Acoustic data assimilation for estimating energy transfert parameters of a micronekton model

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Micronektonic organisms

- Smallest organisms able to swim
- Size range : 3 to 30 cm

Figure: Cephalopods (*Histioteuthis sp.*)

Figure: Crustaceans (*Euphausia sp.*)

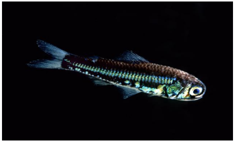


Figure: Small fish (*Myctophidae sp.*)

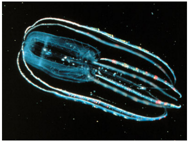


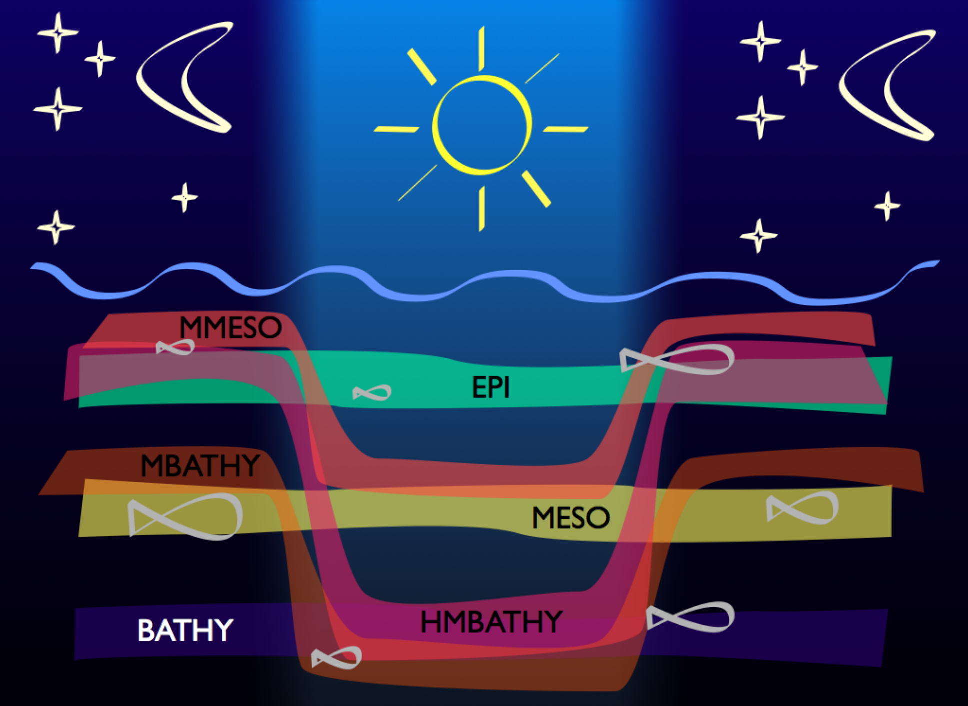
Figure: Cnidarian (*Bolinopsis sp.*)

Choice of these organisms

- **Key element of the food web** : between phytoplankton and top predator
- **Level of the food web less known** : phytoplankton globaly observed by ocean color satellites, predators mouvement study by satelitte tracking
- **Enormous global biomass** still not precisely known (from 10^9T to 10^{10}T, Irigoien 2014)
- Need of biomass fields to **study their predator** (heavily exploited or protected).

SEAPODYM Forage

- Model of **micronektonic biomass**
- **Eulerian framework**
- **Development times** function of **temperature** (growth is faster in warmer ecosystem)
- Idealised ocean with **3 vertical layers** (boundaries function of the eutrophic depth) and a **realist horizontal description** of the oceans
- Biomass divided into **functional groups** according to their diel vertical migration behaviour.


MMESO
EPI
MBATHY
MESO
BATHY
HMBATHY

Trophic chain and energy flux

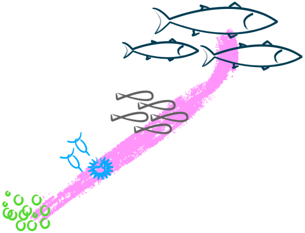


Figure: Simplified trophic chain with energy fluxes.

