PNEC (French National Program of Coastal Environment)

MICROBENT project

Coupling of carbon, oxygen and nitrogen cycles in sediments from a Mediterranean lagoon :

an in-situ micro-electrodes and modelisation study

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The Thau Lagoon, France

LOICZ Conference, Egmond aan Zee, Netherlands - 27-29 June, 2005

MICROBENT

(French National Program of Coastal Environment)

Collaboration of 17 laboratories

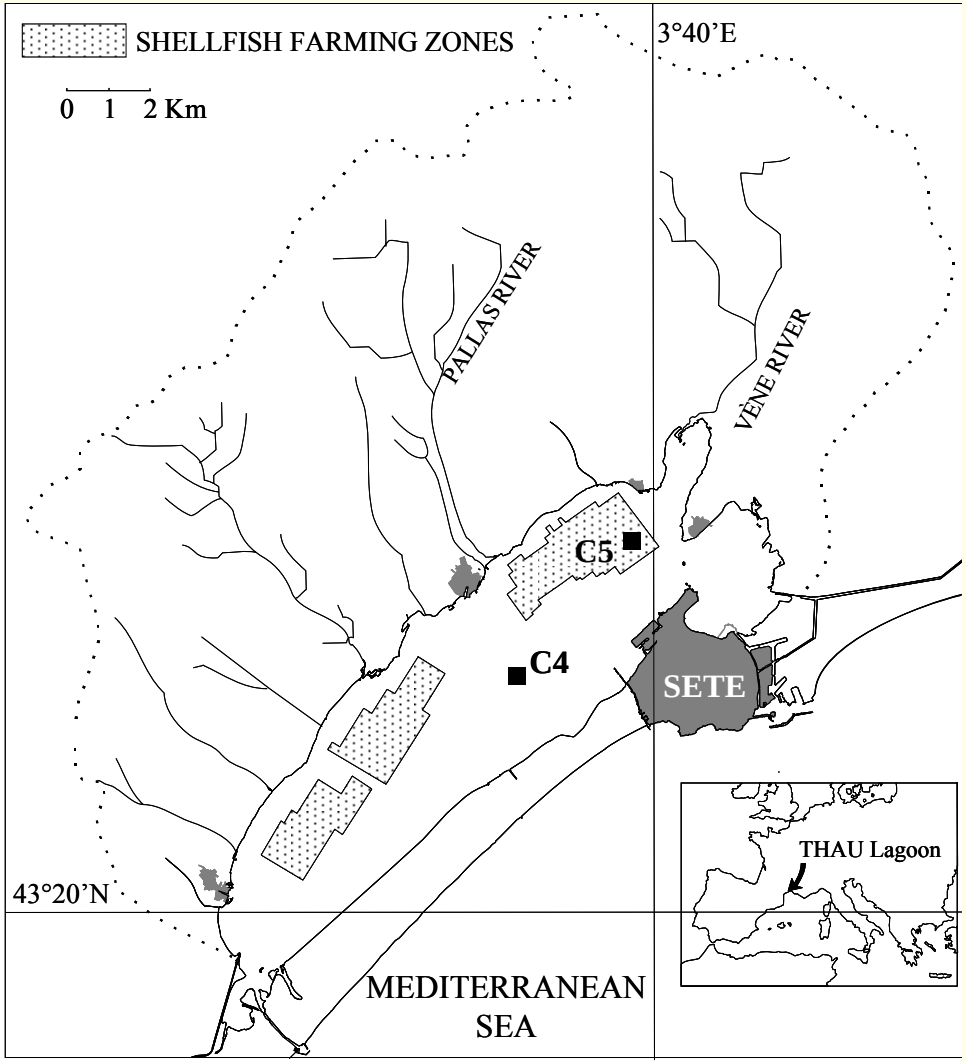
« biological filter » (contaminant transfer)

« physical filter » (deposition/erosion, bioturbation, sedimentary records)

Study of **reaction** and **transport** processes at the SWI

« diagenetic filter » (reaction processes)

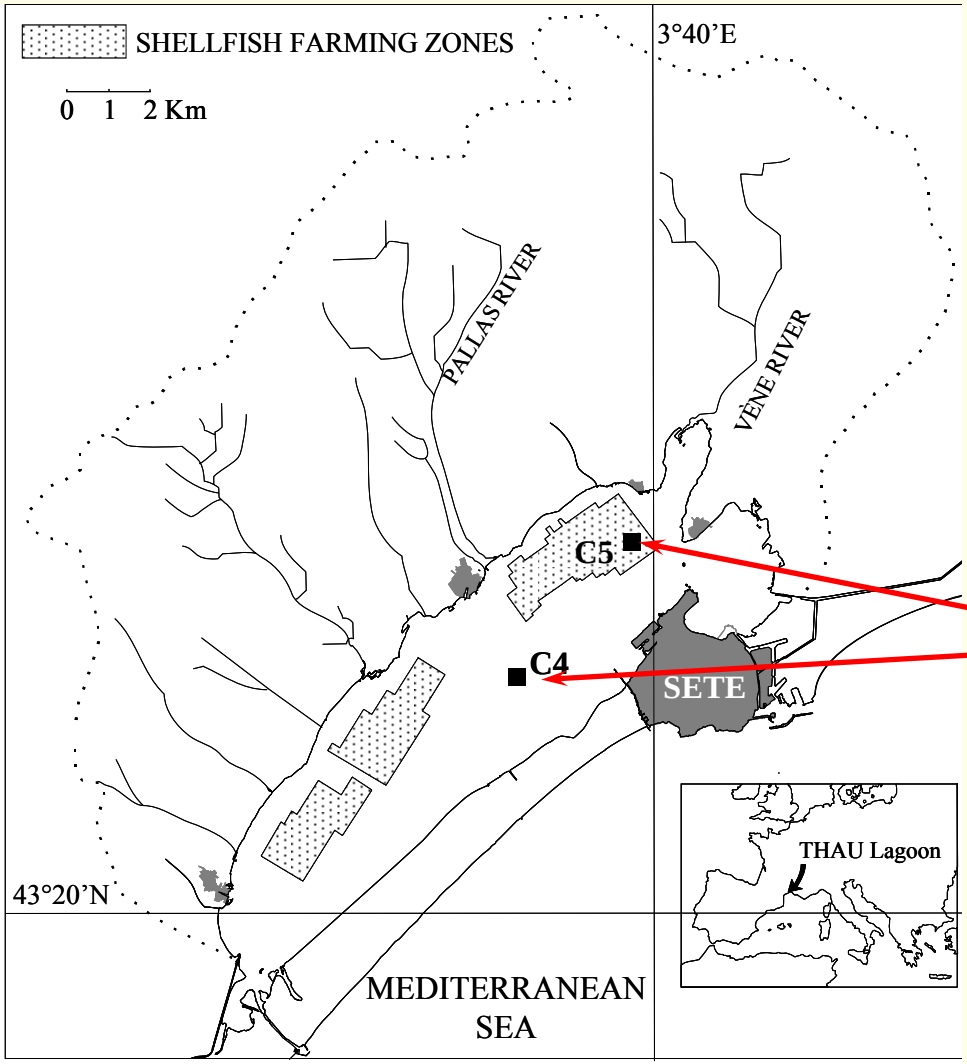
- **Nutrients (N, P) dynamics at the SWI**
- **Benthic flux of metals / organometals at the SWI**
- **O_2 dynamics and coupling with C and N cycles**
- **Trace metals (U, Hg, Cd) diagenesis**



