The status of the Bering Sea: July – December 1998

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Dr. Phyllis J. Stabeno, a physical oceanographer at the Pacific Marine Environmental Laboratory (PMEL) of NOAA, conducts research focussed on understanding the dynamics of circulation of the North Pacific, Bering Sea and their adjoining shelves. She is the PMEL Director of NOAA Fishery Oceanography Coordinated Investigations (FOCI), and by applying her knowledge of physical processes to fisheries oceanography, she plays a vital role in its success. FOCI research focusses on building sustainable fishery resources in the Gulf of Alaska and Bering Sea while maintaining a healthy ecosystem. Phyllis is also a Principal Investigator on several research elements for other programs, including: Southeast Bering Sea Carrying Capacity (Coastal Ocean Program), the Bering Sea Green Belt: processes and ecosystem production (Arctice Research Initiative) and Prolonged Production and Trophic Transfer to Predators: processes at the inner front of the southeast Bering Sea (National Science Foundation). This research seeks to improve our understanding of ecosystems through the integration of physical and biological phenomena.

Observations of the eastern Bering Sea shelf continue to provide a strong example of an ecosystem undergoing significant physical and biological change. Both 1997 and 1998 showed unusual conditions in the physical oceanographic and meteorological environment. These included enhanced transport in the Bering Slope Current, above normal sea surface temperatures, strong wind mixing late May and weak summer winds. Anomalous weather conditions in spring 1997 and 1998 caused significant changes in physical and biological features of the southeastern Bering Sea. These in turn contributed to extensive die-off of seabirds, a rare coccolithophore bloom (which continues to this day) and a commercial failure of salmon runs.

Significant changes in this ecosystem are of particular concern since the eastern Bering Sea provides approximately half the fish and shellfish caught in the United States. It is also home to at least 450 species of fish, crustaceans, and mollusks; 50 species of seabirds; and 25 species of marine mammals. Major changes in one species within this ecosystem could have profound effects throughout the system. In response to the changing conditions, NOAA scientists convened an international workshop (The FOCI International Workshop on Recent Conditions in the Bering Sea). Several thematic questions served as a focus at the workshop:

- What anomalous conditions were observed in the eastern Bering Sea during 1997 and 1998 and what mechanisms caused these anomalies?
- Is there evidence that these unusual conditions will persist?
- What are the implications for the future of the ecosystem and its living marine resources?

A final report of the workshop was completed and may be found on the web at http://www.pmel.noaa.gov/foci/bs_98workshop/workshop_report.pdf. Further discussion of results in this article can be found in more detail in the report.

The Bering Sea ecosystem is a complex and highly variable environment. Atmospheric forcing occurs on a continuum of temporal scales, including interannual (ENSO), decadal (Pacific Decadal Oscillation), and longer (Global Climate Warming). These in turn effect the physical oceanographic variability of the region, which then cascades through the ecosystem. The strong El Niño of 1997 was followed by a strong La Niña in 1998. Both of these influenced the atmospheric conditions in the Bering Sea. The Pacific Decadal Oscillation (PDO) switched from a strongly negative (cold SST in the eastern Pacific Ocean) to positive (warm SST) values in 1997. Within the time series of the PDO, there is some interannual variability especially associated with ENSO events. During 1998, the PDO has been strongly negative, but this may be more a result of the La Niña, than a change in decadal patterns of the PDO. Although there has been, and continues to be, considerable speculation of a regime shift comparable to the one that occurred in 1977, it is too early to tell. Such a change could have a profound impact on salmon in the Bering Sea, since changes in the PDO appear correlated with salmon production. The sudden climate shifts that occurred in 1923, 1947 and 1976 in the North Pacific substantially altered marine ecosystem in Alaska as well as off Japan, Hawaii, California and Peru. The recent warm period of the PDO has been associated with high salmon production in Alaskan waters. In addition to decadal variability, long-term climate trends must also be considered. From paleoclimatic evidence, it appears that present conditions on the Bering Sea shelf are anomalously warm. During the last decade, the western Bering Sea has cooled while the eastern Bering Sea has warmed.

Atmospheric conditions directly influence the sea surface temperature (SST). Mooring sites (*Figure 1*) funded as part of Southeast Bering Sea Carrying Capacity (a NOAA Coastal Ocean Program) are in their fifth year of collecting data and provide important data to help unravel the changes that are occurring in this ecosystem. The following observations are from these moorings. During summer 1997, SST on the Bering Sea shelf was particularly warm (>4˚C above normal over the southeastern shelf) due to weak winds (shallow mixed layer) and fewer clouds. During 1998, extremely stormy conditions persisted into June. In July, however, winds decreased and calm conditions occurred for the next 6 to 8 weeks. This once again resulted in a shallow mixed layer. In addition, during 1998 sea ice did not intrude deeply over the southeast shelf, and was present for only a short time, which resulted in the retention of some of the heat from the previous year (1997). The weak shallow mixed layer and warm initial conditions resulted in above normal SST (2˚C above normal) for the second year in a row.

