Sound Speed Propagation in the Atmosphere of International Baghdad Airport

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الخلاصة

تم حساب سرعة انتشار الصوت في جو مدينة بغداد الدولي لأوقات النهار والليل لمدة شهرين من سنة 1994. التسجيلات الطقسية مثل درجة الحرارة ودرجة نقطة الندى والضغط الجوي والرطوبة النسبية استخدمت لإنجاز هذا البحث. أظهرت النتائج أن سرعة انتشار الصوت في الأجواء الدافئة والجافة أعلى مما عليه في الأجواء الباردة والرطبة.

ABSTRACT

At the atmosphere of Baghdad airport, the sound speed propagation has been calculated at midday and midnight times for two months, January and April, 1994. Weather records such as air temperature, dew-point temperature, air pressure and relative humidity were came from Baghdad station are used to carried out this work. The results show that at warm and dry atmospheres the sound speed propagation is large, while it is low at cold and moist atmospheres.

INTRODUCTION

The propagation of sound in the atmosphere is a vital subject in the atmospheric boundary layer (ABL), because of increasing noise pollution. This noise is caused by the sounds created human or machine disrupts the activity or balance of human or animal life. The source of most noise is from transportation systems such as airplanes, motor vehicle traffic on roads, and electrical generators. Poor urban planning may also give rise to noise pollution, since side-by-side industrial and residential buildings can result in noise pollution in the residential area. Steady exposure to sounds higher than 80 dB has negative effects on human ears as hearing loss over a long period of time.

Arnolds and others prepared a technique to observe area-averaged air temperature and wind fields in their horizontal and temporal variability. This technique uses the dependence of sound speed on temperature and wind speed to derive the distribution of these quantities within the measuring area (1). In this paper propagation of sound speed will be determined at International Baghdad Airport and then examine its relation to air temperature and relative humidity. The selection of this place came from two reasons: first available measurements at meteorological Baghdad station, and second taking off or on airplanes working in the airport.

DETERMINATION OF SOUND SPEED PROPAGATION

The sound speed, C_d, can be determined in the dry atmosphere with the Laplace approximation:

$$C_d = \sqrt{\gamma_d \frac{p}{\rho}} \quad (1)$$

where $\gamma_d (= c_p/c_v = 1.4\ [1])$ is the specific heat ratio with c_p specific heat under constant pressure and c_v specific heat under constant volume, P the air pressure and ρ the air density. From the application of the ideal gas equation, which requires that the sound pressure, $P_s \ll P$ and the frequency of the free molecule movement $f_s \ll 10^5$ kHz, and molecular weight ($\mu_d = 28.97\ \mathrm{kg.kmol^{-1}}$), follows:

$$C_d = \sqrt{\gamma_d \frac{R_L T}{\mu_d}} \tag{2}$$

where R_L is the gas constant for humid air and T is the air temperature in °K. For moist air (2):

$$C_d = \sqrt{\frac{\gamma_d R_L T}{\mu_d}\left(1 + 0.28\,\frac{e}{P}\right)} \tag{3}$$

where e is the partial pressure of water vapour. Substituting Eq. (2) in Eq. (3), it can be obtained the sound speed of moist air (C_m) in terms of the sound speed for dry air, as follows (2):

$$\left.\begin{array}{l} C_m = C_d\sqrt{1 + 0.28\,\frac{e}{P}} \\ C_m = C_d\left(1 + 0.14\,\frac{e}{P}\right) \quad \text{for } T < 30\,^{\circ}\mathrm{C}, \frac{e}{P} < 4\% \end{array}\right\} \tag{4}$$

The partial pressure can be calculated by (3)

$$e = e^{1.81 + \frac{17.27\,T_d}{237.3 + T_d}} \tag{5}$$

where T_d is the dew-point temperature in °C.

The surface meteorological observations such as air temperature, dew-point temperature and atmospheric pressure used in this work are obtained from Iraqi Meteorological Office (IMO) for weather Baghdad station (located at latitude 32° 14" N, longitude 44° 14" E and elevation 31.7 m above the mean sea level). These data are for two months: January and April, 1994, and for two significant times over a day which are at midday 12 and midnight 00 UTC. In the research of ABL, it is convenient to use the smaller scales of time, approximately smaller than one day, to describe any physical quantity. Therefore, the chosen months are sufficient to show the significant differences in the results of C_m.

RESULTS AND DISCUSSION

Daily variation of sound speed propagation

Before calculating C_m by Eq. 4, T_d data were used to determine the partial pressure of water vapour by use of Eq. 5. Daily time series for the C_m values for each time, i.e. 00 and 12 UTC, are presented in Figs. 1a and 1b, respectively. In general, values of Cm for April are larger than those for January, especially for 12 UTC. The difference between Cm values at time 12 UTC is almost larger than that for another time. During all days in

April, there is no significant increase in C_m which its mean values are about 342 ms^{-1} at day and 338 ms^{-1} at night but with large fluctuating. In contrast, the values of C_m gradually increase from the beginning of the months to their ends in January. The largest value of C_m (356 ms^{-1}) is at 12 UTC (Fig. 1a), while its value is 350 ms^{-1} at 00 UTC (Fig. 1b).

