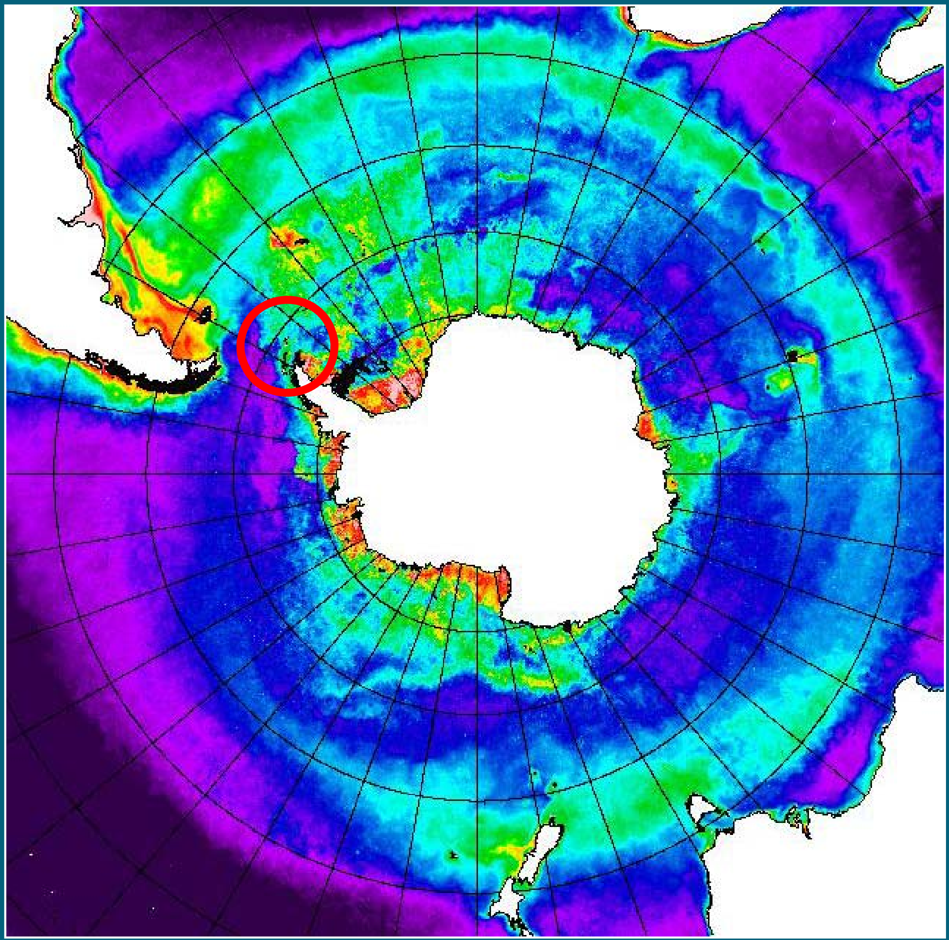
Overview of the Southern Scotia Sea Natural Iron Fertilization Study

Zhou, UMass Boston

Blue Water Zone (BWZ) Team

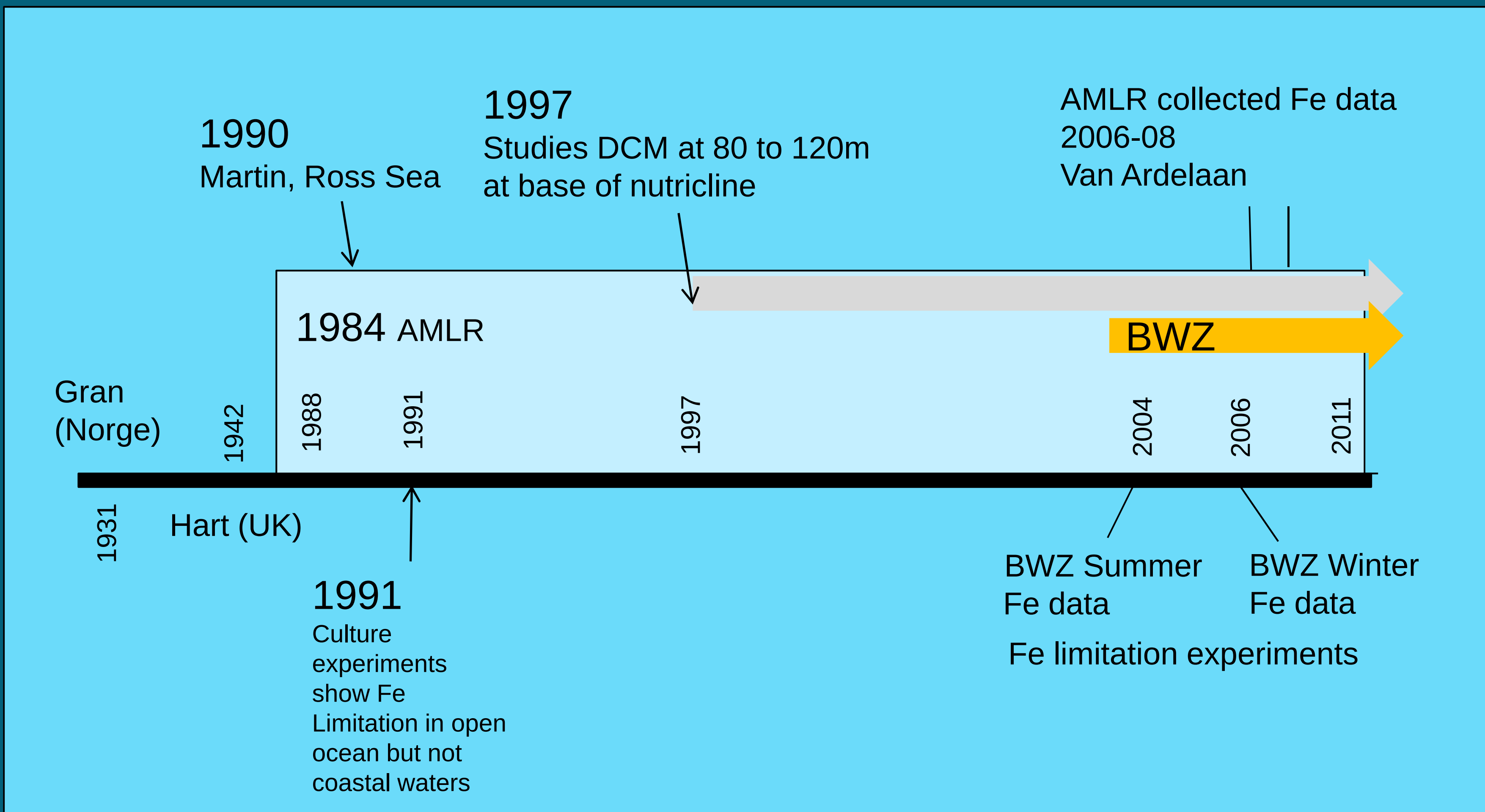
- Azam F, SIO
- Barbeau K, SIO
- Charette M, WHOI
- Holm-Hansen O, SIO
- Gille S, SIO
- Jiang M, UMass Boston
- Measures C, UHawaii
- Mitchell BG, SIO
- Reiss C, NOAA-SWFSC
- Selph K, UHawaii
- Zhou M, UMass Boston
- Many others



Composite Chl in Jan (Mitchell et al.)

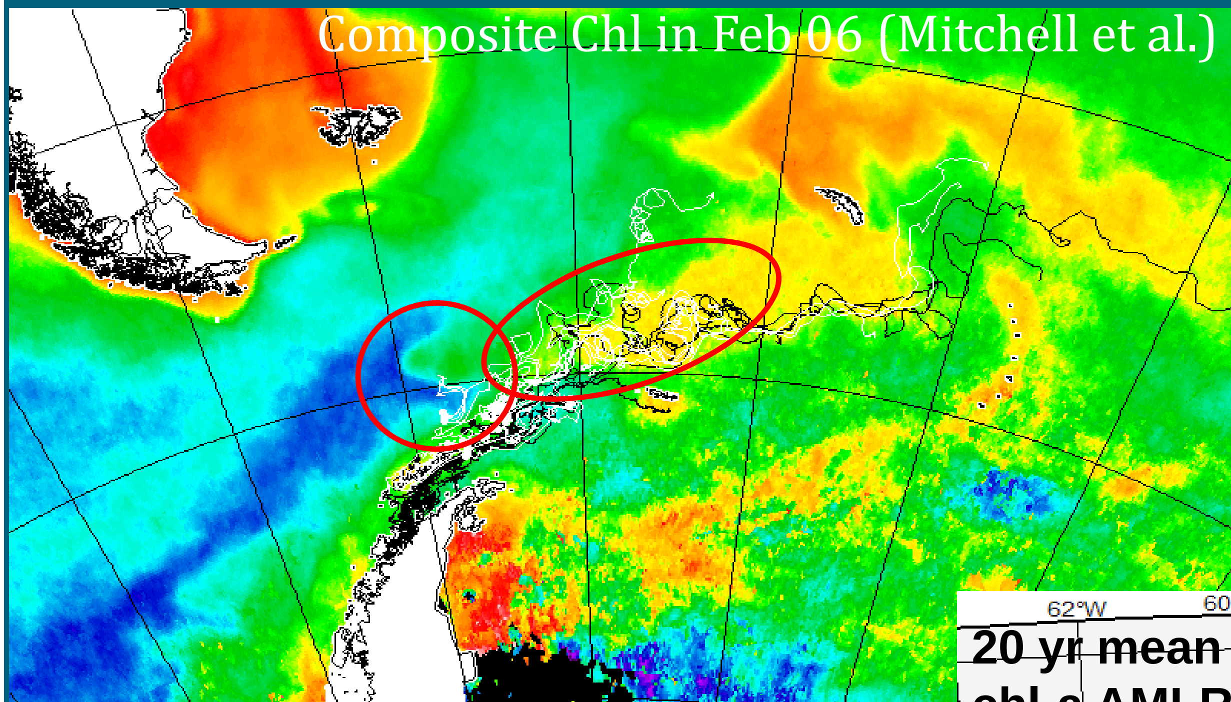
BWZ Team

Brief History of iron work in Southern Ocean and during US BWZ and AMLR

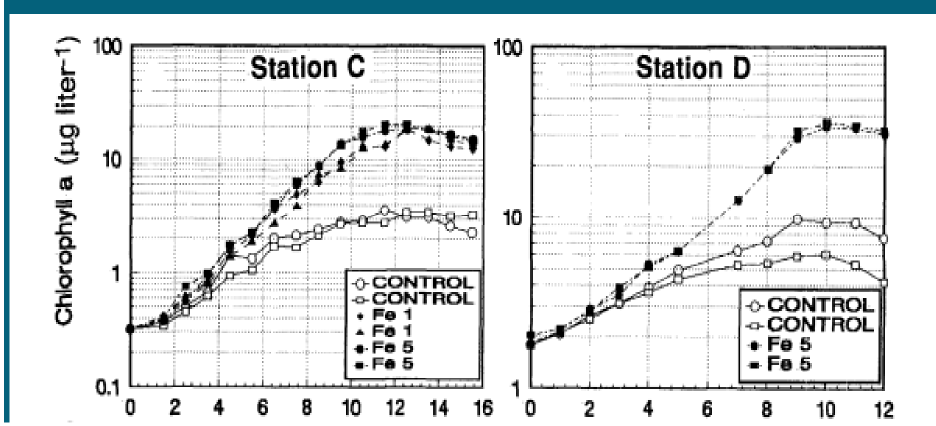


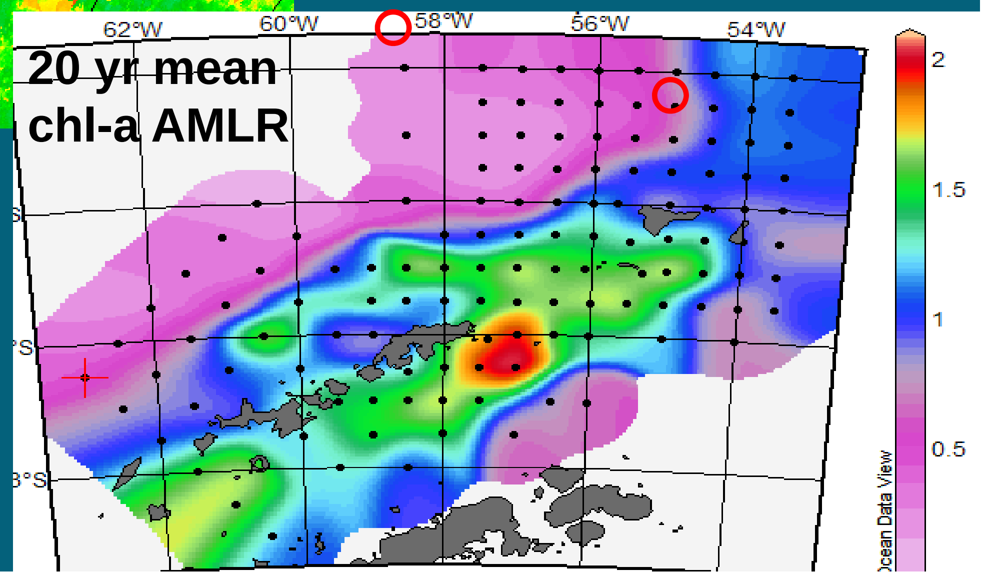
Motivations

- Transformation between the low and high productive waters
- Longevity of a phytoplankton bloom and C-export



