Exercise 4

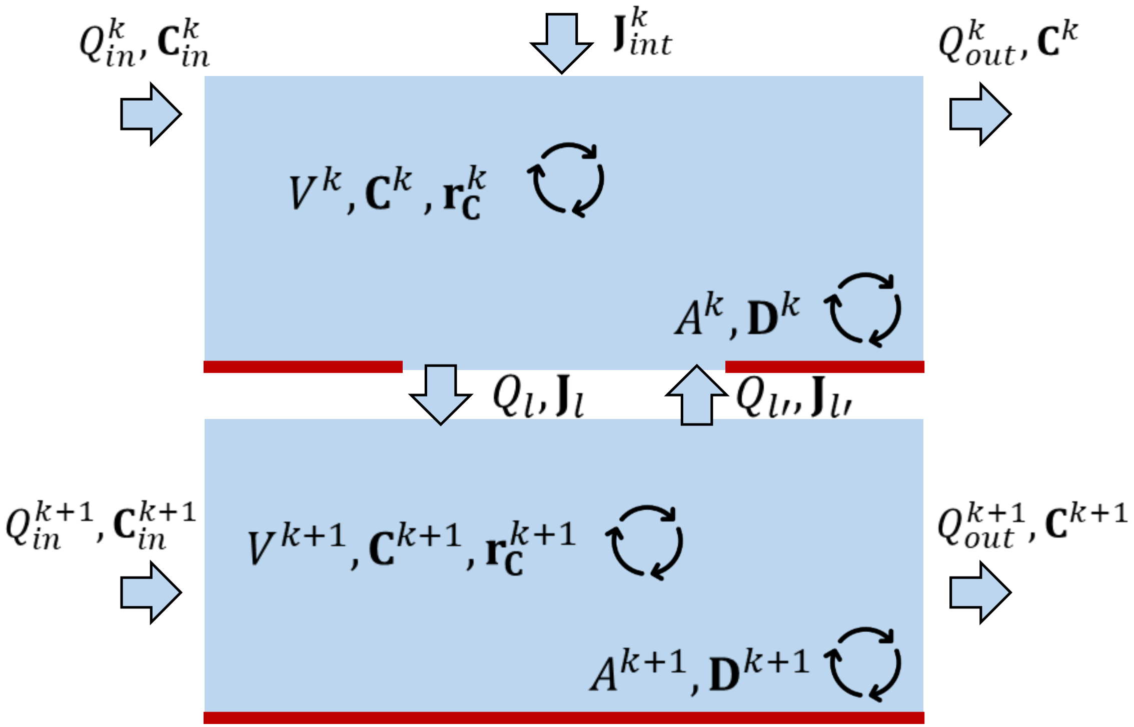
Modelling Aquatic Ecosystems FS24

Today's agenda

- Introduction to today's model 11.4
- Work on the exercise on your own
- Break
- Discuss the results and
  the questions of the exercise
- Work on your own model and
  take the opportunity to ask questions

Recap of last weeks

- Process stoichiometry (chapter 4.3)
- Biological processes (chapter 8)
  - Primary production, respiration, death, consumption
  - Mineralization (oxic, anoxic)
  - Nitrification
- Mass balance in a continuous multi-reactor system (chapter 3.3)
- Physical processes (chapters 6.1 to 6.3)
  - Transport and mixing in lakes (stratification, plunging of inflows, horizontal and vertical mixing)
  - Sedimentation
  - Gas exchange

