Level up ocean carbon observations: Successful implementation of a novel autonomous total alkalinity analyzer on a commercial Ship of Opportunity

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The observation and documentation of the marine carbon cycle is of utmost importance because of probable future changes such as ocean acidification, warming or deoxygenation. Over decades, ship-based observatories (Ships of Opportunity – SOOP) equipped with sensors measuring the CO₂ partial pressure ($pCO_2$) in the surface seawater form the backbone of the global ocean carbon observation system. However, one severe shortcoming of the current carbon-SOOP observatory is the fact that it mostly only measures $pCO_2$ which is required to calculate the net air-sea CO₂ flux. Full insight into the marine CO₂ system for important aspects such as net biological production, ocean acidification, and marine calcification requires the measurement of two out of the four measurable variables of the marine CO₂ system which are $pCO_2$, total alkalinity ($A_T$), dissolved inorganic carbon ($C_T$) and pH. The so far common workaround is the calculation of $A_T$ from sea surface temperature and sea surface salinity using established parameterizations. Unfortunately, this procedure leads to high uncertainties and is particularly prone to regional bias. Therefore, autonomous $A_T$ measurements are necessary. Our study describes the implementation of a novel autonomous analyzer for seawater $A_T$, the CONTROS HydroFIA® TA system (Kongsberg Maritime Contros GmbH, Kiel, Germany) on a North Atlantic SOOP line based on the merchant vessel M/V Atlantic Sail (Atlantic Container Line). The first main part of this work deals with the installation of the analyzer, for which several circumstances must be taken into account: 1) The system’s typical drift behavior, 2) stabilization measurements and cleaning procedures, and 3) the waste handling. We present our installation in detail and how we handle the named issues. Another major problem during automated long-term campaigns is the provision of sufficient reference seawater for regular quality assurance measurements and subsequent drift correction. We tested ten different container types and materials with minimum 5L volume (e.g. gas sampling bags) for their suitability as long-term seawater storage. As a result, only one gas sampling bag based on polyvinylidene fluoride (PVDF) featured the high-quality requirements and was chosen as reference seawater storage. The second main part focusses on the measured sea surface $A_T$ data from the first four unattended measurement campaigns. In order to prove the success of the installation, we compared the measurements with 1) discrete samples (taken manually only during the first two transits), and 2) calculated $A_T$ values based on established parameterization. The gained results show very promising consistency between the measured values and the $A_T$ range and variability of the monitored region. We conclude that the implementation of the CONTROS...
HydroFIA® TA system on a SOOP line was successful and brings ocean carbon observations to a new level.