Projecting net primary production in a sea of uncertainty: next steps and why should we care?

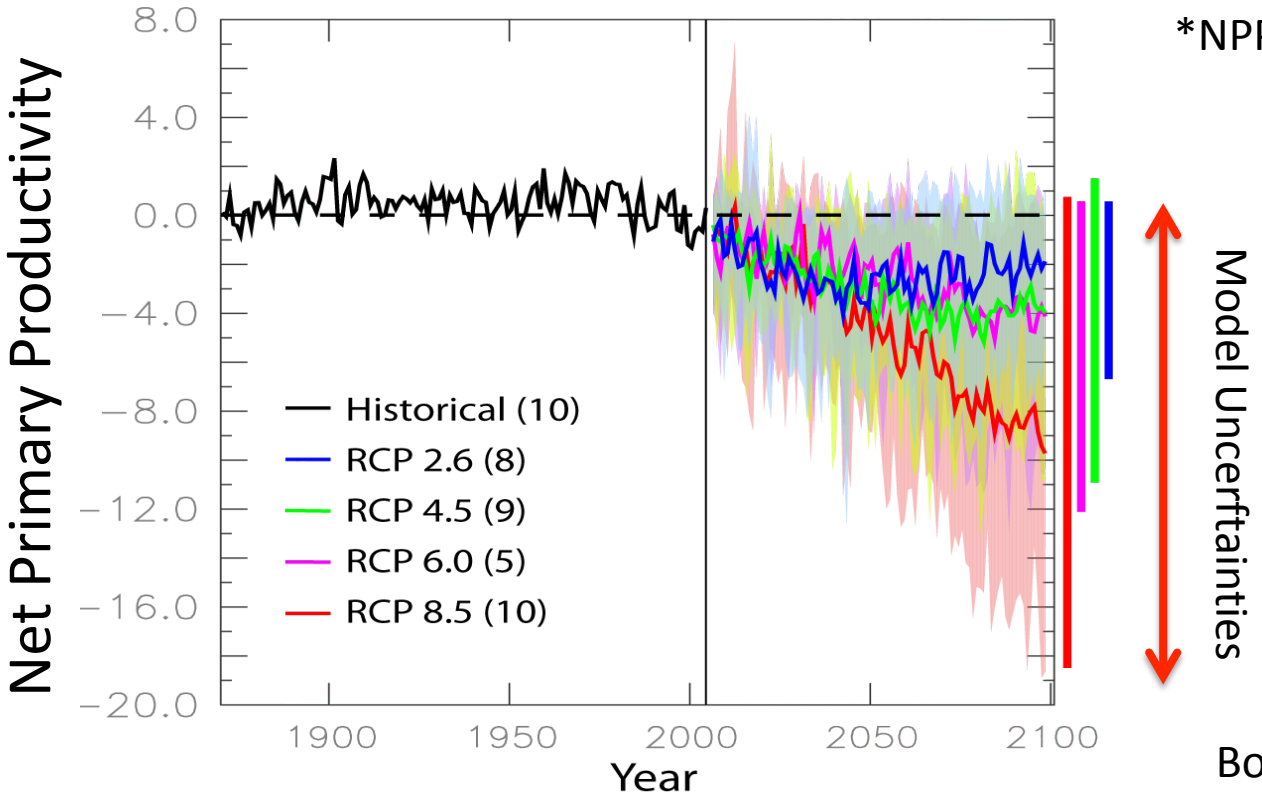
Laurent Bopp[1]

Co-authors : Olivier Aumont, Lester Kwiatkowski, Priscilla Le Mezo, Olivier Maury, Alessandro Tagliabue, Corentin Clerc, Léo Dupont, Roland Séférian, Christian Ethé

1. Institut Pierre-Simon Laplace / CNRS & Ecole Normale Supérieure Paris , France

Projections of NPP from CMIP5…

Open ocean NPP* is projected to fall globally depending on RCP scenario (medium confidence). The estimated decrease will occur by up to 9% by 2100 under the RCP8.5 business-as-usual climate scenario (relative to 1990, low confidence) (IPCC, 2014).



*NPP = Net Primary Production

Bopp etal. 2013

NPP projections for… projecting food webs

Lotze et al. (2019, FushMIP) projects a decline in animal biomass in response to climate change - between -5% and -17% depending on the scenario.

>> First model-intercomparison

of that kind, using:

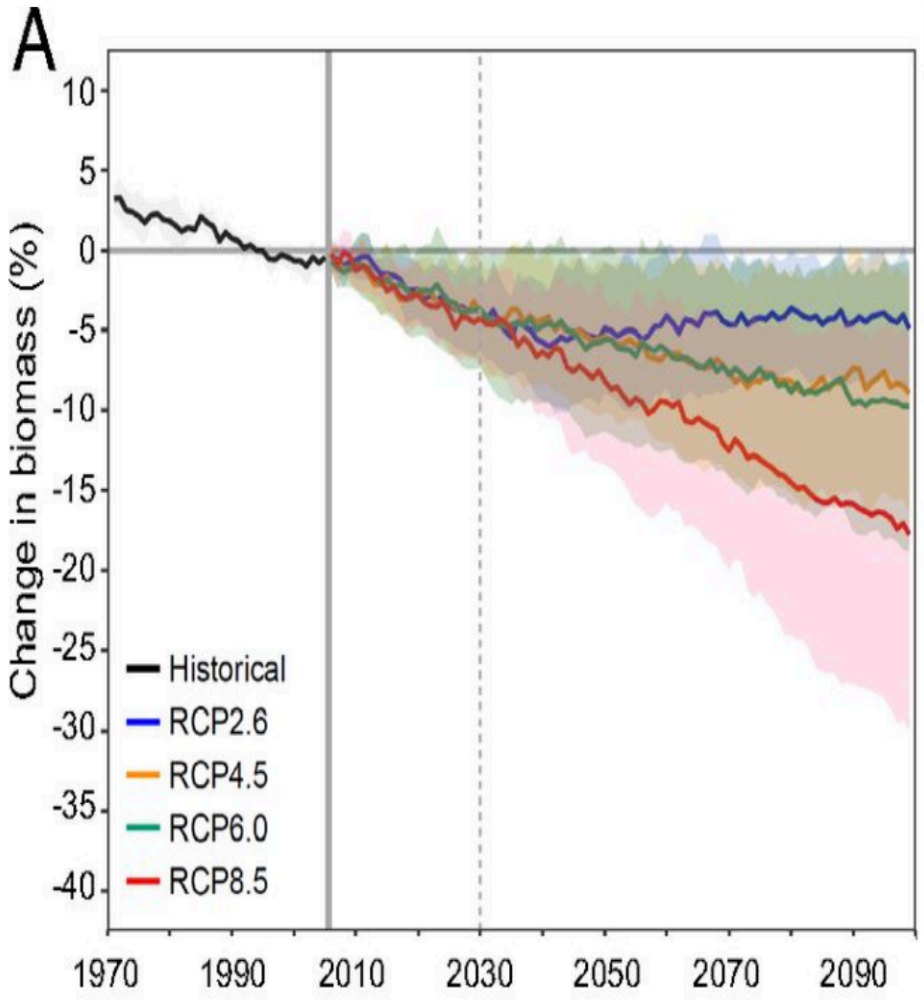
4 scenarios,

2 Earth System Models

6 ecosystem models

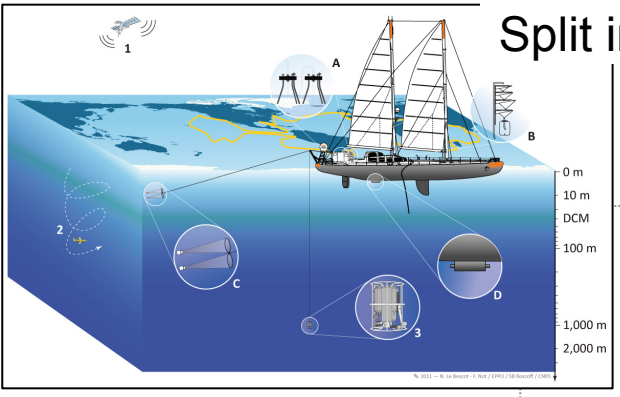
(size-based & species-based)

