Satellite Driven Studies of Climate-mediated Changes in Antarctic Food Webs

April 23, 2013

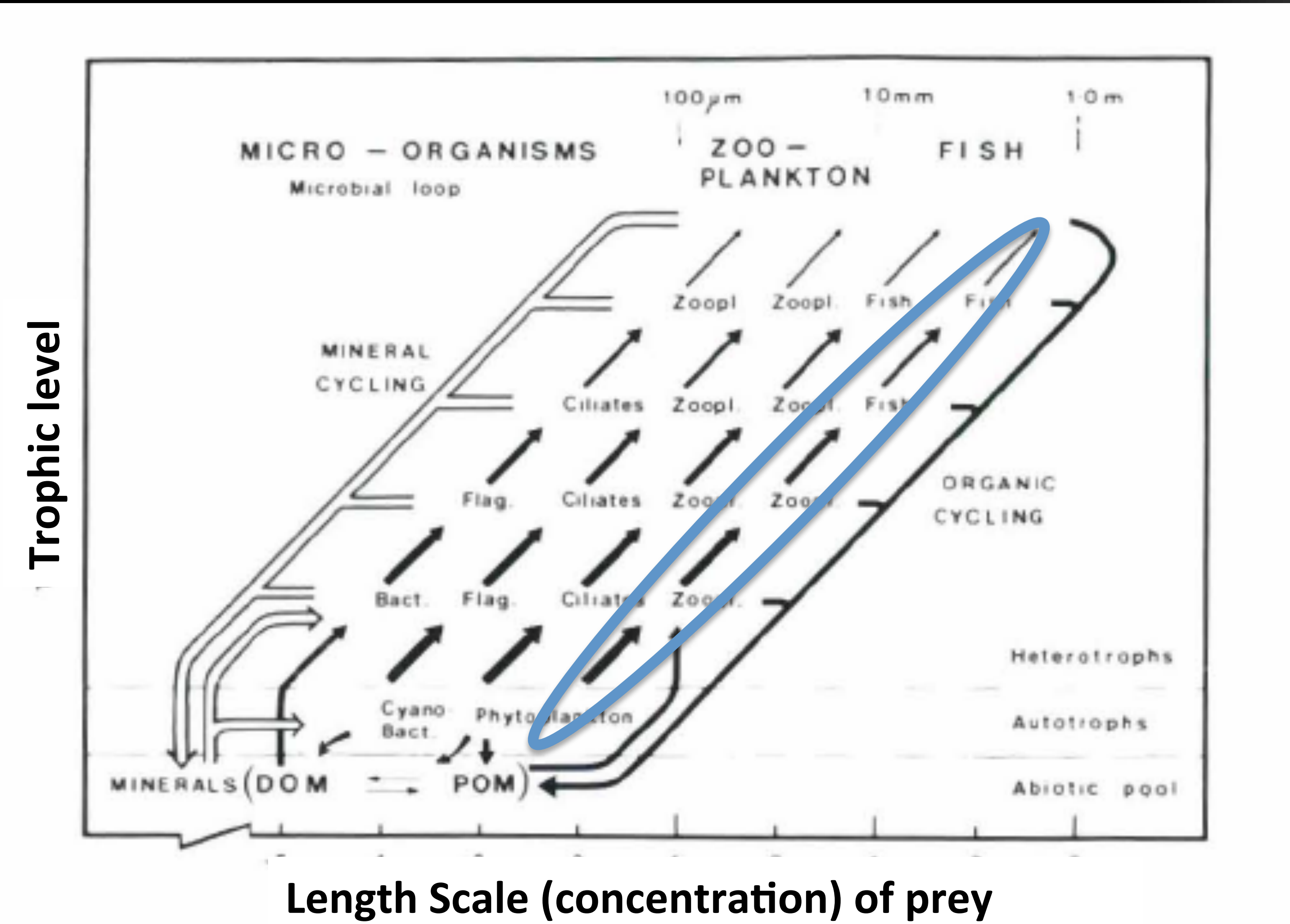
Matthew Oliver, Megan Cimino, Andrew Irwin, William Fraser, Josh Kohut, Oscar Schofield, Mark Moline, et al.

College of Earth, Ocean, and Environment
University of Delaware
Rutgers Coastal Ocean Observation Lab
Universitas Montis Allisoniani Sackvillae MDCCCXXXIX Litterae Religio Scientia
Palmer Station Antarctica LTER
NASA

Satellite Driven Studies of Climate-mediated Changes in Antarctic Food Webs

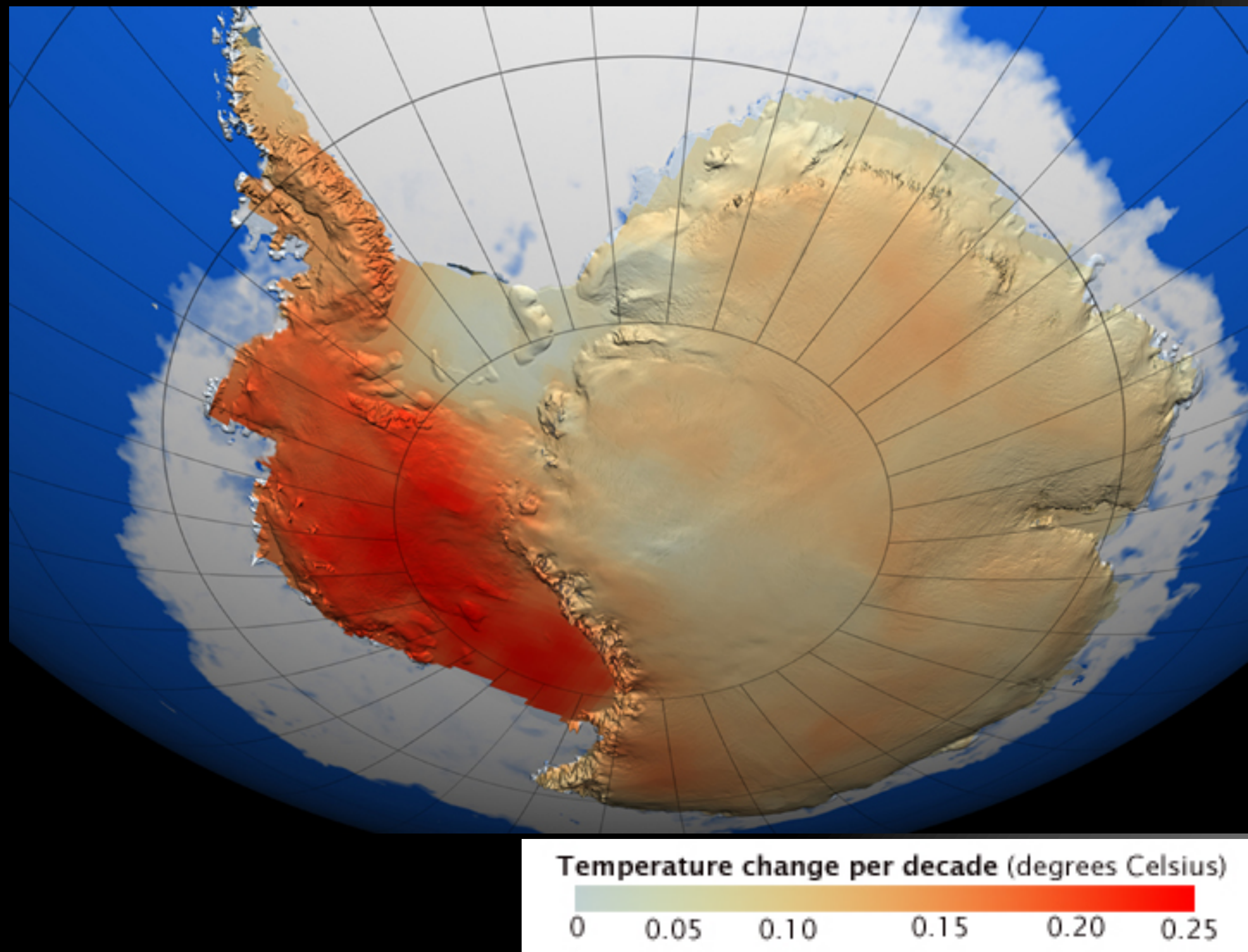
Larger starting prey supports large predators with fewer trophic steps

Changes in lower trophic levels could be transferred to upper trophic levels



Azam et al, 1983

West Antarctic Peninsula is Rapidly Warming



Recent Changes in Phytoplankton Communities Associated with Rapid Regional Climate Change Along the Western Antarctic Peninsula

Martin Montes-Hugo,[1] Scott C. Doney,[2] Hugh W. Ducklow,[3] William Fraser,[4] Douglas Martinson,[5] Sharon E. Stammerjohn,[6] Oscar Schofield[1]

The changes in phytoplankton are at least regional (West Antarctic Peninsula)

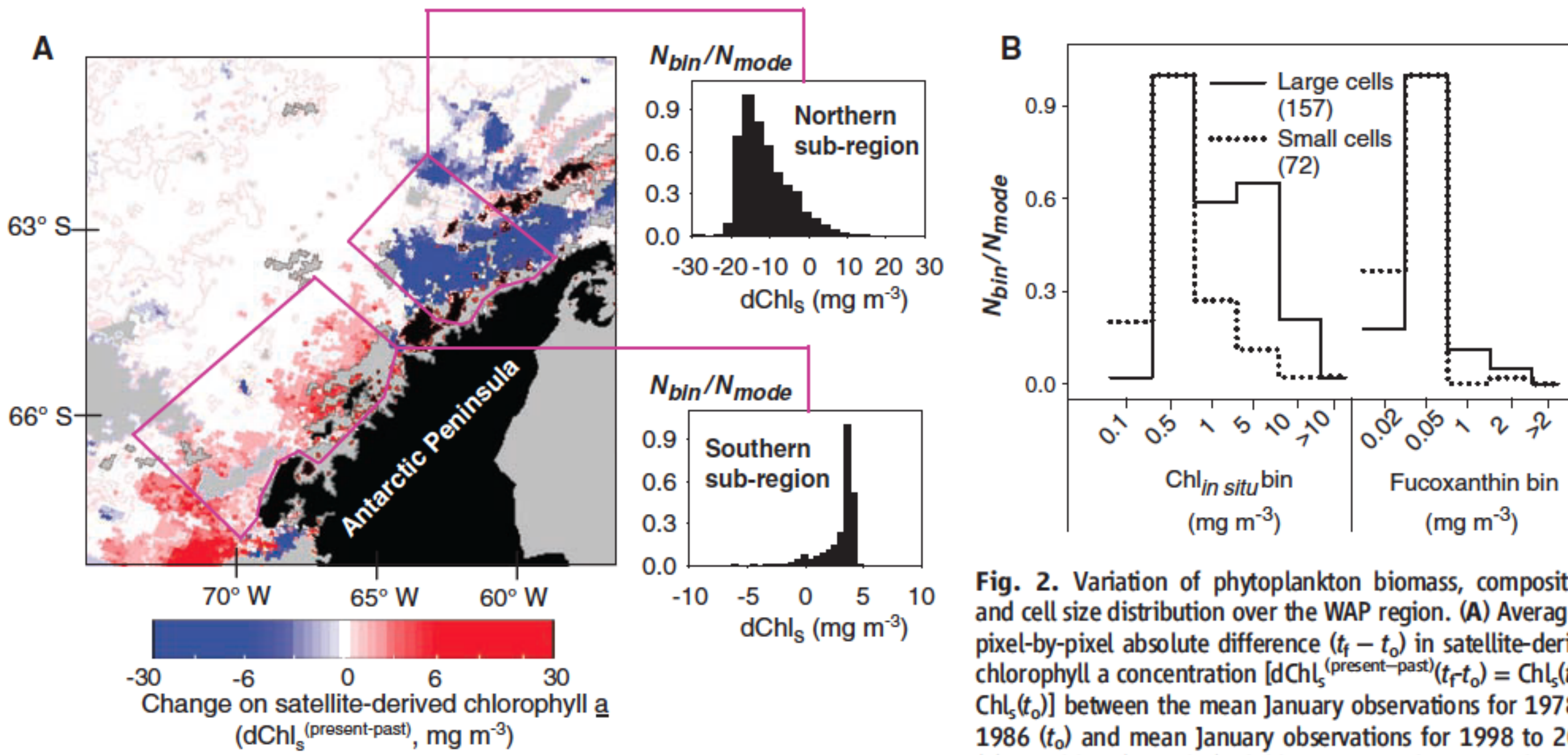
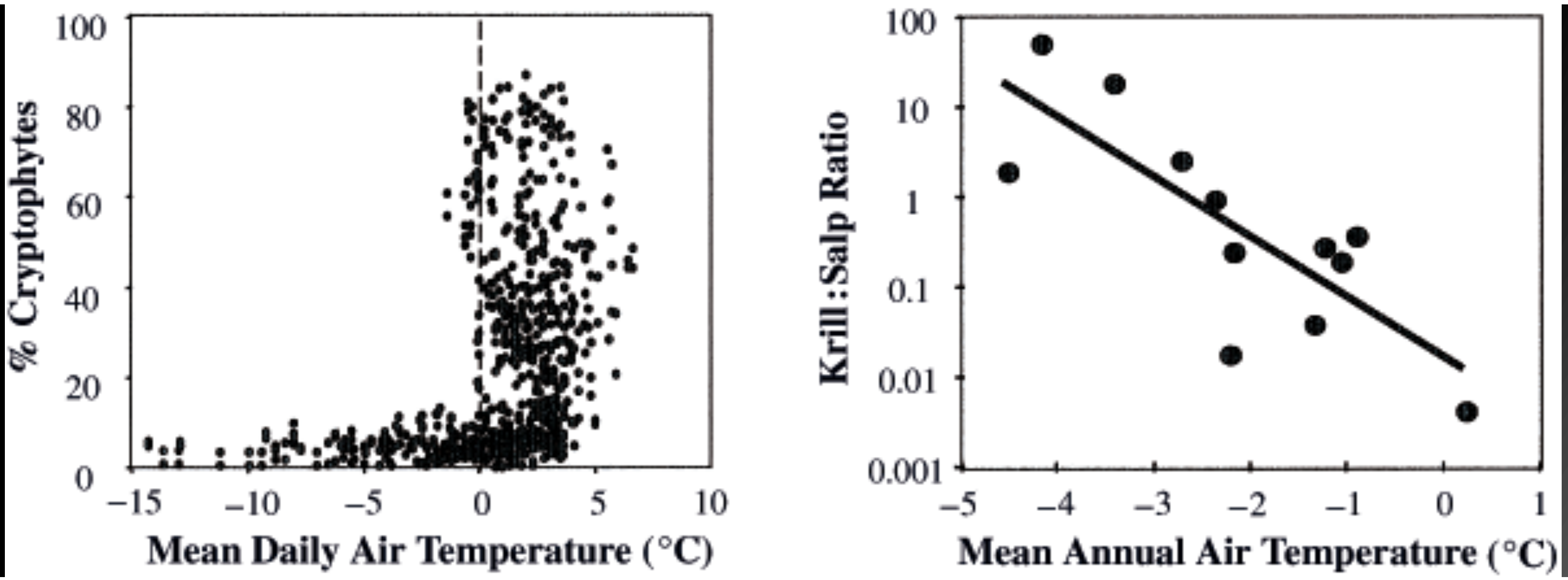