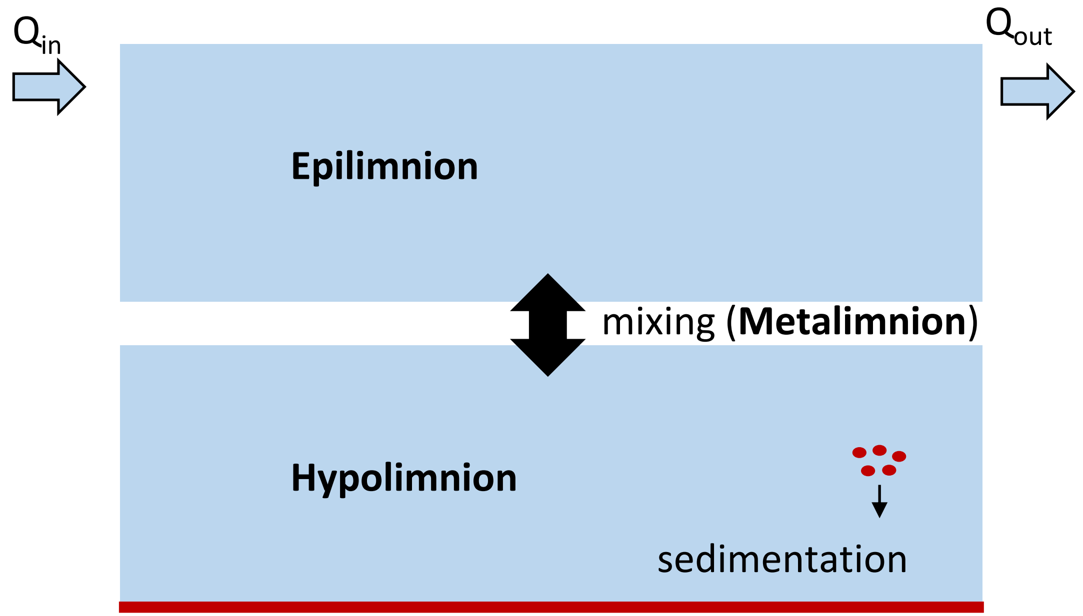


Advection-diffusion-reaction equation:

$$\frac{\partial C}{\partial t} + \frac{\partial (v_x C)}{\partial x} + \frac{\partial (v_y C)}{\partial y} + \frac{\partial (v_z C)}{\partial z} = \frac{\partial}{\partial x}\left(D_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y \frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(D_z \frac{\partial C}{\partial z}\right) + r$$

Two box biogeochemical-ecological lake model

Physical Representation



Biogeochem/ecological processes:

1. Growth, death, respiration: ALG, ZOO
2. Nitrification
3. Mineralization: oxic, anoxic
4. Sedimentation

Consider the following env. factors:

1. Temperature
2. Light intensity
3. Seasonality of physical parameters; Exchange summer vs. winter

Process table of today's model

Process	Substances / Organisms	Rate
Growth of algae NO_3^-		ρ_{gro,ALG,NO_3^-}
Growth of algae NH_4^+		ρ_{gro,ALG,NH_4^+}
Respiration of algae		$\rho_{resp,ALG}$
Death of algae		$\rho_{death,ALG}$
Growth of zooplankton		$\rho_{gro,ZOO}$
Respiration of zoopl.		$\rho_{resp,ZOO}$
Death of zooplankton		$\rho_{death,ZOO}$
Nitrification		ρ_{nitri}
Oxic mineral. of org. part.		$\rho_{miner,ox,POMD}$
Ox. min. of org. part. in sed.		$\rho_{miner,ox,SPOMD}$
Anox. min. of org. part. in sed.		$\rho_{miner,anox,SPOMD}$
Sed. of deg. org. part.		$\rho_{sed,POMD}$
Sed. of inert org. part.		$\rho_{sed,POMI}$

Table 11.9: Process table of the model for biogeochemical cycles in a lake.

Time to work on Exercise 4

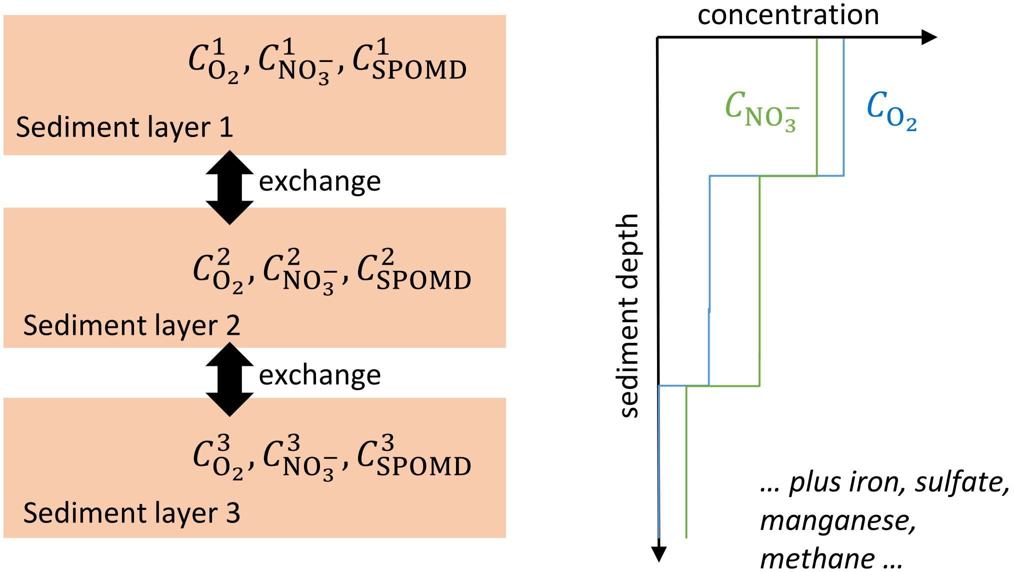
How and why do we differentiate oxic and anoxic mineralization ?

