Palmer LTER: 1997 seasonal sea-ice variability in context

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To understand the ecological impact of sea ice is to appreciate the complex matrix of physics and biology. A recent study (Smith et al. 1998) explores this complex matrix and proposes a set of sea ice indexes for quantifying the variability of sea ice on scales relevant to ice-ecosystem interactions. The approach recognizes the need for multiple spatial and temporal scales and for consistency in how these scales are defined and interpreted. A variety of temporal scales is needed to capture both the seasonal and interannual variability of the physics and the biology. Additionally, a variety of spatial scales is needed to capture the regional extent of physical influence and the distribution and migration patterns of species within the ecosystem. Once sea ice indexes are identified, they provide not only a quantitative and consistent definition of the timing and magnitude of sea ice but also a common context to better resolve ice-ecosystem dynamics. This work will highlight a few of the spatial and temporal scales explored in Smith et al. (1998) by examining 1997 sea-ice variability in the context of previous daily (1991-1997) and monthly (1979-1998) seasonal sea ice coverage.

Passive microwave satellite data provide the only continuous time-series of sea ice coverage in the polar regions. Sea-ice concentrations derived from these data are available from the National Snow and Ice Data Center's Distributed Active Archive Center at the University of Colorado (http://www-nsidc.colorado.edu/). We have used these data to describe the spatial and temporal variability and to identify trends of regional Southern Ocean sea ice (Smith et al. 1998; Stammerjohn and Smith 1996,1997). Here we summarize the seasonal variability of sea ice in the Palmer LTER study region, emphasizing the period when Palmer LTER field studies began (1991) to the most recently available satellite data (March 1998).

