goldschmidt
California 2014

Impact of submarine groundwater discharge on biogeochemical processes and benthic fluxes in coastal sands

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Warnemünde, Germany.

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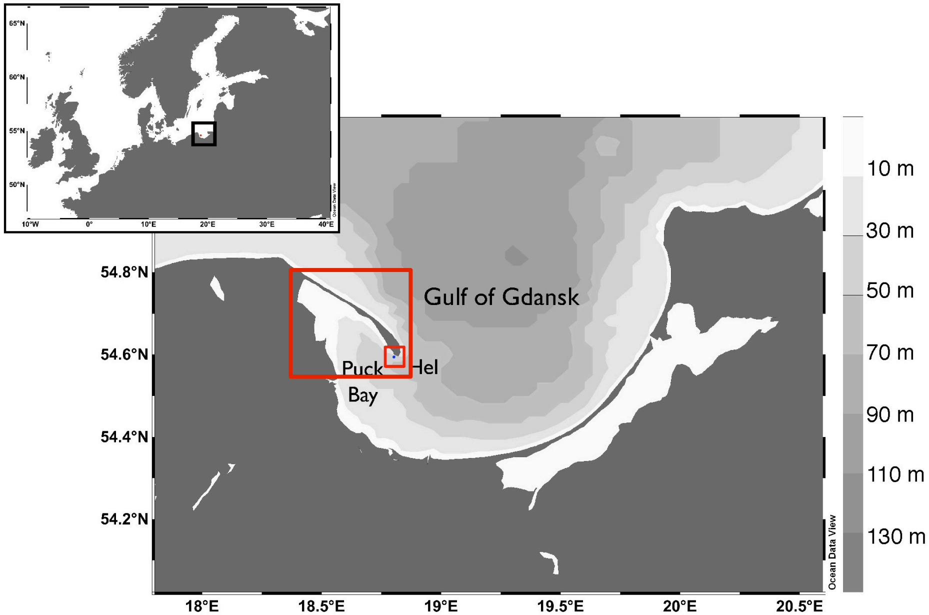
IOW

Max Planck Institute
for Marine Microbiology



Area of study



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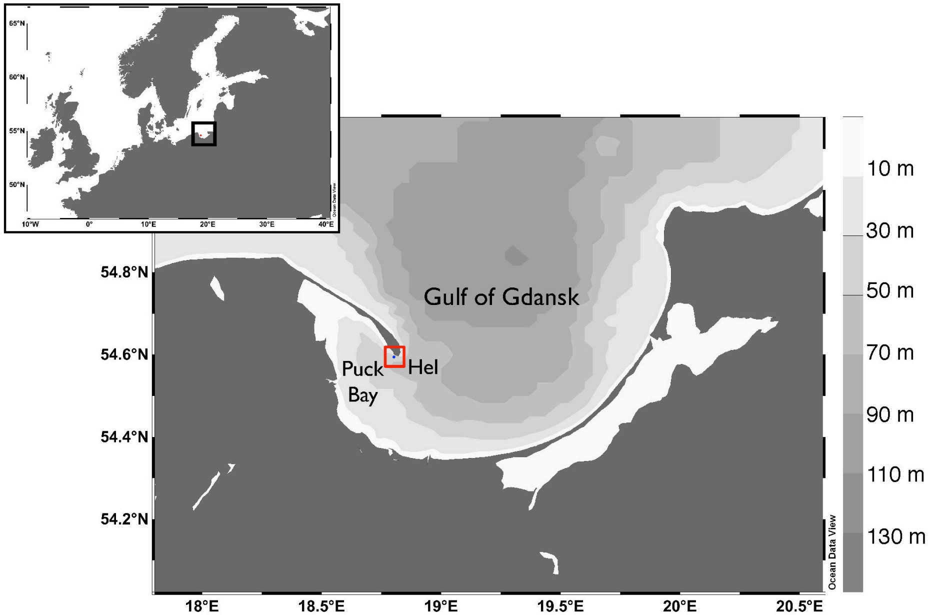


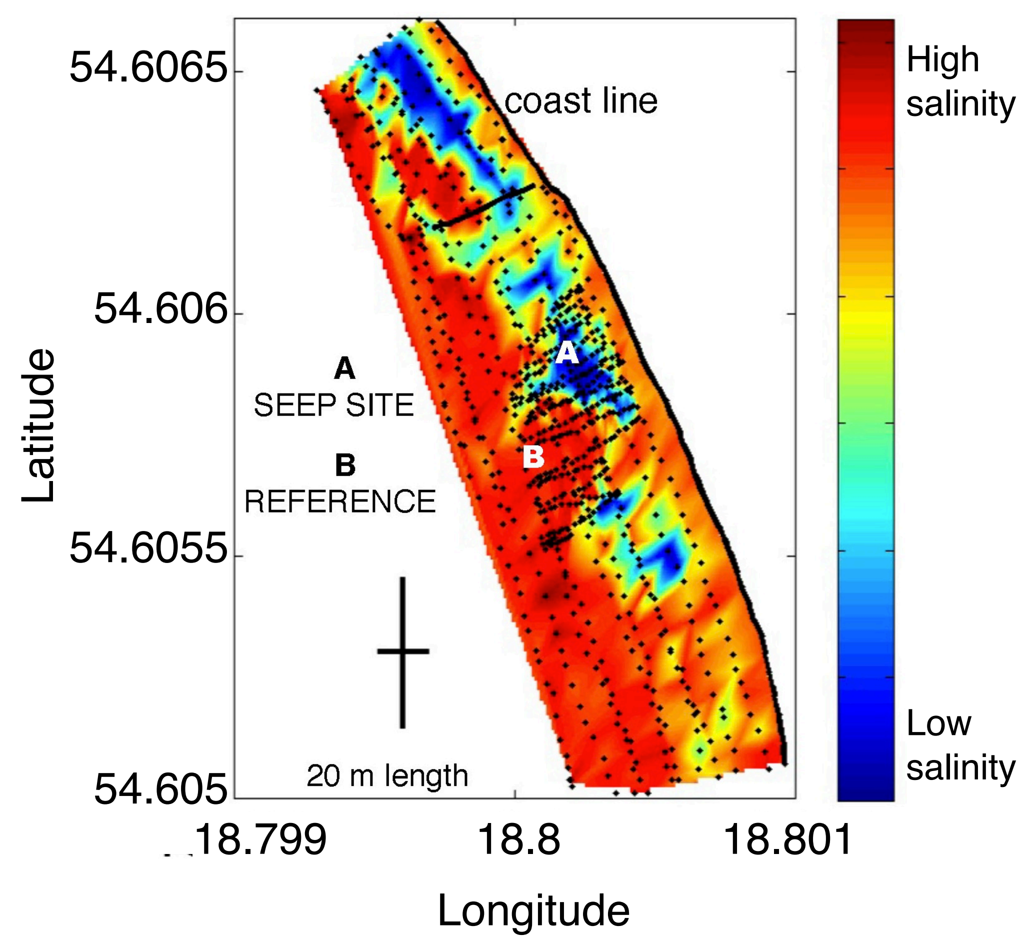
Low-salinity groundwater escapes at the coast line of Hel Peninsula through seeps within permeable sandy near shore sediments

- What is the fate of solutes supplied by SGD in the surface sediments?

- How does the presence of SGD impact aerobic benthic processes?

August 2011

Map of the main seepage areas obtained by high resolution survey (10 cm b.s.f.) with a conductivity sensor



August 2011

Water column parameter	Seep / Reference
Oxygen	270-320 µmol L-1
Temperature	18-20 °C
Salinity	7 PSU

Sediment parameter	Seep	Reference
TOC (20 cm) %	0.14 (0.15-2cm)	0.11(0.17-2cm)
Grain size (µm)	388	312
Permeability (x10 $^{-11}$ m ^{2})	1.95	2.32

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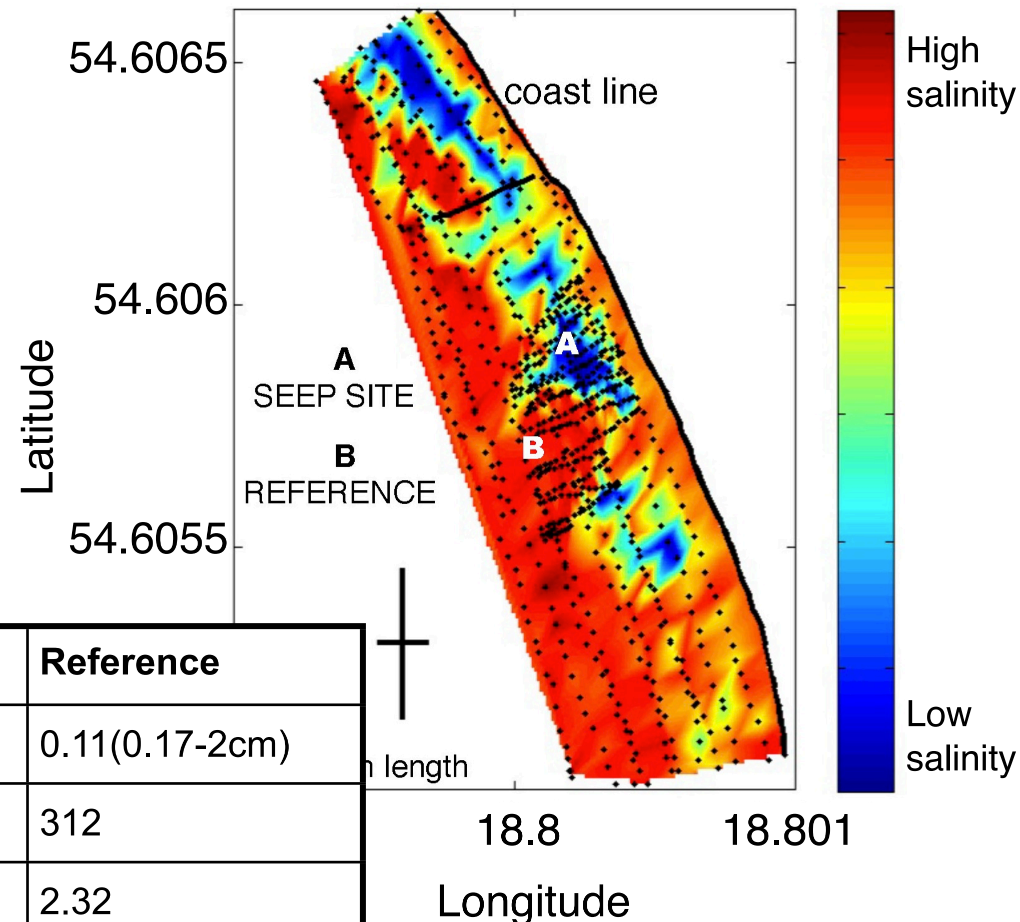
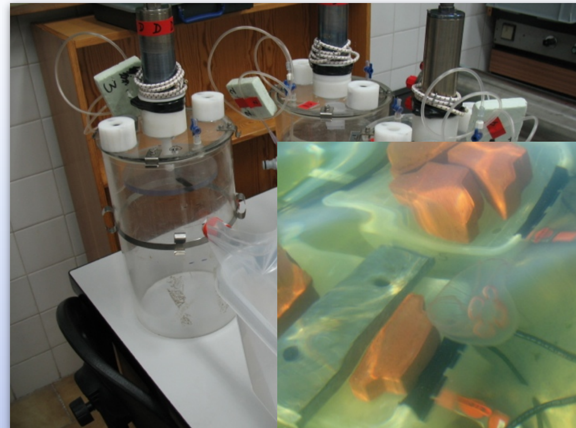
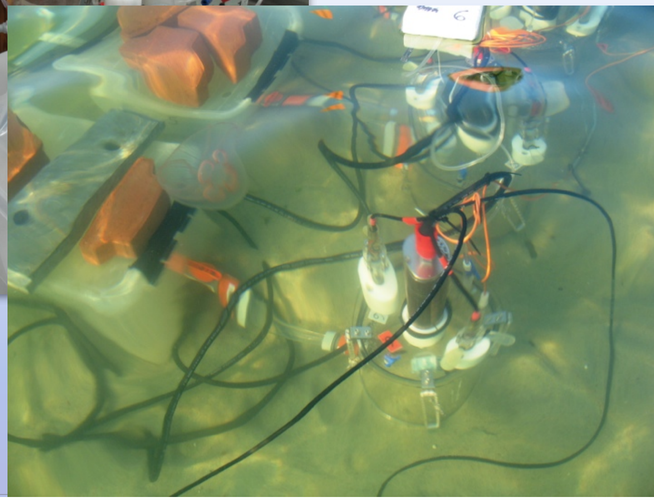






