Oceanic iron cycle change and its impact on marine productivity in the 21st century: a projection using CESM1

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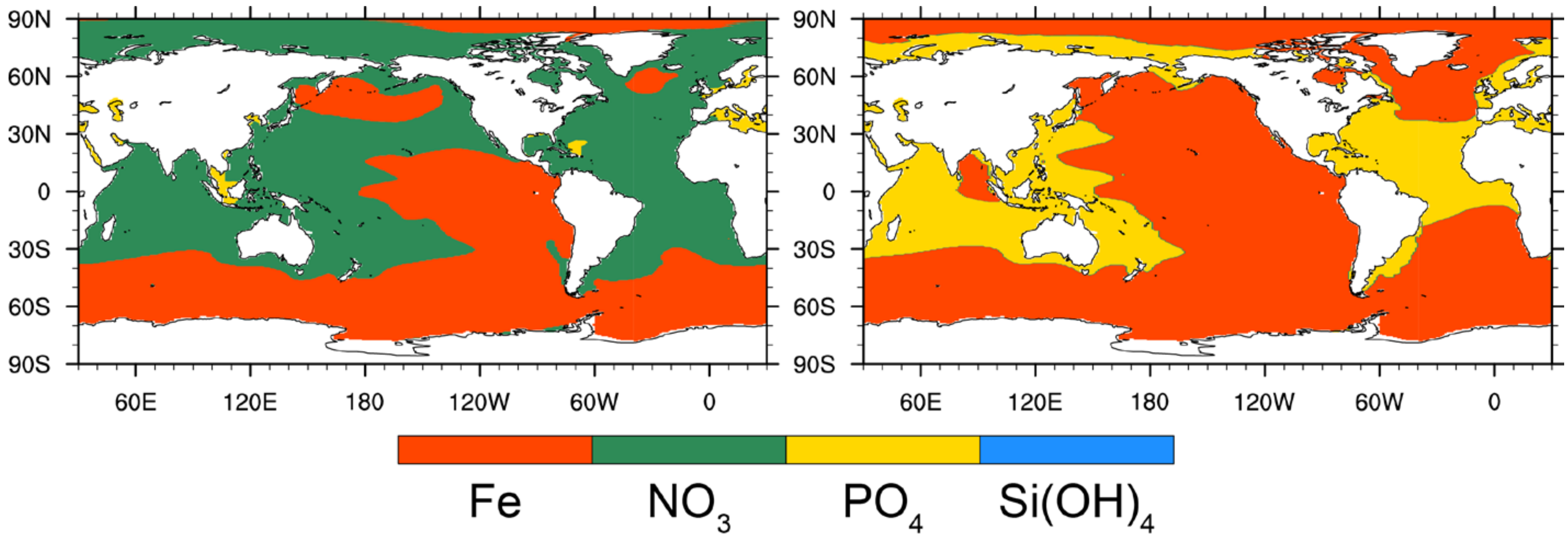
CESM BGCWG Meeting on Mar. 1st 2012 at NCAR

Importance of Iron

Spatial distribution of limiting nutrients
for small phytoplankton and diazotrophs (N_2 fixers).



Iron is regarded as a key element
to understand future production change.

