Mechanisms for enhanced trophic productivity in Barrow Canyon, Chukchi Sea

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PacMARS-SOAR Workshop, January 2013

Outline

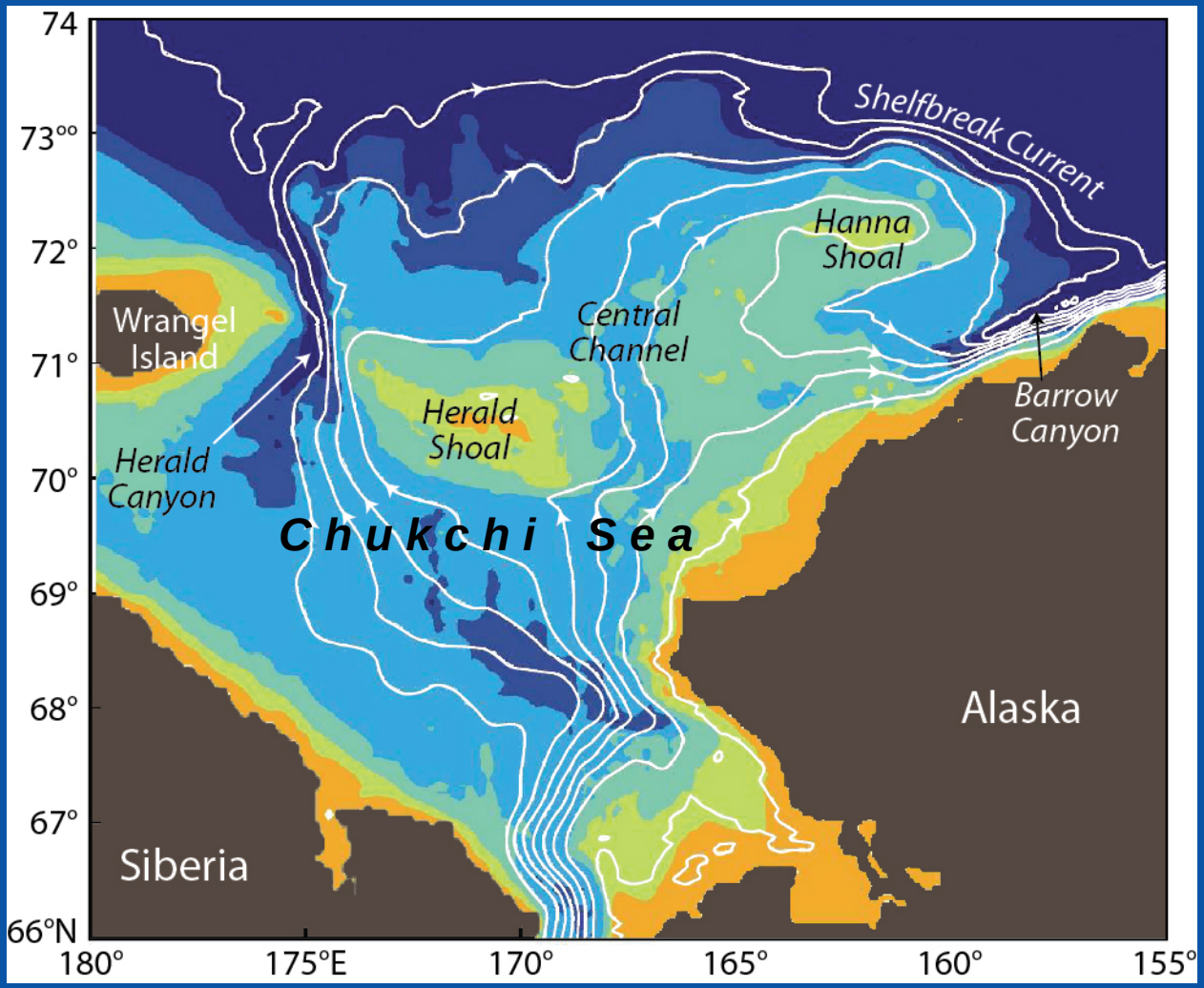
1. Quick review of the circulation in the Chukchi Sea
2. Defining the Barrow Canyon hotspot
3. Mechanisms for enhanced nutrient delivery to the canyon

Wrangel Island, summer 2009
Photo by Christine Patrick

Pacific water inflow to the Arctic

Models (and data) indicate three primary flow paths.

Note that all roads lead to Barrow Canyon!

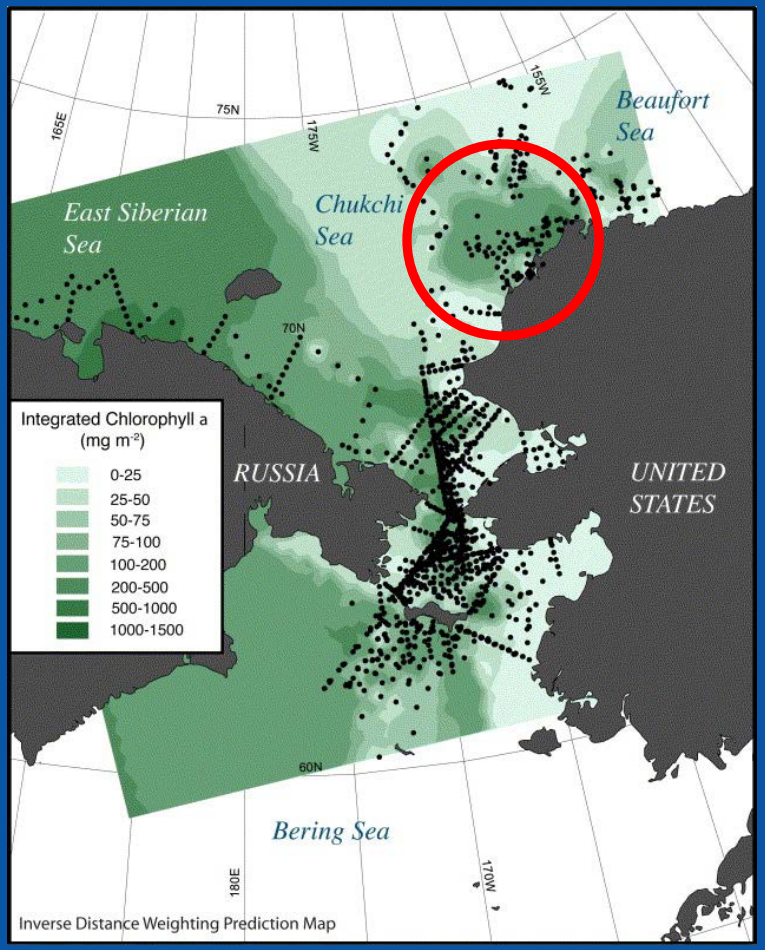


Barotropic streamlines (Spall, 2007)

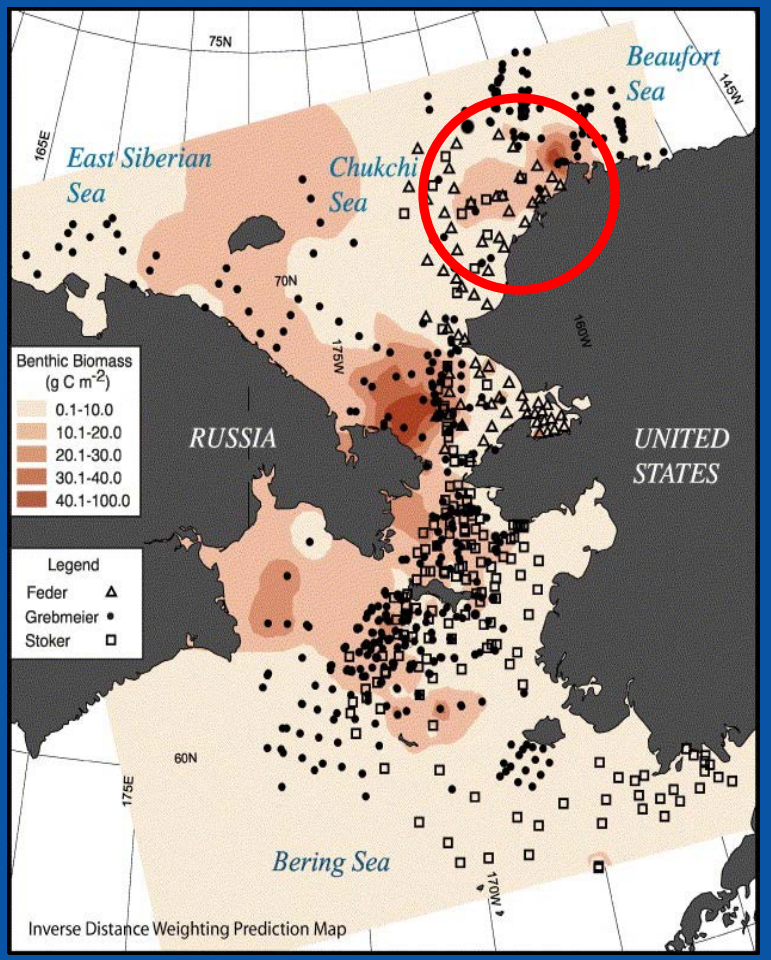
Is Barrow Canyon a hotspot?

