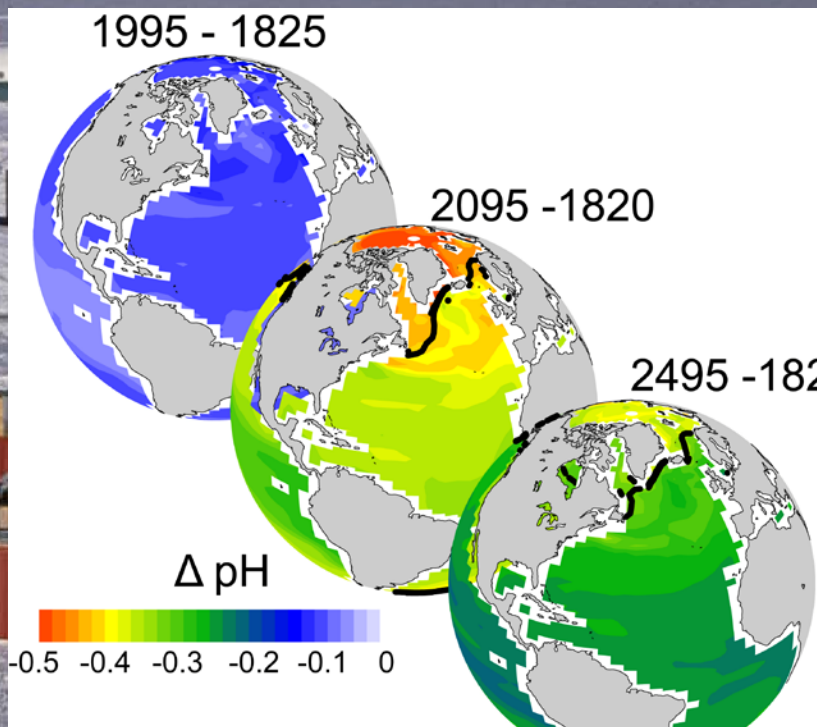# Projected 21st century decrease in marine productivity: a multi-model analysis

M. Steinacher, F. Joos, T.L. Frölicher, L. Bopp, P. Cadule, V. Cocco, S.C. Doney, M. Gehlen, K. Lindsay, J.K. Moore, B. Schneider, J. Segschneider

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Steinacher et al., Biogeosciences, 2010

How does marine net primary productivity change under global warming?

What are the underlying mechanisms of change?

How to combine information from several models into a quantitative projection?

Experimental Setup

Four different Earth System Models with different
representations of the marine biogeochemical cycle and
marine ecosystems:

- CSM1.4-carbon; simplified marine productivity
formulation
- CCSM3.5; BEC ecosystem model
- IPSL-CM4-LOOP; PISCES ecosystem model
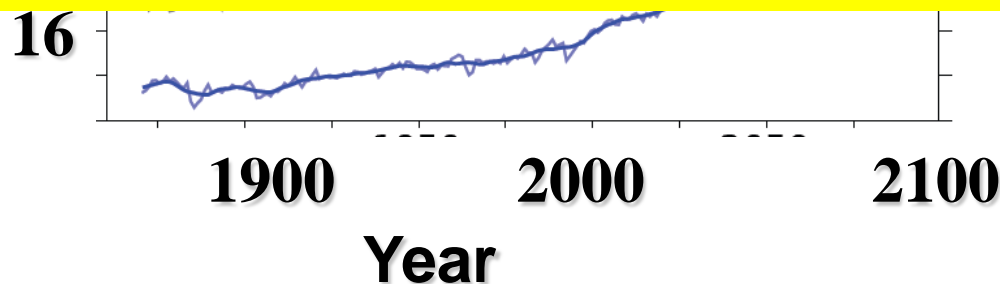- ECHAM5-MPIOM; HAMOCC5.1 ecosystem model

