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Recent sea-ice advances in Baffin Bay/Davis Strait and retreats in the Bellingshausen Sea

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ABSTRACT. Recently reported decreases in the summertime ice coverage of the Bellingshausen Sea over the period 1988–91 have been mentioned in the popular press with some loss of the larger spatial and temporal context in which they occurred. Experience over the past two decades with the continually lengthening satellite record has frequently revealed prominent increases or decreases in regional or even hemispheric sea-ice coverage which last for a several-year period and are then reversed. Also, in almost any several-year period in the short satellite record available, at least one region could be highlighted as having prominent ice-cover increases and at least one as having prominent ice-cover decreases. In the 1988–91 period of low ice coverage in the Bellingshausen Sea, mid-winter sea-ice extents noticeably increased in the Baffin Bay/Davis Strait region. Placed in the longer temporal context of ice extents since the late 1970s, the ice-extent increases from 1988 to 1991 in Baffin Bay/Davis Strait conform much better with an interpretation of cyclically varying wintertime ice extents than with one of a long-term upward trend. The time series for the Bellingshausen Sea also shows marked multi-year fluctuations and, although in the 1989–91 period the summertime coverage was unusually low, the wintertime ice coverage noticeably increased.

1. INTRODUCTION

Jacobs and Comiso (1993) recently reported some interesting and perhaps significant decreases in summertime sea-ice coverage in the Bellingshausen Sea west of the Antarctic Peninsula, from 1988 through early 1991. The decreases were explained on the basis of recorded inter-annual differences in surface winds and air temperatures, yet shortly after their publication they were featured in a *New York Times* article with the title, "A vast polar ice sheet mysteriously vanishes" (Sullivan, 1993). At the end of the *Times* article, though, it was indicated that the ice coverage in the region had returned, in 1993, to its "normal" condition prior to the 1988–91 decreases. A strong 3 year change in regional sea-ice coverage is by no means unusual; and when it can be explained on the basis of inter-annual contrasts in atmospheric forcings, as by Jacobs and Comiso (1993), it is not considered mysterious by scientists familiar with sea-ice phenomena. (The *Times* article's title is most likely not the responsibility of the article's author, but it remains a problem in view of the misperceptions relayed to the public.)

In this period of high interest in climate change and the potentially disastrous alterations that human activities could be precipitating, it is particularly important that a balanced picture be provided. If nothing else, this will lessen the chances that the reporting of truly significant changes (whether gradual or abrupt) will be diluted because of too many earlier false cries of "fire", or, in this case, "ice disappearance". Because sea-ice decreases conform easily with a concept of climate warming, the short-term, seasonally dependent sea-ice decreases in the Bellingshausen Sea can be taken out of context and highlighted as supposed evidence of global warming. It is important to keep in mind that over the course of the satellite record available so far, all several-year periods show some regions experiencing ice-cover increases and others ice-cover decreases. To be specific to the 1988–91 period, this paper presents data showing marked sea-ice increases in the Baffin Bay/Davis Strait region (Fig. 1) occurring over approximately the same time-frame as the reported low ice coverages in the Bellingshausen Sea. The 1988–91 Baffin Bay/Davis Strait ice increases are then placed in the longer temporal context of the fluctuations of the Baffin Bay/Davis Strait ice cover since 1978 and compared with the fluctuations in the Bellingshausen Sea. The latter fluctuations, furthermore, are shown to contain wintertime ice-cover increases over the 1989–91 period, earlier highlighted for its low summertime ice extents.

2. SATELLITE DATA SOURCES

The sea-ice data used for this study are derived from the same satellite data sets as used by Jacobs and Comiso (1993). These are passive-microwave brightness temperatures from the Scanning Multichannel Microwave Radiometer (SMMR) on NASA's Nimbus 7 satellite and the Special Sensor Microwave Imager (SSMI) on a satellite of the Defense Meteorological Satellite Program (DMSP).

