# The status of the Bering Sea in the second half of 1997

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*Dr. Phyllis Stabeno, a physical oceanographer at the Pacific Marine Environmental Laboratory (PMEL) of NOAA, conducts research focused 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 focuses 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 (Arctic 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 unmderstanding of ecosystems through the integration of physical and biological phenomena.*

The Bering Sea, a northern extension of the North Pacific Ocean, is the world's third–largest semi–enclosed sea. It is divided into almost equal parts of a basin (maximum depth 4000 m) and a shallow, broad eastern shelf (*Figure 1*). Abundant fish and game in the Bering Sea have supported Asians and North Americans since prehistoric times. Presently, the sea is the most productive marine ecosystem for the United States and one of the most productive in the world. The U.S. fishery there provides about 40% of the U.S. fish and shellfish output.

The environment of the Bering Sea is highly variable. For instance, seasonal sea ice extent fluctuates over 1000 km. The Bering Sea is ice–free in the summer, but ice may extend over the shelf south to the Alaska Peninsula and eastern Bering Sea shelf break in winter. In addition, large interannual variations (100s of km) occur in maximal sea ice extent. The North Pacific (including the Bering Sea) displays considerable decadal variability; over one–third of the interannual variability of the winter Aleutian Low since 1900 is at decadal scales. This variability is influenced nearly equally by two larger atmospheric variability patterns, a tropical/temperate Pacific North American (PNA) pattern and an Arctic/NE Asia pattern, termed the Arctic

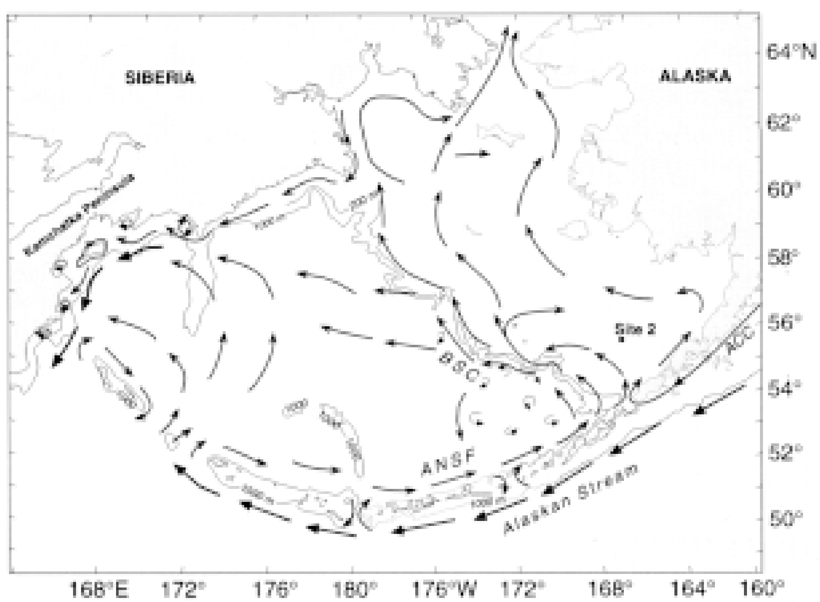


*Fig. 1* *A schematic of the mean circulation in the eastern Bering Sea. The Bering Slope Current (BSC) and Aleutian North Slope Current (ANSC) are shown. Site 2, the location of the temperature measurements, is indicated.*

Oscillation (AO). There was a drift to deeper (lower sea level pressure) Aleutian Low around 1977, and there appears to be a return to pre–1977 conditions after 1989, driven primarily by changes in the AO.

Climate variability in turn affects the ecosystem. Alterations in storm tracks and storm intensity modify vertical mixing and the extent of sea ice, with greatest ice production occurring in years when the Aleutian Low is well developed and winds from the north are common. Changes in atmospheric forcing influence the exchange with adjacent oceans (North Pacific and Arctic Oceans) and the circulation on both the basin and shelf. The position and strength of the Bering Slope Current in turn influences the basin–shelf exchange of heat, salt, and nutrients for primary production.

The extremes in atmospheric forcing and its effect on the ecosystem were readily evident in 1997. Unusually weak winds during summer (*Figure 2*) and greater than usual solar insulation resulted in an anomalously shallow mixed layer and unusually warm sea surface temperature in the Bering Sea. These events were likely related, in part, to the atmospheric perturbations associated with the strong equatorial El Niño, as well as decadal variability. In addition, transport in the Bering Slope Current was approximately twice that previously observed (6–7 x $10^6$ $m^3 s^{-1}$) and the flow along the 100 m isobath (*Figure 1*) was much reduced. There was a lack of on-shelf flow evident in the trajectories of satellite–tracked drifter. This lack of flux onto the shelf could have been a contributing factor in the reduced amounts of nutrients found on the shelf in 1997.

