Austral Winter and Spring Controls on the Food Web at Palmer Station, West Antarctic Peninsula (WAP)

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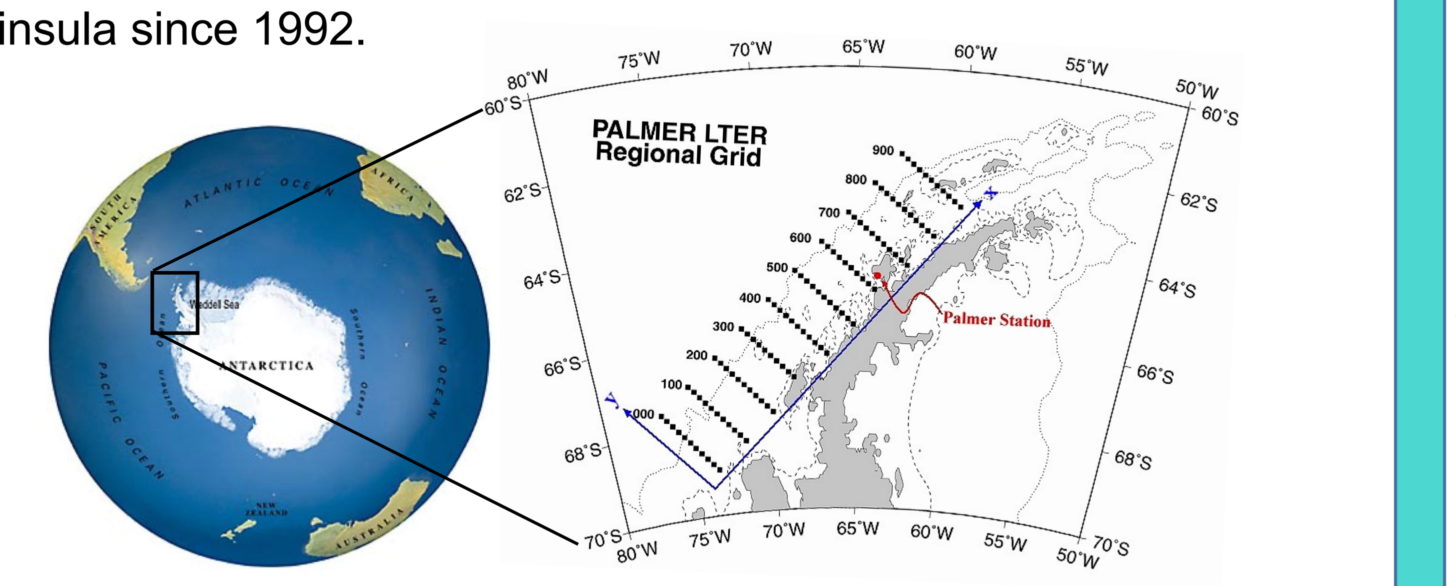
Introduction

The WAP is experiencing rapid climate change and one of the fastest rates of winter warming on Earth[1]. Recent warming and declines in WAP sea ice have been associated with changes at key trophic levels in the food web including a reduction in phytoplankton biomass[2], shifts in phytoplankton community composition in the northern WAP[2], and reductions in Antarctic krill[3], *Euphausia superba*, the main trophic link between phytoplankton and many apex predators in Antarctic food webs.

