Modelling Community Structure

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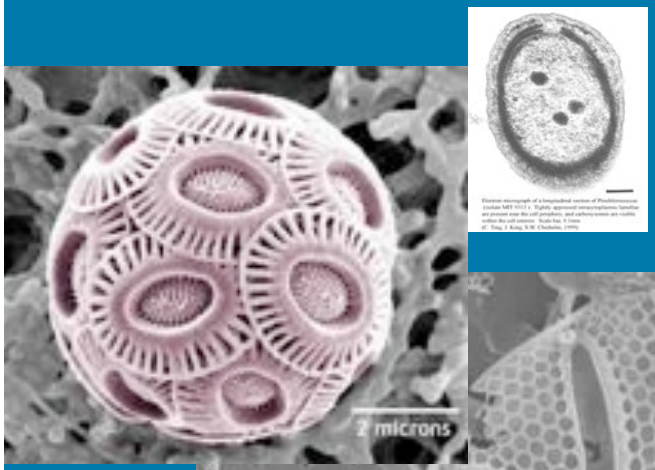
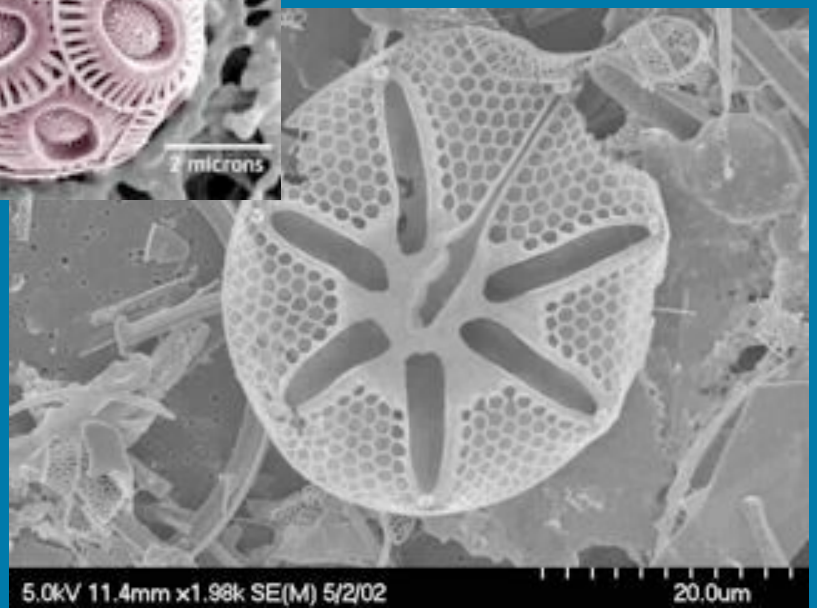


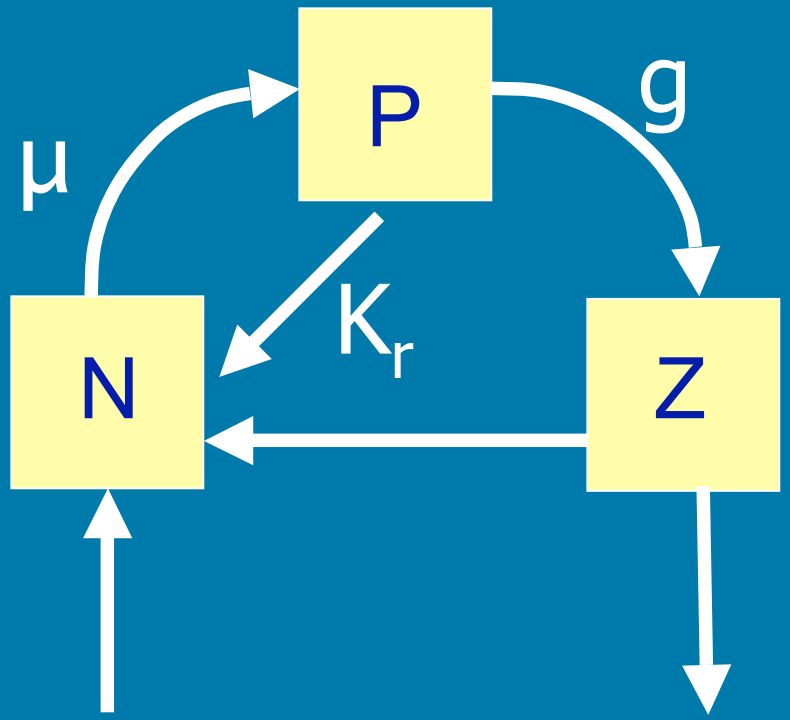


Community structure impacts:

- Export production
- Biogeochemical cycles
- Optical properties

Modelling Marine Ecosystems

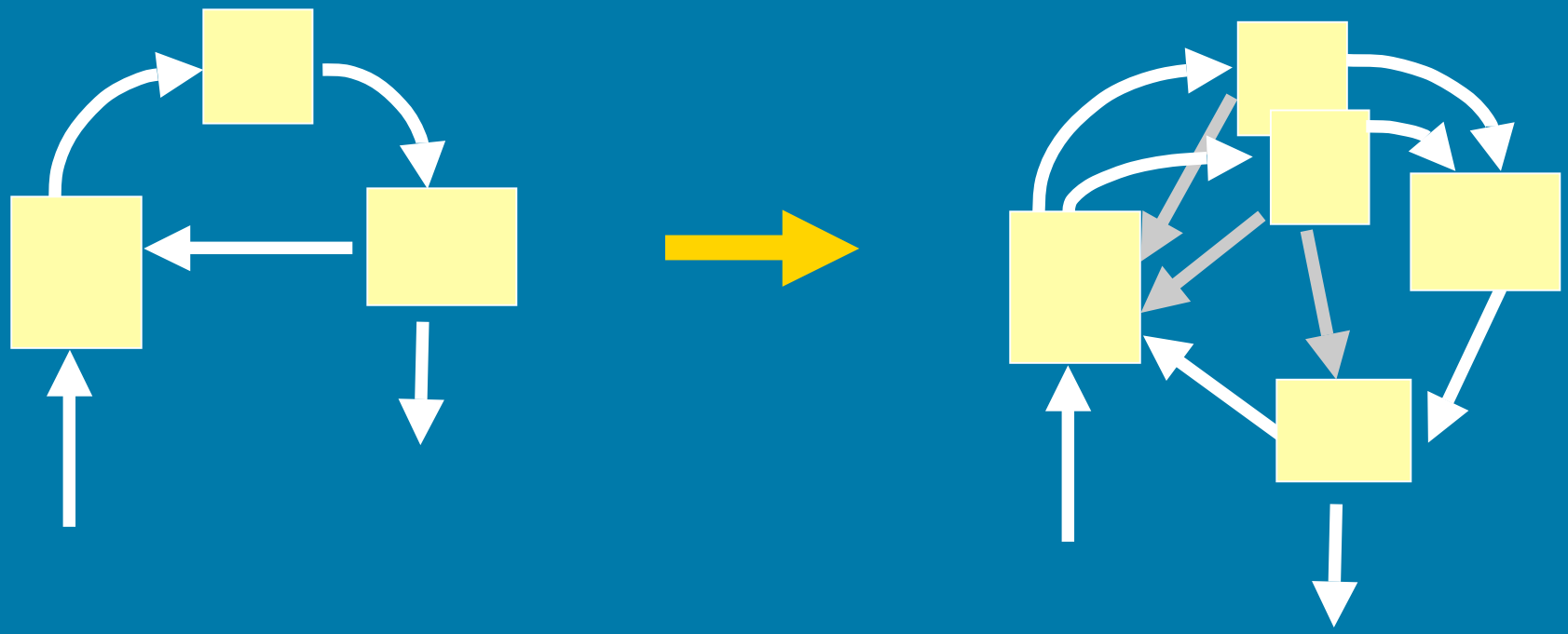
- Physiological processes are parameterized
- Rates regulated by values of governing coefficiencts



$$\frac{dP}{dt} = P\left(\mu - K_r - gZ\right)$$

Riley (1946)

