MEECE
Marine Ecosystem Evolution in a Changing Environment

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Climate change impacts on shelf and coastal marine ecosystems: contrasting ocean-shelf exchange, stratification and temperature effects on the NW European shelf

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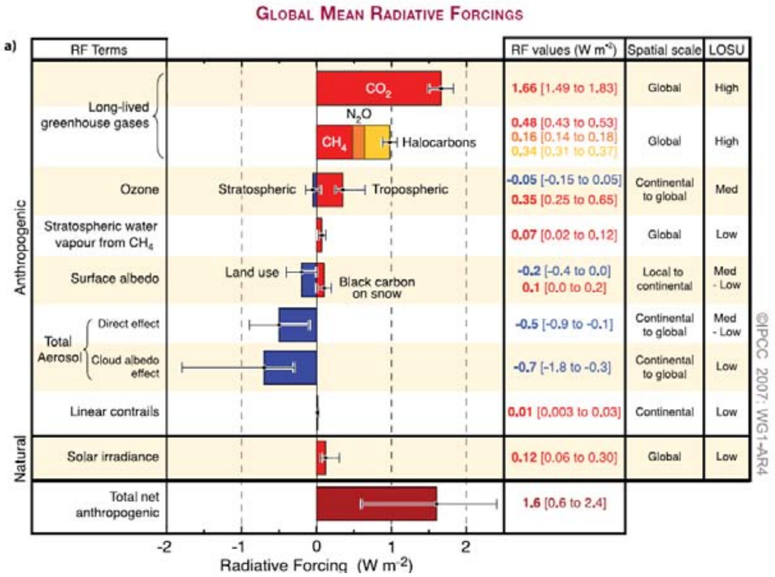
PML | PLYMOUTH MARINE LABORATORY

Met Office

Climate impacts on shelf sea ecosystems

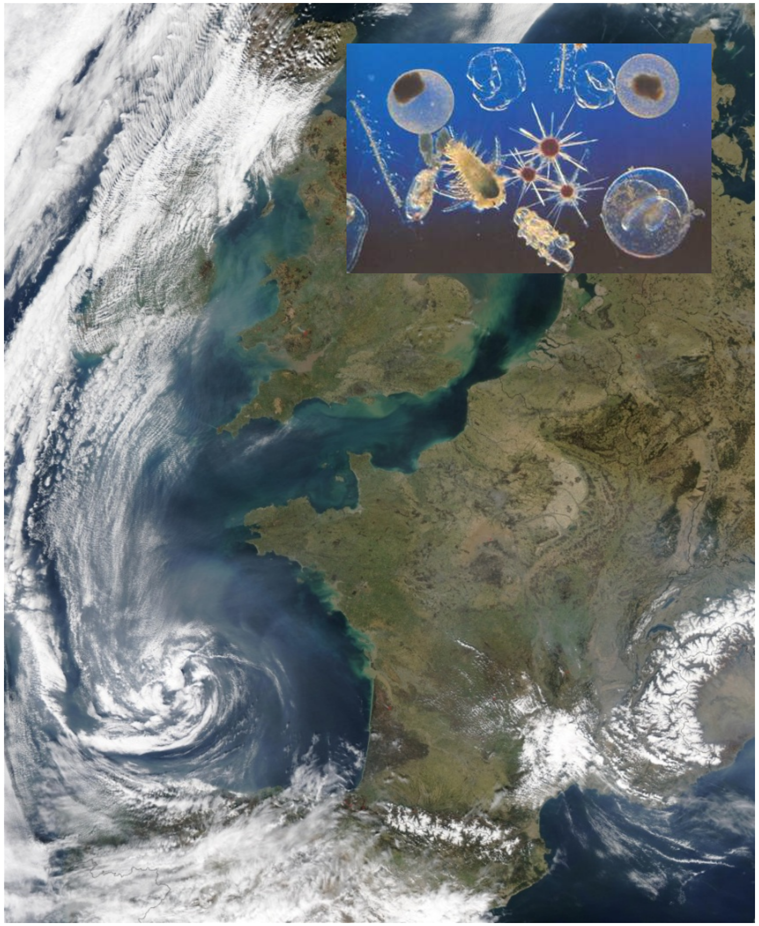
Changes in global radiative forcing



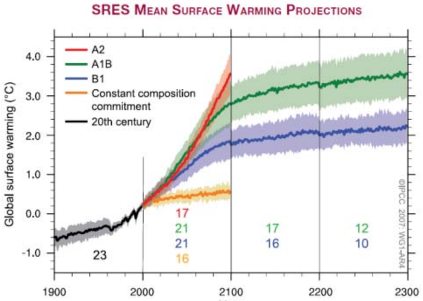
An extreme downscaling problem

?

Changes in phytoplankton growth



Views of climate impacts on phytoplankton growth



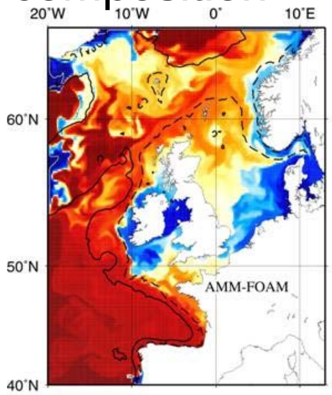
OA-GCMs

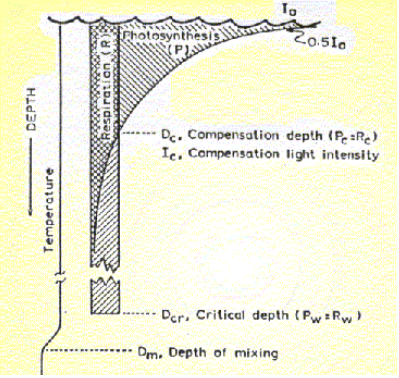
The hypothesis:
Three key physical drivers

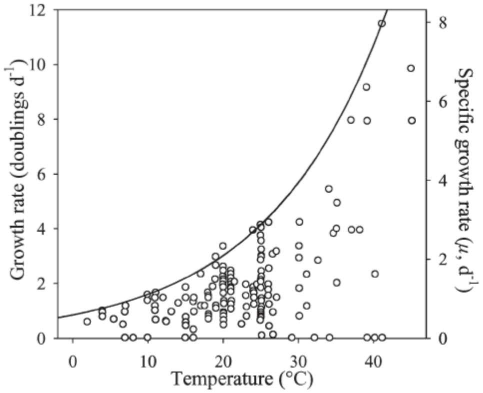
Biogeochemical composition

Phytoplankton blooms

Physiological response







Huthnance et al (2011);
Wakelin et al (2009)

Sverdrup (1953)

Eppley (1972)

