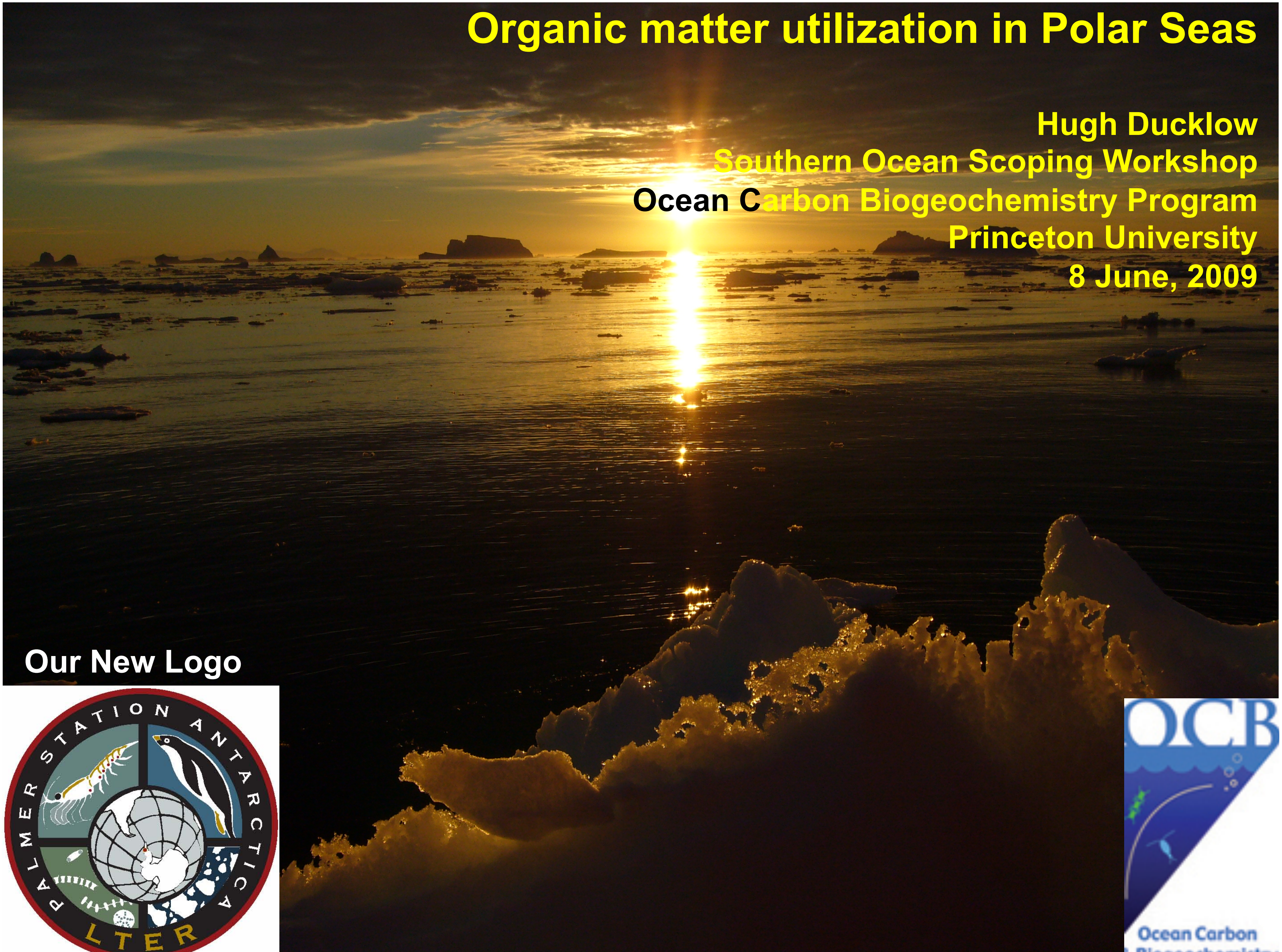


Organic matter utilization in Polar Seas

Hugh Ducklow
Southern Ocean Scoping Workshop
Ocean Carbon Biogeochemistry Program
Princeton University
8 June, 2009

Our New Logo

This Ocean Carbon and Biogeochemistry (OCB) scoping workshop in Princeton, New Jersey, will focus on carbon cycling and marine ecosystems in the context of climate variability in the Southern Ocean….

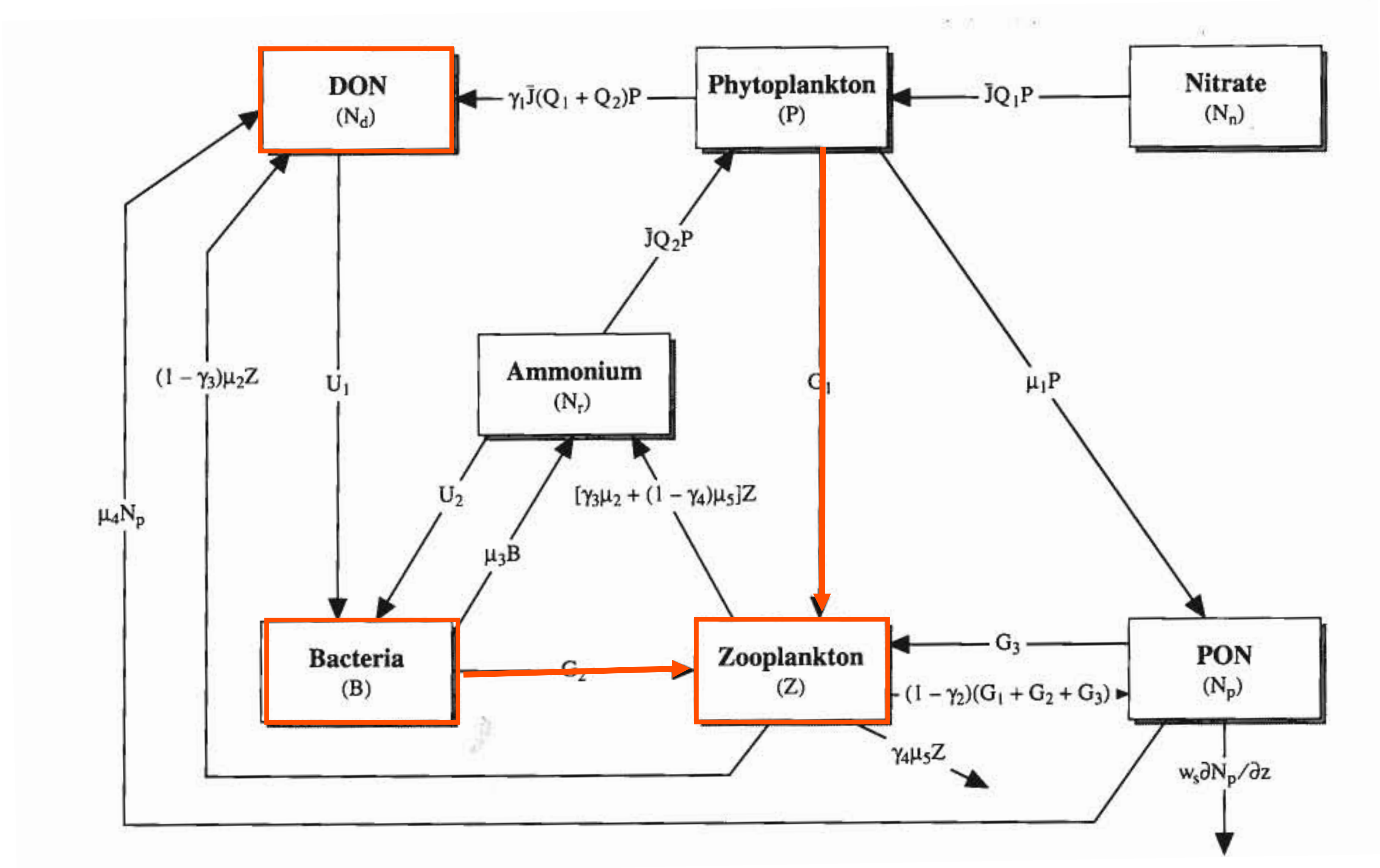
Despite increased efforts to understand these processes, significant discrepancies still exist between models and observations, and a number of key processes remain poorly quantified.

There is a clear and increasing need to develop a coordinated approach that advances our understanding of climate variability in the Southern Ocean and its implications for ecosystem dynamics and biogeochemical cycling.

From my invitation letter:

We would like to invite you to provide a plenary presentation dealing with **"Marine food webs and ecosystems: the need to represent the effects of ecosystem processes on carbon cycles".** This presentation should present an overview the current status of research in this area and provide a basis for subsequent working group discussions.

Fasham et al. 1990: utilized for JGOFS Planning



Most of the global ocean has microbial-biogeochemical/ecosystems that cycle most of the primary production through dissolved organic matter

(including mid-latitude regions characterized by phytoplankton blooms and the Arctic).

In the Southern Ocean, most of the primary production cycles through particulate organic matter.

(including permanently open-ocean and marginal ice zones)

This seems like something we should understand better

(if we want to predict the carbon cycle in the future)

OUTLINE

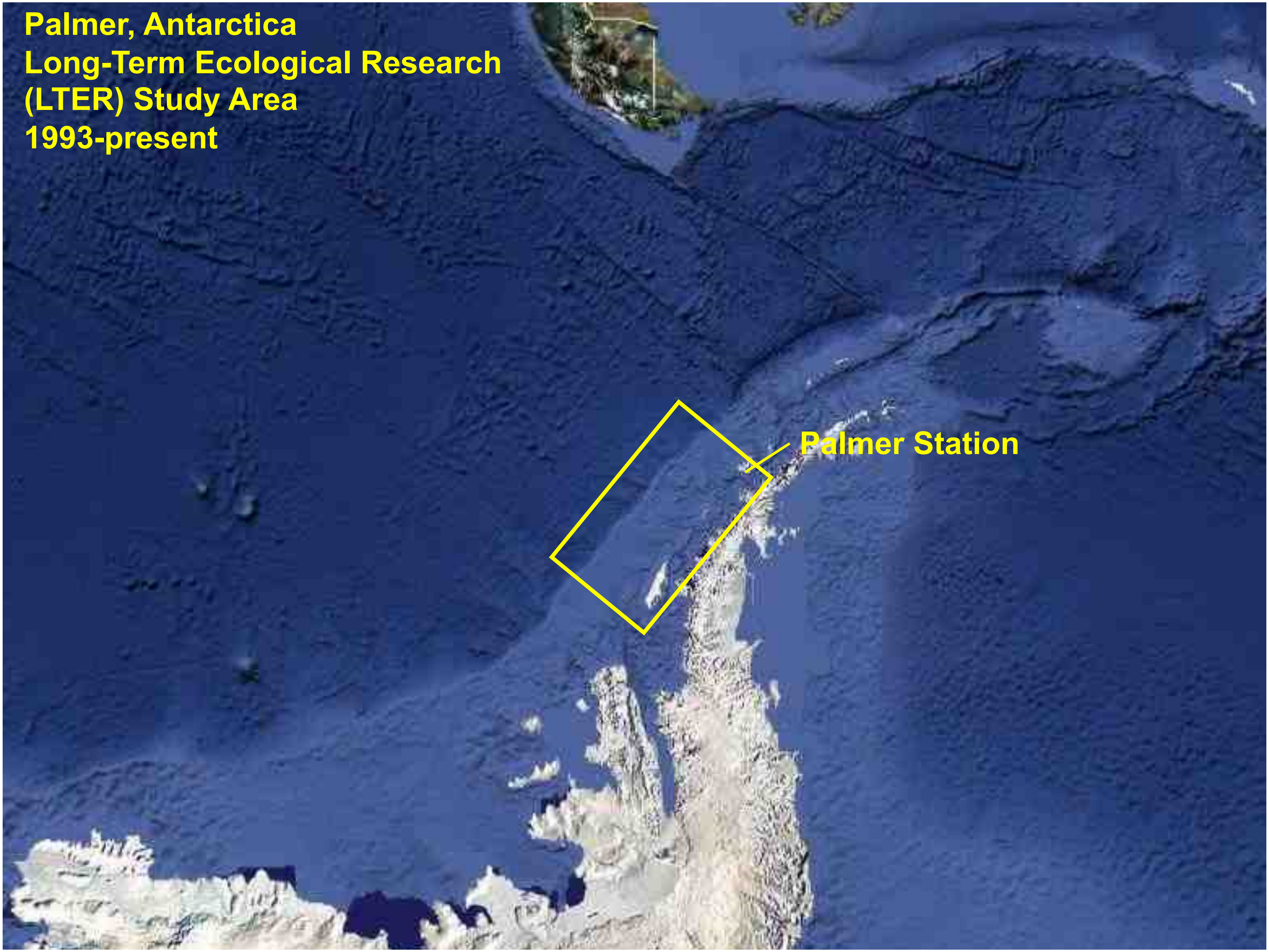
Observations of POC and DOC in Antarctica and Hawaii