In situ incubations (benthic chambers)

21 hours (day/night at seep and reference site)

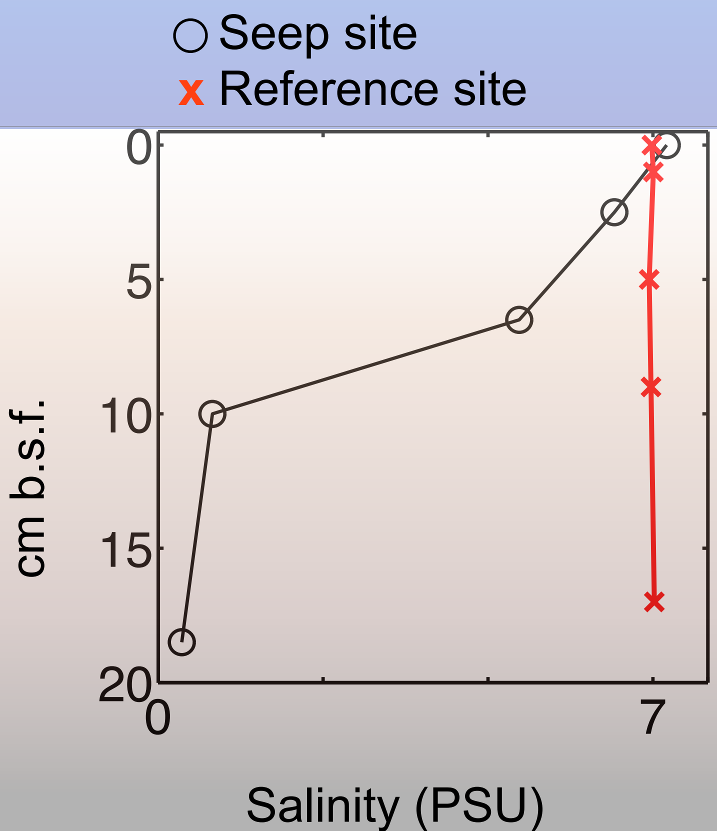
(DIC $\delta^{13}C_{DIC}$ Fe^{2+} Mn^{2+} Na^{2+} SO_4^{2-} PO_4^{3-} + SGD rates, O_2 benthic flux)

Porewater profiles

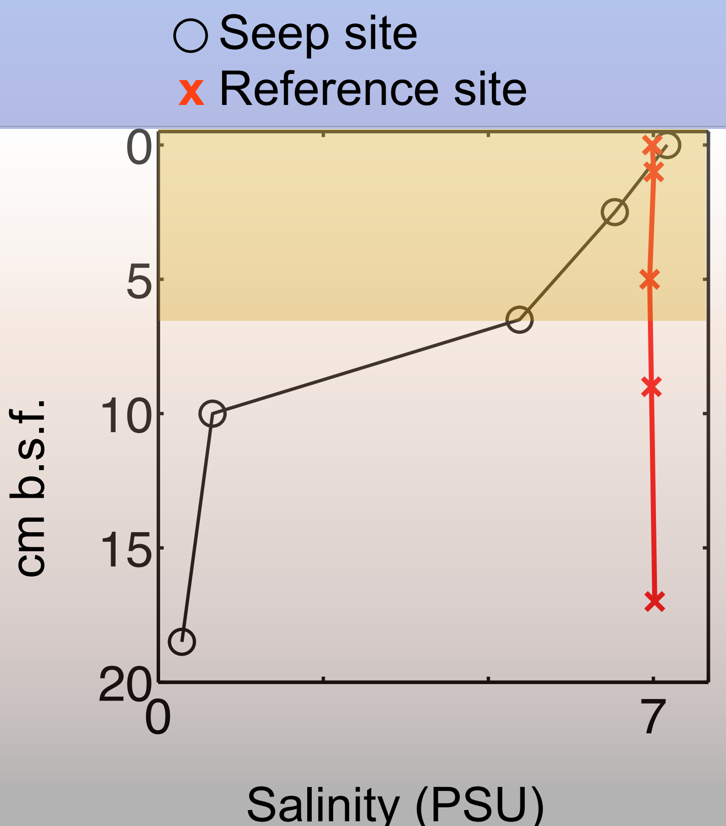
Samples from 5 depths (1-18 cm b.s.f. at seep and ref.) extracted in situ with a porewater lance and ex situ with rhizons

(DIC $\delta^{13}C_{DIC}$ Fe^{2+} Mn^{2+} Na^{2+} SO_4^{2-} PO_4^{3-})

Pore water profiles



Pore water profiles: seep site two-layer structure



Intense advective transport

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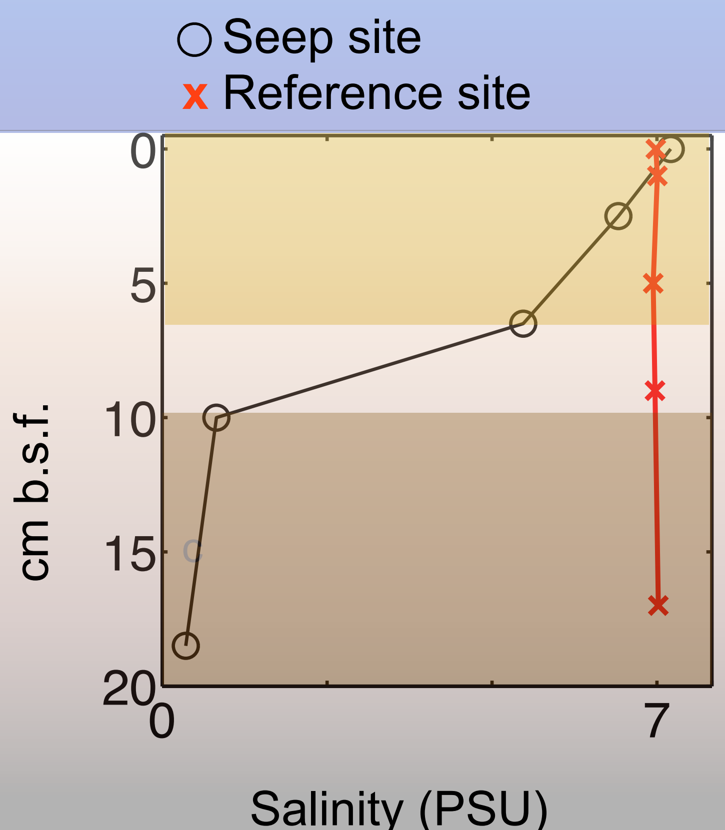
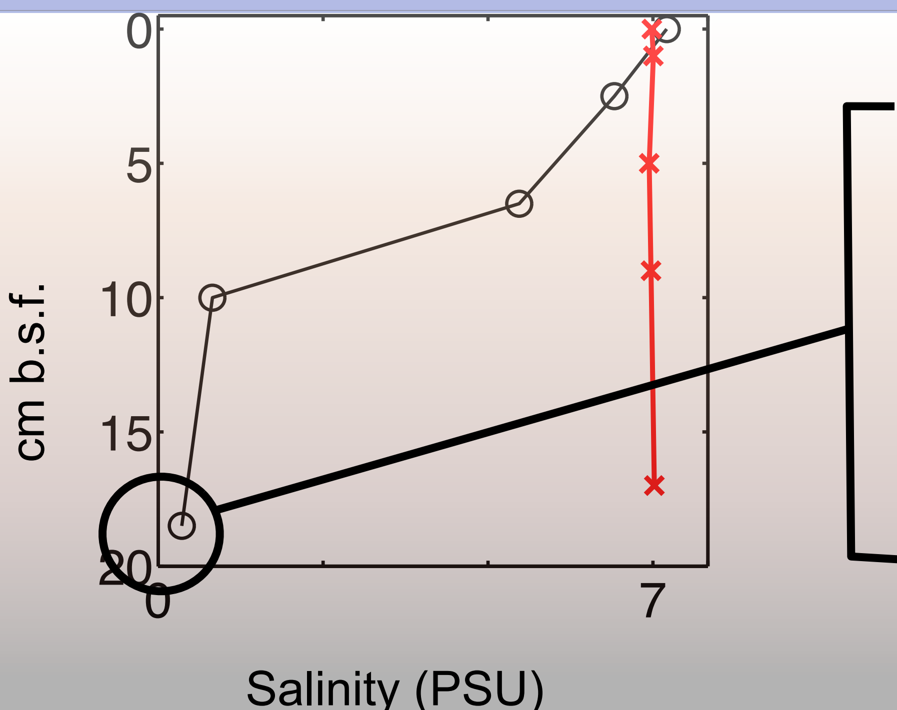


Intense advective transport

No exchange with bottom water

Groundwater characteristics

	Sal. (PSU)	O_2 µmol L^{-1}	DIC mmol L^{-1}	$\delta^{13}C_{DIC}$ ‰	Fe^{2+} µmol L^{-1}	Mn^{2+} µmol L^{-1}	Ca^{2+} µmol L^{-1}	Mg^{2+} µmol L^{-1}	SO_4^{2-} mmol L^{-1}	PO_4^{3-} µmol L^{-1}	HS^- µmol L^{-1}	CH_4 µmol L^{-1}
Bottom water	7	300	1.7	0.3	0.07	0.04	2.5	8.5	4.6	0.6	0	-
Ground-water (18 cm b.s..f)	0	0	6.4	-13.6	1	5.4	1	0.6	0.03	60	300	300

