Studying the impact of particle resuspension for modeling and predicting Hypoxia on the Black Sea shelf

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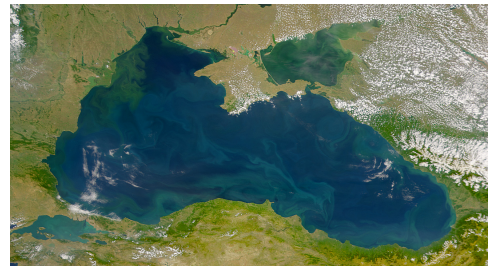
with L. Vandenbulcke, M. Ricker,
M. Grégoire & J. Staneva
as part of NECCTON



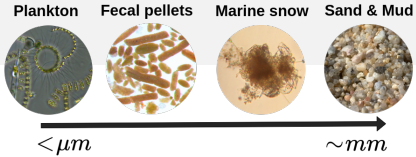
LIÈGE université

Helmholtz-Zentrum hereon

C.E.C.I

MAST Modelling for Aquatic SysTems

Suspended matter and particle resuspension



SPM: wide range of **biogenic** and **mineral** origins

- River load
- Biological activity
- **Resuspension of sediments in shallow areas due to currents and waves**

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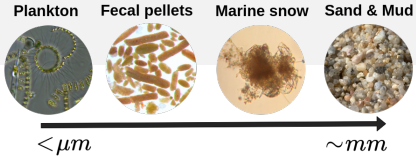

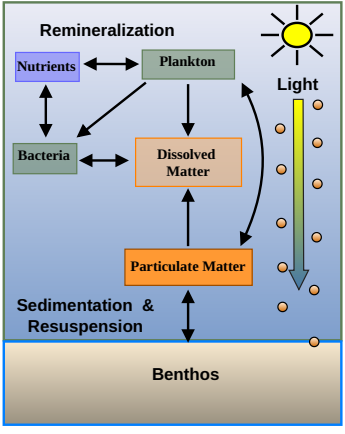

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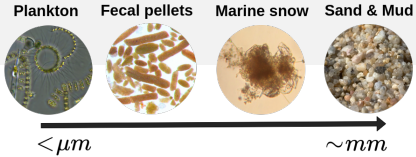

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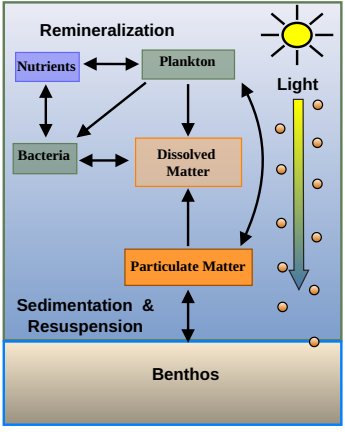
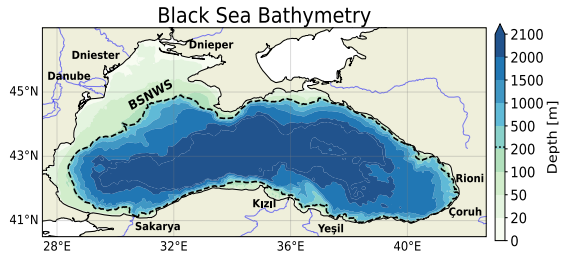
- Modeling studies showed this for
  - Baltic Sea (Almroth-Rosell 2011, 2015)
  - Gulf of Lion (Moriarty 2017)
  - Gulf of Mexico (Justic 2014, Moriarty 2018)
  - Chesapeake Bay (Feng 2015, Moriarty 2021)
- **Today:** Focus on Particulate Organic Matter **(POM)**



The Black Sea and its North-Western shelf

- World's largest semi-enclosed anoxic basin with thin oxygenated layer
  - Oxygen inventory in decline (Capet 2016)
- Shelf: Extensive area of primary productivity
  - Shallow: waves impact bottom
  - Anthropogenic pressure: Eutrophication and Hypoxia



