Introduction to (a corner of) Marine Ecosystem Modeling

Keith Lindsay (NCAR)
S. Doney (WHOI), K. Moore (UC-Irvine)

Outline of Presentation

- What is an NPZD model?
- Plankton Functional Groups (PFTs)
- CCSM BEC model
- Model Validation

What is an NPZD model?

N Nutrient
nitrate, ammonium,
phosphate, silicate, iron, etc.

P Phytoplankton
photosynthesizers

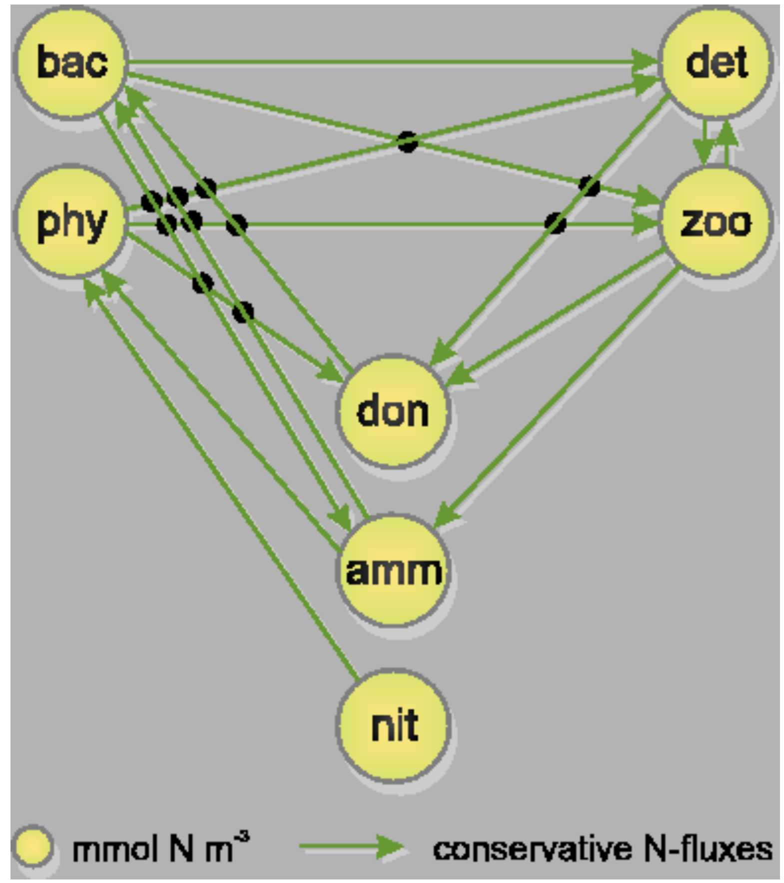
Z Zooplankton
grazers

D Detritus

<u>Canonical Example</u>

Fasham, Ducklow, McKelvie, Journal of Marine Research, Vol. 48, pp. 591-639, 1990.

Many more variations are used…



Fasham model diagram from www.gotm.net

Simple NPZ Model

$$\frac{dP}{dt} = \mu_0\left(\frac{N}{k_N + N}\right)\left(1 - e^{\alpha E/\mu 0}\right)P - g\left(\frac{P}{k_P + P}\right)Z - m_P P$$

Nutrient limitation — Light limitation — Grazing — Mortality

$$\frac{dZ}{dt} = ag\left(\frac{P}{k_P + P}\right)Z - m_Z Z$$

$$\frac{dN}{dt} = -\mu_0\left(\frac{N}{k_N + N}\right)\left(1 - e^{\alpha E/\mu 0}\right)P + (1-a)g\left(\frac{P}{k_P + P}\right)Z + m_P P + m_Z Z$$

- Three coupled ordinary differential equations
- Mass conservation

How do you estimate parameters and functional forms?

- Laboratory & field incubations
  - P-I curves
  - Nutrient uptake curves
- Tune/Optimize against field data
- Previous Models

Plankton Functional Groups (PFTs)

- Categorize plankton species by how they function and use representative groups
- Example definition from Le Quéré et al., Global Change Biology, Vol. 11, pp. 2016-2040, 2005.
  - Explicit biogeochemical role
  - Biomass and productivity controlled by distinct physiological, environmental, or nutrient requirements
  - Behavior has distinct effect on other PFTs
  - Quantitative importance in some region of the ocean

MAREMIP Models – Stage 0

Model: Property:	PlankTOM5	PISCES	NEMURO	CCSM-BEC
pPFTs (phyto)	3: Diatoms* Coccolithophores** Nanophytoplankton^	2: Diatoms Nanophytoplankton	2: Small phyto^ Large phyto*	3: Diatoms Nanophytoplankton Diazotrophs
zPFTs (zoo)	2: Microzooplankton^^ Mesozooplankton	2: Microzooplankton Mesozooplankton	3: Small zoo (micro) Large zoo (meso) Predatory zoo (macro)	1: Generic zoo
Physics	NEMO	NEMO	COCO	CCSM
Who	UEA	IPSL	JAMSTEC/Hokkaido	Woods Hole