Fig. 2. Variation of phytoplankton biomass, composition, and cell size distribution over the WAP region. (**A**) Average of pixel-by-pixel absolute difference ($t_f - t_o$) in satellite-derived chlorophyll a concentration [$dChl_s^{(present-past)}(t_f\text{-}t_o) = Chl_s(t_f) - Chl_s(t_o)$] between the mean January observations for 1978 to 1986 (t_o) and mean January observations for 1998 to 2006 (t_f). Positive (negative) $dChl_s$ corresponds to an increase (decrease) of Chl_s with respect to the 1970s. Negative (by a factor of ~2, northern subregion, upper histogram) and positive (by a factor of ~1.5, southern subregion, lower histogram) trends in Chl_s are evident in the satellite data. N_{bin}/N_{mode} is the relative frequency of observations per bin, normalized by the mode. Gray pixels indicate areas without data or without valid geophysical retrieval due to cloud and sea ice contamination; black pixels indicate land. (**B**) Histograms of contribution of diatoms (fucoxanthin marker) and phytoplankton communities dominated by large (≥20 μm) versus small (<20 μm) cell diameter to total in situ chlorophyll a concentration ($Chl_{in\ situ}$). Phytoplankton cell size spectra were computed from satellite imagery (1998 to 2006) (*16*), and phytoplankton pigments were measured over the northern and southern WAP subregions and during 1993 to 2006 Palmer-LTER cruises. Number of samples used to construct each histogram shown in parentheses.

Changing Phytoplankton Community Composition in the WAP

Alteration of the food web along the Antarctic Peninsula in response to a regional warming trend

MARK A. MOLINE*, HERVÉ CLAUSTRE†, THOMAS K. FRAZER‡, OSCAR SCHOFIELD§ and MARIA VERNET¶



Global Change Biology (2004) 10, 1973–1980, doi: 10.1111/j.1365-2486.2004.00825.x

Prey Items are changing with changing ice in the WAP.

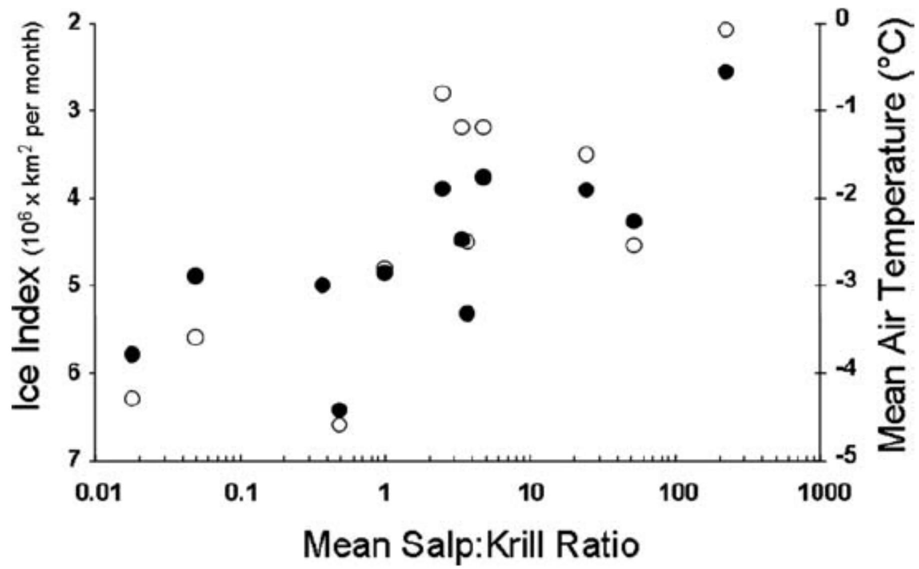


Figure 22. Ratio of mean abundances of salps to Antarctic krill (No. 1000 m^{-3}) as a function of the regional sea-ice index (open circles) and mean air temperature for the Antarctic Peninsula (closed circles). Drawn from Table 1 in Loeb *et al.* (1997).

Penguins are following suit with the change

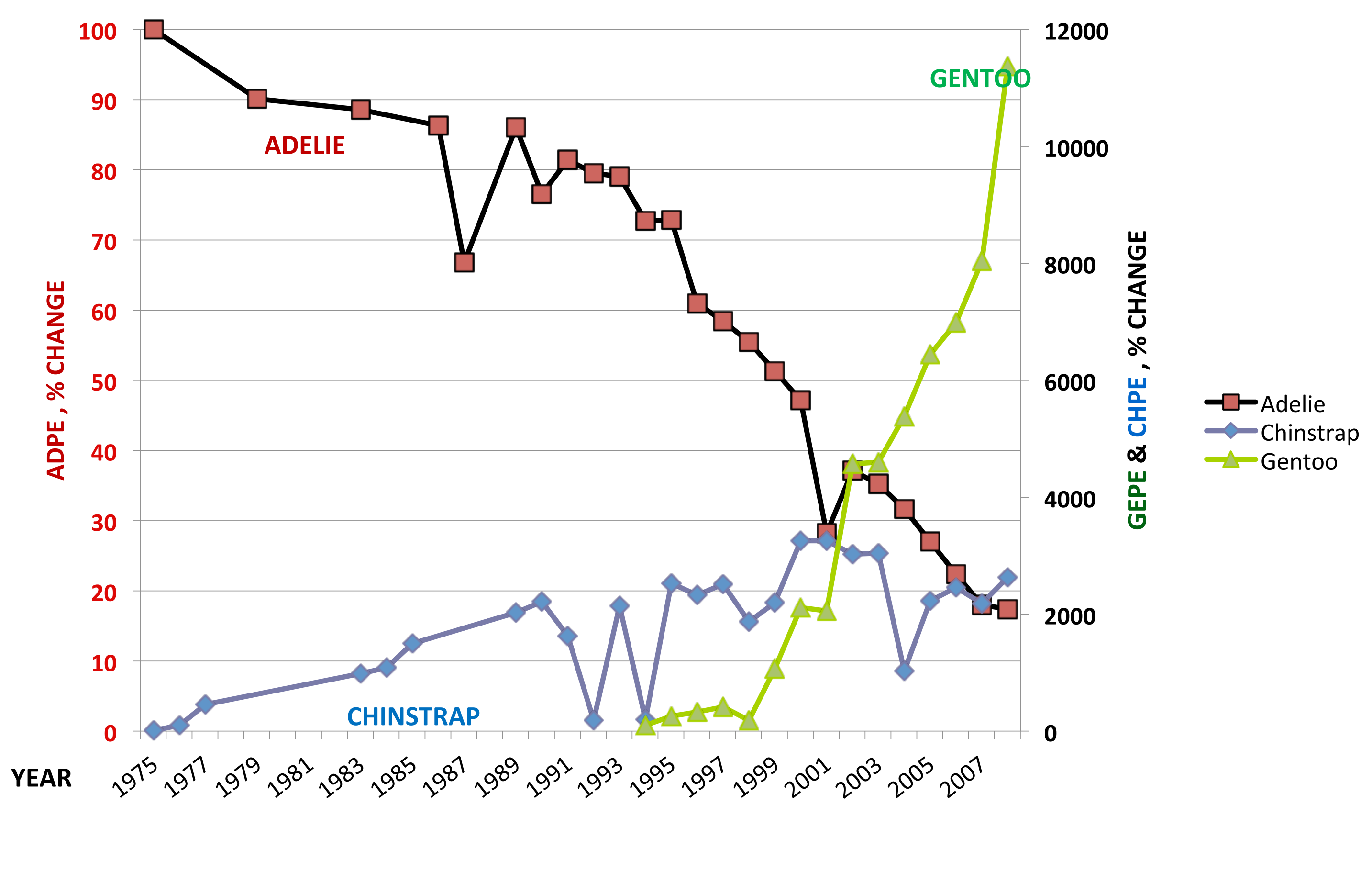
REVIEW

18 JUNE 2010 VOL 328 SCIENCE

How Do Polar Marine Ecosystems Respond to Rapid Climate Change?

Oscar Schofield,[1*] Hugh W. Ducklow,[2] Douglas G. Martinson,[3] Michael P. Meredith,[4] Mark A. Moline,[5] William R. Fraser[6]

NASA funded review of the system.



Short Food Webs Increase Chance of Prediction
Hypothesis: Environment Predicts Populations of Penguins

Global Change Biology

Global Change Biology (2012), doi: 10.1111/gcb.12016

Satellite data identify decadal trends in the quality of *Pygoscelis* penguin chick-rearing habitat