1. Barrow Canyon has one of the highest levels of primary productivity and benthic biomass in the western Arctic

Integrated chlorophyll

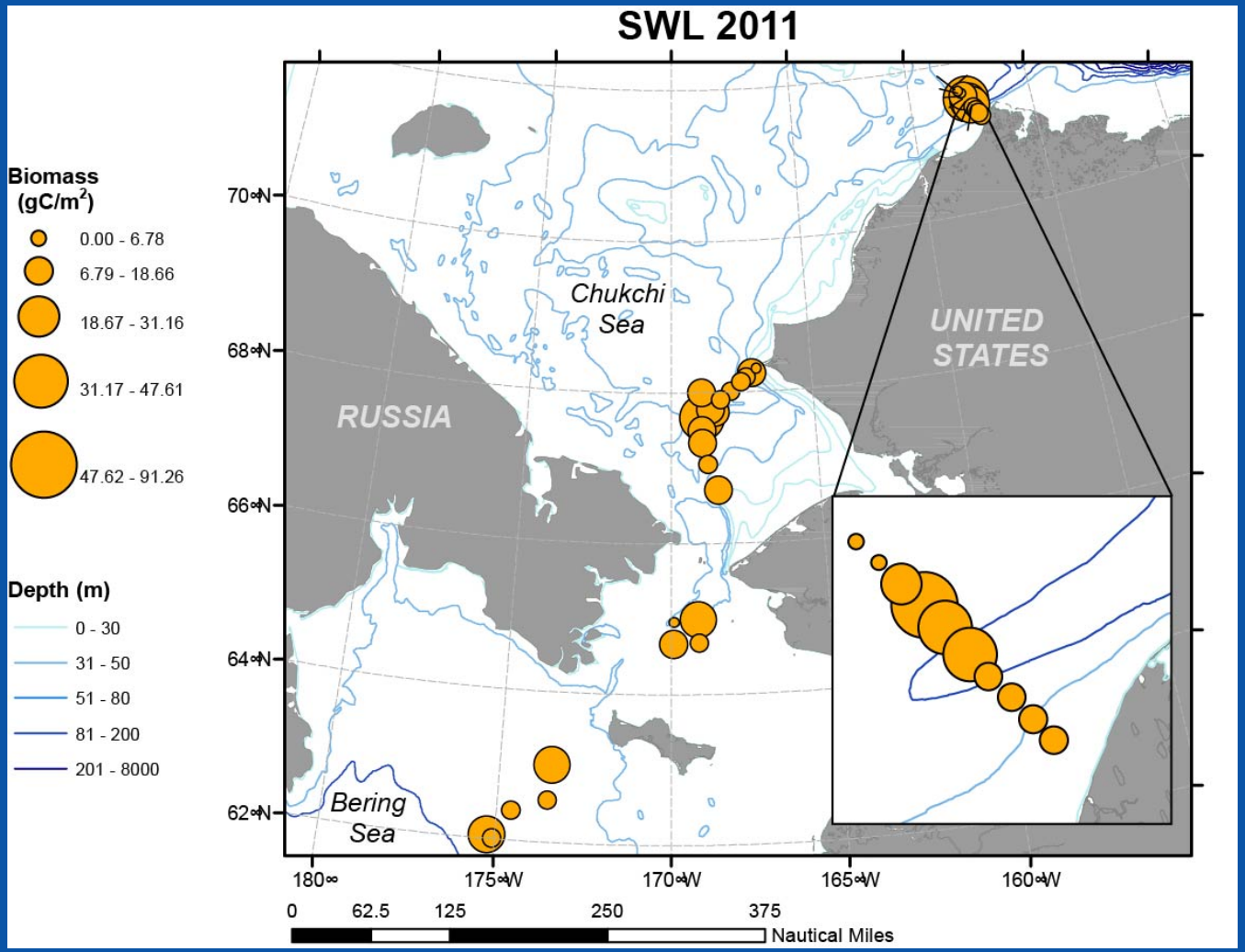


Benthic biomass



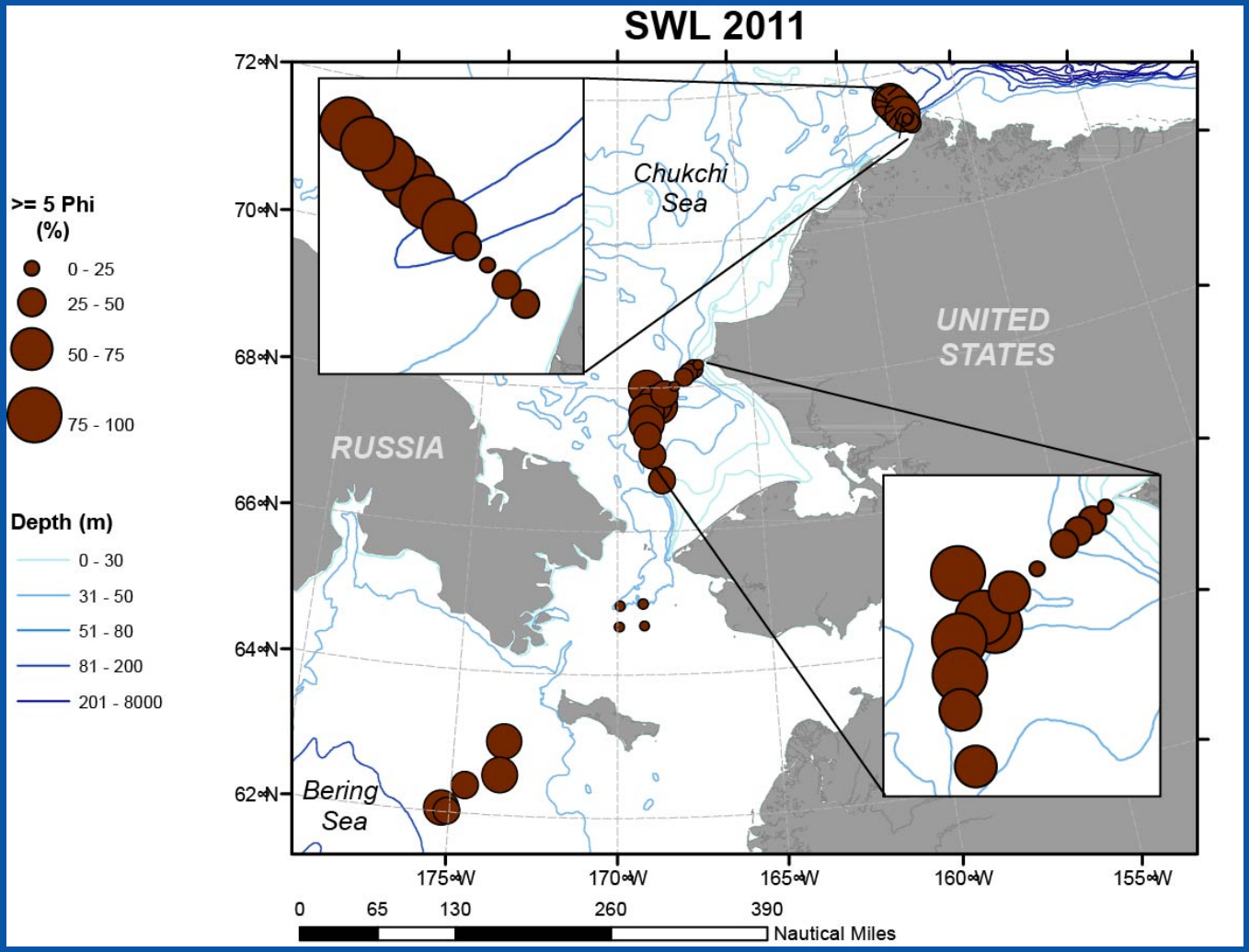
From Grebmeier et al. (2006)

SWL 2011 Benthic Biomass (gC/m2)



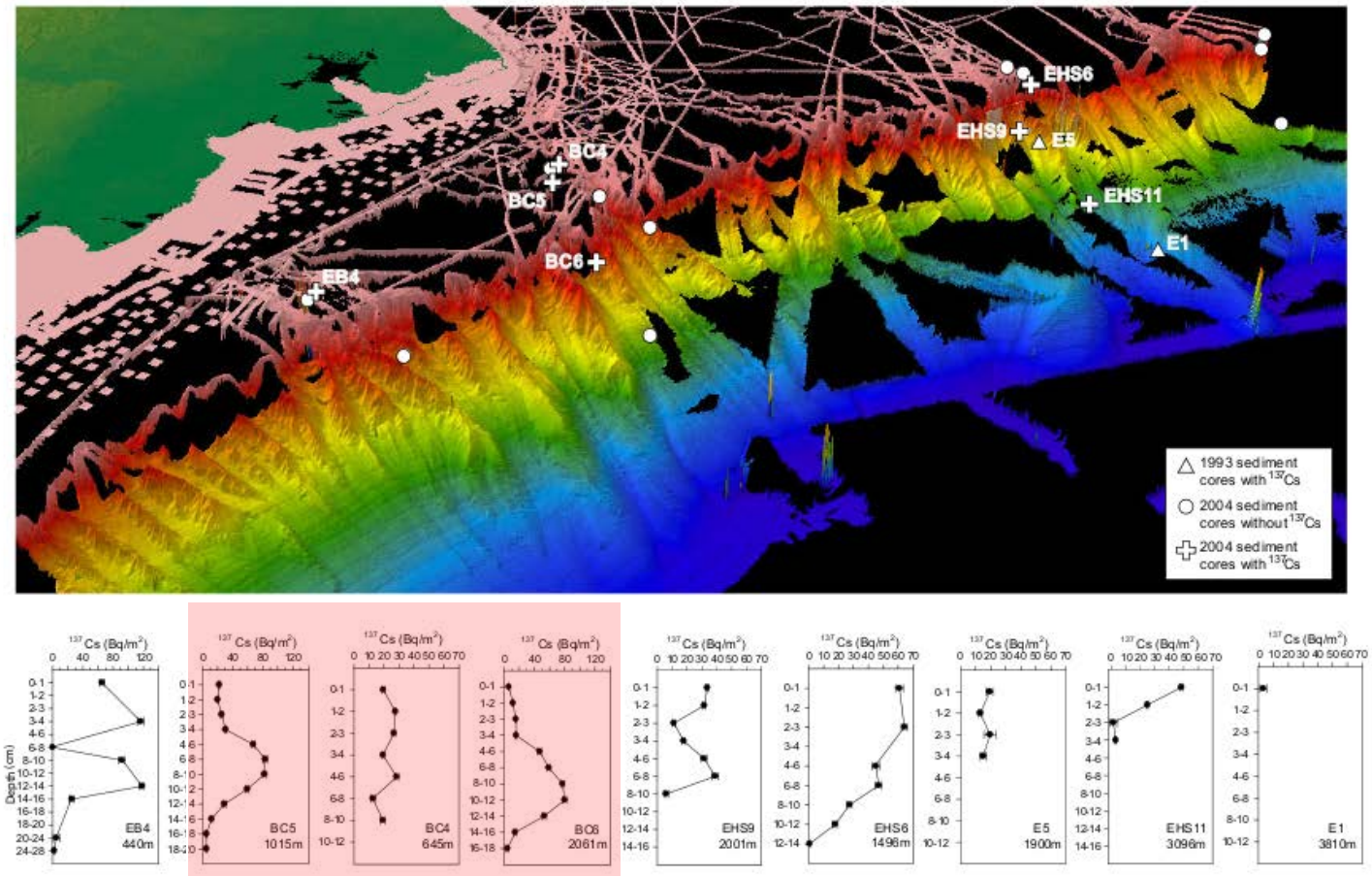
From J. Grebmeier

2011 sediment silt and clay (%)



From J. Grebmeier

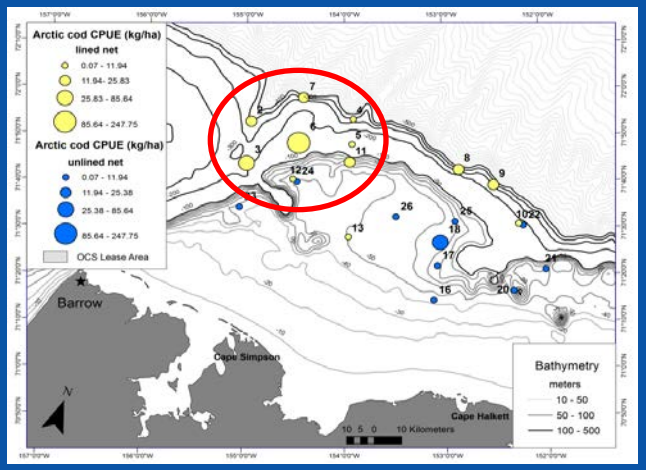
2. Barrow Canyon has high deposition rates

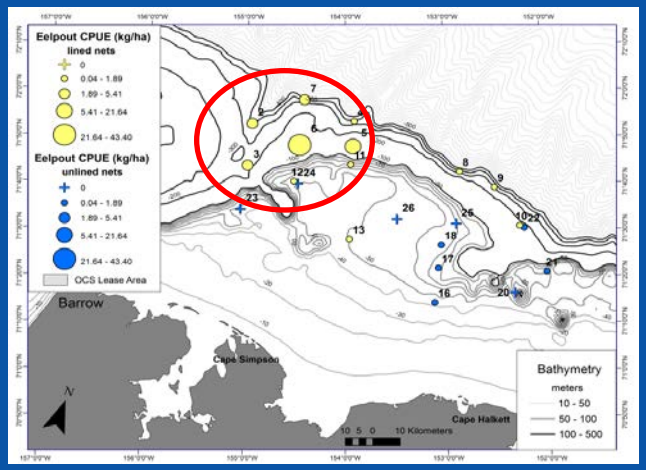


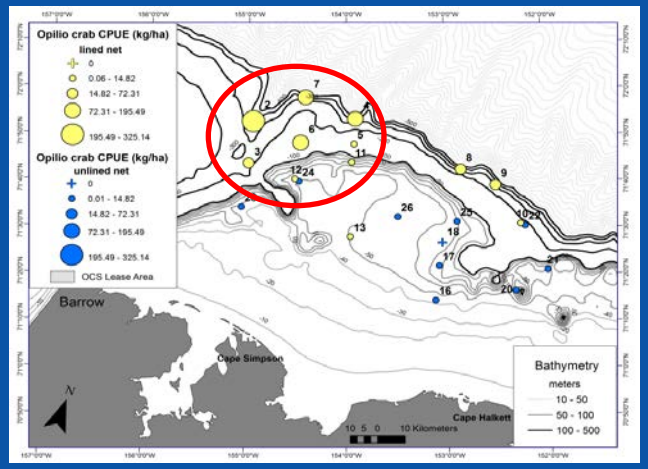
Multibeam data courtesy of Margo Edwards (top); ^{137}Cs profiles for bottom sediments showing high sedimentation to >2000 m along slope and in Barrow Canyon (Pirtle-Levy et al. 2009)

