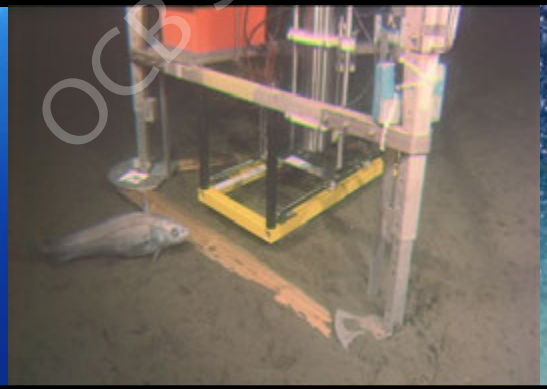
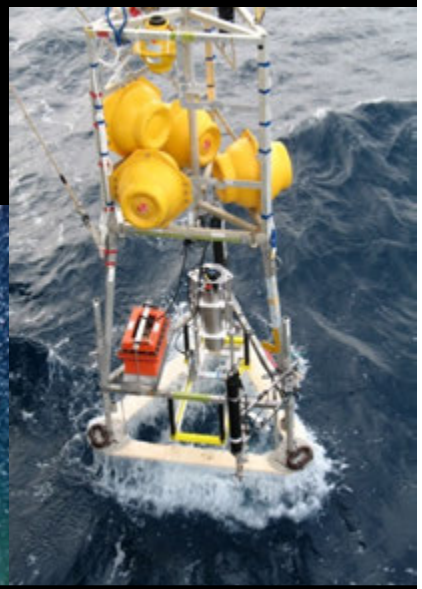
Hadal trenches hot spots for organic carbon cycling in the deep ocean

Ronnie N Glud

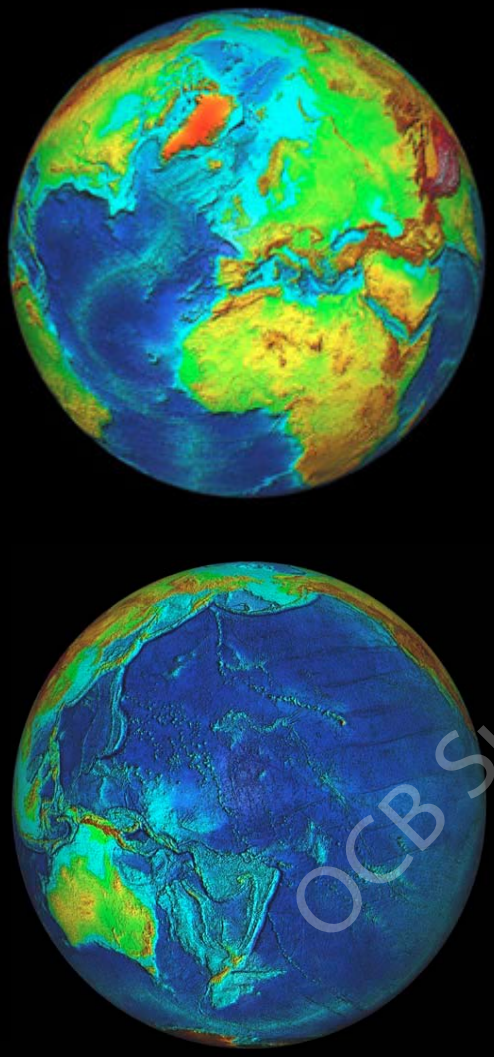
University of Southern Denmark
Department of Biology – Nordcee

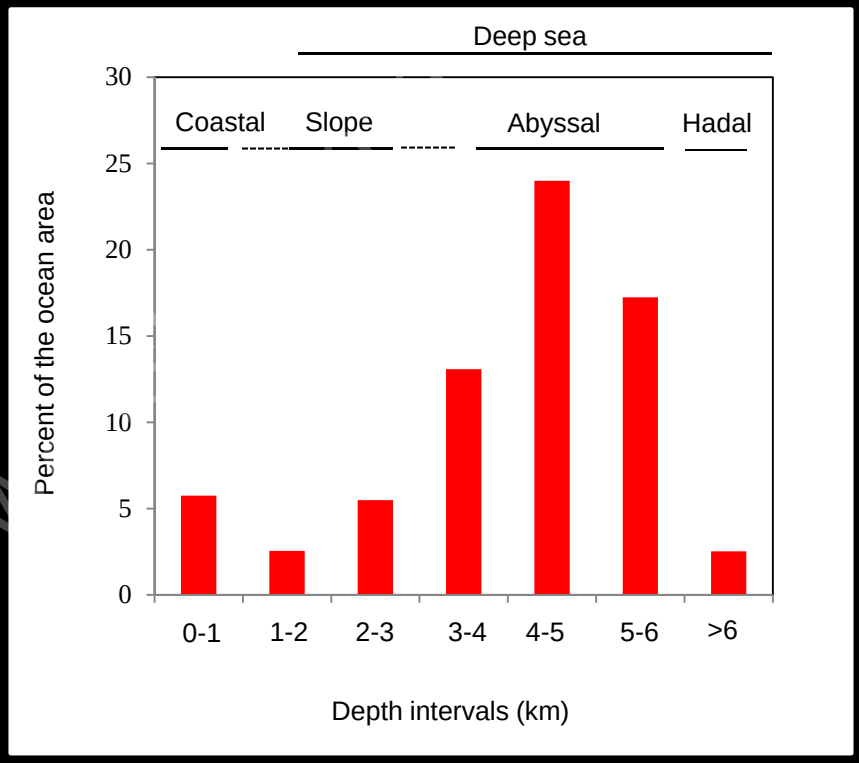
&
Tokyo University for Marine Science and Technology





71% of Earth is covered by ocean

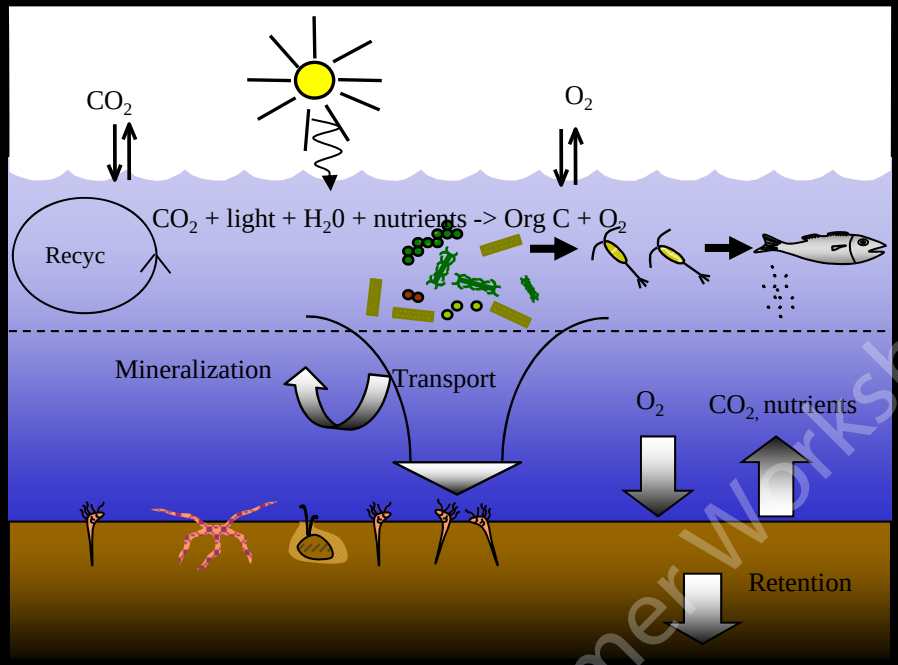


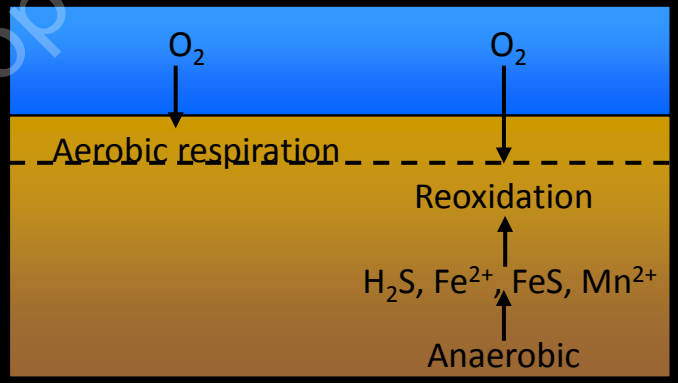


The average water depth of the ocean is 3.8 km

The deep sea cover >60% of Earth

Benthic mineralization; a key component of element cycling and redox conditions on Earth

