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Assimilation of pCO2 data into a global biogeochemical model

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As part of the CARBOOCEAN project measurements of the partial pressure of carbon dioxide (pCO_2) in the Atlantic Ocean have been collected since 2001. As part of our commitment to this project we have developed a new method for assimilating pCO_2 data into coupled physical-biogeochemical models. Our method is based upon a sequential framework and may be split into two parts. Firstly observation minus model differences of pCO_2 are calculated and these differences are processed into pCO_2 increments using standard data assimilation techniques. However, as pCO_2 is a diagnostic variable these increments cannot be directly applied to the model as would normally be the case in data assimilation. Instead a second stage of the assimilation process is required that converts pCO_2 increments into their prognostic components: temperature, salinity, Dissolved Inorganic Carbon (DIC) and alkalinity. In our method temperature and salinity are assumed error free, so that pCO_2 increments are converted purely into increments in DIC and alkalinity. Such a process is still underdetermined, so in DIC/alkalinity phase space the DIC/Alkalinity increments are taken to be perpendicular to the local line of constant pCO_2. Given a linear relationship between pCO_2 and DIC/alkalinity, such increments form the shortest possible increment vector in the phase space. Once calculated, DIC and alkalinity increments can be applied directly to the model. In our application, where only surface data was available, increments were applied down to the base of the mixed layer and spread horizontally by filtering with two second order autoregressive functions.

To test our method we assimilated the CARBOOCEAN data into a 2006 run of the NEMO-HadOCC global biogeophysical model and compared the results to a control with no assimilation. For the assimilating experiment an optimal interpolation type of data assimilation was used to calculate the initial pCO_2 increments before converting these to DIC/alkalinity increments. Increments were applied using an incremental analysis update technique. Results from this experiment show that, despite extremely limited data, assimilation significantly reduced the RMS and mean errors of the model. Application of pCO_2 increments in the northern North Atlantic made a significant difference to the seasonal cycle, with assimilation moving the model closer to the Takahashi pCO_2 climatology. Results in the southern North Atlantic were less good, as errors in biological draw down caused there to be a poor seasonal cycle. The reason pCO_2 assimilation of a small amount of data was able to produce such significant improvement to the model was because pCO_2 increments persisted in the model for a considerable length of time. Some increments were observed to last for more than 6 months.