The role of model structure in simulating changes in oceanic new production over the 21st century

Jay Brett, University of Hawaii Manoa
Manoa collaborators Kelvin Richards, Kate Feloy
NCAR collaborators Dan Whitt, Matt Long, Frank Bryan
Funded by NSF

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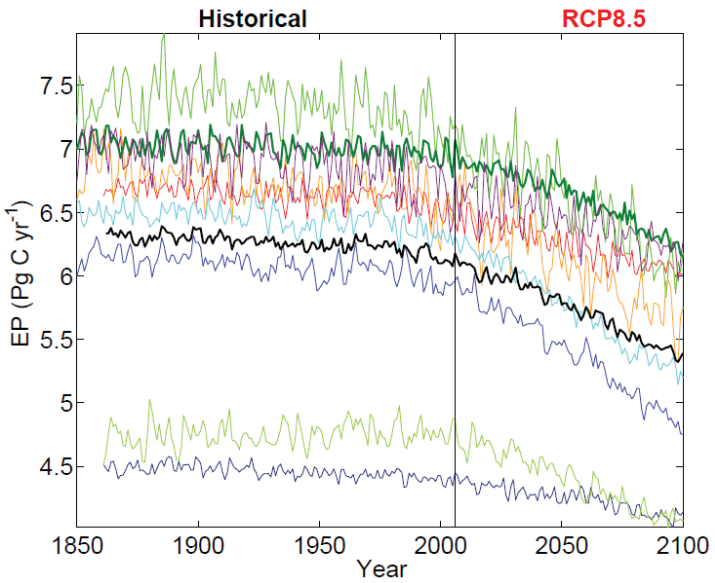
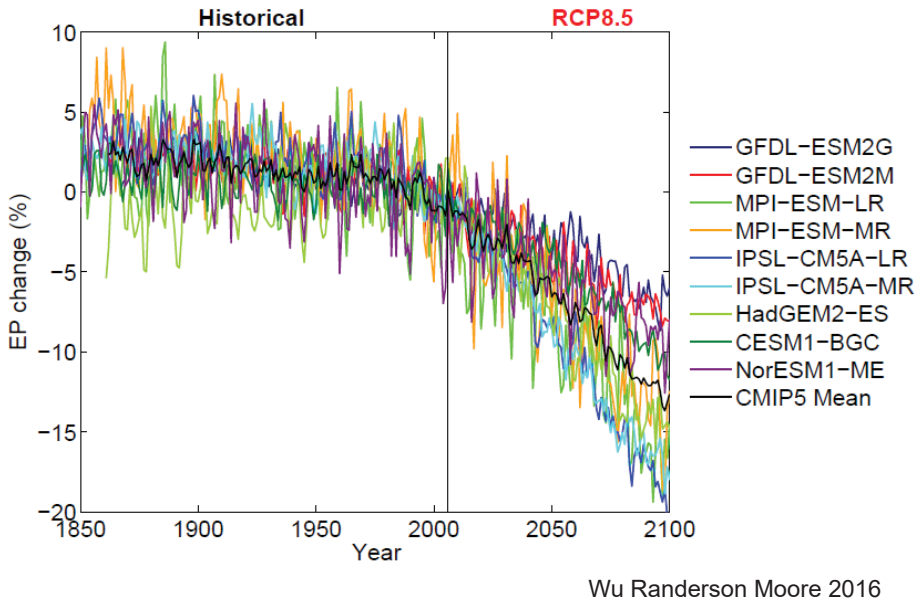
Premise

Under global climate change, new production decreases overall, but mechanisms and amount vary between locations and models.





Wu Randerson Moore 2016

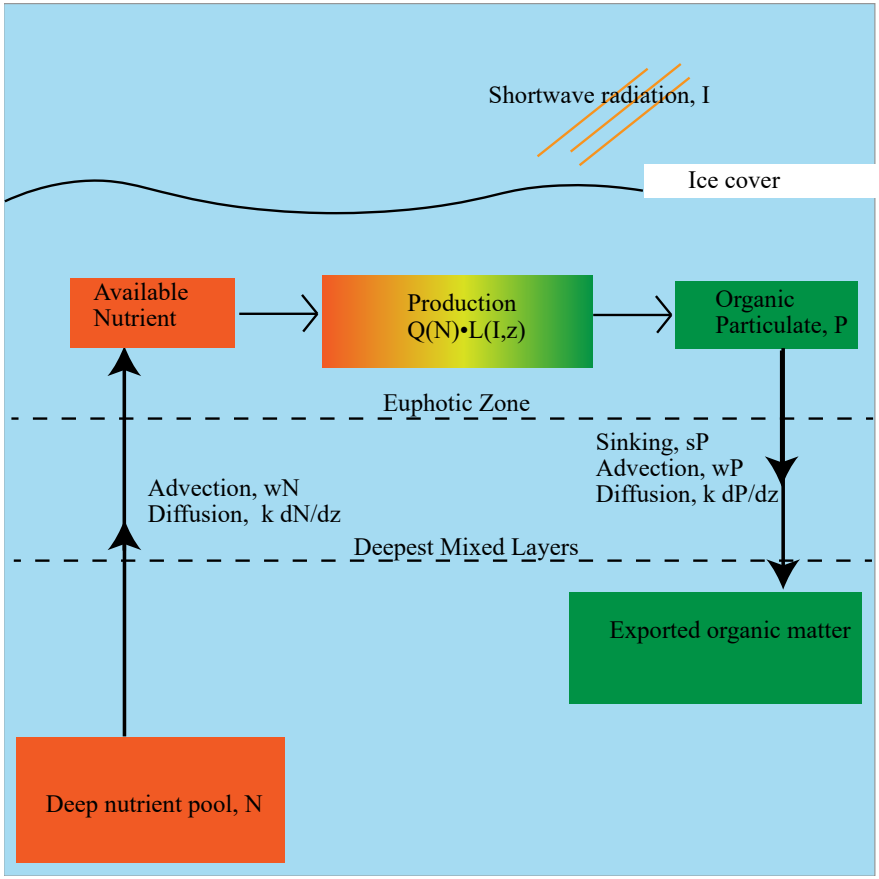
Questions

- Under a climate perturbation, how do physical changes drive changes in new production rates?
- How well can an idealized model project new production?
- What is the role of the model structure for production in the spatial patterns of projected change?

Outline

Idealized biogeochemical tracers

A pair of idealized tracers is the minimum for entrainment, production, and export.
NUTRI: idealized nutrient, fixed value below 1km.
PARTI: idealized organic particulate (phyt. and detritus)



Idealized Tracers

NUTRI: idealized nutrient, fixed value below 1km.
PARTI: idealized organic particulate (phytoplankton and detritus)

$$\frac{dN}{dt} = -\mu_0 QL + S_1,$$
$$\frac{dP}{dt} = \mu_0 QL - \text{decay} + \text{sinking},$$
$$Q = N/(k_N + N),$$
$$L = 1 - e^{\alpha I}, \quad I = I(z, MLD),$$
$$S_1 = \begin{cases} 0 & \text{if } z > -1km \\ 20 - N & \text{if } z < -1km \end{cases}$$

Production parameters

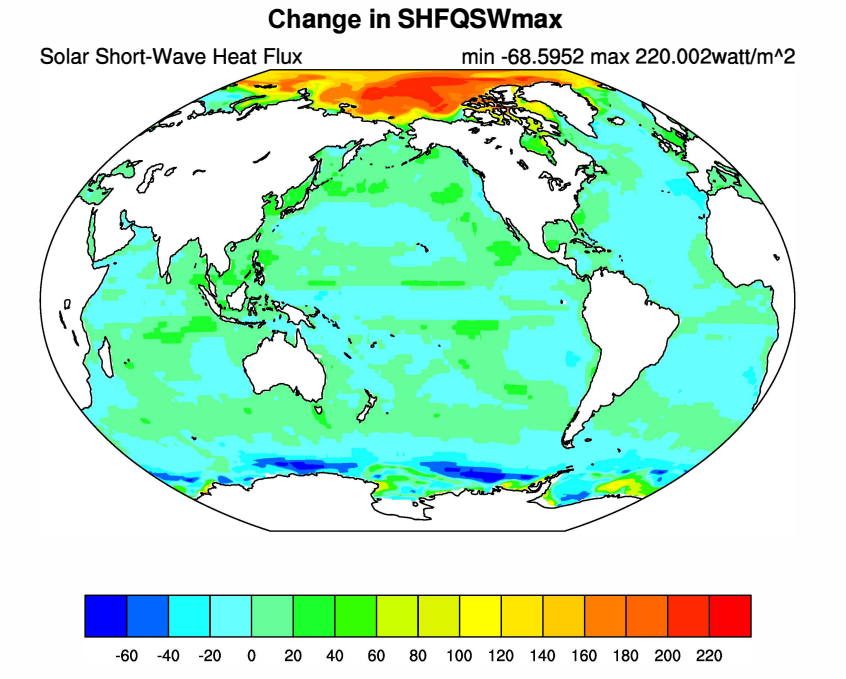
Variable	Low	Medium	High
α	0.0125	0.05	0.2
μ_0	0.125	0.5	2
k_N	0.25	1	4

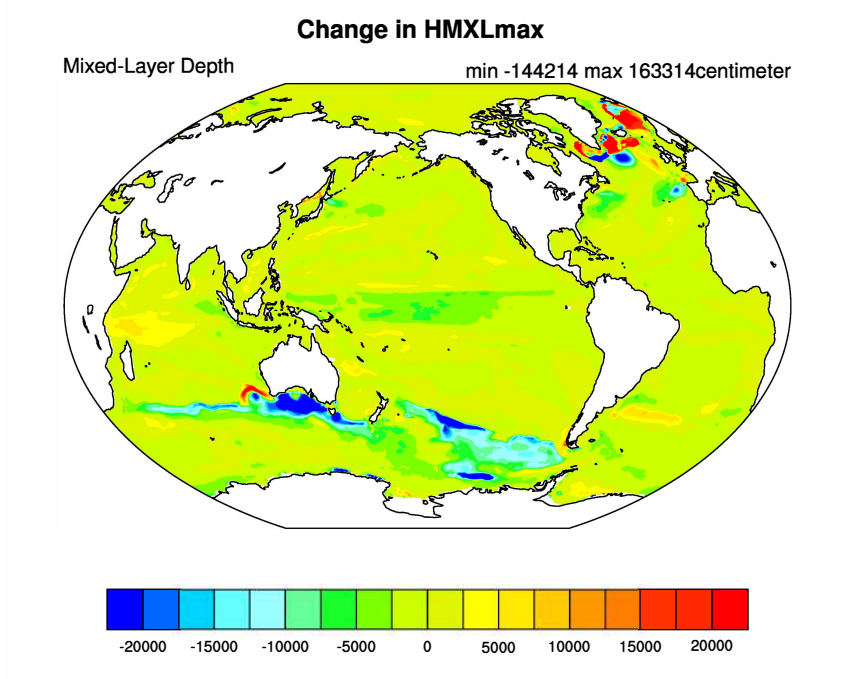
Highlighted members (0.05, 0.125, 0.25) and (0.2, 2, 1).
Set of 12 have all k_N for (α, μ_0)= (0.0125,0.5) (0.05,0.125) (0.2,0.125) (0.2,2).

