

The background of the cover is a grayscale visualization of turbulent flow, showing complex, swirling patterns of light and dark regions. A white rectangular box is located in the upper left quadrant.

2nd Edition

**MULTISCALE AND
MULTIRESOLUTION
APPROACHES IN
TURBULENCE**

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

Pierre Sagaut • Sébastien Deck • Marc Terracol

Imperial College Press

2nd Edition

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LES, DES and Hybrid RANS/LES Methods:
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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 multigrid/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.

Contents

<i>Foreword to the Second Edition</i>	vii
<i>Foreword to the First Edition</i>	ix
1. A Brief Introduction to Turbulence	1
1.1 Common Features of Turbulent Flows	1
1.1.1 Introductory concepts	1
1.1.2 Randomness and coherent structure in turbulent flows	3
1.2 Turbulent Scales and Complexity of a Turbulent Field . . .	5
1.2.1 Basic equations of turbulent flow	5
1.2.2 Defining turbulent scales	8
1.2.3 A glimpse at numerical simulations of turbulent flows	14
1.3 Inter-scale Coupling in Turbulent Flows	15
1.3.1 The energy cascade	15
1.3.2 Inter-scale interactions	17
2. Turbulence Simulation and Scale Separation	21
2.1 Numerical Simulation of Turbulent Flows	21
2.2 Reducing the Cost of the Simulations	23
2.2.1 Scale separation	24
2.2.2 Navier–Stokes-based equations for the resolved quantities	24
2.2.3 Navier–Stokes-based equations for the unresolved quantities	26

2.3	The Averaging Approach: Reynolds-Averaged Numerical Simulation (RANS)	26
2.3.1	Statistical average	26
2.3.2	Reynolds-Averaged Navier–Stokes equations	28
2.3.3	Phase-Averaged Navier–Stokes equations	29
2.4	The Large-Eddy Simulation Approach (LES)	31
2.4.1	Large and small scales separation	31
2.4.2	Filtered Navier–Stokes equations	33
2.5	Multilevel/Multiresolution Methods	35
2.5.1	Hierarchical multilevel decomposition	36
2.5.2	Practical example: the multiscale/multilevel LES decomposition	38
2.5.3	Associated Navier–Stokes-based equations	39
2.5.4	Classification of existing multilevel methods	41
2.5.4.1	Multilevel methods based on resolved-only wave numbers	41
2.5.4.2	Multilevel methods based on higher wave numbers	42
2.5.4.3	Adaptive multilevel methods	43
2.6	Summary	44
3.	Statistical Multiscale Modelling	51
3.1	General	51
3.2	Exact Governing Equations for the Multiscale Problem	54
3.2.1	Basic equations in physical and spectral space	54
3.2.2	The multiscale splitting	59
3.2.3	Governing equations for band-integrated approaches	60
3.3	Spectral Closures for Band-integrated Approaches	62
3.3.1	Local versus non-local transfers	62
3.3.2	Expression for the spectral fluxes	64
3.3.3	Dynamic spectral splitting	67
3.3.4	Turbulent diffusion terms	68
3.3.5	Viscous dissipation term	68
3.3.6	Pressure term	69
3.4	A Few Multiscale Models for Band-integrated Approaches	69
3.4.1	Multiscale Reynolds stress models	69
3.4.2	Multiscale eddy viscosity models	70

3.5	Spectral Closures for Local Approaches	71
3.5.1	Local multiscale Reynolds stress models	71
3.5.1.1	Closures for the linear transfer term	72
3.5.1.2	Closures for the linear pressure term	73
3.5.1.3	Closures for the non-linear homogeneous transfer term	74
3.5.1.4	Closures for the non-linear non-homogeneous transfer term	76
3.5.2	Local multiscale eddy viscosity models	77
3.6	Achievements and Open Issues	78
4.	Multiscale Subgrid Models: Self-adaptivity	85
4.1	Fundamentals of Subgrid Modelling	85
4.1.1	Functional and structural subgrid models	85
4.1.2	The Gabor–Heisenberg curse	86
4.2	Germano-type Dynamic Subgrid Models	91
4.2.1	Germano identity	91
4.2.1.1	Two-level multiplicative Germano identity	91
4.2.1.2	Multilevel Germano identity	93
4.2.1.3	Generalized Germano identity	94
4.2.2	Derivation of dynamic subgrid models	94
4.2.3	Dynamic models and self-similarity	97
4.2.3.1	Turbulence self-similarity	97
4.2.3.2	Scale separation operator self-similarity	104
4.3	Self-Similarity Based Dynamic Subgrid Models	106
4.3.1	Terracol–Sagaut procedure	106
4.3.2	Shao procedure	110
4.4	Variational Multiscale Methods and Related Subgrid Viscosity Models	112
4.4.1	Hughes VMS approach and extended formulations	112
4.4.2	Implementation of the scale separation operator	117
4.4.3	Bridging with hyperviscosity and filtered models	120

