RESEARCH NOTE

LOW-LEVEL JETS AS MONITORED BY A TRI-AXIAL ACOUSTIC SOUNDER IN ILE–IFE, NIGERIA

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Abstract

A Sensitron tri-axial acoustic sounder has been used to monitor existence of low-level jets in the atmospheric boundary layer at Ile-Ife (7.5N, 4.5E), Nigeria. From about 400 sets of wind data processed for the period: June - September 1991, low-level jets of speeds ranging between 6.0 ms^{-1} and 12.50 ms^{-1}, were observed at the 220 m, 330 m, 650 m and 700 m heights. Also it was found that the jets were prominent only in the early hours, that is, 0400-0900 GMT, and in the late afternoons, 1400-1800 GMT.

The occurrences of the low-level jets are attributed to the influence of positive temperature gradient (i.e. the temperature inversion) on the wind speed as associated with the nocturnally varying phenomena.

1. Introduction

The jet stream is a current of very strong winds high above the earth's surface. Cases of low level-jets which otherwise is known as wind maxima, exist within the atmospheric boundary layer (ABL) have also been reported (Bonner, 1968; Findlater, 1971). Bonner (1968) has made a classification of the low-level jets to establish that in all cases, a wind maxima exists when the air flow peaks between 5.0 ms^{-1} and 20 ms^{-1} and it is persistent within the first 1.5 km. Findlater (1974) found that over India, the low-level jets are located in the same geographical area and are prominent within the stably stratified layer of the atmosphere (mostly in night time conditions).

The low-level jet is influenced significantly by the characteristics of the atmospheric boundary layer. Solar heating, nocturnal cooling of the land surface and friction between the flow and the surface (shear production) are factors stimulating the development of the atmospheric boundary layer. According to Incecik (1989), the transfer of momentum and heat fluxes between the atmosphere and the earth surface determines the strength of the jets or air-current (sheet) in the ABL. Thus, the state of the atmospheric boundary layer is necessary for the description of the wind maxima (low-level jets) (see Mahoney *et al.*, 1972).

The frequent classes of low-level jets can be interpreted as resulting from the turbulent mixing down of the flow aloft to the surface through a surface based inversion. Bedard *et al.* (1977) showed that most of the total numbers of significant low-level jets come from these events. Therefore, low-level jet is a significant phenomenon in itself, and it also has notable effects on the weather and weather-related operation such as landing and taking-off of aircrafts (Bonner, 1968). The low-level jet may be useful in the prediction of deep (cumulonimbus) convection. Also their occurrences can enhance the spread or intensification of forest fires.

The SODAR (sound detection and ranging) system can be used routinely for making doppler measurement of profile of wind velocity from the surface up to heights ranging between 50 m and 1000 m. Hence, it is very appropriate for detecting and monitoring of low-level jets (both the speed and direction) in the ABL. Adedokun and Holmgren (1991) have found the sodar system to be quite useful for meteorological research and operational weather forecast purposes particularly for predicting wind shear zones at airports. Taconet and Weil (1982) have used a sodar system to study the Eulerian vertical velocity field during the early morning convection. Sodars have also been proven successful in investigating thermal plumes which dominate convection and to compare with those predicted by different models (Cole *et al.*, 1976).

From the sodar echogram, the pattern of the atmospheric turbulence versus time so displayed is

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revealing about the state of the ABL. Much more information can be extracted when additional meteorological observations are made in conjunction with the facsimile record. Therefore, the sodar is reliable for the study of low-level jets and wind shear (Chen, 1980).

2. Data Analysis

The mean wind profile data obtained from the sodar (manufactured by SENSITRON AB, Sweden) used for this study, included the radial velocities from the echo intensities of the *u*, *v*, and *w* antennae for the period: July-Septeber, 1991. The data collection was on daily basis and an integration time of 30 minutes was used. The sodar data were further reduced using a computer software (GEOSOFT).

