Phytoplankton-Zooplankton Modeling

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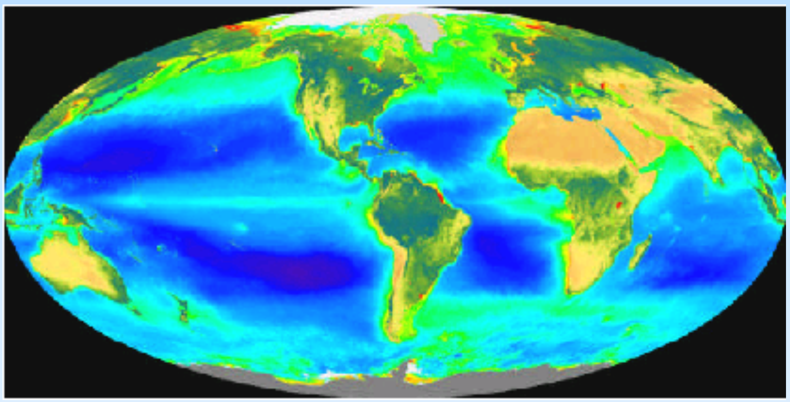
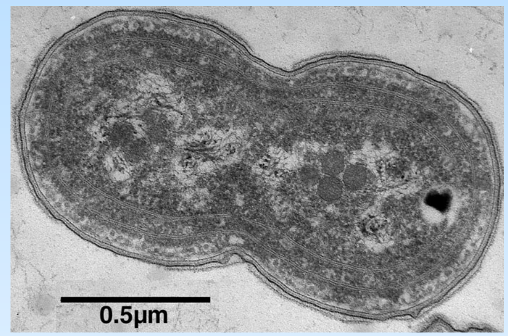
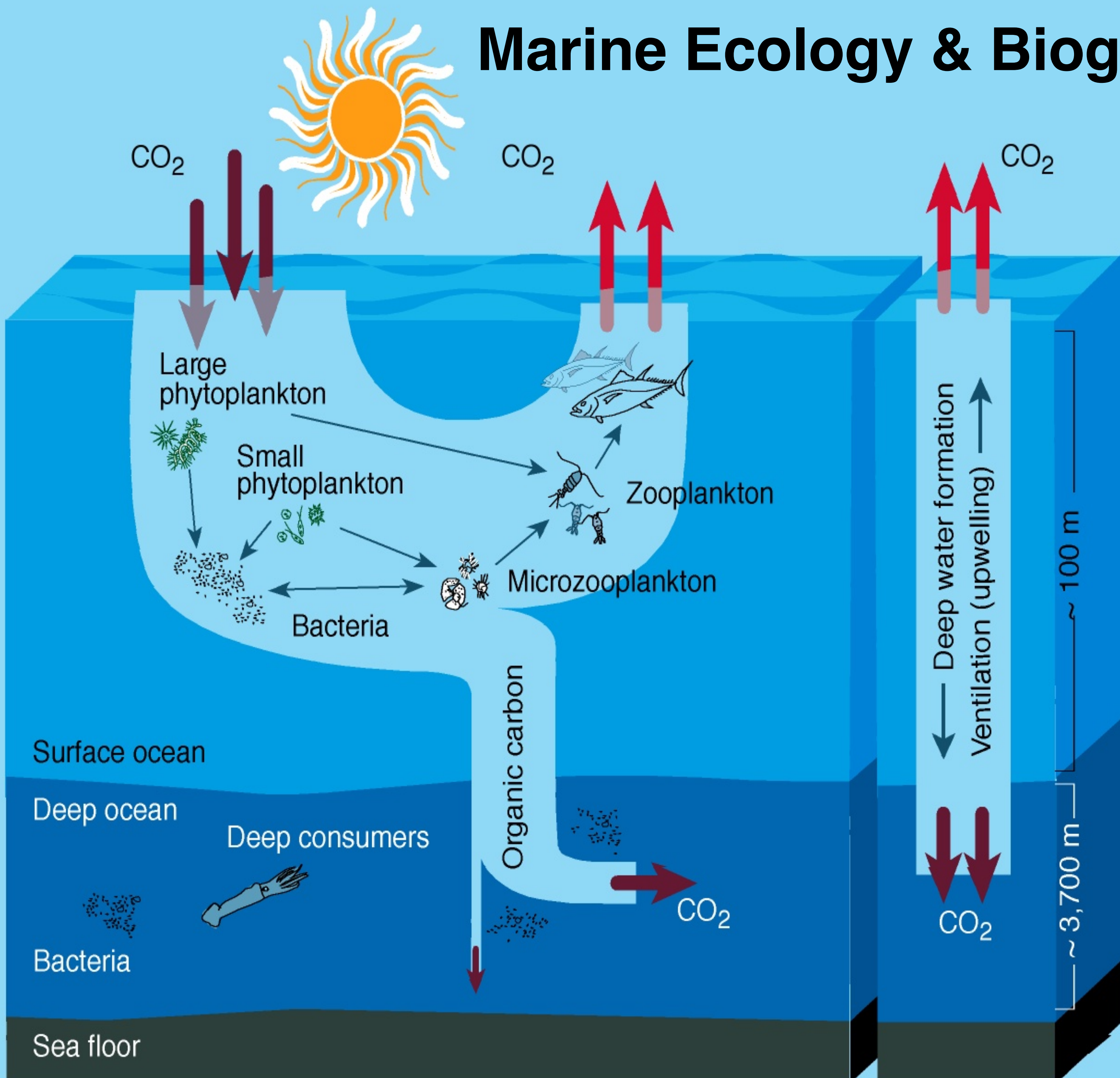
NCAR ASP Colloquium 2013





Supported by:

Marine Ecology & Biogeochemistry



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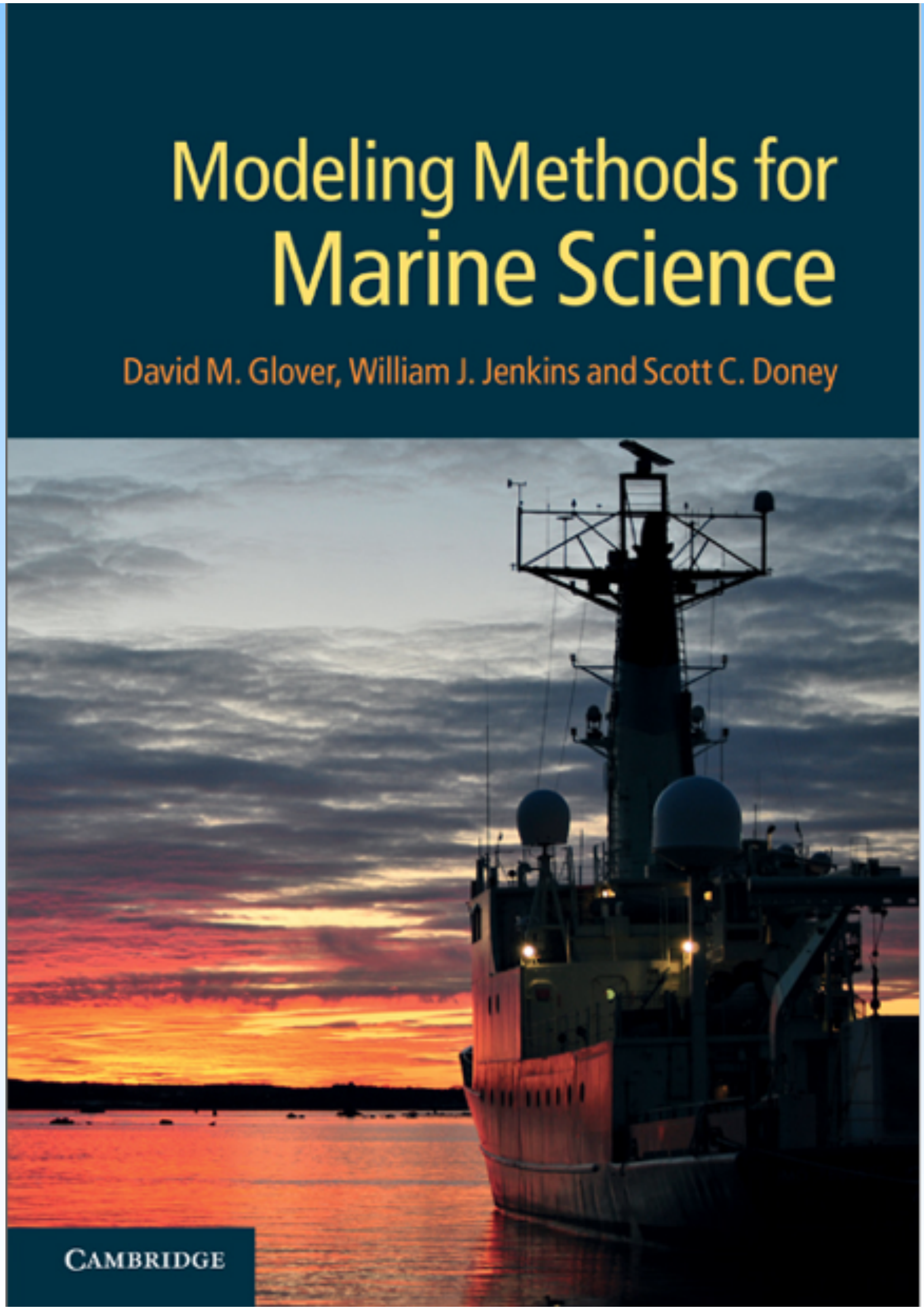
Model Elements Depend on Science Questions

Carbon Cycle & Biogeochemistry

Ecology & Food-webs

- Phytoplankton, zooplankton, bacteria, …
- Biological interactions (growth, predation, competition, disease, vertical migration, …)



Glover, D.M., W.J. Jenkins, and S.C. Doney, 2011: Modeling Methods for Marine Science
Cambridge University Press
Cambridge, UK, 592 pp.
www.cambridge.org/glover
ISBN-13: 9780521867832

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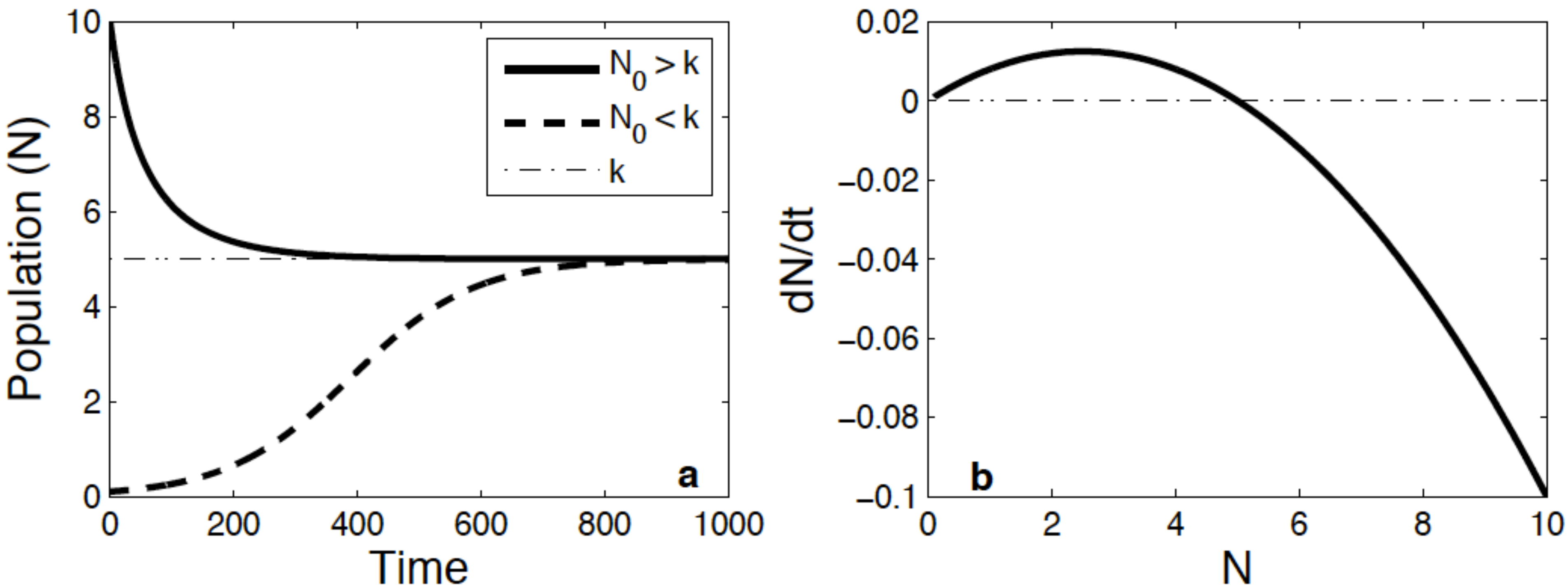
Simple Population Model

Logistic model

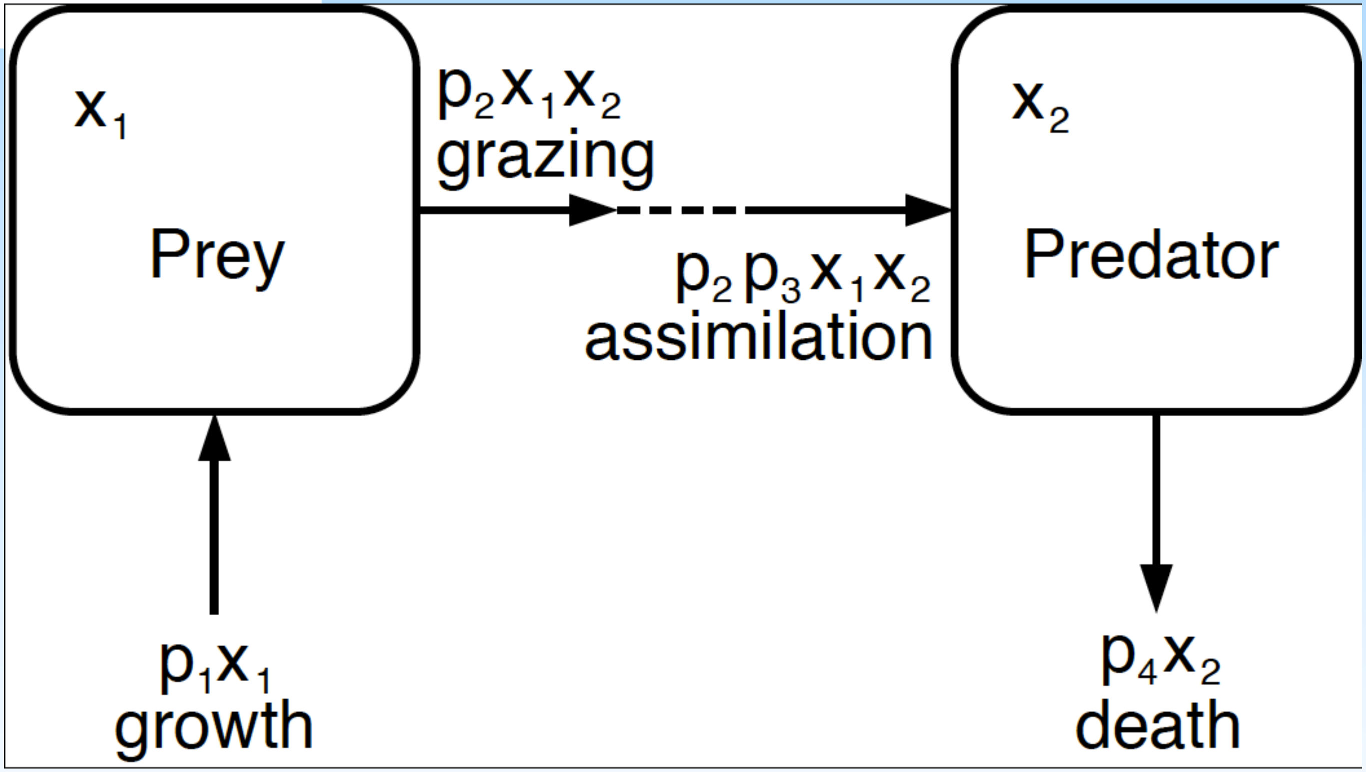
$$\frac{dN}{dt} = \mu\left(1 - \frac{N}{k}\right)N$$



