2. ISUD
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"Time-Space characteristics of stratified shear layer from UVP measurements"

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Introduction

The flow pattern studied, is a stratified shear layer, consisting of a fresh water flowing on a salted water bed. The instabilities developing under the effect of the velocity gradient are mainly convective and thus develop with time and space during their propagation downstream. A European contract[1] on the estuaries of rivers constitutes the framework of this study, which deals in particular on the interaction between fresh water and sea water, zone in which occur, under the control of the hydrodynamic conditions, the main part of the physicochemical and biological phenomena. The measure of a velocity profile in space and time, as given by Ultrasonic Doppler Method (UVP device from Met-Flow), is well adapted to analysed the stability of such a flow and allows a comparison between the waves properties experimentally observed and the theoretical results given by a linear stability analysis.

Experimental conditions

The experiment is performed in a water channel schematically represented in figure 1. Two layers of equal depth (D=10 cm) and different densities are initially superposed and progressively sheared. The tunnel is 20 cm wide, 30 cm deep and 300 cm long. In the upper layer, the fresh water flows from the left side to the right side of the tunnel at a given flow rate corresponding to the mean velocity U_1. In the under layer, the salty water (initial concentration of NaCl : 10g/l) is coming from the right side and its flow rate is driven by a fixed pressure condition.

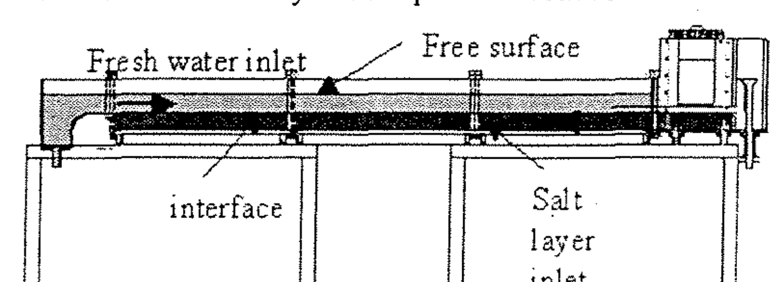

Figure1 : *Experimental loop*

[1] Financial supported by the European program MAS3-CT96-0049

The ultrasonic probe is placed horizontally in the meddle of the shear layer. The zero of the spac co-ordinate is located at 4 cm from the entrance. The specifications of the UVP used, are tabulate below:

Basic ultrasonic frequency	4 MHz
Spatial resolution	2.22 mm
Number of points in space	128
Number of points in time	1024
Acquisition frequency	16.39 Hz

Results

The development of the instabilities is illustrated figure 2. Rodamine is added to the salty wate which appears red in the laser sheet. The local gradient of concentration is still very steep, while th waves are developed enough for the expression of non linearity. The initial conditions $\{U_i, \rho\}$ of th layer are characterised by a global Richardson number $Ri_D = \frac{g}{\rho}\frac{\Delta\rho}{\Delta U_i^2} D$.

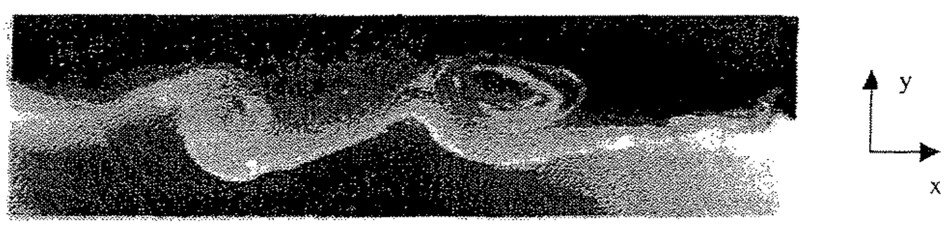

Figure 2 : *Interface between fresh and salty water under unstable conditions.*

The ultrasonic probe gives the longitudinal (horizontal) component $u(x,t)$ of the velocity. On example of the velocity field is given (Figure 3), for $Ri_D = 8.14$. The instabilities of th concentration gradient layer are clearly visible on the longitudinal component of the velocity. A large spectrum of wave length and celerity is observable, even some waves which propagat upstream. In order to measure the dispersion relationship $f(\omega,k) = 0$ the 2D Fourier transforr $\tilde{u}(k,\upsilon)$ of $u(x,t)$ is applied (Figure 4). $f(\omega,k) = 0$ is given by the line of the maximum of energy i the Fourier plan, which then appears as a very powerful tool for analysing the dynamics of th instabilities.

This experimental dispersion relationship is compared, with success, to the theoretical dispersio relationship, obtained from a linear stability model derived from the temporal model proposed b Lawrence et al. [1991] (Figure 6). The velocity and concentration profiles used are given figure 5.

