HOT DAYS ALONG THE WEST ANTARCTIC PENINSULA

LTER Palmer has maintained a 19 year time series along the West Antarctic Peninsula

The Boss!

PI Hugh Ducklow (MBL)
Bacteria-Biogeochemistry

Current team

Bill Fraser (Polar Associates)
- Penguins & Fish

Karen Baker (Scripps)
- Data management & Informatics

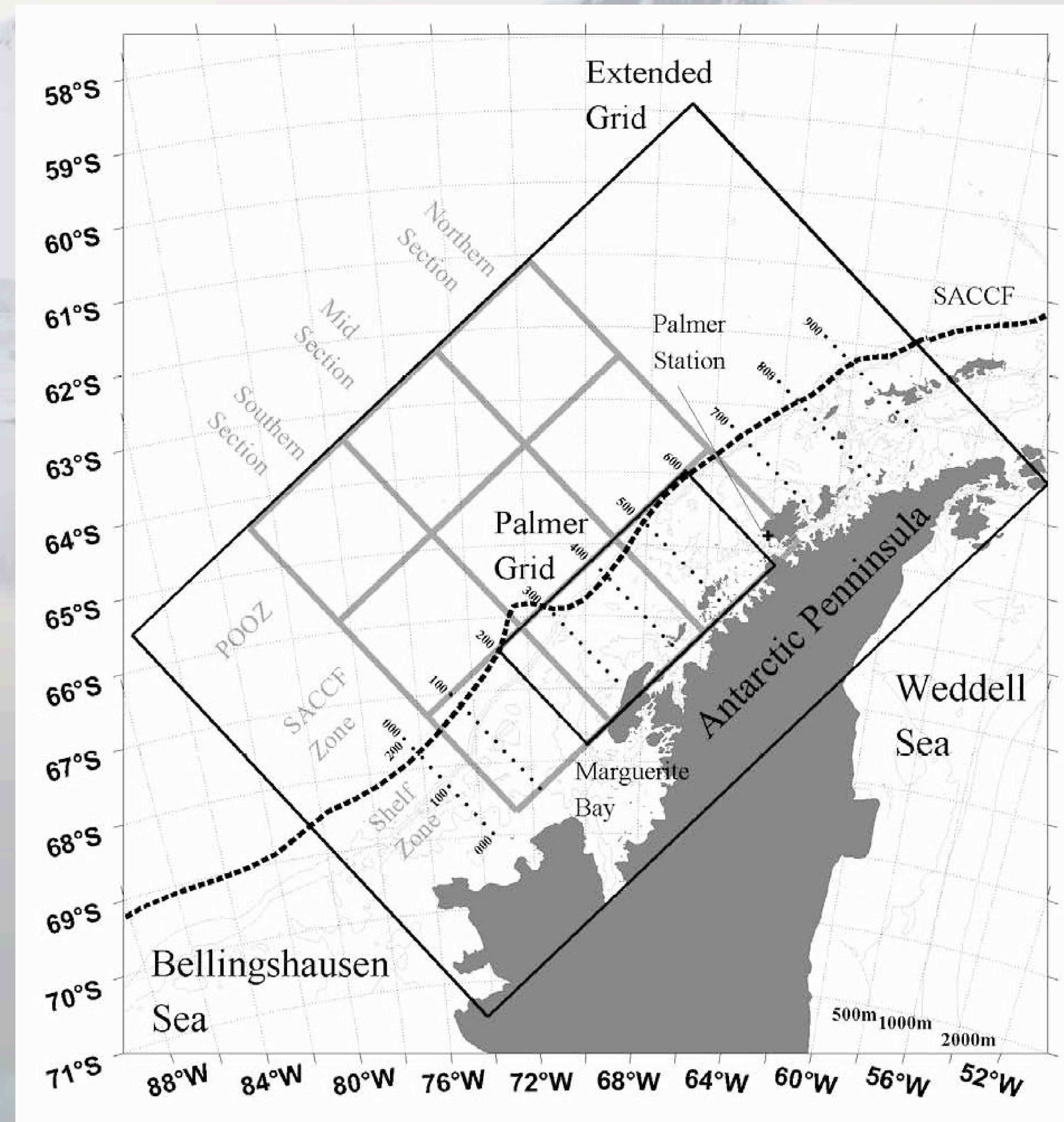
Scott Doney (WHOI)
- Ocean Modeling

Beth Simmons (Scripps)
- Education & Outreach

Oscar Schofield (Rutgers) - Phytoplankton
Doug Martinson (LDEO) - Ocean Physics
Debbie Steinberg (VIMS) - Zooplankton

Sharon Stammerjohn (UCSC)
- Climate and Ice

Our Current grid



Acknowledgements to past LTER PIs: Ray Smith, Barbara Prezelin, Robin Ross, Langdon Quetin, Dave Karl, Maria Vernet, Eileen Hoffman, John Klinck, Dave Karl

The man!

?olar Biol (1992) 11:525–531

Polar Biology
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Increases in Antarctic penguin populations: reduced competition with whales or a loss of sea ice due to environmental warming?

William R. Fraser*·**, **Wayne Z. Trivelpiece***, **David G. Ainley** and **Susan G. Trivelpiece***

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Received 25 June 1991; accepted 6 August 1991

Summary. A central tenet of Antarctic ecology suggests that increases in Chinstrap Penguin (*Pygoscelis antarctica*) populations during the last four decades resulted from an increase in prey availability brought on by the decrease in baleen whale stocks. We question this tenet and present evidence to support the hypothesis that these increases are due to a gradual decrease in the frequency of cold years with extensive winter sea ice cover resulting from environmental warming. Supporting data were derived from one of the first, major multidisciplinary winter expedition to the Scotia and Weddell seas; recent satellite images of ocean ice cover; and the analysis of long-term surface temperature records and penguin demography. Our observations indicate there is a need to pay close attention to environmental data in the management of Southern Ocean resources given the complexity of relating biological changes to ecological perturbations.

Introduction

Populations of many krill-eating, Southern Ocean predators have exhibited significant changes during the last four decades. Notable among these, have been increases in the abundance of Chinstrap Penguins (*Pygoscelis antarctica*), which breed mainly on the Antarctic Peninsula and islands of the Scotia Sea (Watson 1975). At many colonies, numbers have increased 6–10% per annum (Laws 1985), and at some localities fivefold increases have occurred in the last 20 years (Rootes 1988). Chinstraps have also expanded their range southward along the western side of the Antarctic Peninsula (Parmelee and Parmelee 1987; Poncet and Poncet 1987) into areas historically dominated by the closely related adelie Penguin (*P. adeliae*; Fig. 1). A central tenet of Antarctic ecology explains these population changes in terms of a presumed increase in food availability that resulted from the decrease in baleen whale stocks due to commercial whaling (Sladen 1964; Emison 1968; Conroy 1975; Croxall and Kirkwood 1979; Croxall and Prince 1979; Croxall et al. 1984). This tenet is based on the fact that the dominant component in the summer diets of both Chinstraps and whales is the Antarctic krill (*Euphausia superba*). Although this tenet has been widely accepted, the possible mechanism by which a decrease in whales could have led to an increase in Chinstraps has not been questioned (cf. Horwood 1980). Indeed, the long-standing view has simply been that whaling led to a "krill surplus" that was used by krill-eating predators when competitive release altered the existing patterns of consumption (Laws 1985).

Although this whale reduction hypothesis has clearly been useful in guiding research on trophic interactions in the Southern Oceans, it is now apparent that increases in Chinstrap populations have not been mirrored by their sympatric, most closely related congener, the Adelie Penguin. Adelies share a significant portion of their range on the Antarctic peninsula and islands of the Scotia Arc with Chinstraps (Watson 1975). Alike in size and general appearance, both exhibit broad ecological similarities, not the least of which is a predominance of krill in their summer diets (Volkman et al. 1980; Trivelpiece et al. 1987, 1990; Trivelpiece and Trivelpiece 1990). Yet, when compared to Chinstraps, population increases in Adelies have not been as substantial, and at many sites appear to represent nothing more than recovery after human disturbance and exploitation (Poncet and Poncet 1987). Adelies, in fact, have declined noticeably at several localities on the Antarctic Peninsula, a change considered "unexplainable" by Poncet and Poncet (1987). This raises an interesting challenge to the whale reduction hypothesis: If the decrease of baleen whale stocks actually led to a krill surplus, why have populations of the ecologically similar Adelies residing in the same geographical areas shown such different responses?

Here we propose that the answer to this question does not rest with the idea of a krill surplus. Instead, we suggest

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Key point: If the decimation of baleen whale populations did in fact lead to a "krill surplus", why were krill-dependent , top predator populations exhibiting such dichotomous trends?

The man!

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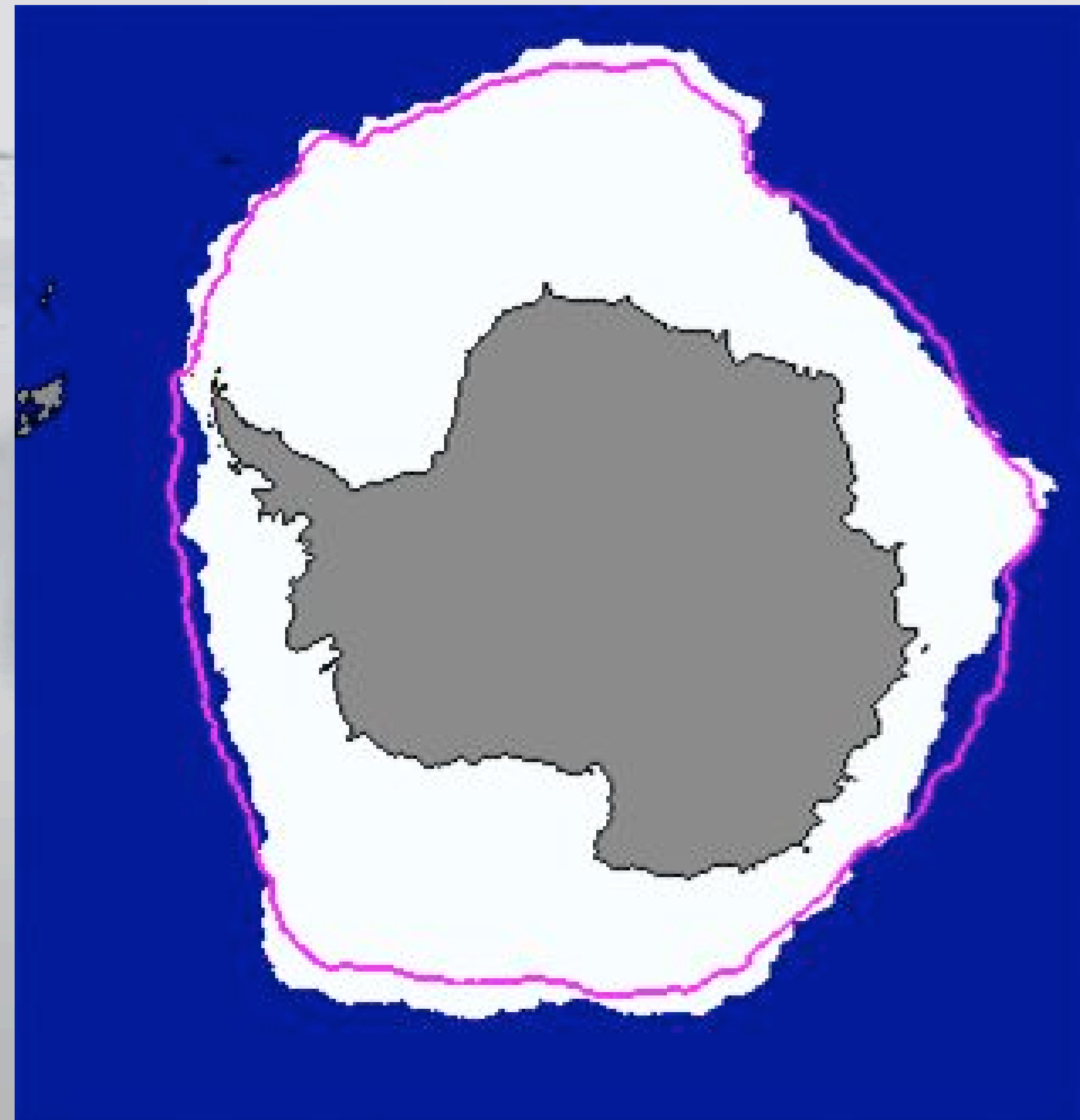
"...the day bird people have something to tell us about climate warming is perhaps the day logic in climate science is abandoned..."

Anonymous Reviewer, Nature

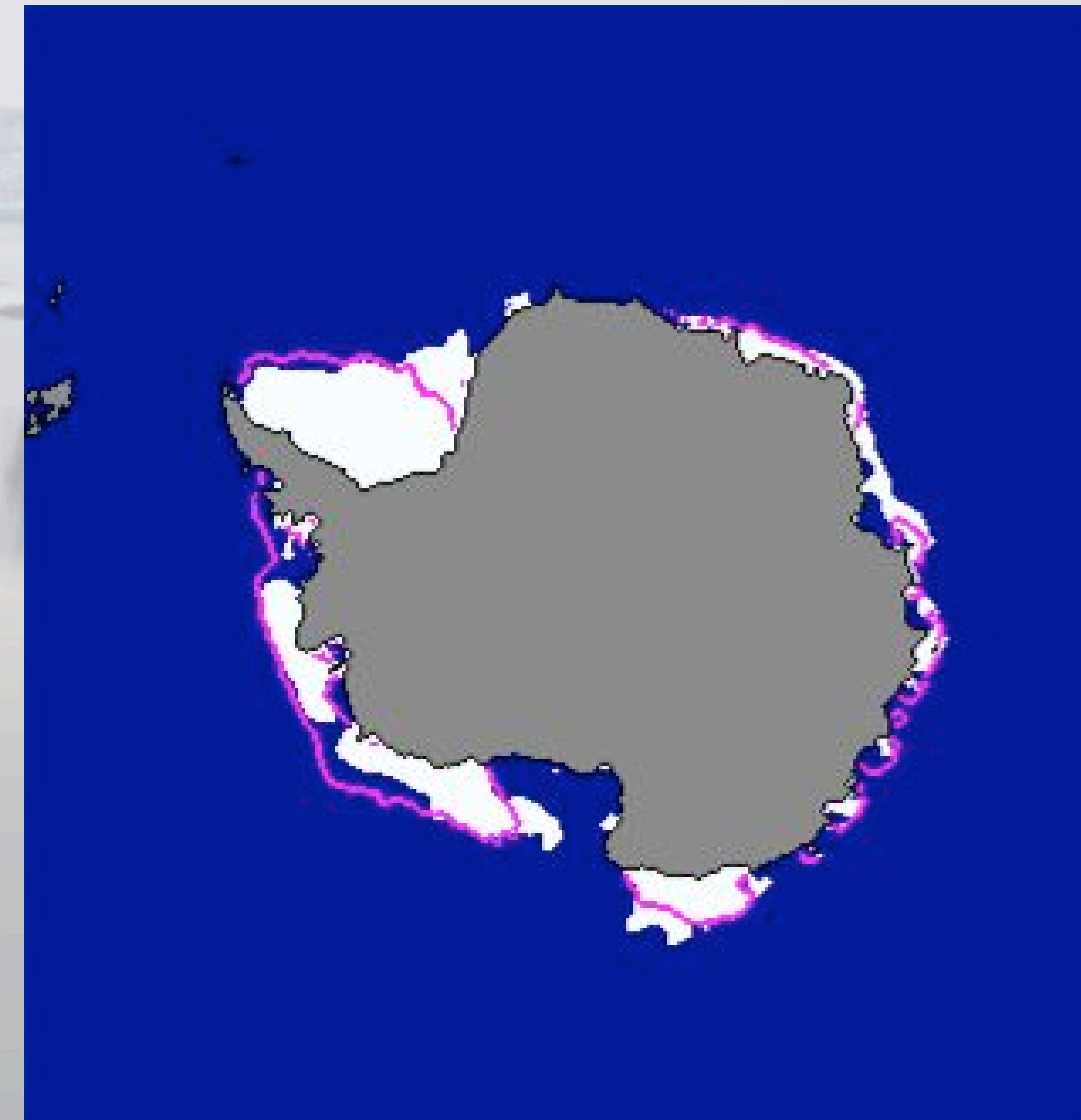
"...a paper that creates this kind of controversy should be positive for science and the journal..."

G. Hempel, Editor, Pol. Biol.

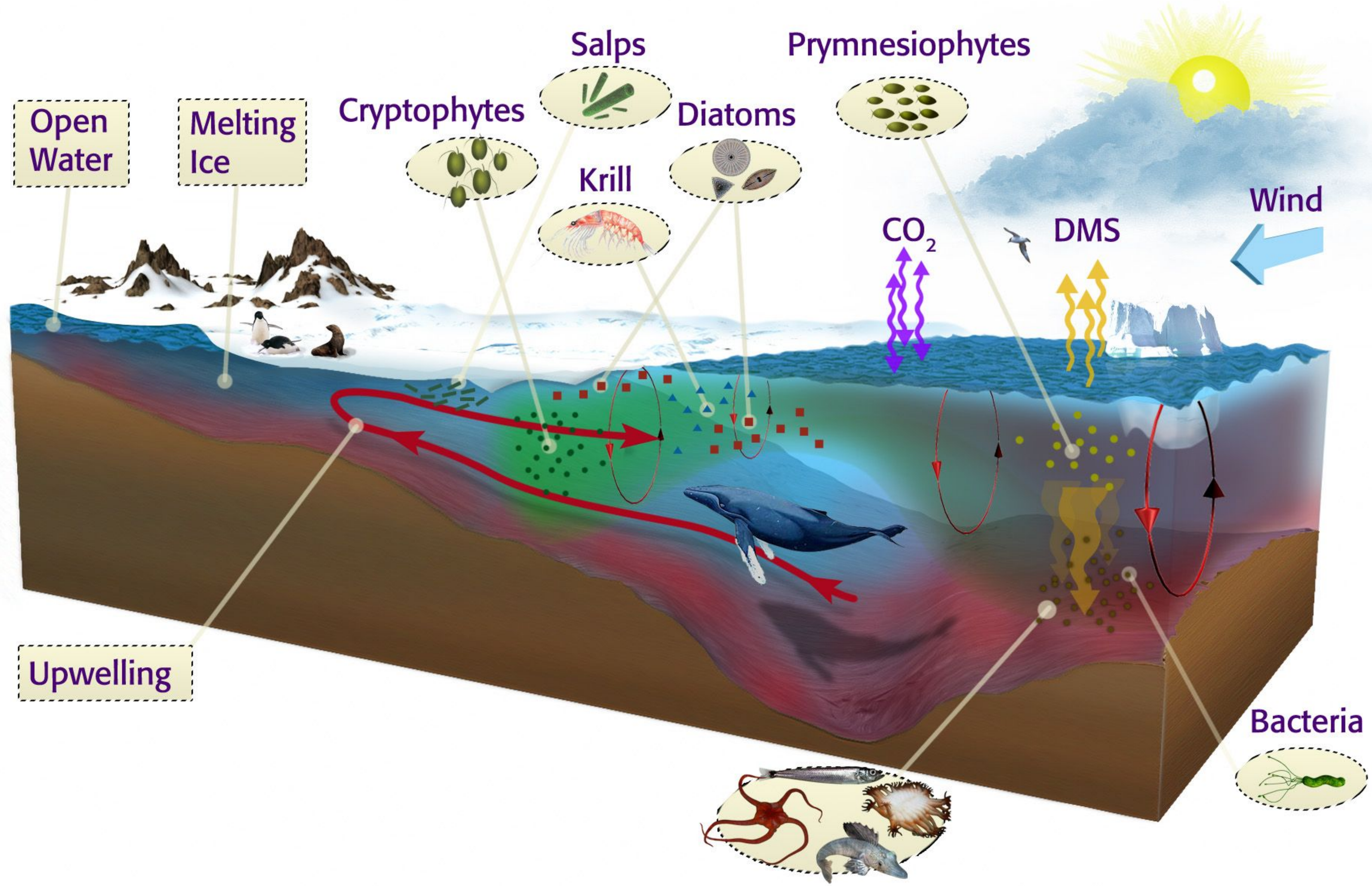
The central hypothesis when the LTER began was that sea ice timing and magnitude structure the productivity and composition of the Antarctic ecosystem. The ice dynamics are driven by large-scale interactions of the atmosphere and ocean.



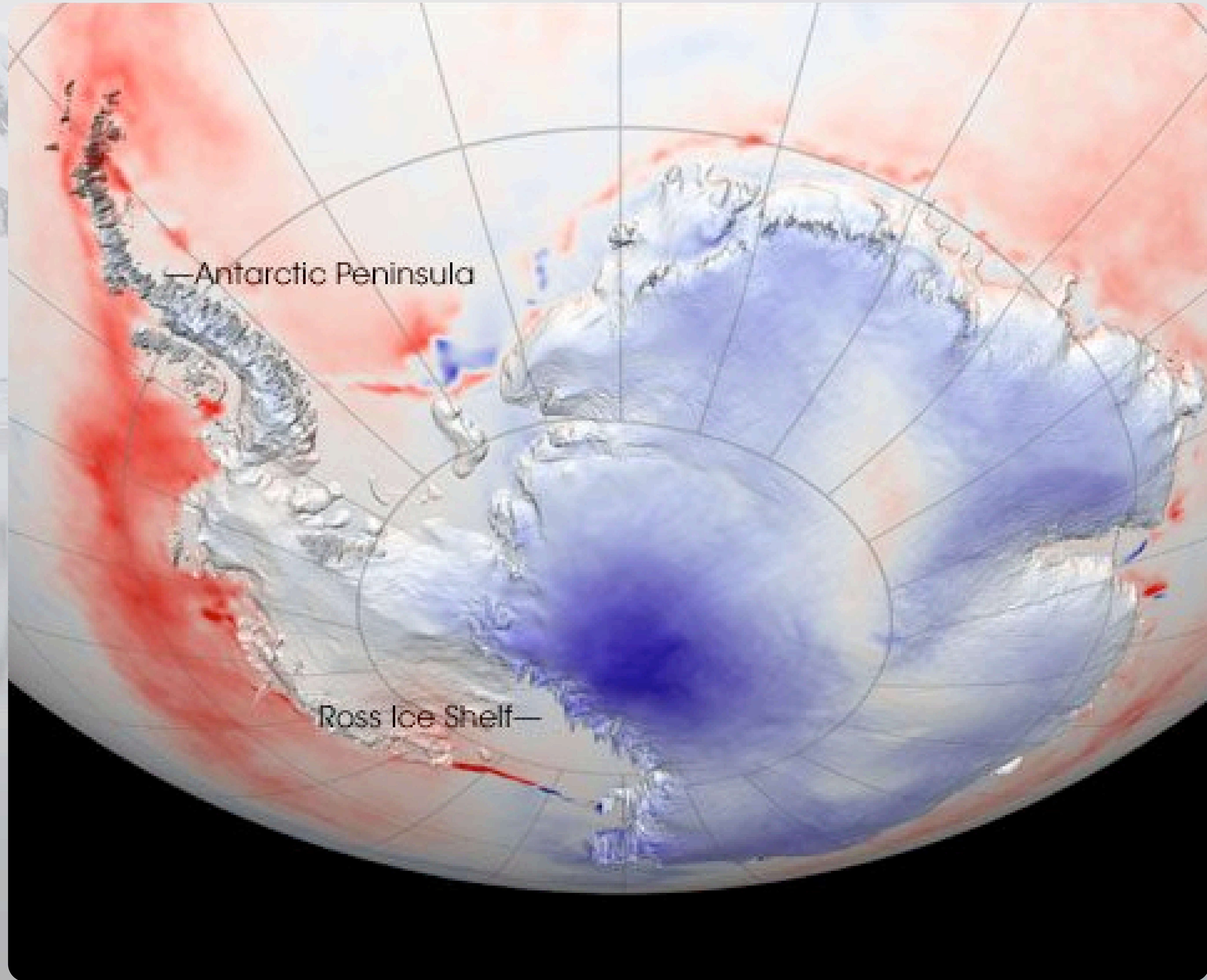
Winter 2007



Summer 2007

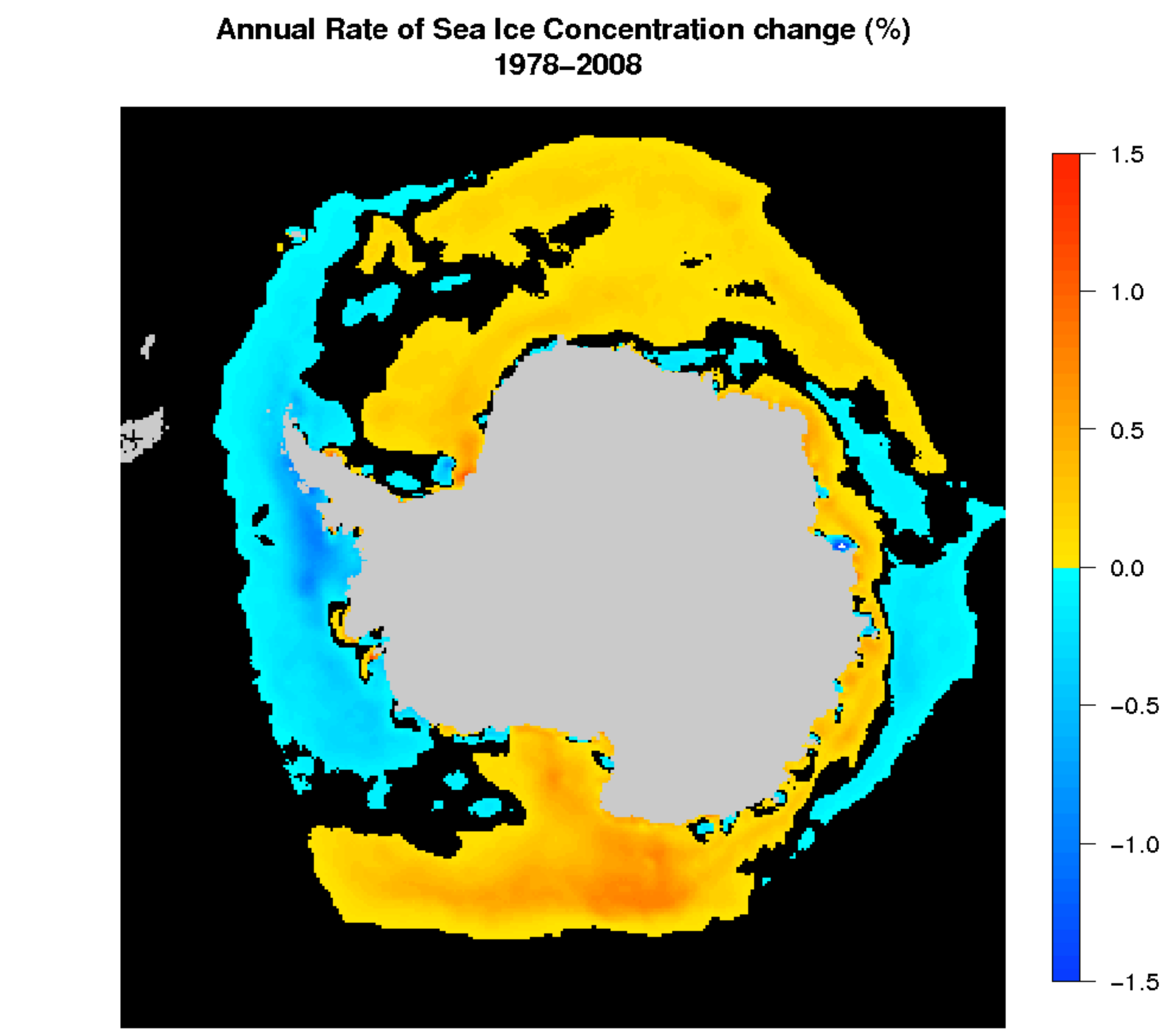


Open Water
Melting Ice
Cryptophytes
Salps
Krill
Diatoms
Prymnesiophytes
CO_2
DMS
Wind
Upwelling
Bacteria



Temperature Trends (degrees C per year)