In the analysis, the Nieuwstadt (1984) equation was applied to the specific cases of pronounced low-level jets. This equation is stated as:

$$h = KU^{\propto} \quad (1)$$

where h is the height of the mean wind speed at the axis of the jet, $\propto$ is the gradient, and U is mean wind speed at the jet axis. K is a constant.

Linearising Eq. (1) by taking the logarithmic values, we obtain,

$$log\,(h) = log\,(K) + \propto log\,(U) \quad (2)$$

If we take 50 m as the lowest sodar measurement height (i.e. U_{50}) then Eq. (1) can similarly be expressed as:

$$H = KU^{\propto}_{50}$$

so that,

$$log(H) = log(K) + \propto log(U_{50}) \quad (3)$$

where H corresponds to the stated 50 m height.

3. Results and Discussion

The study area is located at Ile-Ife (7.5°N, 4.5°E) and is within the tropical forest zone in the south west part of Nigeria. Its weather is determined primarily by the meridional movement of the inter-tropical Discontinuity, ITD line (see Balogun, 1980). Generally in West Africa, two prominent seasons exist: the harmattan (or dry) and the rainy season. At Ile-Ife, the dry season starts normally in late October and continues till February of the following year. In the rainy season, the location is under very deep convective activities and because of influx of warm and moist southwesterlies (trade winds), and there is thunderstorm occurrence and heavy rainfalls. The thunderstorm in most cases is accompanied by squall lines.

The location experiences strong winds particularly in the wet months. Thus the vertical gradient of the wind speed is much pronounced most of the time. Equally, in the dry season, the wind field (in the boundary layer) is largely controlled by the frictional drag imposed on the wind flow (or wind sheet) by the underlying surface characteristics.

For the cases presented in this study, in the morning of June, 19th 1991, stratocumulus/cumulus cloud appeared in the sky and later on it became sunny with fair weather cumulus. This situation is similar to what has been observed on 30th of the same month. In this particular case, the sodar wind data revealed that there were strong air current (low-level jets) at at the following times, 0400-0900 GMT and 1400-1800 GMT.

The analysis of the flow at low-level revealed a well defined axis of maximum current of air in the wind profile as shown in the Figures 1a and b. In Fig. 1a, a jet appears at 250 m height at about 0500GMT, 500 m at about 0800 GMT, 650 m and about 850 m height respectively for the same time periods. The low-level jets became pronounced again at 1600 GMT. The profiles are similar to those reported by Findlater (1971) over a region in India. The same wind maxima was observed also in Fig. 1b but at different heights and times. The prominence of the air current can be clearly seen as one considered the wind-height cross-section (contour) shown in Figures 2a and b. The low-level jet can be noticed around the epicenter of the contour lines. That is, a wind speed of 7.0 ms^{-1}about 1153 GMT for the height of 550 m. The height at which a low-level jet attains its maximum speed marks the location of the core of the jets.

At about 0830 GMT, the jet becomes prominent at about 350 m height. This current of air peaks to about 5 ms^{-1} around 1200 GMT and became turbulent at 800 m height. From an application of the Nieuwstadt (1984) equation to the cases reported, the value for α, which is the gradient, is obtained as 3.3 ms^{-1} approximately. The average wind speed here is 3.5 ms^{-1}. The differences must have been as a result of lowest height recognized by sodar (50 m) while that used by Nieuwstadt was 10 m. Studies of available sodar data for 19th and 30th June, 19th, 24th and 25th July, 7th, 15th and 19th August 1991 considered for this research reveal some prominent low-level jets. When the surface heating is nearing the maximum,

