Perspectives in Ecosystem Modelling

Tom Anderson
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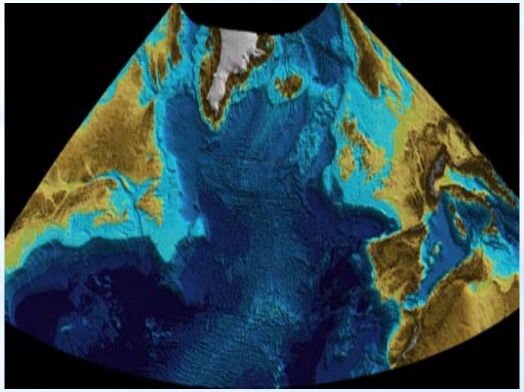


BASIN meeting, Hamburg, 23-25 Jan 2007

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

- Aim: Identify and document the state of the art of climate-related ecosystem research in the North Atlantic and associated shelf seas.

- Models need to resolve “feedbacks of global change on the structure, function, and dynamics of North Atlantic ecosystems”

- Models “must concentrate the biological resolution at the level of the species or trophic level of interest”

From Report of the first BASIN workshop, Reykjavik, 11-15 March 2005

- Need to consider: phytoplankton group composition

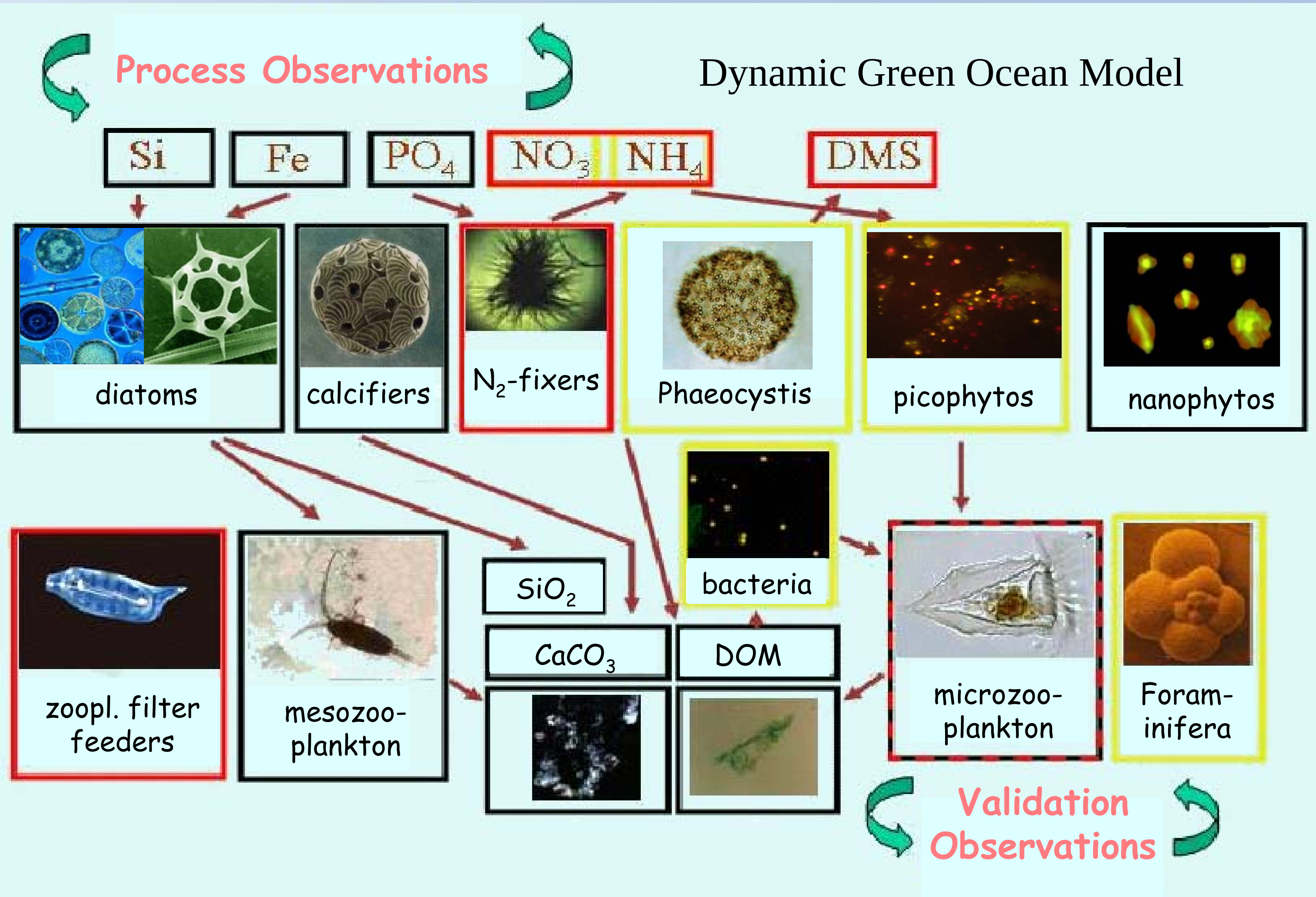
  effects on zooplankton production

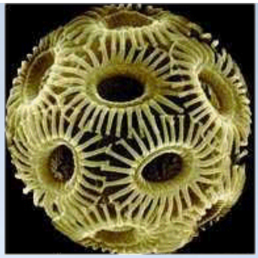
  higher trophic levels, e.g. planktivorous fish

  - trophic linkages

- "impossible to provide high resolution for all species involved in the ecosystem"

From Peter Wiebe's talk yesterday


Process Observations
Dynamic Green Ocean Model
Si
Fe
PO4
NO3
NH4
DMS
diatoms
calcifiers
N2-fixers
Phaeocystis
picophytos
nanophytos
bacteria
zoopl. filter feeders
mesozoo-plankton
SiO2
CaCO3
DOM
microzoo-plankton
Foram-inifera
Validation Observations

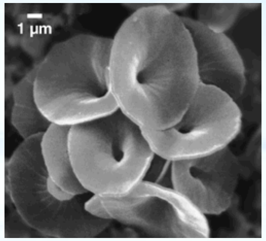


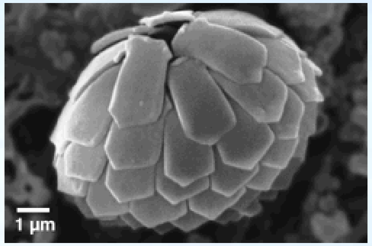
Adding complexity: problems

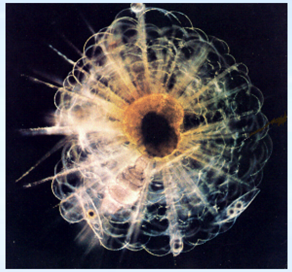
- Poorly understood ecology

high light | low Si | high N:P

- Aggregation

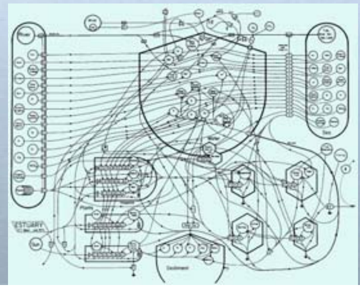






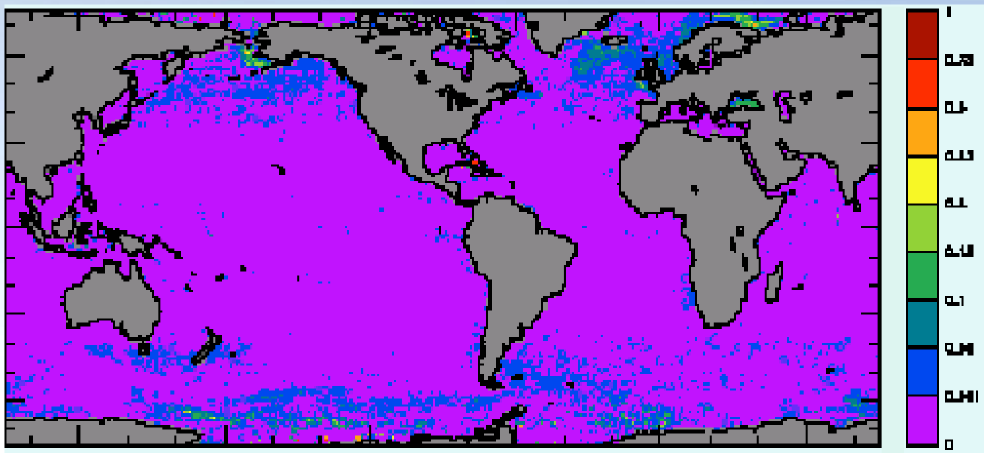
- Lack of validation data

- All in the interactions

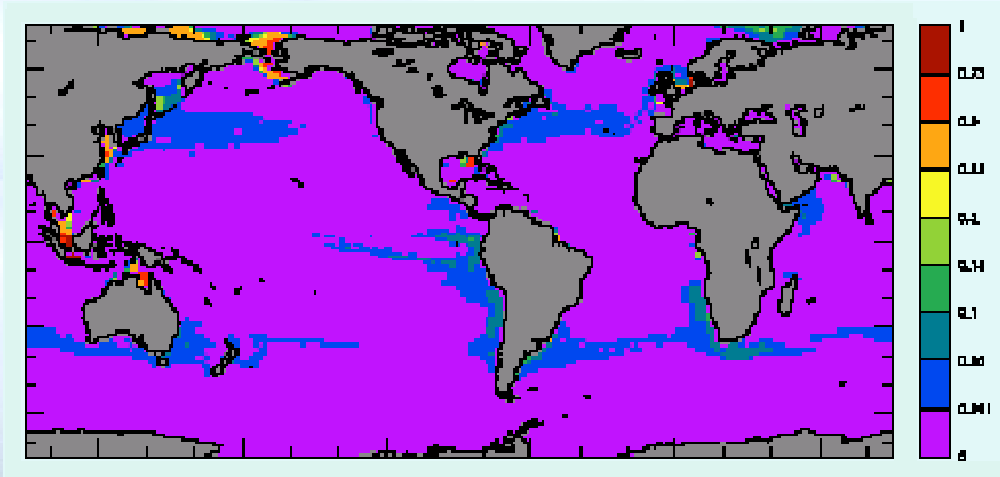


<u>Frequency of coccolithophore blooms</u>

Based on SeaWiFS



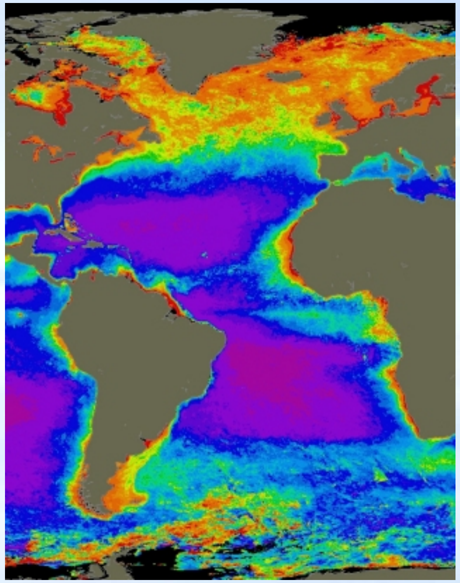
DGOM



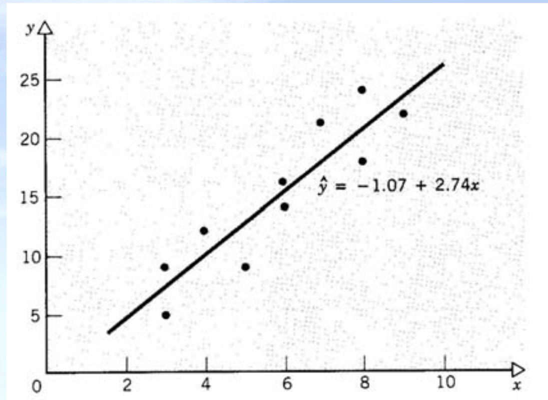
Le Quéré et al. (2006)

