Modeling ocean variability and biogeochemical cycles

NCAR Team

Bill Large, Gohkan Danabasoglu,
Nancy Norton, Keith Lindsay, & Matthew Long

CESM Ocean Model Working Group Meeting

14 December 2011

Decadal and regional climate prediction using Earth System Models (EaSM)

MOBY: Modeling Ocean Variability and Biogeochemical Cycles

- Goals:
  1. Use a multi-scale modeling approach to examine meso- and submesoscale dynamics in key regions of climate variability;
  2. Include biogeochemical models to study the interaction of ecosystems with mesoscale turbulence in the context of climate change;
  3. Quantify the rectified effects of mesoscale physical, chemical, and biological interactions and develop parameterization strategies to improve coarse resolution models.

- Broader impacts:
  The proposed research is key to our understanding and modeling the ocean and life within it, the evolution of life within the ocean over earth history, the global cycle of carbon and nutrients, the conservation and exploitation of the ocean's natural resources, management of fisheries, geoengineering. . . and ocean acidification, among many other grand challenges.

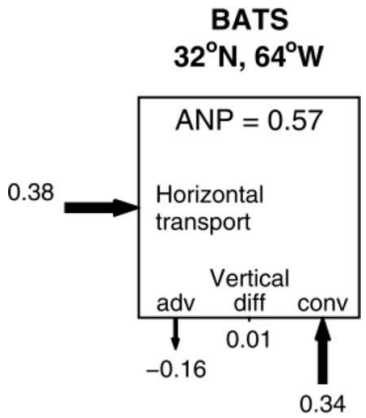
Model resolution impacts nutrient budgets. Community composition?

Nitrate budget [mol N m−2 yr^{-1}]

Model resolution

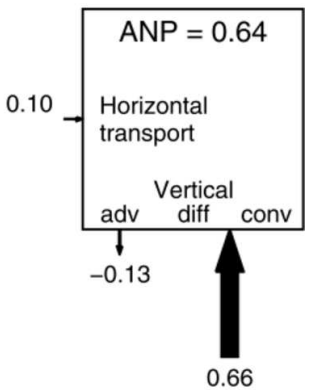
2.0°

Fasham et al. (1993)



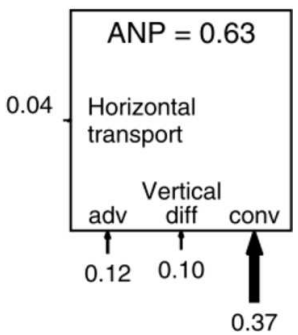
0.33-0.4°

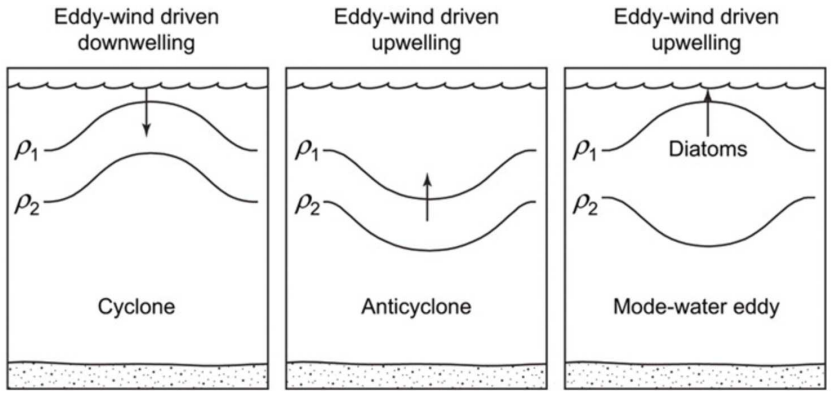
Oschlies et al. (2000)



0.1°

McGillicuddy et al. (2003)