THAU Lagoon (Hérault, France)

total area = 75 km²
shellfish-farming area = 15 km²
watershed area = 300 km²
total volume = 340 Mm³
mean depth = 4.5 m
10 % of the French shellfish production
sea exchanges = 800 Mm³/year

Rapport Ifremer, 2004



Cruises :

December 2001

April 2002

August 2002

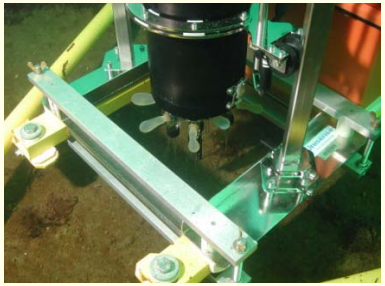
January 2003

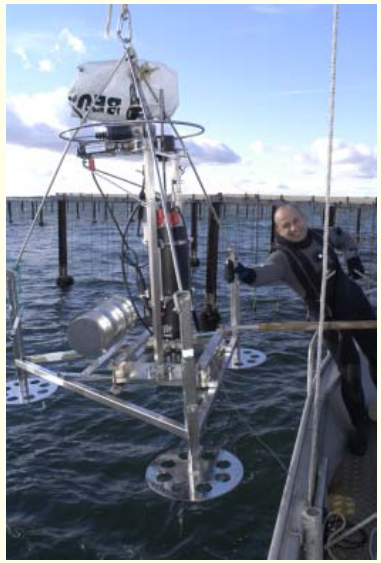
May 2003

C4 and C5 = 8 m depth

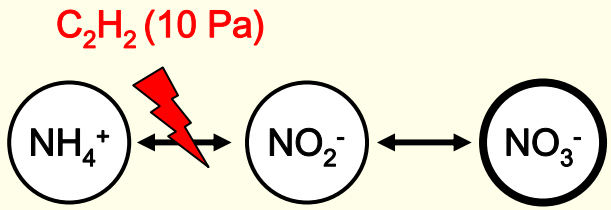
THAU Lagoon

(Hérault, France)

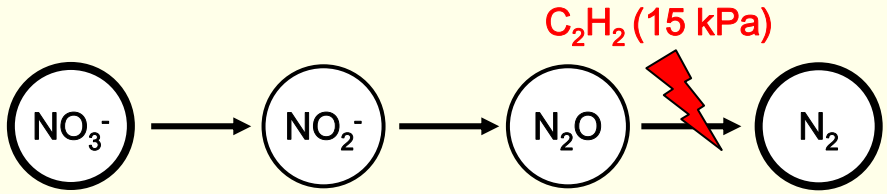




Vertical profiles of dissolved oxygen micro-electrodes (resolution of 100-200 µm) are obtained together with resistivity and pH measurements. The measuring electrodes are moved vertically by a pre-programmed motorised system.



Nitrification



Denitrification

O_2 Micro-electrodes :

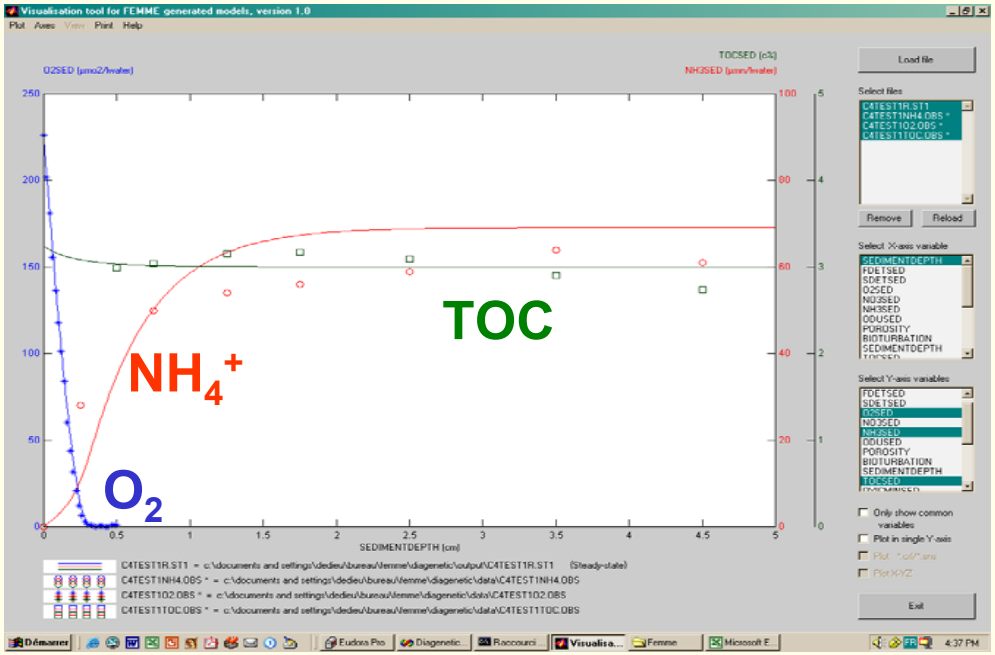
- to determine the fine scale of O_2 vertical distribution
- to calculate diffusive exchanges through the SWI & consumption rates (space and time scales)