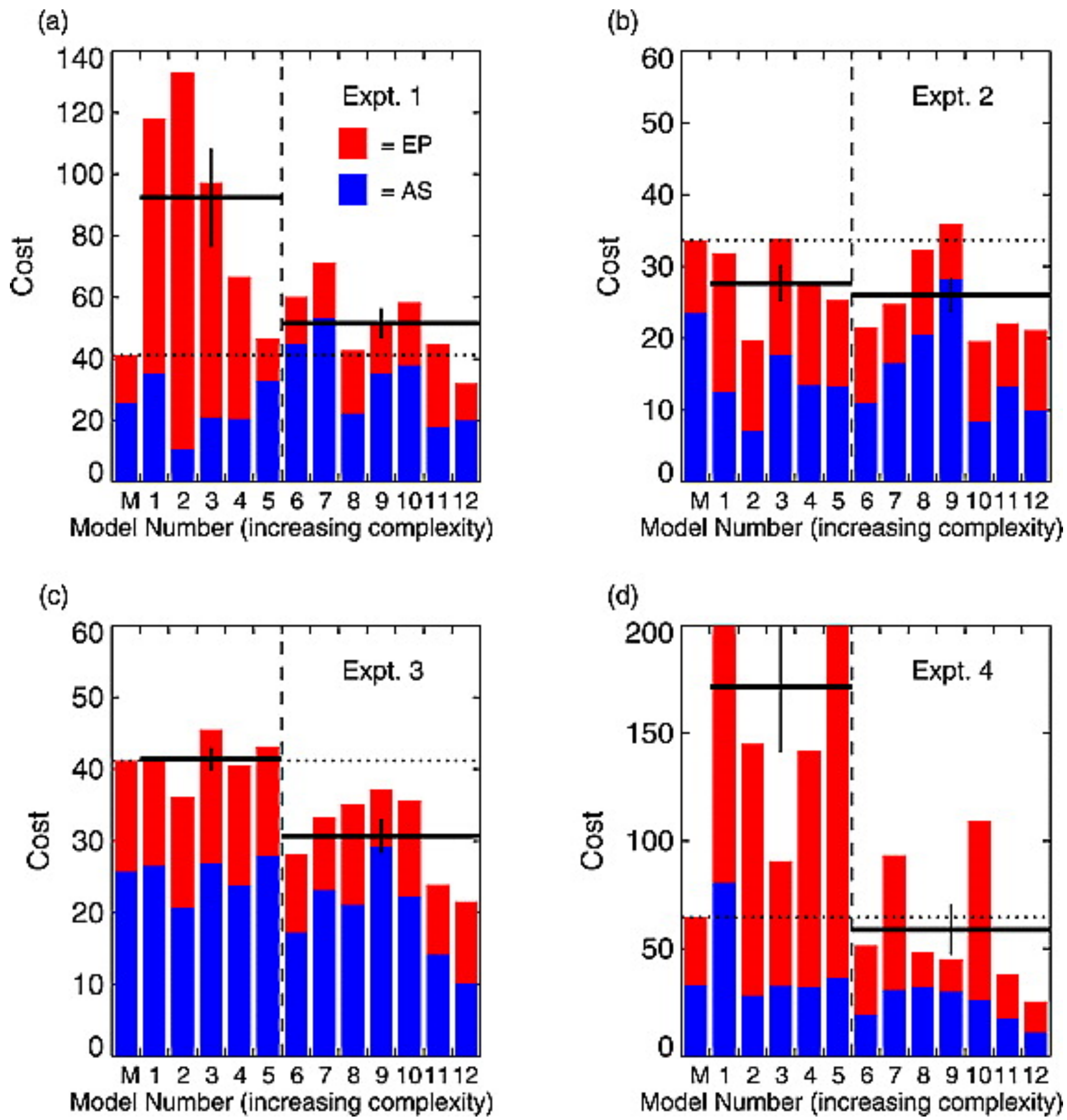
* silicifiers; ** calcifiers, ^ mixed phytoplankton, ^^ protozooplankton

Skill & Portability in 12 Different NPZD models
Friedrichs et al., JGR-Oceans, 2007.

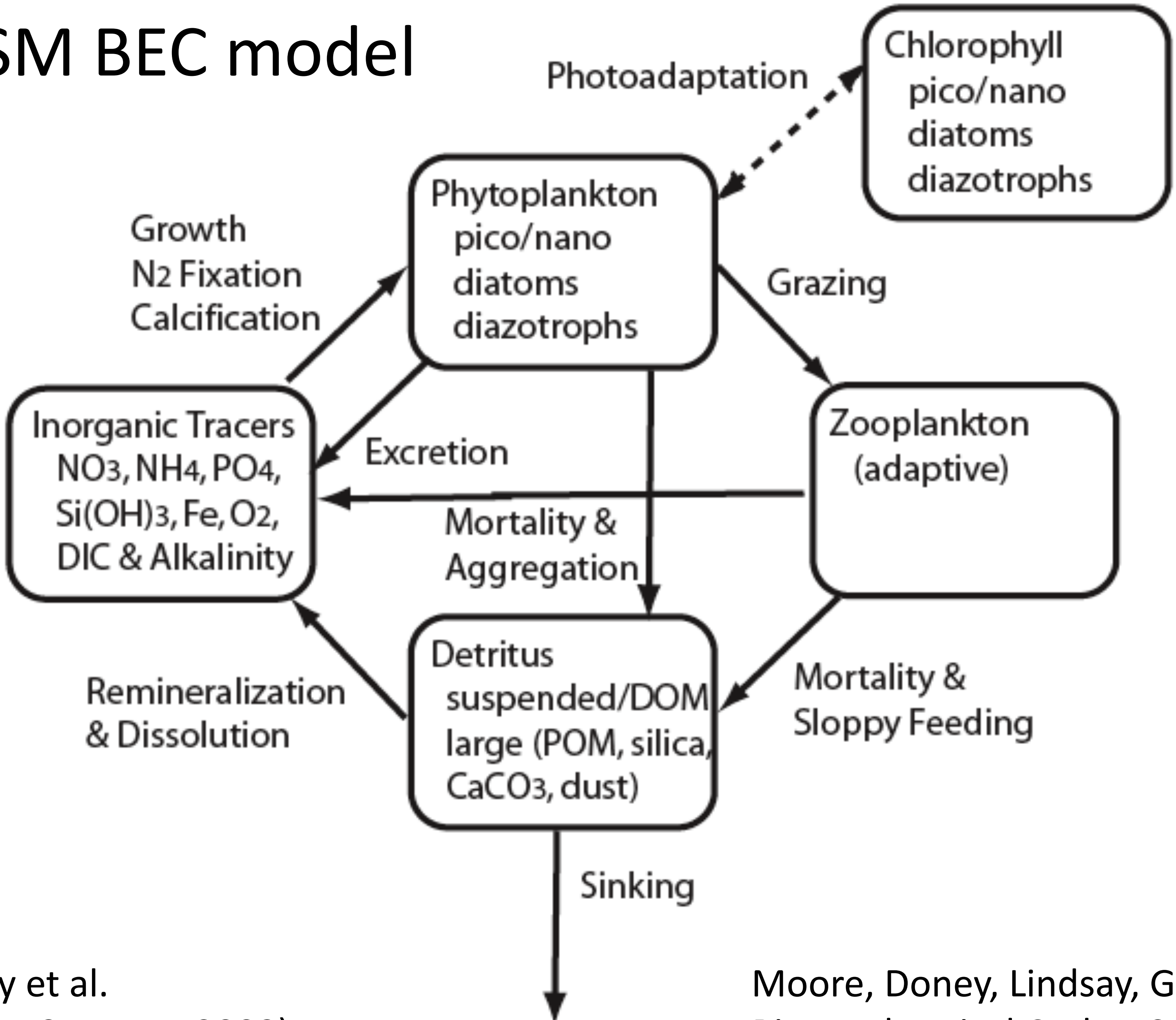
(b) Simple models do just as well as more complex models when tuned for specific sites.

