RAPID CLIMATE CHANGE AND ECOSYSTEM RESPONSE AT PALMER STATION, ANTARCTICA

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The Ecosystems Center, MBL
SCAR Open Science Conference, Buenos Aires, August 2010

Outline

Overview of PAL: LTER Network, Study Area and Observing System

1. Rapid Climate Change on the West Antarctic Peninsula (WAP): ***Large changes in air & sea temperatures***

2. Changes in ecosystem at all trophic levels ***(phytoplankton to penguins)***

3. Process studies to test hypotheses about mechanisms of change

Palmer Antarctica Long Term Ecological Research Project

US LTER Network

26 Sites

2 Antarctic, 2 Arctic, 9 marine/coastal

26 total

Palmer LTER Study Region along the WAP: 300 x 700 km: Process Studies Embedded in a Long-Term Observational Context

600 400 300 200 100 000 -100

200 180 160 140 120 100 080 060 040

Sediment Trap

Palmer Station (US)

Anvers Island

LTER local Time series
Semi-weekly, Oct -April

Rothera Base (UK)

BAS RaTS Local Time Series
Weekly, year-round

Avian Island

Charcot Island

Satellite remote sensing
ocean color (chlorophyll)
surface temperature
sea ice, 1978-present

Antarctic Peninsula

Annual Hydrographic Survey
(CTD-Rosette, Net Tows)
Thermistor Moorings

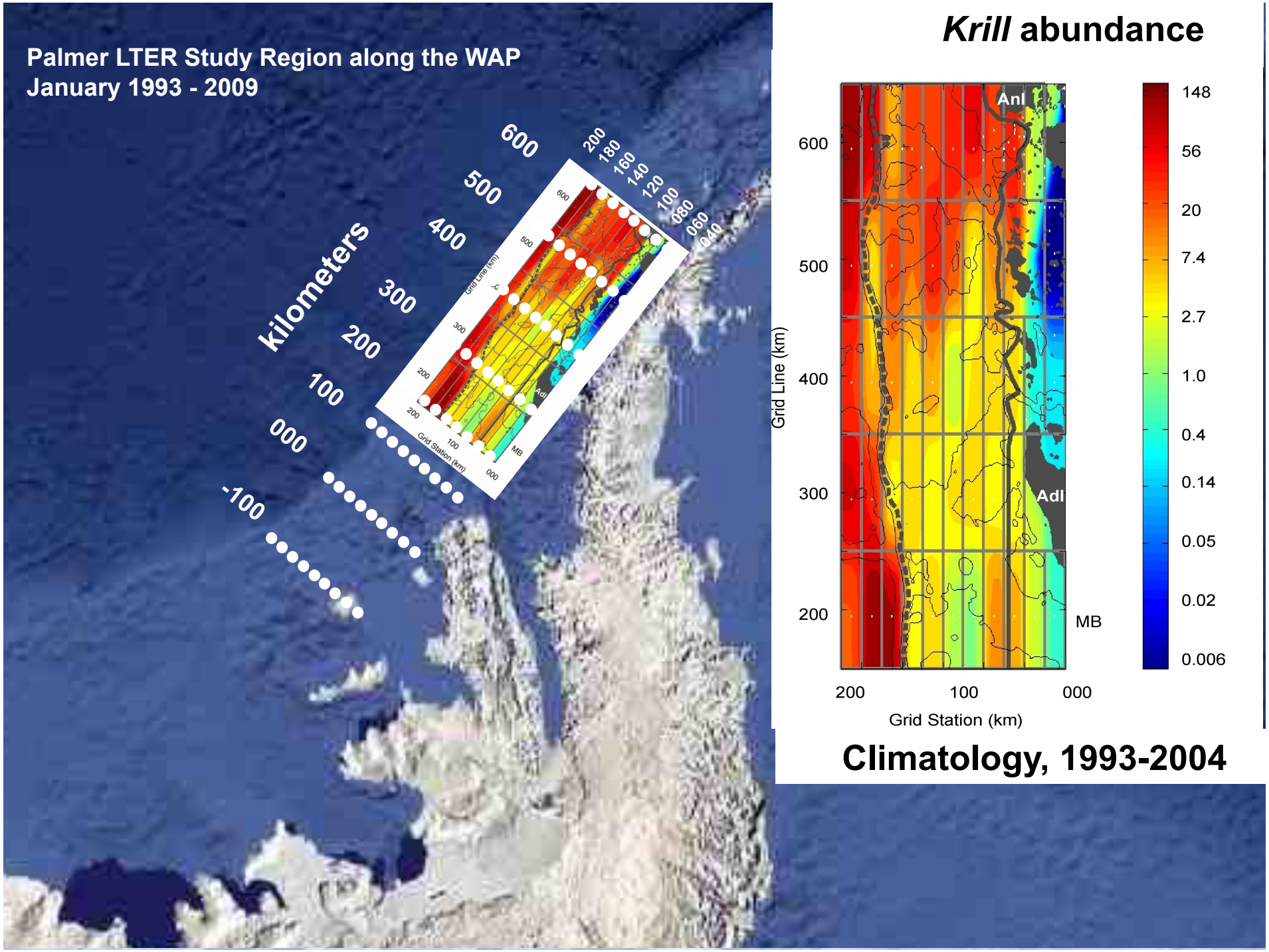
Adélie Penguin Colonies

Process Studies

SLOCUM Glider Base

Canyons & Deeps

Palmer LTER Study Region along the WAP
January 1993 - 2009



Krill abundance

Climatology, 1993-2004

Palmer LTER Marine Food web (simplified)

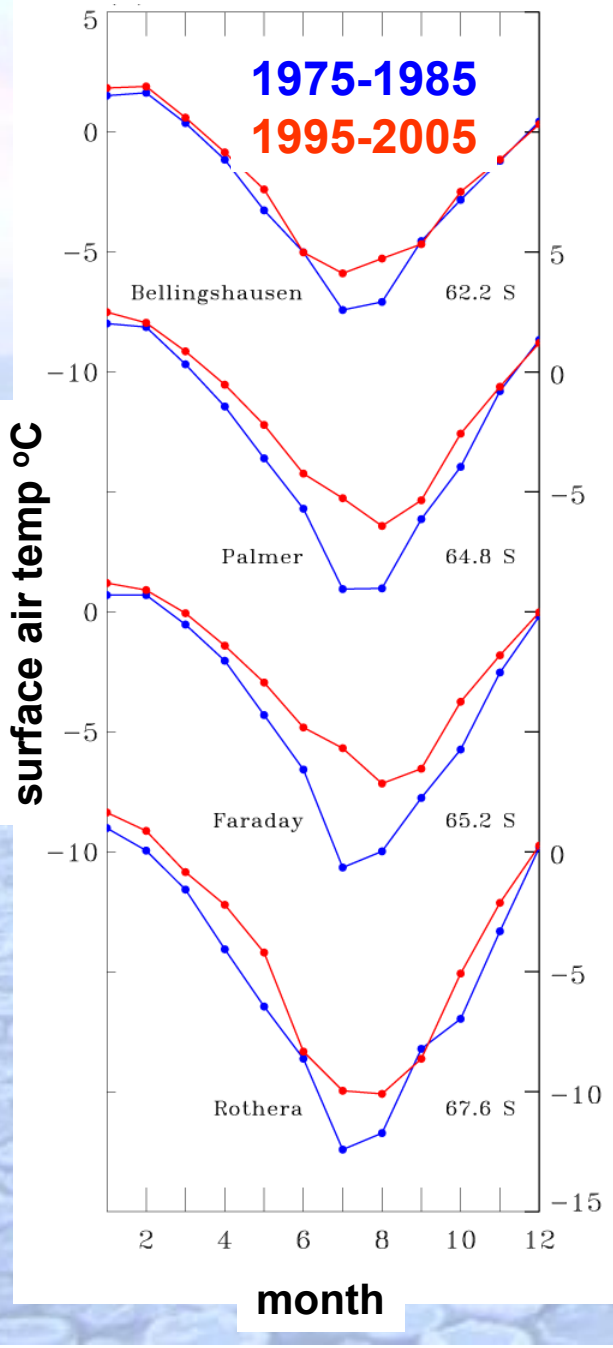
nutrients

CO2

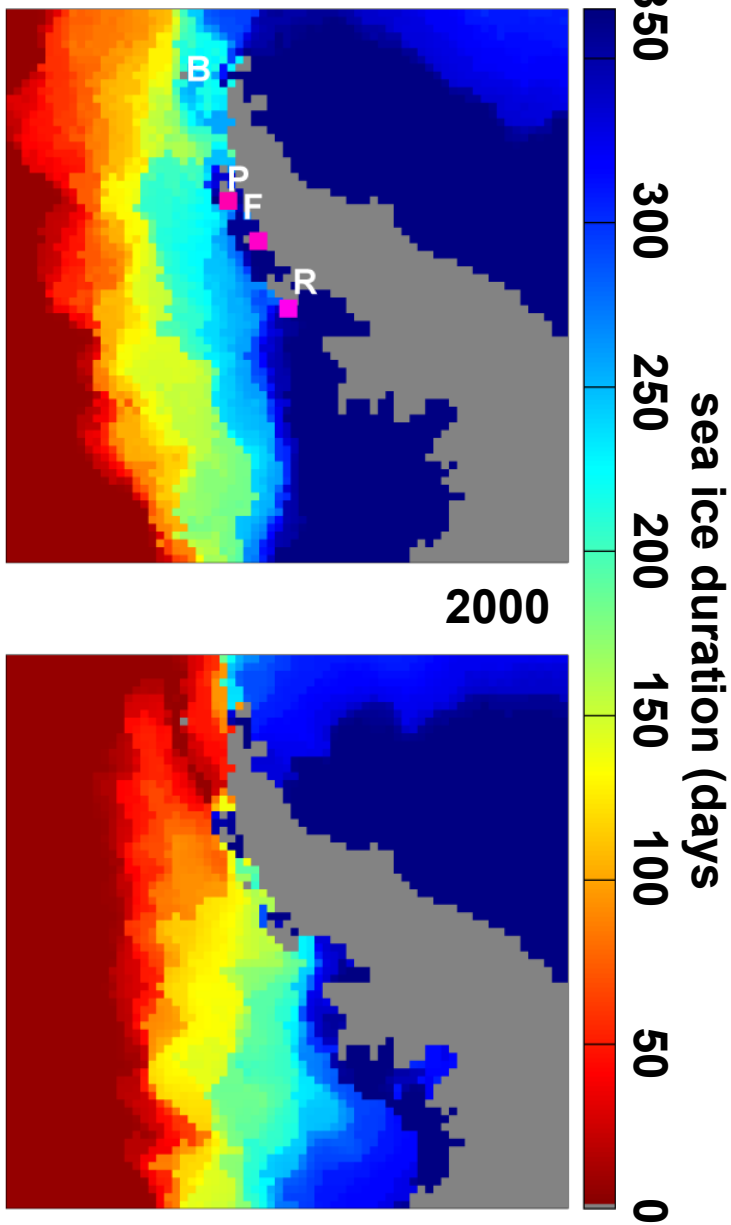
confirmed decade-scale changes in these groups

1. CLIMATE WARMING

Temperature



Sea Ice Duration 1980



Surface air temperature and sea ice duration gradients along the WAP

Warmer with less sea ice cover in the north; colder and more sea ice in the south.

