Collaborative Proposal: Understanding Arctic Marine Biogeochemical Response to Climate Change for Seasonal to Decadal Prediction Using Regional and Global Climate Models

Synopsis: This project will use the Regional Arctic System Model (RASM), comprised of marine biogeochemistry (mBGC) components in the eddy-resolving ocean and sea ice models to ***advance understanding and prediction of the Arctic biogeochemical system,*** including shelf-basin and vertical nutrient exchange, the subsurface chlorophyll maximum, ice edge and under ice blooms and their role in ecosystem response to climate change. It builds on the recent and ongoing research by the PIs, including the development and evaluation of mBGC components for global sea ice / ocean models and the high-resolution RASM.

Intellectual Merit: There are many physical processes, such as mesoscale eddies, mixed layer dynamics, ocean coastal and boundary currents, upper ocean stratification, varying sea ice cover, marginal ice zone (MIZ) expansion and ice edge upwelling that influence nutrient transport, light availability and ocean stratification, which are critical to marine primary production (PP) and carbon cycling in the Arctic Ocean. Such processes and feedbacks among them might be intimately involved in the recent dramatic changes observed in the Arctic, yet their representation in state-of-the-art global climate and Earth System models (GC/ESMs) is limited due to coarse spatial resolution. Existing data suggest that changes in biological communities of the Arctic marginal seas are concurrent with shifts in regional atmospheric and hydrographic forcing. We hypothesize that:
1. Nutrients are transported from shelves to the Arctic Basin through narrow currents and eddy transport across the shelf break. The temporal and spatial variation of ***eddy transport is a critical factor controlling the observed distribution of primary production*** in the Arctic Basin.
2. Blooms under sea ice cover and along the expanding MIZ are due to enhanced stratification and greater light penetration through ice that is thin and frequently covered by melt ponds. ***High spatial resolution simulation is critical to resolving such blooms and processes controlling them***.
3. In addition, we contend that ***representation of spatial and temporal patterns of primary production will be improved by high spatial resolution in RASM-mBGC***, which will facilitate more accurate estimates of the arctic marine carbon budget.
To address these hypotheses, we will evaluate and synthesize RASM-mBGC results with available ocean, sea ice and biogeochemical data to investigate the significance of high spatial resolution (~5-50 times higher than currently used in global models) in ***representing critical physical and biological processes controlling Arctic marine primary production*** and to facilitate the development of strategies to prepare and adapt to consequences of climate change. We will also compare outputs from RASM-mBGC and the Community Earth System Model (CESM), consisting of the same ocean, sea ice, and marine biogeochemistry model components to:
• Quantify the magnitude of biogeochemical inaccuracies in coarse resolution models
• Assess the role of 'missing' processes on spatio/temporal biogeochemical property distributions
• Determine the need for explicit representation or upscaling of small-scale arctic processes and feedbacks in GC/ESMs.

Broader Impacts: Our K-12 education strategy focuses on grassroots efforts for the PIs to present special classes. Within the college environment, PIs will use problems encountered in this project to aid teaching of undergraduate and graduate biological and physical science courses. Project findings and simulation results will be broadly disseminated through peer-reviewed publications, presentations at conferences and workshops, public lectures and the project website. The proposed work targets key points of the 2013-2017 US Arctic Research Plan (National Science and Technology Council, 2013), especially combining the use of regional and global Earth System Models to improve the skill and reduce uncertainty in climate projections in the Arctic. Project outcomes will aid the U.S. meeting its arctic obligations and interests in line with the National Strategy for the Arctic Region (Office of the President, 2013), DOD Arctic Strategy (2013) and Navy Arctic Roadmap (2013) regarding the need for tools to provide operational forecasting and climate projection capabilities in the Arctic. All the above are discussed in detail in section C8.