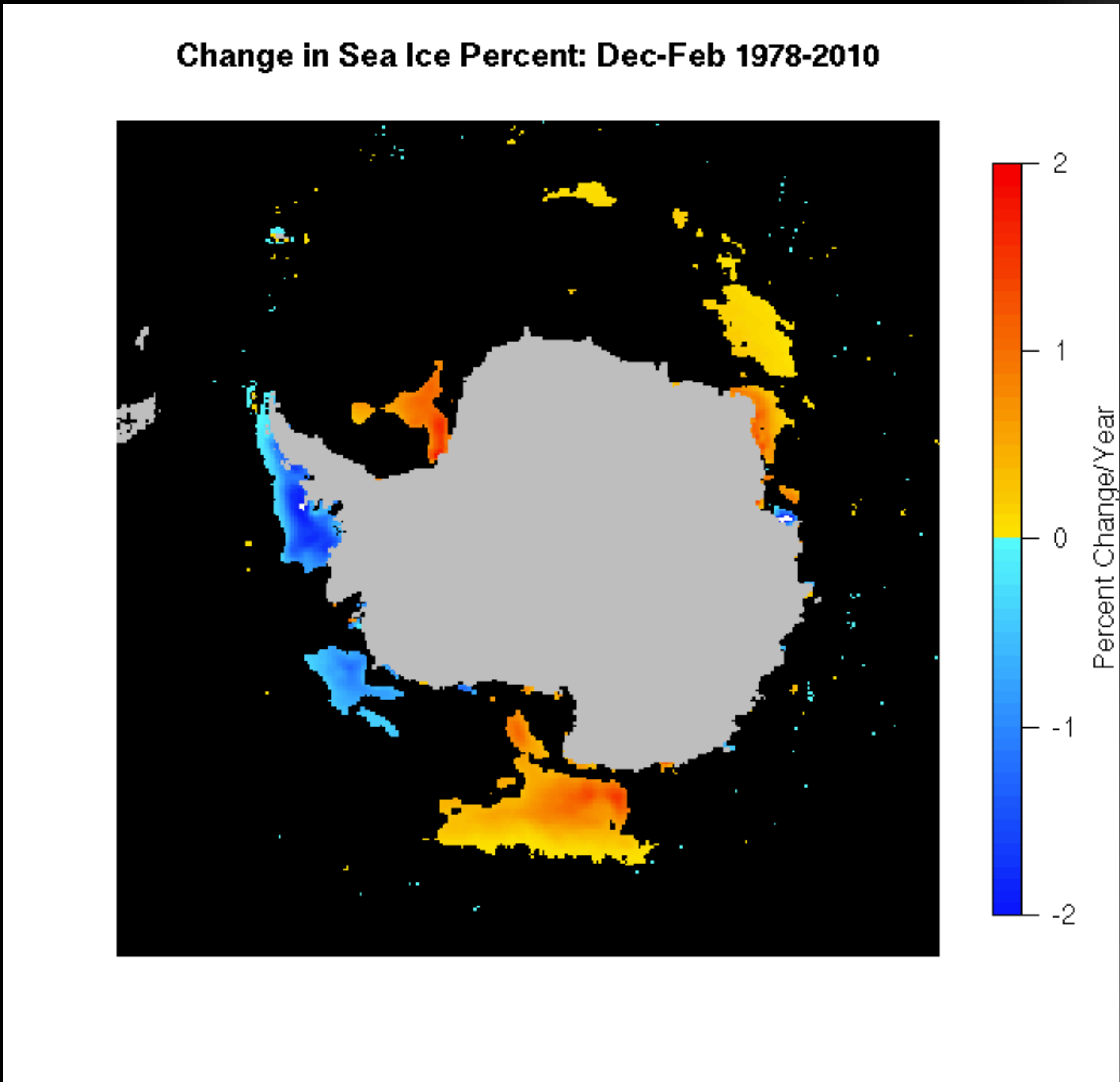
MEGAN A. CIMINO*, WILLIAM R. FRASER†, ANDREW J. IRWIN‡ and MATTHEW J. OLIVER*

$$\Delta Penguin = \beta \cdot \Delta Environment + \varepsilon$$

The error term encapsulates small scale or cyclical environmental variation, and any top-down component. This is a <u>bottom-up</u> approach.

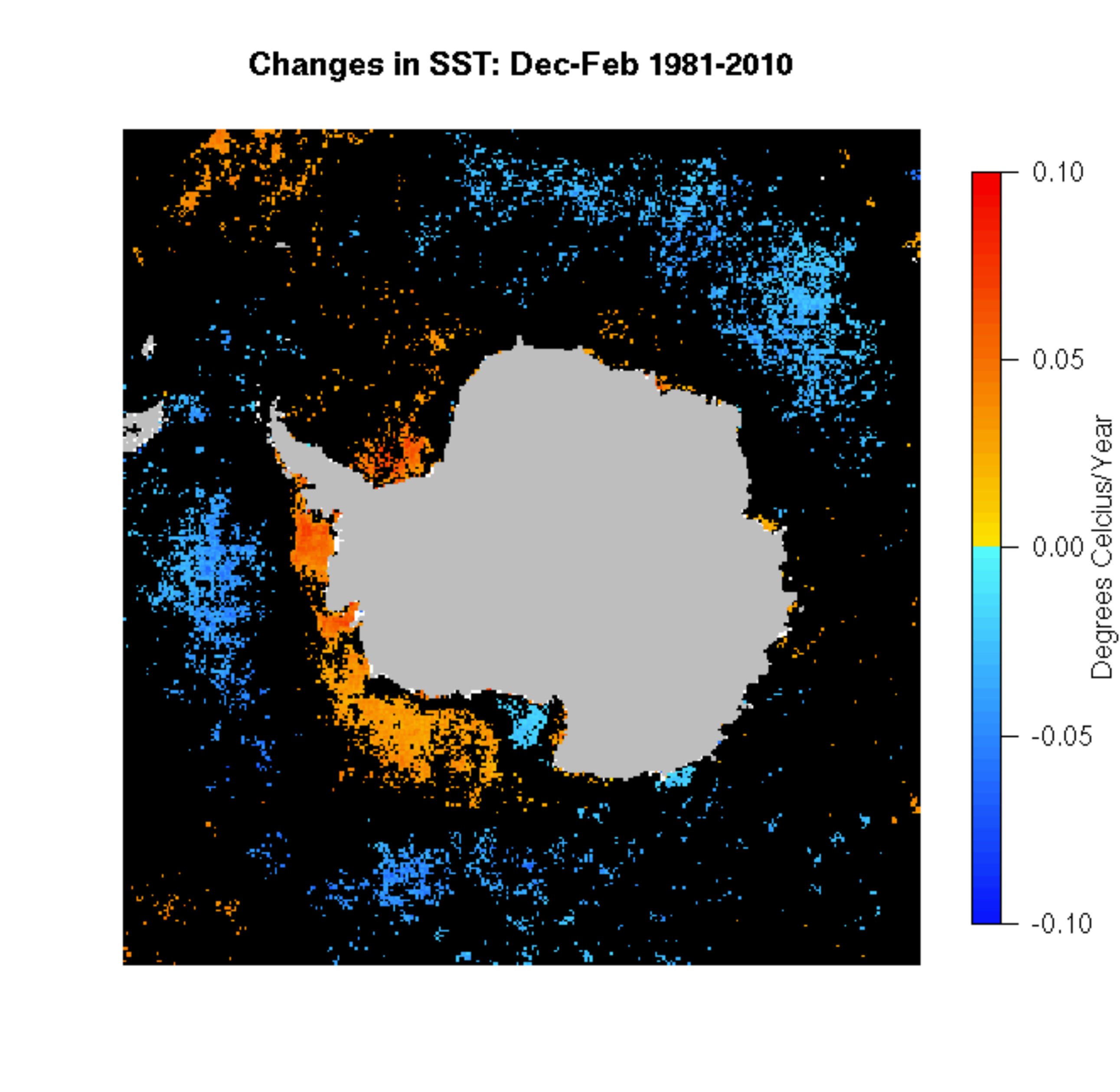
Look for places with big climate perturbations

West Antarctic Peninsula is Loosing Ice During the Summer Months (Winter too)



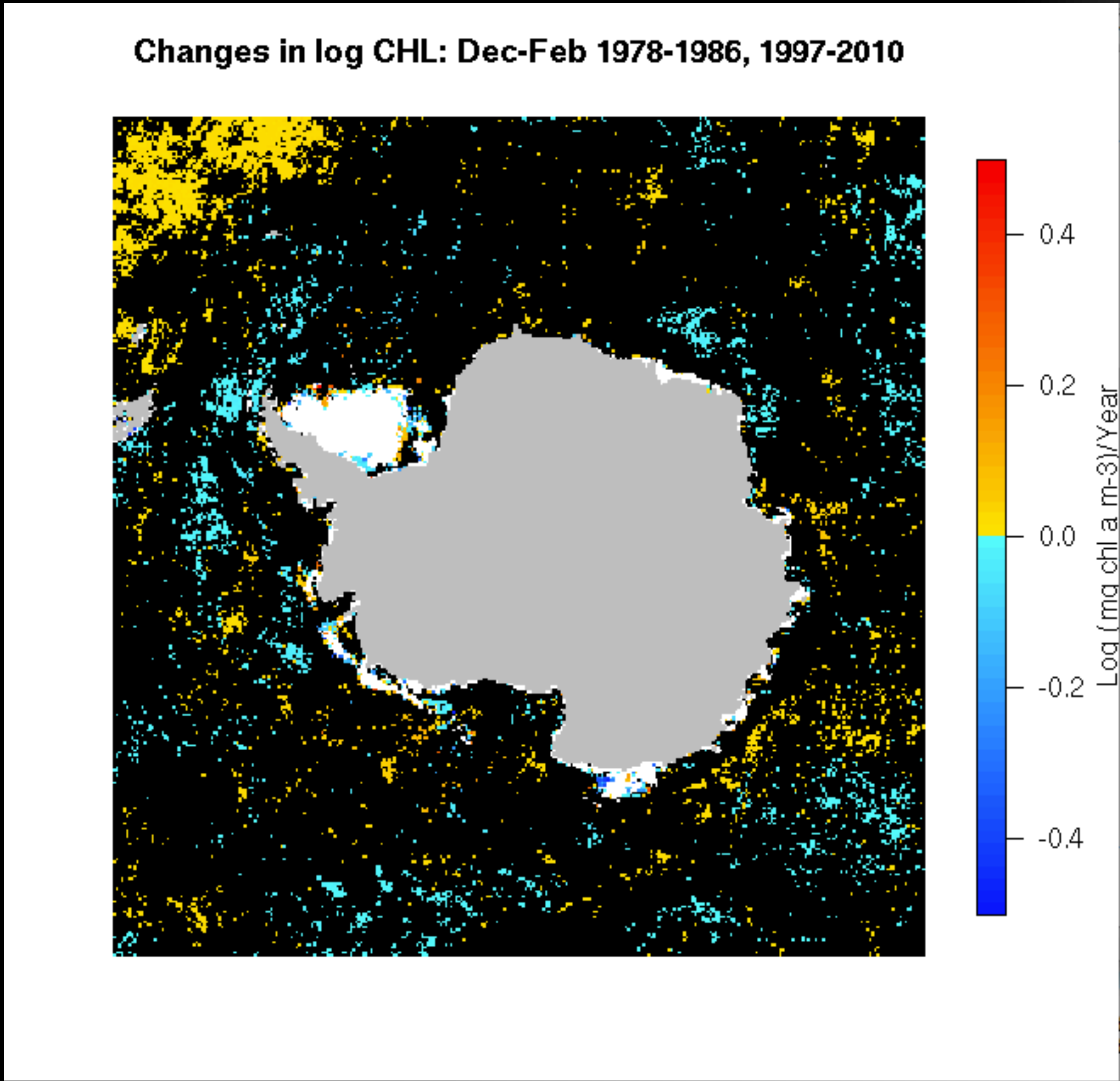
Look for places with big climate perturbations

West Antarctic Peninsula is Warming up during Summer Months



Look for places with big climate perturbations

Chlorophyll isn't as clear of a signal on big scales



Problem

We have penguin location information, but not many population counts

$$P(+Penguin \mid Environment) = \frac{P(Environment \mid +Penguin)P(+Penguin)}{P(Environment)}$$

Change the terms of the hypothesis

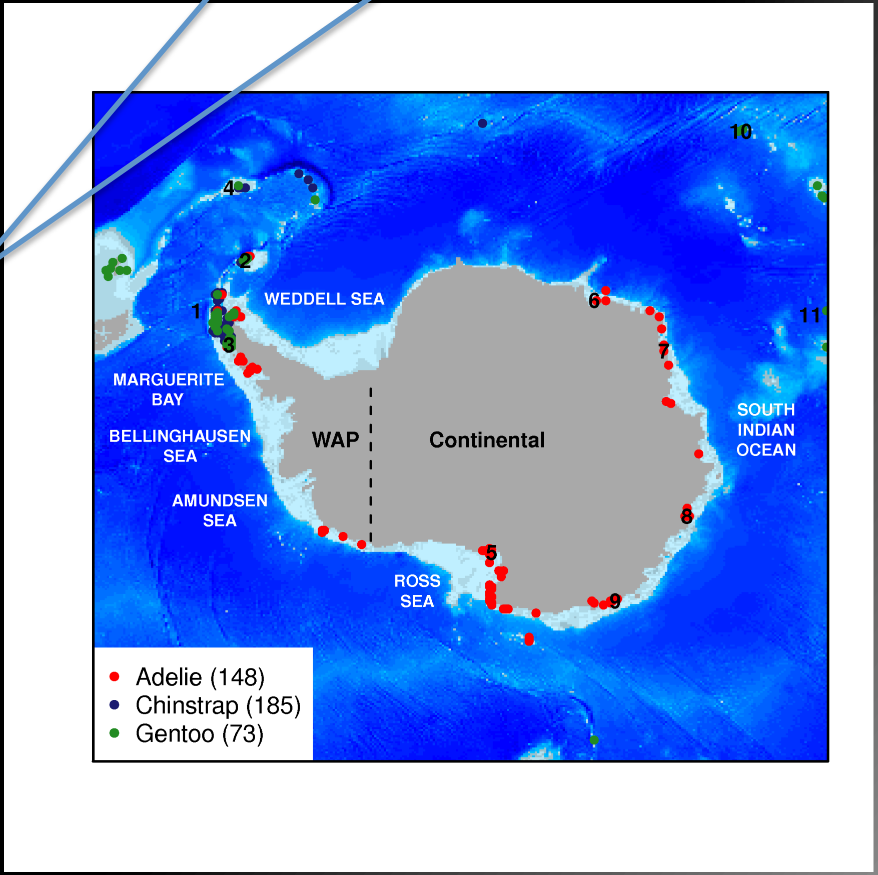
The probability of finding a specific penguin species dependent on the environment

