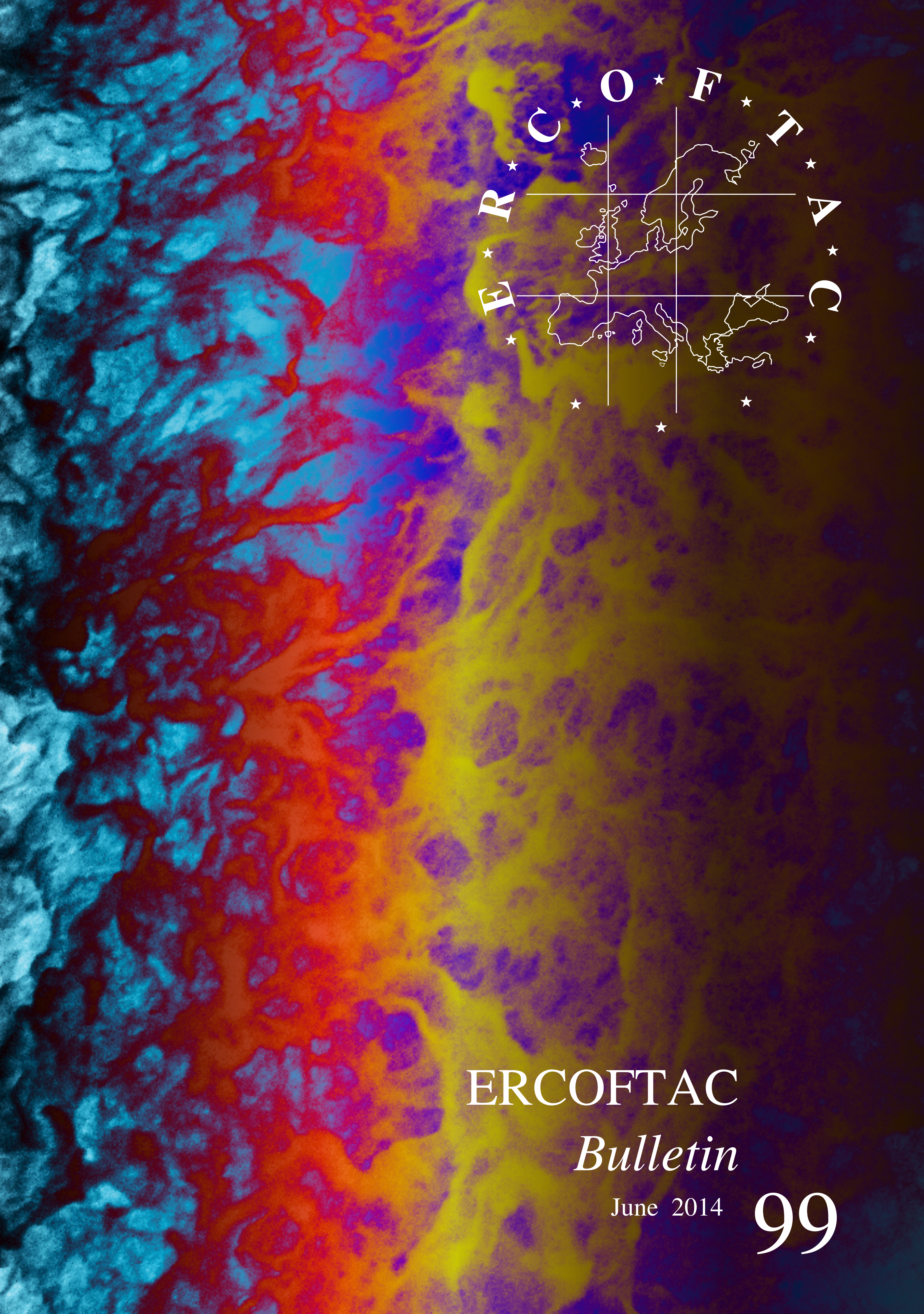

ERCOFTAC
Bulletin

June 2014

99

European Research Community on Flow, Turbulence and Combustion

ERCOFTAC is a leading European association of research, education and industry groups in the technology of flow, turbulence and combustion. The main objectives of *ERCOFTAC* are: To promote joint efforts of European research institutes and industries with the aim of **exchanging technical and scientific information**; to promote **Pilot Centres** for collaboration, stimulation and application of research across Europe; to stimulate, through the creation of **Special Interest Groups**, wellcoordinated European-wide research efforts on specific topics; to stimulate the creation of advanced training activities; and to be influential on funding agencies, governments, the European Commission and the European Parliament.

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NEXT *ERCOFTAC* EVENTS

ERCOFTAC Autumn Festival	*ERCOFTAC Committee Meetings*
October 16th 2014	October 17th 2014
Saint Etienne du Rouvray, France	Saint Etienne du Rouvray, France

The ERCOFTAC Best Practice Guidelines for Industrial Computational Fluid Dynamics

The Best Practice Guidelines (BPG) were commissioned by ERCOFTAC following an extensive consultation with European industry which revealed an urgent demand for such a document. The first edition was completed in January 2000 and constitutes generic advice on how to carry out quality CFD calculations. The BPG therefore address mesh design; construction of numerical boundary conditions where problem data is uncertain; mesh and model sensitivity checks; distinction between numerical and turbulence model inadequacy; preliminary information regarding the limitations of turbulence models etc. The aim is to encourage a common best practice by virtue of which separate analyses of the same problem, using the same model physics, should produce consistent results. Input and advice was sought from a wide cross-section of CFD specialists, eminent academics, end-users and, (particularly important) the leading commercial code vendors established in Europe. Thus, the final document can be considered to represent the consensus view of the European CFD community.

Inevitably, the Guidelines cannot cover every aspect of CFD in detail. They are intended to offer roughly those 20% of the most important general rules of advice that cover roughly 80% of the problems likely to be encountered. As such, they constitute essential information for the novice user and provide a basis for quality management and regulation of safety submissions which rely on CFD. Experience has also shown that they can often provide useful advice for the more experienced user. The technical content is limited to single-phase, compressible and incompressible, steady and unsteady, turbulent and laminar flow with and without heat transfer. Versions which are customised to other aspects of CFD (the remaining 20% of problems) are planned for the future.

The seven principle chapters of the document address numerical, convergence and round-off errors; turbulence modelling; application uncertainties; user errors; code errors; validation and sensitivity tests for CFD models and finally examples of the BPG applied in practice. In the first six of these, each of the different sources of error and uncertainty are examined and discussed, including references to important books, articles and reviews. Following the discussion sections, short simple bullet-point statements of advice are listed which provide clear guidance and are easily understandable without elaborate mathematics. As an illustrative example, an extract dealing with the use of turbulent wall functions is given below:

- Check that the correct form of the wall function is being used to take into account the wall roughness. An equivalent roughness height and a modified multiplier in the law of the wall must be used.
- Check the upper limit on $y+$. In the case of moderate Reynolds number, where the boundary layer only extends to $y+$ of 300 to 500, there is no chance of accurately resolving the boundary layer if the first integration point is placed at a location with the value of $y+$ of 100.
- Check the lower limit of $y+$. In the commonly used applications of wall functions, the meshing should be arranged so that the values of $y+$ at all the wall-adjacent integration points is only slightly above the recommended lower limit given by the code developers, typically between 20 and 30 (the form usually assumed for the wall functions is not valid much below these values). This procedure offers the best chances to resolve the turbulent portion of the boundary layer. It should be noted that this criterion is impossible to satisfy close to separation or reattachment zones unless $y+$ is based upon $y*$.
- Exercise care when calculating the flow using different schemes or different codes with wall functions on the same mesh. Cell centred schemes have their integration points at different locations in a mesh cell than cell vertex schemes. Thus the $y+$ value associated with a wall-adjacent cell differs according to which scheme is being used on the mesh.
- Check the resolution of the boundary layer. If boundary layer effects are important, it is recommended that the resolution of the boundary layer is checked after the computation. This can be achieved by a plot of the ratio between the turbulent to the molecular viscosity, which is high inside the boundary layer. Adequate boundary layer resolution requires at least 8-10 points in the layer.

