Prédire les risques de contamination des prédateurs du micronecton par ^{137}Cs après Fukushima

Couplage de modèle d'écosystème et équation radio-écologique

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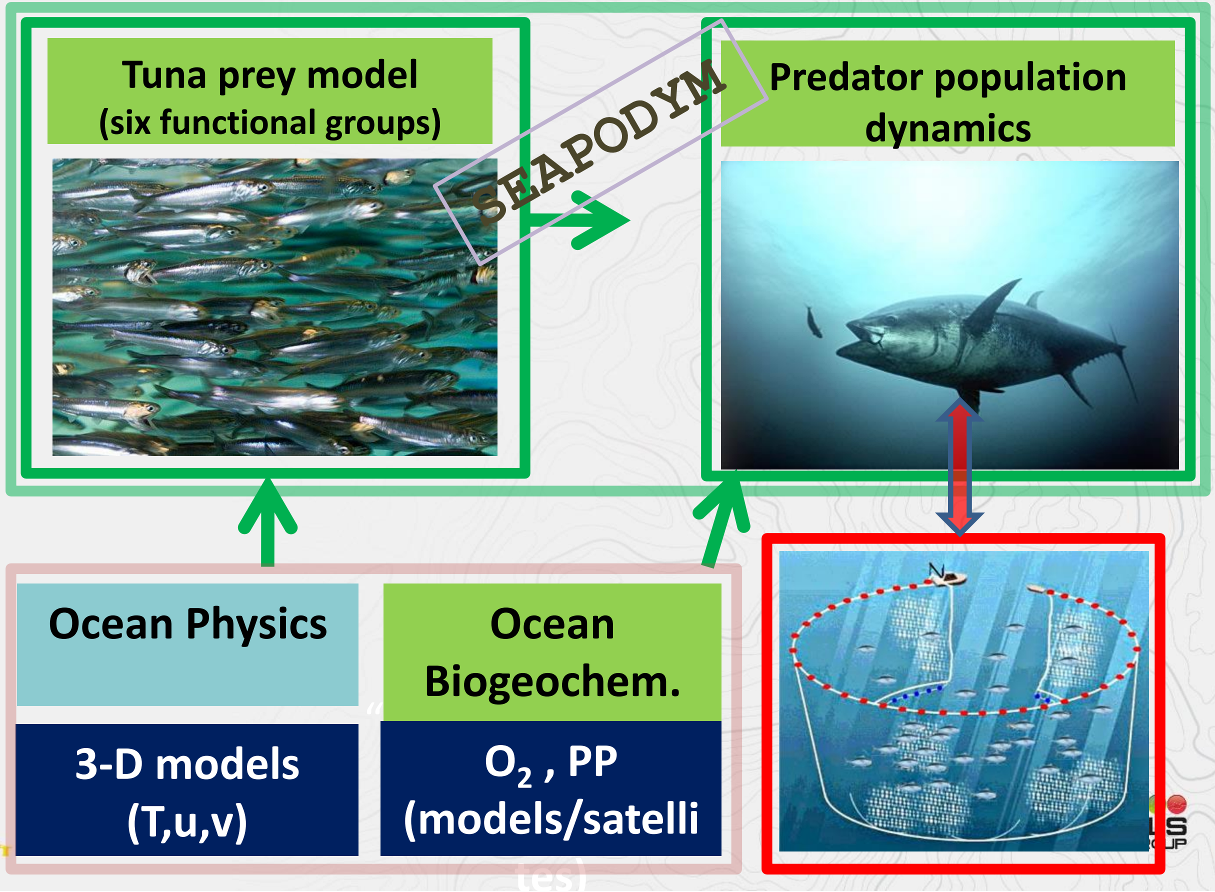
Modèle d'Ecosystème

