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REVIEWS

Physics of Hot Plasmas. Edited by B. J. RYE and J. C. TAYLOR. Oliver and Boyd, 1970. 455 pp. £8.

This is a collection of lectures given by eleven distinguished plasma physicists at the ninth Scottish Universities' Summer School in Physics, which was sponsored by the Scottish Universities and NATO at Newbattle Abbey in August 1968. The aim of the school was to provide a course balanced between theory and experiment and to highlight some of the recent developments in plasma physics. With the great diversity of material contained in the volume there are few general observations that one can make, so I shall just describe the contents in general.

The first two chapters are on kinetic theory. The first by W. B. Thompson, contains *inter alia* a succinct account of the application of Boltzmann's equation to the calculation of transport coefficients. It is an excellent introduction to the subject. The second chapter by C. Oberman is somewhat more advanced, being based on the work of Klunontovich and Dupree on weakly turbulent plasmas. The reader is presented with very lengthy equations in which it is difficult to trace the physics, and the chapter is incomplete, lacking either practical formulae or comparison with experiment. R. J. Tayler's account of plasma waves and oscillations is a clear and comprehensive survey, providing a good introduction to the subject. And a similar comment applies to E. G. Harris's excellent review of plasma instabilities, but neither chapter contains any references to experiments.

In chapter 5, J. Killeen gives an account of some of the computational studies, for both fluid and kinetic models, that have been made of plasma behaviour. The importance of the 'computational physics' approach to the elucidation of instabilities in the non-linear phase is made clear. The next chapter on turbulence by M. G. Rusbridge is rather slight, considering the importance of the subject, but perhaps this reflects its difficulty and the incomplete nature of much of the theory. Experimental work is sadly lacking, as are also computational studies.

Chapters 7 (H. Völk) and 8 (J. W. M. Paul) on collisionless shocks cover the physics of this complicated and important topic in a reasonably comprehensive manner. These are the first chapters in which experiments are discussed at length, and Paul especially manages a good balance between experiment and theory. Chapters 9 (laser.produced plasmas) and 11 (light scattering experiments) by S. A. Ramsden deal mainly with experimental aspects. Chapter 11 is a good introduction to a newly developed diagnostic tool, which is particularly useful for investigating plasma turbulence.

The production and containment of high density plasmas is rather sketchily discussed by G. B. F. Niflett and the final chapter is an excellent survey of plasma diagnostics based on refractivity.

It is my opinion that too many expensive books covering conferences and schools, with a large number of authors writing disjoint and quite unco-ordinated chapters, are now being published. The 'balance between theory and experiment' aimed at is only partially achieved in that most of the authors reckon to deal entirely with one aspect or the other, reflecting the aptly named 'theoretical *divisions*' or 'experimental *divisions*' of plasma laboratories. However, this book does contain some excellent articles by distinguished plasma physicists, and is certainly worth adding to the plasma physics section of any library. It will be a most valuable introduction to advanced plasma physics for graduate students already familiar with the basic ideas of the subject.

L. C. WOODS

Clear Air Turbulence and its Detection. Proceedings of a Symposium held at Boeing Scientific Research Laboratories, Seattle, Washington, 14–16 August 1968. Edited by Y. H. PAO and A. GOLDBURG. Plenum Press, 1969. 542 pp. $22.50, £9.4.

General impression

As stated in the foreword to this conference proceedings, there has been a resurgence of interest in clear air turbulence (CAT) in recent years, the impetus for which has come primarily from aeronautical interests, but also from other disciplines, which for a variety of reasons, have become interested in free shear layer turbulence.† These other disciplines include meteorology, oceanography, fluid dynamics, radio and radar propagation and aeronomy.

This conference was of some importance for three reasons: (*a*) It is an example of inter-disciplinary communication at a comparatively early stage. Representatives from different disciplines had gathered together at one place and time but were still overcoming the customary barriers to effective communication. (*b*) The conclusions of the conference (stated in foreword) show that by and large, the right questions are being formulated and new ideas emerging. (*c*) Fresh impetus was given to further research activities, particularly those of an inter-disciplinary nature.

However, this review appears more than two years after the conference and some of the matter discussed is now somewhat dated (perhaps another measure of the significance of this conference?) and some of the papers were written from a rather isolated viewpoint without always clarifying their contribution to the subject as a whole. That this gives a somewhat disjointed impression does not detract in any way from the efficient job of editing achieved by Dr Pao and Dr Goldburg. For these reasons, this reviewer recommends that the most appropriate place for the volume is on the shelves of a reference (rather than a personal) library.

Subject matter

After an opening paper by Professor Fleagle on the significance of clear air turbulence to meteorology in which he mentions the (now well known, but still disputed) estimate that the rates of energy dissipation by internal friction and by boundary layer friction are comparable—an important theme which is

† Now generally thought to manifest itself in the atmosphere as CAT where it occurs on the appropriate scales.

not developed in any significant way in subsequent papers—the editors have divided the remainder into five main sections.

Part I. The Origin and Nature of CAT.

Part II. The Observational Results of CAT.

Part III. The Forecasting of CAT.

Part IV. The Detection of CAT.

Part V. Panel Discussion and Conclusion. (There were also accounts of the discussions after each individual paper.)

Part I

I found this section to be the most interesting as it contained some interesting theoretical ideas which (to my knowledge) had not appeared before the date of this conference. In particular, Badgeley (whose paper should perhaps be coupled with that of Reed in Part II) realizes the importance of identifying the synoptic scale processes responsible for producing a favourable environment for CAT to occur and be maintained from a *dynamical* viewpoint rather than from the conventional (dare one say traditional?) static approach, i.e. Badgeley considers the term $(1/Ri)\partial Ri/\partial t$ rather than Ri; if Ri is being reduced by some process, then turbulence will eventually occur whatever the critical value of Richardson number is; this latter value is seen to be of rather academic interest in this context.

