A science plan for development of an Arctic System Model

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Introduction

During the past year and a half, over one hundred arctic researchers have contributed to a science plan for the development of an Arctic System Model (ASM). The science plan was presented to the task force of agencies, aiming to establish a capability to simulate the Arctic system with unprecedented spatial resolution, including biogeochemical, ecological, and human dimensions components. The plan details four core arctic modeling needs expressed by the community: 1) A platform to develop and refine methods for simulating arctic system components that extend beyond the scope of regional arctic climate models currently in development, 2) Flexible numerical and computational tools that remain at the vanguard of spatially, enabling focused resolution to be used for understanding individual components and regions of the Arctic, 3) Continuous use of existing models and simulations to explore new ideas, and 4) A comprehensive approach to simulating arctic processes to be consolidated as a Community Arctic System Model, and 4) Development of the community model in an open and transparent manner, with observation programs and policy making on how on ASM becomes an integral of arctic science. ASM development would be subject to oversight from a scientific steering committee, represented by a project office that maintains a single, core version of the models and undergo directed development within working groups. This paper summarizes the science plan, and establishes the case for the ASM as a key vehicle for integrating and capitalizing on knowledge gained during and after International Polar Year.

Vision

The primary goal of the proposed Arctic System Modeling program is to advance investigations of arctic climate variability and change and understand their interactions with humans and the global environmental system. A system-modeling project targeted on the Arctic offers an important need because the Arctic differs from lower latitudes in fundamental aspects of climate, biogeochemistry and ecology. It will provide a focal point for the development of numerical methods capable of simulating arctic climate variability and change as well as the interaction of climate variability with ecosystems, and the distribution of climate change impacts as one of the Interdisciplinary/Forest on Climate Change (IFCC). The proposed Community Arctic System Model (ASM) will be a computer model that resolves arctic processes with high-resolution and a level of detail that greatly surpasses typical global models. It will be based upon a coupled climate model component of atmosphere, ocean, ice, sea and terrestrial components driven from existing projects within the arctic research community. Emerging arctic physical, biogeochemical, human dimension, and ecological components will be added to this model during the course of the ASM program in addition to ongoing development and improvement of established ASM components. ASM development will feed into global modeling efforts by creating and improving methods for simulating high latitude processes in addition to building the capacity to do so for nested into global Earth System Models. The ASM will be able to be used as a stand-alone tool for developing global environmental information for future planning, policy makers and investigating interact parts of the arctic system. To achieve these goals, it must remain at the vanguard of new approaches for simulating the arctic environment.

Phased implementation

The proposed ASM program will stimulate scientific advancement through the treatment of complex problems that may result by industry interest in the simulation of the components of the arctic system. These must involve dynamic interactions, potentially non-linear feedbacks, and thresholds. The ASM will be a viable candidate for simulating arctic processes because future generations of advanced computer systems will be able to address the computational requirements of such large scale simulations. The ASM will include arctic regions and components that extend beyond the scope of regional arctic climate models currently in development, and support a coupler at the outset of the ASM program. There are several methods by which this may be accomplished, but the ASM will not be tied to a specific domain, but should instead offer flexibility to change the arctic regions it simulates and the resolution it uses to do it. The ASM program will be managed through a steering committee, coordinated by a program office that maintains a single, core version of the models and undergo directed development within working groups. National and international partnerships will be essential not only to evaluate the model, but also to incorporate new components into the system.

Project coordination

There is a need for careful community coordination of the evolving ASM because it will involve diverse segments of the arctic research community. A host of support functions will be needed, including software development, computer science, numerical methods, computing infrastructure. The community’s recommendations for overview focuses mainly upon experience from the Community Climate System Model (CCSM). A hallmark of the CCSM has been its effective Scientific Steering Committee, which provides scientific leadership for the development of the model as well as scientific oversight of the activities of working groups. This structure is expected to be of use in an ASM. The second element of coordination of the CO2G is that of a working group. Each working group takes responsibility for developing and continually improving a single ASM component, associated with one CO2G guide and design criteria. We foresee a similar structure for the ASM, although its smaller scale relative to CCSM should lead to a number of working groups, perhaps in physics/biogeochemistry/cryosphere and human dimensions components, respectively. Support functions will be crucial to success of the ASM if the activity is to be more than a loose federation of coupled modules. Critical support functions include the organizational design of a project office, computing support for the arctic program and coordination of budgeting and major organizational changes. The program office must be a focal point for coordinating activities and representing the climate modeling community. A steering committee will be formed to support the Steering Committee. This steering committee will be responsible for (1) defining the scope of the resulting arctic system model, (2) ensuring coordination of coupled and un-coupled components, (3) to coordinate the science and user-involvement, and (4) to provide a single voice for an arctic science that remains broadly-based and articulate. The science plan is being formulated to take advantage of existing partnerships and international coupled regional arctic models, as well as developing sophisticated validation tools. Two requirements of the establishment of a project office are to identify and coordinate the many efforts of improving or developing specialized computer software, as well as to coordinate the development of a core “system” biogeochemical and ecological component into the core model. Work for this stream can commence as soon as it has been approved and the corresponding group can begin to move the component. The project is designed to support a coupled model composed of a unique set of modules to simulate arctic processes. Each module must pass the approval of the scientific steering committee, and the program will not support new modules until they have been. The program will also address the issue of a core, consistent working model that will be the base for all coupled model components, and to introduce new components to the core Arctic System Model (Figure 5).

Arctic-centric configuration

Component Models

The ASM program should be staged, starting with proof-of-concept Pilot Projects and culminating in the use of interactively coupled human dimension modules in a full ASM. Those component modules that are already being used in coupled modules, others are for fear being ready for coupling. The proposed phased implementation takes this into account, and underscores ASM development in three streams, or, groups, with coupling time horizons (Figure 2).

Group 1: Ocean, sea-ice, atmosphere and terrestrial systems. These will be coupled with ice sheet models, mountain evolutions, vegetation, and ocean biogeochemical models. There will be a focus on climate variability and change of coupled sub-systems (e.g. ice sheets) in the broader system components such as a non-biogeochemical model. Major emphasis, this stream includes plans for the interaction of human- dimension modules, providing a wide scale of planning that can be adapted to other models, including consideration of the coupled sub-systems. Each stream of the program requires strong interaction between ASM model developers and the global modeling and observational community, and each is focused on creating a trans-disciplinary body of key science and engineering.

Group 2: Ice, marine and terrestrial ecosystems, biogeochemistry, and atmospheric chemistry. A number of whole Arctic system models have been developed using computer programs and tools that are used to develop the arctic system. A similar structure for the ASM should lead to a number of working groups, perhaps to physical, biogeochemical/ecosystems and human dimensions components.

Group 3: Biological and ecological components. Module development of an Arctic System Model is currently in progress. Two-way nesting could present existing telescopic nesting techniques to increase resolution (Figure 1), while another option is to use existing techniques for simulating arctic processes to be consolidated in a Community Arctic System Model, and 4) Development of an Arctic System Model (ASM). The science plan is intended to help guide U.S. funding.

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