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The impact of submesoscale fronts on turbulent air-sea heat fluxes in the Southern Ocean: Results from the first Saildrone circumnavigation of Antarctica

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The Southern Ocean is fundamental for our climate, accounting for 75% of the total oceanic heat uptake and absorbing 93% of excess heat arising from global warming. However, direct observations of air-sea heat fluxes are still scarce, particularly at small spatial and temporal scales. This study investigates the effect of fine-scale frontal activity (0.1 km–10 km) and sampling bias on measured turbulent heat fluxes in the Southern Ocean using high-resolution hydrographic and meteorological data collected by three autonomous surface vehicles (Saildrones) during their 2019 circumnavigation of Antarctica. We show that the uncertainty in observed air-sea heat fluxes increases with reduced sampling frequency. To have a 90% chance of capturing the mean turbulent heat flux within ±1 Wm^2, the required sampling resolution is less than 30 km in summer and less than 10 km in winter. Surface temperature-driven density fronts were found to be numerous throughout the in situ datasets and ranged in length-scales from sub-kilometer to mesoscale (order of 0.1 km–100 km). The magnitude and variability of the turbulent heat flux gradient over these fronts tends to decrease with increasing frontal length, suggesting a strong coupling between heat fluxes and front size, thereby underscoring the need to capture fine-scale oceanographic features to better resolve air-sea fluxes of heat.