Levins (1966) distinguished between:

realism
(complexity)



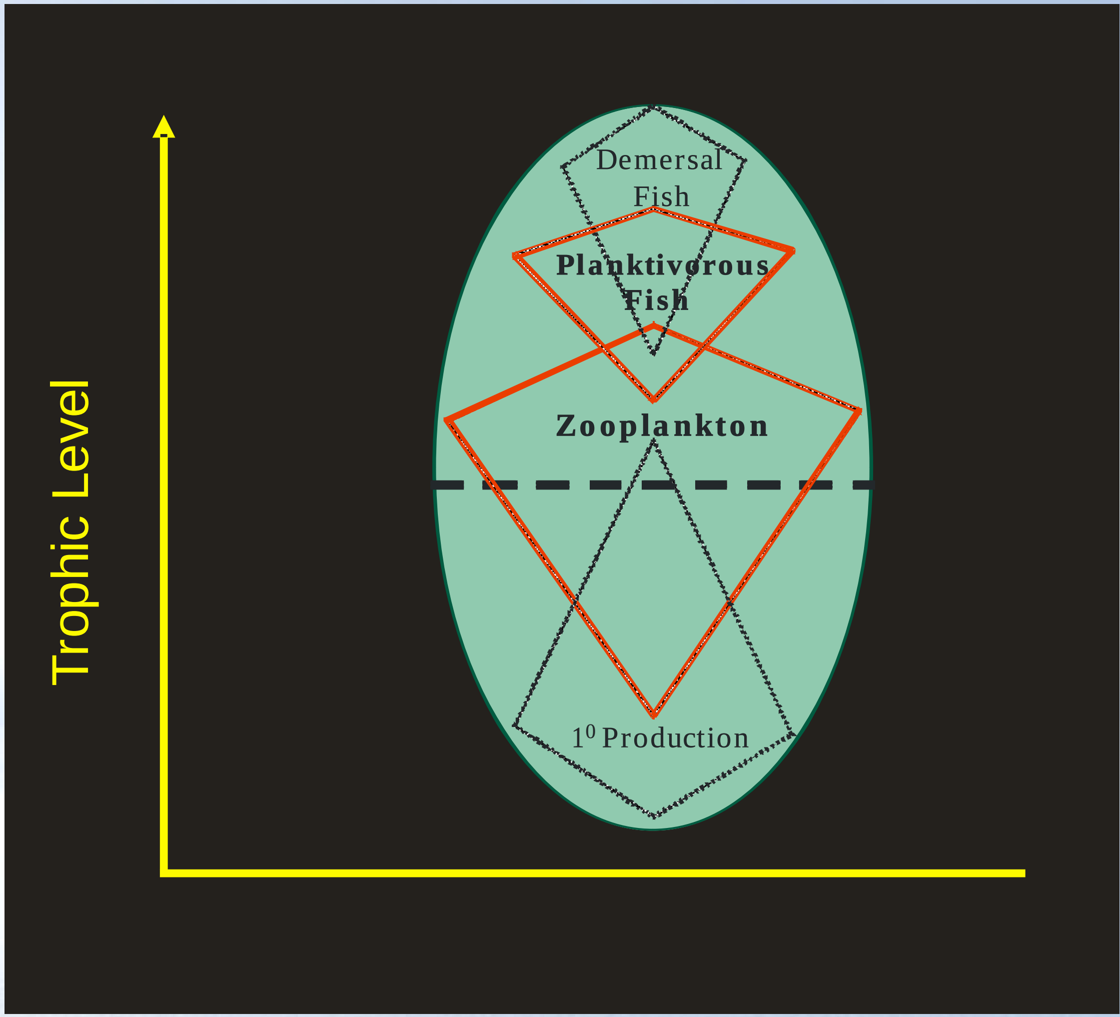
generality



accuracy

Levins (1966) “The strategy of model building in population biology”
American Scientist 54, 421-431.

Throwing everything but the kitchen sink into models is an unreliable option



Rhomboid Approach

The rhomboids indicate the conceptual characteristics for models with different species and differing areas of primary focus.

Rhomboid is broadest where model has its greatest functional complexity i.e., at the level of the target Organism.

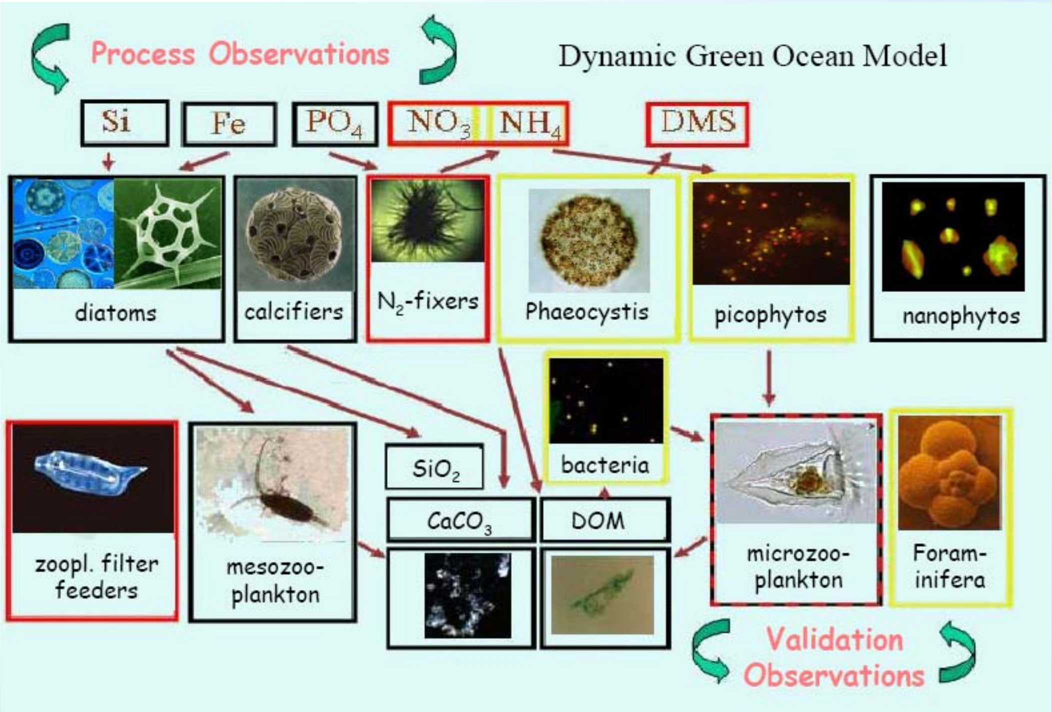
deYoung et al, 2004

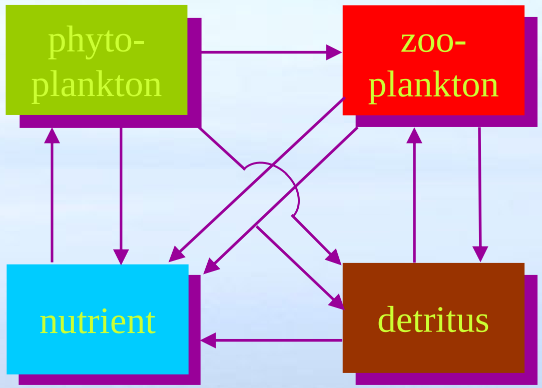
NPZD models are able to capture basic variability in chl, primary production

NPZD models “are generally able to accurately simulate seasonal cycles of plankton variables in specific ocean areas. However, their generality across ocean basins and their ability to represent spatial and temporal variability are limited”

Quote from Report of the first BASIN workshop, Reykjavik, 11-15 March 2005

DGOM vs NPZD comparison (QUEST)