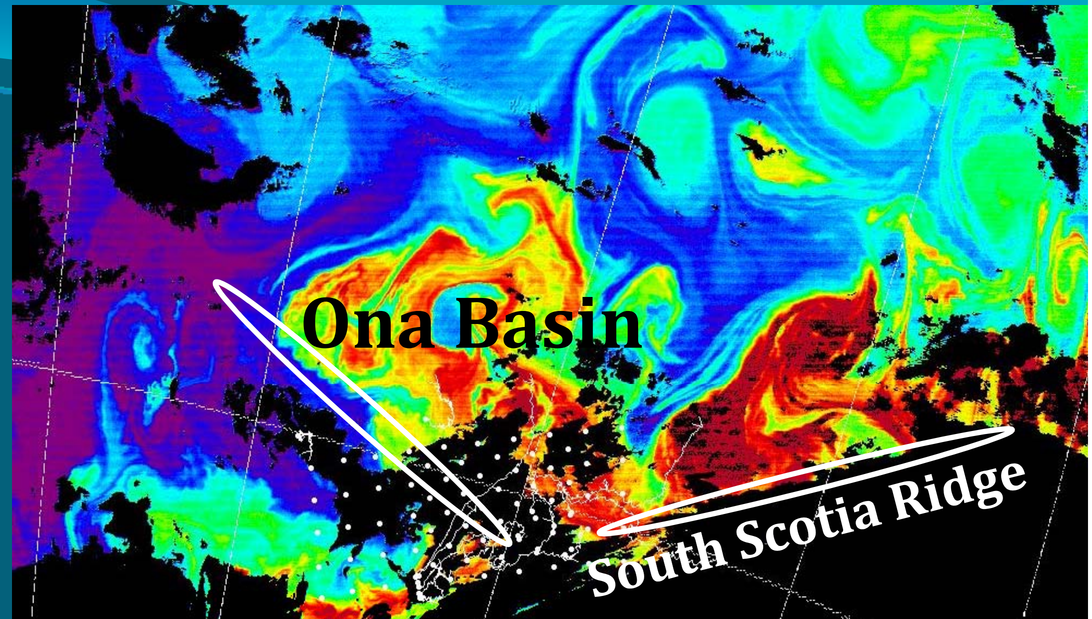
Early AMLR work demonstrated the Fe limitation in the ACC surface water (Helbling et al. 1991)





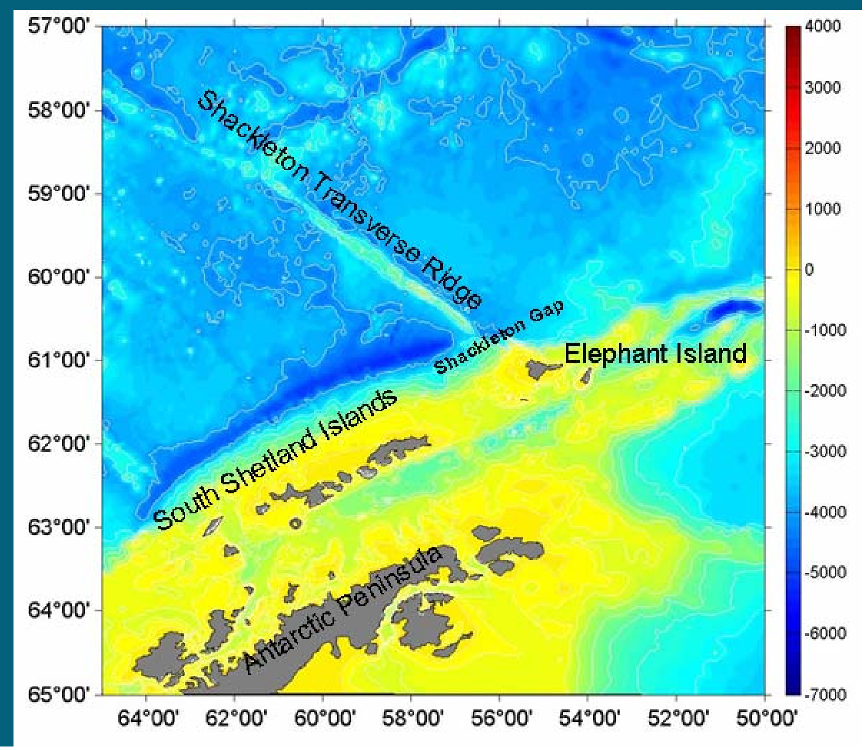
Research topics

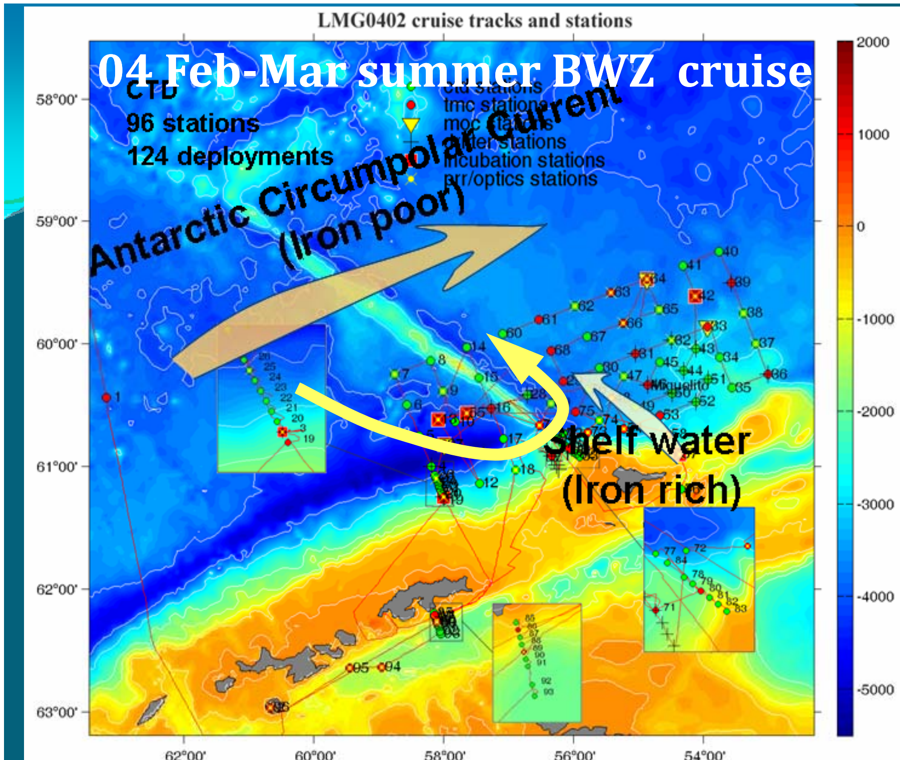
A Kaleidoscope of iron fertilization in the SO driven by large scale circulation and eddy processes from days, months to years

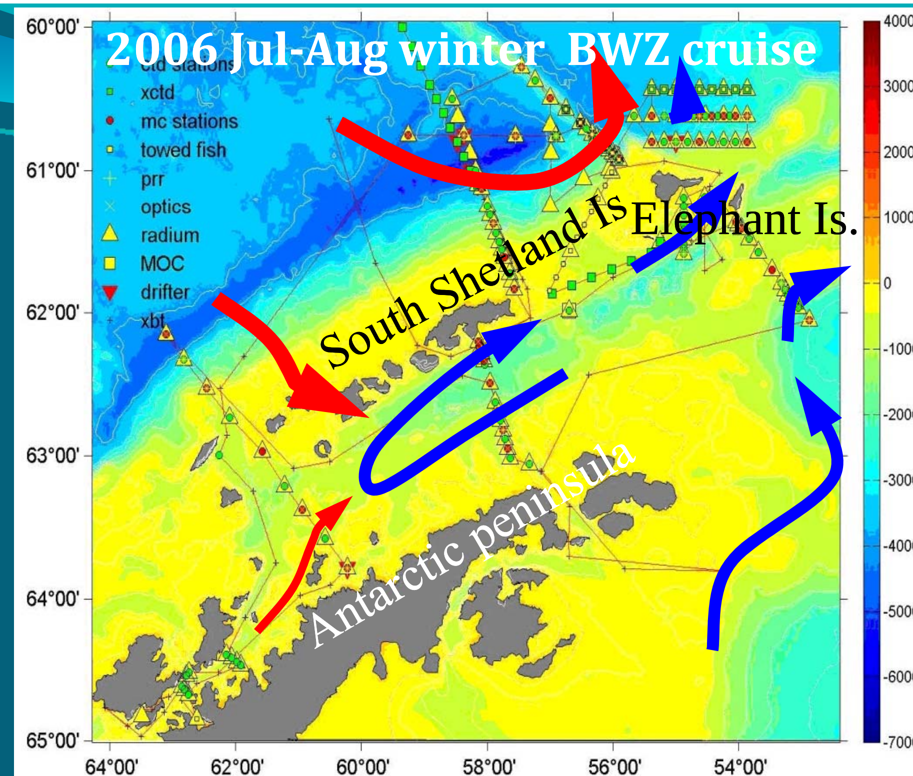


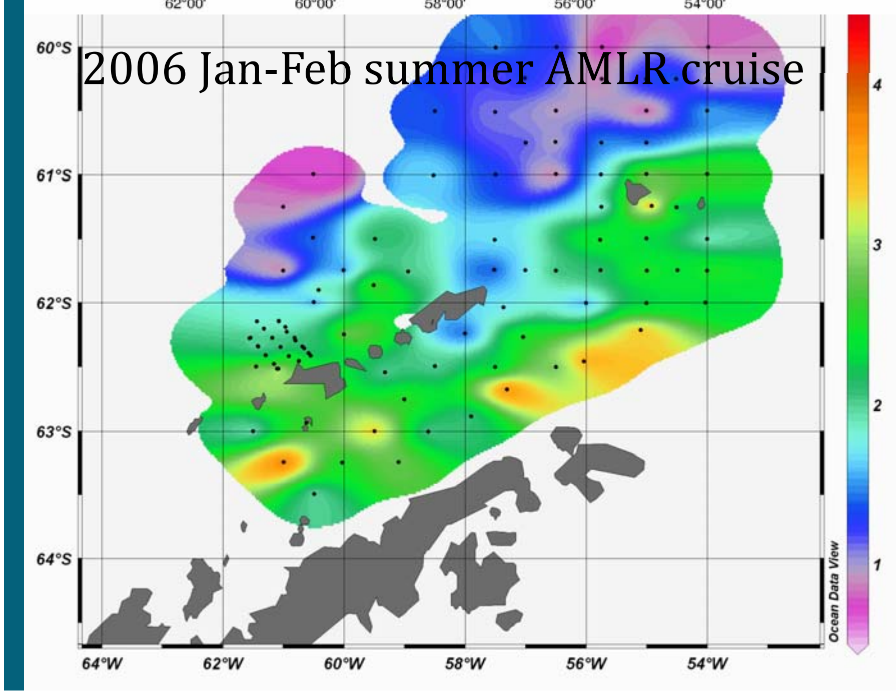
A Kaleidoscope of Iron Limitation in the SO

- Physical processes delivering iron
- Fe sources and transport
- Responses of primary production and export to Fe addition
- Fe and C recycling
- Ecosystem evolution







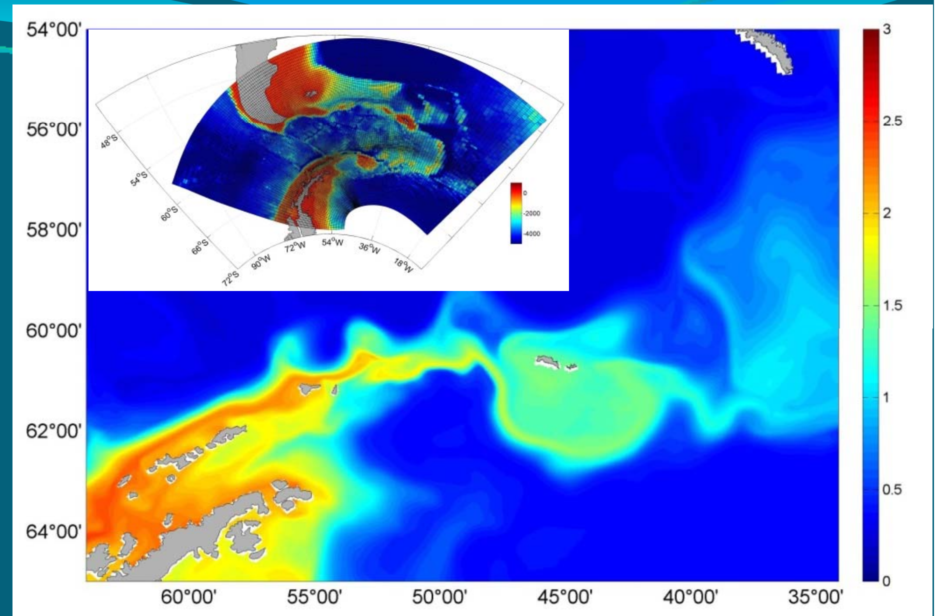


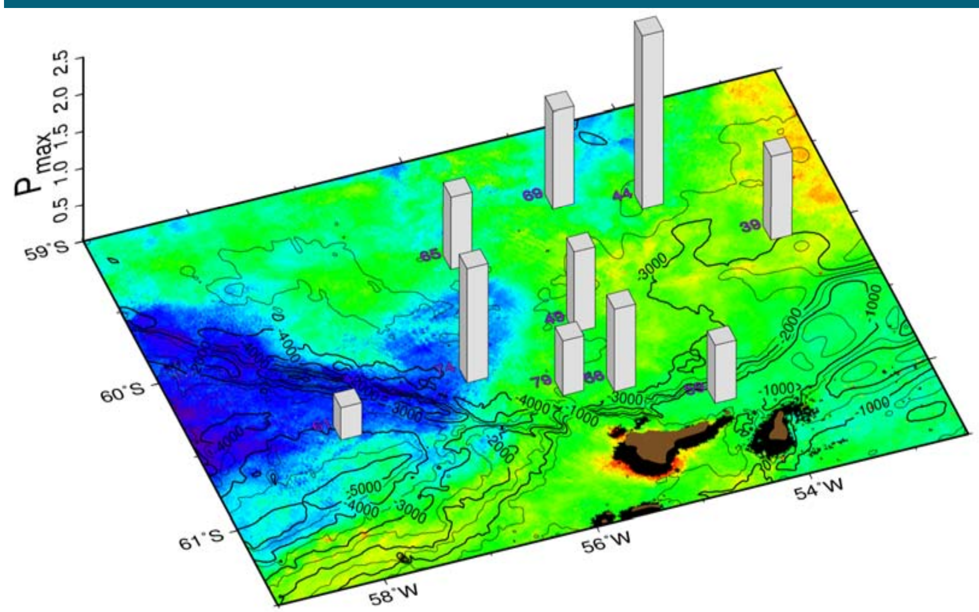
BWZ (AMLR) major activities

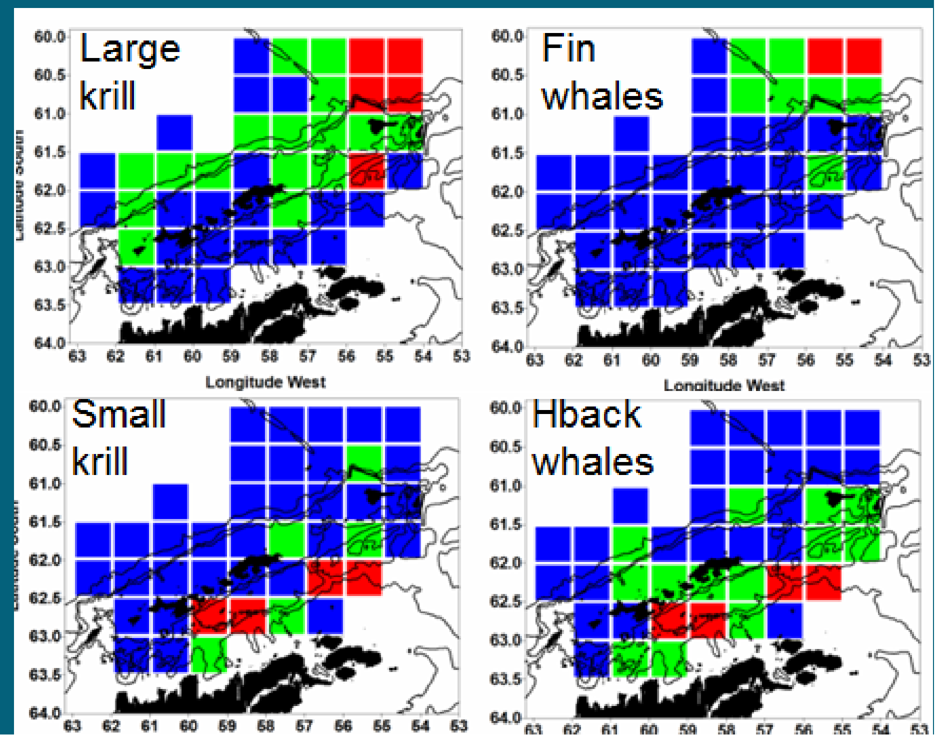
- 2004 Feb-Mar cruise
  Identify physical & iron processes
- 2006 Feb-Mar cruise
  Identify diffusion & export processes
- 2006 Jul-Aug cruise
  Identify winter physical processes
  & iron source