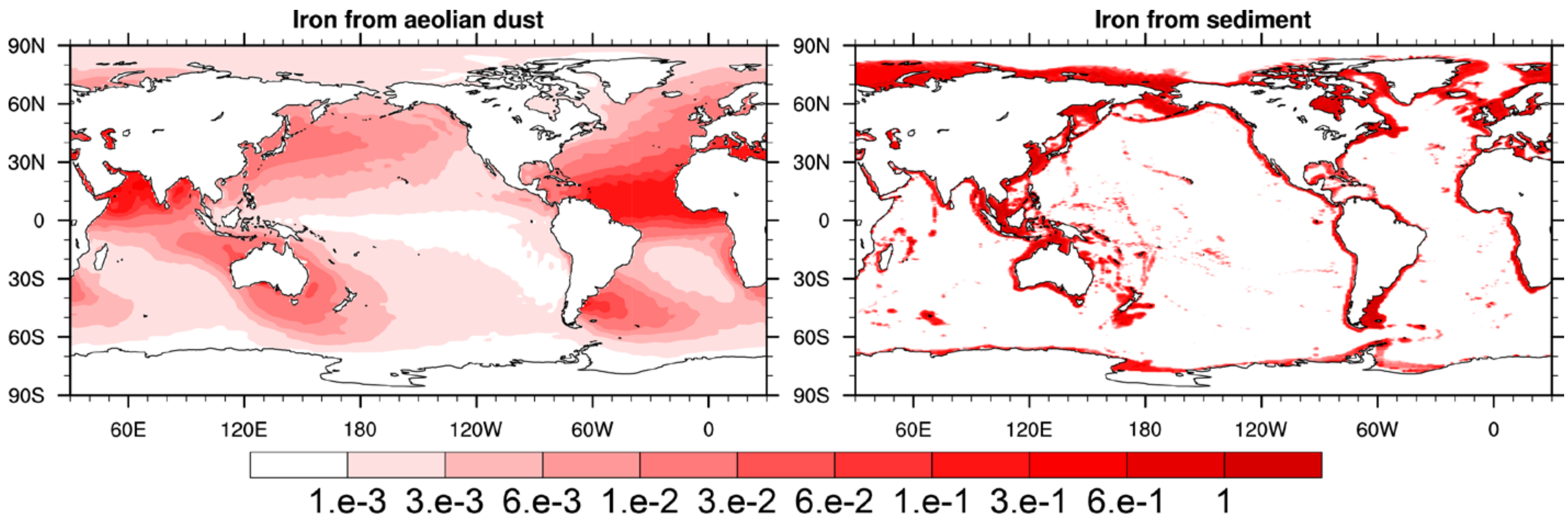
Motivation of this study

- How does iron cycle change in the future climate?
- Does the iron cycle change influence on carbon cycle?
- If it does, then does it work as a positive or negative feedback?
- How large is that?

Data analyzed in this study

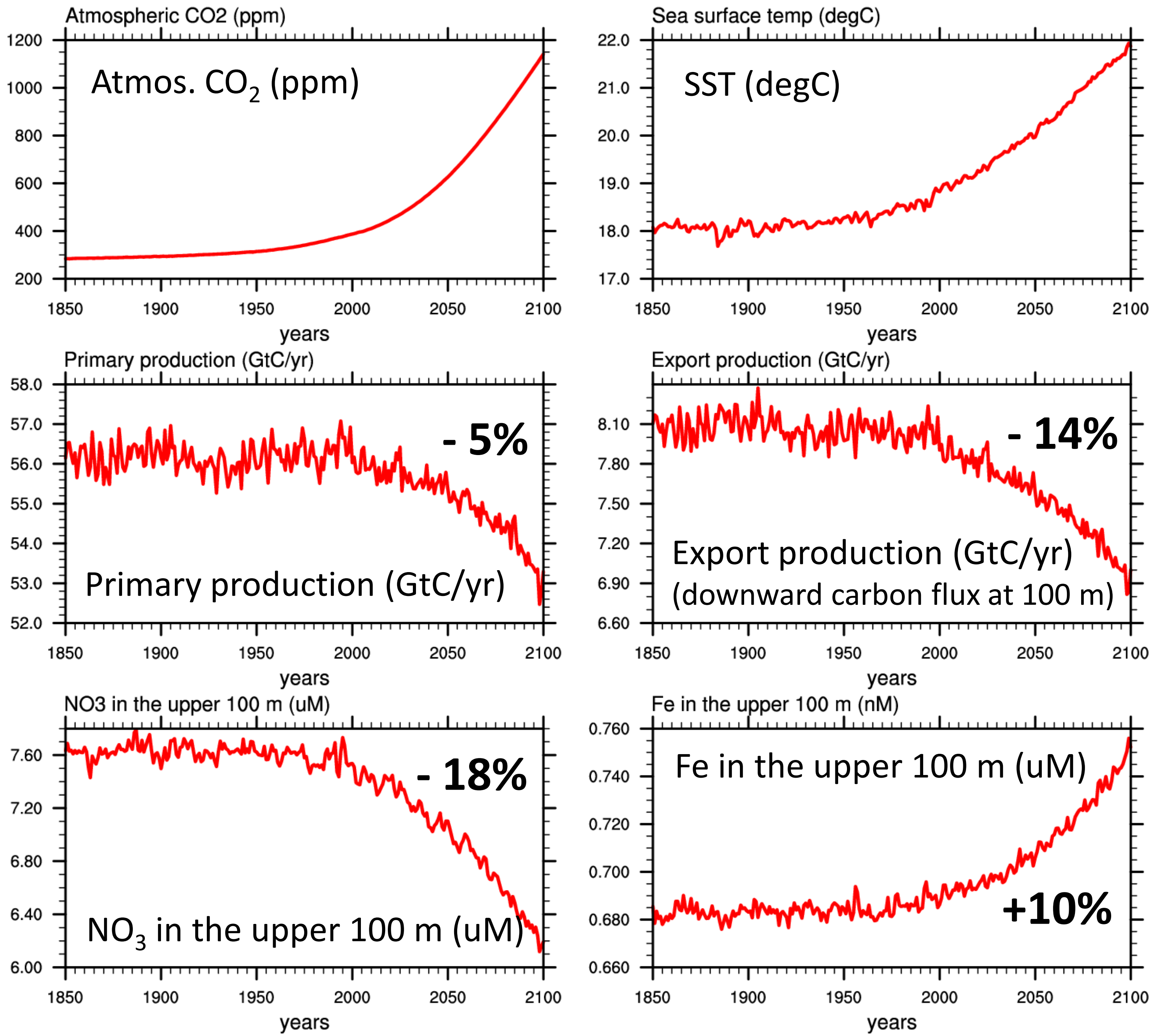
- CESM1, 1 deg.
- RCP8.5, a prognostic carbon cycle case
- The simulated period is from 1850 yr to 2100 yr.
- We mainly discuss climatological difference between late 21C (avg. 2071-2100) and mid 19C (avg. 1850-1879).