Acetylene-blockage Method :

- to quantify the nitrification and denitrification rates

Diagenetic Model :

- to determine the relative proportion of OM mineralization pathways
- to quantify interactions between O_2, C and N in sediments



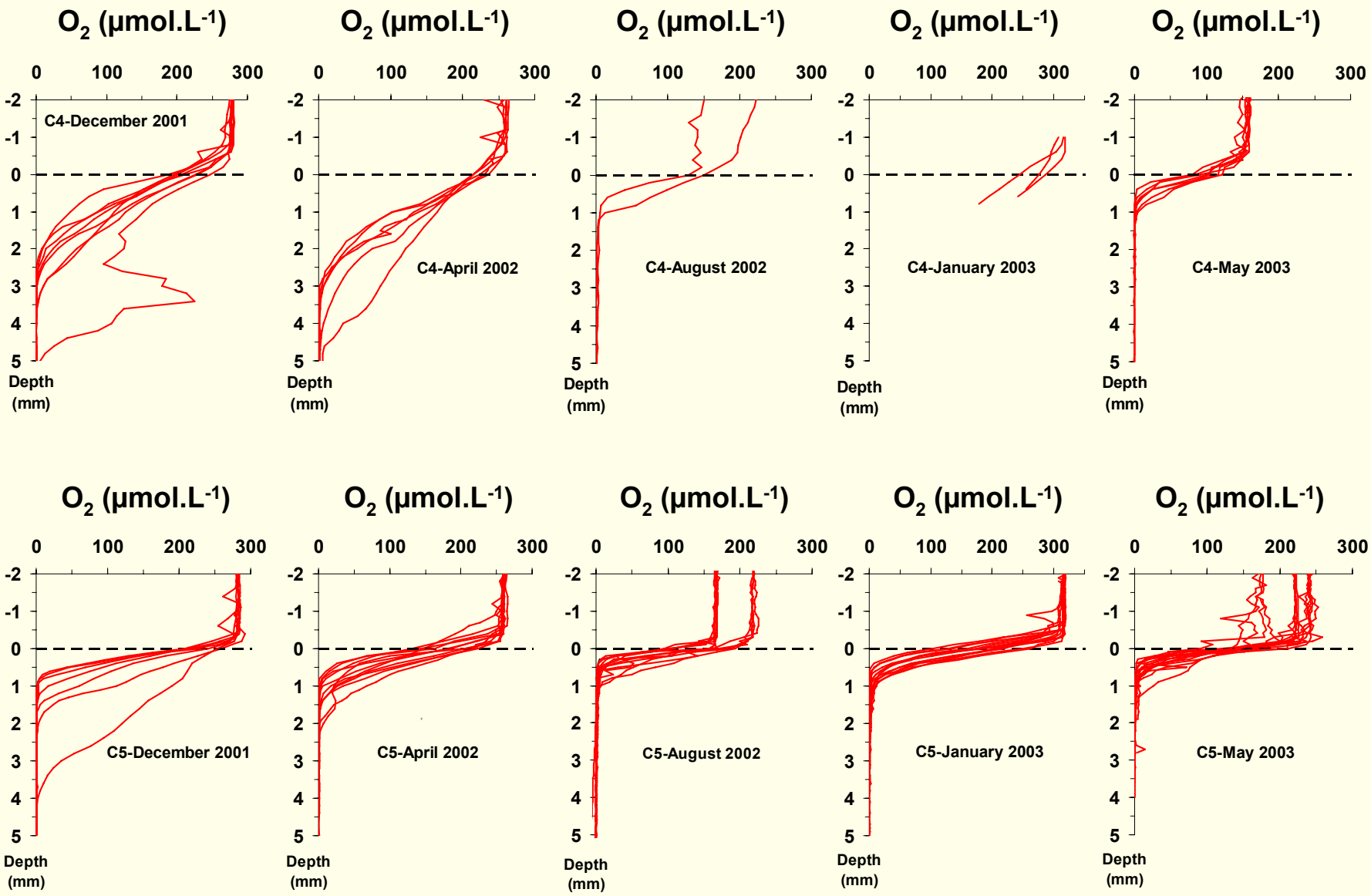
FEMME

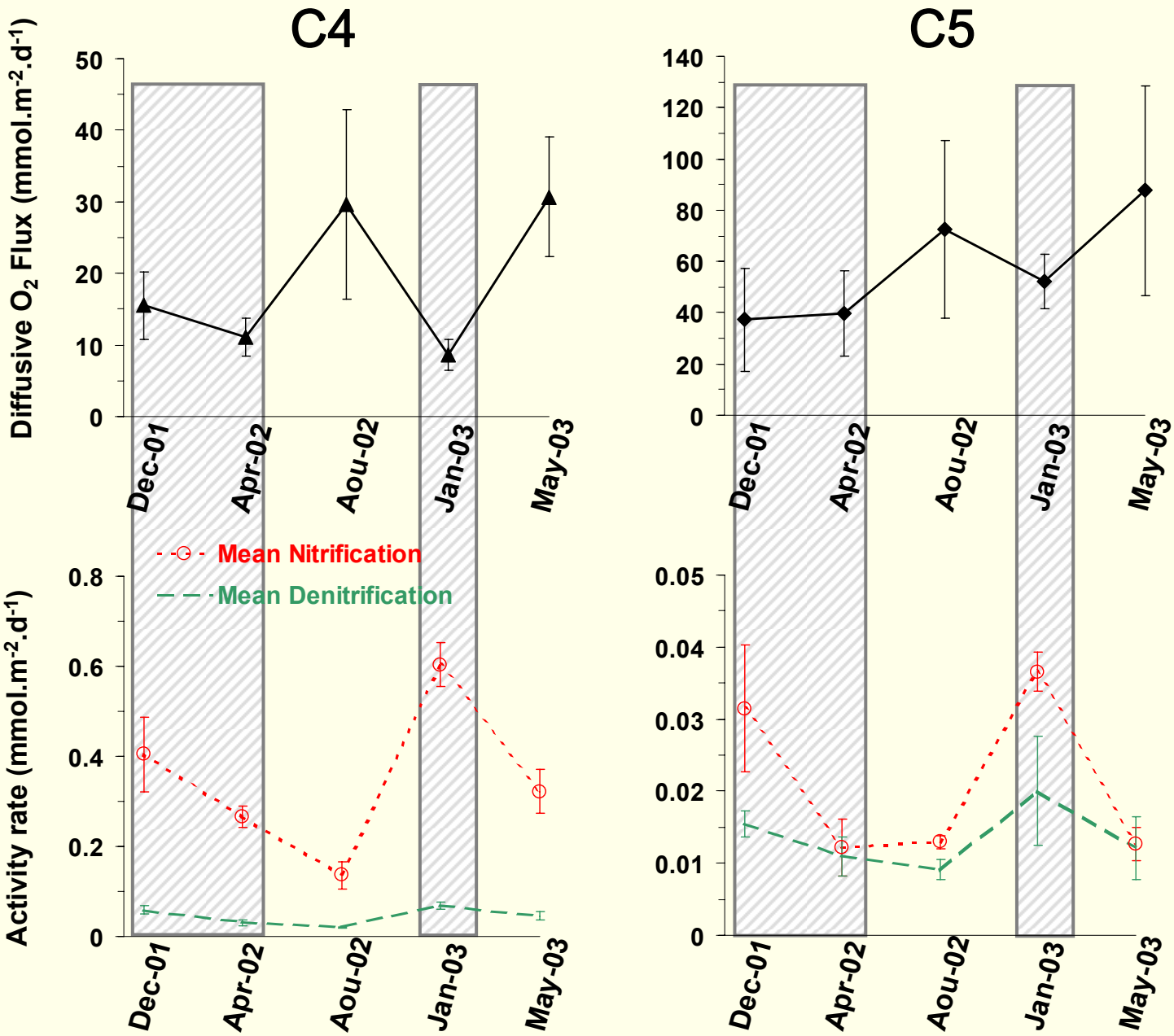
A Flexible Environment for Mathematically Modeling the Environment

Netherlands Institute of Ecology
(*Soetaert et al. 1996a, b)*

Multicomponent Reactive Transport Model

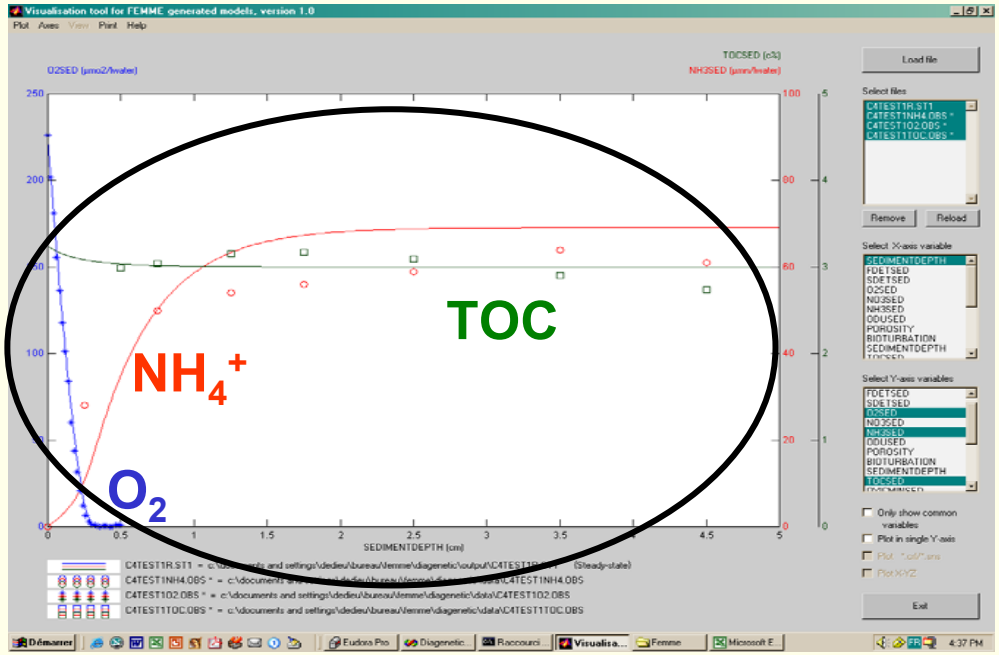
- 1D - Fortran code
- many functional units (steady state solvers, fitting routines, …)
- graphic interface for model outputs
- already tested *(Soetaert et al. 2002)*


O2 (µmol.L-1)
0 100 200 300
-2 -1 0 1 2 3 4 5
Depth (mm)
C4-December 2001
C4-April 2002
C4-August 2002
C4-January 2003
C4-May 2003
C5-December 2001
C5-April 2002
C5-August 2002
C5-January 2003
C5-May 2003


C4
C5
Diffusive O_2 Flux (mmol.m^{-2}.d^{-1})
Activity rate (mmol.m^{-2}.d^{-1})
Mean Nitrification
Mean Denitrification
Dec-01
Apr-02
Aou-02
Jan-03
May-03

Diagenetic Model :

- to determine the relative proportion of OM mineralization pathways
- to quantify interactions between O_2, C and N in sediments



