Uncertainty in Earth System Models: Benchmarks for Ocean Model Performance and Validation

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[A] MOTIVATION:

Marine life increases the efficiency of global ocean in taken up more CO_2 and thus helps to alleviate the impact of atmospheric concentrations. Accurate projection of the influence of climate change on marine ecosystem and biogeochemical trends depends on the improvement of intrinsic representation of marine processes in contemporary Earth System Models (ESMs) and advancement in observational studies. We present the International Ocean Model Benchmarking tool to analyze diagnostic simulations and validate prognostic results..

[B] INTRODUCTION:

The ocean takes up atmospheric CO_2 by means of the solubility pump, initiated when the atmospheric gas dissolves in ocean water as a result of concentration gradients between the atmosphere and ocean surface water. Another way is through the biological pump, as marine phytoplankton uses atmospheric CO_2 to form organic carbon via the process of photosynthesis. These two complementary pumps serve as significant components of the marine carbon cycle and ultimate sequestration of carbon as detritus sink to ocean depths and cold surface ocean waters migrate downwards to form part of deep waters.

In 2015, mean ocean CO_2 sink increased from 2.6 ±0.5 $GtCyr^{-1}$, obtainable over the last decade, to 3.0 ±0.5 $GtCyr^{-1}$ [Le Quéré et al., 2016]. The increase in the amount of CO_2 and residual heat taken up by the ocean is currently influencing its circulation, biogeochemistry and the entire marine ecosystem. In addition, ocean vertical stratification resulting from increasing surface warming is set to reduce global-integrated primary production and export fluxes. Continuous warming of the global ocean may eventually limit or inhibit the efficiency of the ocean to serve as a sink. It is not clear yet where the tipping points lie.

To improve our understanding of processes in the global ocean and the implications of multiple stressors on marine life, the International Ocean Model Benchmarking (IOMB) package has been developed to analyze contemporary ocean model performance using high quality observational dataset. This effort helps to quantify uncertainties in ESMs, enhance future model development and further explicate marine contributions to climate-carbon cycle feedbacks. IOMB offers a strategic platform to engage the ocean science community in assessing marine biogeochemistry and general circulation models in support of sixth Coupled Model Intercomparison Project (CMIP6).

(a) (b) (c)

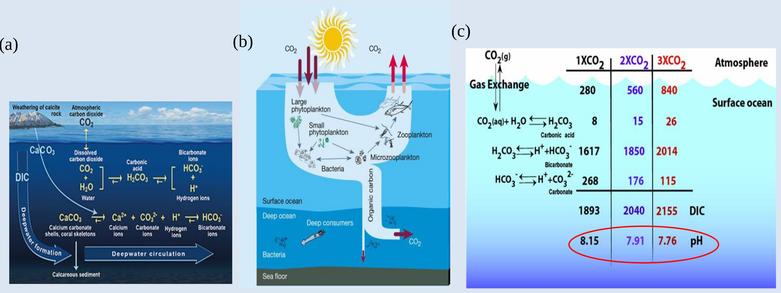
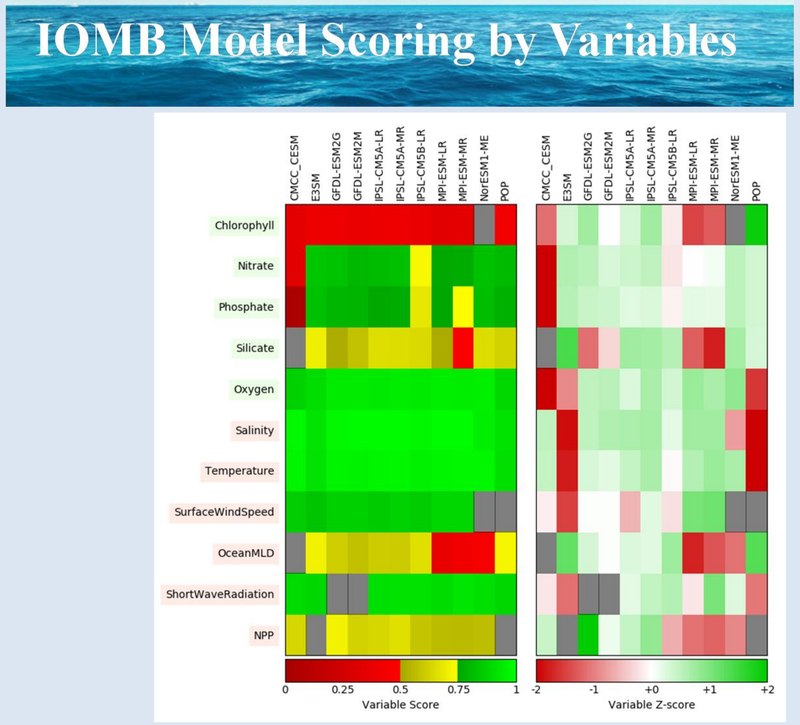


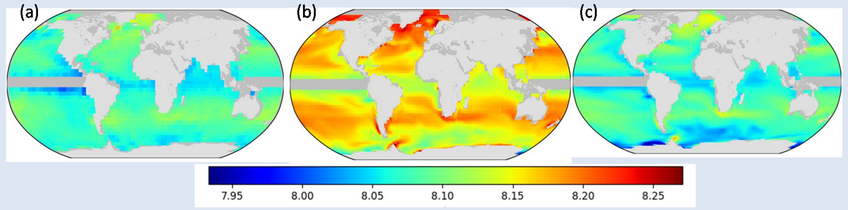
Fig a: Solubility carbon pump, extract from NOC, V.Byfield
Fig b: Biological carbon pump from S. Chisholm, "Oceanography: Stirring times in the Southern Ocean"
Fig c: Change in carbon chemistry, extract from PMEL

