APECOSM (A*pex* P*redators* ECOS*ystem* M*odel*)

Quick overview and application to scenarios development

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Introduction

- Global changes are pushing oceans' ecosystems toward unknown states with no-analogues in the past.

- This creates an urgent need for
  - *Anticipating future threats and opportunities.*
  - *Elaborating mitigation and adaptation strategies,*
  - *Factoring long-term issues into present day governance.*

- We lack a robust theory that would keep valid beyond observed states with minimal stationarity assumptions

- APECOSM seeks for a mechanistic theory based on first principles to formalize ecosystem dynamics
  - *Understand, interpret and generalize observations,*
  - *Guide and stimulate empirical studies,*
  - *Provide sound basis to applications: conservation, resource management, scenarios & projections.*

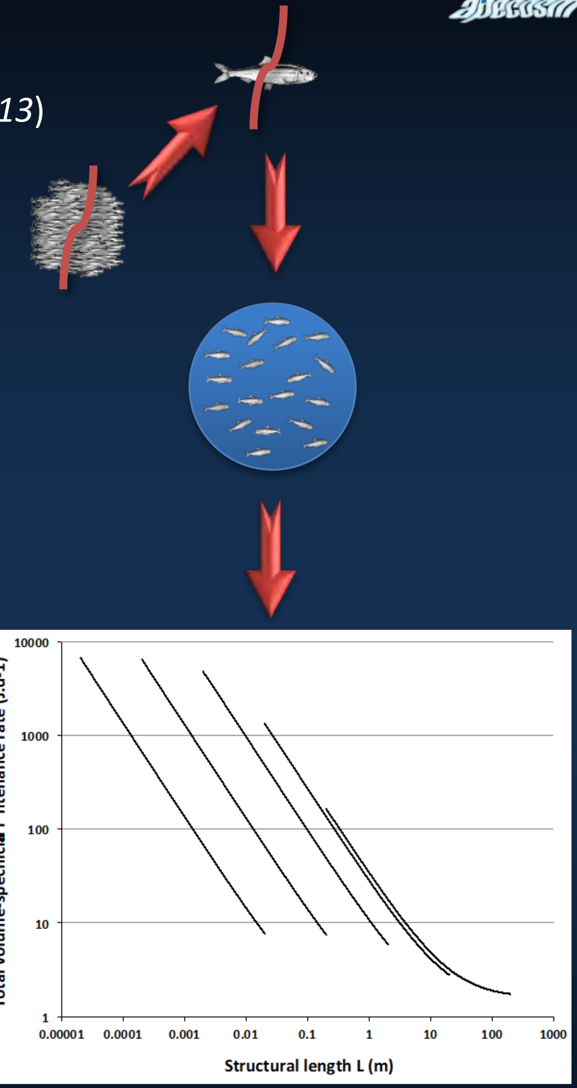
  Conceive and think the complexity of ecosystems' dynamics and evolution

APECOSM: integration of individual / population / community levels

- Formulate individual dynamics from invariant properties,
  - Predation, metabolism (DEB) (*Maury et al., 2007; Maury et Poggiale, 2013*)
  - Behaviour: 3D movements (*Faugeras et Maury, 2007*)
  - Effects of schools dynamics (*Maury, 2017*)

- Upscale the individual model to population level
  - Population dynamics based on individual processes (*Maury, 2010*)
  - Eulerian state equation
  - Individual flux through a 7D state-space

- Upscale the population model to the community level
  - Considers the functional importance of species' size and individuals' size (*Maury et al., in press*)



APECOSM: integration of individual / population / community levels

➥ Formulate individual dynamics from invariant properties,

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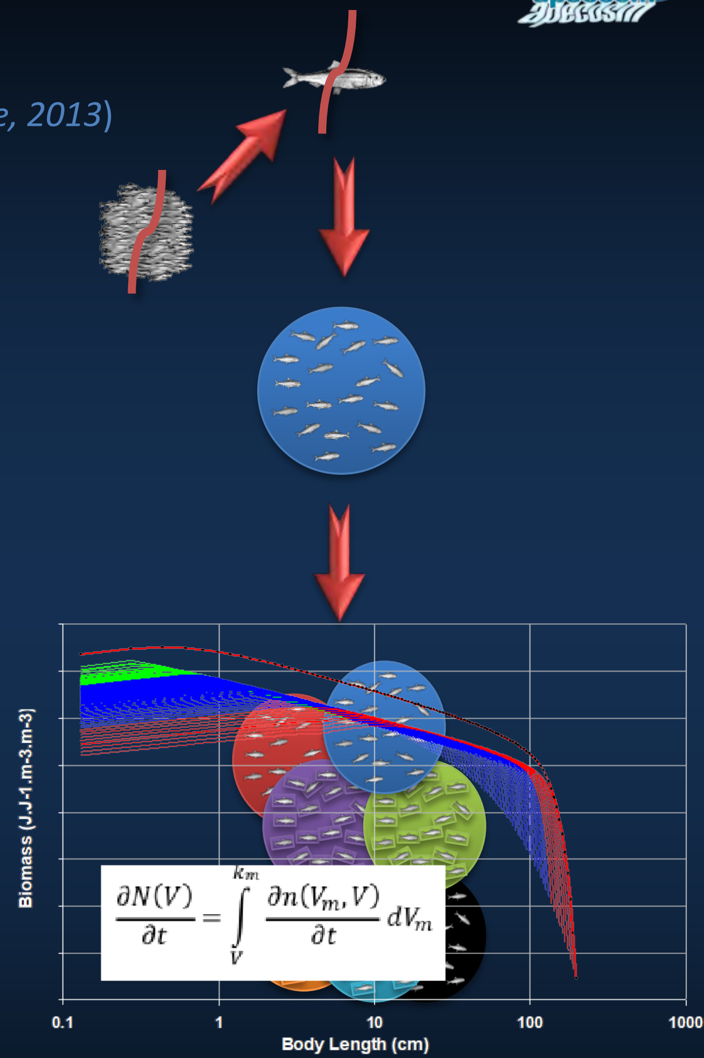
➥ Upscale the population model to the community level

- Considers the functional importance of species' size and individuals' size (*Maury et al., in press*)
- Trait-based approach (*Maury et Poggiale, 2013*)
- Eulerian 4D state equation (*Guiet, 2016*)



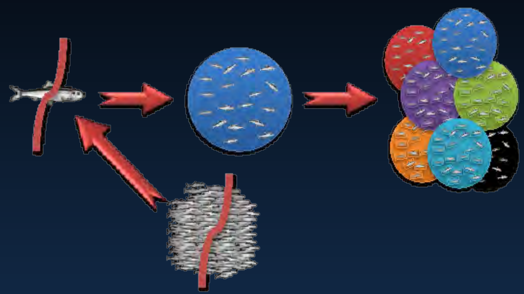
◎ Consistency between organization levels

◎ Inter-dependence of the state equations at each level of organization

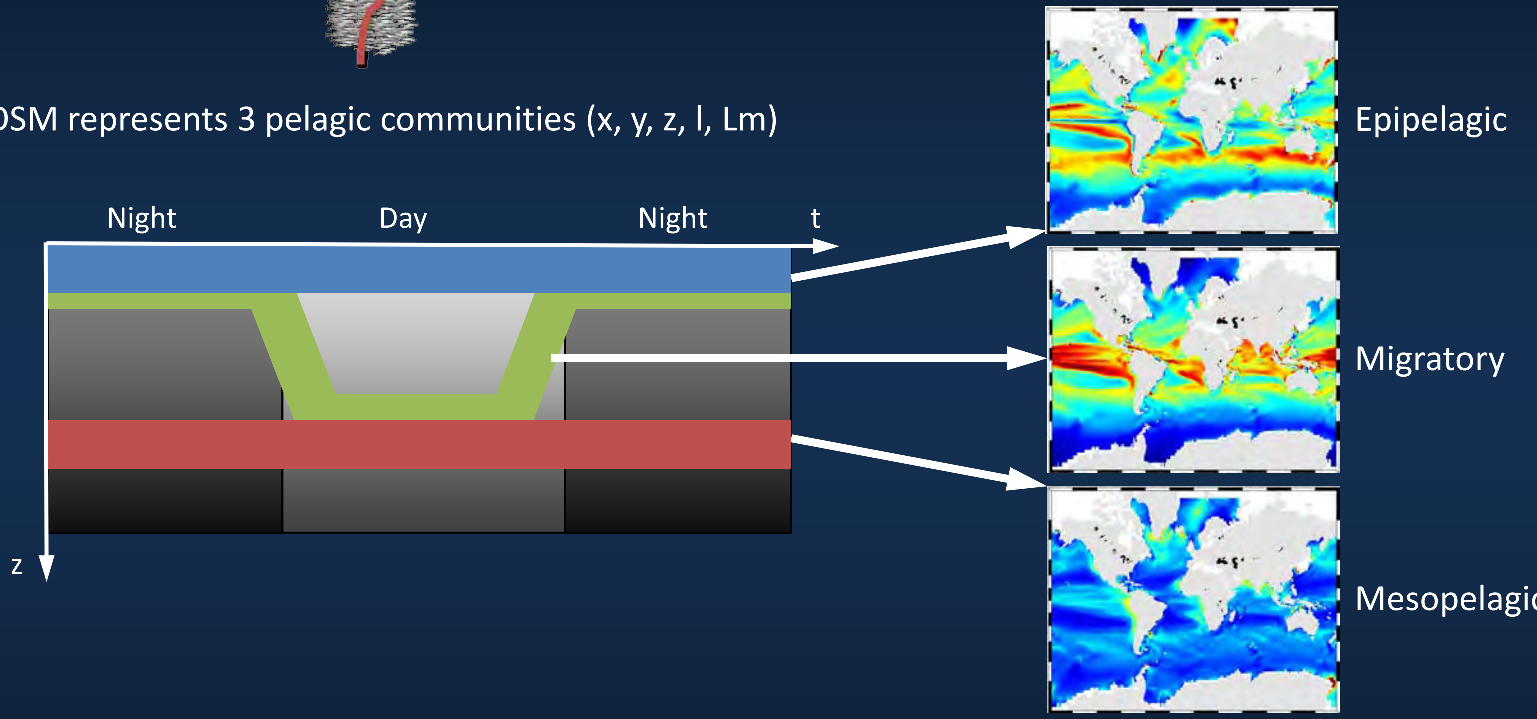
◎ Individuals, populations & communities share the same parameters