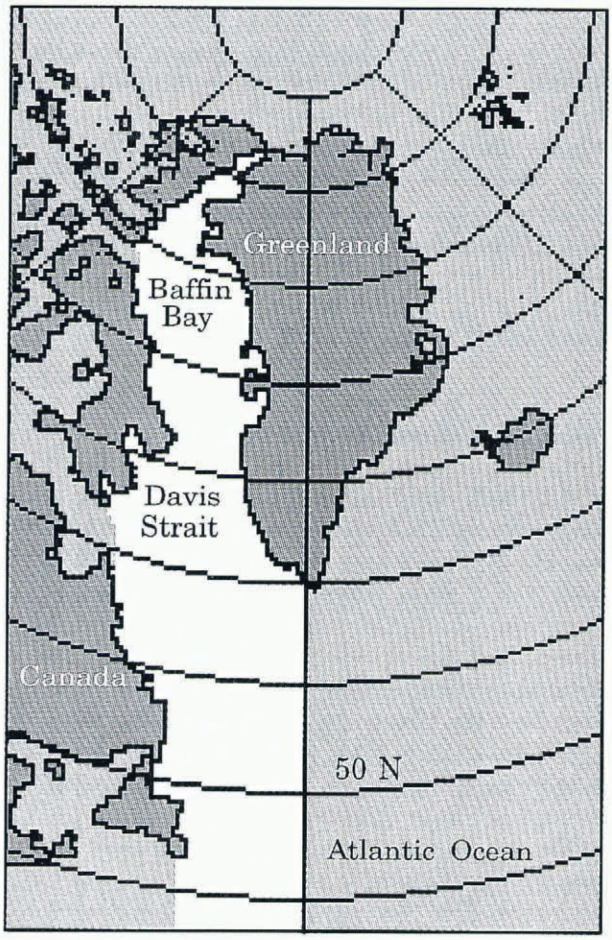

Fig. 1. Identification, in white, of the Baffin Bay/Davis Strait region used in the generation of the plots of Figures 2 and 3. The region can be seen to extend well south of Davis Strait, encompassing the Labrador Sea and a small part of the North Atlantic.

The former data cover the period from late October 1978 through mid-August 1987, and the latter data the period since early July 1987. The huge value of the passive-microwave data for sea-ice studies centers on the sharp contrast in microwave emissions between sea ice and open water and the relative absence of atmospheric interference with the microwave signal. This combination of factors allows the ready identification of the sea-ice edge and the calculation of approximate sea-ice concentrations (percentage areal coverages) within the ice pack.

The SMMR is a ten-channel instrument receiving both vertically and horizontally polarized radiation at five frequencies between 6.6 and 37 GHz. The SMMR data have been used extensively in sea-ice research, and a compilation and analysis of the full 8.8 year of SMMR sea-ice data for both polar regions, plus details on the theory of microwave imagery and reviews of much of the past work using the SMMR data, can be found in a recent SMMR sea-ice atlas by Gloersen and others (1992). The algorithm for calculating ice concentrations uses the 18 and 37 GHz SMMR data and obtains ice concentrations having a spatial resolution of approximately 55 km and an estimated accuracy of $\pm 7\%$ (Gloersen and others, 1992).

The SSMI is a seven-channel instrument receiving vertically polarized radiation at 22.2 GHz plus both vertically and horizontally polarized radiation at 19.4, 37.0 and 85.5 GHz. These data have been converted to ice concentrations using the same algorithm as used for the SMMR data, although with adjustments to account for the replacement of the 18.0 GHz SMMR channels with the 19.4 GHz SSMI channels. The algorithm adjustments were made by D. Cavalieri, K. St. Germain and C. Swift (personal communication, 1993) and involve new tie points plus a more sophisticated weather filter incorporating the 22.2 GHz SSMI information. The SSMI radiative data, the SMMR radiative data and the SMMR-derived sea-ice concentrations are all available on CD-ROMs from the World Data Center A for Glaciology and National Snow and Ice Data Center in Boulder, Colorado, U.S.A.