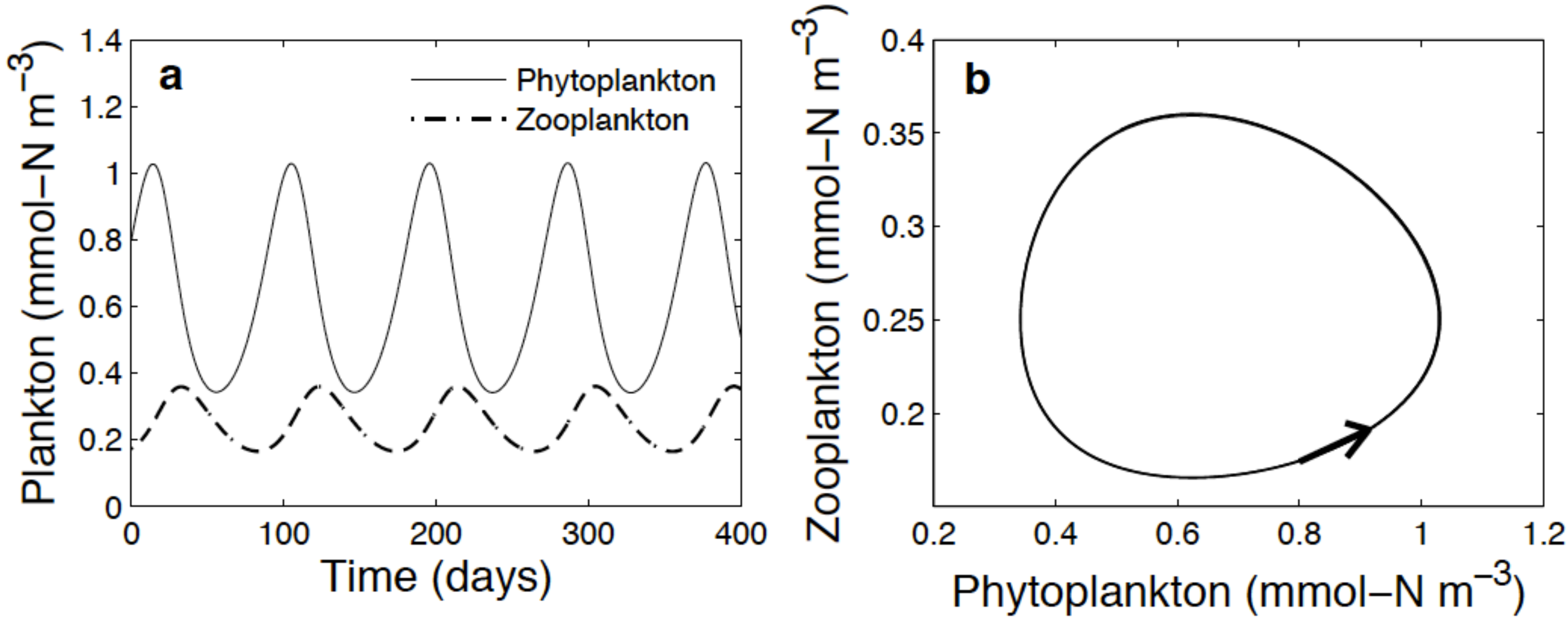
Lotka-Volterra Predator-Prey Model

$$\frac{dP}{dt} = \mu P - gPZ$$

$$\frac{dZ}{dt} = \gamma gPZ - mZ$$



Lotka-Volterra Predator-Prey Model



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

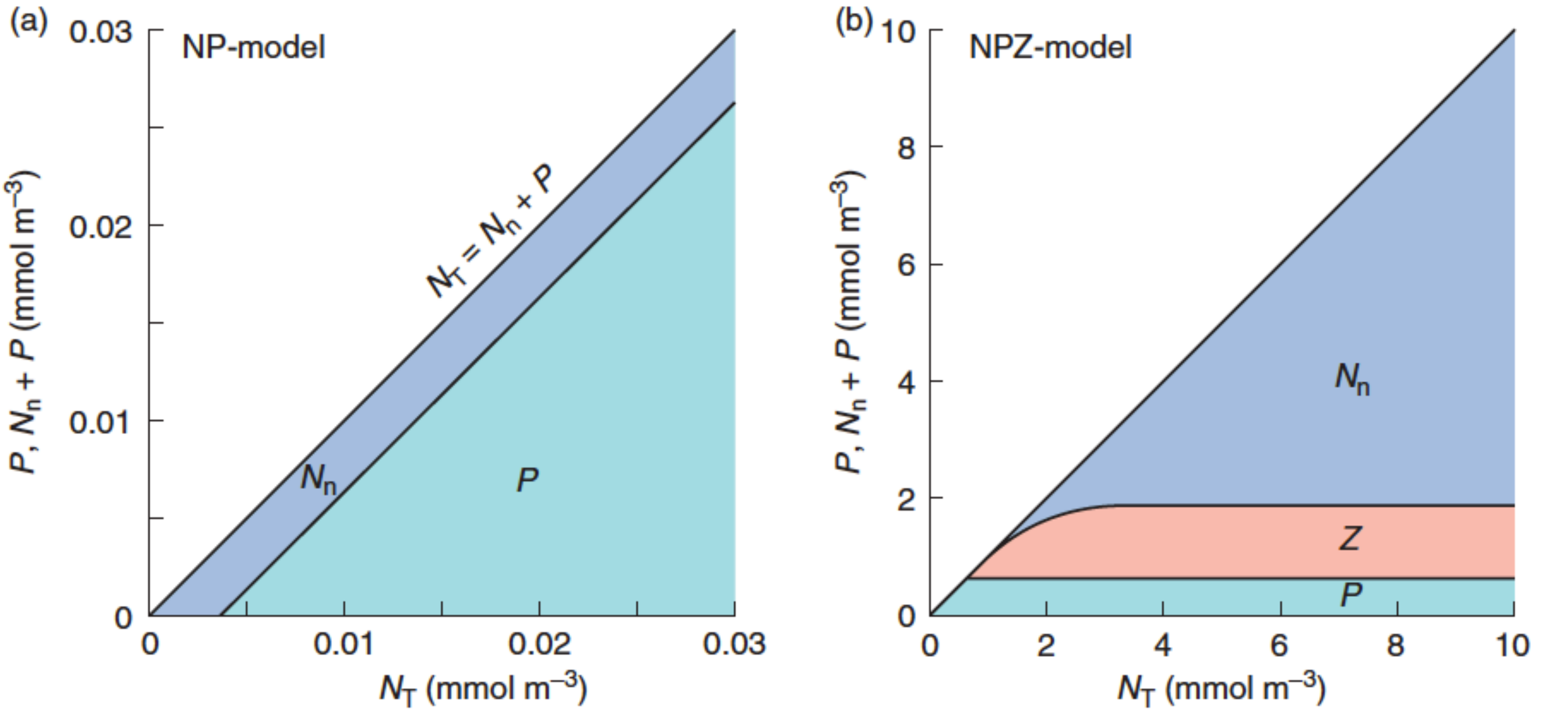
$$\frac{dZ}{dt} = a g \left(\frac{P}{k_P + P} \right) Z - m_Z Z$$