Outline

Climate Perturbation– Timeslice

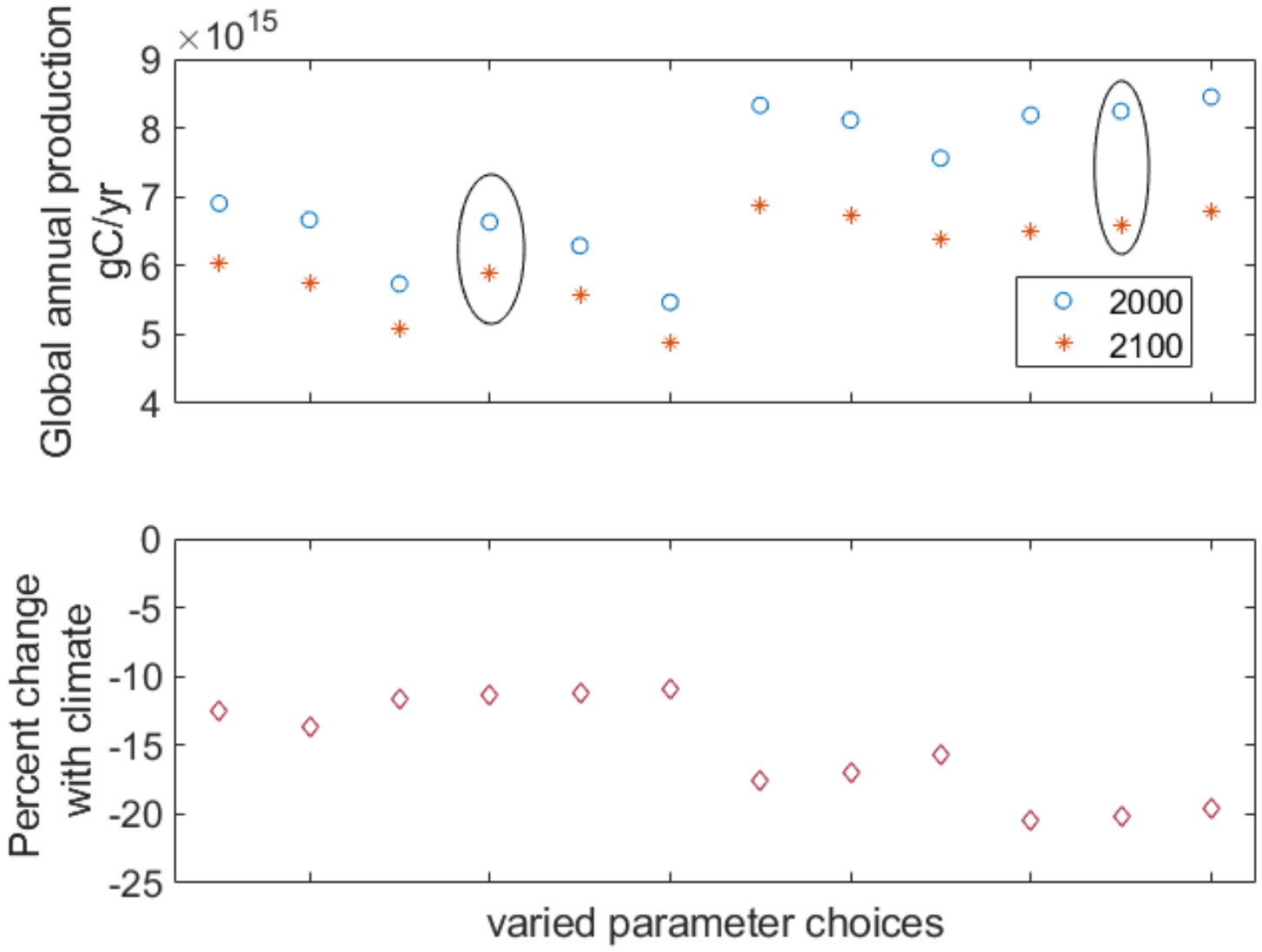
Uses Large Ensemble to perturb T, S, forcing based on the difference between 2000 and 2100. Changes in HMXL and SHF_QSW are most important.



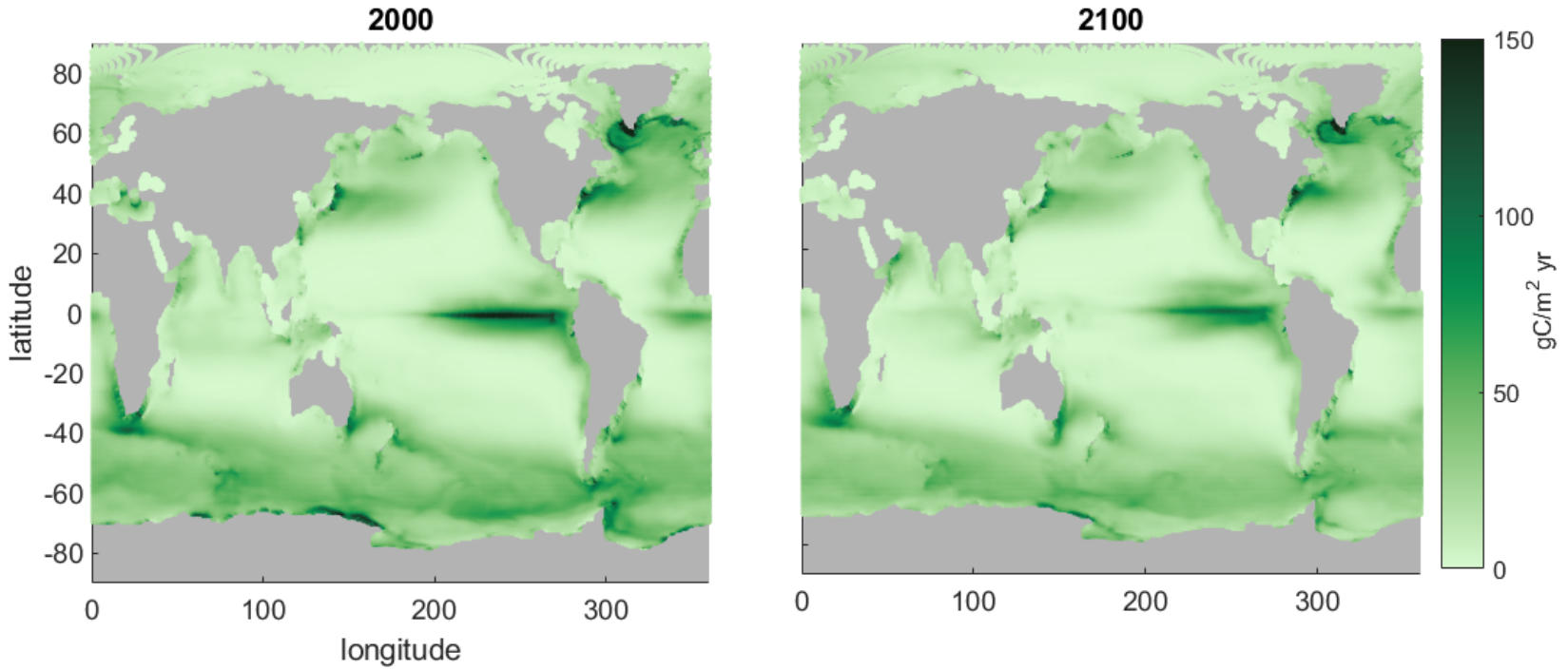


Outline

New production magnitudes are reasonable

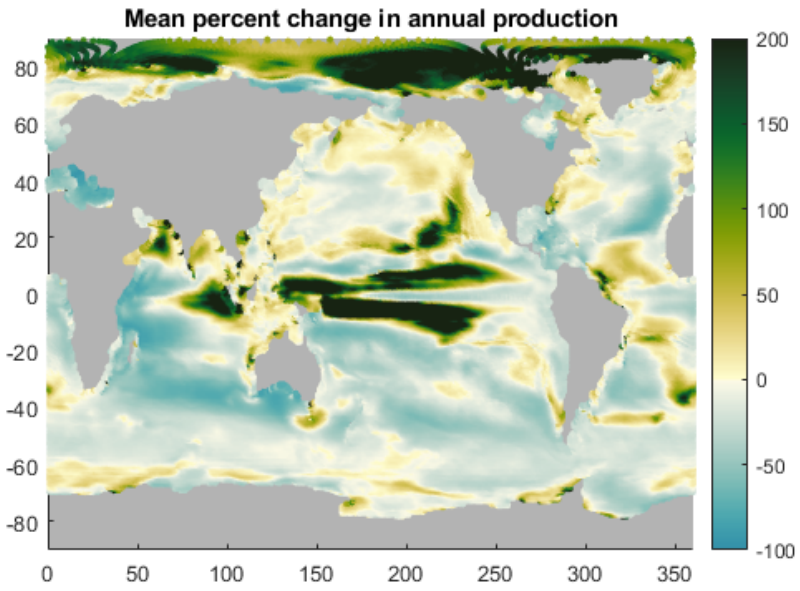


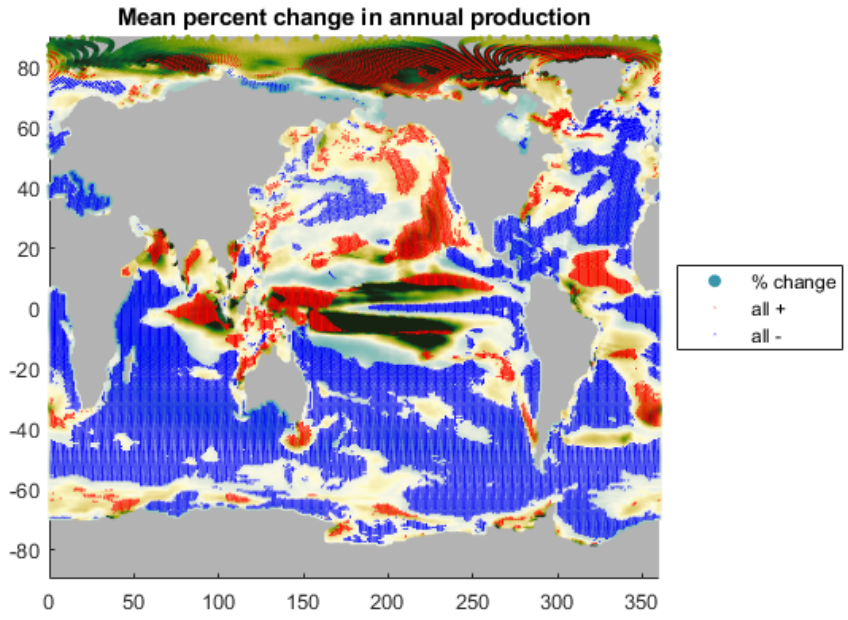
Production patterns are reasonable



Annual production, top 100m, mean of 12 parameter cases.