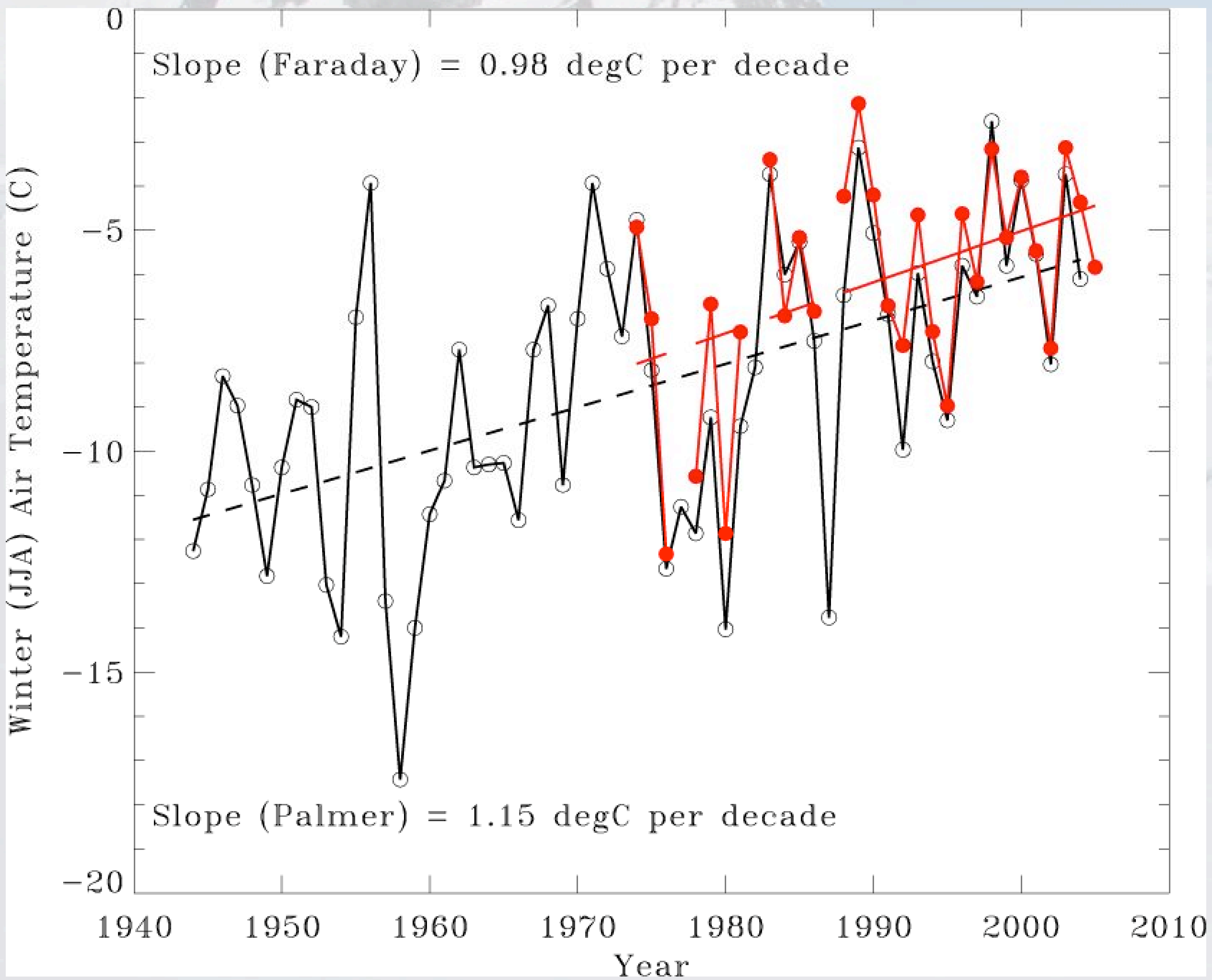
10 year analysis annual trends



ice decline

The WAP peninsula is experiencing the largest winter warming on Earth

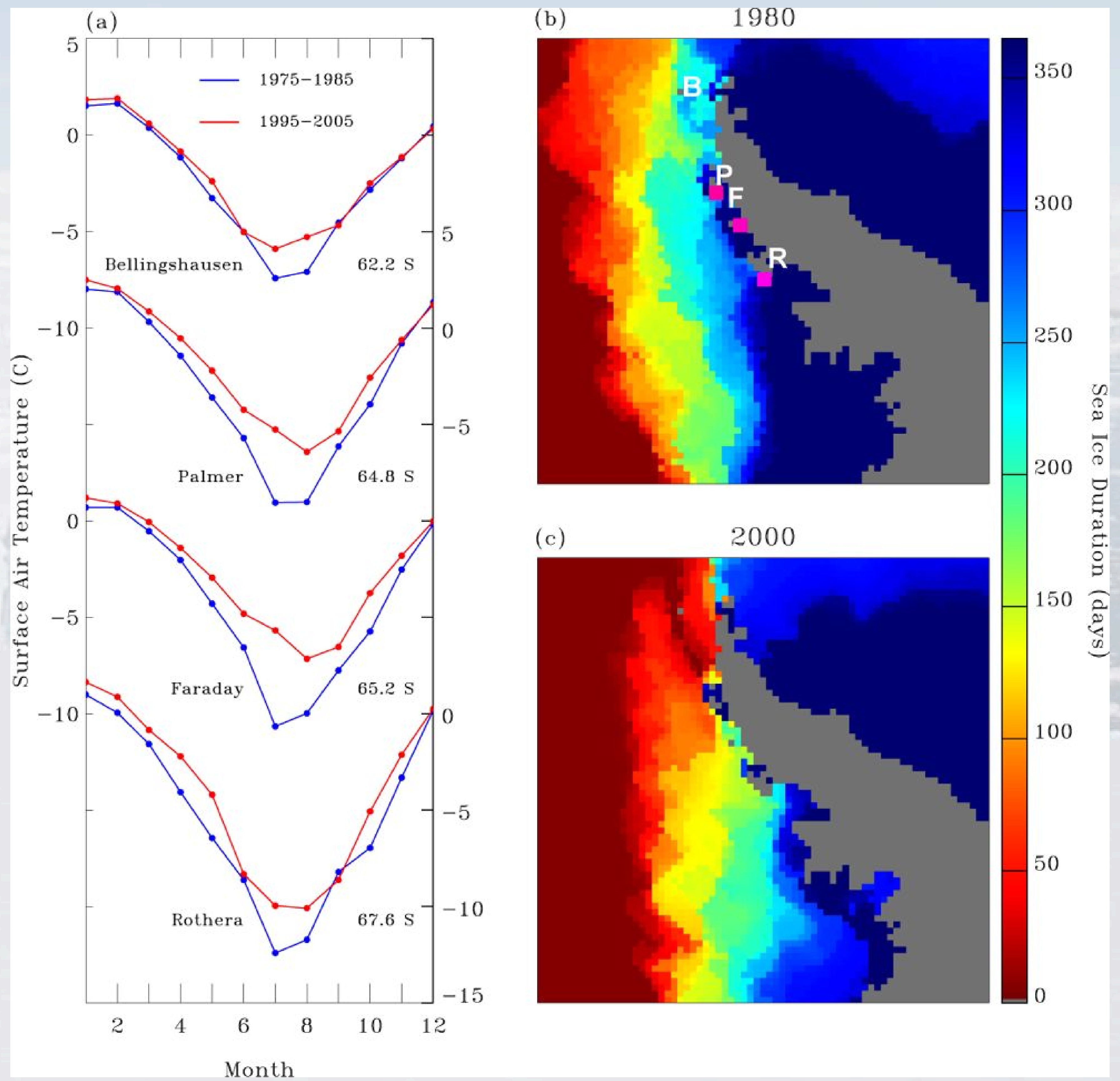
Mean Winter Temperatures



Black is British Faraday & Ukraine Vernadsky Station
Red is US Palmer Station

Air temperature increases over the peninsula

Sea ice duration drops



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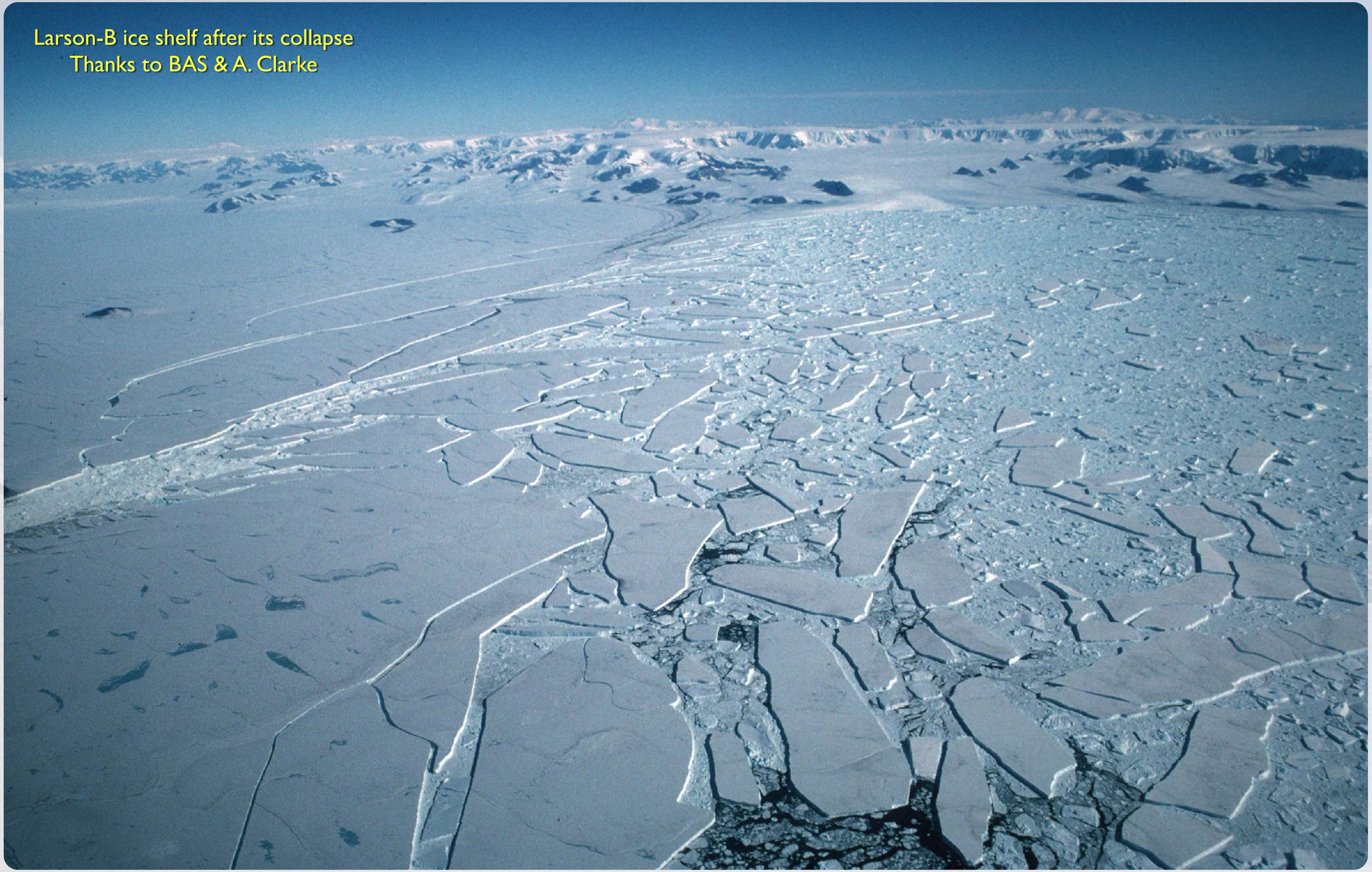
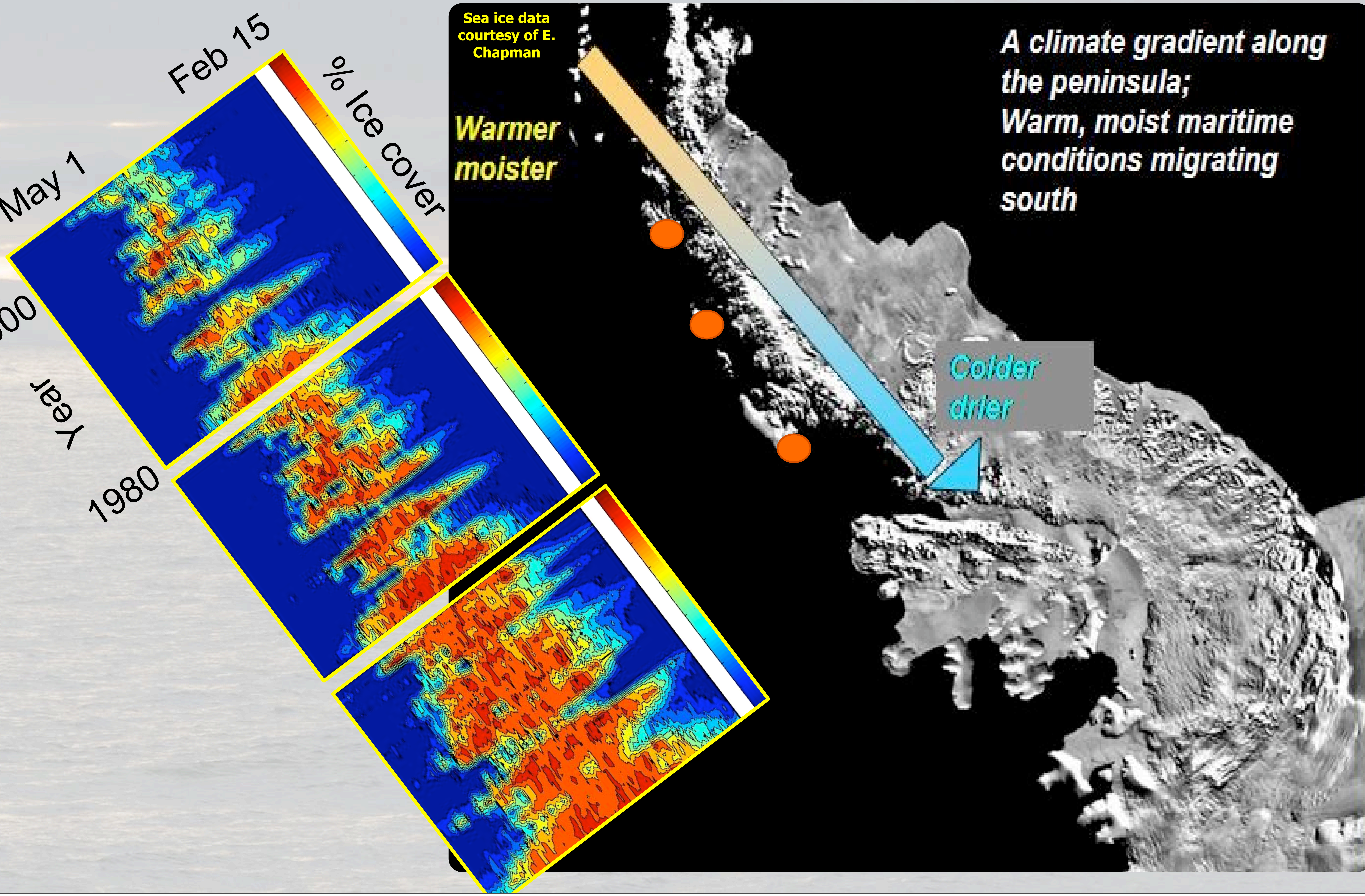


Melt pools on surface of King George VI Sound

(from a BAS twin otter, January 2004)

Seasonal ice has declined over the few decades resulting to a climate migration to the South



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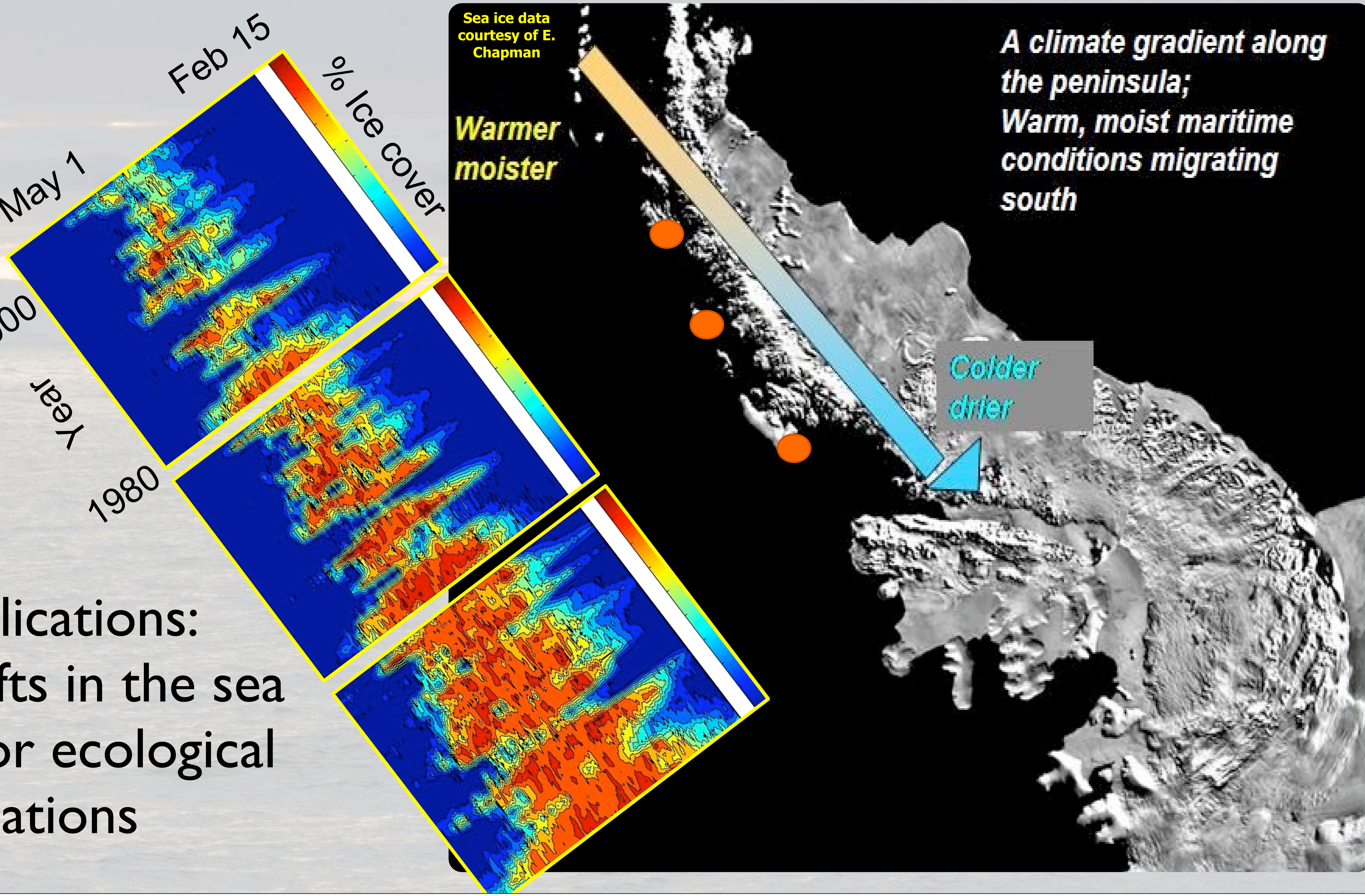


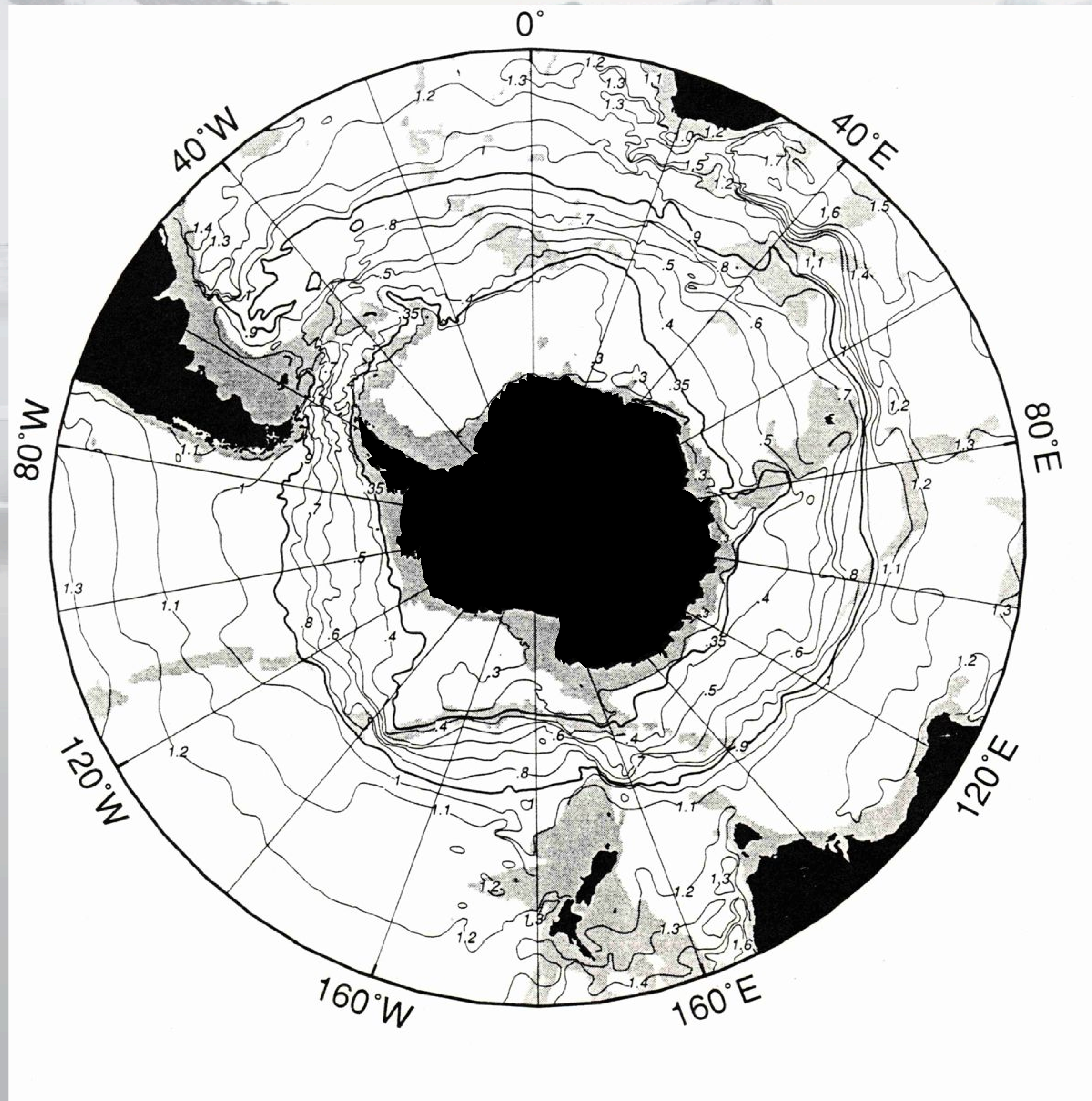
Key Implications:
Regional shifts in the sea ice has major ecological implications

1990


Palmer Station in the present
photo by Bill Fraser

Plants at Palmer Station, the greening of Antarctica

Heat input from Antarctic Circumpolar Current (ACC - world's largest ocean current = ~30,000 Niagara Falls). The heat is driven onto the shelf by intensification of upwelling-favorable winds.



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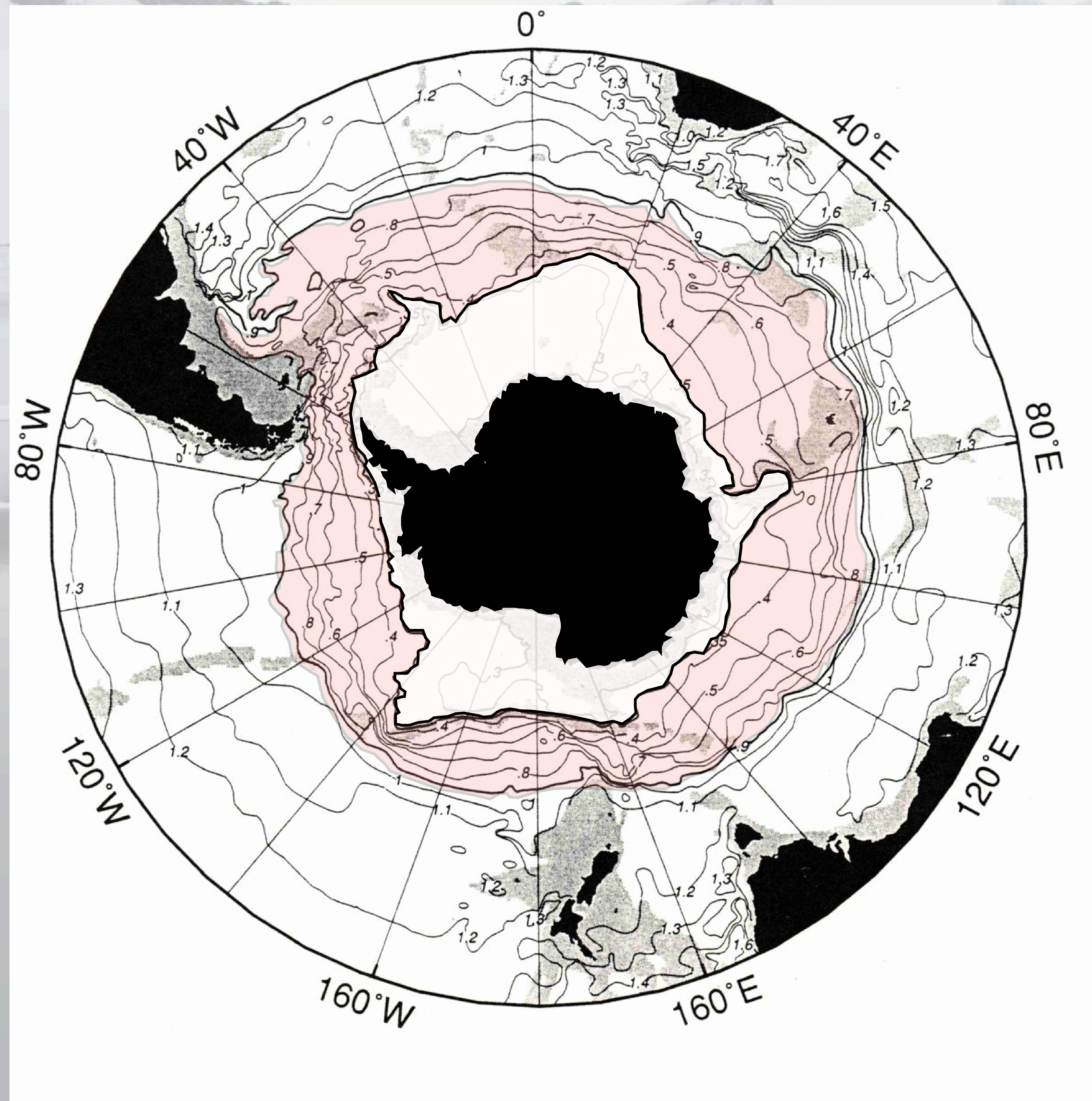

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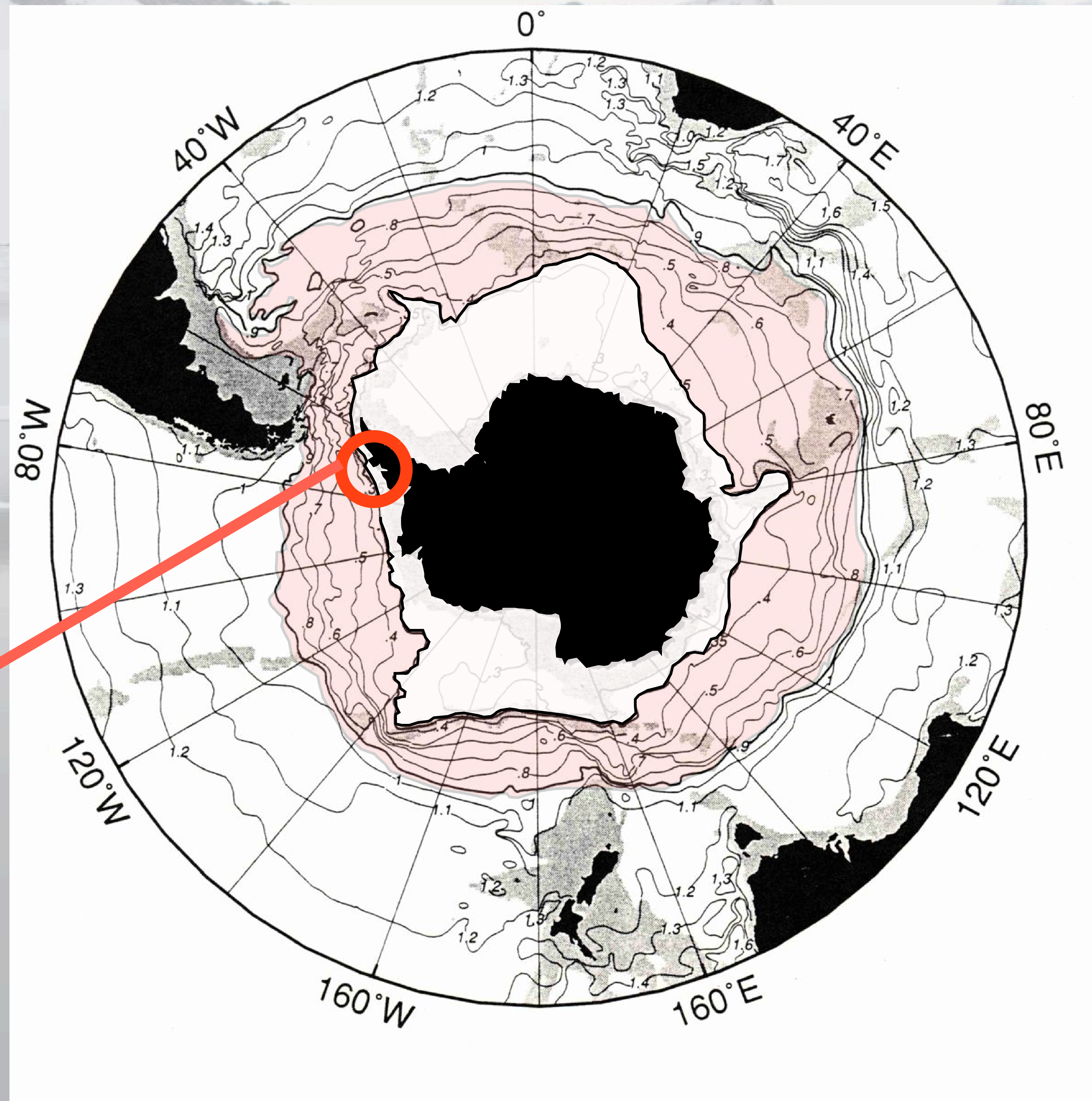
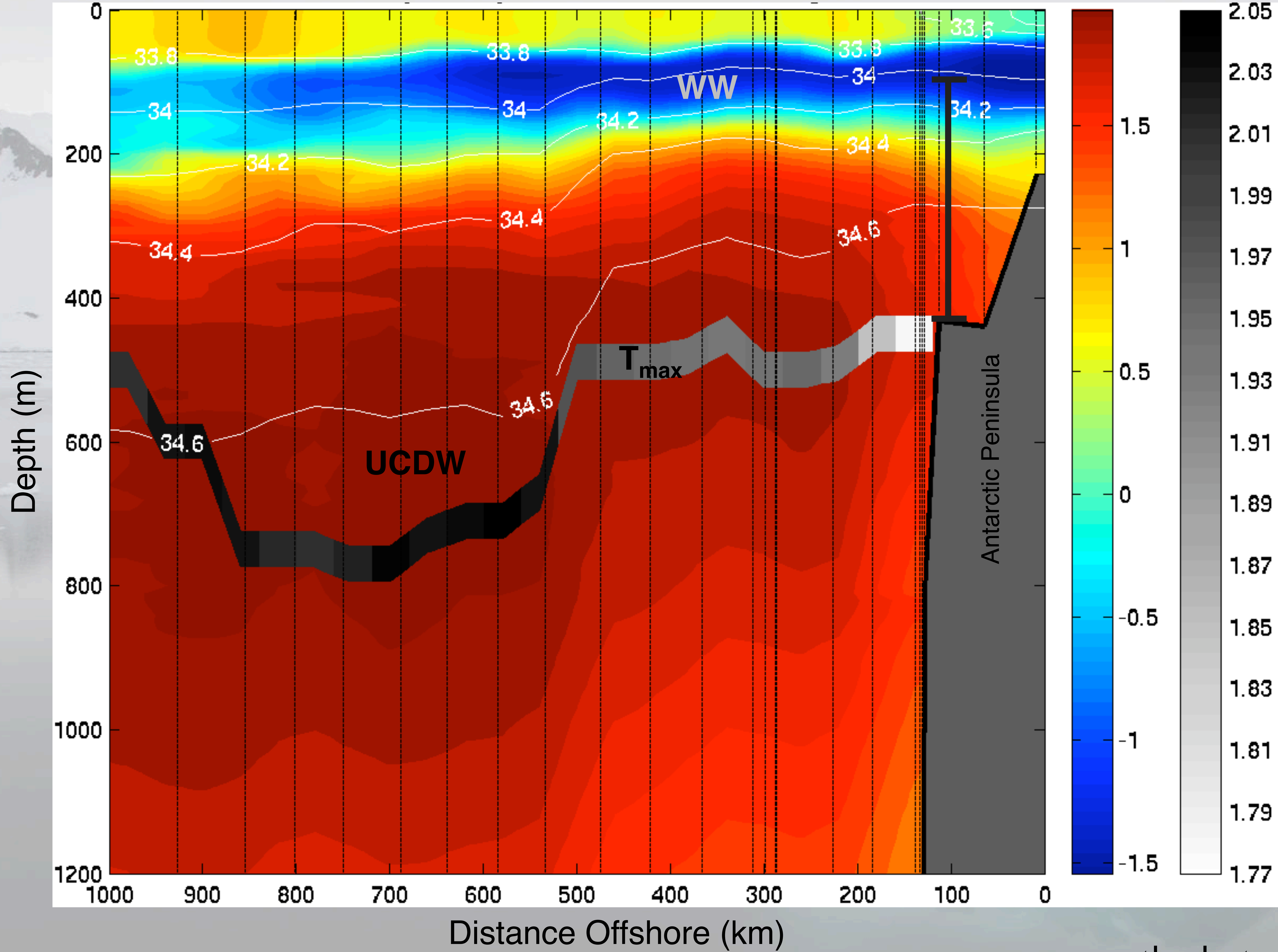
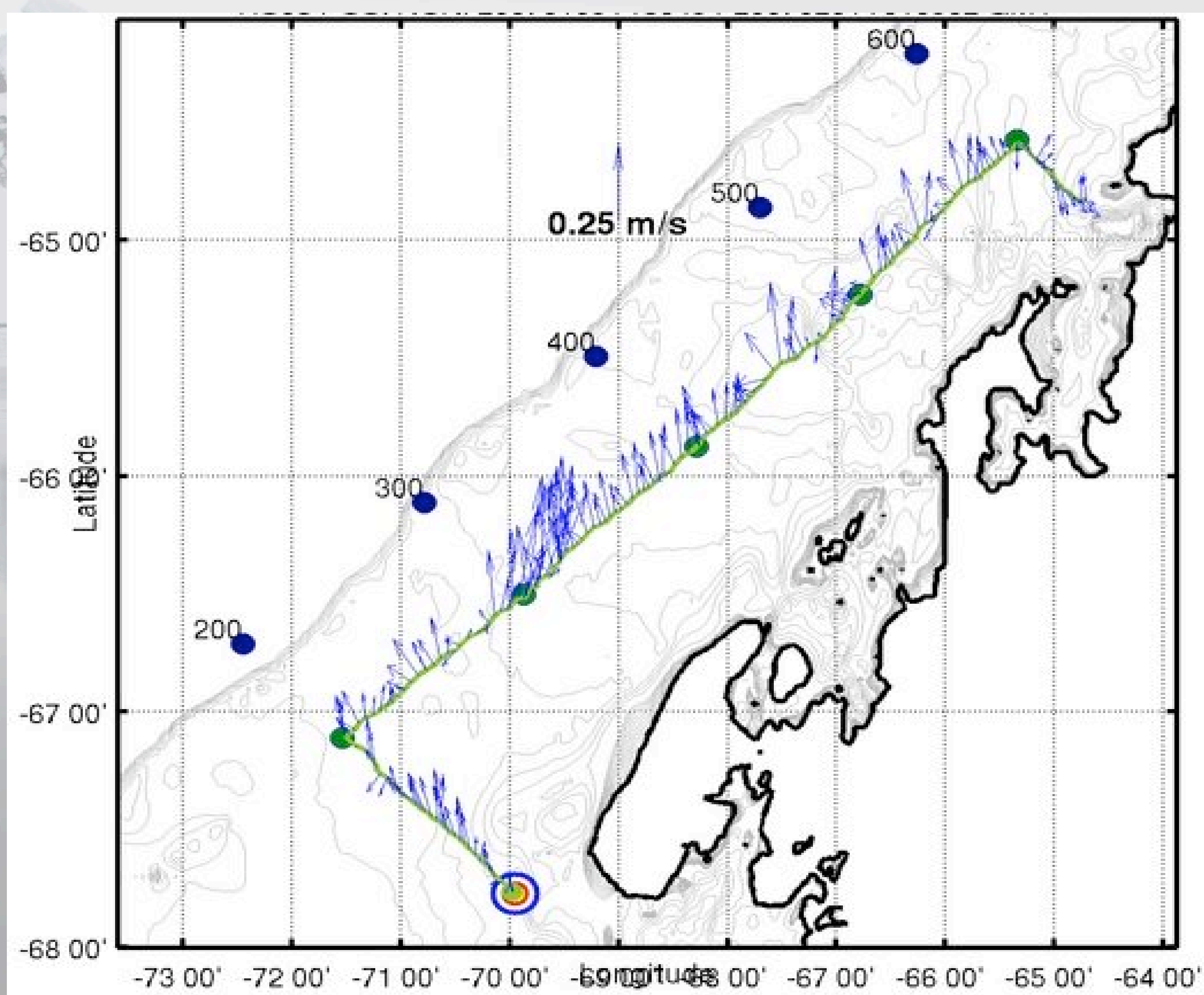