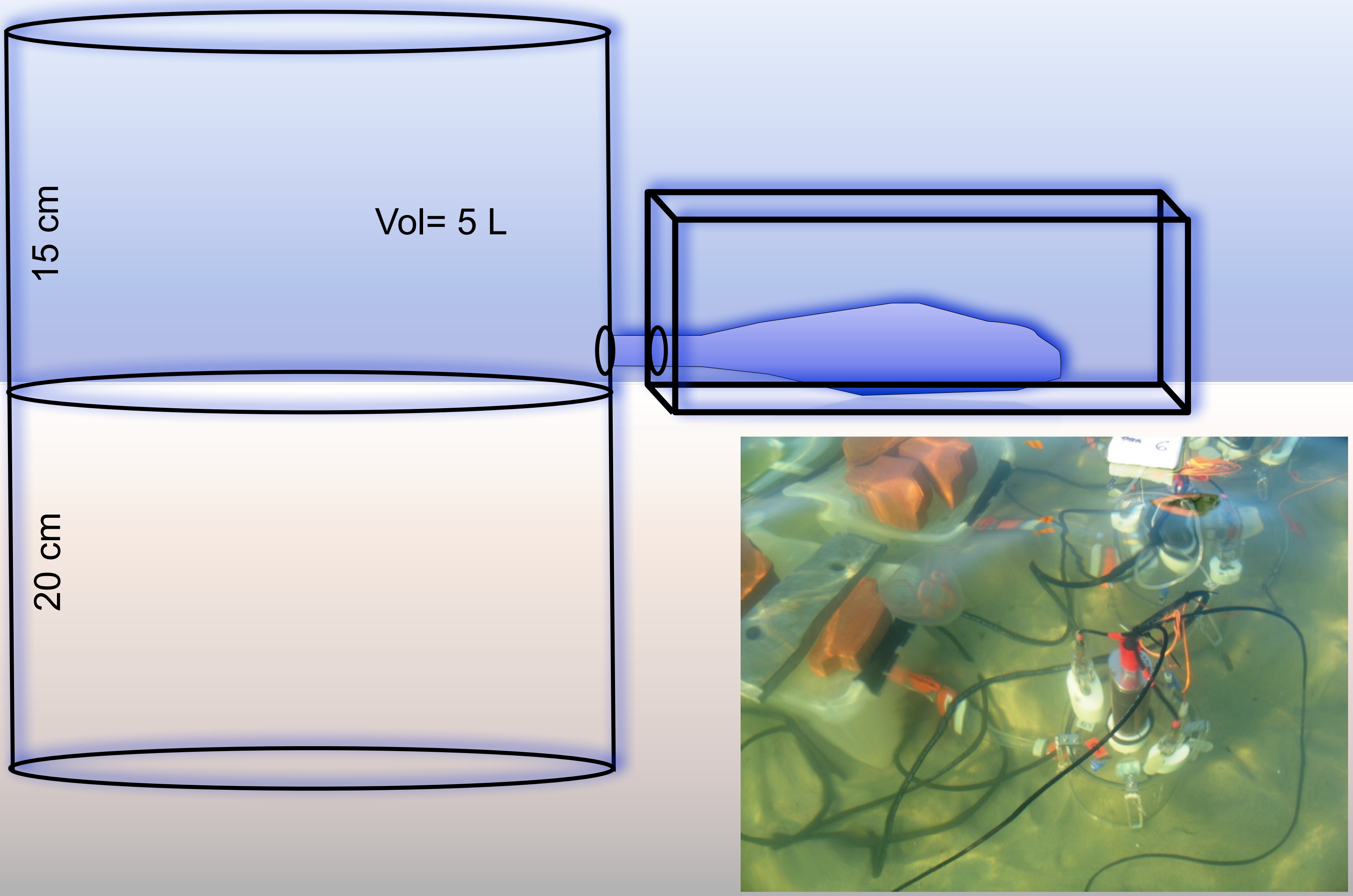


Fresh, anoxic , DOC (up to 7 mg L^{-1})

Enriched in

- DIC ($\delta^{13}C_{DIC}$ signature -13.6 ‰)
- Methane (300 µmol L^{-1})
- Sulfides (300 µmol L^{-1})
- Phosphates and Silicates (60, 600 µmol L^{-1})

Seepage meters-benthic chambers



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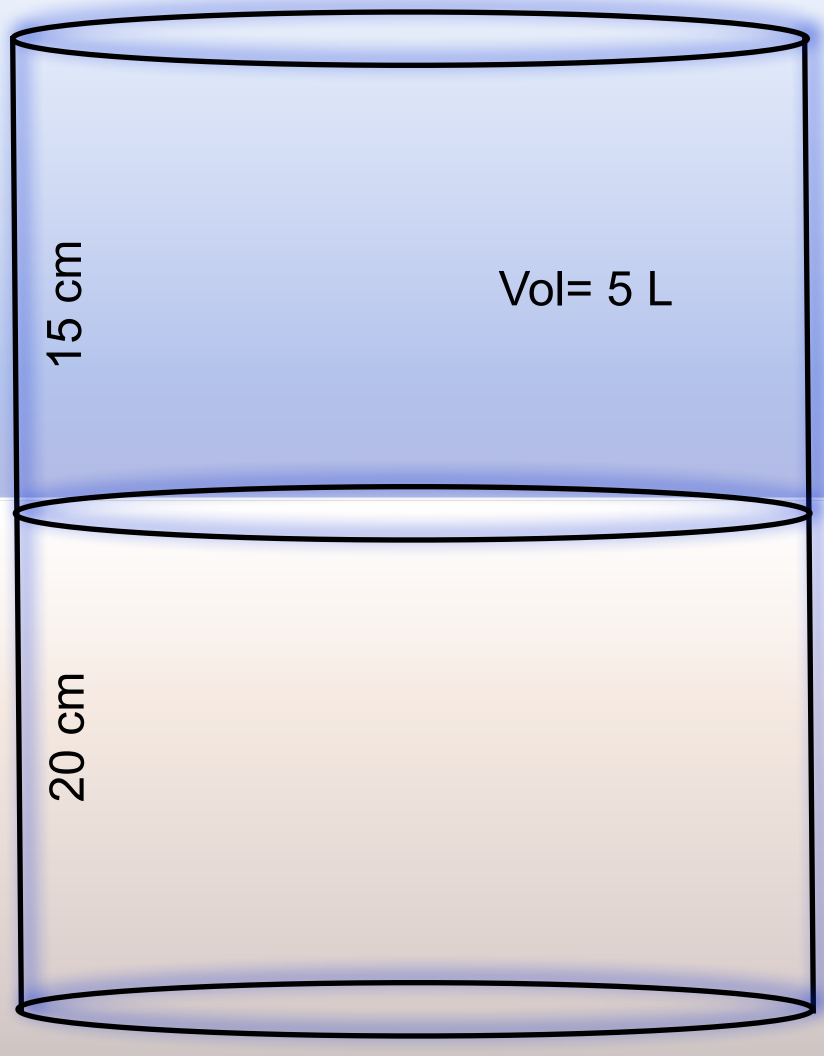
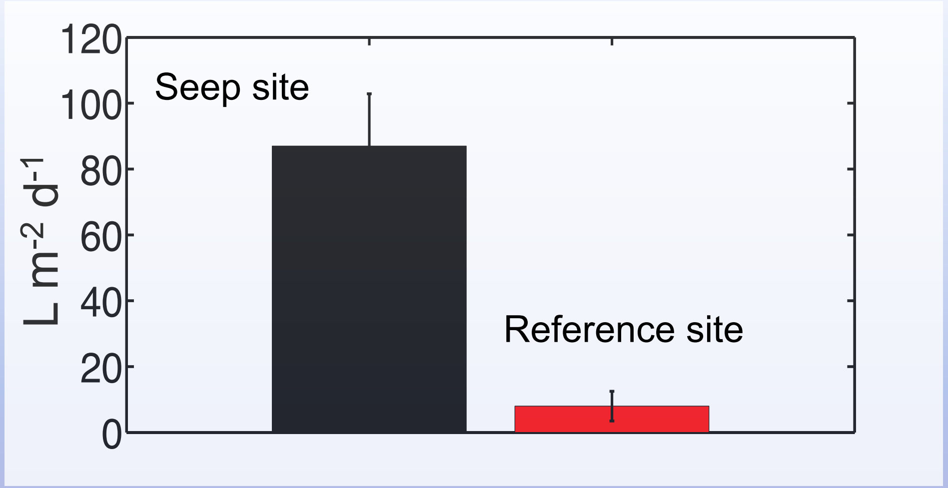
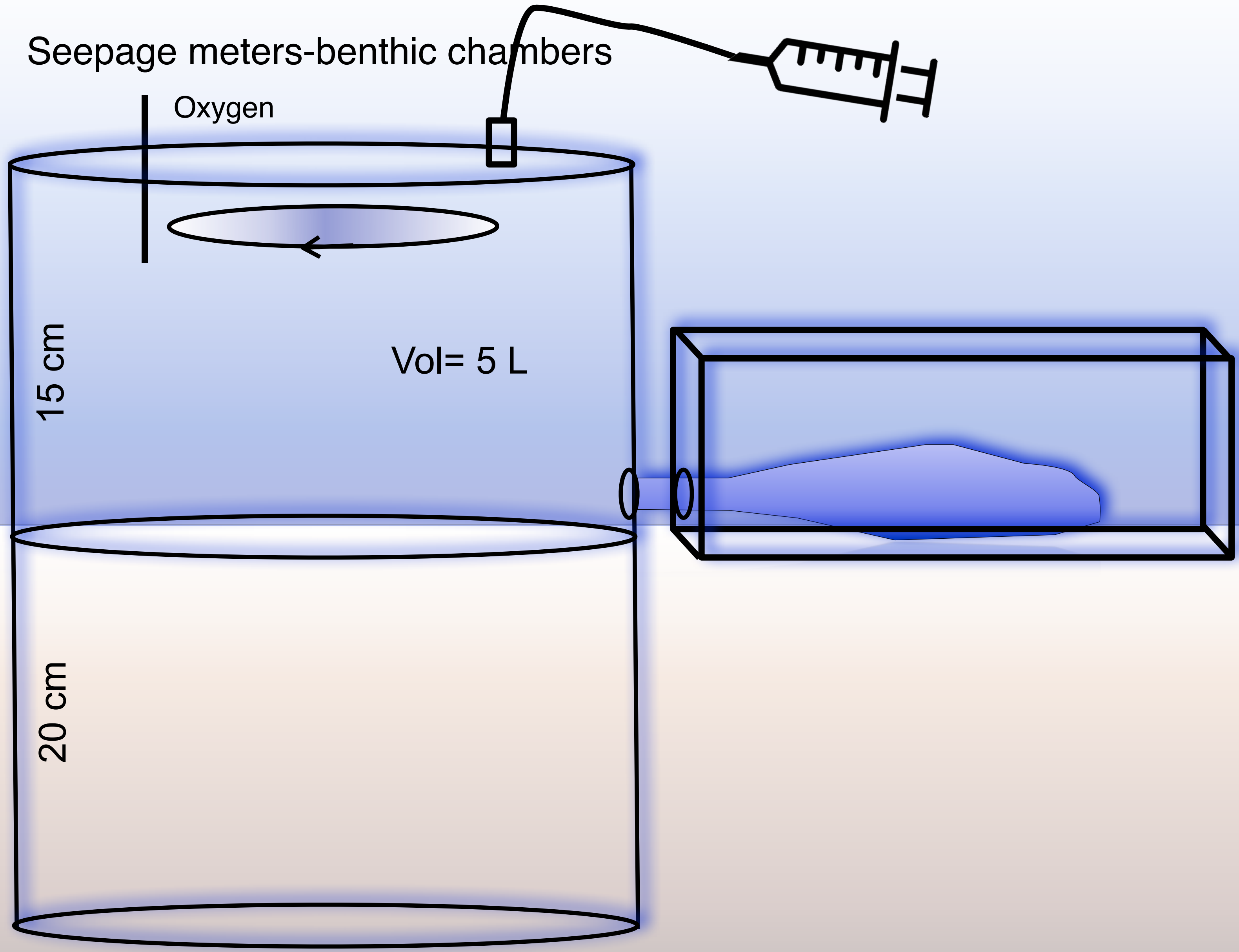
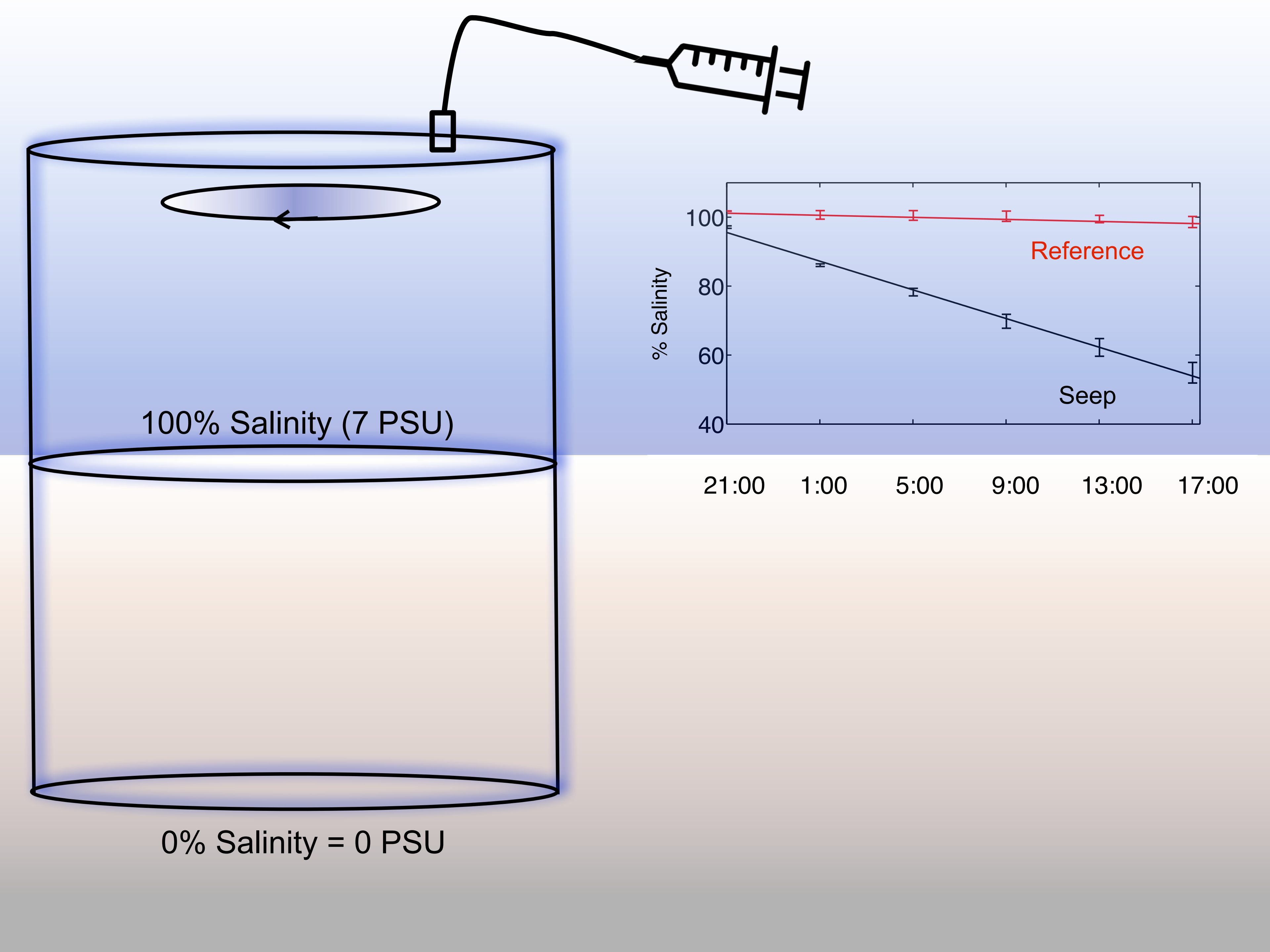