(c) More complex models do better at multiple sites with single parameter sets.

(d) More complex models perform better at different sites when tuned for one site.



CCSM BEC model



Doney et al.
(J. Mar. Systems, 2009)

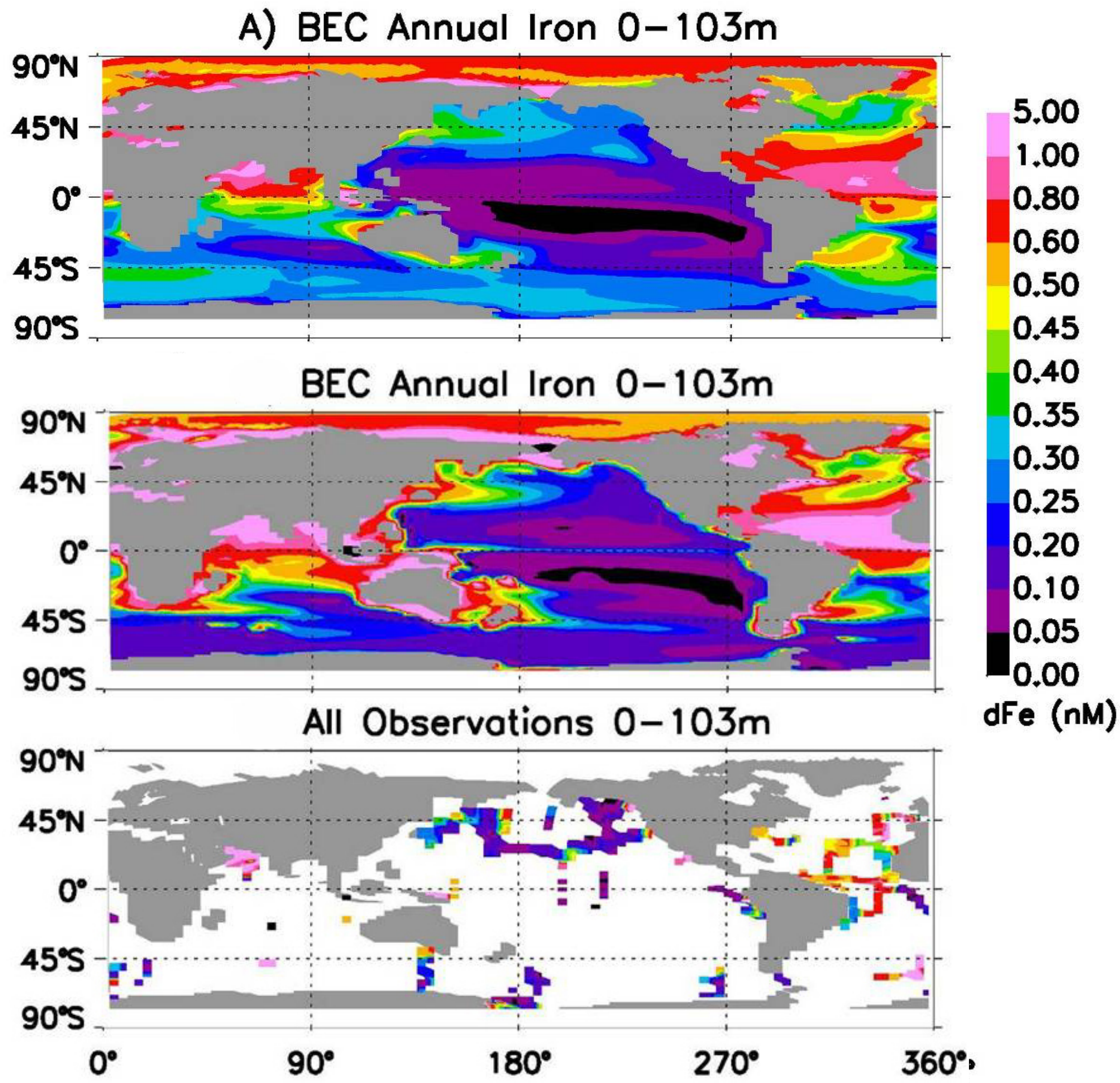
Moore, Doney, Lindsay, Global Biogeochemical Cycles, 2004.

