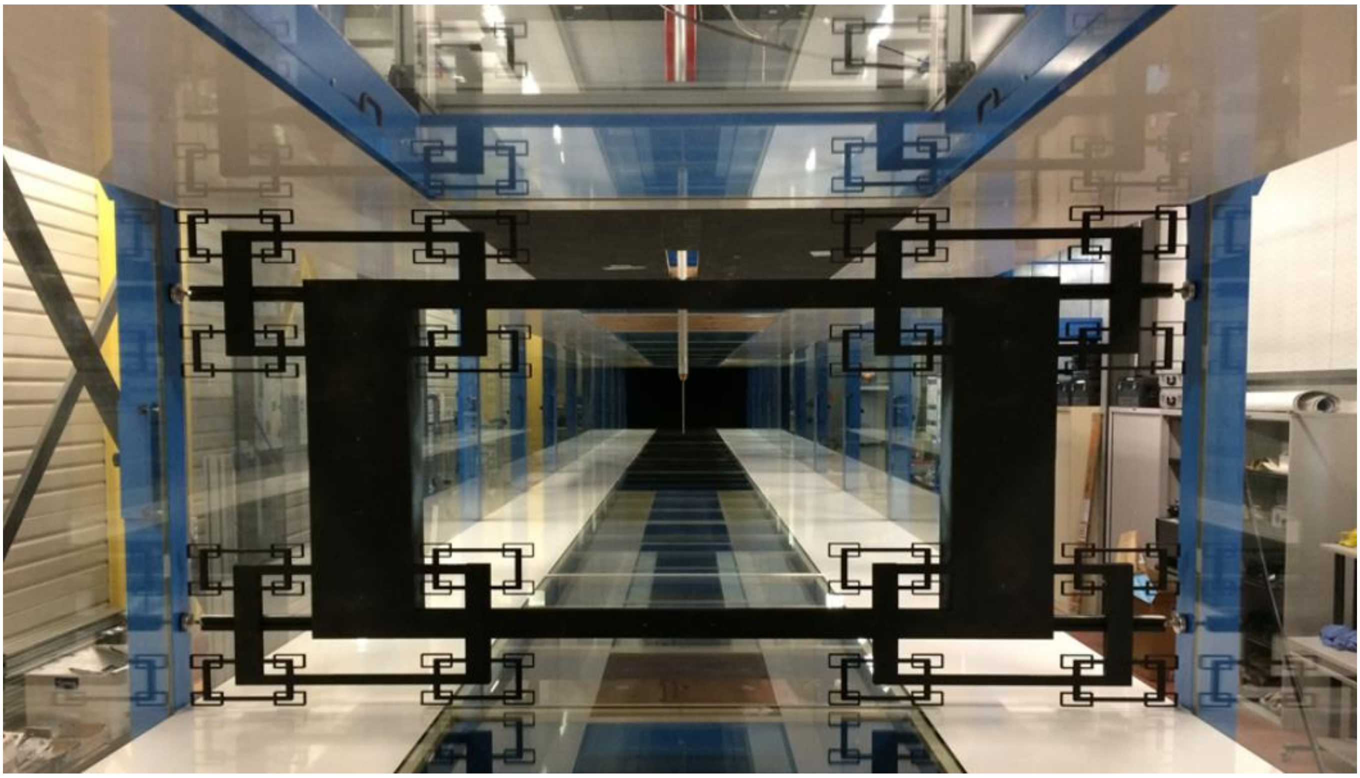
LILLE TURBULENCE PROGRAMME 2023

OPENING WORKSHOP ON TURBULENT FLOWS

Villeneuve d'Ascq, Cité Scientifique, M6 Building
20-22 June 2023

https://lmfl.cnrs.fr/workshop/ltp-2023-home/



The aim of this workshop is to discuss approaches to turbulent flows which go beyond Kolmogorov equilibrium cascades by taking explicit account of non-stationarity and/or non-homogeneity either in a statistical sense or in the local sense of dynamic intermittency. Kolmogorov equilibrium describes the spatio-temporal average of statistically homogeneous isotropic turbulence. Non-equilibrium is manifest in fluctuations around this equilibrium either in time for spatial averages or in space for time averages and in deviations from such equilibrium by the presence of statistical non-homogeneity and/or non-stationarity/turbulence decay. Non-equilibrium is therefore present in all turbulent flows which implies that various turbulent energy transfer and/or production mechanisms in both scale and physical spaces need to be taken into account to understand turbulence physics, including turbulence cascades, turbulence dissipation and intermittent fluctuations. Different universality classes of non-equilibrium may need to be defined by considering the presence or absence of different types of large-scale coherent structures and different regions of flows in terms of turbulence production, turbulence transport and proximity to the turbulent/non-turbulent interface which is an extreme but ubiquitous instance of local non-homogeneity/intermittency/near-singularity. There are consequences for important leading order properties of a raft of boundary-free turbulent flows including growth rates of turbulent shear flows such as turbulent wakes, jets and mixing layers where approaches based on momentum and force balances need to be confronted with approaches where turbulent energy balances and therefore turbulence dissipation play a leading role. There are also consequences for wall flows such a turbulent channel flows and various types of turbulent boundary layers which need to be elucidated and where both momentum and energy transfers, as well as wall-blocked coherent structures, are key.

TUESDAY 20 JUNE 2023

12:30-14:00 : WELCOME AND BUFFET LUNCH

14:00-14:40: YVES POMEAU -- Applications of a new model of turbulence: mixing layer, plane Poiseuille, turbulent wake…

14:40-15:20: MARTIN OBLIGADO -- Energy cascades in the turbulent wake of a wind turbine.

15:20-16:00: TEA/COFFEE BREAK AND DISCUSSIONS

16:00-16:40: KOSTAS STEIROS -- Experimental investigation of the primary and secondary vortex streets in the wake of bluff bodies.

16:40-17:20: ELISABETTA DE ANGELIS -- Scale-by-scale budgets and cascades near turbulent/nonturbulent interfaces.

17:20-18:00: NICOLAS MAZELLIER -- A near wake analysis of a swirling porous disk : application to wind turbine.

