Combined use of DART and SOLENE-microclimat to investigate the impact of urban surface characteristics on LST estimations

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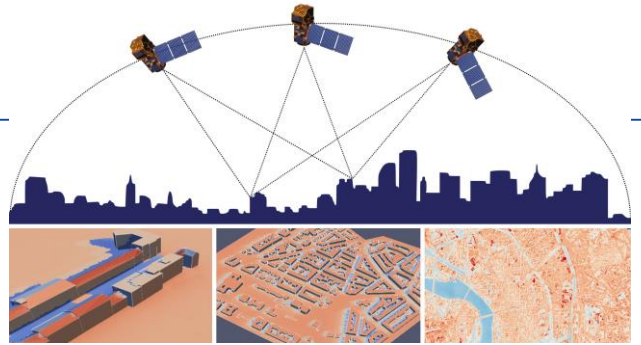
CONTEXT AND OBJECTIVES



Upcoming thermal infrared (TIR) satellite missions will allow for unprecedented investigation of the urban climate

➔ Accurate and comparable LST over cities

Challenge due to urban surface heterogeneity and 3D structure:

- Which surface parameters should be considered in LST retrieval algorithms?
- What are the uncertainties induced by methodological assumptions or unknown urban surface properties?

➔ Detailed modelling of 3D radiative processes

Combining DART and SOLENE-microclimat to investigate the impact of urban surface on LST estimation at the future satellite missions scale

DART

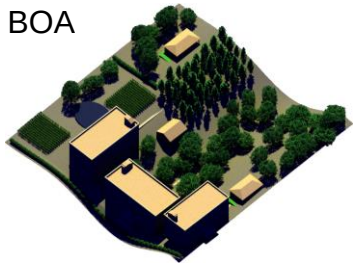
- Radiative transfer model to simulate remote sensing observations and radiative budget of urban and natural landscapes
- Developed at **CESBIO** since 1992
- Team: 10 persons
- Free licenses from Toulouse III University

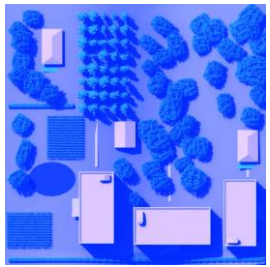
- C++ ($5x10^5$ lines), GUI (3D display, SQL DB, sequential run for any parameter, import/export,…)

More info : *https://dart.omp.eu*

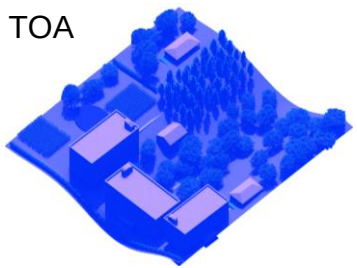
DART simulated BOA and TOA images
(0.4, 0.56, 0.67µm)

BOA

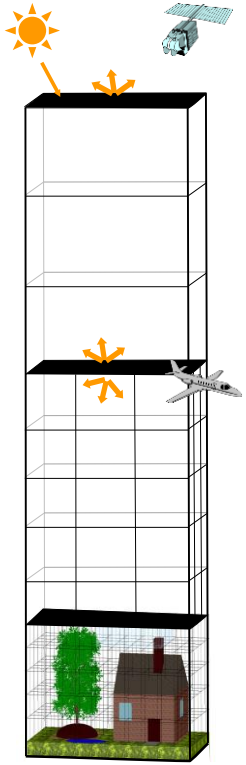




TOA



DART: Inputs, Processes and Products



Inputs

Acquisition configuration
- Satellite / plane location
- Date or sun direction
- Sensor characteristics

Optical/Structure databases
- Atmosphere: $t_{gas}(l)$,...
- Surface: optical properties or biochemistry

Scene (city, forest…) geometry
- Topography, land cover,…
- Objects: trees, houses,…
- Distance between plants,…

3D LAI, ...

