Coastal Hydrographic Responses in the Northern Gulf of Alaska to the 1997–98 ENSO Event

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Abstract

The El Niño–Southern Oscillation events for the past 22 years including the 1997–98 event have been captured by a long time series hydrographic station in the northern Gulf of Alaska. These events appear as positive subsurface temperature anomalies with the 1997–98 event being nearly 3 standard deviations above normal at 250 m. The mechanism for this heat transport is uncertain but an enhanced California Undercurrent or Kelvin wave propagation are likely candidates. This connection with tropical events could have implications on biological production in the Gulf of Alaska.

Background

Temperature and salinity versus depth at the mouth of Resurrection Bay, Alaska (60°N, 149°W) in 263 m of water have been measured since 1970 with sampling intervals ranging from hours to months. Since 1990, the sampling has been more regular, approximately monthly. The location was originally selected for its proximity to research vessel berthing facilities in Seward for logistical reasons. However, the station is also located in the Alaska Coastal Current, ensuring good connection with the regional coastal circulation.

The atmospheric forcing for this site includes seasonal heating, wind stress and buoyancy forcing in the form of freshwater discharges. The region is dominated by the Aleutian Low in winter and has a slight influence from the North Pacific High in summer. Intense winter downwelling is followed by weak summer upwelling. The freshwater discharge is greatest in autumn and least in early spring. The maximum discharge leads the maximum winds by about 3 months, and this enables to winds to force a coastal convergence of the low density surface water in the winter, which should intensify the Alaska Coastal Current at this time.

The monthly means of salinity and temperature at standard depths have been determined (Figures 1–3). The monthly mean temperatures (Figure 1) from 0–50 m are minima in March increasing a maximum at the surface of more than 13°C in August followed by lessor maxima at depth up to 3 months later. This seasonal temperature cycle is similar for the upper 100 m. Below 150 m the temperature cycle peaks in January with amplitudes of less than 0.5°C. The mean temperature at 250 m is slightly greater than that at 200 m. The monthly mean salinity (Figure 2) and density (Figure 3) are very similar since salinity here controls the water density. The minimum surface salinity is in August with the minima at increasing depths taking place later in the year. The minimum salinity at 100 m is in February, 6 months out of phase with the surface salinity minimum. The minimum vertical stratification is in March with the maximum in August. The minimum surface salinity leads the maximum in runoff by about two months. This could be a consequence of the autumn increase in winds, mixing the upper layers. Such mixing is evident in the autumn temperature inversions. The salinity and density