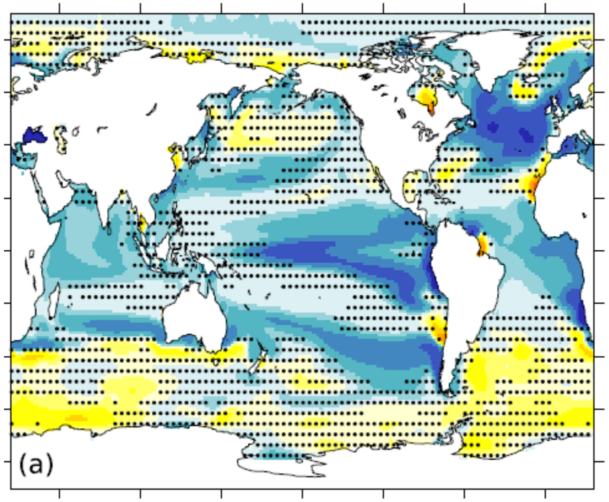
Ocean-shelf exchange

Turbulence-stratification-mixing Interplay

Growth rate response to temperature: autotrophic and heterotrophic

Downscaling

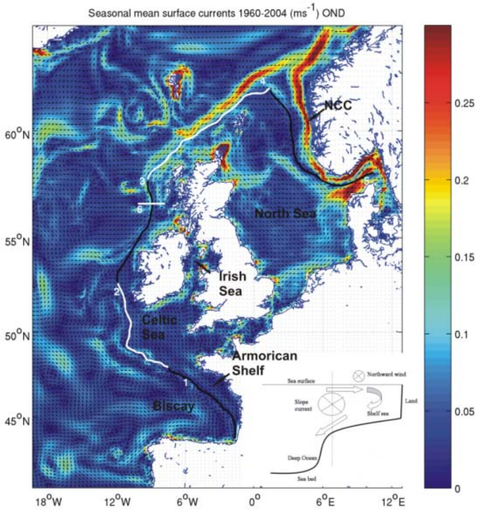
IPSL



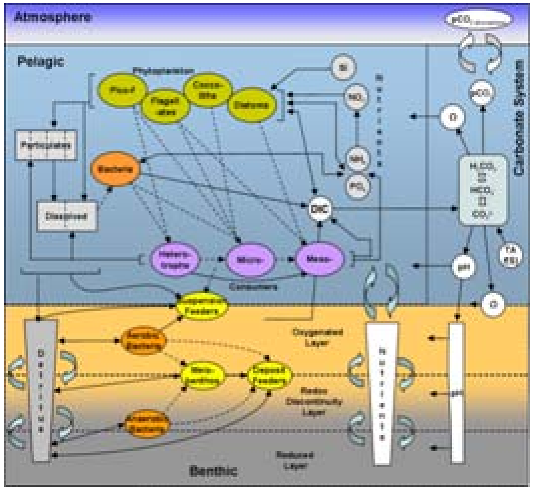
Global Earth System Model
Ocean-Atmosphere-Ice-Ecosystem

Atmospheric conditions:
Temp., Precip., Wind, Radiation

POLCOMS



ERSEM



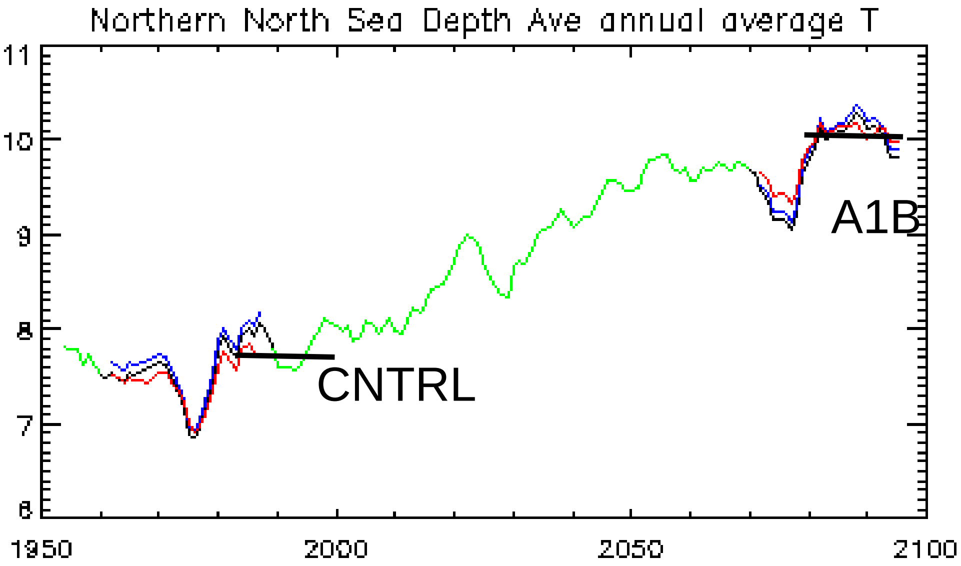
Oceanic: T, S, N

Fine resolution regional hydrodynamics model

Regional ecosystem model

Forced by IPSL-CM4 inc PISCES
Same models as used in QUESTFISH

The Timeslice Experiments



Consider A1B minus CNTRL

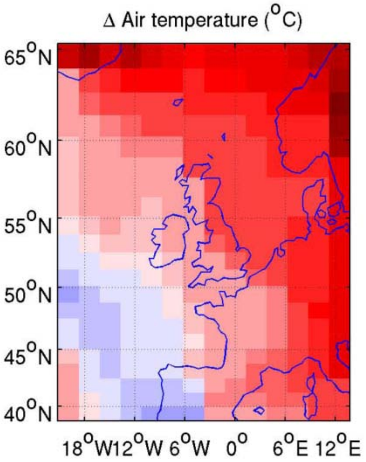
A1B = 2082-2099
CNTRL = 1983-2000
18years + 5 year ’spin-up’
Reference:
ERA40 = 1960-2004

For details, validation and many results see:
Holt, et al , 2012. Oceanic controls on the primary production of the northwest European continental shelf: model experiments under recent past conditions and a potential future scenario. *Biogeosciences* 9, 97-117.

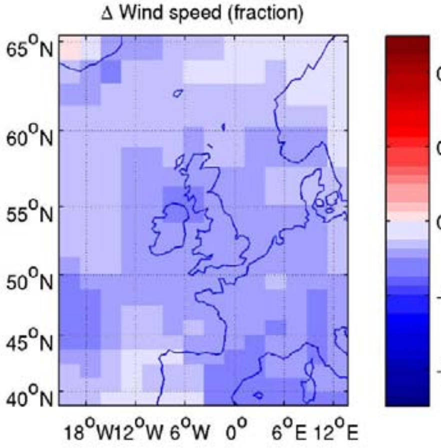
Assumes:
Timeslices are long enough to:
1. Adjust to new conditions (‘spin-up’)
2. Average-out internal variability
Both marginal here

These experiments…..

