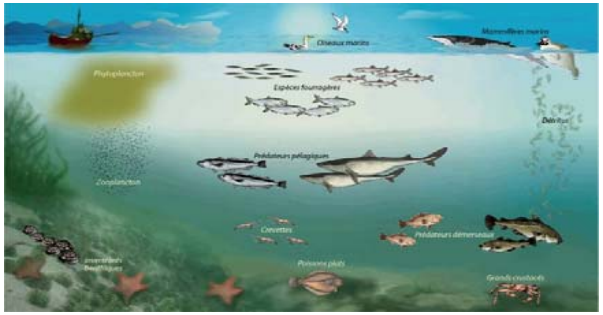
Modélisation end-to-end

des écosystèmes marins

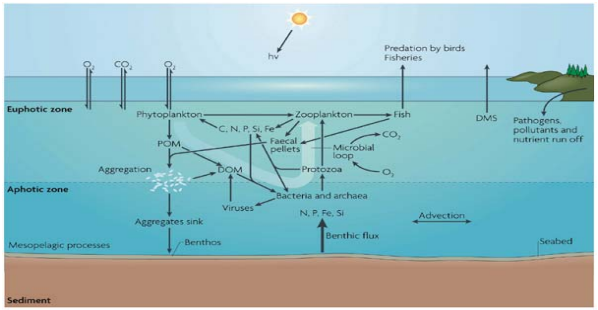
Seatech Week, Brest

Marine ecosystems: A dual perspective

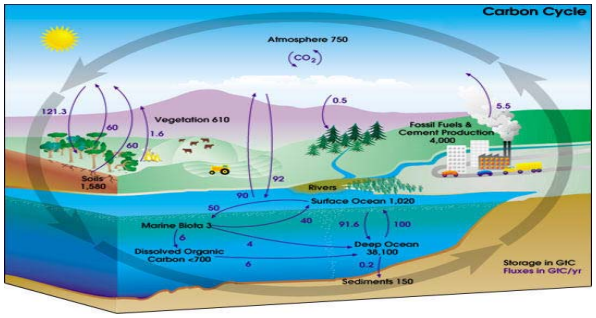


Lower trophic levels

Upper trophic levels

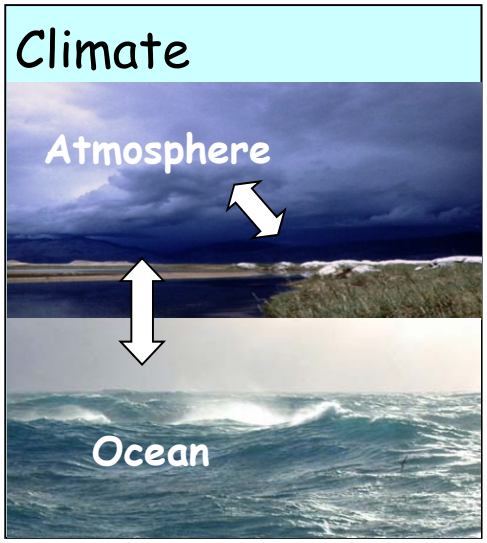


Biogeochemistry



Fisheries

The different levels of interactions

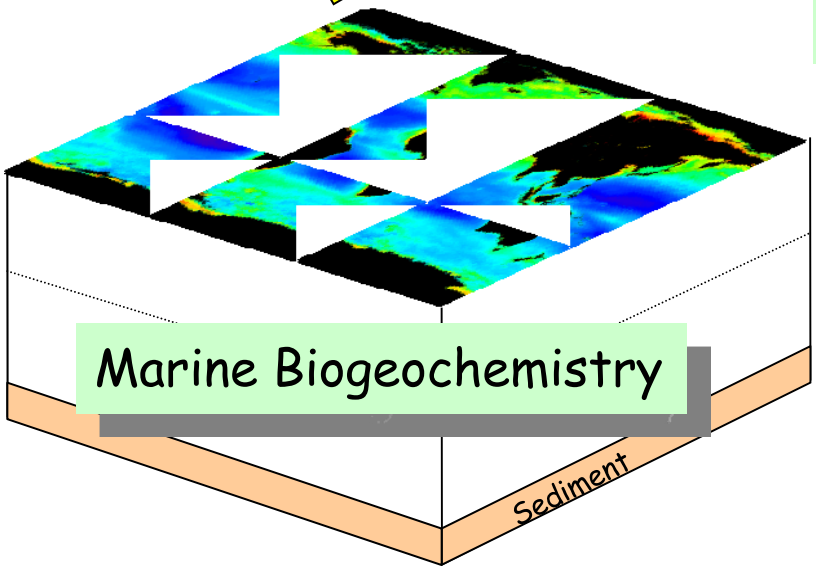


Market

Fisheries, fleets

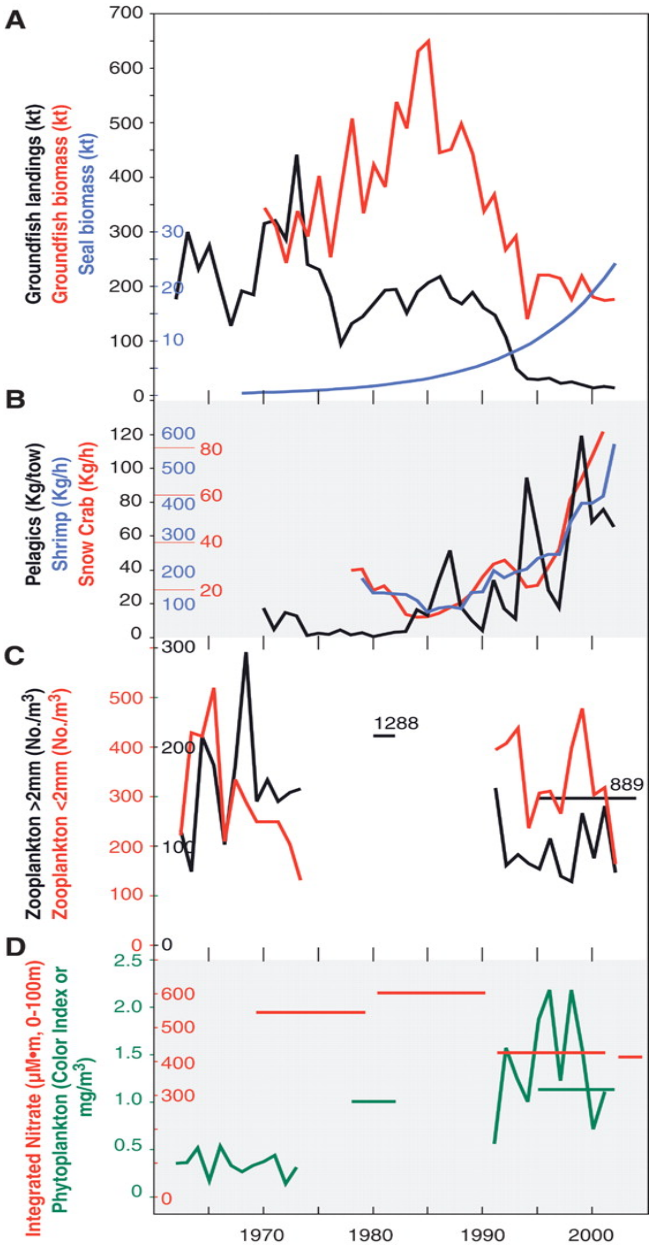
Atmospheric Components :
CO_2, DMS, CH4, N2O,…