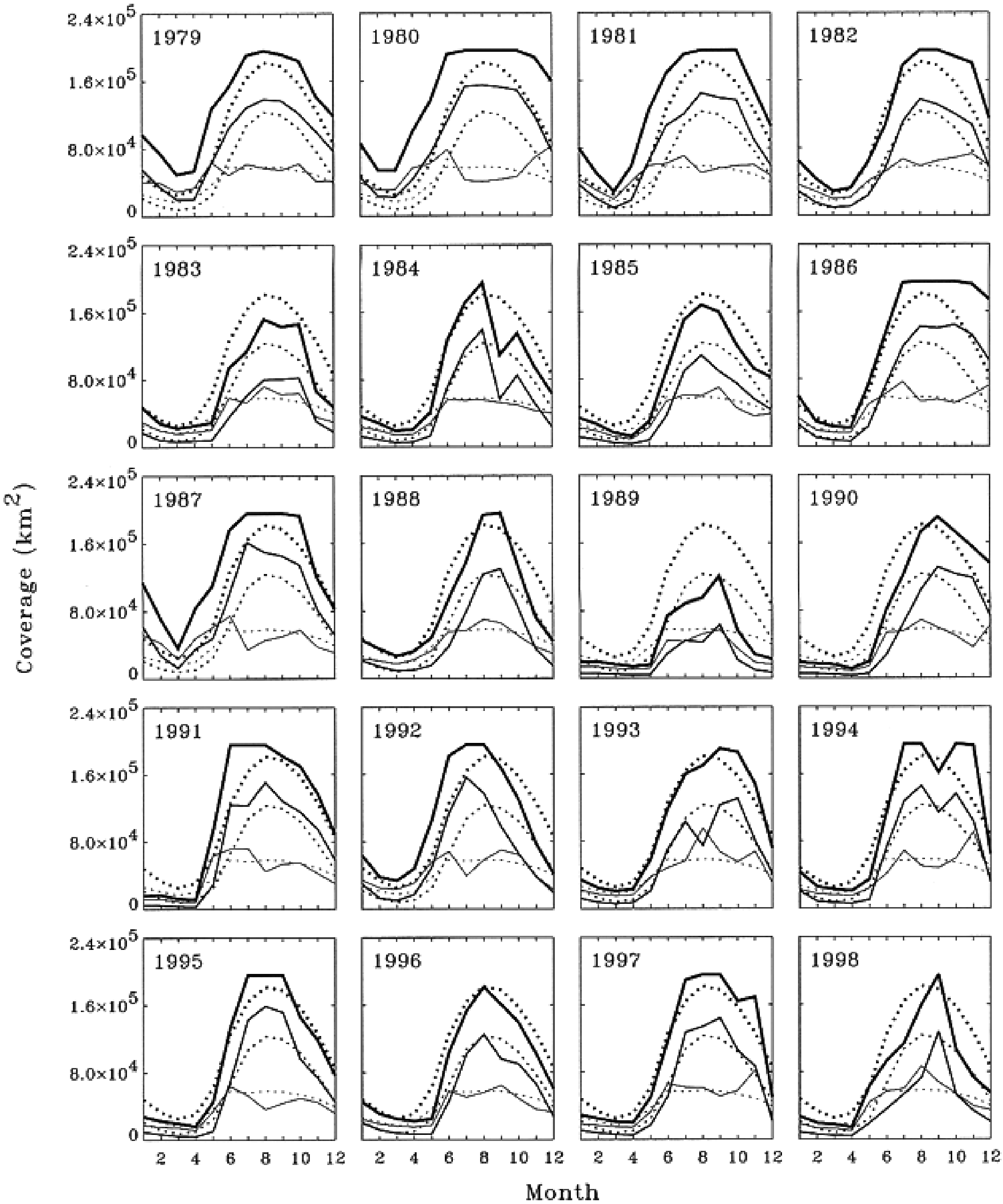

Figure 1. Annual curves of monthly sea ice extent (thick line), sea ice area (medium line) and open water area (thin line) for the Palmer LTER region. Dotted lines represent the means (11/78-3/98) for each sea ice variable.

Figure 1 shows the monthly averages of sea ice extent, sea ice area, and open water area from January 1979 to March 1998 for the Palmer LTER study area. The dotted lines denote the long-term means and accentuate the variability in the annual progression of sea ice. For example, years 1991 and 1992 had above-mean autumn sea-ice coverage, indicating rapid and early sea ice growth that, in turn, lead to an early winter maximum. Year 1992, in contrast to 1991, had below-mean spring sea-ice coverage, indicating an extremely early spring sea-ice retreat. Other years with above-mean spring sea-ice coverage (1993, 1994 and 1997) indicate a late spring sea ice retreat. Season averages for all of the Palmer LTER years (1991-97) reveal averaged that all years except 1993 and 1996 had above-mean winter sea ice extent and that all years except 1992 had below-mean summer sea-ice extent.

Smith et al. (1998) observed that the monthly anomalies persisted from the late 1970s to the late 1980s, so that several years of positive monthly anomalies followed several years of negative monthly anomalies, an oscillation that repeated twice. However, the anomalies in the 1990s show less persistence, and variability between seasons is higher. This is illustrated in figure 2, where daily data for year 1997 and for the Palmer LTER mean (January 1991 to December 1997) are contrasted to monthly data for the historical mean (November 1978 to March 1998). The nonlinear shift in the Palmer LTER mean with respect to the historical mean (whereby different months show different shifts from the longer-term mean) is due to the greater variability within the seasonal cycle in the 1990s versus the 1980s.