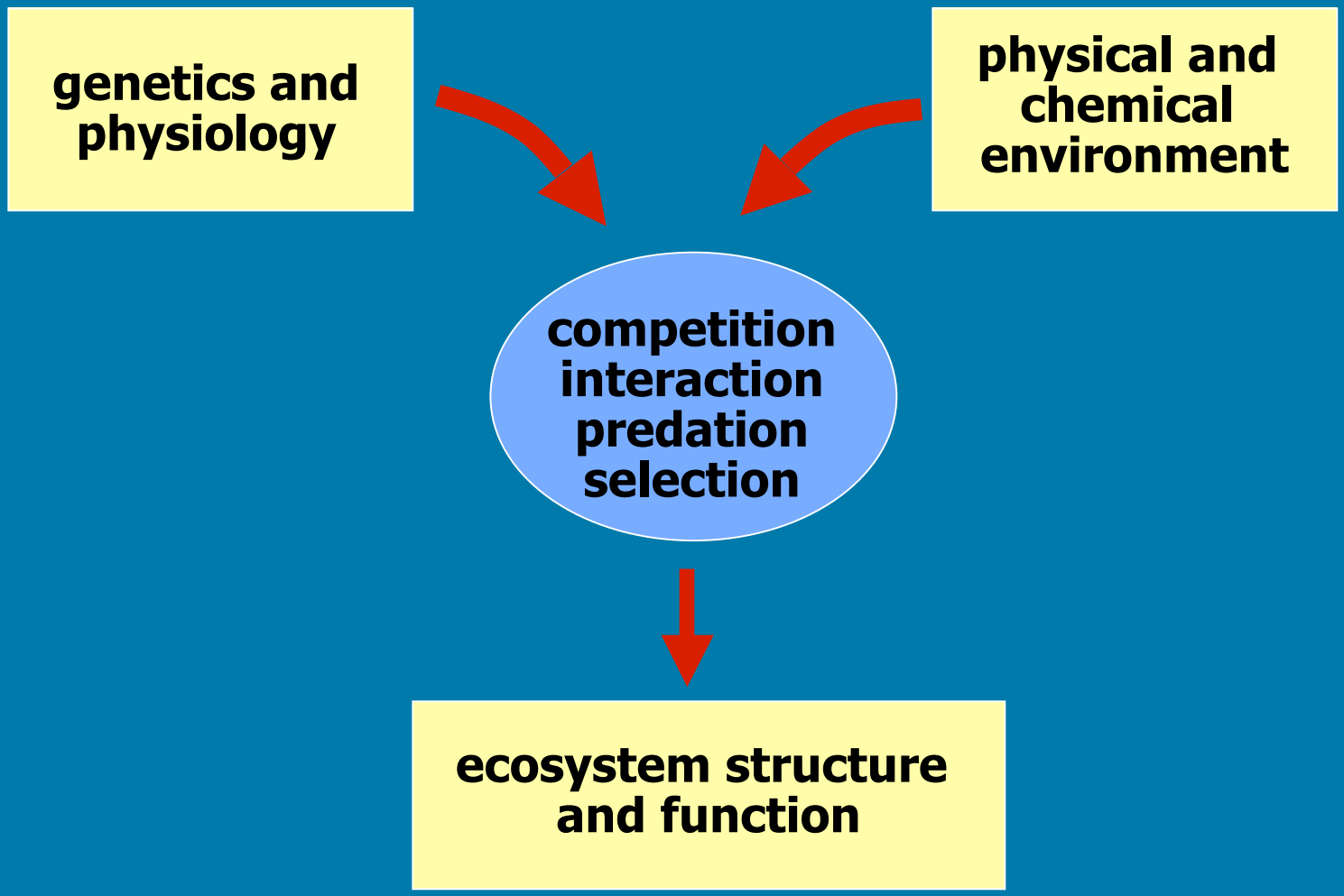
Incrementally increase food web resolution



NPZ model

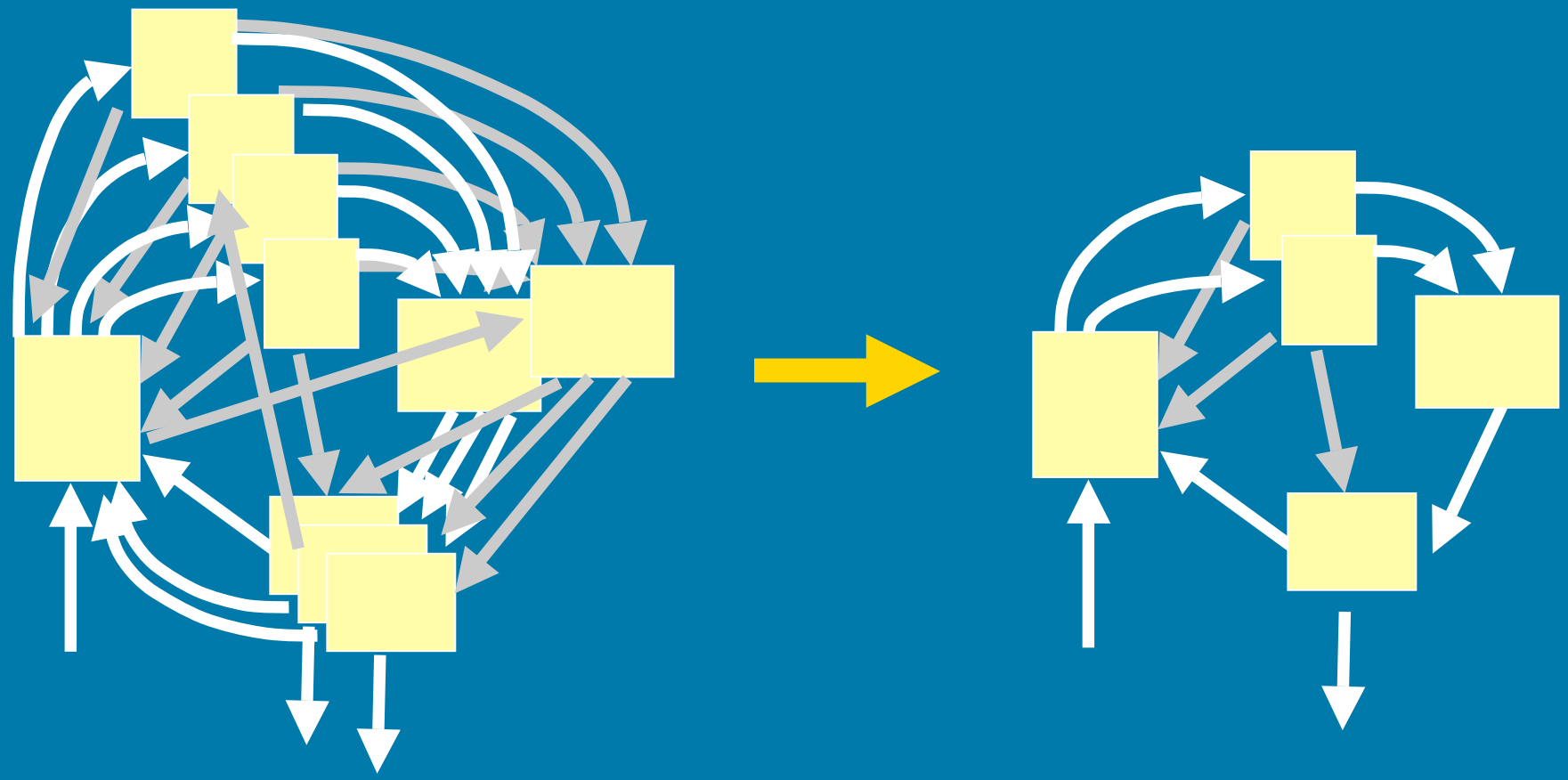
incremental enhancement

What sets ecosystem structure?