Seepage rates

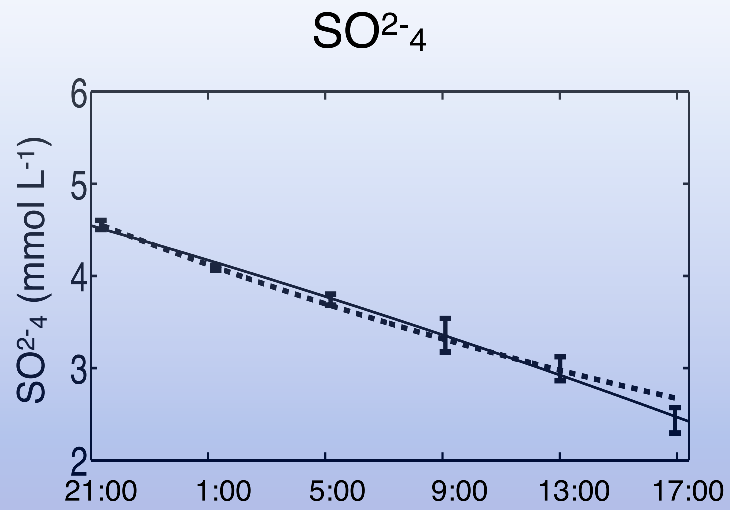


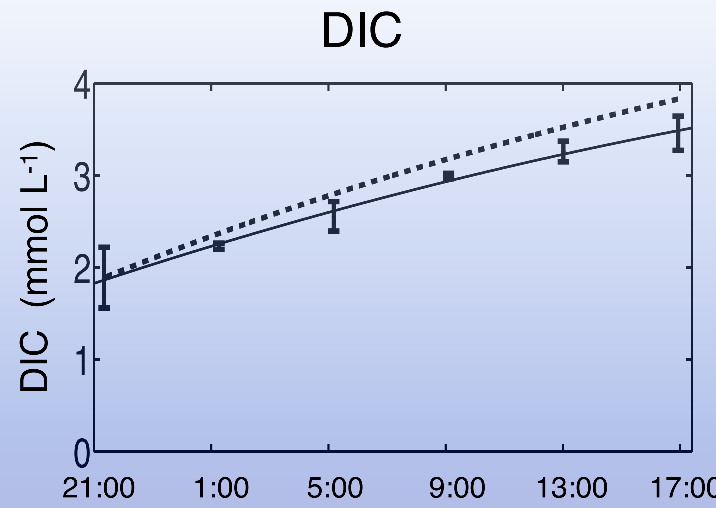
Seepage meters-benthic chambers



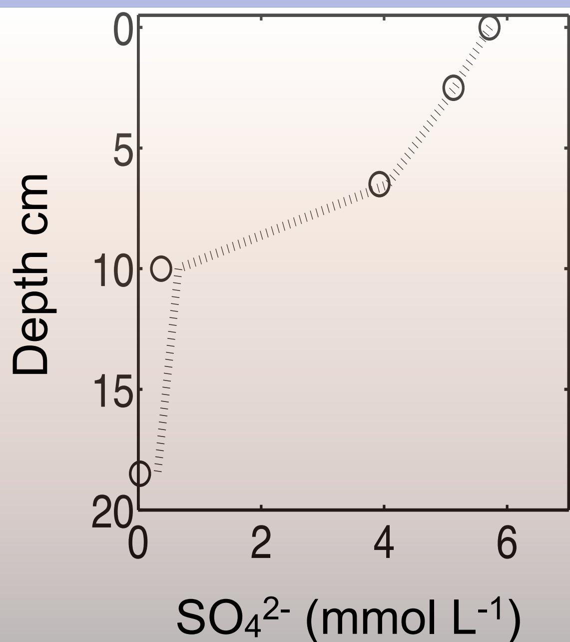

100% Salinity (7 PSU)
0% Salinity = 0 PSU
% Salinity
100
80
60
40
Reference
Seep
21:00
1:00
5:00
9:00
13:00
17:00

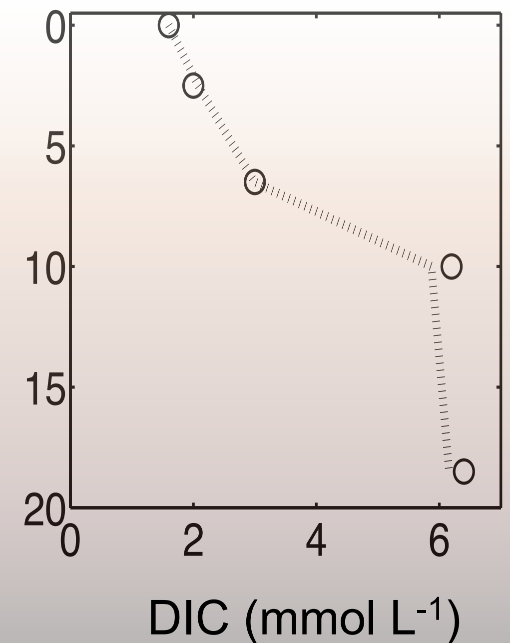
Temporal and spatial solute concentration gradients- Conservative behavior