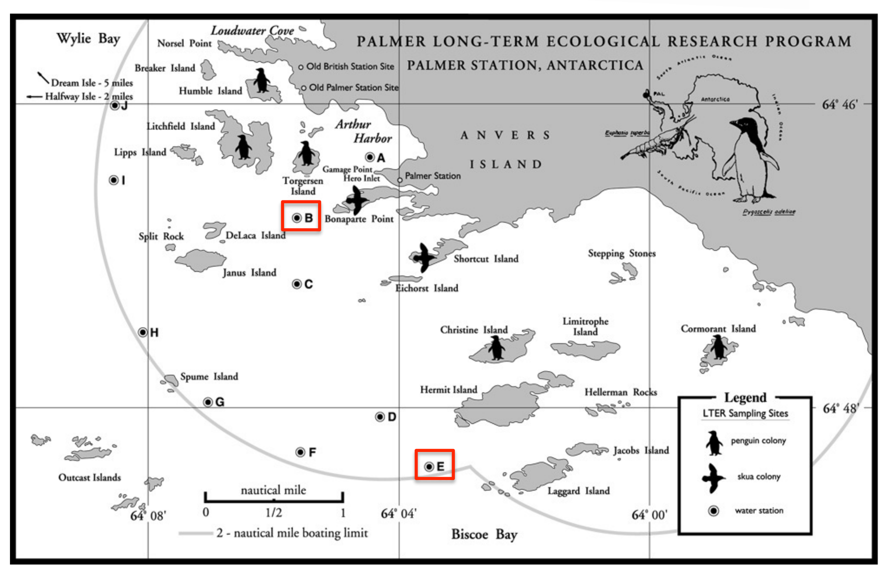
In addition to long-term changes, the WAP ecosystem is characterized by high interannual variability[4,5,6]. The mechanisms by which climate variability ripples through the food web along the western continental shelf region of the WAP remain poorly understood, yet understanding these interactions is essential to determine ecosystem responses to climate change. Here we used over two decades of data collected by the Palmer Long Term Ecological Research program (PAL-LTER) to determine how large-scale climate and local physical forcing affect the food web of this Antarctic ecosystem.

Study Site

In 1990, PAL-LTER was designated as the first polar biome LTER site in the Southern Hemisphere. Scientific research is centered in and around Palmer Station, located in the northern WAP region (*right*), and an annual January cruise has been conducted along the entire peninsula since 1992.

