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ANTARCTIC SEA ICE VARIATIONS 1973-75

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6

ABSTRACT

Variations in the extent and concentration of sea ice cover on the Southern Ocean are described for the three-year period 1973-75 using information derived from the Nimbus-5 passive microwave imager (ESMR).

INTRODUCTION

Sea ice concentration (percent ice cover) is derived from the microwave brightness temperature and used to determine monthly averages of 1) total extent of ice-laden ocean (area having at least 15% ice cover) and 2) the area of ocean covered by highly concentrated ice (85-100% concentration). These areas of ice coverage are obtained for the entire Southern Ocean and for each of 5 sectors (Figure 1) into which the region has been divided.

SECTORS FOR ANALYSIS OF ANTARCTIC SEA ICE

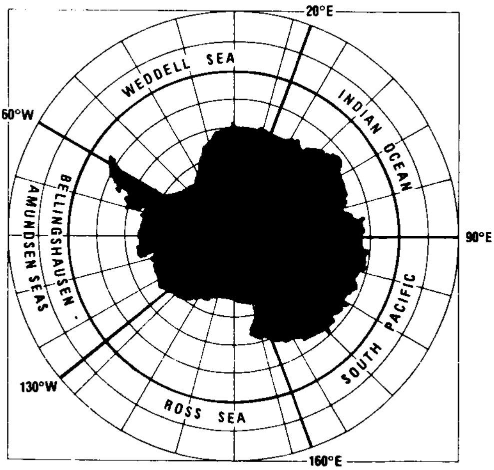

Figure 1

Most previous analyses of the seasonal and inter-annual variations of the sea ice cover have been limited to study of the position of the boundary between open ocean and the ice pack. Although the boundary is usually well-defined, such analysis does not consider changes in the actual area of ice versus open water within the ice pack. Because the heat exchange between the ocean and atmosphere is affected by the area of ice cover and its thickness, changes in the maximum extent of the ice pack alone might not be a significant indicator of changes in the climatic effects of the sea ice cover.

Ice concentration (C) is determined by taking the measured brightness temperature T_B to be a linear combination of the sea ice brightness temperature and open ocean brightness temperature (plus background) in proportion to the area covered by each as described by Zwally and Gloersen (1977):

$$C = \frac{T_B - 135K}{\epsilon_I T_o - 135K} \quad (1)$$

where ϵ_I is the ice emissivity, T_O is the ice near-surface temperature, and 135K is the brightness temperature of sea water (120K at 1.55 cm wavelength plus 15K of atmospheric and cosmic background). The appropriate value of emissivity for first year sea ice at 1.55 cm wavelength is 0.92 (Zwally and Gloersen, 1977). This is also a good overall value for the Southern Ocean because only a small portion of the Antarctic sea ice exhibits a multiyear microwave signature. A significant improvement in the accuracy of the ice concentration results from estimating a T_O for each location for each month in contrast to using a constant T_O. The ice temperature is taken to be colder than the sea surface by 0.75 of the difference between the sea surface freezing point and the climatological air temperature (Taljaard et al., 1969) for air temperature below freezing. The value of 0.75 is supported by unpublished field measurements of the ice and air temperatures (Ramseier, private communication). The ice extent ($C \geq 15\%$) and the highly concentrated ice ($C \geq 85\%$) areas are obtained by summing the areas of resolution cells comprising the digital ice concentration maps created from T_B maps using Equation 1.

COMPLETE SOUTHERN OCEAN

The ocean area of the southern hemisphere affected by ice cover (15 - 100% concentration) decreases to a minimum of about 4 x 10^6 km^2 in February and increases to a maximum of about 20 x 10^6 km^2 in September. Clearly the ice decay proceeds more rapidly than the February - September ice growth. Well over half the areal reduction of ice extent occurs within the 2 month period mid-November - mid-January.

The data show a mild trend toward less ice extent between 1973 and 1975, particularly during the growth season. However, they do not show a similar trend for the area of waters withhighly concentrated ice. In 1973 the maximum ice extent occurs in late September or early October, but is 2-4 weeks earlier in 1974 and 1975. Most of the interannual difference in total ice extent is due to the Weddell Sea sector where a major polynya formed in 1974 and 1975. There is a tendency for a decrease of ice in one sector to be compensated by an increase in another, as can be seen by comparing the Weddell and Ross Seas in 1973 and 1974.