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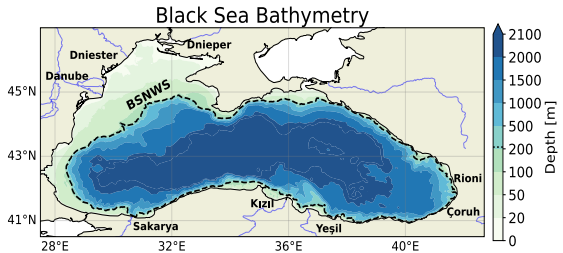
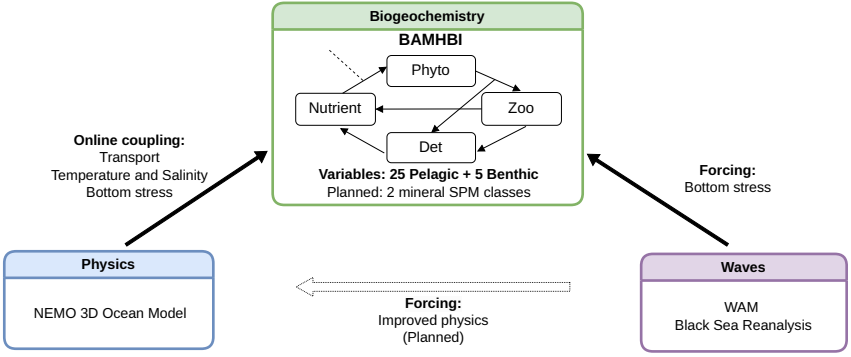


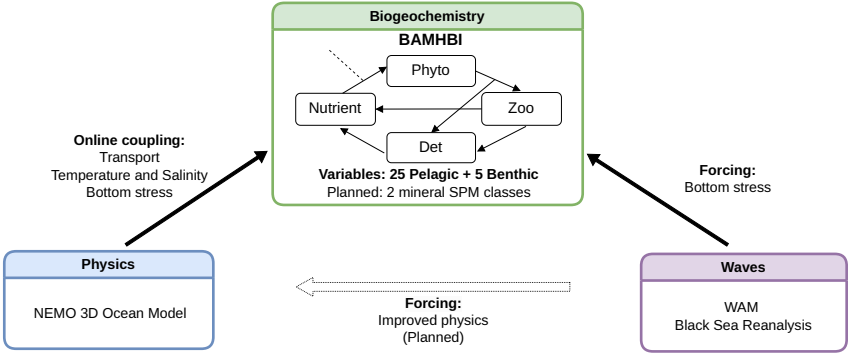
- MAST group in Liege:
  - Biogeochemical reanalyses and forecasts (CMEMS)
  - Numerical modeling studies (Gregoire 2008,2010, Capet 2013, 2016)