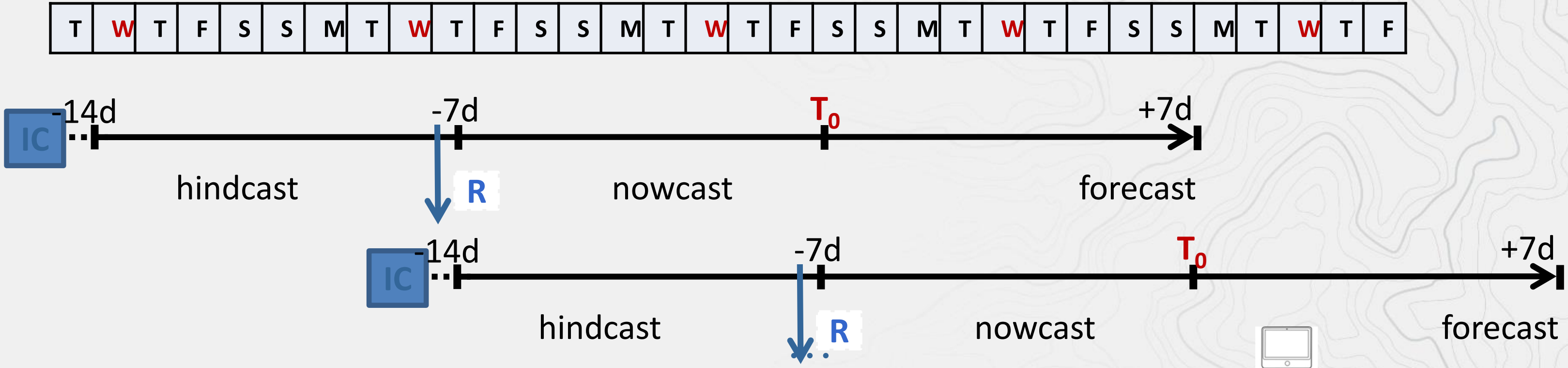
- Resolves the dynamics in 4 dimensions:
  1) age
  2) time
  3-4) 2d-space (within three pelagic layers defined by euphotic depth)

- Based on advection-diffusion-reaction equations with ageing term

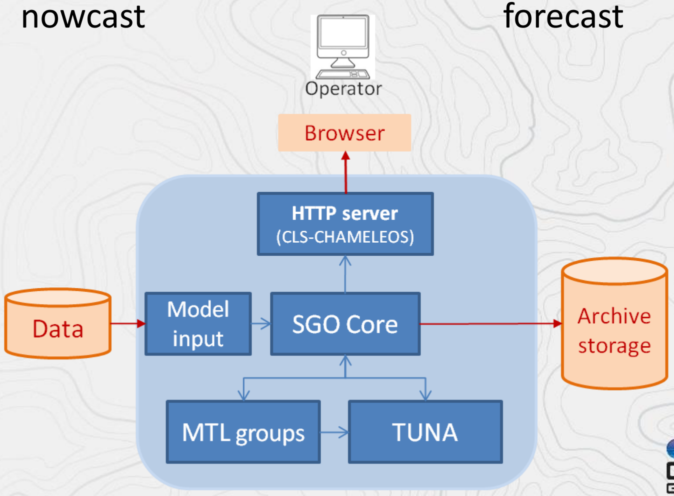
- Includes parameter estimation approach



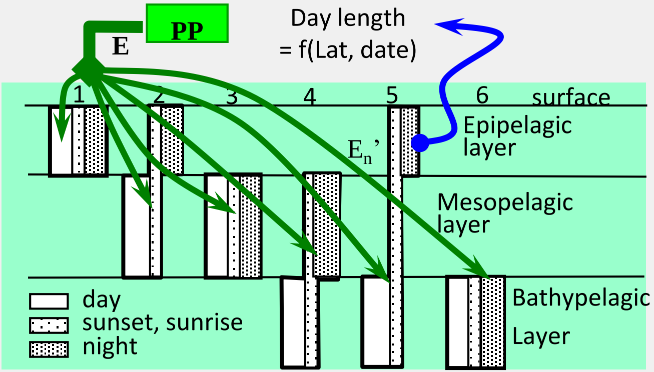
Modèle opérationnel



- Physical fields provided by MERCATOR operation model PSY3V3 (http://www.mercator-ocean.fr/)
- Biogeochemical data (primary production and euphotic depth) derived from satellite ocean color data with VGPM model (Berenheld & Falkovski, 1999; Morel et al,. 1989). CLS product.

