5A.11 SIMULATING THE CLIMATE AND SURFACE MASS BALANCE OF GREENLAND WITH A REGIONAL CLIMATE MODEL

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1. INTRODUCTION

The response of the Greenland ice sheet to climate change is a major factor in sea level changes, and even the current surface mass balance (SMB) of the ice sheet has many uncertainties. Changes in ablation and accumulation rates from alterations to atmospheric temperatures and circulation are likely, and a useful method of improving our understanding to be capable of making believable predictions is numerical modeling.

Atmospheric climate models can now reproduce the main patterns of temperature and precipitation over the ice sheet (Hanna and Valdes 2001; Murphy et al. 2001). High horizontal resolution is necessary in order to resolve the impact of small-scale orographic forcing on both surface air temperature and precipitation, and so the use of a limited area model (LAM) has many advantages. A LAM is much less computationally expensive than a global model of the same resolution, but the domain chosen must include the regions where the main atmospheric forcings originate.

This study investigates the use of an atmospheric LAM for simulating the climate and SMB of Greenland. We also consider the impact of changing to recent and accurate data sets of the Greenland orography and ice sheet extent of the National Snow and Ice Data Center (NSIDC) (1997). We introduce the model used in the next section, then show some results of the model simulations.

2. THE HADAM3 MODEL

HadAM3 is the latest atmospheric-only configuration of the UK Meteorological Office's Unified Model suite of atmosphere and ocean models. Over Greenland its performance agrees reasonably well with observations (Murphy et al. 2001). It is a grid-point, hydrostatic model with 19 'hybrid' vertical levels and is forced with climatological sea surface temperatures and sea ice cover. Pope et al. (2000) describe HadAM3 in detail.

HadAM3 considers the ice sheet as 50 m of snow cover. Four soil levels exist in the vertical, and the top two are taken to be snow wherever it lies. Albedo varies between a snow-free and a deep-snow albedo that has a weak temperature dependence. Surface energy balance is assumed, so that the surface temperature is at or below freezing and extra energy is used to melt snow.

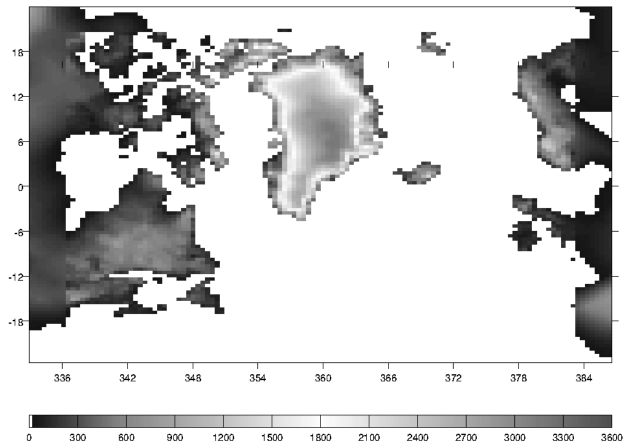

Figure 1: The horizontal domain of the HadAM3 Greenland limited area model (GLAM) configuration. The orography is that of the National Snow and Ice Data Center.

The Greenland limited area model (GLAM) has the same physics and parameterizations as the global HadAM3. We use a horizontal resolution of 0.44°on a rotated grid so that grid size is reasonably constant over the entire domain. Figure 1 shows the domain, centered near the south-east of Greenland and includes the entire North Atlantic storm-track region. The lateral boundaries are forced by output from the global HadAM3 (3.75° by 2.5°), updated every six hours so as to include the important features of the diurnal cycles.

We are currently performing ten-year, present-day simulations of the global and GLAM configurations of HadAM3, one using the default orography (the US Navy) and ice sheet extent (covering Greenland entirely), and the other with those of the NSIDC that differ only over Greenland. We present some preliminary results from the first four years of these simulations. In the next section we examine the SMB results of the NSIDC simulation, and examine the sensitivity to different orographic and ice sheet boundary conditions.

3. THE SURFACE MASS BALANCE

Murphy et al. (2001) showed that the global version of HadAM3 simulated a reasonable surface

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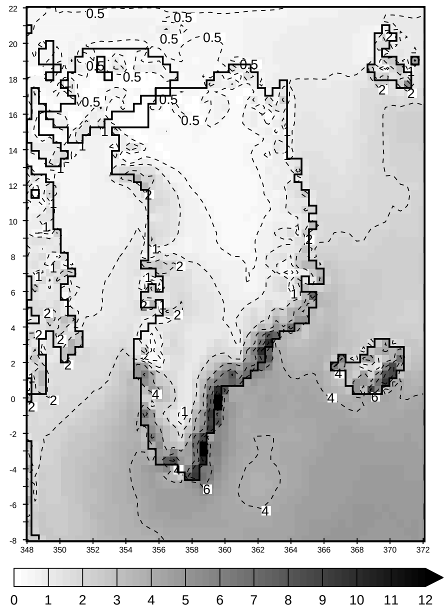

Figure 2: *The mean annual total precipitation simulated over four years by the Greenland LAM. Contour intervals are 0.5 mm/day between 0 and 1, then 2 mm/day from 2 to 12.*

mass balance of Greenland, but that the surface boundary conditions of the model needed to be improved. In particular, precipitation was neither sufficiently enhanced by orographic uplifting nor was moisture inhibited from moving deep over the ice sheet by the barrier formed by the ice sheet. Also, melting was overestimated in the coastal regions, particularly in the west of Greenland. These errors were due to the low resolution of the model and the complete ice sheet extent over Greenland in the global HadAM3 model.

Using the GLAM has improved these two errors considerably. Figure 2 shows the four-year mean annual precipitation in the NSIDC simulation. It clearly shows the enhancement of precipitation along the south-east coast of Greenland due to the orographic uplifting of moist air masses that are advected towards the South Dome from stationary and transient lows between Greenland and Iceland. The maximum mean precipitation is 14.0 mm/day. This plot also shows that the precipitation is mostly confined to the coast, and that the South Dome is the location of a precipitation minimum. These are significant improvements over the simulations of the global model, and clarifies the importance of high horizontal resolution in simulating the dynamical effects of the orography on the precipitation. Precipitation along the coast and south of the Greenland plateau are better than in the simulations with the US Navy orography, but the maximum in the north-west of Greenland is weaker and perhaps poorer in the NSIDC simulation. However, the precipitation simulated by GLAM does agree very well with the observed distribution of Ohmura et al. (1999).

The mean summer melting in the NSIDC GLAM simulations also shows that increased resolution and the NSIDC ice mask overcome most of the errors in the global simulations. These remove most of the anomalously high melting in the US Navy global and GLAM simulations where the model had available to it large thicknesses of ice to melt that do not exist. Thus the total amount of melting is much reduced, but may be too low overall because of too high albedos in HadAM3. This GLAM simulation with the NSIDC appears to reproduce the observed patterns quite well.

4. CONCLUSIONS

The HadAM3 GLAM shows good potential for simulating the climate and surface mass balance of Greenland. We are currently extending the length of the simulations to 10 years. The sensitivity of circulation patterns and their impact on the climate and SMB to the orography used are being assessed. We are also investigating the use of downscaling schemes to simulate the main impacts of small-scale orographic forcing on the surface mass balance, including dynamic downscaling of precipitation, from the global HadAM3 output. These two high-resolution modeling methods provide complementary techniques for improving the representation of ice sheets in climate models.

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