Project title: Collaborative Proposal: Improving Decadal Prediction of Arctic Climate Variability and Change Using a Regional Arctic System Model (RASM)
Federal award identification number: DE-SC0006643
Project period: 9/1/11 to 8/31/16
Reporting period: 9/1/11 to 8/31/16
Budget period: 9/1/11 to 8/31/16
Principal Investigator: William J. Gutowski, Jr., 3021 Agronomy Hall, Iowa State University, Ames, IA 50011, gutowski@iastate.edu, 515-294-5632

Accomplishments

1. What are the major goals of the project?

This project will develop and apply a regional Arctic System model for enhanced decadal predictions. It builds on successful research by four of the current PIs with support from the DOE Climate Change Prediction Program, which has resulted in the development of a fully coupled Regional Arctic Climate Model (RACM) consisting of atmosphere, land-hydrology, ocean and sea ice components. An expanded RACM, a Regional Arctic System Model (RASM), will include ice sheets, ice caps, mountain glaciers, and dynamic vegetation to allow investigation of coupled physical processes responsible for decadal-scale climate change and variability in the Arctic. RASM will have high spatial resolution (~5-50 times higher than currently practical in global models) to advance modeling of critical processes and determine the need for their explicit representation in Global Earth System Models (GESMs).

2. What was accomplished under these goals?

The primary outcome of the project was the development of the Regional Arctic System Model (RASM).

Model development, testing and application

We implemented in RASM the optional reading in of time-varying GHGs into WRF's radiation schemes, and time-varying extended ocean SSS and SST into the flux coupler (CPL). With these features, atmospheric and ocean surface boundary conditions used to force RASM have been generated from NCAR CCSM4. Additional changes are allowing RASM to ingest time-varying ocean lateral boundary conditions. These new features allow RASM to simulate future Arctic climate, which will advance understanding of future climate change. Additional changes are allowing RASM to ingest time-varying ocean lateral boundary conditions.

Iowa State University (ISU), in conjunction with the Cassano group at the University of Colorado (CU) has performed numerous regional climate model (RCM) studies over the Arctic, using two domains. While the domains differ in size, they both encompass vital components of the Arctic climate system. In the first study, Glisan et al., (2013) analyzed how changing the spectral nudging coefficient in a polar-optimized version of the Weather Research and Forecasting (WRF) model affected mean and extreme precipitation and temperature events across four high-latitude analysis region. Spectral nudging had been invoked in the model to remove high-latitude circulation biases that appeared when no nudging was used. We found that an order of magnitude decrease in the default WRF nudging coefficient yielded physically realistic extremes, without an unnecessarily large and artificial numerical correction in the large scale forcing. Additional work is examining the sensitivity of model storm tracks along the North Pacific and North Atlantic to varying the spectral nudging and model top height. Initial results have shown the model's North Pacific storm tracks improve with reduced spectral nudging strength and increased

model top height relative to the default values, when compared with behavior in the ERA-Interim reanalysis.

After the spectral nudging study, we began simulation on the smaller Coordinated Regional Climate Downscaling Experiment (CORDEX) Arctic domain, with the same polar-optimized WRF model. These simulations established the physical credibility of WRF simulations for extreme behavior in summer (Glisan and Gutowski, 2014a) and winter (Glisan and Gutowski, 2014b) seasons. They also gave insight into the nature of extremes in select Arctic regions. Additionally, we showed that topography plays an important role in the dynamical processes producing widespread precipitation events in high-latitude North America.

We have used the polar-optimized WRF to evaluate circulation regimes in the Arctic atmosphere (Fisel and Gutowski, 2011) and their relationship to extremes in daily temperature (Fisel and Gutowski, 2016). Further work is evaluating how the potential for extreme weather will change in the future, projected climate of the Arctic.

The most recent component of ISU/CU research endeavor involves the analysis of polar temperature and precipitation extremes using Self-organizing maps (SOMs). Our results (Cassano et al. 2015a, 2015b, Glisan et al. 2016) show that the polar-optimized WRF simulates well physical processes creating daily widespread events in Alaska. Moreover, SOMs are a powerful tool in diagnosing physical characteristics leading to extreme. In a broader sense, we are confident that the SOM technique gives us another method for analyzing changes in present and future climate extremes.

