Effects of sedimentary microenvironments on the vertical distributions of O_2 and DOC in coastal marine sediments : scales of variability

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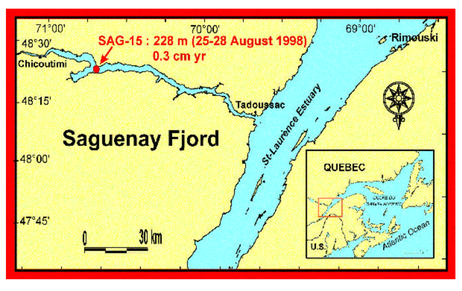
Abstract

Using a nested experimental design, 32 vertical profiles of dissolved oxygen (O_2) and dissolved organic carbon (DOC) were measured in a box core collected in the Saguenay Fjord (Quebec, Canada), using a voltammetric microelectrode for O_2 and a UV detection based microanalyzer for DOC. The fluxes of O_2 and DOC were estimated from the profiles and analyzed statistically (nested ANOVAs) to assess the relative contributions of different spatial scales to their variability. The results show that sedimentary microenvironments on scales smaller than 16 cm^2 accounted for more than 69% of the total spatial variability but do not have a significant effect on the fluxes on spatial scales greater than 16 cm^2. This variability should be taken into account when using microprofiling to estimate fluxes.

Introduction

A striking feature of coastal marine sediments is the marked heterogeneity. This heterogeneity is often associated with the presence of biogenic structures (e.g., burrows; Aller, 1988) or banding (Anderson and Meadows, 1978). These structures are geochemically different from their surrounding environment and are defined as sedimentary microenvironments (Anderson and Meadows, 1978). Although the existence of sedimentary microenvironments is well documented, the spatial scale on which they occur is poorly known. The aim of the present study is to determine the relative contribution of different spatial scales on the variability of O_2 and DOC fluxes across the sediment-water interface and to investigate the influence of sedimentary microenvironments on the geochemistry of coastal marine sediments.

Study site



Methods

The experiment was carried out using a nested design (Fig. 1) on a 256 cm^2 surface area box core collected at 228 m depth in the Saguenay Fjord (Quebec, Canada). The vertical distributions of O_2 and DOC (Fig. 2) were measured with submillimeter resolution in the top five cm using a Hg/Au amalgam voltammetric microelectrode for O_2 (Brendel and Luther, 1995) and a UV detection based microanalyzer for DOC (Deflandre and Gagné, submitted). The diffusive fluxes for O_2 and DOC across sediment water interface were then estimated using the Bouldin model (1968) for oxygen with $D_{O2}=0.9\times10^{-6}$ cm^2 s^{-1} and Fick's First Law (Berner, 1980) for DOC with $D_{DOC}=1\times10^{-6}$ cm^2 s^{-1}. Spatial maps (Fig. 3) were generated using the Krigging mesh interpolation feature of the Golden'Surfer program.