⇒ **Impact of particle resuspension not studied yet**

Modelling framework

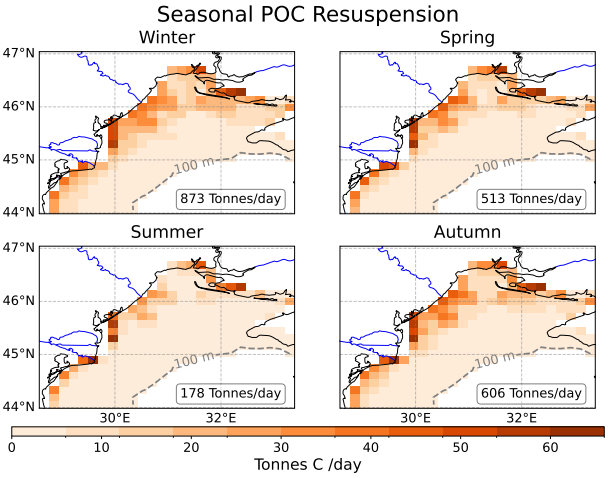


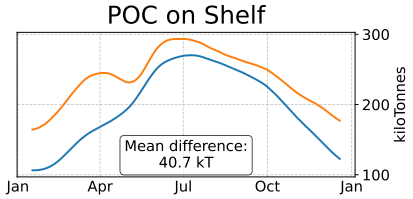
Modelling framework

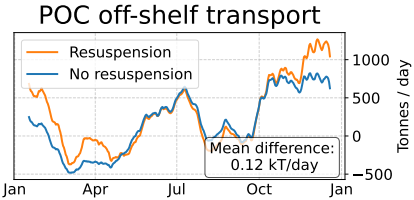


- Resuspension due to combined current and wave-bottom stress:
  $|\vec{\tau}_{\text{current}} + \vec{\tau}_{\text{waves}}| > \tau_{\text{crit}}$
- **Setups:** With resuspension vs without resuspension
- Simulations at 15km resolution cover 1995–2024

Simulated resuspension of particles





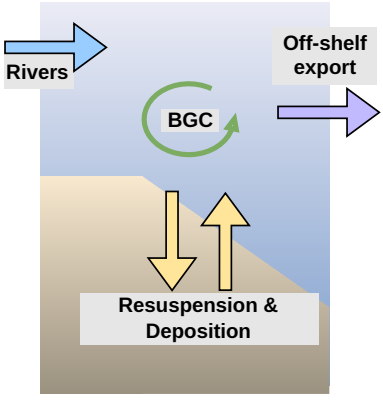


⇒ Clear resuspension, shelf content and POC export peak in winter

Accounting: The fate of resuspended Particulate Organic Matter

Physics:

in kT/day	River	Resusp.	Export	Depo
Resusp.	0.91	**0.57**	**0.31**	8.85
No Resusp.	0.91	0	0.19	**10.86**



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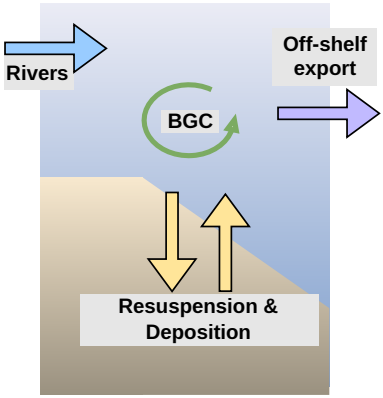
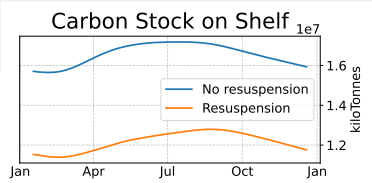
Biogeochemistry:

in kT/day	Remineral.	POC Grazing	Mort (P)	Mort (Z)
Resusp.	**5.27**	**16.79**	7.71	**0.90**
No Resusp	4.51	13.85	**11.75**	0.79

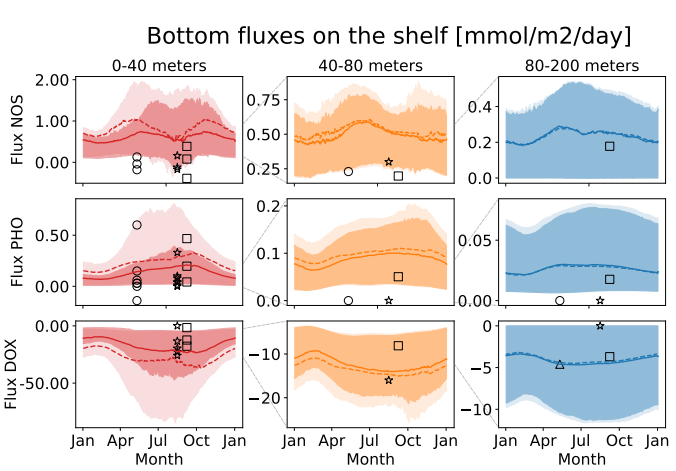


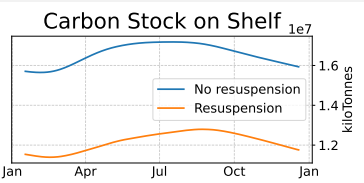
⇒ Impact on BGC (internal recycling) larger than mere resuspension

