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Institute of Marine and Coastal Sciences
Coastal Ocean Observation Lab

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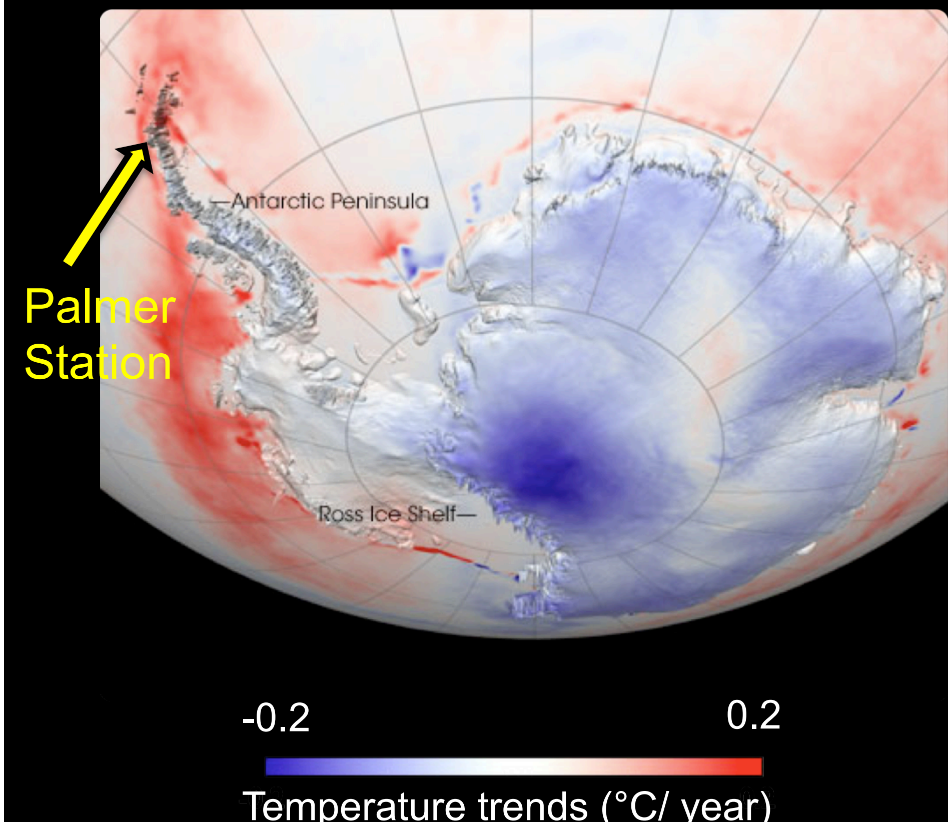
IMPACT OF CANYON DYNAMICS ON THE SPRING PHYTOPLANKTON BLOOM

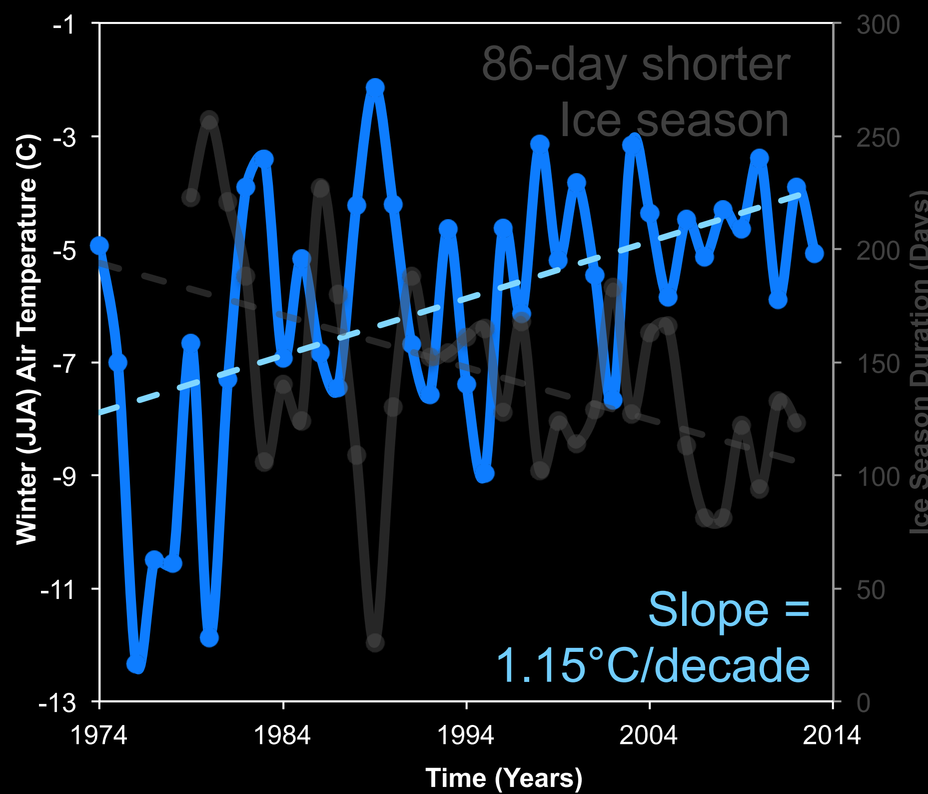
(PALMER DEEP CANYON, WEST ANTARCTIC PENINSULA)

Filipa Carvalho, Oscar Schofield,
Nicole Couto, Josh Kohut

Graduate Student Talks, October 21st, 2014

Mean Winter Temperature is Increasing in the West Antarctic Peninsula (WAP)

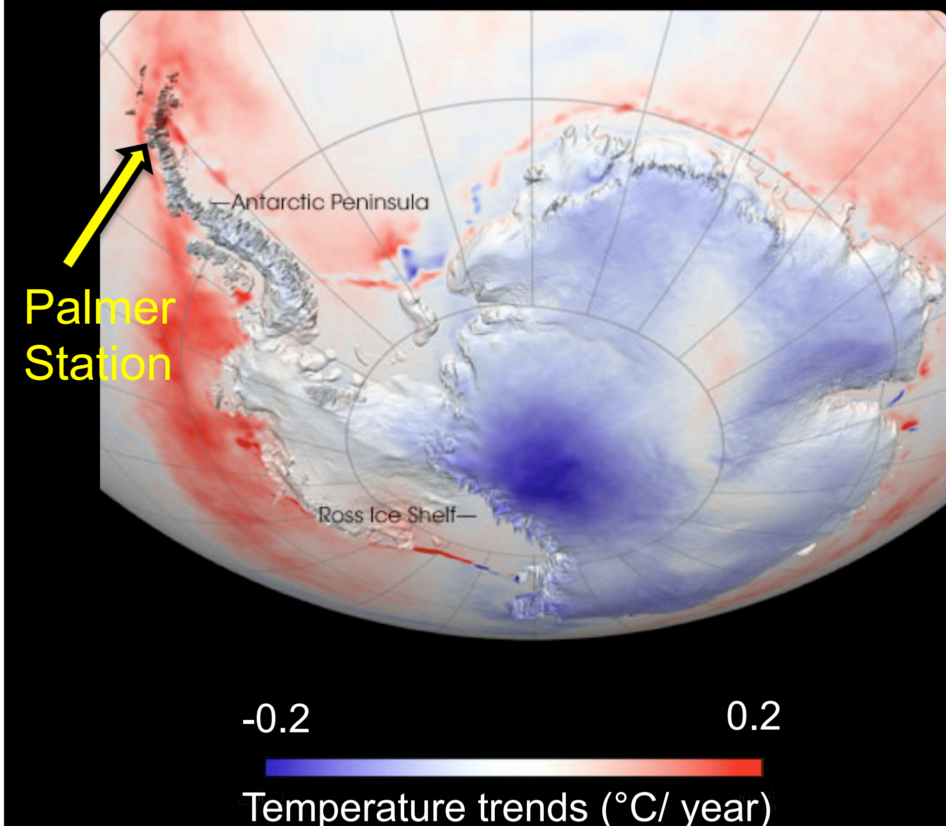


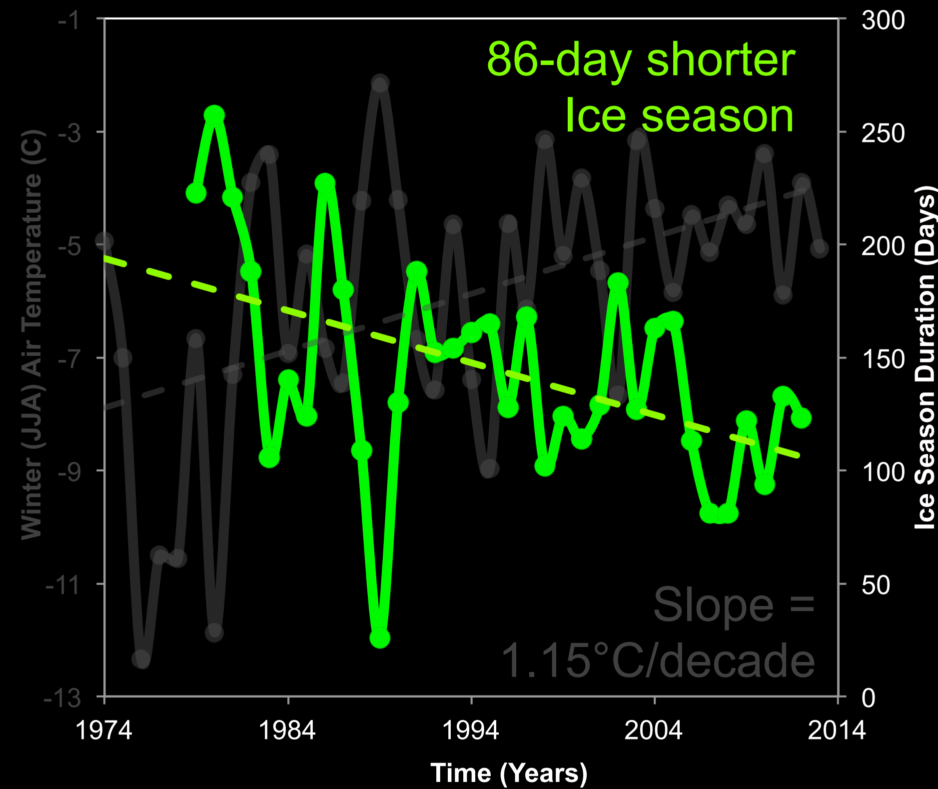


NASA/Goddard Space Flight Center Scientific Visualization Studio. Data provided by Larry Stock

Data Source: Palmer Station Weather

Ice Season Duration is Decreasing in the West Antarctic Peninsula (WAP)

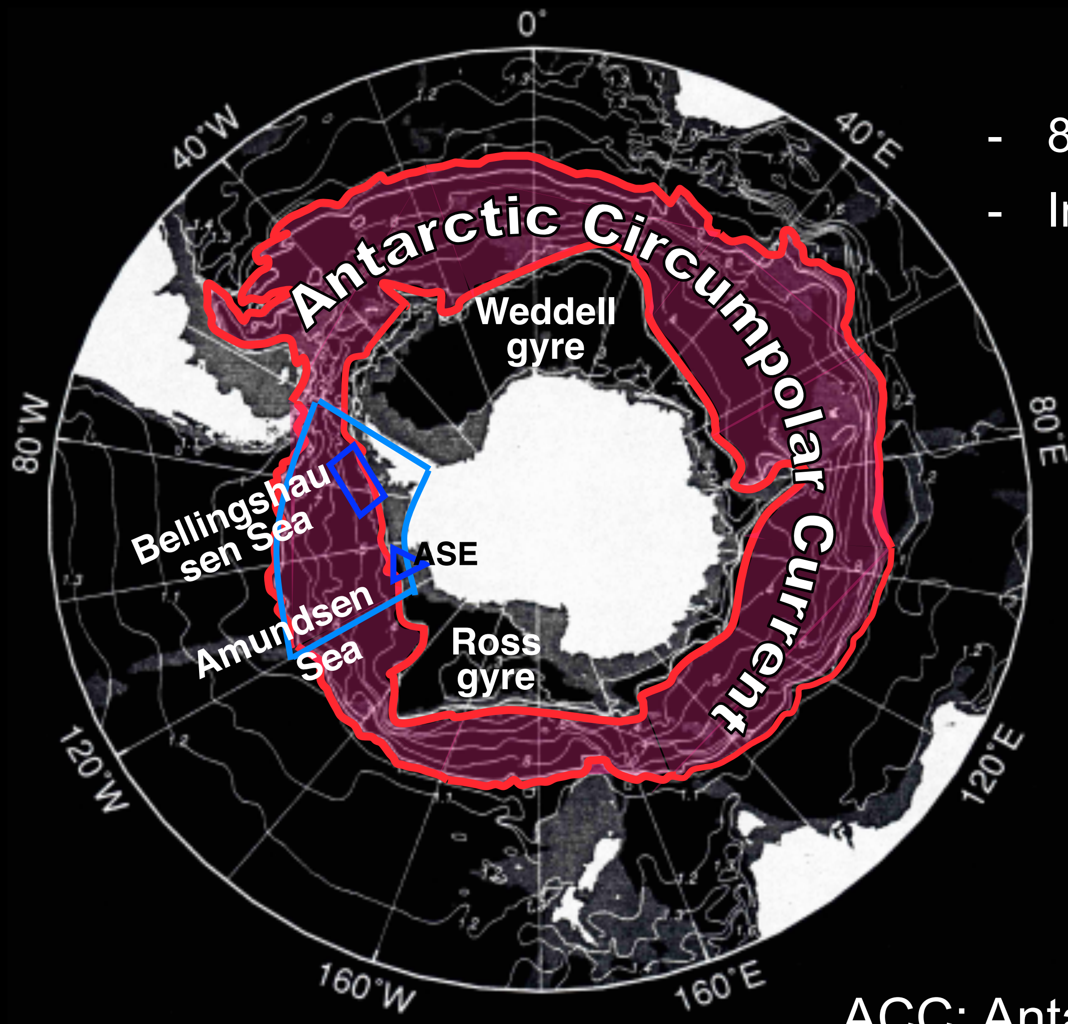




NASA/Goddard Space Flight Center Scientific Visualization Studio. Data provided by Larry Stock

Data Source: Palmer Station Weather

UCDW Intrusion onto the Shelf
Warming of Shelf Water



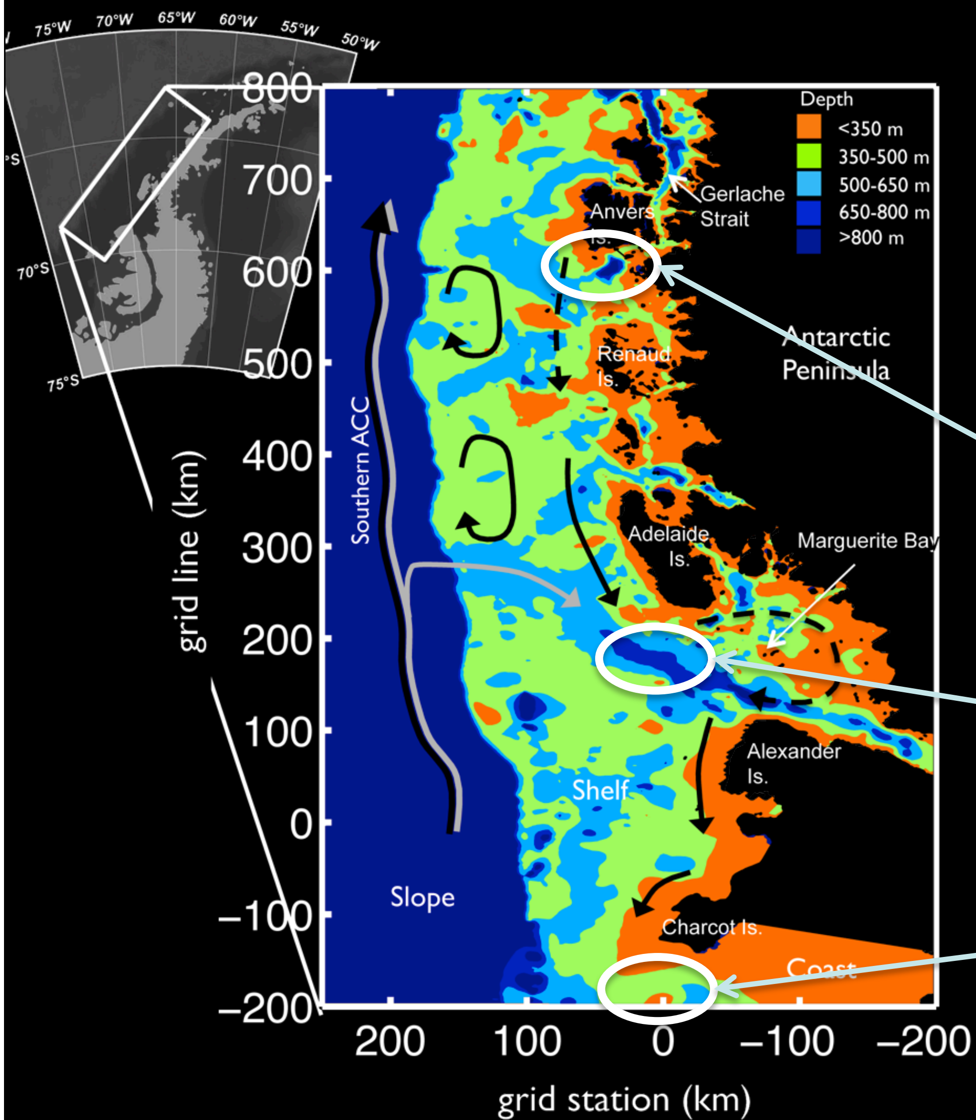
- 87% of glaciers are in retreat
- Increase in the ocean heat content

