Multi-Model Analysis of Biogeochemical Feedbacks from the Global Ocean

O. O. Ogunro[1], F. M. Hoffman[1], N. Collier[1], W. Fu[2], O. W. Wingenter[3], S. M. Elliott[4]

[1]CCSI, Oak Ridge National Laboratory, [2]UC Irvine, [3]New Mexico Tech., [4]COSIM, Los Alamos National Laboratory

ogunrooo@ornl.gov

CLIMATE CHANGE SCIENCE INSTITUTE
OAK RIDGE NATIONAL LABORATORY

Los Alamos NATIONAL LABORATORY EST. 1943

[A] MOTIVATION:

Marine phytoplankton plays a significant role in the global carbon cycle as one quarter of anthropogenic CO_2 emissions end up in the ocean. Life in the ocean increases the efficiency of marine environments to take up more CO_2 and reduces the rise in atmospheric concentrations. However, challenges with appropriate representation of physical and biological processes in Earth System Models (ESMs) undermines the effort to quantify seasonal to multi-decadal variability in ocean uptake of atmospheric CO_2 .

[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.

Although our understanding of marine inorganic carbon chemistry has developed at a fundamental level, there are still some key questions with respect to seasonal to decadal variability of marine biogeochemistry and the roles of planktons in atmospheric CO_2 uptake [e.g., Achterberg, 2014]. Understanding biological and physical processes in the global ocean is crucial in answering these questions as atmospheric CO_2 would have increased by almost 200 ppm in the absence of the biological pump [Sarmiento and Toggweller, 1984]. Thus, it is essential to validate marine biogeochemical representations in contemporary ESMs. Appropriate quality control of the marine carbon cycle representation in ESMs could be achieved by promoting unique ways to use observational datasets to constrain model results and inform future model developments.

In a bid to improve analyses of marine contributions to climate–carbon cycle feedbacks, the International Land Model Benchmarking (ILAMB) project at ORNL is now expanding to meet the growing benchmarking needs of ocean biogeochemistry models. This expansion includes modification of the ILAMB package to satisfy some intrinsic demands of the Ocean community, and use the generated International Ocean Model Benchmarking (IOMB) package to validate DOE ocean model biogeochemistry results with observational datasets. This verification and validation system will also be employed to analyze outputs from other international ocean models, including those that contributed results to the fifth phase of Coupled Model Intercomparison Project (CMIP5) and to CMIP6.

