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Human-induced changes to the global ocean water masses and their time of emergence

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The World Ocean is rapidly changing, with global and regional modification of temperature and salinity evident at the surface and depth. These changes have widespread and irreversible impacts including sea-level rise, changes to the oxygen and carbon contents of the ocean interior, or changing habitats, diversity and resilience of ecosystems. While the most pronounced temperature and salinity changes are located in the upper few hundred metres, changes in water-masses at depth are already observed and will likely strengthen and persist in the future as water-masses form at the surface and propagate in the deep ocean along density surfaces, storing the anthropogenic signal away from the atmosphere for decades to millennia. Here, using 11 climate models, we define when anthropogenic temperature and salinity changes are expected to emerge from natural background variability in the ocean interior. On a basin-scale zonal average, the model simulations predict that in 2020, 20–55% of the Atlantic, Pacific and Indian basins have an emergent anthropogenic signal; reaching 40–65% in 2050, and 55–80% in 2080. The well-ventilated Southern Ocean water-masses emerge very rapidly, as early as the 1980s-1990s, while the Northern Hemisphere emerges in the 2010s to 2030s. Additionally, dedicated idealized simulations of the IPSL coupled climate model are examined to study the role of each separate surface forcing on the time scales associated with the patterns of temperature and salinity change under a global warming scenario, and the influence of excess versus redistributed heat and salt. Our results highlight the importance of maintaining and augmenting an ocean observing system capable of detecting and monitoring anthropogenic changes.