Organic matter mineralization and nitrogen transformations during stagnation of the Gotland Sea deep water

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Measurement programme, MAR 2003 – OCT 2007:

Variables:

total CO_2 (C_T,min)

O_2

H_2S

NO_3^-

NH_4^+

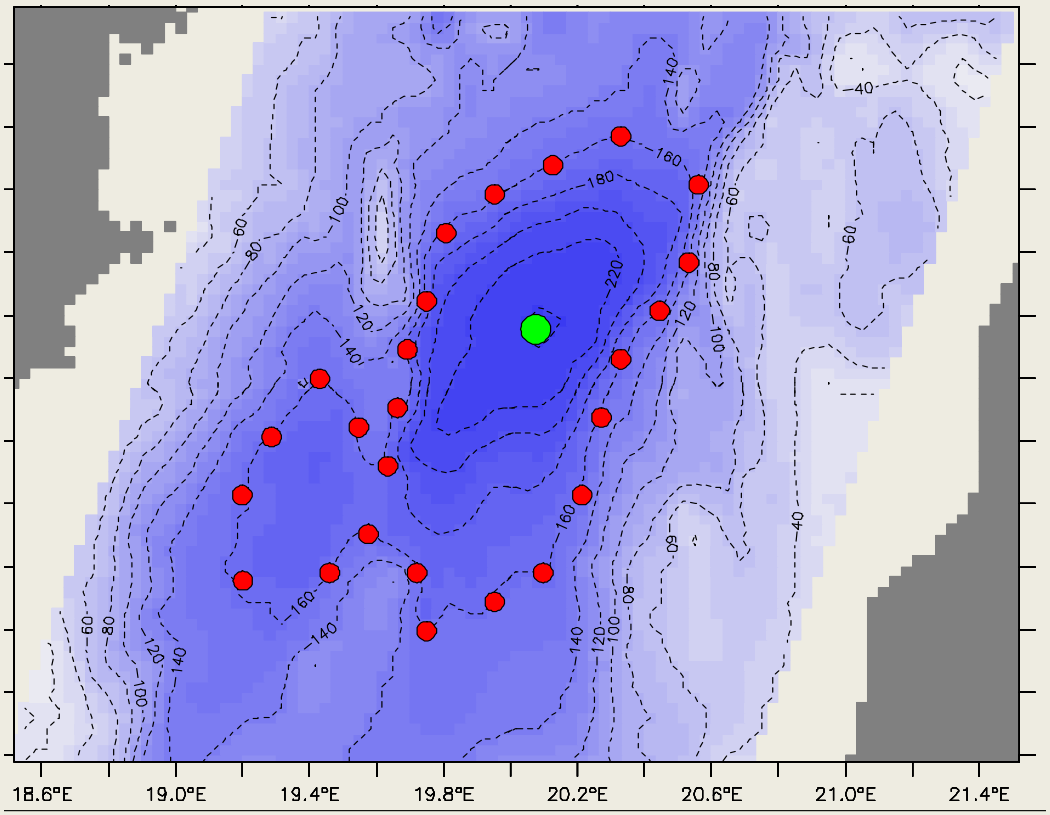
PO_4^{3-}

Temporal resolution:

2 – 3 months

Depth resolution:

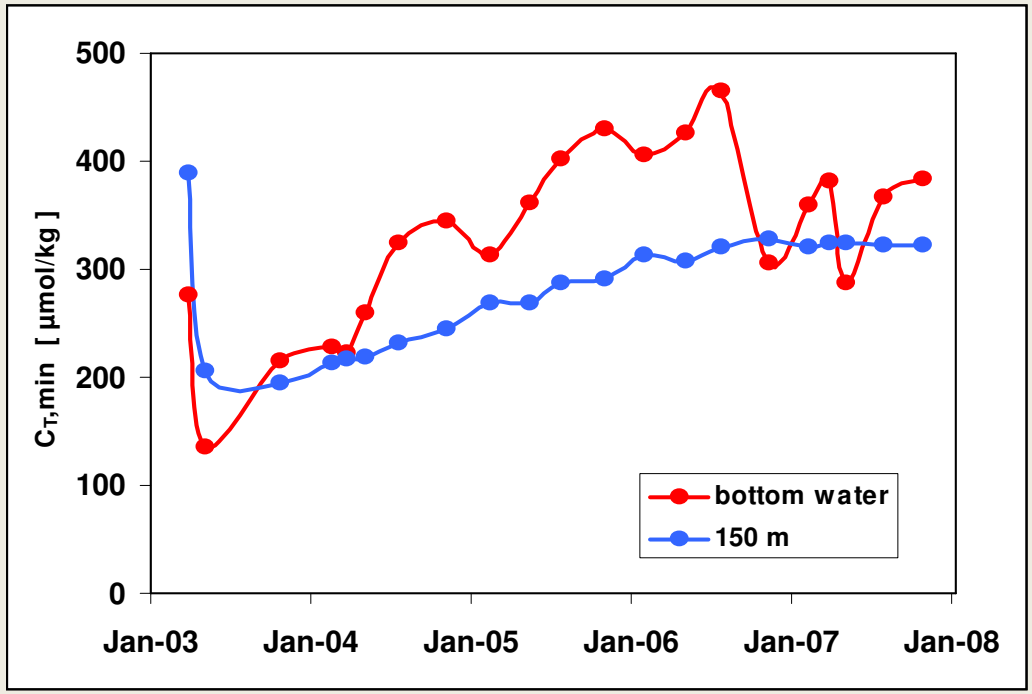
25 m + bottom water



Subdivision in boxes:

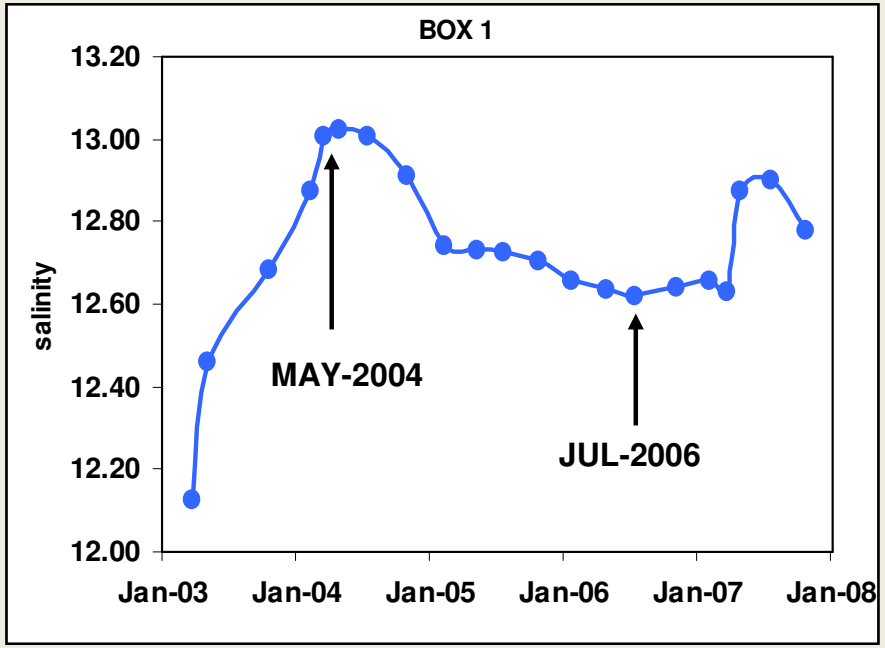
BOX #	Depth [m]	area [km²]	sediment area [km²]	volume [km³]
1	> 225	464	464	3.8
2	200 - 225	1160	696	20.8
3	175 - 200	2120	960	39.7
4	150 - 175	4680	2560	84.9

Time series of the mineralization fraction of total CO_2, C_T,min:

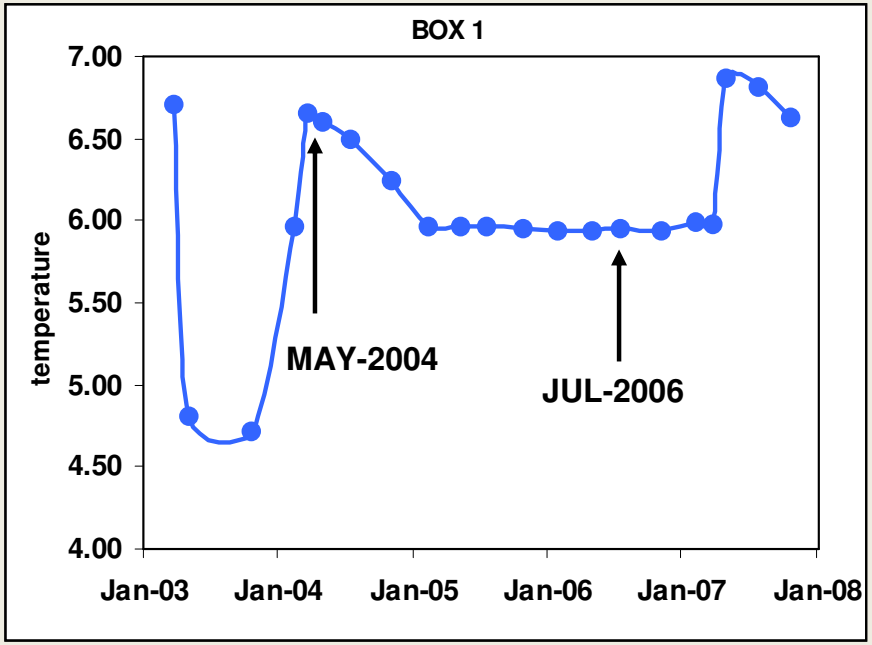


Identification of a period of stagnation:

salinity



temperature



Determination of mixing coefficients, k_{mix}:

$$F_S = k_{mix} \cdot \frac{\Delta S}{\Delta z}$$

-separately for each time interval;

- gradients: difference in salinity between two neighbouring boxes divided by the distance between the center of the boxes; averaging of the gradients at the beginning and the end of the considered time interval;

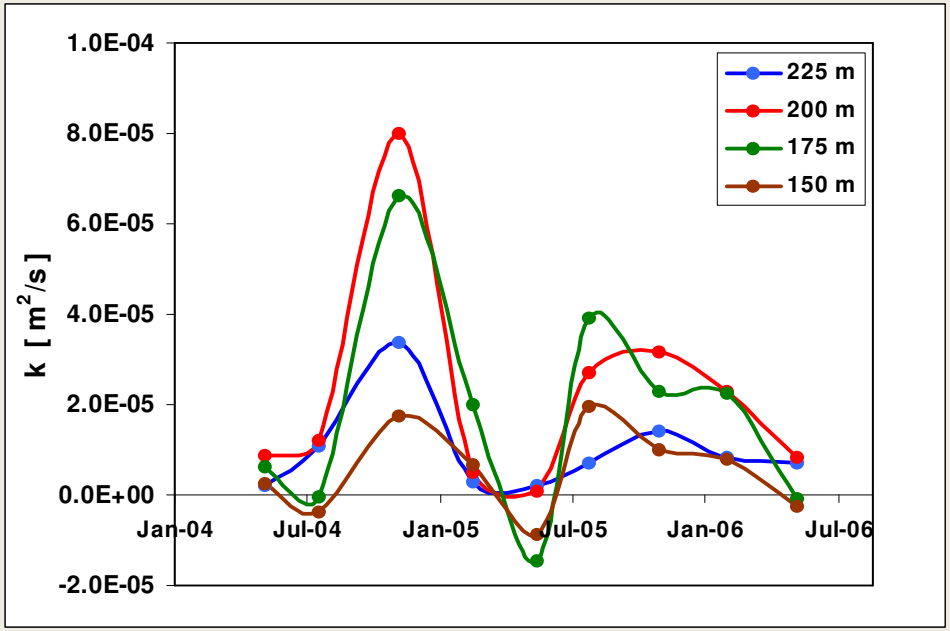
- fluxes: obtained from salt mass balances for each time interval:

$$F_S(1 \rightarrow 2) = (\Delta S_1 \cdot V_1 / A_1) / \Delta t)$$

$$F_S(2 \rightarrow 3) = -F(1 \rightarrow 2) + (\Delta S_2 \cdot V_2 / A_2) / \Delta t)$$