BWZ (AMLR) major activities

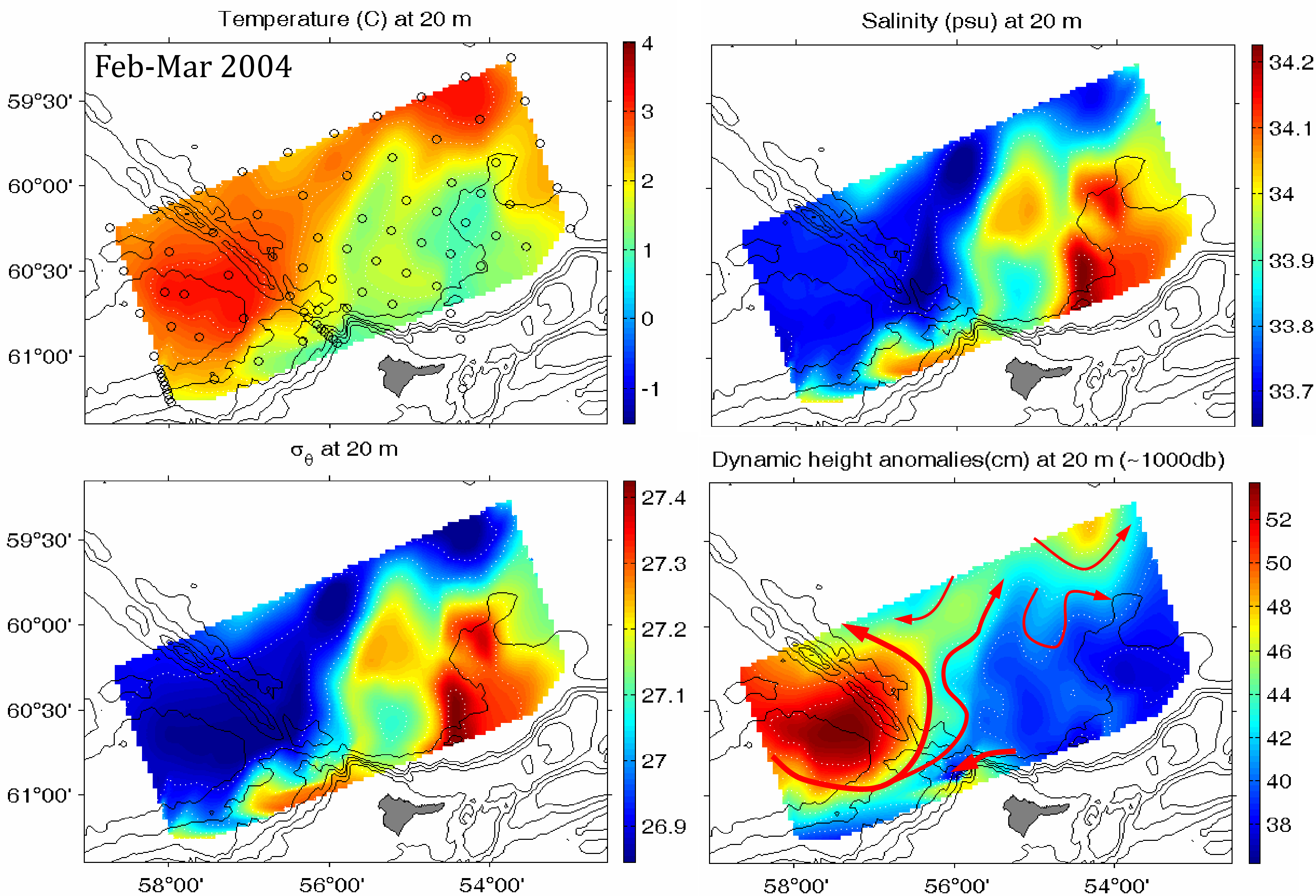
- Synthesis between disciplines
  - o Coupled processes
  - o 15 years of AMLR data
  - o Ecosystem responses to Fe
- Model development:
  - o Short-long term PO processes
  - o Finding iron sources
  - o Transport-dispersion processes
  - o Fe-ligand-microbial loop
  - o Chl, PP and C-export models

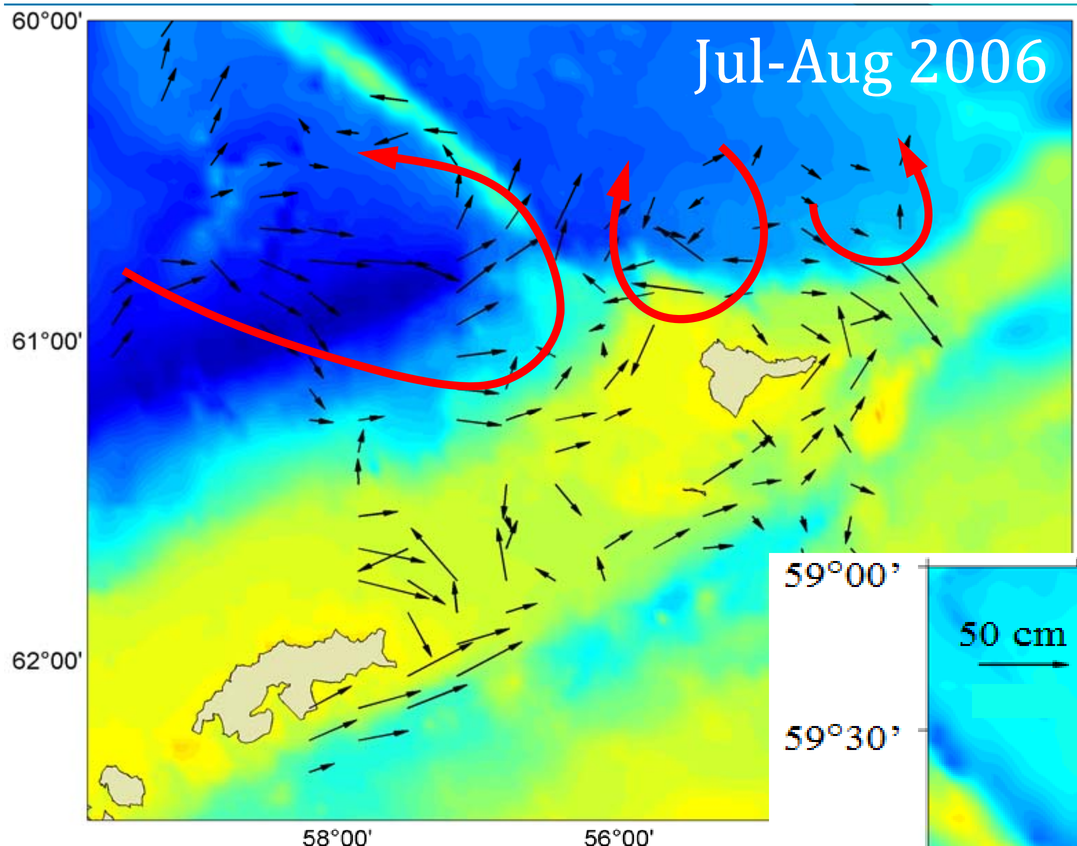






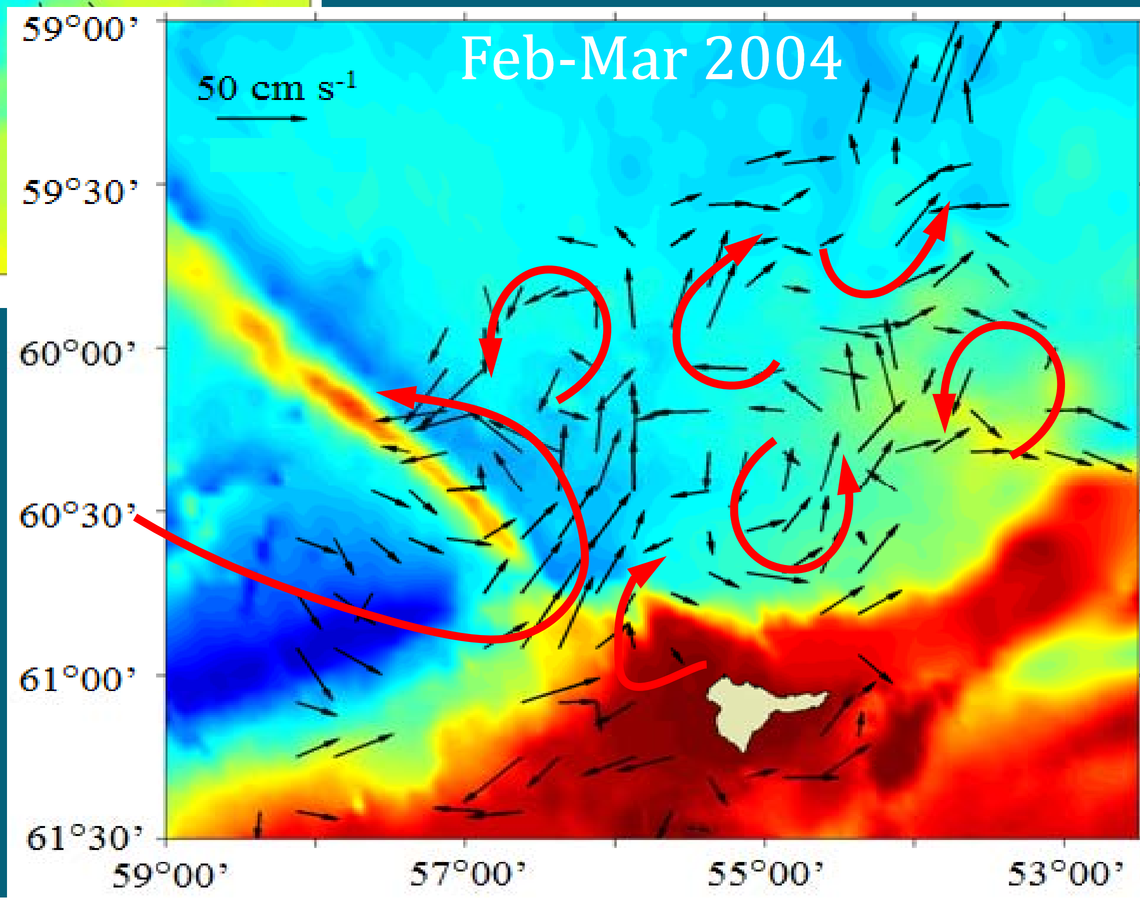
PO processes: Large scale ACC detouring and offshelf transport





