Review of 3D ecosystem modelling of the North Sea shelf system

by

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1. Strategy

- **information about the models from the literature**
  - **list of models**
  - **definitions:**
    - **a) verification:** **checking that the mathematical equations are solved numerically correct**
    - **b) validation:** **establishing the agreement between predictions and observations**
- **examples for validation exercises from articles**
- **judging the models from the applications**
- **aggregation of validation steps in a table**

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Review of three-dimensional ecological modelling related to the North Sea shelf system Part 1: models and their results

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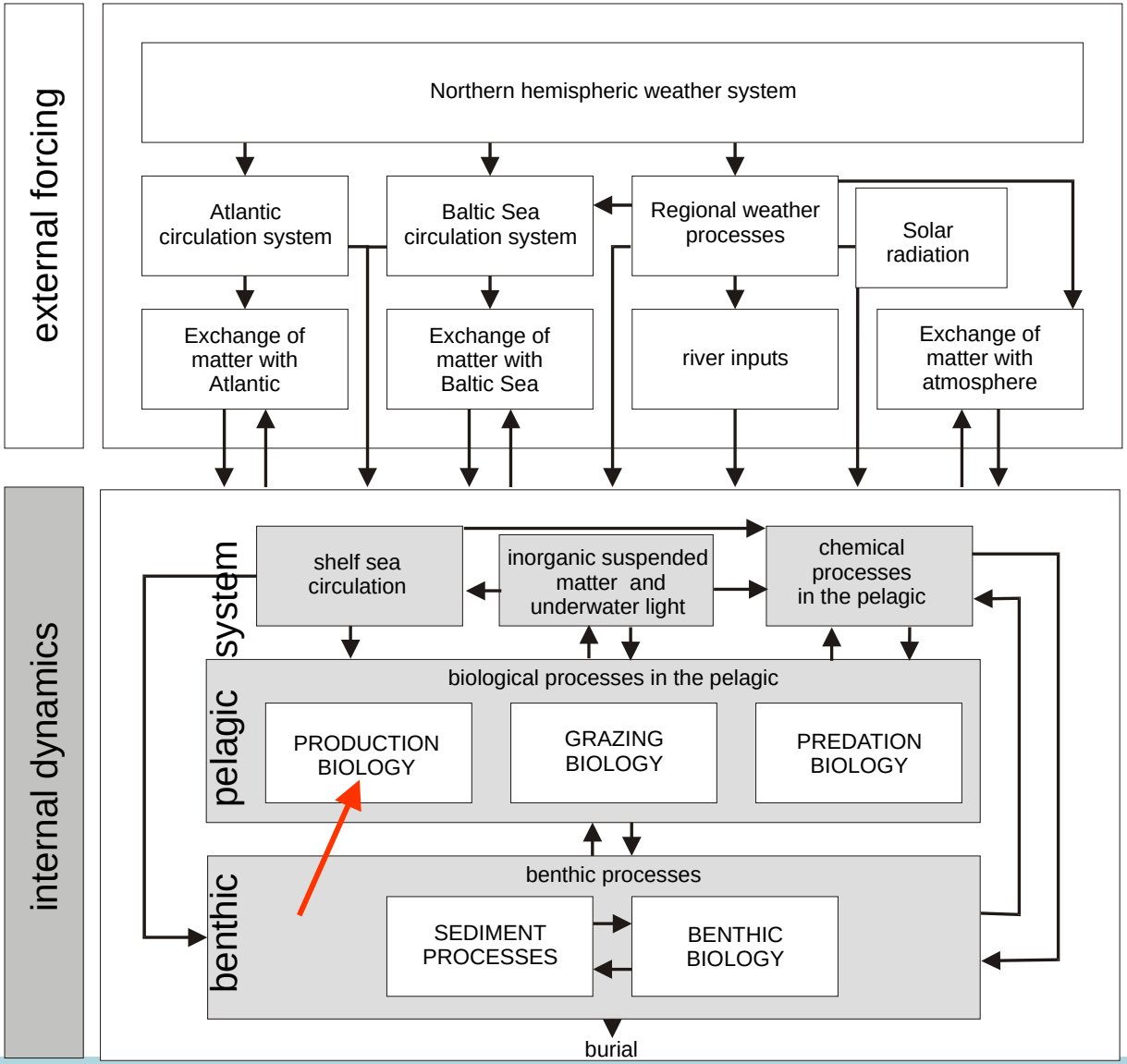
Abstract

The state-of-the-art in modelling the marine ecosystem of the greater North Sea is reviewed, providing an overview especially about three-dimensional models that describe and predict how the marine ecosystem of the greater North Sea area functions and how concentrations and fluxes of biologically important elements vary in space and time, throughout the shelf and over years, in response to physical forcing. Articles with a strong concentration on modelling

