INSTITUTO
ESPAÑOL DE
OCEANOGRAFÍA

CONSEJO SUPERIOR
DE INVESTIGACIONES
CIENTÍFICAS

Modelling the ecology & evolution of marine plankton at the global ocean using «continuous-trait» functions

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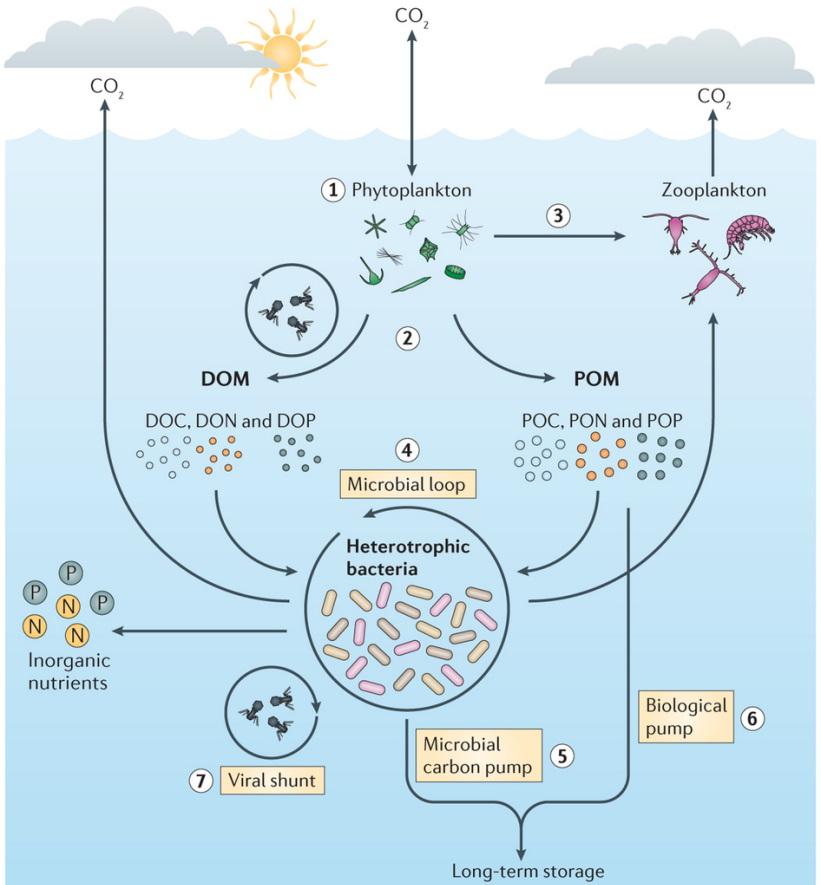
- The Ocean Globe Laboratory (`www.oceanglobe.org`)

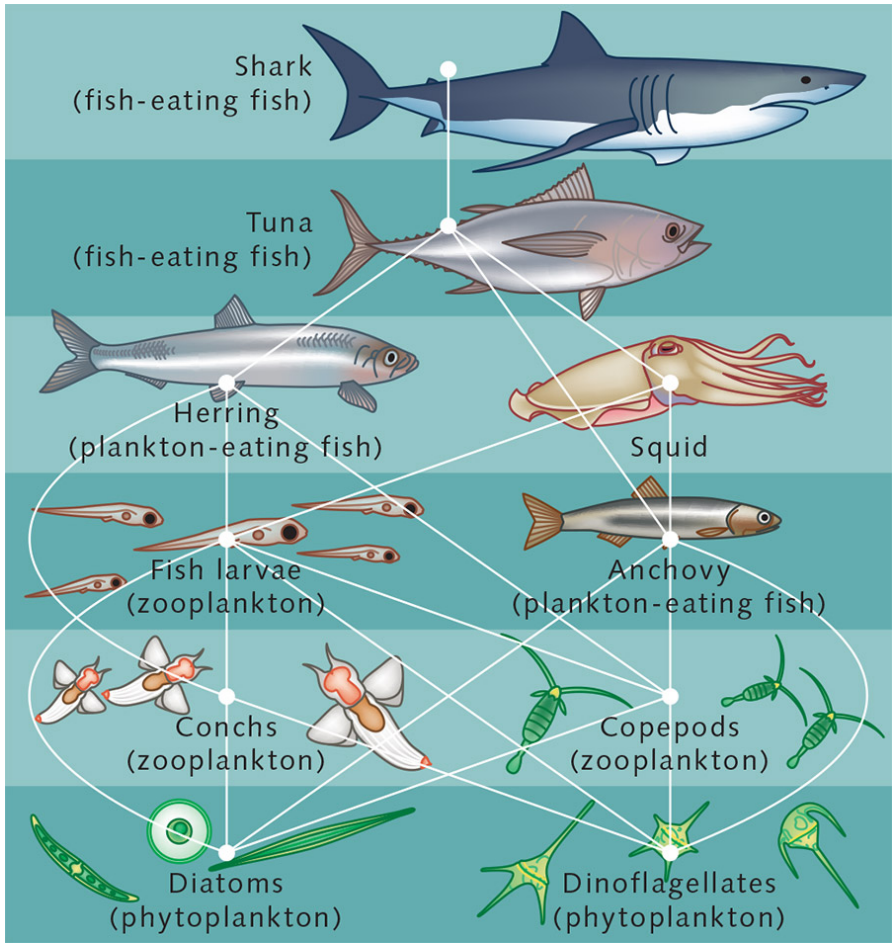
Goal of numerical modelling :: simplify reality to better understand it

- Study and understanding the several **mechanisms** that may be operating
- Obtain **quantitative** estimates of the processes (e.g. primar production)
- Predict **future** trajectories of the marine ecosystem (ecological state)