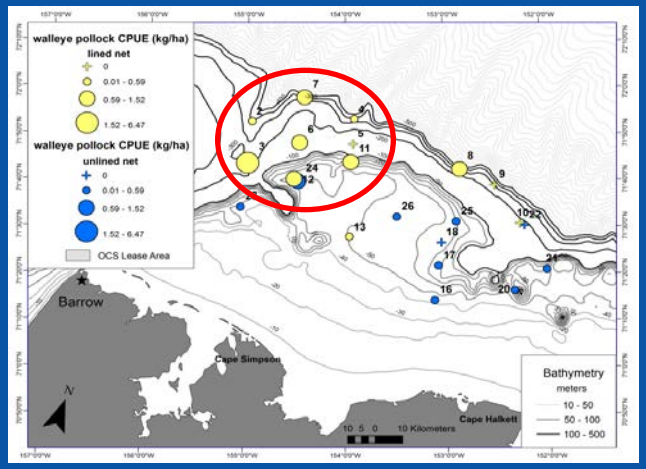
From L. Cooper

3. There are enhanced numbers of demersal fish in the vicinity of Barrow Canyon







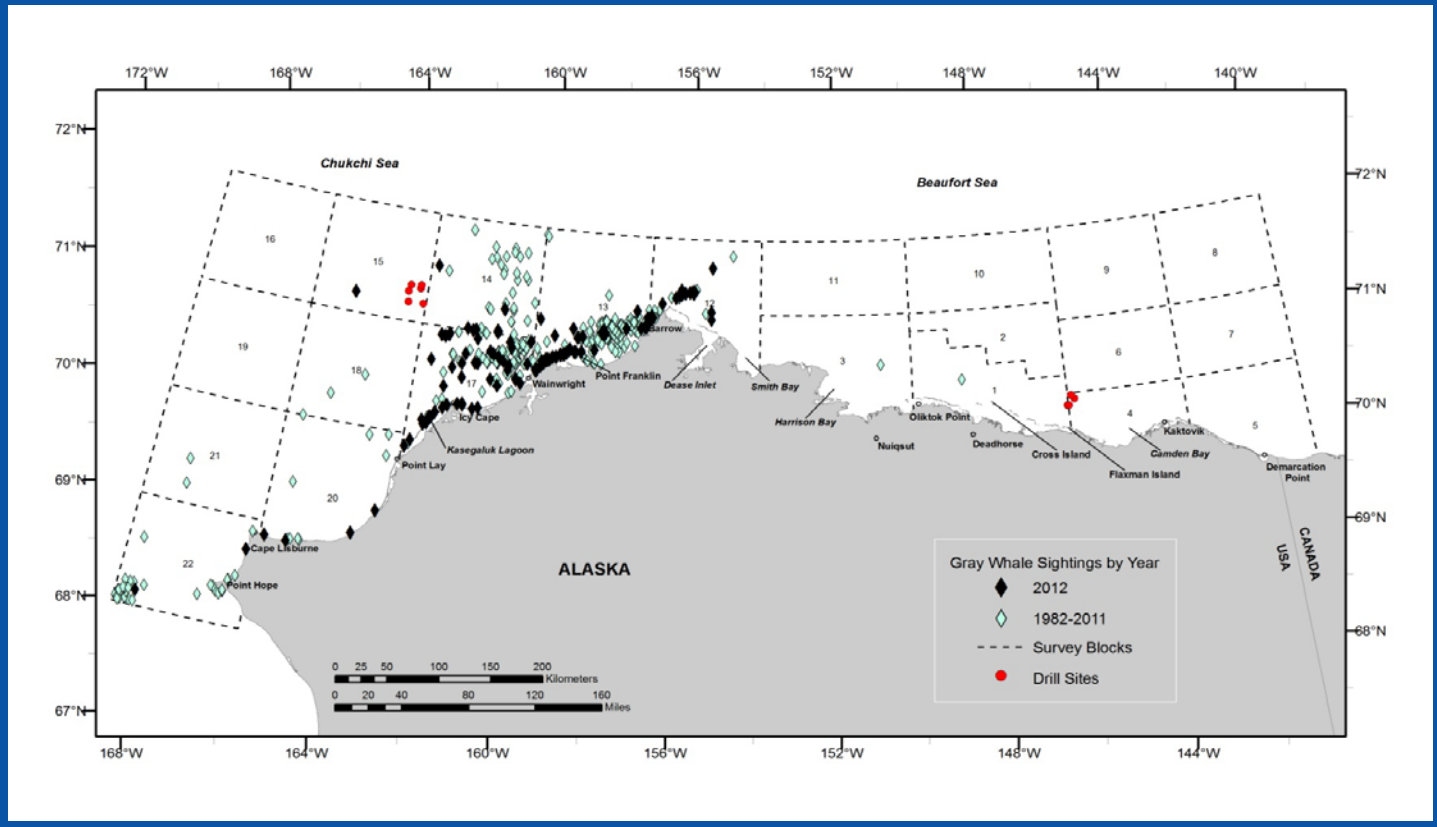


NOTE: CPUE scales are different among species

From S. Parker-Stetter, J. Horne, L. Logerwell, K. Rand

4a. The vicinity of Barrow Canyon is a fertile feeding ground for Gray Whales

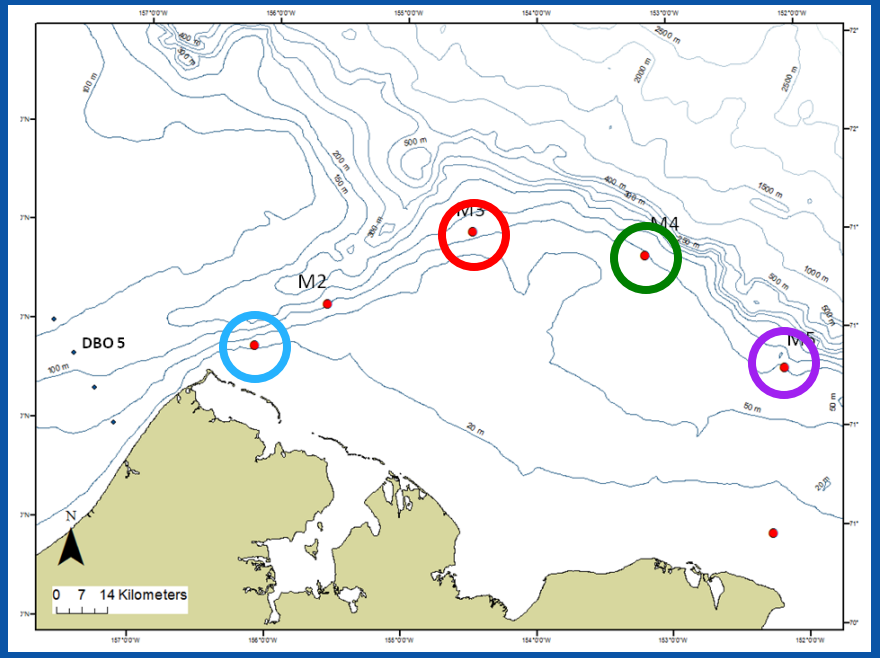
Aerial Surveys of Arctic Marine Mammals Gray Whale Transect Sightings

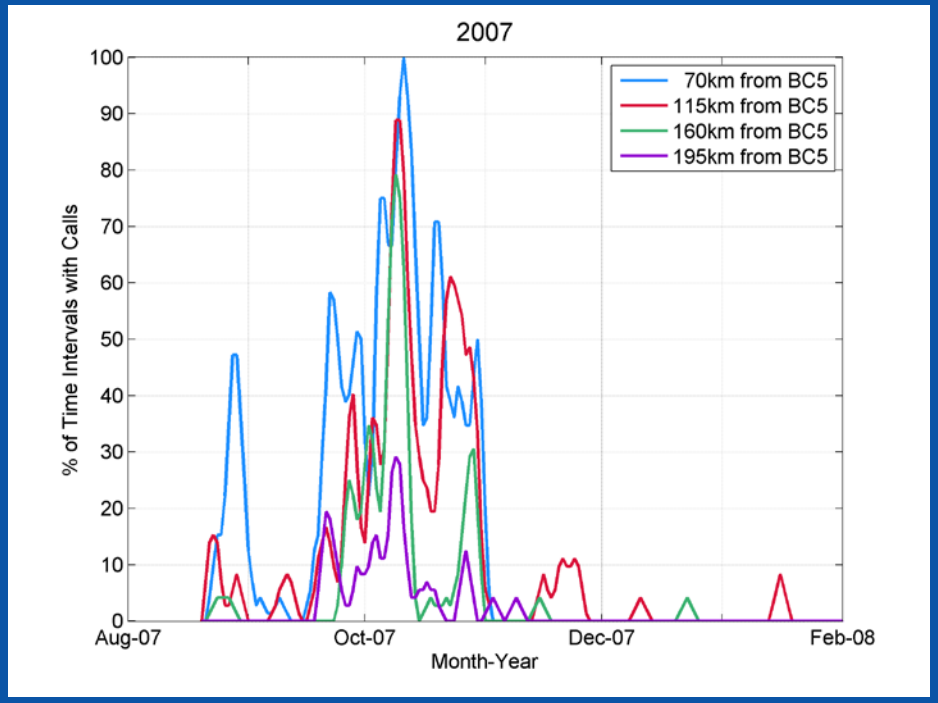


Years with light sea ice cover: 1982, 1986, 1987, 1989, 1990, 1993-2012

From M. Ferguson

4b. Greater occurrences of Bowhead whale calls are detected near Barrow Canyon

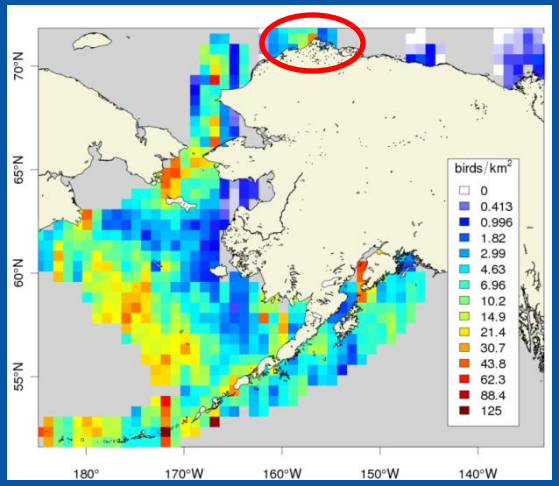




From C. Berchok and S. Grassia

5. Barrow Canyon region has high densities of various seabirds

Total bird density throughout Alaska. Barrow Canyon area shows enhanced densities

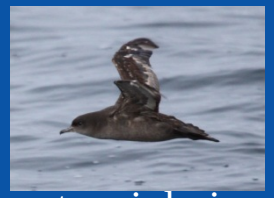


Seabird surveys, 2006-2012

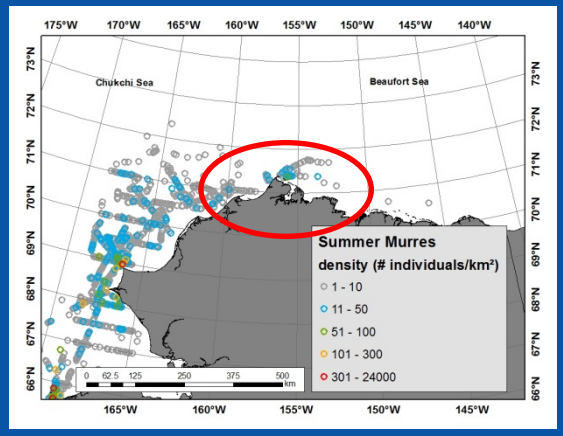
km surveyed & bird densities (birds/km^2)
Densities calculated in 3-km segments, averaged within cells

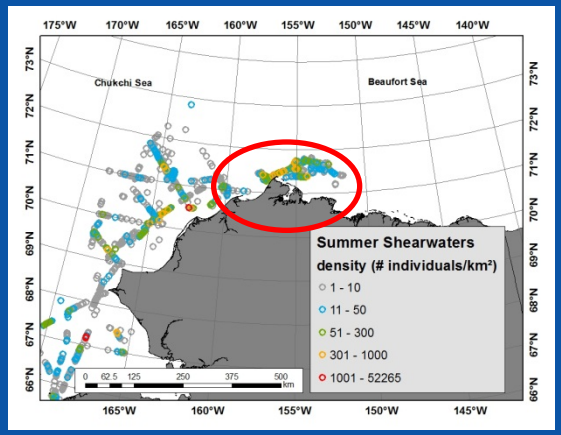
Examples:

Murres
(divers, eat fish & inverts)



Shearwaters
(surface-plungers, eat mainly inverts)





From K. Kuletz and B. Hurley

Why Is Barrow Canyon a hotspot?

