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**Title:** Salinity Signatures of Gulf Stream Eddies: Statistics Over 15-Years of L-band Radiometer Observation

**Abstract:** Fifteen years of satellite SSS products are used in conjunction with microwave SST and Gulf-Stream eddy databases (Census and altimetry) to build up statistical composites of thermo-haline surface anomalies for anti-cyclonic and cyclonic on each side of the Gulf stream main path. The variability of the SSTA and SSSA carried by these meso-scale eddies with typical radii  $R \sim 50$  km is revealed as function of regions, season, eddy size, rotational sign, and lifetime. The thermal signature of Warm Core Rings (WCR) is primarily driven by air-sea heat flux, leading to rapid decay and high seasonal sensitivity. WCRs exhibit their highest thermal intensity in Winter and Spring, frequently exceeding  $2.0^\circ\text{C}$ . In contrast, Summer thermal signatures are the weakest, often dropping below  $1.0^\circ\text{C}$  due to solar "masking" that reduces the surface temperature gradient between the eddy and the surrounding water. Thermal decay is highly linear in Summer ( $R^2 = 0.97$ ), losing intensity rapidly as the eddy ages. Winter decay is more erratic ( $R^2 = 0.3$ ) due to sporadic storm-driven cooling. The transition from a dipolar to a monopolar SSTA structure as the rings age further supports the hypothesis that WCRs undergo a dynamical relaxation as they propagate away from the high-shear environment of the Gulf Stream North Wall. Salinity acts as a conservative tracer, making its intensity less dependent on atmospheric forcing and more dependent on the internal water mass and lateral mixing. Unlike temperature, haline intensity is often highest in Summer and Autumn. Haline intensity does not follow the same linear westward decay as temperature. The Summer SSTA decay is roughly 25 times faster than SSSA decay. SSSA remains robust through all subregions studied, demonstrating the ability of WCRs to transport salty Sargasso Sea water deep into the Mid-Atlantic Bight. The near-zero decay slopes indicate that the salinity core remains trapped and intact even as the thermal signature vanishes. The evolution of Sea Surface Density Anomaly (SSDA) provides a view into the ring's stability: in Summer, the rapid cooling (decreasing SSTA) dominates the density budget, leading to a significant increase in core density as the ring ages. In Winter, the density anomaly remains more stable, suggesting that the colder background environment and deeper mixed layers reduce the relative impact of the ring's thermal decay on local buoyancy. In winter, the ring maintains its density structure more effectively because the background waters are already cold, making the salinity anomaly the dominant factor in preserving the ring's physical identity. While the individual components (WCRs are warm/salty, they decay over time) are well-known, our specific integration of propagated error bars for the seasonal density ratio provides a very clear, quantitative "fingerprint" of WCR aging that was often only discussed qualitatively in larger-scale studies.

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