Fig. 1 - Experimental design

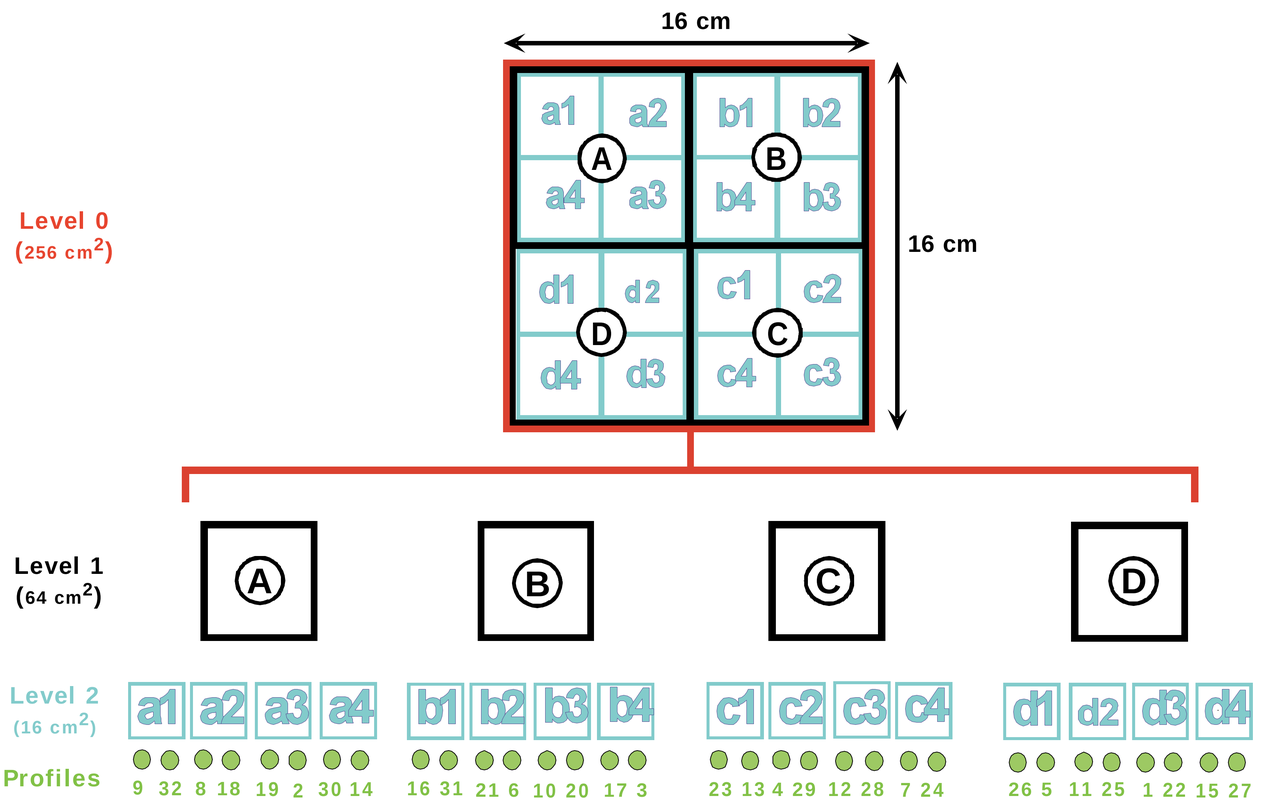


Fig. 2 - High resolution profiles of O_2 and DOC

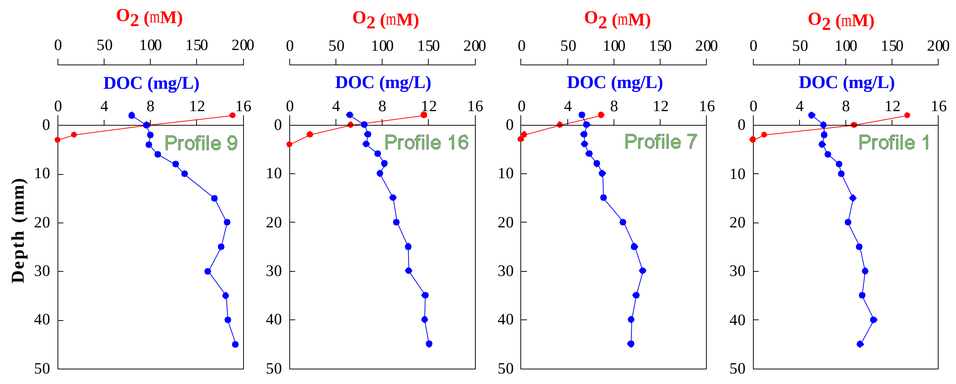
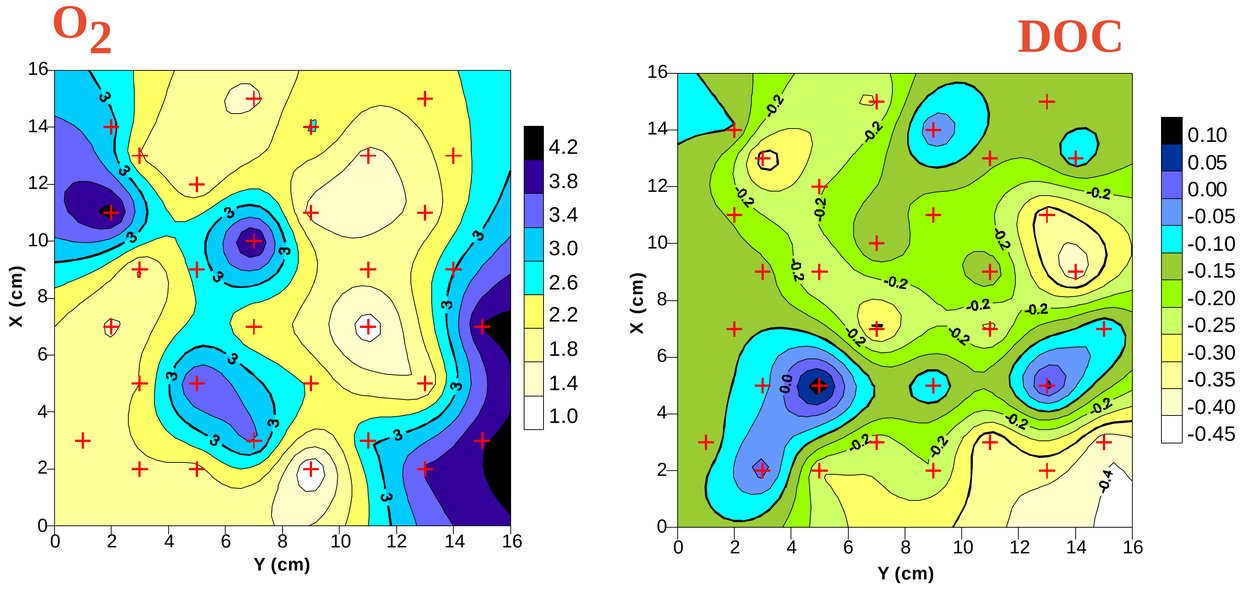


