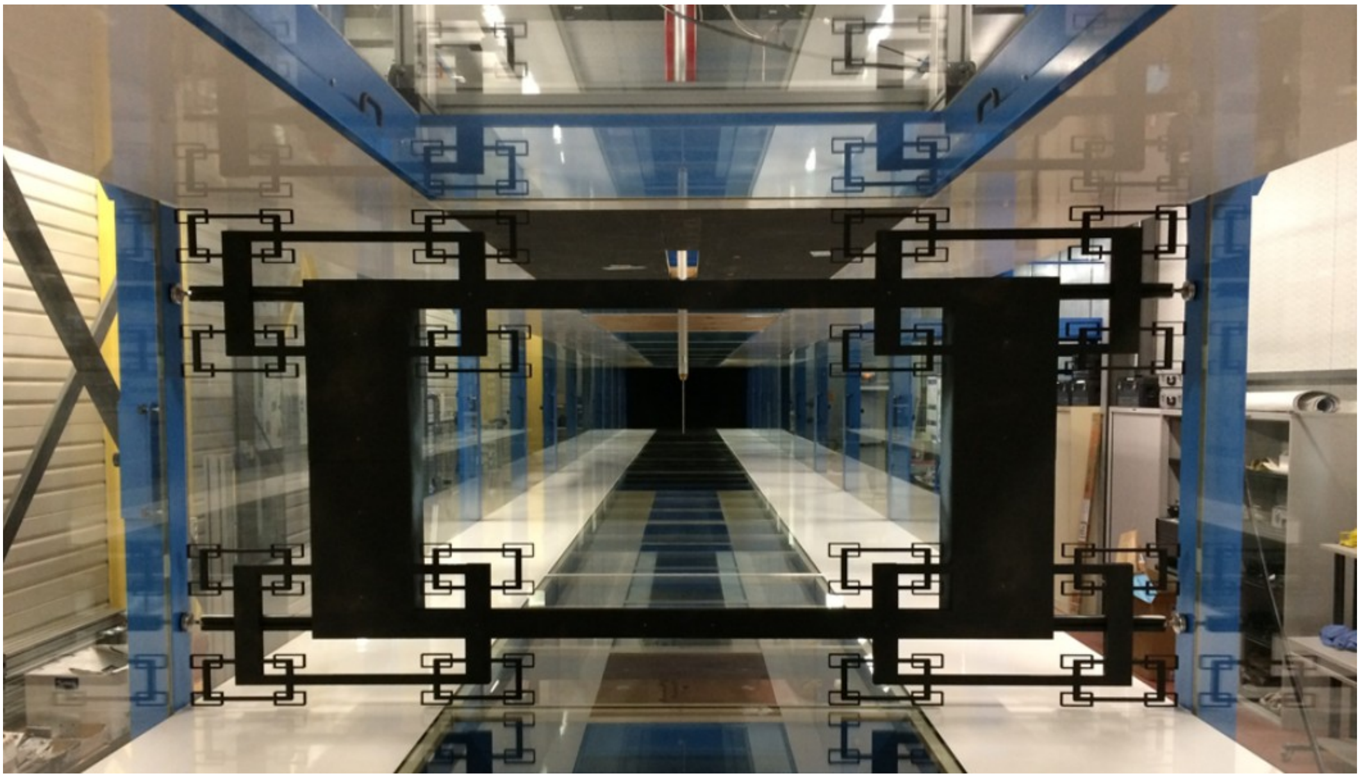
LILLE TURBULENCE PROGRAMME 2024

OPENING WORKSHOP ON TURBULENT FLOWS

Villeneuve d'Ascq, Cité Scientifique, M6 Building
18-20 June 2024

https://lmfl.cnrs.fr/workshop/ltp-2024-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 18 JUNE 2024

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

14:00-14:40: YVES POMEAU – Flood of rivers as a subcritical bifurcation

14:40-15:20: MARTIN OBLIGADO– Intermittency and dissipation in turbulent wakes

15:20-16:00: JOE KLEWICKI – On scaling adverse pressure gradient turbulent boundary layer statistics

16:00-16:40 : TEA/COFFEE BREAK AND DISCUSSIONS

16:40-17:20: YUTARO MOTOORI – Hierarchy of coherent vortices in turbulent boundary layers and channel flow

17:20-18:00 : JOHN FARNSWORTH – Minimizing the distortions induced by mean shear within 3D reconstructions of turbulent flows from time-resolved sPIV measurements.

