Collaborative Research: Towards Advanced Understanding and Predictive Capability of Climate Change in the Arctic using a High-Resolution Regional Arctic Climate System Model

YEAR 4 PROGRESS REPORT

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University of Washington
Co-PI: Dennis P. Lettenmaier

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This report summarizes work at the University of Washington over the course of the subject project. The primary activities conducted during the past 12 months are summarized below.

Phase 1: Climate system component studies via one-way coupling experiments

This task proposed to conduct the off-line simulation of Arctic climate and hydrology by using uncoupled climate system component models. We performed a set of simulations (from 1979 to 1999) with the VIC (Variable Infiltration Capacity) land surface scheme implemented at 100 km EASE-Grid across the Pan-Arctic domain to provide a consistent baseline hydroclimatology for the region. The meteorological data consist of daily time-series of precipitation (for the period 1979 through 1999), maximum temperature, minimum temperature, and wind speed. Monthly time-series precipitation was estimated by adjusting the Willmott and Matsuura [2001] grids for gauge undercatch, as described by Adam and Lettenmaier [2003], and for orographic effects, as described by J. C. Adam et al. [2005]. Monthly maximum and minimum temperatures were created mainly from the Climate Research Unit (CRU) Version 2 data set of T. D. Mitchell et al. Streamflow observations at various basin outlets, satellite-based snow cover extent, observed lake freeze-up and break-up, sited monitored summer permafrost maximum active layer thickness were used to evaluate various simulated hydrologic variables. The results indicate that the VIC model was able to reproduce these hydrologic processes in the Arctic region.

Phase 2: Development of the Regional Arctic Climate System Model (RACM)

As part of the development of a state-of-the-art RACM including high-resolution atmosphere, ocean, sea ice, and land hydrology components, we implemented the macroscale hydrologic model VIC (Variable Infiltration Capacity) within the CCSM4 (Community Climate System Model) system. The VIC model has been successfully coupled with WRF/CAM through the new coupling architecture CPL7. Several new VIC features have been implemented within the CCSM4 structure over the last year: VIC can now run at sub-hourly time step, and can directly use rainfall and snowfall amounts provided by the flux coupler rather than performing its own partitioning based on surface air temperature. The energy balance for snow covered area has also been revised. Following implementation of these and other improvements, CAM/VIC has successfully run for more than 16 years (1988-2003) over the global f19_g16 grid with prescribed ocean and sea ice (this work is reported in Zhu et al. (2011)). The current CAM/VIC simulation shows similar wet bias to CESM (Community Earth System Model) which is basically caused by CAM4 circulation biases, e.g., over arid regions such as Australia, central and southern Africa. The run basically captures temperature patterns but has a large cold bias over northern China and Tibet. We expect that this cold bias will be alleviated by ongoing model physics modifications that account for albedo changes currently occurring due to relatively small amounts of new snow over the large CAM grid cells. At the same time, the fully coupled RACM (WRF-VIC-POP-CICE) successfully runs more than 5 years over the Arctic regional grid wr50a. We are now working to improve the snow simulation, and are in the process of running a 15 year (1989- 2003) simulation to evaluate model performance. We are also updating the current version of VIC in RACM to the newest version (VIC4.1.2), which has improved cold land processes (frozen soil scheme, dynamic lake/wetland model and spatially distributed snow model), and have initiated efforts to parallelize VIC, and to implement the VIC stream routing model in RACM, so as to provide freshwater fluxes to the RACM ocean model.

Phase 3: Physical feedback studies focusing on changes in Arctic sea ice using the fully coupled model

This task proposed to examine the physical feedback processes over the region, focusing on the central role of the Arctic Ocean's sea ice as a mediator in atmosphere-ocean interaction using the fully coupled RACM. We have conducted a preliminary examination of the influence of sea ice condition on global climate by performing simple sea ice sensitivity experiments over the global region using coupled WRF/VIC for January and February 2001. The simulations with decreasing sea ice coverage show a significantly warmer climate than those with maximum sea ice extent. We plan to further explore the sea ice – albedo feedback and its impact on land surface and atmosphere using the fully coupled RACM in a multidecadal simulation.

References

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