Forecasting nonlocal climate impacts for mobile species using multivariate spatio-temporal extensions to empirical orthogonal function analysis

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Abstract

Societal responses to COVID-19 have illustrated the great public value of accurate epidemiological forecasts; climate change has a similar potential to upend commerce and necessitates accurate decadal forecasts of community impacts. In this talk, I discuss modern extensions to Empirical Orthogonal Function (EOF) analysis involving multivariate spatio-temporal models, and how it can be used to jointly analyze climate change and community ecology. EOF analysis is widely used to identify modes of variability from spatially distributed environmental measurements (e.g., the El Nio Southern Oscillation is primary mode of variability in sea surface temperatures in the Pacific Ocean), but is less common in community (or epidemiological) modelling to understand modes of community variability. I specifically argue that EOF analysis is one potential approach to study ?ecological teleconnections,? wherein individual movement generates mechanistic associations (and resulting correlations) between community dynamics occurring at geographically distant locations. I begin by adapting EOF analysis for multivariate, spatially unbalanced, zero-inflated, and right-skewed data that are common in community ecology, and show that movement of bottom-associated species in the eastern Bering Sea contains the finger-print of major climate indices. I then couple an EOF of ocean physics to spatially integrated measurements of juvenile survival, and show that this ?EOF regression? can identify spatial areas that are maximally correlated with time-series residuals for recruitment as well as forecasting end-of-century recruitment. I conclude by fitting an EOF end-to-end ecosystem model to ocean physics measurements and climate-linked projections, planktonic primary and secondary producers, juvenile (pelagic) and adult (demersal) fish samples, seabirds, and fishing effort. This analysis shows greater spatial overlap between predators, juvenile, and adult walleye pollock in warm years, along with decreased overlap between adult pollock and the summer fishery, or juvenile pollock and nutritious prey. These warm conditions are projected to continue under likely climate scenarios, so resulting decadal-scale projections illustrate ?community reassembly? involving this commercially important fishery. I conclude by recommending a coordinated ?Grant Challenge? for habitat science to inform spatial management, which would address these nonlocal effects, as well as additional indirect and counterfactual effects that complicate habitat science and conservation.