Mixing coefficients:

- maximum during winter;
- negative values at 175 m and 150 m indicate slight lateral intrusions;



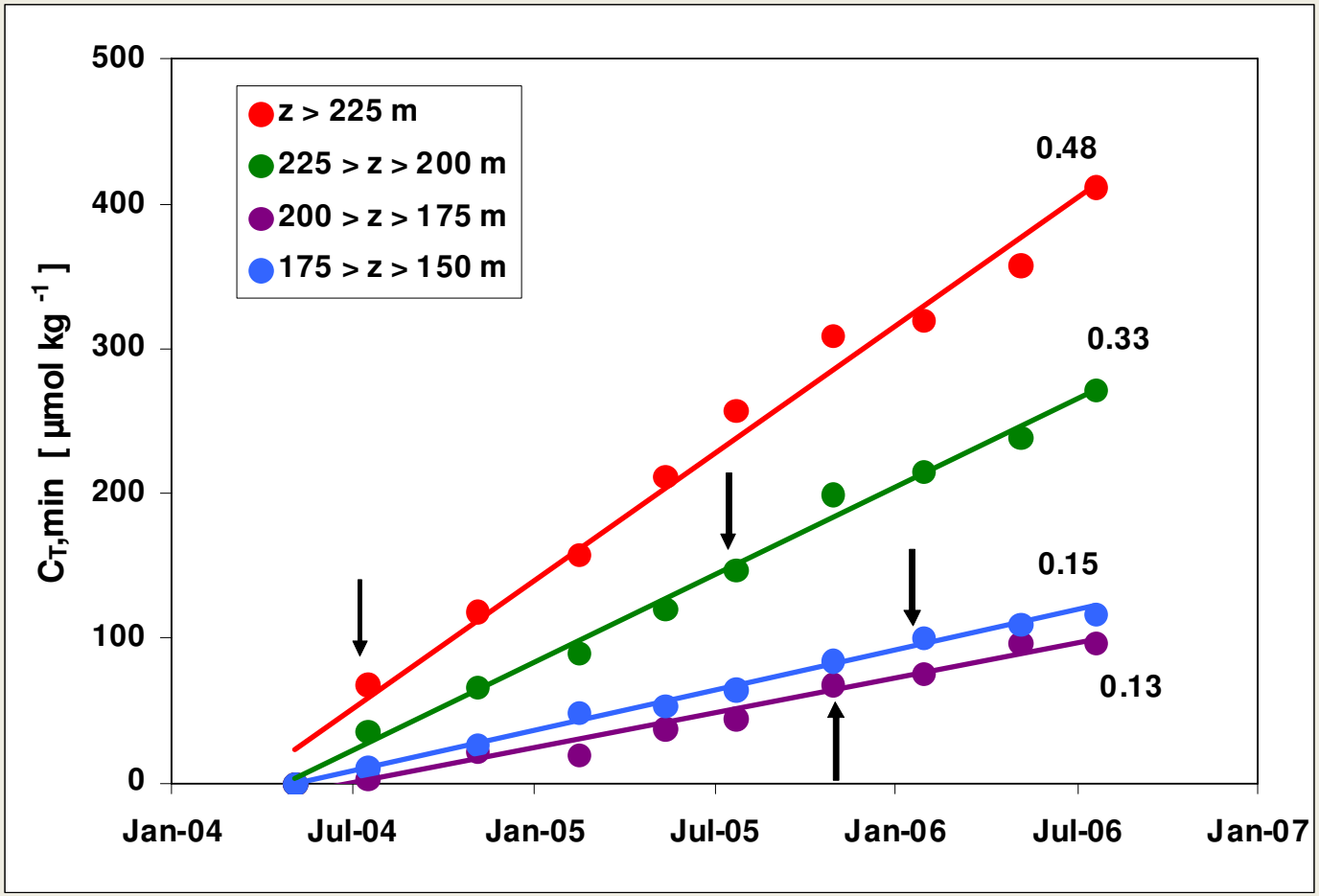
Mass balances for biogeochemical constituents:

$$\frac{\Delta c_n}{\Delta t} = \frac{A_{n-1} \cdot F_{n-1} + A_n \cdot F_n}{V_n} + Q_n$$

n – box number
c – concentration
Δt – time interval
A – area
V - volume
F – vertical flux between boxes
Q – sink/source