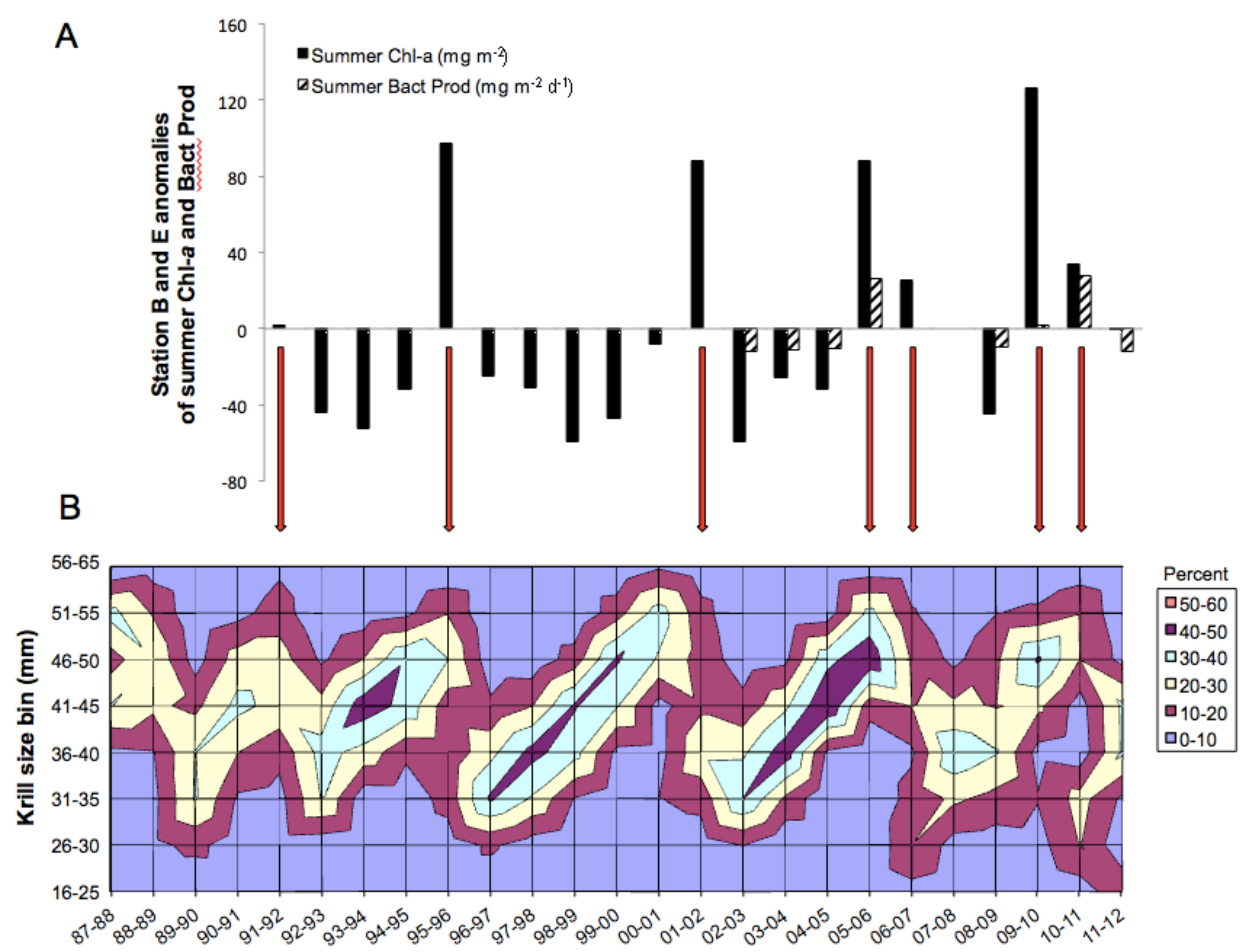


Palmer Station study sites include an inshore station (Station B; depth ≈ 75 m) and an offshore station (Station E; depth ≈ 200 m).

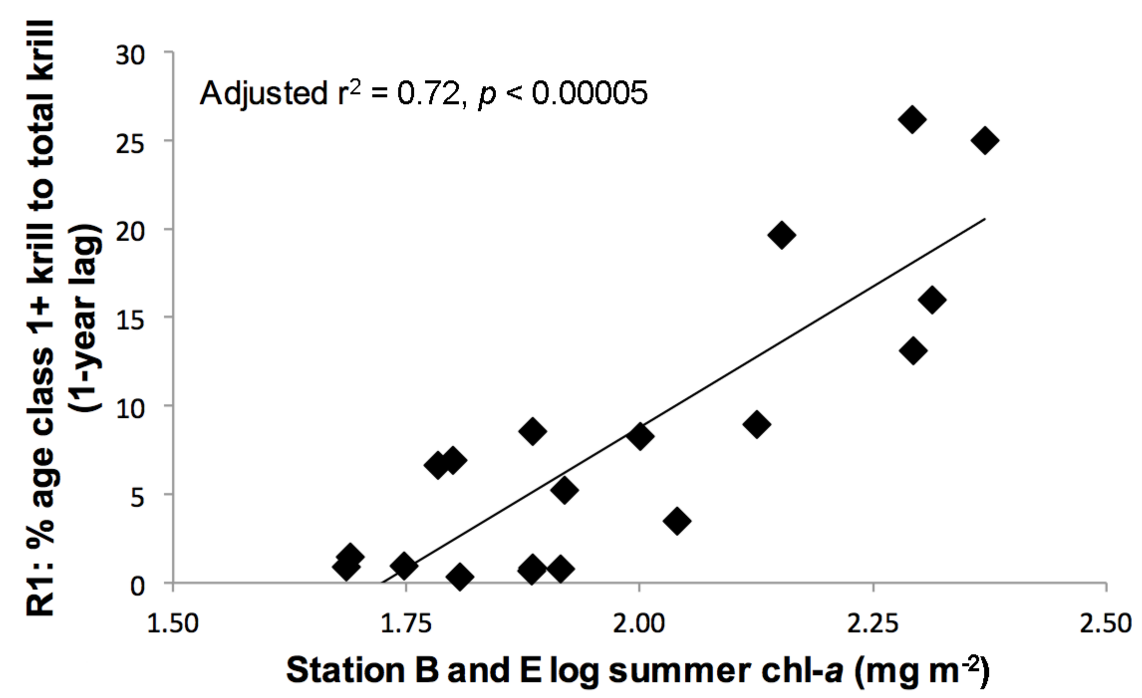


Interannual Variability

Positive anomalies in depth-integrated chlorophyll-*a* concentration (chl-*a*) and bacterial productivity at Palmer Station occurred on average every 4-6 years.



