A study on sea ice variation in Lützow-Holmbukta, Antarctica, with satellite data

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Abstract
Characteristics of sea-ice variation including breakup events in Lützow-Holmbukta, Antarctica, have been investigated for the period of 1980-2003. According to satellites images, it is found that spatial and temporal scales for breakups are different among each event and that breakups have occurred at least 19 times. The geographical sites of breakups are almost the same in the bay and commencement is usually in autumn. The 1997/1998 event covered a wide area and was of long duration. Since then, autumn to early winter breakup has continued until winter 2003. It is suggested that dominant southerly wind field, small snow depth and mild winter prior to the breakup are factors which favor breakup events. Long-term monitoring of such a coastal sea-ice condition is important and useful for better understanding of the Antarctic and global change.

1. Introduction

Land fast-ice covers almost throughout the year in Lützow-Holmbukta, Antarctica. Satellite images show that the ice field has frequently broken up there. Appearance of open water resulting from breakup performs active air-sea interaction, and will have an influence on regional climate and oceanic environment. The purpose of this study is to reveal a mechanism for the coastal sea-ice variation.

The Japanese Antarctic Research Expeditions (JAREs) have conducted satellite, meteorological, and snow depth observations at Syowa Station. Furthermore, wintering activities reports of JAREs are referred to estimate the ice condition. Then, some factors for sea-ice breakup are discussed based on these historical data.

2. Characteristics of sea-ice breakup in Lützow-Holmbukta

2.1 Where have the breakups occurred in the bay?

Figure 1 shows a typical appearance of the large-scale breakup from NOAA/AVHRR image. The image by thermal-infrared channel with resolution of ~1km is processed for features with relatively high surface temperatures to be presented in dark gray to black tones. As for the case of winter 1997, ice formation and discharge have been repeated through mid-winter 1998. Almost the breakup events occur north-central to eastern area of the bay. The boundary between unstable outflow and stable ice field is nearly consistent with the location of continental shelf break referred from the bathymetric chart (GEBCO). At the shallow region, stable ice field has a tendency to be left. Dynamic effect from ocean current or waves should be studied as a future work.

2.2 History of sea-ice breakup

Using satellite images and the JAREs wintering reports, breakup events have been compiled as shown in Figure 2. Here, "breakup" period is defined as occurrence of ice outflow to the south of 68.83S. In summer season, vigorous melting or water opening have been found at the eastern area of the bay as shown in Figure 2. Breakups frequently occur at autumn season and at least 19 times for the last 24 years. It is remarkable trend that breakups have been continued every year since 1997.

3. Discussion

Melting feature at summer season, as observed at the eastern area of the bay, is induced from strong insolation and high temperature. In this section, physical factors for breakup events occurred in autumn season are mainly discussed according to the historical data. The following three factors are possible to be considered; 1) dominant southerly wind, 2) snow depth, 3) air temperature anomaly (*Ushio, in press*).

3.1 Surface wind field

Table 1 shows frequencies percentage of surface wind direction for the case study of 1997 event. On April, before the remarkable breakup occurrence at early winter, strong northeasterly wind has blown at about twice as frequent as the normal value. Northeast wind at Syowa is usually very strong accompanied with blizzard. Such a strong onshore wind brings great swell inside the bay and causes fast-ice field to be broken down.

Southerly wind during the period from May to July has also blown with high frequencies as shown in Table 1. The frequent offshore wind is considered to transport broken ice floes northward. Thus the peculiar wind field contributes to occurrence of large breakup in July 1997.

3.2 Snow cover effect

Snow cover on ice plays an important role on heat exchange in the atmosphere-ice-ocean system. When snow depth is large, melting and refreezing cause formation of superimposed ice (like a mechanism for accumulation at temperate glaciers). Snow cover effect should be considered to estimate mass balance for sea ice. Such a snow metamorphosis affects mechanical properties of sea ice. Thick ice and much snow cover contribute to growth of hard ice floe, so ice field will be stable against heavy weather condition. In the Figure 2, years with much snow cover, above 60cm as maximum increase for each year, are indicated by asterisk. During the period of previous and middle of 1990s, much snow depth years have continued and coincide with relatively stable situation or no breakup era. For the other period, frequent breakup link up small snow cover. If snow depth is small, absorption of solar radiation is active from spring to summer and upward growth by superimposed ice is not expected.

