THE FIRST INTERNATIONAL WORKSHOP ON LATTICE BOLTZMANN FOR WIND ENERGY

25. - 26. February 2021

ONLINE

LBWind 2021

OST Ostschweizer Fachhochschule

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UPPSALA UNIVERSITET

UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Département d'informatique

LBWind 2021

The First International Workshop on Lattice Boltzmann for Wind Energy

WELCOME

Dear LBM experts, fans and enthusiasts,

We would like to warmly welcome you to The First International Workshop on Lattice Boltzmann for Wind Energy ONLINE, hosted by the Eastern Switzerland University of Applied Sciences (Switzerland) and co-organised by the University of Geneva (Switzerland), Uppsala University (Sweden) and IFP Energies nouvelles (France).

The Lattice Boltzmann Method (LBM) has shown to be a promising method for running faster high-fidelity simulations, therefore reducing computational power. We at the Eastern Switzerland University of Applied Sciences see a very high potential for LBM to be applied in many wind energy applications, including for wind farm control and optimisation, for aero-acoustic blade design and for wind turbine aerodynamic and structural optimisation design using fluid-structure interactions. However, we recognise that there a many barriers to be overcome in order for LBM to be applied successfully to these areas.

In this event, we therefore bring the international Lattice Boltzmann community together with the wind energy community for the first time, with the goal of developing strategies for improving the implementation of LBM in the wind energy industry. Participants will get inspired from the four key-note talks from well-regarded international experts in the field and be able to ask their specific questions in the Q&A sessions. They will hear about state-of-the-art open source tools and listen to presentations about research related to LBM and wind energy. Finally, there are many opportunities for participants to interact with each other in the guided break-out discussions.

We hope you enjoy this event and hope to meet you in person next year for The Second International Workshop on Lattice Boltzmann for Wind Energy.

Best regards,

Chair of the Organising Committee

Sarah Barber, Eastern Switzerland University of Applied Sciences

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The First International Workshop on Lattice Boltzmann for Wind Energy

PROGRAMME

Thursday, 25th February, 2021

TIME	PRESENTER	TOPIC
08:15 - 08:30	Sarah Barber	Welcome
08:30 - 09:00	Ilya Karlin	Lattices and Models
09:00 - 10:15	Plenum / Groups	Benefits And Challenges Of LBM And How To Overcome Them
10:15 - 10:45		Coffee Break
10:45 - 12:15	Plenum	Open Source LBM Tool Presentations
12:15 - 13:15		Lunch Break
13:15 - 13:45	Manfred Krafczyk	Towards Real-Time Micro-Climate And Multi-Physics Prediction Of Urban Systems With Kinetic Methods
13:45 - 15:00	Plenum / Groups	The Wind Resource - Atmospheric And Wind Modelling
15:00 - 15:30		Coffee Break
15:30 - 16:30	Martin Schönherr	GPGPU-accelerated Urban Scale LBM-Simulations of Spatio-Temporal Fine Dust Dispersion in Wind Flow
	Philippe Mercier	The Effect Of Turbulence Production On The Harvestable Energy Of Tidal Flows

Friday, 26th February, 2021

TIME	PRESENTER	TOPIC
08:30 - 09:00	Christophe Coreixas	On The Use Of LBMs In The Industry: Grid Refinement, Subgrid Scale Model And Wall Law
09:00 - 10:15	Plenum / Groups	Best Practice LBM / Guidelines
10:15 - 10:45		Coffee Break
10:45 - 12:15	Qingqing Ye	Effect Of Vortex Generators On NREL Wind Turbine: Aerodynamic Performance And Far-Field Noise
	Mikael Grondeau	Toward Direct Prediction Of Flow Noise Around Airfoils Using An Adaptive Lattice Boltzmann Method
	Martin Geier	A Sliding Grid Method For The Lattice Boltzmann Method Using Compact Interpolation
12:15 - 13:15		Lunch Break
13:15 - 13:45	Ralf Deiterding	Application Of Lattice Boltzmann Methods For Wind Simulation Turbine Wake
13:45 - 15:00	Plenum / Groups	Wind Turbine Modelling
15:00 - 15:30		Coffee Break
15:30 - 17:00	Henrik Asmuth	Validation Of LBM Actuator Line Simulations Within The IEA Task 29 Wake Inflow Benchmark
	Helen Schottenhamml	A Holistic CPU/GPU Approach For The Simulation Of Wind Turbines Using The Actuator Line Model
	Henry Korb	Coupling LBM And Reinforcement Learning For Wind Farm Control
17:00 - 17:30	Sarah Barber	Closing