Bacterial Production/Carbon utilization (Palmer LTER)

Bacterial:Primary Production Ratio as an ecosystem diagnostic (BP:PP): Global synthesis (JGOFS Redux)

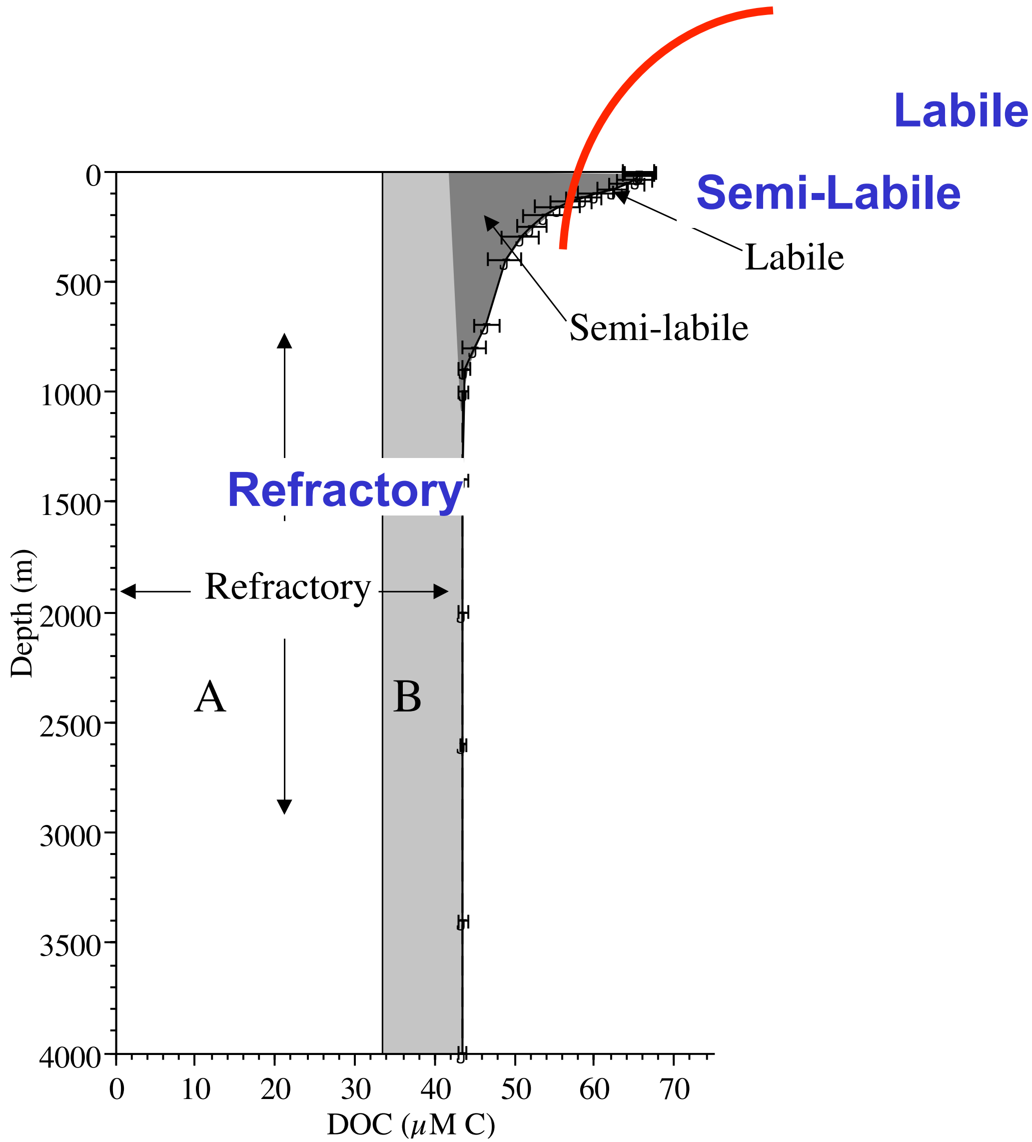
Modeling microbial – organic matter fluxes

Scoping statement


Palmer, Antarctica
Long-Term Ecological Research
(LTER) Study Area
1993-present
Palmer Station

Palmer Station and LM GOULD seen from Torgerson Island

Oceanic DOC vertical distribution

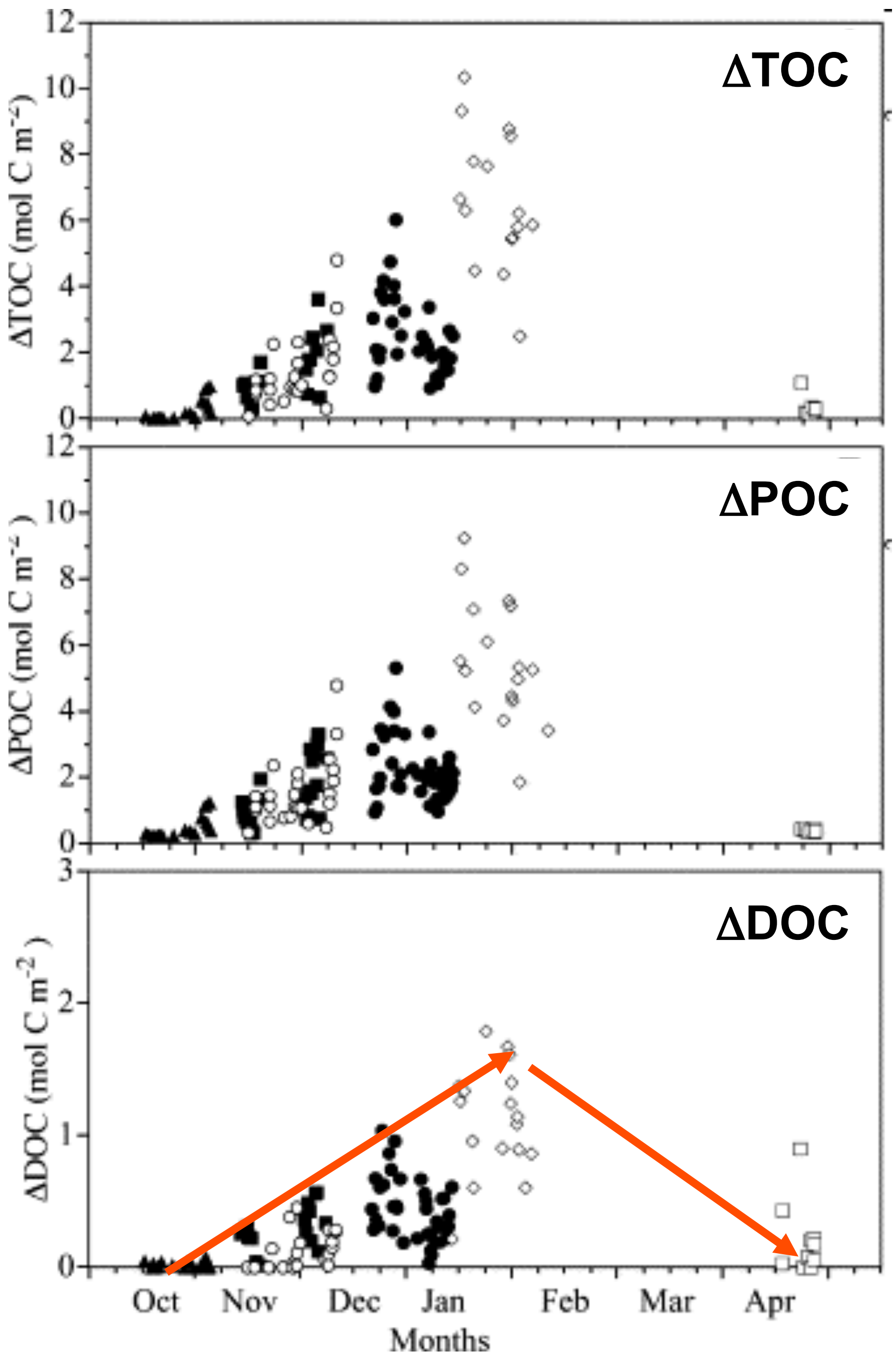


Labile: nanomolar, T=hours/days
Semi-labile: 0-50 μM, T=100 d
Refractory: 35-45 μM, T=1000 y

Excess (Δ-) DOC above deepwater Background concentration is available for export with resumption of convective overturn in winter.

This is exportable DOC

Net production in summer may or may not consume the exportable DOC before winter.



Seasonal production and utilization of semilabile DOC (ΔDOC) in the Ross Sea

(US JGOFS AESOPS, 1996-97)

ΔDOC: $[DOC_{surface}] - [DOC_{deep}]$

ΔDOC = 0 in winter

Net production in spring-summer

Net utilization in autumn

No exportable DOC at start in winter mixing.

Symbols signify different cruises, years.

Carlson et al (2000)

In the Ross Sea, 90% of the seasonal PP accumulated* in the particulate pool.
In the Sargasso Sea, 90% of the bloom PP accumulated* in the dissolved pool.

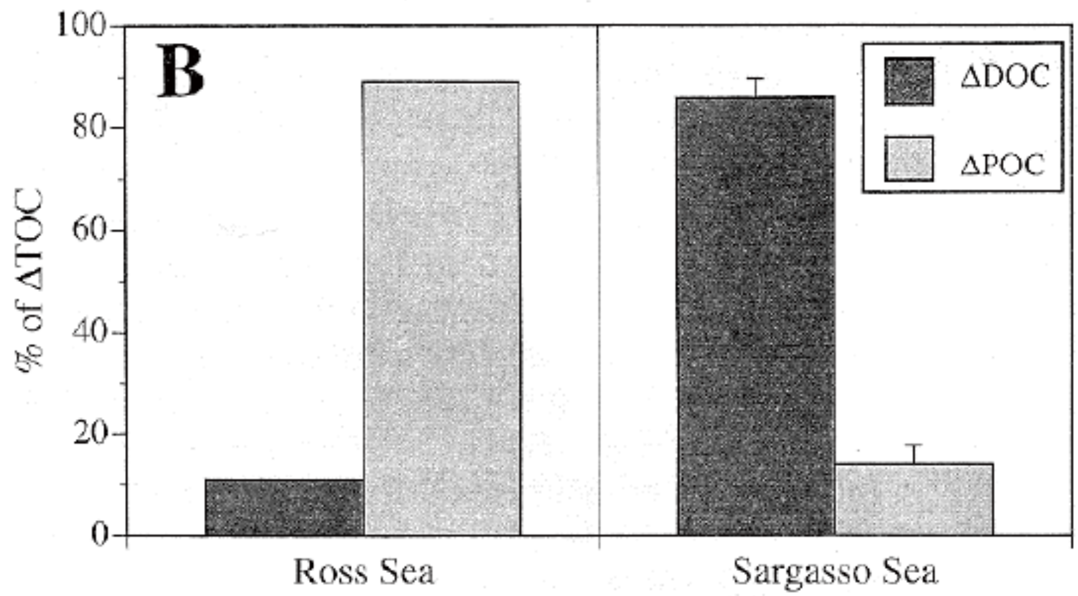


Fig. 4. A. Stocks of DOC and POC that which accumulated during blooms in the Ross Sea (RS) and the Sargasso Sea (SS). B. The percentage of TOC that accumulated as POC and DOC in the Ross Sea and Sargasso Sea. Error bars represent standard error.

