P1.20 SENSITIVITY OF ANTARCTIC PRECIPITATION TO SEA ICE CONCENTRATIONS IN A GENERAL CIRCULATION MODEL

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1. INTRODUCTION

Antarctic precipitation and accumulation have the potential to increase significantly as global temperatures increase and sea-ice cover decreases. Expanded ice-free areas around Antarctica could allow greater evaporation, resulting in greater precipitation. Interannual variations in sea ice cover may also influence Antarctic precipitation and climate.

Determining the relationship between sea ice cover and Antarctic precipitation using observational data is hampered by sparse and unreliable precipitation data and limited meteorological analyses. The analysis of net moisture flux convergence over Antarctica by Cullather et al. (1998) show interannual variations in precipitation minus evaporation (P-E), although different climatic analyses produce different P-E signals.

Climate models can be useful tools in isolating and diagnosing the effect of one contribution to the climate system. In this study, Antarctic sea-ice concentrations from satellite data are varied in global climate simulations, to determine their impact on Antarctic climate, and precipitation in particular.

2. MODEL DESCRIPTION

The NCAR Community Climate Model version 3 (CCM3, Kiehl et al., 1996) atmospheric GCM is used here in climate simulations with prescribed sea surface temperatures and ice concentrations. The CCM3 is run at spectral resolution T42 (approx. 2.8° by 2.8°) and 19 vertical levels. The CCM3 atmosphere is connected to the sea ice and ocean surface by the NCAR CSM Flux Coupler (Bryan et al, 1996), modified for the Parallel Climate Model (Weatherly and Zhang, 2001). Surface fluxes (sensible and latent heat, moisture, longwave and shortwave radiation) are computed separately for ice-covered and ice-free fractions of a grid cell. The ice concentrations and the ice-atmosphere fluxes are computed on a 27-km cartesian grid over both poles. These fluxes are then interpolated to the CCM3 T42 grid. So while the model uses high-resolution ice concentrations, the atmosphere only sees combined fluxes on the larger grid.

3. DATA

Sea ice concentrations for the model boundary conditions were calculated from the Scanning Multichannel Microwave Radiometer (SMMR) and the Special Sensor Microwave/Imager (SSM/I) brightness temperatures. Monthly mean concentrations were computed for the years 1979 through 1991. This data was provided by J. Maslanik at the National Snow and Ice Data Center on the 25-km resolution EASE grid over both polar regions (NSIDC, 1997). The ice concentrations were interpolated to the 27-km cartesian grid used in the PCM's ice component for its ice model. Climatological monthly averages were computed from the 13 years of data, as well as the maximum and minimum concentrations over all years at each grid point for each month.

4. EXPERIMENTS AND RESULTS

Several sets of climate simulations were performed, all of which used the global climatological monthly SSTs and monthly Arctic ice concentrations the same in all runs. The Southern Hemisphere (SH) ice concentrations were varied in the runs in the following way:

- the **Control** run simulated 25 years with the climatological monthly SH ice concentrations,
- a **Maximum** run simulated 25 years with the maximum monthly ice concentrations,
- a **Minimum** run simulated 25 years with the maximum monthly ice concentrations,
- an ensemble of five **Interannual** runs of 13 years each using the concentration data for 1979 through 1991. The five runs were independent, starting from different initial conditions. The purpose of performing ensemble runs is to determine a significant response by averaging the runs, reducing the natural variability.

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The total SH ice area in the Maximum and Minimum runs are shown in Fig. 1. The Maximum is about 50% larger than the Minimum in all months. This difference results in monthly surface-air temperature differences (not shown) as much as 8 C greater in the Minimum run than in the Maximum run. This is simply the difference between the prescribed SST in open water and the computed surface temperature over the sea ice. This difference is greatest in late winter (July-Aug.-Sept.) and least in late summer (Jan.-Feb.-Mar.). As a result, there are greater sensible and latent heat and moisture fluxes into the atmosphere in the Minimum run.

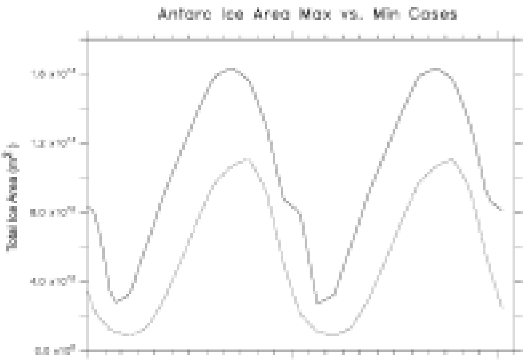

Fig. 1. Total Southern Hemisphere ice area (m^2) for Maximum (solid) and Minimum (dashed) runs, plotted over two identical annual cycles.

The effect of ice concentrations on the precipitation is shown in Fig. 2. The precipitation in the Minimum run is about 25% greater than the Maximum run in all months. The spatial pattern of the precipitation difference is shown in Fig. 3, which shows the greatest difference along the topographic coastal boundary. This shows that, for different annual or climatological conditions, the sea ice cover has a significant impact on precipitation around Antarctica.

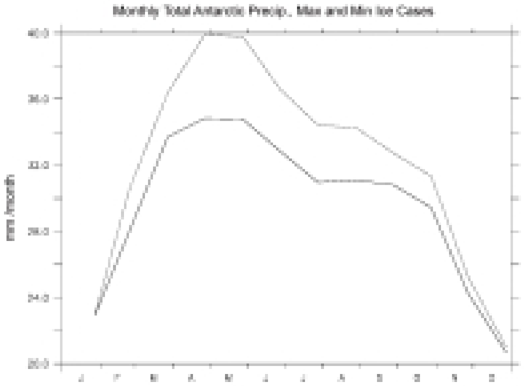

Fig. 2. Precipitation (mm/month) averaged 65°S to 90°S, for Maximum (solid) and Minimum (dashed) runs, 20-year averages.