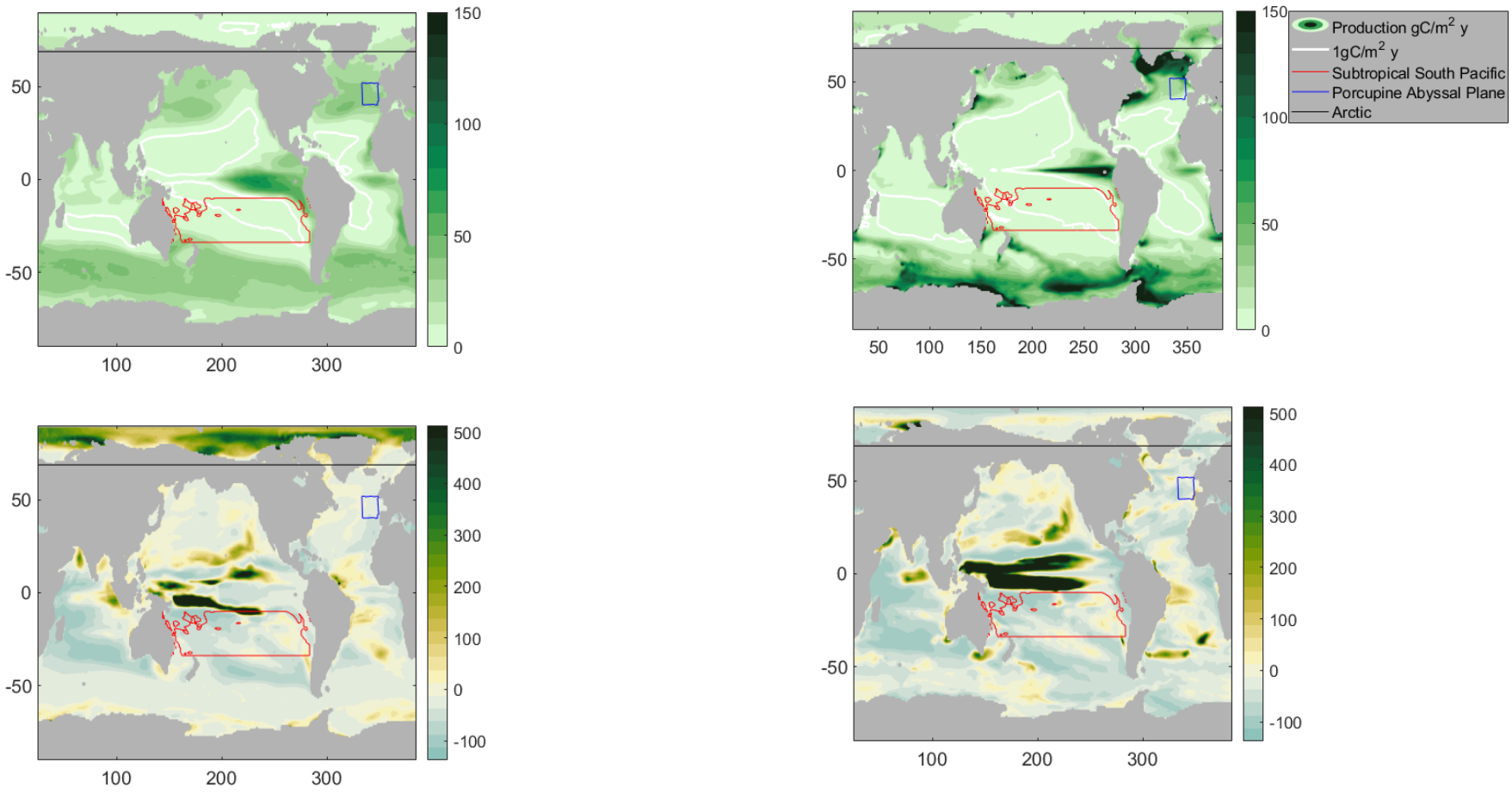
Production change





Outline

Production patterns

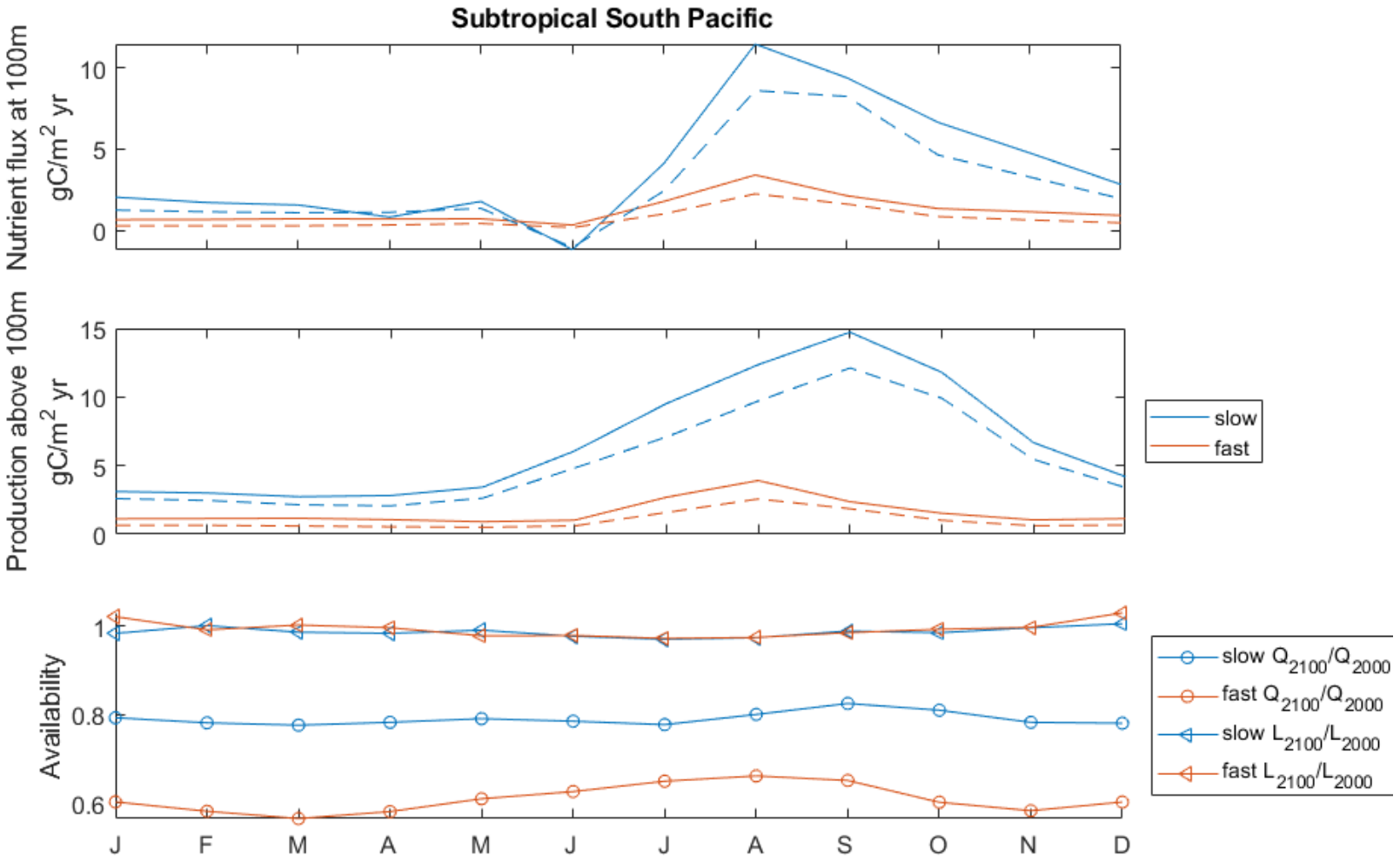


Global decreases in new production of 11% and 19%.

