

Ecosystem Modelling on the European Shelf

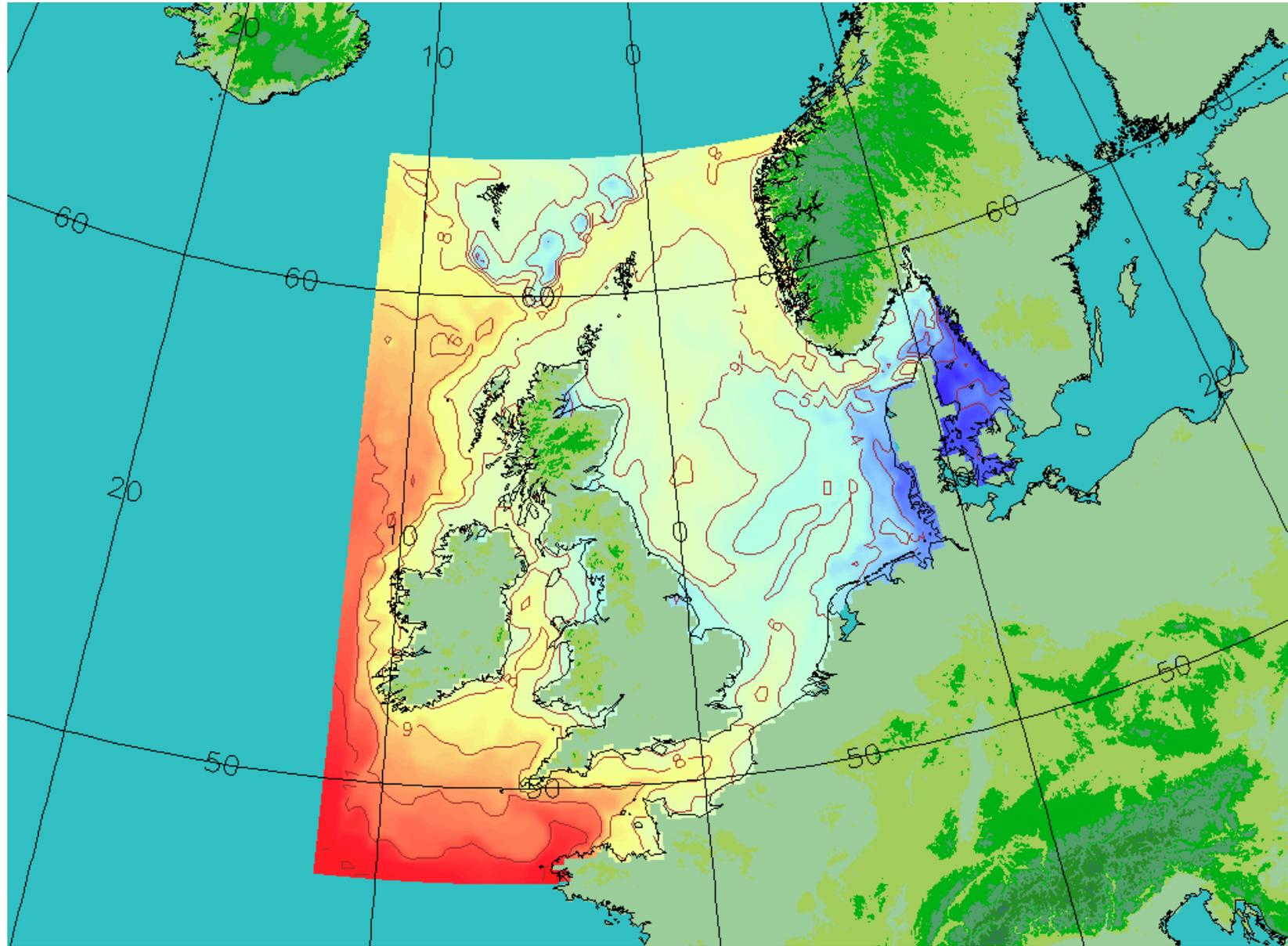
Basin meeting
Hamburg 23-25th Jan 2007

Icarus Allen (PML)

J Blackford, K Lewis, A Taylor, T Smyth, R Torres (PML)

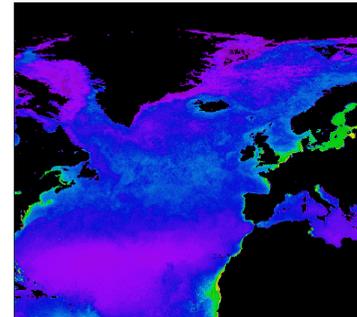
J Holt, R. Proctor, S Wakelin (POL)

J Siddorn (Met Office)



Some Science questions:

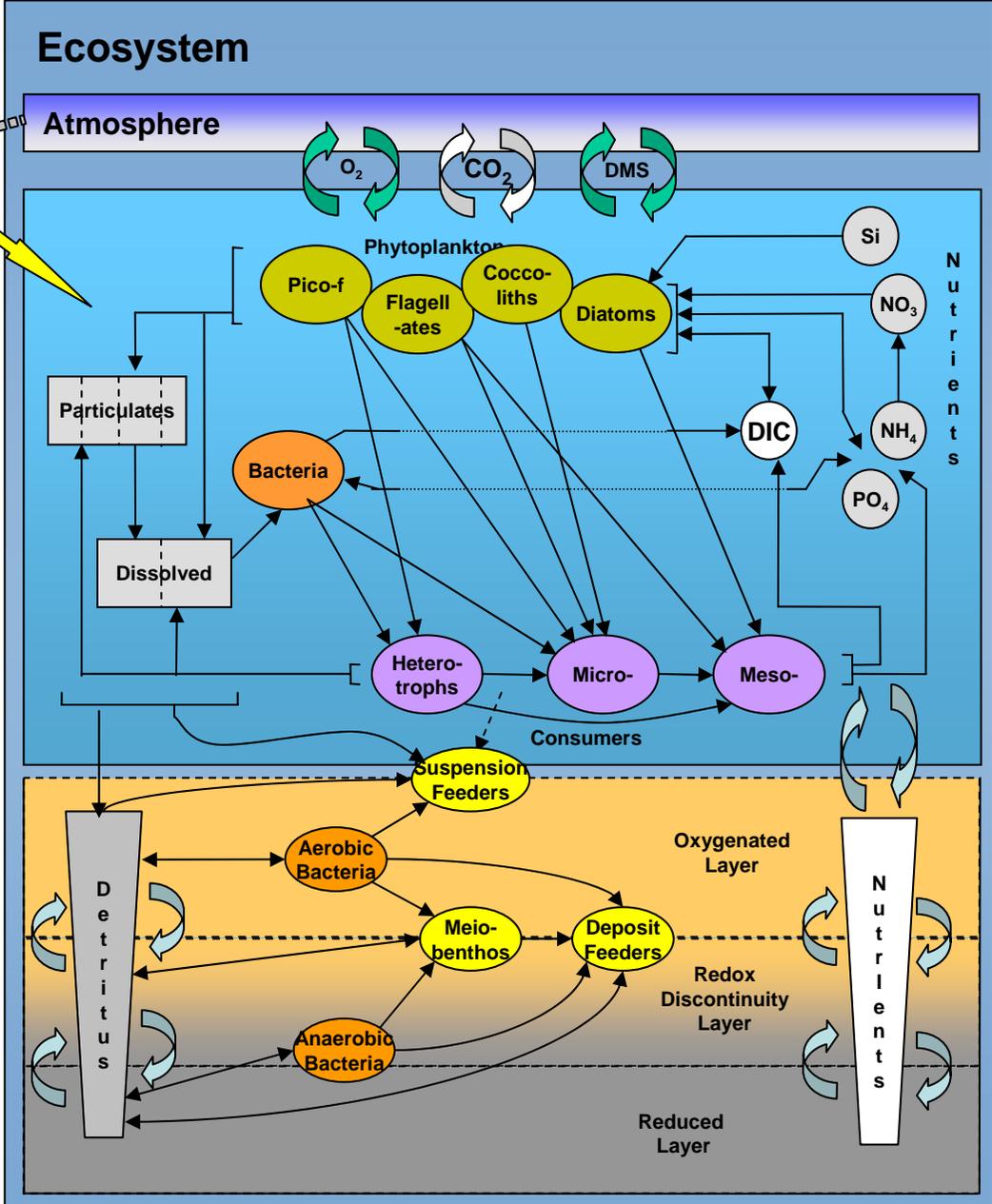
- Resolving relative impacts of shelf seas exchange, with land, ocean and atmosphere
- NW shelf Source or sink for C, N, P?
- Do the models contain climate change signals
- What is the uncertainty in the models, can we reduce it?



Marine System Modelling

ERSEM - key features

- Carbon based process model
- Functional group approach
- Resolves microbial loop and POM/DOM dynamics
- Complex suite of nutrients
- Includes benthic system
- Explicit decoupled cycling of C, N, P, Si and Chl.
- Adaptable: DMS, CO₂/pH, phytobenthos, HABs.
- Consequently flexible and applicable to a wide range of global ecosystems.**