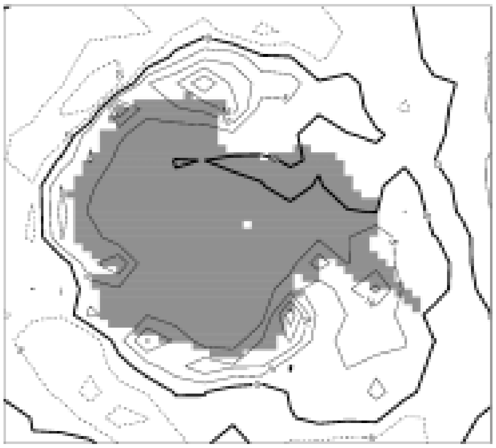

Fig. 3. Precipitation difference (mm/month) between the Minimum and Maximum runs, 20-yeay annual average. Contours are 5 mm/month.

The ensemble of five Interannual runs is intended to test whether sea-ice cover affects precipitation (and climate) on a seasonally-dependent time scale. The monthly ice concentration data provide greater spatial and temporal variability to the surface boundary condition. Analyzing both the concentration data and model results require consideration of this variability. The monthly anomalies of total Antarctic sea ice area are shown in Fig. 4, averaged over two periods, 1979-1987 and 1988-1991. The later period has greater ice area in the fall and winter (March-August) and less ice in spring. The earlier period is opposite in phase, with more ice in spring.

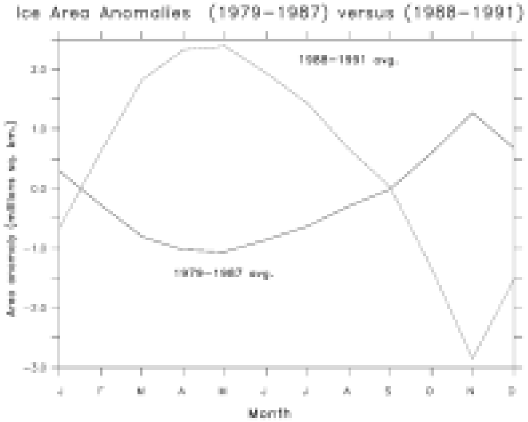

Fig. 4. Monthly ice area anomalies (10^6 m^2) from SSM/I data averaged over 1979-1987 (solid) and 1988-1991 (dashed).

The effect on monthly precipitation anomalies in the model is shown in Fig. 5, averaged over the two periods. The precipitation anomalies also show differences between the two periods; however, they are of the *same* sign as the ice anomalies, i.e., less precipitation in fall and winter in 1979-1987, and more precipitation in fall and winter in 1988-1991. This is converse to the results of the Maximum and Minimum runs.

A number of mechanisms may explain why the Interannual results respond differently. In all of the runs, the periods and locations of less ice cover coincide with warmer surface temperatures and greater sensible and latent heat fluxes to the atmosphere. In the Interannual runs, however, the spatial variability of the ice cover can provide greater moisture flux in one region, resulting in greater vapor transport and precipitation in other regions. The total (circumpolar) precipitation and ice area anomalies may be in phase in this case, while the regional responses may be out of phase. Further regional analysis will be performed to determine how the local precipitation responds to ice concentrations on this interannual basis.

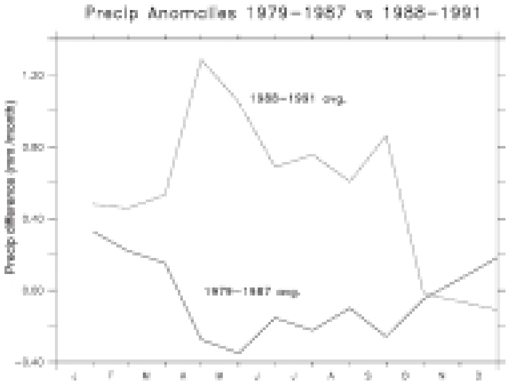

Fig. 5. Precipitation anomalies (mm/month) averaged over 65°S to 90°S, over the 5-run Interannual ensemble, for 1979-1987(solid) and 1988-1991 (dashed).

5. CONCLUSION

Precipitation on and near Antarctica increases significantly in response to lower sea ice concentrations, and decreases with higher concentrations. This confirms the hypothesis that, in a warming climate with less sea ice, increased precipitation may result from ice cover decreases alone. The concentrations used are taken from satellite data. The Maximum and Minimum cases used here are moderately unrealistic; they are outside the range of observed ice areas for 1979-1991 by as much as 20%. But they show the model is can respond to this moderate change in ice cover.

The observed interannual variations in sea ice concentrations used as boundary conditions also have regional impacts on temperature and moisture flux, and presumably on local (and downwind) precipitation. Further analysis will show the relationship between regional ice cover and precipitation. Any overall circumpolar impact on precipitation is not likely to be significant when compared to the natural variability, as observed regional anomalies in ice cover tend to cancel.

6. ACKNOWLEDGEMENTS

The author thanks Tom Bettge, Tony Craig, Warren Washington, Gary Strand, and Yuxia Zhang for assistance with the model, and Jim Maslanik for the ice data. This research was sponsored by the National Aeronautical and Space Administration

Office of Earth Science Polar Programs.

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