Lotze et al., PNAS 2019



NPP projections for… projecting biodiversity

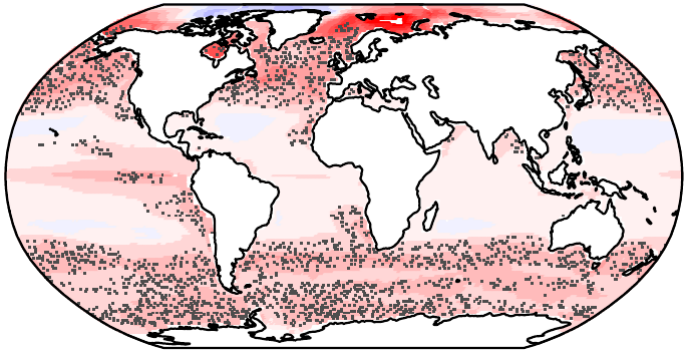
***Tara* Oceans** sampling & Diversity Statistical Models



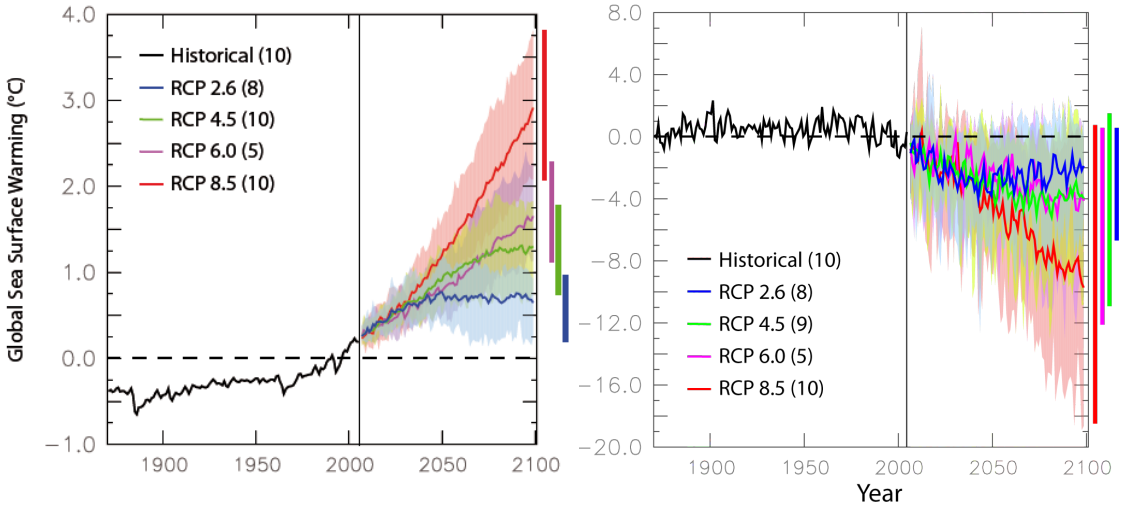
Split in **major func./tax. groups**

α-diversity = f(Temp, Chl, …)

e.g., Copepods
Projected change in α-diversity



Climate Models : temperature & Chlorophyll

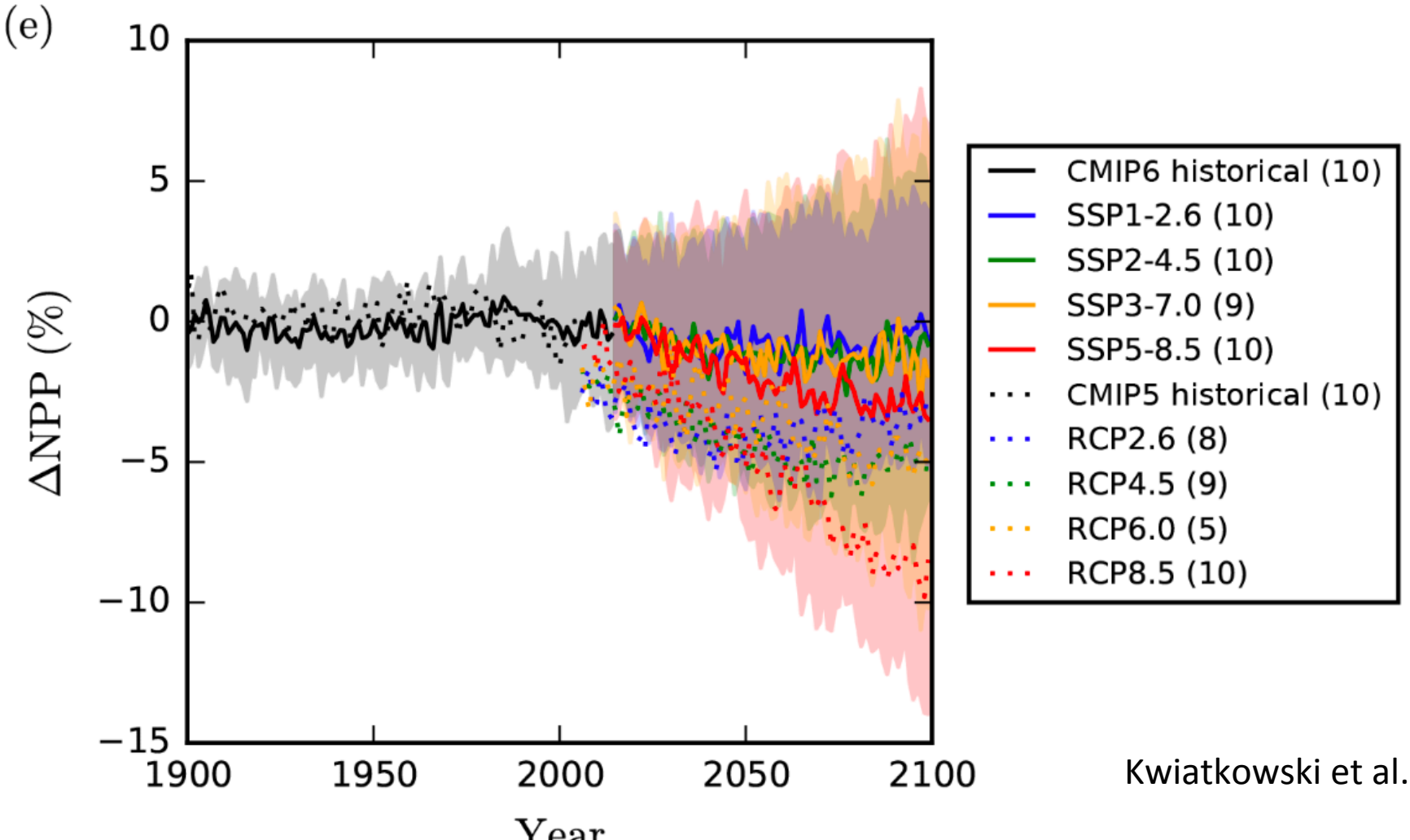


Ibarbalz et al., Cell, 2019

From CMIP5 to CMIP6…

Large increase in projected NPP uncertainties

→ "… *low confidence* in the projected global decline in net primary production" (IPCC AR6 Chap3, 2022)