External iron forcing

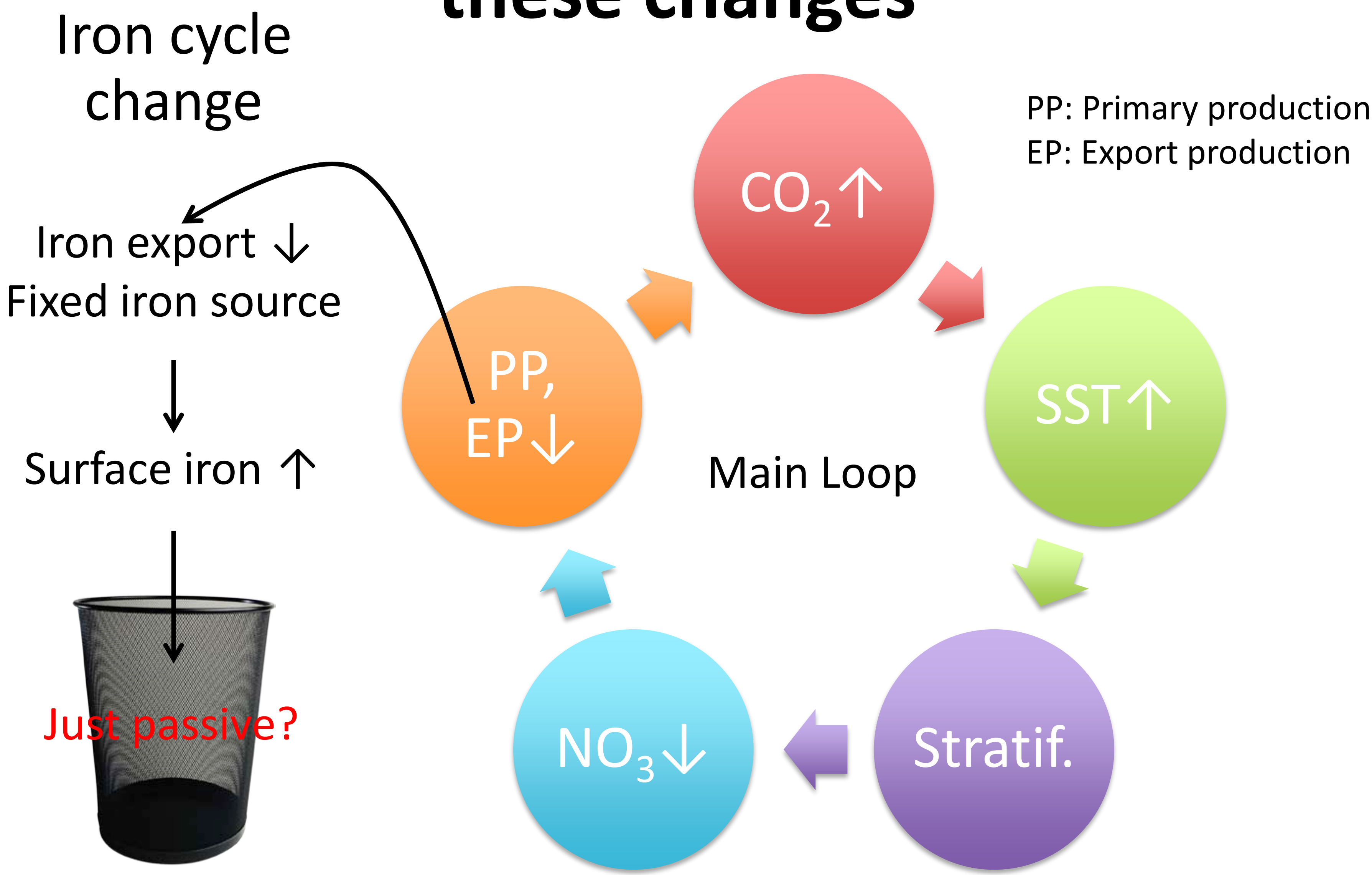


Units are in mmol/m2/yr, iron from sediments is vertically integrated over the upper 1000 m

These external forcing is fixed in this simulation.