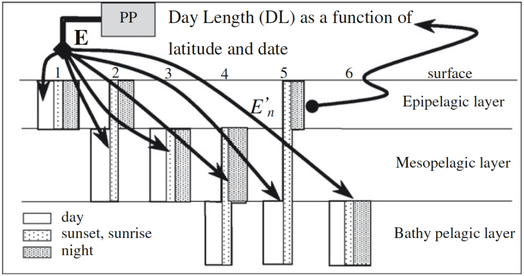
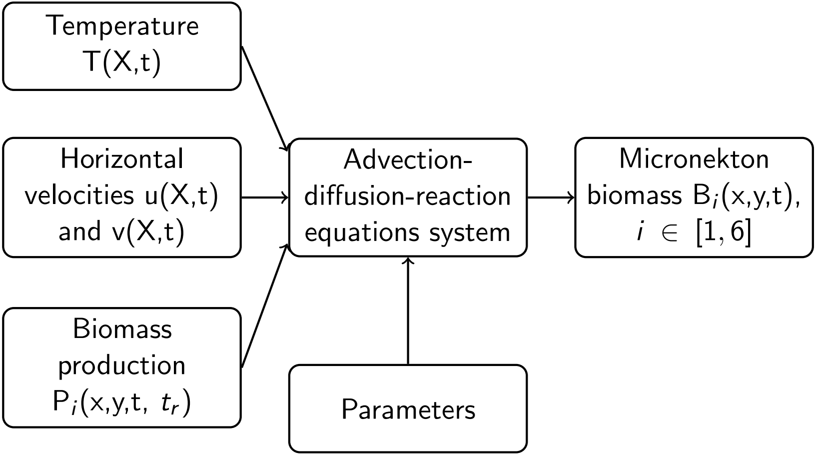


Figure: Schematic of energy transfert in the model. $\sum_{i=1}^{6} E_i' = 1$

Model diagram

X=(x,y,z)
τ : cohort age
i : functional group



Equations of the model

Equation of **biomass** B_i, i functional group (in $gWW.m^{-1}$)) :

$$\frac{\partial B_i}{\partial t} = D(\frac{\partial^2 B_i}{\partial x^2} + \frac{\partial^2 B_i}{\partial y^2}) - \frac{\partial}{\partial x}(\bar{u} B_i) - \frac{\partial}{\partial y}(\bar{v} B_i) \underbrace{-\lambda B_i}_{Mortality} + \overbrace{E'_i \, P_i(x, y, t, t_r)}^{Recruitment}$$

where $t_r(T(X,t))$, $\lambda(T(X,t))$, $(\bar{u},\bar{v})$ are velocities averaged over inhabited layers and $\sum_{i=1}^{6} E'_i = 1$.

Equation of **biomass production** $P_i(x, y, t, \tau)$, i functional group (in $gWW.m^{-1}.d^{-1}$) :

$$\frac{\partial P_i}{\partial t} = D(\frac{\partial^2 P_i}{\partial x^2} + \frac{\partial^2 P_i}{\partial y^2}) - \frac{\partial}{\partial x}(\bar{u} P_i) - \frac{\partial}{\partial y}(\bar{v} P_i) - \frac{\partial P_i}{\partial \tau}$$

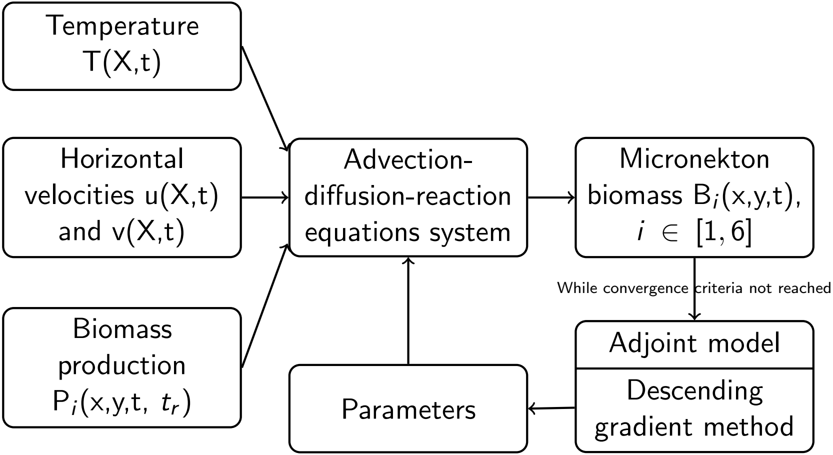
with the initial condition $P_i(t, \tau = 0, x, y) = c\, E\, PP(t, x, y)$ and Neumann boundary condition.

Estimation of energy coefficients E_i'

X=(x,y,z)

τ : cohort age

i : functional group



Data used

38kHz bio-acoustic density (NASC)

- Data acquisition possible **during day and night**.
- **Good coverage** of the global ocean (data available in the four major oceanic bassins).
- Not invasive.
- **High-resolution data** from subsurface to range depth (function of the frequency, 800 to 1200 m for 38kHz).
- **BUT** some organisms are still undetectable to active acoustic devices (swim bladder issues).

