Title: **Collaborative Research: Advancing Arctic Climate Projection Capability at Seasonal to Decadal Scales**

Synopsis: This interdisciplinary project will apply the Regional Arctic System Model (RASM) at process resolving configurations to (i) advance understanding of physical processes and feedbacks involved in Arctic amplification of global climate change and (ii) understand and potentially reduce uncertainty in prediction of arctic climate change at seasonal to decadal scales. In addition, a hierarchy of RASM and the Community Earth System Model (CESM) configurations will be used to investigate space dependence of model parameters of relevance to Arctic amplification and to optimize and improve model simulations against observationally based metrics. RASM is designed as a regional counterpart to CESM, with the same ocean and sea ice components and coupling framework. Its atmospheric component, the Weather and Research Forecasting (WRF) model, allows dynamical downscaling of output from the CESM Community Atmospheric Model (CAM). In addition to its own land model, the Variable Infiltration Capacity (VIC), RASM will also use the CESM land model (CLM), to better understand each model advantages and limitations in simulating Arctic land processes (i.e. hydrology and dynamic vegetation) and to facilitate their potential merger. The project builds upon successful research by the PIs with support from the following programs: DOE Regional and Global Climate Modeling, ONR Arctic and Global Prediction and NSF Office of Polar Programs.

Intellectual Merit: The project's main goal is to match arctic surface climate sensitivity to particular processes and space-dependent parameters and identify spatio-temporal changes in these relationships using a hierarchy of models evaluated against observationally based metrics. We will: (i) quantify the added value of using regional models for downscaling arctic simulations from global climate and Earth System models (GC/ESMs), (ii) address the impacts of high resolution, improved process representation and coupling between model components on predictions, (iii) identify the most important processes and provide guidance to optimize the parameter space for future high resolution GC/ESMs, using CESM as a test bed. We will use RASM and CESM historical output to examine mass, heat, moisture, and salt/freshwater convergence to and budget within the Arctic and to investigate natural climate variability in the Arctic, including that externally forced from outside and internal to the pan-Arctic region (i.e. outside/within the RASM domain). Finally, we will run seasonal to decadal predictability studies with RASM ensembles generated using CESM 21st century decadal scenarios. The following three science hypotheses will be addressed with the above approach.

Hypothesis #1 - There are scale dependent surface feedbacks that can influence the rate of Arctic wide response to anthropogenic climate forcing. An accelerated shift toward seasonal sea ice cover will happen sooner than currently predicted by GC/ESMs due to a combination of physical processes and feedbacks, currently under-represented or not represented at all in GC/ESMs, in addition to global warming.

Hypothesis #2 - Mesoscale processes and their interactions are critical to improved representation of the past and present state of the Arctic Climate System, which determines the initial climate state used for prediction of future climate change. By utilizing a high spatio-temporal resolution in RASM's individual components and in their coupling relative to CESM, we expect to advance representation of many critical physical processes controlling arctic climate and its variability.

Hypothesis #3 - RASM will demonstrate significant gains in simulating the past and present states of arctic climate and will help optimize varying parameter space for future high-resolution global simulations, which will improve prediction of arctic change, especially at seasonal to decadal scales.

Broader Impacts: This project will address increasing societal needs for improved arctic seasonal to decadal climate predictions. It will facilitate further progress in arctic climate change prediction by optimizing parameter space in key physical parameterizations for improved climate simulation and prediction at increasing spatial and temporal resolutions. It will capitalize on the synergy between the development of regional and global climate models and their use in the assessment and attribution of arctic climate variability. This project will test climate model sensitivity to spatial resolutions not yet realistic in GC/ESMs. Findings from this research will (i) guide future improvements of CESM and other GC/ESMs, (ii) afford considerable computational savings over established parameter uncertainty quantification techniques and for historical and scenario simulations using ESMs and (iii) facilitate better prediction of impacts of arctic climate change to inform adaptation policy. As such, this project directly addresses several key requirements of the Variability and Change element of the current FOA and the RGCM program, including the (i) construction of multi-model Arctic test-bed tool, (ii) development of systematic evaluation metrics and (iii) evaluation of arctic climate variability and change, as well as the (iv) advancement of uncertainty quantification methods to (v) guide model development and improvement and (vi) improve confidence in future arctic climate change projections.