NITROGEN-ENRICHED DISCHARGES FROM A VAST WATERSHED INTENSIFY RED TIDE BLOOMS IN SOUTHWEST FLORIDA

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Karenia brevis (red tide) blooms on Florida's Gulf Coast have severely impacted regional ecosystems, coastal economies, and public health, and a scientific and policy debate has emerged as to whether these blooms are primarily natural or anthropogenic. Recent research suggests that natural processes explain offshore bloom initiation and shoreward transport, while anthropogenic nutrient inputs may intensify coastal blooms. However, past correlation studies have failed to detect compelling links between coastal blooms and watershed covariates indicative of anthropogenic inputs. We contend that linking anthropogenic inputs to bloom intensification ("the anthropogenic hypothesis") is fundamentally a causal hypothesis and explain why correlation is neither necessary nor sufficient to demonstrate causality. Our empirical investigation leverages the fact that systematic temporal patterns may reveal systematic cause-and-effect relationships. Using time series derived from in-situ sample data, we applied singular spectrum analysis—a non-parametric spectral decomposition method—to recover deterministic signals in the dynamics of *K. brevis* blooms and upstream water quality and discharge covariates in the Charlotte Harbor region between 2012 and 2021. Next, we applied causal analysis methods based on chaos theory—i.e., convergent cross-mapping and S-mapping—to detect and quantify persistent, state-dependent interaction regimes between coastal blooms and watershed covariates. We found that nitrogen-enriched Caloosahatchee River discharges consistently intensified K. brevis blooms. Flows were typically most influential at the earliest stages of blooms, while the influence of total nitrogen concentrations was strongest during bloom growth/maintenance stages. These results suggest that discharges and nitrogen inputs may influence blooms through distinct yet synergistic causal mechanisms. Additionally, we traced this anthropogenic influence upstream to Lake Okeechobee (which discharges to the Caloosahatchee River) and the Kissimmee River basin (which drains into Lake Okeechobee), suggesting that watershed-scale nutrient management and modifications to Lake Okeechobee discharge protocols will likely be necessary to mitigate blooms.

<u>PRESENTER BIO</u>: Dr. Medina is a postdoctoral researcher at the UF Center for Coastal Solutions. He has expertise in chaotic dynamics and causality in complex environmental systems, with applied experience in coastal/wetland hydrology, water quality, and ecology.