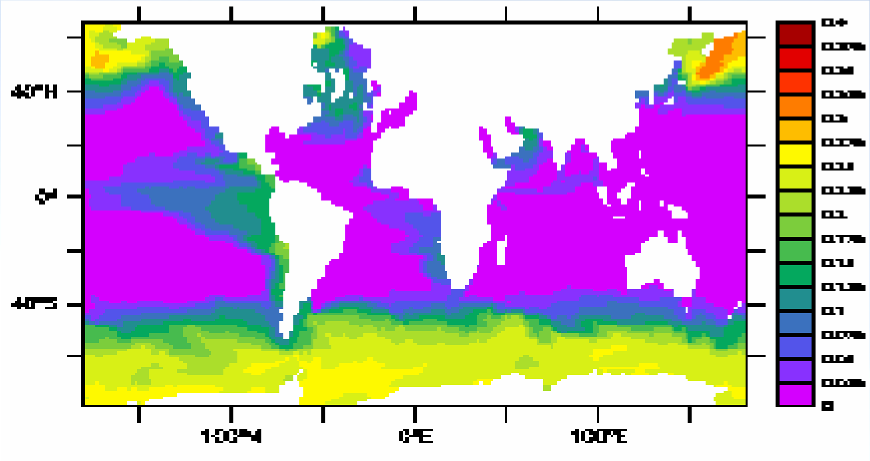


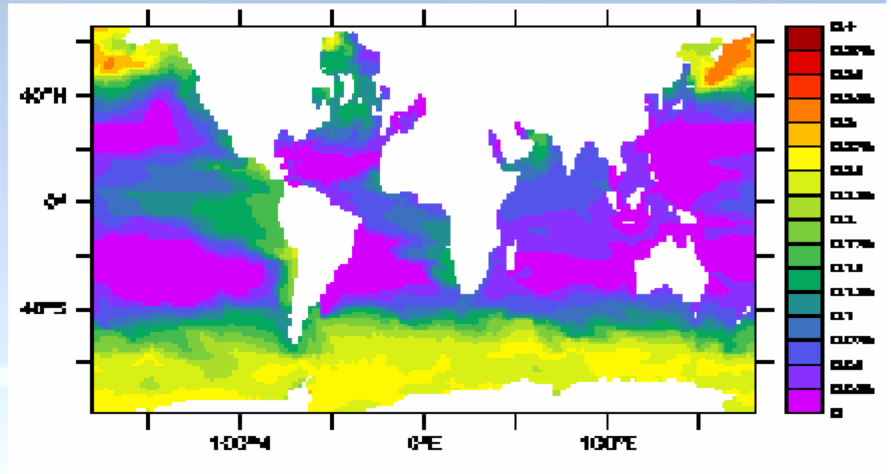


NPZD

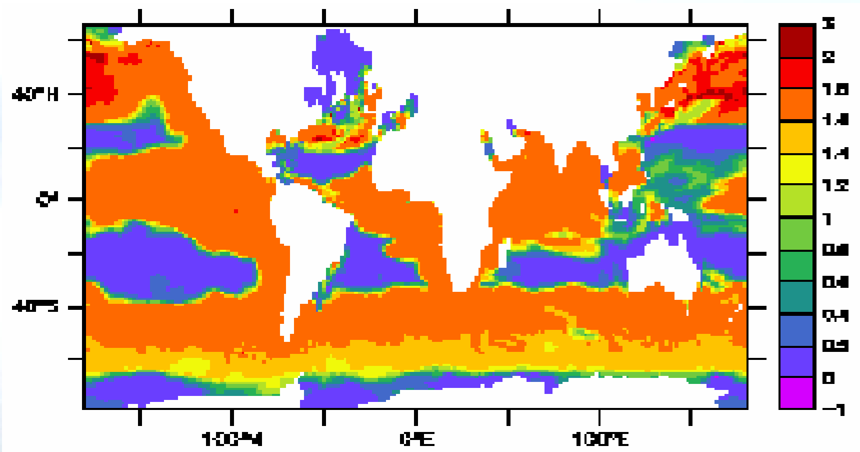
3N3P2Z2D

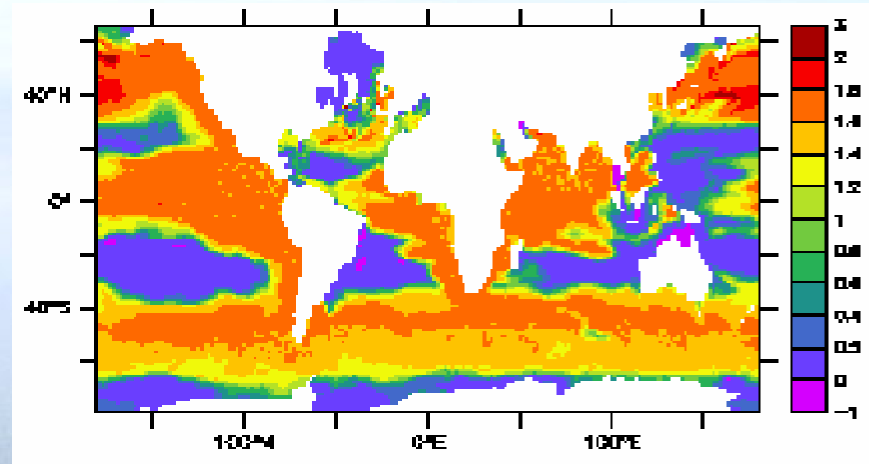
PO_4





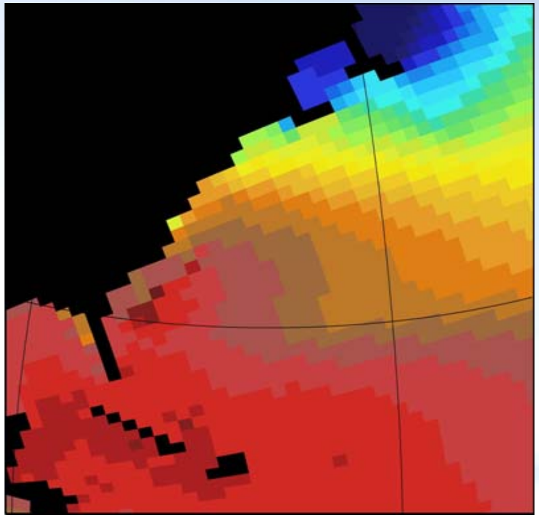
phytoplankton



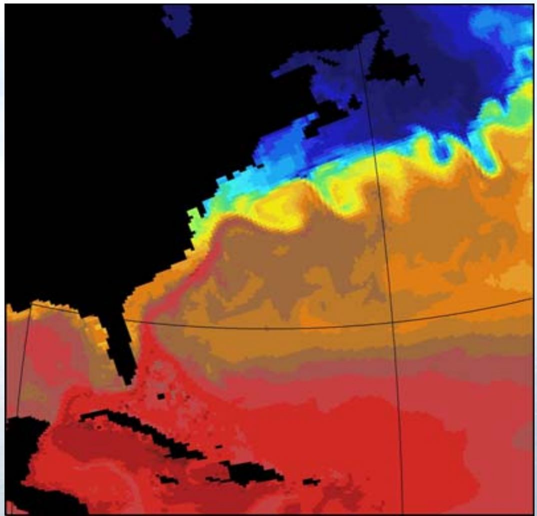


(Boreal spring)

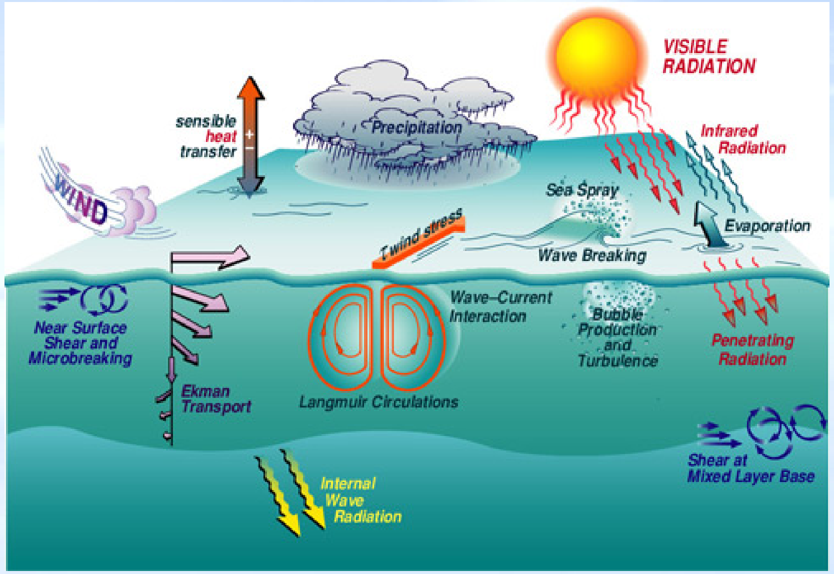
Physics

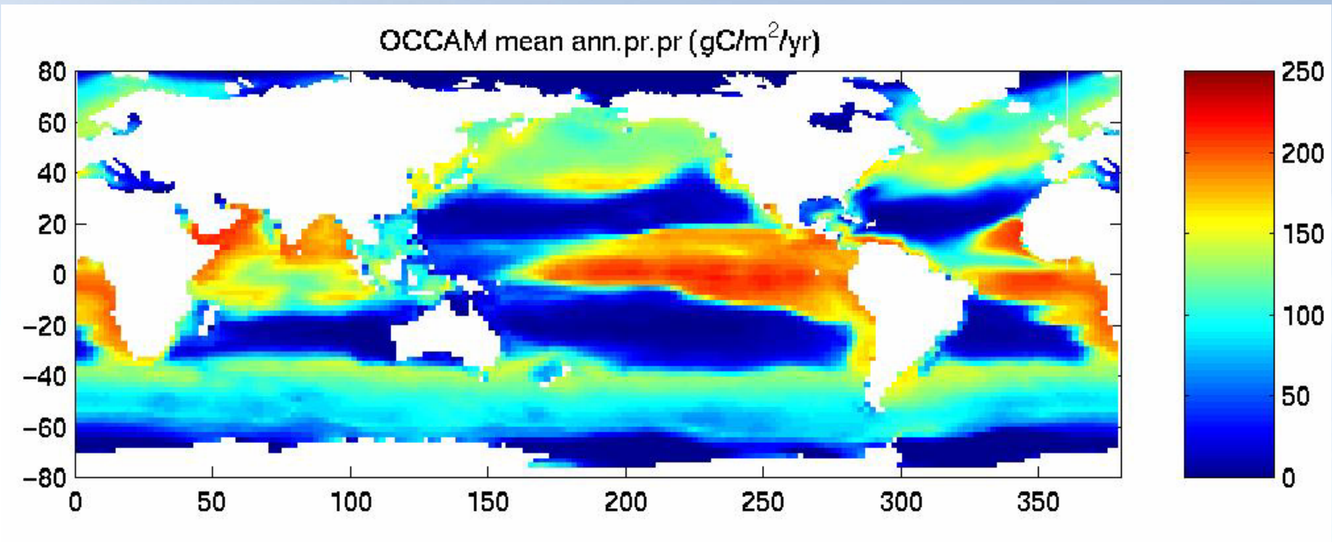


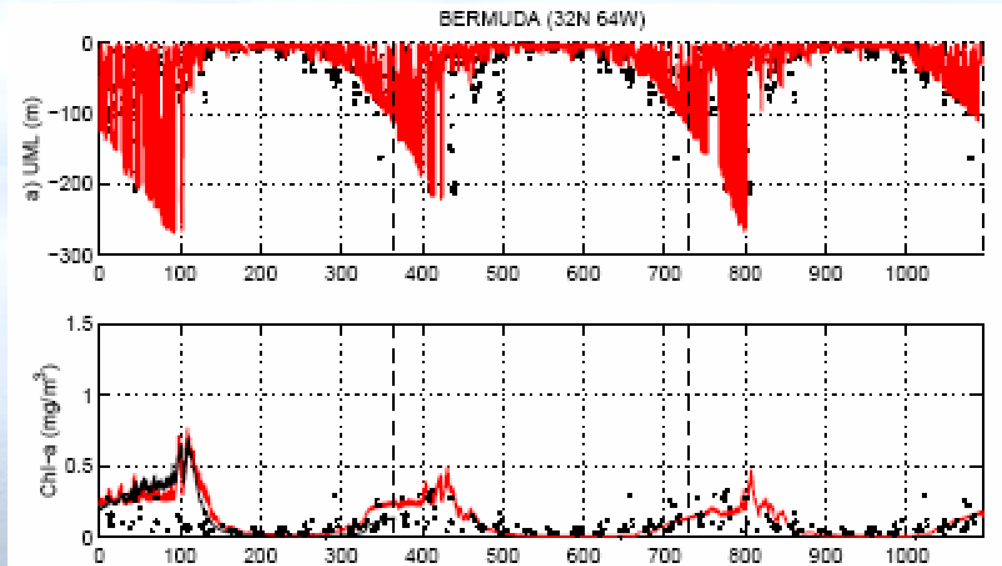
1 degree



1/4 degree



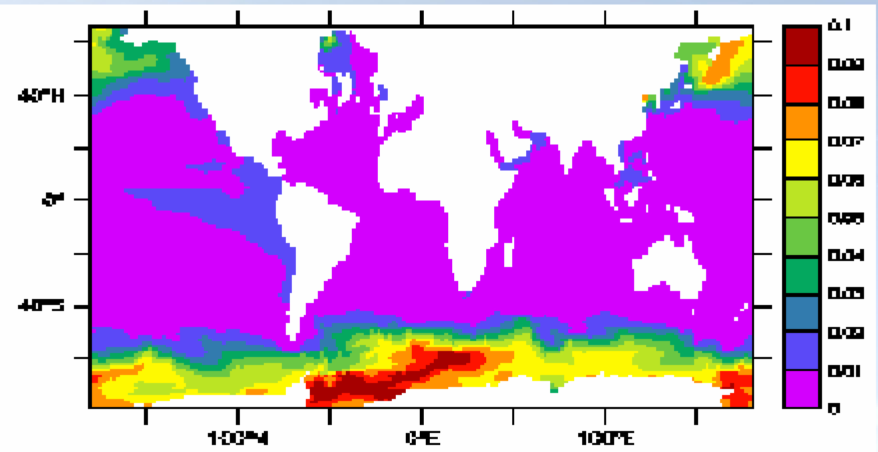




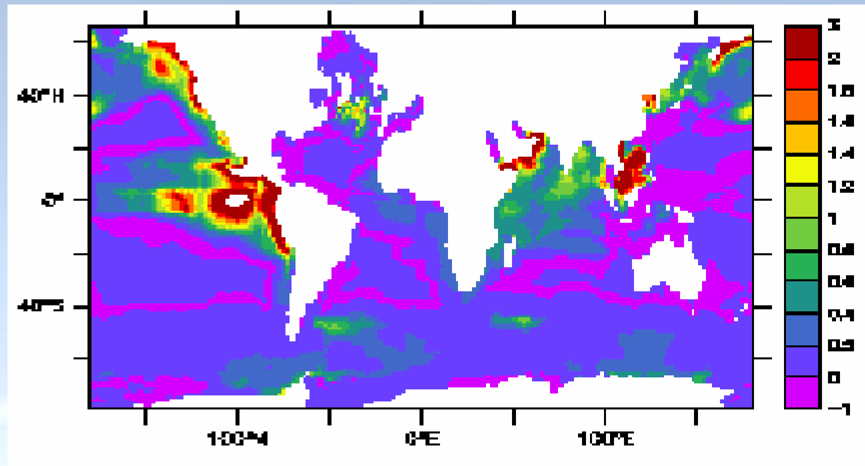
(Popova et al., 2006)

"Small changes in physical forcing fields can produce greater changes in plankton distributions than substantial changes in ecosystem model complexity" (Friedrichs et al., 2006)

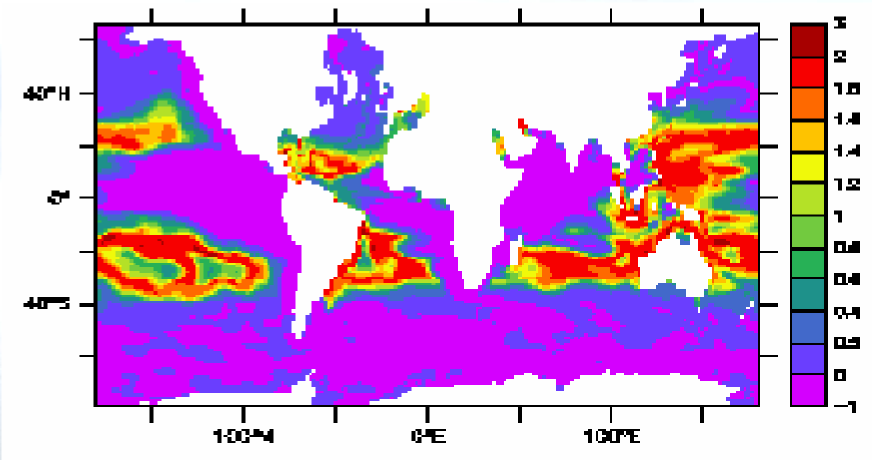
Friedrichs et al. (2006). Deep-Sea Res. II 53, 576-600.