Different analysis of the signal $u(x,t)$ are processed using the combinations between the variables of the 2 conjugated planes $P\{x,t\}$ and $\tilde{P}\{k,\nu\}$. Figure 7 gives an example of the measure of the spatial growth rate k_i of a given frequency υ using the plan $\tilde{\tilde{u}}(x,\upsilon)$.

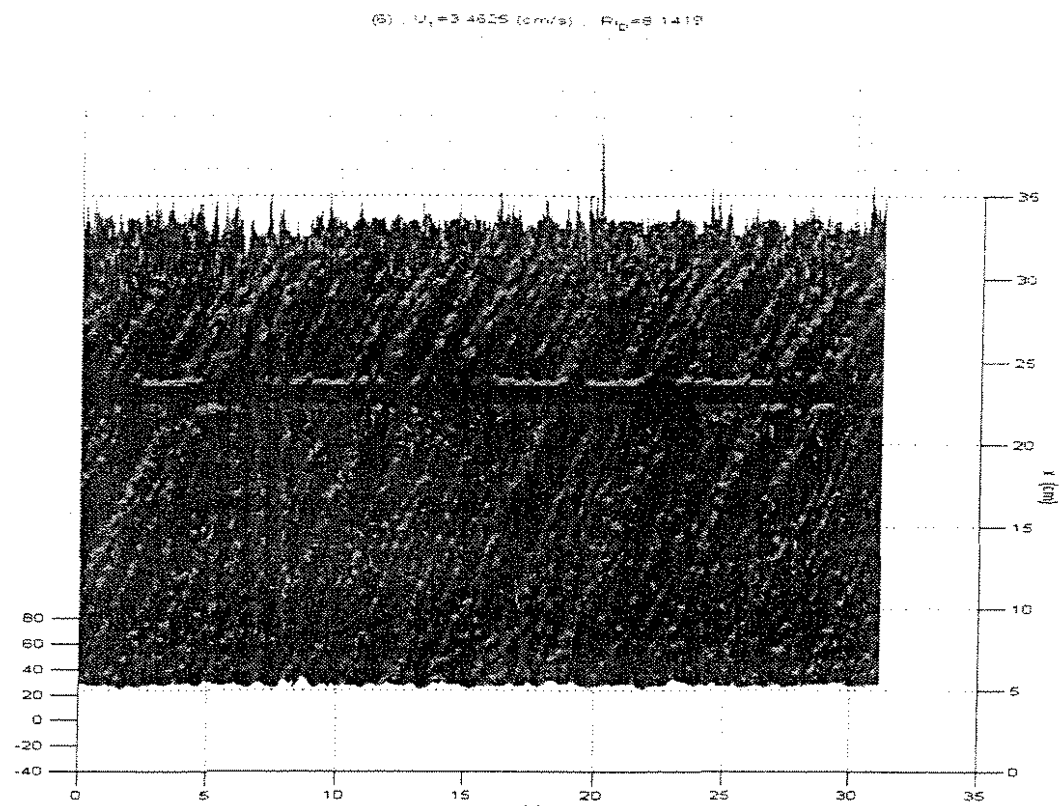

Figure 3 : *Velocity profiles versus time and space for a concentration of 10g/l NaCl and a velocity U_i=3.46cm/s.*

