

Scaling Up: Modeling Efforts For Primary Production

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Aquatic Primary Production:

An assessment of current methodological approaches to
building community consensus

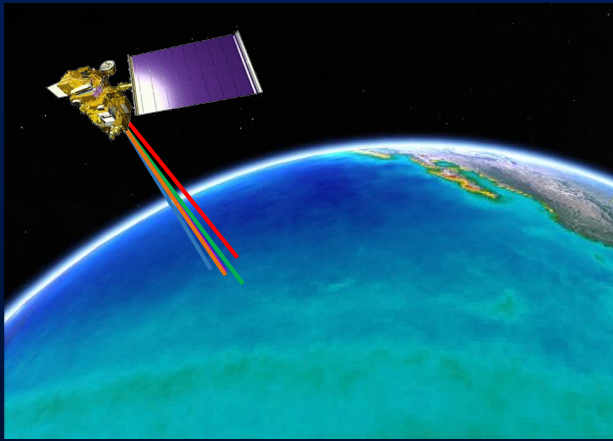
December 5th, 2018

Ocean Color Remote Sensing: Science & Challenges

Ocean Color ($R_{RS}(\lambda)$)



Net Phytoplankton Production (NPP)
Growth Rates (μ)

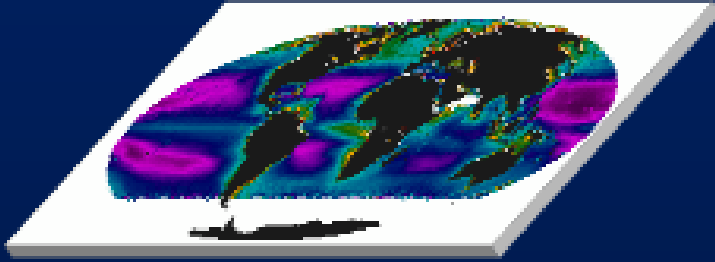


Physiology
Sub-surface DCMs



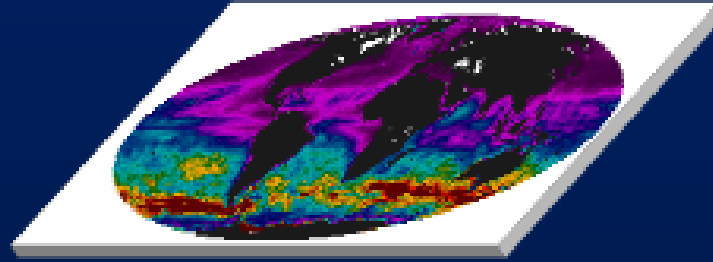
NPP Models: Central Currency

Chlorophyll a



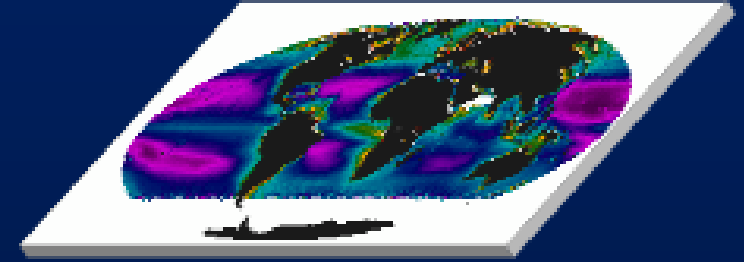
Eppley et al. 1985
Behrenfeld and Falkowski 1997
Howard and Yoder 1997
Scardi 2001
Morel and Maritorena 2001
Carr 2002
Kameda and Ishizaka 2005
Armstrong 2006
Asanuna et al 2006
Tang et al. 2008

Carbon



Behrenfeld et al. 2005
Westberry et al. 2008

a_{phi}

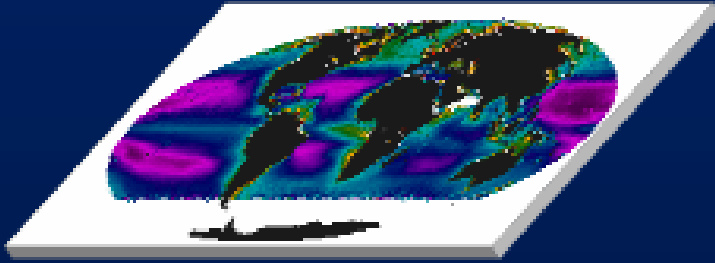


Antoine and Morel 1996
Melin and Hoepffner 2001
Ondrusek et al. 2001
Marra et al. 2003
Smyth et al 2005
Uitz et al. 2008
Silsbe et al. 2016