WEDNESDAY 19 JUNE 2024

09:00-09:40: JORAN ROLLAND – Using learnt stochastic model to study the regime change of a bistable wake

09:40-10:20: NICOLAS MAZELLIER – Investigation of the turbulent entrainment in a separating/reattaching flow

10:20-11:00: KOJI NAGATA – Unsteady dissipation scaling in the near and far field of grid turbulence

11:00-11:40 : TEA/COFFEE BREAK AND DISCUSSIONS

11:40-12:20: MORITZ LINKMANN – Energy fluxes and small-scale turbulence in magnetohydrodynamic turbulence

12:20-14:20: LUNCH AND DISCUSSIONS

14:20-15:00: CHRISTOPHE JOSSERAND – Singularity driven turbulence

15:00-15:40: JERRY WESTERWEEL – Relating turbulent interfaces to coherent structures

15:40-16:20: MICKAEL BOURGOIN – Molding homogeneous and isotropic lagrangian turbulence into a non-homogeneous free shear turbulent jet

16:20-17:00: TEA/COFFEE BREAK AND DISCUSSIONS

17:00-17:40: SZYMON MALINOWSKI – Challenges in subgrid parameterizations in numerical weather and climate models– NextGEMS project perpspective

17:40-18:20: REMI ZAMANSKI – Interplay between self-induced agitation and large-scale forcing in bubble swarms

19:30: WORKSHOP DINNER IN CENTRE OF LILLE

THURSDAY 20 JUNE 2024

09:00-9:40: SUSUMU GOTO – Attenuation of turbulence due to finite-size solid particles

09:40-10:20: JIAXING SONG – Scaling regimes in rapidly rotating thermal convection at extreme Rayleigh numbers.

10:20-11:00 JAKUB NOWAK – Energy cascades in the convective atmospheric boundary layer : analysis of structure functions

11:00-11:40: AMELIE FERRAN – Inertial particles in a turbulent interface.

11:40-12:00 DISCUSSIONS and 12:00-14:00 : CLOSING BUFFET LUNCH

Flood of rivers as a subcritical bifurcation

Y. Pomeau

CNRS, Laboratoire d'Hydrodynamique, École Polytechnique, France

Even though floods have been observed forever, as reported in very ancient texts, their scientific understanding has attracted little attention. Turbulence there is fundamental because this involves high Reynolds number flow in rather complex situations. With Martine Le Berre and Serge Mora we used, as did Chézy long ago, very basic balance of momentum to relate the averaged fluid velocity and the flow geometry. This yields a relation between the flow input and the local topography of the river bed. As the flow rate increases this relation may be not one to one, which explains that flooding is subcritical and that the water recedes far more slowly than it raises, as observed. This opens the way to rational studies (much needed !) of the phenomenon based on the knowledge of topography of the river bed.

Intermittency and dissipation in turbulent wakes

M. Obligado

LMFL, Lille, France

Recently, several advances have been achieved in terms of describing the energy cascade within a turbulent wake. Nevertheless, little attention has been paid to how large- and small-scale intermittency are affected by the geometry of the wake generator nor in terms of its spatial evolution.

We present a series of experiments, performed in different wind tunnels, where the turbulent wake generated by different bodies is characterised up to 50 diameters downstream of them. Hot-wire anemometry allowed us to access both the turbulent dissipation and to characterise the intermittency of the flow. While some features of the former can be described using the dissipation constant, the intermittency will be studied using two different quantities:

- The intermittency constant, first introduced by Kolmogorov's 1962 theory, and later redefined (Castaing et al., Physica D 46 (1990)). Globally, it quantifies departures from self-similarity within the inertial range.

- The Rice constant, defined as the ratio between the Taylor length scale and the average distance between the zero crossings of the streamwise fluctuating velocity. This quantity provides a scalar quantification of the departures of the velocity time derivatives probability density function from a Gaussian distribution.

Our results include a set of axisymmetric bluff bodies, with both fractal and regular peripheries. Furthermore, different circular cylinders were also tested, allowing us to cover both planar and axisymmetric turbulent wakes.