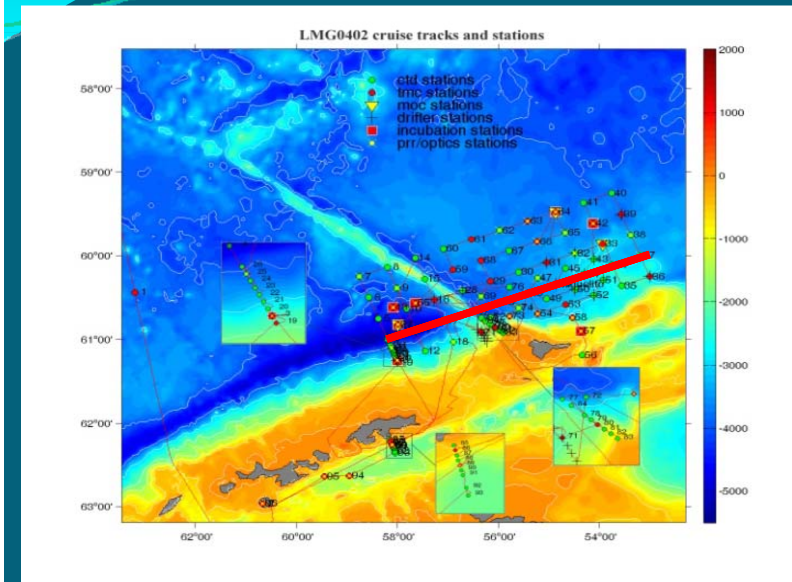
Seasonal variability

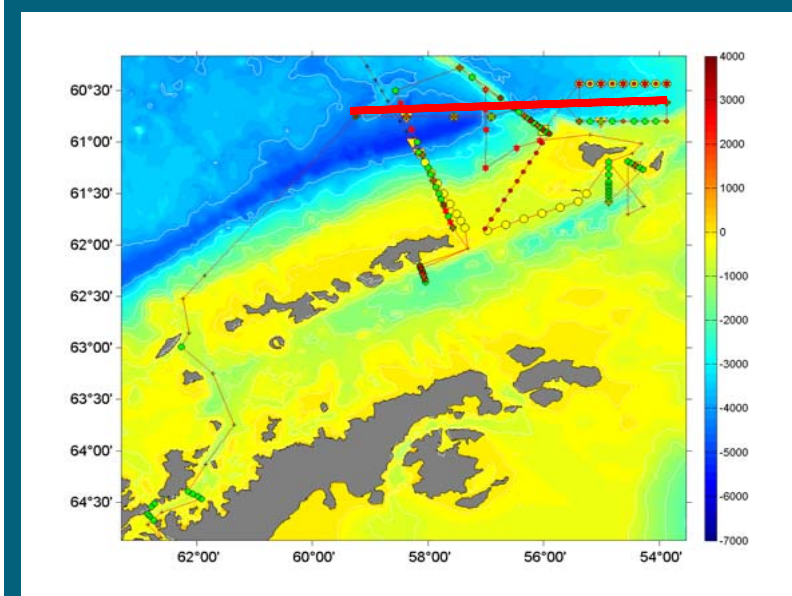
- Large-scale
- Mesoscale

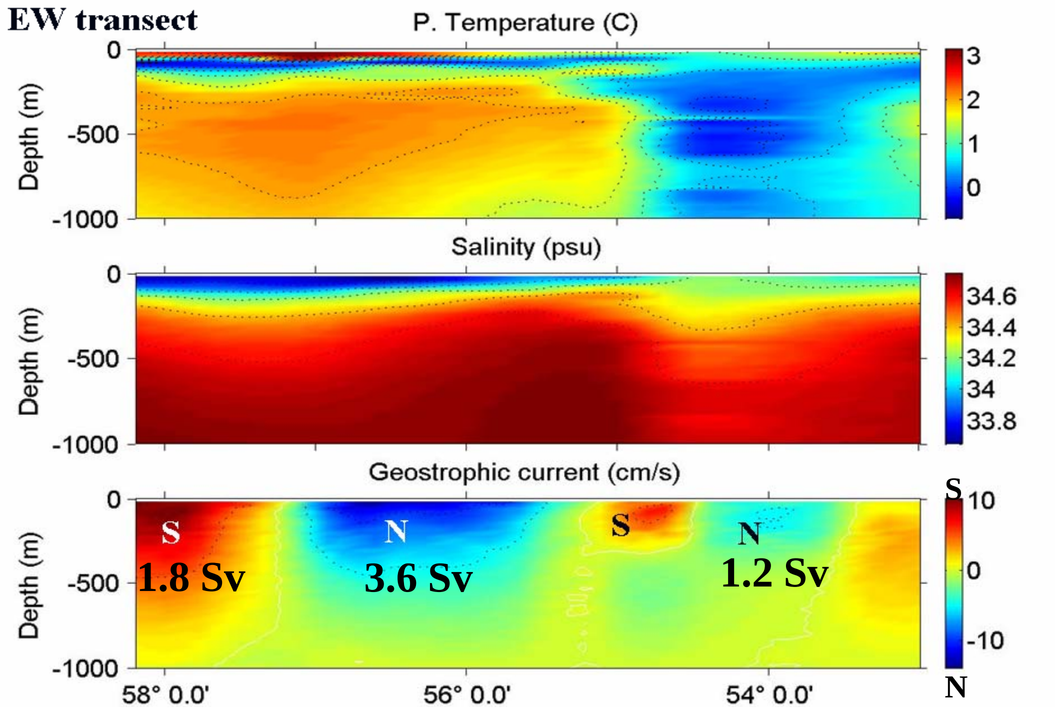


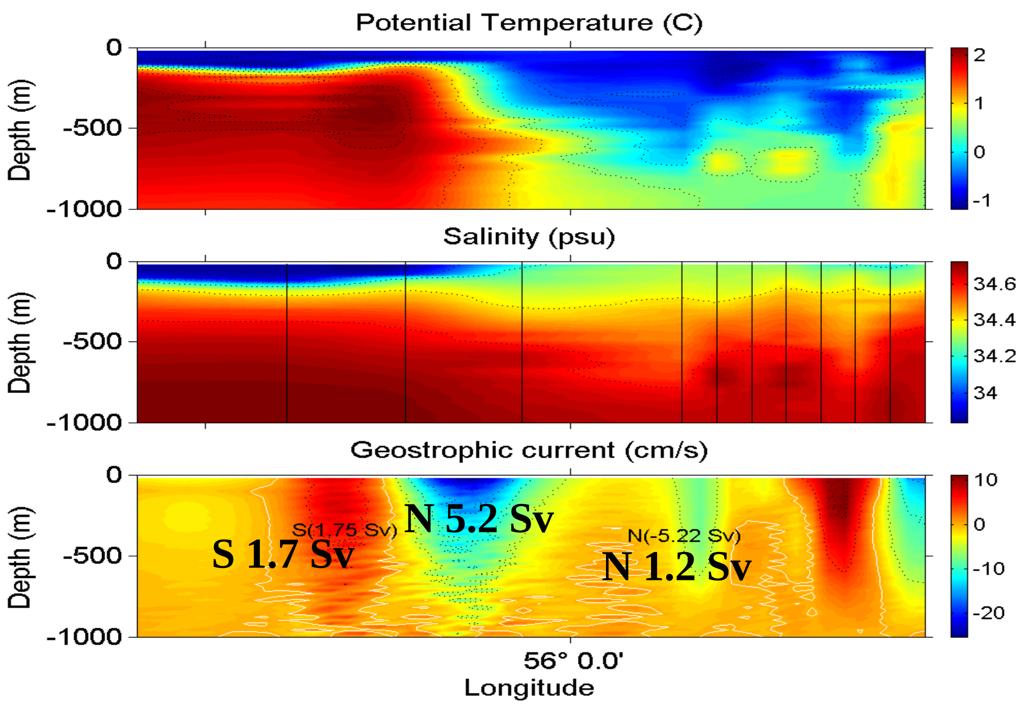
- Permanent features
- Mesoscale jets and eddies

Yearly around offshelf transport

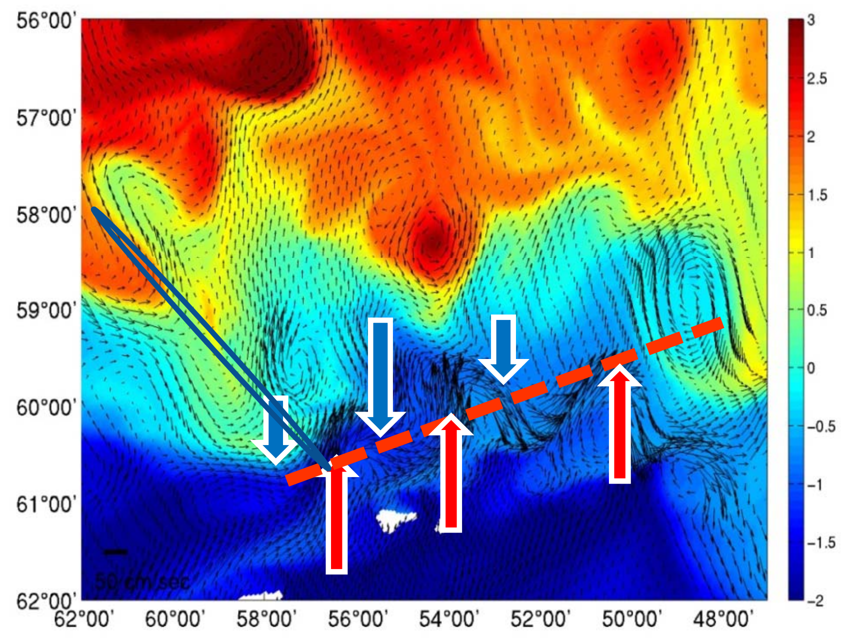




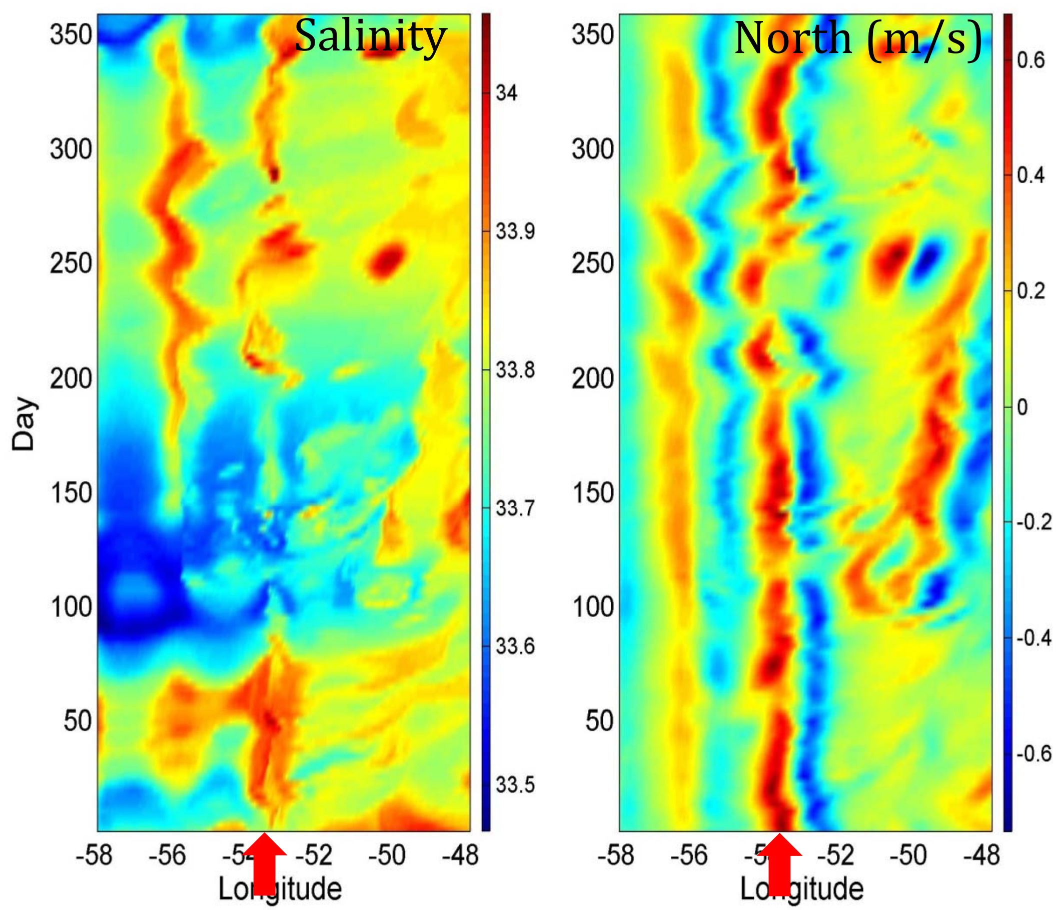




PO processes: Seasonal Cycle of the Off-shelf Transport



- The jet in the Shackleton Gap is relatively stable driven by the ACC
- Locations of the offshelf transport are also relatively fixed



Large-scale

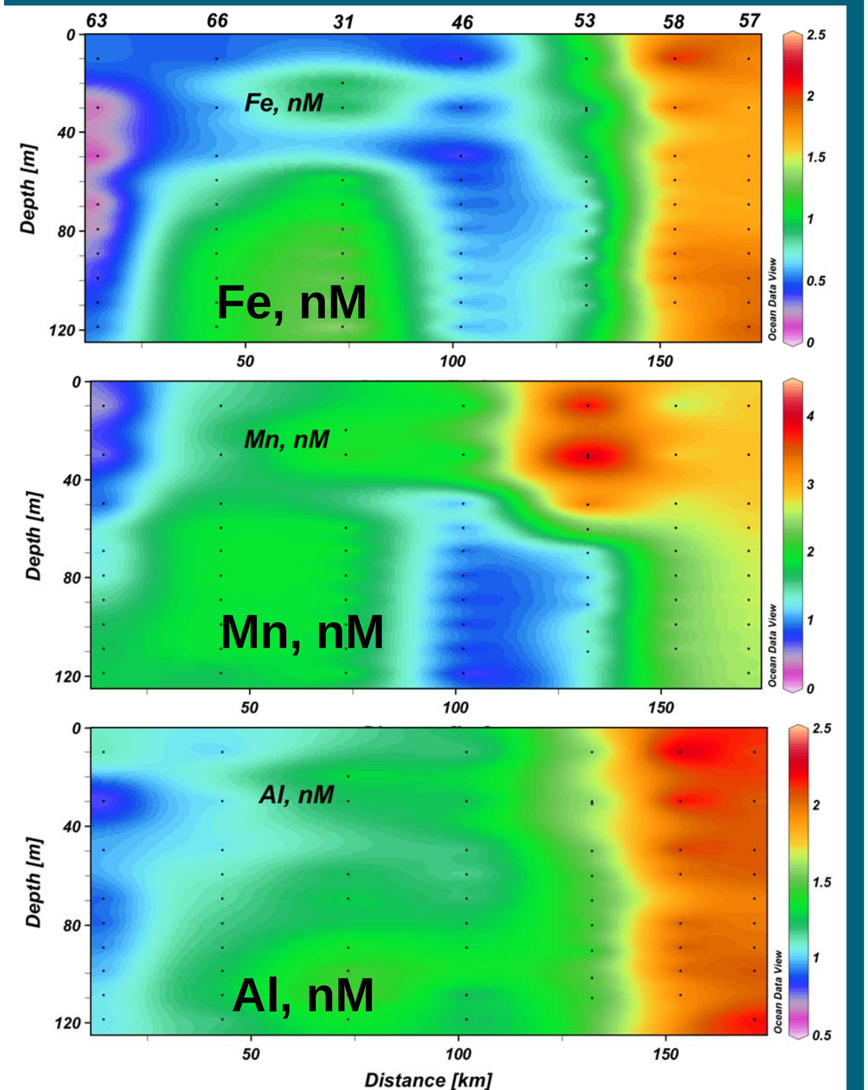
Shelf water flux in upper 100 m

$=1.8\times10^5\ m^3\ s^{-1}$ (0.18Sv)

