Glider observations of downwelling processes and zooplankton distributions in Clayoquot Canyon

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Motivation

To understand the mesoscale mechanisms in a downwelling regime around a submarine canyon that influence zooplankton distribution, which in turn helps describe biological habitats in offshore waters.
West Coast of Vancouver Island: Biological Habitat

Observations suggest canyons are biological habitat (e.g. for whales)

Submarine canyons enhance upwelling and downwelling and could aggregate zooplankton

State of the Oceans, 2015
Canyon Dynamics and Zooplankton Aggregations

Upwelling/downwelling creates vertical flows that zooplankton swim against to maintain ideal light levels
Canyon Dynamics and Zooplankton Aggregations

Canyon eddies can retain zooplankton
Glider Campaign: Clayoquot Canyon

January 30 – February 18 2017, 9 Canyon Transects
Glider Advantages

1. Obtain high time and space resolution data over extended periods of time
2. Collect observations during adverse weather conditions, including stormy downwelling seasons
3. Equipped with a range of specialized sensors

Glider drawing credit: Robin Matthews
Glider Sensor Instrumentation

- Hydrophone
- CTD
- Echosounder 300 kHz
Zooplankton around Clayoquot Canyon

![Diagram showing zooplankton distribution around Canyon Head and the pycnocline.](image)
Zooplankton around Clayoquot Canyon

[Map showing locations and pycnocline]

Integrated $S_v$ Above Pycnocline [dB]

Pycnocline

Canyon Head
What physical processes influence the distribution of zooplankton in Clayoquot Canyon?
Northwest Current

Depth averaged velocities show northwest current

— precondition for downwelling
Canyon Downwelling Hypothesis

Strong northward currents over the canyon suggest downwelling may occur.
Canyon Downwelling Hypothesis

Strong northward currents over the canyon suggest downwelling may occur:

- Deeper pycnocline over canyon
Pycnocline Definition

Density difference from a near-surface value

\[ z_{pyc} = z(\rho - \rho_{25m} = 0.4 \, \text{kg/m}^3) \]
Deeper pycnocline found within canyon
Deeper pycnocline found within canyon
Deeper pycnocline found within canyon

... even later on, though less prominent
Pycnocline tends to be deeper near canyon head
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– Clearly seen before Feb 9 2017
Pycnocline Depth: Temporal Distribution
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Pycnocline deepens for first half of mission
Pycnocline Depth: Temporal Distribution

Pycnocline deepens for first half of mission

Storm passes through which coincides with a shoaling the pycnocline
Pycnocline Depth: Temporal Distribution

Pycnocline deepens for first half of mission

Storm passes through which coincides with a shoaling the pycnocline

Second storm has little influence on pycnocline depth
Convolution of Space and Time

Wind at Estevan

Glider 1

Glider 2

Glider 3

Pycnocline Depth [m]

Distance from Canyon Head [km]
Some Open Questions

Given the slow moving nature of gliders, it can be difficult to separate spatial and temporal features within the data.
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– Are canyon dynamics the only process influencing the pycnocline depth?
Suggestions That Canyons are Important

Pycnocline tends to be deeper near canyon head
Canyons Dynamics May Not be the Only Important Process

It appears that there is a strong temporal signal in the pycnocline depth

- Steady deepening despite multiple transects of shelf break
- Sometimes transient storms appear to be important
Some Open Questions

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– Are canyon dynamics the only process influencing the pycnocline depth?

– Are other temporal processes also at play?
Potential Temporal Processes

In addition to canyon-driven downwelling, additional processes at play may be
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1. Temporal variability in wind-driven coastal downwelling
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2. Transient storm dynamics
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3. Eddy feature
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1. Temporal variability in wind-driven coastal downwelling
2. Transient storm dynamics
3. Eddy feature
4. Coastal trapped wave
Implications for Zooplankton Distribution

Is zooplankton backscatter also correlated with pycnocline depth and proximity to the canyon?
Zooplankton Distribution: Above Pycnocline

Integrated zooplankton $S_v$ larger at deeper pycnocline depths and closer to the canyon head.

![Graphs showing correlation between zooplankton depth integrated $S_v$ and pycnocline depth, and distance to canyon head. $R^2 = 0.44$ for pycnocline depth, $R^2 = 0.35$ for distance to canyon head.]
Summary

Understanding zooplankton distributions requires accounting for mechanisms that give rise to **spatial** and **temporal** variability.

It can be difficult to untangle **spatial** and **temporal** information and processes from glider data, but we see evidence that both are occurring:

- **Spatial Canyon Dynamics**: deeper pycnocline found near canyon head

- **Temporal Dynamics**: steady deepening of pycnocline over time, storms disrupt pycnocline depth features
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