IMPACT OF CANYON DYNAMICS ON THE SPRING PHYTOPLANKTON BLOOM (PALMER DEEP CANYON, WEST ANTARCTIC PENINSULA)

Filipa Carvalho, Oscar Schofield, Nicole Couto, Josh Kohut

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Mean winter temperature is increasing in the West Antarctic Peninsula (WAP).

Temperature trends (°C/year)

Palmer Station

NASA/Goddard Space Flight Center Scientific Visualization Studio. Data provided by Larry Stock.
**ICE SEASON DURATION IS DECREASING IN THE WEST ANTARCTIC PENINSULA (WAP)**

Temperature trends (°C/year)

Slope = 1.15°C/decade

86-day shorter Ice season

Data Source: Palmer Station Weather
- 87% of glaciers are in retreat
- Increase in the ocean heat content

UCDW: Upper Circumpolar Deep Water

ACC: Antarctic Circumpolar Current
WAP: West Antarctic Peninsula
**WAP Canyons: “Biological Hotspots”**

- “Biological Hotspots” along the Peninsula associated with **deep undersea canyons**.

  - Palmer Deep Canyon (near Anvers Island)
  - Margarite Trough (near Avian Island)
  - Newly discovered canyon (near Charcot Island)

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*Eveleth et al., In Prep.*
WAP CANYONS: “BIOLOGICAL HOTSPOTS”

- Penguin Colonies at costal termini of cross-shelf canyons/troughs
- Predictable/elevated food availability;
- Phytoplankton growth in canyon heads;

Eveleth et al., In Prep.
WAP Canyons: “Biological Hotspots”

- Penguin Colonies at coastal termini of cross-shelf canyons/troughs
- Predictable/elevated food availability;
- Phytoplankton growth in canyon heads;

But what is actually driving this increased productivity?

Eveleth et al., In Prep.
**Bloom Initiation Hypotheses:**

- **H1:** The main control of the bloom initiation is the upwelling of nutrients from the Upper Circumpolar Deep Water (UCDW);
- **H2:** The main control of the bloom initiation is the shoaling of the mixed layer depth, increasing, this way, the light availability to the phytoplankton community.
TESTING THE CANYON HYPOTHESIS

– Physical forcing of the bloom
  • Mix Layer Depth
  • Water stability and stratification
  • Canyon Circulation

– Physiological Responses (FIRE glider)
  • Mainly photosynthetic efficiency
PHYSICAL FORCING OF THE BLOOM – WHAT TO LOOK AT?

• 18 Slocum Glider Deployments
  – Over 16 000 water column profiles

• Sensors:
  – CTD (Temperature, Salinity, Depth)
  – Fluorescence
  – FIRe & PAR
  – Backscatter
  – Oxygen
Palmerton Deep Canyon Bathymetry
PALMER DEEP CANYON BATHYMETRY

Maximum depth ~ 1400 m
PALMER DEEP CANYON BATHYMETRY

Palmer Station
18 GLIDER DEPLOYMENTS: GOOD COVERAGE IN HEAD OF CANYON

Palmer Station
GLIDER ANALYSIS – RU05-276 (WARM WATER SHOALING)
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GLIDER ANALYSIS – Ru05-276
(WARM WATER SHOALING)
**IMPORTANT VARIABLES**

- **Tmin** – Temperature minima in each profile
- **Depth Tmin** – Depth of Tmin
- **ΔSigma-Theta\textsubscript{Tmin-0}**

\[
\Delta \text{Sigma} - \text{Theta}_{T_{\text{min}-0}} = \frac{\text{Sigma Theta}_{T_{\text{min}}} - \text{Sigma Theta}_{\text{surface}}}{\text{Depth}_{T_{\text{min}}} - \text{Depth}_{\text{surface}}}
\]

High Δ Sigma-Theta\textsubscript{Tmin-0}:
- Winter Water (Tmin) is shallow
- Increased Stratification (density differences are big)