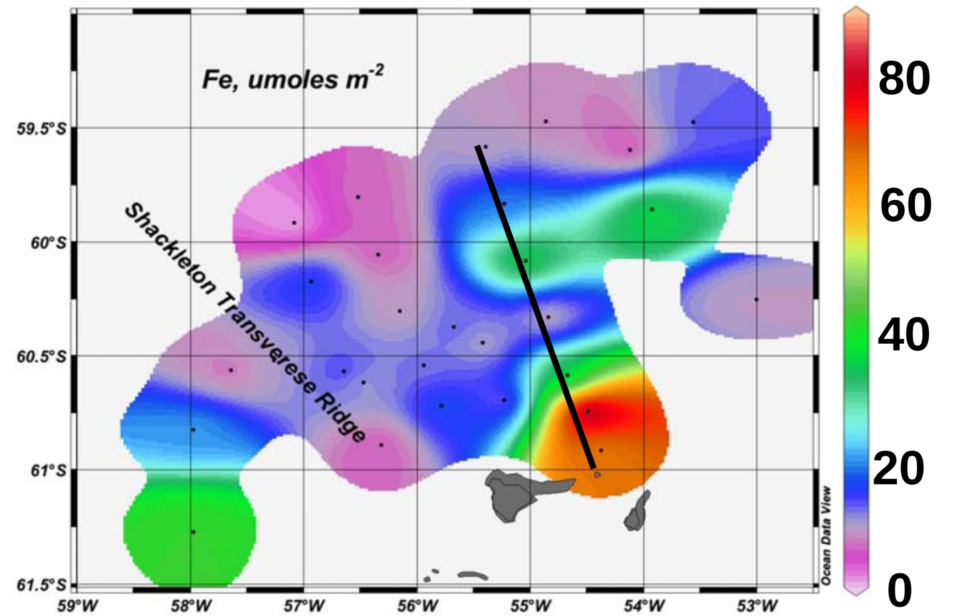
=180 Hudson Rivers

(Hudson=$10^3\ m^3\ s^{-1}$)

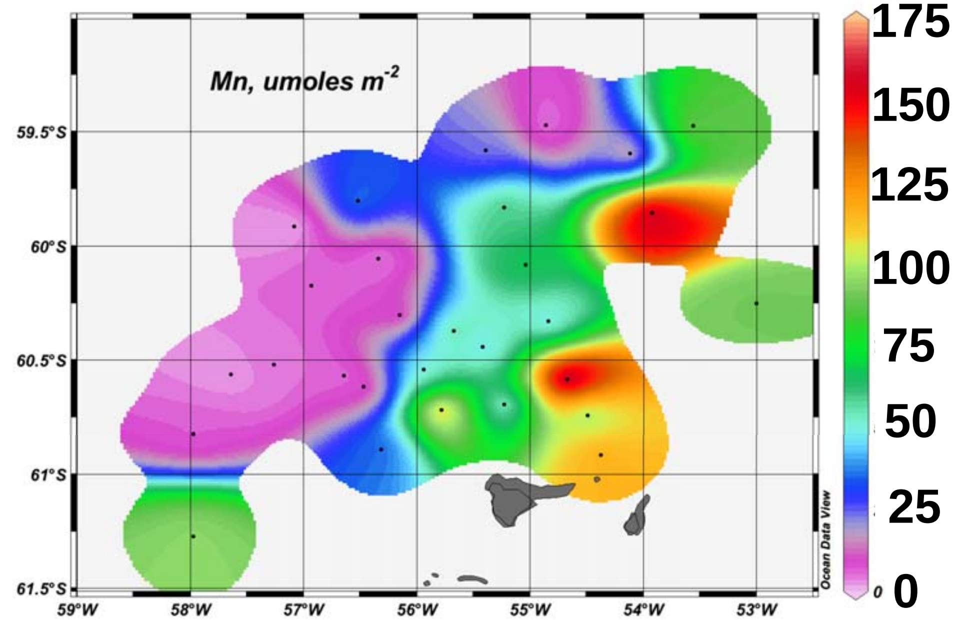
Fe source: Rich iron in the shelf waters (Feb-Mar 2004)



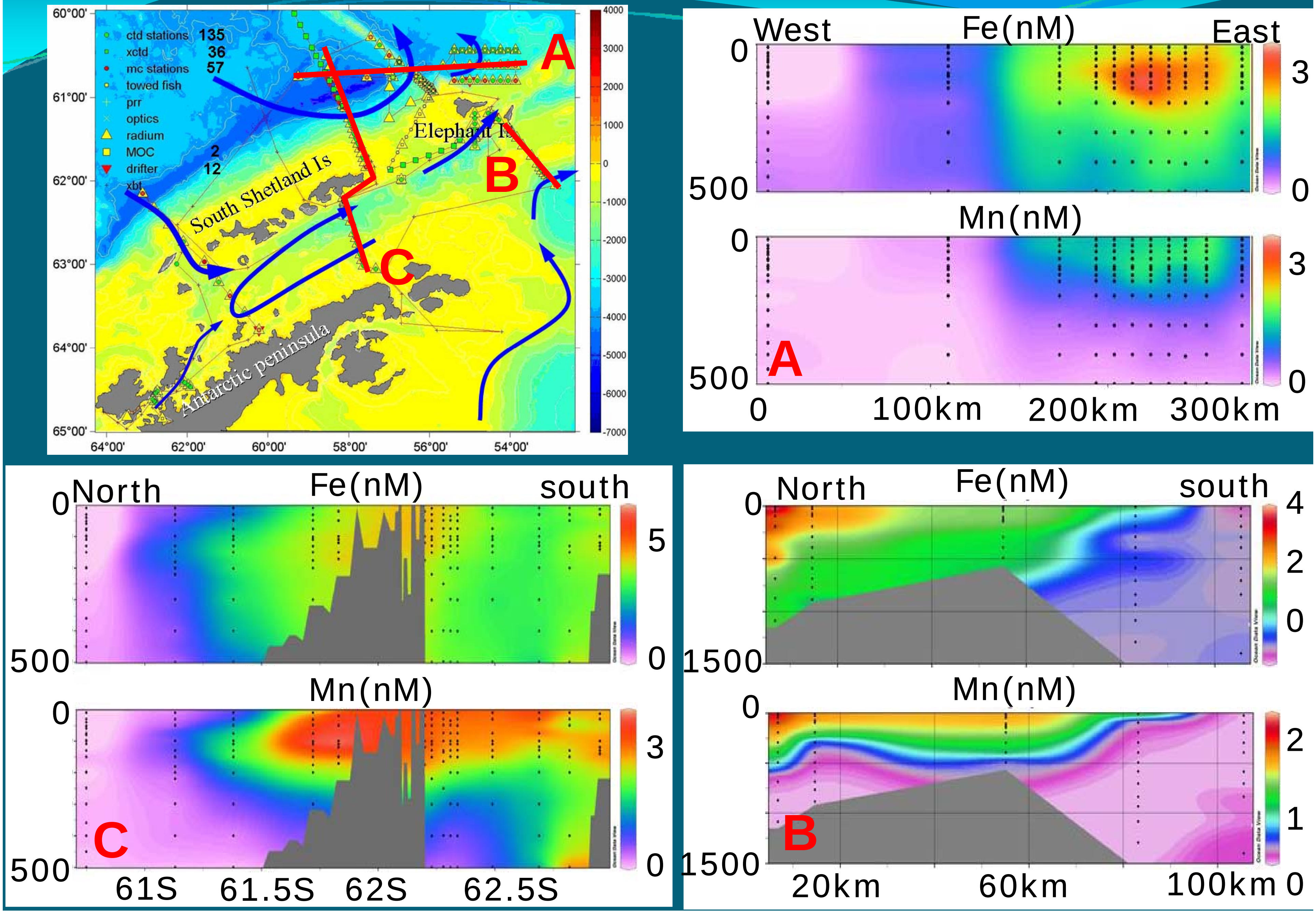
Fe in upper 50 m (μmols m^{-2})



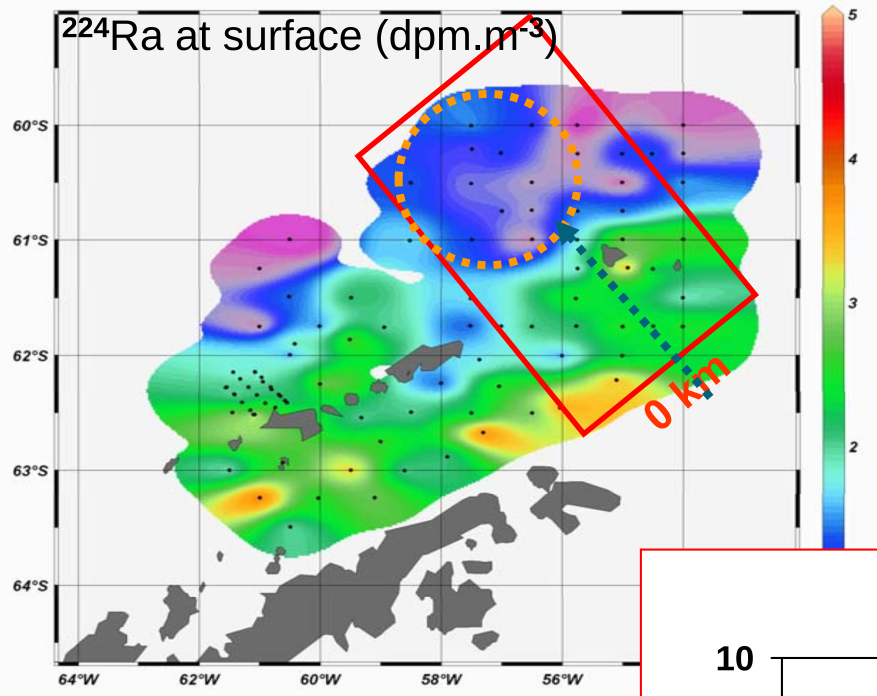
Mn in upper 50 m (μmols m^{-2})

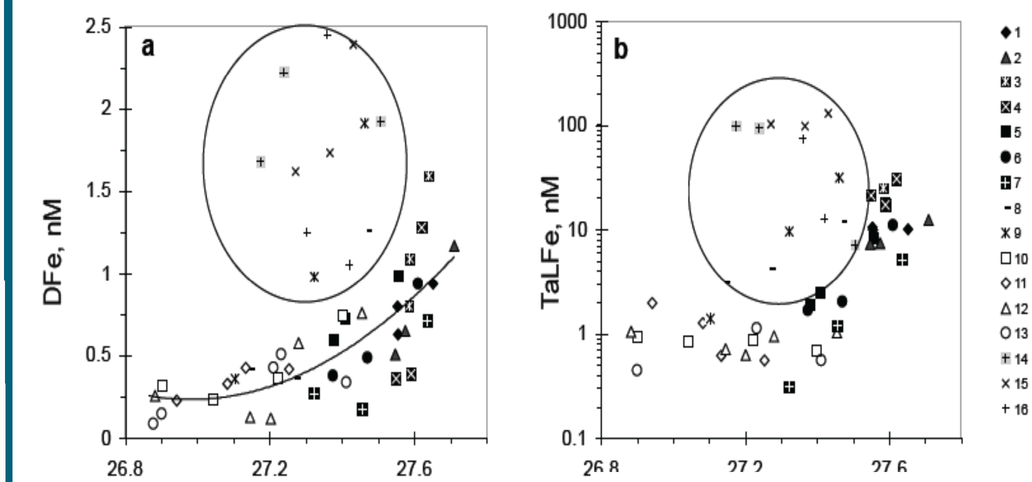


Fe source: Rich iron in the shelf waters (Jul-Aug 2006)



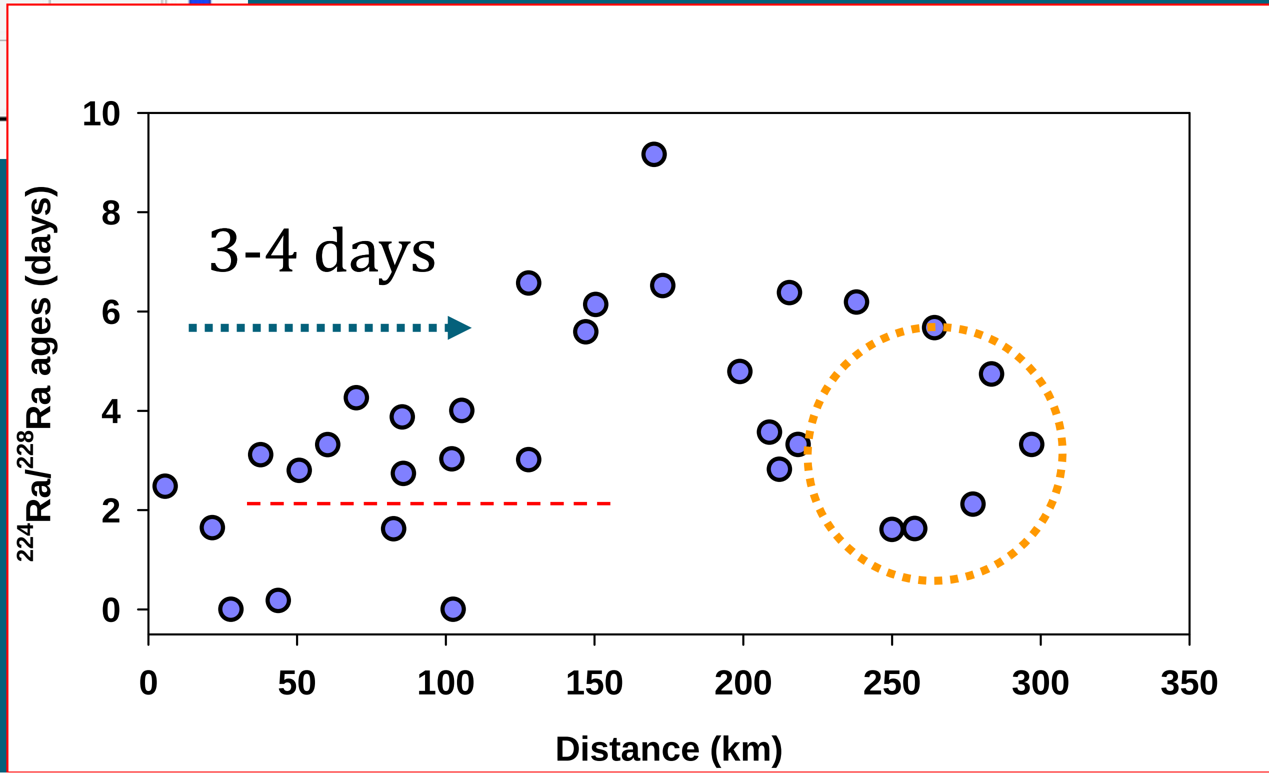
Iron sources: Water ages and offshelf transport from Ra