WEDNESDAY 21 JUNE 2023

09:00-09:40: JOACHIM PEINKE -- A general joint multipoint approach to turbulence and its thermodynamical interpretation - Reflection on a new definition of turbulent structures

09:40-10:20: ALBERTO VELA-MARTIN -- Non-equilibrium and irreversibility in the turbulence energy cascade: implications for subgrid-scale modelling

10:20-11:00: TEA/COFFEE BREAK AND DISCUSSIONS

11:00-11:40: MATTHIAS WACHTER -- The turbulent-nonturbulent interface (TNTI) in the atmosphere between Prandtl and Ekman layer

11:40-12:20: WOUTER BOS -- Scaling in inhomogeneous and unsteady turbulence

12:20-14:20: LUNCH AND DISCUSSIONS

14:20-15:00: ALEXANDRE ALEXAKIS -- How far does turbulence spread?

15:0O-15:40: CHRISTOS VASSILICOS --Beyond scale-by-scale equilibrium

15:40-16:20: TEA/COFFEE BREAK AND DISCUSSIONS

16:20-17:00: FABIEN THIESSET -- Turbulent iso-sets.

17:00-17:30: TOM FRIDLENDER – On plasmas dielectric barrier discharge integration for grid generated turbulence

20:00: WORKSHOP DINNER IN CENTRAL LILLE

THURSDAY 22 JUNE 2023

09:00-9:40: SZYMON MALINOWSKI -- Turbulence in clouds: nonstationary, nonuniform anisotropic and intermittent. How to analyze airborne data?

09:40-10:20: LUMINITA DANAILA -- Multi-scale interactions in the atmosphere. Application to the prediction of heat waves and urban heat islands

10:20-11:00: TEA/COFFEE BREAK AND DISCUSSIONS

11:00-11:40: MARTA WACLAWCZYK -- Non-equilibrium turbulence in the atmospheric boundary layer.

11:40-12:20: DISCUSSION

12:20-14:00: CLOSING BUFFET LUNCH

Applications of a new model of turbulence: mixing layer, plane Poiseuille, turbulent wake

Y. Pomeau

CNRS, Laboratoire d'Hydrodynamique, École Polytechnique, France

Practically most analytical models of turbulence rely on the concept of "turbulent viscosity" of Boussinesq. Any expression of this turbulent viscosity depends on a length scale, the mixing length (mishungweg in Prandtl's original). Such a length is hard to make explicit in most concrete geometries. Relying on basic symmetries of the Euler equations (geometrical and Galilean invariance) we have proposed an explicit integral closure relating the turbulent stress and the whole structure of the average velocity field. The equation to be solved is the balance of momentum. We found explicit solutions with some unexpected features in standard examples like the mixing layer and the turbulent plane Poiseuille flow. The latter exhibits a triple deck structure with a viscous sublayer near the wall, a logarithmic boundary layer farther away and a fully developed inhomogeneous turbulent flow in the core. The small viscosity limit displays an interesting dependence on the logarithm of the Reynolds number that could explain for instance the striking dependence of the friction constant of a sphere at Reynolds numbers in the million range.

