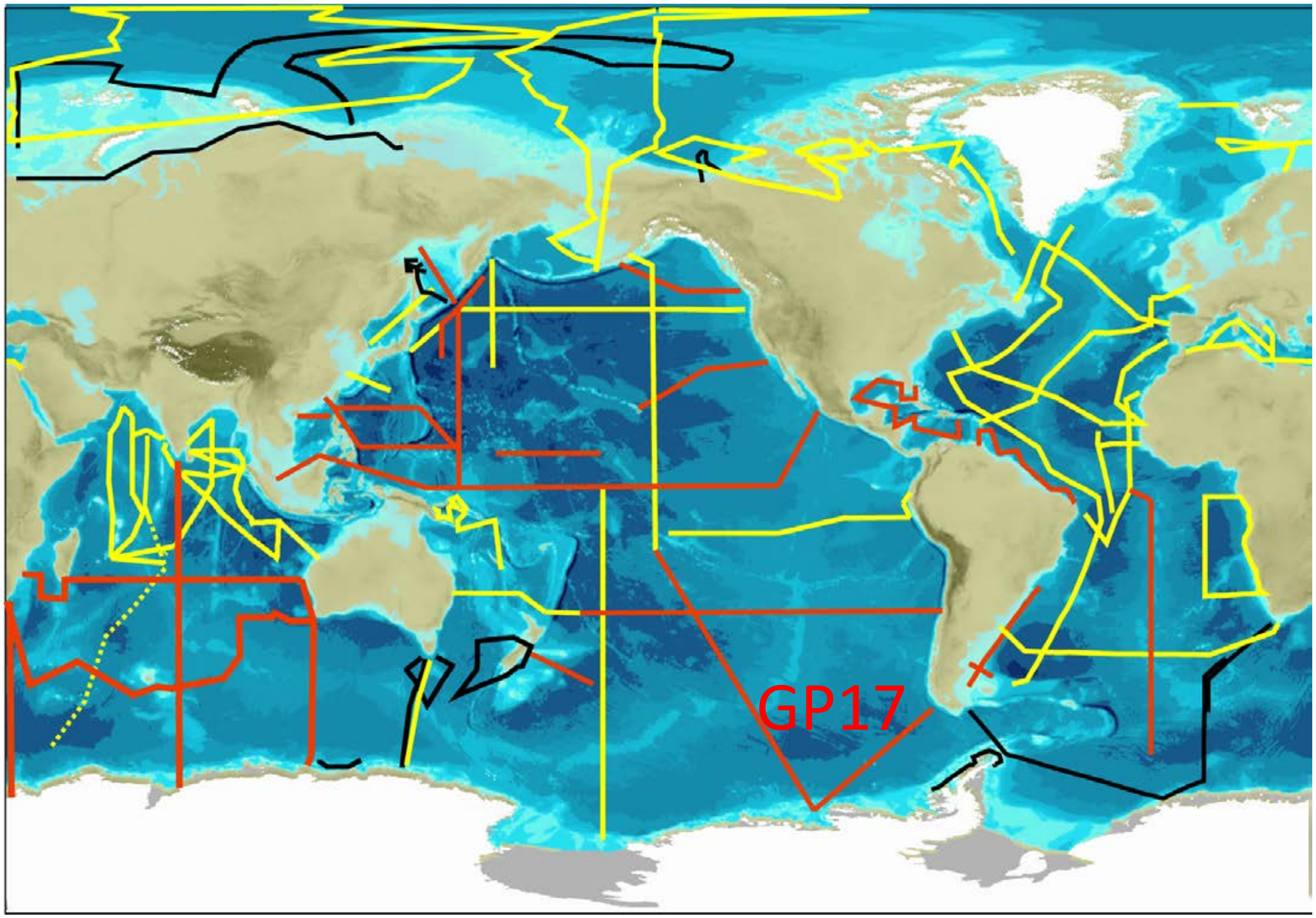
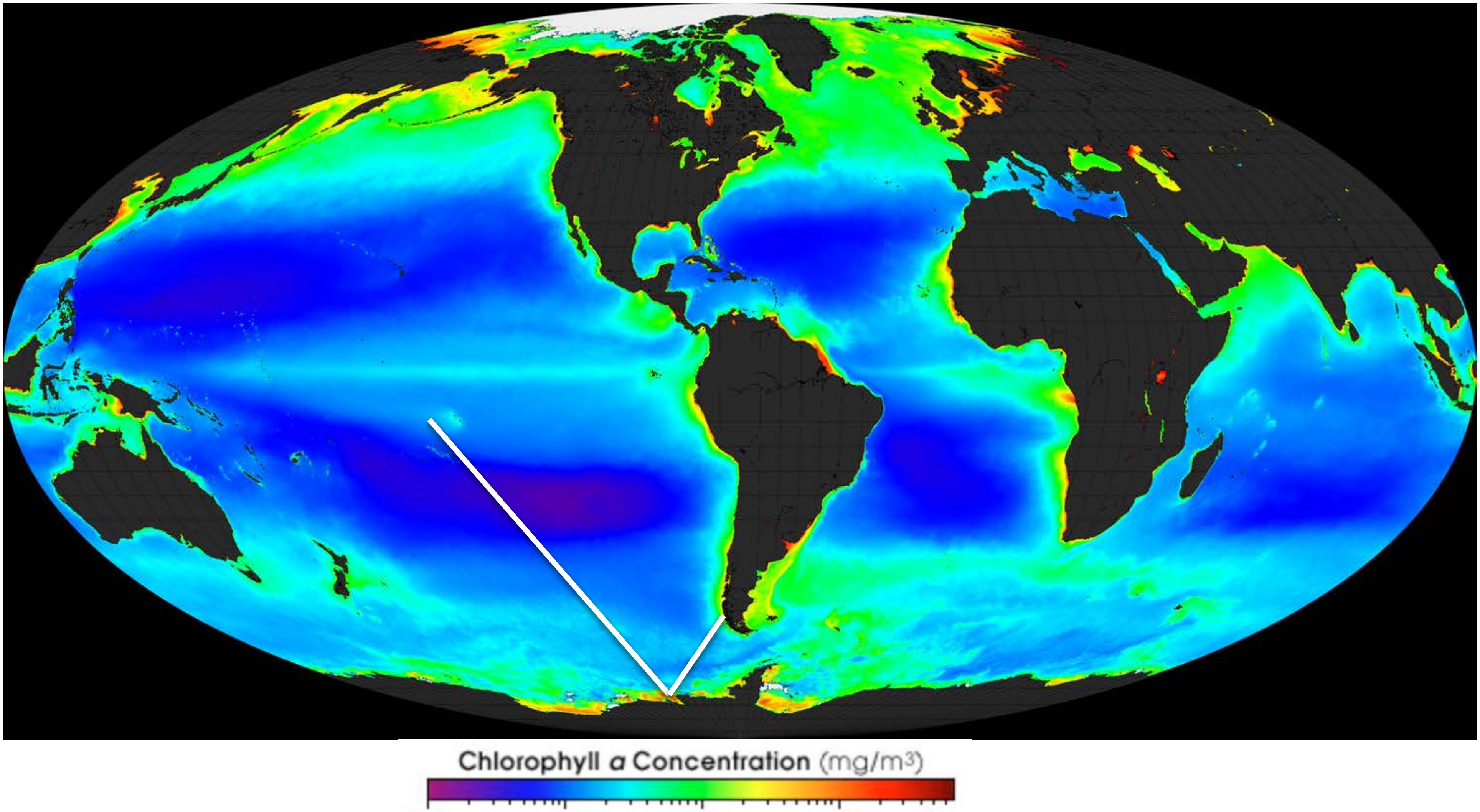
GP17 in the context of the global survey



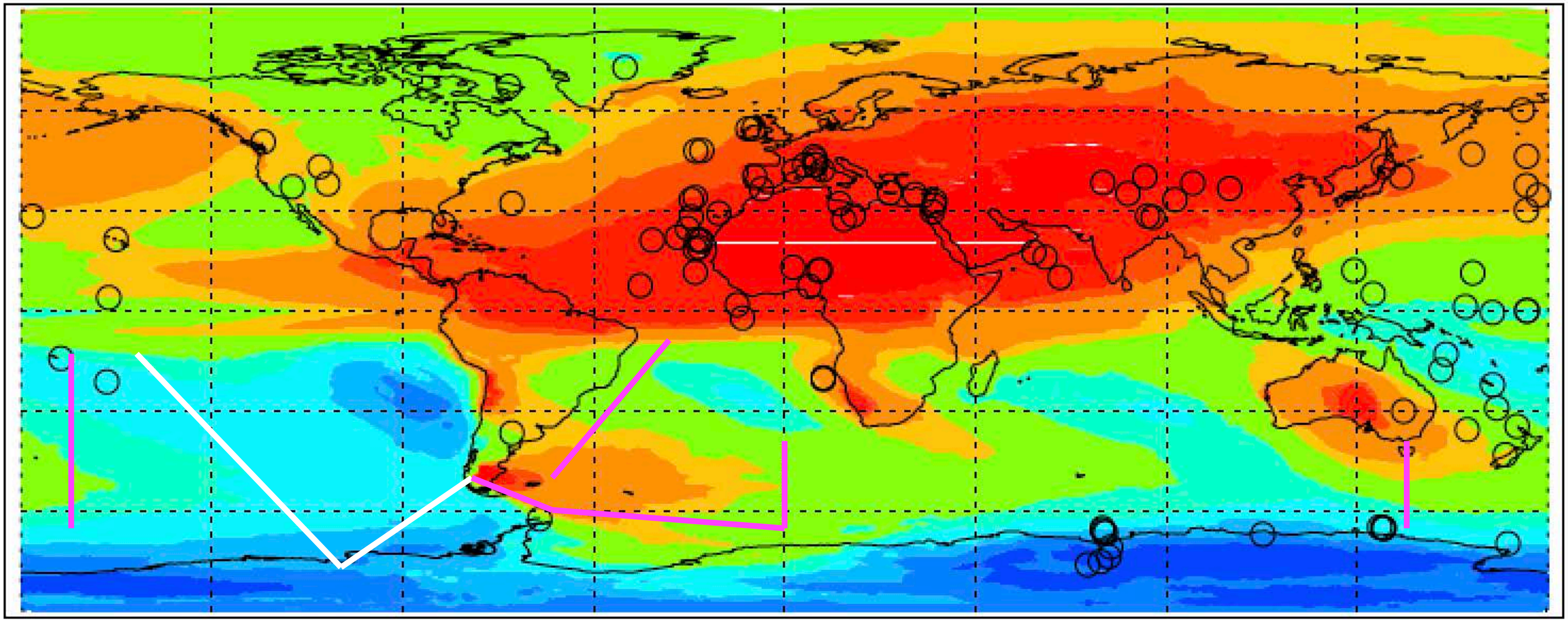
SeaWiFS - Annual Mean Chlorophyll



https://earthobservatory.nasa.gov/IOTD/view.php?id=4097

GP17 - Lowest model dust flux in the Southern Ocean

b. Model Deposition (g m^{-2} yr^{-1})



Are surface Fe concentrations correlated with modern (model) dust flux?
Test by comparing GP17 with other sections (pink).

Dust model of Albani, Mahowald et al., 2014

Motivation for the GP17 Section

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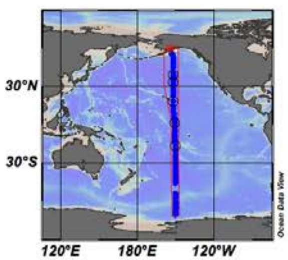
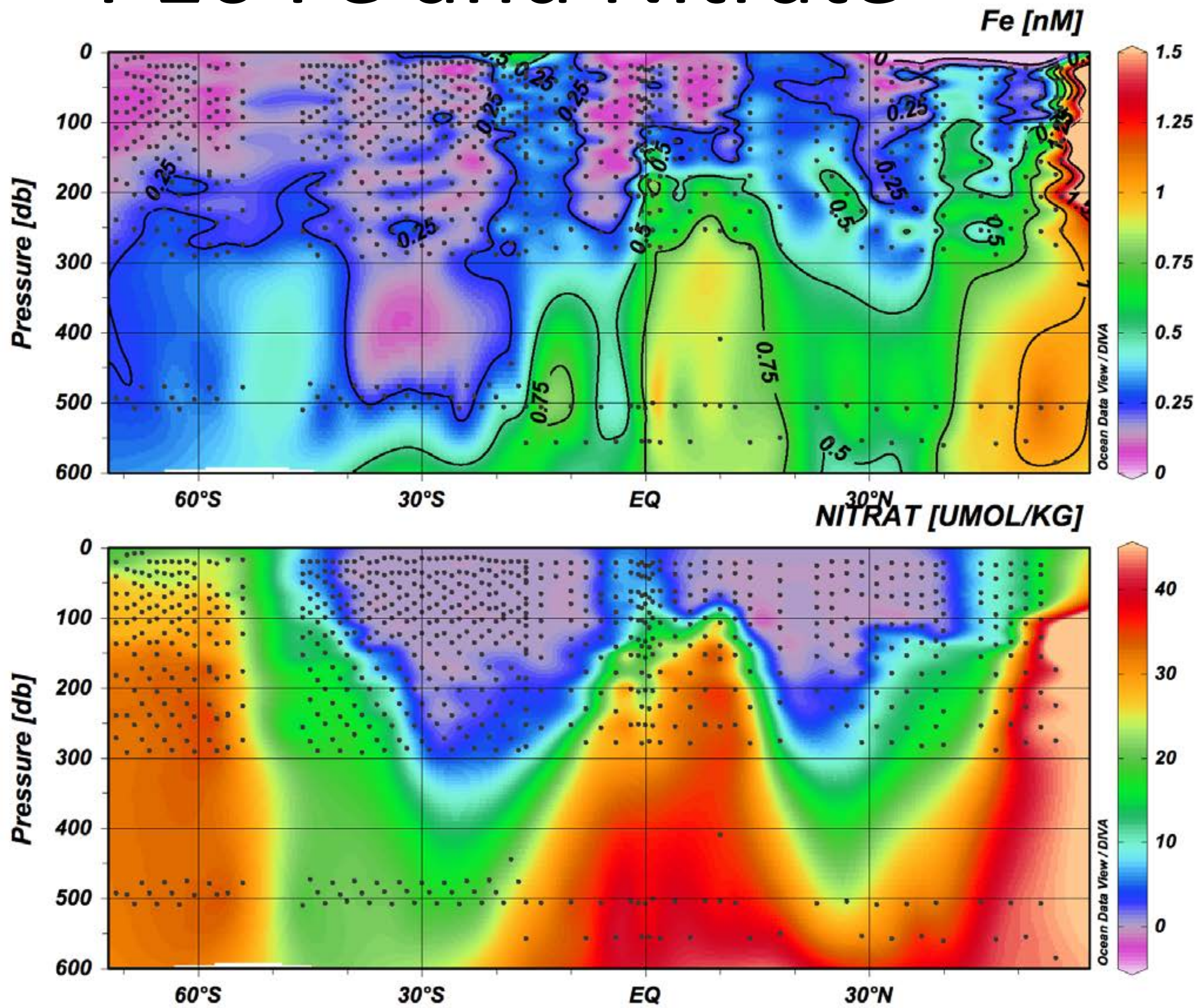
P16 Fe and Nitrate



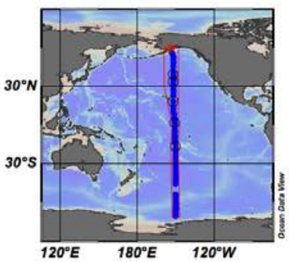


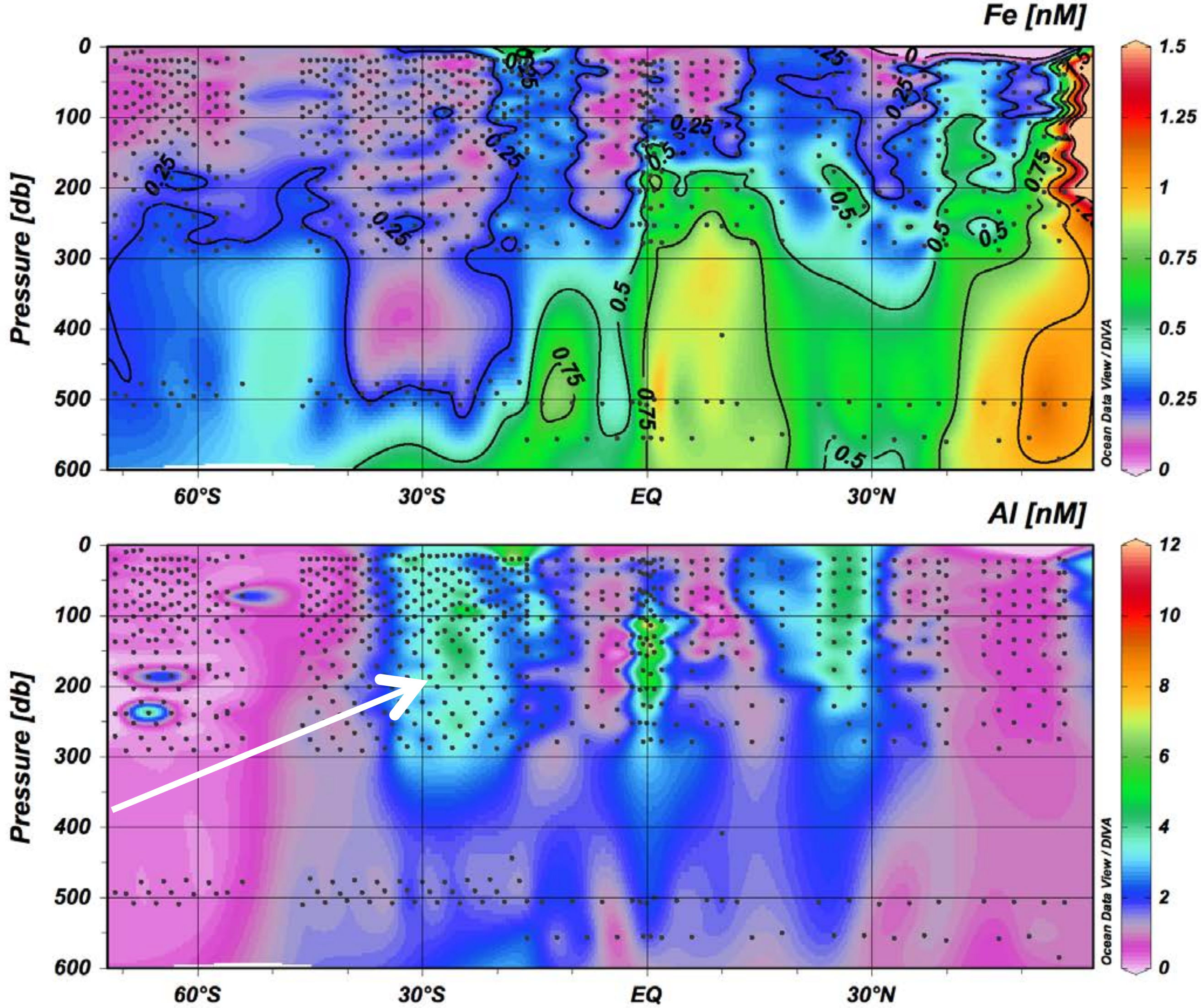
Fe and N have similar distributions in the north, dissimilar in the south.

Causes & consequences for ecosystems?