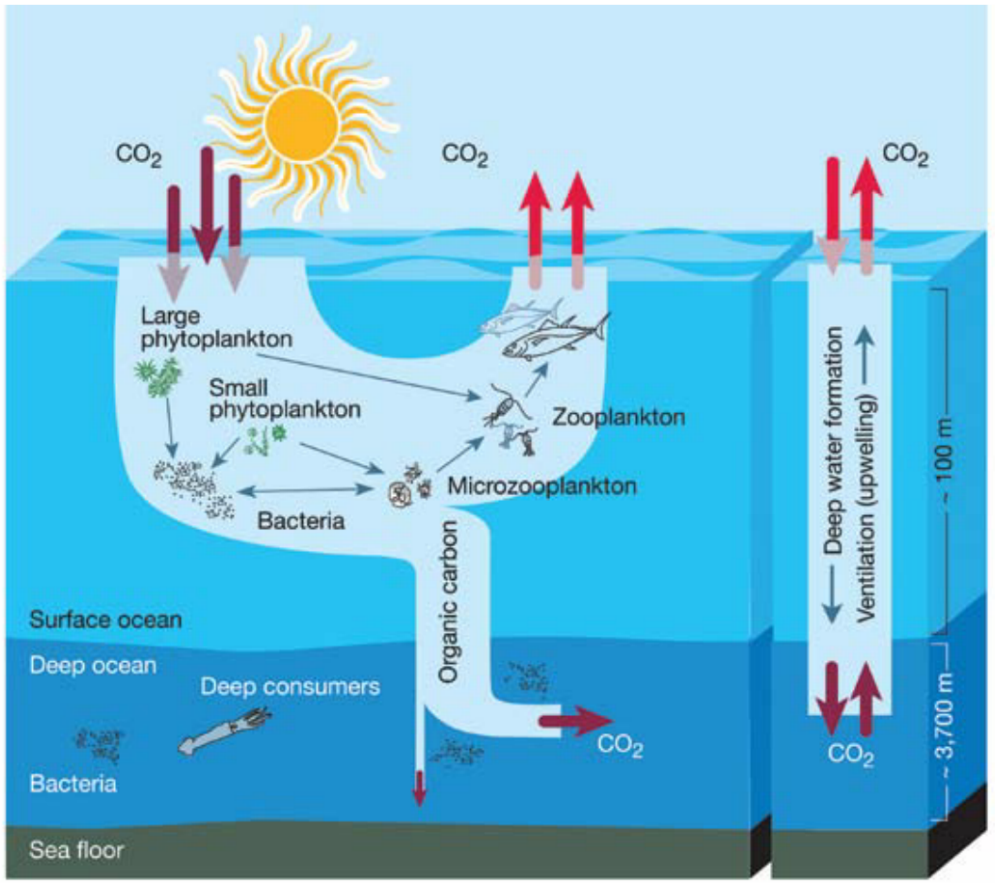


Nature Reviews | Microbiology

Trophic transfer efficiency of mass and energy

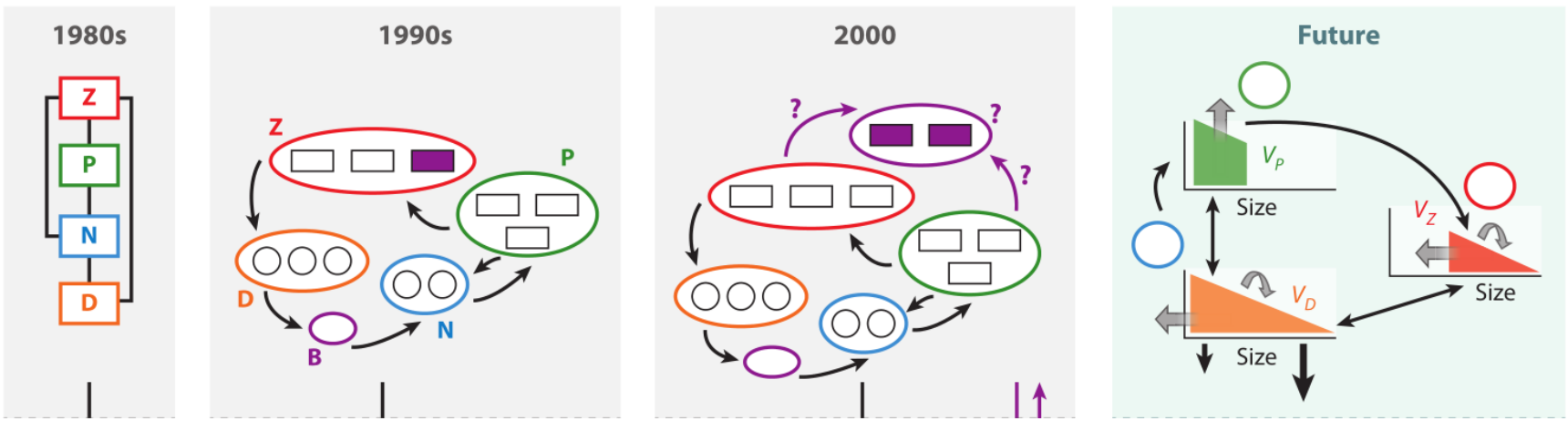


Biological pump efficiency of carbon sequestration



Temporal evolution of numerical models of marine ecosystems

- 1980's :: Models that resolve the bulk properties NPZD (nutrient, phy, zoo, detritus)
- 1990's :: Models that resolve the several plankton functional types (e.g. PlankTOM)
- 2000's :: Models that resolve the diversity of plankton ecotypes (e.g. MIT Darwin)
- 2010's :: Models that resolve the size-spectra of plankton (e.g. Ward et al.)
- 2020's :: Models that resolve the adaptive evolution of plankton (e.g. SPEAD)



LINES OF RESEARCH

- **Macroecology of plankton**
- What are the **causes** that explain the observed patterns of planktonic diversity?
- Role of oceanic dispersion, competitive interactions, and environmental filtering?
- Global distributions of plankton abundance or biomass, productivity, and diversity

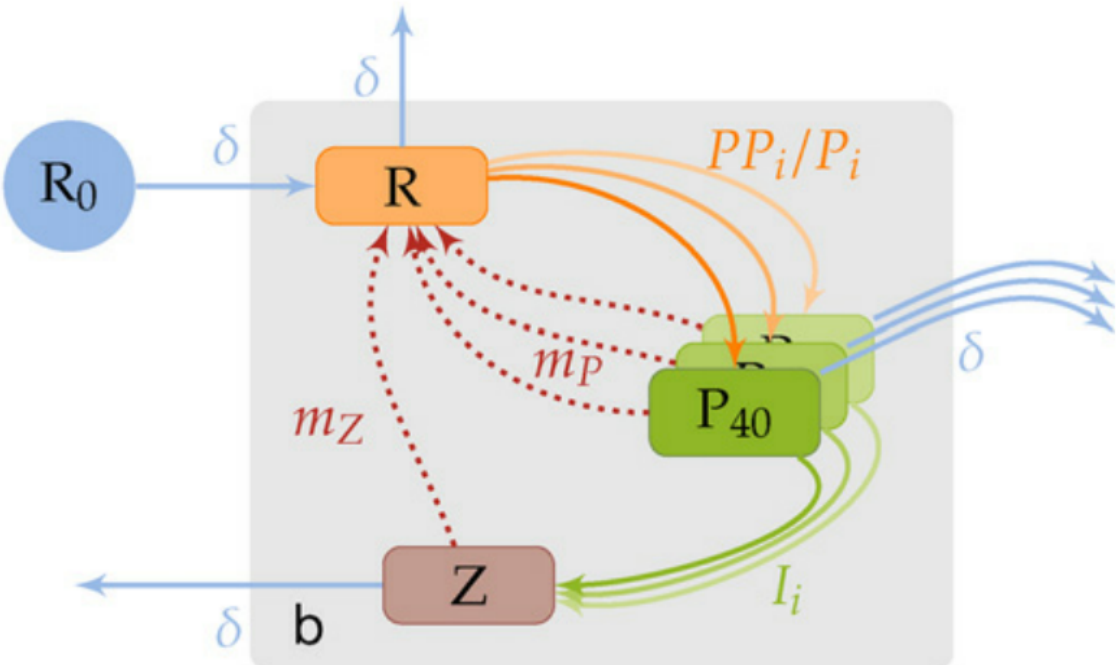
- **Ecosystem functioning**
- What are the **effects** of planktonic diversity on major ecosystem functions?
- Role of diversity on stabilizing aggregate- or community-level properties
- Role of diversity on increasing the productivity of the ecosystem

- **Adaptive dynamics**
- How does **evolution** operates in planktonic organisms at ecological scales?
- Role of trait-diffusion to simulate the adaptive evolution of ecological traits
- Use of continuous-trait models to simulate evolving plankton populations

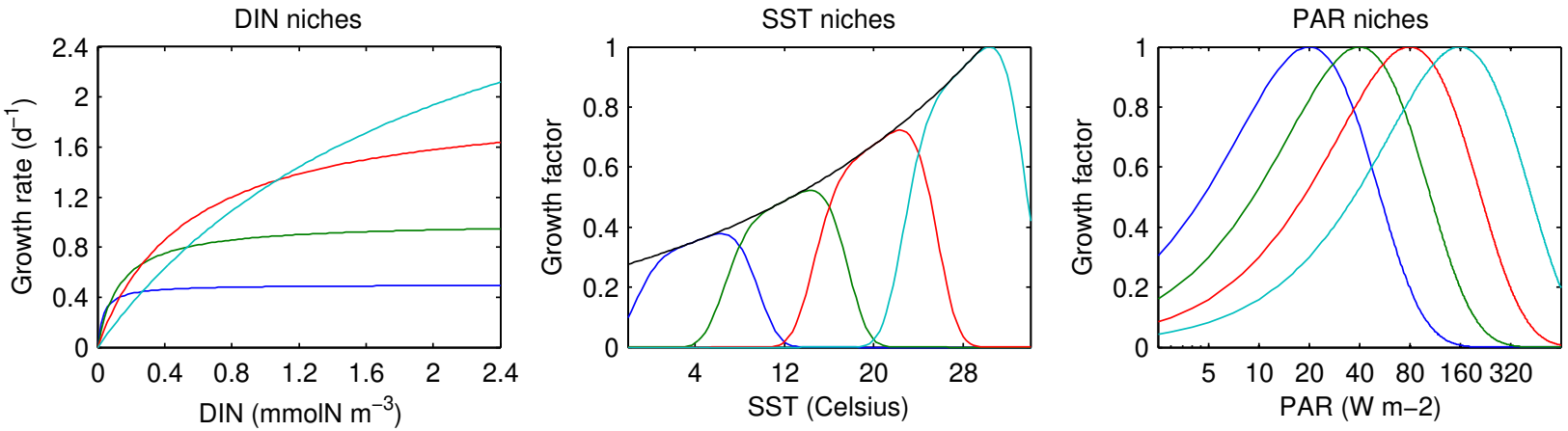
Community Assembly

- Plankton ecotypes interact among them and the enviroment
- The physiology of ecotypes affects their local ecological fitness
- Selection of best performing ecotypes by competition and filtering