3. BAFFIN BAY/DAVIS STRAIT

For the 1988–91 period, the Baffin Bay/Davis Strait region experienced mid-winter increases in sea-ice extents, calculated from the SSMI data as 1.34×10^6 km^2 in February 1988, 1.41×10^6 km^2 in February 1989, 1.57×10^6 km^2 in February 1990, and 1.60×10^6 km^2 in February 1991 (Fig. 2; in 1989 and 1990 the March values exceed the February values, whereas in 1988 and 1991 the highest values are in February). Disregarding Baffin Bay proper, with its near-total ice coverage in each February, the percentage increases would be considerably higher, but even with Baffin Bay included, the rise is substantial (Fig. 2).

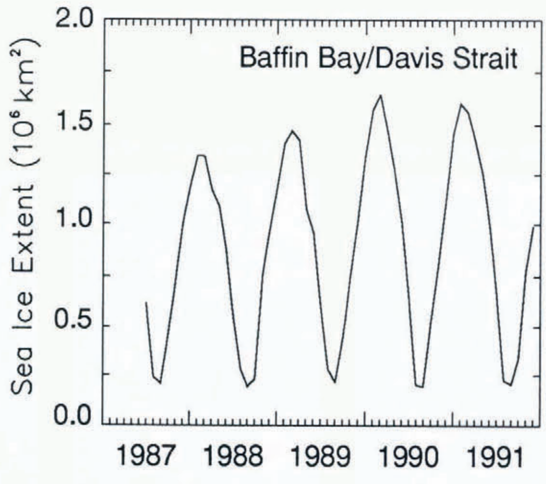

Fig. 2. Monthly average ice extents in the Baffin Bay/Davis Strait region from July 1987 through December 1991, from the satellite passive-microwave data of the DMSP SSMI. Major tick marks along the horizontal axis occur at January of each year.

The availability of SMMR data allows the Baffin Bay/Davis Strait time series of Figure 2 to be extended backwards to November 1978. When this is done, the extended time series reveals the 1988–91 ice-extent increases to be part of a fluctuating pattern with wintertime ice extents approximately level in the period 1979–81, increasing 1981–84, decreasing 1984–88 and

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increasing 1988–91 (Fig. 3). The appearance is of a cyclical behavior with a period of about 6–7 year (Fig. 3), although the time series is far too short to establish the existence of a regular cycle.

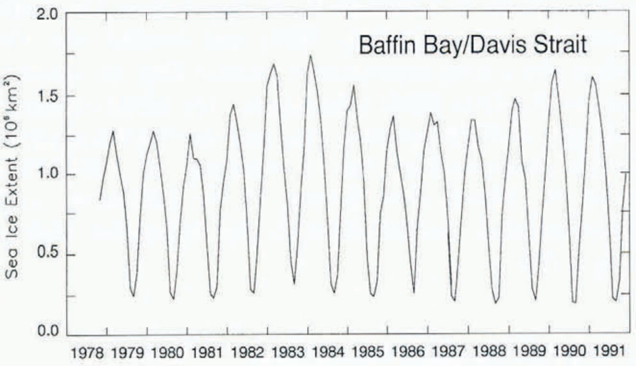

Fig. 3. Monthly average ice extents in the Baffin Bay/Davis Strait region from November 1978 through December 1991, from the satellite passive-microwave data of the Nimbus 7 SMMR and the DMSP SSMI. The data records from the two instruments overlapped in July and August 1987, and both sets of values are plotted for those two months. Tick marks along the horizontal axis occur at January of each year.

Figure 4 provides images of sea-ice concentrations in the Baffin Bay/Davis Strait region in mid-February of 1984, 1985, 1986 and 1987, the major period of ice-extent decreases in the SMMR and SSMI records plotted in Figure 3. Focussing on Davis Strait between 60° and 65° N, it can be seen that most of the strait was ice-covered in mid-February 1984 but that the strait was largely free of ice throughout its eastern two-thirds in mid-February of each of the three succeeding years (Fig. 4). This contrast, along with lessening ice concentrations to the north, in the eastern part of Baffin Bay, was in the same direction as and comparably dramatic to the 1988–91 situation in the Bellingshausen Sea. Yet the ice cover in Baffin Bay/Davis Strait successfully rebounded (Fig. 3), as have the ice covers in other seas and bays following their own differently timed decreases (e.g. Parkinson and Cavalieri, 1989).