Experiment
- preindustrial spin-up
- historical emissions and following SRES A2

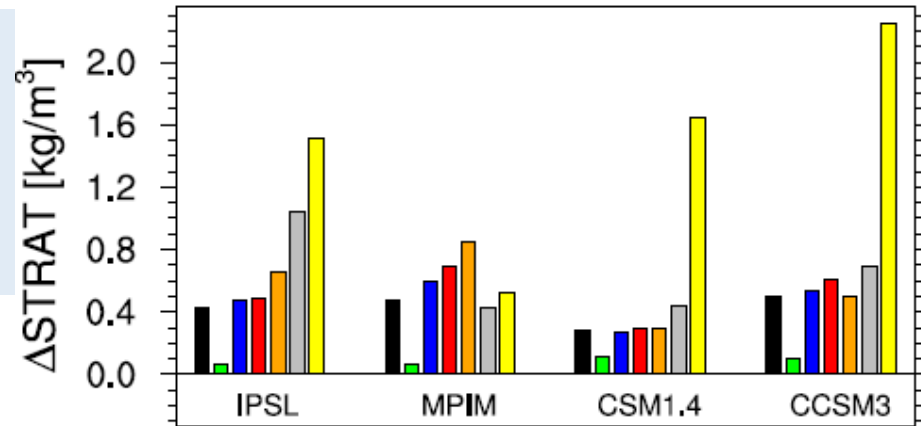# Projected marine net primary productivity and SST
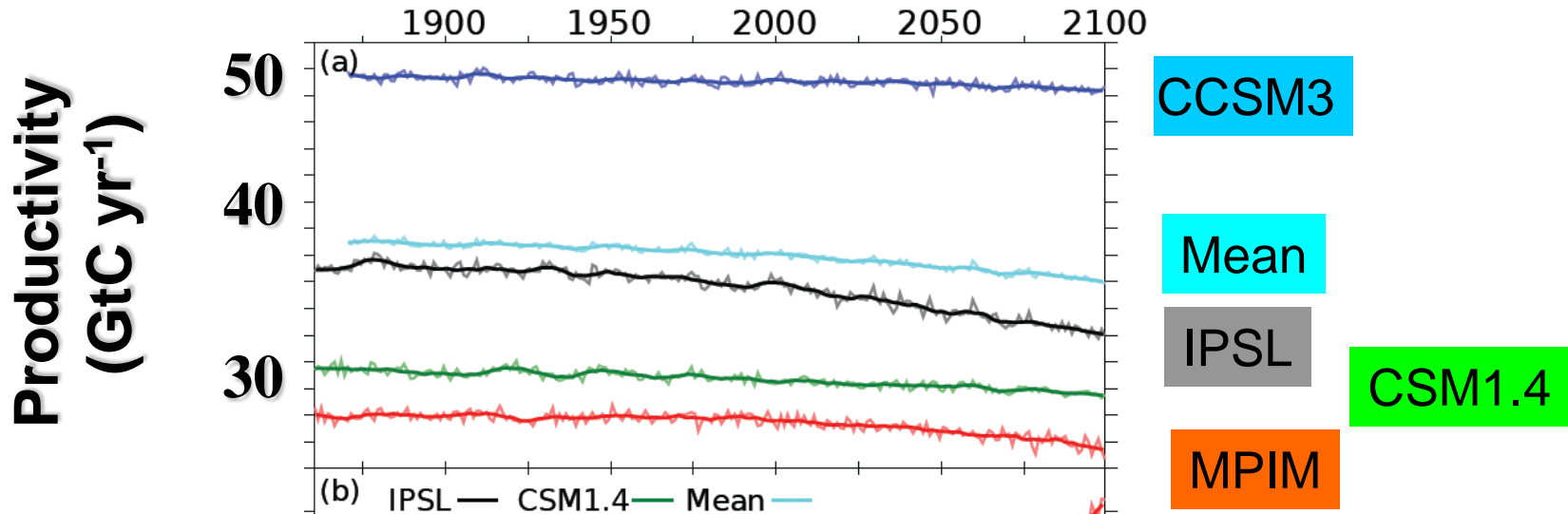
All model project a decrease in global marine net primary productivity between 2% and 20% by 2100