Our large experimental dataset allows to understand the development of intermittency in turbulent wakes in two different ways. First, we will show how the degree of small-scale intermittency is directly controlled by large scale structures. Moreover, a universal relation between the dissipation and the intermittency constants can be found, as one evolves as the inverse of the other.

On scaling adverse pressure gradient turbulent boundary layer statistics

J. Klewicki

The University of Melbourne, Melbourne, Australia

Data from large Reynolds number experiments and existing well-resolved Large Eddy Simulations are used to investigate the scaling behaviours of the turbulent stresses in boundary layers subject to modest adverse pressure gradients (APGs). Physical experiments at friction Reynolds numbers of about 8,000 were conducted in the Flow Physics Facility (FPF) at the University of New Hampshire, while the smaller Re simulations are those of Bobke et al. JFM (2017). The Clauser pressure gradient parameter for the flows investigated is at most between 1 and 2. Wall-normal velocity spectra and Reynolds shear stress co-spectra from the wind tunnel experiments provide clear evidence that distance-from-the-wall scaling (observed in zero pressure gradient boundary layers) exists across the inertial layer of the APG flows. Despite this, analysis of the mean momentum equation indicates that a logarithmic mean velocity profile is unlikely for the APG flow. The reason for this is connected to the characteristic velocity being different from the friction velocity – a result that is evidenced through analysis of the stress budget equation. The efficacy of the resulting hybrid velocity scale is demonstrated using the wind tunnel and LES data, while further analysis leads to the hypothesis that non-equilibrium conditions become apparent when the leading order balance of terms in the stress budget changes, e.g., via rapid variation of the pressure gradient.

Hierarchy of coherent vortices in turbulent boundary layers and channel flow

Y. Motoori

Osaka University , Osaka, Japan

Developed turbulence consists of vortices at various scales. We conduct direct numerical simulations of turbulent boundary layers and turbulent channel flow at frictional Reynolds numbers higher than 1000 to show a concrete picture of the hierarchy of coherent vortices in wall turbulence. The largest vortices, which are attached to the wall, form hairpins in turbulent boundary layers, whereas in turbulent channel flow, they tend to be quasi-streamwise vortices. Although there is such a difference at the largest scale in the two types of wall turbulence, the generation mechanism of smaller vortices is common: they are created due to the vortex stretching from the larger-scale ones. In this talk, we also discuss the transport of small particles in wall turbulence in terms of the hierarchy of coherent vortices.

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

J. Farnsworth

University of Colorado Boulder, Boulder, USA

The efficacy of reconstructing a 3D volume of time-evolving 3 component velocity from planar experimental measurements is explored within strongly shear-distorting turbulent flows. A common approach to convert the temporal dimension into the streamwise spatial dimension is Taylor's frozen turbulence hypothesis where the mean velocity is imposed as the convective velocity. In flows with a strong mean shear-rate the instantaneous turbulence structure is distorted when a traditional Taylor's hypothesis method is used to reconstruct 3D volumes. In the current study, we compare existing methods that extend the classical Taylor's hypothesis approach to retain time-locality in the convective velocity in order to accurately reconstruct a 4D (time-resolved) velocity field for accurate analysis of turbulence structure. Specifically, we analyze a local mean convective velocity approach (Pinton & Labbe 1994) as well as an instantaneous convective velocity approach (Fratantonio et al 2021) using time-resolved sPIV measurements in transverse and longitudinal planes within the near-wall surface layer of a canonical flat-plate turbulent boundary layer at Re_θ=7,700. The reconstruction methods are evaluated based on their ability to preserve both the statistical properties of the flow and the instantaneous structure of the turbulence eddies as well as the streamwise extent to which these methods can be applied.

Using learnt statistic model to study the regime change of a bistable wake

J. Rolland

LMFL, Lille, France

When two parallel bars of thickness H, in a flow at Reynolds number R=HU/nu 10000, are brought close enough (as measured by the Gap ratio G/H Fig 1 (a)), the wakes of the two bars merge and the jet coming out of the two bars is no more fluttering symmetrically but can point sideways toward either of the bars (Fig. 1 (b)). Owing to the turbulent environment, from the incoming turbulence to the turbulent wake, the jet direction can abruptly change, rendering this flow bistable (Fig 1 (b,c)). Given the simplicity of the configuration, this flow is thus a good model configuration to test methods of study of bistability. I will present the result of processing of data sampled by PIV in the LMFL windtunnel during three campaigns (Fig 1). If time permits, I will also present preliminary numerical modelling using URANS.