Complements of Chris Measures & Mariko Hatta

P16 Fe and Al

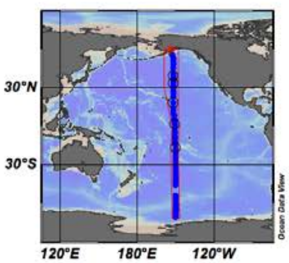


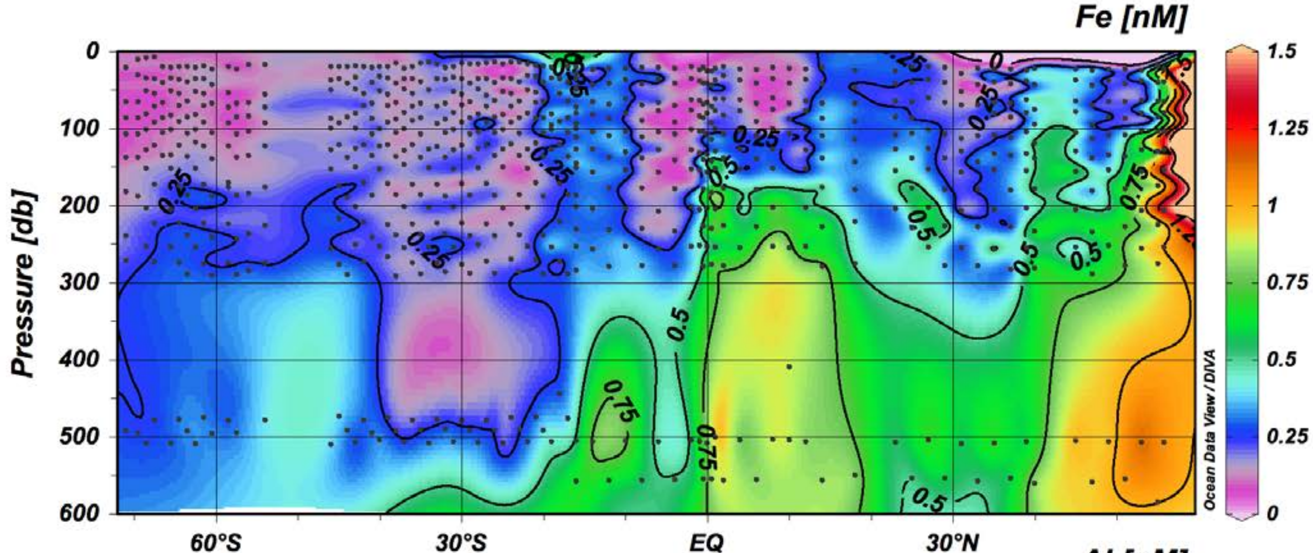


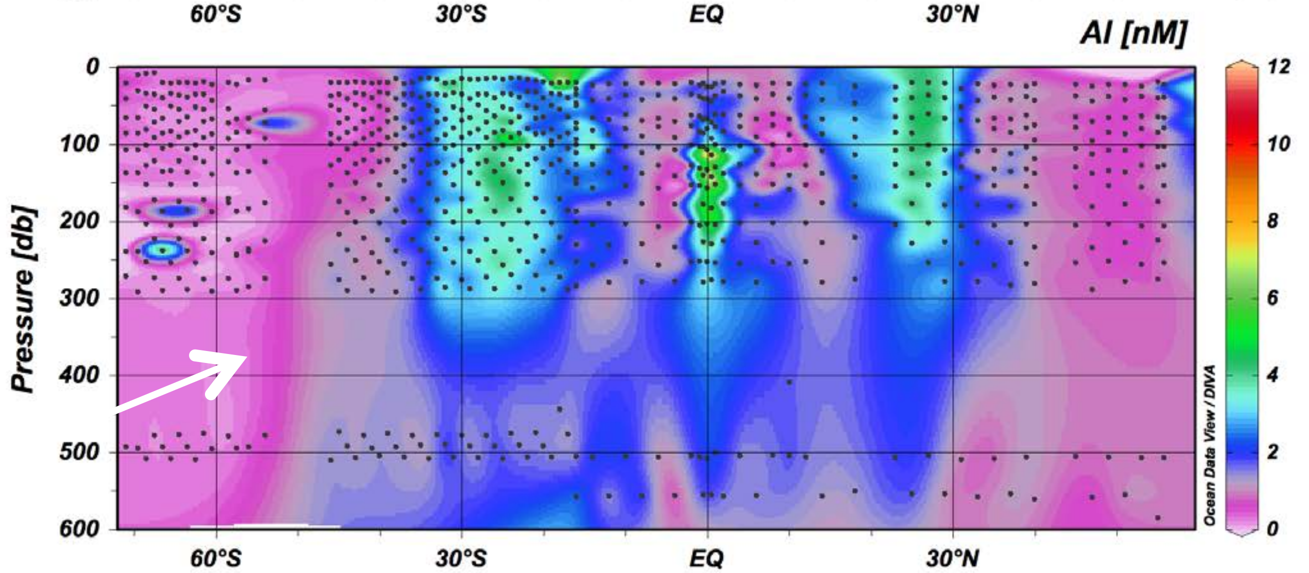
SPSG: High Al coincides with low Fe – ultra-low scavenging intensity?

Complements of Chris Measures & Mariko Hatta

P16 Fe and Al



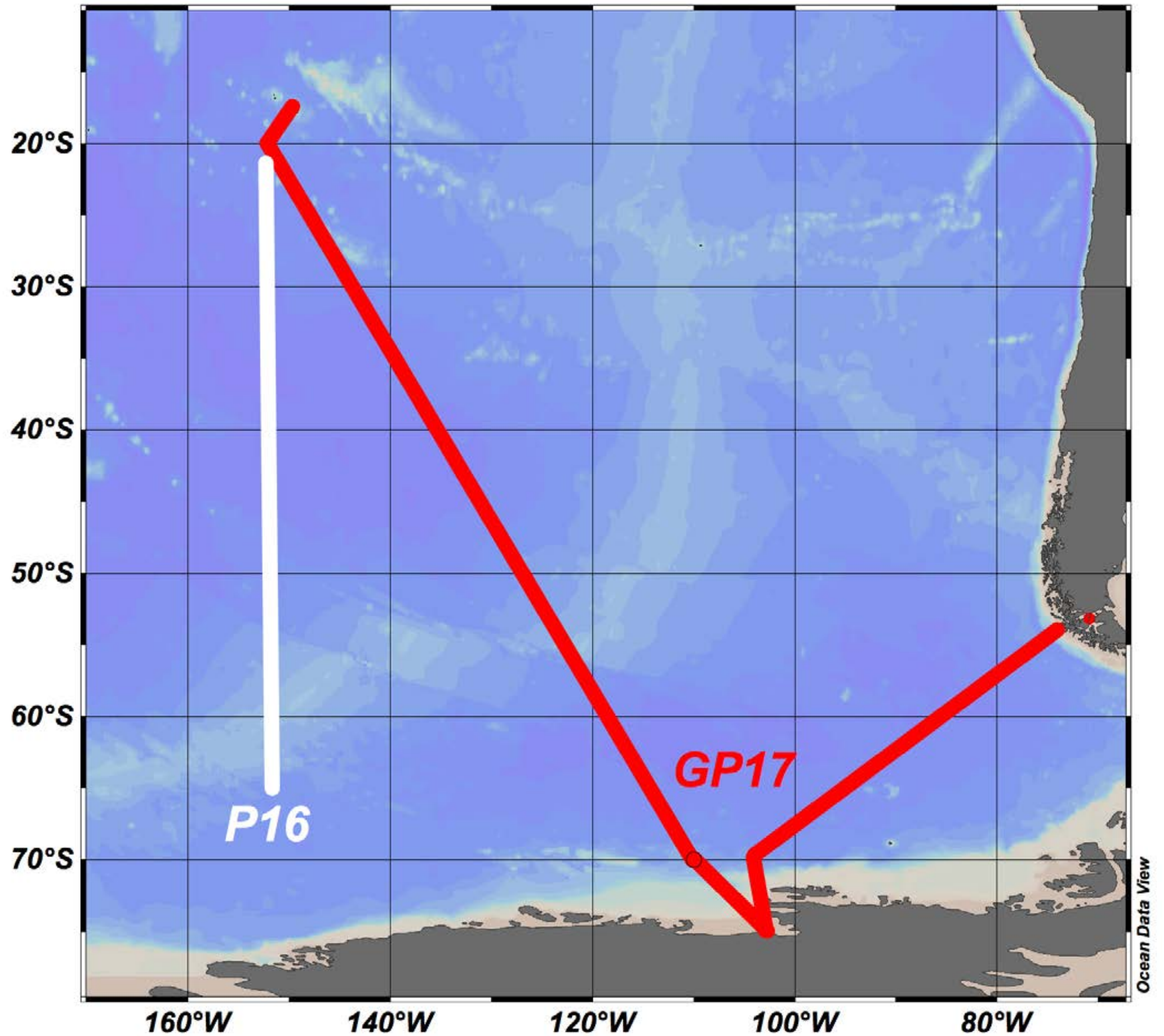




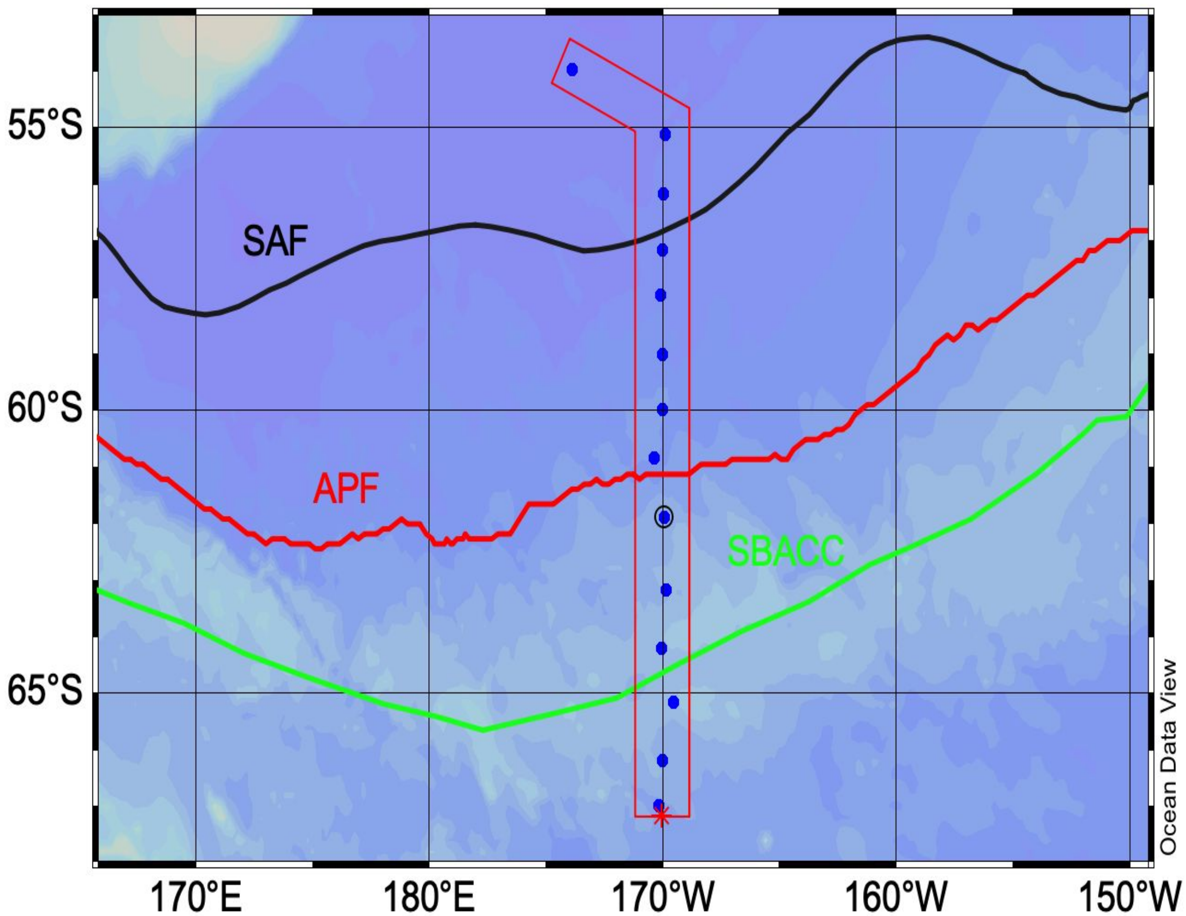
Low Al in the Southern Ocean – diatom scavenging?

Complements of Chris Measures & Mariko Hatta

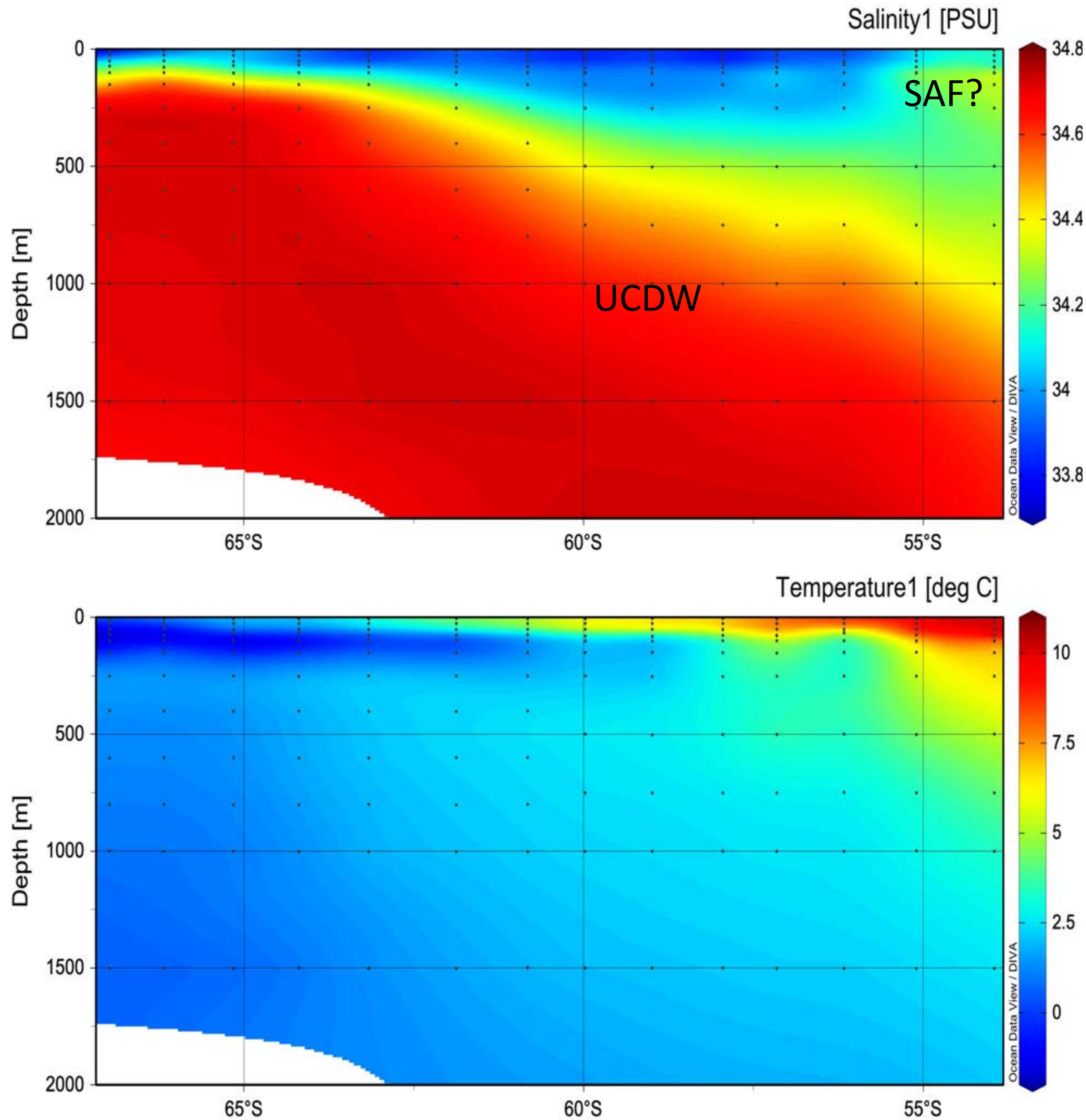
GP17 Tentative Cruise Track



NBP1702 with Orsi climatological fronts



Temp and Salinity

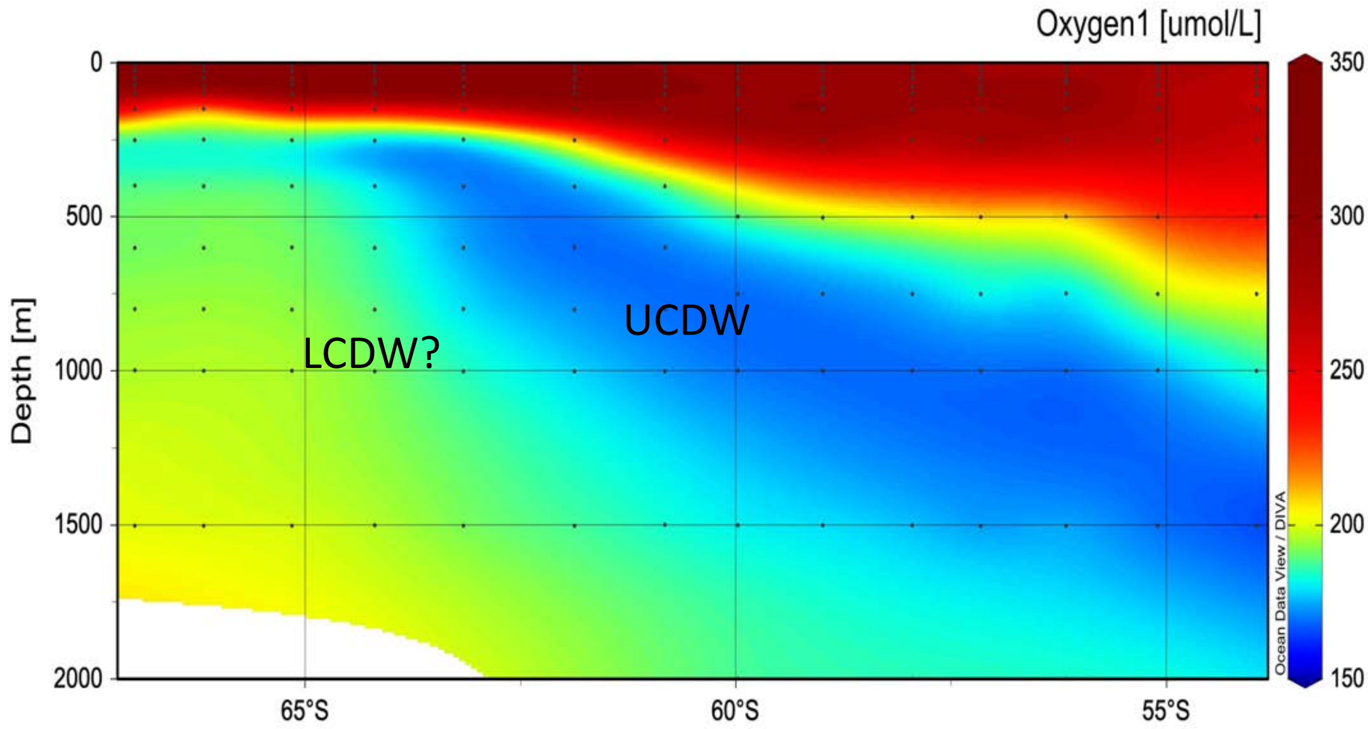


A little tricky to say what the northward extent of the subsurface T minimum is – seems to go much further north than what you'd usually call the APF