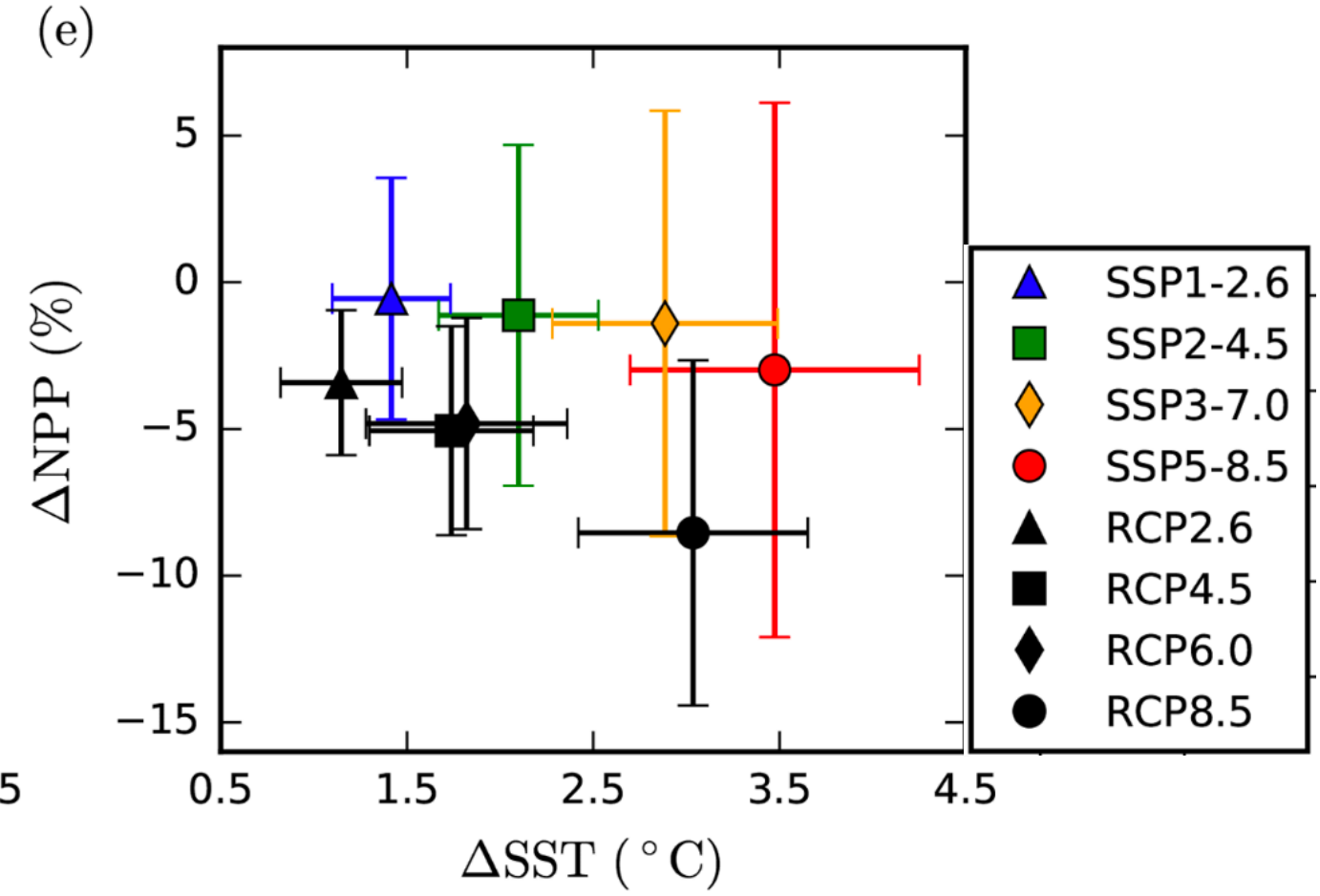
Kwiatkowski et al. 2020

From CMIP5 to CMIP6…

NPP changes (2090 vs 1880) for similar high-emission scenario :

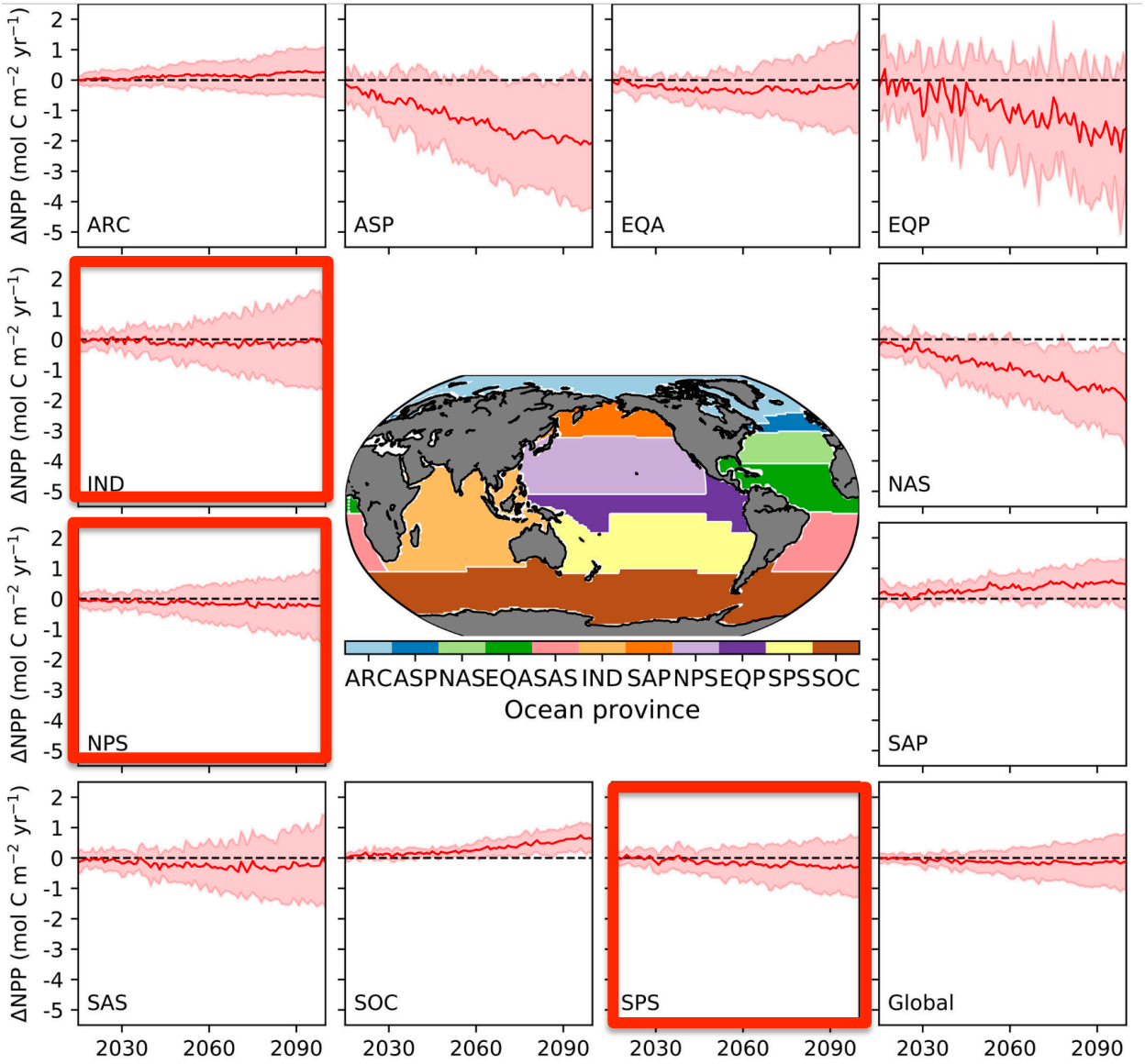
CMIP5 - RCP8.5 : **ΔNPP at −8.5 ± 5.9 %**