Atmospheric CO2 (ppm)
Atmos. CO2 (ppm)
Sea surface temp (degC)
SST (degC)
Primary production (GtC/yr)
- 5%
Primary production (GtC/yr)
Export production (GtC/yr)
- 14%
Export production (GtC/yr)
(downward carbon flux at 100 m)
NO3 in the upper 100 m (uM)
- 18%
NO3 in the upper 100 m (uM)
Fe in the upper 100 m (nM)
Fe in the upper 100 m (uM)
+10%
years

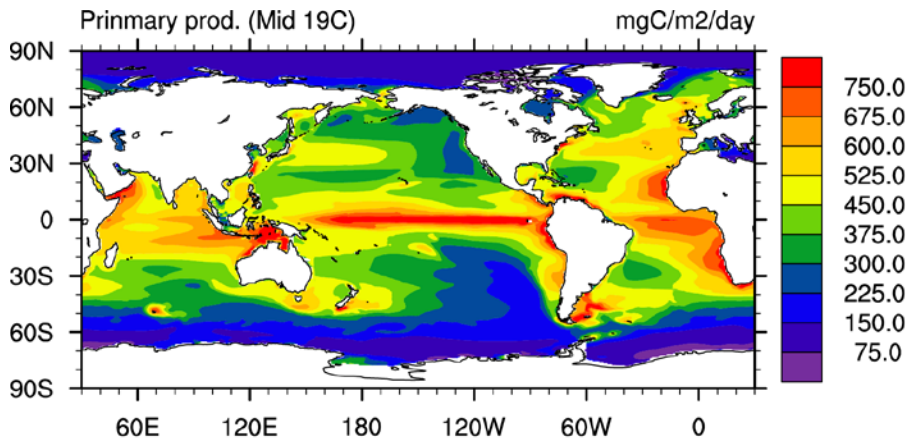
A simple idea explaining these changes



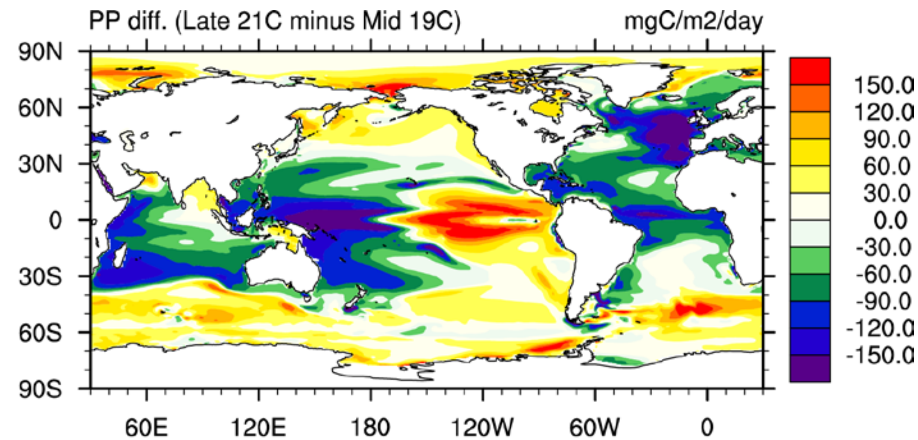
Spatial maps of the productivity and the difference

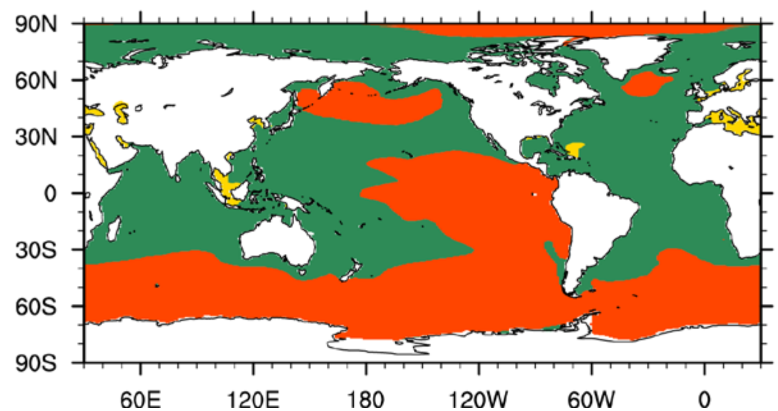
-2.2 GtC/yr

PP in the Mid 19C



PP (Late 21C – Mid 19C)





Iron limitation areas (red)

- The production change is NOT spatially homogeneous.
- Elevated production is observed mainly in the iron limited areas.

Global and Regional sum of the PP and EP change (Late 21C – Mid 19C)

	Global	Iron limited	the other
Primary Production	-2.2	+2.2	-4.4
Export Production	-0.91	+0.19	-1.1

Units are GtC/yr.

