ESTIMATES OF THE SURFACE HEAT FLUXES IN ANTARCTIC WATERS

Fazal Ahmed, S.A.R. Sultan and M.O. Moammar
Faculty of Marine Science, King Abdulaziz University, P.O.Box:1540, Jeddah-21441, K.S.A.

The Antarctic continent spreads from 90°S to about 66.5°S latitude. However the northern continental limit is far from being precise. During winter the ice extends the solid surface of the continent as far as 60°S doubling the surface area of the "continental effect" from 13.6 x 10^6 km^2 to 27.0 x 10^6 km^2. During summer the sea ice breaks, melts and drifts about. The absence of the continental limits has caused the oceanographers to establish the "subtropical convergence" as the limit between the southern ocean and the rest of the world oceans. In the region between the Antarctic convergence and the continent of Antarctica the surface waters are subjected to extreme climatic conditions. In winter the surface layer is homogeneous with temperature almost at freezing point (-1.85° to -1.88°C). During summer the amount of absorbed radiations is small (snow reflects about 80%). The melting of ice consumes a greater portion of radiations and the warming of water is less. Therefore the sea surface temperature in summer warms to about -0.5°C. At the American Amunden-Scott base installed at the south pole itself at an altitude of 2800m, the mean monthly values of air-temperature are -25°C and -62°C. At Vostock Station (78°30'S; 107°E) at 3500 m altitude the mean annual temperature is -56°C and the minima observed are from -88°C to -85°C. Antarctic summer arrives when the earth is closest to the sun (Perihelion).

Oceanographic and Meteorological Data:
We have attempted to compute the heat balance terms on the basis of formulas by Budyko (1974). Some of the meteorological and oceanographic data were collected during the Trans Antarctic Expedition (1989-90). These data were supplemented by the data (1956-1988) made available by the national climatic center of NOAA (National Oceanic and Atmospheric Administration). Monthly means of sea surface temperature in Antarctic waters and meteorological data at a station (77°51'S; 166°39'E) 33 m above sea level are given in table 1.

Absorbed Solar Radiations:
The amount of solar radiations upon the surface of the earth decreases from equator towards the poles. However, there is a minimum at about 60°S, and then a pronounced increase on the Antarctic continent. Budyko (1982) gives 70K cal cm^{-2}yr^{-1} (93 wm^{-2}) near 65°S and 120 K cal cm^{-2} yr^{-1} (160 wm^{-2}) at the south pole. The Albedo of the Antarctic is high (82-84%) with a slight decrease in summer. Therefore, the absorbed radiations adjusted to the Manne Meteorological Station (77°51'S, 166°39'E) are approximately 25 wm^{-2}.  

Table I: Monthly means of the Sea Surface Temperature and Meteorological data (1956-1988) at a station (77°51'S; 166°39'E) 33m above the sea level.

<table>
<thead>
<tr>
<th>Month</th>
<th>SST °K</th>
<th>Ta °C</th>
<th>RH %</th>
<th>Wind m/s</th>
<th>SVP at SST</th>
<th>VP at Ta</th>
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<td>1</td>
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<td>63.4</td>
<td>6.87</td>
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</table>

Components of Surface Heat Fluxes:

The processes of heat exchange between water and atmosphere take place at the air-sea interface. The methods of determining these fluxes are summarized by Pond (1975) and Kraus (1972). The Bulk Aerodynamic method is widely used and demands the recording of various independent environmental information (Meteorological and Oceanographic Data). Bunker (1976), Hastenrath and Lamb (1978) and others have discussed the difficulties in choosing the formulas over oceanic regions.

In this method a bulk transfer coefficient $C_S$ is defined so that the flux $F_S$ is

$$F_S = \rho C_S \overline{w} \Delta S$$

$\overline{w}$ is the mean wind speed.

