The 1997–98 EL Niño in the Bering Sea as Compared with Previous ENSO Events and the “Regime Shift” of the Late 1970’s

H.J. Niebauer
Atmospheric and Oceanic Science
Univ. Wisconsin-Madison, Madison
WI 53706-1695
U.S.A.
e-mail: niebauer@sunset.mateor.wise.edu

The Bering Sea undergoes exceptional seasonal as well as extreme interannual variability. In the mean, winter sea ice advance exceeds 1000 km while in summer the Bering Sea is ice free. However, interannual ice variability is as great as 400 km.

The interannual variability of the Bering Sea depends in large part on the winter variability of the Aleutian low. Results of analyses (e.g., Niebauer, 1988) of the Aleutian low, monthly mean ice cover from the Bering Sea, and the Southern Oscillation Index (SOI), show that before a regime shift in the late 1970s, below normal ice cover in the Bering Sea was typically associated with El Niño. That is, El Niño conditions caused the Aleutian low to move eastward of normal carrying warm Pacific air from the south over the Bering Sea. Sea and air temperatures were above normal under winds from the south or less strongly from the north. Conversely, above normal ice cover was associated with La Niña conditions which caused the Aleutian low to move westward of normal allowing higher pressure to move over the Bering Sea. Sea and air temperatures were below normal under stronger winds from the north.

In the late 1970’s, a “regime shift” or “step” occurred in the climate of the north Pacific causing, among many other effects, a 5% reduction in the ice cover in the eastern Bering Sea (Figure 1) as well as shifts in the position of the Aleutian low. The overall reduction in ice cover can be traced to an overall increase in El Niño conditions which has resulted in an increase in the influence of the Aleutian low over the eastern Bering Sea (Niebauer, 1998). However, during El Niños since the regime shift, the Aleutian low has been moving even farther to the east causing winds to blowfrom the east and north off Alaska instead of from the south. This has caused ice advance during El Niños (as during this last El Niño of 1997–98) whereas before the regime shift, the ice retreated during El Niño (Niebauer, 1998).

This shift in the organization of ENSO (El Niño–Southern Oscillation) events has had a strong effect on the statistical correlation between the Southern Oscillation Index and Bering Sea ice cover. This Aleutian low movement has caused the correlation

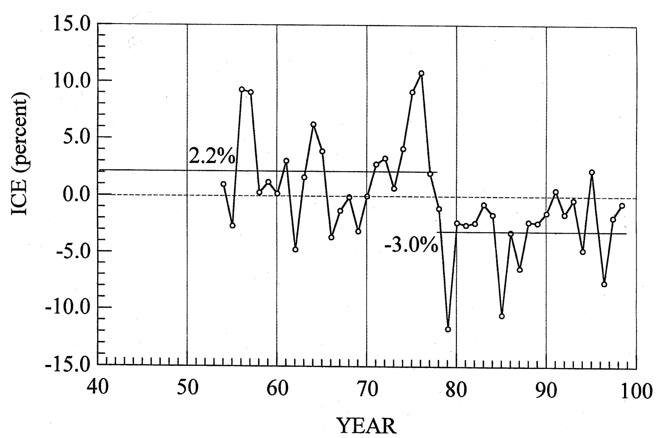

Figure 1. *Winter averaged (NDJFM) percent ice cover anomalies for the Bering–Chukchi Seas for the period 1954–98. Average anomalies for the periods 1954–77 and 1977–98 are also shown. The difference in the means is statistically significant at the 0.005 level. For comparison, standard deviations of ~6.6% and ~4.8% were obtained for the 44-year long monthly mean and winter mean sea ice anomalies time series respectively (After Niebauer, 1998).*

