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CONTENT: Improved estimates of open ocean CO_2 parameters from T, S and O_2 data for underway and profile applications

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CONTENT (CONsisTency EstimatioN and amounT) is a method, which combines parameterizations of four carbonate system parameters (dissolved inorganic carbon, total alkalinity, pH and pCO_2, obtained from the CANYON neural network parameterization, Sauzède et al., 2017). CONTENT uses the overdetermined system to improve accuracy for each individual parameter, and to provide a local uncertainty estimate based on the consistency of these calculations. Together with the spatio-temporal density of the parameterization's reference data, the consistency allows users to verify the local validity of estimates and thus reliable interpretation. CONTENT provides a more accurate estimate for all four parameters, especially for pCO_2 with a global accuracy estimated for CANYON at 7.6 % (30 μatm at 400 μatm) and up to 3.3 % (13 μatm at 400 μatm) for CONTENT. The performance and usefulness of CONTENT are evaluated against various types of datasets, including underway pCO_2 observations from cruises across the Atlantic, pCO_2 profile data acquired by a profiling float in the Equatorial Atlantic, and surface pCO_2 estimated from profiling float pH data in the Southern Ocean. The results are highly encouraging and promise to offer new ways to address spatial and temporal variability (in particular short-term) using existing autonomous observation networks. Furthermore, at the global scale, CONTENT surface pCO_2 estimates from CTD-O_2 and Argo-O_2 profile data are unbiased compared to a Surface Ocean CO_2 Atlas-based climatology. The synergetic link of observation systems like Argo-O_2 together with CONTENT for the water column structure and voluntary observing ship data collected in SOCAT for accurate surface pCO_2 will improve ocean CO_2 inventory and flux estimates. Finally and based on the complete CO_2 system description provided by CONTENT, the temporal trend and distribution of the Revelle buffer factor is analyzed solely based on CTD-O_2 and Argo-O_2 observations and the GLODAPv2 dataset. We find a global increase of +0.26 $\pm$ 0.28 (1σ) units per decade and an increase in time about 50 % higher and significant at latitudes above 45° N and S. This application illustrates the potential and utility that such transfer functions with realistic uncertainty estimates provide to ocean biogeochemistry and global climate change research.