3. What opportunities for training and professional development has the project provided?

Two junior scientists were supported on this project. J. Glisam worked on this project as a graduate research assistant while completing his Ph.D. His Ph.D. was based on work completed for the RASM project. He later received partial support as a postdoctoral scientist. B. Fisel also worked on this project. He completed an M.S. and will be completing his Ph.D. soon. They both gained experience in model formulation, application and analysis in a high performance computing environment. They also learned how to collaborate with a multi-institutional research team while also gaining experience presenting results at conferences and publishing peer-reviewed research papers.

4. How have the results been disseminated to communities of interest?

Members of the Gutowski research group at the Iowa State University were the lead authors on 7 peer reviewed publications that have been completed or submitted on work related to this project. Members of the Gutowski research group were authors or co-authors on 19 international and national conference presentations, many invited, on work related to this project.

Products

Journal article: Multiregime states of Arctic atmospheric circulation
Journal: *Journal of Geophysical Research*
Publication date: 2011
Publication status: Published
Volume: 116
First page number or eLocation ID: D20122
Issue:
Publication location: Ames, IA

Authors: Fisel, B. J., W. J. Gutowski, Jr., J. M. Hobbs, and J. J. Cassano
Publication identifier type: DOI
Publication identifier: doi: 10.1029/2011JD015790
Acknowledgement of DOE support: Yes
Peer reviewed: Yes

Journal article: Effects of Spectral Nudging in WRF on Arctic Temperature and Precipitation Simulations.
Journal: *Journal of Climate*
Publication date: 2013
Publication status: Published
Volume: 26
First page number or eLocation ID: 3985
Issue:
Publication location: Ames, IA
Authors: Glisan, J.M., W. J. Gutowski, J. J. Cassano and M E. Higgins
Publication identifier type: DOI
Publication identifier: doi: 10.1175/JCLI-D-12-00318.1
Acknowledgement of DOE support: Yes
Peer reviewed: Yes

Journal article: WRF Summer Extreme Daily Precipitation over the CORDEX Arctic
Journal: . *Journal of Geophysical Research*
Publication date: 2014a
Publication status: Published
Volume: 119
First page number or eLocation ID: 1720
Issue:
Publication location: Ames, IA
Authors: Glisan, J.M., and W. J. Gutowski
Publication identifier type: DOI
Publication identifier: doi: 10.1002/2013JD020697
Acknowledgement of DOE support: Yes
Peer reviewed: Yes

Journal article: WRF Winter Extreme Daily Precipitation over the CORDEX Arctic
Journal: *Journal of Geophysical Research*
Publication date: 2014b
Publication status: Published
Volume: 119
First page number or eLocation ID: 10,738
Issue:
Publication location: Ames, IA
Authors: Glisan, J.M., and W. J. Gutowski
Publication identifier type: DOI
Publication identifier: doi: 10.1002/2014JD021676
Acknowledgement of DOE support: Yes
Peer reviewed: Yes

Journal article: Synoptic Conditions During Wintertime Temperature Extremes in Alaska
Journal: *Journal of Geophysical Research*
Publication date: 2015
Publication status: Published
Volume: 120
First page number or eLocation ID: 3241
Issue:

Publication location: Ames, IA
Authors: Cassano, J. J., E. N. Cassano, M. W. Seefeldt, W. J. Gutowski and J. M. Glisan
Publication identifier type: DOI
Publication identifier: doi: 10.1002/2015JD024404
Acknowledgement of DOE support: Yes
Peer reviewed: Yes

Journal article: Analysis of WRF extreme daily precipitation over Alaska using self-organizing maps
Journal: . *Journal of Geophysical Research*
Publication date: 2016
Publication status: Published
Volume: 121
First page number or eLocation ID: 7746
Issue:
Publication location: Ames, IA
Authors: Glisan, J.M., W. J. Gutowski Jr., J. J. Cassano, E. N. Cassano, and M. W. Seefeldt
Publication identifier type: DOI
Publication identifier: doi: 10.1002/2016JD024822
Acknowledgement of DOE support: Yes
Peer reviewed: Yes

