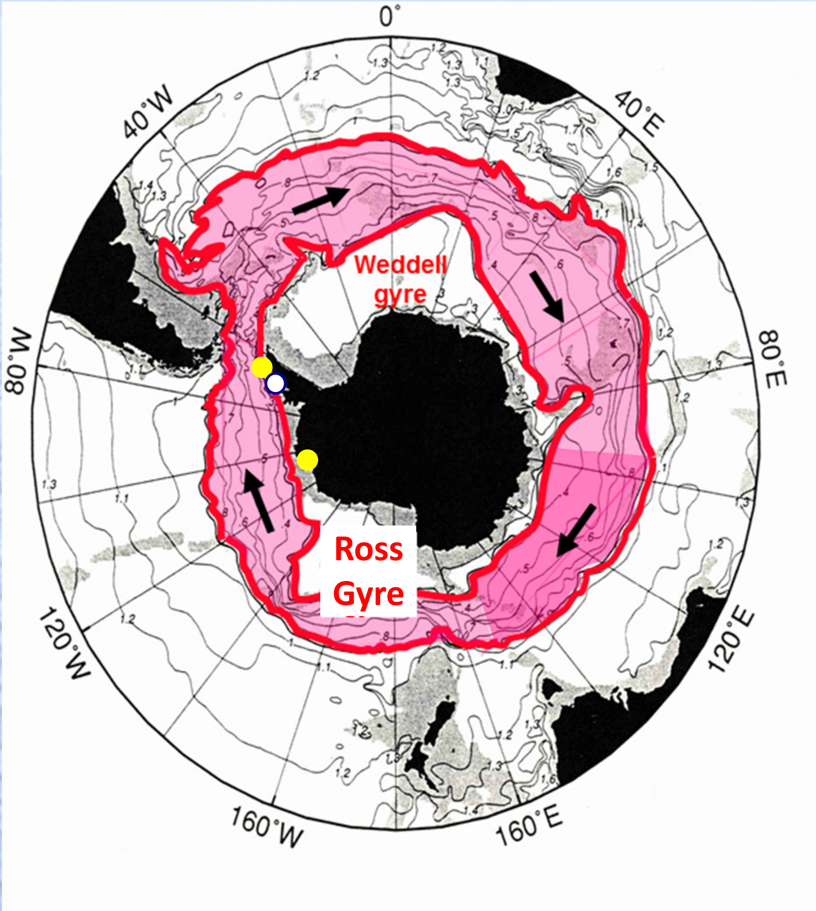
Export fluxes, net and new production in West Antarctica

H. Ducklow & M. Stukel, LDEO

OCB-2013



Outline:

Overview of study region, climate warming, diatom bloom-dominated ecosystem (but changing)

Export production (sediment traps, Thorium-234)

Gross Oxygen Production ($^{17}\Delta$-GOP) and **Net Community Production** (O_2-Ar)

New Production ($^{15}NO_3$ uptake; NO3 drawdown, Iodide production)

Acknowledgements

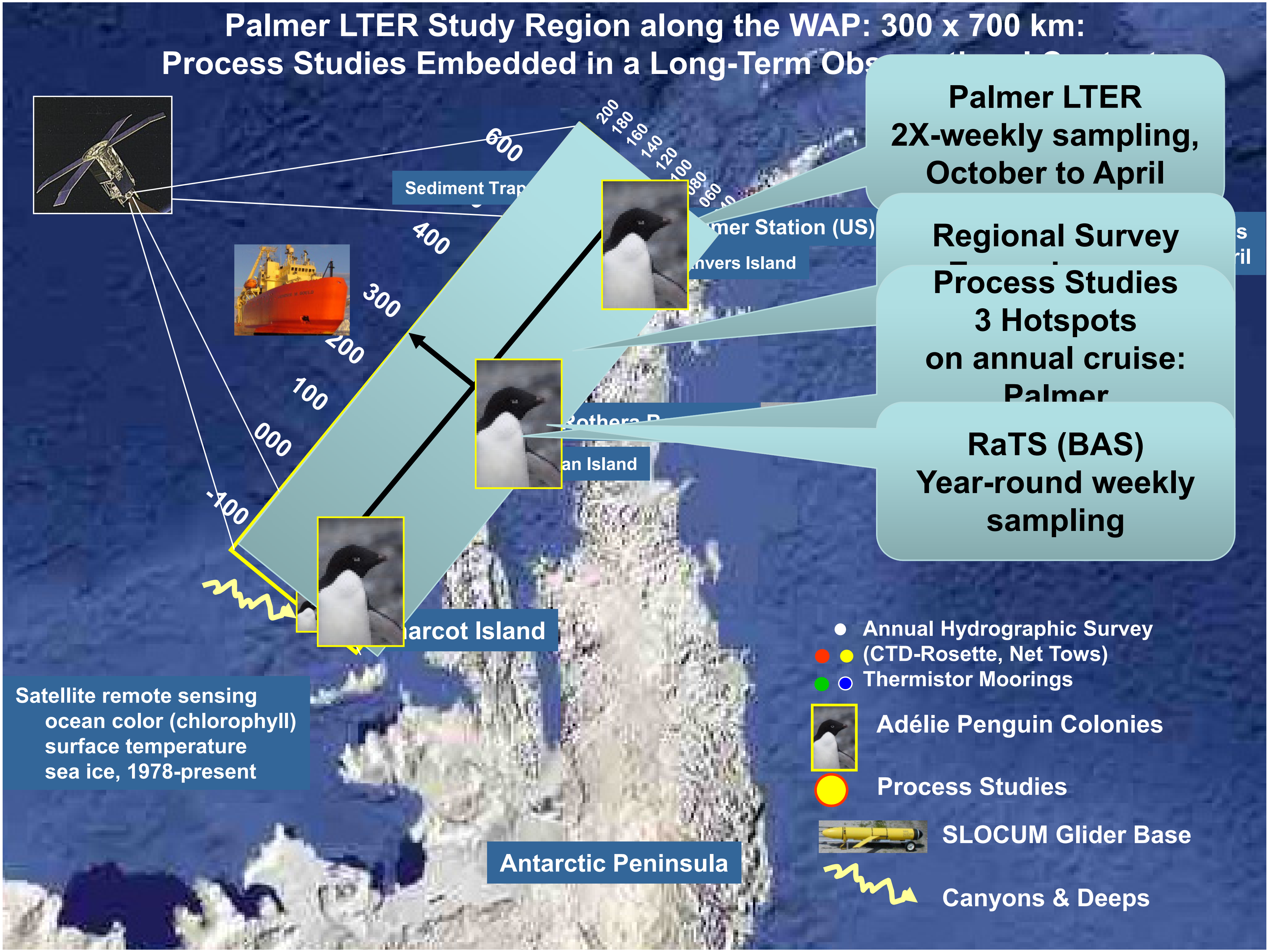
Traps: Anton Post, Matt Erickson (MBL)
Thorium-234: Ken Buesseler, Stephanie Owens (WHOI), Mike Stukel (LDEO).

$^{17}\Delta$-GOP, O_2-Ar: Kuan Huang, Mike Bender (Princeton), Nicolas Cassar, Rachel Eveleth, Bruce Barnett (Duke)

$^{15}NO_3$ uptake: Keith Weston (UEA & BAS) et al. DSR1 75:52-66

Nitrate drawdown: Marco Pedulli (UMass)

Iodide production: Tim Jickells, Rosie Chance, Alex Baker (UEA)

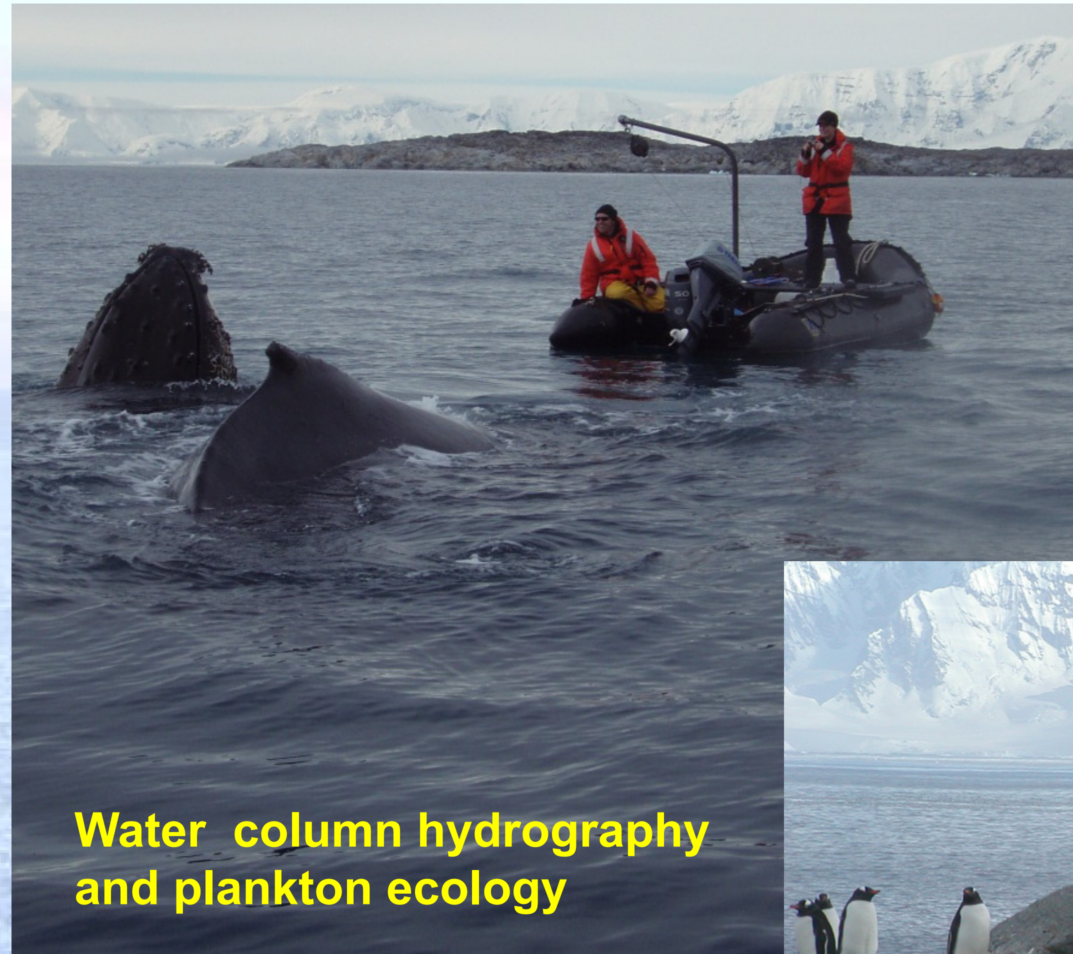

Palmer LTER Study Region along the WAP: 300 x 700 km:
Process Studies Embedded in a Long-Term Obs
Palmer LTER
2X-weekly sampling,
October to April
Regional Survey
Process Studies
3 Hotspots
on annual cruise:
Palmer
RaTS (BAS)
Year-round weekly
sampling
Sediment Trap
600
400
300
200
100
000
-100
200
180
160
140
120
100
080
060
mer Station (US)
nvers Island
an Island
arcot Island
Satellite remote sensing
ocean color (chlorophyll)
surface temperature
sea ice, 1978-present
Antarctic Peninsula
Annual Hydrographic Survey
(CTD-Rosette, Net Tows)
Thermistor Moorings
Adélie Penguin Colonies
Process Studies
SLOCUM Glider Base
Canyons & Deeps

Palmer Station Antarctica (1968-present)
home of:
Palmer, Antarctica Long Term Ecological Research (LTER)
Project, 1990-2014