I will present the peculiar regime changes, from symmetric to bistable to tristable as the gap ratio is decreased. They can be characterised using simple statistical quantities such as the weighted position of the jet, the jet width, time series of the leading POD modes, their PDF, as well as the mean first passage time before a change of direction of the jet. However, using a stochastic model discovery method, that can select an analytical form for the model and the coefficients in it, is also enlightening for the study of the bistability and the change of regimes. Indeed, from a given value of the control parameters, the regime type is contained in the selected terms in the model, the sign of the coefficients and their amplitude. This is particularly helpful when the behaviour of the multistable system is atypical. This procedure also shows some ability to capture the main features of the system from short time series. Quantities such as the mean first passage time usually requiring long time series to be estimated with precision can then be approximated from resimulations of the model.

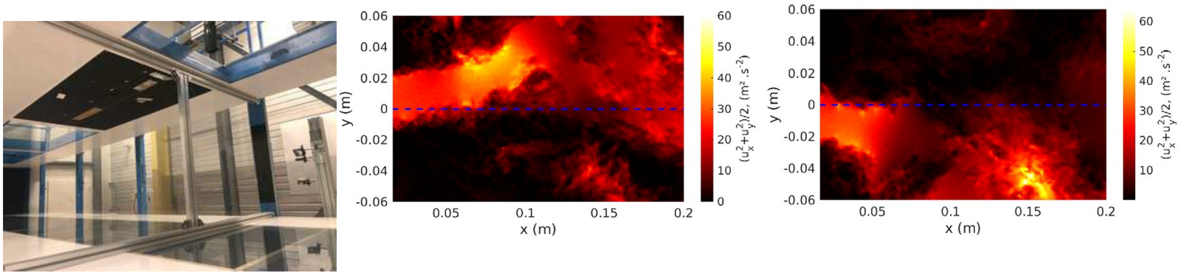


Figure 1: (a) photography of the experimental configuration of the double parallel bars in the LMFL wind tunnel. The flow is coming from the right. (b) Horizontal kinetic energy per unit mass computed from velocity measured by PIV in the wake behind the two parallel bars at the beginning of the measurement run. (c) Same field, 250s later.

Intermittency and dissipation in turbulent wakes

N. Mazellier

PRISEM, Orleans, France

In this work, we report the experimental investigation of a canonical separating/reattaching shear-layer controlled via a synthetic jet. A mean energy budget, applied on a control surface, is performed to characterize the effect of the forcing. Using a sudden expansion model, the head loss coefficient is inferred independently of the control surface dimensions. It is found that the mean energy loss coefficient scales with mass entrainment.

Unsteady dissipation scaling in the near and far field of grid turbulence

K. Nagata

Kyoto University, Kyoto, Japan

A time-dependent analysis of the global and local fluctuating velocity signals is conducted to assess the scaling laws for non-equilibrium turbulence. Instantaneous velocity signals measured in the near and far field of grid turbulence are analyzed. The corresponding analysis is also applied to the DNS database of temporally evolving grid turbulence in a cubic domain. The results show that the local statistics follow the non-equilibrium scaling both in the near and far field (or early and late periods of decay) although the global statistics follow the non-equilibrium scaling only in the near field.