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

- Three coupled ordinary differential equations
- Mass conservation

Zooplankton & Nutrient Partitioning

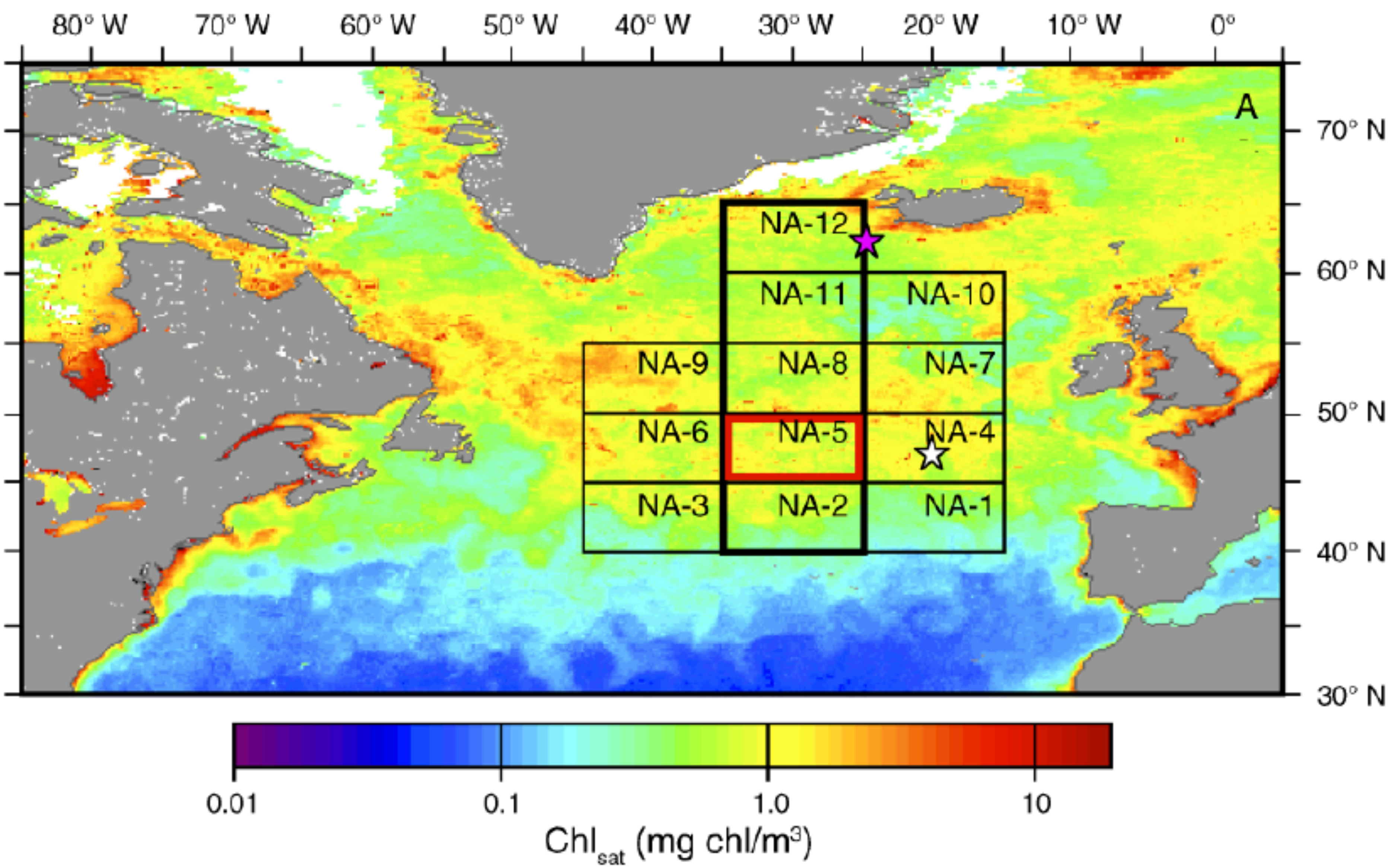
Steady-state (supply=export)