All such statements of advice are gathered together at the end of the document to provide a ‘Best Practice Checklist’. The examples chapter provides detailed expositions of eight test cases each one calculated by a code vendor (viz FLUENT, AEA Technology, Computational Dynamics, NUMECA) or code developer (viz Electricité de France, CEA, British Energy) and each of which highlights one or more specific points of advice arising in the BPG. These test cases range from natural convection in a cavity through to flow in a low speed centrifugal compressor and in an internal combustion engine valve.

Copies of the Best Practice Guidelines can be acquired from:

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WORKSHOP 'ASTROFLU III' ORGANIZED BY HENRI BÉNARD PILOT CENTER, SIG 35 AND SIG 4 NOVEMBER 20-21, 2013, ECOLE CENTRALE DE LYON, FRANCE

C. Cambon, A. Naso, F.S. Godeferd and A. Cadiou

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Motivations and objectives

Based on the success of our two events 'ASTROFLU', principally organised by the Henri Bénard PC in Lyon, 12-13/11/2008 and 15/12/2011, the aim of this application was to once again gather the fluid mechanics specialists from the physics, engineering, astrophysics, and mathematics communities in order to exchange ideas and collaborate on our common interests.

The main theme of our first event was pulsating stars, because of the shared interest on *highly compressible flows,* theory, computation and modelling, and with particular emphasis on shock / turbulence interactions. The second theme on *rotating shear flows* was addressed in ASTROFLU II. There is a strong parallel between (rotating) accretion discs in the astrophysical applications, and rotating shear flows in geophysics (ocean, atmosphere), and in engineering (turbomachinery). The tools we use are often very similar, but we use multiple terminologies, and, crucially, tend to publish in separate journals. To give an example, astrophysical community uses a linear spectral method known as the 'shearing box', but this is called 'Rapid Distortion Theory' in the fluid mechanics literature (see e.g. [11]). Its nonlinear extension by DNS in astrophysics is also very similar to the pseudo-spectral DNS (Orszag / Patterson) using coordinates comoving with the mean shear (from Rogallo 1982 [10]), with now the 'snoopy' code from Geoffroy Lesur (Grenoble) used in the astrophysical community since 2008 (e.g. [6].) There is a large scientific network of astrophysicists engaged in the study of rotating accretion disks, possibly including the effects of stratification and MHD : e.g. François Rincon and Carlo Cossu, Toulouse, Gordon Ogilvie, Michael Proctor, DAMTP, Cambridge, and some in other countries. Our local team on 'Waves and Turbulence' is directly involved in these studies [13], with our colleague Abdelaziz Salhi currently rebuilding his own group in Tunis, in close connection with the Henri Bénard PC. Exchange between the fluid mechanics and astrophysics communities is essential to the development of the fields. In the last event ASTROFLU III, a large emphasis was also given to studies in geophysics, from the Earth to rapidly rotating giant planets.

Our aim is to favour better communication between different groups or individuals disseminated in the Lyon-Grenoble area. At the national scale, this is an opportunity to involve all the French Pilot Centres, as well as SIG 4 and SIG 35.

Round tables and general discussions

The meeting began on November 20 with informal talks and discussions introduced by the main organizer. Linear theory for the dynamics of fluctuations with given 'distorting' mean flow (e.g. as for the so-called Rapid Distortion Theory) can be combined to an evaluation of a feed-back from the fluctuating to the mean flow, assuming different time scales for fluctuating and mean parts. In conventional hydrodynamics, such a feed-back is ensured by the gradient of the Reynolds stress tensor, which is zero in the limit of statistical homogeneity restricted to fluctuations. The more physical context of a slowly varying (in space) Reynolds stress tensor was addressed as 'quasi-homogeneous' flow by J. C. R. Hunt and coworkers. Very recently, this approach yield revisiting Unstable (quasi-) Homogeneous Stratification (UHS) with many applications to atmospheric, oceanic, and astrophysical flows, not to mention the controlled fusion by inertial confinment. This problem can be introduced by the study of the turbulent mixing zone which results from the Rayleigh-Taylor instability. The first phase of the instability, when a heavy fluid (top) and a light fluid (bottom) begin to inter-penetrate, under gravity effect, is not considered. On the other hand, UHS is relevant for the further development of the mixing zone, when its thickness is sufficiently large, with the related dynamics of turbulent velocity and concentration field [5]. In this application, the mean flow characteristic is the (unsteady) thickness of the mixing zone, related to the gradient of the mean concentration, the counterpart of the Reynolds stress tensor is the vertical flux of (fluctuating) concentration, and horizontal spatial averaging is used.

The same context is illustrated by studies of planetary flows, in which linear response and feed-back from generalized Reynolds stresses are essential. The mean flow is extracted by zonal averaging, so that the mean velocity profile is a single meridional (from equator to poles) zonal velocity profile. The two-way coupling between the zonal-direction- dependent fluctuating velocity field includes essentially linear response for the mean → fluctuating action. Application to zonal jets in rapidly rotating planets is very encouraging, with illustration to Earth's atmosphere in [1].

A second round-table took place on November 21, just before the talks reported below, following a general assembly of the Henri Bénard PC. In addition to the topics detailed here, it was decided to promote more common research activities on environmental challenges in a large alpine area, from Lyon to Turin (e.g. the Institute for

Atmospheric Sciences and Climate, with our collegue Antonello Provenzale).

Finally, the workshop gathered about 30 participants, with three doctoral and post-doctoral students. It is labeled **W2013-14**, and ERCOFTAC sholarships are acknowledged.

Contents of the talks

Michael Le Bars (IRPHE, Marseille, France) presented 'Understanding exchanges across turbulent/stratified zones interfaces' [8].

In many geophysical and astrophysical situations, a turbulent fluid layer is separated from a stably stratified one by a relatively sharp but deformable interface. Examples include the convective and radiative zones in stars, the atmospheric convective layer and overlying stratosphere, the Earth's outer core... While motions in the stratified layer are often neglected, it actually supports oscillatory motions called gravito-inertial waves (GIW) excited by Reynolds stresses, entropy fluctuations and interface deformations associated with the turbulence. Besides their direct observation as for instance in asteroseismology, GIW transport energy, carry momentum, break, mix and are thus essential for accurate models of global climate and solar or core dynamics. Global integrated models including length scales and time scales spanning many orders of magnitude are required to fully address motions in turbulent and stratified zones and to understand the details of the highly non-linear couplings between rotation, meridional circulation, turbulence and waves: this is clearly very challenging from both analytical and numerical points of view. Here, we present results from two complementary laboratory experiments using water as a working fluid and salt or temperature to control the relevant buoyancy effects, allowing to address the whole range of relevant physical issues in simplified models. Both experiments are performed on a rotating table. In the first set-up, we take benefit from the unusual property of water that its density has a maximum value near 4oC to study its convective and oscillatory motions in a tank with a bottom boundary at about 0 C degree and a hotter upper surface. High precision local measurements of temperature fluctuations are performed simultaneously in the convective and stratified zones to produce the corresponding power density spectrum and probability density function. In the second set-up, a turbulent jet generated by injection of water impinges upon the interface between a uniform density layer and a stratified one of salted water. Precise velocity measurements are carried out non-intrusively using Particle Imaging Velocimetry in both regions. Our combined results show that (i) the interface acts as a filter which mostly allows for the passing of low frequency perturbations, while (ii) the further propagation of the excited waves in the stratified zone gives rise to a selective wave damping, focusing the transported energy and momentum around given frequency values corresponding to given propagation angles. We explain those results by simple analytical model, allowing their extension to natural configurations.

Denis Gillet (Observatoire de Haute Provence, France) presented the 'Shock waves and turbulence in stellar atmosphere'.[3]

The understanding of the 'missing temperature', called microturbulence by the astro-physicists, which appears when we want to modelize the width of stellar line profiles. In the framework of the two limiting turbulent regimes called 'incompressible' and 'pressure released', and expecting that the dissipation is negligible ('rapid distortion' or RDT case), it is shown that the turbulence amplification in the atmosphere of a radially pulsating star is not only due to the global compression of the atmosphere during the pulsation. Strong shock waves propagating from the deep atmosphere to the very low-density layers also play a role in the turbulence variation, especially when they become very strong i.e., hypersonic. The predicted turbulence amplification induced by the global atmospheric compression is consistent with the solenodial RDT. For shocks, the predicted turbulence amplification in the "pressure released" regime is overestimated with respect to stellar observations when the compression rate becomes larger than 2 which corresponds to a limit Mach number near 2. Thus, when radiative effects take place, the present turbulence amplification theory breaks down. A new approach is required.