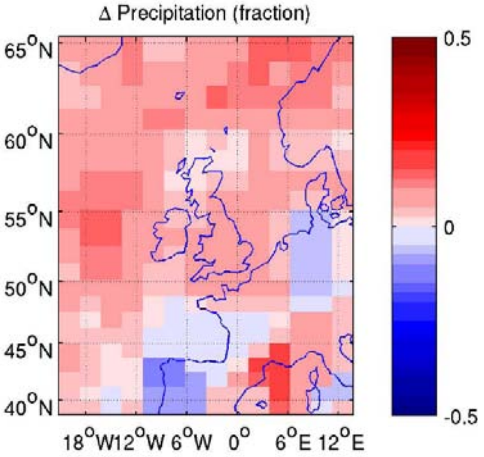
- ARE NOT PREDICTIONS and NOT PROJECTIONS
- We shake the system and see what happens
- We choose for these SENSITIVITY experiments a perturbation that is DYNAMICALLY CONSISTENT and arises from a PLAUSABLE future radiative forcing scenario (A1B)
- This is NOT UNIQUE, but the diagnostics of the response gives important information on SYSTEMS BEHAVIOUR.



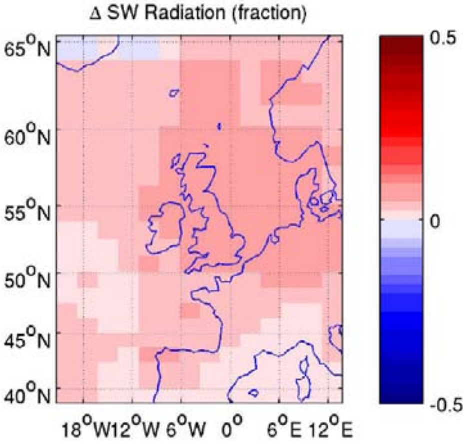
Δ Air Temp.



Δ_f Wind



Δ_f Precip.

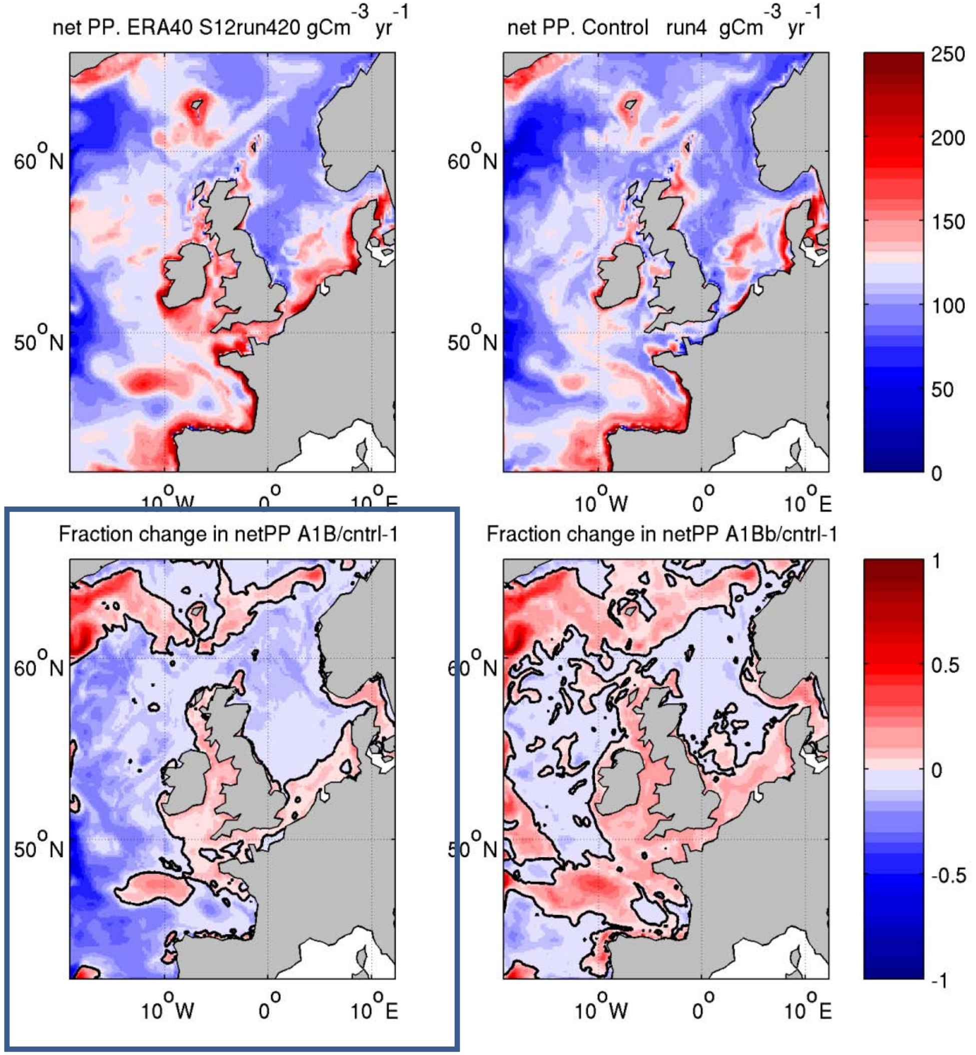


Δ_f SW Rad.