Why Is Barrow Canyon a hotspot?

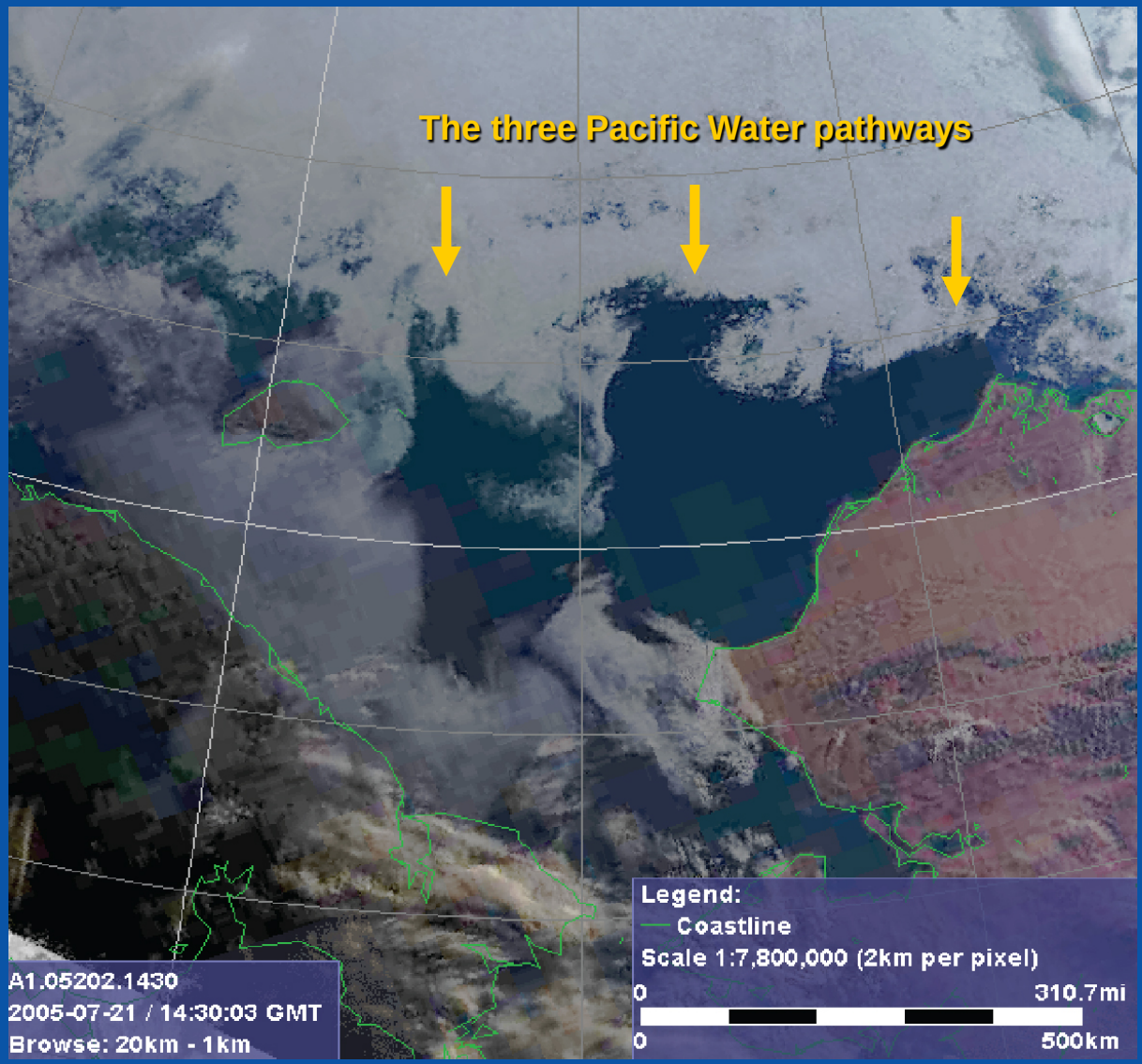
It starts with primary productivity, which depends on sunlight and nutrient supply to the water column.

Barrow Canyon has special attributes with regard to both of these.

1. Barrow Canyon receives lots of sunlight

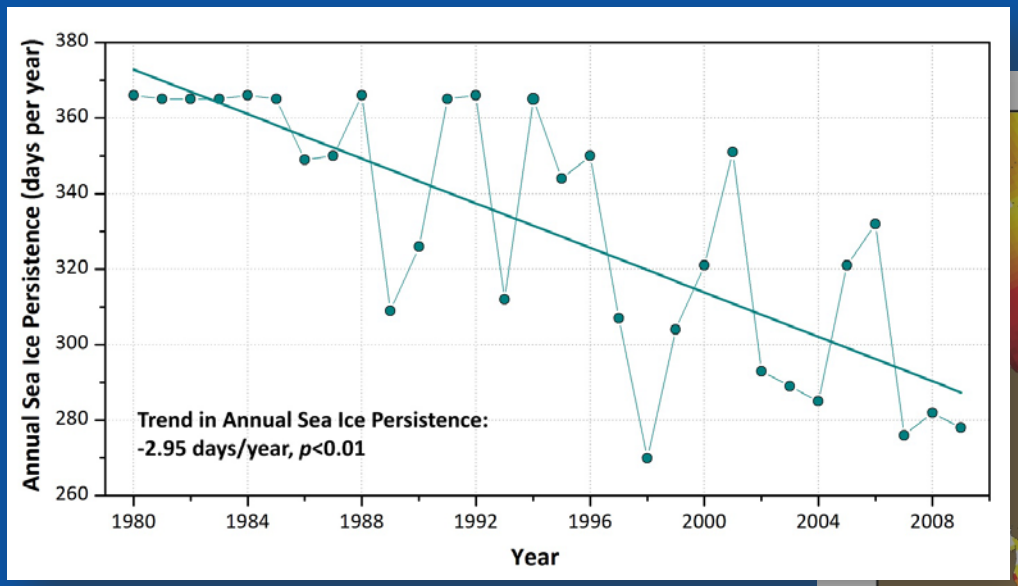
Ice melt-back in the spring

The Barrow Canyon region opens up early in the season, allowing more sunlight to penetrate the water column.



Trends of ice persistence

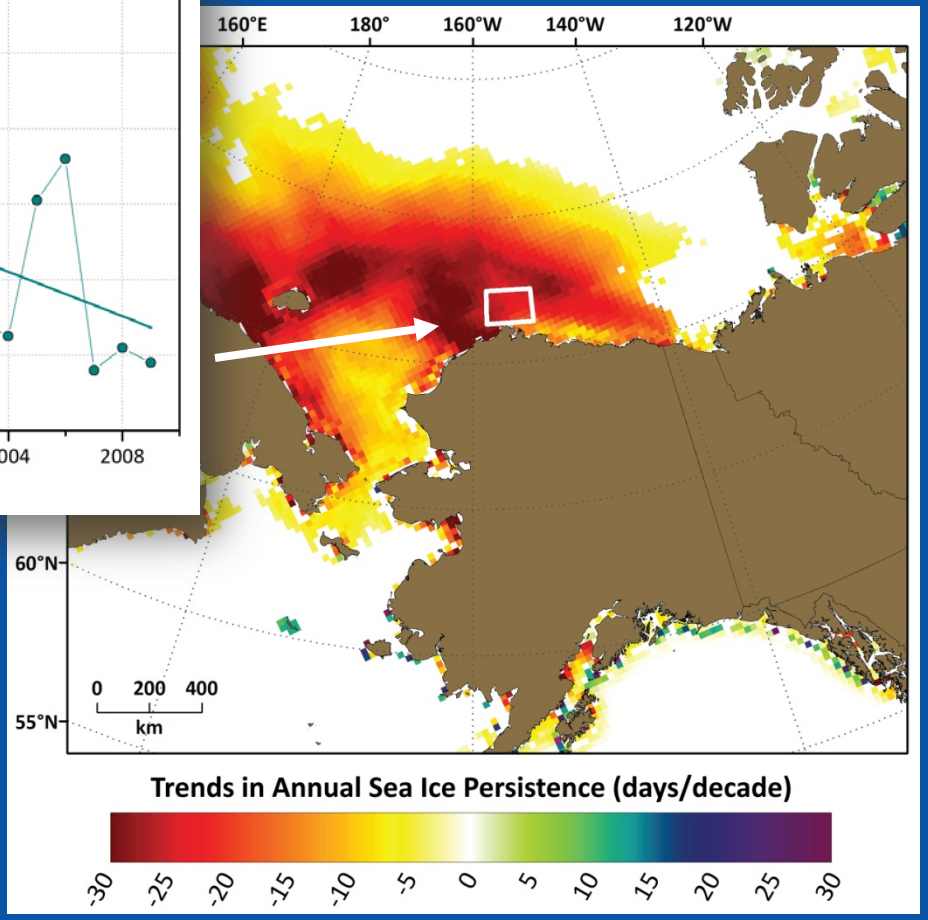
Barrow canyon is experiencing significantly longer periods of open water



Annual sea ice persistence within Barrow Canyon. The trend over this thirty year record shows a loss of sea ice cover of 2.95 days/year.

From K. Frey

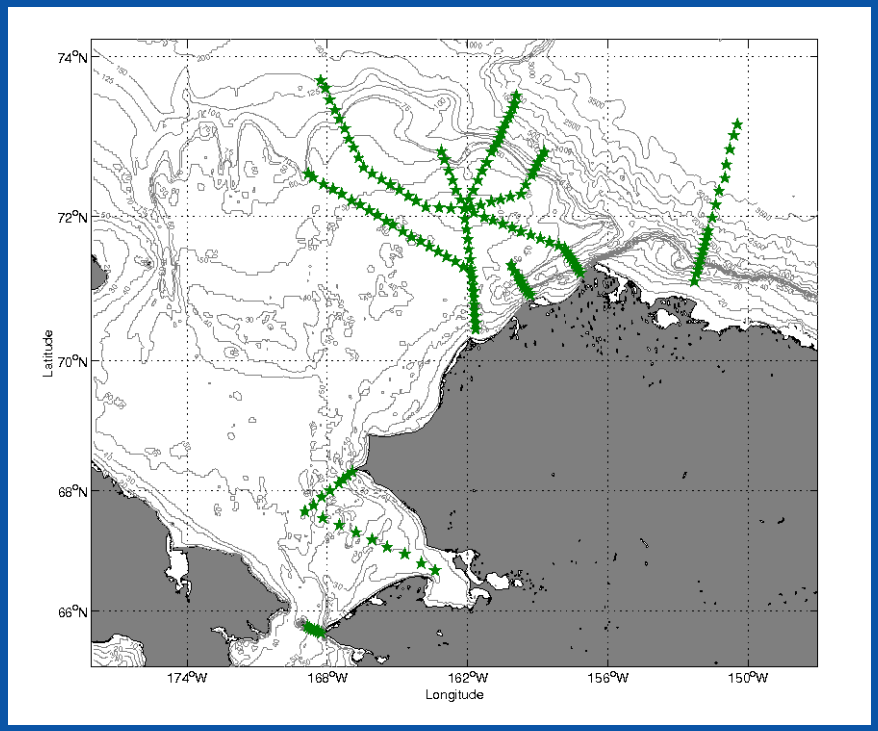
Spatial representation of annual sea ice persistence trends (1979-2008) based on SMMR and SSM/I sea ice concentrations.