Alternative modelling strategy:

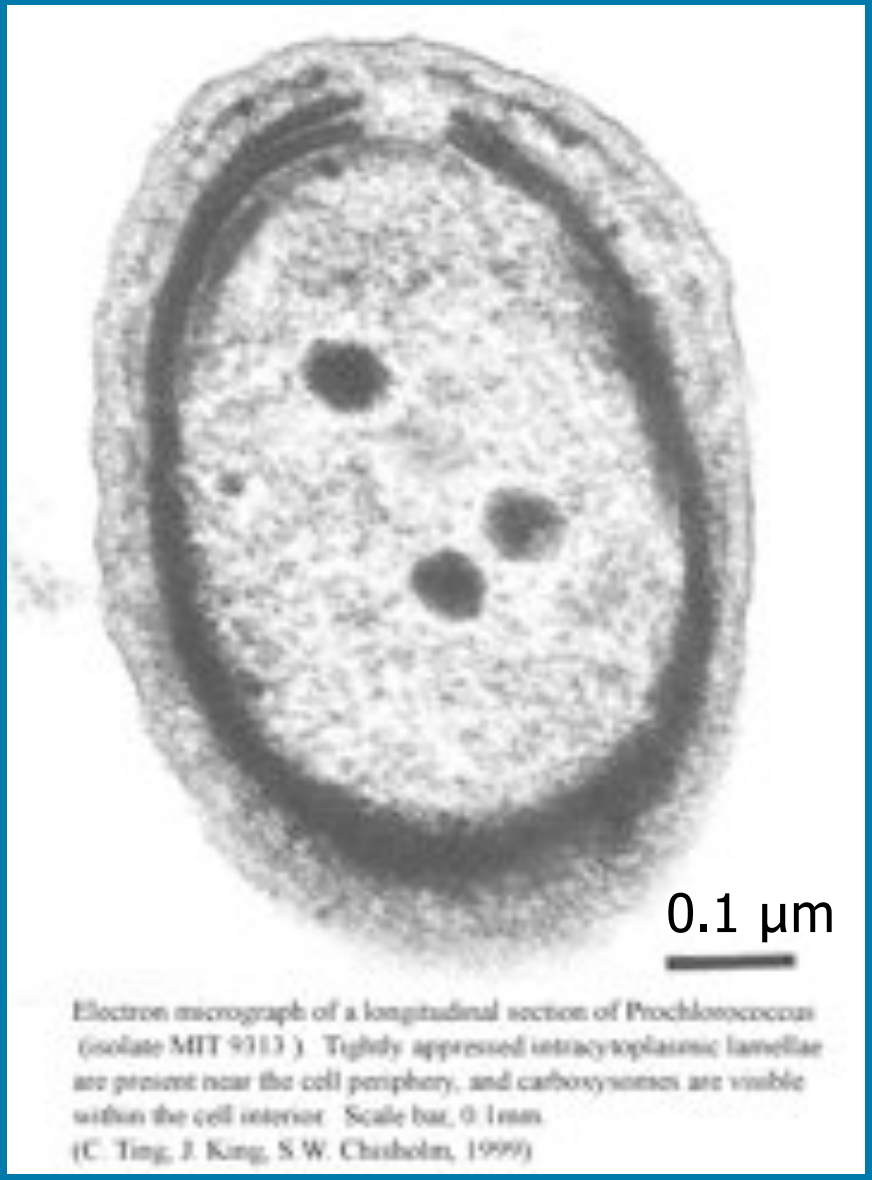
- **initialize many potentially viable phytoplankton types**
- **system self-organizes …**



Complex initialized food web

self-organized state

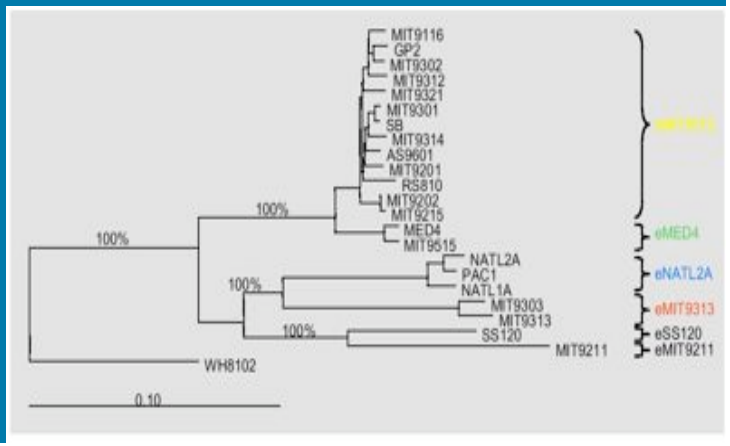
Prochlorococcus



Electron micrograph of a longitudinal section of Prochlorococcus (isolate MIT 9313). Tightly appressed intracytoplasmic lamellae are present near the cell periphery, and carboxysomes are visible within the cell interior. Scale bar, 0.1 mm.
(C. Ting, J. King, S.W. Chisholm, 1999)

- cyanobacteria
- occupies tropics and subtropics
- cannot utilize NO_3 (?)