Benjamin Favier (Cambridge and City University London) presented 'Rotating fluids and inertial waves: from fluid mechanics to astrophysics' [4].

Understanding the gravitational tidal interactions between two orbiting bodies is an important unsolved problem in astrophysics. It is often the case that one or more of the bodies involved in the interaction is wholly or partly composed of fluid layers, such as a star or giant planet, an ice giant with a thick atmosphere, or a terrestrial planet with deep ocean. The processes by which the orbits and spins of these bodies evolve due to tidal interaction are poorly understood. Since all astrophysical fluid bodies rotate, it is important to understand the effect that rotation has on the rates of tidal dissipation. This is particularly important because rotating flows support oscillatory motions called inertial waves. These waves are restored by the Coriolis force and can be excited by low frequency tidal forcing when the absolute value of the forcing frequency (in a frame rotating with the fluid) is less than twice the spin frequency of the body. The importance of these waves at contributing to tidal dissipation has been emphasised in recent years. In nearly adiabatically stratified convective regions, internal gravity waves are not supported and the excitation and dissipation of inertial waves might play a dominant role. We perform one of the first studies into the nonlinear evolution of tidally excited inertial waves in a uniformly rotating fluid body, exploring a simplified model of the fluid envelope of a planet (or the convective envelope of a solar-type star) subject to the gravitational tidal perturbations of an orbiting companion. Our model contains a perfectly rigid spherical core, which is surrounded by an envelope of incompressible uniform density fluid. By performing high-resolution numerical simulations, using a combination of pseudo-spectral and spectral element methods, we investigate the effects of nonlinearities, which lead to time-dependence of the flow and the corresponding dissipation rate. Angular momentum is deposited non-uniformly, leading to the generation of significant differential rotation in the initially uniformly rotating fluid, i.e. the body does not evolve towards synchronism as a simple solid body rotator. This differential rotation modifies the properties of tidally excited inertial waves, changes the dissipative properties of the flow, and eventually becomes unstable to a secondary shear instability provided that the Ekman number is sufficiently small. We finally discuss some limitations of our simplified model, and propose avenues for future research to better understand the tidal evolution of rotating planets and stars.

Tomás Tangarife (Ecole Normale Supérieure de Lyon) presented

'Kinetic theory of atmospheric jets.'

Turbulent geophysical flows have the property to develop self-organisation into large-scale coherent structures, namely zonal jets. The approach described here [1] allows to obtain an equation for these jets, as a mean flow equation, averaged over the zonal direction. On the other hand, the dynamics of the fluctuating flow, with its full zonal variability, reduces to linear dynamics. This linear approximation is shown to be valid in the asymptotic limit where the time scale of forcing (by the mean) is much larger than the inertial time scale. This result gives a useful theoretical justification of the 'rapid distortion' limit in a rather complex flow, and perfectly illustrates the two-way coupling mediated by the feedback from the meridional gradient of Reynolds stresses.

Aimie Moulin (Laboratoire des Ecoulements Géophysiques & Industriels, Grenoble) presented, with A. Wirth 'A drag-induced barotropic instability in air-sea interaction' [7].

They discuss a new mechanism that induces barotropic instability in the ocean. It is due to air-sea interaction with a quadratic drag law and horizontal viscous dissipation in the atmosphere. We show that the instability spreads to the atmosphere. The preferred spatial scale of the instability is that of the oceanic baroclinic Rossby radius of deformation. It can only be represented in numerical models, when the dynamics at this scale is resolved in the atmosphere and the ocean. The dynamics is studied using two superposed shallow-water layers, one for the ocean and one for the atmosphere. The interaction is due to the shear between the two layers. The shear applied to the ocean is calculated using the velocity difference between the ocean and the atmosphere and the quadratic drag law. In one-way interaction the shear applied to the atmosphere neglects the ocean dynamics, it is calculated using the atmospheric wind, only. In two-way interaction it is opposite to the shear applied to the ocean. In the one-way interaction the atmospheric shear leads to a barotropic instability in the ocean. The instability in the ocean is amplified, in amplitude and scale, in two-way interaction and also triggers an instability in the atmosphere.

Alexandre Pieri (Institute of Atmospheric Science and Climate, Turin, Italy) presented 'Cross helicity in baroclinic turbulence.'

Combined effects of rotation, stratification and shear are a common feature of geophysical fluid dynamics. The misalignment of vertical system rotation and spanwise mean-shear-vorticity induces a mean vorticity component in the streamwise direction, and this is exactly balanced by an additional buoyancy gradient in the horizontal direction. This is similar to the 'geostrophic front adjustment' in geophysical flows. Accordingly, combination of both vertical and additional horizontal mean stratification results in tilting the isopycnal lines, triggering the baroclinic instability. The analysis of Salhi & Cambon [12] in the above context is continued here using high-resolution DNS and an original analogy with cross-helicity, defined in magnetohydrodynamics, with analysis of aligment properties [9]. From the three basic frequencies, 2Ω (system vorticity), S (vertical shear rate) and N (Brünt-Väisälä frequency for vertical stratification), are defined the Richardson number $Ri = N^2/S^2$ and the baroclinicity parameter $\epsilon_B = S\Omega/N^2$, which control the baroclinic instability. With respect to the stratified shear case without Coriolis effect, the limit for instability is shifted from $Ri \sim 0.1$ to $Ri = 1$. Finally, a dramatic transient growth is studied for Ri slightly larger than $Ri = 1$, in connection with bypass transition, using a generalized 'vortex-wave' decomposition [2]. In the most recent study emphasised in the talk [9], a detailed analysis of probability density function for the (baroclinic counterpart) of cross-helicity is provided. A net preference for positive cross-helicity is shown to be related to a new aligment mechanism. This is crucial for understanding the dynamics of buoyancy driven flows.

References

[1] F. Bouchet, C. Nardini & T. Tangarife (2013), 'Kinetic theory of jet dynamics in the stochastic barotropic and 2D Navier-Stokes equations,' *J. Stat. Phys.* **153**, 4, 572–625.

[2] D. Chagelishvili, A. G. Tevzadze, G. Bodo and S. S. Moiseev (1997), 'Linear mechanism of wave emergence from vortices in smooth shear flows,' *Phys. Rev. Lett.* **79**, 3178.

[3] Y. A. Fadeyev & D. Gillet (2004), 'The structure of radiative shock waves,' *Astronomy & Astrophysics* **420**, 423-435.

[4] B. Favier, A. J. Barker, C. Baruteau & G. I. Ogilvie (2014), 'Non-linear evolution of tidally forced inertial waves in rotating fluid bodies,' *Monthly Notices of the Royal Astronomical Society*, first published online, doi: 10.1093/mnras/stu003.

[5] B. -J. Gréa (2013), 'The rapid acceleration model and growth rate of a turbulent mixing zone induced by Rayleigh-Taylor instabilities,' *Phys. Fluids* **25**, 015118.

[6] G. Lesur & J. C. B. Papaloizou (2009), 'On the stability of elliptical vortices in accretion discs,' *Astronomy & Astrophysics* **498**, 1.

[7] A. Moulin & A. Wirth (2014), 'A drag induced dynamic instability in air-sea interaction,' *Journal of Physical Oceanography* **44** (2), 733–741.

[8] S. Perrard, M. Le Bars, P. Le Gal (2013), 'Experimental and numerical investigation of internal gravity waves excited by turbulent penetrative convection in water around its density maximum', *in Studying Stellar Rotation and Convection (M.-J. Goupil et al. eds.), Lecture Notes in Physics* (865), 239-257.

