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Decomposing oceanic temperature and salinity change using ocean carbon change

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As the planet warms due to anthropogenic CO2 emissions, the interaction of surface ocean carbonate chemistry and the radiative forcing of atmospheric CO2 leads to the global ocean sequestering heat and carbon, in a ratio that is near constant in time: this enables patterns of ocean heat and carbon uptake to be derived. Patterns of ocean salinity also change as the earth system warms due to hydrological cycle intensification and perturbations to air-sea freshwater fluxes.
Local temperature and salinity change in the ocean may result from perturbed air-sea fluxes of heat and freshwater (excess temperature, salinity), or from reorganisation of the preindustrial temperature and salinity fields (redistributed temperature, salinity).
Here, we present a novel method in which the redistribution of preindustrial carbon is diagnosed, and the redistribution of temperature and salinity estimated using only local spatial information.
We demonstrate this technique in the NEMO OGCM coupled to the MEDUSA-2 Biogeochemistry model under a RCP8.5 scenario over 1860-2099.
The excess changes are thus calculated.
We demonstrate that a global ratio between excess heat and temperature is largely appropriately regionally with key regional differences consistent with reduced efficiency in the transport of carbon through the mixed layer base at high latitudes.
On centennial timescales, excess heat increases everywhere, with 25+/-2 of annual global heat uptake in the North Atlantic over the 21st century.
Excess salinity meanwhile increases in the Atlantic but is generally negative in other basins, consistent with increasing atmospheric transport of freshwater out of the Atlantic.
In the North Atlantic, changes in the inventory of excess salinity are detectable in the late 19th century, whereas increases in the inventory of excess heat does not become significant until the early 21st century. This is consistent with previous studies which find salinification of the Subtropical North Atlantic to be an early fingerprint of anthropogenic climate change.

Over the full simulation, we also find the imprint of AMOC slowdown through significant redistribution of heat away from the North Atlantic, and of salinity to the South Atlantic.
Globally, temperature change at 2000m is accounted for both by redistributed and excess heat,

but for salinity the excess component accounts for the majority of changes at the surface and at depth.
This indicates that the circulation variability contributes significantly less to changes in ocean salinity than to heat content.

By the end of the simulation excess heat is the largest contribution to density change and steric sea level rise, while excess salinity greatly reduces spatial variability in steric sea level rise through density compensation of excess temperature patterns, particularly in the Atlantic.
In the Atlantic, redistribution of the preindustrial heat and salinity fields also produce generally compensating changes in sea level, though this compensation is less clear elsewhere.

The regional strength of excess heat and salinity signal grows through the model run in response to the evolving forcing.
In addition, the regional strength of the redistributed temperature and salinity signals also grow, indicating increasing circulation variability or systematic circulation change on timescales of at least the model run.