USING ACOUSTICS TO REMOTELY ASSESS BIOMASS IN DRAKE PASSAGE

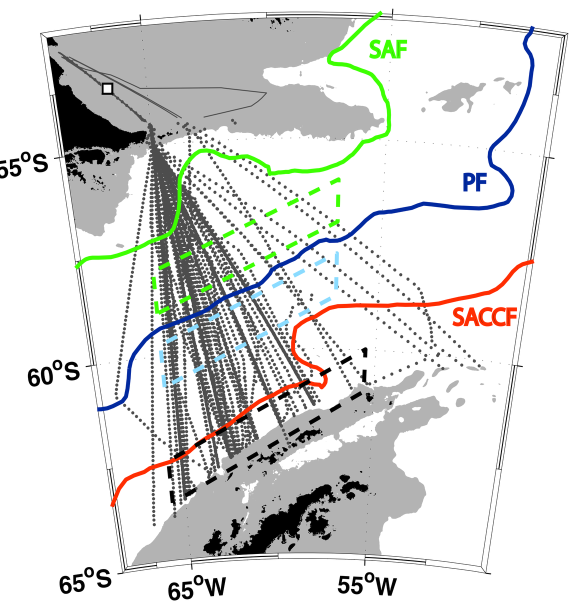
Teresa Chereskin[1], Zoé Koenig[2], Janet Sprintall[1], Valerie Loeb[3], Jarrod Santora[4], and Kim Dietrich

[1]Scripps Institution of Oceanography , [2]Université Pierre et Marie Curie, [3]Moss Landing Marine Laboratories, [4]University of California Santa Cruz

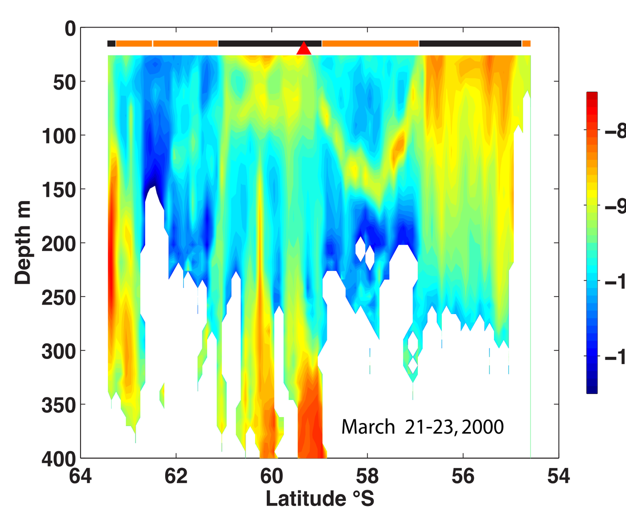
1. INTRODUCTION

The major fronts of the Antarctic Circumpolar Current play an important role in structuring zooplankton communities within Drake Passage. Monitoring a large marine ecosystem in the harsh conditions of the Southern Ocean poses significant challenges, since *in situ* observations are sparse and are mostly collected in summer. Macrozooplankton surveys of the entire passage were made in the early part of the last century during the Discovery Expeditions (Mackintosh, 1934), but sampling in recent decades has been focused south of the SACCF where Antarctic krill, *Euphausia superba*, is the dominant zooplankton.

The ARSV Laurence M. Gould (LMG) collects underway data on transits of Drake Passage 2-4 times per month in all seasons. This study uses 238 ADCP transects collected over a 12-year period to remotely sense the characteristics of the near-surface scattering layer. We also present preliminary results from the first systematic net sampling effort since the Discovery Expeditions specifically focused on describing the zooplankton species assemblages across Drake Passage.



LMG ship tracks and the locations of the main fronts: Subantarctic Front (**SAF**), Polar Front (**PF**), and Southern ACC Front (**SACCF;** from Orsi *et al*., 1995). Dashed boxes denote regions used in this study.



