The sensitivity of the circulation, stratification and primary production of the Northwest European continental shelf to climate change

Jason Holt, Sarah Wakelin, Graham Tattersall, Roger Proctor,
Icarus Allen, Jerry Blackford, Tim Smyth
Jason Lowe, Mark Galliani
Mike Ashworth

Met Office

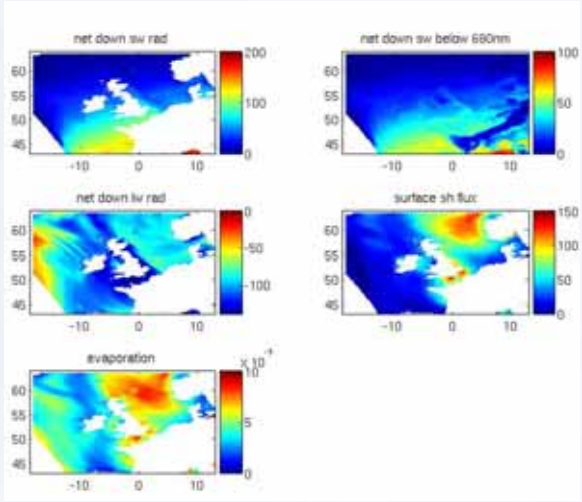
Proudman Oceanographic Laboratory
NATURAL ENVIRONMENT RESEARCH COUNCIL

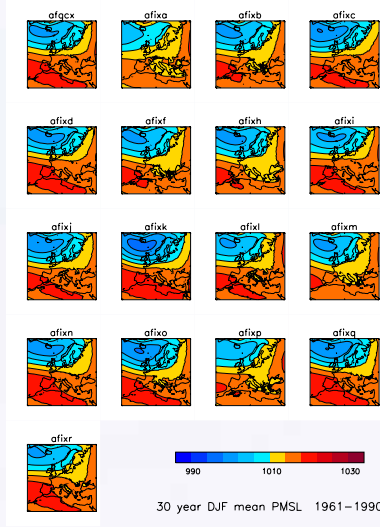
PML PLYMOUTH MARINE LABORATORY

UK Climate Impacts Programme

NCOF
The National Centre for Ocean Forecasting

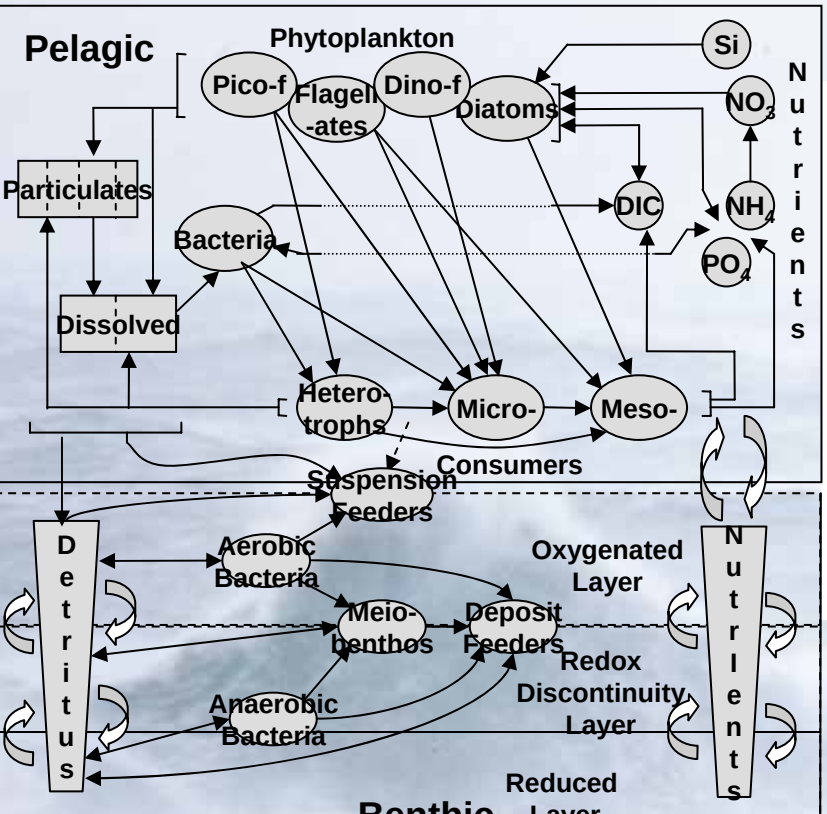
RCM forced POLCOMS-ERSEM

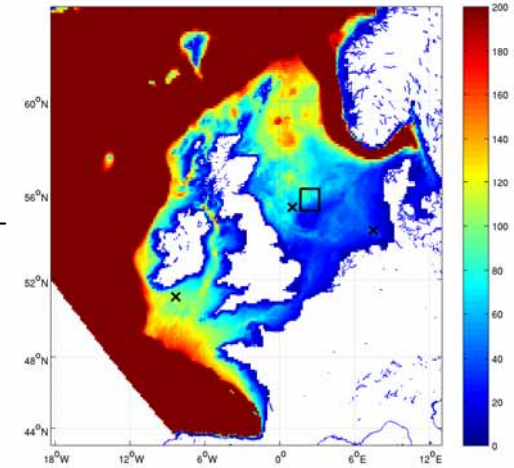




Climate model Ensemble HadRCM

Ecosystem model





3D Hydrodynamic model

Forcing:

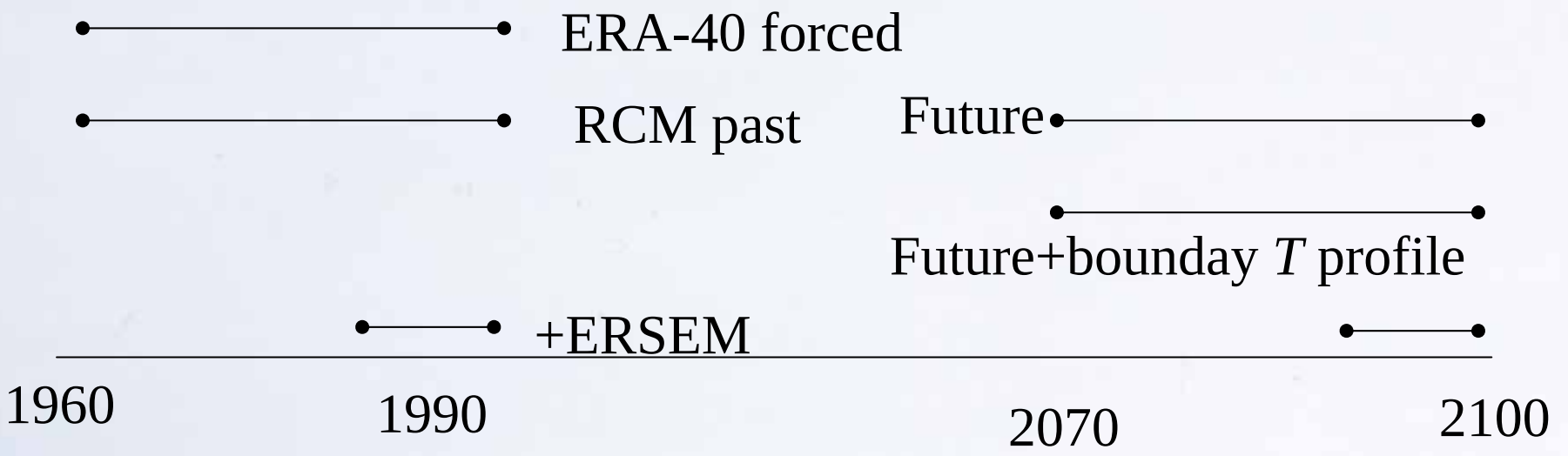
What changes?

- Heat flux, air-temp, wind, SW flux, precip.
- River discharge

What doesn't change?