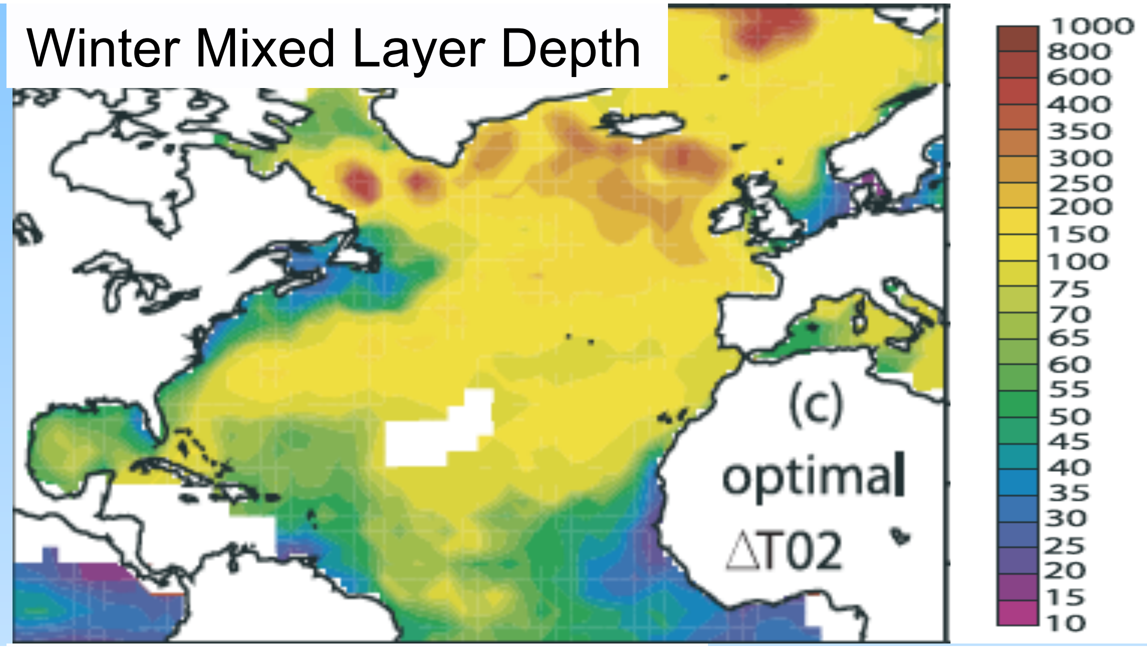
N supply →

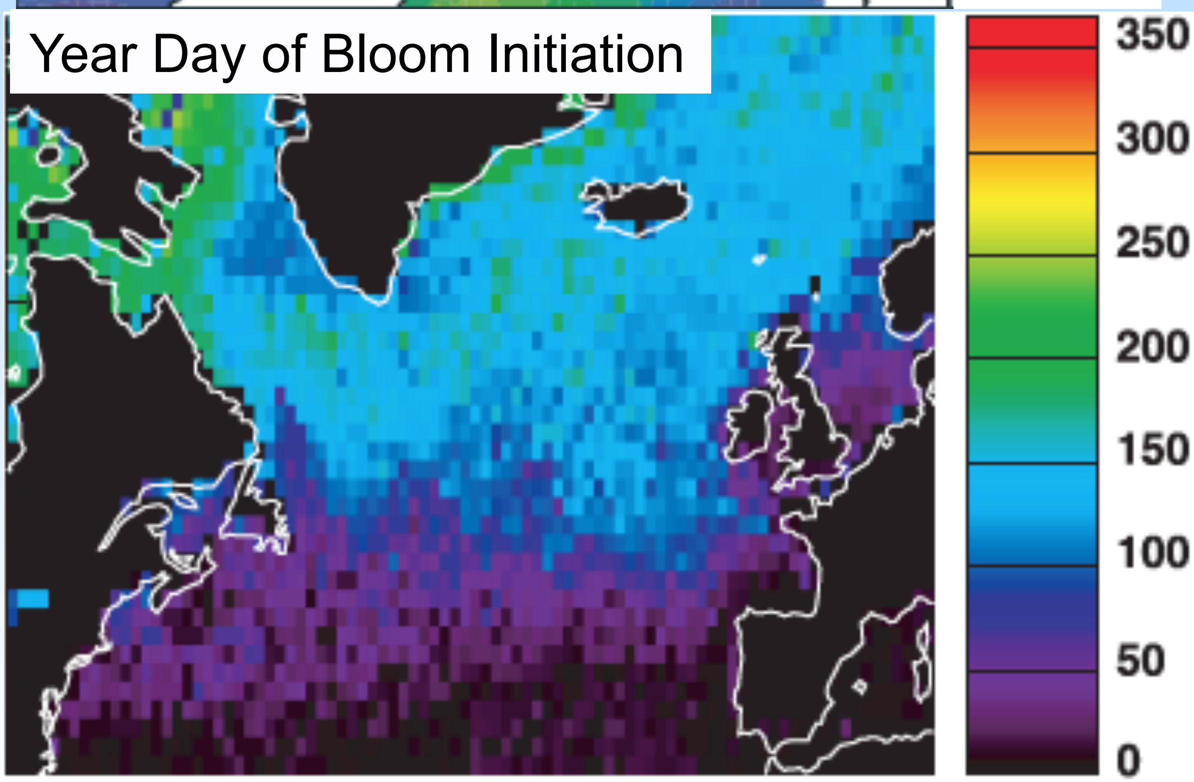
N supply →

$$\gamma m_P P = Supply$$

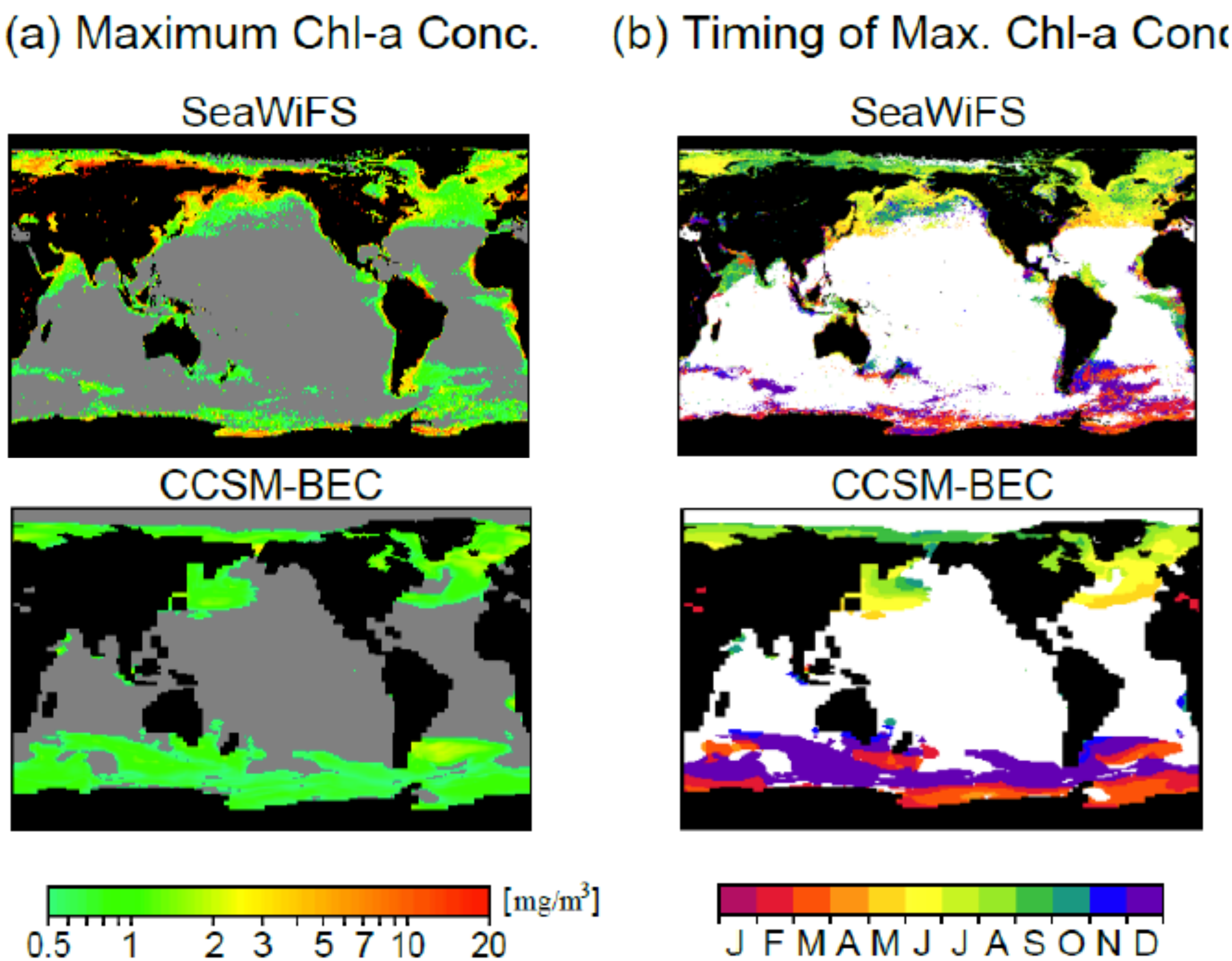

80° W
70° W
60° W
50° W
40° W
30° W
20° W
10° W
0°
70° N
60° N
50° N
40° N
30° N
A
NA-12
NA-11
NA-10
NA-9
NA-8
NA-7
NA-6
NA-5
NA-4
NA-3
NA-2
NA-1
0.01
0.1
1.0
10
Chl_sat (mg chl/m³)

