Update on doctoral dissertation research: lake models application and comparison in Lake Taihu
Outline

- Background
- Model principle
- Motivation
- Experimental design
- Model modification
- Preliminary results
- Future work
Background


• Surface energy and radiation balance module is critical to surface flux calculation and lake body energy distribution. Especially surface flux calculation is relied on robust simulation of surface temperature.

• Vertical turbulent mixing is an important role in lakes, Production of TKE by wind shear (forced convection) and an unstable density stratification is produced in the water column (natural convection) are two main drivers.
CLM4-LISSS model

1. Conservation of Energy
2. Empirical model
3. Parameterization

k-ε model

1. Heat Transfer Equation
2. TKE Equation
3. TKE model

Sun

Air

Surface Flux

Water

Temperature

diffusivity

Soil
Motivation

• CLM4-LISSS model does integrated preparation on conservation of surface energy and surface flux calculation, Does this model perform better in this respect?

• k-ε model owns heat transfer equation and TKE equation, how about the turbulent diffusivity simulation results compared with CLM4-LISSS model?

• Find out the distribution of surface eddy diffusivity ($K_e$) in different season and different weather condition. The diurnal variation of $K_e$? which meteorological factor affect variation of $K_e$?
Experimental design

Data: acquired from The Taihu Eddy Flux Network, BFG site from 2012 to 2015
Model modification on eddy diffusivity

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

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

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

\[ f(R_i) = (1 + 37 R_i^2)^{-1} \]

Neutral condition:

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

\[ D - d \quad d \]

\[ k_{e(j)} = 0.02_8 \cdot {v_{kc}} \cdot {w_s(c)} \cdot \text{lake}(c,j)/p_0 \cdot \exp(-k_s(c) \cdot \text{lake}(c,j))/(1.8 + 37 \cdot r_i(j) \cdot r_i(j)) \]

\[ k_{e(j)} = 0.02_8 \cdot {v_{kc}} \cdot {w_s(c)} \cdot (2 - \text{lake}(c,j))/p_0 \cdot \exp(-k_s(c) \cdot \text{lake}(c,j))/(1.8 + 37 \cdot r_i(j) \cdot r_i(j)) \]
Model modification on Parameter adjustment

**k-ε model:**

**Table 2** k-ε model parameter values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Nominal Value (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_{wc}$</td>
<td>light attenuation coefficient for water</td>
<td>$1 \text{ m}^{-1}$</td>
</tr>
<tr>
<td>$K_m$</td>
<td>specific light attenuation coefficient for macrophytes</td>
<td>$0.01 \text{ m}^2\text{gDW}^{-1}$</td>
</tr>
<tr>
<td>$d$</td>
<td>water depth</td>
<td>$2\text{ m}$</td>
</tr>
<tr>
<td>$C_k$</td>
<td>mixing length coefficient</td>
<td>$0.1 \text{ (Herb [2005])}$</td>
</tr>
<tr>
<td>$C_D$</td>
<td>drag coefficient</td>
<td>$1.0 \text{ (Finnigan [2000])}$</td>
</tr>
<tr>
<td>$K_h$</td>
<td>hypolimnetic diffusivity</td>
<td>$0.03 \text{ m}^2\text{d}^{-1}\text{(Herb [2005])}$</td>
</tr>
<tr>
<td>$C_w$</td>
<td>wind correction coefficient</td>
<td>$1.0$</td>
</tr>
<tr>
<td>$nz$</td>
<td>number of discrete depth increments</td>
<td>$50$</td>
</tr>
<tr>
<td>$\Delta t$</td>
<td>time increment</td>
<td>$30\text{min}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass (gdw/m³)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>75</td>
<td>50</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Plant height (m)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.32</td>
<td>0.64</td>
<td>0.96</td>
<td>1.28</td>
<td>1.6</td>
<td>1.2</td>
<td>0.8</td>
<td>0.4</td>
<td>0</td>
</tr>
</tbody>
</table>

**CLM4-LISSS model:** Parameter setting is roughly same with Deng’s Paper
Model modification on freezing temperature

![Temperature Graphs]

- **Graph a:** Comparison of observed (T_obs) and modelled (T_model) temperatures at freezing temperature (Tfrz=0 °C).
- **Graph b:** Comparison at a different freezing temperature (Tfrz=-13 °C).
- **Graph c:** Detailed view of temperature fluctuations with different freezing temperatures.
- **Graph d:** Additional comparison including revision details for temperatures ranging from 0 to -23 °C.

