Physical Oceanography of Submarine Canyons: Research at UBC

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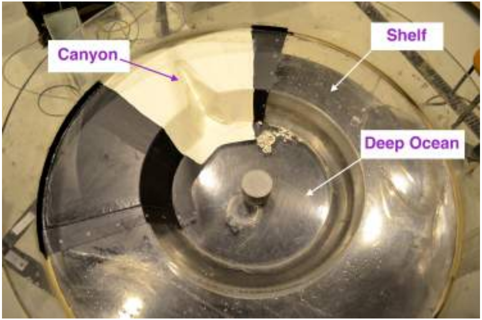
Research methods

- Physical models
- Numerical models
- Collaboration with observationalists



Submarine canyons

- Regions of enhanced upwelling
- Key for cross-shelf break exchange, including nutrient flux onto the shelf

Image from http://creagrus.home.montereybay.com/MtyBay.html

Shelf-break restriction on flow

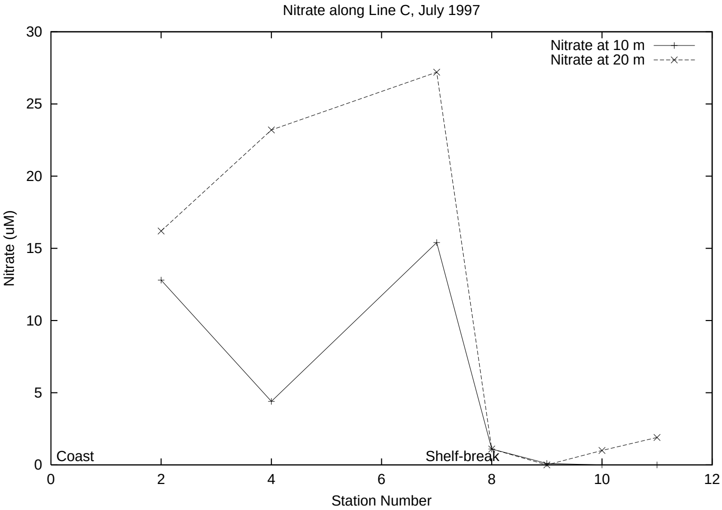
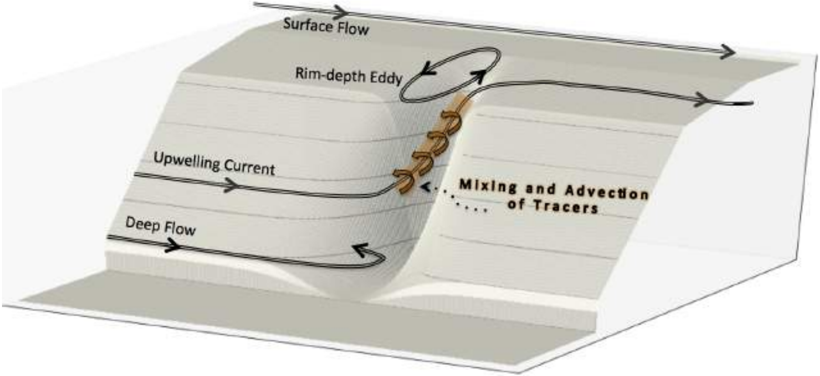


Image modified from *Allen (2004)*.

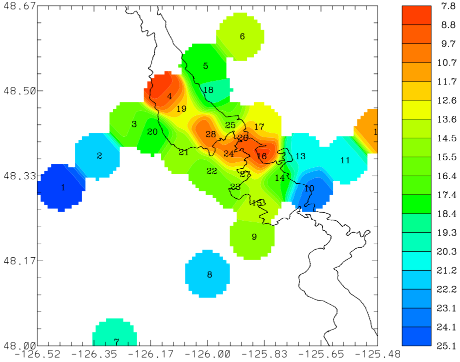
Basic flow circulation in a canyon



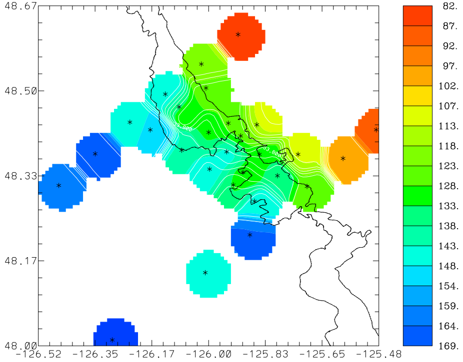
Advection driven phase of upwelling in a short canyon.

