OCEAN ACIDIFICATION IMPACTS ON FUTURE PHYTOPLANKTON COMMUNITIES

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Gordon and Betty MOORE FOUNDATION

NSF

META-ANALYSIS OF PHYTOPLANKTON OA EXPERIMENTS

See Poster: Morris et al

- Literature review (49 papers, 154 experiments)
- Comparison between growth at ambient and elevated pCO_2
- Define Growth Rate Response (GRR):

$$GRR = \frac{\text{growth rate at elevated } pCO_2}{\text{growth rate at ambient } pCO_2}$$

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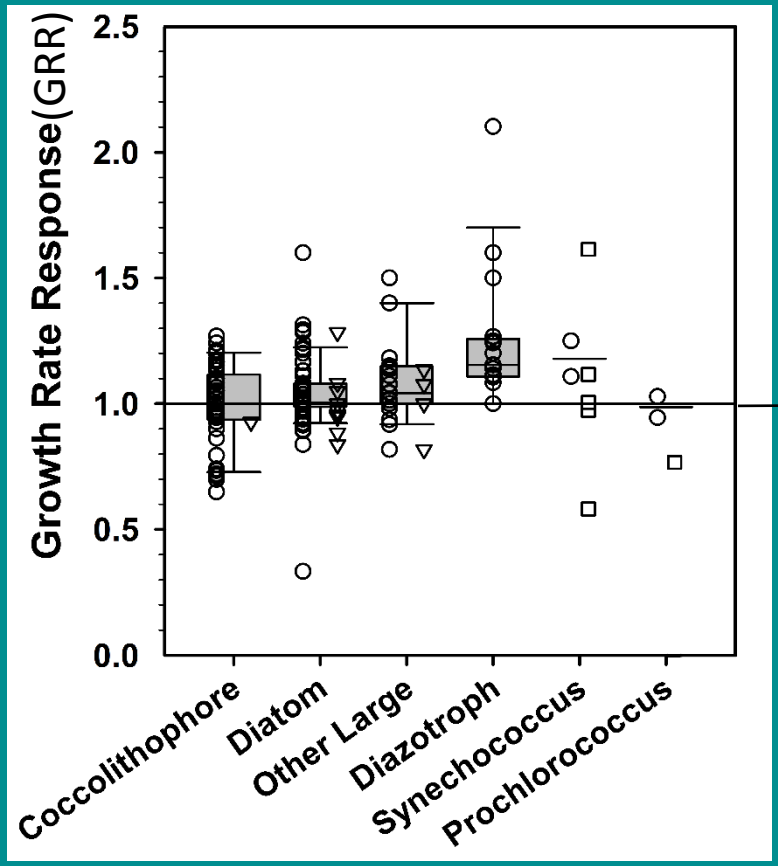

increased growth rate under enhanced CO_2

decreased growth rate under enhanced CO_2

- single species short term exp
- single species long term exp
- shipboard exp

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Dutkiewicz et al., Nature Climate Change, in press

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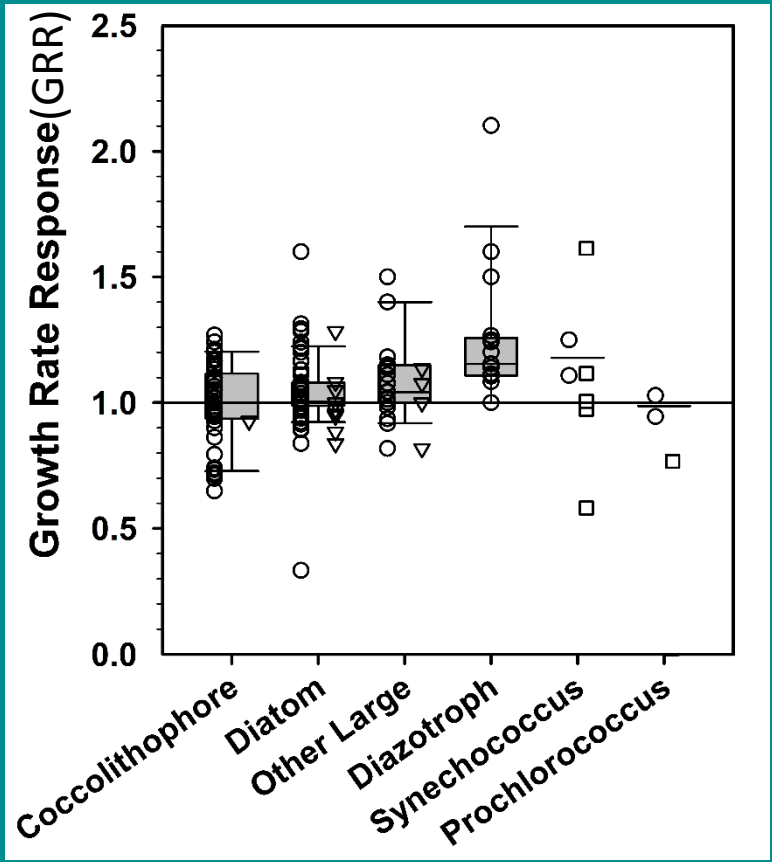


What is implication of this range to phytoplankton communities in the future ocean?

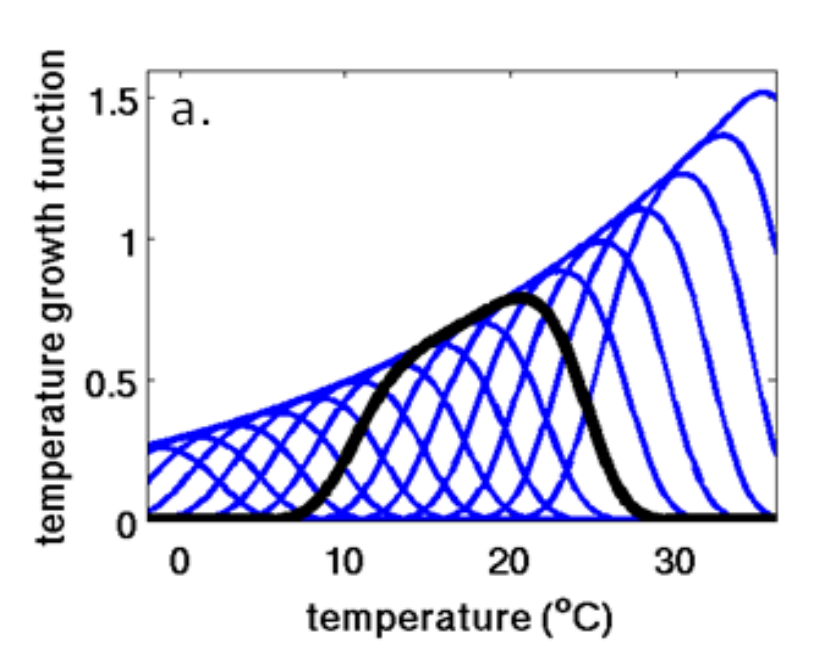
Use an biogeochemical/ecosystem model as a laboratory

Dutkiewicz et al., Nature Climate Change, in press

ECOSYSTEM MODEL LABORATORY DESIGN

- 3-D global ocean model embedded in a earth system model of intermediate complexity
- Ocean biogeochemistry: C, N, P, Si, Fe, Alkalinity; DOM, POM
- Ocean ecosystem: 96 phytoplankton types in 6 functional groups
  (growth is function of I, T, nutrients, pCO_2)
  2 grazers
- 1860 spinup
  1860 – 2100 business as usual emissions scenario

ECOSYSTEM MODEL LABORATORY DESIGN



16 phytoplankton “types” within each functional group, each with different temperature optimum