CMIP6 - SSP5-8.5 : **ΔNPP at −3.0 ± 9.1 %**



Kwiatkowski et al. 2020

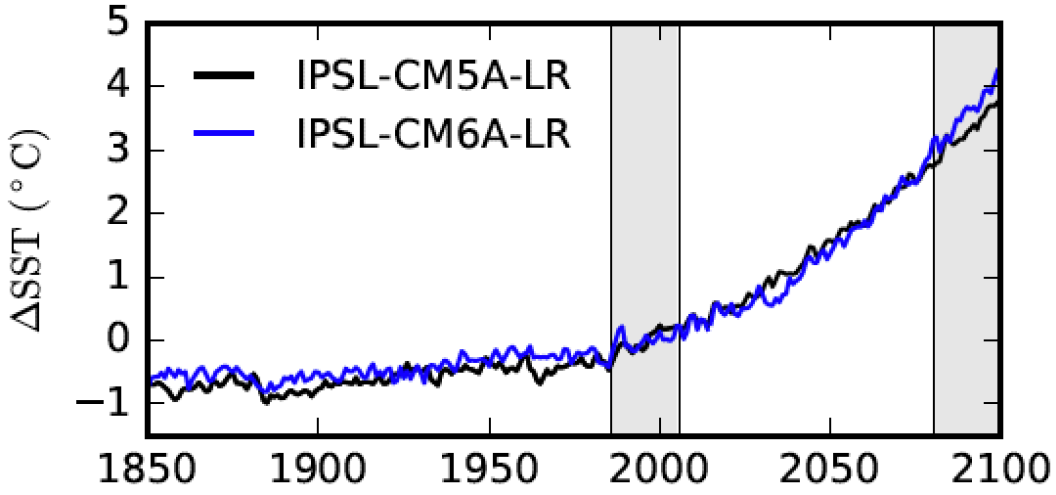
NPP Projections from CMIP6 : Regions



Large uncertainty most notably in the Indian-Pacific (tropics / subtropics)

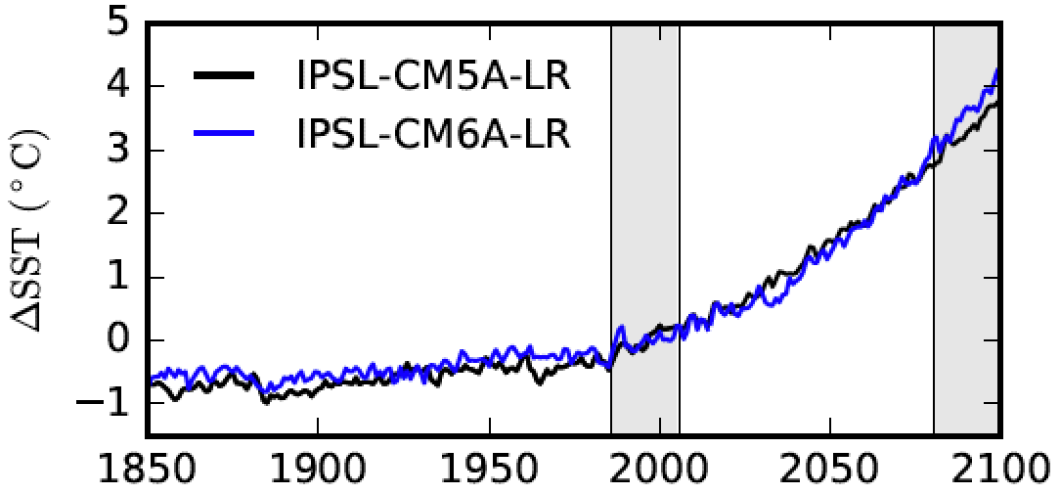
Tagliabue et al. 2021

From CMIP5 to CMIP6… with IPSL-CM

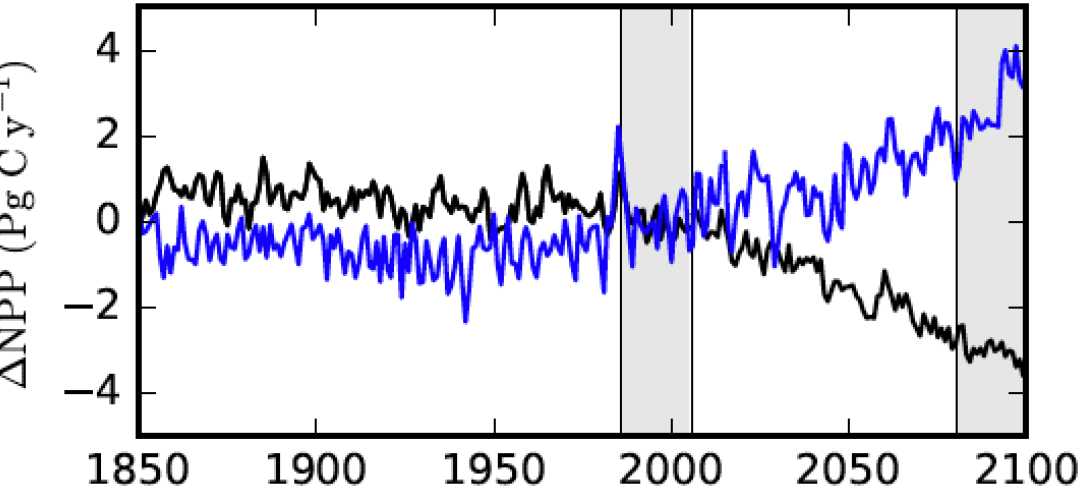


Similar Warming for :
IPSL-CM5A-LR under RCP8.5
& IPSL-CM6A-LR under SSP585

From CMIP5 to CMIP6… with IPSL-CM



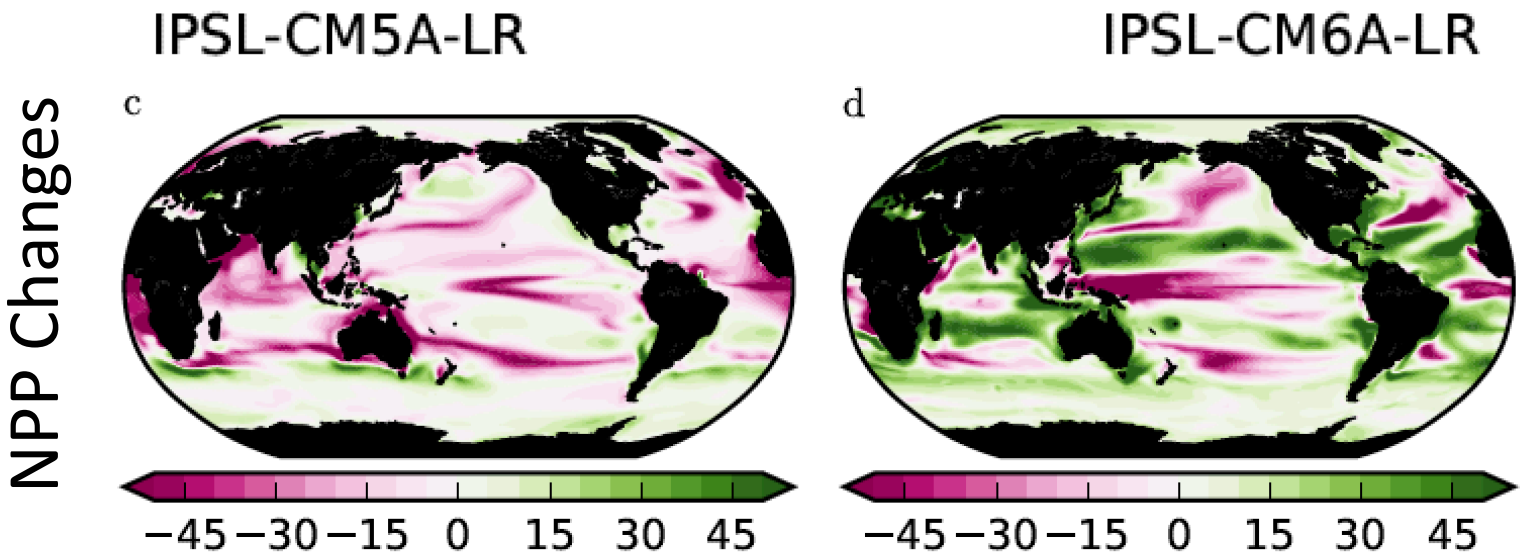
Similar Warming for :
IPSL-CM5A-LR under RCP8.5
& IPSL-CM6A-LR under SSP585