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KEYNOTE 1

Lattices and Models

ILYA KARLIN,
ETH ZÜRICH

This presentation shall discuss some questions regarding the application of lattice Boltzmann simulations to wind turbines. From the fluid dynamics viewpoint, the following topics seem to be relevant and need attention: a. lattice Boltzmann models for moderately compressible flow, from high subsonic to supersonic, at high Reynolds numbers; b. fluid-structure interaction. I shall review some existing operations on discrete particles' velocities and discuss some models that may be useful for the type of problems encountered in the domain of interest of this workshop.

About The Speaker

Professor Ilya Karlin is faculty member at the Department of Mechanical and Process Engineering, ETH Zürich, Switzerland. He was Alexander von Humboldt Fellow at the University of Ulm (Germany), CNR Fellow at the Institute of Applied Mathematics CNR "M. Picone" (Rome, Italy), and Senior Lecturer in Multiscale Modeling at the University of Southampton (England). His main research interests include exact and nonperturbative results in kinetic theory, fluid dynamics, Lattice Boltzmann method and model reduction for combustion systems.

KEYNOTE 2

Towards Real-Time Micro-Climate And Multi-Physics Prediction Of Urban Systems With Kinetic Methods

MANFRED KRAFCZYK,
TU BRAUNSCHWEIG

The proportion of the world`s population living in cities will increase to more than 70% in the coming decades. The resulting settlement density will lead to numerous challenges regarding the controlled interaction between built infrastructure, transport and urban microclimate, to name a few. A key challenge will therefore be to understand and predict such interactions to make urban systems more robust and resilient. In my talk, I will address modeling and complexity issues and show, with some simplified examples, that in the next few years we may be able to predict key aspects of transport problems in urban systems in (at least) real time using kinetic methods, namely the Lattice Boltzmann method and / or Gas Kinetic Schemes.

About The Speaker

Manfred Krafczyk obtained his Physics diploma at TU Dortmund in 1991. He was granted a SIEMENS-scholarship to conduct his Ph.D. studies on Lattice Gas Methods which he finished in 1994 with honors. Most of his PostDoc time until 2000 was spent at TU Munich working on Lattice Boltzmann methods with shorter stays at ETH Zürich, Universidad de Caracars (Venezuela) and ICASE (Nasa Langley, USA). Since 2001 he is full professor for Computational Modeling in Civil Engineering at TU Braunschweig. He serves as Ass. Editor for Computers & Mathematics with Applications, Computers and Fluids, as Editorial Board Member J. of Applied and Computational Mechanics, Advances in Engineering Software and as reviewer for more than forty national and international scientific journals and funding agencies. MK has authored more than a hundred publications focusing on theory, implementation and application of LB methods in international journals.

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KEYNOTE 3

On The Use Of LBMs In The Industry: Grid Refinement, Subgrid Scale Model And Wall Law

CHRISTOPHE COREIXAS, UNIVERSITY OF GENEVA

Computational fluid dynamics is commonly used by engineers to optimize the performance of designs of interest, before building prototypes and running physical tests. The development of such designs is obviously cost-driven, which forced people working in the industry to rely on (unsteady) Reynolds-averaged Navier-Stokes ((U)RANS) solvers for the past decades, in order to achieve minimal development costs. These solvers are particularly useful to investigate steady states, and phenomena with a particular frequency (vortex shedding, rotor-stator interaction, etc), while allowing overnight industrial simulations. Nevertheless, they fail at reproducing highly unsteady and detached flow dynamics. On the contrary, solvers allowing for large-eddy simulations (LES) lead to accurate prediction of such behaviors. Yet, this comes at the cost of increased (i) mesh complexity, (ii) wall-clock time, and (iii) hardware requirements.
To overcome the LES crisis, a number of methodologies have been proposed. Among them, this talk focuses on octree-based grid-refinement, subgrid-scale models, and wall laws. All of them are discussed in the context of lattice Boltzmann methods, which are, by essence, particularly well-suited for high-fidelity simulations due to their low-dissipative properties, and interesting parallel performance.