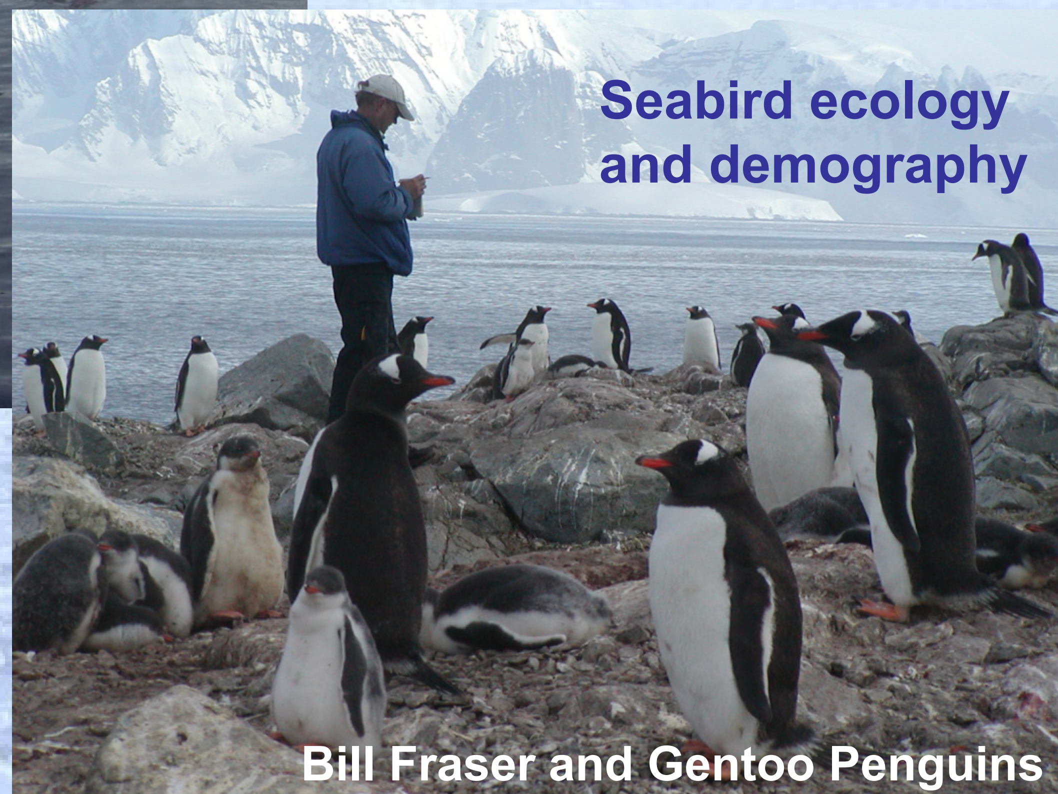
Sarah Laperriere, 17 October, 2012

open year-round, 45 people, reached almost only by sea

Local-scale science near Palmer Station Daily-weekly sampling Oct to April

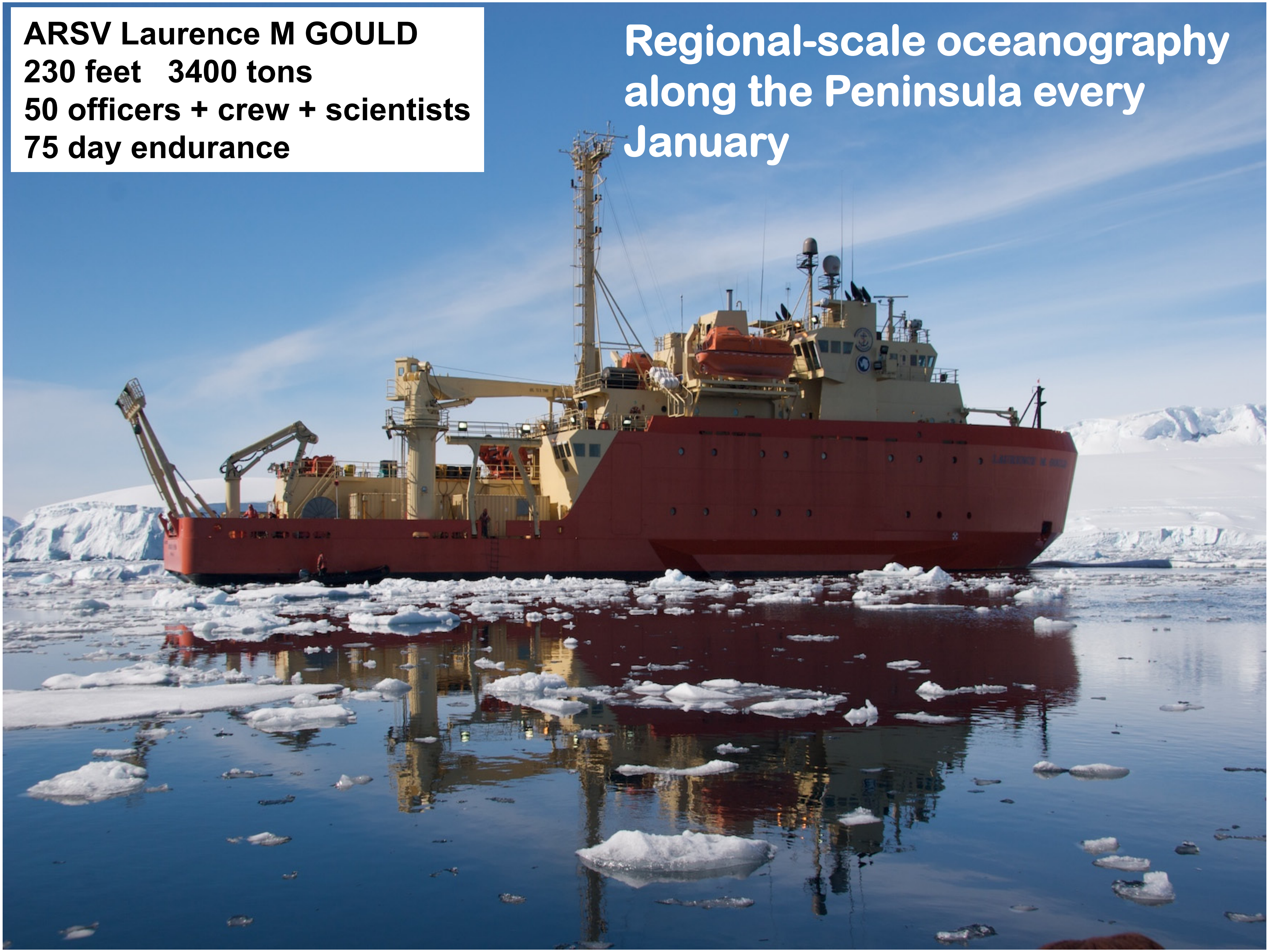


Water column hydrography and plankton ecology

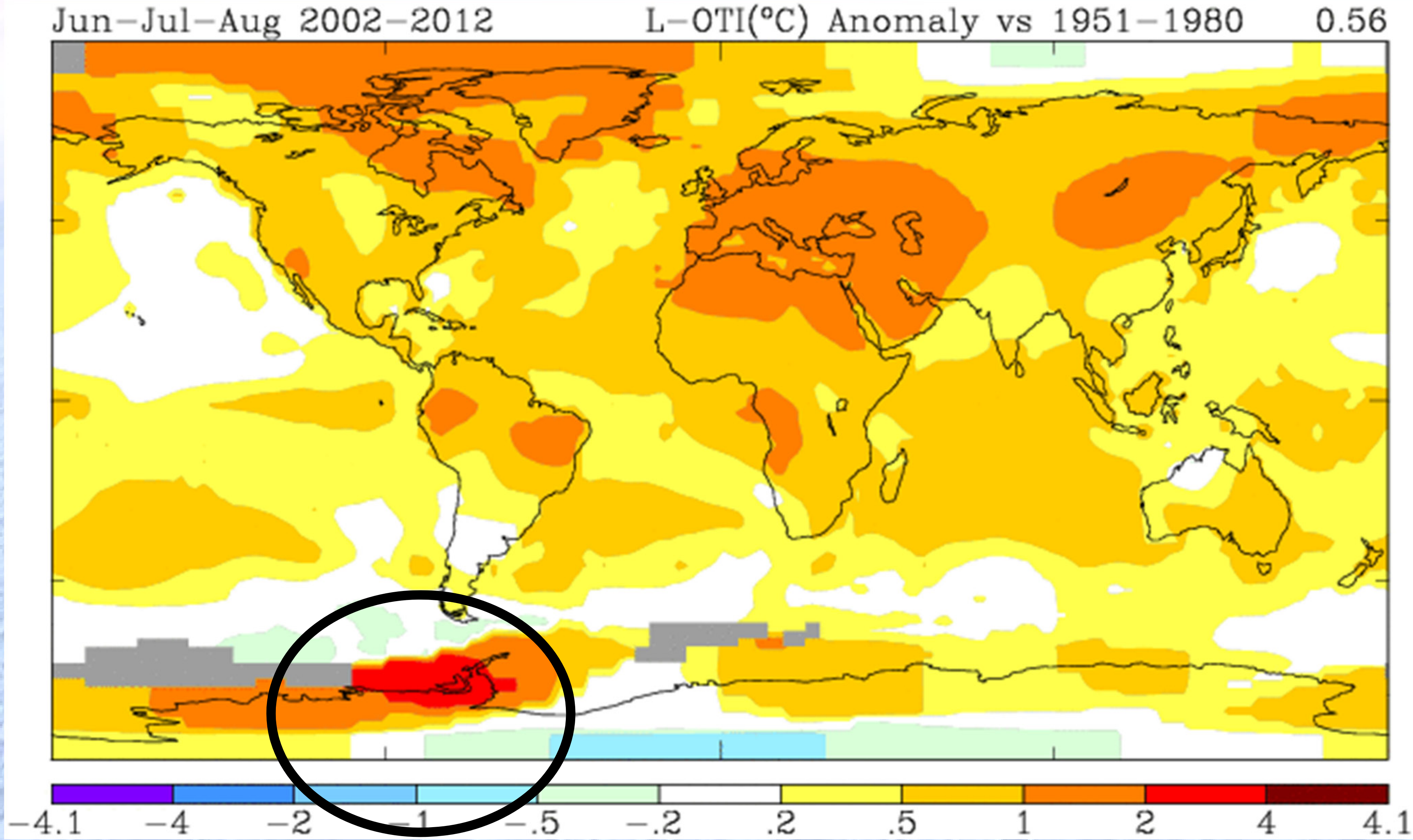


Seabird ecology and demography

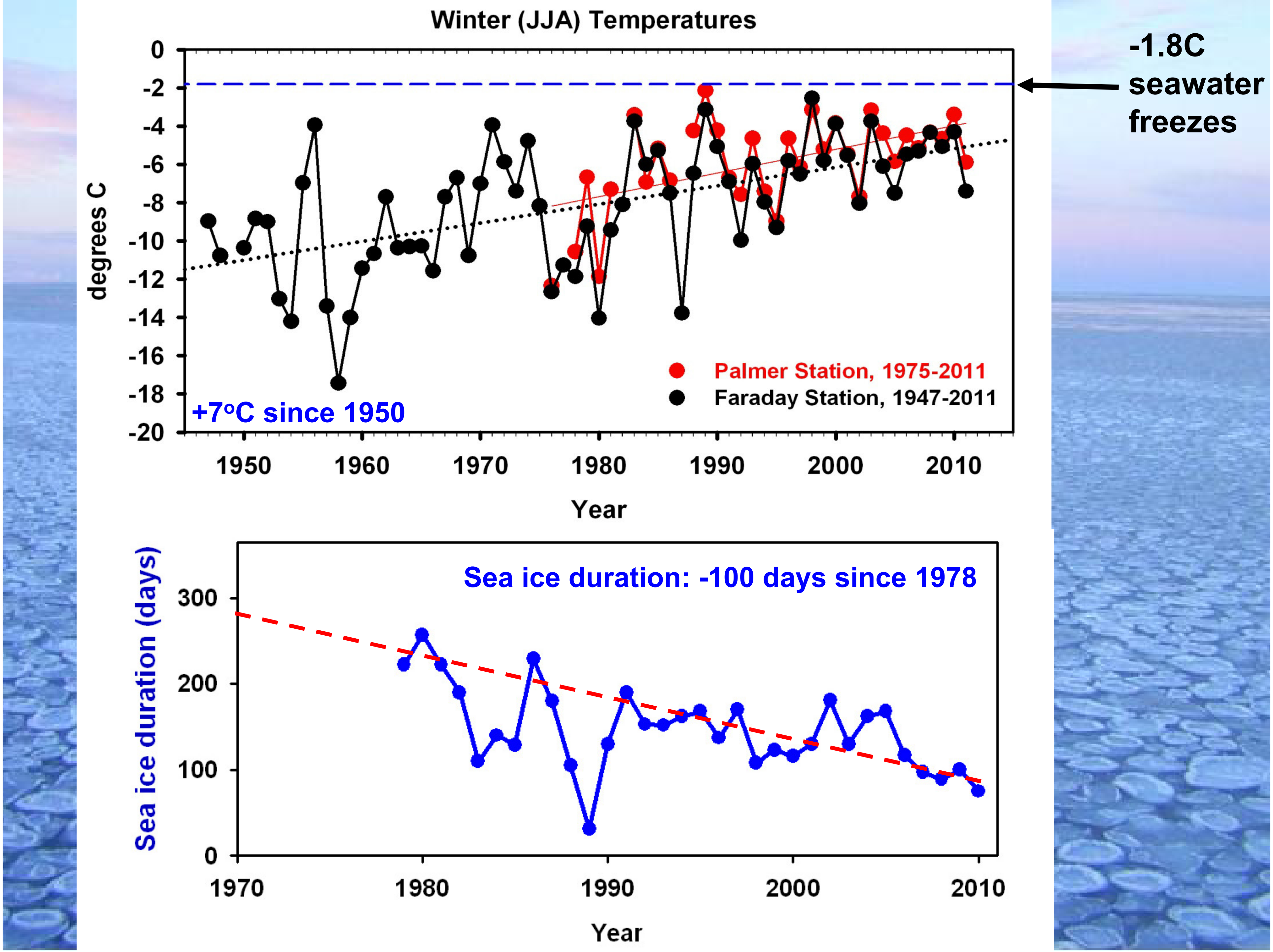
Bill Fraser and Gentoo Penguins


ARSV Laurence M GOULD
230 feet 3400 tons
50 officers + crew + scientists
75 day endurance
Regional-scale oceanography along the Peninsula every January

