P1.20

MODELLING THE FUTURE OF CANADIAN ARCTIC ICE

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1. INTRODUCTION

The possibility of global warming significantly modifying ice cover in northern Canadian waters is a concern resource managers and others are taking seriously. If the rate of ice melt was to increase, the nature and intensity of human activity in the Arctic would change. For example, a longer open water season or thinner ice would allow more transportation through the Canadian Archipelago, resulting in development of commercial and industrial activities. The Canadian government is concerned about issues of sovereignty, regulation and law enforcement. Consequently, the ability to predict ice cover over the next 20 to 50 years would be very valuable in preparing for the future.

With the intent to provide a long−term forecast of Arctic ice cover, especially for the application of Canadian interests, two regions are modelled from 1950−2029 using a coupled ice−ocean model. One region is the Arctic Ocean, which includes Hudson Bay, the North Atlantic and the Canadian Archipelago. The other region is the Canadian Archipelago.

As this is a project in progress, the work so far has concentrated on the Arctic model, and will be the focus of this abstract. The model will be compared against observations for 1950−1999, and a forecast will be shown for 2029. The Canadian Archipelago model is still at a preliminary stage, and will be introduced briefly.

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2. ATMOSPHERIC FORCING

2.1 Source of Data

Since an atmospheric model is not included in this project, we are limited to observations, or output from forecasting atmospheric models. The atmospheric forcing is from the National Center for Environmental Prediction (NCEP, Kalnay *et al*., 1996) and the Canadian Centre for Climate Modelling and Analysis (CCCMA, Flato *et al*., 2000).

Surface forcing variables are monthly air temperature, specific humidity, precipitation, surface pressure, windspeed and windstress. Windstress is calculated using NCEP monthly 10m wind and is rescaled using windspeed, which is averaged monthly from daily NCEP 10 m wind. (Steiner *et al*., 2003).

At CCCMA, several simulations are run with varying greenhouse gas (CO_2) levels. For this project, output from their CGCM2 (Coupled General Circulation Model) scenario A2 and B2 are used. Both of the A2 and B2 scenarios are run with the same values of CO_2 from 1850−1990, but in 1990, the A2 levels increase at a faster rate than the B2 scenario. The B2 simulation represent more conservative estimates of CO_2 and result in a cooler atmosphere. The CGCM2 global model (3.75 deg) is run with a coupled atmosphere−ice−ocean model.

2.2 Description of simulations

Several cases are run. The first case uses only observationally based atmospheric data from NCEP, and is used as a validation run; The forcing is monthly averaged timeseries data from 1950−1999.

Two other simulations use a combination of NCEP and CCCMA data for a forecast run from 1950−2029. To maintain the trends seen in the atmospheric CCCMA data from increased CO_2, the monthly anomalies from the CCCMA model for 1950−2029 are added to the 40 year (1950−1990) climatological mean from NCEP. The CCCMA model underestimates the ice cover in the Arctic, and it is hoped using a higher resolved regional model with a modified surface forcing would improve the ice forecast. One forecast simulation uses the CCCMA A1 anomalies, where the other run applies the B2 scenario anomalies.

3. MODEL DESCRIPTION

Both the Arctic and the Canadian Archipelago model use a MOM2.2 based 3−dimensional ocean model coupled to an ice−snow model. The ice model uses Hibler (1979) dynamics, Parkinson and Washington (1979) thermodynamics and second−order moment (SOM) advection (Prather, 1986; Merryfield and Holloway, 2003). The surface parameterization for longwave is from Rosati and Miyakoda (1988).

The Arctic model has a horizontal resolution of approximately 55km and 29 vertical levels. Climatological monthly mean temperature and salinity values from Polar science center Hydrographic Climatology (Steele, *et al.*, 2001) are used for the open boundaries at Bering Strait and the North Atlantic. The open boundary velocities and streamfunction are from a global model.