MIT darwin model

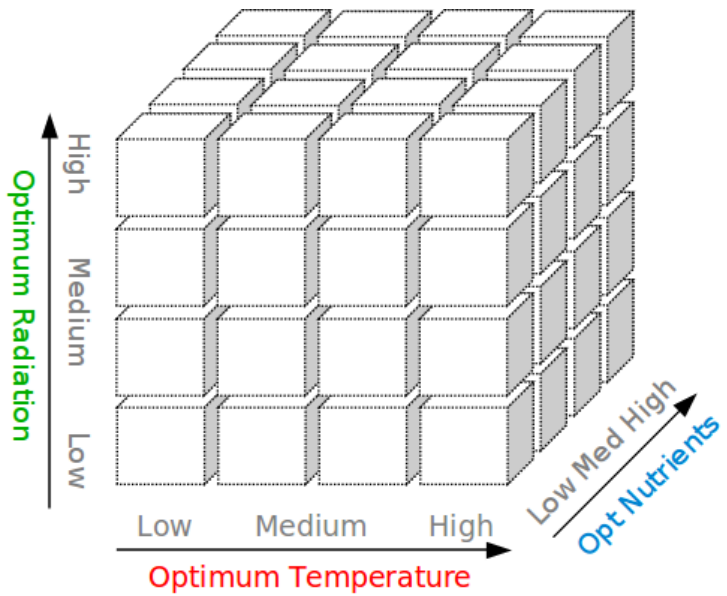


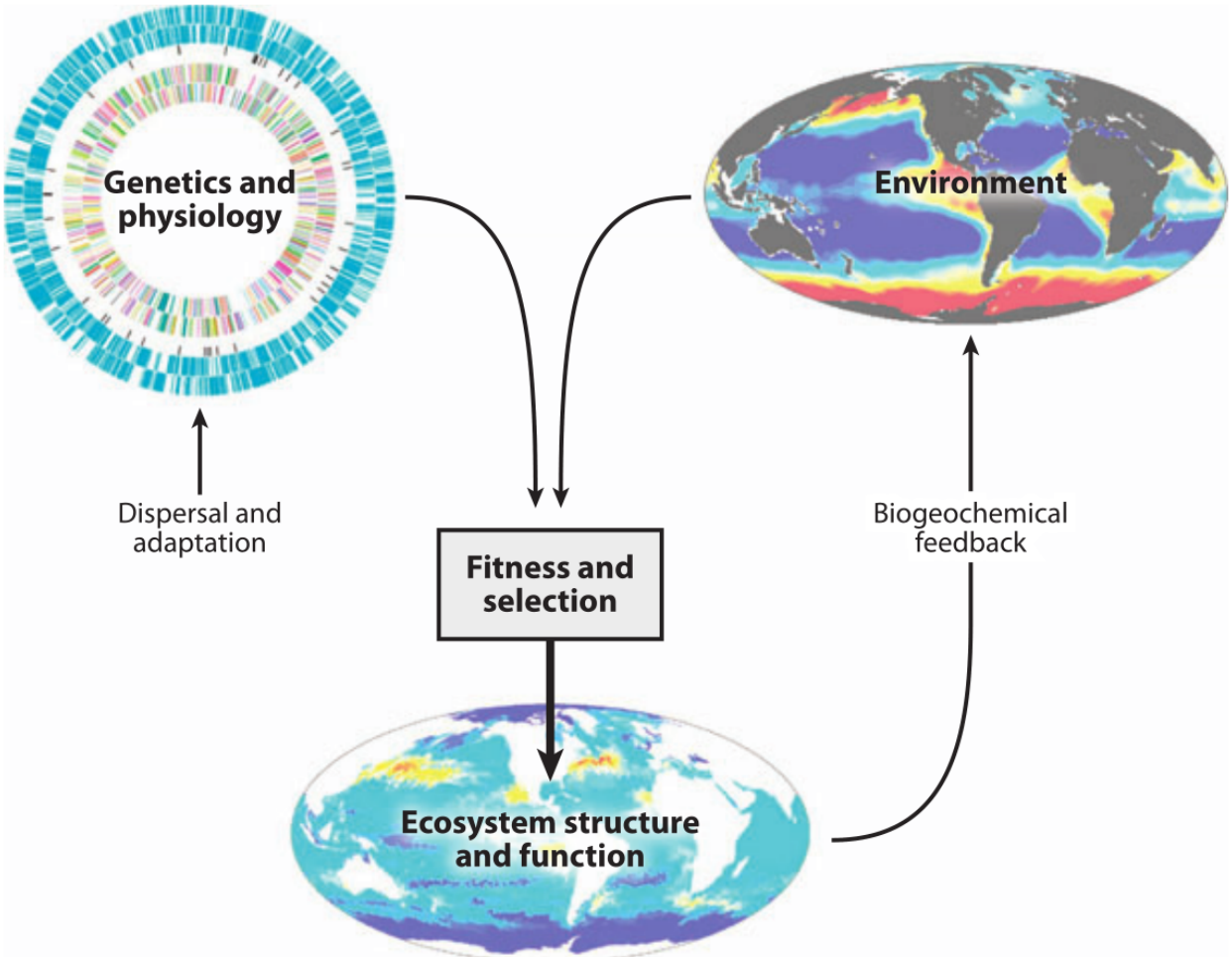
64 phytoplankton ecotypes



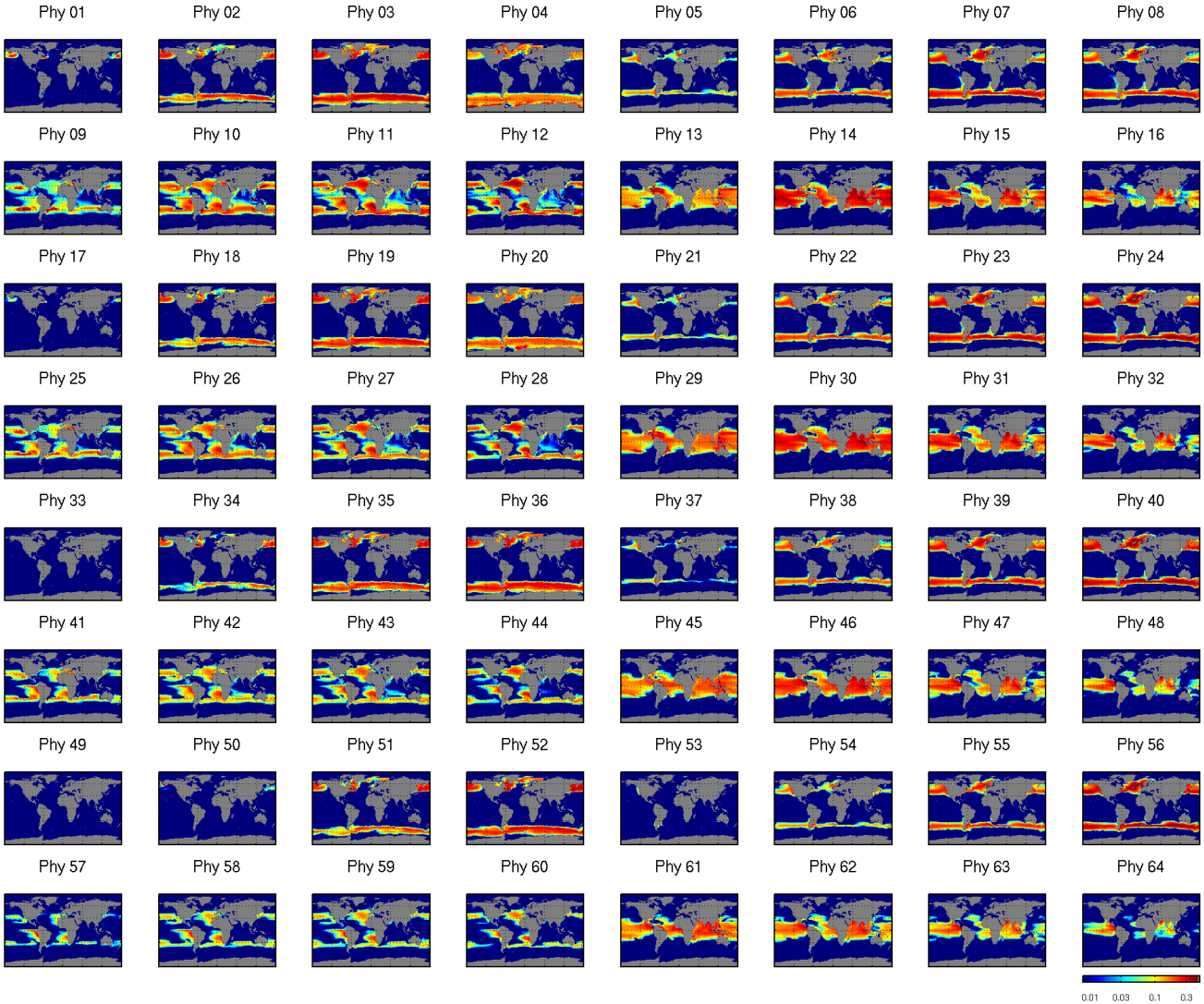
64 phytoplankton ecotypes

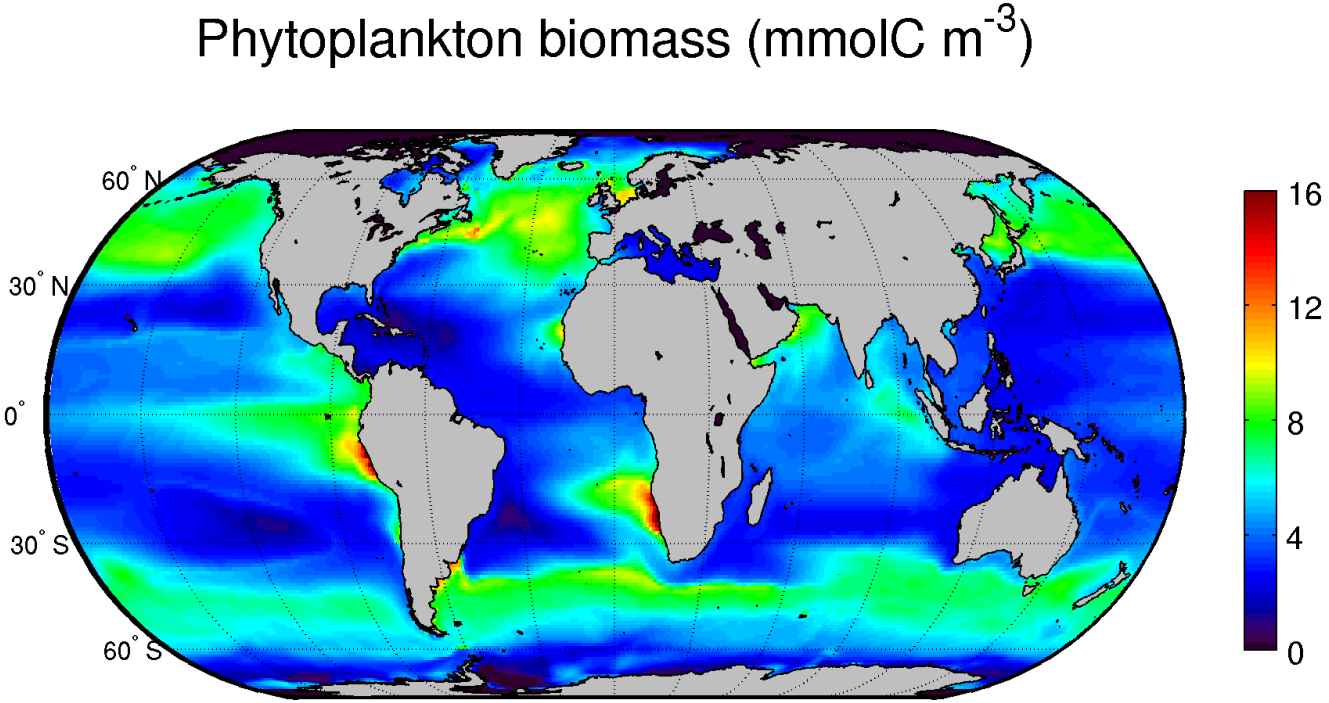