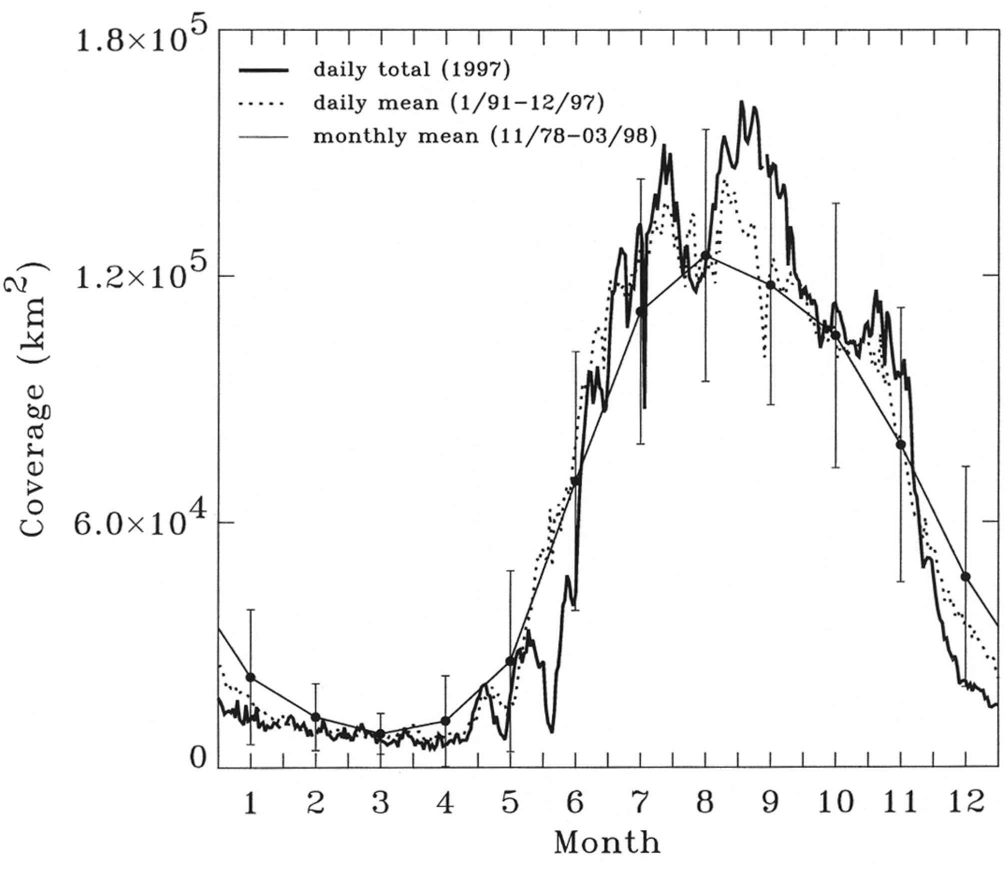

Figure 2. Palmer LTER 1997 daily sea ice area (thick line), with daily mean (1/91-12/97, dotted line) and monthly mean (11/78-3/98, thin line) with standard deviation.

Year 1997 exemplifies the 1990s trend in two ways. First, sea-ice coverage in summer, early autumn, and late spring is below not only the long-term mean but often also the Palmer LTER mean. Second, sea-ice coverage from late autumn to early spring is not only above the long-term mean but often also the Palmer LTER mean. Figure 2 also illustrates the quasi-weekly oscillations in the daily time-series. A recent preliminary study of the high-frequency variability of sea ice in the western Antarctic Peninsula region shows that the movement of sea ice and the consequent changes in surface concentrations are largely due to wind forcing from passing weather systems (Stammerjohn et al. 1998).

The Palmer LTER study region spans 6 degrees of latitude, from a southern region of fairly consistent winter sea-ice coverage to a northern region of extremely high variability. As an example of the various spatial scales of sea-ice variability, figure 3 shows 1997 monthly sea-ice coverage for several regions surrounding the Antarctic Peninsula. In general, the Bellingshausen and Palmer LTER regions have extremely low sea ice in the summer and high sea ice in the winter. Both of these regions encompass broad latitudinal bands of seasonal sea-ice coverage. The southwest Peninsula annual curves of sea ice extent and area are distinguished by broad winter maximums, which are typical of colder, more southern regions (though the extremely low summer sea ice is also notable). The Weddell Sea annual curves of sea ice extent and area are most notable for the extremely high spring sea ice and, consequently, late spring sea ice retreat. The northern Peninsula shows a mix of highly seasonal sea ice (from the northwest) and perennial sea ice (from the east). The late autumn advance is probably due to the late advance in the western Antarctic Peninsula region, while the late spring retreat is more due to the late spring retreat in the eastern Antarctic Peninsula region (also reflected in the greater Weddell region). The differences and similarities among the regions in figure 3 stress the importance of defining the relevant spatial scales of physical forcing and biological response.