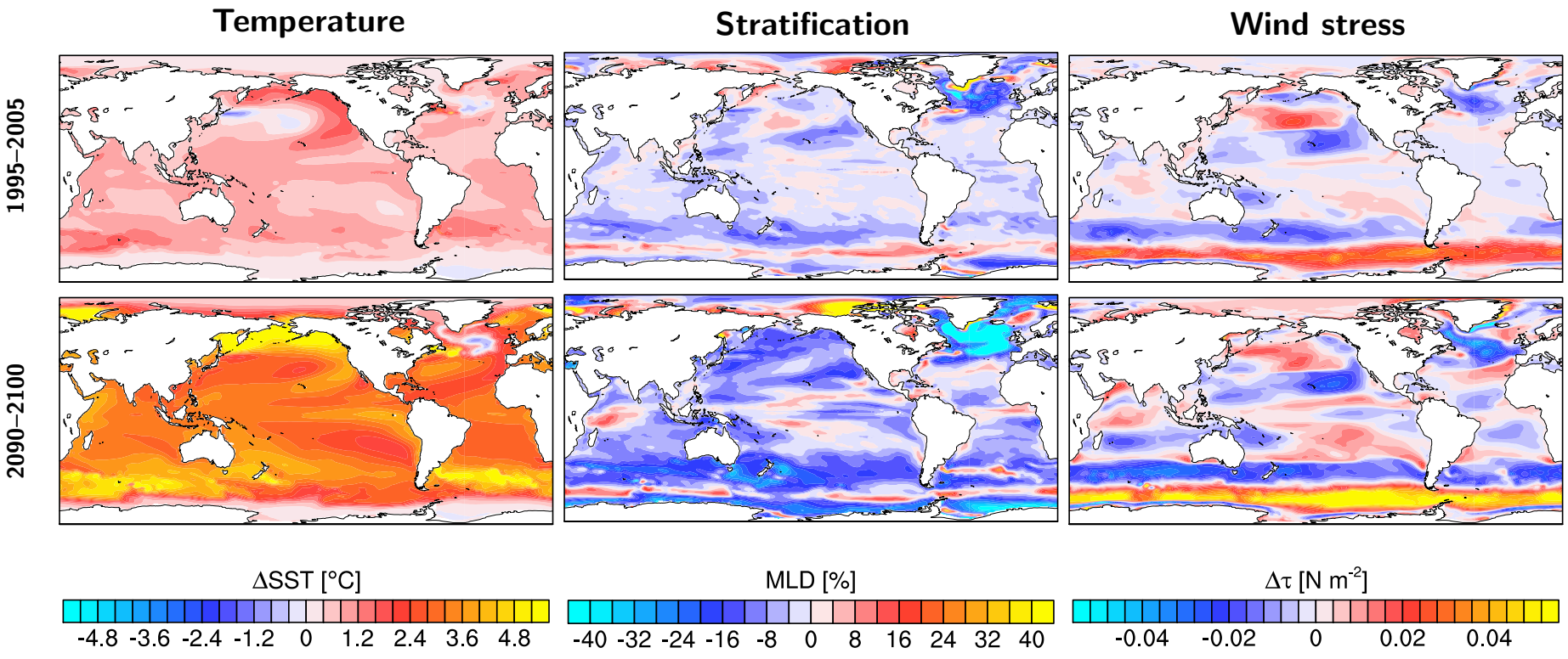
- Three models, similar predictions of annual new production (ANP);
- Coarse resolution: nitrate supply via horizontal advection
  (z-level mixing in Fasham et al. 1993);
- Eddy-driven vertical fluxes compensate for mean Ekman downwelling in 0.1° model.

McGillicuddy et al. (2003, 2007)