Primary Features of BEC Model

- Fixed C:N:P ratios in plankton (24 tracers)
- Variable Fe:C, Si:C, Chl:C ratios
- Implicit coccolithophores
- Fe cycle improved in Moore, Braucher, Biogeosciences, Vol. 5, 2008, pp. 631-656.

Original BEC

Improved BEC
sediment Fe source
Fe scavenging



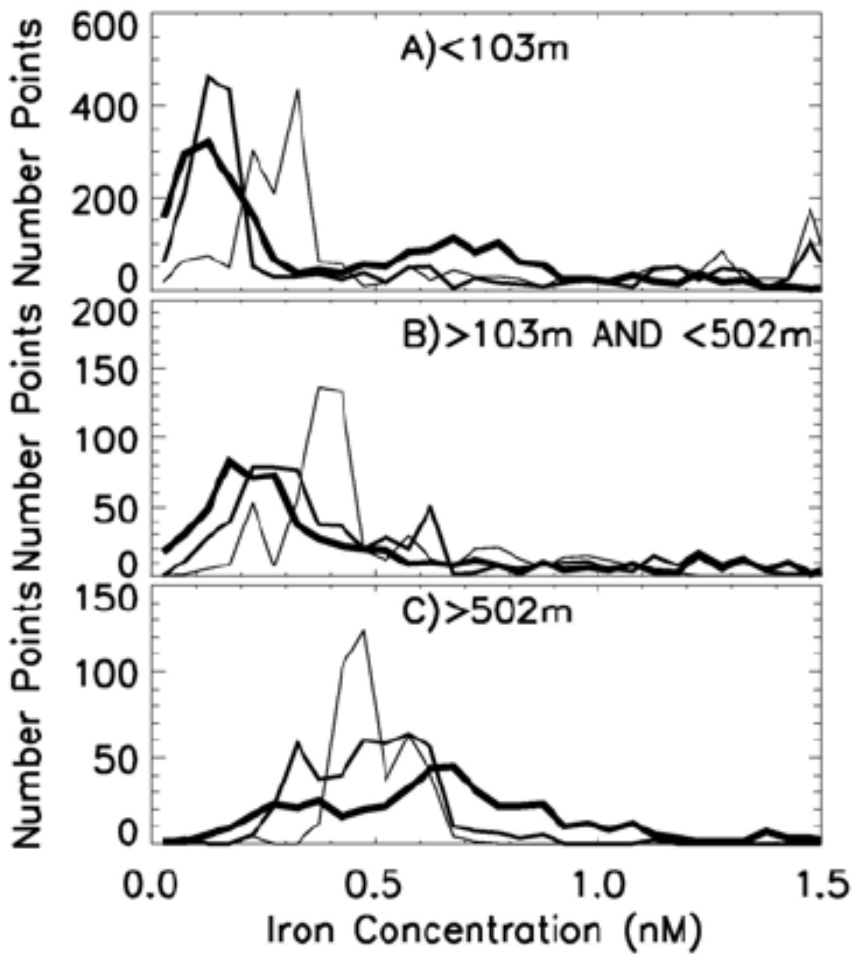
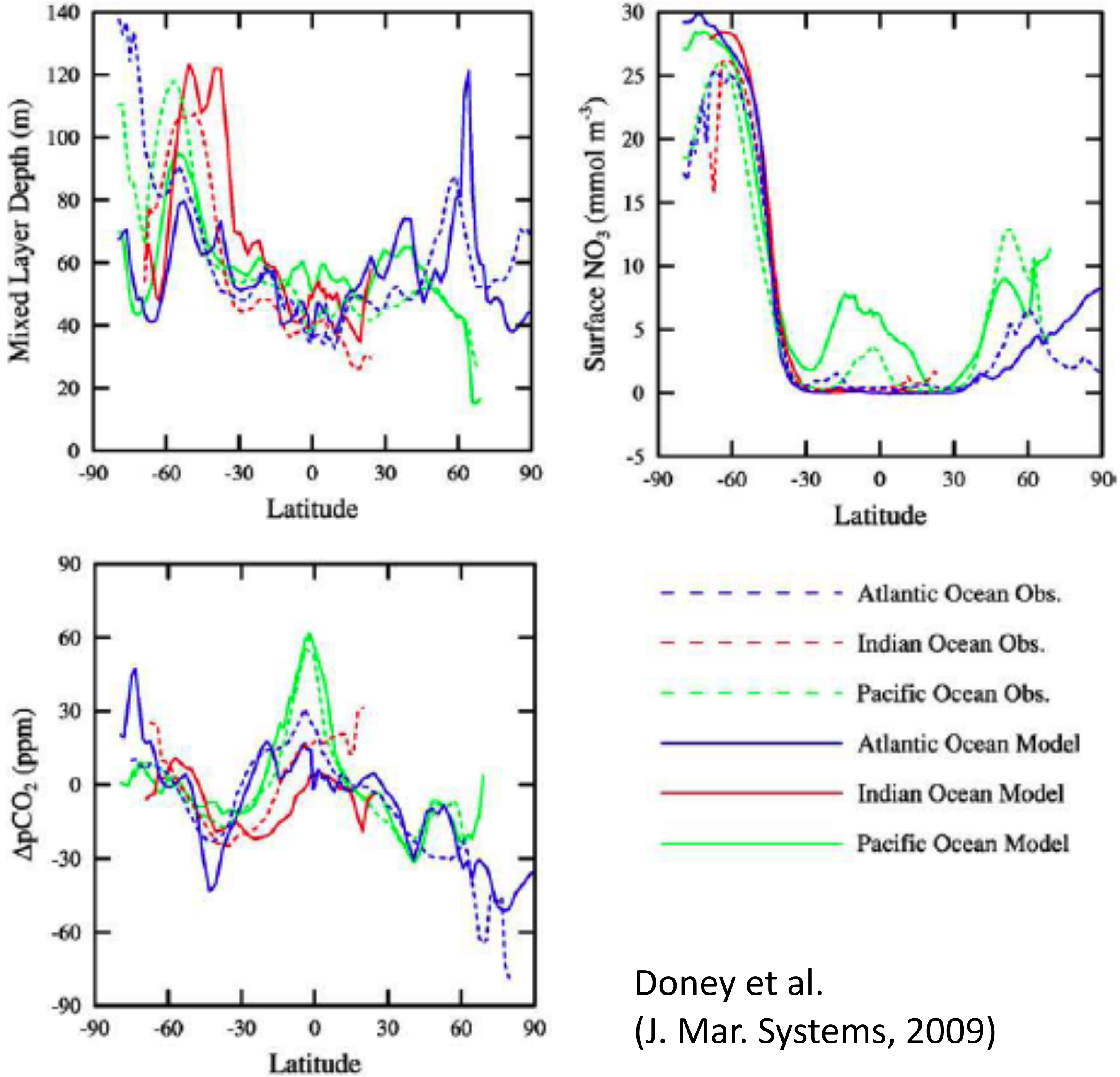