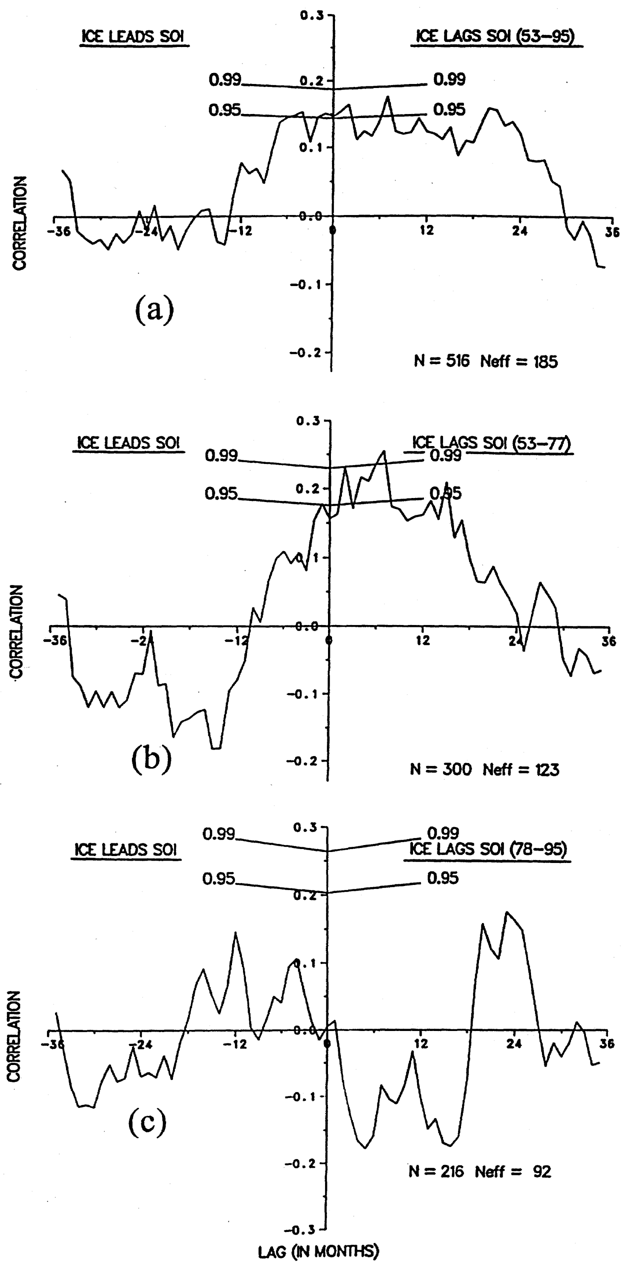

__Figure 2.__ Cross-correlation plots of monthly mean Bering Sea time series SOI = southern oscillation index vs. ICE = sea ice. Panel (a) is for 1953–95, panel (b) is for 1953–77, and panel (c) is for 1978–95. The x-axis is the lag in months between data sets. N is the number of data points while, Neff is the number of effective or independent data points available for use in calculating the significance levels shown on each plot as calculated via Trenberth (1984) and Zar (1984) (From Niebauer, 1998).

of ice with the SOI to change sign compared to before the "regime shift" (Niebauer, 1998). For the period 1953–78 (i.e., before the regime shift), the correlation coefficient was positive (less ice during and following El Niño, and more ice during and following La Niña) with ice lagging the SOI by ~7 months (Figure 2).

In strong contrast, after the regime shift, for the period 1978–95, the correlation coefficient changes sign (Figure 2). The change in sign of the correlation means that since the regime shift, **decreases** in ice are now associated with El Niño events. An important point (as outlined above) is that this is consistent with El Niño-associated Aleutian lows becoming even more intense and moving even farther east following the regime shift. These more easterly Aleutian low pressure patterns are forcing winds northward off the Pacific into interior Yukon/Alaska where the winds turn westward carrying continental air out over the Bering Sea. Before the regime shift, during El Niño, the Aleutian low was not so far east so that the northward winds carried warm north Pacific air over the Bering Sea.

In considering the specific example of this latest El Niño of 1997–98, in the mean, during the winter the Aleutian low was more intense and eastward of normal in teleconnection with the Southern Oscillation. However, in November and again in March, the Aleutian low was directly over the Bering Sea causing strong below normal ice conditions in November and slightly below normal ice conditions in March and April (Figure 3). But in December, January and February, the Aleutian low moved so far to the east that winds over the Bering Sea were from the northeast resulting in above normal ice conditions as well as colder than normal air and sea temperatures under abnormally cool winds (Figure 3).

This relationship between SOI and ice provides the possibility of predicting ice conditions because of this long duration lag of statistically significant correlation (Figure 2), and because of (or perhaps in spite of) the change in sign of correlation between ice and SOI through the climate shift.

