Simulation on temperature and flux in submerged macrophytes region of Lake Taihu on the basis of two models

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Beijing, May 11, 2017
Background

- There are over 2300 lakes which size is more than 1 km$^2$ in our country and lakes have notable influences on local weather and climate due to low albedo and high heat capacity.

- Weather and climate forecast in lake basins need to rely on lake models for surface momentum, heat and water fluxes as the boundary conditions.

- Vertical turbulent mixing is an important role in lakes, which controls the temperature profile and the distribution of dissolved oxygen, nutrients and phytoplankton.

- The structure of the hydro-dynamical part of one dimensional lake models can be classified into diffusive models with simple parameterization schemes and models based on turbulence closure schemes.
Model principle

**CLM4-LISSS model:**

![CLM4-LISSS model schematic](image)

**k-ε model:**

![Parameterization of one-dimensional water column model with submerged macrophytes](image)

**Table 1** Comparison between different lake model’s Parameterization schemes

<table>
<thead>
<tr>
<th>Lake model</th>
<th>Vertical structure / number of layers</th>
<th>Parameterisation of turbulent fluxes at the lake-atmosphere interface</th>
<th>Turbulent mixing Parameterisation</th>
<th>Treatment of heat flux at the water-bottom sediments interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLM4-LISSS, Subin, 2012</td>
<td>Multilayer/10 layers</td>
<td>An extended scheme from CLM4 model, MOST</td>
<td>Henderson-Sellers parameterisation of eddy diffusivity, buoyant convection</td>
<td>Heat conductance in bottom sediments</td>
</tr>
<tr>
<td>k-ε model, Herb, 2005</td>
<td>Multilayer/50 layers</td>
<td>Empirical equations</td>
<td>Calculate K using TKE equation</td>
<td>Zero heat flux</td>
</tr>
</tbody>
</table>
Model principle:

Heat transfer equation:

Thermal diffusion equation:

Data: acquired from The Taihu Eddy Flux Network, mainly BFG site from January 2012 to December 2013

CLM4-LISSS model:

$k$-ε model:
Model modification on Parameter adjustment

**k-ε model:**

<table>
<thead>
<tr>
<th>Model modification on Parameter adjustment</th>
<th>Table 2 k-ε model parameter values</th>
</tr>
</thead>
</table>

- CLM4-LISSS model:
  - Parameter setting is roughly same with Deng's Paper.
Model modification on eddy diffusivity

**k- ε model:**\[ K_z = C_k Z_m \sqrt{E} \]

**CLM4-LISSS model:**\[ K_z = m_d (k_m + k_e); \quad m_d = 0.02 \]

\[ K_e = K_{e0} f(R_i) \]

Neutral condition:
\[ K_{e0} = k u_* z \]
\[ u_* = u_{*0} \exp(-k^* z) \]
\[ k^* = 6.6 U_2^{-1.84} \sqrt{\sin \varphi} \]

\[
\begin{align*}
ke(j) &= 0.02 * vkc * ws(c) * z \text{lake}(c,j) / p0 * \exp(-ks(c) * z \text{lake}(c,j)) / (1. \_r8 + 37. \_r8 * ri(j) * ri(j)) \\
ke(j) &= 0.02 * vkc * ws(c) * (2 - z \text{lake}(c,j)) / p0 * \exp(-ks(c) * z \text{lake}(c,j)) / (1. \_r8 + 37. \_r8 * ri(j) * ri(j))
\end{align*}
\]
The Temperature Performance of model

Figure 3 Time series of observed water temperature profile for DOY 121(2013)-365(2013) at BFG site
Figure 4 Time series of predicted water temperature profile for DOY 121(2013)-365(2013) at BFG site calculated by CLM4-LISSS model
**Figure 5** Time series of predicted water temperature profile for DOY 121(2013)-365(2013) at BFG site calculated by $k-\varepsilon$ model
Figure 6 The relationship between measured and predicted Sensible heat flux and latent heat flux in daily scale (green dots: k-ε model and cyan dots: CLM4-LISSS model)
The distribution of eddy diffusivity

Figure 7  Monthly-average eddy diffusivity profile at BFG station simulated by CLM4-LISSS model (cyan line) and k-ε model (green line) over two full year cycle
Figure 8 Comparison on daily-mean predicted eddy diffusivity (a: 0-0.5m; b: 0.5-1m; c: 1-1.5m; d: 1-2m) in different season (green dots: Spring; red dots: Summer; yellow dots: Autumn; blue dots: Winter) at BFG site between k-\(\varepsilon\) model and CLM4-LISSS model
Try to establish an integrated lake model consisting of surface flux calculated by MOST theory and water temperature and eddy diffusivity calculated by thermal diffusivity equation, turbulent diffusivity equation and turbulent dissipation equation.
Conclusions

• CLM4-LISSS model and k-ε model has good performance in water temperature and surface flux prediction.

• There exists similar diurnal composite of mean eddy diffusivity in spring, summer and autumn at BFG station, The trend of winter is reversed compared with other seasons.

• Eddy diffusivities simulated by both model exist difference in number but have well linear relationship, especially in shallow layer. However, tuned eddy diffusivity didn’t bring better water temperature performance results.
Thank you