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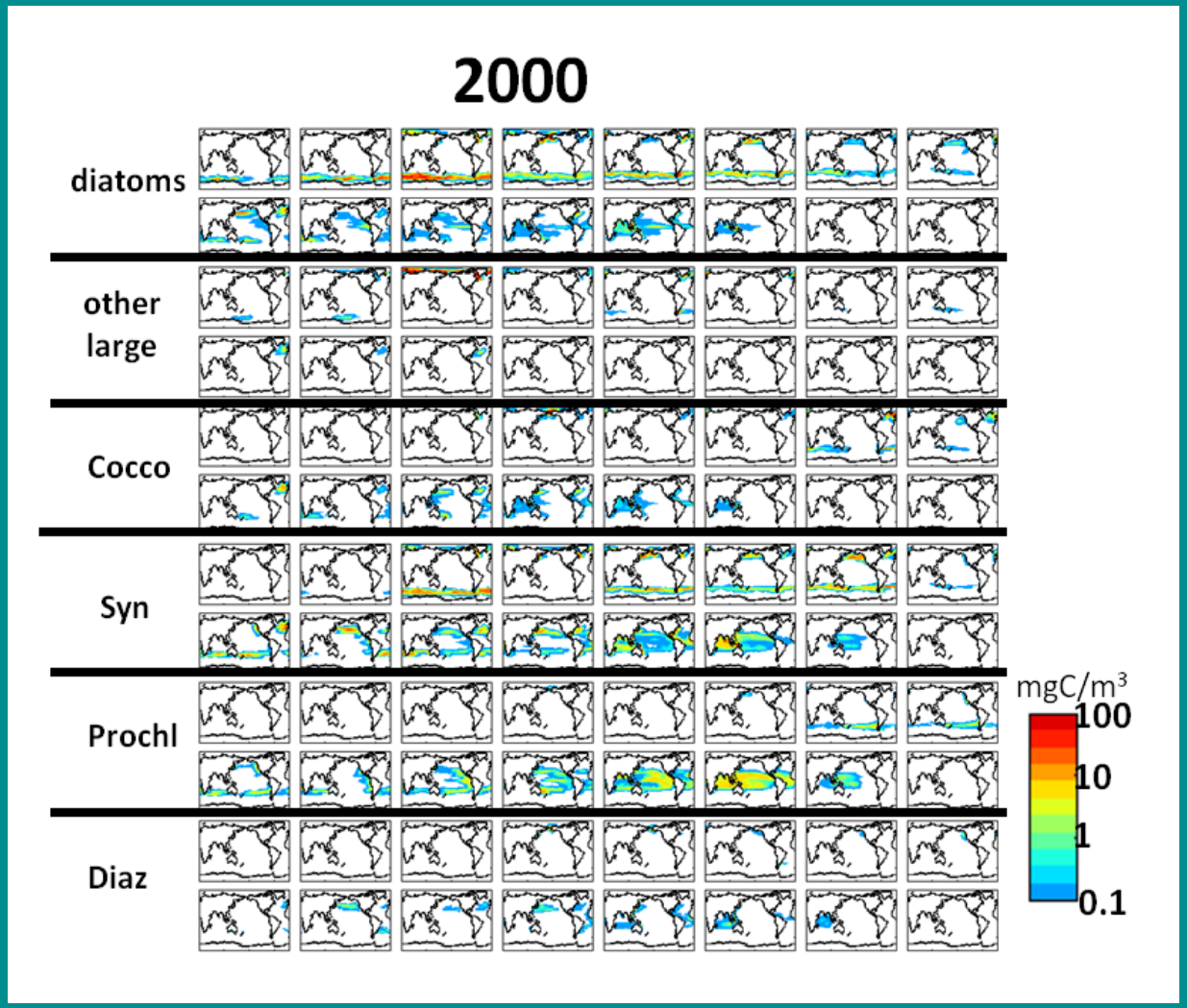
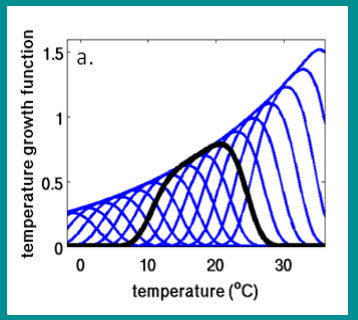


phytoplankton “types” arranged in order of temperature optimum



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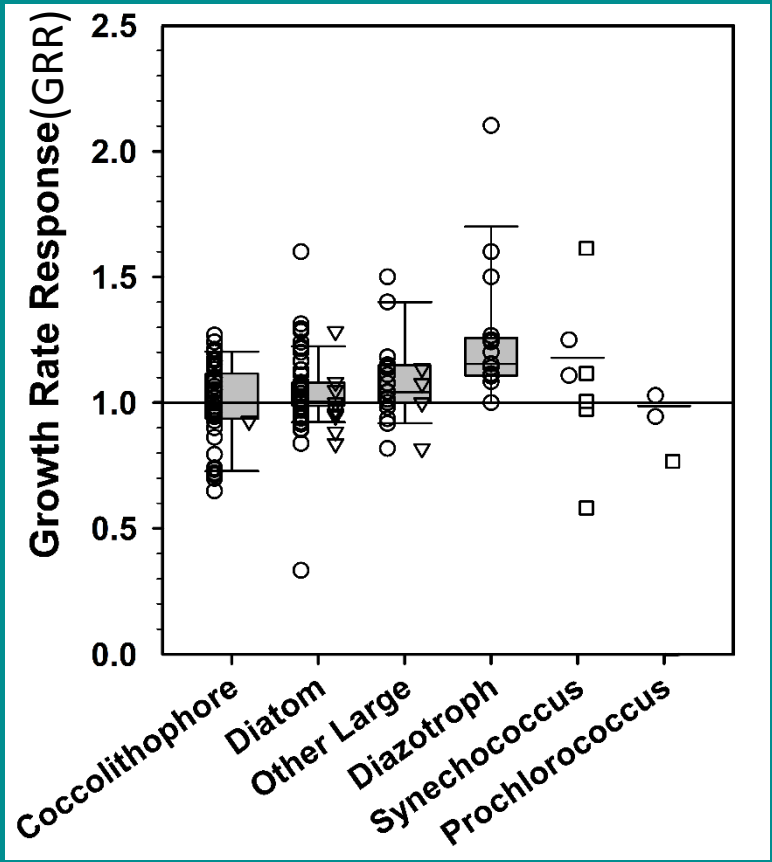

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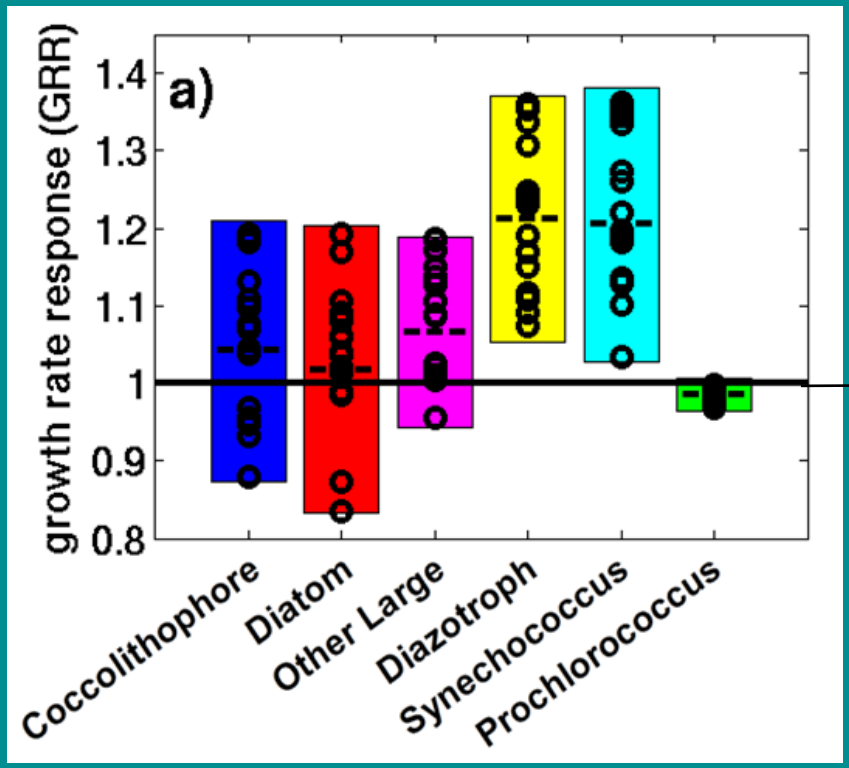

