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Modelling the Microbial Carbon Pump in a changing ocean: current state and future directions

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Background 1

- The Microbial Carbon Pump (MCP) is the bacterially mediated transformation of DOC from labile (easy degradable) to recalcitrant (long lasting) forms (*Jiao et al 2010*)

- Depending on its life time, recalcitrant DOC (RDOC) is divided in different fractions (from semi-labile to ultra-refractory, *Hansell, 2013*)

Background 2

Why is the MCP important?

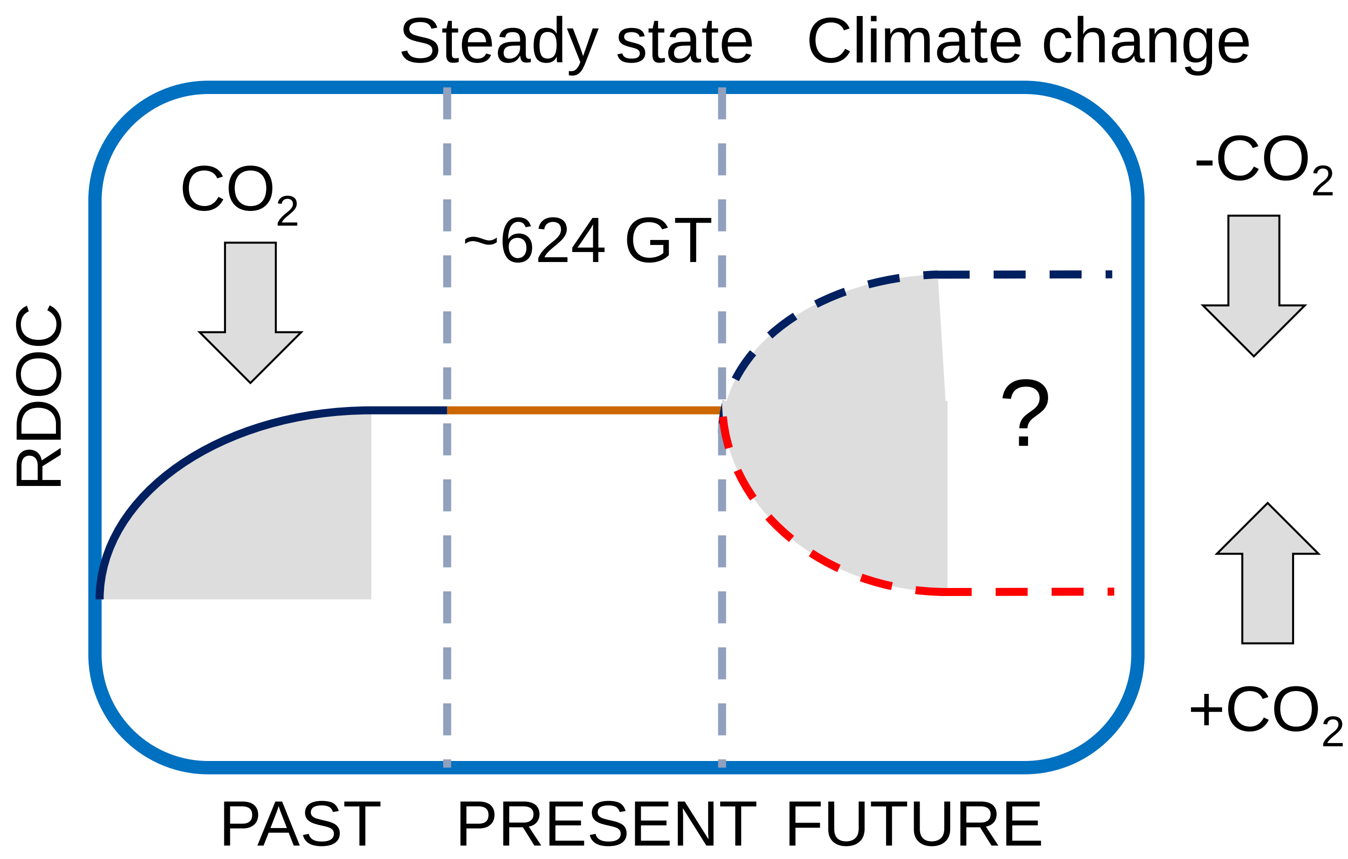
- Bacterial production of RDOC is an important mechanism for carbon storage, acting along with the biological carbon pump (BCP).

- Up to 4.5 % of annual PP is transformed by MCP into semi labile DOC and up to 0.023% into refractory DOC (Benner and Herndl, 2011).

- MCP is potentially sensitive to climate change . E.g. MCP:BCP could increase with decreasing nutrients (Jiao et al., 2010 and 2014)

Why do we need to model the MCP?