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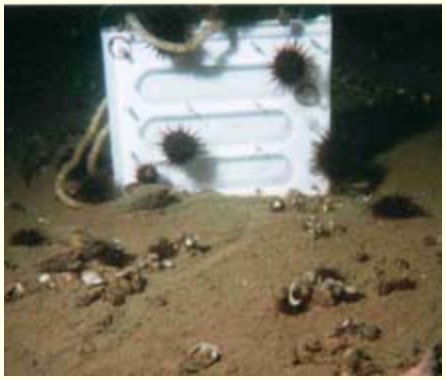
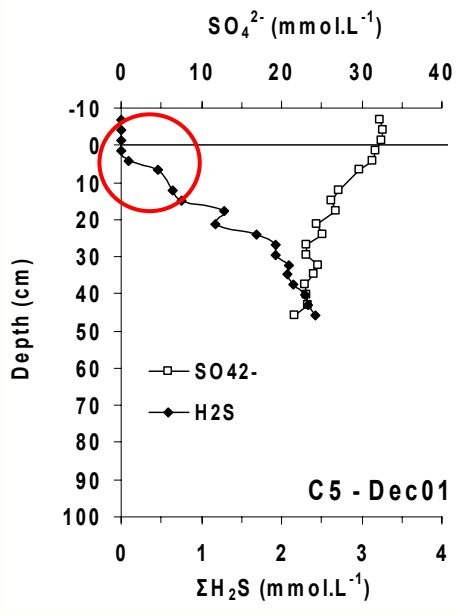
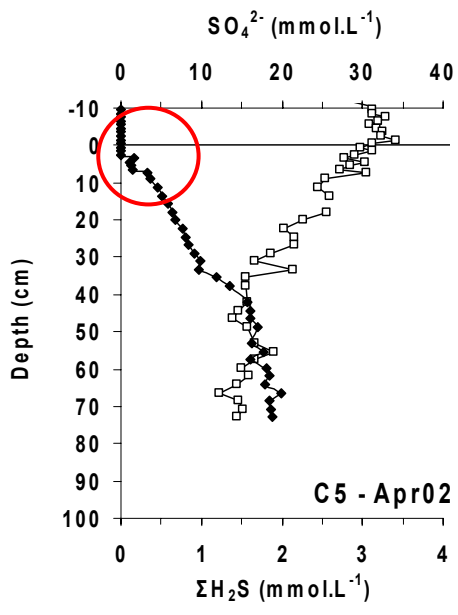
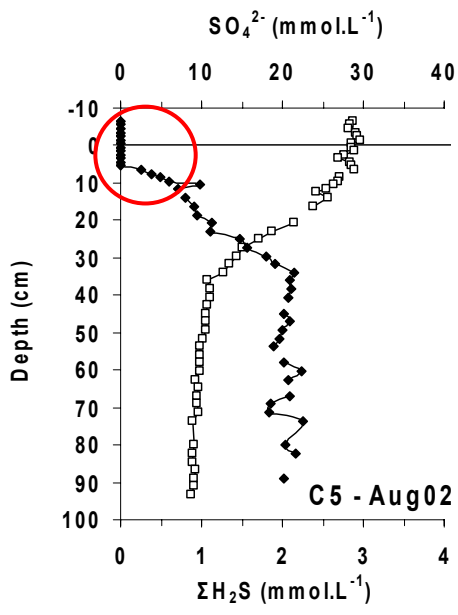
SO_4^{2-} and ΣH_2S profiles (peepers)