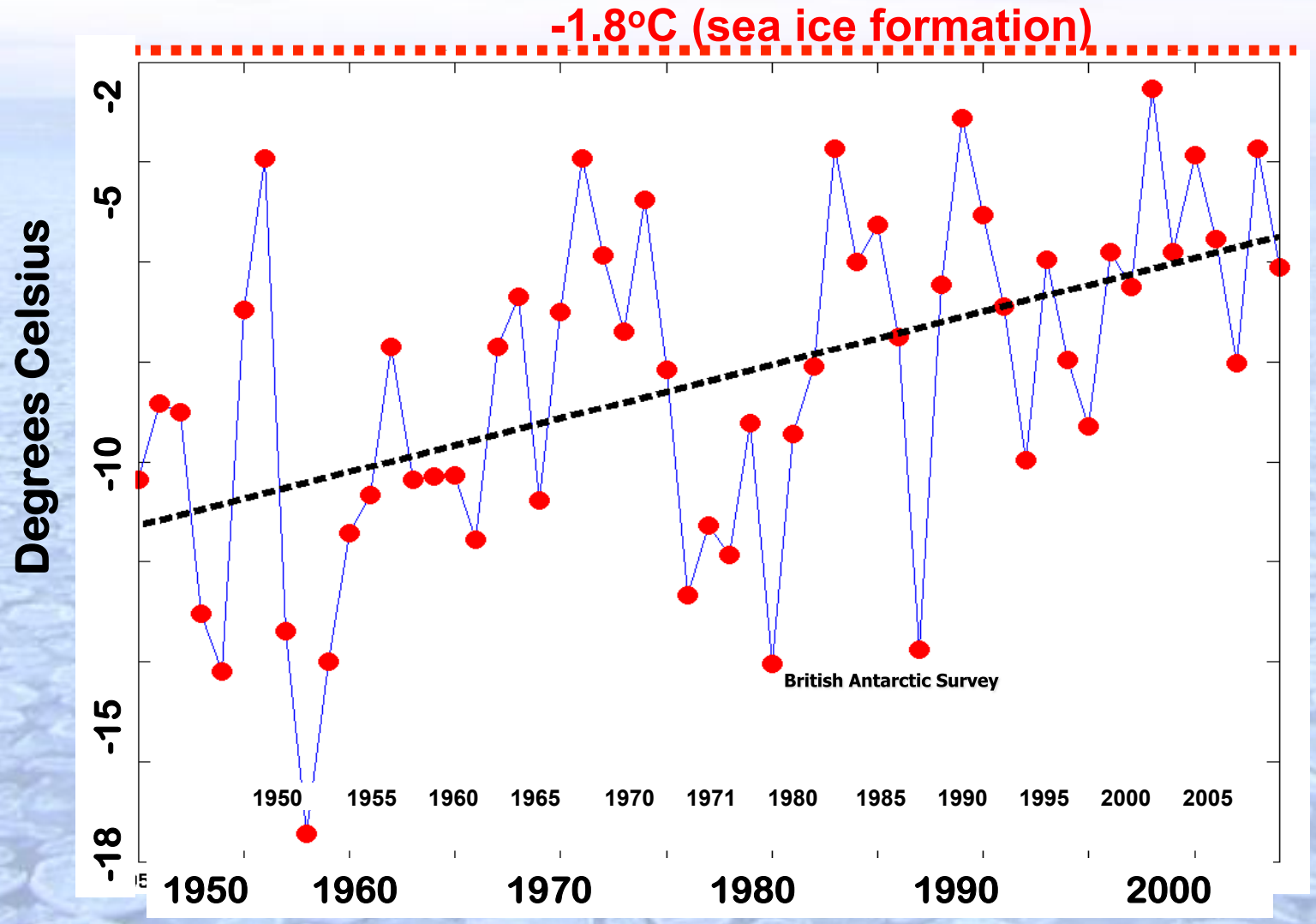
Reduction in sea ice duration: 83 days since 1978

Sharon Stammerjohn

1. Climate change along the WAP

Average winter (June-July-August) temperature (Faraday Base)

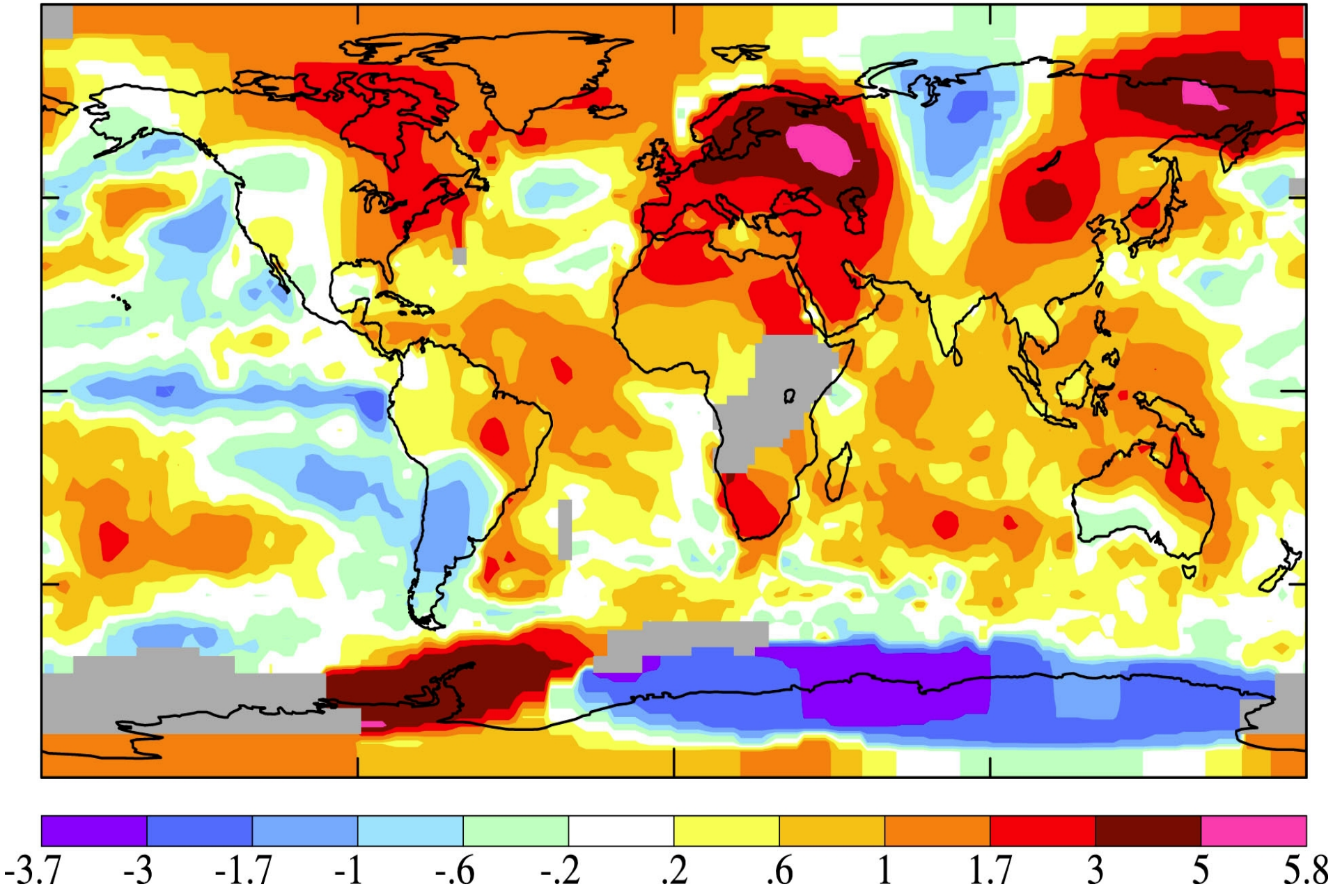
+1.1°C per decade: 6°C (11F) since 1950: 5 x global average



July 2010 Surface Temperature Anomaly (°C)

[Base Period: 1951-1980]

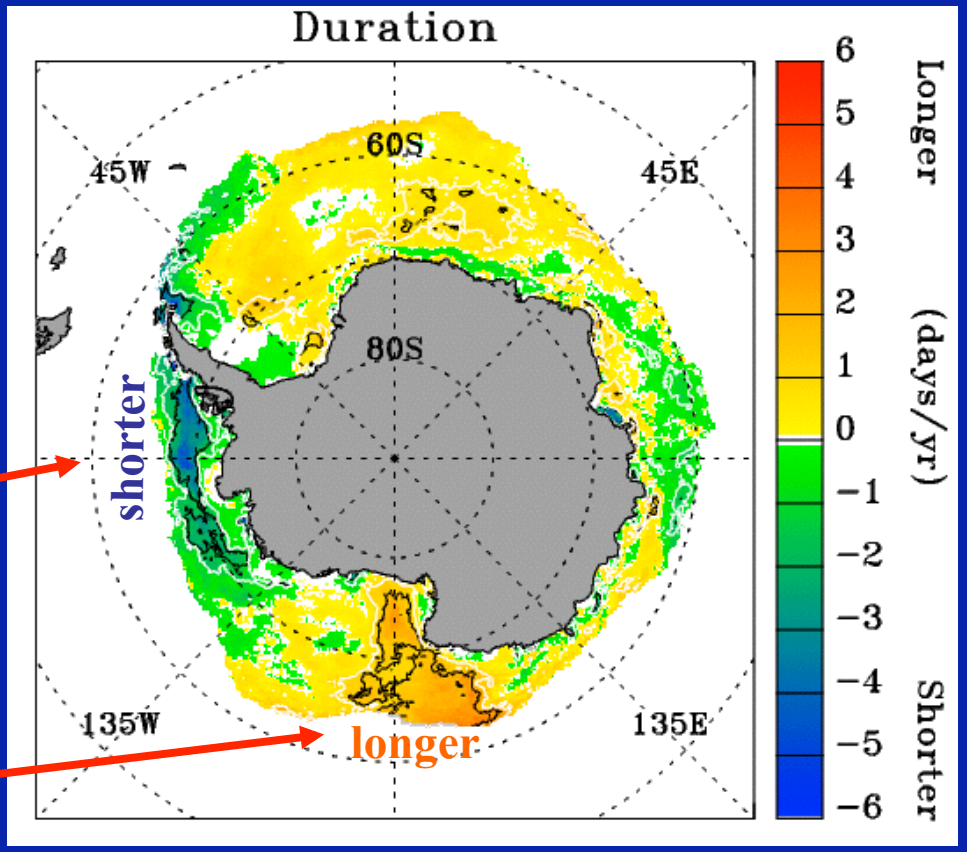
.55



Antarctic Seasonal Sea Ice Trends

AP-Bellingshausen-Amundsen Sea Region (*AP/BA*)

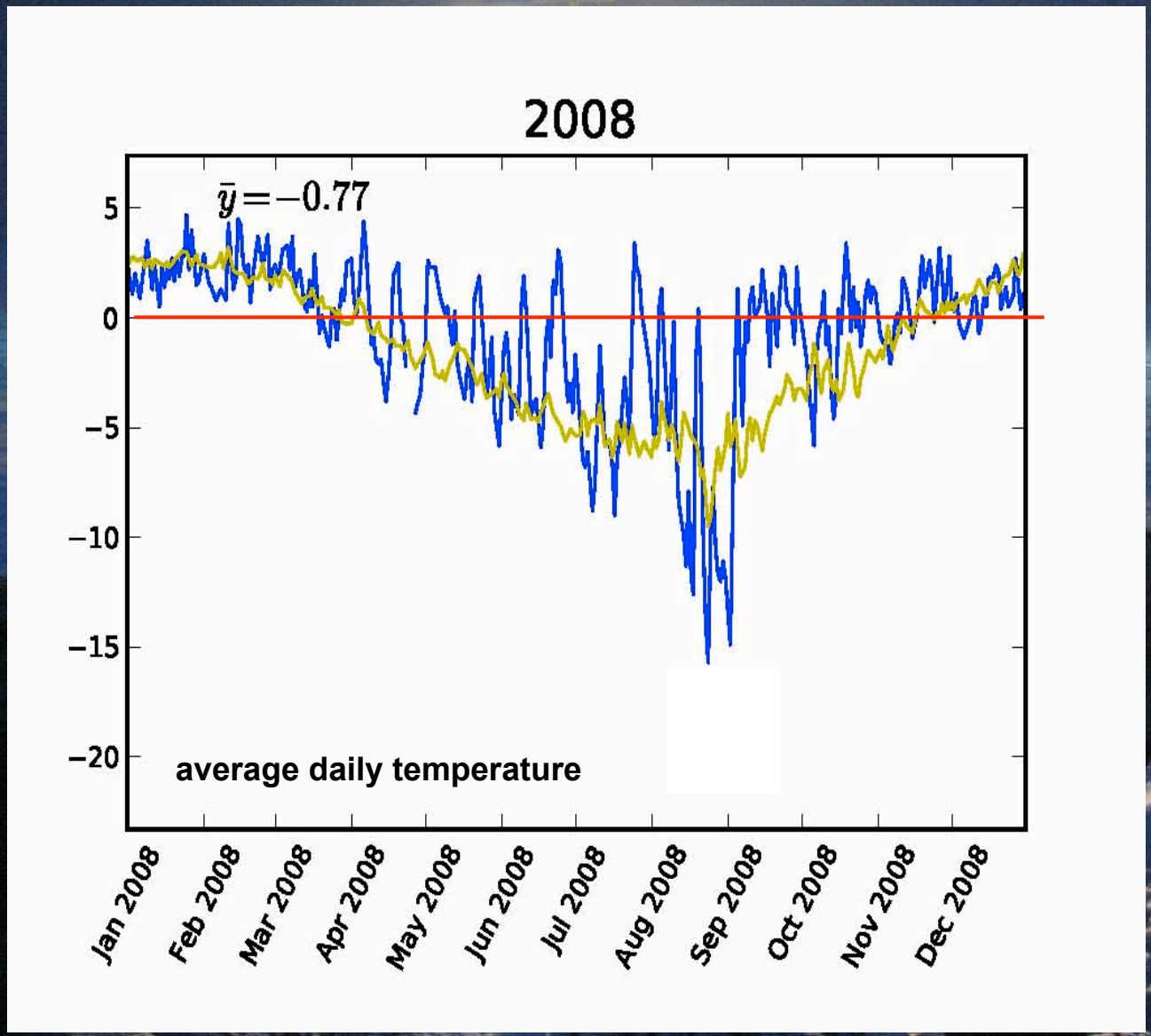
Western Ross Sea Region (*wRS*)



