Name: Riley Brady

Research Statements

This information is vital to the overall evaluation of your application.

Field of Interest and the Role of Computational Science

Describe an important, outstanding scientific or engineering challenge in your field of interest. What would be the impact on the field and/or on science, engineering and/or society in general if this challenge could be successfully addressed? How could high performance computing and mathematics help address all or part of the challenge you have described?

It is difficult to make multi-decadal predictions of climate change impacts, particularly over regional scales where uncertainty is high. This is because our evolving climate responds to a number of factors: anthropogenic global warming (AGW), internal climate variability (ICV), such as El Nino events, and random external forcings, such as volcanic eruptions. As we are fundamentally unable to predict the last factor, our ability to model and separate the relative impacts of AGW and ICV will be the key to making more accurate multi-decadal forecasts.

Historically, climate model developers initialized their models from a single state and forced them with a range of future emissions scenarios. While this method quantifies uncertainty due to AGW, it can only be used to forecast the combined impacts of AGW and ICV--by using a single set of initial conditions, variability in the natural climate is suppressed. More recently, climate modeling centers, such as the National Center for Atmospheric Research (NCAR), have begun to experiment with round-off level differences in model initialization, allowing small differences to propagate through the chaotic climate system. In turn, they generate an ensemble, or a range of ‘possible realities.' Through this, one can consider uncertainty due to natural variability, estimating the resilience of the AGW ‘signal' to the background ‘noise' of ICV.

Due to the high computational costs associated with producing such an ensemble, the NCAR climate prediction ensemble is simulated at a coarse spatial resolution (1° x 1°). This is fine for forecasting large-scale phenomena--such as global precipitation--but makes forecasting finer-scale phenomena--such as complex regional ecosystems--much more difficult. Fortunately, one can use high performance computing approaches such as dynamical and statistical downscaling to resolve this issue.

The future of climate science relies on high performance computing to make the most skillful forecasts possible with the tools available today. The availability of these forecasts will be invaluable to policy- and decision-makers. Due to the long-term thermal inertia of the oceans, the actions of society today will impact the Earth for decades to come.

Research Using High-Performance Computing and/or Large Data Analysis

Describe the particular science or engineering problem that you would like to pursue in your research. How could you use high performance computing and mathematics to help address this problem? How would you demonstrate the success of your approach?

Eastern Boundary Upwelling Ecosystems (EBUE) occur at the eastern edge of ocean basins, where cross-shore pressure gradients mediate alongshore winds that produce upwelling currents. These currents provide nutrient-rich waters from depth, fueling productive ecosystems that cover 5% of the ocean surface, but contribute to 25% of global fish catch. Thus, the response of EBUE to climate change is of critical concern for food security.

EBUE are controlled from the bottom-up by phytoplankton. As such, it is crucial to investigate biogeochemistry (BGC) in EBUE by exploring changes in water chemistry, nutrients, and so on. However, BGC in EBUE is sensitive to atmospheric and oceanic variability; one must consider internal climate variability to make accurate forecasts of BGC.

Modelers now perturb the initial conditions of their climate models to generate an ensemble of ‘possible realities' from which they may extract the relative impacts of anthropogenic and natural climate change. However, it is computationally-intensive to generate a BGC ensemble with this method. Whereas a physical ocean model uses temperature and salinity to track flow (2 tracers), BGC models use as many as 30 chemical tracers, increasing the computational cost roughly 6-fold. To date, ocean BGC ensembles are only available at a coarse spatial resolution (1°x1°). This is an issue because previous research shows that coarse-resolution models fail to capture small-scale variability in ocean BGC, as compared to observations.

I propose a novel approach to generating multi-decadal predictions of BGC in the California Current System (CCS), the most observationally-dense of EBUE. Using a method called dynamical downscaling, I will force the boundary conditions of a regional high-resolution (0.1°x0.1°) physical and BGC model of the CCS with iterations of the perturbed initial conditions coarse-resolution model. By doing so, I may isolate the influence of large-scale climate variability on future BGC in the CCS. While there are many ways to demonstrate success in this approach, the most marked indicator would be if my dynamically-downscaled high-resolution runs captured more BGC variability than that of the stand-alone coarse-resolution climate model.

Program of Study

Describe how the courses listed in your planned program of study would help prepare you to address the challenges you have described in questions 1 and 2. Discuss your rationale for choosing these courses.

Projects addressing the challenge of generating skillful multi-decadal