APECOSM, an E2E model of marine ecosystems

- Mechanistic model articulating individual, population and community levels



- APECOSM represents 3 pelagic communities (x, y, z, l, Lm)



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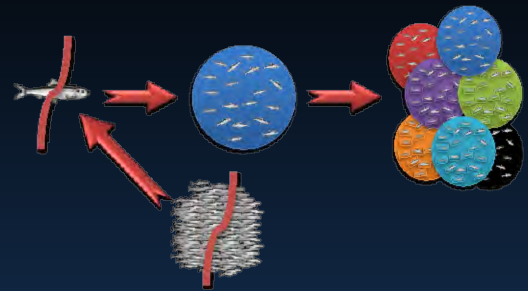

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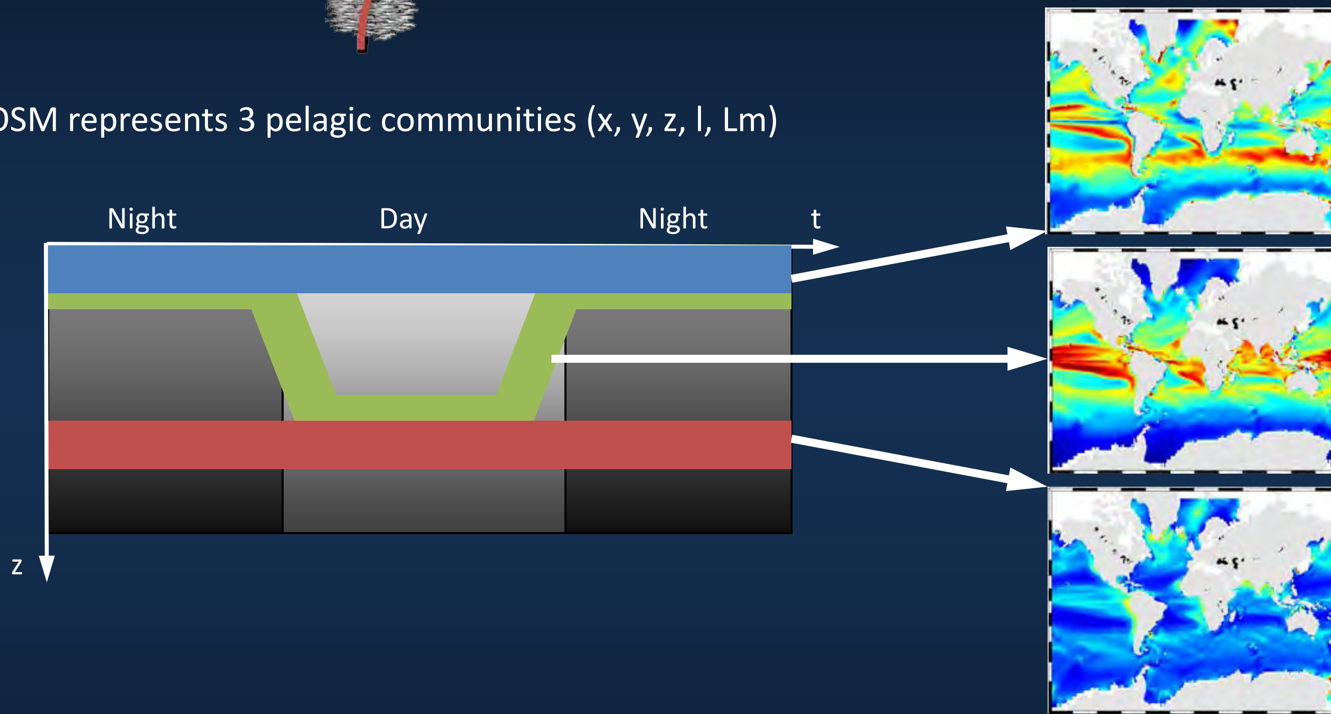
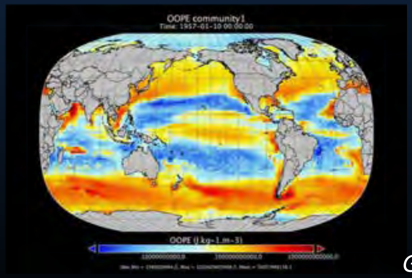