Before the regime shift, the occurrence of El Niño and La Niña conditions was about even. Since the regime shift, El Niño conditions are about 3 times more prevalent (Niebauer, 1998). The result is a general warming of the Bering Sea associated with the 5% decrease in ice cover. There is evidence (Mantua et al., 1997; Minobe, 1997) that this regime

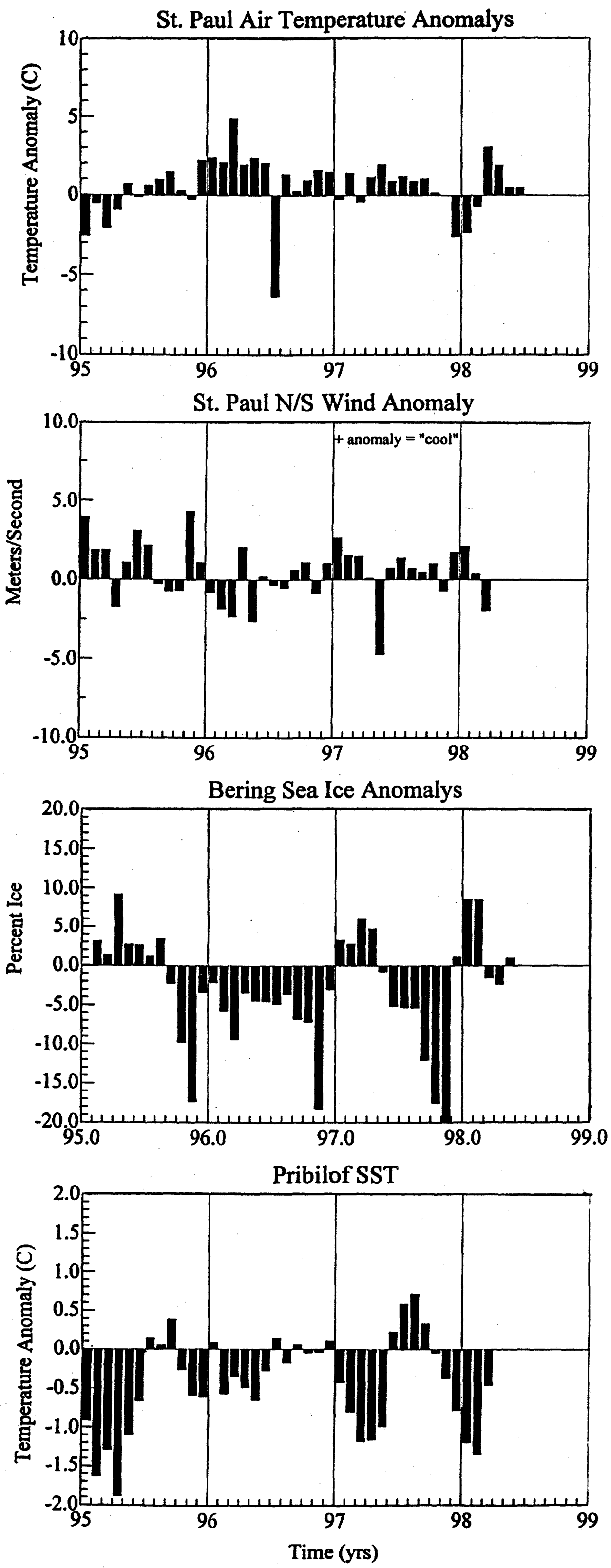

Figure 3. *Monthly anomalies of Bering Sea air temperatures (top panel), surface winds (second panel), sea ice (third panel) and sea surface temperature (bottom panel) for the period 1995 to ~mid-1998.*

shift is the latest in a series of climate shifts going back to at least the late 1800's, and may be due to a 50–70 year oscillation in a north Pacific atmospheric–ocean coupled system.

ENSO events are probably not the only phenomena causing interannual variability in the Bering Sea. In addition to ENSO events, the atmospheric circulation over the North Pacific is probably also sensitive to local SST anomalies. In some winters, the atmospheric teleconnection mode called the Pacific-North American pattern (PNA), and/or the Western Pacific oscillation (WPO or WP), a north–south dipole over the western north Pacific, are prominent, with substantial effects on the Aleutian low.

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