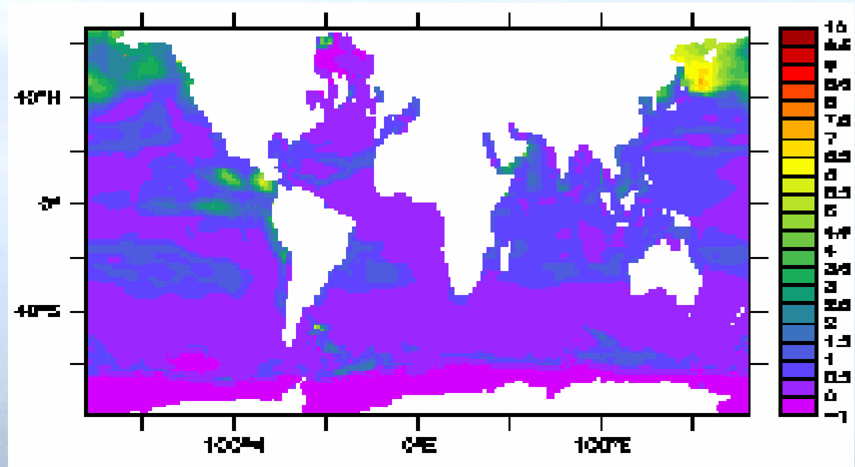
silicate



diatoms

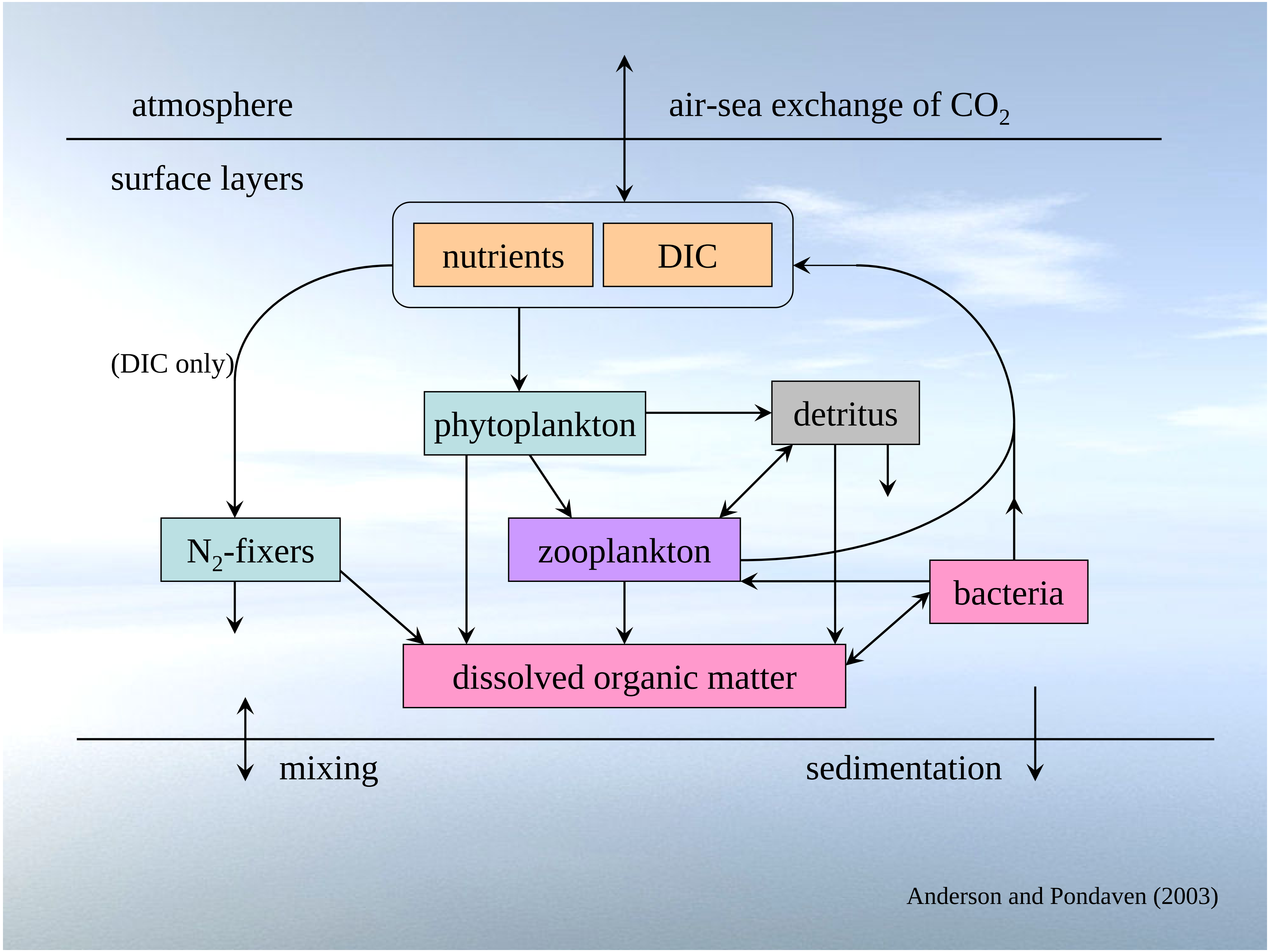


coccolithophores



mesozooplankton

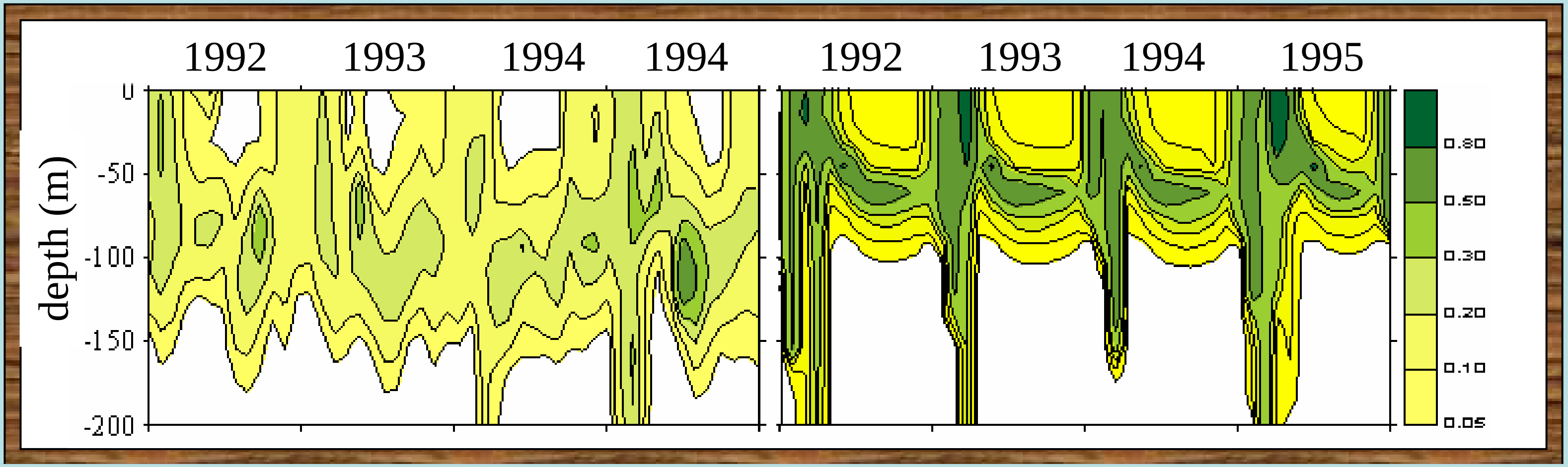
Complex models may be usefully applied to regional domains



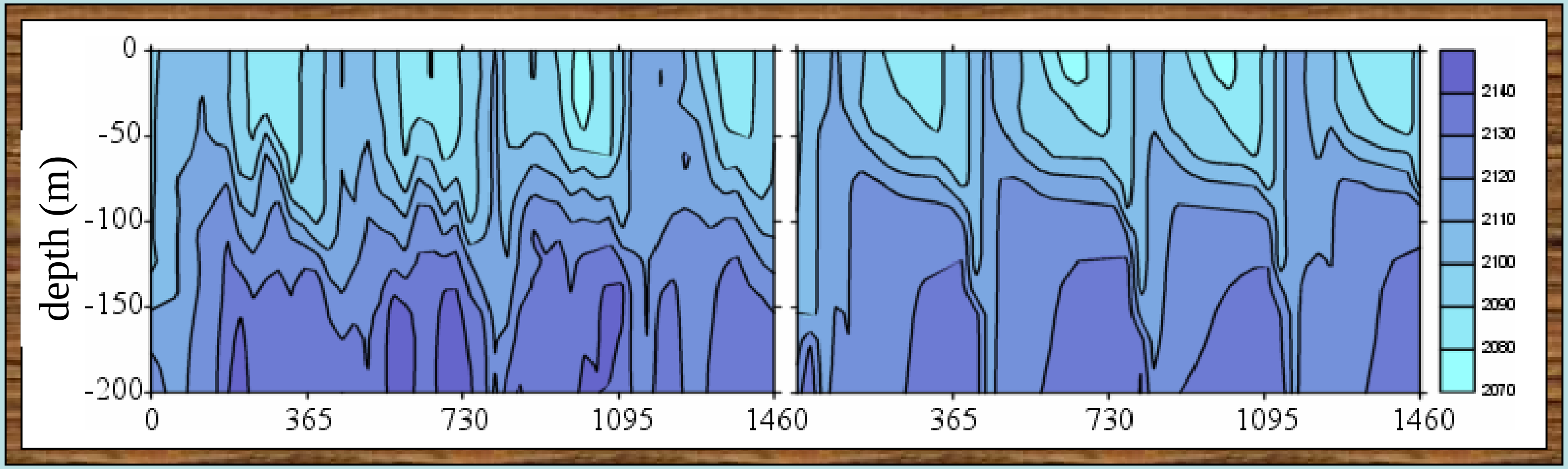
atmosphere
air-sea exchange of CO_2
surface layers
nutrients
DIC
(DIC only)
phytoplankton
detritus
N_2-fixers
zooplankton
bacteria
dissolved organic matter
mixing
sedimentation
Anderson and Pondaven (2003)

