J1.9 ATMOSPHERIC FORCING OF THE COSMONAUT SEA POLYNYA

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1. INTRODUCTION

The formation of polynyas in the Antarctic sea ice pack has importance in the climate system as they influence the surface exchanges of heat, moisture/salt, and momentum between the atmosphere and ocean. Open-ocean polynyas in particular are an important aspect of climate variability because of their relative size (up to 2% of the overall Antarctic sea ice cover) and likely impact on ocean ventilation, bottom water formation, and atmospheric circulation.

The Cosmonaut Sea (Fig. 1) is the site of the recurring formation of an open-ocean polynya. The divergence zone implied by the barotropic ocean currents was theorized to be a mechanism leading to the formation of the Cosmonaut Sea polynya (Gordon and Comiso 1996). Their theory invoked the conservation of potential vorticity, in which a fluid column was compressed between the Antarctic Circumpolar Current and the coastal current. To conserve potential vorticity, a fluid column would have to stretch, causing vigorous upwelling of circumpolar deep water. The heat provided from the upwelling would be sufficient to maintain an ice free region.

Using a coupled atmosphere-sea ice model with a specified oceanic heat flux, we have determined that a polynya was formed in the model under favorable atmospheric conditions. The polynya was not maintained in the model due to the oceanic forcing alone.

2. MODEL AND EXPERIMENT DESCRIPTION

The ARCSyM contains a hydrostatic, primitive equation atmospheric model with a terrain following vertical coordinate with a land surface exchange-vegetation model and radiative transfer scheme. ARCSyM also includes a dynamic/thermodynamic sea-ice model (see Lynch et al. 1995; Bailey and Lynch 2000 for details). The oceanic component for this experiment was a uniform mixed-layer with a prescribed oceanic heat flux of 15 W m^{-2} underneath the sea ice, except for a patch of 200 W m^{-2} where the polynya was expected to occur. Additionally, annual mean surface currents were prescribed from the simulation of Beckmann et al. 1999.

The model simulations were performed for a Cosmonaut Sea domain at 20 km resolution (Fig. 1) for the period of June - August, 1988. The model was initialized and driven at the boundaries using ECMWF analyses produced at NCAR (Trenberth 1992). Initial ice concentration was provided from satellite passive microwave (SSM/I) analysis.

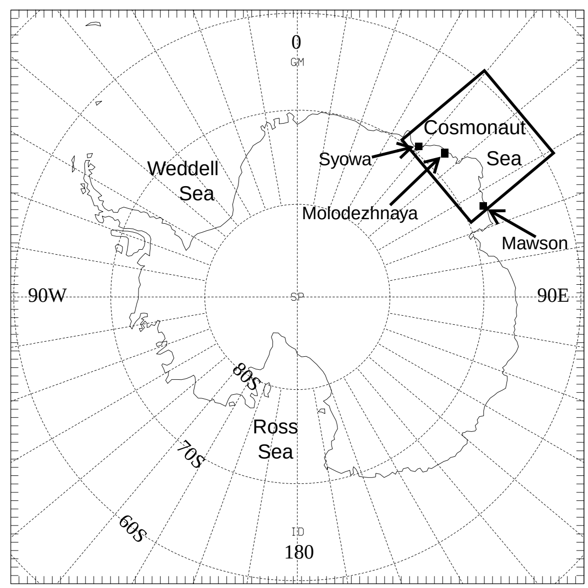

Figure 1. Location of Cosmonaut Sea model domain.

3. SOME RESULTS

The sea ice concentration from the model for August 6-8, 1988 is presented in Fig. 2. The polynya does not appear until the 7th and begins to disappear by the 8th. This time period corresponded to the appearance of a strong cyclonic system in the atmosphere both in the model and the large-scale analyses. This cyclonic system interacted with the katabatic winds to create regions of divergence over the polynya. The model polynya occurs roughly at the same time as that in the passive microwave data, but not as strongly. The size of the polynya continued to fluctuate throughout the month corresponding to divergent atmospheric periods.

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was indeed consistent with a sensible heat polynya mechanism. The rapid ice regrowth present in the coastal areas and typical of latent heat polynya formation was not present in the open ocean polynya.