NB: Not an exhaustive list

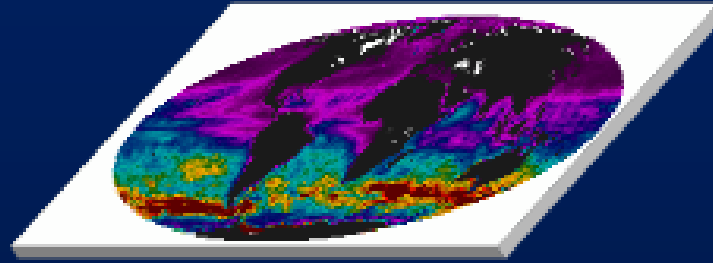
NPP Models: Central Currency

Chlorophyll a



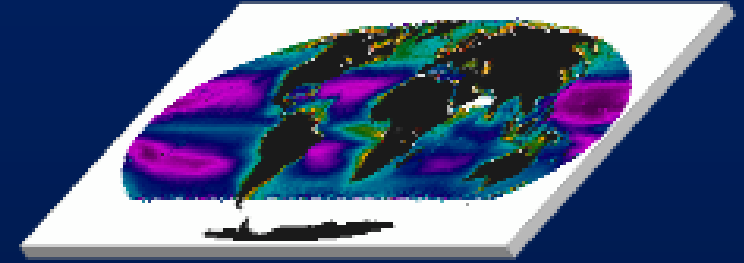
Empirical

Carbon

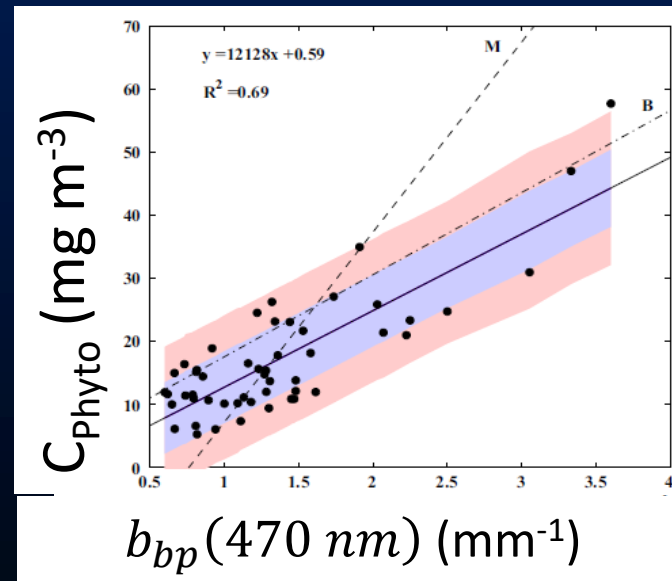
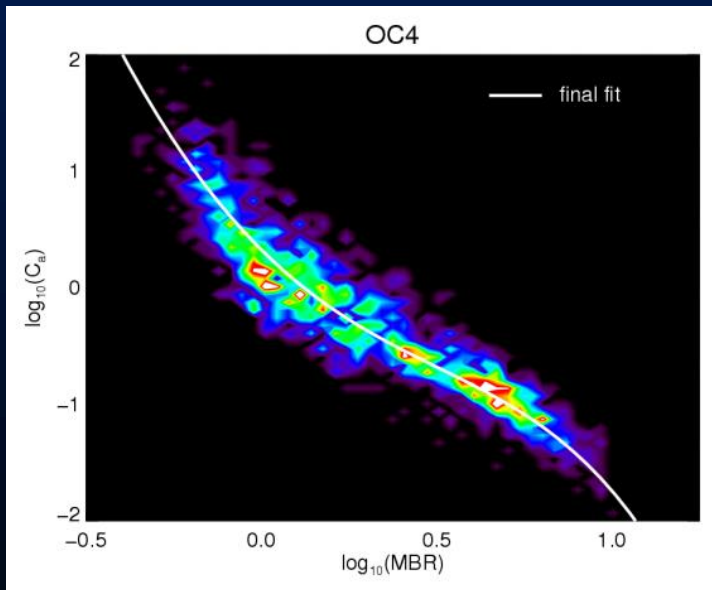