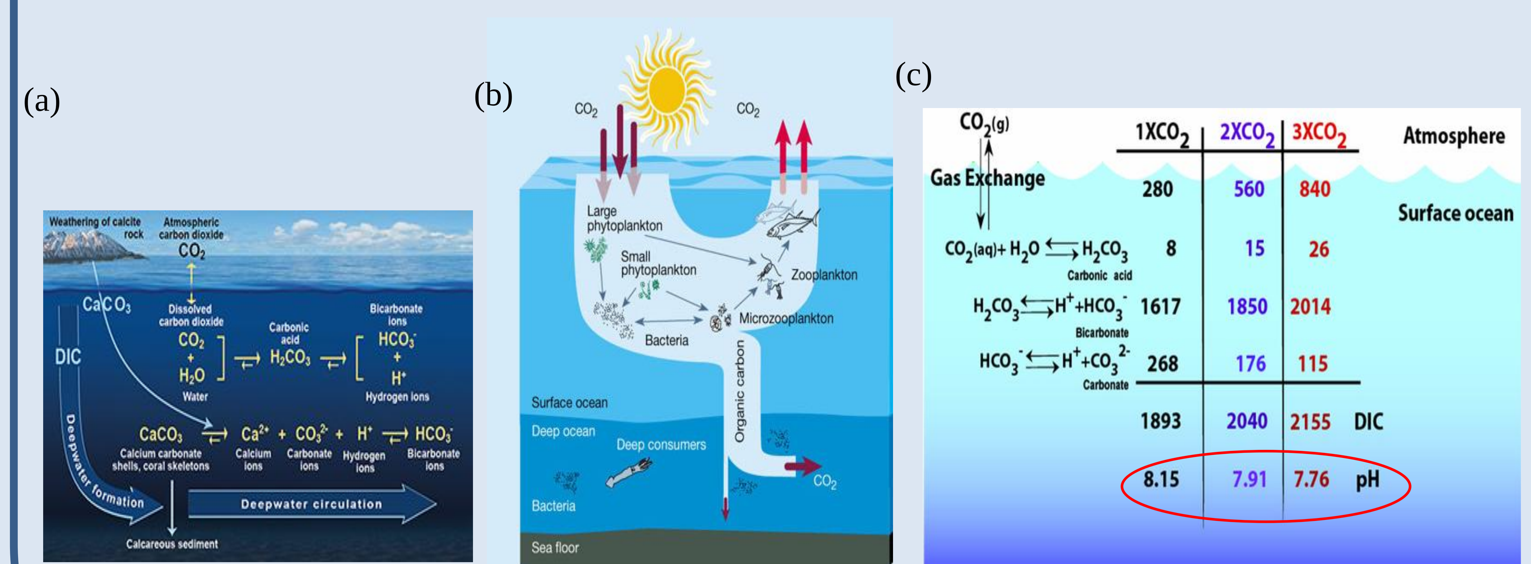
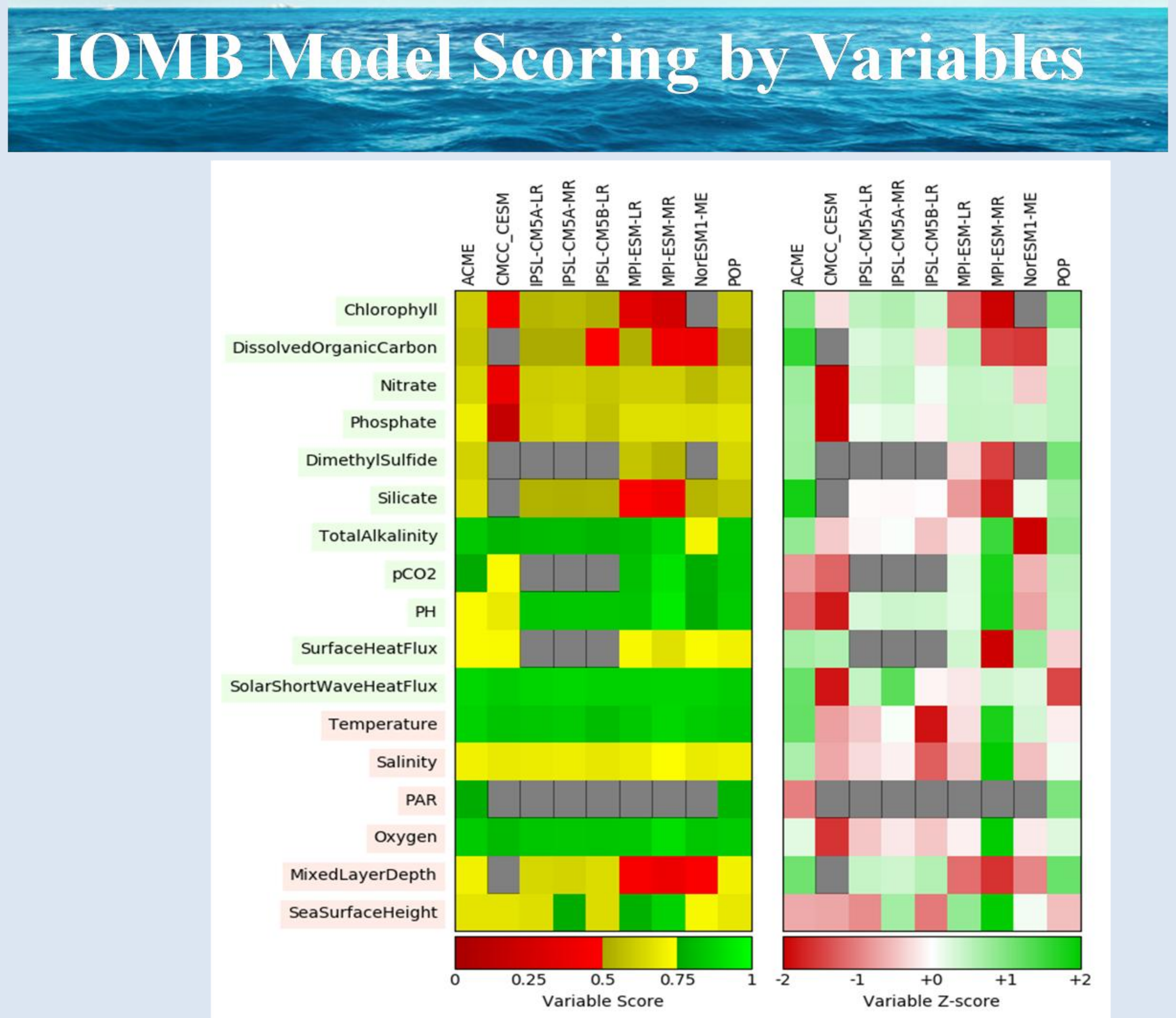