UCDW: Upper Circumpolar Deep Water

ACC based on climatological dynamic topography of *Orsi et al.*, DSR, 1995

ACC: Antarctic Circumpolar Current
WAP: West Antarctic Peninsula

WAP Canyons: *"Biological Hotspots"*



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

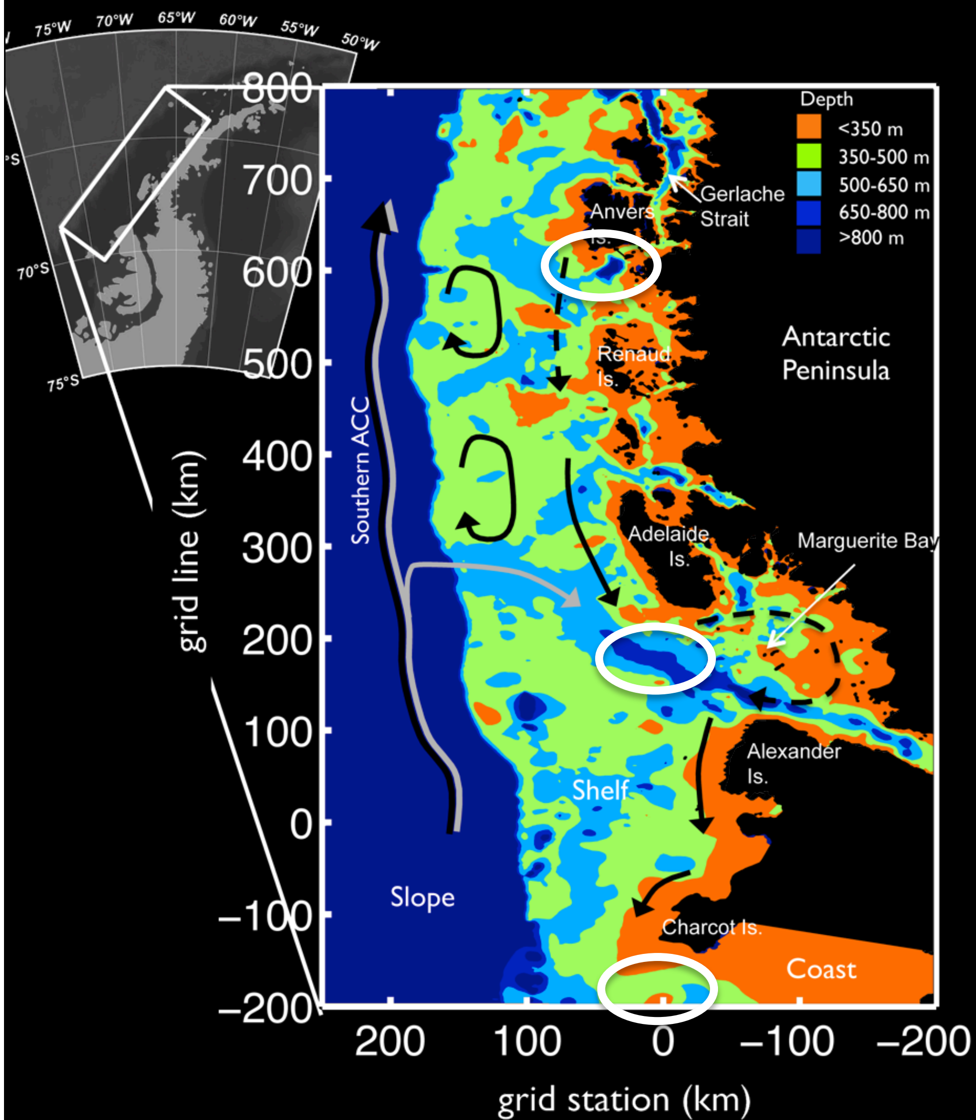
Palmer Deep Canyon (near Anvers Island)

Margarite Trough (near Avian Island)

newly discovered canyon (near Charcot Island)

Eveleth et al., In Prep.

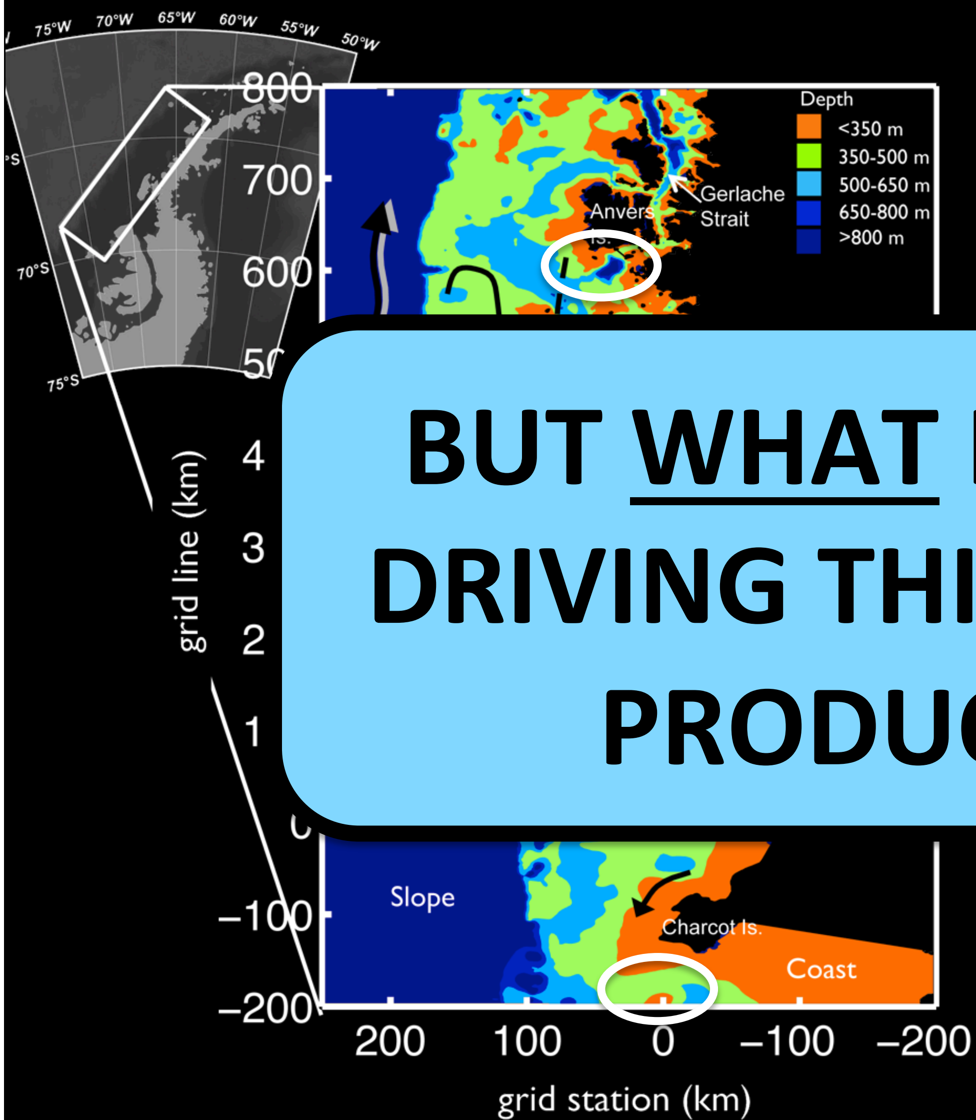
WAP Canyons: *"Biological Hotspots"*



- 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 costal ... shelf
- ... food
- ... th in canyon heads;

BUT WHAT IS ACTUALLY DRIVING THIS INCREASED PRODUCTIVITY?

Eveleth et al., In Prep.

Bloom Initiation Hypotheses:

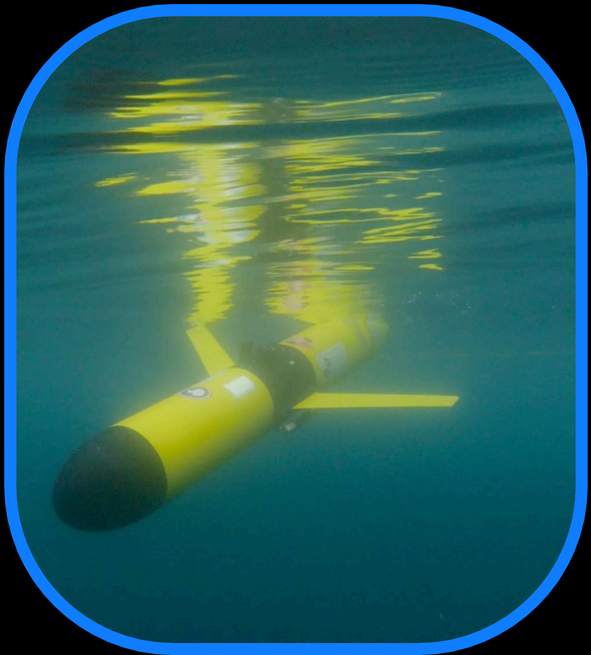
- H1: The main control of the bloom initiation is the upwelling of nutrients from the Upper Circumpolar Deep Water (UCDW);

- 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

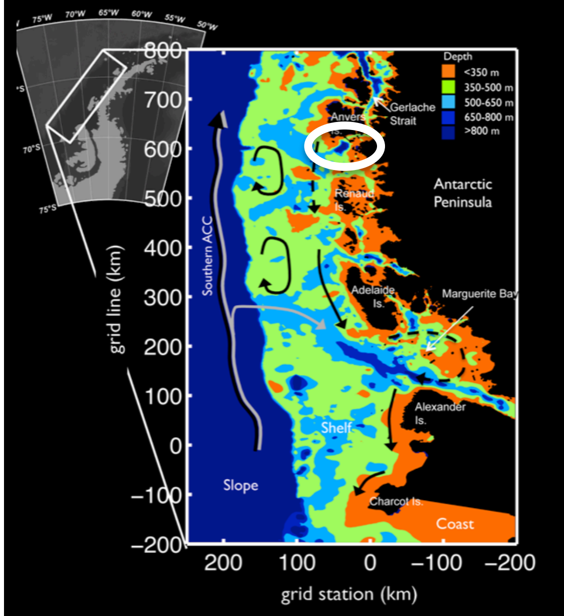
- Physical forcing of the bloom
  - Mix Layer Depth
  - Water stability and stratification
  - Canyon Circulation
- Physiological Responses (FIRe glider)
  - Mainly photosynthetic efficiency

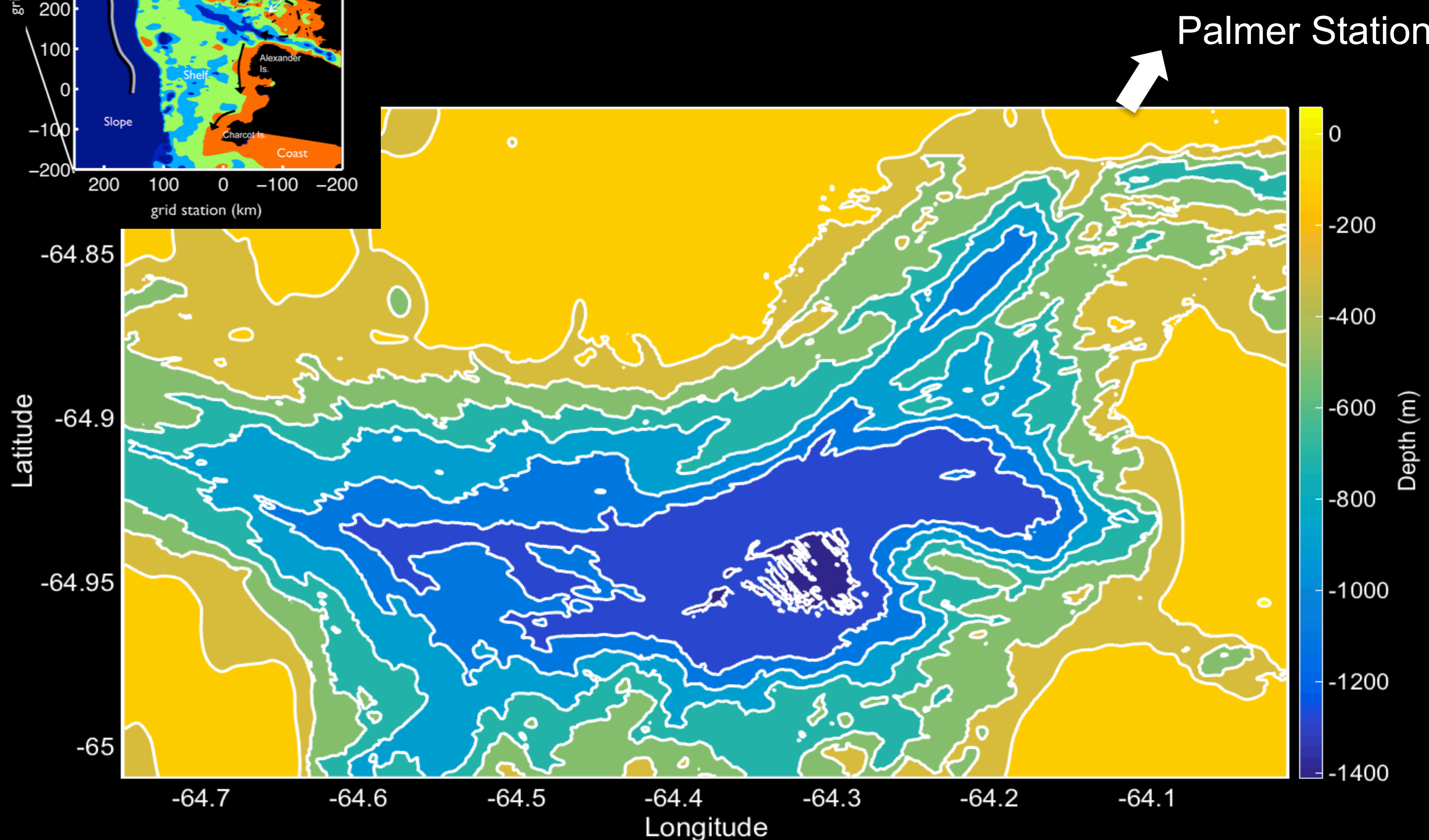
Physical forcing of the Bloom – What to Look at?