Data Model

Chl

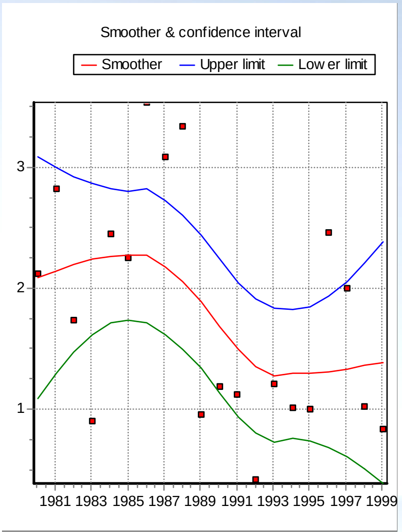


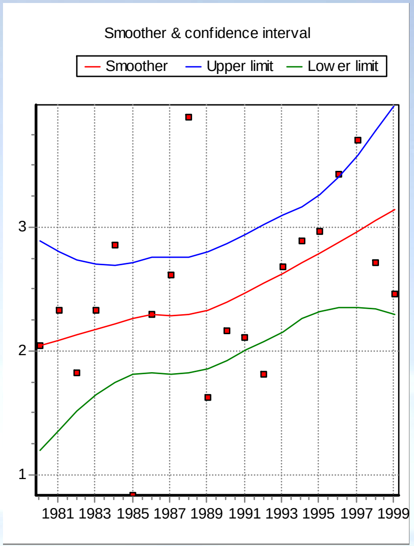
DIC



Baltic Sea

Alheit et al. 2005

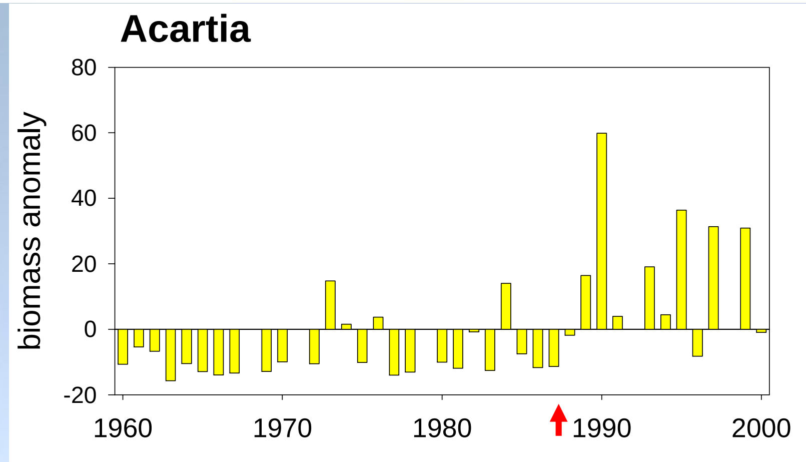


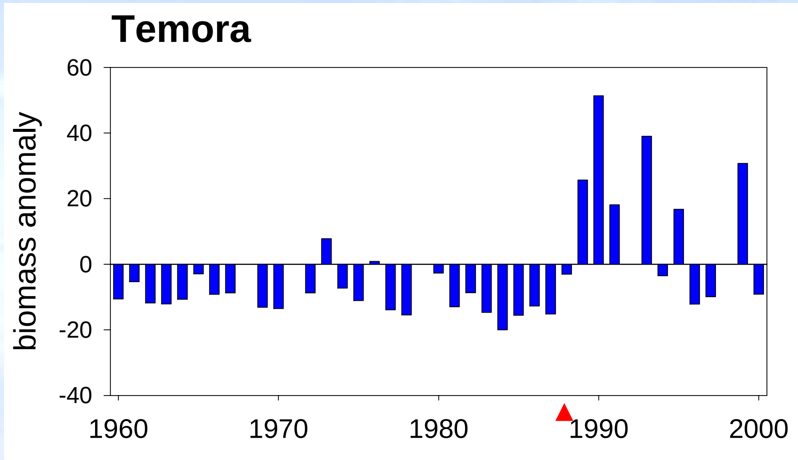


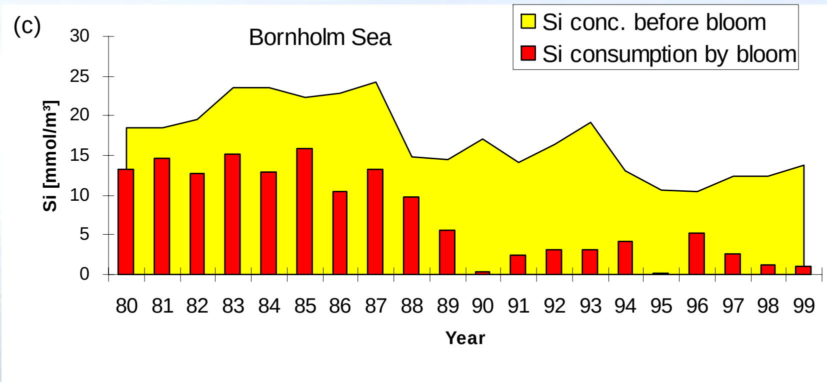
Diatoms

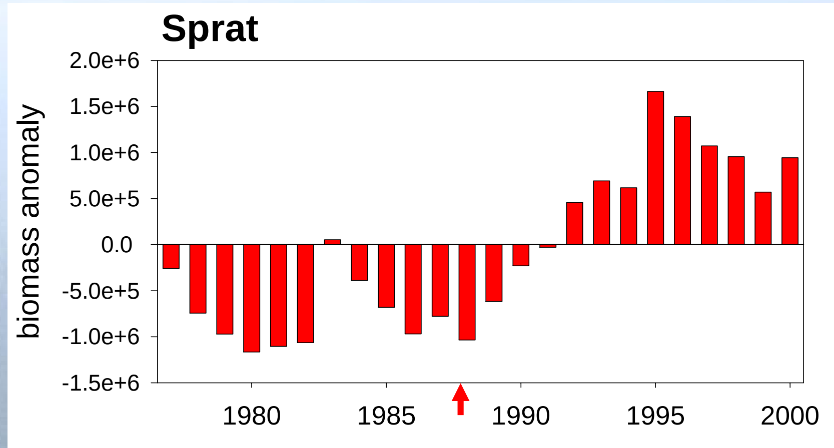
Dinoflagellates

Wasmund and Uhlig2003



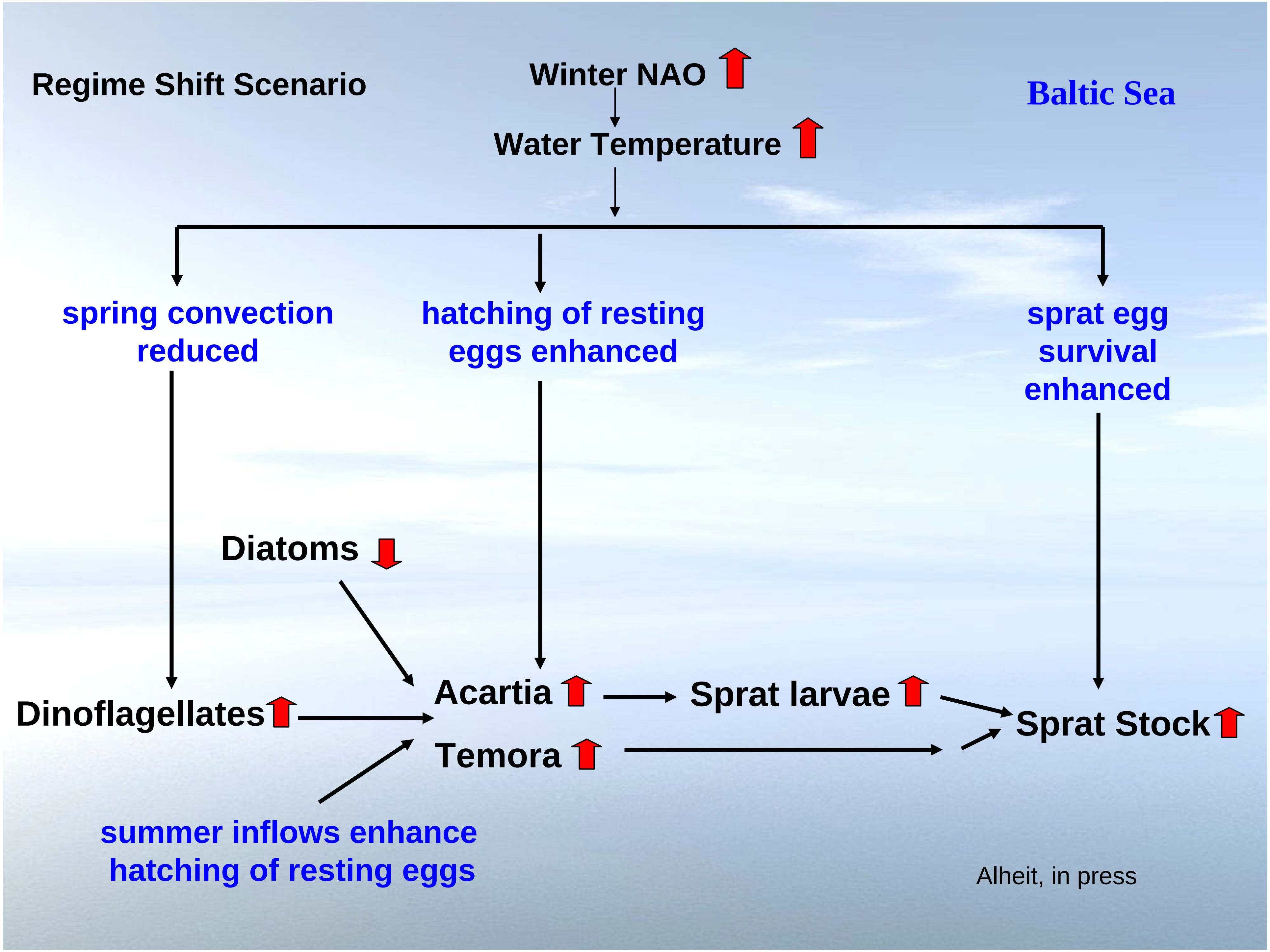






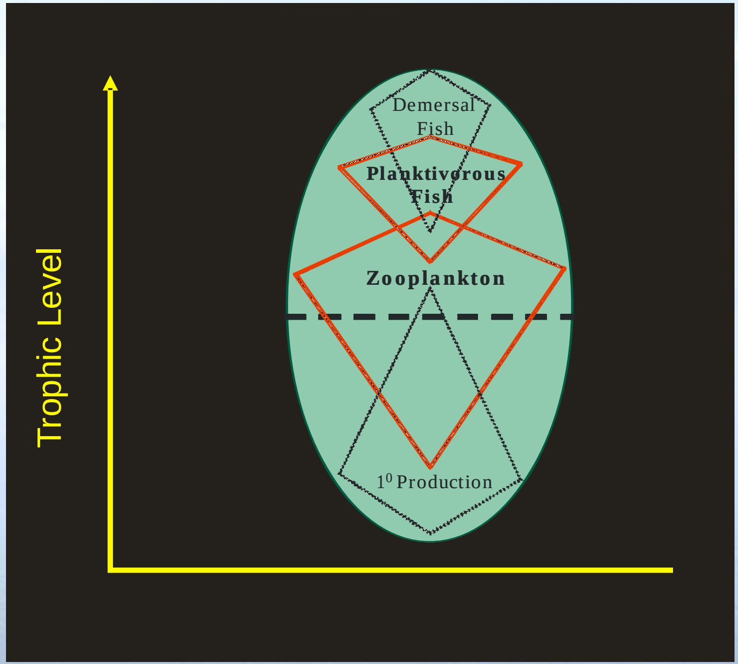
Silicate

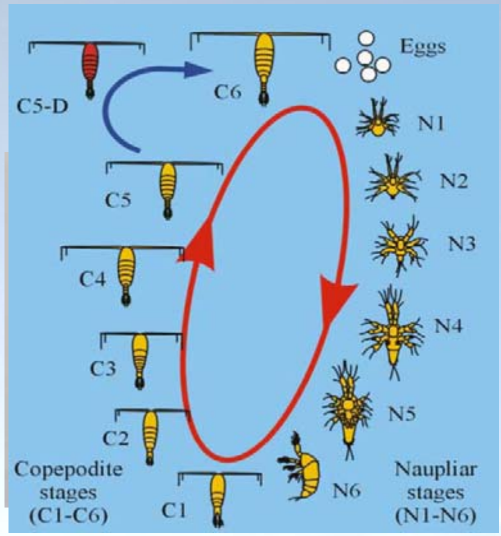
Wasmund et al. 1998


Regime Shift Scenario
Winter NAO
Water Temperature
Baltic Sea
spring convection reduced
hatching of resting eggs enhanced
sprat egg survival enhanced
Diatoms
Dinoflagellates
Acartia
Temora
Sprat larvae
Sprat Stock
summer inflows enhance hatching of resting eggs
Alheit, in press

Basin scale models: concentrate complexity at trophic levels of interest

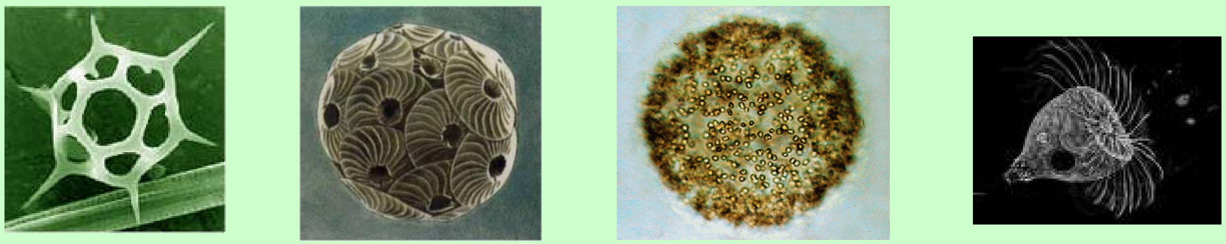
But how to do it?