Epipelagic

Migratory

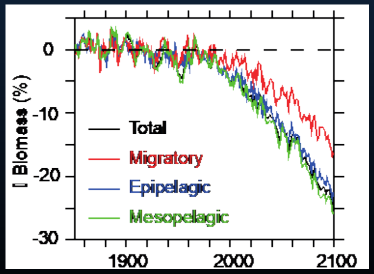
Mesopelagic

- For studying processes



Guiet et al., 2016

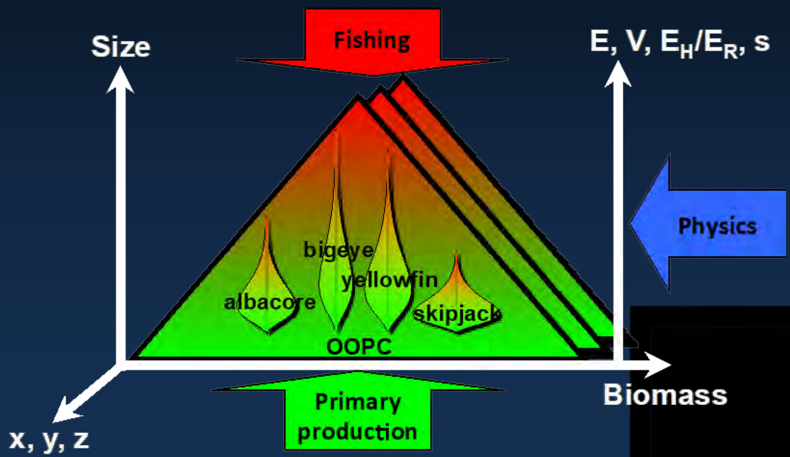
- For projections and scenarios



Lefort et al, 2015

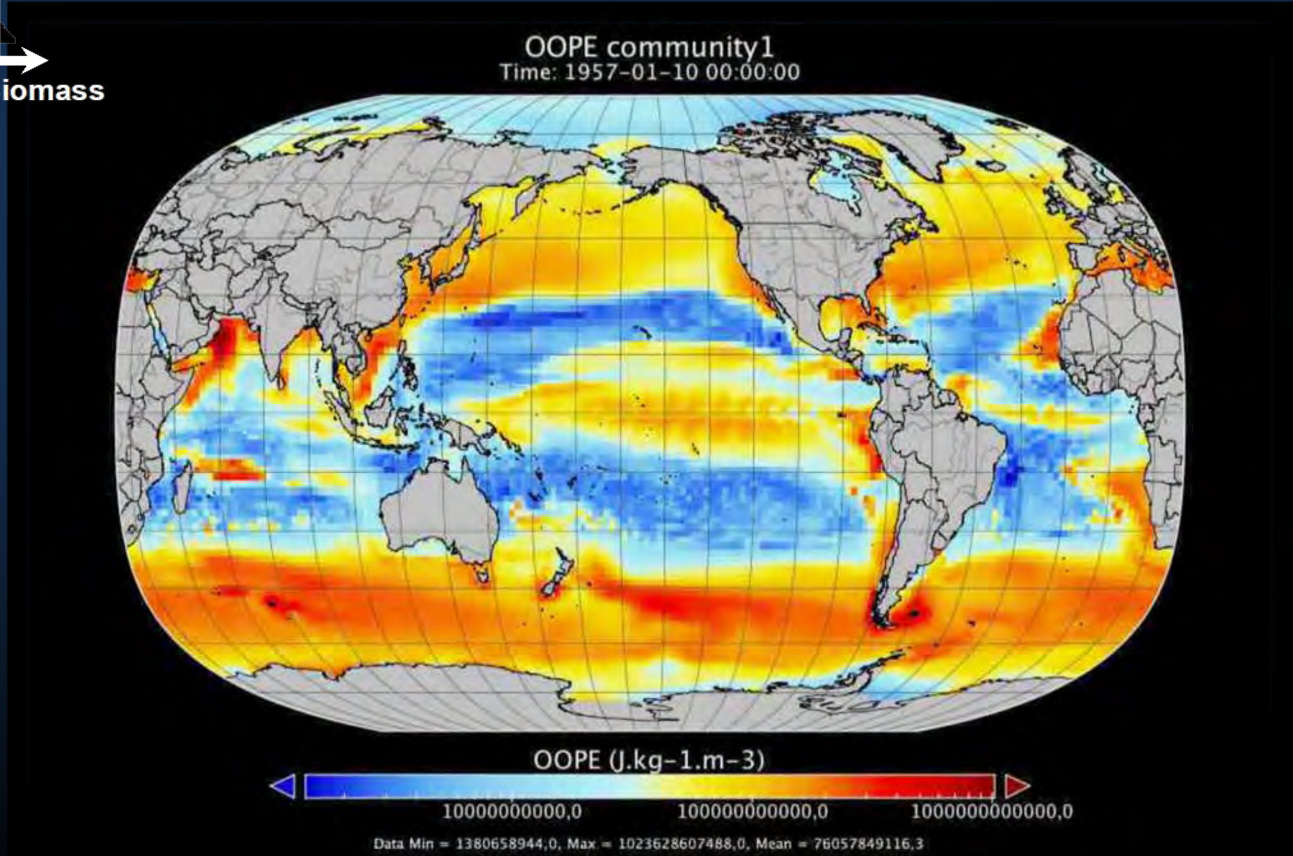
APECOSM simulates marine ecosystems

- Articulates species and communities



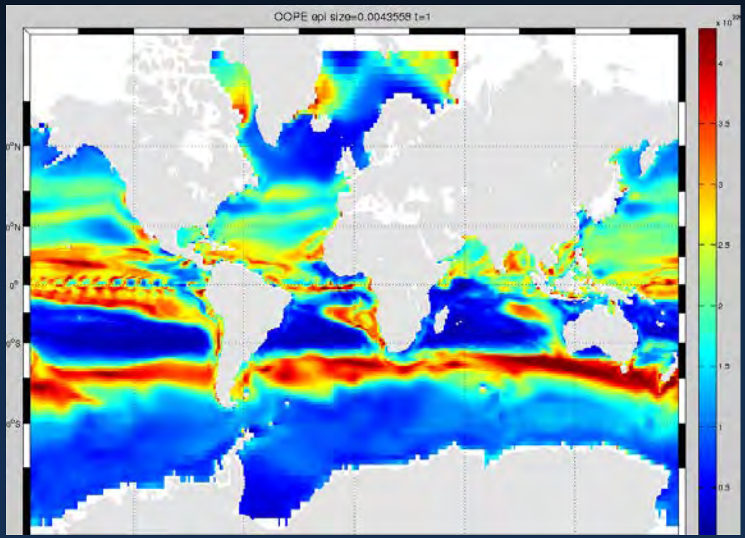
- global horizontal grid ORCA2 (x=180 y=148 z=46)
- size V=100 size classes [1mm, 2m]
- 3 generic communities