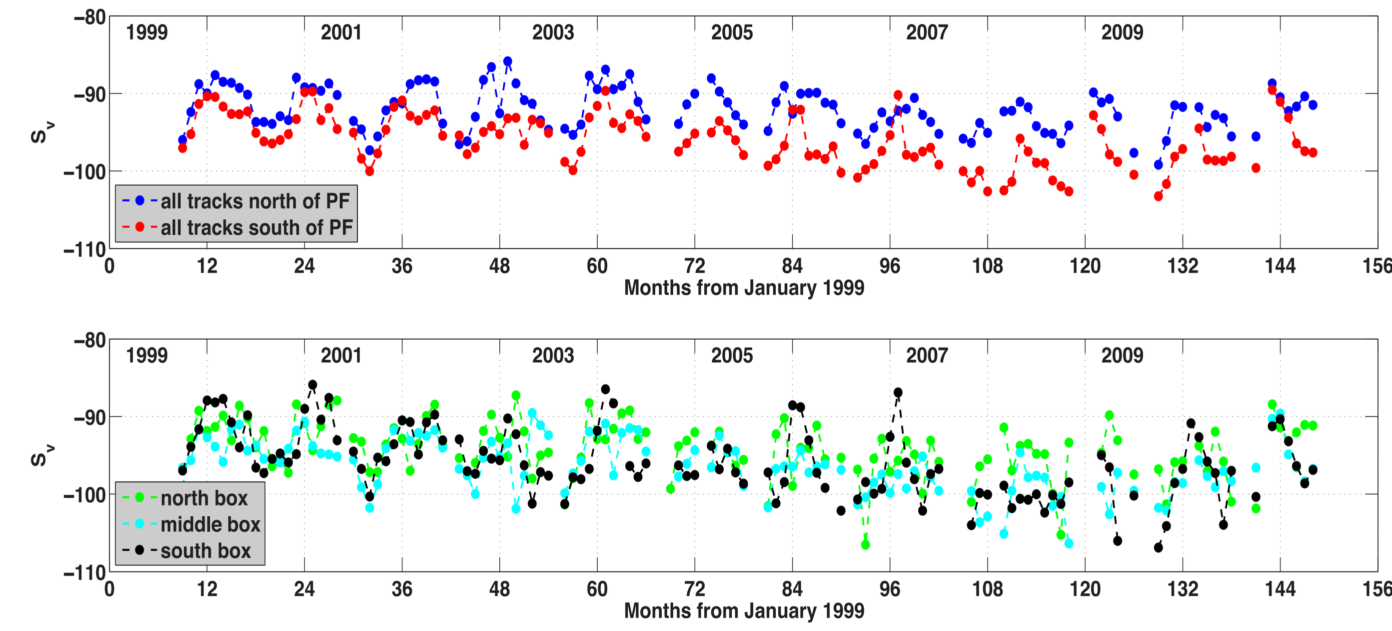
Backscattering strength from a typical 2-day crossing. The colored line at the top indicates time of day (daytime is denoted by orange; nighttime by black). The red triangle marks the location of the Polar Front. (Adapted from Chereskin and Tarling, 2007.)

2. BACKSCATTERING STRENGTH

Backscattering strength was calculated as a function of latitude and depth for each transect. A dominant pattern observed in backscattering strength is diel vertical migration, a known behavior in which zooplanton descend to greater depths to escape predation during daylight hours and ascend to feed at night. Typically the daytime descent is in a distinct layer (aggregation) whereas the nighttime increase is more diffuse (dispersion). Also apparent is a deeper layer in the depth range 200 m to 300 m that is typically present at night.

For this study backscatter is averaged from the first good depth bin at 26 m to a cutoff depth of 154 m. The cutoff depth was chosen to include the near-surface layer that migrates diurnally but to exclude the deeper layer that is only sampled at night.