Fig. 10. Binned iron concentration values from the observations (thickest line), the New BEC simulation (medium line), and the Old BEC simulation (thin line) over depth ranges of 0–103 m **(A)**, 103–502 m **(B)**, and from greater than 502 m **(C)**.

Model Validation
Examples of Data Sets

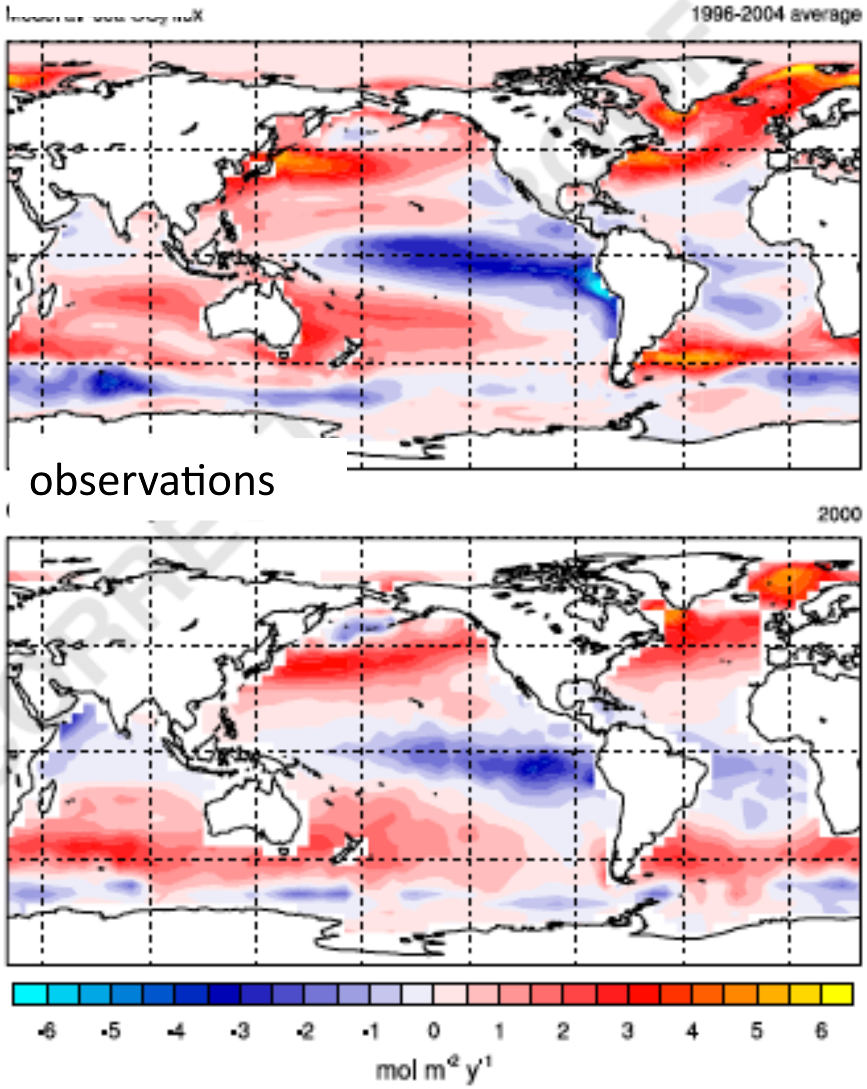
- Macronutrients (PO_4, NO_3, SiO_3) from WOA
- pCO_2 and CO_2 Flux assembled by Takahashi
- Surface Chl measured by satellite
- Productivity estimated from satellite
- JGOFS study sites
- HOTS & BATS timeseries