Authors: Koji Nagata, Yulin Zheng, and Tomoaki Watanabe

Energy fluxes and small-scale turbulence in magnetohydrodynamic turbulence

M. Linkmann

University of Edinburgh, Edinburgh, UK

In turbulent flows of electrically conducting fluids, such as liquid metals or plasmas in the fluid approximation, magnetic field and flow fluctuations interact, resulting in complex energy transfer and conversion processes. Here, we discuss the dominant physical processes that transfer kinetic and magnetic energy across scales and make connections with the small-scale structure of the velocity field. In regions of high strain, current sheets are stretched by large-scale straining motion into regions of magnetic shear at smaller scales. Magnetic energy is transferred from large to small scales predominantly by this current-sheet thinning process, while contributions from processes such as current-filament stretching – the analogue to vortex stretching – is negligible. The small-scale magnetic shear generated by current-sheet thinning in turn drives extensional flows at smaller scales, while hydrodynamic processes such as vortex stretching and strain self-amplification are strongly depleted. Hence, unlike in three-dimensional hydrodynamic turbulence, kinetic energy is transferred from large to small scales almost exclusively by the generation of regions of small-scale intense strain induced by the Lorentz force. We connect the observed depletion of vortex stretching and strain self-amplification to the small-scale structure of the velocity field. Consequences of these results to subgrid-scale modelling of magnetohydrodynamic turbulence are discussed.

Singularity driven turbulence

C. Josserand

CNRS, Laboratoire d'Hydrodynamique, École Polytechnique, France

While singularities in Navier-Stokes equations is still a question of scientific debates, it is tempting to question how these extreme event would affect the turbulent behavior. We use a simplified model of fluid flows, the focusing nonlinear Schrodinger equation to investigates such dynamics. The self-focusing NLS equation has the advantage to exhibit finite-time singular solutions in any dimension D, which are described by a simple solution of a nonlinear self-similar universal equation. We will describe how a turbulent regime emerges fwhen forcing is applied at large scale while dissipation is added at short ones. If provides an understanding of the role of singularities in the dissipation of a turbulent flows and reproduces, among other aspects, the observed anomaly of dissipation in the limit of zero viscosity.

Relating turbulent interfaces to coherent structures

J. Westerweel

TU Delft, Delft, Netherlands

In an experiment on a turbulent jet seeded with fluorescent dye we detect the turbulent- nonturbulent interface in a frame that moves, on average, with the interface. This significantly prolongs the observation time of scalar- and velocity structures and enables the measurement of two coherent structures. One structure, the finite-time Lyapunov field (FTLE), quantifies transport barriers of fluid parcels, the other structure highlights barriers of diffusive momentum transport. These two complementary structures depend on large-scale and small-scale motion, respectively, and are, therefore associated with the growth of the turbulent region through engulfment or nibbling, respectively. We discuss a novel approach to finding the turbulent-nonturbulent interface from the measured fluorescence field. Conditional averages teach that the turbulent-nonturbulent interface is not associated with the barrier of diffusive momentum transport, but that there is a relation with the large-scale ridges of the FTLE. Inside the turbulent jet other interfaces exist between two regions with approximately uniform dye concentration. It appears that these turbulent-turbulent interfaces discriminate even stronger between the coherent structures.

Authors: A.R. Khojasteh, L.E. van Dalen, C.V.B. Been, J. Westerweel & W. van de Water

Molding homogeneous and isotropic lagrangian turbulence into a non-homogeneous free shear turbulent jet

M. Bourgoin

LPENSL, Lyon, France

Practical turbulence is often non-homogeneous and anisotropic, leading to great modeling and simulation challenges, in particular when it comes to capture simultaneously the large scale details while accurately describing all the multi-scale complexity down to small scale intermittency, what usually requires extremely costly high resolution simulations. We propose an efficient approach to predict turbulent multi-scale statistics of non-homogeneous flows with high accuracy and low computational cost. The model leverages detailed knowledge of readily available velocity signals from idealized homogeneous turbulence and transforms them into Lagrangian trajectories of a realistic turbulent jet. The resulting spatio-temporal statistics are compared against experimental jet data showing remarkable agreement at all scales. In particular the intermittency phenomenon is accurately mapped by the model to this inhomogeneous situation, as observed by higher-order moments and velocity increment probability density functions. Crucial to the advancement of turbulence modeling, the transformation is simple to implement for the jet configuration, with possible extensions, maybe, to other inhomogeneous flows such as wind turbine wakes and canopy flows, to name a few.

Contributors : Mickaël Bourgoin, Bianca Viggiano, Thomas Basset, Raul Bayoan Cal, Laurent Chevillard, Charles Meneveau, Romain Volk

Challenges in subgrid parameterizations in numerical weather and climate models

S. Malinowski

Institute of Geophysics, University of Warsaw, Polland

Numerical models of weather and climate are aimed at resolving large scales of atmospheric flows, treating small scales, including turbulence, as sub-grid processes. Unfortunately, parameterizations of these processes, in particular cloud convection and turbulent transport, are far from satisfactory. In the presentation I will stress some problems with these parameterizations identified in the course of our (Institute of Geophysics, University of Warsaw) engagement in the NextGEMS (Next Generation Earth Modelling Systems) project.