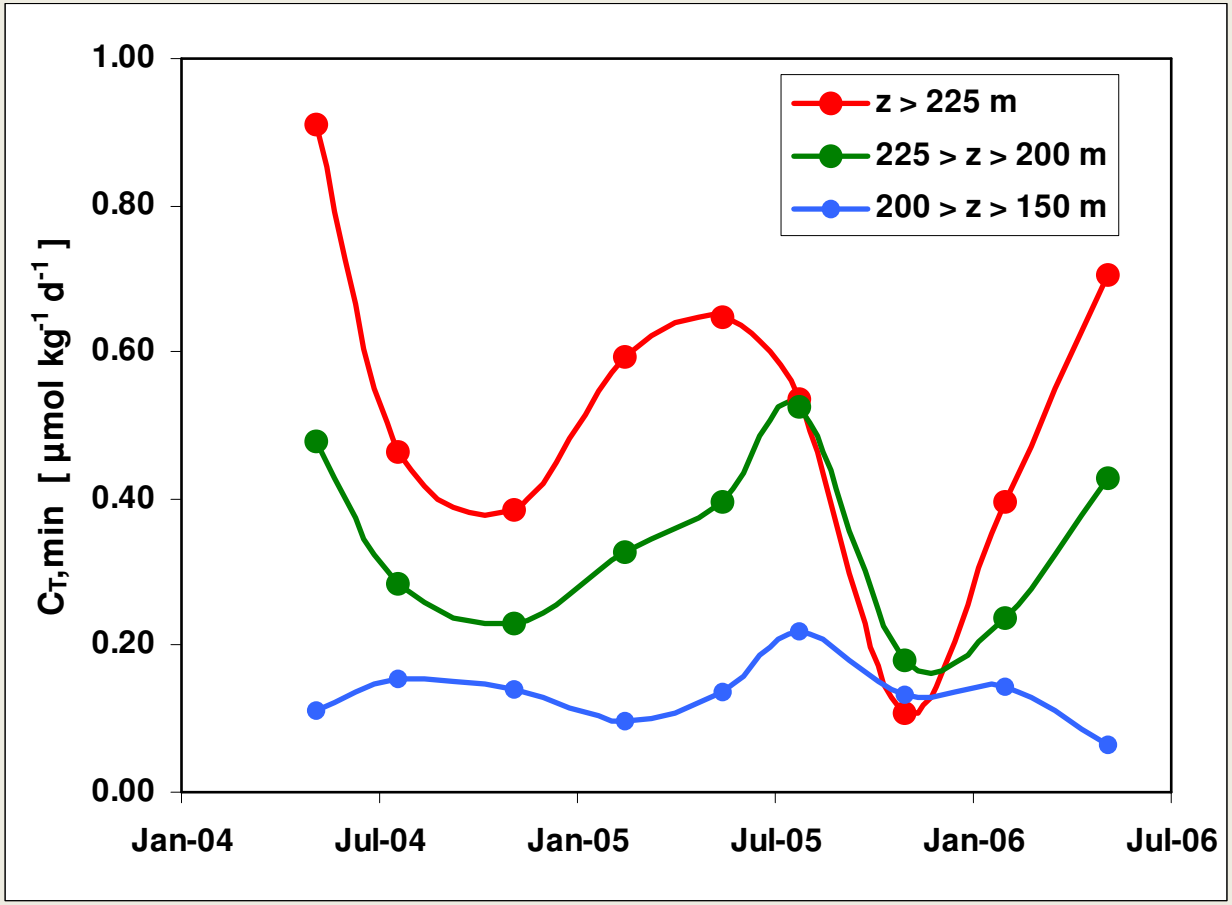
Accumulated C_T,min increase during stagnation in different sublayers:

- the arrows indicate the transition to anoxic conditions;
- mean mineralization rates vary between 0.48 and 0.13 (µmol/kg)/d;



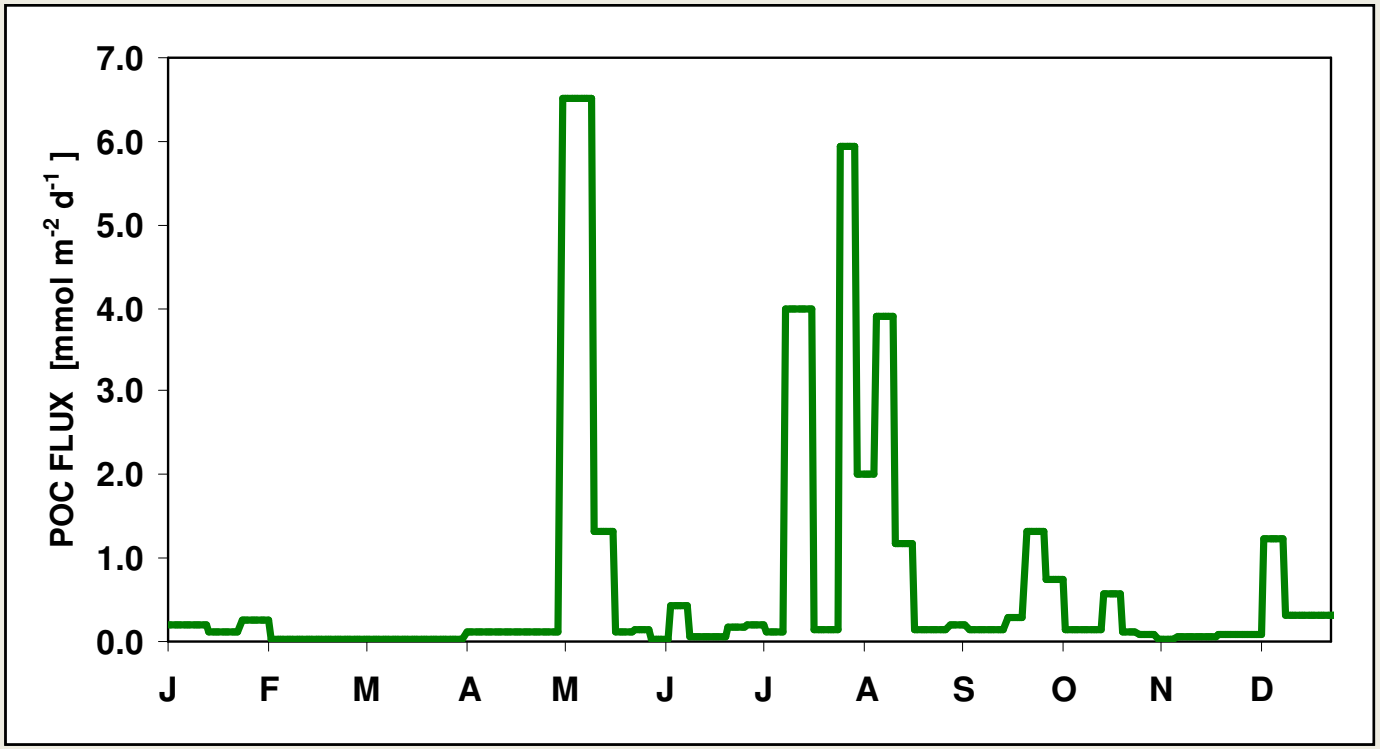
Mineralization rates for individual time intervals:

- maxima during May – July (July – November);
- no seasonal signal above 200 m;



POC fluxes obtained from a sediment trap deployed at 180 m:

- data from 1999;
- data used to estimate the mineralization kinetics;



