PARIS-REGION-PHD-2020

Sponsored by Région Ile-de-France[1] and Leosphere[2]

Title

Characterization of wind and turbulence profile spatiotemporal variability in the Paris Region Atmospheric Boundary Layer for Air Quality, Urban Meteorology and future local airborne transport applications.

Scientific motivation, relevance and timeliness

Air quality and meteorology (heat, humidity, clouds, precipitation) **in the urban environment** are strongly affected by **dynamical and turbulent** processes occurring in the **atmospheric boundary layer**. These processes include fluxes (sources) of momentum, heat, moisture and various gases and aerosols from the surface to the atmosphere, mixing at the top of the boundary layer through entrainment, mixing within the boundary layer, as well as ventilation by horizontal advection, with atmospheric stratification (stable, neutral or convective conditions) being of great importance.

This topic is particularly relevant and timely as several partners within the DIM QI2[3] are currently engaging in research to prepare for the 2024 Paris Olympics. Météo-France is preparing a new forecast model with 100-m resolution to improve weather prediction in the Paris region in 2024. Better measurements of the vertical structure of the atmospheric boundary layer, the wind, the turbulence and their spatiotemporal variability are required in the urban environment to evaluate the new high-resolution forecasts.

Several field campaigns are planned in summer 2022 to study chemical and physical atmospheric processes in the Paris region atmospheric boundary layer with support from MOPGA and ANR funds. While the mesoscale mean flow wind speed and direction are important drivers urban terrain and canopy morphology induce not only complex circulations down to the micro scale but the augmented surface roughness also alters the average flow. The presence of open areas with reduced surface roughness (such as rivers, lakes, or large green spaces) can cause channelling. Evaporative cooling associated e.g. with parks or nearby forests can generate fluxes that are strongly contrasted to the built environment. Clouds at the top of the boundary layer generate mixing and alter radiative fluxes compared to clear-sky conditions. More precise measurements of atmospheric dynamics are required to study these processes and their impact on air quality and meteorology.

A new COST action (PROBE 2019-2024)[4] was recently initiated to promote the use of profilers in the atmospheric boundary layer for new applications, providing opportunities for international collaborations in the field of wind profiling measurements in urban environments. Low-altitude airborne transport by drones is a new application that has the potential to develop in the future. Better characterization of spatial and temporal variability of wind and turbulence would be useful to quantify risks associated with this activity.

1 https://www.iledefrance.fr/paris-region-phd-2020
2 https://www.leosphere.com/
3 https://www.dim-qi2.fr/
4 https://www.cost.eu/actions/CA18235/#tabs|Name:overview

Scientific research questions

The three-year PhD work will focus on three main scientific questions:

Question 1 (Q1). With what spatial and temporal resolutions, spatial extent, and uncertainties can wind horizontal and vertical components be retrieved from Doppler Lidar measurements over an urban environment characterized by large horizontal and vertical surface heterogeneities?
Approach: A scanning Doppler Lidar will be deployed for the duration of the project. Scanning strategies will combine Plan-position Indicator PPI scans (conical scans) to describe the wind flow at different elevations and Range-height Indicator RHI scans (vertical slice scans) to measure the vertical structure of windshear. RHI scan measurements will also be used to retrieve 2-D wind fields based on new numerical methods developed from machine learning for data assimilation (learning algorithms). Computationally efficient methods will be sought to be able to process the very large amounts of data produced by the Doppler Lidar. Retrievals of turbulence characteristics (e.g. u', v', w') will also be investigated.
Innovation: (1) Deploy and operate a scanning Doppler Lidar in an urban environment; (2) perform wind field (and turbulence) retrievals using computationally efficient machine learning techniques; (3) validate the retrievals using ancillary measurements (mast measurements and vertically pointing Doppler Lidar).

Question 2 (Q2). How are the profiles of mean wind speed and direction, and turbulence characteristics over the urban area affected by meso-scale circulations? How does the urban morphology (river, parks, building heights) influence these wind and turbulence profiles and their horizontal variability?
Approach: A set of conditions thought to affect wind and turbulence characteristics will be identified and classified (such as wind direction, season, time of the day). For each class of conditions, the wind and turbulence characteristics will be analysed (case studies and statistical approach). This will generate key information necessary to better understand atmospheric circulation in the urban environment and horizontal and vertical mixing.
Innovation: This study will strive to provide a comprehensive view of the spatiotemporal variability of the wind field in a complex urban environment. This innovative study will serve as entry point to several applications such as urban weather (impact of mixing on spatiotemporal distribution of heat), air quality (impact of mixing and dilution on gas and aerosol concentrations), and local air transport (impact of wind and turbulence on drone flights).

Question 3 (Q3). How does the ABL develop and decay under various forcing conditions? How does the residual layer and the presence of clouds affect these variations? What is the relation between the ABL dynamical structure and aerosol mixing?
Approach: The Doppler Lidar measurements will be used to derive ABL height and stability index based on existing methods. The variability in ABL height diurnal cycle will be studied based on different conditions, such as wind direction, season, types of cloud present, stability profile. ABL heights and its variability derived from the Doppler Lidar will be compared to ABL heights derived from backscatter Lidars also deployed in the urban environment. This will allow better understanding of the links between mixing of aerosols and vertical structure of turbulent mixing.
Innovation: Combine aerosol backscatter Lidars and Doppler (wind/turbulence) Lidar to better understand links between aerosol mixing and ABL dynamics.