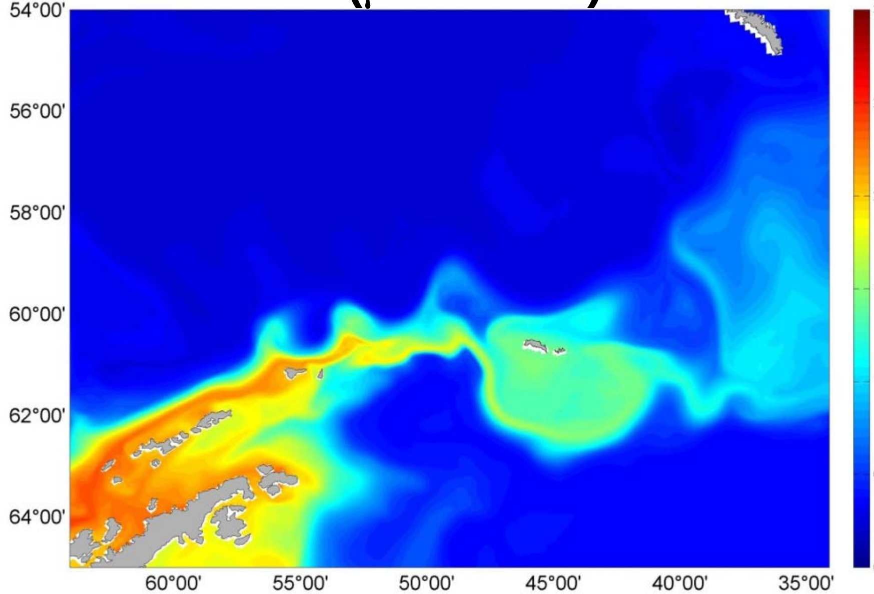
Van Ardelan et al. 2010

Fast advection limits Fe biological uptake and allows quick Fe export to greater distances

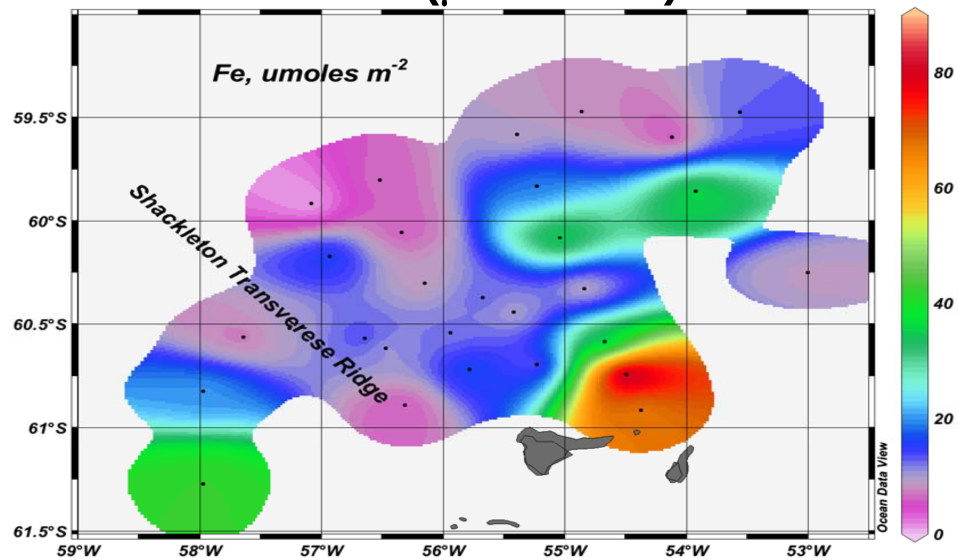


Responses to Fe: Relationship between Fe & phytoplankton

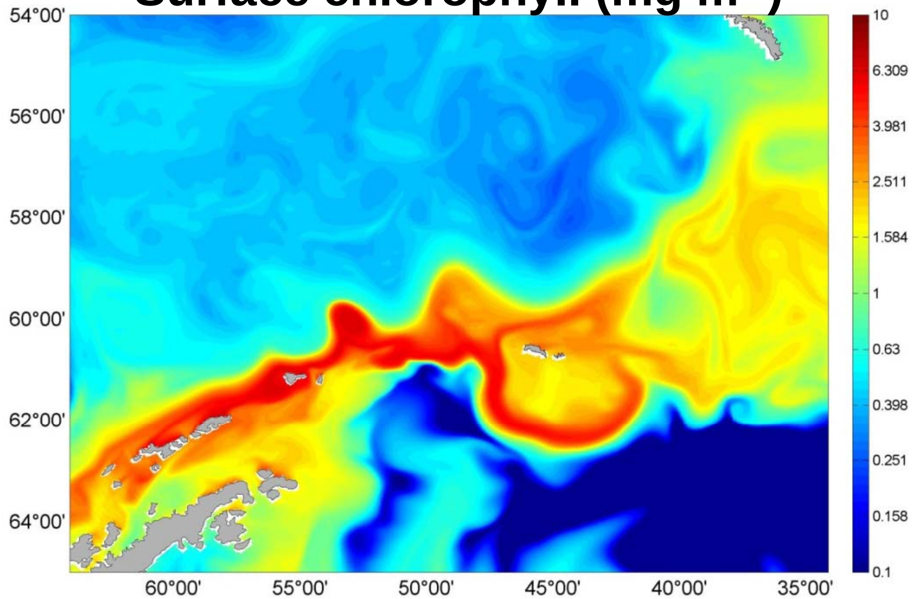
Fe (μmols m^{-3})



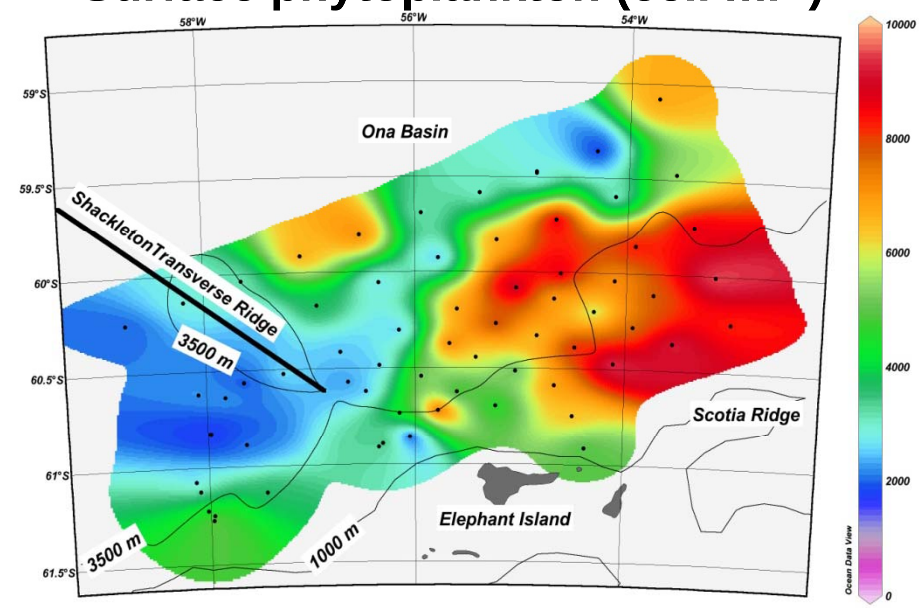
Fe (μmols m^{-2})



Surface chlorophyll (mg m^{-3})

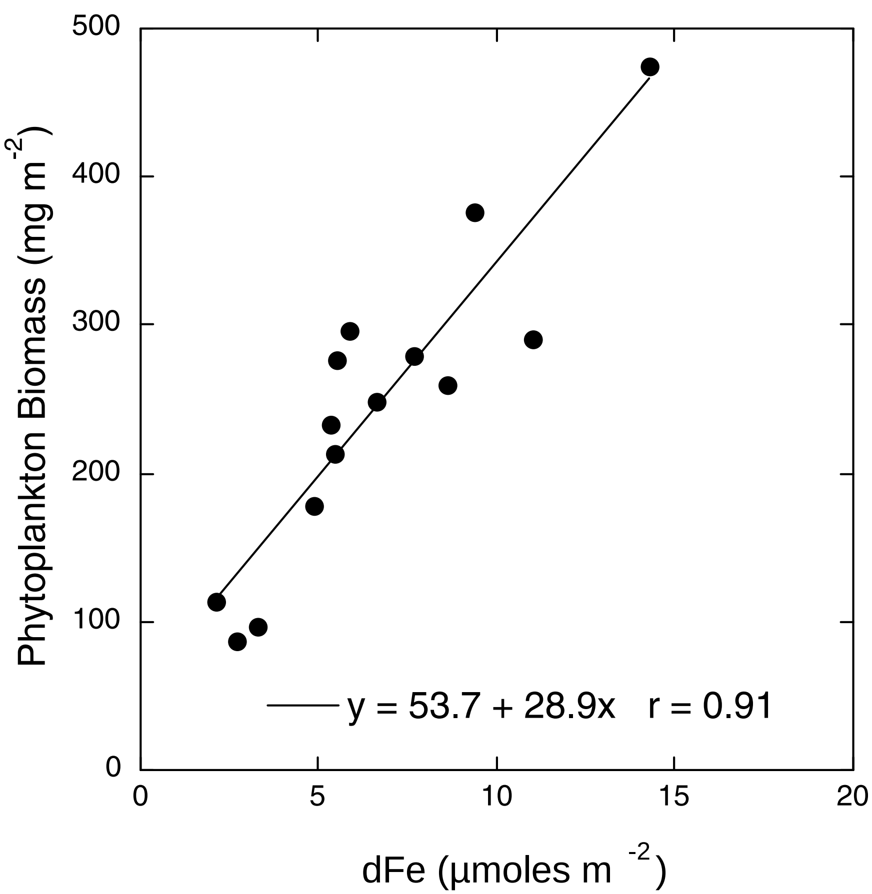


Surface phytoplankton (cell ml^{-1})

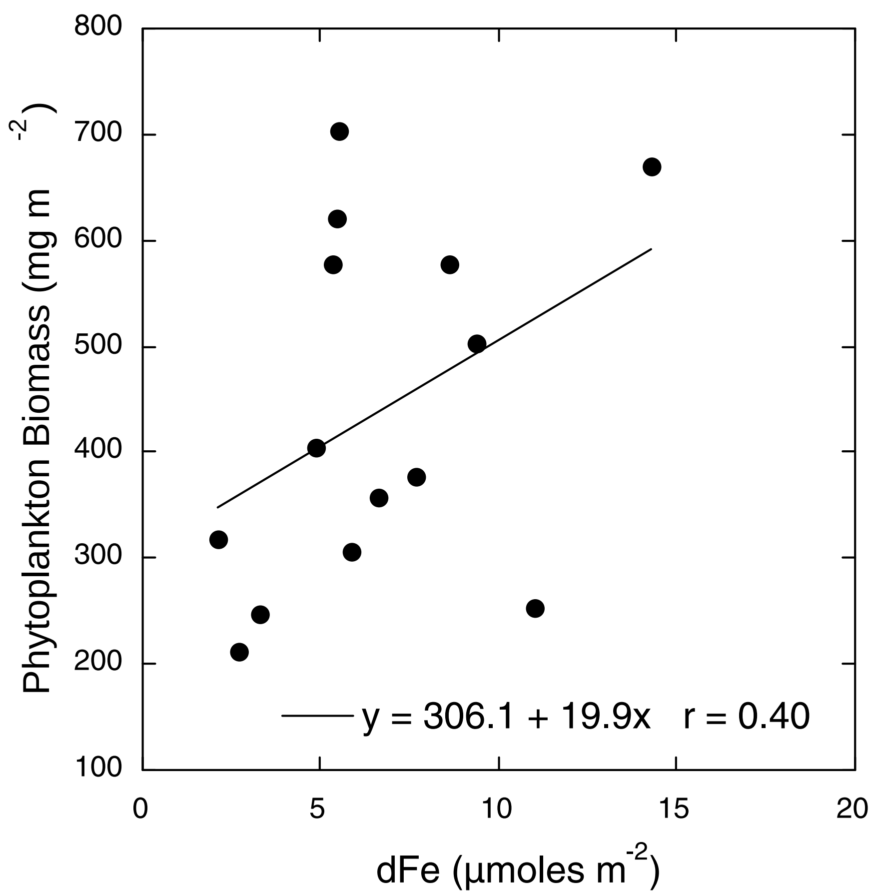


Responses to Fe: Relationship between Fe & phytoplankton

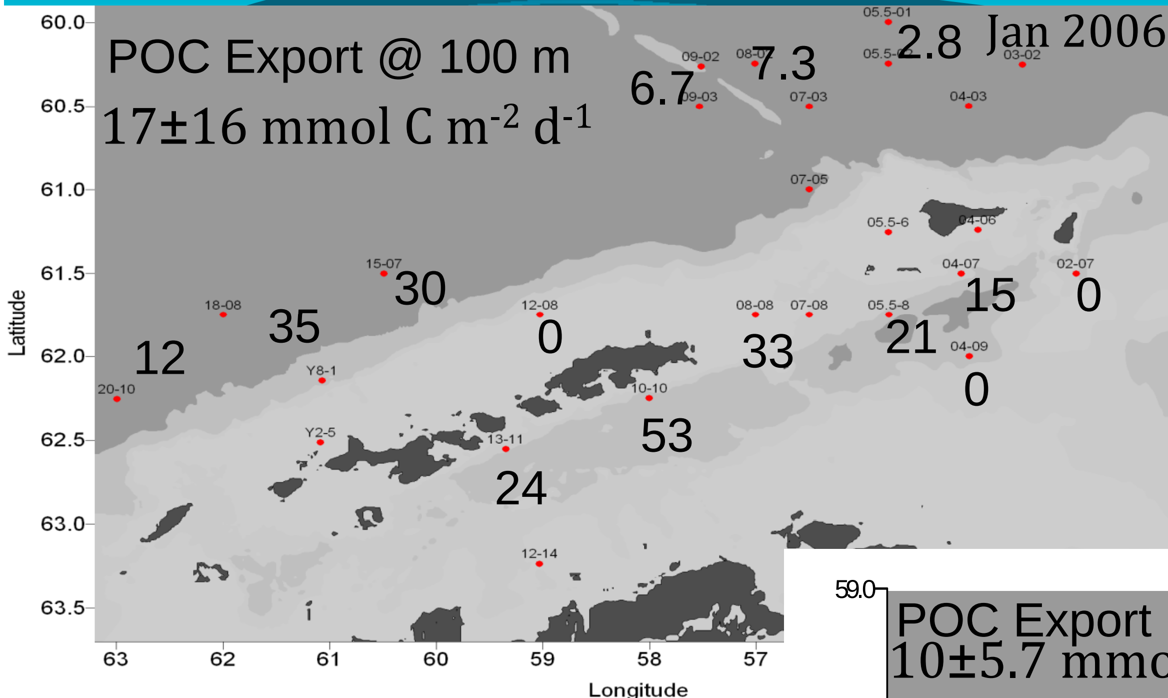
Nanoplankton (<20 µm cells)