NASA GISS temperature anomalies June-July-August 2002-12

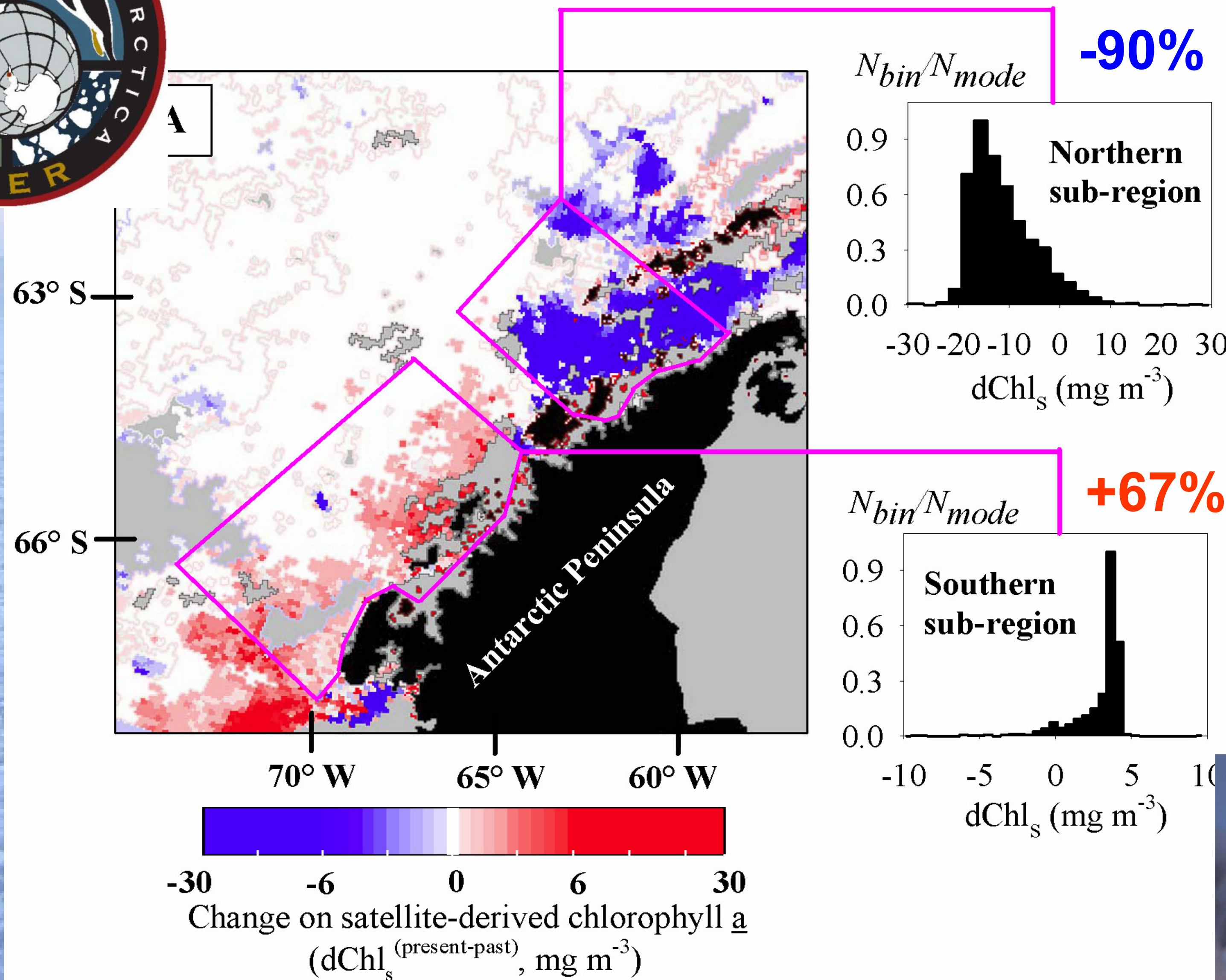


Degree C anomaly relative to JJA 1950-1980


Winter (JJA) Temperatures
-1.8C seawater freezes
degrees C
+7°C since 1950
Palmer Station, 1975-2011
Faraday Station, 1947-2011
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
1950
1960
1970
1980
1990
2000
2010
Year
Sea ice duration: -100 days since 1978
Sea ice duration (days)
300
200
100
0
1970
1980
1990
2000
2010
Year


69 South, 100 km from Charcot Island in Jan 2012: summer sea ice!
2 km inside ice edge: the original characteristic of polar ocean ecosystems before warming

Palmer LTER: Changes in phytoplankton (1978-86 to 1998-2006) in response to sea ice loss: CZCS to SeaWiFS

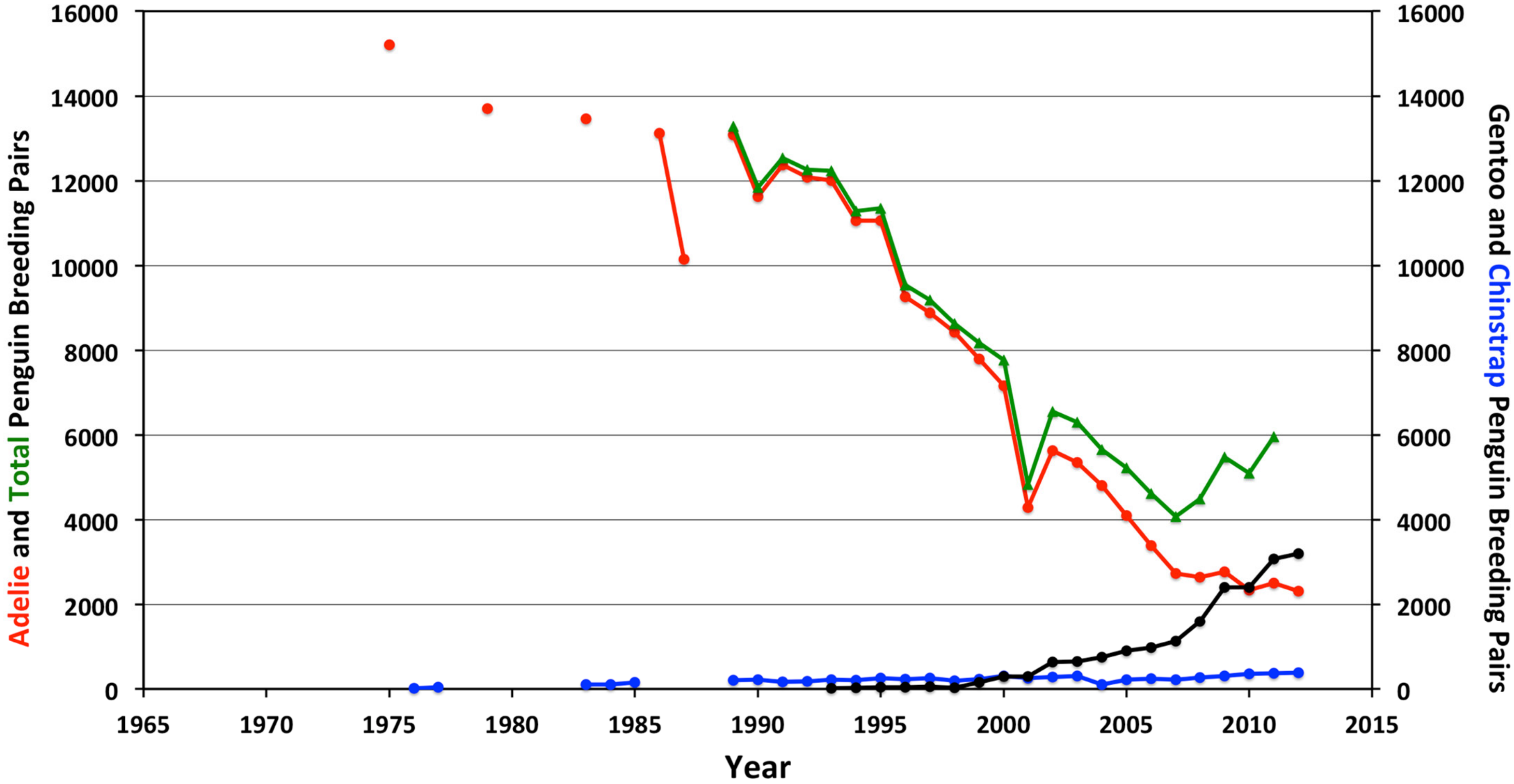


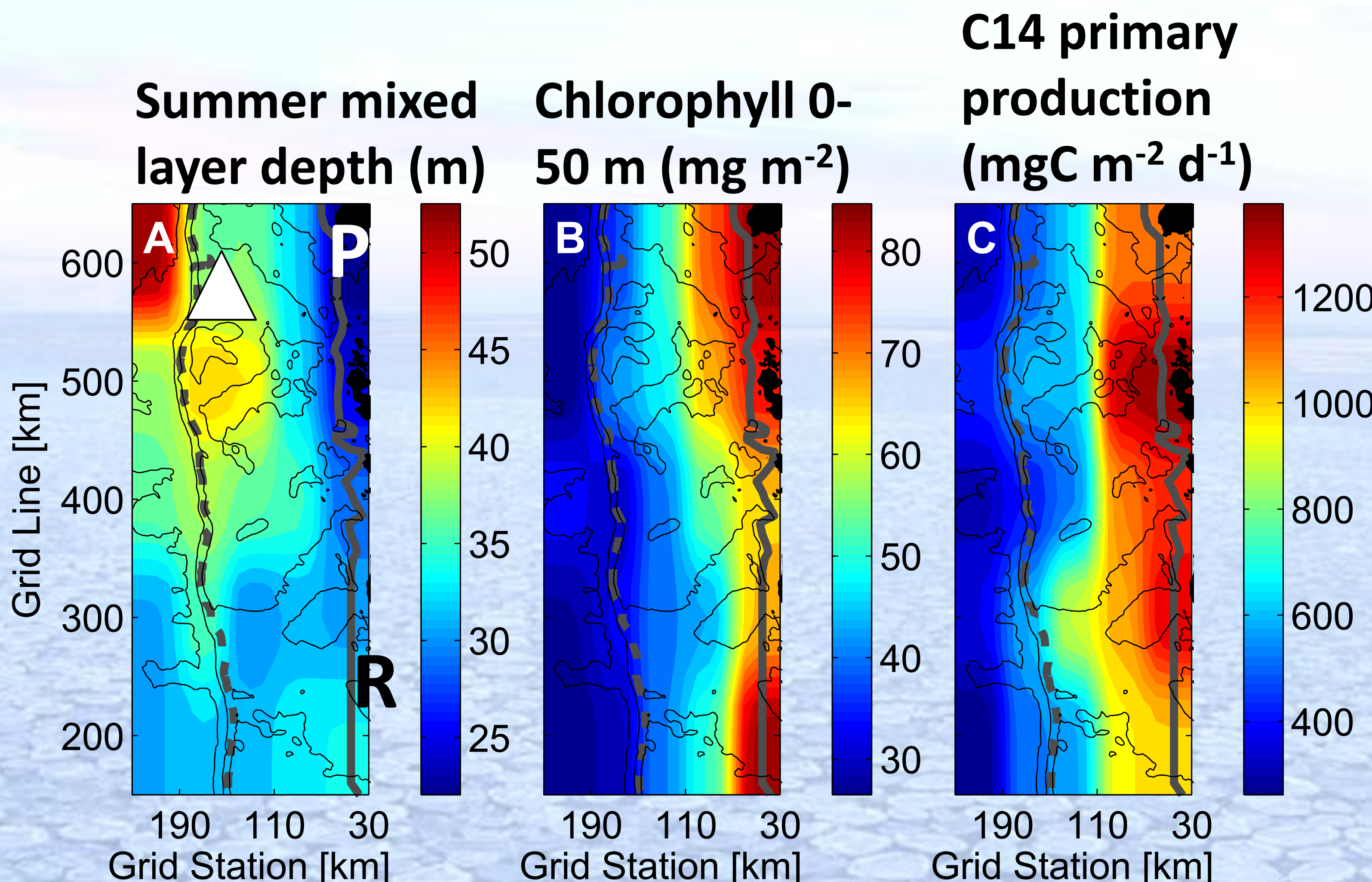
Montes-Hugo et al Science 2009

Palmer region penguin populations, 1975-2012

Adélie penguins: 80% decline (native, ice-obligate species)