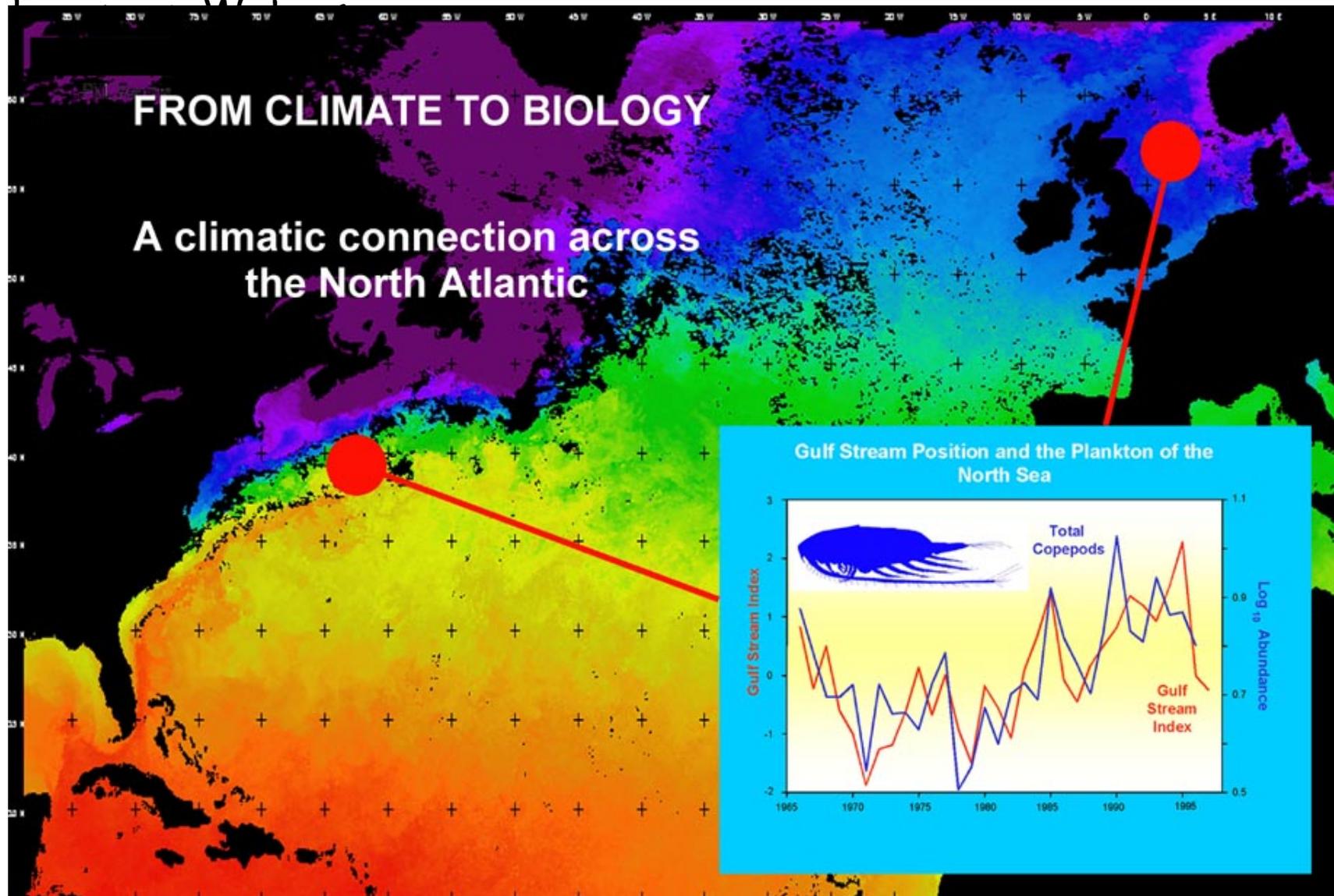


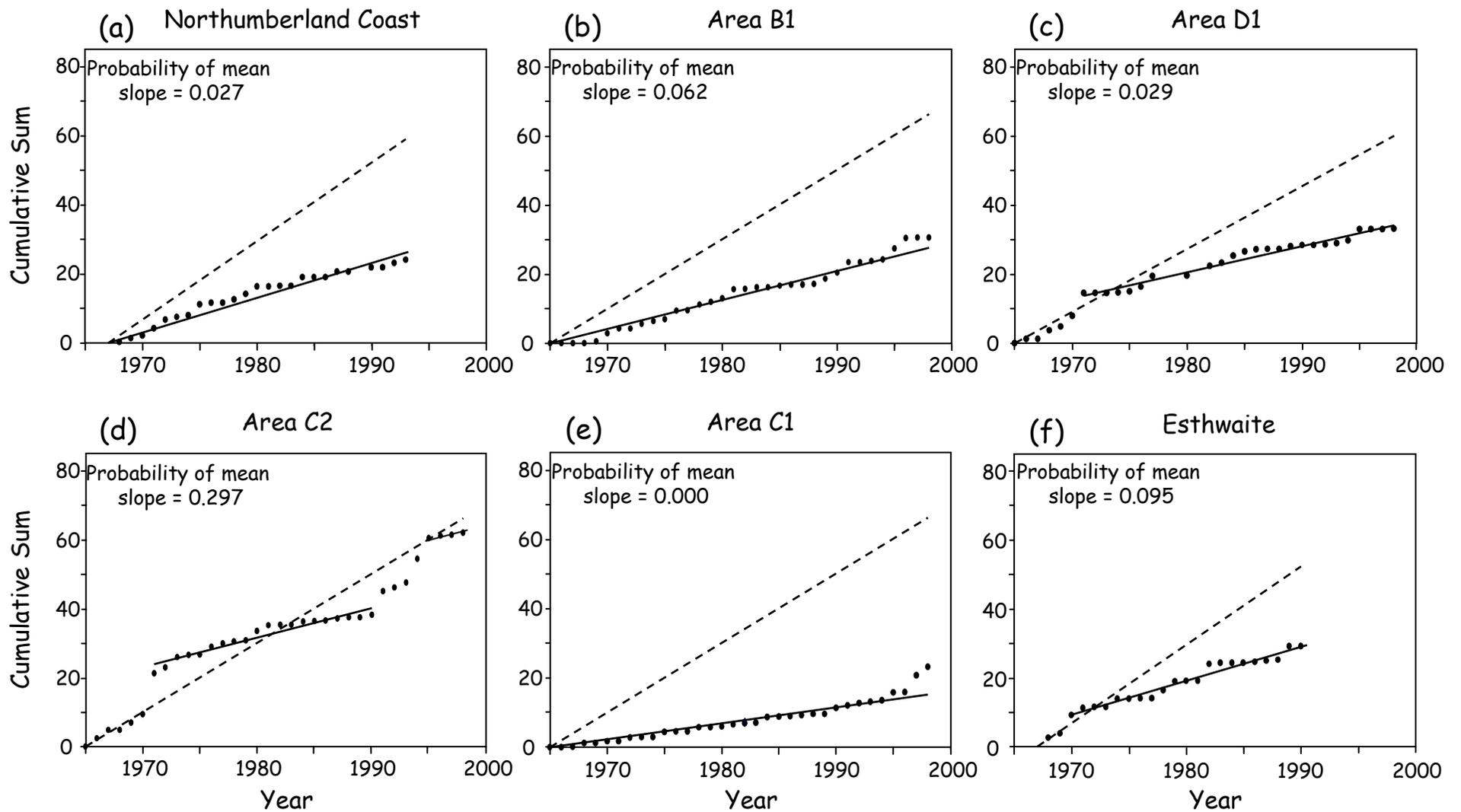
Ecosystem response to climate in ERSEM

J. I. Allen, AH Taylor

Taylor, Allen & Clarke Nature 2002

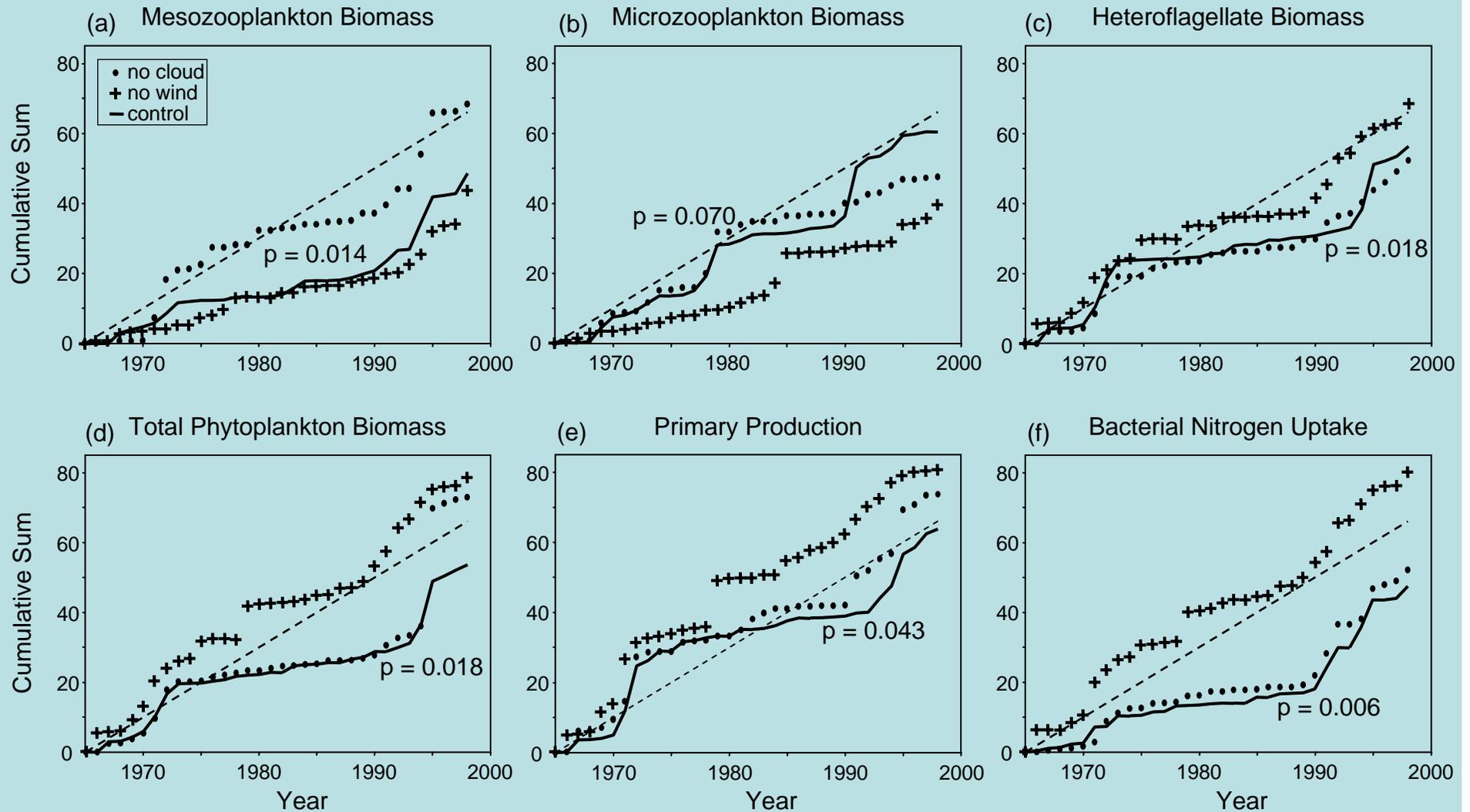
A relationship has been found between the position of the North Wall of the Gulf Stream and zooplankton populations in Northern



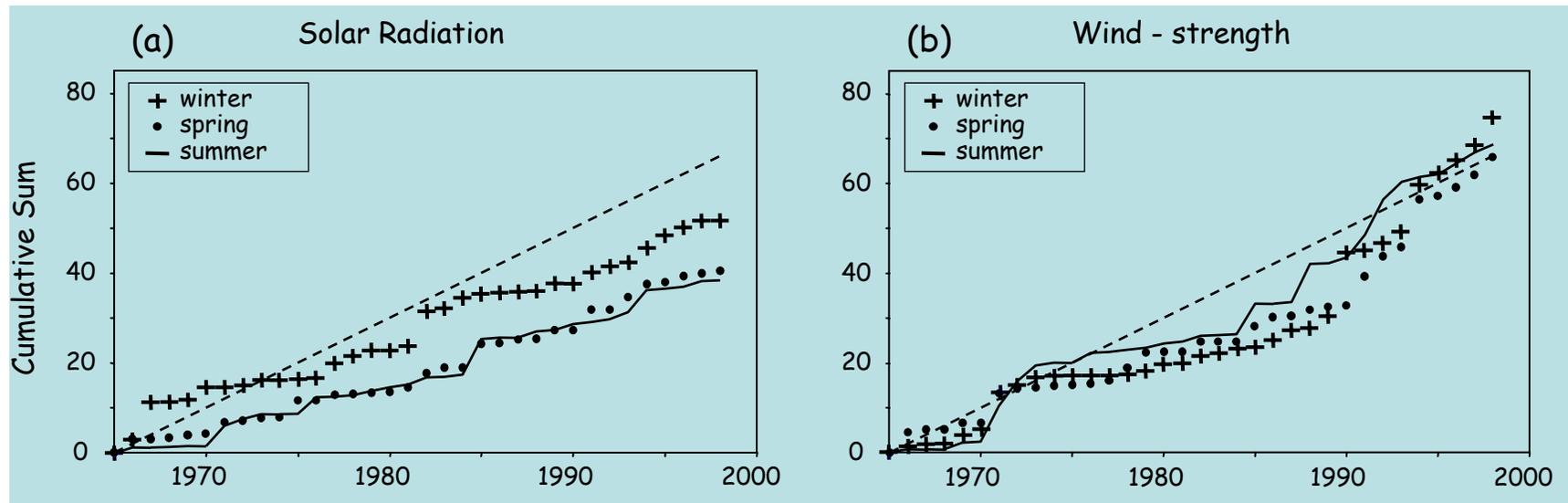


Association between plankton populations and the
Position of the Gulf Stream

GNSW signal is found in 19 out of 25 biological fluxes and variables tested



Association between model functional groups and the position of the Gulf Stream



GSNW signal is scattered through the meteorological data rather than localized in any particular subset.