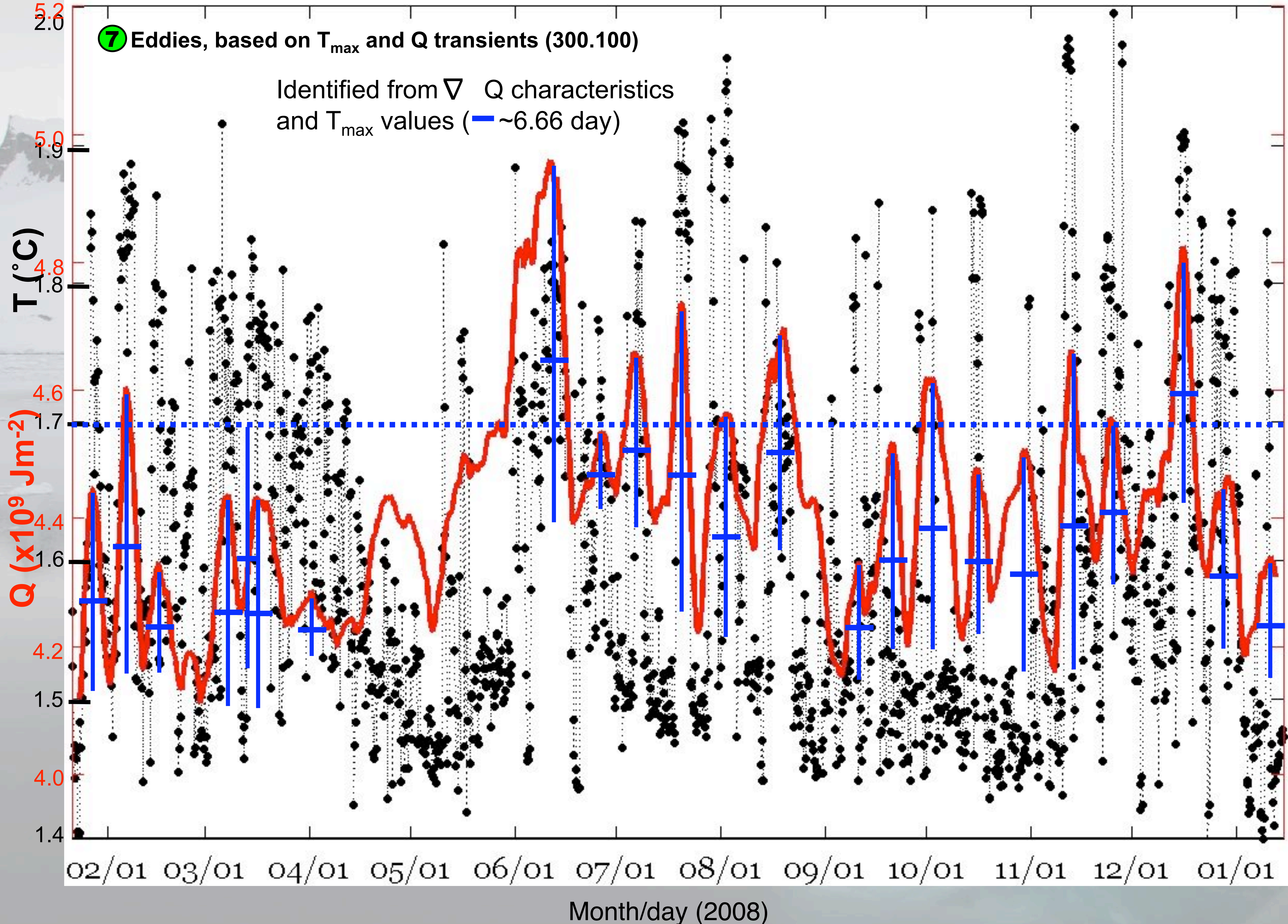
The WAP is the only location in the Antarctic where the ACC is adjacent to the shelf break. The ACC is Antarctica's warmest water



thanks to Doug Martinson

Upwelling favorable winds result in Ekman mass transport offshore





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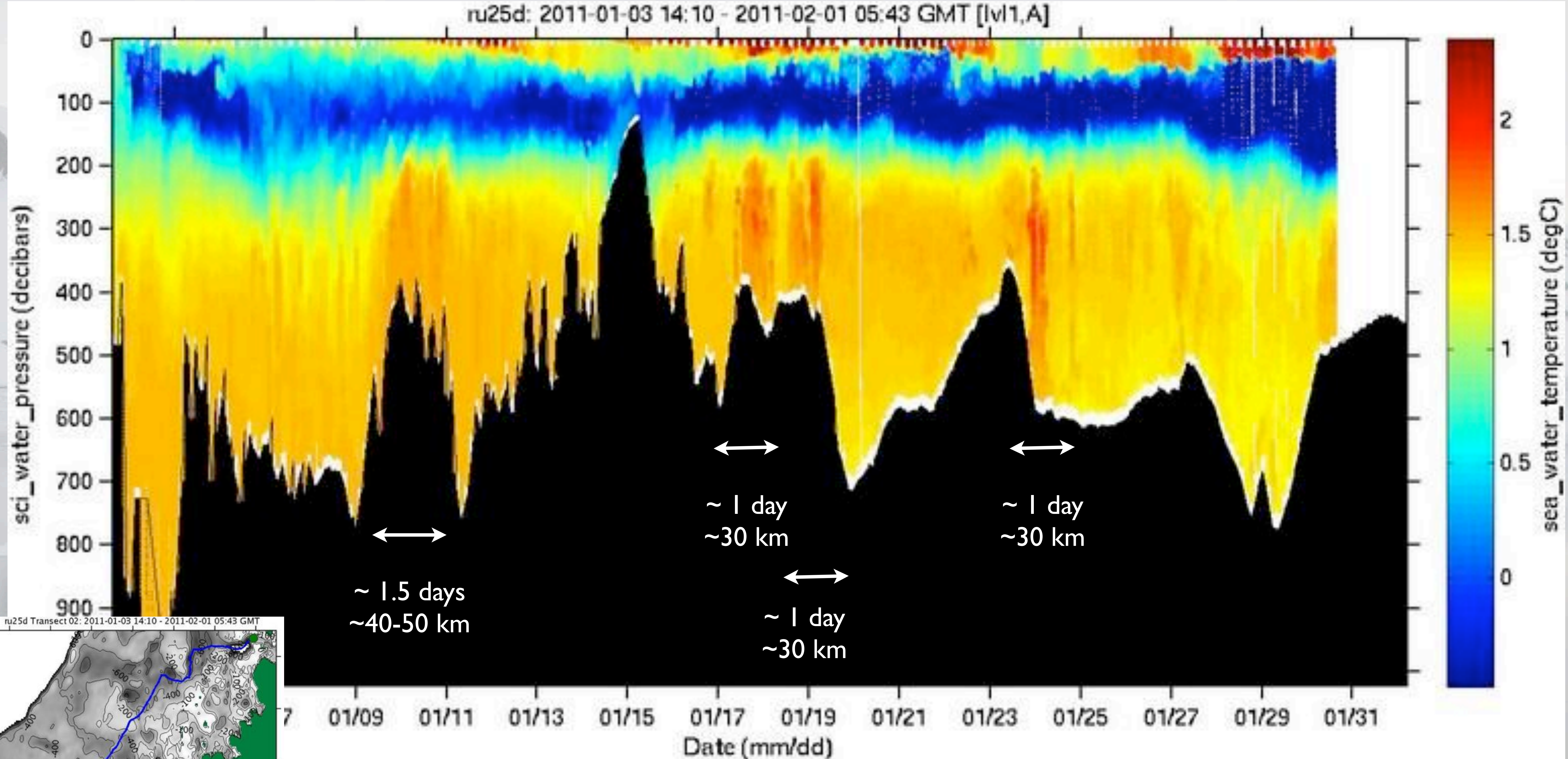
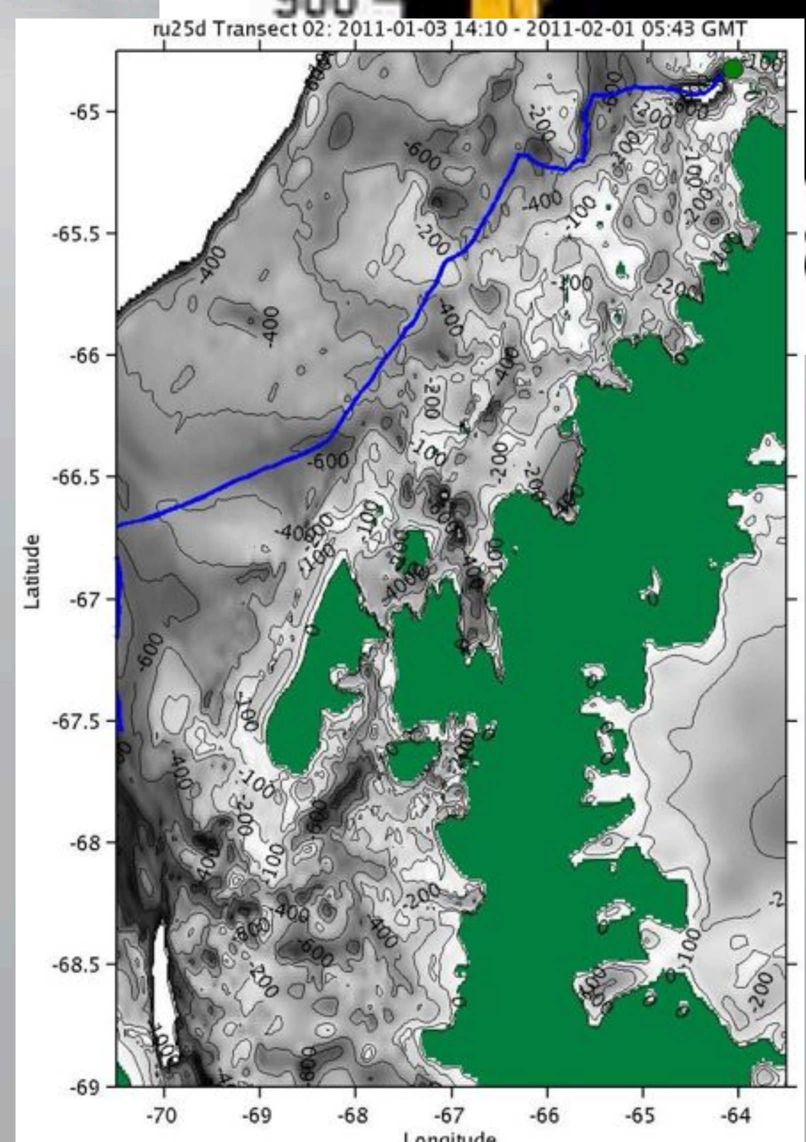
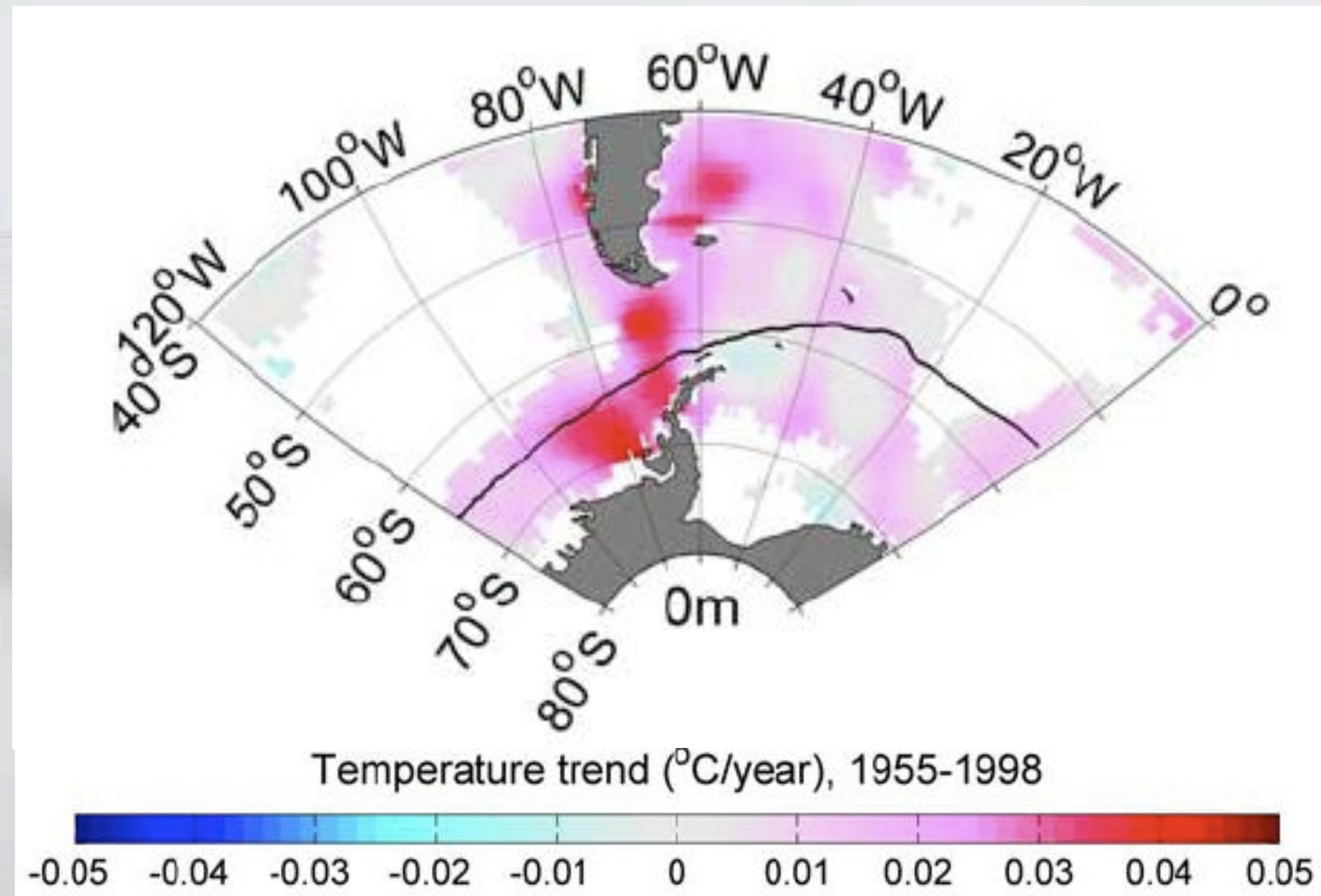




2011: Eddies moving across shelf?

Heating on the WAP is driven by circulation and intrusion of the of the ACC onto the WAP continental shelf.

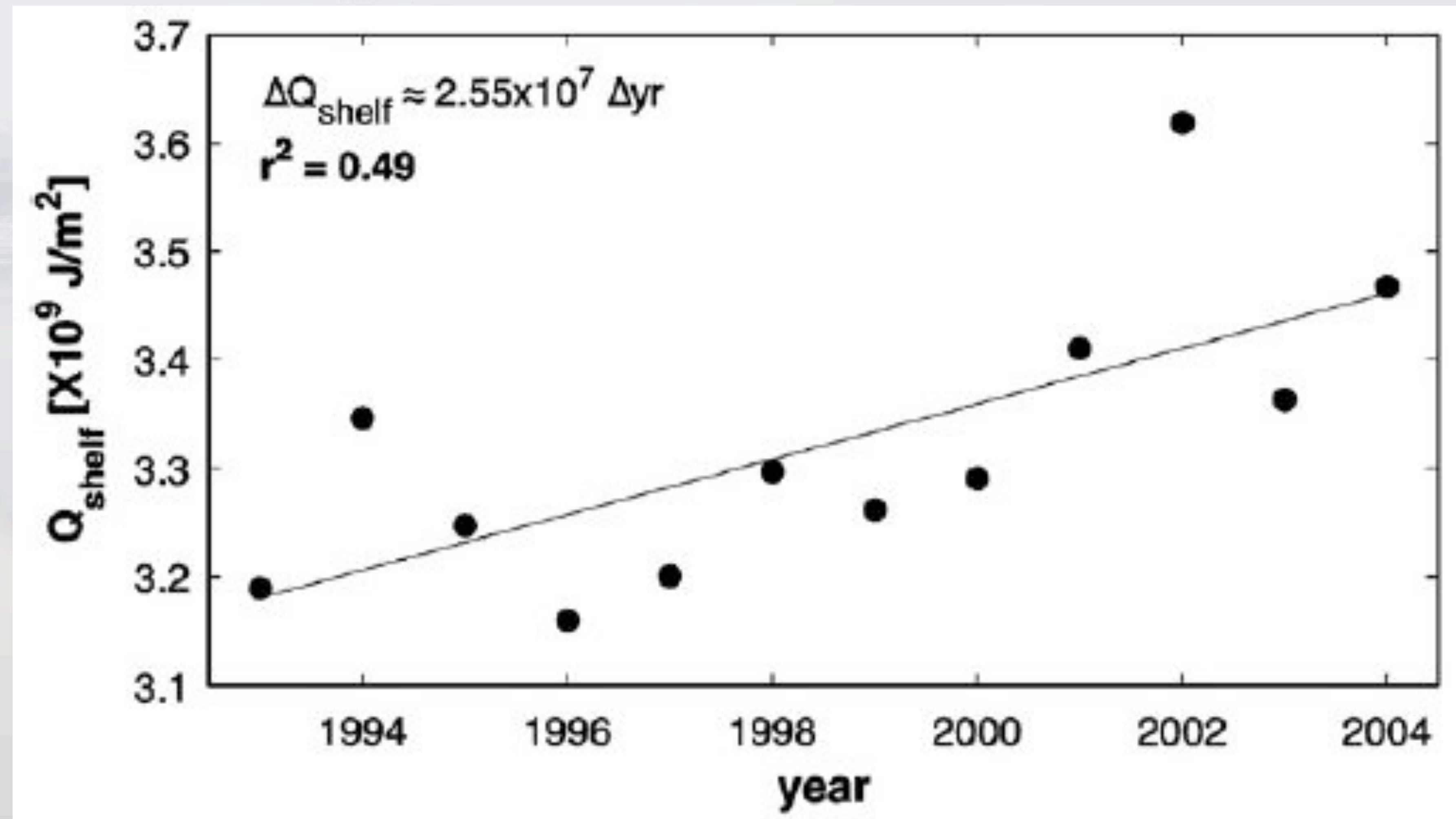
Meredith and King 2005



Summer sea surface temperature increasing +0.4 C/year

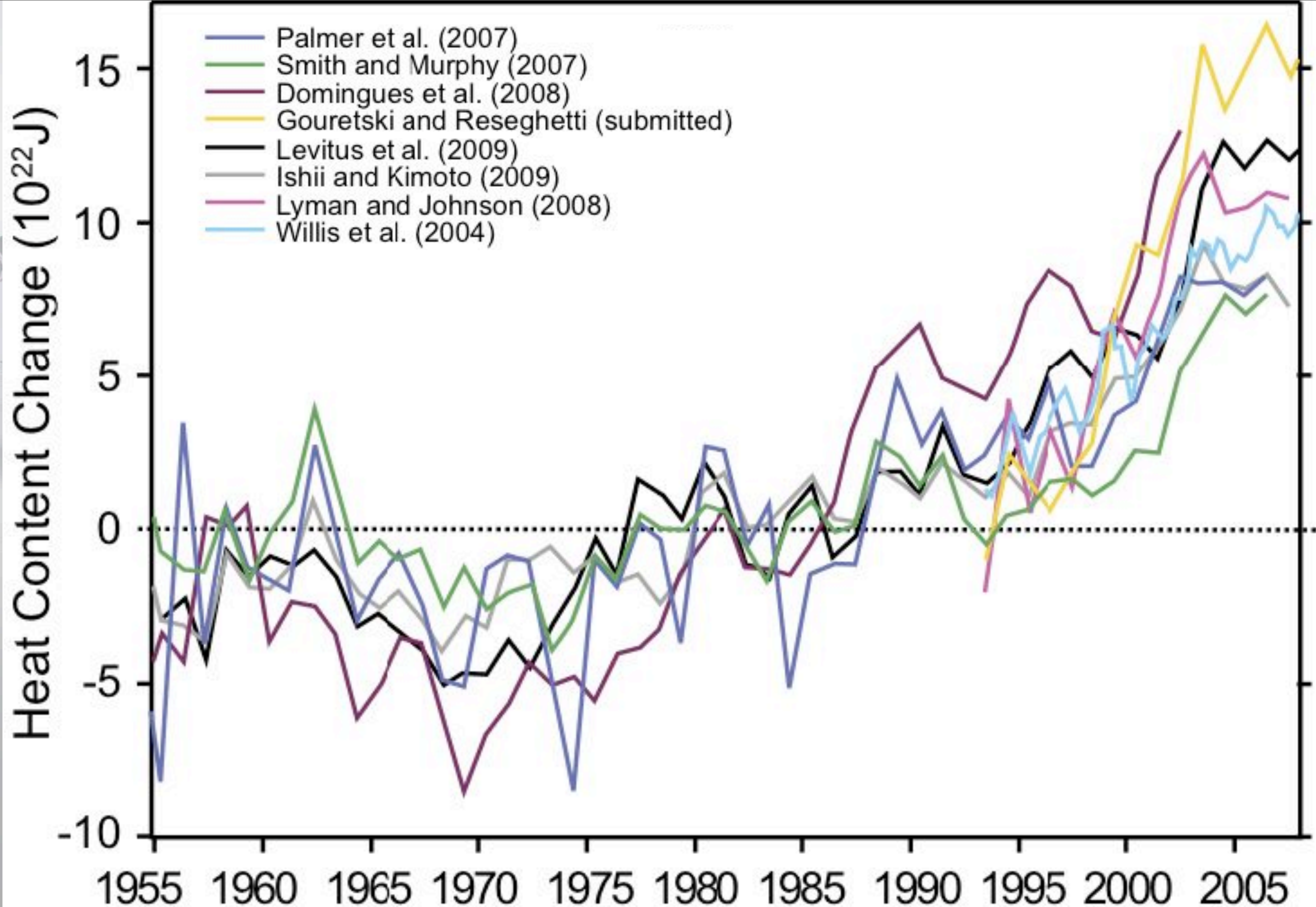
Evidence of solar ocean warming

Martinson et al. 2008

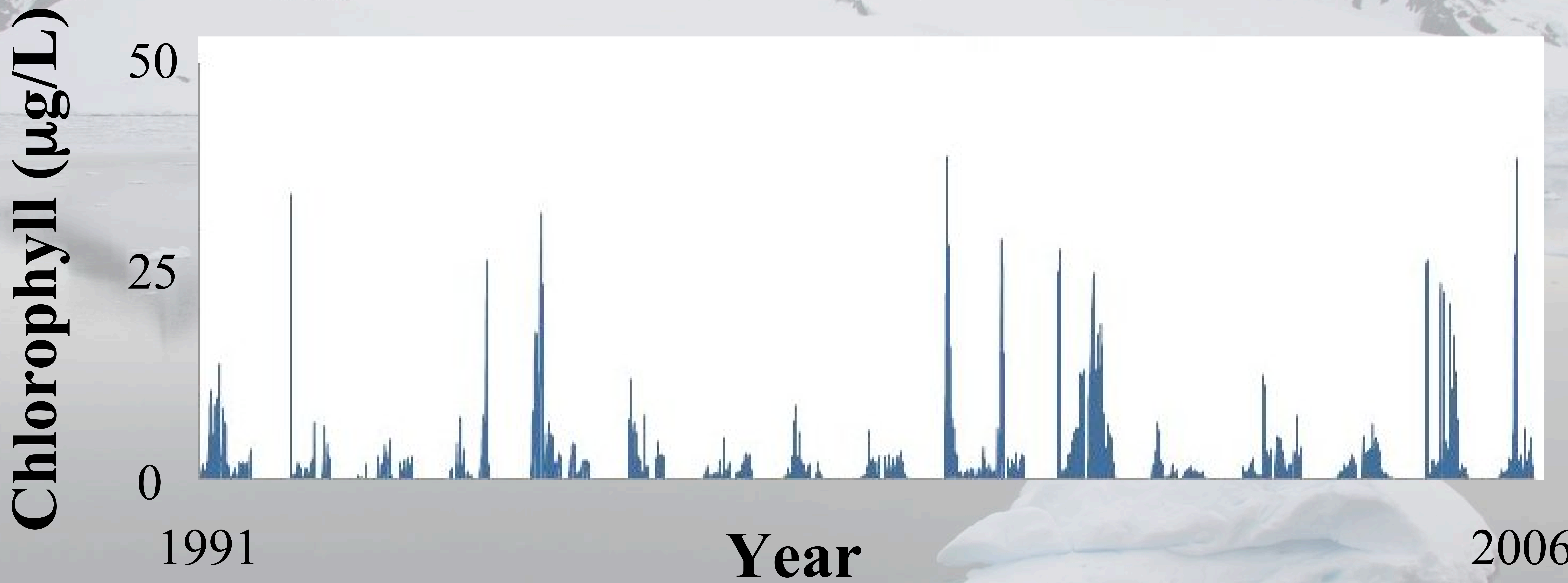


Ocean heat content increasing on the continental shelf of the WAP

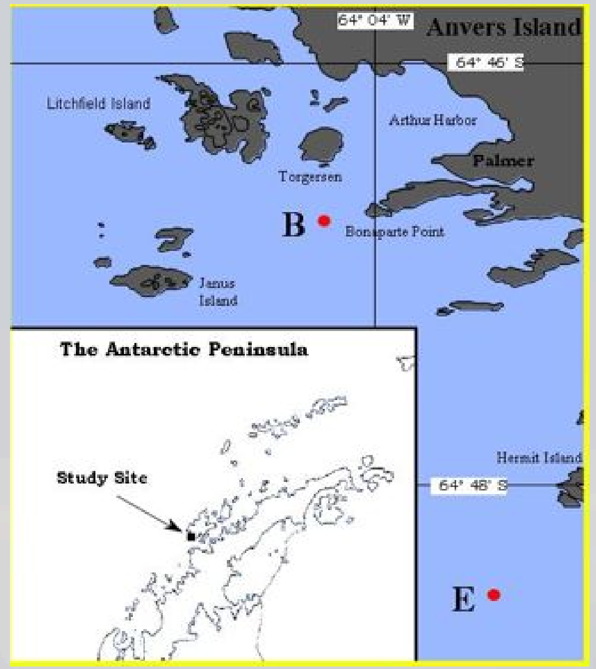
Evidence of increased upwelling of Circumpolar Deep Waters