Sets up a nice natural experiment between the WAP and the Continent

So Far, we have decent estimates of

$$P(+Penguin)$$

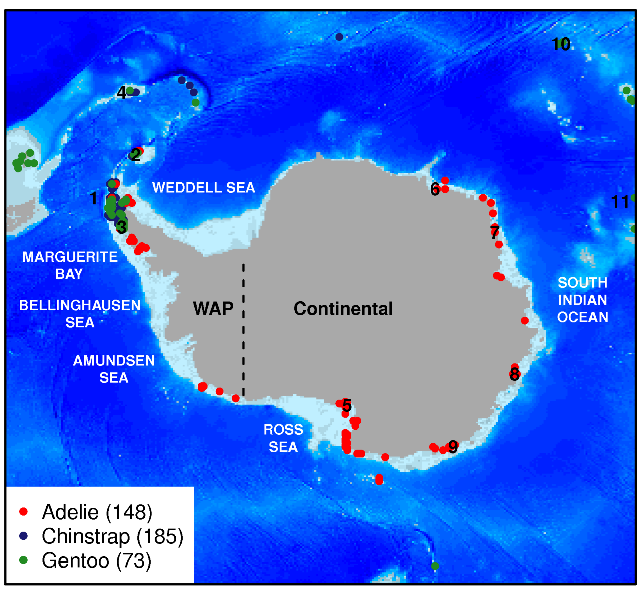
$$P(Environment)$$

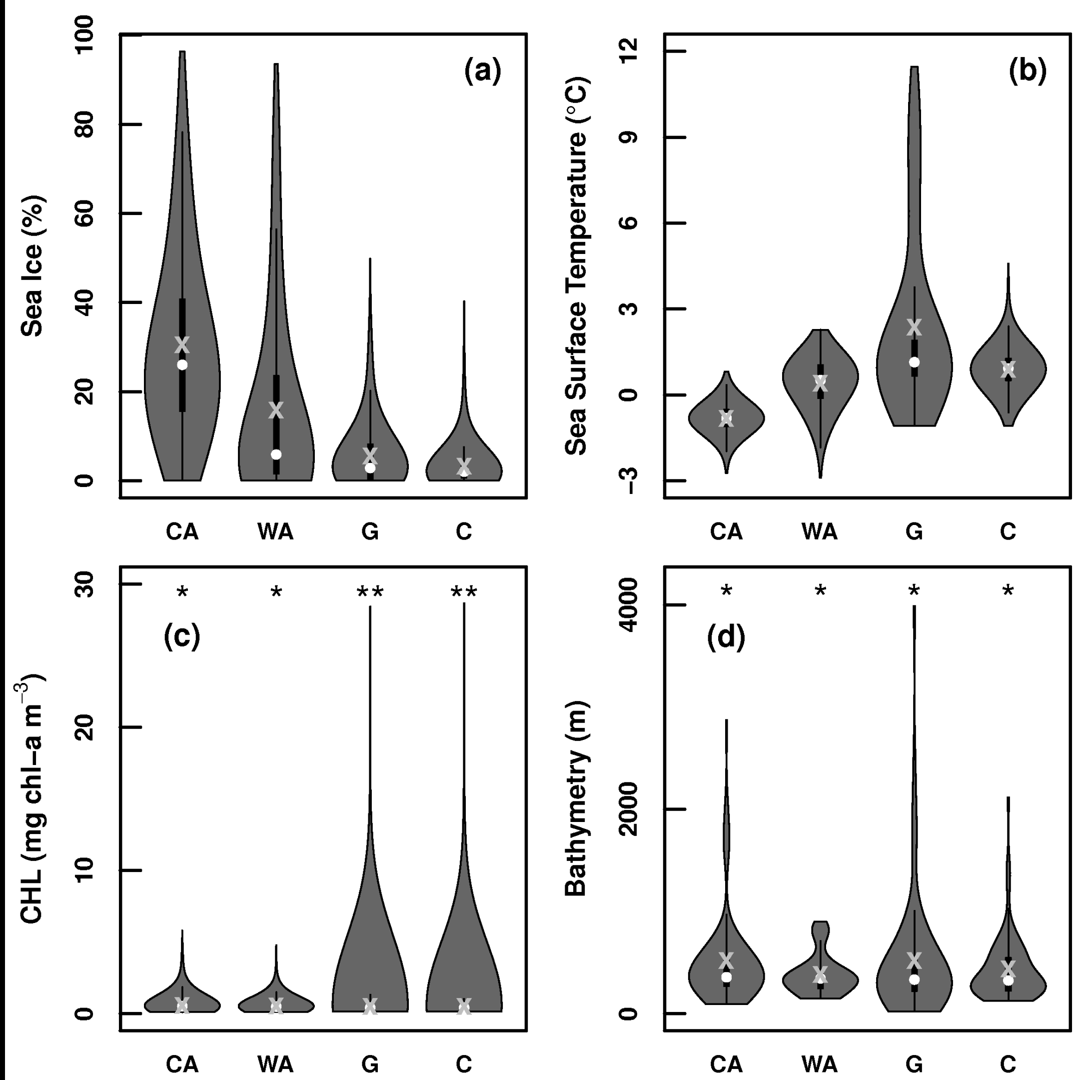


$$P(+Penguin \mid Environment) = \frac{P(Environment \mid +Penguin)\boxed{P(+Penguin)}}{\boxed{P(Environment)}}$$

$$P(Environment \mid +Penguin)$$

Satellite Driven Niche Space of Chick Rearing Habitat (CRH)