All of these graphs, apart from the wind strength in winter, have probabilities of well over 0.1, implying that the *GSNW* signal is only a weak constituent of these atmospheric data.

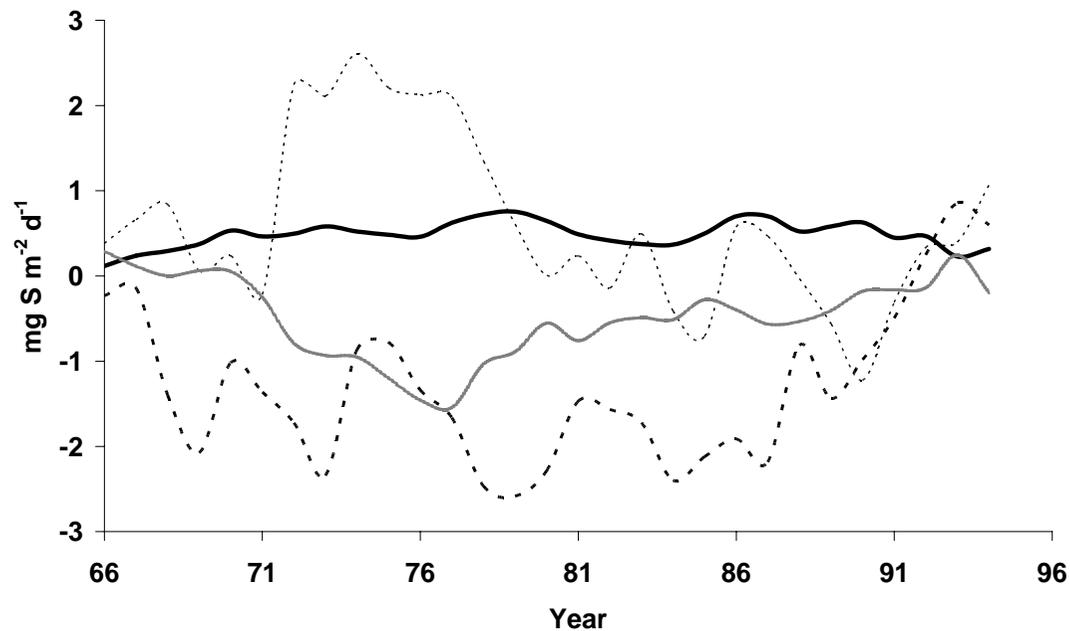
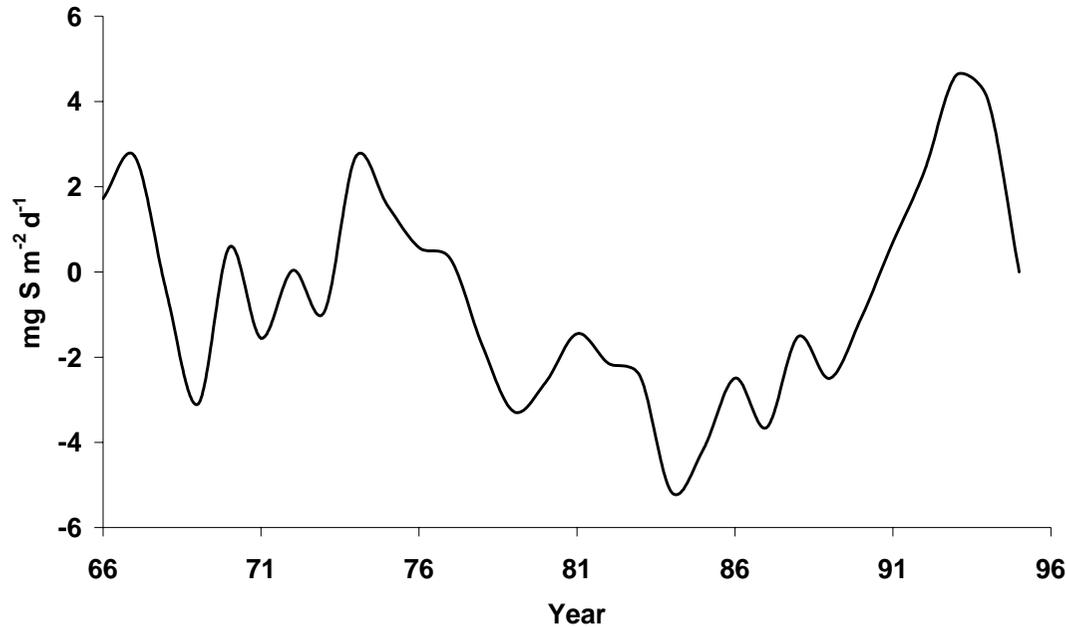
These probabilities are much larger than those obtained from the ERSEM output.

Qualitative validation

Table 1. A comparison between the annual average of phytoplankton functional group and total biomass generated by the model corresponding annual average CPR data. The values are the probability of the CUSUM relationship between the model output and CPR data being random. The CPR data is for the stratified central North Sea (WinCPR Vezzulli et al., 2005), the region simulated by the model. Probabilities of less than 10% are highlighted. The species were chosen to match those used by Leterme et al., (2005) in their analysis of North Atlantic phytoplankton change.

	Model diatoms	Model flagellates	Model dinoflagellates	Model total phytoplankton
Diatoms				
<i>Thalassionema nitzschiodes</i>	0.15	0.4	0.16	0.19
<i>Thalassiothrix longissima</i>	0.05	0.06	0.09	0.05
<i>Thalassiosira</i> spp.	0.06	0.62	0.8	0.14
Dinoflagellates				
<i>Ceratium furca</i>	0.14	0.12	0.007	0.09
<i>Ceratium fusus</i>	0.2	0.31	0.04	0.15
<i>Ceratium horridum</i>	0.34	0.28	0.01	0.35
Phytoplankton Colour Index (PCI)	0.01	0.44	0.44	0.004

Can the model reproduce a regime shift?



Subtract mean and add residuals

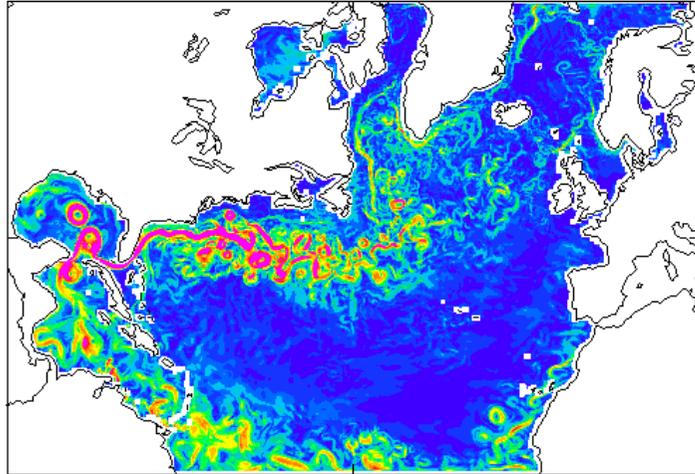
Summation plots of decadal variability of a) annual daily mean gross production of DMSP and b) the annual daily mean gross production of DMSP by diatoms (solid black line), flagellates (heavy dash), picoplankton (light dash) and dinoflagellates (grey).

Successive positive residuals produce an increasing slope, while successive negative residuals produce a decreasing slope.

A succession of values similar to the mean show no slope.

Allen et al 2006 Tellus B

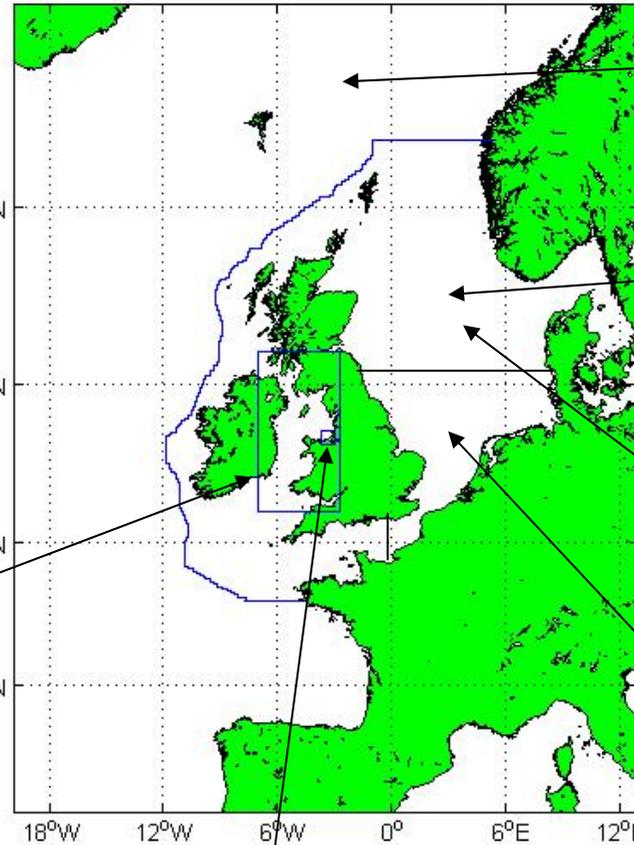
Model Domains



Met office FOAM model

Blue =
POLCOMS-ERSEM

b.c.'s



Atlantic Margin
 $1/6^{\circ} \times 1/9^{\circ}$

Medium resolution
Continental shelf
 $1/10^{\circ} \times 1/15^{\circ}$

High resolution
Continental shelf
 $1/40^{\circ} \times 1/60^{\circ}$

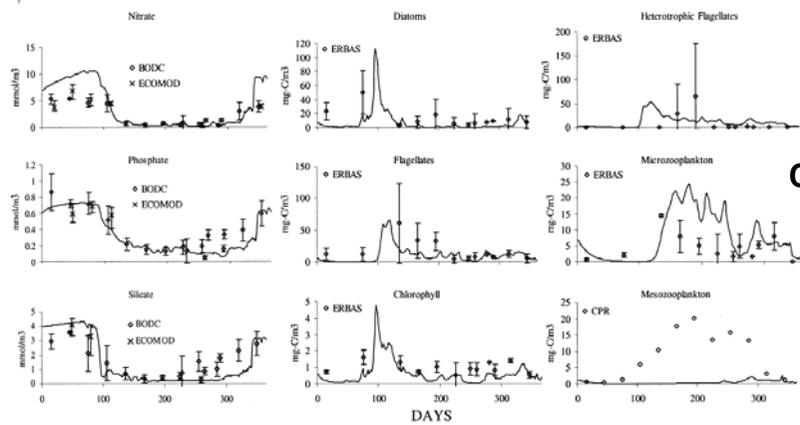
S. North Sea
 $1/40^{\circ} \times 1/60^{\circ}$