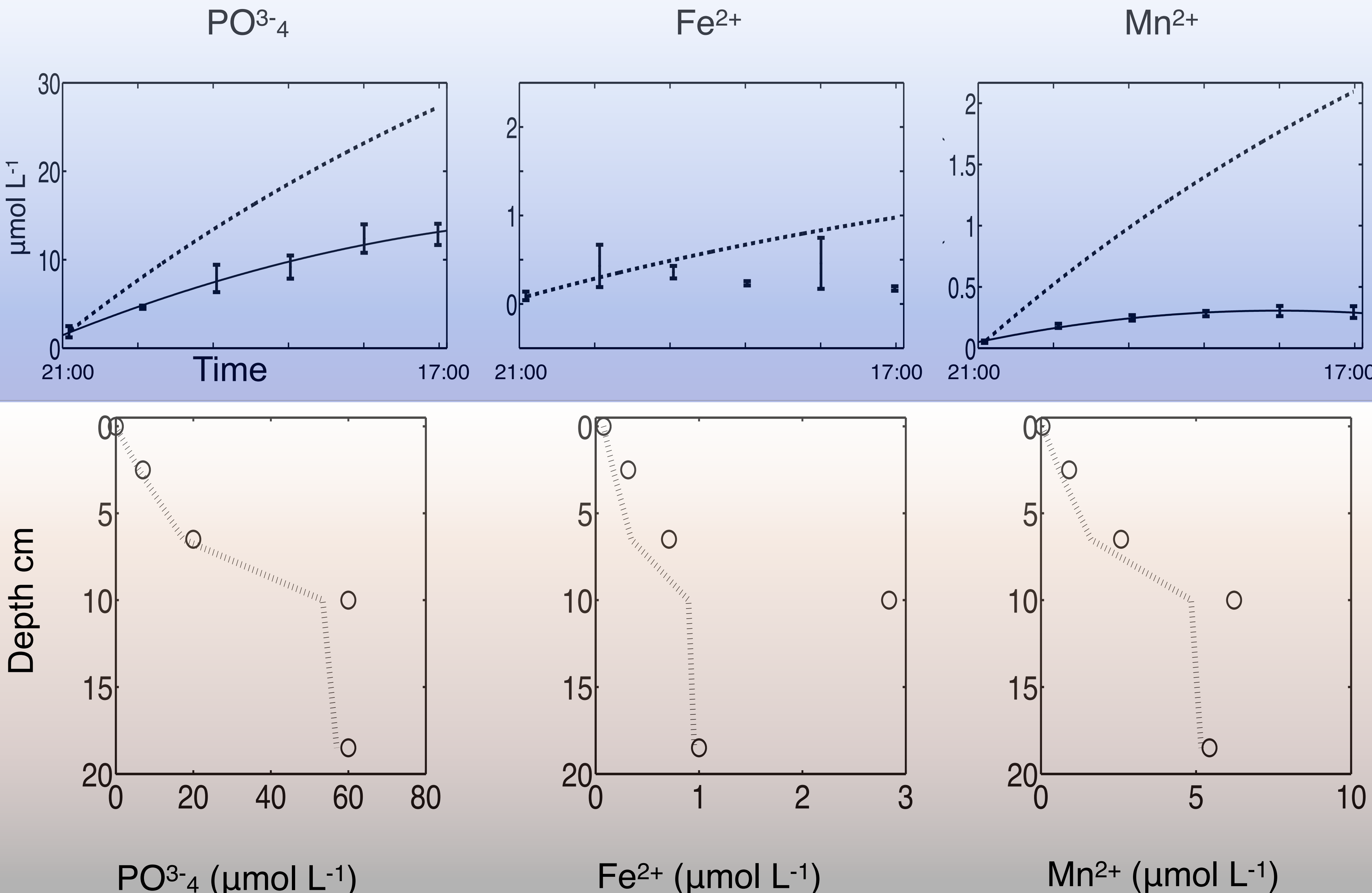


Time

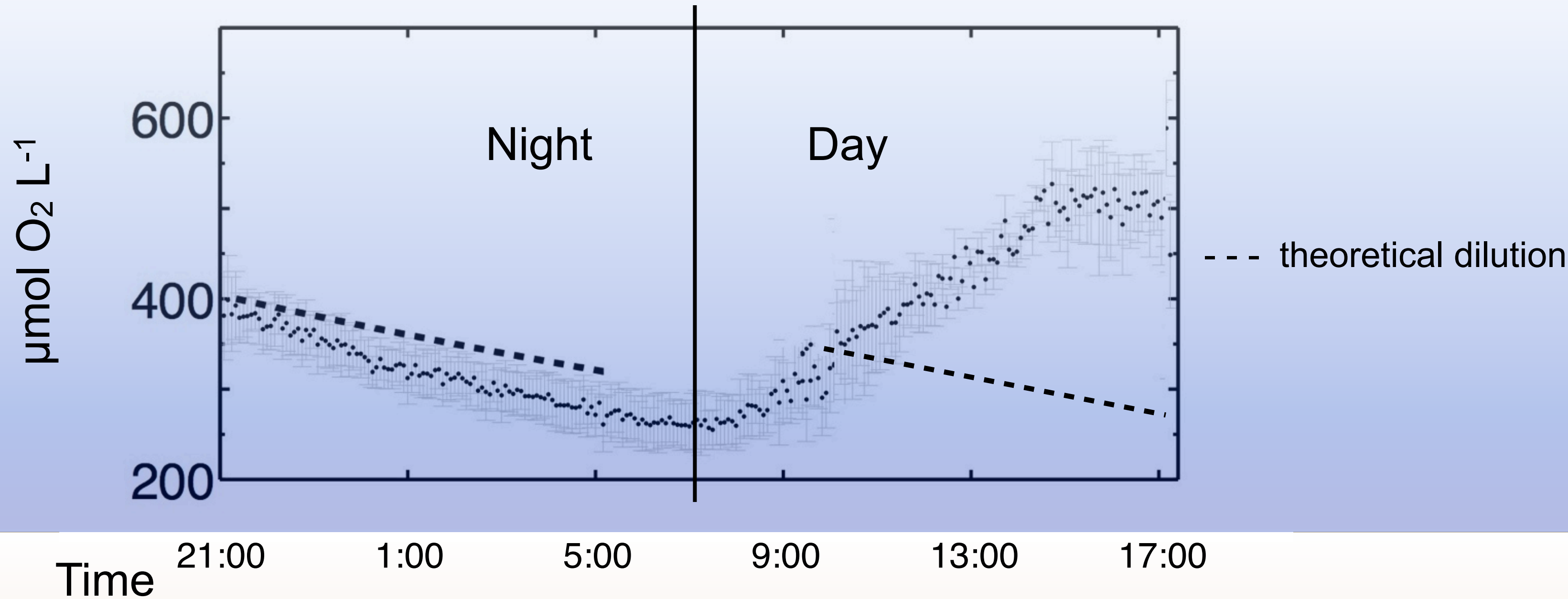




Temporal and spatial solute concentration gradients- Non conservative behavior



Temporal oxygen concentration gradients



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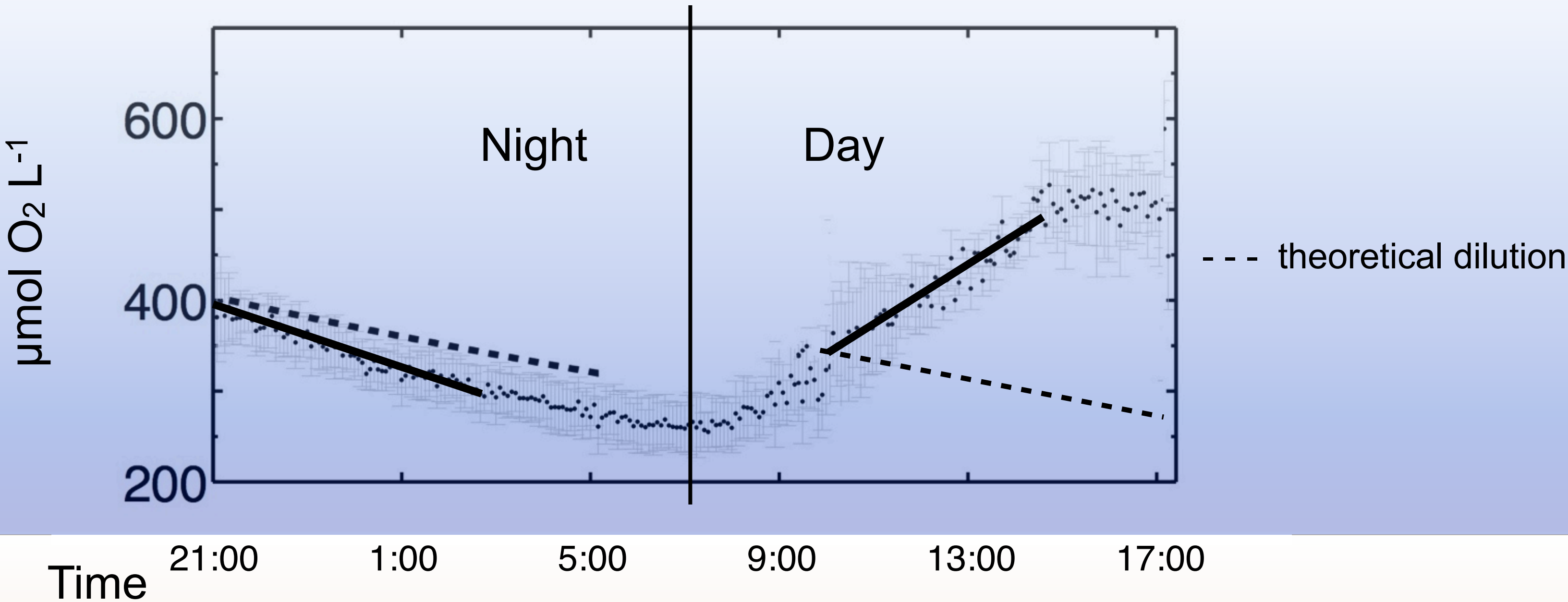
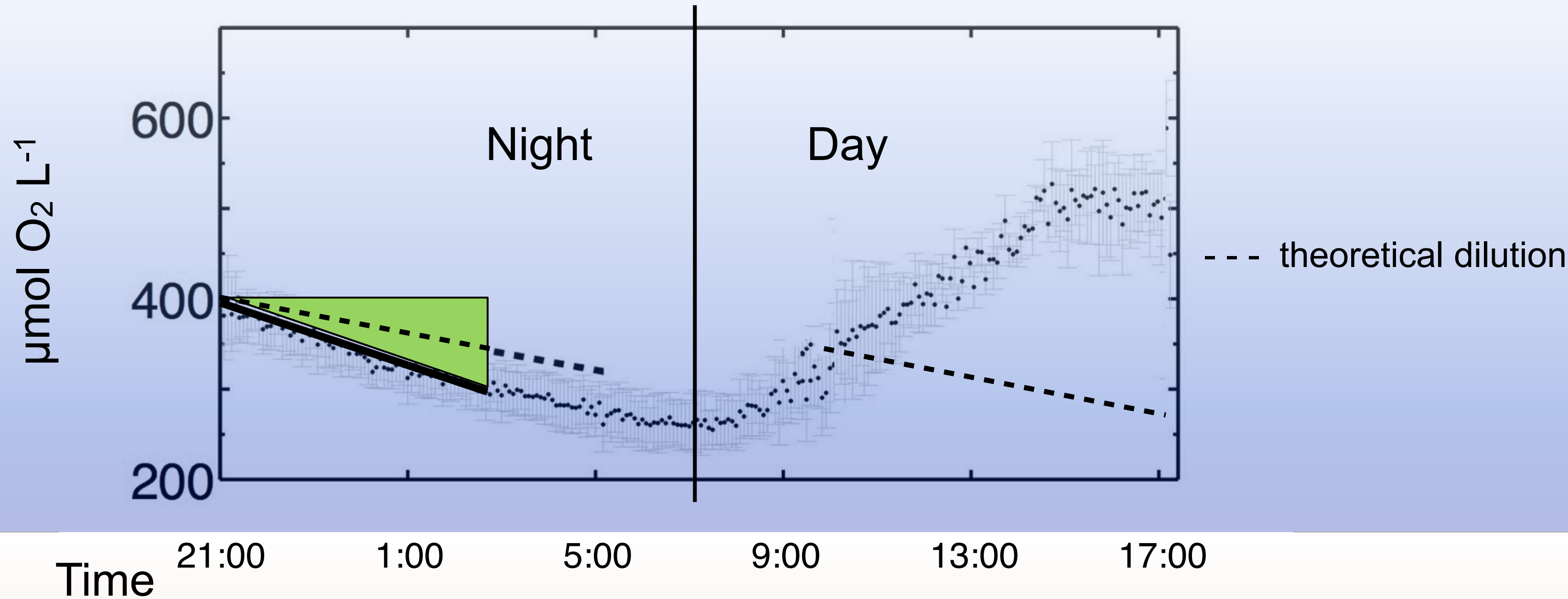


Benthic oxygen flux

= based on slope of linear regressions of solute concentration time series (optode readings) for dark and light periods.

Temporal oxygen concentration gradients



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Measured oxygen flux = all processes of oxygen removal and release.

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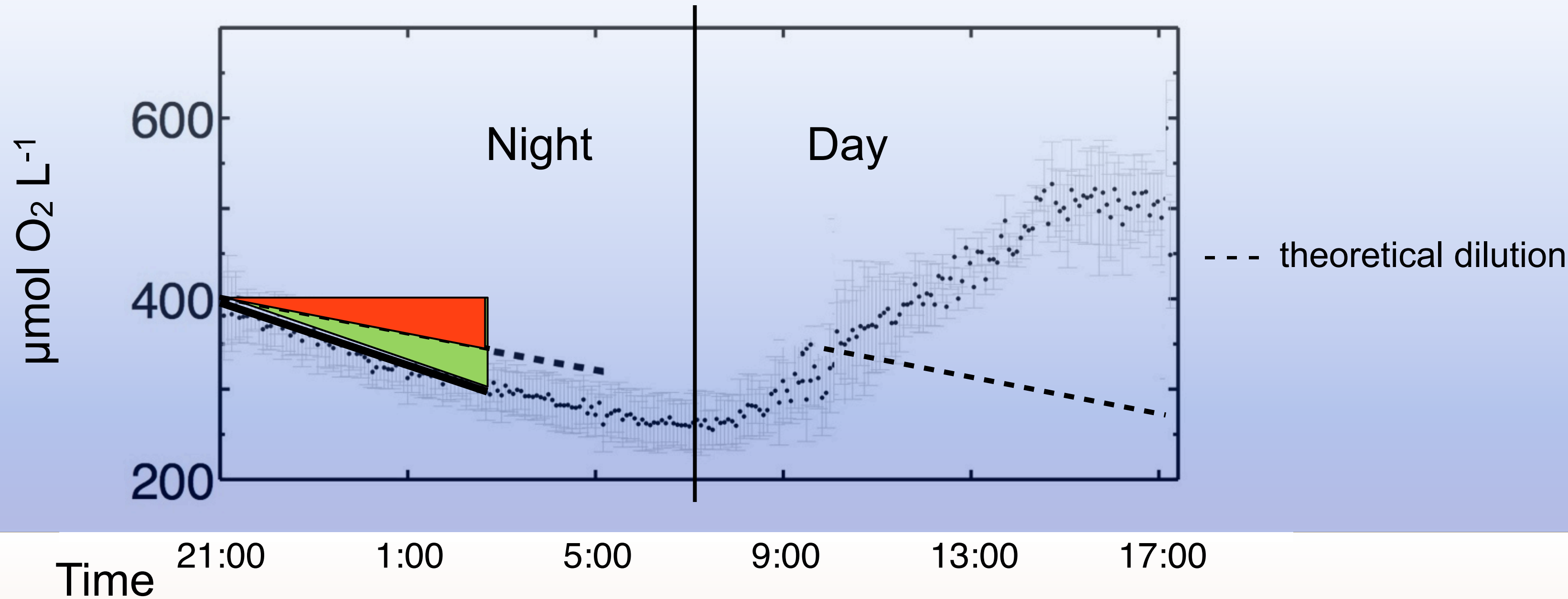