Scorer adopts a similar approach on a smaller scale by discussing the processes reducing Ri following the motion in standing waves. He also considers forms of centrifugal instability which may lead to CAT that may occur in standing wave troughs or crests, or on a larger scale in flow in which the vertical component of absolute vorticity approaches zero.

Turning to the mechanism of transition, Pao describes his theoretical and laboratory work on the investigation of breaking of both standing (rotors) and travelling internal waves as a direct result of topography. Pao was led to suggest that severe CAT may be the result of a finite disturbance in tilted and non-parallel flows at high altitude. Wave breaking appeared to occur in flows of high Ri which led Pao to warn against the use of Ri for predicting the onset of clear air turbulence. I would suggest (with some diffidence) that the mechanism discussed by Pao forms an important exception to what is now thought to be the predominant mechanism of Kelvin–Helmholtz instability (KHI) which, of course, is dependent upon the Ri of the layer involved. Vertical velocities associated with KHI are of the order of the wind change across the layer and not the wind speed itself as in rotors.

Long, in a theoretical study, concludes that the curvature of the density profile is essential for maintaining turbulence remote from a boundary. He assumes constant heat and momentum fluxes in a non-rotating fluid which suggests his conclusions are more applicable to the ocean thermocline and atmospheric boundary layer, but may contribute to an understanding of the meso or even micoscale aspects of CAT and its feedback effect on its immediate environment. It is not obvious that fluxes of momentum and heat will be constant in CAT.

Faller and Kaylor's suggestion of the formation of longitudinal roll vortices with axes parallel to the thermal wind in an already turbulent layer is of interest but its relevance to CAT is not apparent (to me) as their theory assumed the basic flow to be geostrophic. Dynamical considerations suggest that CAT is most likely to be associated with highly non-geostrophic flow.

Part II

Most of this section is devoted to description of investigations of CAT with instrumented research aircraft. There were the usual collection of spectra with discussions of why they did (or did not) conform to the $-\frac{5}{3}$ power law, and the usual attempts (sometimes of doubtful validity) to establish empirical associations of CAT with features of the horizontal or vertical wind and temperature field. The net result did not appear to add significantly to the understanding of the basic problem. This appears to stem from two basic causes. (*a*) The organization which can fund and run an expensive aircraft programme is inevitably aviation oriented, with the result that the scientific direction of its flight projects is often inadequate due to a lack of meteorologists and/or fluid dynamicists of repute. (*b*) The sheer difficulty of using an aircraft effectively at all in CAT studies. In contrast to dye streak experiments in the ocean thermocline (where one can *see* the turbulence) a pilot is flying 'blindfold' and cannot observe developments of the flow on a time-scale comparable to the flight duration.

This is not intended to belittle or discourage further aircraft projects, rather the reverse; it may be that some of the new ideas now emerging may provide more positive scientific direction to these projects than in the past.

Other papers in this section include a description by Reed of widespread, persistent CAT in a region of marked upper frontogenesis, and the important point is made that 'widespread CAT is tied to and conditioned by the synoptic pattern'. Reed, and Businger in Part I, touch on the importance of the question of transfer of energy from the synoptic scale to CAT but do not develop this point to any significant extent.

The section ends with a paper by Fichtl, Camp & Vaughan on detailed wind and temperature profiles using high resolution radar and balloons 'with knobs on' (Jimspheres) to damp out aerodynamically induced gyrations of the balloon on ascent. Since the vertical resolution obtained was approaching 100 m—i.e. scales comparable to the characteristic thickness of CAT layers, the authors could perhaps have made some useful analysis of the distribution of Ri in thin layers and compared it with Ri defined over a thick layer ($\sim$ 2 km).

Part III

This section contains only two papers: Colson presented a further statistical analysis of the empirical association of synoptic features with CAT based on extensive data collected during an exercise organised in 1965 by the International Commission of Aviation Organizations. It was concluded that 'the differences in frequency of high level turbulence on land as compared to that over water was not as great as had been expected'. To what extent this result may be affected by aircraft avoidance procedures (e.g. of mountain wave conditions over the Rockies) is not discussed. The other paper by Collis, Endlich & Mancuso discussed various aspects such as computer techniques for forecasting probability of CAT encounter; the climatology of CAT; analysis of high resolution wind profiles (produces a spectrum of fluctuations in vertical wind speed which exhibits a -3-power law dependence); and the use of lidar for detecting wave motion in cirrus cloud (uses ice particles as reflecting source).

Part IV

This section commences with a realistic review by Atlas of the state-of-the-art in the detection field. His conclusion was that the use of powerful radar was proving an effective research tool, but that its operational possibilities were limited (although he includes an interesting costing exercise demonstrating the feasibility of a limited ground based operational system). Atlas was not optimistic about other methods of which the principal ones discussed were infra-red or microwave technique.

The section continued with papers on investigations of clear air echoes at high and low levels with radar, including one (Hardy, Glover & Ottersten) showing one of the first positive identifications of KHI billows in a clear atmosphere. Finally, there are a few papers on infrared and microwave techniques which do not (in my opinion) alter the poor outlook for airborne CAT detection in any way.

Part V

This consists of a Panel Discussion, in which members were asked to consider whether the proceedings were relevant to the problems of the aviation world; and a Floor Discussion in which the topics discussed were: the importance of non-stationary and inhomogeneous turbulence; the difficulty of observation and detection; and the importance of ordered motion.

W. T. Roach