Irish Sea
 $1/40^{\circ} \times 1/60^{\circ}$

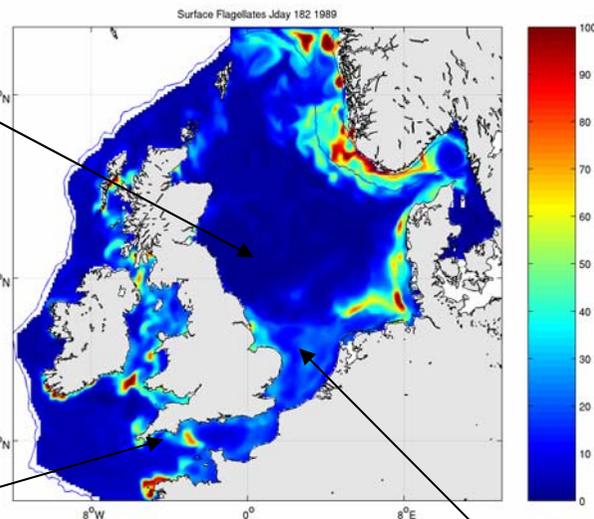
Liverpool Bay
 $1/400^{\circ} \times 1/600^{\circ}$

1 way coupling ocean to shelf – the future is unstructured grids (ICOM, under dev)

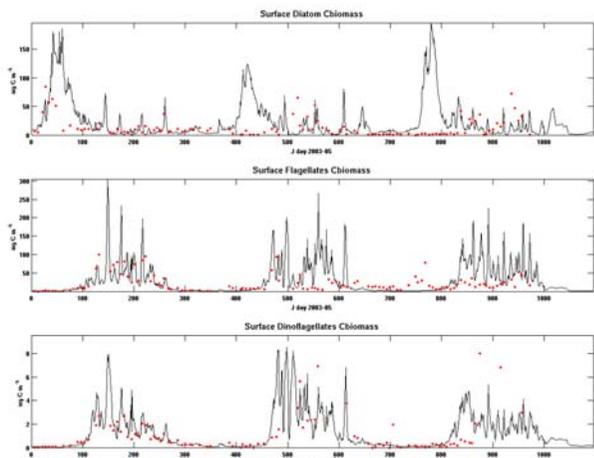
How good is the current model?



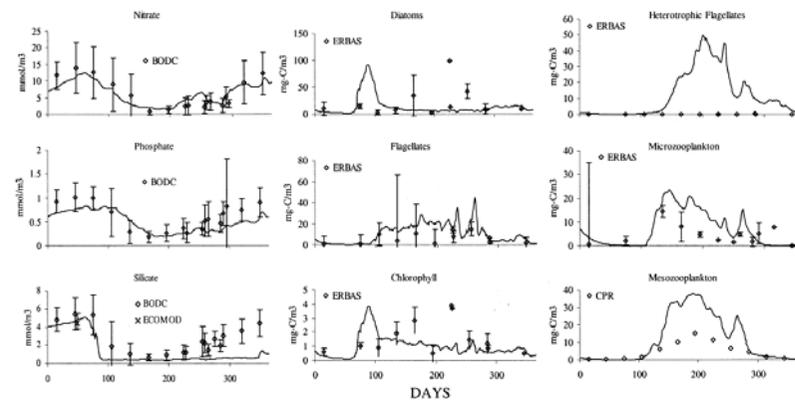
CS



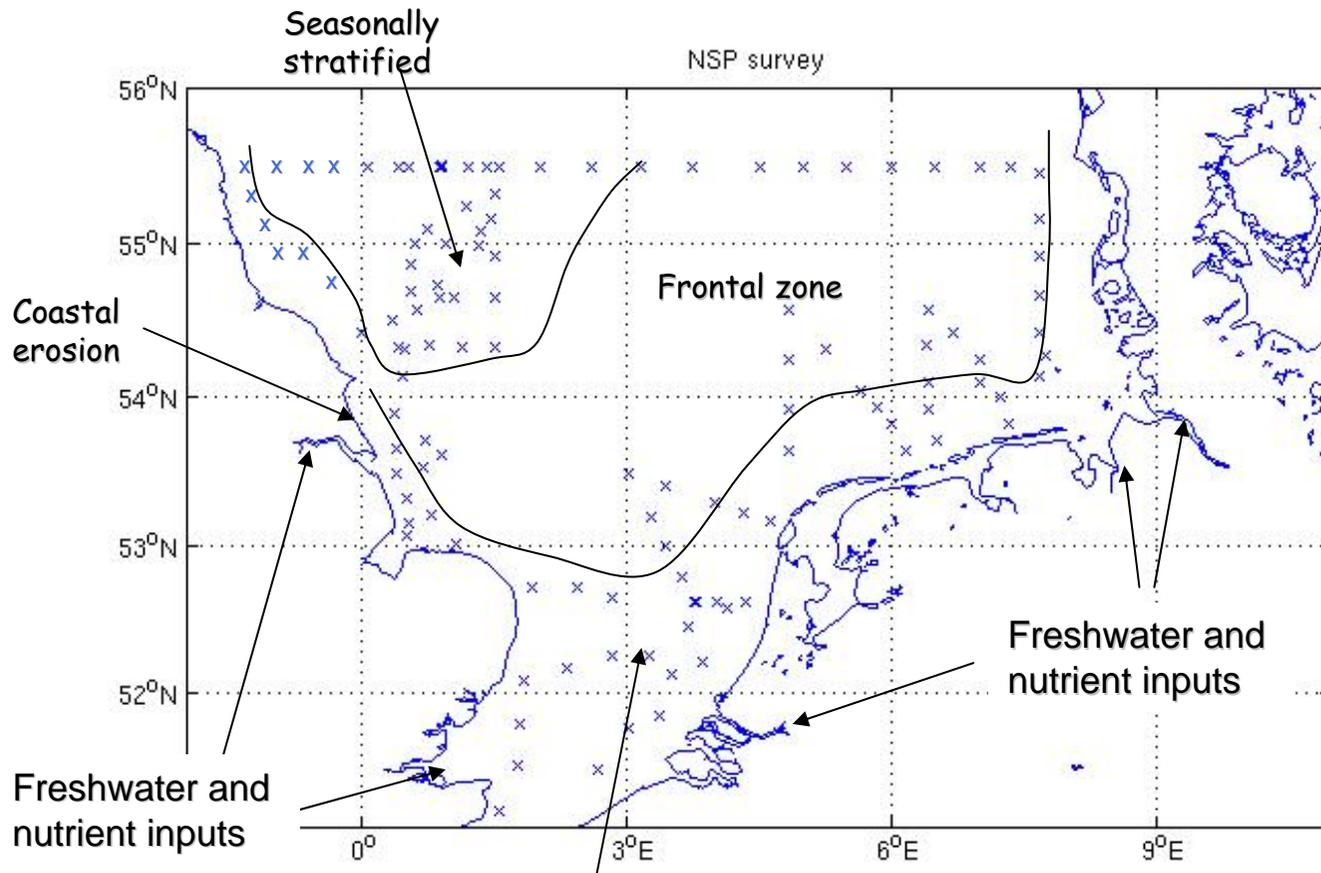
L4



AB



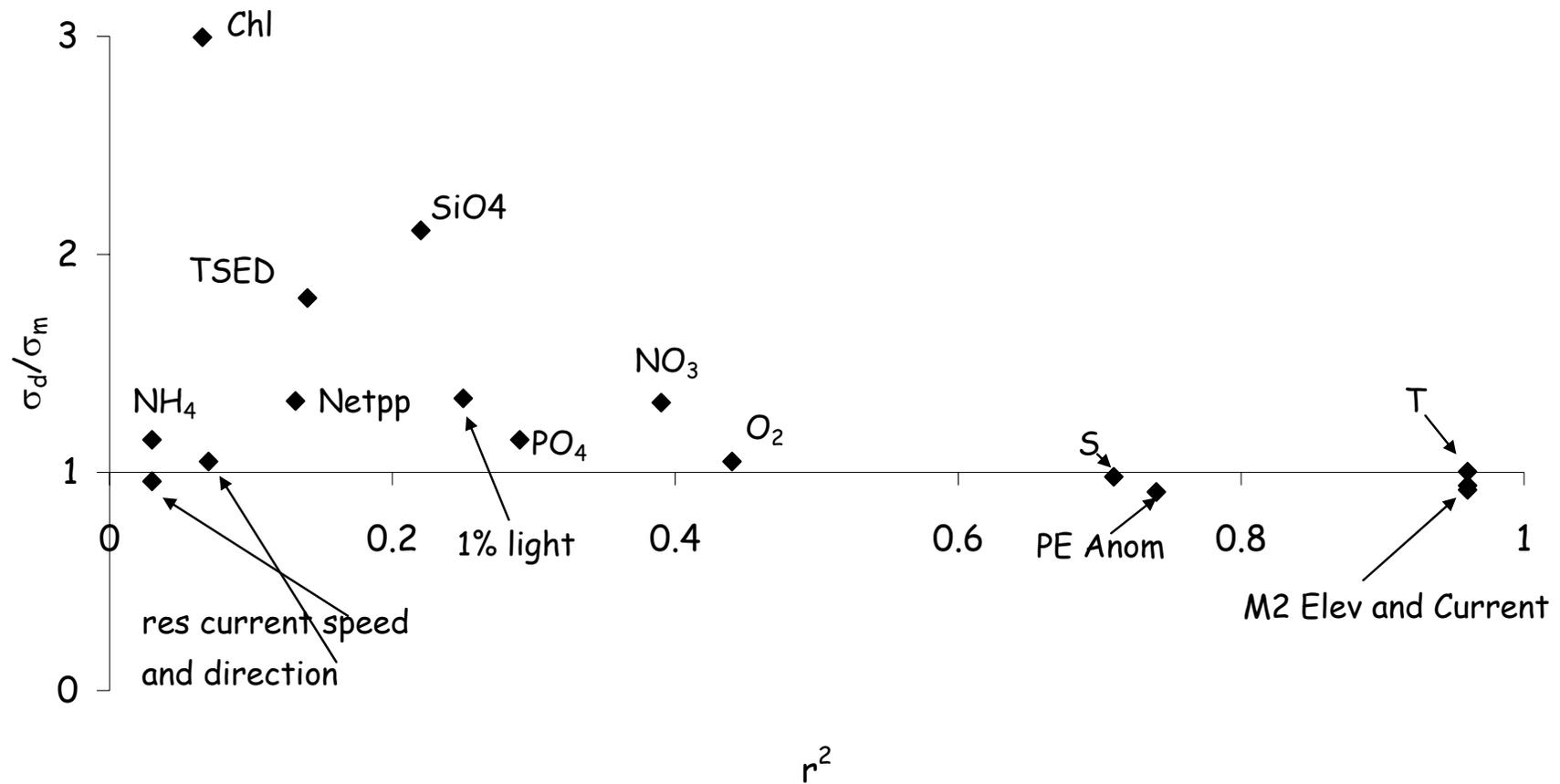
The most comprehensive data set : North Sea Project 1988-1989