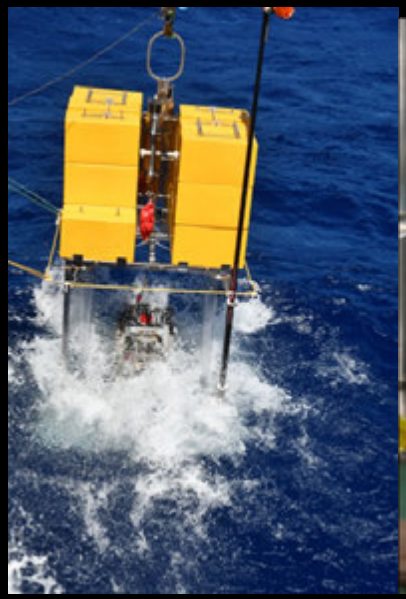


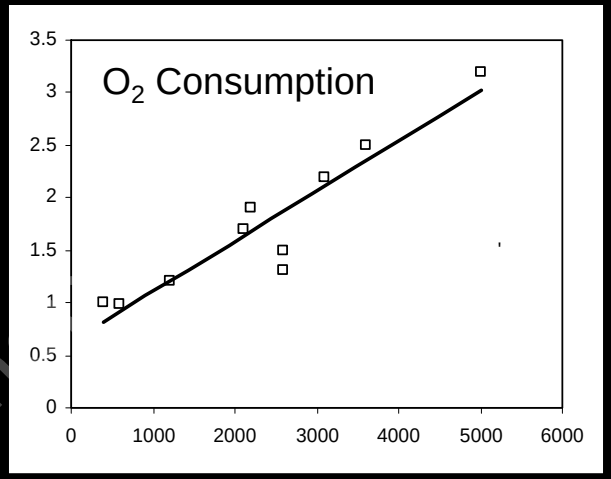


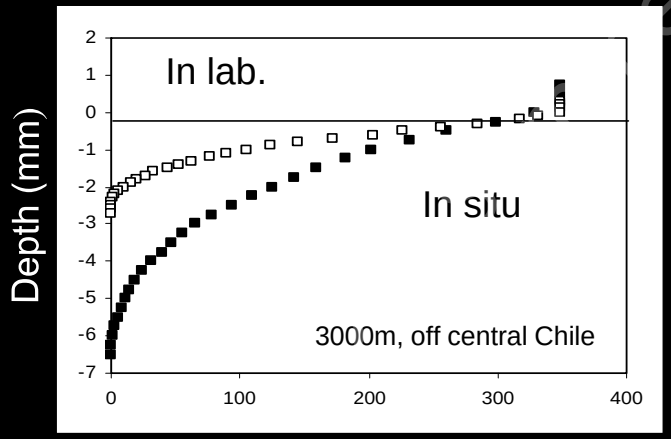
On the short timescale the sea bed act as a source of CO_2 and nutrients, but on geologic time scale it acts as a sink for C & nutrients.

The O_2 consumption of the sea bed represent a robust proxy for the total mineralization of organic material in sediments

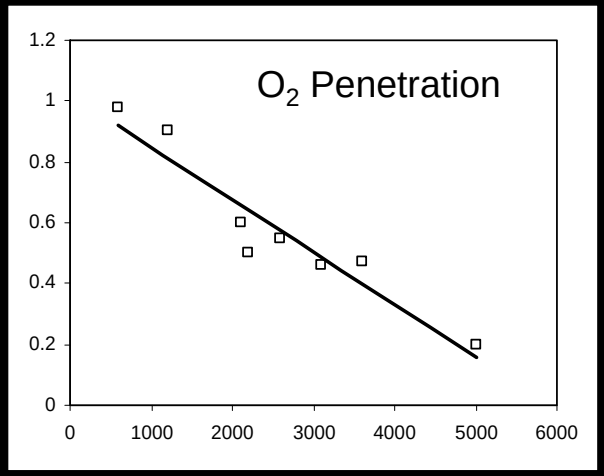
In situ measurements of benthic O_2 uptake





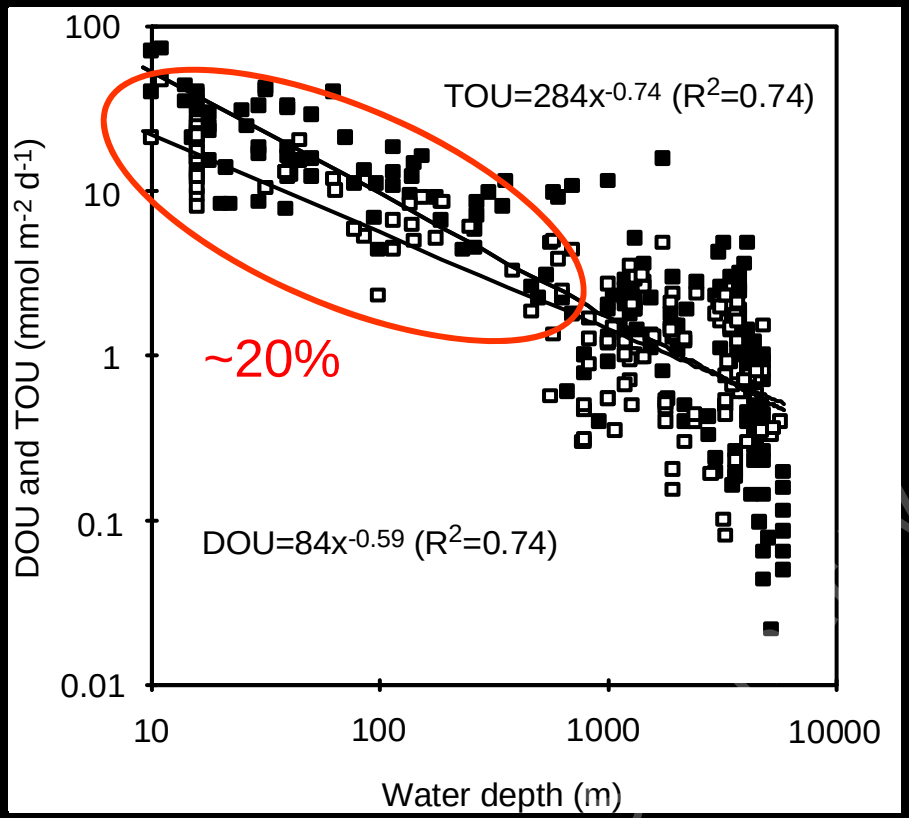


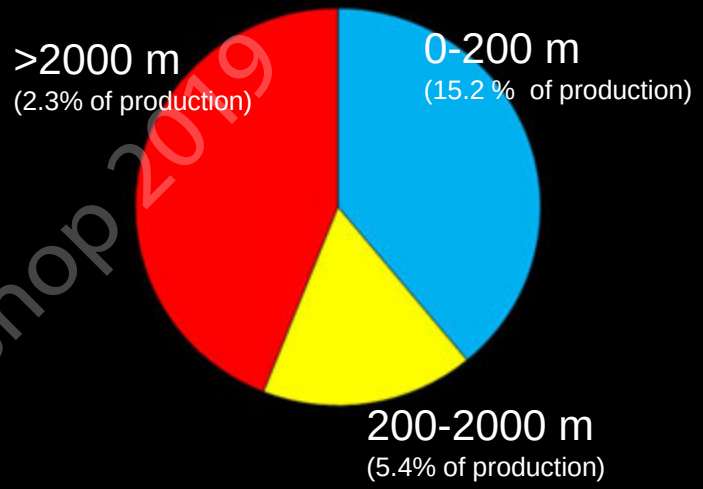
O_2 (µmol L^{-1})



Glud et al (1994, 1999)

The global database and large scale gradients



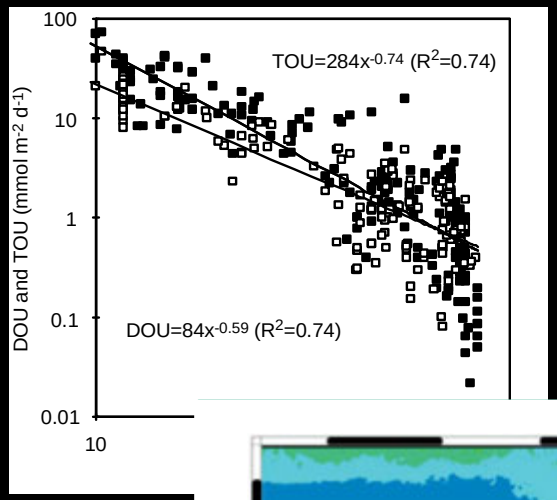


Global benthic mineralization 1.52 Gt C yr^{-1}

(3.3% of global pelagic PP)

Glud (2008)

