GEOMATICS SYNTHESIS PROJECT SYMPOSIUM

Thursday 8 November, 2012
Oostserre, BKCity
OVERVIEW

1. Introduction
2. Background
3. Site Description
4. LASER/F
5. Field Campaign
6. Simulation Results
7. Computational Fluid Dynamics
8. Conclusions and Recommendations
The effect of 3D geometry complexity on simulating radiative, conductive, and convective fluxes in an urban canyon.
Teledetection, Radiométrie et Imagerie Optique (TRIO)  
(Laboratoire des Sciences de l’Image, de l’Informatique et de la Télédetection (LSIIT), University of Strasbourg)  

+  
Transport Phenomena Group  
(Chemical Engineering, TU Delft)
We wondered...
What level of effort with 3D modeling is required to accurately simulate heat flux?
Research question:
How does 3D geometry complexity affect the accuracy of simulating heat flux in an urban canyon?

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Research question:  
How does 3D geometry complexity affect the accuracy of simulating heat flux in an urban canyon?

Hypothesis:  
Increasing the level-of-detail increases accuracy of the simulation.
INTRODUCTION RESEARCH APPROACH

Phase I + II
Data acquisition, pre-processing, and sensitivity tests.
INTRODUCTION RESEARCH APPROACH

Complex 3D geometry  
3D geometry scenarios  
| LASER/F |

Meteorological data  
Forcing file  

Thermal imagery

Phase I + II  
Data acquisition, pre-processing, and sensitivity tests.
INTRODUCTION RESEARCH APPROACH

Complex 3D geometry

Meteorological data

Thermal imagery

3D geometry scenarios

Forcing file

LASER/F

Output

Project output onto image

Compare results

Phase I + II
Data acquisition, pre-processing, and sensitivity tests.

Phase III
Comparison of the results
**INTRODUCTION**

**RESEARCH APPROACH**

- Complex 3D geometry
- Meteorological data
- Thermal imagery

**Phase I + II**
Data acquisition, pre-processing, and sensitivity tests.

**Phase III**
Comparison of the results

**Phase IV**
Analysis and conclusions

- LASER/F
- Project output onto image
- Compare results

- Output
- Wind profile
- Conclusions and recommendations

- 3D geometry scenarios
- Forcing file
- CFD MODEL
BACKGROUND URBAN CANYON SCALE STUDIES

Character of an urban canyon
i. geometry → solar illumination
ii. surface thermal properties → flux
iii. streetscape elements → mech. turbulence

Geometry of an urban canyon
i. orientation
ii. aspect ratio (H/W)
iii. sky view factor
Character of an urban canyon
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Geometry of an urban canyon
i. orientation
ii. aspect ratio (H/W)
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aspect ratio and wind flow
SITE DESCRIPTION RUE DE L’ARGONNE

- 170m
- 20m wide
- 15-20m tall
- AR = 0.75 - 1
LASER/F MODEL

- Triangulated mesh
- Heat flux calculated for each triangle mesh
- Surface temperature derived from energy balance equation
Inhomogeneous complexity in the model
Incomplete building envelopes
How should it be simplified?
LASER/F BASELINE DETERMINATION
LASER/F SEVEN SIMULATION SCENARIOS
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1. **Closed**

2. **Roofs**

3. **Windows**

4. **Grass**

5. **Balconies**

6. **Vertex Welding**
LASER/F SEVEN SIMULATION SCENARIOS
Measurements for the forcing file:
1. air temperature
2. air pressure
3. relative humidity
4. wind speed
5. wind direction
6. incoming direct solar radiation
7. incoming diffuse solar radiation
8. outgoing longwave radiation
FIELD CAMPAIGN THERMAL IMAGING

24hr measurements
1 Rue de l’Argonne
9 images x 20 epochs

radiant exitance (reflected and emitted energy)
FIELD CAMPAIGN THERMAL IMAGING

24hr measurements
4 Rue de l’Argonne
16 images x 20 epochs
SIMULATION RESULTS COMPARISON METHOD
**SIMULATION RESULTS**

Comparison Method

Simulated (LASER/F) vs. Measured (FLIR camera)
SIMULATION RESULTS COMPARISON METHOD

Simulated (LASER/F)
1. Filter out sky and windows

Measured (FLIR camera)
1. Filter out sky and windows
SIMULATION RESULTS COMPARISON METHOD

Simulated (LASER/F)
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Measured (FLIR camera)
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2. Generalize measurements
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Measured (FLIR camera)
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3. Compare results
RESULTS RADIANT EXITANCE BEHAVIOUR

1 Rue de l’Argonne

- behaviour/shape
- warming period
- effect of balconies

Graph showing the radiant exitance behaviour with different scenarios.