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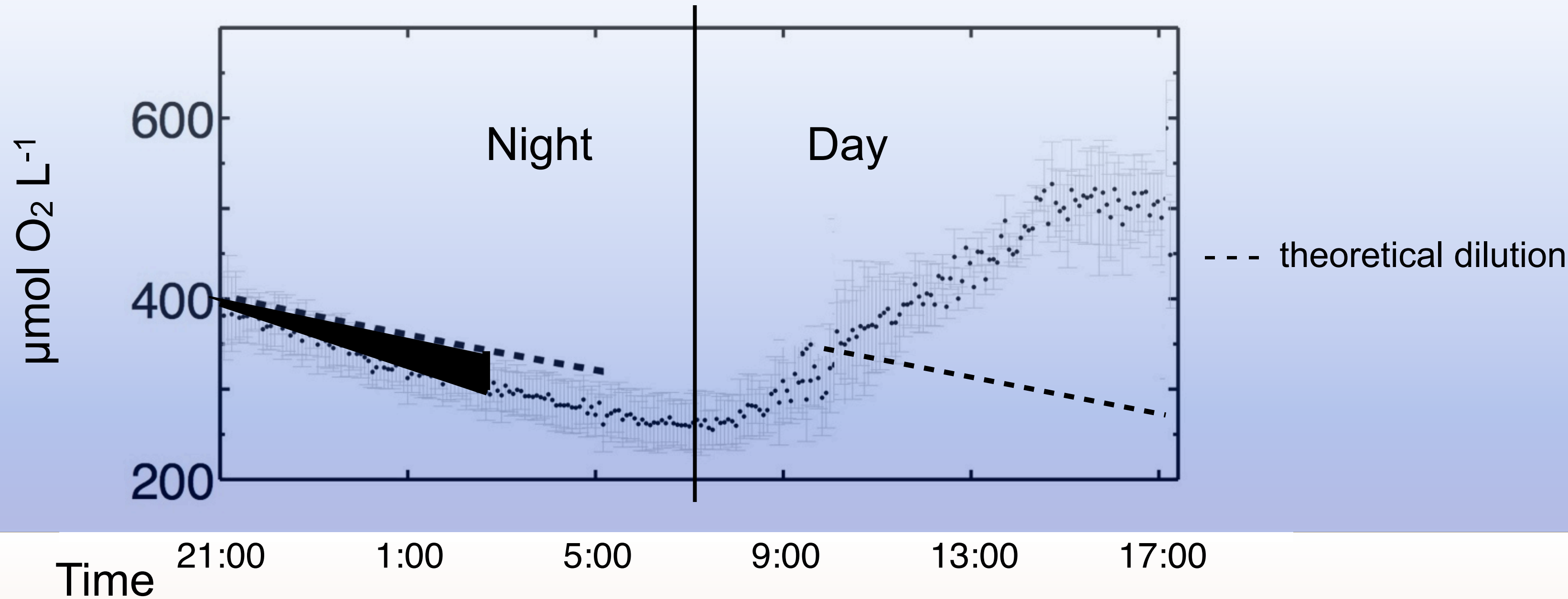

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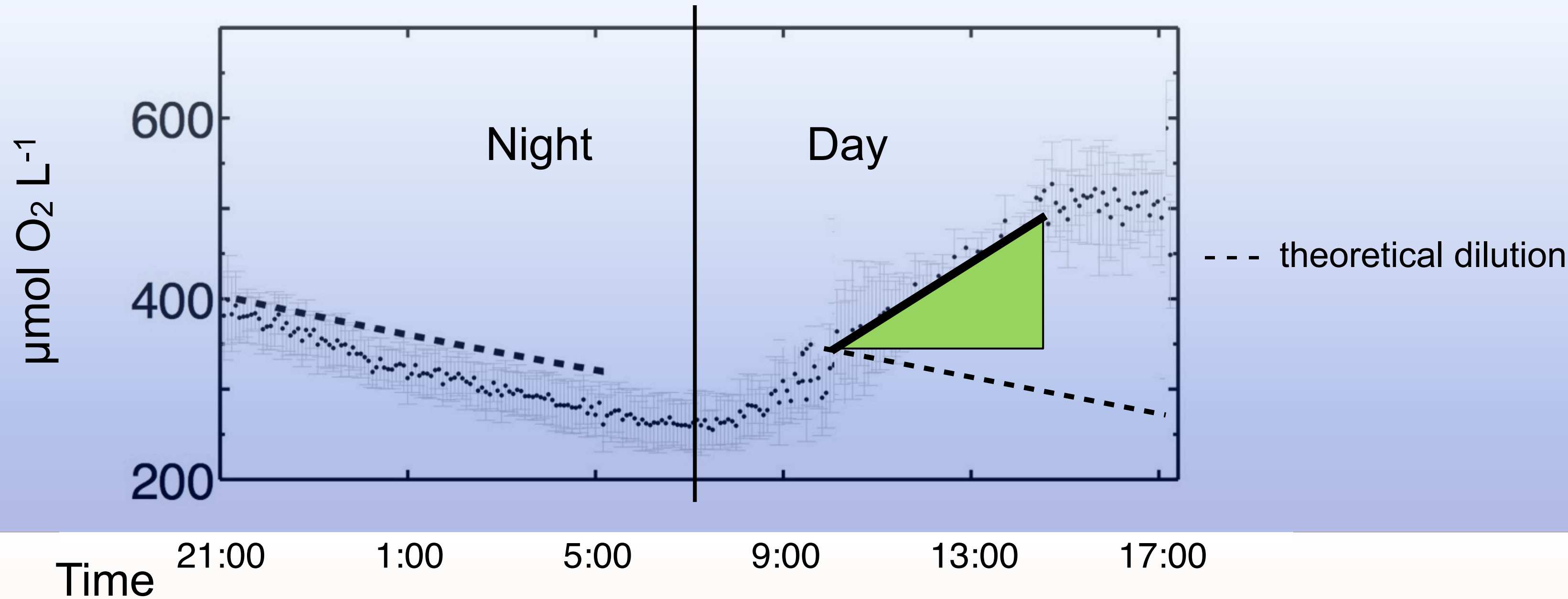
Net oxygen flux = corrected for SGD-related apparent flux

Temporal oxygen concentration gradients



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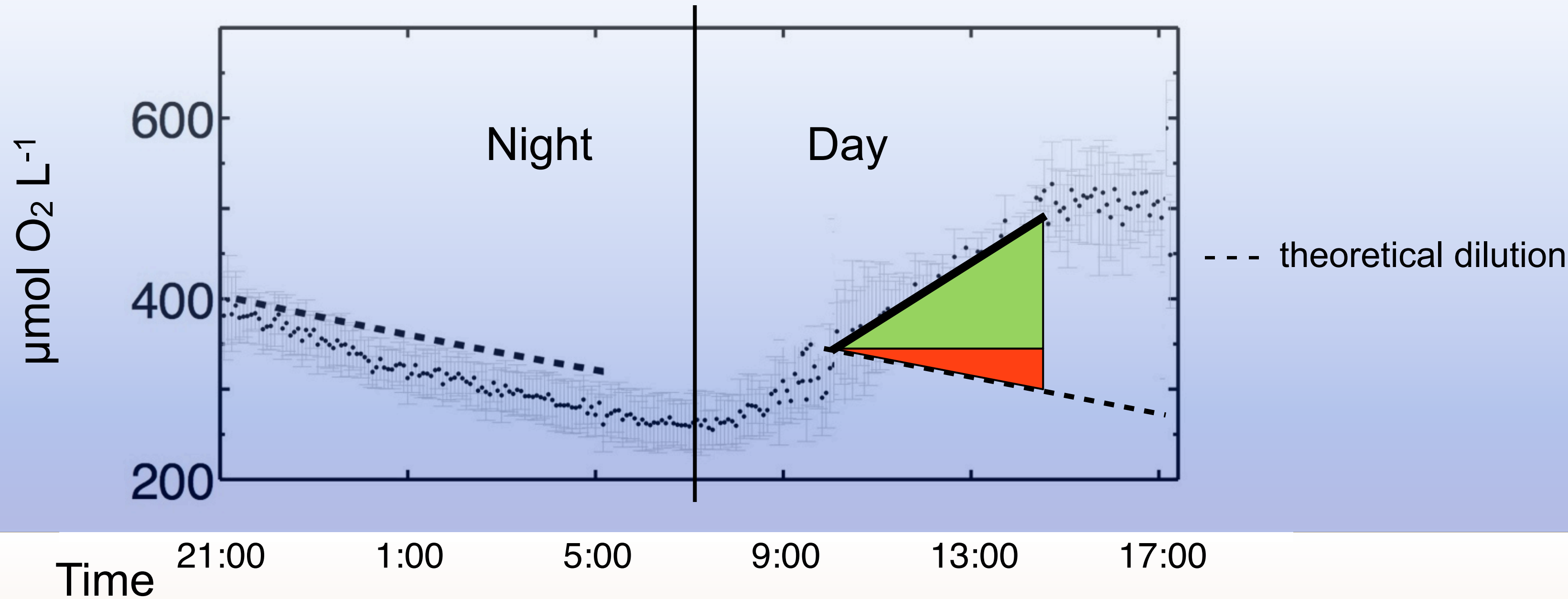

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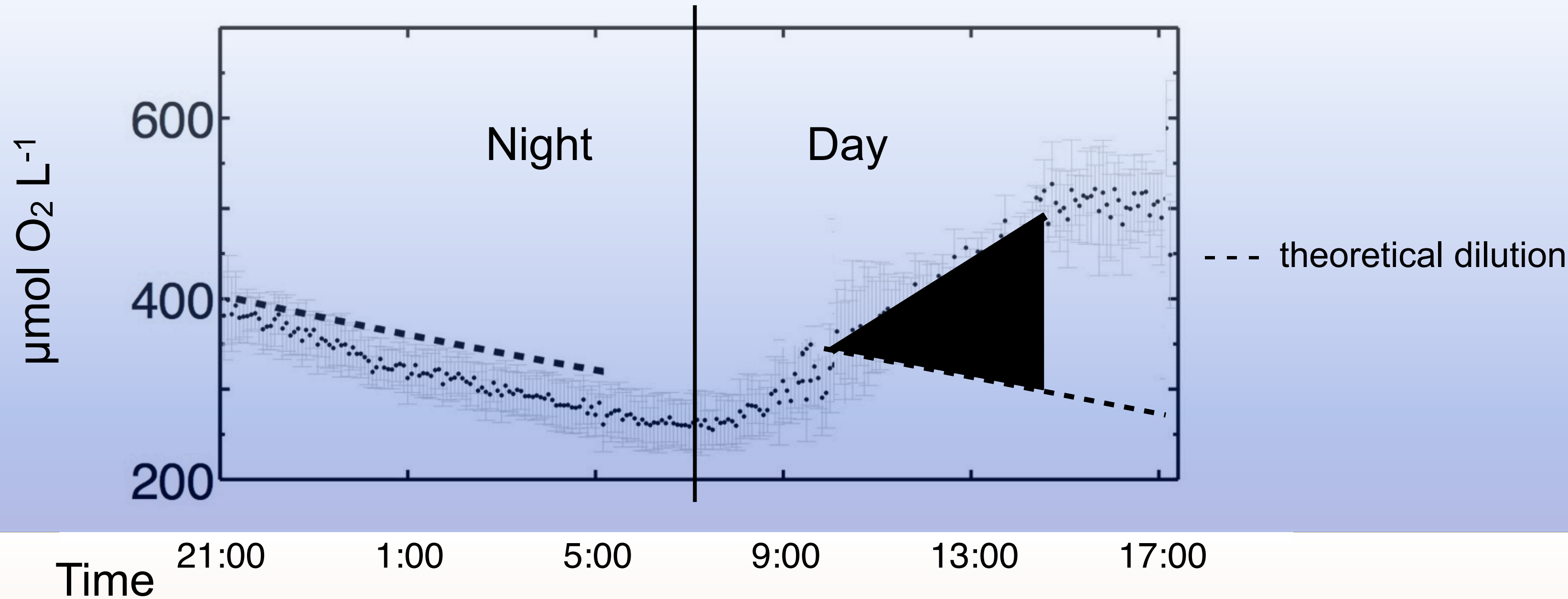