Modules

Direction
Sun & viewing directions

Phase
Values per spectral band

Mockup
Atmosphere & Earth mock-up

DAO: mock-up direct creation

DART
Photon / Ray tracking

Outputs

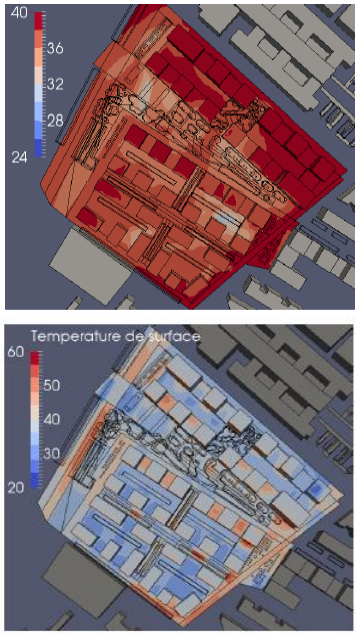
Remote sensing
- Radiometer images (L, ρ, T): satellite, airborne, in-situ + per scene element & ortho.
- $\{\bar{\rho}, \overline{T}, \overline{L}\ \forall\Omega\}$ in SQL database
- LiDAR: FW, point cloud, PC
- SIF (fluorescence)

3D radiative budget, 3D SIF

Post processing
- Inversion: maps of OP
- Sensor broadband,...

SOLENE-MICROCLIMAT

- Set of urban microclimate simulation tools (radiation budgets, thermal and aeraulic balances) for modelling at neighbourhood level
- For urban planning and its impact on various issues: urban heat island, thermal comfort, energy consumption of buildings, …
- Developed by CRENAU (Nantes School of Architecture) in the 1990s and at **CEREMA** since 2017



Air temperature

Surface temperature

Air and surface temperatures of the future Paris Olympic Village simulated with SOLENE-microclimat

More info : *https://aau.archi.fr/crenau/solene/*

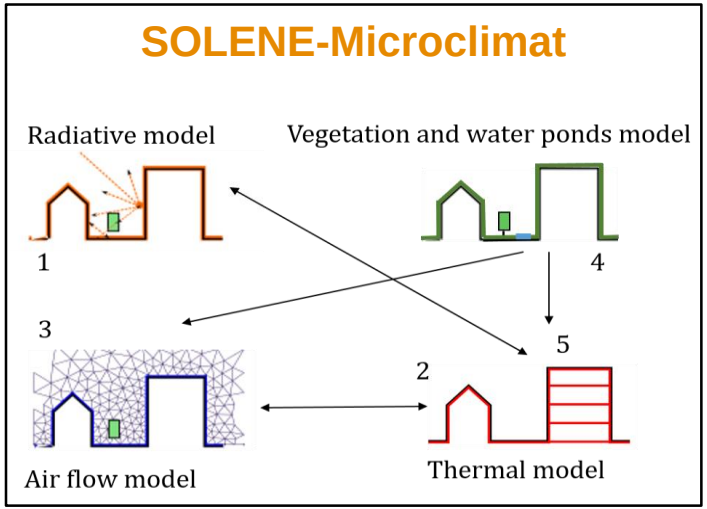
SOLENE-MICROCLIMAT

Urban microclimate simulation tool coupling a thermo-radiative model for surface temperature calculation and CFD (Computational Fluid Dynamics) for airflow calculation

Inputs

Real or future weather file

Materials thermal + radiative properties



Outputs

Urban environment:
LST, air temperature (+ district comfort indicators)

Inside building:
wall temperature, air temperature or energy needs

METHODOLOGY

Both models allow for 3D detailed representation of the urban landscape

DART

3D high spectral resolution radiation transfers + remote sensing observations

… require LST as input (no thermal model)