increased growth rate under enhanced CO_2

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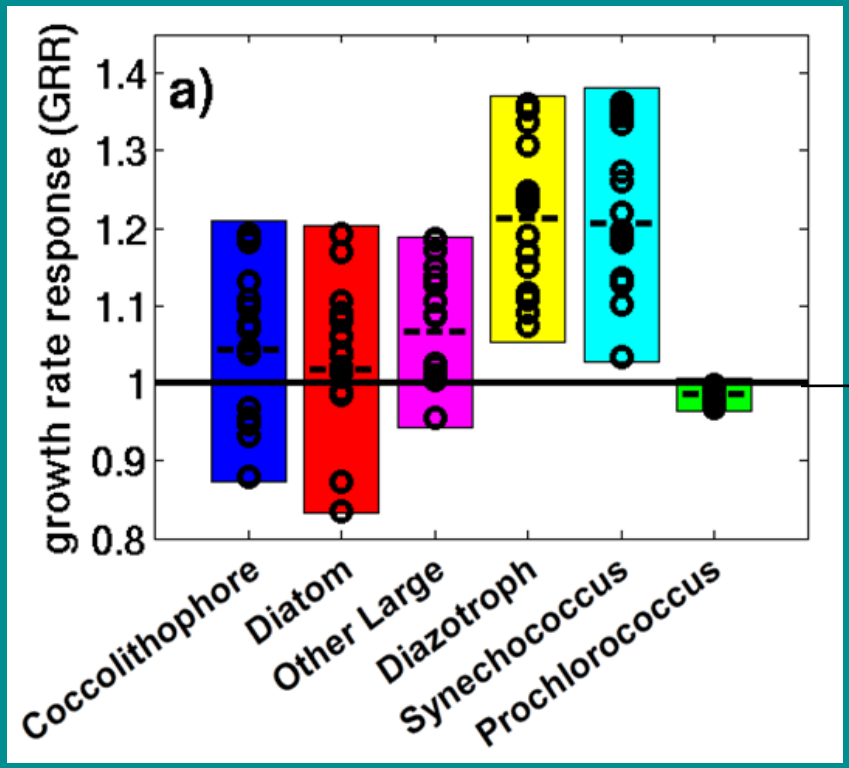

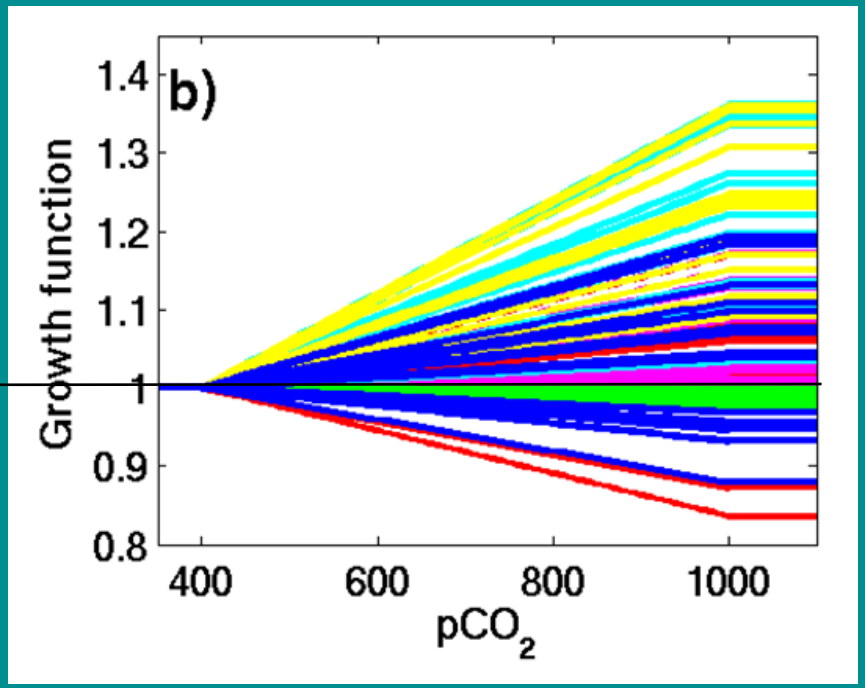

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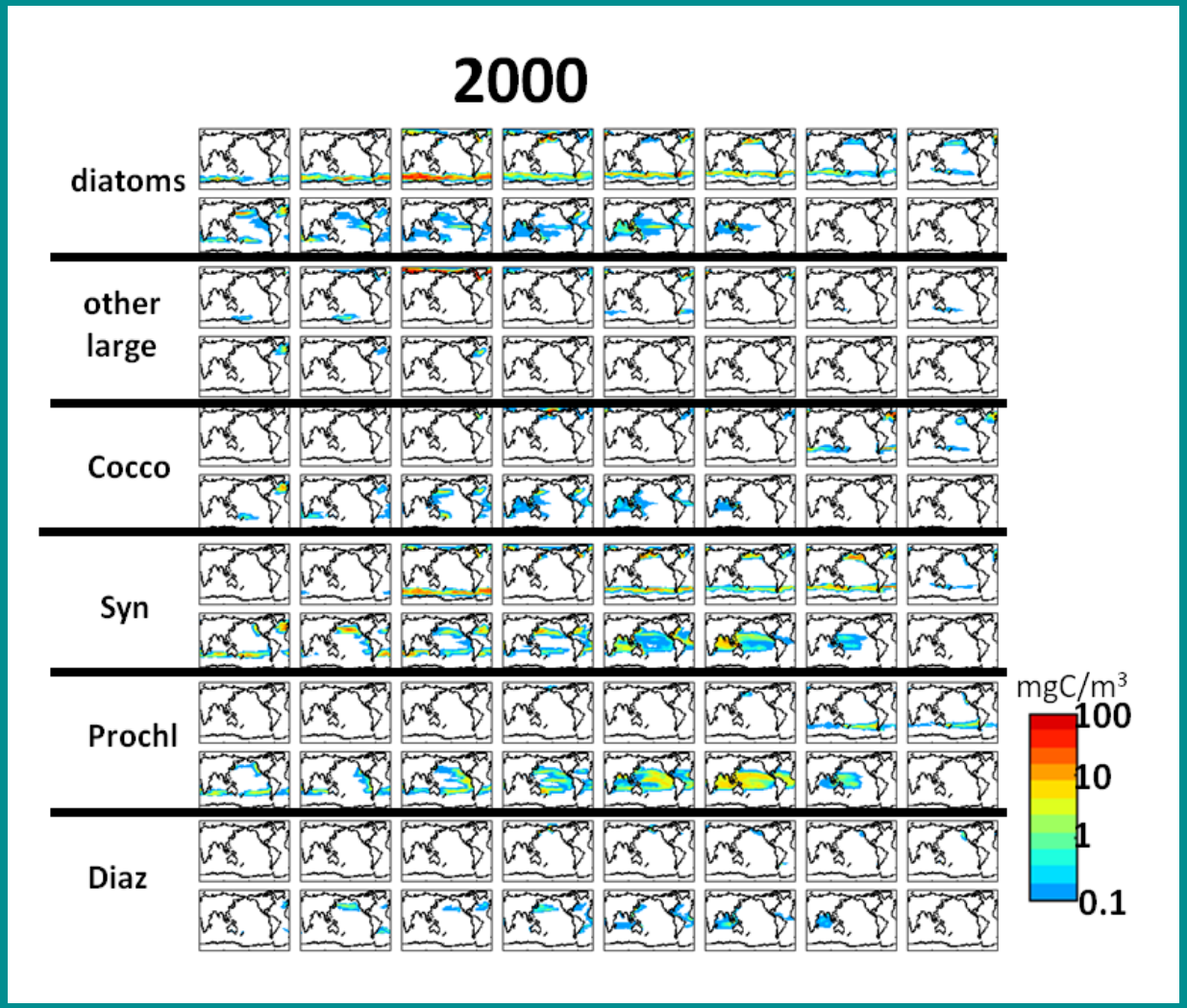