The largest decrease in the area of highly concentrated ice occurs with a dramatic one month decrease of 6 x 10^6 km^2 from October - November of 1973 and with a slower two month decrease of slightly less total magnitude in October - December of 1974 and September - November of 1975. This decrease preceeds by about a month the largest decrease in total ice extent discussed above. This reduction of highly concentrated ice could be due to an increase in ice divergence or more likely to a decrease in new ice production in newly formed leads.

WEDDELL SEA SECTOR

Of the 5 sectors, the Weddell Sea contains the largest areal extent of sea ice. Roughly one-third of the Southern Ocean's sea ice area is within this region, and not surprisingly, its ice area also reaches a peak in September and descends to a minimum in February. In the Weddell Sea, however, the area of highly concentrated ice as well as the ice extent peaks consistently in September, and the magnitude of this peak is considerably greater in 1973 than in either of the other 2 years. The area of ice extent in the Weddell Sea is also greatest in 1973. A large area of open water surrounded by ice, a polynya, occurred in 1974 and 1975 but not in 1973. This highly significant feature accounted for nearly half the area difference in ice extent shown. Of the five sectors the Weddell Sea has the largest proportion, about half, of highly concentrated ice. This reflects the confining effect of the Antarctic Peninsula in reducing the ice divergence in comparison to more open seas.

