UNIVERSITY OF MARYLAND

The Burgers Program for Fluid Dynamics

Nineteenth Annual Symposium

Friday, October 7th, 2022, 1:00 to 5:00 pm
Jeong H. Kim Engineering Building
Rooms 1107 & 1111

Institute for Physical Science and Technology
College of Computer, Mathematical and Natural Science
A. James Clark School of Engineering
University of Maryland, College Park

Program:
1:00 – 1:05

Welcoming Remarks

Jim Duncan
The Burgers Program for Fluid Dynamics, University of Maryland
Department of Mechanical Engineering and the Institute for Physical Science and Technology

1:05 – 1:50

Numerical simulation of particle-laden flow for improved plastic recycling (to be presented online)

Hans Kuerten
Department of Mechanical Engineering,
Eindhoven University of Technology

1:50 – 2:00

Break, informal discussions

2:00 – 2:45

The complex story of how wind turbines affect near-ground properties (to be presented in person)

Cristina L. Archer
Department of Geography and Spatial Sciences
University of Delaware

2:45 – 3:30

Graduate student and post-doctoral poster session. Refreshments served

3:30 – 4:15

Obtaining desired trajectories for bodies free to move in the wake of a rotating cylinder (to be presented in person)

Yahya Modarres-Sadeghi
Department of Mechanical and Industrial Engineering,
University of Massachusetts, Amherst

4:15 – 5:00

Exoplanet atmospheres as a natural fluid dynamics laboratory: from ultra-hot Jupiters to temperate rocky exoplanets (to be presented in person)

Thaddeus Komacek
Department of Astronomy
University of Maryland

5:00 – 6:00 ***Reception and Announcement of Best Posters***

ABSTRACTS and BIOGRAPHIES

Numerical simulation of particle-laden flow for improved plastic recycling

Hans Kuerten

Abstract: Magnetic density separation (MDS) is an innovative technique that separates different types of plastic particles according to their different mass density. To this end an effective vertical mass density gradient in a liquid is created by applying a strong magnetic field to a ferrofluid. Particles transported by this liquid settle at the height where their mass density equals the effective fluid mass density. To obtain a high separation efficiency, it is important that the level of turbulence in the liquid is kept as small as possible. The liquid is first guided through a honeycomb in which the flow is relaminarized. However, in the wakes of the honeycomb cell walls disturbances are created, which together with the effect of the particle motion may lead to turbulent flow further downstream. We developed a numerical simulation method, based on point-particle direct numerical simulation, to study the separation efficiency of this device. In particular we consider the effects of particle collisions. Results of two-particle collisions are validated by means of comparison with experimental results obtained from 3D particle tracking velocimetry for various particle shapes. Also the effects of the honeycomb on the separation efficiency are studied.

Biography: Since 2014 Hans Kuerten is full Professor of Mechanical Engineering at Eindhoven University of Technology in the field of numerical simulation of multiphase flow. He received his PhD in Applied Physics at Eindhoven University of Technology in 1987 and afterwards was an assistant professor in the Department of Applied Mathematics at the University of Twente. In 1998 he became an associate professor in the Department of Mechanical Engineering at Eindhoven University of Technology. Since 2016 he is the local director of the J.M. Burgerscenter at Eindhoven University of Technology.

The complex story of how wind turbines affect near-ground properties

Cristina L. Archer

Abstract: Wind energy has been growing steadily in the U.S. and worldwide in the past decades. As wind farms are increasing in size and number, however, concerns are rising about possible undesirable effects of wind turbines near the Earth's surface, in particular on surface temperature. The mechanism generally proposed is that turbulence generated in the wind turbine wakes enhances vertical mixing near the ground. Wakes are plume-like volumes downwind of wind turbines that are characterized by lower wind speeds (i.e., a wind speed deficit) and higher turbulent kinetic energy (TKE) than the undisturbed upwind flow.
Here we study vertical mixing in the wakes of wind turbines using both observations and simulations.

The observational component is the VERTical Enhanced miXing (VERTEX) field campaign in late summer 2016, during which we measured near-surface turbulent fluxes, wind speed, temperature, and moisture under and outside of the wake of a wind turbine located near the shore in Lewes, Delaware. To further understand wakes of single versus multiple turbines (i.e., overlapping wakes), we conducted large-eddy simulations (LES) with the Weather Research and Forecasting Model (WRF-LES), with the turbine modeled as a generalized actuator disk.

We report that atmospheric stability strongly controls the temperature response to the wake, with warming observed in stable conditions, slight cooling under unstable conditions, and slight warming or no change under neutral conditions. The best measure of stability in the field is found to be the temperature lapse rate between hub height and the ground.

The second finding is that vertical mixing near the ground is not enhanced by wind turbine wakes. In VERTEX, friction velocity, TKE, and wind speed are found to be reduced near the ground under the wake, while sensible heat flux and moisture are not significantly affected by the wake. The LES results also indicate a reduction of vertical momentum flux below single and overlapping wakes. As such, enhanced vertical mixing cannot be the mechanism responsible for the temperature changes.