SOLENE-microclimate

Complete 3D energy balance ➔ LST at metric scale + air temperatures

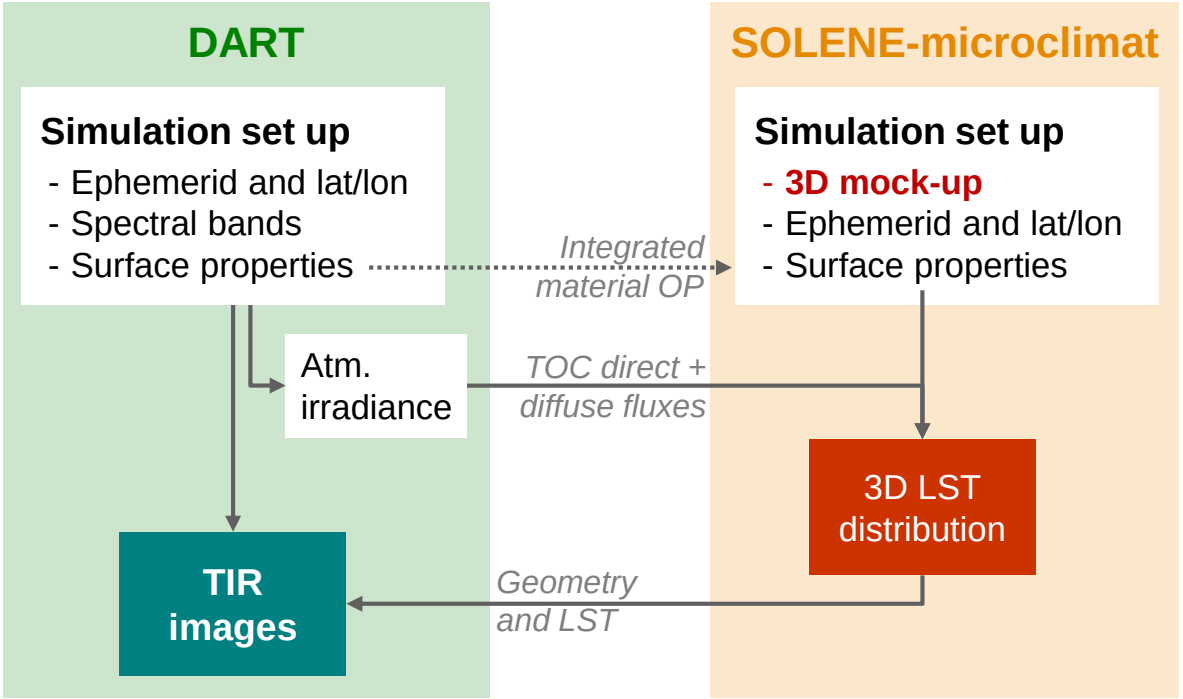
… simplified radiative budget for 2 broad bands (solar + TIR)

➔ **Chain DART with SOLENE-microclimate to generate TIR images with a physically based LST distribution in the scene**

METHODOLOGY

Chaining assuring coherence between:

- Date and location
- Mock-up geometry
- Material optical properties
- Atmospheric radiative forcing