Regional response and dominant mechanisms

enhanced stratification
& reduced MLD,
& slowed circulation

Legend:
- ■ Global (black)
- ■ Southern Ocean (green)
- ■ Permanently stratified ocean (blue)
- ■ 30N-30S global (red)
- ■ 30N-30S Pacific Ocean (orange)
- ■ North Atlantic (grey)
- ■ Arctic Ocean (yellow)

Regional response and dominant mechanism

enhanced stratification

- **Same mechanism operating in all four models in low and mid-latitudes and North Atlantic: enhanced stratification – reduced nutrient input – reduced productivity**

- Different regime in the Arctic and parts of SO: reduced light and T limitation – increased productivity

- Arctic: CSM, CCSM & MPI productivity increase versus increased nutrient limitation and reduced productivity in IPSL


STRAT [kg/m³]

2.0
1.6
1.2
0.8
0.4

.4   CCSM3

.4   CCSM3

-160   IPSL   MPIM   CSM1.4   CCSM3

North Atlantic
Arctic Ocean
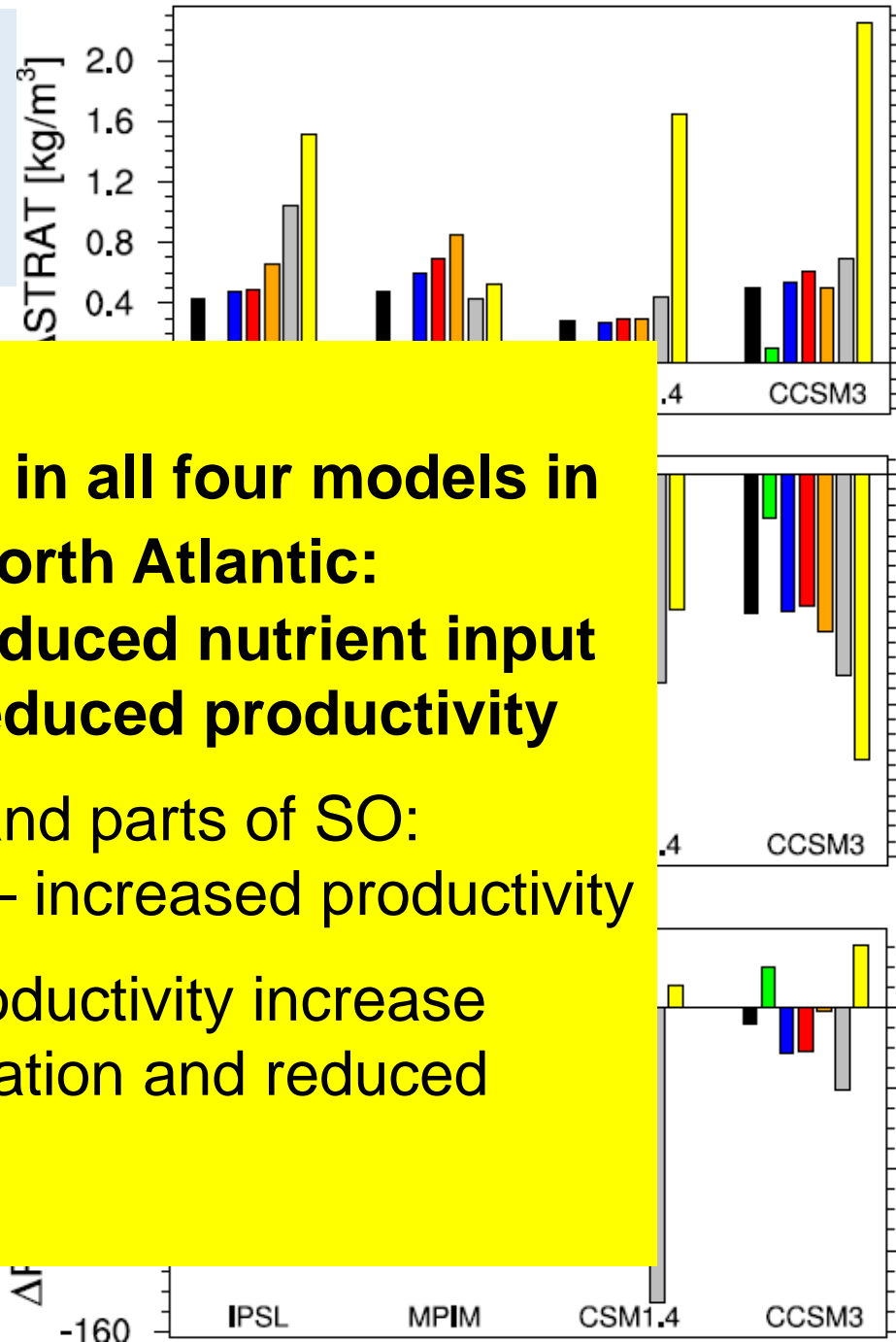
Projected decrease in zonal-mean productivity at almost all latitudes