About The Speaker

Christophe Coreixas is an aeronautical engineer who graduated from ISAE-SUPAERO (Toulouse, France) in 2014. During his master thesis, he evaluated the ability of lattice Boltzmann methods (LBMs) to accurately simulate aeroacoustic phenomena in an industrial context. He further obtained his PhD diploma (Fluid Dynamics) in 2018 from the INP Toulouse, while working at CERFACS. His PhD thesis was dedicated to the derivation of new collision models and methodologies to accelerate the design of efficient compressible LBMs. He is now working as a Post-Doc at the University of Geneva, in the Computer Science Department of the Faculty of Sciences. Christophe is specialized in Computational Physics and Applied Mathematics, and works on the application of LBMs to aeronautical, multiphysics and biomedical fields.

KEYNOTE 4

Application Of Lattice Boltzmann Methods For Wind Simulation Turbine Wake

RALF DEITERDING, UNIVERSITY OF SOUTHAMPTON

The rotors of horizontal axis wind turbines create large-scale turbulent rotating wake structure whose understanding is of critcial importance for wind park operation. Since the lattice Boltzmann method (LBM) is time-explicit and intrinsically low in numerical dissipation, it is well suited for high-resolution large eddy simulation (LES) of wind turbine wake fields. Our parallel block-structured adaptive mesh refinement framework AMROC allows modeling wind turbines as resolved moving surface mesh structures embedded into a hierarchical Cartesian LBM mesh. Using our previously developed prototype wind turbine and actuator models, we compare the wake prediction behavior of several LBM operators, LES models and embedded boundary stencils. The inner workings of the AMROC system, and how LBM schemes are incorporated, will also be described.

About The Speaker

Ralf Deiterding is Associate Professor in Fluid Dynamics at the University of Southampton (UoS). He joined UoS in 2015 after appointments at the California Institute of Technology, Oak Ridge National Laboratory and the German Aerospace Center (DLR). His research focuses on the development and application of innovative high-resolution and multiscale simulation methods for computational fluid dynamics (CFD), in particular dynamically adaptive high-fidelity LES based on lattice Boltzmann methods, parallel adaptive finite volume methods for complex multi-physics problems, detonation research and fluid-structure interaction modelling with large deformations. He is the main author of the freely available simulation frameworks AMROC and Virtual Test Facility (VTF).

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PRESENTATIONS

MARTIN SCHÖNHERR, TU BRAUN-SCHWEIG

GPGPU-Accelerated Urban Scale LBM-Simulations Of Spatio-Temporal Fine Dust Dispersion In Wind Flow

Martin Schönherr, Anna Wellmann, Martin Geier, Manfred Krafczyk

Urbanization is a worldwide phenomenon and the improvement of air quality in urban regions is a basic necessity. Miscellaneous investigations have been conducted to decrease air pollution as e.g. by particulate matter (PM) in urban regions. PM (aka fine dust) is a critical pollutant inducing various health threats. Minimizations of the exposure to particulate matter are presently discussed by political stakeholders. The effectiveness of suggested measures e.g. closing particular streets is unclear and related measurement campaigns are expensive. Thus, numerical simulations appear to be a useful approach to evaluate the potential success of specific measures especially during the planning phase.
This work focused on simulating pollution emitted by motorized vehicles as they are among the primary emitters of PM. The core component of this work is a physics-based simulation of the pollutant's transient distribution in an urban district. This work explores the feasibility of real-time
large-eddy simulations of turbulent multicomponent flow over urban canopies at the neighborhood scale. For a realistic spatio-temporal definition of the PM emitters, an additional implementation of a traffic simulation approach was included. The inner-city traffic simulation is based on an extended Nagel-Schreckenberg model. To increase computational performance, both the traffic and the CFD simulation was parallelized and ported to run on a General-Purpose Graphic Processing Unit (GPGPU). The implemented testcase was a 500 m by 500 m section of a densely built inner city area from Basel, Switzerland. Therefore, several real time hours e.g. during the morning rush hour were simulated. The pollution distribution at several instances in time were compared and analyzed for multiple wind configurations. Basically, this developed approach could serve as a rational basis to study the implications of pollution reduction measures related to individualized traffic in urban spaces.