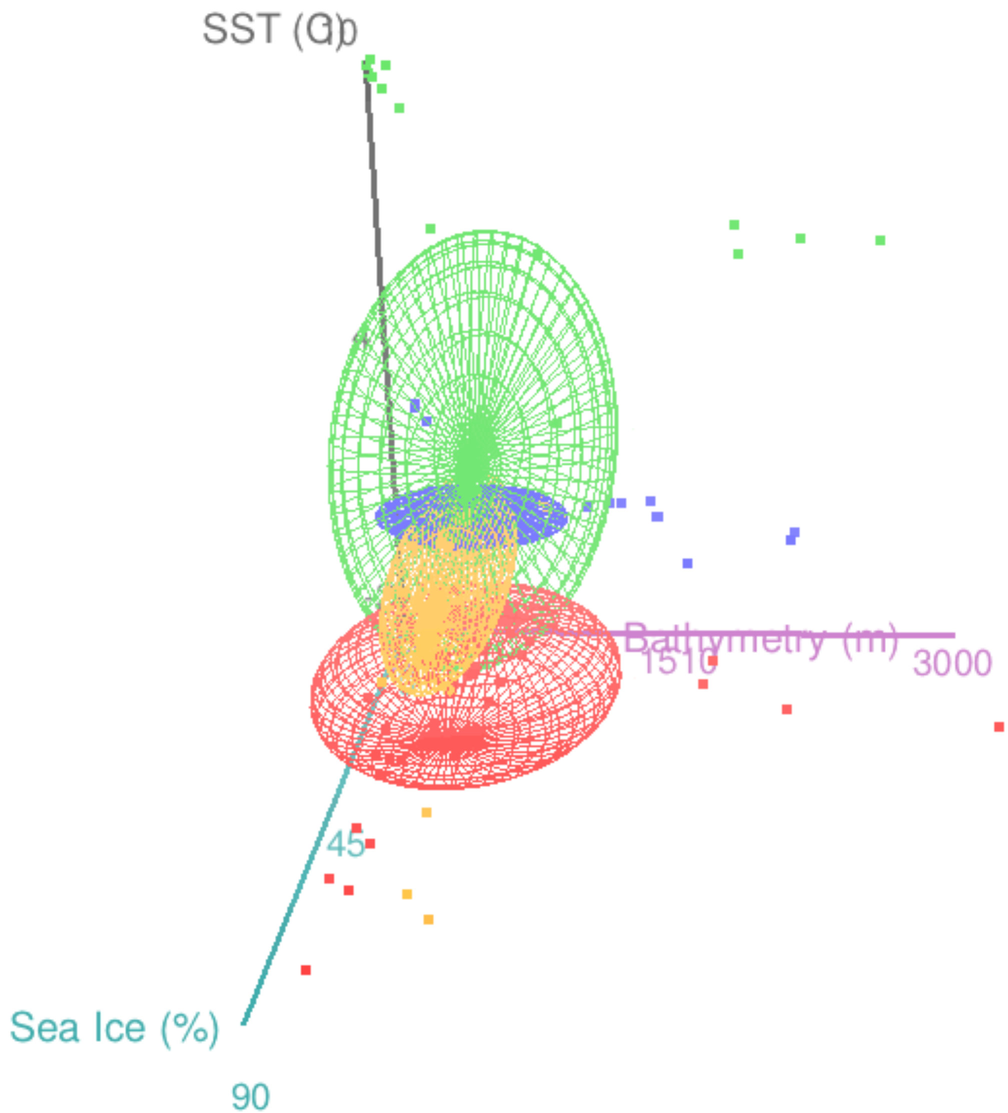


Continental Adélie

WAP Adélie

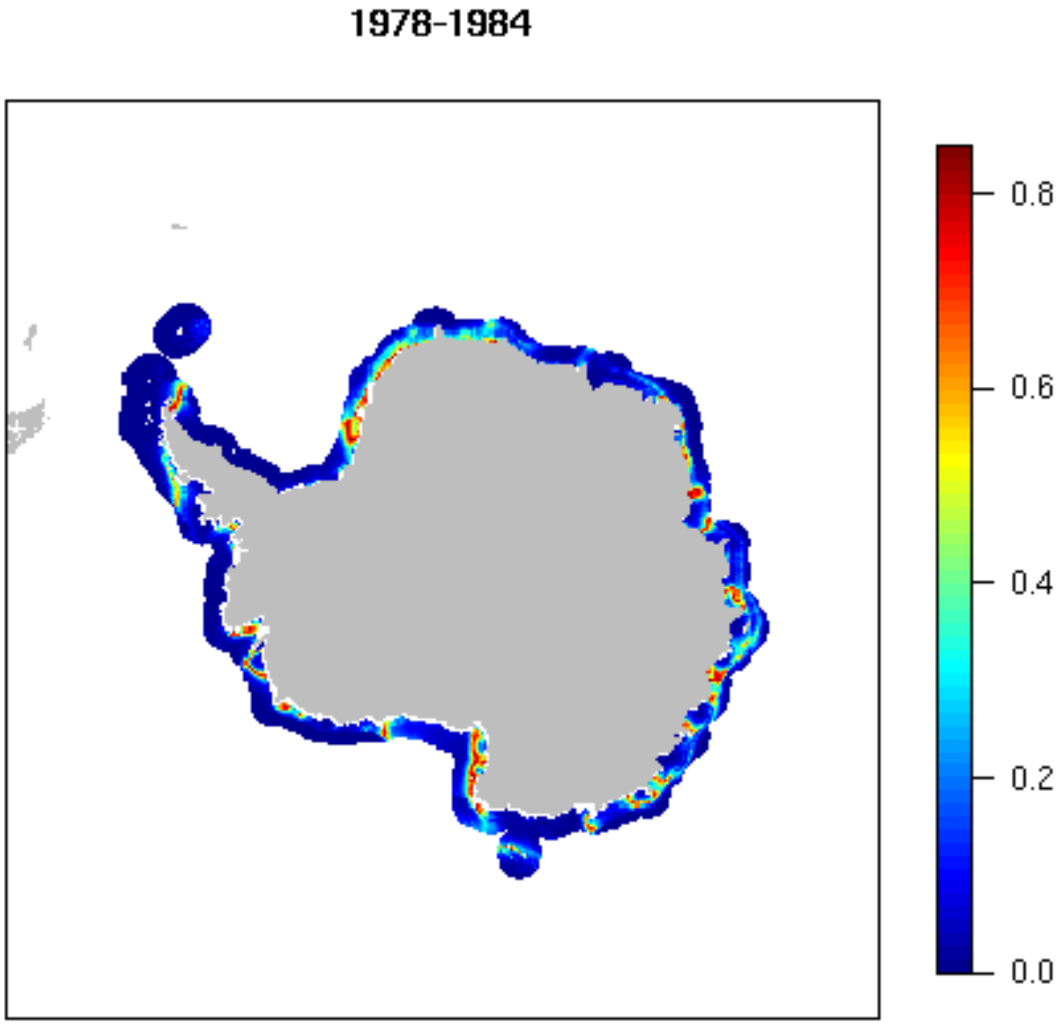
Chinstrap

Gentoo



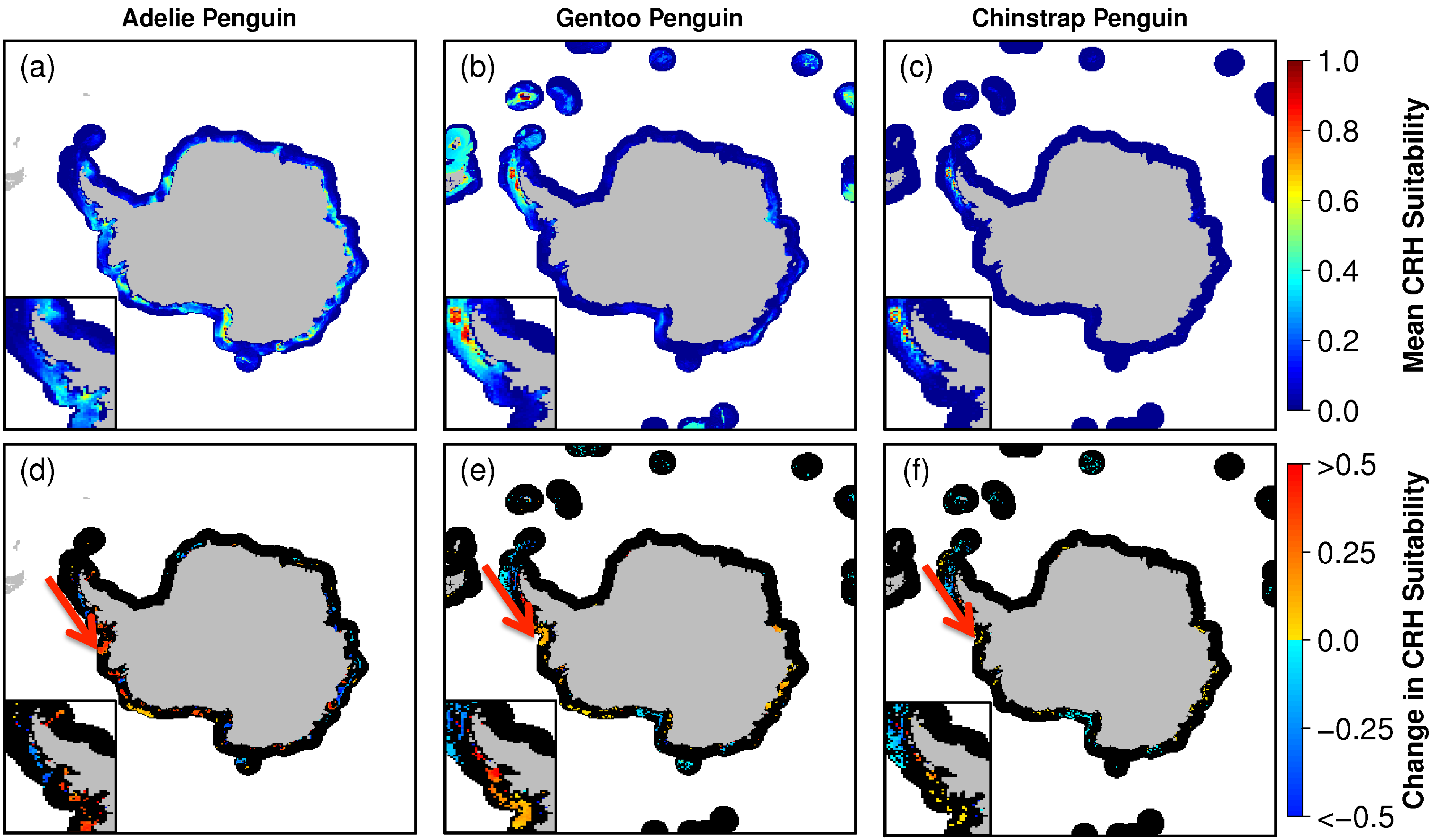
$$P(+Penguin \mid Environment)$$

Satellite Driven Niche Space of Chick Rearing Habitat (CRH)



Quantify the distribution and the 30 year trend of CRH Niche Space

So What?



Problem

$$\Delta Penguin = \beta \cdot \Delta Environment + \varepsilon$$

We have a lot of location information for penguins, not but sparse records for penguin counts.

$$CRH = P(+Penguin \mid Environment)$$

We can collapse the environment to an expected time series of penguin probabilities (CRH)

$$\Delta Penguin \approx \beta \cdot CRH + \varepsilon$$

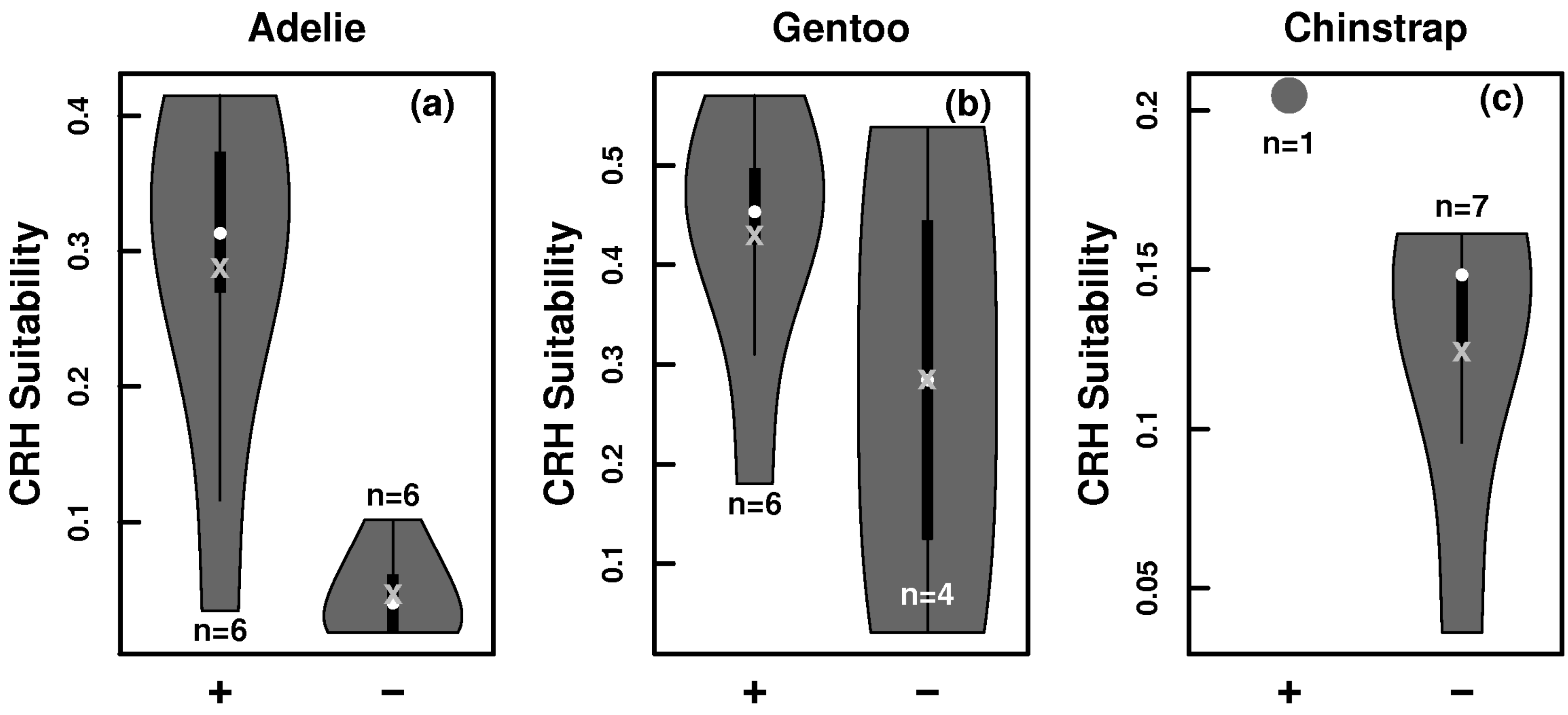
We can treat Penguin as a factor, and determine if CRH is the same across each factor (ANOVA)

Problem

Hypothesis: Environment Predicts Populations of Penguins

$$\Delta Penguin \approx \beta \cdot CRH + \varepsilon$$

The error term encapsulates **small scale cyclical environmental variation, and any top-down component**