5.	Structural Multiscale Subgrid Models: Small Scales Estimations	123
5.1	Small-scale Reconstruction Methods: Deconvolution	124
5.1.1	The velocity estimation model	126
5.1.2	The Approximate Deconvolution Model (ADM)	132
5.1.2.1	The original ADM approach of Stolz, Adams and Kleiser	132
5.1.2.2	Example of application	136
5.1.2.3	Alternative formulation by explicit filtering	140
5.1.2.4	Alternative regularization by standard subgrid models	141
5.1.2.5	Relaxation-based approaches	142
5.1.2.6	Subgrid scales estimation by approximate deconvolution	148
5.2	Small Scales Reconstruction: Multifractal Subgrid-scale Modelling	150
5.2.1	General idea of the method	150
5.2.2	Multifractal reconstruction of subgrid vorticity	151
5.2.2.1	Vorticity magnitude cascade	152
5.2.2.2	Vorticity orientation cascade	154
5.2.2.3	Reconstruction of the subgrid velocity field	155
5.3	Variational Multiscale Methods	156
5.4	Multigrid-based Decomposition	157
5.5	Global Multigrid Approaches: Cycling Methods	161
5.5.1	The multimesh method of Voke	162
5.5.2	The multilevel LES method of Terracol <i>et al.</i>	165
5.5.2.1	Cycling procedure	165
5.5.2.2	Multilevel subgrid closures	167
5.5.2.3	Examples of application	172
5.6	Zonal Multigrid/Multidomain Methods	174
6.	Unsteady Turbulence Simulation on Self-adaptive Grids	183
6.1	Turbulence and Self-adaptivity: Expectations and Issues	183
6.2	Adaptive Multilevel DNS and LES	188
6.2.1	Dynamic local multilevel LES	189

6.2.2	The dynamic multilevel (DML) method of dubois, jauberteau and temam	193
6.2.2.1	Spectral multilevel decomposition	194
6.2.2.2	Associated Navier–Stokes-based equations	196
6.2.2.3	Quasi-static approximation	197
6.2.2.4	General description of the spectral multilevel method	197
6.2.2.5	Dynamic estimation of the parameters i_1 , i_2 and n_V	199
6.2.3	Dynamic global multilevel LES	201
6.3	Adaptive Wavelet-based Methods: CVS, SCALES	205
6.3.1	Wavelet decomposition: brief reminder	206
6.3.2	Coherency diagram of a turbulent field	208
6.3.2.1	Introduction to the coherency diagram	208
6.3.2.2	Threshold value and error control	210
6.3.3	Adaptive wavelet-based direct numerical simulation	213
6.3.4	Coherent vortex capturing method	213
6.3.5	Stochastic coherent adaptive large-eddy simulation	214
6.4	DNS and LES with Optimal AMR	219
6.4.1	Error definition: surfacic versus volumic formulation	219
6.4.2	<i>A posteriori</i> error estimation and optimization loop	221
6.4.3	Numerical results	224
7.	Global Hybrid RANS/LES Methods	227
7.1	Bridging between Hybrid RANS/LES Methods and Multiscale Methods	227
7.1.1	Concept: the effective filter	227
7.1.2	Eddy viscosity effective filter	229
7.1.3	Global hybrid RANS/LES methods as multiscale methods	231
7.2	Motivation and Classification of RANS/LES Methods	232

7.3	Unsteady Statistical Modelling Approaches	236
7.3.1	Unsteady RANS approach	237
7.3.2	The Semi-Deterministic Method of Ha Minh	240
7.3.3	The Scale Adaptive Simulation (SAS)	246
7.3.4	The Turbulence-Resolving RANS approach of Travin <i>et al.</i>	250
7.4	Global Hybrid Approaches	252
7.4.1	The Approach of Speziale	253
7.4.2	Limited Numerical Scales (LNS)	257
7.4.2.1	General idea of LNS	257
7.4.2.2	Example of application	257
7.4.3	Blending methods	258
7.4.3.1	General idea of blending methods	258
7.4.3.2	Applications	260
7.4.4	Other approaches: PITM and PANS	263
7.4.4.1	Partially Integrated Transport Model (PITM)	263
7.4.4.2	Partially Averaged Navier–Stokes (PANS)	265
7.4.5	Detached Eddy Simulation	266
7.4.5.1	General idea	266
7.4.5.2	DES based on the SA model	268
7.4.5.3	Possible extensions of standard SA-DES	271
7.4.5.4	Examples	273
7.4.5.5	DES based on the $k - \omega$ model	273
7.4.5.6	Extra-Large Eddy Simulation (XLES)	277
7.4.6	Grey-Area Modelled-Stress-Depletion (MSD) Grid and Induced Separation (GIS)	279
7.4.7	Further interpretation of MSD: non-local error analysis	283
7.4.8	Delayed Detached Eddy Simulation (DDES)	286
7.4.8.1	Formulation	286
7.4.8.2	Improved Delayed Detached Eddy Simulation (IDDES)	289
7.4.9	Zonal Detached Eddy Simulation (ZDES)	292
7.4.9.1	Formulation	292
7.4.9.2	Implementation	294
7.4.9.3	Interpretation and further discussion	298