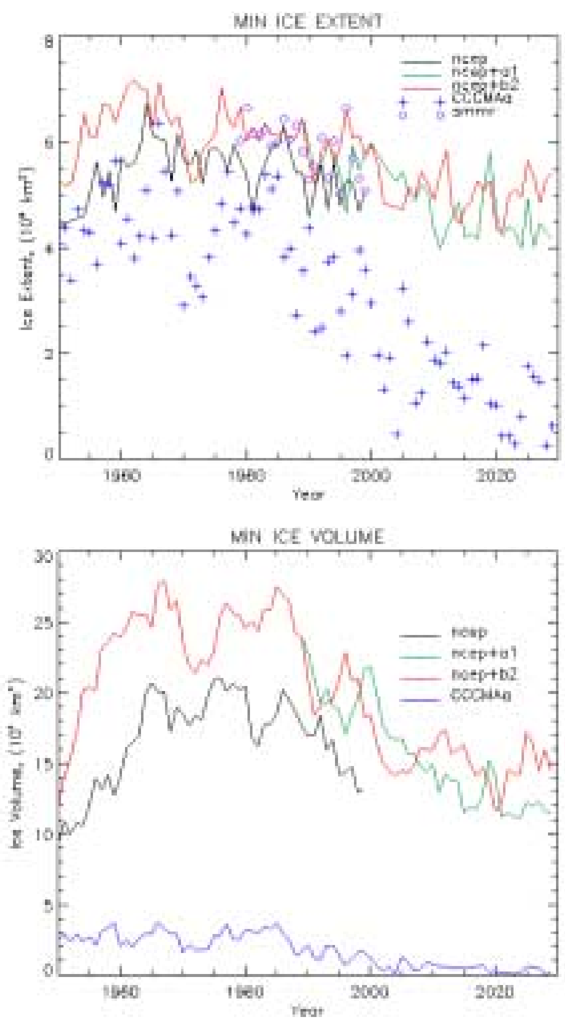
The Canadian Archipelago region is modelled at a finer resolution of 20km; forcing data for its northern and southern open ocean and ice boundaries will be taken from the Arctic model. The model has 24 vertical levels, cutting off the bathymetry at 1200m to maximize vertical resolution.

4. ARCTIC MODEL RESULTS

4.1 Comparison to observations

An accurate ocean sea ice validiation is difficult due to sparse observations available in the Arctic. However, satellite data provides good ice extent data since 1979. Ice thickness is poorly observed although general trends of thickness per region are known. Figure 1 shows minumum ice extent and volume for three cases: a) **NCEP only** forcing, b) NCEP climatology plus CCCMA (**A1**) anomaly and c) NCEP climatology plus CCCMA (**B2**) anomaly. Also shown is the ice volume and extent from the CCCMA model (A1) as interpolated to the 55km Arctic region model grid. The satelite derived data is shown for 1979−1996 on the ice extent plot (diamonds) showing that the model is producing reasonable (although variable) ice extent.

Figure 1:
Minimum ice extent and volume for 1950−2029.



The Arctic domain and ice thickness is shown in Figure 2, for the NCEP only case compared against Bourke and Garrett's (1987) representation of ice thickness, as derived from submarine data. Both plots use 1m contour interval, but the model plot does not show its ice edge. Winter is defined as January, February and March.

Both the model and observation and show a similar pattern, although the model's ice along the north coast of Greenland and the Archipelago is too thin, being 5−6m instead of 6−7m. The NCEP+CCCMA anomaly cases (where A1 and B2 are the same until 1990) show the same pattern with thicker ice in the western Arctic (not shown).

Figure 2:
Winter ice thickness for 1960−1982.