Energy cascades in the turbulent wake of a wind turbine

M. Obligado

LEGI, Grenoble, France

This talk will focus on the relevance of new findings in turbulence modelling for wind energy applications. In particular, we will assess the nature of the energy cascade in scaled wind turbines under distinct operating conditions: different Reynolds numbers, tip speed ratios and background flows (laminar and turbulent). In a series of experiments performed at Oldenburg's large wind tunnel, the near and far wake of a scaled wind turbine have been studied. We will discuss how some properties of the energy cascade can be inferred from all conditions covered, and their consequences in terms of the spatial development of the turbulent wake.

Experimental investigation of the primary and secondary vortex streets in the wake of bluff bodies

K. Steiros

Imperial College London, UK

The shear layers that bound a turbulent wake are known to roll up and form large scale vortices. In the near wake this is due to the vortex shedding instability, while in the far wake this is due to the secondary street instability. Both phenomena are of high engineering interest, as they are responsible for the generation of fluctuating loads and for increasing the momentum transport between the wake and the outer flow. In this talk I will present experimental data (PIV and HWA) from measurement campaigns conducted at Imperial College London and LMFL, on the characterization of these two phenomena. Focus will be placed on (i) ways of suppressing these phenomena, (ii) the influence that these phenomena have on the mean flow, and (iii) the stability of the near and far mean velocity profiles.

Scale-by-scale budgets and cascades near turbulent/non-turbulent interfaces

E. De Angelis

Cardiff University, UK

Starting from an alternative decomposition of the turbulent field, a multi-dimensional statistical formalism for the description and understanding of turbulence in free-shear flows is proposed and applied to the symmetries of a planar temporal jet and a planar temporal plume. The theoretical framework is based on the exact equation for the second-order moment of the two-point velocity increment and allows us to trace the spatially evolving cascade processes at the basis of turbulence mixing and entrainment.

A near wake analysis of a swirling porous disc: application to wind turbine

N. Mazellier

PRISME, Orleans, France

Porous discs are popular devices used to mimic the wake of wind turbines at the laboratory scale. So far, the solidity has been the main parameter to design porous disc with the aim to match the wake deficit of wind turbine. In this study, we investigate the role of swirl by modifying the usual porous disc design. It is found that swirl is a key ingredient to achieve self-similarity in the intermediate wake region where scaling laws are well predicted by non-equilibrium turbulence.

A general joint multipoint approach to turbulence and its thermodynamical interpretation- Reflection on a new definition of turbulent structures

J. Peinke

Carl Von Ossietzky University, Germany

We discuss a statistical joint-multipoint characterization of turbulence by Fokker-Planck equation. This leads to production values of entropy for each velocity value. The statistics of the entropy fluctuations fulfill the integral fluctuation theorem of non-equilibrium thermodynamics. For fixed entropy values instantons can be worked out, which we call entropons. So far we see that negative entropy events and corresponding entropons are linked to intermittency. In a more speculative way, which is open for discussion, concepts to extend this approach to energy and entropy cascades are presented, which opens a possibility to define coherent structures in a turbulent field by negative entropy values. In such an approach, these structures are statistically entangled with the unstructured part of the field via the fluctuation theorem. As a last point the possibility to define further thermodynamical quantities like temperatures, free energy … is sketched.