Trophic food web

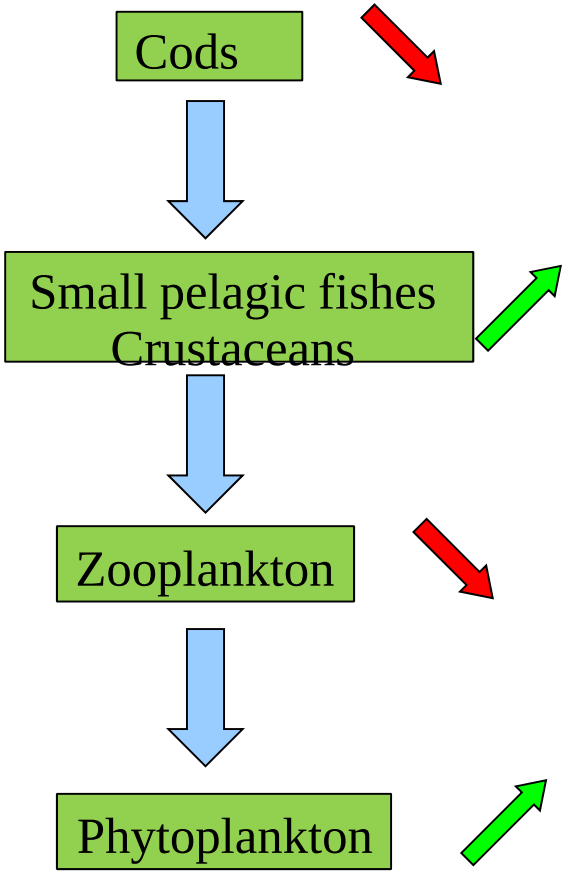


Marine Biogeochemistry

An example of E2E interactions: Trophic cascade

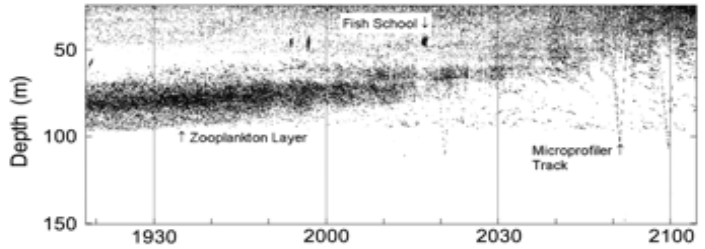


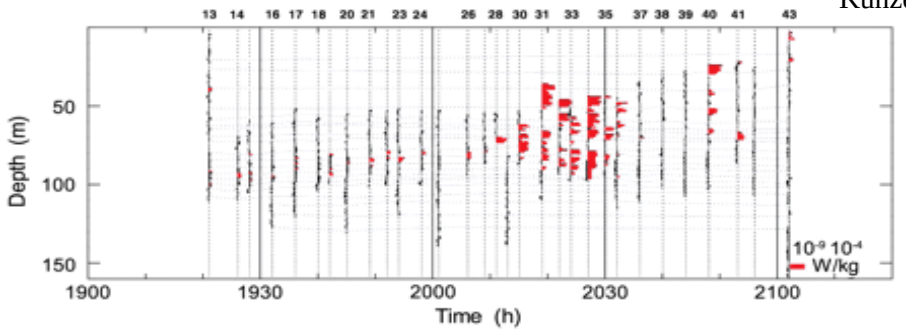
Cascade in the Northern Atlantic ocean



Another example of E2E interactions: Biomixing

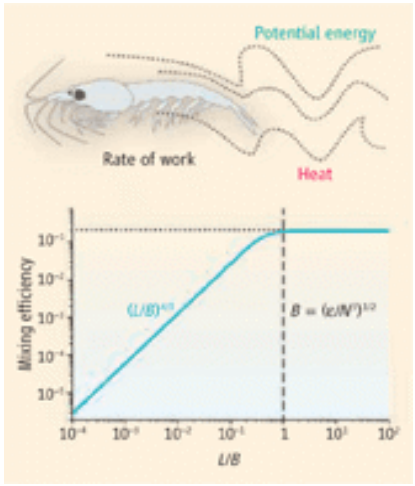
Observations show increased turbulence during DVM



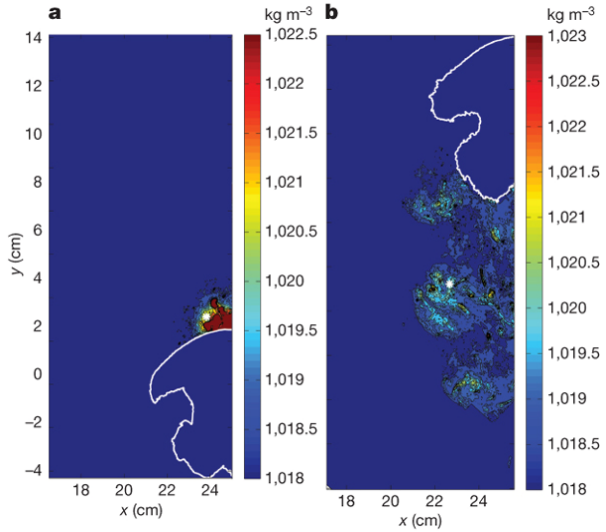


Kunze et al., 2006

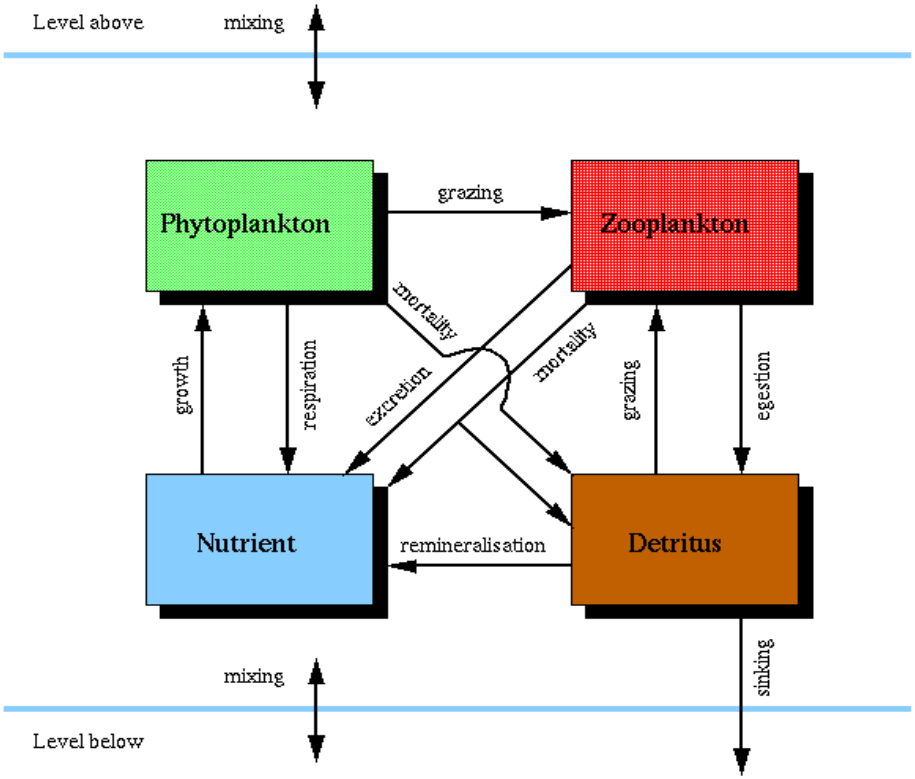
Dissipation of mechanical energy ?



