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HEAT BUDGET OF A SHORE POLYNYA, DRONNING MAUD LAND COAST, ANTARCTICA DURING AUSTRAL SUMMER SEASON, 1987-88

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1. INTRODUCTION

Polynya, an isolated water body surrounded by ice, influences local climate considerably. The ocean-atmosphere interaction over the polynya helps in increasing the heat losses several times higher than from the region which is covered with ice. Amongst the Antarctic polynyas, the Weddel polynya has mostly drawn the attention of investigators and some suggestions have been proposed for its evolution (Carsey, 1980; Gordon, 1982). East of Weddel Sea, smaller shore-type polynyas are also known to exist especially along the Dronning Maud Land coast. Ever since the first Indian Antarctica expedition of 1982, a coastal polynya off the Indian ice shelf station 'Dakshin Gangotri' has become a regular visiting place for the supply vessels which bring expedition members/material to the icy continent. Some studies on the biological productivity and chemical aspects of this polynya have been made by Sengupta and Qasim (1982) and Pant (1986). Detailed investigations on heat exchange between the ocean and atmosphere have been carried out more for Arctic polynyas (Smith, 1981; Topham et al, 1983 and Smith et al 1983) as compared to those near Antarctica. Fast tidal flows across shallow regions in the Arctic archipelago are responsible for stronger mixing causing the surface waters to be warm and remain above the freezing point. These warm waters thereby enhance sensible heat flux which is found to be more than 50% of the total heat loss (Harteg et al, 1983).

Recent investigation of Ramesh Kumar and Sadhuram (1989) on heat balance of shore polynya in the Queen Maud Land coast of Antarctica has sought the balance of seasonal surface heat gain against the heat loss through oceanic interior processes affecting steady conditions. However, the examination of sea surface temperature (SST) variation in the same polynya during 1987-88 austral summer season has aroused some interest in reinvestigating its heat budget as SST has showed a decreasing trend. We present here the evolution of the heat budget of the polynya with additional information on advection rates using moored current meter data.

2. DATA AND METHODS

Fig.1 shows the area of the polynya off the Dronning Maud Land coast of Antarctica where the ship 'MV THULELAND'

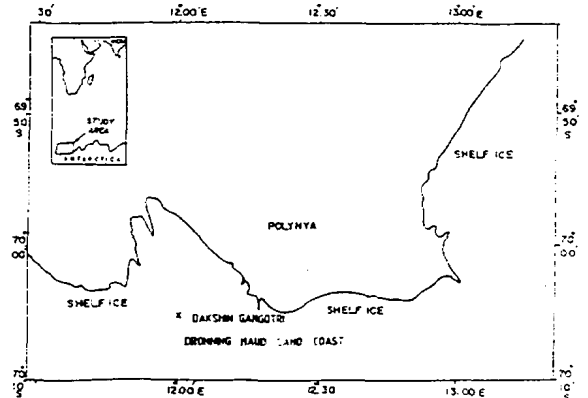


Fig.1 Location of the shore polynya off Dronning Maud land Coast, Antarctica.

was remained during the period from 30 December to 28 February, 1988. Necessary information for the computation of various surface heat balance components using bulk-aerodynamic method was taken from the ship's log of surface meteorological observations which were recorded at a 6-hourly interval. Though errors are possible due to non-uniform level of observations and structure of the ship, they have been usually considered not more than 20% (Hastenrath and Lamb, 1979).

3. RESULTS

Daily averages of various heat fluxes are estimated and their evolutions are presented in figures 2 to 5. The variation of incoming global radiation (Q_1) shows, in general, a seasonal decreasing trend during January-February (Fig.2). High values up to 300 W m^{-2} occur in the middle of January while the incidence of values as low as 50 W m^{-2} is seen at the end of February. The effect of cloudiness (N) on Q_1 is quite evident from the variation of N which is seen as the mirror image of Q_1 .

Latent heat flux (Q_e) shows (Fig. 3) a rather steady regime in January whereas in February an increasing trend is seen. The role of vapour pressure difference ($e_s - e_a$) on Q_e is felt more in January. On the other hand, winds strengthened by about six times, influence Q_e in February.

A conspicuous result of the present study is the occurrence of sensible heat flux (Q_s) around the same order as that of evaporative heat flux (Q_e). This shows Q_s as an important one in surface heat loss

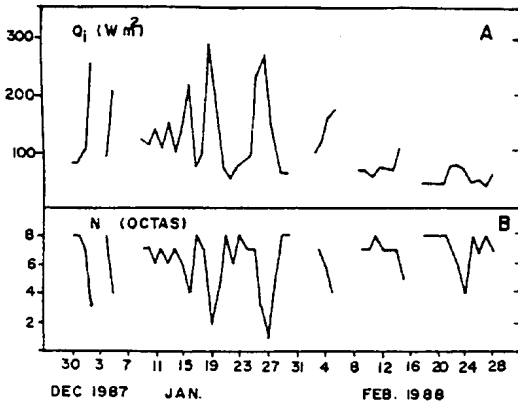


Fig.2 Daily variation of (A) global radiation and (B) cloud amount.