Chinstrap & Gentoo penguins: new immigrants, now >50% of total

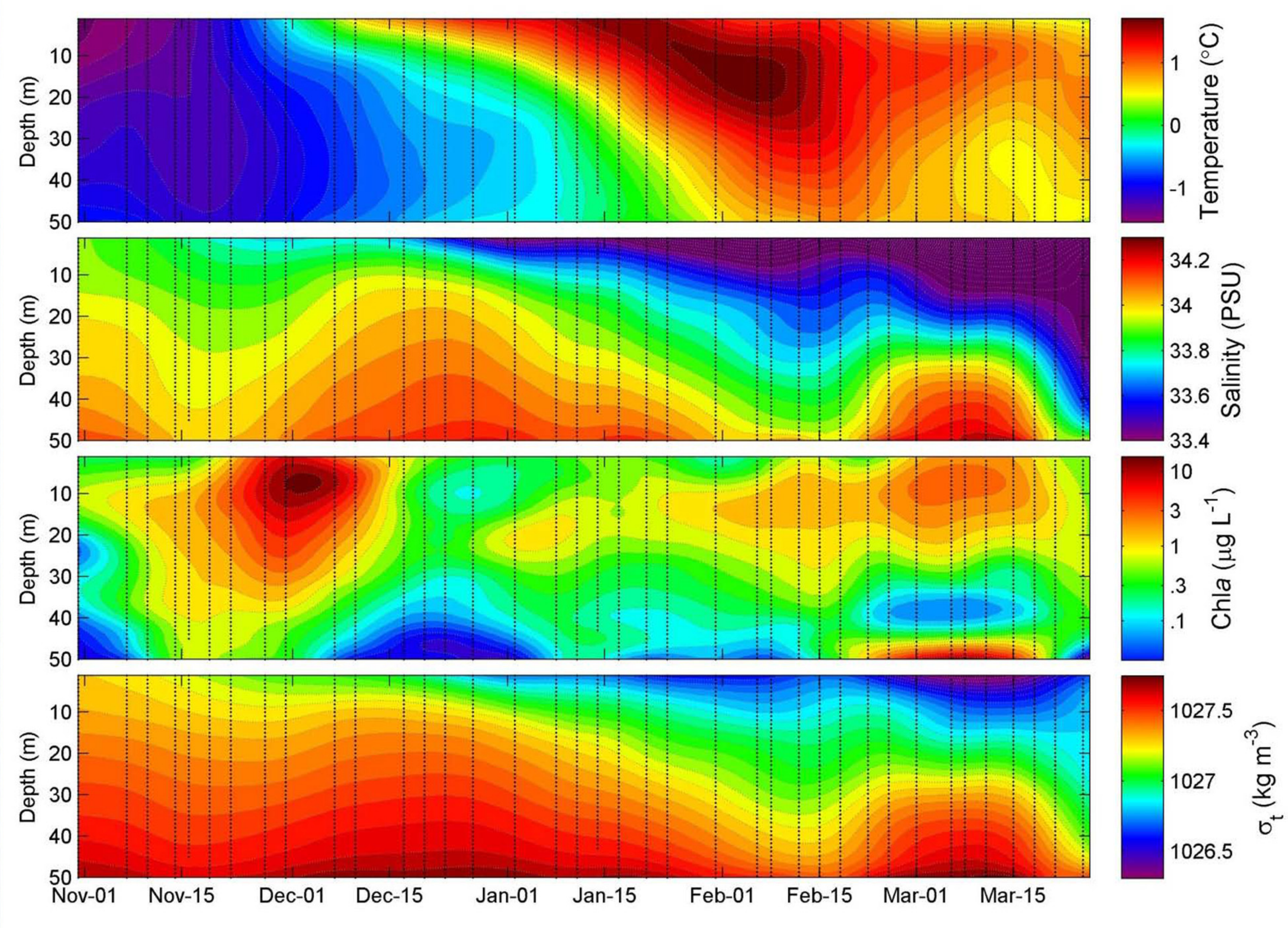




LTER Survey Grid Climatologies, January 1995-2013

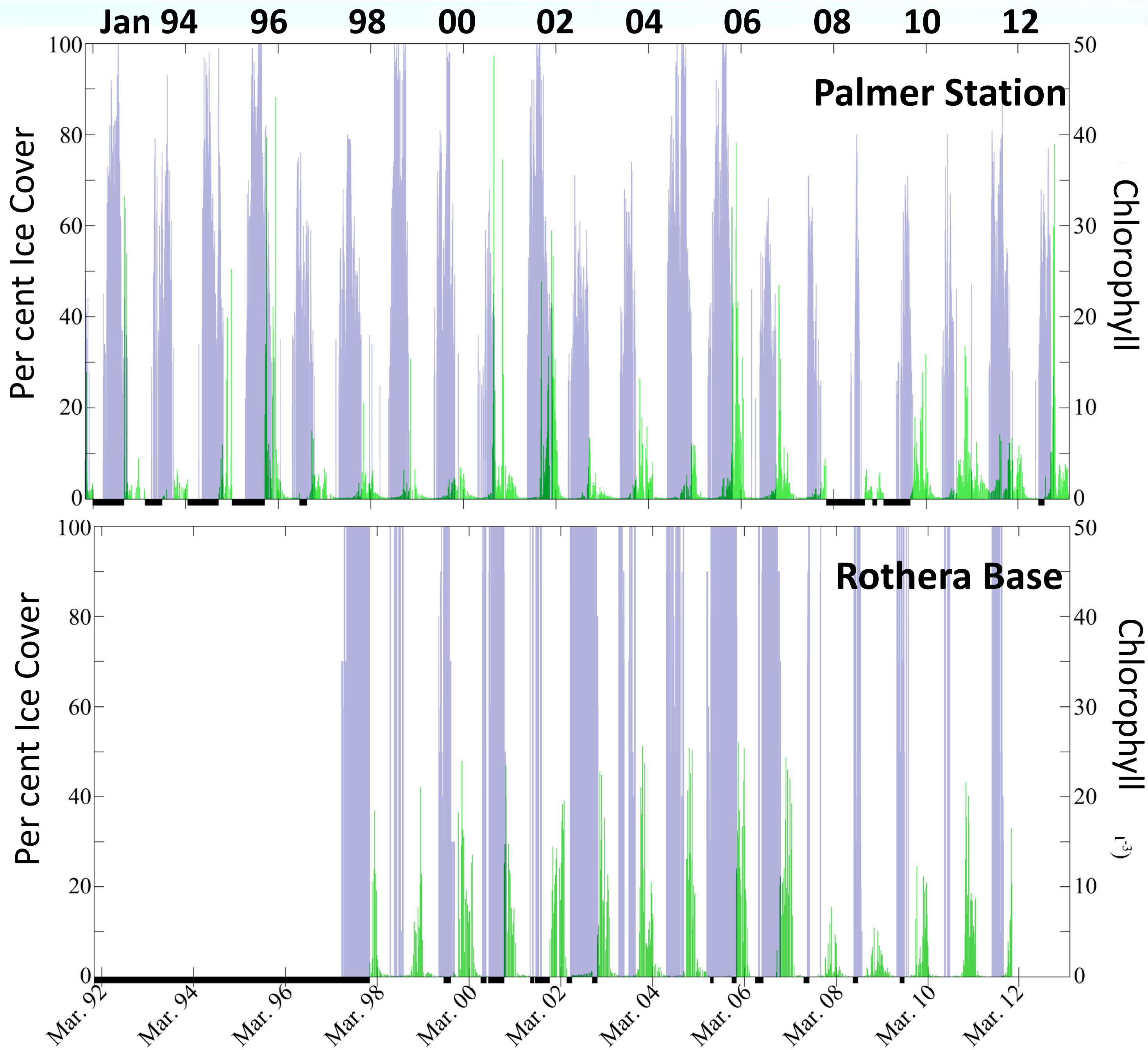
P: Palmer Station, R: Rothera Base, △ Sed Trap

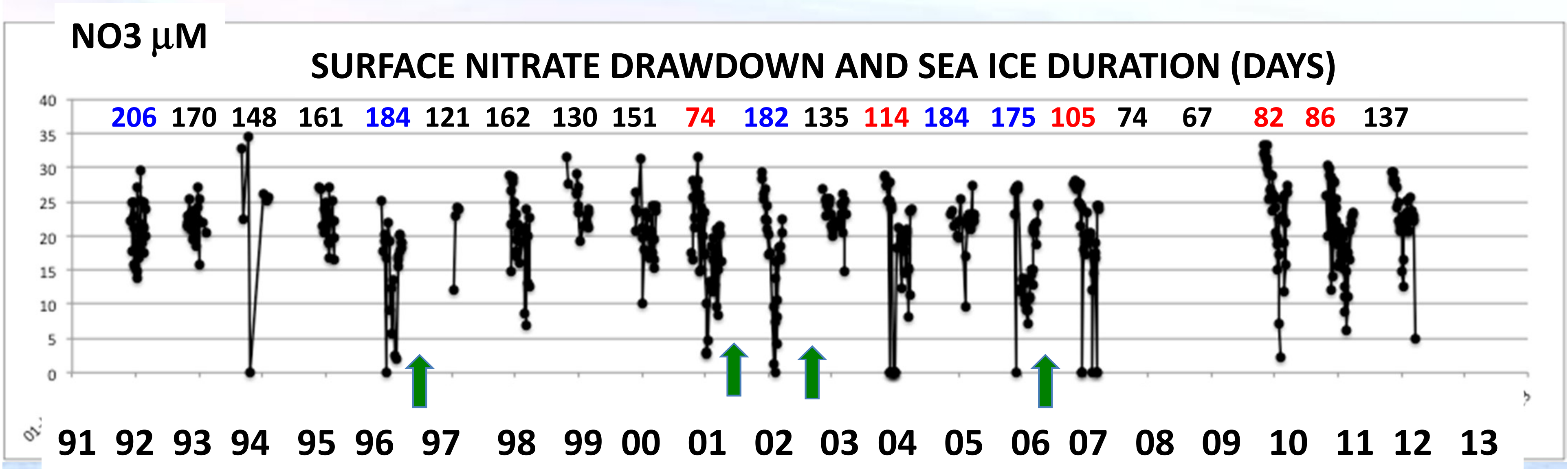
Palmer LTER Station E, 3 km offshore, Oct 2012 – March 2013



PAL LTER Data, figure courtesy Philippe Tortell

Sea Ice and Phytoplankton Blooms





Surface NO3 depletion (< 5 µM) in 8 of 19 seasons. 5 longest and 5 shortest ice duration years: No clear relationship with drawdown. NO3 depleted in 4/5 shortest ice years.

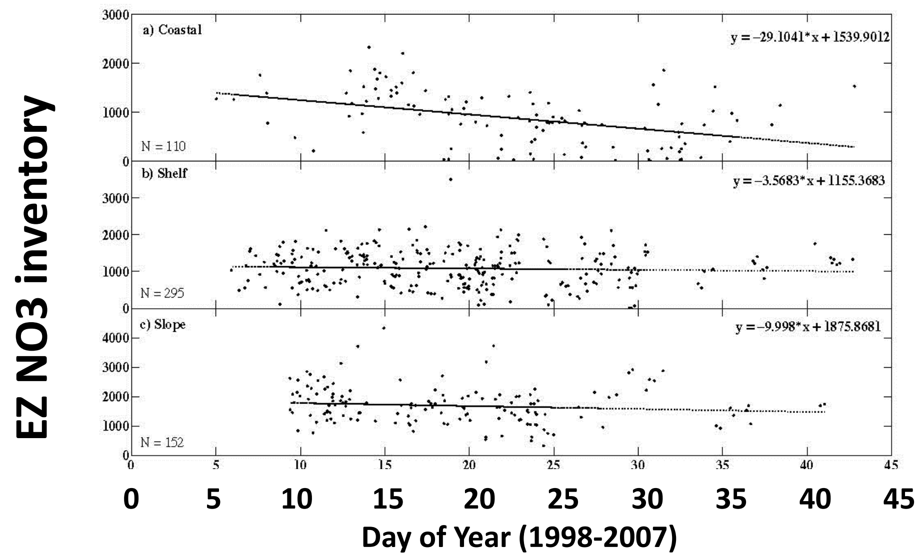
depletion years – high chl diatoms? non-depletion yrs – iron limited? cryptophytes?

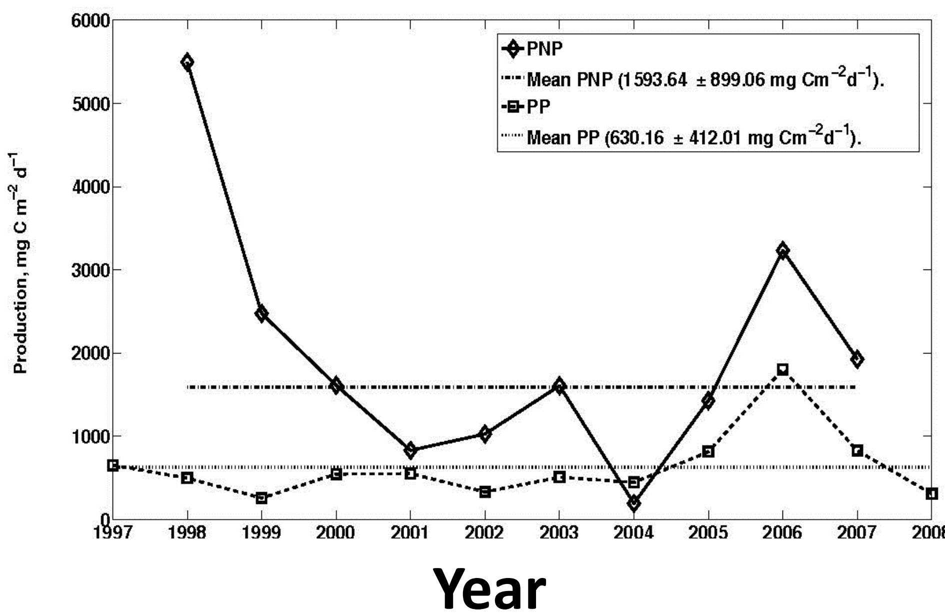
M. Pedulli, PhD thesis, 2013;
OCB Poster:

Potential New Production (PNP) from NO3 drawdown

mean NO3 drawdown
13 mmol N m^{-2} d^{-1}

mean potential new production (January)
1257 mgC m^{-2} d^{-1}



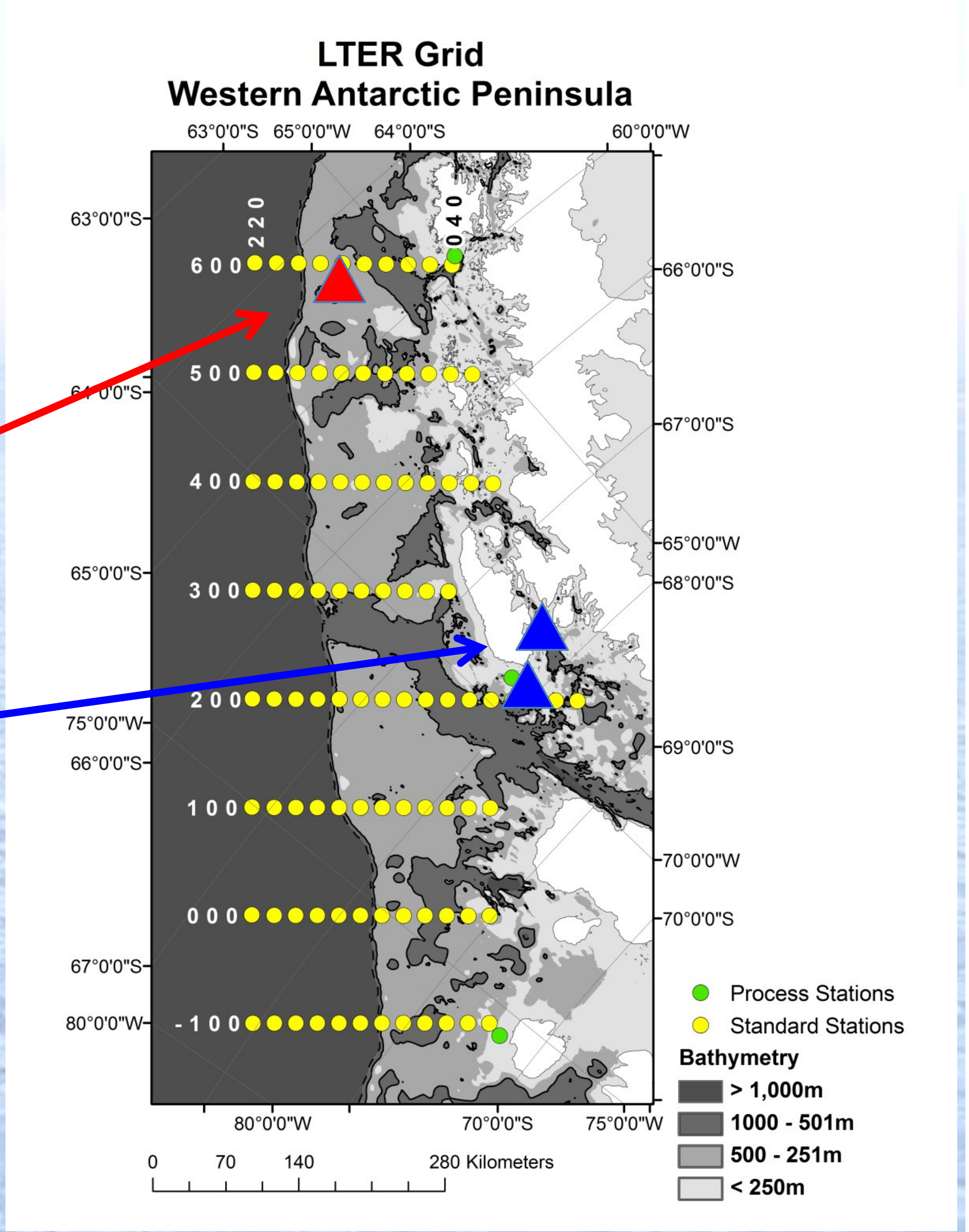


LTER and RaTS Moored Sediment Trap deployments:

LTER: 1992-2013
170 m, 350 m deep

RaTS: 2005-2007
200 m, 520 m deep

All using McLane Mark IV conical traps

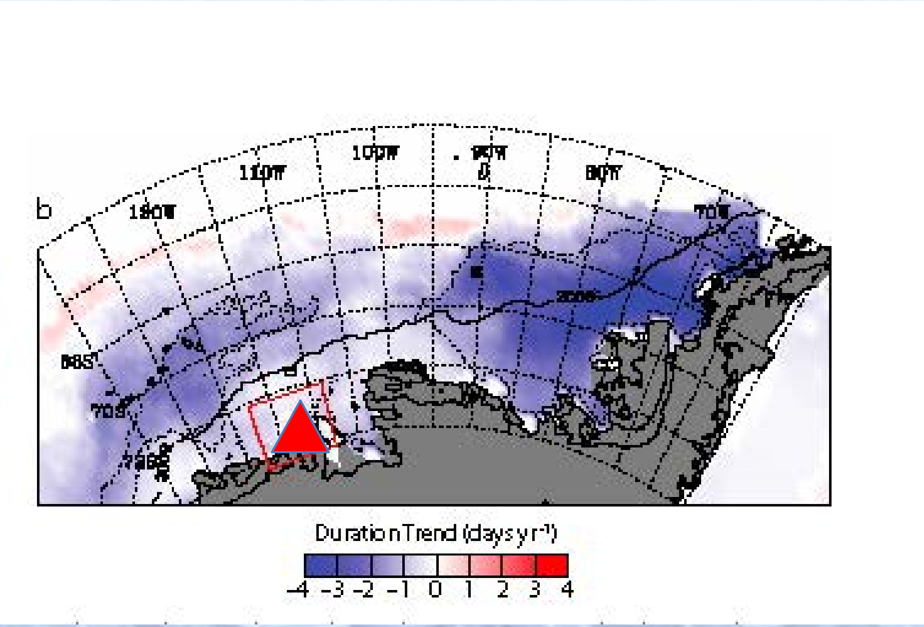


Amundsen
Sea
Polynya
International
Research
Expedition

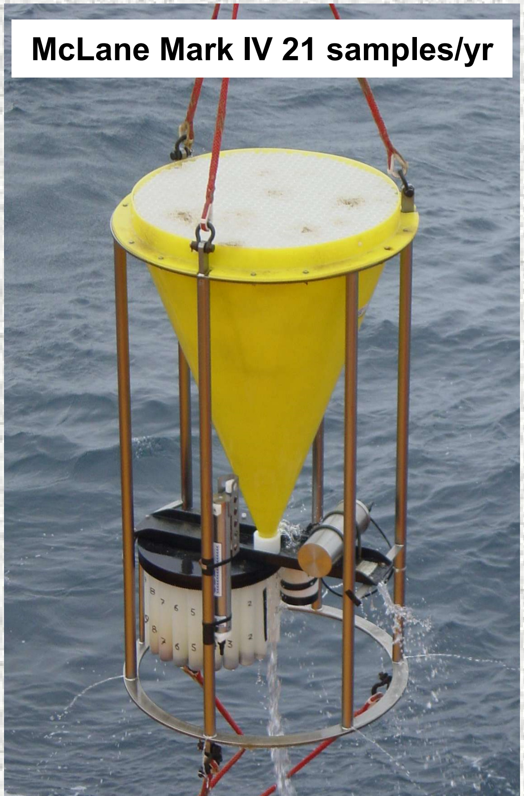
Technicap Cylindrical Trap,

350 m

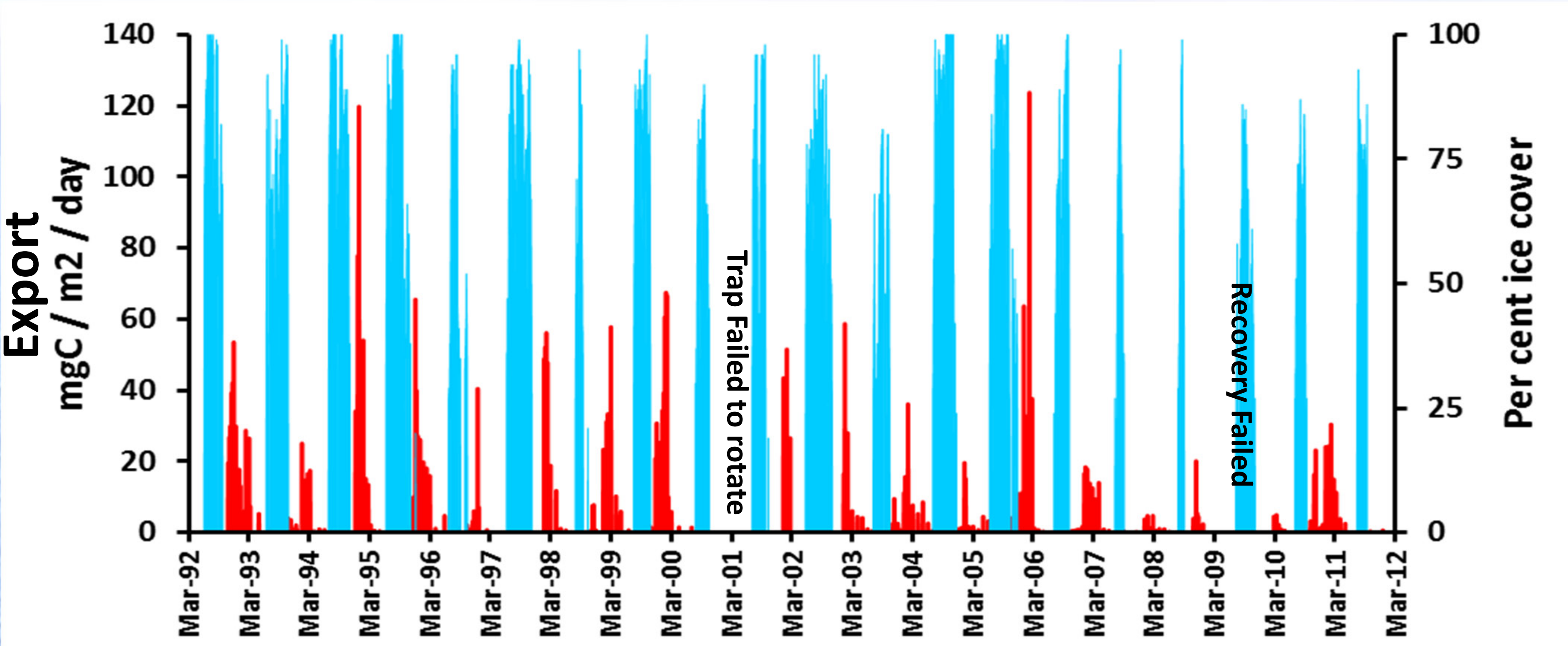
500 m deep



LTER Sed Traps

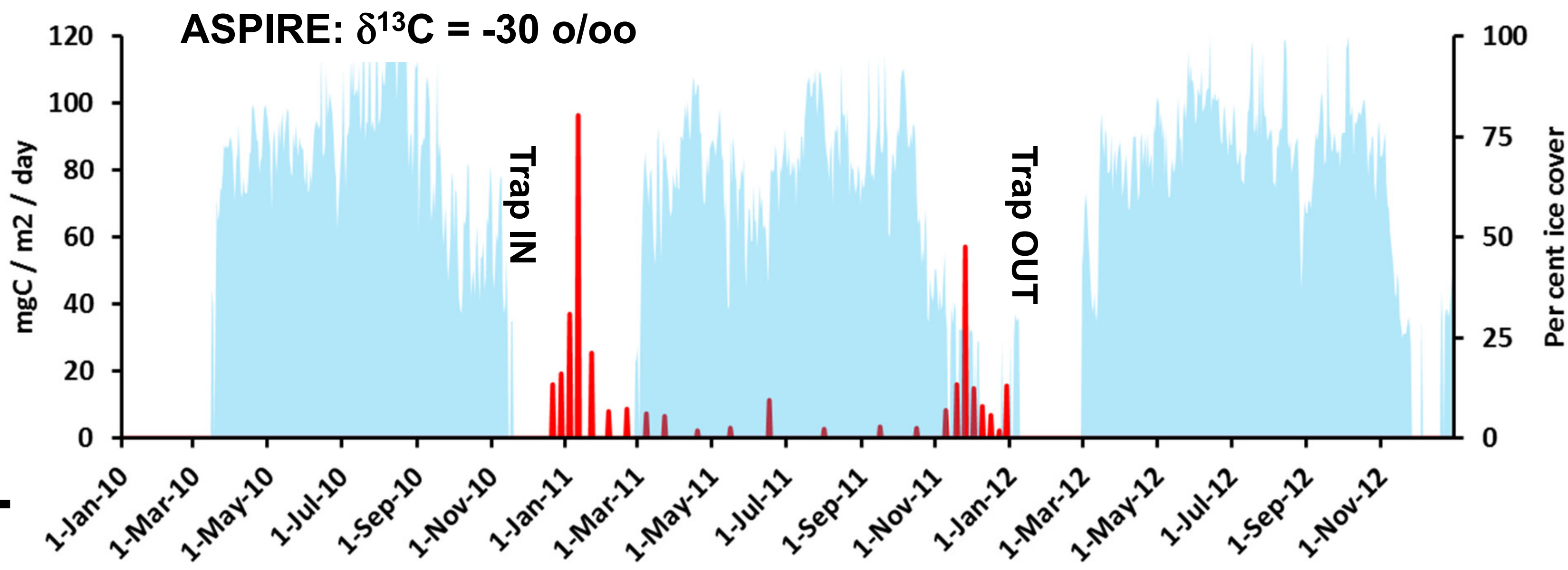


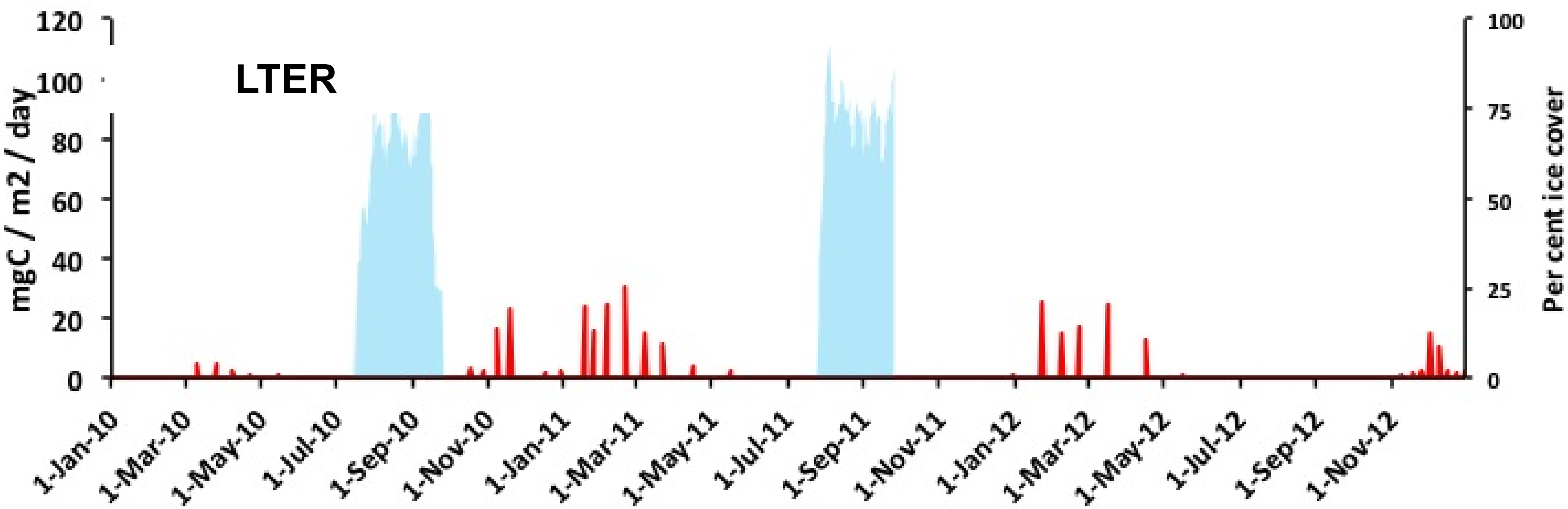
LTER Export flux and % Sea Ice Cover



Dave Karl Era → ← **Duck Era**

Export


ASPIRE: δ13C = -30 o/oo
Trap IN
Trap OUT
mgC / m2 / day
Per cent ice cover
120
100
80
60
40
20
0
100
75
50
25
0
1-Jan-10
1-Mar-10
1-May-10
1-Jul-10
1-Sep-10
1-Nov-10
1-Jan-11
1-Mar-11
1-May-11
1-Jul-11
1-Sep-11
1-Nov-11
1-Jan-12
1-Mar-12
1-May-12
1-Jul-12
1-Sep-12
1-Nov-12


LTER
mgC / m2 / day
Per cent ice cover
120
100
80
60
40
20
0
100
75
50
25
0
1-Jan-10
1-Mar-10
1-May-10
1-Jul-10
1-Sep-10
1-Nov-10
1-Jan-11
1-Mar-11
1-May-11
1-Jul-11
1-Sep-11
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1-Mar-12
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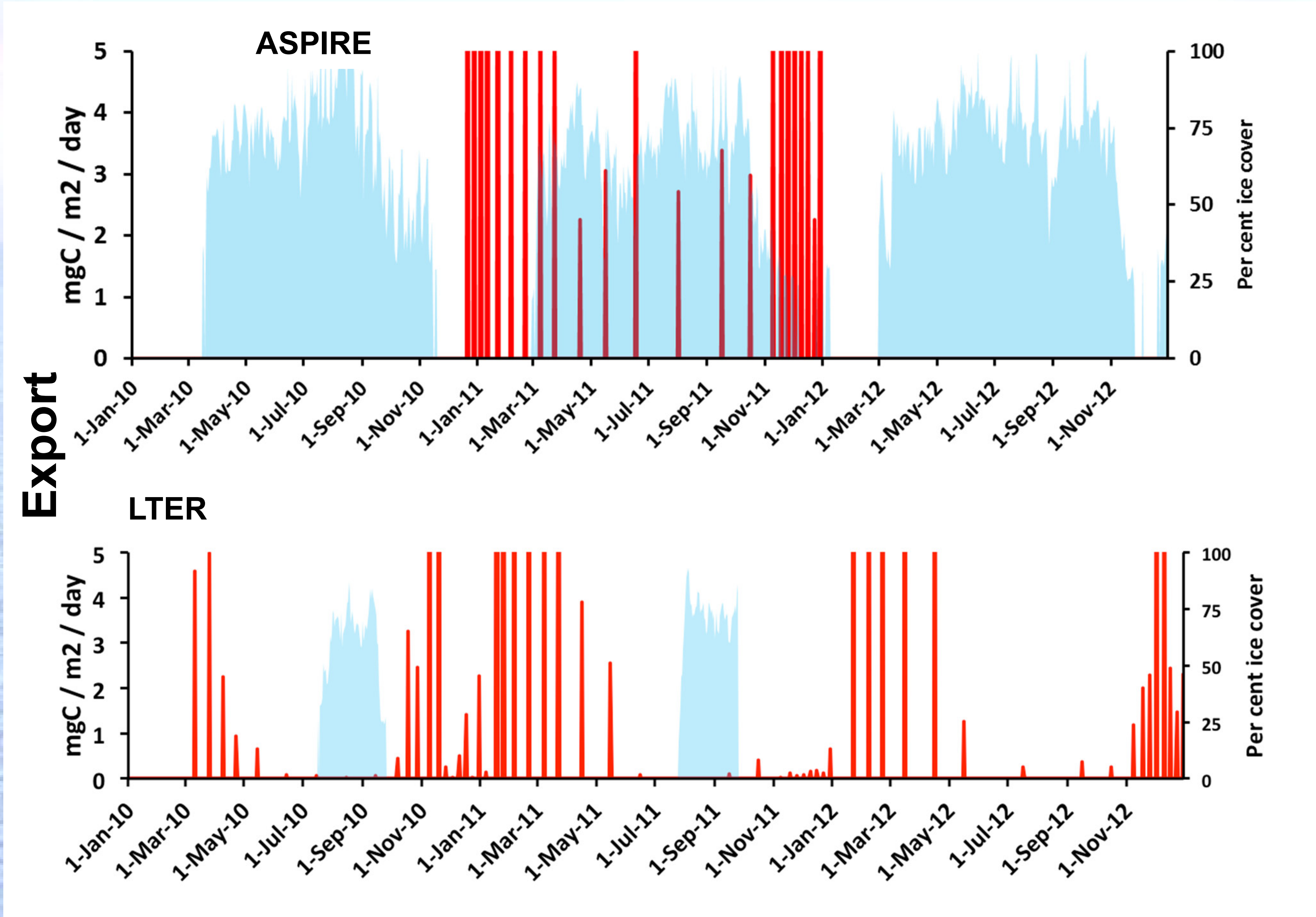
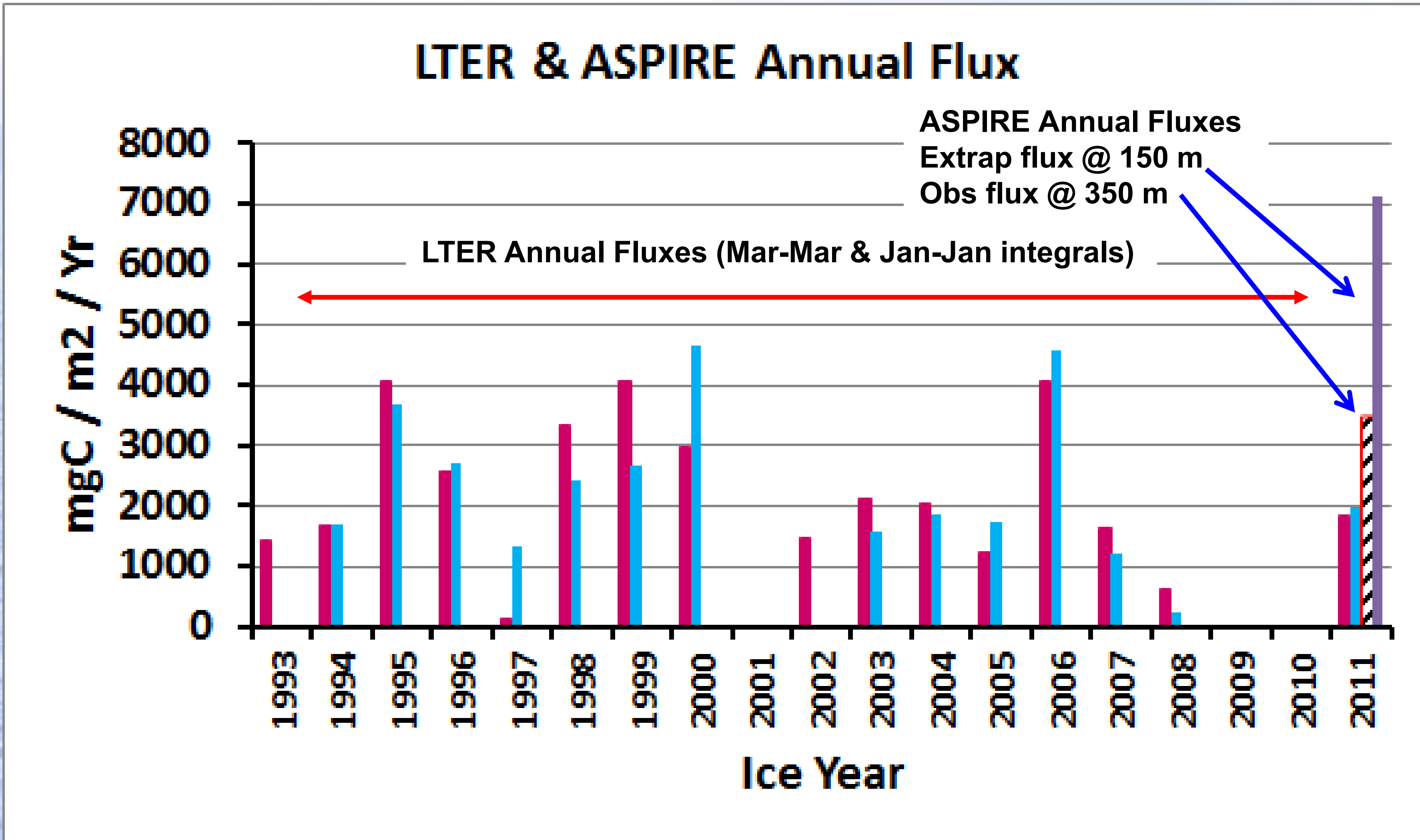
1-Jul-12
1-Sep-12
1-Nov-12



Export
ASPIRE
mgC / m2 / day
Per cent ice cover
0
1
2
3
4
5
0
25
50
75
100
1-Jan-10
1-Mar-10
1-May-10
1-Jul-10
1-Sep-10
1-Nov-10
1-Jan-11
1-Mar-11
1-May-11
1-Jul-11
1-Sep-11
1-Nov-11
1-Jan-12
1-Mar-12
1-May-12
1-Jul-12
1-Sep-12
1-Nov-12
LTER
mgC / m2 / day
Per cent ice cover
0
1
2
3
4
5
0
25
50
75
100
1-Jan-10
1-Mar-10
1-May-10
1-Jul-10
1-Sep-10
1-Nov-10
1-Jan-11
1-Mar-11
1-May-11
1-Jul-11
1-Sep-11
1-Nov-11
1-Jan-12
1-Mar-12
1-May-12
1-Jul-12
1-Sep-12
1-Nov-12