- environmental niche: temperature + light + nutrient



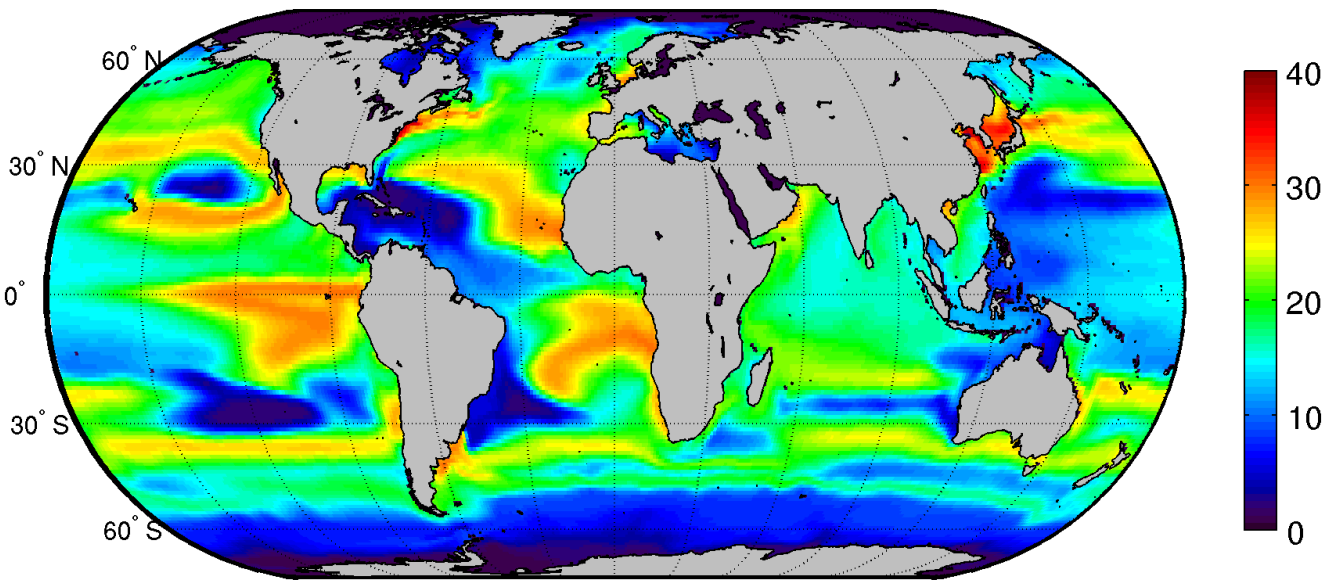

Genetics and physiology
Environment
Dispersal and adaptation
Fitness and selection
Biogeochemical feedback
Ecosystem structure and function

