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Examining the relationship of the response of North Atlantic ocean heat, salt, and volume circulations to perturbations - a multi-decadal adjoint sensitivity study

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Observational field studies, for example the RAPID array and the Argo float program, have put in place instruments to monitor the circulation in the North Atlantic. In our study we look at how the circulation in the North Atlantic responds to surface forcing and water-mass perturbations on a global scale over a multi-decadal period. We use adjoint model techniques to examine which circulation shifts correspond to what water-mass and surface forcing changes. We examine and compare the transient sensitivity to surface forcing, initial state and mixing parameters of several important North Atlantic circulation measures in a realistic global ocean model. The measures we examine (heat, volume, and salt transports, as well as heat and salt content) are important gauges of the North Atlantic Ocean climate. Using the calculated sensitivities we answer the question, what surface forcing and water-mass perturbations show up coherently in all our North Atlantic circulation measures.

Our approach uses a next generation automatic differentiation tool (OpenAD) to create spatio-temporal sensitivity maps over a 50-year period, at the resolution of the global ocean model. Using these maps we can calculate correlations between the sensitivities of different circulation measures. Sensitivities that have strong correlations across different measures indicate water-mass and forcing changes that will be readily detected by numerous circulation measuring devices. Sensitivities that have weak correlations project differently onto different circulation measures.