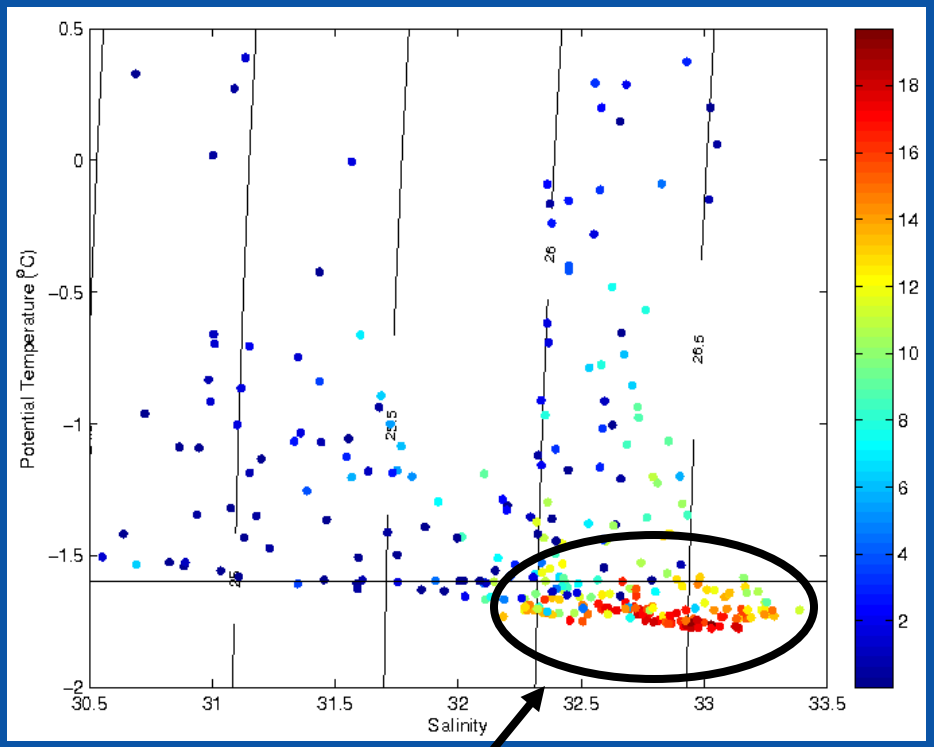
2. Barrow Canyon receives lots of nutrients

Nitrate concentration of Pacific Water

Shipboard survey in summer 2011



Nitrate concentration in T/S space

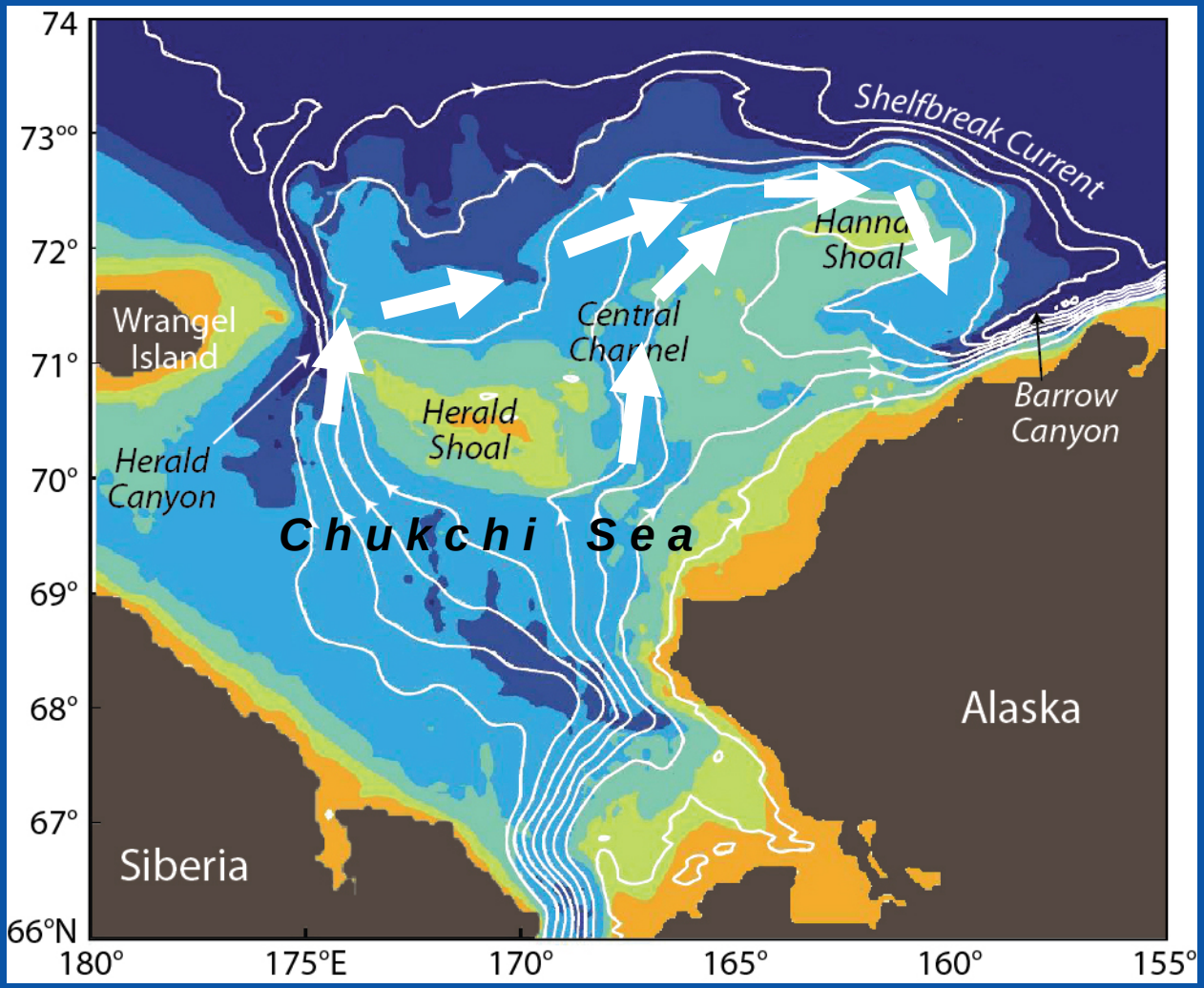


Highest nutrients are in the winter water

Winter water contains the most nutrients. How does winter water enter the canyon?

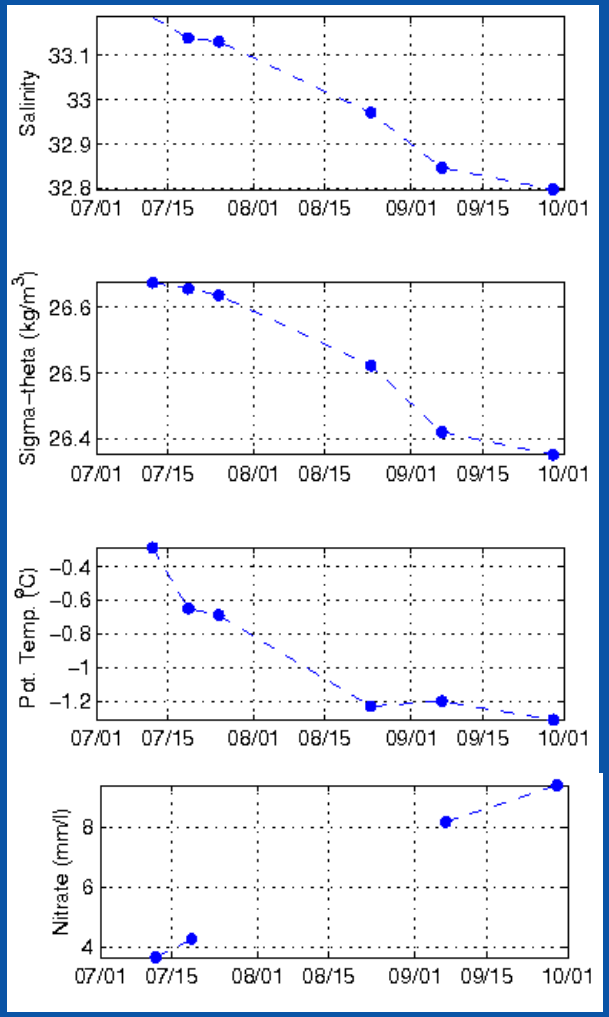
1. Lateral advection from upstream

Winter water drains into the canyon throughout the summer via the "slow pathway"



Barotropic streamlines from Spall (2007)

Time series of winter water properties in Barrow Canyon during summer 2010 (DBO Pilot study)

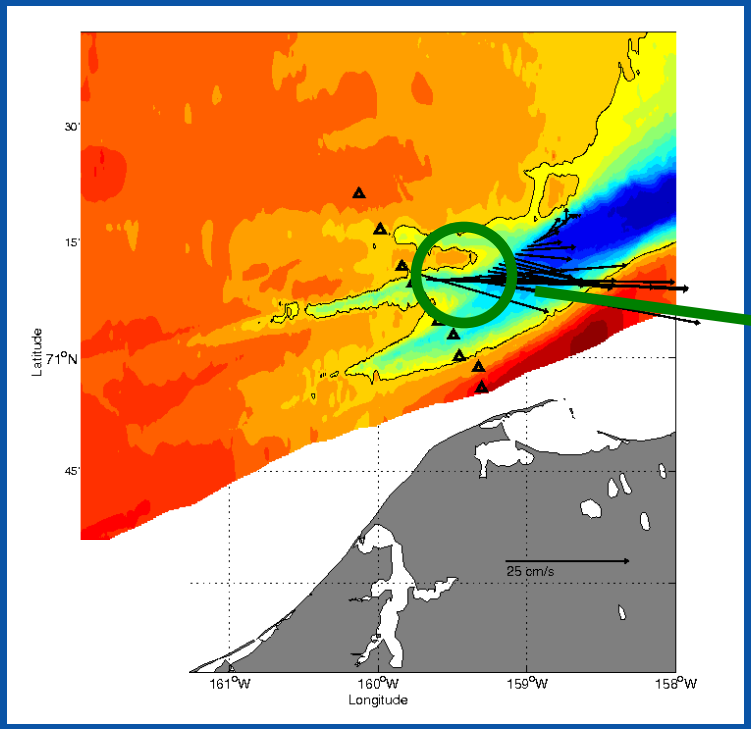


DBO=Distributed Biological Observatory

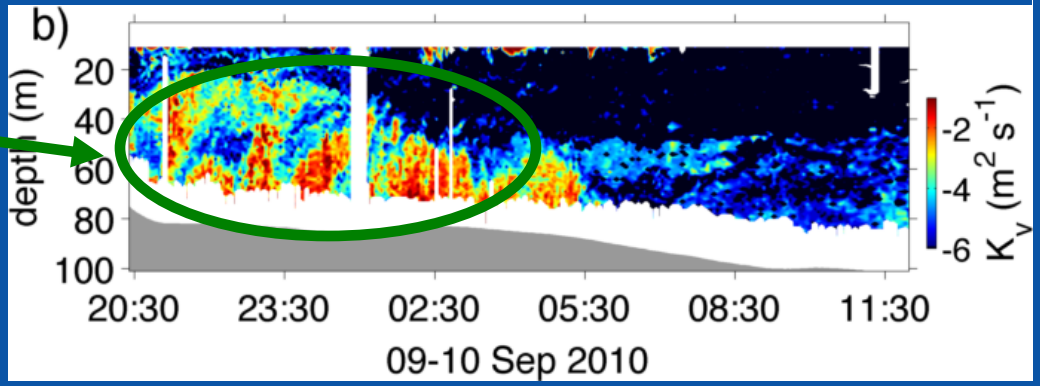
As the summer progresses, the winter water gets fresher, lighter, colder, and higher in nitrate.