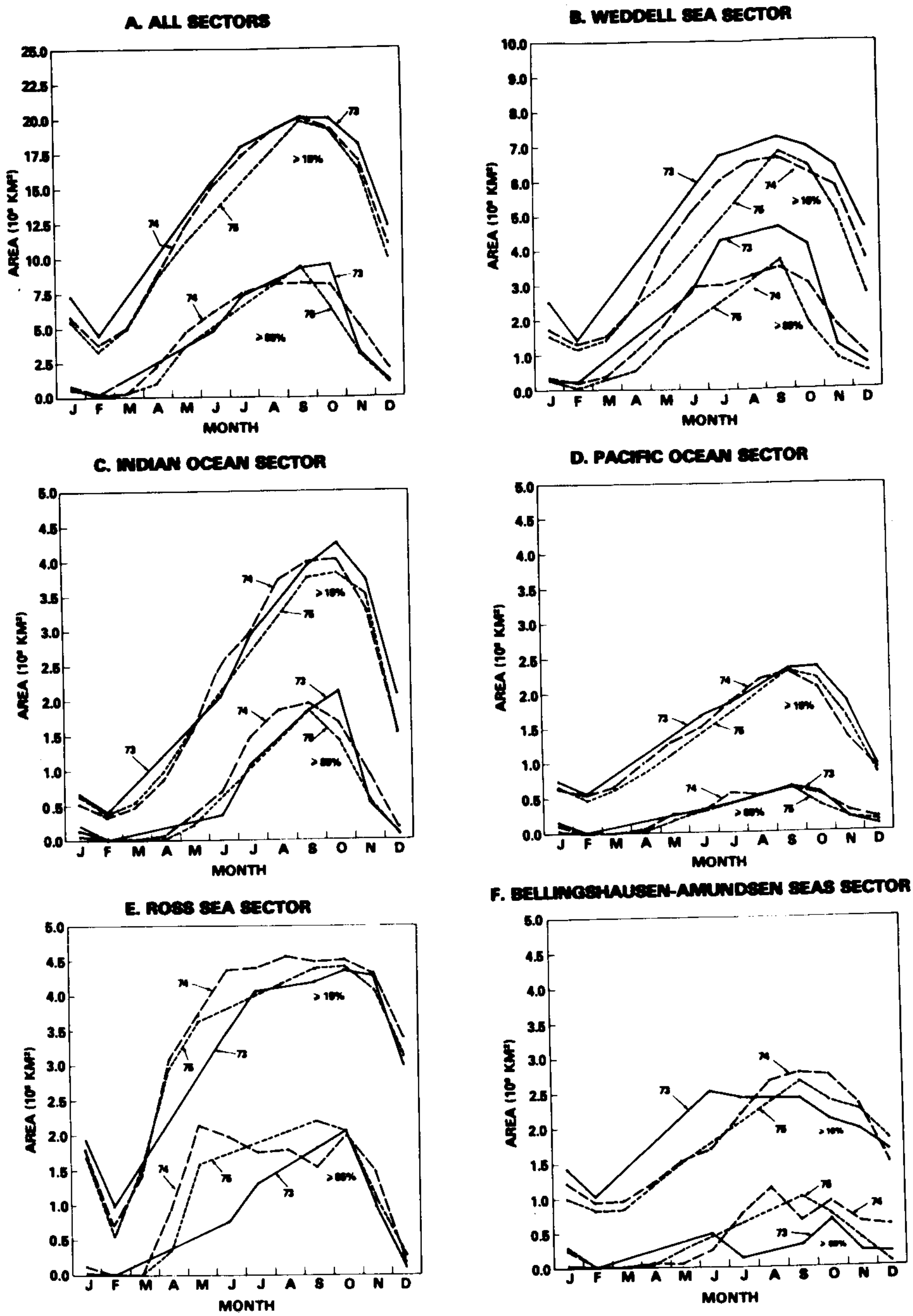

Fig. 2—Areal extent of ocean waters with sea ice concentration at least 15% and with sea ice concentration at least 85%

INDIAN OCEAN SECTOR

The month of peak ice extent in the Indian Ocean is October, not September as in the Weddell Sea, though the month of minimum extent is again February. The peak month for highly concentrated ice is also October for 1973 and 1974, though by October of 1975 the area of highly concentrated ice has decreased substantially from September. It is interesting that in this sector the winter of peak ice extent for the 3 years, in October 1973, is followed the next summer by the 3-year minimum, suggesting the difficulty of forecasting ice extent by persistence.

PACIFIC OCEAN SECTOR

With the Antarctic Continent extending equatorward to 67^{o}S, the Pacific Ocean sector has the smallest sea ice extent of the 5 sectors. The ice extent peaked in September with a magnitude of about 2.3×10^6 km^2 in both 1974 and 1975. In 1973 the September areal extent was also 2.3×10^6 km^2, but in that earlier year the area increased very slightly during October. In all 3 years the area of highly concentrated ice peaked in September, and the minimum of both ice extent and highly concentrated ice occurred in February. The small interannual variations in the Indian Ocean and the Pacific Ocean reflect that the ice is principally influenced by temperature and is less affected by winds of the weaker synoptic systems in these regions.

ROSS SEA SECTOR

The data for the Ross Sea Sector reflect much variability among the 3 years. This is indicated particularly by the 3 contrasting curves for highly concentrated ice, which peak in October for 1973, in September for 1975, and much earlier, in May for 1974. The 1974 occurrence of a relative minimum of highly concentrated ice in September may be due to advection of ice as discussed in relation to the Bellingshausen-Amundsen Seas. The year 1974 also witnessed an unusually large expansion of the ice extent between February and June. A comparison between 1973 and 1974 shows that the summer with the lower minimum (1974) was followed by a rapid growth of ice area and a consequent higher maximum. As in the period October 1973 - February 1974 in the Indian Ocean Sector, this phenomenon is further evidence of the difficulty of forecasting by persistence.

BELLINGSHAUSEN - AMUNDSEN SEAS

As with the Ross Sea to the west, the Bellingshausen - Amundsen Seas show a highly variable cycle of sea ice over the 3 years. These facts could be interrelated. For example, the unusually high amount of ice in the Bellingshausen and Amundsen Seas in June of 1973 could reflect an unusually strong eastward transport of ice from the Ross Sea which had lesser ice at that time. Non-occurrence of such transport in the 2 succeeding years could account for the greater late-fall Ross Sea ice extents in those years.

CONCLUDING REMARKS

With data assembled for only a 3 year time period, it is only possible to point out some interesting suggestive evidence. Many more years of data are required before firm conclusions can be drawn on the nature of interannual variability of Antarctic sea ice. Some interannual variation is shown in the phase and amplitude of maximum and minimum in the curves for all sectors, but the curves for the individual sectors were much more variable. This suggests a large scale interaction among the regions. Also, the different sectors show varying proportions of highly concentrated ice, indicating regionally different meteorological and oceanographic processes.

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