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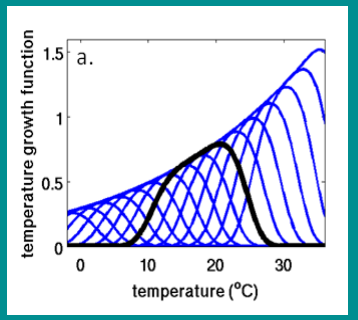
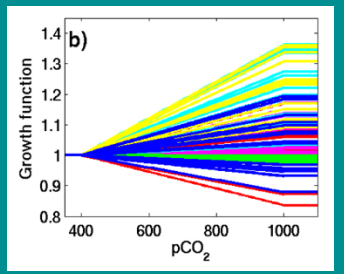


each "type" has random assignment of growth rate response to elevated pCO_2 (GRR)



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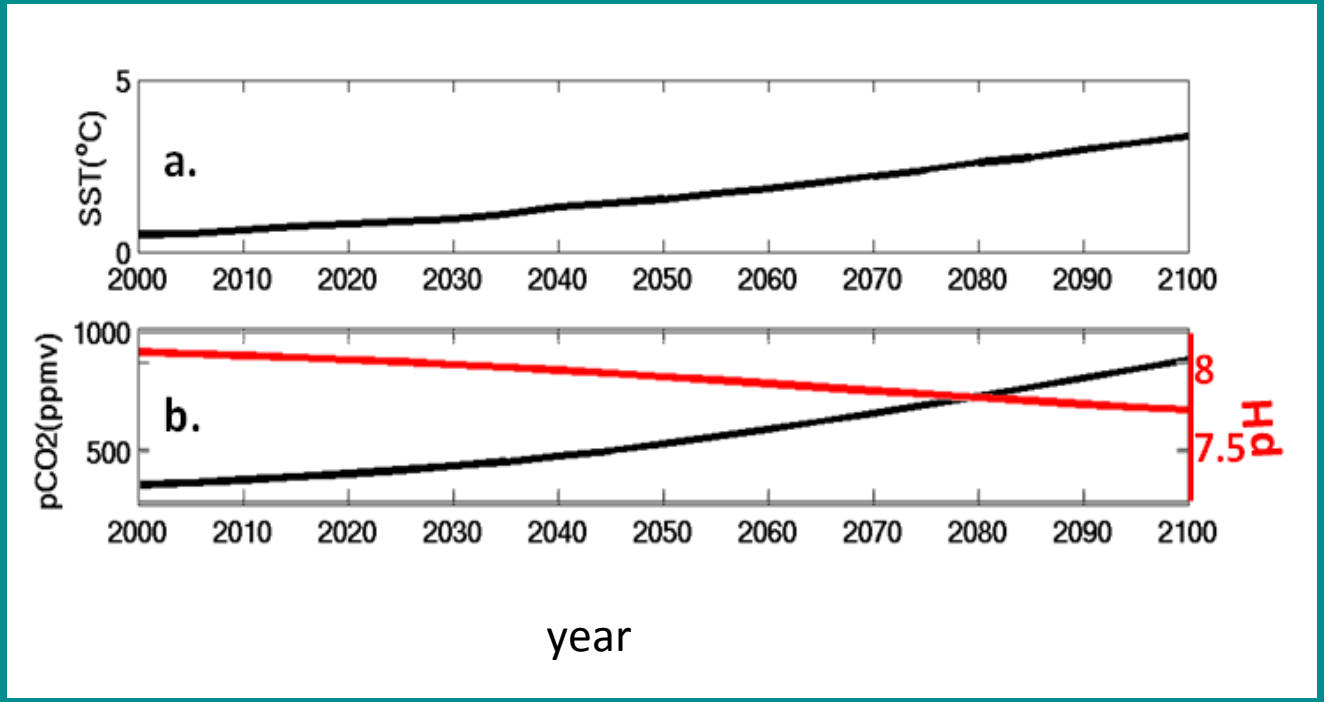
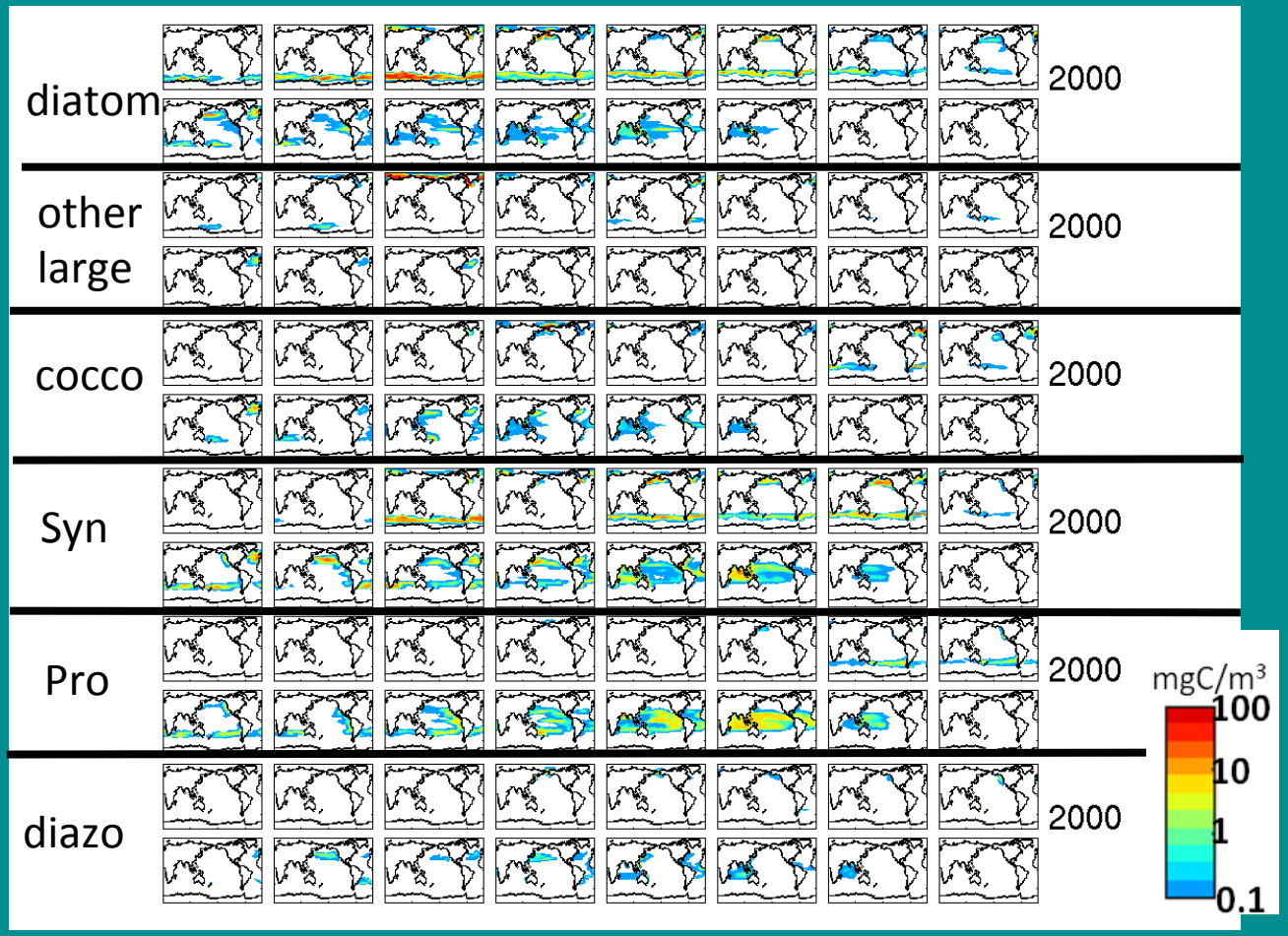


Business as Usual emissions scenario
(similar to RCP8.5)