Fig a: Solubility carbon pump, extract from NOC, V.Byfield

Fig b: Biological carbon pump from S. Chisholm, "Oceanography: Stirring times in the Southern Ocean"

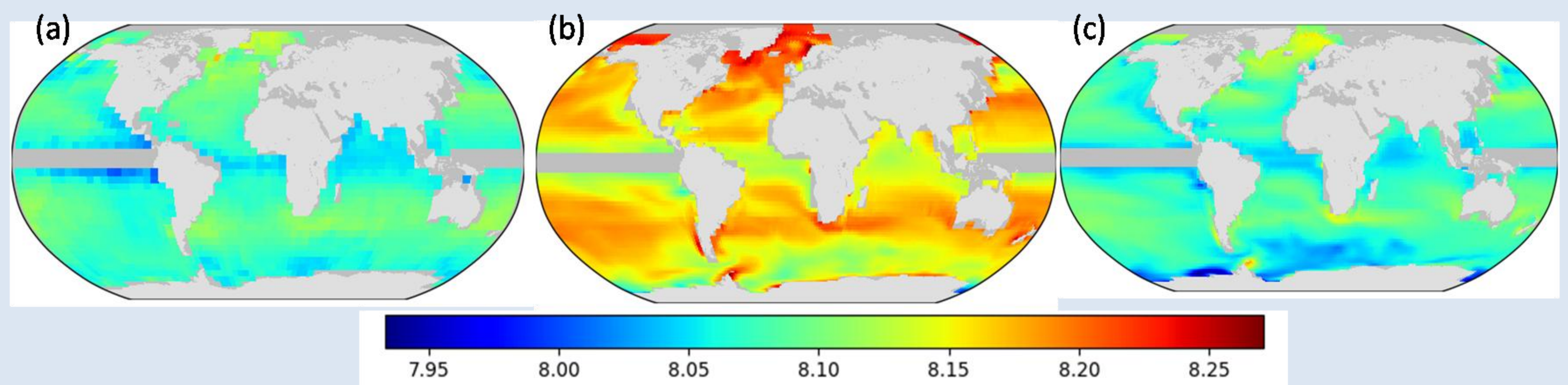
Fig c: Change in carbon chemistry, extract from PMEL

[C] INTERNATIONAL OCEAN MODEL BENCHMARKING (IOMB)