2. Enhanced mixing at the bottom of the canyon can flux nutrients upward into the euphotic zone

Winter water draining into Barrow Canyon



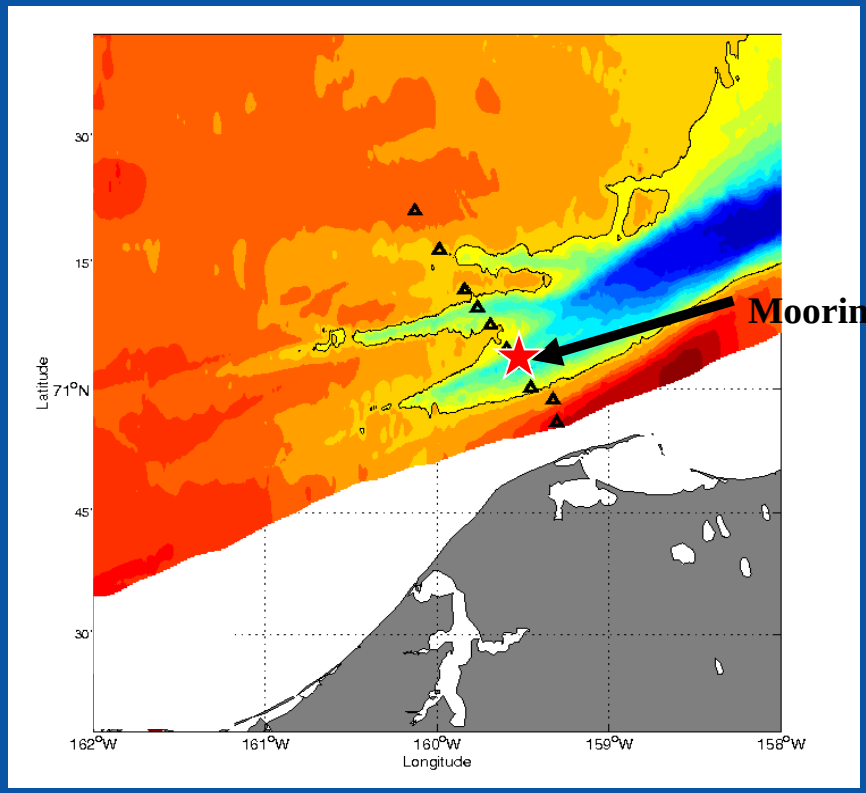
Enhanced diffusion at the head of the canyon



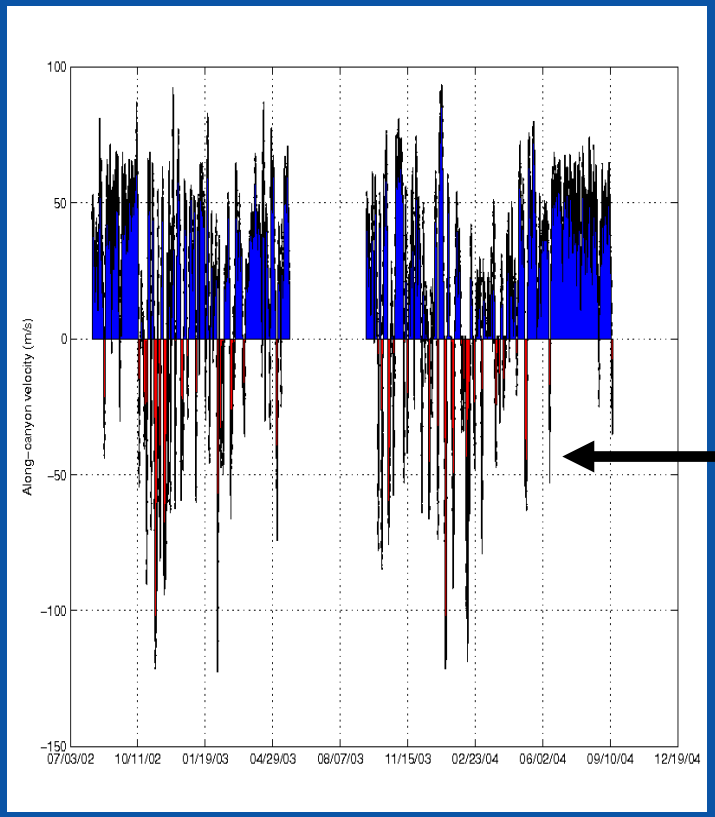
Summertime survey of Barrow Canyon in 2010, including microstructure measurements (Shroyer, 2012)

3. Upwelling brings winter water from the basin into the canyon

Mooring deployed for 2 years at head of canyon

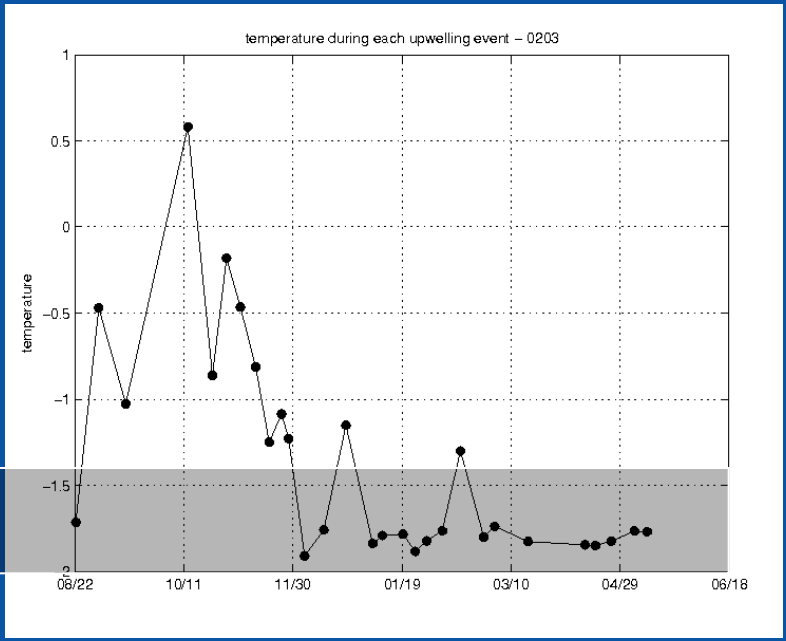


Along-canyon currents



Upwelling events in Barrow Canyon are very common

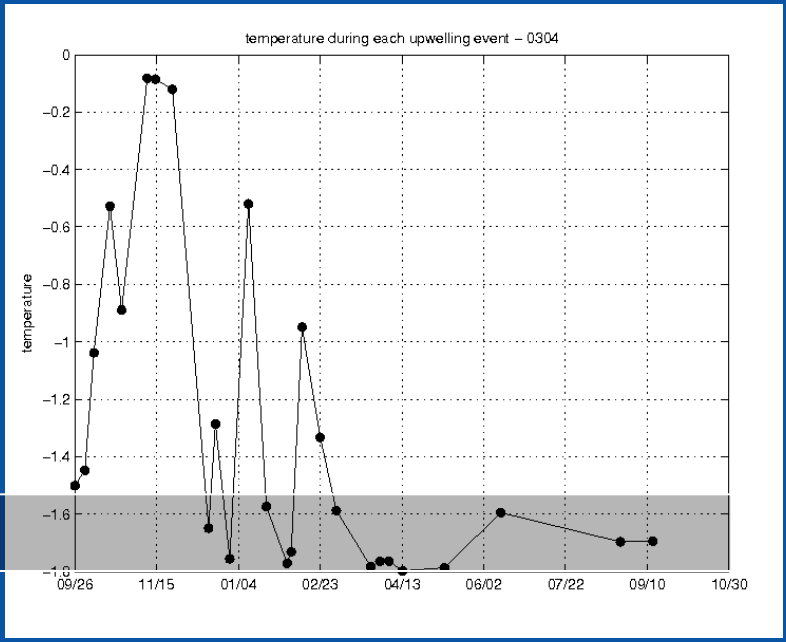
Temperature of water upwelled into Barrow Canyon