The weather patterns and the extreme oceanic conditions directly affected the ecosystem. The relatively warm and calm summer brought a rare bloom of coccolithophorid phytoplankton to the eastern Bering Sea. The bloom was evident in the first *SEAWIFS* imagery and was also noticed and photographed by astronauts on the high latitude flight in August. There were scattered reports of bloom continuing into at least October. In addition the largest die–off of short tail shear waters ever recorded in Bering Sea occurred. The commercial salmon fishery in Bristol Bay was declared a commercial failure. The calm pattern that dominated summer, ended with the arrival of four storms in September (*Figure 1*). This pattern of storms continued through January. A mooring, at site 2 (*Figure 1*) on the middle shelf, was maintained throughout the winter, and temperature (*Figure 3*) was measured throughout the water column. The two-layer structure characteristic of this shelf is clearly evident. Daily average upper layer temperature reached 14˚C during part of August, while temperatures

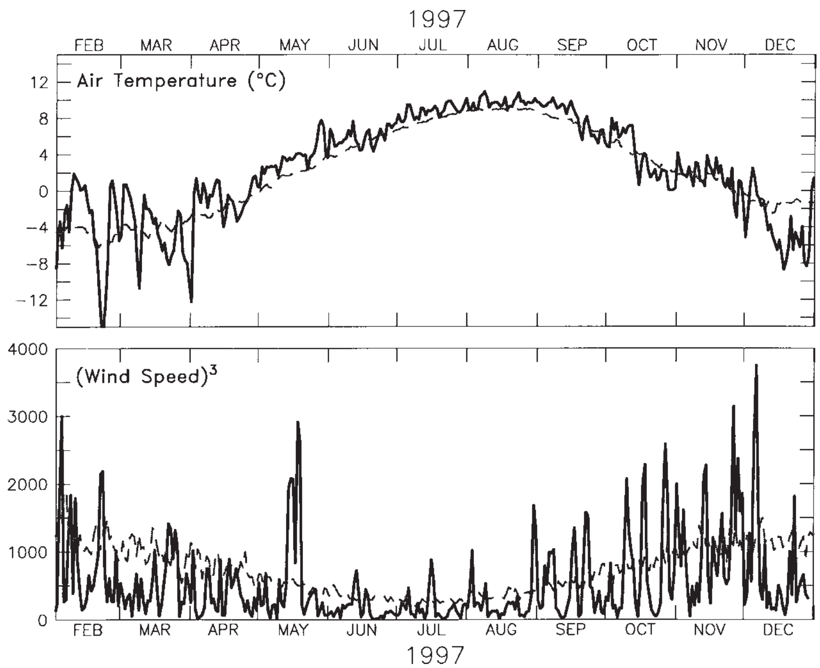


*Fig. 2 A time series of air temperature and wind speed measured at St. Paul Island.*

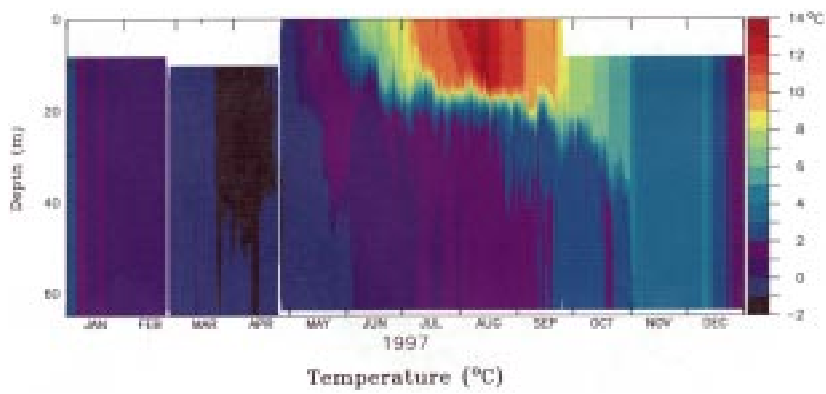


*Fig. 3 Temperatures measured at Site 2. Temperature was measured ~3m½ in the upper 30 m and ~5 m below that. There were four separate mooring deployments. The very cold temperatures evident in April 1997, resulted from melting of sea ice. At this depth the water depth is 70 m.*

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to correct the sedimentation rates for the effects of sediment mixing. In contrast to the shelf region, extremely high apparent sedimentation rates (0.2~0.7 cm/yr) were found in the slope region of the Okinawa Trough with elevated concentration of organic carbon (Chung and Chang, 1995). Spatial variations of the sedimentation rate in the study area indicate that sediments from the East China Sea are transported from the shelf and buried in the slope region. The distributions of biomarkers in the sediments in the shelf and slope regions were investigated by Dr. W.-L. Jeng and they also indicate that the slope is a depocenter for materials from the shelf. The focusing phenomenon of East China Sea sediments in the southern Okinawa Trough will be investigated in the future.

