Spatial patterns and environmental controls of particulate organic carbon in surface waters in the conterminous United States

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Objectives:

- Carbon cycling in inland waters has been identified as an important but poorly constrained component of the global carbon cycle.
- The Fifth Assessment Report on the International Panel on Climate Change (IPCC) highlighted carbon export, burial, and outgassing from inland waters as critical but insufficiently investigated processes that may affect the global carbon budget.
- In order to better understand the terrestrial aquatic interface's effect on the carbon cycle, this study was designed to investigate the spatial variability and environmental controls of particulate organic carbon (POC) concentration across the conterminous U.S. and eighteen major water resource regions.
- Major objectives were: 1) to identify key variables controlling POC concentration across U.S. riverine systems; 2) to characterize spatial patterns of POC concentration across the riverine systems; and 3) to provide insights into future investigations of riverine POC-related carbon sources and sinks.
- Field POC concentration data was compiled from 1145 USGS gauge stations listed in the Geospatial Attributes of Gages for Evaluating Streamflow (GAGES-II) dataset as well as total nitrogen, total phosphorus, suspended sediment and chlorophyll-a observations, when available, from 1973-2015.
- Variables considered in this study include climate conditions, hydrological factors, land cover, soil properties (soil texture, topographic factors, dam density, and water quality
- The authors use generalized linear models (GLMs) to test how environmental factors impact POC concentrations at both the national and regional scales.

New Science:

- The study demonstrates substantial spatial variability in POC concentration (1.32 $\pm$ 2.56 mg C/L, mean $\pm$ one standard deviation) across the surface waters in the United States, with stations located in the upper Mississippi River basin and the Piedmont region in the eastern U.S. reporting the highest POC concentrations.
- Water resources regions located in Missouri, the Upper Mississippi, and the Lower Colorado, have higher average POC concentration than other regions
- Regional scale analyses reveal substantial variation in environmental controls of POC concentrations across eighteen major water resource regions in the U.S and demonstrated that POC concentration and associated environmental controls also vary non-monotonically from headwaters to large rivers.
- Suspended sediment and chlorophyll-a explain 26% and 17% of the variability in POC concentration, respectively.
- At the national level, twenty-one environmental factors combined can explain about 40% of the spatial variance in POC concentration.
- At the national scale, factors that have significant impacts include soil properties, drainage area, total phosphorous concentration, and dam density.
- The GLM model analyses suggest that POC concentration is affected synergistically by multiple variables.
- Most of the selected environmental factors have statistically significant correlation with POC concentration but each individual factor has a fairly low explanatory power for the POC variability.
- Only four variables (total phosphorous, total nitrogen, forest land cover, and soil water content) each can explain more than 10% of the POC variability.

- A large portion (60%) of the variability in POC concentration is unexplained by the selected variables and linear models, indicating that additional factors and nonlinear processes should be considered in order to better represent the complexity of riverine POC modeling.

Significance:

- Although the importance of carbon cycling at the terrestrial-aquatic interface is well known, inclusion of these processes into regional and global carbon cycling investigations has been jeopardized by the significant uncertainties in the magnitude, variability, and environmental controls of riverine carbon.
- This analysis was designed to identify factors that have significant linear impacts on POC and these factors are also expected to be related to important physical processes regulating POC concentration, therefore the results are important for informing future modeling efforts.
- The findings demonstrate the complexity of the multiple factors affecting POC and suggest that, in addition to the properties of the selected river basin, in-stream processes (e.g. aquatic primary production, sediment deposition and remobilization) may further complicate the spatial patterns of POC concentration.
- This complexity, along with the large unexplained uncertainty, calls for the development of process-based, non-linear methodologies that consider coupled terrestrial-aquatic processes regulating supply, removal and transformation of POC in order to better understand the carbon flux.
- Discrepancies between this study and the SPAtially Referenced Regressions On Watershed attributes (SPARROW) model investigations of total organic carbon (TOC) further illustrate that riverine POC and dissolved organic carbon (DOC) may be regulated by different processes and thus need to be investigated separately, and also that land covers may have less significant impacts on POC than DOC.
- The negative impacts from urban areas may be attributable to the special hydrological processes and sediment transport in urban areas but need to be further analyzed in cases of non-causative correlations.
- The authors suggest that the findings and explanations in this study should be further tested in the future to explore the complex interplays among soil erosion, sediment deposition/mobilization and carbon cycling.
- Also, because hydrological and biological processes both have significant seasonal variability, how these processes regulate POC concentration over finer temporal scales is a subject for further exploration.
- To reduce uncertainties due to noncausative correlations, more extensive field experimental exercises with the aim of collecting concurrent environmental data over large regions are required in the future.