Seasonal Progression of Bloom

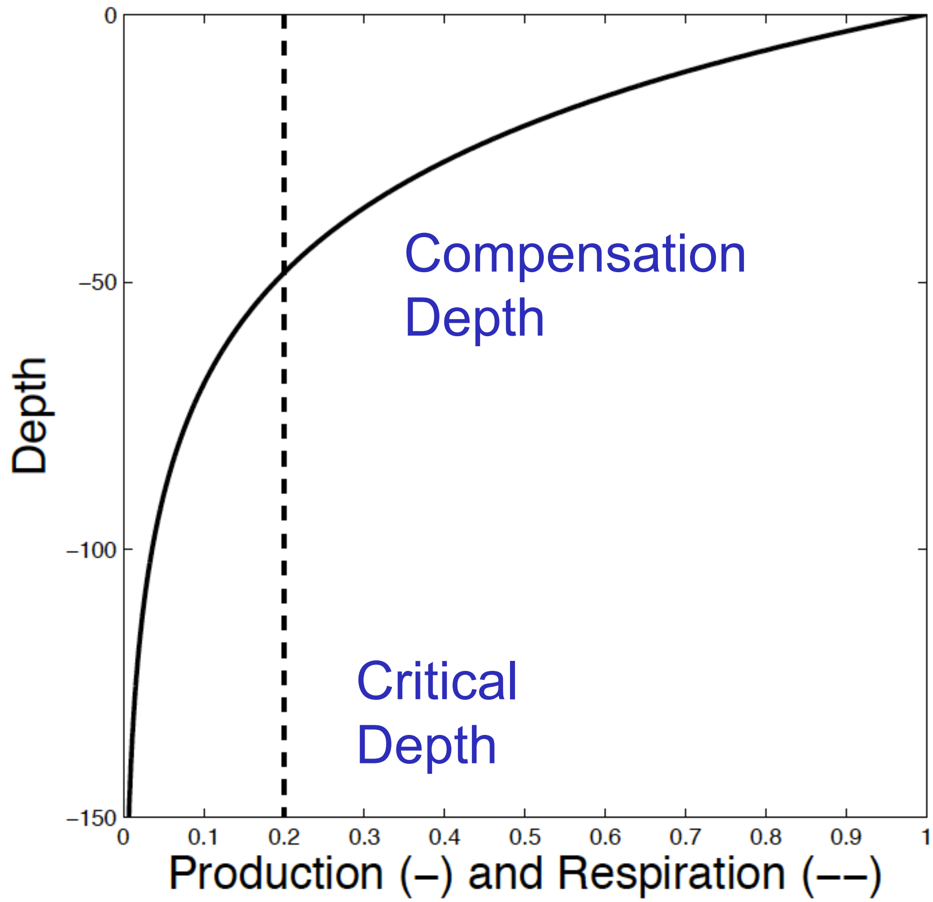




Siegel et al.
Science 2000



Hashioka et al. Biogeosci. submitted



Sverdrup Bloom Model

Light

$$I(z) = I_0 e^{-kz}$$

Production

$$PP(z) = \alpha I_0 e^{-kz}$$

Compensation Depth

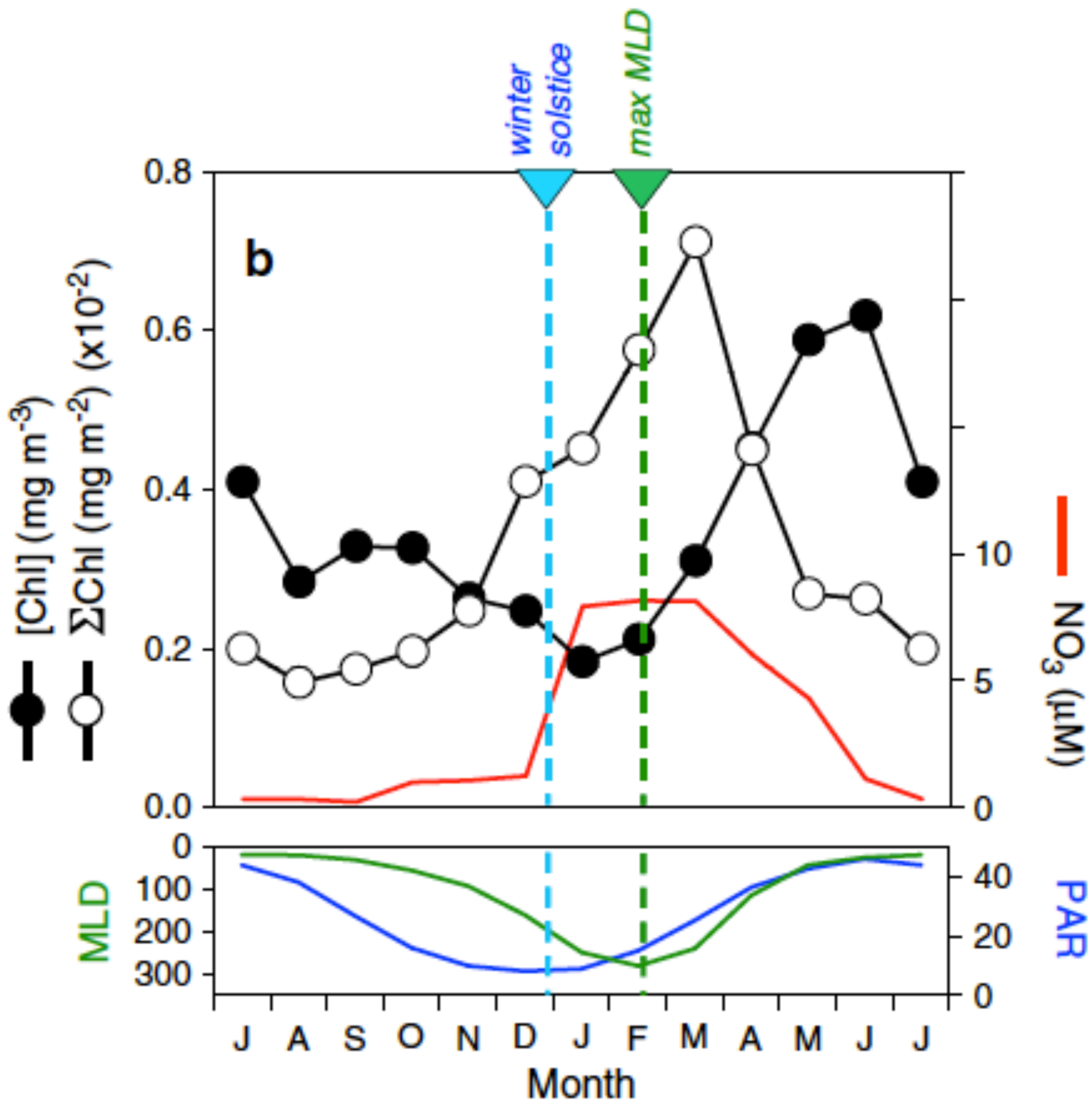
$$PP(z_{comp}) = R(z_{comp})$$

Critical Depth

$$\int_0^{z_{cr}} PP\,dz = \int_0^{z_{cr}} R\,dz$$

Bloom occurs when either light increases of mixed layer shoals so that $Z<Z_{cr}$