3. SPATIO-TEMPORAL PATTERNS



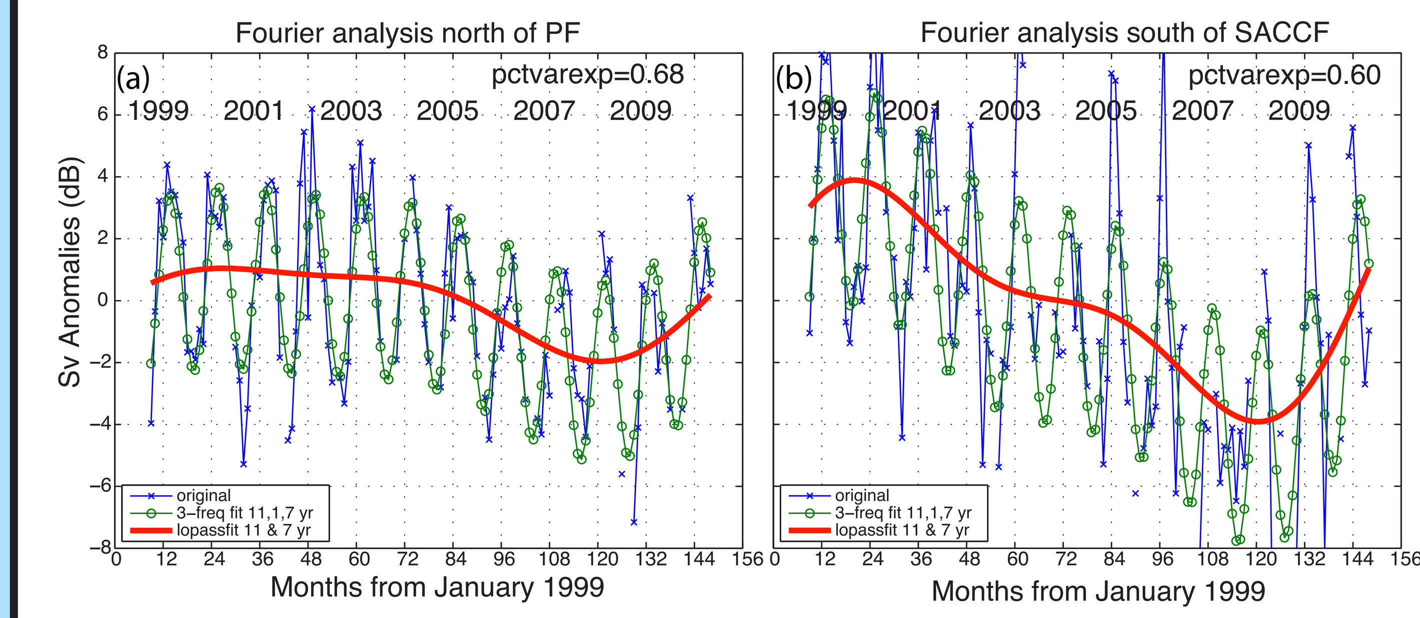
Backscattering strength was averaged over depth, month and geographic region.

TOP: Monthly averages of depth-averaged backscattering strength from all observations north (**blue**) and south (**red**) of the mean location of the Polar Front (shown on the map at far left).

BOTTOM: Monthly averages of depth-averaged backscattering strength from observations within the rectangular regions shown on the map at far left. The north box (**green**) lies between the Subantarctic and Polar Fronts. The middle box (**cyan**) lies between the Polar and Southern ACC Fronts. The southern box (**black**) lies south of the Southern ACC Front.

- There is a pronounced annual cycle in all 5 time series, with backscattering strength increasing by about 6 dB from late winter (August) to spring (November).
- The summer maximum backscatter level north of the Polar Front is significantly higher than the maximum level south of the Polar Front.
- There is a long-term trend in all 5 time series, with backscattering strength decreasing from 2001 to 2008. The trend is most pronounced south of the SACCF.
- The above patterns are robust using only daytime/nighttime observations (not shown).

