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Benthic Carbon Mineralization on a Global Scale
-An Approach of Regionalization based Multi-Regression Analysis-

1. Introduction

The center of our project is a reliable global estimation of benthic nutrient flux rates across the sediment -water interface in the deep sea. Comparable with a synthesis we give answers on this question on the basis of a high quantity of biogeochemical measurements, oceanographic settings, and sedimentary conditions.

Since the data distribution is very sparse and irregular, global models may have an element of uncertainty that can not be ignored. Therefore we turn our attention as well on control parameters of regional biogeochemical benthic processes. Generally benthic nutrient release, e.g. the benthic oxygen uptake is well correlated with control parameters like the primary productivity (Behrenfeld and Falkowski 1996), the export production, or the organic carbon content in surface sediments, but additionally the benthic flux rates are affected by processes which are restricted on a regional scale. Thus, the primary productivity is regionally hardly decoupled from the total organic carbon (TOC) content in surface sediments and thus from the benthic nutrient release. Consequently, we used the TOC content in surface sediments for defining transfer functions to describe e.g. the benthic oxygen uptake. Additionally, the globally high data resolution of about 5520 measurements for TOC in surface sediments, especially in coastal areas, qualify this proxy parameter as suitable for a global application. In Fig. 1 we show global benthic provinces defined by semi-variogram analysis (Fig.2). The resulting TOC distribution pattern is shown in Fig. 3.

2. Results

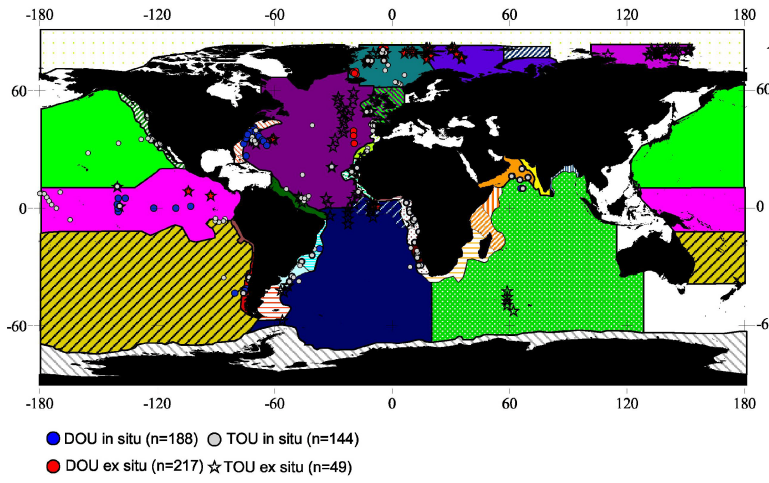


Fig.1: Benthic provinces defined by semi-variogram analysis

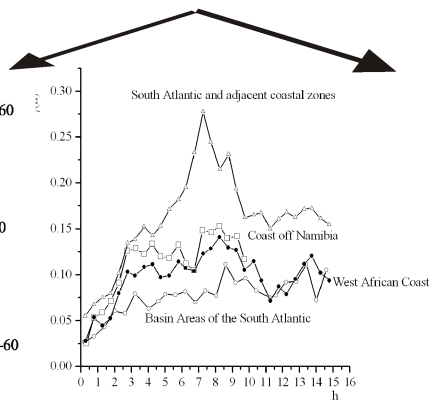


Fig.2: Example of experimental semi-variograms of the southern Atlantic Ocean

2.1 Regionalization

To consider the aspect of regional variability the geostatistical based kriging method is used to define 30 specific spatial limited provinces on a global scale. Therefore modelled idealized theoretical semi-variograms related the spatial variance of TOC (γ) to the distance vector in space (h) from individual sites (Fig.2).