* or cycled through the pool

Carlson et al. 1998

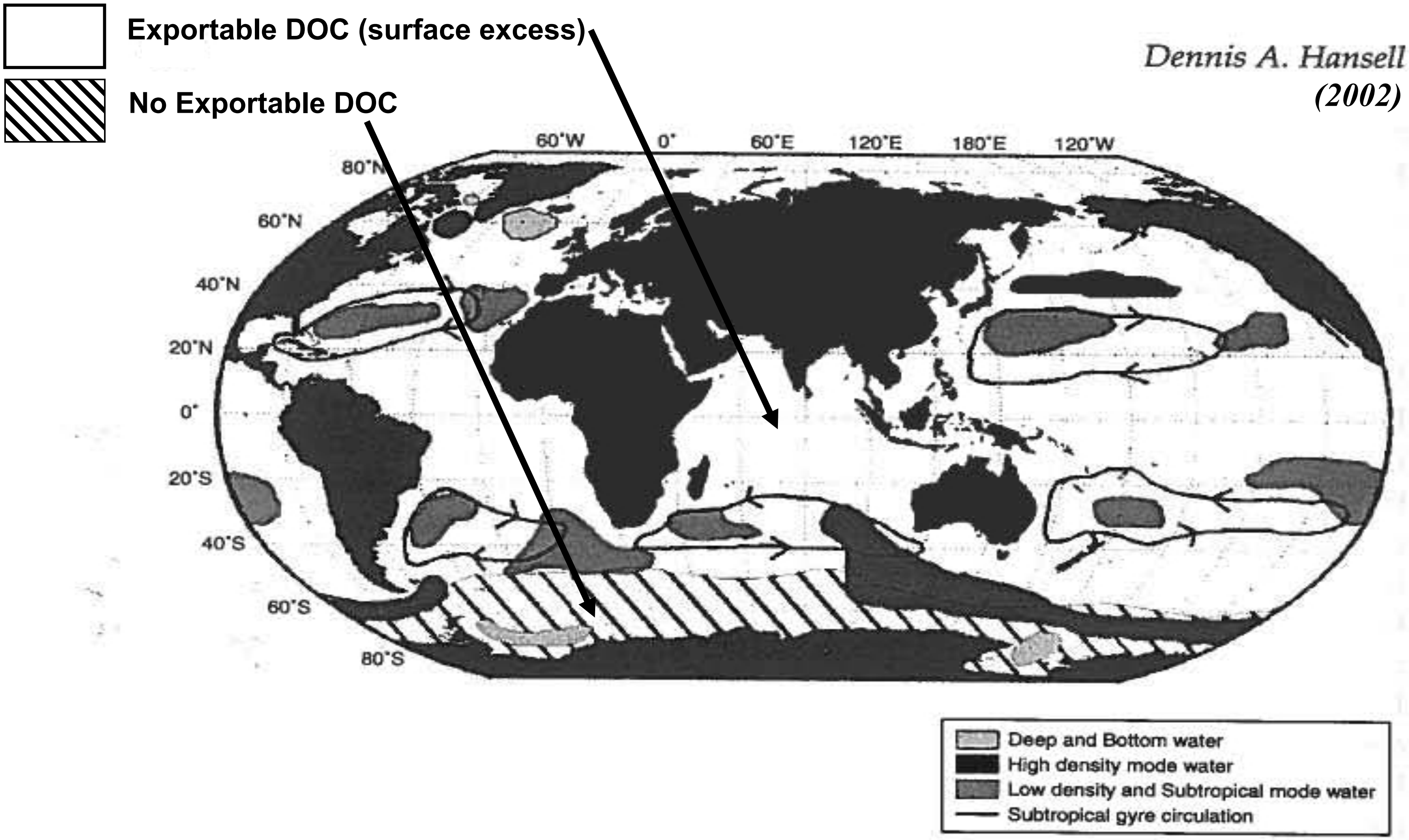
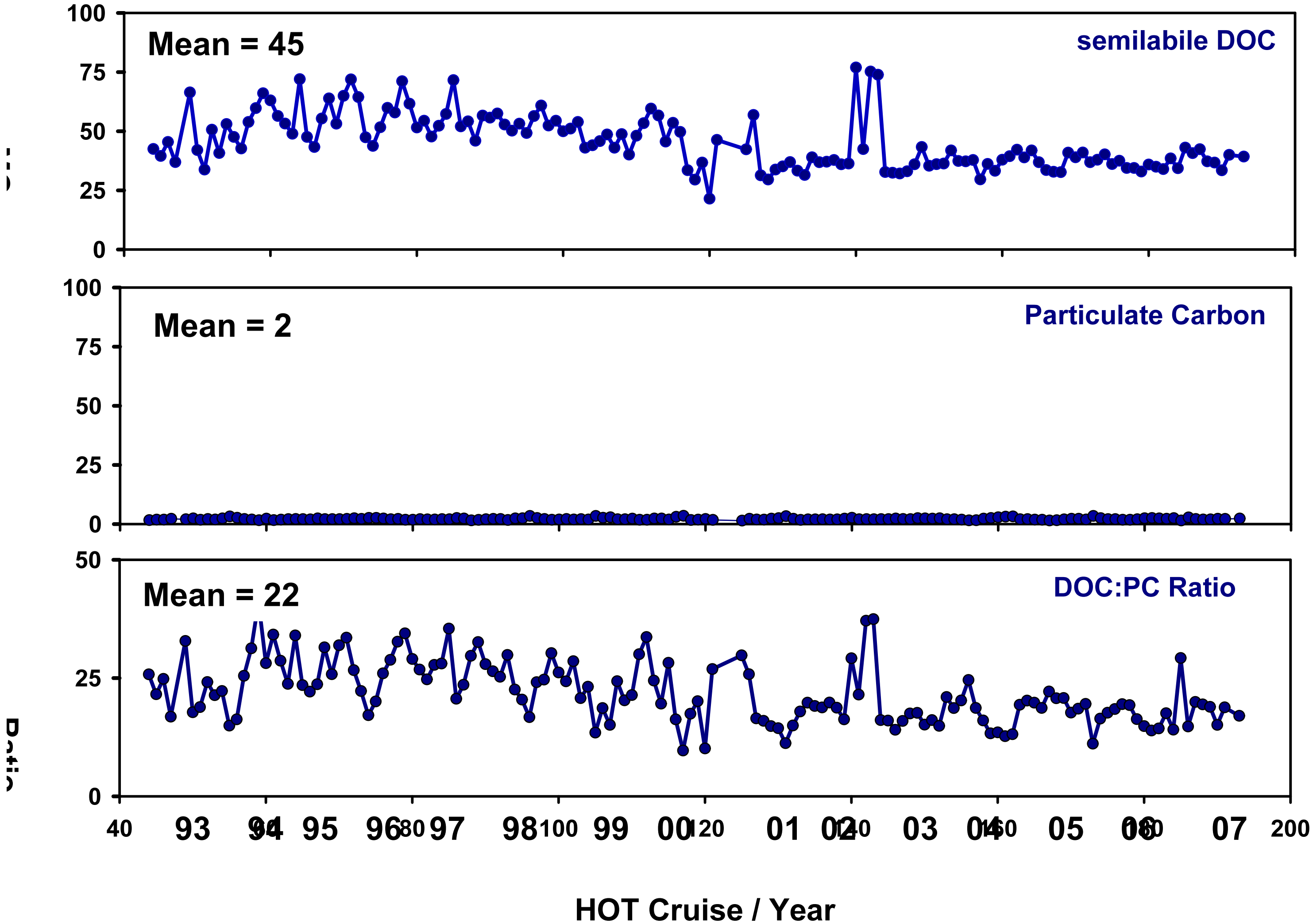
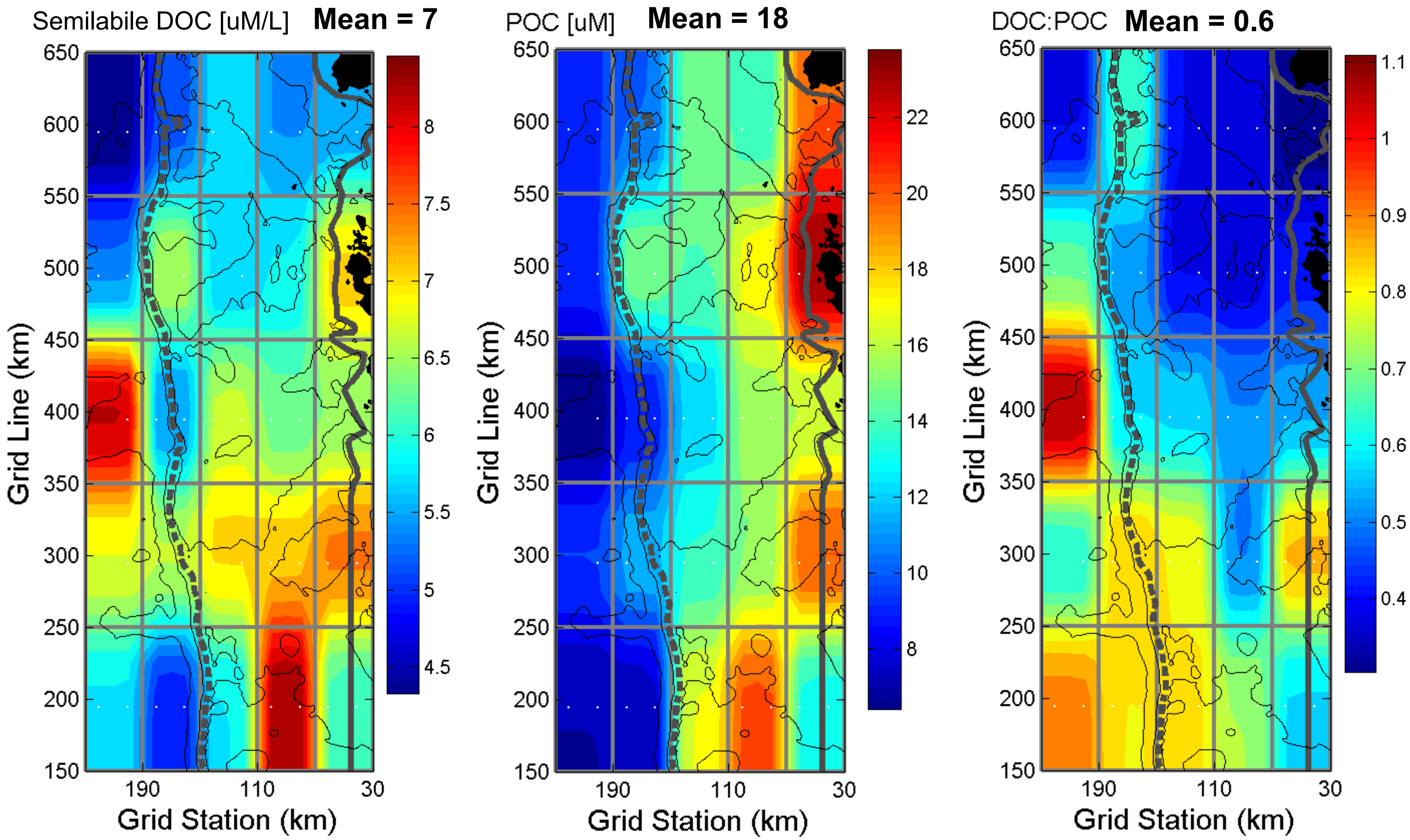


Figure 8 Distribution of sites of water column overturn (from Talley, 1999), general patterns of surface circulation in the subtropical gyres, and proposed distribution of *exportable* DOC. Overlap in the distribution of *exportable* DOC (background field of white) and sites of ocean ventilation (sites colored by gray scale) favors DOC export; a lack of overlap precludes export. The waters of the Southern Ocean (slanted stripes) are without *exportable* DOC present, so where these waters overlap sites of ventilation, little export is expected.