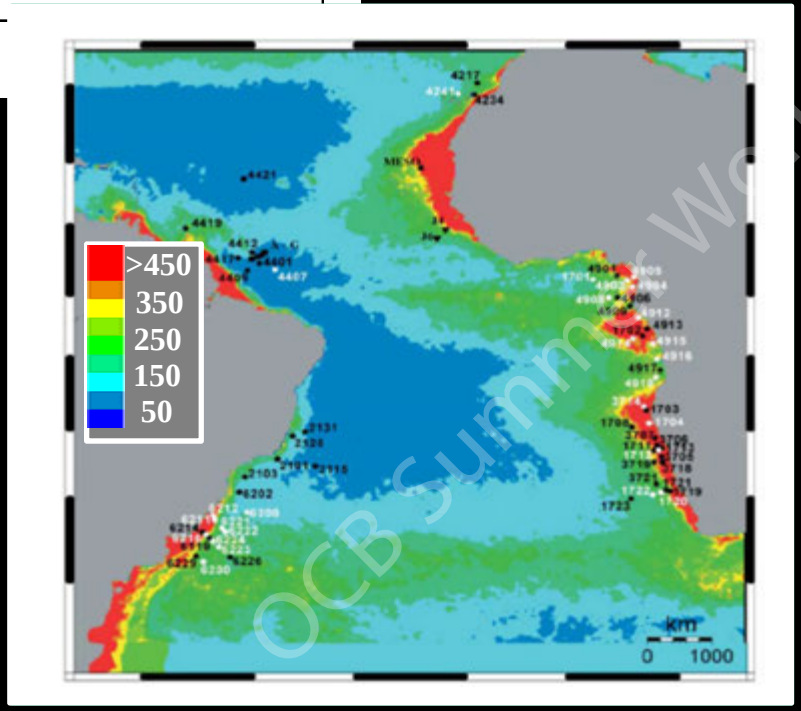
Surface primary production and deep sea mineralization rates



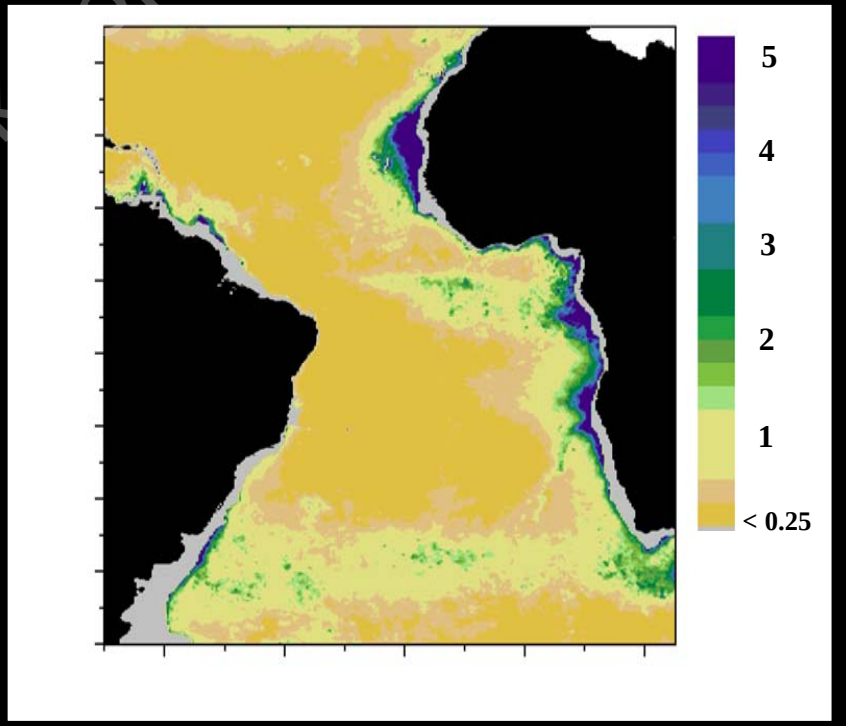
$$TOU = PP^{1.06}\ Z^{-0.49}$$

(integrated values remain unaltered)

PP; Primary production
Z; water depth



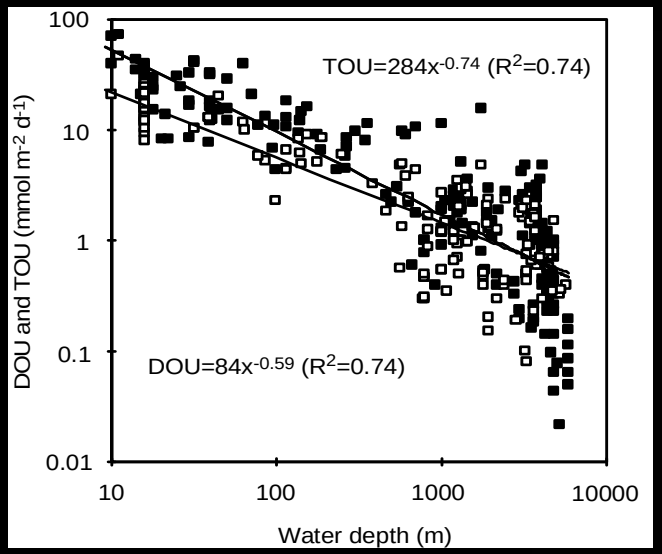
Algae production (PP)
(g C m^{-2} yr^{-1})

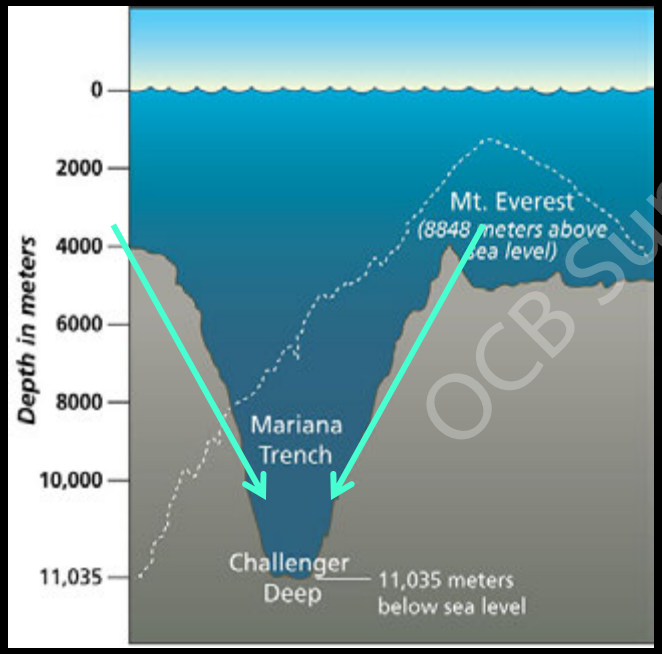


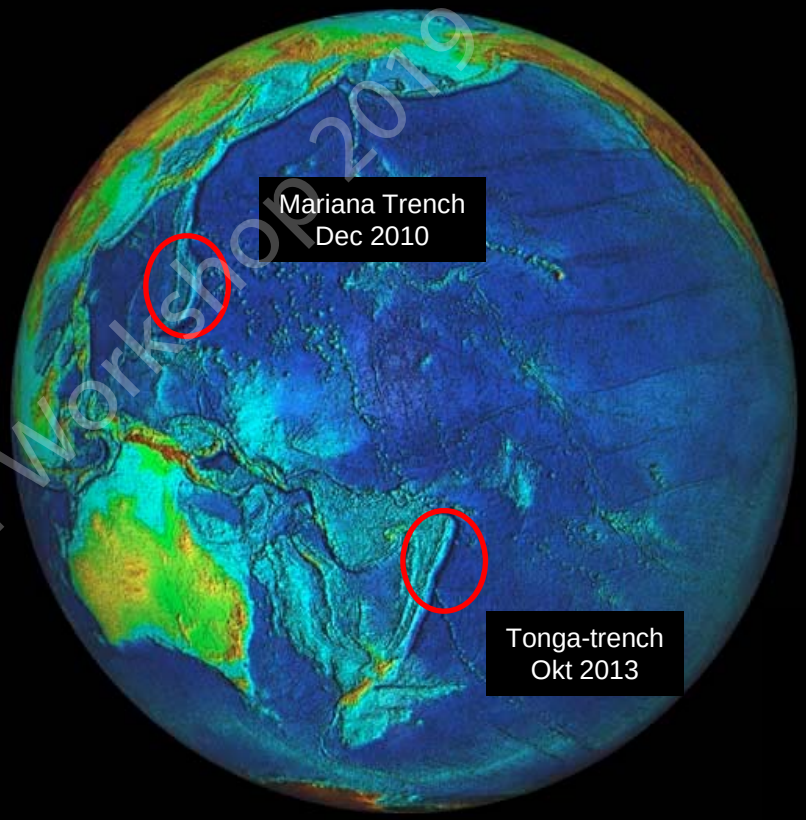
Fauna mediated O_2 consumption
(g C m^{-2} yr^{-1})

Wenzhoefer and Glud (2002)

The seascape; slopes, seamounts & hadal trenches (6-11 km)