4. PERIODICITIES

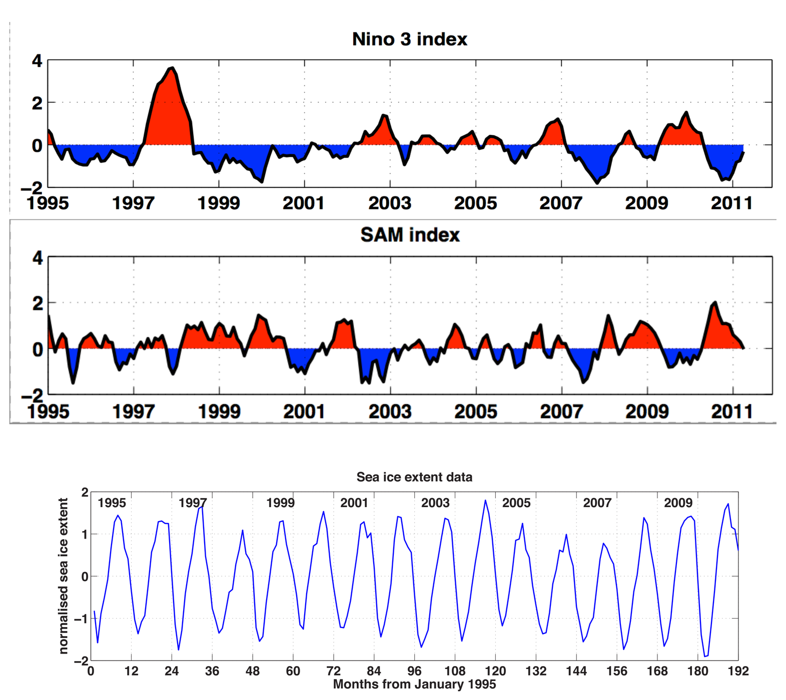


Fourier analyses of the time series of backscattering strength are shown for the region north of the Polar Front (**ABOVE LEFT**) and south of the Southern ACC Front (**ABOVE RIGHT**): original data (blue), the sum of 3 Fourier components accounting for more than 60% of the total variance (green), and the sum of the 2 lowest frequency components (red), providing a low pass filter.

The annual cycle accounts for more than 30% of the variance. Two trends are visible, one with a period of 7 years and another with a period of 11 years.

- Three dominant periods (1, 7, 11) explain more than 60% of the variance.
- There is a negative trend in backscattering strength from 2001 to 2008.
- The trend is approximately linear south of the SACCF, with a decrease in backscattering strength of about 8 dB over a 7-year period.
- North of the PF, there is a very weak trend from 1999 to 2005, followed by a sharp decrease of about 2 dB.

5. RELATION TO CLIMATE MODES



Niño 3 index
(http://www.cpc.ncep.noaa.gov/data/indices)

SAM index
(http://www.cpc.ncep.noaa.gov/data/indices)

Sea ice extent (SIE) index
http://nsidc.org/data/smmr_smmi_ancillary/area_extent.html

ABOVE: Climate indices correlated with backscatter strength south of the SACCF. The Niño 3 and SAM indices are anti-correlated, such that a positive SAM index corresponds to La Niña. The sea ice extent (SIE) record is for the Bellingshausen/Amundsen sector and is dominated by the annual cycle.

