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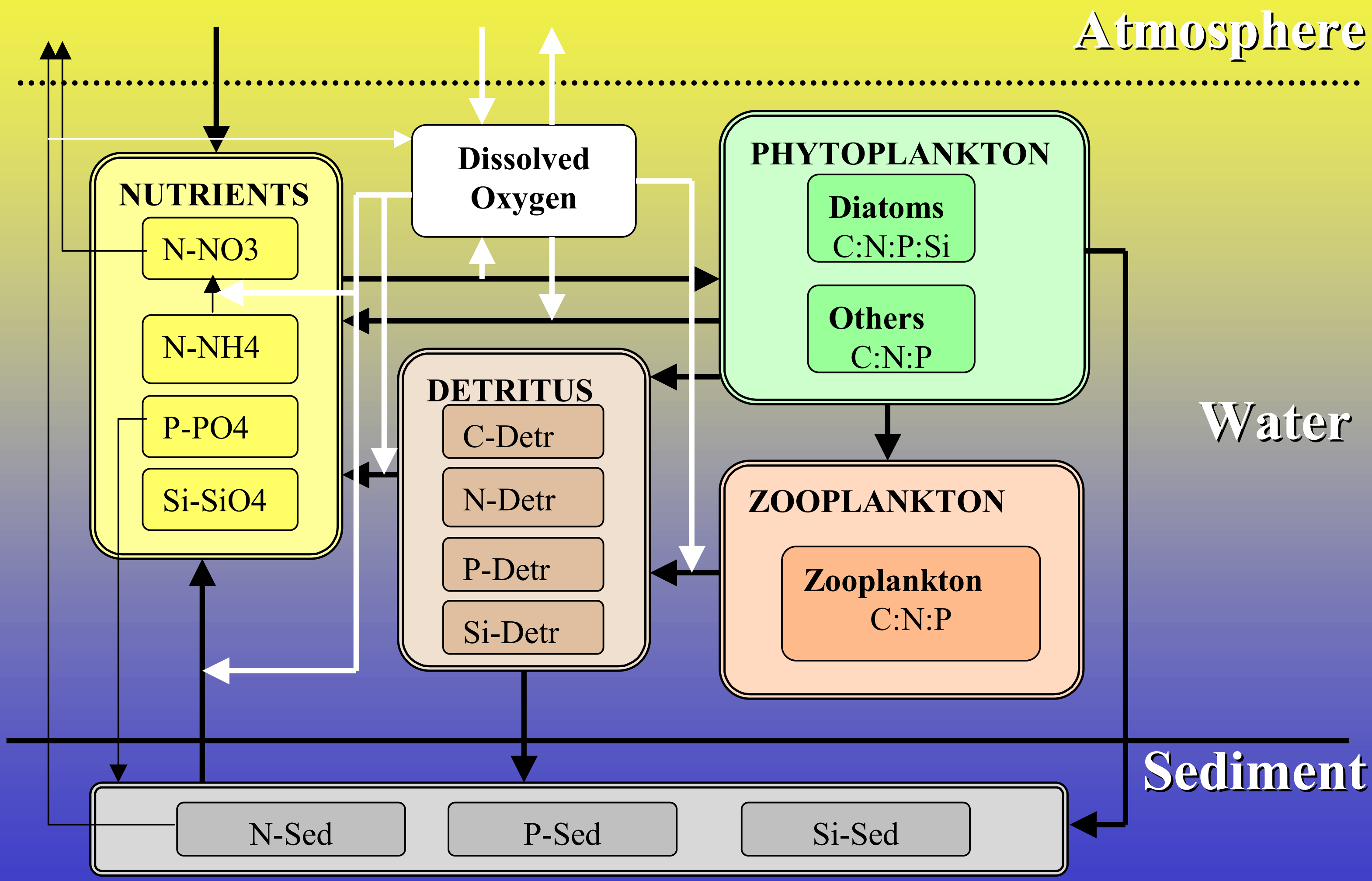
The Ecohydrodynamic Model of the Southern Baltic Sea