The results suggest a possibility that iron cycle change buffers production decrease under the warming condition.

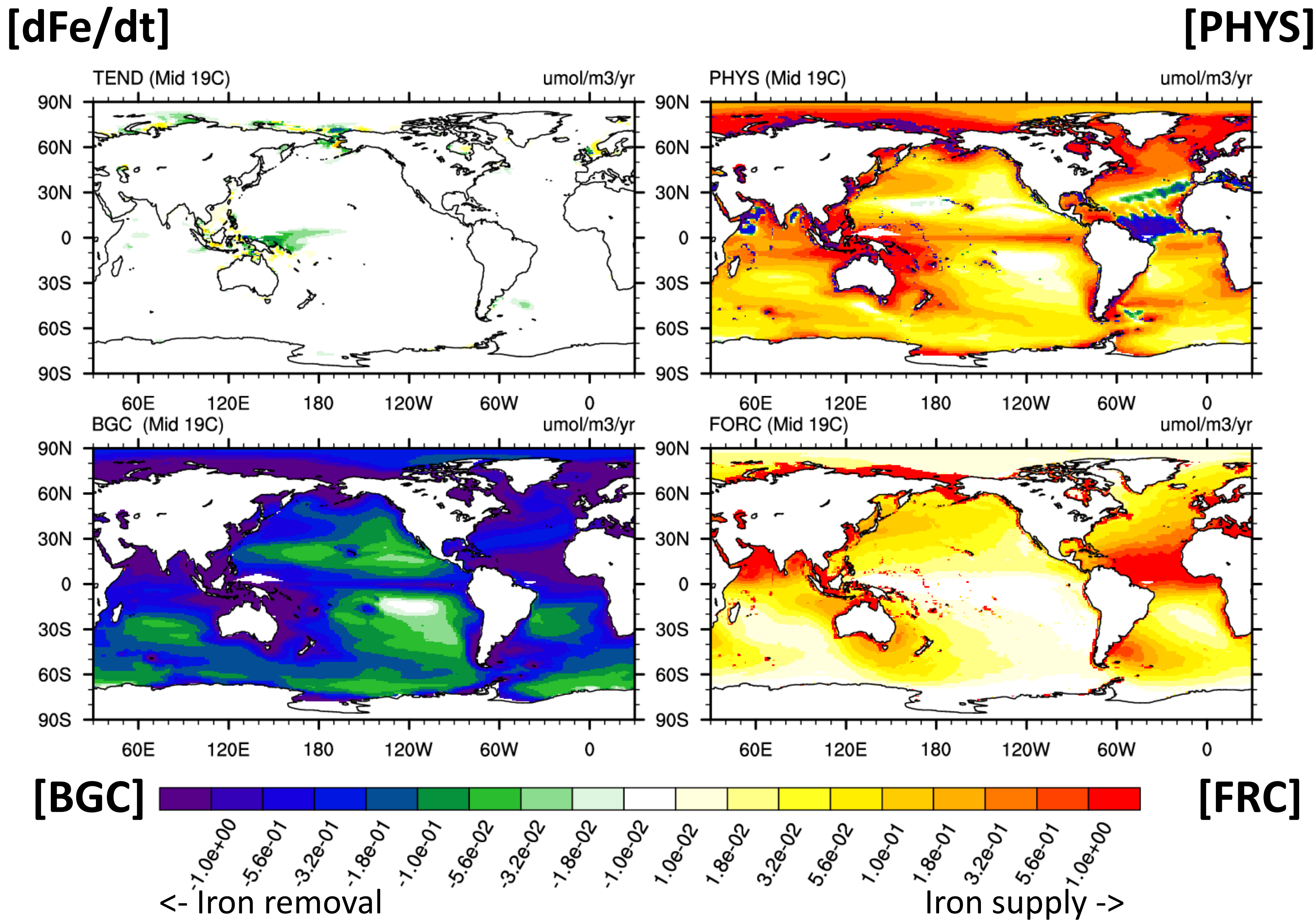
Surface iron budget

$$\left[\frac{\partial Fe}{dt}\right]=[PHYS]+[BGC]+[FRC]$$

[X] represents vertical average in the upper 100 m.

- PHYS: iron transport owing to advection and subgrid-scale mixings
- BGC: iron removal owing to biological uptake and particle scavenging
- FRC: iron supply from the external iron sources

Surface iron budget in the mid 19C.