HOT Organic Carbon Standing Stocks (surface)



LTER S-DOC and POC Climatology, January-February 2003-2008 (n=250)



Particulate and Dissolved Organic Carbon

Site	**POC, μM**	**S-DOC, μM**	**Ratio**
HOT	2	45	22
PAL	18	7	0.6

TROPHODYNAMIC VIEW OF BACTERIAL ECOLOGY

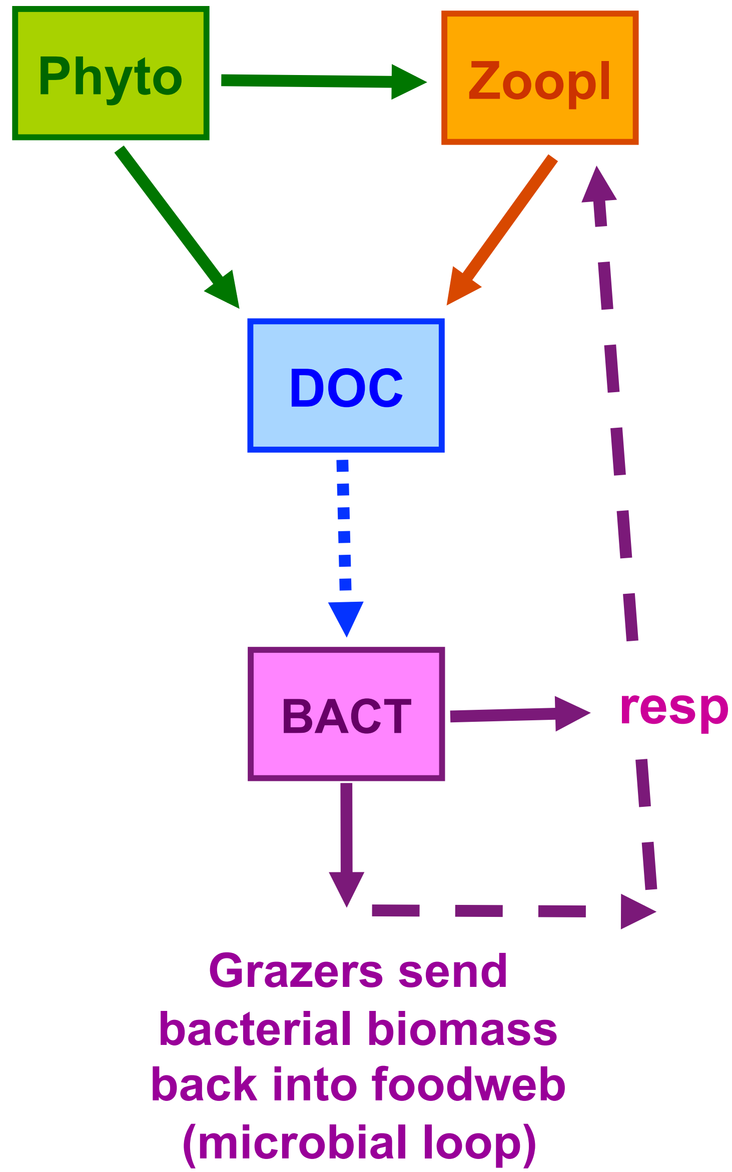
Bacterial biomass production is based primarily on flows of dissolved organic matter from other organisms.

Bacteria are consumed by grazers and this the DOC "lost" from the foodweb is recovered by bacterial activity

This process is the Microbial Loop

We can measure rates of bacterial biomass production and primary production by phytoplankton (photosynthesis) to understand the relationships among these flows.

Global mean BP:PP ~ 10%



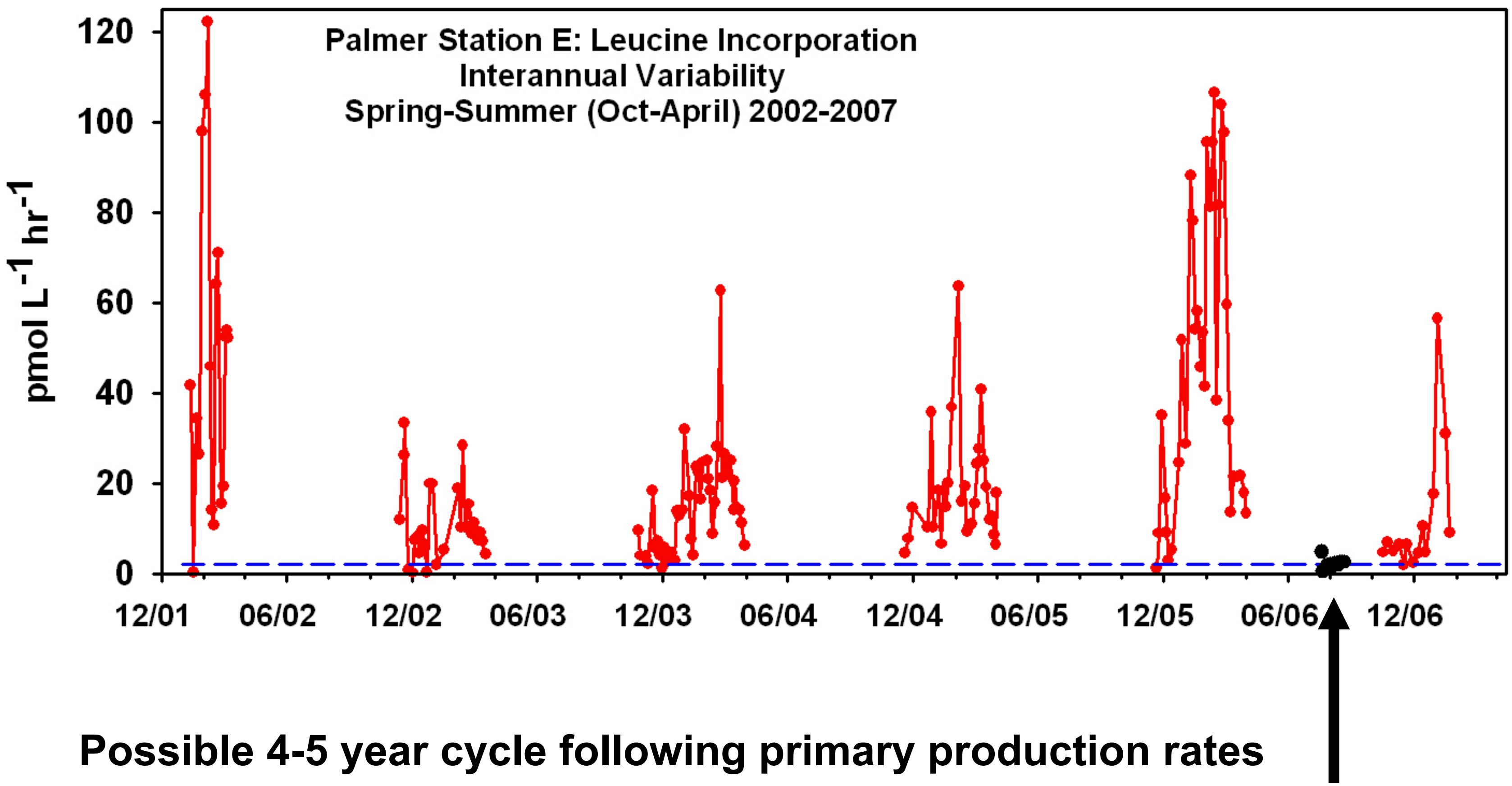
Microbial ecology at Palmer Station:

Humpback whales at Palmer Station E, March 2008


DOC input

Bacteria – Phytoplankton Relationships

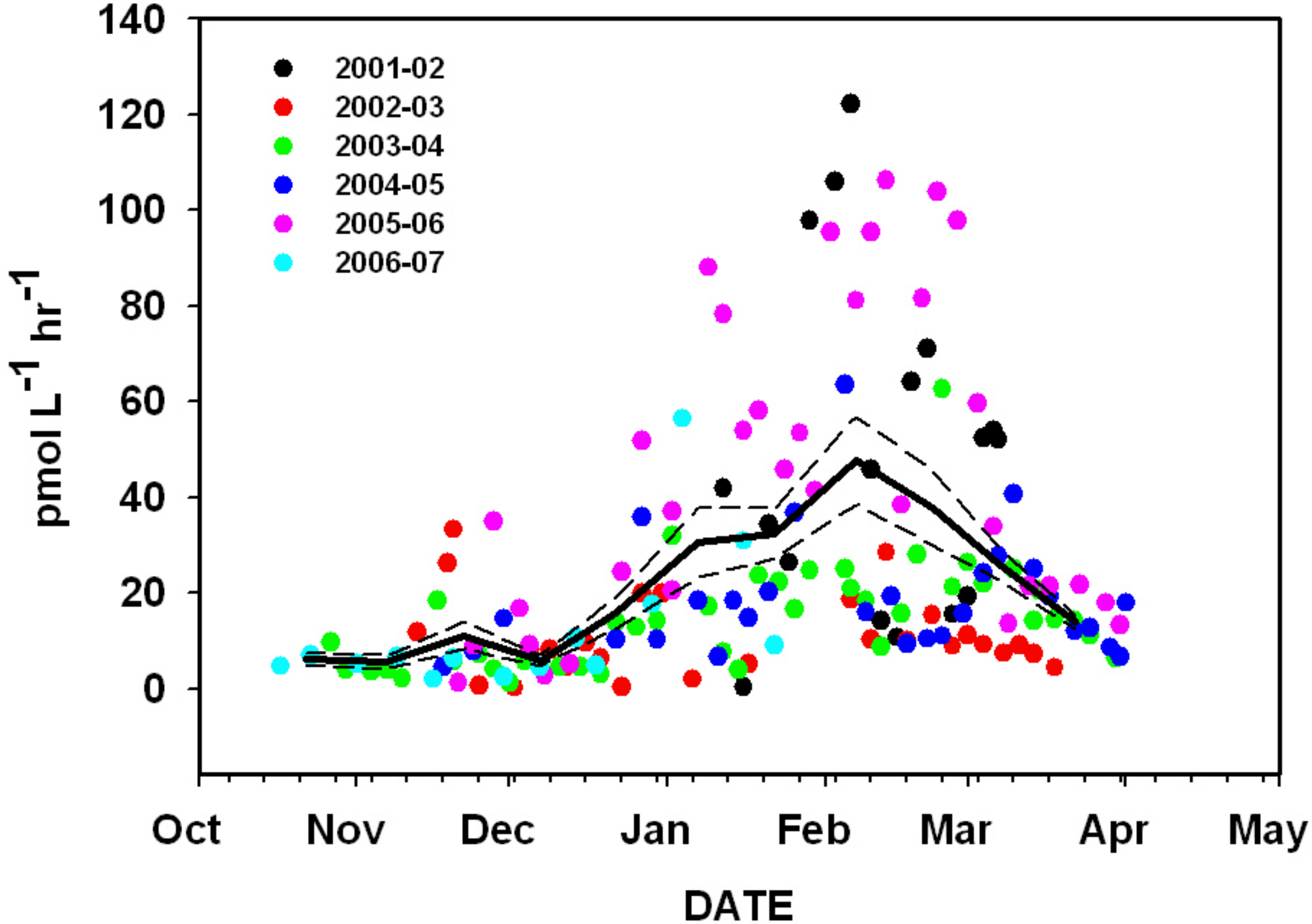
Bacterial production rates measured by radioactive leucine uptake



