Watering practices and urban thermal comfort improvement under heat wave conditions

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ICUC9 - CCMA7: UHI mitigation strategies III: watering processes studies

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Objective: mitigate the Urban Heat Island (UHI)

- Create reactive cities to face heat-wave events

Source: http://www.shutterstock.com
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- Create reactive cities to face heat-wave events
- Improve population thermal comfort
- Implementation of vegetation in the city
- What type of vegetation? What irrigation must be used?

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Urban expansion modeling: NEDUM-2D (Viguié et al., 2014)

- Socio-economic model: macro-economic trends
  Population density, housing surfaces, ...
- “Business as usual” simulation until 2100

Spatial expansion and building typologies of the city of Paris in 2100
SURFEX model

- 1 km horizontal resolution over the Parisian Basin.
- Offline simulation
- 7 days close to 2003 heat-wave. Intensity 38 °C
- Urban model: TEB (Masson, 2000)
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2m-Temperature

Outdoor UTCI
SURFEX model

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- 7 days close to 2003 heat-wave. Intensity 38°C
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2m-Temperature
- Outdoor UTCI
- Trees shadow not computed
- Basic underground hydrology
Plant irrigation scenarios

- **No irrigation**
  - No water supply
Plant irrigation scenarios

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- **Unrestricted irrigation**
  No hydric stress for vegetation
  *Unrealistic but usually used*
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- **Realistic irrigation**
  - Frequency: 8h of irrigation from 11pm to 7am
  - Rate: $3.50L/m^2/day
Pavement watering scenario

- Motivated by Takahashi et al. work (2010)
- Based on the sensitivity analysis of EPICEA (Kounkou et al., 2014)

**Pavement watering**

- Frequency: 3 min per hour
- Rate: 2.80 L/m²/day
Evapotranspiration

Suburbs

City Center

- Unrestricted
- Realistic
- Pavement
- No Irrigation

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Evapotranspiration

**Suburbs**

- Vegetation irrigation

**City Center**

- Pavement watering

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**Suburbs**: vegetation irrigation
Evapotranspiration

- **Suburbs**: vegetation irrigation
- **City center**: pavement watering

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Spatial representation of the UHI during nighttime hours

- Large UHI
- Intensity: 3.5°C in city center
Urban Heat Island: Night

Unrestricted/Realistic:
No effect in city center
-2°C in suburbs

Pavement:
No improvement

2m-Temperature: Differences No Irrigation vs Irrigated scenarios

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Urban Heat Island: Day

- Large UHI
- Intensity: 2.5 °C in suburbs

Spatial representation of the UHI during daytime hours
Objective: Modeling tools | Scenarios | UHI | Thermal Comfort: UTCI | A combined scenario | Conclusions

Urban Heat Island: Day

2m-Temperature: Differences No Irrigation vs Irrigated scenarios

- Unrestricted: -3°C in suburbs
- Realistic: -1°C in suburbs
- Pavement: -1°C in city center
Outdoor Thermal Comfort: UTCI $>32$ °C

- 12h in Strong Heat Stress
- Up to 18h in City Center

Spatial distribution of outdoor strong heat stress conditions for day 7
Spatial distribution of outdoor strong heat stress conditions for day 7

- **Unrestricted**: Overall improvement
- **Realistic**: Improvement in Suburbs
- **Pavement**: Gains in city center

Outdoor Thermal Comfort: UTCI $> 32 \degree C$
Combined scenario: Realistic + Pavement in City Center

Night

Day

2m-Temperature: Differences No Irrigation vs Combined scenarios

Benefits from:
Realistic in suburbs
Pavement in city center
Combined scenario: Realistic + Pavement in City Center

Benefits from:
Realistic irrigation in suburbs
Pavement watering in city center

Distributions of outdoor strong heat stress conditions for day 7
Combined scenario: Realistic + Pavement in City Center

Benefits from:
- Realistic irrigation in suburbs
- Pavement watering in city center
- Almost no extra water supply needed
## Water consumption

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<th>Water demand</th>
<th>Unrestricted</th>
<th>Realistic</th>
<th>Pavement</th>
<th>Combined</th>
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</thead>
<tbody>
<tr>
<td>$10^6 m^3/day$</td>
<td>5.5</td>
<td>4.9</td>
<td>1.5</td>
<td>5.0</td>
</tr>
<tr>
<td>% Seine</td>
<td>18.7</td>
<td>17.3</td>
<td>5.1</td>
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Vegetation location should be considered

Depends on city shapes
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- Water storage in summer conditions?
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Vegetation irrigation: **long term and global** solution for future **reactive cities**
Pavement watering: **emergency** practice with local effects

Water storage in summer conditions?
What type of vegetation to be used?
Any Questions?

References

Viguié et al. 2014, *Technological Forecasting and Social Change*
Masson 2000, *Boundary-Layer Meteorology*
Takahashi et al. 2010, *Sustainable techniques and strategies in urban water management*
Kounkou et al. 2014, *Météorologie (in French)*