Preface

The tenth Summer Program of the Center for Turbulence Research was held during the period June 21st – July 16th, 2004. This year, in addition to our traditional seventeen year sponsorship by NASA's aeronautics program, the CTR summer program acknowledges support from NASA's Sun-Earth Connection Program, the AFOSR Turbulence & Rotating Flows program, and the DOE-ASC program. This additional support allowed us to maintain the diversity of the program that we feel is essential for cross-disciplinary fertilization among aerodynamics, turbulent combustion, aeroacoustics, atmospheric physics, geophysics, astrophysics, etc. The program sponsored 50 participants from fourteen countries; they were hosted by 24 participants from Stanford and NASA-Ames.

This Proceedings volume contains 32 papers that span a wide range of topics that reflect the ubiquity of turbulence. The papers have been divided into six groups: Solar Simulations, MHD, LES and Numerical Simulations, RANS Modeling and Simulations, Stability and Acoustics, and Combustion and Multi-Phase Flow. In some cases, a paper could have fitted in more than one group so the classification is somewhat arbitrary. More detailed summaries of the accomplishments of each group can be found in the overviews that precede the grouped papers.

Solar Simulations aim at providing an understanding of the dynamics of the Sun. Solar observations, which provide a wealth of data on the dynamics of the interior of the Sun, are motivating efforts to develop Large-Eddy Simulations that can be verified by comparison with this data; in turn, these LES simulations are used to provide detailed understanding of the observations. Three efforts concerned simulating the near surface region of the Sun's interior, the convection zone of the Sun, and developing a theoretical model for the interaction of convection with the magnetic field. New advances were made in numerical simulation of radiation. These advances will guide parallelization strategies for the simulation of the near surface region. The global simulation effort showed that the boundary conditions in the radial direction play an important role on the global dynamics. The theory effort provided a model for the source of the fine structures observed in sunspots.

Magneto-hydrodynamics plays an important role in astrophysics as well as in engineering applications such as liquid metal processing. New advances were made in our understanding of the interactions between the magnetic field and turbulence. It was found that at low magnetic Reynolds number the velocity field develops strong dimensional anisotropy under the action of Joule dissipation. In a study of the effects of rotation and mean magnetic field on turbulence, it was found that, at sufficiently high magnetic Reynolds numbers, the turbulence kinetic energy will grow even for cases when rotation is expected to suppress the turbulence. High resolution simulations of compressible MHD turbulence of interest in astrophysical studies, showed a flattening of the density spectrum. Of interest to NASA's exploration program is a simulation of Hall thruster plasmas where it was shown that electron transport associated with azimuthal disturbances can be significant.

The development of models and numerical methods for Large Eddy Simulations (**LES**) continues to be at the core of the Summer Program. This summer one finds movement towards a holistic approach to LES where the definition of the resolved field, the modeling and the numerical method are treated together. The wavelet approach used in LES was shown to be competitive with traditional methods. Progress in the evaluation of the VMS (variational multiscale) approach has shown the definition of a good model is closely tied to the choice of the ideal LES solution. This implies that comparison with experimental data is the most reliable way to evaluate LES methodologies. Progress was also made by evaluating filtering strategies as they impact the fundamental equations, treatment of boundary conditions and commutation errors.

The summer program continues to be a forum where **RANS** (Reynolds-Averaged Navier-Stokes) techniques are developed and evaluated. The rapid time to solution, and limited computational resources required by these methods keep them attractive for applications in industry. Progress was made in modeling the effects on the mean flow, a challenging area in RANS models. Other challenging areas in RANS modeling are cases where the flow is locally unsteady such as in synthetic jets, or where the dynamics (time dependence) is important as in noise predictions. A promising approach for treating synthetic jets as a body force was developed. It was shown that RANS methods are not suitable when predictions of the pressure spectrum is required in computation of noise.

Coupling of analytical tools with numerical solutions were used to provide advances in our understanding of fundamental physics. Theory and simulations were combined to provide an understanding of the coupling between free stream disturbances and the boundary layer dynamics. Multiscale transforms were used to identify the most efficient way to control the wake behind a cylinder. Various formulations for decoupling the compressible flow equations to a noise source and inhomogeneous wave equation were tested using DNS data.

As in previous summer programs, the **Combustion and multi-phase flow** group was the largest of the program; this reflects the strong interest in the subject from three of the four sponsors of the Summer Program. Four areas can be identified: Combustion science & modeling, Two-phase flows, Fires, and Thermoacoustic instabilities and control. New advances were made, with marker field models showing promise at low Damkohler number. A new expression for turbulent burning velocity was tested and showed good agreement with DNS results. Strategies for implementing and parallelizing the filtered-density function (FDF) approach were developed and have shown substantial speed-up compared with direct integration. Other strategies using look-up tables show promise for modeling turbulent diffusion flames. New advances were made in the development of methods for multi-phase simulations. Closely packed droplet models were used to simulate liquid film formation and dense sprays. A mass conserving coupled Volume-of-Fluid/Level-Set method was tested, and it was found that handling cases where surface tension is dominant remains a challenge in spray breakup simulations. New radiation models were developed and tested. As combustion simulation technologies mature, we find increased interest in using them in design and optimization of combustion devices. Modern optimization methods were used to show the potential for control of flame length, temperature and NO_x emission.

This year four review tutorials were given: *Solar Turbulence: order amidst chaos in the deep convection zone* (Juri Toomre), *MHD Turbulence* (Bernard Knaepen), *Wall Turbulence Including Roughness* (Javier Jimenez), and *Computationally efficient implementation of chemistry in turbulent combustion simulations* (Stephen Pope).

The final presentation of research accomplishments on July 16th was attended by a number of colleagues from universities, government agencies, and industry.

Special thanks are due to Millie Chethik for her work on organizing the Program and editing the briefs. Her help in the planning, operation and effective interface with the administrative requirements of Stanford University and NASA Ames Research Center are highly appreciated. Special thanks are also due Dr. Xiaohua Wu for assistance in producing the final briefs.

These Summer Proceedings are dedicated to the memory of William C. Reynolds who passed away in January 2004. His energy, enthusiasm, and genius will reverberate in our hallways forever. He is sorely missed by all of us in the turbulence community.

Parviz Moin
Nagi N. Mansour

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