- 18 Slocum Glider Deployments
  - Over 16 000 water column profiles
- Sensors:
  - CTD (Temperature, Salinity, Depth)
  - Fluorescence
  - FIRe & PAR
  - Backscatter
  - Oxygen

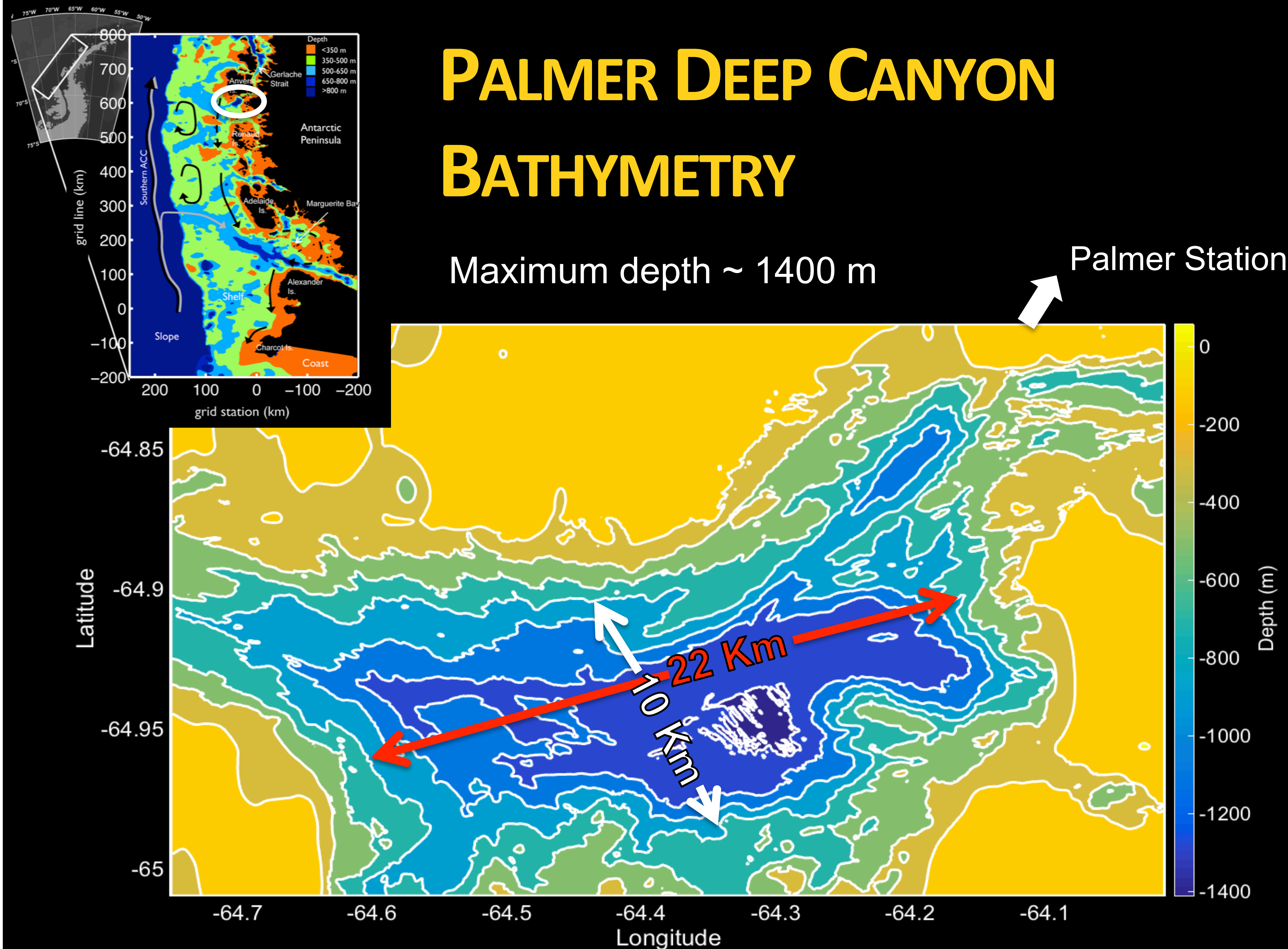
PALMER DEEP CANYON BATHYMETRY



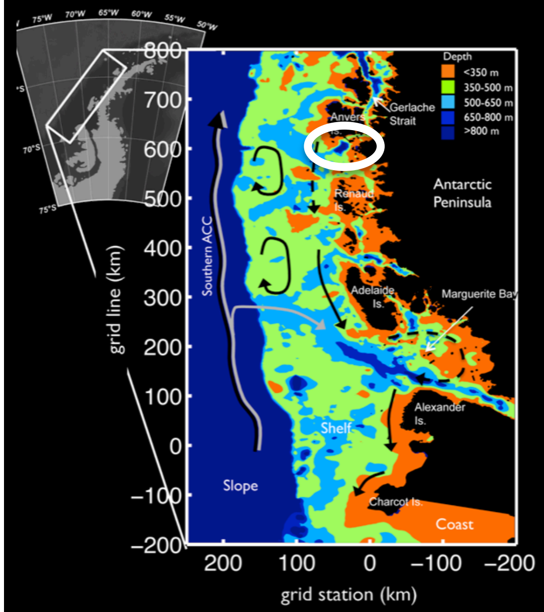


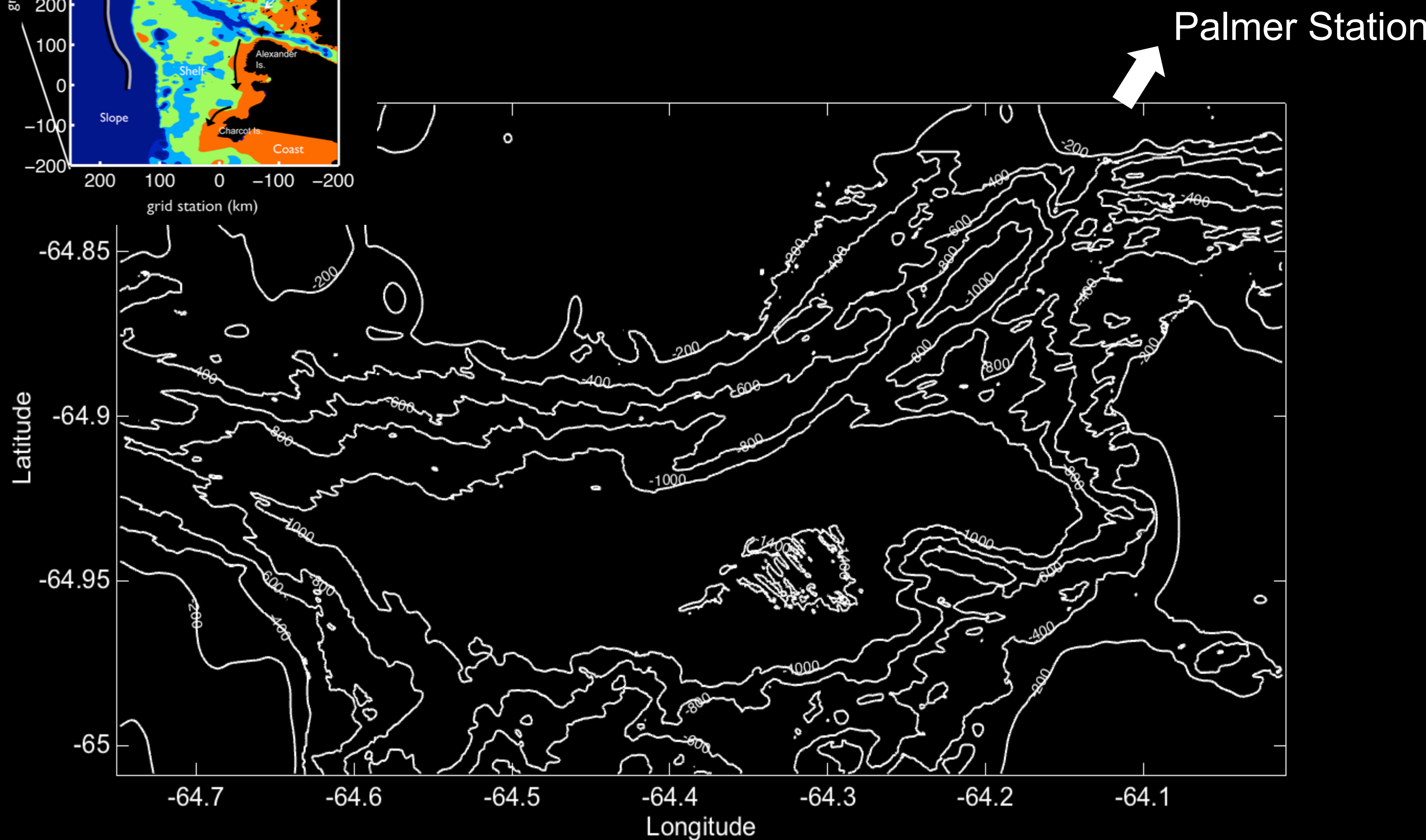
PALMER DEEP CANYON BATHYMETRY

Maximum depth ~ 1400 m

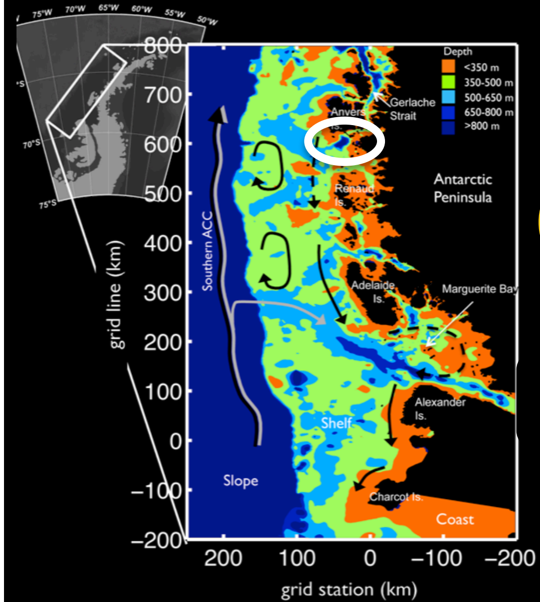


PALMER DEEP CANYON BATHYMETRY



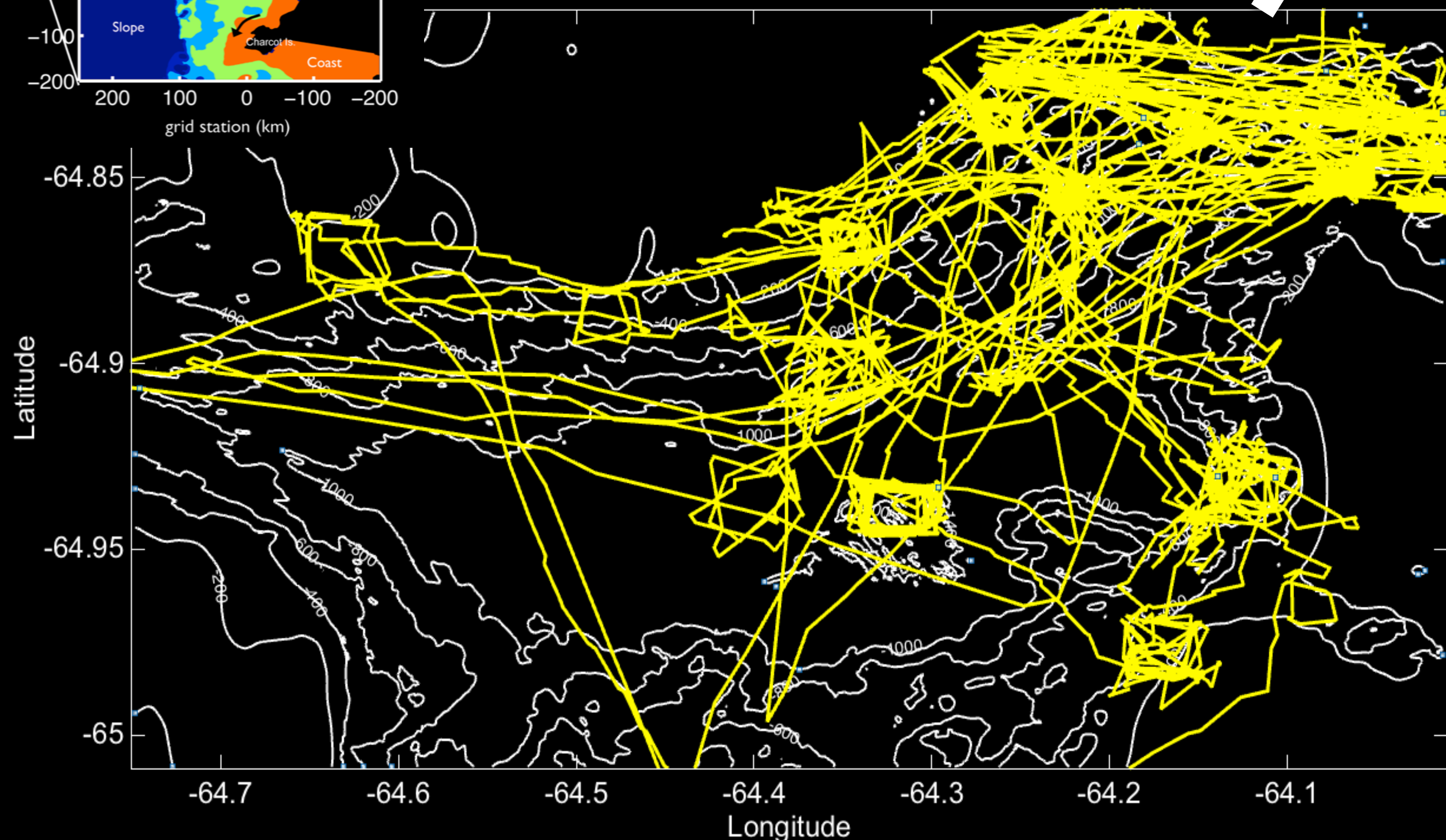


18 Glider Deployments: Good Coverage in Head of Canyon

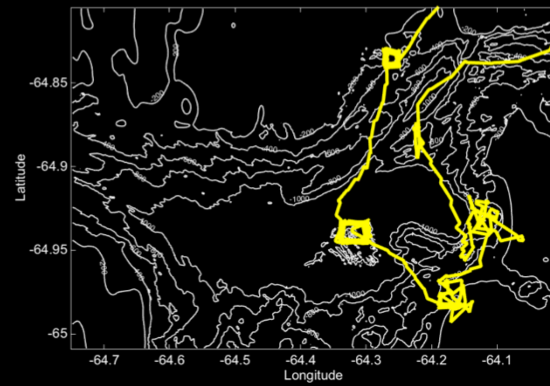


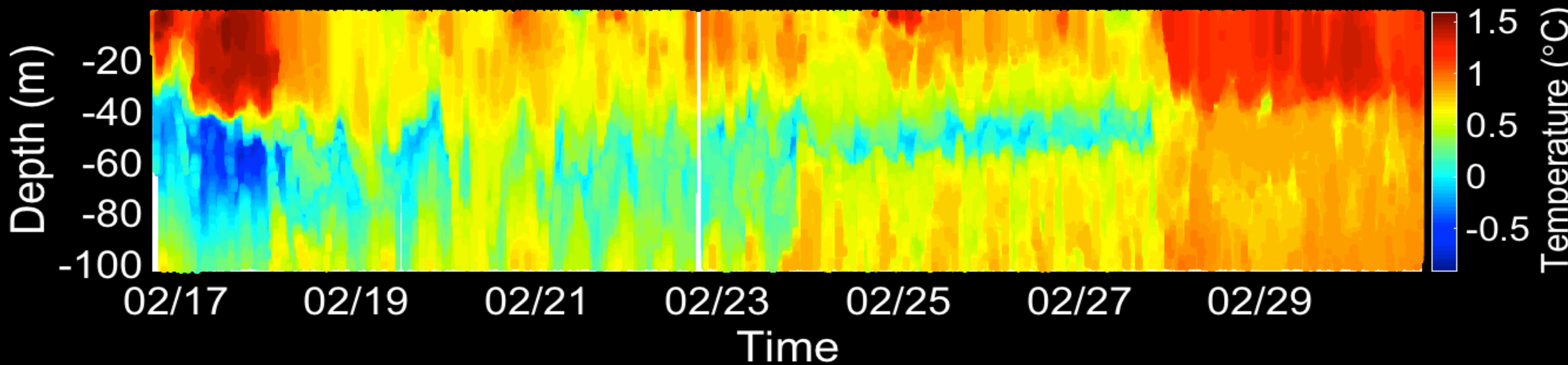
Palmer Deep Giders

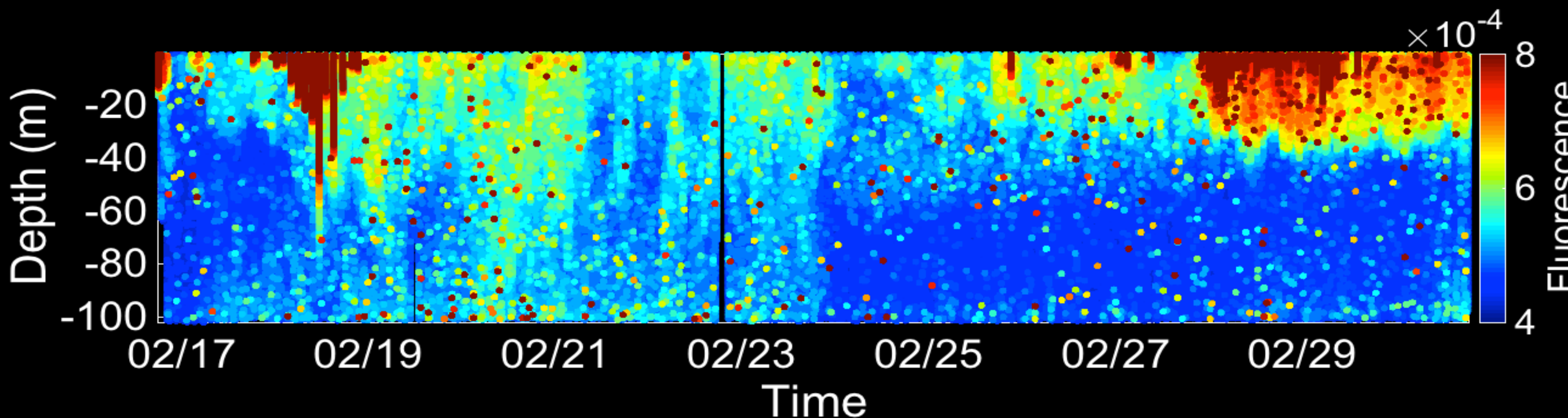
Palmer Station