16 Monthly Cruises surveying 121 stations + Moorings
T, S, Chl, NO₃, PO₄, NH₄, SiO₄, SPM, light, O₂

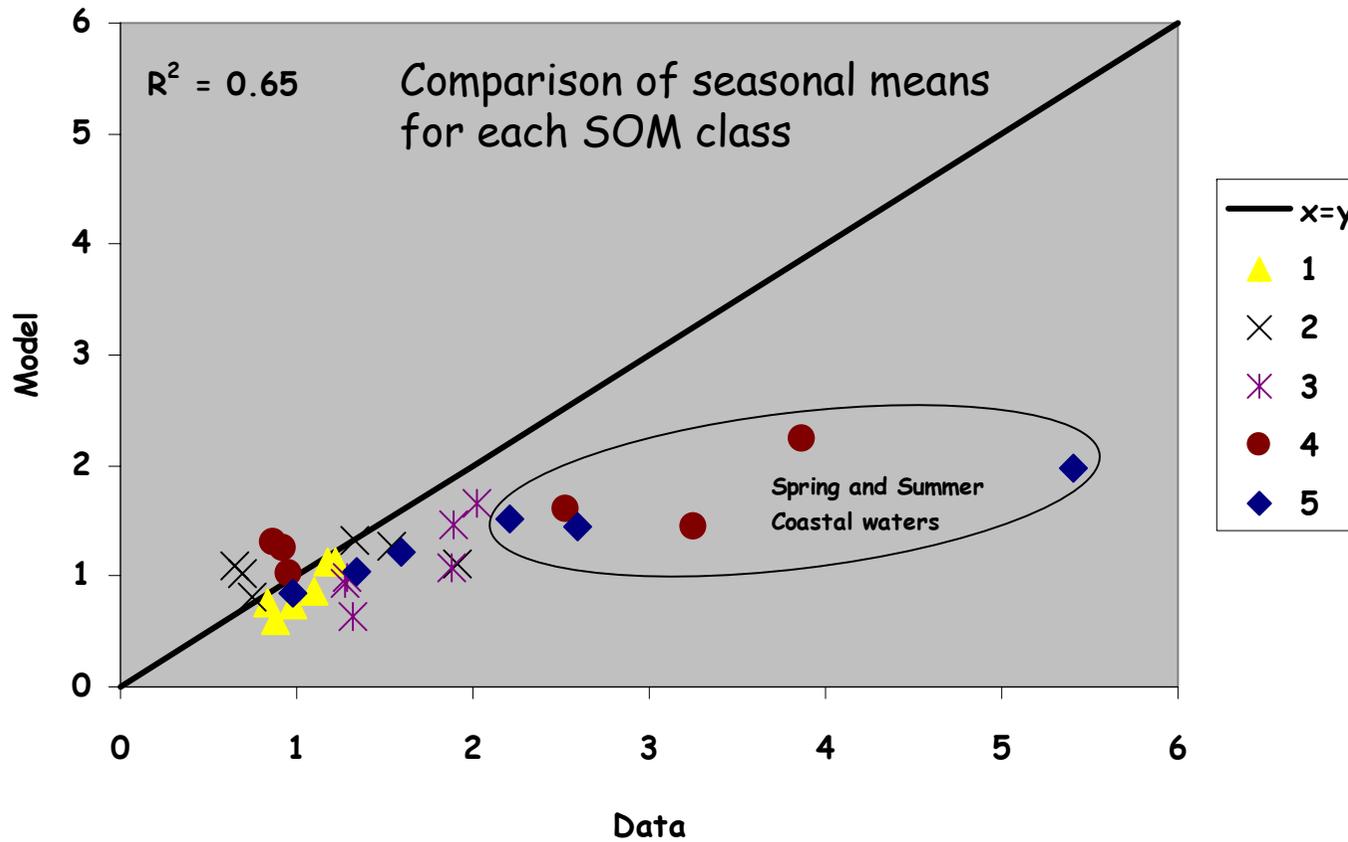
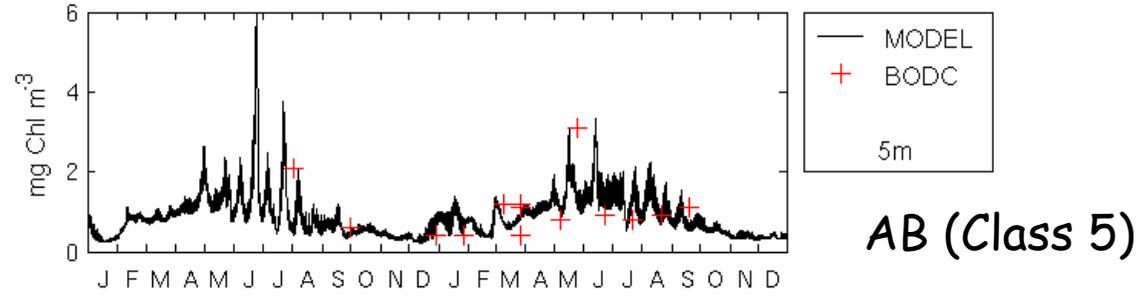
Summary of Model performance

MRSC-North Sea project 1988/89



Allen et al J Mar Sys (in press)

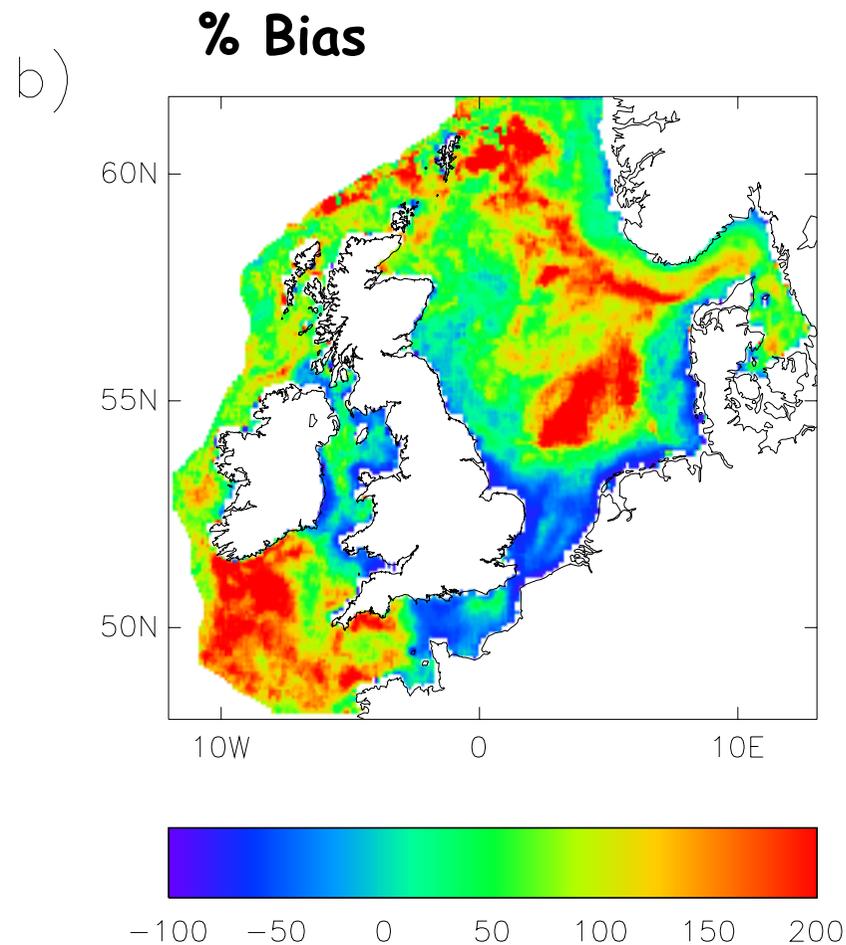
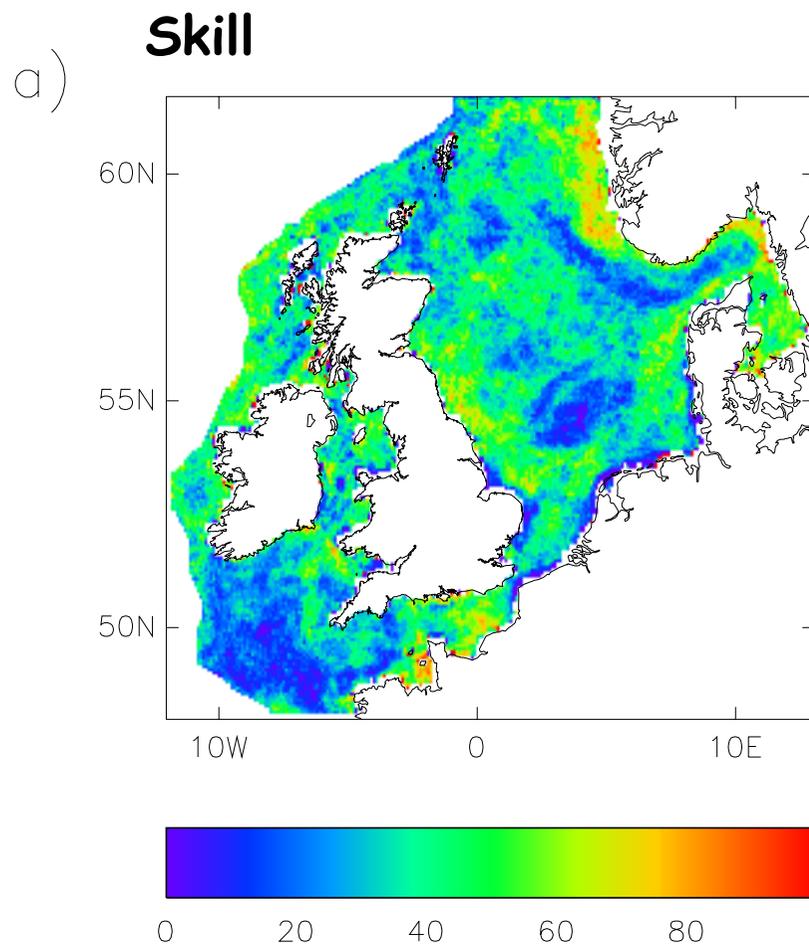
What about chlorophyll?