Calendar of PhD work

Year 1: (Focus on Q1)

- Assist with the deployment of a scanning Doppler Lidar at a site TBD
- Define measurement strategy of a scanning Doppler Lidar
- Develop retrievals of wind and turbulence profiles from Doppler Lidar measurements
- Gather all ancillary data necessary to carry out the validation studies
- Perform studies on urban wind field spatiotemporal characteristics (Q1)
- Present measurements and retrievals at scientific conference and write paper on retrievals of urban wind field spatiotemporal characteristics (Q1)

Year 2: (Focus on Q2)

- Perform analysis of wind and turbulence spatiotemporal characteristics
- Determine surface source area impacting the wind field using existing modelling tools
- Relate wind field variations to atmospheric stability and surface source area characteristics in terms of surface roughness and building morphology
- Present findings at scientific conference and write paper on wind and turbulence in urban environment (Q2)
- Continue monitoring of Doppler Lidar measurements

Year 3: (Focus on Q3)

- Perform studies on ABL development and impact of residual layer and clouds in the urban environment (Q3)
- Determine respective importance of cloud-induced mixing and surface driven mixing for various atmospheric conditions
- Perform studies on links between aerosol and dynamics tracers in the ABL
- Write PhD thesis
- Write paper on ABL development (possibly after submitting thesis manuscript)

Academic and industrial context

Academic context. The research Lab "Laboratoire de Météorologie Dynamique" (LMD) and regional cooperation framework "Institut Pierre Simon Laplace" (IPSL) have long experience in atmospheric remote sensing using Lidars and modelling of chemical and physical processes for weather and air quality applications. LMD/IPSL have been operating the SIRTA atmospheric observatory[5] in Palaiseau for nearly 20 years, and collaborate with other laboratories of IPSL (e.g. LATMOS and LISA) that operate observing platforms in Paris and Créteil[6]. All partners are actively involved in the DIM QI2 and climate and air quality studies for the Paris region urban environment. Dr. Martial Haeffelin at LMD/IPSL, PhD thesis director (HDR, advising 2 PhD students), has more than 25 years of experience in ground-based and satellite remote sensing of aerosols, clouds, wind and temperature in the atmosphere and boundary layer processes. Dr. Simone Kotthaus at LMD/IPSL, PhD thesis co-director (advising 1-2 PhD students), has 10 years of experience in urban micro-meteorology. Her research work focuses on urban climate observations and modelling. Support to introduce machine learning techniques for wind profile retrievals will be sought among a group of IPSL scientists (ESPRI-IA) that are experts in artificial intelligence[7].
The student will register at the graduate school of Institut Polytechnique de Paris[8].

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[5] http://www.sirta.fr

[6] https://observations.ipsl.fr/composition-atmospherique-en-idf.html

[7] https://www.ipsl.fr/Organisation/Les-structures-federatives/SAMA-Statistiques-pour-l-analyse-la-modelisation-et-l-assimilation

[8] https://www.ip-paris.fr/en/home-en/education/phd-programs/

Industrial context. Discussions between LMD/IPSL and LEOSPHERE on atmospheric remote sensing have been on-going for many years without formal collaboration. The motivation of LEOSPHERE to further develop new features and innovative applications for Doppler Lidars in urban environments is a great opportunity to formalize collaboration with LMD on this topic. Dr. Jana Preissler, application manager, scientist in meteorology and aviation weather, will be the PhD student advisor at LEOSPHERE. She has also 10 years of experience in atmospheric remote sensing in the academic world, which will support consistent advising between the laboratory and the company. Dr. Ludovic Thobois, scientific partnership manager with LEOSPHERE for meteorology and aviation applications and an expert in Doppler Lidar remote sensing, will be a great asset for this collaboration.

DIM QI2 "JO2024" and ANR "H2C" projects will provide great opportunities for regional and national collaborations, while the PROBE COST action will be a perfect framework for international collaborations. Dissemination will be done through scientific papers and participation to international conferences and workshops.

Application:

Deadline:

- Early application: from today until 15 September 2020
- Latest application: 15 October 2020
- Latest starting date of PhD work: 1 January 2021

PhD Scholarship sponsored by Région Ile-de-France and Leosphere.

Application documents

- detailed CV (Master of science or equivalent degree is expected)
- motivation letter (motivation to pursue PhD, motivation for the proposed research topic). Include a description of your qualities that make you a suitable PhD candidate. Present your current situation.
- letters of reference from a prior advisor, tutor or employer
- information regarding your scores in graduate-level scientific classes

Applications should be sent by email to

- martial.haeffelin @ ipsl.fr
- simone.kotthaus @ ipsl.polytechnique.fr
- When you apply, make sure to use the following text in the subject field of your email "PhD Paris Region 2020 Application"

You may contact us prior to applying if you need additional information.