### *5. Concluding remarks*

Focusing in the southern East China Sea, the KEEP project has provided an excellent opportunity for a multidisciplinary collaboration among oceanographers in China (Taipei) and generated significant results to further the present appreciation of the processes operating in ocean margin systems. The participation of international collaborations in the project is welcomed. The publications and data originated from the KEEP project can be found at our web site (http://keep.oc.ntu.edu.tw) and in the forthcoming special issue of Continental Shelf Research.

### *References*


Biscaye, P. E., R. F. Anderson and B. L. Deck (1988) Fluxes of particles and constituents to the eastern United States continental slope and rise: SEEP-II. Cont. Shelf Res., 8, 855-904.

Biscaye, P. E. and R. F. Anderson (1994) Fluxes of particulate matter on the slope of the southern Mid-Atlantic Bight: SEEP-II. Deep-Sea Res., 41, 459-509.

Chen, Y.-L. (1995) Phytoplankton composition and productivity in response to the upwelling off northeastern Taiwan, Proc. Nat. Sci. Counc., ROC, Part B.

Chen, C.-T. (1996) The Kuroshio Intermediate Water is a major source of nutrients on the East China Sea continental shelf. Oceanologica Acta, 19, 523-527.

Chiu, T.-S. (1991) Variation of ichthyoplankton density across the Kuroshio edge exchange area with implications as to the water masses. TAO, 2, 147—162.

Chung, Y. and W.-C. Chang (1995) Pb-210 fluxes and sedimentation rates on the lower continental slope between Taiwan and the south Okinawa Trough. Cont. Shelf Res., 15, 149-164.

Gong, G.-C., K.-K. Liu and S.-C. Pai (1995) Prediction of nitrate concentration from two end member mixing in the southern East China Sea. Cont. Shelf Res., 15, 827-842.

Gong, G.-C., Y.-L. Chen and K.-K. Liu (1996) Chemical hydrography and chlorophyll distribution in the East China Sea in summer: implications in nutrient dynamics. Cont. Shelf Res., 16, 1561-1590.

Guo, Y.-J. (1991) The Kuroshio. Part II. Primary productivity and phytoplankton. Oceanogr. Mar. Biol. Annu. Rev., 19, 155-189.

Huang, K.-M. and S. Lin (1995) The carbon-sulfide-iron relationship and sulfate reduction rate in the East China Sea continental shelf sediments. Geochem. J., 29, 301-315.

Li, Y.-H. (1994) Material exchange between the East China Sea and the Kuroshio Current, TAO, 4, 625-631.

Liu, K.-K., G.-C. Gong, C.-Z. Shyu, C.-L. Wei, and S.-C. Pai (1992) Response of Kuroshio upwelling to the onset of northeast monsoon in the sea north of Taiwan: Observations and numerical simulation. J. Geophys. Res., 97, 12511-12526.

Shiah, F.-K., G.-C. Gong, and K.-K. Liu (1995) A preliminary survey on primary productivity measured by the C-14 assimilation method in the KEEP area, Acta Oceanogr. Taiwanica, 34, 1-15.

Tang, T.-Y., Y. Hsueh, Y.-J. Yang and J.-C. Ma (in press) Continental slope flow northeast of Taiwan, J. Phys. Oceanogr.


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in the lower layer remained below 3˚C. The depth of the upper mixed layer remained less than 20 m through August. In September, with the occurrence of several storms, the mixed layer deepened and the lower layer began warming. By November, 1997 the water column had become well mixed and continued to cool reaching approximately 1.9˚C at the end of December. Similar timing and temperatures were observed in the fall and winter of 1996.

Continued measurements in the Bering Sea are planned this year by programs funded by the National Science Foundation (research on prolonged production along the structure front at ~50m isobath) and by the National Oceanic and Atmospheric Administration (annual trawl surveys conducted by the Alaska Fisheries Science Center/National Marine Fisheries Service; monitoring from biophysical platforms and hydrographic sections by the Southeast Bering Sea Carrying Capacity (Coastal Ocean Program); biophysical measurements of the green belt by the Arctic Research Initiative; and research by the Fisheries Oceanography Coordinated Investigations). These measurements will be of particular interest to see if there is a repetition of 1997.