=> 6,66.10^8 grid points; 2 time steps / day

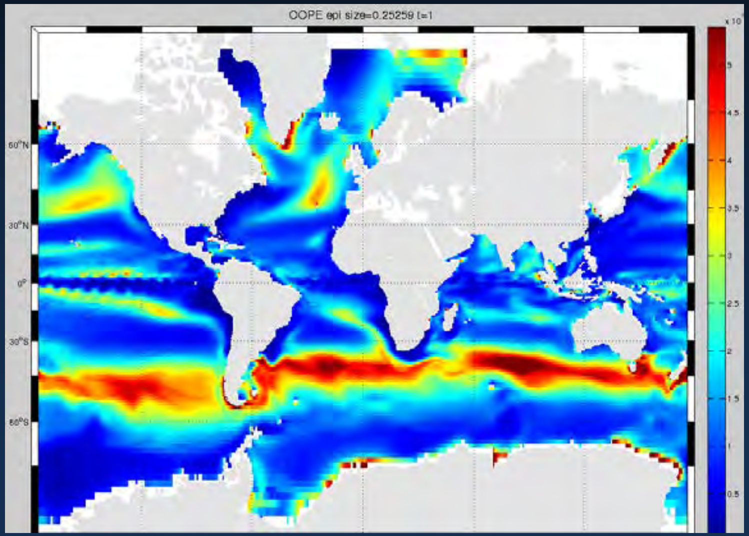


Communities in APECOSM: 5D numerical grid

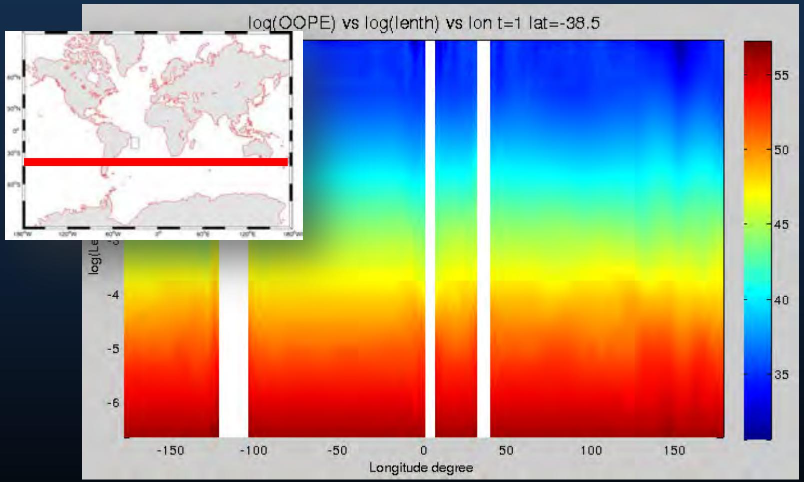
Epipelagic 4mm



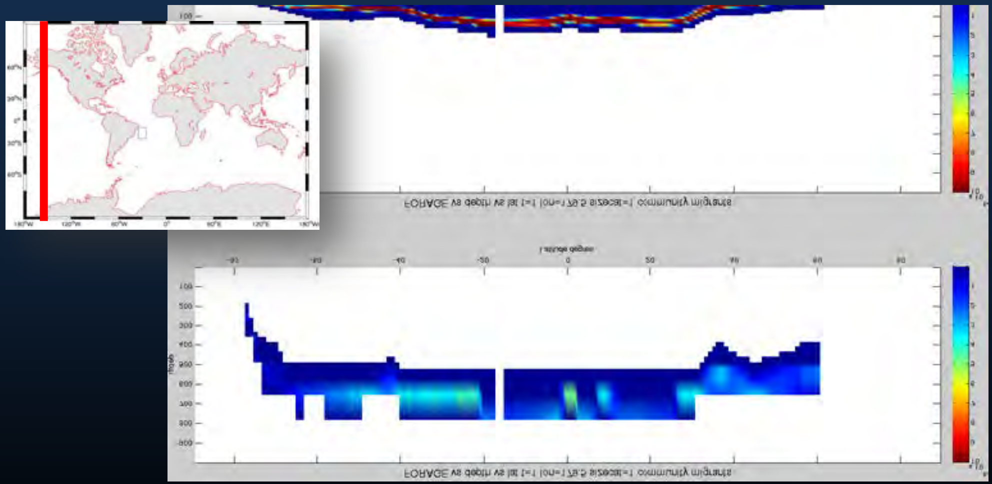
Epipelagic 25cm



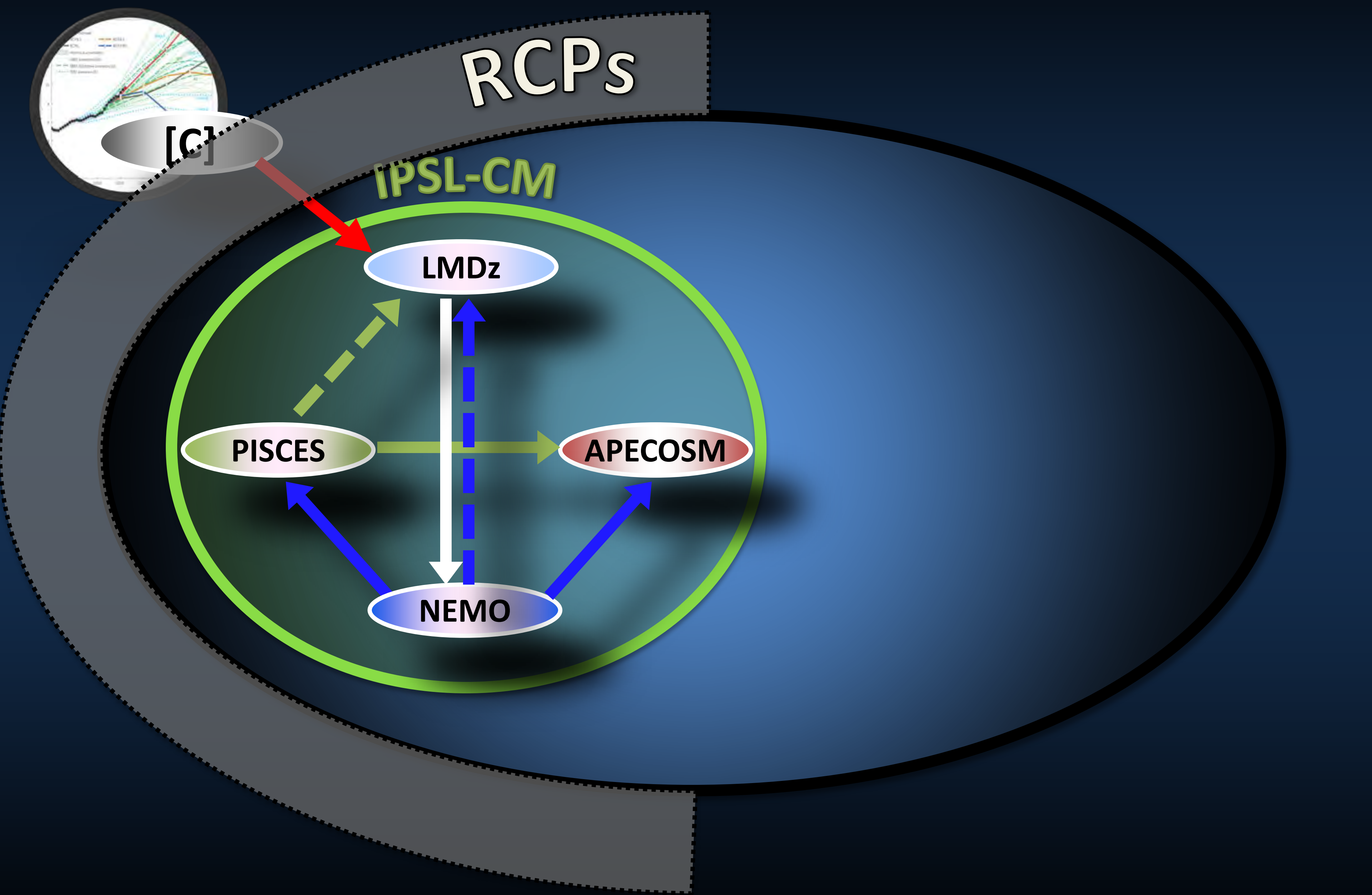
Size $V^{1/3}$



Depth z



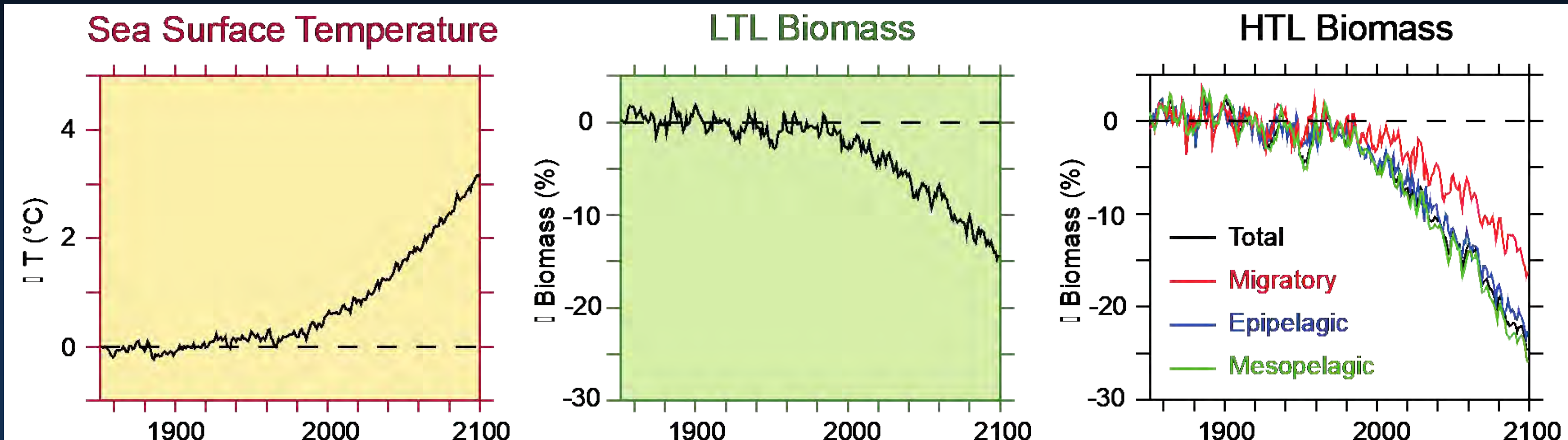
APECOSM is coupled to the IPSL Earth System Model



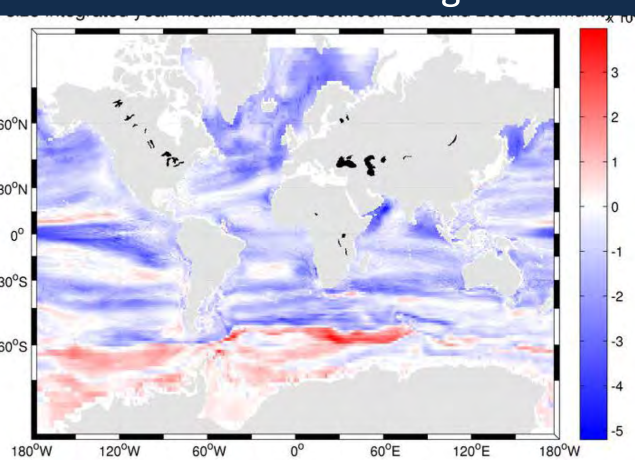
Projections:

Climate change impacts on global marine ecosystems (Lefort et al., 2015)

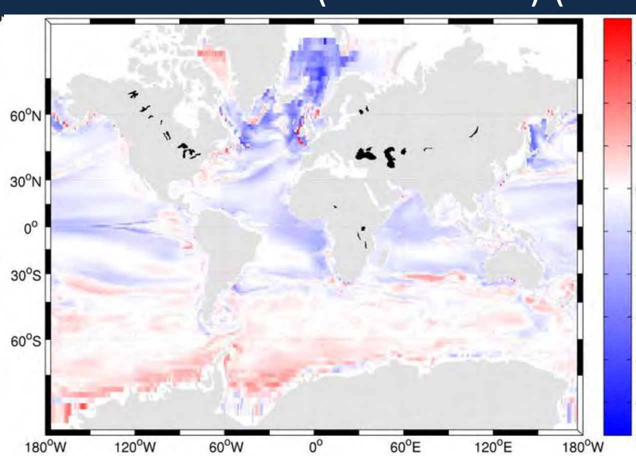
Projected global averaged change from 1860 to 2100



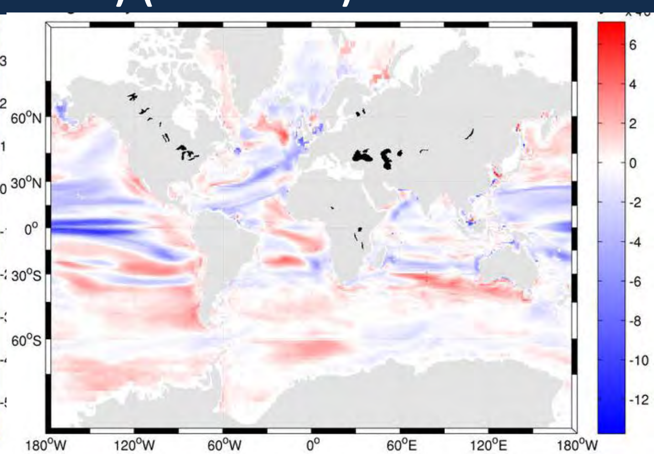
Size integrated anomalies of biomass (1mm to 2m) **(2096-2105)-(2006-2015)**