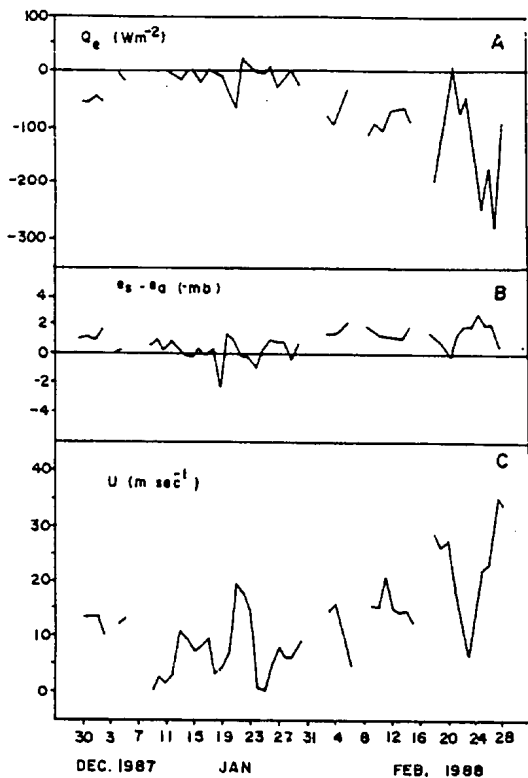


Fig.3 Daily variation of (A) latent heat flux, (B) vapour pressure difference and (C) wind speed.

processes (Fig.4) unlike in tropics where Q_s is not significant. Q_s is mainly positive during January gaining heat due to negative values of sea-air temperature difference ($T_s - T_a$). The seasonal evolutions of both wind speed and $T_s - T_a$ show increasing seasonal trends similar to those of Q_e and Q_s .

The variability of net heat exchange (Q_N) across the sea surface (Fig.5), in general, indicates a net heat gain of about 150 W m^{-2} in January and rather a strong net heat loss during February. Maximum net heat loss values go up to 600 W m^{-2} towards the end of

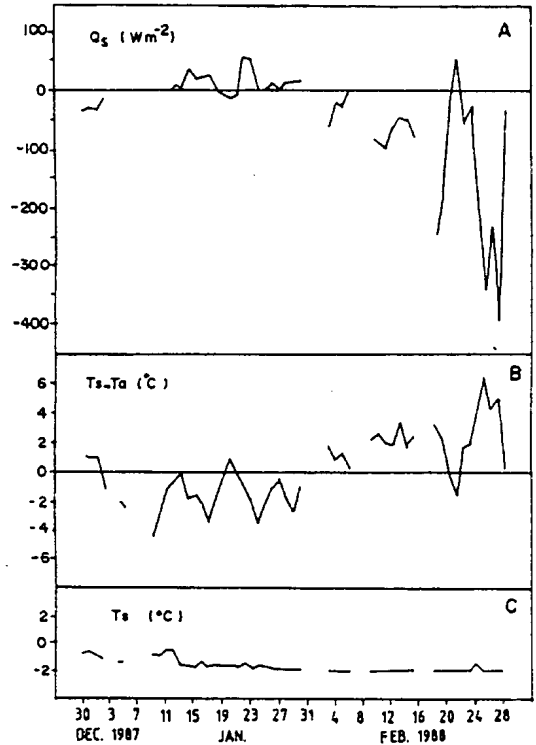


Fig.4 Daily variation of (A) sensible heat flux, (B) sea-air temperature difference and (C) sea surface temperature.

February compensating the heat gain of the previous month. On an average, Q_N during the study period is found to be around 20 W m^{-2}

The low net heat gain impedes the faster growth of polynya. The ice cover in the polynya is found to decrease by about 30% only during the observational period. The amount of heat spent for the melting of ice is computed in order to examine the effect of melting of ice on the heat budget of the polynya. A total mass of ice with an average thickness of 1 m and density of 910 Kg m^{-3} , works out to be of the order of $5.0 \times 10^{11} \text{ Kg}$ when the entire area of polynya (554 km^2) is considered to be covered with pack ice. When 30% of this mass has been melted during the two months observational period, the rate of heat utilised for melting is estimated to be around 17 W m^{-2} which is very close to the order of net surface heat gain. This balance tries to inhibit a raise in SST and it is further expected that the surface heat exchange processes play a minor role in the changes of heat content of upper water column. On the contrary, SST is found to decrease with time. In order to examine the variability of heat content of the water column, a few time series depth-temperature profiles have been examined. From these profiles, it is seen that temporal variations in thermal structure are minimum below 50 m, and accordingly the heat content computations were limited to this depth range. The ave-

average rate of heat content change ($\partial H/\partial t$) works out to be around -45 W m^{-2}