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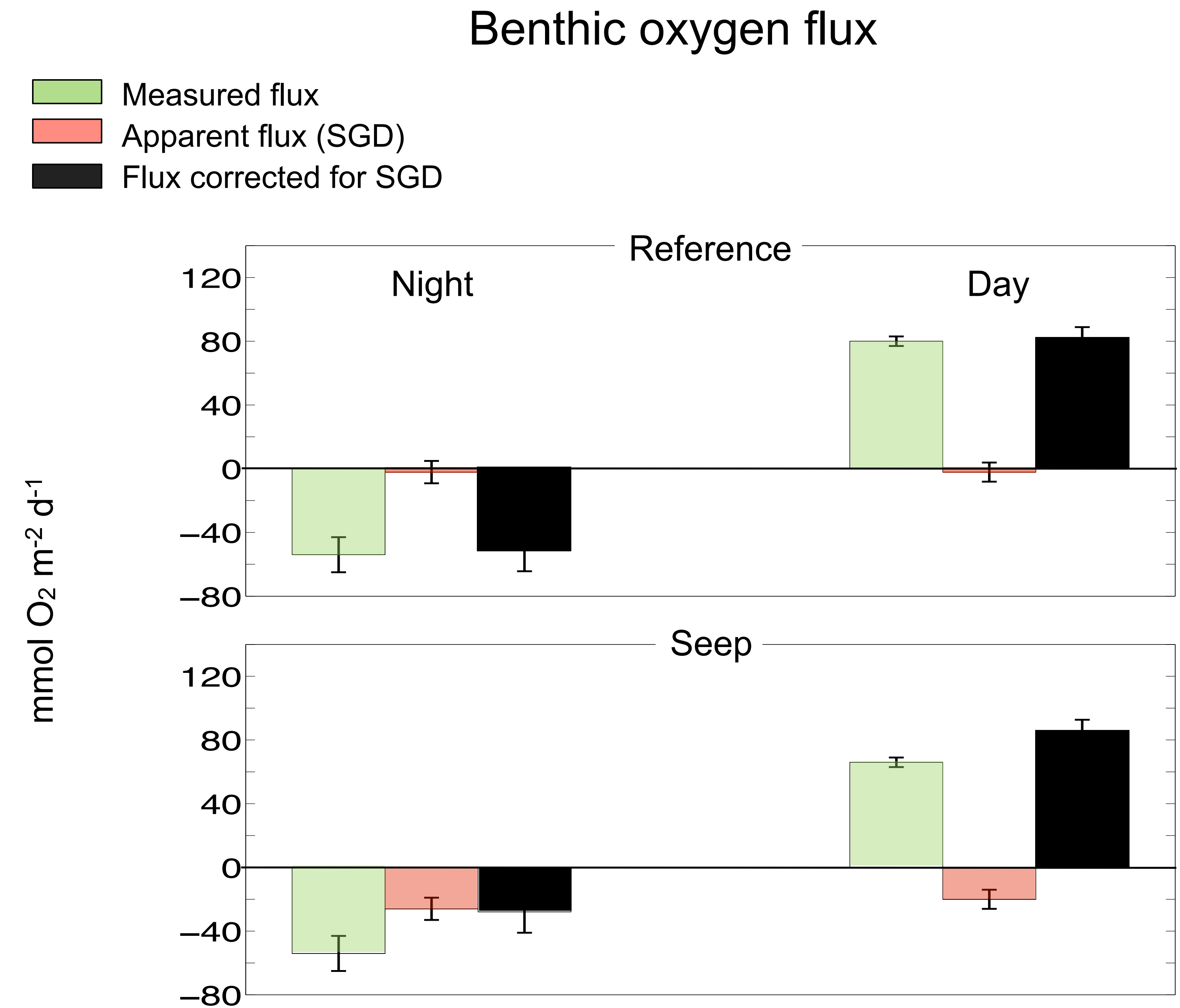
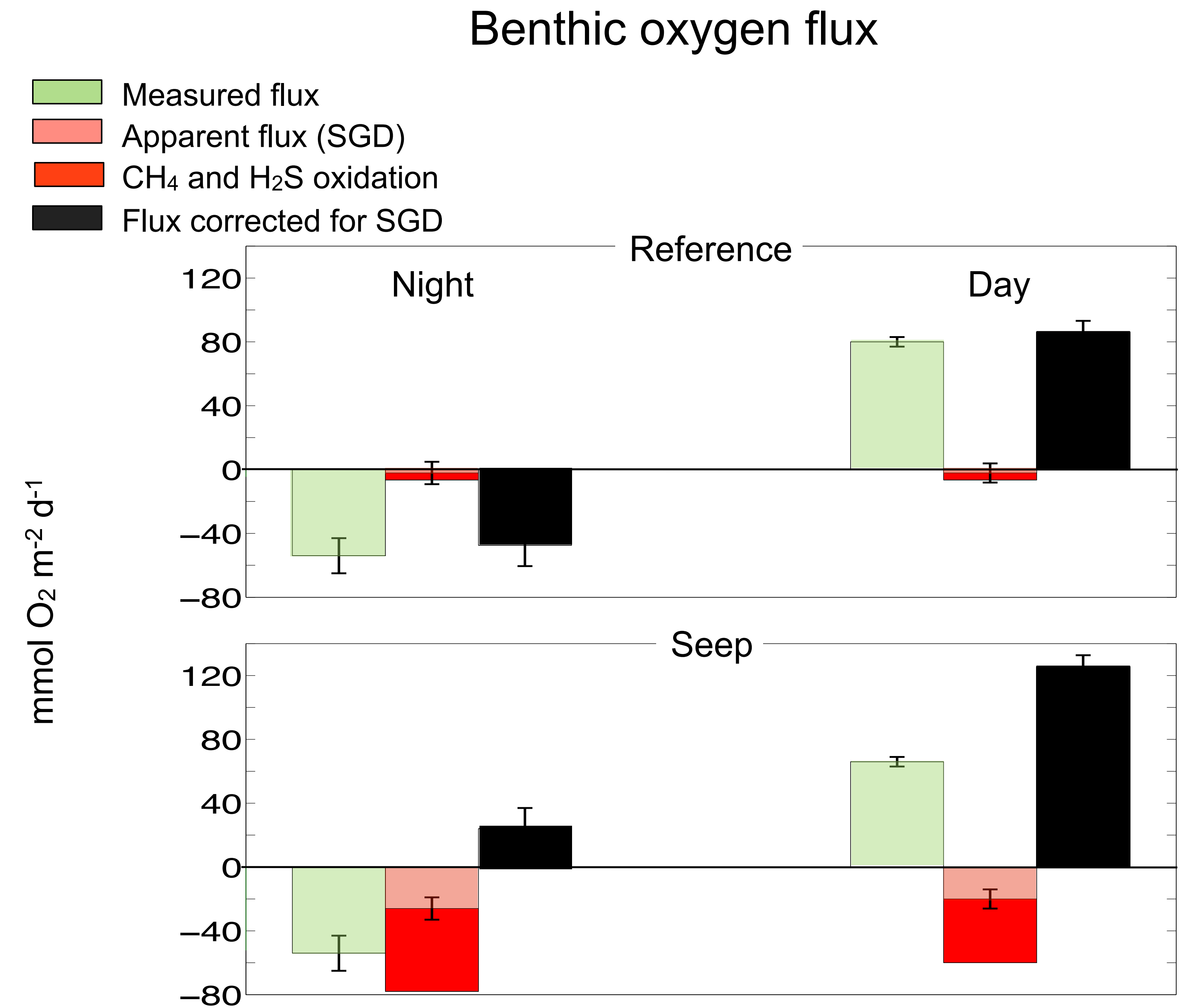


Benthic oxygen flux
Measured flux
Apparent flux (SGD)
Flux corrected for SGD
Reference
Night
Day
120
80
40
0
−40
−80
mmol O_2 m^{-2} d^{-1}
Seep
120
80
40
0
−40
−80


Benthic oxygen flux
Measured flux
Apparent flux (SGD)
CH4 and H2S oxidation
Flux corrected for SGD
Reference
Night
Day
Seep
mmol O2 m-2 d-1
120
80
40
0
−40
−80

- Oxygen may be fully used to oxidize H_2S and CH_4

O_2

$$HS^{\bullet} + O_2 \rightarrow HO^{\bullet} + SO^{\bullet}$$

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

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H_2S

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- If so, no oxygen would be left for OM mineralization..

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OM mineralization ?

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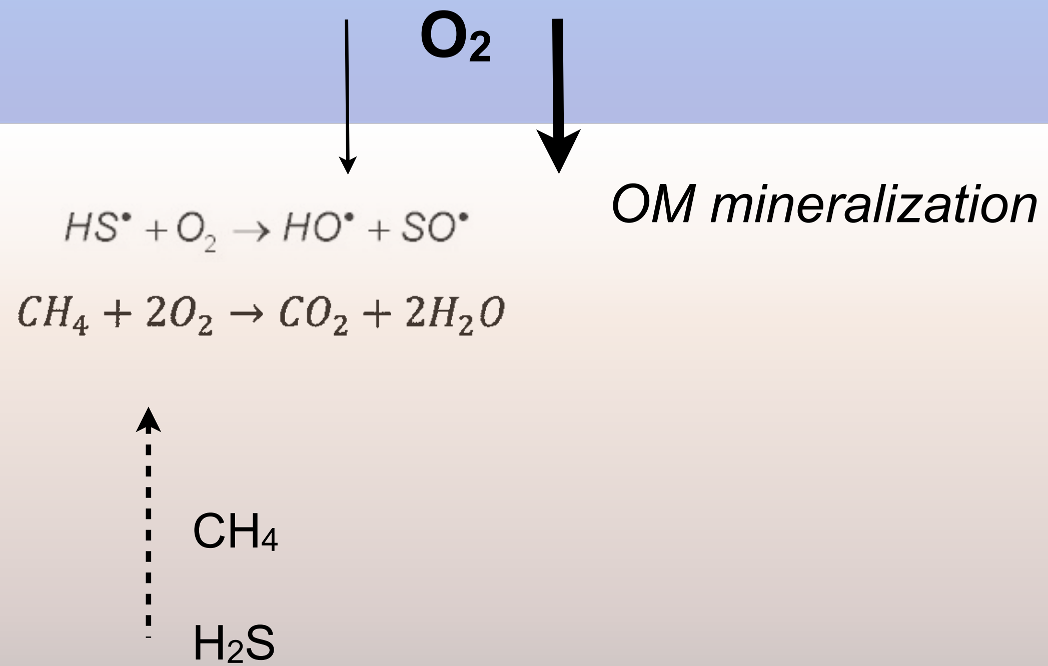