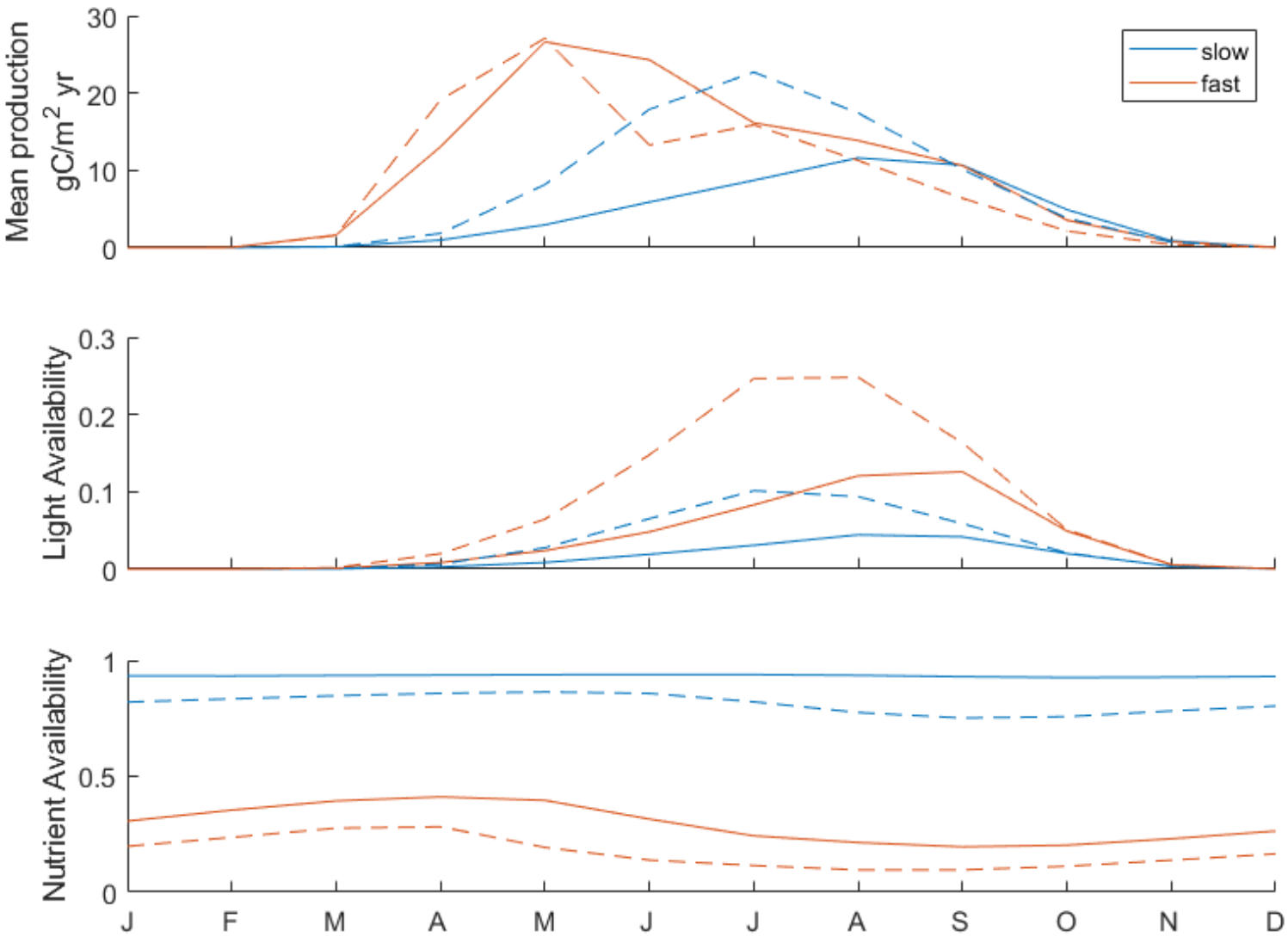
$(0.05, 0.125, 0.25)$ $(0.2, 2, 1)$

(α, μ_0, k_N)

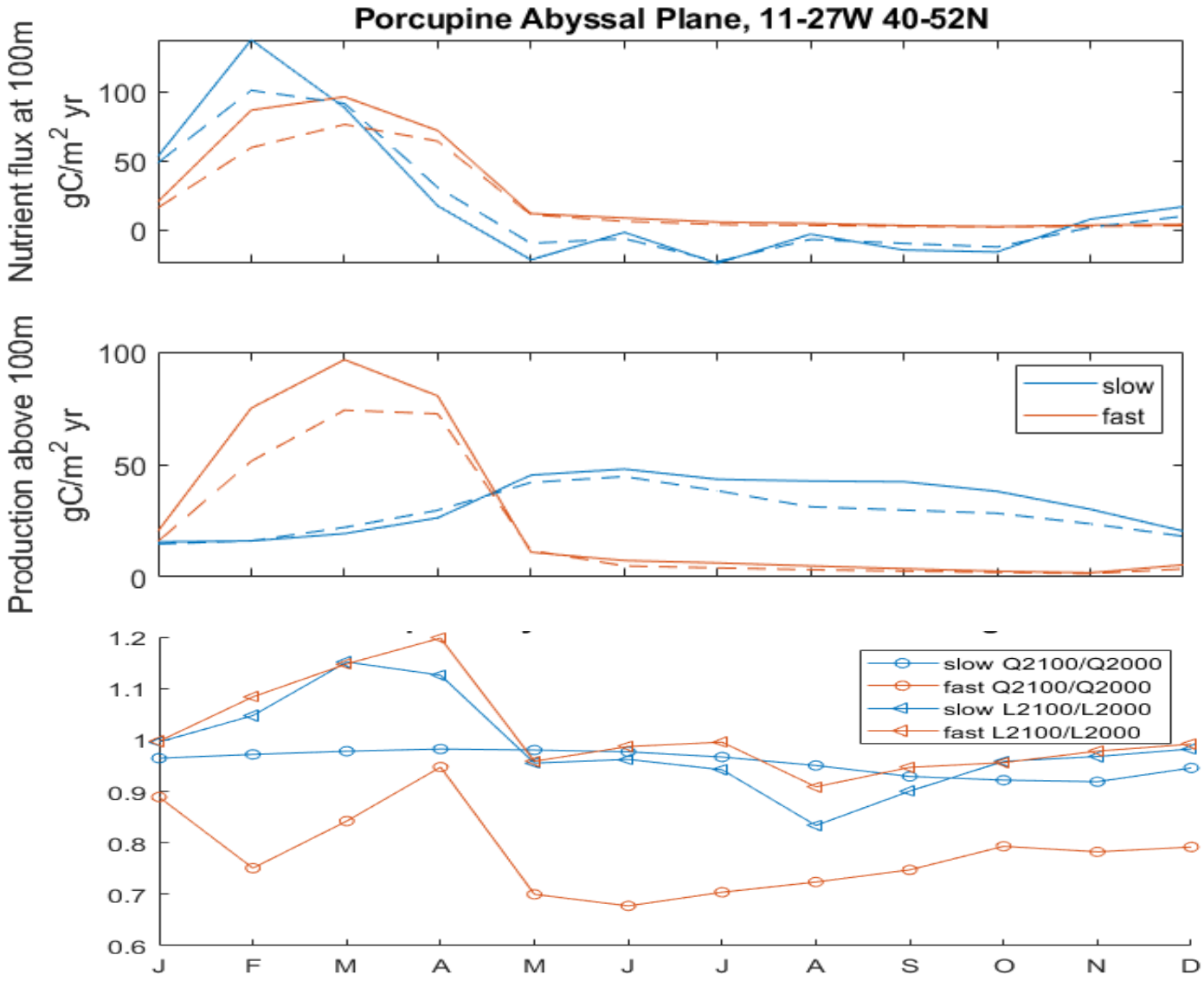
South Pacific



Arctic


Mean production
gC/m^2 yr
30
20
10
0
slow
fast
Light Availability
0.3
0.2
0.1
0
Nutrient Availability
1
0.5
0
J
F
M
A
M
J
J
A
S
O
N
D

Porcupine Abyssal Plane



Conclusions

- Idealized tracers behave reasonably well