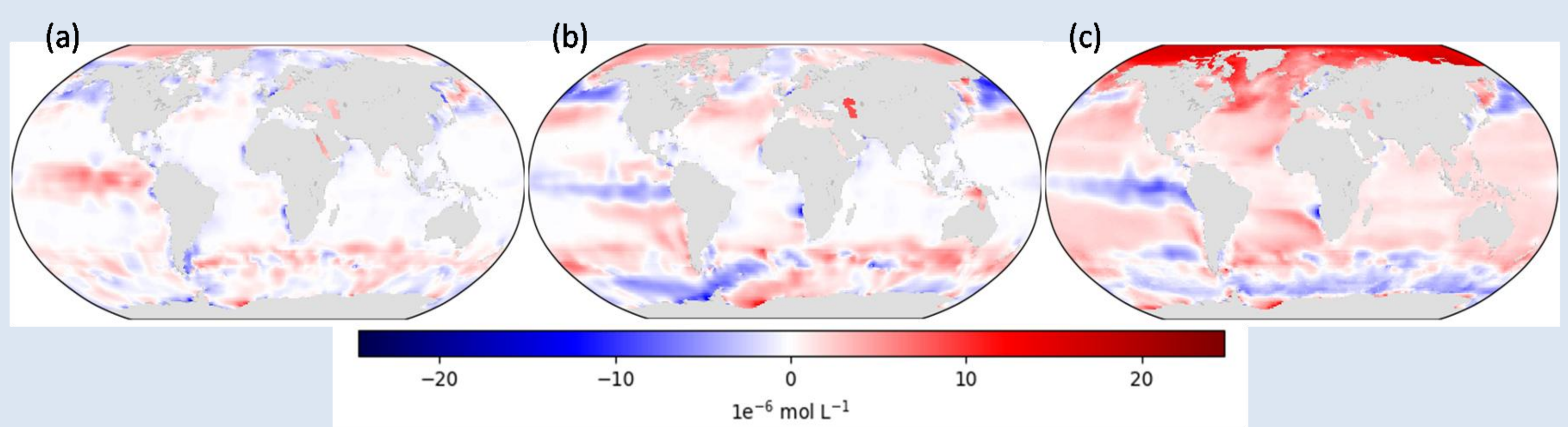
Benchmarking overview for some variables in DOE (ACME and POP) and CMIP5 ESMs

[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

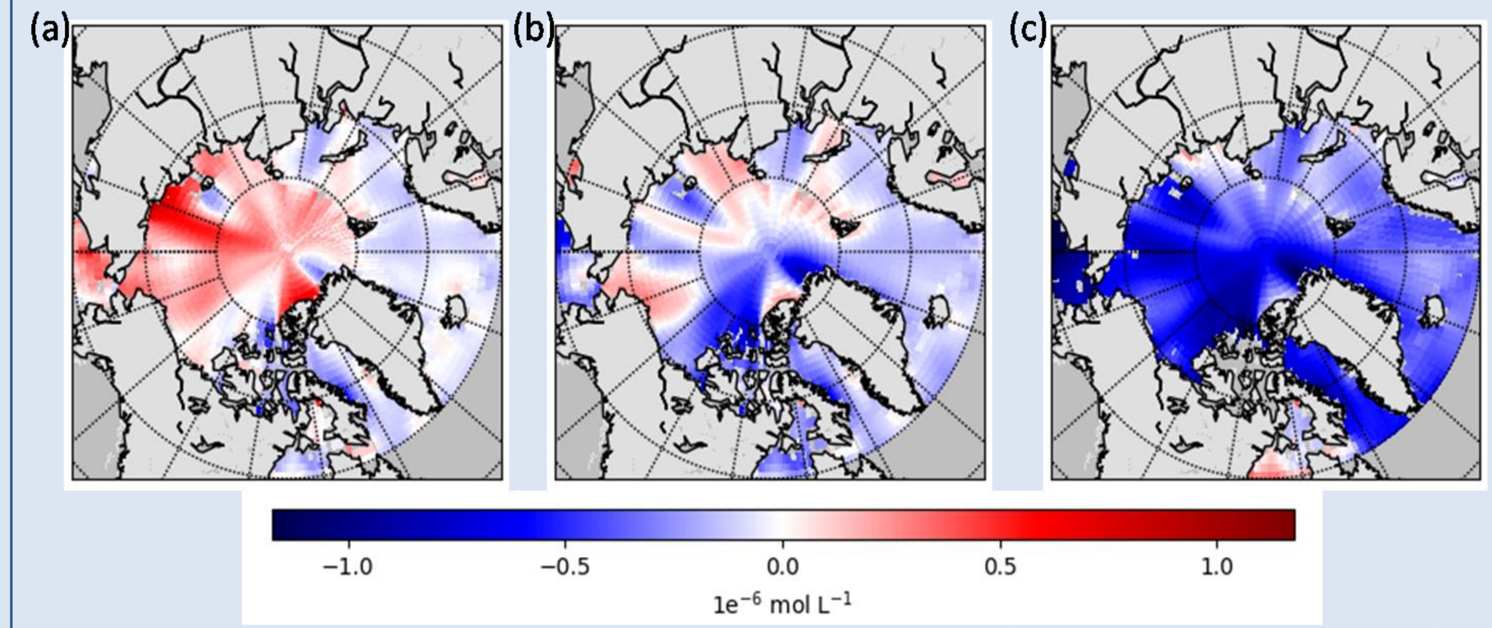
- Single forcing simulations show that the current state of the global ocean can be partially explained by the deposition and uptake of anthropogenic emissions.
- Combined effects of two or more of these forcings on ocean biogeochemical cycles and ecosystems are challenging to predict as additive and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