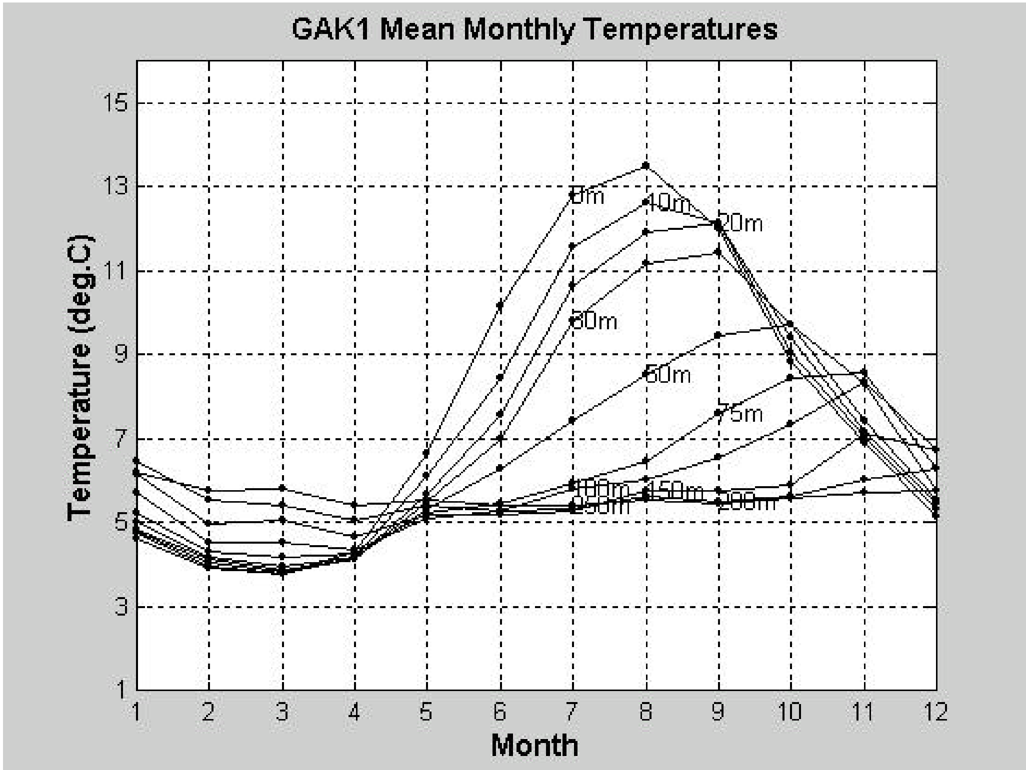

Figure 1. *Seasonal cycle in temperature at GAK 1.*

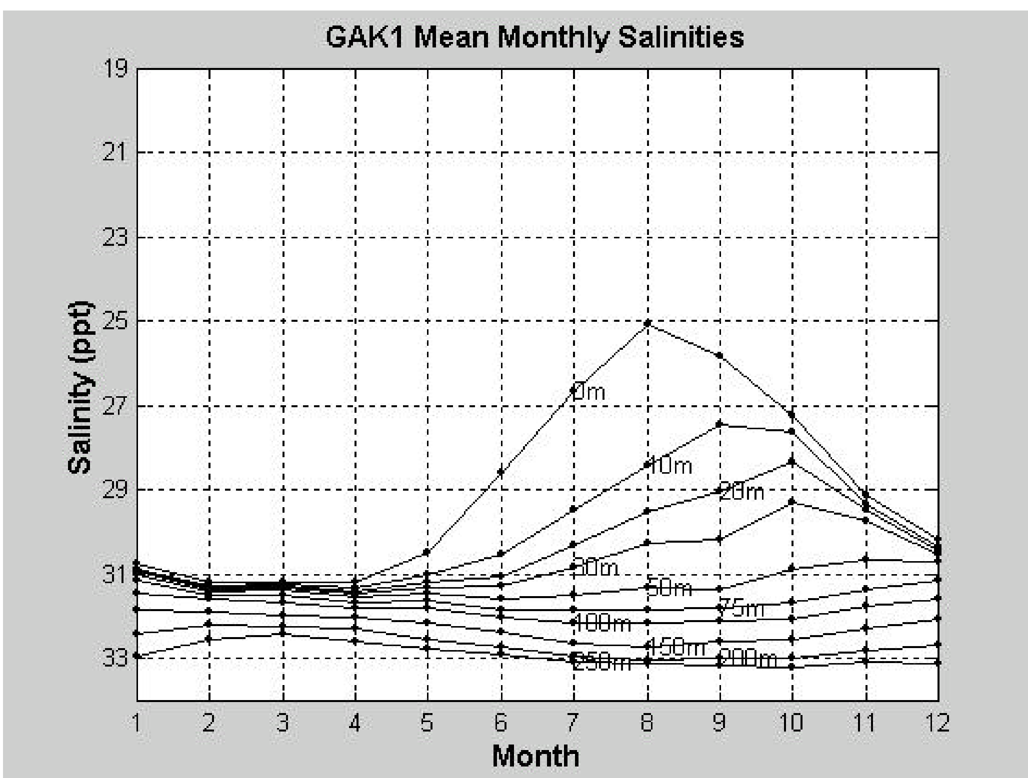

Figure 2. *Seasonal cycle in salinity at GAK 1.*

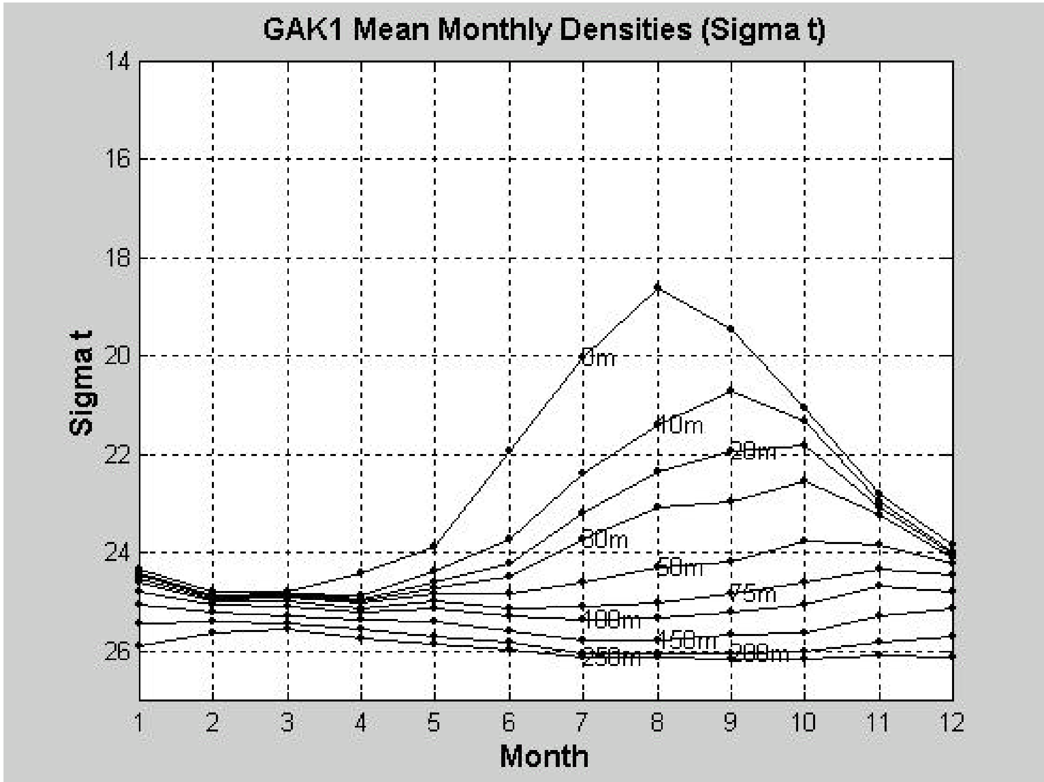

Figure 3. *Seasonal cycle in water density at GAK 1.*

variations at 150 and deeper are out of phase with those at the surface suggesting a different mechanism for their control. The upper 100 m of this water column appear to fluctuate on a seasonal basis under the influence of vertical mixing.

The monthly means of temperature and salinity are subtracted to yield anomalies of salinity and temperature over the water depth of 263 m. The anomalies of salinity and temperature are coherent with depth, suggesting that they are advected into the region rather than being induced by local surface evaporation, runoff, heating and cooling.

Salinity Anomalies

The salinity anomaly (Figure 4) was greatest in the early 1970s followed by a pattern of positive and negative values. The major periodicities of salinity at the surface are 4 and 9 years but only about 5 and 3%, respectively, of the variance is explained by fluctuations at these periods. ENSO is associated with the 4-year period and the 9-year periodicity of the surface salinity is consistent with decadal atmospheric variations found in the Arctic. Near bottom at 250 m, the 4-year period accounts for more than 8% of the variance while the fluctuations at 14–15 years can explain more than 10%. Coastal freshwater discharge is a potential driving force and has dominate periodicities of 4 and 16 years, but this can only explain 2 and 3% of the variability, respectively. The relatively small amount of salinity variance explained by ENSO suggests that it is not a major factor in interannual salinity variability at any depth. The relatively coherent salinity anomaly signal with depth suggests that the horizontal advection of these anomalies is important rather than local surface forcing by atmospheric processes.

