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PhD thesis offer

Title : Investigate the impact of directional effects induced by urban 3D structure on upcoming thermal infrared satellite missions land surface temperature products

Reference : **PHY-DOTA-2022-20** *to be use in all communication*

Start date : October 2023	**Deadline for application :** 15/05/2023

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, TRISHNA or SBG, 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 ranging from 37 to 60 m. At these resolutions, the nature and 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 among the different missions, a good understanding of these effects is necessary.

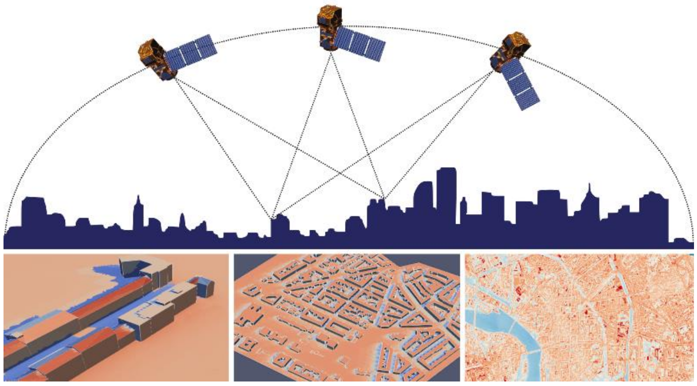
LST is usually acquired by remote observations of emitted thermal radiation. However, the three-dimensional structure of cities complicates observations due to the non-uniform solar heating of urban facets, inducing anisotropy in the surface thermal emission at the local scale. As a result, the remotely 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 a 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. 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 same in 3D.

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 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
- 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



References :

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- 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 will be co-founded by ESA and the reasearch work will be performed in collaboration with:

• Laure Roupioz (ONERA)
• Xavier Briottet (ONERA)
• Jean-Philippe Gastellu (CESBIO)
• Françoise Nerry (CNRS, ICUBE)
• Mark Irvine (INRAE)
• Benjamin Koetz (ESA)

Hosting laboratory at ONERA	**PhD supervisors**
Department : DOTA	Nom : Françoise Nerry and Laure Roupioz
Location : Toulouse, France	Laboratory : ICUBE/ONERA
Contact : Laure ROUPIOZ	Email : f.nerry@unistra.fr
Email : laure.roupioz@onera.fr	laure.roupioz@onera.fr

Pour plus d'informations : https://www.onera.fr/rejoindre-onera/la-formation-par-la-recherche