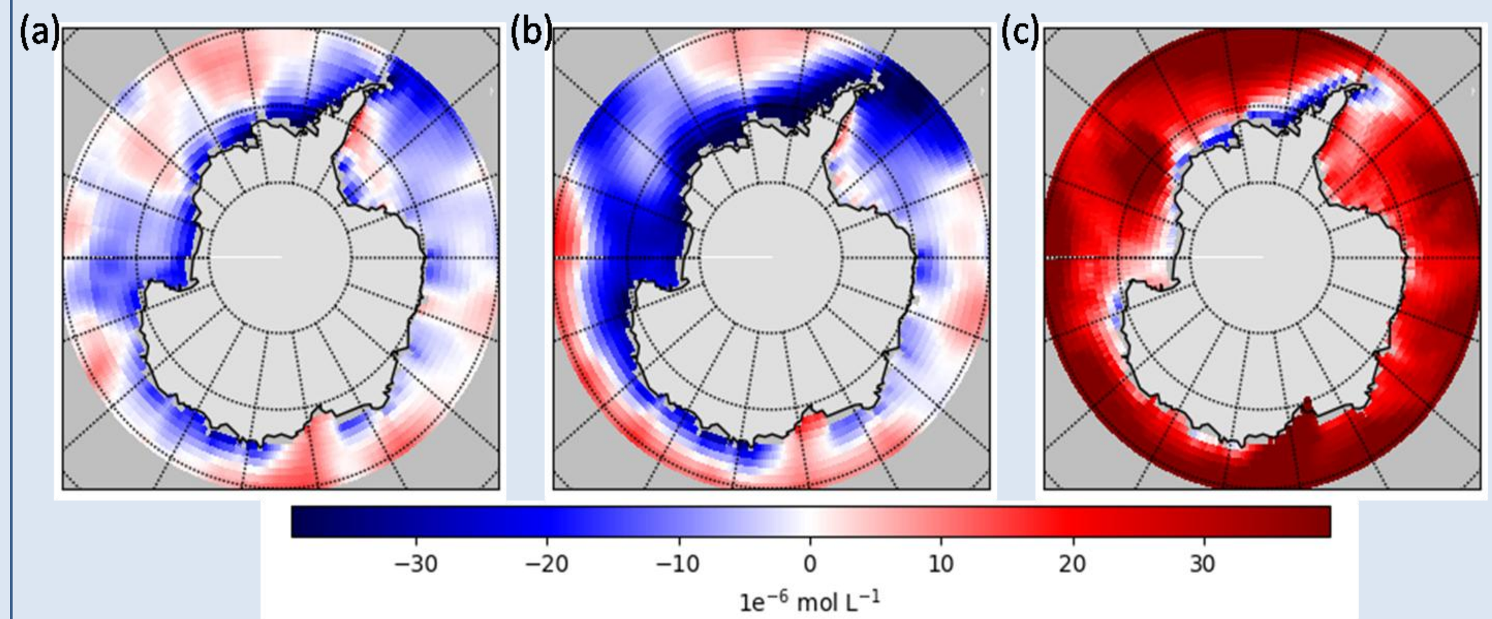
Nitrate concentrations: Temporally Integrated mean bias (a) ACME (b) POP (c) NorESM1-ME

