MFGA-IDT2 workshop: Astrophysical and geophysical fluid mechanics: the impact of data on turbulence theories

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D. Schertzer[1,2] **and E. Falgarone**[3]

[1]Laboratoire de Météorologie Dynamique, Université P. et M. Curie, case 99, 4 Pl. Jussieu, F-75252 Paris Cedex 05, France
[2]On leave to Laboratoire de Modélisation en Mécanique, Université P. et M. Curie, case 126, 4 Pl. Jussieu, F-75252 Paris Cedex 05, France
[3]Radioastronomie Millimetrique, Ecole Normale Superieure 24 rue Lhomond, F-75005 Paris, France

1 Facts about the Workshop

This workshop was convened on November 13-15 1995 by E. Falgarone and D. Schertzer within the framework of the Groupe de Recherche Mécanique des Fluides Géophysiques et Astrophysiques (GdR MFGA, Research Group of Geophysical and Astrophysical Fluid Mechanics) of Centre National de la Recherche Scientifique (CNRS, (French) National Center for Scientific Research). This Research Group is chaired by A. Babiano and the meeting was held at Ecole Normale Superieure, Paris, by courtesy of its Director E. Guyon.
More than sixty attendees participated to this workshop, they came from a large number of institutions and countries from Europe, Canada and USA. There were twenty-five oral presentations as well as a dozen posters. A copy of the corresponding book of abstracts can be requested to the conveners.
The theme of this meeting is somewhat related to the series of Nonlinear Variability in Geophysics conferences (NVAG1, Montreal, Aug. 1986; NVAG2, Paris, June 1988; NVAG3, Cargese (Corsica), September, 1993), as well as seven consecutive annual sessions at EGS general assemblies and two consecutive spring AGU meeting sessions devoted to similar topics. One may note that NVAG3 was a joint American Geophysical Union Chapman and European Geophysical Society Richardson Memorial conference, the first topical conference jointly sponsored by the two organizations. The corresponding proceedings were published in a special NPG issue (Nonlinear Processes in Geophysics 1, 2/3, 1994). In comparison with these previous meetings, MFGA-IDT2 is at the same time specialized to fluid turbulence and its intermittency, and an extension to the fields of astrophysics. Let us add that Nonlinear Processes in Geophysics was readily chosen as the appropriate journal for publication of these proceedings since this journal was founded in order to develop interdisciplinary fundamental research and corresponding innovative nonlinear methodologies in Geophysics. It had an appropriate editorial structure, in particular a large number of editors covering a wide range of methodologies, expertises and schools. At least two of its sections (Scaling and Multifractals, Turbulence and Diffusion) were directly related to the topics of the workshop, in any case contributors were invited to choose their editor freely.

2 Goals of the Workshop

The objective of this meeting was to enhance the confrontation between turbulence theories and empirical data from geophysics and astrophysics fluids with very high Reynolds numbers. The importance of these data seems to have often been underestimated for the evaluation of theories of fully developed turbulence, presumably due to the fact that turbulence does not appear as pure as in laboratory experiments. However, they have the great advantage of giving access not only to very high Reynolds numbers (e.g. 1012 for atmospheric data), but also to very large data sets.
It was intended to:
(i) provide an overview of the diversity of potentially available data, as well as the necessary theoretical and statistical developments for a better use of these data (e.g. treatment of anisotropy, role of processes which induce other nonlinearities such as thermal instability, effect of magnetic field and compressibility...),
(ii) evaluate the means of discriminating between different theories (e.g. multifractal intermittency models) or to better appreciate the relevance of different notions (e.g. Self-Organized Criticality) or phenomenology (e.g. filaments, structures),
(iii) emphasise the different obstacles, such as the ubiquity of catastrophic events, which could be overcome in the various concerned disciplines, thanks to theoretical advances achieved.

