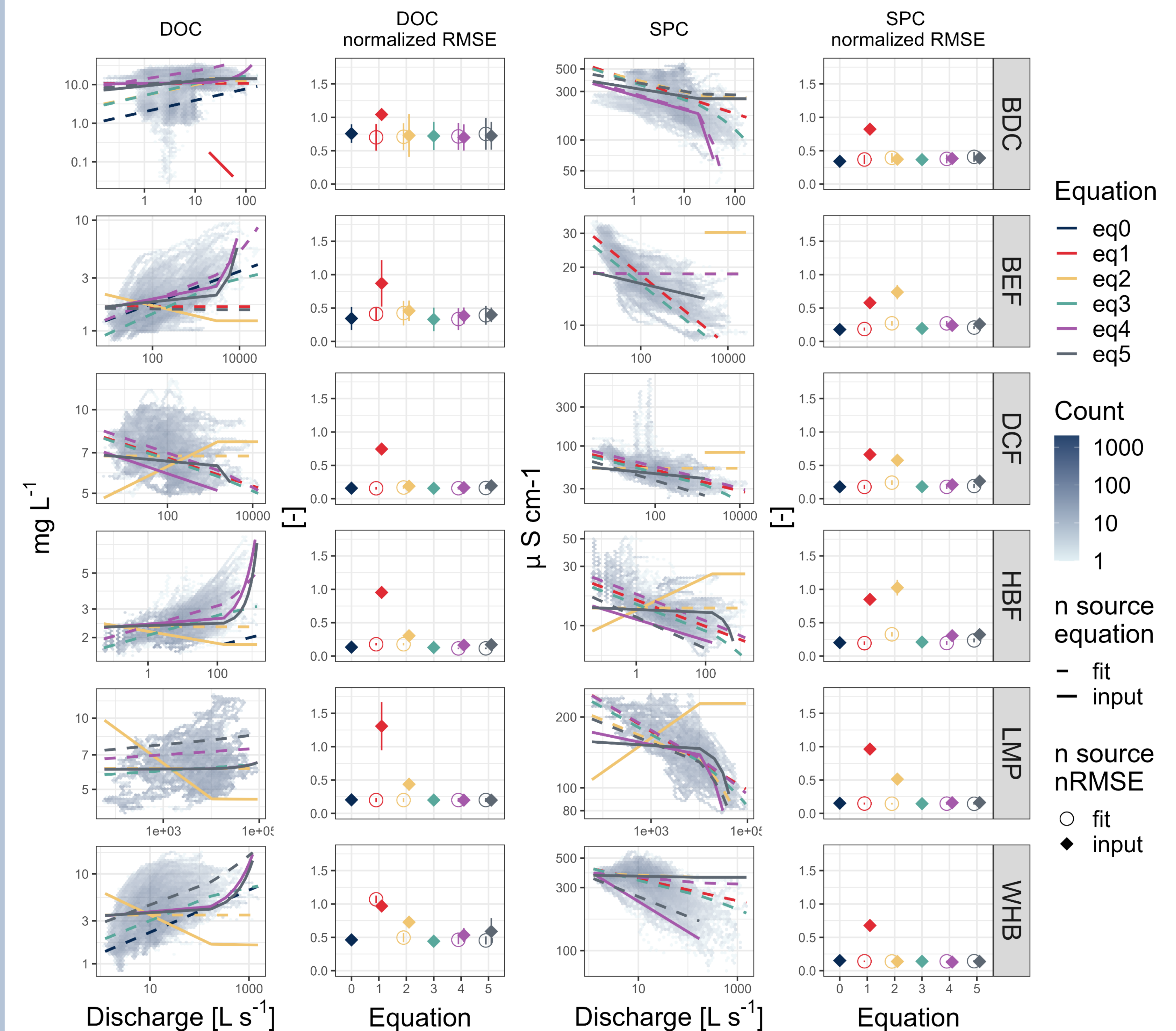


Figure 3. 15-minute specific conductance and discharge data as density plots (blue intensity represents the density of values on distributed polygons in the space). The respective C-Q model simulations are over the density plots; note that the lines are only plotted if the simulated concentrations are in the range of observed C and Q values. At the right of each plot are the normalized RMSE for each equation when the n values are fitted and provided as input by the recession analysis

Conclusions

- Representing DOC dynamics could require advanced models to effectively account for non-linear, spatiotemporal, and biochemical processes
- SPC dynamics can be represented using C-Q models, particularly in larger catchments where generalized processes dominate
- Analyzing C-Q relationships may require fitting the recession n-value coefficient to accurately capture underlying catchment processes, especially when using n derived from recession analysis
- Simple dilution effects rarely explain C-Q relationships, which requires a multi-model framework with detailed analysis of parameter sensitivity and DOC controls to draw process-based conclusions

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