4. THE BELLINGSHAUSEN SEA

SMMR/SSMI time series of monthly average sea-ice extents over the 1978–91 period are given in Figure 5 for both the Bellingshausen Sea region (62°–100° W) of Jacobs and Comiso (1993) and the extended Bellingshausen/Amundsen Seas region (60°–130° W) used in Gloersen and others (1992) and other works. For the Bellingshausen/Amundsen Seas, wintertime (August–September) ice extents decreased noticeably from 1979 to 1980 and slightly more, with fluctuations, from 1980 through 1983, then increased relatively rapidly and systematically from 1983 through 1986, reaching a peak in 1986 that exceeded the initial peak in 1979 (Fig. 5). Sharp ice-extent decreases followed over the next 2 year, then increases in 1989 and 1990, and a slight decrease in 1991, all suggesting a fluctuating inter-annual behavior of the wintertime ice extents. When examined alone, the Bellingshausen Sea shows similar fluctuations, though with differences in the details, including wintertime ice-extent increases from 1979 to 1980 and decreases from 1988 to 1989 (Fig. 5). The Bellingshausen Sea time series

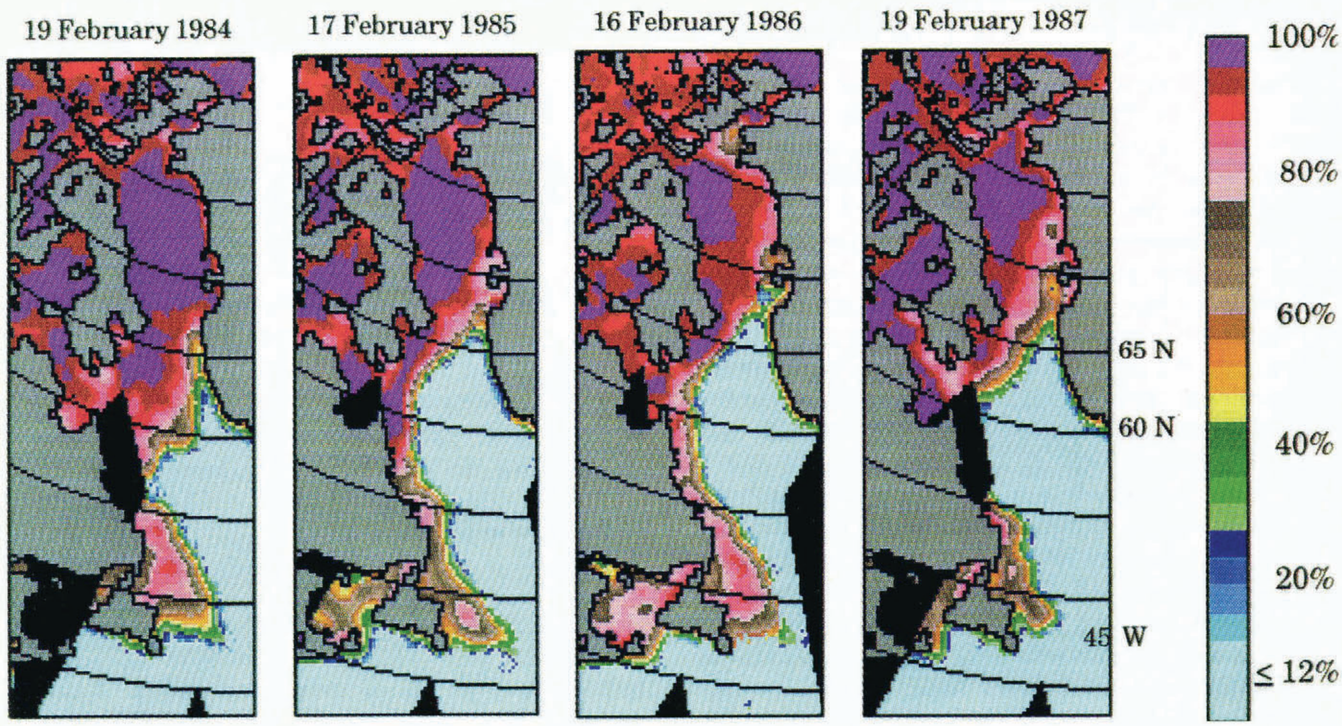

Fig. 4. Color-coded sea-ice concentrations in Baffin Bay/Davis Strait and surroundings for 19 February 1984, 17 February 1985, 16 February 1986, and 19 February 1987, as derived from the data of the Nimbus 7 SMMR. Black indicates missing data.

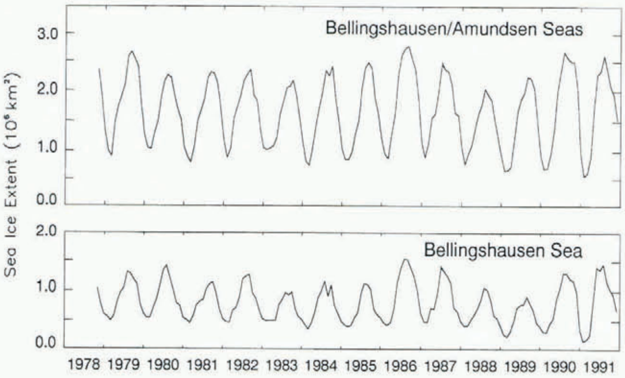

Fig. 5. Monthly average ice extents in the Bellingshausen Sea and the combined Bellingshausen/Amundsen Seas from November 1978 through December 1991, from the satellite passive-microwave data of the Nimbus 7 SMMR and the DMSP SSMI. Tick marks along the horizontal axis occur at January of each year.

