## Exploring the impact of model and data uncertainties in the detection and attribution of upper-ocean warming

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Large-scale increases in upper ocean heat content (OHC) are evident in the observational record of the past fifty years. Several studies have made use of well-established detection and attribution (D&A) methods to demonstrate that the observed changes are consistent with model-based estimates of the OHC response to increasing concentrations of greenhouse gases, and inconsistent with model estimates of natural variability. The recent identification of systematic XBT biases in observational OHC records has led to new estimates of global scale OHC variability and trends. This provides motivation for a re-examination of previous D&A findings. In the present study, we use these newer estimates of OHC change to further examine the causes of ocean warming. We perform a comprehensive assessment of the sensitivity of ocean heat content D&A results to: 1) measurement biases in observations; 2) incomplete, time-varying spatial coverage of observational data; 3) methods used to remove residual drift from model simulations; and 4) the inclusion or neglect of volcanic forcings in model simulations. Our OHC D&A analysis is conducted in a multi-model framework, in which results from over a dozen coupled models are used to estimate the response to external forcing and the noise of natural internal variability. Signal-to-noise ratios (S/N) show some sensitivity to the model and data uncertainties considered. However, our results corroborate earlier studies and suggest that the positive identification of a human-caused warming signal in observed basin scale OHC changes is robust to these uncertainties. The large S/N ratios obtained at 40-year time scales have inspired us to repeat our analysis at sub-basin scales.