Data from Rebecca Robinson & Mark Brzezinski

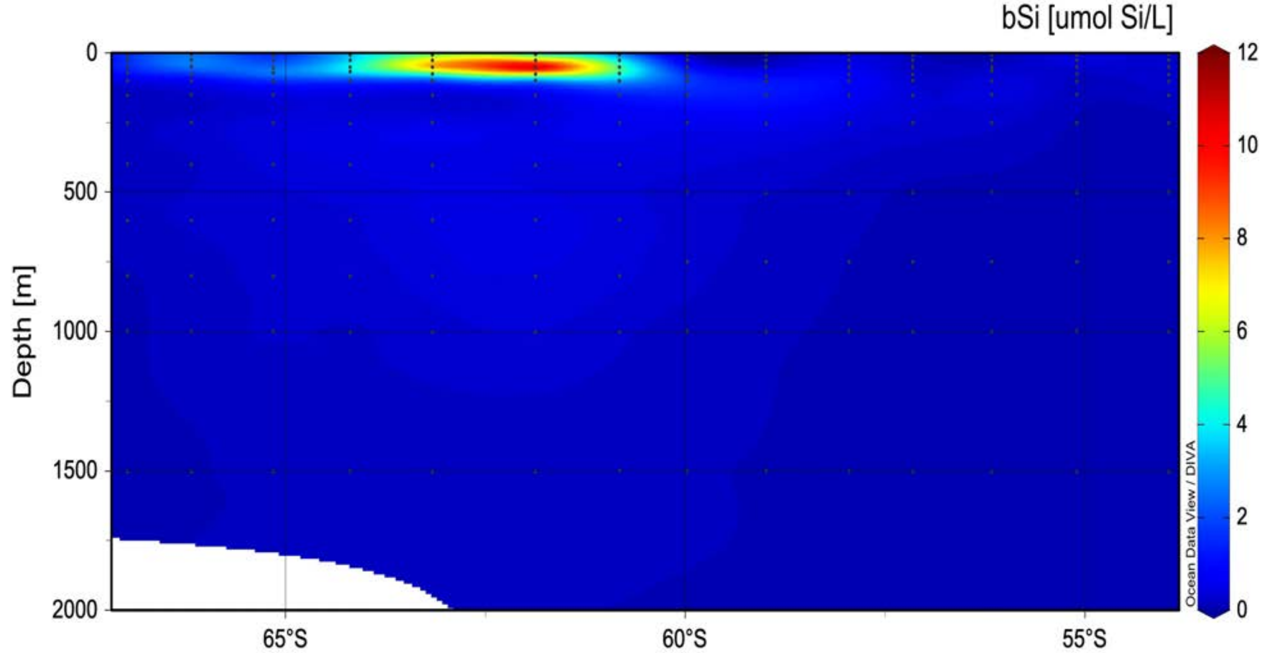
Oxygen

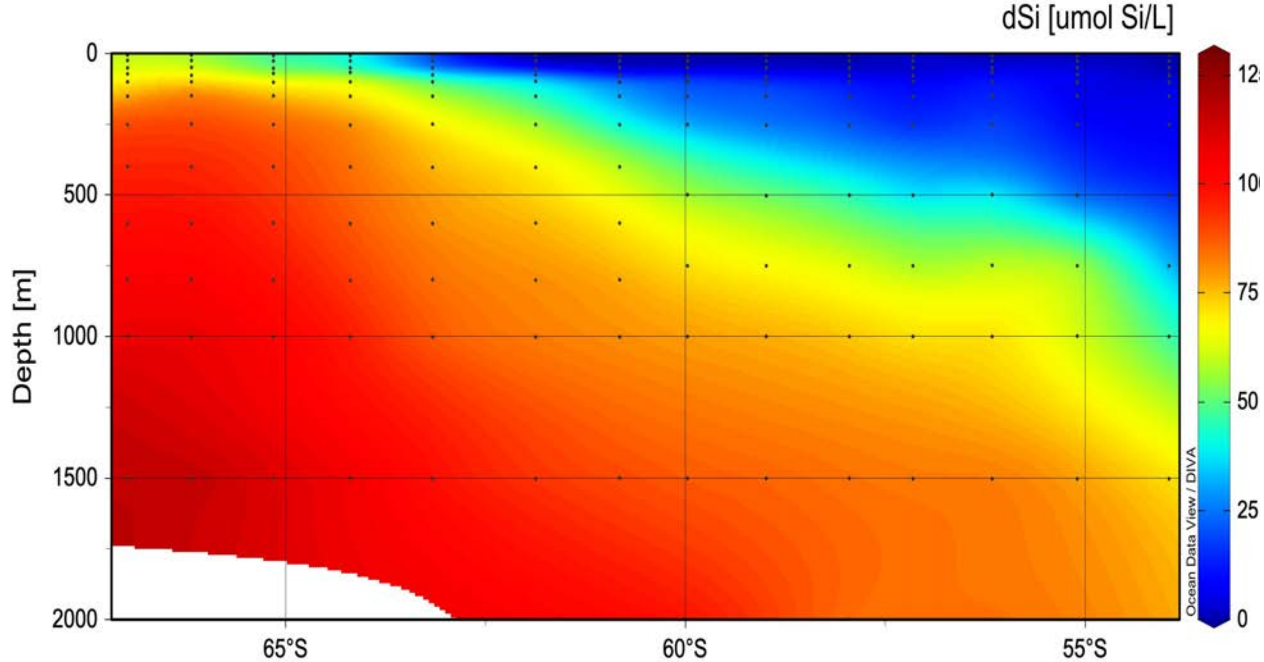
Obvious O_2 minimum associated with UCDW



Data from Rebecca Robinson
& Mark Brzezinski

dSi and bSi

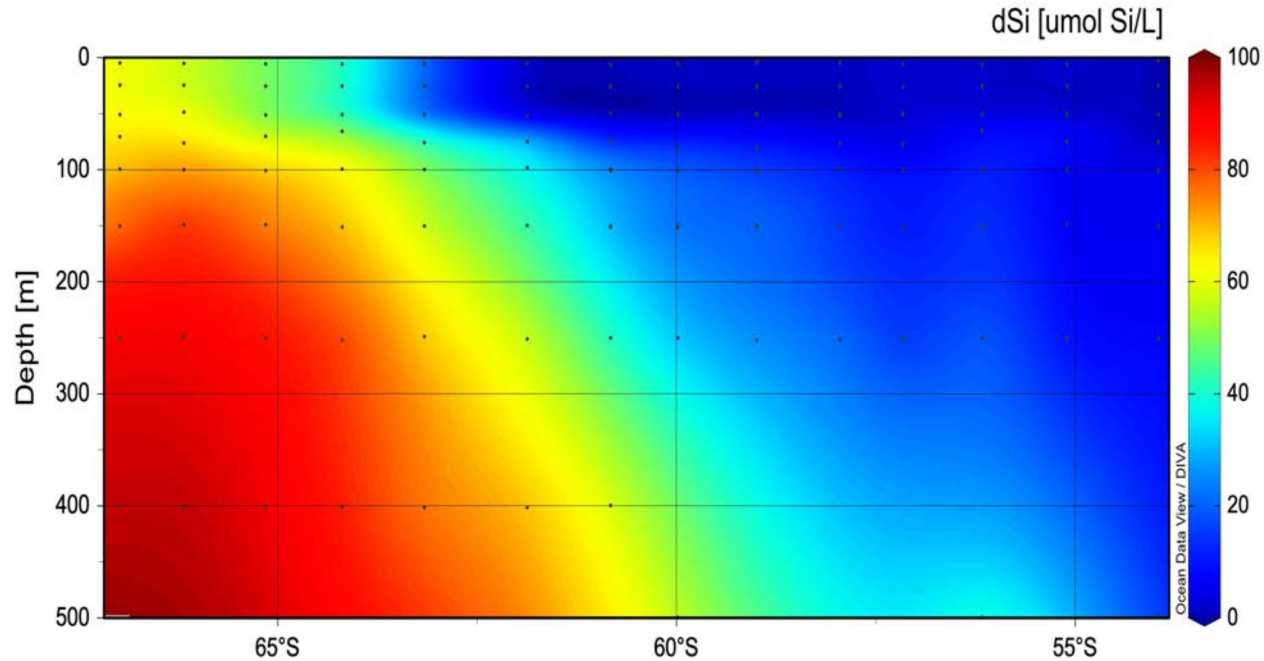


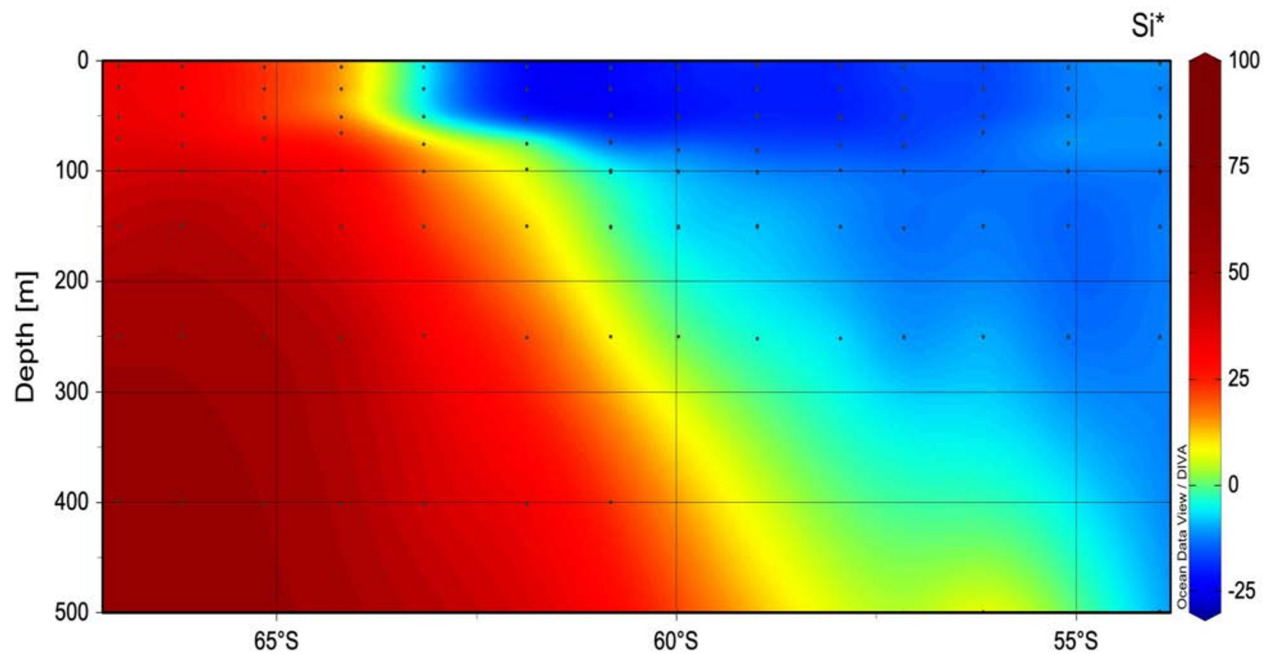


Consistency between $SiOH_4$ drawdown at 61-63ºS with highest bSi values there – region of most intense diatom productivity. High $SiOH_4$ south of 63S (incomplete utilization of nutrients supplied by deep winter mixing?), low $SiOH_4$ in waters carried north of ~61S by Ekman transport

Data from Rebecca Robinson & Mark Brzezinski

Picture from Si* is the same – surface Si* values are lowest at 62S, higher but still negative at 63S, and positive at 64S.





Note 500m depth scale

$$Si^* = [Si] - [NO_3]$$

Data from Rebecca Robinson & Mark Brzezinski

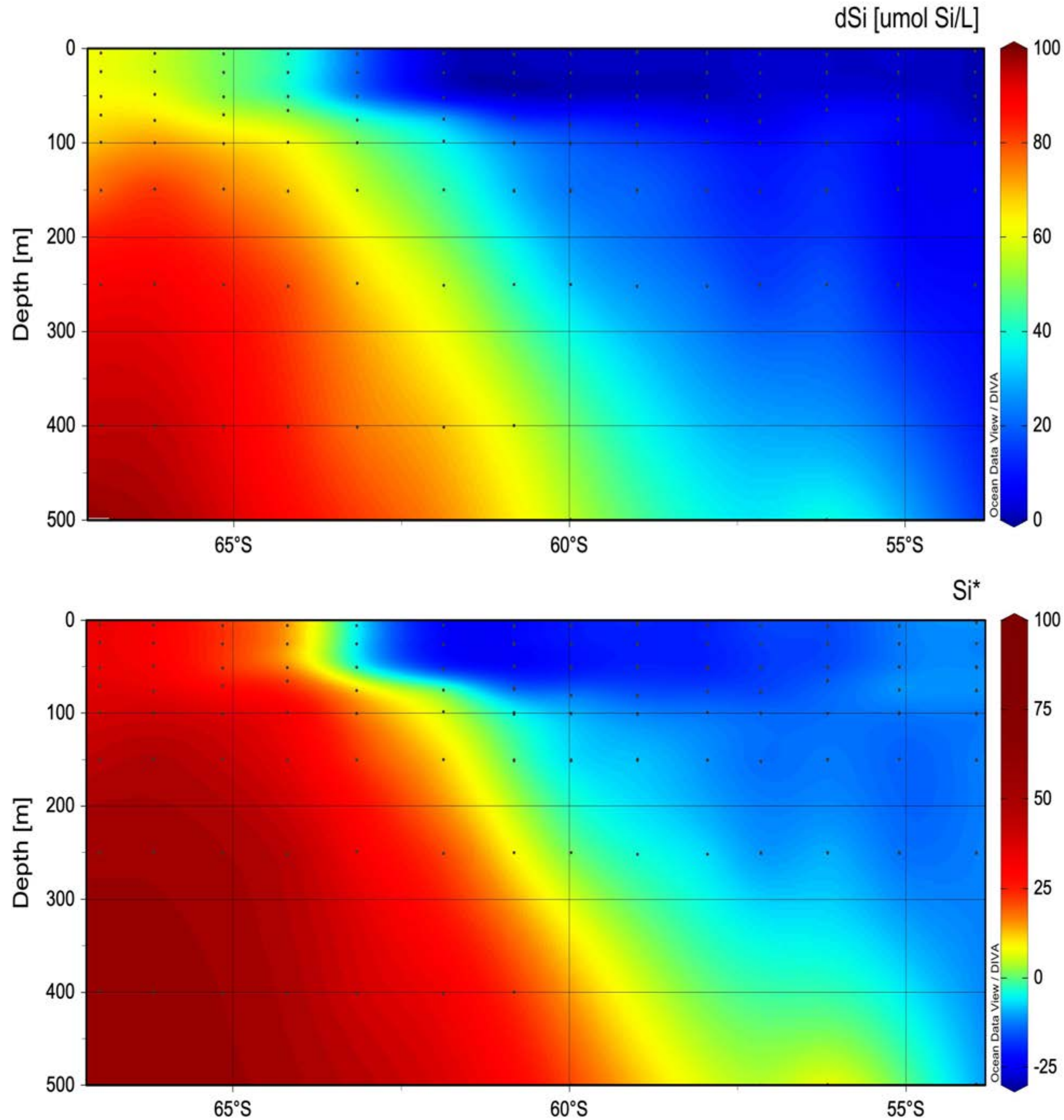
Picture from Si* is the same – surface Si* values are lowest at 62S, higher but still negative at 63S, and positive at 64S.

Entire SH nutrient source has negative Si* because of processes occurring here

Note 500m depth scale

$$Si^* = [Si] - [NO_3]$$

Data from Rebecca Robinson & Mark Brzezinski

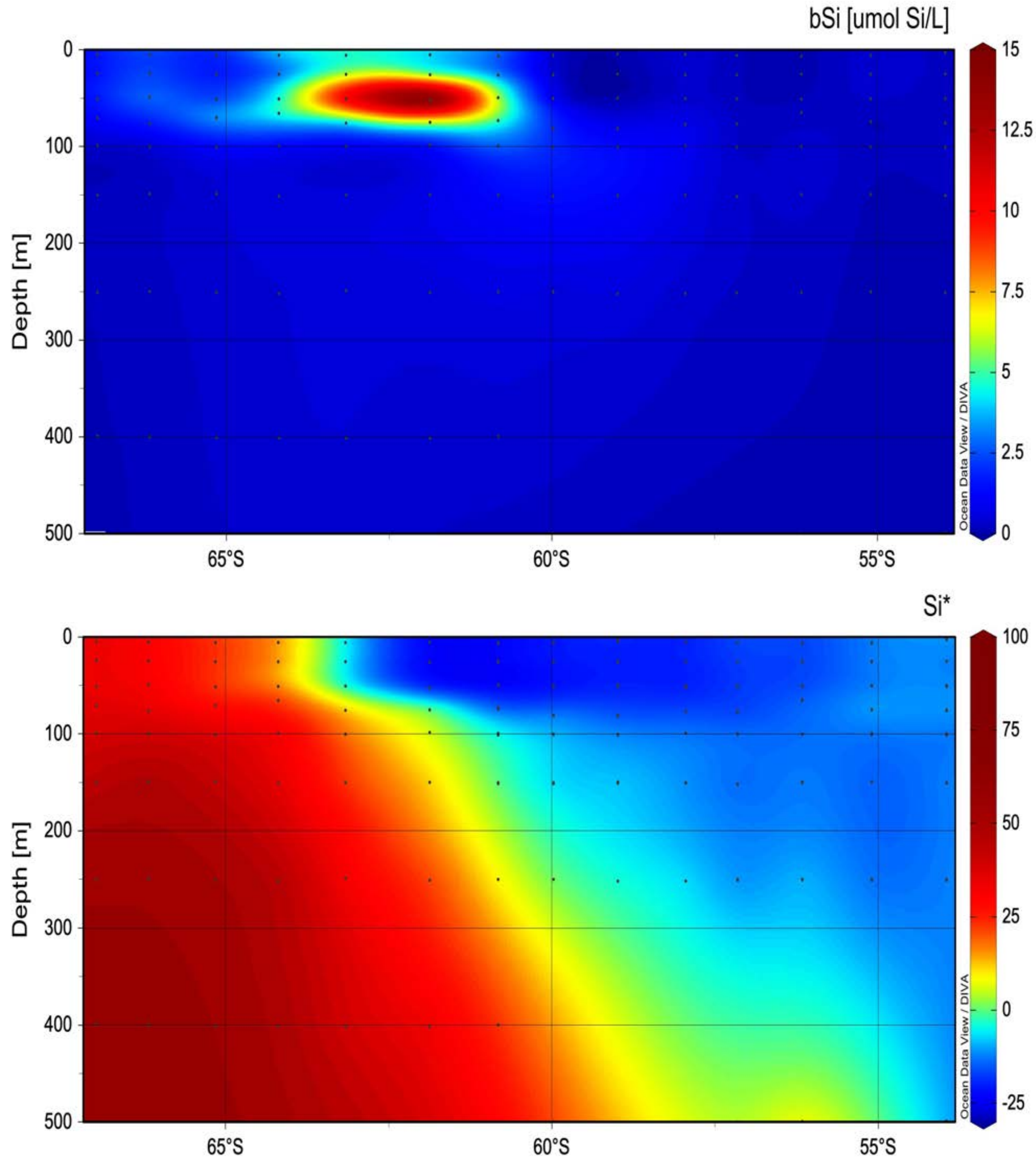


What is the source of dFe to support this diatom growth?