ECOSYSTEM MODEL LABORATORY RESULTS



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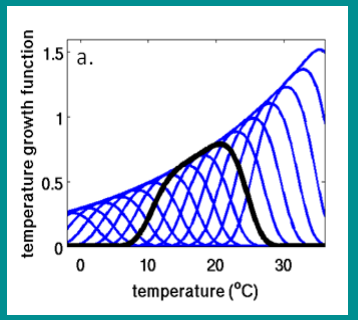

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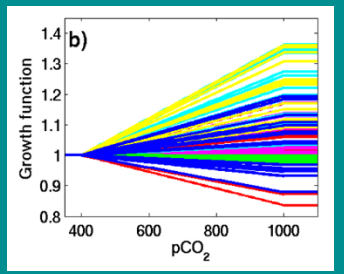

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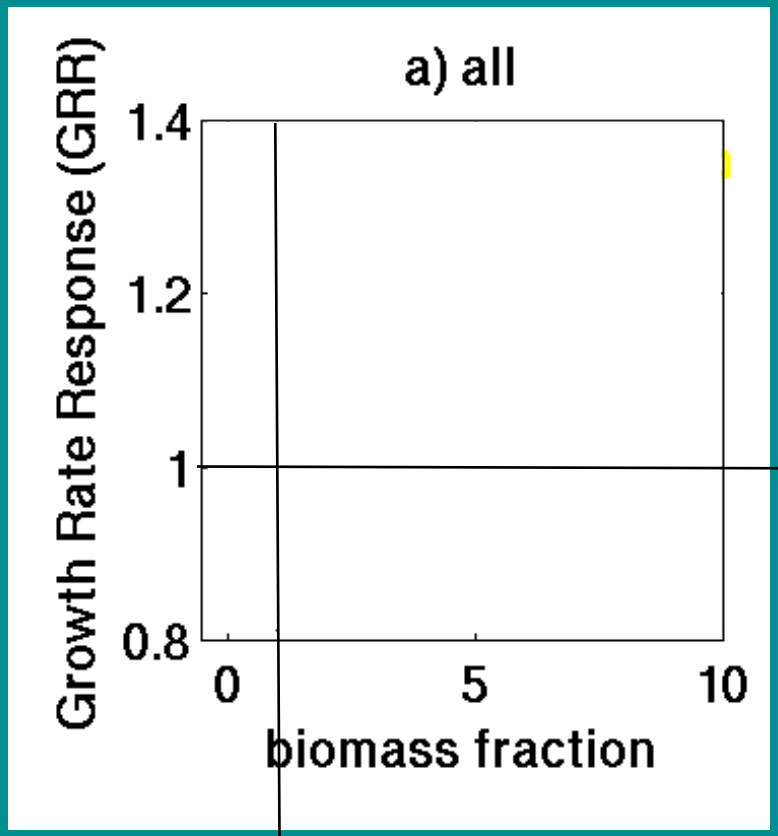


$$GRR = \frac{\text{growth rate at elevated } pCO_2}{\text{growth rate at ambient } pCO_2}$$

increased growth rate under enhanced CO_2

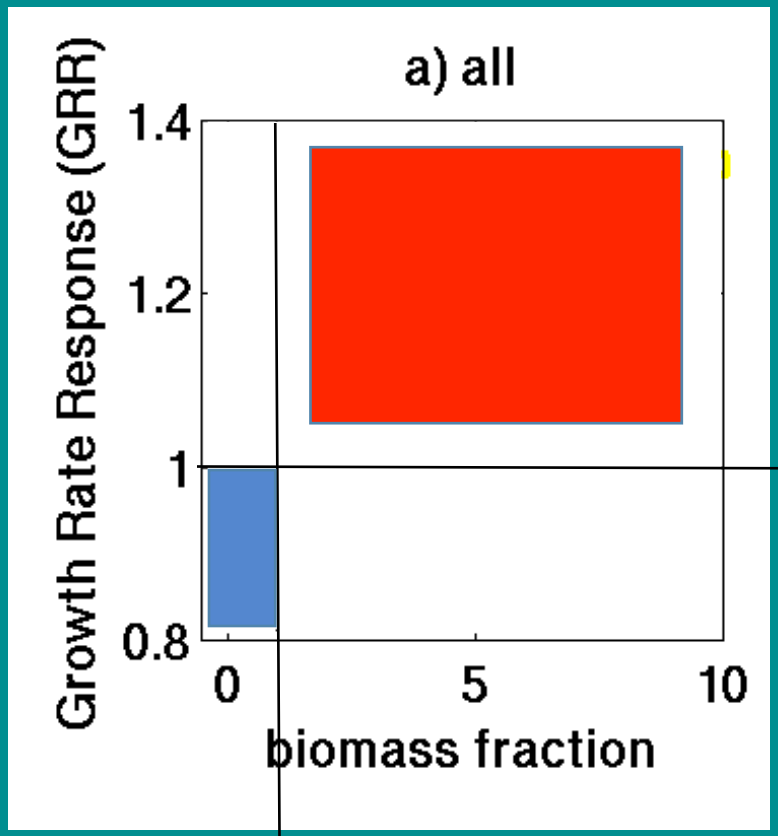
decreased growth rate under enhanced CO_2

decreased biomass

increased biomass by 2100

$$\text{biomass fraction} = \frac{\text{integrated biomass at 2100}}{\text{Integrated biomass at 2000}}$$

ECOSYSTEM MODEL LABORATORY RESULTS



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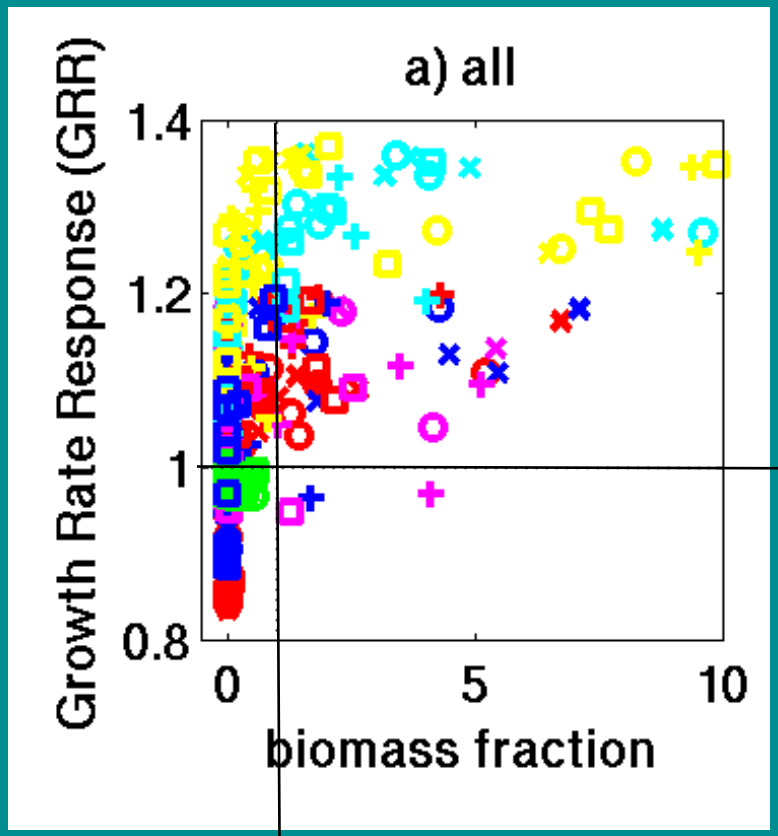

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increased growth rate under enhanced CO_2

decreased growth rate under enhanced CO_2

diatom
other large
coccolithophores
Synecochoccus
Prochlorococcus
diazotrophs

decreased biomass

increased biomass by 2100

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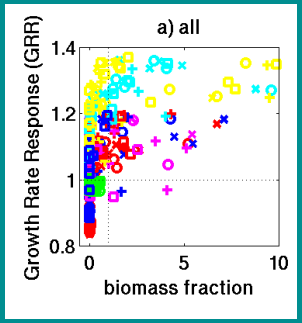
SUMMARY

- Response relative to competitor matters: range in response to enhanced pCO_2 leads to significant rearrangement of communities