System North Sea



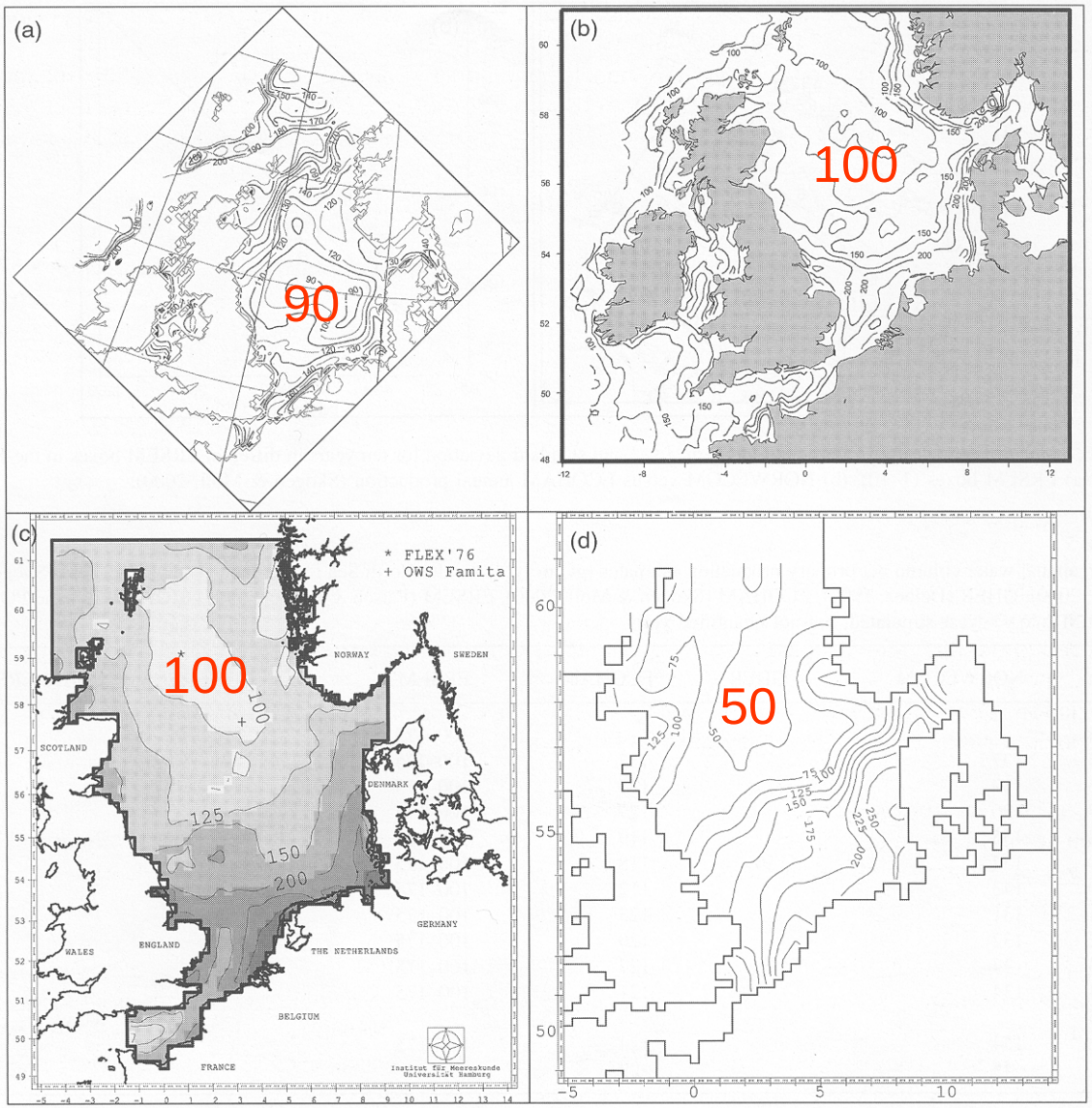


Fig. 4. Regional distribution of annual primary production for different ecosystem models. (a) NORWECOM (Skogen et al., 1995), (b) GHER (Delhez, 1998), (c) ECOHAM (Moll, 1998), (d) ERSEM (Pätsch & Radach, 1997).

Table 3
State variables in the selected North Sea models, sorted by the number of pelagic state variables

No	Name	Pelagic				Benthic	
		Matter cycle State variables	Nutrients DOM	Phytoplankton Bacteria	Zooplankton Detritus/POM	Matter cycle State variables	Nutrients Zoobenthos
3	ECOHAM **1**	P 2	one bulk no	one bulk no	not explicit no	P 1	not explicit no
6	COHERENS	N,O 8	two explicit no	one bulk no	not explicit two functional	no 0	no no
1	NORWECOM	N,P,Si 8	three bulk no	two functional no	no two functional	N,P,Si,O 5	not explicit no
4	ELISE	N,P,Si 10	three bulk no	two functional no	no three functional	N,P,Si 3	three bulk no
-> ECOSMO		(12)					
2	GHER	N 16	two explicit one bulk	two functional one bulk	one bulk one bulk	N 1	not explicit no
-> ECOHAM2		(13+10)					
-> ECOHAM3		(14+10)					
7	POL3dERSEM	N,P,Si,O 35	four explicit one bulk	three functional one bulk	three functional one bulk	N,P,Si,O 18	four explicit three functional
-> MIRO&CO		(29)					
4	ERSEM II	N,P,Si,O 43	four explicit four bulk	four functional three functional	three functional four functional	N,P,Si,O 22	four explicit three functional

new: MIRO&CO-3D using COHERENS, ECOSMO using HAMSOM, ECOHAM2 and ECOHAM3 using HAMSOM

Lacroix et al. (2006) Schrum et al. (2006) Moll&Stegert (2006), Pätsch&Kühn (in prep.)