Entire SH nutrient source has negative Si* because of processes occurring here

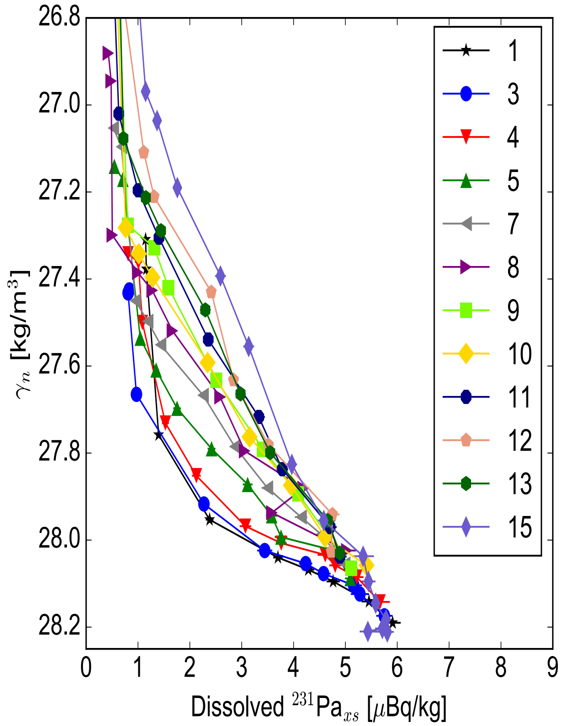
$$Si^* = [Si] - [NO_3]$$

Data from Rebecca Robinson & Mark Brzezinski

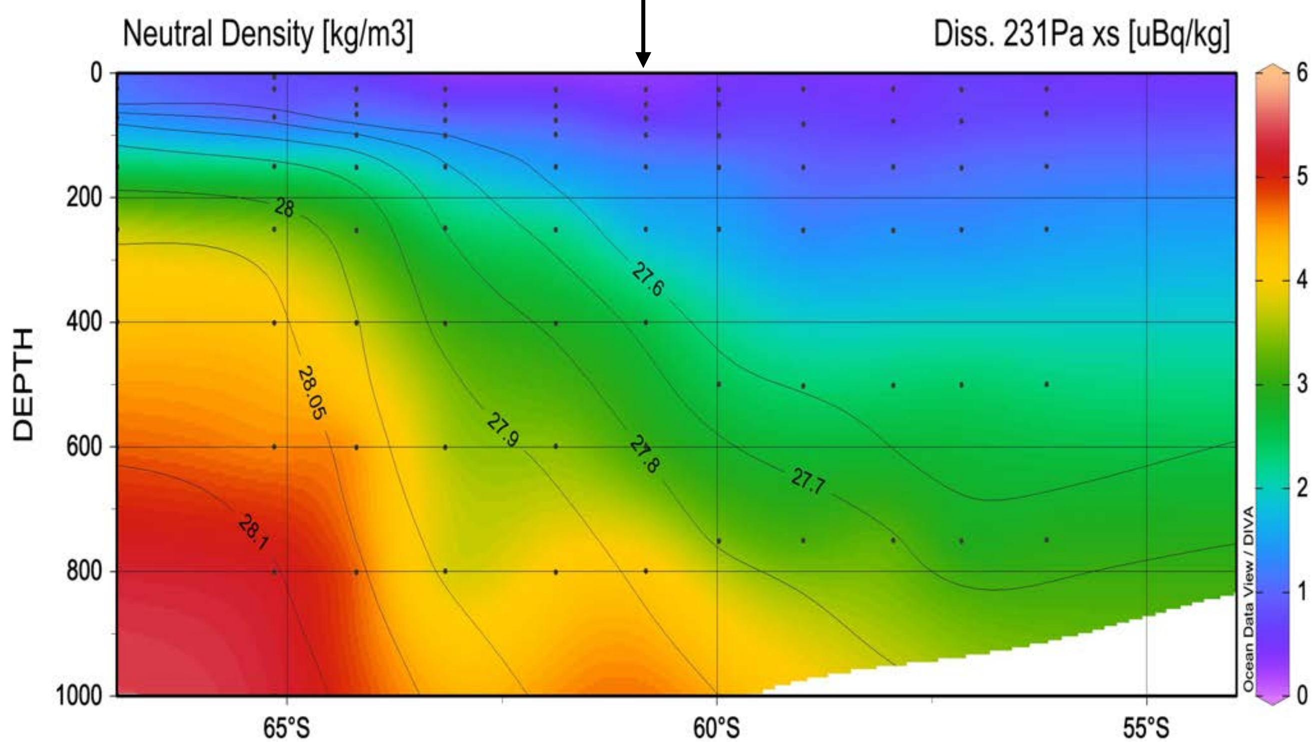


Nutrient data is consistent with locations of most intense Pa removal and decoupling along neutral density surfaces.

Strongest isopycnal ^{231}Pa gradients at/below yn=27.6 open up between station 7 (62S) and station 5 (63S)



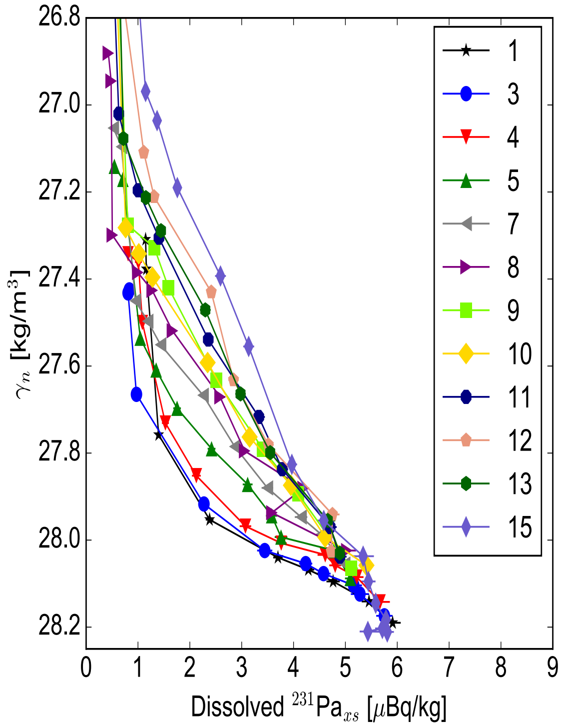
Lowest surface Pa from 63S-61S



What other TEIs are scavenged by opal as well? Al?

Nutrient data is consistent with locations of most intense Pa removal and decoupling along neutral density surfaces.

Strongest isopycnal ^{231}Pa gradients at/below yn=27.6 open up between station 7 (62S) and station 5 (63S)



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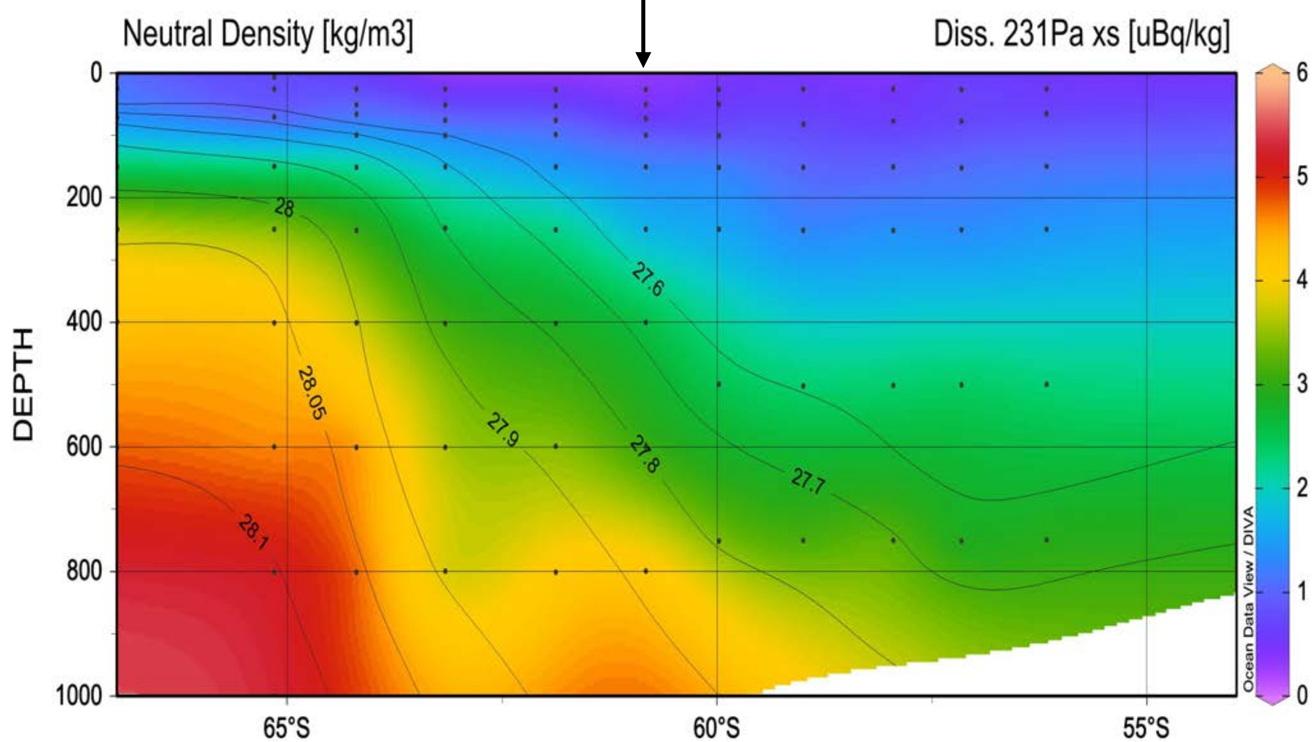


Sampling resolution

Standard GEOTRACES sampling at 5° resolution could miss the zone of maximum diatom productivity

Higher resolution sampling is essential

Iron source and implications South of the APF

JGOFS Hypothesis:

Fe scarcity limits dSi utilization south of the SBACC

Implications:

- dFe in upwelled UCDW is sufficient for complete dSi consumption
- dFe is much lower in LCDW upwelled further south

Question: If so, is higher dFe in UCDW hydrothermal?

Iron source and implications North of the APF

Fe Recycling Hypothesis:

Landing: Aerosol source of Fe is sufficient for PP in the N Pacific

Aerosol Fe is insufficient for PP in the S Pacific

(P6 TEI data + Satellite-based models)

H1: Lateral source of bioavailable dFe

H2: Plankton recycle Fe more efficiently in the S Pacific (Rafter hypothesis)

Invoked by Schlosser et al. for S Atlantic

Testable using siderophore measurements (Rene Boiteau/ Dan Repeta)

Particles in the SPSG with ultra low dust fluxes should have high Fe/Ti ratios if there is a source of dFe from upwelling or from lateral transport by currents.

N fixation: Controls and Consequences

GP15 + GP17 will sample:

3 regimes w/o N fixation (SNP, EqPac, So Ocean)
2 regimes with N fixation (NPSG, SPSG)

Wang et al., Nature, 2019 (w/ News & Views by Gruber)
offer predictions (hypotheses) about global N fixation
testable with GEOTRACES data on GP15 + GP17

Do dissolved and particulate TEI data (including N isotopes)
support these paradigms?
What role does Fe play?

Compare with N Atlantic (GA03) to test hypothesis that
low P limits N fixation in the N Atlantic
(needs GEOTRACES nano nutrients)

So Ocean processes set end-member water mass micronutrient composition

Biological uptake:

For Cd, Zn, others (?) is much greater in the Southern Ocean than at lower latitudes. Why?

H1: Response to Fe limitation

H2: dMe in upwelled water exceeds ligand concentration

High concentrations of free inorganic ions

"Luxury" uptake of free metal

So Ocean processes set end-member water mass micronutrient composition

Regeneration:

For Cd, Zn, others (?) is much greater in the Southern Ocean
than at lower latitudes (because of high uptake).

High latitude data needed to set end-member Me/P ratios

Essential for OMPA analysis to derive regenerated TEIs
at lower latitudes

Not only micronutrients
e.g., OMPA evidence for substantial benthic REE source

So Ocean processes set end-member water mass micronutrient composition

Regeneration:

For Cd, Zn, others (?) is much FASTER in the Southern Ocean than at lower latitudes (because of high uptake).

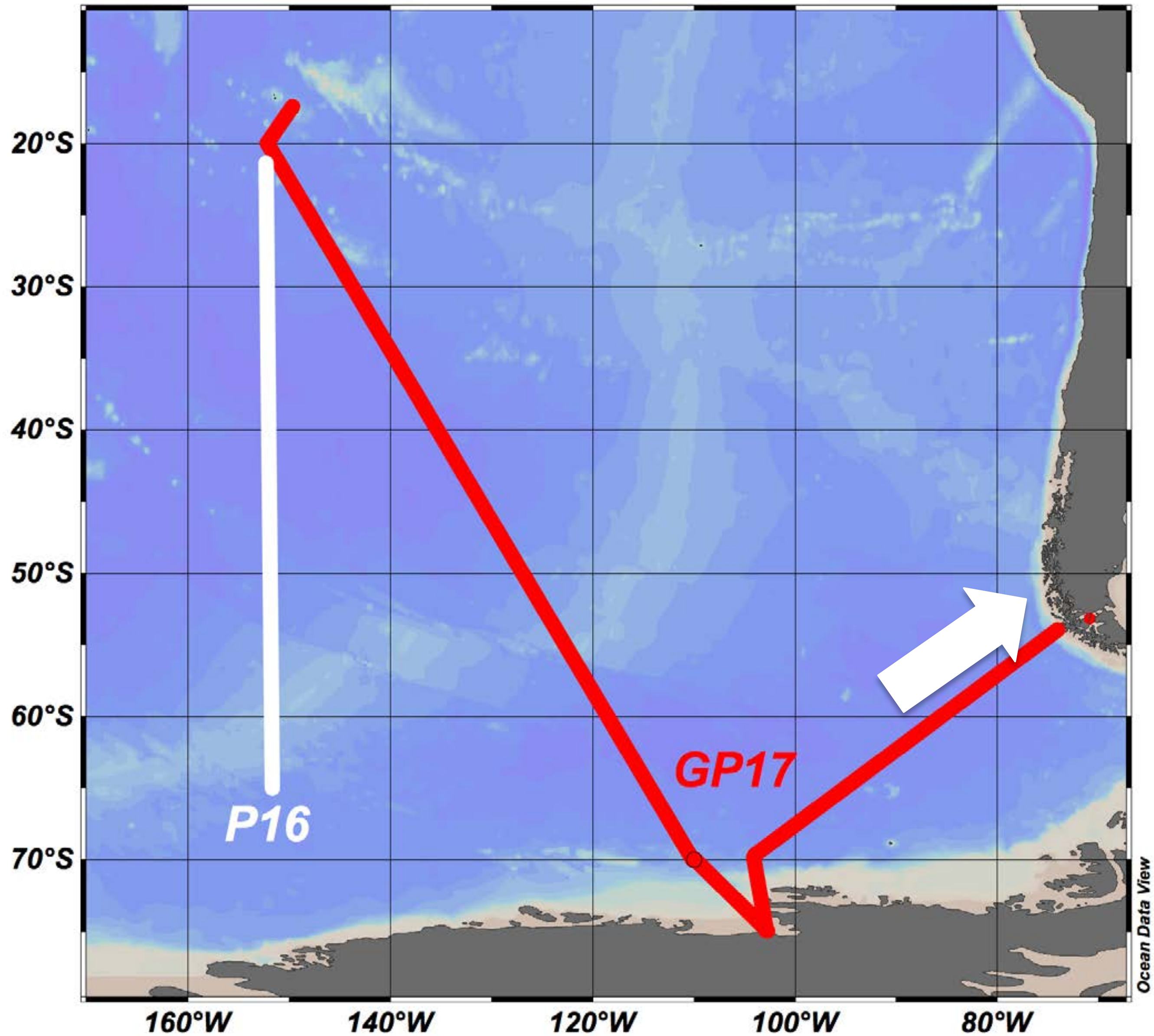
But - Martin power law absolute "b" values (0.2 − 0.5) seem to be too small (both in SoOc and at low latitudes)

Based on inverse model of Roshan et al. (2018)

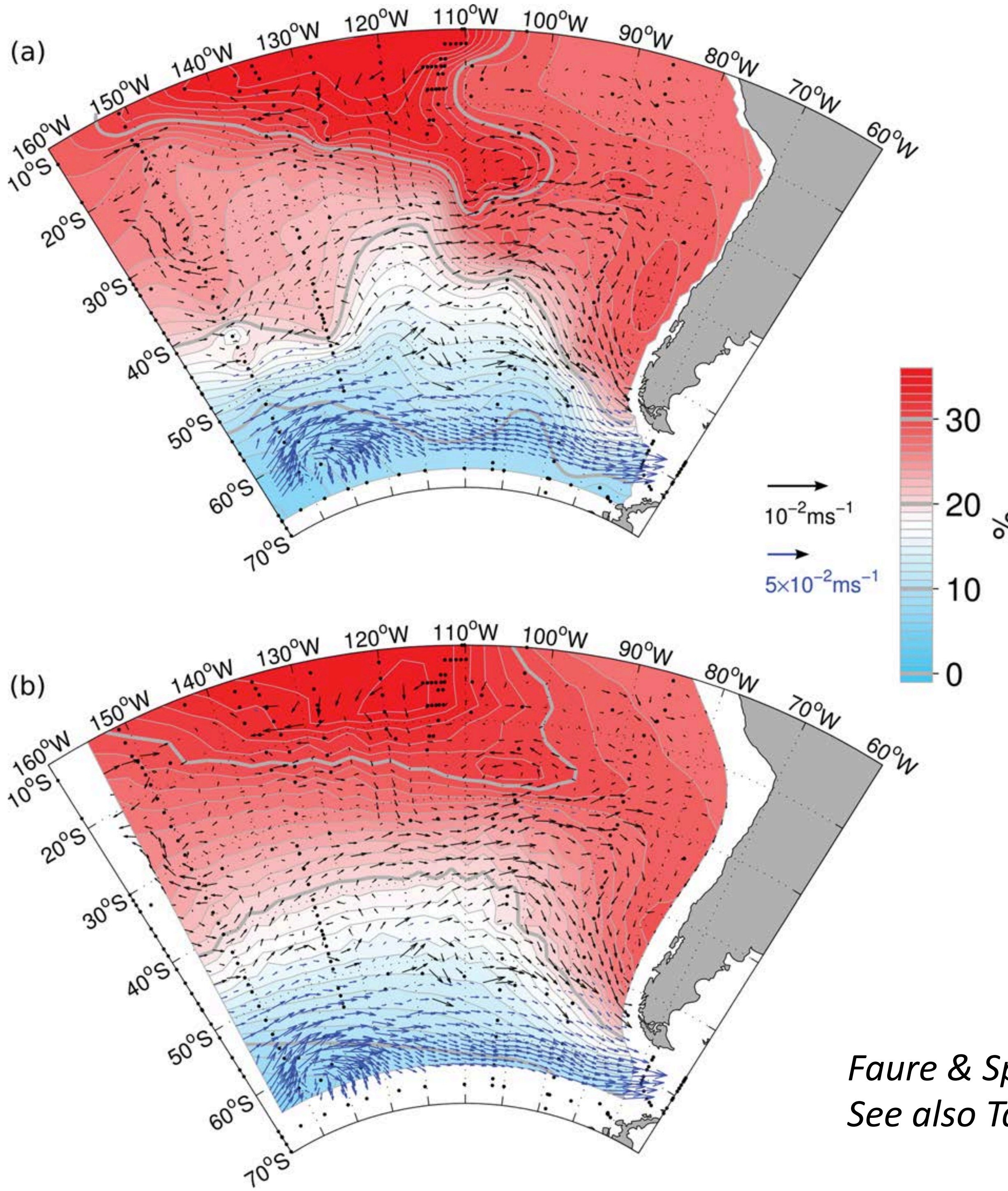
Testable using GEOTRACES data

Calculate "b" values for TEIs across gradients in nutrients, productivity and ecosystems

Sampling off Chile



PDW flux to SoOcean concentrated along eastern boundary



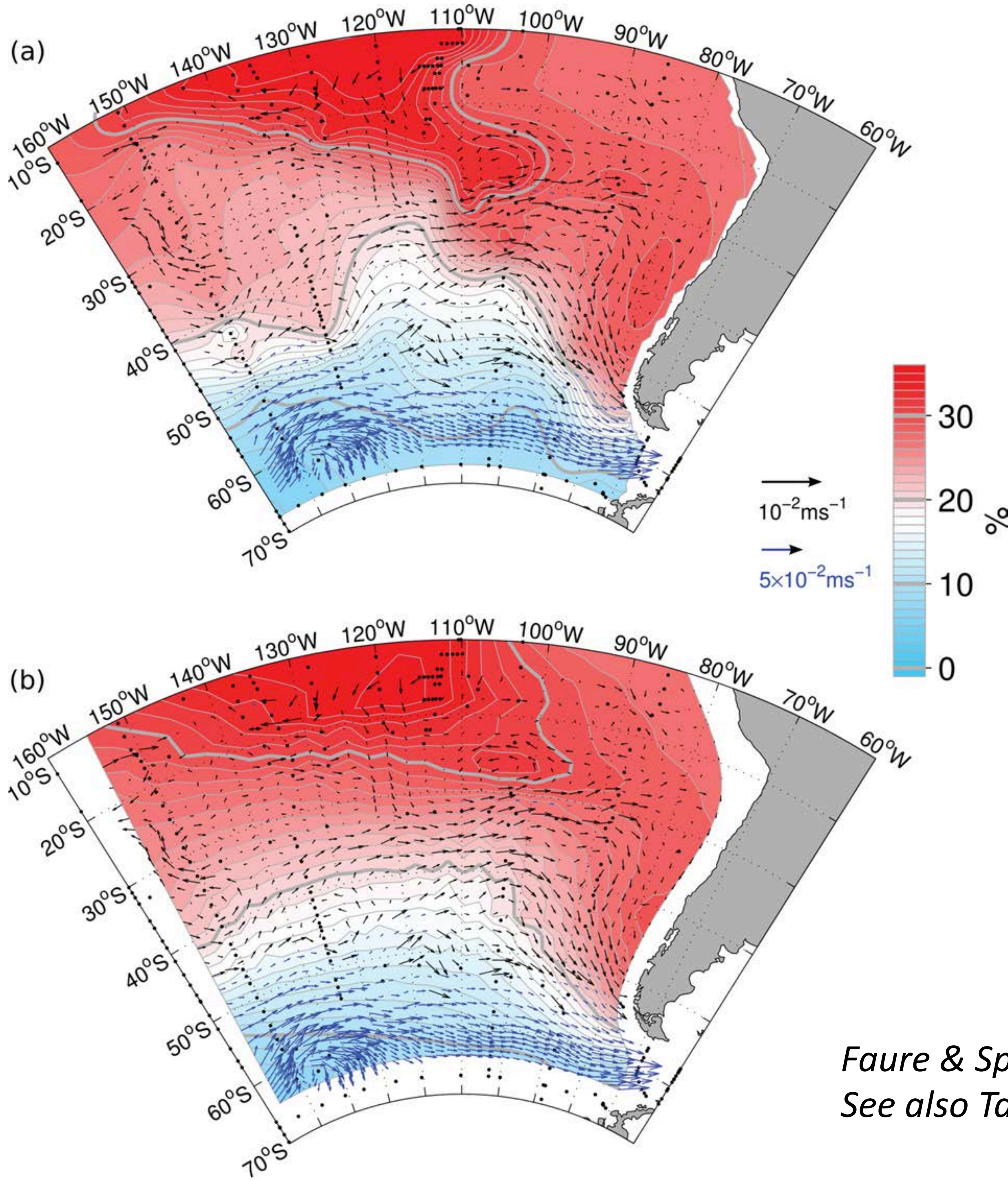
^{3}He distribution and flow in the layer $27.98\ kg\ m^{-3} < \gamma^n < 28\ kg\ m^{-3}$

a) Observations

b) Posterior mean

Faure & Speer, 2012
See also Tamsitt et al. 2017, 2018

PDW flux to SoOcean concentrated along eastern boundary



High resolution sampling needed approaching Chile margin.