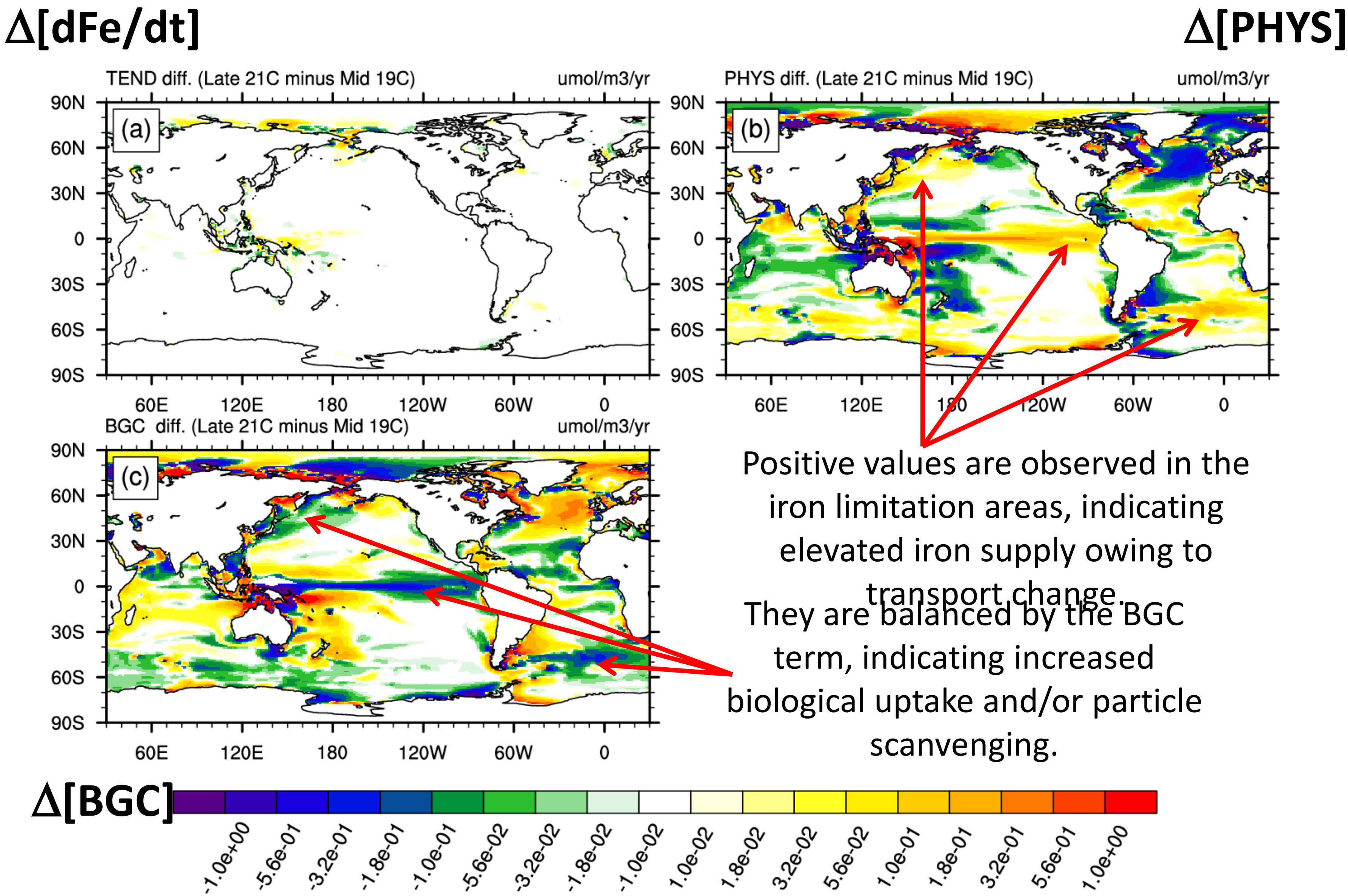


Surface iron budget difference

$$\Delta\left[\frac{\partial Fe}{dt}\right]=\Delta[PHYS]+\Delta[BGC]+\Delta[FRC]$$

[X] represents vertical average in the upper 100 m.
"Δ" represents the difference between Late 21C and Mid 19C.

Surface iron budget difference (late 21C – mid 19C)



Positive values are observed in the iron limitation areas, indicating elevated iron supply owing to transport change.

They are balanced by the BGC term, indicating increased biological uptake and/or particle scanvenging.

