PhD position

« Multifractality of surface temperature of vegetated canopies in relation to atmospheric turbulence »

The temperature of vegetated land surfaces is a key variable through evapotranspiration for assessing the water balance of these surfaces. Its monitoring by high-resolution infrared (IRT) remote sensing measurements from space satellites, as planned in the future space missions HyspIRI (NASA, USA) or THIRSTY (CNES in cooperation with NASA and more recently with ISRO in India), will allow to assess the state and evolution of the water resources of cultivated landscapes. However, to improve the observation ability and diagnostic of the water balance of vegetated surfaces, uncertainties on IRT measurement should be reduced and, above all, a better understanding of the physical meaning of the measure for complex surfaces such as surfaces with vegetation of several meters high, is crucial.

Like many dynamic systems present in nature, the instantaneous surface temperature of a vegetated surface obtained from an IRT camera is characterized by complex spatial and temporal structures with strong irregularities involving different scales. The origin of this variability is multiple. For bare surfaces, this variability is mainly related to the turbulence of the atmosphere, which modifies the heat exchanges between the surface and the atmosphere, or even to the humidity of the soil. On the other hand, for vegetated surfaces one must add the variability related to the spatial distribution of the vegetation, in particular the depth of the canopy through its gaps, and the heterogeneity of the thermodynamic properties of the vegetation elements and soil. These different sources of variability are particularly constraining for the interpretation of IRT images. Therefore, they must be quantified in order to assess the extent to which IRT measurements at the proposed resolution (60-80 m) are representative of average surface temperatures as assumed by meteorological models.

This PhD will focus on the relative impact of the atmospheric turbulence compared to the vegetation spatial variability seen by the measure, on the IRT measurements of vegetated surfaces of different depths (crops, forests, etc.). The addressed issues will be as follows:

- To what extent does atmospheric turbulence affect IRT measurements of surface temperature fluctuations of a vegetated surface?
- What is the relationship between the fluctuations of the surface temperature of an IRT measure and the turbulence of the atmosphere? Do they respond to a scaling law consistent with the turbulence one? What is the sensitivity of these fluctuations to the spatial resolution of the measure?
- To what extent are IRT measurements representative of mean surface temperatures as assumed in meteorological models?

We propose to address these issues through a multifractal analysis of 1D and 2D high-frequency meteorological fields (surface temperature, wind speed, air temperature) obtained from measurements on masts over different vegetated surfaces. Compared to standard statistical methods limited to the second order moment (energy spectrum, variogram), the multifractal analysis is more adapted to the non-Gaussian character of the turbulence at the top of the canopy. For simplicity, we will limit ourselves to horizontally homogeneous plant surfaces or to a combination of two homogeneous surfaces (juxtaposition of forest - clearing or sparse cover). This last case will enable us to approach different depths of cover and thus different turbulence scales on the same image. The identification of scaling laws of surface temperature fluctuations will allow to develop a multifractal stochastic model to assist in the interpretation-correction-simulation of IRT images, or even to virtually increase their spatial resolution. The ultimate interest of this approach is to be extended to the landscape scale, which is much more complex by nature.

The originality of this PhD is its multidisciplinarity between multifractal analysis, turbulence, atmospheric physics, remote sensing. All these disciplines are necessary to address the complexity of the PhD issues. For this, the student will be followed by a consortium of 2 laboratories (ISPA[1] et LOMA[2]), depending on 2 internationally well-recognized research institutes (INRA et CNRS), specialized in micrometeorology, multifractal analysis, and IRT measurement.

Expected profile

- Master or engineer in applied mathematics, physics, mechanics, complex signal processing
- Good experience in programming under Matlab, Linux environment
- Excellent writing skills, fluent in English
- Rigorous, autonomous, creative and motivated by working in a research environment

Supervision and working conditions

The PhD student will be co-supervised by:

- **Dr. Sylvain Dupont** (INRA Research Director), specialist in micrometeorology;
- **Dr. Alain Arneodo** (CNRS Research Director emeritus), specialist in multifractal analysis;
- **Dr. Mark Irvine** and **Dr. Jean-Pierre Lagouarde** (respectively INRA Engineer and Research Director), specialists in IRT measurement.

The PhD student will be integrated within the Environmental Mechanics team of the ISPA lab and within the ISPA and LOMA lab consortium formed for this PhD. The student will benefit from the scientific and methodology experience of the consortium, as well as their national and international collaborations.

The PhD student will be based at the ISPA lab in Bordeaux (France), and will have strong interactions with the LOAM lab. Both labs offer an excellent scientific environment, members of the Labex COTE and Idex of Bordeaux University. ISPA is located at INRA campus, within a few minutes from downtown Bordeaux, and LOMA is located within the campus of the University of Bordeaux. The PhD student will be registered at the "Sciences and Environment" doctoral school of the University of Bordeaux.

The PhD funding will be a merit-based doctoral contract of the University of Bordeaux. The gross salary will be about 1750 € (including social security for illness, maternity and unemployment, as well as financial help for public transportation and canteen) during a three year period. The PhD is expected to start by Fall 2017.

How to apply?

Any Master student interested in this project is required to send his/her CV to Sylvain Dupont (sylvain.dupont at bordeaux.inra.fr) and to submit his/her candidature on the website of the "Sciences and Environment" doctoral school of the University of Bordeaux **before June 2nd 2017** (tabs : *doctorat > offre de thèses > Consulter l'offre de thèses 2017 -2018 ... et candidater > spécialité physique de l'environnement*).

1 Interactions Sol Plante Atmosphère, INRA Bordeaux
2 Laboratoire Ondes et Matière d'Aquitaine, CNRS Bordeaux