Characterizing Upwelling Events in the Western Arctic

OS35O-08

Chrysanthi Tsimitri (C.Tsimitri@students.uu.nl), Aristotle University of Thessaloniki, Greece Current Address: Utrecht University, 3508TC Utrecht, the Netherlands
Robert S Pickart (rpickart@whoi.edu), Woods Hole Oceanographic Institution, MS21, Woods Hole, MA, 02543, United States

Abstract

Mooring data from the shelfbreak of the Beaufort Sea are used to identify and characterize the upwelling events over the period 2002-3. An objective scheme is used to define the events, of which there are 22 between September and May. Using the timeseries of temperature, salinity and velocity, as well as wind data from Pt. Barrow, Alaska weather station, a canonical upwelling event is described. The variation about this canonical state is investigated using two indices, one that measures the effectiveness of the winds in driving upwelling, and the other measuring the magnitude of the water-column response. Comparison of these indices shows a high correlation as expected; however, it reveals that other factors, such as pack-ice or the tracks of the storms must play an important role in dictating how the shelfbreak current responds to the upwelling-favorable winds.

Area of study and data sets

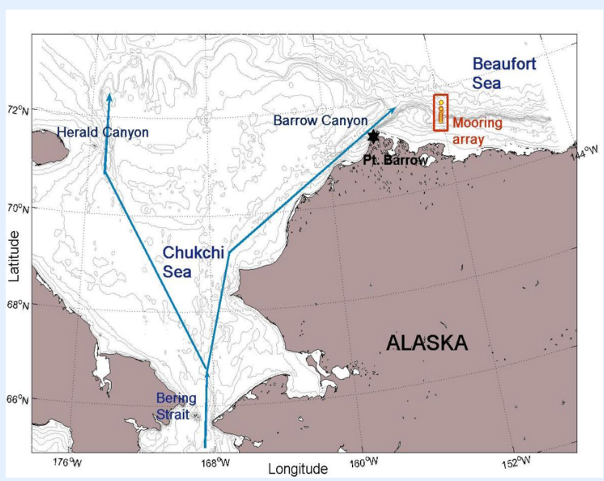


Figure 1: The study area of the Western Arctic with a schematic of the two main branches of the Pacific inflow. A mooring array was located east of Barrow canyon, across the Beaufort shelfbreak, from August 2002 to August 2003.

The shelfbreak current of the Beaufort Sea flows eastward on average, but has a strong seasonal nature. From fall to spring its flow frequently reverses due to easterly winds (Pickart, 2004).

Reversals are usually accompanied by a flux of heat and salt, originating in the underlying water masses, toward the shelf, that change the properties of the resident waters. Such events, considered as upwelling events, can be regarded as a mechanism contributing to shelf–basin exchange.

Wind forcing has been recognized as the most important driving force for coastal upwelling (Smith, 1968). Wind data (direction and speed) from Pt. Barrow, Alaska weather station are used to examine the conditions under which the studied events occur. Because of the coastal topography of the region, winds flowing from the east are expected to trigger upwelling, and higher wind speeds to increase the intensity of the phenomena.

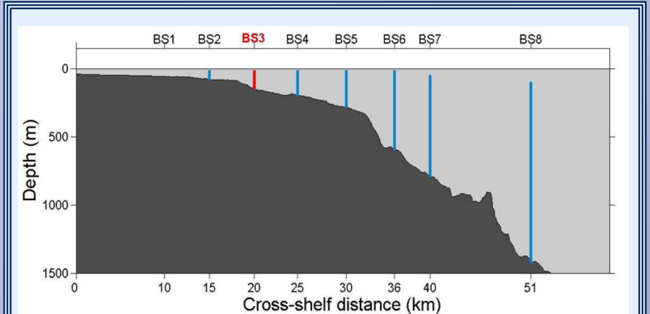


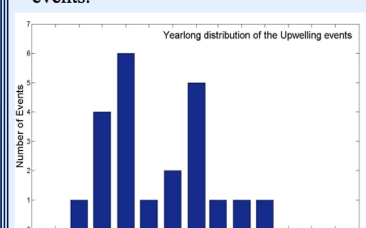
Figure 2: The cross-shelf bathymetry of the Beaufort shelfbreak and slope, and the spatial arrangement of the mooring array. The blue lines indicate moored profilers that were equipped with CTD sensors, with upward-facing ADCPs. In this study the salinity, temperature and velocity timeseries of the BS3 site were used.

Defining Upwelling

A reversal of the current from eastward to westward and a simultaneous appearance of a warm and saline water are considered evidence of upwelling. Accordingly, three criteria were applied, one to each one of the timeseries obtained from the moored profilers:

1. Westward direction of the alongstream velocity from 60m to 150m depth
2. Salinity > 33.8
3. Temperature > 0.8 C

22 groups were found and they were characterized as upwelling events.



• All of the events occurred from September to May.

•November is the dominant month with 6 events, (the most intense event also occurred in this month)

The time distribution of events correlates well with wind direction. During the upwelling period (September to May) the winds are predominantly easterly, while in summer they are westerly.

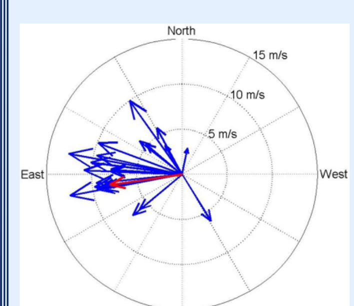


Figure 4: Mean wind vectors for each of the 22 events (blue vectors) and the overall mean wind vector for all of the events (red vector). The overall mean direction is **261T**, which is almost due west, and the mean wind speed is **8.3 m/s**. In general the individual upwelling events show small variation around the computed mean.

