Revisions made to MyLake v.1.2.1

21.08.07 by Tuomo Saloranta

The basis for the revisions implemented in code v.1.2.1 and described here were mainly to improve the robustness and performance of the MyLake v.1.2 code. In addition, the photodegradation of DOC as well as two phytoplankton groups were added to the code. Some of the revisions were based on issues that arose during applications and testing of MyLake v.1.2. These revisions are implemented in two new code files (convection_v12_1a.m, solvemodel_v12_1b.m) and a new parameter file.

NB! In order to implement the new parameter file correctly, the vector index “40” must be changed to “48” in code file “modelinputs_v12.m” (rows 53-55). In addition, to avoid annoying "division by zero" warnings under polar night conditions, one can add the Dayfrac==0 condition on the if-statement on row 76 in heatflux_v12.m, like this:

if((isnan(GR))|(Dayfrac==0)) % if global radiation input is missing, or Dayfrac=0, calculate total transmissivity from formulaes

1. Problems encountered with v.1.2

Three model performance issues were noted during test simulation of some 350 lakes in a batch with climatological mean monthly forcing and assumedly no river input (CRU/Euregi simulations; see the corresponding research note), as well as with simulations in Lake Vansjø:

1) The lake ice cover on/off date sometimes “flips” and produced e.g. up to 40 on/off dates during one year for a lake with the minimum mean monthly air temperature slightly above zero. As there was no threshold limit for ice cover, these “flips” usually occurred in the beginning of the freezing period. This issue was resolved by introducing a frazil ice process as explained below (section 2.1).
2) There were some negative values in chlorophyll and dissolved P for some lakes. In the code there was a restriction that phytoplankton cannot grow more than there is dissolved P left. However, there was a convection process between the calculation of the growth rates and their application which mixed the profiles sometimes so that negative values were generated. These negative values caused also some numerical instability. This issue was resolved by rearranging some lines of the code as explained below (section 2.2).
3) The new spring/autumn turnover algorithm in the revised convection file (used since june 2006, see the development log) produced some abnormal peaks in temperature. These were probably related to complications caused by the river inflow. This issue was resolved by taking the older version of the convection file into use, and modifying it slightly (section 2.2).

2. Solutions

2.1 Frazil ice

In the initial phase of formation of ice cover the ice crystals are suspended in the water column (so-called “frazil ice”). After the mass of this frazil ice grows the ice crystals eventually float to the surface and form a slushy layer which freezes to form the initial ice cover. The more wind and turbulence in the water column there is the more frazil ice the water column can sustain before it forms the initial ice cover. In the MyLake v.1.2.1 the frazil ice is handled as explained in the following.

When supercooled water is encountered this is turned into ice (by turning the sensible heat deficit in the supercooled water into latent heat of freezing). In the previous version 1.2 of the model code this formed the initial ice cover. However, now this ice is defined as frazil ice and allowed to accumulated up to a threshold thickness (now set to 3 cm, but this could later be defined e.g. as function of the wind mixing energy) before it is turned into the initial solid ice cover in the model. It is first after the formation of this solid ice cover that the ice related processes are enabled in the model (new calculations for heat fluxes, no wind mixing, new albedo, etc.). Thus the model functions in "open water mode" under frazil ice conditions. The "thickness" of frazil ice (i.e. the volume of frazil ice divided by the lake surface area) increases whenever new supercooled water is encountered, and decreases whenever the water column receives heat to melt the frazil ice. Since no mixing depth of the frazil ice is modelled, the possible excess heat (in case all the frazil ice is melted) is distributed similarly as the original heating profile.

2.2 Code rearrangements

In order to solve the problem encountered with the spring/autumn turnover code in the revised convection file, this file was replaced by the original convection code, where only the surface temperature "jumps" over the temperature of the maximum density are controlled (instead of all such jumps in the water column, as in the revised version). Three lines are modified in the original code (see convection_v12_1a.m). Also in solvemodel_v12_1b.m, the spring/autumn turnover is only allowed after the two first occasions of convection_v12_1a.m, after surface heat flux calculations. The previous temperature profile variable is updated after each occasion of convection_v12_1a.m. The new modifications to the original convection file did not change significantly the 1990-1999 TotP, Chl, or suspended solids mean values in Lake Vansjø-Storefjorden (old: 17.467; 6.502; 0.00344; new: 17.468; 6.502; 0.00344). If purely non-surface jumps occur, the model code now displays a note about this on the command line.

In order to solve the problem encountered with the negative chemistry values, the calculation of the growth rate in solvemodel_v12_1b.m was moved to after the solving of the temperature profile and the consequent convection routine. The PAR light profile is here recalculated too. These new code modifications did not change significantly the 1990-1999 TotP, Chl, or suspended solids mean values in Lake Vansjø-Storefjorden (old: 17.467; 6.502; 0.00344; new: 17.382; 6.474; 0.00343).

3. Other new features

3.1 Photodegradation of DOC

The DOC in the water column was in the previous version 1.2 of the model code modelled as a passive dissolved tracer. In the MyLake v.1.2.1 a photodegradation process due to solar radiation is added and the rate of degradation ΔC_{DOC} [mg m^{-3} day^{-1}] is formulated in the following way:

$$\Delta C_{DOC} = C_{DOC} \cdot y_q \cdot \beta_{DOC} \cdot (1/E_{PAR}) \cdot I_{PAR}$$

where C_{DOC} is the DOC concentration [mg m^{-3}] (taken from the previous time step in the model), y_q is the degradation quantum yield [mg DOC / mol quanta], β_{DOC} is the optical cross-section of DOC [m^2 mg^{-1} DOC], E_{PAR} is the energy of photons [J/mol quanta], and I_{PAR} is the PAR irradiation [J m^{-2} day^{-1}]. Thus two new parameters y_q and β_{DOC} are introduced in the model code.

3.2 Two phytoplankton groups

A new phytoplankton group, in terms of a new chlorophyll (P_{Chl}) variable, is introduced in the model code. In practise this means that a second set of values is given for six phytoplankton-related parameters: the settling velocity w_{Chl}, light saturation level of photosynthesis I', specific loss rate at 20 °C $m(20)$, the maximal attainable specific growth rate at 20 °C $\mu'(20)$, the half-saturation parameter P' and the optical cross section of chlorophyll β_C. Now two different phytoplankton growth and loss rates are calculated, but otherwise the solving of the equations remain the same as before in the model code. The resuspension of chlorophyll from sediments is assumed to be divided equally (50-50) between the two phytoplankton groups. The variable for dissolve tracer (*Cz*) in the model code is now adopted for the second phytoplankton (chlorophyll) group.

3.3 Miscellaneous

The model parameter file was extended to cover the eight new DOC and second phytoplankton group parameters. *NB! In order to implement this extended file correctly, the vector index "40" must be changed to "48" in code file "modelinputs_v12.m" (rows 53-55).*

As the old variable for dissolve tracer (*Cz*) is now used for the second phytoplankton (chlorophyll) group, the "tracer_switch" variable has become redundant in the code and must be set equal to 1. (This variable is retained in the convection code for version compatibility).

A small bug was corrected in the calculation of the attenuated solar radiation (variable "Attn_z"). This bug caused the sum of "Attn_z" to be slightly above one (should be equal to one).

(12/11/2007)
A bug, which caused a model error with latitudes north of the polar circle (ca. 66 N), was fixed.