Darwin's mechanism



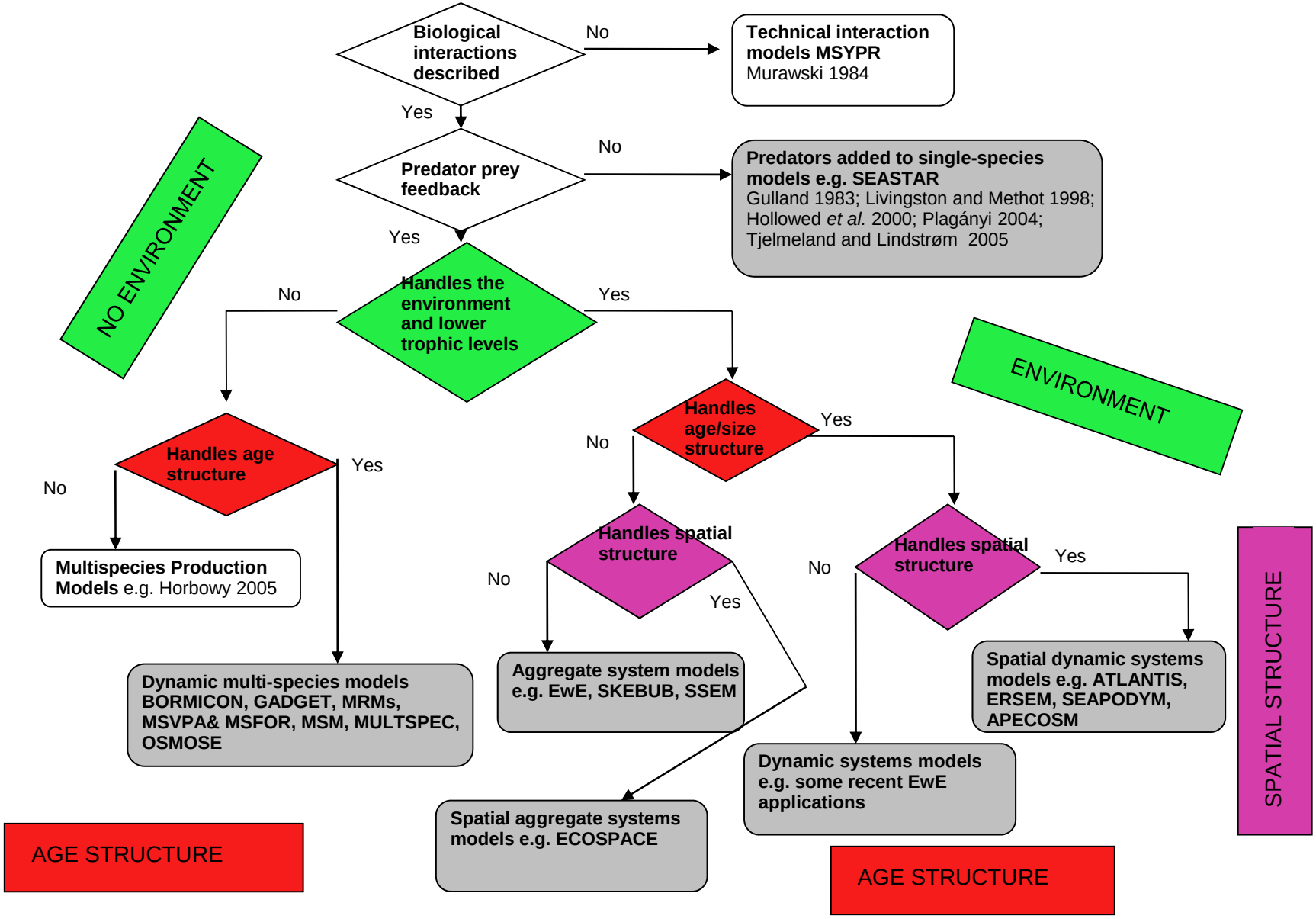
End-to-end ecosystem models: lower trophic levels



(after Fasham et al., 1990)

- 4+ Compartments
- Coupled to various cycles (carbon, oxygen, DMS ...)
- Nutrients are transported by ocean circulation
- Monod/Quota/Mechanistic formalisms
- No representation of the higher trophic levels

End-to-end ecosystem models: Upper trophic levels



MACROES

A MACRoscope for Oceanic Earth System Studies

PI : Olivier Aumont, LPO, Brest

- 7 participating labs, about 20 researchers involved
- The total budget is about 4 M€, 1.2M€ supported by ANR.
- A 4 years project: From 2010 to 2013

Cliotop, February 2010

MACROES: The objectives

Main Objective:

- Better **understand/predict** the **integrated dynamics** of marine ecosystems within the context of **overfishing** and **global change**

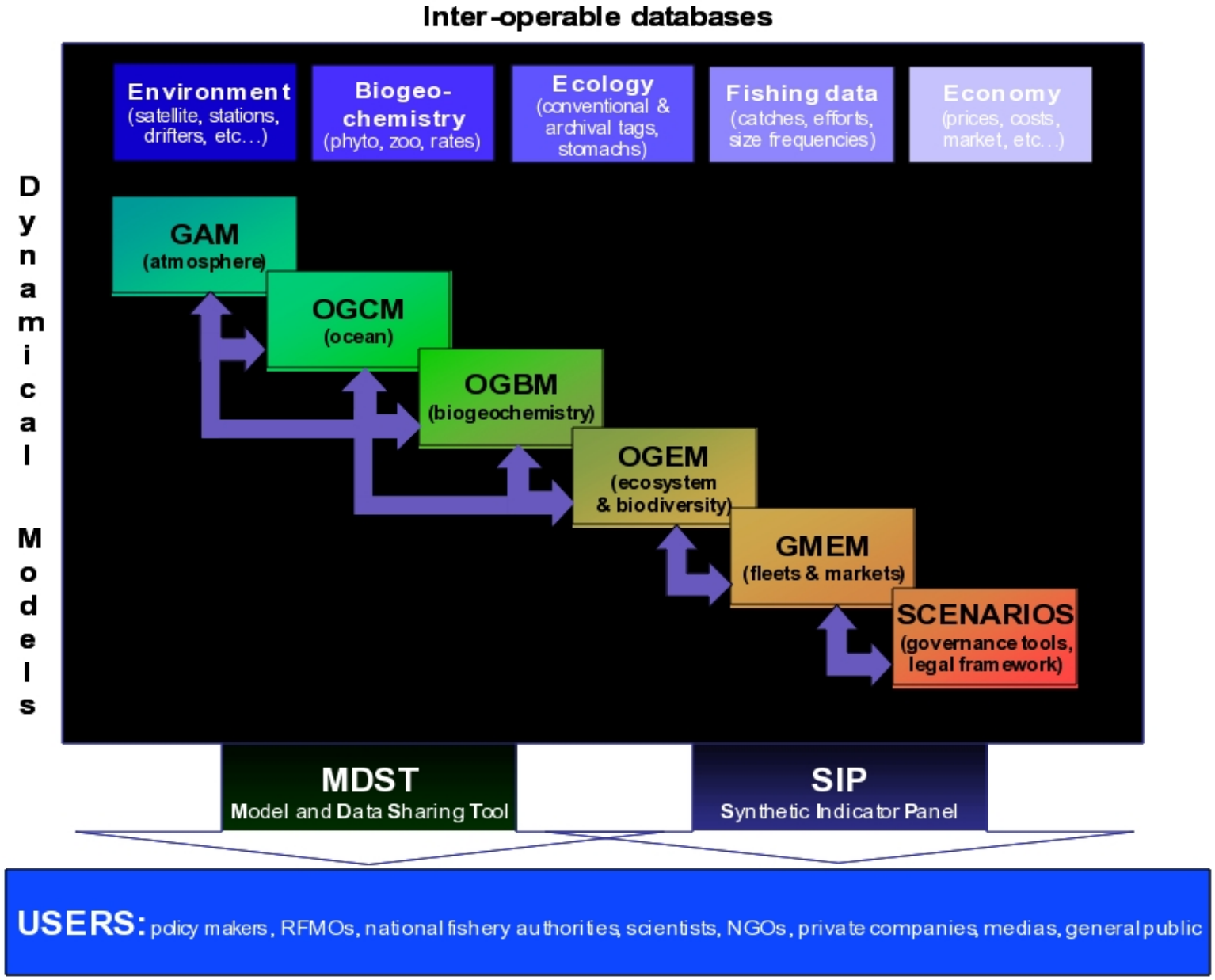
3 scientific questions :

- What is the role of reciprocal interactions and of biodiversity on the functioning and structure of marine ecosystems (including physics)?