Epipelagic



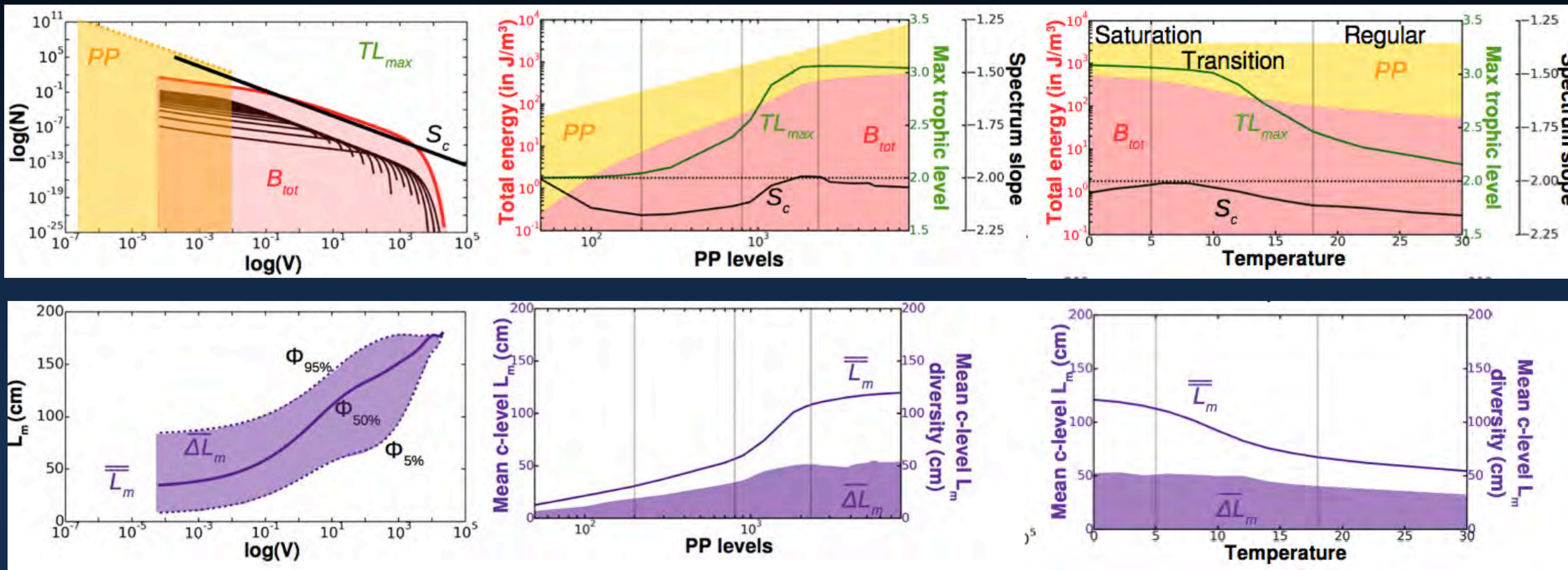
Mesopelagic

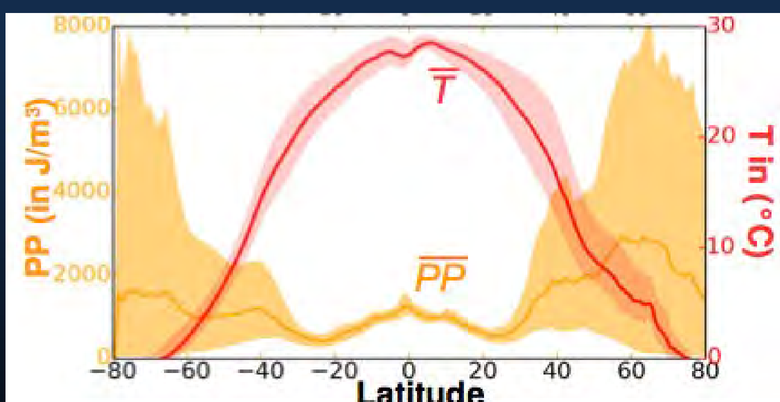


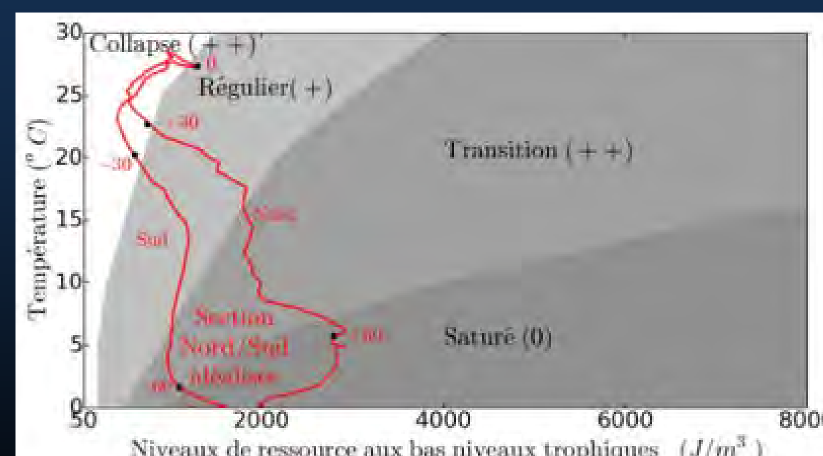
Migratory

Process studies

Temperature and primary production effects on marine communities (Guiet et al., 2016)

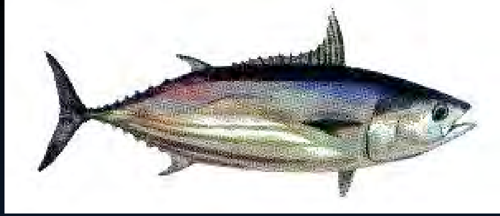




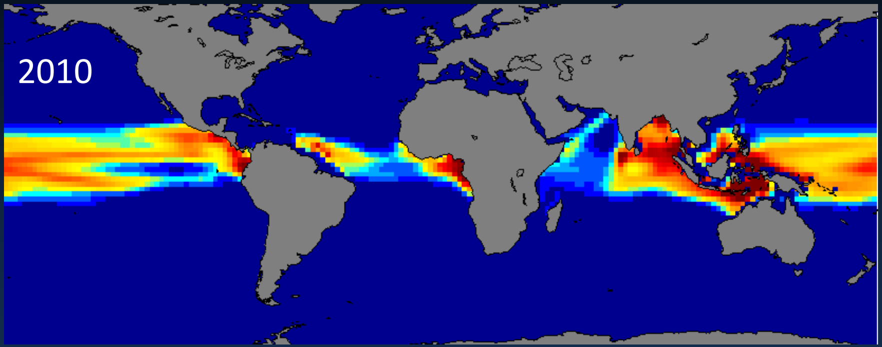


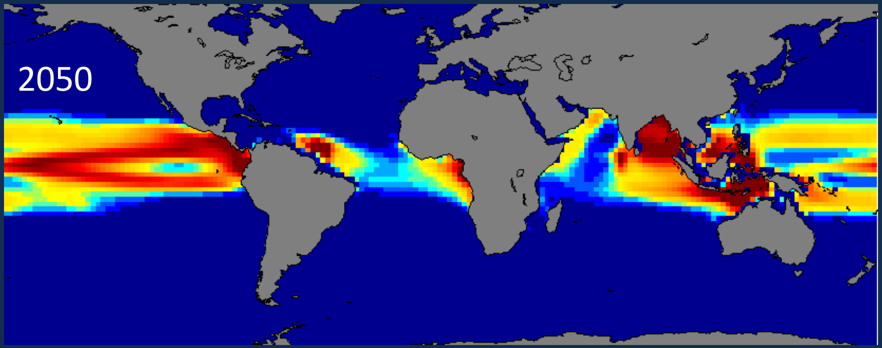
Guiet et al., 2016

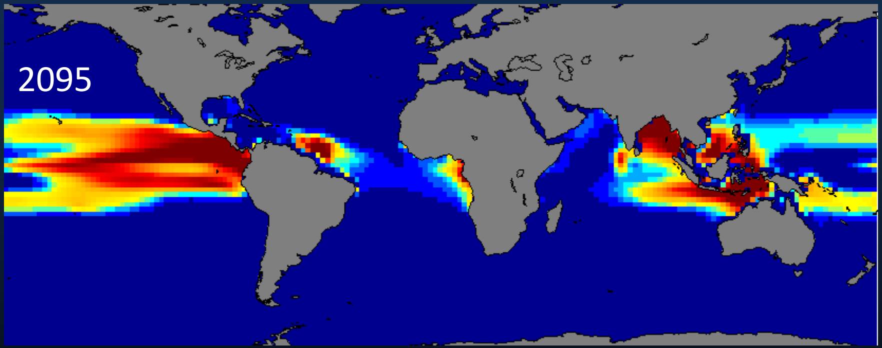
Climate impacts on tunas (Dueri et al., 2014)



