Characteristics and dynamics of wind-driven upwelling in the Alaskan Beaufort Sea

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Introduction

The Beaufort shelfbreak jet advects Pacific water from Barrow Canyon towards the Canadian Arctic Archipelago. It abuts the eastward-flowing Atlantic Water boundary current located offshore and downslope. Driven by easterly winds, upwelling is common along the Beaufort shelfbreak and takes place throughout the year during varying ice conditions. It is one of the primary mechanisms of shelf-basin exchange in the Alaskan Beaufort Sea. This study uses 6 years of mooring data to quantify various aspects of upwelling across the Beaufort shelfbreak.

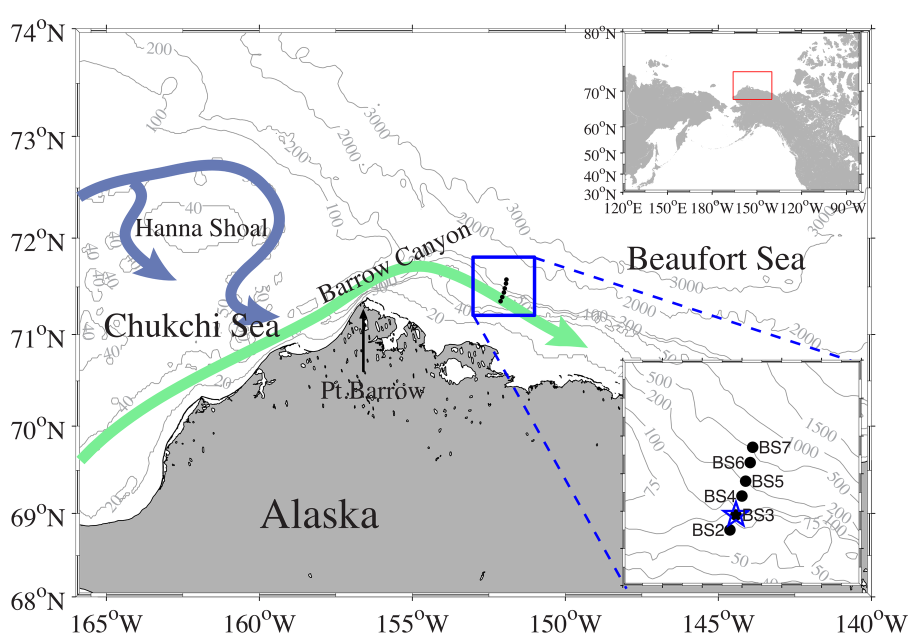

Fig. 1. Locations of the moorings and the schematic circulation.

Upwelling

1. We identify upwelling as times when the near-bottom potential density at mooring BS3 in the center of the shelfbreak jet is greater than the climatological monthly mean (6 years data) and the alongcoast wind is easterly (negative). A total of 115 events were identified.
2. The upwelling index (UI) is defined as the time integral of the near-bottom potential density anomaly over each event.