Years: 2012 to 2015.
CLM4-LISSS model:

About spin up
k-ε model:
Surface Temperature Performance

- CLM4-LISSS model
- k-ε model
- Observation

Temperature $T_s$ (°C)

Year 2012
Surface Flux Performance

Sensible Heat

- CLM4-LISSS model
- k-ε model

\[ R^2 = 0.72 \]
\[ R^2 = 0.59 \]

\[ R^2 = 0.68 \]
\[ R^2 = 0.61 \]

\[ n = 12457 \]
Year 2012

\[ n = 13692 \]
Year 2014

\[ n = 15513 \]
Year 2013

\[ n = 14662 \]
Year 2015

‘n’ represents the total number of half-hourly observations
Latent Heat

![Graphs showing model vs. observation with R² values for different years and models.](image)
Turbulent diffusivity Performance

2012 CLM4-LISSS model k-ε model

The dotted line represents winter, spring, summer and autumn
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Case analysis: **DOY 202-250 Year 2012**

*Water temperature profile performance (CLM4-LISSS model, k-ε model, observation)*
<table>
<thead>
<tr>
<th></th>
<th>CLM-LISSS model</th>
<th></th>
<th>k-ε model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variation rate (T)</strong></td>
<td>-30% -20% -10% 10% 20% 30%</td>
<td><strong>Variation rate (T)</strong></td>
<td>-30% -20% -10% 10% 20% 30%</td>
</tr>
<tr>
<td>$K_e$</td>
<td>3.9% 2.8% 1.5% -1.6% -2.8% -4%</td>
<td>$K_e$</td>
<td>6% 3.9% 1.9% -1.9% -3.2% -4.2%</td>
</tr>
<tr>
<td><strong>Variation rate (DR)</strong></td>
<td>-30% -20% -10% 10% 20% 30%</td>
<td><strong>Variation rate (DR)</strong></td>
<td>-30% -20% -10% 10% 20% 30%</td>
</tr>
<tr>
<td>$K_e$</td>
<td>0.13% 0.04% 0.01% -0.02% -0.07% -0.12%</td>
<td>$K_e$</td>
<td>2.21% 1.42% 0.67% -0.75% -1.43% -1.91%</td>
</tr>
<tr>
<td><strong>Variation rate (U)</strong></td>
<td>-30% -20% -10% 10% 20% 30%</td>
<td><strong>Variation rate (U)</strong></td>
<td>-30% -20% -10% 10% 20% 30%</td>
</tr>
<tr>
<td>$K_e$</td>
<td>-33% -22% -11% 11% 21% 32%</td>
<td>$K_e$</td>
<td>-38% -25% -13% 13% 26% 40%</td>
</tr>
</tbody>
</table>
Summary

• Both CLM4-LISSS model and k-ε model have been applied in Lake Taihu, CLM4-LISSS model have better performance in simulation of surface temperature and surface energy flux.

• Two models have similar simulation trend on turbulent diffusivity. But there exists magnitude difference of vertical turbulent diffusivity and difference expend with depth.

• Wind variation seems to be leading factor of turbulent kinetic energy distribution.
Future work

• It is still doubtful that the result of spring and winter’s predicted water temperature, turbulent kinetic energy and the magnitude of vertical turbulent diffusivity.

• Aim to quantify the contribution of turbulent kinetic energy distribution.

• Try to establish lake surface flux dataset based on BCC_AGCM’s future scenarios climate data and verify it.
Upcoming...
Thank you