Year: 2100

IPSL
MPIM
CSM1.4
CCSM3
Mean

ΔProductivity (GtC yr^{-1} deg^{-1})
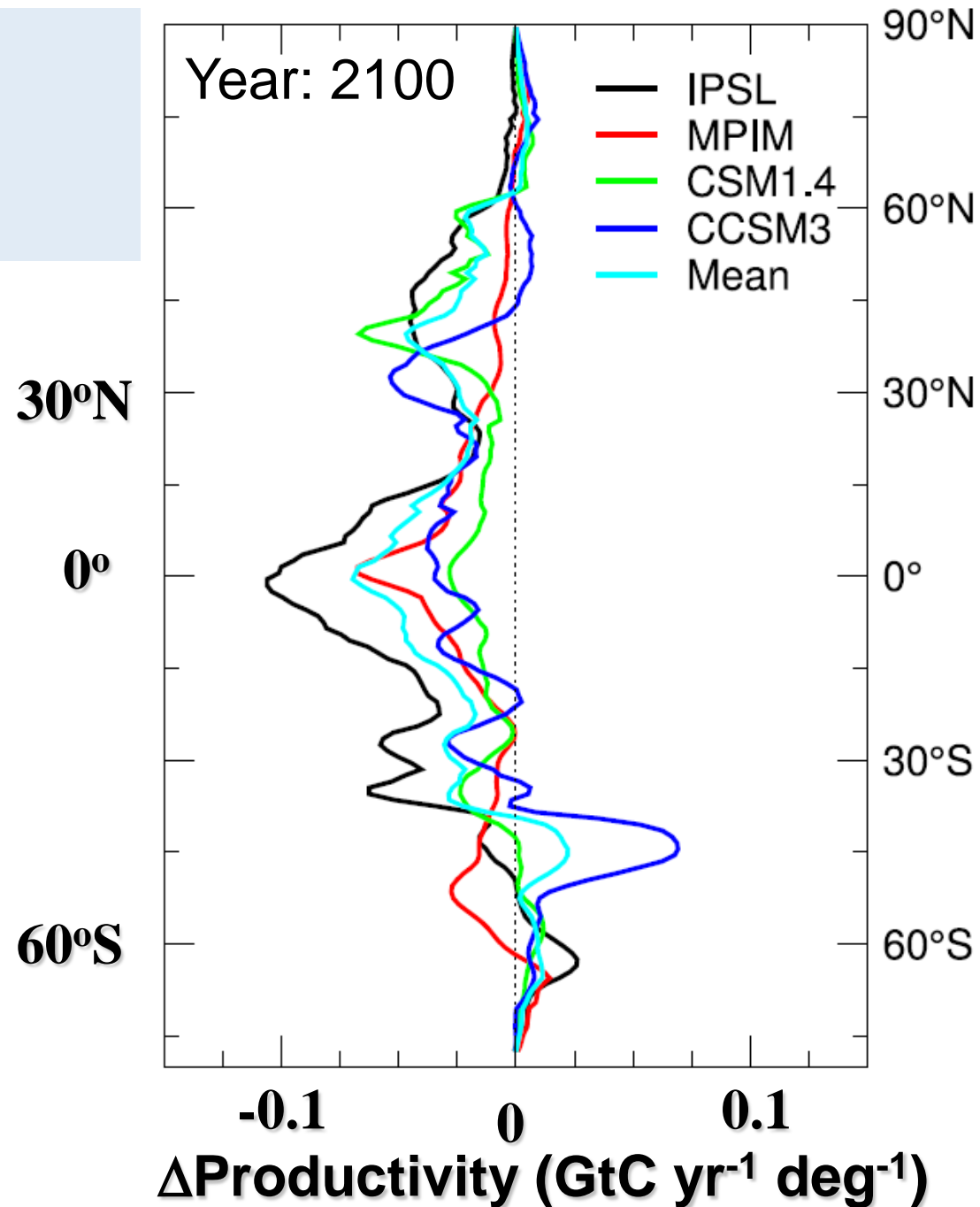
Large discrepancies between Earth System
Models and empirical approach of Sarmiento et al