- six genetically distinct "ecotypes"
- correlated physiological variations

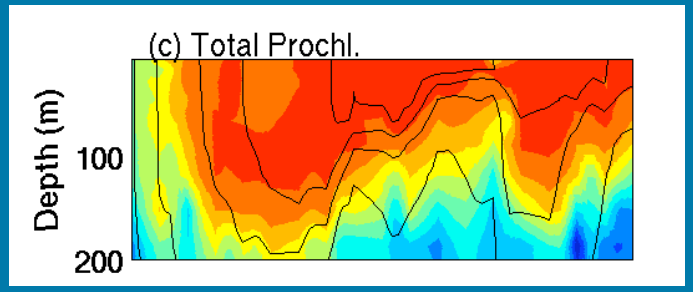


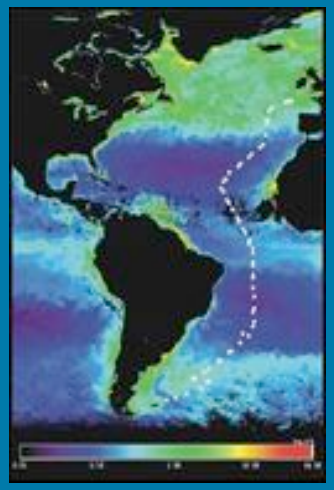
Chisholm lab

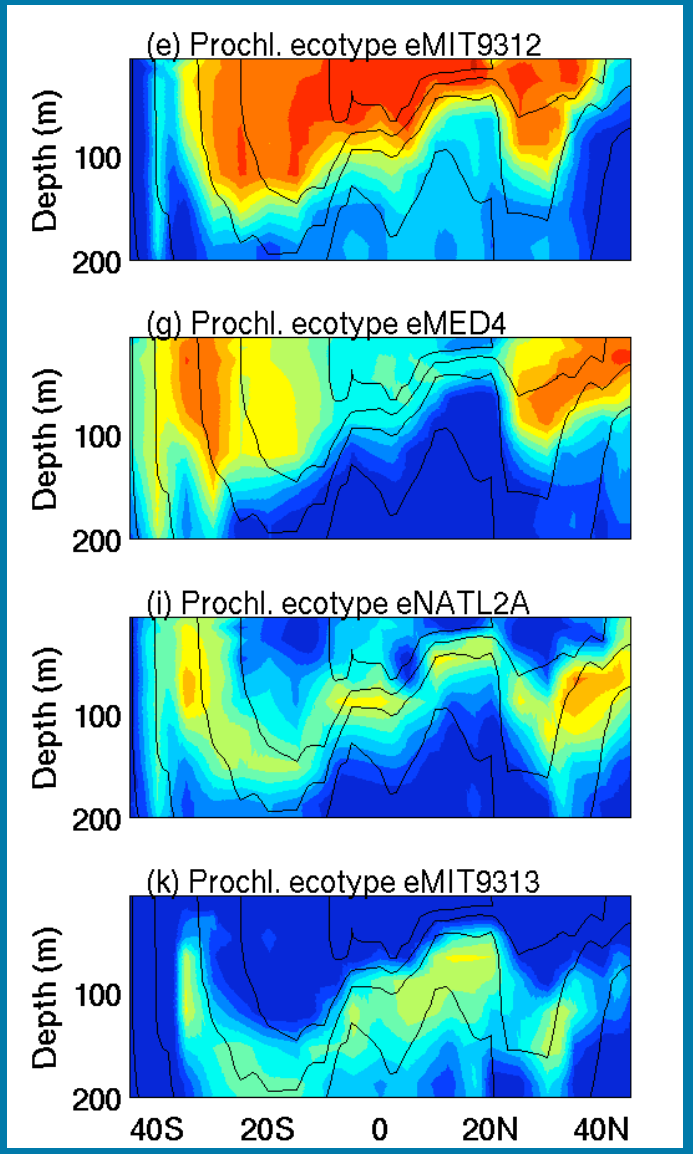
Observed *Prochlorococcus* abundance on AMT13 track

Total

ecotypes





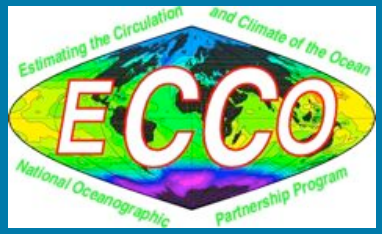


Johnson et al. (2006)

Global Model

ENVIRONMENT

- MITgcm, global configuration
  - ECCO-GODAE 1^{o}x1^{o} circulation state estimate
  - (Wunsch & Heimbach, 2006)
- Explicit P, N, Fe, Si cycles