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REVIEW OF THREE-DIMENSIONAL ECOLOGICAL MODELLING RELATED TO THE NORTH SEA SHELF SYSTEM. PART II: MODEL VALIDATION AND DATA NEEDS

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Abstract The aim of this review is to provide an overview of the status of validation of eleven biogeochemical and ecological models of the greater North Sea (COHERENS, CSM-NZB, DCM-NZB, DYMONNS, ECOHAM, ELISE, ERSEM, FYFY, GHER, NORWECOM, POLCOMS-ERSEM) showing the realism achieved as well as the problems hindering a better degree of validity of the models. Several of the models were able to reproduce observations of the state variables

2. Regional distributions

models:

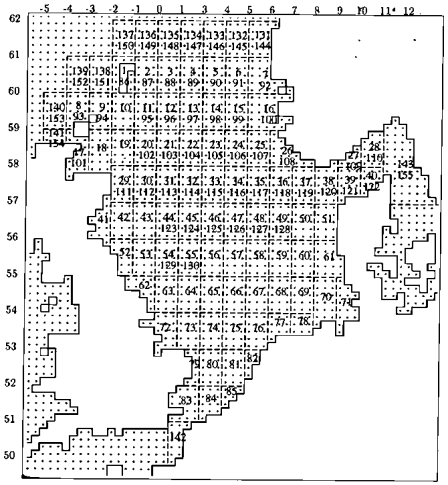
CSM-NZB
DYMONNS
ECOHAM
ERSEM
NORWECOM

data sets:

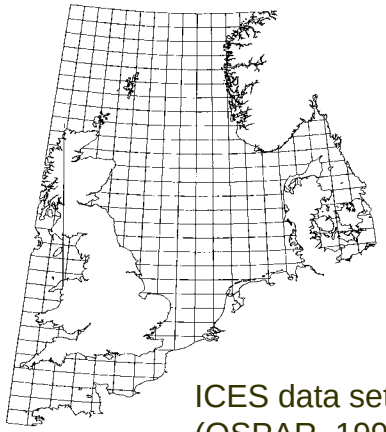
ICES, NOWESP, ERSEM „climatological seasonal/ monthly means (averaged for many years)“:

variables	no of data
temp, salt, spm	10^6
nutrients	10^5
chlorophyll	10^4
other biol.	sparse

Box structure for model set-ups and corresponding data averaging (Radach et al., 1997): box structure for:



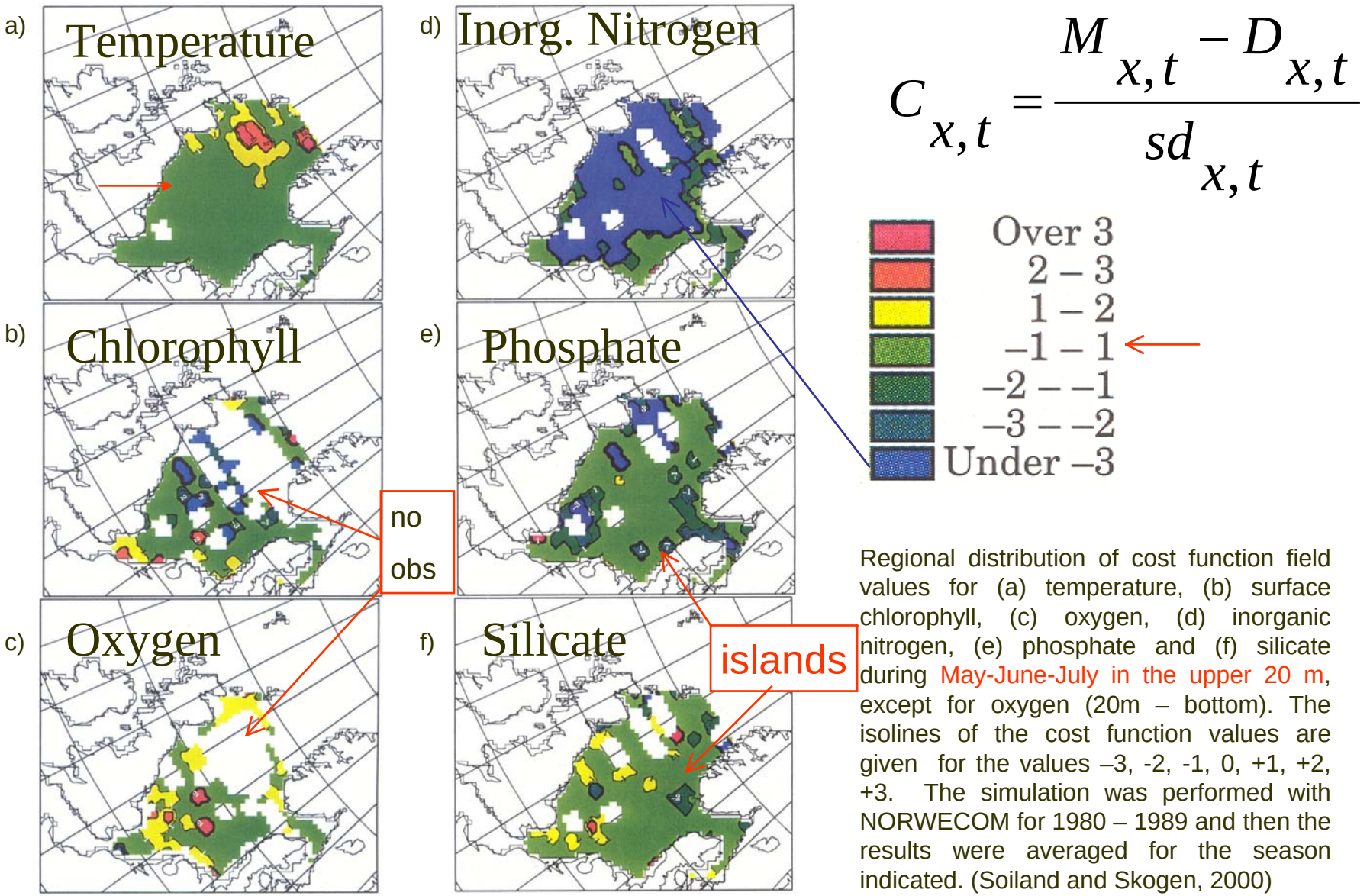
130-box version of ERSEM II (Pätsch & Radach, 1997)



ICES data set (OSPAR, 1998; Moll, 2000)

Cost function field value

$$C_{x,t} = \frac{M_{x,t} - D_{x,t}}{sd_{x,t}}$$



Regional distribution of cost function field values for (a) temperature, (b) surface chlorophyll, (c) oxygen, (d) inorganic nitrogen, (e) phosphate and (f) silicate during May-June-July in the upper 20 m, except for oxygen (20m – bottom). The isolines of the cost function values are given for the values –3, -2, -1, 0, +1, +2, +3. The simulation was performed with NORWECOM for 1980 – 1989 and then the results were averaged for the season indicated. (Soiland and Skogen, 2000)

Summary Regional distribution

- reproduction of horizontal gradients in the mean seasonal distributions can be simulated in coincidence with climatological observations for many state variables

!

- phosphorus and silicate distributions were simulated best

- less well for nitrate (and ammonia)

- no model provided a good chlorophyll distribution in spring

3. Annual cycles

models: **data sets:**

- ERSEM

CSM-NZB „climatological monthly means

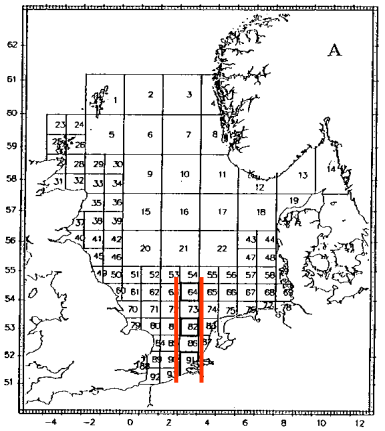
DYMONNS (averaged for many years)“:

ECOHAM	grid name	no of boxes
	nd015/025	25
	nd130 (1°)	130/155
ERSEM (box)	nd159	138/159

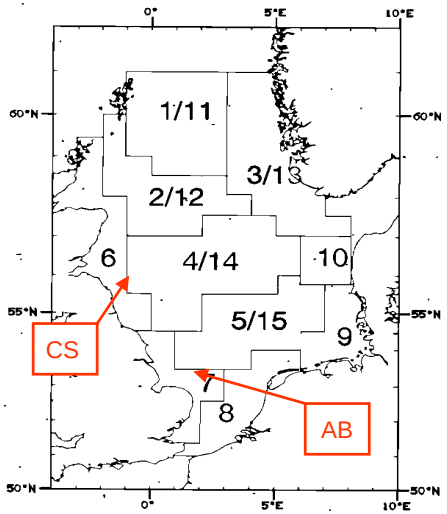
ERSEM (3d)

- NERC-NSP, annual cycle 1988/89

Box structure for model set-ups and corresponding data averaging (Radach et al., 1997): box structure for:

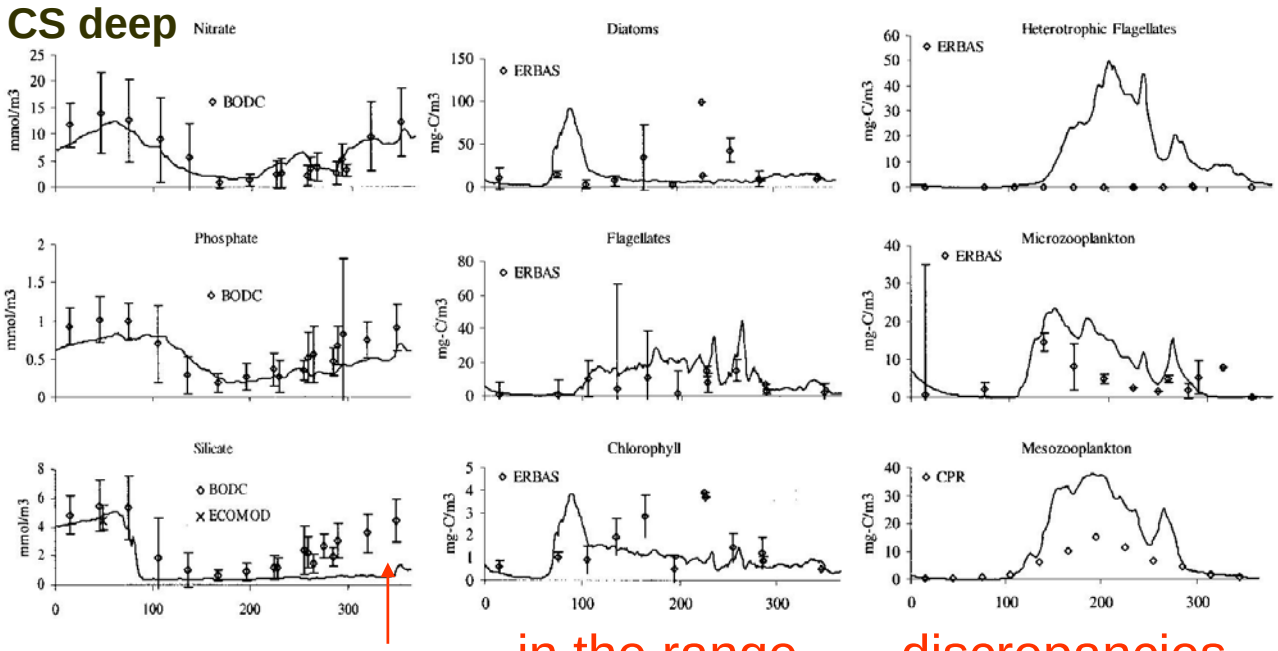


15-box version of ERSEM I (Baretta et al., 1995)



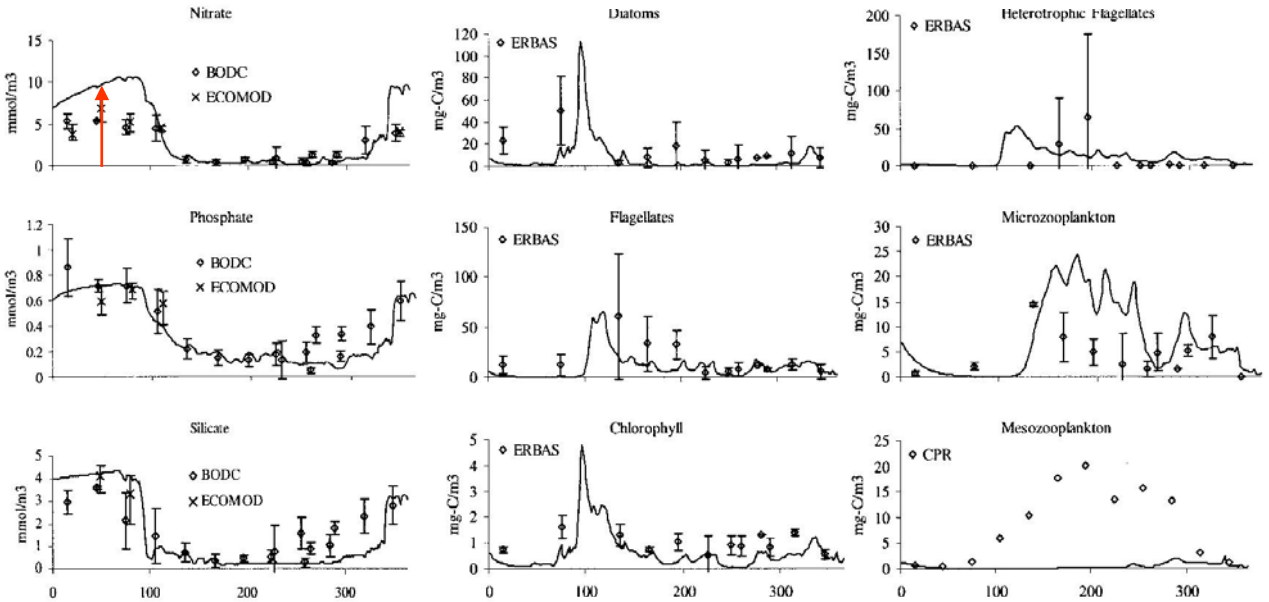
138-box version COCOA of ERSEM (Lenhart et al., 1997).