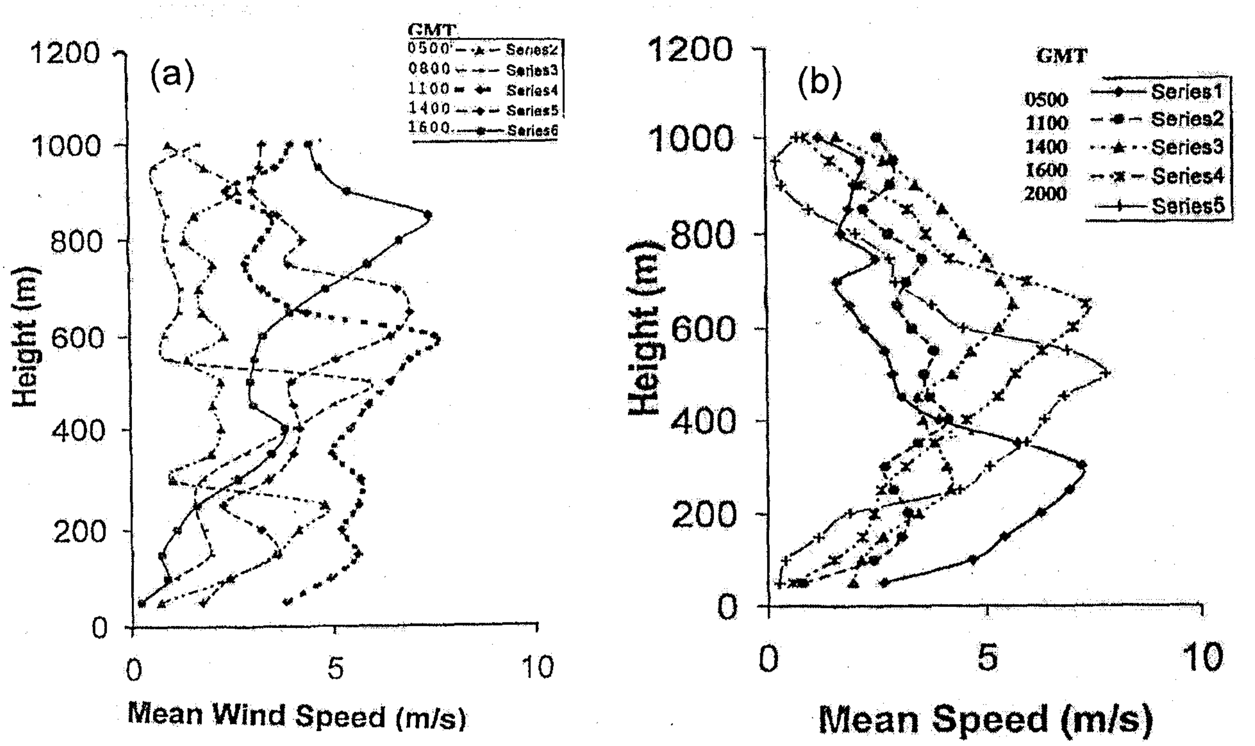

Fig. 1: Occurrences of low-level jets at OAU, Ile-Ife, Nigeria on (a) 19/06/1991, and (b) 07/08/1991

minimum speeds were recorded during the day about 1100 GMT. The currents of air (jet streams) were prominent at 250 m, 350 m, 650 m, and 730 m heights. These strong winds persisted without change of direction and there are some evidences to suggest that the occurrences of low-level jet streams are associated in some ways with outbreaks of cool air.

On the average, the speed of the core of the jet streams during the afternoon is about two-third of the early morning values. The height of the wind maxima is marked by minimum turbulence. This is due to the fact that the maximum of the viscous stress is at the ground, decreasing upwards till it becomes zero at a level which is the height of the low-level jet maximum.

4. Conclusion

The principal aim of this study has been to study specific cases of low-level jet within the atmospheric boundary layer using the sodar and to analyze the wind fields that are associated with them. The height at which a low-level jet attains its maximum speed is an important parameter as it marks the location of the core of the jet. The main benefit of this study is its application to ensure air craft safety. Pilots could be warned of any significant low-level jet stream and wind shear during take off or landing.

From this study, it is found that the occurrence of low-level jets within the atmospheric ABL is common in the wet season (associated with thunderstorms) but rarely occur in dry season.