Change in net Primary Production

ERA40

Control



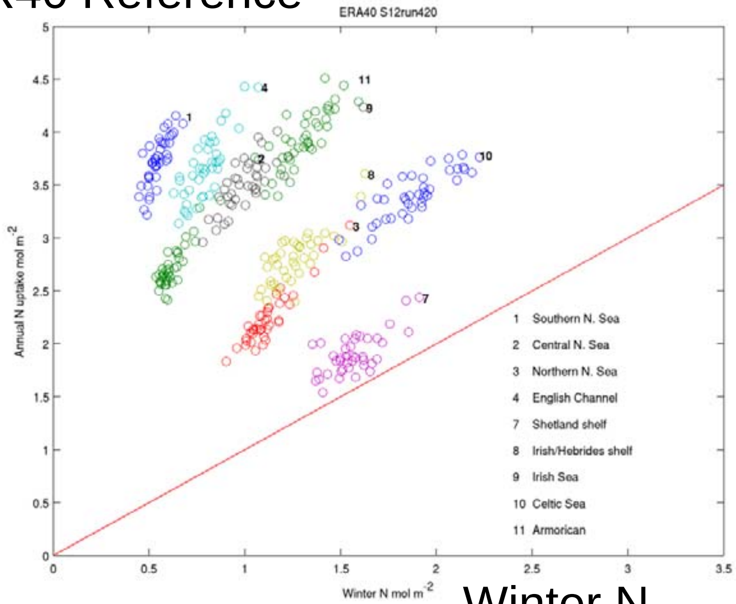
Fractional Change: A1B

Regional winter N v’s N uptake following year

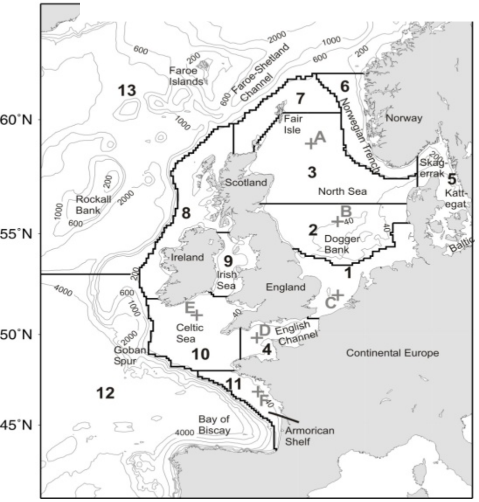
ER40 Reference

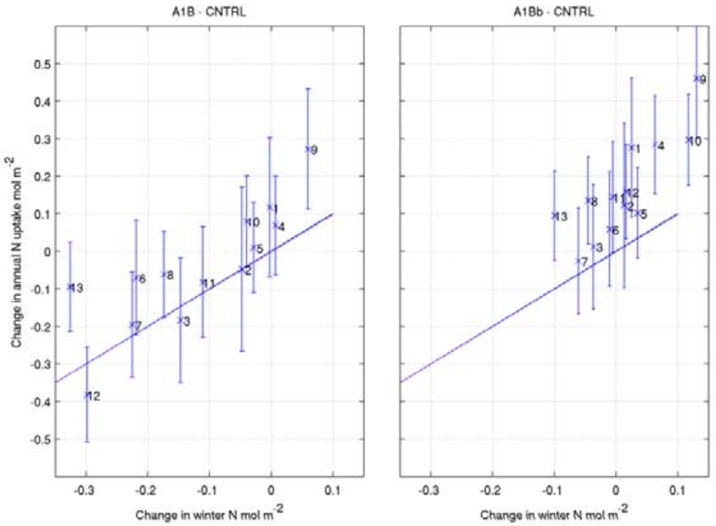
A1B - CNTRL

N uptake

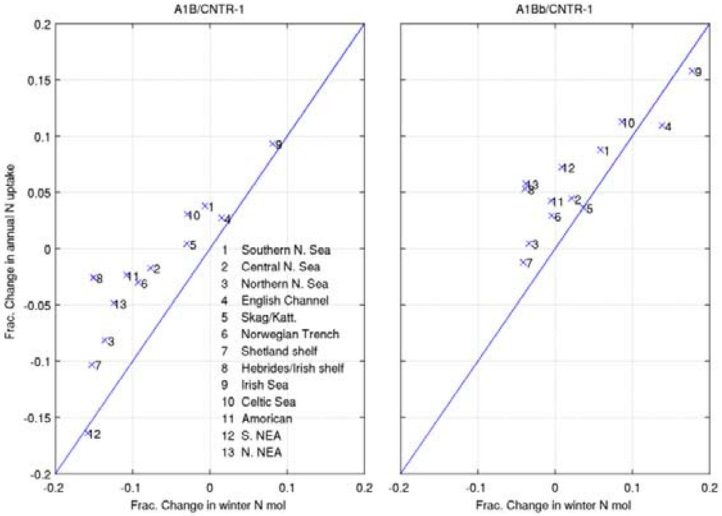


Winter N





Δf N uptake



Δ_f Winter N

Transport across 200m isobath

Volume Flux

DIN Flux

Mean DIN

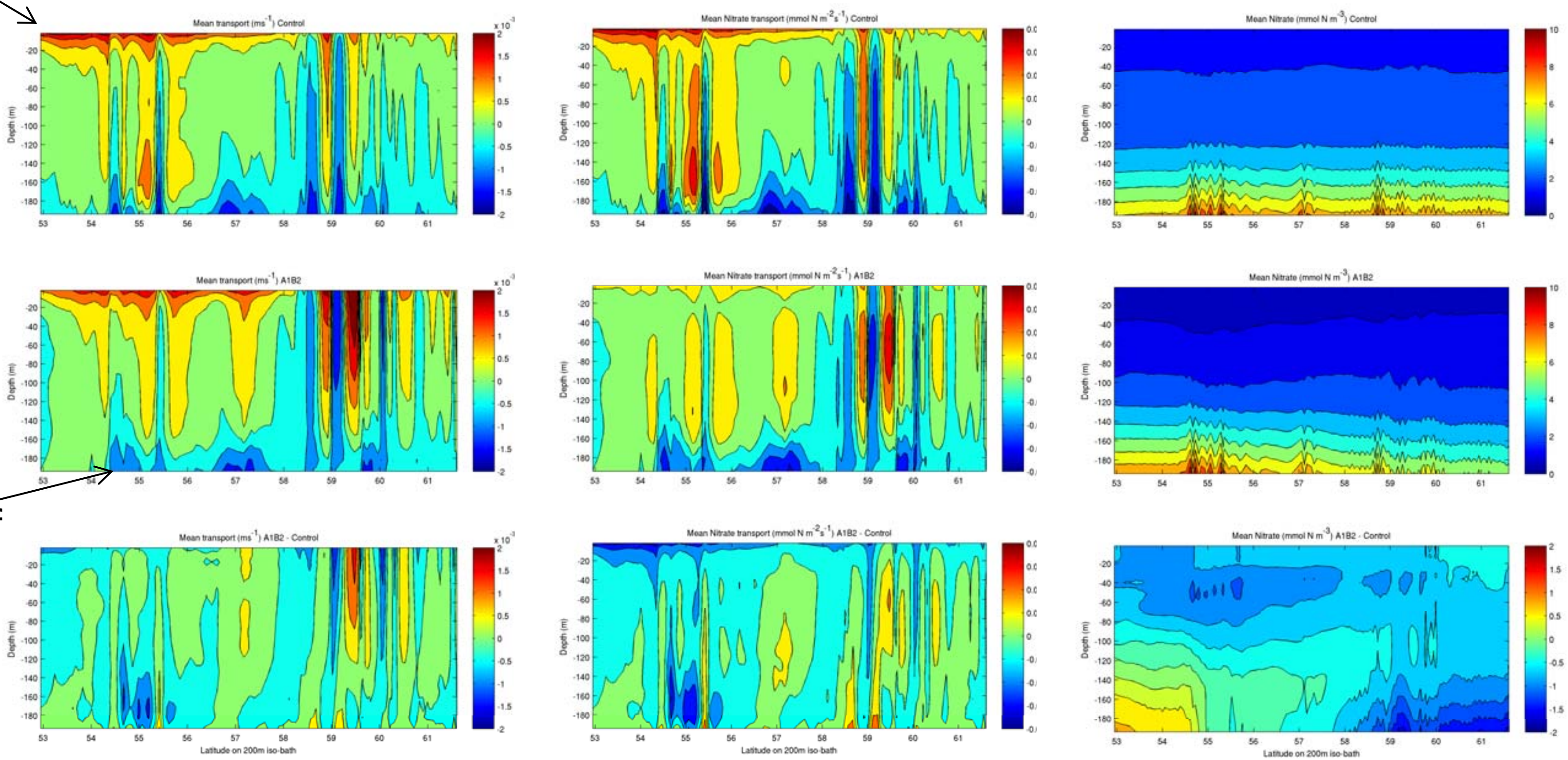