Torgersen Island 1991
Photo: Mark Moline

Torgersen Island 2011
Photo: Mark Moline

The Plan

Assessment

Satellite Tags

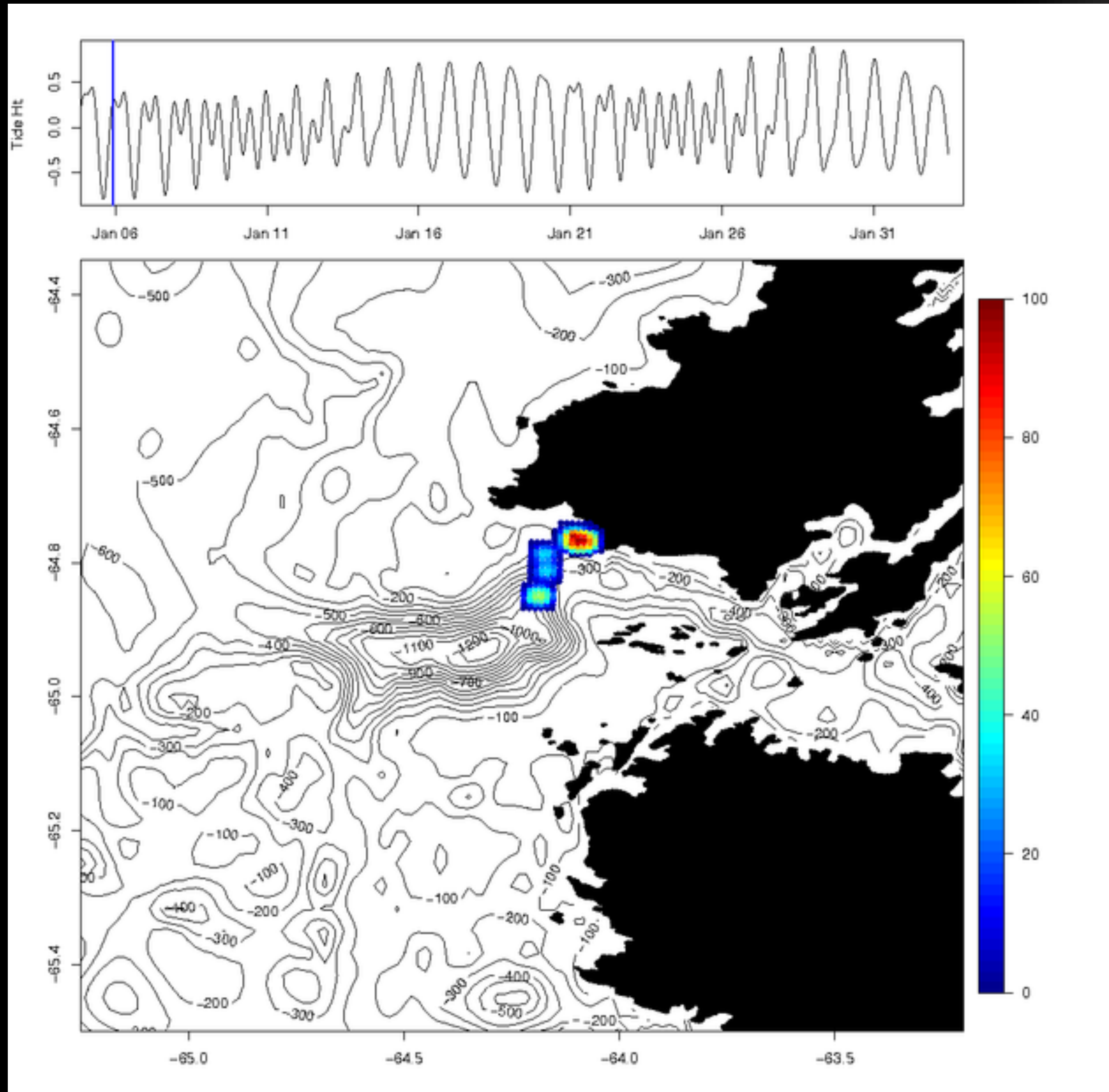
ARGOS

Position

Mission Planning

Deployment

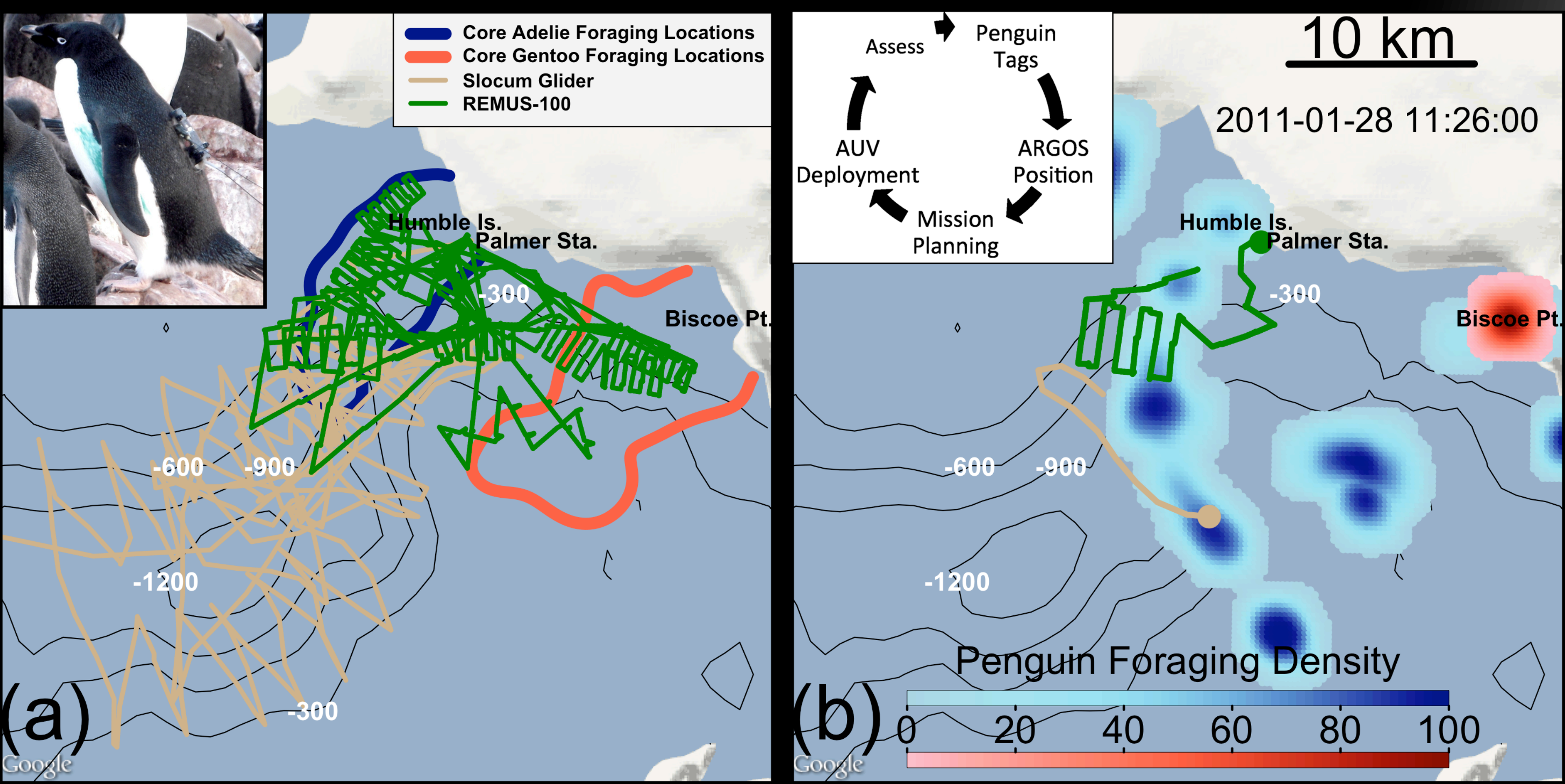
Near-Real Time Mapping of Penguin Foraging Locations



Oceanography 25(3):120–121, http://dx.doi.org/10.5670/oceanog.2012.84.

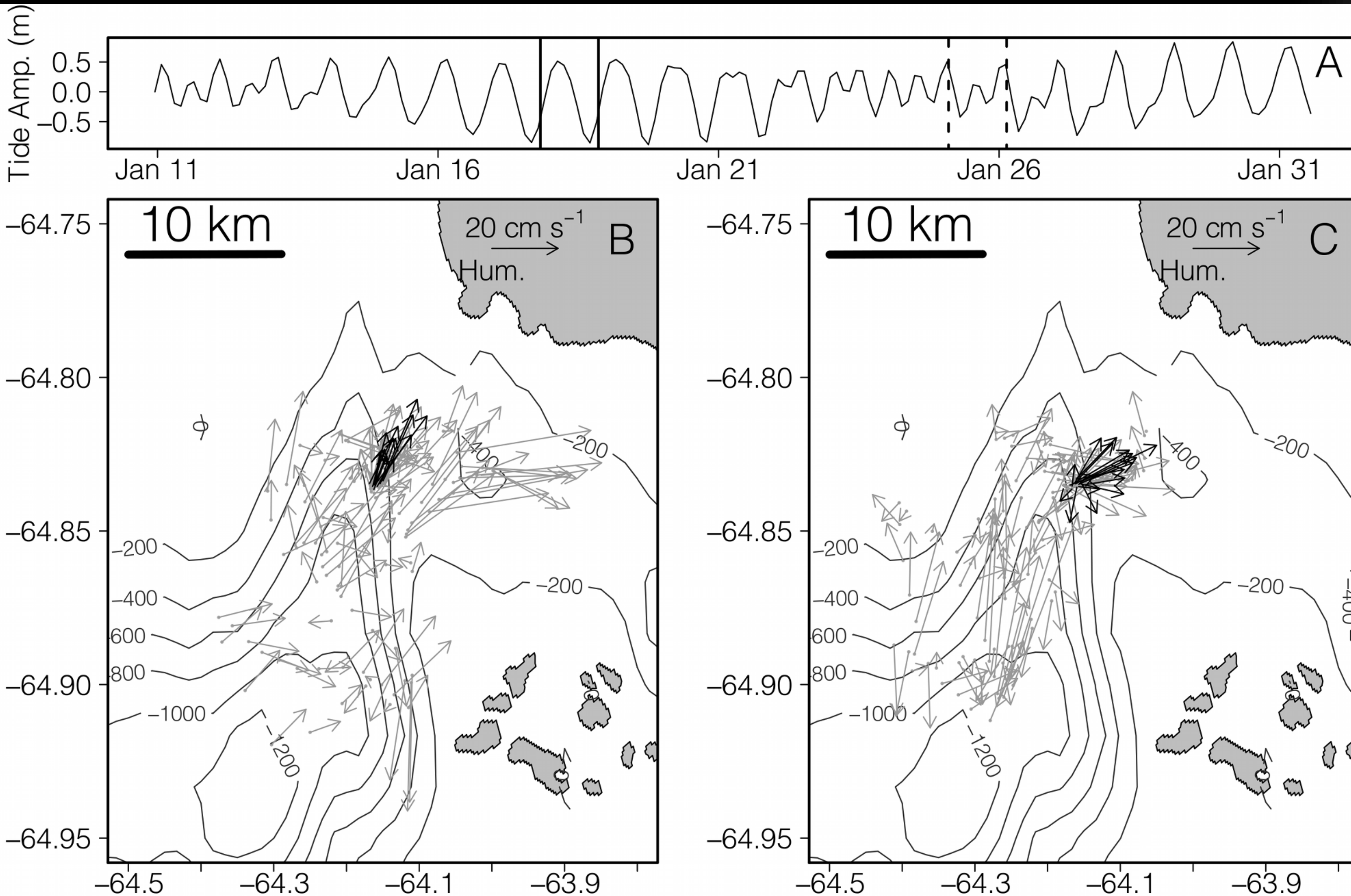
Letting Penguins Lead: Dynamic Modeling of Penguin Locations Guides Autonomous Robotic Sampling