- Oceanic conditions (apart from a fixed warming profiles)
- Ecosystem boundary conditions
- River nutrient load
- Inherent optical properties
- TIDAL FORCING

Experiments

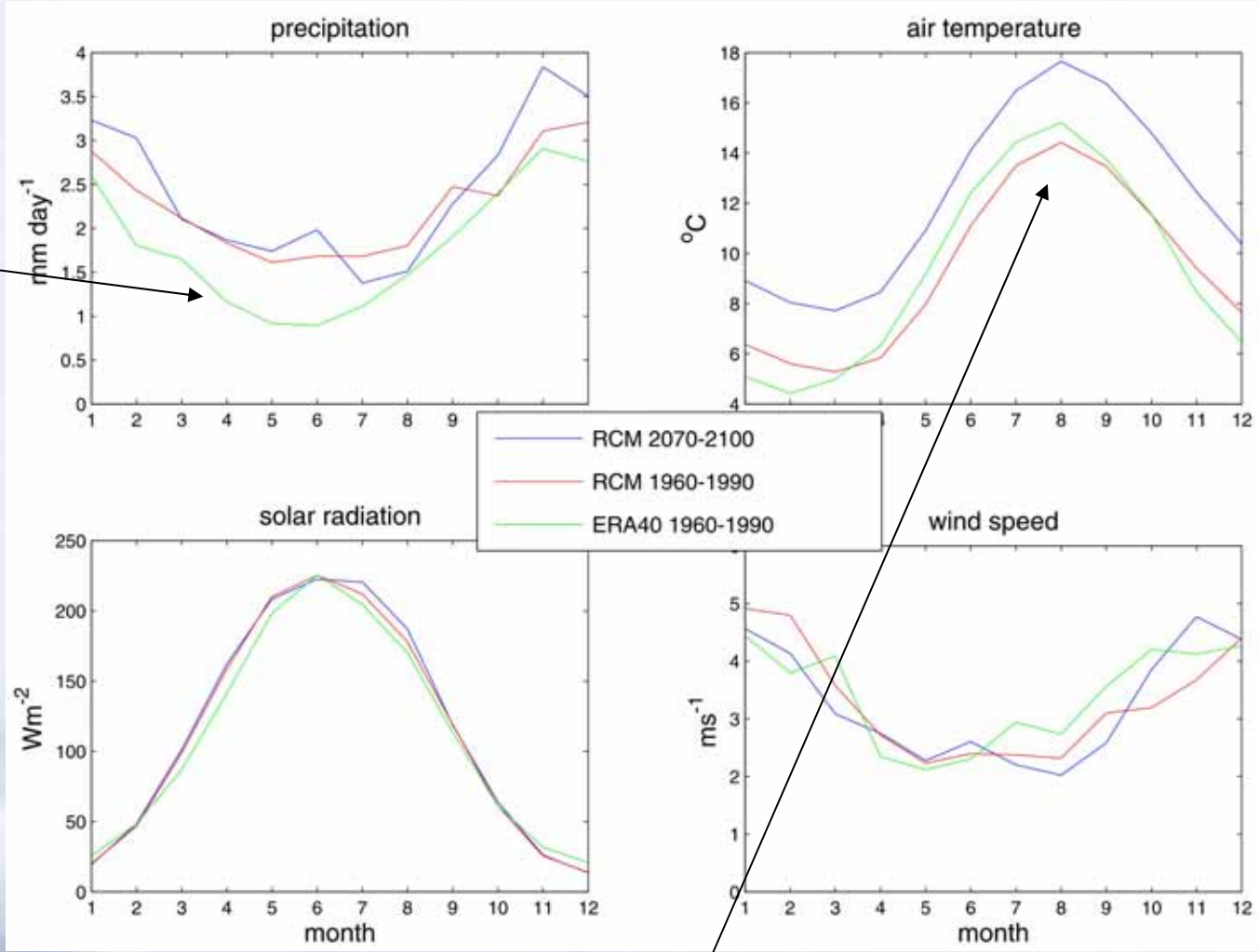


ERA-P RCM-P RCM-F RCM-FB

Each 30-yrs with ecosysem model run in the last 10 (ignore 1st year of ecosysem)

