Are marine ecosystems headed toward a new productivity regime?

July 16 2015

Phytoplankton have been projected to produce less organic material as the oceans' temperatures rise—with carry-on effects for higher levels of the food web. Based on new climate model simulations, a team of scientists from Sydney and Kiel suggests now that this assumption might be misleading. According to the researchers, ocean productivity might be pushed into a completely new regime in the more distant future.

Human-induced carbon dioxide (CO_2) emissions to the atmosphere are projected to rise to up to 30 gigatonnes of carbon per year by 2100, assuming a "business-as-usual" scenario. As a result, global mean temperatures are projected to increase by almost five degrees Celsius. According to a team of scientists from the Climate Change Research Centre at the University of New South Wales (UNSW), Australia, the Australian Research Council's Centre of Excellence for Climate System Science and GEOMAR Helmholtz Centre for Ocean Research Kiel, these changes might have the power to shift the ocean into a fundamentally different type of production regime. Although simulations with more complex models need to be integrated and analysed, the study published in the current issue of the *Environmental Research Letters* demonstrates that predictions made for the next 100 years might not be valid in the more distant future.

"We integrated a 600-year simulation starting in the year 1800 and followed the IPCC's Representative Concentration Pathway RCP 8,5", Dr. Karin Kvale, modeller at UNSW and GEOMAR explains. The three slightly different models run by the Australian and German scientists

first showed a decline in ocean productivity. The slowdown is due to the fact that warming waters are also stratified more strongly and less mixing can take place. If less water from the deep reaches the sunlit top layer, fewer nutrients are available for phytoplankton and primary production - the production of organic material from inorganic carbon for example through photosynthesis - decreases. This short-term result was in line with our current understanding of near-future shifts in productivity.

But starting about the year 2000, rising water temperatures cause respiration rates to pick up. "Rates of heterotrophic consumption, such as from bacteria, metabolic processes and from plankton that live on organic matter from other organisms, increase faster than rates of primary production", Dr. Kvale summarizes. "Eventually, this unbalanced ratio pushes global primary production away from being driven by the physical limitation of access to newly upwelled nutrients from deeper ocean layers. The new regime is essentially driven by the biology itself." In a future ocean system with more heterotrophy, carbon and nutrients will be recycled more effectively near the surface than they are now, and less carbon will be exported and stored in the deep. This will also have implications for the ocean's ability to absorb carbon dioxide from the atmosphere and to mitigate the effects of global change.

Currently, the models do not include the possible effects of decreasing calcification and the greater susceptibility of the aragonite form of calcium carbonate to dissolution on carbon export. Either of these phenomena would both hasten and magnify the transition to more heterotrophy by further reducing carbon export from the surface. Therefore, more complex models need to be developed and integrated to better understand the potential long-term changes and possible tipping points that could occur in a high-CO2 world, the scientists emphasize. "Our study indicates possible surprise changes in the ocean's more

distant future and we think that it is important to consider longer-term predictions", Dr. Kvale states. "But many uncertainties have to be discussed and analysed - both concerning the drivers of this massive change and its possible effects."

More information: Kvale, K.F., Meissner, K.J., Keller, D.P., 2015: Potential increasing dominance of heterotrophy in the global ocean. *Environmental Research Letters*,10, DOI: 10.1088/1748-9326/10/7/074009

Provided by Helmholtz Association of German Research Centres