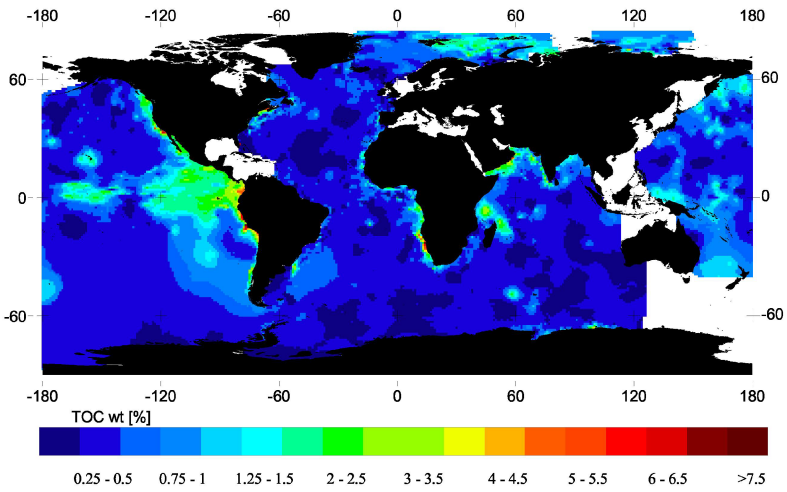
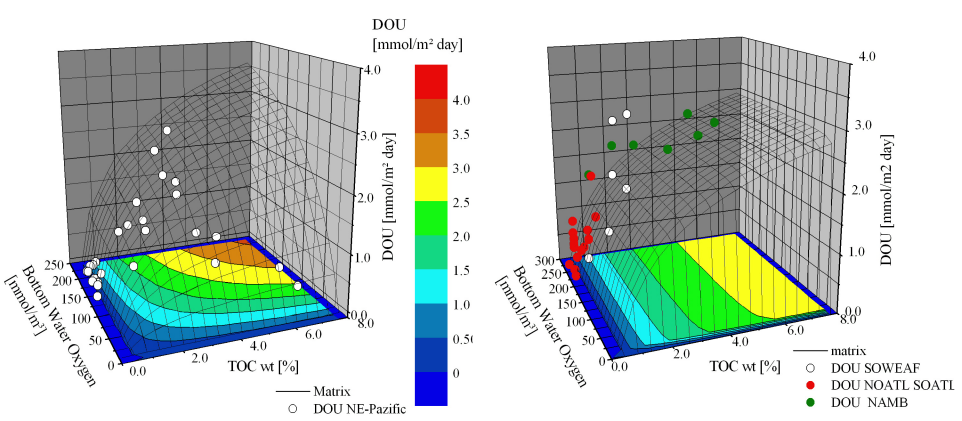


Fig.3: Global distribution pattern of TOC in surface sediments (< 5cm sediment depth)

TOC distribution pattern processed by applying the kriging interpolation method using the semi-variograms in the regionalized benthic zones.

2.2 Multiple Regression

The global oxygen consumption was estimated by applying a 3D general relation between the diffusive benthic oxygen flux (DOU), the organic carbon content in surface sediments (TOC) and the bottom water oxygen concentration as the limiting parameter (modified after Cai and Reimers 1995). A global compilation of about 188 in situ DOU measurements, the TOC data base and a compilation of bottom water oxygen concentrations (GEOSECS, WOCE) were used to calibrate the relationship in 14 higher ranking zones by multi-non linear regression analysis. The influence of bottom water concentrations in the oxygen rich deep water of the southern and northern Atlantic ocean is negligible, thus the relationship is reduced to a simple log-linear relation between the TOC content in surface sediments and the in situ oxygen fluxes (> 1000m WD). Applying these transfer functions, the benthic carbon mineralization for a wide range of the global ocean was estimated from the oxygen fluxes. We obtain an overall rate of oxygen consumption of 70 ·10^12 mol/yr and an annually minimum of particulate organic carbon that actually reaches the seafloor with 5.4·10^13molC/yr (64·10^13gC/yr, see Fig. 7)



4a: Example from the NE Pacific (including West coast) 4b:Example from the North and South Atlantic (including West coast). NAMB=Namibia, NOATL SOATL= N- and S- Atlantic basin area, SOWEAF= SW African margin

3D plot of multiple regression analysis between DOU, TOC in surface sediments and bottom water oxygen at the sediment water interface

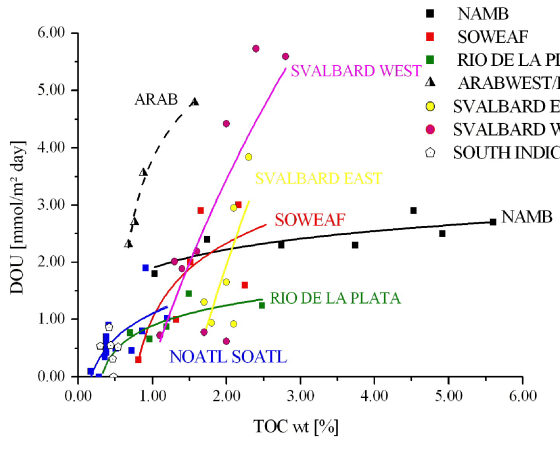


Fig. 5: Examples of 2D log-linear regression curves defined for the benthic provinces

$$DOU_{est} = \frac{[\ln(TOC_{meas} + D) \cdot A + B]}{[BW_{meas} + C]} \cdot BW_{meas}$$

modified after Cai&Reimers (1996)

