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PhD position

Title : Development of a correction model for directional temperature effects adapted to urban environments for upcoming satellite thermal infrared images

Reference : **PHY-DOTA-2025-02**
(to use in all future exchanges)

PhD expected start: October 2025	**Deadline for application:** 15/05/2025

Keywords : Thermal Infrared, Land Surface Temperature, Directional effect, 3D, Urban

Expected qualification:

- Master degree or equivalent in remote sensing, signal or image processing
- Knowledge in radiative transfer, machine learning and Python programming language
- Ability to work independently, good communication and teamwork skills

Project description:

Land surface temperature (LST) is a key variable for urban micro-climatology studies. Upcoming thermal infrared (TIR) satellite missions, such as LSTM (ESA), TRISHNA (CNES/ISRO) or SBG (NASA) will allow for unprecedented investigations of the urban heat island effect. These missions will provide several images per week acquired at different viewing angles with a ground resolution of 50 to 60 m, overcoming the current limitation between having high spatial resolution or high temporal resolution to study urban microclimatic phenomena. At these resolutions, the nature and three-dimensional (3D) structure of the urban surface will have a significant impact on the directionality of the measured temperatures. Therefore, to generate accurate LST products comparable whatever the viewing angles, a good understanding of these effects is necessary.

LST is usually acquired by remote observations of emitted thermal radiation. However, the 3D structure of cities complicates observations due to the non-uniform solar heating of urban facets, inducing anisotropy in the surface thermal emission at the local scale. As a result, the remotely sensed urban LST varies intrinsically with the viewing angle of the sensor. These variations can be extremely large, evaluated to range between 5 and 7 K and up to 10 K during an airborne campaign over Toulouse (Lagouarde et al., 2010).

Models have been developed to apprehend this directional behaviour and to normalise the brightness temperature to standard observation geometry at the city scale. Lagouarde et al (2010, 2012) modelled these directional effects over large urban areas using two radiative transfer tools, Solene-Microclimat and TEB (Town Energy Balance). More recently, Krayenhoff and Voogt (2016) obtained similar results with TUF3D and SUM on highly simplified urban landscapes, showing that the anisotropy strongly depends on the urban morphology (orientation, building shape and height/distance ratio). These studies focused on urban scenes at the city scale. More recently, Zheng et al. (2020) evaluated the directional effects at the canyon scale and showed that, for a facade temperature of 340 K, a difference of 4.2 K could be reached between a canyon assimilated to flat ground and the real 3D structure.

Previous studies highlight the need to correct TIR measurements for directional effects in urban environments but are not adapted to the spatial resolution of LSTM, TRISHNA or SBG. The objective of this PhD is therefore to investigate the impact of directional effects induced by urban 3D structure on LST retrieved at the scale of the future TIR satellite missions. The idea is to identify the main driving parameters by modelling and quantifying these directional effects for different urban configurations (building structure, orientation, composition) using radiative transfer tools adapted to a structured 3D environment. This should lead to the development of a semi-physical directional model to correct for directional effects and to normalize the data acquired at varying viewing and illumination geometries. Synthetic and real data from field campaigns such as CAPITOUL (Lagouarde et al. 2008) will be used for validation.

Research plan:

- Providing an updated state of the art on the quantification of directional effect on radiative surface temperature measurements and its modelling in urban environments, along with the analysis of the main classes of urban structures (morphology, material type...);
- Modelling of the directional effects on temperature for different 3D urban configurations along with a sensitivity analysis to define the essential parameters explaining these effects at the LSTM, TRISHNA and SBG scales using radiative transfer tools adapted to a structured 3D environment. The latter will be defined by urban patterns derived from city morphology at a scale of 60 m;

- Development of a semi-physical directional model based on the previous step results to correct for directional effects and to perform an angular normalisation of the temperature;
- Validation of the proposed model using existing airborne datasets acquired at different viewing angles. As the TRISHNA mission is scheduled for launch in 2026, newly acquired satellite data may be processed during the PhD thesis.

References:

- Lagouarde J.P. & Irvine M. Directional anisotropy in thermal infrared measurements over Toulouse city centre during the CAPITOUL measurement campaigns: first results. Meteorol Atmos Phys 102 (2008)
- Lagouarde J.P et al. Modelling daytime thermal infrared directional anisotropy over Toulouse city centre. Remote Sensing of Environment (2010)
- Lagouarde J.P, et al. Experimental characterization and modelling of the nighttime directional anisotropy of thermal infrared measurements over an urban area: Case study of Toulouse (France). Remote Sensing of Environment (2012)
- Krayenhoff E.S., Voogt J. Daytime Thermal Anisotropy of Urban Neighbourhoods: Morphological Causation. Remote Sensing (2016)
- Zheng X. et al. Impact of 3-D Structures and Their Radiation on Thermal Infrared Measurements in Urban Areas. IEEE Transactions on Geoscience and Remote Sensing (2020)

Collaborations:

This PhD work will be performed in collaboration with:

- Laure Roupioz (ONERA)
- Xavier Briottet (ONERA)
- Nicolas Lauret (CESBIO)
- Françoise Nerry (CNRS, ICUBE)
- Mark Irvine (INRAE)

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