But very different NPP !
IPSL-CM5A-LR : -10%
IPSL-CM6A-LR : +10%

Bopp et al. 2022

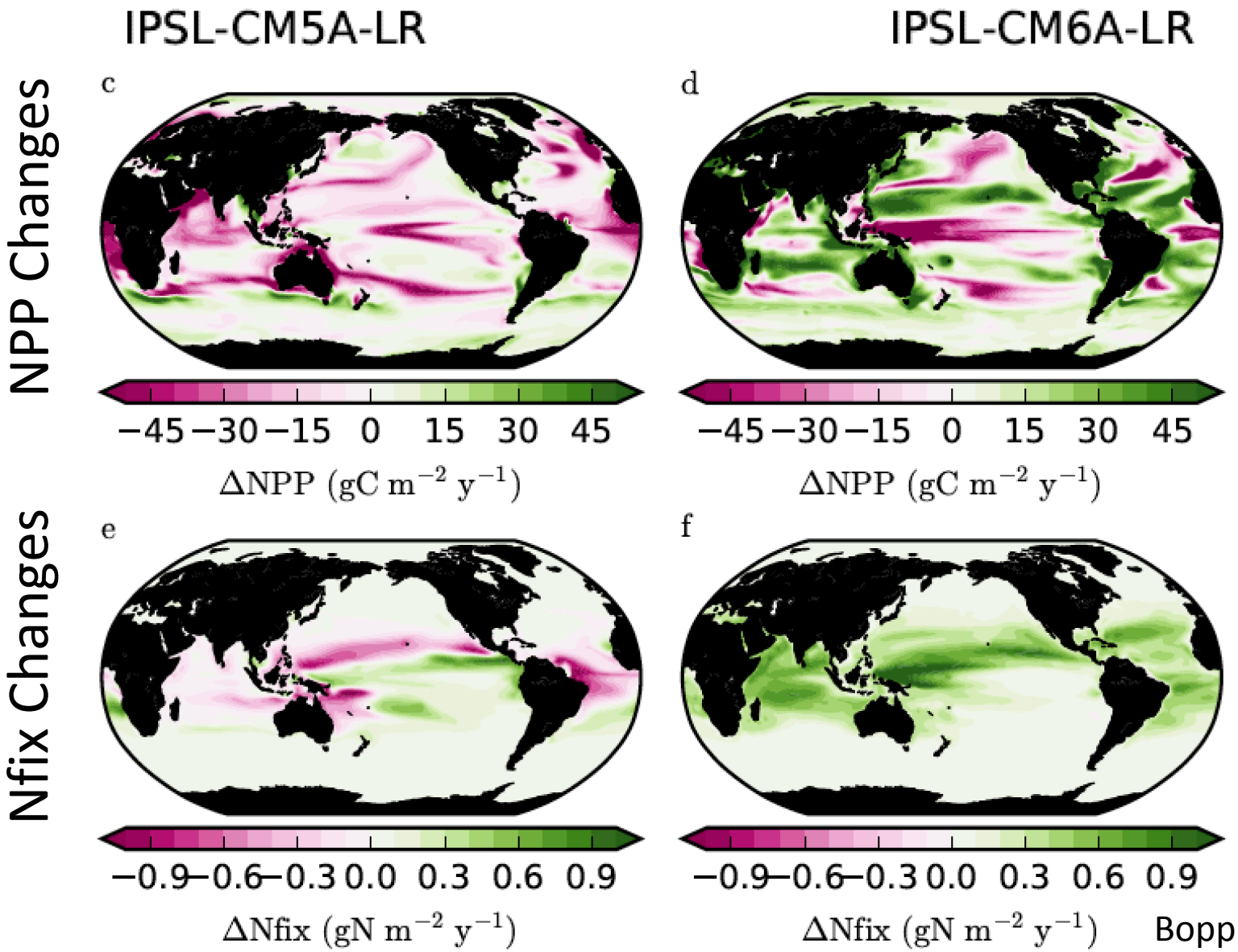
From CMIP5 to CMIP6… with IPSL-CM



→ Major differences in subtropical gyres

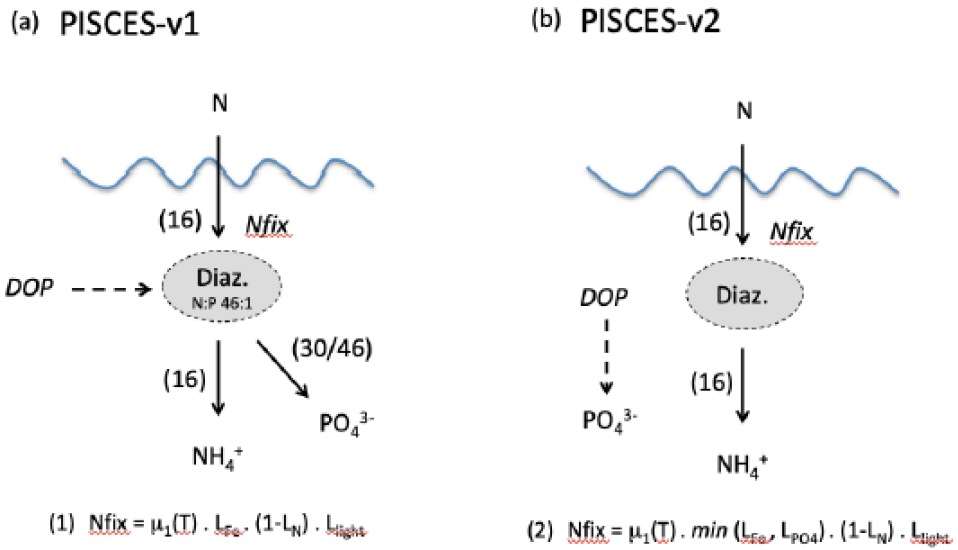
→ More or less similar at high lat and at the eq.