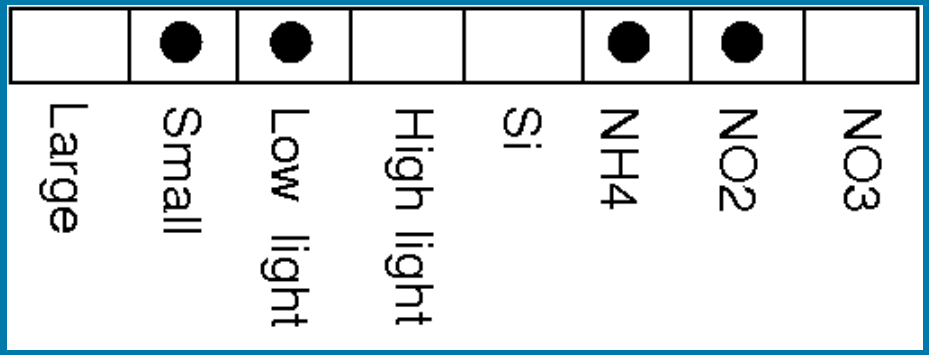


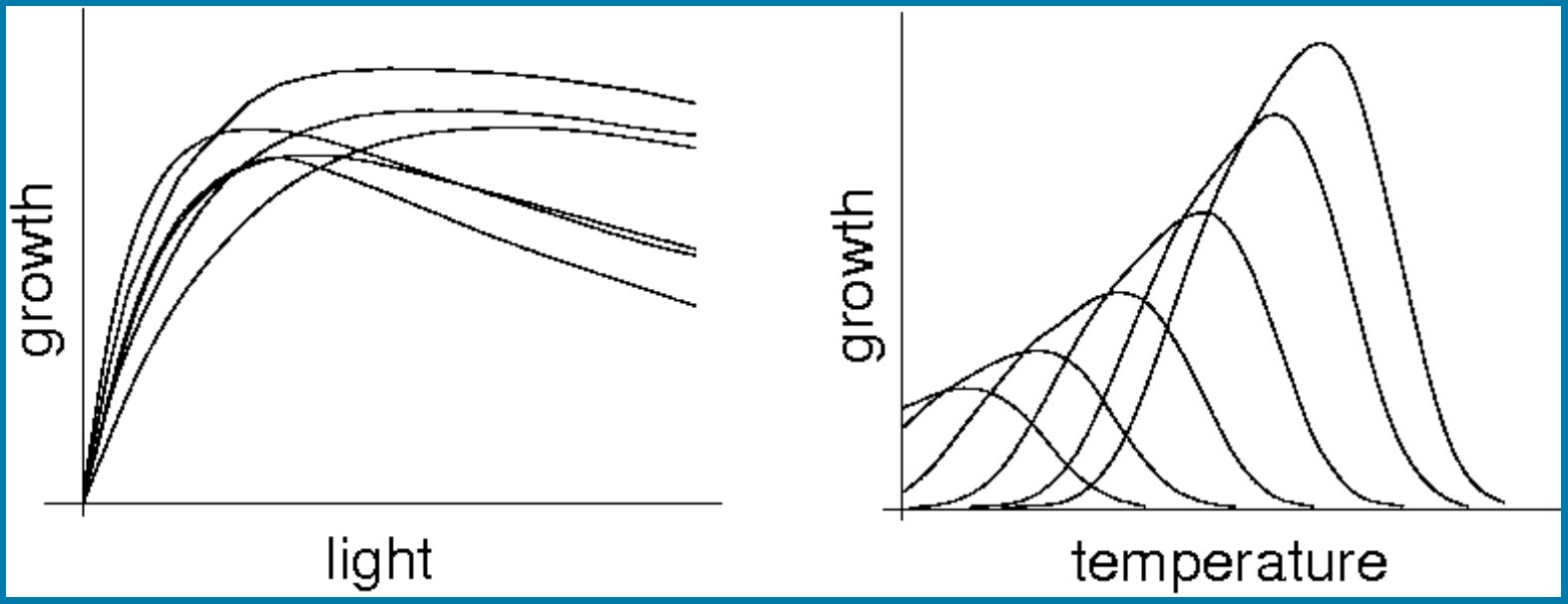
ORGANISMS, PHYSIOLOGY

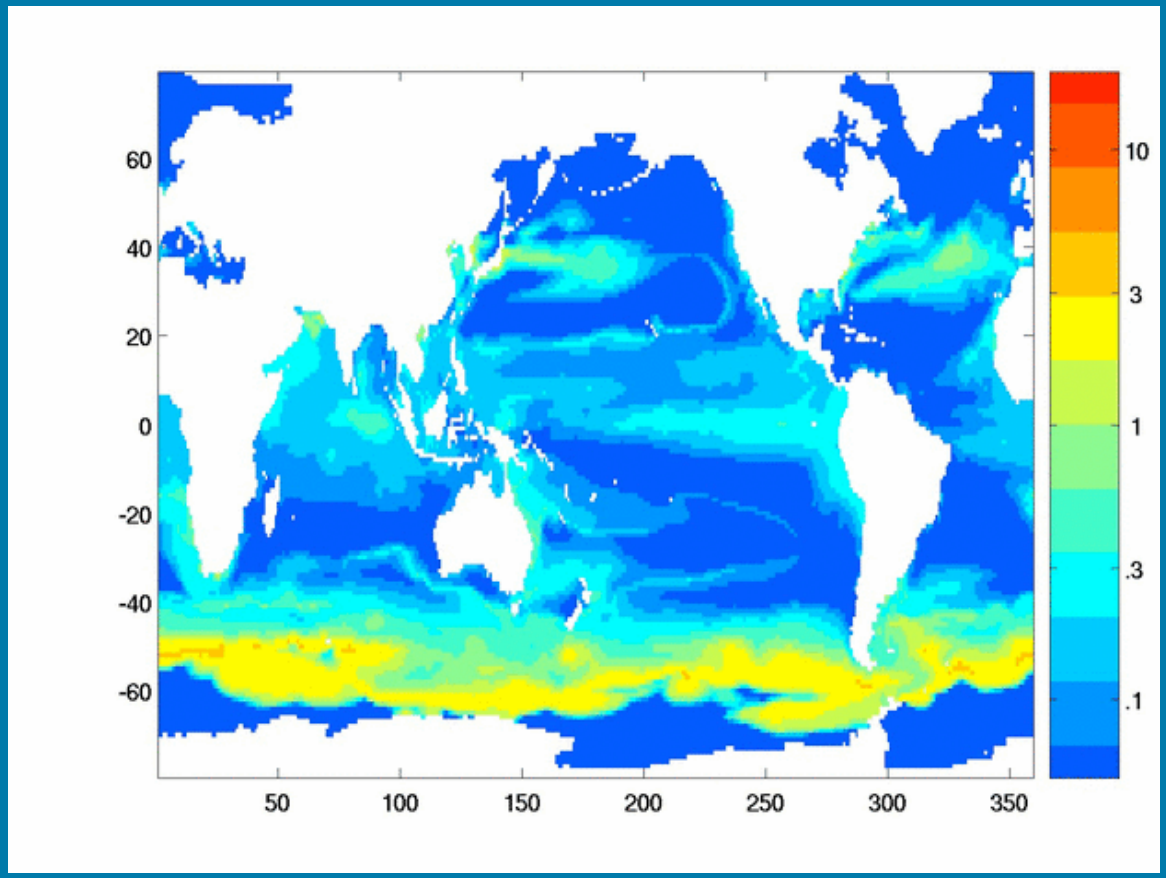
- 78 initial types of phytoplankton
- "Random" physiological traits
- 2 grazers
- Ensemble of integrations, different randomization

Initializing model phytoplankton types

- "Random" assignment of functional properties
- Simple allometric trade-offs



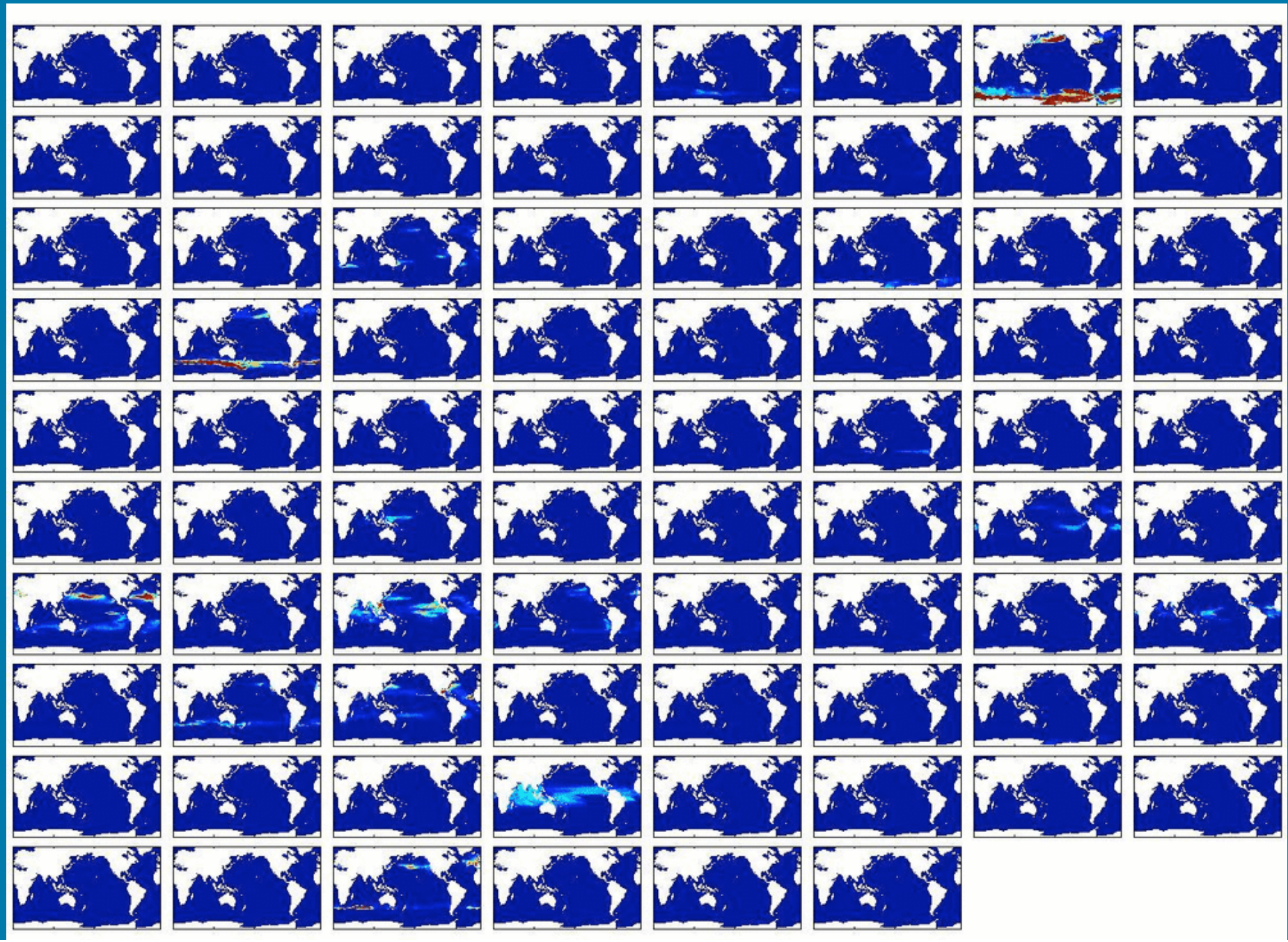




Modeled 0-50m biomass (uM N):