ASPIRE Export Flux
Extrapolated from 350 to 150 meters using Martin coefficient

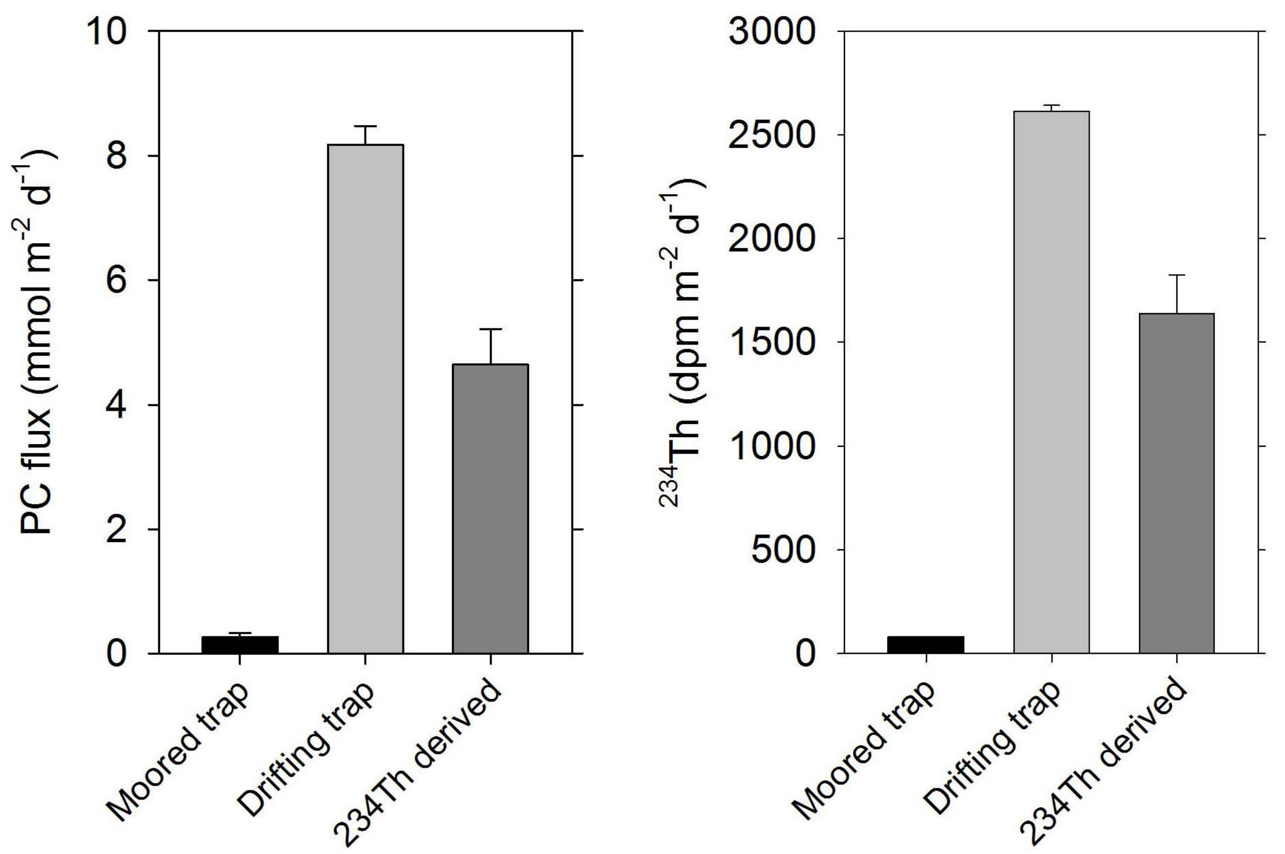


Export Production

What fraction of the annual primary production is exported to depth?

Region	PP gC m^{-2} y^{-1}	Annual Flux gC m^{-2} y^{-1}	e-ratio
WAP	180	2.5	0.01
ASPIRE	88	7.1	0.08
Bermuda	180	9.4	0.05

Particle fluxes, January 2009: Comparison of estimates from traps and Thorium-234 disequilibrium (index of particle removal)



The Moored Trap may be undertrapping by a factor of 10-30 (comparison based on 4 samples in Dec-Jan 2008-09)

Buesseler, McDonnell, Schofield, Steinberg & Ducklow GRL 37 (2010)

WAP Export Production?

What fraction of the annual primary production is exported to depth?

Region	PP gC m^{-2} y^{-1}	Annual Flux gC m-2 y-1	e-ratio
WAP (Trap)	180	2.5	0.01
WAP (Th-234)	180	50	0.28
ASPIRE		??	??

Moored trap fluxes, 2008-13 (mmol C m^{-2} d^{-1})

Month	2008-09	09-10	10-11	11-12	12-13	Avg
December	0.3	--	<0.1	<0.1	0.5	0.2
January	0.2	--	1.1	<0.1	<0.1	0.3
February	--	--	2.3	1.3	<0.1	1.2
Mean	0.2	--	1.1	0.5	0.2	0.5

Compare to Th-234: 4.5 (2009), 10 (2010)

Weston et al. DSR 2013:

Marguerite Bay trap 2005-07

Exportable production:
NO3 drawdown: 13 Mol C m^{-2} y^{-1}
15NO3 new production = 16 Mol C m^{-2} y^{-1}
Trap carbon flux 0.2 Mol C m^{-2} y^{-1}

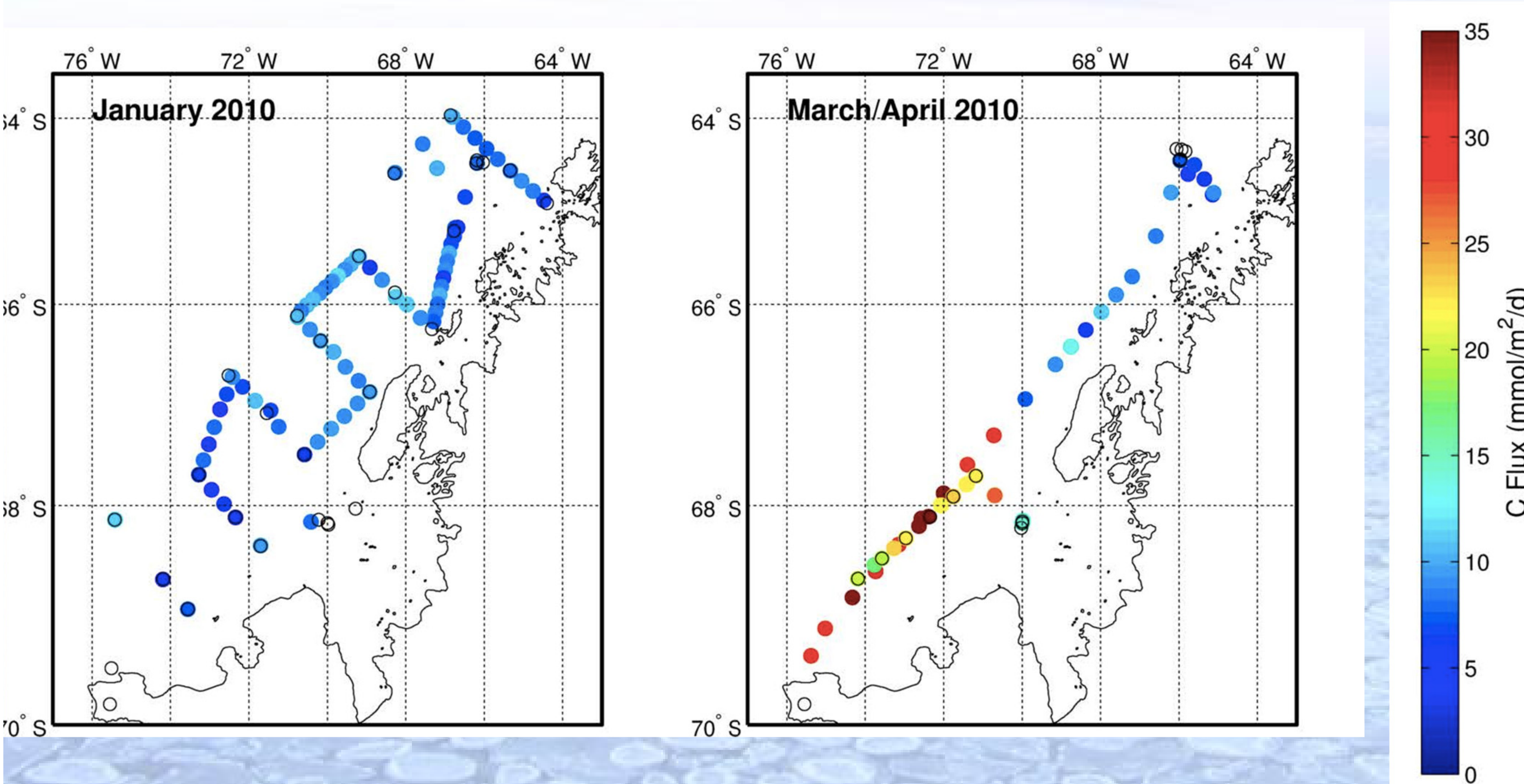
F-ratio from ^{15}N = 0.8

E-ratio: 0.01

"…high recycling, low export system…"

Thorium-234 derived export flux (100 meters)

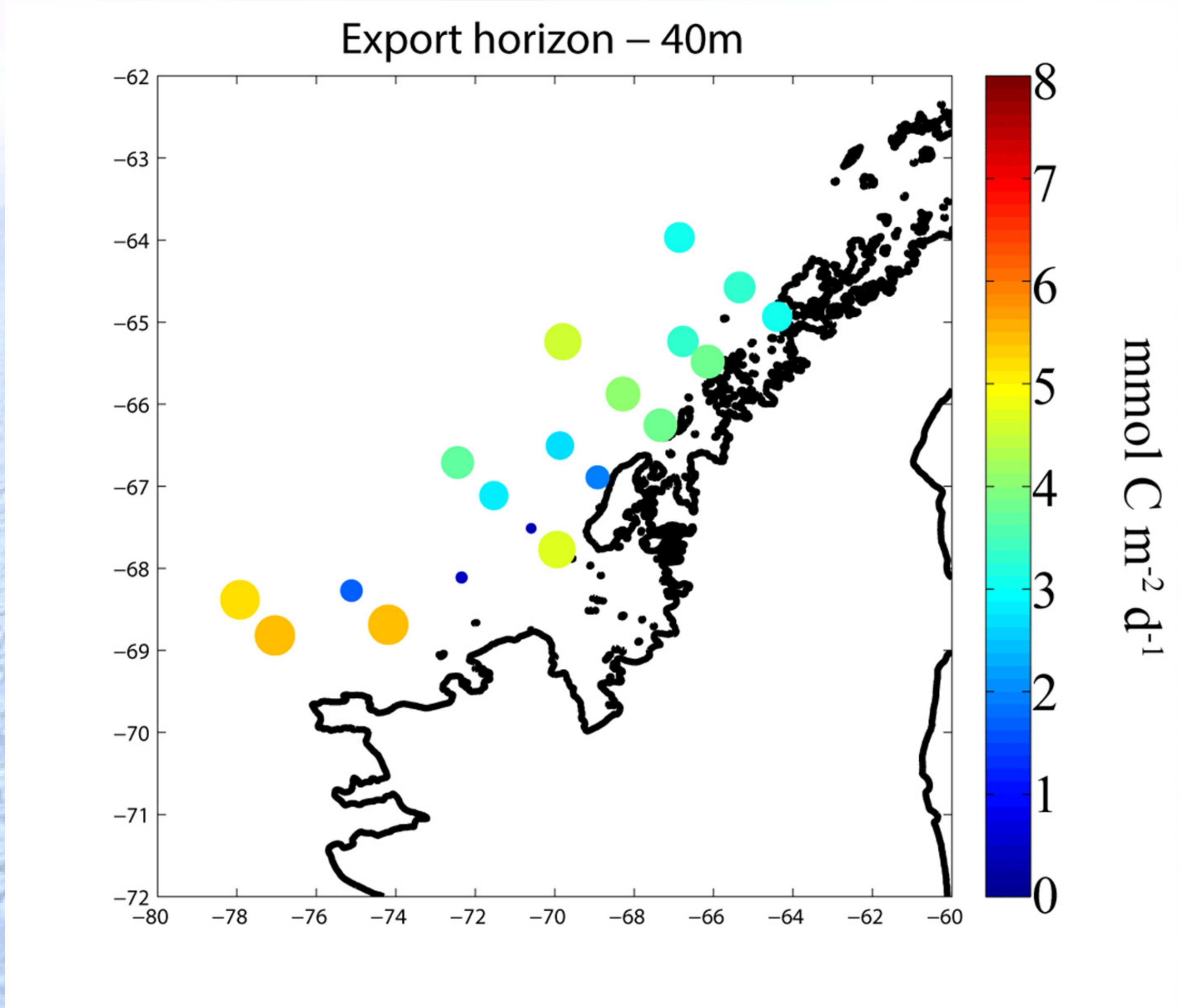
mmol C m^{-2} d^{-1} – Mean 10 (Jan), 4.5 (March)*