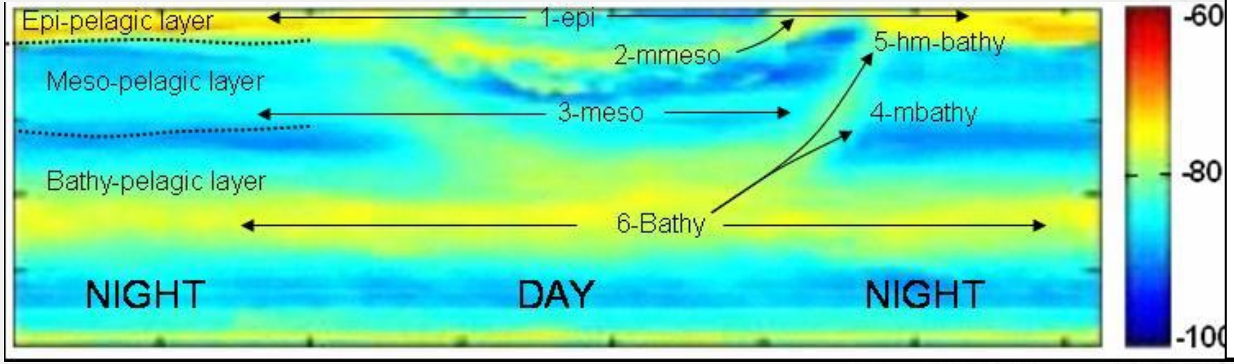


Groupes fonctionnels



Size: 2-20cm

Mar-ECO station North Atlantic, (IMR, Bergen Norway) showing acoustic detection of micronekton:



A model of micronekton
(small prey organisms)

The MODEL: 6 functional groups in 3 vertical layers. Three components exhibit diel vertical migrations, transferring energy from surface to deep layers.

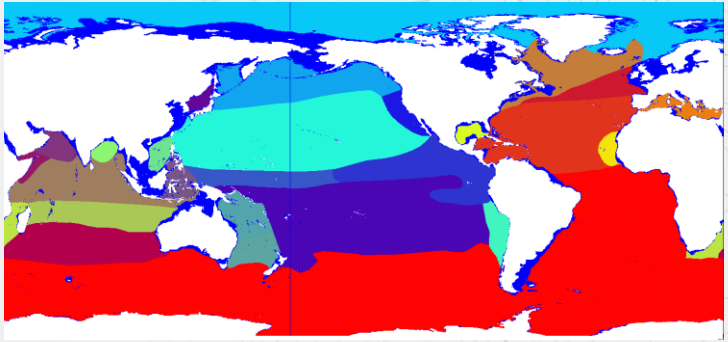
TL = 2.5

The source of energy is the primary production PP.

Equations du modèle SEAPODYM

1- $F'_n(t, a=0, x, y) = c\, E_n^{TL} P(t, x, y)$

2- $\dfrac{\partial F'_n}{\partial t} + \dfrac{\partial F'_n}{\partial a} = D\left(\dfrac{\partial^2 F'_n}{\partial x^2} + \dfrac{\partial^2 F'_n}{\partial y^2}\right) - \dfrac{\partial}{\partial x}(\hat{u}F'_n) - \dfrac{\partial}{\partial y}(\hat{v}F'_n),$



Eco-regions: Sutton et al., 2017

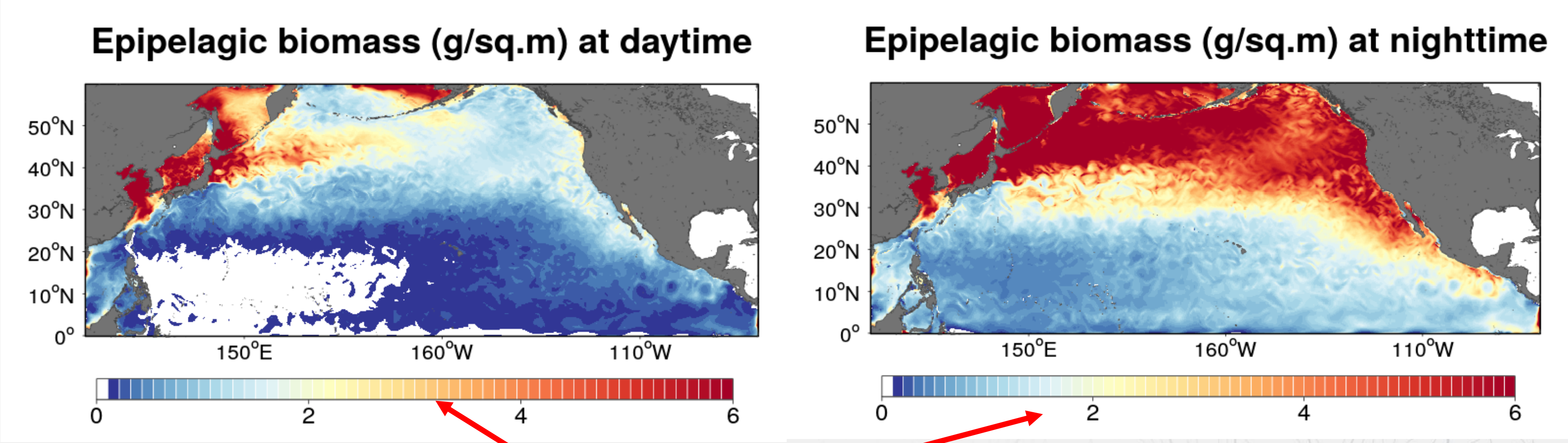
3- $\dfrac{\partial F_n}{\partial t} = D\left(\dfrac{\partial^2 F_n}{\partial x^2} + \dfrac{\partial^2 F_n}{\partial y^2}\right) - \dfrac{\partial}{\partial x}(\hat{u}F_n) - \dfrac{\partial}{\partial y}(\hat{v}F_n) - \lambda F_n + S_{n,\tau_r}$