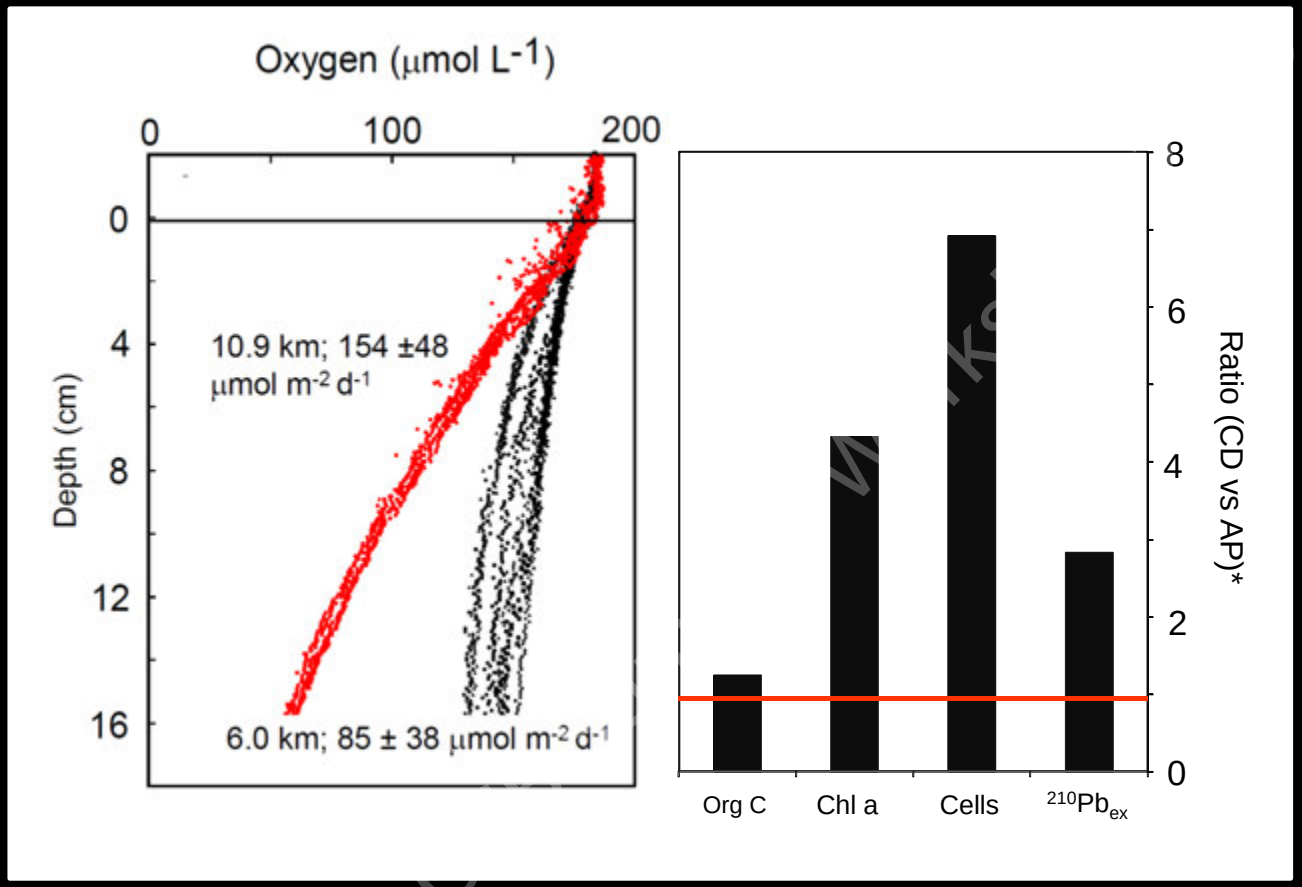




27 hadal trenches, covering an area the size of Australia

(extreme pressure, endemism, depocenters)

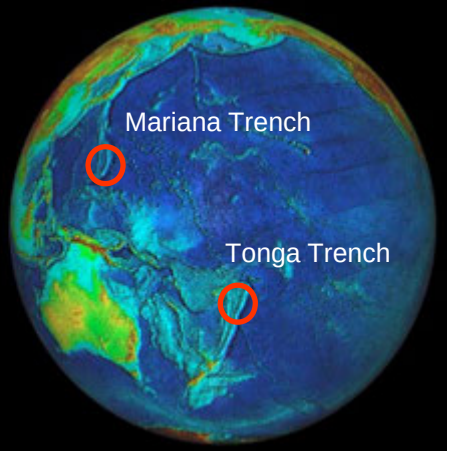
Hadal trenches; hot spots for deposition & turn-over of organic C ?



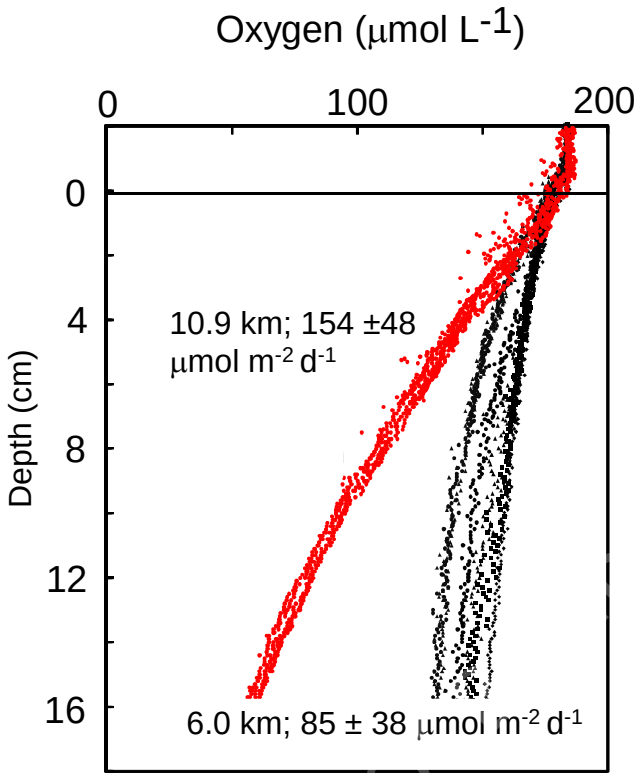
* Depth integrated 0-10 cm

Glud et al 2013

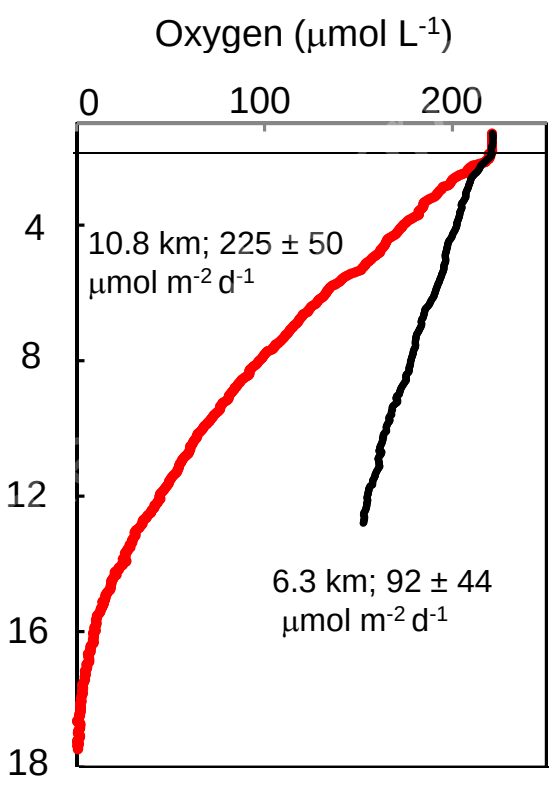
Benthic O_2 consumption in Hadal Trenches



