Eastern Bering Sea - 2004

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Summary. *The very warm winters of the late 1970s and 1980s were followed by cooler winters in the 1990s. This cooling was likely a result of a shift in the Arctic Oscillation and hence a tendency for higher sea-level pressure (SLP) over the Bering Sea. Since 1998, negative SLP anomalies have prevailed, which is indicative of greater Pacific influence and consistent with generally milder winters. The winter of 2004 was anomalously warm (although somewhat colder than the winter of 2003), with temperatures typical of the first decade after the 1977 regime shift. Ice cover in the vicinity of Mooring 2 was below the 1989-2004 average almost all season long, except during a cold spell in late March-early April. Spring air and sea surface temperatures were much above normal.*

The winter of 2004 in the Bering Sea was mild, with mean winter (DJFM) surface air temperature (SAT) at St. Paul of 1.34°C above the 1961-2000 average. Such mild winters are typical for the post-1977 climate regime, particularly during its first decade (Fig. 1a). The shift of 1977 was very sharp, from the near record cold winters of 1975 and 1976 to the near record warm winter of 1979. This shift to a warmer climate and the previous shift to a colder climate in the late 1930s can be detected using the STARS change detection method (Rodionov 2004) at the confidence level $p < 0.01$. At the less strict confidence level of 0.2, the relatively cold period 1990-2000 can be singled out (Fig. 1a). Of these 11 winters, only one winter (1996) was anomalously warm; all other winters were either near or below the 1961-2000 average. This cooling is a manifestation of the decadal-scale climatic variations that occur on the background of multi-decadal climatic regimes (see climate overview for the North Pacific).

The SAT at St. Paul during spring has been generally warm since the late 1970s regime shift (Fig. 1b). During the last three spring seasons (2002-2004), SAT anomalies at St. Paul were greater than 1.7˚C (relatively to the 1961-2000 base period), which is anomalously warm even for the post-1977 regime. Note that apart from a relatively short warm period in the late 1930s, spring SAT anomalies were predominantly negative from the beginning of the record in 1916 until the regime shift in 1977.

Warm (cold) winter climatic regimes in the eastern Bering Sea tend to be associated with the periods of anomalous low (high) SLP, as expressed by the Bering Sea pressure index (BSPI), although the timing of the shifts in the winter SAT and BSPI may not be exactly in the same years (cf. Fig. 1a and 1c). The BSPI is a measure of an overall cyclonic activity in the region and is closely linked with the strength of the Aleutian low. It is important to note that on the year-to-year scale the correlation between the BSPI and winter SAT at St. Paul is week (r = -0.16 for the 1978-2004 period). The reason is that winter climatic conditions in the Bering Sea depend not as much on the strength of the Aleutian low, as on its geographical position (Rodionov et al. 2004). On the multidecadal time scale, anticyclonic anomalies over the Bering Sea reflect the increased Arctic influence on the sea, whereas cyclonic anomalies characterize the increased Pacific influence. Thus a shift of 1977 from a cold to warm multidecadal regime was associated with an abrupt intensification of cyclonic activity over the North Pacific in general and the Bering Sea in particular. During the relatively cold period in the 1990s the BSPI was mostly near or above the 1961-2000 average (Fig. 1c). Since 1998, cyclonic activity in the region intensified again. There was no winter during this later period (1998-2004) when the BSPI was positive. The average BSPI value for this 7-year period was the lowest for any consecutive 7-year period since the record began in 1900.

