Ocean Salinities Reveal Strong Water Cycle Intensification During 1950-2000

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The global evaporation (E) and precipitation (P) surface fluxes set the spatial pattern of surface salinity in the ocean. Collectively, these E-P ocean surface fluxes comprise 75-85% of the climatological annual-mean global water cycle. For this reason, long-term changes to the ocean salinity field provide an insight into water cycle change expressed by E-P changes. When considered in a simplified framework, ocean salinity responds to an amplification and redistribution of E-P and not E or P changes individually, with the advantage that salinity integrates these noisy E-P changes (providing a low-pass filter) over oceanic circulation timescales. Additionally, as the ocean contains 97% of the Earth's free water it's clearly a good place to look for small temporal perturbations.

Using the CMIP3 (Coupled Model Intercomparison Project phase 3) simulations, we diagnose the relationship between the simulated ocean surface salinity and the simulated E-P (water cycle) changes. Using the 20C3M (20^{th} century) and SRES (future 21^{st} century) simulations, explicitly dealing with model drift, and a technique to extract the broad-scale, zonal change patterns, a strong linear relationship is found between changes in the global surface water flux (E-P) and surface salinity over the global oceans. The CMIP3 simulations indicate that spatial salinity patterns amplify at twice the rate of the corresponding E-P patterns. This result suggests that fresh ocean regions become fresher, and salty regions saltier in response to climate change – an ocean proxy for the 'rich get richer' mechanism.

Observed surface salinity estimates suggest a surface salinity spatial pattern amplification of 8% (16±10% K^{-1}) has occurred 1950-2000. Using the CMIP3 relationship between salinity and E-P change, we infer a 4% amplification of observed E-P for 1950-2000. Considering the observed global surface warming of 0.5°C over this period, this suggests a 4% (8±5% K^{-1}) rate of change, closely following the Clausius-Clapeyron relationship (7% K^{-1}). Importantly, the CMIP3 ensemble mean, a frequently used metric to express projected future changes, greatly underestimates the observed 1950-2000 rate of ocean salinity change (8% K^{-1}). Further, if the CMIP3 ensemble mean warming of 2-3K by 2100 is realised; this would imply a water cycle amplification of 16-24% will occur.