Ecological Disturbance & Recovery



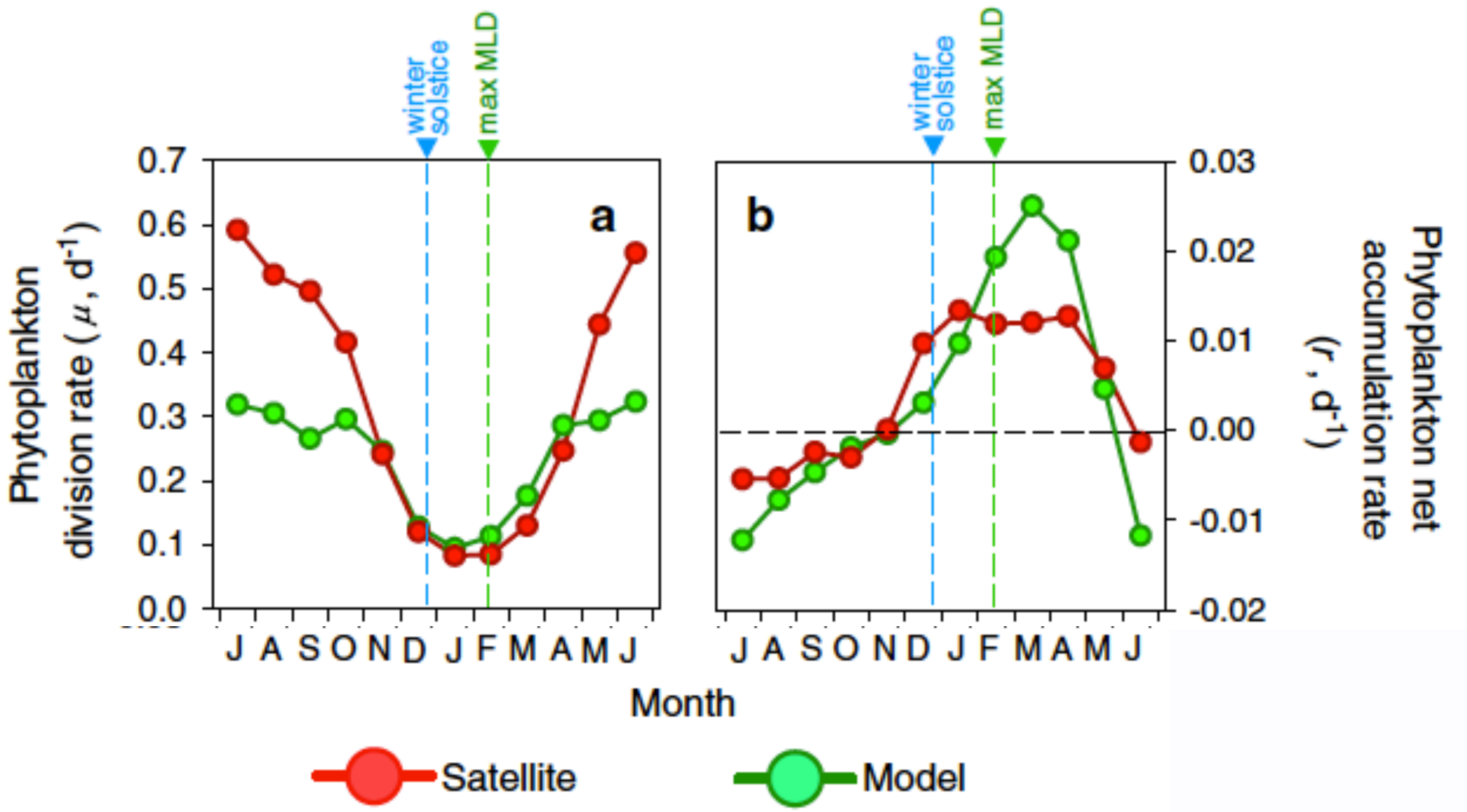
Behrenfeld et al. Global Biogeochem. Cycles 2013

Net specific growth (d^{-1})

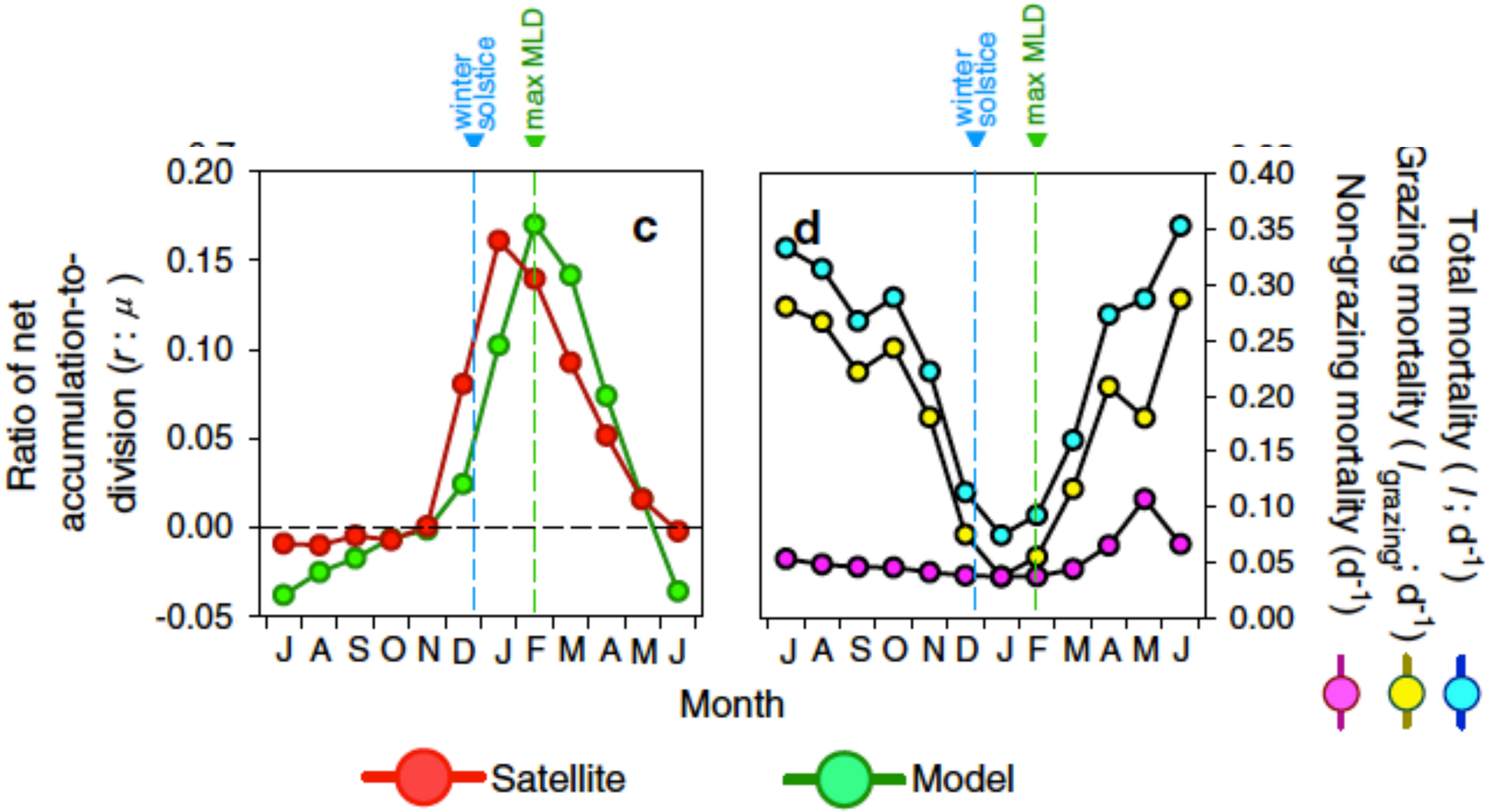
$$r = \frac{1}{\Delta\tau}\ln\left(\frac{C_1}{C_0}\right)$$