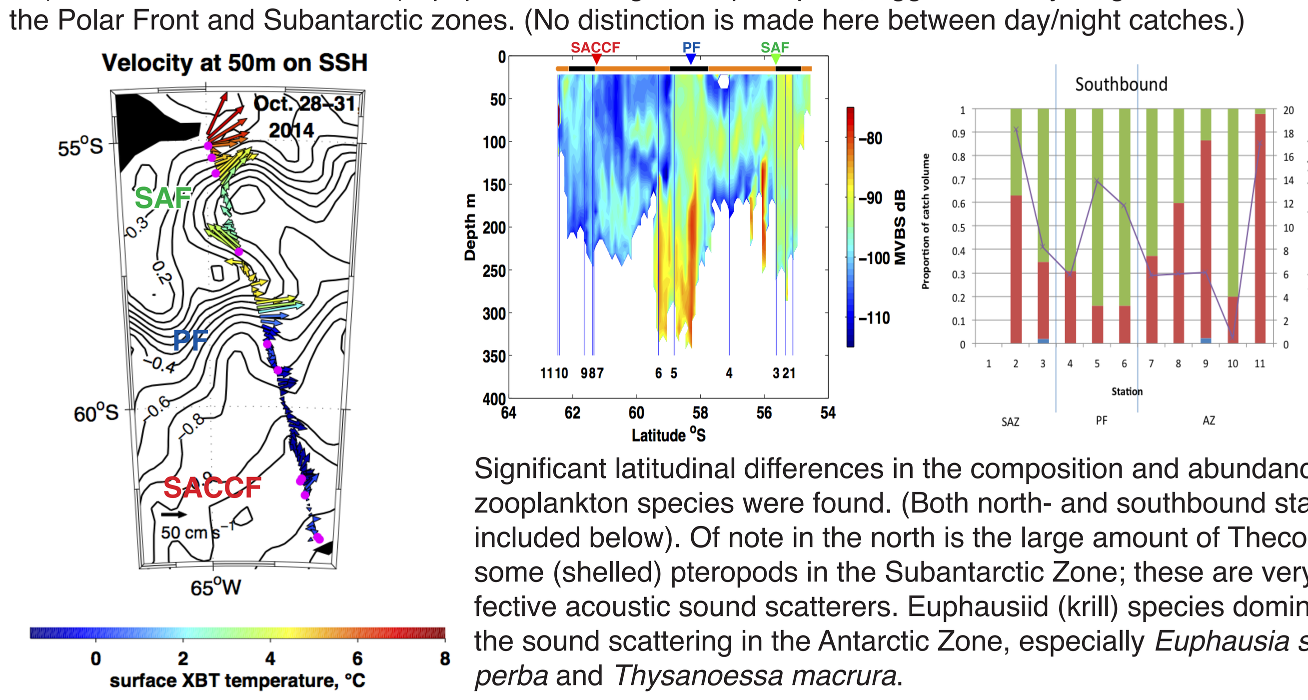
The annual signal was removed from both the backscattering strength and the SIE time series, and the series were low pass filtered, in order to examine interannual variability. The Niño 3 and SAM indices were used as shown above, without further modification.

Significant correlations with lags shorter than 1 year were found between the backscattering strength south of the SACCF and the 3 climate indices:

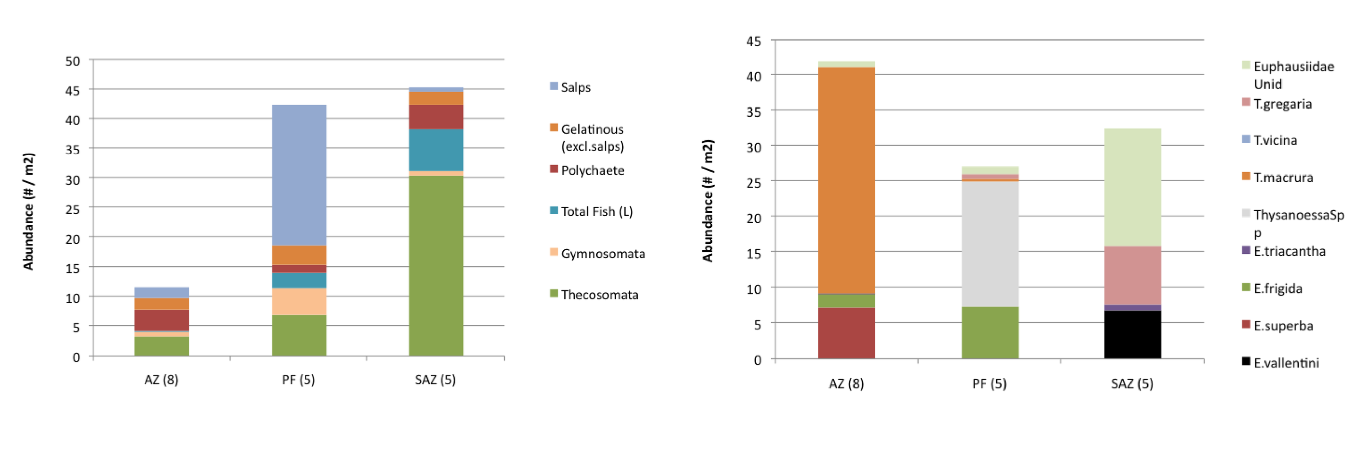
- Niño 3 leads sea ice extent by 6 months, negative correlation of -0.34
- SAM leads sea ice extent by 5 months, positive correlation of 0.3
- SIE leads backscattering strength south of the SACCF by 6 months, positive correlation of 0.6
- Niño 3 leads backscatter strength south of the SACCF by 11 months, negative correlation of -0.3