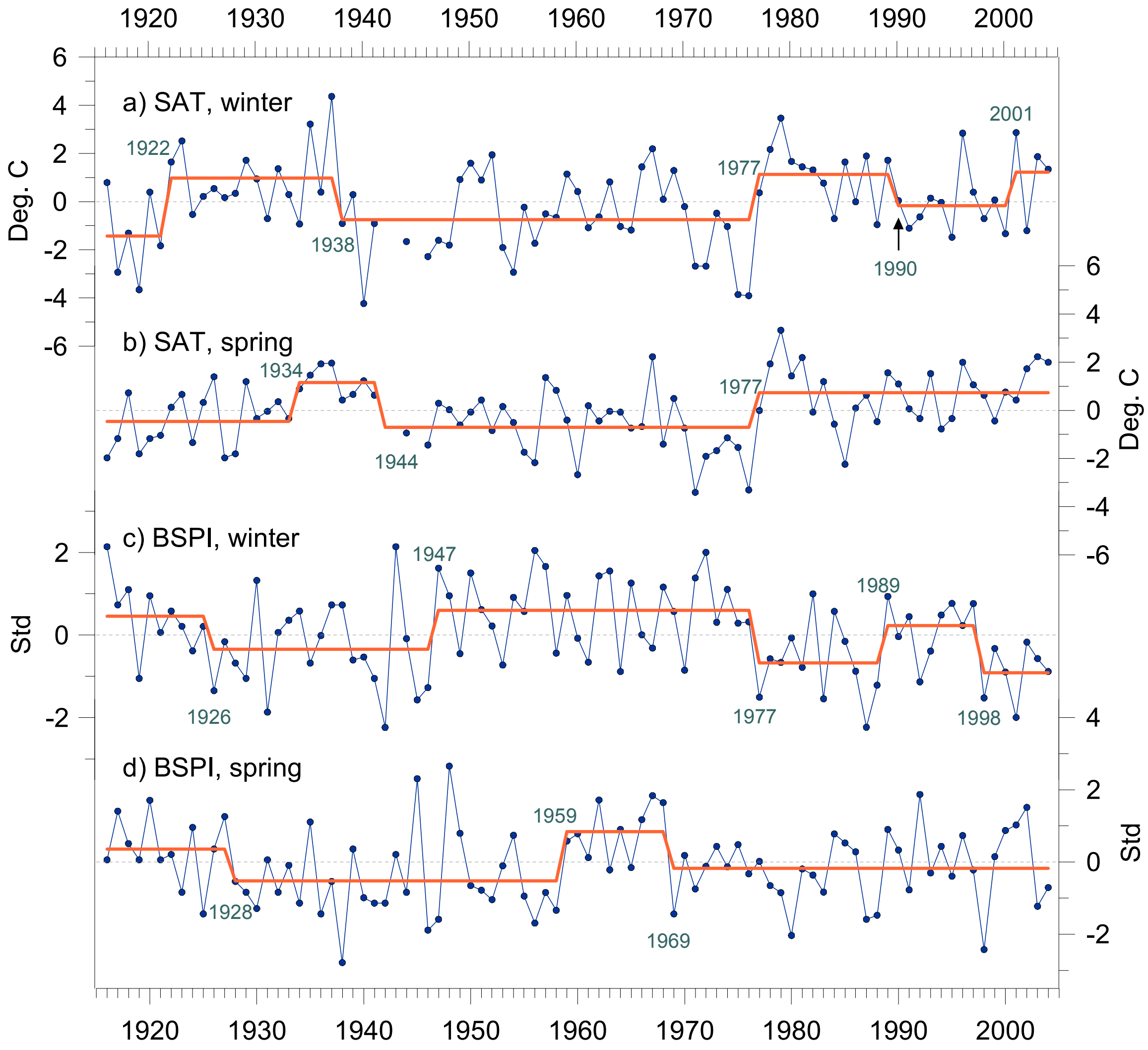

Fig. 1. a) Mean winter and b) spring surface air temperature anomalies in St. Paul, Pribilof Islands, c) winter and d) spring Bering Sea pressure index. The winter months are December through March and spring months are April through June. The base period for calculating anomalies is 1961-2000. The stepwise functions (orange lines) characterize regime shifts in the level of fluctuations of the variables. Shift points were calculated using the STARS method (Rodionov 2004), with the cutoff length of 10 years and significance level of 0.2.

The spring BSPI (Fig. 1d) tended to be negative during the period 1978-1989 and positive since 1990, but the difference between these two periods was not significant enough to qualify as a regime shift. There is no strong correlation between the BSPI and SAT at St. Paul in spring on the interannual time scale. Nor there are any similarities between these two variables in terms of regime shifts. The relationship between atmospheric pressure and thermal conditions in the Bering Sea is more complex in spring than in winter because the dynamic and radiative factors become comparable. When higher-pressure is present over the Bering Sea, there is often also a relatively cold low-level air mass. But it also means lighter winds, less cloud cover, more solar insolation, and hence, greater radiative heating of the ocean. Similarly, anomalously low SLP implies a trade-off between the advection of warm Pacific air and more clouds and hence less solar insolation.