Example: POLCOMS-ERSEM 3d



in the range

discrepancies



Simulation of the 1995 annual cycles of nitrate, phosphate, silicate, diatoms, flagellates, chlorophyll, heterotrophic flagellates, microzooplankton and mesozooplankton:

(a) at station CS (55°30'N, 0°55'E)
(b) at station AB (52°42''N, 2°25'E)

compared to data from different sources. (Allen et al., 2001)

autotrophs

heterotrophs

Summary Annual Cycles

- nearly all models have been tested with climatological monthly mean data, representing the annual cycle
- phosphorus and silicate were simulated best
- nitrate or nitrogen nutrients with less success
- chlorophyll was simulated in the order of magnitude, sometimes overestimated, sometimes underestimated
- the phasing of nutrients and chlorophyll showed differences in times of intense regeneration of nutrients (shallow water)
- discrepancies to data grew with the trophic level
- there is no model that coincided with climatological monthly means for all simulated state variables in all seasons

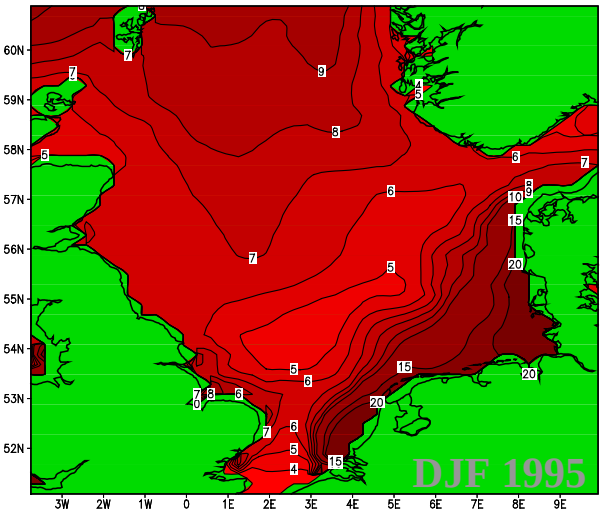
!

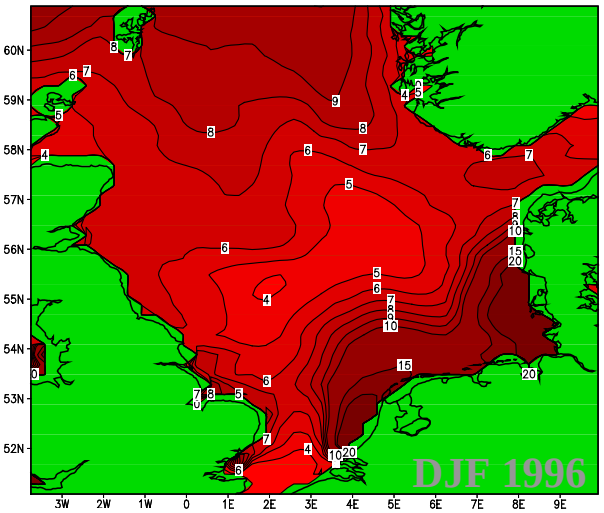
ECOHAM3 validation on nitrate distribution

Simulations

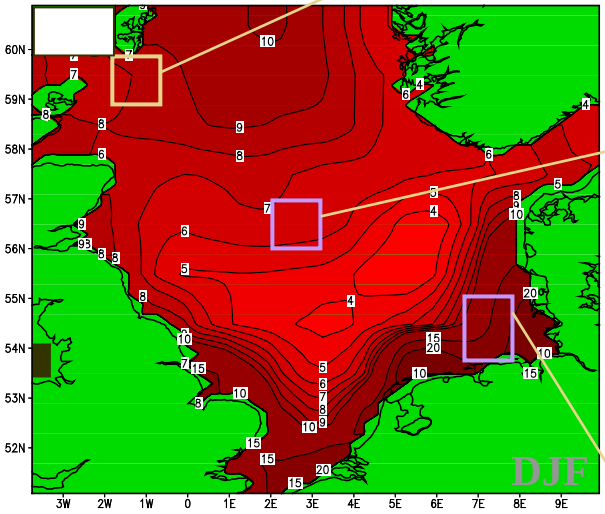
Surface nitrate

(mmol N m^{-3})