Faure & Speer, 2012
See also Tamsitt et al. 2017, 2018

GP17 cruise and proposal timeline

Tentative timeline for discussion (working backwards)

Cruise(s)	Nov 2021 – Feb 2022
Fill-gap proposals	Feb 2021
PI proposals	Aug 2020
Management proposal	Feb 2020

If two ships then back to back or in sequential years?

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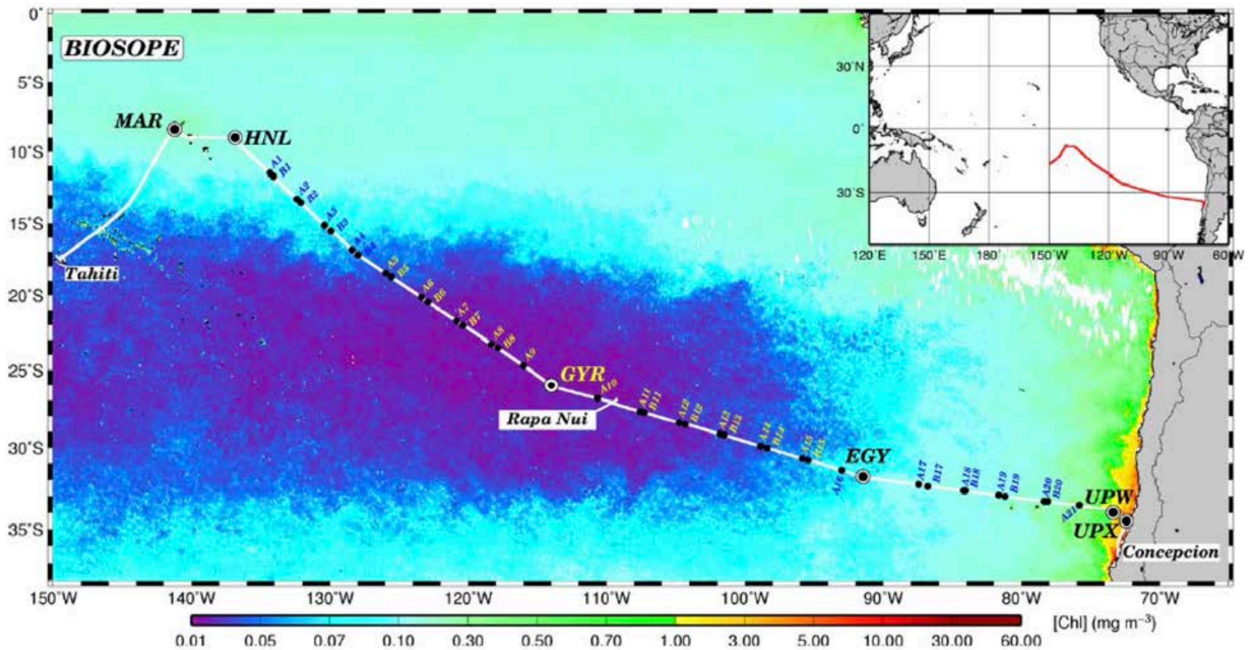
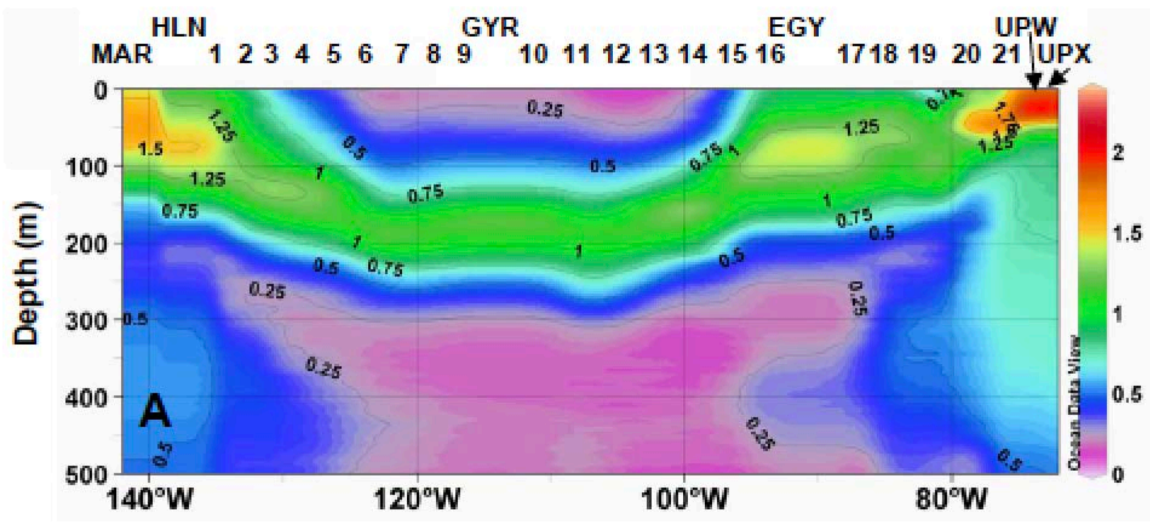
BIOSOPE – Deep Chlorophyll Maximum

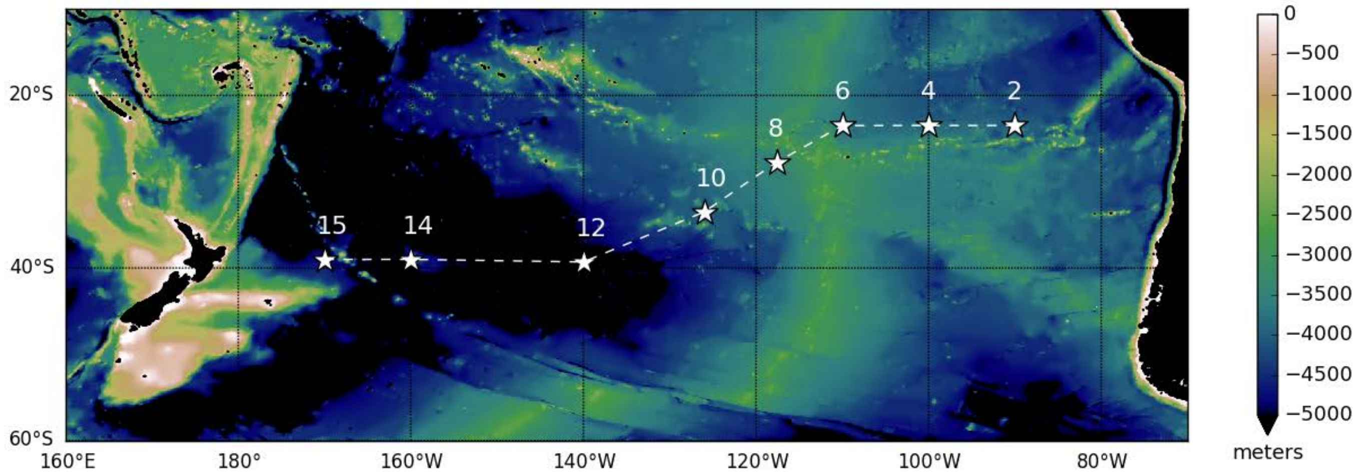




Are colloidal TEIS removed from the DCM under extreme:
1) low dust input
2) Deep DCM?

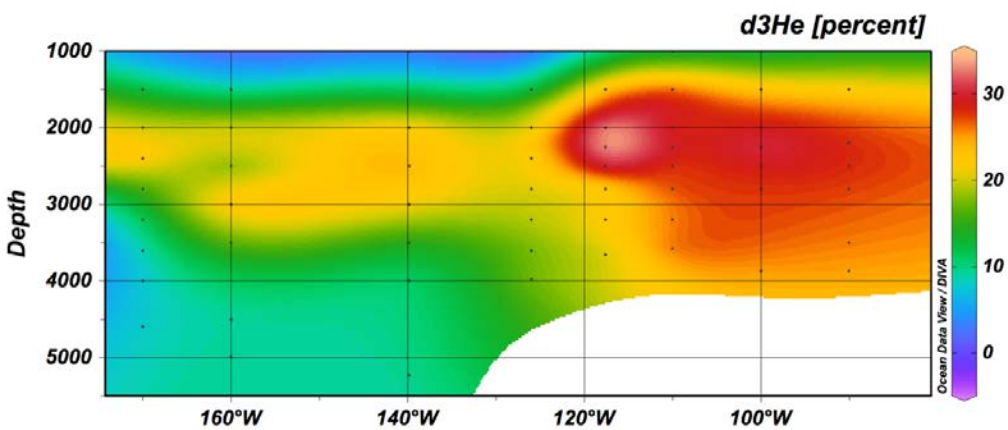
From Claustre et al., 2008

SPG Local hydrothermal signal unlikely



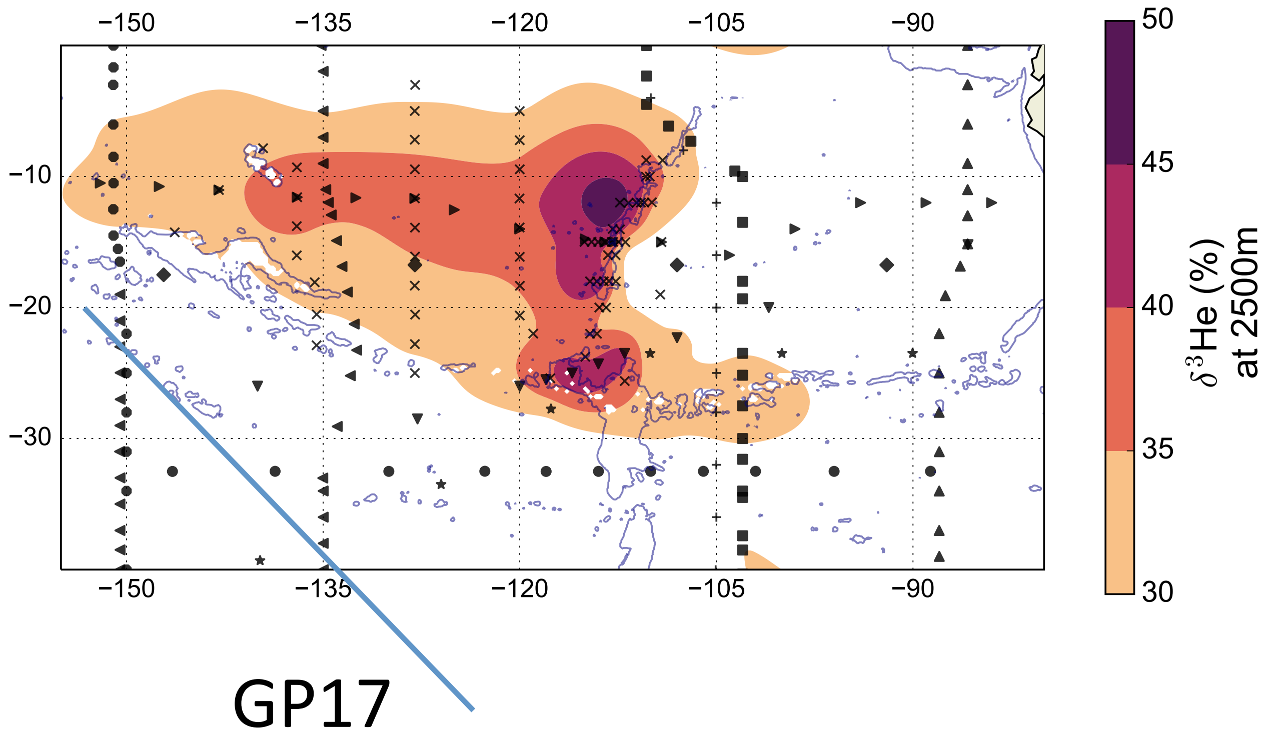
German UltraPac section – 2015/2016

Geostrophic transport is eastward



From Frankie Pavia, LDEO

SPG Local hydrothermal signal unlikely



Updated map δ^3He at 2500 m

From Frankie Pavia, LDEO

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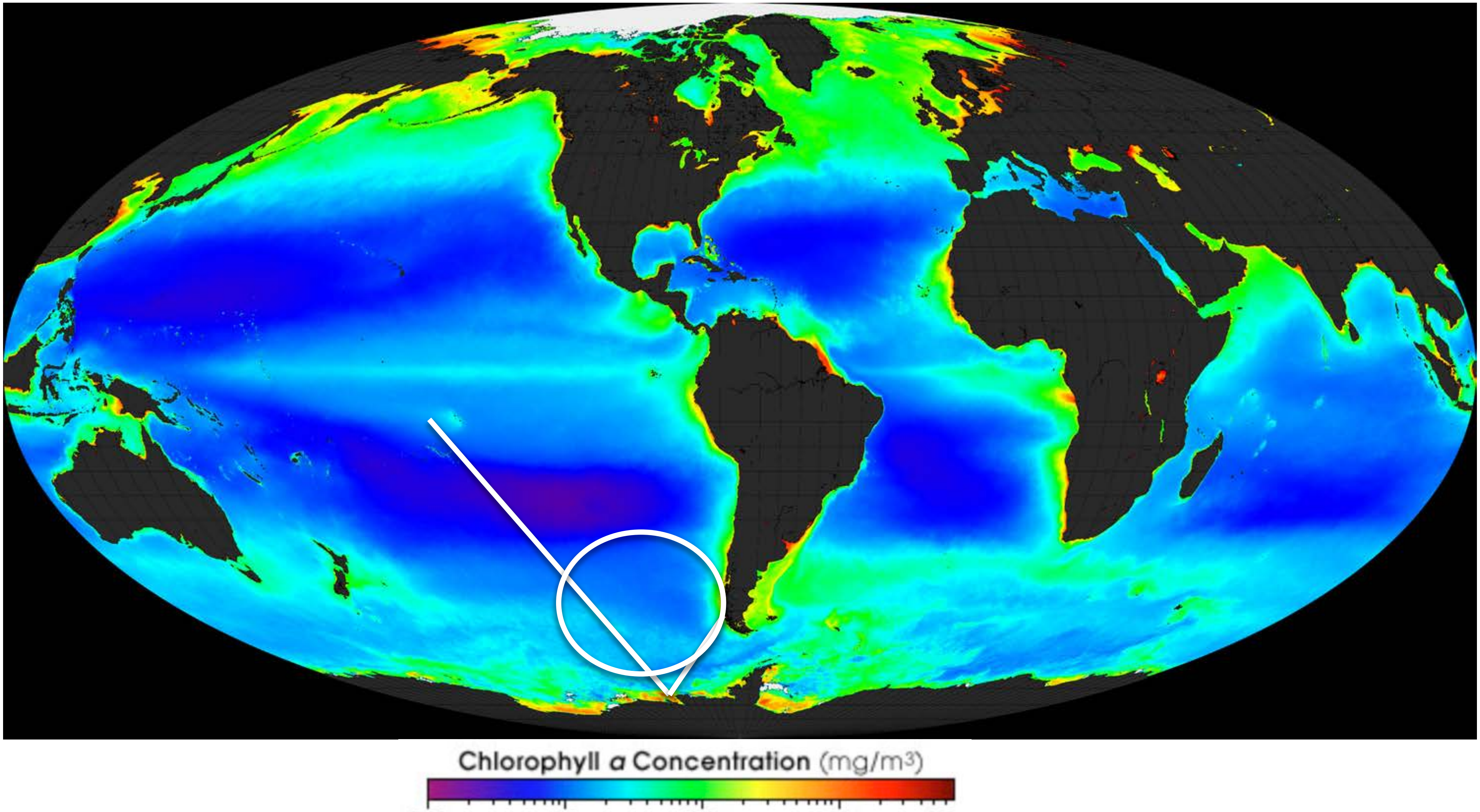
SE Pacific Low Chlorophyll – Why?