From CMIP5 to CMIP6… with IPSL-CM

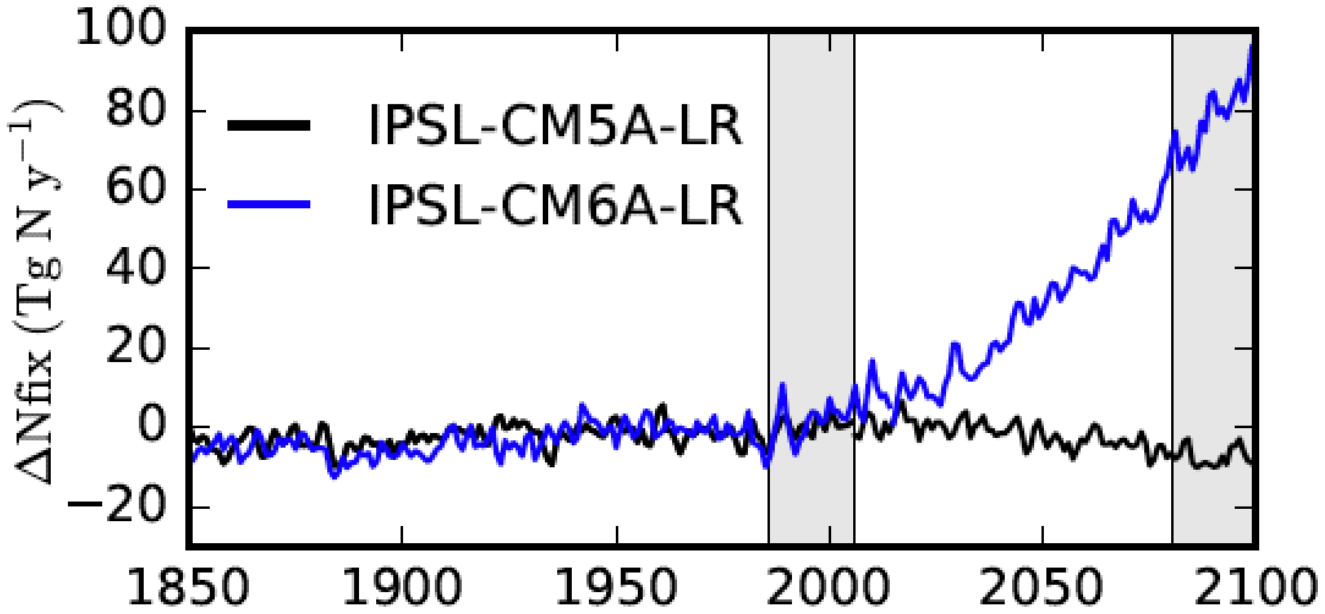


Bopp et al. 2022

From CMIP5 to CMIP6… role of N-fixation

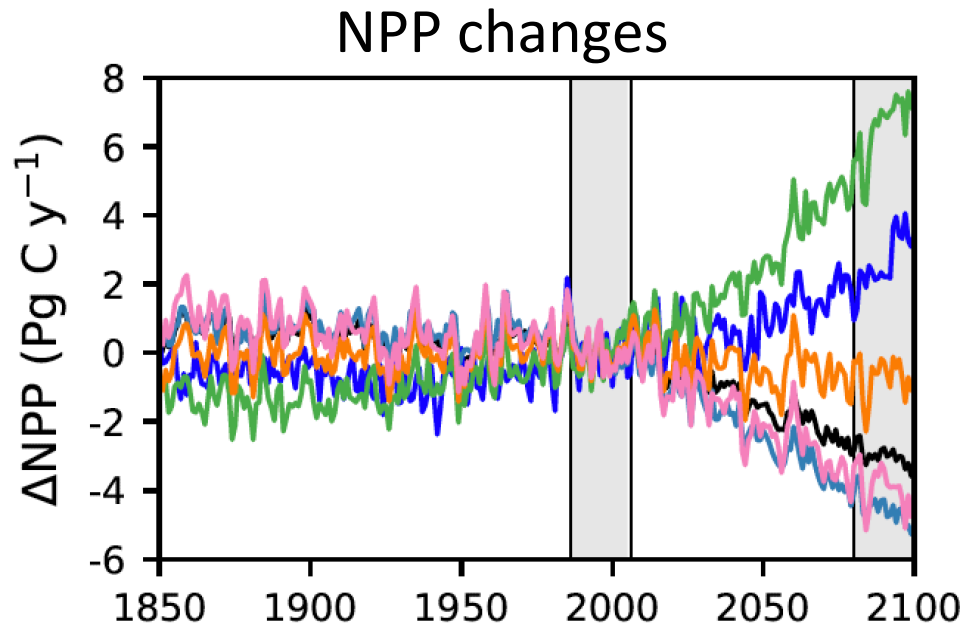


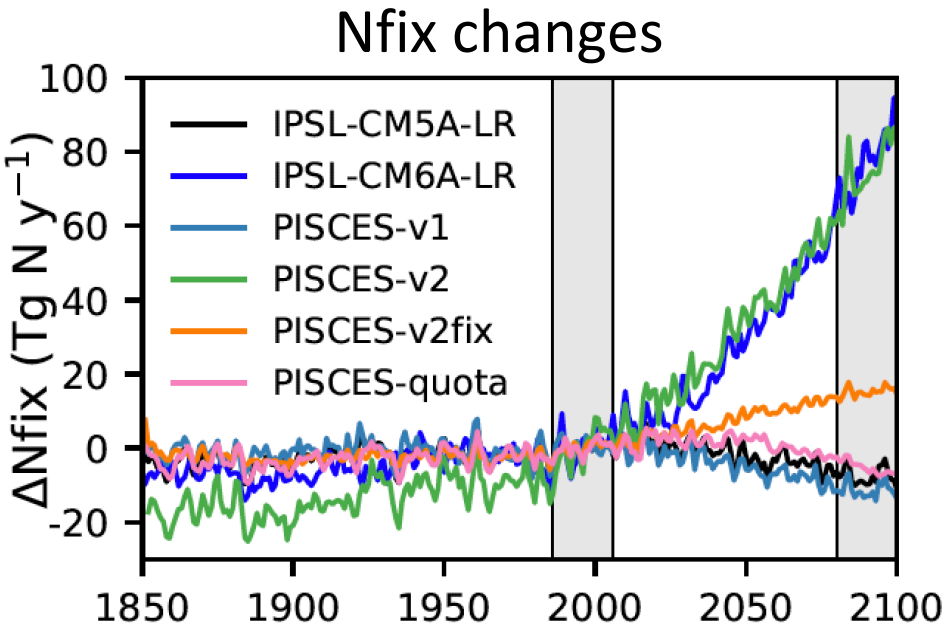
Nfix Changes



Exploring N-fixation responses

Offline simulations with 4 different PISCES versions
Using the same physical forcing
(RCP8.5, IPSL-CM5A-LR)





Bopp et al. 2022

Exploring N-fixation responses - Implications

→ Differences in N-fix parameterization result in divergent NPP responses

→ Most advanced version (PISCES-quota) suggests **moderate Nfix changes**, and slight decrease in NPP,
but **comparison to observations** does not discriminate btw versions

→Despite very contrasting trends in NPP
(1) less divergent export changes
(2) similar and significant reductions in planktonic biomass

(see Bopp et al. Biogeosciences in press)

Conclusions / Perspectives

Persistent Uncertainties in Ocean NPP under climate change…

(1) Identifiying the processes at stake

(e.g. N-fixation)

(2) Estimating how NPP uncertainties project onto other variables

(e.g. plankton biomass)

(3) Constraining Projections using observations

(e.g. emergent constraint)