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

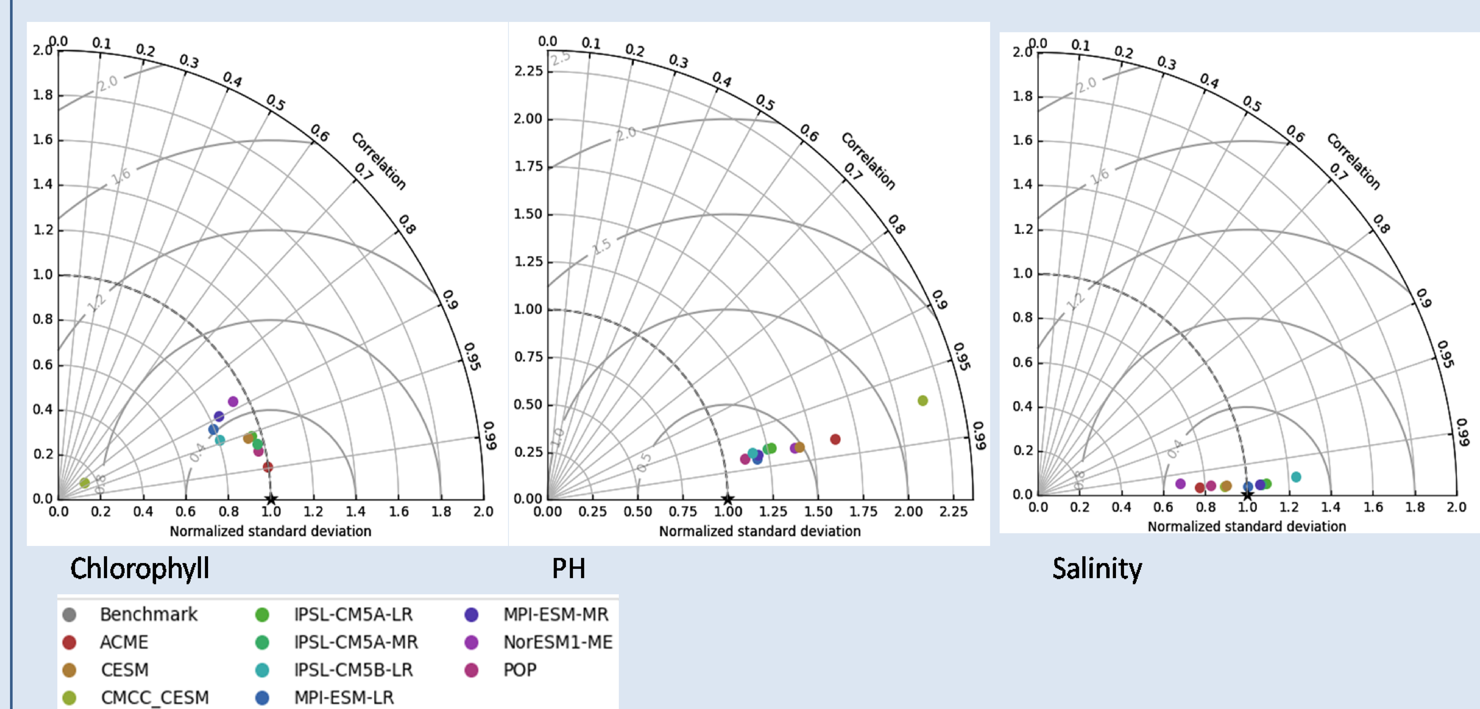
RESULTS CONTD:



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



Silicate concentrations in Southern Ocean : Temporal integrated mean bias for year 2000 (a) ACME (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.
- A benchmarking tool for marine biogeochemical results is indispensable as we continue to improve ESM process representations and understand the dynamics of climate – carbon cycle feedbacks from the ocean.

[F] ACKNOWLEDGEMENT:

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