- When one consistent limiting factor is the main change, projection not sensitive to bgc model (parameters)
- When limiting factor changes or multiple factors change, projections are sensitive

Continuing work: connecting bgc changes back to the physics

PAP high-res studies

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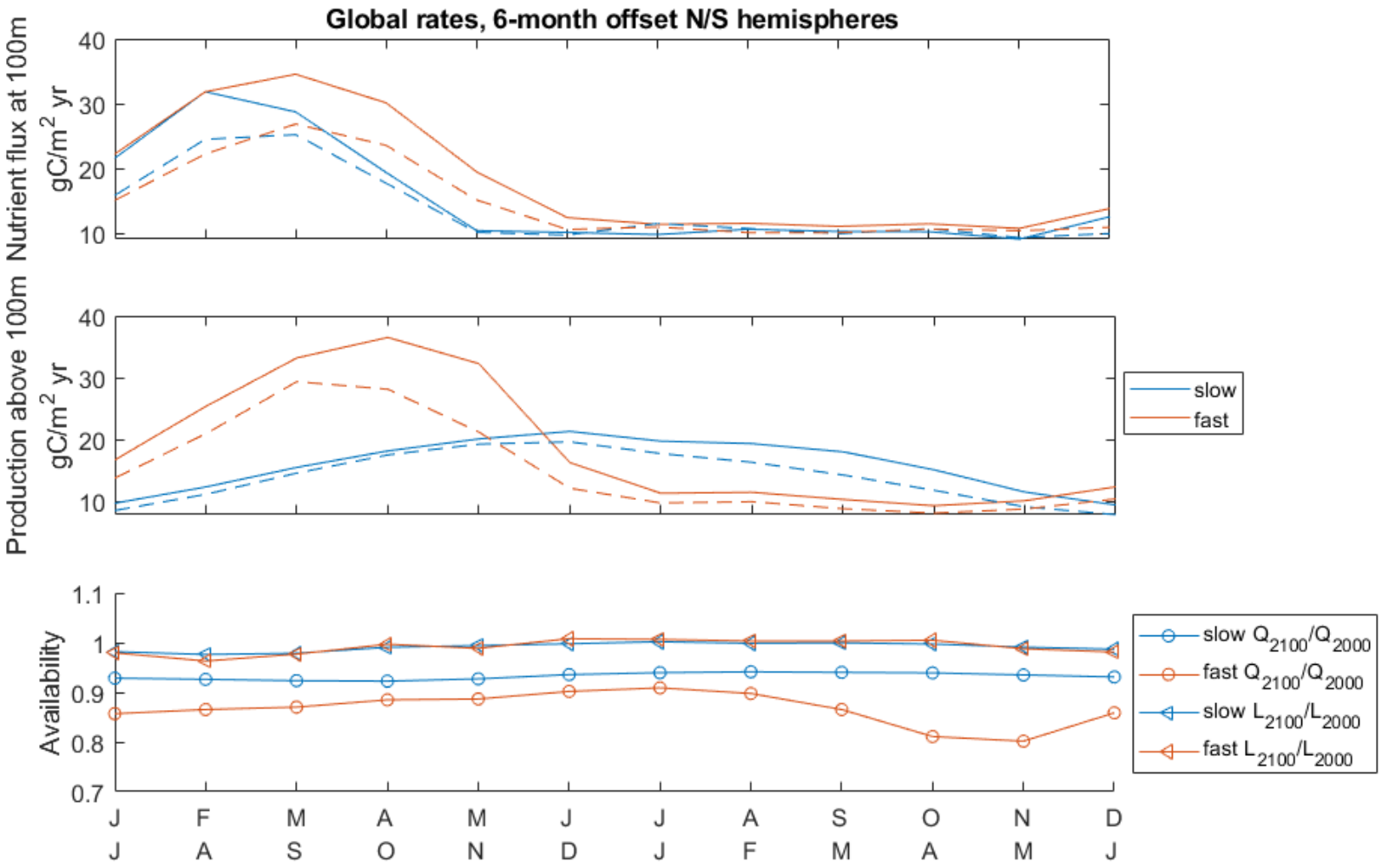
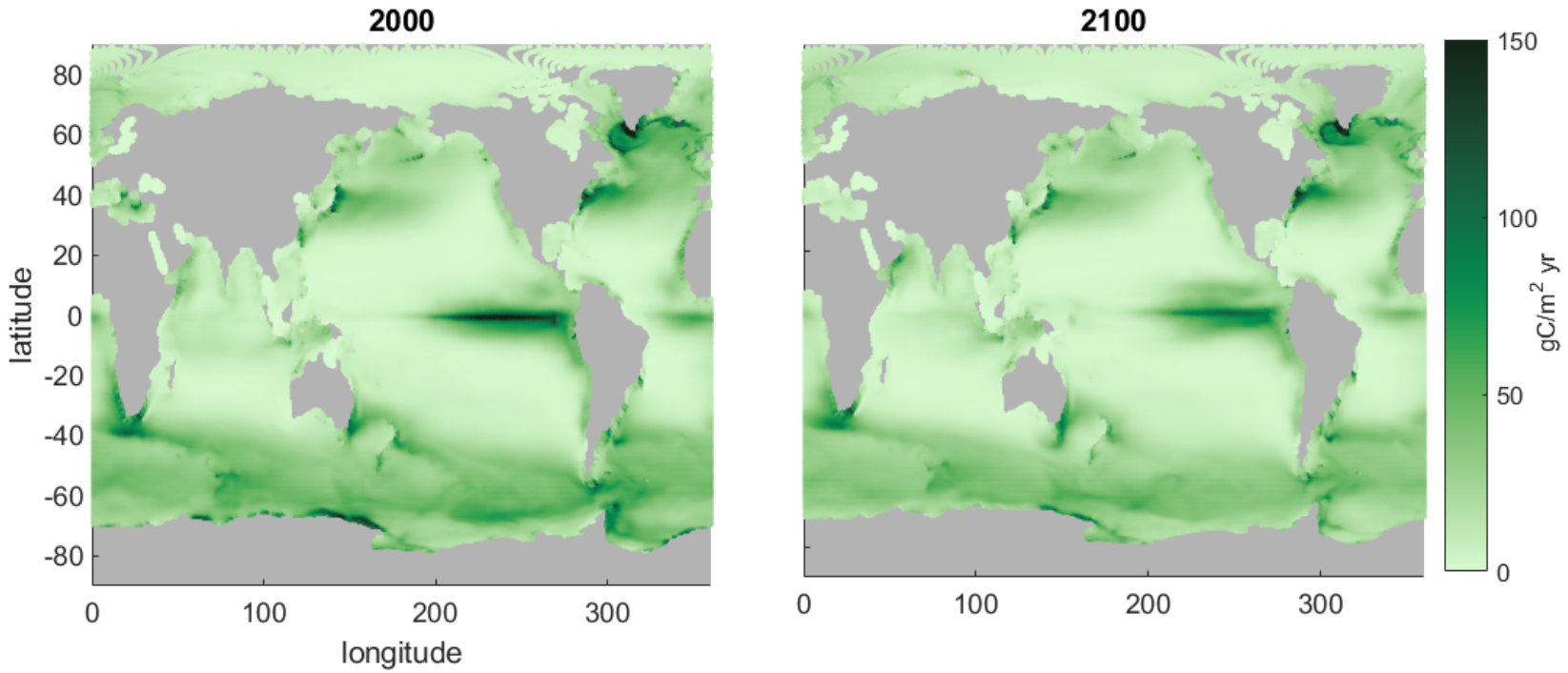
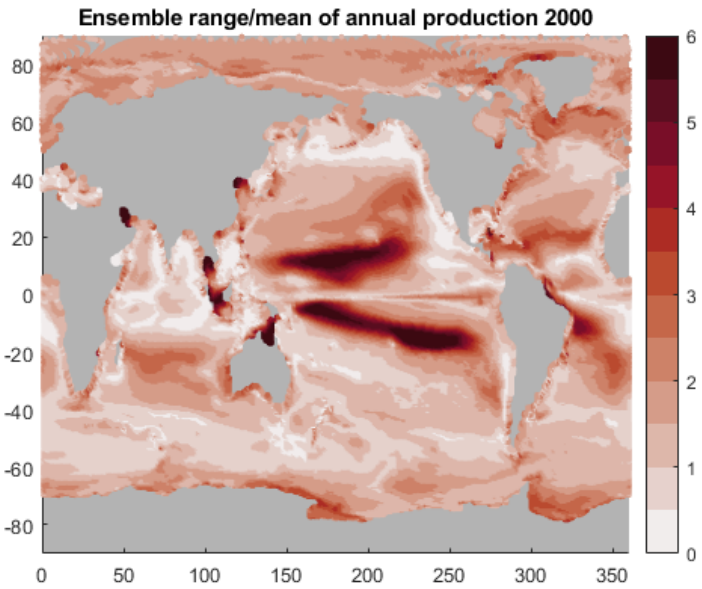
Seasonal production