Non-equilibrium and irreversibility in the turbulence energy cascade: implications for subgrid-scale modelling

A. Vela-Martin

Universidad Carlos III de Madrid, Spain

This talk focuses on the turbulence energy cascade from the framework of statistical mechanics, in which cascades emerge naturally in non-equilibrium ensembles, and the direction of their fluxes can be predicted by equilibrium thermodynamics. By analysing the statistical irreversibility of the enery cascade in physical space, it will be shown that non-equilibrium imposes an almost unidirectional coupling from large to small scales, which has theoretical and practical consequences. In particular, we will see that the energy cascade can be modelled as a purely dissipative and irreversible sink of energy acting on the large scales, which can be exploited to construct models for large eddy simulations (LES) of turbulence. The invariance of the filtered Navier–Stokes equations to divergence-preserving transformations of the subgrid-scale (SGS) stress tensor 1 is exploited here to explore alternative representations of the local SGS energy fluxes. Numerical optimisation procedures are applied to the SGS stress tensor—obtained by filtering isotropic turbulence flow fields—to find alternative stresses that satisfy the filtered Navier–Stokes equations, but that produce negligible backscatter 2 . Fig. 1 shows a visual comparison between the standard and the optimised SGS energy fluxes for the same flow field. Note that both fluxes are physically equivalent but the latter produce substantially less backscatter than the former. These results show that backscatter does not represent a flux of energy from the subgrid to the resolved scales, but conservative spatial fluxes, and that it needs not be modelled to reproduce the local energetic exchange between the resolved and the subgrid scales in LES. These findings corroborate the strong unidirectionallity of the cascade predicted by non-equilibrium statistical mechanics, and show that the cascade can be modelled as an irreversible sink of energy, justifying the extended use of purely dissipative SGS models in LES.

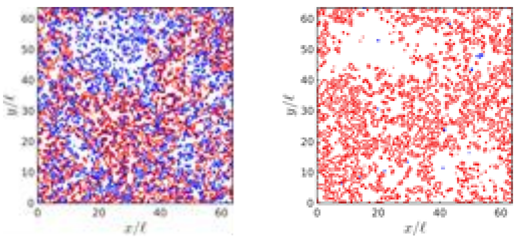


Figure 1: Visualisation of a slice of the SGS energy fluxes in a DNS of isotropic turbulence. The fluxes are calculated at a scale ℓ within the inertial range. (left) standard SGS energy fluxes; (right) optimised SGS energy fluxes. The red contours represent the direct energy cascade (SGS fluxes equal to the mean), and the blue contours the energy backscatter (SGS fluxes equal to zero).

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1 Jiménez J. Fluid Mech. 809, 585–600 (2016).

2 Vela-Martin, J. Fluid Mech. 937, A14 (2022).

The turbulent-nonturbulent interface (TNTI) in the atmosphere between Prandtl and Ekman layer

L. Neuhaus, * M. Wächter *, J. Peinke

Carl Von Ossietzky University, Germany

The interface between the atmospheric Prandtl layer (also known as constant-flux layer) and Ekman layer can be considered as a boundary between a turbulent and a non-turbulent flow. This leads to the hypothesis that its structure and dynamics should be that of a fractal surface. We analyze available field data in heights up to 240m with special regard to subsequent time periods of quasi-laminar and turbulent flow. This interplay of laminar and turbulent flow shows a fractal dimension of 1.36, which is the literature value for turbulent-nonturbulent interfaces (TNTI) [de Silva et al., PRL 111, 2013]. Moreover, the vertical position of this TNTI is found to be changing in a highly dynamical way, which further supports the hypothesis of a fractal interface.

In order to reproduce this interface, a wind tunnel setup was developed, including a fractal grid which covers only the lower half of the cross section. First experiments reproduce a TNTI presenting a fractal structure. More detailed investigations of the interface are planned, including the impact on model wind turbines.

Wind energy converters (WEC) of the current and upcoming generations will extend into height regions where these TNTI effects appear more and more frequently. Their impact on loads and energy conversion still have to be investigated.

Scaling in inhomogeneous and unsteady turbulence

W. Bos

CNRS, LMFA, Lyon, France

One of the major difficulties of realistic turbulent flows is that they are not only multi-scale, but also intrinsically inhomogeneous. A successful description of turbulence needs therefore to take into account both variations in scale-space and in physical (configuration) space. Recently is was illustrated how large-scale unsteadiness can be treated as a perturbation on a statistically steady turbulent flow. This allows to use the Kolmogorov-Richardson cascade as a base-state in a perturbative treatment. We illustrate how inhomogeneity can be treated in a similar way and assess our predictions using Direct Numerical Simulations. Subsequently we show how the novel scaling predictions allow to shed light on experimental observations of integral quantities such as the turbulent dissipation rate.

How far does turbulence spread?