In a more realistic model

Sediment is modelled as different discrete/continuous layers/depth, each with its in-situ substance concentrations:

$$\rho_{\text{miner,ox,SPOMD}} = k_{\text{miner,ox}} \cdot f_{\text{temp}}(T) \cdot f_{\text{lim}}(C_{O_2}) \cdot C_{\text{SPOMD}}$$

$$\rho_{\text{miner,anox,SPOMD}} = k_{\text{miner,anox}} \cdot f_{\text{temp}}(T) \cdot f_{\text{inh}}(C_{O_2}) \cdot f_{\text{lim}}(C_{NO_3^-}) \cdot C_{\text{SPOMD}}$$

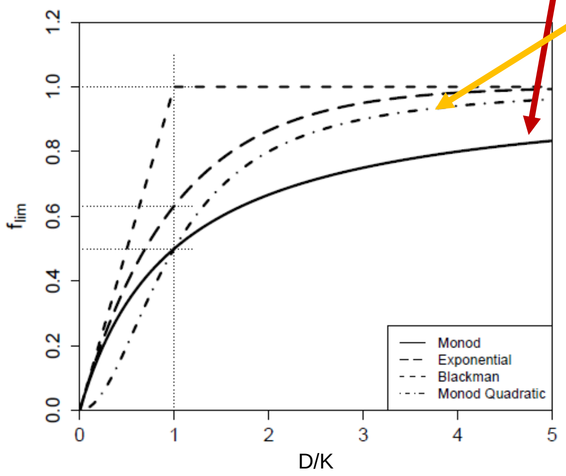


In our two-box model

Sediment is modelled as density of SPOMD at the bottom of the hypolimnion, with substance concentrations of this box:

$$\rho_{\text{miner,ox,SPOMD}} = k_{\text{miner,ox}} \cdot f_{\text{temp}}(T) \cdot f_{\text{lim}}(C_{O_2}) \cdot \frac{D_{\text{SPOMD}}}{K_{\text{SPOMD,miner}} + D_{\text{SPOMD}}}$$