Climate change and the pelagic habitat

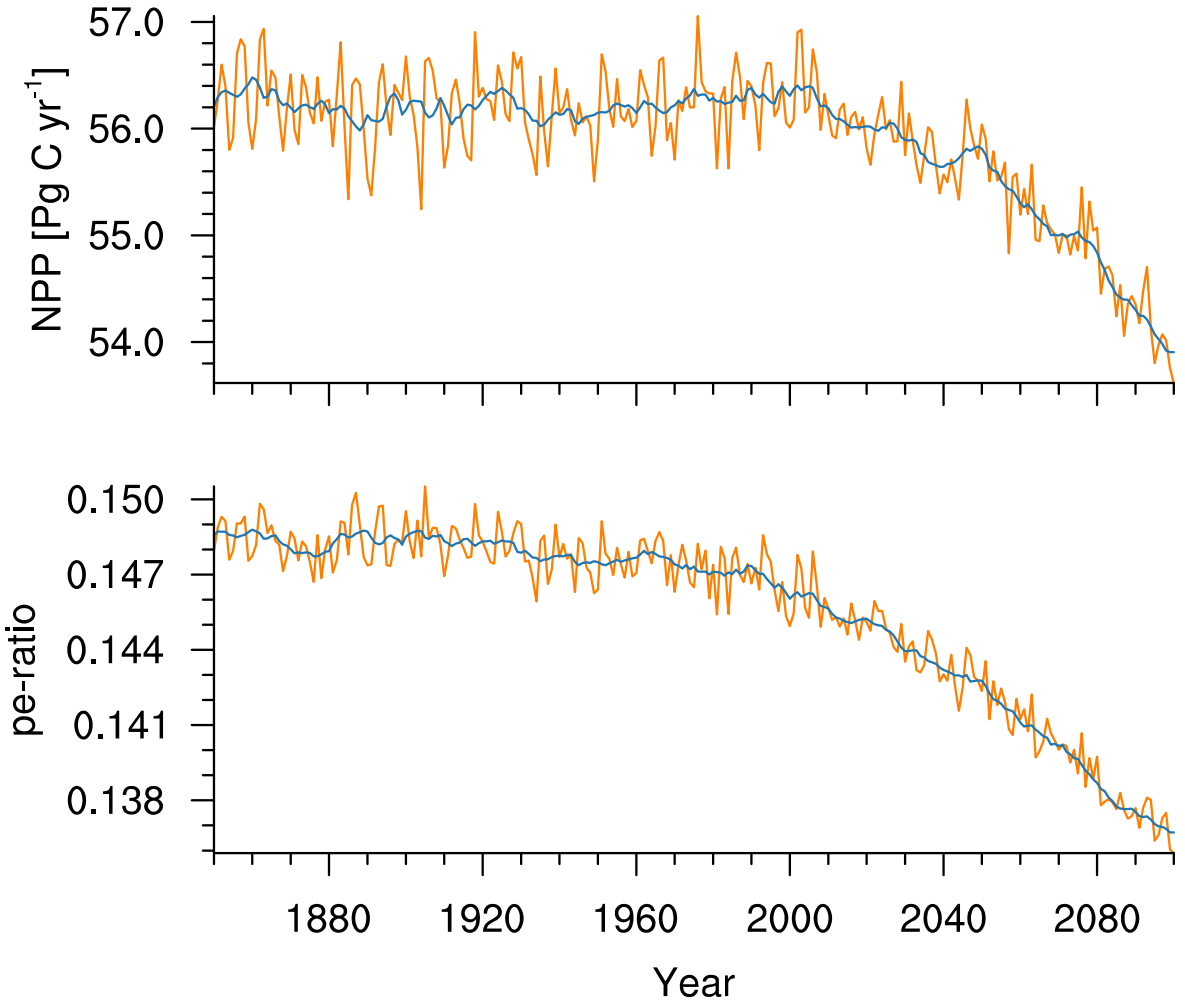
CESM1 results: change relative to 1850 control