$\Delta S = S_A - S_W$, the difference of the property $S$ between air and water. The Bulk Aerodynamic Method is therefore a method of parametrization and is useful for large scale applications. Pond et al. (1974), Fiche and Schmitt (1976), Kondo (1977), Garrott (1977), Smith and Dobson (1984), Esbensen and Reynolds (1981), Large and Pond (1981, 1982), and many others have computed the sensible and evaporative heat fluxes from different regions of the oceans using various transfer coefficient schemes.

(a) Evaporative heat flux:

Smith (1981) tabulated transfer coefficient $(C_E)$ to compute evaporation under different wind speeds and sea-air temperature differences. The average value of the coefficient for Antarctic conditions is about $1.3 \times 10^{-3}$. 
Therefore, the equation for heat loss due to evaporation becomes

$$Q_e = -2.8 \left( e_s - e_a \right) \text{w} \text{m}^{-2}$$

$e_s$ and $e_a$ are the saturated vapor pressure at the sea surface temperature and the vapor pressure at the air temperature respectively.

The annual average evaporative heat flux is about $-60 \text{w} \text{m}^{-2}$.

(b) Sensible heat flux:

The usual Aerodynamic formula yields very high values for the sensible heat flux. Therefore, as an alternate sensible heat flux is computed based on the Bowen's ration $R=Q_h/Q_e$. Pickard (1975) has computed this ratio for different latitudes and is 0.45 for our station. Therefore, the average sensible heat flux computed on the basis of this ratio is about $-27 \text{w} \text{m}^{-2}$.

(c) Net long wave radiations:

We have used the formula given by Budyko (1974) to estimate the net long wave radiations.

$$Q_b = -\delta \sigma T_o^4 \left( 0.254 - 0.005 e_a \right) \left( 1 - cn \right) + 4 \delta \sigma T_o^4 \left( T_o - T_a \right)$$

$T_o$ is the sea surface temperature in $\text{k}^\circ$,

$T_a$ is the air temperature in $\text{k}^\circ$,

$c$ is a factor which depends on latitude (Budyko, 1974) and $n$ is the ratio of cloud cover to clear sky. Based on data the average cloud cover value of 0.62 is used for present calculations. The annual average net long wave radiations are $-50 \text{w} \text{m}^{-2}$.

RESULTS AND DISCUSSIONS

The computed annual averages of sensible, evaporative and net upward long wave radiation fluxes are $-27$, $-60$ and $-50 \text{w} \text{m}^{-2}$ respectively. The sensible heat flux when computed from Bulk Aerodynamic Method using the transfer coefficient of Smith (1981) gives a substantially high value. The reason could be that the sea-air temperature difference is very high when compared with Smith's (1981) values. As an alternate the sensible heat flux is computed from the reported values of Bowen's Ratio (Pickard, 1975). The absorbed solar radiation are $25 \text{w} \text{m}^{-2}$.

The recent monitoring of climatic data by satellites will increase our understanding of air-sea interaction processes. In this paper we have computed values on the basis of conventional techniques. The difference between conventional analyses and satellite scatterometer pressure fields estimates suggest that climatological wind values for the southern hemisphere need to be revised. The average wind speed from Sea Sat is 10 to 20% higher (Katsaros and Brown, 1991) than climatological wind data. The implication is that flux estimates from bulk coefficient formulas will be at least that much higher.

Bromwich (1989) has discussed the strong negatively buoyant Katabatic air streams in the Antarctic.

The understanding of the air-sea interaction processes in Antarctic region is receiving attention from the scientific community due to its potential effect on the climatic changes. The present paper is an effort in this direction and this study substantiates the hypothesis that Antarctic is a great diffuser of heat.
We are thankful to the National Climatic Data Center of NOAA for making available some of the data. The active participation of one of the authors, Dr. Mostafa O. Moammar in the Trans Antarctic Expedition 1989-90 provided the base for this study. The financial support of King Abdulaziz University through Project No.165/412 is highly acknowledged. Thanks to Mr. A. Azzoghd for typing the manuscript.

REFERENCES


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