Challenger Deep

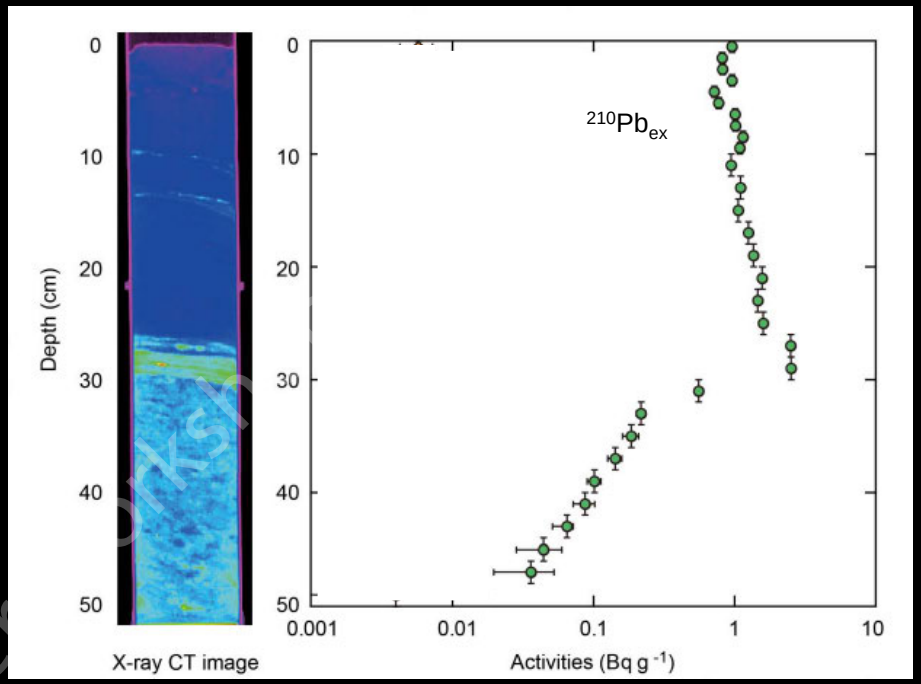


Horizon Deep



Glud et al 2013
Wenzhöfer et al 2016

Japan Trench, Tohoku-Oki earthquake 2011

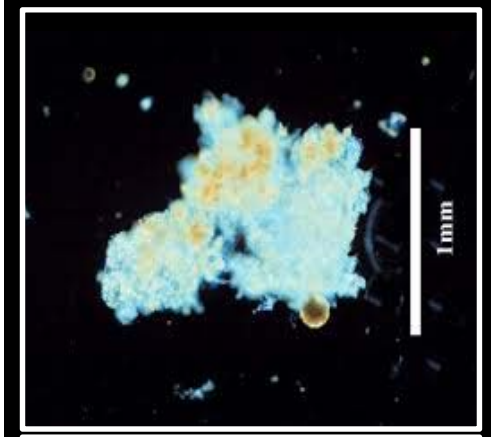


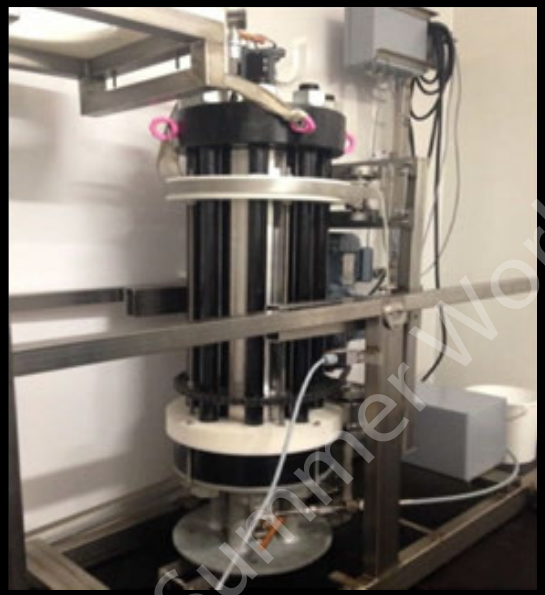
Ca 0.2 km^3 of sediment and 1 Tg Org C was estimated to have been re-deposited to the trench axis

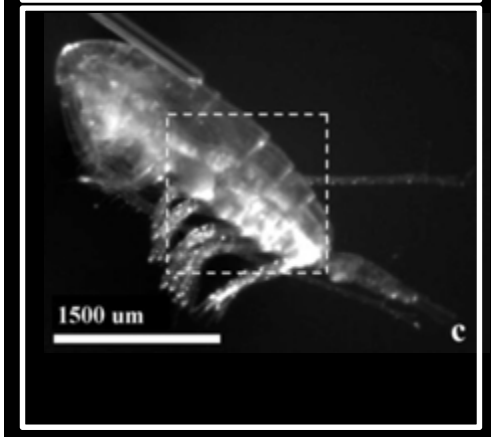
Kioka et al 2019

Oguri et al 2013

Marine snow and pressure effects



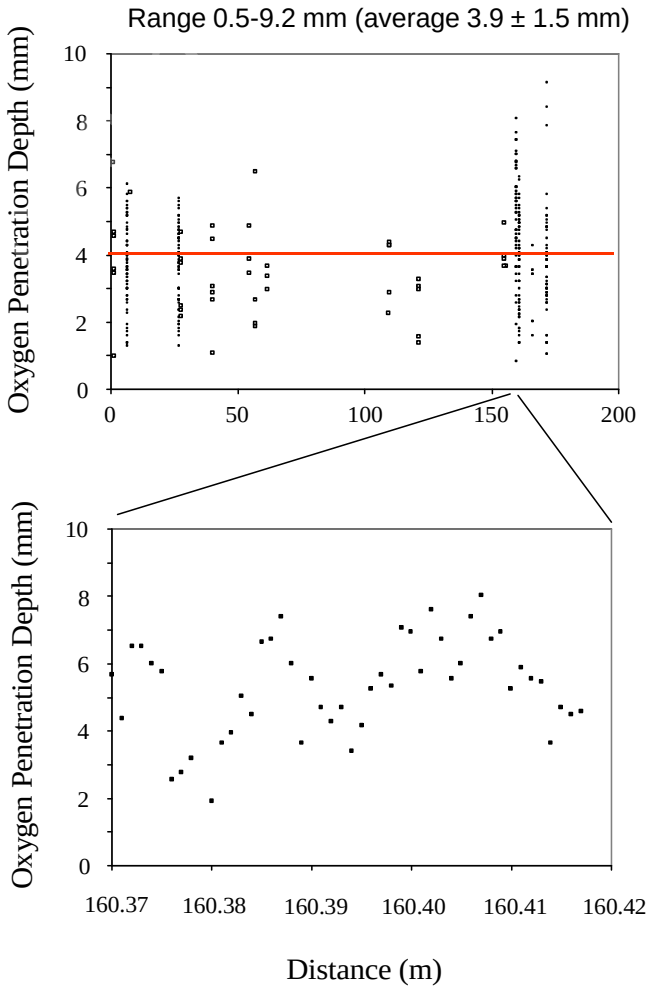




Stieff et al in prog

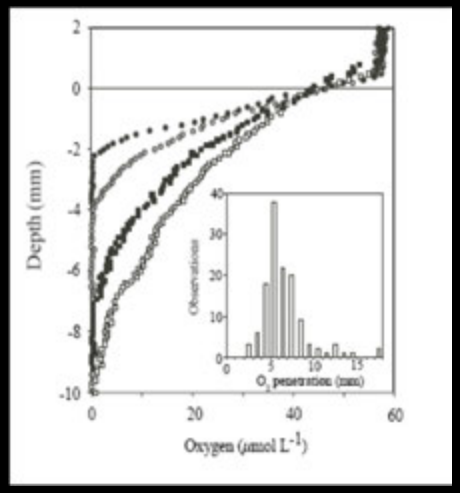
Small scale heterogeneity at the sediment surface; Case Sagami Bay I

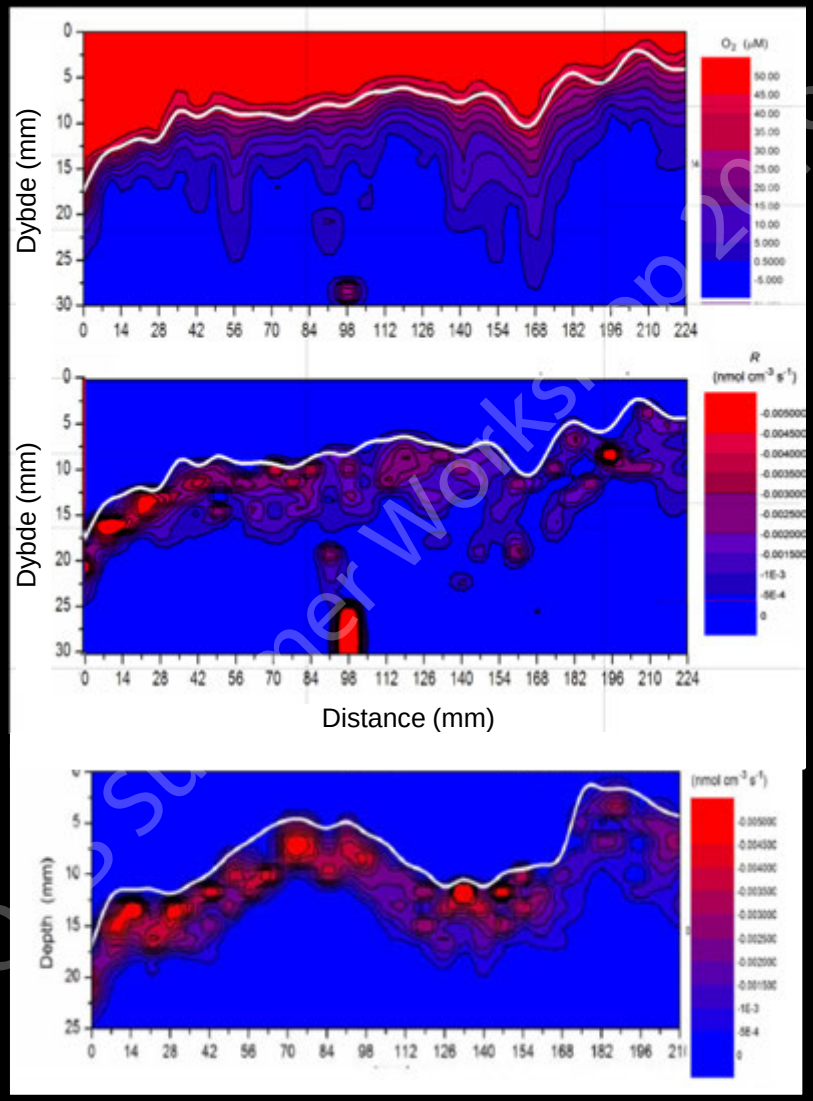
Characteristic patch size in the deep sea < 2.1 cm