From the historical data records in the vicinity of site 2, 138 separate occupations of hydrographic stations were found from 1966-1998. From these and the mooring data from site 2, it is evident that the upper layer typically begins warming in late March or early April, and temperature continues to increase through

Fig. 2 (a) The seasonal sign of near surface temperature at Site 2. Data from the years when moorings were located at this location are indicated by colored lines. Data from hydrographic surveys between 1966 and 1994 are shown as Xs. (b) The depth averaged temperature for the same data shown in panel a.

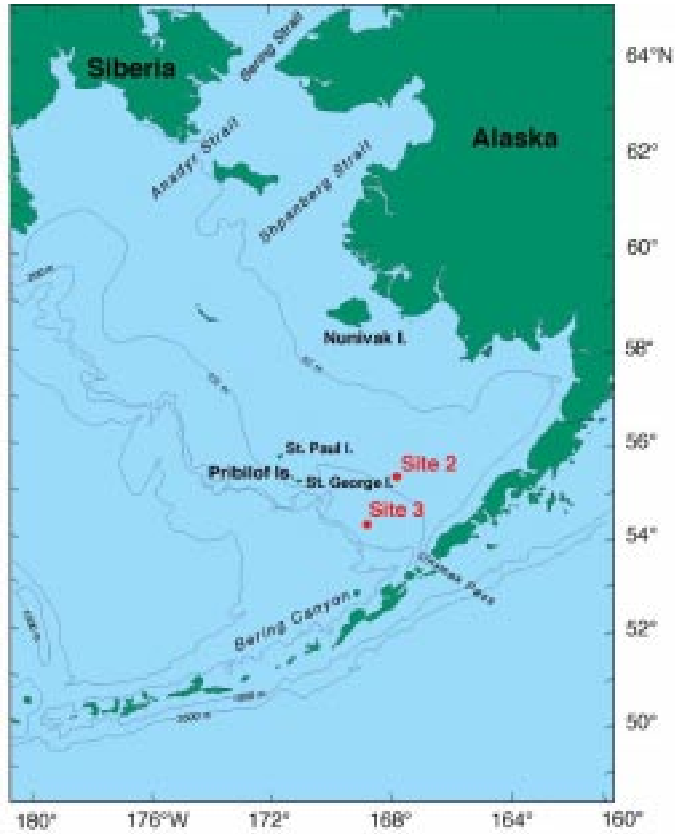
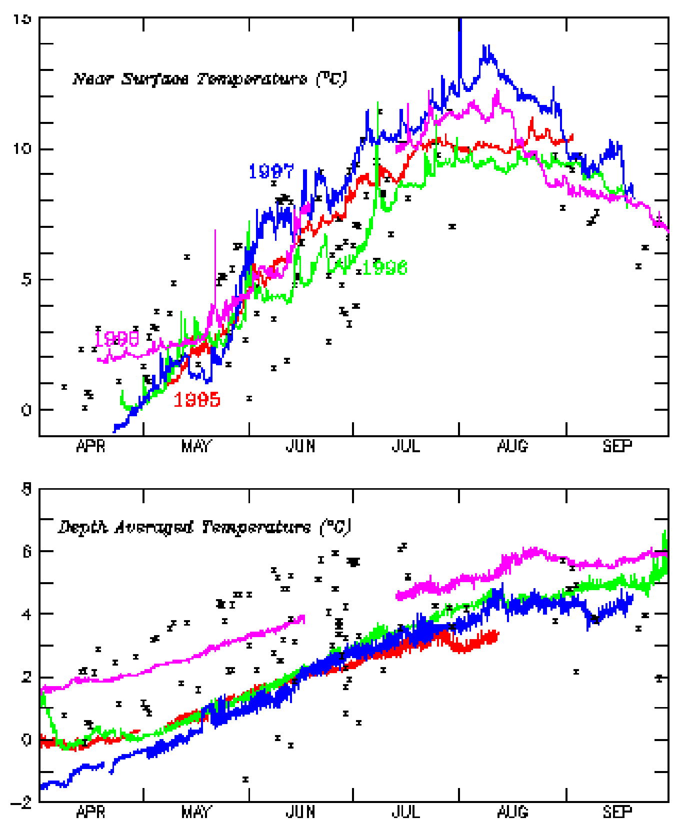


Fig. 1 Geography and place names in the eastern Bering Sea. The location of the two monitoring lists is indicated by bold numerals. The hydrographic transect is show as a solid line. Depth contours are in meters.



early August when maximum SST typically occurs. Prior to 1997, near surface temperatures did not exceed 11.5˚C, but temperatures well above this maximum were observed in the summer of 1997 and to a lesser extent in 1998. While the warmest near-surface temperatures were observed in 1997, the water column as a whole was not particularly warm (*Figure 2b*). It is interesting to note that the warm surface temperatures during 1997 were offset by a shallow mixed layer and cool bottom temperatures so that vertically averaged temperatures were similar to those observed in 1995 and 1996, and cooler than most of the historical temperatures. In contrast the warm surface temperature of 1998 was complemented by the warmer than average bottom temperatures, resulting in the depth averaged temperatures being the warmest of those observed during the last decade. They were however cooler than the warm years of the early 1980s, when PROBES collected data in this region.