Mean Annual forcing in North Sea

Increased precipitation v's ERA-40

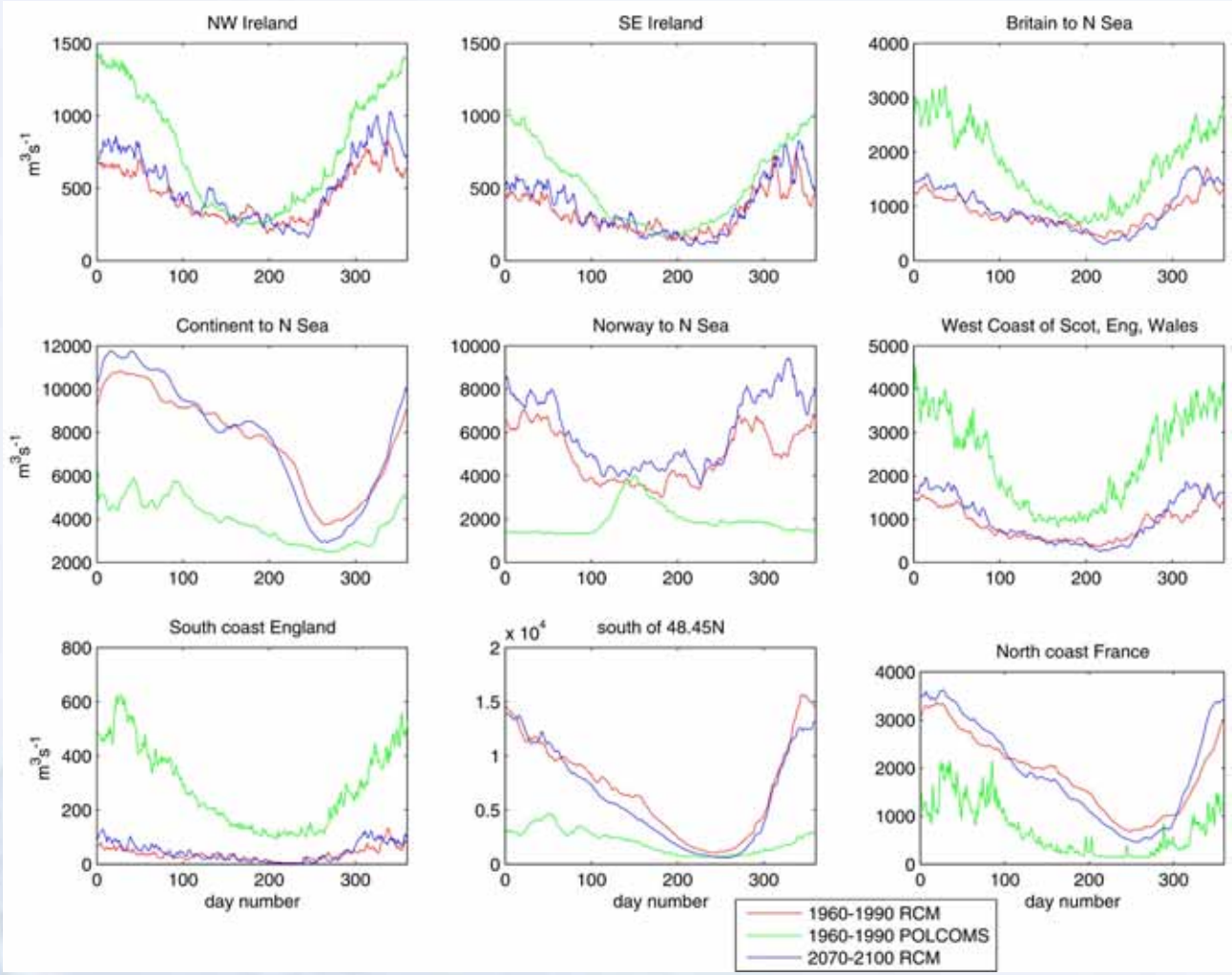


•Summer temperature warming > winter

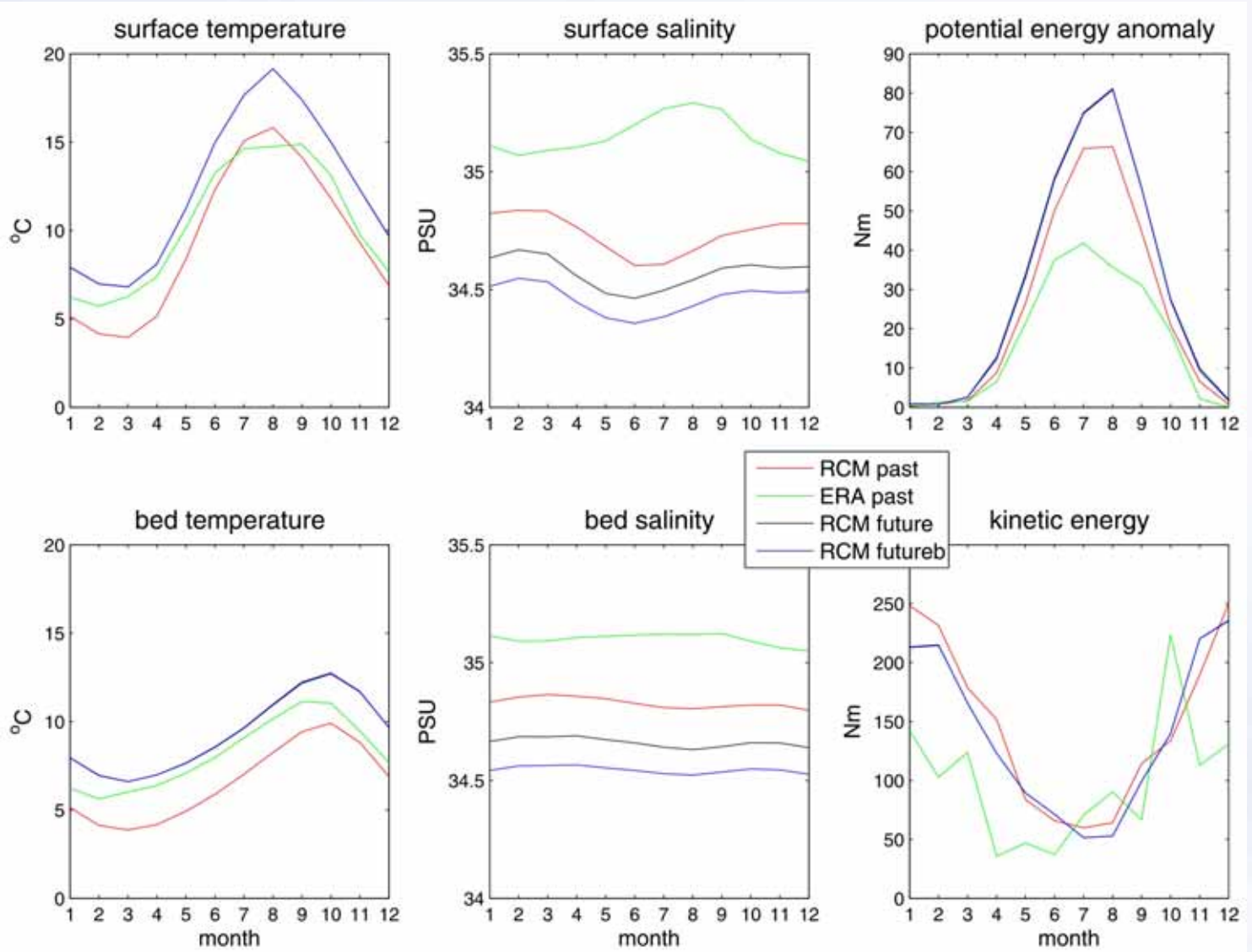
River flows: Mean annual cycle

Increased river flows v's POLCOMS data set (UK biased)

Increase in spring river flow
Future v's past

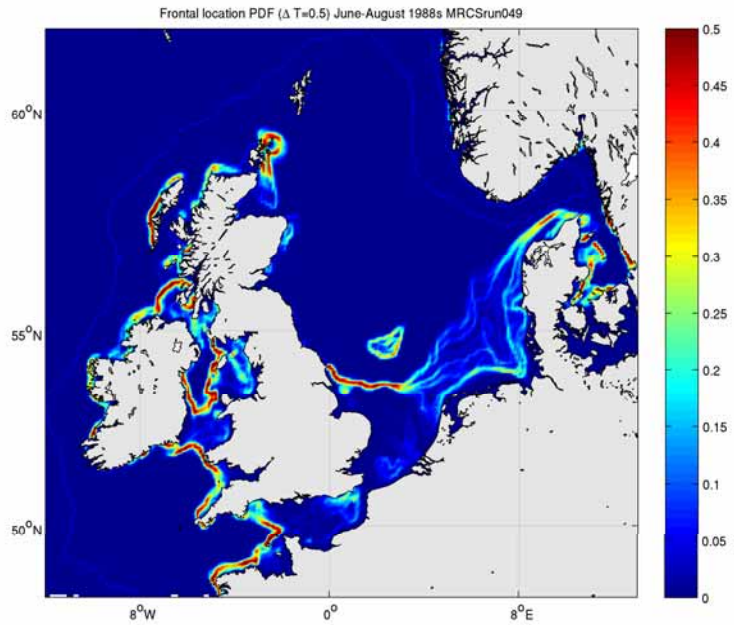


POLCOMS response in North Sea: Mean annual cycle

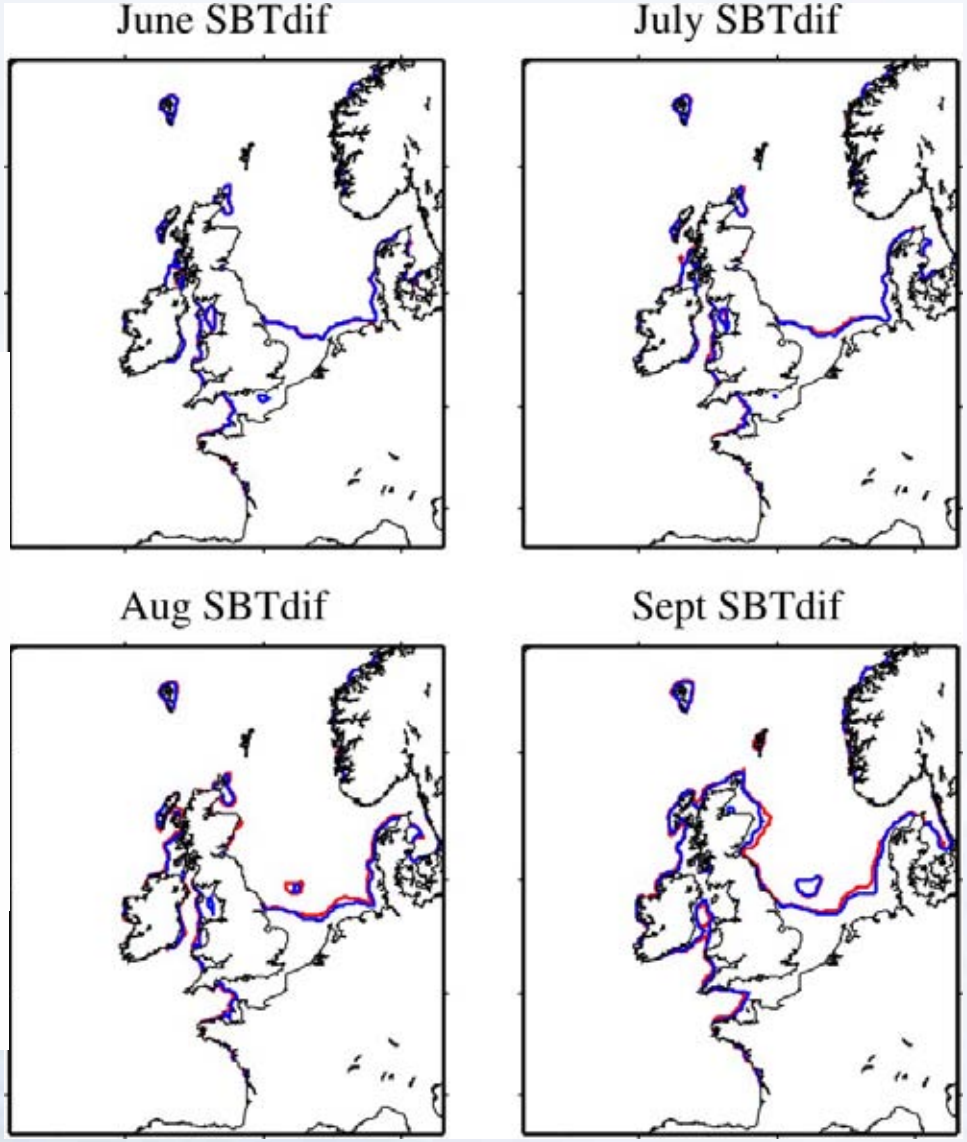


Extent of stratification (mean)

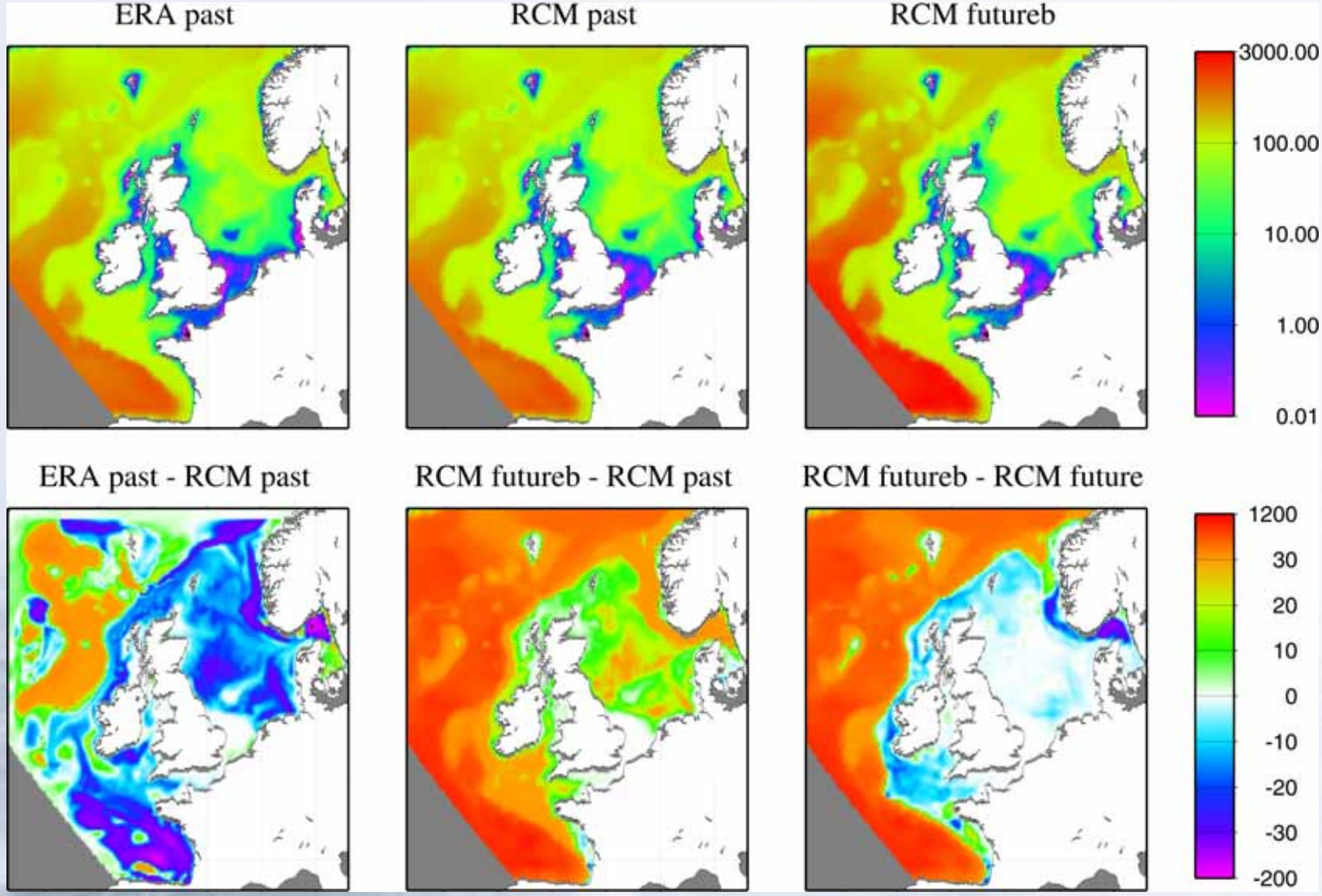
Inter annual variability in frontal positions
ERA forced (10-years)