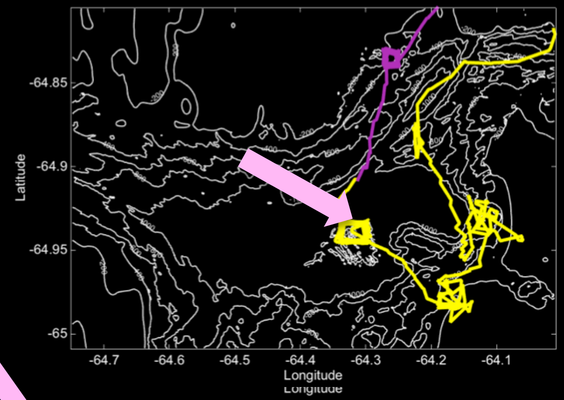
GLIDER ANALYSIS – RU05-276 (WARM WATER SHOALING)

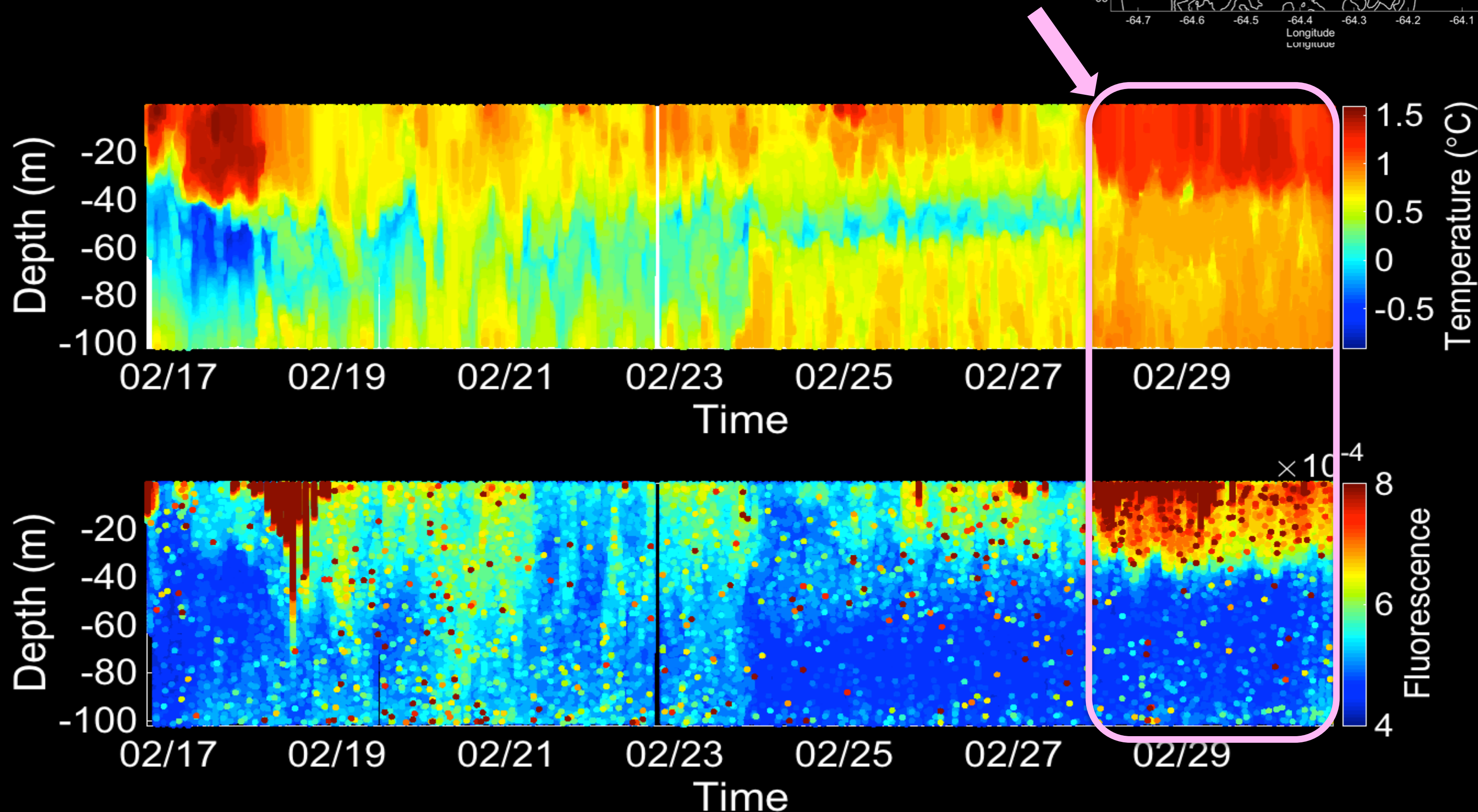






Glider analysis – RU05-276 (Warm Water Shoaling)





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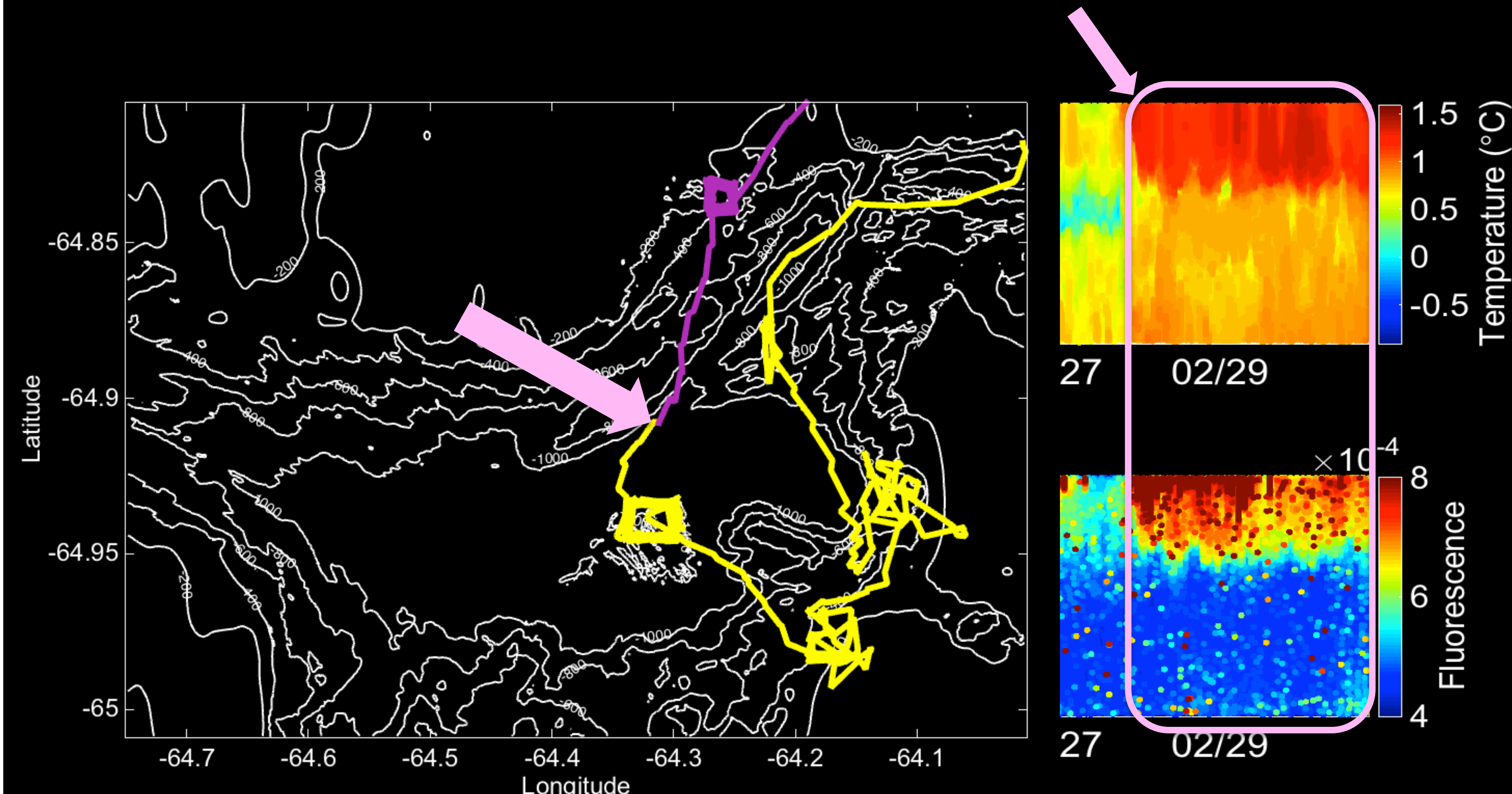
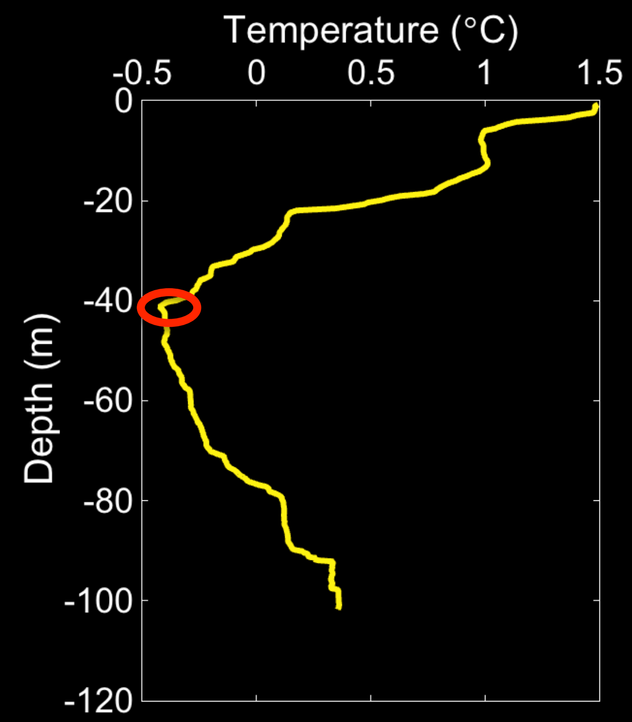


IMPORTANT VARIABLES

- Tmin – Temperature minima in each profile
- Depth Tmin – Depth of Tmin
- ΔSigma-Theta$_{Tmin\text{-}0}$



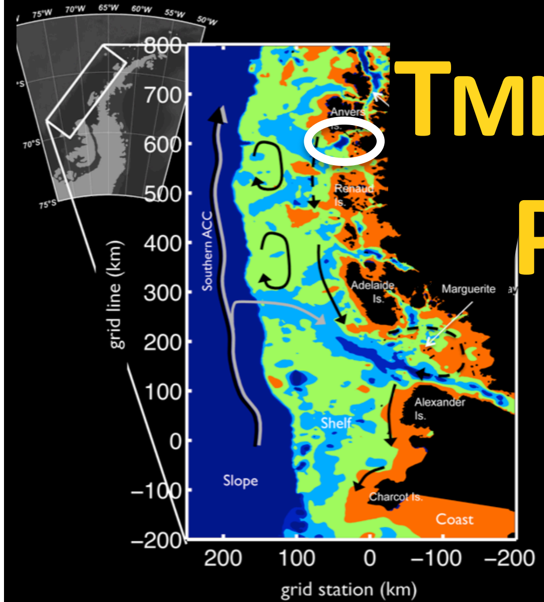
$$\Delta Sigma - Theta_{Tmin-0} = \frac{SigmaTheta_{Tmin} - Sigma\,Theta_{surface}}{Depth_{Tmin} - Depth_{surface}}$$

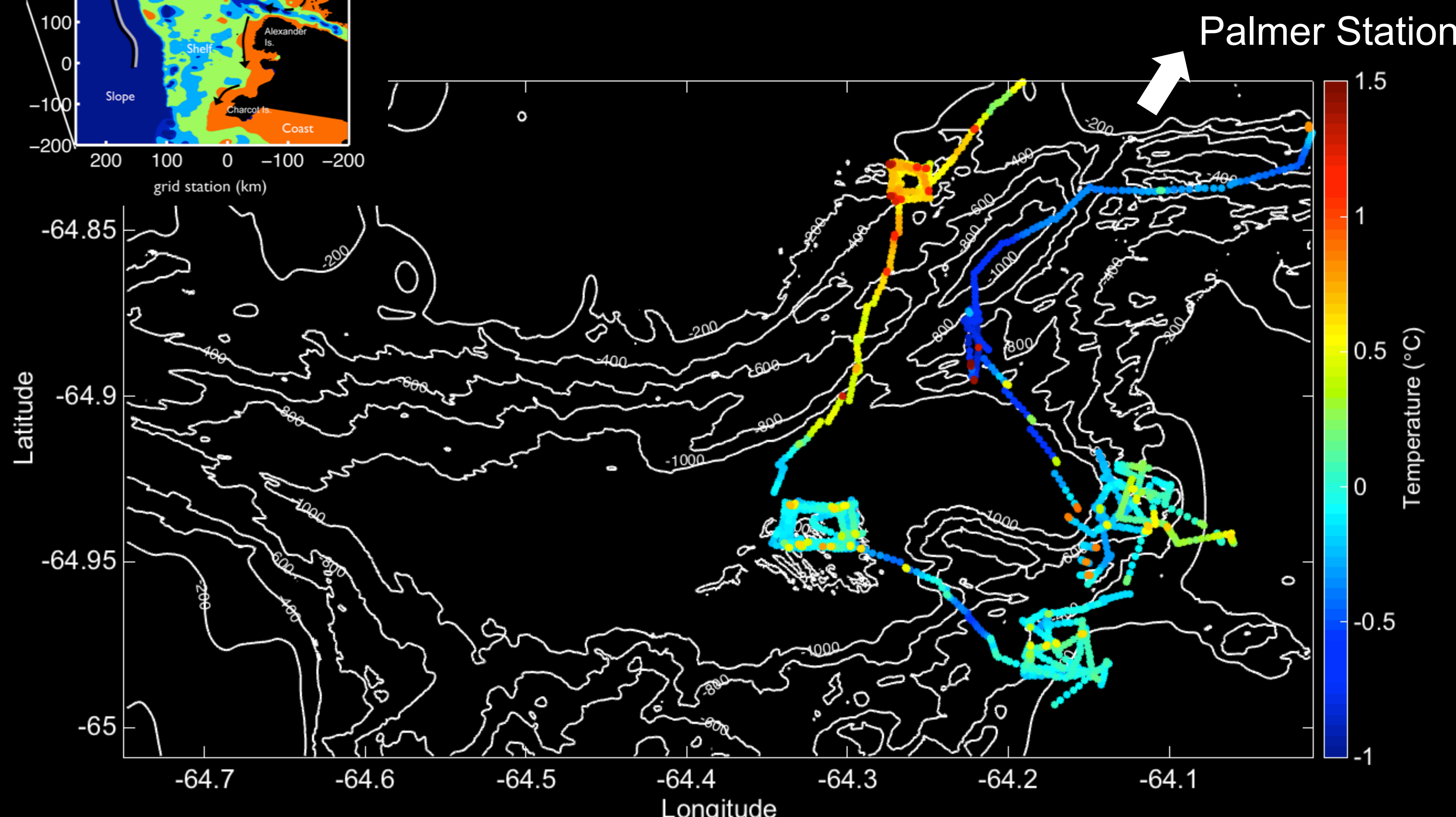
Saba et al, 2014

High Δ Sigma-Theta$_{Tmin\text{-}0}$:

- Winter Water (Tmin) is shallow
- Increased Stratification (density differences are big)

Tmin – Winter Water (Temp < -1°C) Present in the Deeper Channel





Using Gliders to map the Phytoplankton Dynamics

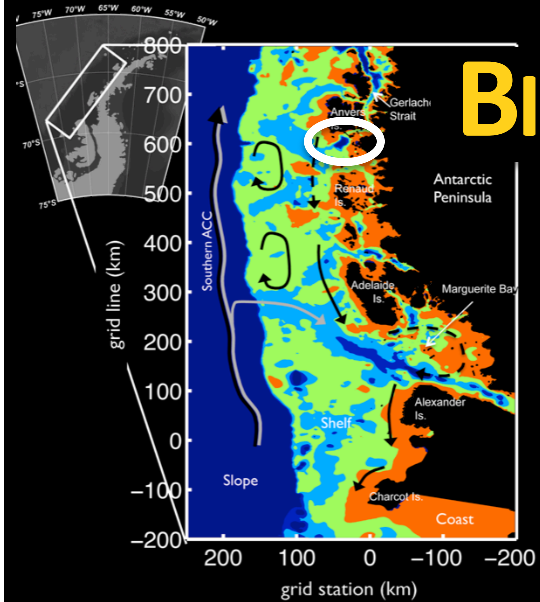
Pros:

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

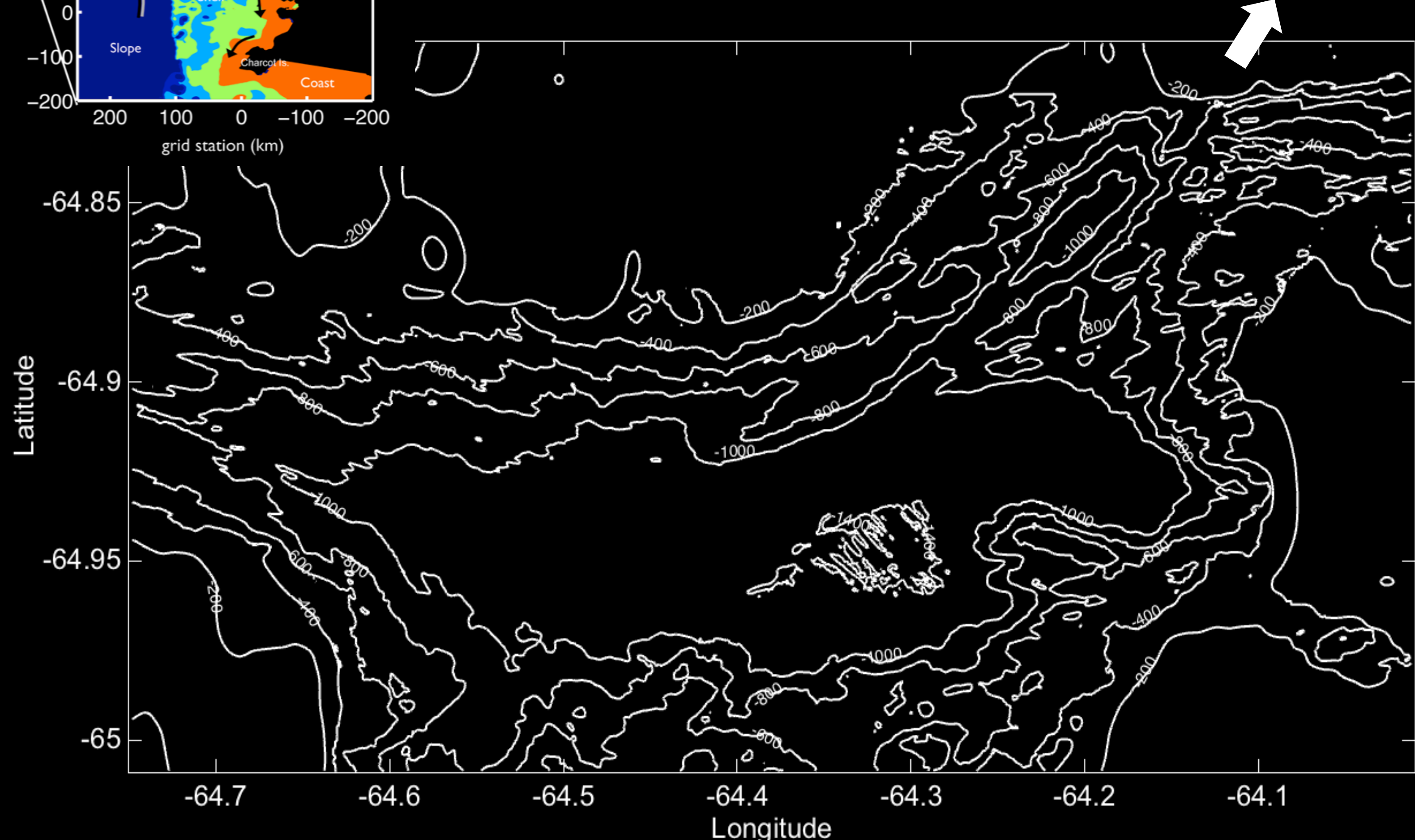
Cons:

- Spatial and temporal resolution: no time series, no spatial map at one timepoint …