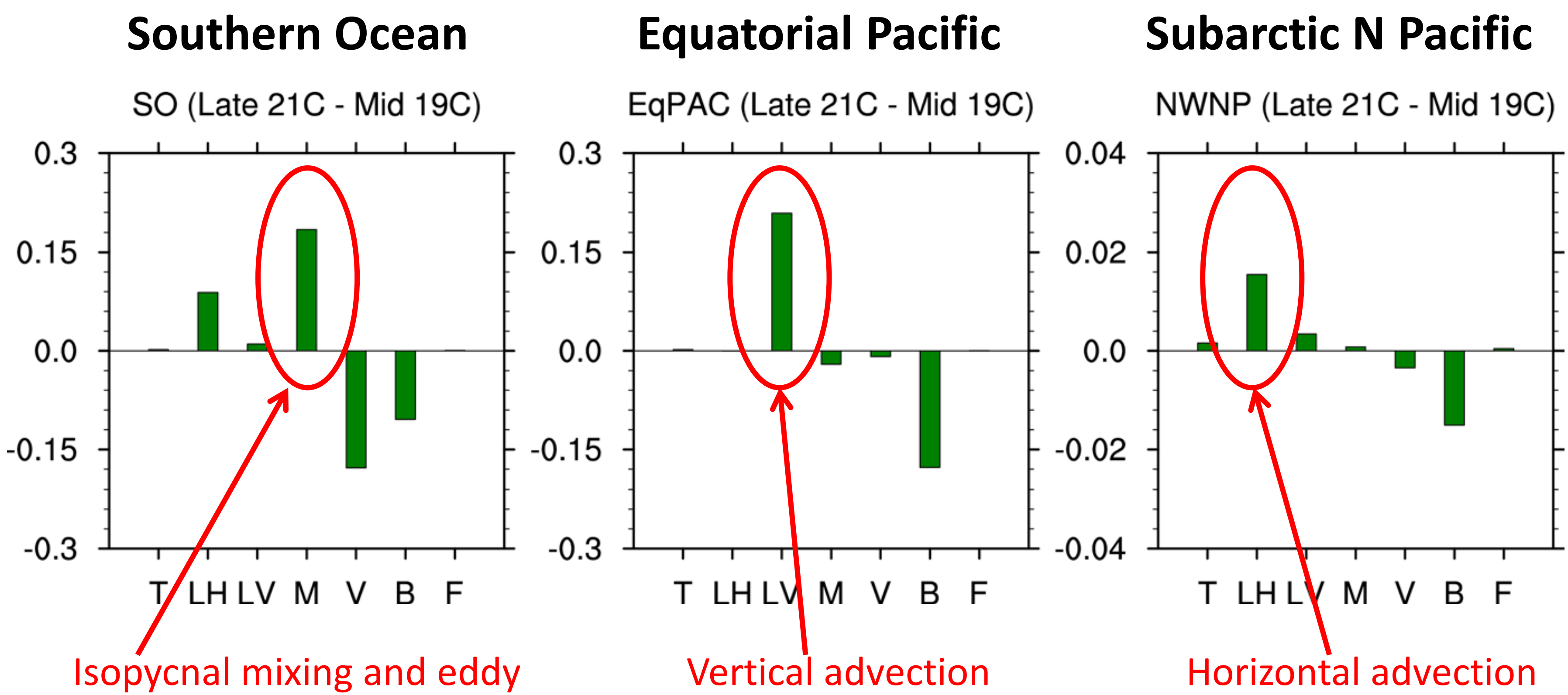
Detailed iron budget change in the iron limitation areas

$$\Delta\left\langle \frac{\partial Fe}{dt} \right\rangle = \Delta\langle LH \rangle + \Delta\langle LV \rangle + \Delta\langle M \rangle + \Delta\langle V \rangle$$

<X> represents horizontal and vertical integral in the upper 100 m of each iron limited area.
"Δ" represents the difference between Late 21C and Mid 19C.

LH: Horizontal advection
LV: Vertical advection
M: Isopycnal mixing and eddy
V: Diapycnal mixing

Difference (Late 21C – Mid 19C) in surface iron budget integrated over the iron limited areas



Units are GmolFe/yr.

Summary of iron cycle change

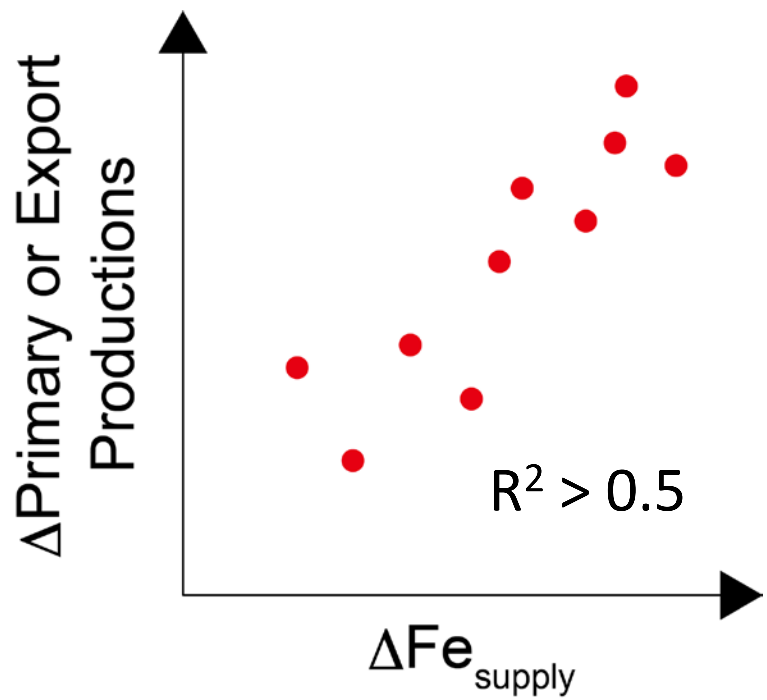
- Iron supply to the surface waters of the iron limited areas is elevated (0.3 GmolFe/yr).
- Major controls of the elevated iron supply are different in each area.
  - Southern Ocean: subgrid-scale mixing
  - Equatorial Pacific: vertical advection
  - Subarctic N Pacific: horizontal mixing