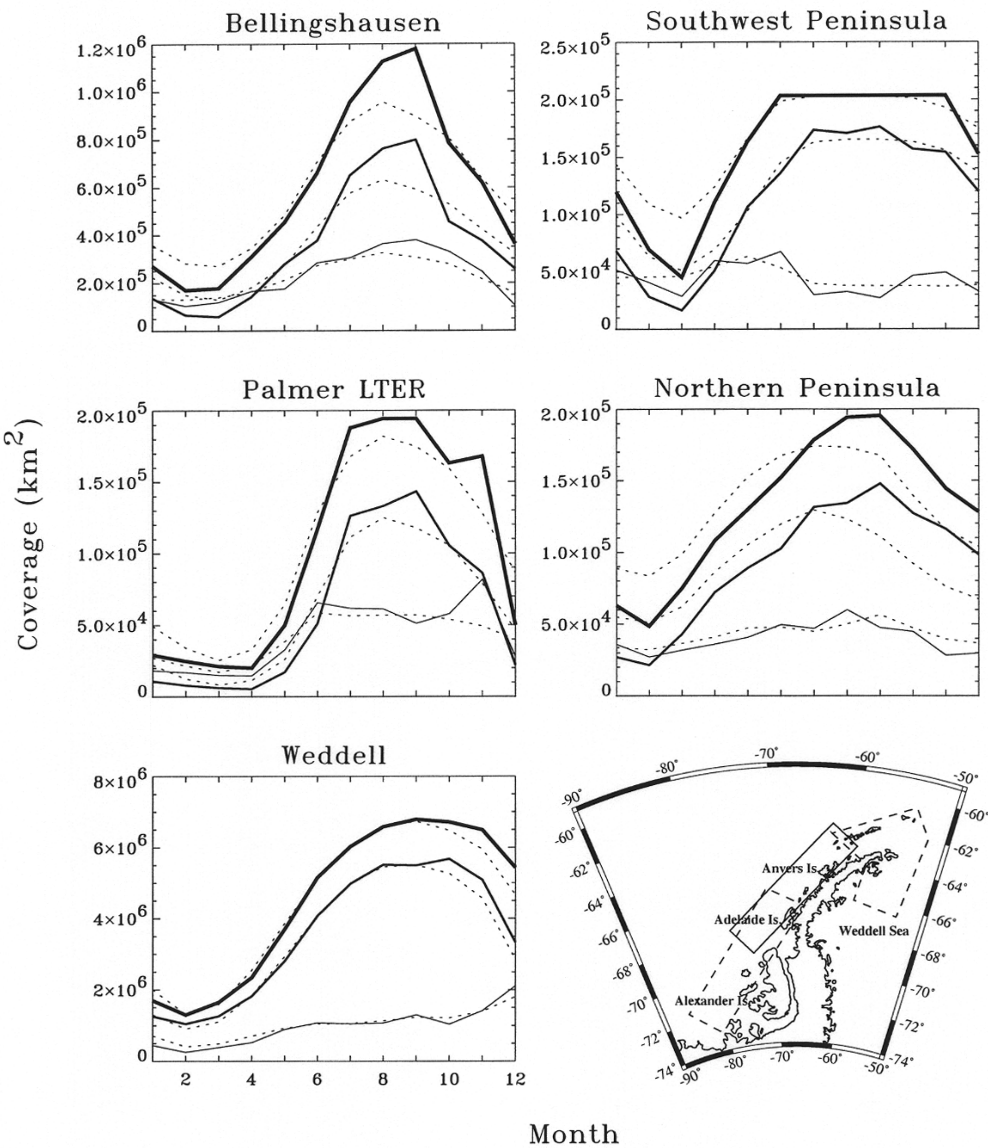

Figure 3. Annual curves of 1997 sea ice coverage for several regions surrounding the Antarctic Peninsula. The last panel shows a map of the southwest Peninsula, Palmer LTER and northern Peninsula regions. The Bellingshausen and Weddell regions include pie sections from 60-90 degrees West and 20 degrees East - 60 degrees West, respectively. Lines are as in Figure 1.

In summary, we have emphasized here the timing of the seasonal progression of sea ice during the Palmer LTER years (1991-1997). With the exception of 1996, all of these years had annual means that were within a half standard deviation of the historical mean. In short, the annual magnitude does not describe the high seasonal variability observed during the Palmer LTER years. As noted in Smith et al. (1995, 1998), the timing of seasonal physical forcing is crucial to many biological processes in the antarctic marine ecosystem, and high seasonal variability does impact ice-ecosystem dynamics. As the 1990s (thus far) exhibit less persistence in anomalous sea-ice coverage than the previous decade did, it is vital to develop consistently defined, multiple, spatial and temporal scales of sea-ice variability.

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