3.3 Air temperature anomaly in the cold season

It is necessary for sea-ice breakup that ice floe should be broken down. Mechanical strength depends on brine volume ratio inside the ice. The brine volume increases with temperature, so mechanical strength lowers by warm environment, because ice temperature follows air temperature variations. Figure 3 shows monthly air temperature for cold season, August to October, in each year since 1980. For the past years, air temperature records the highest value in 1996. This warm winter is considered to be a trigger for the large breakup in 1997.

4. Conclusions

Variation of land fast-ice field has been investigated using satellite images and surface meteorological data. Breakup phenomena are often observed in autumn season. Sea ice condition in Lützow-Holmbukta is generally unstable. Remarkable anomalies for surface wind field, snow cover, and air temperature are presented to consider as possible factors for the breakup. Sea ice processes are important for the navigation of icebreaker SHIRASE as well as understanding of global change mechanism. Monitoring study should be continued with satellite remote sensing and in-situ observations by high technology device.

Table 1. Frequencies percentage of wind direction at Syowa Station in 1997.

wind direction	NE	S / SSE / SE		
year \ month	April (%)	May (%)	June (%)	July (%)
1997	42	13/8/9	12/8/6	12/11/6
NORMAL	22	7/6/4	6/7/6	6/6/4

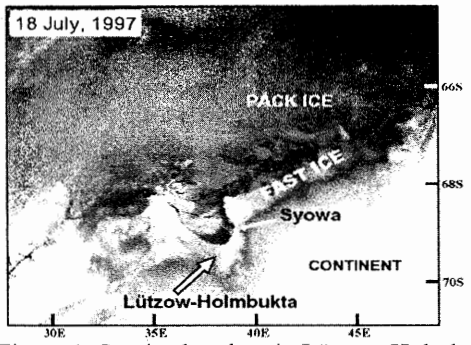

Figure 1. Sea-ice breakup in Lützow-Holmbukta.

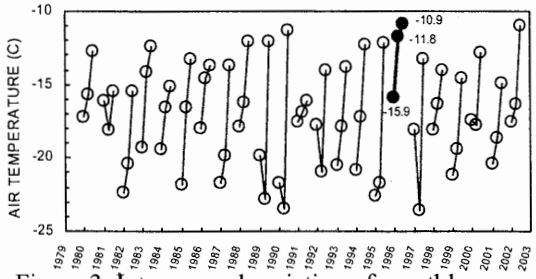

Figure 3. Inter-annual variation of monthly mean air temperature on August, September, and October. Closed circles indicate values of 1996 before breakup.

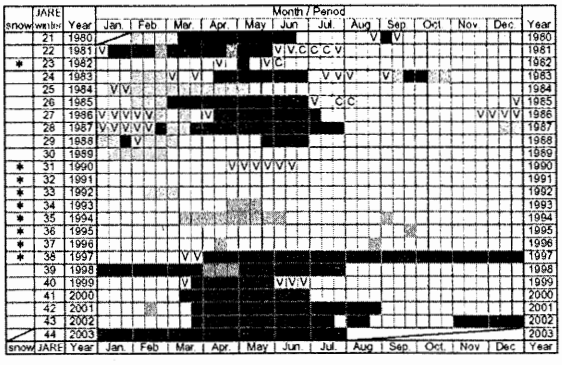

Figure 2. History of sea-ice breakup in Lützow-Holmbukta from 1980 to 2003. Black-colored period: breakup in the bay; hatched: breakup only eastern part; gray: inferred as period with high possibility of breakup; V: v-shaped crack; C: north-south crack; *:year with much snow at Syowa Station.

References

Ushio, S.(2003): Frequent sea-ice breakup in Lützow-Holmbukta, Antarctica, based on analysis of ice condition from 1980 to 2003. Antarctic Record, Vol.47, No.3, *in press*.