Estimate of the Terms of Turbulent Kinetic Energy Budget Equation in a Stratified Flow in Wind Tunnel Experiments.

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Abstract

In the present work, we analyze flow experiments in a wind tunnel with thermal stratification. The objective of the study was to determine the influence of the thermal stratification on turbulence-related quantities. The experimental apparatus consisted of an aluminum plate inserted at the bottom surface of the test section of the wind tunnel. In order to create a thermal stratified layer the plate was cooled down to 5° C and the air entering the tunnel was kept at approximately 25°C. As wind speed increases such stable layer was soon destroyed. Data show that quantities such as temperature, variances, dissipation rates and turbulent fluxes are substantially reduced when the stratification is present. On the other hand, third and fourth order statistical moments, as well as the mean wind speed are little affected by the stratification.

Introduction

The study of flow over surfaces with varying temperature, or simply on surfaces whose temperature differs from the ambient temperature, have served as a challenge for scientists for many years. In this work, a special case of this type of flow will be studied: stratified flow over surfaces with uniform temperatures. In the present work, we analyze flow experiments in a wind tunnel with thermal stratification. The objective of the study was to determine the influence of the thermal stratification on turbulence-related quantities. The experimental apparatus consisted of an aluminum plate inserted at the bottom surface of the test section of the wind tunnel. In order to create a thermal stratified layer the plate was cooled down to 5° C and the air entering the tunnel was kept at approximately 25° C. As wind speed increases such stable layer was soon destroyed. Data show that quantities such as temperature, variances, dissipation rates and turbulent fluxes are substantially reduced when the stratification is present. On the other hand, third and fourth order statistical moments, as well as the mean wind speed are little affected by the stratification.

Materials and Methods

The experiments were conducted in the Aerodynamic Wind Tunnel 3 (TA-3), located in Divisão de Aerodinâmica (ALA / IAE) situated in the Departamento de Ciência e Tecnologia Aeroespacial.

The wind tunnel has the following characteristics:

- System of air recirculation (closed circuit);
- turbulent intensity of approximately 2%;
- a closed test section, rectangular with 500 mm high, 720 mm wide and 1200 mm long.

Two different techniques were used for data acquisition:

- Hot-wire anemometry;
- Particle Image Velocimetry (PIV).

The first was used to obtain the average values of speed and temperature. The PIV was used to obtain the instantaneous wind fields.

To generate a boundary layer a stratified, used a box alummio with water and ice, keeping the temperature of the bottom surface of the tunnel around 5°C.

Results

The results presented here are divided into two stages: - Those obtained with anemometry and the PIV.

Profiles estimated with anemometry

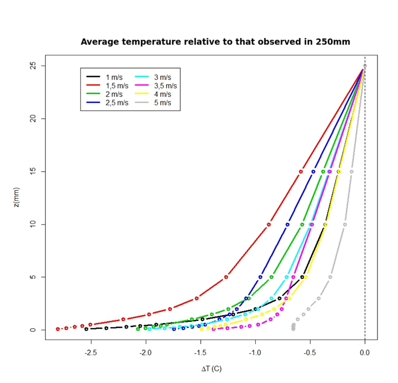

Figure 1: Average temperature profiles in the case of stratified by windaccording the caption.

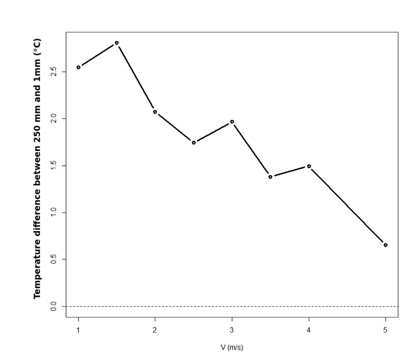

Figure 2: Temperature difference between the lowest and the highest level sampled based on the average wind.

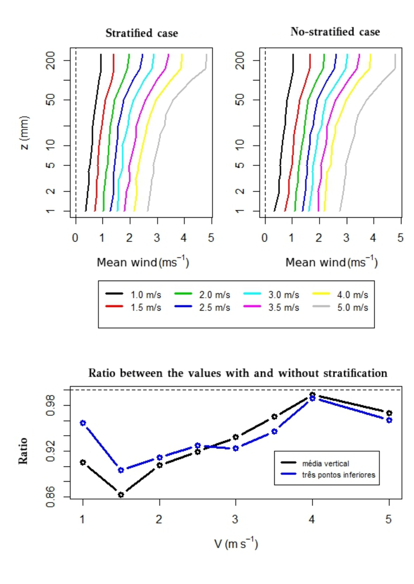

Figure 3: Vertical profiles of mean wind speed for cases with (top left) and without stratification (top right). The bottom pane shows the ratio between the values with and without stratification in average for the whole profile (black line) and the three low points of view (blue line).