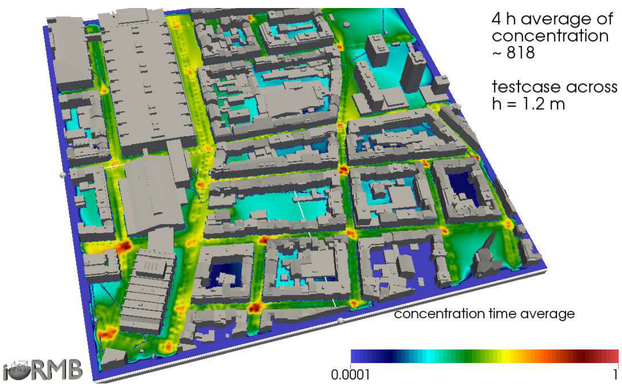

Figure 1: Turbine 1 (blue), Turbine 2 (red), Turbine 3 (green), Total (blue dashed). Generator torque, angular velocity and generated power throughout the training of an RL-agent controlling the generator torque of three turbines without prior constraints.

References
S. Lenz, M. Schönherr, M. Geier, M. Krafczyk, A. Pasquali, A. Christen and M. Giometto: Towards realtime simulation of turbulent air flow over a resolved urban canopy using the cumulant lattice Boltzmann method on a GPGPU, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 189, pp. 151-162, 2019 «Entwicklung und Integration eines Nagel-Schreckenberg Modells in einen CFD Solver zur Simulation von Schadstoffausbreitungen im urbanen Raum», Anna Wellmann, Bachelorthesis, 2019

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PRESENTATIONS

PHILIPPE MERCIER,
UNIVERSITY OF CAEN NORMANDY

The Effect Of Turbulence Production On The Harvestable Energy Of Tidal Flows

P. Mercier, S. Guillou, J. Thiébot, E. Poizot

As wind turbines harvest the kinetic energy of wind, tidal turbines aims at harvesting the kinetic energy of tidal flows. These flows are generated by lunar and solar gravitational forces and are influenced by the coast shape, the sea depth and seabed morphology. In some very specific areas, tidal flows can reach speeds up to 5 ms^{-1}, which, due to the high density of water, represents a high power density of more than 60 kWm^{-2}. However, the tidal power industry is still at a pre-industrial stage, with only a few full-scale prototypes being tested in operational conditions. One of the main obstacles to the development of tidal industry is the harsh conditions that the turbines are subjected to. Tidal flows are turbulent, and turbulence has a strong impact on the turbine wakes, production and structural solicitations. However, the hydrodynamics of tidal flows remain not well known. In particular, the role of the seabed morphology on the generation of turbulence should be investigated. In situ measurements are sparse and do not cover three-dimensional visualisation. Thus, large-eddy simulation could provide insight about this matter. The lattice-Boltzmann method is particularly suited thanks to its efficiency in treating a large amount of mesh nodes in a parallel environment.

Here, the Palabos library is used for the simulation of a 0.34 km^2 part of the Raz Blanchard, one of the most promising tidal power site in the world. With a resolution of 0.34 m near the seabed, the model is validated against measurements for both the velocity and the Reynolds tensor [1]. This validation opens the way to a detailed investigation of turbulent phenomenon at the scale of a small tidal power farm. In the studied area, strong lateral variations of the hydrodynamic condition are observed, with variations of the timeaveraged velocity reaching 20 % at a 100 m distance. As the high velocity zones are characterised by low turbulent intensities, and vice versa, these variations are credited to the variations in turbulence production, that is a transfer of harvestable kinetic energy into turbulent kinetic energy. This shows the importance of micro-siting studies for the deployment of tidal turbines.

The variations in turbulence production are however hard to associate with seabed specificities. In particular, the largest seabed obstacle of the studied domain is not found to have a significant impact on turbulence production. Thus, large-eddy simulation appears to be a compulsory step for the hydrodynamic characterisation of a tidal power site, because it is, to date, the only way of taking into account the complex physical phenomenon resulting from the succession of seabed elements of various shapes and dimensions.

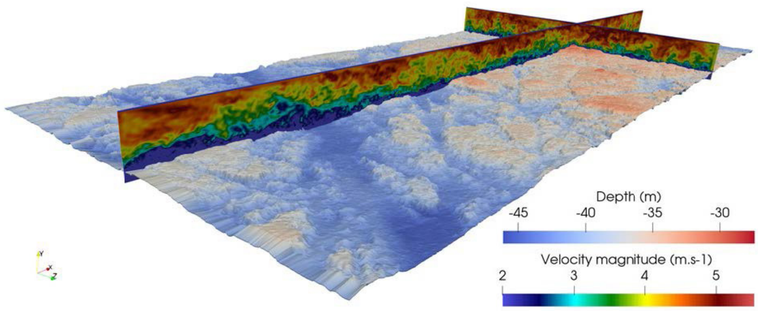

Figure 1: Velocity magnitude in the Raz Blanchard. LBM-LES simulation.