Empirical

a_{phi}



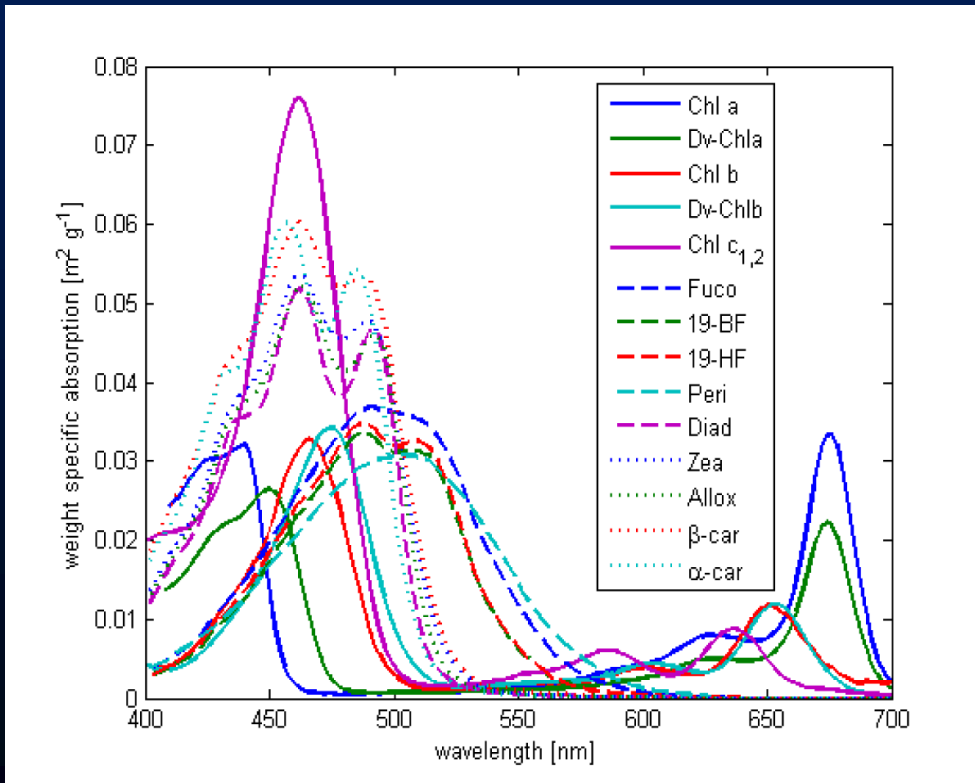
Semi-Analytical



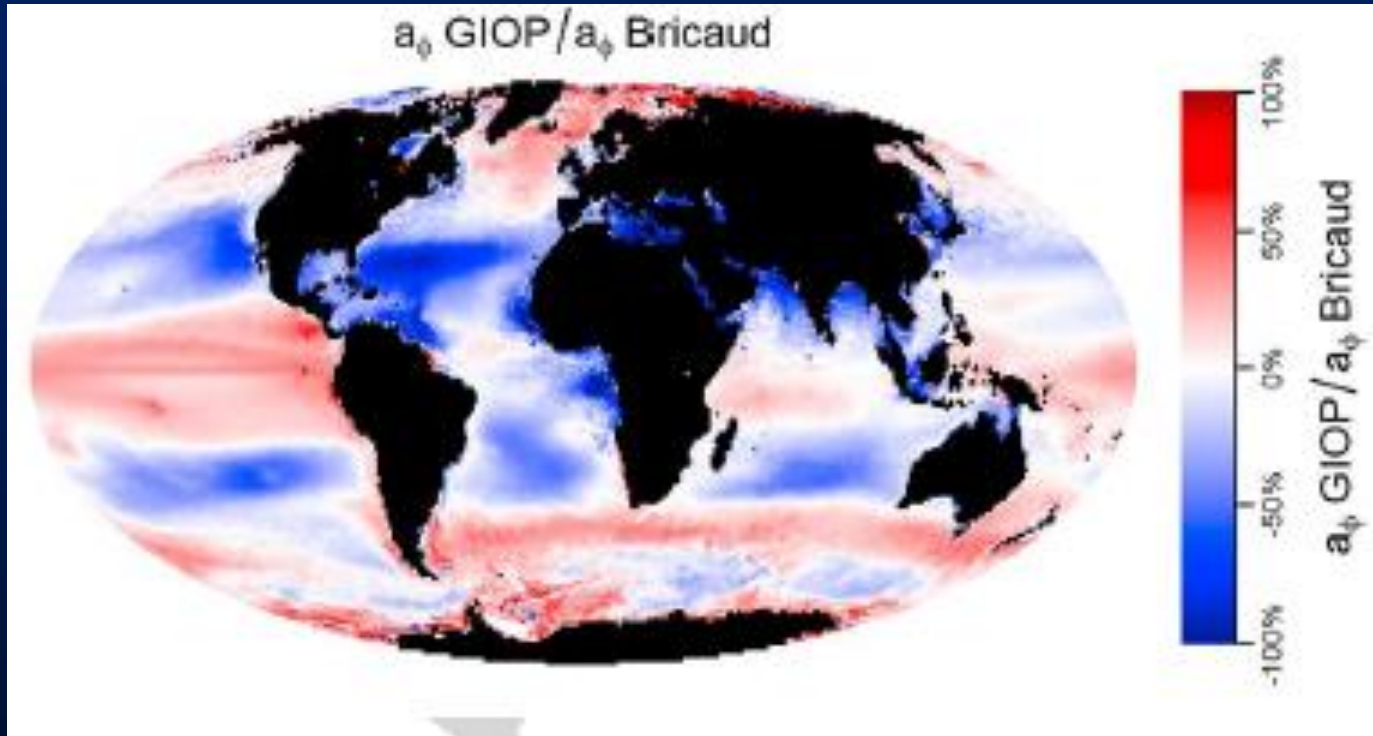
$$R_{RS}(\lambda) \sim \frac{b_b(\lambda)}{a(\lambda) + b_b(\lambda)}$$

NPP Models: Central Currency

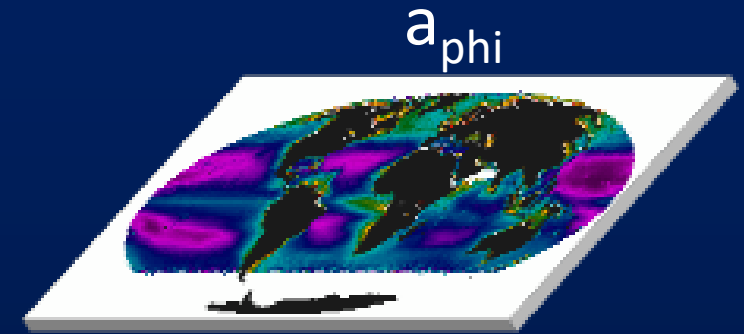
- The phytoplankton absorption coefficient (a_{ϕ}) represents the sum of the product of all photosynthetic and non-photosynthetic pigments and the specific absorbance in-vivo



NPP Models: Central Currency



Annual composite showing the difference between a_{ϕ} derived from The GIOP model vs. a_{ϕ} scaled from chlorophyll a following Bricaud et al. (1998).



Antoine and Morel 1996
Melin and Hoepffner 2001
Ondrusek et al. 2001
Marra et al. 2003
Smyth et al 2005
Uitz et al. 2008
Silsbe et al. 2016