- Base case
- Base case + simple roofs
- Base case + complex roofs
- Base case + windows
- Base case + balconies
- Complex case
- Complex case + vertex welding

Time [hr]: 18 19 20 21 00 03 06 07 08 09 10 11 12 13 14 15 16 17 18 19
Radiant exitance RMSE [W/m²]: 0 10 20 30 40 50 60 70 80 90
RMSE
RESULTS RADIANT EXITANCE BEHAVIOUR

4 Rue de l’Argonne

RMSE

- behaviour/shape
- warming period

Radiant exitance RMSE [W/m²]

Time [hr]
static simulation results

Isosurface of $t_e$ with value 0.200000
Recall

→ A systematic tendency of simulating cooler temperatures.

Why?

→ More convective cooling above podium

Generally 0.5 ms\(^{-1}\) higher wind speeds in LASER/F compared to the CFD model results.
Increased 3D Complexity:

→ Does increase simulation time.
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<th>Simulation time</th>
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<tbody>
<tr>
<td>Base case</td>
<td>7 h 33 min</td>
</tr>
<tr>
<td>Base case + simple roofs</td>
<td>10 h 8 min</td>
</tr>
<tr>
<td>Base case + complex roofs</td>
<td>10 h 11 min</td>
</tr>
<tr>
<td>Base case + windows</td>
<td>15 h 56 min</td>
</tr>
<tr>
<td>Base case + balconies</td>
<td>19 h 1 min</td>
</tr>
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<td>Complex case</td>
<td>46 h 12 min</td>
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**CONCLUSIONS AND RECOMMENDATIONS**

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→ Does increase simulation time.

→ Does not necessarily increase simulation accuracy.

**Study shows:**

→ Different radiant exitance behaviour over time between the two facades - accuracy is affected by daily solar illumination pattern.

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<th>RMSE building 4 (W m⁻²)</th>
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<tbody>
<tr>
<td>Base case</td>
<td>45.84</td>
<td>48.85</td>
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<td>Base case + simple roofs</td>
<td>46.30</td>
<td>44.25</td>
</tr>
<tr>
<td>Base case + complex roofs</td>
<td>42.85</td>
<td>44.59</td>
</tr>
<tr>
<td>Base case + windows</td>
<td>46.93</td>
<td>51.29</td>
</tr>
<tr>
<td>Base case + balconies</td>
<td>36.87</td>
<td>43.39</td>
</tr>
<tr>
<td>Complex case</td>
<td>40.75</td>
<td>44.59</td>
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Study shows:

→ Different radiant exitance behaviour over time between the two facades - accuracy is affected by daily solar illumination pattern.

→ Systematically lower temperatures in LASER/F could be explained by over-simplified wind profile.
Gives an order of magnitude on the effort needed to model urban heat at the canyon scale.
CONCLUSIONS AND RECOMMENDATIONS

RESEARCH CONTRIBUTION

Gives an order of magnitude on the effort needed to model urban heat at the canyon scale.

RECOMMENDATIONS

→ Improve vertical wind profile in LASER/F
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→ Better modeling of building volumes and materials
CONCLUSIONS AND RECOMMENDATIONS

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→ Improve vertical wind profile in LASER/F

→ Better modeling of building volumes and materials

→ Use a model with consistent complexity
CONCLUSIONS AND RECOMMENDATIONS

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RECOMMENDATIONS

- Improve vertical wind profile in LASER/F
- Better modeling of building volumes and materials
- Use a model with consistent complexity
- Thermal image measurements (define ground control points and more overlap between images)
CONCLUSIONS AND RECOMMENDATIONS

RESEARCH CONTRIBUTION

Gives an order of magnitude on the effort needed to model urban heat at the canyon scale.

FUTURE WORK?

- Compare two similar facades
- Compare two or more different canyons
- Run simulation of urban neighbourhood or district