20th Century and RCP8.5



Climate change drives weakening biological pump

Globally integrated NPP and export ratio

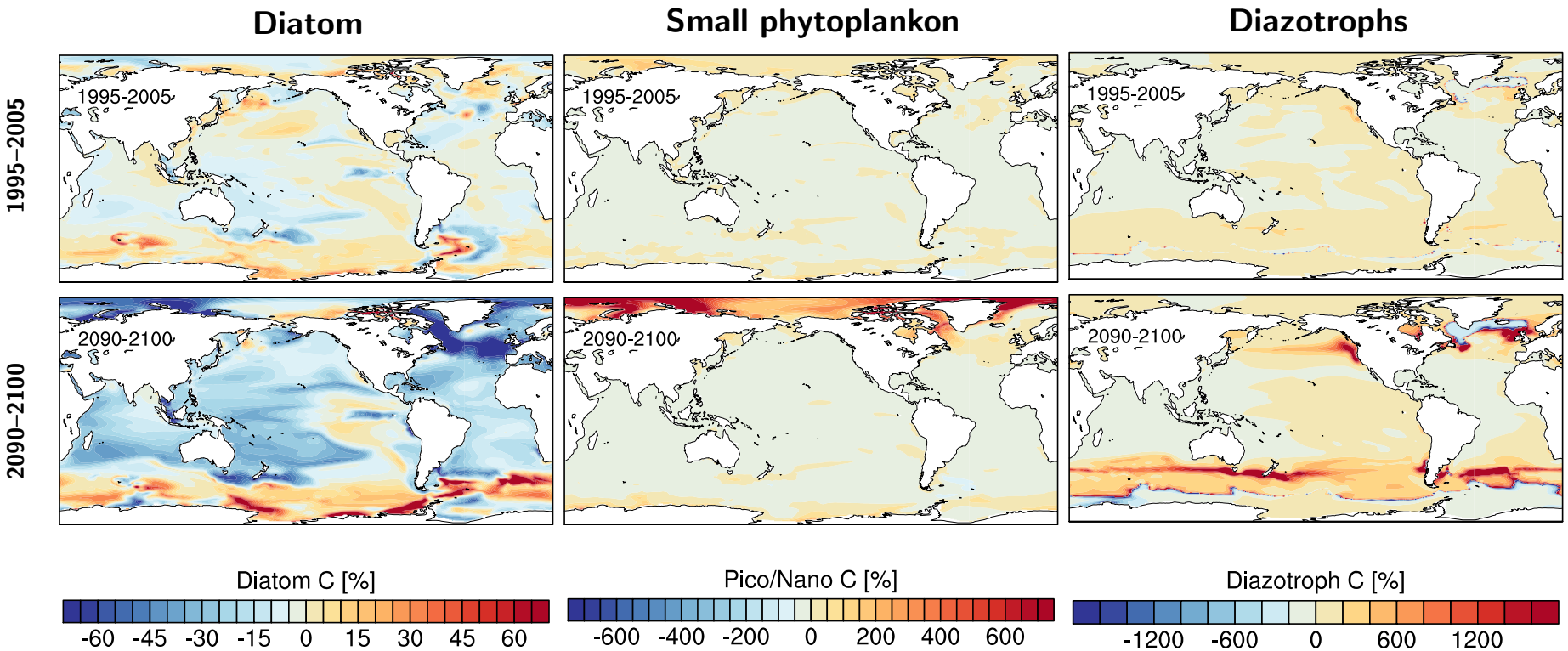


- Less organic C is available to export;
- Less of the available organic C is exported.