BY MATTHEW J. OLIVER, MARK A. MOLINE, IAN ROBBINS, WILLIAM FRASER, DONNA PATTERSON, AND OSCAR SCHOFIELD

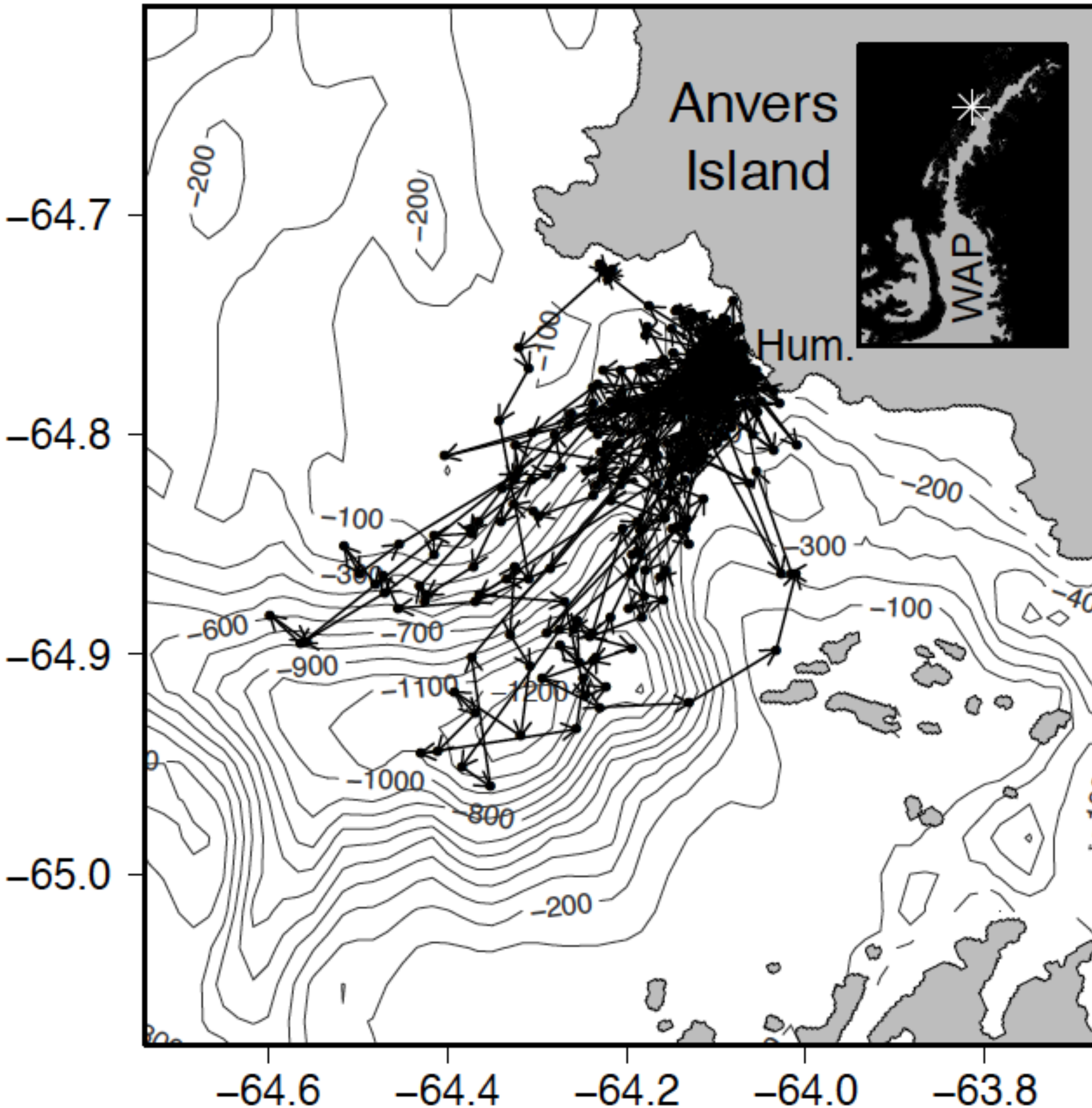


Glider Depth Integrated Currents

Diurnal Tides / Semi-Diurnal Tides



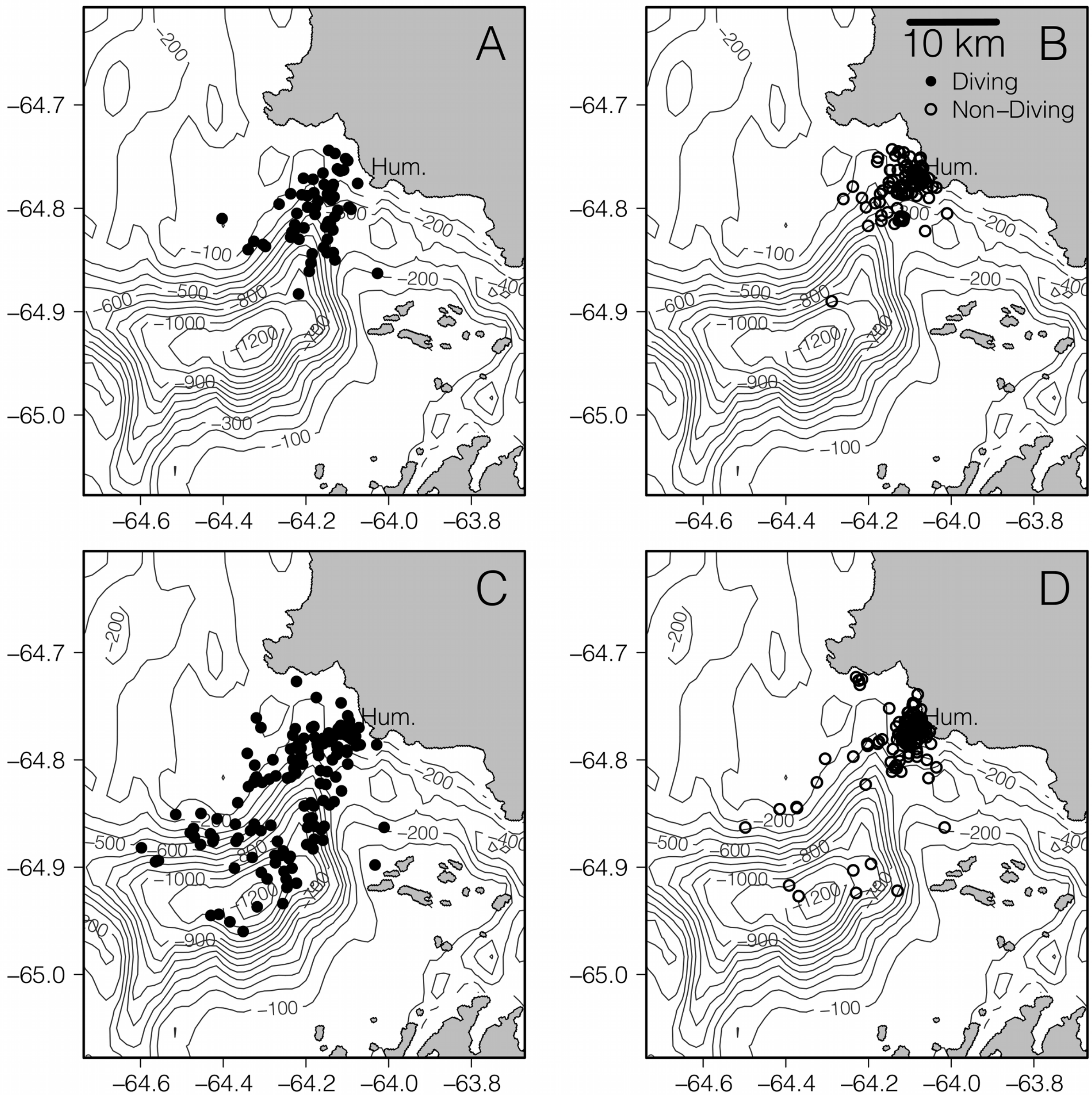
Where did the Adélie penguins go?



Results from 2011 Field Season

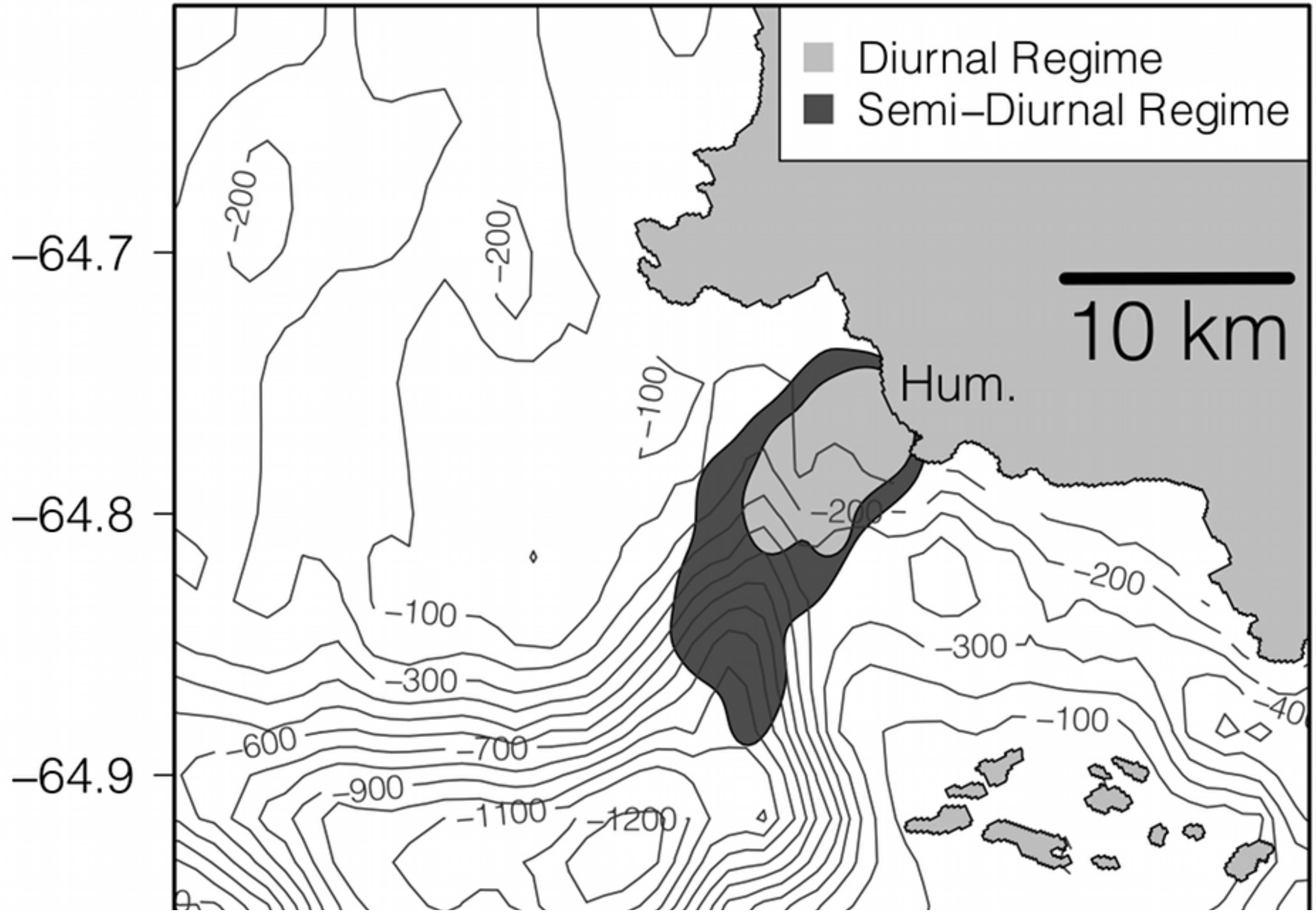
Diurnal

Semi-Diurnal



Results from 2002-2011 Penguin Locations

Why?



OPEN ACCESS Freely available online PLOS ONE

Adélie Penguin Foraging Location Predicted by Tidal Regime Switching

Matthew J. Oliver[1]*, Andrew Irwin[2], Mark A. Moline[1], William Fraser[3], Donna Patterson[3], Oscar Schofield[4], Josh Kohut[4]

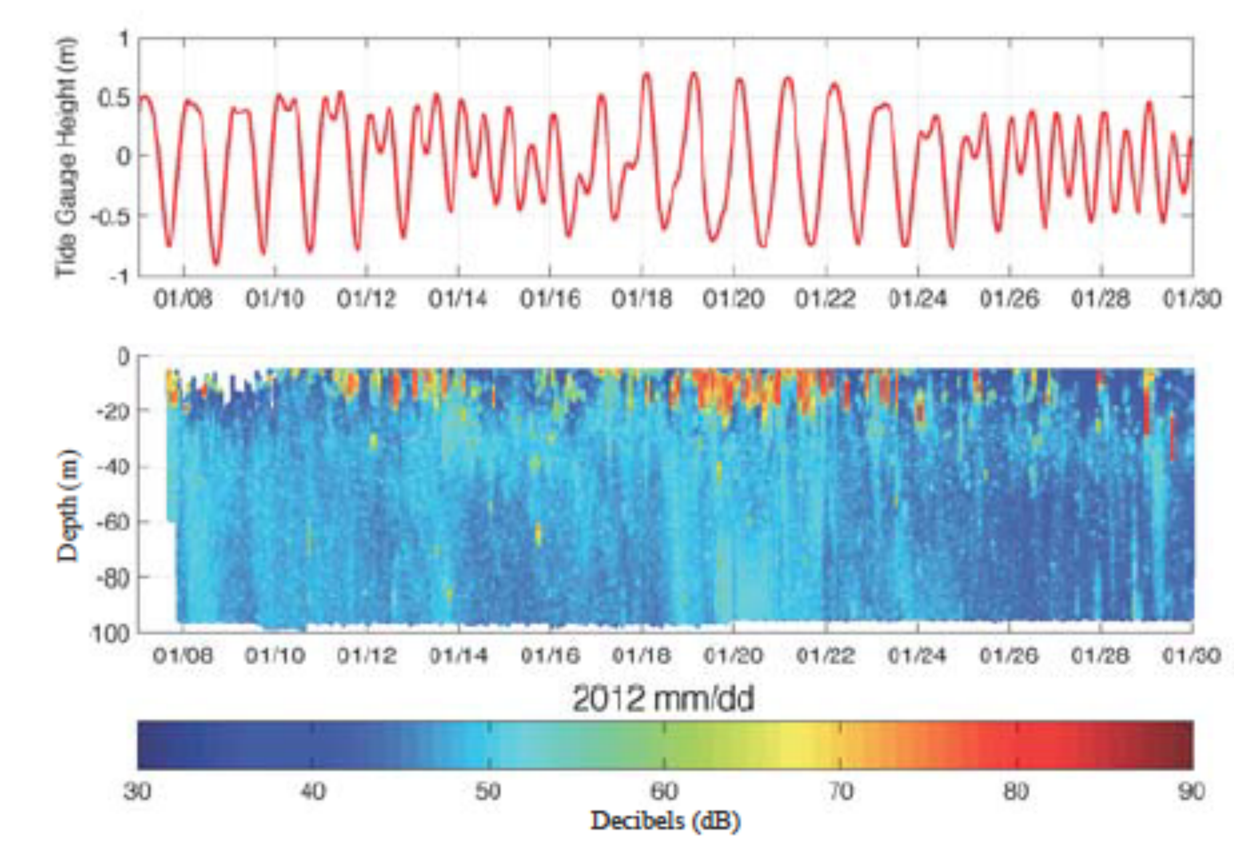
The Hypothesis
Penguin Foraging Location is Driven by Tide Regime