The third finding is that the mechanism that causes the temperature changes near the ground in the presence of wind turbine wakes is the vertical convergence (or divergence) of turbulent heat fluxes. Under stable conditions, the enhancement of the downward turbulent heat flux in the rotor area and the lack of change in surface heat flux cause convergence below the rotor, which induces warming. Vice versa, under unstable conditions, the enhancement of the (weak) upward turbulent heat flux in the rotor area and the lack of change in surface heat flux cause a weak divergence below the rotor, which induces a slight cooling.

Lastly, a wind turbine wake cannot be fully characterized just by the wind speed deficit, because added TKE does not behave like the wind speed deficit. In other words, the wake has a ``dual nature'', with both wind speed deficit and added TKE being necessary to fully characterize it.

Biography: Dr. Cristina L. Archer is the Unidel Howard Cosgrove Career Development Chair in the Environment and a Professor in the Department of Geography and Spatial Sciences and in the Mechanical Engineering Department of the University of Delaware. Dr. Archer is the Director of the Center for Research in Wind (CReW), which focuses on wind energy, in particular offshore, and its integration in the electric grid. She earned a B.S. in Civil and Environmental Engineering from the Politecnico di Milano (Milan, Italy) in 1995, an M.S. in Meteorology from San Jose State University in 1998, and a Ph.D. in Civil and Environmental Engineering from Stanford University in 2004. She was a Postdoc there in 2004-2005 and then worked as an Atmospheric Modeler in the air quality district of San Francisco in 2005-2007. Dr. Archer joined the Carnegie

Institution for Science in 2007 as a Research Associate. She was an Assistant Professor in the Department of Geological and Environmental Sciences of the California State University Chico during 2008-2011. She joined the University of Delaware in 2011. Dr. Archer's research interests include wind power, meteorology, air quality, climate change, numerical modeling, and computational fluid dynamics.

Obtaining desired trajectories for bodies free to move in the wake of a rotating cylinder

Yahya Modarres-Sadeghi

Abstract: In a long-term project, we are designing a robot to provide assistance to patients with walking disabilities by manipulating the flow of water in an underwater treadmill to enable the patients to follow a desired walking trajectory. If a cylinder, placed in flow, is forced to rotate periodically, in a range of system parameters, the frequency of vortex shedding in its wake will follow the rotation frequency of the cylinder. Then if a body is placed in the cylinder's wake, the flow forces that act on the body can be controlled by controlling the cylinder's rotation frequency. I will show how by using this strategy, we have been able to impose desired motions on the bodies that are free to move and are placed in the wake of the cylinder. As an example, we have been able to impose trajectories similar to the human walking gait trajectory to a passive double pendulum placed in the wake of a cylinder forced to rotate. By rotating the cylinder at a desired frequency, we control the frequency of vortex shedding in its wake. These vortices then interact with a hydrofoil that is attached to the double pendulum and produce trajectories very similar to the human walking gait trajectories.

Biography: Yahya Modarres-Sadeghi is a Professor of Mechanical Engineering at the University of Massachusetts Amherst with a research focus on Fluid-Structure Interactions. After receiving his PhD from McGill University in 2006, he spent 3 years at the Massachusetts Institute of Technology as a Postdoctoral Associate. He then moved to the University of Massachusetts in 2009. He is an Associate Editor for the Journal of Fluids and Structures, and a Fellow of the Harvard Radcliffe Institute for Advanced Studies.

Exoplanet atmospheres as a natural fluid dynamics laboratory: from ultra-hot Jupiters to temperate rocky exoplanets

Thaddeus Komacek

Abstract: Atmospheric characterization is the present frontier for understanding the nature of planets that orbit stars other than the Sun. To date, the bulk of the observational study of these exoplanet atmospheres has been performed on the largest and closest-in gaseous planets, colloquially termed ``hot Jupiters." The recent launch of JWST promises detailed characterization of hot Jupiters, along with a first detailed glimpse at the atmospheric composition and climates of temperate Earth-sized exoplanets orbiting small, cool stars. In this talk, I will discuss the current understanding of the atmospheric circulation of hot Jupiters as determined from interpreting astronomical observations with a combination of analytic theory and general circulation modeling. I will introduce the hottest gaseous exoplanets, ``ultra-hot Jupiters,'' as a novel extreme class of exoplanet characterized by thermal dissociation of molecules and patchy mineral cloud coverage. I will then stretch across the continuum of exoplanet atmospheres to discuss the state-of-the-art of modeling rocky exoplanet climates, the assumptions of which will be confronted by JWST observations of temperate rocky exoplanets. I will finally summarize the promising future of exoplanet characterization, including the push in the coming decades toward constraining the atmospheric composition and climate of Earth-sized rocky planets orbiting Sun-like stars.

Biography: Dr. Thaddeus ("Tad") Komacek is an Assistant Professor in the Department of Astronomy at the University of Maryland, College Park. Previously, Tad held a Heising-Simons 51 Pegasi b Postdoctoral Fellowship at the University of Chicago from 2018-2021. He received his Ph.D in Planetary Sciences from the University of Arizona Lunar and Planetary Laboratory in 2018, and bachelor's degrees in Geophysical Sciences and Physics from the University of Chicago in 2013. Dr. Komacek's research focuses on characterizing the atmospheres of exoplanets by developing theoretical and numerical models for their global circulation and climate.