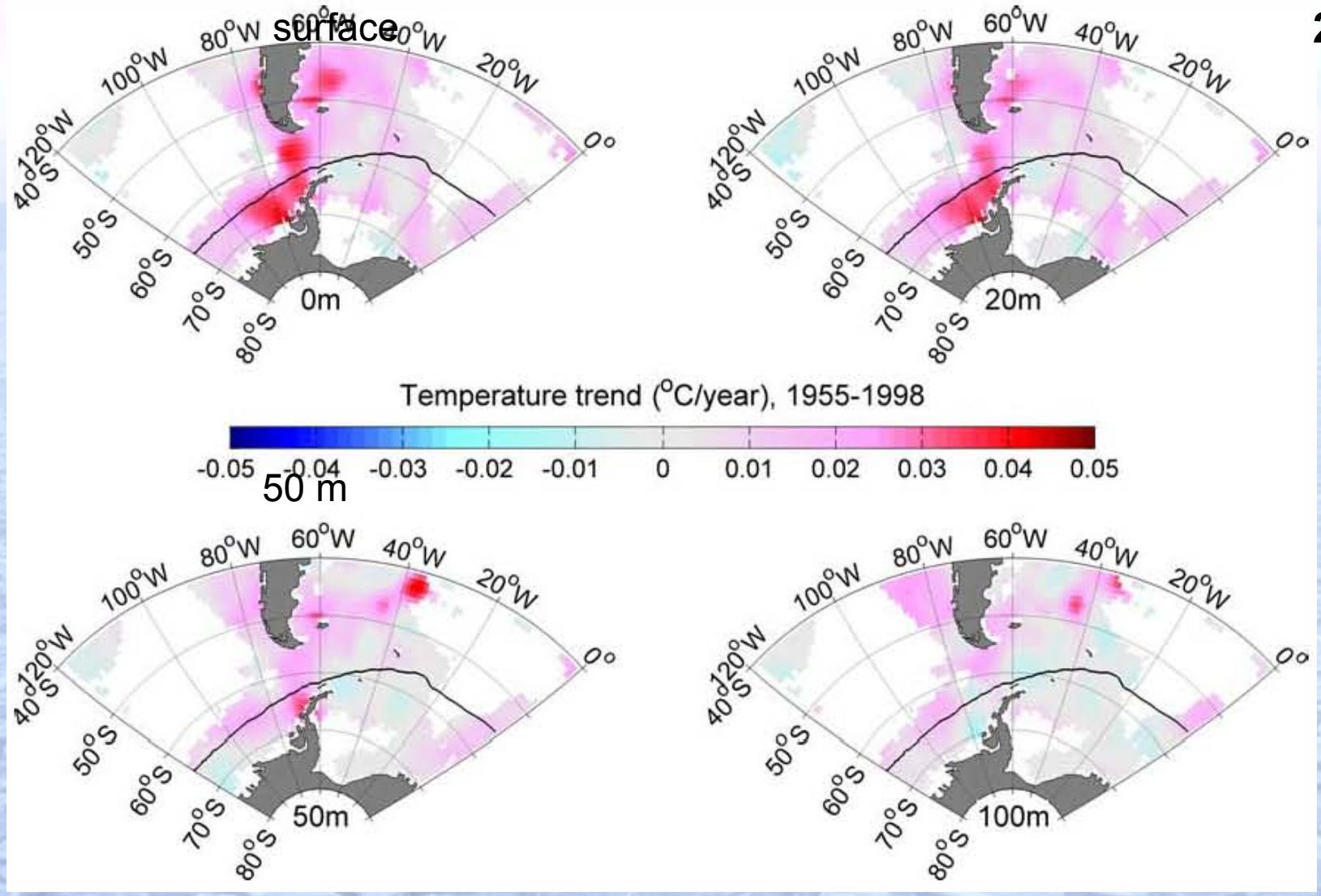
Region	Advance (days)	Retreat (days)	Duration (days)
AP/BA ~0.53 x 10^6 km^2	+48 ± 11 (later)	-35 ± 9 (earlier)	-83 ± 23 (shorter)
wRS ~0.86 x 10^6 km^2	-29 ± 7 (earlier)	+28 ± 6 (later)	+57 ± 13 (longer)

Total Change over 28 years (1979-2006):

(*Stammerjohn et al*, 2008, JGR)

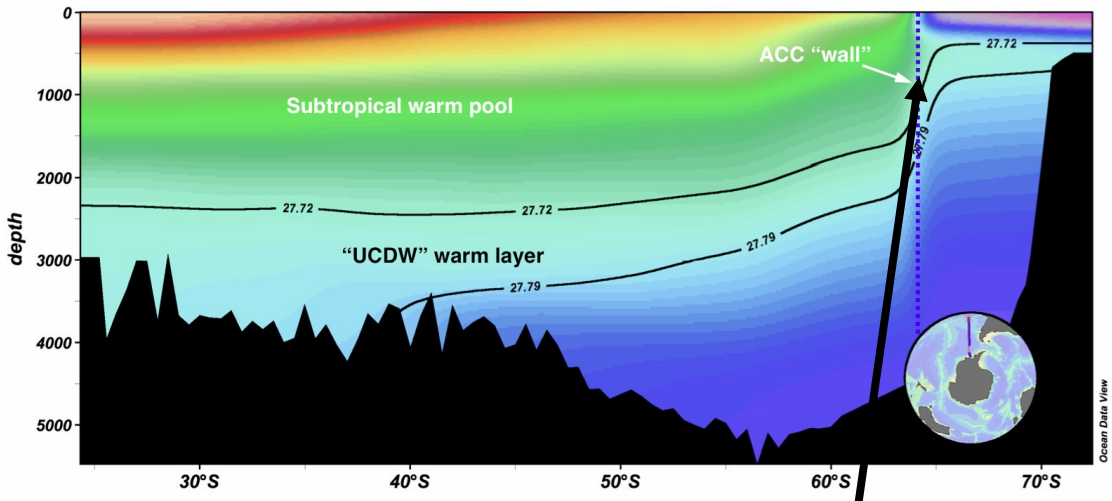

2008
$\bar{y} = -0.77$
5
0
−5
−10
−15
−20
average daily temperature
Jan 2008
Feb 2008
Mar 2008
Apr 2008
May 2008
Jun 2008
Jul 2008
Aug 2008
Sep 2008
Oct 2008
Nov 2008
Dec 2008

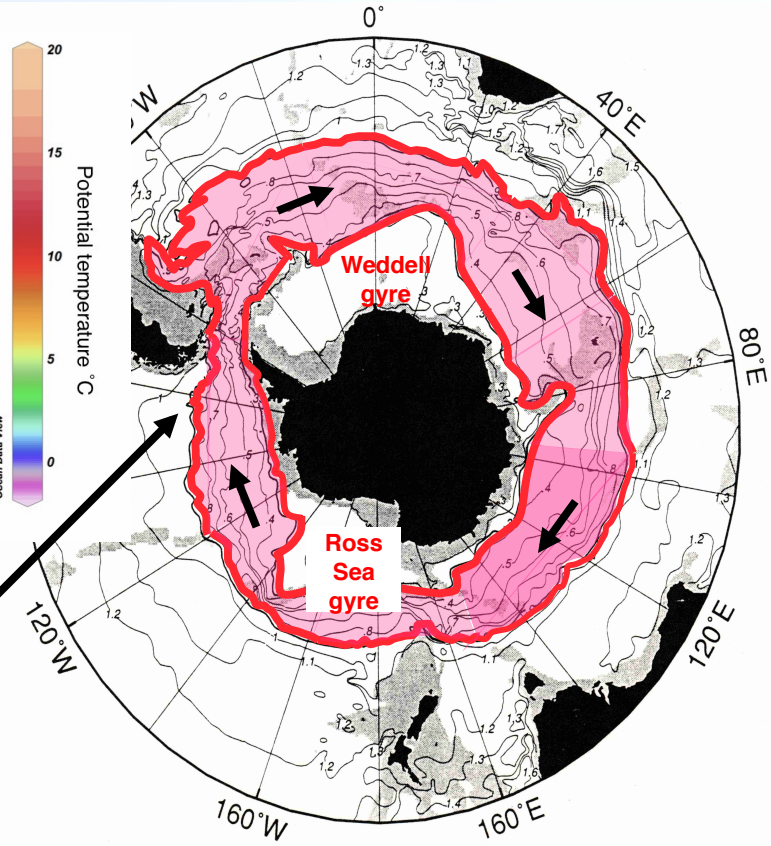
Warming of Water Over Shelf



A warming of ~0.6C in upper 300 m - Meredith et al GRL 2005

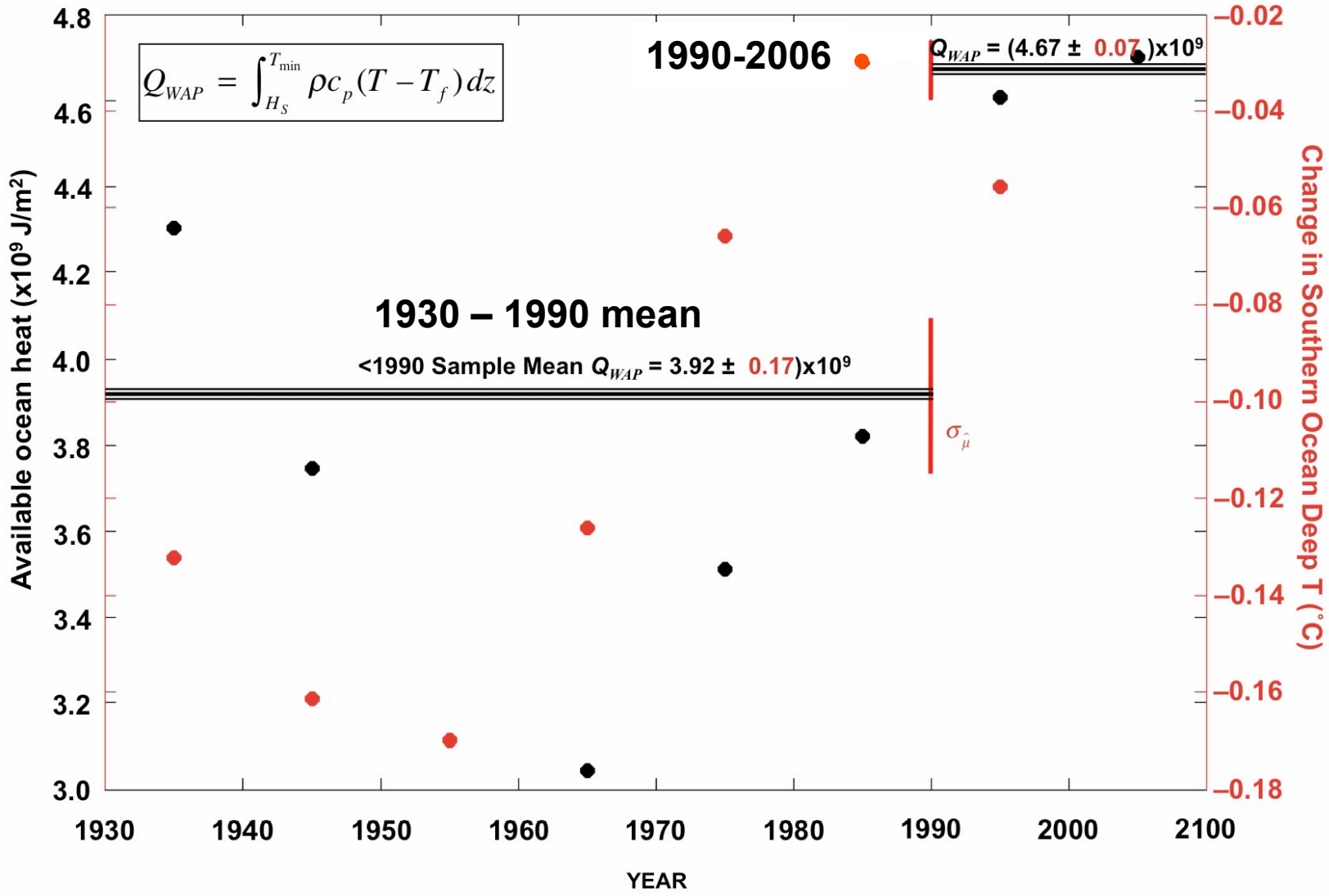
Why so fast ? Heat input from Antarctic Circumpolar Current (Hofmann et al talk to follow)