[9] A. Pieri, F. S. Godeferd, C. Cambon, B. Dubrulle & S. Thalabard (2014), 'On cross-helicity in rotating homogeneous shear-stratified turbulence', *Phys. Rev. Letters*, to appear.

[10] R. Rogallo (1982), 'Numerical experiments in homogeneous turbulence,' *NASA Tech. Mem.* 81315.

[11] P. Sagaut & C. Cambon, *Homogeneous Turbulence Dynamics*, 2008, Camb. U. Press, New York.

[12] A. Salhi & C. Cambon (2006), 'Advances in RDT, from rotating shear flows to the baroclinic instability', *J. Appl. Mech.*, **73**, 449-460.

[13] A. Salhi, T. Lehner, F. S. Godeferd & C. Cambon (2013), 'Wave-vortex mode coupling in astrophysical accretion disks under combined effects of radial and vertical stratification,' *The Astrophysical Journal* **771**, 103, 1–22.

JMBC Course on Combustion 2013

J.A. van Oijen

Eindhoven University of Technology, the Netherlands

October 29 - November 1, 2013
Eindhoven University of Technology Eindhoven, the Netherlands

Organized by:

- dr.ir. J.A. van Oijen (TU Eindhoven),
- prof.dr. L.P.H. de Goey (TU Eindhoven),
- prof.dr. D.J.E.M. Roekaerts (TU Delft)

With contributions of:

- dr.ir. R.J.M. Bastiaans (TU Eindhoven),
- dr. N. Dam (TU Eindhoven),
- prof.dr. Dreier (TU Darmstadt),
- prof.dr. L.P.H. de Goey (TU Eindhoven),
- dr.ing. R.T.E. Hermanns (OWI - RWTH Aachen)
- dr.ir. W. de Jong (TU Delft),
- dr.ir. J. Kok (U Twente),
- dr.ir. J.A. van Oijen (TU Eindhoven),
- prof.dr. D.J.E.M. Roekaerts (TU Delft),
- dr.ir. L.M.T. Somers (TU Eindhoven),
- dr. M.J. Tummers (TU Delft).

Objective

The objective of this 4-day course is to bring the participants to the forefront of modern computational and experimental methods for premixed and non-premixed gaseous combustion processes, by giving insight into the underlying physical/chemical principles and mathematical descriptions. Starting from the governing equations for chemically reacting flows, state-of-the-art models are derived for laminar and turbulent flames, by means of which their physical and chemical behavior are analyzed. Computational issues for modeling these systems are discussed as well.

A further focus is on the use of laser-diagnostic methods, such as LIF, Raman, CARS, and PIV, to measure local species concentrations, temperatures and flow velocities in high-temperature, chemically reacting flow systems. Practical applications are studied for a number of examples, such as engines, gas turbines and furnaces. The theory is tested and illustrated with numerical exercises using a code for modeling 1D-flame structures.

Fifth Edition 2013

The fifth edition of the J.M. Burgers Centre course on combustion, which was held under auspicien of ERCOFTAC, can be looked back upon with a very satisfactory feeling. Twenty-three people, most of them PhD students from Dutch and foreign universities, attended the course but also some participants from industry were present.

The course was given by 10 teachers from 5 different universities and covered a variety of subjects, ranging from fundamentals to applications. The course started with an introduction to combustion by Dr. van Oijen. He gave an overview of the various types of combustion, classifications, and applications. This introduction was followed by a lecture on the mathematical modelling of reacting flows. Dr. van Oijen presented the governing equations and discussed models for moleclular transport and chemistry. The numerical solution of these equations was briefly discussed. Hands-on experience is probably the best way to understand numerical modelling of flames. Therefore, the participants worked with a 1D flame code to study elementary flame structures. The theory of premixed and non-premixed laminar flame structures was checked against the numerical simulations.

In the afternoon, the focus was shifted from modelling to experimenting. Dr. Dam explained the basics of laser-diagnostics. Subsequently, the application of laser-diagnostics in measurements of temperature and species concentrations (Rayleigh, Raman, LIF) was discussed. Not only the theoretical aspects were presented, but also practical ones. Dr. Tummers explained the fundamentals and application of velocity measurement techniques (PIV, LDA) in combustion systems.

The second day started with a lecture by Prof. de Goey on the dynamics of premixed flames discussing flame stabilization, stretch effects and acoustics. This lecture was building on the basic modelling aspects treated the first day. Again the theory was accompanied by a numerical hands-on session, in which flame stretch effects were investigated by using the 1D flame code. The effect of flame stretch on the burning velocity was demonstrated and the influence of the fuel via the Lewis number was investigated. The afternoon was again dedicated to experimental techniques extending the basics discussed on the first day. Dr. Dreier gave an excellent overview of combustion diagnostics focusing on laser diagnostics and new developments in this field.

The morning of the third day was dedicated to turbulent combustion. Prof. Roekearts gave an introductory lecture, which explained the challenges and problems in the modelling of turbulent combustion. Various methods and models were presented in order to give

Figure 1: Prof. Roekaerts teaching spray combustion on the last day of the course

the course pariticpants an overview of the wide range of models. After this introductory lecture, Dr. Bastiaans and Dr. Somers presented flamelet methods for premixed and non-premixed turbulent combustion in the context of RANS and LES. Prof. Roekaerts closed the morning on turbulent combustion modelling by explaining the transported PDF method. In the afternoon, new combustion concepts such as FLOX, MILD, HiTAC and their application in furnaces and engines (PCCI) were presented. Prof. Roekaerts discussed the fundamental aspects, applications and the categorization of these combustion regimes. Dr. de Jong presented a recent study on MILD combustion in the Delft multi-burner furnace. Dr. Somers give an overview of the research on PCCI combustion in IC engines. In both these lectures, the numerical and experimental techniques explained in the earlier lectures were used to study these new combustion concepts in real devices. On the morning of the last day, the multi-physical character of combustion was treated. Prof. Roekaerts gave a lecture on radiation followed by a lecture on spray combustion. Dr. Hermanns discussed the evaporation of heavy liquid fuels and its relation to cool flames. Dr. Bastiaans treated the combustion of solid fuels. The course ended with a lecture on gas-turbine combustion by Dr. Kok with special attention to flame acoustics.

The participants received a well-balanced program containing theoretical and numerical modelling, experimental techniques and applications taught by specialists in the field. The lectures and course material provide the participants a good start for their research activities. Furhtermore, the informal character of the meeting and the ample opportunity to talk and discuss during coffee breaks, lunches and dinner, helped the participants to build up their network and to make new connections with people in the same field. Feedback from the participants indicated that the course was well appreciated, had a fine atmosphere, and was of high level. Some improvements were suggested for the registration procedure. This has been noted and we look forward to an equally successful sixth edition.

Course Material

Textbook quality lecture notes and all presentations are freely available from:
`http://www.combustion.tue.nl/`

REPORT ON THE 'CENTRE HENRI BÉNARD' PILOT CENTRE

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Figure 1: Henri Bénard (1874-1939) in his laboratory. French physicist, best known for his research on convection in liquids that now carries his name, Bénard convection (see an illustration on the other figure)

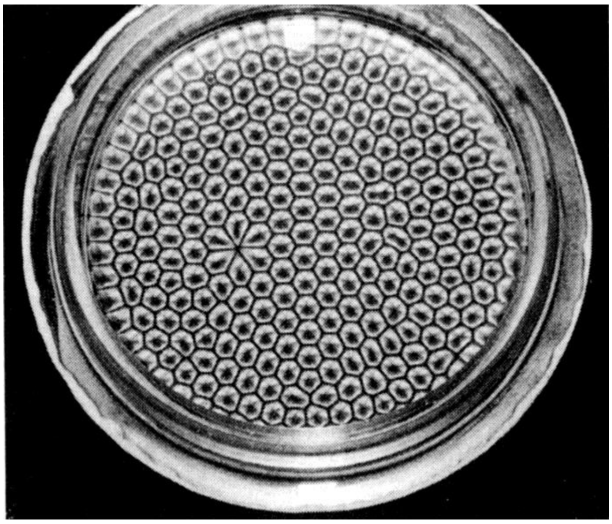

Figure 2: Typical convection cells

Brief History

The Lyon-Grenoble Pilot Centre ('PEPIT' for 'Pôle Pilote pour la Turbulence') was established in 1988, as one of four original ERCOFTAC centres (with Aachen, Lausanne and Turin). From 1988 to 1996, it took the form of a non-profit association under the French 'loi de 1901', with strict regulations and two governing bodies (administrative and scientific). The relationship between the members, both industrial and academic, is now determined by a written agreement, which is much simpler and in accord with the real role of the organisation. *This agreement will be renewed in 2015, and this is an opportunity to re-shape again our Pilot Centre.*