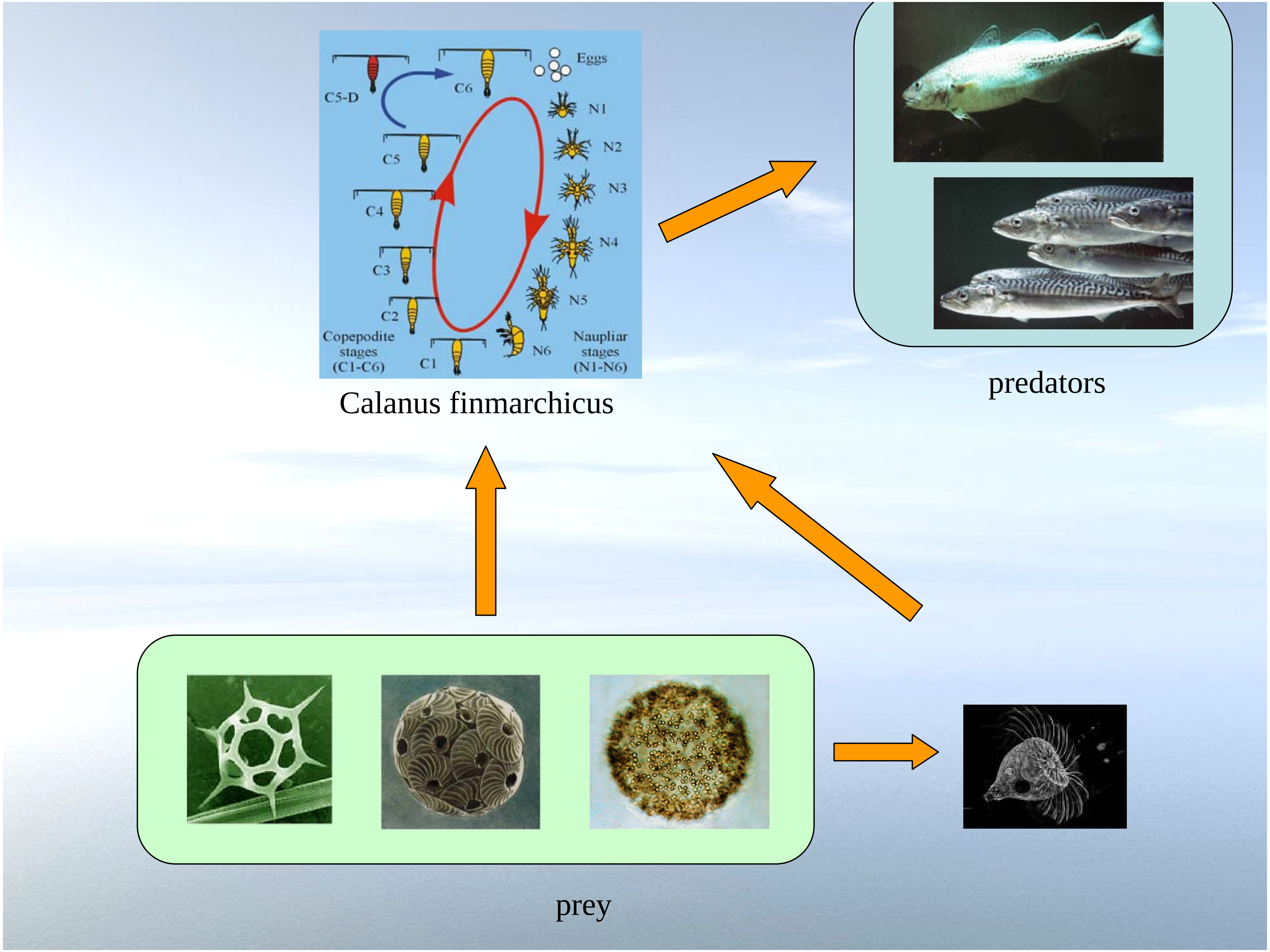


Calanus finmarchicus

predators



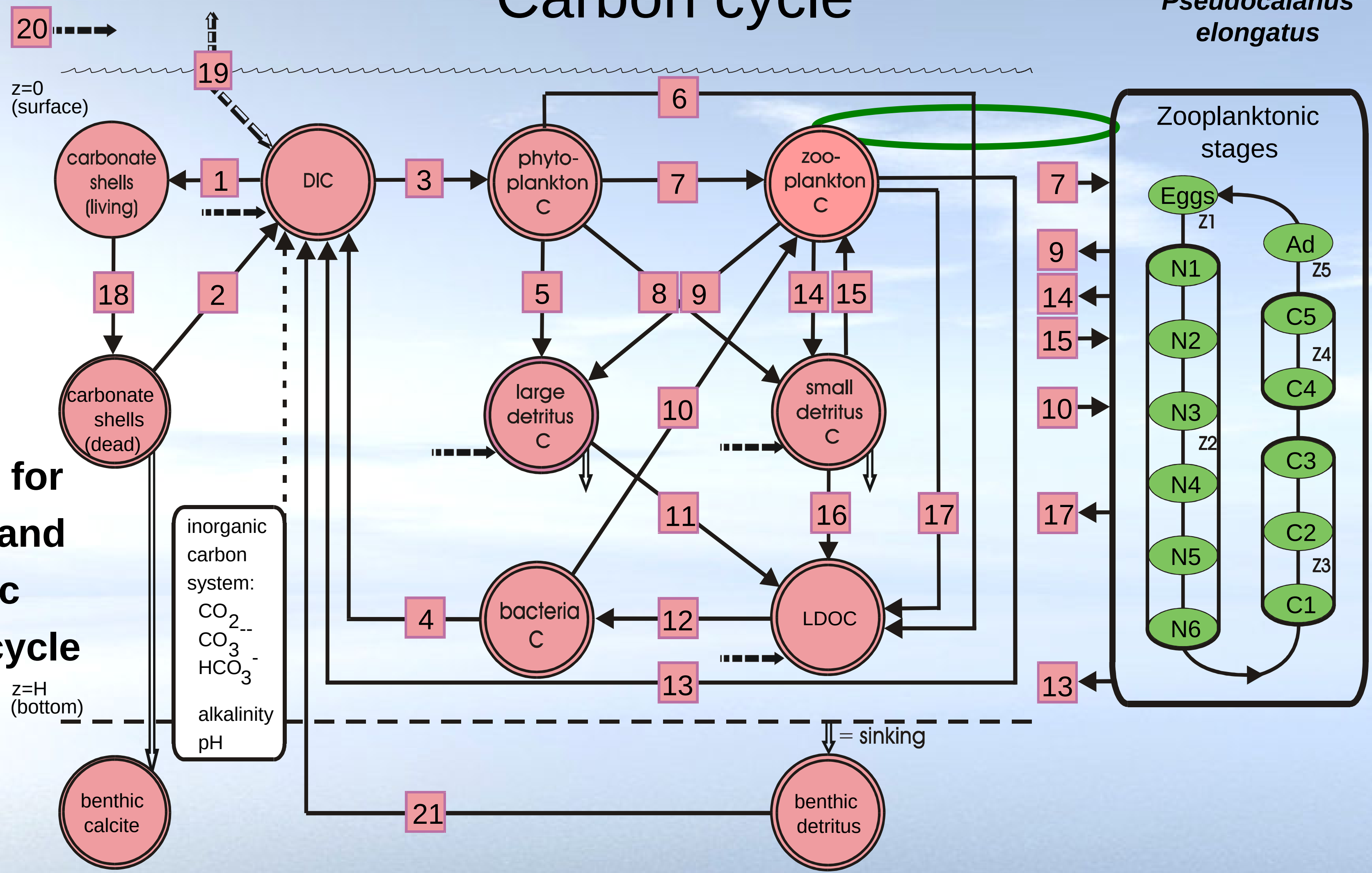
prey


C5-D
C6
Eggs
N1
N2
N3
N4
N5
N6
C5
C4
C3
C2
C1
Copepodite stages (C1-C6)
Naupliar stages (N1-N6)
Calanus finmarchicus
predators
prey

Carbon cycle

model diagram

Pseudocalanus elongatus



FU state variables for

•organic and

•inorganic

carbon cycle

1	- building of shells	6	- exsudation of DOC
2	- dissolution of shells	7, 10, 15	- grazing
3	- net primary production	9, 14	- fecal pellets + mortality
4, 13	- respiration	11, 16	- decay
5, 8, 18	- mortality	12	- uptake of DOC

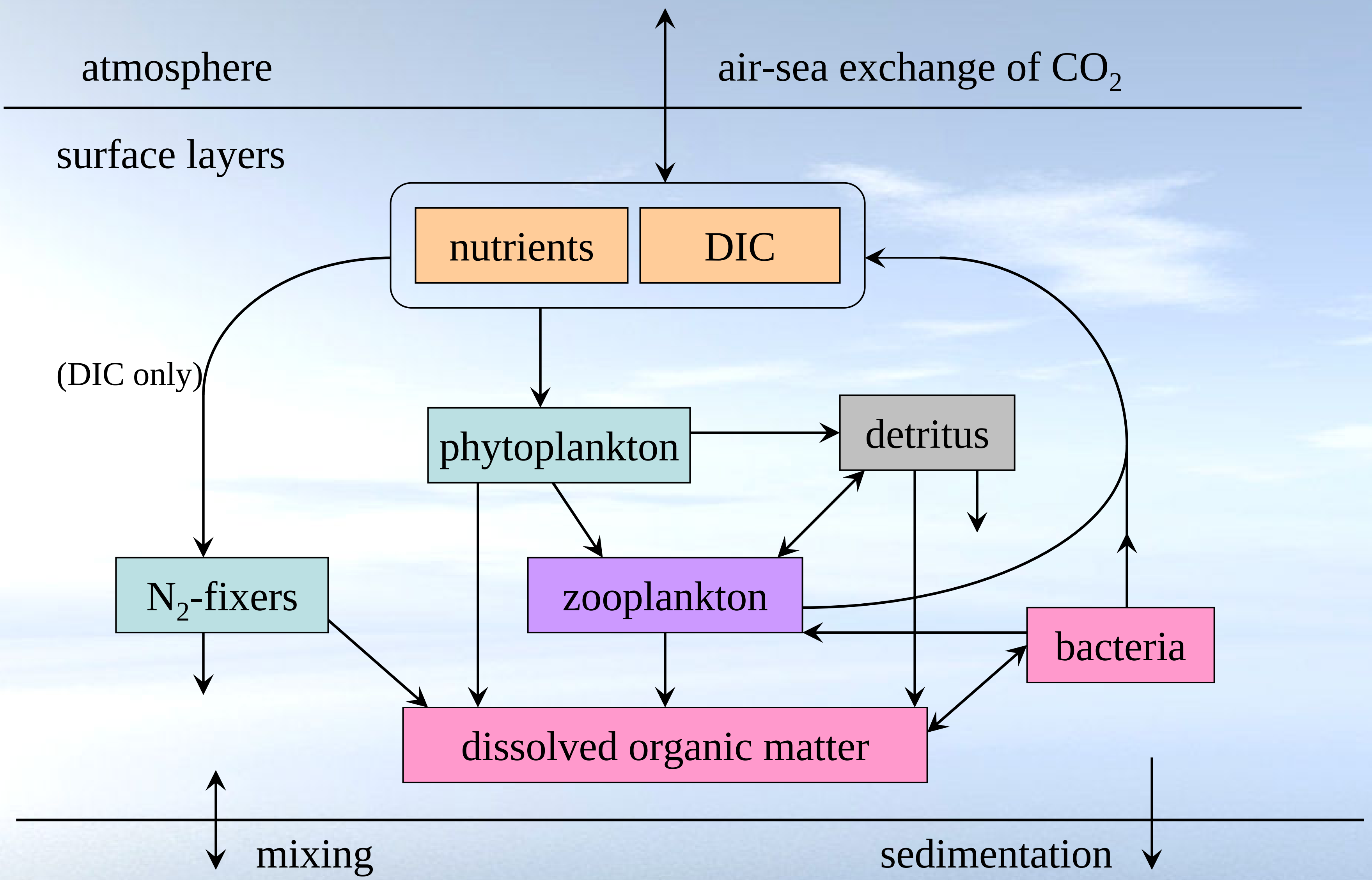
17	- excretion of DOC
19	- atmospheric exchange
20	- river input
21	- benthic regeneration