Variability in ice cover in the Bering Sea depends on both temperature and atmospheric circulation. In turn, sea ice has a profound influence on the physical and biological ocean environment. Prior the climate shift in the late 1970s, the ice cover index (ICI) was predominantly positive (Fig. 2a). After the regime shift, the winters from 1978 through 1989 were particularly mild. During this 12-year period there were only three winters when the ICI was slightly positive. During a relative cooling in the 1990s, the frequency of winters with above normal ice cover increased (8 winters with positive versus only 3 winters with negative ICI values during the period 1990-2000). The more recent winters were very mild again, particularly in 2001, 2003, and 2004 (Overland and Stabeno 2004).

As Fig. 2b illustrates, there is a clear overall downward trend in the ice retreat index (IRI). Since the early 1970s, the index is declining at an average rate of almost 1 day per year, a trend significant at the 95% level. The IRI represents the number of days with ice cover after March 15 in the 2˚ x 2˚ box (56-58°N, 163-165°W) that includes Mooring 2 (57^{o}N, 164^{o}W). Based on the 1973-2004 statistics, the ice usually retreats from this area in the second week of April. During the period 1996-2004, there was only one year (1999) when ice stayed in the vicinity of Mooring 2 after that date. In the late 1990s, the early ice retreat was compensated by its early arrival, and the length of the ice season was near its average value of 85 days. In more recent years, the length of the ice season significantly shortened. Based on ice melt and changes in atmospheric circulation patterns, Stabeno and Overland (2001) report the Bering Sea is shifting to an earlier spring transition. In the winter of 2004, ice cover in the vicinity of Mooring 2 was below the 1989-2004 average almost the entire season, except for a brief cold spell in the end of March and early April (Fig. 3).