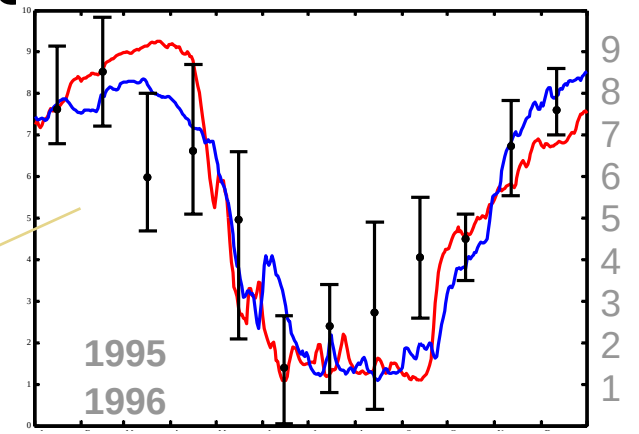


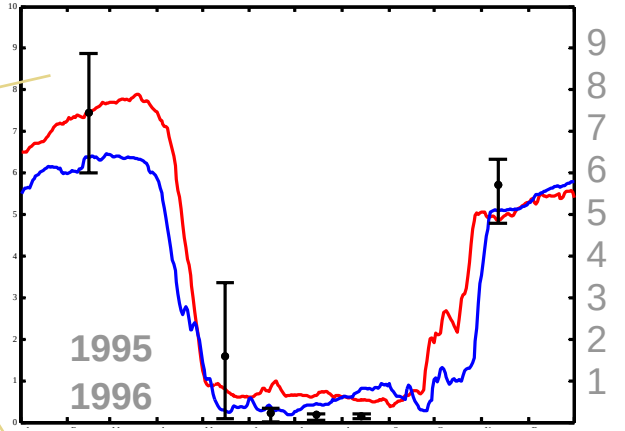


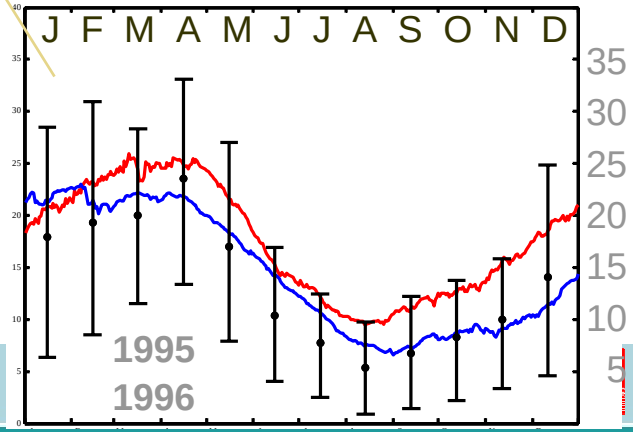
Observations (1984-93)



(Radach & Pätsch, 1997)