As a second important step, the Pilot Centre was relaunched as the 'Centre Henri Bénard' (CHB heeinafter), following a common strong motivation from the LMFA (Ecole Centrale de Lyon), the LEGI (Grenoble) and the LP-ENSL (Physics laboratory of Ecole Normale Supérieure de Lyon, who was not a member of the former PEPIT,) with the first general assembly in July 2006. This renaming [1] reflects a more integrated activity within the centre, which is geographically less limited than PEPIT to the region of Rhône-Alpes. The Centre Henri Bénard is also open to institutions which are thematically close and not located in Grenoble or Lyon. The 'Institut Jean Le Rond d' Alembert' in Paris joined the new CHB from the very beginning. Dassault-Aviation remains the only industrial partner, but contacts are in progress with other ones, this will be rediscussed in the following, in the last section devoted to future activities.

The last report for 'PEPIT' appeared in the ERCOFTAC bulletin in 2004; the first report for the CHB appeared in 2009. This is the second one.

Purpose and Focus

The aims of the 'Centre Henri Bénard' are foremost to promote results of fundamental research for industrial or other aplications. This wants to be done at three levels: First, communications between the research members will be increased to invoke and promote collaborations inside the Pilot Centre. Second, the results are promoted on a national level, to increase their visibility for future applications, be it industrial or others (*e. g.* geophysical). Third, the tight collaboration of the different laboratories produces one of largest scientific communities studying turbulence, and therefore will be used to create an internationally known 'label' to promote the work of the 'Centre Henri Bénard' (CHB hereinafter) worldwide. Turbulence and interactions is the main theme of research of the CHB, with all its special properties such as energy cascades, intermittency, anisotropy, in Eulerian as in Lagrangian frame works. The list of main themes, has evolved since the last report, and is updated as follows:

- Incompressible turbulence subjected to strong energy and anisotropy production, as in sheared and unstably stratified turbulence, from theory to practical modelling
- Compressible turbulence including shock/turbulence interaction

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[1] The name of Henri Bénard was first suggested by Christophe Baudet. Furthermore it was confirmed that pionnering experimental studies of wakes, with visualizations and movies, were carried out by Henri Bénard in the University of Lyon in the early twentieth century.

- Turbulence interacting with weakly reacting scalars
- Interactions of turbulence with inertial particles and bubbles
- Turbulence and waves, with effects of rotation, stratification, aero-acoustics, MHD and plasmas.
- Specific effects of confinement, with theoretical (as in wave turbulence theory) and numerical studies using Immersed Boundary Conditions and penalisation techniques
- Contribution to very high performances computations, using numerical platforms shared by different laboratories

In this updated list, the first theme evolved rapidly for two years, and is very promising for the future; The last two themes are rather new and their importance is increasing. The CHB could be the 'hard core' of a much larger regional research centre, dealing with environment, transport, process engineering and/or energy.

List of PC Members

- DASSAULT Aviation
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  https://www.dalembert.upmc.fr/ijlrda/
  Contact: Pierre Sagaut
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  http://www.ens-lyon.fr/PHYSIQUE/
  Contact: Thierry Dauxois
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  17, rue des Martyrs
  38054 Grenoble Cedex 9
  https://www-drmfmc.cea.fr/sbt/
  Contact: Bernard Rousset

Cooperation and Joint Research

The CHB is satisfactorily active in organising workshops, conferences and Summerschools, as well as supporting several Special Interest Groups (SIGs), as discussed in the next sections. On the other hand, the members have their own activities. Only those activities which could be really better integrated in joint research via the CHB are mentioned below.

Important CFD activities are developed by our industrial partners, for flows or flow/structure interactions in complex geometry, in which only moderate resolutions (coarse grids) are tractable. Practical CFD tools range from RANS to LES (or VLES), with zonal models and hybrid (e.g. RANS/LES) computations. Main applications in CEA Grenoble deal with pipe flows in which heat transfer is a crucial problem; another one is long-term storage of waste material involving heat transfer between metal and concrete, with prediction of aging. With the recruitment of the SBT lab., the study of cryogenic turbulence remains an exciting topic in the CHB, with access to high Reynolds number turbulence and novel experimental approaches ... and a new challenge for LES.

LES of semi-complex flows remains an important activity In LEGI and especially in IJLRA, FRT (Fluides Réactifs et Transfers) group. Simple shear flows (plane channel, Couette flow, rotating or not) are revisited in the LMFA (Faouzi Laadhari) using very high resolution DNS. These activities are connected with experimental and theoretical studies of both turbulent and transitional (by-pass transition) shear flows in the LMFA group 'Turbulence et Stabilité'. Common research between the FRT group of Pierre Sagaut (IJLRA) and the LMFA was not sufficiently supported in the past period, but many domains could be covered in a near future, with uncertainty modelling for CFD — a very strong point in FRT —, theory and modelling for aeroacoustics. The new position of Pierre Sagaut at Université Aix-Marseille will modify our partnership with IJLRA, enforcing a more direct collaboration with his team. Development of the platform LABs, with tractable use of Lattice Boltzmann Modelling (LBM), follows from Pierre Sagaut's impulse. It is in progress in the CHB, especially in LP-ENSL and LMFA, with Emmanuel Lévèque and collaborators.

Important topics in almost all the LEGI teams concern environmental and geophysical flows. Density-stratified flows with and without rotation are particularly addressed in the LEGI. Such flows involve internal waves, gravity, inertial and inertia-gravity, which interact with the nonpropagating, vortical, motion. These flows are subject to instabilities, barotropic and baroclinic. In the LMFA team 'Ondes et Turbulence', the wave-vortex concept is more a mathematical decomposition to analyse linear and nonlinear interactions in rotating stratified flows, using high resolution DNS and sophisticated (anisotropic, multimodal, spectral) statistical models (EDQNM, Wave-Turbulence).

The ANR (French Research Agency) contract 'ANISO' (2009 - 2012) resulted in integrated collaboration on strongly anisotropic flow, especially dominated by rotation [3, 4].

Several experimental studies are developed in the LEGI in the geophysical context, and the moving of Louis Gostiaux in 2012 from LEGI to LMFA is reinforcing the full LEGI / LMFA / LP-ENSL collaboration in this context (e.g. [5]).

Joint reaserch develops in magnetohydrodynamics and plasmas, with a linkage to the worldwide ITER project for fusion by magnetic confinment [6]. In addition to the ANR project SiCoMHD, the DYPFORC (iMUST) regional project focuses on the forcing of a large scale velocity field in a plasma. The ultimate goal of the project is to develop efficient stirring mechanisms in order to generate a large-scale driven turbulent flow in a plasma vessel. This project involves both LMFA and LP-ENSL, with DNS and experiments in progress.

Participation in SIGs

SIG in which CHB was Moderately Active

SIG 1. Large eddy simulations Some members of the LEGI (Grenoble) of the LMFA (Lyon) and of the IJLRA (FRT group, Paris) are individually very active in LES, as recalled in the previous section, but the CHB was only marginally involved in the specific activities of the SIG.

SIG 5. Atmospheric Flow, Turbulence and Dispersion The group of complex flows in LMFA is involved (Richard Perkins) as well as the LEGI (Chantal Staquet, J. P. Chollet). Both urban pollution and pollution in alpine valleys are adressed in a regional project. Lagrangian aspects, with absolute and relative dispersion (one-particle, two-particle, and more) also are very important topics within SIG 35, with related studies in the LMFA team 'Ondes et Turbulence': Theoretical and numerical tools range from RDT (Rapid Distortion Theory), KS (Kinematic simulation, including possibly RDT linear dynamics) to full high resolution DNS. The SIG was recently reshaped, with Vincenzo Armenio as coordinator, and the involvement of CHB members must be re-actived.