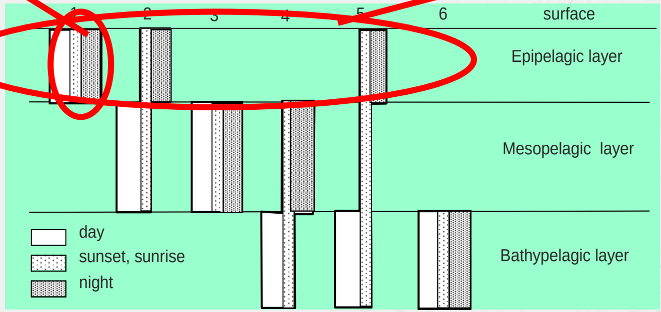
$$S_{n,\tau_r} = \int_{\tau_r}^{a_{max}} F'_n(t, a, x, y)\, da \qquad tr = tr_{max} \cdot f(T)$$

$$\lambda = \frac{e^{\alpha T}}{t_{max}}, \quad \alpha > 0$$

tr_{max} = 60 (days) for zooplankton
tr_{max} = 527 (days) for micronekton

Prédictions du modèle





Couplage avec l’équation de Thomann

Spatial dynamics of ^{137}Cs in biomass

1- Contaminated source: $S_n(t,a=0,x,y) = \left(c\,E_n^{TL}P\right)\cdot Cs_p$

2- Spatial dynamics of $S(t,a,x,y)$, $a<amax(x,y)$

3- Recruitment to contaminated micronekton

$$R_{n_r} = \int_{\tau_r}^{a_{\max}} S_n\left(t,a,x,y\right)da$$

4- Spatial dynamics of contaminated micronekton

Radio-ecology

$$Cs_p = CF_{eq}\cdot Cs_w$$

$$\forall t_k, a, n \quad A_S = S_{t_k ij}/F'_{t_k ij}$$

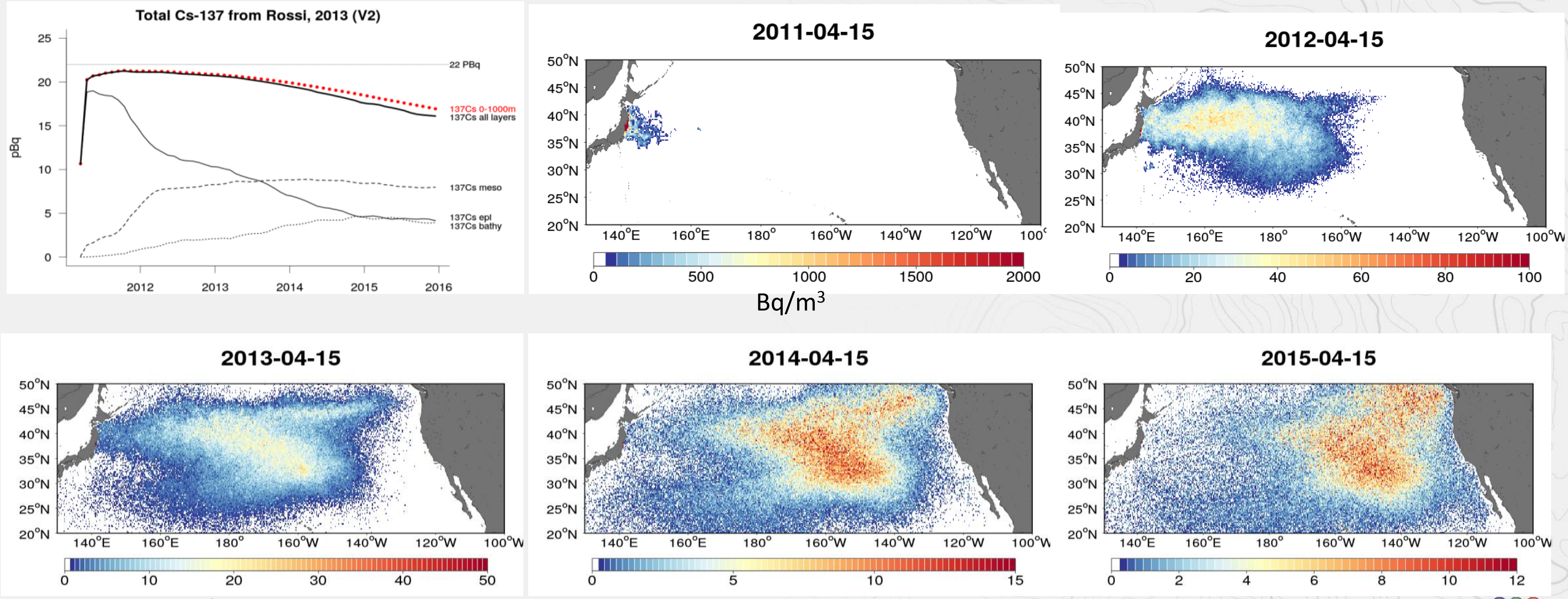
$$\frac{dA_S}{dt} = k_{uS}Cs_w + AE\cdot IR_{pS}Cs_p - k_{ddS}A$$