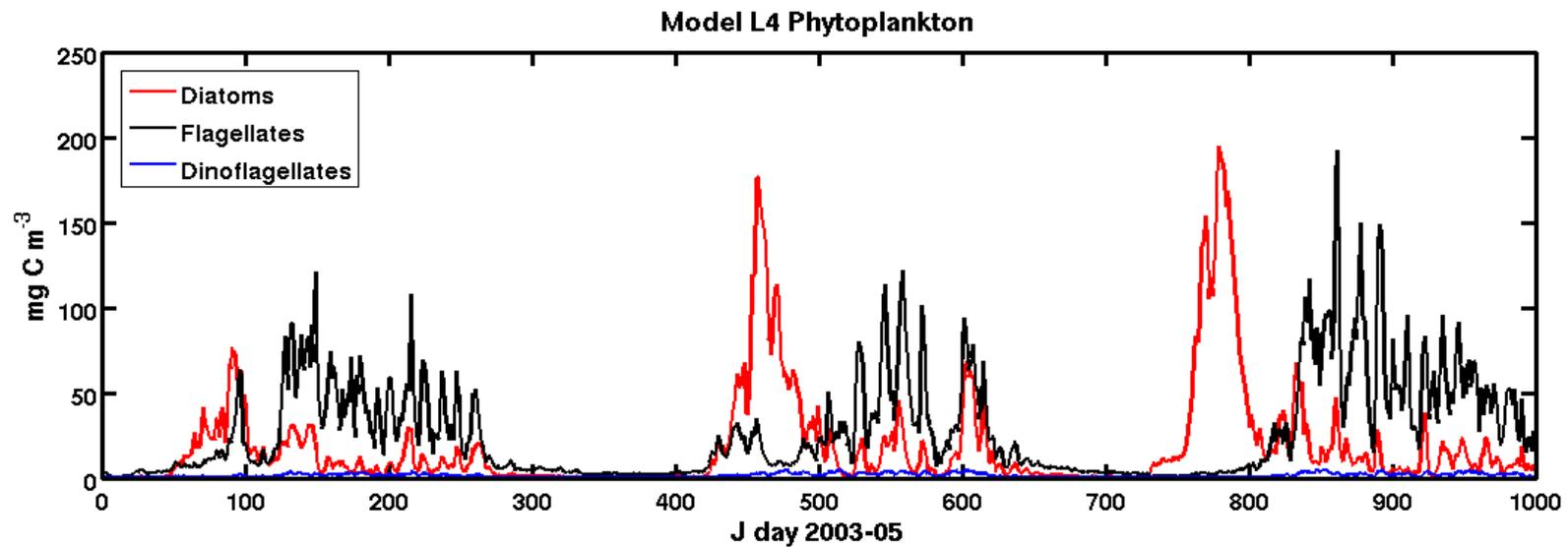
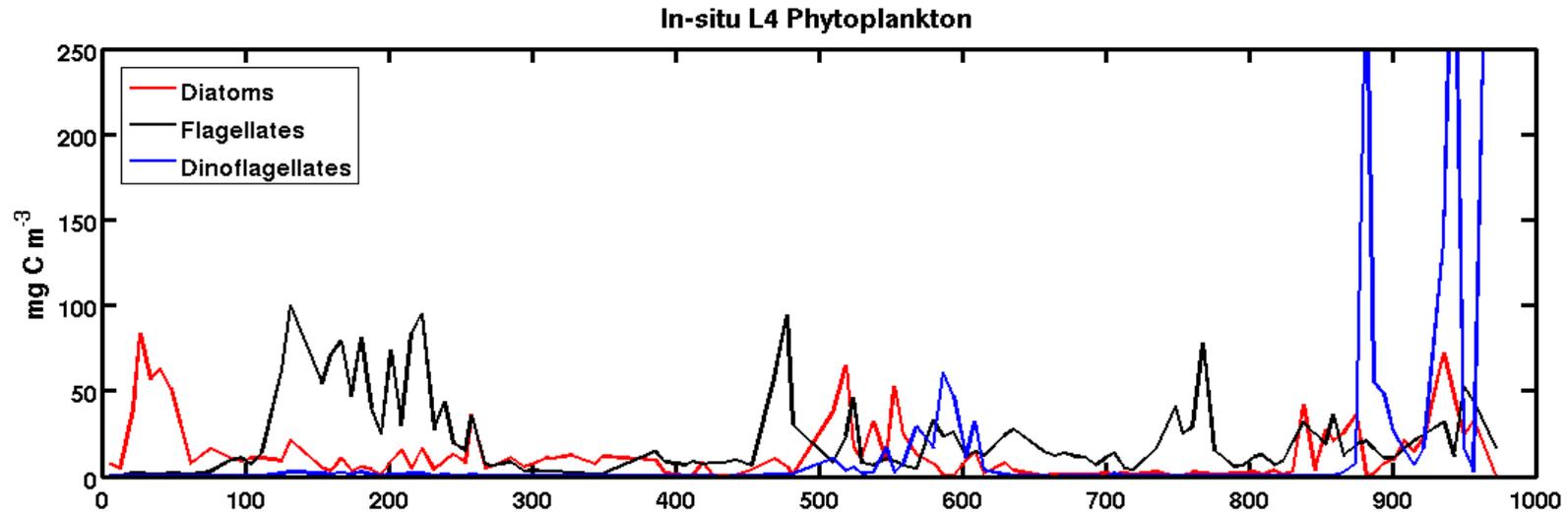
Annual Skill & Bias Maps for Chlorophyll

Model vs SeaWifs 2003

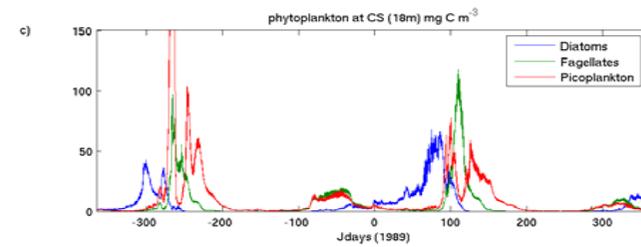
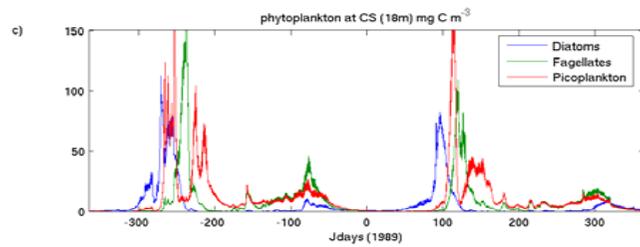
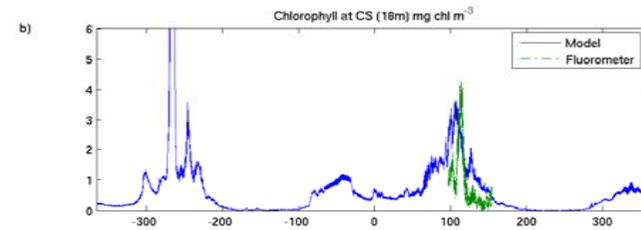
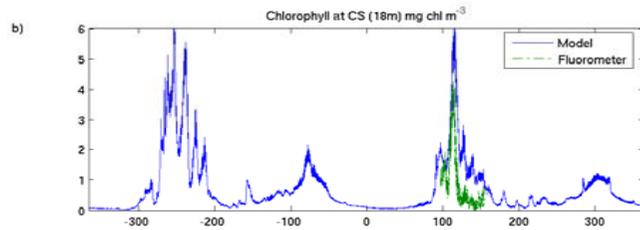
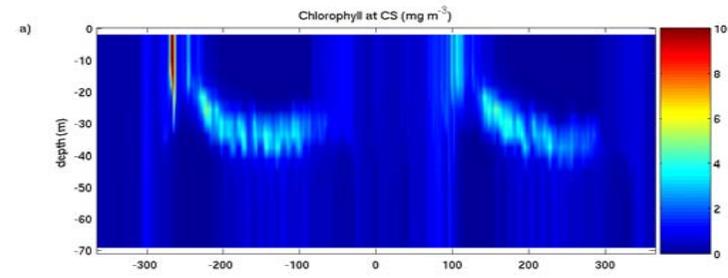
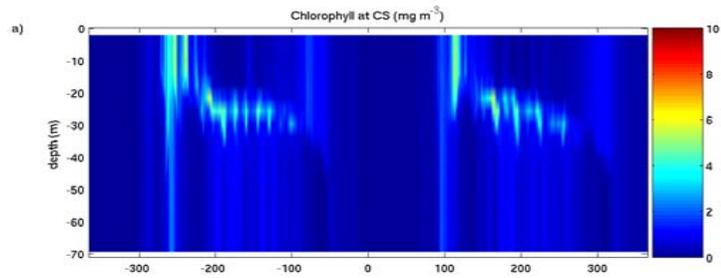
Rolling 7 day hindcast -5 day forecast from this week.



