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# A new method for studying water mass origins on basin scales: using multiple passive tracers to study Atlantic Cold Tongue variability

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Multiple passive tracers are used in a dynamical ocean model to demonstrate a new method to study water mass origins on a basin-wide scale. This method has previously only been used in estuary-scale studies. A case study is chosen to highlight when this multiple passive tracer method may provide benefits over the standard method of tracing water mass origins on basin-scales: using a single passive tracer in an adjoint model. 31 passive tracers are used to determine the origin regions of the Atlantic cold tongue (ACT). At the time of the ACT minimum in sea surface temperature, 38 $\pm$ 3% of the surface water in the central equatorial Atlantic is found to originate in the western side of the basin, with 11 $\pm$ 2% originating in the east. The multiple passive tracer method can show how origin regions change with time, allowing seasonal differences in origin regions to be discerned. The identification of origin regions of cold water that increase their supply to the equatorial Atlantic in phase with the ACT cooling identifies those regions that are important to the ACT variability. Sensitivity tests show that the temporal evolution of the concentrations of such tracers within the ACT region is not sensitive to the month in which the tracers are initialised. The region of the North Brazil undercurrent is found to be the most important origin region for the central Atlantic ACT region, for a 6-8 month lead time. Using the Met Office EN4 observational dataset of ocean temperatures, correlations are found between January temperatures in the North Brazil undercurrent region and both the ACT mean temperature and ACT spatial extent in July-August, significant at the 0.95 level. This suggests that the 6-month lead-time predictability of the ACT may be increased by improved knowledge of the North Brazil undercurrent temperature. Results from previous studies suggest that such increased predictability of the ACT could potentially help improve predictions of the West African monsoon.