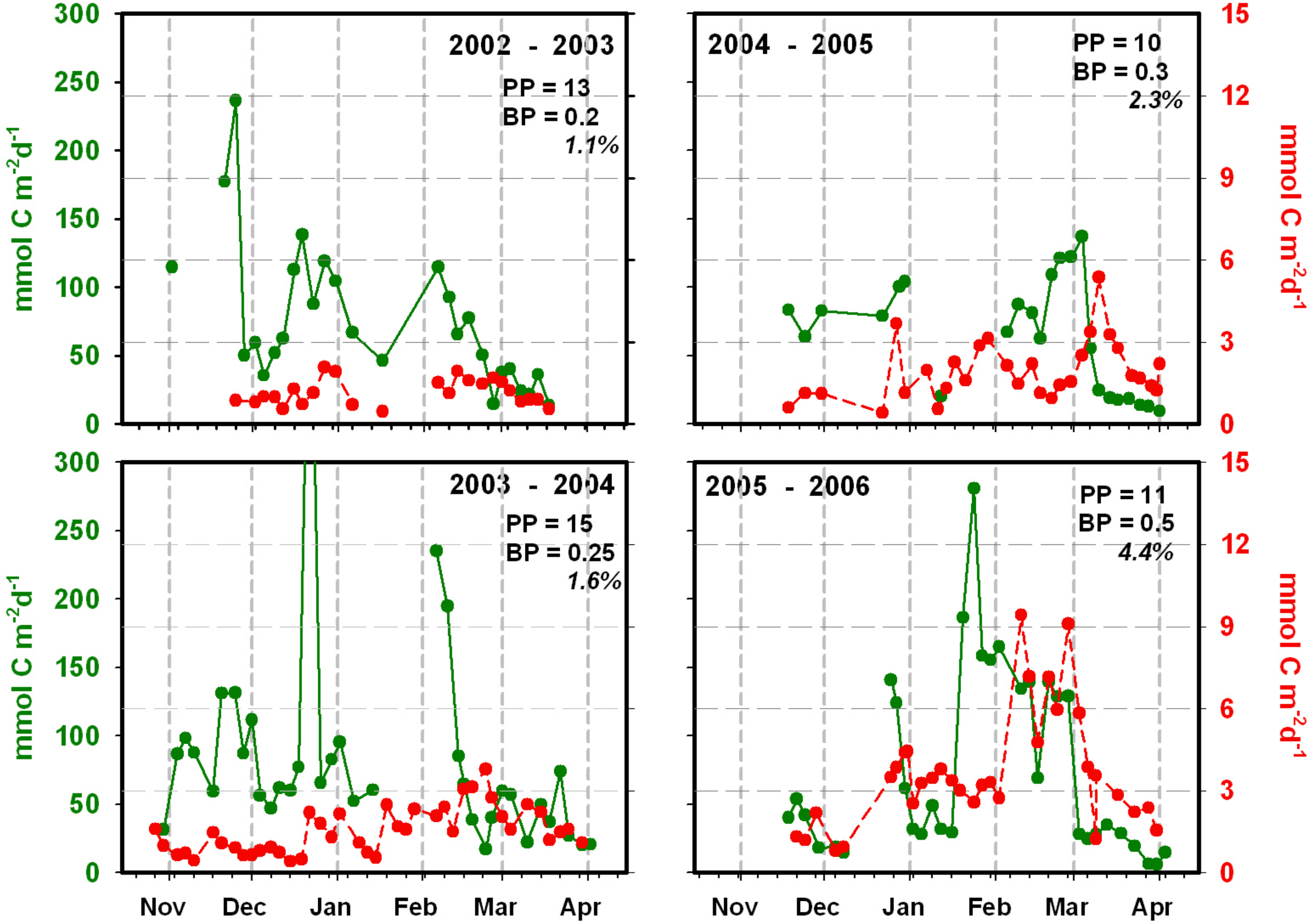
Possible 4-5 year cycle following primary production rates

Mean winter rate:
5 pM/hr; July-Sept 2008

Bacterial Production: Composite Seasonal Cycle and interannual variability

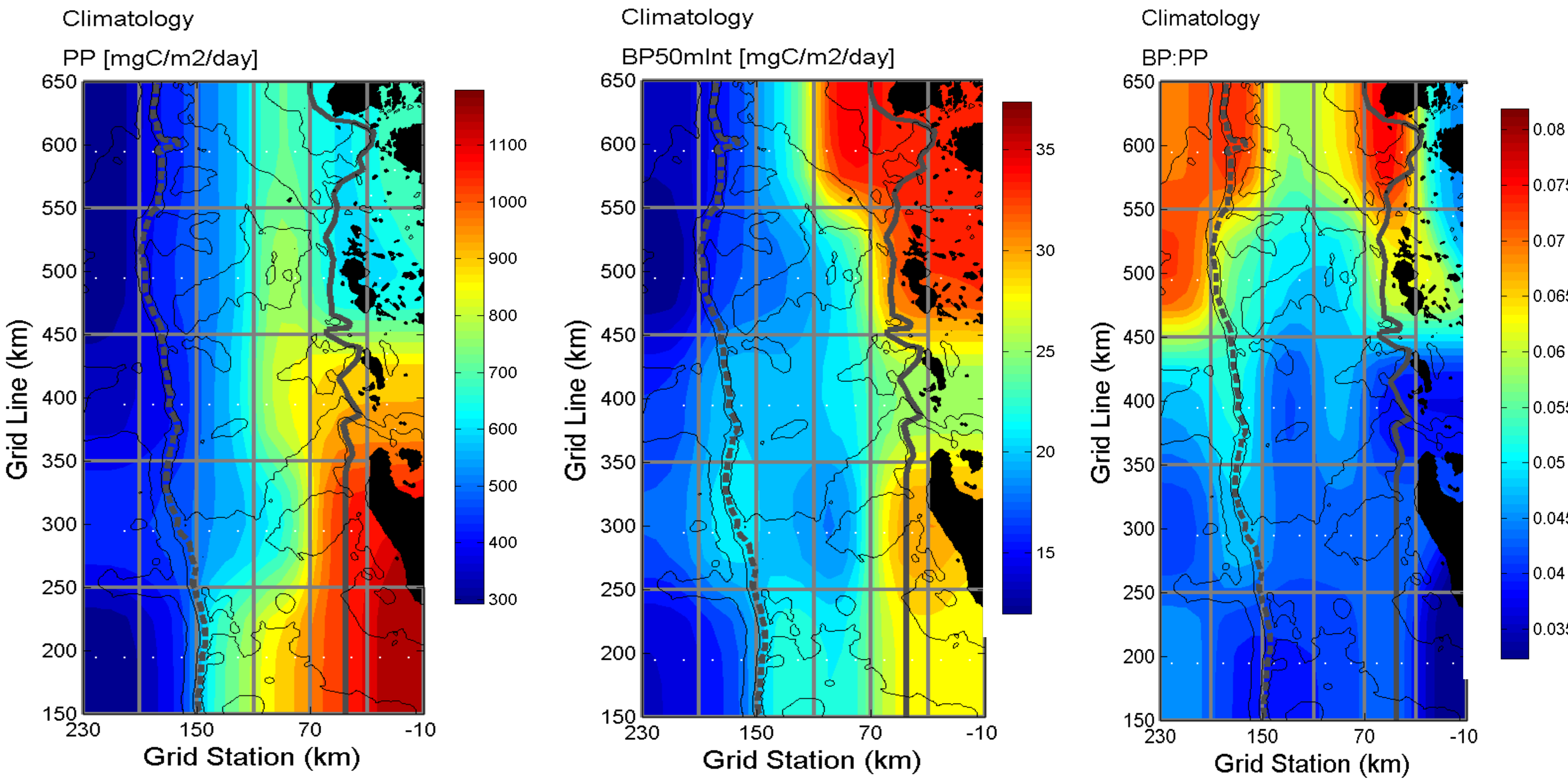


PRIMARY & BACTERIAL PRODUCTION AT Station E

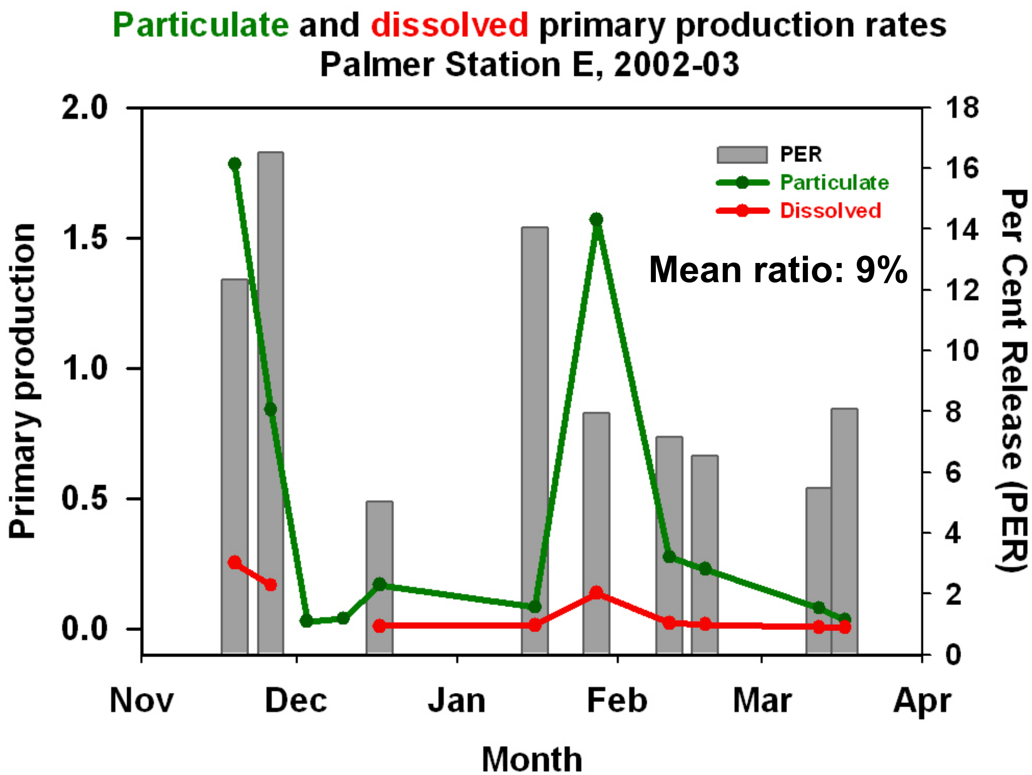


The values in the upper corners are annual integrals over 150 days excluding 01 Apr to 01 Nov. (Mol C m^{-2} a^{-1}). When symbols superimpose daily BP:PP = 5%. Winter adds ~0.06 Mol of BP to these totals (10-20%).

The mean BP:PP is ~2-3%



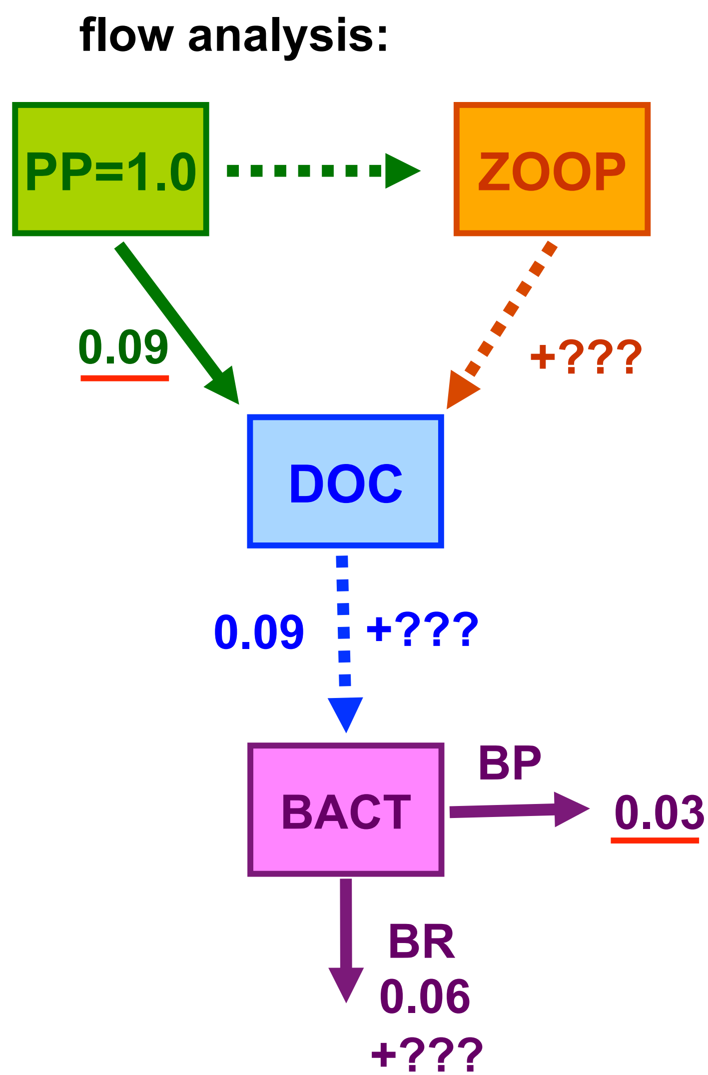
Climatology
PP [mgC/m2/day]
Grid Line (km)
Grid Station (km)
Climatology
BP50mInt [mgC/m2/day]
Grid Line (km)
Grid Station (km)
Climatology
BP:PP
Grid Line (km)
Grid Station (km)



Bacterial production rates follow primary production, seasonally and interannually, but comprise a low fraction of the PP.

Flux of labile DOC from healthy phytoplankton alone is sufficient to satisfy the bacterial demand, assuming reasonable growth efficiency

Will BP change as PP responds to warming?