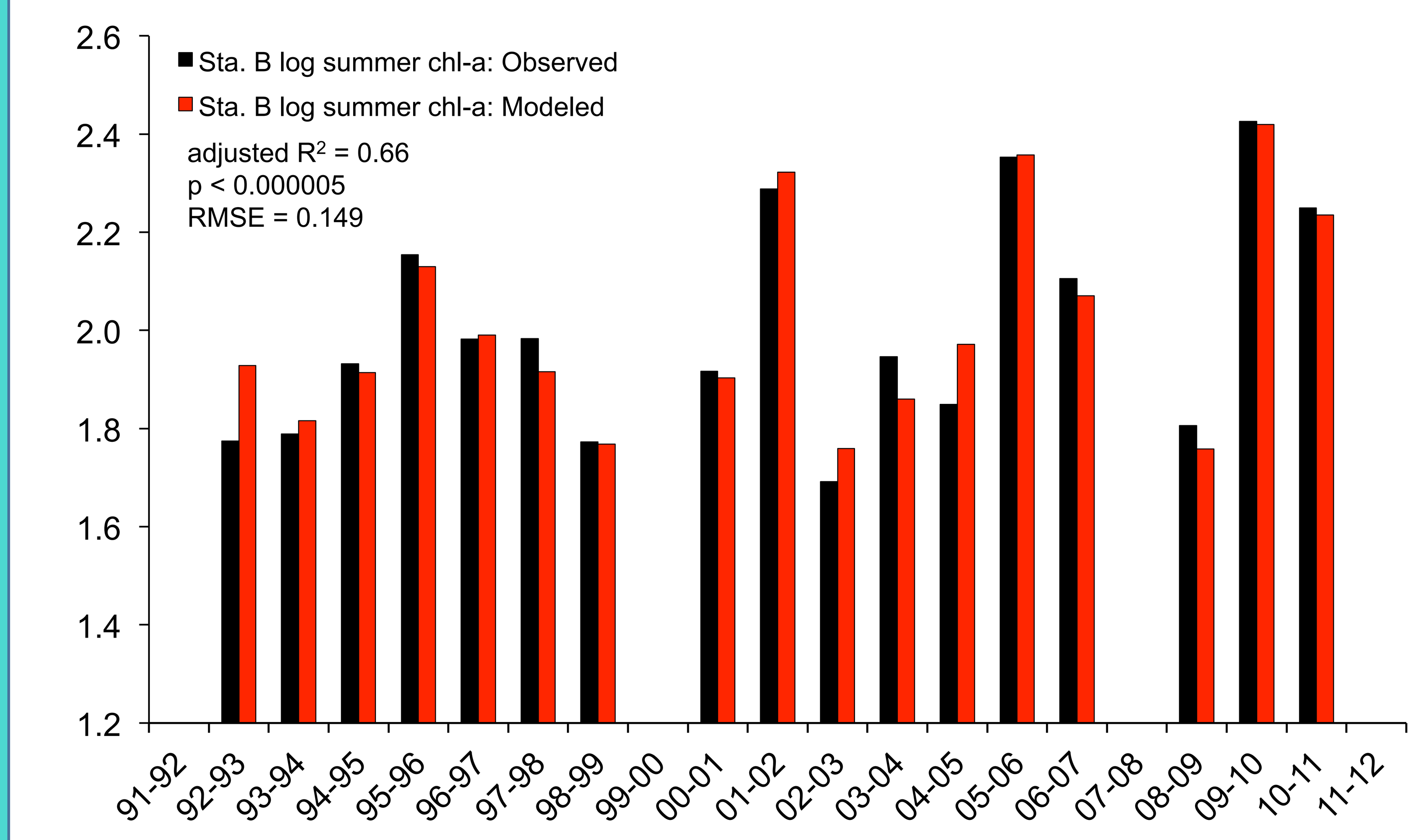
Years of positive anomalies corresponded to statistically significant krill recruitment events, which resulted in the start of a new krill cohort the following season. These krill cohorts were evident in Adélie penguin diets, thus demonstrating a tight coupling within the food web.