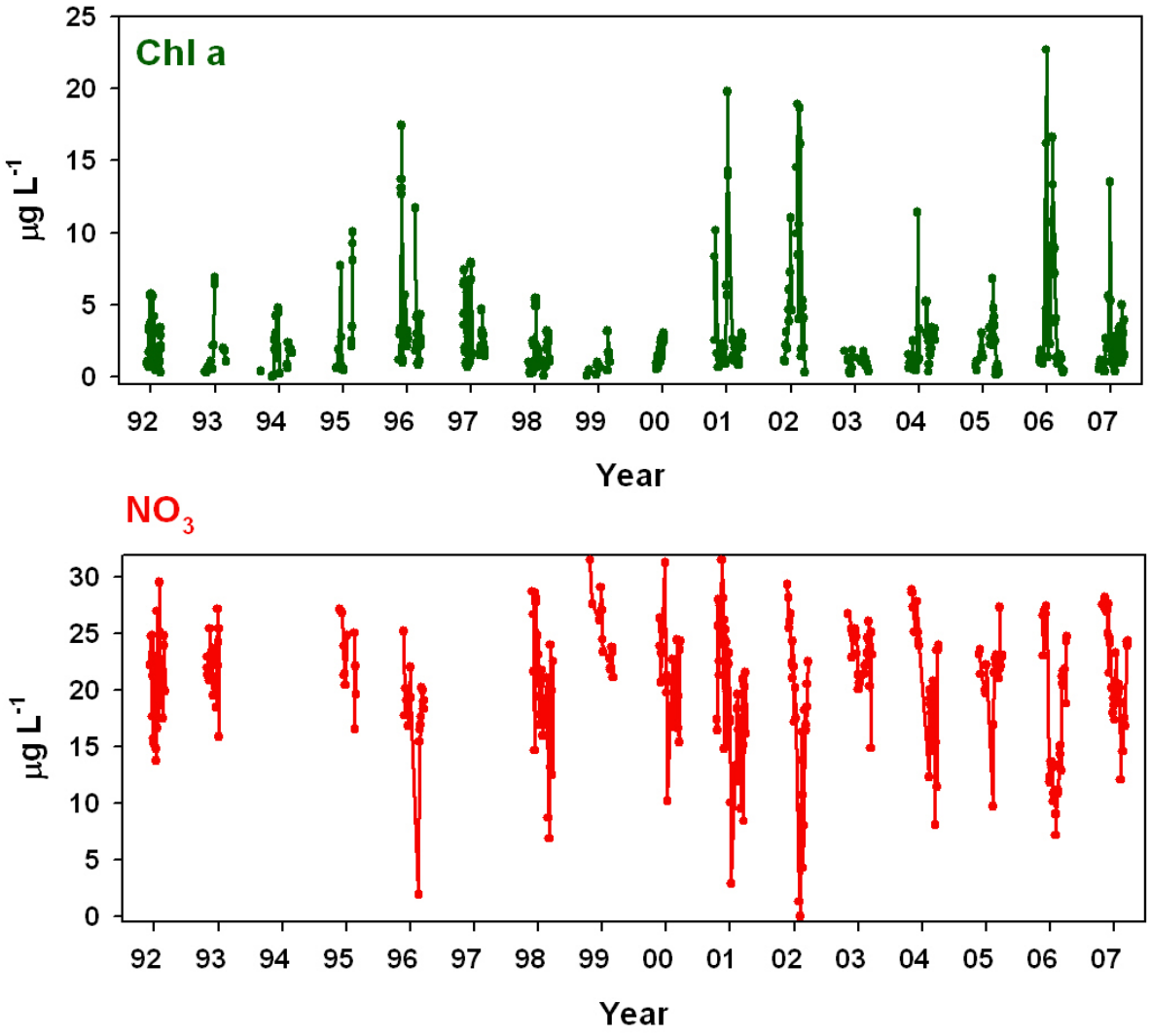
The WAP is the only location in Antarctica where the Antarctic Circumpolar Current (ACC) directly impinges on the shelf break. The ACC is Antarctica's warmest water.

+ 20% Change in heat content over shelf, 1930 - 2010

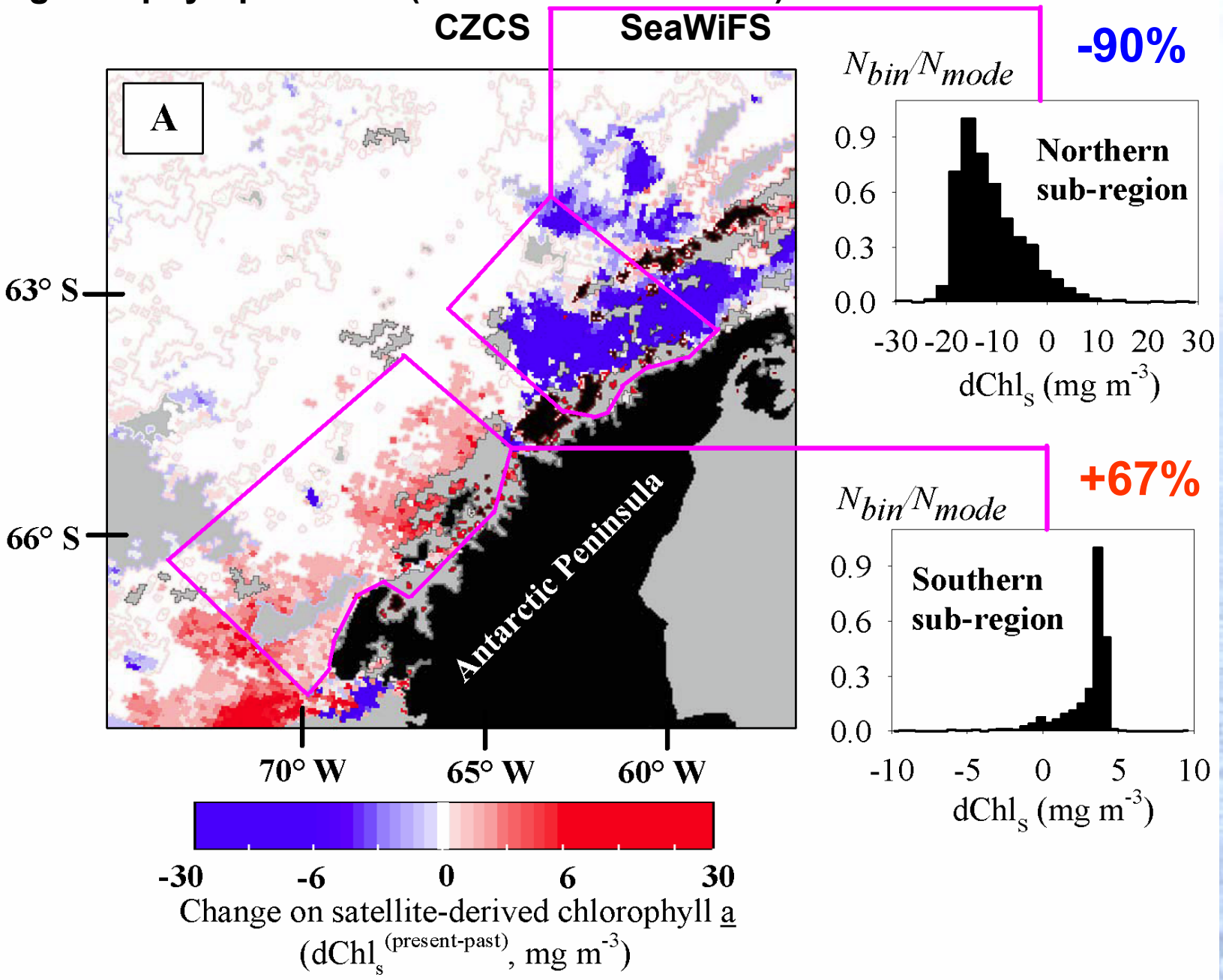


2. ECOSYSTEM RESPONSES

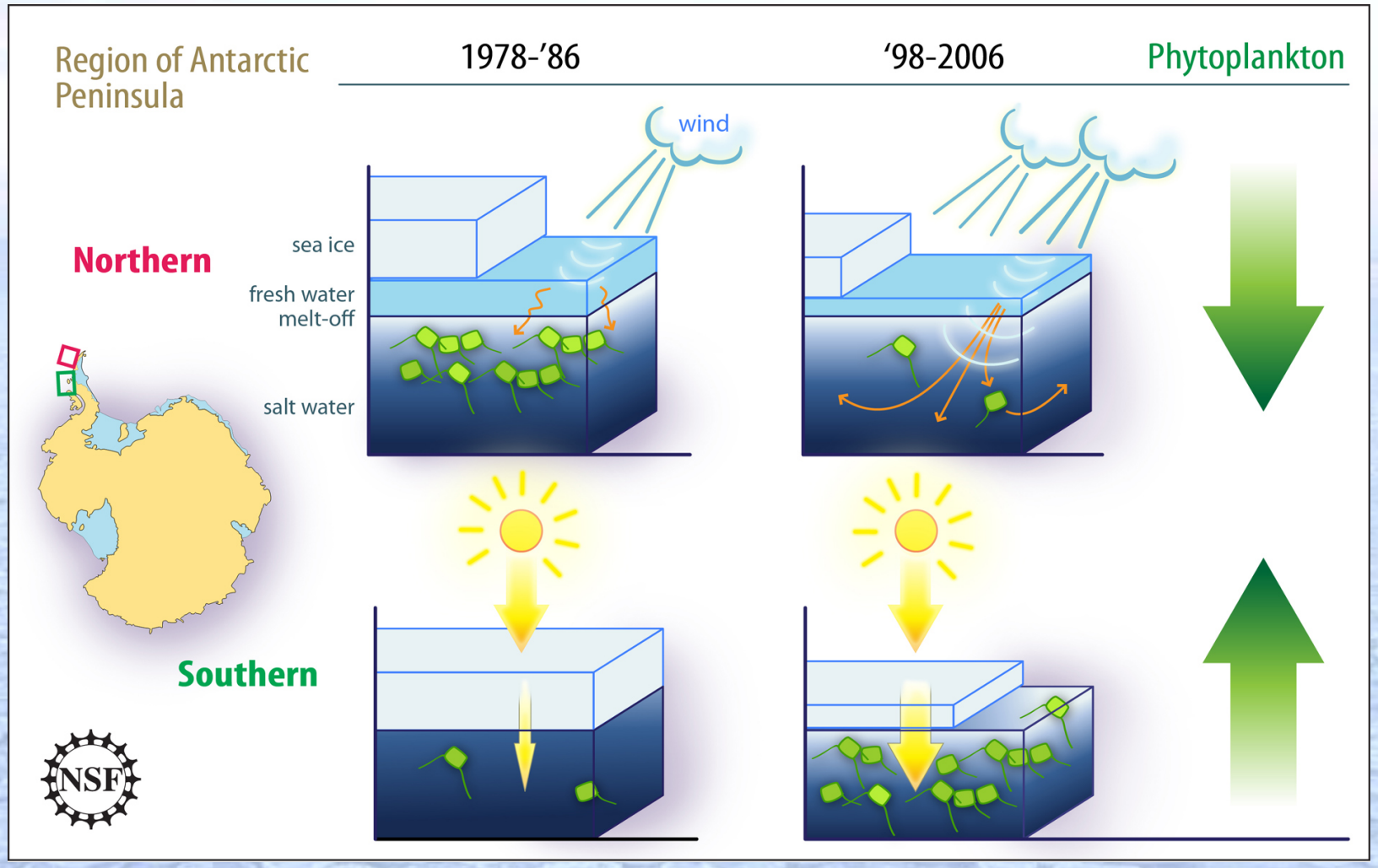
PALMER STATION CHLOROPHYLL AND NITRATE: 1992-2007



Changes in phytoplankton: (1978-86 to 1998-2006)



