J1.19 THE IMPACT OF ARCTIC SEA ICE VARIABILITY ON THE ATMOSPHERE

Uma S. Bhatt*, IARC/Frontier, U. Alaska, Fairbanks, AK
Michael A. Alexander, CDC/NOAA CIRES, Boulder, CO
John Walsh and Michael Timlin, U. Illinois Champaign-Urbana, Urbana, IL
Jack Miller, INE, U. Alaska, Fairbanks, AK

1 Introduction

There is a growing body of observational evidence that the climate in many parts of the Arctic is displaying statistically significant trends. The annual sea level pressure as measured by the International Arctic Buoy Program is 3-4 mb lower during the period 1987-1994 than during 1979-1986 over the central Arctic (Walsh et al., 1996). Arctic surface air temperatures (SAT) have warmed throughout the year (Chapman and Walsh, 1993; Rigor et al., 1999), with the largest trends occurring during spring with values ranging from 0.5-2.5 C/decade. Warming during both winter and spring has resulted in a longer melting season in the eastern Arctic. Observational studies indicate that there have been significant trends in Arctic ice extent, fraction (Cavalieri et al., 1997) and thickness (Rothrock et al., 1999), though of varying sign depending on location. While there is general agreement that these changes in sea ice conditions are a result of changes in atmospheric forcing, it is not clear at present what if any effect is felt by the atmosphere to these changes in the surface ice conditions. Modeling studies such as Herman and Johnson (1978) and Honda et al. (1999) suggest that ice plays a role in changing the atmosphere both locally and on the large-scale.

Given the complicated nature of ocean-ice-atmosphere interactions and the difficulty in simulating Arctic climate using coupled models (see Weatherly et al., 1998), we have focussed on how changes in sea ice influence the atmosphere by performing a suite of AGCM simulations. In this research, we employ the NCAR Climate System Model (CSM) 2.0 to examine the impact on the atmosphere of the observed trends in sea ice extent, fraction and thickness. The overarching question addressed by our study is: to what extent does sea ice variability influence the atmospheric circulation?

We will present findings from ensemble experiments, where the atmospheric model has been forced with observed maximum and minimum ice conditions during winter and summer. From these experiments we will examine how the winter and summer trends in sea ice impact the atmospheric variables and compare the simulated response with the observations.

2 Model and Methods

2.1 Model

The atmosphere component of the NCAR Climate System Model (CSM 2) is a global spectral model with a grid resolution of approximately 2.8 degrees in both latitude and longitude (T42). We employ a configuration of the model which has a prognostic landsurface scheme, a data ocean model, and a data ice model. The model is configured so either ice extent (100% ice covered grid) or concentration (15%-100% ice covered grid) can be specified, which allows for more realistic lower boundary condition experiments. The CSM has been ported to the ARSC (Arctic Regional Supercomputing Center) Cray SV1 and integrated for these fixed lower boundary condition experiments. Additional details about CSM 2.0 can be found in the June 1998 issue of Journal of Climate.

2.2 Experiments

The control experiment (***CNTLe***) has been integrated for 35 years by repeating the mean annual cycle of observed sea ice extent (either 0% or 100% ice cover) and sea surface temperature (sst), based on observations from 1979-99. An ensemble (30 realizations) of sensitivity experiments was integrated from October to April using climatological sst (same as in ***CNTLe***) and observed sea ice extent from the winter of 1982-1983 (**WIN83e**). Based on a hemispheric average for the data period (1979-99), the winter of 82-83 stands out as having the maximum sea ice extent. Additional sensitivity experiments are in progress to investigate the atmospheric response to minimum winter ice extent (1995-96) and both maximum (1995) and minimum (1982) summer ice extent. The present discussion covers the ***WIN83e*** sensitivity experiment.

**corresponding author address:* Uma Bhatt, IARC/Frontier, 930 Koyukuk Dr., U. of Alaska, Fairbanks, AK 99709, bhatt@iarc.uaf.edu

3 Results

Sea ice anomalies are largest in the north Atlantic Sector for the winter of 1982-83, which is characterized by reduced ice extent east of Greenland and expanded ice cover west of Greenland (Fig. 1). Also note that sea ice anomalies are negligible during this winter in the North Pacific. Sea ice was more extensive only for part of the 1982-83 winter season (January-February) and was normal or slightly below normal during the rest of the winter. In contrast, the minimum ice cover winter of 1995-96 has negative anomalies at all longitudes and during all the winter months.

