A1. CARIACO model equations

The ecosystem model equations are similar to those used in Acevedo-Trejos et al. (2016). Most significant changes are that multiple phytoplankton and zooplankton functional types have been added, and that the grazing formulation was expanded to include preferential feeding on certain functional types.

Nitrogen N (and Silicate Si for Diatoms) is assimilated by the phytoplankton types P_i, which are grazed by several zooplankton types Z_j. Mortality of and excretion from plankton, and sloppy feeding by zooplankton contribute to a Detritus D. The phytoplankton types include Nanoflagellates P_n, Diatoms P_{dt}, Coccolithophorse, P_c and Dinoflagellates P_{dn}. There are two Zooplankton types split by size class, named Mikrozooplankton Z_μ and Mesozooplankton Z_λ.

ToDo: Highlight in the equations how grazing works, selective feeding, explain difference in R_j between zooplankton types

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\begin{aligned}
\frac{\partial N}{\partial t} &= K \cdot (N_0 - N) + D \cdot \delta_D^N - \sum_{i=1}^{n_p} [\mu_i \cdot U_i(N_0, Si_0) \cdot L_i(PAR) \cdot T_i(SST) \cdot P_i] \\
\frac{\partial Si}{\partial t} &= K \cdot (Si_0 - Si) - \mu_{dt} \cdot U_{dt}(N_0, Si_0) \cdot L_{dt}(PAR) \cdot T_{dt}(SST) \cdot P_{dt} \\
\frac{\partial P_i}{\partial t} &= \mu_{dt} \cdot U_{dt}(N_0, Si_0) \cdot L_{dt}(PAR) \cdot T_{dt}(SST) \cdot P_{dt} - m_{dt} \cdot P_{dt} - \sum_j [I_j^{tot} \frac{p_{dt,j} \cdot P_{dt}}{R_j} Z_j] \\
\frac{\partial Z_\mu}{\partial t} &= \delta_Z \cdot I_\mu^{tot} \cdot Z_\mu - K_Z \cdot Z_\mu - m_\mu \cdot Z_\mu - g_\mu \cdot Z_\mu^2 \\
\frac{\partial Z_\lambda}{\partial t} &= \delta_Z \cdot I_\lambda^{tot} \cdot Z_\lambda + I_\lambda^\mu * Z_\mu - K_Z \cdot Z_\lambda - m_\lambda \cdot Z_\lambda - g_\lambda \cdot Z_\lambda^2 \\
\frac{\partial D}{\partial t} &= \sum_j [(1 - \delta_Z) I_j^{tot} \cdot Z_j] + \sum_j [m_j \cdot Z_j] + \sum_i [m_i \cdot P_i] - K \cdot D - D \cdot \delta_D^N
\end{aligned}
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where:

$N_0 =$ Nitrogen concentration below below mixed layer [μM],
$N =$ Integrated nitrogen concentration above mixed layer [μM],
$K = \frac{1}{M(t)} \cdot (h^+(t) + \kappa)$ Constant that parameterizes diffusive mixing across the thermocline,
$h^+(t) = \max\left(0, \frac{d}{dt} M(t)\right)$ Function that describes entrainment and detrainment of material,
$\delta_D^N =$ Remineralization rate of nitrogen component of detritus D [$\mu M d^{-1}$],
$\mu_i =$Growth rate of phytoplankton type i [d^{-1}],

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U_i = \begin{cases} \min\left(\frac{N}{N+U_i^N}, \frac{Si}{Si+U_i^{Si}}\right), & \text{if P-type is Diatom} \\ \frac{N}{N+U_i^N}, & \text{otherwise} \end{cases} \quad \text{Nutrient uptake of phytoplankton } i,
$$

$L_i = \frac{1}{M(t) \cdot k_w} \cdot \left(e^{1-\frac{PAR(t)}{Opt_i^I}} + e^{1-\frac{PAR(t)}{Opt_i^I} \cdot e^{-M(t) \cdot k_w}} \right)$ Light dependence of phytoplankton i,
$T_i = e^{0.063 \cdot SST}$ Temperature dependence of phytoplankton i,

$P_i =$ Biomass of phytoplankton type i [μMN],
$m_i =$ Mortality/Excretion rate for phytoplankton type i,

$I_j^{tot} = \mu_j^Z \frac{R_j}{R_j + k_Z}$ Total intake XXX i,
$R_j = \sum_i (p_{ij} P_i)$ Total intake XXX i,

$Z_j =$ Biomass of zooplankton type j [μMN],
$\delta_Z =$ Grazing efficiency of zooplankton on phytoplankton (represents sloppy feeding),
$K_Z = \frac{1}{M(t)} \cdot \frac{d}{dt} M(t)$ Mixing term of zooplankton,
$g_i =$ Higher order predation on zooplankton (quadratic),
$m_j =$ Mortality/Excretion rate for zooplankton type j,