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[1] P. Mercier, M. Grondeau, S. Guillou, J. Thiébot, E. Poizot. Numerical study of the turbulent eddies generated by the seabed roughness. Case study at a tidal power site. 2020, Applied Ocean Research.

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PRESENTATIONS

QINGQING YE,
UNIVERSITY OF ZHEJIANG

Effect Of Vortex Generators On NREL Wind Turbine: Aerodynamic Performance And Far-Field Noise

Qingqing Ye, Francesco Avallone, Wouter van der Velden, Damiano Casalino

Passive flow separation control with vortex generators (VG) is actively used over the wind turbine blade. In this paper, the effect of vortex generators is simulated on a full-scale 2-blade wind-turbine tested at the National Renewable Energy Laboratory. The simulation is performed using Very-Large-Eddy/Lattice-Boltzmann method (VLES/LBM) in the commercial software 3DS PowerFLOW. The analysis focuses on the effect of vortex generators on the aerodynamic performance and far-field noise. The simulation results without vortex generators are compared with the experimental results for validation purposes and they show good agreement.
The instantaneous flow shows the the formation of counter-rotating vortices in the wake of the VG; these vortices transport high momentum fluid toward the blade surface, as shown in Figure 1. Flow separation is effectively delayed in the outboard part of the blade, thus improving the aerodynamic characteristics.
Two main sources of noise are detected without and with VGs. One is the flow separation and shear layer instability over the suction side of the blade, leading to multiple tonal noise components at low and moderate frequencies. The other is the turbulent-boundary-layer trailing-edge noise, causing broadband sound pressure level increase in the low frequency range (f < 1000 Hz). The presence of VGs has trivial effect on overall sound pressure level and directivity. The simulation results indicate that the VGs have the potential to improve the aerodynamic performance without causing any noise penalties.

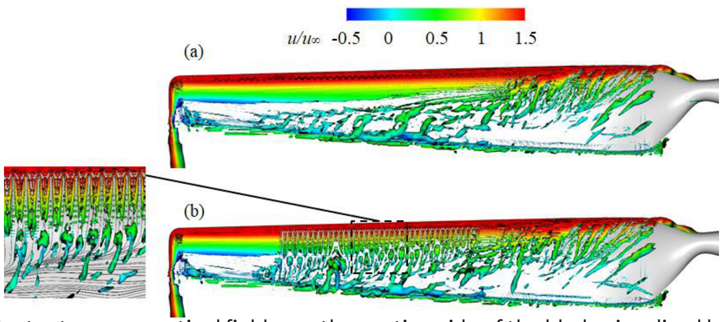

Figure 1: Instantaneous vortical field over the suction side of the blade visualized by the iso-surface of λ_2, coloured by the axial velocity, (a) without VG, (b) with VG.

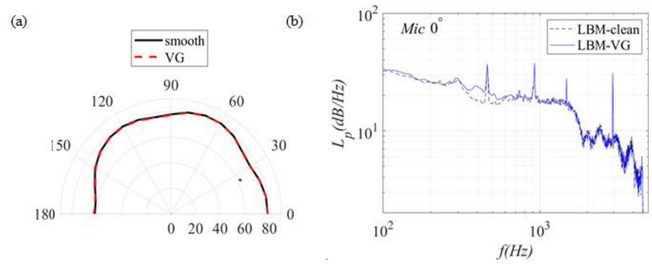

Figure 2: (a) Overall Sound Pressure Level (OSPL) obtained from a circular array of microphones at 2R. Sound pressure level (Lp) obtained from the microphone at 0°.