NPP Models: Physiological Parameterization

Chlorophyll Models

$$NPP = E(\lambda) \times Chl \times P_{B-Opt}$$

Carbon Models

$$NPP = C_{Phyto} \times \mu$$

Absorption Models

$$NPP = E(\lambda) \times a_{Phi}(\lambda) \times \phi_{\mu}$$

Where: $E(\lambda)$ is spectral extrapolation of PAR

C_{Phyto} is phytoplankton carbon biomass

$a_{phi}(\lambda)$, Chl are satellite products

P_{B-Opt} is assimilation efficiency

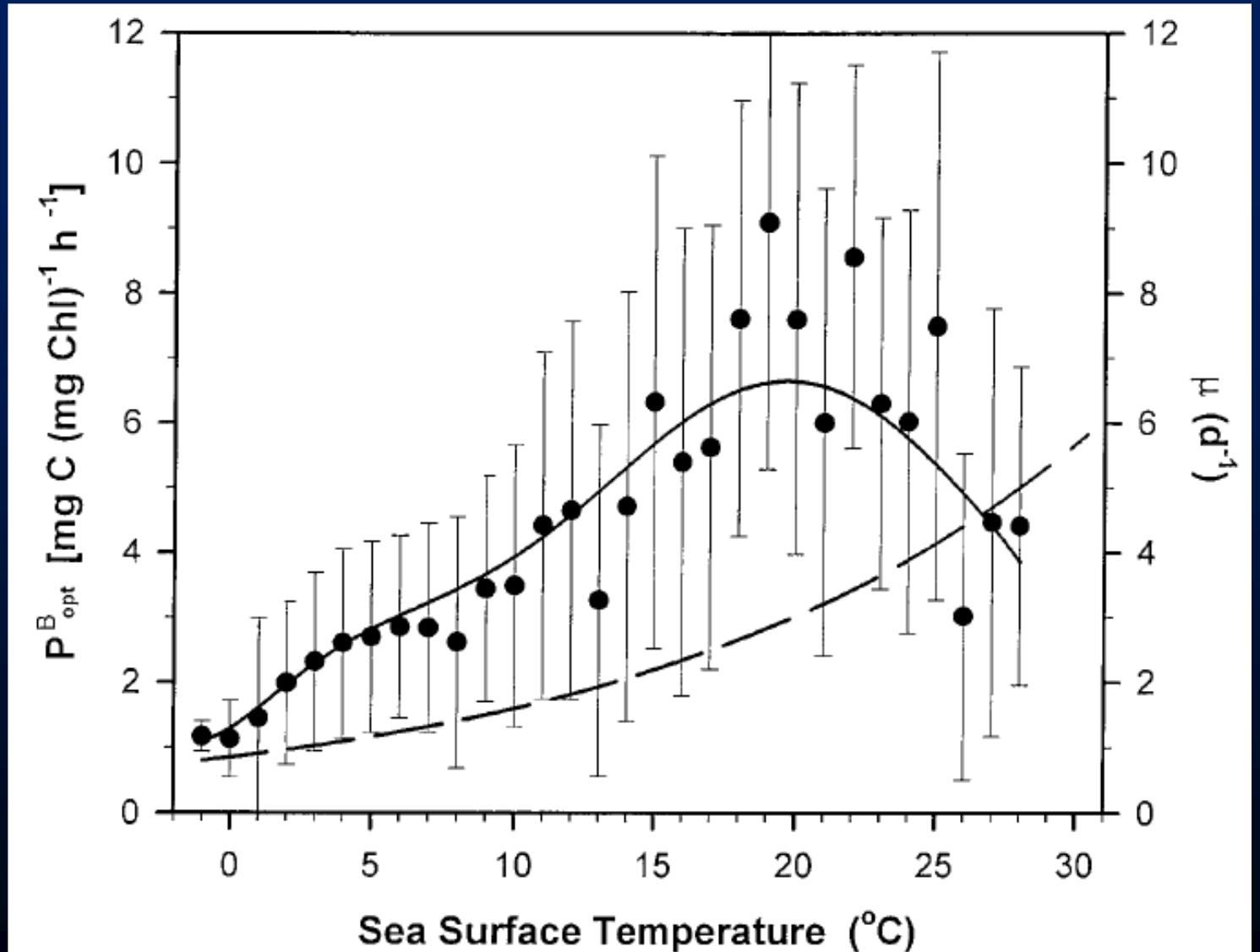
μ is carbon specific growth rate

ϕ_{μ} is the quantum efficiency of growth

NPP Models: Physiological Parameterization

