CALCULATION METHOD FOR OUTDOOR AIR TEMPERATURE OF WOODED URBAN AREA

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Climatic zones for architecture

- Severe Cold
- Cold
- Hot Summer & Cold Winter
- Hot Summer & Warm Winter (Hot-humid area)
- Moderate

Guangzhou
Urban area microclimate

- Outdoor safety, comfort and building energy consumption
- Design phase is most crucial, important and lack of scientific means to support
- Quick and easy prediction
- Urban designers

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CTTC model

- Cluster thermal time constant
- Swaid & Hoffman, 1990
- Heat transfer model + empirical equation

\[ t_a = t_b + t_{sol} + t_{lw} \]

\[ t_{sol} = \sum_{i=0}^{\infty} \frac{1}{h} I (1 - \exp \frac{i}{CTTC}) \]

\[ t_{lw} = \frac{q_{lw}}{h} \]
Unwooded areas

- 2012.9-10, warm sunny days
- Semi-enclosed and enclosed urban areas
- Ground and walls solar radiations
- Area-average TTC of ground and walls

\[ t_{\text{sol}} = \frac{1}{A} \sum_A \sum_{i=0} \left[ \left( A_G \frac{m_G}{h_G} I_G + A_W \frac{m_W}{h_W} I_W \right)(1 - \exp \left( \frac{i}{CTTC} \right) \right) \]

\[ CTTC = \frac{1}{A} \left( A_G TTC_G + A_W TTC_W \right) \]
Purpose

- Field measurements on air temperatures of wooded urban areas
- Analyze heat island intensity
- Test the performance of Green CTTC model
Green CTTC model

- Shashua-Bar & Hoffman, 2002
- CTTC model + Trees’ effect
- Shading effect
- Sensible heat flux of trees

\[ t_{\text{sol}} = \frac{1}{\sum A} \left( \sum_{i=0}^{\infty} \left( A_G \frac{m_G}{h_G} I_G + A_W \frac{m_W}{h_W} I_W \right) (1 - \exp \frac{i}{\text{CTTC}}) + A_T q_{s,T} \right) \]

\[ q_{\text{sol},T} + q_{\text{lw},T} = q_{s,T} + q_{l,T} \]
# Wooded communities

<table>
<thead>
<tr>
<th></th>
<th>A (56%)</th>
<th>B (35%)</th>
<th>C (31%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Green area ratio</strong></td>
<td>56%</td>
<td>35%</td>
<td>31%</td>
</tr>
<tr>
<td><strong>Building density</strong></td>
<td>20%</td>
<td>25%</td>
<td>48%</td>
</tr>
<tr>
<td><strong>Floor area ratio</strong></td>
<td>5.0</td>
<td>4.6</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Field measurements

- 2013.8-10, warm sunny days
- Air temperature at 1.5 m with aspirated radiation shield
- Parameter of LAI, SVF, SAR
Heat island intensity

\[ \text{CHI} = t_{\text{community}} - t_{\text{district}} \]

<table>
<thead>
<tr>
<th>Community</th>
<th>Urban Weather Station</th>
<th>Suburb Weather Station</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day</td>
<td>Night</td>
</tr>
<tr>
<td>A</td>
<td>-1.5</td>
<td>-0.1</td>
</tr>
<tr>
<td>B</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>C</td>
<td>-0.1</td>
<td>-1.0</td>
</tr>
</tbody>
</table>
Heat island intensity

\[ \text{PHI} = t_{\text{point}} - t_{\text{community}} \]

\[ \text{PHI}_{\text{day}} = 1.23 \ \text{SAR} \quad (R^2=0.524) \]

\[ \text{PHI}_{\text{night}} = 0.448 \ \text{SAR} \quad (R^2=0.244) \]

\[ \text{PHI}_{\text{all}} = 0.602 \ \text{SVF} \ 0.541 \ \text{SAR} (R^2=0.618) \]
Sensible heat flux ratio

- Sensible heat flux / Solar radiation absorbed and reflected by trees
- The outliers at 16:00~17:00 are due to abnormal solar radiation records
- $0 \rightarrow 0.4 \rightarrow 0$

$$y = -0.0103x^2 + 0.1455x - 0.1438$$
$$R^2 = 0.9719$$
Green CTTC model

- Before 15:00, measured temperature close to predicted one with 20m height wall
- RSME=0.7°C, d>0.97
- After 15:00, measured temperature goes closely with east boundary due to strong east wind
Green CTTC mode

- Two wooded street canyons
- RSME=0.3°C, d>0.96

Air temperature (°C) vs Time

- 10m
- 15m
- 20m
- Measured
Conclusions

- The heat island intensity of community is recommended to be defined as the air temperature difference between community and district.
- The heat island intensity of point is influenced by parameters of SAR and SVF.
- The sensible heat flux ratio (C value) increases in the morning and decrease in the afternoon, in a range of (0, 0.4).
- The Green CTTC model can predict the trees’ effect well.
- Further studies on advection and water need to be done.
THANK YOU!