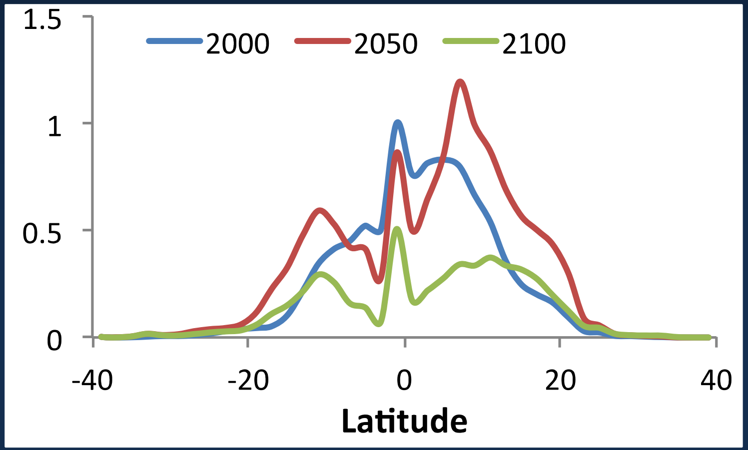
Exploitable biomass - no fishing



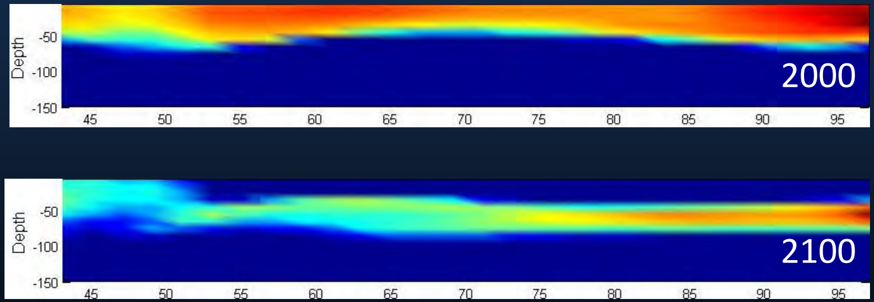




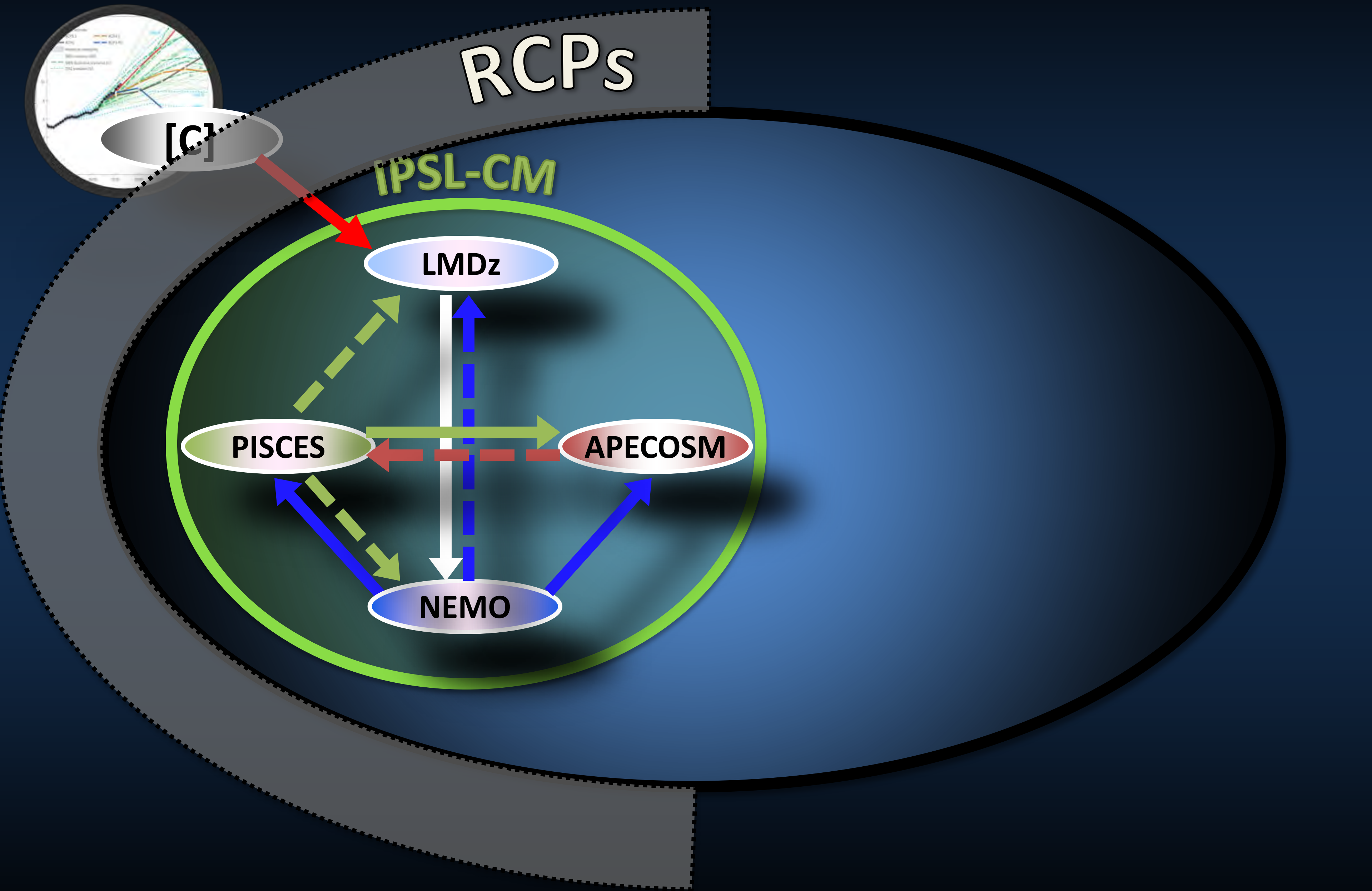
Total biomass - no fishing



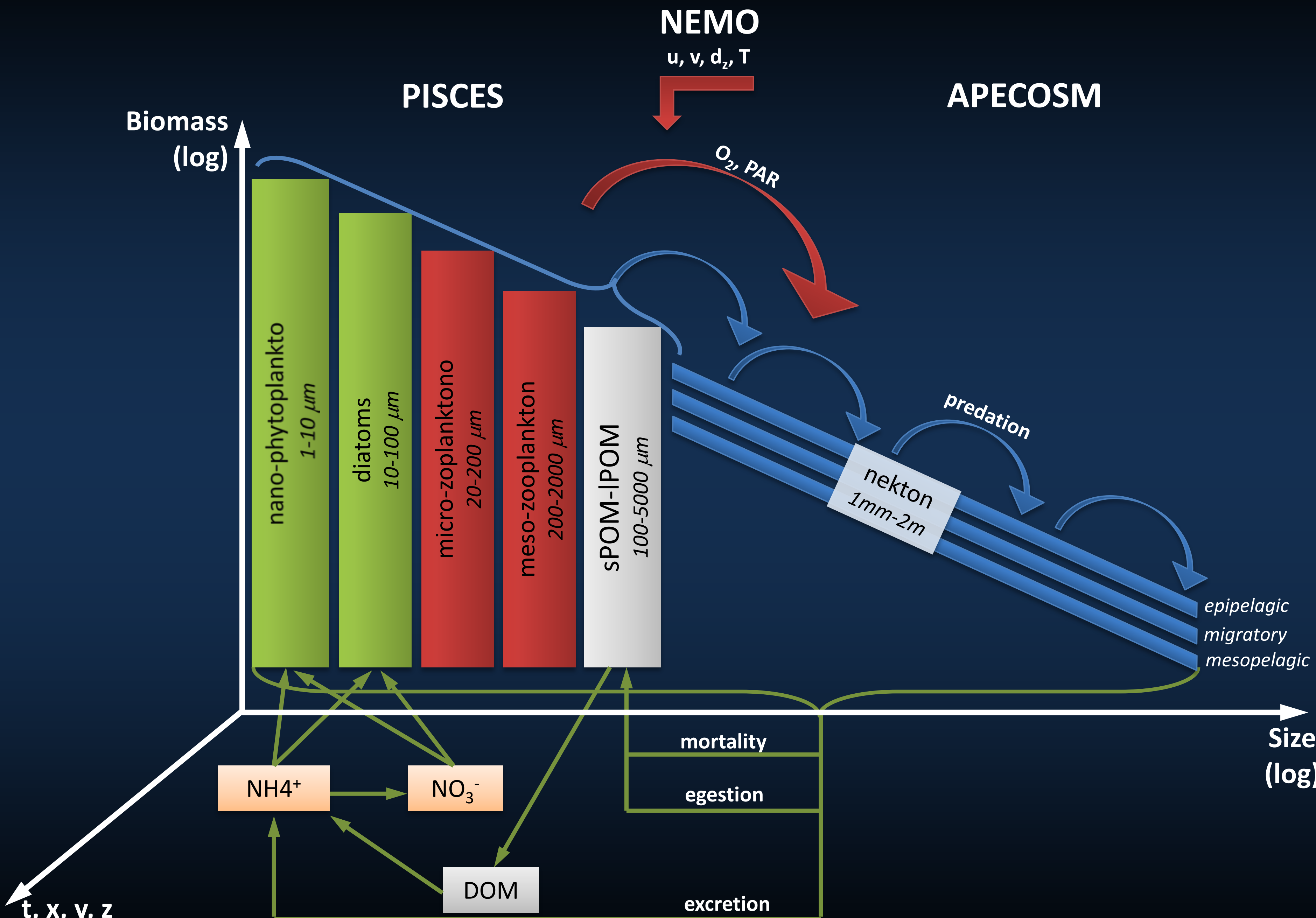
Biomass Indian Ocean (equatorial transect)