The transport in the Bering Slope Current was comparable to what it was in 1997 (~6×10^6 m^3 s^{-1}), which is approximately twice the expected transport. Significant cross shelf transport occurred during 1998. This was evident in the increase in salinity that was observed over the shelf, and was supported by finding of age-0 pollock and oceanic zooplankton along the 50 meter isobath about 400 km from the shelf break. Measured currents on the shelf over the southern Bering Sea were stronger in 1998 than in 1997, particularly along the 50 meter isobath which typically forms the boundary between the coastal domain and the middle shelf. The coccolithophore bloom, which began in early summer 1997 continued through 1998. Coccolithophores are small, photosynthetic cells covered by calcareous plates. Light reflects from the plates giving the water its distinctive milky white color. This bloom was farther north on the shelf during 1998 than in 1997. The flow of water through Spanburg Strait and north through Bering Strait is clearly indicated by the thin stream of coccolithophore rich water flowing northward between the two passes in *Figure 3*. Why the coccolithophore bloom has persisted for so long is not known, but it is possible that limited nitrogen over shelf favored the growth of coccolithophores over diatom species or that the warmer than normal temperatures over the shelf during the last summers provided a favorable environment.

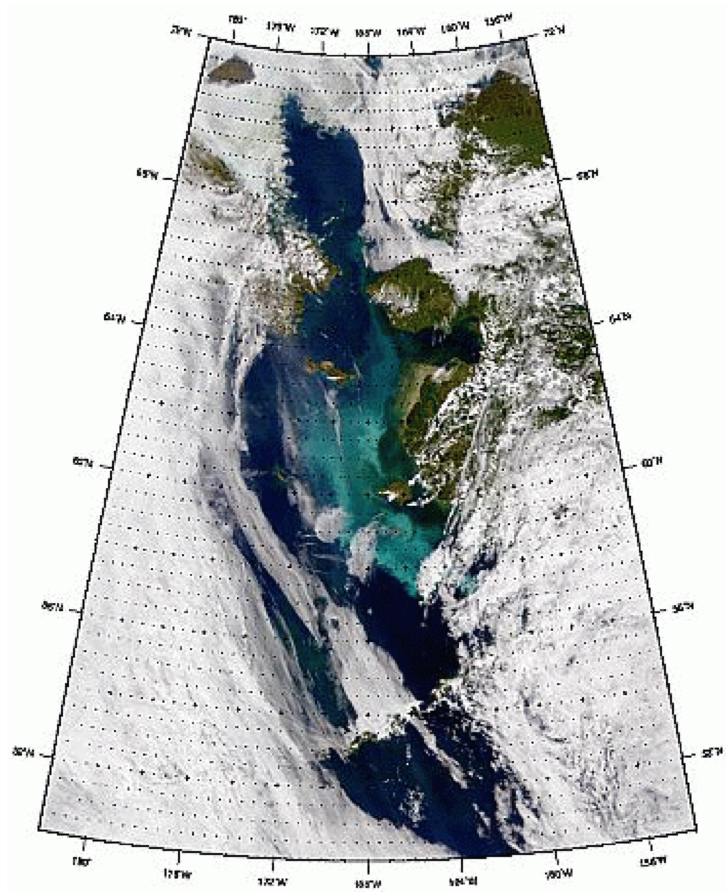


Fig. 3. SeaWiFS true color image from 19 July, 1998, showing the advection of the coccolithophore bloom northward through Bering Strait and into the Chuckchi Sea.

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One principal focus of the meeting was to discuss in detail results obtained from the inter-laboratory comparison. The measurements of total dissolved inorganic carbon were very encouraging. Once the data had been adjusted using the measurement on CRM Batch 45 so as to allow for calibration problems, all the results from the various laboratories involved were consistent with each other. However, for the measurement of alkalinity, though a calibration adjustment improved the degree of agreement, there were still significant discrepancies between the measurements made by the various laboratories. In fact, much of the discussion at the workshop centered on techniques for improving the calibration of these measurements for the future. Results from the workshop will be presented at the WG 13 meeting at PICES VIII in Vladivostok (Oct. 8-9, 1999). A detailed report is being prepared which will be published in both English and Japanese later this year. Both the Technical Workshop, which all found stimulating and informative, and the wonderful hospitality of our hosts, Drs. Yukihiro Nojiri and Koh Harada made the visit to Tsukuba extremely enjoyable.

Our next step should be a Data Workshop (co-sponsored by PICES and JGOFS) planned for the year of 2000. It will enhance the effort to merge the various CO_2 data sets from around the North Pacific and thus lead to an improved overall understanding of the processes affecting the carbon cycle in the region.