[C] INTERNATIONAL OCEAN MODEL BENCHMARKING (IOMB)



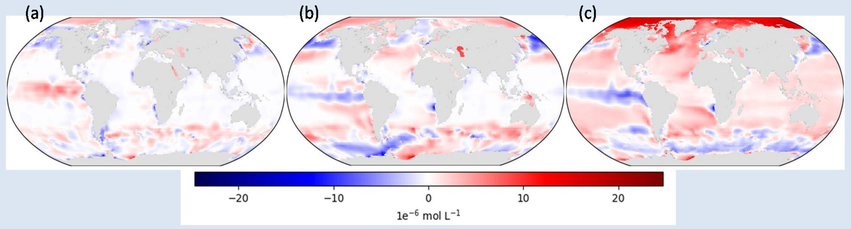
Benchmarking overview for some variables in DOE (E3SM and POP) and CMIP5 ESMs

[D] PRELIMINARY RESULTS: Single Forcing Simulations



Contemporary Global Ocean PH: (a) Observational Dataset – LDEO
(b) IPSL-CM5A-LR Natural Forcing only
(c) IPSL-CM5A-LR GHG Forcing

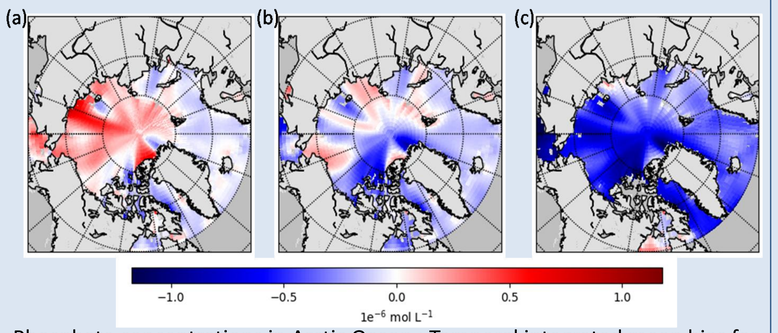
•Single forcing simulations show that the current state of the global ocean can be partially explained by the deposition and uptake of anthropogenic emissions.
•Combined effects of two or more of these forcings on ocean biogeochemical cycles and ecosystems are challenging to predict as additive and antagonistic effects may occur.



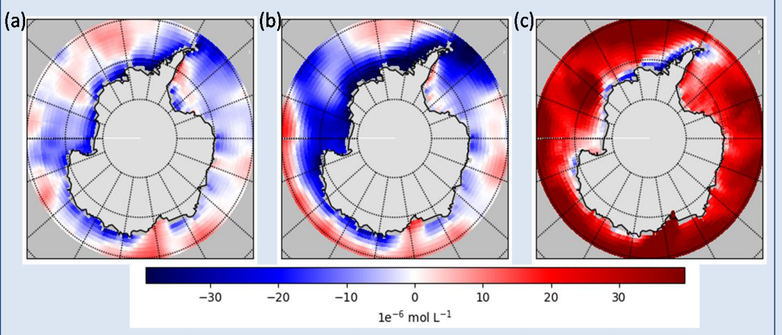
Nitrate concentrations: Temporally Integrated mean bias (a) E3SM (b) POP (c) NorESM1-ME

•Noticeable bias in polar regions and Tropical Pacific
•Biological and physical processes representing Arctic and Southern Ocean could be improved

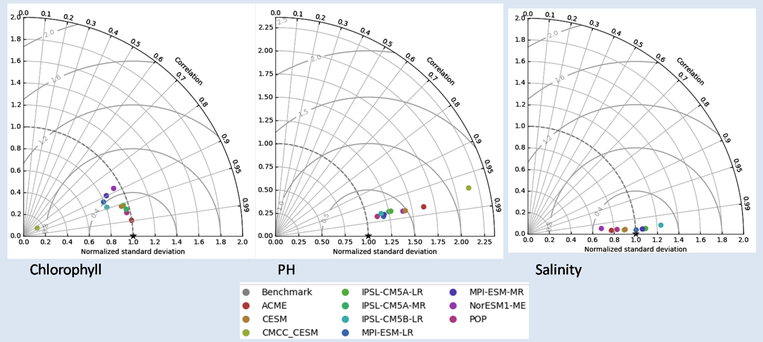
RESULTS CONTD:



Phosphate concentrations in Arctic Ocean : Temporal integrated mean bias for year 2000 (a) E3SM (b) POP (c) IPSL-LR



Silicate concentrations in Southern Ocean : Temporal integrated mean bias for year 2000 (a) E3SM (b) POP (c) IPSL-LR



Taylor diagram showing spatial distributions of some BGC variables relative to OBS

[E] CONCLUSIONS:

•Polar regions continue to show notable biases in biogeochemical and physical oceanographic variables.
•Some of these disparities could have first order impacts on the conversion of atmospheric CO_2 to organic carbon.
•The International Ocean Model Benchmarking (IOMB) package continues to gain traction within the ocean community and contributions are encouraged as we advance on developing the tool for systematic assessment of marine biogeochemistry models in support of CMIP6.

[F] ACKNOWLEDGEMENT:

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