- What is the response of marine ecosystems to global environmental changes, including governance strategies?

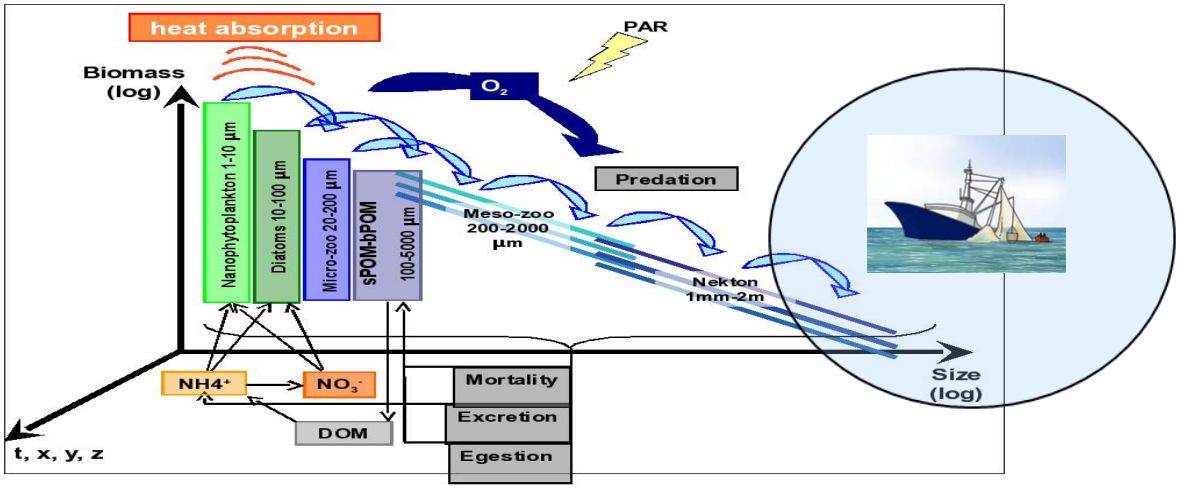
- How to characterize these changes with synthetic indicators which have a meaning for communication and management?

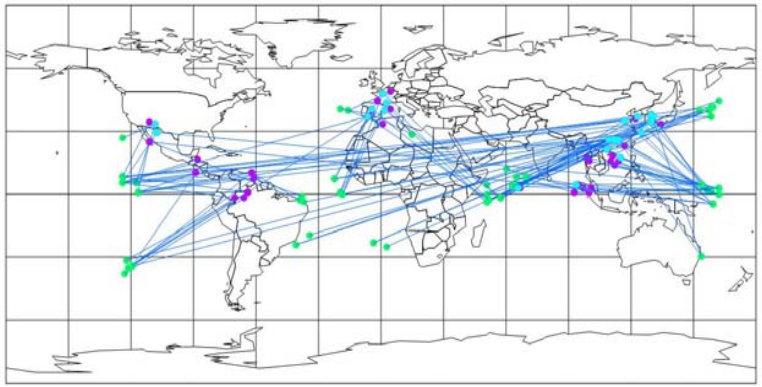
MACROES : The tools (1)



MACROES: The tools (2)