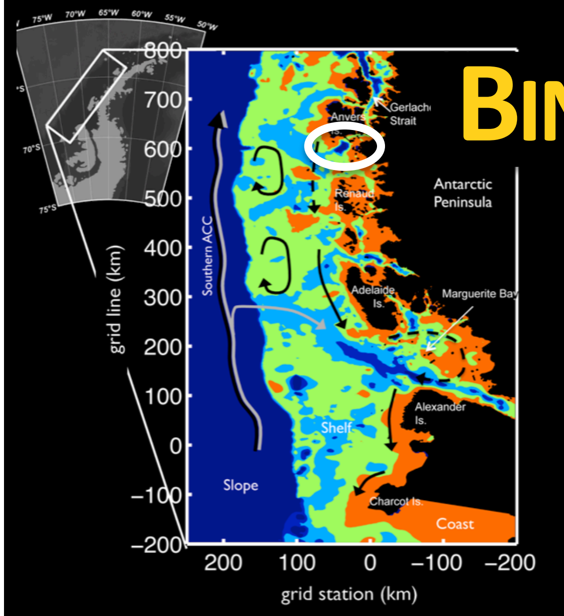
BINNING DATA USING BATHYMETRY

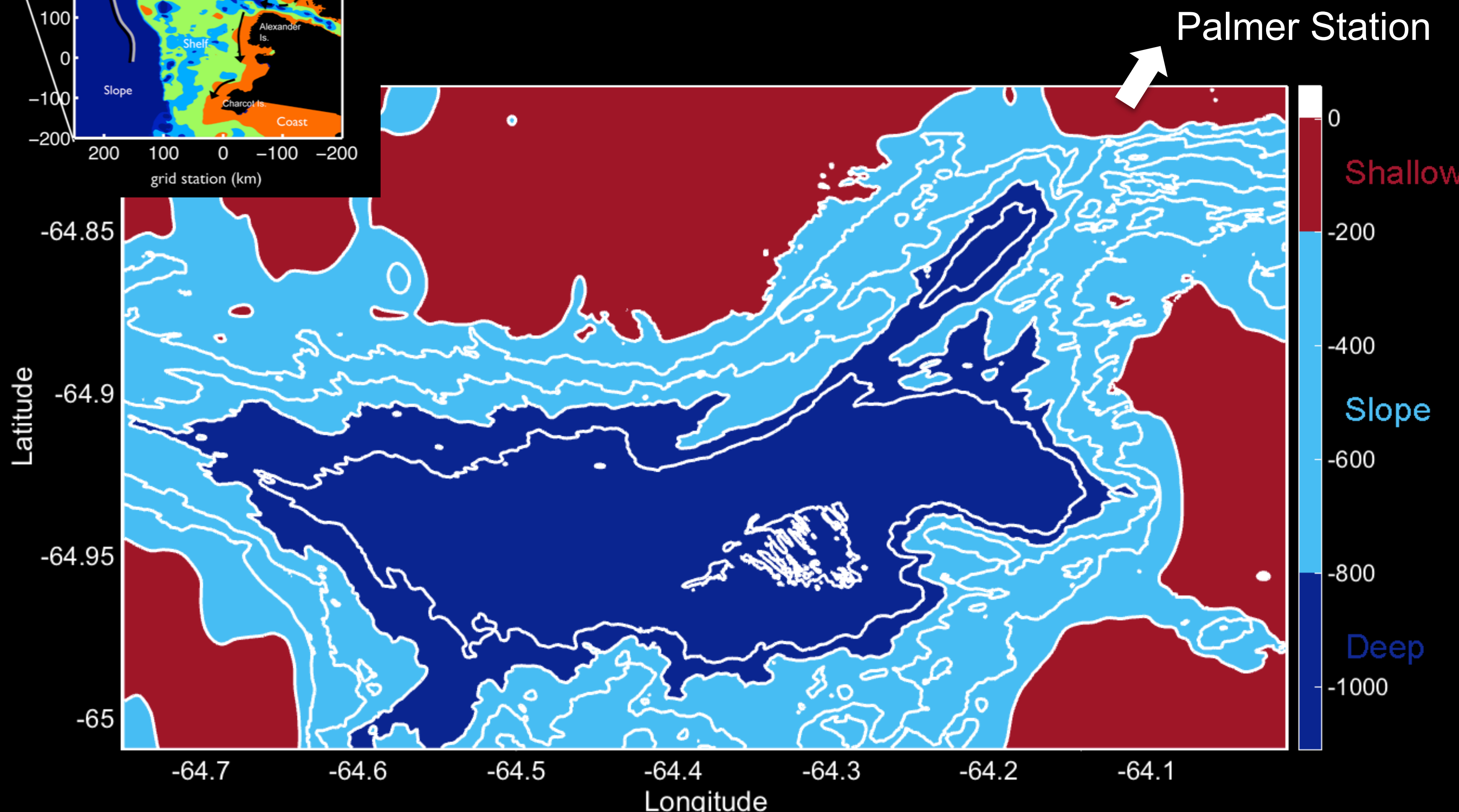


Palmer Station

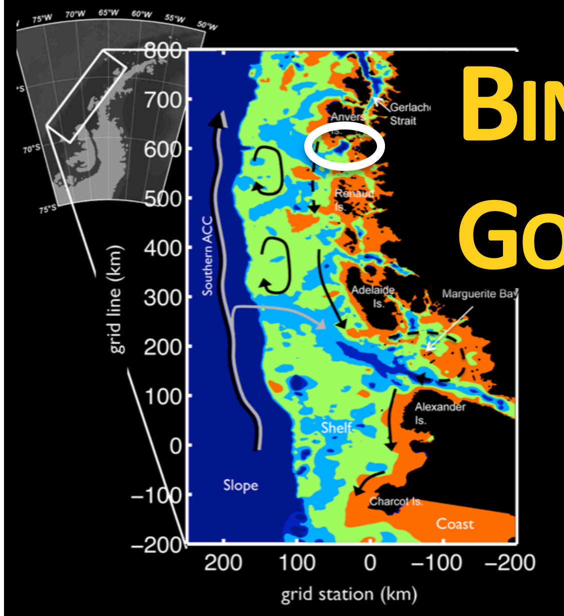


BINNING DATA USING BATHYMETRY

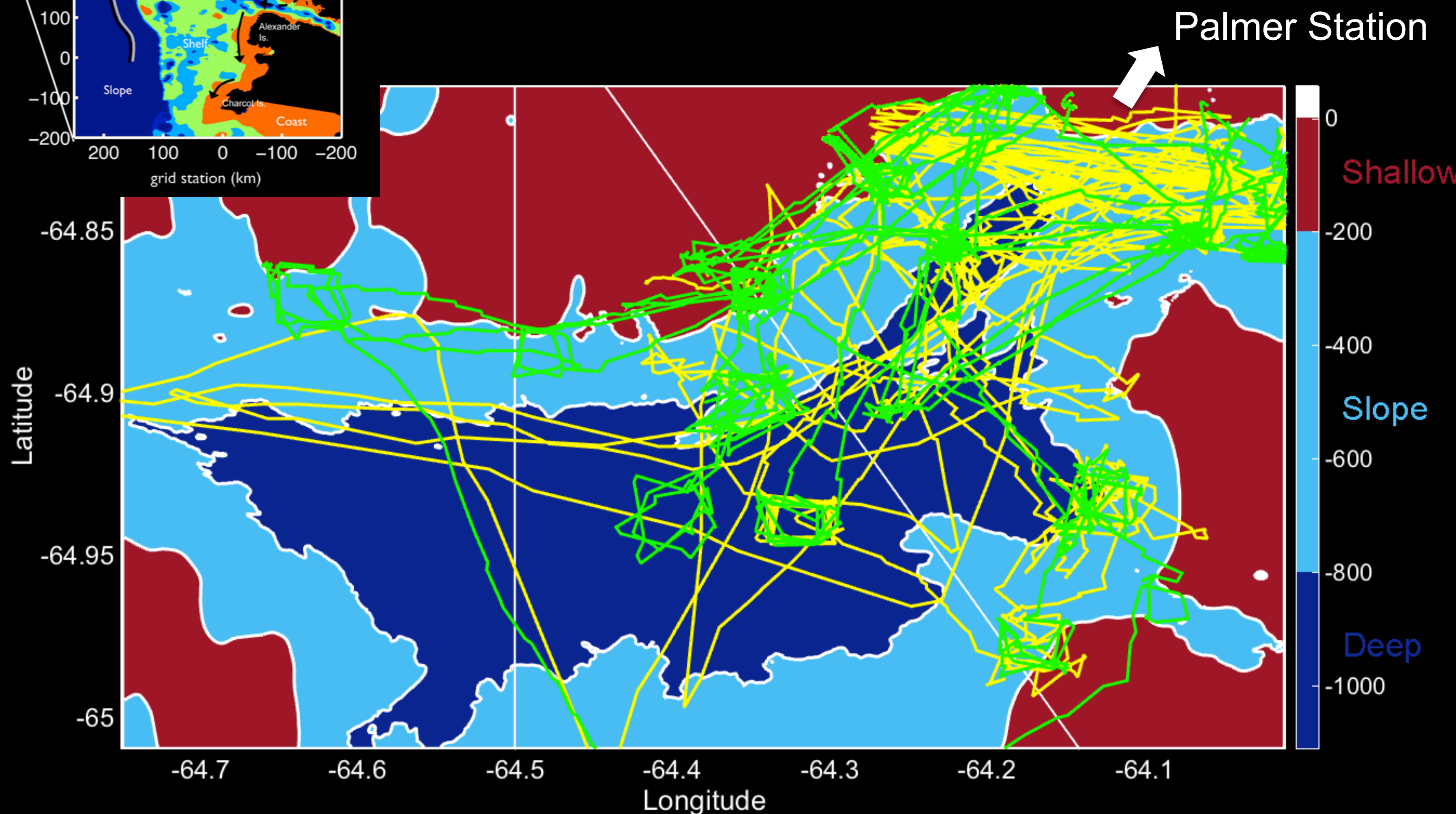




Binning Data using Bathymetry
Good Coverage at Head of Canyon



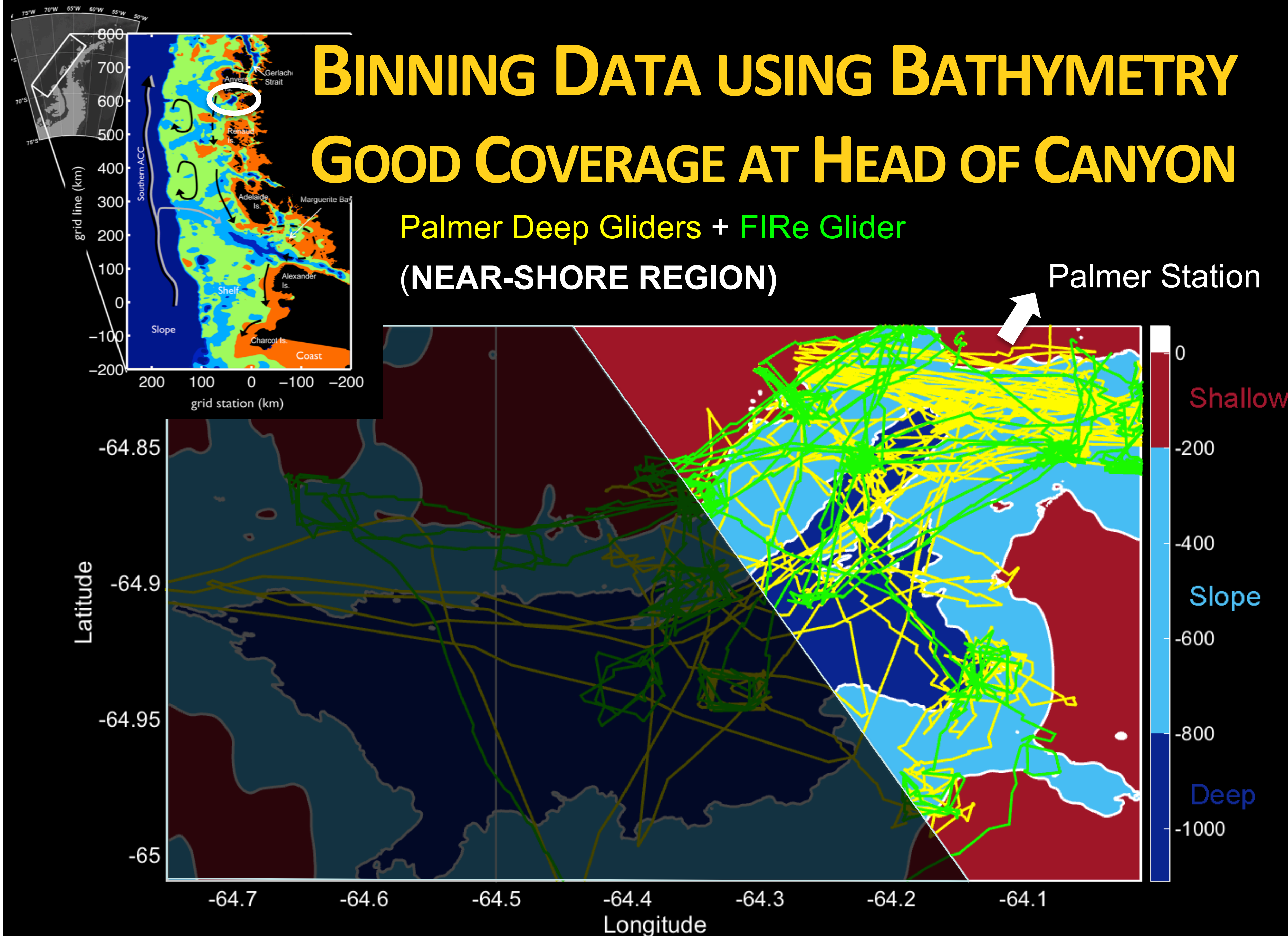
Palmer Deep Gliders + FIRe Glider



Binning Data using Bathymetry
Good Coverage at Head of Canyon

Palmer Deep Gliders + FIRe Glider

(NEAR-SHORE REGION)

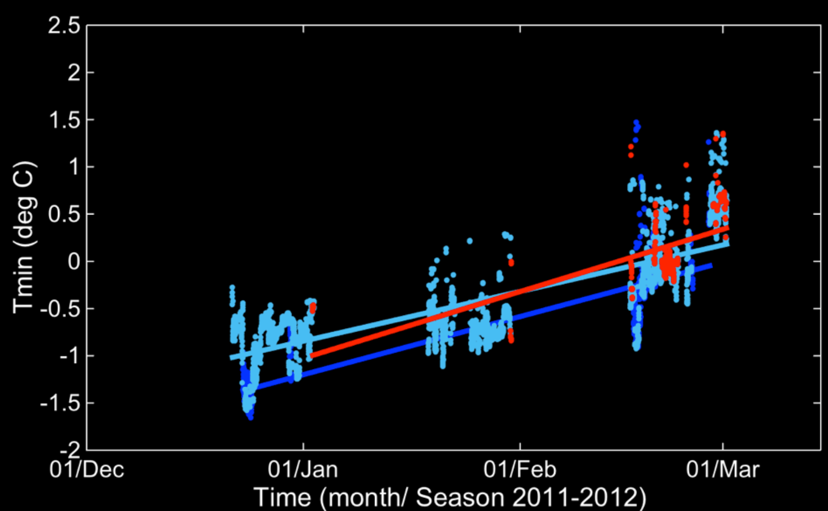


Annual & Seasonal Variability in Tmin

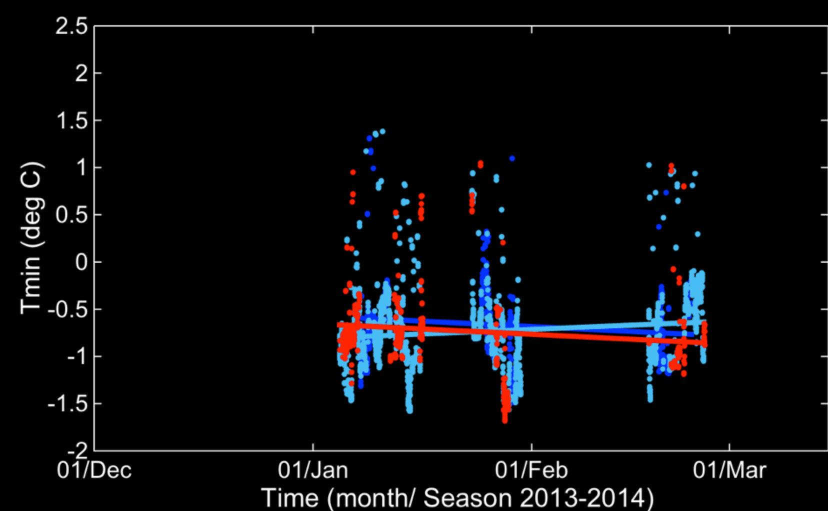
Tmin increases throughout Season

Shallow
Slope
Deep

Season 2011-2012



Season 2013-2014

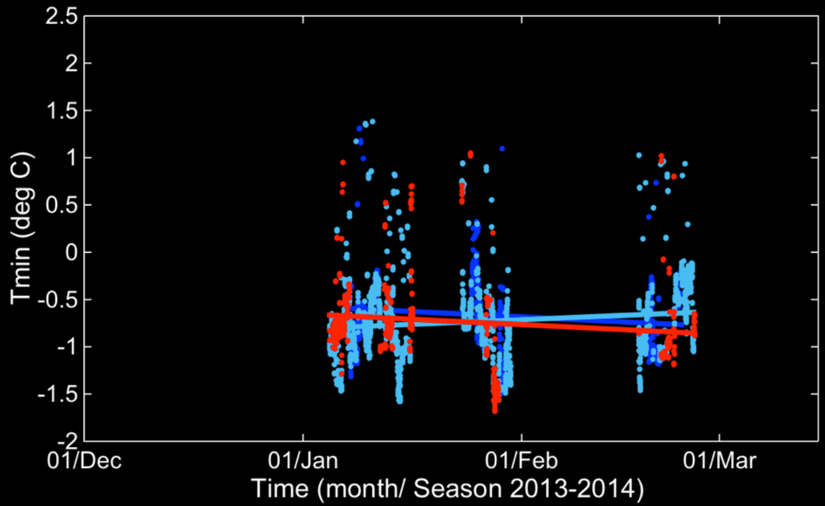


2013-2014 Season: no change in Tmin – Possibly due to late ice retreat?

ANNUAL & SEASONAL VARIABILITY IN TMIN
TMIN INCREASES THROUGHOUT SEASON

Shallow
Slope
Deep

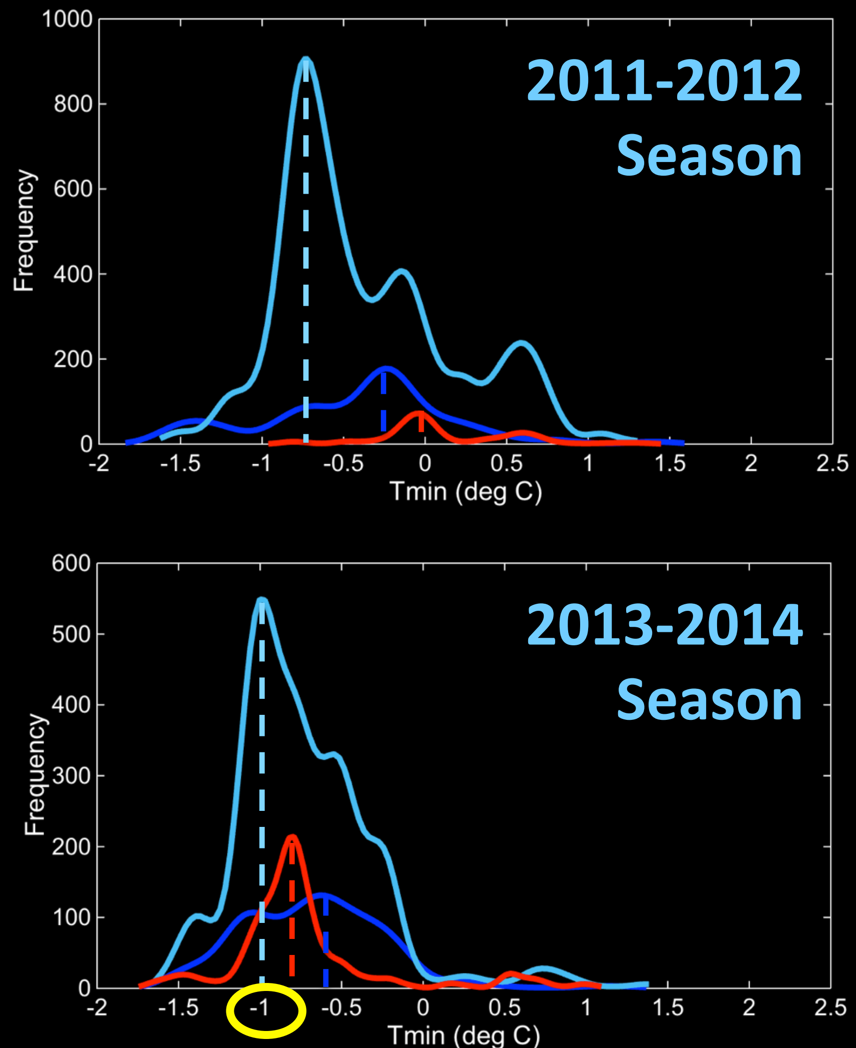
Season 2013-2014



2013-2014 Season: no change in Tmin –
Possibly due to late ice retreat?

Annual & Seasonal Variability in Tmin

Tmin Colder on the Slope



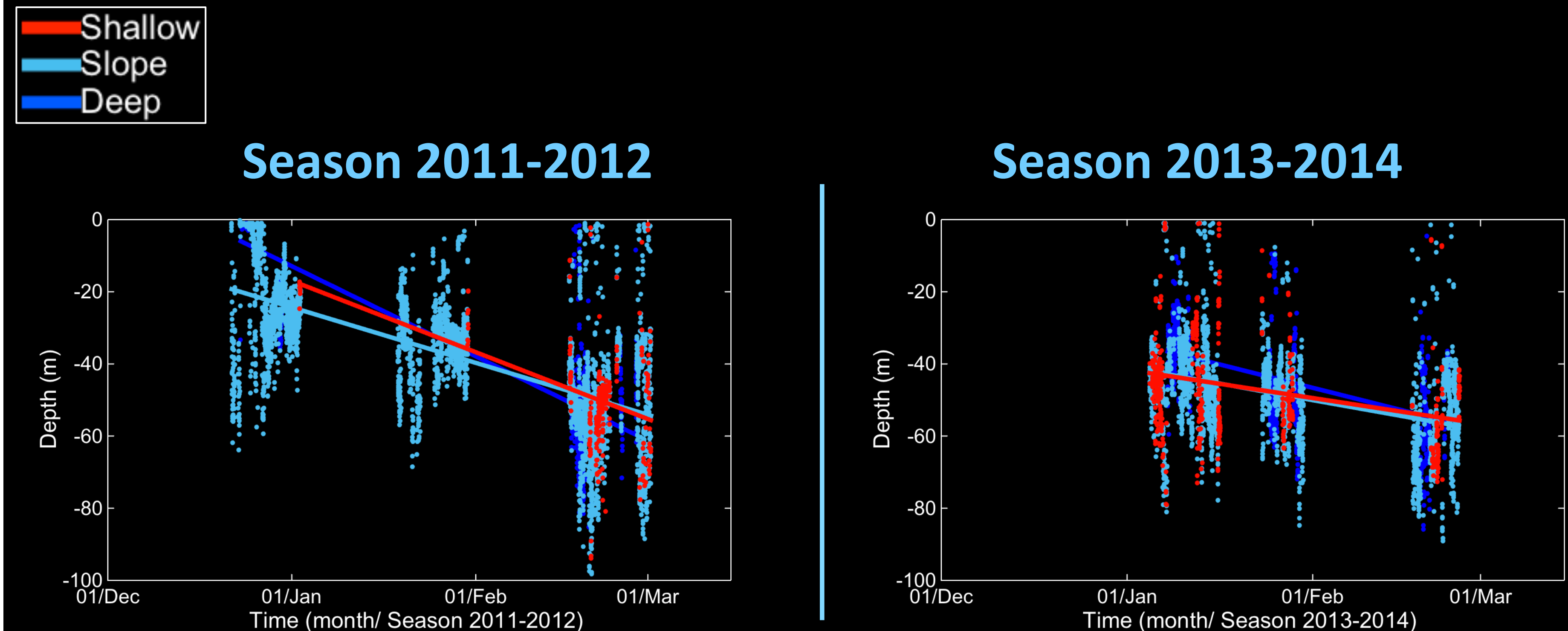
Tmin peaks colder on Slope < Deep < Shallow regions

2013-2014 Season:

- colder in all regions
- Winter water (T<-1°C) present on the slope

Annual & Seasonal Variability in Depth Tmin

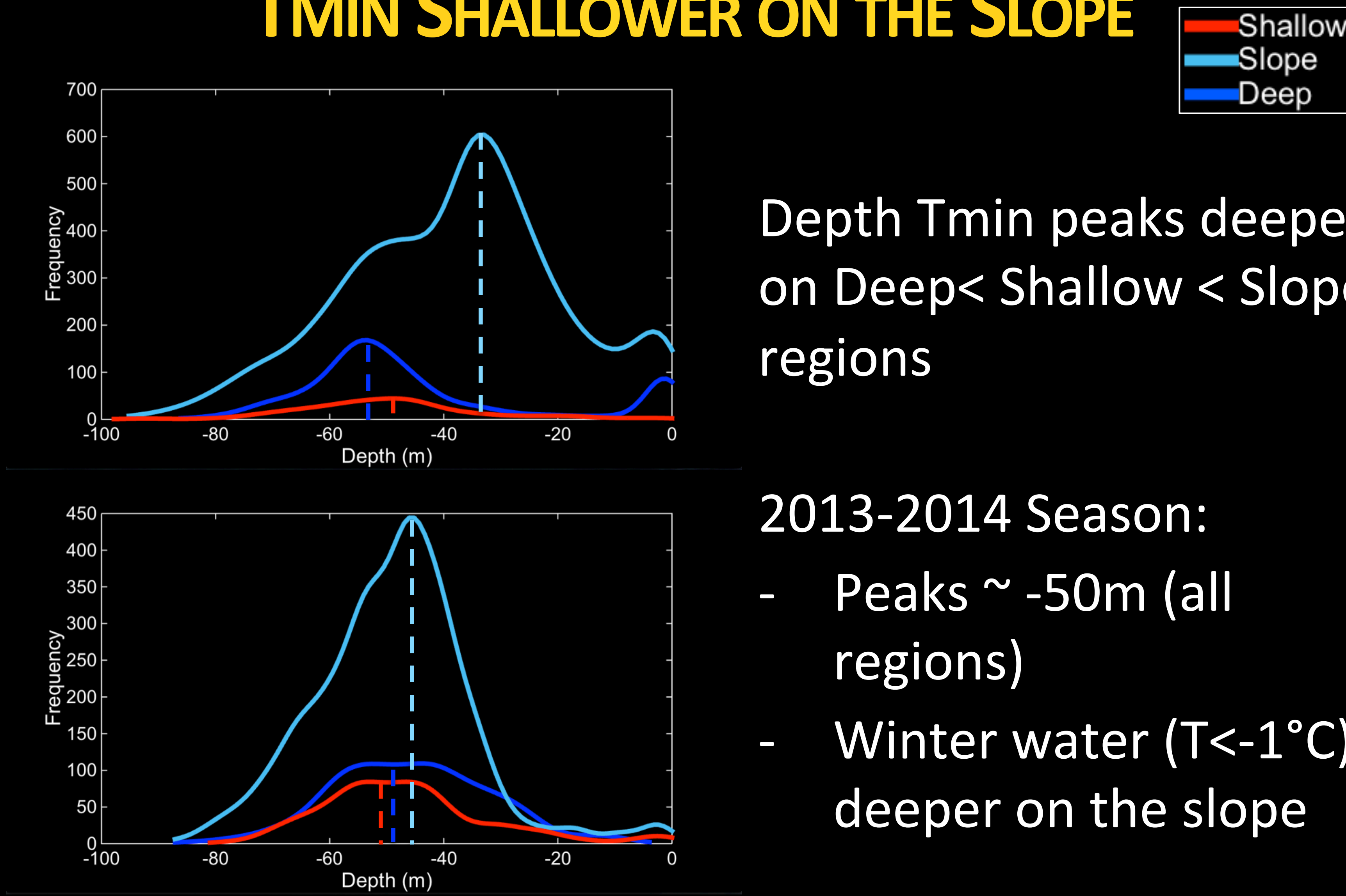
Depth Tmin decreases throughout Season



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

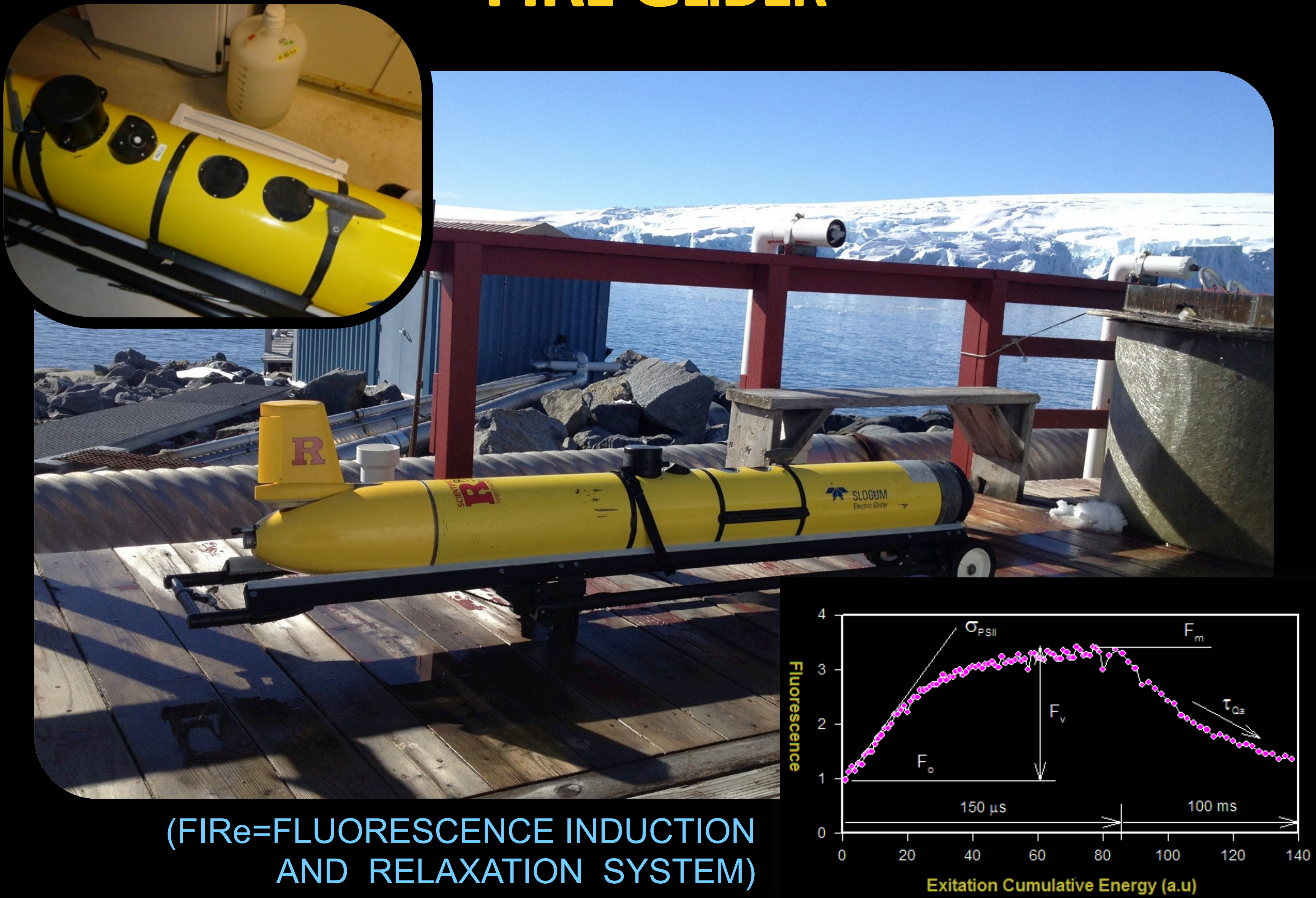
2013-2014 Season:

- 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), Δ Sigma-theta$_{Tmin\text{-}0}$
- 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).

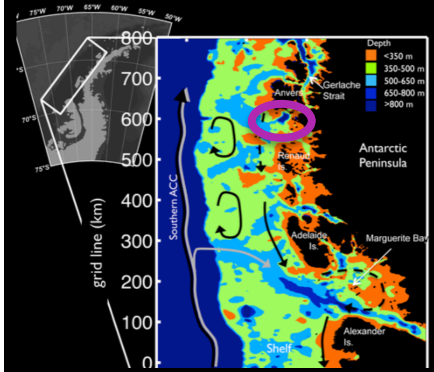
FIRe Glider



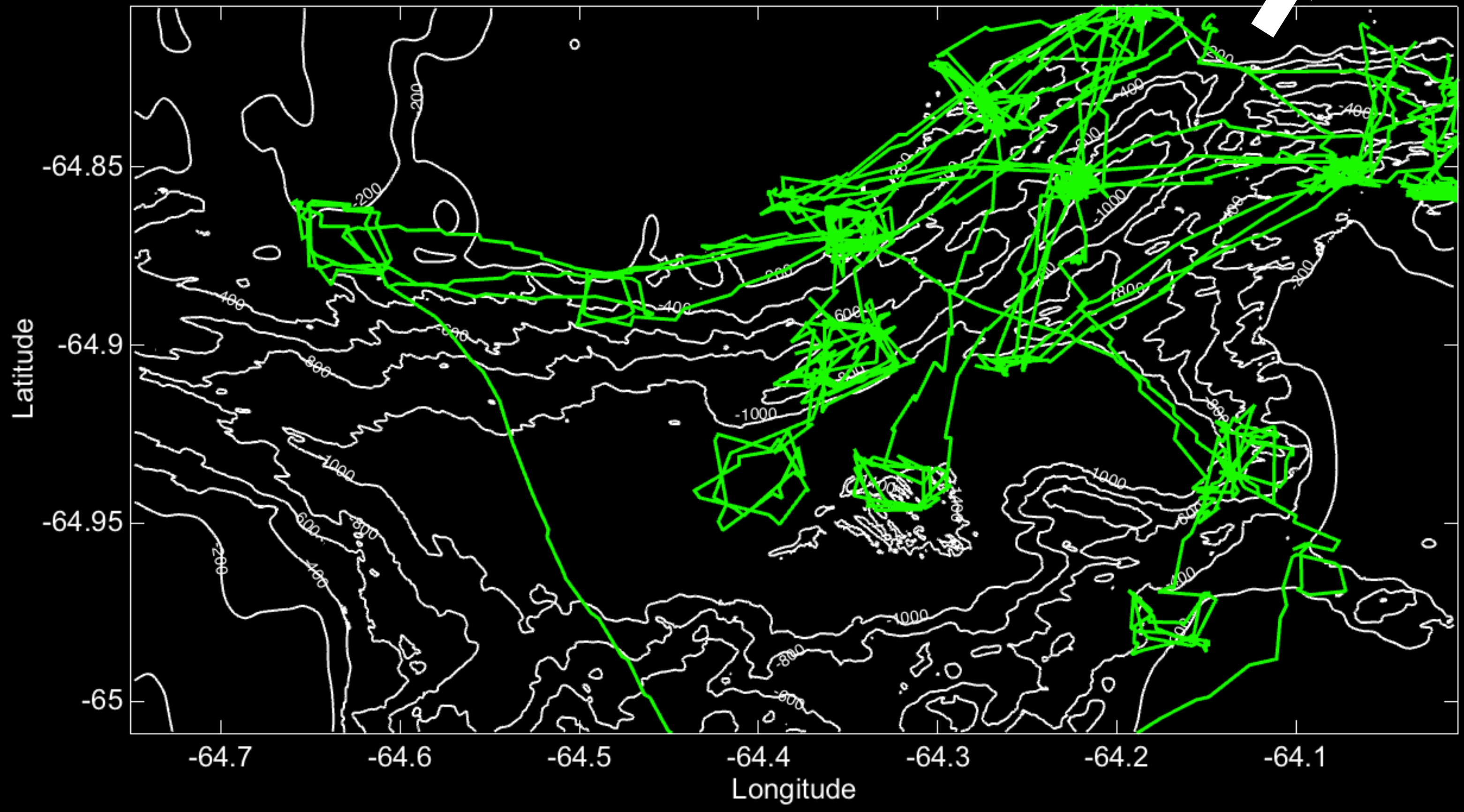
(FIRe=FLUORESCENCE INDUCTION AND RELAXATION SYSTEM)