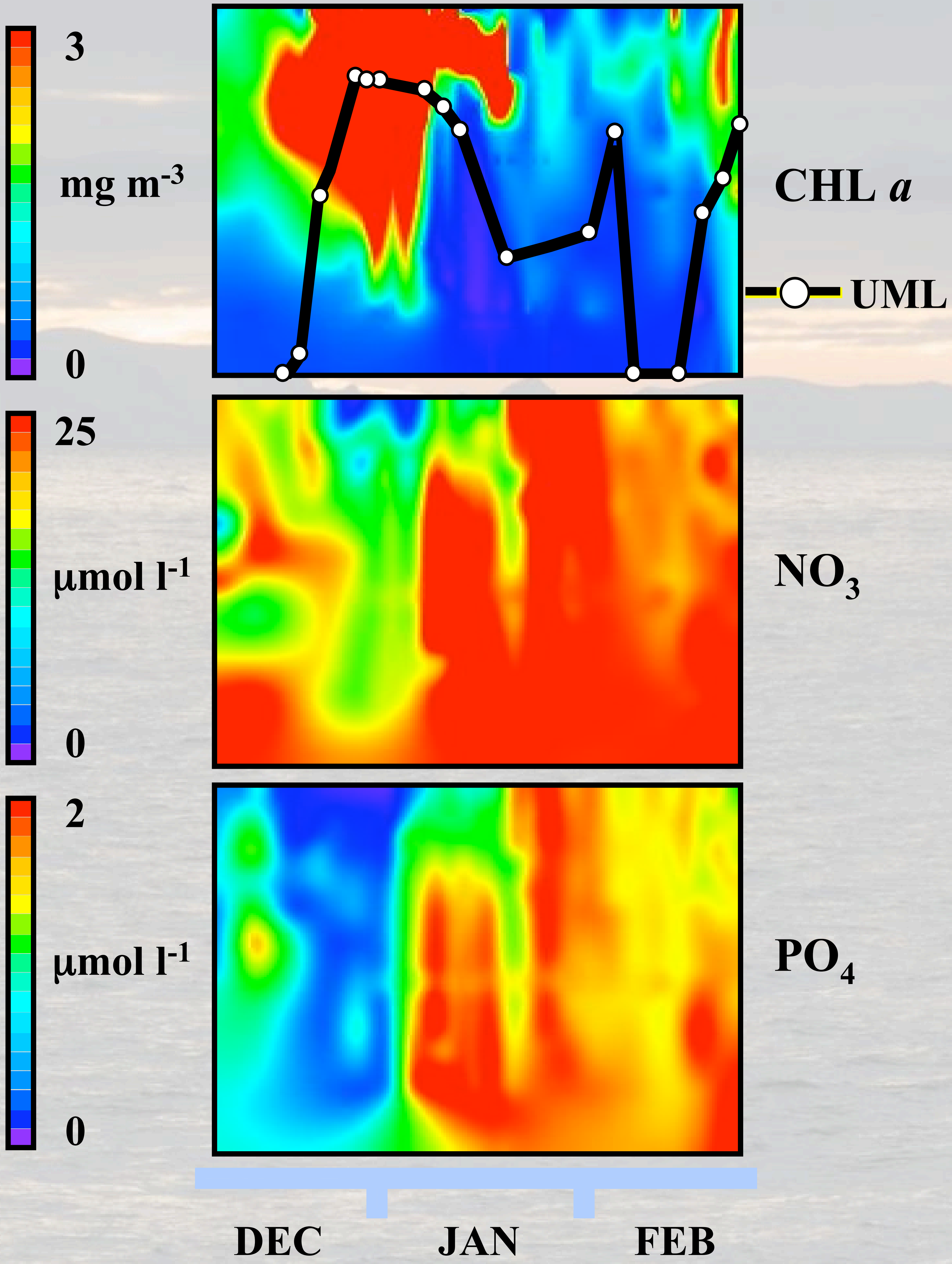

Palmer et al. (2007)
Smith and Murphy (2007)
Domingues et al. (2008)
Gouretski and Reseghetti (submitted)
Levitus et al. (2009)
Ishii and Kimoto (2009)
Lyman and Johnson (2008)
Willis et al. (2004)
Heat Content Change (10^{22}J)
15
10
5
0
-5
-10
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

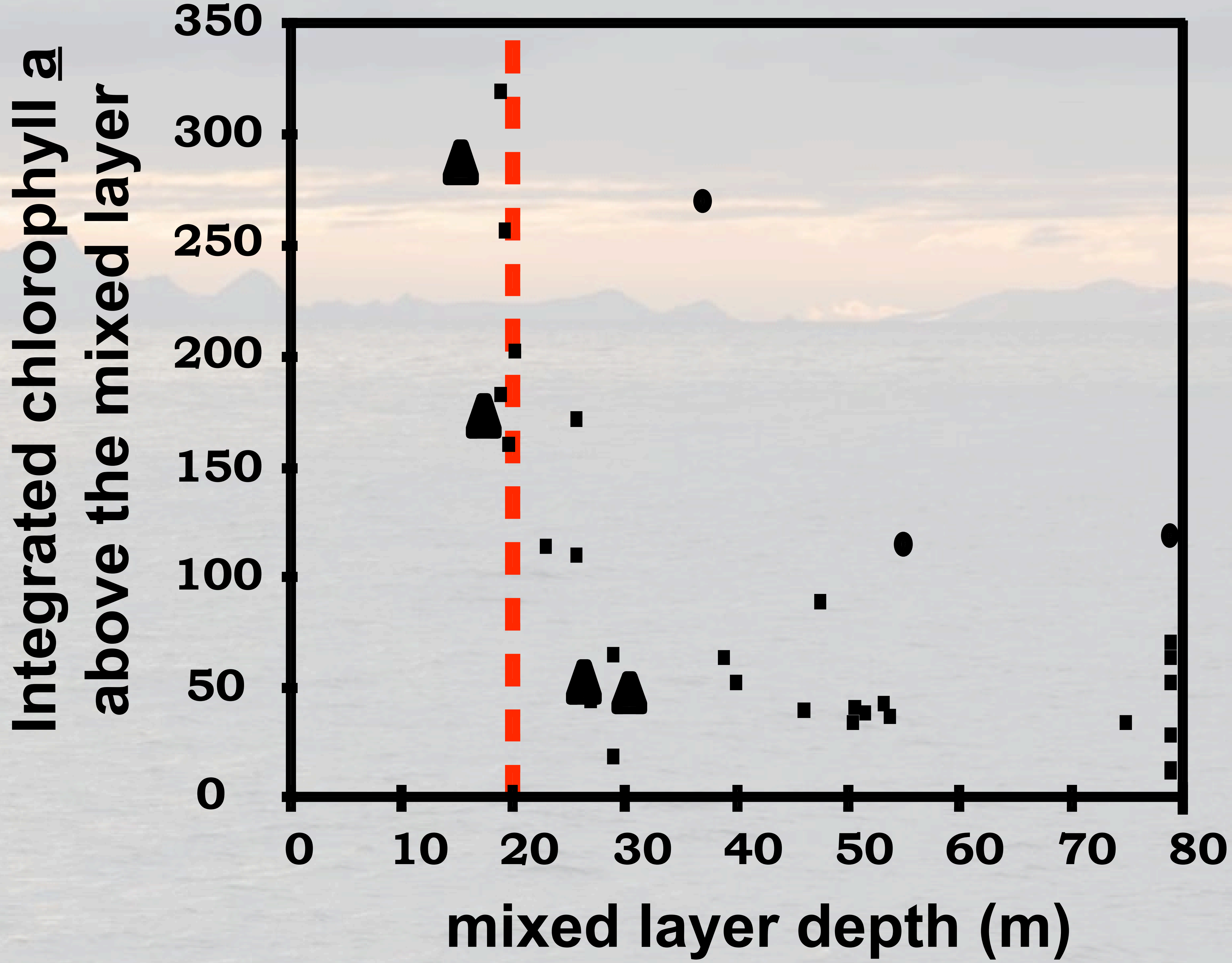
Palmer time series: Phytoplankton show large interannual variability



What regulates phytoplankton blooms in this region?








NSF
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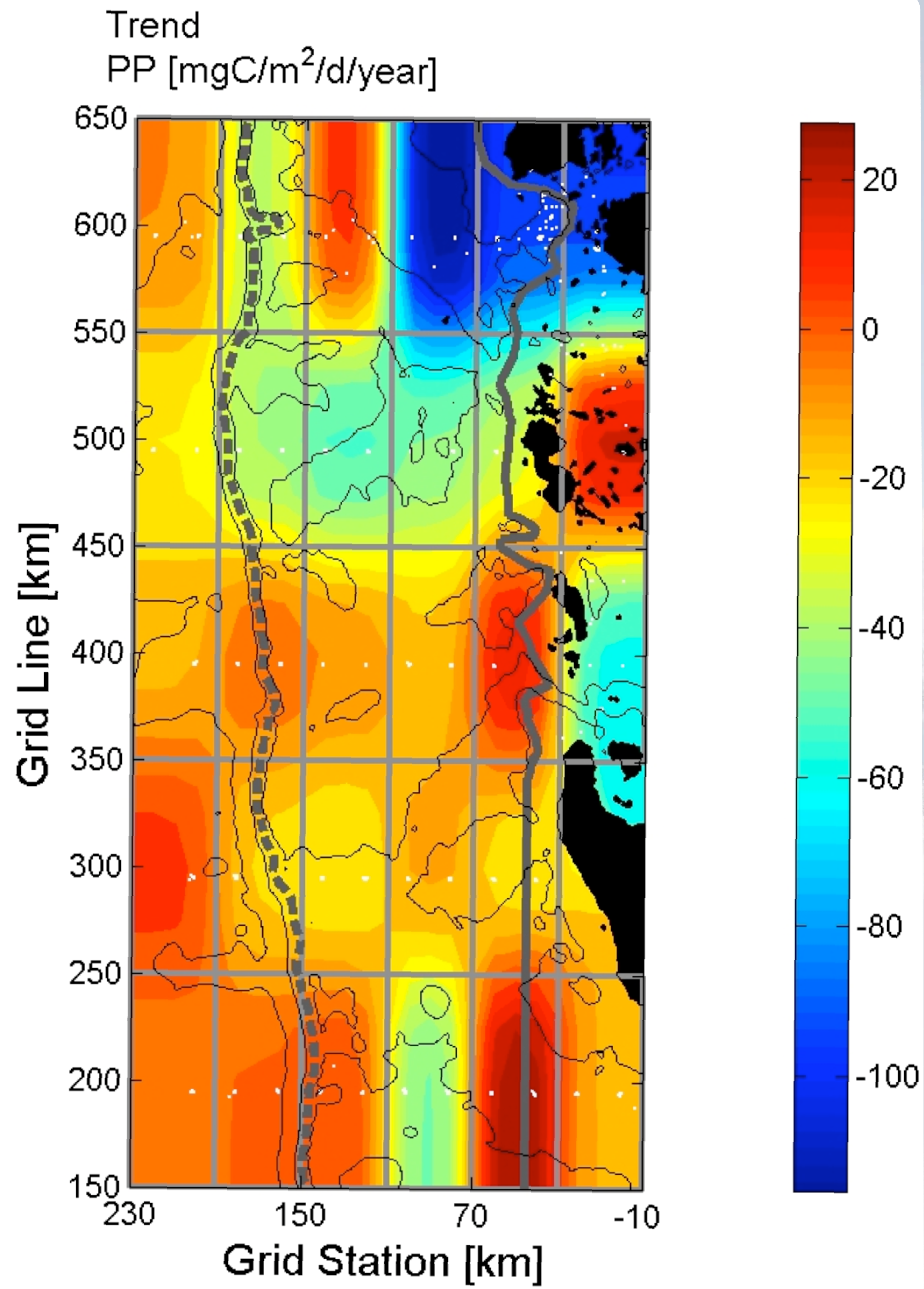
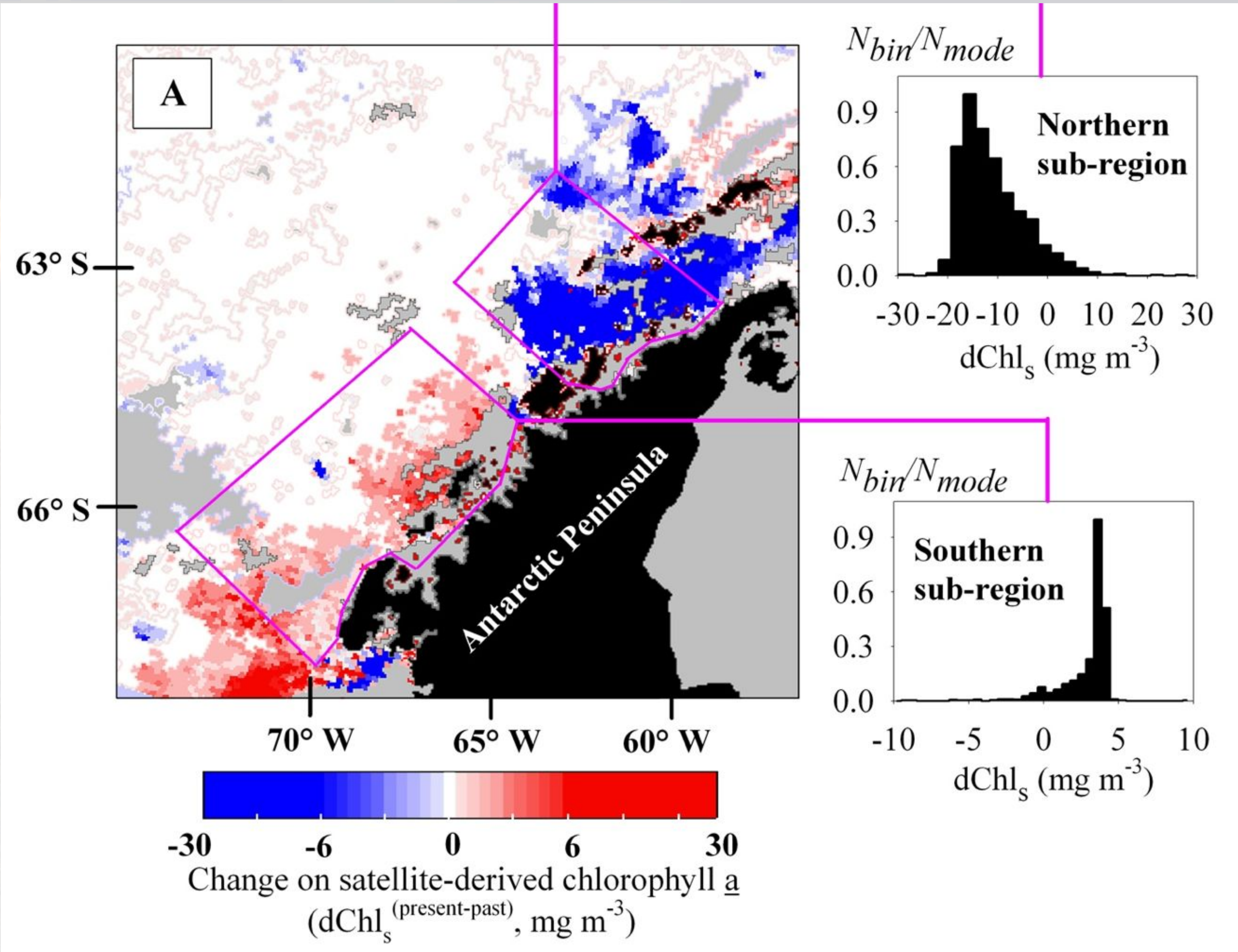
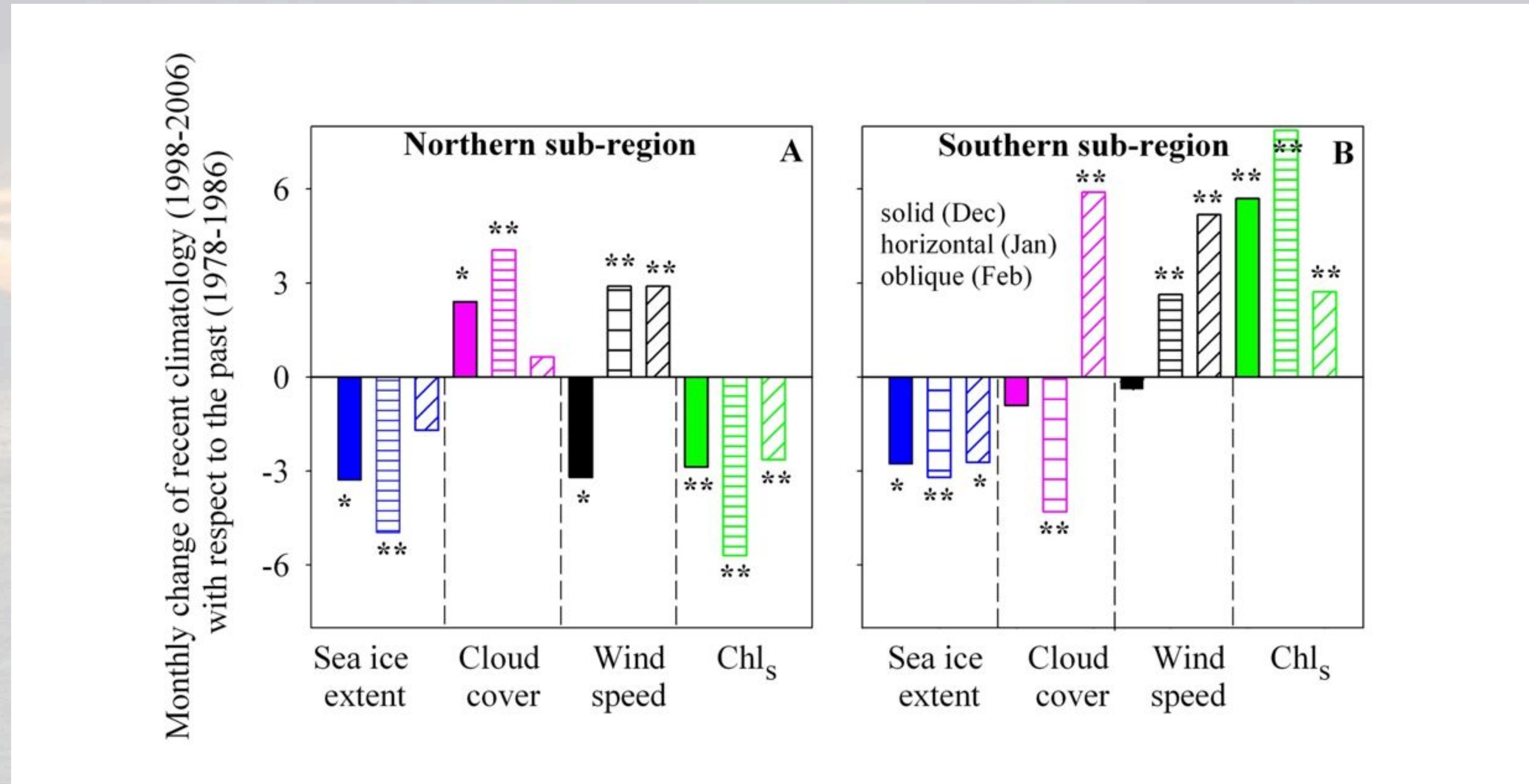


15 year time series of radio-carbon measurements also suggest a North & South gradient

Vernet et al. DSR 2008

The decadal changes have resulted changes in the phytoplankton

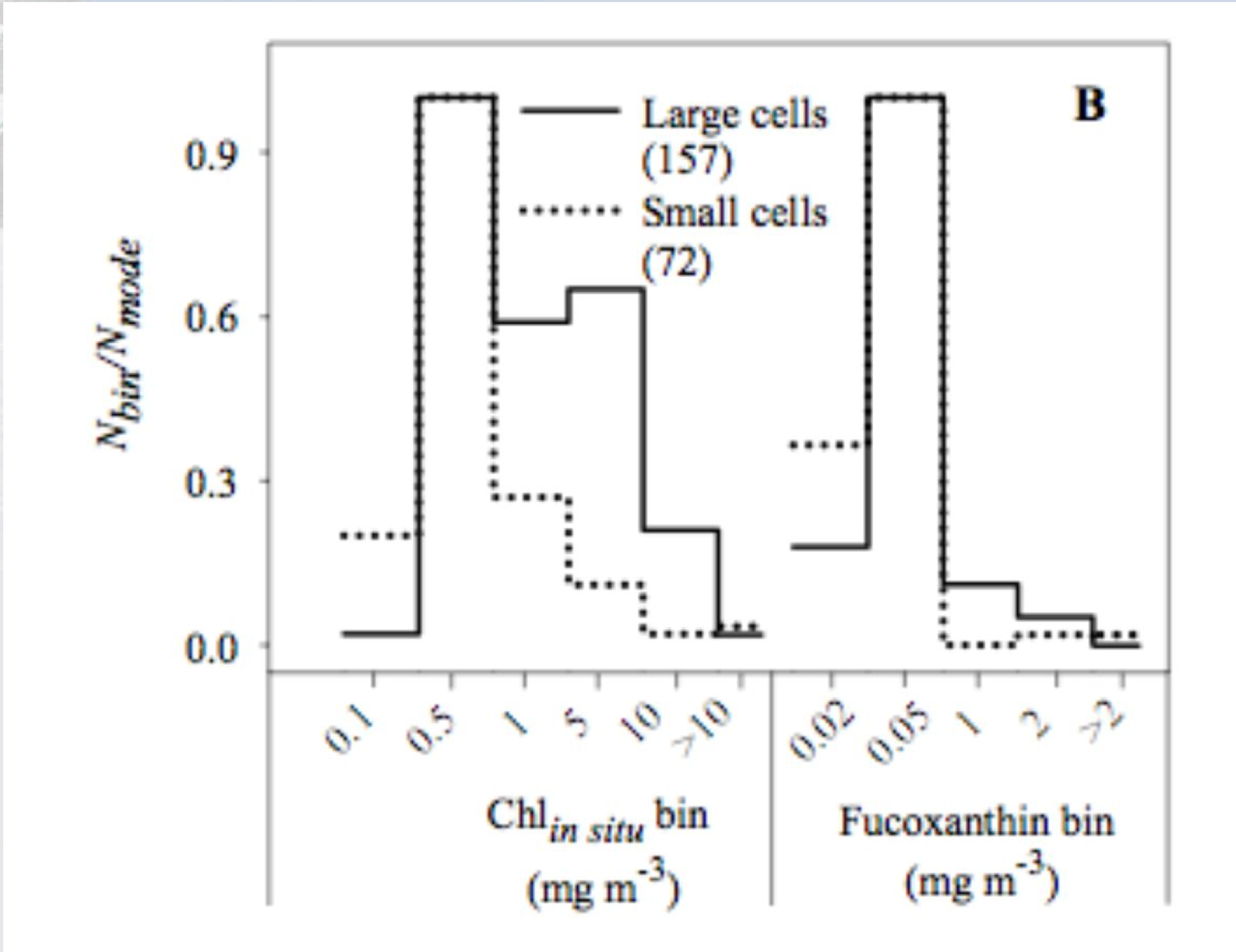




Montes Hugo et al. Science 2009

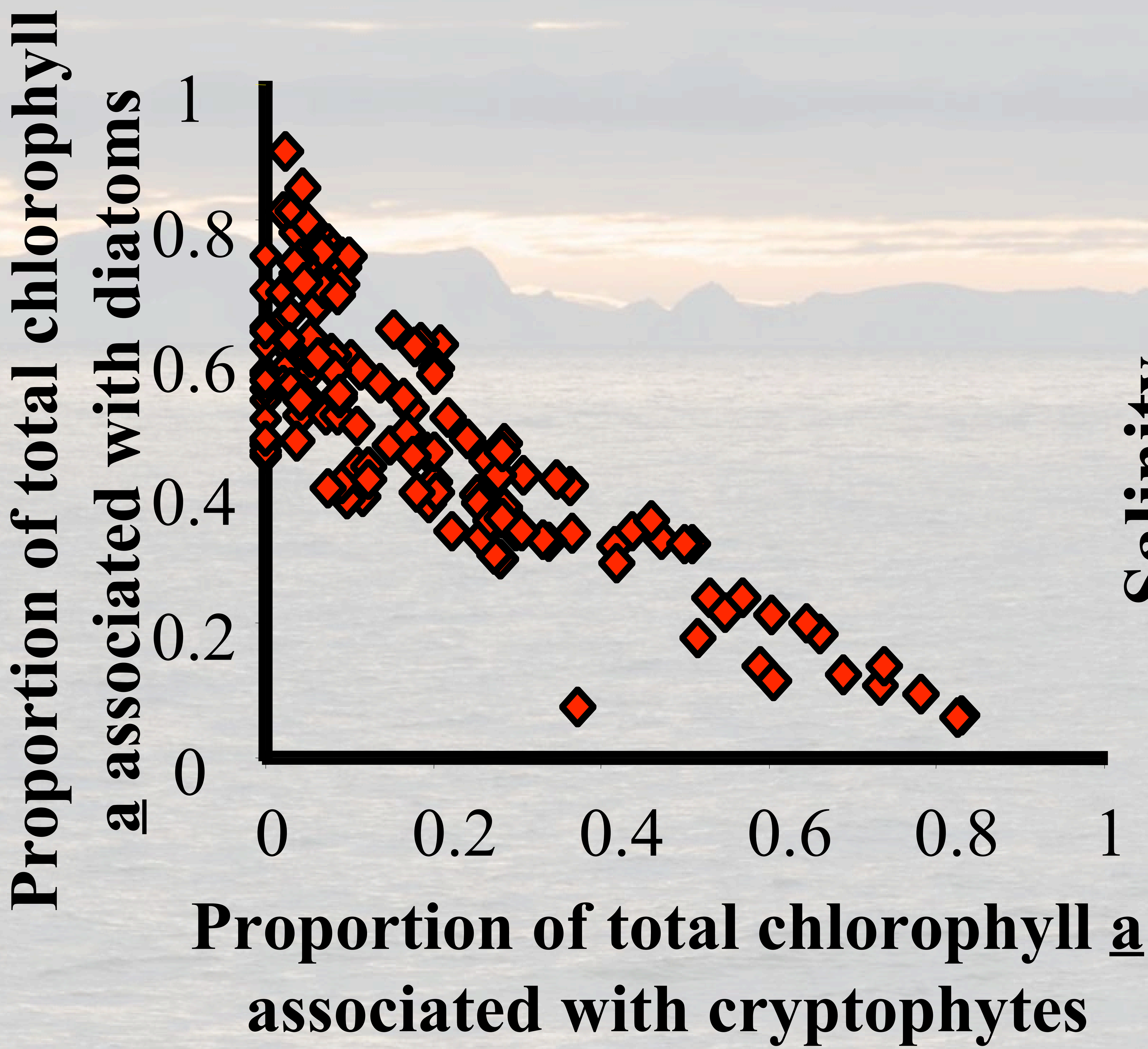
The changes driven by a decline in sea ice, wind and sun

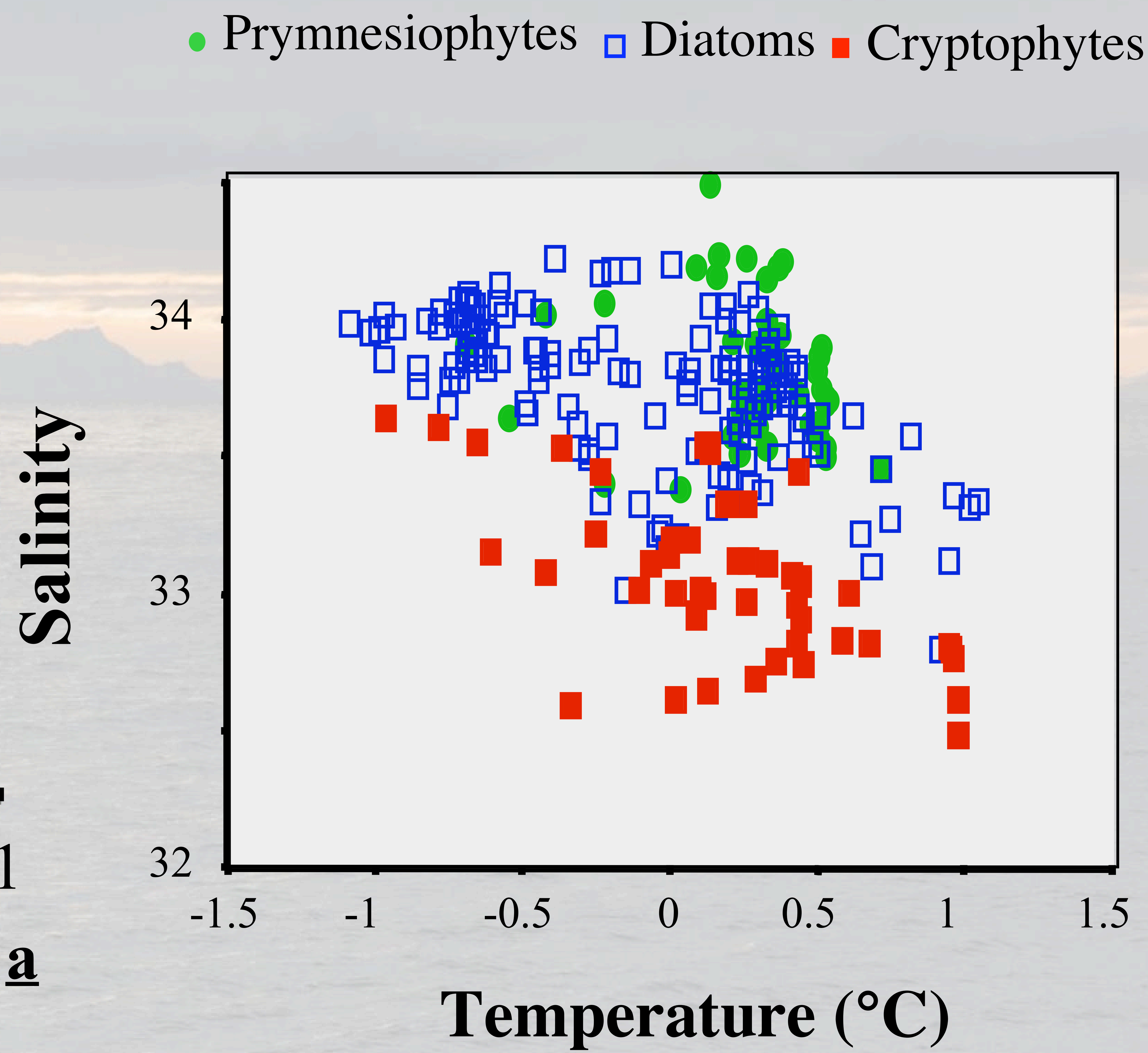
When chlorophyll is high, phytoplankton cells are big and are largely diatoms



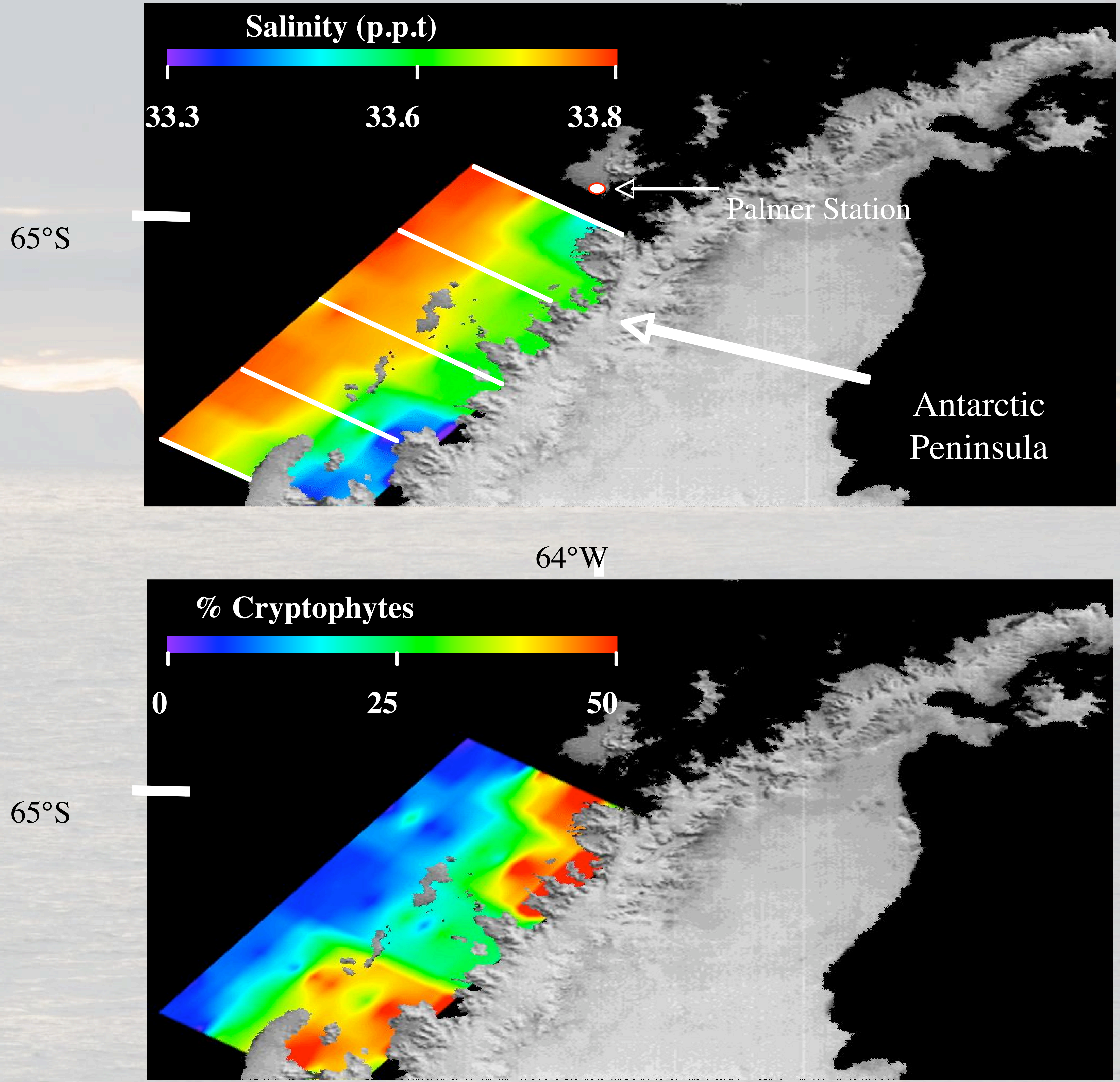
Montes Hugo et al. 2009

Who will dominate the warmer WAP?