SIG 12. Dispersed Turbulent Two Phase Flows There was no strong involvement of the former PEPIT in this SIG. Jean Bataille (LMFA), however, was a very active member of the organising committee, and the present directors of LMFA and LEGI contributed to promote applications to two-phase flows into the CHB activities on turbulence, especially in incorporating multiscale information (*e.g.* PPF (Regional project) and DSPET ANR contracts shared with LP-ENSL.)

SIG 14. Stably stratified and Rotating Turbulence

The LMFA ('Ondes et Turbulence' team) and LEGI are both very active in this area. Wave-vortex interactions are studied in both teams, by means of statistical theories/models and high resolution DNS, up to 2048^3 DNS in LMFA now. Applications to environmental and geophysical flows are more developed at LEGI than LMFA, including (inertia-gravity) wave-breaking, tidal flows, interactions with the polar vortex, etc. In the past this area attracted a lot of interest from EDF (Chatou centre) with excellent joint research within PEPIT; this is no longer the case, due to the retargeting of EDF. On the other hand, joint collaboration under the auspices of the Spanish Centre (José Redondo) remains active. For instance, CHB representants attended the Summerschools in Vilanova, not to mention common studies supported by the 'Marenostrum' supercomputer in Barcelone.

SIG 15. Turbulence Modelling

The LMFA ('Turbulence multi-échelle' team) is involved in this SIG. With respect to SIG 35, this SIG is closer to industrial flow applications, including RANS, URANS, LES/RANS hybrid models, but there exist significant overlapping. Advanced statistical models using Fourier space or additional (with respect to the Reynolds stress tensor) 'structure-based' tensors, which have a degree of complexity intermediate between 'single-point' and 'two-point' closures, are important in both SIG's 15 and 35.

SIG 36. Swirling Flows

LMFA is involved in this SIG, with particular interest from the teams 'Stabilité et transition' and 'Ondes et turbulence'. Important studies deal with confined rotating flows subjected to mean compression, monotonic or periodic (Julian Scott and coworkers, LMFA). Another study concerns the stability, transition, and control of flow on a rotating disc (Benoît Pier, LMFA). The problem of vortex breakdown was also addressed, in collaboration with ONERA (DAFE dept., Laurent Jacquin). The Euromech Colloquium 525 was organised in 2011 at LMFA around these themes.

SIG 4: Turbulence in compressible flows

PEPIT was strongly involved in launching this SIG, then the regretted Pierre Comte acted as coordinator from 2000 to 2011, with the main topic: Large scale structure in compressible flows in relation with mixing, noise and structural efforts. The new coordinator, Joern Sersterhenn, will organise a meeting in coming fall, in Rome, La Sapienza, for retargeting this SIG, with attendance of the CHB.

CHB was very active, or expected to be more active in near future, in the following SIG's.

SIG 35: Multipoint Turbulence Structure and modelling

'Two-point closures' (or TPC), initially the core of this SIG, is perhaps too restricted a topic, and the range of activities in fact covers various multiscale, anisotropic and multimodal aspects, possibly in connection with strong body forces and mean gradients. Inhomogeneity, especially induced by solid walls, is being addressed, from wave turbulence theory to practical models and use of LBM numerical techniques. In addition to classic TPC used in statistical theory, linear theory ('Rapid Distortion Theory' or RDT, stability analysis), weakly nonlinear theory (e.g. wave-turbulence), low-dimension dynamical models, shell-models, Lagrangian models for dispersion (e.g. using Kinematic Simulation, or KS, RDT, nonlinear TPC), have to be considered from a pragmatic view-point, in order, for instance, to suggest guidelines to improve simpler models (single-point closures in RANS, subgrid scale models for LES). Use of symmetry groups (Lie group, Martin Oberlack), in agreement with both dynamical equations and boundary layers, remains very promising. To a lesser extent $So3$ symmetry group and spherical harmonic expansions, which begin to be used in the 'intermittency and scaling' community, will be revisited in connection with fully anisotropic spectral description used for more than two decades in the team 'Ondes et Turbulence', LMFA. The above list of tools is not exhaustive. A special theme issue recently appeared (ERCOFTAC Bulletin 88, September 2011.)

SIG 42: Synthetic Turbulence Models

This SIG was established by ERCOFTAC in February 2007, and coordinated by Franck Nicolleau (Sheffield) from now on. First scientific events were often jointly organised with SIG 35 and/or CHB. This SIG is now autonomous and very active, a special theme issue recently appeared (ERCOFTAC Bulletin 92, September 2012.)

SIG 39: Aeroacoustics

Christophe Bailly (LMFA) is the new coordinator from 2011, and the SIG is very active, with more contribution from the CHB planed for a better integration of joint research and scientific events. A special theme issue recently appeared (ERCOFTAC Bulletin 90, March 2012)

Co-Organisation Of Summer Schools And Workshops

- Winter School 'New Challenges in Turbulence Research I', Ecole de Physique des Houches, February 21-26, 2010. The event, launched by the CHB, was organized by M. Bourgoin, C. Cambon and B. Rousset around four themes: Cryogenic turbulence, new experimental concepts, strong anisotropy, and inertial particles in real configurations. A periodicity of two years was maintained.

- Summer school 'Turbulence and mixing in compressible flows III', Oléron, 2010, mainly organized by Pierre Comte and Jean-Paul Dussauge. Report by Penelope Moffatt is included in the France West Pilot Centre Report by Luminita Danaila (ERCOFTAC Bulletin 91, June 2012)

- Euromech Colloqium 525 'Instabilities and transition in three-dimensional flows with rotation', organised by B. Pier and F. S. Godeferd, Ecole Centrale de Lyon, June 21-23, 2011 (Report in the ERCOFTAC Bulletin 89, December 2011.)

- Workshop 'ASTROFLU II', organised by C. Cambon, A. Pieri & F. S. Godeferd, LMFA, December 15, 2011 (ERCOFTAC Bulletin 91, June 2012.) The first ASTROFLU workshop on astrophysics and turbulence took place in December 11 & 12, 2008. Points of contact are investigated in both astrophysics and fluid mechanics communities, with common progresses in effects of compressibility, rotation, stratification, shear and MHD.

- Spring School 'New Challenges in Turbulence Research II', organised by A. Naso, M. Bourgoin, A. Pumir & B. Rousset, Ecole de Physique des Houches, March 18-23, 2012

- Summer school 'Morphology and Dynamics of Anisotropic Flows', 2011, organised by F. S. Godeferd, L. Danaila & J. -B. Flor, Cargese, Corsica, 18-30 July 2011 (Report in ERCOFTAC Bulletin 91, June 2012.)

- Euromech Colloquium 542 'Progress in Statistical Theory and Pseudo-Spectral DNS', organised by C. Cambon & A. Tomboulides, Ecole Centrale de Lyon, January 15-18 2013 (ERCOFTAC Bulletin 95, June 2013)

- Workshop 'ASTROFLU III', organised by C. Cambon, A. Naso, F. S. Godeferd & A. Cadiou, LMFA, November 19-20, 2013 (to appear in ERCOFTAC Bulletin.)

- Spring School 'New Challenges in Turbulence Research III', organised by M. Gibert *et al.*, Ecole de Physique des Houches, March 16-21, 2014 (to appear in ERCOFTAC Bulletin.)

- Colloquium on triadic closures and beyond, organised by C. Cambon and P. Sagaut, IJLRA, Paris, June 5-6, 2014 (Report to be done.)

Future Activities

As a regional centre, a special effort will be devoted to mutualise information and facilities in the Rhonalpin area. Common scientific meetings and seminars will be accessible to the three labs (LMFA, LEGI, LP-ENSL) via 'visioconferences'. A larger integrated Alpin partnership, with Turin, will take place, from studies of atmospheric dispersion, pollution, to climate prediction.

Re-oriented partnerships will involve the team CEA,DAM,DIF (from the French Atomic Center), with a very promising recent collaboration (e.g. [1, 2]), and the new team of Pierre Sagaut in Marseille. This could favour as well a better collaboration among the three French Pilot Centres.