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Three satellite algorithms combined
with projected physical parameters

Earth System Models
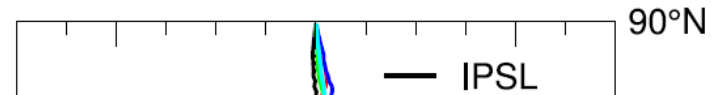
Earth System Models explicitly consider nutrient cycling and nutrient limitation in contrast to the empirical approach
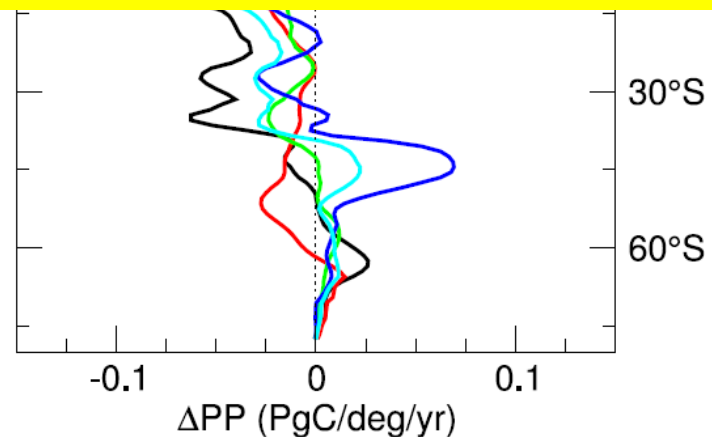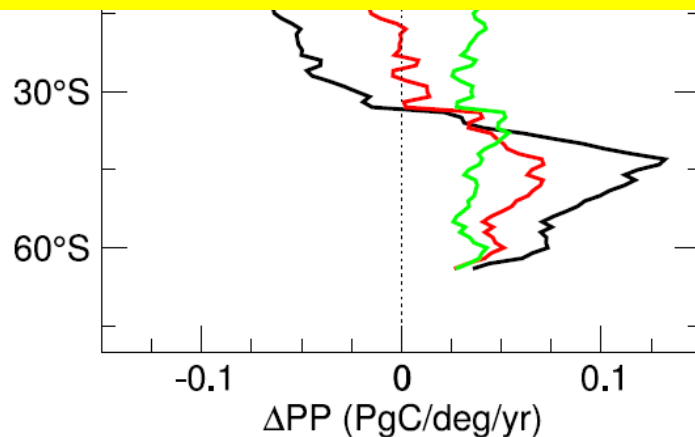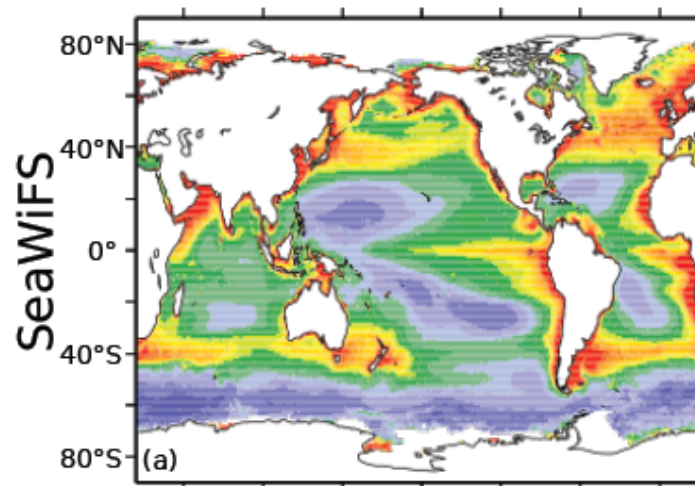
How to combine information from diverse models into a quantitative projection?
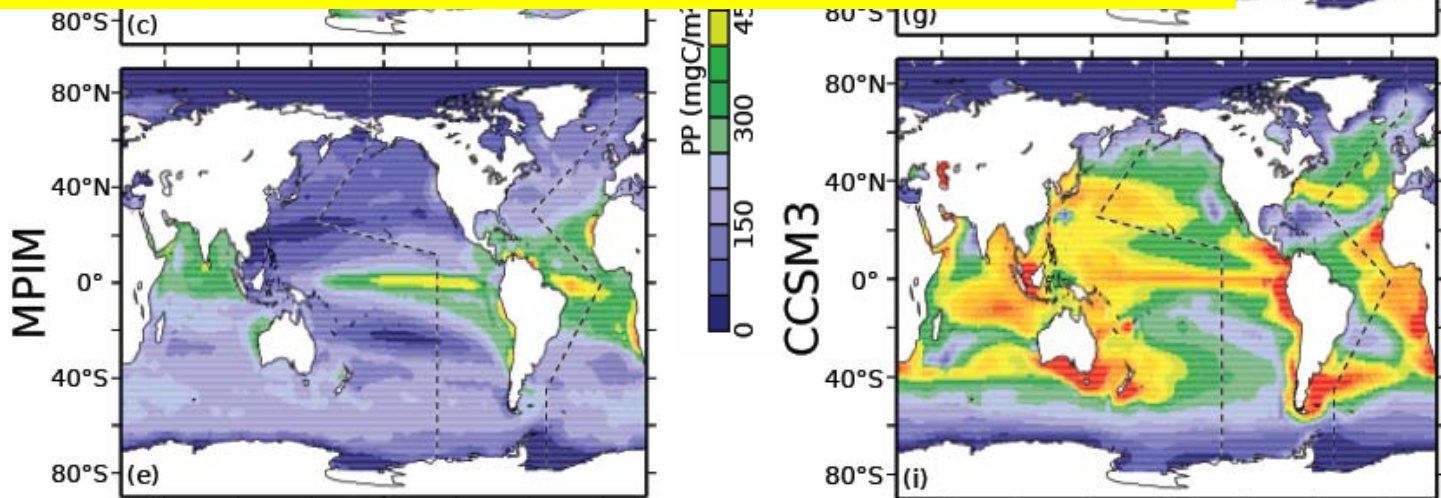
A regional skill-score approach