- We know that the MCP has “built” the amount of RDOC currently present in the ocean
- RDOC is thought to be constant in the current ocean (steady state)
- We do not know how the MCP is reacting to climate change
- We need to model the MCP to test hypotheses on RDOC dynamics in future oceans

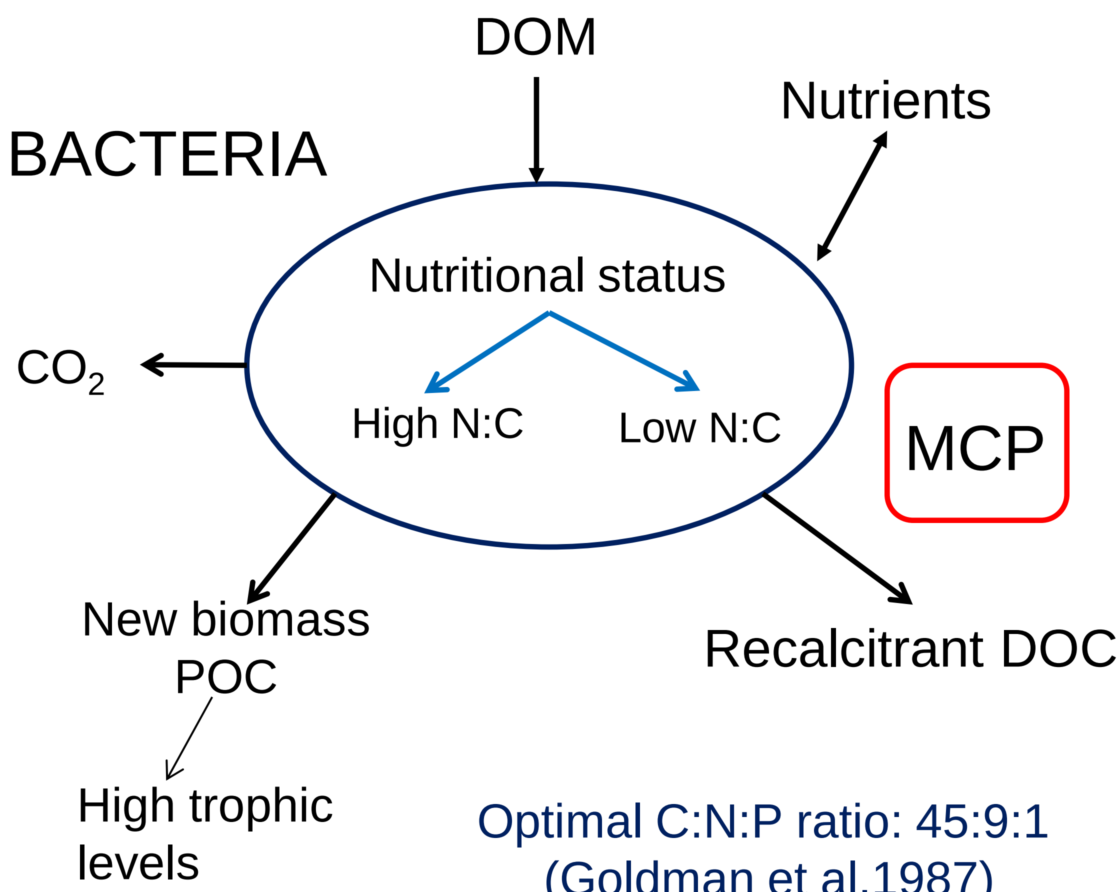


MCP has the potential to impact on future CO_2 concentration in atmosphere

Modelling bacterially-mediated RDOC production

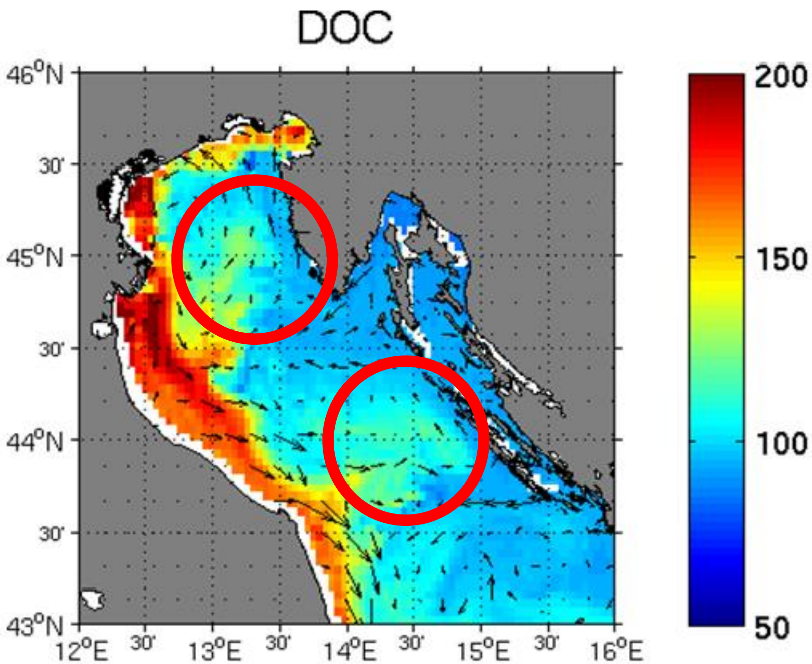
(Polimene et al., 2006a)