Emphasis will be placed on the use of numerical platforms (e.g. Labs code for Lattice Boltzmann Modelling), and related development of industrial partnership. On the other hand, the most sophisticated theoretical tools used for the prediction of turbulence, e.g. in connection with SIG 35 activities, will be adapted to practical models in Engineering and Environment. The outstanding numerical ressources of the CEA team are essential for this objective, as well as its profound experience in buoyant and compressible flows.

An 'ERCOFTAC-FRANCE day' is planed as a satellite meeting of the next ERCOFTAC Autumn Festival, in CORIA, October 15-16 , for a general discussion of all aspects and plans common to the three French Pilot Centres. A more detailed plan for future activities of the CHB will be presented there.

References

[1] A. Burlot, B. -J. Gréa, F. S. Godeferd, C. Cambon & J. Griffond, 'Spectral modelling of high Reynolds number unstably stratified homogeneous turbulence', *J. Fluid Mech.* submitted.

[2] C. Cambon & B. - J. Gréa (2013),'The role of directionality on the structure and dynamics of strongly anisotropic flows', *J. of Turbulence*, 14:1, 50-71.

[3] C. Cambon, L. Danaila, F. S. Godeferd & J. F. Scott (2013), 'Third-order statistics and the dynamics of strongly anisotropic turbulent flows', *J. of Turbulence*, 14:3, 121-160.

[4] M. Duran-Matute, J. -B. Flor, F. S. Godeferd, C. Jause-Labert (2013), 'Turbulence and columnar vortex formation through inertial-wave focusing', *Phys. Rev. E*, **87**, 04100.

[5] M. Mercier, L. Gostiaux, K. Helfrich, J. Sommeria, S. Viboud, H. Didelle, S. Ghaemsaidi, T. Dauxois & T. Peacock (2013), 'Large-scale, realistic laboratory modeling of M2 internal tide generation at the Luzon strait', *Geophys. Res. Lett.*, 2013GL058064.

[6] J. A. Morales, W. J. T. Bos, K. Schneider & D. C. Montgomery (2012), 'Intrinsic rotation of toroidally confined magnetohydrodynamics', *Phys. Rev. Lett.* **109**, 175002.

[7] P. Sagaut & C. Cambon, *Homogeneous Turbulence Dynamics* (2008), Camb. Univ. Press, New York.

ERCOFTAC Workshops and Summer Schools

Title	Location	Date	Coordinators	Organiser
9th International SPHERIC Workshop	Paris, France	3-5/06/2014	Le Touze, D. Violeau, D.	SIG40
Progress in Wall Turbulence: Understanding and Modelling	Villenuve d'Ascq, France	18-20/06/2014	Stanislas, M.	SIG15
Synthetic turbulence, wavelet and CFD	Nuremberg, Germany	30/06-01/07/2014	Delgado, A.	SIG42
IMA7 - 7th Conference of the International Marangoni Association	Vienna,Austria	23-26/06/2014	Kuhlmann, H.	PC Alpe-Danube-
TNF12 – 12th International Workshop on Measurement and Computation of Turbulent Flames	Pleasanton, CA, USA	31/07-02/08/2014	Dreizler, A.	SIG 28
Particles in Flows	Prague, Czech Republic	25-31/08/2014	Bodnar, T.	PC Czech Repub
TURBINTERMARS 2014 - International conference on turbulence and interactions in Marine Systems	Trieste, Italy	18-20/11/2014	Armenio, V.	SIG5

ERCOFTAC Summer Schools, Courses - 2014

Title	Location	Date	Coordinators	Organiser
Cavitation instabilities and rotordynamic effects in turbopumps and hydroturbines	Udine, Italy	7-11/06/2014	d'Agostino, L. Salvetti, M. V.	SIG12 Co: CISM
Summer School on Advanced Instability Methods for Complex Flows	Sao Carlos, Brazil	15-19/09/2014	Hanifi, A.	SIG33

Programme of Events 2014

Dr. Richard E. Seoud

Open for Registration ⟹ `richard.seoud-ieo@ercoftac.org`

Computational Aeroacoustics, II

9-10 October 2014, GE, Munich, Germany
Fees: Members €640, Non-members €995
Course Coordinator: Prof. Christophe Bailly,
EC Lyons, France

9-10 October 2014, GE, Munich, Germany Fees: Members 640, Non-members 995 Course Coordinator: Prof. Christophe Bailly, EC Lyons, France This course is intended for researchers in industry and in academia including Ph.D. Students with a good knowledge in fluid mechanics, who would like to build up or widen their knowledge in the field of aeroacoustics (modeling, computational tools and industrial applications). It will first provide a comprehensive overview of recent insights of aeroacoustics theories (Lighthills analogy and vortex sound theory, extensive hybrid approaches and wave extrapolation methods, duct acoustics). A number of practical problems involving the coupling between CFDs results and CAA will be also thoroughly discussed (e.g. how design a mesh size for aeroacoustics applications using large eddy simulation, inclusion of mean flow effects via hybrid formulations such as the acoustic perturbation equations, presence of surfaces, aeroacoustic couplings,) and realistic applications performed by the instructors (aeronautics, car industry, propulsion, energy,) will be discussed. Advanced computational aeroacoustics methods will be also presented as well as what we can learn from the direct computation of aerodynamic noise. Finally, specific topics reflecting participant interests will be discussed in a final round table session.

Fluid Structure Interaction with Impact on Industrial Applications

16-17 October 2014, EDF, Chatou-Paris, France
Fees: Members €540, Non-Members €875
Course Coordinator: Dr. Marianna Braza, IMFT, France, & Dr. Elisabeth Longatte,
EDF, France

The scope of this course is to bring together the academic and industrial scientific communities in Fluid Dynamics (FD) and Structural Mechanics (SM) on this topic, in order to address the state-of-the-art methods in theoretical, experimental and numerical approaches. The course contents involve fluid-structure interaction phenomena associated with solid structure rotation, fluid-structure coupling involving instabilities, vibrations, separation. A principal goal is to enable researchers in the FSI community with state-of-the-art methods for analysing the fluid-structure interaction phenomena and to come up with quality achievements and best practice guidelines for efficient and secure design. The domains of applications cover a large spectrum including flow and movement induced vibrations in hydrodynamics and in aerodynamics. The course will be composed of ten Key Note Lectures. A large audience coming from the above academic and industrial communities is previewed.

Mathematical Methods and Tools in Uncertainty Management and Quantification IV

4-5 November 2014, AREVA, La Defense, Paris, France
Fees: Members: €640, Non- Members: €995
Course Coordinator: Prof. Charles Hirsch,Em. Vrije Universiteit Brussel,
Pres. Numeca Int'l, Belgium

Uncertainty quantification is a new paradigm in industrial analysis and design as it aims at taking into account the presence of numerous uncertainties affecting the behaviour of physical systems. Dominating uncertainties can be either be operational (such as boundary conditions) and/or geometrical resulting from unknown properties, such as tip clearances of rotating fan blades or from manufacturing tolerances. Other uncertainties are related to models, such as turbulence or combustion should also be considered, or to numerical related errors. Whether bringing a new product from conception into production or operating complex plant and production processes , commercial success rests on careful management and control of risk in the face of many interacting uncertainties. Historically, chief engineers and project managers have estimated and managed risk using mostly human judgment founded upon years of experience and heritage. As the 21st century begins to unfold, the design and engineering of products as well as the control of plant and process are increasingly relying on computer models and simulation. This era of virtual design and prototyping opens the opportunity to deal with uncertainty in a systematic formal way by which sensitivities to various uncertainties can be quantified and understood, and designs and processes optimized so as to be robust against such uncertainties.

After several successful Courses on the applications of UQ, ERCOFTAC decided, based on requests from many participants, to focus the present Course on the mathematical methodologies of UQ, enabling the participants to develop an in-depth understanding of the main methods such as: spectral, including polynomial chaos methods; methods of moments and Monte-Carlo methodologies. The lectures will be given by worldwide recognised experts in these fields, who will cover the basics as well as representative applications.