Model ProDeMo

ProDeMo model scheme



Algorithm

Phytoplankton biomass

$$\frac{\partial[\mathrm{C_i}]}{\partial \mathrm{t}} = \left(G_\mathrm{i} - R_\mathrm{i} - D_{Z\mathrm{i}} - L_i\right)\cdot[\mathrm{C_i}] + V_{\mathrm{s_i}} \frac{\partial[\mathrm{C_i}]}{\partial \mathrm{z}}$$

where:
G_i – growth; R_i – respiration; $D_{Z\mathrm{i}}$ – grazing of phytoplankton;
L_i – natural mortality; i – phytoplankton group (DIAT or nDIAT);

Growth of phytoplankton (G_i):

$$G_i = G_{\max_i} \cdot G_{T_i} \cdot G_{I_i} \cdot G_{B_i}$$

Growth of phytoplankton – temperature dependance

$$G_{T_i} = \exp\left\{ \begin{array}{ll} 2.3\left(\dfrac{T - T_{opt_i}}{T_{opt_i} - T_{\min_i}}\right)^2 & T \le T_{opt_i} \\ 2.3\left(\dfrac{T - T_{opt_i}}{T_{\max_i} - T_{opt_i}}\right)^2 & T \rangle T_{opt_i} \end{array} \right\}$$

Algorithm

Growth of phytoplankton – solar radiation dependance I_{PAR} [W/m^2]:

$$G_{I_i} = \frac{I_{PAR}}{I_{s_i}} \exp\left[1 - \frac{I_{PAR}}{I_{s_i}}\right]$$

The value of I_{PAR} at depth z is given by:

$$\frac{\partial I_{PAR}}{\partial z} = I_{PAR} \cdot \left(\mathrm{Kd}_0 + \mathrm{Kd}_{\mathrm{Chla}} \cdot \sum_i [\mathrm{C_i}] \cdot C_{Chl_i} + \mathrm{Kd}_{\mathrm{OC}} \cdot [\mathrm{C_{DETR}}] \right)$$

Algorithm

Phytoplankton biomass

$$\frac{\partial[\mathrm{C_i}]}{\partial \mathrm{t}} = \left(G_\mathrm{i} - R_\mathrm{i} - D_{Z\mathrm{i}} - L_i\right)\cdot[\mathrm{C_i}] + V_{\mathrm{s_i}}\frac{\partial[\mathrm{C_i}]}{\partial \mathrm{z}}$$

where:

G_i – growth; R_i – respiration; $D_{Z\mathrm{i}}$ – grazing of phytoplankton;
L_i – natural mortality; i – phytoplankton group (DIAT or nDIAT);

Respiration of phytoplankton (R_i):

$$R_i = K_{Rakt_i} G_i + K_{Rstr_i} G_i\left(1 - \frac{1}{G_{B_i}}\right) + D_{Rbie_i}\cdot Q_{Rbie_i}^{T-20}$$

Grazing by zooplankton (D_{Zi}):

$$D_{\mathrm{Zi}} = P_{\mathrm{aval_i}}\cdot Fr\cdot[\mathrm{C_{ZOOP}}]$$

Filtration function:

$$Fr = \frac{Fr_{Z\max}\cdot Q_Z^{T-20}}{1 + \exp\left(a_{fr} - b_{fr}\cdot\sum_i P_{aval_i}[\mathrm{C_i}]\right)}$$

Algorithm

Zooplankton biomass

$$\frac{\partial[\mathrm{C_{ZOOP}}]}{\partial t} = (A_Z - R_Z - L_Z - W_Z)\cdot[\mathrm{C_{ZOOP}}]$$

where: A_Z – assimilation of phytoplankton; R_Z – respiration of zooplankton; L_Z – mortality of zooplankton; W_Z. excretion

Assimilation of phytoplankton by zooplankton

$$A_Z = Z_{As}\cdot Fr\cdot\sum_i P_{aval_i}[\mathrm{C_i}]$$

Respiration of zooplankton (R_Z):

$$R_Z = K_{Zakt_i} A_Z + D_{RbieZ}\cdot Q_{RbieZ}^{T-20}$$

Excretion [d^{-1}]

$$W_Z = Fr\sum_i P_{aval_i}[\mathrm{C_i}] - A_Z$$

Algorithm

Nitrate nitrogen:

$$\frac{\partial[\mathrm{N-NO_3}]}{\partial t} = K_{nN} \cdot Q_{nN}^{T-20} \cdot [\mathrm{N-NH_4}] - K_{dnN} \cdot Q_{dnN}^{T-20} \cdot [\mathrm{N-NO_3}] - \sum_i \left[G_i \cdot [\mathrm{C_i}] \cdot a_{NC_i} \cdot \left(1 - P_{N_i}\right)\right] + \left(S_{NO_3} / \Delta z_H\right)^*$$

where: ()*–valid only for the bottom layer; Δz_H – bottom layer [m]; i – phytoplankton group.