Nutrient-dependent production of RDOC



Optimal C:N:P ratio: 45:9:1
(Goldman et al,1987)

Example 1

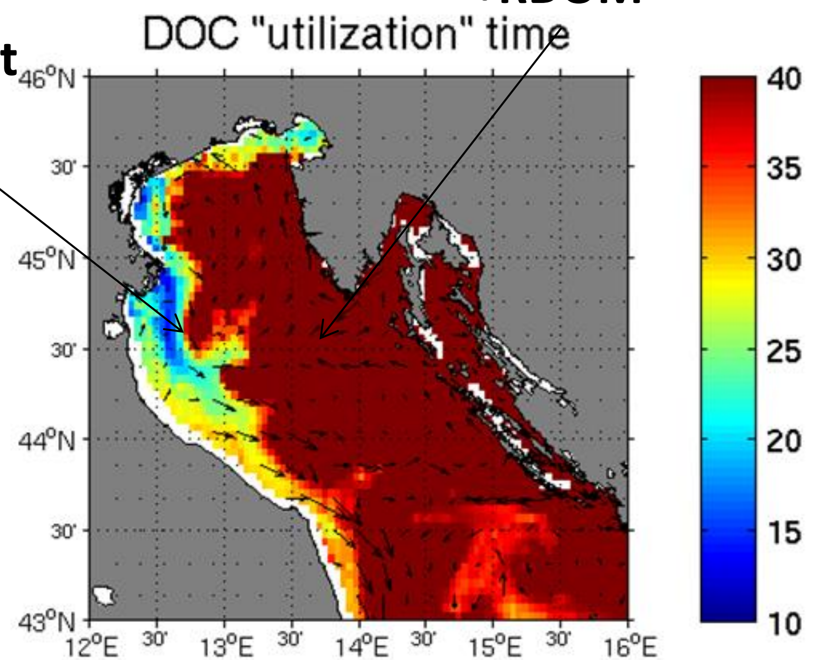


DOC dynamics in the Northern Adriatic Sea

(Polimene et al., 2006b and 2007, JGR)

Low nut +RDOM

High nut +LDOM

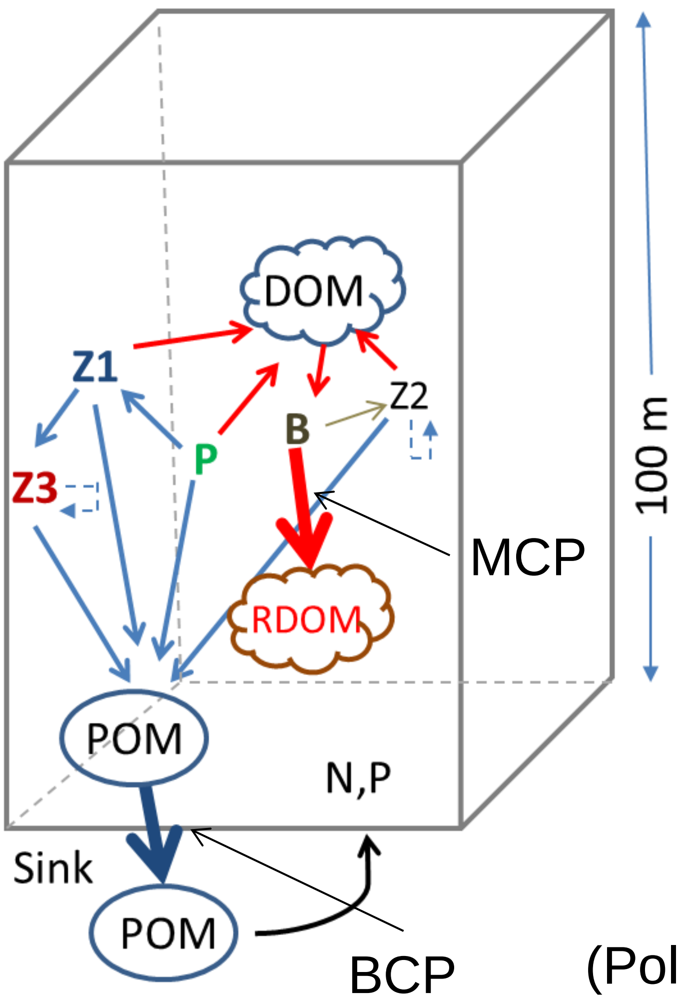


DOC seasonal accumulation driven by nutrient limitation (for bacteria)