How do the upwelling events affect the properties of the water?

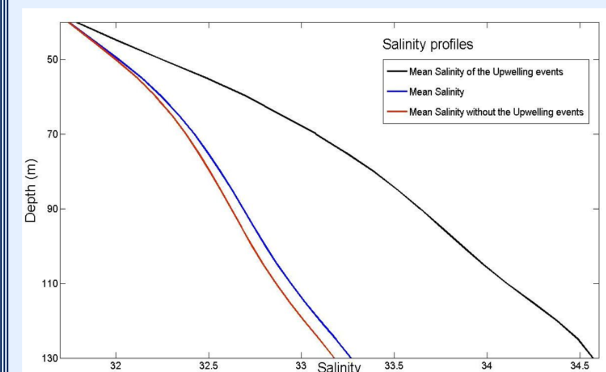


Figure 5. Average salinity profiles. The black line is the average salinity for all the upwelling events, the blue line is the mean salinity for the whole year and the red line is the mean salinity without the upwelling events.

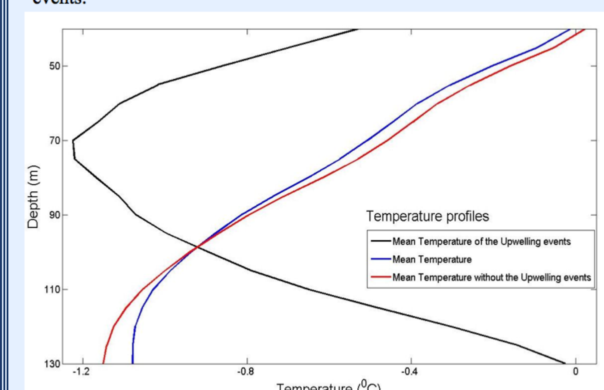


Figure 6. Average profiles of Temperature. The black line is the average temperature for all the upwelling events, the blue line is the mean temperature for the whole year and the red line is the mean temperature without the upwelling events. The yearlong mean value includes the warm summer surface waters.

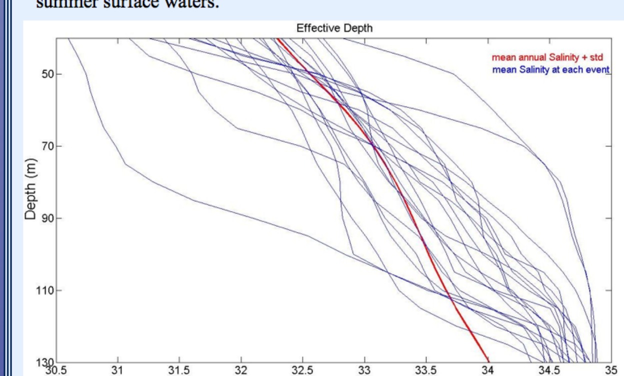


Figure 7. The effective depth for each event is defined as the depth up to which the maximum salinity, for each event, was greater than the annual mean plus the standard deviation for that depth. Based on this, the overall average penetration depth of all the events was computed to be 85 m.

Correlation with the wind

For each upwelling event two indices were used in order to correlate the upwelling events with the wind.

1.The Relative Favorable Wind index, W, measures the effectiveness of the winds in driving upwelling,

$$W = f(V, \delta\theta)$$

V:wind speed, δθ: the deflection of the wind direction from the mean wind direction (261 T),

Both the wind speed and the wind deflection were scaled from 0 to 100, with 100 corresponding to the maximum value, and they were added. The number that resulted was again scaled to a 100-basis scale.

2. The Relative Upwelling Strength index, S, measures the magnitude of the water-column response

$$S = f(t, d, \bar{s}, \overline{T})$$

t: time duration of the event d: effective depth , s: mean salinity at 130 m, T: mean temperature at 130 m

As before, each one of these factors was scaled from 0-100, with 100 corresponding to the maximum value, and they were added. The resulting number was scaled from 0 to 100.

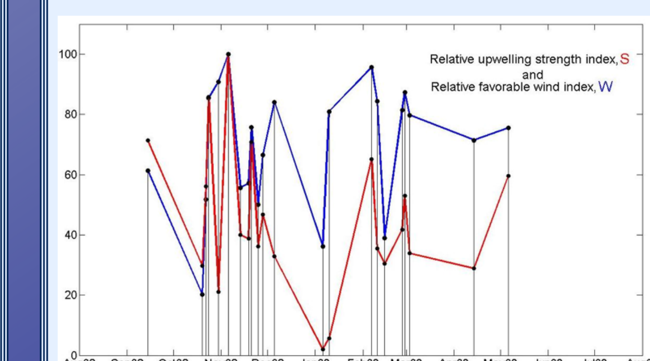


Figure 8. The relative upwelling strength index (red line) and the relative favorable wind index (blue line) for each upwelling event.

Summary

• 22 events occurred in a yearlong period, all of them from September to May

• The mean depth that the upwelled waters reach at the BS3 station (bottom depth of 150m on the upper slope) is 85m

• Comparison of the W and S indices shows a high correlation of the wind to the upwelling, as expected. However, the cases where the two indices have a different behavior reveal that other factors, such as pack-ice or the tracks of the storms, must play an important role in dictating how the shelfbreak current responds to the upwelling-favorable winds.