$$r = \mu - g - s - p - f$$

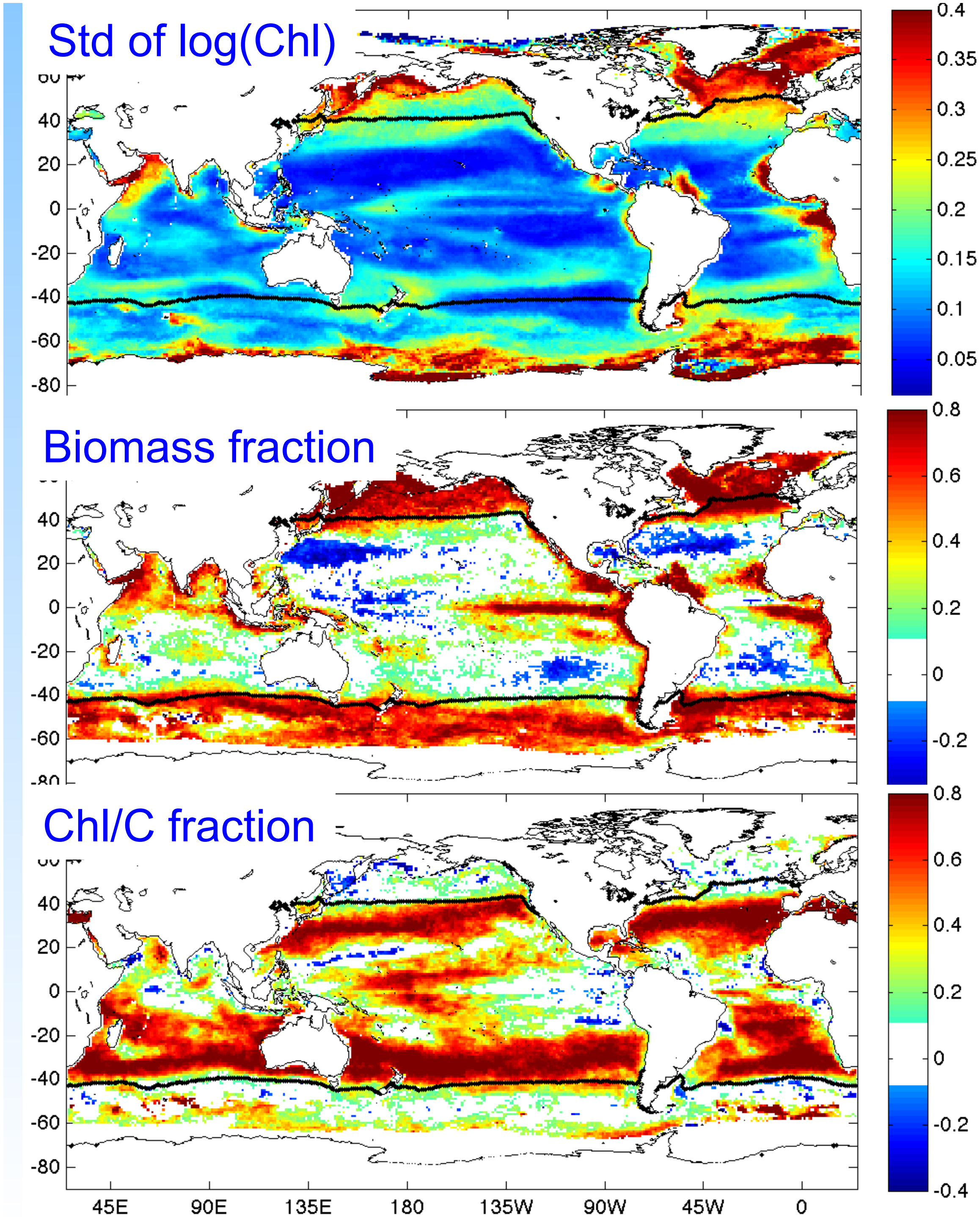
growth – grazing ~ 0



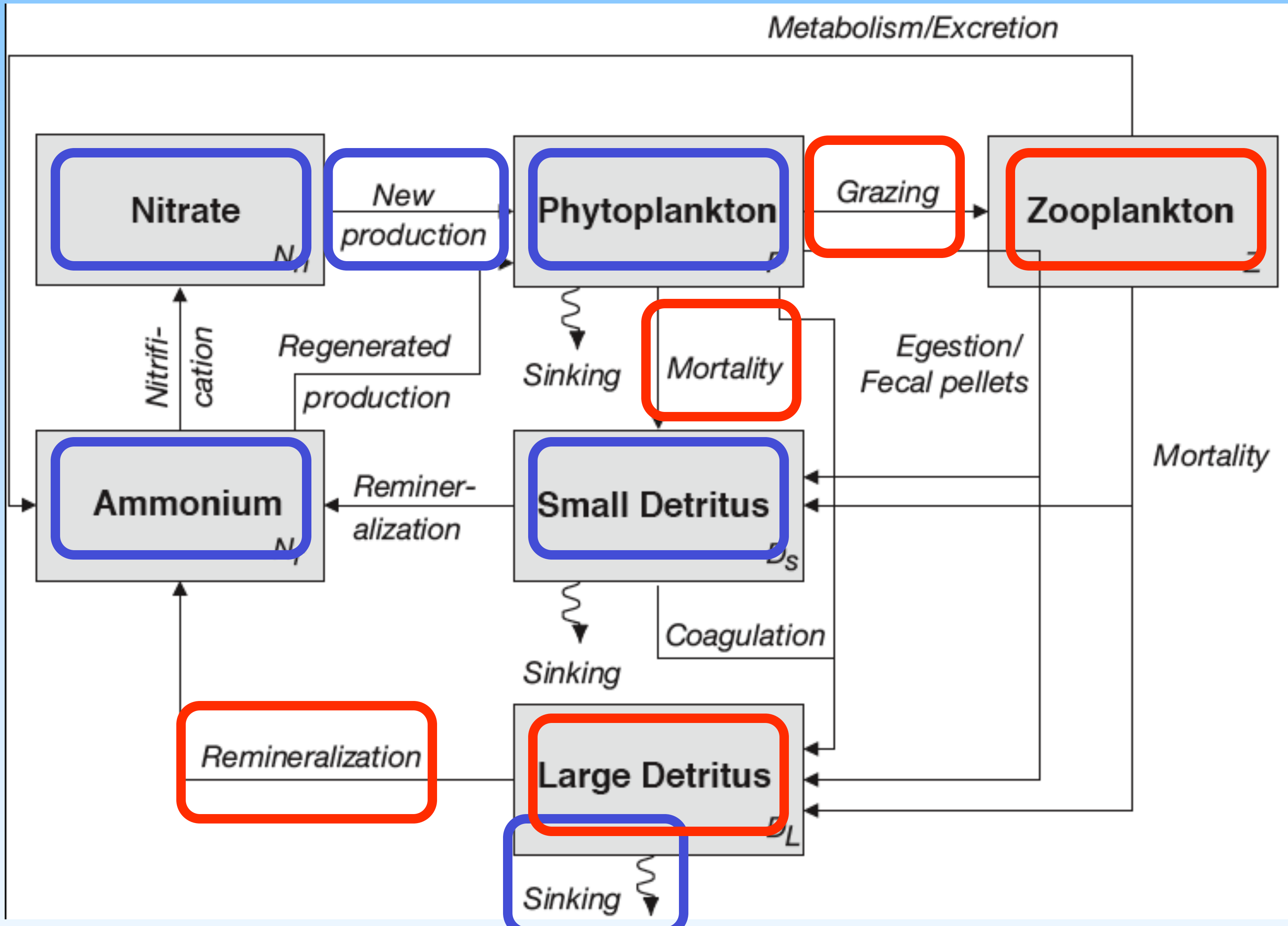
Growth and Loss Terms



Chlorophyll Variability: Biomass vs. Photoacclimation



Siegel et al.
Remote Sensing Environ.
2013



"Stocks" versus "Rates"
C dC/dt

Estimated from data
Unknowns

How do you estimate parameters and functional forms?

Laboratory & field incubations

- Photosyntheis-light curves; nutrient uptake curves
- elemental stochiometry

Comparative analysis

- allometric relationships

Tuned or optimized against field data

- mismatch between parameters and data
- cross-site comparison

Previous models