Upwelling in the Alaskan Beaufort Sea and its impacts on primary productivity

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1. Introduction:
The general circulation of the southern Beaufort Sea consists of wind-driven westward flow in the interior and a buoyancy-driven shelfbreak jet flowing to the east. The jet is often reversed when easterly winds exceed 5 m/s resulting in upwelling. Upwelling can occur during any month of the year and in nearly all ice conditions. The upwelling has the potential to impact the ecosystem since the secondary circulation brings nutrient-rich waters from the halocline into the euphotic zone.

2. Upwelling:
Using data from a mooring array deployed across the shelfbreak jet for two years (Aug 2002 - Sept 2004) and wind data from a nearby weather station, 45 upwelling events were identified. While the upwelling is strongest during times with partial ice cover, the basic response is the same for all seasons. A typical storm response is shown in Fig. 2 for a location in the shelfbreak jet.

3 Biological implications:
Cold, nutrient-rich Pacific water enters the Chukchi Sea each winter through Bering Strait. Some of the water triggers a spring/summer phytoplankton bloom on the shelf, while some is fluxed offshore into the halocline. The shelf bloom is typically over by mid-August, leaving the water column stripped of nutrients.

Upwelling represents a mechanism for re-supplying nutrients to the outer Chukchi and Beaufort shelves in late-summer/early-fall by tapping the reservoir of high-nutrient water in the basin. Evidence of a wind-induced bloom can be seen on Fig. 3 for a storm in August 2010.

4. Upwelling-induced primary productivity:
A nitrate-density relationship was used in conjunction with the mooring data to calculate vertical nitrate fluxes to the euphotic zone during seven upwelling events in open water conditions (August to early-October 2002-2004). Results indicate that upwelling supplied an average of 142 mmol N/m² per open-water season, which converts to 936 mmol C/m² (Table 1). This average is only slightly less than in-situ data measured for the Chuckchi shelf and slope during August 2002 (in storm-free conditions.).

5. Decadal variability of upwelling and productivity:
A 70-yr timeseries (1941-2010) of windspeed, along with a previously determined wind-upwelling relationship, allowed us to establish a long-term record of upwelling on the Beaufort Slope (Fig 4). During this period, 149 open-water storms were deemed sufficiently powerful, and long enough in duration, to allow initiation of a phytoplankton bloom.

Using the carbon uptake from the storms discussed above we estimated the storm-induced carbon production during the open water season of each of the 70 years (Fig.5). Storm count and carbon uptake show an enhancement over the last two decades.

6. Conclusion:
Transport of nutrients into the euphotic zone via upwelling can trigger significant primary production in late-summer and early-fall. This has potential to result in as much carbon uptake as during a storm-free spring/summer bloom. Early-season, under-ice blooms have recently been observed in the Chukchi Sea, and, as the pack-ice continues to melt earlier and freeze later, upwelling in the spring and fall may promote even higher carbon production in the future.