FROM 90 TO 120 KM

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I. The Buoyancy Subrange After Bolgiano

In a stably stratified atmosphere, such as exists around 100 km, the buoyancy forces modify the turbulent spectrum; at large scales, the kinetic energy is seen to be associated predominantly with the horizontal components of the motion (BLAMONT and BARAT, 1967; BLAMONT *et al.*, 1968). Thus, the turbulent field has lost kinetic energy in the small wave numbers, but BOLGIANO (1959, 1962) has shown that this loss occurs over a wide range of scales. A consequence of this loss is the reduction in the rate of inertial transfer of turbulent energy across the spectrum, towards the high wave number end, with the result that the viscous dissipation rate ϵ may be smaller than the rate of generation of turbulent energy as given by the equations of conservation of energy. The possible difference between these two rates is a most significant characteristic of the stably stratified situation.

The kinetic energy extracted from the turbulent field is stored as density fluctuations, produced at a rate χ, which eventually break up into smaller scale components and finally achieves the same fate as that which is transferred through the spectrum inertially and dissipated by viscosity. Thus, the part of the kinetic energy of the velocity field, abstracted from the turbulence by the buoyancy, and which has created the density deviations, is converted to potential energy associated with the irregular density pattern. This energy stored in the irregularities is used for the vertical transport of mass against the force of gravity. In a steady state this transport has to be accompanied by heat transfer; the energy abstracted from the turbulence is expended to achieve a vertical transport of heat.

If the Reynolds number is sufficiently large, the spectrum may divide into three distinct subranges:

1. The buoyancy subrange, where the largest anisotropic eddies are influenced directly by the density stratification:
2. The inertial subrange, in which the anisotropy has been erased and the usual Kolmogorof theory is applicable; and
3. The dissipation subrange at the high wave number of the spectrum, where molecular effects dominate.

The first 2 subranges are separated by the wave number k_B

$$k_B \equiv \chi^{3/4}(g/\rho_0)^{3/2}\epsilon^{-5/4} \qquad (1)$$

ρ is the potential density, ϵ the dissipation rate, and g the gravity acceleration.

The second and third subranges are separated by the viscosity cutoff

$$k_d \equiv (\epsilon/\nu^3)^{1/4} \qquad (2)$$

ν is the kinematic viscosity.

It must be noted that in the buoyancy subrange ϵ is no longer a significant parameter since it is not synonymous with the rate of transfer of kinetic energy across the spectrum. However, the gravity forces and the density fluctuations have to be considered as significant parameters.

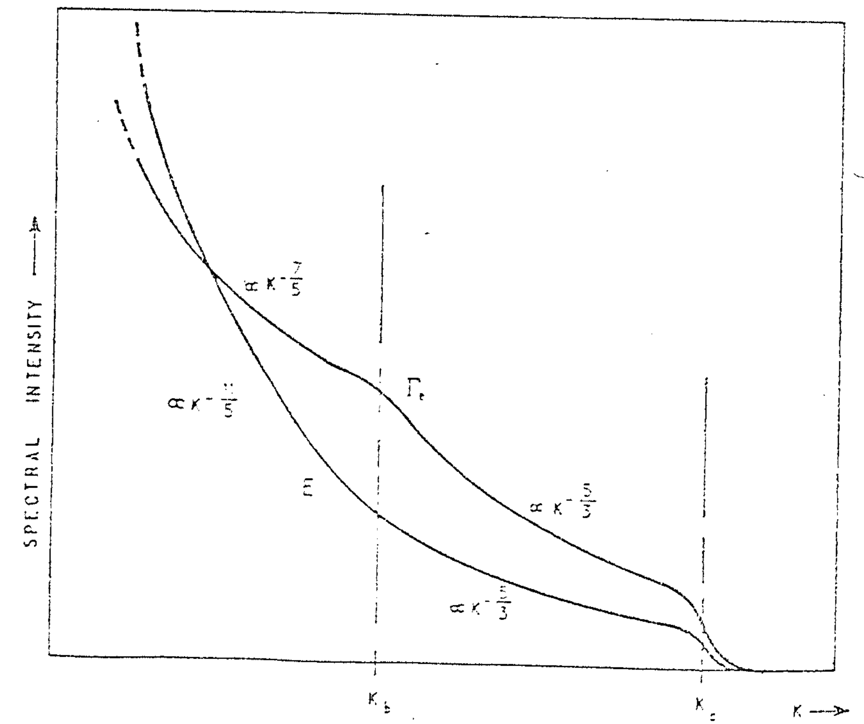


Figure 1 shows typical spectra computed by Bolgiano (E is the kinetic energy, Γ_e the density fluctuations spectrum).