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PRESENTATIONS

MIKAEL GRONDEAU, UNIVERSITY OF SOUTHAMPTON

Toward Direct Prediction Of Flow Noise Around Airfoils Using An Adaptive Lattice Boltzmann Method

Mikael Grondeau, Ralf Deiterding

Wind power converted through wind turbines is becoming one of the main renewable energy sources. As wind turbines grow in size and power, complex engineering problems arise. Among the most pressing is the prediction and reduction of the noise generated by the turbines blades. Indeed, onshore wind turbines often have to be installed in the vicinity of residential areas and can be regarded as a nuisance [1].
This study presents a novel methodology for direct calculation of self-noise generated by immersed objects at low Mach numbers. Our approach is based on the lattice Boltzmann method (LBM) in combination with large eddy simulation (LES). The LBM-LES scheme is integrated into our inhouse AMROC software, which allows for the use of adaptive mesh refinement (AMR) [2].
The LBM-LES-AMR machinery is first successfully applied for predicting the pressure fluctuations generated by a two-dimensional cylinder at Reynolds number Re = 150 and Mach number M = 0.2. Using the same approach, the noise emitted by a three-dimensional airfoil at Re = 500000, M = 0.22 and angle of attack 0 is directly computed from a probe placed above the trailing edge. Results are found to be in good agreement with reference data. Finally, the self-noise over the same airfoil at 10° angle of attack is computed, Fig. 1, and the signals for angles of attack 0° and 10 °are being compared.

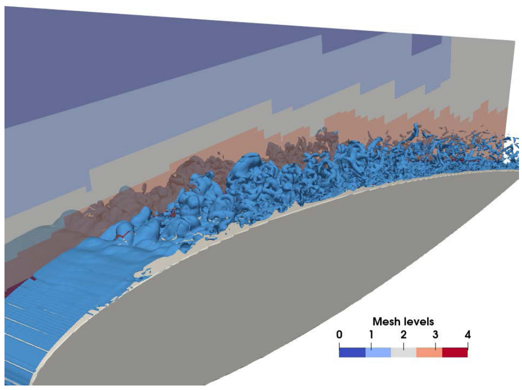

Figure 1: Iso-surface of the instantaneous magnitude of the vorticity vector for the value of 0.75 10•5 s^{-1} in front of a plane depicting by color the domains of different refinement levels. NACA0012 airfoil at 10 angle of attack.

References
[1] B. Nobbs, C. J. Doolan, and D. J. Moreau. «Characterisation of noise in homes affected by wind turbine noise». In: Acoustics 2012. Femantle, Australia, 2012.
[2] R. Deiterding and S. L. Wood. «An adaptive lattice Boltzmann method for predicting wake fields behind wind turbines». In: New Results in Numerical and Experimental Fluid Mechanics X. Ed. by A. Dillmann et al. Vol. 132. Notes on Numerical Fluid Mechanics and Multidisciplinary Design. Springer, 2016, pp. 845857.

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PRESENTATIONS

MARTIN GEIER, TU BRAUN-SCHWEIG

A Sliding Grid Method For The Lattice Boltzmann Method Using Compact Interpolation

Martin Geier, Ehsan Kian Far

Wind turbines are mostly rigid rotating structures. The fluid structure interaction of such structures is efficiently and accurately modeled through overlay grids were a rotating grid slides inside a stationary grid. In this presentation we will discuss a sliding mesh algorithm for the lattice Boltzmann method [1]. The method adopts the compact quadratic interpolation technique known from the compact grid refinement [2]. It obtains the gradients of velocity from the second order cumulants via asymptotic analysis and uses them for increasing the polynomial order of the grid interpolation function. Coriolis and centrifugal forces are accounted for in the moving grid as well as in the interpolation between grids. The nature of the forcing algorithm has to be taken into account in the transfer of the velocity between the static and the rotating grid. As forcing is implemented as a splitting scheme, halve the Coriolis and centrifugal force has to be subtracted from the rotational velocity when data is interpolated from the stationary to the rotating grid. When data is interpolated from the rotating to the stationary grid it has to be taken into account that fluid in a rotating frame of reference is stress free only if it rotates in a circular vortex. The centrifugal and Coriolis forces hence have to be compensated for in order to obtain the correct stresses from which the non-equilibrium cumulants are accurately obtained. Second order convergence of the method has been numerically confirmed.