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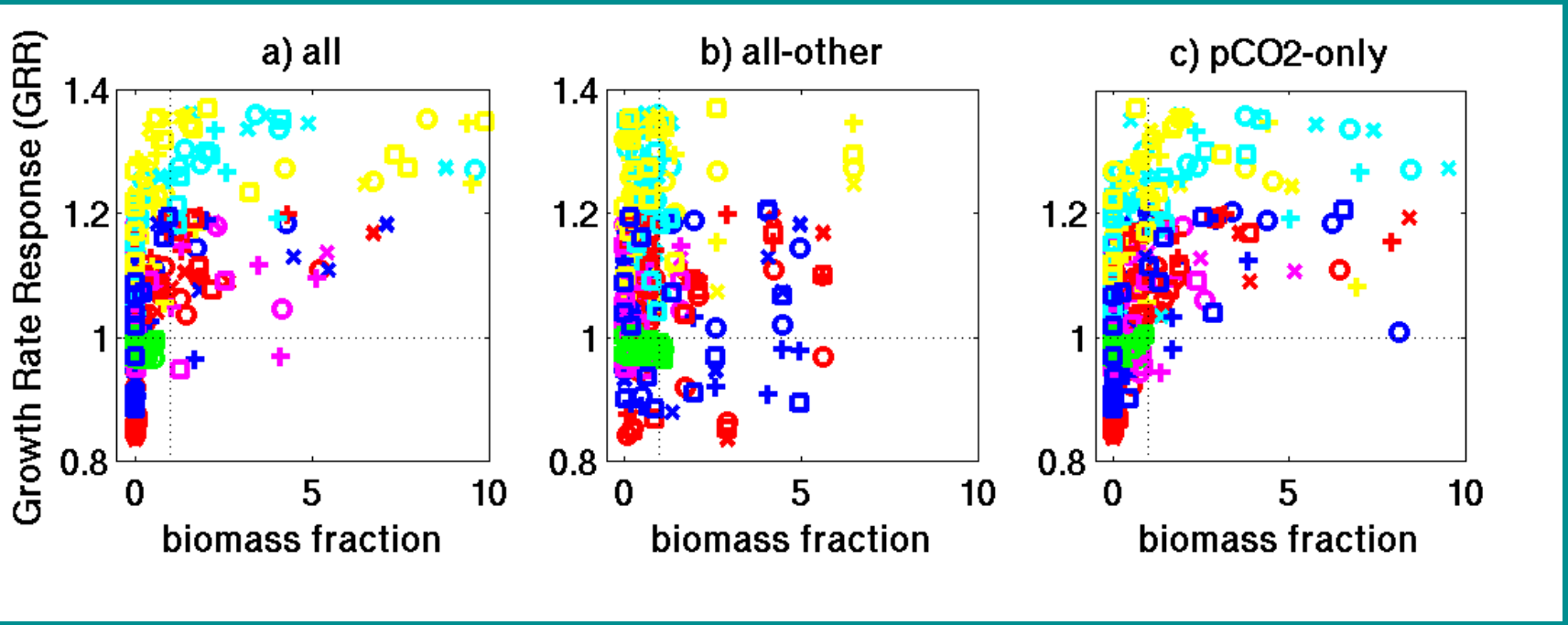
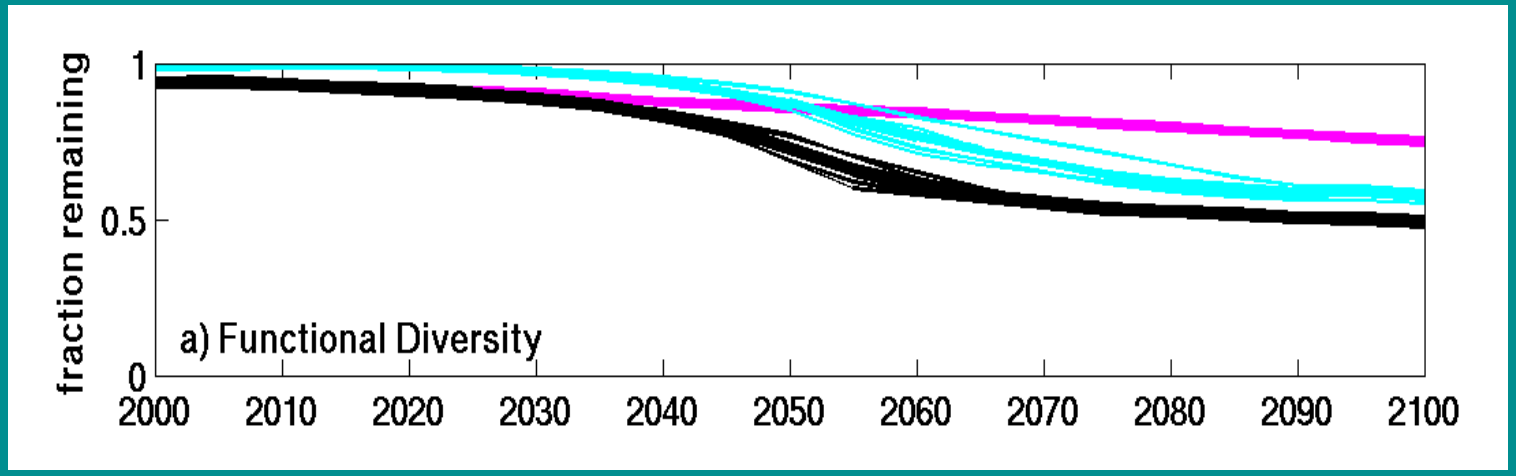


physical changes only (temperature, circulation, seaice); pCO_2 kept at 1860

pCO_2 changes only; temperature, circulation, seaice kept at 1860

ECOSYSTEM MODEL LABORATORY RESULTS

Relative to pre-industrial



year

all stressors **pCO_2 changes only** **physical changes only**

functional composition $C_{fr}(t) = \sum_k^K \min\left(\frac{F_k(t)}{\sum_k^K F_k(t_o)}, \frac{F_k(t_o)}{\sum_k^K F_k(t_o)}\right)$

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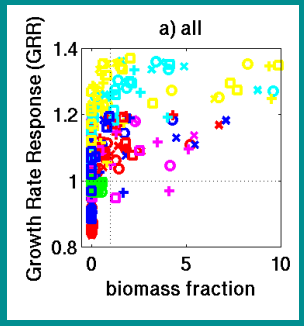

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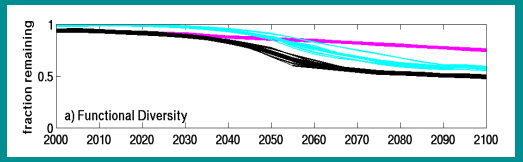

