Preface

The seventeenth biennial Summer Program of the Center for Turbulence Research was held from June 24 to July 20, 2018. CTR hosted seventy-four participants from eight countries, including twenty-six U.S. institutions. Thirty-eight CTR staff members, including graduate students, postdoctoral fellows and faculty, worked alongside the participants and contributed to thirty-six projects spearheaded during the Summer Program. The participants were selected on the basis of quality of their research proposals and their synergy with current scientific interests of CTR. The role of CTR continues to be that of providing a forum for the fundamental study of multi-physics turbulent flows for engineering analysis.

This proceedings volume contains thirty-six reports, which are divided into five groups: Multi-phase Flows, Numerical Methods, Multi-physics and Data-driven Studies, Wall Turbulence, and Combustion. Preceding each group of papers is a technical overview that summarizes the main technical accomplishments.

Research activities in the group of multi-phase flows focused on analysis and modeling of dispersed particle-laden turbulence and two-phase turbulent flows, with particular emphasis on multi-physics aspects. In the area of particle-laden turbulence, the problems addressed by this group included the dispersion of particles in electrified and rotating flows, the interaction of particles with shock waves, and the deposition of sand grains on turbine blades. In the area of two-phase flows, the activities encompassed the analysis and subgrid-scale (SGS) modeling of interactions of interfaces with turbulence, and the mesoscale description of turbulent flows in porous media.

The group on numerical methods emphasized advancing the state of the art of low-dissipation numerics in Large Eddy Simulations (LES) and their compatibility with SGS models, including applications to complex geometries. The latter were illustrated by predictive wall-modeled LES of realistic aeronautical configurations carried out during the Summer Program with turnaround times of industrial relevance. Other activities included performance assessments of hybrid meshes in LES of low Mach-number flows, and developments of Discontinuous Galerkin methods in turbulent flows, including applications to wall modeling and energy transfer.

Data-driven analyses and data-assimilation techniques for turbulent flows were the main areas of research in the group on multi-physics and data-driven studies. The activities involved analyses of rare events in turbulent flows, adjoint-based control, shadowing-based methods for adjoint sensitivities, along with challenging multi-physics applications that included autonomous navigation of swimmers in turbulence, passive scalar mixing through shock waves, supercritical fluids, and supersonic jet noise.

The wall turbulence group focused on fundamental analyses of flow structures near walls, including non-equilibrium and rough-wall boundary layers. The understanding and control of near-wall turbulence, as well as its prediction from wall quantities, occupied most of the attention in the group, with relevant applications to complex surfaces and rapidly-swept boundary layers being also demonstrated during the Summer Program.

Activities related to research on combustion focused on physics, modeling, uncertainty quantification and data analysis. The problems addressed by this group involved SGS modeling of heat-release effects on small-scale turbulence, fundamental studies of reacting discontinuities, simulations of vaporizing fuel droplets in turbulent flows, as well as applications of data-assimilation and deep-learning techniques to important combustion processes such as thermoacoustic instabilities and turbulent premixed-flame propagation.

As in previous years, four weekly tutorials were given during the Summer Program. The topics discussed in the tutorials this year were: “Hypersonic Aerodynamics and Propulsion” by Javier Urzay (Stanford), “Machine Learning and Data Science in Turbulence” by Gianluca Iaccarino (Stanford), “Sensitivity Analyses and Chaotic Dynamics in Turbulence” by Qiqi Wang (MIT), and “Moving Contact Lines” by Kamran Mosheni (University of Florida).

The participants of the 2018 Summer Program presented their accomplishments on July 20. This final event was attended by several colleagues from industry, academia, and government.

The 2018 Summer Program was sponsored by the US Air Force Office of Scientific Research (AFOSR), National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), Department of Energy (DoE), and the Office of Naval Research (ONR). The joint commitment of five different federal agencies to support the Program underscores the importance of understanding and modeling multi-physics turbulent flows for engineering analysis. The wide discretionary mandate they afforded to CTR for selection of the technical projects featured in these volumes has been much appreciated.

We are grateful to Vi Nguyen and Pamela Nelson Foster for their assistance and efficient organization of the 2018 CTR Summer Program, to Steve Jones for his guidance to the external participants who utilized the CTR Certainty cluster for their simulations, and to Curtis Hamman for his help on compiling the manuscripts featured in this volume.

This volume is available online, including color versions of the figures in the reports, at the CTR website:
`http://ctr.stanford.edu/`

Parviz Moin
Javier Urzay