Satellite-based versus modelled productivity

Satellite-based productivy

Models have individual strengths
& deficiencies

Mode productivity
for today

SeaWiFS

(a)

MPIM

CCSM3

(c)

(e)

(g)

(i)

PP (mgC/m

450

300

150

0

Compare fields of satellite-based estimates and simulated productivity

Skill (Taylor, 2001):
- correlation between the two fields
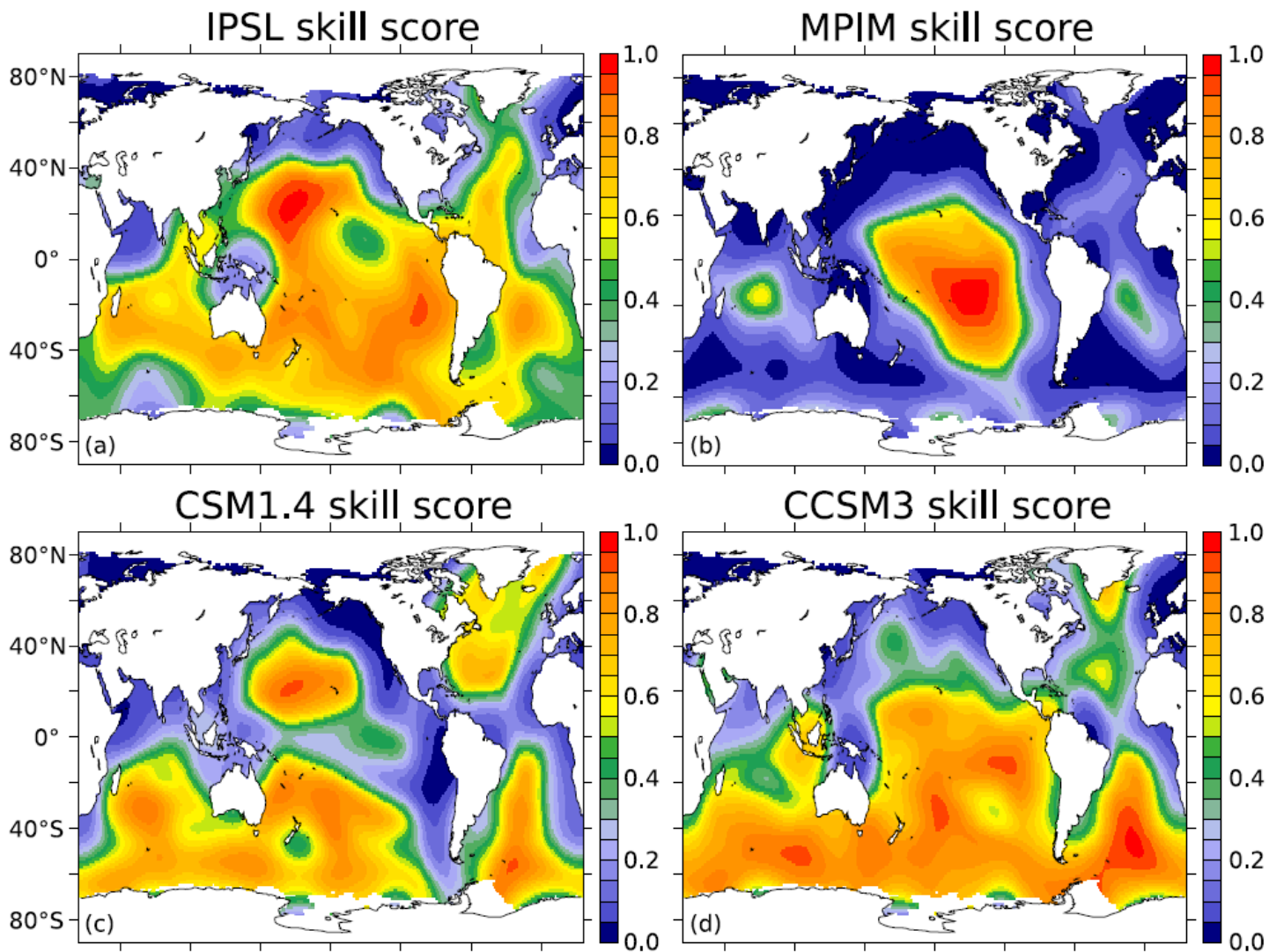**- compares standard deviations of the two fields**

Regional skill at location i:
- weights decrease with distance from location i for calculations of correlation and sdv.

Regional skill scores

Regional skill score weighted multi-model mean

Stippling: none of the skill scores > 0.5

(a) PP (mgC/m²/day)

0   150   300   450   600   750

**productivity
(mgC m⁻² d⁻¹)**

(b) ΔPP (mgC/m²/day)