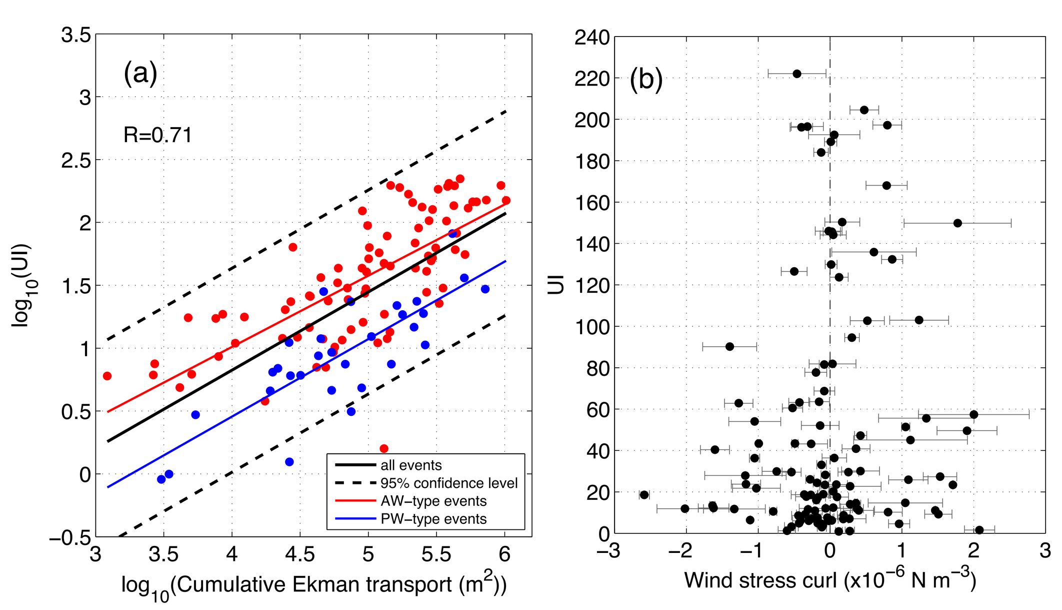

Fig. 2. (a) Value of the upwelling index versus cumulative Ekman transport, defined as $\int_{t_s-t_d}^{t_e-t_d} \tau_s(t)dt/(\rho_0 f)$. *(b) Upwelling index versus local wind stress curl for all of the upwelling events.*

The upwelling is not related to the local wind stress curl, but instead is associated with along-coast wind.

General characteristics

We defined a normalized time (t_n), which ranges from 0 at the beginning of each upwelling event to 1 at the end, and considered as well the conditions just prior to and after the upwelling ($-0.25 \le t_n \le 1.25$). We then constructed a composite event by averaging the 115 events.

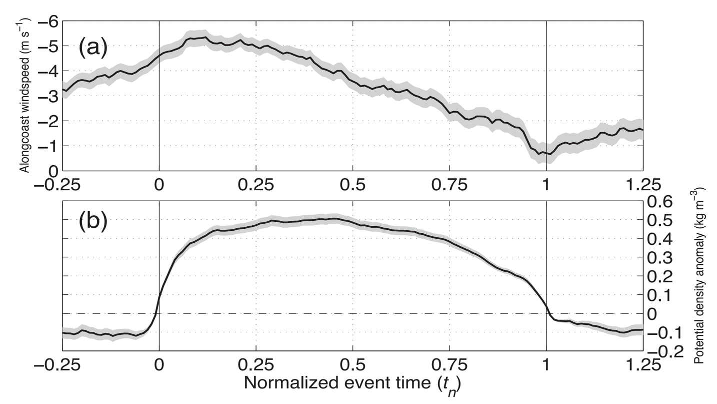

Fig. 3. Composite upwelling event of (a) alongcoast wind and (b) potential density anomaly.

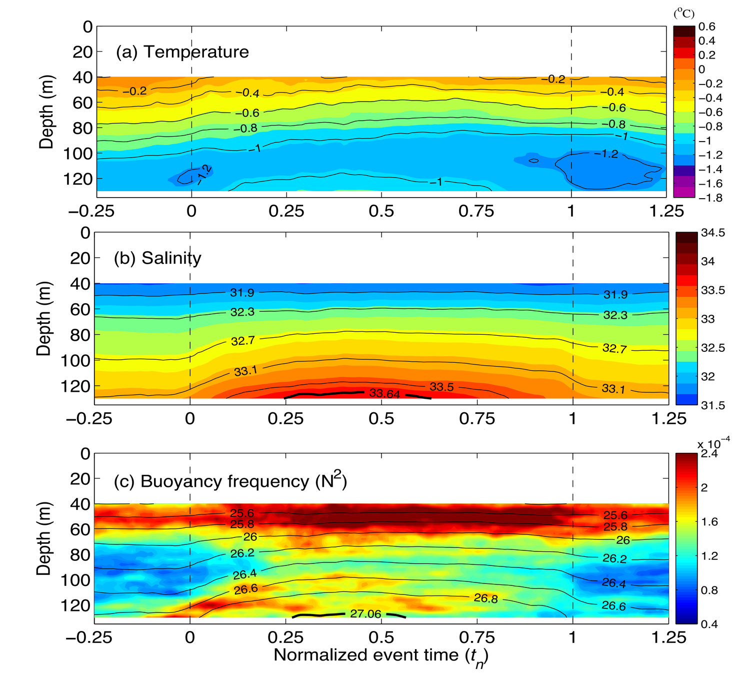

Fig. 4. Composite upwelling event of (a) temperature, (b) salinity, and (c) buoyancy frequency

Velocity structure

1. When the easterly wind is strongest the entire shelfbreak jet is reversed to the west.
2. The cross-isobath flow has a three-layer structure with onshore flow in the surface layer, offshore flow in the middle of the water column, and onshore flow near the bottom.