$$\forall t, n \quad A_F = C_F/F$$

$$\frac{dA_F}{dt} = k_u Cs_w + AE\left(IR_p Cs_p + IR_z Cs_z\right) - k_{dd}A_F$$

Source: Concentration de ^{137}Cs dans l'eau

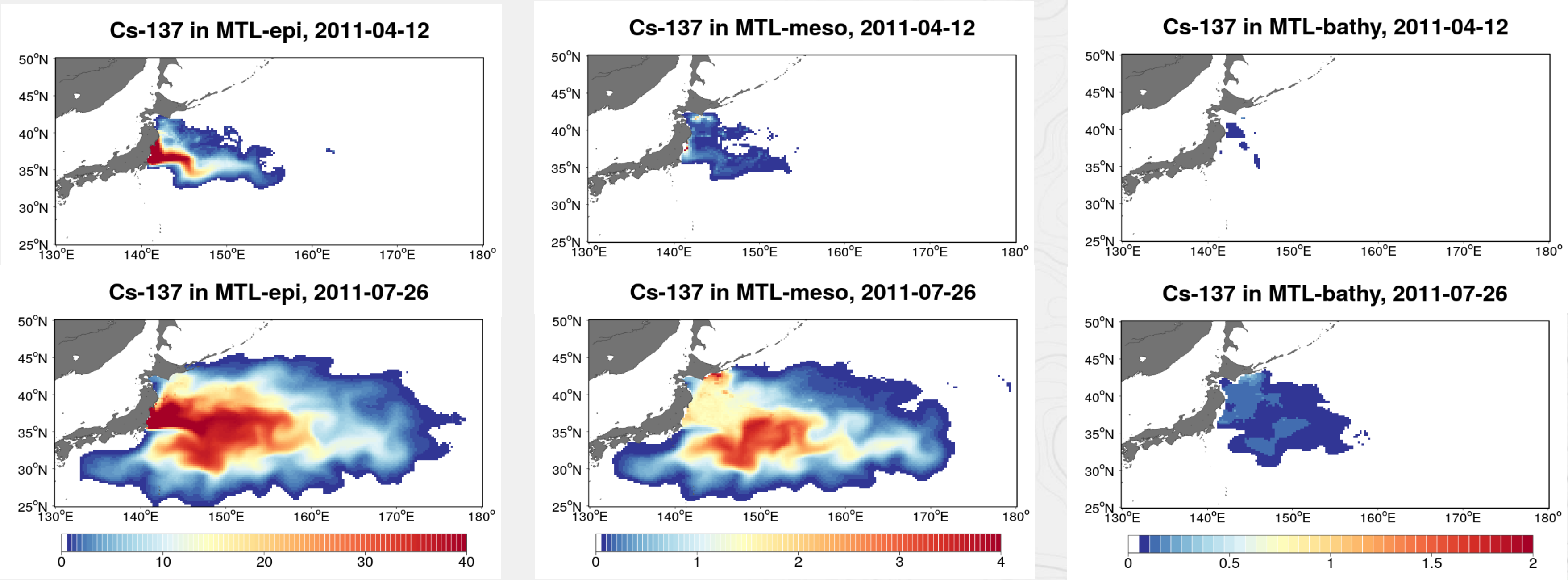
^{137}Cs in water (Rossi et al., 2013)