Feedbacks from ecosystems to biogeochemistry, carbon cycle and climate

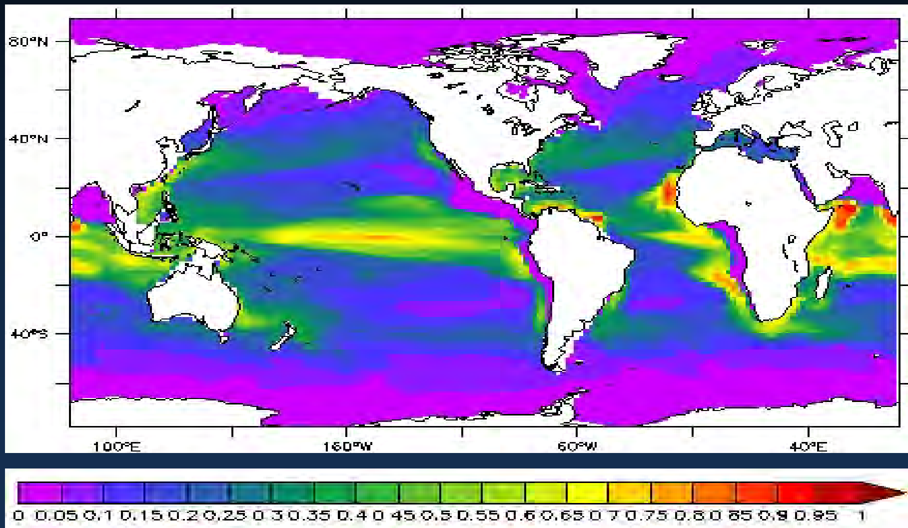


APECOSM can becoupled 2-ways to NEMO-PISCES



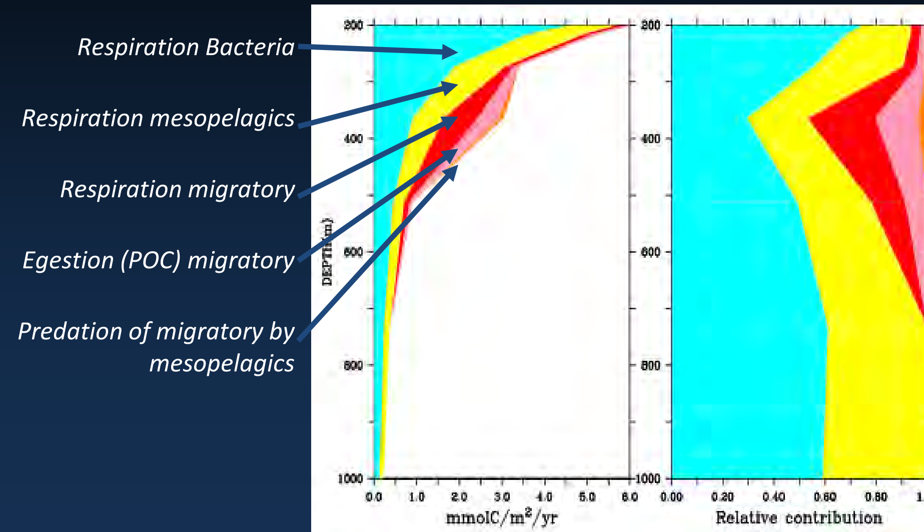
Feedback of ecosystems to the carbon cycle in the IPSL-CM5 earth system model

Active export / POC at 150m (annual mean)



Aumont et al., in review

Production C orga / inorga (annual mean)

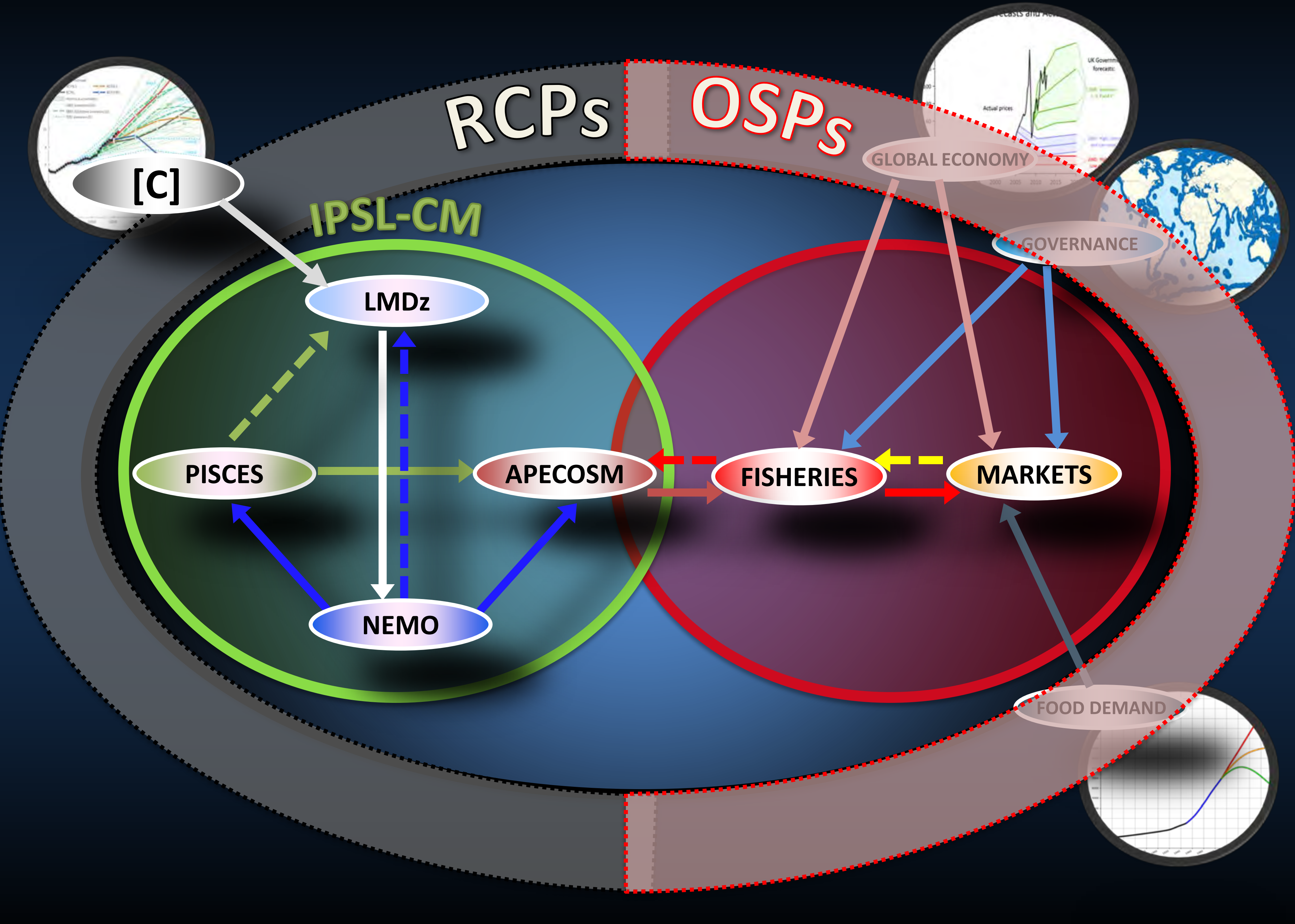


Aumont et al., in review

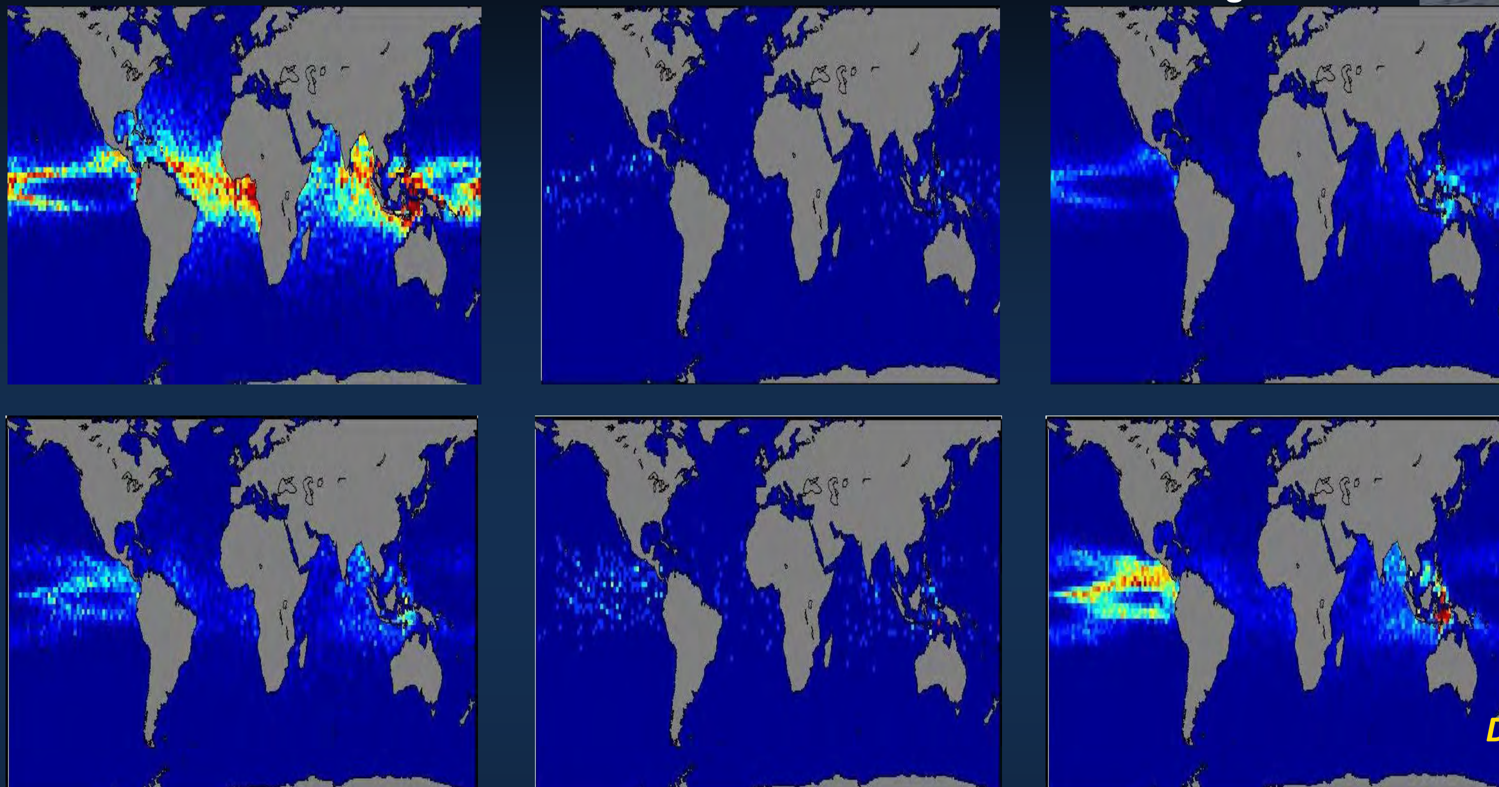
Global Budget in GtC/yr (150m)