$$Foraging = \beta \cdot tide\ regime + (1 | trip) + \varepsilon$$

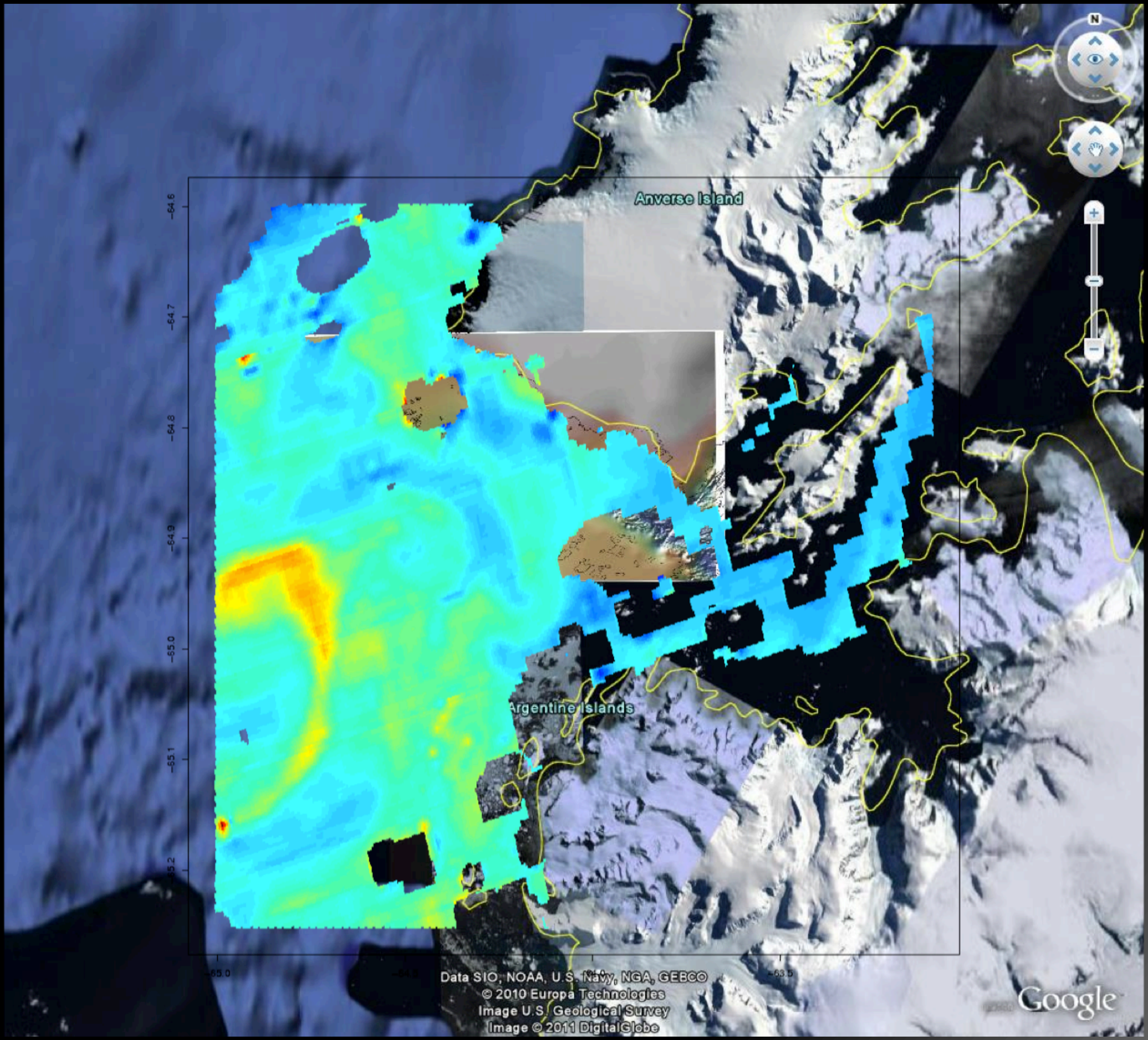
Tide Regime ~ Krill Density

Tidal Currents are strong enough to concentrate Krill

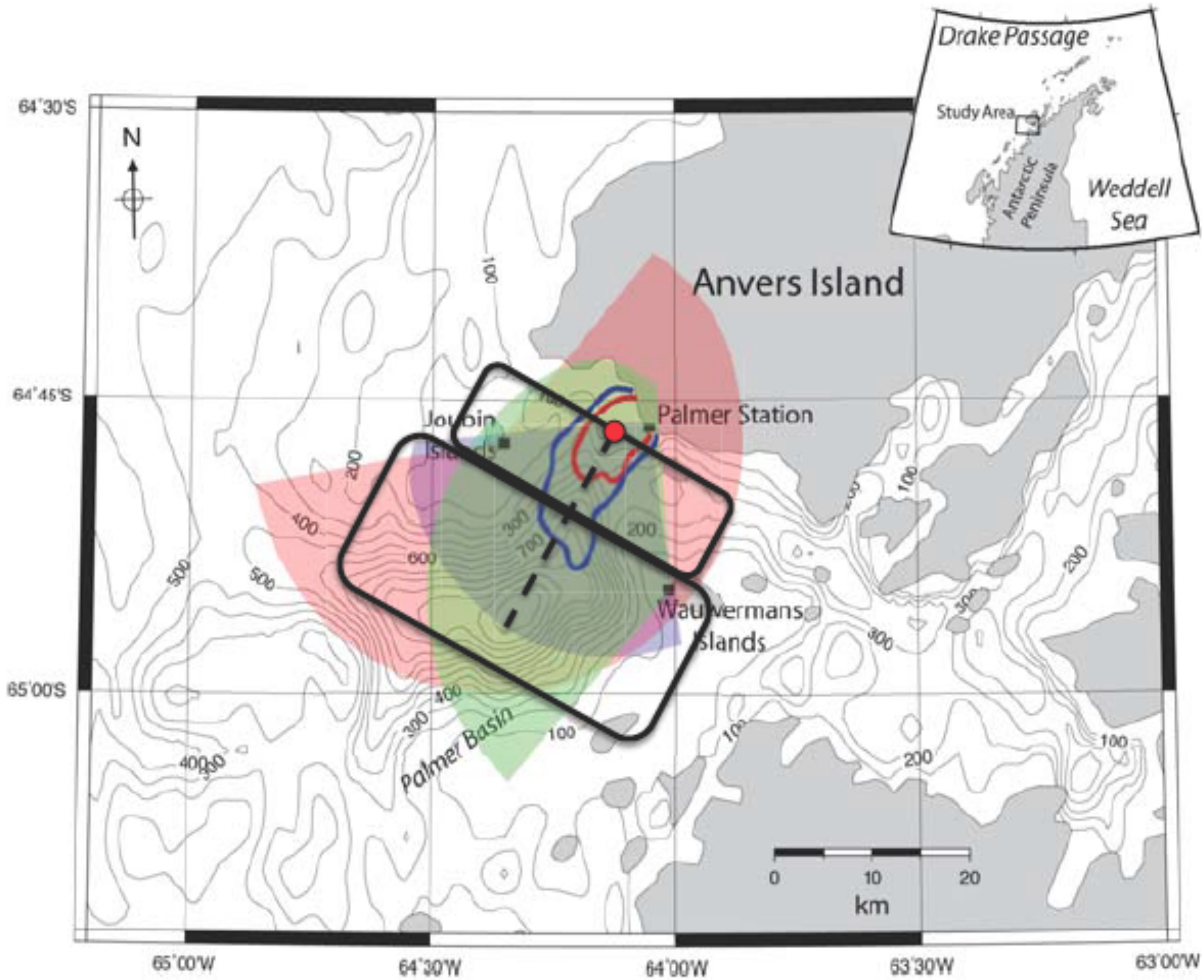
Courtesy: Travis Miles



Spatial Evidence of Tidal Influence



Future Work
Bring Down HF RADAR



Revisiting Original Model

$$\Delta Penguin = \beta \cdot \Delta Environment + \varepsilon$$

The error term encapsulates small scale or cyclical environmental variation, and any top-down component. This is a <u>bottom-up</u> approach.

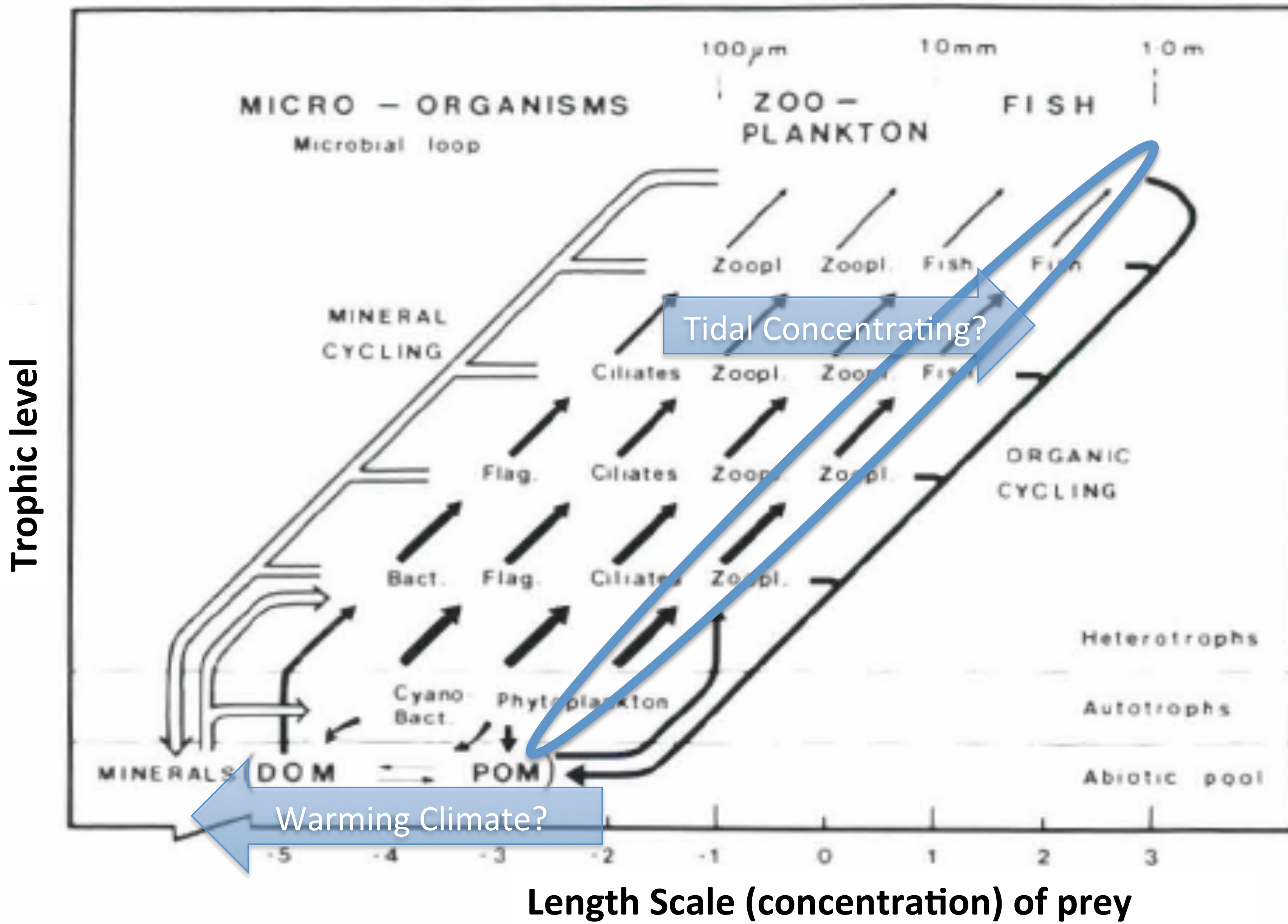
$$\Delta Penguin = \beta \cdot \Delta Environment + \eta \cdot Tides + \varepsilon$$

Implicit Climate Signal

Implicit Resource Concentrating Signal Non-Climate Signal

So What?

Let's speculate



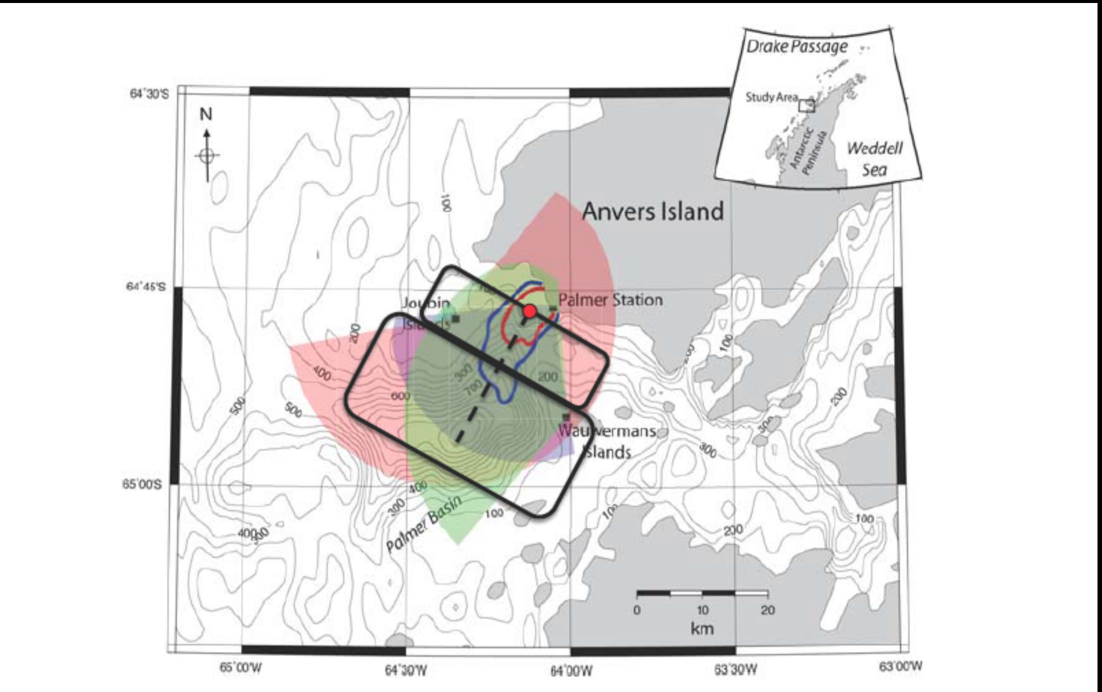
Future work

Does mesoscale variability provide refuge from a changing climate?

$$\Delta Penguin = \beta \cdot \Delta BigScale + \eta \cdot LocalScale + \varepsilon$$

Implicit Climate Signal

Mesoscale Variability



Working with
Josh Kohut (Rutgers)
Bill Fraser (Polar Oceans
Peter Winsor (U of Alaska)
Kim Bernard (OSU)
Megan Cimino (UD)
See Poster!