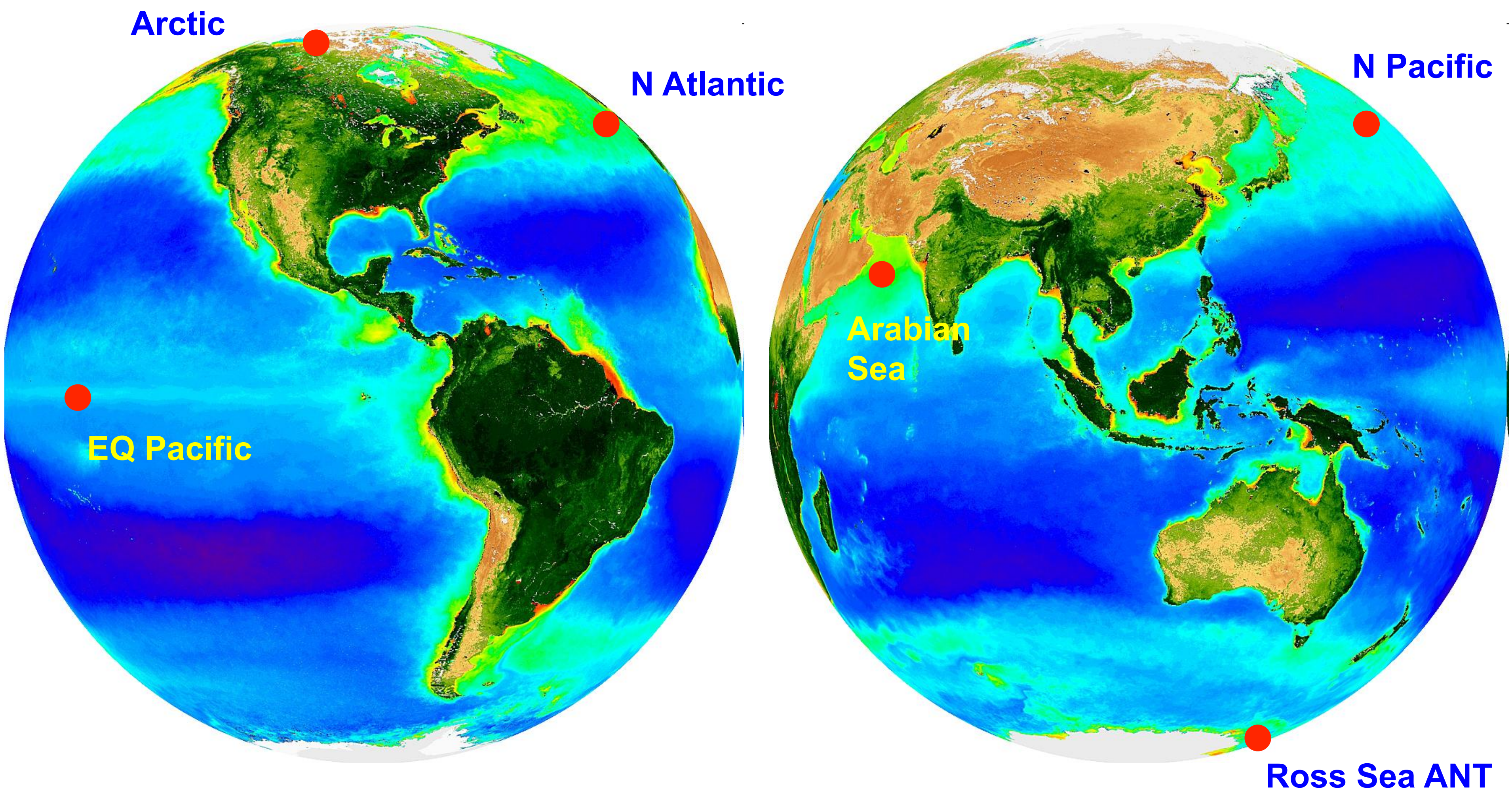


Apparent Growth Efficiency ???

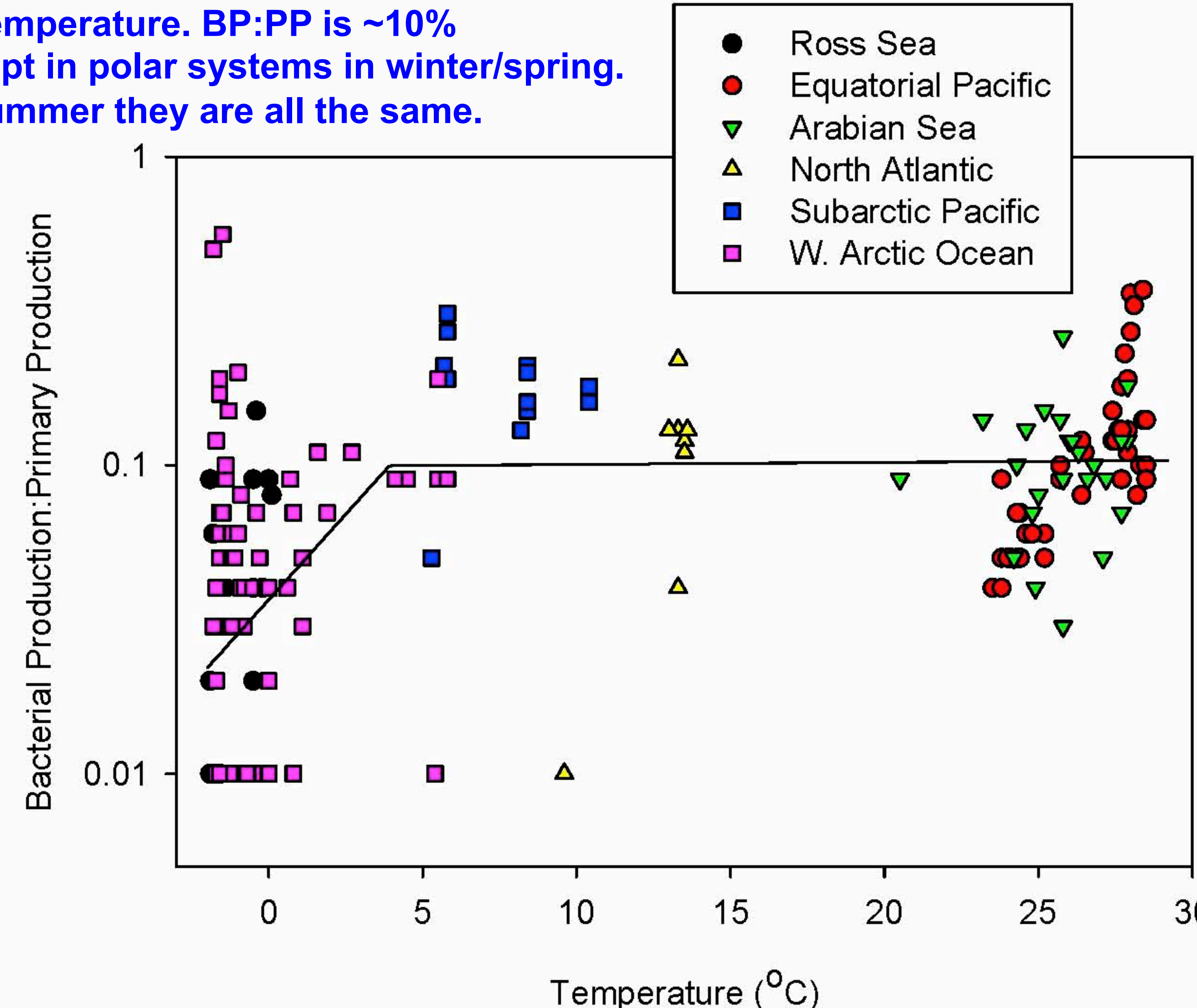
Scenarios:
DOC limitation (low flux)
More flux, lower BGE

Global perspective:

Are polar microbes different from lower latitude systems?
A global meta-analysis (JGOFS bacterial and phytoplankton biomass and production data) ***Kirchman et al. Nature Microbiology 2009***

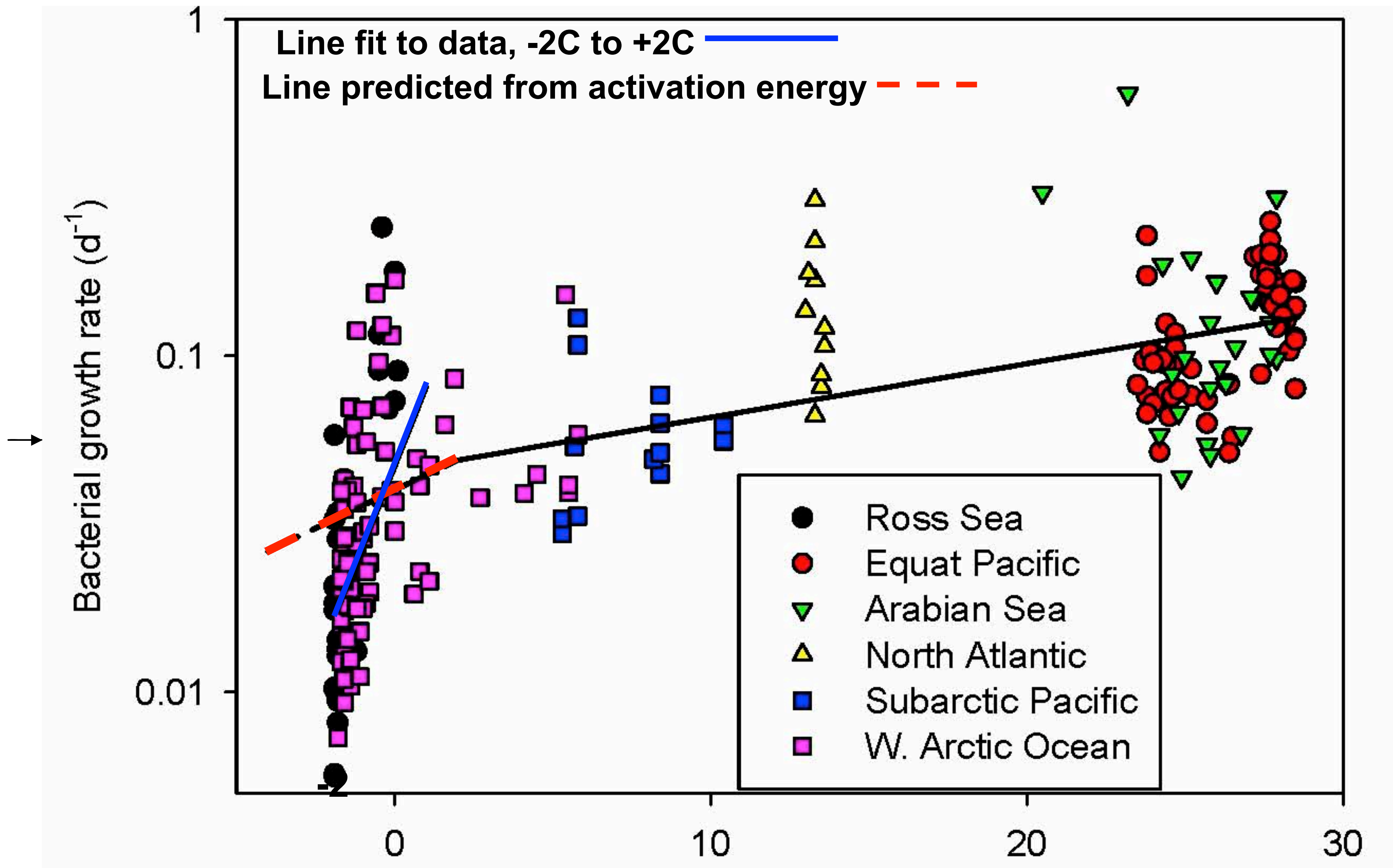


Ratio of bacterial to primary production vs temperature. BP:PP is ~10% except in polar systems in winter/spring. In summer they are all the same.