Chlorophyll Models

$$NPP = E(\lambda) \times Chl \times P_{B-Opt}$$



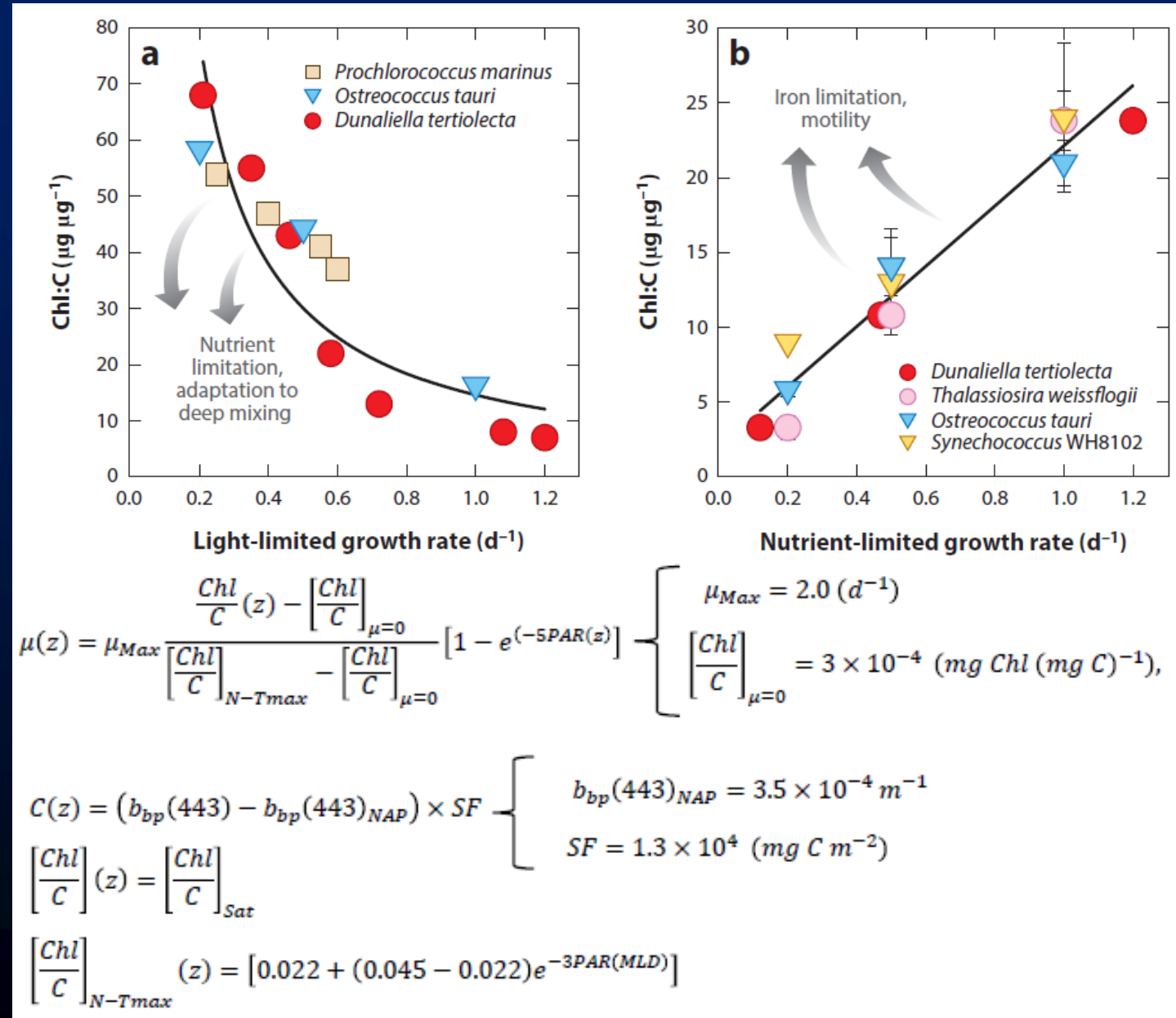
Behrenfeld and Falkowski 1997

NPP Models: Physiological Parameterization

Carbon Models

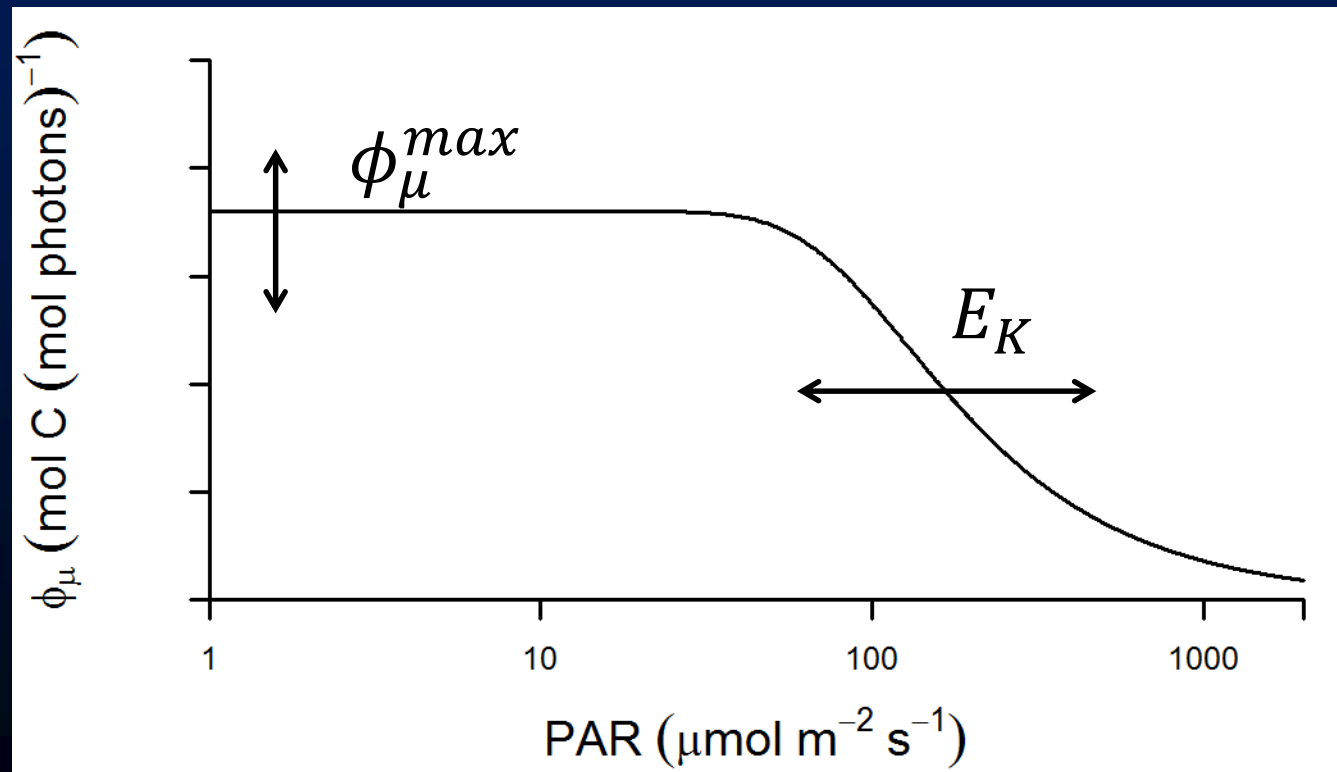
$$NPP = C_{Phyto} \times \mu$$

- Disparate changes in cellular Chl:C in response to light and nutrients confound a direct relationship between Chl *a* and NPP



NPP Models: Physiological Parameterization

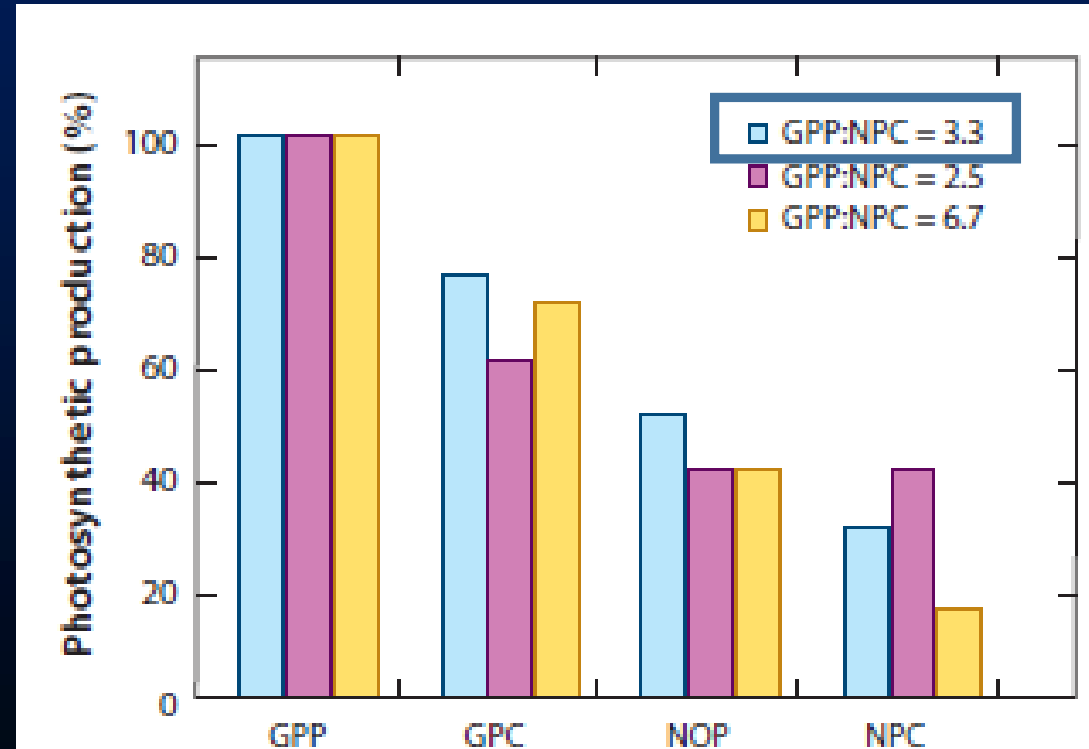
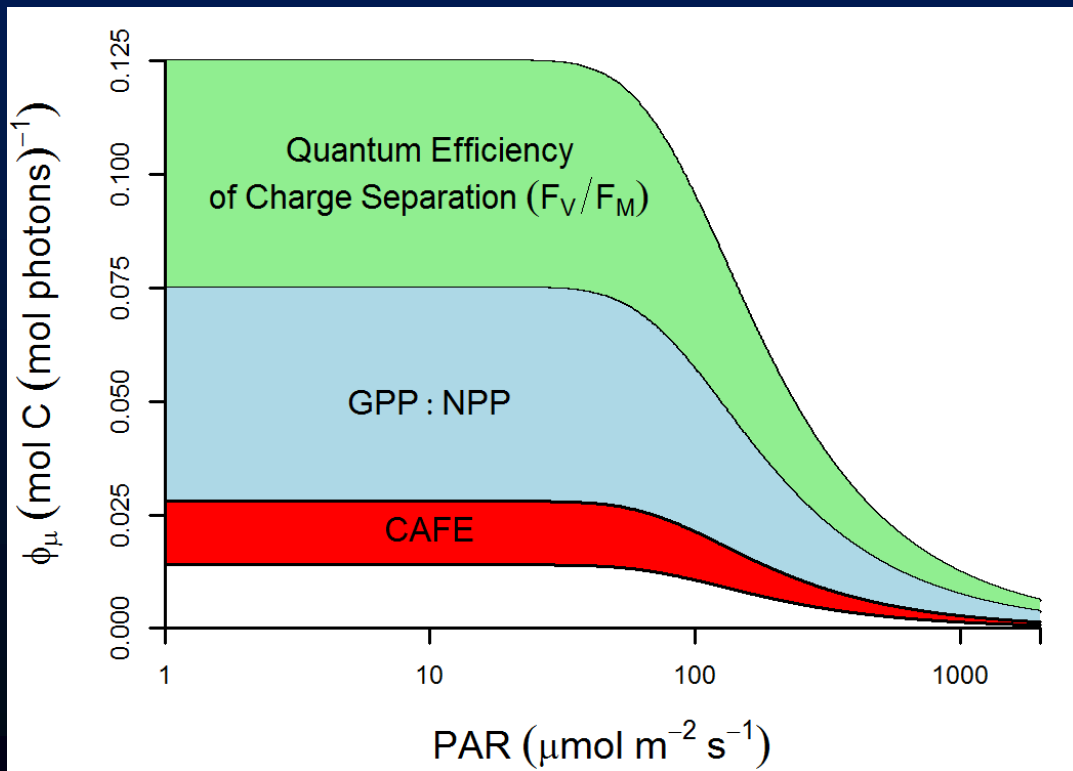
$$\phi_{\mu} = \phi_{\mu}^{max} \times \tanh(E_K/E)$$