Moline et al. GBC 2004



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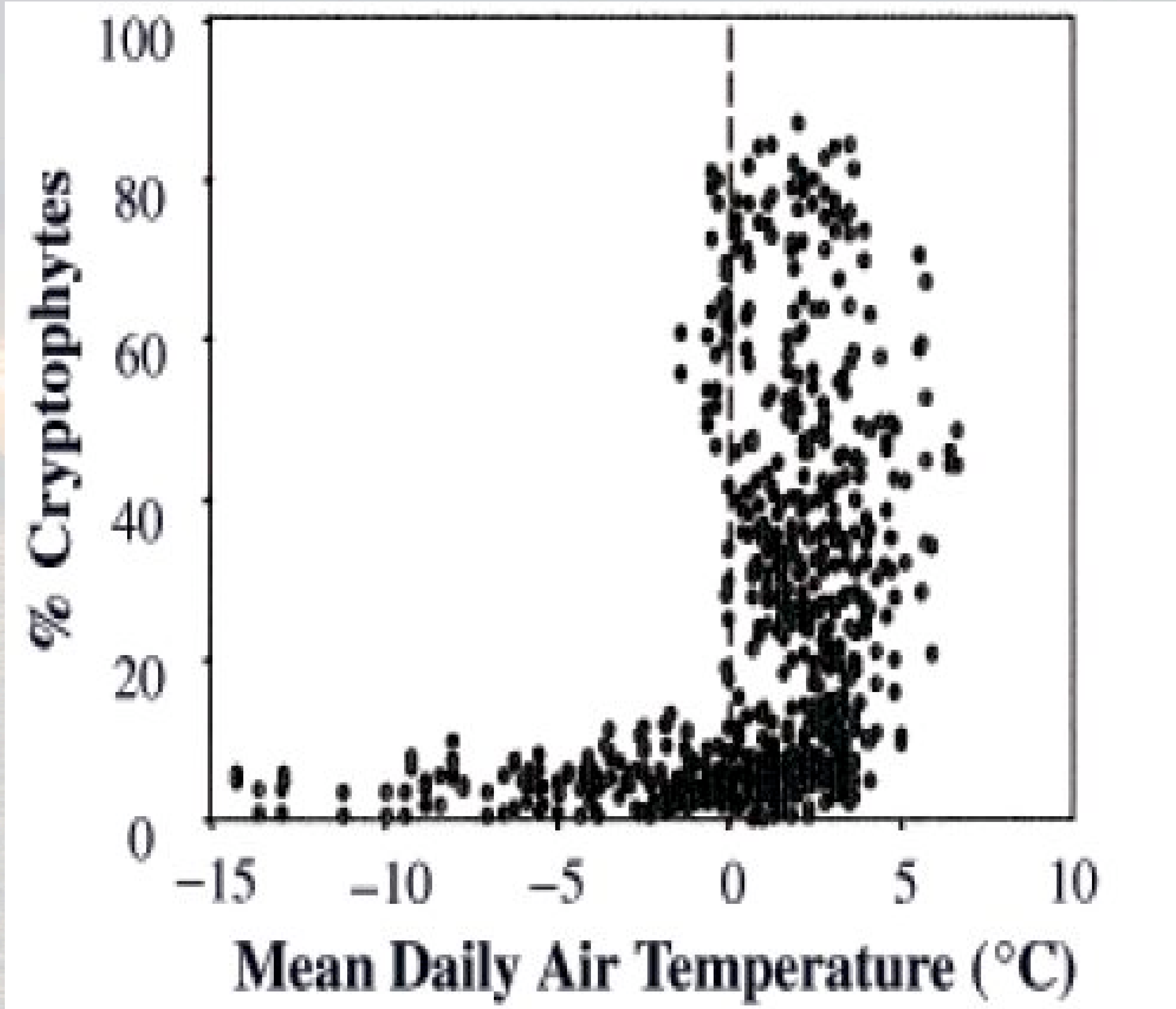

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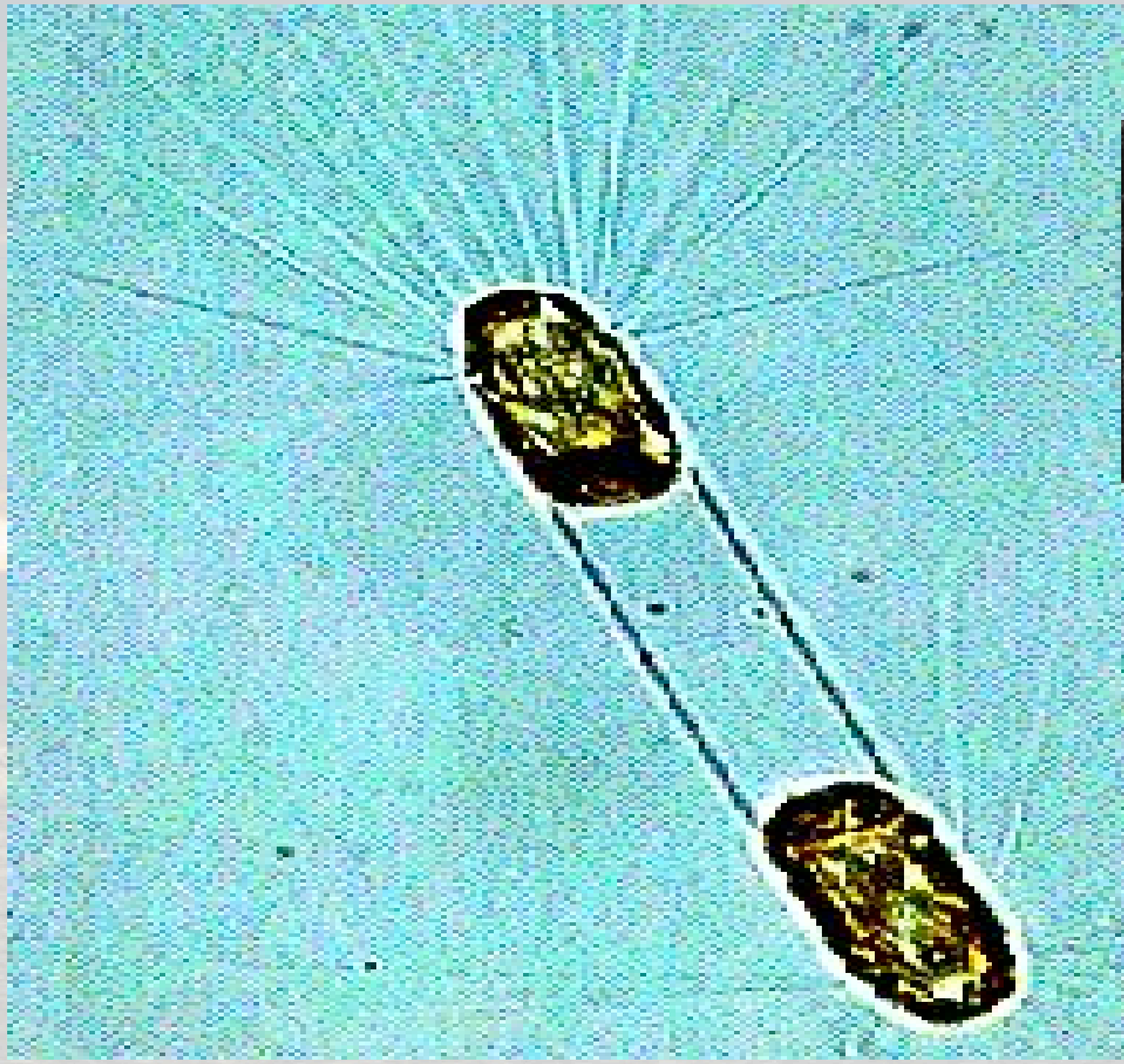
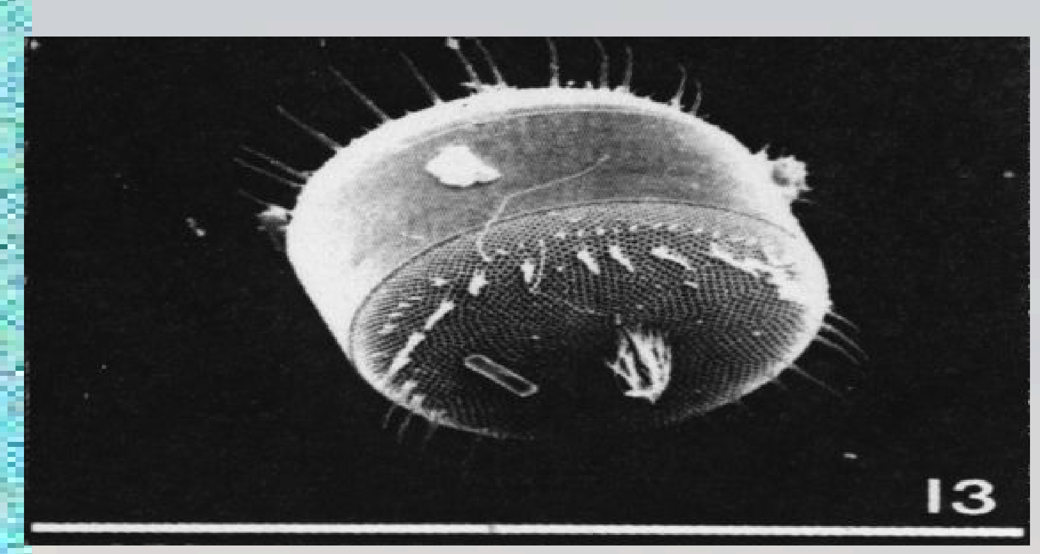
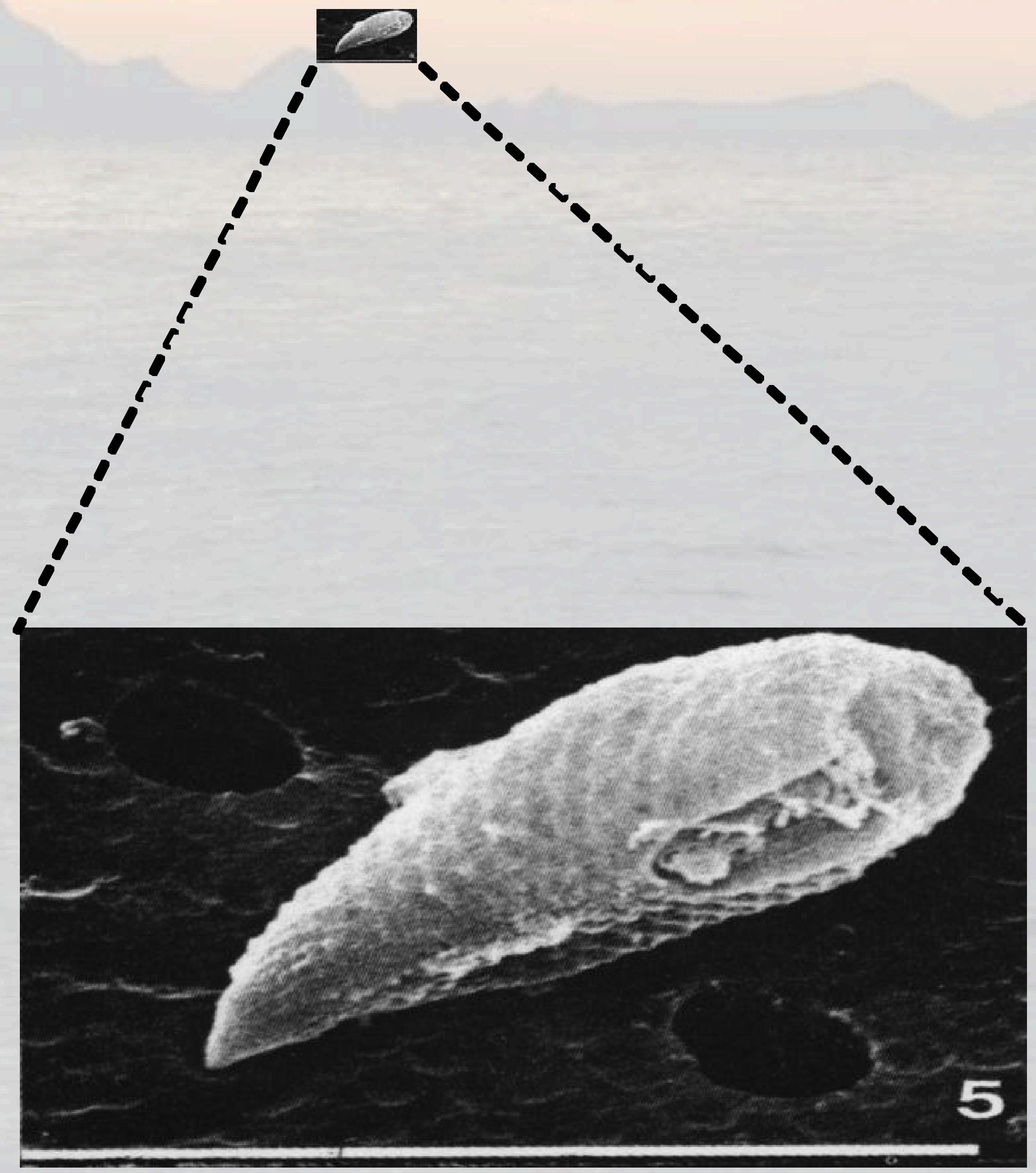


Corethron criophilum



100µm

Thalassiosira antarctica



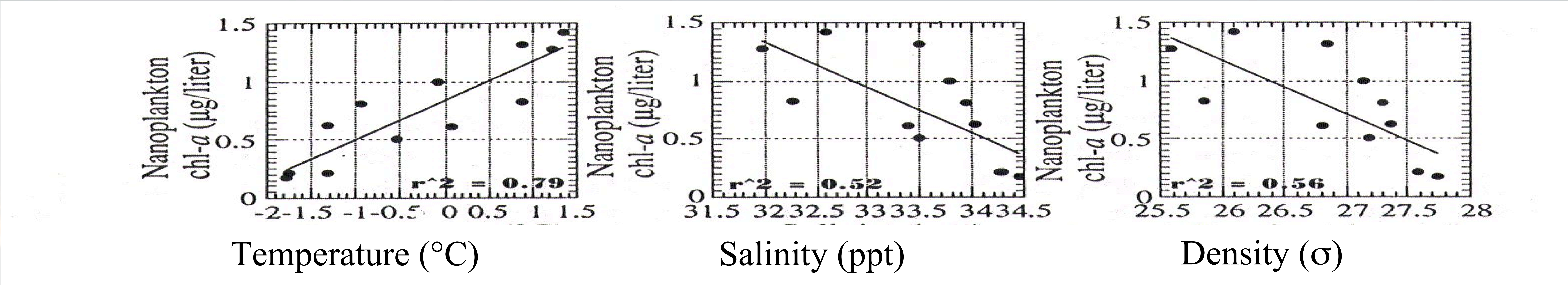
10µm

Cryptomonas cryophila

Palmer Cryptophytes --> 8 ± 2µm

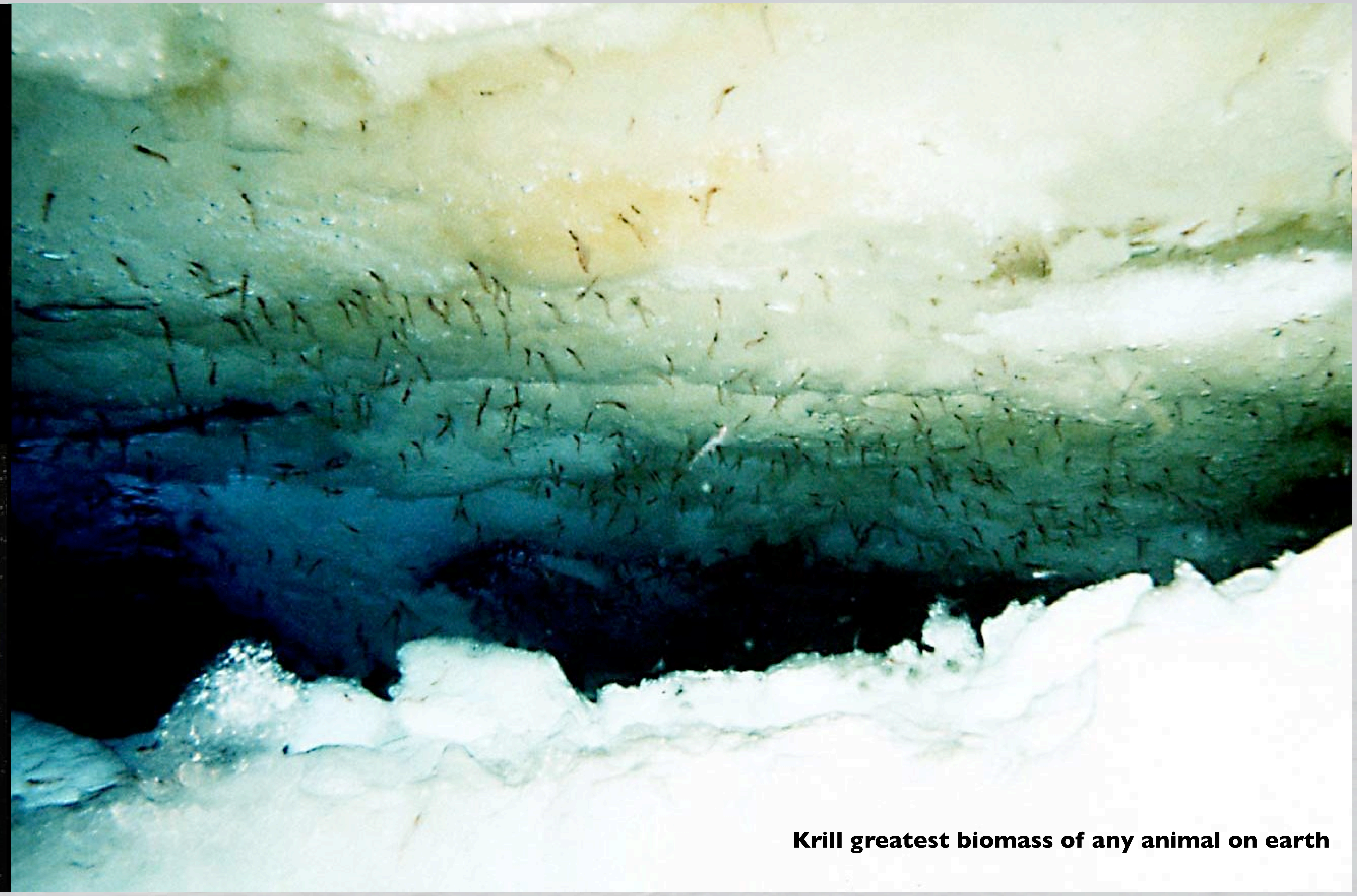
SEM Micrographs from*McMinn and Hodgson* 1993

A general feature in the warming WAP?

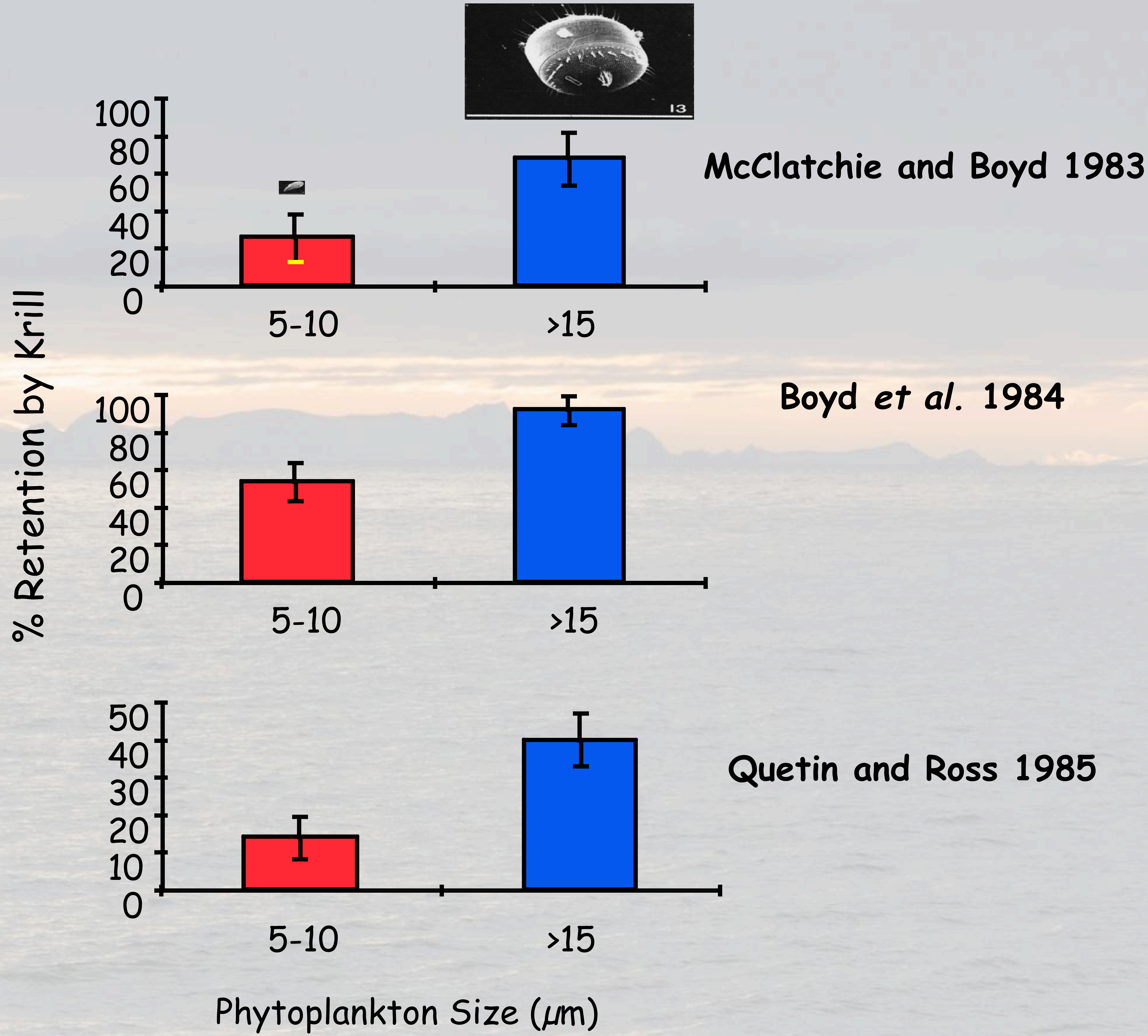


Location	**Reference**
South Shetland Islands	*V illafañe et al.*, 1995; *Kang, S-H et al.*, 1997; *Kang, J-S et al.*, 1997
Weddell-Scotia-Bellingshausen Confluence Areas	*Lancelot et al.*, 1991; *Nothig et al.*, 1991 *Tréguer et al.*, 1991; *Buma*, 1992; *Mura et al.*, 1995; *Kang and Lee*, 1995; *Aristegui et al.*, 1996
Ellis Fjord	*McMinn and Hodgson*, 1993
Bransfield Strait	*Kang and Lee,* 1995; *Kang et al.*, 1995
<u>Historical Data</u>	
Anvers Island	*Krebs*, 1983
Signy Island	*Whitaker*, 1982

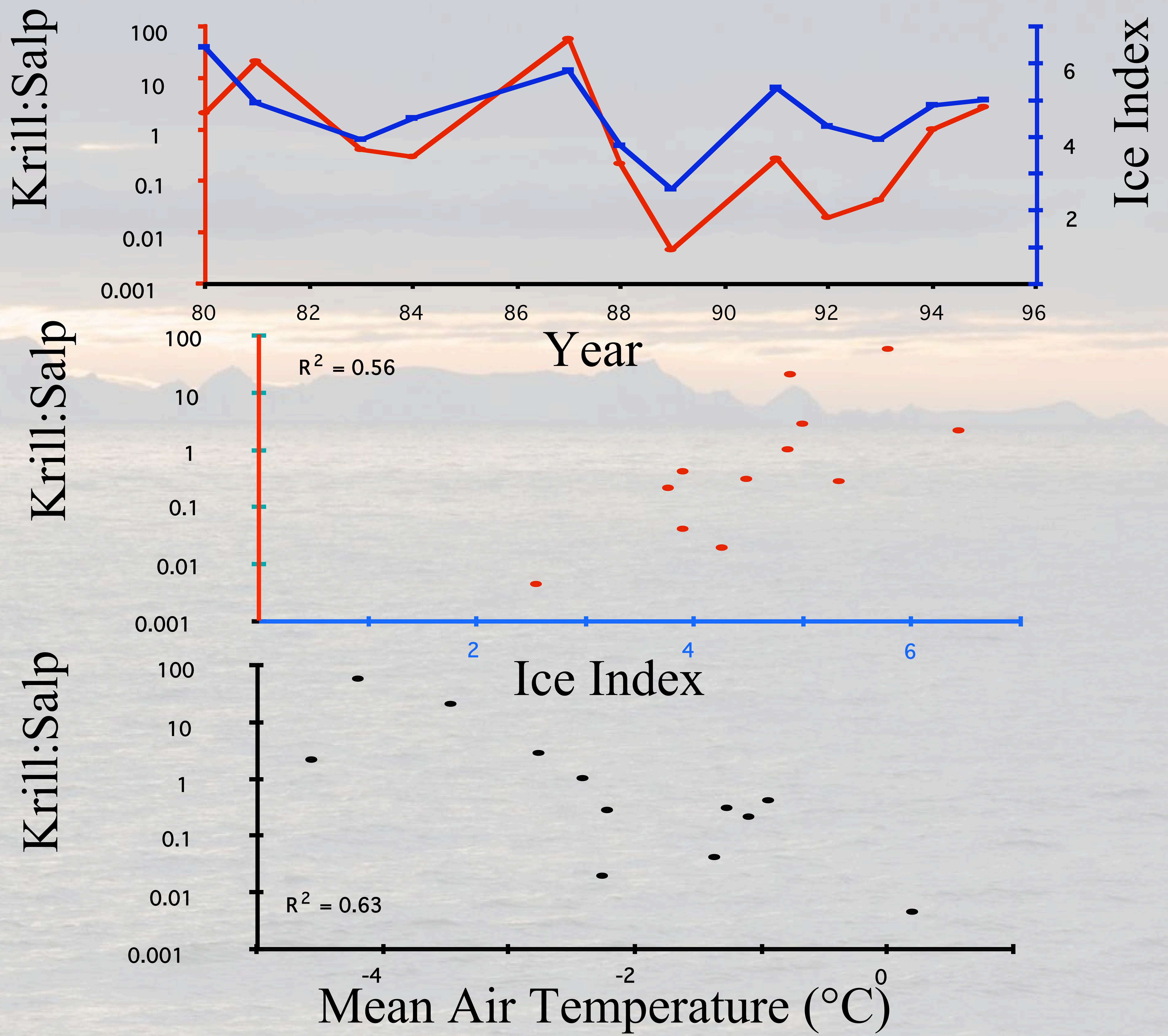
Zooplankton are dominated by krill or salps



Krill greatest biomass of any animal on earth


% Retention by Krill
100
80
60
40
20
0
5-10
>15
McClatchie and Boyd 1983
Boyd et al. 1984
Quetin and Ross 1985
50
40
30
10
Phytoplankton Size (μm)
13