On-shelf

CNTRL

A1B

Off-shelf

A1B2
minus
CNTRL



53°N

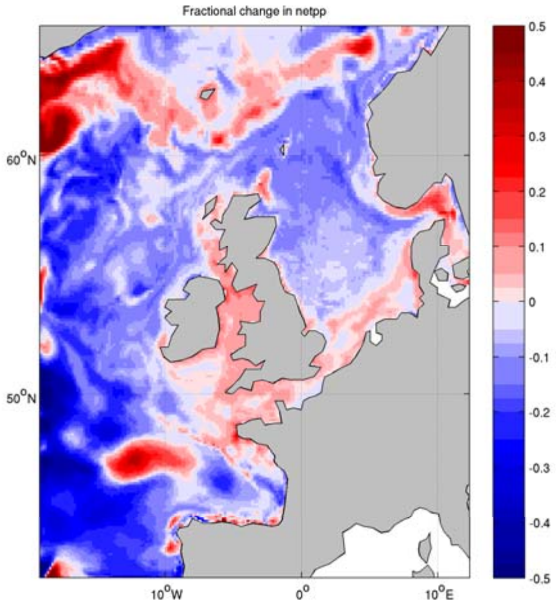
61°N

Small reduction in volume flux

See Holt et al *GRL* 2009

Substantial reduction in DIN concentrations

Process attribution experiments



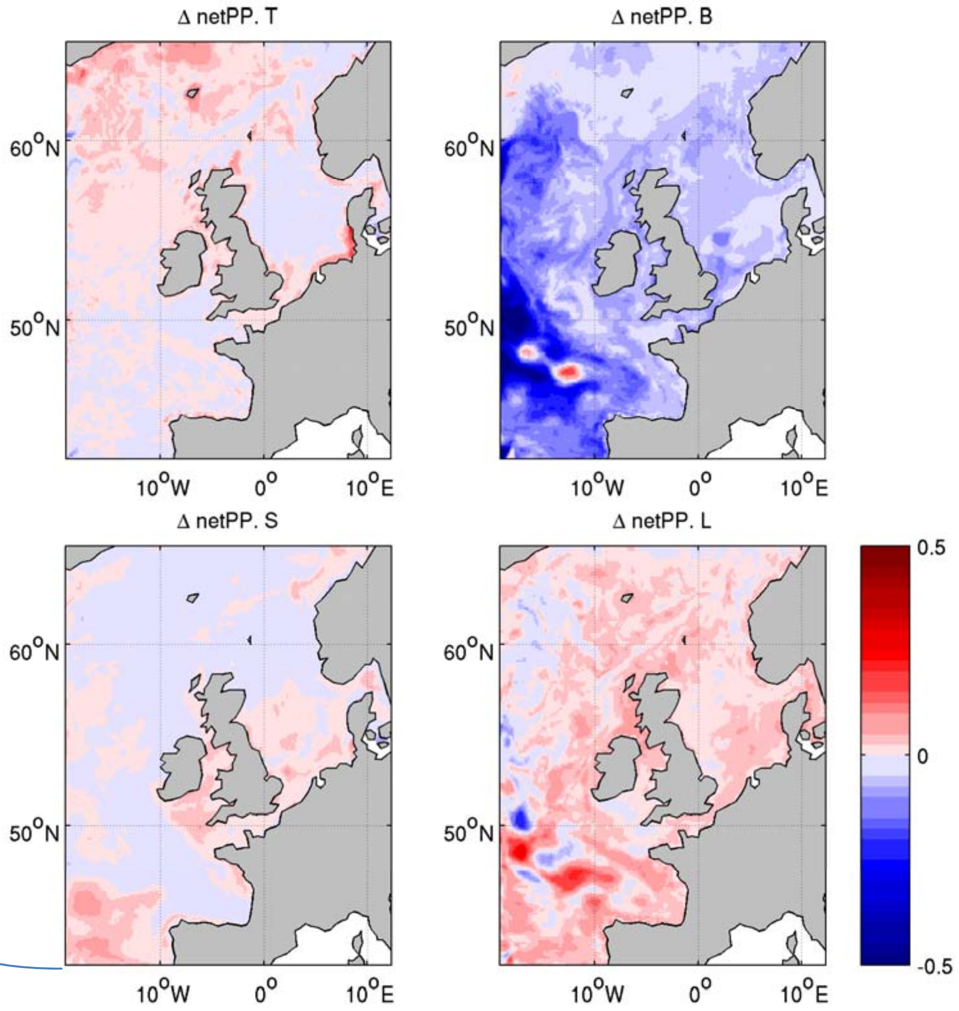
$\Delta V_p = \Delta V - \Delta V_{p'}$

Effect on change in V due to P, including all non-linearities

Pair of time slices with process P absent

Temperature

Boundary N



‘Fast Settling’