Interplay between self-induced agitation and large-scale forcing in bubble swarms

R. Zamansky

IMFT, Toulouse, France

We consider turbulent bubble swarms subjected to both their intrinsic agitation, triggered by the interaction between the bubble wakes, and an external forcing imposed at large scales. The interaction between these two sources of fluctuations depends on their relative power, but also on the range of scales where their energy is distributed.

For this study we performed numerical simulations with a front-tracking method in a periodic domain. The statistically isotropic large-scale forcing would produce a single-phase turbulent flow with a Taylor scale Reynolds number of 150, while the bubble diameter is chosen to lie in the inertial subrange of this flow. The power injected by the bubble buoyancy is varied by changing the gas volume fraction, from 0% to 12%, and for the largest volume fraction, the bubble production dominates over the turbulent forcing.

Overall, it is observed that the bubble motion and the liquid fluctuations at scales larger than the bubbles are dominated by the large-scale stirring. Conversely, on small scales, the flow keeps the characteristic structure of the flow induced by a rising swarm of bubbles. Interestingly, for situations corresponding to turbulence modulation (i.e. when the magnitude of the power injected by the bubbles is lower than that of the large-scale stirring), it is observed that the spectral decomposition of the energy budget can be obtained by superposing the spectra of the plain turbulence case with the ones of pure bubble swarm case.

Authors: Gabriel RAMIREZ, Alan BURLOT, Rémi ZAMANSKY, Guillaume BOIS, Frédéric RISSO

Attenuation of turbulence due to finite-size solid particles

S. Goto

University of Osaka, Osaka, Japan

Solid particles can dramatically attenuate turbulence intensity. In periodic box turbulence, when the velocity relaxation time of the particles is sufficiently long compared to the swirling time of the largest eddies, the particles cannot follow the largest-scale swirling motion and thus take kinetic energy from them. Then, the energy cascade is bypassed resulting in reduced turbulence intensity. In this talk, DNS on turbulence attenuation by spherical and non-spherical particles in turbulent flows under periodic boundary conditions will be presented to verify the physical mechanism described above. The mechanism of turbulence attenuation by solid particles in turbulent channel flow will also be discussed.

Scaling regimes in rapidly rotating thermal convection at extreme Rayleigh numbers

J. Song

Max Planck Institute for Dynamics and Self-Organisation, Germany

The geostrophic turbulence in rapidly rotating thermal convection exhibits characteristics shared by many highly turbulent geophysical and astrophysical flows. In this regime, the convective length and velocity scales and heat flux are all diffusion-free, i.e. independent of the viscosity and thermal diffusivity. The present direct numerical simulations (DNS) of rotating Rayleigh–Bénard convection in domains with no-slip top and bottom and periodic lateral boundary conditions for a fluid with the Prandtl number and extreme buoyancy and rotation parameters (the Rayleigh number up to and the Ekman number down to) indeed demonstrate all these diffusion-free scaling relations. We further derive and verify in the DNS that with the decreasing supercriticality parameter, the geostrophic turbulence regime undergoes a transition into another geostrophic regime, theconvective heat transport in this regime is characterized by a very steep supercriticality parameter dependence.

Energy cascades in the convective atmospheric boundary layer: analysis of structure functions

J. Nowak

Institute of Geophysics, University of Warsaw, Polland

We investigate the scale-by-scale budget of turbulence kinetic energy in convective atmospheric boundary layer in the shallow trade-wind regime over the ocean using in-situ airborne measurements from the EUREC4A field experiment. The trade-wind atmospheric boundary layer consists of a mixed subcloud layer, maintained due to significant surface heat fluxes, and a stably stratified cloud layer, penetrated by intermittent updrafts forming cumulus clouds which cover a few percent in area. The simple and repeatable flight pattern sampled four altitude levels: near-surface, the middle and top of the subcloud layer, and the cloud base. This approach provides acceptable level of convergence for the statistics, e.g. third order structure functions, which is exceptional in airborne measurements.