Model Parameterization: ϕ_{μ}^{max}

Other absorption-based models:

- ϕ_{μ}^{Max} is globally constant: $0.060 \text{ mol C (mol photons)}^{-1}$ (Smyth et al. 2005; Marra et al. (2007)
- ϕ_{μ}^{Max} is globally variable: $0.058 \pm 0.038 \text{ mol C (mol photons)}^{-1}$ (Antione and Morel 1996)

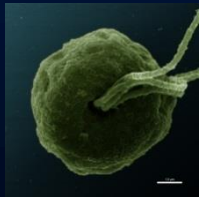
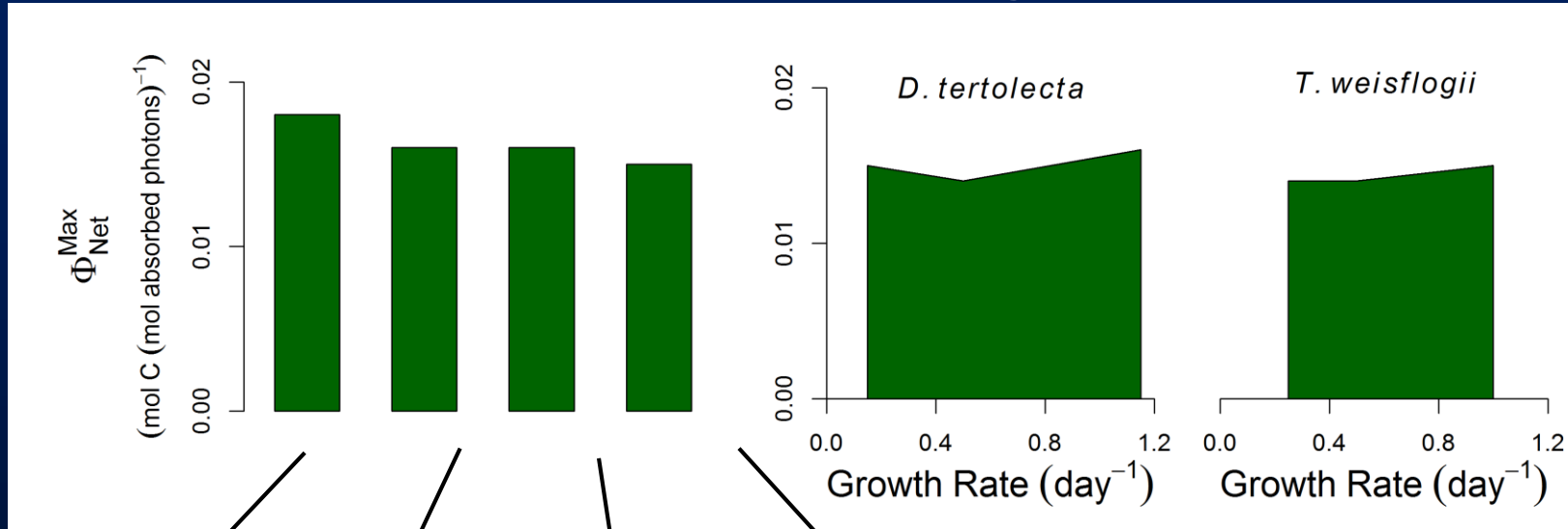


Halsey and Jones 2015. *Ann. Rev. Mar. Sci.* 7:265-280.

Model Validation: ϕ_{μ}^{max}

Light-limited cultures

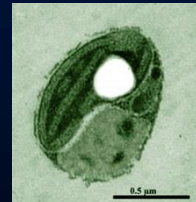
Nitrogen-limited cultures



Micromonas pusilla



Dunaliella tertiolecta



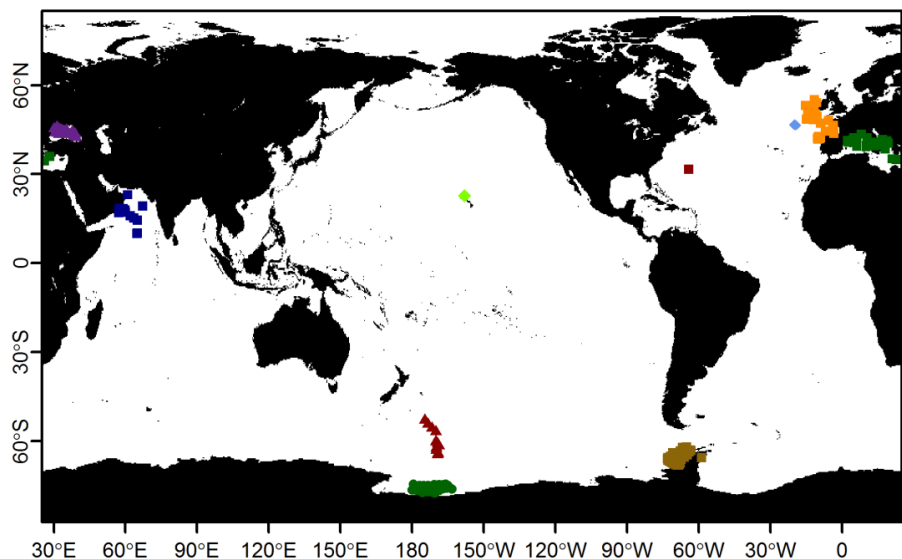
Ostreococcus tauri



Thalassiosira weissflogii

Model Validation – PPARR Approach

- CAFE NPP model results were tested against in-situ NPP measurements at 10 sites ($n=1048$)
- Data and methods follow PPARR4 (Saba et al. 2011)