Summary: Sea Ice, wind and phytoplankton along the WAP 1978-2006



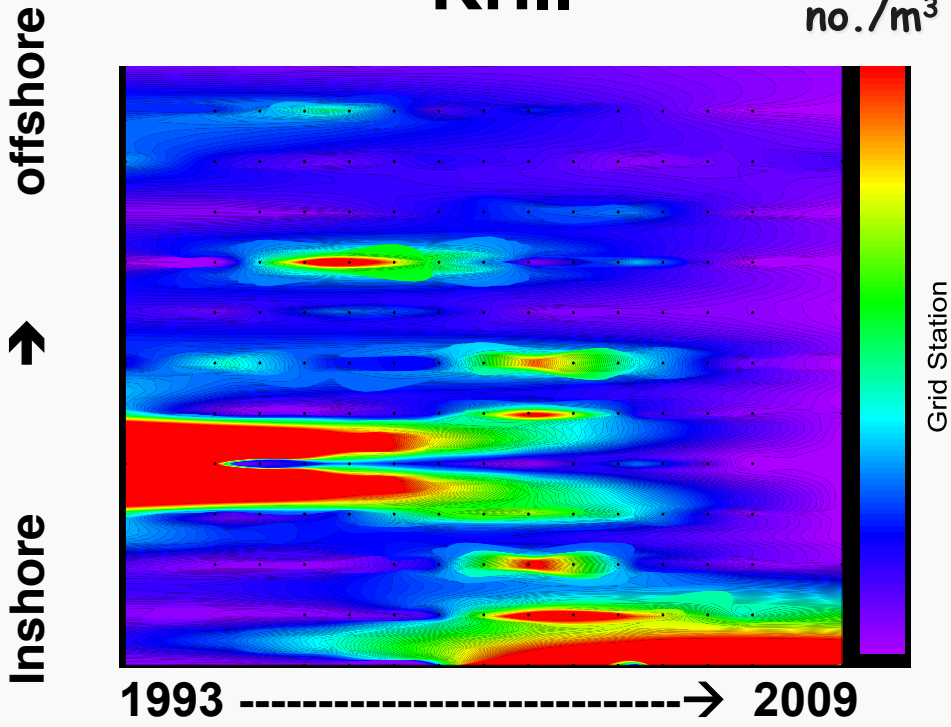
Courtesy Zina Deretsky, NSF

Long-term changes in zooplankton

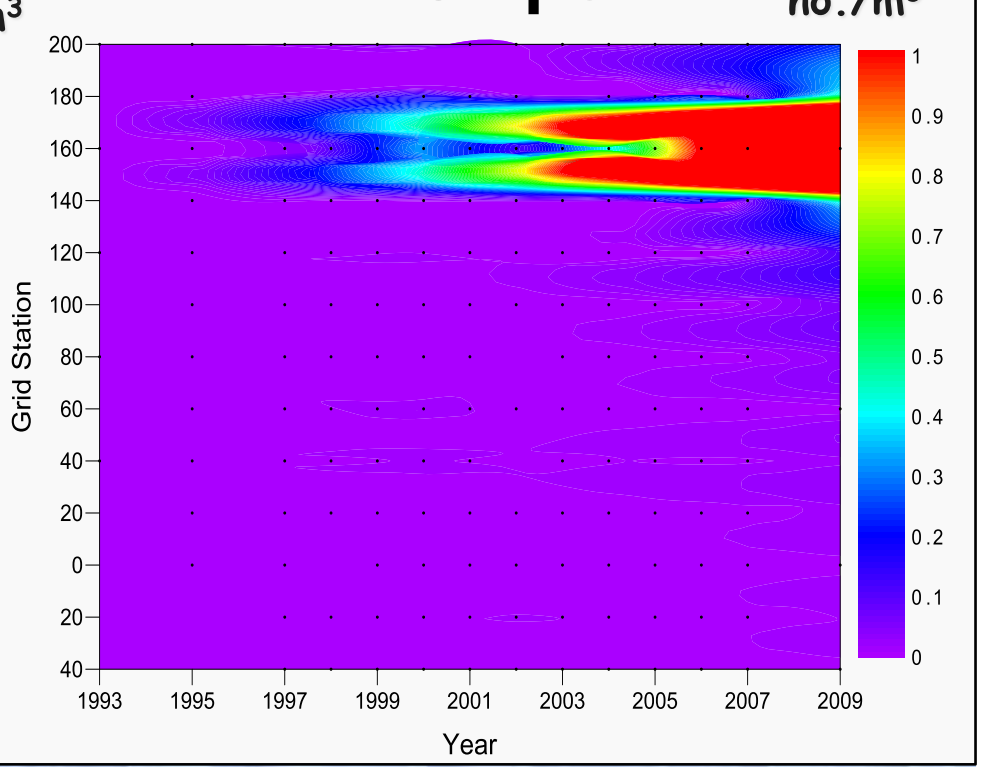
Decreasing and shifting closer inshore?

Increasing over time (and expanding over shelf)?

Krill

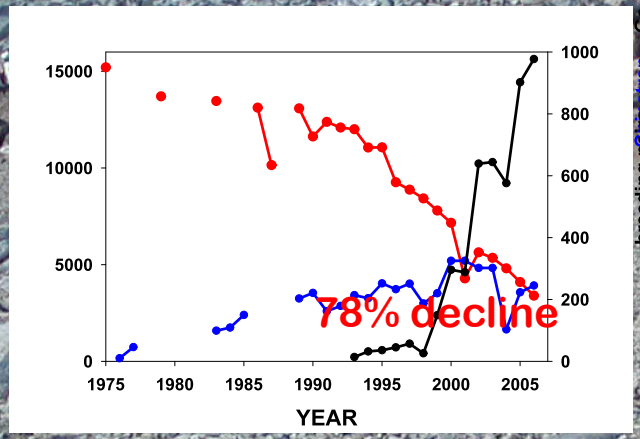


Salps



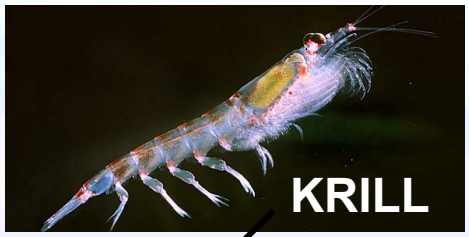
(Line 200 -South)

Penguin Populations in the Palmer Station region (75% decline since 1975)

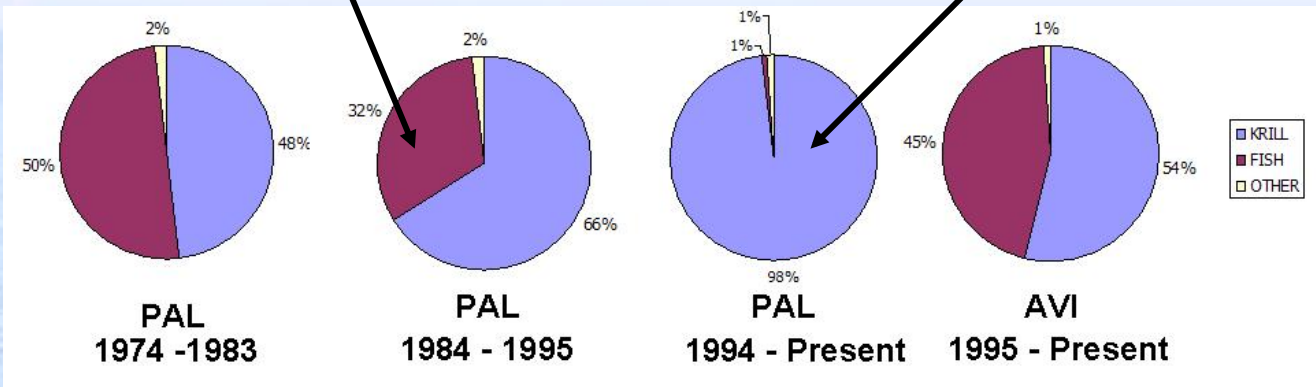


Changing composition of Adélie Penguin Diets, 1974-present
Palmer vs Avian Island Regions