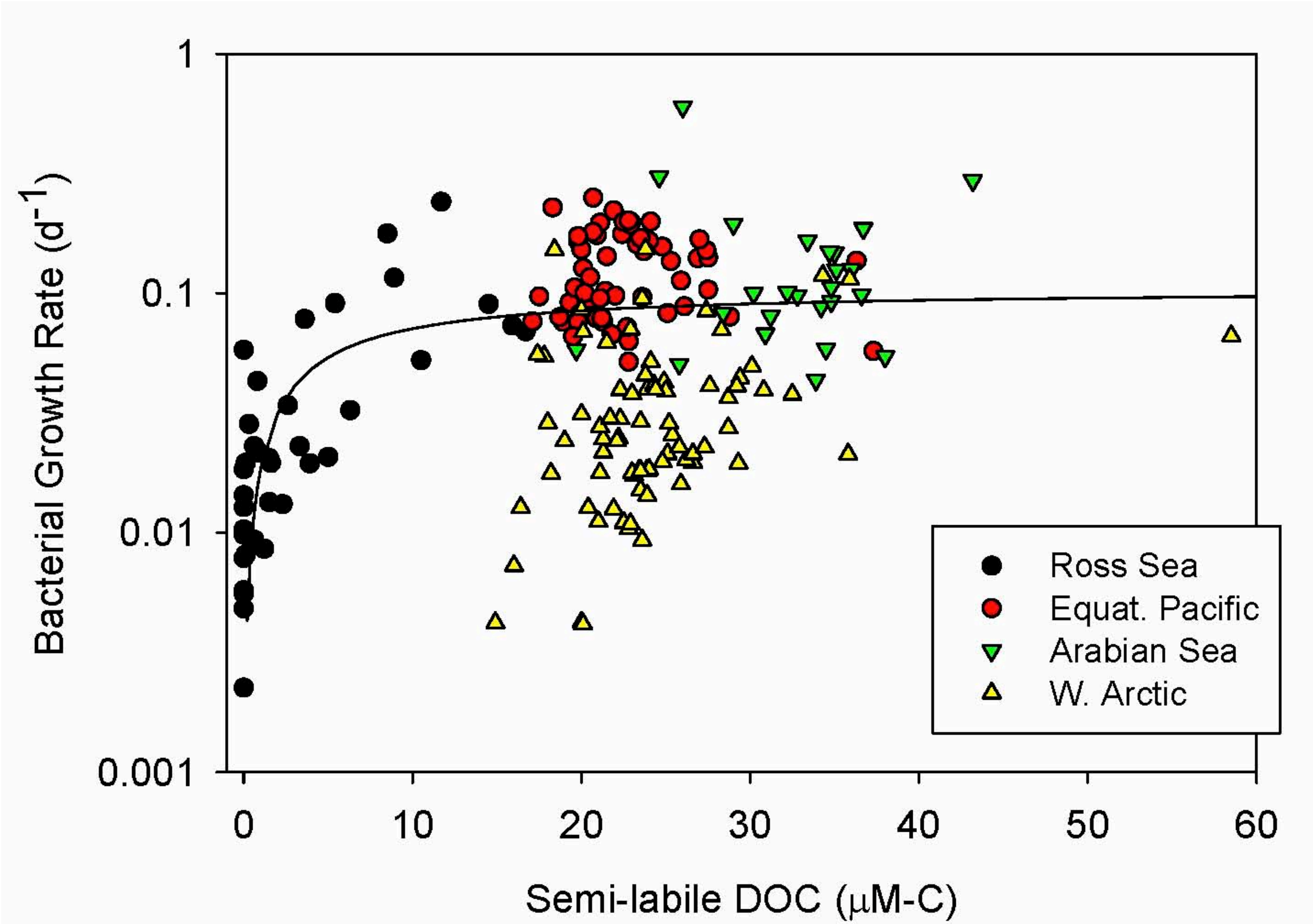
Kirchman et al Nature Microbiology (2009)

Temperature alone is not the answer



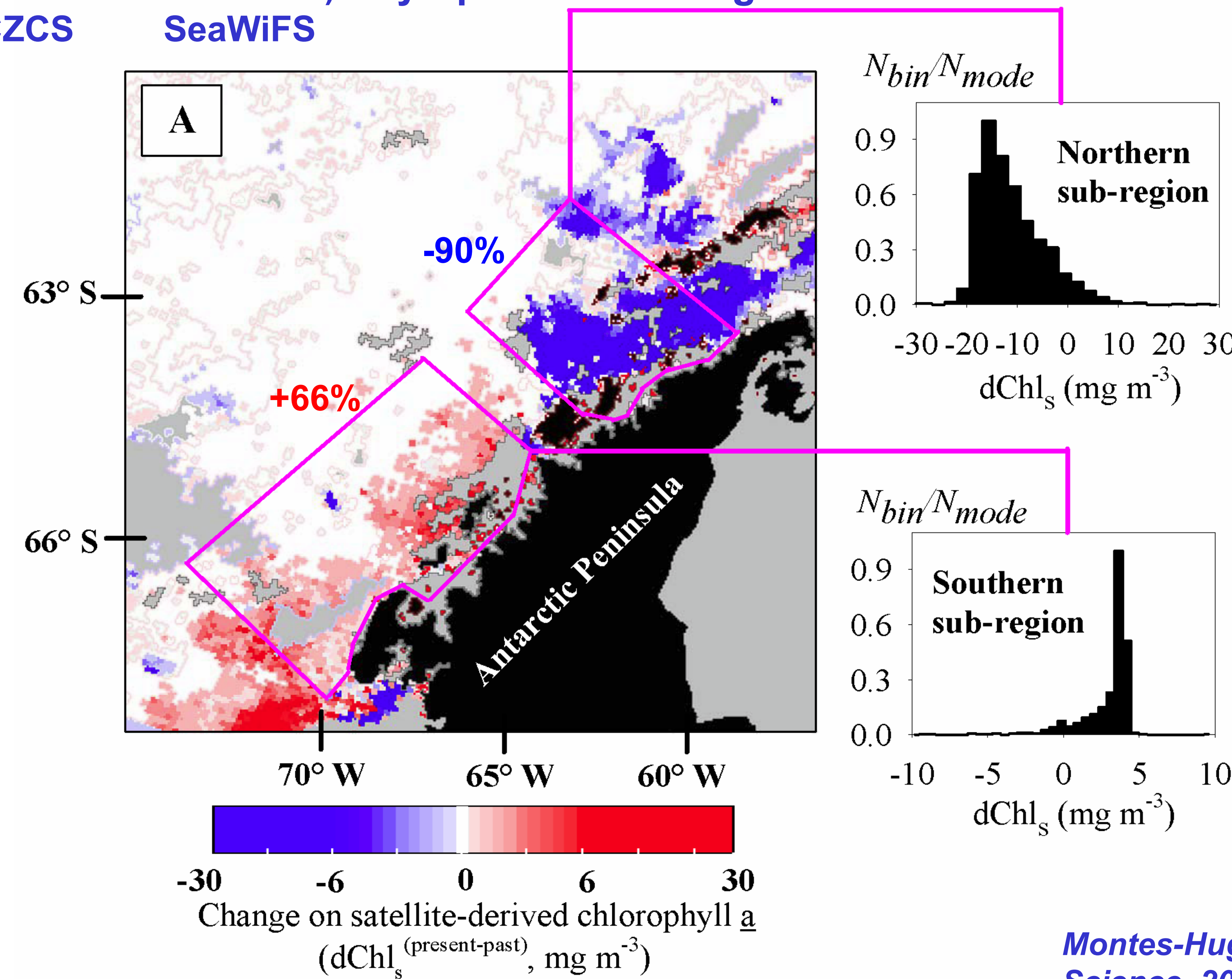
Kirchman et al Nature Microbiology (in review)

Bacterial growth rate and semi-labile Dissolved Organic Carbon



Kirchman et al Nature Microbiology (2009)

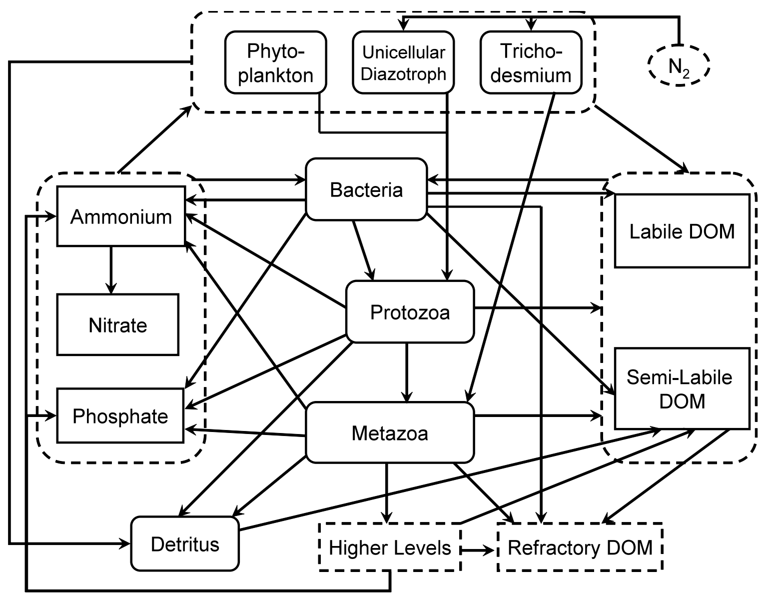
(1978-86 to 1998-2006) Phytoplankton Changes:
CZCS SeaWiFS

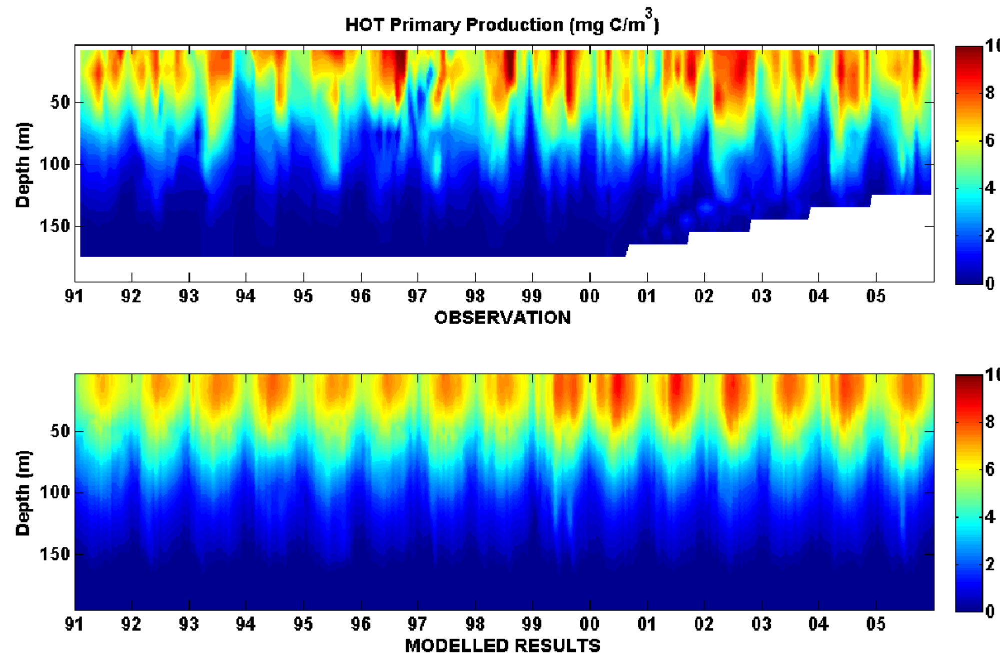


Montes-Hugo et al
Science, 2009

Heterotrophic Microbial Dynamics in the Open Ocean Revealed by Data Assimilative Modeling