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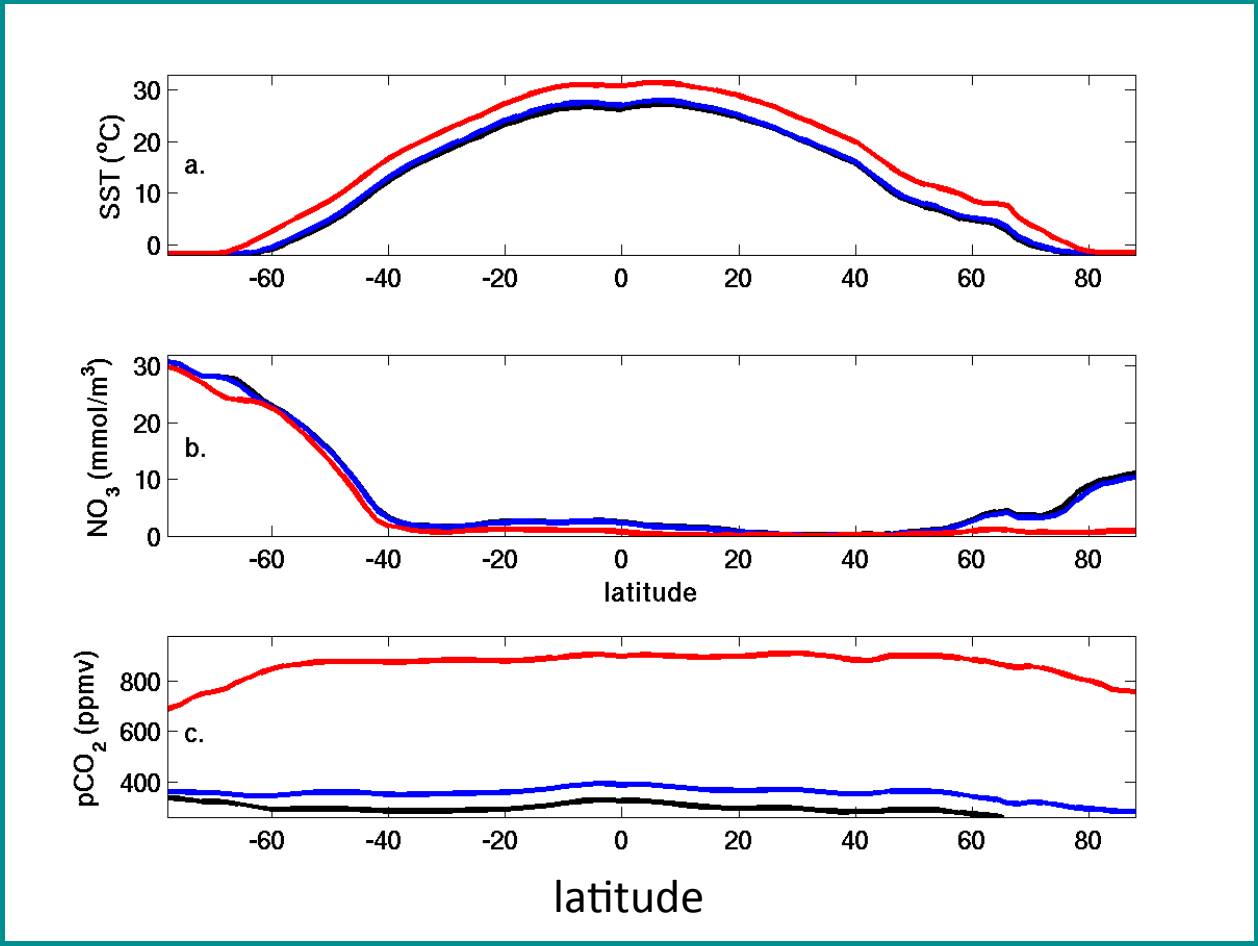


2100

2000

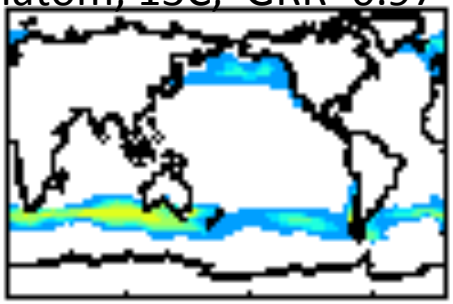
1860

Dutkiewicz et al., Nature Climate Change, in press

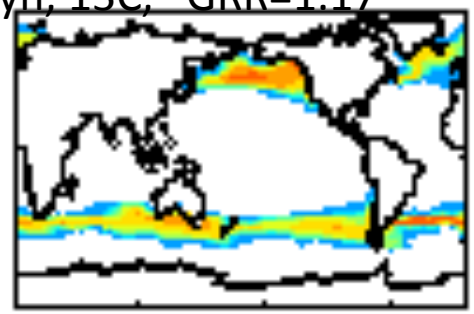
ECOSYSTEM MODEL LABORATORY RESULTS

2000

Diatom, 13C, GRR=0.97



Syn, 13C, GRR=1.17



2100

pCO_2 (1860), all other changes

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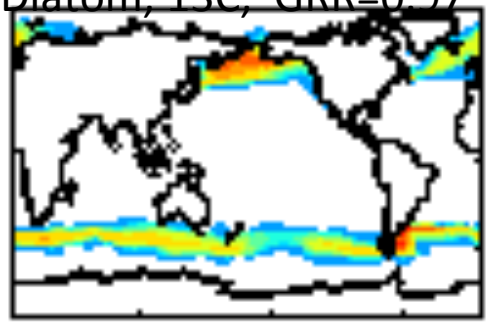

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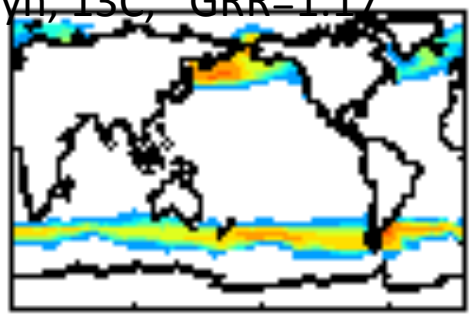

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all changes

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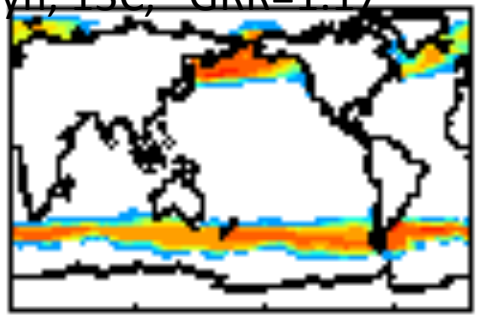

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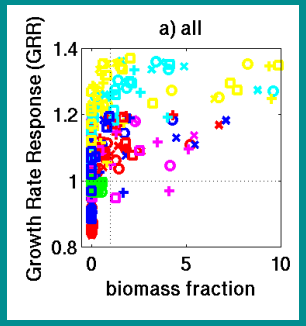

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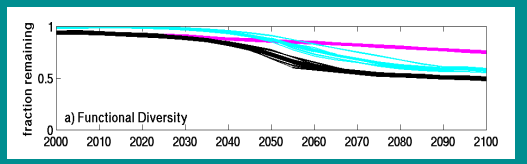
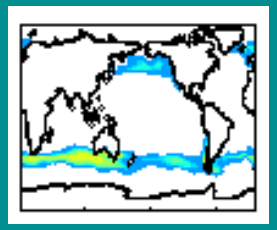
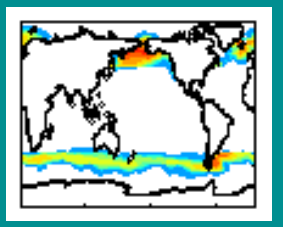


all stressors
pCO_2 changes only
physical changes only

- understanding long timescales of competition- and transport- mediated adjustment essential predicting community changes





2000 **2100**

MUSINGS

"… all models are wrong, but some are useful"
G. Box

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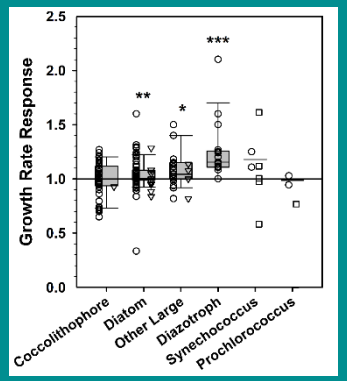
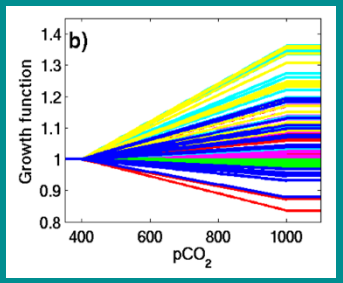
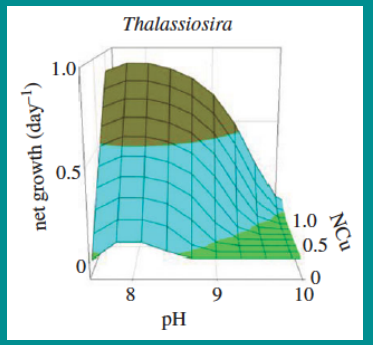
since transport of and long timescale competition important: models are essential along with lab and fields studies to further our understanding of long term OA driven changes

FUTURE MODEL NEEDS

- experiments of competition both inter- and intra-functional groups
- long term (evolution) responses
- need experiment over full range of probable pCO_2 to obtain better response function
- need to understand synergistic response to multiple stressors
- Include calcification/N_2 fix changes etc