-400   -100   -25   0   25   100   400
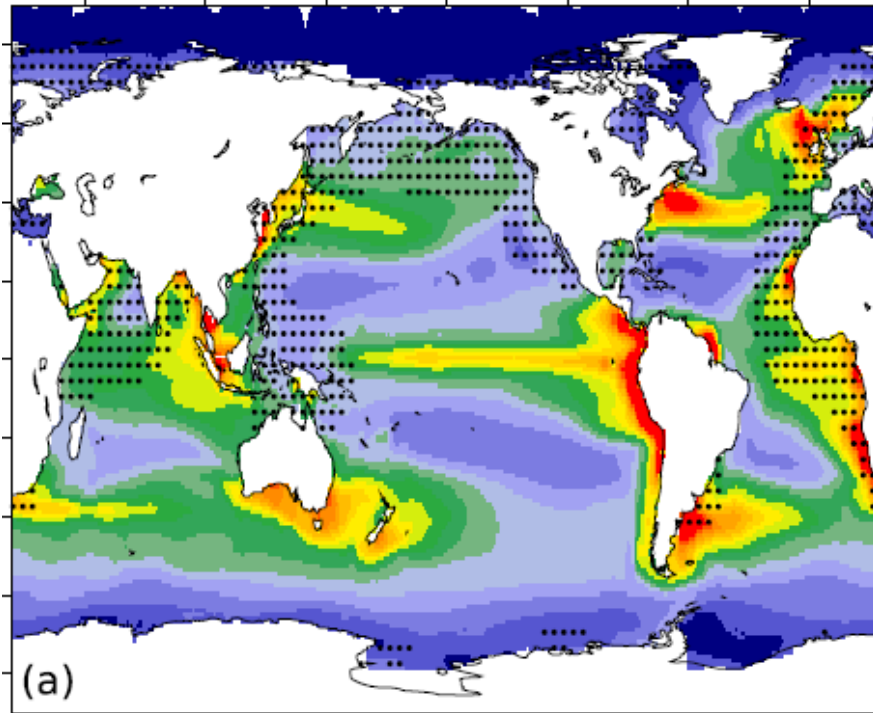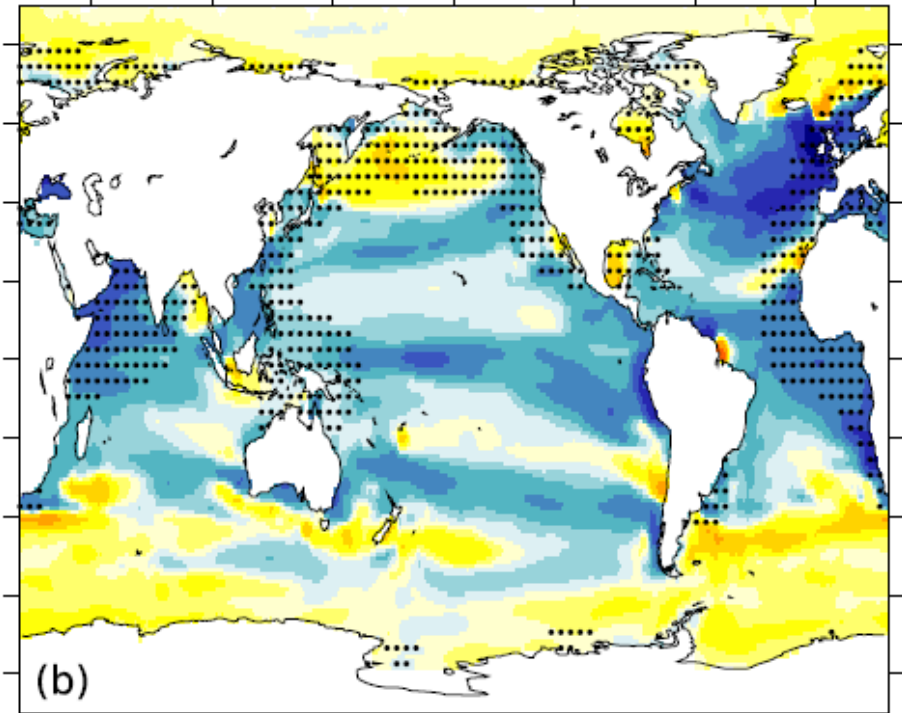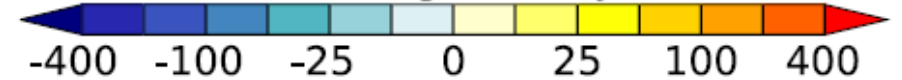
**Δproductivity
(mgC m⁻² d⁻¹)**

Conclusions

- All models project a decrease in marine net primary productivity under global warming

- Dominant mechanism in low and mid-latitudes and NA: increased stratification and reduced nutrient input
    -> reduced productivity & export

- A regional skill score metric has been developed that may be useful for multi-model averaging

  For caveats and more information:
       Steinacher et al., BG, 2010