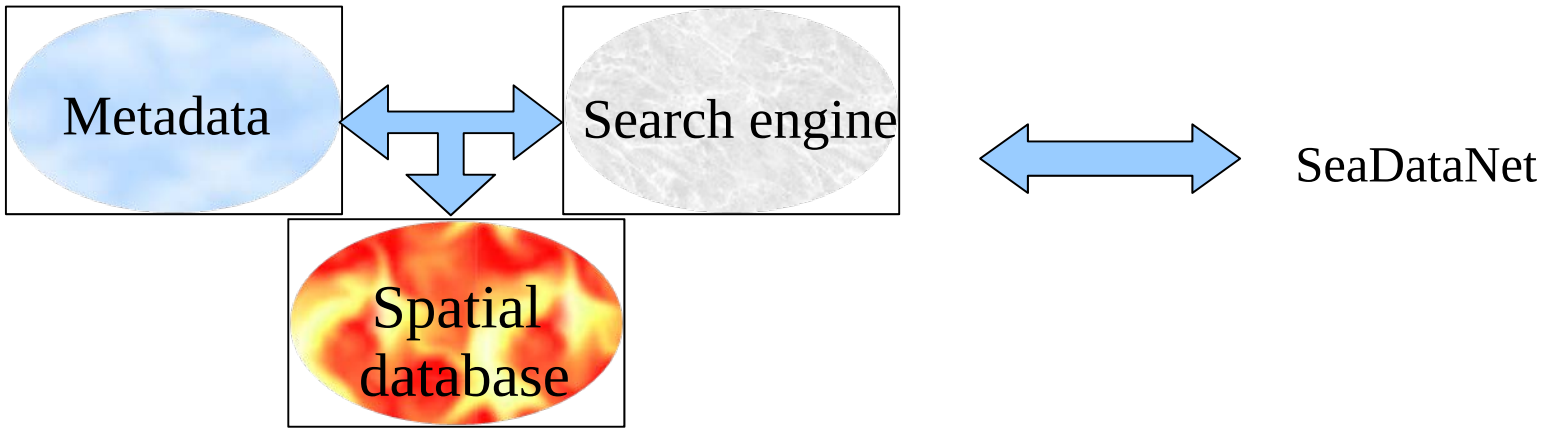
- **Models :**





NEMO ⟺ PISCES ⟺ APECOSM ⟺ EDM ⟲ CET

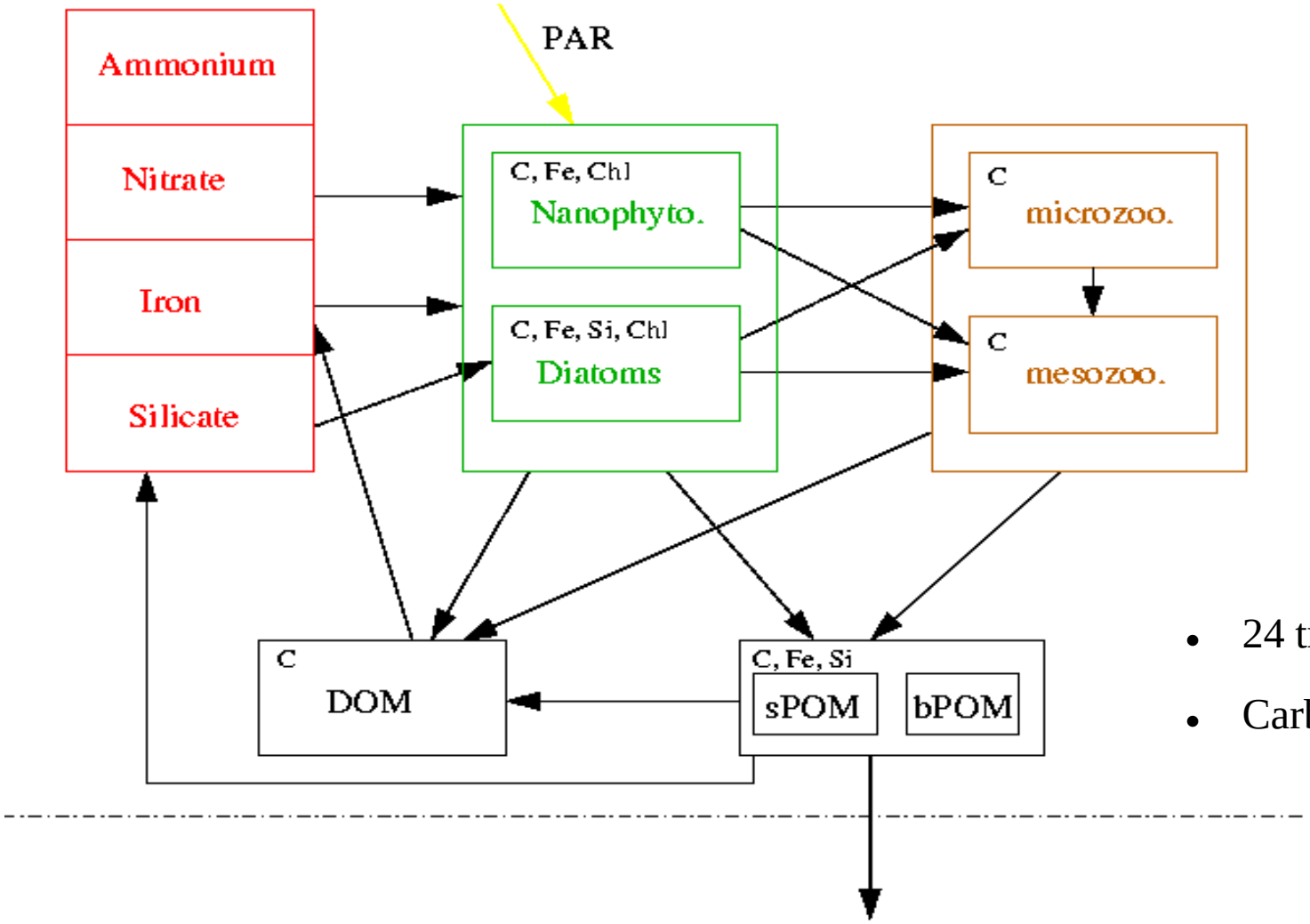
- **Databases:**



MACROES: MDST

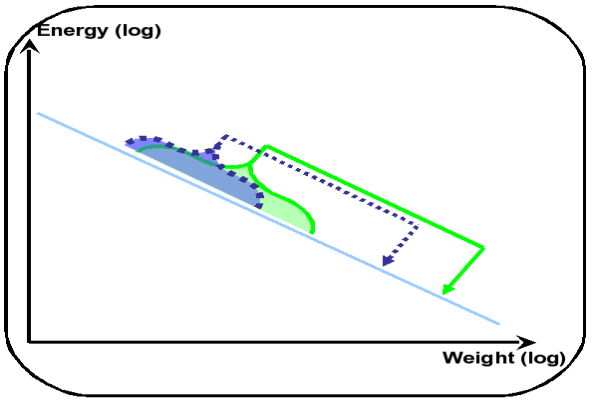
http://vmmdst-proto.mpl.ird.fr/MDST/

The LTL model: PISCES



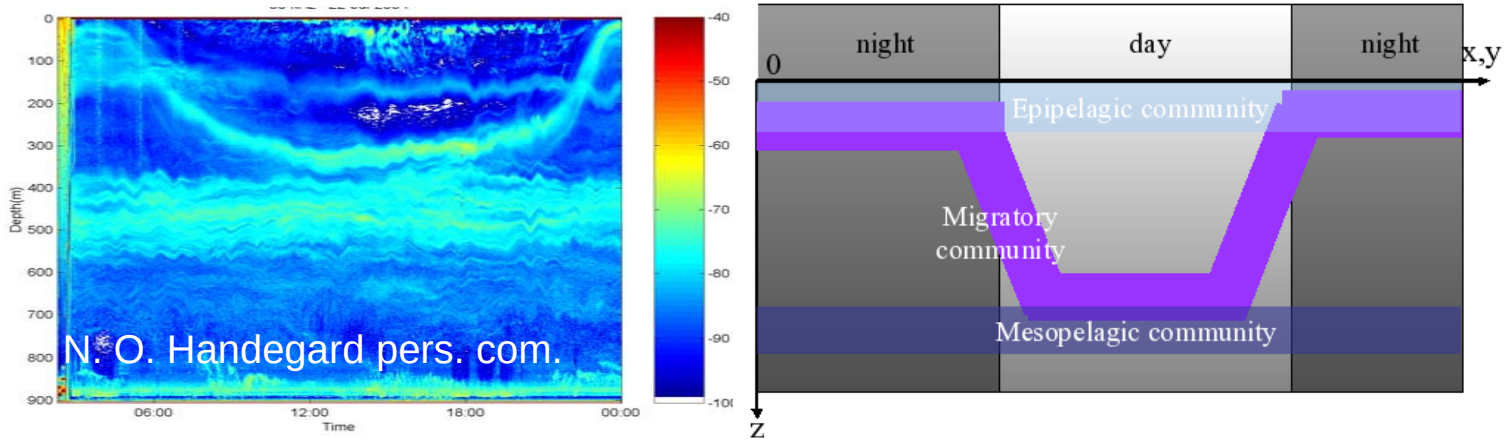
- 24 tracers
- Carbon cycle, O2

The UTL model: APECOSM



- Mass and energy are conserved
- Size is structuring opportunistic trophic interactions
- Size & temperature are controlling metabolism (DEB theory) using simplifications
- The ecosystem is divided into 3 Open Ocean Pelagic Communities (OOPC)

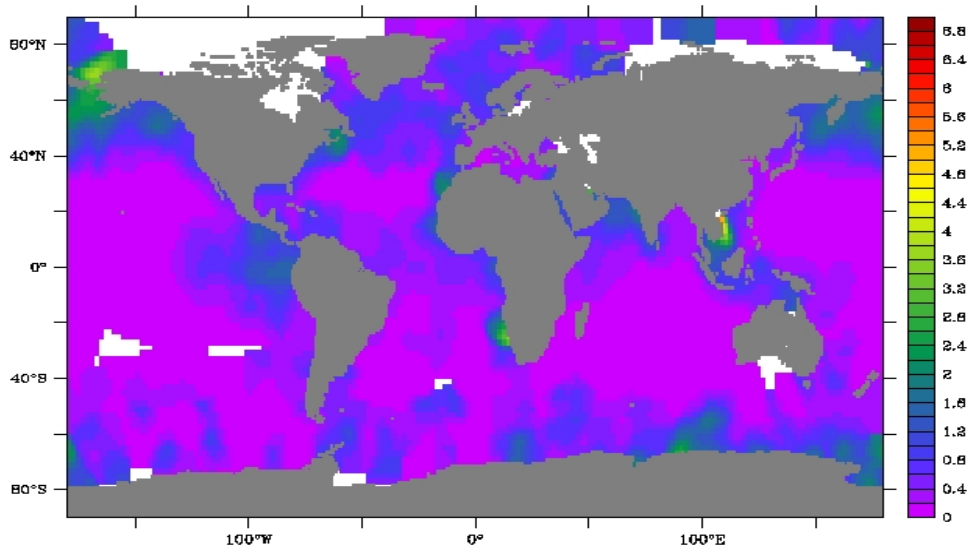
  Depth distribution is constrained by light, oxygen, food and temperature