Shortwave radiation

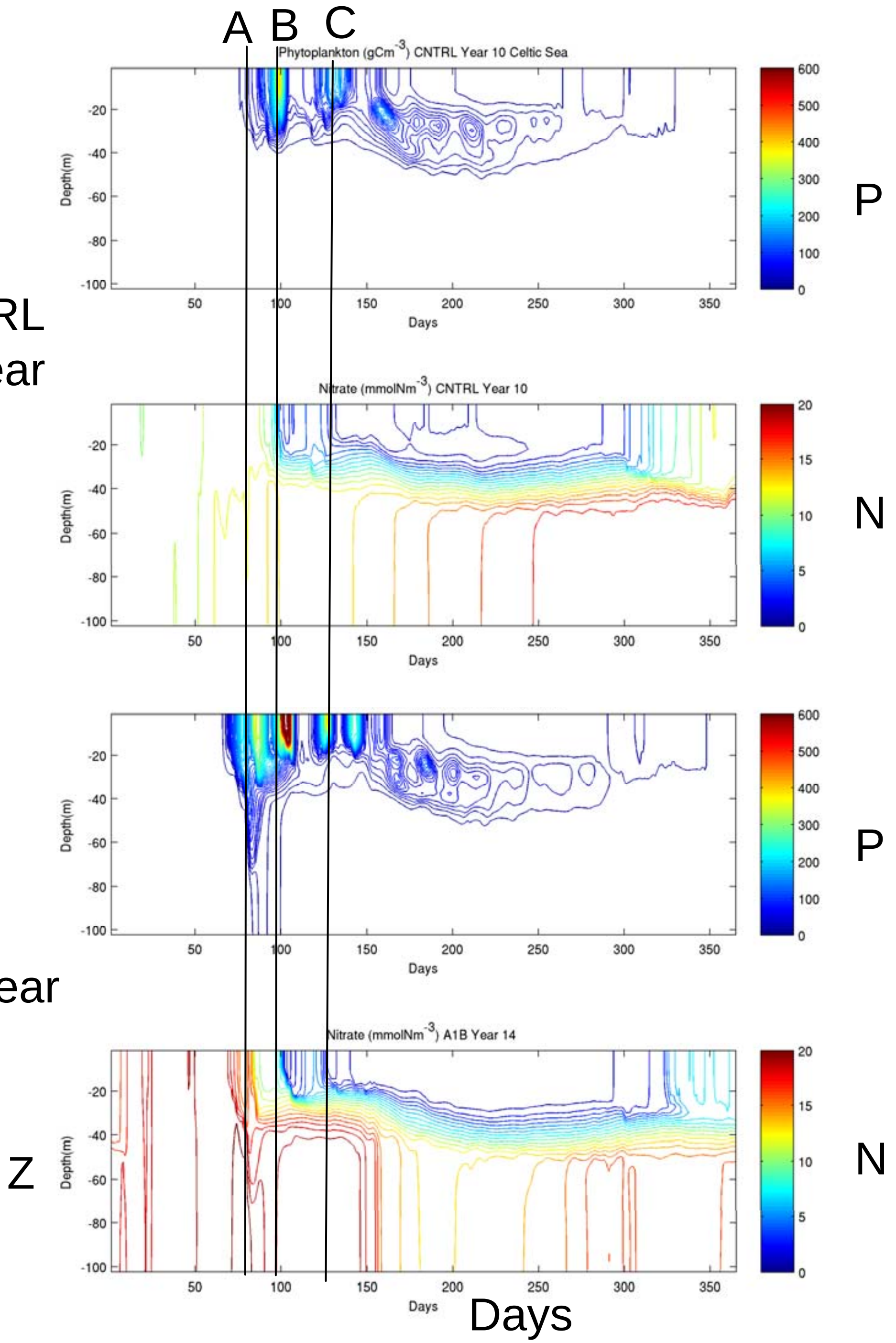
Seasonal Profiles: Celtic Sea

In A1B
- Earlier commence of growth (A)
- Stratification starts about same time (B)
- Surface layer depleted of N at about same time (C)
- Longer pre-stratification bloom*
- More efficient use of winter Nutrients
- Can be counteracted by reduced diapycnal mixing

*Phytoplankton respond to reduced mixing but full depth nutrient flux still active. Huisman et al *L&O* (1999) ‘critical turbulence’

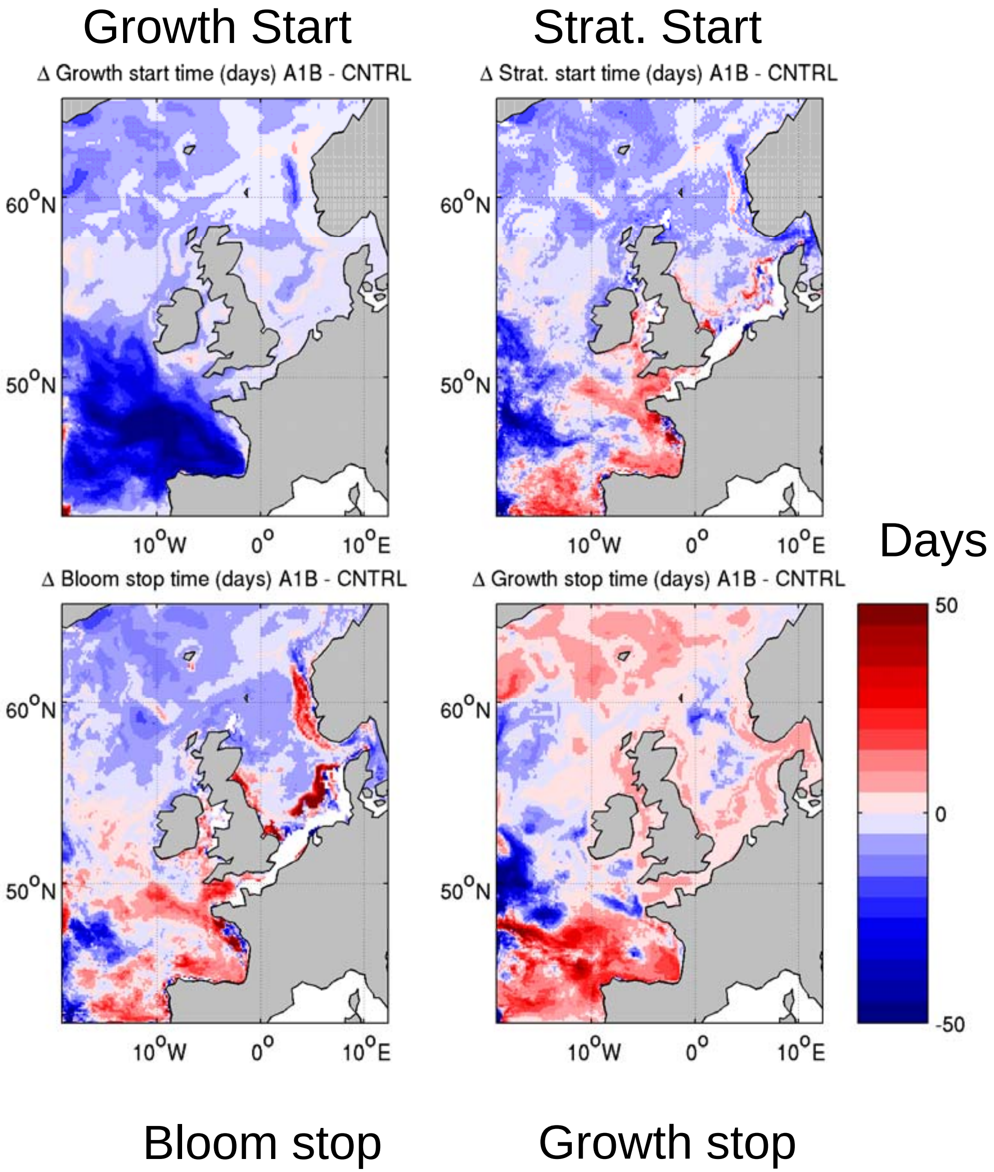
CNTRL
eg year

A1B
eg year



Changes in key times in seasonal cycle

- Growth Start netpp > $0.1 gCm^{-2}d^{-1}$
- Strat. Start = max dN/dt
- Bloom stop N>20% wint N
- Growth Stop netpp < $0.1 gCm^{-2}d^{-1}$