Phytoplankton Seasonal Succession at L4



Impacts of turbulence

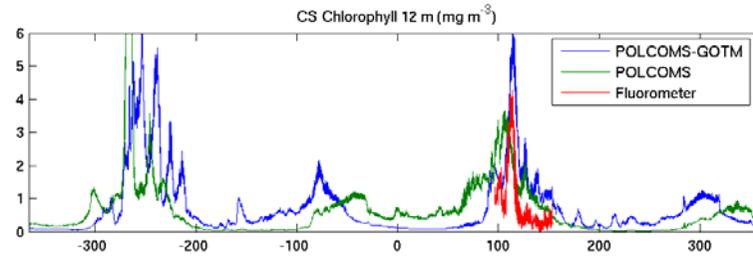


POLCOMS-GOTM

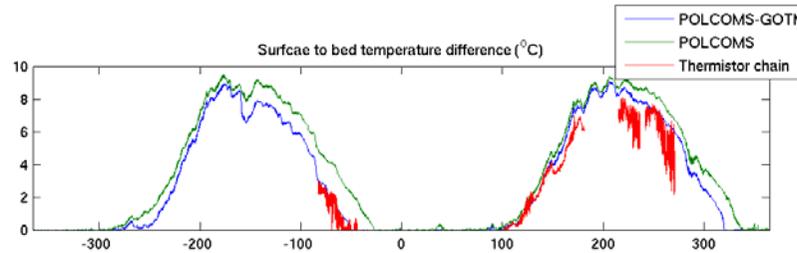
POLCOMS

Influence of turbulence

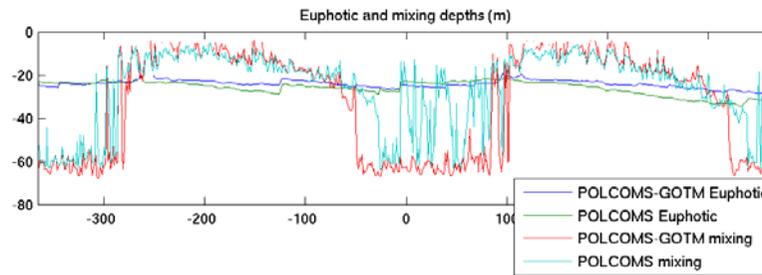
Chlorophyll



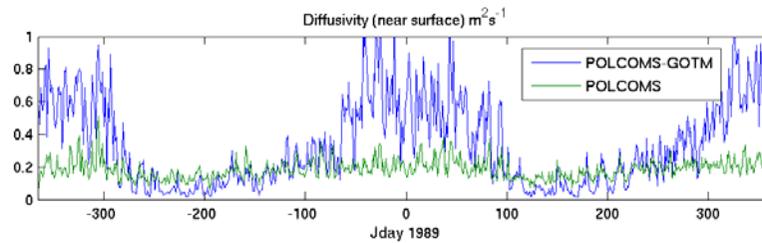
Stratification



Mixing Depth



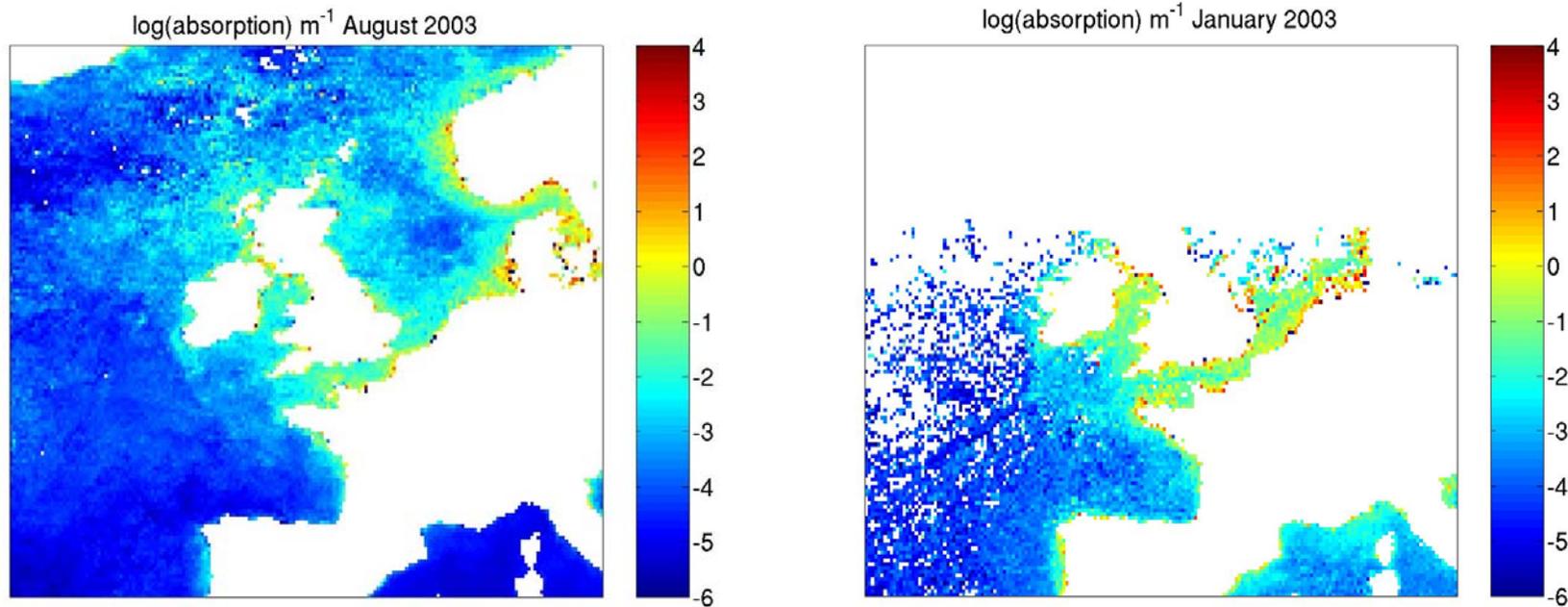
Diffusivity



1988

1989

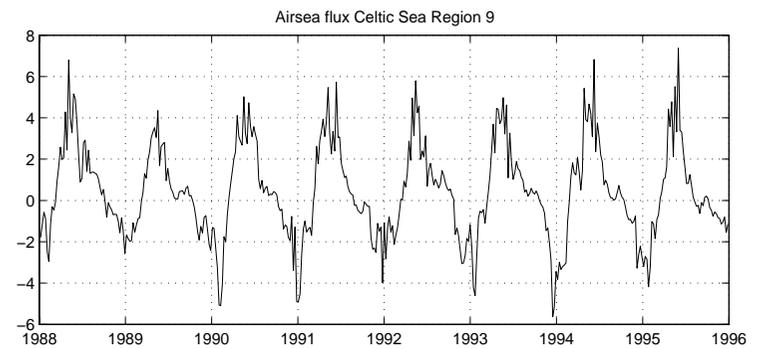
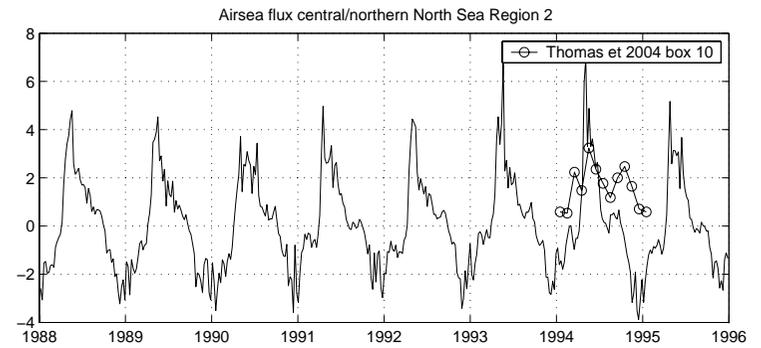
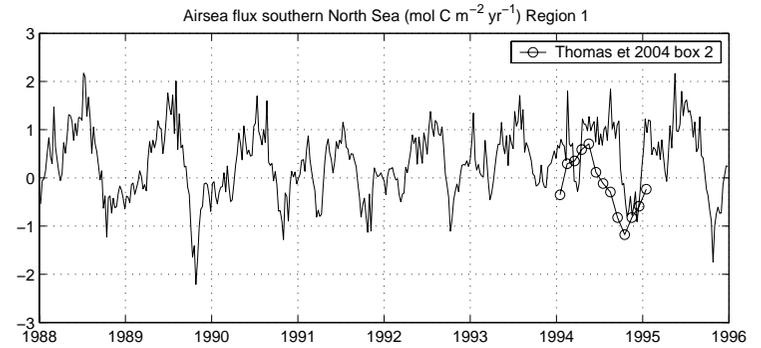
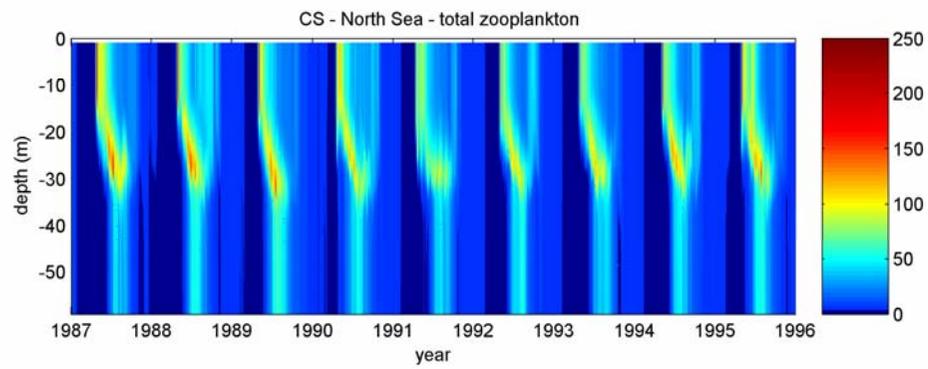
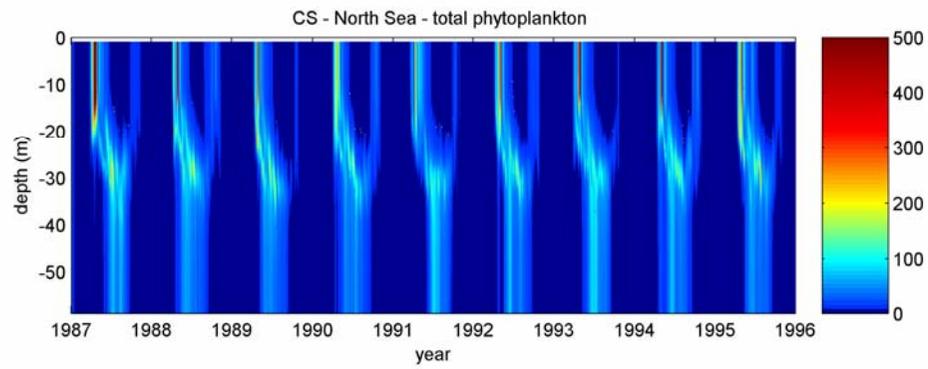
Constraining the light field



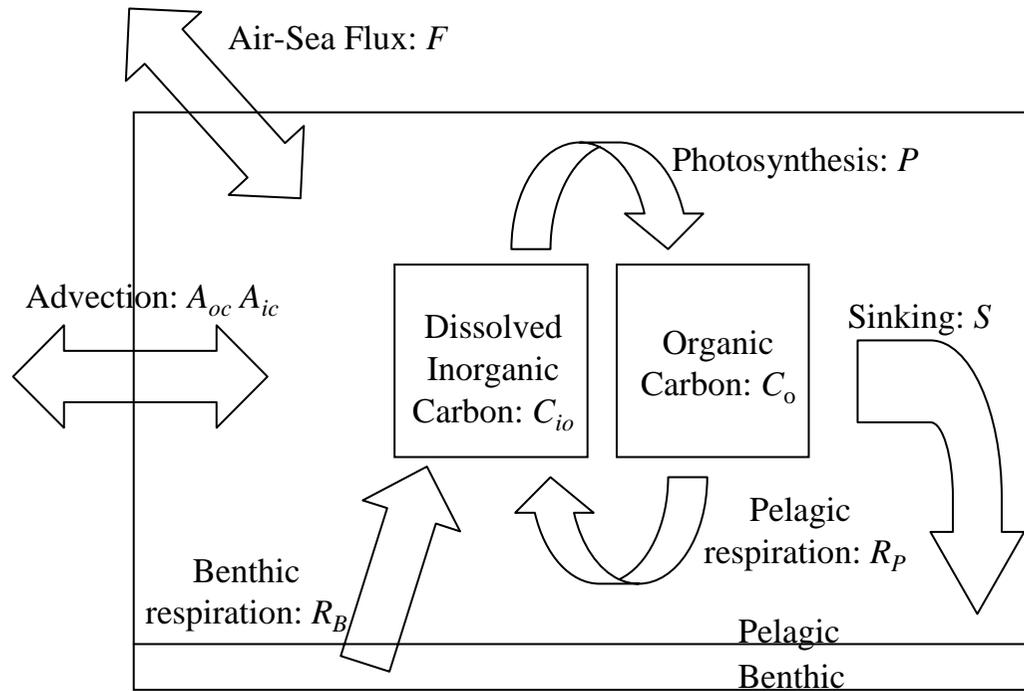
Non-biotic absorption (excluding pure water component) from SeaWiFS. Monthly mean fields for August and January 2003. –used as a climatology to drive the model.

An assimilation system is under construction.

10 year Hindcast (86-96)