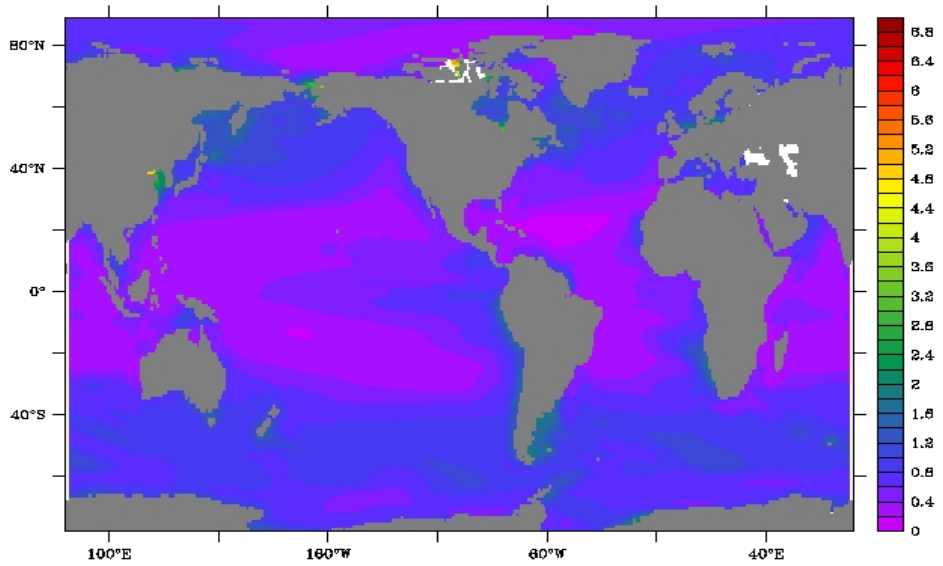
- Each OOPC is divided into n size-classes which are user defined