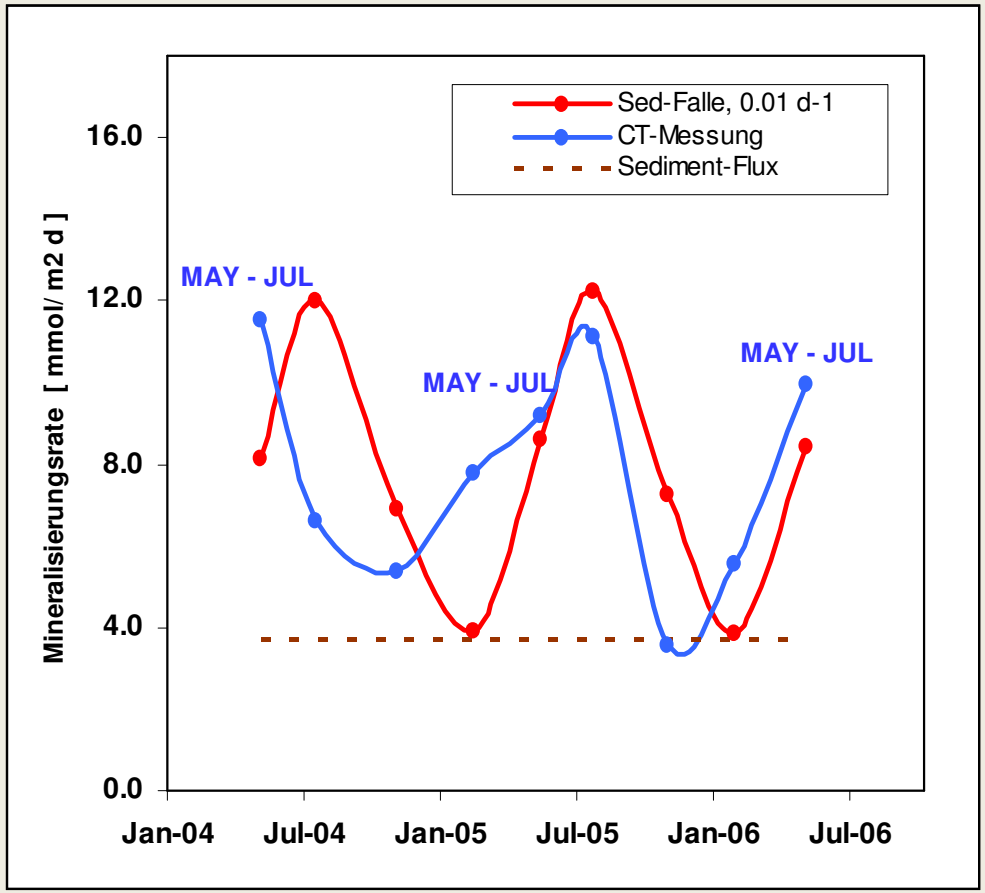
(F. Pollehne, unpublished)

Mineralization kinetics:

$$-\frac{dc_{org}}{dt} = \frac{dC_T}{dt} = k_{min} \cdot c_{org} \cdot \cancel{c_{oxi}}$$

$$c_{oxi} : O_2, NO_3^-, SO_4^{2-}$$

- modelling the mineralization rates using the POC flux data;
- least square fit yielded best agreement with observed rates for $k_{min} = 0.01\ d^{-1}$;
- minima correspond to mineralization of refractory organic matter accumulated in deeper sediment layers;



Redox balance:

		µmol L^{-1} y^{-1}	mmol m^{-2} y^{-1}	O_2 equivalents µmol L^{-1} y^{-1}
oxidation	**C_{org}**	**63.6**	**2024**	**- 78.9**
	NH_4^+	**2.8**	**89**	**-2.1**
reduction	**O_2**	**22.3**	**709**	**22.3**
	SO_4^{2-}	**20.1**	**638**	**40.1**
	NO_3^-	**5.1**	**161**	**6.3**
balance				**-12.3**

Oxidant demand for the mineralization of organic matter:

- low oxidant consumption in the intial phase of the O_2 depletion/H_2S formation;
- oxidation by MnO_2 ?