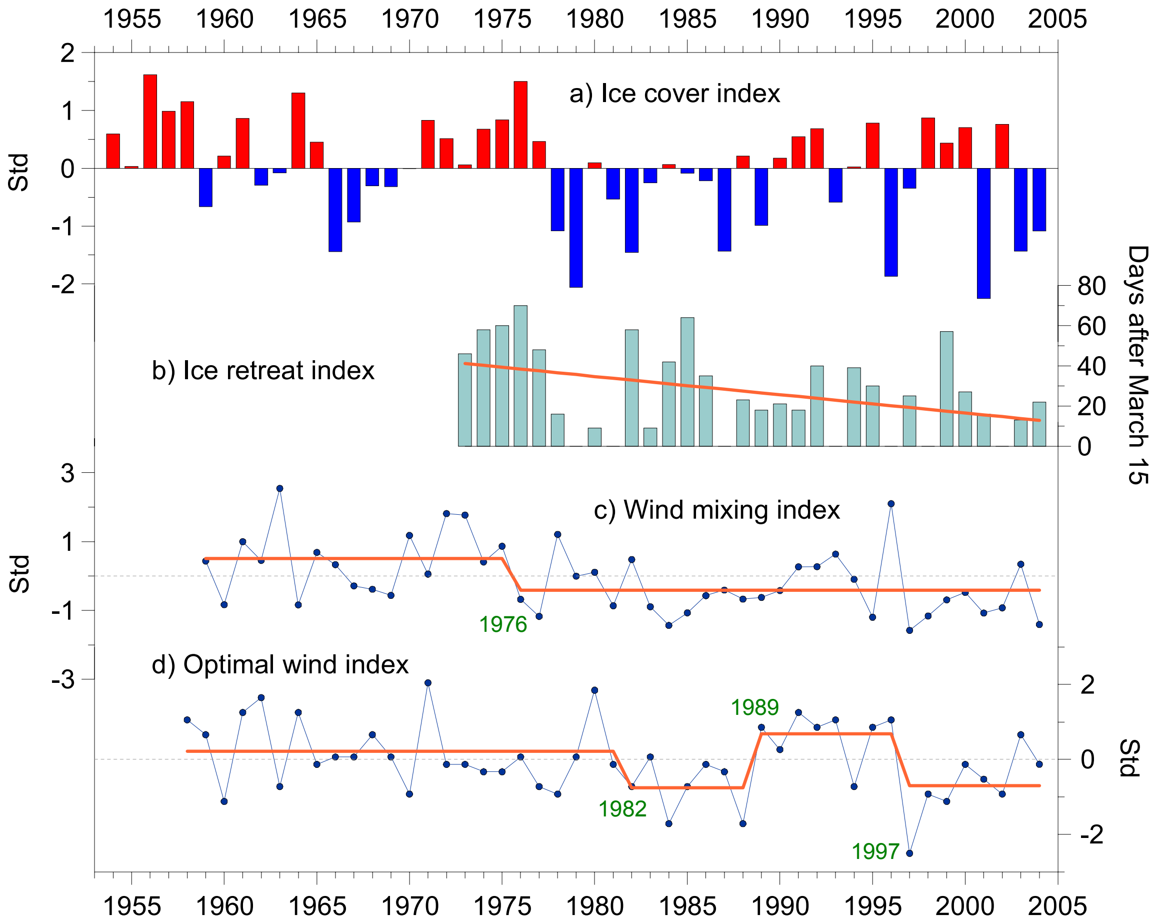

Fig. 2. a) Ice cover index, 1954-2004, b) ice retreat index and its linear trend (orange line), 1973-2004, c) wind mixing index (June-July) at Mooring 2, 1959-2004, and d) optimal wind index for successful larval feeding (1 May – 15 July), 1958-2004. The stepwise functions (orange lines) characterize regime shifts in the level of fluctuations of the variables. Shift points were calculated using the STARS method (Rodionov 2004), with the cutoff length of 7 years and significance level of 0.2.

Sea surface temperatures in May, after ice has retreated from the southeastern Bering Sea, appears to be, to a large extent, a product of processes operating during the previous winter. For example, the MaySST index (average SST over the SE Bering Sea) is significantly correlated with winter indices such as the ICI, $r = 0.50$ ($P < 0.05$), and winter surface air temperature in St. Paul, $r = 0.59$ ($P < 0.01$), for the period 1970-2003. The MaySST index is also a good predictor for the summer bottom temperature as illustrated in Fig. 4. The correlation coefficient between these two variables is $r = 0.82$ ($P < 0.001$) for the period 1982-2003. In 1999, the MaySST index reached the record low value since the beginning of observations in 1970. Since then this index has increased steadily. Due to the very mild winter and spring of 2003, the MaySST index in that year reached the highest value since 1981. Mean May SST in 2004 remained well above normal.

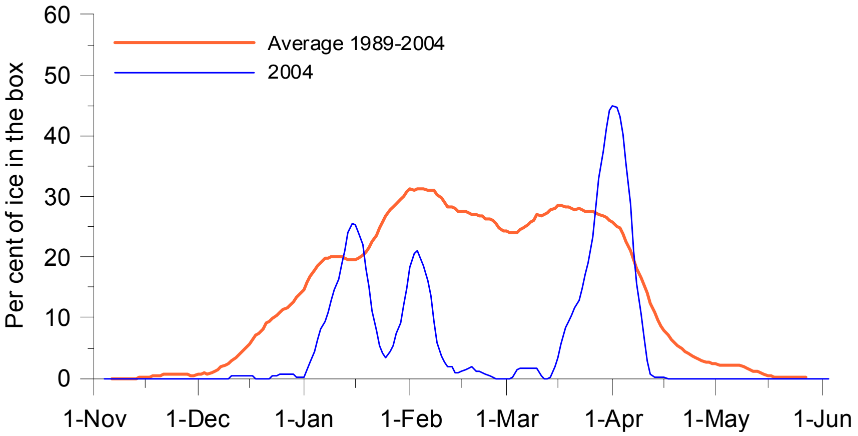

Fig. 3. Percentage of ice cover in the 2˚ x 2˚ box (56-58°N, 163-165°W) during the winter of 2004.