64 phytoplankton ecotypes

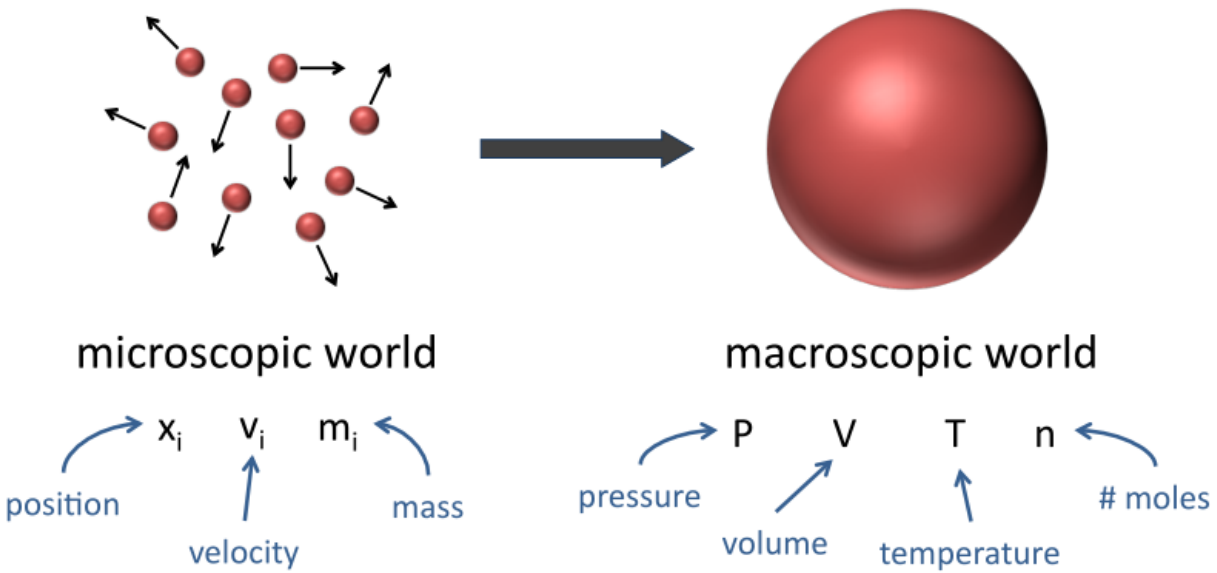



Phytoplankton biomass (mmolC m-3)
60° N
30° N
0°
30° S
60° S
16
12
8
4
0

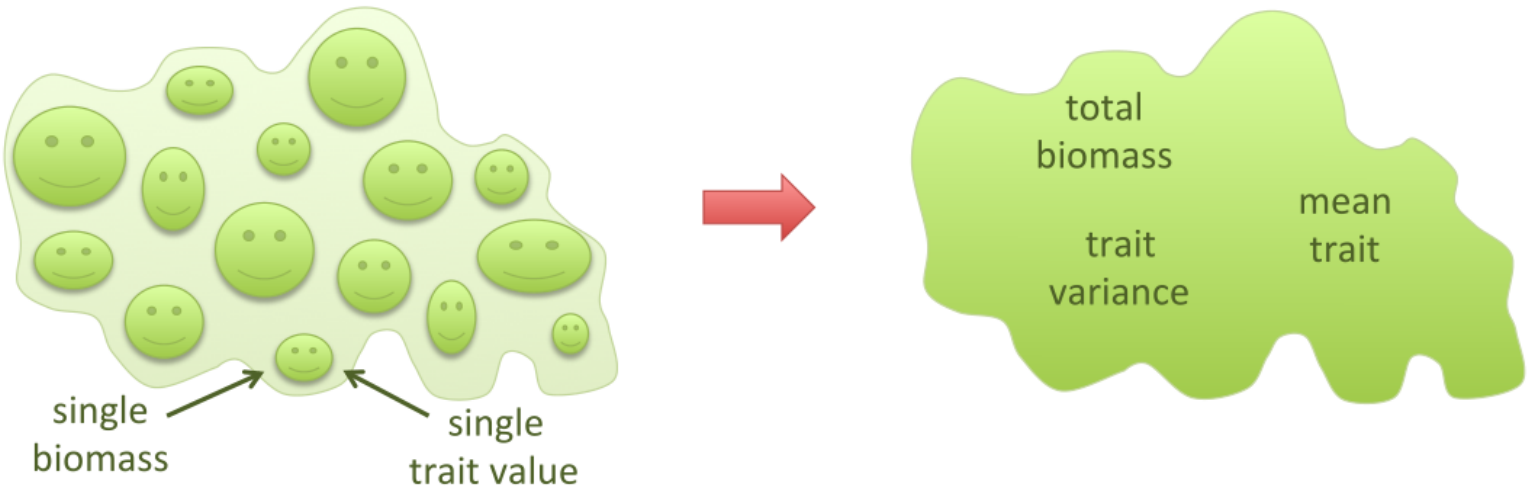
Phytoplankton diversity (# species)



Continuous approx of discrete entities :: physics



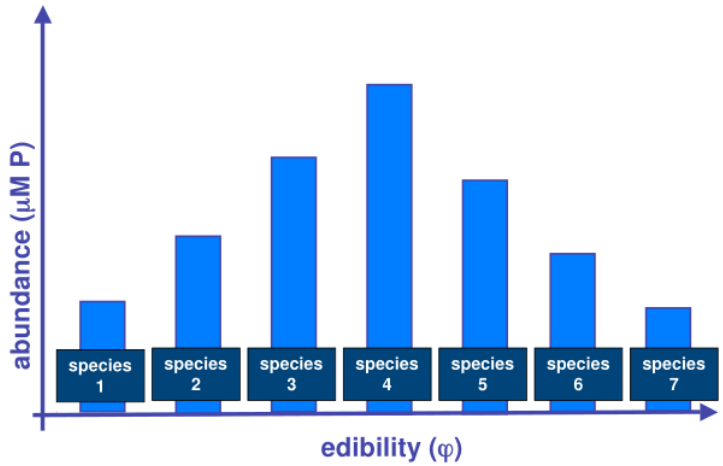
Continuous approx of discrete entities :: ecology



individual properties

aggregate-group properties

Adaptive dynamics :: «Trait diffusion» creates diversity



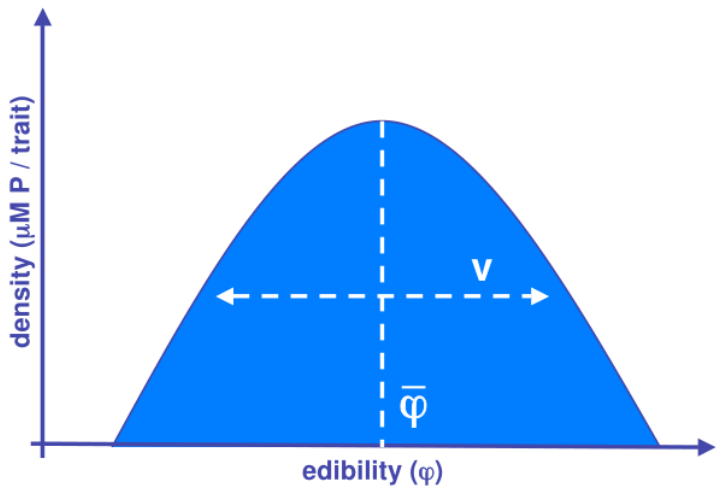
$\Rightarrow$

full model

$$\frac{dP_1}{dt} = r(\varphi_1)\, P_1$$

$$\vdots$$

$$\frac{dP_n}{dt} = r(\varphi_n)\, P_n$$



$\Rightarrow$

aggregate model

$$\frac{dP_T}{dt} = \left[r(\bar{\varphi}) + \frac{1}{2} v \frac{\partial^2 r(\bar{\varphi})}{\partial \varphi^2} \right] P_T$$

$$\frac{d\bar{\varphi}}{dt} = v \frac{\partial r(\bar{\varphi})}{\partial \varphi}$$

$$\frac{dv}{dt} = v^2 \frac{\partial^2 r(\bar{\varphi})}{\partial \varphi^2}$$

TD :: discrete model

$$\frac{\partial P_i}{\partial t} = \overbrace{U_{P_i} - G_{P_i} - M_{P_i}}^{\text{Biological interactions}} + \overbrace{\frac{\partial^2 (k_x P_i)}{\partial x^2}}^{\text{Trait diffusion}}$$

$$k_x = \nu_x u_i = \text{mutation coeff}\,[trait^2 day^{-1}]$$

TD :: continuous model

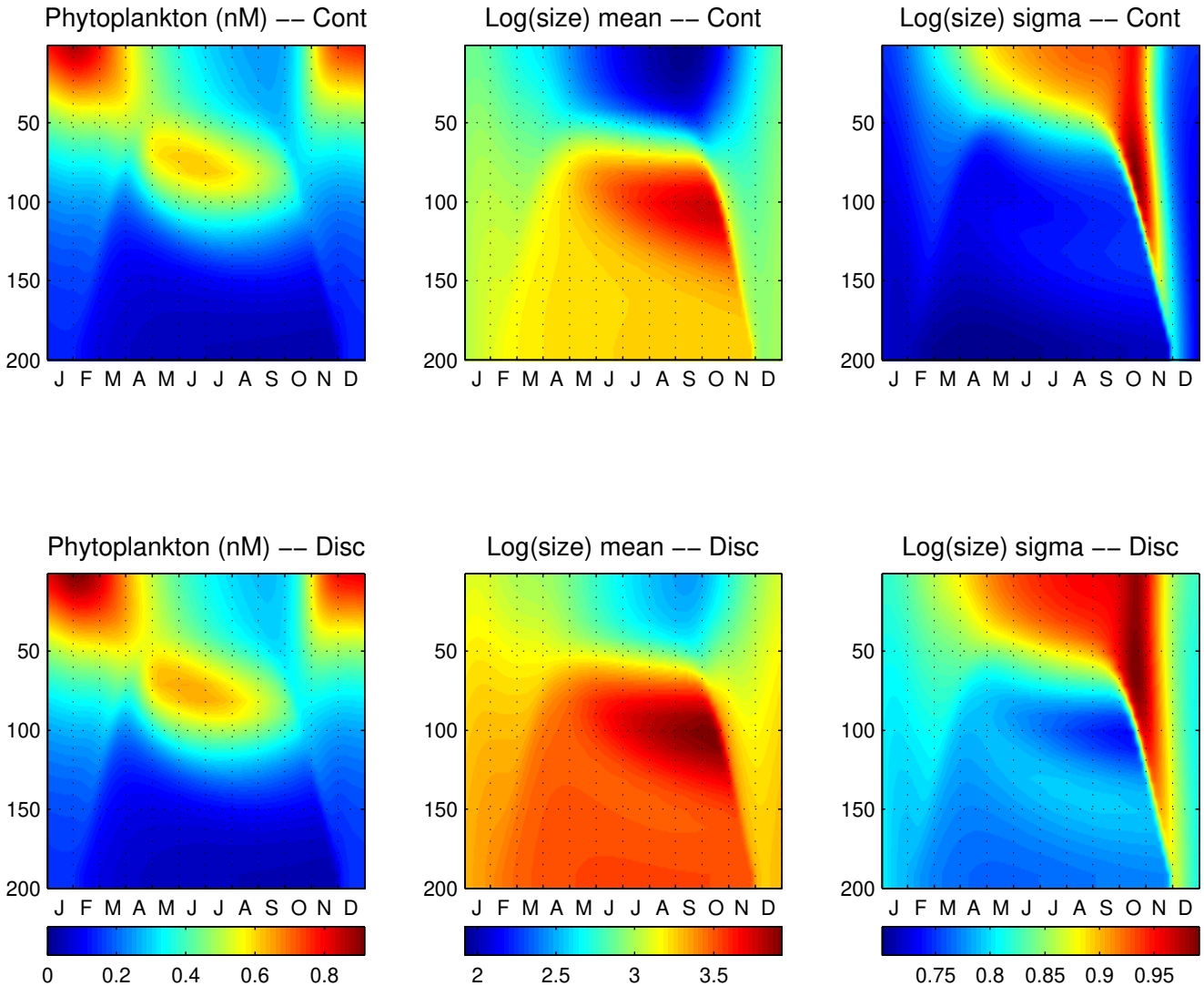
$$\frac{\partial \overline{x}}{\partial t} = \sigma_x^2 \frac{\partial a}{\partial x}$$

$$\frac{\partial \sigma_x^2}{\partial t} = 2\,\nu_x \left(u + (1/2)\,\sigma_x^2 \frac{\partial^2 u}{\partial x^2} \right) + (\sigma_x^2\,\sigma_x^2) \frac{\partial^2 a}{\partial x^2}$$