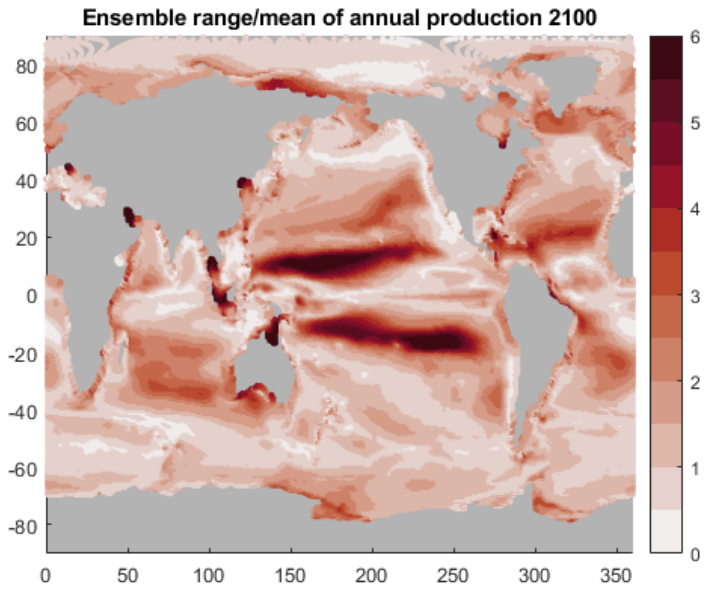


Production patterns

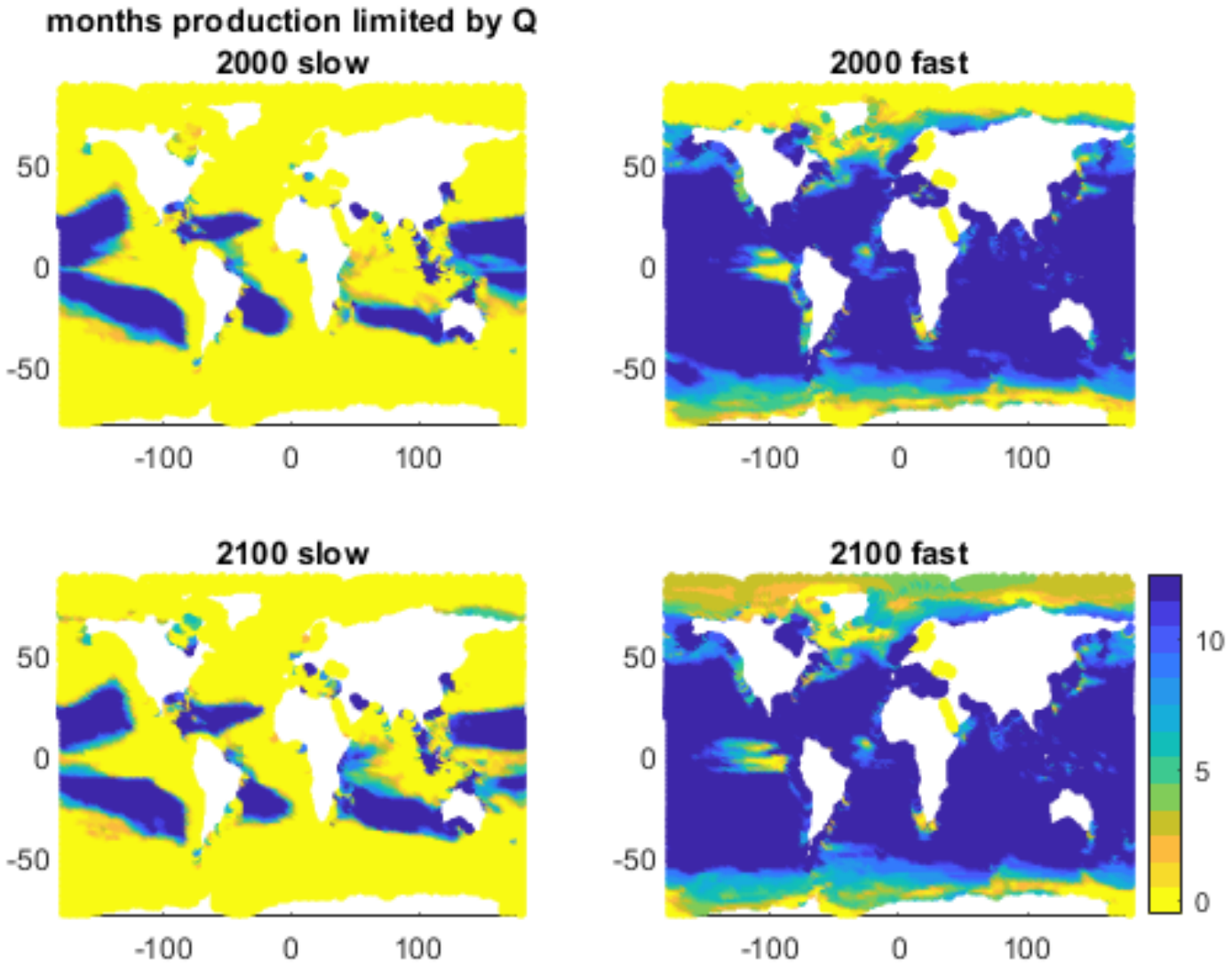


Range of production

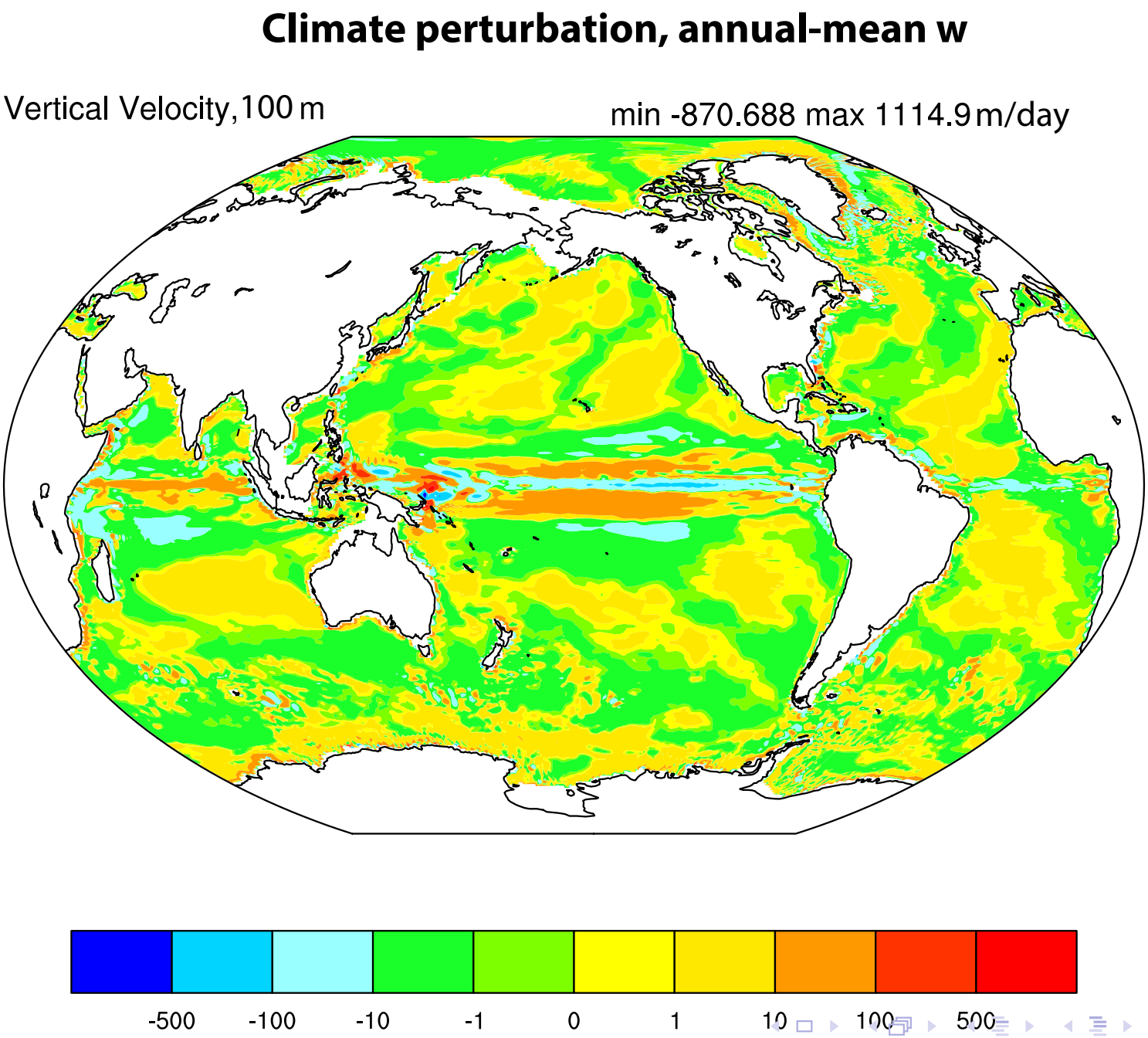




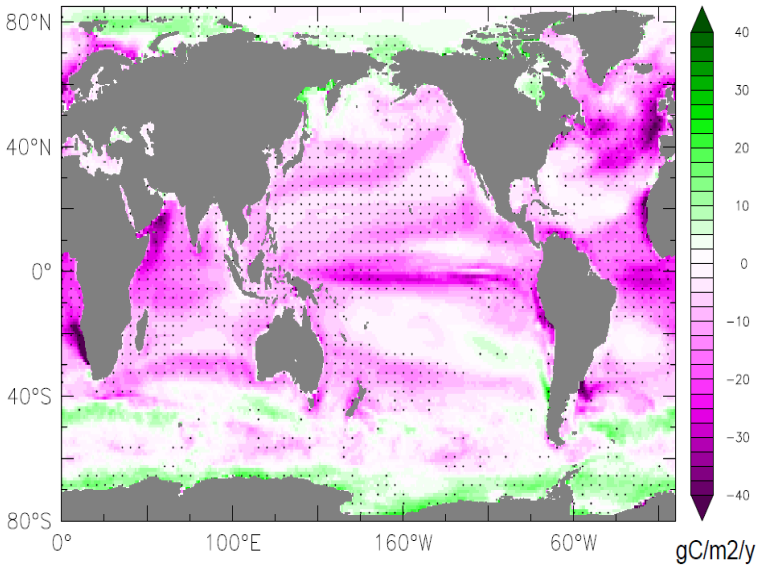
Production limitations

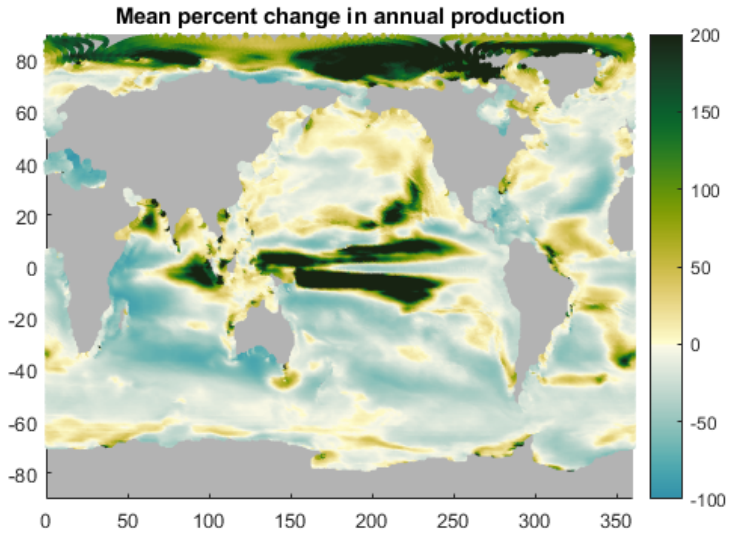


Vertical velocity changes at 100m