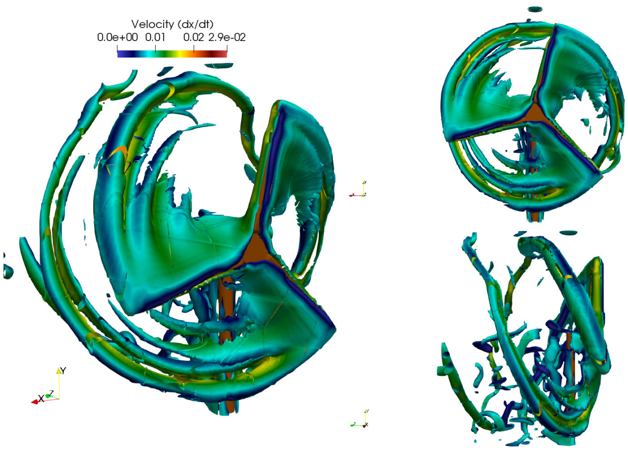

Figure 1: Overlay grid simulation of a wind turbine with the cumulant lattice Boltzmann method. A homogenous resolution with 112×112×192 grid nodes on the stationary grid was used.

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PRESENTATIONS

HENRIK ASMUTH,
UNIVERSITY OF UPPSALA

Validation Of LBM Actuator Line Simulations Within The IEA Task 29 Wake Inflow Benchmark

Henrik Asmuth, Karl Nilsson, Stefan Ivanell

The multi-physics multi-scale nature of wind turbine wakes makes their modelling one of the largest challenges in wind energy research [1]. A particular obstacle for the validation of numerical models is the scarcity of detailed physical measurements of full-scale wind turbines operating in realistic atmospheric conditions. One of the most detailed full-scale experimental datasets available to date has been obtained within the DanAero experiment at the Tjaereborg wind farm (Denmark) [2]. As part of the latest phase of IEA Task 29 (Phase IV: Detailed Aerodynamics of Wind Turbines) several benchmarks have been designed based on the DanAero database. In this talk we will present recent results from the subtask 3.3 focused on waked inflow conditions. In total, six different numerical models from three different institutions participated in this benchmark, including dynamic wake meandering models (DWM), steady-state RANS as well as large-eddy simulations (LES). We will discuss general uncertainties and challenges in the benchmark as well as the evaluation of the different models. Furthermore, we will particularly focus on the performance of one of the participating models, i.e. an actuator line LES approach [3] using the cumulant lattice Boltzmann method [4]. Exemplary result (mean normal and tangential blade forces) can be found in Fig. 1 (LBM results referred to as LB-LES).

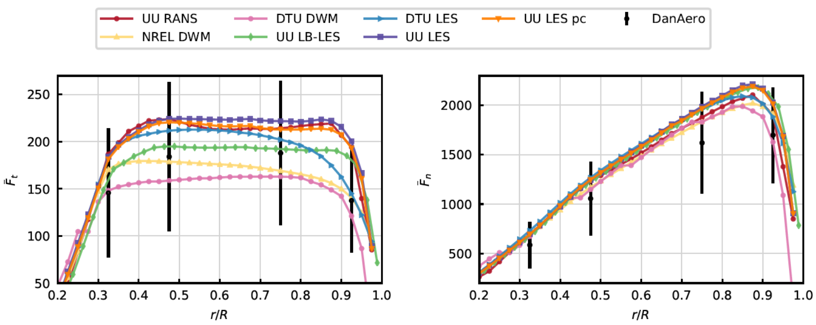

Figure 1: Mean tangential forces F_t and normal forces F_n (averaged over one 10 min bin) along one blade of the turbine.

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[1] Veers P, Dykes K, Lantz E, Barth S, Bottasso C L, Carlson O, Clifton A, Green J, Green P, Holttinen H, Laird D, Lehtomäki V, Lundquist J K, Manwell J, Marquis M, Meneveau C, Moriarty P, Munduate X, Muskulus M, Naughton J, Pao L, Paquette J, Peinke J, Robertson A, Sanz Rodrigo J, Sempreviva A M, Smith J C, Tuohy A and Wiser R 2019 Science 366
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PRESENTATIONS

HELEN SCHOTTEN-HAMML, IFP ENERGIES NOUVELLES

A Holistic CPU/GPU Approach For The Simulation Of Wind Turbines Using The Actuator Line Model