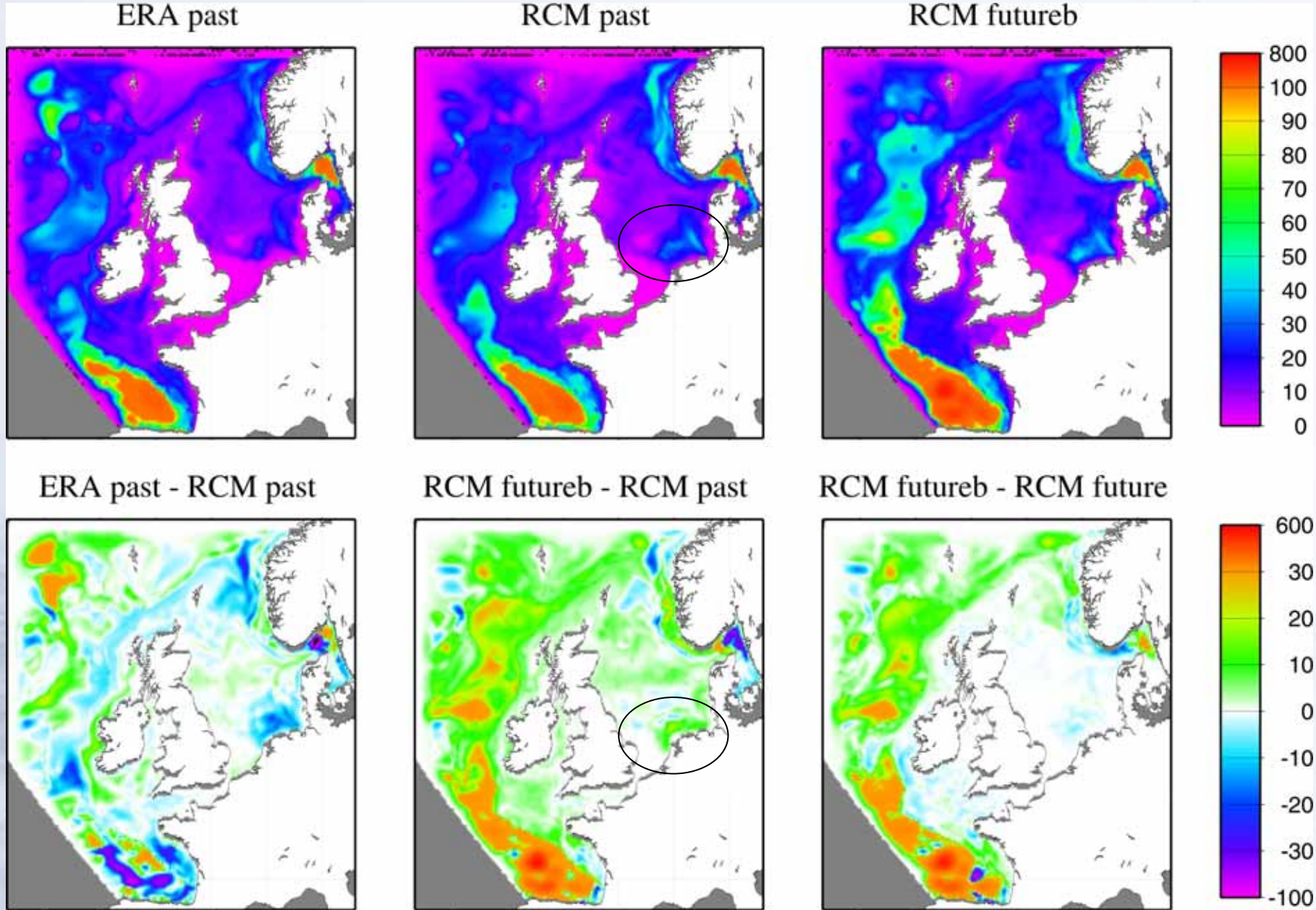
Relates to gradients of h/u^3



Mean August Potential Energy Anomaly



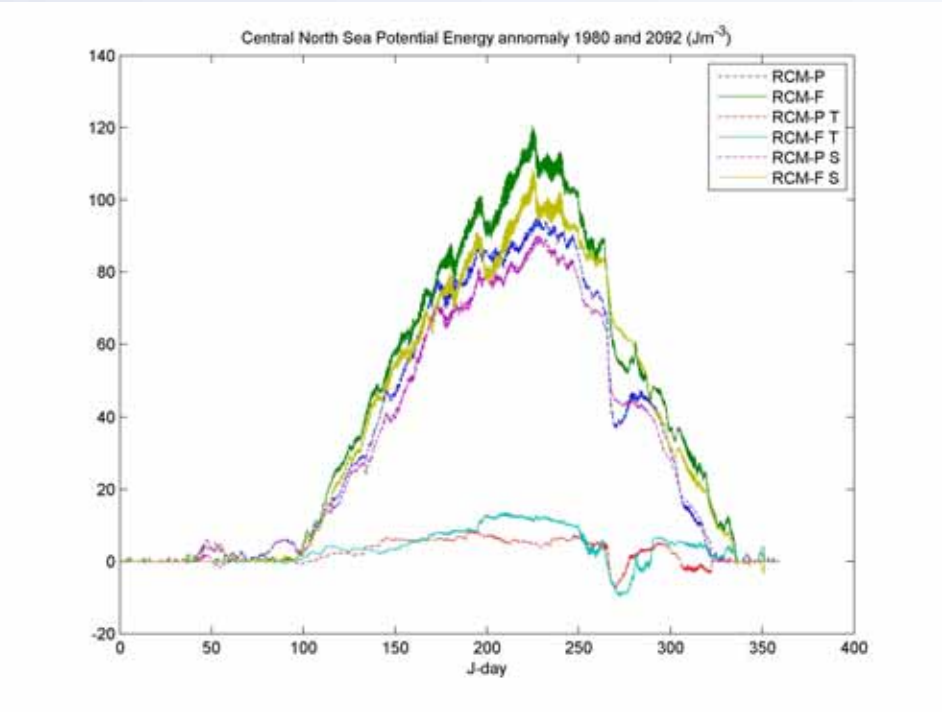
S.D. August Potential Energy Anomaly



Time series in Central North Sea

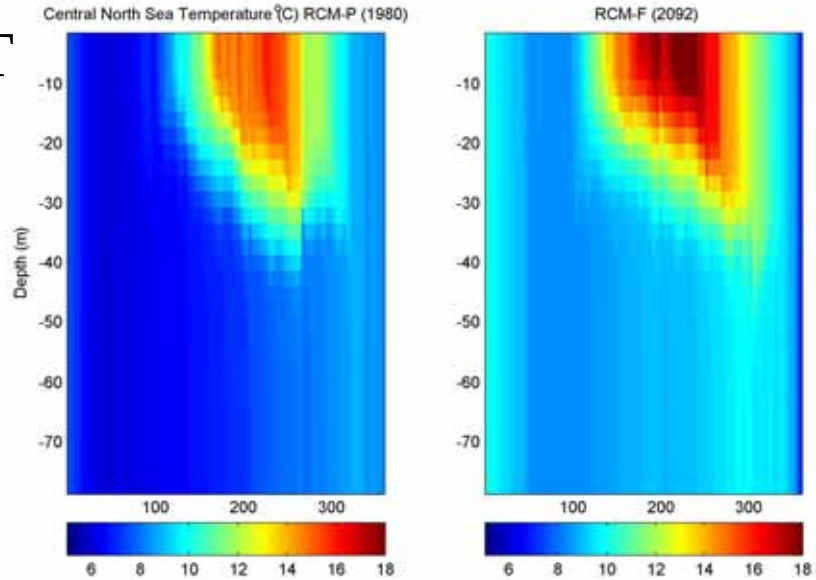
Enhanced stratification
Enhanced role of salinity