Winter Water

2002-3

31 winter water events over two years

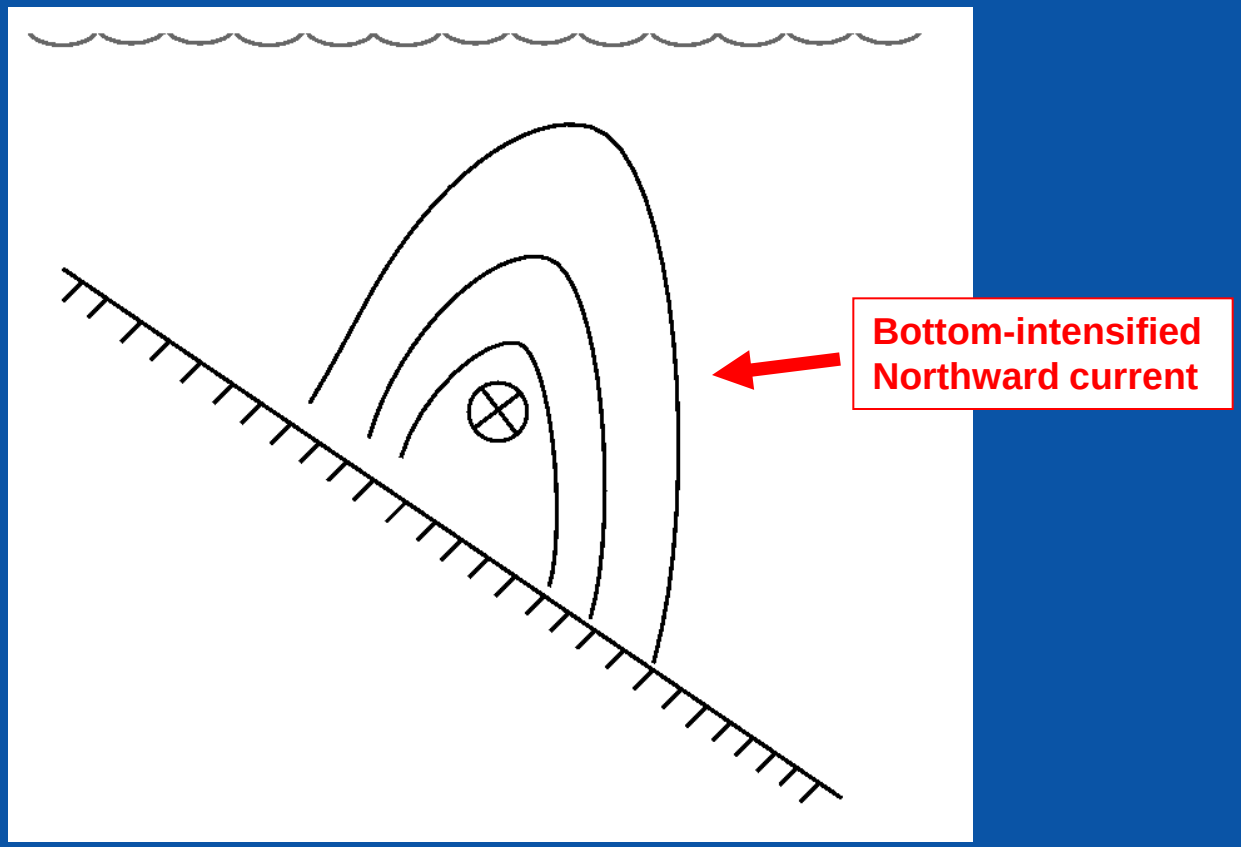


Winter Water

2003-4

4. In the absence of storms, the dynamics of the down-canyon flow pumps winter water upward

Schematic of current flowing through Barrow Canyon



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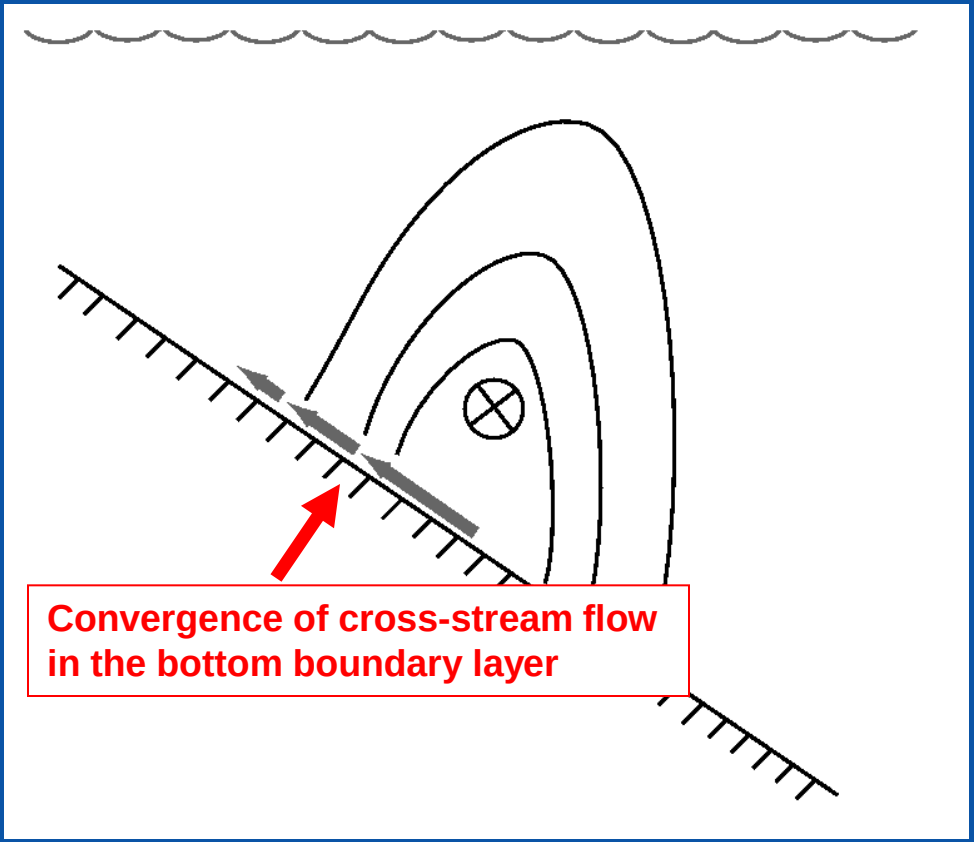
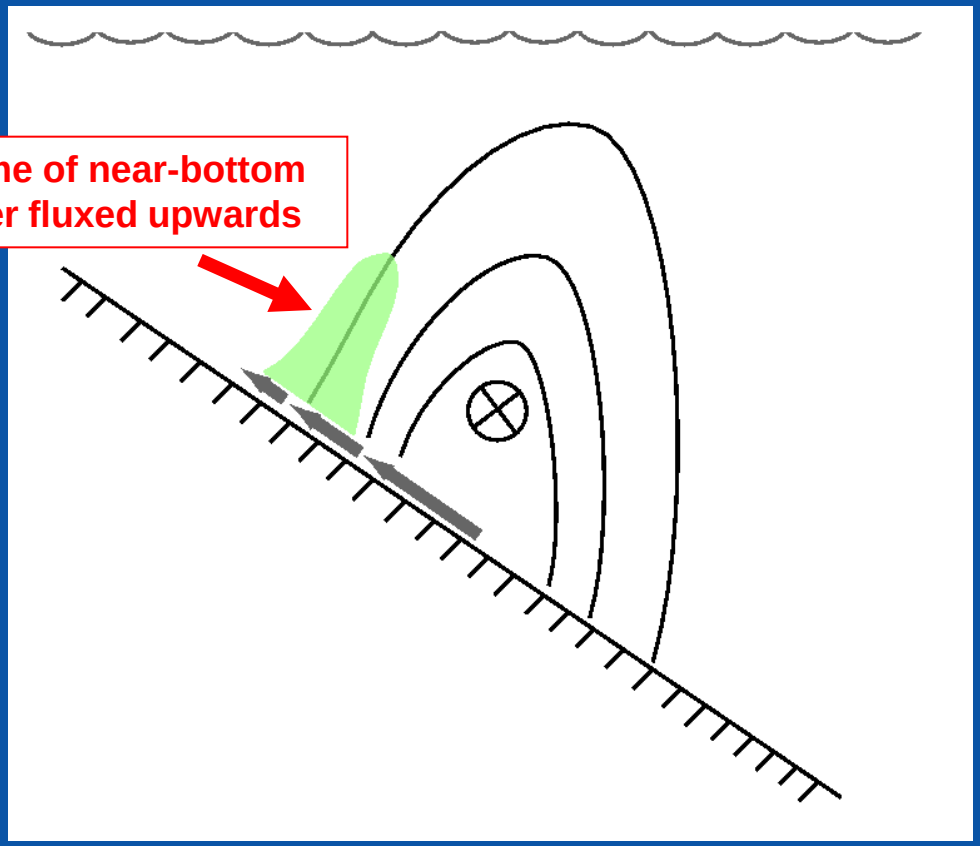
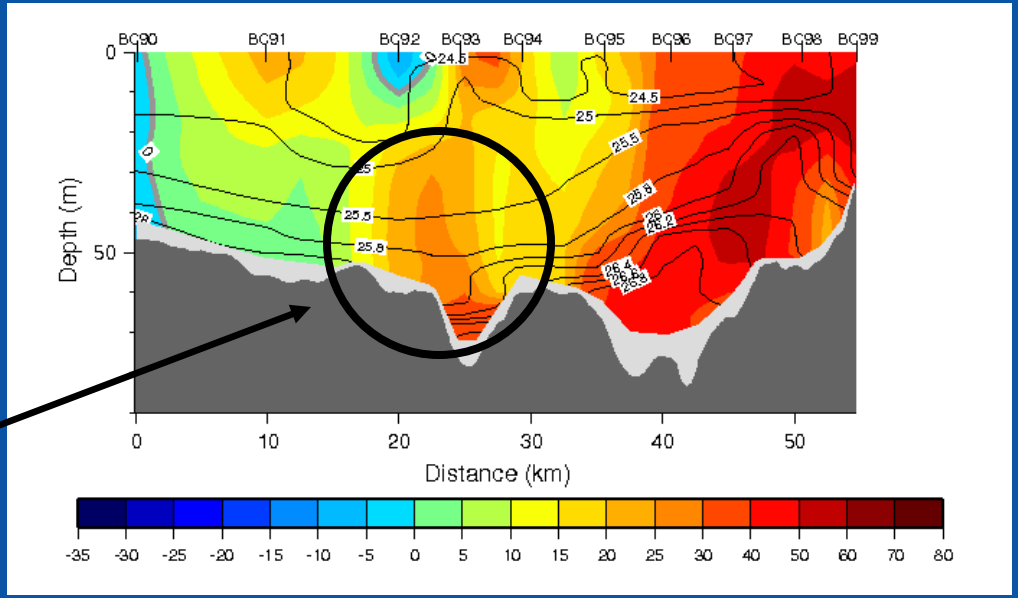


Schematic of current flowing through Barrow Canyon



Absolute Geostrophic Velocity (cm/s)

Section across the head of Barrow Canyon in 2010

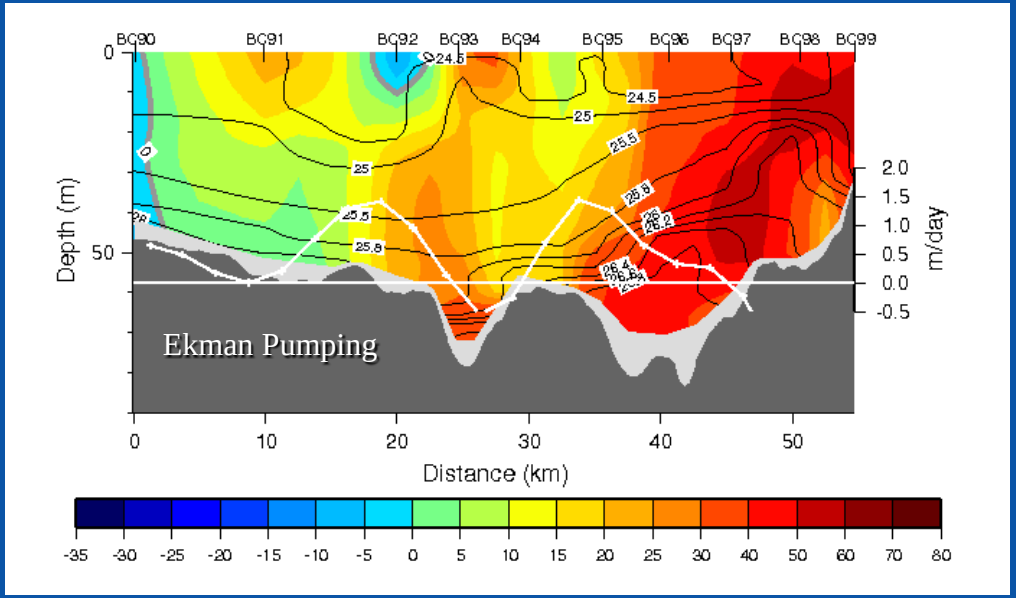


bottom-intensified northward current

Looking northward

Absolute Geostrophic Velocity (cm/s)

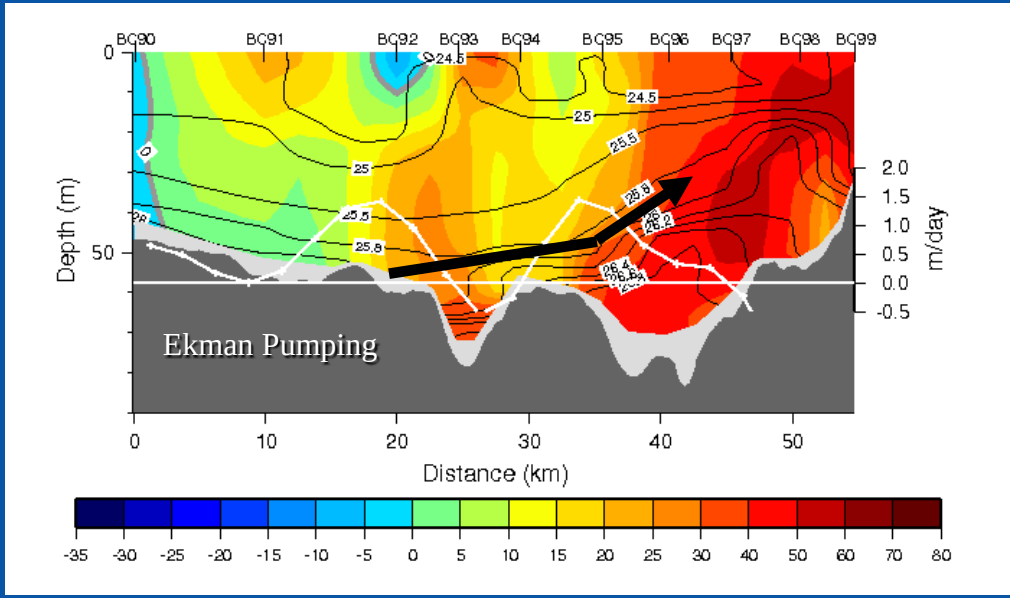
Section across the head of Barrow Canyon in 2010