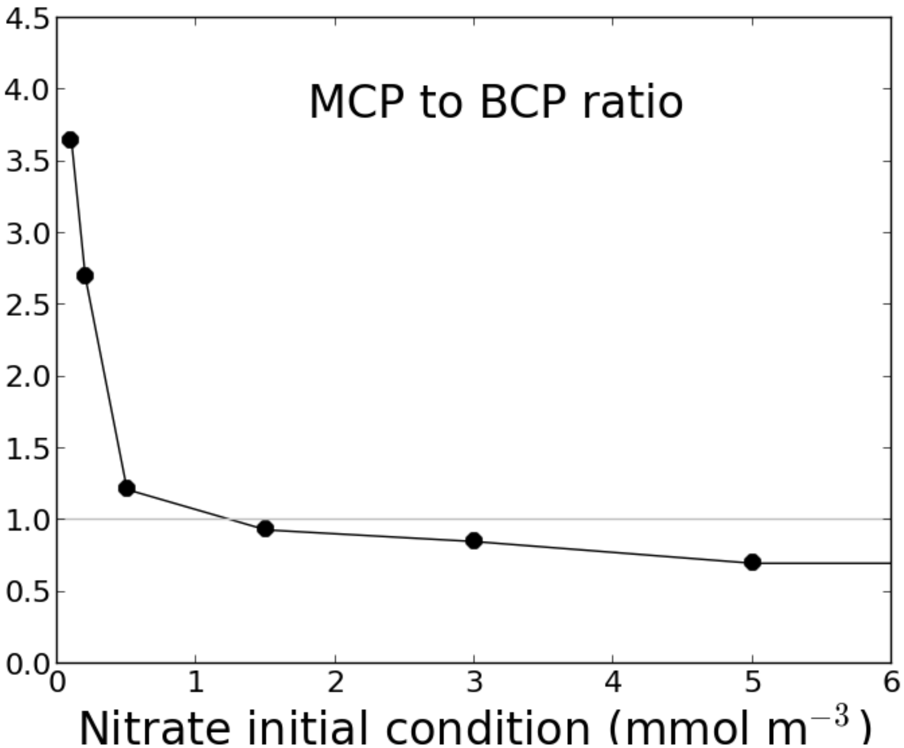
Example 2: Are we able to model the MCP?

A first attempt to simulate the variability of MCP with respect to the BCP in an idealised system