reveals that the low 1989 wintertime ice extents reported by Jacobs and Comiso were followed by much higher wintertime ice extents in 1990 and 1991, with each of the final two years having ice-extent maxima amongst the highest of the SMMR/SSMI period (Fig. 5).

The summertime situation presented by Jacobs and Comiso (1993) is more dramatic, only near-coastal ice remaining east of 90° W on 28 February 1989 and in the entire Bellingshausen Sea on 14 February 1991. However, Jacobs and Comiso show considerably more ice in the intervening year; and even in the extreme year, 1991, nearly the entire region exhibiting open water also experienced open water within the 1973–87 time-frame of the earlier satellite passive-microwave data sets, even on a monthly average basis (Parkinson, 1992; plate 1). More specifically, nearly all that part of the Bellingshausen Sea exhibiting open water in February 1991 also experienced open water in February during the years 1973–76 of data coverage by the Nimbus 5 Electrically Scanning Microwave Radiometer (ESMR) (Parkinson, 1992; plate 3). The lowest summertime ice extents in the Bellingshausen Sea in the satellite passive-microwave record 1973–91 came in the years 1974–76 (ESMR data, available from the National Snow and Ice Data Center, Boulder) and 1989–91, near the beginning and end of the series and hence not suggestive of a long-term trend. Furthermore, in the most extreme case shown by Jacobs and Comiso, on 14 February 1991, the minimal sea-ice coverage in the Bellingshausen Sea coincided with an unusually heavy ice coverage in the nearby Weddell Sea, on the opposite side of the Antarctic Peninsula (Jacobs and Comiso, 1993, fig. 1).