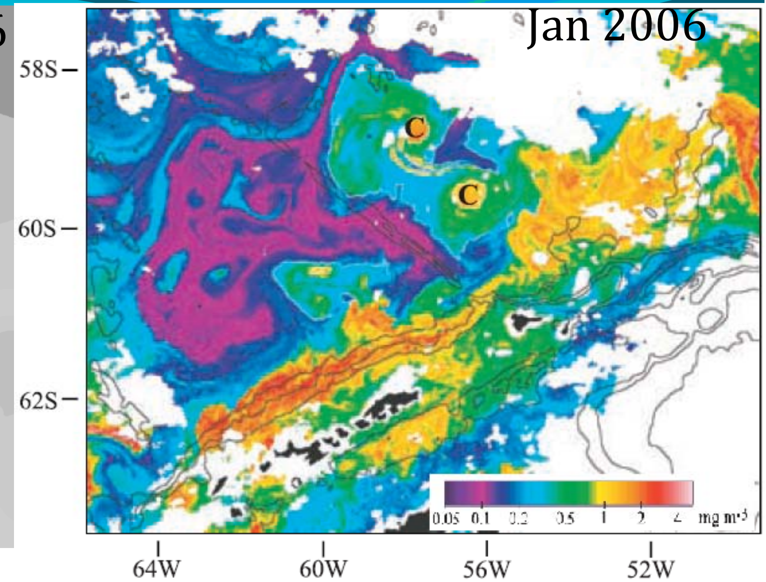


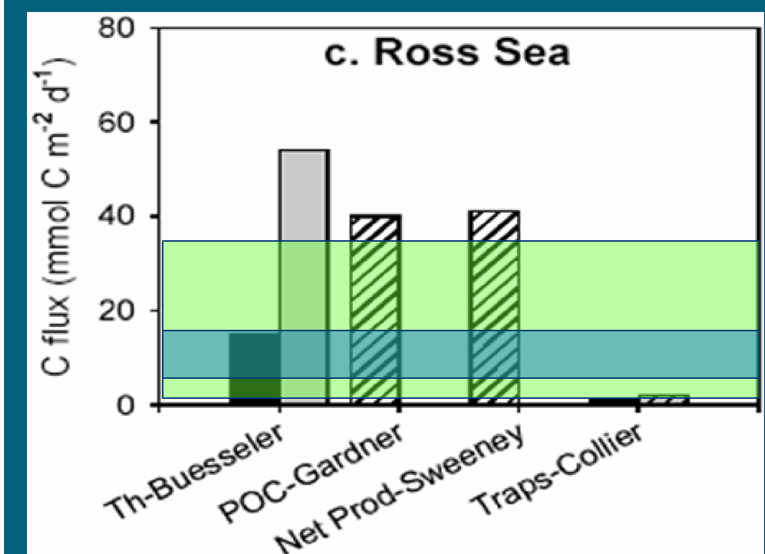
Microplankton (>20 µm cells)



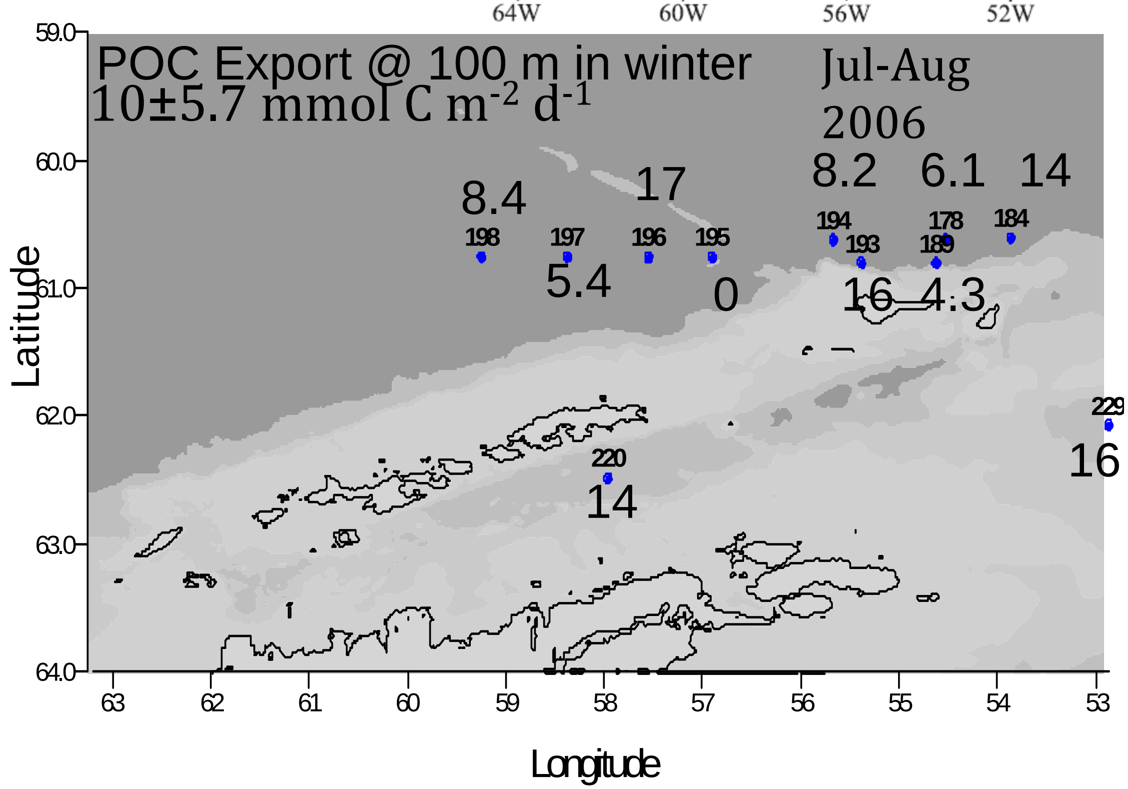
Responses to Fe: C–Export in S. Drake Passage



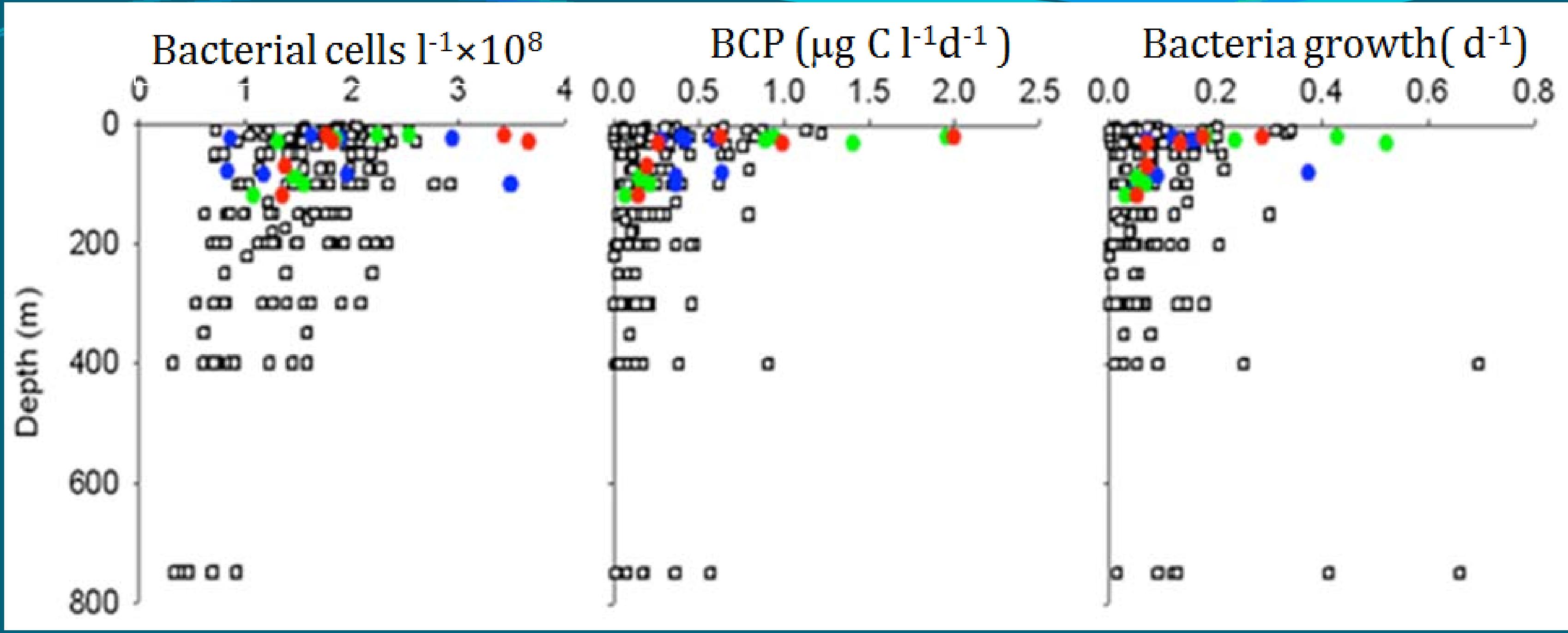




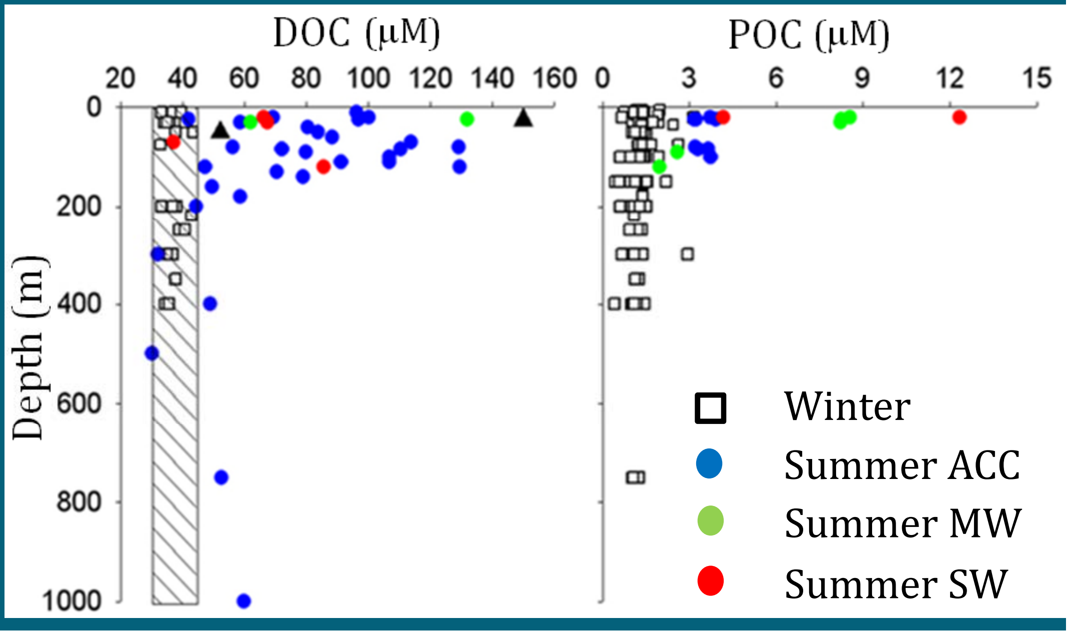
Comparing to Buesseler et al. 2006



Responses to Fe: Chl, DOC and Bacteria production



- Low cell # in both systems
- Summer µ is surface intensified
- Between Summer and winter
  - 50 fold reduction in PP
  - 2 fold reduction in BCP
  - BCP in winter supported by DOC
- POC represented only between 7% and 2% of the total pool



Question 1. What is the scale of the Fe plume?

In the upper 100 m:

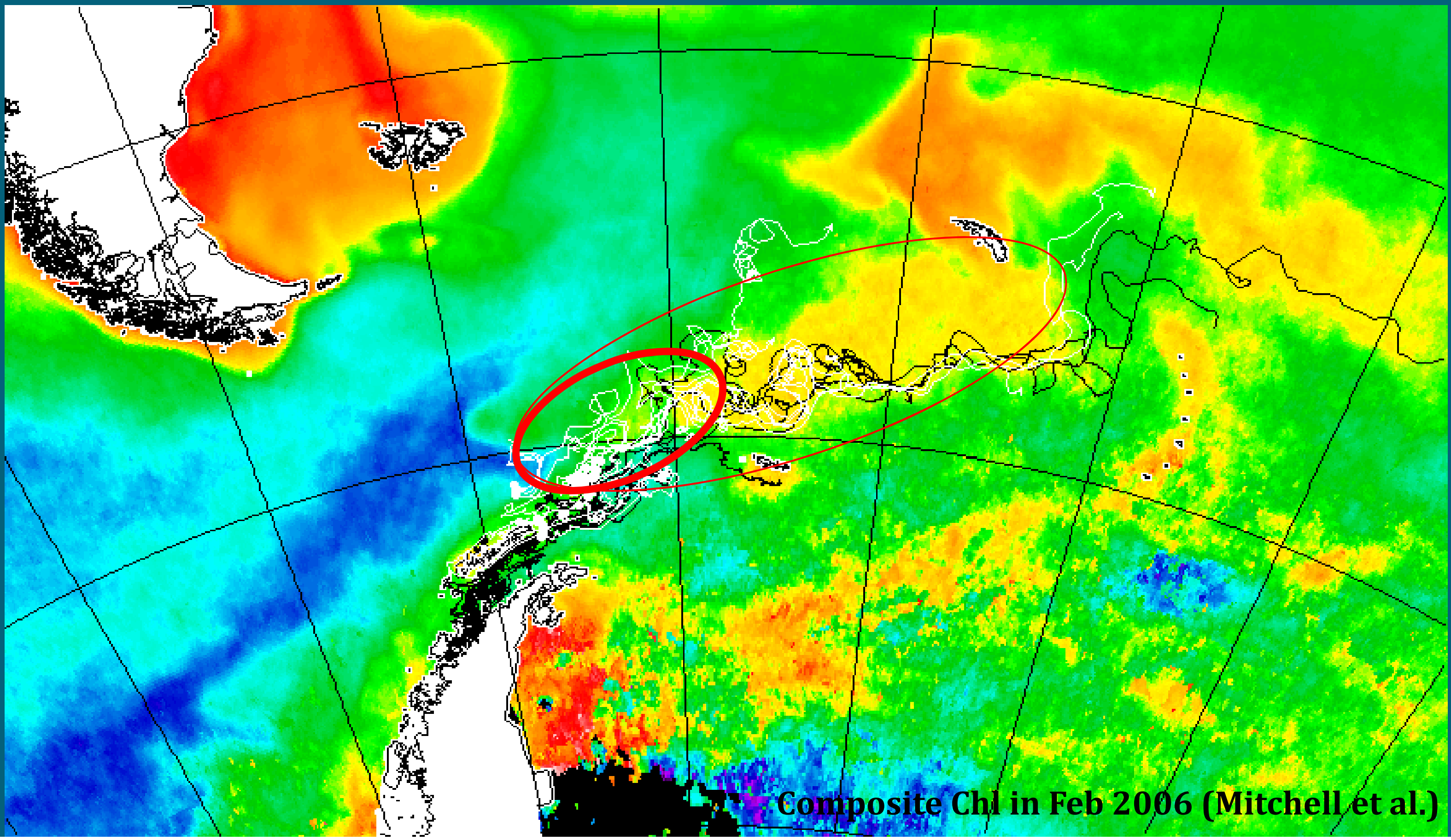
Fe offshelf flux:	1.4×10^4 mol Fe d^{-1}
POC export:	10 mmol C m^{-2} d^{-1}
Fe : C	1:1-5$\times10^5$ mol:mol

Fe offshelf flux

= Area × POC export

Area: 68-680 $\times10^3$ km^2

Diameter : 400-900 km



Question 2. Is the stability of a community limit the C-export?