box model

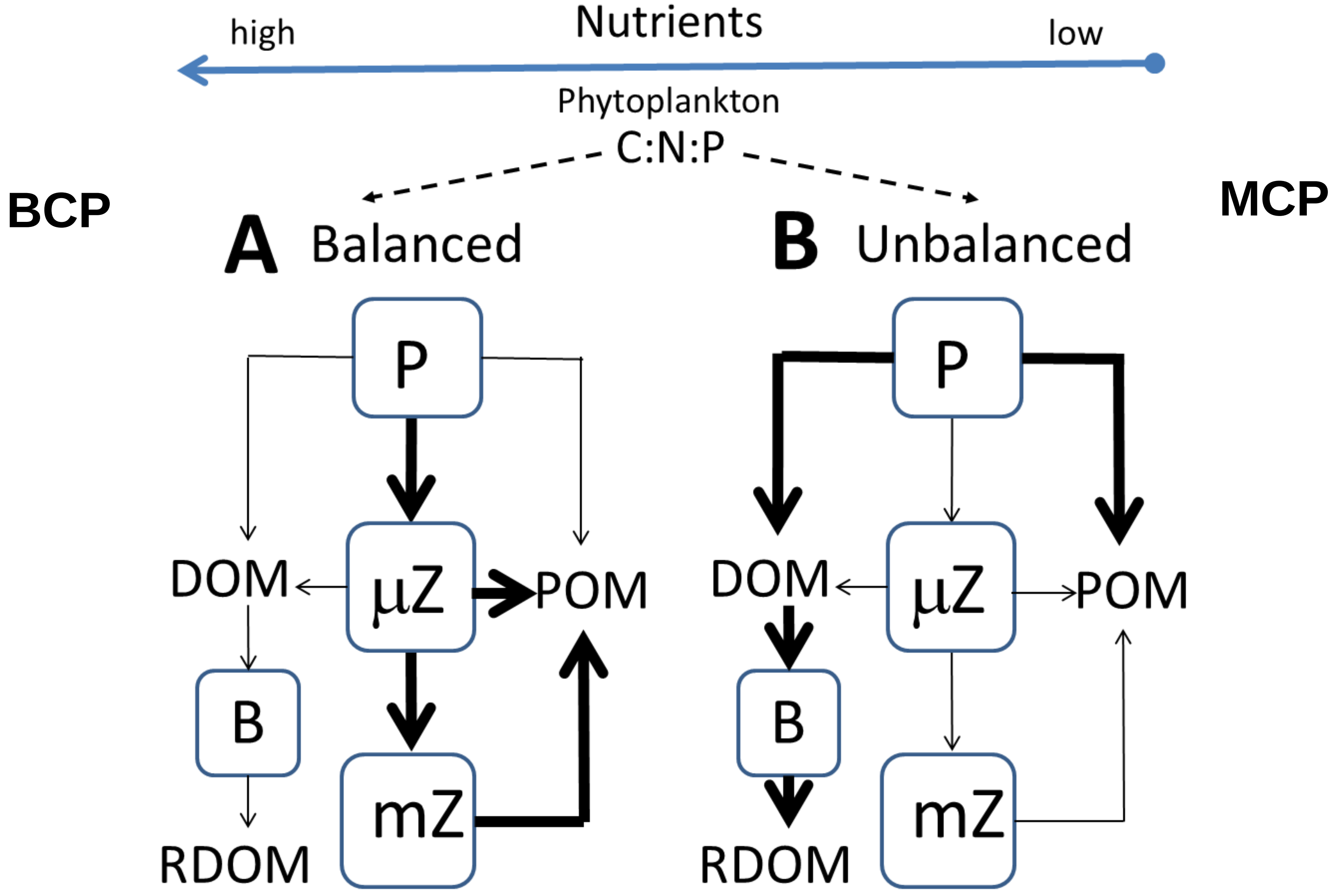


MCP:BCP could vary depending on nutrient (Jiao et al., 2010; 2014)



(Polimene *et al.*, 2017a)

Our conceptual framework



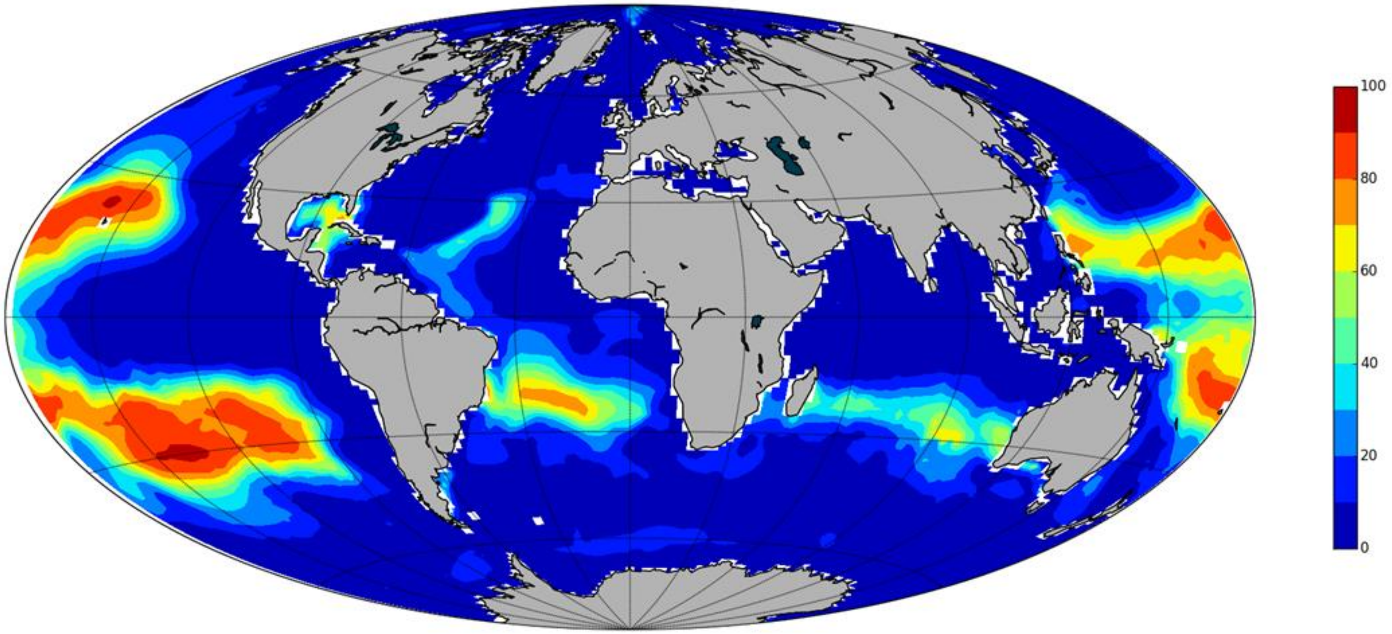
(Polimene *et al.*, 2017a)