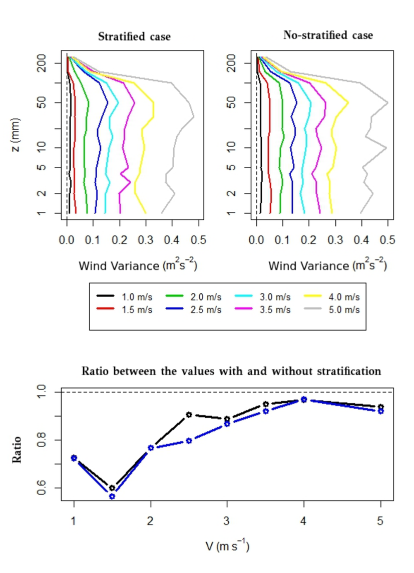

Figure 4: Upper panels show the profiles of the variance of the fluctuations of the longitudinal wind, for cases with (top left) and without stratification (top right). Bottom panel shows the ratio between the values with and without stratification in average for the whole profile (black line) and the three low points of view (blue line).

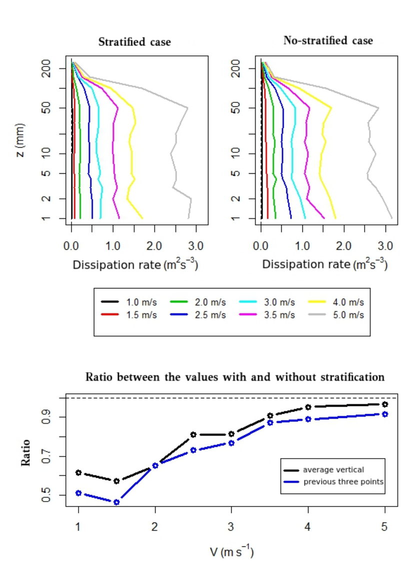

Figure 5: Upper panels show the profiles of the dissipation rate for cases with (top left) and without stratification (top right). Bottom panel shows the ratio between the values with and without stratification in average for the whole profile (black line) and the three low points of view (blue line).

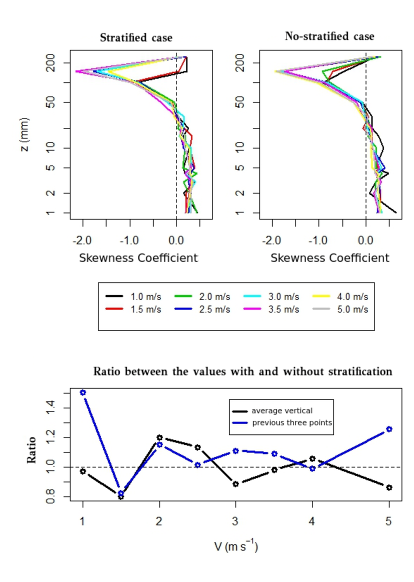

Figure 6: Upper panels show the profiles of the Skewness Coefficient for cases with (top left) and without stratification (top right). Bottom panel shows the ratio between the values with and without stratification in average for the whole profile (black line) and the three low points of view (blue line).

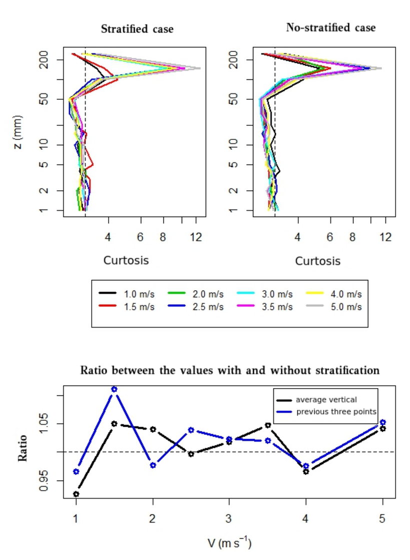

Figure 7: Upper panels show the profiles of the kurtosis for cases with (top left) and without stratification (top right). Bottom panel shows the ratio between the values with and without stratification in average for the whole profile (black line) and the three low points of view (blue line).