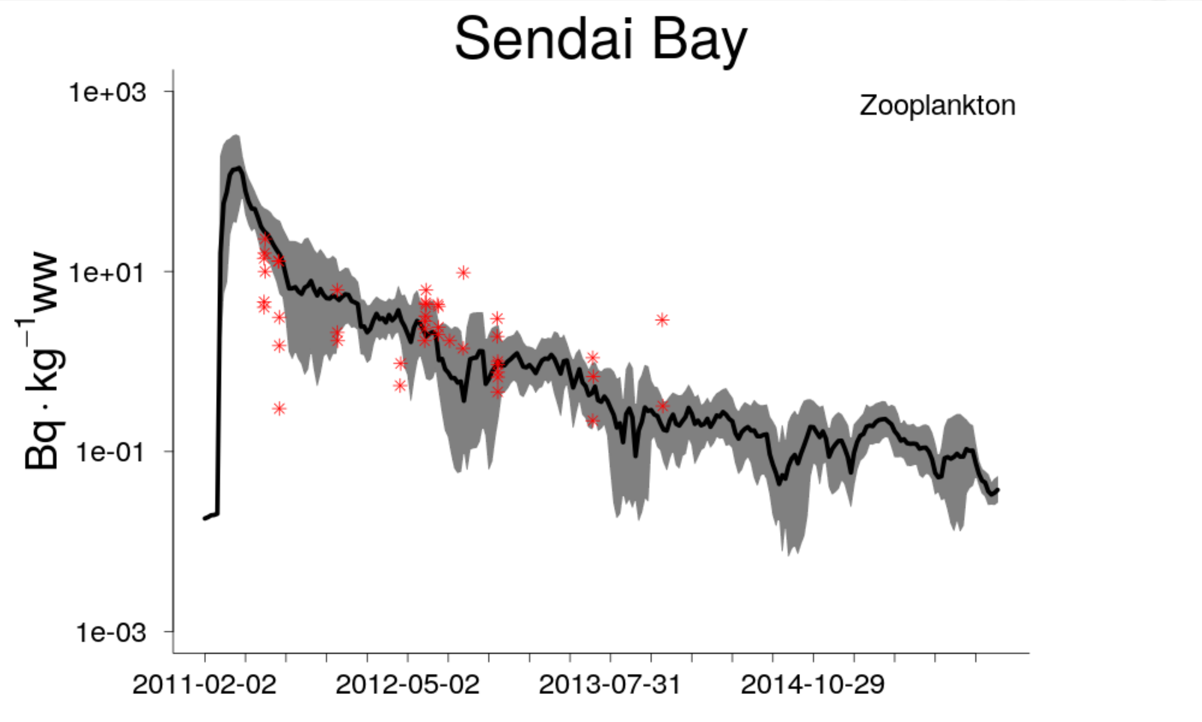
Predictions: ^{137}Cs dans micronecton

^{137}Cs activity (Bq/kg) in micronekton groups:

Epipelagic | Mesopelagic | Bathypelagic



Validation: ^{137}Cs dans zooplancton



Field data:
Kitamura et al., 2013
Credit: M. Belharet

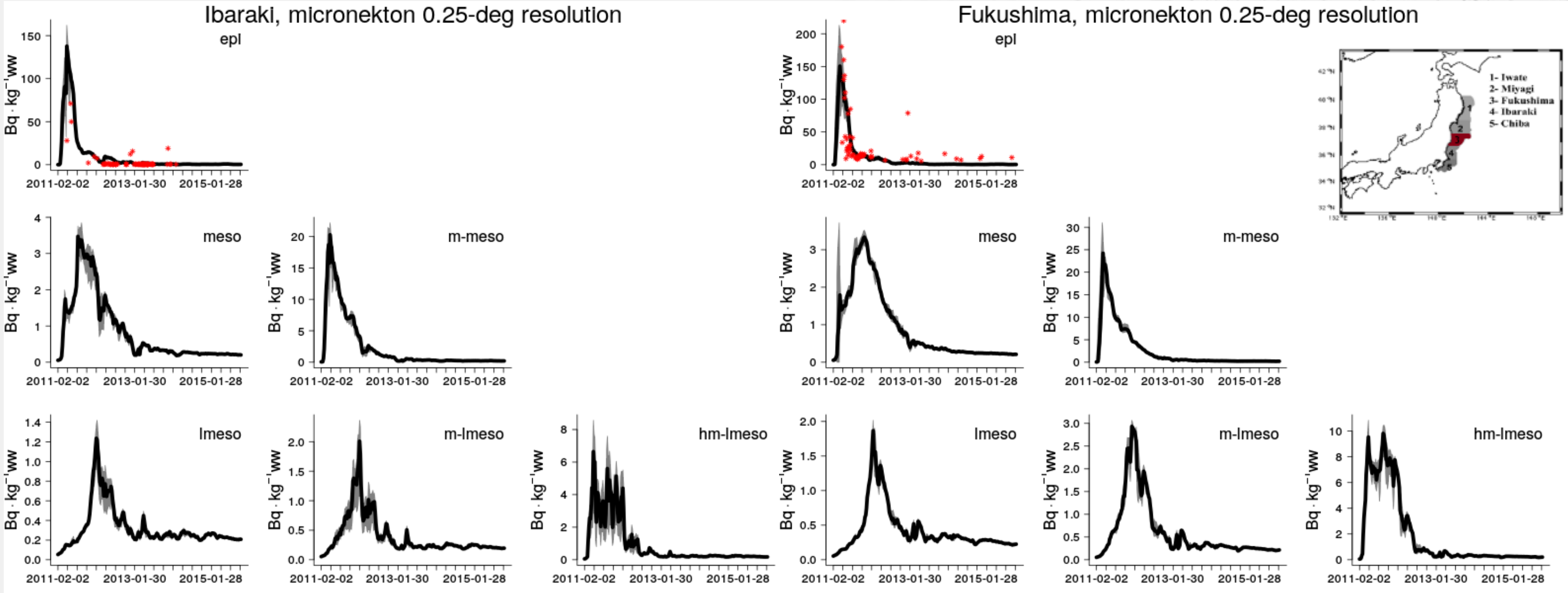
* : observations

Solid line : median of predicted ^{137}Cs activity in zooplankton

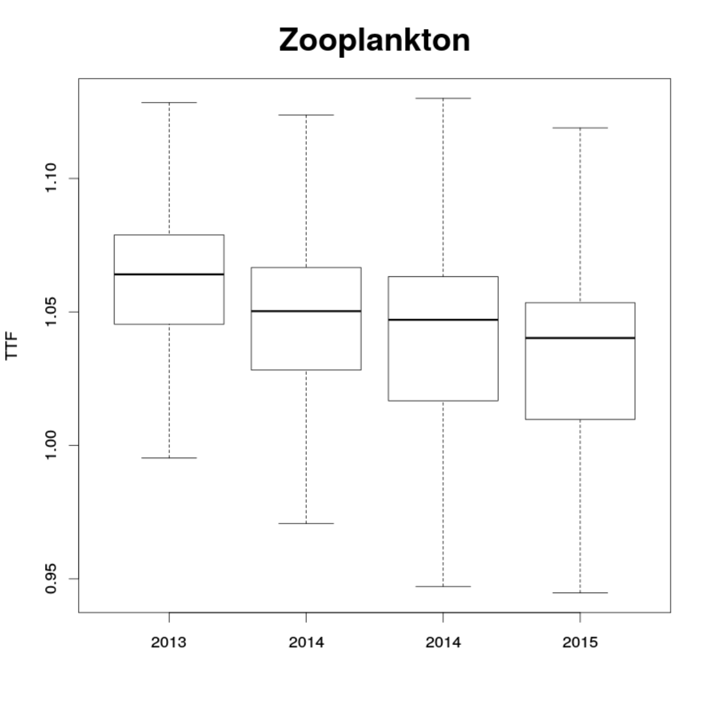
Grey area : $\mu \pm \sigma$

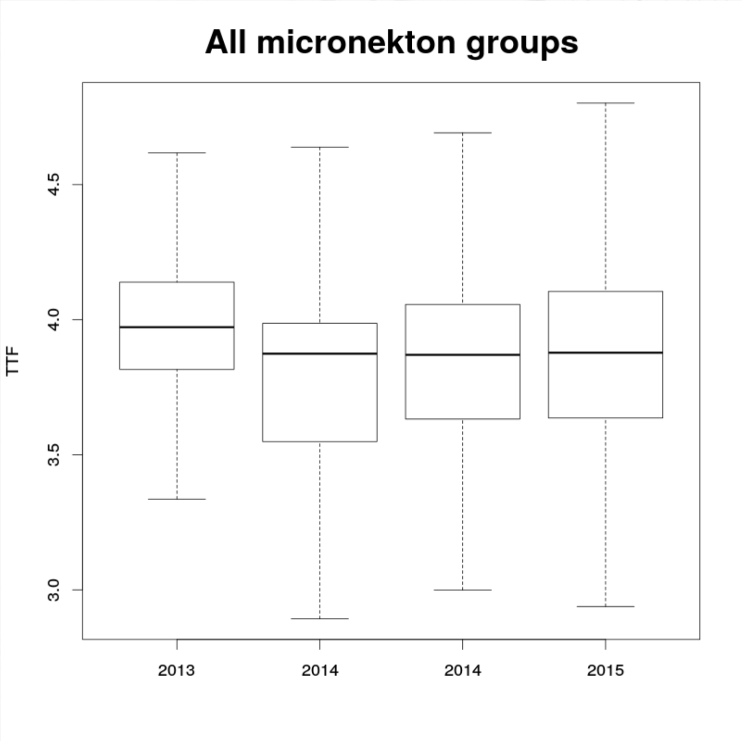
Validation: ^{137}Cs dans micronecton

Predictions for six functional groups: longer time of development -> later contamination