Ammonium nitrogen:

$$\frac{\partial[\mathrm{N-NH_4}]}{\partial t} = M_N \cdot [\mathrm{N_{DETR}}] + \sum_i \left(R_i - G_i \cdot P_{N_i}\right) \cdot [\mathrm{C_i}] \cdot a_{NC_i} + R_Z \cdot [\mathrm{C_{ZOOP}}] \cdot a_{NC_Z} - K_{nN} \cdot Q_{nN}^{T-20} \cdot [\mathrm{N-NH\,4}] + \left(S_{NH_4} / \Delta z_H\right)^*$$

Phosphate phosphorus:

$$\frac{\partial[\mathrm{P-PO_4}]}{\partial t} = M_P [\mathrm{P_{DETR}}] + \sum_i \left(R_i - G_i\right) \cdot [\mathrm{C_i}] \cdot a_{NC_i} + R_Z \cdot [\mathrm{C_{ZOOP}}] \cdot a_{PC_Z} + \mathrm{Vs_{SP}} \cdot \mathrm{f_{PIP}} \cdot \frac{\partial[\mathrm{P-PO_4}]}{\partial z} + \left(S_P / \Delta z_H\right)^*$$

Silicate silicon:

$$\frac{\partial[\mathrm{Si-SiO_4}]}{\partial t} = M_{Si} [\mathrm{Si_{DETR}}] + \sum_i \left(R_i - G_i\right) \cdot [\mathrm{C_i}] \cdot a_{SiC_i} + R_Z \cdot [\mathrm{C_{ZOOP}}] \cdot a_{SiC_Z} + \left(S_{Si} / \Delta z_H\right)^*$$

Algorithm

Dissolved oxygen

$$\frac{\partial[\mathrm{DO}]}{\partial t}=\frac{R_{DO}}{\Delta z}+\left[\sum_i (G_i-R_i)[\mathrm{C_i}]-R_Z[\mathrm{C_{ZOOP}}]-M_C\cdot[\mathrm{C_{DETR}}]-\left(S_C\Big/\Delta z\right)^*\right]\cdot a_{OC}+$$

$$+\left[-\sum_i R_i[\mathrm{C_i}]a_{PC_i}-R_Z a_{PC_Z}[\mathrm{C_{ZOOP}}]-M_P\cdot[\mathrm{P_{DETR}}]-\left(S_P\Big/\Delta z\right)^*\right]\cdot a_{OP}+$$

$$+\left[-\sum_i R_i[\mathrm{C_i}]a_{SiC_i}-R_Z a_{SiC_Z}[\mathrm{C_{ZOOP}}]-M_{Si}\cdot[\mathrm{Si_{DETR}}]-\left(S_{Si}\Big/\Delta z\right)^*\right]\cdot a_{OSi}+$$

$$+K_{dnN}\cdot Q_{dnN}^{T-20}\cdot[\mathrm{N\text{-}NO_3}]a_{ON_{dn}}-\left[K_{nN}\cdot Q_{nN}^{T-20}\cdot[\mathrm{N\text{-}NH_4}]+\left(S_{NO_3}\Big/\Delta z\right)^*\right]a_{ON_n}$$

fluxes from/to atmosphere according to the reaeration and oversaturation:

$$R_{DO}=\begin{cases}\left(R_{DOW}\cdot U_{10}^2\cdot(C_{ST}-[\mathrm{DO}])\right)^{**} & \textit{where } [\mathrm{DO}]\le C_{ST}\\ B_{DO}\cdot(C_{ST}-[\mathrm{DO}]) & \textit{where } [\mathrm{DO}]>C_{ST}\end{cases}$$

()** - only for the surface layer