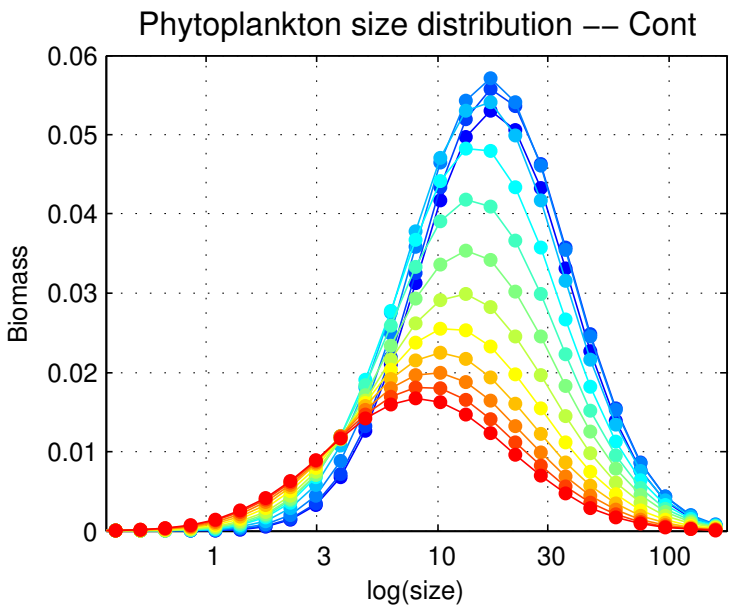
$$\frac{\partial P}{\partial t} = P \left(a + (1/2)\,\sigma_x^2 \frac{\partial^2 a}{\partial x^2} \right)$$

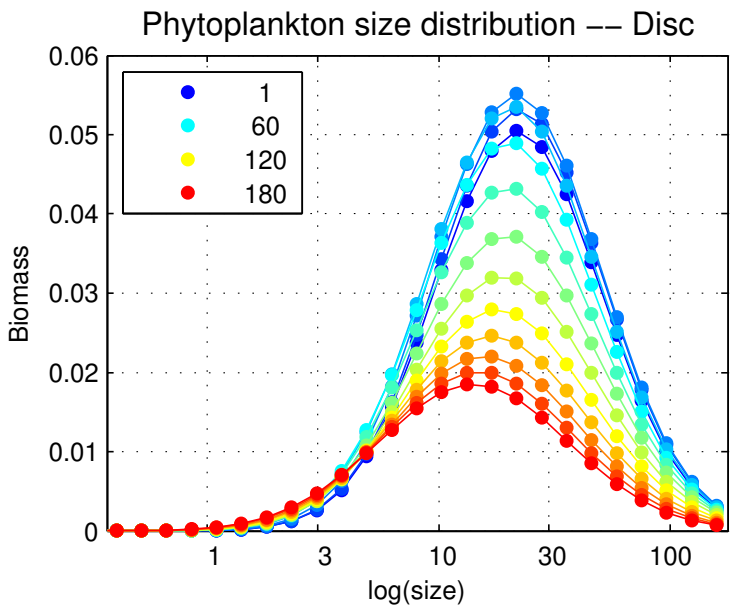
$$a = (u - g - m) = \text{uptake} - \text{grazing} - \text{mortality}$$