Resuspension impact on the Seabed (Soetaert model)



Resuspension impact on the Seabed (Soetaert model)



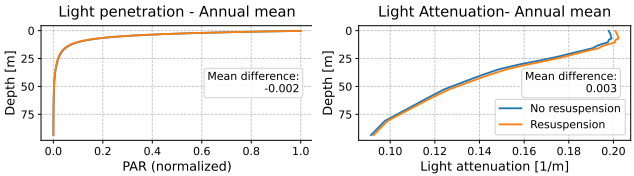


- Oxygen flux strongest indicator that resuspension scenario is more realistic
- Work in progress: Water column concentrations as further indicators

Biogeochemical impacts

Light:

- Almost no light availability decrease



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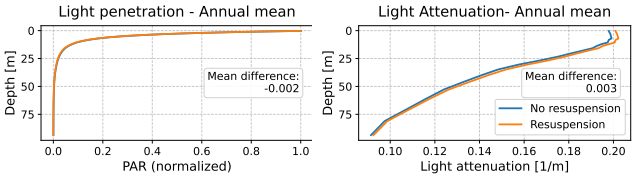
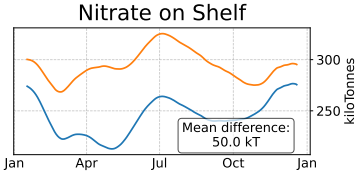
Nutrients:

- Higher nutrient availability throughout year
- POC and PON remineralized





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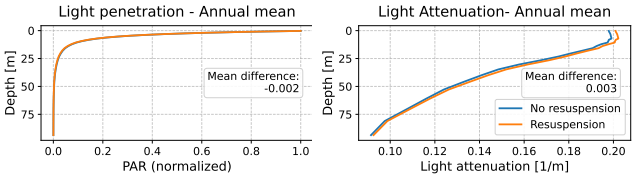
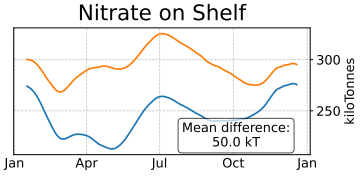
Net Primary Production

- Annual shelf NPP increases by 3.4% with resuspension

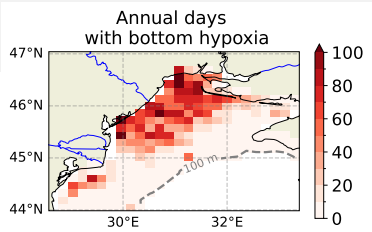
Winter	Spring	Summer	Fall
+0.7%	+4.9%	+6.2%	+1.9%





$\Rightarrow$ Nutrient availability more important

Changes in bottom hypoxia due to resuspension



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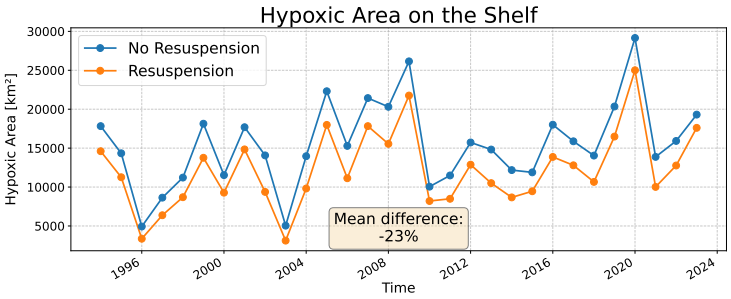