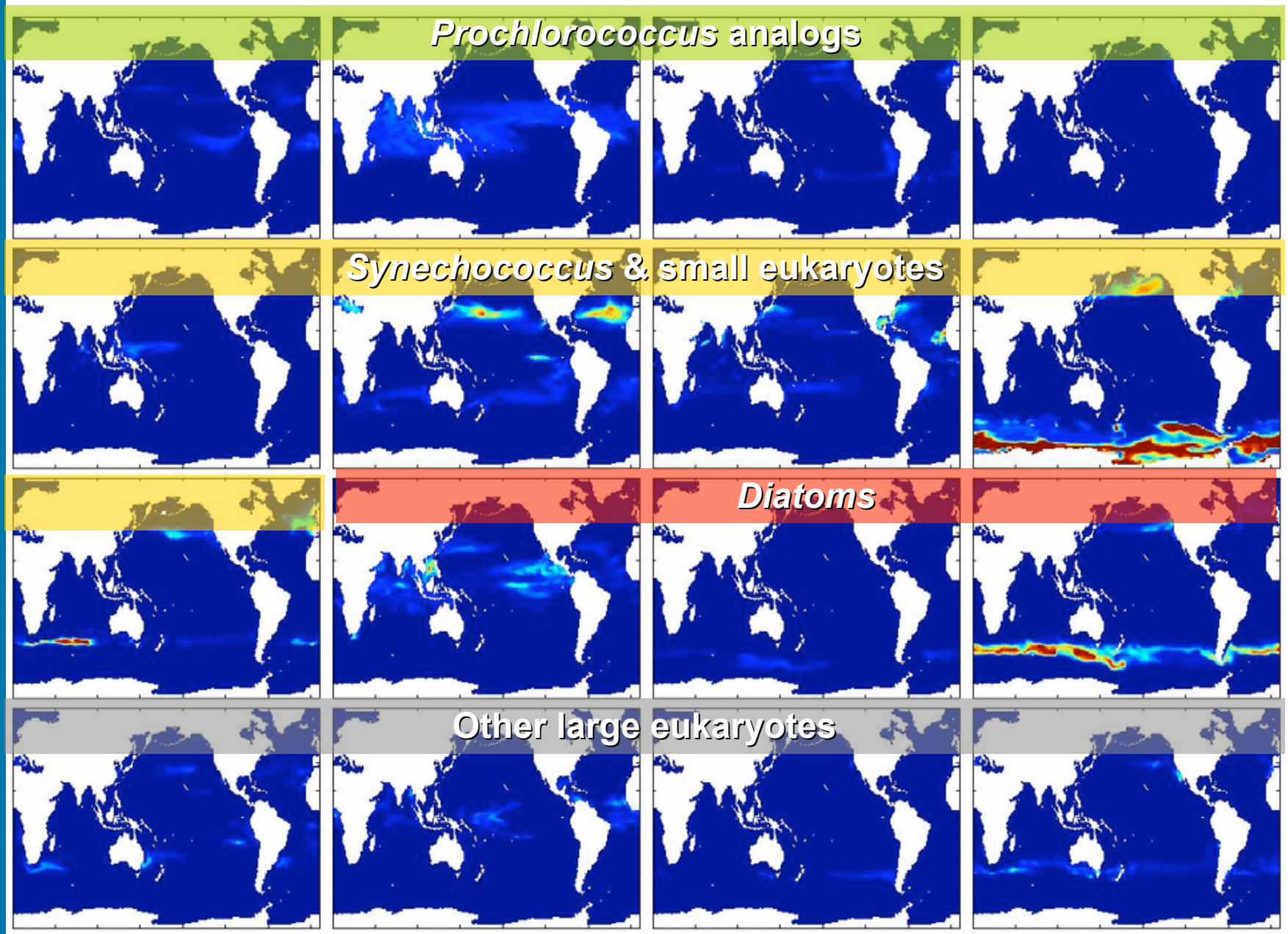
10th annual cycle, single ensemble member

Single ensemble member, all functional types, 0-50m



Single ensemble member, all functional types, 0-50m

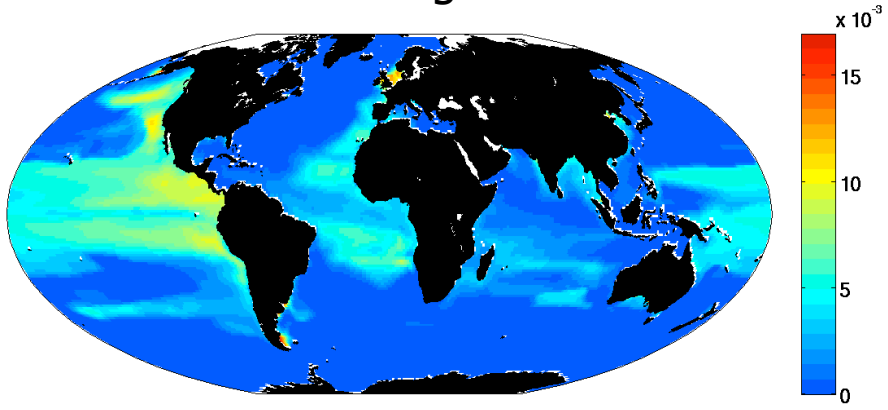
Emergent biogeography – 16 most abundant phytoplankton types



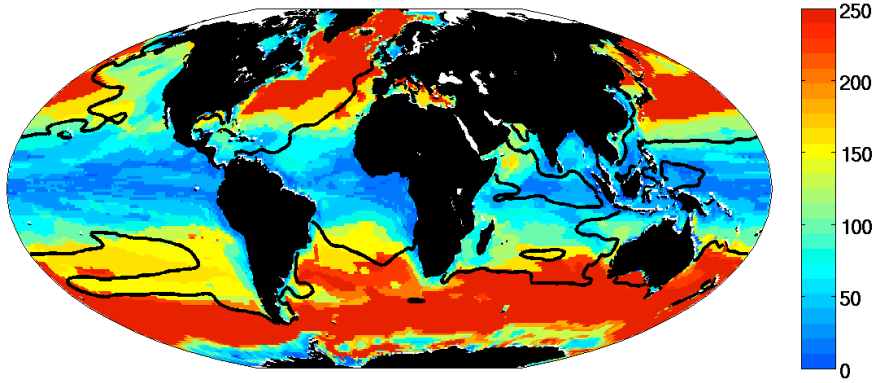
Ecology of *Prochlorococcus* analogs

- *Prochlorococcus* dominate in most stable regions (c.f. Bouman et al., 2006)

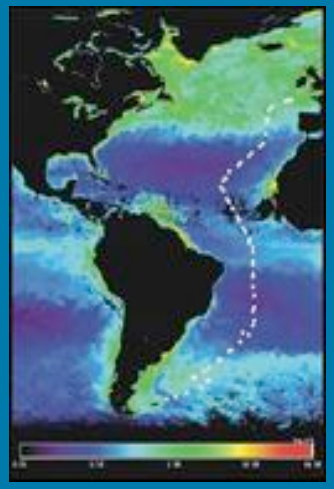
Prochlorococcus biomass (mmol P/m3): annual 0-50m average