*** Moored trap fluxes are 0.1 – 2.5**

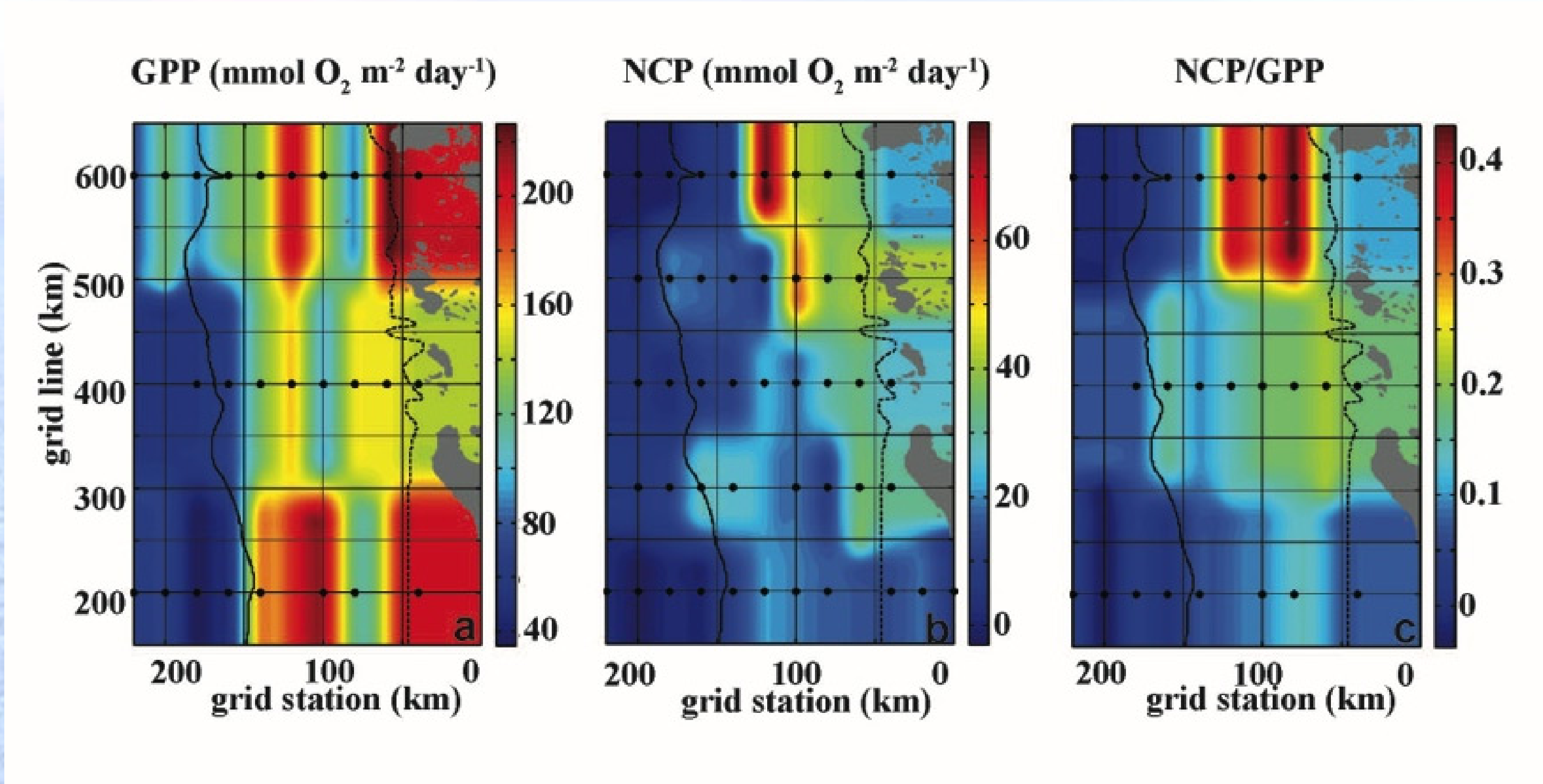
Stephanie Owens, PhD Thesis WHOI-MIT, 2013

Depth distribution of Thorium 234 export



Mike Stukel, LDEO, 2013

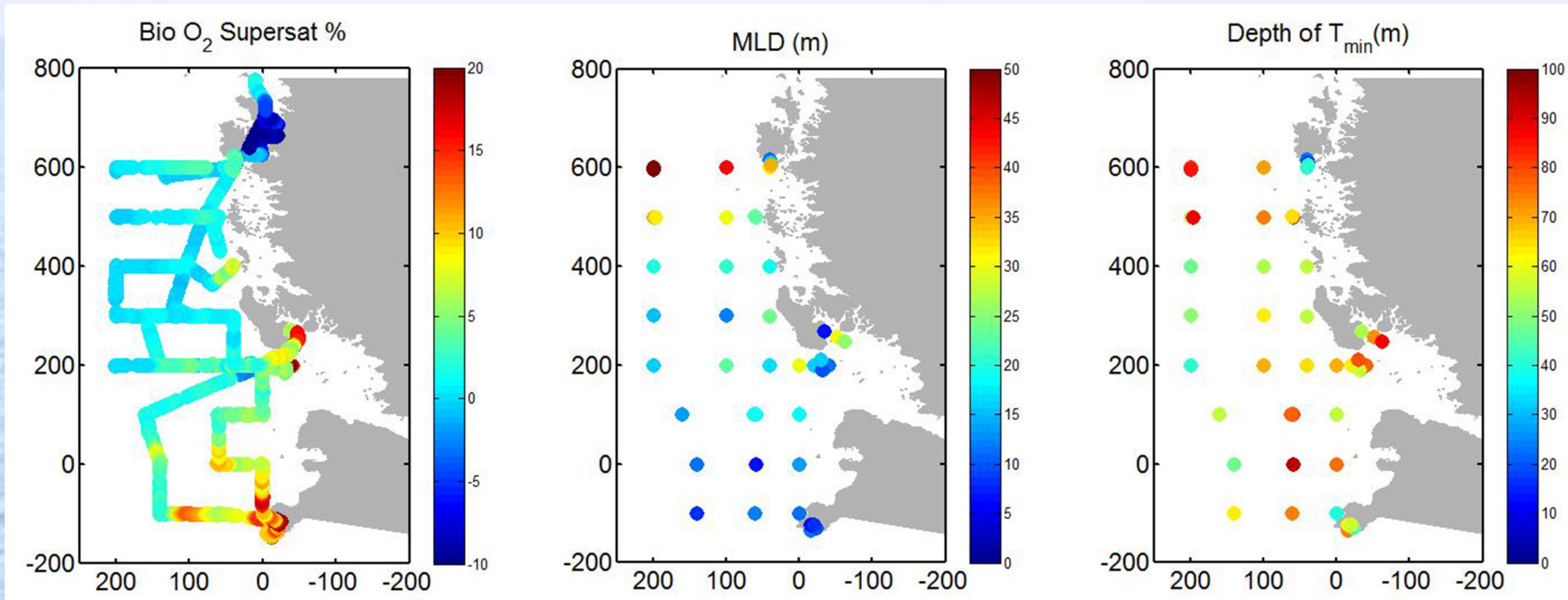
GPP (^{17}O), NCP (O2/Ar) and GPP:NCP January 2008



Discrete surface water samples (i.e., ML) from CTD casts
Have data for 2008-2013

Kuan Huang, GBC 26 (2012)

Biological oxygen supersaturation, underway, 2013



Continuous equilibration inlet mass spectroscopy (EIMS)
Will have data for 2012-2014

Rachel Eveleth, Nicolas Cassar, 2013

LTER Gross, Net and Export Production (January 2010)

Gross Primary Production (ML)	84.9 +/- 28.5 mmol C m^{-2} d^{-1}	(24 to 150)
Net Community Production (ML)	26 +/- 16	(5 to 63)
NOP:GOP (O2)	0.19	(0.03 to 0.54)
NCP:GPP (C)	"F" = 0.38	
Th234 C Export (EZ)	8.7 +/- 2.4	(3 to 12)
Trap Flux (170 m)	0.5 +/- 0.7	(0.02 to 2.3, Dec-Feb)
C14-PP (EZ)	542 +/- 503	(66 to 2372)

NCP and GPP courtesy K Huang & M Bender, Princeton Univ
Th234 courtesy S Owens & K Buesseler, WHOI

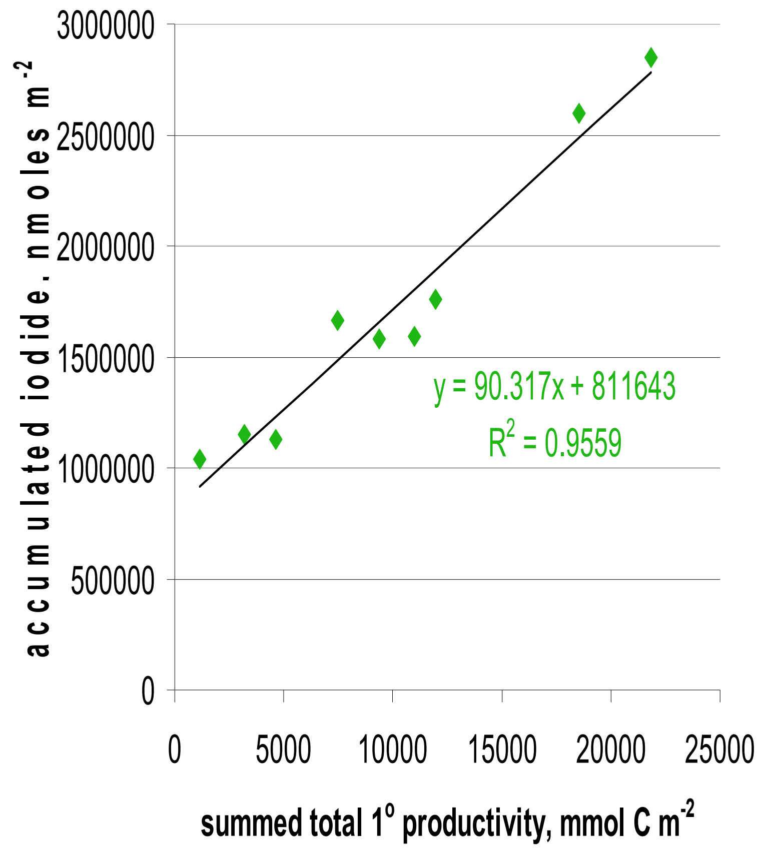
Iodide accumulation as an indicator of seasonal new (or maybe total?) production (Chance, Jickells, Baker et al 2010

Theory of Iodide as a productivity indicator
Campos et al 1996

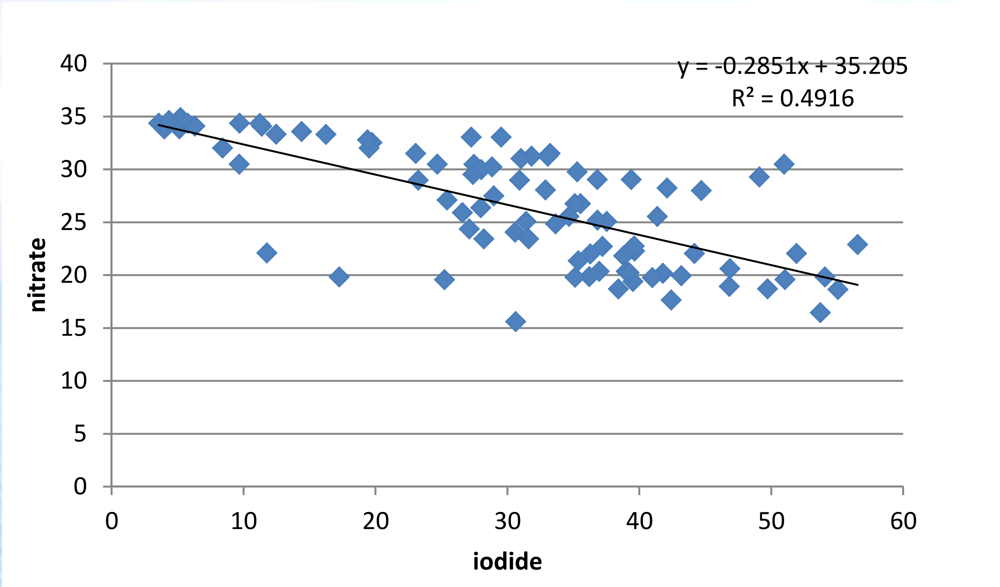
$IO_3^- \longrightarrow I^-$ Biological linked to primary production

$I^- \longrightarrow IO_3^-$ very slow (months)

Hence Iodide (I^-) production potentially contains a record of productivity



Seasonal Production Estimates



Chance, Jickells, Baker
2012 LTER Samples.

I/C assimilation ratio:

1.6×10^{-4}

Seasonal Iodide accumulation

20-150 nmol / liter

22 – 35 Mol C m^{-2}

(NO3 drawdown: 8)

Summary

1. Time series don't begin at BATS and end at HOT
2. Moored sediment traps have uncertain accuracy but most probably undertrap by order of magnitude
3. But they yield one of our only year-round carbon flux records; only source of physical samples for biological, chemical analyses
4. Most of the flux is in the ice-free (or nearly ice-free) period
5. But there was significant flux in winter too (ASPIRE)
6. Overall, Amundsen Sea fluxes were higher than at LTER site (even not accounting for depth difference)

Summary, cont'd

6. Trap contents appear to be dominated by phytodetritus in Amundsen, krill fecal pellets in LTER traps.
7. New technologies offer better resolution in space & time, improved estimates of production available for export
8. GPP > NCP > Th234 Export > Trap catch; NCP:GPP = 0.2 (apparent e/f ratio = 0.4, consistent with preconceived ideas about Antarctic foodweb & biogeochemical dynamics
9. NCP>Th234 implies horizontal export or DOC export
10. How much do the traps undertrap? How much remineralization between 100 & 300 meters?


Thanks very much for your interest

Acknowledgements

US National Science Foundation

US Antarctic Program & Support Contractors

Many colleagues & collaborators

Questions?