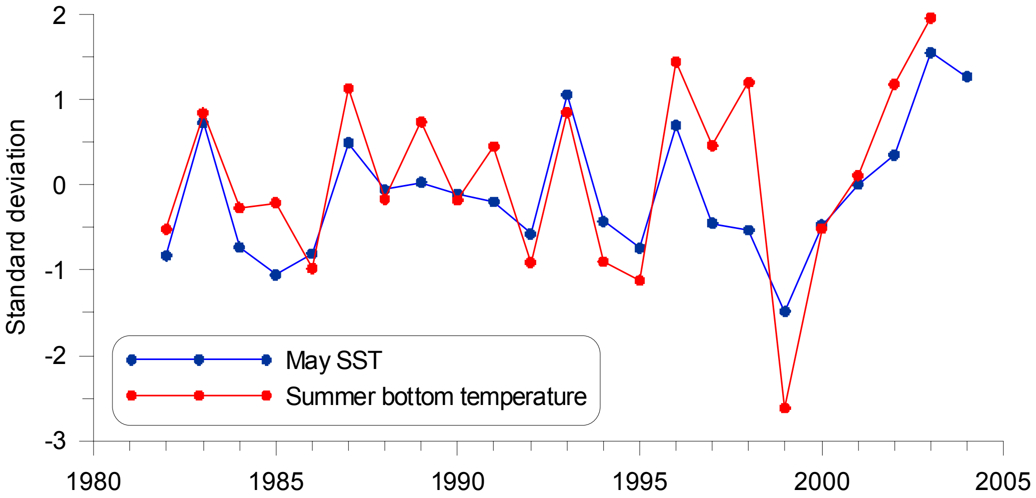

Fig. 4. The MaySST index and mean summer bottom temperature in the southeastern Bering Sea.

Two indices were chosen to characterize wind conditions in the Bering Sea. The wind mixing $u*^3$at Mooring 2 provides a good measure of warm season storminess. The quantity $u*^3$ represents the rate at which turbulent energy is supplied to the ocean by the winds, and ultimately relates to the rate of mixing at the base of the upper mixed layer. This exchange can be important to the ecosystem because it represents a mechanism for the transfer of nutrients from water below the pycnocline into the euphotic zone. This mechanism appears to be important in early summer over the Bering Sea shelf, through its role in sustaining primary production after the spring bloom. Fig 2c shows that during the warm climate regime since the late 1970s (and particularly since 1983) the wind mixing index tends to be negative. One prominent exception was the summer of 1996, which was very windy. As the observations at Mooring 2 indicate, that summer featured a thicker upper mixed layer, a weaker thermocline, and sustained primary productivity relative to the other years (Stabeno et al. 2001). It should be noted that

The second wind-related index tracks wind speeds favorable for successful larval feeding. Formally, it refers to the number of days each year during the period 1 May through 15 July in which the daily average wind speed was in the range 4.8 to 9.5 ms^{-1} at the location of Mooring 2. It is based on the study of Megrey and Hinckley (2001), which used a process oriented individual-based model (IBM) of walleye pollock larvae to evaluate the influence of wind-generated turbulence on feeding. Feeding success depends on turbulence through the latter's effects on the rate at which pollock larvae would encounter prey. The time series of the optimal wind index (Fig. 2d) shows that there were relatively high number of optimal wind speed days during the period 1989-1996, while the periods 1982-1988 and 1997-2002 stand out as having low frequencies of wind speeds in this optimal range.

In summary, the main characteristic of the Bering Sea climatic conditions in the last 4 years is a year-to-year persistence in lack of sea ice, warm bottom temperatures, and warm air temperature anomalies in late winter through summer, even though the Arctic Oscillation and Pacific Decadal Oscillation indices have shown large interannual variability. Bering Sea indicators should be watched closely over the next 5 years to see whether the ecosystem is experiencing a substantial biogeographical shift northward in response to changing temperature and atmospheric forcing (Overland and Stabeno 2004). If this shift continues over the next decade, it will have major impacts on commercial and subsistence harvests as Arctic species are displaced by sub-Arctic species.

References

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