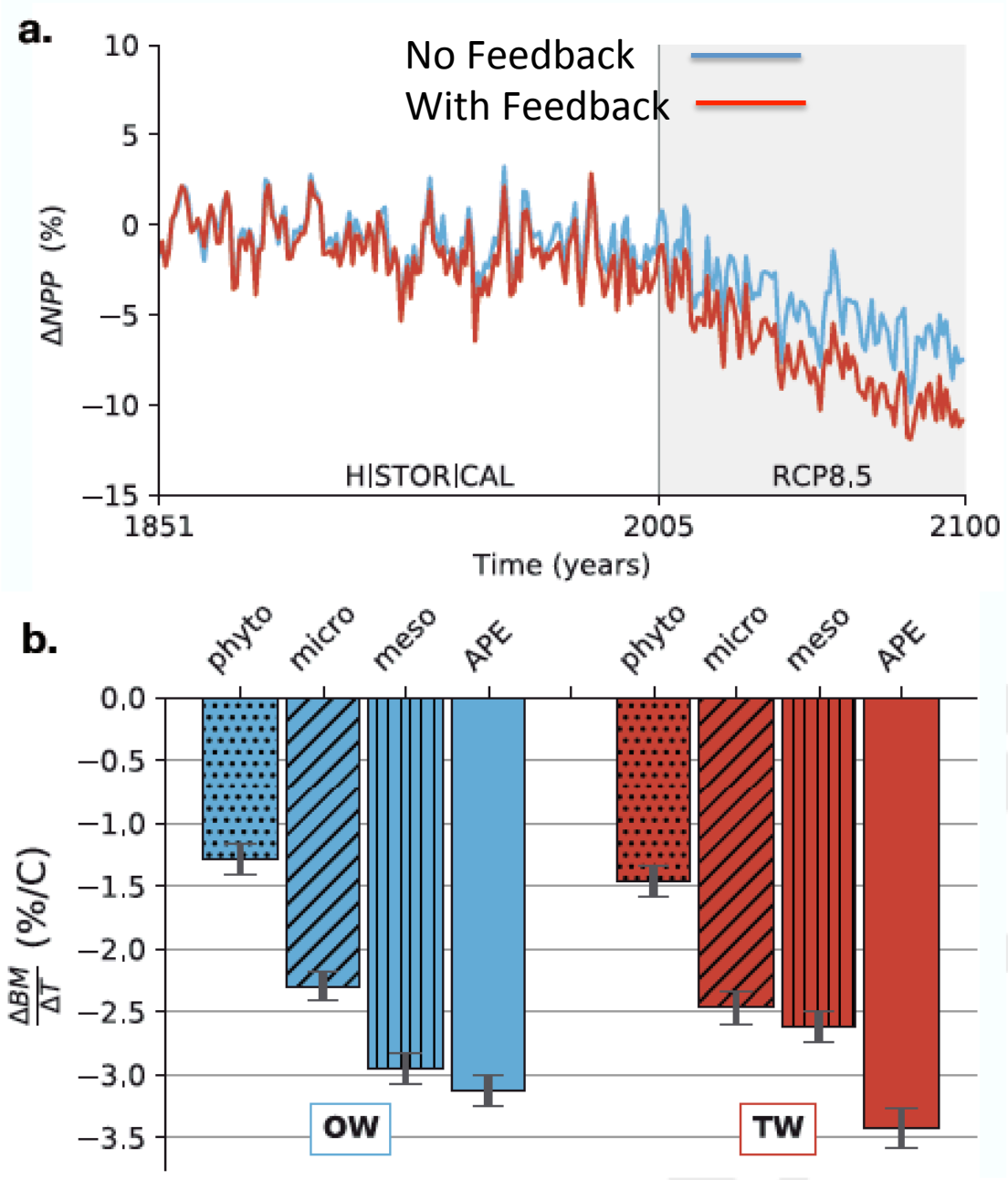
(4) and exploring non-represented mechanisms / processes

(e.g. coupling to higher trophic levels)

High trophic level feedbacks on ocean NPP

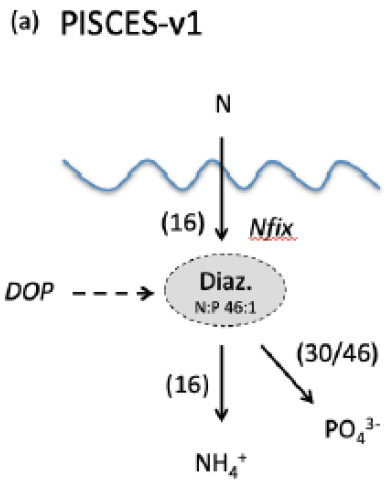
- Biogeochemical Model coupled two-ways to an upper trophic level model (PISCES-APECOSM)
- Climate change projections using two-way and one-way versions

- Results show signigicant impact on NPP (few %)
- Due to top-dow effect from high-trophic levels

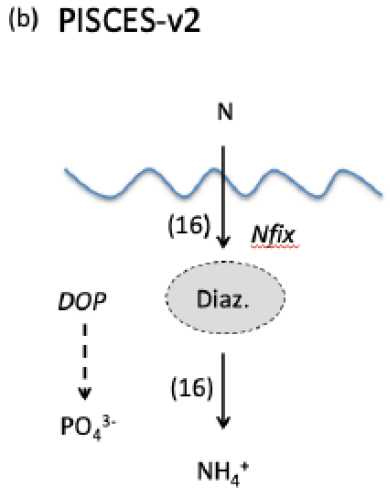


Dupont, Le Mezo et al. Submitted

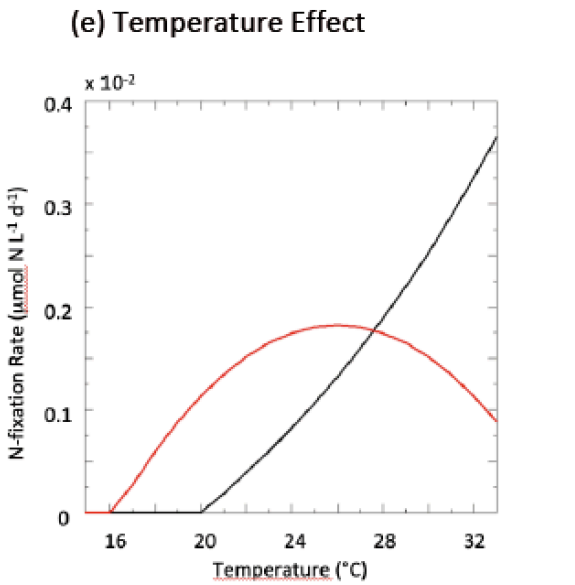
Exploring N-fixation responses



(1) $Nfix = \mu_1(T) \cdot L_{Fe} \cdot (1-L_N) \cdot L_{light}$

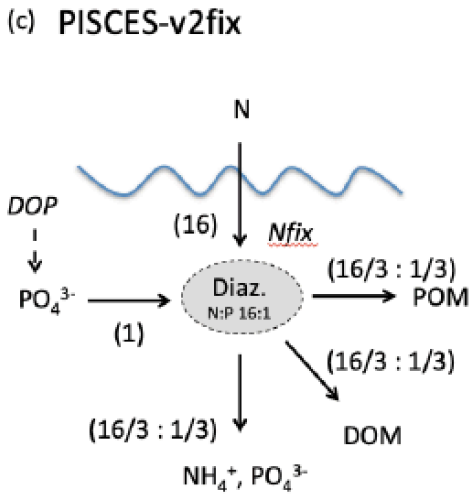


(2) $Nfix = \mu_1(T) \cdot min\,(L_{Fe}, L_{PO4}) \cdot (1-L_N) \cdot L_{light}$

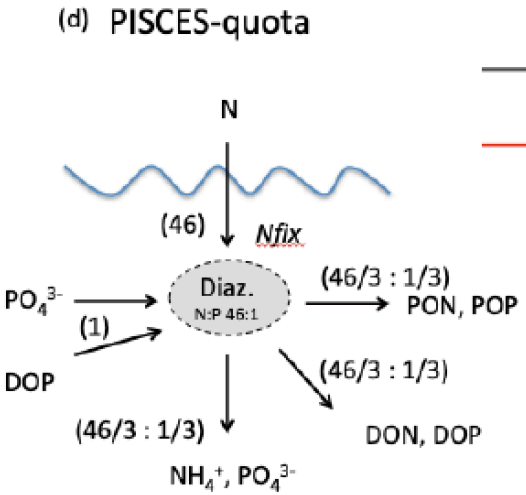


$\mu_1 = 0.08\ 10^{-2}\ max(0., 0.6\,(1.066^T - 2.15))$

$\mu_2 = 1.75\ 10^{-2}\ max(0., -0.001096\,T^2 + 0.057\,T - 0.637)$
(Breitbarth et al. 2007)