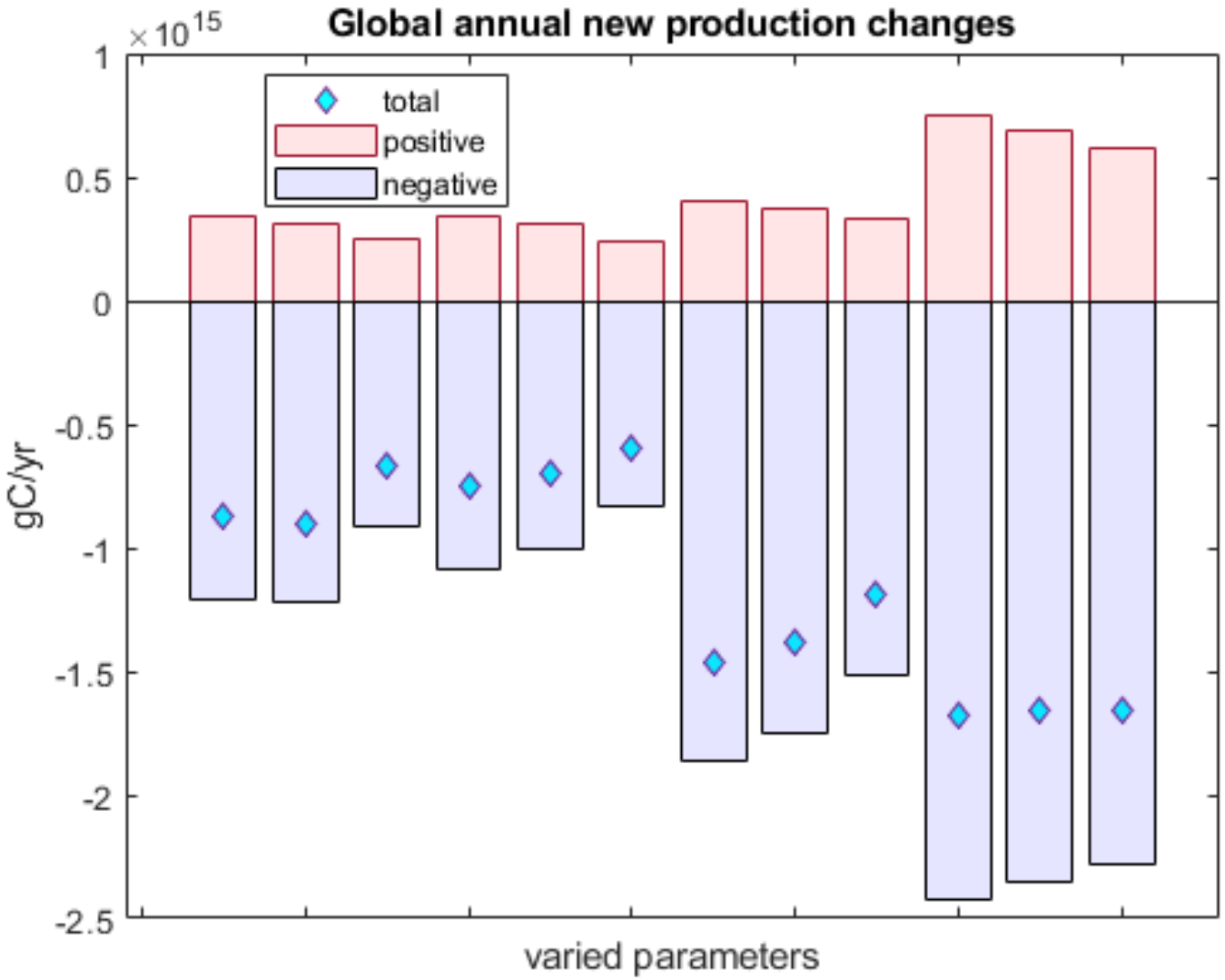


Production change in multi-model context

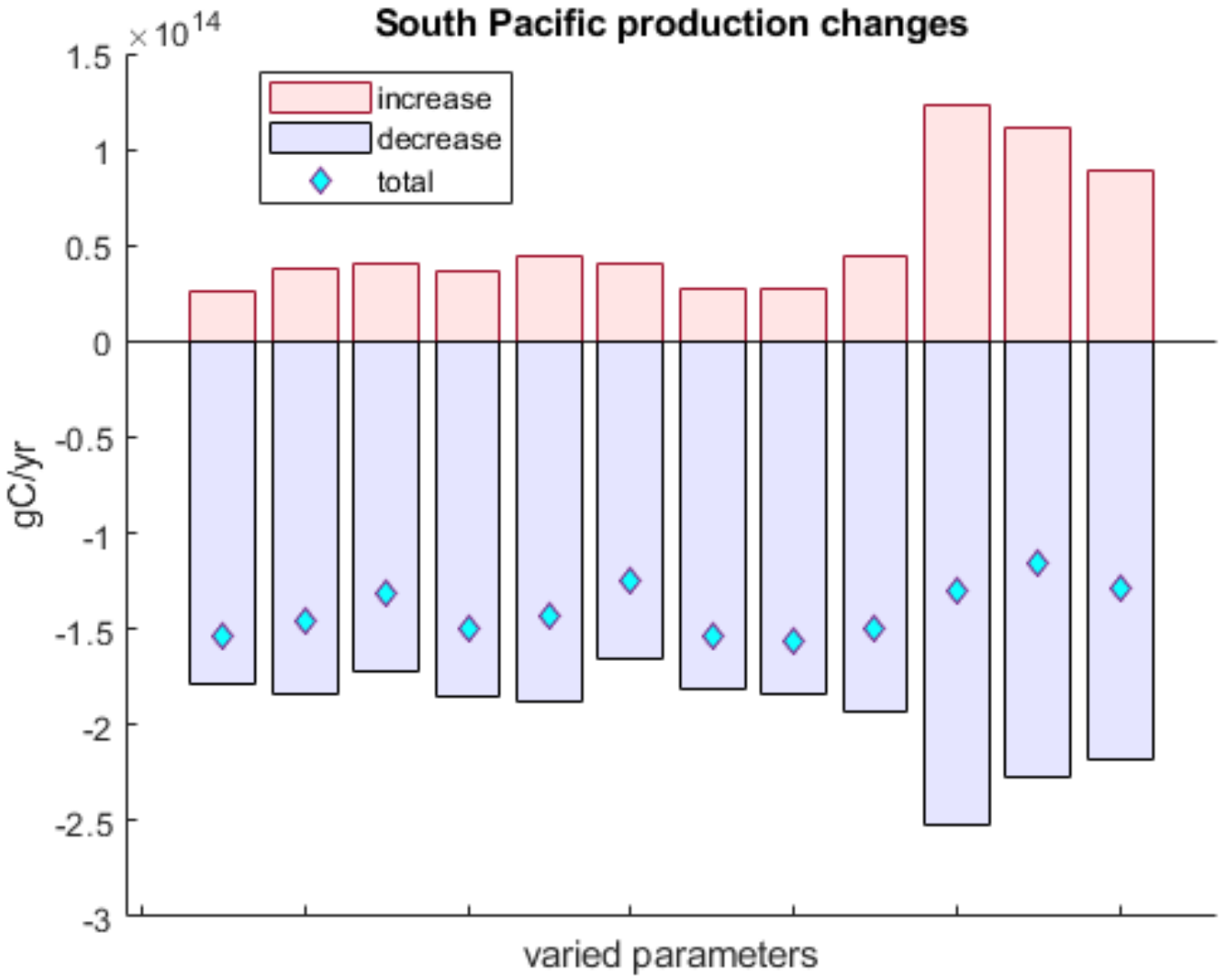




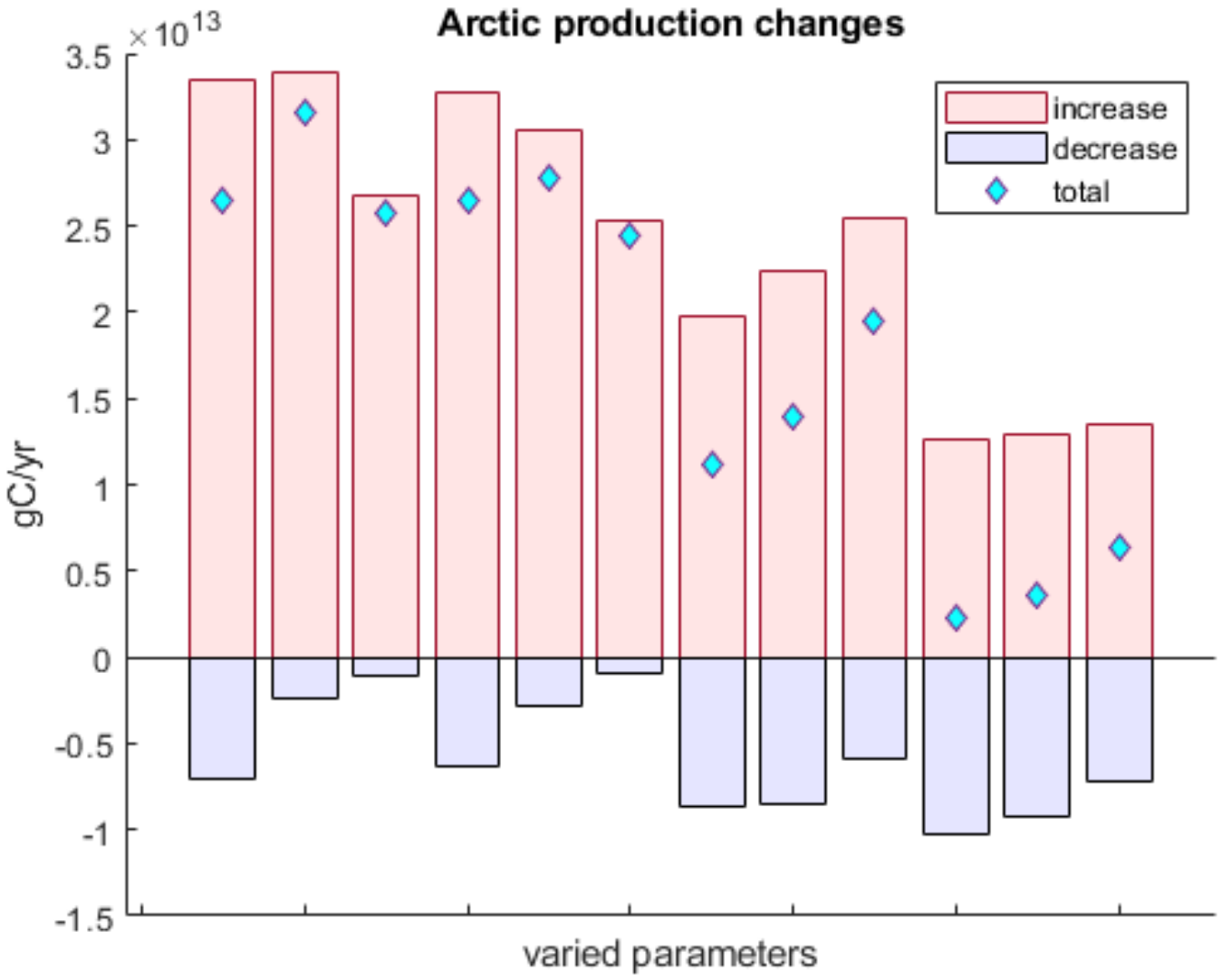
Global production change ensemble



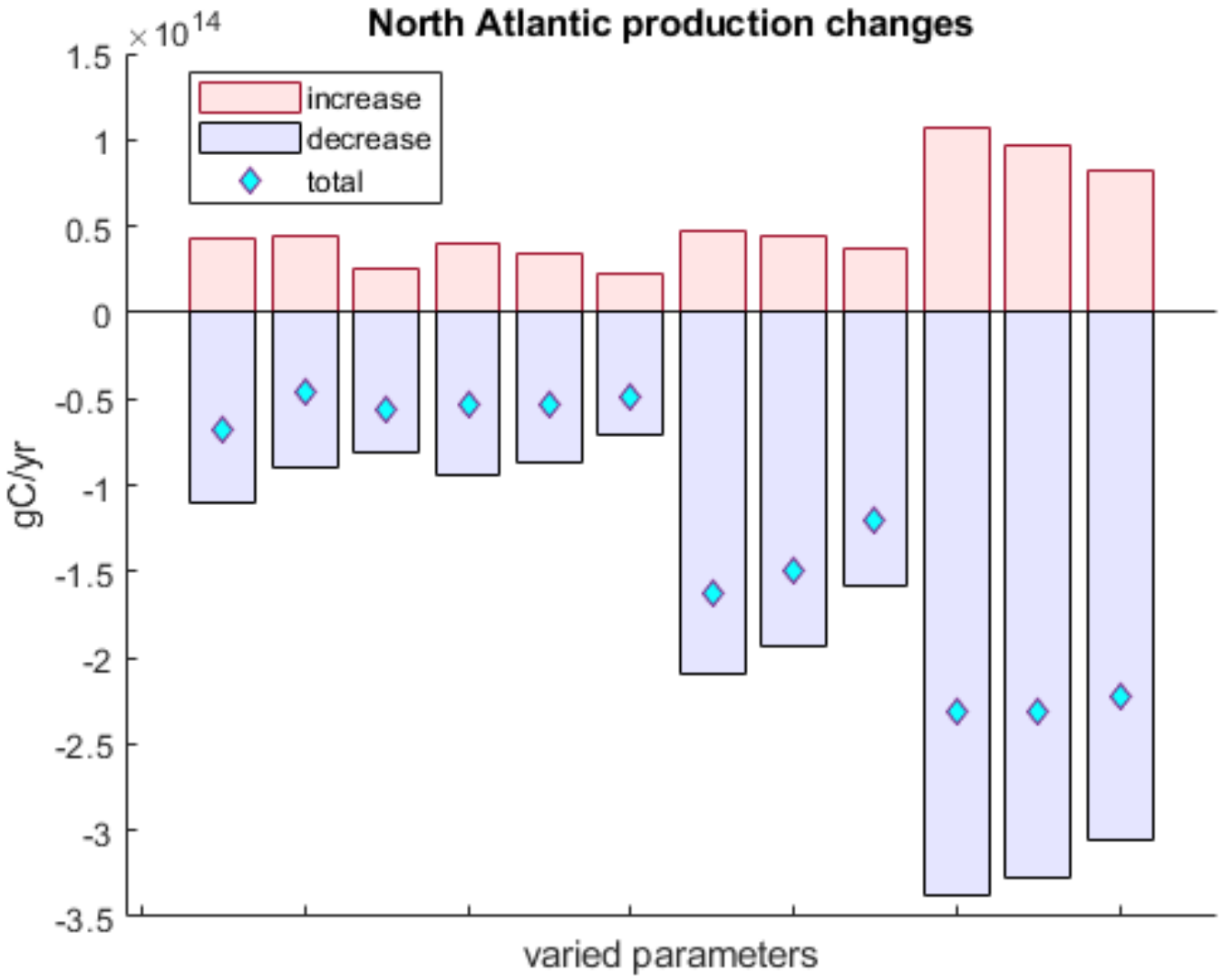
South Pacific production change ensemble