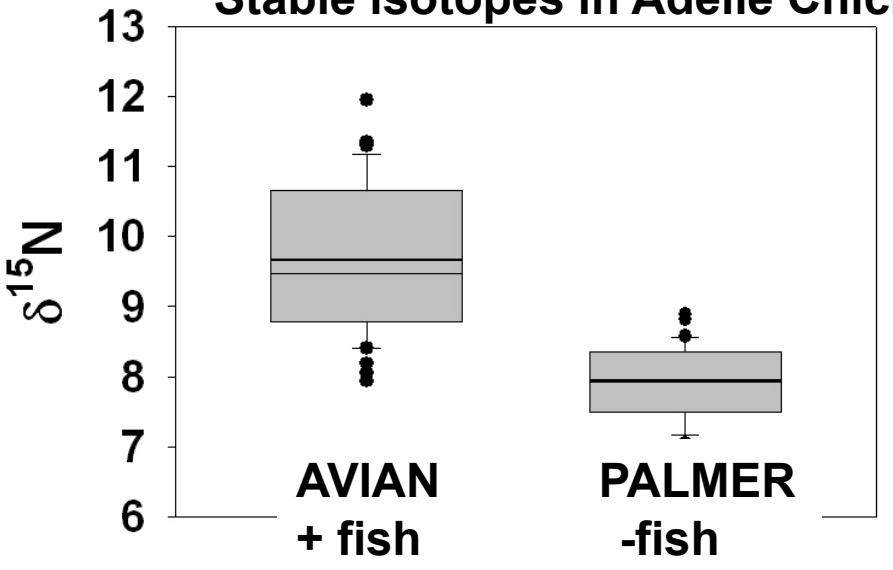
Antarctic Silverfish

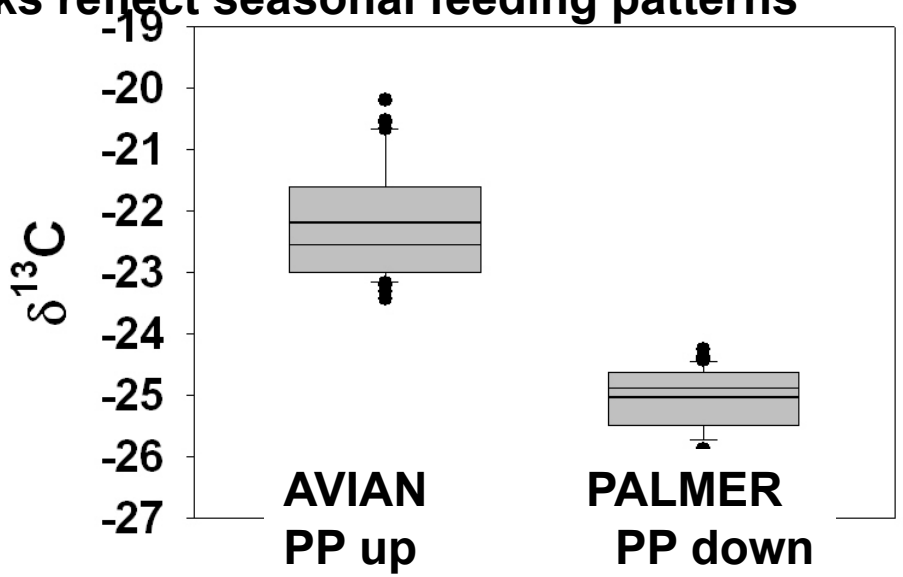


KRILL

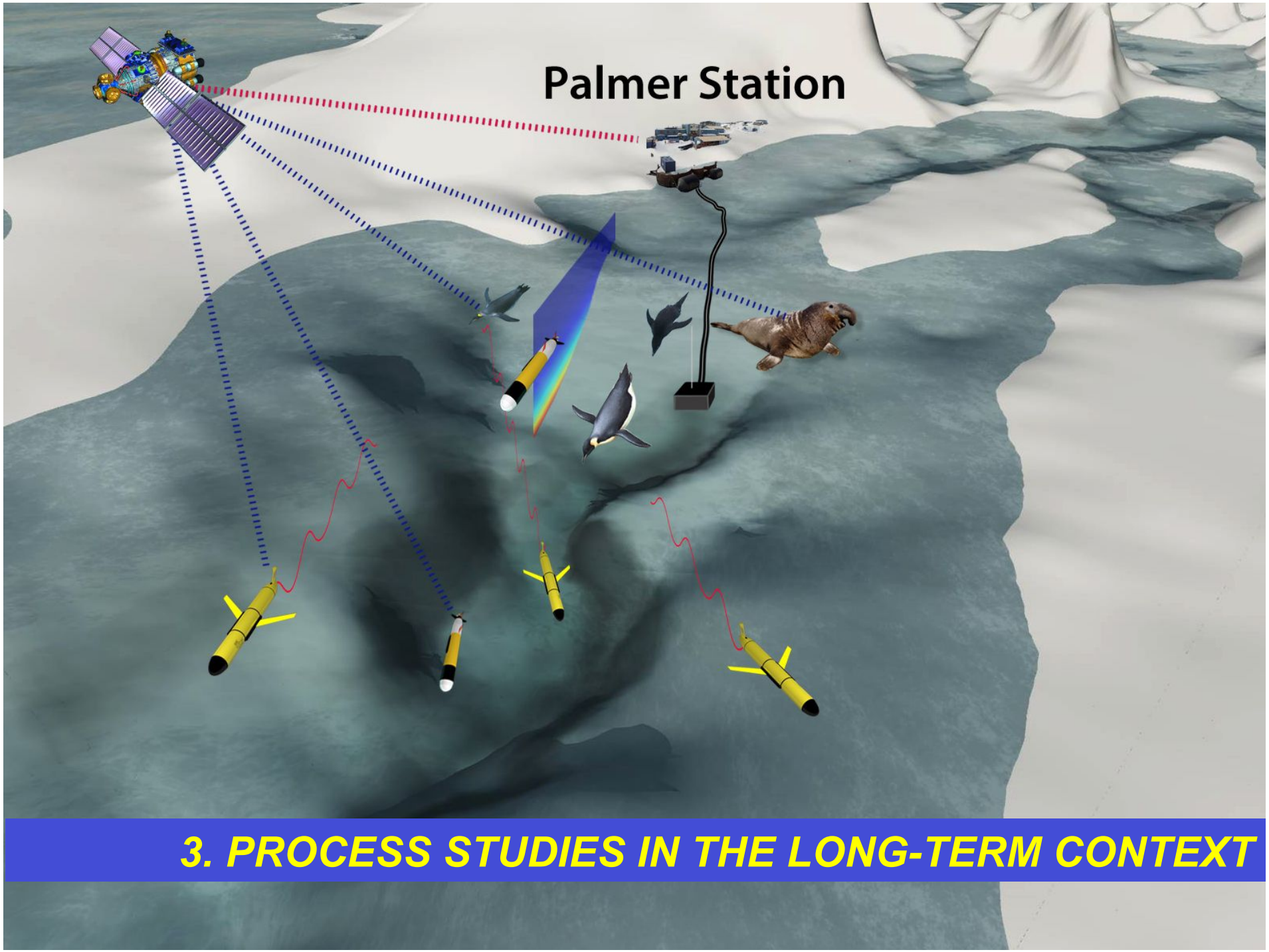


Stable isotopes in Adelie Chicks reflect seasonal feeding patterns



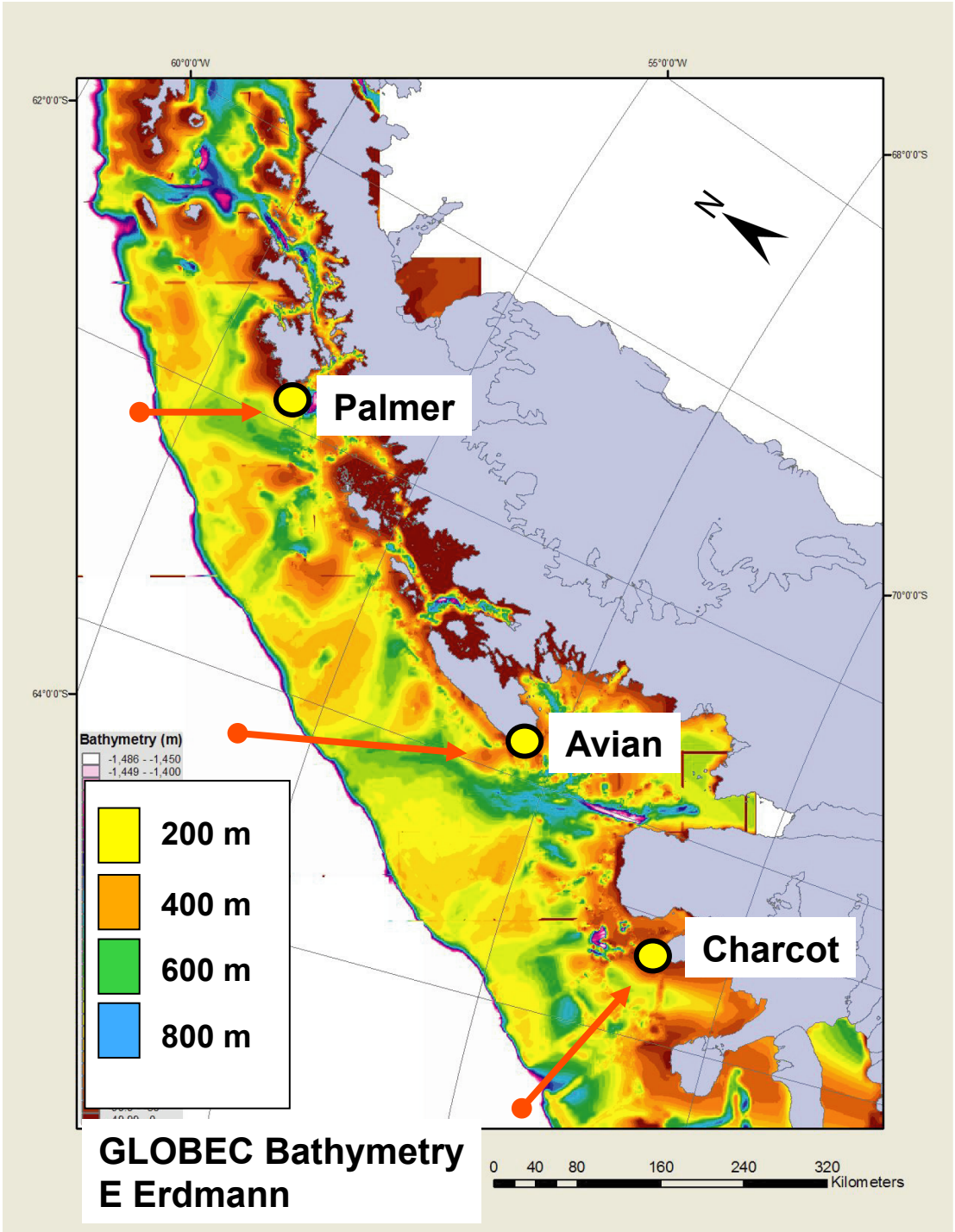


Isotopes: Kristen Gorman



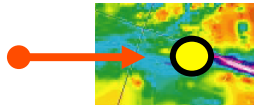
3. PROCESS STUDIES IN THE LONG-TERM CONTEXT

Penguins and Bathymetry



Yellow-green-blue shading: Deeper water – troughs and canyons cutting across the shelf

Penguin colonies proximal to canyons

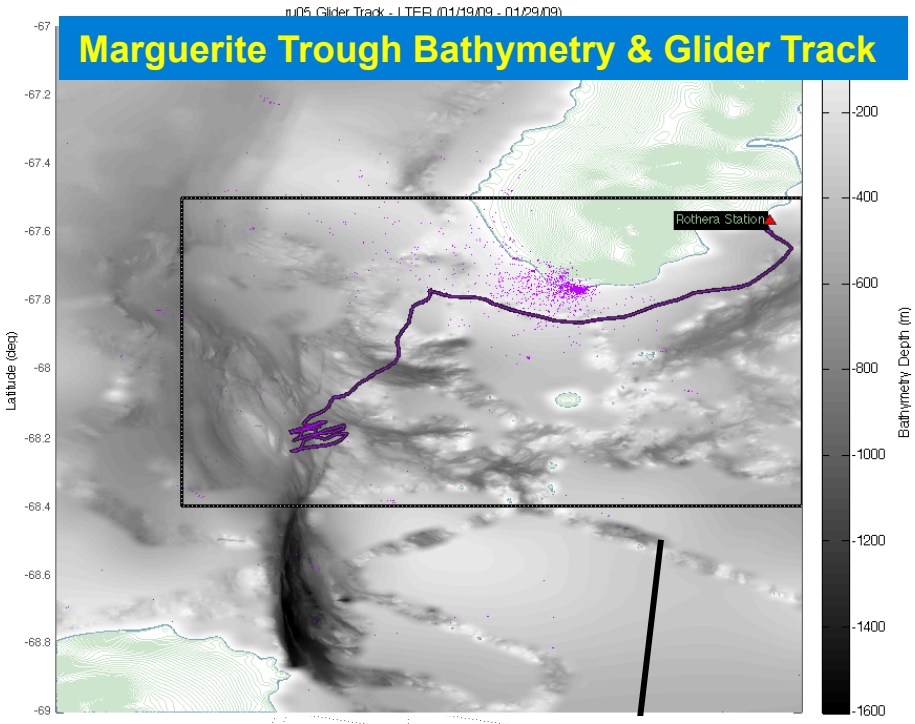


Hypothesis: Penguins concentrate foraging activity over canyon heads and/or polynyas associated with upwelling of warm, chlorophyll-rich) offshore Upper Circumpolar Deep Water (UCDW).

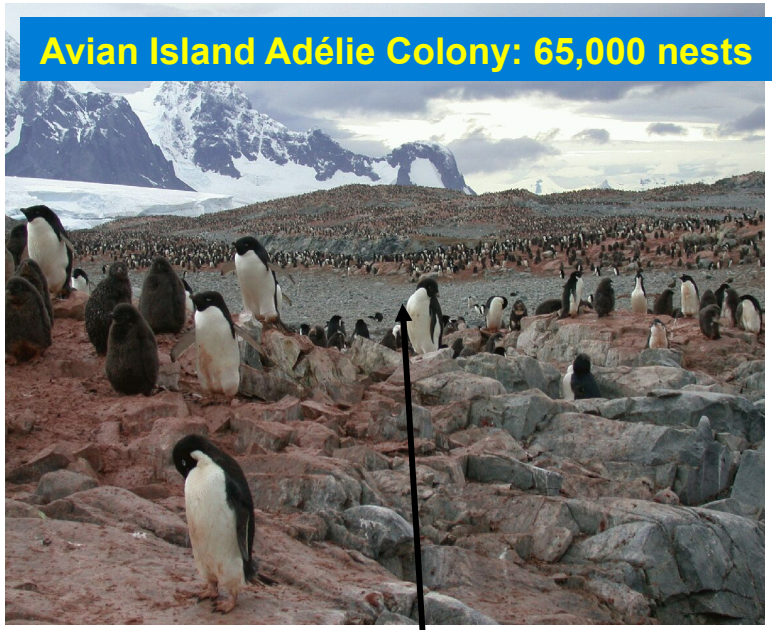
Combine penguin satellite tags and SLOCUM Glider surveys of foraging areas.


Beth Simmons, Tina Haskins
WRC
SLOCUM
ELECTRIC

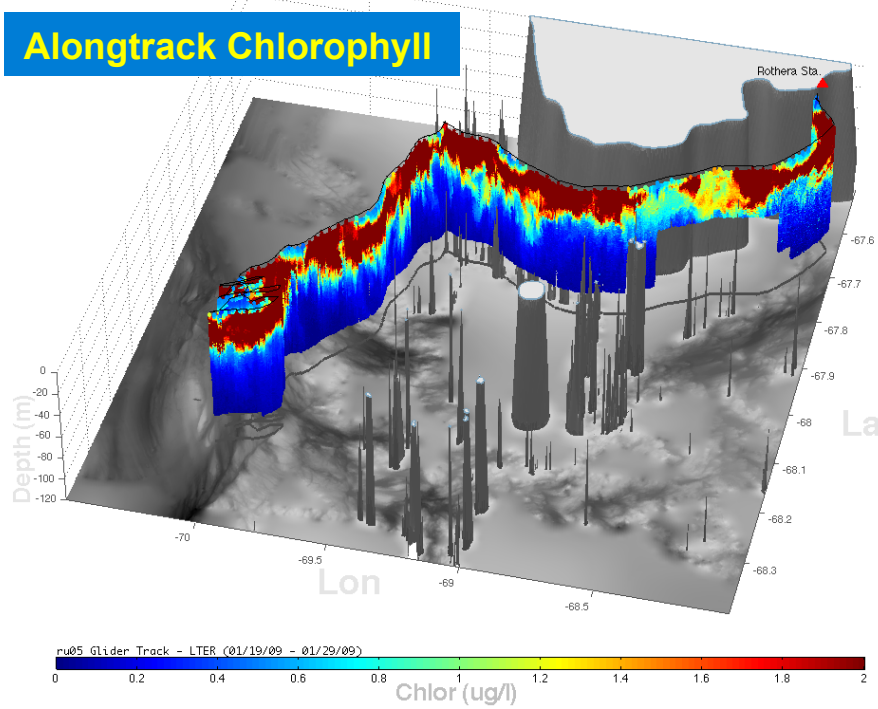
Marguerite Trough Bathymetry & Glider Track



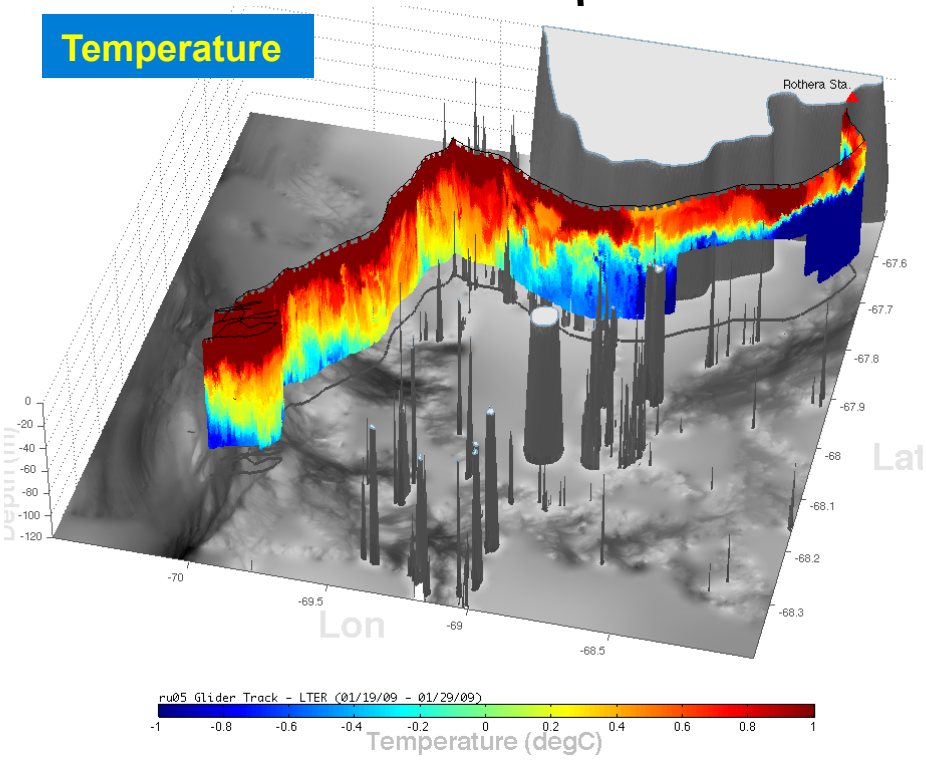
Avian Island Adélie Colony: 65,000 nests