Best Practice For Engineering CFD III (3rd delivery)

26-27 November, 2014, CMT-Motores Trmicos, Valencia, SPAIN
Fees: Members €640, Non- Members €995
Course Coordinator: Prof. Charles Hirsch,Em. Vrije Universiteit Brussel,
Pres. Numeca Int'l, Belgium

This course is targeted atrelatively new and improving CFD analysts in engineering industries and consultancies. It providesthe knowledgeto effect a step-change in the accuracy and reliability of CFD practices across a range of engineering applications relevant to the power generation, aerospace, automotive, built environment and turbomachinery sectors amongst others. This course is directly relevant to engineering applications of CFD for single-phase, compressible and incompressible, steady and unsteady,turbulent flows, with and without heat transfer. Much of the content will also be relevant to even more complex engineering applications. The main focus will be on RANS applications, but an introduction to the special considerations required by LES and hybrid methods is also given. The course provides the means for CFD analysts to significantly enhance their use of commercial and open-source CFD software for engineering applications. In particular, it provides guidance on best practices and highlights common pitfalls to be avoided.

ERCOFTAC / SIG 42

10th Conference on Synthetic Turbulence Models

Synthetic turbulence, wavelet and CFD

4th and 5th September 2014, Erlangen, Germany
LSTM University of Erlangen-Nuremberg, Germany

Organisers

A. Delgado, LSTM University of Erlangen-Nuremberg, Germany
Long Zhou, LSTM University of Erlangen-Nuremberg, Germany
F. Nicolleau, University of Sheffield, UK
T. Michelitsch, Université Pierre et Marie Curie, France
A. Nowakowski, University of Sheffield, UK

Website

http://www.sig42.group.shef.ac.uk/SIG42-10.htm

Audience

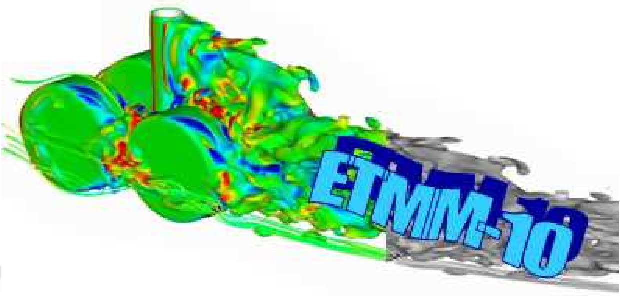
This conference on synthetic turbulence organised by ERCOFTAC/SIG 42 is open to anyone interested in flow modeling and/or "synthetic turbulence" including (but not restricted to) Kinematic Simulation (KS). More fundamental talks on particle dispersion in turbulent flows or fluid dynamics are also welcome.

Motivation

KS is widely used in various domains, including Lagrangian aspects in turbulence mixing/stirring, particle dispersion/clustering, and last but not least, aeroacoustics. Flow realisations with complete spatial, and sometime spatio-temporal, dependency, are generated via superposition of random modes (mostly spatial, and sometime spatial and temporal, Fourier modes), with prescribed constraints such as: strict incompressibility (divergence-free velocity field at each point), high Reynolds energy spectrum. Recent improvements consisted in incorporating linear dynamics, for instance in rotating and/or stably-stratified flows, with possible easy generalisation to MHD flows, and perhaps to plasmas. KS for channel flows have also been validated. However, the absence of "sweeping effects" in present conventional KS versions is identified as a major drawback in very different applications: inertial particle clustering as well as in aeroacoustics. Nevertheless, this issue was addressed in some reference papers, and merits to be revisited in the light of new studies in progress. A further goal of this conference is to bring people from different disciplines together. In particular recent emerging fractal approaches have the potential to provide the framework for the construction of new synthetic turbulent flows. Interdisciplinary contributors are especially invited to contribute.

Related topics

Synthetic models of turbulence (KS and others), Lagrangian aspects of turbulence, vortex dynamics and structure formation, particle dispersion/clustering, vorticity and multiphase flows, vortex methods, DNS/LES and related techniques, turbulent flows and multiscale (fractal) shapes



ETMM 10

10th International ERCOFTAC Symposium on Engineering Turbulence Modelling and Measurements

17 - 19 September 2014
Don Carlos Resort, Marbella, Spain

Symposium website: www.etmm10.info

Organizers
Prof. Michael Leschziner, Chairman, Imperial College
Prof. Wolfgang Rodi, Co-chairman, Karlsruhe Institute of Technology
The ETMM Series of Conferences

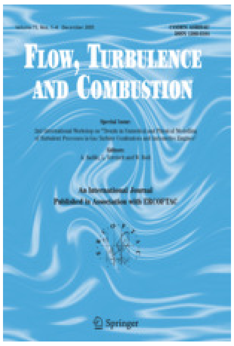
Aims

The ETMM series of symposia aims to provide a bridge between researchers and practitioners in Flow**,**Turbulence and Combustion by reporting progress in the predominantly applied, industrially-oriented areas of turbulence research.This includes the development, improvement and application of statistical closures, simulation methods and experimental techniques for complex flow conditions that are relevant to engineering practice; the modelling of interactions between turbulence and chemistry, dispersed phases and solid structures; and the symbiosis of modelling, simulation and experimental research.

Major Themes

- Novel modelling and simulation methods for practically relevant turbulent flows, including interaction with heat and mass transfer, rotation, combustion and multi-phase transport
- Novel experimental techniques for flow, turbulence and combustion and new experimental studies and data sets
- Innovative applications of modelling, simulation and experimental techniques to complex flows, industrial configurations and optimisation problems
- High-speed aerodynamics, acoustics and flow control with emphasis on turbulence processes
- Modelling, simulation and measurements of environmental and bio-spherical flows

Abstracts are invited for submission by **15th January 2014**, via the Symposium Website.
Final manuscripts and updated abstracts are due by **1st July 2014**.



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An International Journal Published By Springer
In Association With ERCOFTAC

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Best Practice Guidelines for Computational Fluid Dynamics of Dispersed Multi-Phase Flows

Editors

Martin Sommerfeld, Berend van Wachem
&
René Oliemans

The simultaneous presence of several different phases in external or internal flows such as gas, liquid and solid is found in daily life, environment and numerous industrial processes. These types of flows are termed multiphase flows, which may exist in different forms depending on the phase distribution. Examples are gas-liquid transportation, crude oil recovery, circulating fluidized beds, sediment transport in rivers, pollutant transport in the atmosphere, cloud formation, fuel injection in engines, bubble column reactors and spray driers for food processing, to name only a few. As a result of the interaction between the different phases such flows are rather complicated and very difficult to describe theoretically. For the design and optimisation of such multiphase systems a detailed understanding of the interfacial transport phenomena is essential. For single-phase flows Computational Fluid Dynamics (CFD) has already a long history and it is nowadays standard in the development of air-planes and cars using different commercially available CFD-tools.

Due to the complex physics involved in multiphase flow the application of CFD in this area is rather young. These guidelines give a survey of the different methods being used for the numerical calculation of turbulent dispersed multiphase flows. The Best Practice Guideline (BPG) on Computational Dispersed Multiphase Flows is a follow-up of the previous ERCOFTAC BPG for Industrial CFD and should be used in combination with it. The potential users are researchers and engineers involved in projects requiring CFD of (wall-bounded) turbulent dispersed multiphase flows with bubbles, drops or particles.

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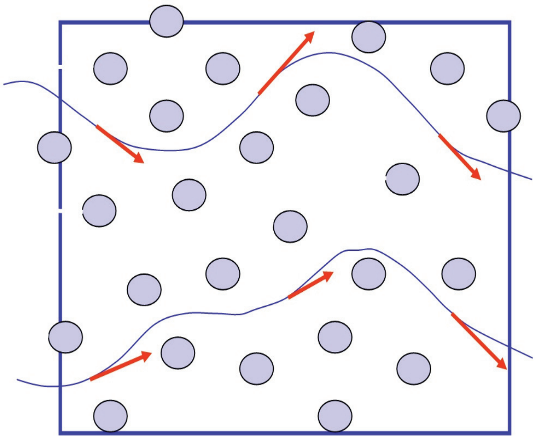

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