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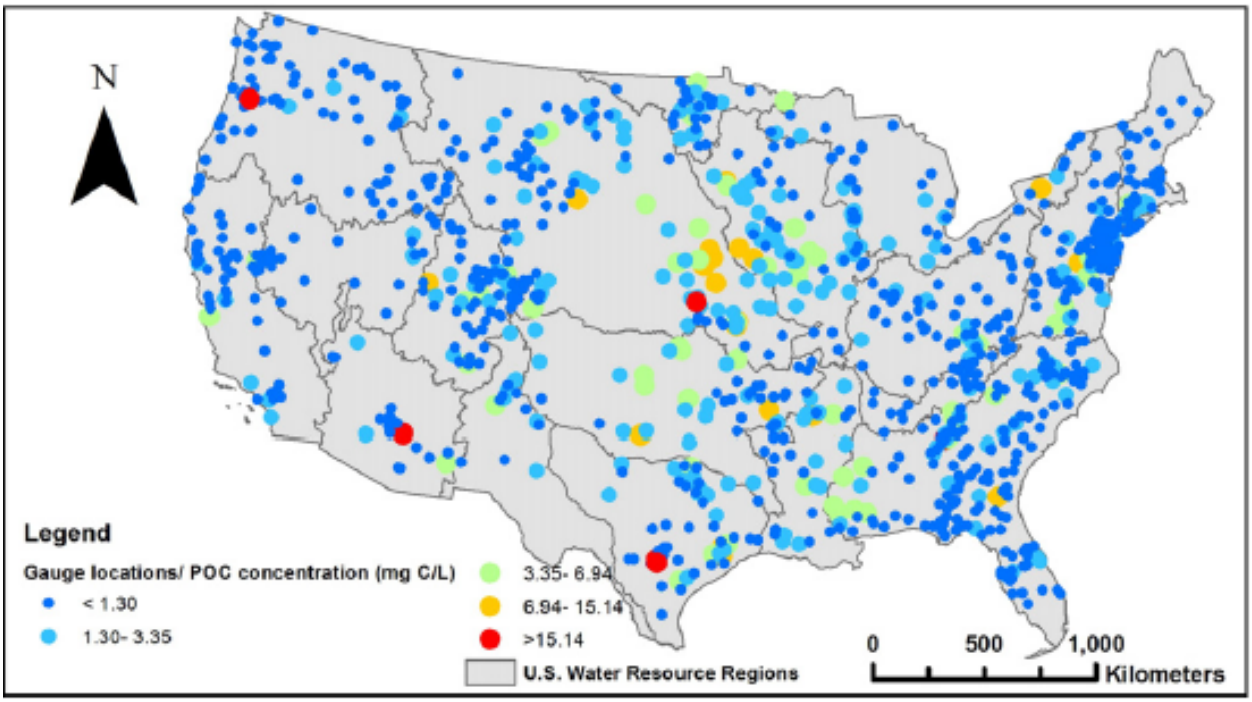

Figure 1. POC concentration at the 1145 U.S. Geological Survey gauge stations.

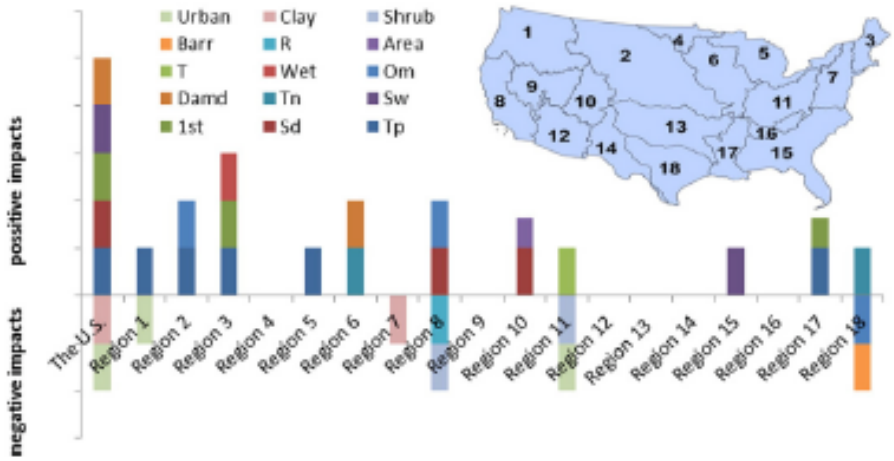

Figure 4: Factors with significant impacts on POC over the entire U.S. and the 18 water resource regions (Om: soil organic matter; Wet: wetland; T: temperature; R: runoff; Area: drainage area for each station; Barr: percentage of barren land; Urban: percentage of urban area; Shrub: percentage of shrub area; Crop: percentage of cropland; Clay: percentage of soil clay; Sw: soil water content; Sd: soil bulk density; Slop; average slope of the drainage area; 1st: percentage of first order watersheds; Tn: total nitrogen in waters; Tp: total phosphorus in waters; Damd: dam density).