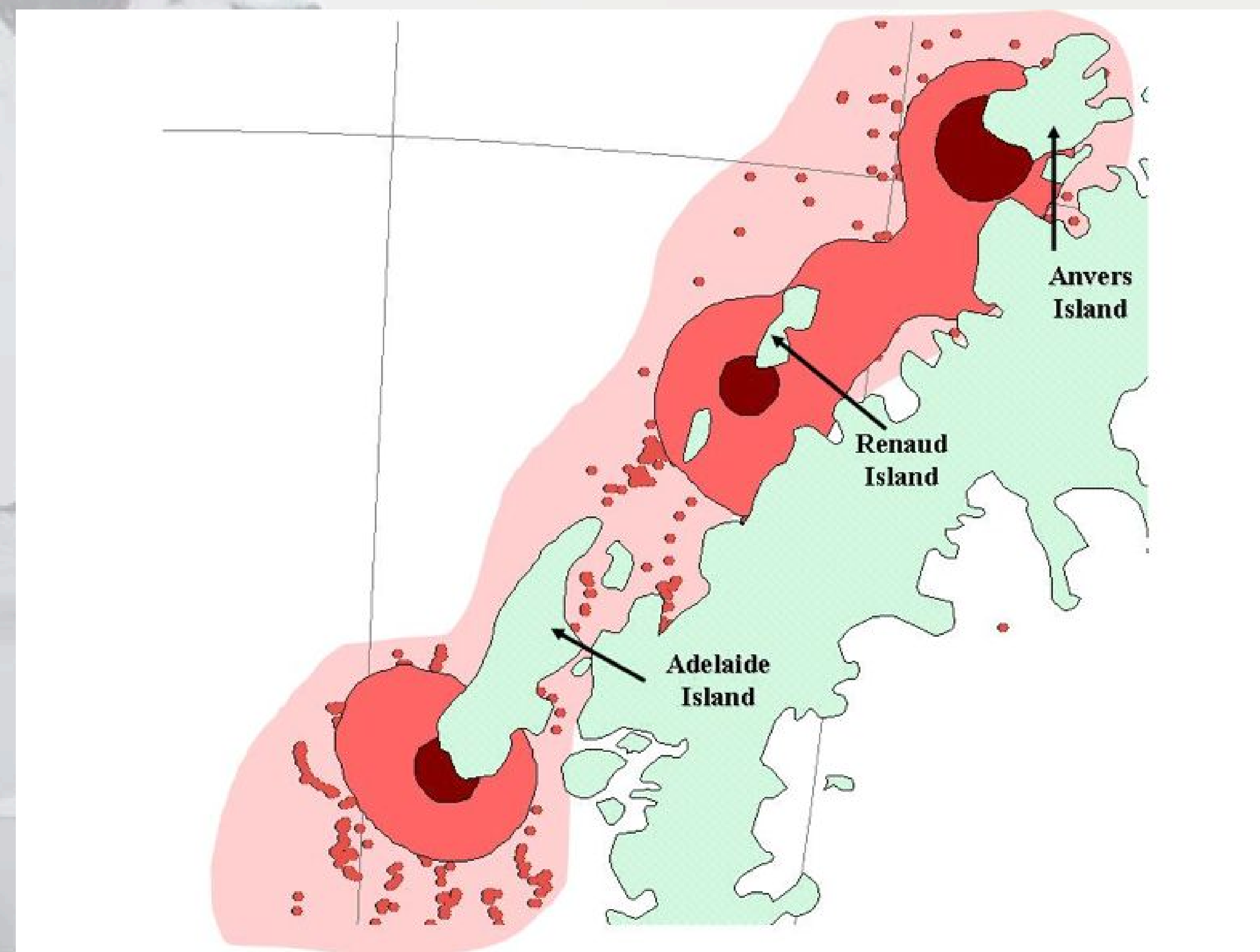
From *Loeb et al.*, 1997



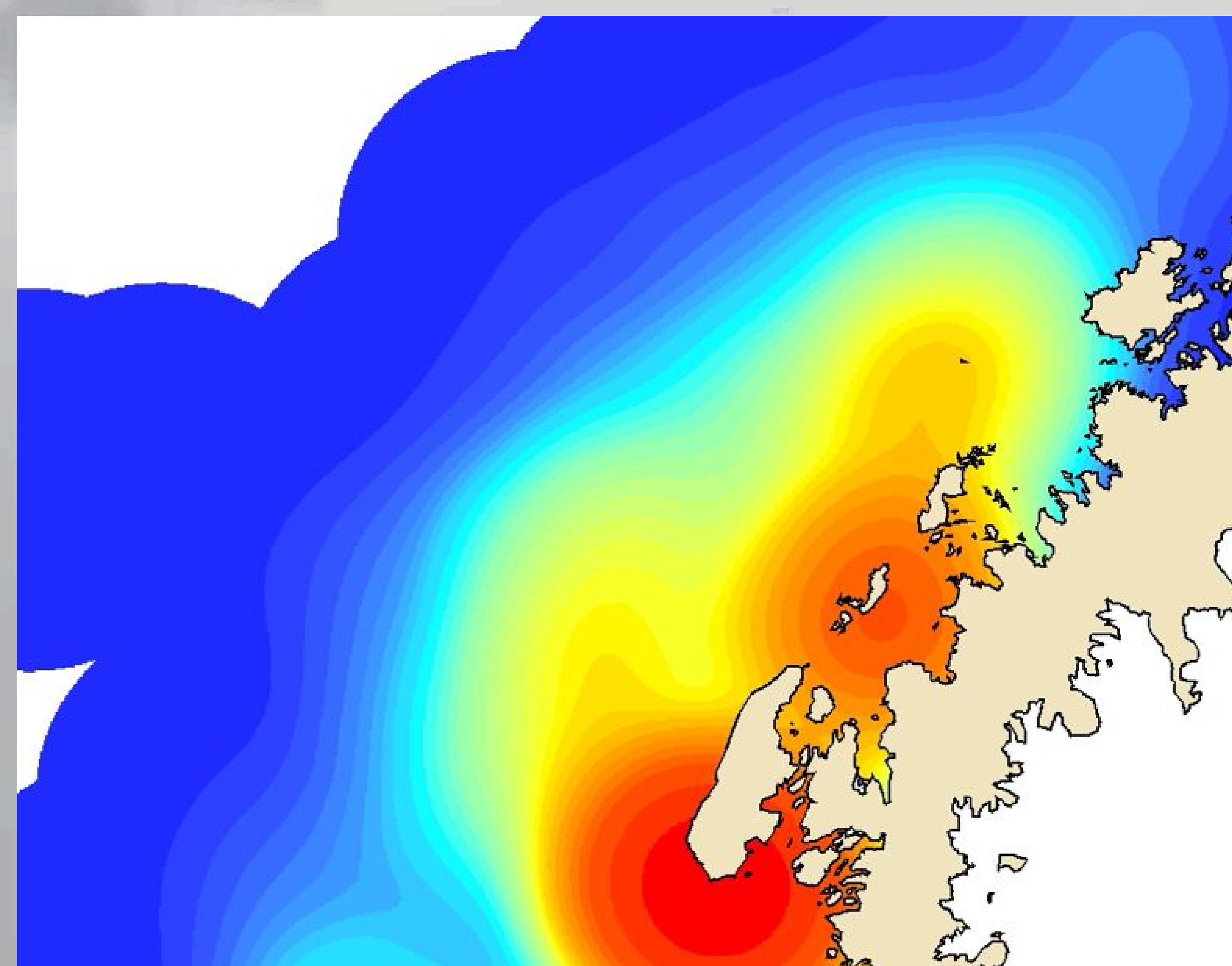
Is there an impact on higher trophic levels?

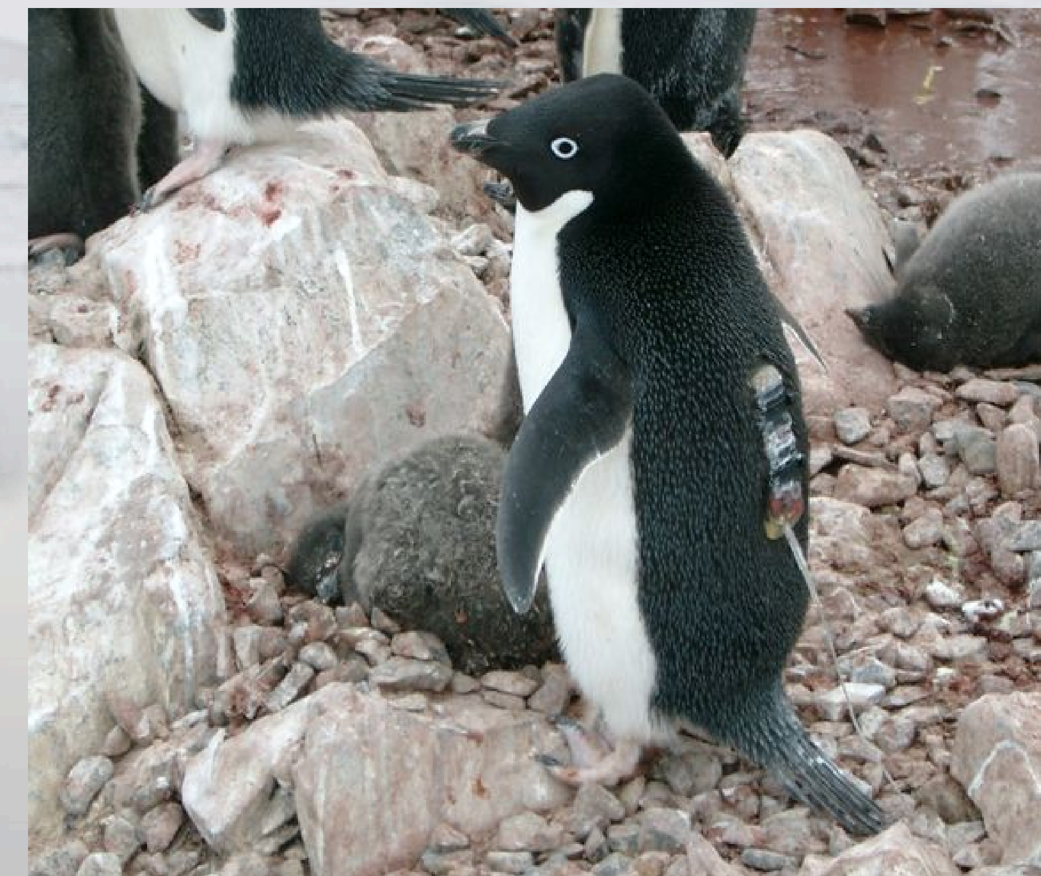
One focus idea of the LTER is testing, is that system is undergoing climate migration. We have structured sampling around the major Adelie penguin breeding areas along the peninsula.

Summer foraging areas for Adelie penguins

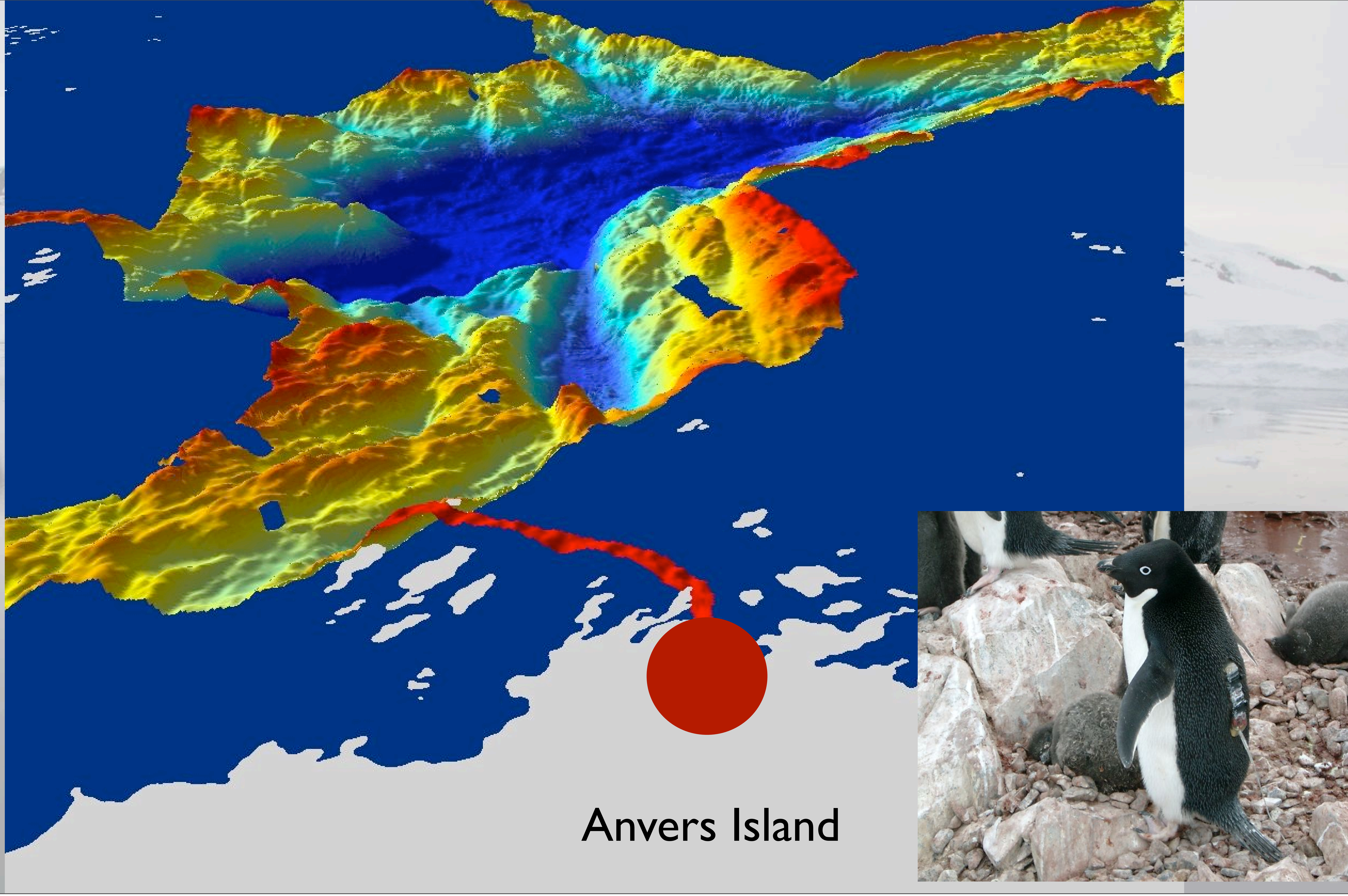


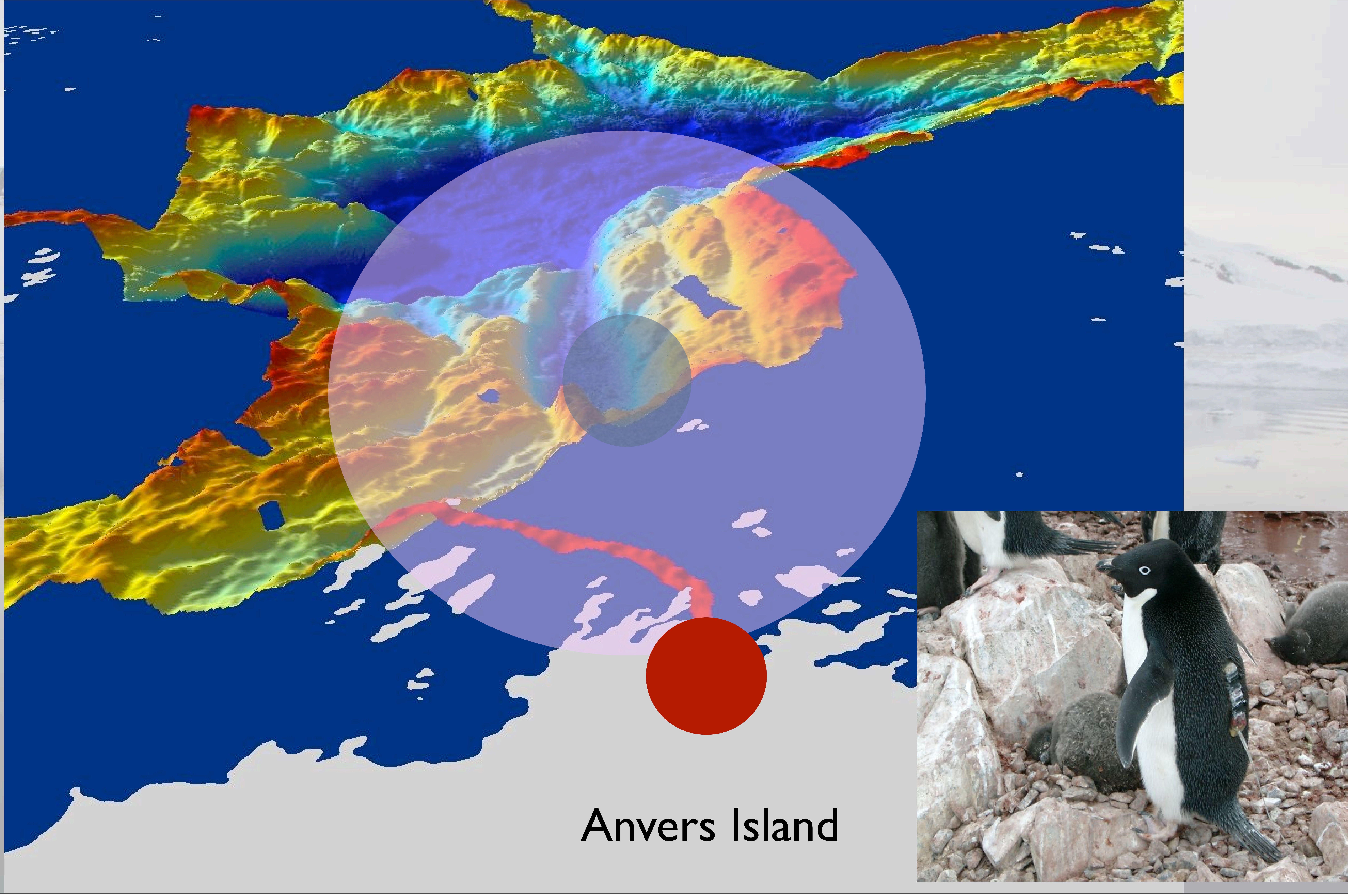
Winter foraging areas for Adelie penguins



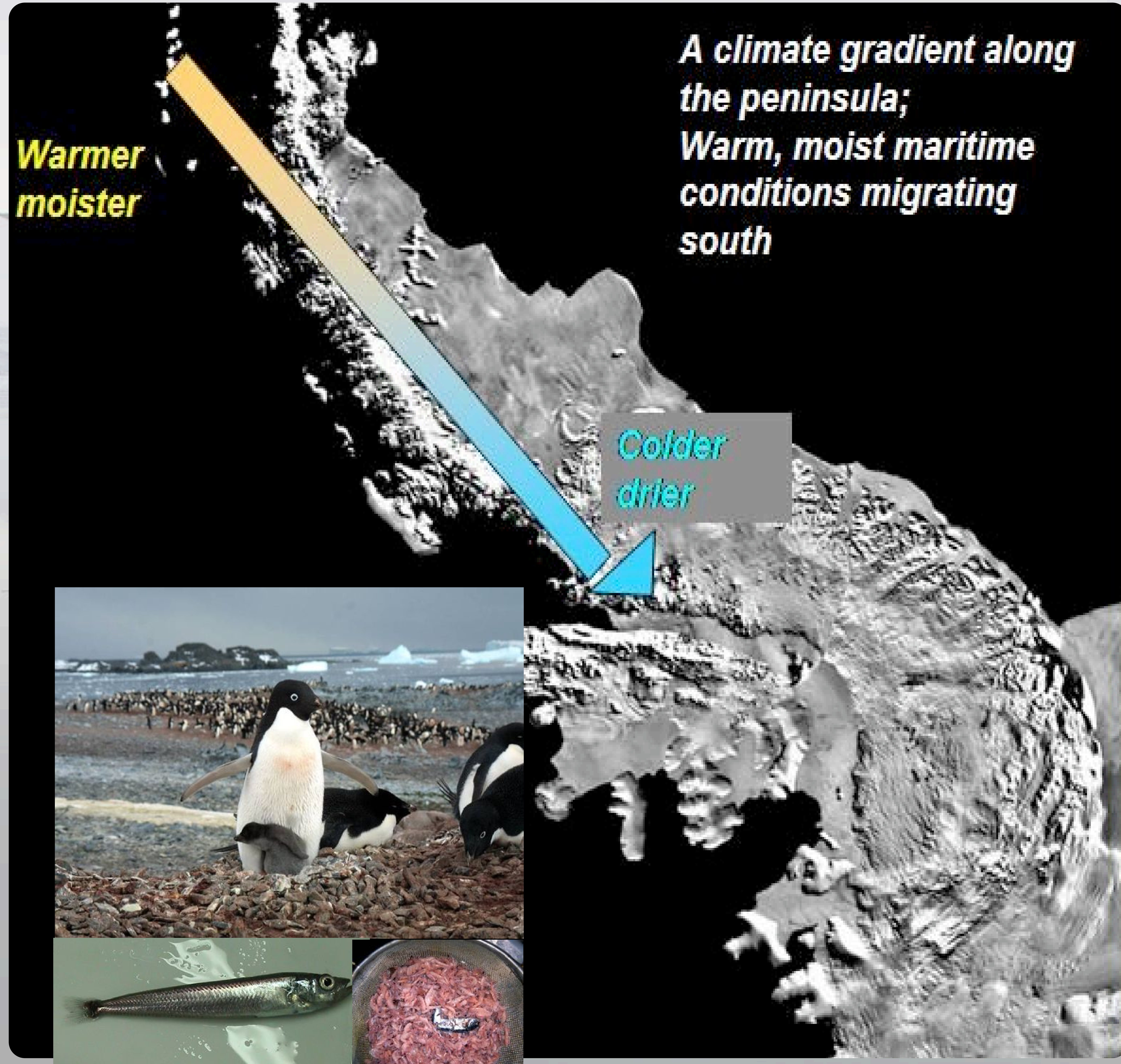


To be expanded by NASA grant awarded in Dec.