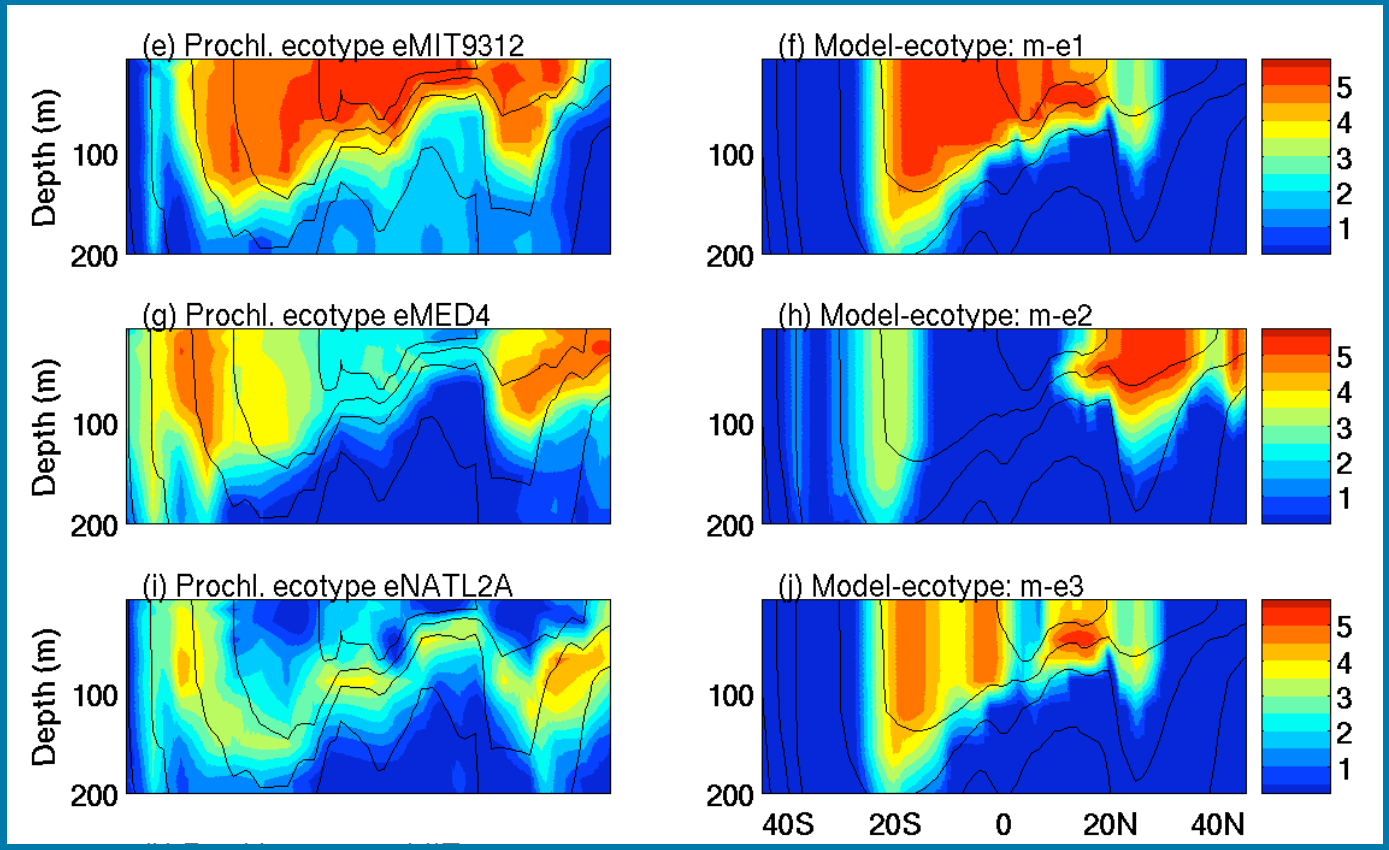


Annual range of mixed-layer depth (m)



Plausible analogs of *Prochlorococcus* on AMT13 track





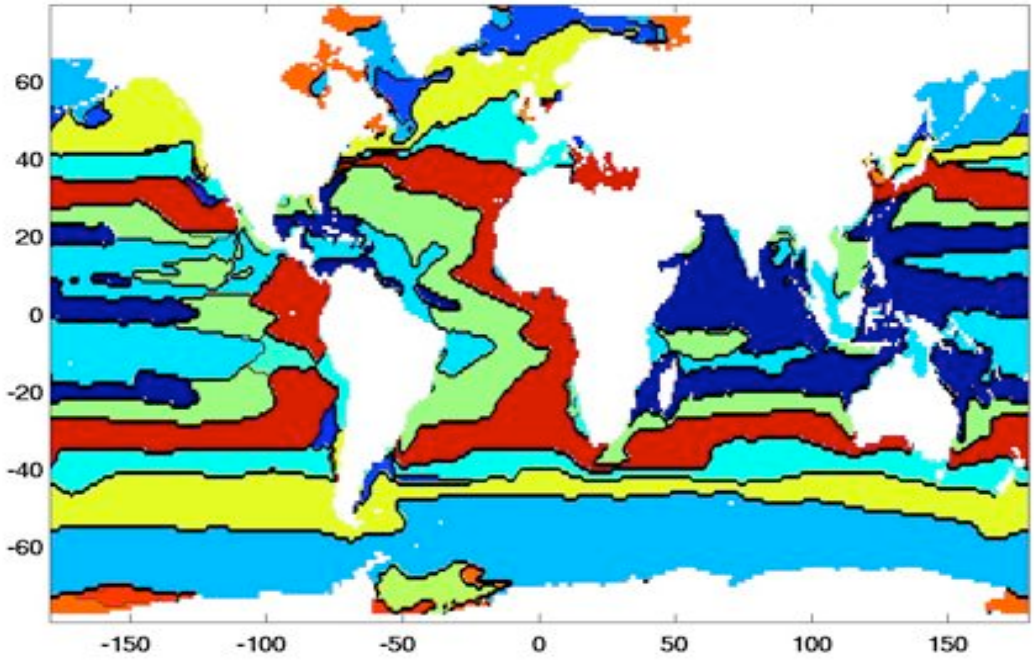
***Prochlorococcus* ecotypes**
AMT13 (Johnson et al., 2006)

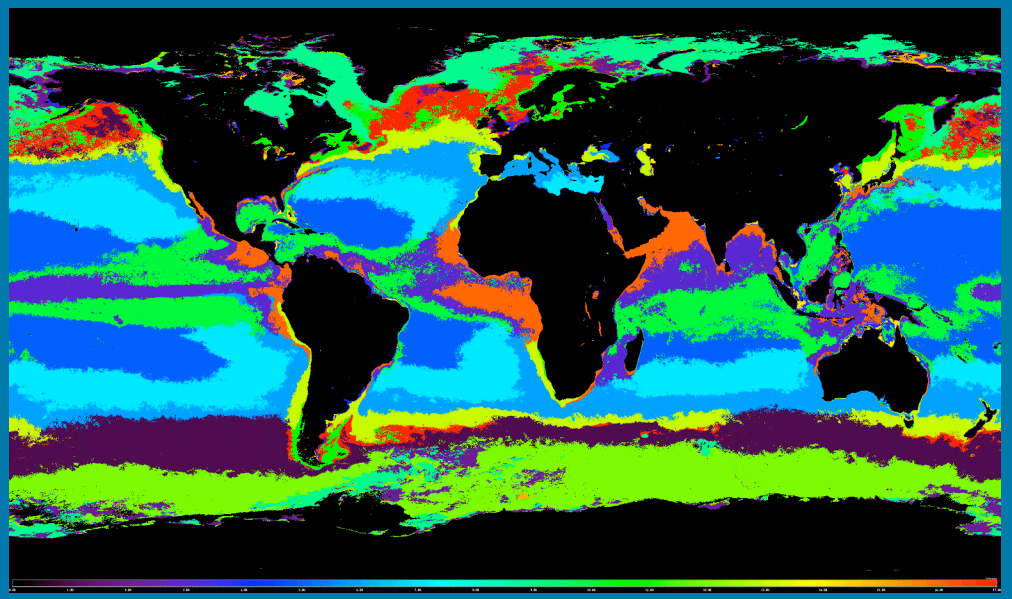
model-ecotypes

Model-ecotypes consistent with observed counterparts in habitat, corresponding physiology, and abundance ranking.