Data used

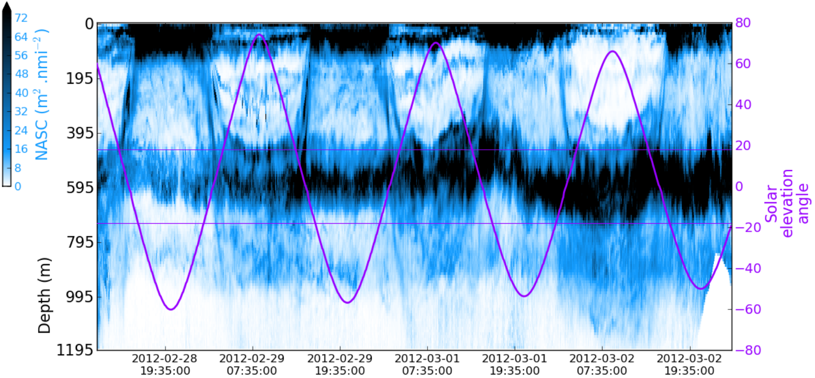


Figure: Bio-acoustics density transect. From Mauritus Island toward the Austral Ocean, March 2012.

Observation and prediction operators

To avoid inter calibration and unit conversion issues : use of ratios of biomass

$$\rho^{obs}_{\Omega,n}(x,y,t) = \left\langle \frac{\int_{Z_n^{down}}^{Z_n^{up}} NASC(x(t),y(t),z,t)dz}{\int_{Z_3^{down}}^{Z_1^{up}} NASC(x(t),y(t),z,t)dz} \right\rangle_{x,y,t}$$

$$\rho^{pred}_{\Omega,n}(x,y,t) = \frac{\sum_{i,N(i,\Omega)=n} \langle B_i(x,y,t)\rangle_{x,y,t}}{\sum_{i=1}^{6} \langle B_i(x,y,t)\rangle_{x,y,t}}$$

where $N(i,\Omega)$ is the layer inhabited by the group i during the period Ω.

Negative log-likelihood function

Observed ratios follow a log-normal distribution.
N_{obs} : nombre d'observations

$$L^- = \overbrace{N_{obs}\left[\left(\sum_{i=1}^{6} E_i'\right) - 1\right]^2}^{\text{Regularisation term}} + \frac{1}{2}\sum_{n=1}^{3}\sum_{k=1}^{N_{obs}}\Big(ln(\rho^{obs}_{\Omega,n}(X_k, Y_k, T_k)) - ln(\rho^{pred}_{\Omega,n}(X_k, Y_k, T_k))\Big)^2$$

E_i' Spatial variation

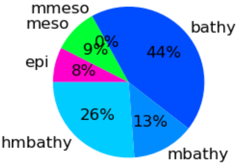


Figure: Global

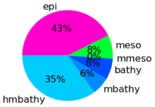


Figure: Pacific

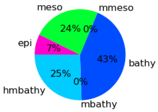


Figure: North Atlantic

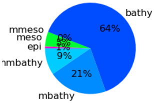


Figure: Tazmania

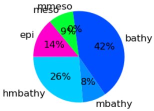


Figure: South Indian

E_i' optimised values in various basin scale
Observations separated by bassin scale

E'_i Interannual variation

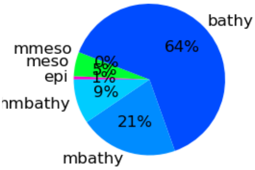


Figure: Tasmania

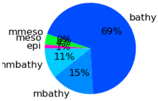


Figure: 2009

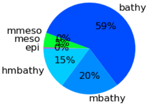


Figure: 2010

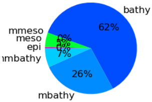


Figure: 2011

E'_i optimised values
Observations in the same area (Tasmanian Sea), during the same season (Winter), for different years

E_i' Seasonal variation

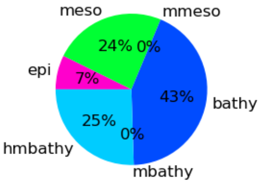


Figure: North Atlantic

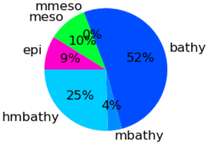


Figure: Winter

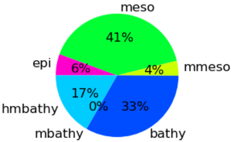


Figure: Summer

E_i' optimised values
Observations in the same exact position (mooring), during different season

Questions raised by the results

This coefficient was thought to be universal among all the seasons and the type of ecosystem. Probable causes :

- Issue in the modelisation temperature related process : parametrisation of time development

$$\lambda = \lambda^0 exp(t_{curv} T)$$

$$t_r = t_r^0 exp(t_{curv} T)$$

- Issue in the definition of vertical layer boundaries : euphotic depth, thermocline, pycnocline...

Future work

Sensibility analysis w.r.t

- **Parameter** : Controled and non-controled
- **Forcing fields** : primary production, temperature, velocities
- **Definition of layers boundaries** : euphotic depth, thermocline, pycnocline...

Modelisation of observation errors.