Validation: facteurs de transfert trophique

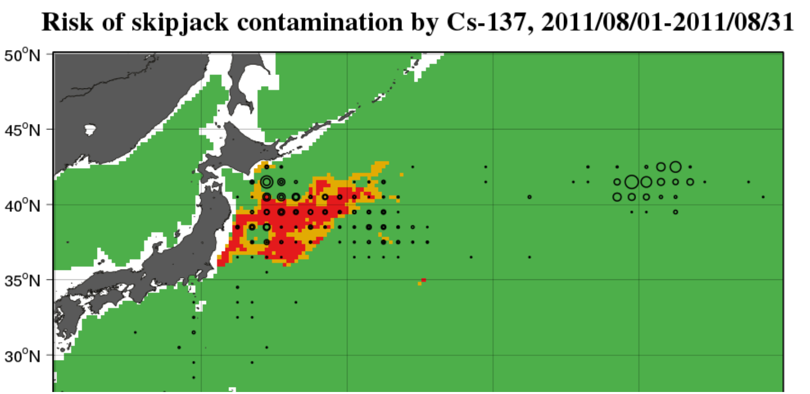


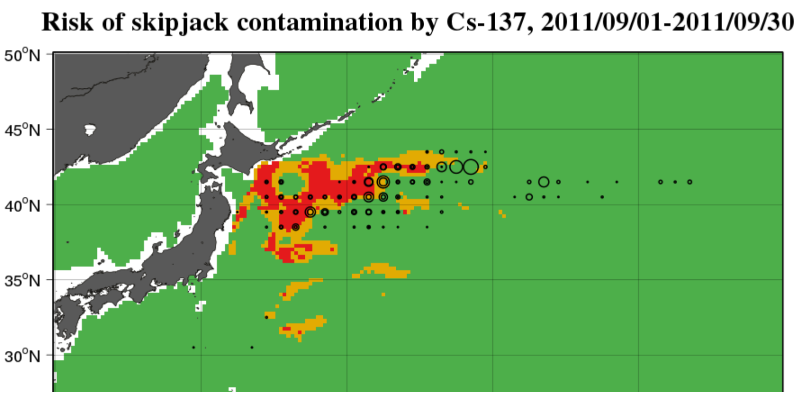


Cartes de risque = l'habitat contaminé

Cs-137 concentrations -> habitat modeling approach -> indicators of contamination for top predator species.

$$I_a = \mathbf{\Theta}_a \times \left(\tau\,\mathbf{Ce} + (1-\tau)\,\mathbf{C}^{\mathrm{T}}\mathbf{e}\right) \qquad \mathbf{C} = \begin{array}{c} \begin{pmatrix} C_{11} & 0 & 0 \\ C_{21} & C_{22} & 0 \\ C_{31} & C_{32} & C_{33} \end{pmatrix} \end{array}\begin{array}{l} \text{epi} \\ \text{meso} \\ \text{lmeso} \end{array} \qquad \Theta_{a,l} = f\left(O_{2l};\boldsymbol{\theta}_{O_2}\right)\cdot g\left(T_l;\boldsymbol{\theta}_{T,a}\right)$$





Ex.: *Contamination index computed for skipjack tuna in September 2011 (red = high risk; orange = medium risk; green = no risk). The circles show the distribution of skipjack catches in September 2010 (the catch data for Sep 2011 were not available).*

Conclusions

- Modeling: phytoplankton, zooplanktoon , micronekton and tuna habitat
- Parameterization: assimilation from water, elimination and ingestion rates
- Preliminary validation from data: Yutaka Tateda and Mokrane Belharet (Kitamura et al., 2013)
- Preliminary validation from known ratios: TTF et CF
- Future plans: further work on model validation and uncertainty estimation
  (sensitivity analysis), publication (I quarter of 2018);
  high resolution simulations (?), operational model (end of 2019)

MERCI POUR VOTRE ATTENTION!

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