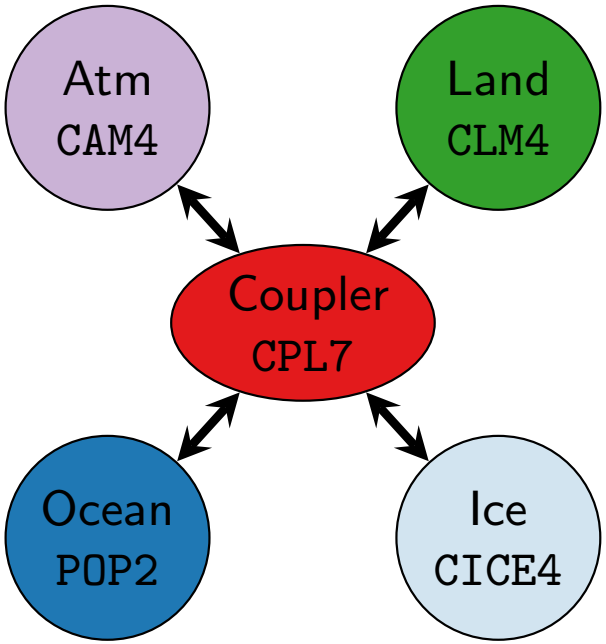
Shifts in community composition

CESM1 results: change relative to 1850 control

20th Century and RCP8.5

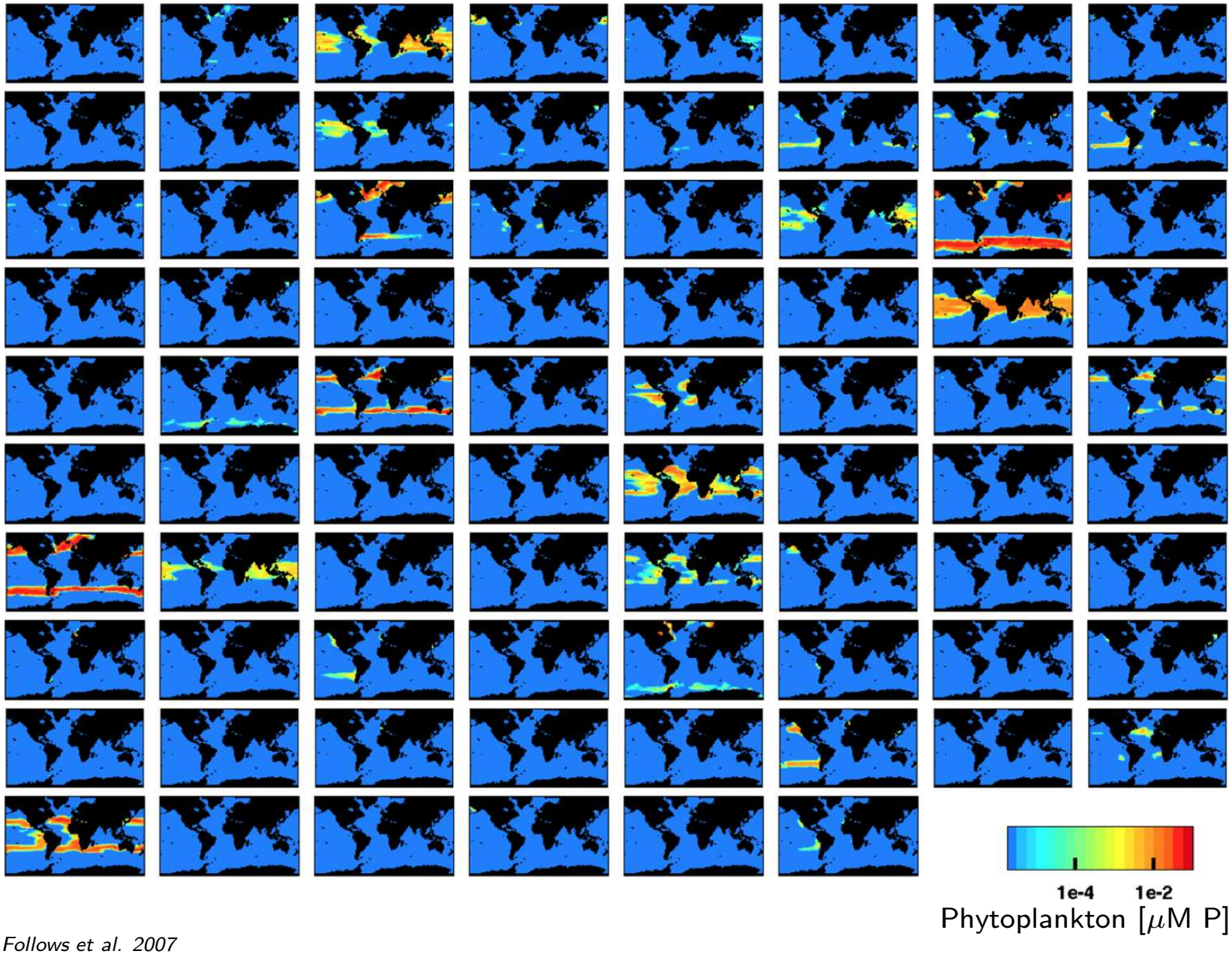


Community Earth System Model



- Energy and mass conserving;
- Internal climate variability;
- External perturbations (i.e. CO_2 emissions).

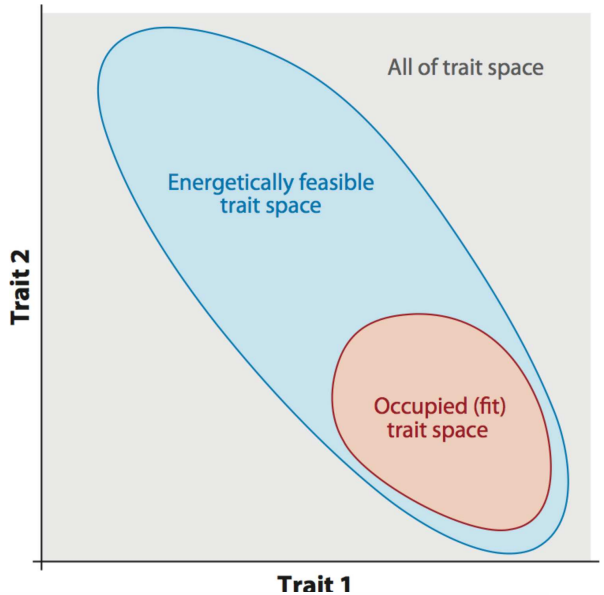
Darwin: Universal distribution, local selection