Glud et al 2005;
Middelboe et al 2006

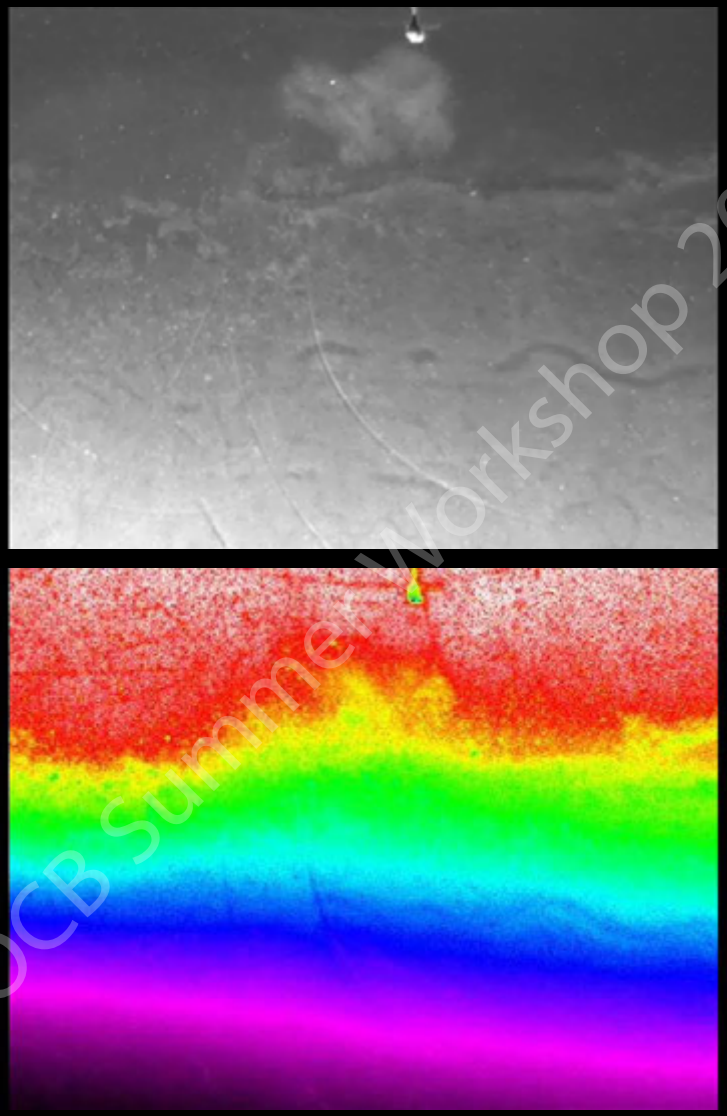
Microscale variation in deep sea sediments (case Sagmi Trough)





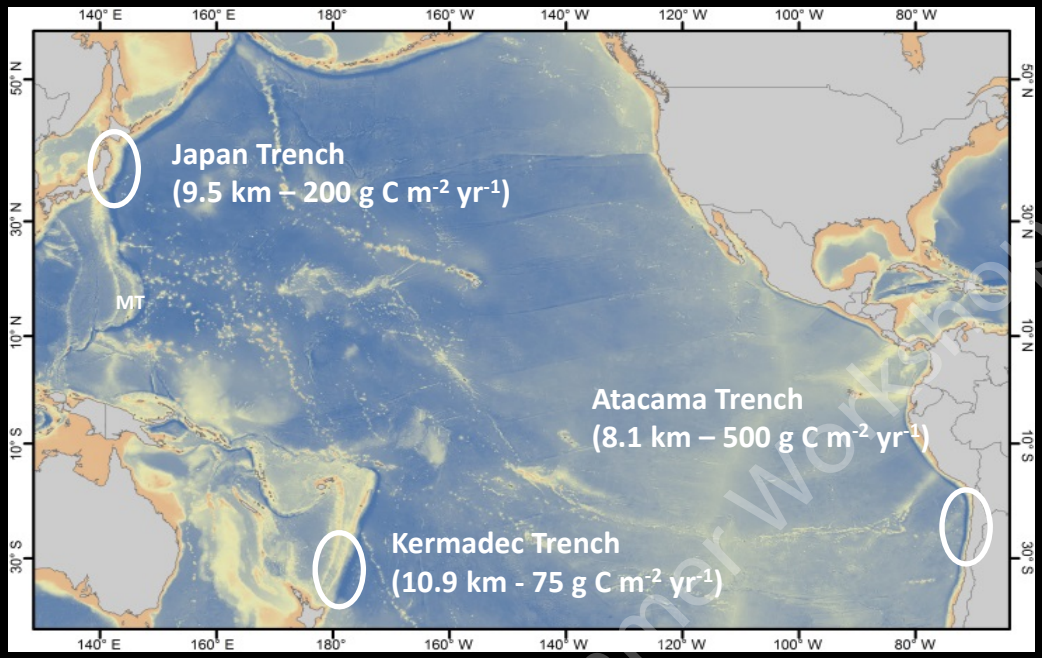
Glud et al 2009

Microscale variation in deep sea sediments



Aggregate ca 2 mm in diameter

HADES-ERC (2016 - 2021)
Sediment diagenesis and microbiology of hadal trenches



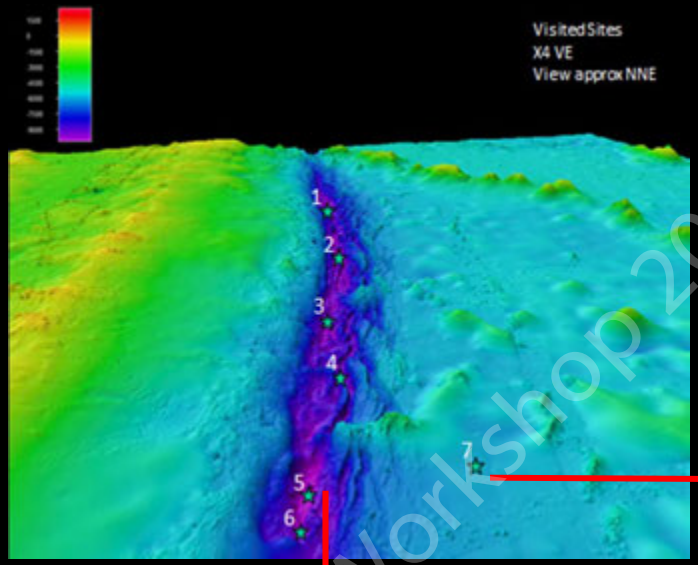
Objective 1: Development of 3 autonomous in situ instruments for hadal exploration and pressure chambers for laboratory investigations

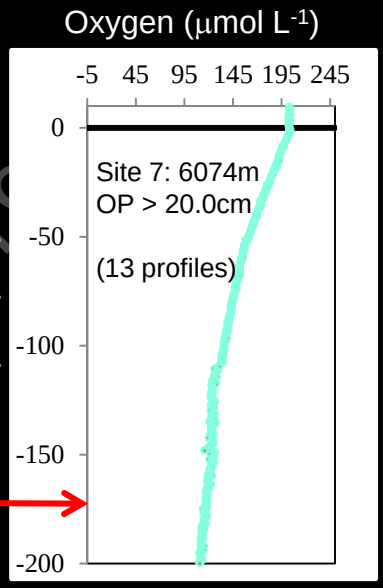
Objective 2: Exploration and quantification of biogeochemical function of hadal trenches (carbon and nitrogen cycles)

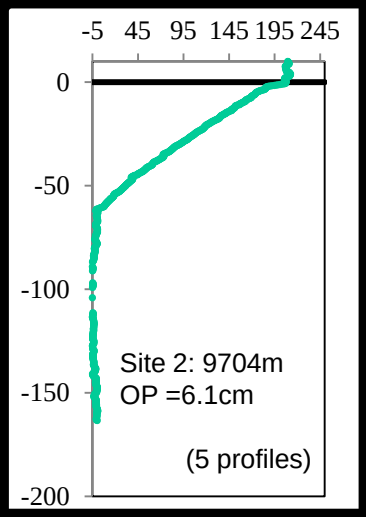
Objective 3: Exploration of microbial communities, biogeography and viral controls in hadal trench sediments.

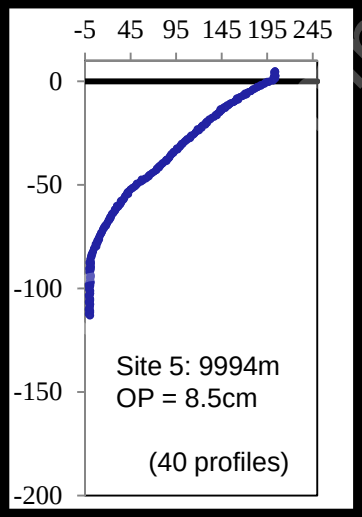
erc European Research Council

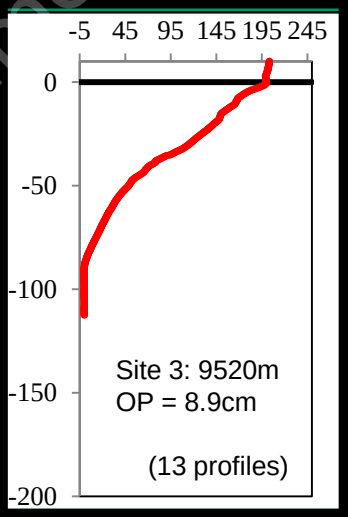
Benthic mineralization in the Kermadec & Atacama trenches I