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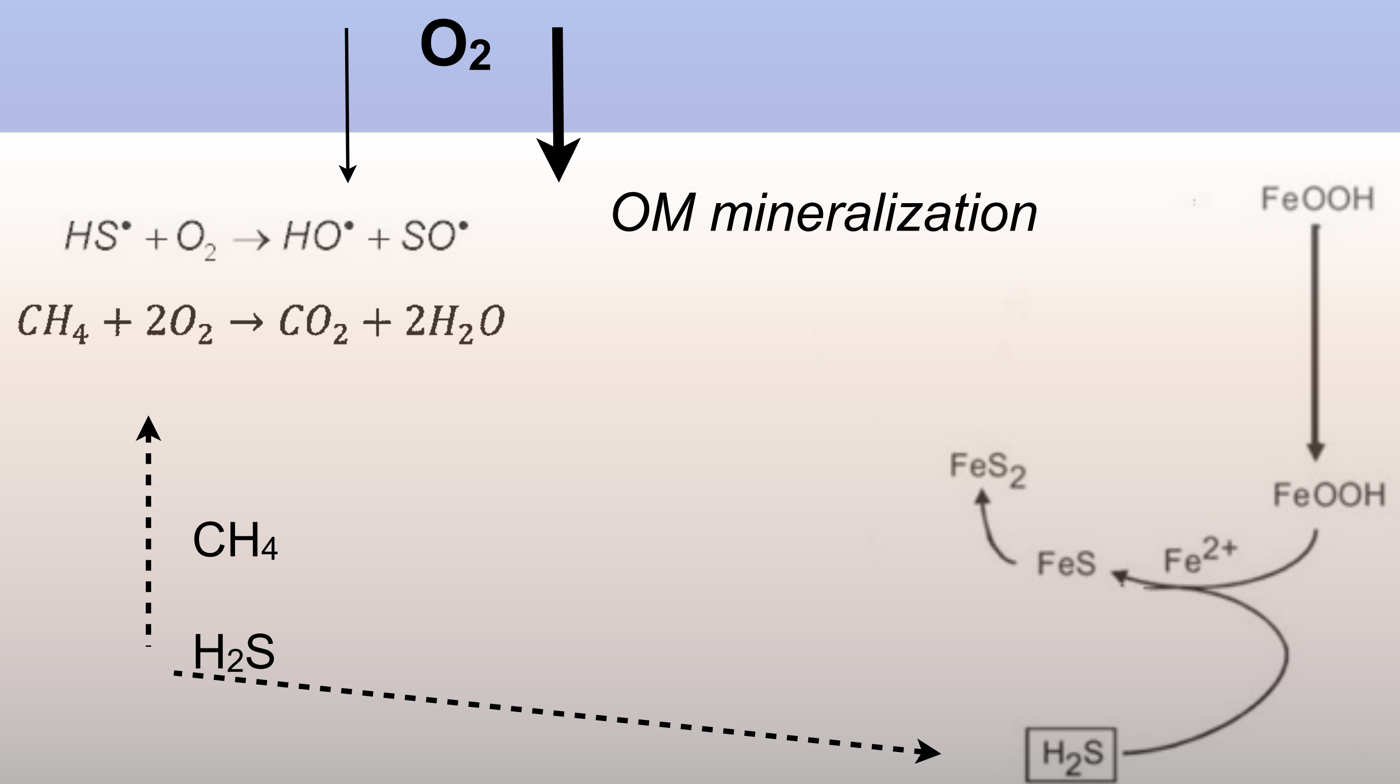

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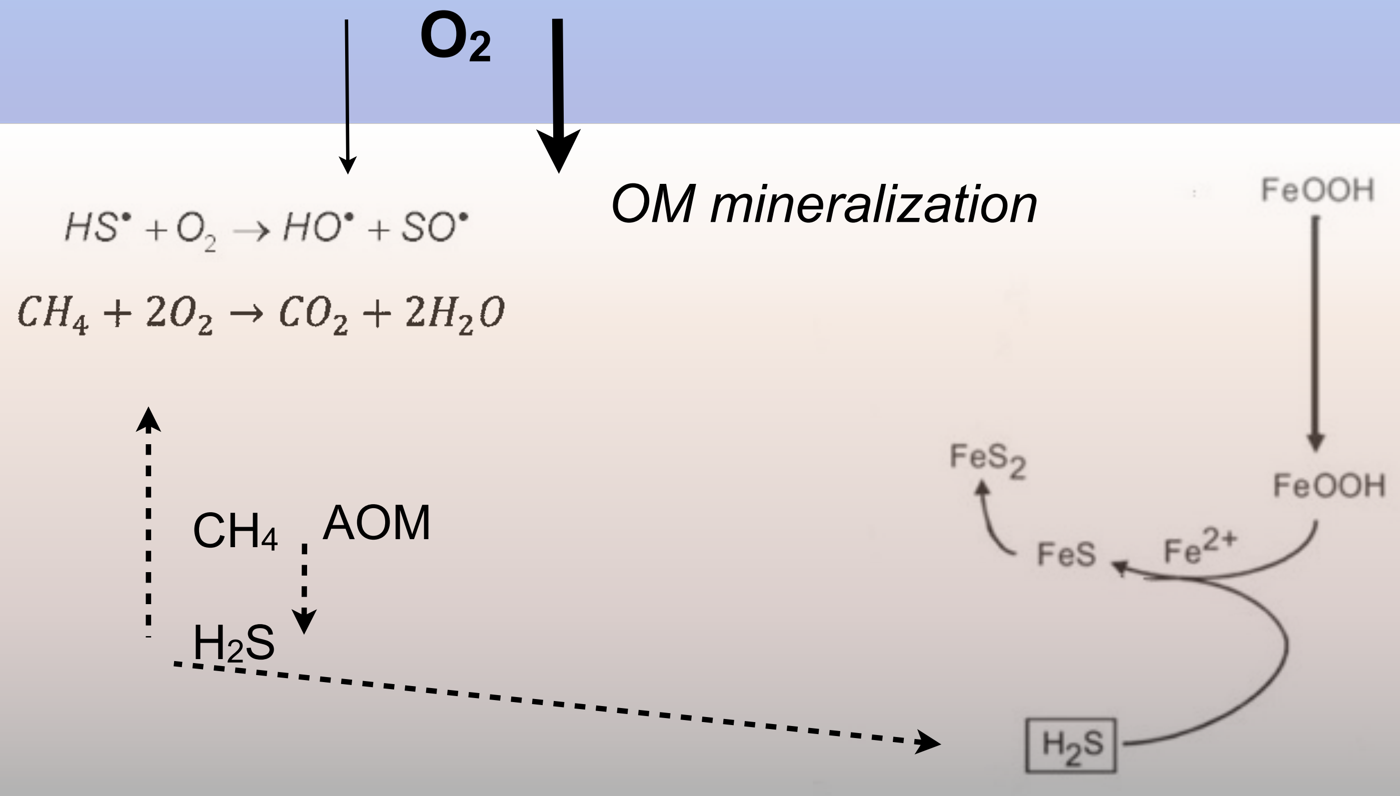

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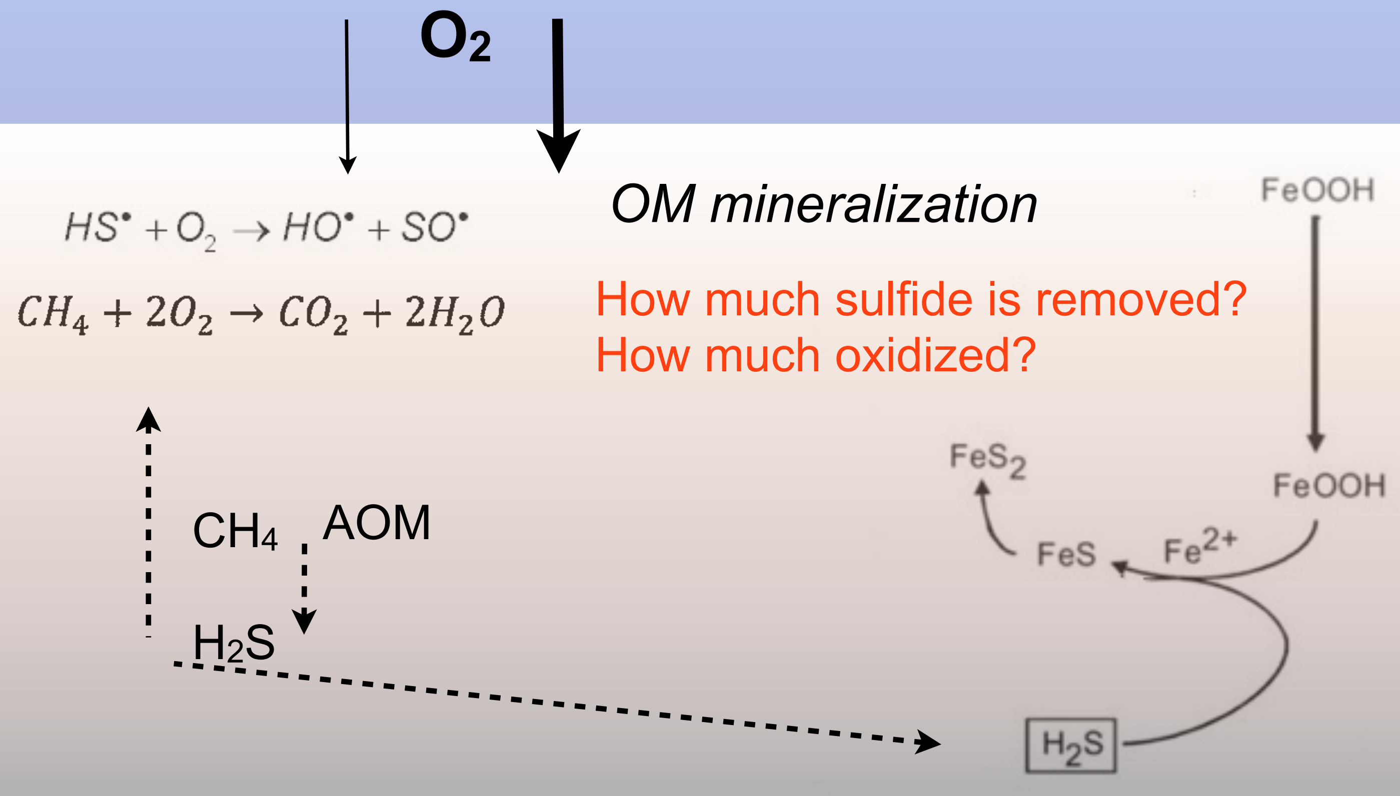
Open questions



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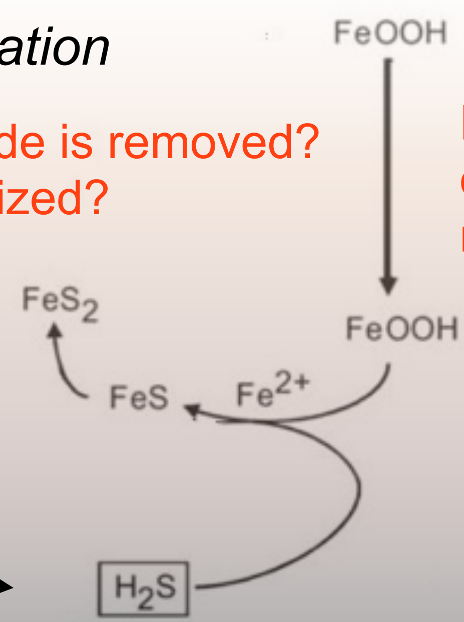
How much sulfide is removed?
How much oxidized?

How (and when) is the oxidized iron pool replenished?

CH_4 AOM

H_2S



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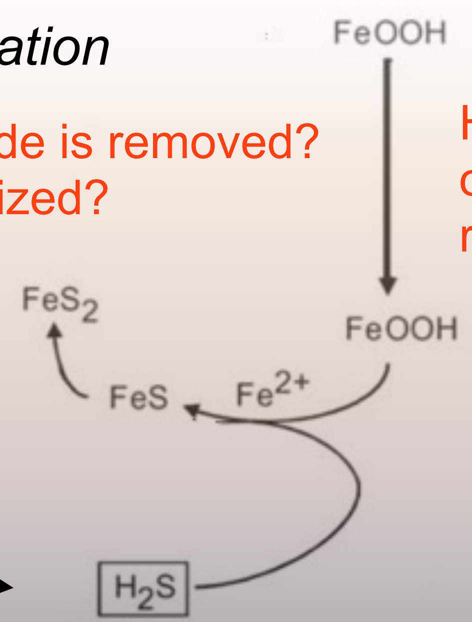
CH_4 AOM H_2S

Which methane oxidation pathway?



Conclusions

Combining porewater sampling and flux measurements with “seepage meter-benthic chambers” seem to be a trustworthy approach to tackle accumulation or removal of groundwater constituents along its flowpath and the effect on benthic coastal systems

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- Oxygen fluxes at the reference site match previous studies that identified aerobic respiration as the major OM remineralization pathway.

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- Both sites show similar bulk oxygen fluxes and are net autotrophic
- Oxygen fluxes at the reference site match previous studies that identified aerobic respiration as the major OM remineralization pathway.
- At the seep site seepage of anoxic waters significantly contributes to oxygen uptake and anaerobic mineralization pathways may play a more prominent role.

Acknowledgments

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SENSEnet
International Sensor Development Network

AMBER

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Leibniz Institute for Baltic Sea Research Warnemünde
IOW

AWI
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