Computed Ekman Pumping

Section across the head of Barrow Canyon in 2010

Absolute Geostrophic Velocity (cm/s)

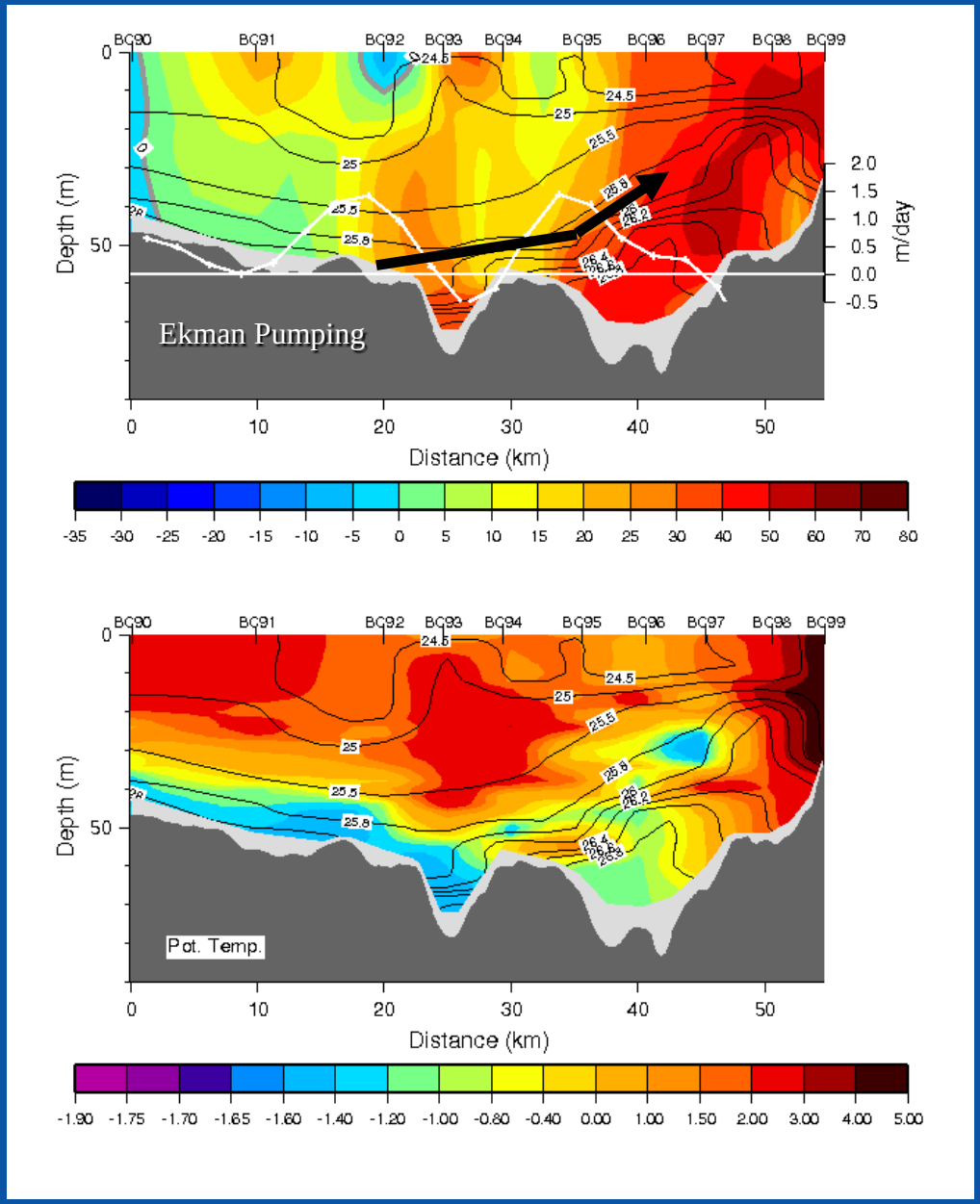


Computed Ekman Pumping

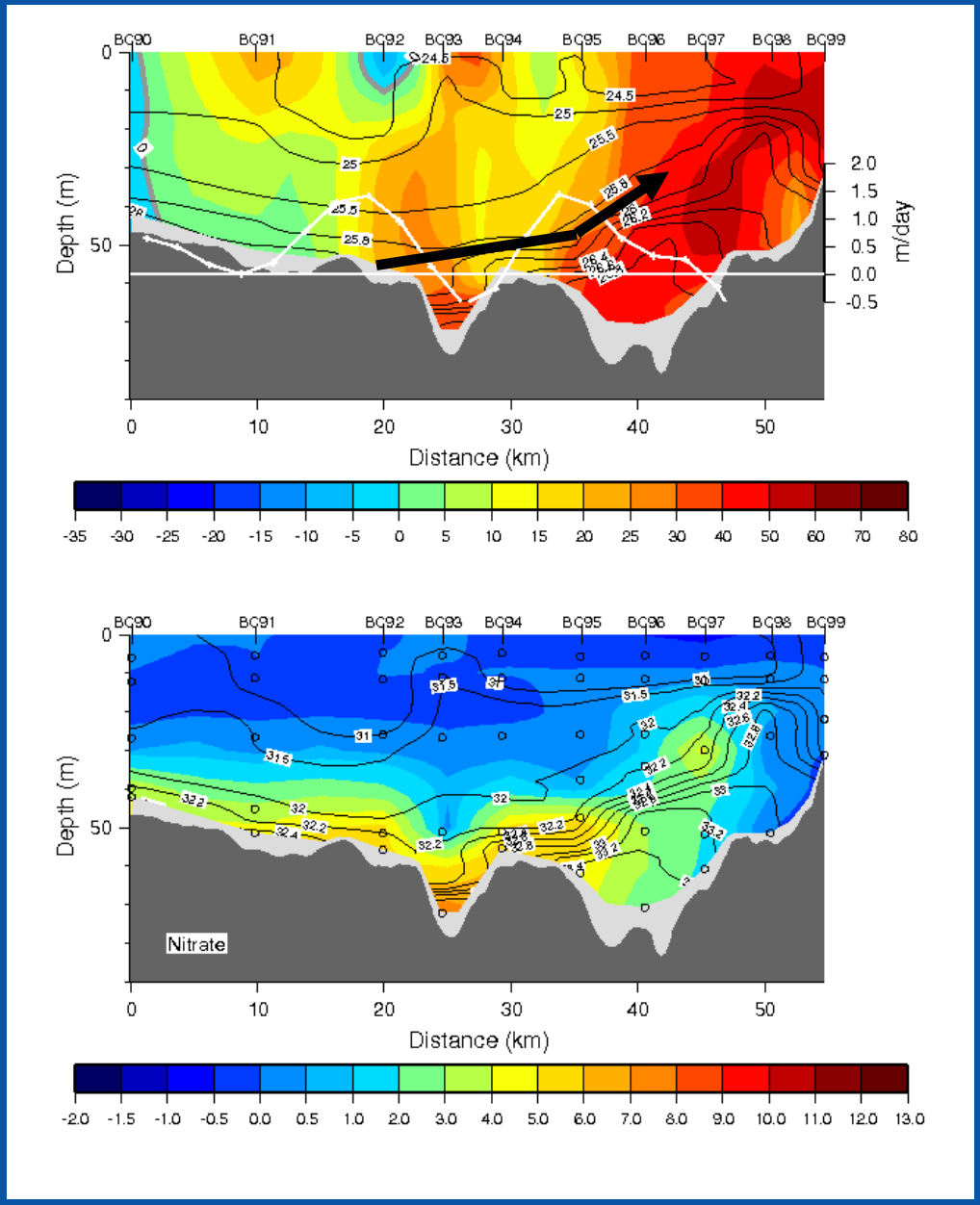
Pumping should occur along density surfaces

Section across the head of Barrow Canyon in 2010

potential temperature

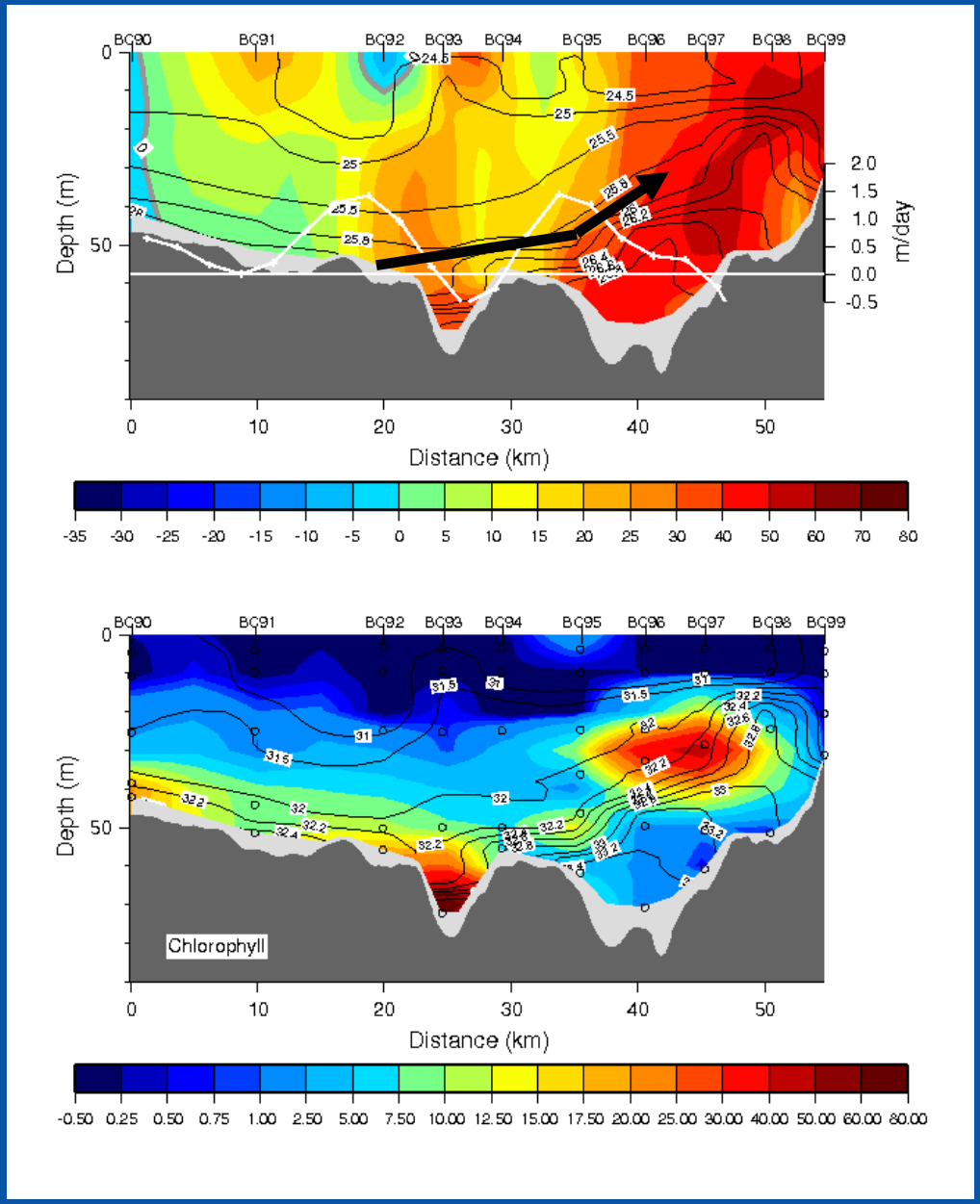


Section across the head of Barrow Canyon in 2010



nitrate

Section across the head of Barrow Canyon in 2010



chlorophyll

Conclusions

1. Barrow Canyon is characterized by enhanced trophic productivity.

2. A longer open water season means more sunlight penetrates the water column.

3. A variety of physical mechanisms transport high-nutrient winter water into the euphotic zone.