Follows et al., *Science* (2007)

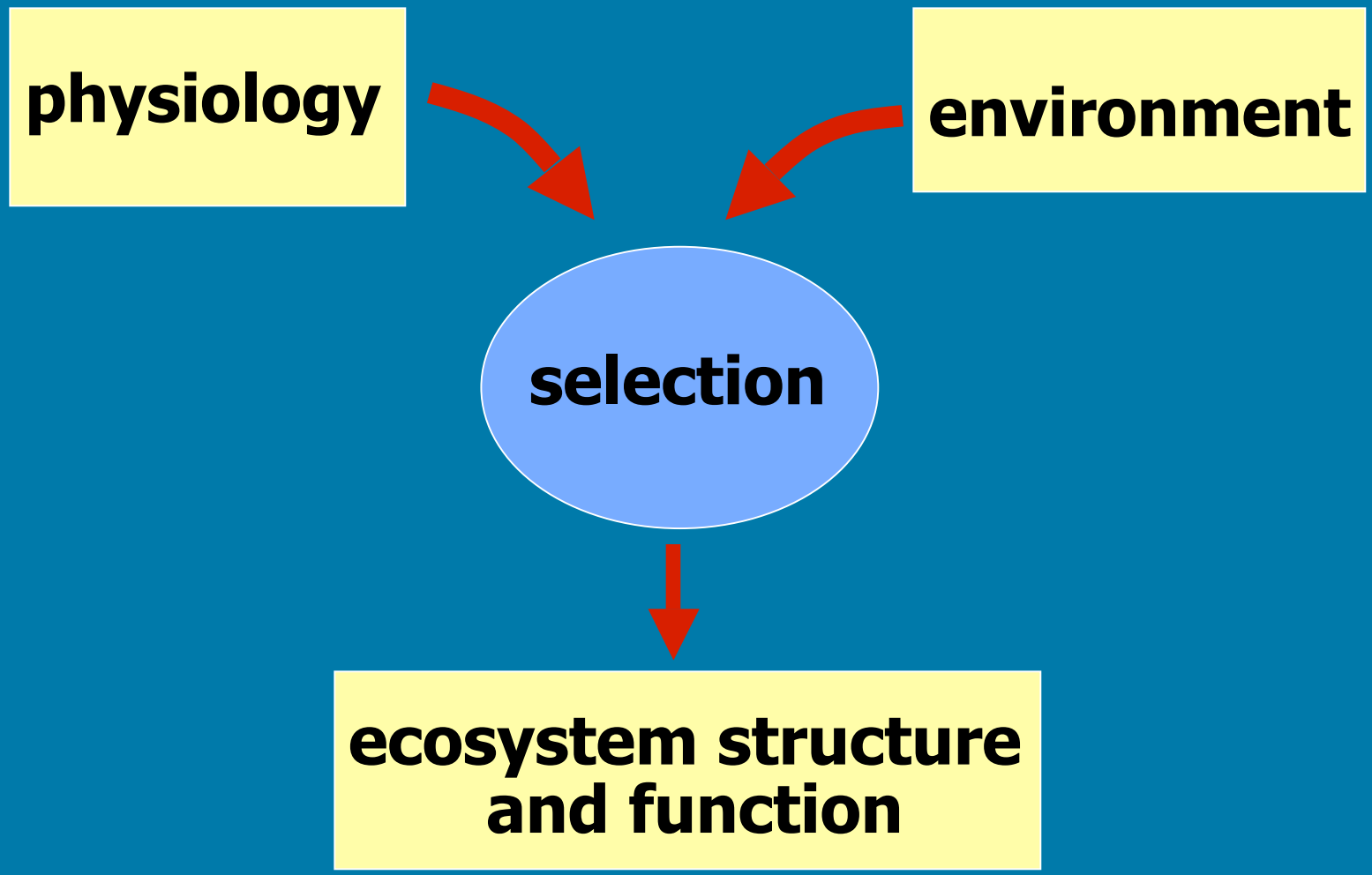
Model “provinces” - mapped by locally most abundant phytoplankton type





Matt Oliver *et al:* Provinces determined from SST and radiance

c.f. Mark Dowell *et al*


physiology
environment
selection
ecosystem structure
and function

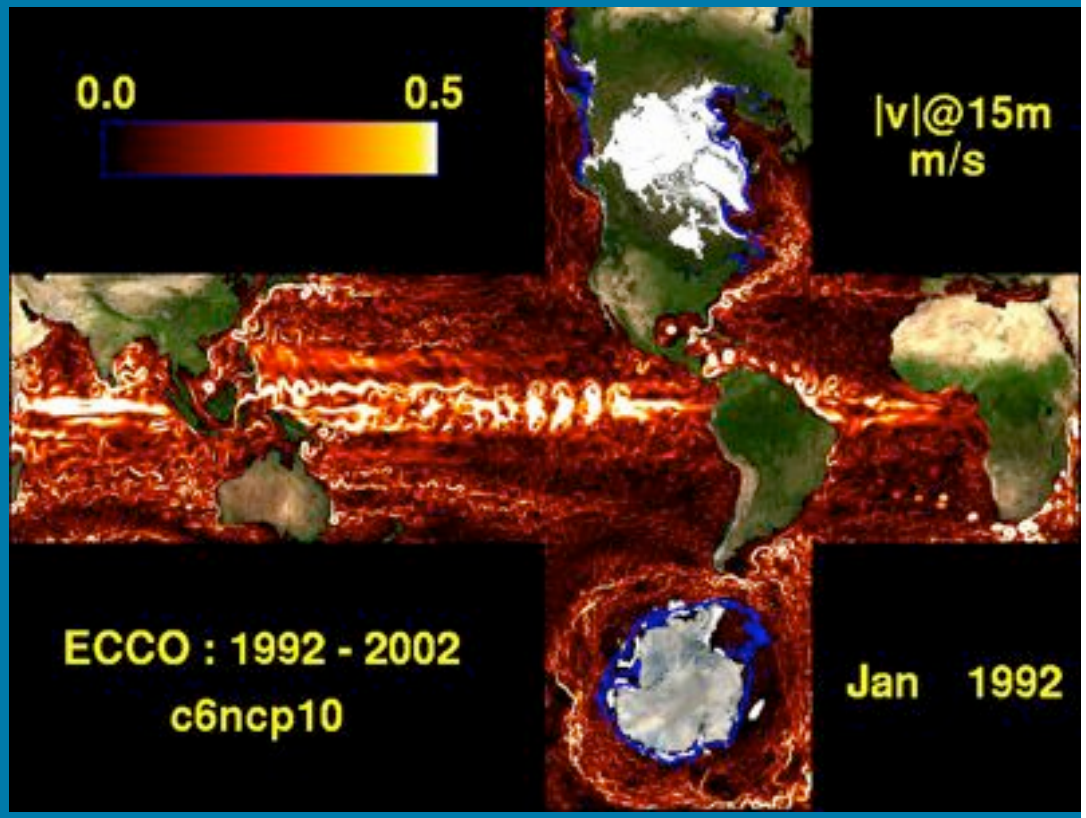
Physiology

- Generalized allometry
  - Resolve several size classes
  - Laws (1975), Irwin et al (2006), Armstrong (1999)
- Implications for radiative transfer
  - Explicit regulation of spectrum by community size structure
  - Ciotti et al (2002), Finkel (2001)

Environment

- Effect of highly variable environment on
  - Diversity?
  - Community structure?

ECCO2 model
Chris Hill, Dimitris Menemenlis



SUMMARY

- Self-organizing description of marine ecosystem
  - explicit selection according to relative fitness
  - dynamic representation of diversity, community structure
  - focus on physiology/environment, not parameter tuning

- *Prochlorococcus* data provide unique test and application
  - suitable to address genomic observations

- Next steps
  - generalized allometric approach
  - higher resolution environment (ECCO2)
  - …

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