PEA

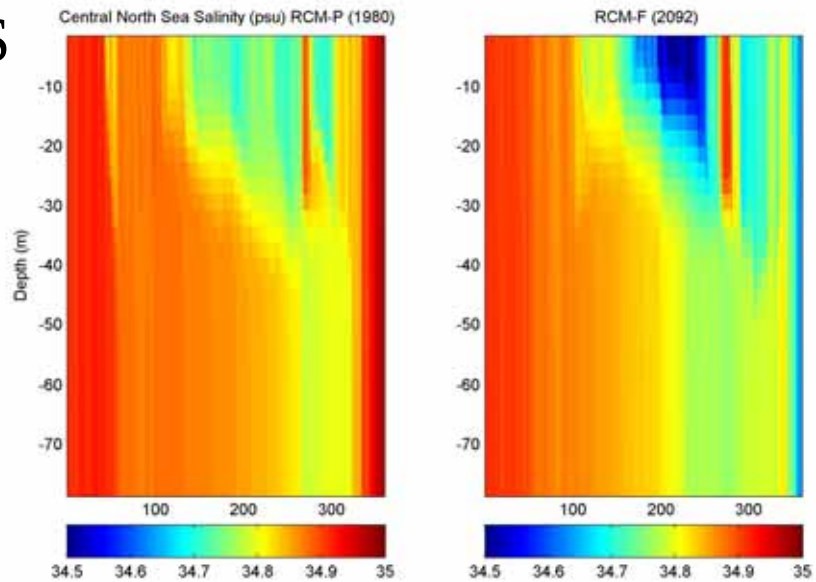


RCM-P RCM-F

T



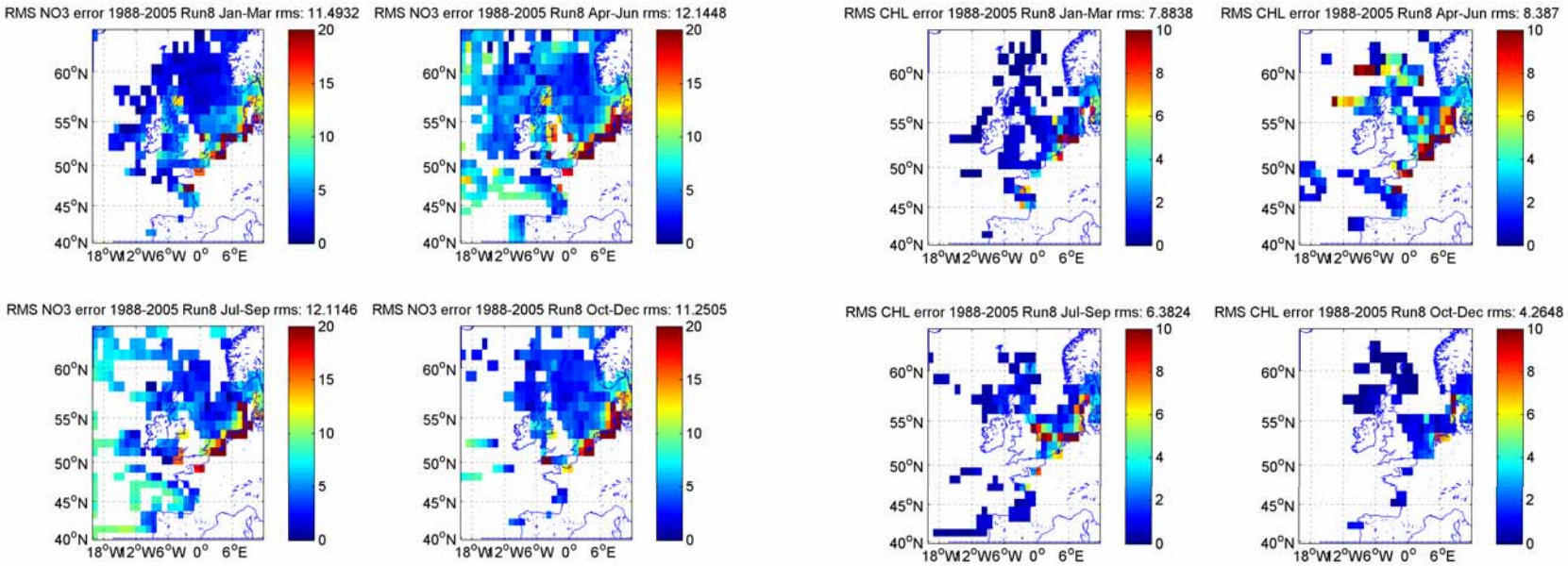
S



Validation:

For 1988-2005
ICES data base holds for Atlantic Margin Model:
56000 CTD casts
56000 Nitrate measurements
32000 Oxygen measurements

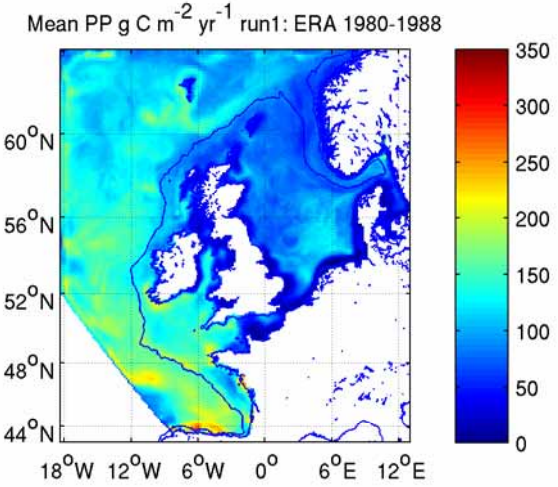
See: in *J. Mary Sys.*
Holt et. al 2005
Lewis et al. 2006
Allen et al. 2007
'Error quantification…'