In general, the derived scale-by-scale budget is approximately close up to the length-scales of about 200 m. The component of buoyancy forcing related to humidity variations typically dominates over the contribution corresponding to temperature only.

At the near-surface and mid-subcloud levels, we observe a behaviour close to a Kolmogorov equilibrium over inertial length scales from a few to about 100m. At scales r larger than 1 km there is a balancebetween turbulence dissipation rate on the one hand and, on the other, buoyancy-generated turbulence production rate W (r) minus interspace turbulence transport rate T (r). A small portion of the energy at scales between 100 and 1000 m is transported from the near-surface levels towards higher altitudes. A sharp drop of W(r)-T(r) occurs from r= 1km to r=100m which is accompanied by a sharp rise of down-scale nonlinear turbulence transfer. Because of this sharp drop there is negligible contributions at scales r smaller than 100 m of buoyancy-generated turbulence production and turbulence transport in physical space, and this gives rise to the Kolmogorov equilibrium observed at these scales. At

the top-subcloud and cloud-base levels, the budget at scales above 10 m is far from Kolmogorov equilibrium. In the range of scales from about 40 to 300 m, the buoyancy-generated turbulence production appears length-scale-independent and nearly equals the down-scale nonlinear turbulence transfer. Once the clouds are excluded from the records at cloud-base level, the transport in physical space plays a dominant role. Here, and at the top-subcloud level, the transportexhibits a power-law length-scale dependence with an exponent close to 2/3 over a range from 10 m to about 300 m. The effect of stably stratified environment is visible in negative values of the buoyancy term at cloud-base level with clouds removed. We speculate that the energy supplied by physical transport from other locations is partly transfered down the turbulence cascade and partly used to perform work against stable stratification.

Information about the workshop

The 3 days workshop will take place at the LMFL

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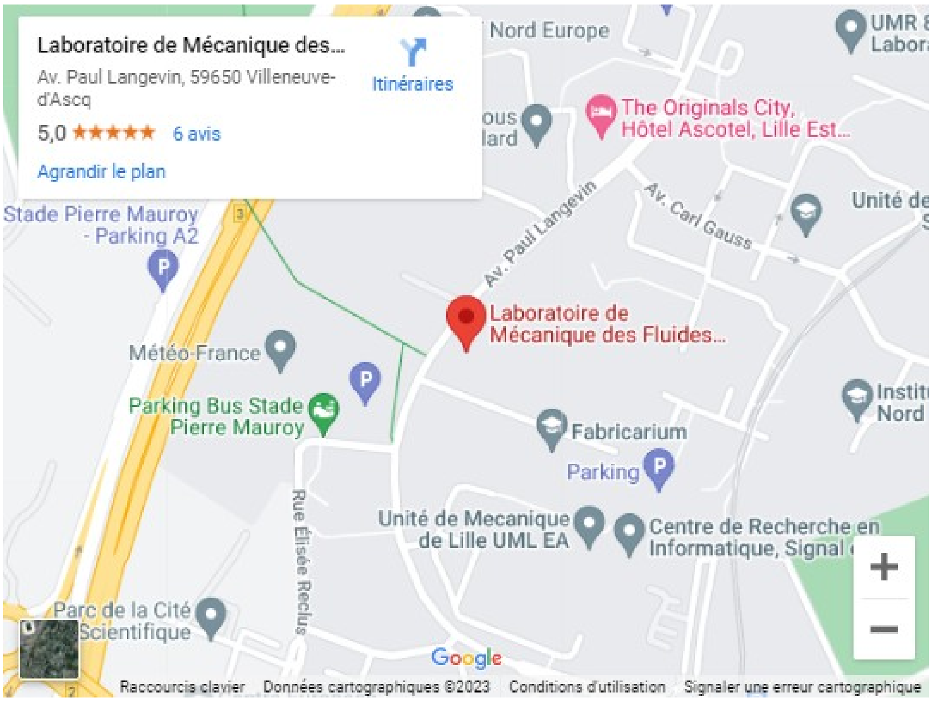

Lille is easily accessible by fast train from Paris (1h), Brussels (30mn) and London (1h30) or directly through Lille-Lesquin airport from several European cities

Metro :

Workshop Dinner on Wednesday 19 June- 19h30

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