Data from Metzger *et al.*, submitted, with permission



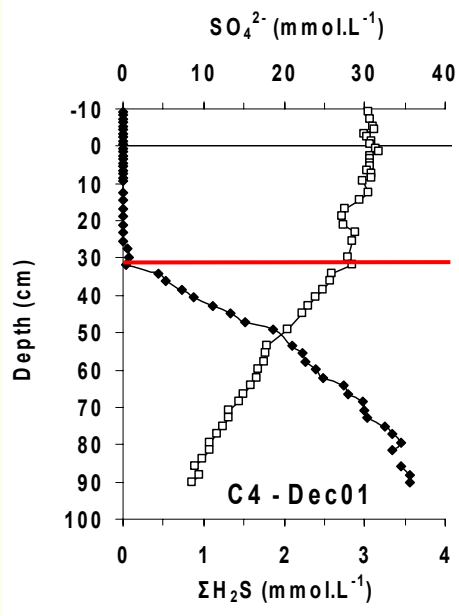


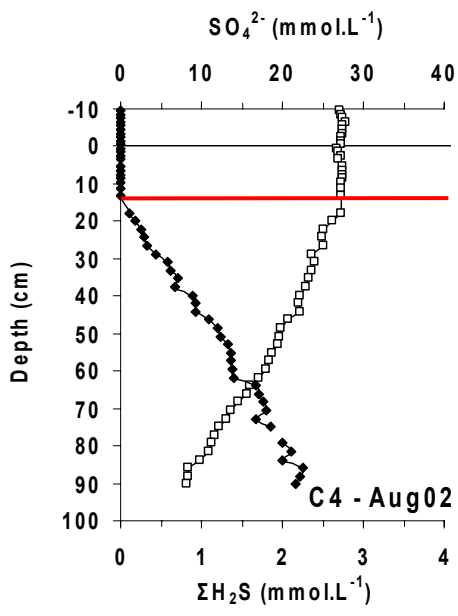


Presence of sulphurs under the sediment-water interface at station C5

⇩

Test of the sulphurs inhibition on nitrification





Sulphurs inhibition on nitrification

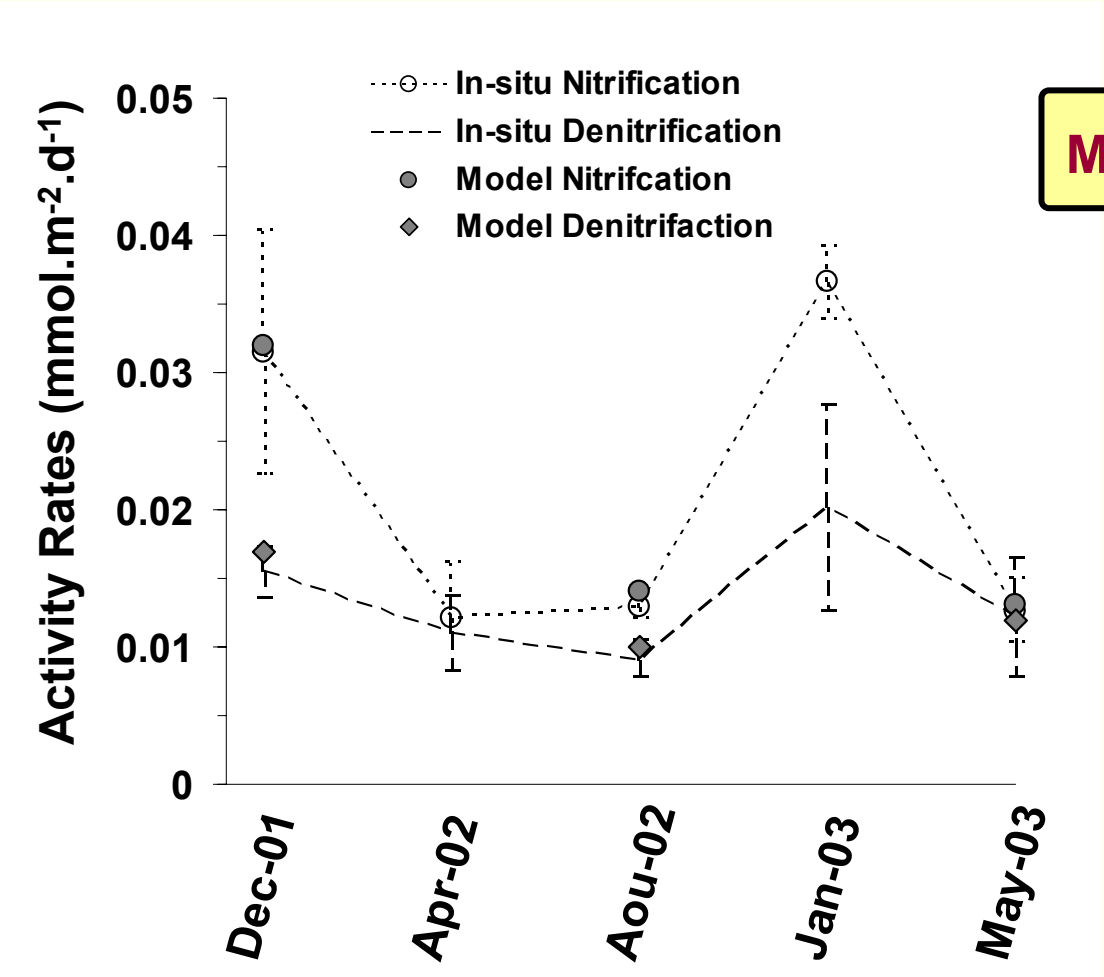
$$\text{nitrification} = f(R_{nit}, NH_3, O_2, \ldots) \times \text{inhibition term}$$

+

$$1 - \frac{ODU}{ODU + Kin_{ODU}^{Nit}}$$

Kin_{ODU}^{Nit} = Half-saturated ODU concentration for nitrification inhibition

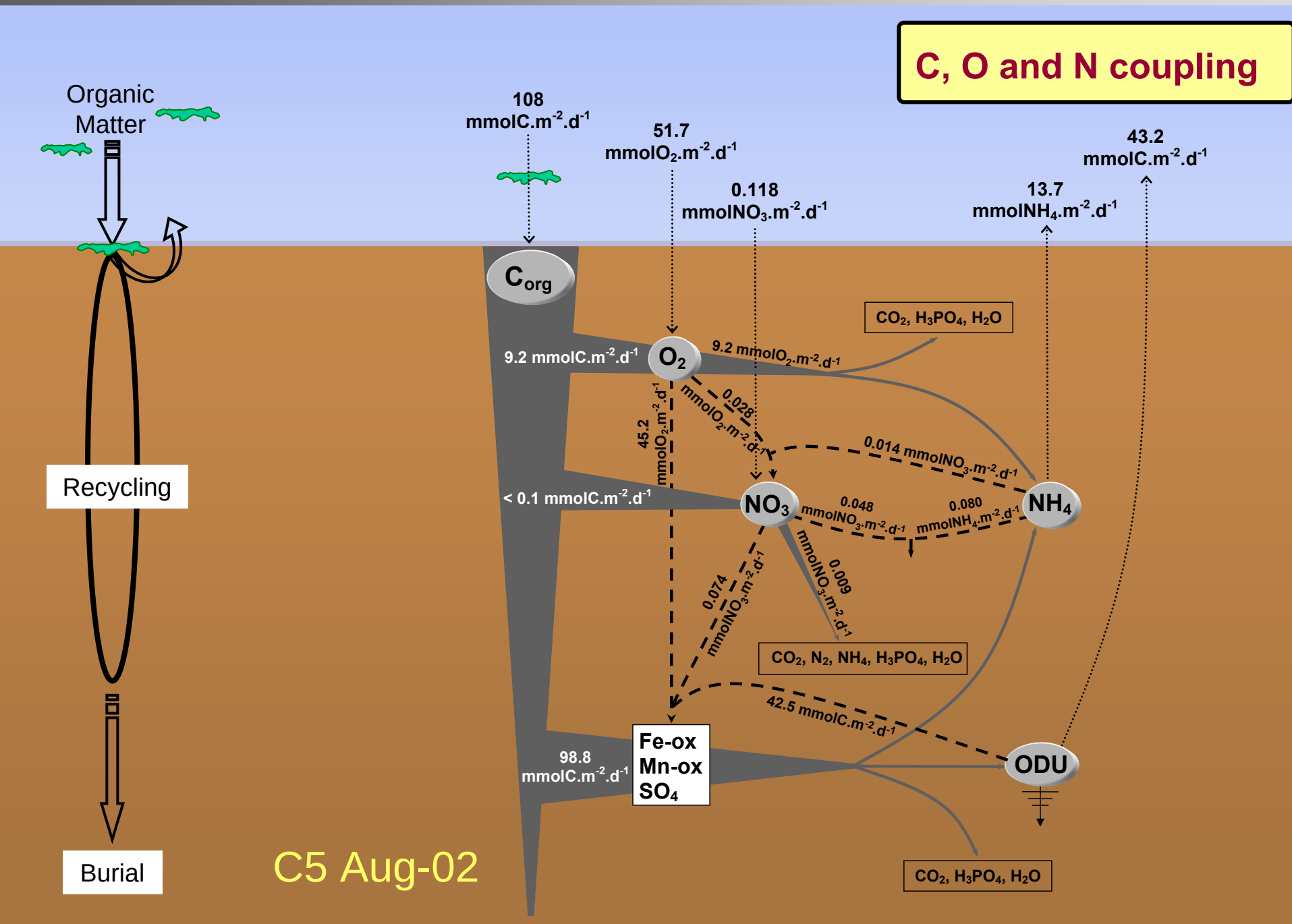
ODU = Oxygen Demand Unit (ΣH_2S, NH_4^+, Fe^{2+}, Mn^{2+})