MACROES: NEMO-PISCES-APECOSM

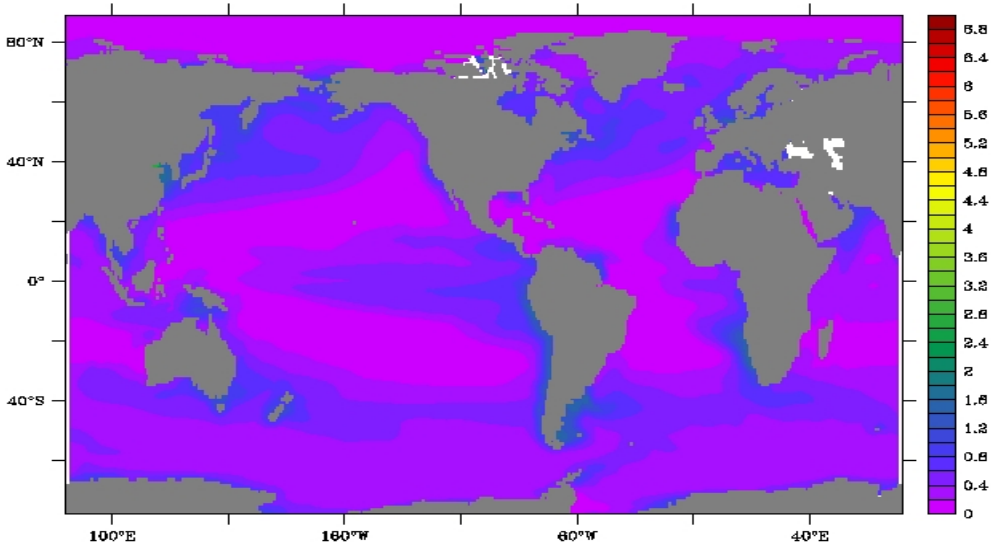
From COPEPOD-2005 zooplankton database



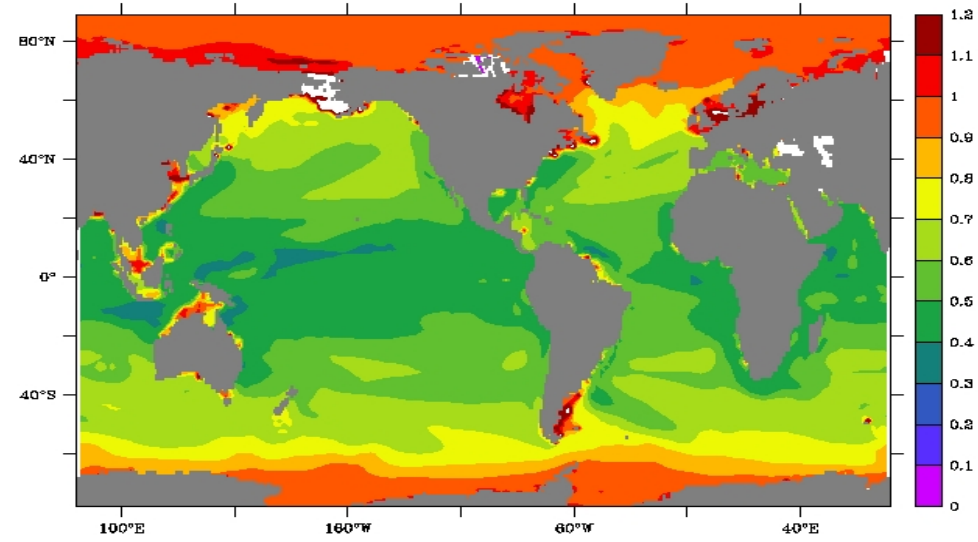
From NEMO-PISCES-APECOSM



From NEMO-PISCES-APECOSM



Night/day Ratio



PISCES and APECOSM: The limitations

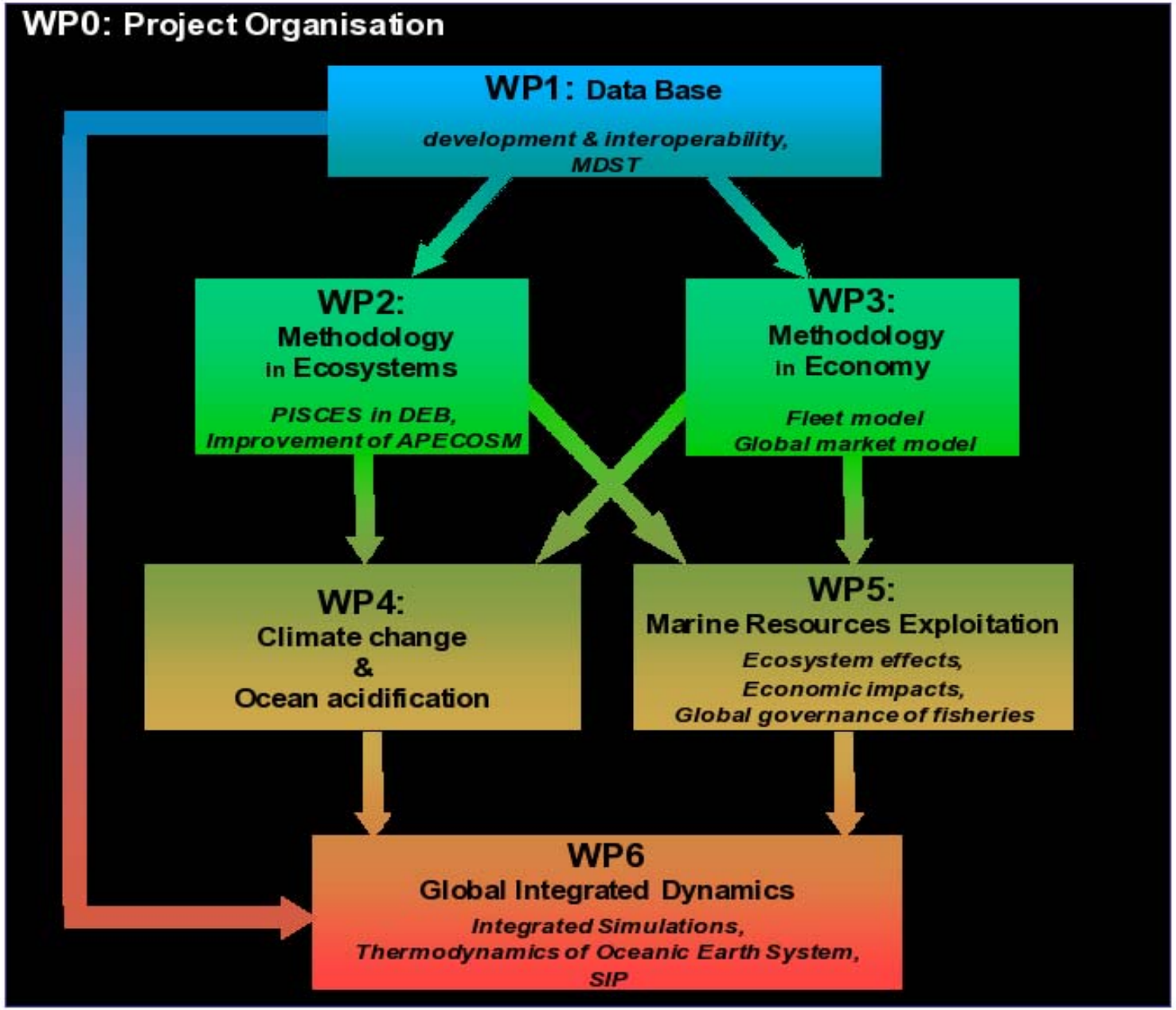
PISCES

- **The major drawback of this model is that it is a Monod Model**
  - No variable Redfield ratios, co-limitations are not correctly modeled
- **Mesozooplankton is highly unrealistic**
  - No life stages, no vertical migration at all scales
  - Mortality is a closure term

APECOSM

- **No biodiversity**
  - In each size class, all individuals are supposed adults
  - All individuals have identical feeding behaviors (visual, tactile, ...)
- **Isolated communities**
  - No exchange between the communities
  - No difference between adults and juveniles
- **No schooling/swarming**

MACROES: The scientific program



The methodological developments: Biogeochemistry

- **Mostly all models do exist currently but ...**
  - To be predictive, there is a need to be mechanistic
  - The different levels of biodiversity need to be accounted for
- **PISCES, the biogeochemical model**
  - Adopt the DEB formalism for the biogeochemical model PISCES

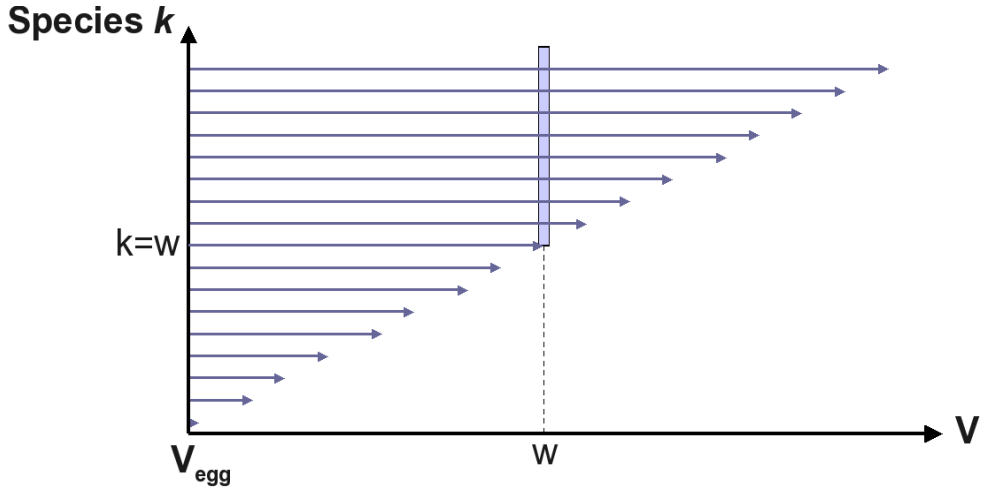
This choice will allow to have a consistent theoretical framework for the whole ecosystem

- **APECOSM, introduce some description of the biodiversity**

Species are defined by their maximum size

Their parameters depend on this max size

Then, potentially add alternative communities



The methodological developments: The problems

For all the methodological developments that are planned

two main difficulties :

- **The increasing complexity of the models:**

✓ Tuning the models becomes an extremely difficult “game”

✓ Understanding the behavior of the models is tricky

✓ The cost of the models can become prohibitive

- **The lack of data**

✓ Obvious problem which is recurrent for all modeling exercise

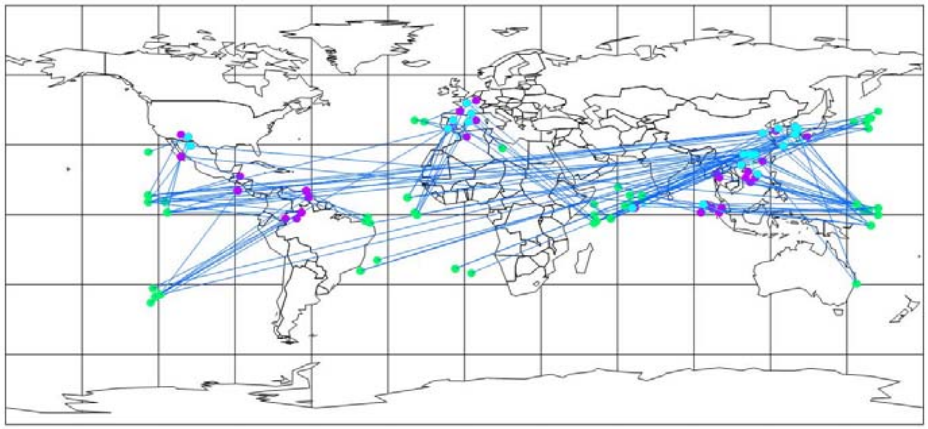
✓ Even more acute for mid-trophic levels

✓ Acoustic/optical data (LEMAR, others). Ongoing discussion with P. Brehmer.

The methodological developments in economy

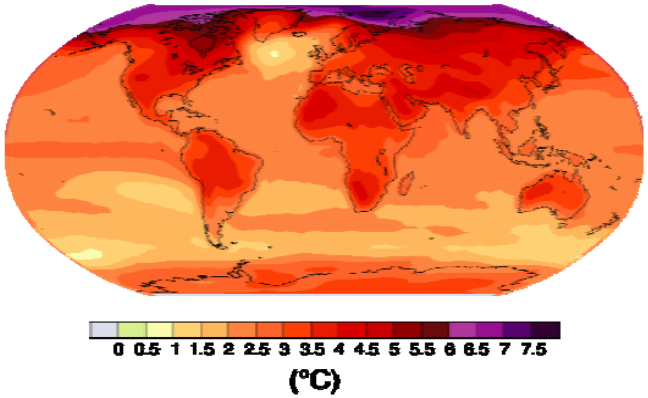
- **Effort dynamics model (EDM)**
  - The EDM will be a **dynamic and explicit spatial model**
  - The EDM will be designed to produce **mid-term scenarios** (up to 15 years)
  - The EDM will take into account **governance conditions** defining access to resources