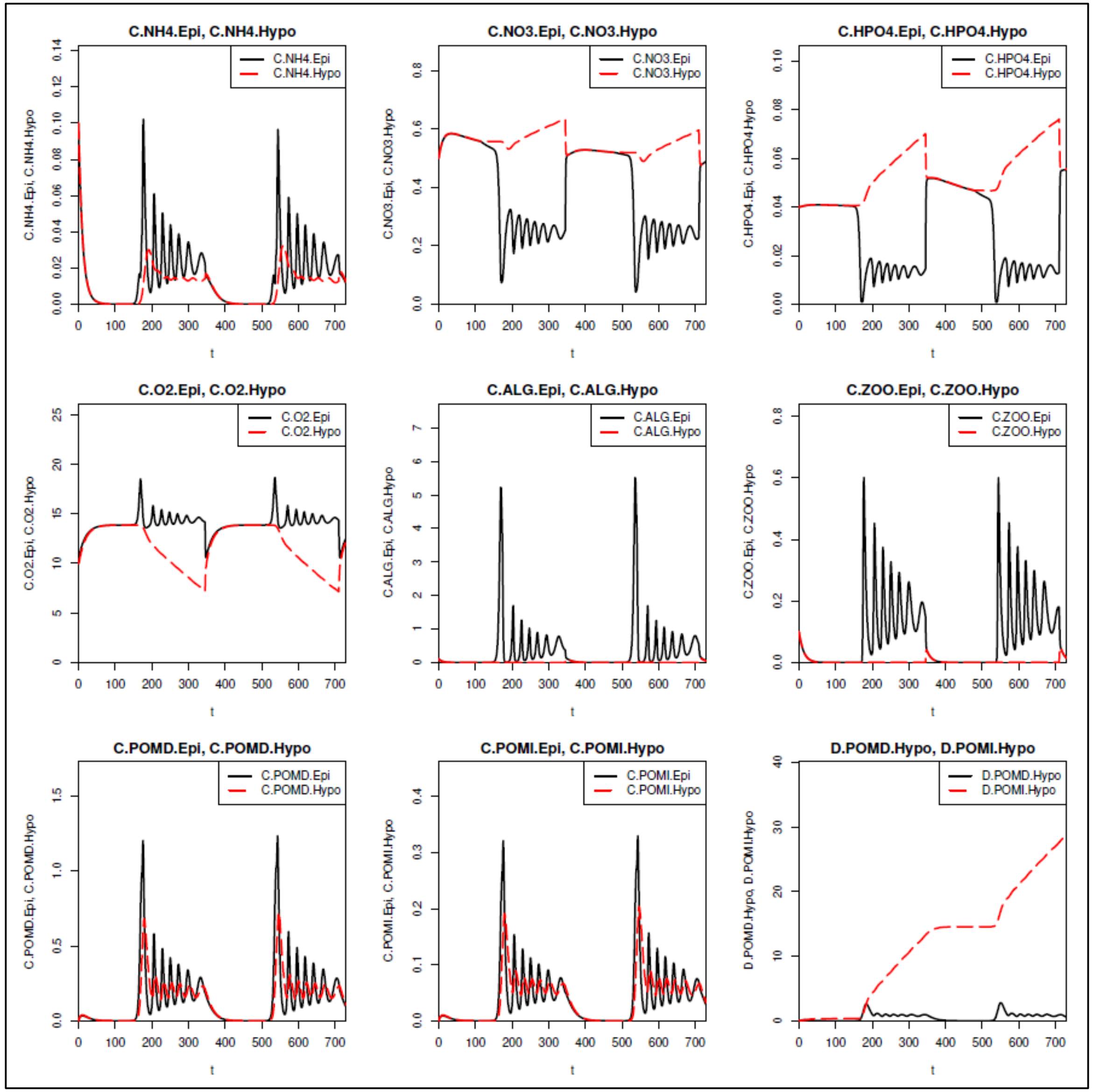
$$\rho_{\text{miner,anox,SPOMD}} = k_{\text{miner,anox}} \cdot f_{\text{temp}}(T) \cdot f_{\text{lim}}(C_{NO_3^-}) \cdot \frac{D^2_{\text{SPOMD}}}{K^2_{\text{SPOMD,mner}} + D^2_{\text{SPOMD}}}$$



Discuss the results

Process	HPO$_4^{2-}$ gP	NH$_4^+$ gN	NO$_3^-$ gN	O$_2$ gO	ALG gDM	ZOO gDM	POMD gDM	POMI gDM	SPOMD gDM	SPOMI gDM
	Substances / Organisms									
Growth of algae NO$_3^-$	−		−	+	1					
Growth of algae NH$_4^+$	−	−		+	1					
Respiration of algae	+	+		−	−1					
Death of algae	0/+	0/+		0/+	−1		$(1-f_I)Y_{ALG,death}$	$f_I Y_{ALG,death}$		
Growth of zooplankton	+	+		−	$\frac{-1}{Y_{ZOO}}$	1	$\frac{(1-f_I)f_e}{Y_{ZOO}}$	$\frac{f_I f_e}{Y_{ZOO}}$		
Respiration of zoopl.	+	+		−		−1				
Death of zooplankton	0/+	0/+		0/+		−1	$(1-f_I)Y_{ZOO,death}$	$f_I Y_{ZOO,death}$		
Nitrification		−1	+	−						
Oxic mineral. of org. part.	+	+		−			−1			
Ox. min. of org. part. in sed.	+	+		−					−1	
Anox. min. of org. part. in sed.	+	+	−						−1	
Sed. of deg. org. part.							−1		1	
Sed. of inert org. part.								−1		1

Table 11.9: Process table of the model for biogeochemical cycles in a lake.