Station C5

Model-Data Comparison

⇨ Good fit with the field data


C, O and N coupling
Organic Matter
Recycling
Burial
C5 Aug-02
108 mmolC.m-2.d-1
51.7 mmolO2.m-2.d-1
0.118 mmolNO3.m-2.d-1
13.7 mmolNH4.m-2.d-1
43.2 mmolC.m-2.d-1
Corg
O2
NO3
NH4
ODU
Fe-ox
Mn-ox
SO4
9.2 mmolC.m-2.d-1
9.2 mmolO2.m-2.d-1
45.2 mmolO2.m-2.d-1
0.028 mmolO2.m-2.d-1
0.014 mmolNO3.m-2.d-1
< 0.1 mmolC.m-2.d-1
0.048 mmolNO3.m-2.d-1
0.080 mmolNH4.m-2.d-1
0.074 mmolNO3.m-2.d-1
0.009 mmolNO3.m-2.d-1
42.5 mmolC.m-2.d-1
98.8 mmolC.m-2.d-1
CO2, H3PO4, H2O
CO2, N2, NH4, H3PO4, H2O
CO2, H3PO4, H2O

- a **seasonal negative correlation** of oxygen demand intensity and nitrogen processes rates
- a **spatial variation** of nitrifying and denitrifying bacteria activities at the lagoon scale
- the **oxic zone thickness** also plays a significant role in the nitrogen dynamics
- The addition of a **nitrification inhibition term** (by hydrogen sulfide) in the diagenetic model improved the fit quality of data set
- The diagenetic model also pointed out a **higher and fresher material** input at station under the shellfish farming than outside.

		Dec 2001	Aug 2002	May 2003
C4	% OxicMin	34	21	18
	% Denit	1	< 1	< 1
	% AnoxicMin	65	79	82
C5	% OxicMin	27	9	9
	% Denit	< 1	< 1	< 1
	% AnoxicMin	73	91	91

- The main degradation pathway for both sites and all cruises = **anoxic degradation**
- more than **80** and **70%** of oxygen was used to **re-oxidized by-products** from anaerobic reactions, the rest being used to the strict oxic mineralization

% des réactions lors de la dégradation de la matière organique

		Dec-01	Aug-02	May-03
C4	% Oxic	34	19	18
	% Denit	< 1	< 1	< 1
	% Anoxic	65	81	82
C5	% Oxic	27	8.5	9
	% Denit	< 1	< 1	< 1
	% Anoxic	73	91.5	91

		Dec-01	Aug-02	May-03
C4	% O_2Min	36	28	29
	% O_2Nit	7	< 1	2
	% O_2ODU	57	71	69
C5	% O_2Min	38	17	18
	% O_2Nit	< 1	< 1	< 1
	% O_2ODU	62	82	82

Respiration aérobie (% O_2Min)

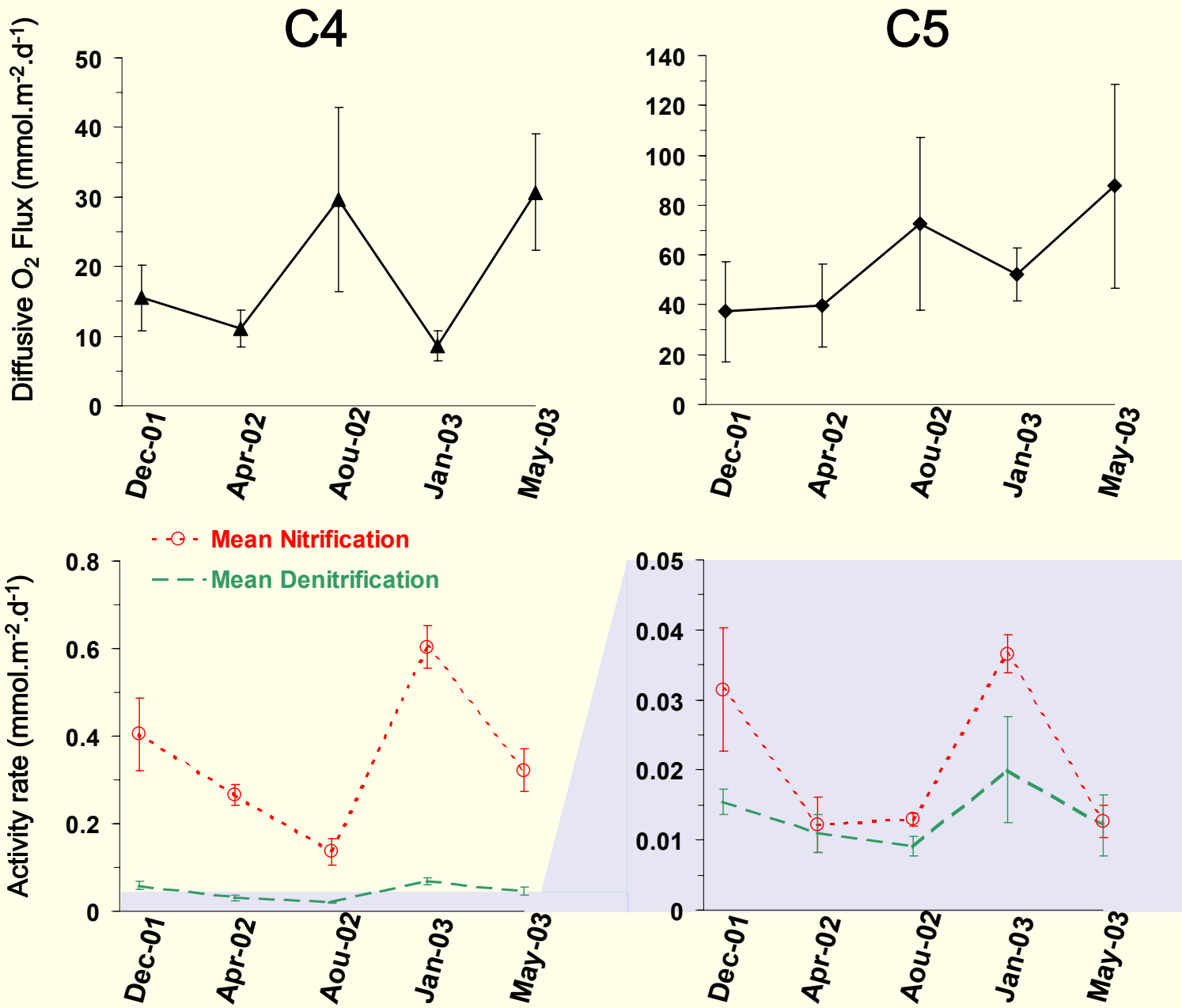
Nitrification (% O_2Nit)

