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Eddies and Fronts: Distinct roles of mesoscale SST features in modulating the North Atlantic Atmosphere

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Mesoscale ocean features with spatial scales on the order of 100 km, including transient eddies and fronts, play a critical role in ocean–atmosphere interactions. Sea surface temperature (SST) provides a common framework for representing mesoscale ocean variability, motivating an examination of how different SST structures influence the atmosphere. In this study we investigate the atmospheric response to mesoscale eddies and fronts using Weather Research and Forecasting (WRF) simulations, applying three different SST forcing regimes.

Simulations are conducted from September 2005 to September 2006, a year characterized by a neutral wintertime North Atlantic Oscillation (NAO) index. To isolate the contributions of distinct mesoscale features, we design three 30-member ensembles that differ only in their SST forcing. The first ensemble is forced with a full-resolution SST field. The second ensemble uses a spatially smoothed SST field, generated by applying a Gaussian filter that removes features smaller than 300 km. The third ensemble uses a temporally smoothed SST field, generated by applying a low-pass filter that removes SST variability persisting for less than 90 days. Comparing these ensembles allow us to separate the atmospheric responses to general small-scale SST variability, transient mesoscale eddies, and quasi-stationary fronts.

The results suggest that transient mesoscale eddies primarily influence the upper troposphere, where enhanced upward fluxes of heat and moisture strengthen the subtropical jet. In contrast, quasi-stationary SST fronts, such as within the Gulf Stream, exert their strongest influence in the lower troposphere, where increased moisture fluxes enhance midlatitude precipitation. Together, these findings highlight the related yet distinct roles of different mesoscale ocean features in the North Atlantic atmosphere: transient eddies intensify the zonal subtropical jet, while fronts modulate meridional-depth cell.