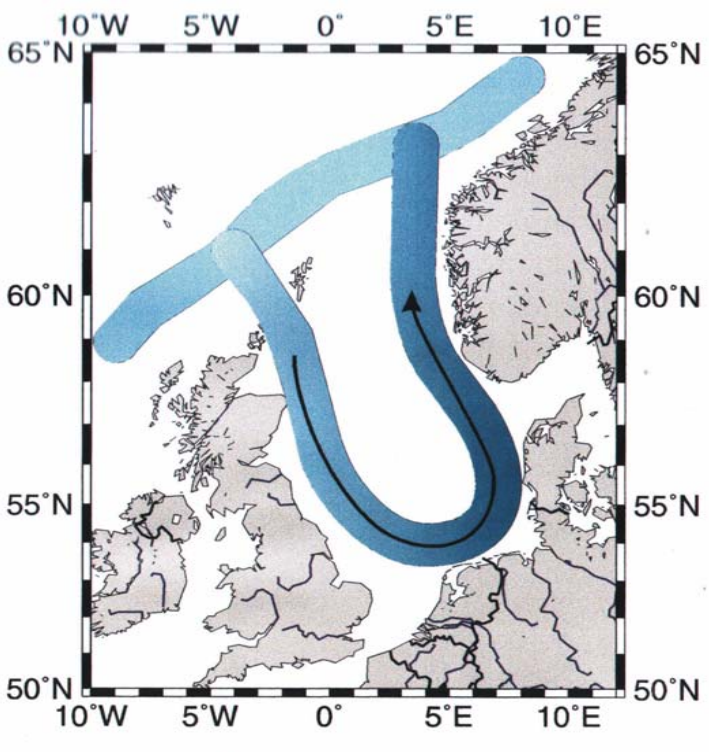






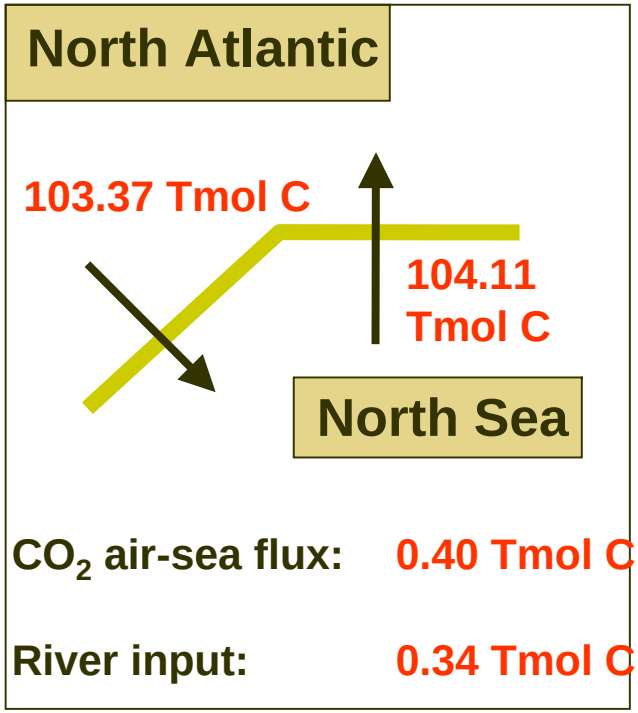
ECOHAM3 Carbon shelf-ocean exchange

Concept: bypass mode of the shelf pump

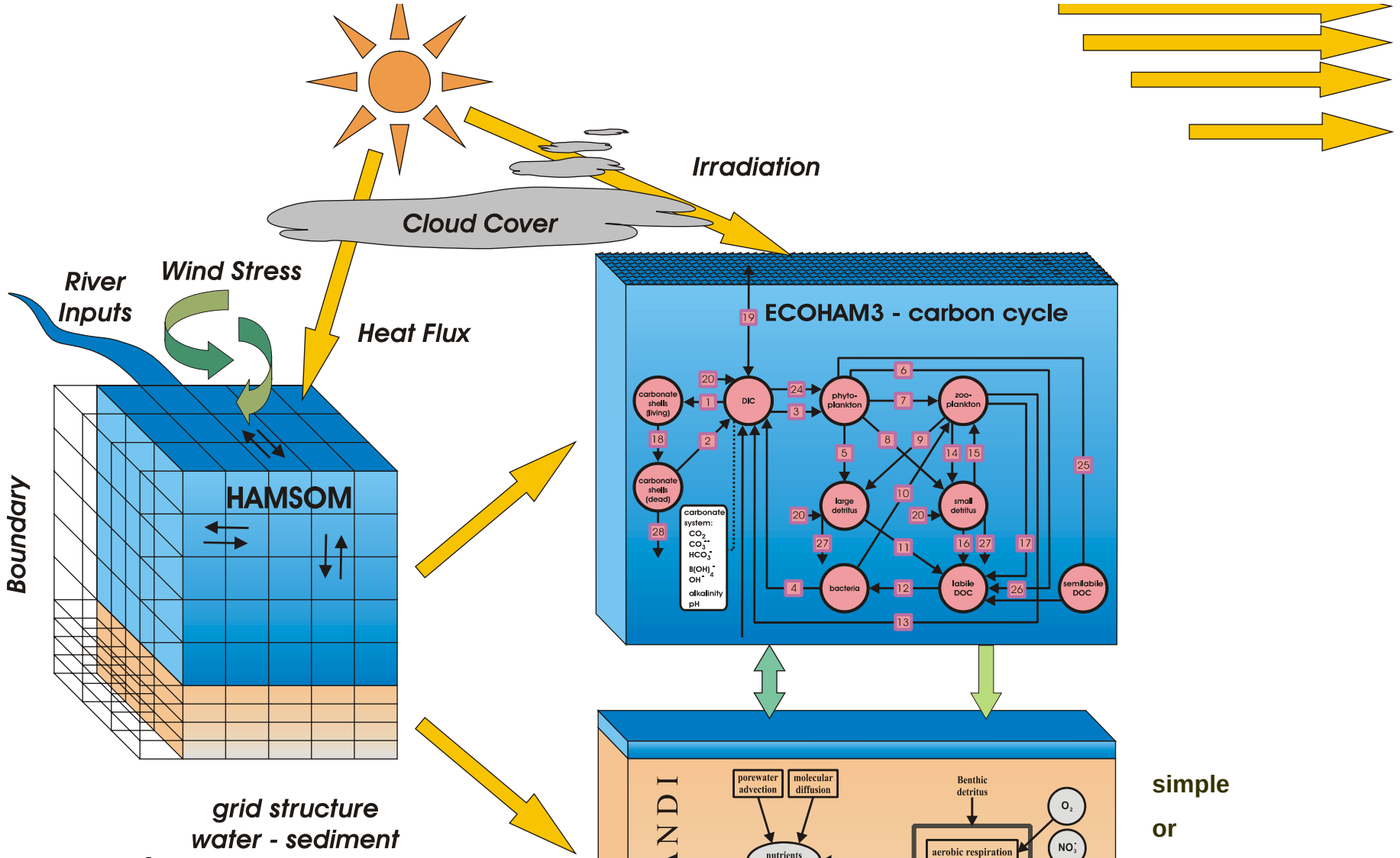


Thomas et al., 2004

Model results for 1996



J. Pätsch & W. Kühn



Concept of pelagic-benthic coupling HAMSOM-ECOHAM-CANDI

simple

or

complex

Sediment Diagenesis Modelling

Thanks for your attention

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