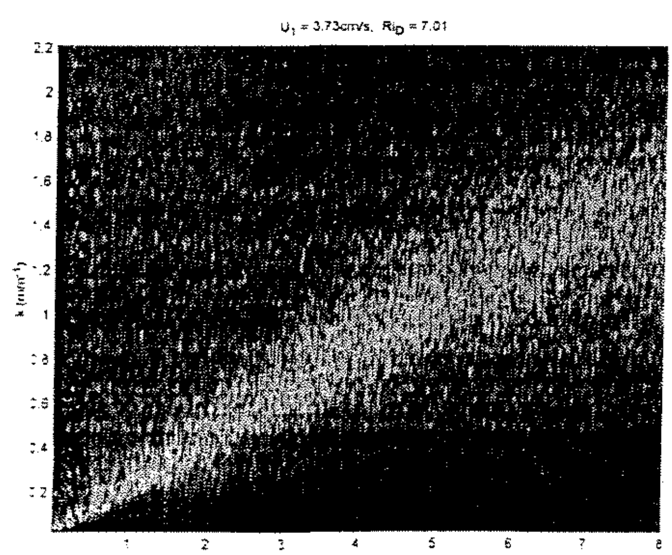

Figure 4: *Velocity amplitudes $\tilde{u}(k,\upsilon)$ in the Fourier plan.*

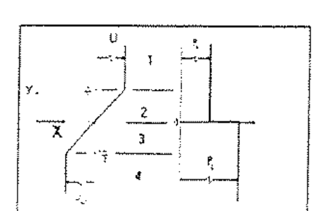

Figure 5: *From Lawrence 1991*

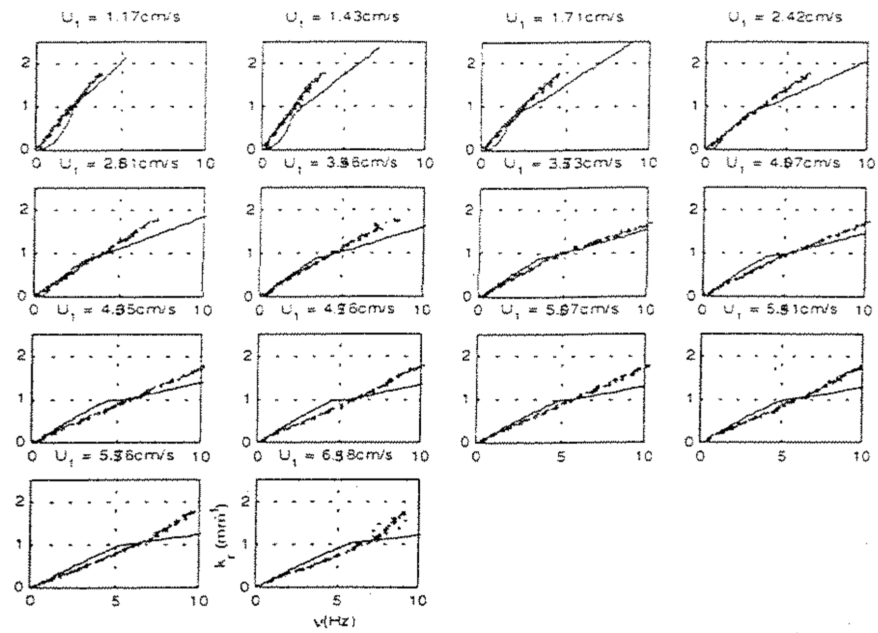

Figure 6: *Dispersion relationship for 14 values of U_1 corresponding to Ri_D={71.4,47.7,33.4,16.7,12.3,8.14,7.01,5.89,5.16,4.31, 3.79,3.33,2.94, 2.55} :- dotes results from the experimental Fourier plan,-line results from the linear stability analysis*

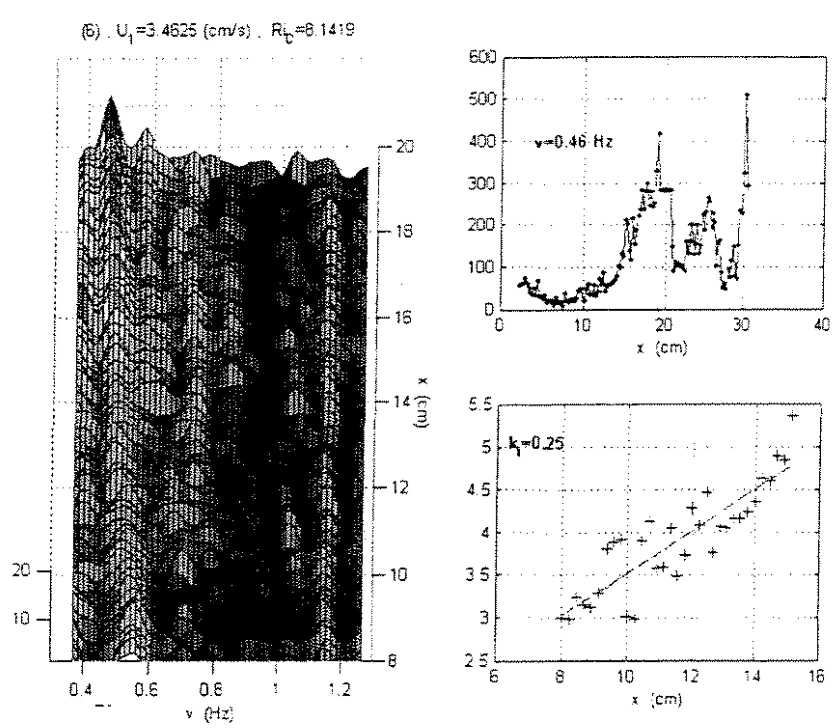

Figure 7 : *Measure of* the spatial growth rate k_i of a given frequency $\upsilon = 0.46\,Hz$ using the plan $\tilde{\tilde{u}}(x, \upsilon)$ for Ri_D=8.14.

Reference

Lawrence et al. J. of Fluid Mechanics, 1991.