Question 4: Look at the mass balance for P and N. If there is a difference between input and output + accumulation, where does it come from?

```
# Phosphorus mass balance:

nr.days  <- (as.numeric(rownames(res.11.4)[nrow(res.11.4)])-as.numeric(rownames(res.11.4)[1]))
nr.steps <- (nrow(res.11.4)-1)

F.in.P  <- c(HPO4   = param$Q.in*param$C.HPO4.in*nr.days*86400/1e6)
F.out.P <- c(HPO4   = sum(param$Q.in*res.11.4[,"C.HPO4.Epi"])*nr.days/nr.steps*86400/1e6,
             ALG    = sum(param$Q.in*res.11.4[,"C.ALG.Epi"]*param$alpha.P.ALG)*
                        nr.days/nr.steps*86400/1e6,
             ZOO    = sum(param$Q.in*res.11.4[,"C.ZOO.Epi"]*param$alpha.P.ZOO)*
                        nr.days/nr.steps*86400/1e6,
             POMD   = sum(param$Q.in*res.11.4[,"C.POMD.Epi"]*param$alpha.P.POM)*
                        nr.days/nr.steps*86400/1e6,
             POMI   = sum(param$Q.in*res.11.4[,"C.POMI.Epi"]*param$alpha.P.POM)*
                        nr.days/nr.steps*86400/1e6)
Acc.P   <- c(HPO4   = param$A/1e6*
                      ((param$h.epi*res.11.4[nrow(res.11.4),"C.HPO4.Epi"]+
                          param$h.hypo*res.11.4[nrow(res.11.4),"C.HPO4.Hypo"])-
                       (param$h.epi*res.11.4[1,"C.HPO4.Epi"]+
                          param$h.hypo*res.11.4[1,"C.HPO4.Hypo"])),
             ALG    = param$A/1e6*param$alpha.P.ALG*
                      ((param$h.epi*res.11.4[nrow(res.11.4),"C.ALG.Epi"]+
                          param$h.hypo*res.11.4[nrow(res.11.4),"C.ALG.Hypo"])-
                       (param$h.epi*res.11.4[1,"C.ALG.Epi"]+
                          param$h.hypo*res.11.4[1,"C.ALG.Hypo"])),
             ZOO    = param$A/1e6*param$alpha.P.ZOO*
                      ((param$h.epi*res.11.4[nrow(res.11.4),"C.ZOO.Epi"]+
                          param$h.hypo*res.11.4[nrow(res.11.4),"C.ZOO.Hypo"])-
                       (param$h.epi*res.11.4[1,"C.ZOO.Epi"]+
                          param$h.hypo*res.11.4[1,"C.ZOO.Hypo"])),
```

…

Run this part of the script to get the average mass fluxes of P and N (input, output and accumulation) (see Table 11.11)

Flux	Substances	Phosphorus (t/a)	Nitrogen (t/a)
Input	HPO_4^{2-}, NO_3^-	**12.6**	**158**
Output	HPO_4^{2-}, NO_3^-, NH_4^+	**9.3**	**127**
	ALG, ZOO, POMD, POMI	1.2	11.5
Accumulation	HPO_4^{2-}, NO_3^-, NH_4^+	**1.2**	**-7.4**
	ALG, ZOO, POMD, POMI	0.0	0.1
	SPOMD	0.0	0.2
	SPOMI	**1.0**	**8.6**
Loss	Denitrification of NO_3^-	0.0	**18.0**

Process	Substances / Organisms								Rate
	NH_4^+ gN	NO_3^- gN	N_2 gN	HPO_4^{2-} gP	HCO_3^- gC	H^+ mol	H_2O mol	POM gDM	
Anoxic miner.	+	−	+	+	+	?	?	−1	$\rho_{\text{miner,anox,POM}}$

Table 8.6: Process table of anoxic mineralization.

Work on your own model

- If you didn’t tell us yet which model you chose, it’s time to do it!
  Team up with someone, choose a topic and inform us which one you picked.
- Read the assignment carefully and start thinking about how to modify today's model 11.4.
- Don’t hesitate to ask questions !