Model constraints on the anthropogenic carbon budget and acidification of the Arctic Ocean

JENS TERHAAR[12], JAMES ORR[1], MARION GEHLEN[1], CHRISTIAN ETHE[1], PIERRE REGNIER[2], LAURENT BOPP[3]

[1] LSCE/IPSL, CEA-CNRS-UVSQ, Université Paris-Saclay, 91191 Gif-sur-Yvette, France

[2] Department of Earth and Environmental Sciences, Université Libre de Bruxelles, 1050 Bruxelles, Belgium

[3] LMD, IPSL, CNRS/ENS/Ecole Polytechnique/UPMC, 24 rue Lhomond, 75231 Paris, France

The Arctic Ocean is particularly vulnerable to ocean acidification. Average Arctic surface waters are projected to be undersaturated with respect to aragonite by 2050, earlier than in all other ocean regions. The main driver of ocean acidification is the increase of CO2 in the atmosphere and its consequential uptake by the ocean. While data-based studies have assessed storage of anthropogenic carbon (C_{ant}) in the Arctic Ocean, models have the potential to provide complementary information on the overall C_{ant} budget. For instance, here we find that three-fourths of simulated C_{ant} that is stored in the Arctic is delivered laterally from neighboring oceans based on simulations in a global ocean circulation model (NEMO) forced by reanalysis data and coupled to the biogeochemical model (PISCES). This lateral influx increases with resolution as the simulated circulation becomes more realistic. That leads to an increase of C_{ant} in the Arctic Ocean, from 1.6 Pg C in 2005 for our coarse-resolution model (2°) to 2.2 Pg C for our eddy-admitting model (0.25°). This increase in C_{ant} storage implies greater acidification at higher resolution, e.g., an increase in the shoaling of the aragonite saturation horizon (ASH) between 1960 and 2012 from 40 m (2°) to 190 m (0.25°). The large sensitivty of that shoaling to resolution results from relatively minor changes in DIC (and pH), given the weak vertical gradients in DIC and Ω_{arag} near the depth of the ASH. At the surface, resolution does not affect basin-wide average pH, but it does alter local extremes, e.g., decreasing minimum surface pH on the Siberian shelf in 2012 from 8.0 to 7.5 as model resolution is improved. Simultaneously, the minimum Ω_{arag} decreases from 0.9 to 0.1, emphasizing the key nature of properly resolving river inputs. To further assess effects due to riverine delivery change, we made idealized sensitivity tests, independently increasing riverine DIC, DOC, and nutrients by 1% yr-1. When riverine DOC is doubled, after 70 years, basin-wide average pH decreases by 0.015. Yet when riverine DIC is doubled, and along with it total alkalinity (TA), the riverine TA/carbon ratio increases and consequently average ocean pH (+0.016).