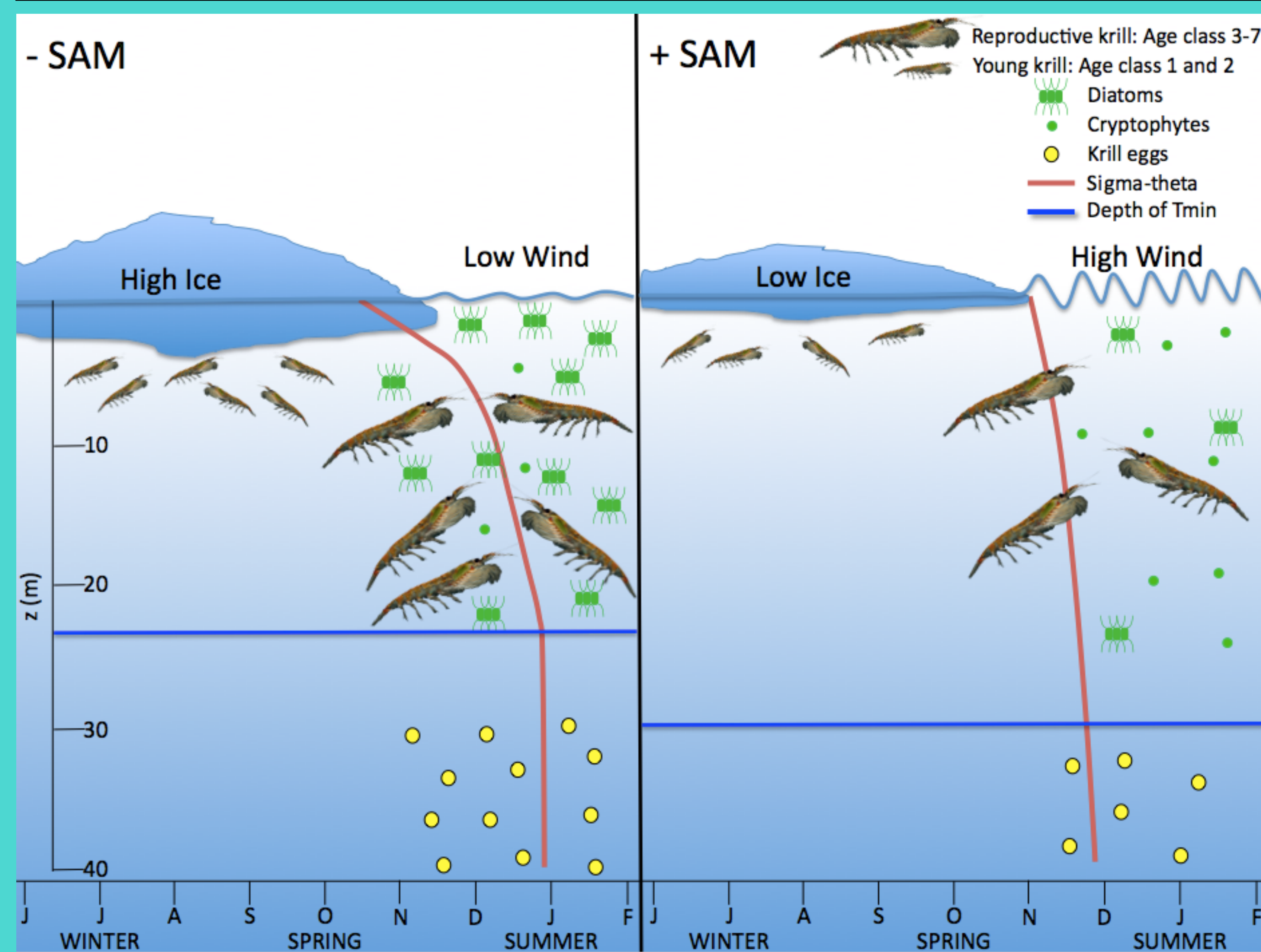
Mechanisms

We conducted a stepwise regression analysis to determine how well various combinations of identified local (i.e., wind, water column stability, sea ice) and large-scale (SAM) physical forcing could simulate variations in depth-integrated chl-*a* for each summer.

For Stations B and E, physical forcing accounted for 66% and 54% of summer depth-integrated chl-*a* variability, respectively. Summer chl-a was constrained by physical processes in the preceding winter/spring and a negative phase of the Southern Annular Mode (SAM). Favorable conditions for phytoplankton, specifically diatoms, were increased winter ice extent and duration, reduced spring/summer winds, and increased water column stability via enhanced salinity-driven density gradients. Station B is presented here.



Summary



Global climate models project increases in positive SAM events[7]. Repercussions of this projection are the continued increase in the strength of north-westerly winds[8], increase in temperature[9], and decline in sea ice[10]. These trends will act to further reduce water column stability and decrease bacterial productivity, phytoplankton biomass, favorable krill prey (diatoms), and krill recruitment.

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References:
1) Vaughan, D.G. *et al*. Recent rapid regional climate warming on the Antarctic Peninsula. *Climatic Change* **60**, 243-274 (2003).
2) Montes-Hugo, M. *et al*. Recent Changes in Phytoplankton Communities Associated with Rapid Regional Climate Change Along the Western Antarctic Peninsula. *Science* **323**, 1470-1473 (2009).