Growth Start

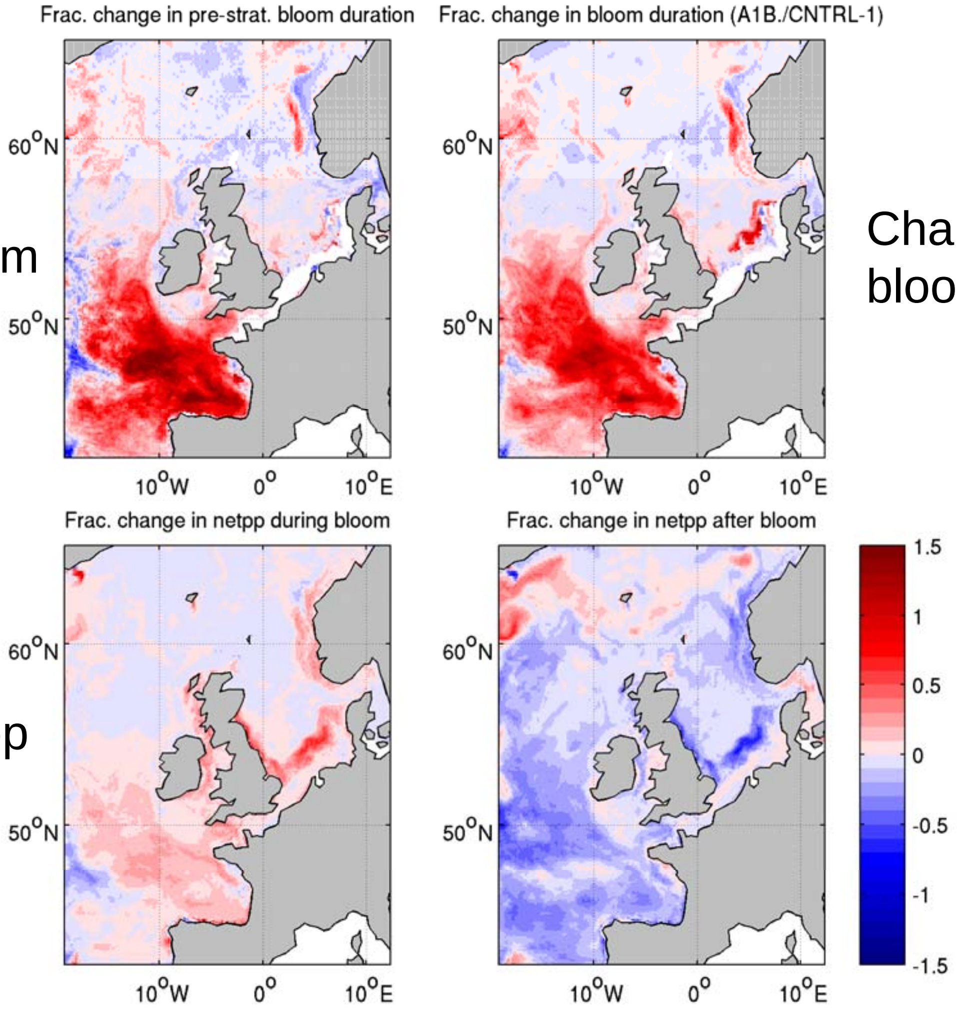
Strat. Start

Bloom stop

Growth stop

Days

Changes in bloom production



Frac. change in pre-strat. bloom duration

Frac. change in bloom duration (A1B./CNTRL-1)

Frac. change in netpp during bloom

Frac. change in netpp after bloom

Change in
pre-strat. bloom
duration

Change in
bloom duration

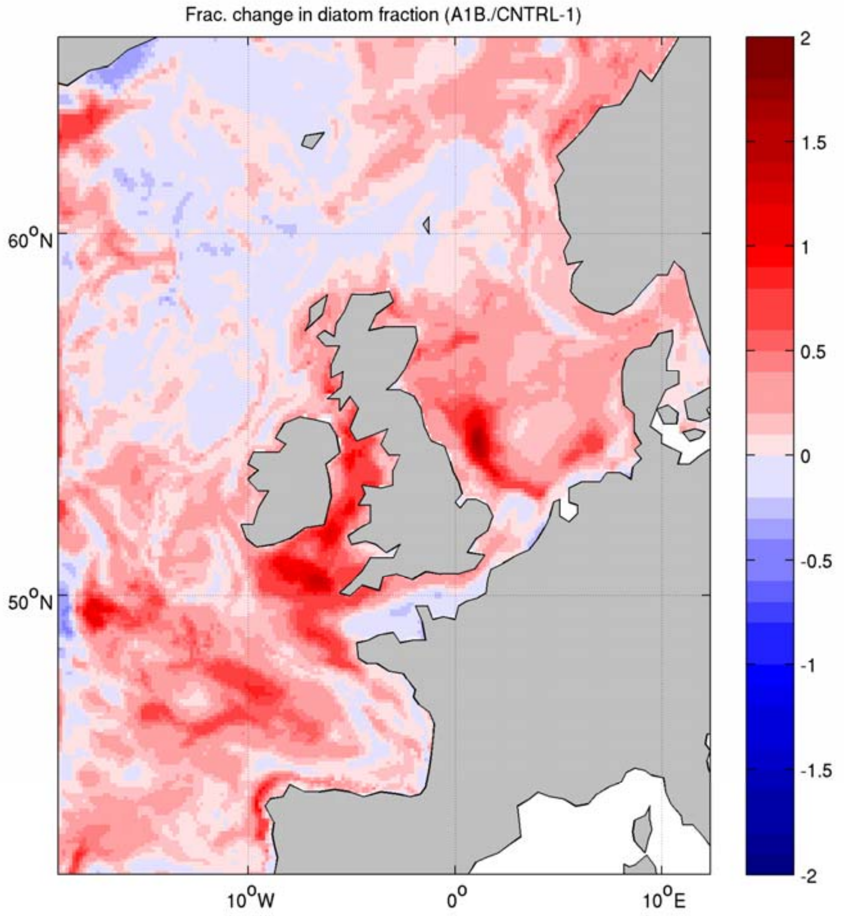
Change in netpp
during bloom

Change in
netpp after
Bloom.
(diapycnal
mixing)

