Measurement of the impact of buildings on meteorological variables

BSA 2017 – Building Simulation Applications
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Introduction

Building energy use

Residential
- 34%
- 27%
- 11%
- 28%

Other sectors
- 34%
- 11%
- 28%

Transport
- 44%

Industries
- World (IEA, 2012)
- France (ADEME, 2013)

Energy use inside buildings

Specific electricity (light, ...)
- 16%
- 6%

Cooking
- 6%

Sanitary hot water
- 10%

Heating/Air conditioning
- 68%

France (ADEME, 2013)
Introduction

Urban climate: Meso-scale models

WRF (Skamarock et al., 2008)
Meso-NH (Lafore et al., 1997)
FVM (Clappier et al., 1996)

Rugosity
Influence of obstacles
- Additional term in equations

BEP (Martilli et al., 2002)
UCM (Kusaka et al., 2001)
TEB (Masson, 2000)

Buildings / Streets
Solar radiation

Walls, roofs & streets
Window
Cooling/ Heating

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Experimental setup

EPFL Campus, Lausanne, Switzerland

Semi-urban setup

- different from BUBBLE experiment
## Instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Brand</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D sonic anemometers</td>
<td>Gill</td>
<td>WindMaster</td>
</tr>
<tr>
<td>Meteorological station</td>
<td>Gill</td>
<td>GMX 300</td>
</tr>
<tr>
<td>Surface temperature sensor</td>
<td>Optris</td>
<td>OPTCSLT15K</td>
</tr>
</tbody>
</table>

Table 1 – List of instruments
MoTUS

h = 25.5 m
h = 21.5 m
h = 17.5 m
h = 13.5 m
h = 9.5 m
h = 5.5 m
h = 1.5 m
Results

Wind speed profile

Highly impacted vertical wind profile
Air temperature calculation

$$\theta_a = \frac{\theta_s}{1 + 0.32 \left( \frac{e}{P} \right)}$$

$$e = RH \times 100 \times \left( 6.11 \times 10^{\frac{7.5 \theta_m}{237.3+\theta_m}} \right)$$

‘\(\theta_a\)’ – Air temperature corrected (K)
‘\(\theta_s\)’ – Sonic temperature (K)
‘\(\theta_m\)’ – Air temperature Maximet (K)
‘\(e\)’ – Vapor pressure (Pa)
‘\(P\)’ – Air pressure (Pa)
‘\(RH\)’ – Relative humidity
Results

Air temperature

Very good agreement between corrected air temperature and measured one
Convective heat transfer coefficient

\[ h_c = 5.678 \left[ m + n \left( \frac{U}{0.3048} \right) \right] \]

\[ h_c = 2.8 + 3U \]

‘\( h_c \)’ – convective coefficient
‘\( U \)’ – wind speed (\( \text{ms}^{-1} \))
‘\( m, n \)’ – Constants
## Results

### Heat transfer coefficient

<table>
<thead>
<tr>
<th>Floor</th>
<th>$h_c ,(W/m^2.K)$</th>
<th>Relative difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>7.0</td>
<td>35%</td>
</tr>
<tr>
<td>2nd</td>
<td>7.2</td>
<td>34%</td>
</tr>
<tr>
<td>3rd</td>
<td>8.1</td>
<td>26%</td>
</tr>
</tbody>
</table>

### Heat transfer coefficient 2

\[
h_c = 5.678 \left[ m + n \left( \frac{U}{0.3048} \right) \right] \]

\[
h_c = 2.8 + 3U
\]

Table 2 – Heat transfer coefficients
Results

Energy calculation over EPFL campus.

But how useful are localized data?

<table>
<thead>
<tr>
<th>Real consumption</th>
<th>30,000 MWh</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Localized data</td>
<td>32,600 MWh</td>
<td>8%</td>
</tr>
<tr>
<td>Meteonorm</td>
<td>34,400 MWh</td>
<td>15%</td>
</tr>
</tbody>
</table>

Table 3 – Comparison of energy consumption
Conclusions and Perspectives

MoTUS – Measurements

- High frequency measurement over vertical axis
- Long term monitoring of meteorological variables
- Preliminary results confirms previous findings
- Aim is to improve energy consumption calculation

Future steps:

- Develop new parameterization schemes for models
- Inclusion of radiation measurement and surrounding surface temperatures.
Thank you for your attention!

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