Carbon Budgets

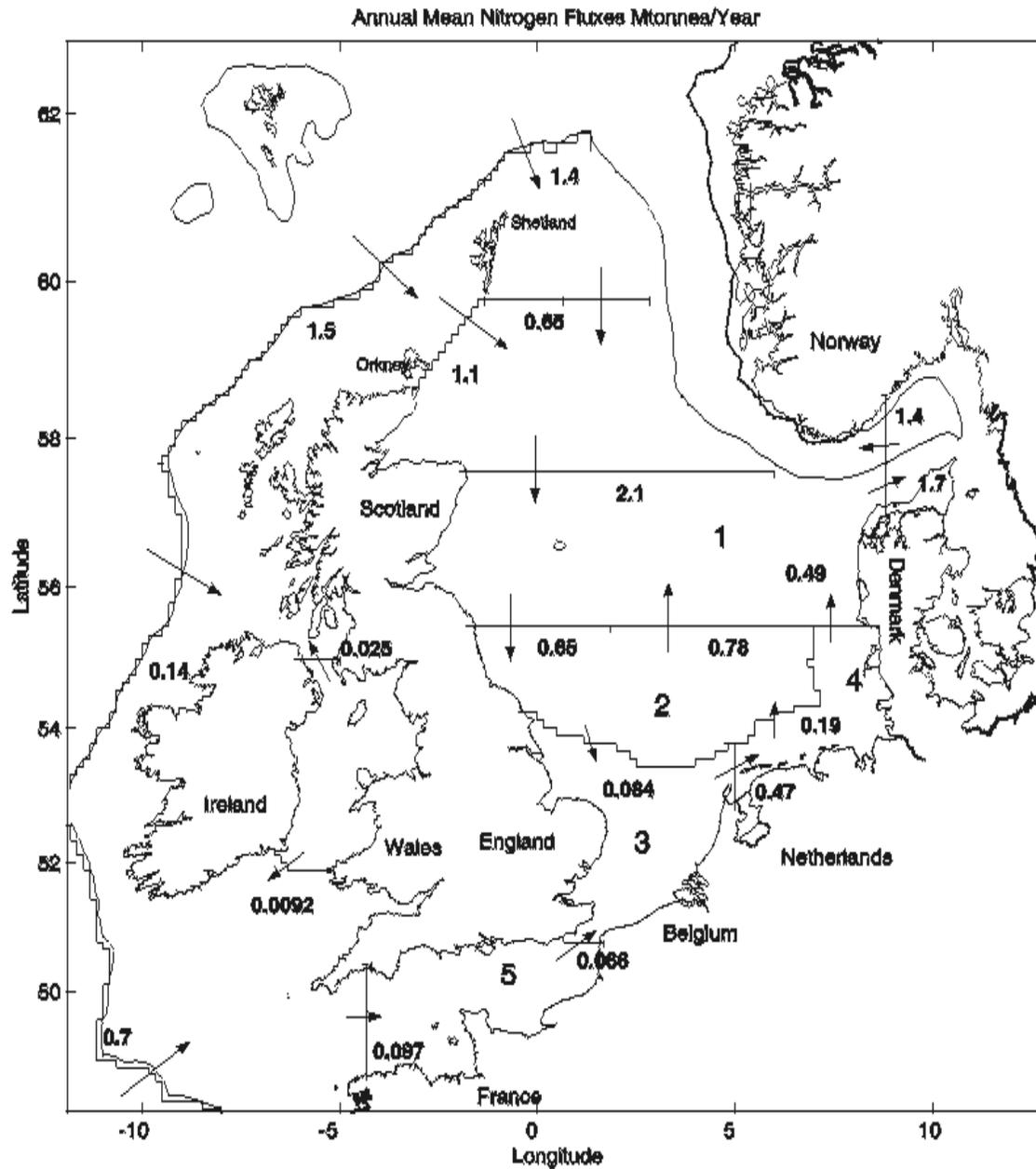


Summary of carbon fluxes integrated for 1988-1995, relative to the total organic and inorganic carbon pools in the model.

Organic C budget	$\times 10^{12} \text{ mol C yr}^{-1}$	Min/max
Photo. – Resp.	0.52	0.36/0.67
Advective flux divergence	0.38	0.25/0.66
Settling to Benthic model	-0.80	-0.74/-0.82
Tendency dC_o/dt	0.09	-0.07/0.21
Inorganic C Budget		
Advective flux divergence	-0.20	-0.06/-0.39
Air-sea exchange	0.12	0.0005/0.28
Benthic respiration	0.62	0.59/0.65
Tendency dC_{io}/dt	0.01	-0.10/0.16

Small export of inorganic carbon from the shelf
 Note importance of benthic respiration

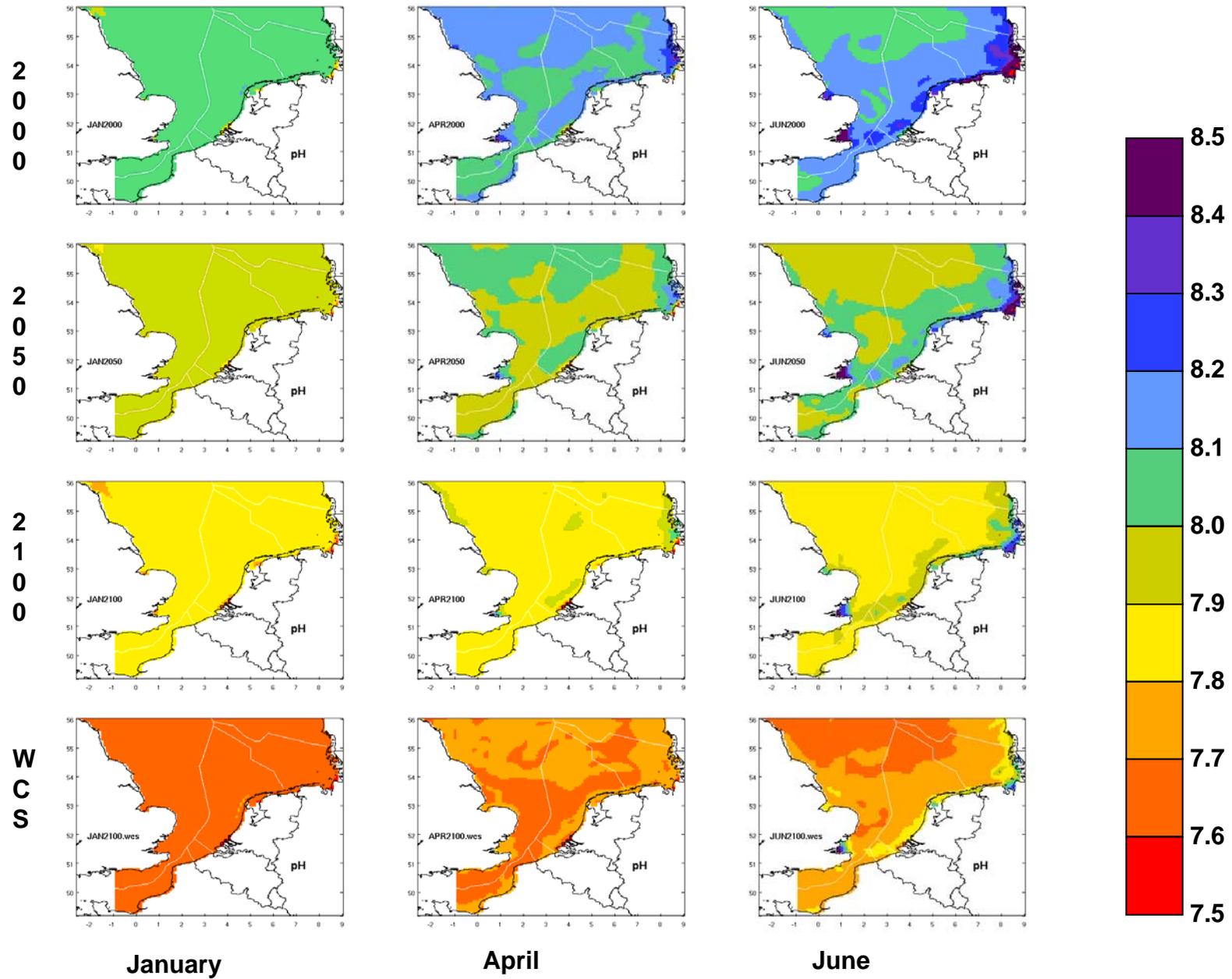
Nutrient Budgets



North Sea is a sink for oceanic nitrogen and phosphate

Proctor et al 2003

Simulations of SNS pH

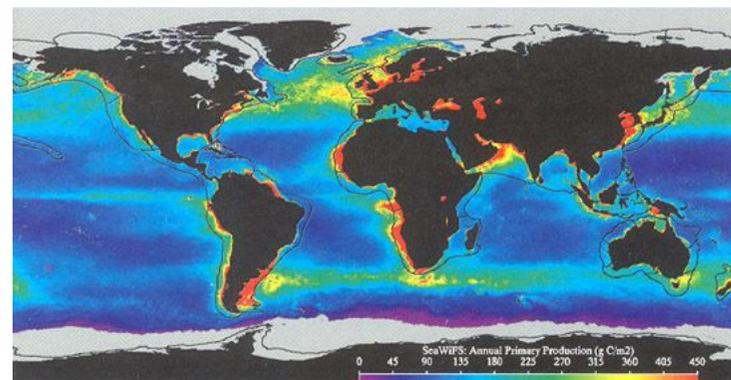


Global Coastal Ocean Modelling System



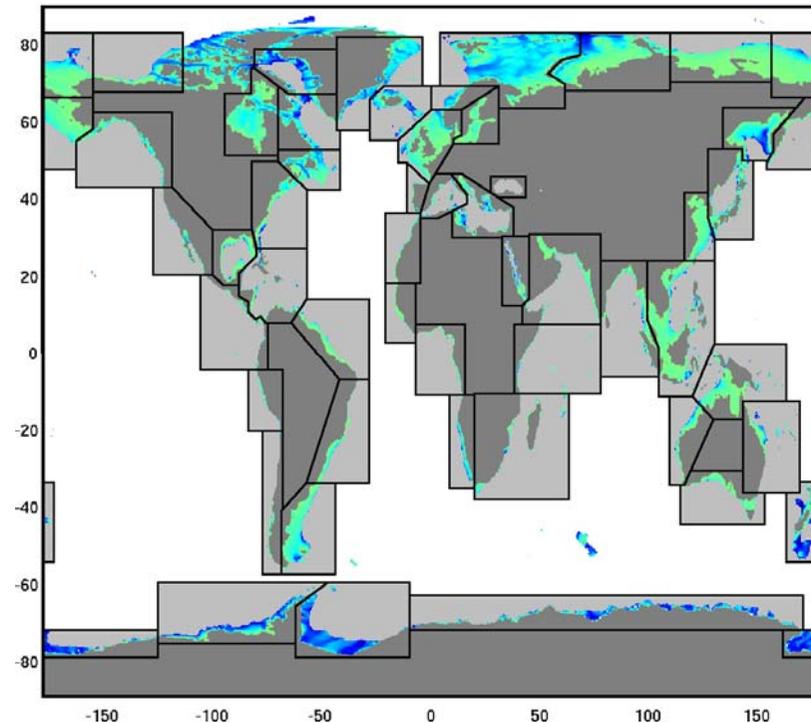
- Shelf seas are the most biologically productive regions of the world's ocean and so have an important role in the global carbon cycle
- They are generally poorly resolved or absent from global climate models, which also often do not include appropriate processes (e.g. tides)
- GCOMS aims to develop a computationally efficient and flexible system for simulating the carbon budget of shelf seas around the world and provide the basis for their inclusion into an earth systems model

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Global Coastal Ocean Modelling System

- The GCOMS project aims to extend the POLCOMS-ERSEM work on the NW European shelf to seas around the world using a series of automatically configured large scale model domains
- Because of the need for high resolution shelf seas require ~ 70 times the computational resources of the rest of the worlds oceans
- This leads to a distributed approach to flexibly exploit the available computer resources



Gaps

- Plankton succession
- Nutrient regeneration
- Links to higher trophic levels (2 way)
- 2 way coupling with the ocean
- Light climate (spm vs. cdom, terrestrial vs. in situ)
- Physical models good enough to allow the biological models to be parameterised without having to compensate for missing physics.
- High resolution physics – turbulence
- Data assimilation
- Operational models push them to the limits

Data

- Long term time-series (coastal observatories)
- Land derived inputs ~(freshwater, nutrients, cdom, dic ect...)
- Atmospheric inputs (N, P, fe)
- High quality met forcing
- VOS
- Much more biological information (biomass, rates, foodweb structure etc...)
- Benthic data (biomass and fluxes)

Issues

- NW Shelf, Source of C, sink of N and P: How will climate change affect this balance and what are the likely consequences for the ecosystem?
- Climate change impact on benthic system; what are feedbacks on the ecosystem?
- Can we find climate change indicators in 3D models (e.g. biota NOA relationships)?
- Acidification