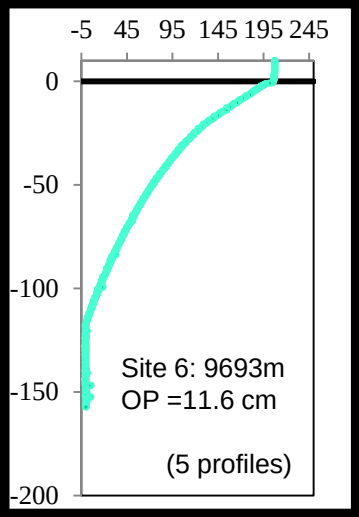


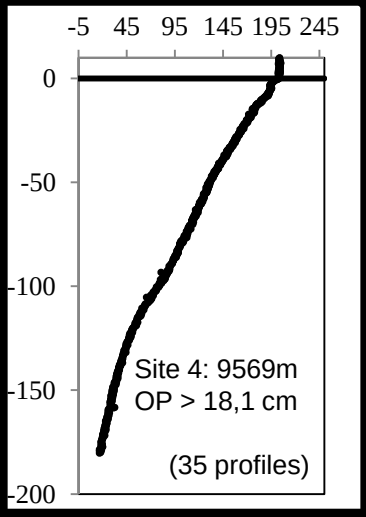








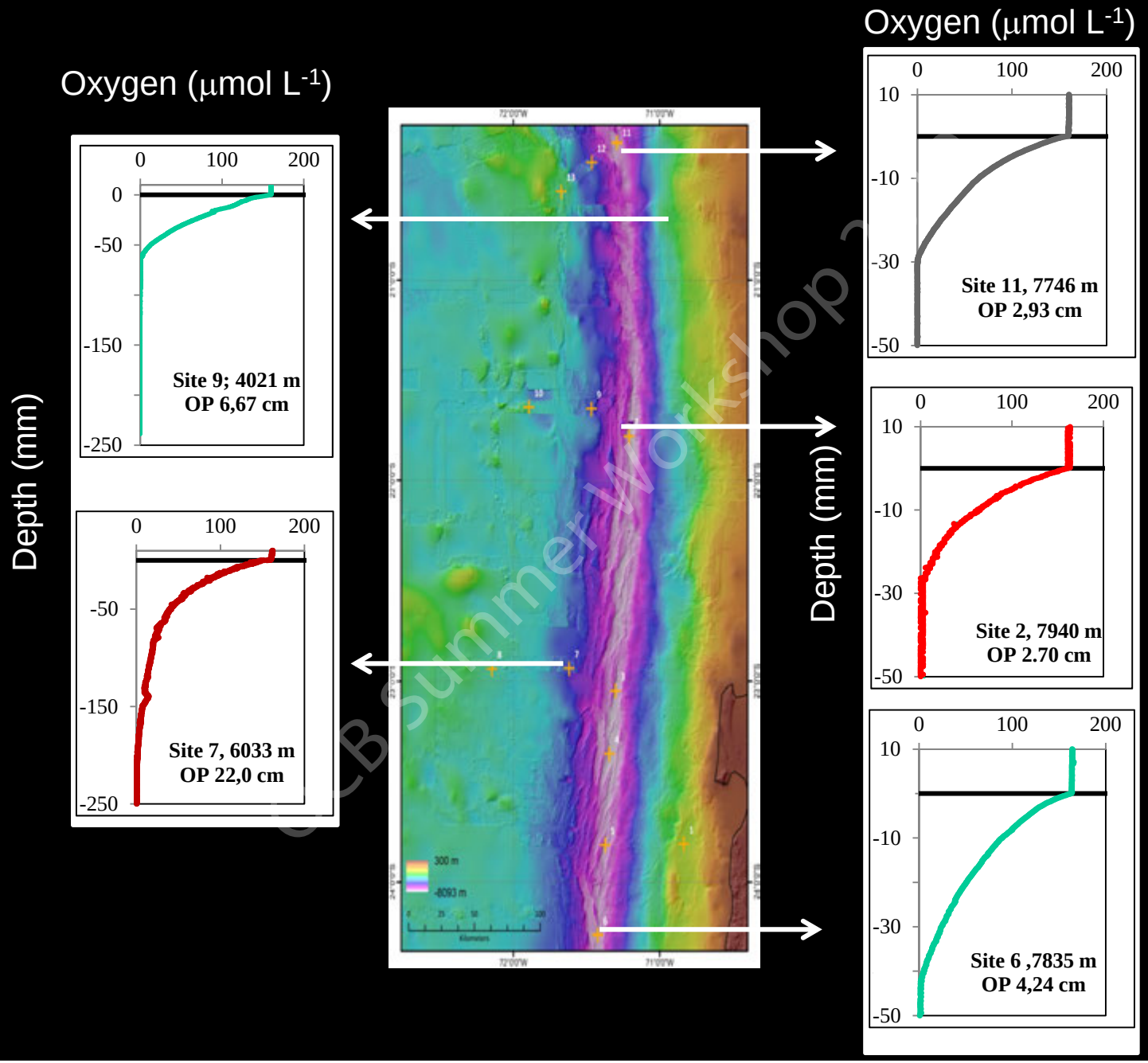




Depth (mm)

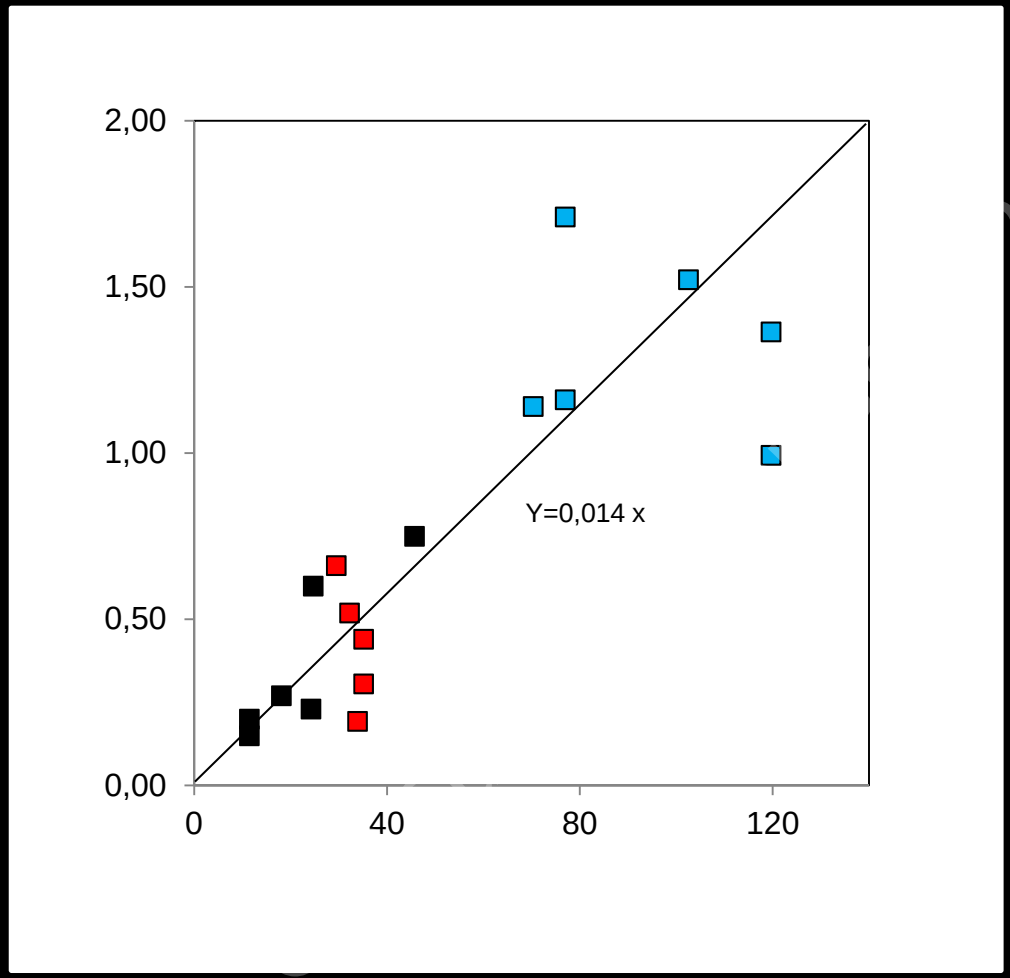
Oxygen (µmol L-1)

Benthic mineralization in the Kermadec & Atacama trenches II



Benthic mineralization in the Kermadec & Atacama trenches II

O_2 consumption in hadal sediments versus surface production



O_2 uptake mmol m^{-2} d^{-1}

Estimated surface production mmol C m^{-2} d^{-1}*

Annual average based on one decade of remote sensing data
(Wenzhoefer & Glud 2002)