Temperature Anomalies

The temperature anomalies (Figure 5) were below normal in the early 1970s, increasing to above normal in 1977–98. The 1980s brought anomalies with broad temporal scales while shorter duration events were found in the 1990s, punctuated by the 1997 upper layer warming, then a mid-depth and deep warming in 1998. The dominate periods of the surface temperature anomalies are 5 (<3%) and 9 (3%) years with the majority of the variance contained in the interdecadal periods. In the lower layers (150–200 m) a 5-year period (10%) fluctuation is accompanied by interdecadal fluctuations with a period of

19–20 years that accounts for about 30% of the variance. Thus, the temperature and salinity anomalies differ in their dominate time scales. Using an increase of one standard deviation as an indicator of ENSO (Figure 6) all prior ENSO events (1977, 1982–93, 1987, 1992–93 and 1997–98) can be seen in the 250-m temperature anomaly record with the exception of the 1972 ENSO that did not propagate to high latitudes. The 1997–98 event has produced an anomaly that exceeds 3 standard deviations. It reached its maximum in February 1998 and was back below the ENSO threshold by May. It must be noted that in comparing these measurements with prior ENSO events, since September 1990, sampling has been approximately monthly rather than irregularly as was the case with the "ship of opportunity" sampling. It is uncertain as to whether the ENSO signal propagates only in the subsurface layers only or whether it propagates throughout the water column but is masked by other forcing in the upper layers.

What are the possible causes for this ENSO signal? The lack of a salinity signal with this temperature elevation suggests that the baroclinic flow in the region is not altered. However, a barotropic forcing such as the change in the California and Alaska Currents could bring warmer water into the region. The alongshore gradient of bottom temperature at 250 m is uncertain but might be about half that in the surface layers that is about 1°C/ 200 km. A poleward excursion of about 600 km would cause the observed temperature elevation of about 1.4°C. Since the salinity gradients are parallel to the coast, there would be no salinity change. To accomplish this shift, there would have to be an increase in the coastal current of about 8 cm/s over 3 months. In either case, the ENSO signal is superimposed on a decadal deep temperature signal and its effect on biological productivity depends on both the amplitudes and phases of these cycles.

Hydrographic sampling at GAK 1 will continue and the suite of parameters will be expanded to include nutrients as part of the Northeast Pacific GLOBEC program. These hydrographic data are available on-line at
http://www.ims.alaska.edu:8000/GAK1/GAK1.dat.

