Ocean biogeochemical responses to AMOC variability in a changing climate

Jerry Tjiputra, Uni Research Climate, Bjerknes Centre for Climate Research, Bergen, Norway

I. Rationale: AMOC impact on simulated equilibrium interior oxygen
One of the key questions related to future climate prediction is the stability of the ocean overturning (THC) and how its responses to the ongoing anthropogenic climate change. The functioning of ocean biogeochemistry and distributions of biogeochemical tracers are tightly coupled with the THC. Doney et al. (2004) show that the representation of ocean transport and dynamics directly affects the predicted ocean carbon cycle variables. Thus, changes in THC will influence ocean biogeochemical processes through altering the carbon sources and sinks, which then could feedback to the climate.

Using a single coupled biophysical ocean model (HAMOCC-MICOM, Tjiputra et al., 2013) configured for different setups, we show that different AMOC strengths lead to different equilibrium states of ocean biogeochemical tracers (e.g., dissolved oxygen, Figs. 1 and 2).

II. AMOC-induced changes in North Atlantic oxygen and phosphate
We simulated climate change under the RCP8.5 scenario with NorESM and to illustrate the sensitivity of interior biogeochemical tracers to AMOC, additional scenario with strong climate engineering based on stratospheric aerosol injection on top of the RCP8.5 (RCP8.5-CE, Tjiputra et al., 2015) was performed. A termination simulation where CE is stopped abruptly in 2100 is also simulated and resulted in rapid decrease in AMOC over the subsequent decade (Fig. 3). Figure 4 shows that climate change reduces interior oxygen and phosphate concentrations. Signals in the intermediate depth up to 2000m emerge relatively fast, within few years after AMOC perturbation (see simulation with CE termination), whereas in deeper layer, changes also occur but at a slower pace.

III. Biological vs. physical contribution of oxygen changes
Change in the interior phosphate projected in the future (e.g., Fig. 4) reflects, to some extent, the change in large scale overturning circulation. This is not obvious for the interior oxygen. Figure 6 shows that weaker overturning circulation leads to a broad, but mostly in the upper 1000m, reduction in the North Atlantic Oxygen.

Increased preformed oxygen at 1000m depth south of Iceland could indicate a shallower overturning cell in the future. AMOC-induced change in surface nutrient also leads to reduction in biological production, and consequently reduction in remineralization (oxygen consumption, AOU in Fig. 6) in the near ocean. Fig. 6 also indicate that biological remineralization in the future is projected to occur at more shallow depth.

IV. Time of Detectable Change (ToDC)
Here, we explore the detectability of biogeochemical tracer changes in response to the projected climate change. We define Time of Detectable Change (ToDC) as the year where the seasonal cycle exceeds twice of the natural standard deviation for five continuous years. The ToDC is calculated relative to the present day period, i.e., mean over 2006-2015 period. In the North Atlantic, Fig. 7 shows that ToDC for temperature, alkalinity, and oxygen would emerge earlier in the subtropical and earliest in the North Atlantic drift region. In the Labrador Sea, oxygen ToDC will occur earlier than temperature.

VI. Impact on benthic ecosystem
Anthropogenic carbon uptake reduces the saturation state of carbonate ion in the ocean, which could be detrimental for calcareous organisms. Future AMOC reduction ameliorate this negative impact on benthic ecosystem as less undersaturated watermass will be transported into depth.

V. Detecting climate change in the Labrador Sea

In the North Atlantic, large seasonal cycle is embedded in the surface temperature and oxygen signals, thus hinders the climate signal. Surface Alkalinity increase in seasonal cycle (potentially due to changes in evaporation and precipitation) but still within the natural variability envelope. In the intermediate depth, the model simulates decadal variability in temperature and alkalinity, but climate change signal for temperature is projected to emerge in the 2nd half of the 21st century. The oxygen signal at 2000m depth emerges much earlier, and could be related to the combination of biological and physical changes.

References
BjerknesCentre, We acknowledge funding from the FAGE – Fast Global Changes administered by UniNor, DJI/Applied Center for Environmental Science and project ORGANIC (No. 249264/EE)/funded by the research council of Norway. This research is a contribution to the Ignition Centre for Climate Research.