Global (preliminary) Simulation

MODELLING FRAMEWORK: ORCA-ERSEM, 2 degrees

MCP vs BCP: [MCP/(MCP+BCP)]*100

BCP=particle export at 100 metre depth (annual mean)
MCP=integrated C flux (100 m) from Bacteria to RDOC



(Simulation performed by S. Sailley at PML)

Fine-scale model validation (Polimene et al., 2017b)

Degradation and transformation of phytoplankton-derived DOM by the marine bacterium *Alteromonas sp.*

Diatom culture
(*Chaetoceros calcitrans*)

phytoplankton cells were lysed to generate a DOM-rich medium (DOM "soup")

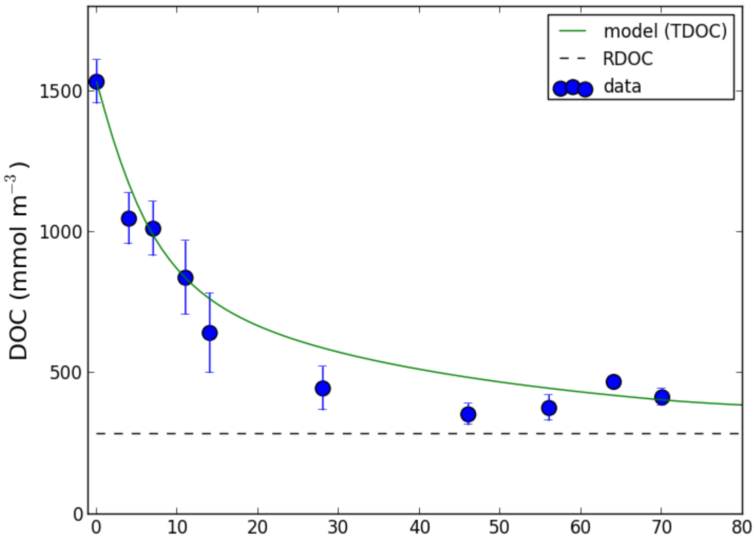
DOM "soup"

Bacterial culture (3 replicates)

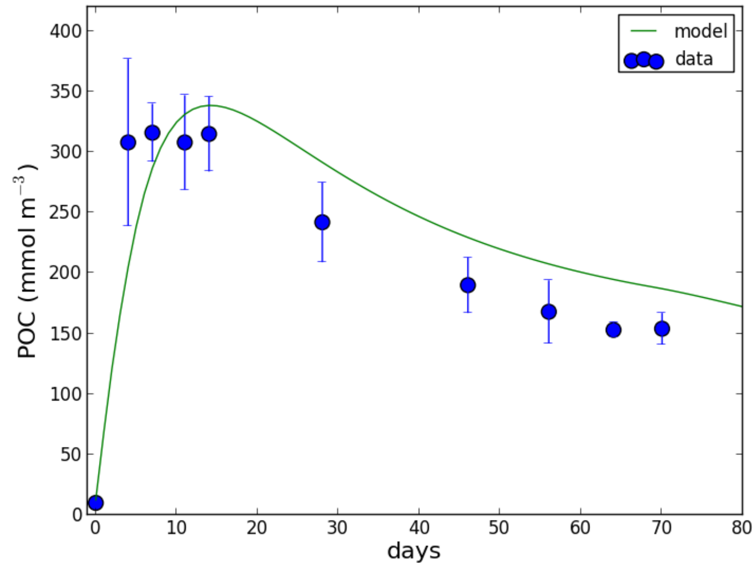
The cultures were placed at a temperature of 15 C and followed for 170 days

Results (Polimene et al., 2017b)

