PhD Offer

PhD title: Improvement of short-term urban microclimate prediction with thermal infrared remote sensing: inverse modelling of the energy budget at the district scale

Discipline: Civil engineering (thermal modelling), remote sensing

Key words: prediction, microclimate, heat wave, remote sensing, thermal infrared, inverse modelling

Structure or location: Cerema BPE (Nantes, France)

Doctoral school: ED SDU2E (http://sdu2e.obs-mip.fr/)

Supervisors / directors: Laure Roupioz, Marjorie Musy

Co-supervisors: Auline Rodler, Xavier Briottet

Expected date to start: before October 2022, as soon as possible

Funding: Cerema

Context and objectives

Due to climate change, more frequent and intense heat waves are expected. In urban areas, these heat waves are amplified by the urban heat island (UHI) phenomenon, which is evaluated by estimating the difference in air temperature or surface temperature (SUHI: Surface Urban Heat Island) between the city and its rural environment. The UHI has an important influence on the comfort and health of urban residents.

The UHI can be estimated from sufficient measurements of the air temperature in the city. This method is expensive in terms of time and equipment and can be replaced by results from simulations of large-scale urban microclimatology models (*TEB, ARPS Canopée, etc*). Those models require a detailed knowledge of the urban morphology and the nature of the urban surfaces. However, the results obtained depend directly on the good knowledge of the thermal and radiative properties of urban surfaces. An alternative is to use spatial data in the thermal infrared (TIR) domain giving access to the surface temperature with the advantage of covering the whole city and its rural environment but the disadvantage of not providing the air temperature. Moreover, such measurements are available at hectometric to kilometric spatial resolutions. Such resolutions are insufficient to estimate this index at the district scale. Finally, remote sensing data at high spatial resolution have low revisit rates (from a few days to a month), which is a real drawback for UHI forecasting.

This PhD will take place as part of the ANR project DIAMS[1] which aims to prepare the use of high spatial and temporal resolution thermal infrared satellite data to support modelling for the diagnosis and short-term forecasting of urban microclimate during heat waves. IRT imagery allows to estimate the

[1] DIAgnostic, Modélisation & gestion de la Surchauffe urbaine en période de canicule : apports croisés des outils de simulation microclimatique et de l'imagerie IRT

land surface temperature (LST) of a given area and consequently to estimate the SUHI of an urban area. The final goal of the DIAMS project is to exploit these LST at district scale to derive local air temperatures and urban thermal comfort indicators based on microclimatic modelling. The assimilation of LST derived from satellite images during the simulations will allow to calibrate the surface temperature values calculated by the model, thus correcting the uncertainties related to the parameterization of the thermal and radiative properties of the materials, which are often difficult to obtain in urban areas.

The PhD student will contribute to this project by addressing the following scientific objectives:

- To propose a robust method, adapted to urban environments, to exploit IRT remote sensing data and obtain surface and air temperatures at the district scale, leading to urban heat island maps.
- To develop an inverse model based on LST and the microclimate tool to identify the important parameters and their respective values to be used as input to the prediction tool.
- To propose a short-term prediction model (real time prediction or a 2-3 day forecast) of the overheating conditions in a district during a heat wave.

Once these objectives are reached, the following associated applications will be considered:

- Production of indicators to identify areas sensitive to overheating as well as cooler areas in the district.
- In case of an expected heat wave, microclimatic forecast simulations will be carried out on different zones at district scale by applying satellite images as initial condition and weather prediction as input.

Main steps and methodology

Four main steps are identified:

The first step will contribute to a state of the art focusing on the combine use of microclimatic models developed in the laboratory (Solene-Microclimat, ProLB, etc.) and TIR data, as well as on short-term prediction of microclimatic variables. A benchmark between microclimate tools will be carried out during the ANR project to identify the most relevant model, which will then be used in this PhD.

The second step will be to study the capacity of microclimatic model to integrate TIR data on urban realistic configurations and to assimilate LST values derived from TIR data. During this step, different approaches to assimilate satellite data with a spatial resolution around 60m to a model working at a finer scale will be considered.

As a third step, different sensitivity analyses will be performed:

- Sensitivity to the spatial attribution of LST derived from TIR images (LST identical for all surfaces; separation of roofs, grounds, and façades LST; differentiation of façades depending on the orientation) and to the uncertainties of those LST. The air temperature in the urban district will be deduced from these simulations.
- Sensitivity to the parameters used to calculate the surface temperatures in the model. Once the parameters are ranked according to their influence degree, an inverse method will help to identify them. These parameters can be for example the characteristics of the district and will help to parametrize the prediction tool.
- Sensitivity of the air temperature estimation to the assimilation time step of the surface temperatures. Steps of 2 hours to some days will be tested with our data set.

- Sensitivity to spatial resolution of the TIR image. The spatial resolution of the future TIT satellite mission TRISHNA (60m) will be tested and more.

The fourth step will consist in exploring two prediction methods on a case study:

- Direct use of the microclimate tool with the parameters identified at the district scale and integrating predicted weather data.
- The construction of a metamodel of the district which can be initialized with LST and the parameters identified thanks to the microclimate model Solene-microclimat.

The first modelling method will allow to estimate the evolution of the climatic variables in the district. The second will only give access to mean values. Both approaches will be tested and compared on different districts and only one approach will be kept. The uncertainty on the air temperature prediction will also be assessed.

To apply

Contact: Laure.Roupioz@onera.fr, marjorie.musy@cerema.fr

Please provide:

- A curriculum vitae
- A copy of identity card or passport
- A copy of your Master grades (at least the grades of master 1 if grades of master 2 are not available yet)
- A copy of your latest Degree (master's degree, engineering degree, research master's degree)
- A cover letter to explain your motivation to follow and defend these PhD's topic (2 pages max)
- A recommendation letter