Other views of the system

Change in community composition:
diatom fraction

Earlier blooms favour diatoms
and more efficient winter Si use

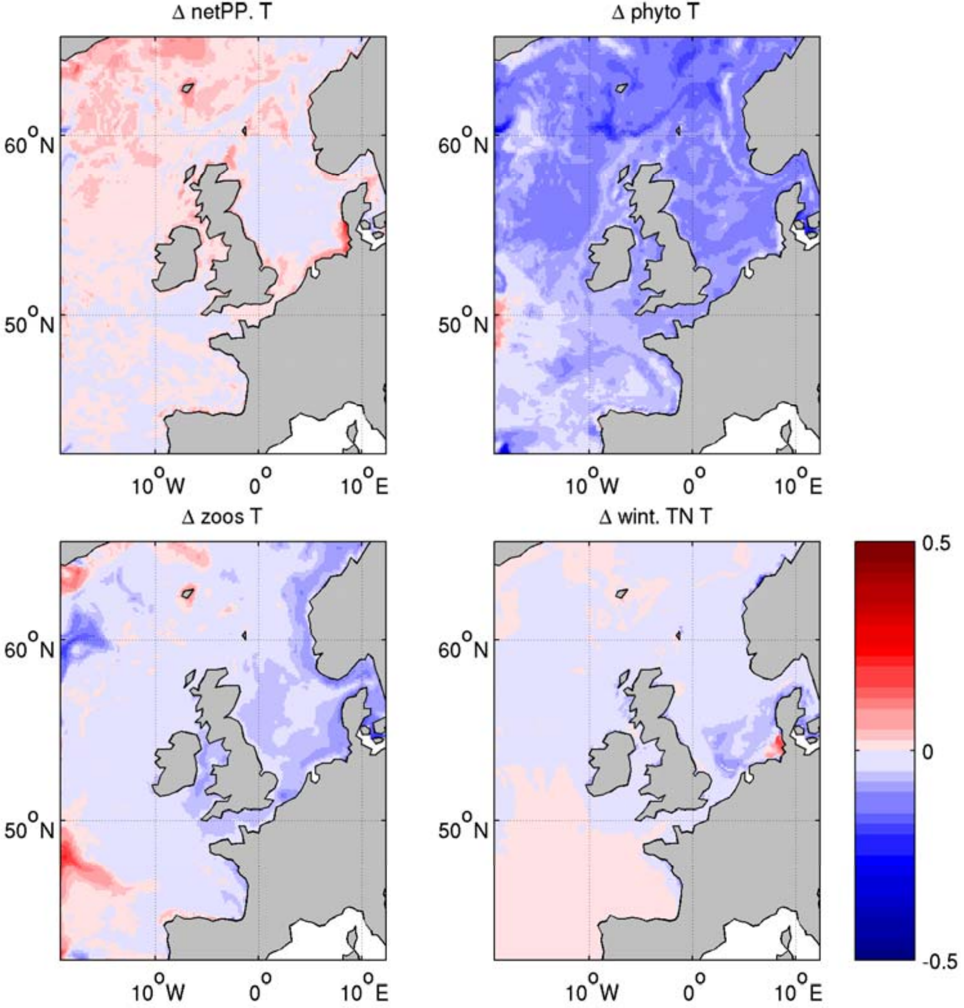


Temperature effects

- Temperature dependence is much more apparent on plankton biomass than netPP
- Heterotrophs and autotrophs have same q10 parameterisation

Δ netpp T

Δ Phyto biomass T



Δ Zoo biomass T

This is not the future…….

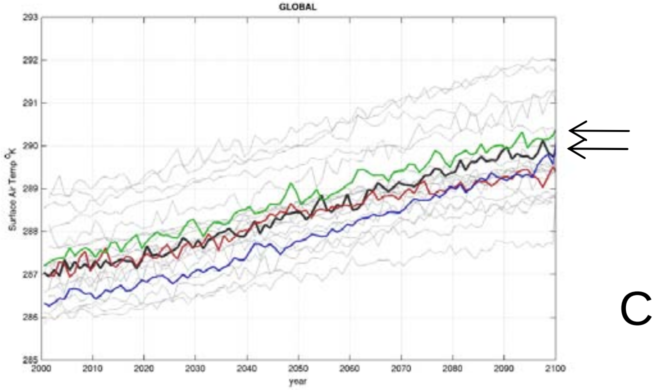
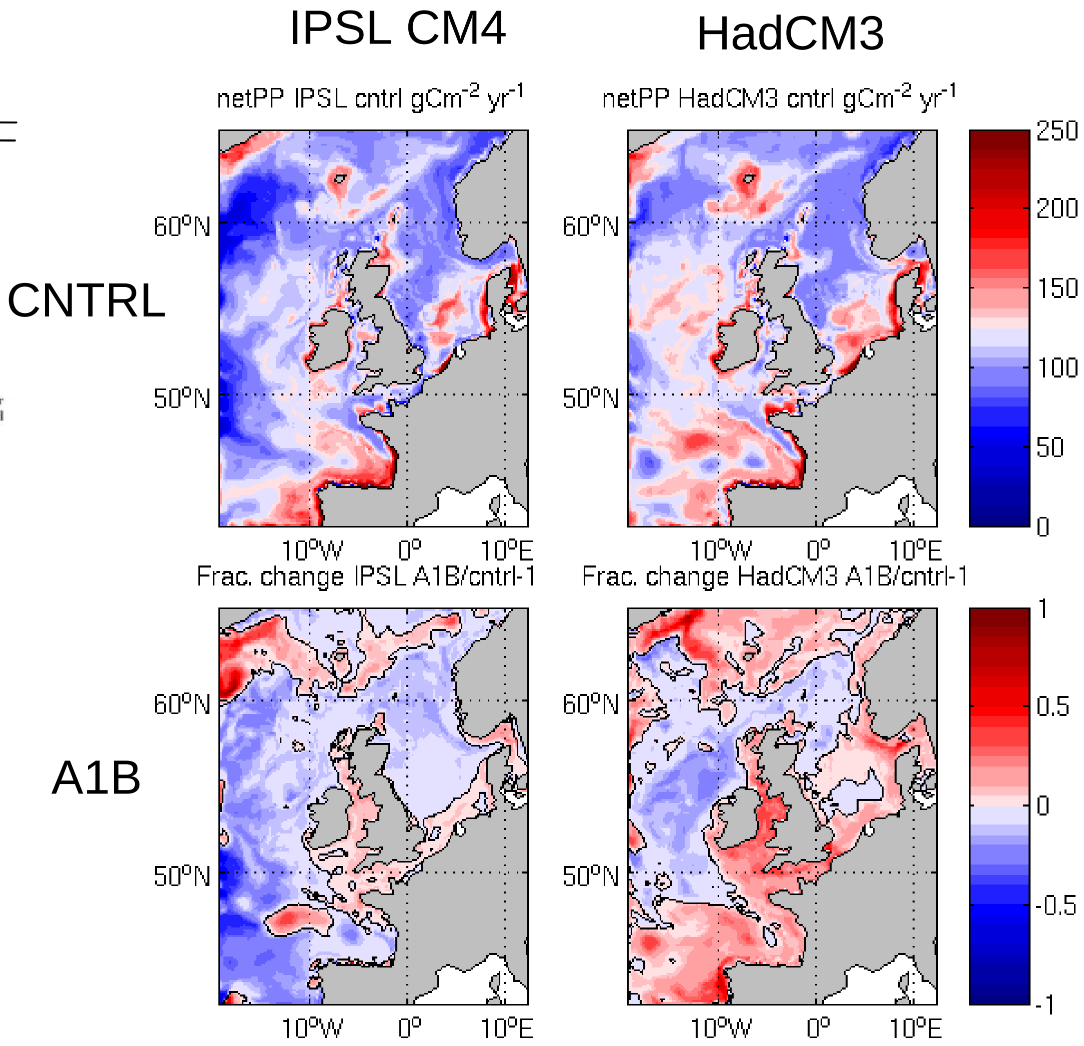


Figure 2: Global mean two metre air temperature from 23 IPCC AR4 climate simulations under the SRESA1B scenario. Highlighted are the IPSL (black), GFDL (red), HadCM3 (green) and HadGEM1 (blue) two metre air temperatures.



Conclusions

- Climate change impacts in shelf seas are highly nuanced, with multiple competing drivers
- This is a robust analysis of the response of the system, but need a description of likelihood to make projections
- Oceanic nutrients and stratification are first order controls of netPP changes, whereas temperature is a secondary effect in this model
- Subtle changes in mixing due to changes in light and wind mixing conditions have substantial effects on:
  - Bloom timing
  - Community structure
  - Total netPP
- But light (cloud cover) is an uncertain element in climate models
- Mixing in weakly/intermittently stratified conditions is weakness of the present generation of turbulence models