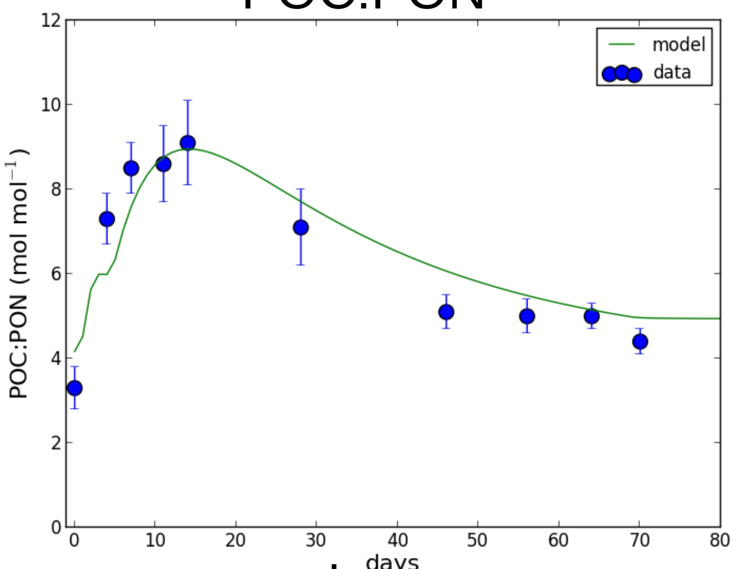
DOC



POC (bacterial C-biomass)

