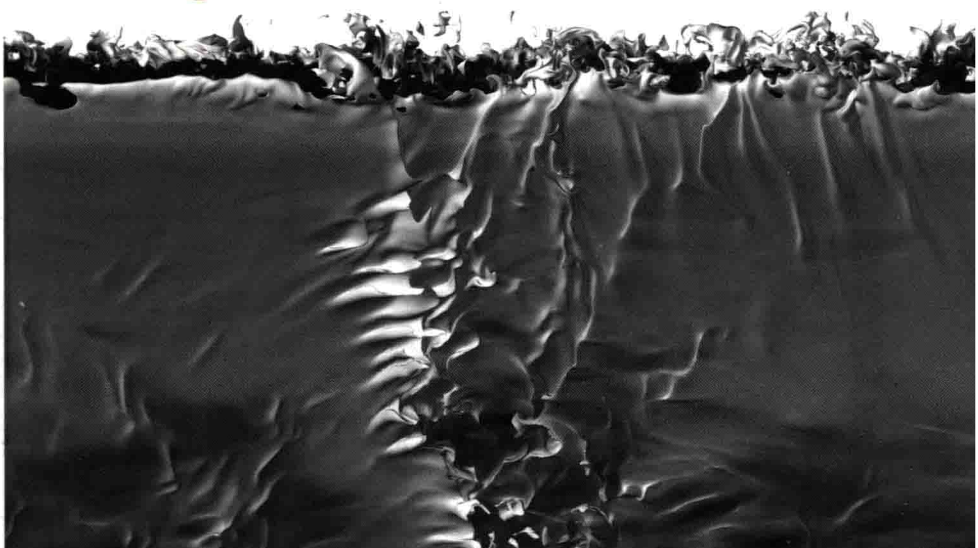
2nd Edition

MULTISCALE AND MULTIRESOLUTION APPROACHES IN TURBULENCE

LES, DES and Hybrid RANS/LES Methods:
Applications and Guidelines

Pierre Sagaut • Sébastien Deck • Marc Terracol



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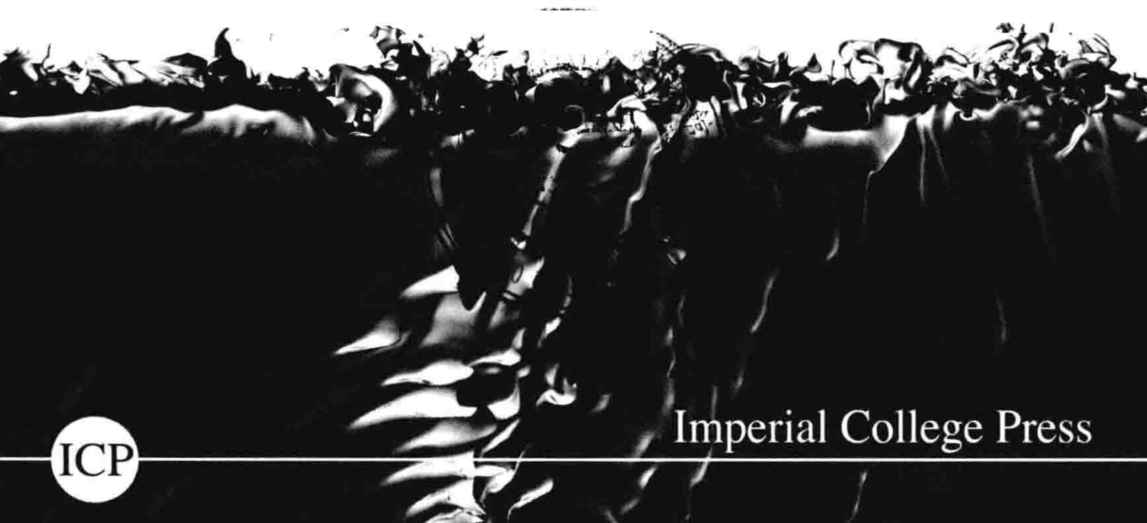

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"... the answer, my friend, is blowin' in the wind ..."

Bob Dylan

Foreword to the Second Edition

The treatment of turbulence, increasingly, draws both on modeling concepts related to traditional Reynolds Averaging of the Navier–Stokes equation (RANS), and on the resolution of the unsteady three-dimensional large and medium flow structures as in traditional Large-Eddy Simulation (LES). Without a doubt, such combined methods carry very much power, especially for separated flow, vibration and noise, and will be very widespread at least for the first half of this century. Also without a doubt, they are conceptually more complex than either RANS or LES, appreciably increase the burden on code developers and users, can evolve rapidly, and are classified by some as "dangerous toys". They often mingle numerical and modeling errors. LES always did this, but this is probably more the case for the newer methods. To add to the difficulties for users and for code writers, the CFD field is competitive and a few components of the methods are kept secret, either for industrial reasons, or for competitive advantage over other suppliers of software (sometimes, it's simply careless scientific writing).