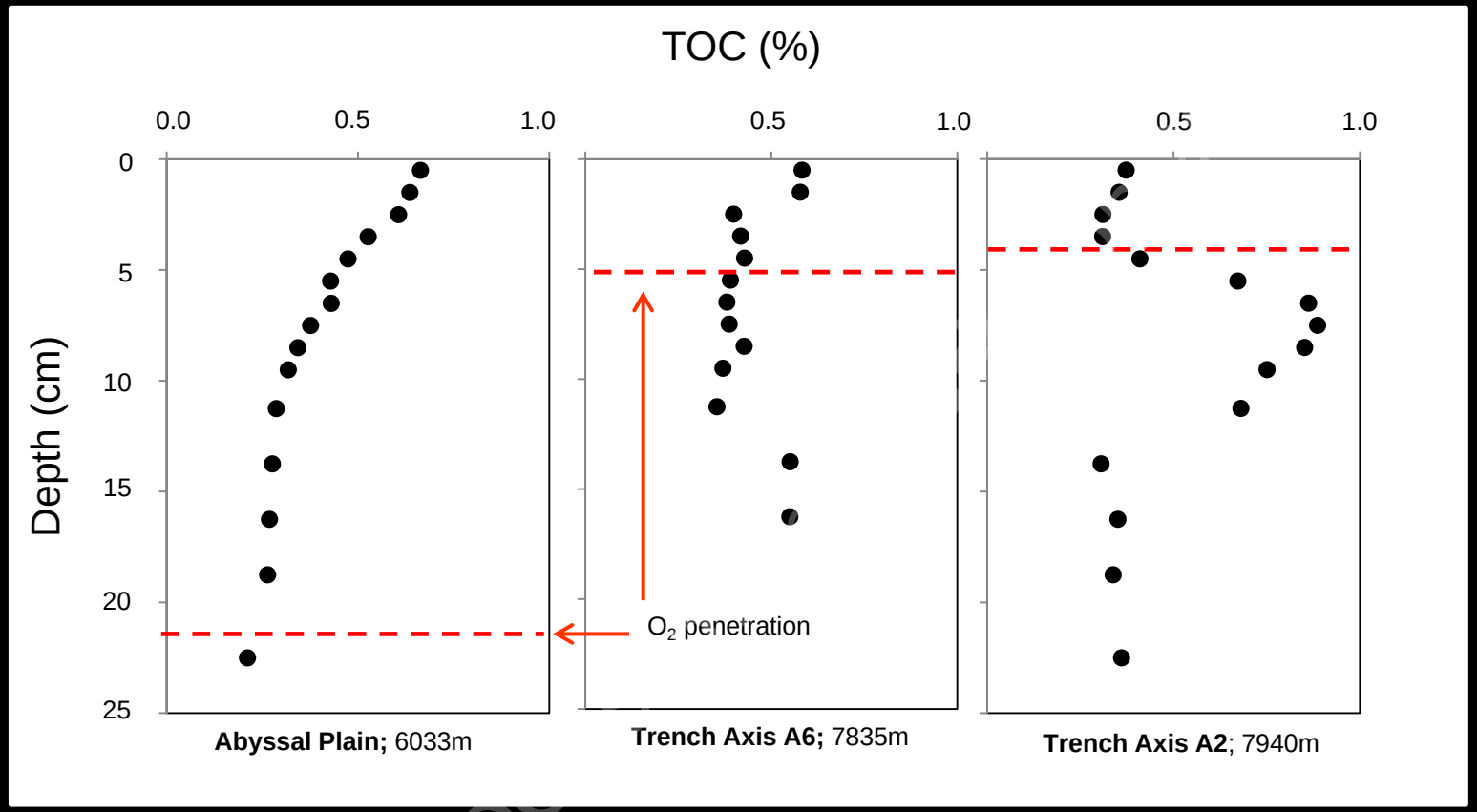
Glud et al 2013
Wenzhoefer et al 2016
Lou et al 2017

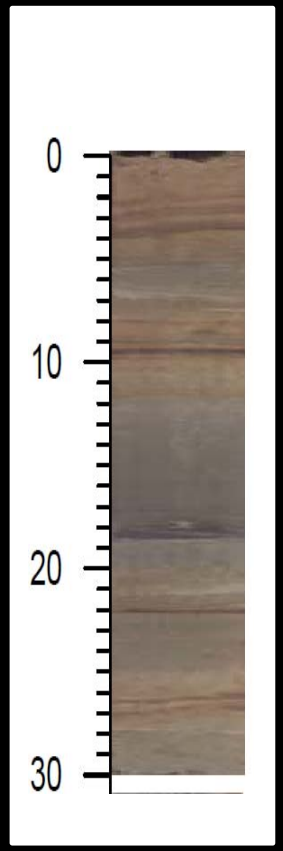
Mariana (10.9),
Tonga (10.8),
Izu Bonin (9.2),
New Brittan (8.2),
Mussau Trench (7.0)

Kermadec Trench (10.0)

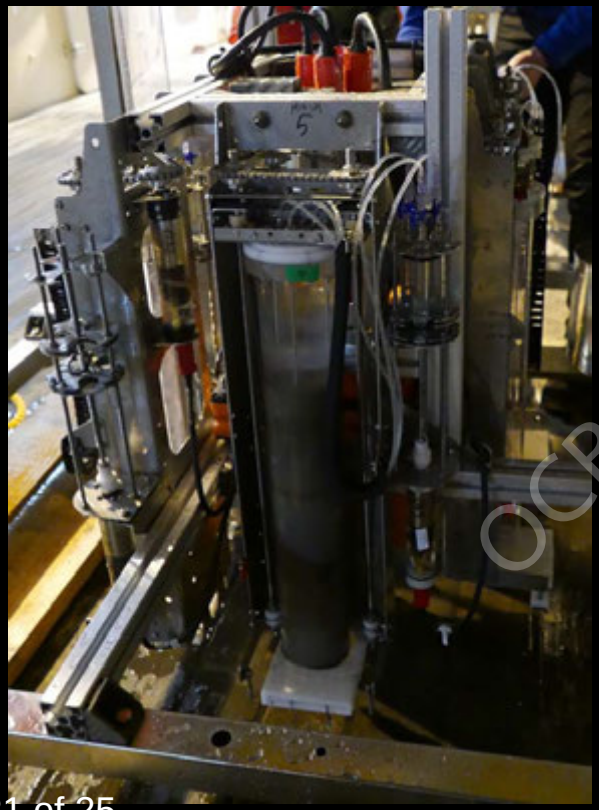
Atacama Tremch (8.1)

Benthic diagenesis and organic carbon availability

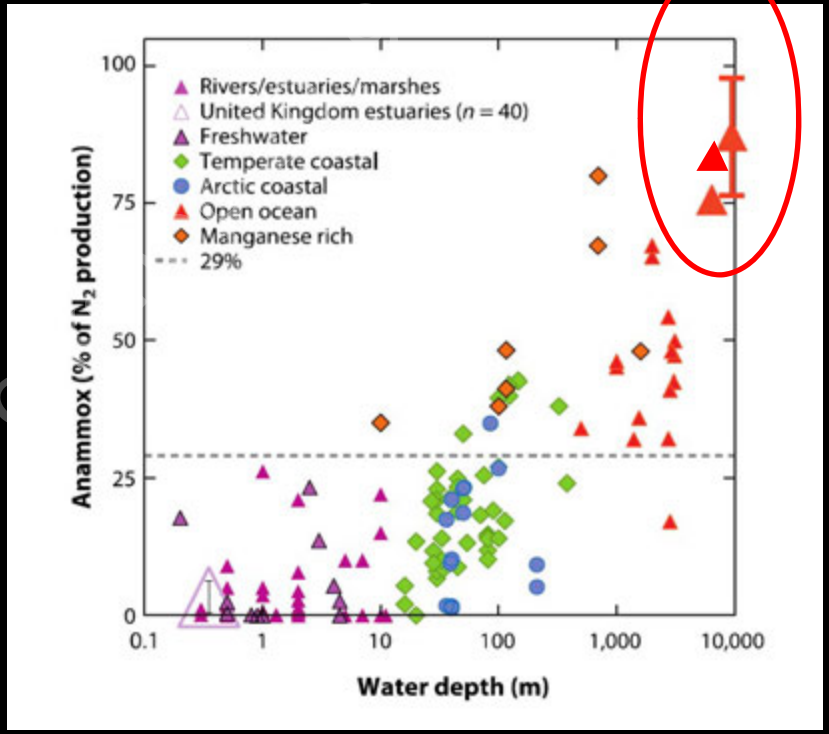




In situ measurements of anaerobic diagenesis



N_2 production in hadal sediments (Kermadec, Atacama, Izu-Bonin)



Thamdrup 2012

Sulfate reduction in hadal sediments (Atacama)

(SO_4^{2-} + Org C $\rightarrow$ CO_2 + H_2S)

Sulfate reduction (nmol cm^{-3} d^{-1})

Key messages & current research focus

1) Hadal trenches are deep sea hot spots for deposition & mineralization of organic material
2) Hadal trenches exhibit high temporal and spatial variability
3) Rate measurements require innovative technical solutions

Questions;

1) What are the sources, nature and pathways of organic material supply sustaining elevated biological activity in hadal sediments?
2) What are the degradation pathways/efficiency and who are the microbial key players ? (Biogeography & anerobes)
3) What is the role of virus, protozoan and meiofauna in shaping hadal microbial communities and for hadal biogeochemical function?

Thanks to the very many collaborators, students and technicians.

and the funding agencies – most importantly:

Atacama Team Marts 2018

European Research Council
European Union
Danish National Research Fund
Danish National Science Research Council
The villum Foundation