Fig. 3 - Spatial distributions of O_2 and DOC fluxes(mmol m^{-2} d^{-1}) at the sediment water interface



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Results-Discussion

Statistical treatment

Average fluxes of O_2 and DOC on different spatial scales were compared using a parametric one-way ANOVA. Neither O_2 nor DOC fluxes differed significantly among the areas of level 1 (P=0.6789 and P=0.6943, respectively). Variance homogeneity was previously tested using Bartlett tests (P=0.0840 and P=0.4052, respectively). Similar conclusions were reached using Kruskal-Wallis non-parametric ANOVAs (P=0.8396 and P=0.7275, respectively). The same tests were used to compare fluxes between the different areas of level 2. Here again, there was no significant difference among the fluxes (One-way ANOVAs, P=0.4774 and P=0.1899; Bartlett tests, P=0.3229 and P=0.6075; and Kruskal-Wallis ANOVAs, P=0.6090 and P=0.2132, respectively).

- F_{O_2}
  - Level 1 0%
  - Level 2 7.30%
  - Error
    - Analitical precision 5% (Luther et al., 1998)
    - Level 2 (inside) 87.70%
- F_{DOC}
  - Level 1 0%
  - Level 2 28.85%
  - Error
    - Analitical precision 2% (Deflandre and Gagné, submitted)
    - Level 2 (inside) 69.42%

(Expressed in % of total spatial variability)

Nested ANOVAs show that most of the variability in both O_2 and DOC fluxes (i.e., 87.7 and 69.4%) can be attributed to spatial scales smaller 16 cm^2.

The contribution of sedimentary microenvironments in geochemistry

Estimated O_2 fluxes varied between 0.95 and 4.44 mmol m^{-2} d^{-1} (Fig. 3). DOC fluxes varied between - 0.40 and + 0.15 mmol m^{-2} d^{-1} indicating a general tendency for a diffusive flux out of the sediment (Fig. 3). However, the latter result suggests that, on small scales, the sediment can be both a source and a sink of DOC.

In spite of the heterogeneity on small spatial scales, there was no significant effect on the fluxes at scales greater than 16 cm^2. Consequently, the relative effect of sedimentary microenvironments seems to be negligible on larger spatial scales. This may be due to a random distribution of the many different microenvironments present. Therefore, microenvironments would not introduce an artifact when large surfaces area cores are sampled, such as when entire box cores are sliced and squeezed for porewater collection. However, when small surfaces are sampled, which is the case with microelectrodes, the presence of microenvironments may introduce errors.

References

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