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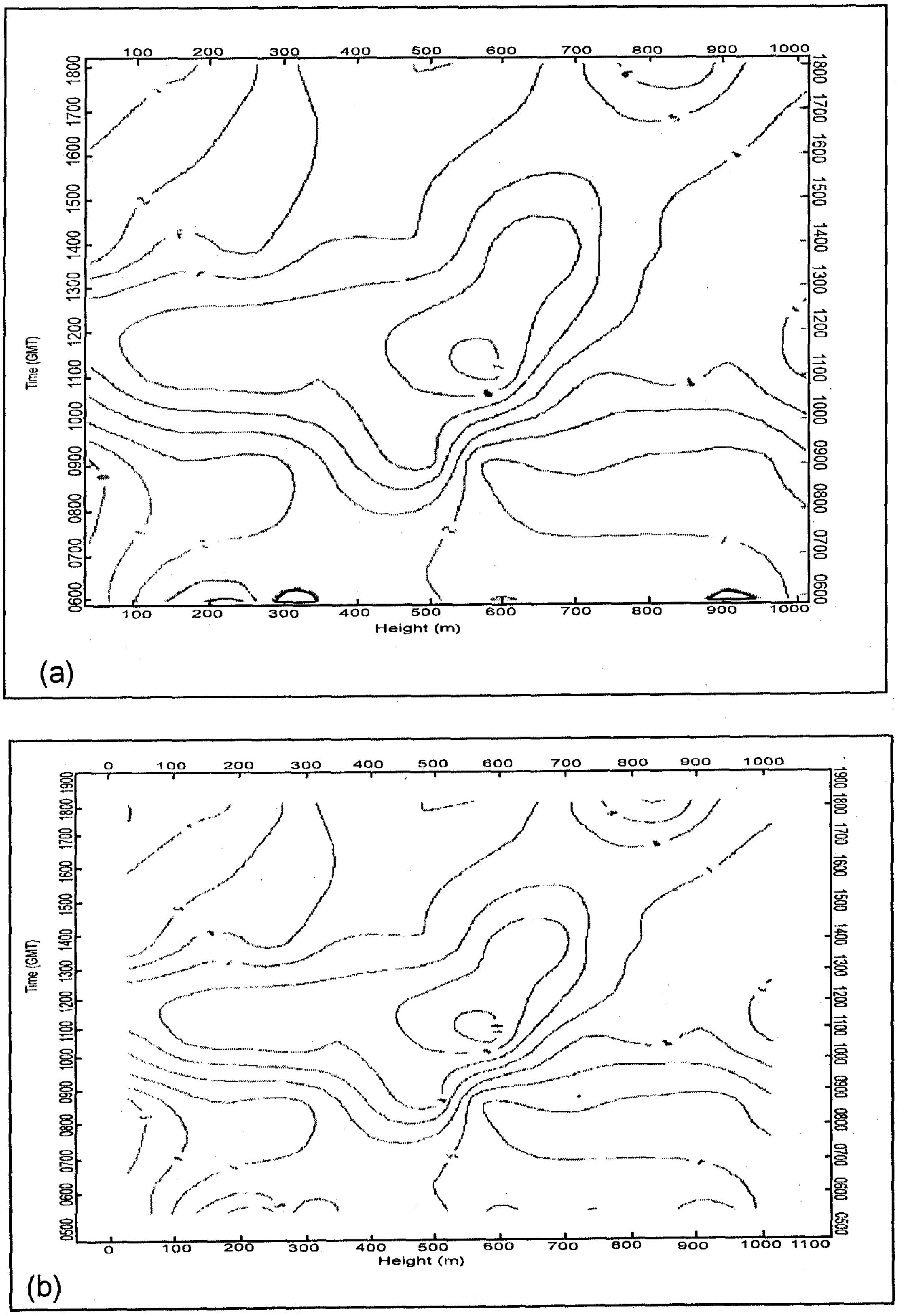

Fig. 2 : Sodar winds used for prospecting for cases of pronounced jet occurrence between 0600 and 1800 GMT on (a) 19/06/1991, and (b) 24/08/1991

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