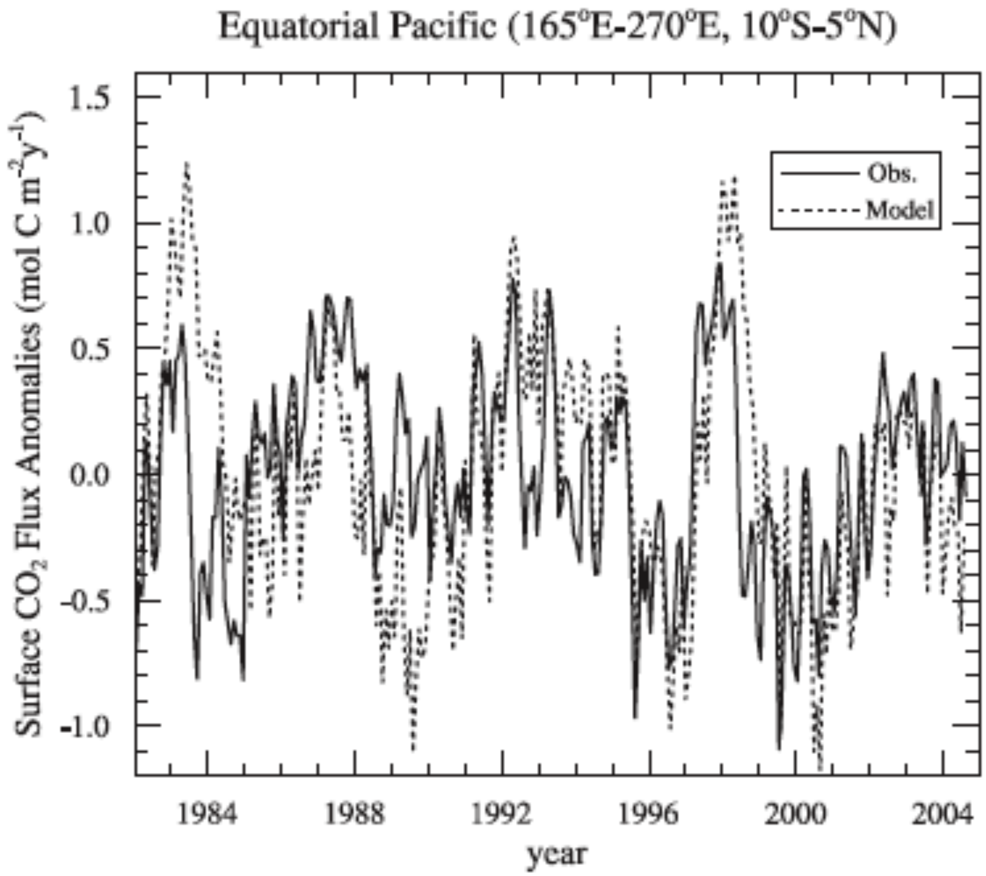


Doney et al.
(J. Mar. Systems, 2009)