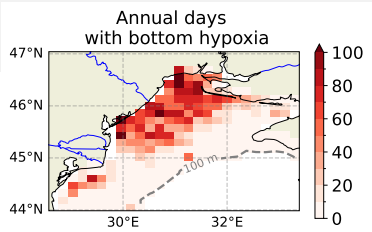

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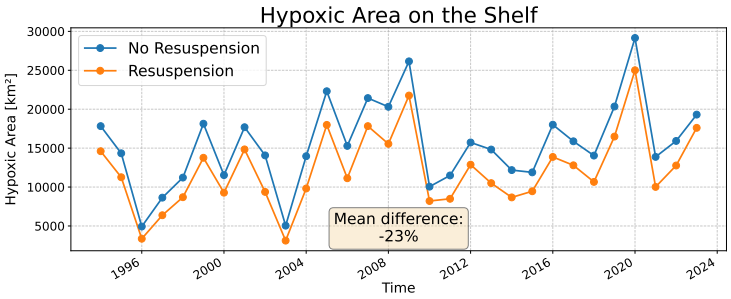
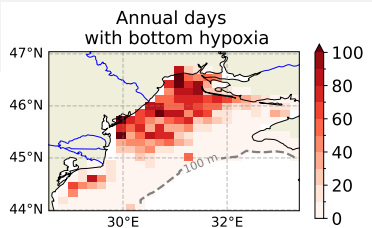
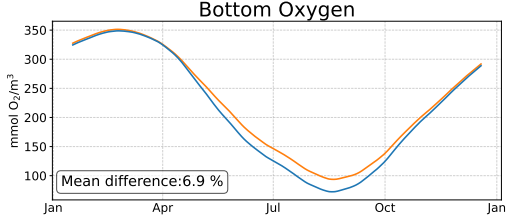
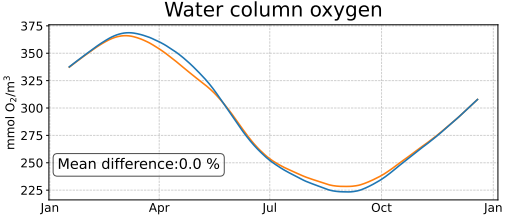








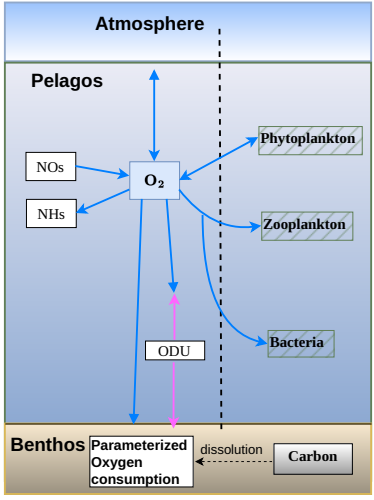
Why does resuspension lead to increased bottom oxygen?

Bottom oxygen consumption in summer (kT O_2/day):

	Sediment consumption	Respiration	Oxidation	Nitrification
Resusp.	31.21	6.31	0.11	0.47
No Res.	42.64	5.17	0.25	0.47
Diff.	**-11.43**	1.14	-0.14	0.00

$\Rightarrow$ Sediment O_2 consumption driving process

- Benthic model: O_2 consumption $\sim$ Carbon stock
- Carbon stock decreased due to resuspension



Critical considerations

- Prior studies (e.g. Almroth-Rosell, Moriarty): Resuspension **decreases** oxygen
  - Simplified benthic model ⇒ underestimated remineralization?
  - Currently no mineral SPM included ⇒ Light limitation underestimated?
- Black Sea: Unique seasonal resuspension?
  ⇒ Validate with satellite SPM data
- Resuspension parameters highly empirical
  ⇒ Consider ensemble approach to cover range of literature values
- Current resolution 15km
  ⇒ Upgrade to 2.5km expected to increase reliability

Conclusions: Particle Resuspension and Hypoxia in the Black Sea

1. Shelf POM resuspension peaks in winter
   ⇒ Major impact on POM budget

2. Resuspension reduces bottom hypoxia (in our model)
   ⇒ Decreased sediment O_2 consumption dominates other effects

3. Biogeochemical model validation on the shelf crucial
   ⇒ Novel approaches needed due to sparse in-situ data

4. Reliable hypoxia predictions essential
   ⇒ Key focus: Understanding resuspension related uncertainties

Thank you for your attention!