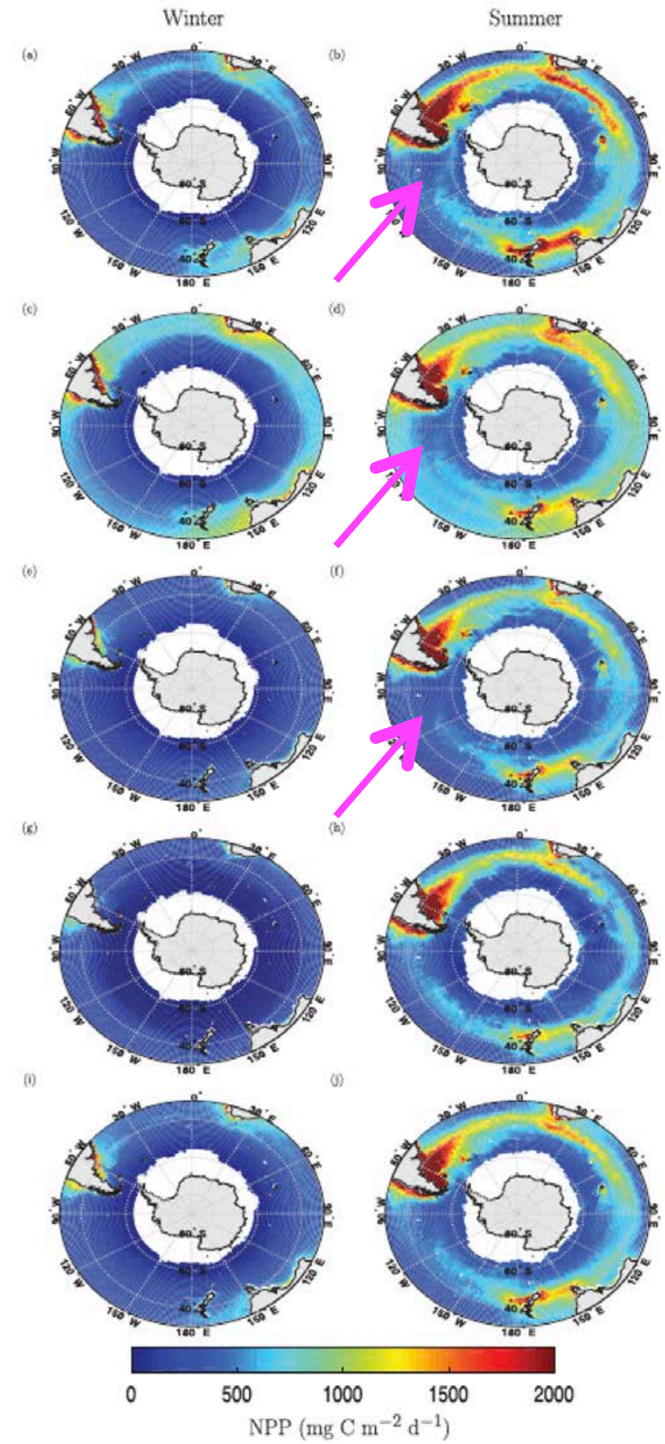


https://earthobservatory.nasa.gov/IOTD/view.php?id=4097

SE Pacific Low Chlorophyll represented in different NPP models

Winter (left) and summer (right) NPP

From Arteaga et al., JGR-O, 2018



SE Pacific Low Chlorophyll represented in different NPP models

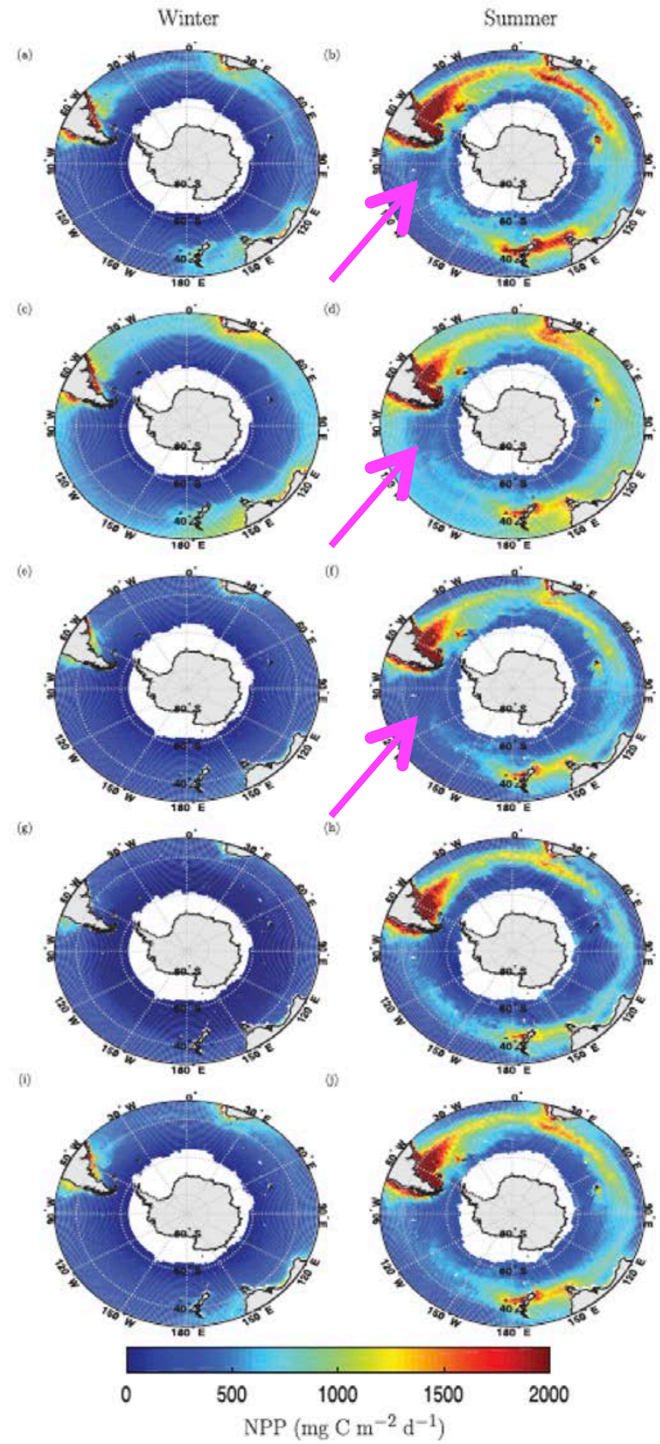
Winter (left) and summer (right) NPP

From Arteaga et al., JGR-O, 2018

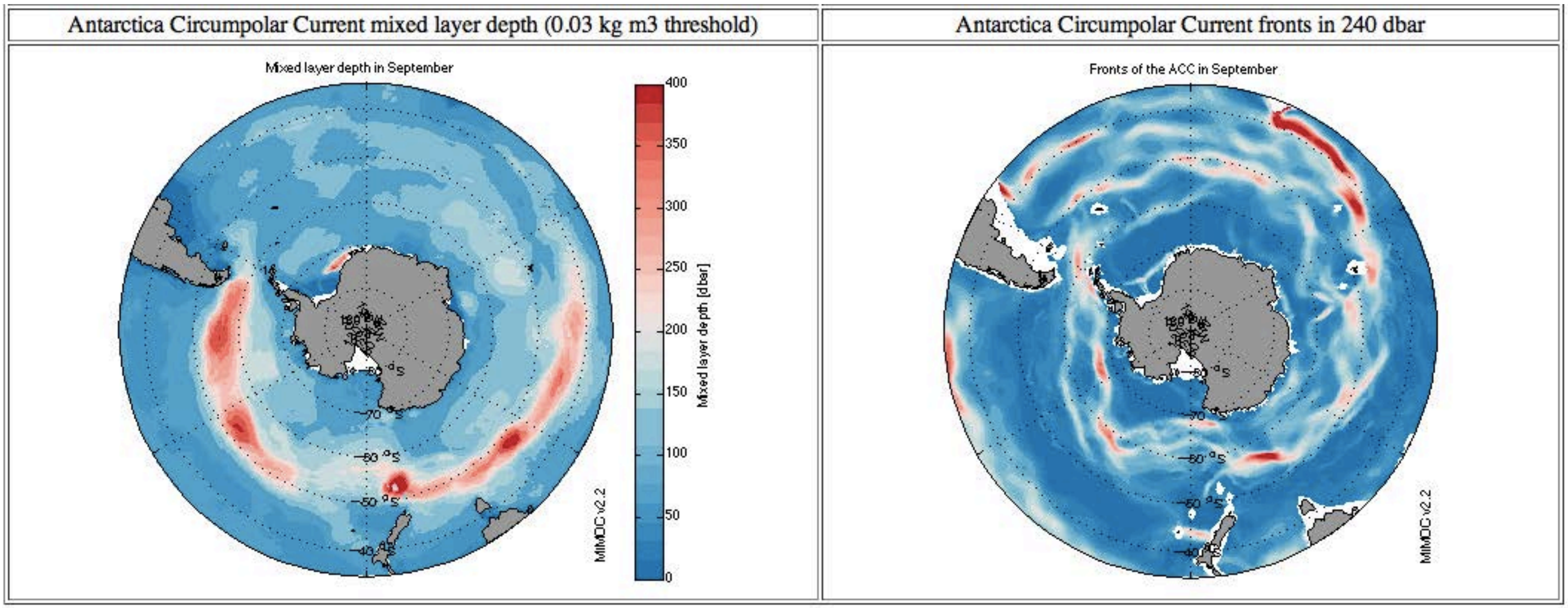
Why?

Low Fe supply?

Deep mixed layers?

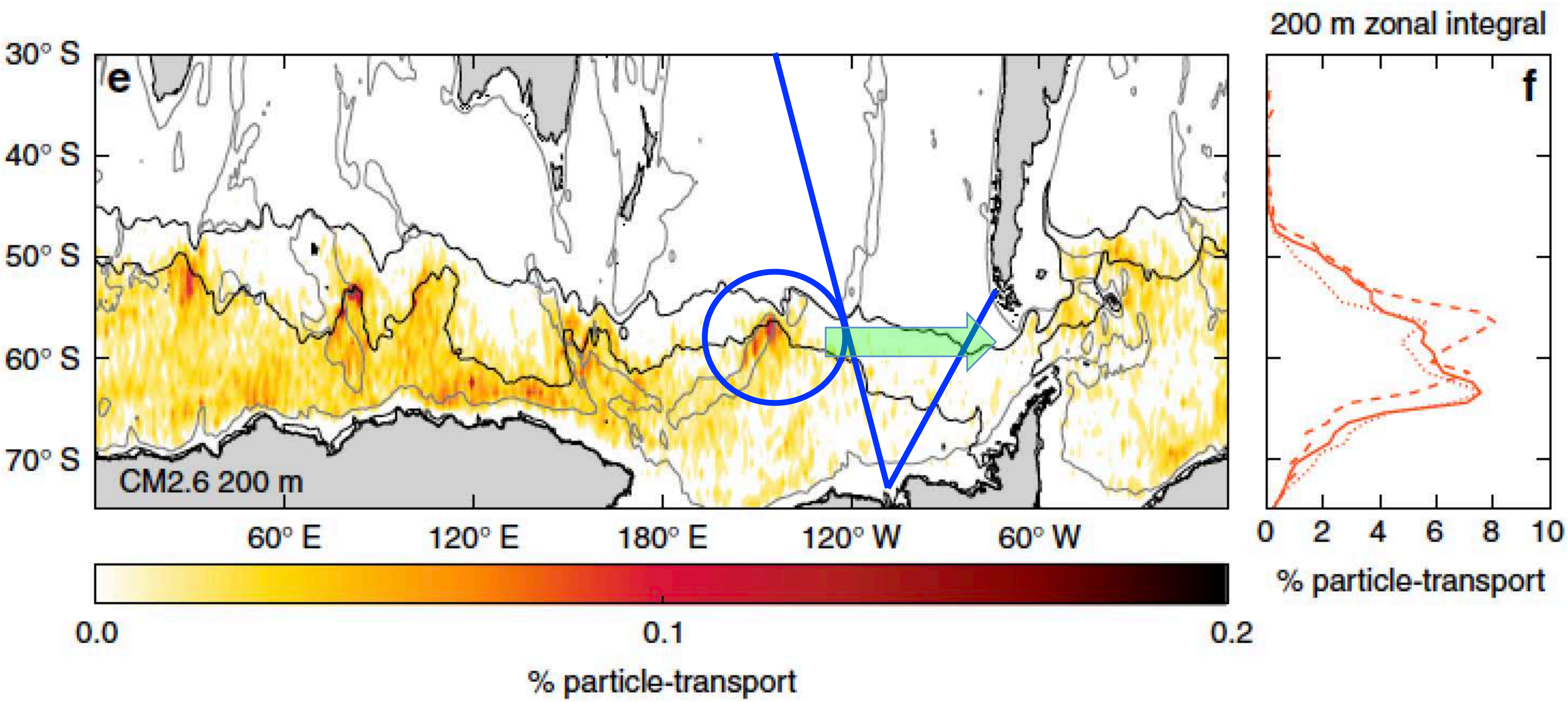


SE Pacific – Deep Winter Mixed Layers



But MLD in summer seems not to be exceptional.
Snapshot from monthly animation at:
https://www.pmel.noaa.gov/mimoc/mimoc_gallery.html

Eddy-driven upwelling hot-spots associated with topography



Locations where particles released in deep water at 30°S upwell across 200 m.
Upwelling is concentrated in 5 regions of topography
GP17 will sample at 2 locations downstream of PAR hot spot − Fe gradient?

Tamsitt et al., 2017

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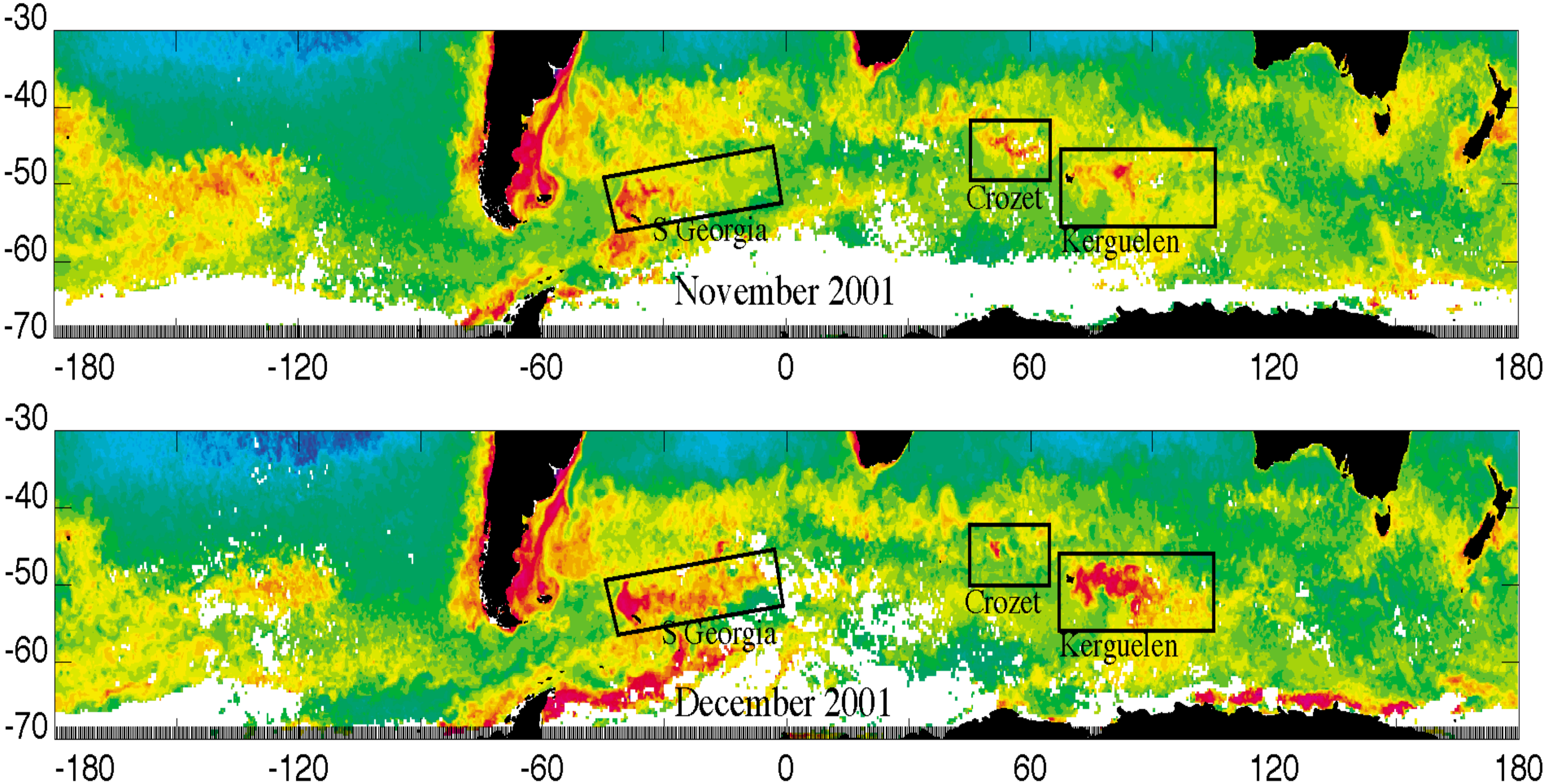
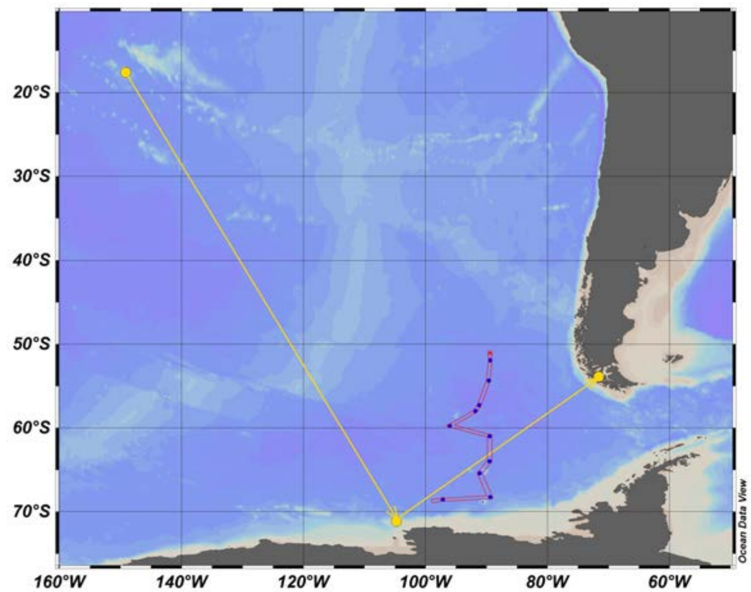
High biomass in some areas suggest benthic source of iron stimulating phytoplankton growth



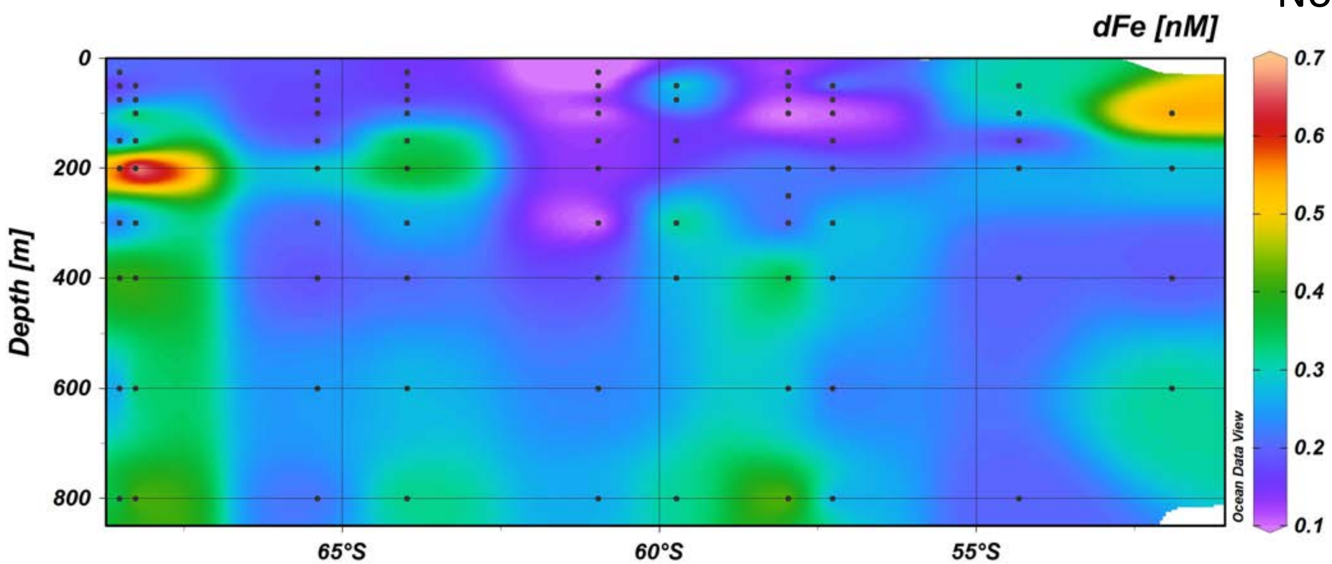
SeaWiFS Images prepared for CROZEX Program
Courtesy of Raymond Pollard SOC

South-to-North section of dissolved Fe near 90°W (in red on map) from de Baar et al. (1999)