Air-sea CO_2 Flux

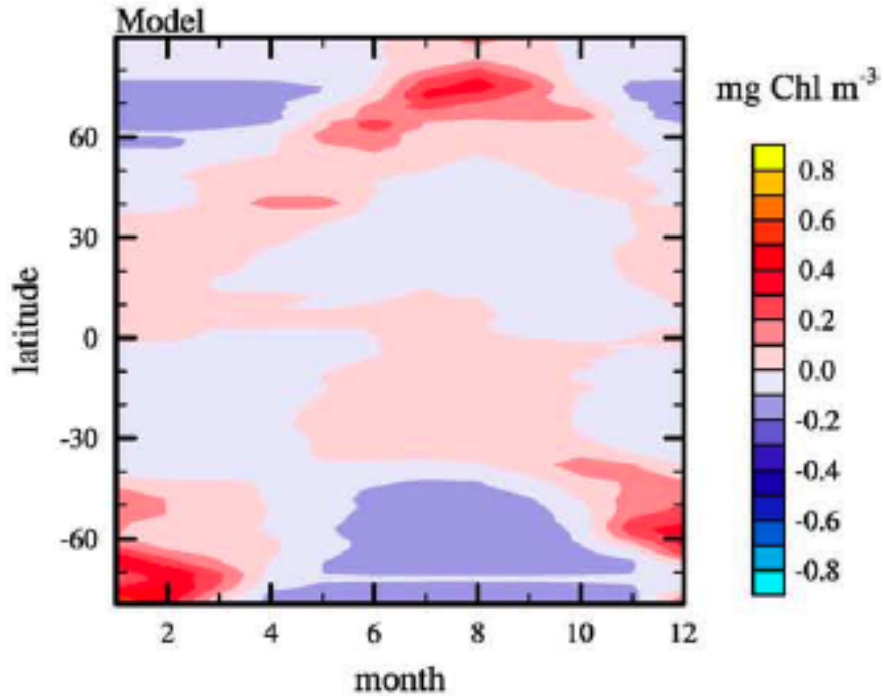
model

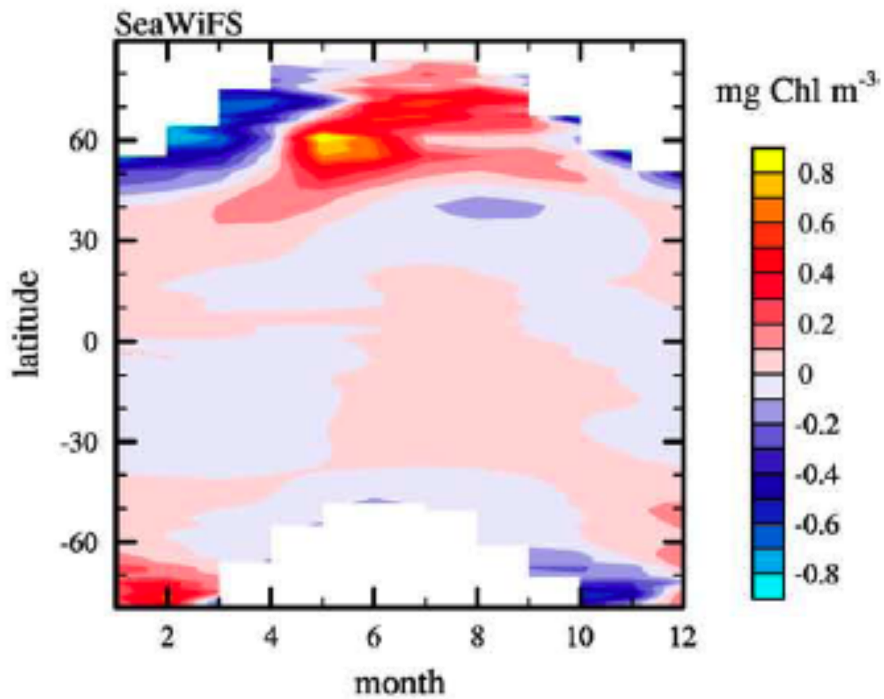


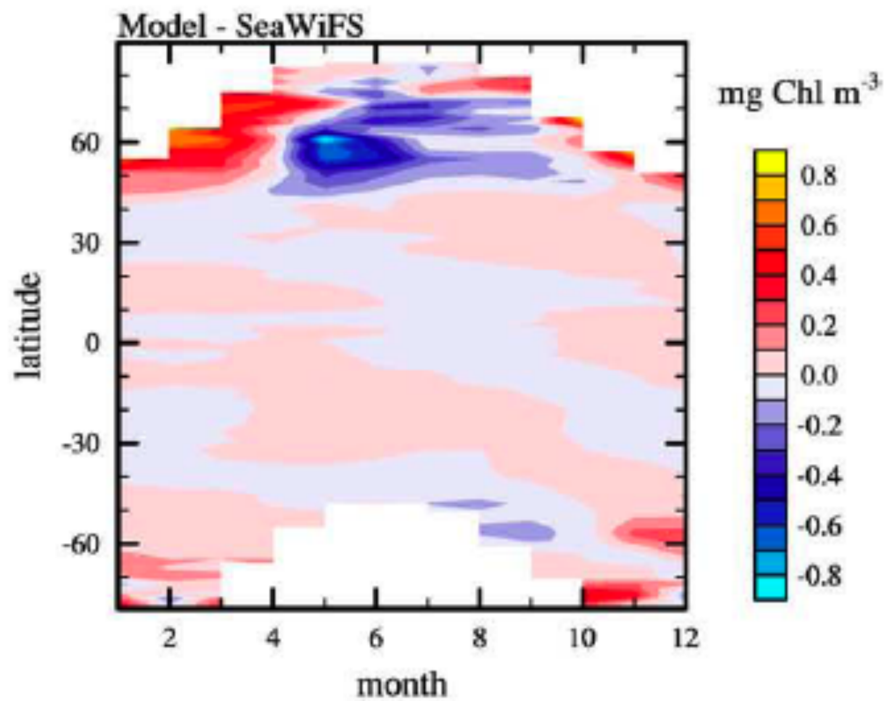


Doney et al. (Deep-Sea Res. II, 2009)