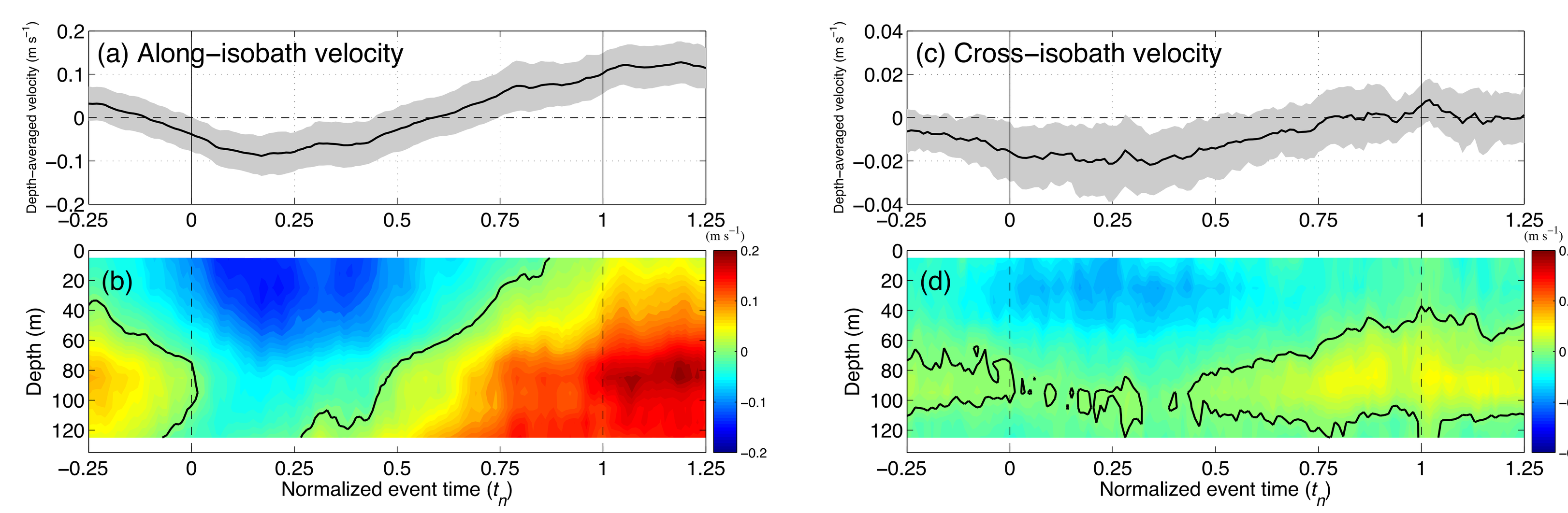

Fig. 5. Composite upwelling event of along-isobath velocity and cross-isobath velocity. Both the depth-mean and depth-dependent fields are shown.

3. The orientation of the reversed shelfbreak jet is slightly onshore which overwhelms the cross-isobath surface Ekman transport.

Seasonal influences on upwelling

PW-type upwelling: only Pacific water is upwelled, occurs during the warm months.
AW-type upwelling: Atlantic water is also upwelled, common in spring and winter.

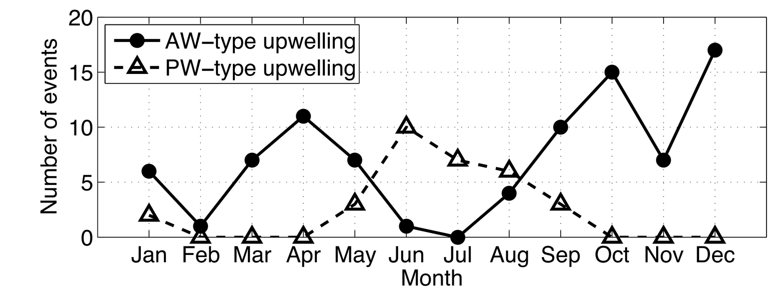

Fig. 6. Seasonal variation of the occurrence of AW-type upwelling and PW-type upwelling events.