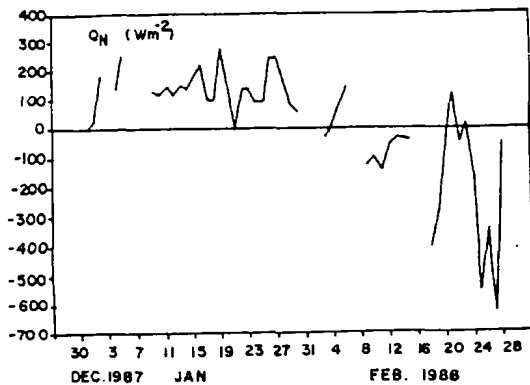


Fig.5 Daily variation of net surface heat flux.



Fig.6 Time series plots of (A) wind speed (-----) and wind direction (\rightarrow) and (B) stick diagram of currents.

indicating that processes of heat advection from the region are at work.

Necessary computations of heat advection by the currents have been carried out using a limited current meter data set. The required information on the flow velocity has been obtained from an array of current meters moored in the polynya for a limited period in spite of the hostile weather. It is interesting to observe that though the prevailing winds are mainly from east with more or less consistent direction, the variability of currents seems to be dominant with a near diurnal tidal component (Fig.6). This suggests that barotropic processes are important in the coastal circulation of Antarctica.

The vectorially averaged current for the observational period is towards NNE with u and v components of 1.8 and 3.6 cm s^{-1} respectively. The meridional variation of heat content ($\partial H/\partial y$) across the northern boundary of the polynya is estimated to be $25.4 \times 10^2 \text{ J m}^{-3}$. By taking these into consideration, the average advective rate for the observational period works out to be 97 W m^{-2} . It is interesting to note that this order is comparable with that of change in heat content, further suggesting the importance of advective processes in the heat budget of the shore polynya off Dronning Maud Land Coast, Antarctica. However we point out that a larger time-series data set of currents with an adequate vertical resolution especially in the surface layer is necessary for more reliable estimates of heat advection.

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5. References

- Carsey, F. D., 1980: Microwave observations of the Weddell polynya. *Mon.Wea.Rev.*, **108** 2032-2044.
- Gordon, A. L., 1982: Polar Oceanography. *Rev.Geophy.Space.Phy.*, **21**(5) 1124-1131.
- Hartog, G. D., S. D. Smith, R. J. Anderson, D. R. Topham, and R. G. Perkin, 1983: Investigation of a polynya in the Canadian Archipelago, 3, surface heat flux. *J.Geophy.Res.*, **88**(C5) 2911-2916.
- Hastenrath, S and P. J. Lamb, 1979: Climatic Atlas of Indian Ocean, Part I, Surface climate and atmospheric circulation. University of Wisconsin, Madison. 109pp.
- Ant, A., 1986: Studies on Antarctic phytoplankton. Third Scientific expedition to Antarctica, Tech.Pub.NO.3. Department of Ocean Development, New Delhi. 87-96.
- Ramesh Kumar, M. R., and Y. Sadhuram, 1989: Surface heat budget of a polynya in the Queen Maud Land, Antarctica, during austral summer. (submitted to Cont. Shelf. Res.)
- Senguptha, R., and S. Z. Qazim, 1982: Chemical oceanographic studies along a section from 32°S to Antarctica in the south western Indian Ocean. Scientific report of first Indian Expedition to Antarctica, Tech.Rep.No.1, Department of Ocean Development, New Delhi. 26-77.
- Smith, S. D., 1981: Coefficients for sea surface wind stress and heat exchange. Rep.No.Bi-R-81-19, Bedford Institute of Oceanography.
- Smith, S. D., R. J. Anderson, G. D. Hartog, D. R. Topham, and G. R. Perkin, 1983: Investigation of a polynya in the Canadian Archipelago, 2, structure of turbulence and sensible heat flux. *J.Geophy.Res.*, **88**(C5) 2900-2910.
- Topham, D. R., R. G. Perkin, S. D. Smith, R. J. Anderson, and G. D. Hartog, 1983: Investigations of a polynya in the Canadian Archipelago, 1, Introduction and Oceanography. *J.Geophy.Res.*, **88**(C5) 2888-2899.