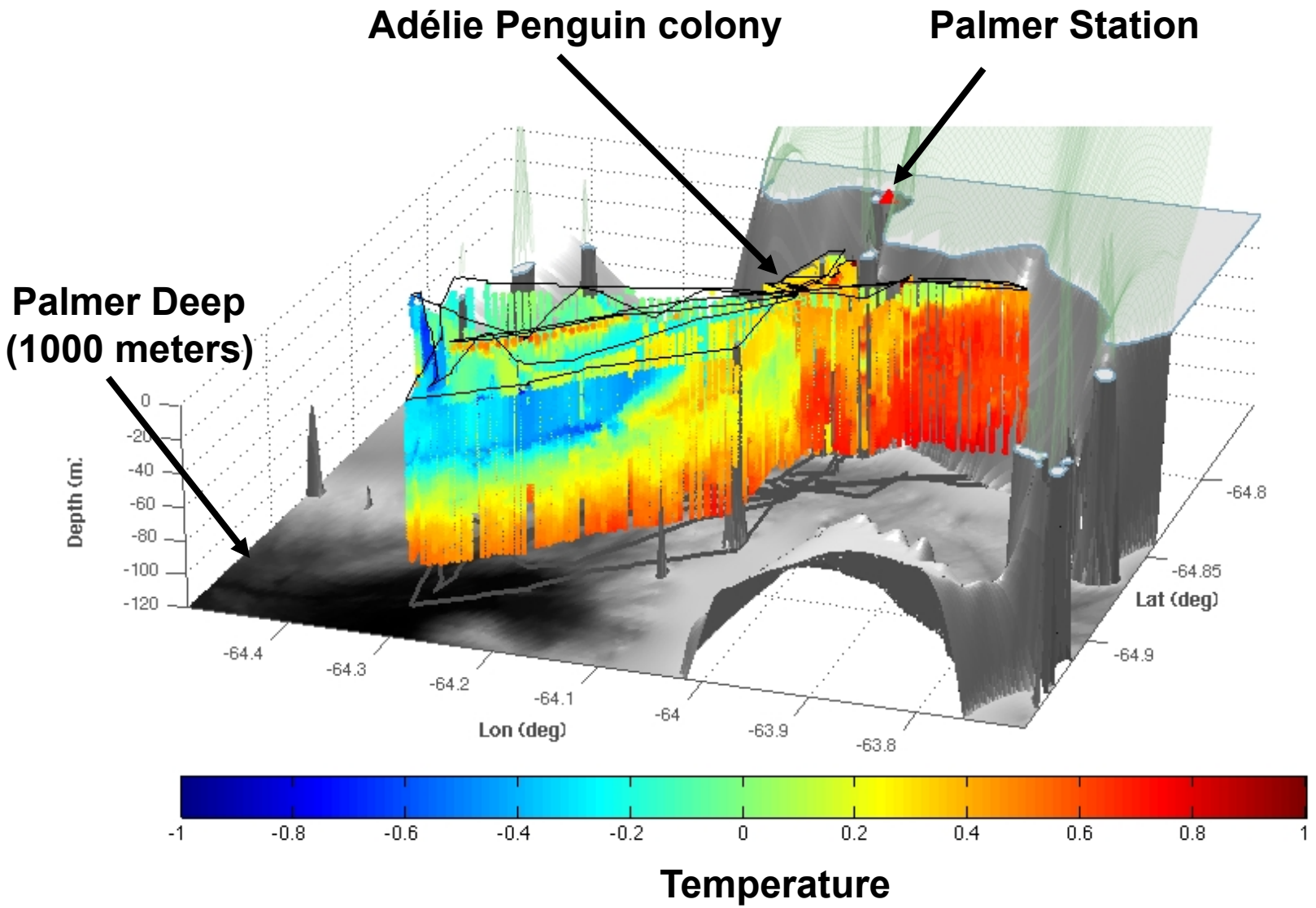


Alongtrack Chlorophyll

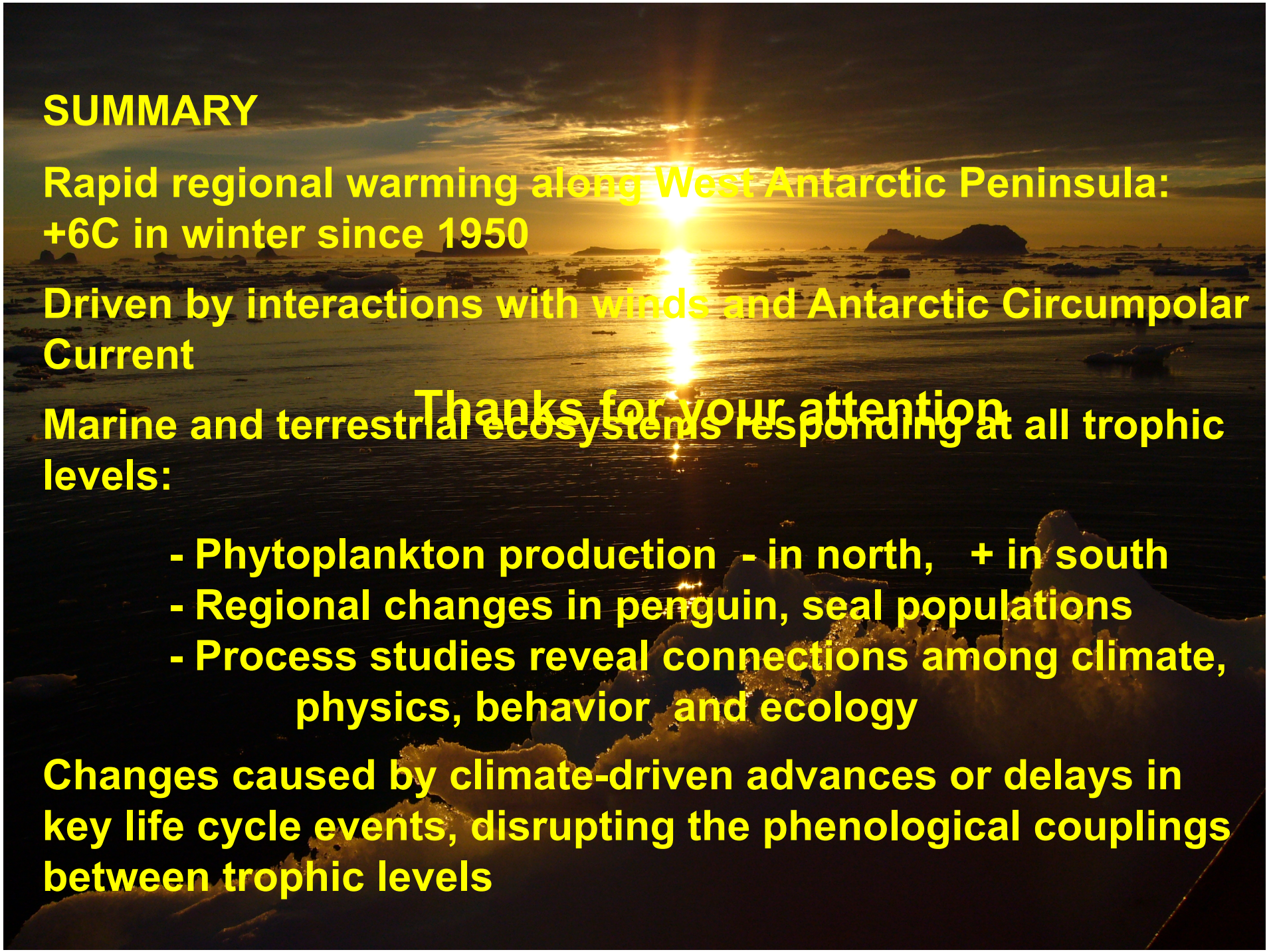


Temperature

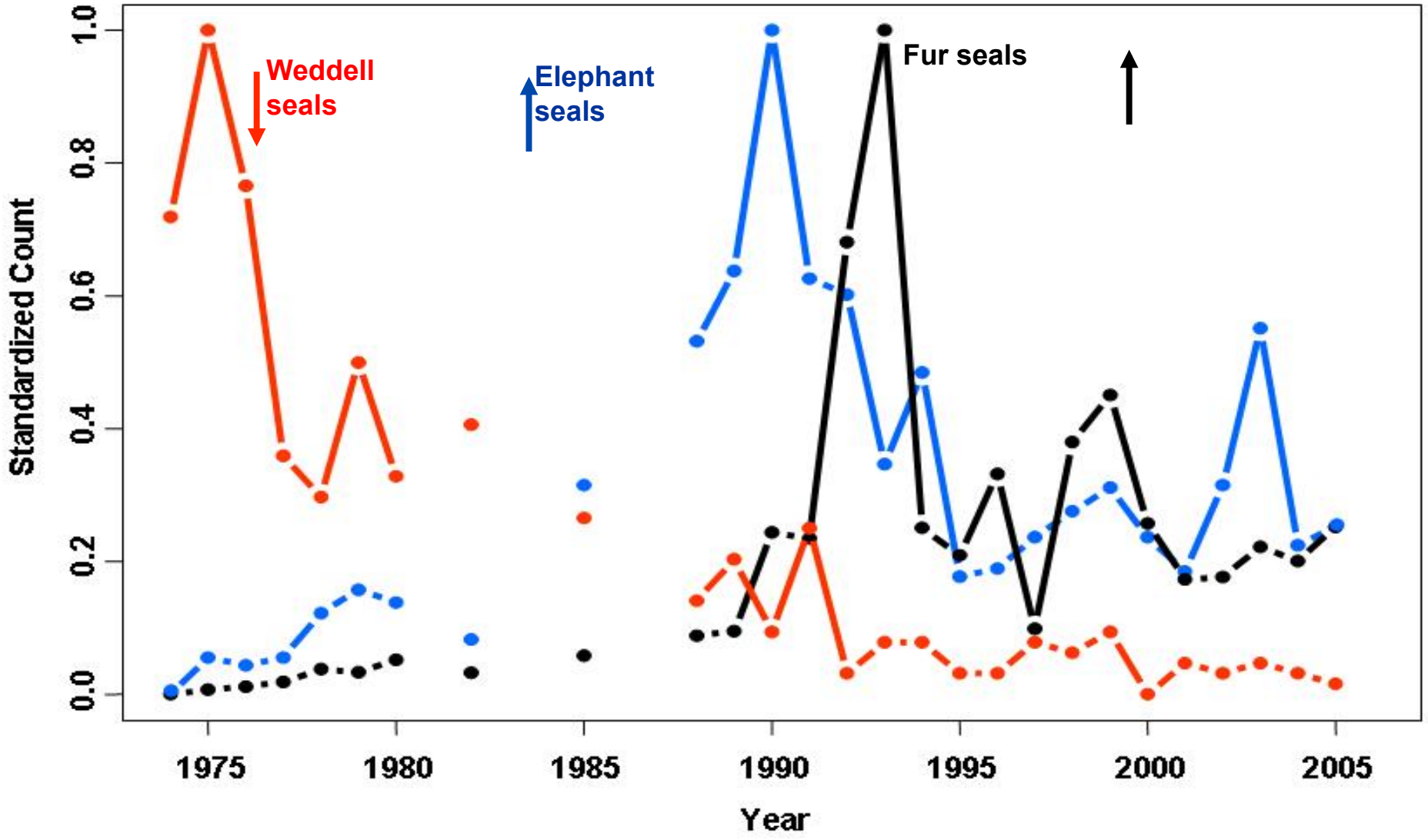




Palmer Deep Glider Survey, December 2010


SUMMARY
Rapid regional warming along West Antarctic Peninsula: +6C in winter since 1950
Driven by interactions with winds and Antarctic Circumpolar Current
Thanks for your attention
Marine and terrestrial ecosystems responding at all trophic levels:
- Phytoplankton production - in north, + in south
- Regional changes in penguin, seal populations
- Process studies reveal connections among climate, physics, behavior and ecology
Changes caused by climate-driven advances or delays in key life cycle events, disrupting the phenological couplings between trophic levels

Changes in seals at Palmer Station 1975 - 2006



Ice-dependent: Adélies, Crabeater & Weddell seals.
Ice-independent: Chinstrap & Gentoo penguins, Elephant & fur seals Bill Fraser.

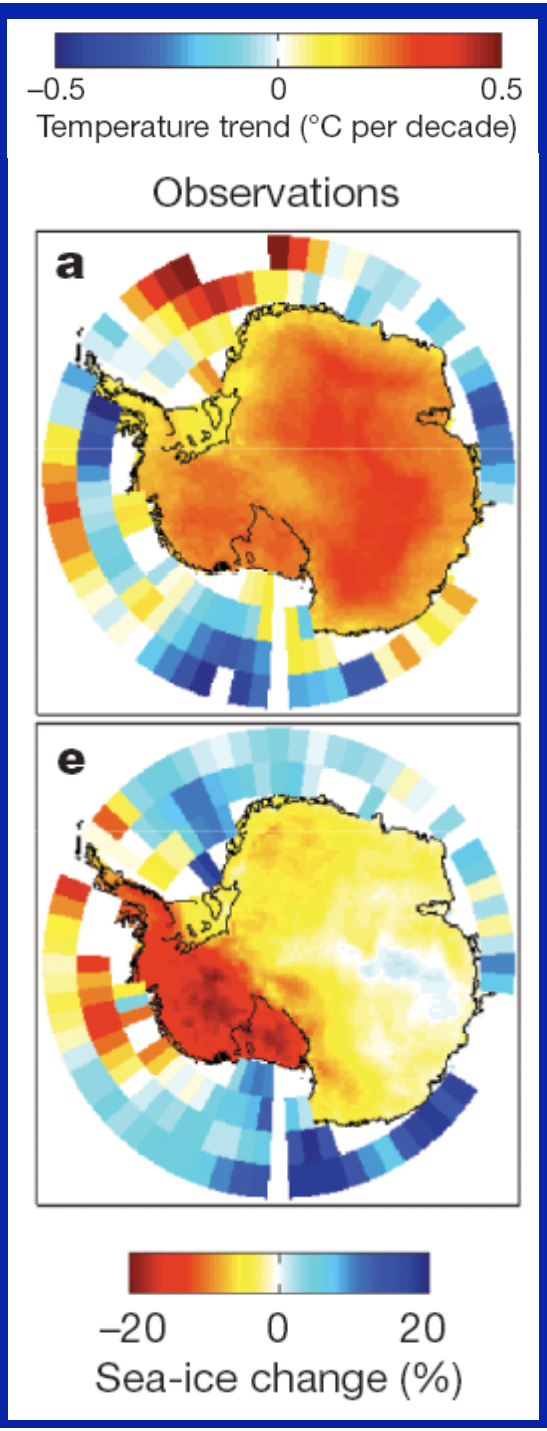
Where is the Surface Warming Occurring?