Empirical approaches

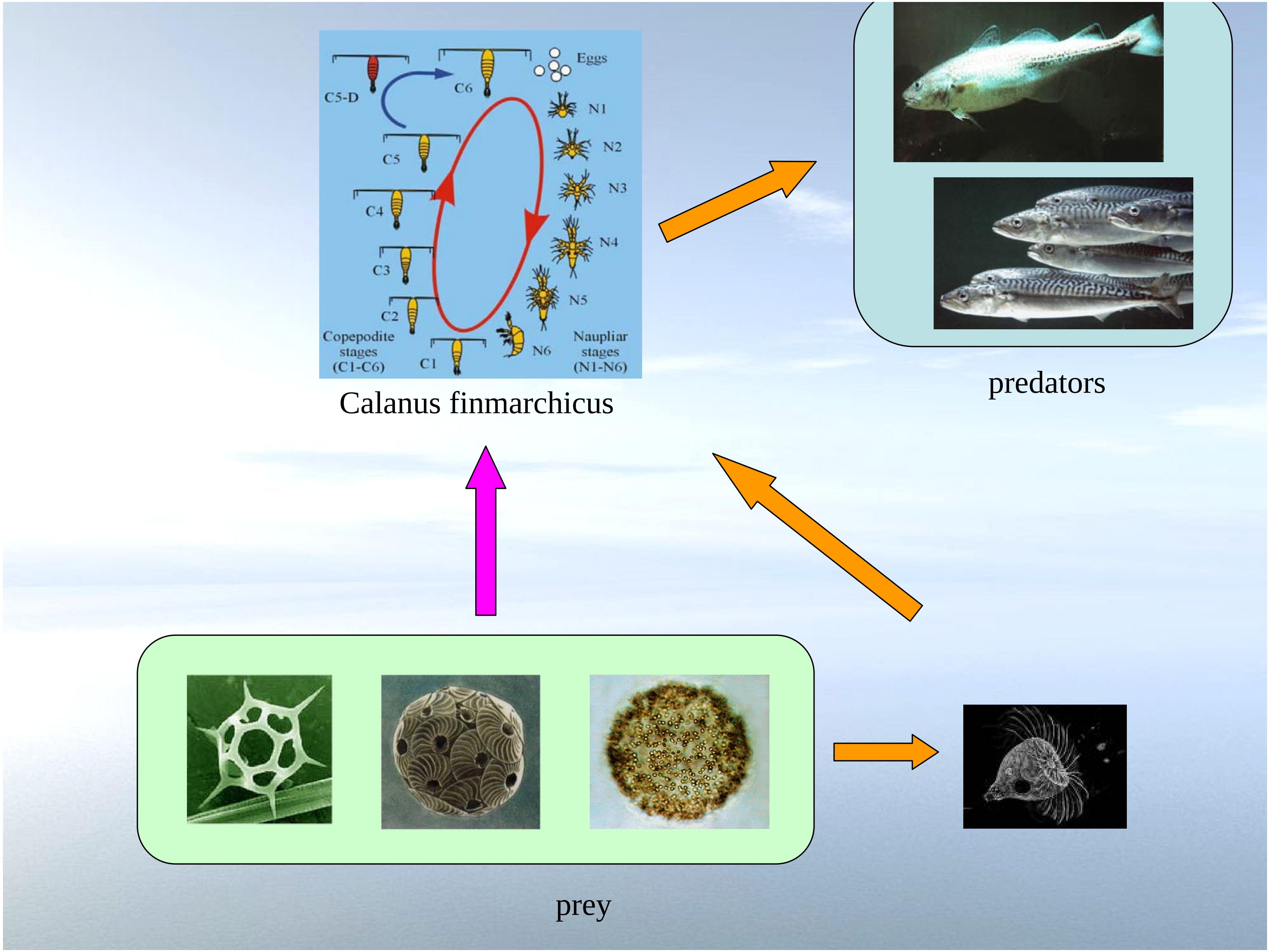
Example: Moore et al. (2002) made calcification 5% of the photosynthesis by small phytoplankton.

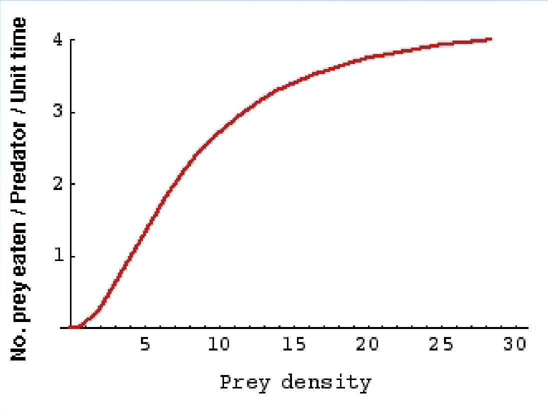
"At present it is not possible to model dynamically or predict calcite formation in the ocean"

Moore, K.J. et al. (2002). Deep-Sea Res. II 49, 403-462.

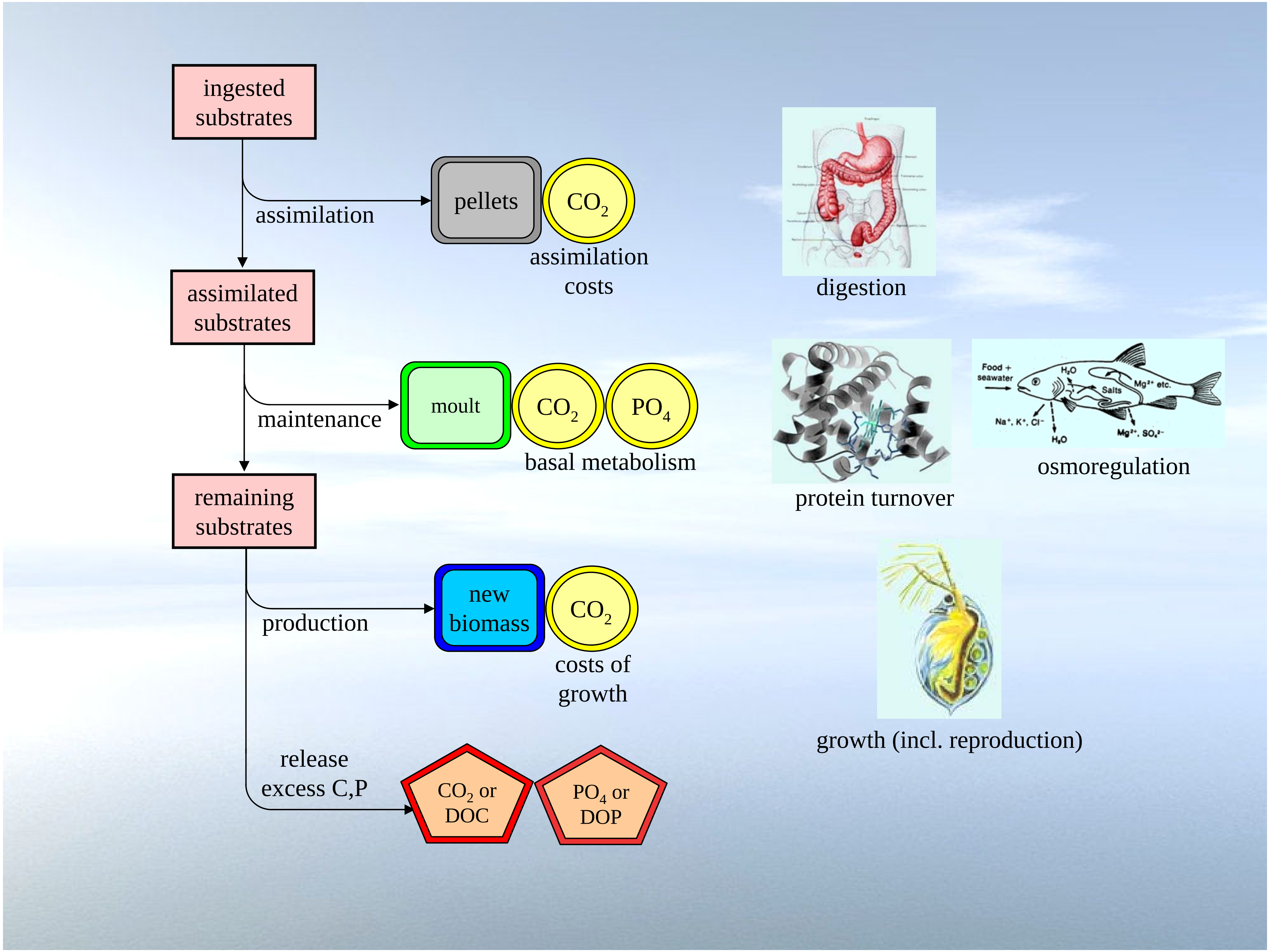

atmosphere
air-sea exchange of CO_2
surface layers
nutrients
DIC
(DIC only)
phytoplankton
detritus
N_2-fixers
zooplankton
bacteria
dissolved organic matter
mixing
sedimentation
Anderson and Pondaven (2003)

Let’s not forget the interactions!