- **Catch-effort trade model**
  - A data and demand analysis to define the relevant market for tuna products
  - A demand function econometric model will be designed and the parameters estimated to be used in the CET model



Network of the model

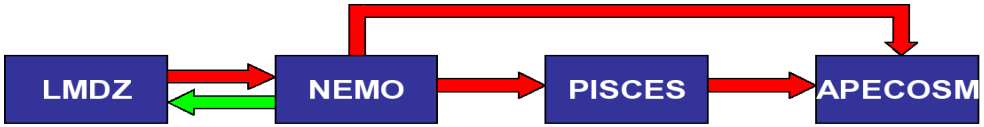
Climate change and ocean acidification



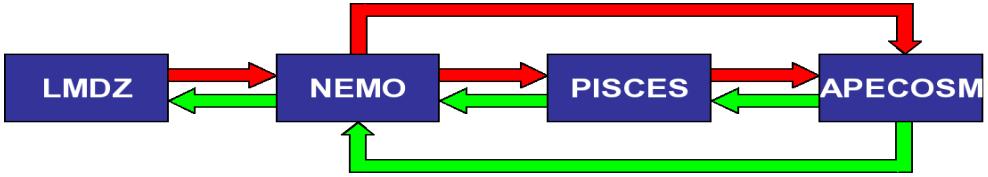
?

Marine ecosystems

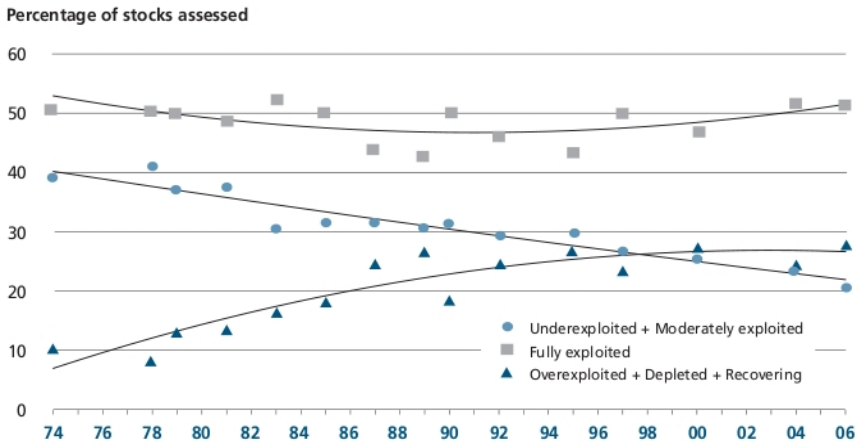
1) Analyze the impact of global changes in an uncoupled mode

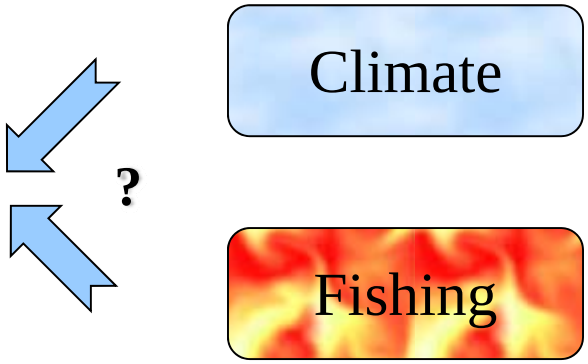


2) Analyze the retroactions between the different levels

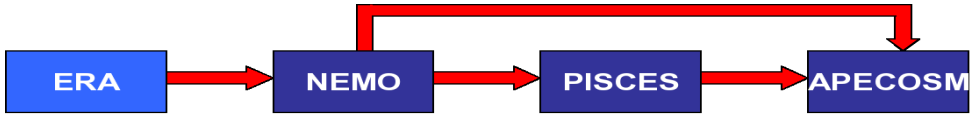


Marine ressources and governance



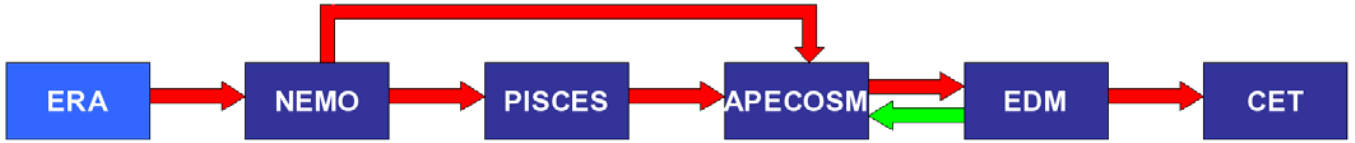


1) Simulate the past 50 years without fishing pressure



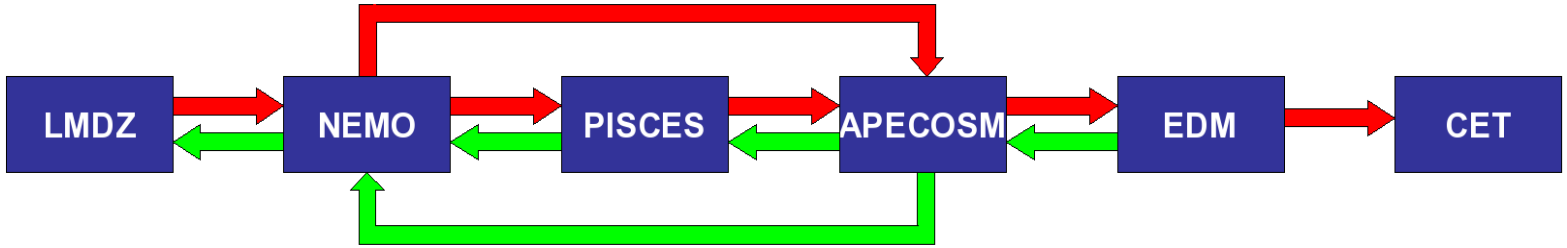
2) Simulate the past 50 years with fishing pressure

3) Simulate the past 50 years with fishing pressure and tuna market



Synthesis

- **Integrated dynamics along most probable CO2 and governance scenario(s)**



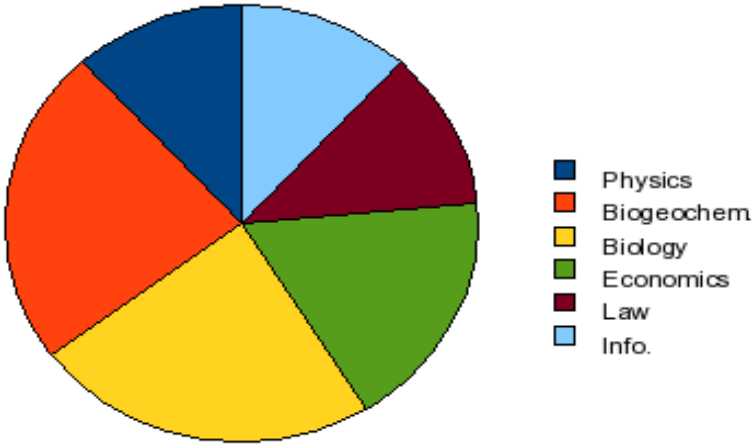
This last step should be more considered as a demonstration of the capabilities of the system

- **Definition of a Synthetic Indicator Panel**

  - Select appropriate indicators for monitoring and detecting unusual trends, tipping points or non reversible climate-related or fishing induced changes
  - Difficult task that will require the input from all participants
  - Input from CLIOTOP community ?

Macroes : The community

Academic fields



19 researchers+11 positions funded by MACROES

A total of 500 people.month

One of the biggest challenge of the project is to bring people from very different communities on a same project to create an interdisciplinarity community