(*Steig et al*, 2009, Nature)

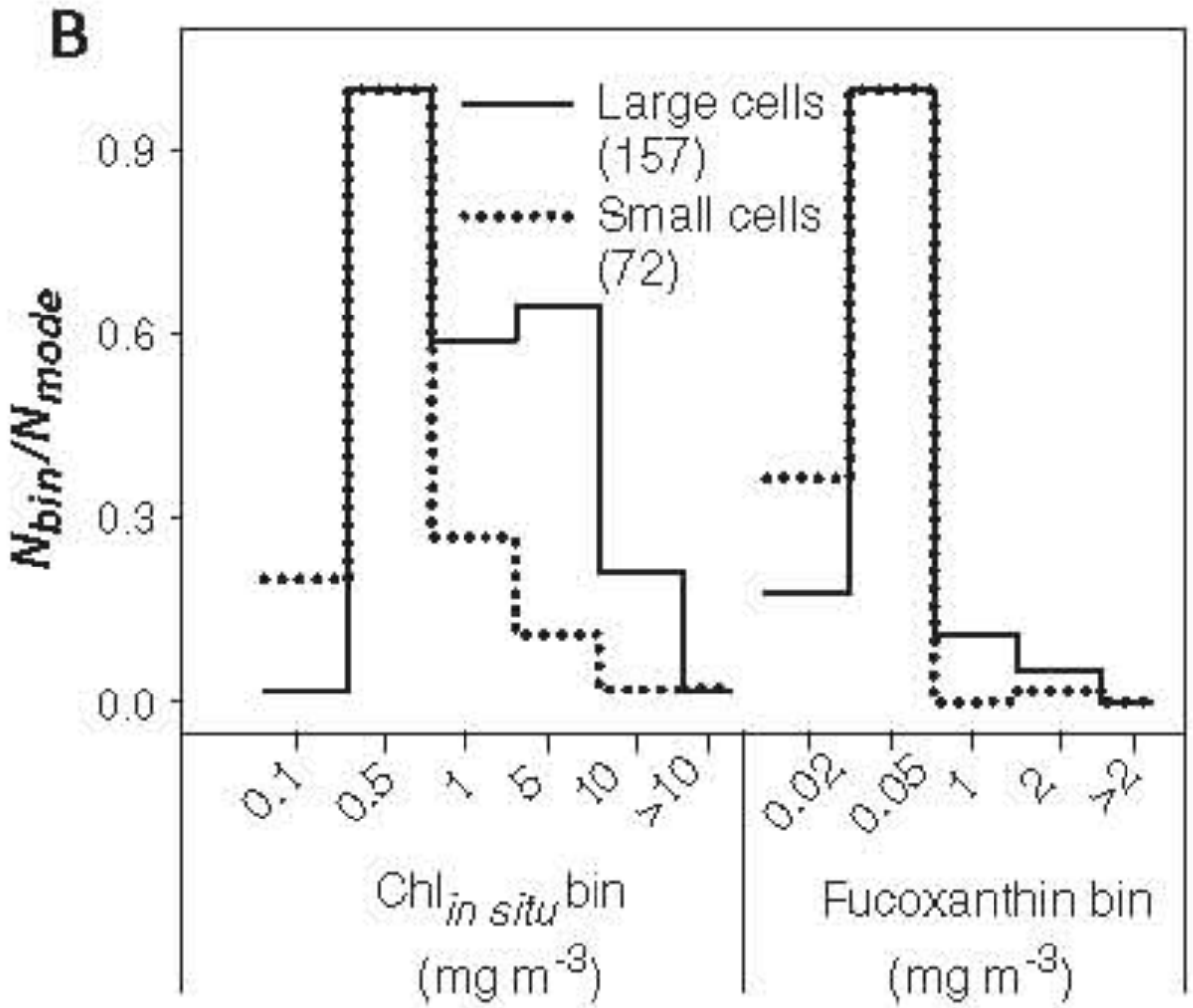
Over all of continental Antarctica, but particularly over West Antarctica last 25 years

Warming trend difficult to explain without radiative forcing of increasing greenhouse gas concentrations

Seasonal (autumn-winter-spring) & regional (West Antarctica) warming indicates more than spring-time ozone-related changes in the Southern Annular Mode (SAM)



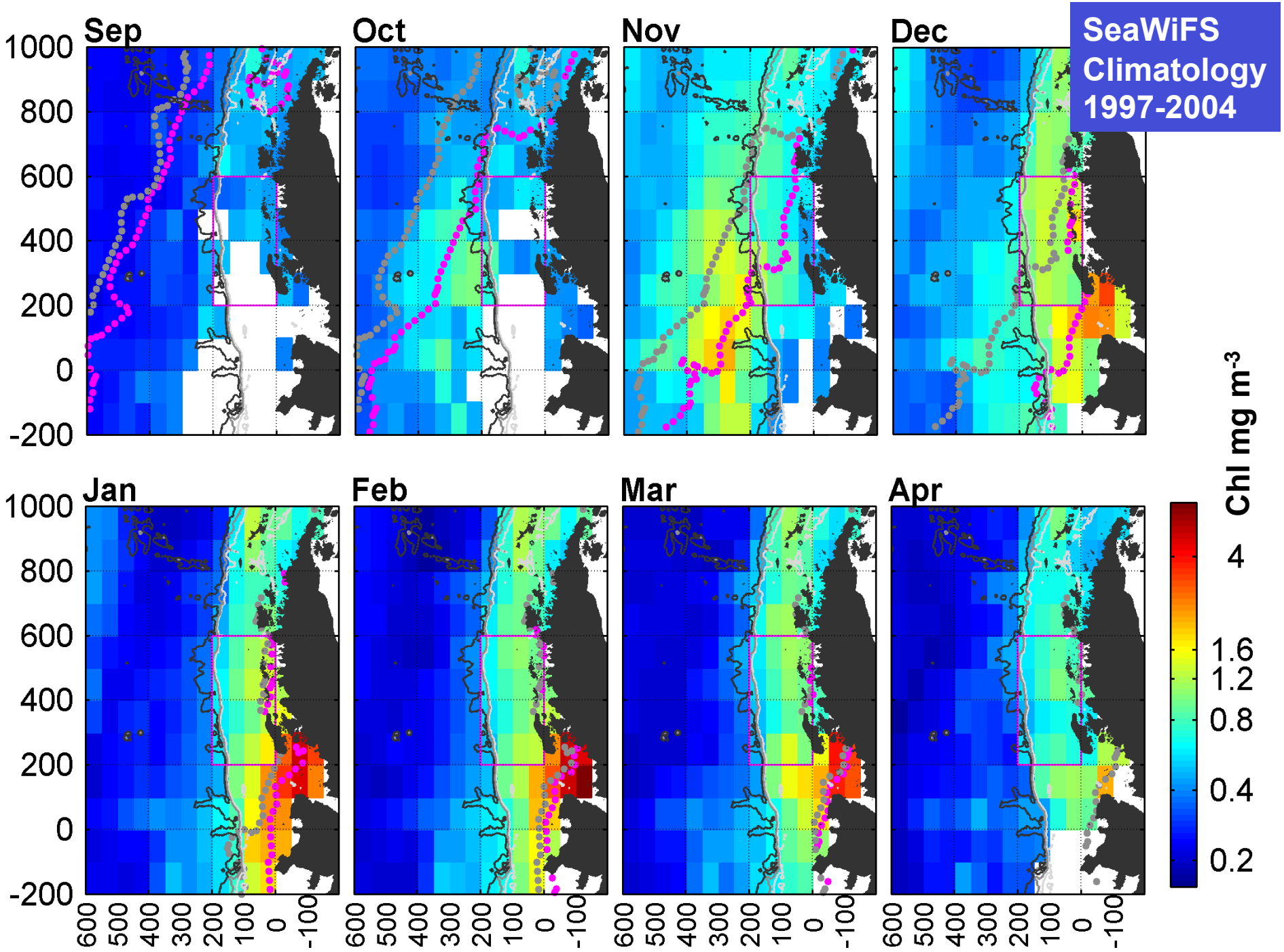
Changes in Community Composition: cell size and diatoms



Cell size derived from SeaWiFS particulate backscattering spectra

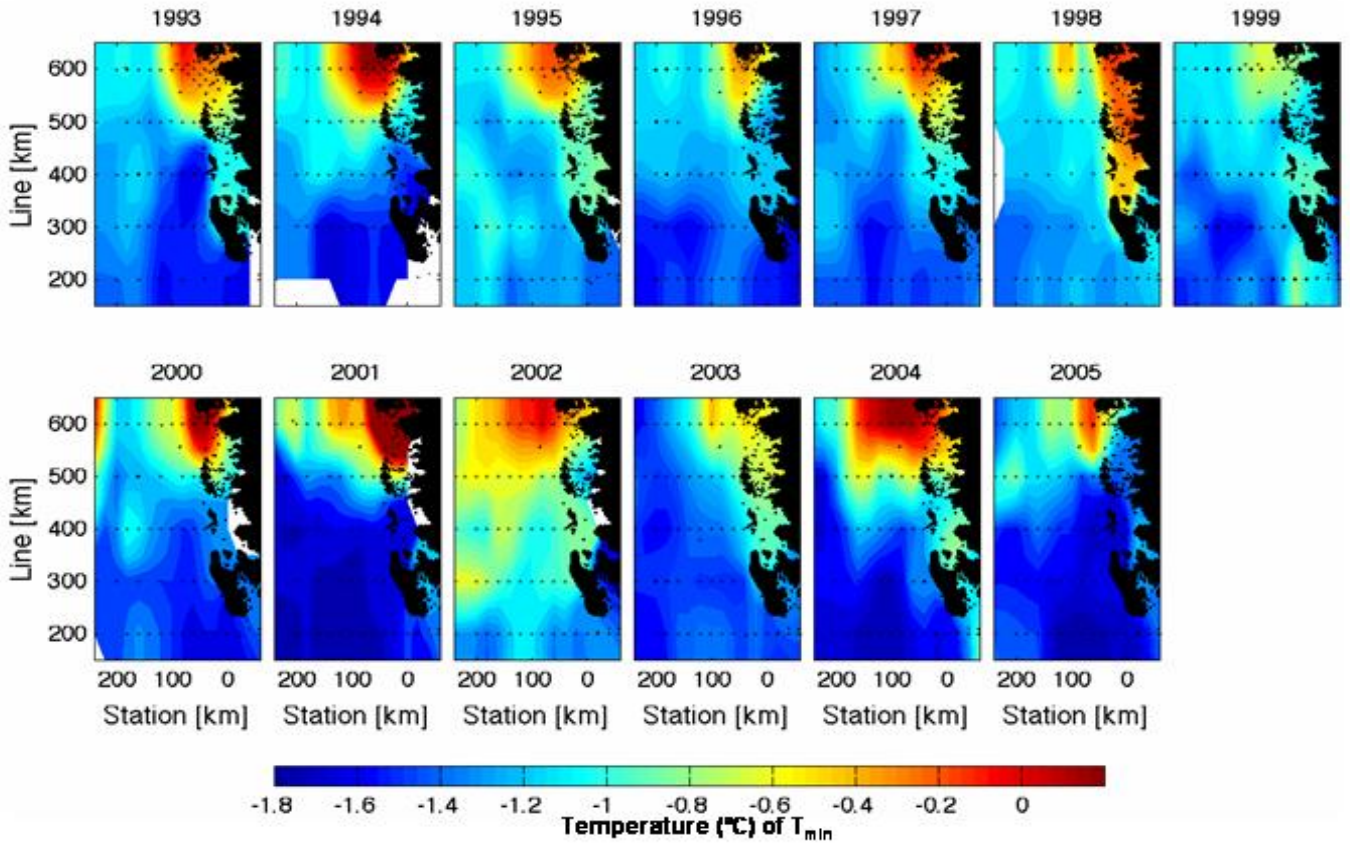
(Montes-Hugo 2007)

High Chl: larger cells and more diatoms; Low Chl: smaller cells and fewer diatoms


SeaWiFS
Climatology
1997-2004
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
1000
800
600
400
200
0
-200
600
500
400
300
200
100
0
-100
Chl mg m-3
4
1.6
1.2
0.8
0.4
0.2

Effect of physical environment: change in fish habitat space

Coldest water in water column, (January) 1993 – 2005:



no silverfish >0°C (red areas)