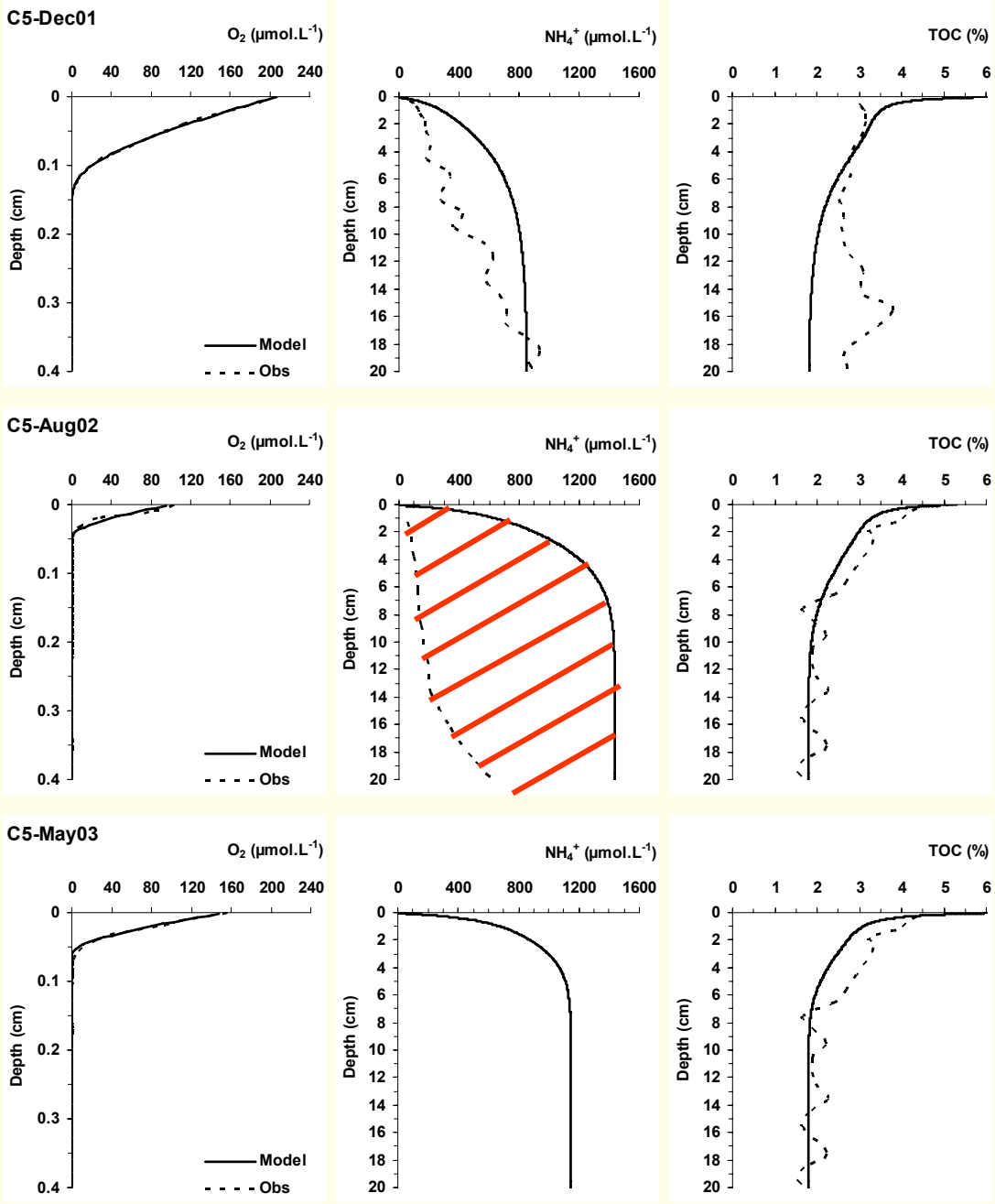
Oxydation des produits réduits (% O_2ODU)

} **% Oxic**

Dénitrification (% Denit)

Minéralisation Anoxique (% Anoxic)


C4
C5
Diffusive O_2 Flux (mmol.m^{-2}.d^{-1})
0
10
20
30
40
50
0
20
40
60
80
100
120
140
Dec-01
Apr-02
Aou-02
Jan-03
May-03
Mean Nitrification
Mean Denitrification
Activity rate (mmol.m^{-2}.d^{-1})
0
0.2
0.4
0.6
0.8
0
0.01
0.02
0.03
0.04
0.05



Model-Data Comparison

⇨ Good fits with O_2
Adequate fits with TOC

⇨ Bad fits with NH_4
(summer periods)