3) Atkinson, A., Siegel, V., Pakhomov, E. & Rothery, P. Long-term decline in krill stock and increase in salps within the Southern Ocean. *Nature* **432**, 100-103 (2004).
4) Fraser, W. R. & Hofmann, E. E. A predator's perspective on causal links between climate change, physical forcing and ecosystem response. *Mar. Ecol. Prog. Ser*. **265**, 1-15 (2003).
5) Loeb, V. J., Hofmann, E. E., Klinck, J. M., Holm-Hansen, O. & White, W. B. ENSO and variability of the Antarctic Peninsula pelagic marine system. *Antarctic Sci*. **21**, 135-148 (2009).
6) Venables, H. J., Clarke, A. & Meredith, M. P. Wintertime controls on summer stratification and productivity at the western Antarctic Peninsula. *Limnol. Oceanogr*. **58**, 1035-1047, http://dx.doi.org/10.4319/lo.2013.58.3.1035 (2013).
7) Marshall, G. J. *et al*. Causes of exceptional atmospheric circulation changes in the Southern Hemisphere. *Geophys. Res. Lett*. **31**, L14205, doi:10.1029/2004GL019952 (2004).
8) Hall, A. & Visbeck, M. Synchronous variability in the Southern Hemisphere atmosphere, sea ice and ocean resulting from the Annular Mode. *J. Clim*. **15**, 3043-3057 (2002).
9) Bracegirdle, T. J., Connolley, W. M. & Turner, J. J. Antarctic climate change over the twenty first century. *J. Geophys. Res*. 113, D03103, doi: 10.1029/2007JD008933 (2008).
10) Stammerjohn, S. E., Martinson, D. G., Smith, R. C., Yuan, X. & Rind, D. Trends in Antarctic annual sea ice retreat and advance and their relation to El Ninõ-Southern Oscillation and Southern Annular Mode variability. *J. Geophys. Res*. **113**, C03S90, doi:10.1029/2007JC004269 (2008).