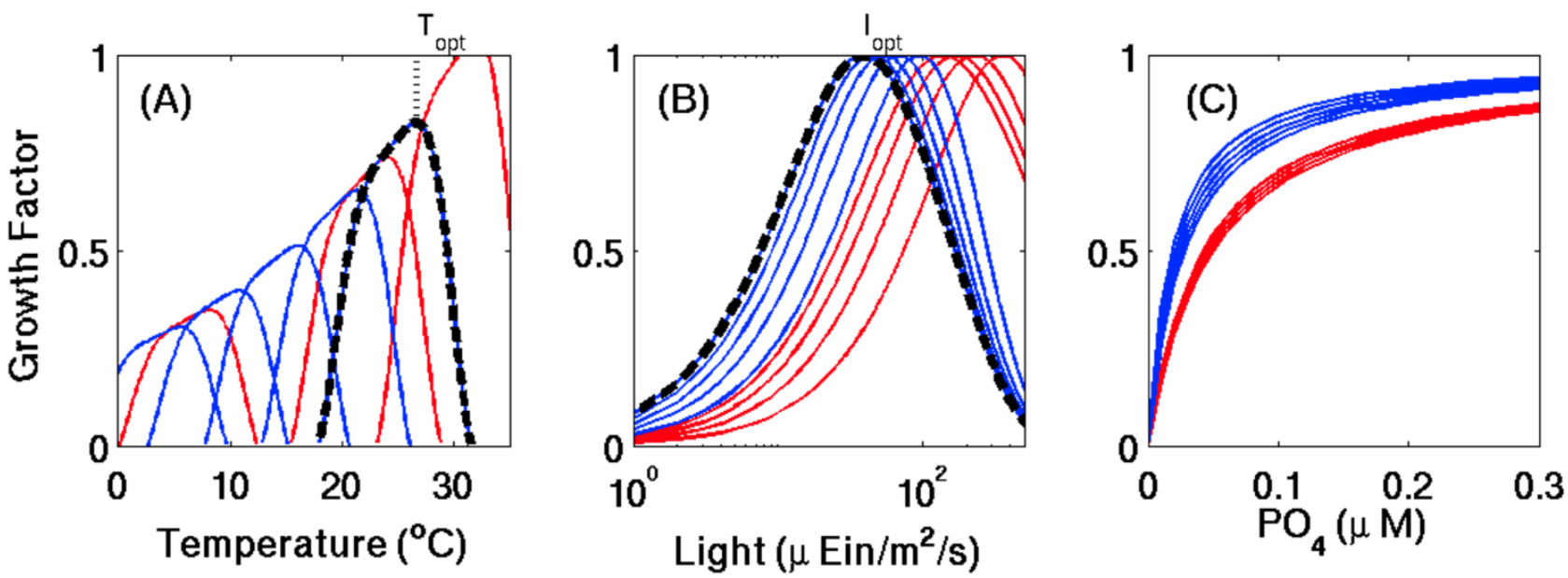
Follows et al. 2007

Darwin: span trait space, respect physiological trade-offs

Energetic trade-offs constrain physiology→
environment selects

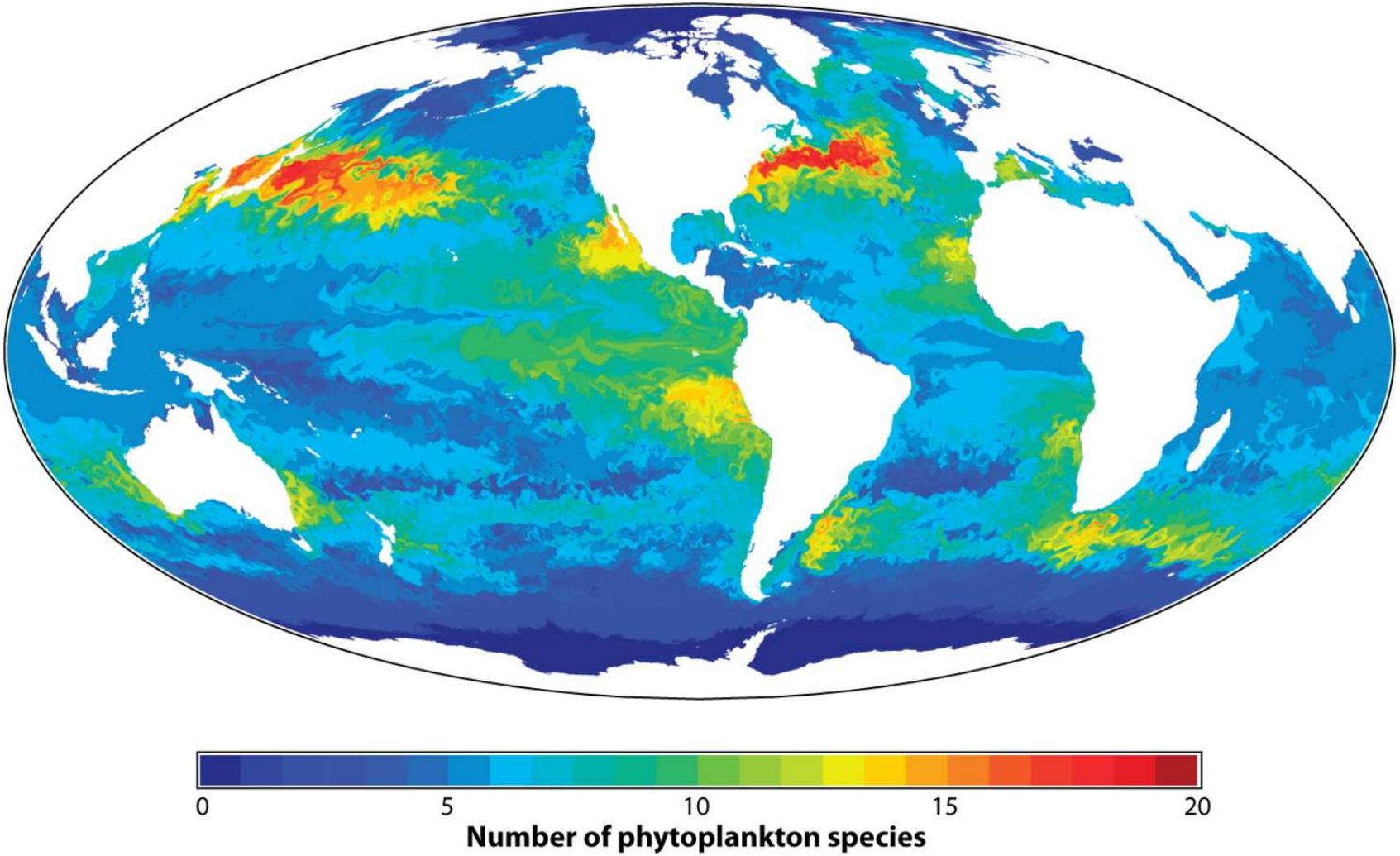


Transfer functions define species array



Follows et al. 2007, Follows & Dutkiewicz 2011

Energetic circulation: high species richness



Follows & Dutkiewicz 2011

MOBY :: CESM-Darwin

Research questions

1. How does resolution affect ecosystem dynamics and biogeochemical fluxes?

2. Do eddy-parameterizations provide adequate representations?

3. How are diversity and ecosystem function interrelated?

4. Which PFTs are most essential to capture climate effects?

CESM POP-Darwin integrations (priority)

Time slice	POP-PE (1°)	POP-NE (1°)	POP-RE (1/10°)
1850	2	?	?
Present-day	1 ?	?	4 ?
2100	3	?	?

n = Coupled, *n* = Ocean-ice

PE = parameterized eddies, NE = no eddies, RE = resolved eddies