A realistic multi-layer snow model for the Los Alamos sea ice model

Progress Report 2003-04

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1. Project objectives

In the course of the proposed project, we will first construct a thermodynamic ice/snow model with multiple snow layers. We will then add important physical processes such as liquid water flow, metamorphosis, redistribution by wind, and snow ice formation. Where appropriate, we will adapt parameterizations developed recently for modeling snow on land. We will test the model first in single-column mode using existing data sets from the Arctic and Antarctic, then on a global scale. Our end goal is an accurate, physically realistic, computationally efficient snow model that will improve simulations of polar weather and climate for the many users of the Los Alamos sea ice model (CICE) and the NCAR Community Climate System Model (CCSM).

2. Statement of Progress

Theoretical and numerical activity: The major tasks completed in the first year of this project include:

(1) Transfer of the CICE model to UCSC - In this effort most challenges arose from the fact that at LANL the model is run in an SGI environment and the source code had to be modified to port it into the Sun Microsoft Solaris environment used by the UCSC PI. Because of continuing updates to the CICE model and changes in the operating system at LANL, we ultimately decided that it is more efficient to arrange for the UCSC PI and his student to gain access to the LANL computer system to run the CICE model in its native environment. The UCSC personnel

will be certified for use of LANL computers after they return from their Antarctic fieldwork in late 2004.

(2) Modification of the CICE model to include multiple snow layers – During a December 2003 meeting at UCSC we reviewed the current CICE code, which was hardwired for a single snow layer. We developed a plan for modifying the thermodynamic and transport schemes to allow for an arbitrary number of snow layers of equal thickness and density. Recoding began in March 2003 following the release of CICE version 3.1 and was finished several months later. We developed and coded a new algorithm for computing the vertical temperature profile in multiple snow and ice layers. We also revised several modules to ensure that volume and energy in the new snow layers are conserved during transport and ridging. This completes the first stage of model development.

(3) Acquisition of atmospheric data from the SHEBA experiment for use in model calibration – We identified and obtained from Dr. R. Moritz (U. Washington) an integrated SHEBA dataset over the annual cycle (http://www.atmos.washington.edu/~roode/SHEBA.html). SHEBA was the Surface Heat Budget of the Arctic Ocean field experiment, carried out in 1997-98 to provide data for improving representation of the Arctic in climate models. The fine temporal and vertical resolution of the SHEBA dataset makes it ideal for validating our model. Additional snow layers should improve simulation of the rapid changes in surface temperature and cloudiness observed at SHEBA.

(4) Acquisition of a single-column atmosphere model - We acquired from the National Center of Atmospheric Research the latest version of the single-column Community Atmosphere Model. This model, which includes a full suite of cloud and radiation physics, will be coupled to the ice-snow model and forced laterally using SHEBA data.

(5) Development of an off-line model by the UCSC graduate student – Ian Howat has been focusing his efforts on exploring and comparing the published models of terrestrial snow cover. Through this work, Ian aims to identify the key processes that must be included in a multi-layer snow model and to evaluate different approaches to parameterization of these processes.

Visits and exchanges of personnel: Dr. W. Lipscomb visited UCSC on 12-13 December 2003. Dr. S. Tulaczyk visited LANL for two days in June 2004. During his visit he gave an IGPP seminar entitled “Outburst floods beneath modern Antarctic ice sheet: Observational evidence and quantitative modeling.”

Progress of the graduate student towards Ph.D.: Ian Howat is a fourth-year graduate student in the Department of Earth Sciences at UCSC. He passed his qualifying examination in the fall 2003 and attained the status of a doctoral candidate. This project will constitute one of the final stages of his dissertation research. Ian anticipates that he will graduate toward the end of 2006.

Publications and pursuit of external funding*:* No publications resulted from this project and we have not pursued external funding.

LANL facilities used in this research: Hardware resources used: SGI computing platforms, guyot and mauve. Software resources used: the CICE model. LANL expertise: Dr. W. Lipscomb.

Budget expenditures: The bulk of the grant budget is used for partial support of the UCSC graduate student (Ian Howat) with the remaining funds used for travel and operating expenses.