■ Arabian Sea ● Ross Sea ■ WAP ◆ NABE ■ Med. Sea
▲ Black Sea ▲ APFZ ◆ HOT ■ BATS ■ NEA

Metadata	Chl	PAR	SST	MLD	NPP
BATS	0.097	17.8	21.78	83.26	218.98
BATS	0.096	29.38	20.88	123.05	306.06
BATS	0.207	32.16	20.01	125.13	799.44

AGU PUBLICATIONS

Global Biogeochemical Cycles

RESEARCH ARTICLE

10.1002/2016GB005521

Key Points:

- A mechanistic net phytoplankton production (NPP) model that exploits state-of-the-art satellite ocean color analyses is presented
- A comparison to direct NPP field measurements shows higher model skill relative to other published NPP models

The CAFE model: A net production model for global ocean phytoplankton

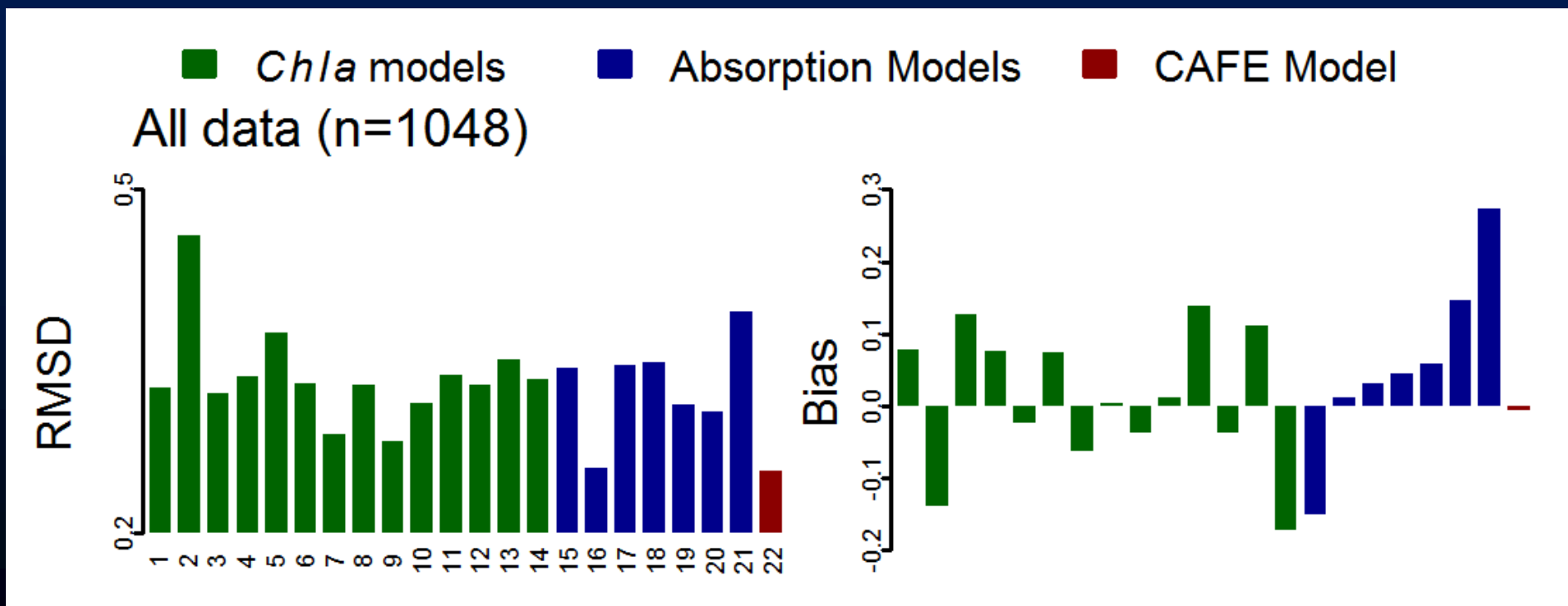
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¹Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oregon, USA, ²Now at Horn Point Laboratory, University of Maryland Center for Environmental Sciences, Cambridge, Maryland, USA, ³Department of Microbiology, Oregon State University, Corvallis, Oregon, USA