A. Alexakis

CNRS, ENS Paris, France

How locally forced turbulence spreads in space is investigated with direct numerical simulations. We consider turbulence in a long channel of length L for which the injection of energy is achieved by a random forcing that is localized in space over a region of length $l \ll L$. At long times a profile of energy distribution in space is formed that takes the form of a power law away from the injection region. The energy fluxes in Fourier and real space are investigated as a function of the Reynolds number.

Beyond scale-by-scale equilibrium

J.C. Vassilicos

CNRS, LMFL, France

Homogeneous turbulence, and more specifically turbulence in scale-by-scale equilibrium, played a leading role in the turbulence research of the second half of the twentieth century. This talk will present new results within the framework of a research activity which has followed these developments over the past ten to fifteen years and which concerns turbulence which is out of scale-by-scale equilibrium either because it is non-stationary or because it is non-homogeneous or both.

Turbulent iso-sets

F. Thiesset

CNRS, CORIA, France

A scale-by-scale kinematic framework of iso-sets in turbulence is presented and used to characterize passive scalar mixing, turbulent reacting fronts and isothermal supersonic turbulence.

On plasma dielectric barrier discharge integration for grid generated turbulence

T. Fridlender, N. Benard, J.P. Bonnet and E. Moreau

CNRS, PPRIME, France

Plasma Dielectric Barrier Discharge (DBD) actuators simply consist of a dielectric plate separating one grounded electrode from an exposed conductor. When the exposed conductor is supplied with a high AC voltage, a surface discharge is ignited and its electromechanical transfer results in local unsteady forcing. Flush-mounted plasma DBD actuators have successfully been used to control instability mechanisms by affecting coherent structures arising from planar mixing layers and axisymmetric jets among other flow configurations. Lately, the geometrical versatility of DBD systems has enabled their integration as wake control systems for jet grids, and are currently being investigated in controlling turbulence generated by a square-mesh grid of relatively low solidity (σ = 0.31).

These grids have attracted attention due to the close experimental similarity between turbulent motion in their far-wake and homogeneous and isotropic turbulence. Researchers have explored altering the grid geometry to fractal designs or implementing active mechanical parts for the purpose of studying numerous applications such as scalar mixing and transport, wind energy or even the fundamental features in multi-scale turbulent flows. Here, preliminary results obtained with high-speed planar particle image velocimetry (44 kHz) indicate that DBD systems can have the potential to influence the initial conditions in the wake of the aforementioned square-mesh grid. Specifically, the authority of the discharge over coherent structures arising from the square-rod wakes is being investigated to understand how it impacts turbulent motion in the far-field.

Turbulence in clouds: nonstationary, nonuniform anisotropic and intermittent. How to analyze airborne data?

S. Malinowski

University of Warsaw, Polland

There is no general theory of turbulence. While we investigate atmospheric turbulence, we usually use theoretical tools developed in mid 20th century under assumption of homogeneous, uniform, stationary and isotropic turbulence, despite the fact that we know that the turbulence we study does not fulfill these assumptions. In high-resolution numerical simulations we can, at least, diagnose some properties of turbulence from 3-D, evolving in time, fields of velocity components and thermodynamic variables. But analyzing airborne data, i.e. time series collected along the 1-D complicated trajectory of a research aircraft, such diagnostics was, so far, hardly available. In this talk I will present new approaches which allow to diagnose nonstationarity, intermittency and anisotropy of turbulence from airborne measurements. I will focus on the measurements collected in and around clouds as well as within the atmospheric boundary layer and cloud fields. Acknowledgments: The research presented was supported by Polish National Science Centre projects 2013/08/A/ST10/00291, 2018/30/M/ST10/00674, 2020/37/B/ST10/03695.

Multi-scale interactions in the atmosphere. Application to the prediction of heat waves and urban heat islands