South

North

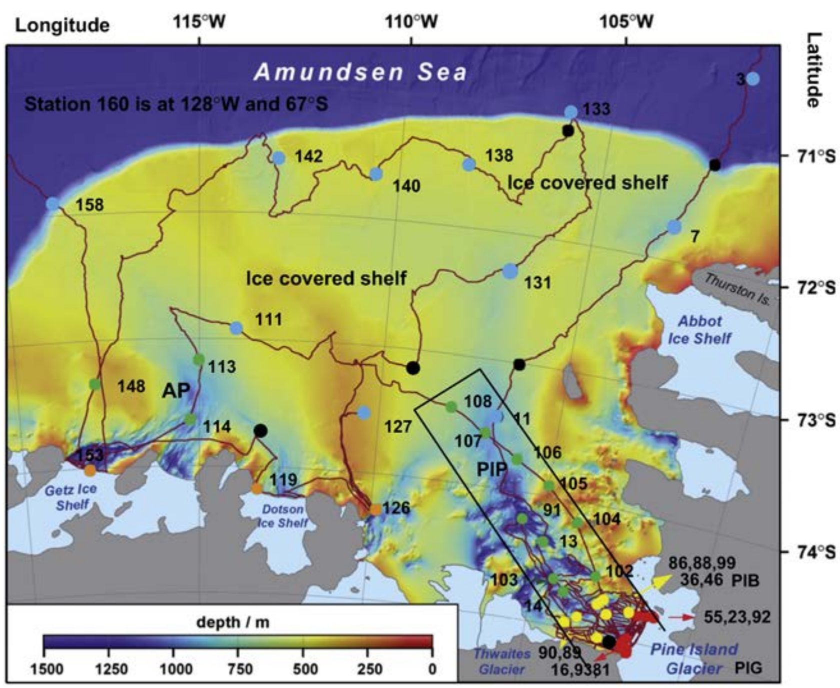


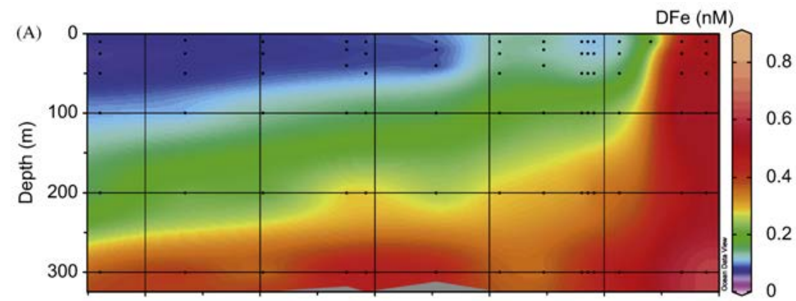
Amundsen sea summary from Pete Sedwick

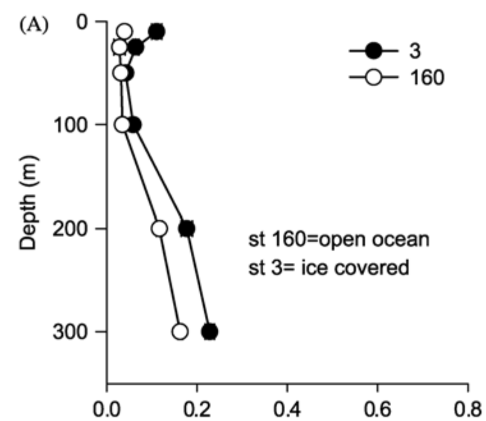
Dissolved Fe data from Pine Island Polynya (Gerringa et al., 2012) and GPpr03 cruise report

North South

North-to-South DFe section along box in map





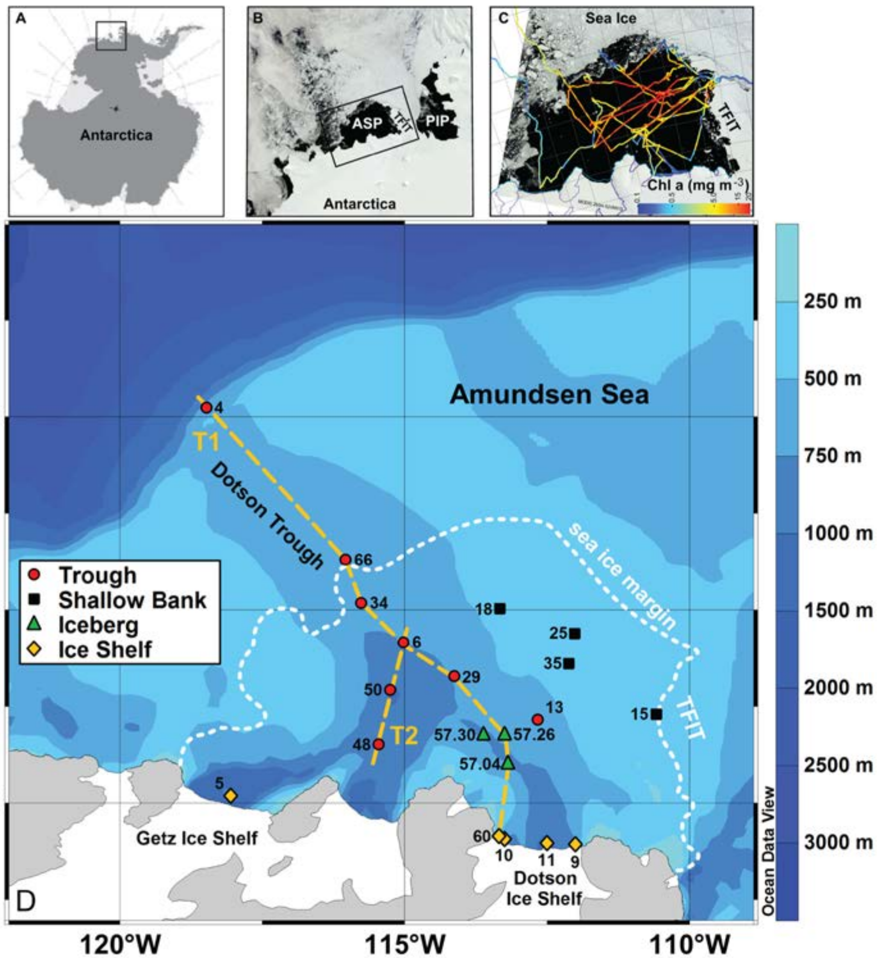


North-to-South DFe section along box in map

DFe profiles from Stn 3 (see map) and Stn 160 (in ACC near 66°30'S, 128°W)

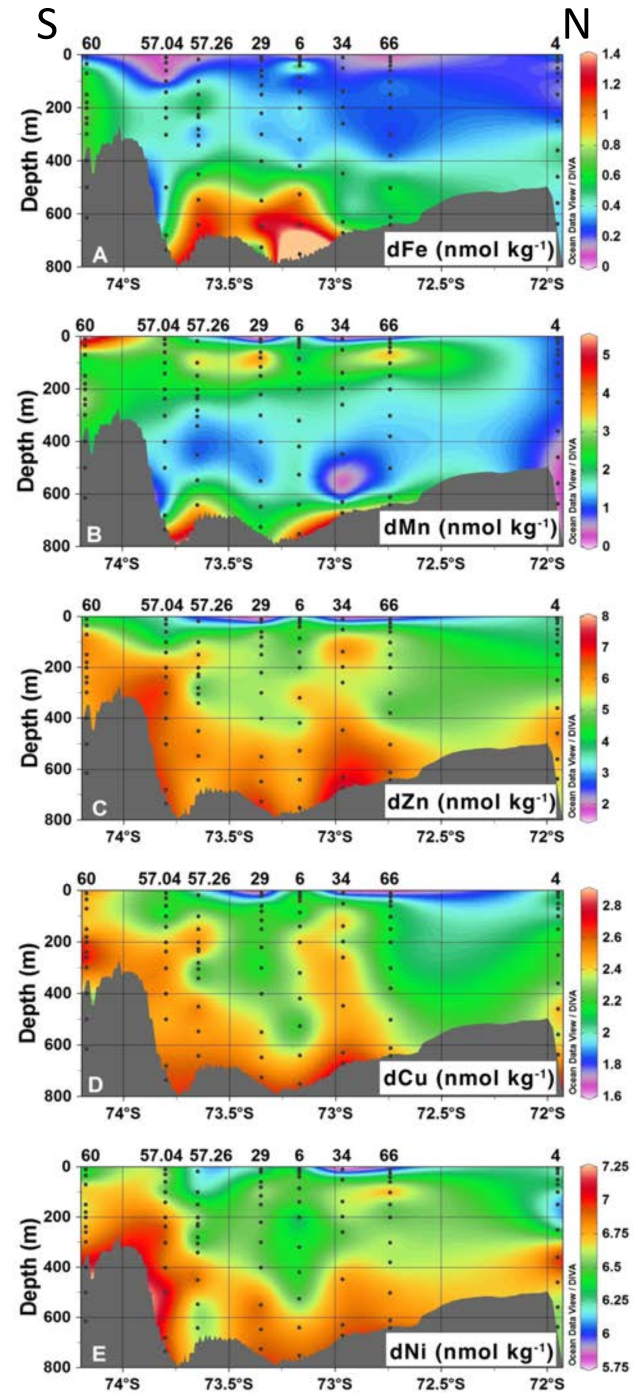
Amundsen sea summary from Pete Sedwick

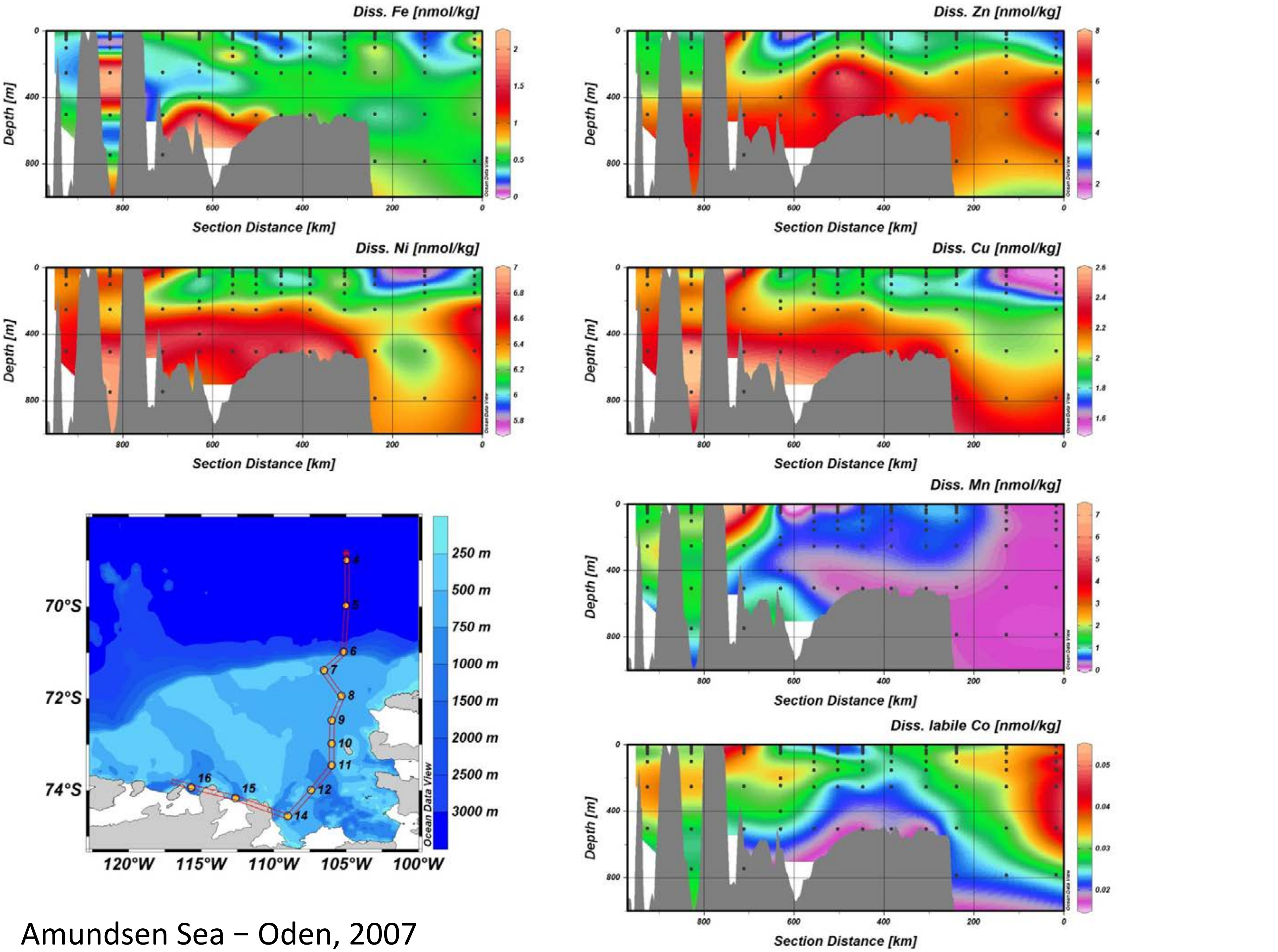
Dissolved trace metal data from Amundsen Sea Polynya (Sherrell et al., 2015) – Shelf sediment and ice shelf metal sources.



North-to-South DFe section along box in map
Does not extend beyond shelf break.

Amundsen sea summary from Pete Sedwick

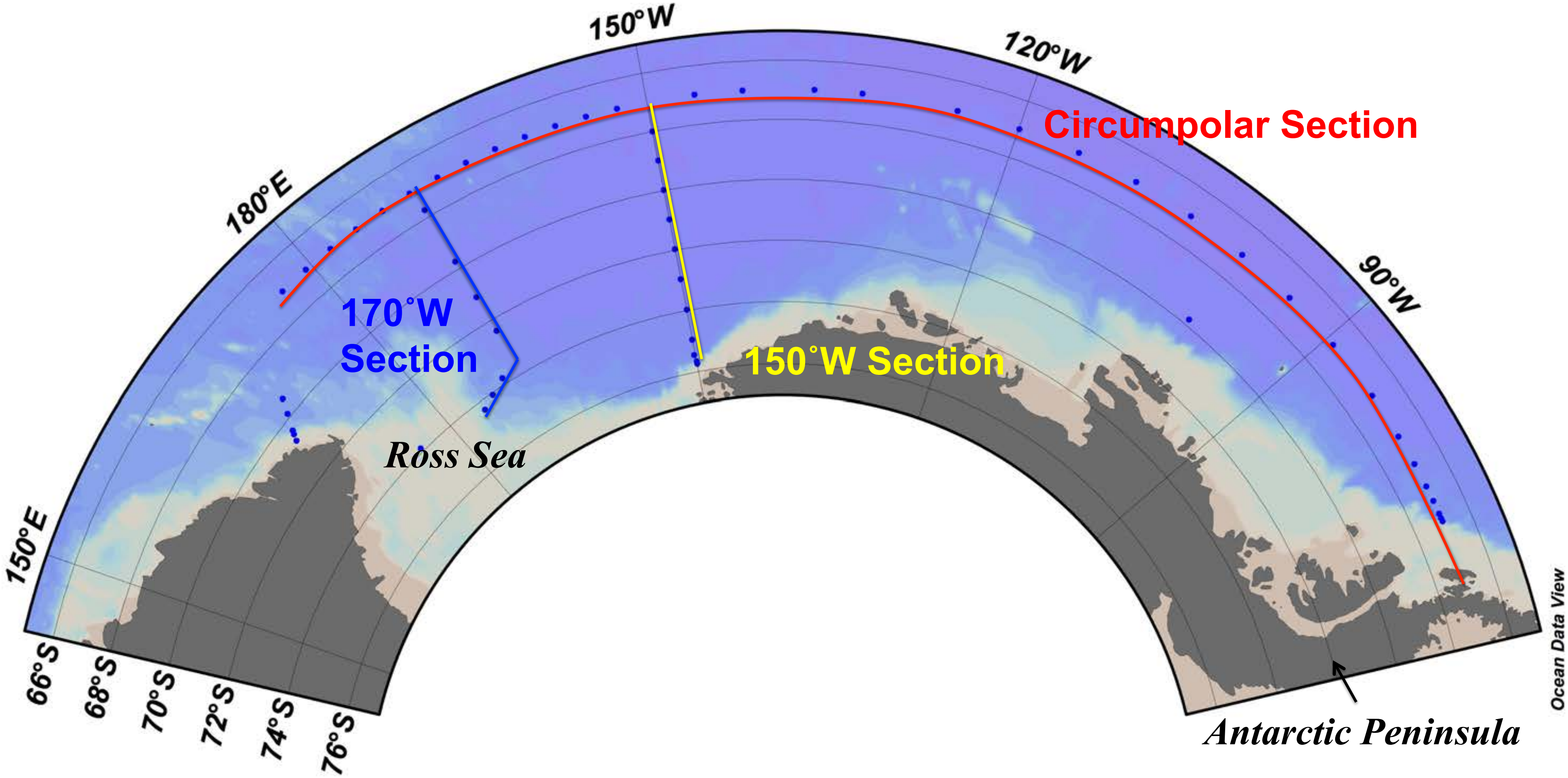




Amundsen Sea − Oden, 2007

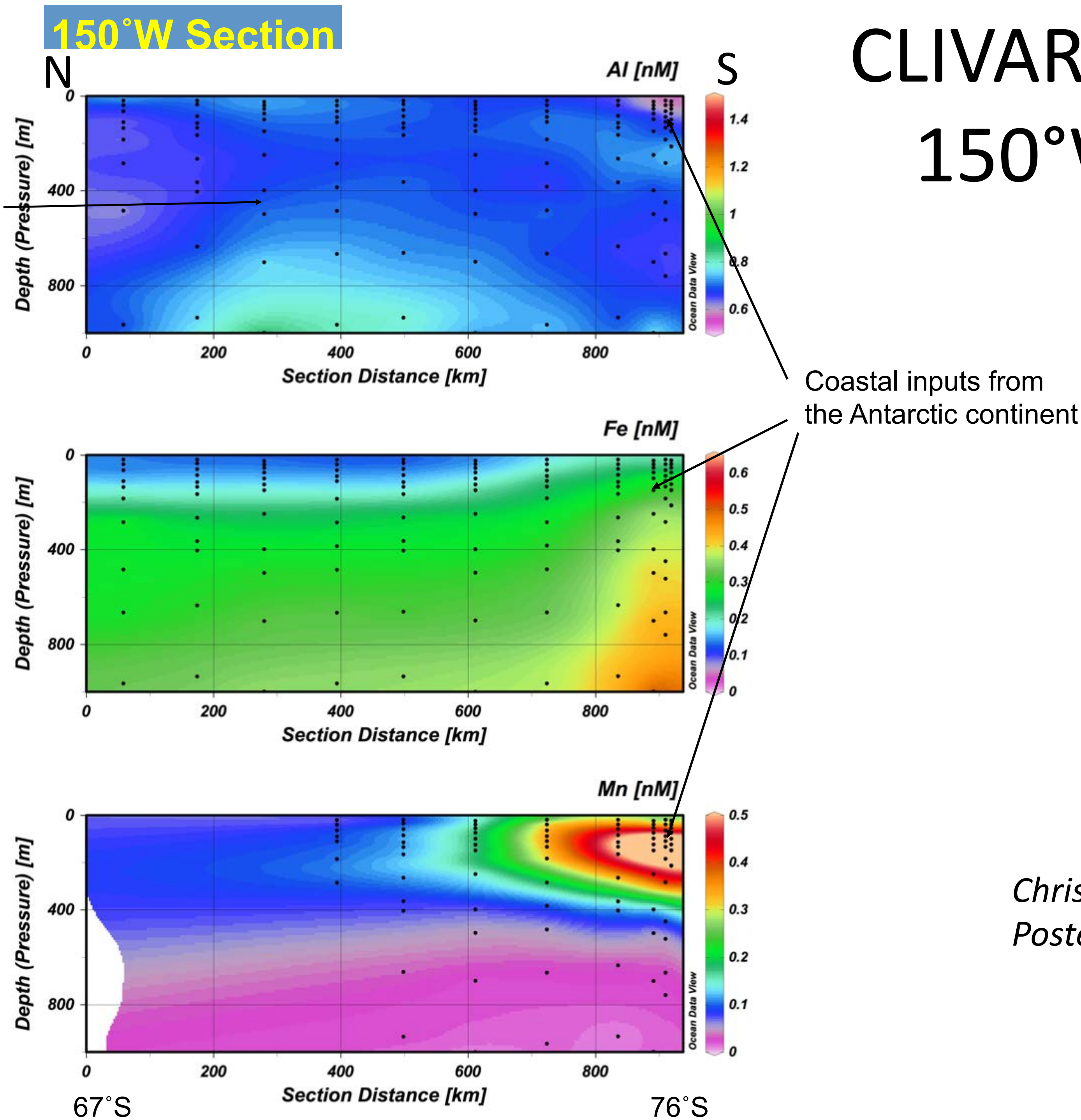
High TM concentrations (except Mn) extend beyond the shelf break - *Sherrell unpublished*