	Flux (GtC/yr)	Contribution
POC flux	5.1	68%
DOC flux	1.1	15%
Active flux	1.3	17% (20%)
Total	7.5	100%

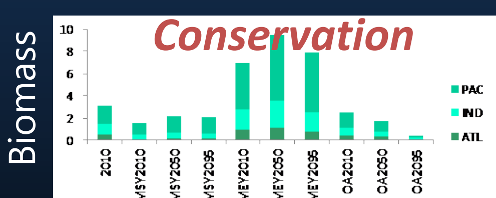
Integration from climate to fishing

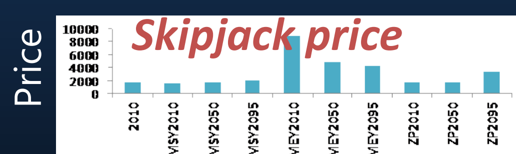


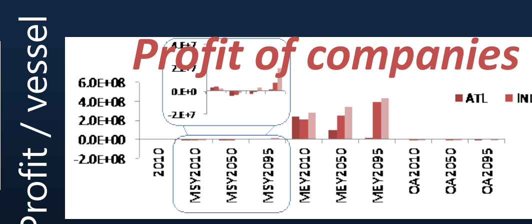
Governance strategies (APECOSM-E; RCP8.5 / SSP3)

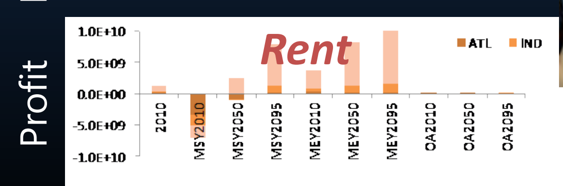


Dueri et al., 2016





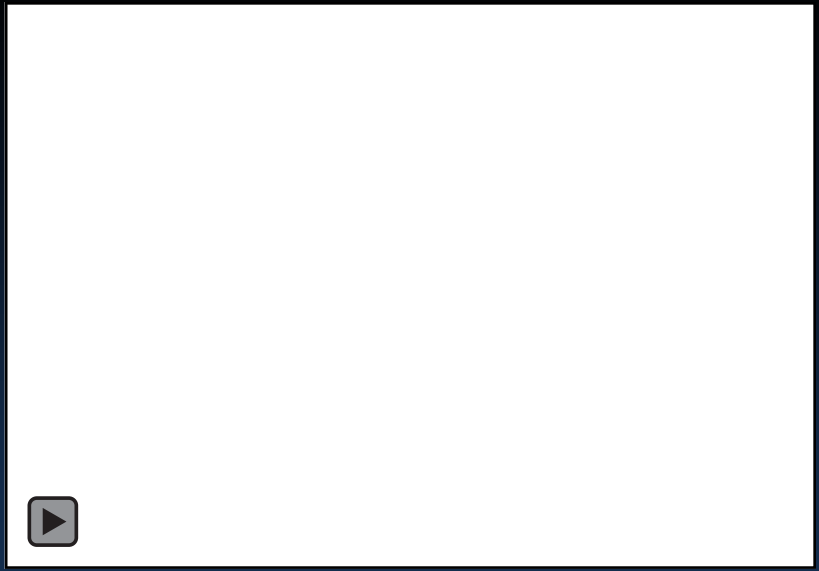




Conclusion

➡ APECOSM: a tentative to progress a mechanistic theory of marine ecosystems,

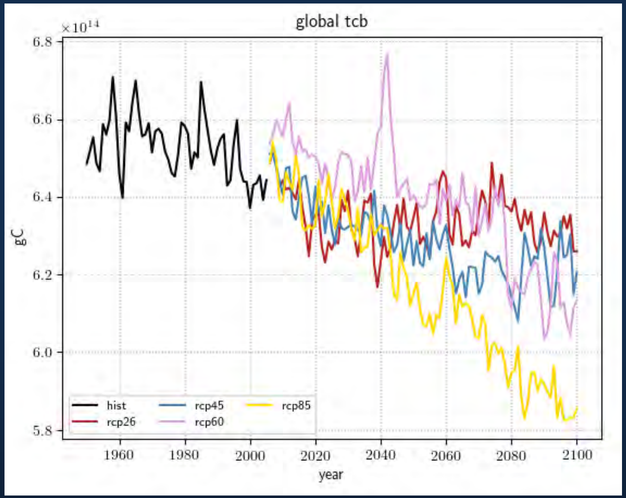
- Articulates individual, population and community levels,
- Represents socio-ecosystems through coupling with physics, biogeochemistry and bio-economy



➡ APECOSM contributed to FISHMIP phase 1

- Couldn’t run with GFDL forcing that was provided 2D
- Had tremendous problems with IPSL-CM forcing's due to problems with the regridded files provided

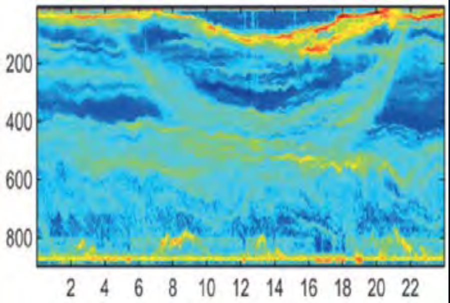
→ Recommend using native grids for forcing files



➡ FishMIP phase 2 has a great potential but great challenges ahead

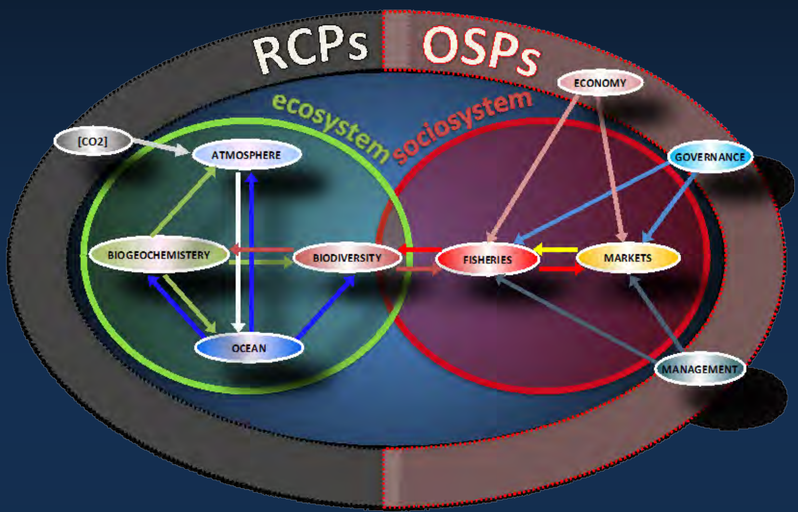
- Extend OSPs (SSPs) to represent global fisheries including quantitative effort pathways
- Develop a set of contrasted global marine ecosystems & fisheries scenarios by combining compatible RCPs and OSPs
- Undertake an actual comparison of models
- Synoptic observations are critically lacking for calibrating, assessing & improving the models

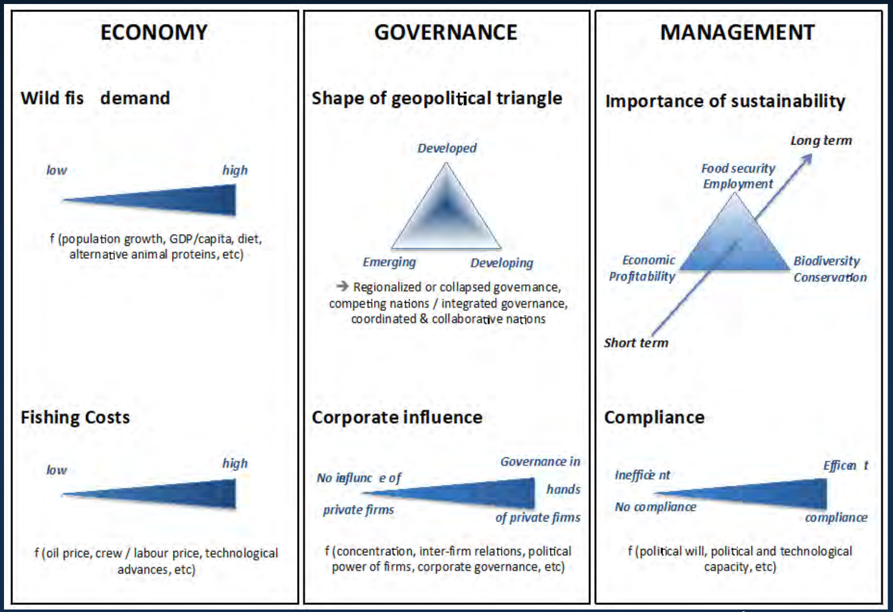
→ Promote global acoustic data collection and compilation



Building scenarios for global marine socio-ecosystems

➥ From «*Shared Socio-economic Pathways (SSPs)*» to «*Oceanic System Pathways*»





Maury et al., 2017

➥ Faire de la construction de scénarios une démarche participative impliquant les acteurs

- CLIOTOP, RFMOs, NGOs, industrie, FAO, …
- Réintégrer le long terme à la gestion,
- Elaborer des stratégies de gouvernance vers la durabilité
- Evaluer les alternatives et les options