TD :: Depth resolved seasonality

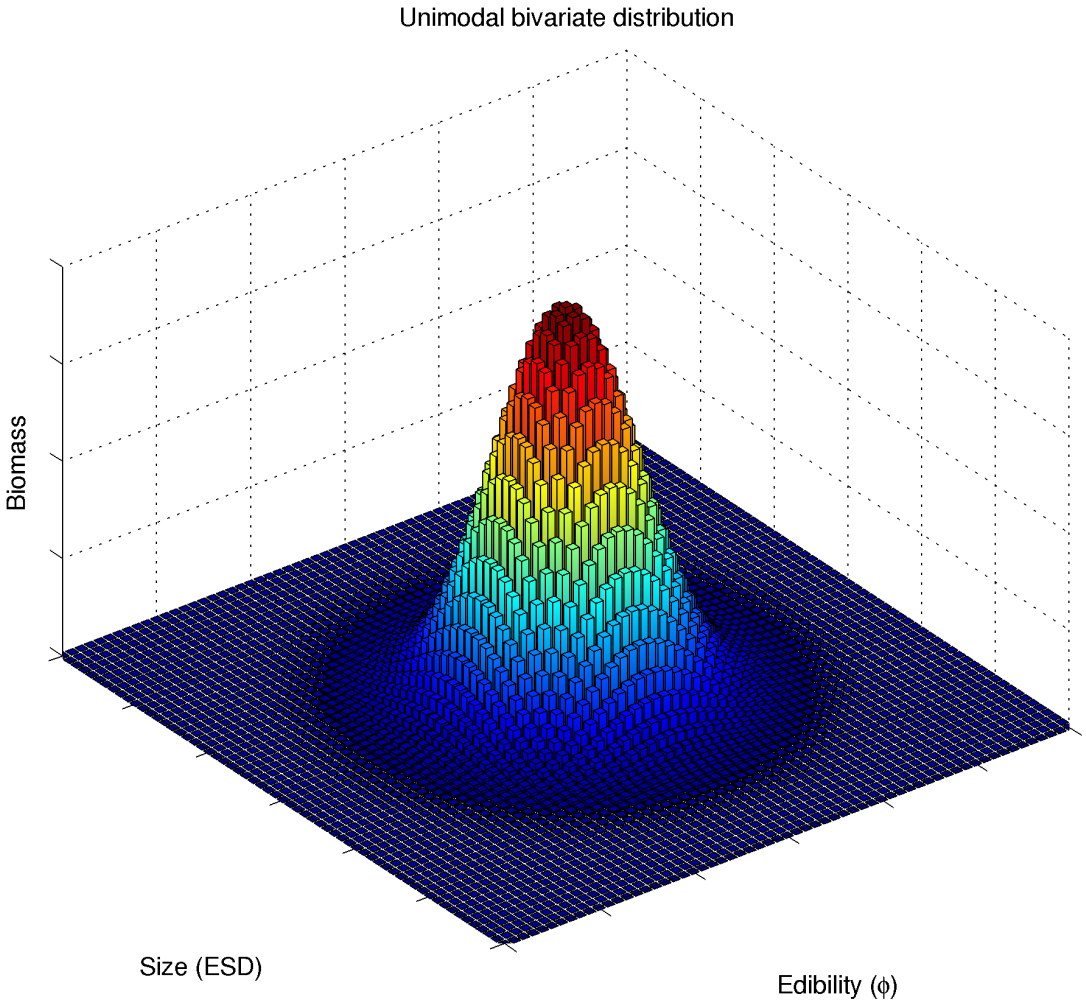


Fitness Landscapes ■ 1-trait: N_{opt}

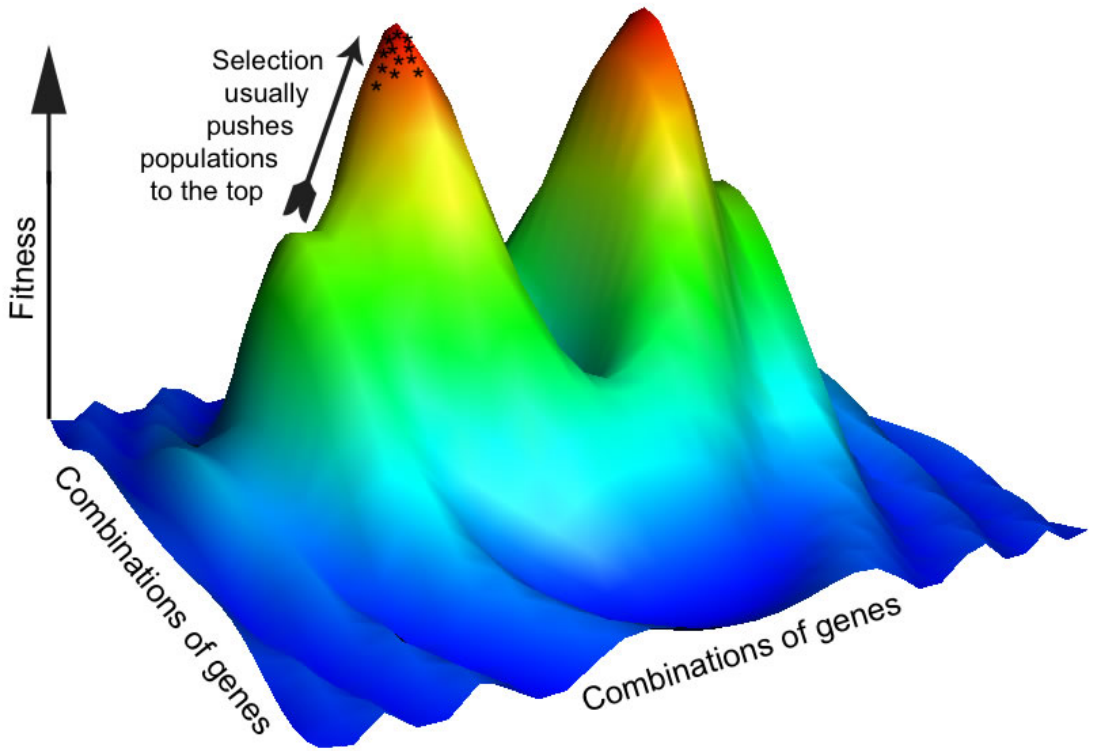




Fitness Landscapes ■ 2-traits: N_{opt}, T_{opt}



Fitness Landscapes ■ 2-traits: N_{opt}, T_{opt}



Fitness Landscapes ■ 2-traits: N_{opt}, T_{opt}

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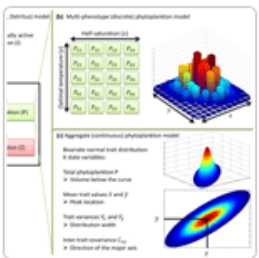
Model description paper

13 Apr 2021



SPEAD 1.0 – Simulating Plankton Evolution with Adaptive Dynamics in a two-trait continuous fitness landscape applied to the Sargasso Sea

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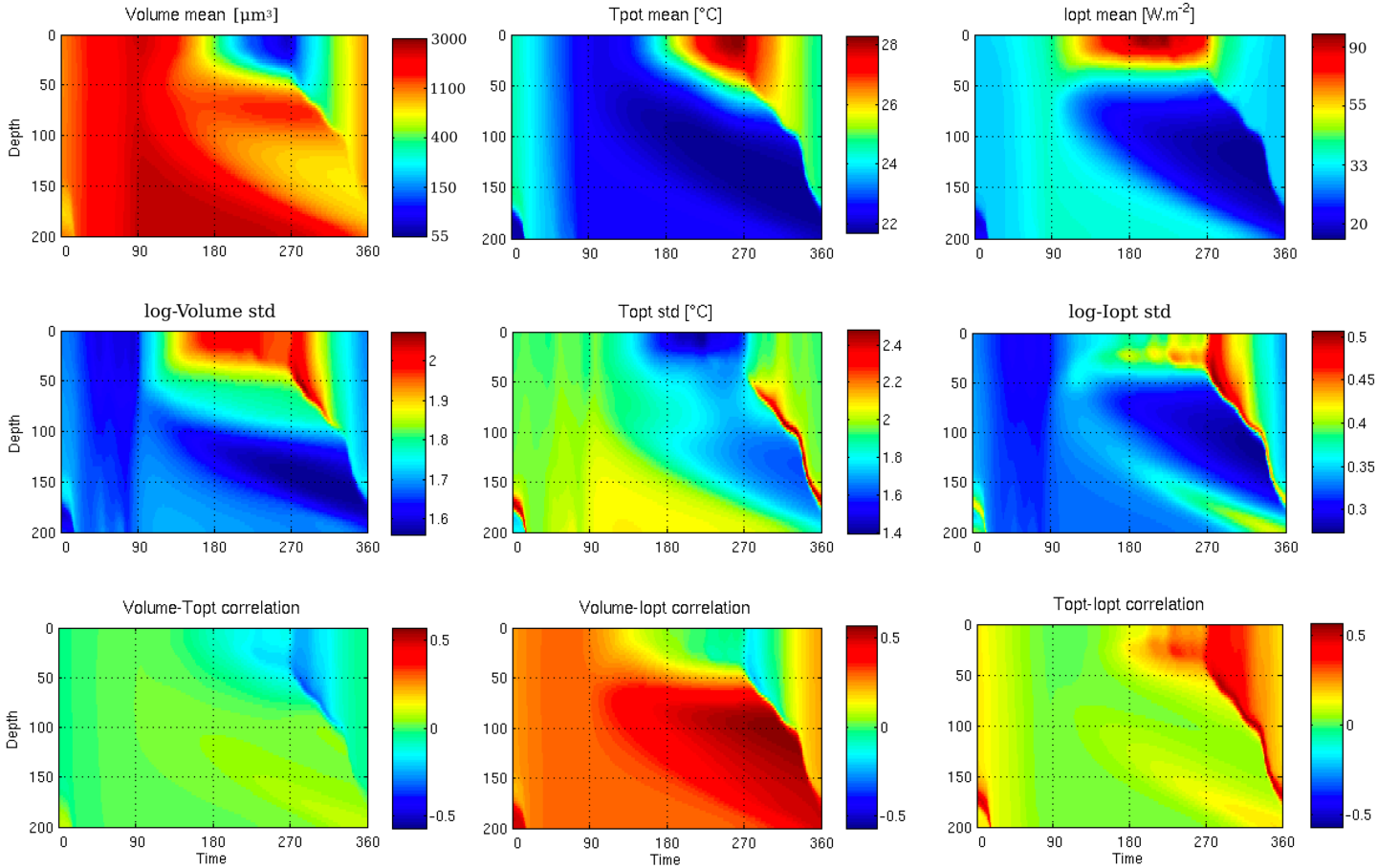
Fitness Landscapes ■ 3-traits: N_{opt}, T_{opt}, I_{opt}