CLIVAR SP4 - 2011



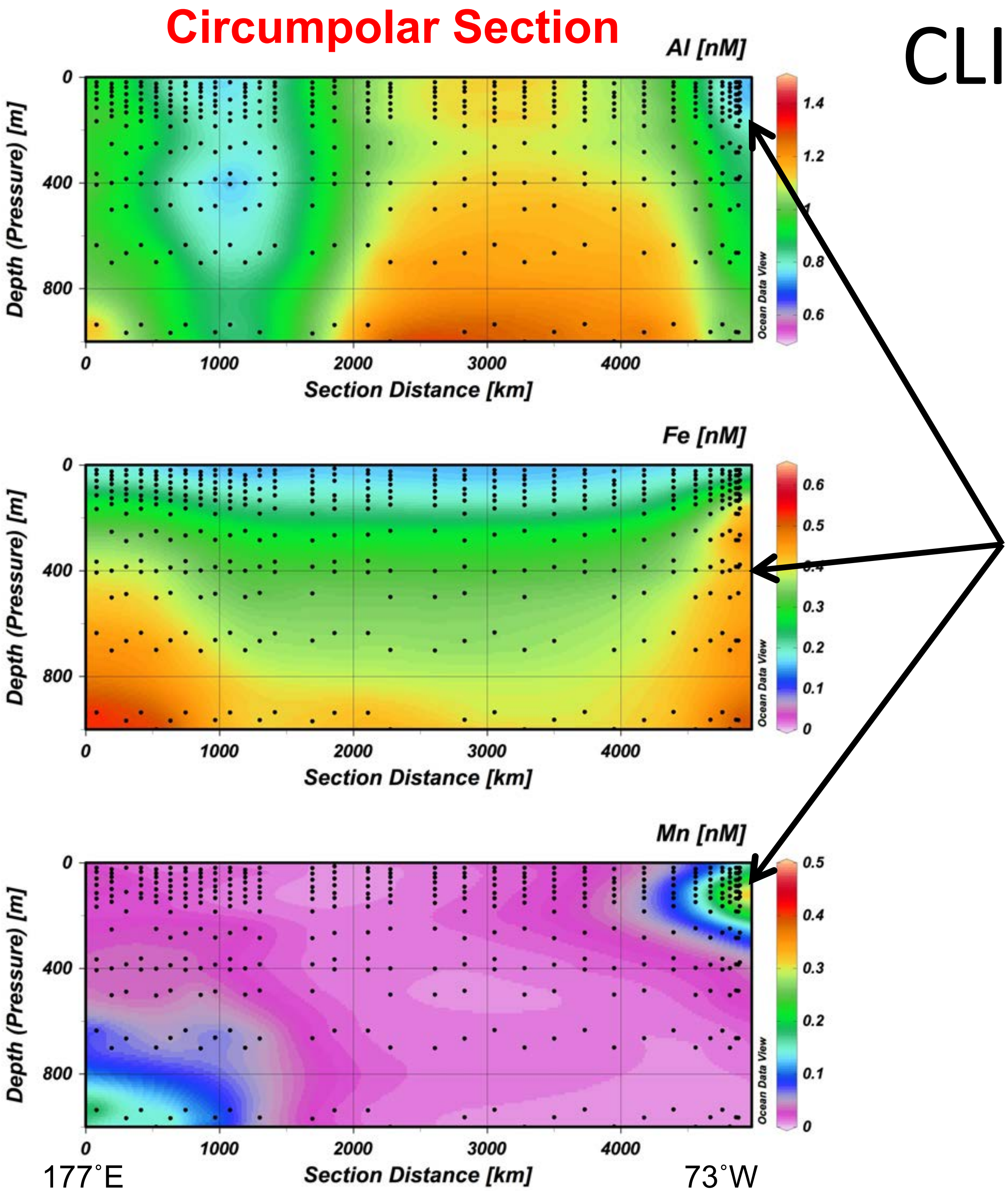
Chris Measures – unpublished data, figures from Poster at 2012 OSM

CLIVAR SP4 – 2011
150°W Section



Chris Measures – unpublished, Poster at 2012 OSM

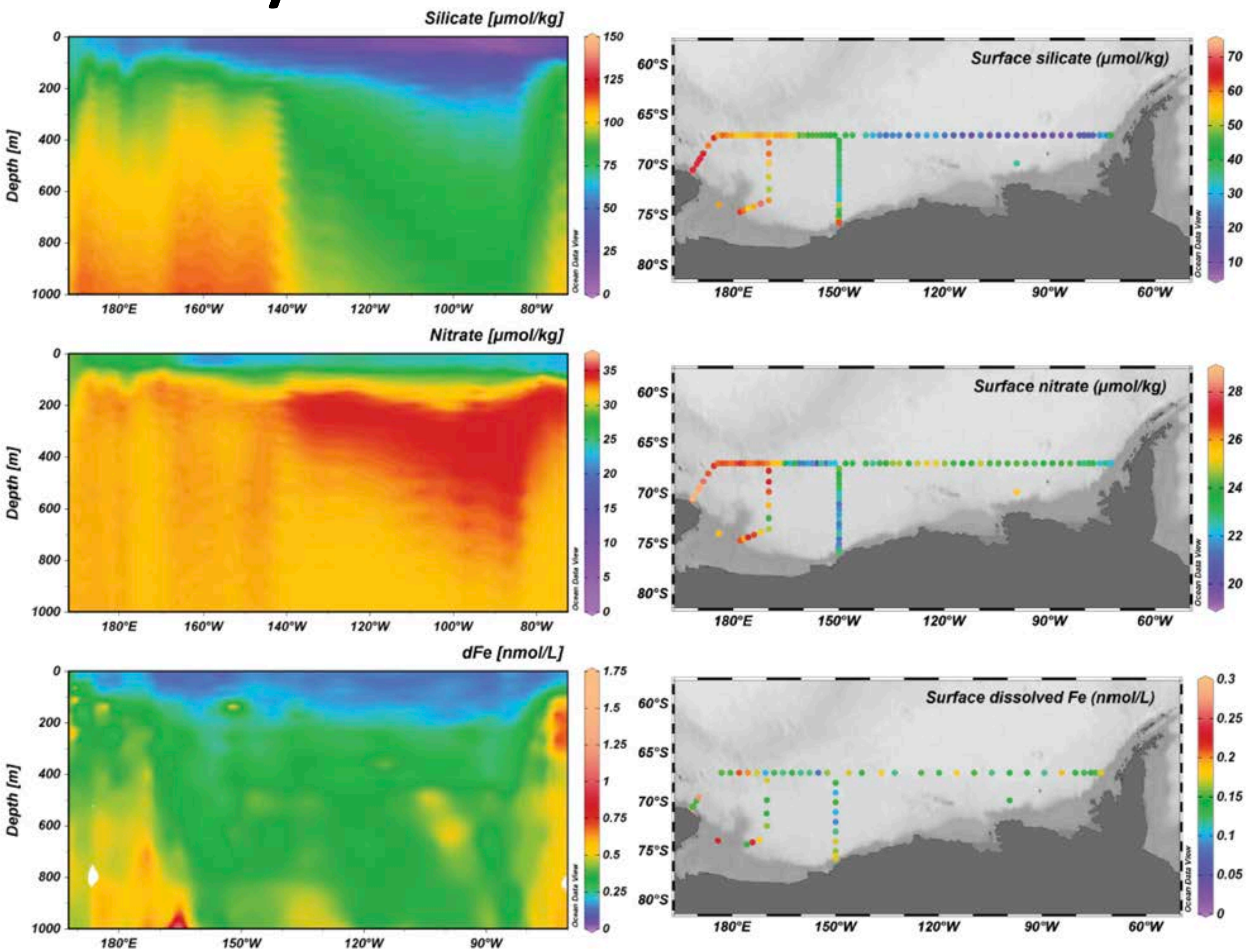
CLIVAR SP4 – 2011 Circumpolar Section



Coastal inputs of Fe and Mn from Antarctic Peninsula

Chris Measures – unpublished, Poster at 2012 OSM

East – West gradients in macronutrients May also influence diatom productivity



High NO_3 and low Si in the east;
Uniformly low Fe except near margins

Nowotarski, Morton, Neeley, Hatta, Landing, Measures, Grand - Poster
Complements of Pete Morton

Motivation for the GP17 Section

1) Ultra-oligotrophic South Pacific Gyre

Low dust, productivity, particles – impact on scavenging?

Record deep DCM – impact on colloid cycling?

2) Southern Ocean regulation of global biological pump efficiency

Upwelling hot spots – source of Fe?

Dust vs. upwelling sources of micronutrients

SE Pacific low biomass – control by Fe, MLD, other?

3) Dispersal of continental sources of micronutrients

Basal melt

Subglacial meltwater runoff

Extent of signal

- TM from coastal sources extend off the shelf.
- How far, and to what extent do they contribute micronutrients to the broader Southern Ocean?
- Provenance and rate tracers are needed.

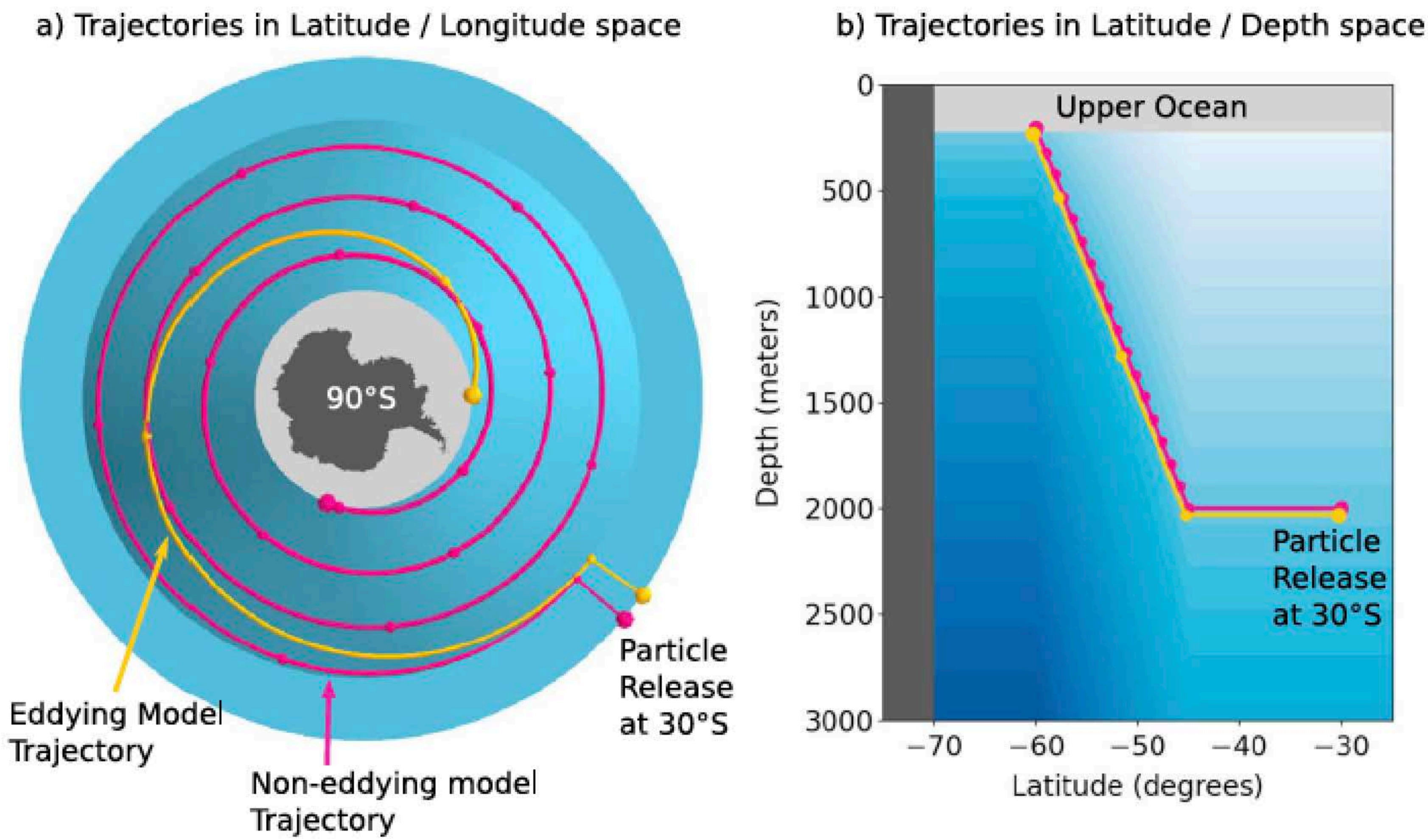
Challenges - Uncertainty about Sea Ice

Motivation for the GP17 Section

1) Ultra-oligotrophic South Pacific Gyre
   Low dust, productivity, particles – impact on scavenging?
   Record deep DCM – impact on colloid cycling?
2) Southern Ocean regulation of global biological pump efficiency
   Upwelling hot spots – source of Fe?
   Dust vs. upwelling sources of micronutrients
   SE Pacific low biomass – control by Fe, MLD, other?
3) Dispersal of continental sources of micronutrients
   Basal melt
   Subglacial meltwater runoff
   Extent of signal
4) Outflow of Fe carried by Pacific Deep Water
   Large Fe sources from margins and ridges
   How much reaches Southern Ocean?
   Stabilization of Fe (and other TEIs) by ligands

Can’t rely on models for Fe supply from deep water to SoOcean euphotic zone

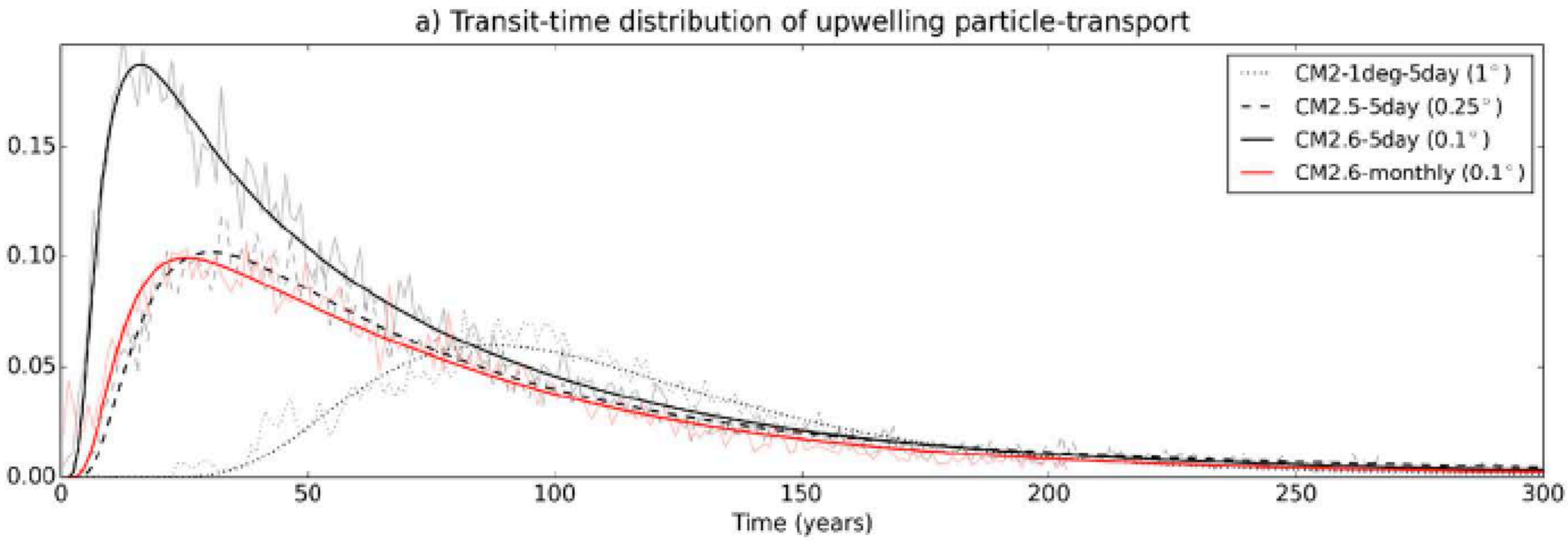
Upwelling trajectory depends on model resolution



Magenta = 1° resolution; Yellow = 0.1° Resolution

Drake et al., GRL, 2018

Upwelling transit time to 300-m isobath depends on model resolution

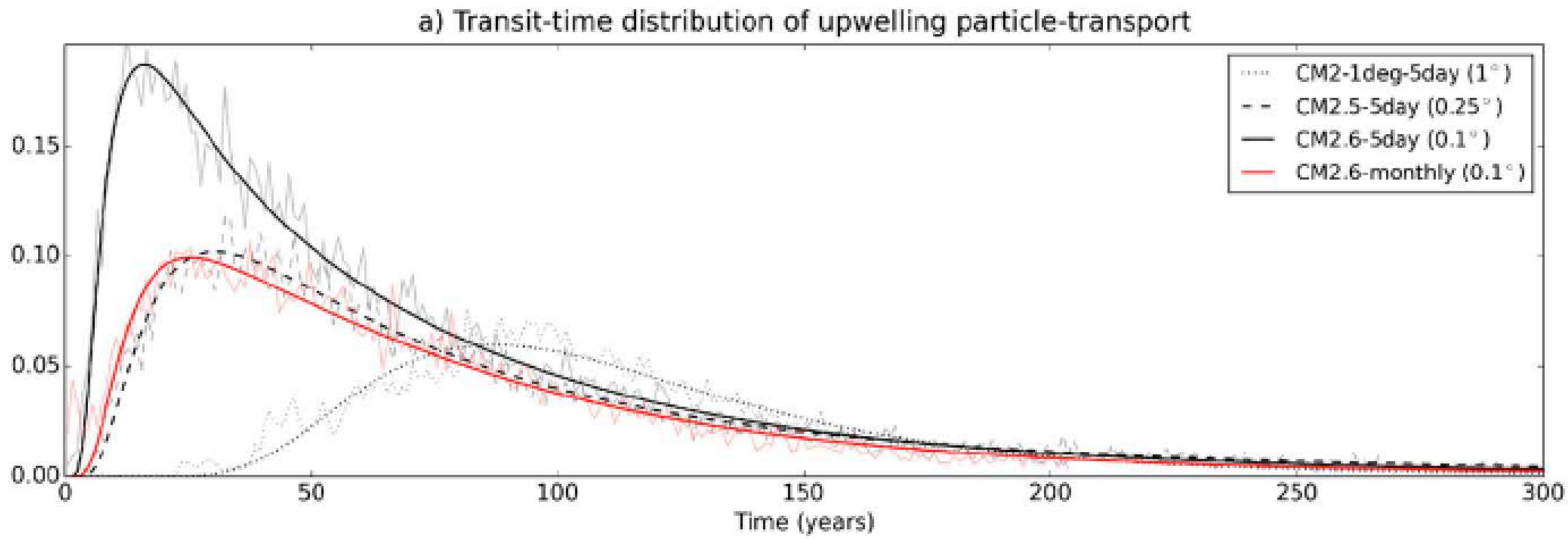


Lagrangian timescales of CDW upwelling decrease from 87 years to 31 years to 17 years as the ocean resolution is refined from 1° to 0.25◦ to 0.1°.

Drake et al., GRL, 2018;

Similar results in Tamsitt et al.,. 2017: " The timescale for half of the deep water to upwell from 30° S to the mixed layer is ~60–90 years."

Upwelling transit time to 300-m isobath depends on model resolution



Lagrangian timescales of CDW upwelling decrease from 87 years to 31 years to 17 years as the ocean resolution is refined from 1° to 0.25◦ to 0.1°.

The timescale upwelling is comparable to the residence time of dFe in the deep ocean.

With large uncertainties in both transit times and residence times one needs empirical constraints on the supply of dFe to the Southern Ocean euphotic zone by upwelling.

GP17 Plausible Logistics – requires Palmer