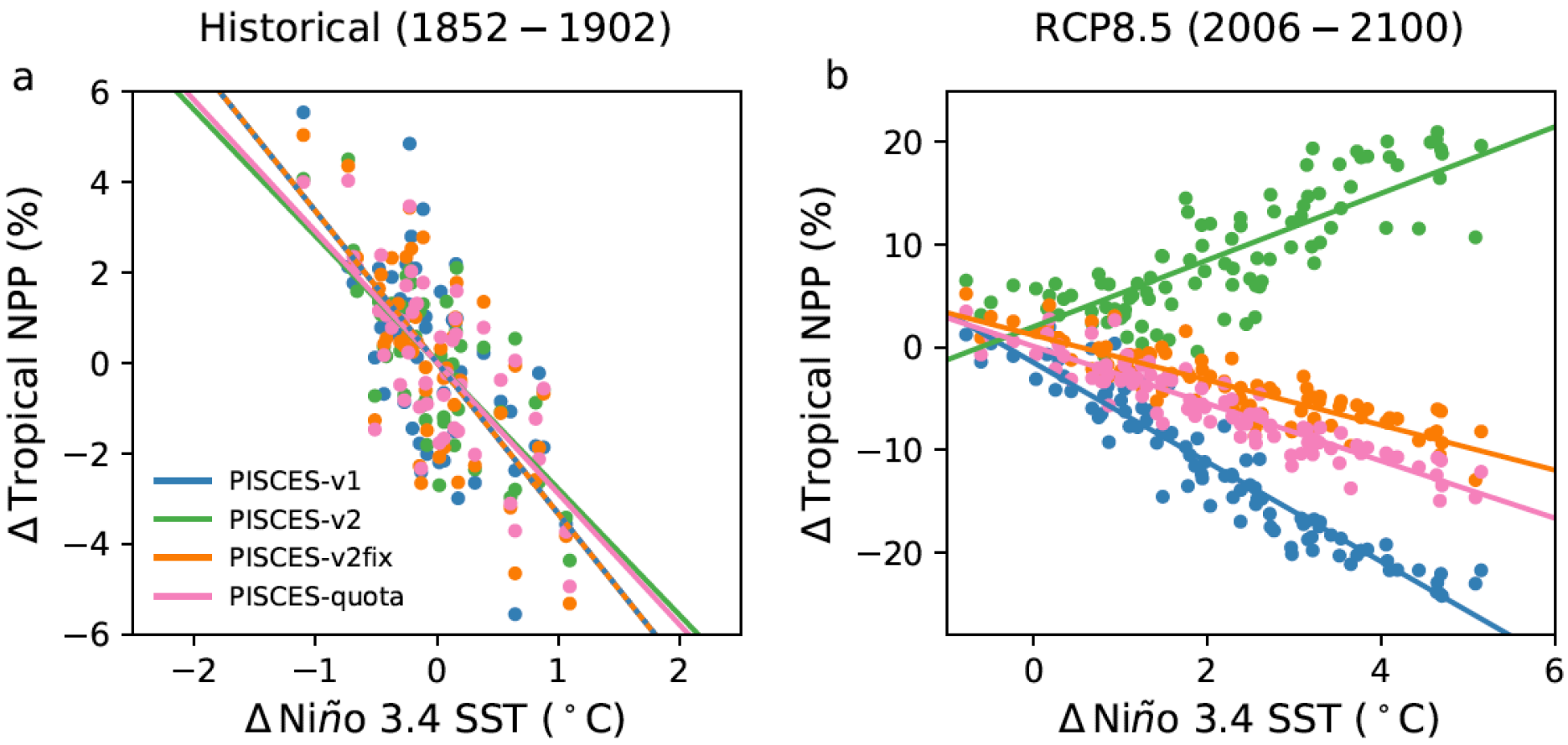
(3) $Nfix = \mu_2(T) \cdot min\,(L_{Fe}, L_{PO4}) \cdot (1-L_N) \cdot L_{light}$



(4) $Nfix = \mu_2(T) \cdot min\,(L_{Fe}, L_{PO4,DOP}) \cdot (1-L_N) \cdot L_{light}$

Which version should we trust?

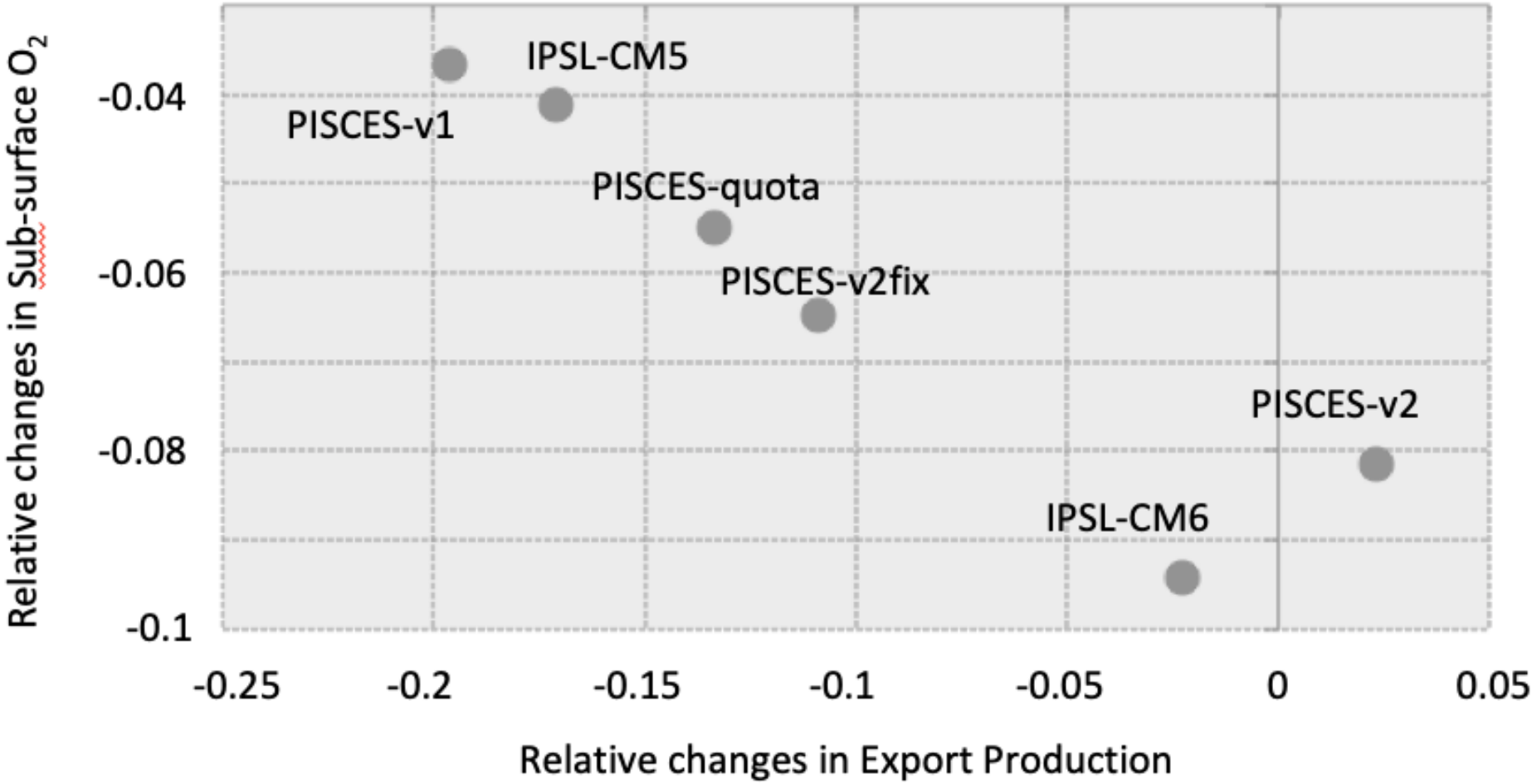
2. Emergent Constraint ?



→ Not conclusive….as emergent constraint does not hold

Which version should we trust?

3. Implications − export and dexoygenation



Which version should we trust?

3. Implications − plankton biomasses

Model Version	Phyto biomass (TgC)	Zoo biomass (TgC)
PISCES-v1	1031.0 -70.2 (-6.8%)	1160 -203.6 (-17.5%)
PISCES-v2	893.0 -40.0 (-4.5 %)	765.9 -49.2 (-6.4%)
PISCES-v2fix	886.3 -42.4 (-4.8 %)	741.4 -86.7 (-11.7%)
PISCES-quota	826.9 -45.5 (-5.5%)	822.0 -94.5 (-11.5%)

→ Much less differrence for changes in plankton biomasses…