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Title: Demystifying spatial confounding

Abstract:
Spatial confounding is a fundamental issue in regression models for spatially indexed data. It arises because spatial random effects, included to approximate unmeasured spatial variation, are typically not independent of the covariates in the model. This can lead to significant bias in covariate effect estimates. Despite extensive research, it is still a topic of much confusion with sometimes puzzling and seemingly contradictory results. Here, using a straightforward spatial mixed model formulation, we present a broad theoretical framework that brings mathematical clarity to the mechanisms of spatial confounding, providing explicit and interpretable analytical expressions for the resulting bias. From these, we see that it is a problem directly linked to spatial smoothing, and we can identify exactly how the features of the model and the data generation process affect the size and occurrence of bias. Our results also clarify the ideas around various methods for bias adjustment. Our comprehensive and mathematically explicit approach clears up past confusion and, indeed, demystifies the issue of spatial confounding