Summer (100m)

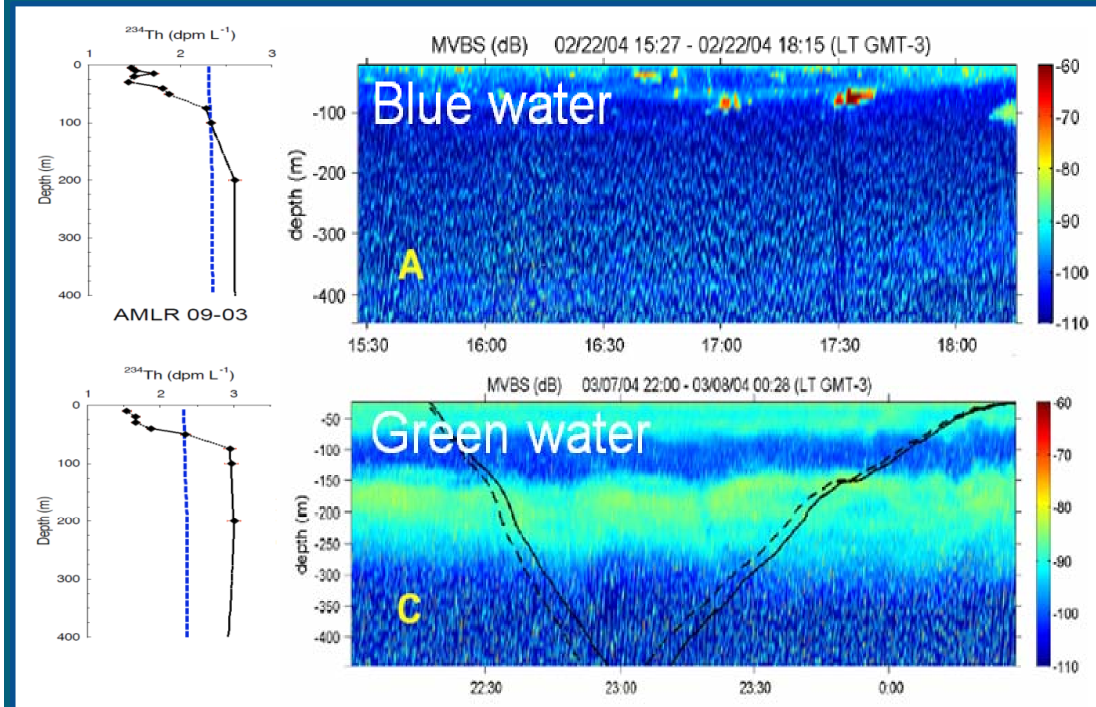
PP: 46 mmol C m^{-2} d^{-1}

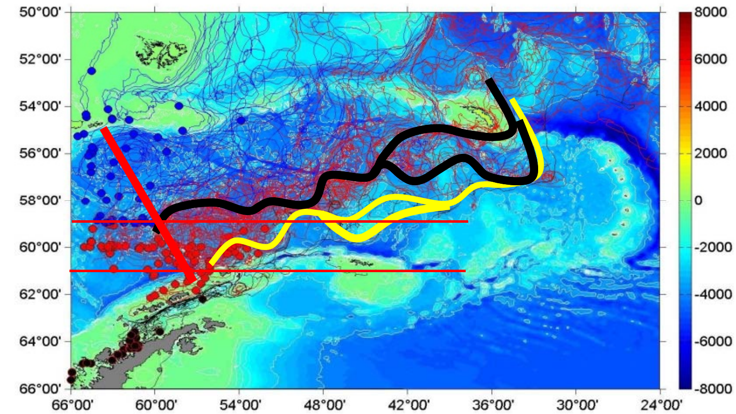
C-export: 17 mmol C m^{-2} d^{-1}

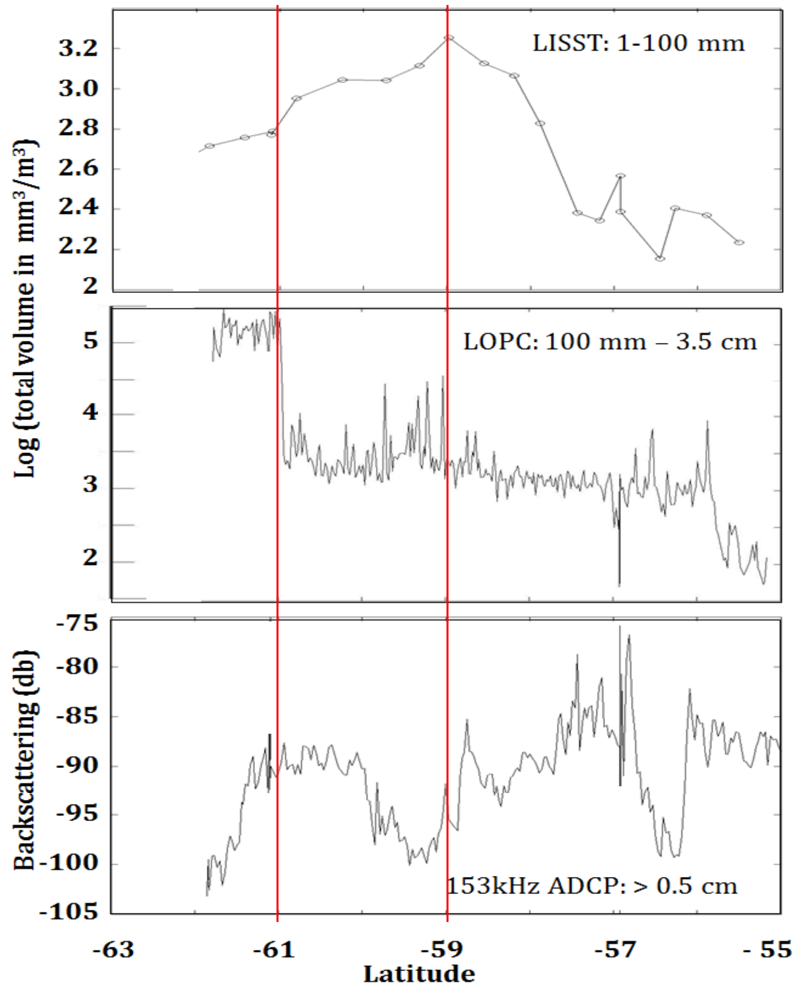
Zp (>100µm): 250 mmol C m^{-2}

Grazing (5-10% zp): 13-25 mmol Cm^{-2} d^{-1}

Significant grazing below 100 m







Question 3. Zp processes in winter

In winter (500 m)

Excess DOC: 4.7 mol C m^{-2}

Zp (1μm-3 cm): 5.2 mol C m^{-2}

Zp resp (10%): 520 mmol C m^{-2}

C-export (100m): 17 mmol C m^{-2} d^{-1}

Consumption (500 m)

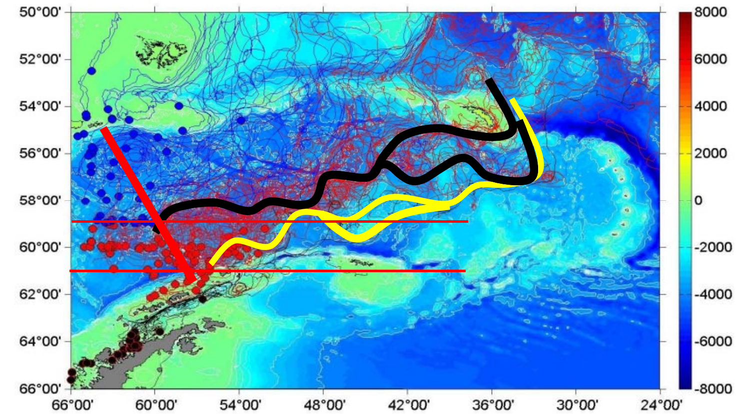
Excess DOC: 4.7 mol C m^{-2}

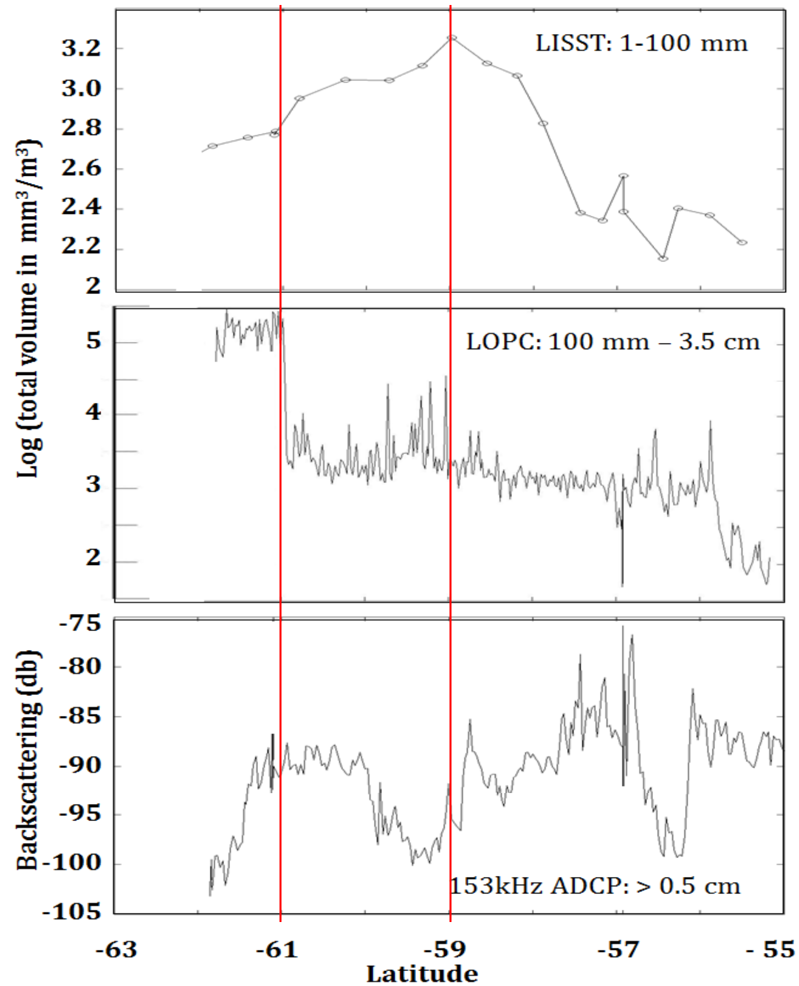
Zp (1μm-3 cm): 5.2 mol C m^{-2}

Zp resp (10%): 520 mmol C m^{-2}

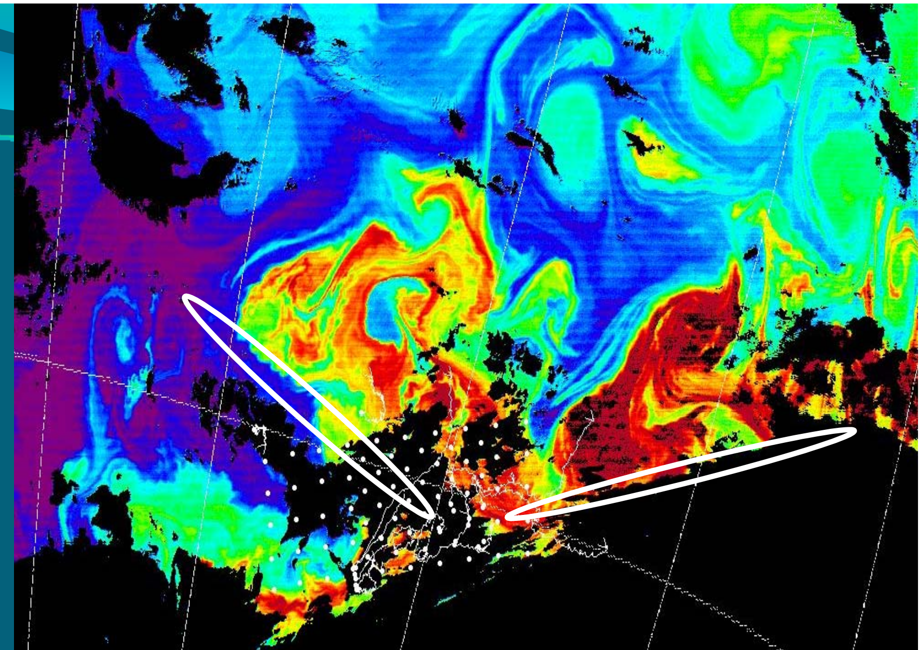
C-export (100m): 17 mmol C m^{-2} d^{-1}

More than 90% of zp will die over winter





Question 4. Advection decoupling Fe, PP and C-export



High productivity occurs at the boundaries between the ACC and shelf surface waters where there are strong boundary currents.