Flynn et al, 2015

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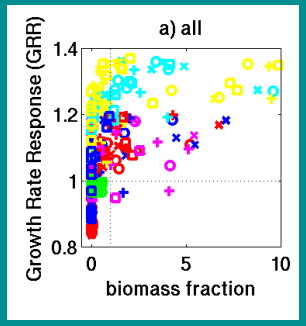

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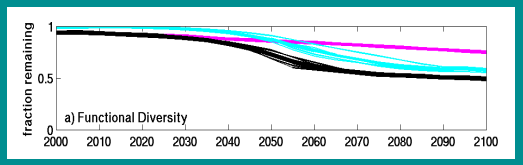

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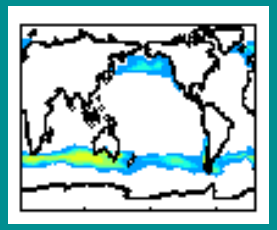
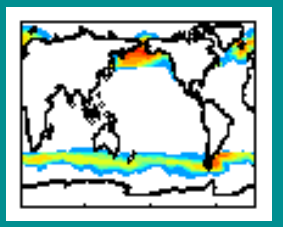
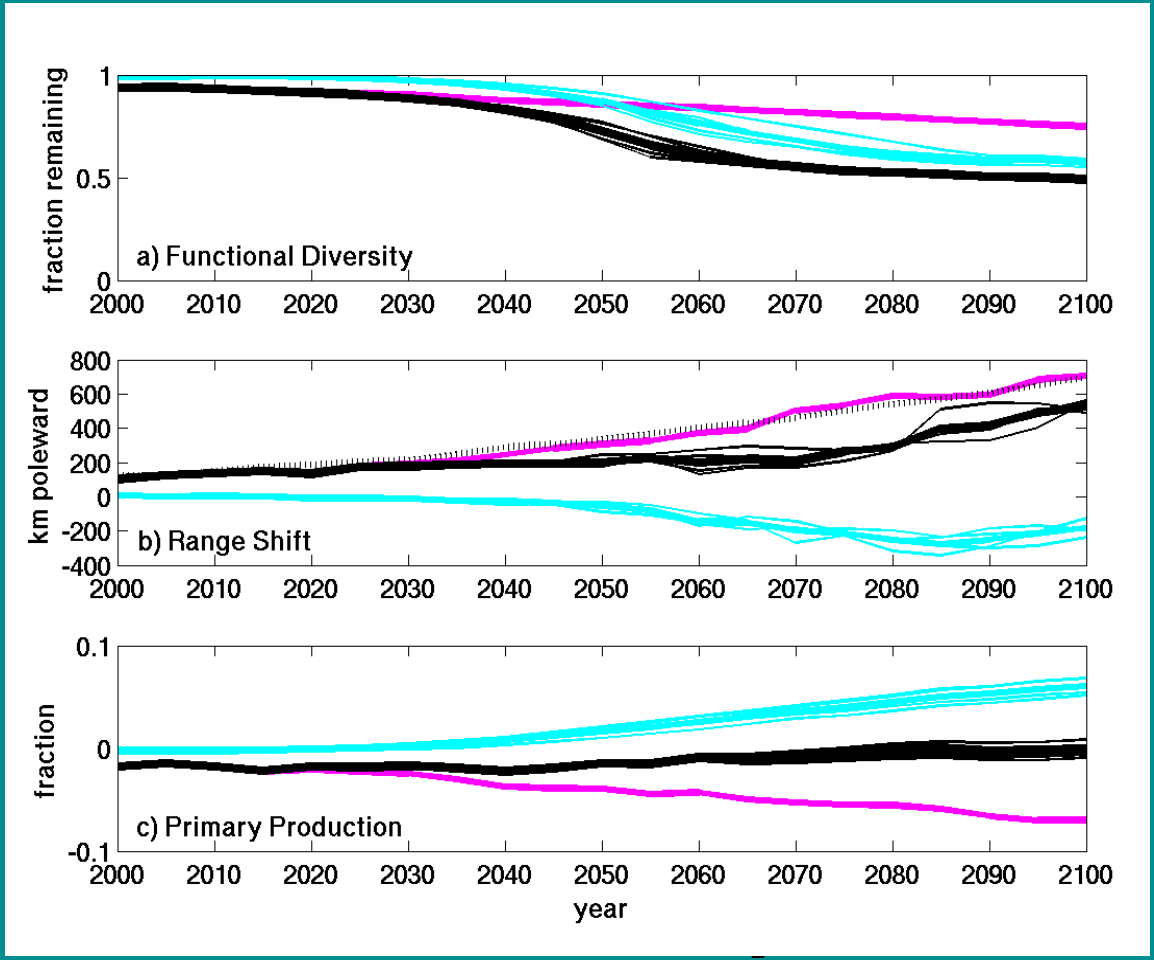




2000 2100

EXTRA SLIDES

ECOSYSTEM MODEL LABORATORY RESULTS



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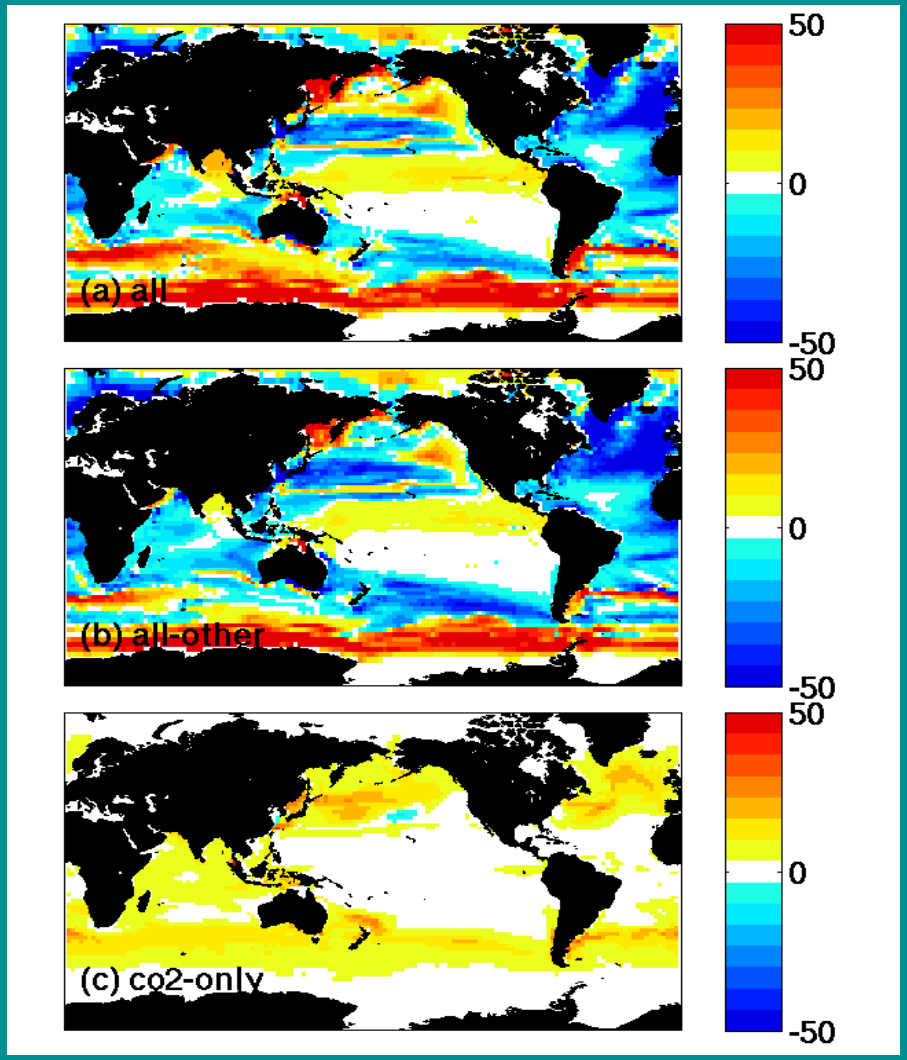

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