Surface temperature (sst, ice temperature and land temperature) has the largest anomalies at the ice edge, with anomalies up to +8C east of Greenland and -6C to the west (Fig. 2). Patterns of 1000 mb air temperature anomalies (not shown) resemble those of surface temperature with warm air of up to +3.5 C east of Greenland. Sea level pressure anomalies (Fig. 3) display higher than normal pressure north of the ice edge and anomalously low pressure south of the ice edge in the Atlantic and Pacific sectors. In the Atlantic sector where the ice anomalies are largest the model slp anomalies are nearly opposite of the observed (Fig. 4), suggesting a negative feedback, consistent with recent ice-GCM studies (Deser et al., personal communication).

Net surface heat flux (turbulent and radiation) anomalies are largest along the ice edge (Fig. 5) and are primarily due to latent and sensible heat fluxes. The sign convention used in Fig. 5 indicates that the net flux is directed out of the surface, so positive values mean anomalous warming of the surface (ice or ocean). Increased precipitation anomalies east of Greenland (Fig. 6) are consistent with a warmer surface and enhanced specific humidity anomalies (not shown). Large scale positive anomalies in precipitation are found well south of the ice edge in both northern oceans. While potentially interesting, the statistical significance of these precipitation composites has yet to be determined.

In the north Atlantic sector, anomalies of 500mb height (Fig. 7) are similar in structure to those of model slp (Fig. 3). The height anomalies are opposite the observed height anomalies for 1982-83 (Fig. 8) in the north Atlantic, consistent with model and observed slp patterns. It is curious that in the north Pacific, where local ice edge anomalies are small, there are relatively large anomalies in 500mb height and slp that resemble the observations.

4 Conclusions

We present results from a sensitivity experiment ensemble (30 cases) where the atmosphere is forced with observed sea ice anomalies from the winter 82-83. The strongest response in the surface temperature, 1000 mb air temperature, turbulent heat fluxes, and specific humidity is found in the high latitudes in the vicinity of the ice edge anomalies. In the north Atlantic sector, model induced sea level pressure anomalies are opposite the observed, consistent with the findings of Deser et al. (personal communication).

Grid point and field significance tests are in progress to determine the robustness of the response. In addition, results from the minimum ice winter and the summer sensitivity studies will be presented.

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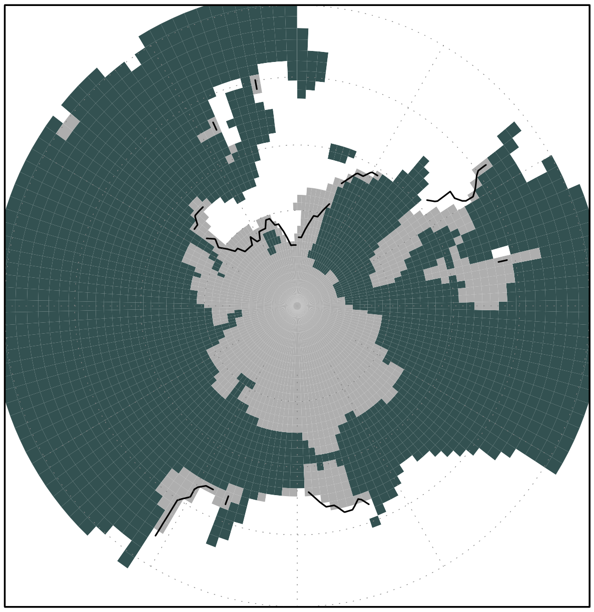

Fig 1 Climatological sea ice extent for the period 1979-1999 shown in light gray shading. Sea ice edge for January-February 1983 is depicted by a solid bold line.

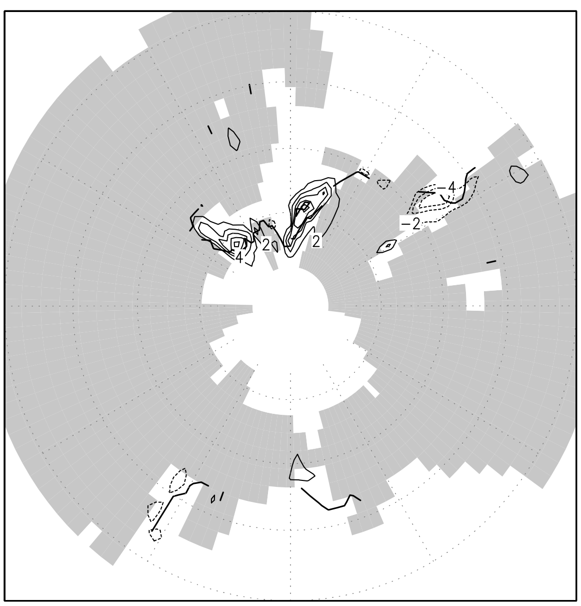

Fig 2 November-March surface temperature anomalies for Win83e simulation (Win83e-control) in C. Ice edge for January-February 1983 is depicted by a solid bold line. C.I. is 2 C.