18 Glider Deployments During LTER

Palmer Deep Giders + FIRe Glider

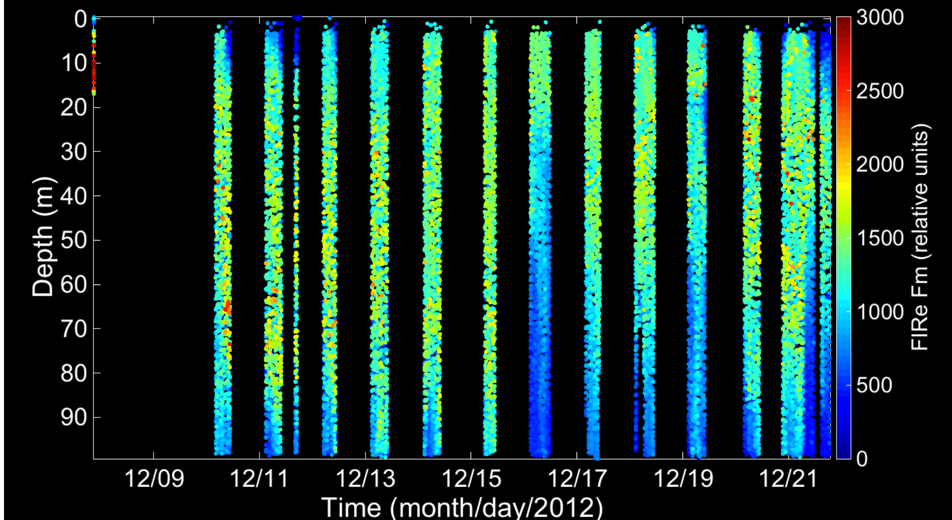


Palmer Station

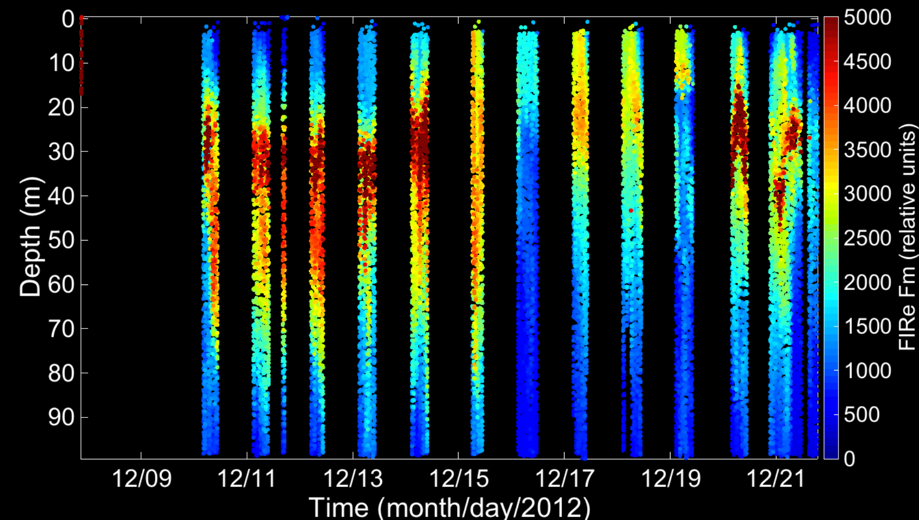


FIRe Glider Data Correction - Fm

Before correction

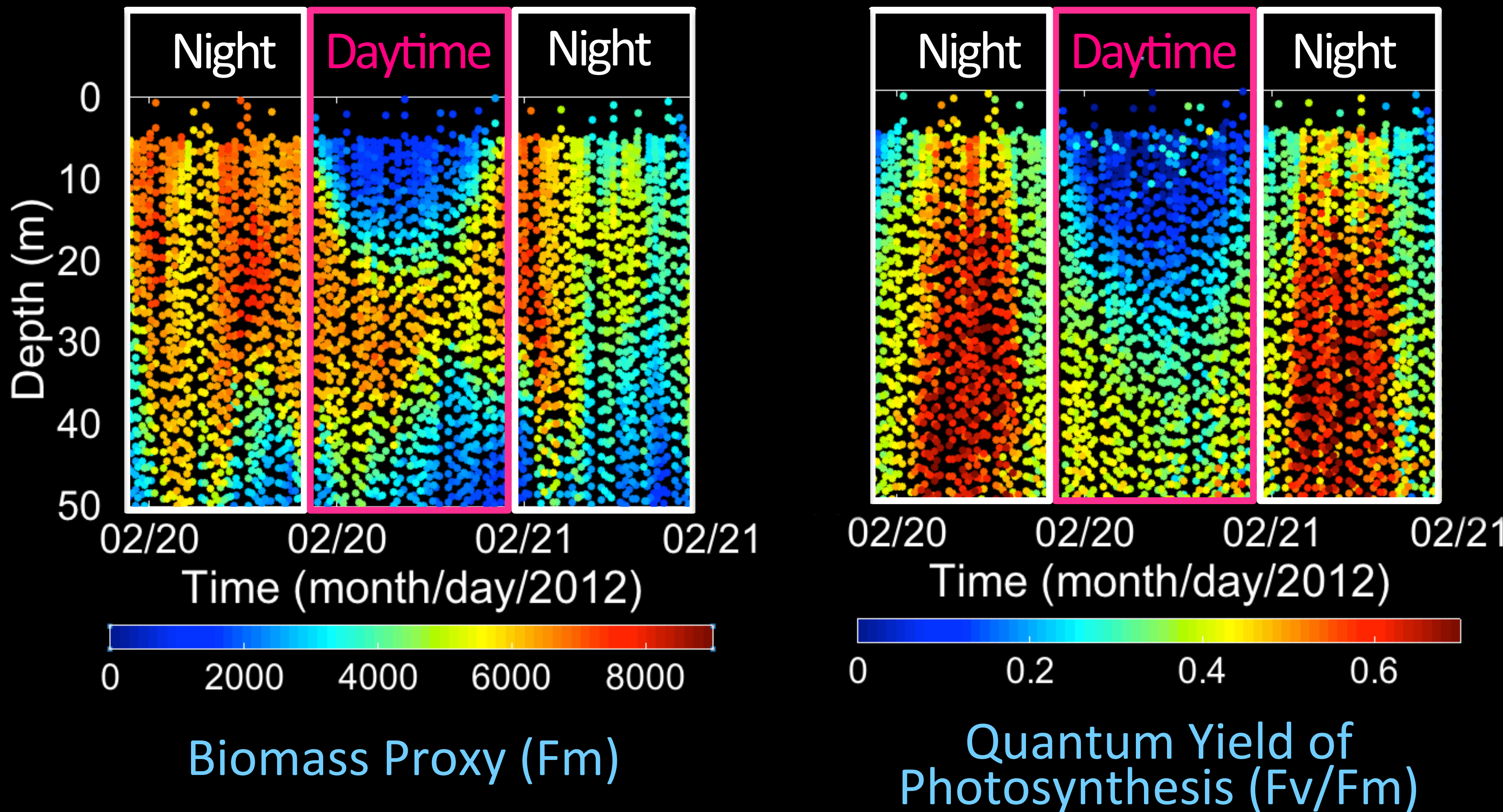


After correction

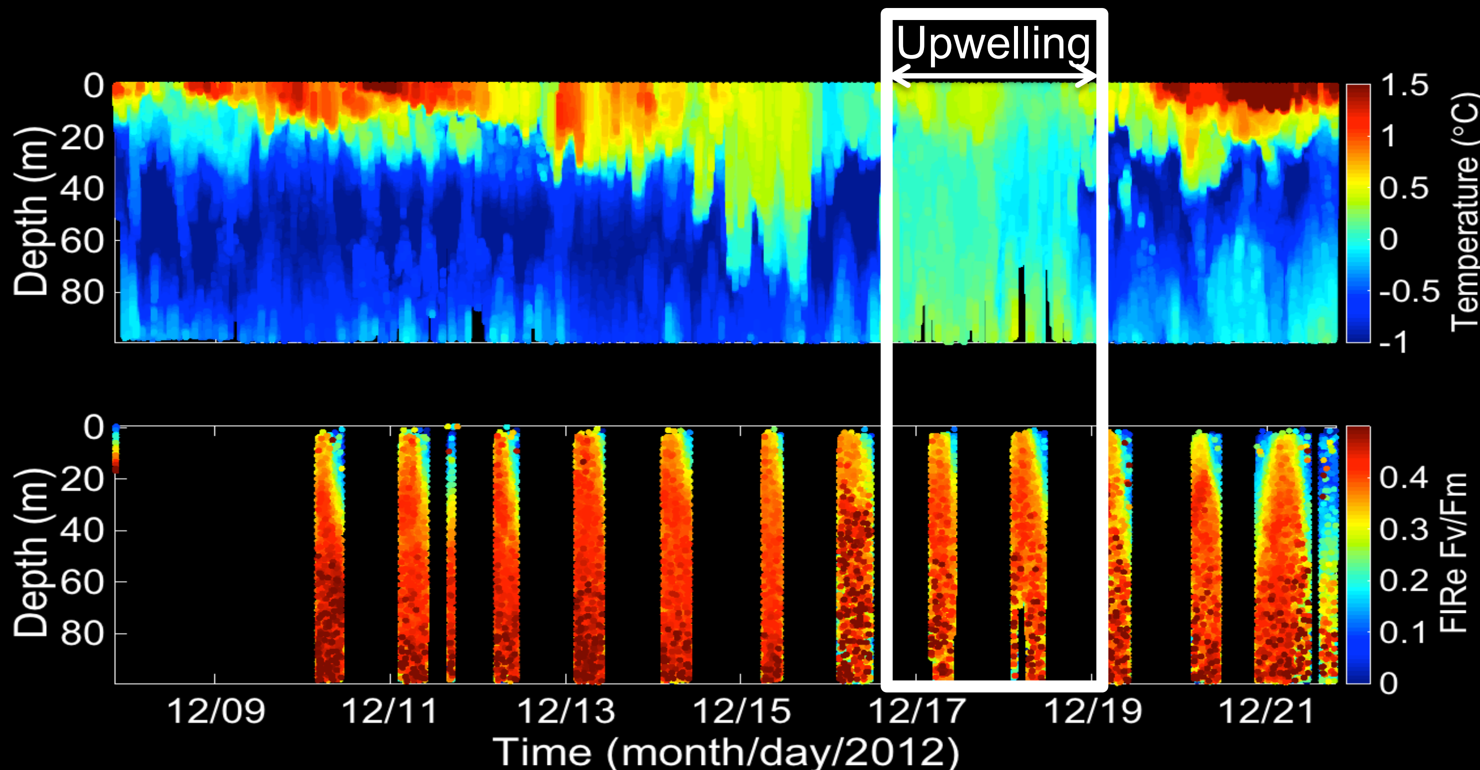


- Fm - proxy for phytoplankton biomass (relative units)
- Need in situ water collection and chl measurements through fluorometric method

DAYTIME AFFECTS PHOTOSYNTHETIC EFFICIENCY (NON-PHOTOCHEMICAL QUENCHING)



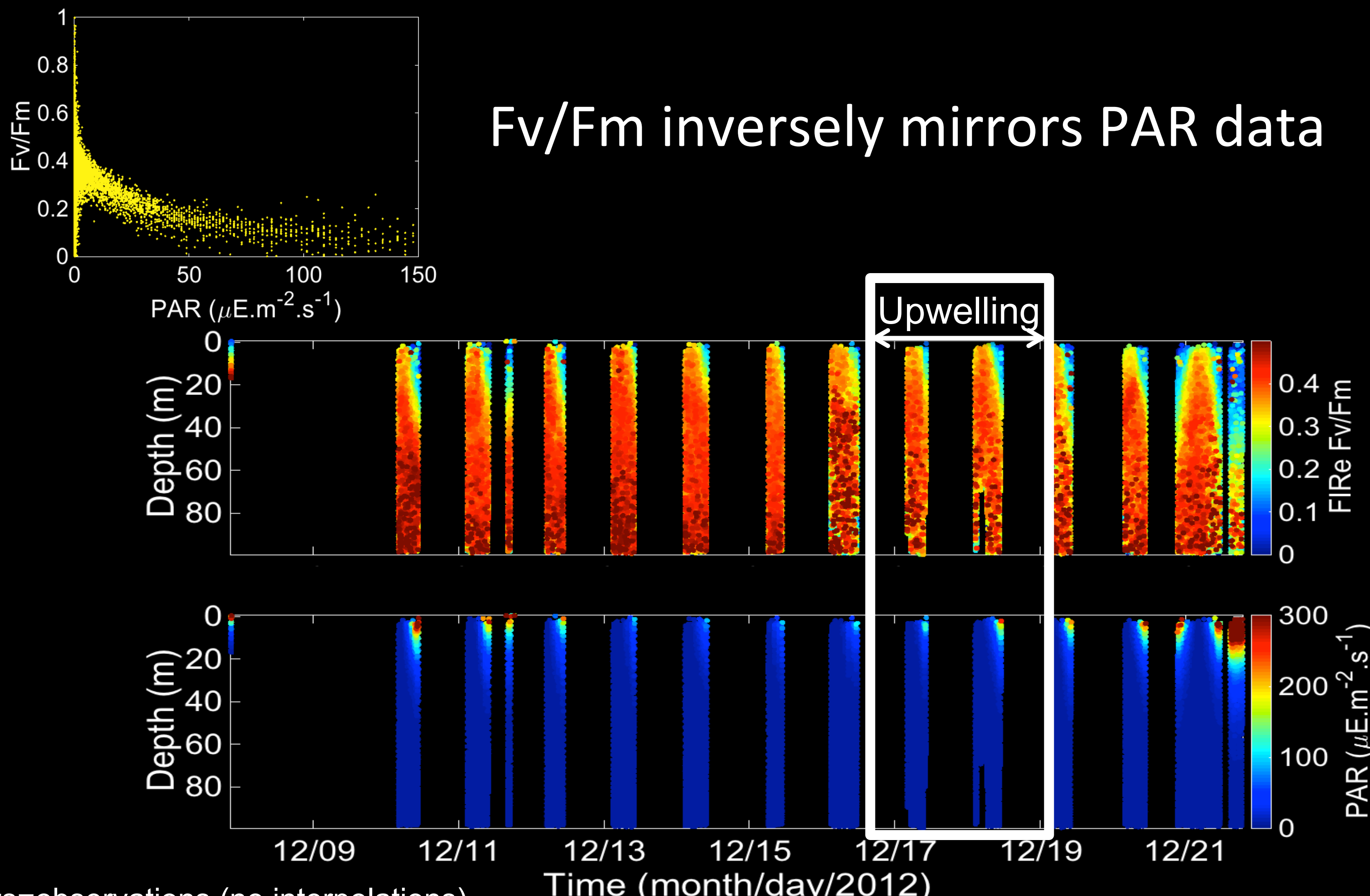
FIRe in an Upwelling Event: Light is the Main Driver of the Bloom



Photosynthetic Efficiency (Fv/Fm) fairly constant & high

Points=observations (no interpolations)

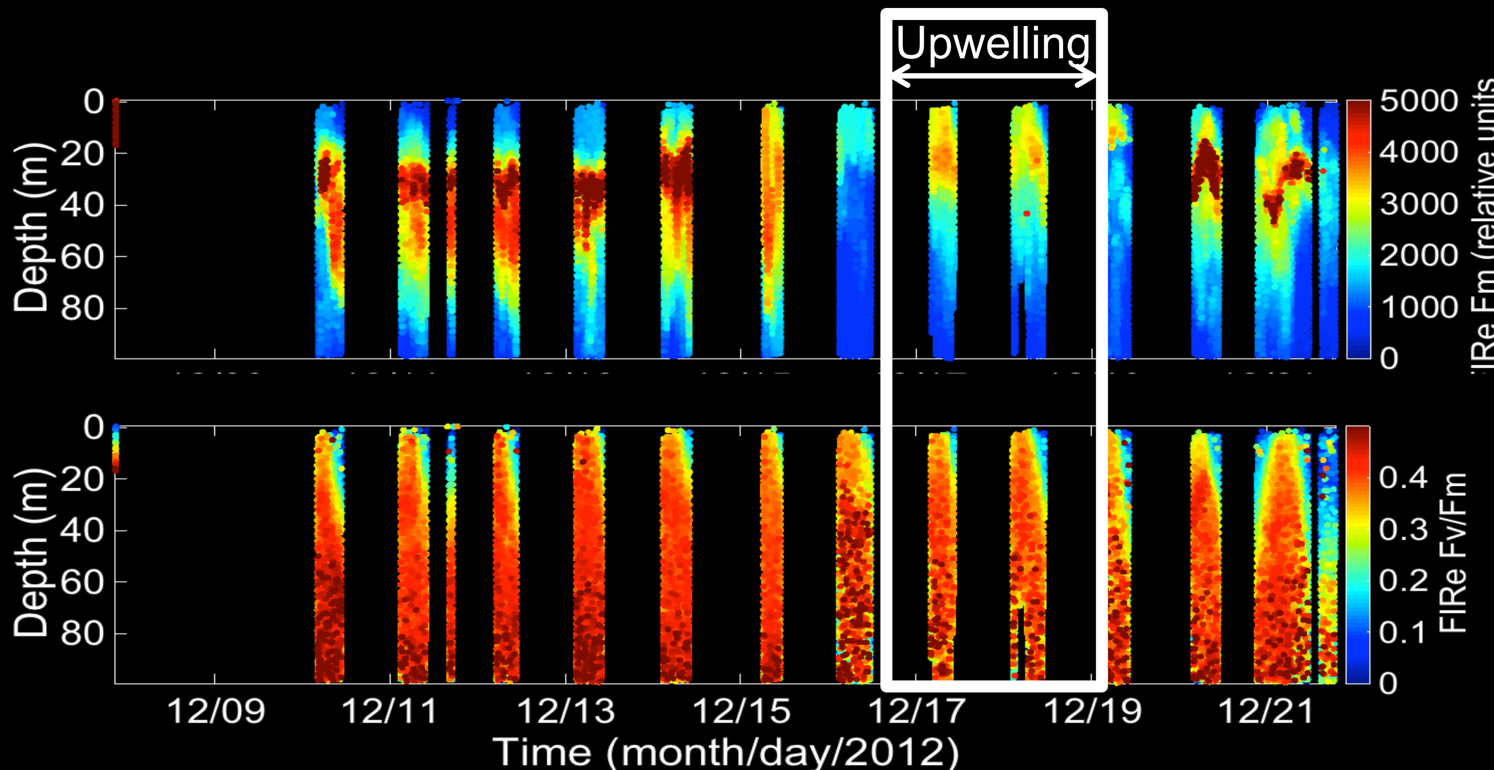
FIRe in an Upwelling Event: Light is the Main Driver of the Bloom



Fv/Fm inversely mirrors PAR data

Points=observations (no interpolations)

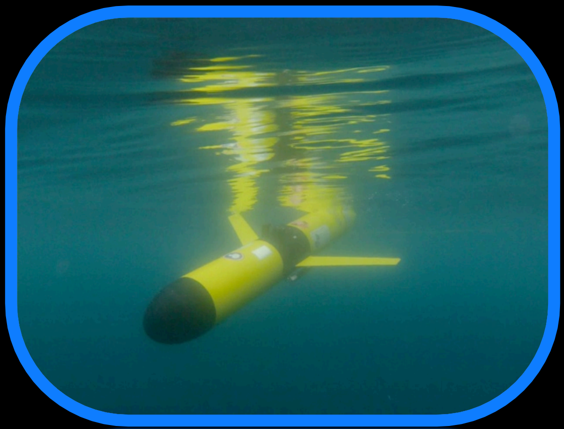
FIRe in an Upwelling Event: Light is the Main Driver of the Bloom



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 (σ_{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.

PALMER STATION ANTARCTICA LTER

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