PROOF OF CONCEPT

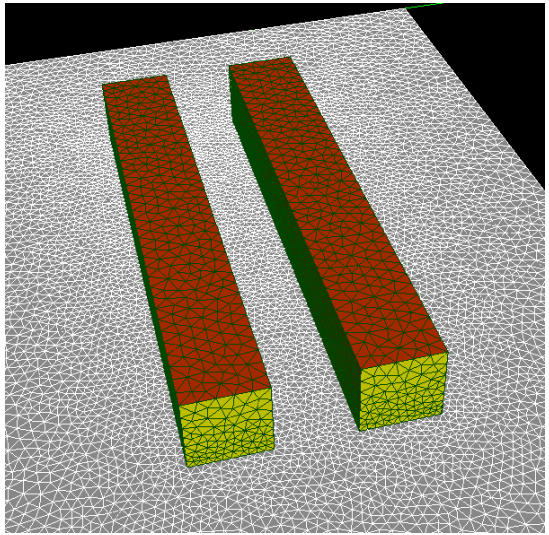
Geometry
+ physical properties

→

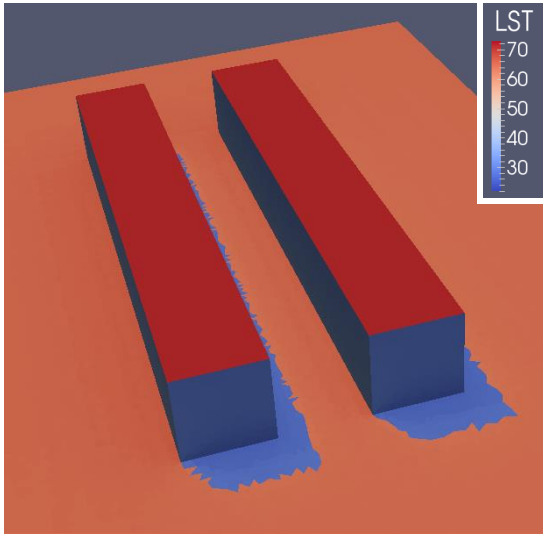
Energy budget
simulation

→

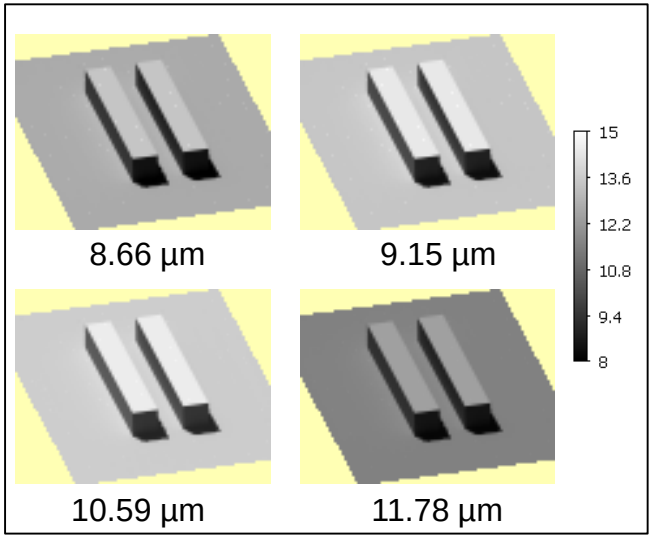
Radiative transfer and
images simulation



Mock-up
(Road, wall, roof)



LST - SOLENE-microclimat
(15/06, 12h UTC)



TOA radiance - DART
(1m, TRISHNA bands, vz=60-va=75)

PRELIMINARY RESULTS

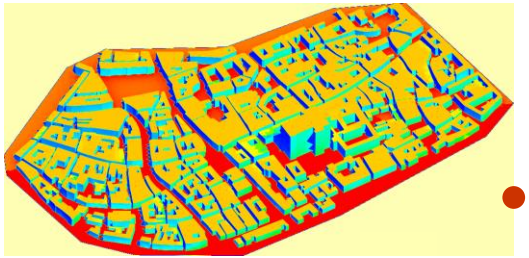
Strasbourg, cathedral district
15th June 2021, 9h UTC

LST - SOLENE-microclimat

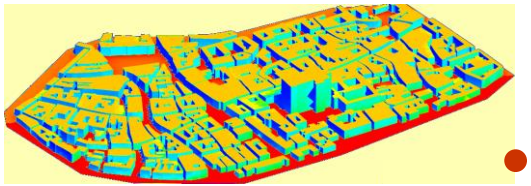
Brightness temperature at different view zenith (vz) angles - DART

vz = 15°

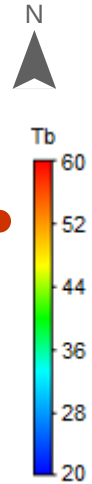
vz = 30°



vz = 45°



vz = 60°



= Sun position

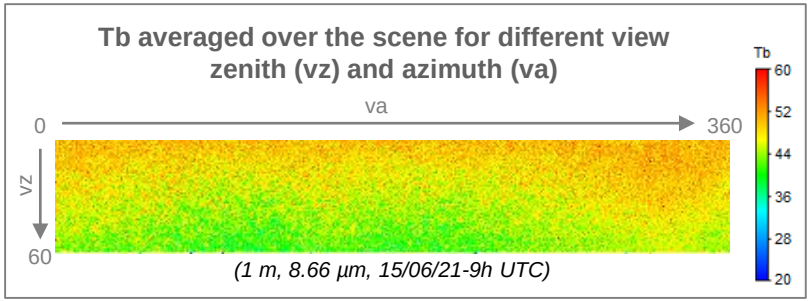
CONCLUSIONS AND PERSPECTIVES

This chaining will allow to investigate the impact of urban surface heterogeneity and 3D structure on LST estimation based on:

- Detailed DART simulation of radiative exchanges in the urban canopy for any sensor configuration
- Physically based 3D LST distribution in the scene from SOLENE-microclimat

Further works at upcoming thermal infrared satellite missions scale (40-60 m)

- Improve urban LST taking into account adjacency and cavity effects
- Evaluate uncertainties due to unknown OP, local LST and methodology assumptions
- Investigate directional effects to generate comparable LST products



Thank you!

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