Blue Green Solutions to mitigate urban heat islands - High resolution monitoring and modelling of thermal fluxes

Scientific context:
Urban areas are facing a broad range of challenges due to unsustainable urbanization, degradation of natural capital, as well as an expected increase in intensity and frequency of extreme weather events due to climate change. This should exacerbate the environmental impacts directly (stormwater) or indirectly (urban heat island and biodiversity degradation) related to the water cycle. Blue Green Solutions (BGS), such as green roofs or vegetated swales, are particularly efficient to reduce the potential impact of new and existing urban developments with respect to these issues. Although BGS benefits are perceived, promoters are still reluctant to implement them (or only on aesthetic considerations). Some methodologies and tools have therefore to be developed to better understand the thermo-hydric behaviour of such infrastructure in relation with biodiversity, and to assess their performances through scales (from the material to the development project).

Such a tool able to assess these environmental performances has not been achieved for now because of the complexity of the urban environment and several scientific issues that must be overcome: (i) poor knowledge about the physical processes involved in the thermo-hydric BGS behaviour (and especially infiltration and evapotranspiration), and (ii) lack of a modelling tool coupling thermic and hydrological functioning at the urban scale.

Objectives:
To overcome these issues, the proposed PhD thesis will study the thermo-hydrologic behaviour of BGS (green roofs in priority). It is particularly focussed on:

- Coupling hydrology and thermic by representing as precisely as possible the evapotranspiration flux,
- Characterizing the spatio-temporal variability of the related processes over a wide range of scales (from the material to the district scale);
- Contributing to the development a scientific network devoted to BGS monitoring to expand knowledge and fulfill the lack of feedback concerning the functioning of existing BGS.

Work plan:
This PhD thesis will combine experimental and modelling activities.
First of all, it will pursue the large scale monitoring of the Green Wave through the development of the multi-scale Fresnel platform at Ecole des Ponts

(https://hmco.enpc.fr/Page/Fresnel-Platform/en). A wireless sensor network is currently implemented on the vegetated infrastructure to measure water content and temperature. Such devices will make possible the capture of the space-time variability of retention and infiltration processes. In addition, the PhD student will implement a scintillometer, which is specially adapted to measure sensible heat flux. Combined with the other sensors, it will make possible the estimation of latent heat flux (evapotranspiration) with high resolutions. He will also participate to local experiments made with a portable transpiration chamber.

In order to respond to non-stationary stakes, multifractal-based tools will be applied on the collected data to characterize the space-time variability of thermo-hydric flux (infiltration and evapotranspiration for instance), but also to generate and reproduce the phenomena at other scales (larger or smaller). These methods and framework enable a statistical physics approach of complex phenomena in particular stochastic simulations of geophysical fields based on their scaling laws. It is thus possible to describe and simulate the variability of intermittency beyond the mean field and to study its extremes.

Finally, the PhD student will develop a thermo-hydric coupling. It will be obtained by combining two existing models adapted to urban environment (at the district scale). Multi-Hydro and SOLENE-microclimat models have recently been improved to represent a set of possible BGS, and to assess their performances in stormwater management and outdoor comfort respectively. The PhD student in charge of this coupling will participate to some training courses to handle both softwares, and will be helped in her/his tasks by local modelling experts. She/He will also contribute to the creation of a database related to the BGS which will be used to validate the modelling (a short stay in Imperial College London is also planned for this purpose).

Research framework and perspectives:
This PhD thesis will be carried out into the framework of the EVNATURB ANR French project. EVNATURB aims to develop a platform to assess some of the eco-system services (i.e. stormwater management, urban cooling, or biodiversity conservation) provided by Blue Green Solutions at the district scale, and to promote the re-naturation of cities. Based on a consortium of researchers belonging to Ecole des Ponts ParisTech, Cerema Ouest, Cerema Ile-de-France, and AgroParisTech, EVNATURB intends to put an emphasis on an interdisciplinary, multi-scale and multi-physics approach.

The final platform -in which the current PhD work will be integrated- will be designed to be used by any stakeholder involved in urban development projects (planners, architects, engineering and environmental certification companies...) and to help them to implement BGS and evaluate which ones are the most appropriate for a particular project depending on its environmental objectives and constraints, and particularly for obtaining environmental certifications.

Some industrial collaborations have already been identified and will participate in the follow-up of the project: (i) VulkaTech (http://www.vulkatec.de) which is

an international company specialised in building materials and planting substrates made of natural igneous minerals pumice and lava stone, (ii) Certivéa (http://www.certivea.fr/) which is a subsidiary of CSTB private company (Centre Scientifique et Technique du Bâtiment) and a referent in evaluation and certification for many types of construction, (iii) Société du Grand Paris (https://www.societedugrandparis.fr/) which is a pubic institution in charge of the Grand Paris development project, and (iv) Bureau d'étude Gally (http://www.paysage.gally.com/) which is a farming and landscape design company whose mission is to promote the construction of more liveable and sustainable cities.

Profile of the candidate:
The candidate should have skills in the mathematical modelling of mechanics (graduated in fluid mechanics or environmental physics), have capabilities in computer simulations, and be of interest for the experimental follow-up.

Administrative part:
This 3-year PhD will be hosted in Hydrology, Meteorology and Complexity laboratory at Ecole des Ponts ParisTech (HM&Co/ENPC), Champs-sur-Marne (France) under the supervision of:

- Pierre-Antoine VERSINI (HM&Co), researcher in hydrology and coordinator of the EVNATURB project
- Daniel SCHERTZER (HM&Co), professor, director of the Chair Veolia and expert in multifractals
- Marjorie MUSY (CEREMA Nantes), director of research and expert in microclimatology
- David RAMIER (CEREMA Trappes), researcher in hydrology and expert in water and heat fluxes between soil and atmosphere

The net monthly salary will be around 1600 euros.

The PhD should start before 31st June 2018.

Contact: pierre-antoine.versini@enpc.fr (+33 (0)1 64 15 37 54)