3D parameter function, the 4 parameters A, B, C and D are individual for each benthic province

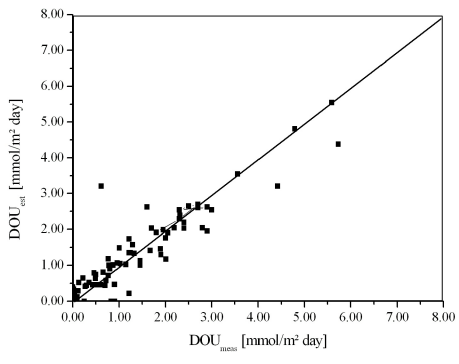


Fig:6.: Estimation results of example provinces shown in Fig. 5

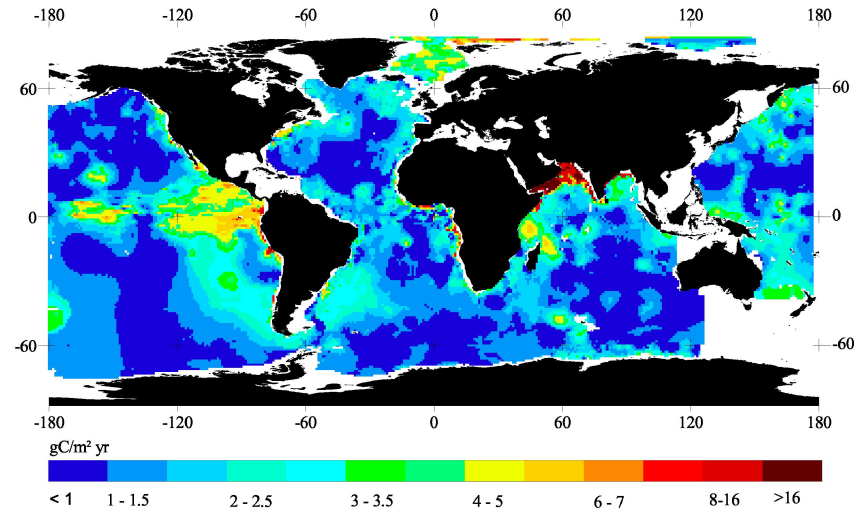


Fig. 7: Mineralization of organic carbon in surface sediments, calculated from oxygen uptake (> 1000m WD)

References:

Behrenfeld, M. J. and P. G. Falkowski (1996).
"Photosynthetic rates derived from satellite-based chlorophyll concentration."
Limnology and Oceanography 42(1): 1-20.

Cai, W.-J. and C. E. Reimers (1995).
"Benthic oxygen flux, bottom water oxygen concentration
and core top organic carbon content in the deep northeast Pacific Ocean."
Deep Sea Research Vol.42, No.10: 1681-1699.

Data sources

Bathymetry
(ETOPO5)/GTOPO30
NGDC/ WDC MGG
(National Geophysical Data Center/
World Data Center for marine Geology and Geophysics, Boulder)
USGS
(US Geological Survey)
www.ngdc.noaa.gov/mgg/global/seltopo.html
www.edcdaac.usgs.gov/gtopo30/gtopo30.html

Primary Productivity
OPD
(Oceanographic Productivity Database); P.G. Falkowski
(Rutgers University)
Data compilation of primary production
(http://marine.rutgers.edu/opp/Production/VPGMRes.html)

Bottom Water Oxygen
GEOSECS Data
IRI/LDEO (Climate Data Library
WOCE Data
WOD/WOA (World Ocean Database and World Ocean Atlas 1998)
http://ingrid.ldgo.columbia.edu/
http://www.nodc.noaa.gov/OC5/data_woa.html
http://www-ocean.tamu.edu/WOCE/uswoce.html

Sediment surface data
Total organic carbon (TOC)
Data base:
PANGAEA
(Projekte: ADEPD, BIGSET,
SFB 261, JGOFS, SINOPS)
M. Diepenbrock
(Univ. Bremen, FB5)
www.pangaea.de

Unpublished data:
Romankevich E.A., Vetrov A.A. (2001)
Vetrov A.A., Romankevich E.A., Benenson M.A. (1997)
(Shirshov Institute of Oceanology, Russ. Academy of Sciences, Moscow)
Unpuplished data (ADEPD Projekt)
P. Müller, T. Wagner
(Univ. Bremen, FB5
Dierk Hebbeln
(Univ. Bremen)
Tim Jennerjahn
(Univ. Bremen)
Gesine Mollenhauer
Literature data