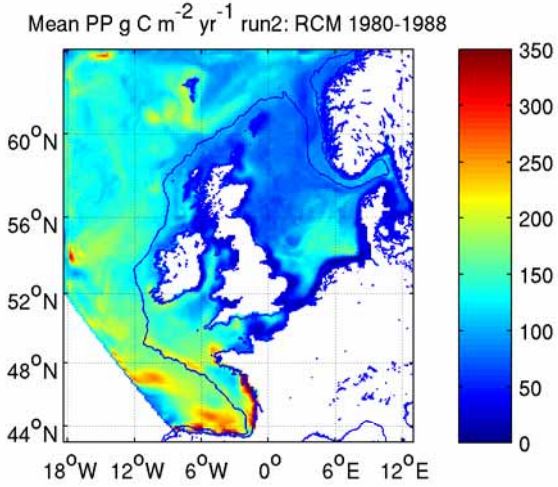


Typically ~50% rms error ~17% +ve bias

Primary production

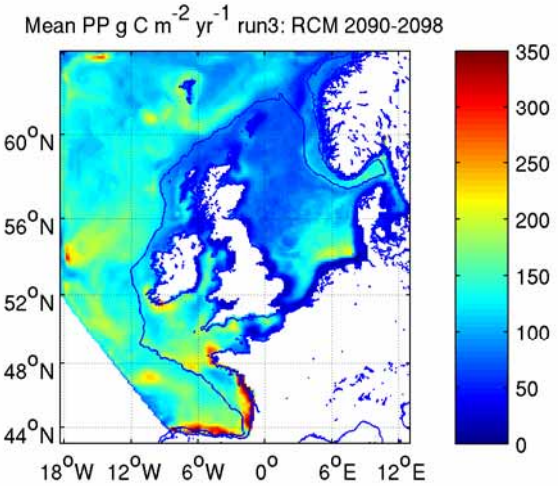
ERA

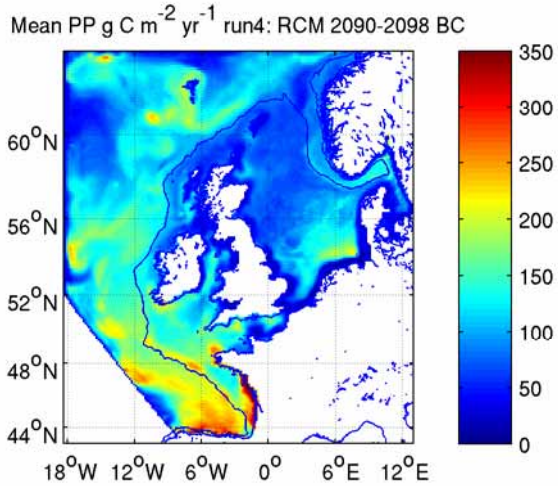




RCM-P

RCM-F

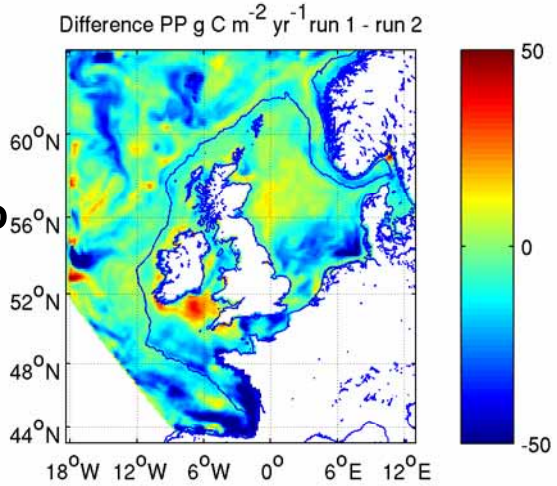


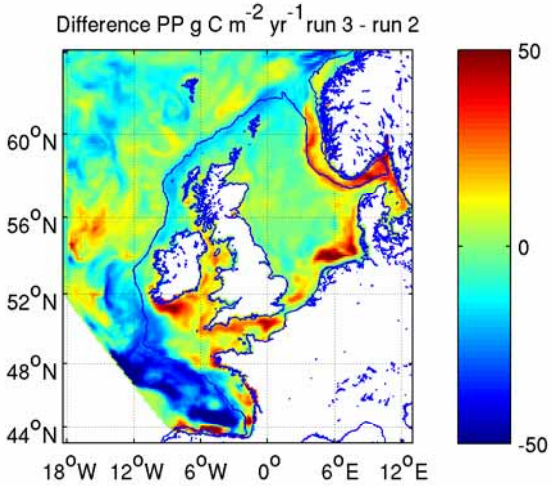


RCM-FB

Change in Primary production

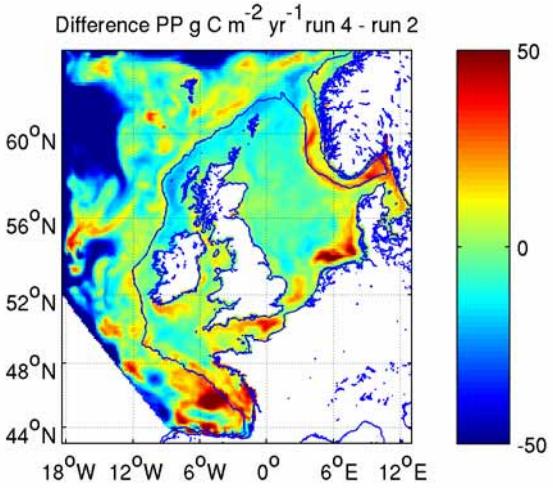
ERA-RCM-P

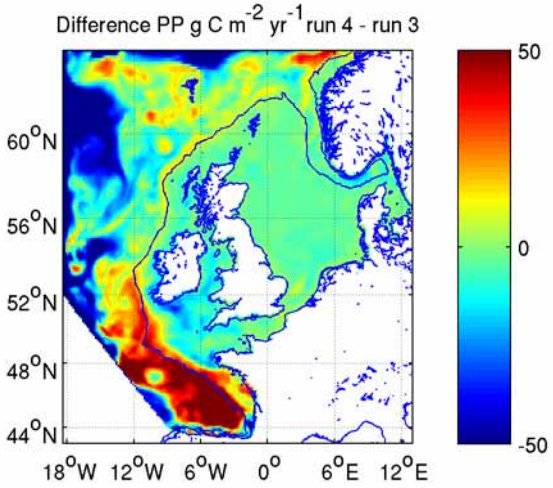




RCM-F – RCM-P

RCM-FB – RCM-P





RCM-FB – RCM-F

Production on shelf

Pg C^{-1}	ERA	RCM-P	RCM-F	% CHANGE
• <50m	0.11	0.15	0.16	+8%
• 50-100m	0.12	0.13	0.13	+4%
• 100-200m	0.13	0.15	0.15	-4%

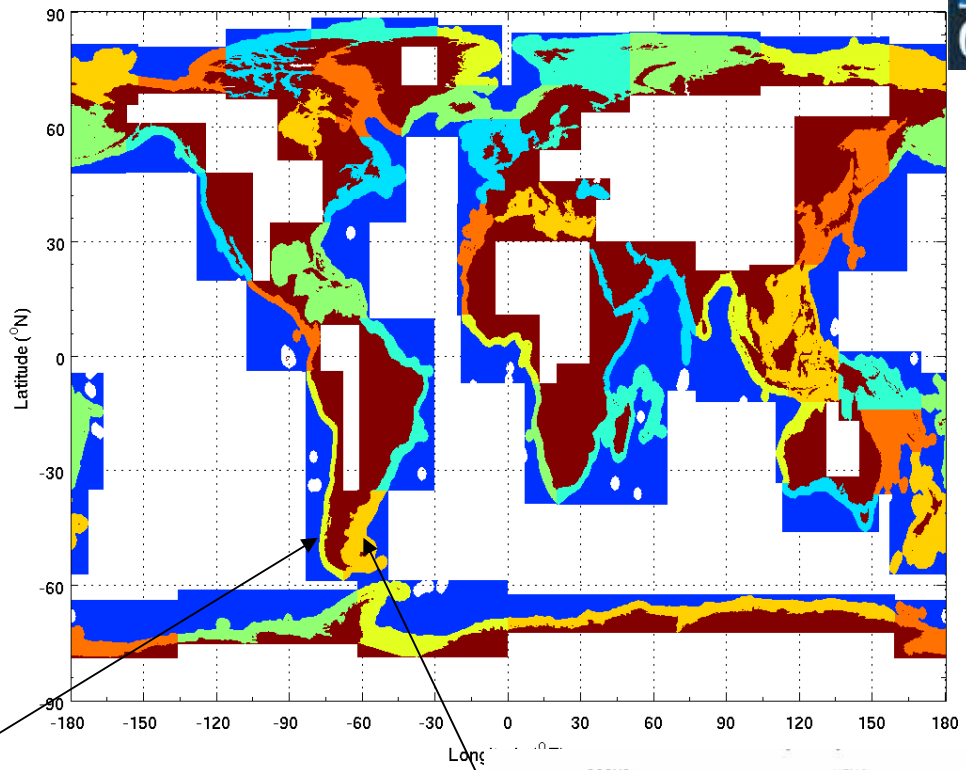
BUT

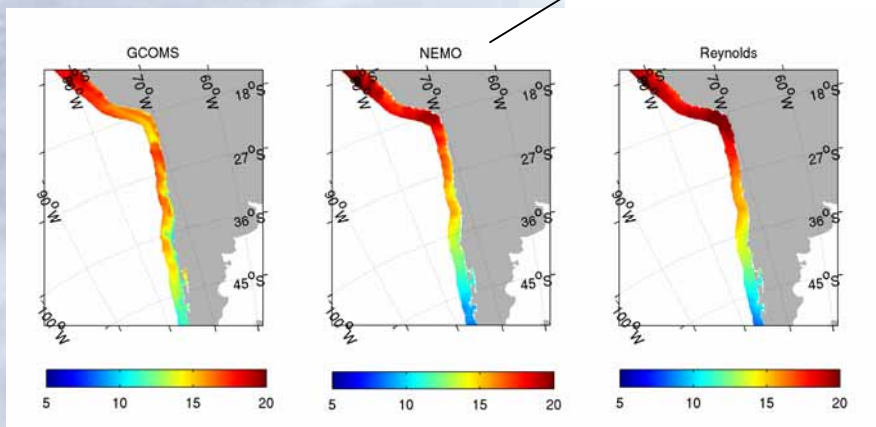
Change is largest in near coastal zone – where the model uncertainties are largest.

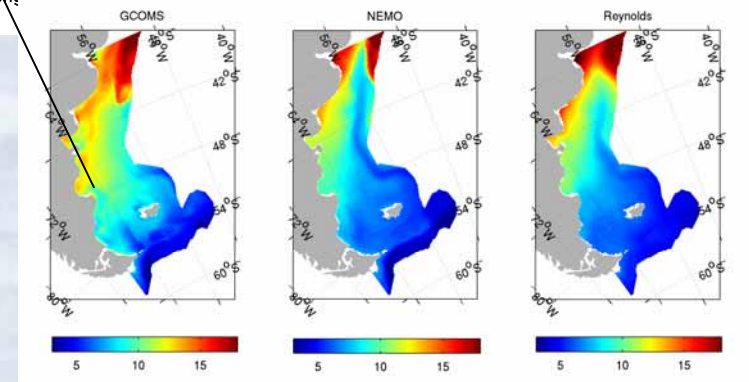
- Variability in river-loading
- Variability in optical properties (SPM and CDOM)
- Skill of ecosystem models in highly turbid, turbulent regions

The Global Coastal Ocean Modelling Project

- Taking this approach to all shelf seas around the global
- Automatically generated regional models nested in to and an OGCM







Conclusions

- Substantial change between ERA-40 and RCM forced simulation (e.g. annual cycle in salinity is reversed)

From RCM past to Future:

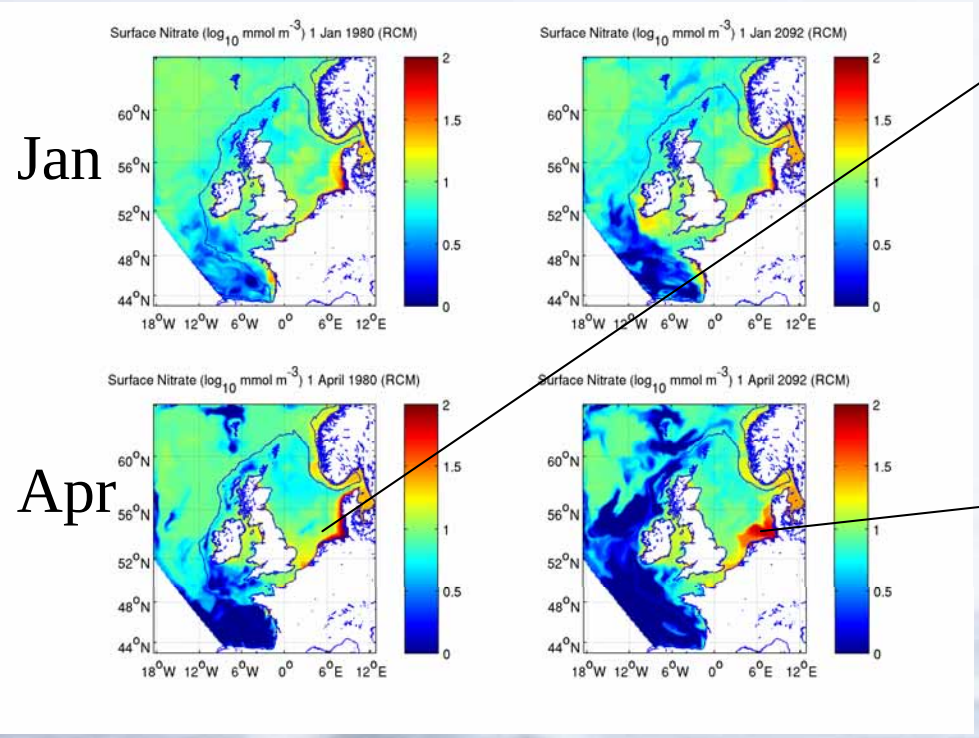
- Increase in Potential Energy Anomaly
  - Both temperature and salinity component
  - Change in paradigm away vertical flux dominated?
- Largest changes expected where energetic constraints are weakest (e.g. small gradient in h/u^3) e.g. German Bight
- Weak increase in primary production – particularly in near coastal zone