Image modified from *Allen and Hickey (2010)*.

Circulation around Barkley Canyon



24 sigma-T depth (m)



26 sigma-T depth (m)

from *Allen et al. (2001)*.

Upwelling quantification

Scaling scheme by Allen and Hickey (2010) in terms of stratification N, canyon geometric parameters (L, W_{sb}), incoming flow velocity U, Coriolis parameter f and a canyon Rossby number $\mathcal{R}$.

Depth of upwelling

$$Z(U, N, L, \mathcal{R})$$

Upwelling flux

$$\Phi(U, W_{sb}, L, N, f, \mathcal{R})$$

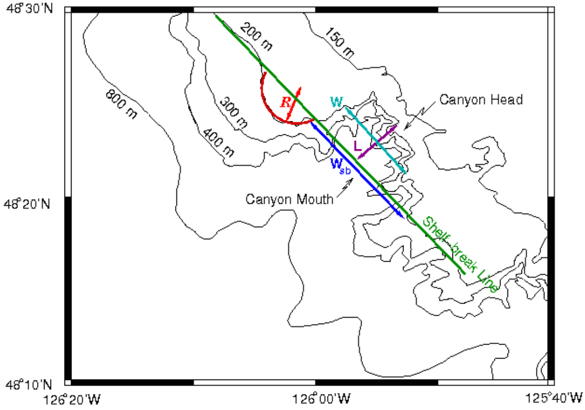


Figure from *Allen and Hickey (2010)*.

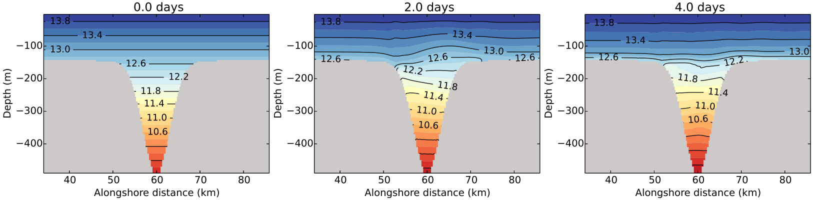
Mixing and stirring

- Enhanced mixing due to breaking internal tides and internal waves (Hickey, 1995).
- Observations: Diapycnal diffusivity κ_D is very high (about two orders of magnitude) compared to levels outside.
  E.g.:

Monterey Canyon	$\kappa_d \approx 2.5 \times 10^{-2} m^2 s^{-1}$	Carter and Gregg (2002)
Ascension Canyon	$\kappa_d \approx 3.9 \times 10^{-3} m^2 s{-1}$	Gregg et al. (2011)
Gaoping Canyon	$\kappa_d \approx 10^{-2} m^2 s^{-1}$	Lee et al. (2009)

- Patterns of diapycnal diffusivity are highly variable in time and space = geography of mixing.

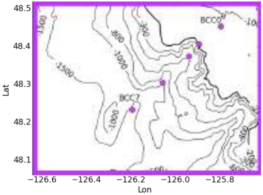
- Stirring inside the canyon along isopycnal surfaces that tilt considerably during upwelling.

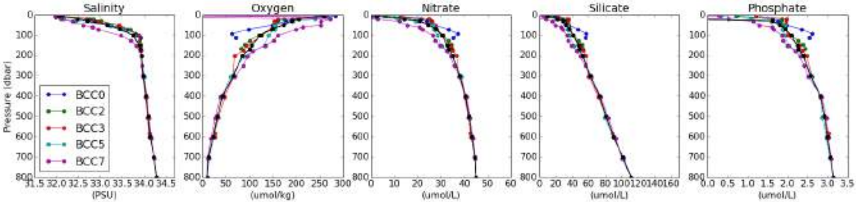


- To go from estimates of water transport to tracer flux onto the shelf consider mixing + stirring of tracers.

