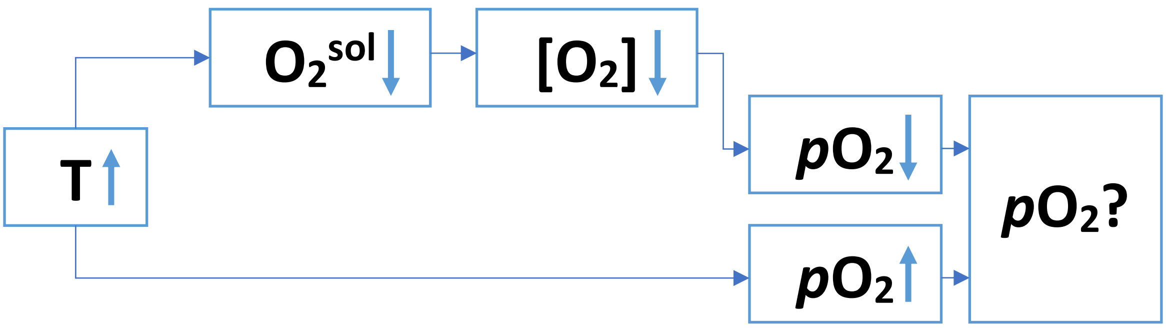
Master thesis project

Effects of ocean warming and deoxygenation on marine ecosystems

Marine O_2 concentrations are decreasing and projected to continue to decrease during the 21st century and beyond (e.g., Kwiatkowski et al., 2020; Frölicher et al., 2020; Oschlies, 2021). The main drivers of the O_2 decrease are warming, changes in biological cycling of O_2, and ocean circulation/ventilation – their relative importance varies in space and time (e.g., Frölicher et al., 2020). Besides mean changes in O_2, extreme O_2 events are projected to increase in intensity, duration, and frequency (Gruber et al., in press). Both the mean changes and extreme O_2 events can greatly impact marine life. Indeed, drastic reductions in habitat viability are to be expected across species (Clarke et al., 2021; Deutsch et al., 2015; Gruber et al., in press; Oschlies, 2021).

When discussing O_2, too few studies recognize that it is the combination of partial pressure of O_2 (pO_2) and O_2 solubility, not just concentration ($[O_2]$), that is relevant for marine species (Seibel, 2011; Verberk et al., 2011). The ratio between pO_2 supply and demand of a species determines habitat viability and species biogeography (Clarke et al., 2021; Deutsch et al., 2020). As temperature affects both pO_2 supply and demand, the net effect of warming on marine species is not straightforward:
A) Regarding O_2 supply, warming decreases $[O_2]$ due to reduced O_2 solubility while pO_2 increases due to increased gas diffusion rates (Verberk et al., 2011) (Figure below);
B) pO_2 demand on the other hand increases with increasing temperature (Verberk et al., 2011).
The adverse impact of warming on organisms is determined by increased pO_2 demand (a function of among others temperature) exceeding increased pO_2 supply (a function of temperature and $[O_2]$) – not simply a reduction in O_2 solubility or pO_2 (Verberk et al., 2011). First results show that the opposing effects of warming on solubility and gas diffusion rates can lead to a masking effect in pO_2 supply. Furthermore, there are also indications that the effect of temperature on habitat viability can be masked by the effect of pO_2.



An improved understanding and description of the changes in temperature/$[O_2]$/pO_2 will support marine biogeochemists in their study of marine O_2 as well as the impact of O_2 changes on marine life. Several research questions can be addressed within this context, which could be explored in a MSc thesis project. Depending on the focus, the Earth System Model output available in the Horizon2020 COMFORT project and CMIP6 can be used. An initial start can be made with the GFDL-ESM2M model output which is available in-house (Dunne et al., 2012, 2013). The COMFORT output goes beyond CMIP6 by providing 3D output at daily resolution of marine biogeochemistry (piControl, historical, SSP5-8.5) and would be useful when looking at extreme events.

Project goals

1. Quantify the contributions of temperature and O_2 (as well as masking effects) on 21st century pO_2 changes;
2. Compile the COMFORT project model data ('big data', hundreds of TB) to assess model differences in pO_2 projections (and their extremes values) including at depth;
3. Compiling observational timeseries of O_2 and temperature and using these to evaluate the model's performance;
4. Calculating impact of warming and deoxygenation on marine species using the Aerobic Growth Index (Clarke et al., 2021).

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