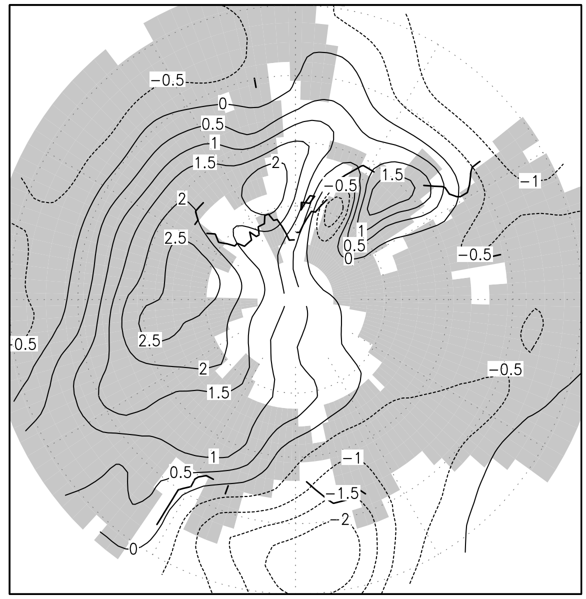

Fig 3 November-March sea level pressure anomalies for Win83e simulation (Win83e-control) in mb. Ice edge for January-February 1983 is depicted by a solid bold line. C.I. is 0.5 mb.

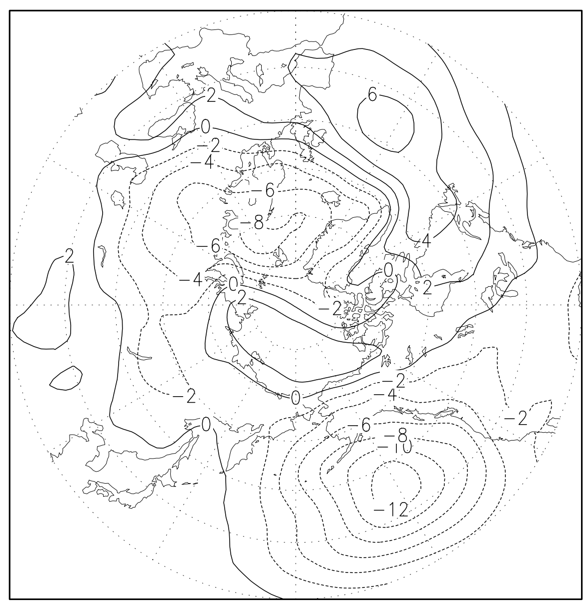

Fig 4 Observed November 1982-March 1983 sea level pressure anomalies from the NCEP/NCAR Reanalysis in mb. Sea level pressure means were based on the years 1958-1998. C.I. is 2 mb.

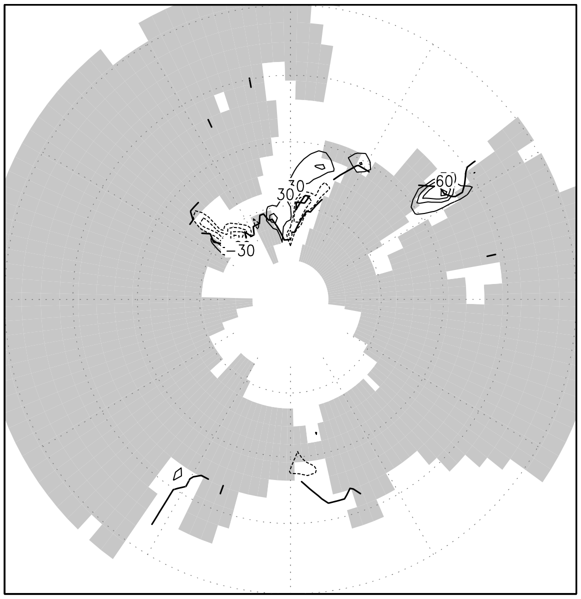

Fig 5 November-March net surface heat flux anomalies for Win83e simulation (Win83e-control) in W/m^2. Ice edge for January-February 1983 is depicted by a solid bold line. C.I. is 30 W/m^2.