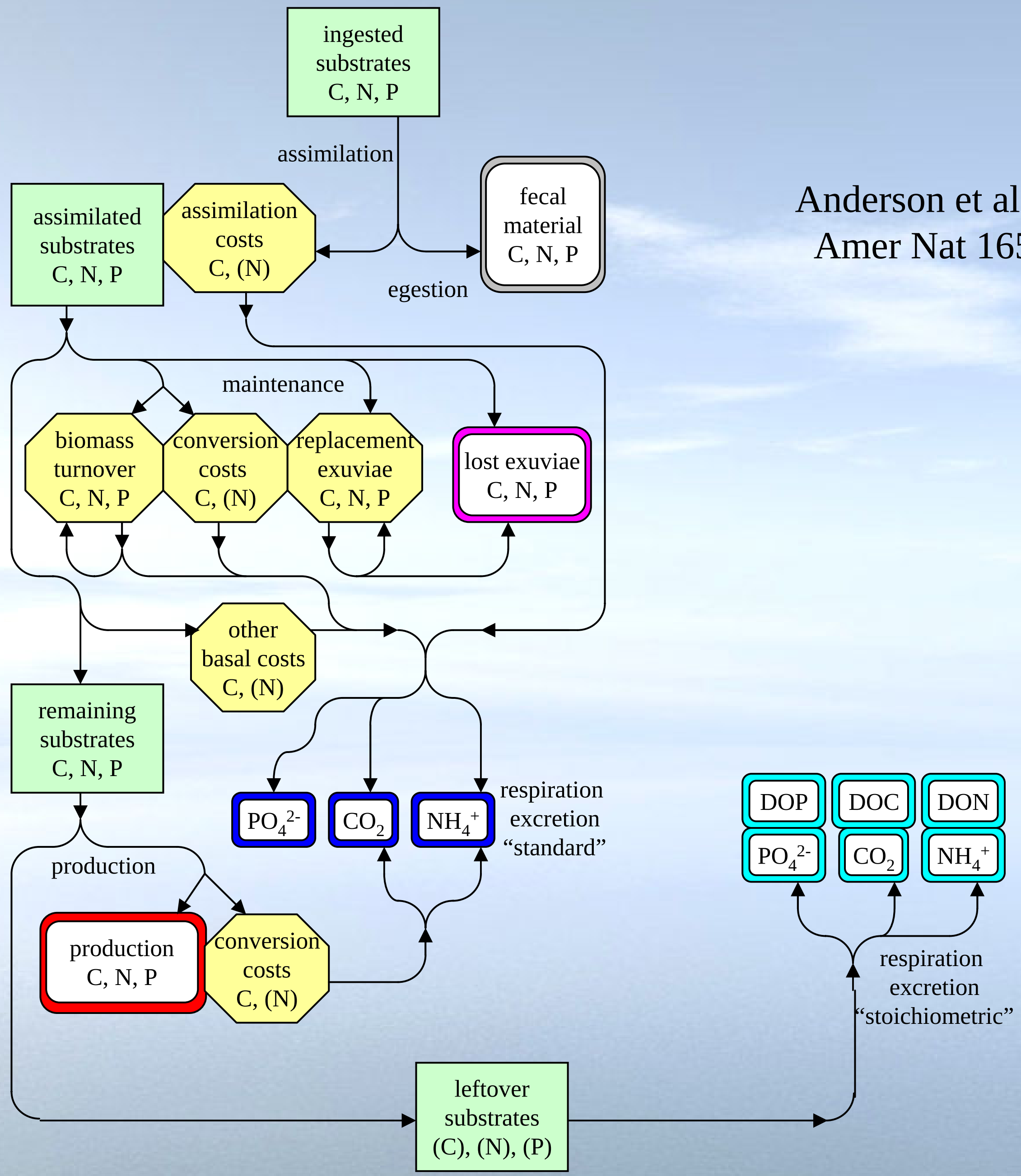

Eggs
C6
C5-D
N1
N2
C5
N3
C4
N4
C3
N5
C2
Copepodite stages (C1-C6)
C1
N6
Naupliar stages (N1-N6)
Calanus finmarchicus
predators
prey



production = gross growth efficiency * intake

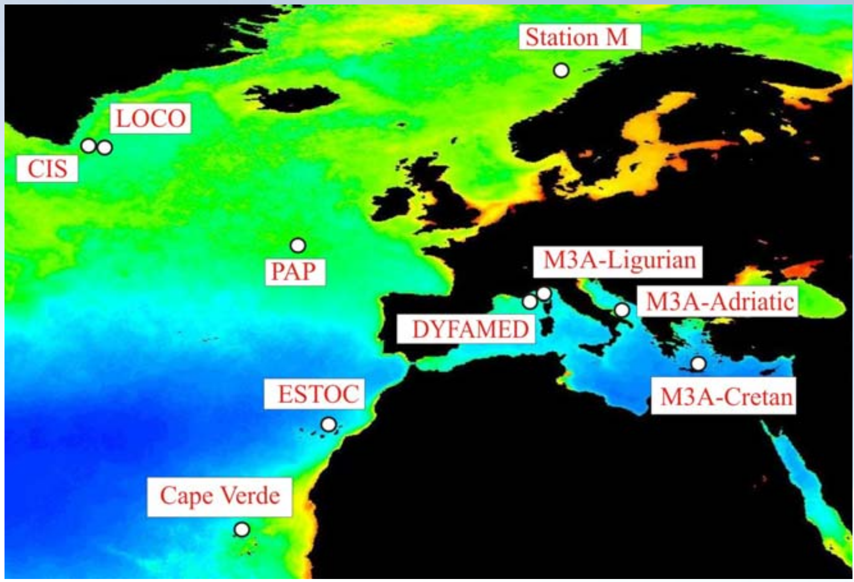

ingested substrates
assimilation
pellets
CO_2
assimilation costs
assimilated substrates
maintenance
moult
CO_2
PO_4
basal metabolism
remaining substrates
production
new biomass
CO_2
costs of growth
release excess C,P
CO_2 or DOC
PO_4 or DOP
digestion
protein turnover
Food + seawater
H_2O
Salts
Mg^{2+} etc.
Na^+, K^+, Cl^-
H_2O
Mg^{2+}, SO_4^{2-}
osmoregulation
growth (incl. reproduction)

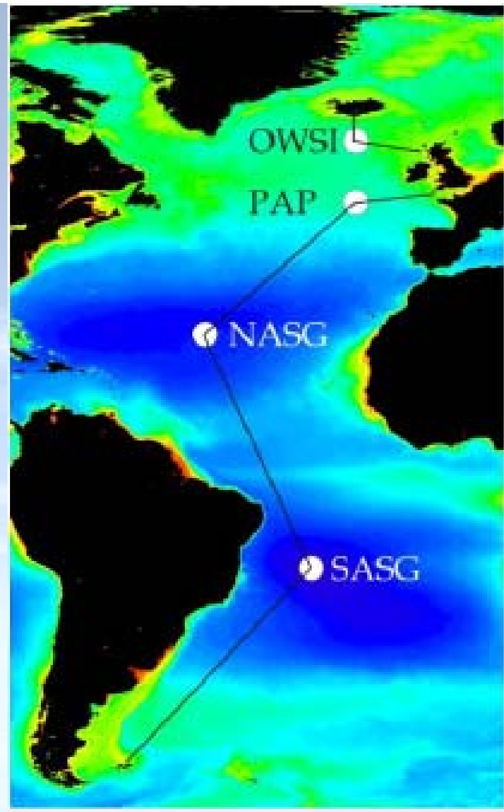
Anderson et al. (2005)
Amer Nat 165, 1-15



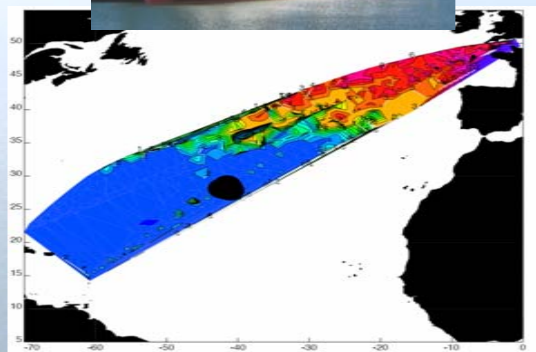
Rigorous validation required

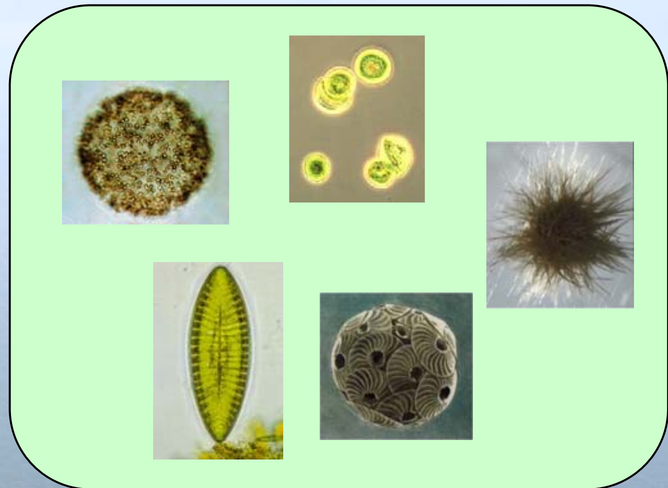
Quantification of model uncertainty


Station M
LOCO
CIS
PAP
M3A-Ligurian
M3A-Adriatic
DYFAMED
ESTOC
M3A-Cretan
Cape Verde


OWSI
PAP
NASG
SASG


Portsmouth
Brest
Bilbao

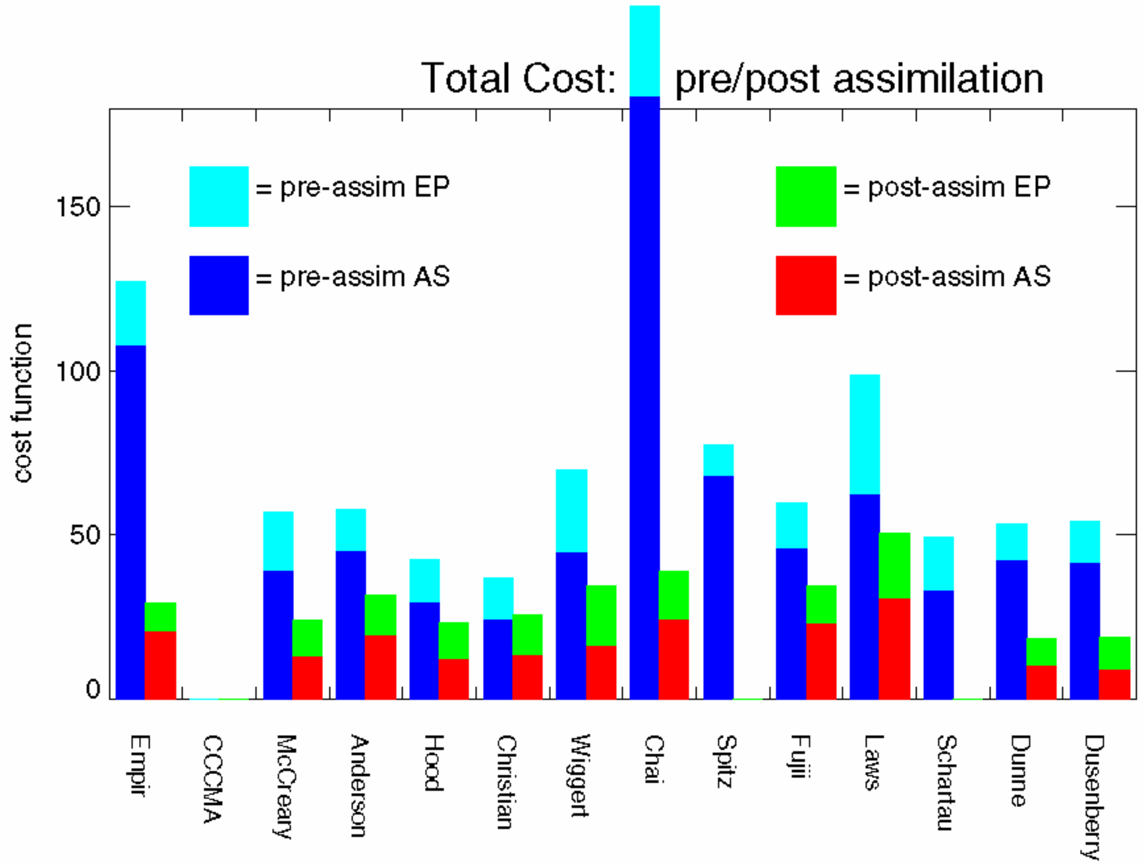




US JGOFS Regional Ecosystem Testbed Project

Marjorie Friedrichs

Arabian Sea Process Study (ASPS),
Antarctic Environment and Southern Ocean Process Study (AESOPS),
Equatorial Pacific Process Study (EqPac),
second iron enrichment experiment (IronExII),
Bermuda Atlantic Time-Series Study (BATS), and
Hawaii Ocean Time-series (HOT)



Total Cost: pre/post assimilation
= pre-assim EP
= pre-assim AS
= post-assim EP
= post-assim AS
cost function
150
100
50
0
Empir
CCCMA
McCreary
Anderson
Hood
Christian
Wiggert
Chai
Spitz
Fujii
Laws
Schartau
Dunne
Dusenberry

Conclusions

- Adding complexity ad infinitum to models won't work. Complexity should be concentrated at trophic levels of interest, but care must be exercised to ensure that interactions with other trophic levels are adequately represented, and system feedbacks of interest represented.

- NPZD models do a generally good job of simulating bulk properties, e.g. chl, primary production; attention to physics and model forcing is important.

- Adding additional complexity, with robust parameterisations, poses a major challenge for the modelling community.