Journal article: Development of the Regional Arctic System Model (RASM: Near surface atmospheric climate sensitivity
Journal: *J. Climate*
Publication date: 2017
Publication status: Published
Volume: 30
First page number or eLocation ID: 5729
Issue:
Publication location: Boulder, CO
Authors: Cassano, J.J., A. DuVivier, A. Roberts, M. Hughes, M. Seefeldt, M. Brunke, A. Craig, B. Fisel, W. Gutowski, J. Hamman, M. Higgins, W. Maslowski, B. Nijssen, R. Osinski, and X. Zeng
Publication identifier type: DOI
Publication identifier: 10.1175/JCLI-D-15-0775.110.1175/JCLI-D-15-0775.1
Acknowledgement of DOE support: Yes
Peer reviewed: Yes

Journal article: Arctic Model Dynamical Regimes and Temperature Extremes
Journal: *Journal of Geophysical Research*
Publication date: TBD
Publication status: In review
Volume:
First page number or eLocation ID: TBD
Issue:
Publication location: Ames, IA
Authors: Fisel, B. J., and W. J. Gutowski
Publication identifier type: DOI
Publication identifier: TBD
Acknowledgement of DOE support: Yes
Peer reviewed: Yes

Intellectual property detail

Technologies and techniques detail

Other products detail

Participants and other collaborating organizations

Participant detail

Participant: William Gutowski
Project Role: Principal investigator
Funding support if other than this award: Gutowsk's academic year salary was paid by Iowa State University
Contribution to project: Gutowski oversaw aspects of model development, application and output analysis and coordinated his group's research activities with other RASM collaborators.
International collaboration: No
International travel: No

Participant: Justin Glisan
Project Role: Graduate research assistant, then postdoctoral scientist
Funding support if other than this award: None
Contribution to project: Glisan performed multiple simulations to test and analyze polar-optimized WRF's behavior under the implementation of spectral nudging. He also performed simulations and analyses validating the model's ability to simulate processes yielding extreme precipitation events in the arctic. He prepared results from his research for his Ph.D. thesis, presentations at conferences and publications in peer-reviewed journals.
International collaboration: No
International travel: No

Participant: Brandon Fisel
Project Role: Graduate research assistant
Funding support if other than this award: None
Contribution to project: Fisel implemented and tested model changes to allow ingestion from GCM output of time varying greenhouse gases, ocean sea-surface temperature and salt (where specified) and ocean lateral boundary conditions. He further analyzed Arctic atmospheric circulation regimes and their influence on the occurrence of Arctic temperature extremes. He prepared results from his research for his M.S. and Ph.D. theses, presentations at conferences and publications in peer-reviewed journals.
International collaboration: No
International travel: No

Partner detail

Naval Postgraduate School, University of Colorado, University of Washington, University of Arizona, University of California/Santa Cruz, Los Alamos National Laboratory, University of Texas at El Paso.

Other collaborators
N/A

Impact

1. What is the impact on the development of the principle discipline(s) of the project?

This project has led to the development and performance analysis of the Regional Arctic System Model (RASM). RASM is a high resolution regional model that couples atmosphere, ocean, sea ice, and land model components.

2 What is the impact on other disciplines?
By focusing on coupled Arctic climate, this project implicitly addresses multiple disciplines, including oceanography, sea ice, atmosphere, and land hydrology as well as multi-connections among those disciplines.

3. What is the impact on the development of human resources?

Two junior scientists were supported through funds from this project at Iowa State University. One completed his Ph.D. thesis based on research funded by this project and the other completed his M.S. thesis and has nearly completed his Ph.D. thesis based on research funded by this project.

4. What is the impact on physical, institutional, and information resources that form infrastructure?
N/A

5. What is the impact on technology transfer?
N/A

6. What is the impact on society beyond science and technology?

Outcomes from this work aid Arctic stewardship and U.S. interests in line with the National Strategy for the Arctic Region (Office of the President, 2013) and the need for practical tools to better understand and predict Arctic climate for commercial, operational, and policy making purposes.

7. Foreign spending
N/A