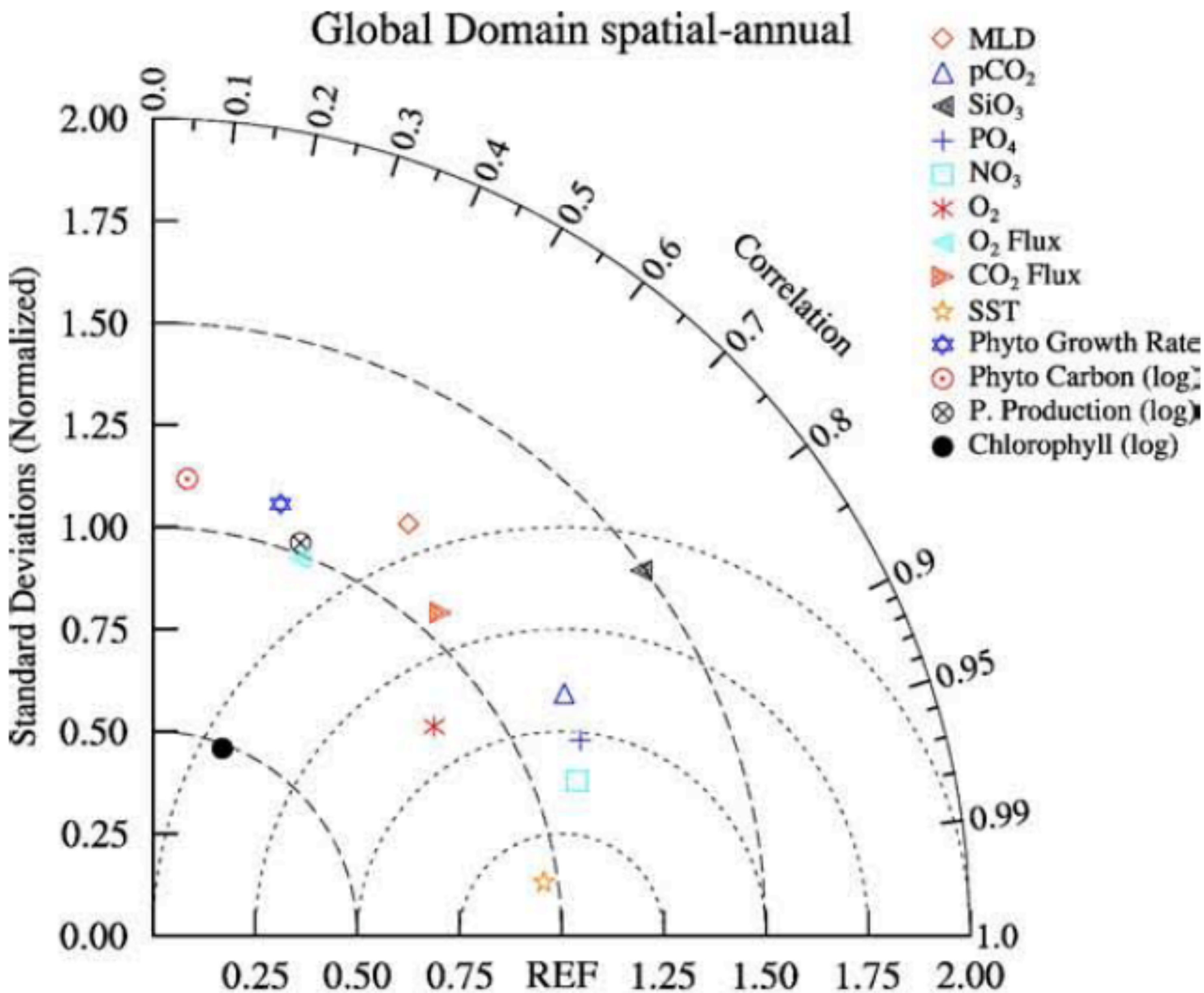
Satellite Ocean Color Comparison

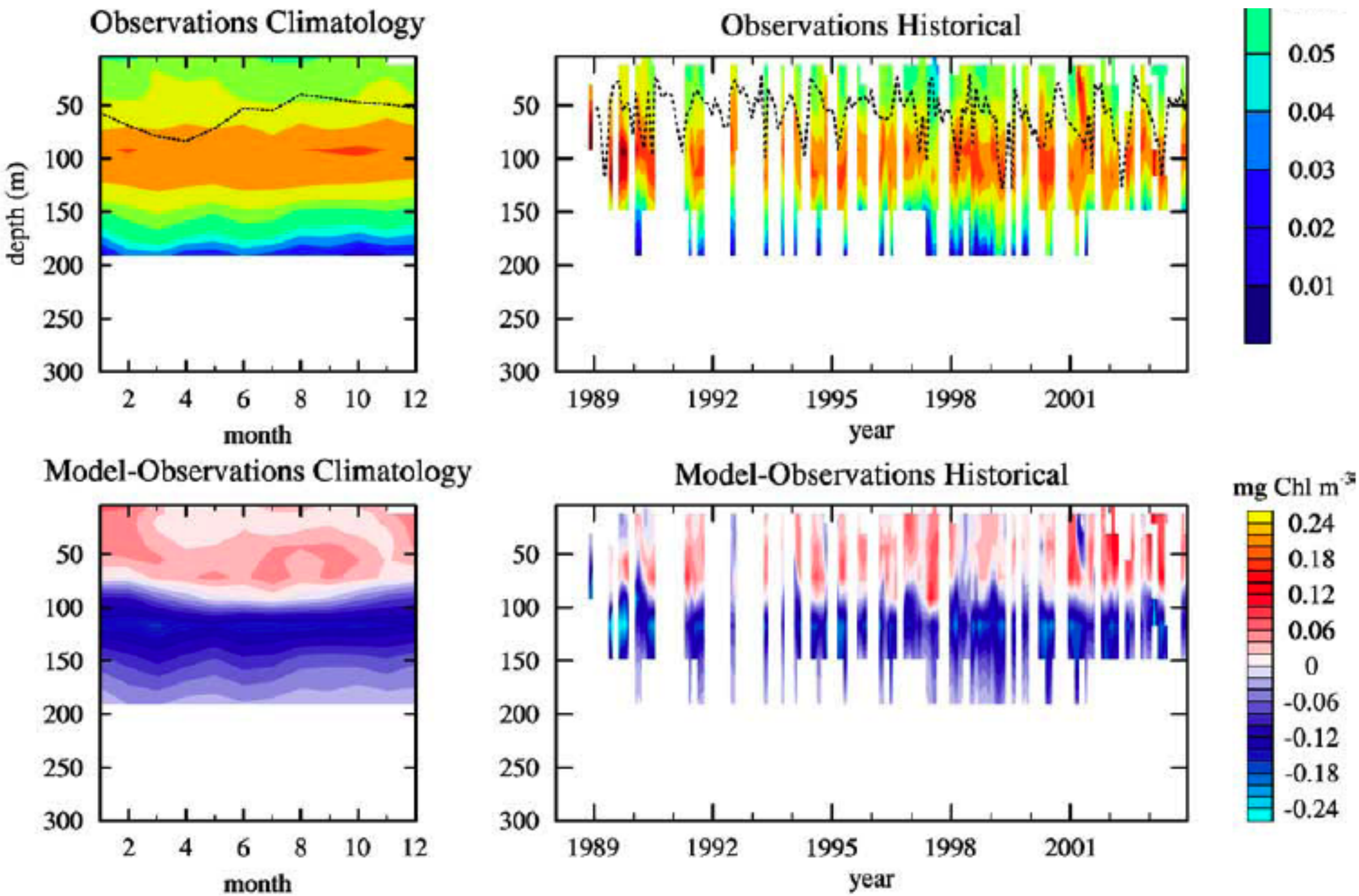






Taylor Diagram





Observations Climatology
Observations Historical
Model-Observations Climatology
Model-Observations Historical
depth (m)
month
year
50
100
150
200
250
300
2
4
6
8
10
12
1989
1992
1995
1998
2001
0.05
0.04
0.03
0.02
0.01
mg Chl m-3
0.24
0.18
0.12
0.06
0
-0.06
-0.12
-0.18
-0.24

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Skill assessment for coupled biological/physical models of marine systems

Craig A. Stow [a,*], Jason Jolliff [b,1], Dennis J. McGillicuddy Jr. [c,2], Scott C. Doney [c,3], J. Icarus Allen [d,4], Marjorie A.M. Friedrichs [e,5], Kenneth A. Rose [f,6], Philip Wallhead [g,7]