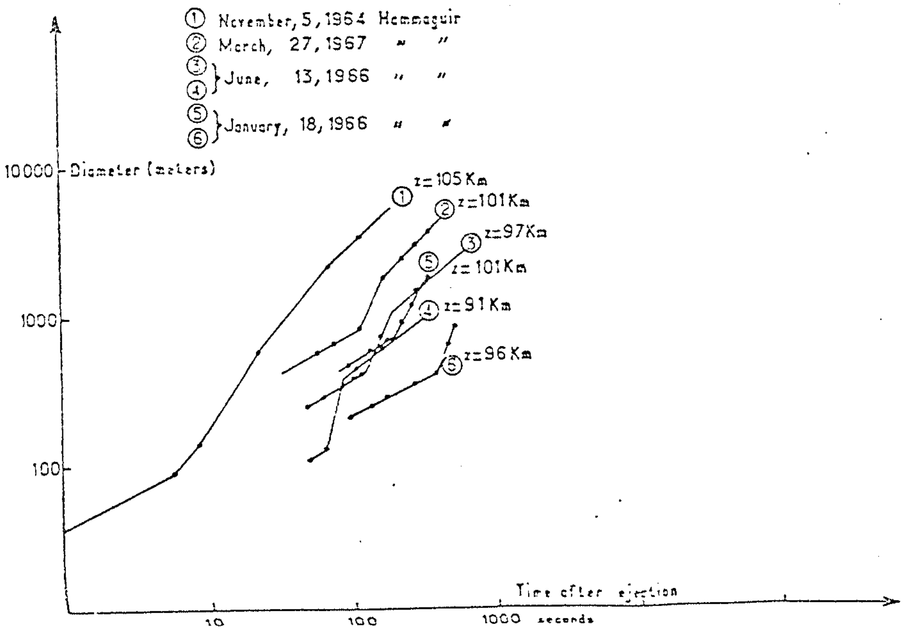
One important point is that k_B and k_d are influenced oppositely by the variation of the stability

$$s = \frac{\bar{\rho}\partial}{\partial z} = \frac{\rho}{T}\left(\frac{g}{R}\frac{\gamma-1}{\gamma} + \frac{dT}{dz}\right). \tag{3}$$

Increasing lapse of density tends to increase χ but to decrease ϵ; then k_B becomes larger when k_d becomes smaller. In a very stable situation, the inertial subrange may disappear completely and the whole structure would become anisotropic.

II. Measurements of Diffusion Coefficients

The variation of the diameter d of various Na clouds ejected from rockets at the same place was measured as a function of time (Hammaguir) and under the same situation (evening twilight). Each value is averaged over an altitude of 250 to 700 m in order to disregard the structure of the cloud. The measured diameter is what BARAT (1966) has called diameter at given contrast and is devoid of errors due to multiple scattering of light inside the cloud. Figure 2 shows the results.



1. For the 5 measurements below 100 km of altitude the variation is qualitatively the same:

a. immediately after ejection

$$\bar{d}^2 = ct \qquad c = \text{constant} \tag{4}$$

b. for values of d superior to a certain value d_1

$$\bar{d}^2 = c_1 t^{5\pm1} \qquad c_1 = \text{constant} \tag{5}$$

c. for values of d superior to a certain value d_2

$$\bar{d}^2 = c_2 t^2 \qquad c_2 = \text{constant} \tag{6}$$

2. In contrast, for the only value obtained at 105 km — and the best from the experimental point of view — the variation is different:

a. immediately after ejection (as before)

$$\bar{d}^2 = ct \qquad c = \text{constant} \tag{4'}$$

b. but later, for a value of d superior to a certain value d_1

$$\bar{d}^2 = c_3 t^3 \qquad c_3 = \text{constant} \tag{7}$$

3. A complete interpretation of these experimental facts is outlined below:

a. immediately after ejection the dispersion obeys a molecular law

b. the t^5 law can be deduced directly from the spectrum of the buoyancy subrange where $E(k) \simeq k^{-4/5}$ (Figure 1).

c. the t^3 law would correspond to a normal inertial or Kolmogorof subrange, but if the large values of the Reynolds number, necessary to the existence of such a subrange do not appear at 100 km, we can at least account for this t^3 law as due to a pseudo inertial subrange where there is equilibrium all along the spectrum between the external energy input and the dissipation losses.

d. the t^2 law can be related to the existence of a wind gradient. TCHEN (1953) has shown that in this case, the spectrum can take the shape $E(k) \simeq k^{-1}$ which would generate a t^2 law.

III. Interpretation

1. Altitudes below 100 km. Figure 3 represents the variation with altitude of the value of the discontinuities d_1 and d_2 which have been found in the diffusion of the Na clouds. On the same diagram the variation of the internal scale l_0 measured by TEITELBAUM (1964) has been plotted with the independent method of the structure functions of density of contaminant. This l_0, as defined by Teitelbaum, corresponds to the viscosity cutoff $1/k_d$. On the other hand, d_1 is the smallest dimension of the buoyancy subrange $d_1 \simeq 1/k_B$. The following experimental facts are obtained:

is nearly constant. The passage of wave like motions through this medium