For all these reasons the present treatise, in its second edition after six years, is essential as well as unique. It is very ambitious, as it proposes to analyze the full spectrum of current turbulence treatments, from pure steady RANS to Direct Numerical Simulation (DNS), in a deep and impartial manner. This makes it very helpful, especially for researchers entering the field, who otherwise only have the optimistic and often incomplete accounts by the scientists who proposed each method (and a few books summarizing European research programmes such as DESider). There is an excellent balance between seeking a theoretical basis to predict the worth of a method, and reporting on complete tests, which leave "no place to hide" for the method's weaknesses. Just like the first edition, this significant revision has references that are only months old. The supporting work is considerable.

The authors are very active researchers and have experience organizing knowledge, writing chapters and entire books in this field. The English is almost flawless, which is rare with 400 pages. The organization, with four levels of chapter, section and sub-sections, makes navigation very effective.

The authors' fairness made them include approaches which, in my biased opinion, will not stand the test of time. However, the reader does not need to spend much time on them, and besides we learn from all mistakes, and from pondering ideas which are in some sense seductive, but are actually flawed or just inefficient.

The authors have created numerous original figures to visualize the concepts, notably sketches in real space and in wave space, and also obtained figures from many leading researchers. Their reproduction is very good, as is the typesetting and equations, and in general the book is a pleasure to hold. Thus, equations are the focus, correctly since they enter the codes and contain the validity of the method; but physical intuition is also a major theme of the book. This is also appropriate, since our treatment of turbulence is still so reliant on good approximations, as opposed to exact results. It is essential for users of turbulence treatments to build their awareness of the internal physics of their solutions, and of the level of validation of the method used, depending on the problem. A slight limitation is that compressibility and other added complications such as combustion and atmospheric physics are not emphasized at all. The non-linearity of the incompressible Navier–Stokes equations is creating enough difficulty and fascination through turbulence.

The authors are to be commended for a very substantial contribution to science and engineering.

Philippe R. Spalart,
Boeing Commercial Airplanes, Seattle,
March 2012.

Foreword to the First Edition

Turbulence modeling is a complex subject and methods developed to deal with it are numerous and diverse. Many schools of thought exist and communication and understanding among them is often lacking. Comparisons may be odious but they need to be made and explored if a scientific discipline is to progress. This is why *Multiscale and Multiresolution Approaches in Turbulence* is so timely. It brings together many topics not found in one place before. A number have appeared only in very recent research papers and here grace the pages of a book for the first time. The proximity invites comparisons and suggests a greater unification of turbulence methodology than is at first apparent. The subject of the work is modeling, but the dual themes, expressed in the title, are multiscale and multiresolution approaches. These words conjure up fundamental and computational concepts, and, indeed, the text presents both in an integrated way. Multiscale and multiresolution methods have attracted enormous recent interest in a variety of scientific disciplines, and they seem to provide the ideal framework for organizing much, if not all, contemporary turbulence research.

The treatment begins in Chapter 1 with a brief introduction to turbulence ideas, including randomness, coherent structures, turbulent length and time scales, the Kolmogorov energy cascade, and transfers of energy between scales. In Chapter 2, the enormous cost of direct numerical solution of the Navier–Stokes equations is used to motivate the practical need for modeling. This amounts to approximating the effects of unrepresented scales and the basic strategies are described next, namely, Reynolds-Averaged Numerical Simulation (RANS) and Large-Eddy Simulation (LES), and are followed by a discussion of multilevel methods. Chapter 3 deals with statistical multiscale concepts and various RANS models are presented, including eddy viscosity and Reynolds stress models. Chapter 4 is concerned with multiscale subgrid models and self-adaptivity in LES. Fundamental ideas are introduced, along with the Germano identity, dynamic models, self-similarity, and Variational Multiscale (VMS) methods. Chapter 5 presents structured multiscale subgrid models for LES based on the estimation of small scales. Various reconstruction techniques are described, including deconvolution, multifractal, and multigrid, in addition to zonal multi-grid/multidomain methods. Unsteady turbulence simulations on self-adaptive grids are discussed in Chapter 6, covering dynamic multilevel and adaptive wavelet methods, and DNS and LES with Adaptive Mesh Refinement (AMR). Global hybrid RANS/LES approaches are presented in Chapter 7, including unsteady statistical modeling, blending, and Detached Eddy Simulation (DES). The theoretical basis of zonal RANS/LES methods commences Chapter 8 and is followed by a discussion of inlet data generation and turbulence reconstruction techniques.

This text is a very important addition to the literature on turbulence. It provides an excellent introduction to many areas of contemporary research and it systematically organizes many seemingly disparate approaches within its dual themes of multiscale and multiresolution methodology. Researchers will find it useful as a guide to the strengths and weaknesses of current technology, a classification system within which new developments will likely fit, and a hierarchy for locating methods to compare with. Student and expert alike will benefit greatly by reading it from cover to cover, and will also find it a reference work of lasting value.

Thomas J.R. Hughes,
University of Texas, Austin,
November 2005.

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