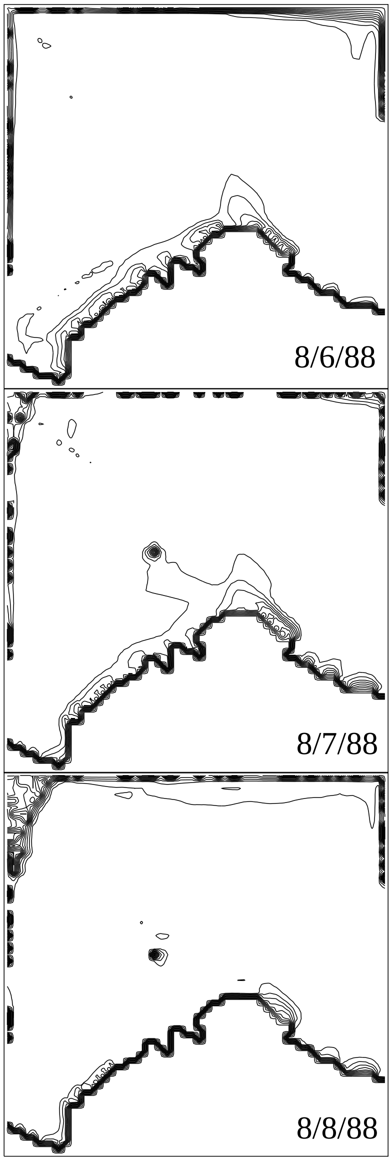

Figure 2. Sea ice concentration for August 6, 7, and 8, 1988. (Contour interval is 0.1).

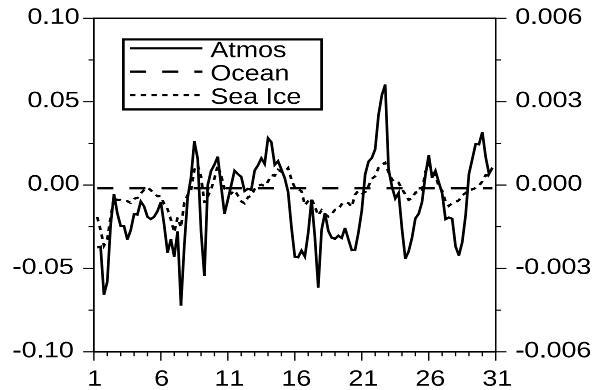

Figure 3. Atmospheric, sea ice, and ocean divergence. (Units are 10^3 x s^{-1}. Atmospheric scale on left, sea ice and ocean scales on right.)

The time series of atmospheric, sea ice, and oceanic divergence, in the vicinity of the open-ocean polynya is presented in Fig. 3. The oceanic divergence is constant due to the specified ocean currents. The atmospheric and sea ice divergence times series were well-correlated ($r^2 = 0.77$). This implies that the sea ice in the open-ocean polynya was generally and primarily wind-driven.

4. CONCLUSIONS

In these experiments, a polynya was simulated in the open ocean, away from the coast, in addition to recurrent coastal polynyas. The formation of this polynya

It was also found that the polynya would not form in the model due to oceanic forcing alone. The correlation of the sea ice and atmospheric divergence suggests that the sea ice would not remain over this region long enough to be affected. This was verified in the model simulations by prescribing a large region of excessive oceanic heat. This simulation only produced a polynya when the sea ice was advected out of the region by atmospheric forcing, or remained stationary for an extended period over the surplus heat flux region.

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REFERENCES

Bailey and Lynch, 2000: Development of an Antarctic Regional Climate System Model. Part I: Sea ice and large-scale circulation. *J. Climate*, **13**, 1337-1350.

Beckmann, A., H. H. Hellmer, and R. Timmermann, 1999: A numerical model of the Weddell Sea: Large-scale circulation and water mass distribution. *J. Geophys. Res.*, **104**, 23 375-23 391.

Comiso, J. C., and A. L. Gordon, 1996: Cosmonaut polynya in the Southern Ocean: Structure and variability. *J. Geophys Res.*, **101**, 18 297-18 313.

Lynch, A. H., W. L. Chapman, J. E. Walsh, and G. Weller, 1995: Development of a regional climate model of the western Arctic. *J. Climate*, **8**, 1555-1570.

Trenberth, K. E., 1992: Global analyses from ECMWF and atlas of 1000 to 10 mb circulation statistics. *NCAR Technical Note*, **TN-373+STR**.