Examination of the individual data points plotted in Figure 5 reveals that for each of the eight months June 1986–January 1987, extending from late autumn through the entire winter and spring seasons and into early summer, the ice extents in the Bellingshausen Sea exceeded the corresponding monthly extents in each of the preceding 7–8 years, back to the beginning of the SMMR record. This is true also for the autumn month of April 1987. Yet, 2–3 years later, ice extents in every month of 1989 were less than the corresponding extents throughout the 1979–86 period, with the one exception that the June 1989 ice extents exceeded the June 1985 ice extents. This illustrates that even when an unusually extensive ice coverage extends into all seasons (e.g. June 1986–January 1987 plus April 1987), it does not necessarily presage continued extensive ice coverage. Similarly, unusually low ice extents, such as those in 1988–89 and in the summers of 1990 and 1991, do not necessarily presage continued low ice extents, as evidenced by the high wintertime ice extents in the Bellingshausen Sea in 1990 and 1991 (Fig. 5).

5. DISCUSSION

The satellite passive-microwave records available since the early 1970s show a fluctuating inter-annual behavior in sea-ice extent in many sea-ice regions of both the Northern and Southern Hemispheres (e.g. Parkinson and Cavalieri, 1989; Gloersen and others, 1992). This fluctuating behavior has the danger that regional changes persisting over several years can be highlighted out of context and generate false impressions amongst both scientists and non-scientists. Previously reported low ice coverages in the Bellingshausen Sea in the summers of 1989–91 and the winter of 1989 are here placed in the context of longer time series for the Bellingshausen Sea over the period 1978–91 and similar time series for the larger region of the Bellingshausen/Amundsen Seas and the Northern Hemisphere region of Baffin Bay/Davis Strait. For each of the regions, the appearance of the 1978–91 time series is more suggestive of a fluctuating or even somewhat cyclical behavior than of a long-term trend, although the record is far too short to establish the existence of any regular inter-annual cycle. The summertime ice extents of 1989–91 in the Bellingshausen Sea were unusually low for the 1978–91 period; but they were comparable with the summertime ice extents in the earlier years 1974–76, as calculated from the Nimbus 5 ESMR data. The low wintertime extents in 1989 were followed by substantially greater wintertime ice extents in both 1990 and 1991. Furthermore, the years 1989–91 experienced rising wintertime ice extents in both the Baffin Bay/Davis Strait region and the Bellingshausen/Amundsen Seas region. The placement of the 1989–91 data into the longer-term context of the SMMR/SSMI 1978–91 record, with its prominent fluctuations, should help forestall ascribing a climatic significance, from the data available so far, to either the recent low summertime ice coverage in the Bellingshausen Sea or the recent expanding wintertime ice coverage in the Bellingshausen Sea, the Bellingshausen/Amundsen Seas, or Baffin Bay/Davis Strait.

Of course the short data record and incomplete theory are no more sufficient to predict confidently a continued cyclical behavior in any of the regional ice covers than they would be to predict a continued upward or down-ward trend. The sea-ice research community remains hindered by the brevity of the data sets and by the large amount of inter-annual variability shown within them. Confident recognition of climate change will likely require documented changes in a suite of variables, with those changes exhibiting spatial patterns around the globe that can be explained by a consistent theory, likely through numerical simulation. In the case of sea ice, modeling results over the past several years for simulated climates under conditions of increased atmospheric CO_2 have considerably adjusted the early generalized first-order expectations, that increased CO_2 through increasing temperatures would lead to reduced sea-ice coverages. Although likely valid on a global scale, this first-order expectation could require adjustments on regional scales, as altered ocean currents and wind systems could lead to marked increases in sea ice in some regions, coincident with marked sea-ice decreases in other regions. Indeed, Washington and Meehl (1989) simulate a more extensive sea-ice cover in the Greenland and Norwegian Seas and a less extensive ice cover in Hudson Bay under one increased-CO_2 scenario (their fig. 32b), and Manabe and others (1992) simulate a more extensive and thicker sea-ice cover in the Weddell and Ross Seas and a less extensive and thinner ice cover in the Arctic Ocean under another increased-CO_2 scenario (their figs 10 and 11). For the sea-ice data to be strongly supportive of one climate change scenario vs another, they will need to be examined on a broad spatial scale and for a variety of regional differences.

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