Anvers Island

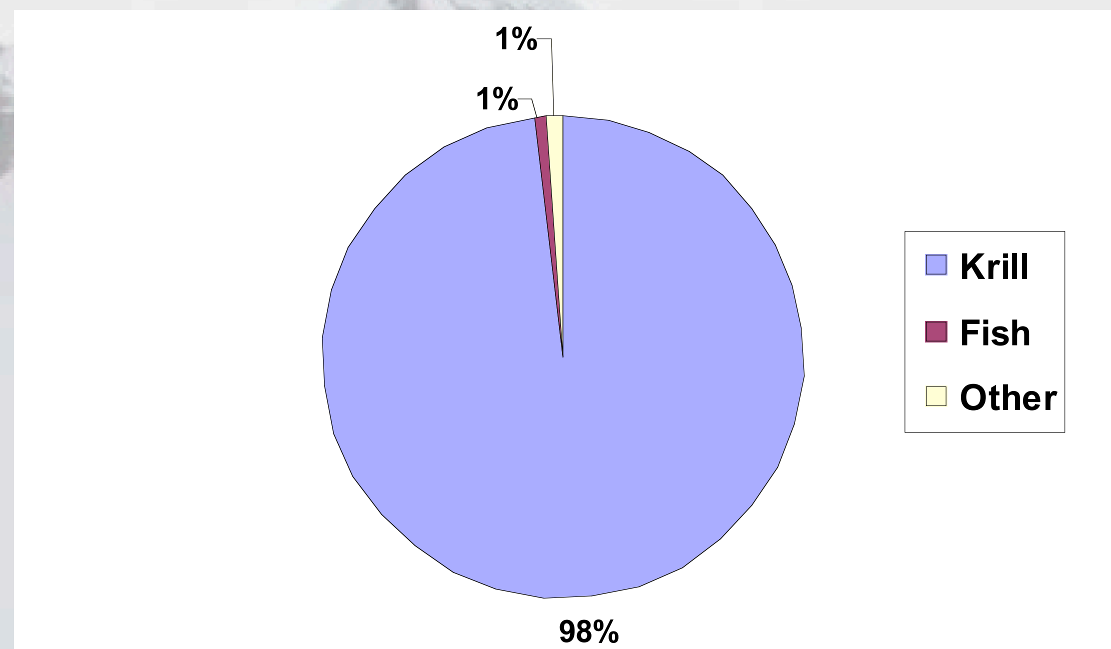

Anvers Island

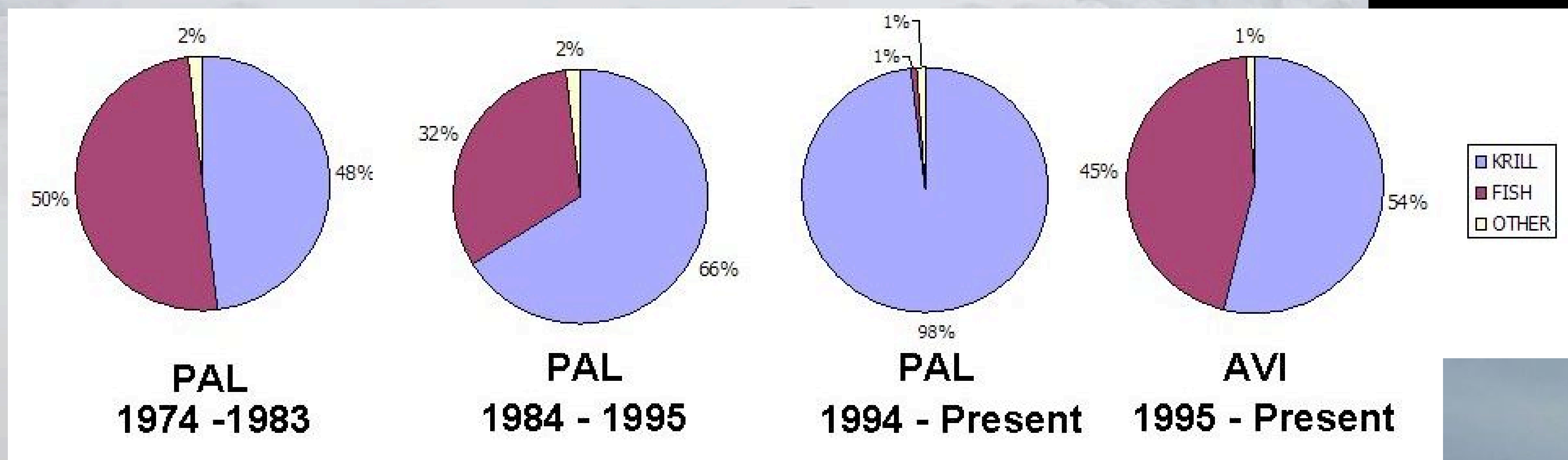
Changing diets for the Adelie penguins

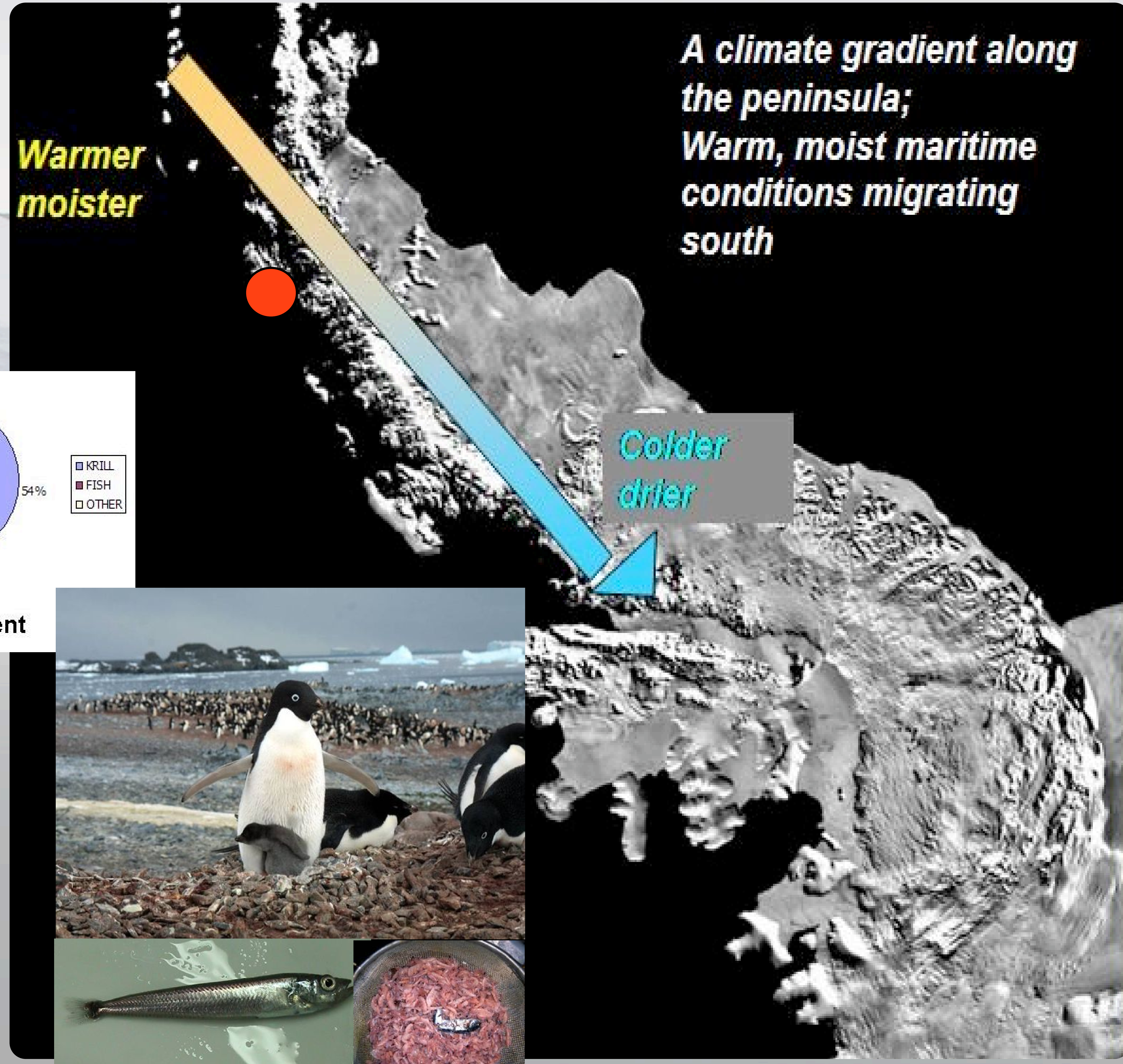


Changing diets for the Adelie penguins

1994-
present

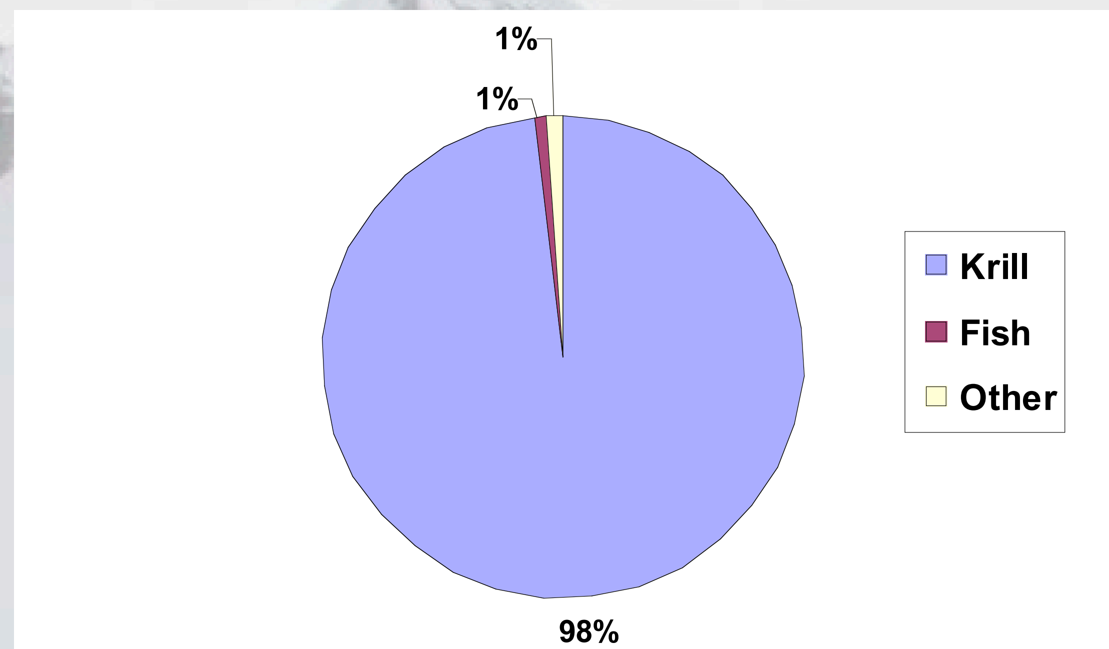


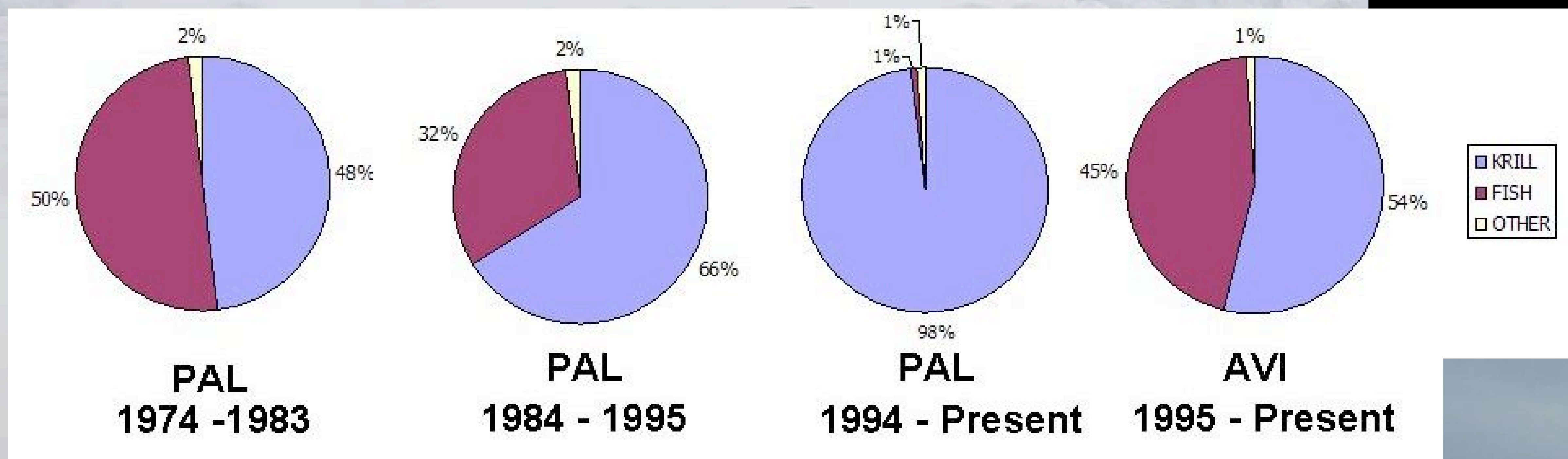


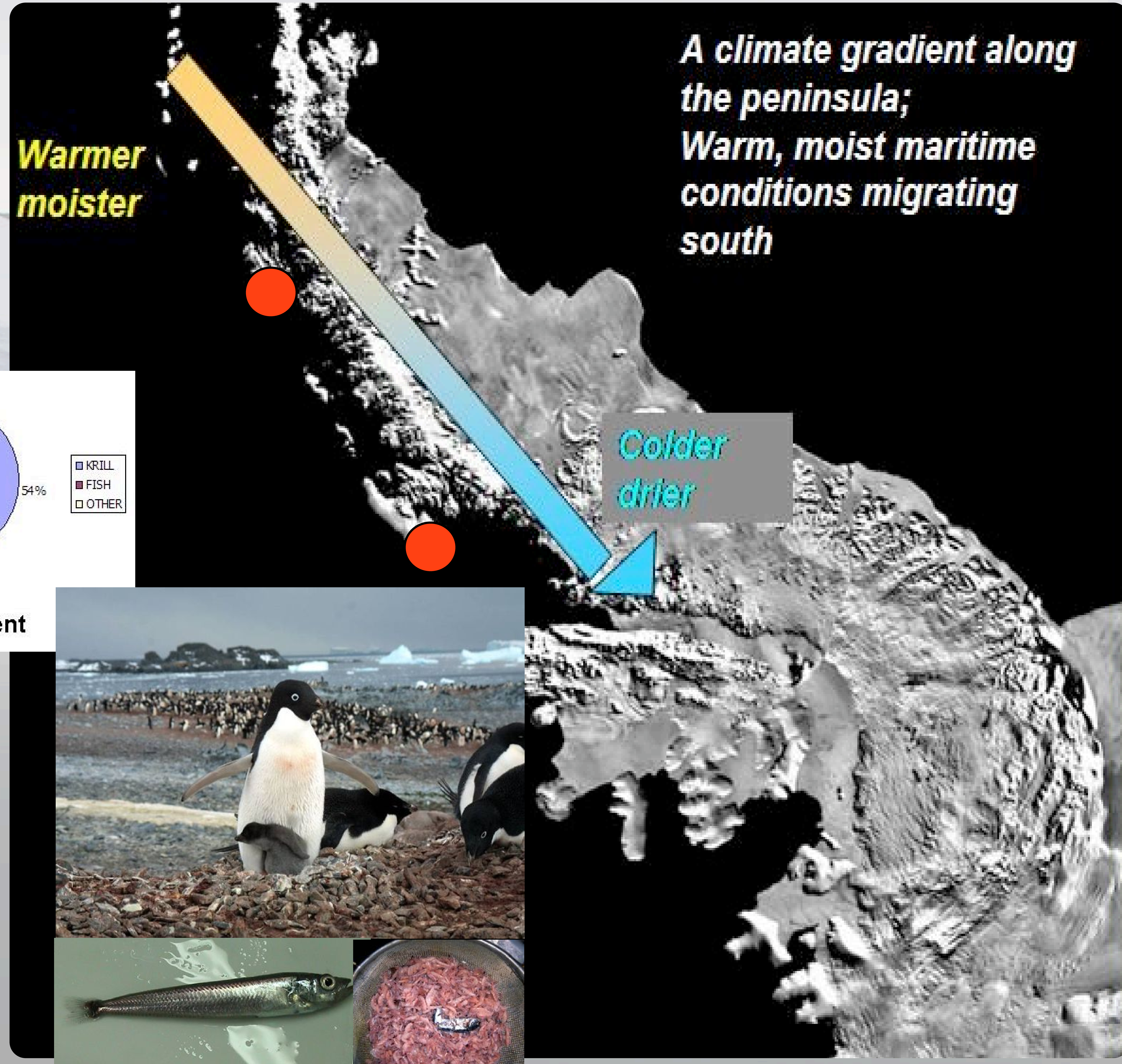


Changing diets for the Adelie penguins

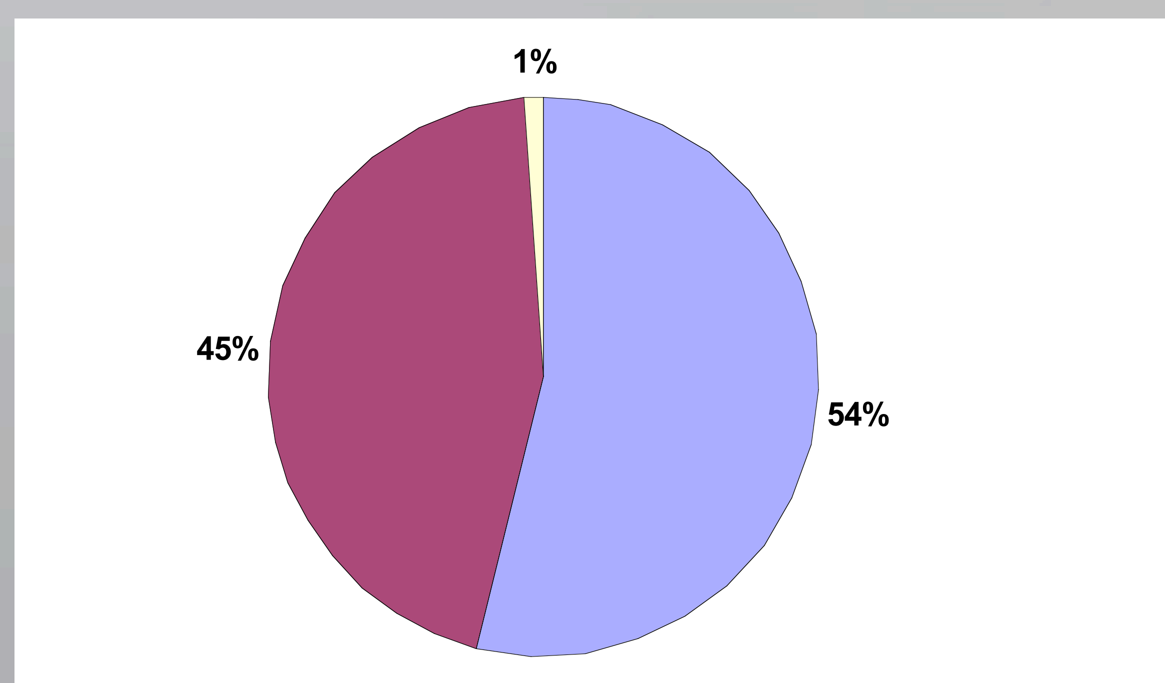
1994-
present

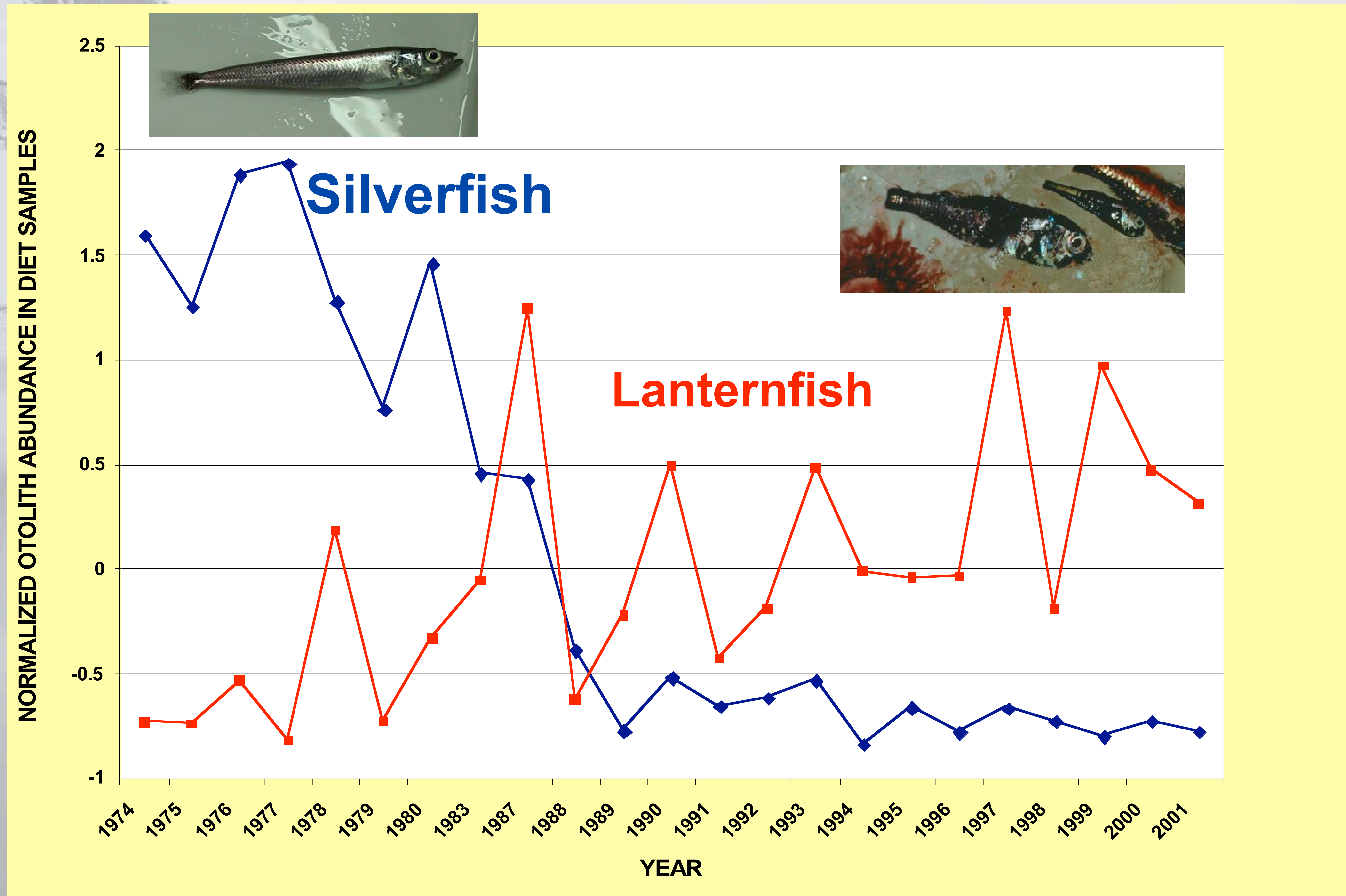






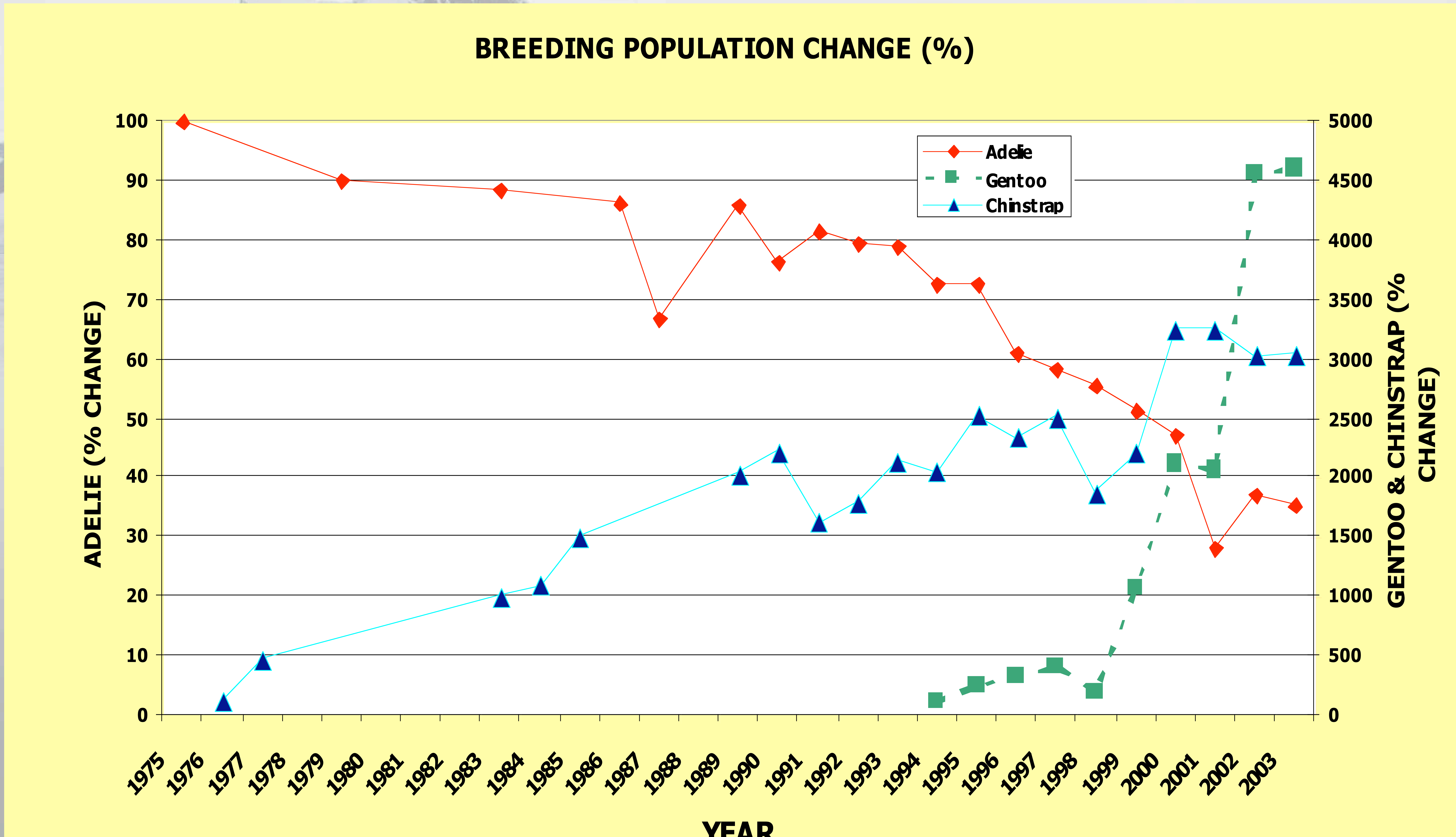
1995-
present





Silverfish
Lanternfish
NORMALIZED OTOLITH ABUNDANCE IN DIET SAMPLES
2.5
2
1.5
1
0.5
0
-0.5
-1
1974
1975
1976
1977
1978
1979
1980
1983
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
YEAR

If that was not enough, warmer temps leads to more moisture and more snow. Breeding failure...........

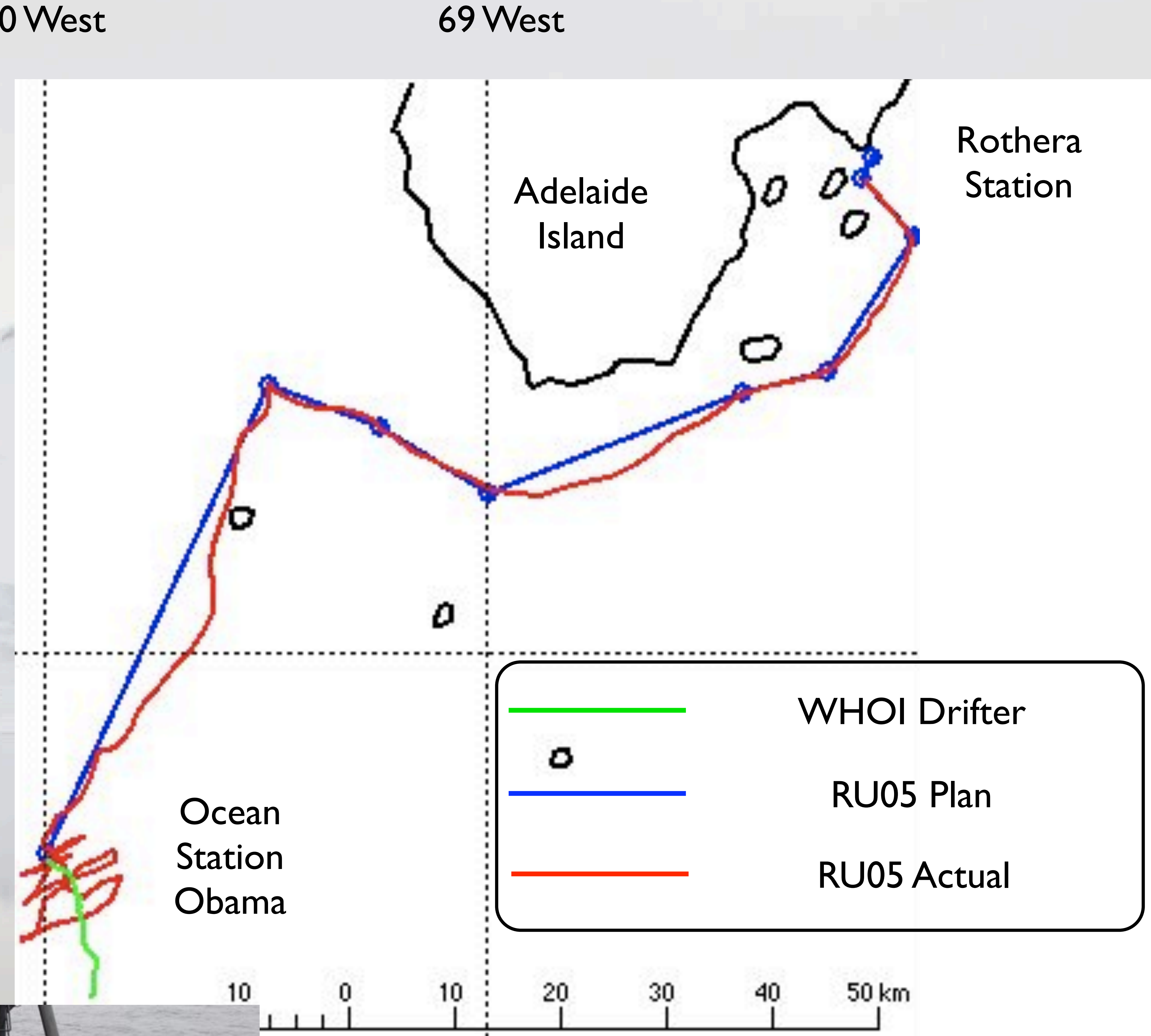

BREEDING POPULATION CHANGE (%)
ADELIE (% CHANGE)
GENTOO & CHINSTRAP (% CHANGE)
YEAR
Adelie
Gentoo
Chinstrap
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003


Adelie penguins
Weddell seals
Chinstrap penguins
Gentoo penguins
Fur seals
Elephant seals
100
80
60
40
20
0
7000
6000
5000
4000
3000
2000
1000
0
1975
1980
1985
1990
1995
2000
2005
YEAR

Old Day Communication

HAM Operator Coms Palmer Station 1988

Brave New Day



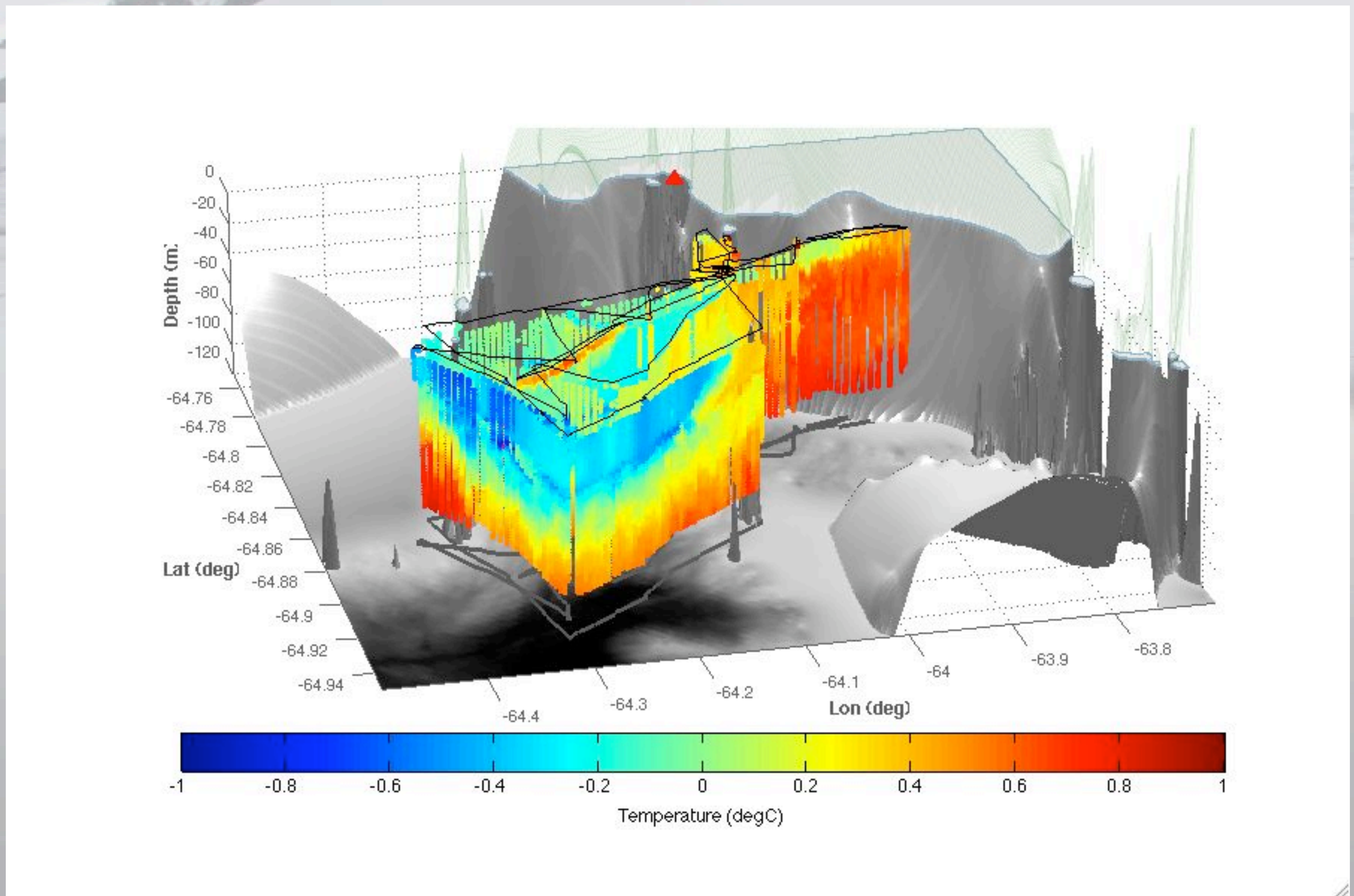
RV Gould

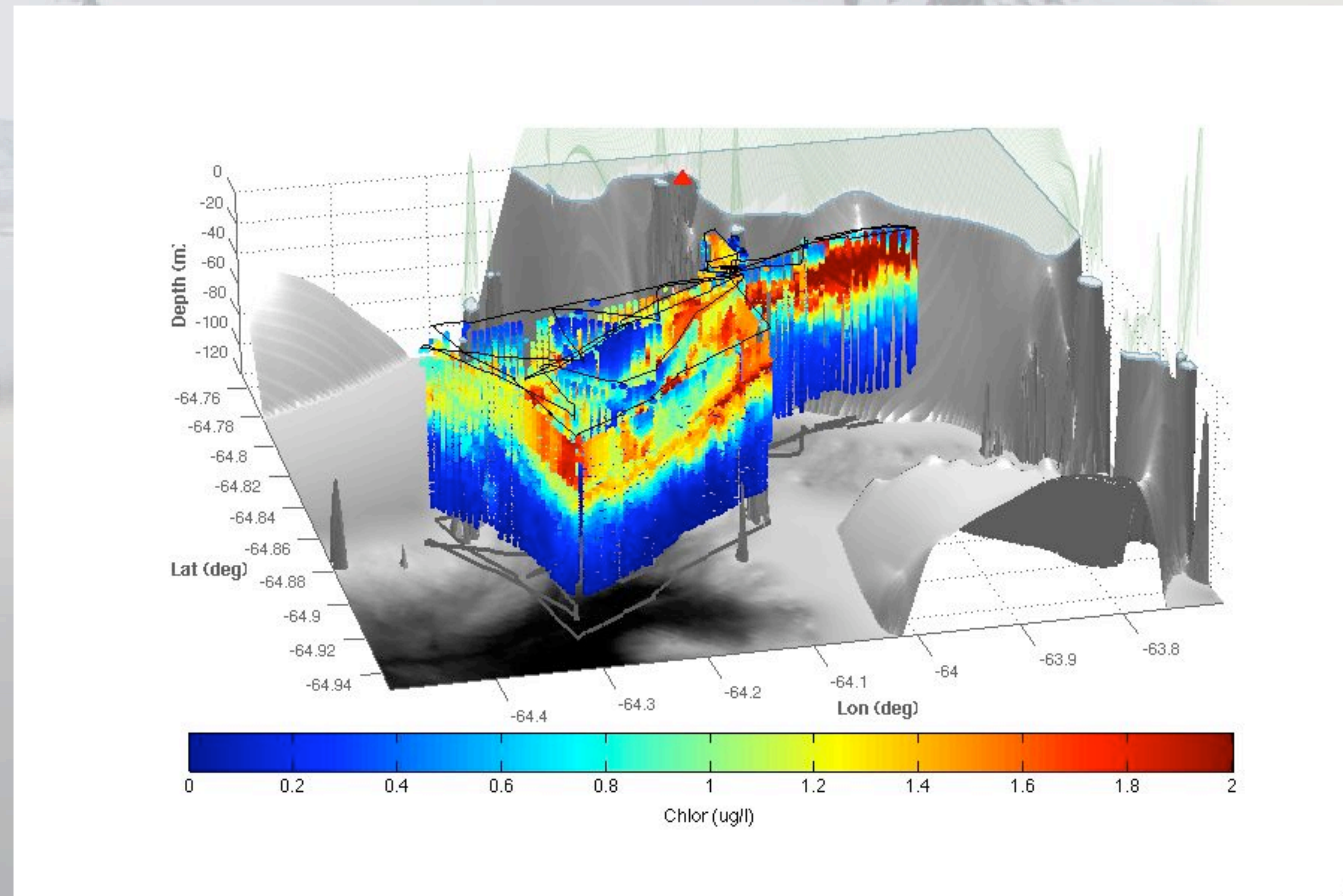
Rothera Base

Real time comms

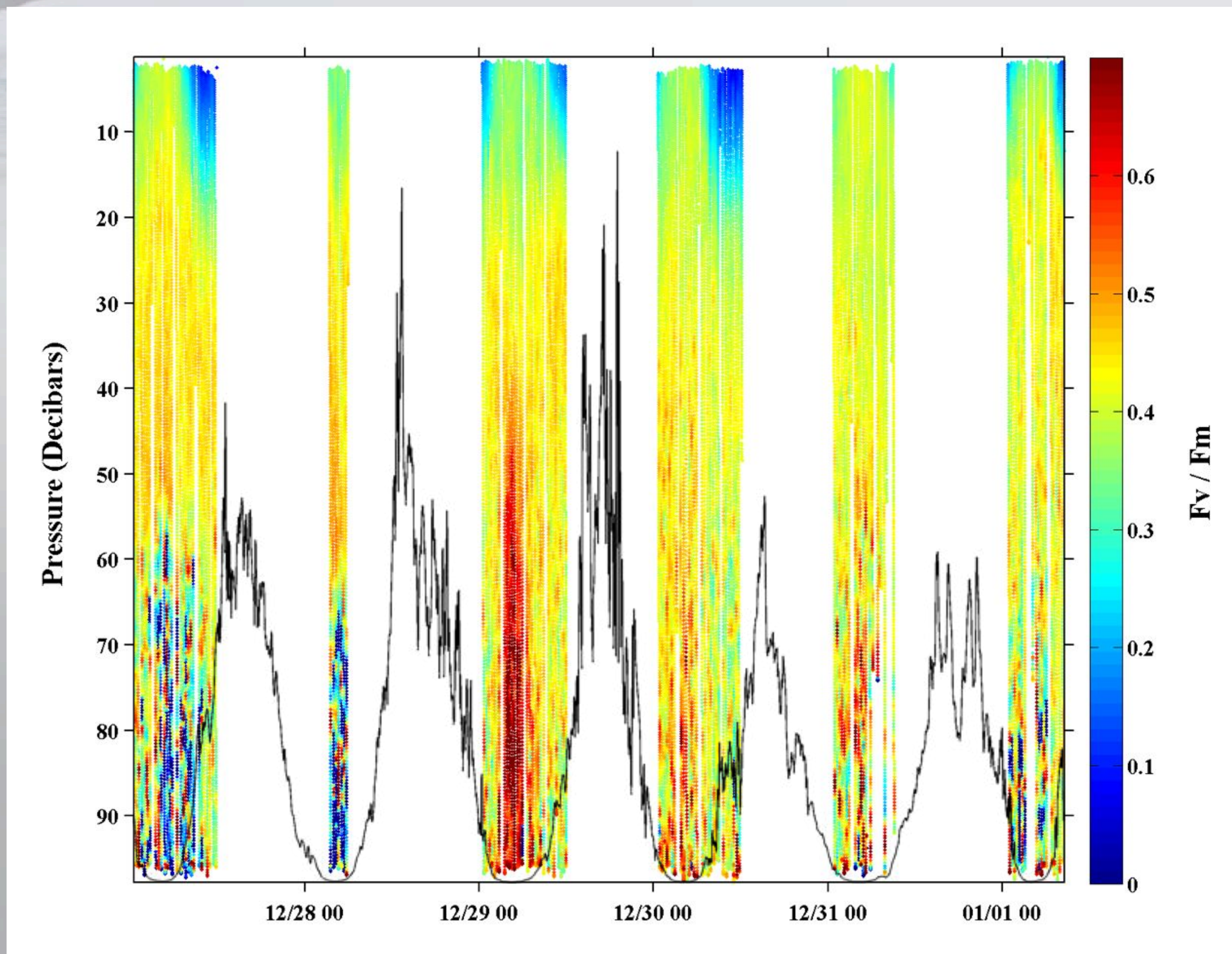
Rutgers COOLroom

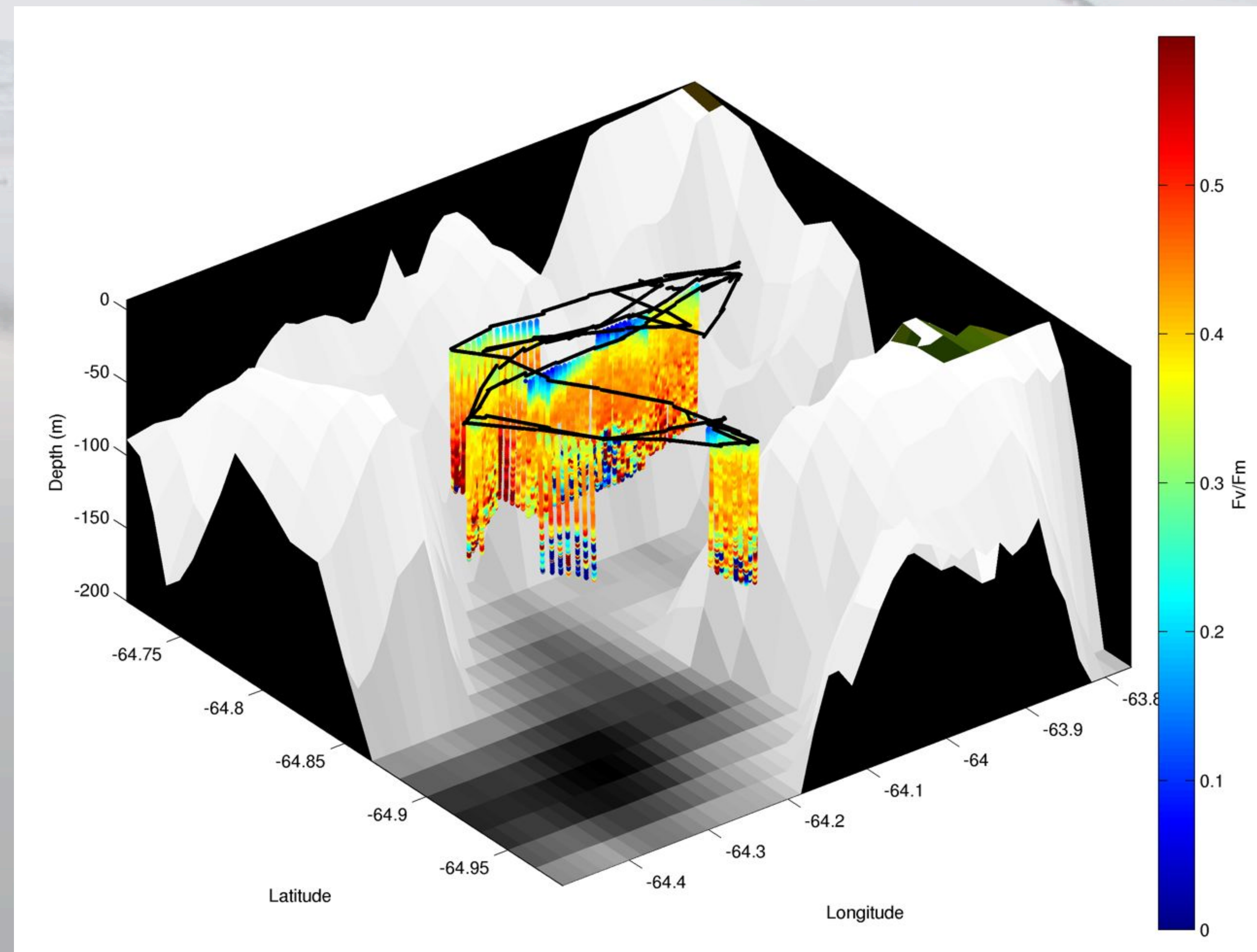
Enhanced productivity is associated with the warm upwelled water