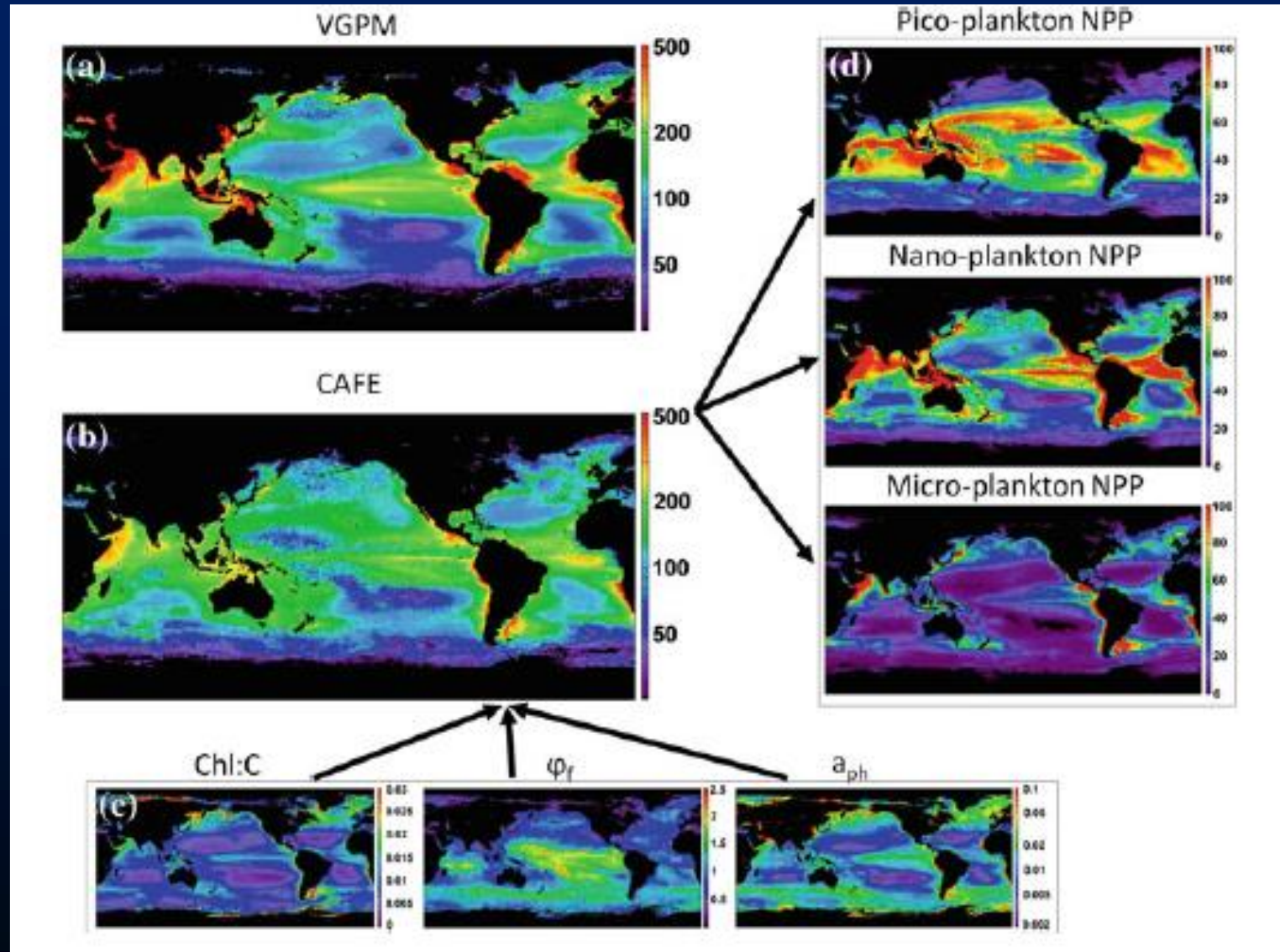
Model Validation – PPARR Approach

$$RMSD = \left(\frac{1}{n} \sum_{i=1}^n \Delta(\log_{10} NPP_{mod} - \log_{10} NPP_{obs})^2 \right)^{0.5}$$

$$Bias = mean(\log_{10} NPP_{mod}) - mean(\log_{10} NPP_{obs})$$

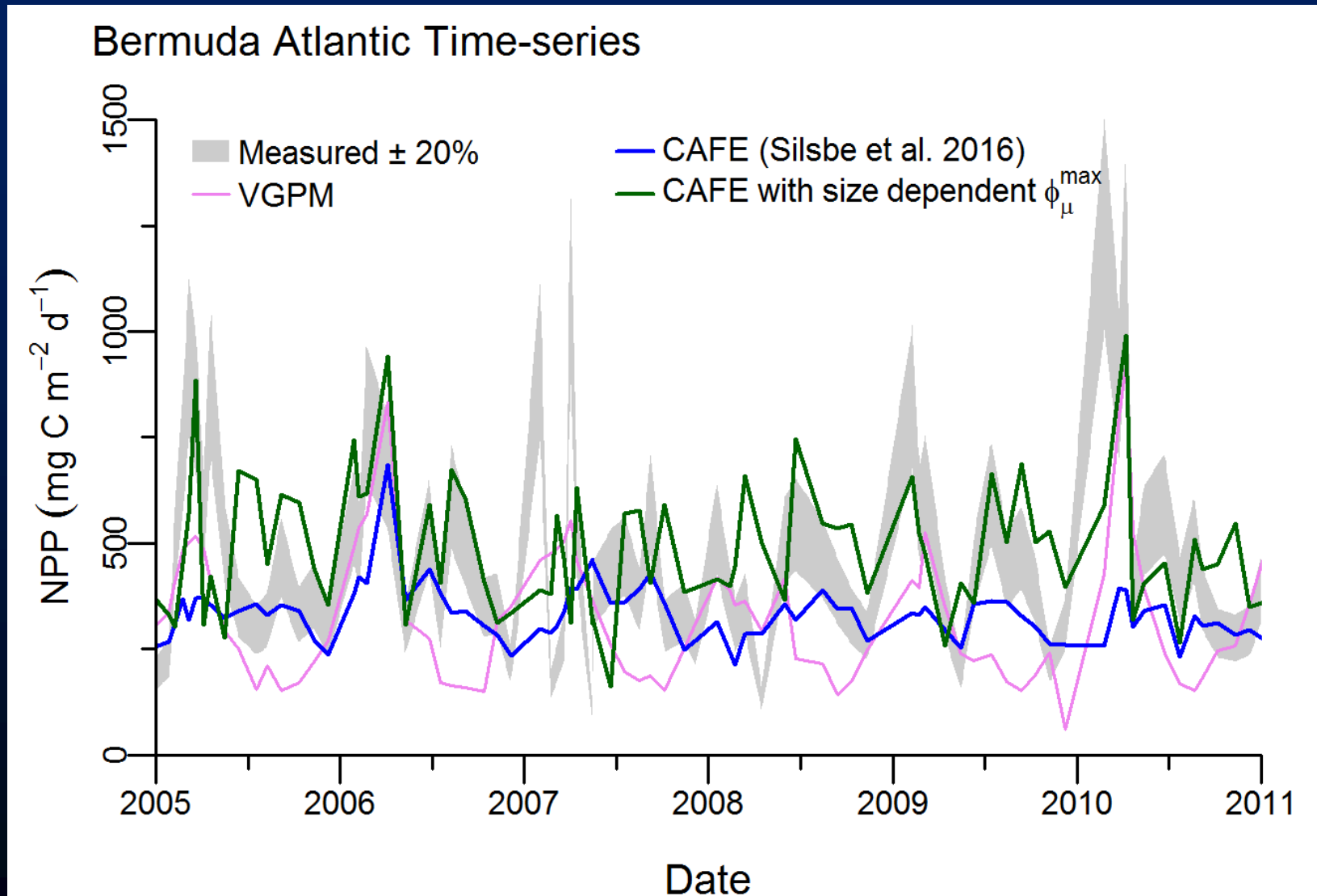


Future Directions



Westberry and Behrenfeld 2013. Oceanic Net Primary Production.

Future Directions



Questions?