Profiles estimated with PIV

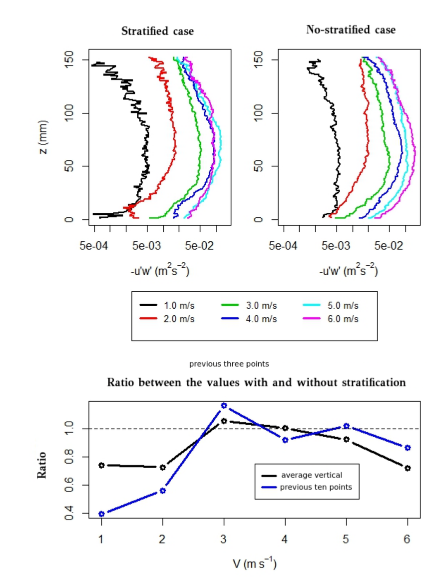

Figure 8: Upper panels show the profiles of the absolute values of vertical turbulent momentum flux for cases with (top left) and without stratification (top right). Bottom panel shows the ratio between the values with and without stratification in average for the whole profile (black line) and the ten lowest points of view (blue line).

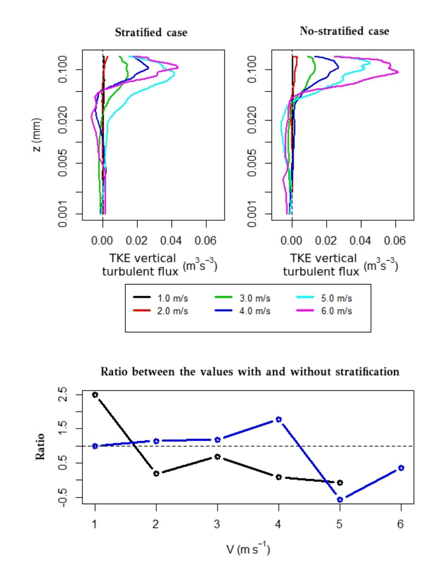

Figure 9: Upper panels show the profiles of the absolute values of TKE vertical turbulent flux for cases with (top left) and without stratification (top right). Bottom panel shows the ratio between the values with and without stratification in average for the whole profile (black line) and the ten lowest points of view (blue line).

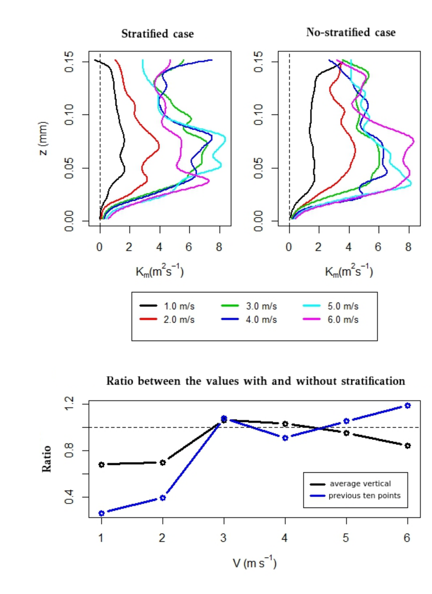

Figure 10: Upper panels show the profiles of the turbulent vertical diffusivity of momentum for cases with (top left) and without stratification (top right). Bottom panel shows the ratio between the values with and without stratification in average for the whole profile (black line) and the ten lowest points of view (blue line).

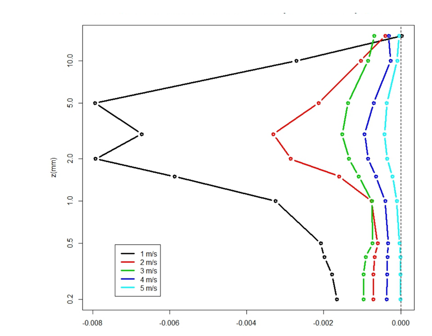

Figure 11: Terms of thermal destruction, estimated by the theory K, for different values of wind speed. In each case, the profiles were normalized by the average rate of dissipation vertically.

Conclusions

- Acontece a formao de uma camada estratificada, que rapidamente destruda por ventos de intensidade moderada.Even in the case of weak wind considered 1 m / s, the stratified layer that was formed could not be characterized as a very stable boundary layer, and Richardson number below 0.1;
- Although not a very stable stratification, other quantities associated with turbulent flow, in addition to the temperature profile showed substantial reduction in cases of weaker wind. Among these, we highlight the variances of the turbulent velocity fluctuations, the turbulent vertical momentum flux and coefficients of eddy diffusivity;
- Other quantities were not significantly affected by thermal stratification. Among these, the most relevant is the mean wind profile. Statistical moments of the third (skewness) and fourth order (kurtosis) also had no relevant changes between cases with and without stratification.

Acknowledgements

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