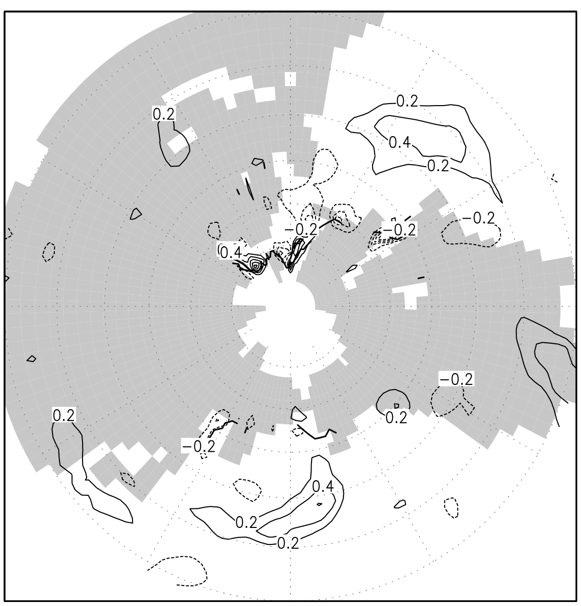

Fig 6 November-March net precipitation anomalies for Win83e simulation (Win83e-control) in mm/day. Ice edge for January-February 1983 is depicted by a solid bold line. C.I. is 0.2 mm/day.

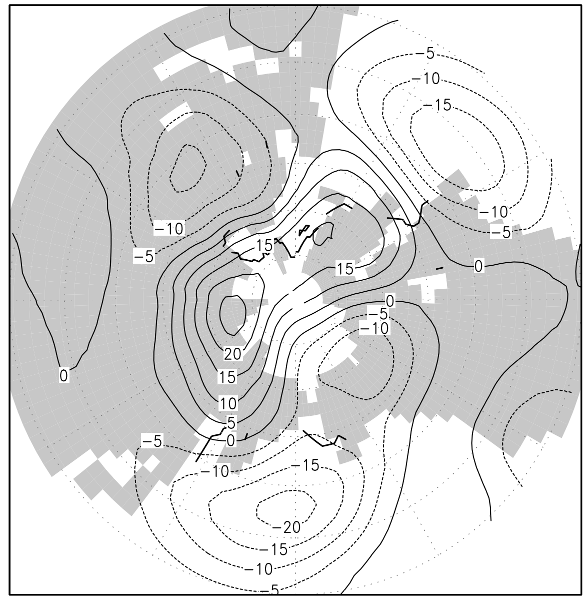

Fig 7 November-March net 500mb height anomalies for Win83e simulation (Win83e-control) in geopotential meters. Ice edge for January-February 1983 is depicted by a solid bold line. C.I. is 4 gm.

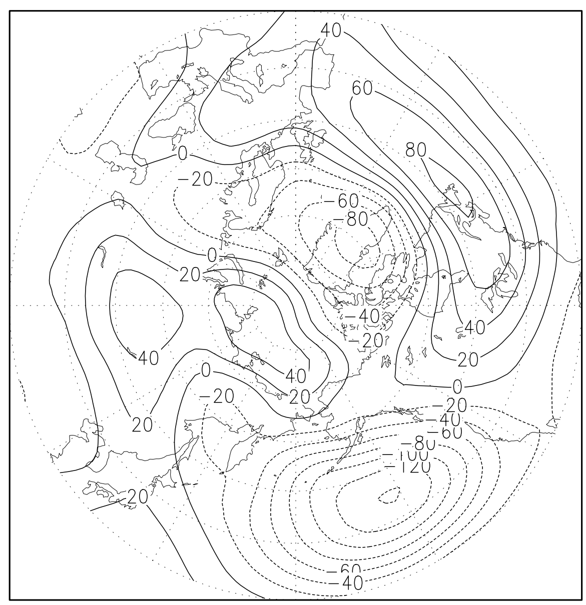

Fig 8 Observed November 1982-March 1983 500mb geopotential height anomalies from the NCEP/Ncar Reanalysis in geopotential meters. Means were calculated using data from the years 1958-1998. C.I. is 20 gm.