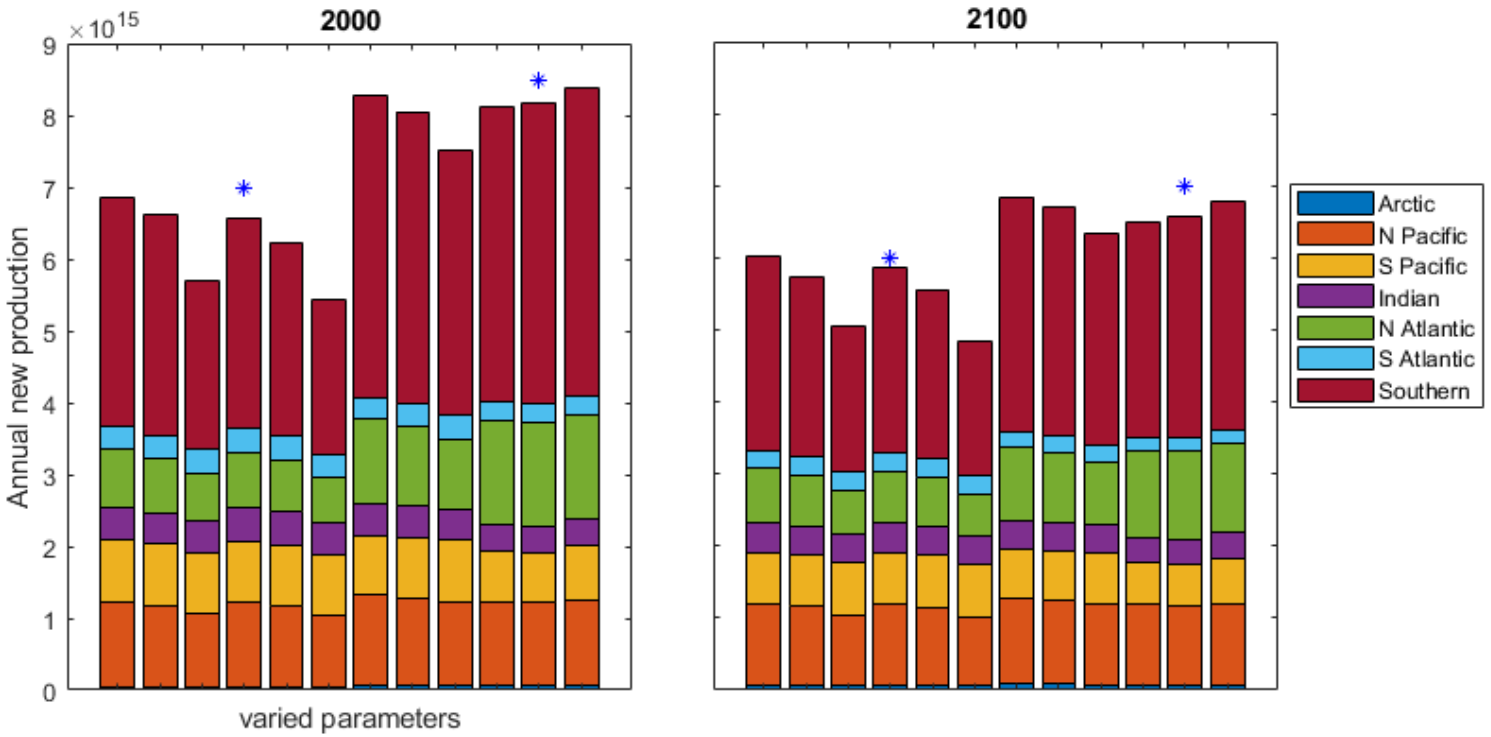
Arctic production change ensemble



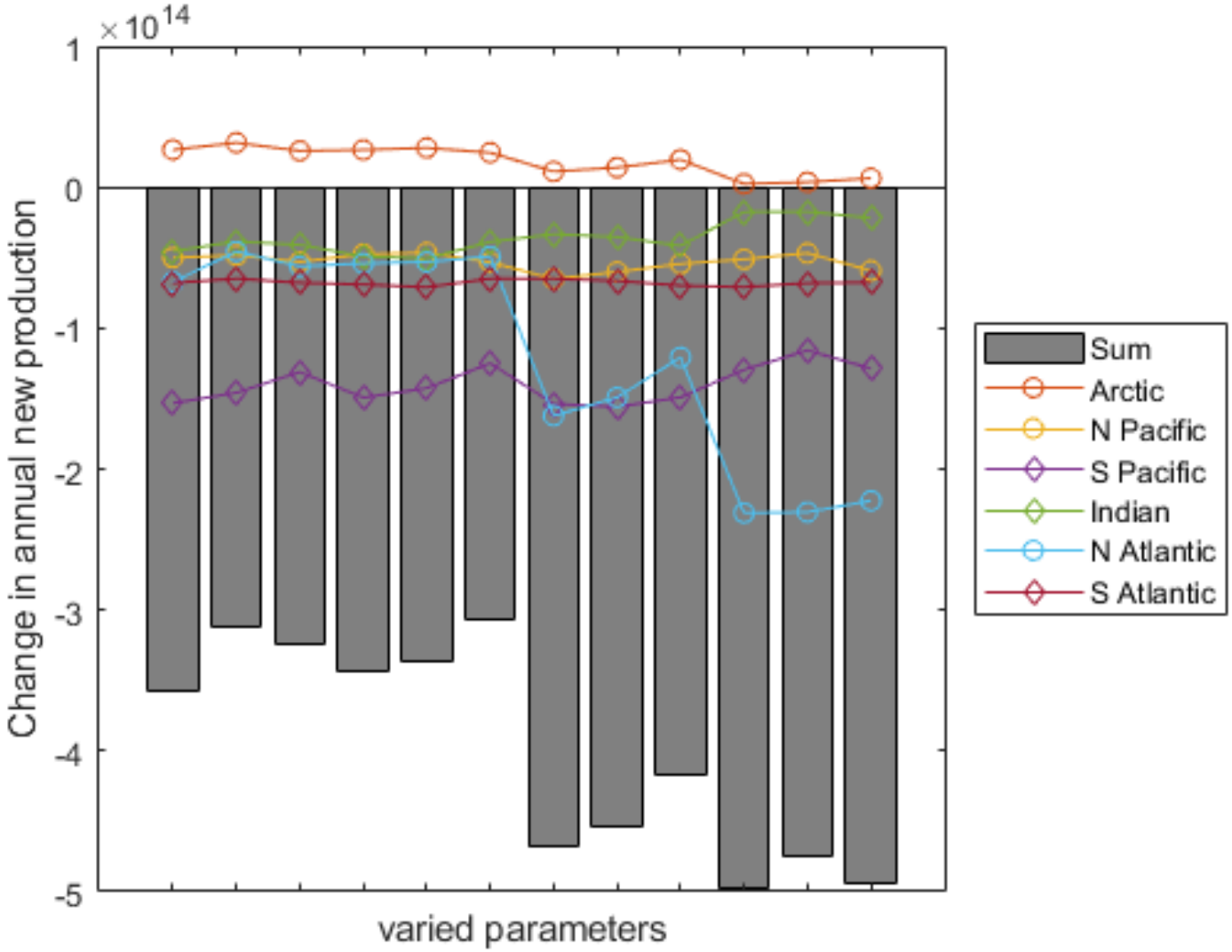
North Atlantic production change ensemble



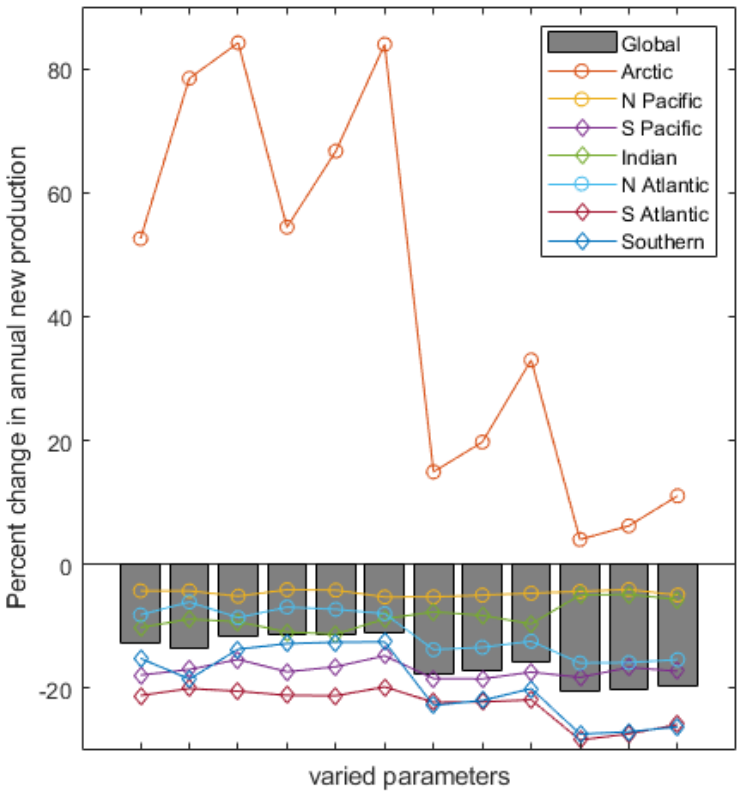
Ensemble global production rates

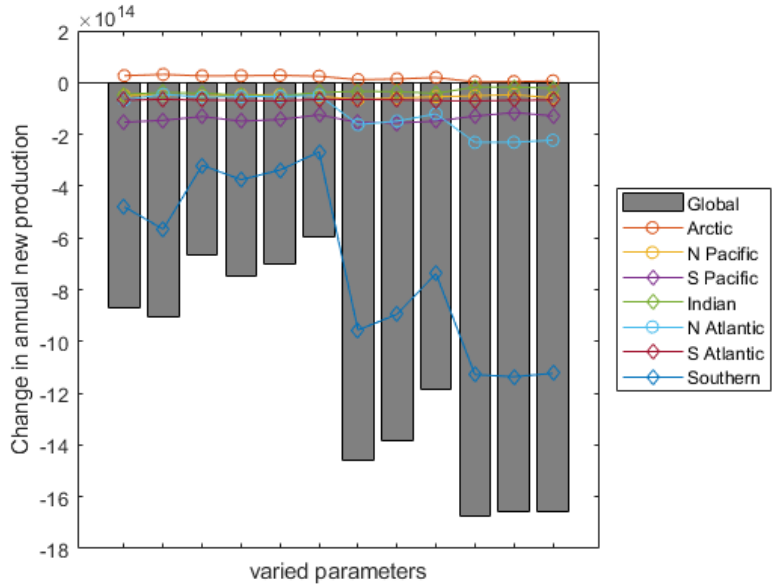


Production decreases in all but Arctic



Ensemble basin production changes





Parameters

Variable	Low	Medium	High
α	0.0125	0.05	0.2
μ_0	0.125	0.5	2
k_N	0.25	1	4
w_s	0	5	10
σ	1/365	1/60	1/30

27 runs with $w = 0$ and $\sigma = 1/60$.
Highlighted members (0.05, 0.125, 0.25, 5, 1/365)
and (0.2, 2, 1, 10, 1/30).
Set of 12 have all k_N for (α, μ_0)= (0.0125,0.5) (0.05,0.125)
(0.2,0.125) (0.2,2).