Helen Schottenhamml, Ani Anciaux-Sedrakian, Frederic Blondel, Ulrich Rüde

In course of the ongoing energy revolution - the transition from fossil to renewable energy sources - wind energy plays an increasing role in the production of clean energy. Eciently simulating and predicting wind farm ows and the interactions between turbines and turbulent wakes remains a major challenge. We approach this challenge by coupling the Lattice-Boltzmann method with an Actuator Line model [2] for the turbines using the multi-physics software framework waLBerla [1].
Due to its inherently local time evolution scheme, the Lattice-Boltzmann method is well suited for large scale applications on highperformance computing systems. This holds, in particular, for the acceleration using Graphical Processing Units (GPU). However, we do not want to restrict the end user to computing systems with graphic cards but to preserve also the CPU-only capabilities. To this end, we present a holistic CPU/GPU approach for the simulation of wind turbines. Notably, this holistic approach is based on a mutual code base for CPU and GPU that disposes of the necessity of implementing and maintaining two dierent versions of physical models for CPU and GPU. The proposed design results not only in the prevention of code divergence of physical models but also eases the implementation of new models. In the long run, it even facilitates the setup of hybrid simulations. After validating the implementation with respect to physical properties and accuracy, we further comment on the performance and the speed-up properties of our approach. We present how the whole simulation time is reduced using a GPU card. The performance gain factor, as illustrated, is more than 5 when running on one core (Skylake) and one GPU (P100) compared to one CPU with 18 cores without any accuracy loss.

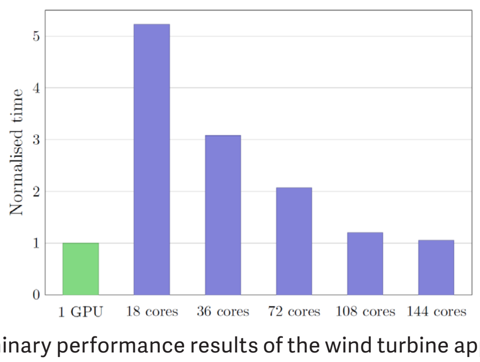

Figure 1: Preliminary performance results of the wind turbine application for CPUs and GPU simulations using the holistic implementation.

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The First International Workshop on Lattice Boltzmann for Wind Energy

PRESENTATIONS

HENRY KORB,
TU DRESDEN

Coupling LBM And Reinforcement Learning For Wind Farm Control

Henry Korb, Henrik Asmuth, Merten Stender, Stefan Ivanell

This presentation discusses the application of reinforcement learning (RL) to develop new wind farm control strategies to increase total power production. Recently, the interest in the area of wind farm control has shifted towards dynamic control strategies aiming at the mitigation of wake effects. So far, these approaches relied on adjoint simulations or surrogate models to find optimal control strategies. Hence, they either depend on the knowledge of the entire state of the flow-field or require a model of the wake behaviour. Here we explore an approach that is solely based on information obtainable in a real-world scenario and does not require any prior knowledge of the wake behaviour. A RL-agent with knowledge of the turbine state and a reduced flow field state, as similarly obtainable from LIDAR measurements, is trained via a coupling to an LBM-LES simulation of a small wind farm of three turbines. The agent is employed to develop a new control strategy without prior constraints. While the resulting strategy does not exceed the power production of a greedy-controlled park, it highlights how the use of LBM allows the application of data-intensive optimization algorithms. Possible difficulties in the problem formulation are identified and new set-ups alleviating these issues are proposed. It is concluded that RL is a promising approach for wind farm control under sparse data.

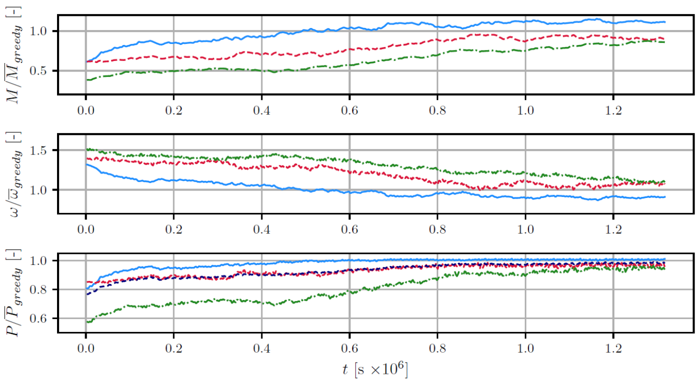

Figure 1: Turbine 1 (blue), Turbine 2 (red), Turbine 3 (green), Total (blue dashed). Generator torque, angular velocity and generated power throughout the training of an RL-agent controlling the generator torque of three turbines without prior constraints.

References
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