The intensified iron supply probably contributes to the increased production in the iron limited area.

Impact of the iron cycle change on carbon cycle

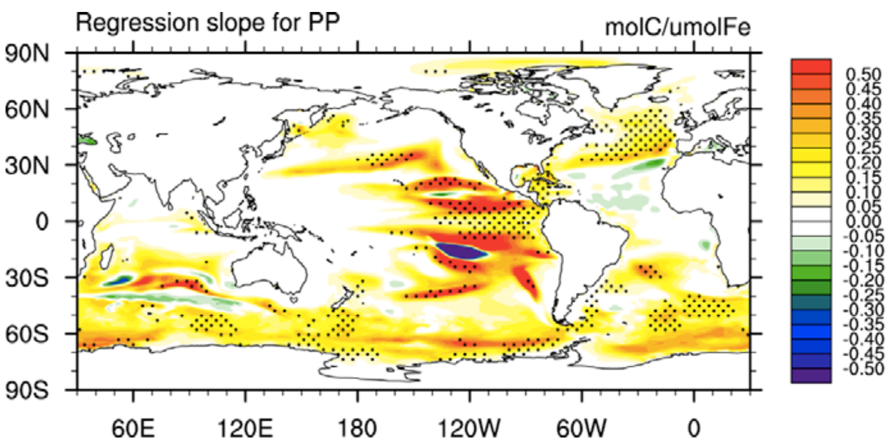
Even in the iron limited areas, productivity can be increased by other factors: alleviation of light and temperature conditions.

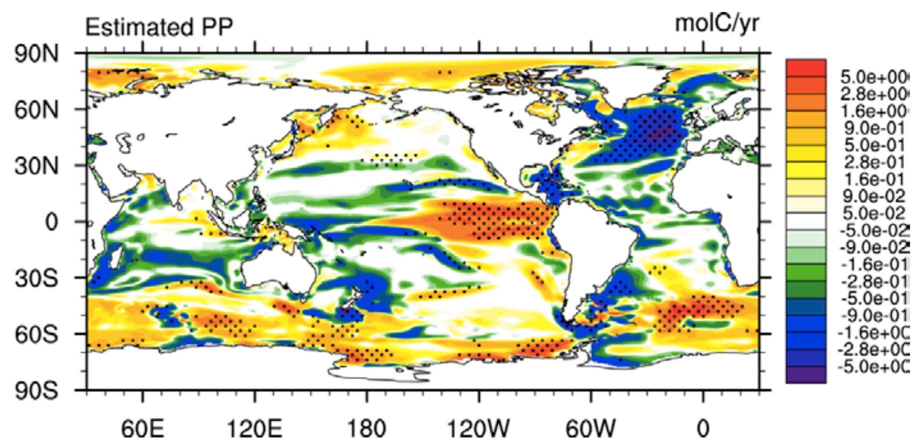
Iron driven areas



dPP/dFe$_{supply}$
(dots:R^2>0.5)

ΔPP (molC/yr)





ΔPP$_{byFe}$: PP change driven by iron cycle change

Integrate ΔPP over the dotted areas only within the iron limited areas.

Global and Regional sum of the PP and EP change (Late 21C – Mid 19C)

	Global	Iron limited	the other
Primary Production	-2.2	+2.2 (+0.55)	-4.4
Export Production	-0.91	+0.19 (+0.09)	-1.1

Units are GtC/yr.

(X) represents ΔPP_{byFe} and ΔEP_{byFe}.

Iron cycle change buffers
the production decrease in this simulation.

Summary

- We analyzed results of a RCP8.5 run simulated by the CESM1.
- Although the simulated marine productivity decreases in the global scale, it increases in the iron limited areas (ΔPP: 2.2 GtC/yr, ΔEP: 0.19 GtC/yr).
- Parts of the production increase is driven by elevated iron supply to the iron limited area (ΔPP_{byFe}: 0.55 GtC/yr, ΔEP_{byFe}: 0.09 GtC/yr).
- Iron cycle change buffers the production decrease in this simulation.