L. Danaila

Universite de Rouen, France

The climate system is described by approaches focusing on Zonal jets, Waves and Eddies, hypothesizing that they act at separate space/time scales. However, recent studies have shown that, for the atmosphere and oceans, wavelike features interact with turbulent cascades and give rise to distinct regimes that are crucial for mixing and dissipation. In these planetary fluids, turbulent statistics at smaller scales appear to be correlated with the long-time and large-scale field of the same quantity. For example, local, strong fluctuations of temperature are affected by daily, seasonal, and even interdecadal phenomena. The aim of this contribution is to provide physical arguments for this conditioning of the smaller scales by the largest ones. To achieve this aim, we investigate turbulent statistics at each one of a range of scales, for several phases of the large-scale, long-time, phenomena. Our methodology consists in the use of transport equations for second-and fourth-order moments of the temperature field, at one-and two-points (i.e., filtered at different space scales). The emphasis is on the interaction between the temperature gradient's large-scale dynamics, which acts as a forcing, and the second- and fourth-order moments – namely the energy and the flatness, or kurtosis – of the temperature field at smaller scales. Terms in the equations are assessed against ERA5 reanalysis data for the wind velocity and temperature fields over the Euro-Atlantic region, at the 500 hPa pressure level. We highlight the nature of different phenomena such as diffusion production, and advection, conditioned by the season and the local behaviour of large-scales, such as the jet stream. Applications concern prediction of heat waves (e.g., summer 2003) and urban heat islands.

Non-equilibrium turbulence in the atmospheric boundary layer flows

M. Waclawczyk

Institute of Geophysics, University of Warsaw, Polland

Turbulence in the atmosphere is subject to rapid changes associated with changes of forcing. Examples are the collapse of the convective boundary layer which takes place after sunset, or the decay of turbulence in clouds located on rising thermals after they reach capping inversion. It can be expected that statistics of such strongly non-stationary turbulence will be described by non-equilibrium scaling relations and that presence of non-equilibrium may affect parametrization schemes. The main difficulty connected with researching turbulence in the free atmosphere is that it cannot be investigated systematically by way of controlled experiments. Our knowledge and understanding of its processes come from airborne measurements and research campaigns. The amount of information that they provide is limited. Another part of the problem is related to the limitations of sensors and measurement errors. In this talk results of data analysis from remote as well as in-situ measurements of atmospheric turbulence will be presented. It will be shown that available information, although limited, allows for the detection of non-equilibrium states. Such analysis provides new information on dynamics of atmospheric processes.

Information about the workshop

The 3 days workshop will take place at the LMFL

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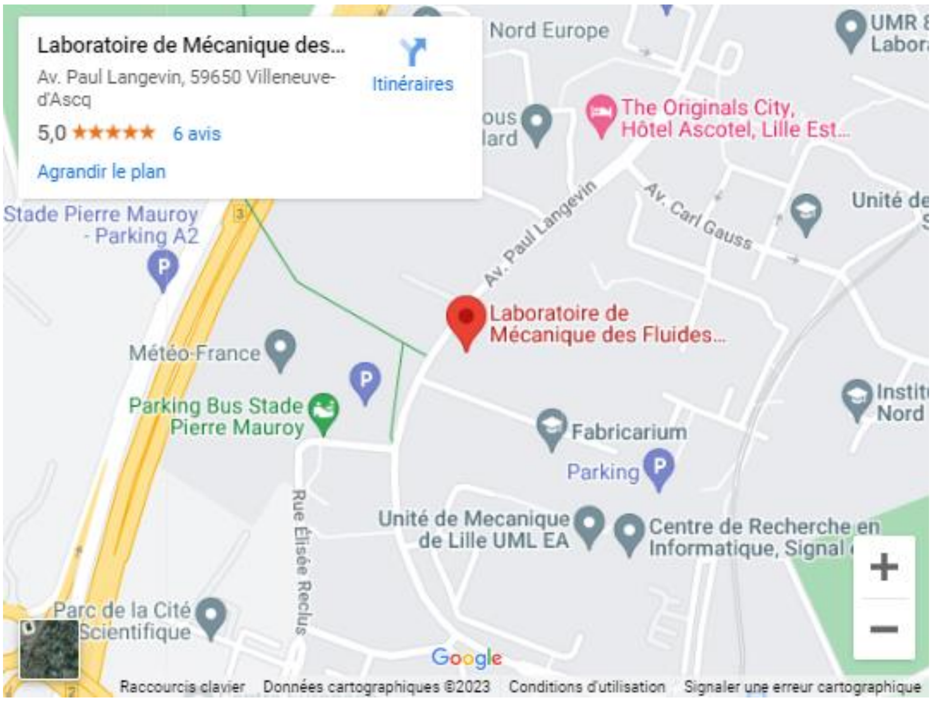

Lille is easily accessible by fast train from Paris (1h), Brussels (30mn) and London (1h30) or directly through Lille-Lesquin airport from several European cities

Metro :

Workshop Dinner on Wednesday 21 - 20h00

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