Saba et al, 2014
TMIN – WINTER WATER (TEMP < -1°C) PRESENT IN THE DEEPER CHANNEL

Palmer Station
Using Gliders to Map the Phytoplankton Dynamics

Pros:
- High Resolution profiles of the water column
- Long deployments – high number of profiles

Cons:
- Spatial and temporal resolution: no time series, no spatial map at one timepoint …
Binining Data Using Bathymetry
Binning Data Using Bathymetry
Binning data using Bathymetry Good Coverage at Head of Canyon

Palmer Deep Gliders + FIRE Glider
BINNING DATA USING BATHYMETRY
GOOD COVERAGE AT HEAD OF CANYON

Palmer Deep Gliders + FIRe Glider

(NEAR-SHORE REGION)
Annual & Seasonal Variability in Tmin
Tmin increases throughout season

Season 2011-2012
Season 2013-2014

2013-2014 Season: no change in Tmin – Possibly due to late ice retreat?
ANNUAL & SEASONAL VARIABILITY IN TMIN
TMIN INCREASES THROUGHOUT SEASON

2013-2014 Season: no change in Tmin – Possibly due to late ice retreat?
**Annual & Seasonal Variability in Tmin**

Tmin peaks colder on Slope < Deep < Shallow regions

2013-2014 Season:
- colder in all regions
- Winter water (T<-1°C) present on the slope
ANNUAL & SEASONAL VARIABILITY IN DEPTH Tmin DECREASES THROUGHOUT SEASON

Season 2011-2012

Season 2013-2014

2013-2014 Season: smaller decrease in depth in Tmin – Possibly due to late ice retreat?
ANNUAL & SEASONAL VARIABILITY IN Tmin
TMIN SHALLOWER ON THE SLOPE

Depth Tmin peaks deeper on Deep < Shallow < Slope regions

2013-2014 Season:
- Peaks ~ -50m (all regions)
- Winter water (T<-1°C) deeper on the slope
Moving Forward with the Physical Data Analysis

- MLD (different definitions)
  - Buoyancy Frequency ($N^2$), $\Delta$ Sigma-theta$_{T_{\text{min-0}}}$

- Compare to the inter-annual variability (related to sea ice and wind)

- Annual/seasonal anomalies.

- Physical-Biological connections:
  - Maps of chlorophyll distribution
  - Changes within the timescale of a bloom (pre-bloom, bloom and post-bloom conditions).
(FIRe=FLUORESCENCE INDUCTION AND RELAXATION SYSTEM)
18 GLIDER DEPLOYMENTS DURING LTER

Palmer Deep Giders + FIRe Glider
FIRE GLIDER DATA CORRECTION - FM

- Fm - proxy for phytoplankton biomass (relative units)
- Need in situ water collection and chl measurements through fluorometric method
DAYTIME AFFECTS PHOTOSYNTHETIC EFFICIENCY (NON-PHOTOCHEMICAL QUENCHING)

Biomass Proxy (Fm)

Quantum Yield of Photosynthesis (Fv/Fm)
**FIRE in an Upwelling Event:**

**Light is the Main Driver of the Bloom**

Photosynthetic Efficiency ($F_v/F_m$) fairly constant & high

Points = observations (no interpolations)
FIRE in an Upwelling Event: Light is the Main Driver of the Bloom

Fv/Fm inversely mirrors PAR data

Points=observations (no interpolations)
FIRE in an Upwelling Event: Light is the Main Driver of the Bloom

Fm decreases – Due to mixing? Deepening of the MLD?

Points=observations (no interpolations)
MOVING FORWARD WITH THE FIRE GLIDER ANALYSIS

Look at:

- Absorption cross-section ($\sigma_{PSII}$)
- Differences between regions/bathymetry
- Correlations with mixed-layer depth (MLD)
CONCLUSIONS

• Annual presence – study overall trends and unique events

• Light (shoaling of the mixed layer) as the main driver of the bloom;

• Full sunlight promotes an inhibition process on the cells;

• Nutrients still important when surface waters are nutrient limited.