Barkley Canyon Nutrient Profiles

Collected during Pathways Cruise 2013 (R/V Falkor)





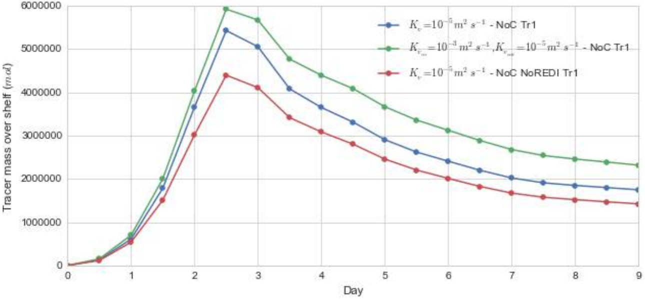
linear exponential logarithmic sqrt+linear potential

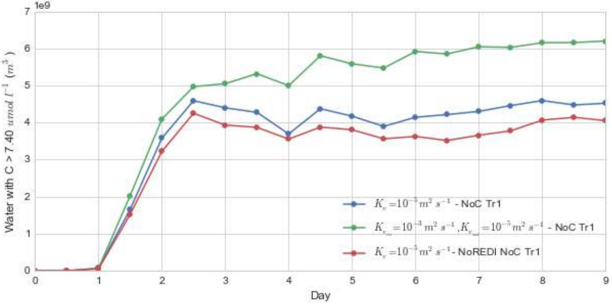
Tracer scaling

Numbers for Barkley canyon suggest that

- Vertical advection and diapycnal diffusivity are both relevant for the distribution of tracers.
- Horizontal advection dominates over isopycnal diffusivity ($Pe_h >> 1$).
- Diapycnal diffusion acts faster than isopycnal diffusion.
- Second derivatives may be important, especially for nitrate and oxygen.

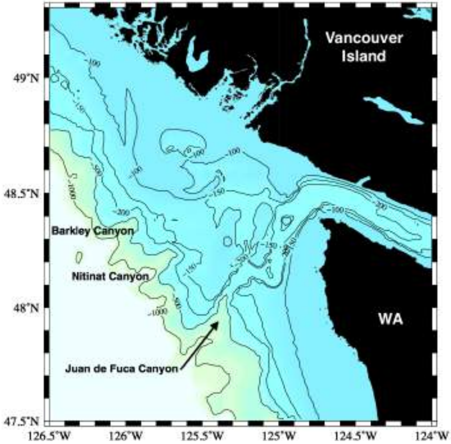
Sensitivity studies





Long term goal

Quantify the enhanced flux of tracers (such as nitrate, oxygen-deficit, dissolved inorganic carbon) onto the continental shelf due to small topography such as submarine canyons.



Thank you!

Photo credit: Ocean Networks Canada (www.oceannetworks.ca)

*Characteristic values used to estimate non-dimentional numbers

Number	Value	
L	6.40×10^{3} m	Allen and Hickey (2010)
W_{sb}	1.30×10^{4} m	
D_h	138 m	
U^*	6.60×10^{-2} ms^{-1}	
N	$5 \times 10^{-3} s^{-1}$	
Ω	2.23×10^{-4} ms^{-1}	
Z	2.17×10^{1} m	Calculated from data
κ_I	2 m^{2}s^{-1}	Ledwell et al. (1998)
κ_D	3.90×10^{-3} m^{2}s^{-1}	Gregg et al. (2011)

According to Buckingham-π theorem:

10 parameters - 4 dimensions = 6 non-dimensional groups

Group	Symbol	Definition	Description
π_1	Pe_h	$\frac{LU^*}{\kappa_I}$	Horizontal Peclet number
π_2	Pe_v	$\frac{Z\Omega}{\kappa_D}$	Vertical Peclet number
π_3	K	$\frac{Z^2}{L^2}\frac{\kappa_I}{\kappa_D}$	Diffusivity ratio
π_4	Γ	$\frac{Z}{L}\frac{\delta_v C}{\delta_h C}$	Gradient ratio
π_5		$-\frac{Z\delta_v^2 C}{\delta_v C}$	Vertical curvature to gradient ratio
π_6		$\frac{L\delta_h^2 C}{\Gamma \delta_h C}$	Horizontal curvature to gradient ratio

Sensitivity studies