6. PILOT STUDY: BIOLOGICAL SAMPLING ON LG1410

LG1410 was the first cruise of a pilot study to make systematic net sampling on Drake Passage transects in order to describe zooplankton species assemblages. ADCP velocity observations, XBT temperature observations, and sea surface height from altimetry (AVISO) help identify the ACC fronts. A large scale meander in the SAF/PF was evident in late October when 11 net tows were made; locations are marked by magenta circles on the map and by vertical lines on the backscatter section. There is a pattern of greater representation of large size fraction zooplankton individuals (krill, amphipods) in and south of the SACCF (Antarctic Zone, AZ) versus small size fraction (copepods, chaetognaths, pteropods, eggs and early stages of crustaceans) in the Polar Front and Subantarctic zones. (No distinction is made here between day/night catches.)



Significant latitudinal differences in the composition and abundance of zooplankton species were found. (Both north- and southbound stations included below). Of note in the north is the large amount of Thecosome (shelled) pteropods in the Subantarctic Zone; these are very effective acoustic sound scatterers. Euphausiid (krill) species dominate the sound scattering in the Antarctic Zone, especially *Euphausia superba* and *Thysanoessa macrura*.



7. CONCLUSIONS

We expect that changes in the Southern Ocean due to climate warming are visible in ecosystem dynamics; this study used underway shipboard observations of the upper ocean scattering layer as a proxy to observe these changes. The observed interannual variability is consistent with recent observations of decline in krill stock in southern Drake Passage (e.g., Atkinson *et al*., 2004). Ideally, with coincident zooplankton samples for calibration and species identification such as collected during LG1410, ADCP backscattering strength will be a useful tool to monitor the Drake Passage ecosystem.

The main conclusions are:

- Temporal variability in backscattering strength for the period 1999-2012 was dominated by 3 periods of 1, 7 and 11 years that explained more than 60% of the variance.
- The annual cycle is consistent with the biological nature of the scatterers. There is a fourfold increase (6 dB) from late winter to spring.
- The spatial distribution shows consistently higher backscattering strength north of the Polar Front. This variation is due at least in part to latitudinal differences in the composition and abundance of zooplankton species.
- There is a long-term trend, with backscattering strength decreasing from 2001 to 2008 in Drake Passage. The decline is most pronounced south of the SACCF, with a decline of about 1 dB/year, where the acoustic sound scatterers are dominated by Antarctic krill, *Euphausia superba.*
- Interannual variability is correlated to climate indices (Niño 3, SAM, SIE). The backscattering strength south of the SACCF has significant correlations at lags of less than 1 year; north of the SACCF the significant correlations are at longer lags (not shown).

8. ACKNOWLEDGMENTS

The National Science Foundation Office of Polar Programs sponsored this research through grants PLR-1341431 (Chereskin and Sprintall) and PLR-1347911 (Loeb and Santora). The underway ADCP program is carried out in partnership with Eric Firing and Jules Hummon (University of Hawaii). Thanks are also due to Sharon Escher (SIO), the captains and crews of the ARSV Laurence M. Gould and to Raytheon Polar Services Corporation for excellent logistical and technical support.

9. REFERENCES

Atkinson, A., Siegel, V., Pakhomov, E.A., and P. Rothery. 2004. Long-term decline in krill stock and increase in salps within the Southern Ocean. ***Nature*, 432**, 100–103.

Chereskin, T.K. and G.A. Tarling. 2007. Interannual to diurnal variability in the near-surface scattering layer in Drake Passage. ***ICES Journal of Marine Science*, 64**, 1617-1626.

Mackintosh, N. A. 1934. Distribution of the macrozooplankton in the Atlantic sector of the Antarctic. ***Discovery Reports*, 9**, 65-150.

Orsi, A.H., T.Whitworth III and W.D. Nowlin Jr. 1995. On the meridional extent and fronts of the Antarctic Circumpolar Current. ***Deep-Sea Research I*, 42**, 611-673.

RD Instruments, 1998. Calculating absolute backscatter in narrowband ADCPs. Field Service Technical Paper 003 (FST-003).