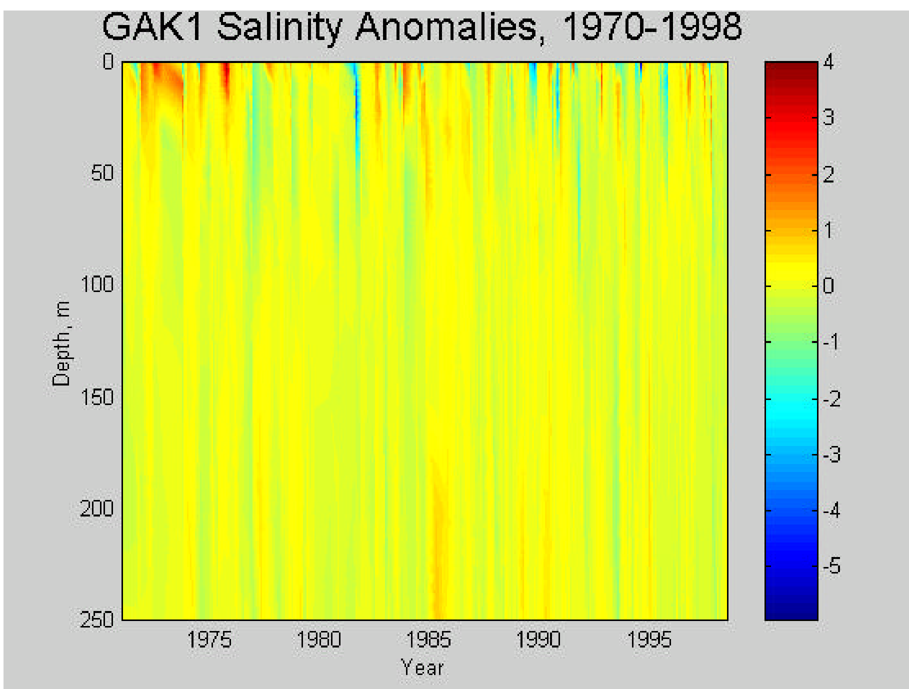

Figure 4. *Salinity Anomalies at GAK 1.*

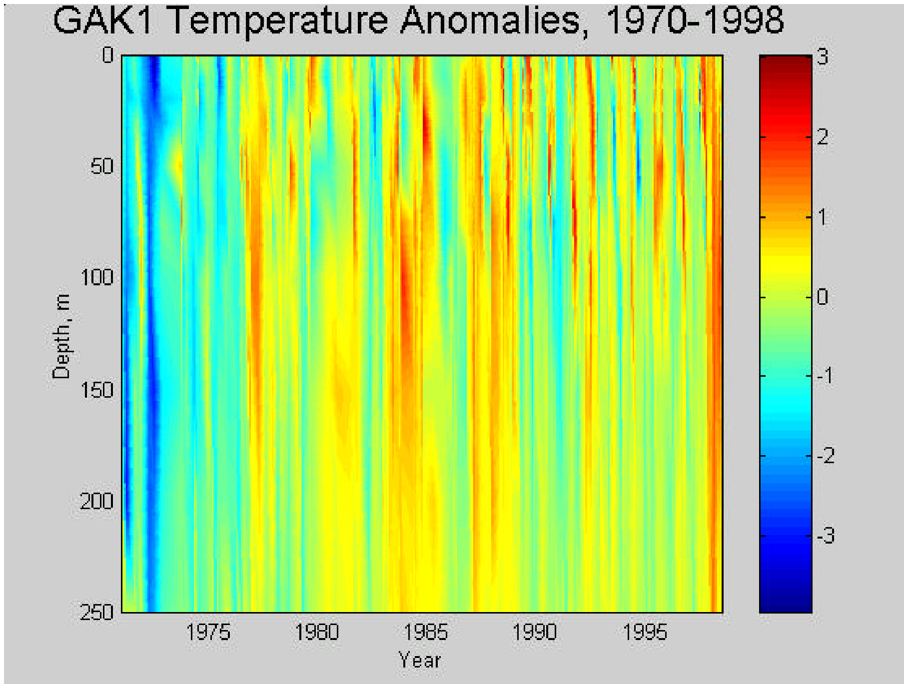

Figure 5. *Temperature Anomalies at GAK 1.*

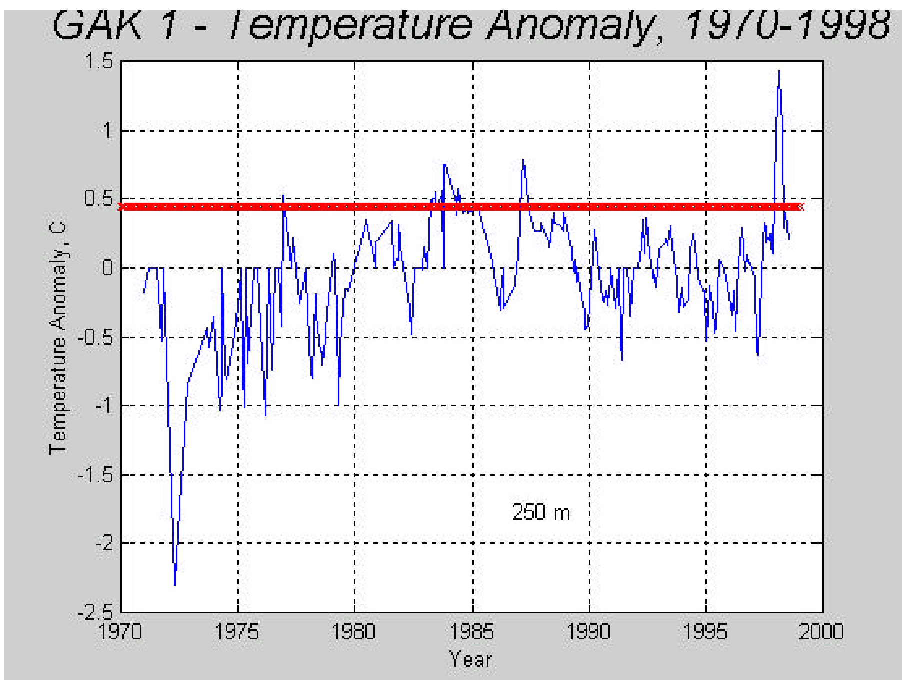

Figure 6. *Temperature Anomalies at 250 m depth at GAK 1 with + one standard deviation (red) used as the threshold for ENSO events.*

References

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