3 Outlines of the Workshop

During the two days of the workshop, the series of presentations covered many manifestations of turbulence in geophysics, including: oceans, troposphere, stratosphere, very high atmosphere, solar wind, giant planets, interstellar clouds... up to the very large scale of the Universe.
The presentations and the round table at the end of the workshop pointed out the following:
- the necessity of this type of confrontation which makes intervene numerical simulations, laboratory experiments, phenomenology as well as a very large diversity of geophysical and astrophysical data;
- presumably a relative need for new geophysical data, whereas there have been recent astrophysical experiments which yield interesting data and exciting questions;
- the need to develop a closer intercomparison between various intermittency models (in particular Log-Poisson /Log Lévy models).
Two main questions were underlined, in particular during the round table:
- the behaviour of the extremes of intermittency, in particular the question of divergence or convergence of the highest statistical moments (equivalently, do the probability distributions have algebraic or more rapid fall-offs?);
- the extension of scaling ranges; in other words do we need to divide geophysics and astrophysics in many small (nearly) isotropic subranges or is it sufficient to use anisotropic scaling notions over wider ranges?

4 The contributions in this special issue

Recalling that some of the most useful insights into the nature of turbulence in fluids have come from observations of geophysical flows, Van Atta gives a review of the impacts of geophysical turbulence data into theories. His paper starts from Taylor's inference of the nearly isotropy of atmospheric turbulence and the corresponding elegant theoretical developments by von Karman of the theory of isotropic turbulence, up to underline the fact that the observed extremely large intermittency in geophysical turbulence also raised new fundamental questions for turbulence theory. The paper discusses the potential contribution to theoretical development from the available or currently being made geophysical turbulence measurements, as well as from some recent laboratory measurements and direct numerical simulations of stably stratified turbulent shear flows.
Seuront et al. consider scaling and multiscaling properties of scalar fields (temperature and phytoplankton concentration) advected by oceanic turbulence in both Eulerian and Lagrangian frameworks. Despite the apparent complexity linked to a multifractal background, temperature and fluorescence (i.e. phytoplankton biomass surrogate) fields are expressed over a wide range of scale by only three universal multifractal parameters, H, α and C_1. On scales smaller than the characteristic scale of the ship, sampling is rather Eulerian. On larger scales, the drifting platform being advected by turbulent motions, sampling may be rather considered as Lagrangian. Observed Eulerian and Lagrangian universal multifractal properties of the physical and biological fields are discussed.
Whereas theoretical models provide different scaling laws for fluid and MHD turbulent flows, no attempt has been done up to now to experimentally support evidence for these differences. Carbone et al. use measurements from the solar wind turbulence and from turbulence in ordinary fluid flows, in order to assess these differences. They show that the so-called Extended Self-Similarity (ESS) is evident in the solar wind turbulence up to a certain scale. Furthermore, up to a given order of the velocity structure functions, the scaling laws of MHD and fluids flows are experimentally indistinguishable. However, differences can be observed for higher orders and the authors speculate on their origin.
Dudok de Wit and Krasnosel'skikh present analysis of strong plasma turbulence in the vicinity of the Earth's bow shock with the help of magnetometer data from the AMPTE UKS satellite. They demonstrate that there is a departure from Gaussianity which could be a signature of multifractality. However, they point out that the complexity of plasma turbulence precludes a more quantitative understanding. Finally, the authors emphasise the fact that the duration of records prevents to obtain any reliable estimate of structure functions beyond the fourth order.
Sylos Labini and Pietronero discuss the problem of galaxy correlations. They conclude from all the recently available three dimensional catalogues that the distribution of galaxies and clusters is fractal with dimension $D \approx 2$ up to the present observational limits without any tendency towards homogenization. This result is discussed in contrast to angular data analysis. Furthermore, they point out that the galaxy-cluster mismatch disappears when considering a multifractal distribution of matter. They emphasise that a new picture emerges which changes the standard ideas about the properties of the universe and requires a corresponding change in the related theoretical concepts.
Chilla et al. investigate with the help of a laboratory experiment the possible influence of the presence of a large scale structure on the intermittency of small scale structures. They study a flow between coaxial co-rotating disks generating a strong axial vortex over a turbulent background. They show that the cascade process is preserved although strongly modified and they discuss the relevance of parameters developed for the description of intermittency in homogeneous turbulence to evaluate this modification.