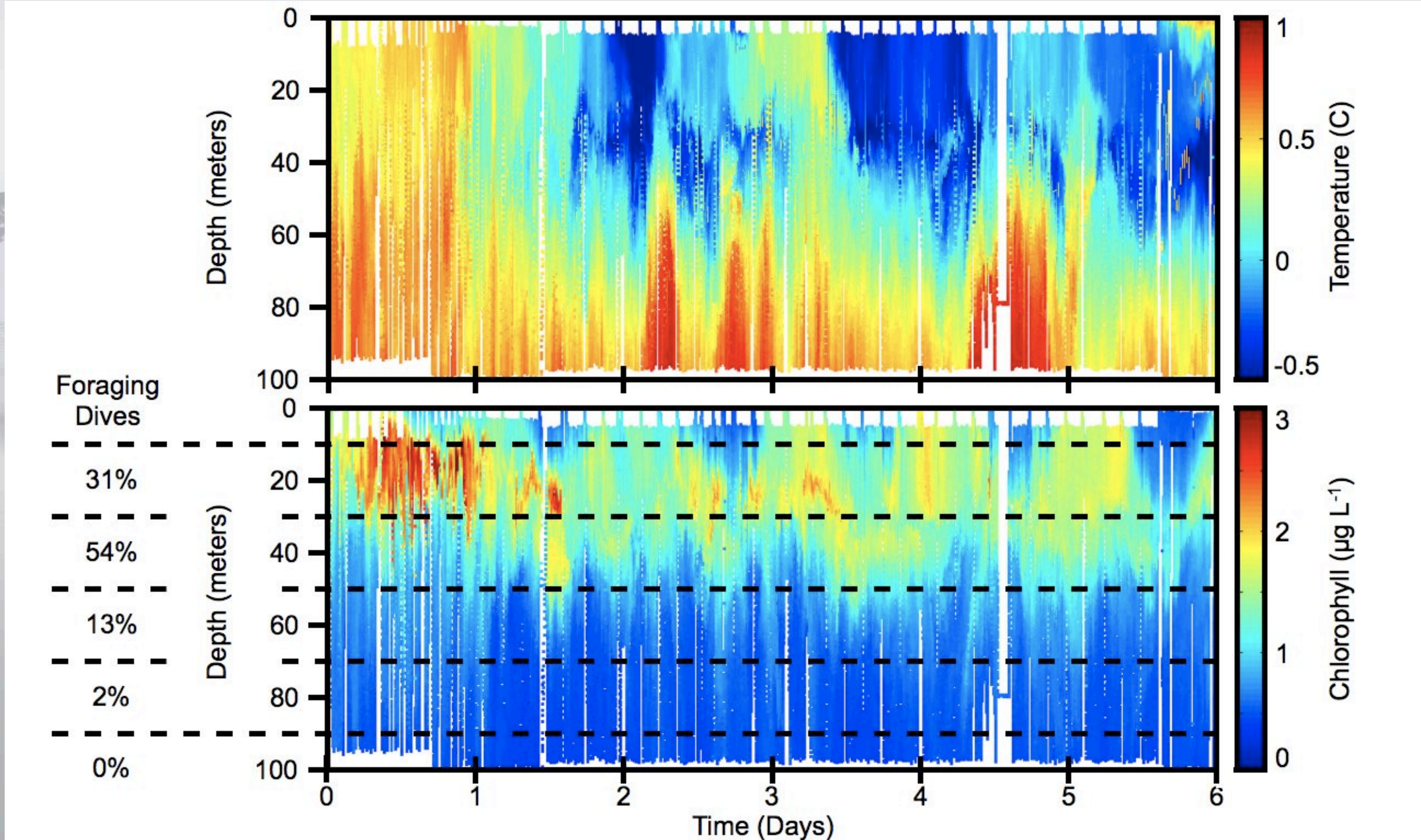




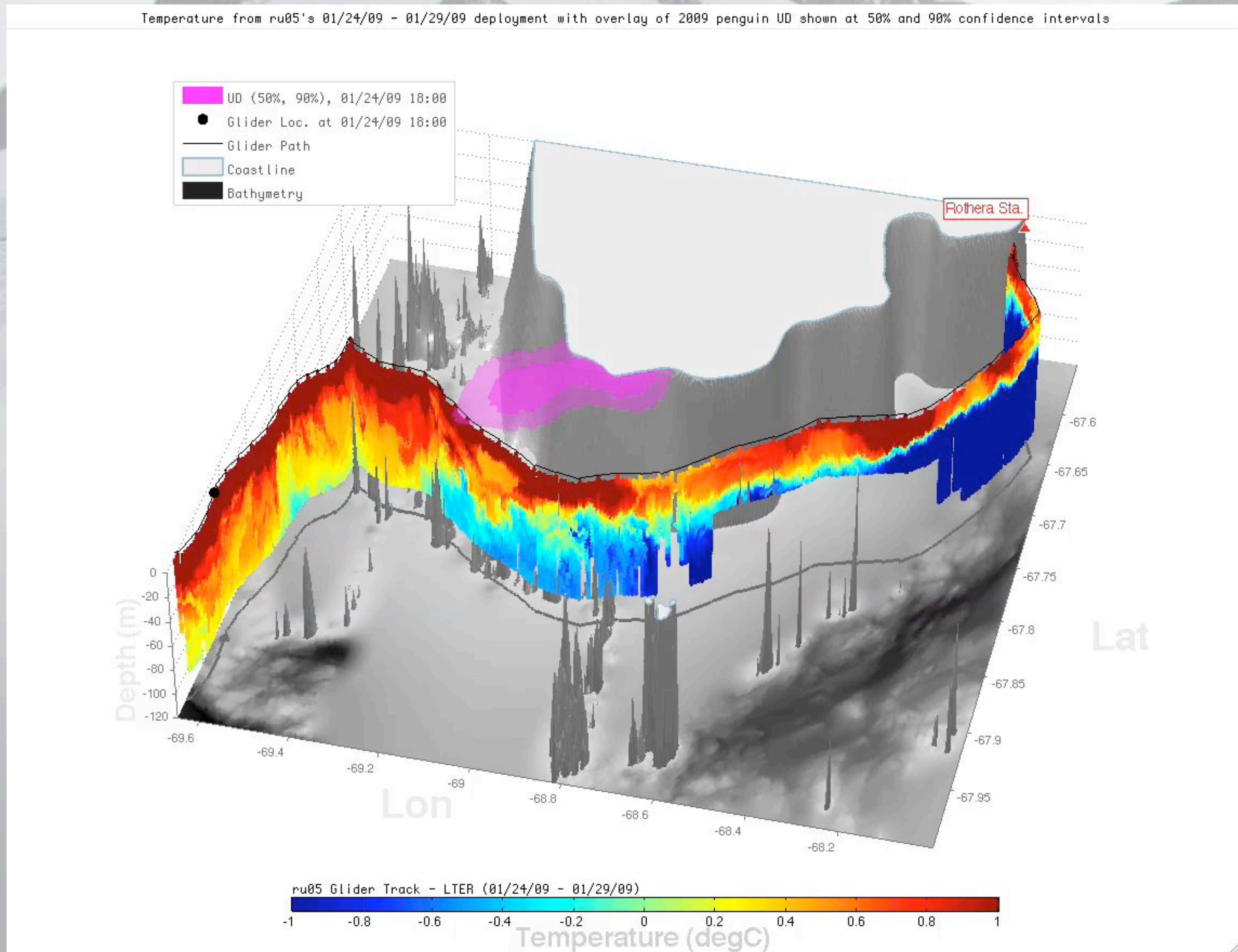
Glider measurements of Fv/Fm indicate that the phytoplankton populations associated with upwelling are healthy

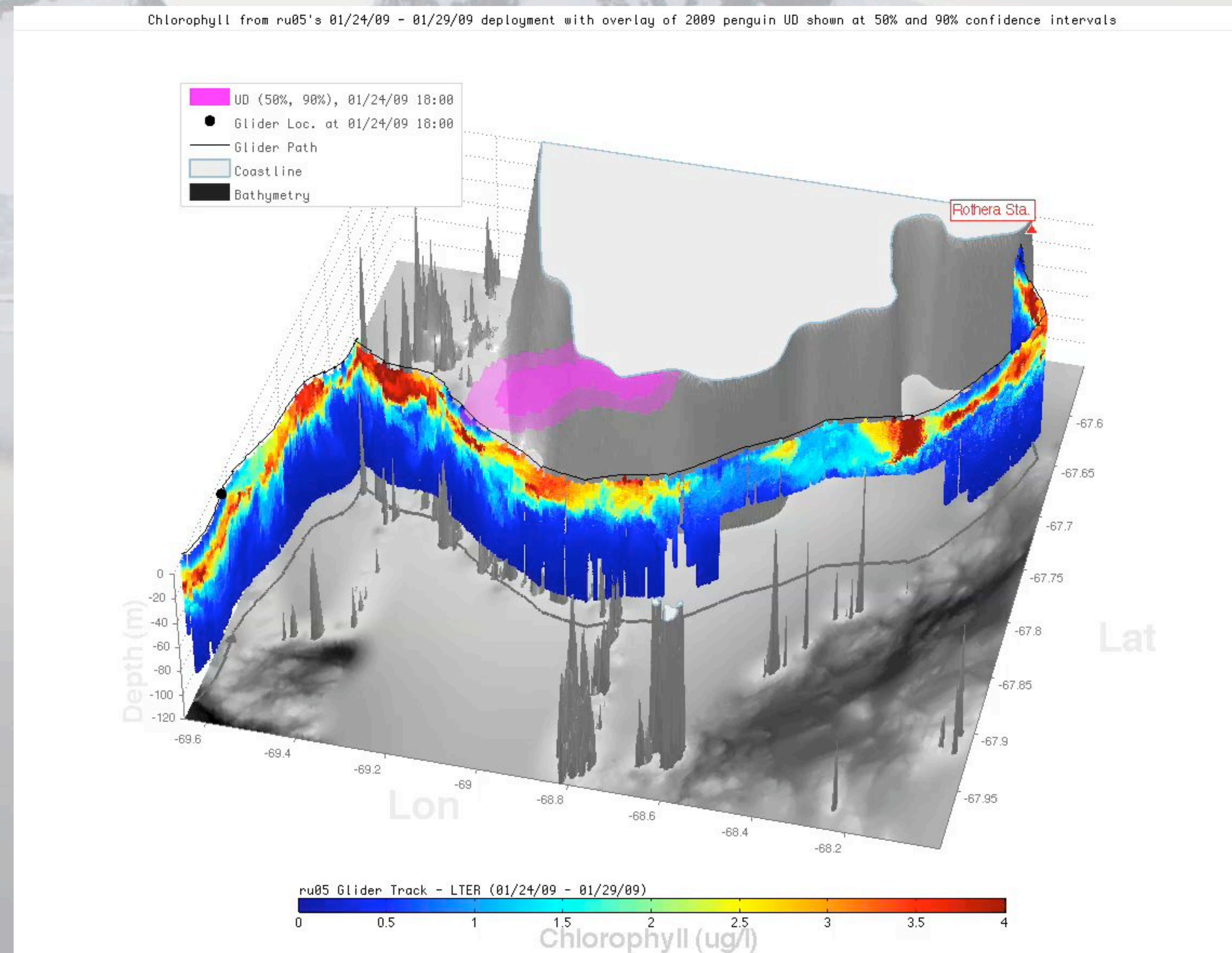






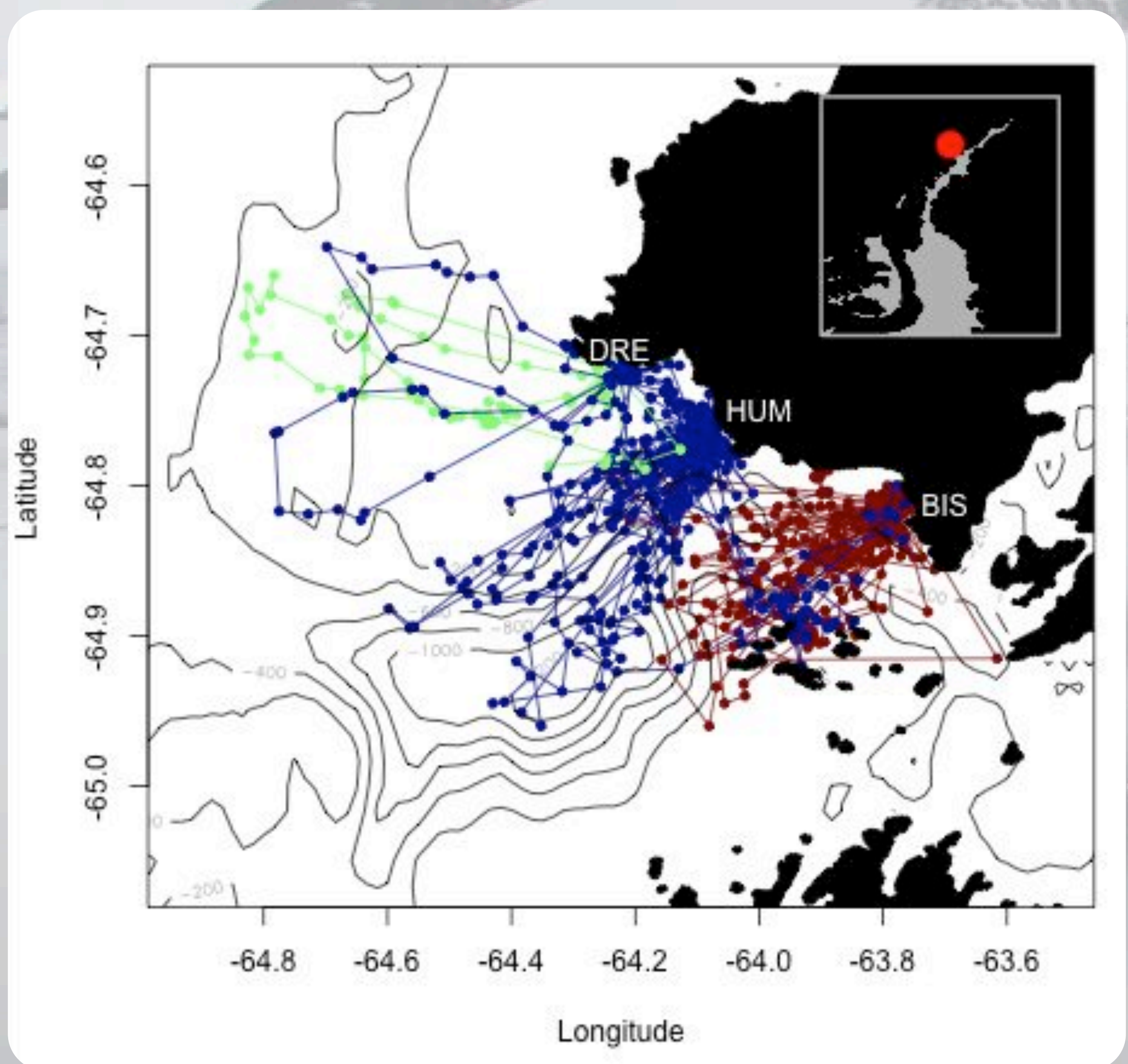
Foraging Dives
31%
54%
13%
2%
0%
Depth (meters)
Temperature (C)
Chlorophyll (μg L-1)
Time (Days)
0
20
40
60
80
100
1
0.5
0
-0.5
3
2
1
0
1
2
3
4
5
6


Temperature from ru05's 01/24/09 - 01/29/09 deployment with overlay of 2009 penguin UD shown at 50% and 90% confidence intervals
UD (50%, 90%), 01/24/09 18:00
Glider Loc. at 01/24/09 18:00
Glider Path
Coastline
Bathymetry
Rothera Sta.
Depth (m)
Lon
Lat
ru05 Glider Track - LTER (01/24/09 - 01/29/09)
Temperature (degC)

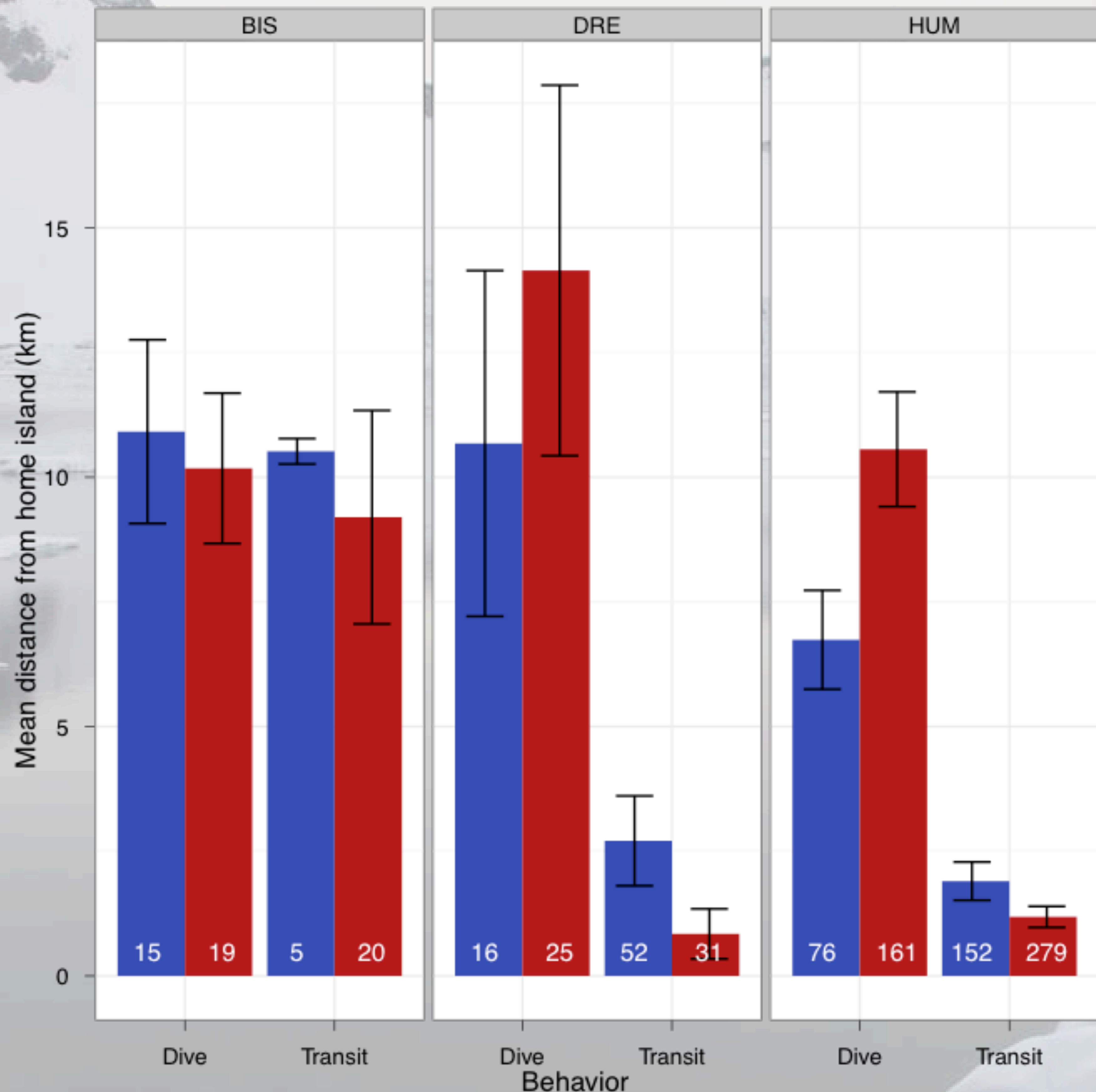

Chlorophyll from ru05's 01/24/09 - 01/29/09 deployment with overlay of 2009 penguin UD shown at 50% and 90% confidence intervals
UD (50%, 90%), 01/24/09 18:00
Glider Loc. at 01/24/09 18:00
Glider Path
Coastline
Bathymetry
Rothera Sta.
Depth (m)
Lon
Lat
ru05 Glider Track - LTER (01/24/09 - 01/29/09)
Chlorophyll (ug/l)

Results from the 2011 field season: Tidal structuring of the penguin foraging

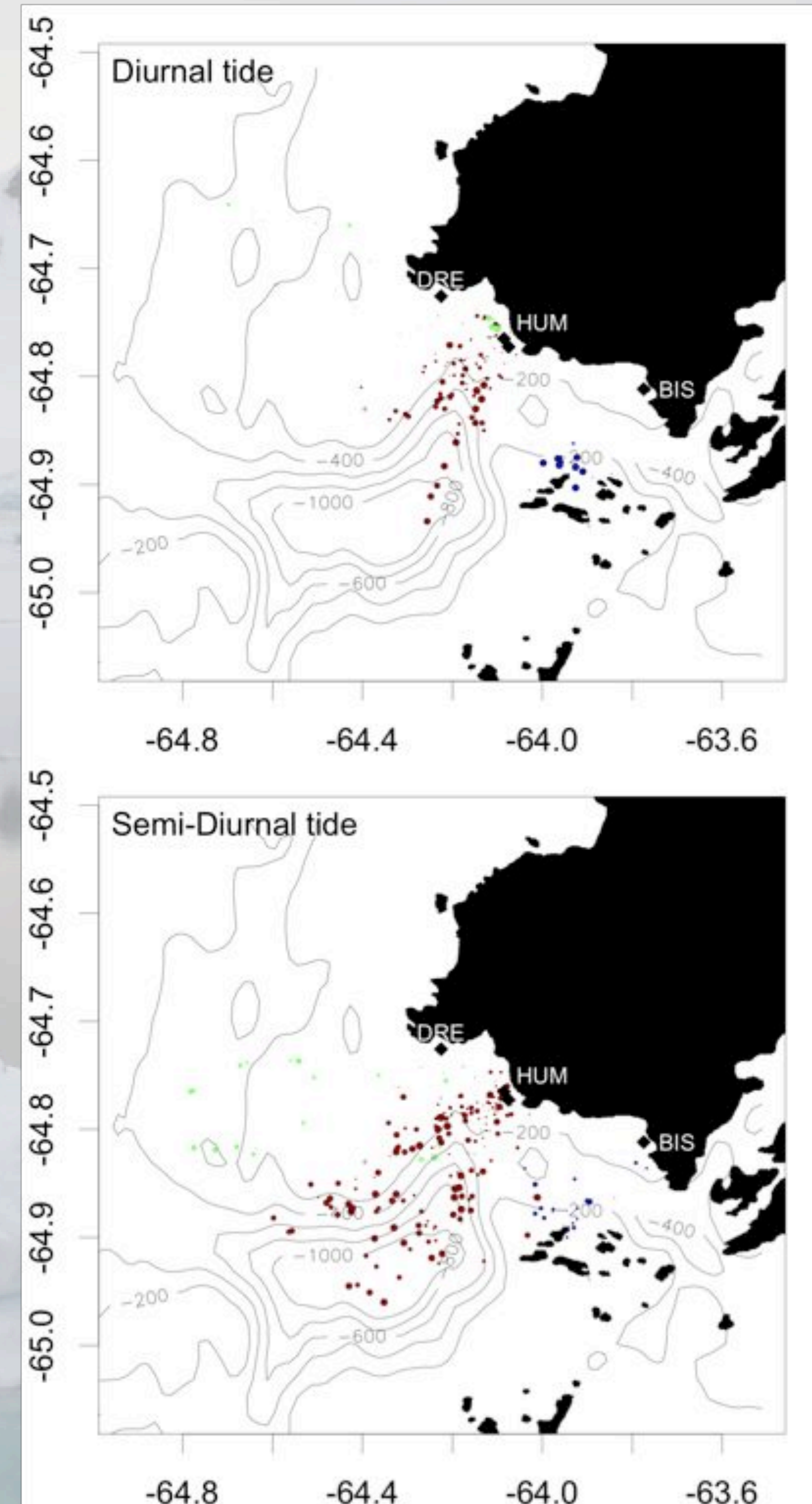
Moline, Oliver, Frazer, Kohut, Schofield



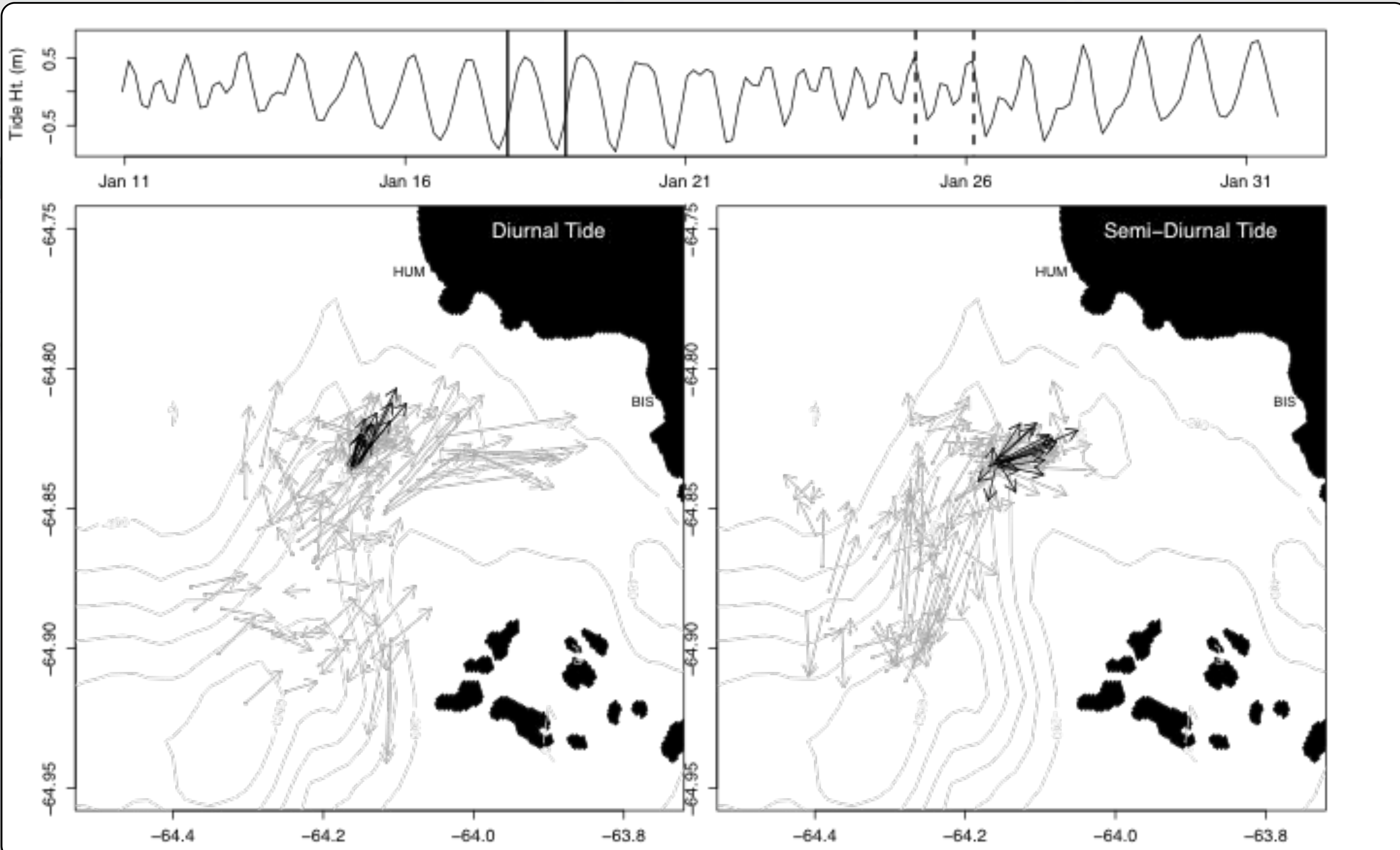
Radio-tagged penguins
Adelie (blue)
Gentoo (red)
Chinstrap (green)



Blue = semi-diurnal tides
Red = diurnal tides



Glider currents



Conclusions:

Minor variations in the ocean state can have profound impacts on polar ecosystems

These profound changes are occurring in many polar oceans, changes appear to be accelerating

New technologies offer a mode to study and understand these changes, so it is time hopefully speed up our uphill trek to quantitative understanding, animals will help show us the way