1. The primary factor determining the type of upwelling is the seasonal variation in the PW-AW interface depth offshore of the shelfbreak.

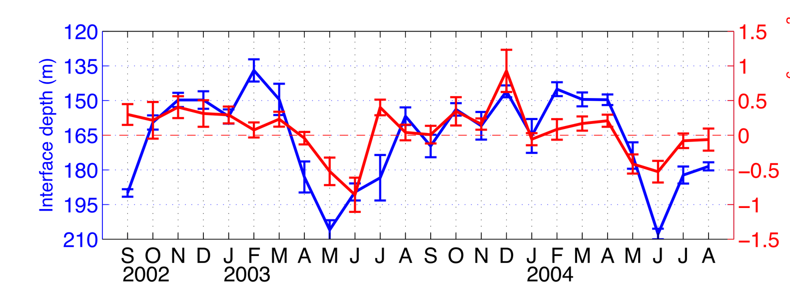

Fig. 7. Time series of monthly-averaged PW-AW interface depth and monthly area-averaged wind stress curl.

2. The wind stress curl near the boundary is strongly linked to the variation in PW-AW interface depth: negative wind stress curl pumps the interface down during summer, and positive curl lifts it in winter.

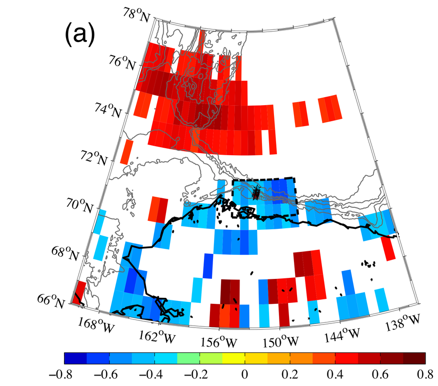

Fig. 8. Spatial distribution of the correlation coefficient of wind stress curl at each point versus the PW-AW interface depth from the moorings.

3. The zero-curl line is located south of the mooring array during the summer months and north of it remainder of the year.

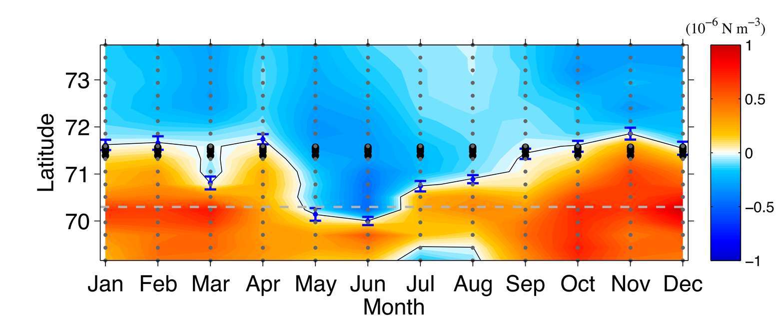

Fig. 9. Latitude-time distribution of the climatological monthly mean wind stress curl close to 152°W for the time period 2000 – 2013.

4. The two atmospheric centers of action – the Beaufort High (BH) and the Aleutian Low (AL) – control the variation of local wind stress curl, which in turn alters the PW-AW interface depth and dictates the type of upwelling.

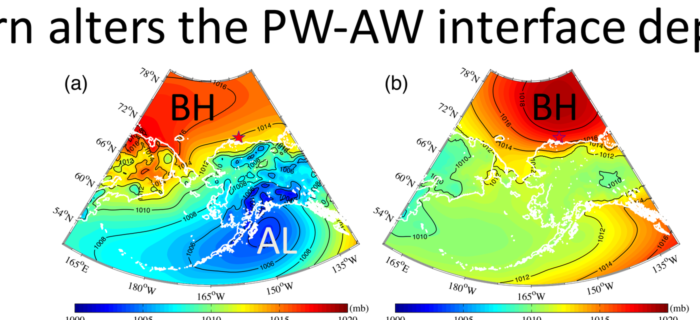

Fig. 10. Composite sea level pressure (mb) for the months when wind stress curl is (a) positive, and (b) negative.

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