NCEP forced run **Bourke and Garrett (1987)**

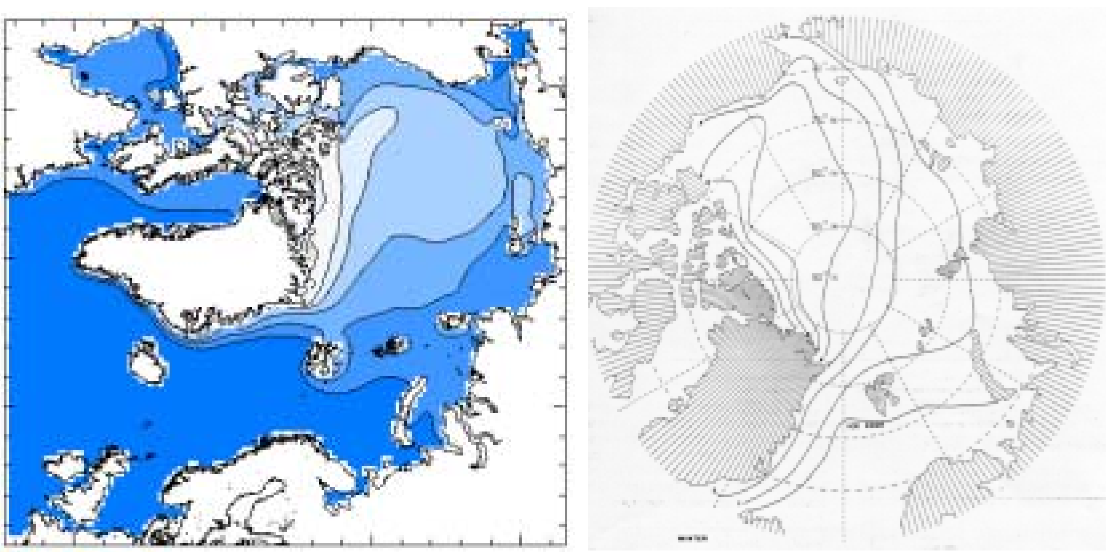
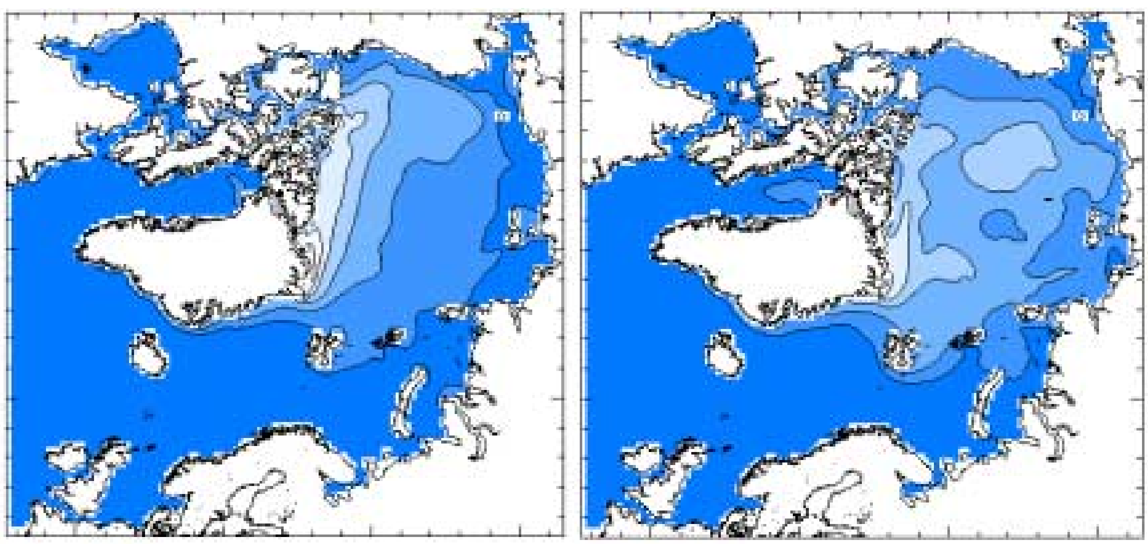


Figure 3:
Annually averaged ice thickness for 2029

NCEP clm + CCCMA A1 **NCEP clm + CCCMA B2**



4.2 Sea ice forcast

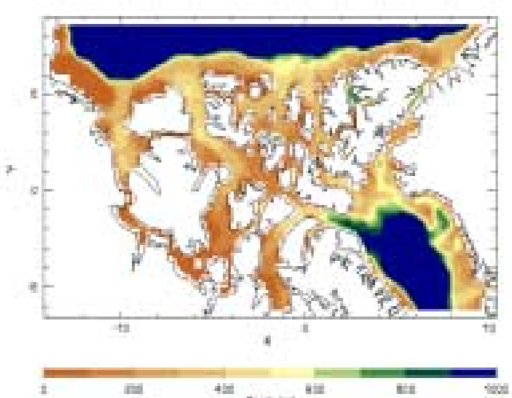
Figure 1 shows that the regional Arctic model forecasts retain most of their ice from 2000 onward, unlike the results from the CCCMA model which significantly loses ice. Of the two forecasts, the conservative run (NCEP+B2) has more ice extent and volume in year 2029 than the NCEP+A1 run.

Sensitivity studies (not shown) indicate that the modelled ice thickness is very sensitive to changes in shortwave, albedo, snow cover and windstress, and that different choices in method and parameterizations results in significantly varying forcing and ice characteristics. With this in mind, annually averaged ice thickness for year 2029 is shown in Figure 3. Overall, even though the NCEP+B2 forced model has a greater ice extent and volume, it has thinner ice along the Greenland coast compared to the NCEP+A1 run.

5. CANADIAN ARCHIPELAGO AND OTHER WORK

Considering the potential impacts of global warming on the Canadian Archipelago, long term forecast of ice cover in Northwest Passage is of particular importance. The same forcing used in the Arctic model will be applied to the Canadian Archipelago grid, as shown below. Work is in progress to better understand ice processes through heat and freshwater diagnostics and sensitivity studies.

Figure 4: Bathymetry of Canadian Archipelago model,
with depths greater than 1200 m cutoff.



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