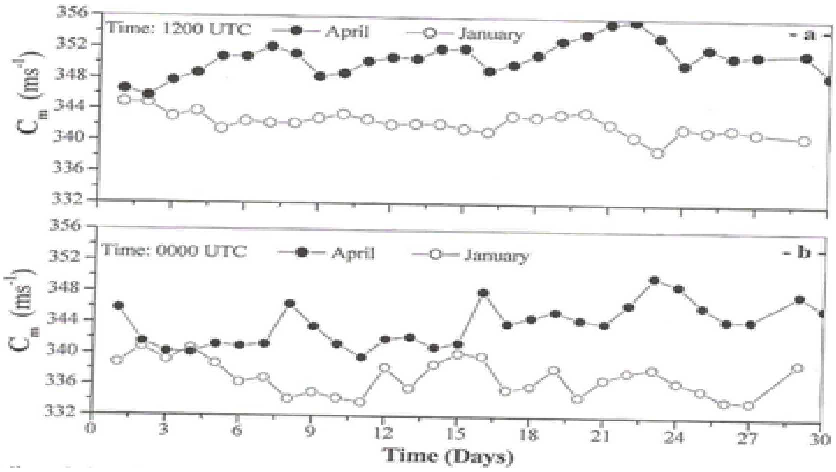

Fig-1: Daily variation of C_m at (a) time 12 and (b) 00 UTC for April and January, 1994.

Sound speed variation with some weather elements

In this section, the dependence of sound speed propagation on the independent variables such as air temperature, T, and relative humidity, RH, is presented in Figs. 2 and 3, respectively. In these figures all T and RH data for two times plotted against , C_m, whereas C_m values at 00 UTC separate obviously from those at 12 UTC. The linear increase for C_m with lower scatter with increasing T is clear and then solid line drawn in Fig. 2 represents the best fit for these data given by:

$$332.3 + 0.57\, T\, (^\circ C) \qquad (6)$$

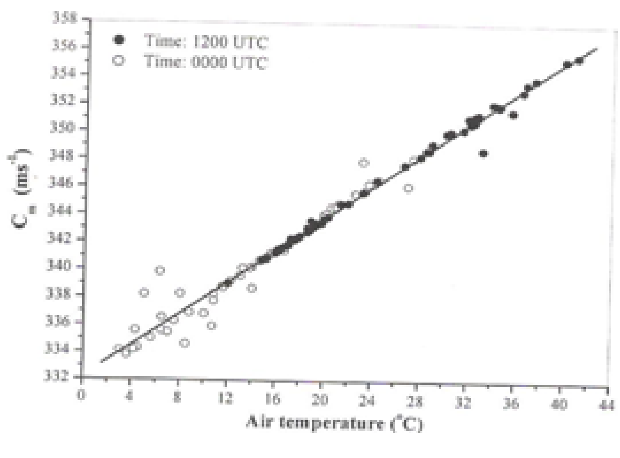

Fig- 2: Relation between C_m and air temperature for all data used in this paper.

In contrast, the C_m values decrease inversely with increasing RH, whereas large scatter is observed. It can be seen that higher Cm values occur at low RH, while lower C_m data concentrate at high RH, as shown in Fig. 3. However, the following expression is expressed the best line passing through the data points:

$$C_m = 318.3 + 38.4\, e^{-RH/127} \quad (7)$$

From the two above paragraphs, it can be concluded that at warm atmospheres with low humidity, the sound velocity propagation is faster than in cold atmospheres with high humidity.

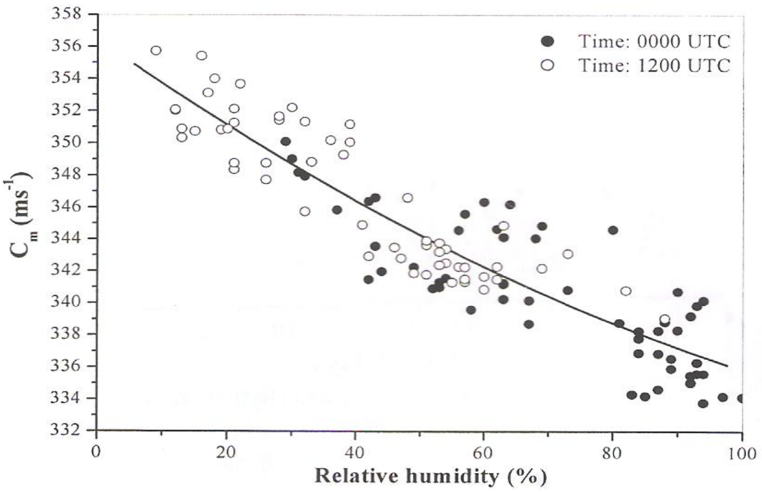

Fig- 3: Variation of C_m with relative humidity for all data used in this paper.

We can conclude:

Based on the recorders for air temperature and relative humidity, the propagation of sound velocity has been calculated in the atmosphere of Baghdad airport. These records were at midday and midnight times for two months: January and April. I can be concluded that for both times at April the propagation velocity of sound is higher than that at January. Also it found that C_m increases linearly with increasing T, while it decreases inversely with increasing RH.

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