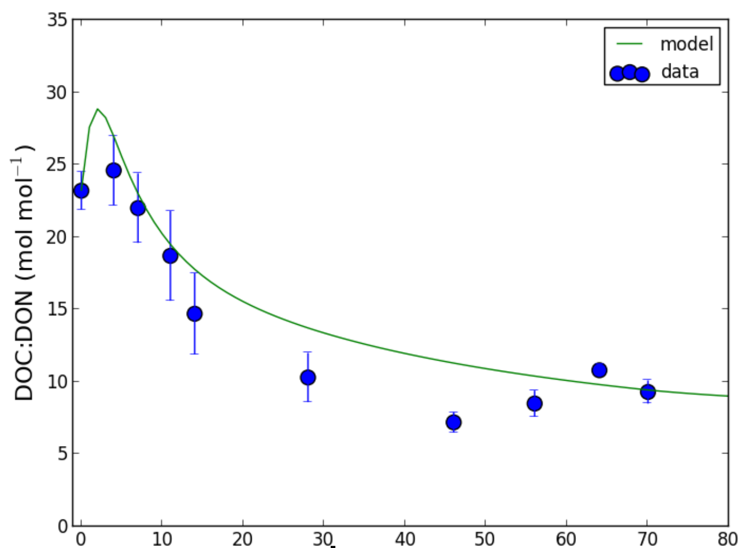


POC:PON



days

DOC:DON

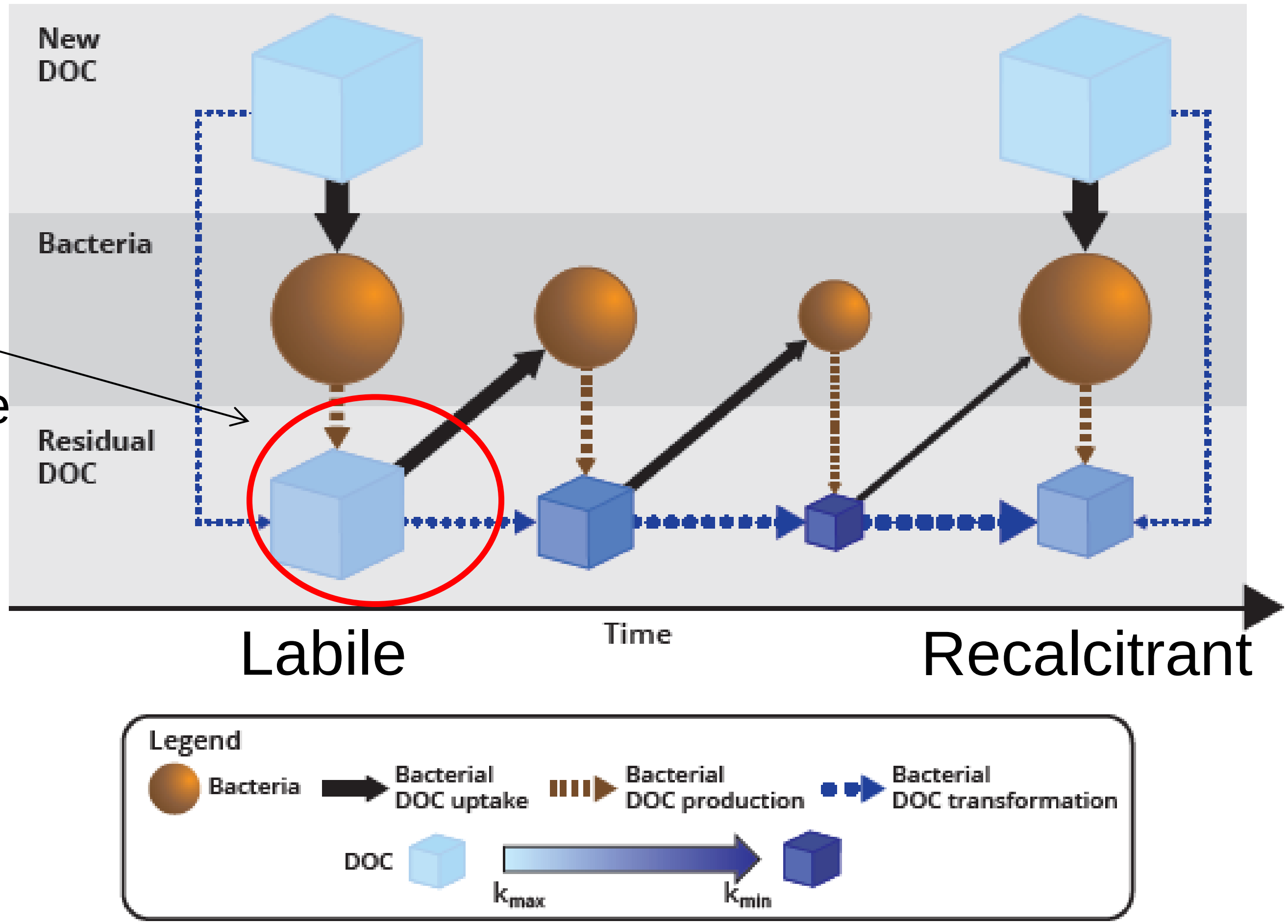


days

Limitations

MCP can be seen as a continuous process progressively transforming LDOC into RDOC

We are only modelling
the first step
(i.e. the semi-labile DOC fraction)



In previous examples, the refractory fraction of the recalcitrant DOC pool is not modelled

Polimene et al., 2018, NSR

Future directions

RDOC chemical finger print

- By using advanced analytical techniques (FT-ICR-MS) it is possible to identify refractory DOM fingerprint (Lechtenfeld et al 2014)

- RDOC production has been observed in bacterial cultures (Lechtenfeld et al 2015; Osterholz et al 2014)

- If microbial RDOC production can be estimated in cultures, model formulations can be developed.

Future direction: From the lab to the global ocean

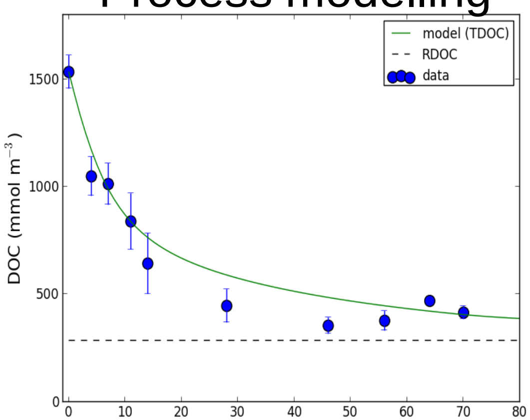
Multidisciplinary information need to by synthesized to develop models to assess the role of the MCP in present and future oceans

DOM production

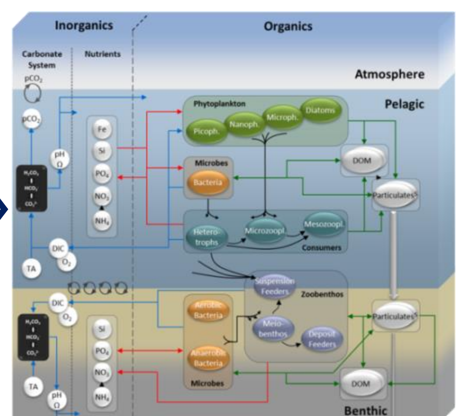
DOC degradation

RDOC analyses

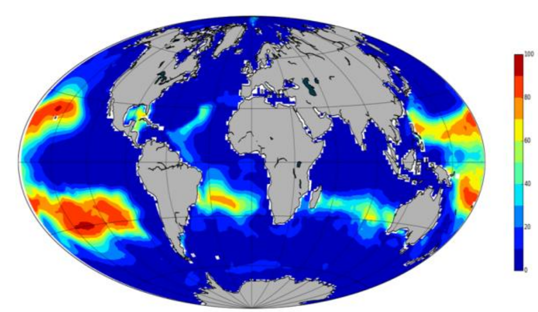
Process modelling



Ecosystem Modelling



Global simulations/predictions



Conclusions

- ❖ Modeling MCP is needed to investigate carbon cycle in a changing ocean and related climatic feedback

- ❖ Current models have potential but also limitations

- ❖ New model developments are underway..

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