***All hands on deck! Improved ocean carbon sink estimates by combining models and data***

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Since the preindustrial era, the ocean has removed about 40% of fossil $CO_2$ from the atmosphere, and it will eventually absorb at least 80% of human $CO_2$ emissions. There is no doubt that the ocean is a critical player in the global carbon cycle, but many uncertainties remain. In this talk, I discuss the multiple approaches that my group is using to reduce current uncertainties and illuminate needed future steps. First, I show that global reconstructions of the ocean carbon sink from sparse surface data can constrain the large-scale mean sink and its seasonality; however, new observations will be required to constrain variability and trends. Second, I use machine learning to merge observations and models to estimate the sink for 1959-2022 and, at the same time, to reveal large-scale model biases. These biases propagate forward, driving much of the future uncertainty in the sink under both high and low-emission scenarios. The clearest paths forward to improved ocean carbon sink quantification are (1) making targeted observations to fill identified gaps, and (2) reducing mean-state biases in modeled circulation and biogeochemistry.