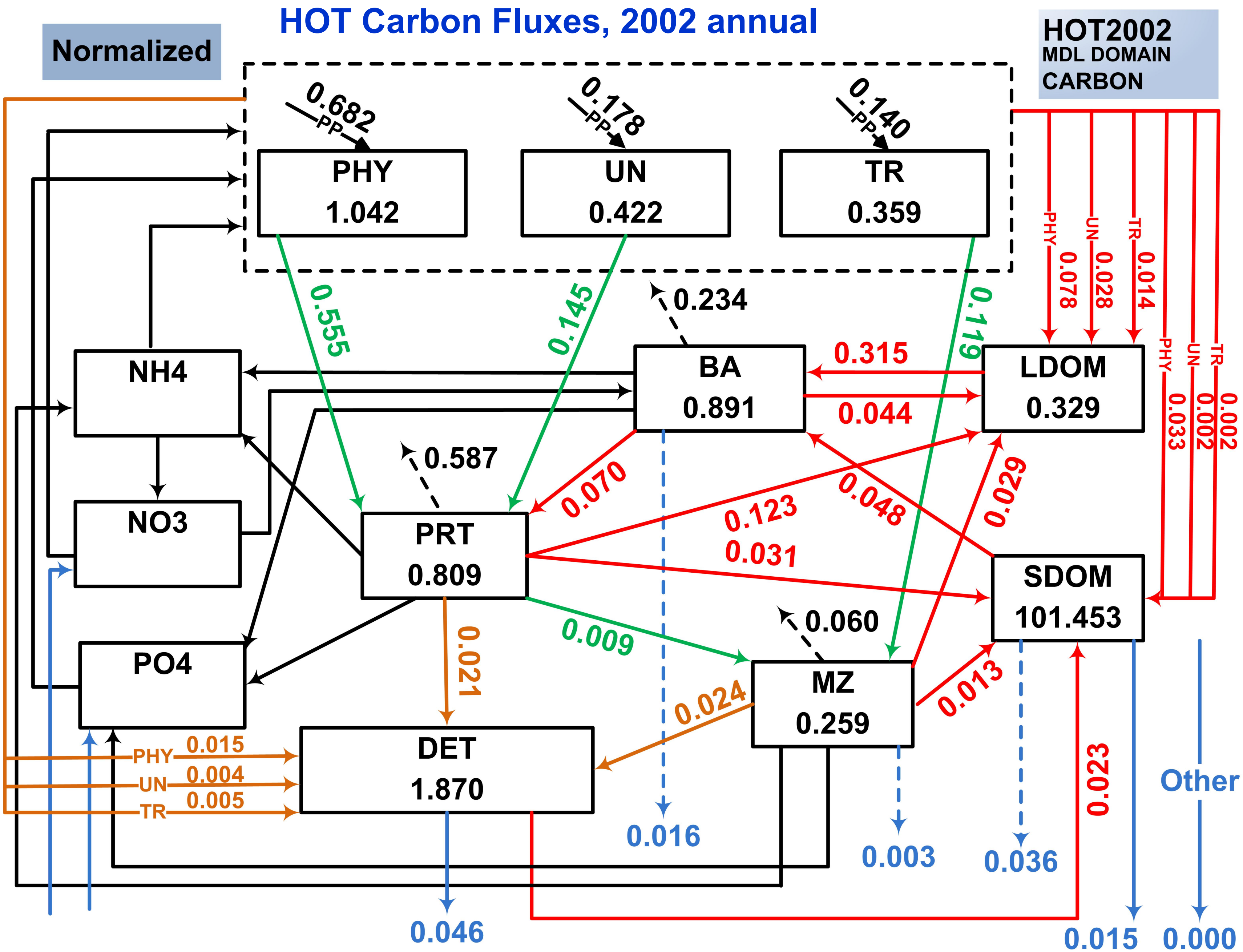
Yawei Luo*, Hugh Ducklow, Marjy Friedrichs, Scott Doney and Matthew Church



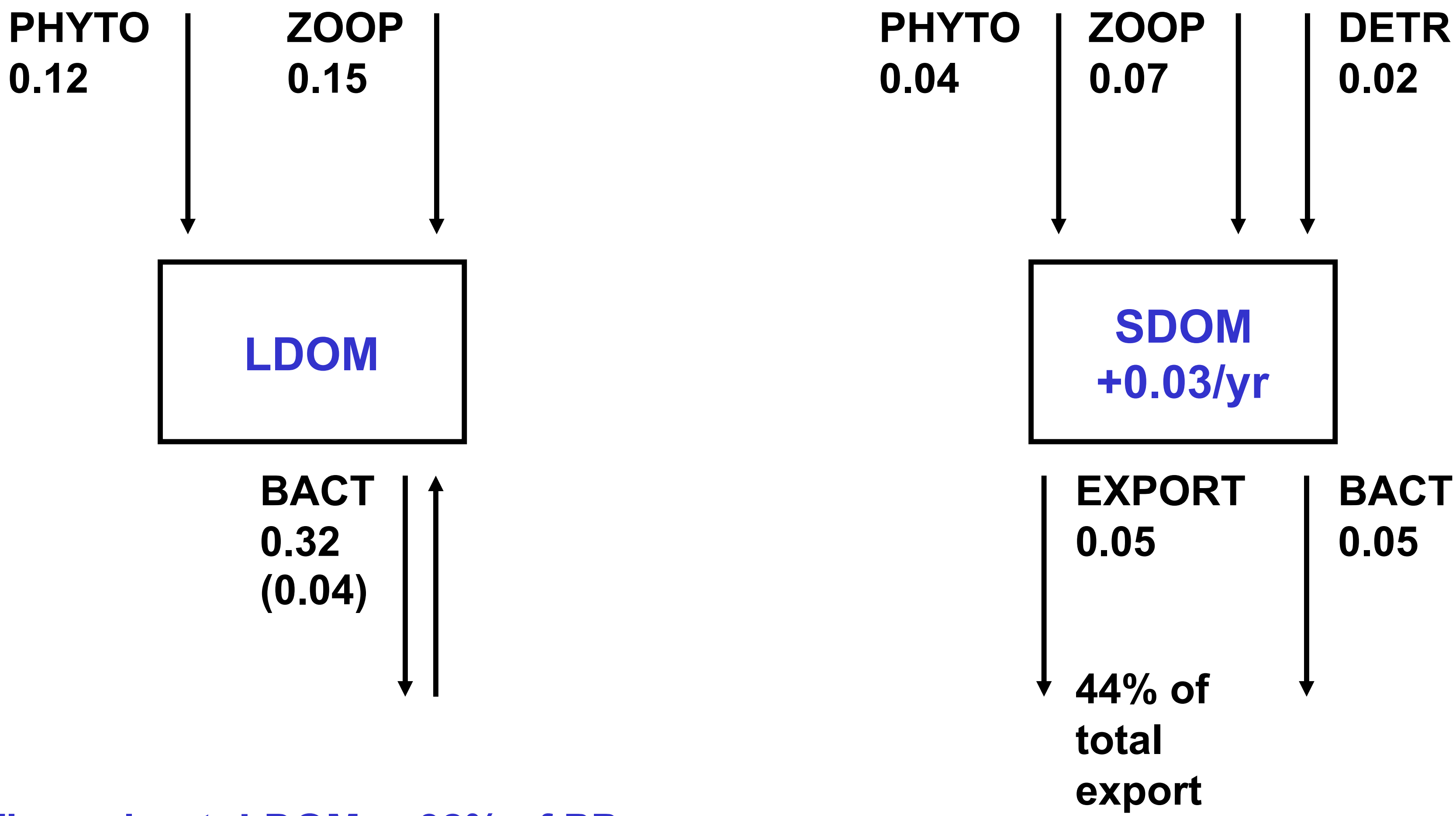


Multi-element (C,N,P), variable stoichiometry
Optimized with HOT data (NO3, PO4, NH4, DOC, DON, DOP, Bact #, PP, BP, Export, Zoop, CHL, POC, PN, PP

** PhD, Brown Univ/MBL 2009; Aquat. Microb. Ecol. Submitted.*


HOT Carbon Fluxes, 2002 annual
Normalized
HOT2002
MDL DOMAIN
CARBON
0.682 PP
0.178 PP
0.140 PP
PHY 1.042
UN 0.422
TR 0.359
0.555
0.145
0.119
0.234
BA 0.891
LDOM 0.329
0.315
0.044
NH4
NO3
PO4
PRT 0.809
0.587
0.070
0.123
0.048
0.031
0.029
SDOM 101.453
PHY 0.078
UN 0.028
TR 0.014
PHY 0.033
UN 0.002
TR 0.002
0.009
0.060
MZ 0.259
0.013
0.021
0.024
DET 1.870
PHY 0.015
UN 0.004
TR 0.005
0.016
0.003
0.036
0.023
Other
0.046
0.015
0.000

HOT DOM Annual Fluxes normalized to PP = 1.00



Throughput: LDOM – 32% of PP
SDOM – 13% of PP
TOTAL – 45% of PP

Y Luo et al. 2009 (submitted)

SCOPING Statement/Questions:

Is the Southern Ocean unique in how organic matter is cycled, stored and exported?

What are the mechanisms and agents of cycling and transformation?

What is the role of temperature?

What about plankton community composition?

NEEDS:

More work in winter (what fuels BP in winter?)
Better areal coverage (is Peninsula an anomaly? Is it already changed?)

More process and experimental studies (Δtemp, Δorg matter, ΔCO2, Fe)

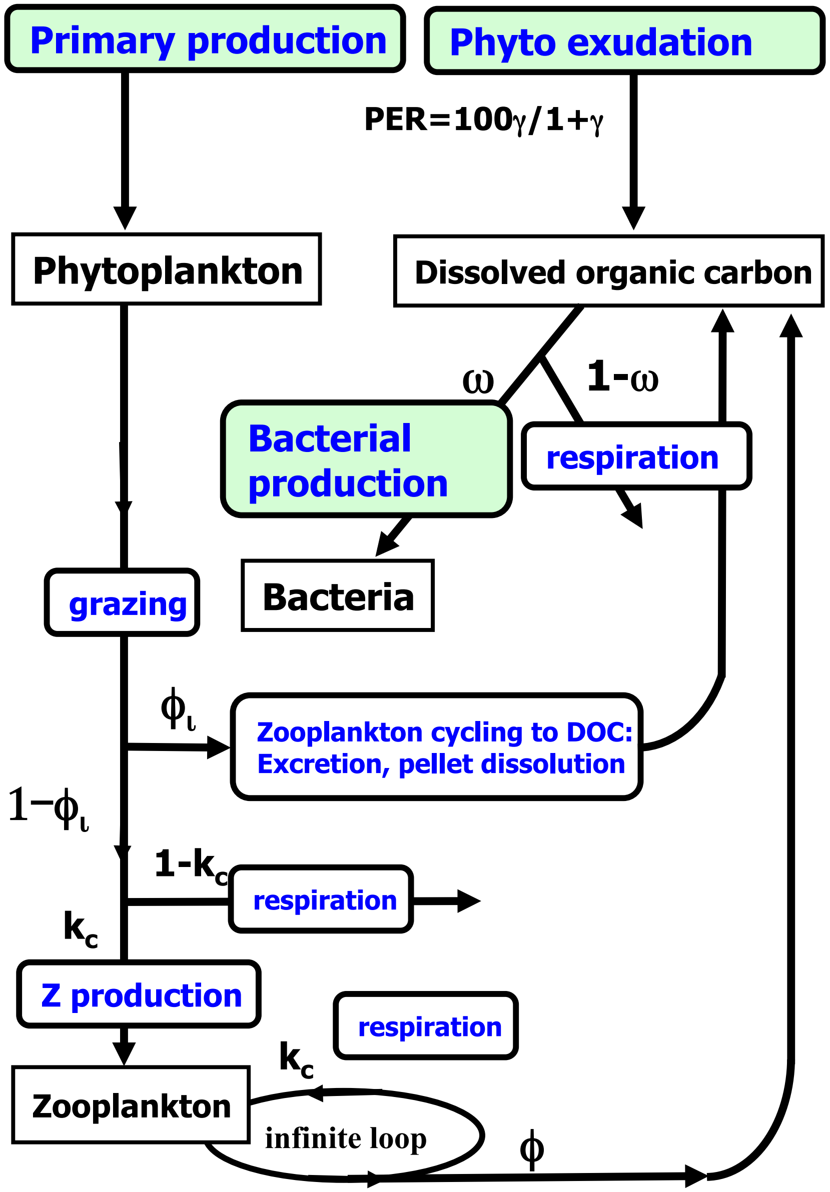
Better models and data to optimize & test them

QUESTION: How will Southern Ocean ecosystems change as warming migrates south?

SCOPING Statement
ARSV Laurence M GOULD
Last USAP cruise, May 2010
What do we need in the next 10 years?
What will be there for us?


Thanks:
OPP 0823101 (Palmer LTER)
Dave Kirchman
Yawei Luo
Matthew Church
Scott Doney
Matthew Erickson
Marjy Friedrichs
Xelu Moran
Alison Murray

Why 10%?



Oceanic BP Flow analysis (with Tom Anderson):

1. Consider first internal sources in near steady-state regimes.
2. Examine labile DOC fluxes & utilization.
3. Analyze physiological & trophic processes supplying DOC pools.
4. Derive BP from PP, DOC flux and ϕ, k_c, ω (zooplankton & bacterial growth efficiency, and DOC allocation).
5. Is BP "too high"?

   Is a subsidy needed?