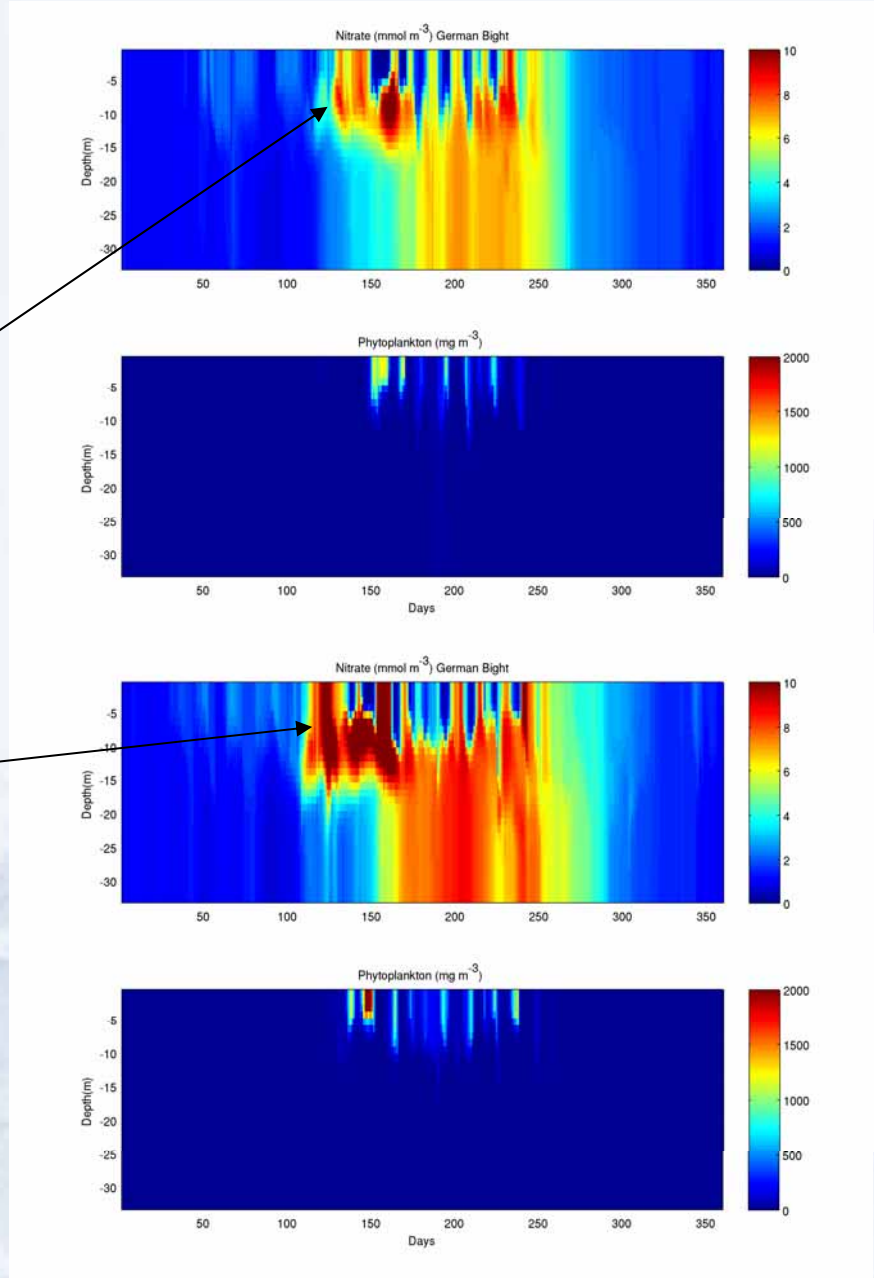
Time series in the German Bight

RCM-P RCM-F

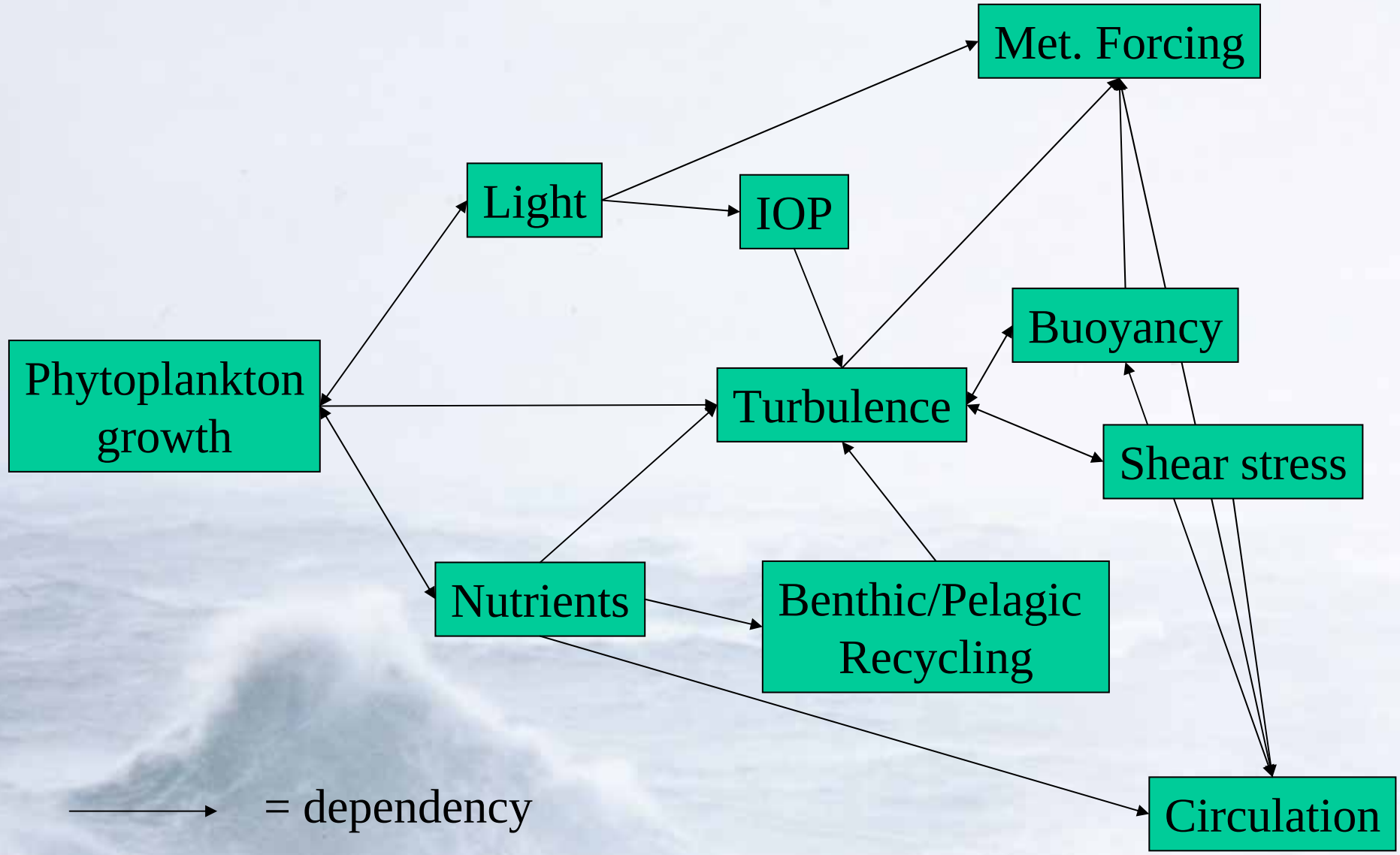
Jan

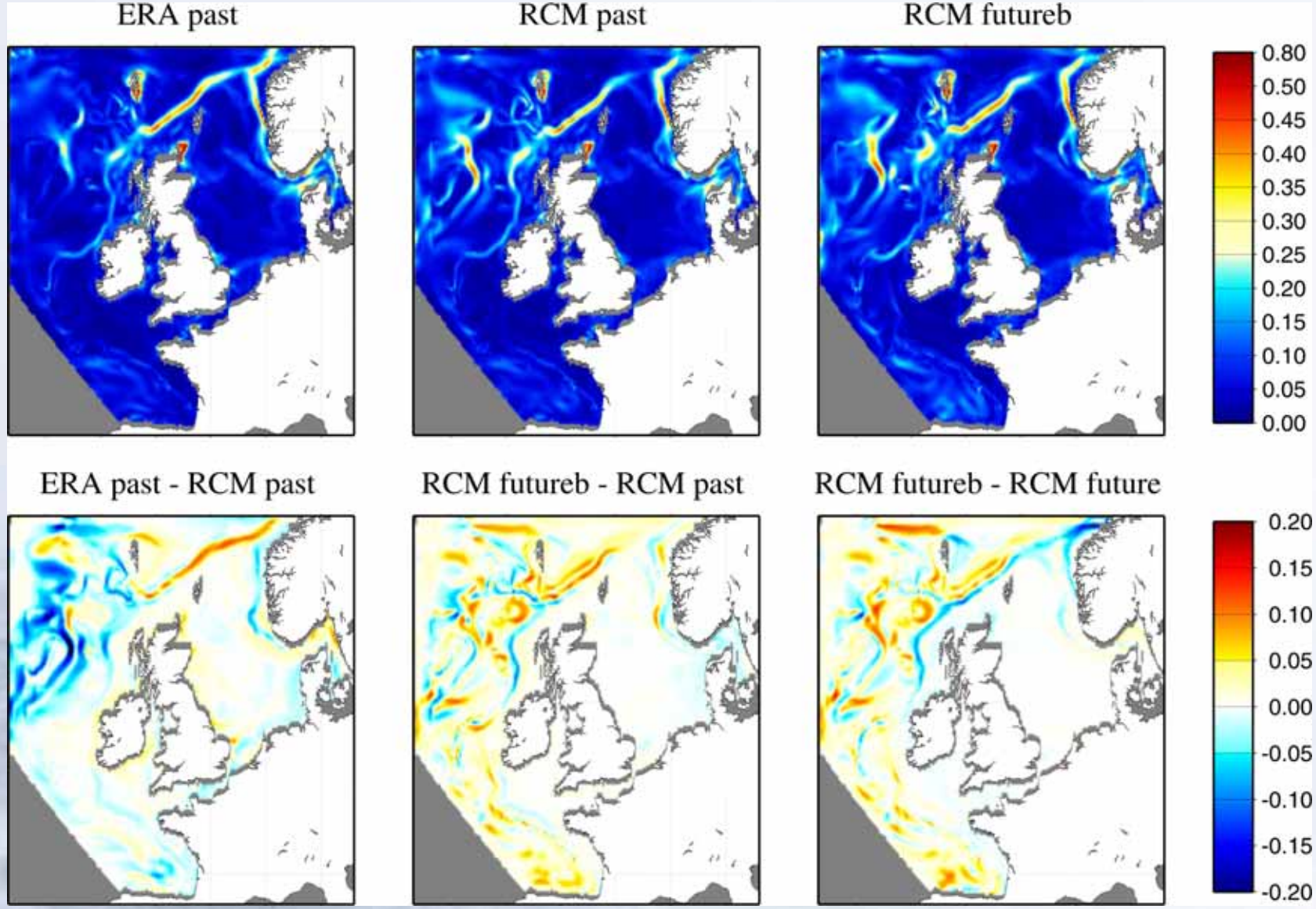
Apr



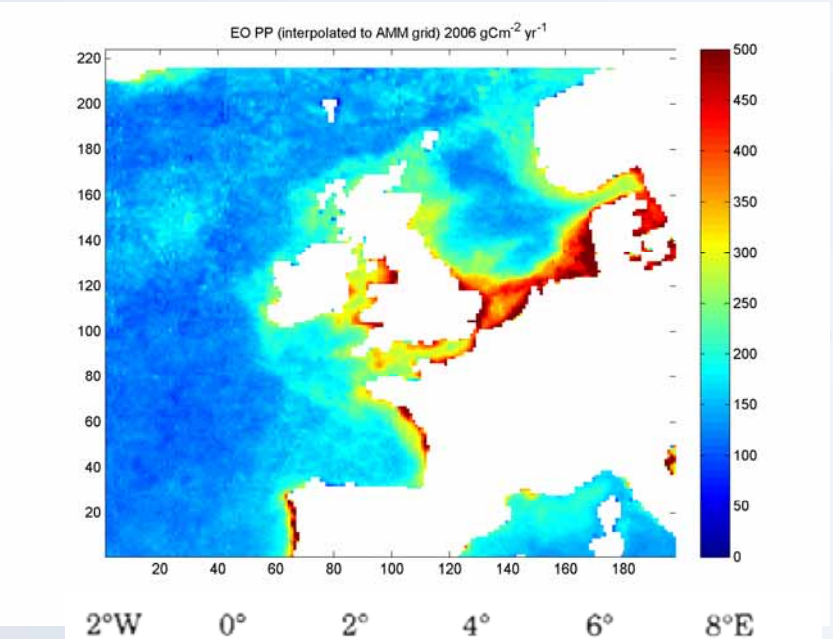


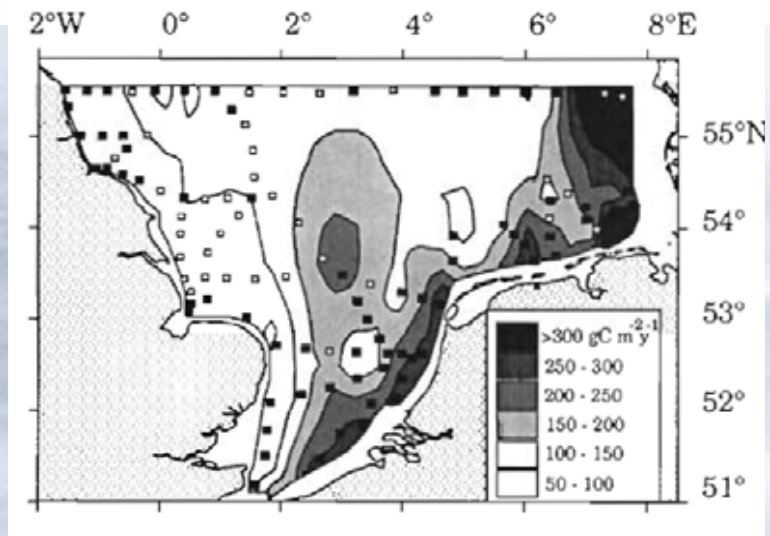
Physical controls of phytoplankton growth




ERA past
RCM past
RCM futureb
0.80
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
ERA past - RCM past
RCM futureb - RCM past
RCM futureb - RCM future
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20

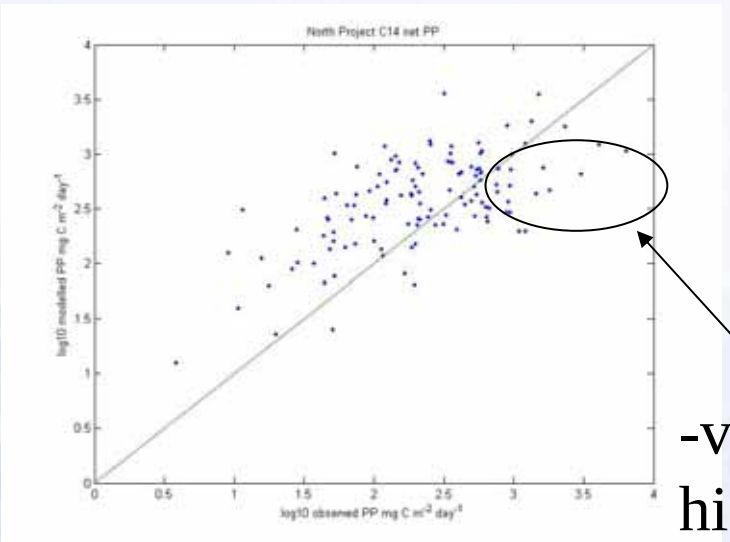
The primary production problem: what are we shooting at ?





Joint and Pomeroy (1993)

- Satellite PP models are contaminated by CDOM and SPM
- Direct observations are sparse especially in near coastal-regions



-ve bias at high PP

POLCOMS-ERSEM