- MITgcm + DARWIN + SPEAD
- Depth-resolved simulation 1D



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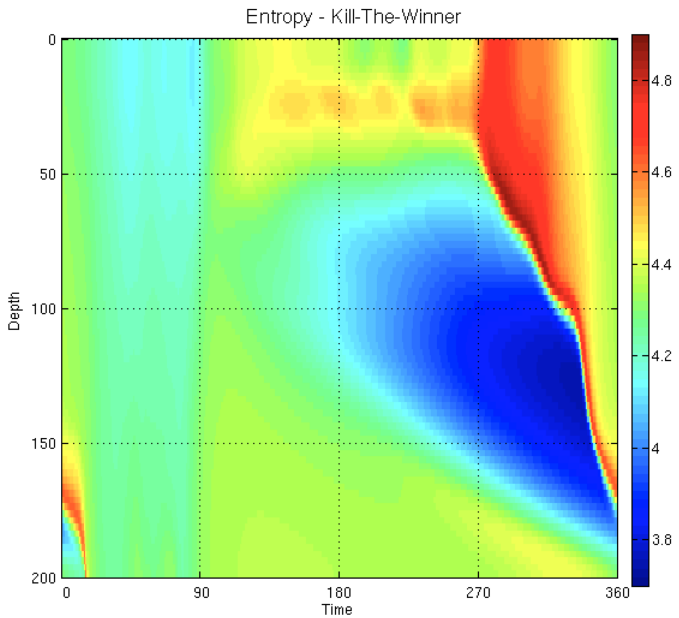
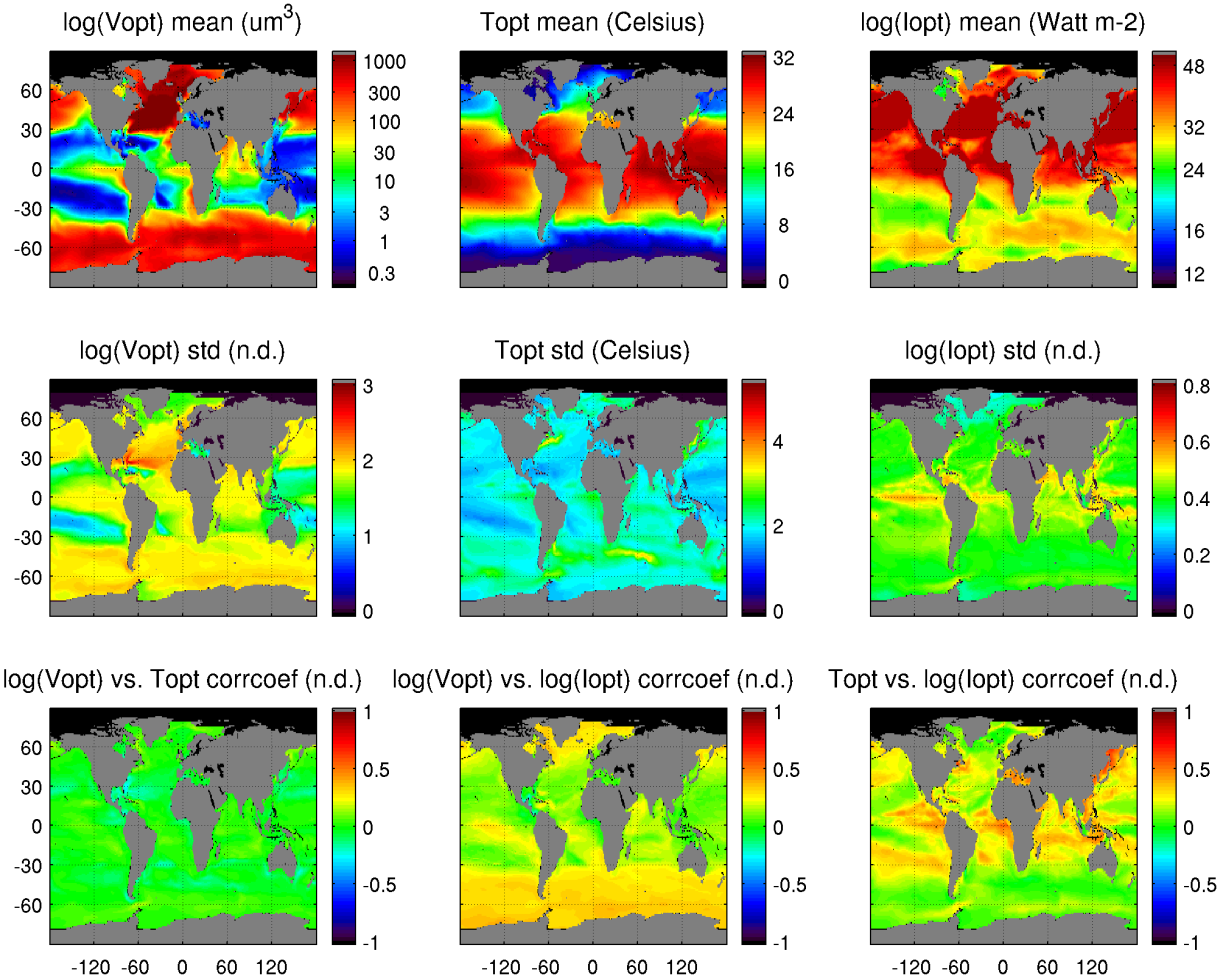


Fitness Landscapes ■ 3-traits: N_{opt}, T_{opt}, I_{opt}

- MITgcm + DARWIN + SPEAD
- Global ocean simulation 3D



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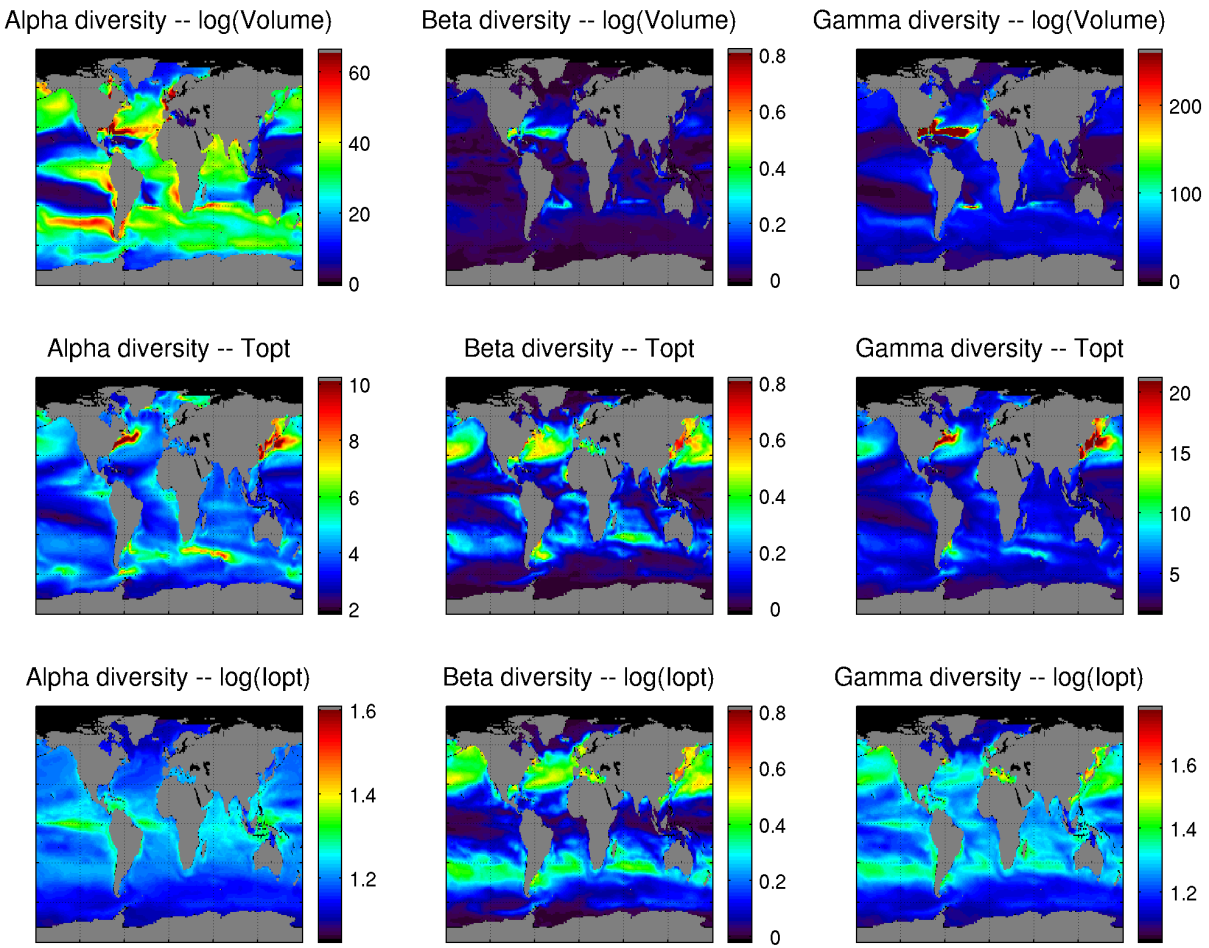
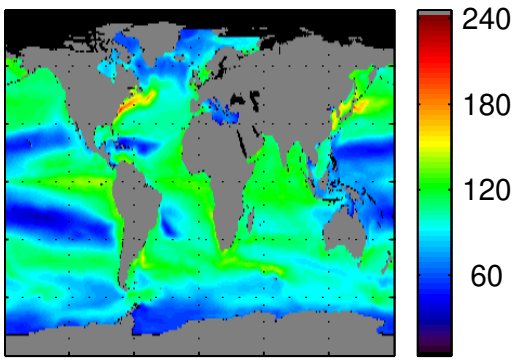


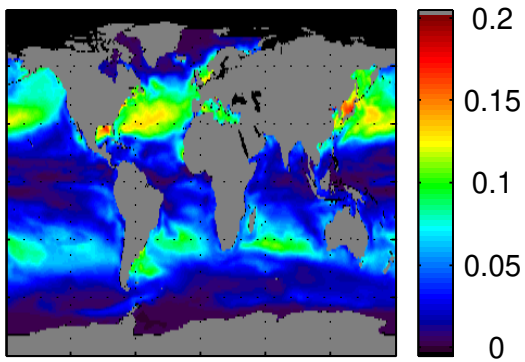
Fitness Landscapes ■ 3-traits: N_{opt}, T_{opt}, I_{opt}

- MITgcm + DARWIN + SPEAD
- Global ocean simulation 3D

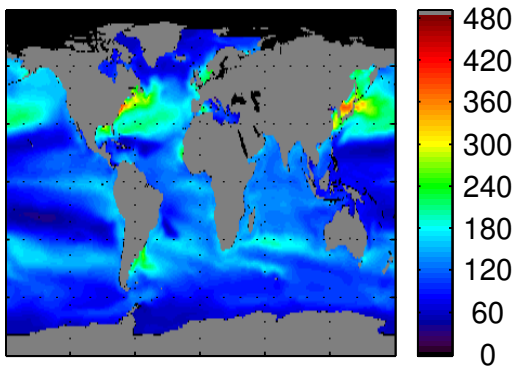
Alpha diversity



Beta diversity



Gamma diversity



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