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# Letters to the Editor

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## LOW LEVEL WIND SHEAR AT BOMBAY AIRPORT ON CLEAR NIGHTS

Low level wind shear (LLWS) as a hazardous phenomenon for landing and take off operations of aircraft has been recognised (ICAO 1987.) ICAO classification of strength has been followed here.

Though mostly strong to severe LLWS are known to be associated with convective phenomena, some times they occur in fair weather also. For the last 5 to 6 years a number of LLWS cases have been reported by aircraft at Bombay airport, many during fair weather period, particularly on clear nights. Quite a few of them have been found to be strong to severe. It is proposed to indicate a possible cause of such occurrences.

Dayakishan (1977) reported that there was sudden rise of temperature of the surface on clear nights with strong inversion. He took cases when the rise had been 3° C or more and reported 35 cases during 1970-1977. Climatologically, on these nights strong inversions of intensity 10-12° C/km existed between 400-600 m from the ground. Before the sudden rise the wind was always calm. Therefore, the rise in temperature was due to the churning in the inversion layer when due to turbulence the warm air from above was brought down to the surface.

Turbulence is connected with Richardson number, $R_i$ given by :

$$R_i = \frac{g}{\theta}\frac{d\theta/dz}{(dv/dz)^2}$$

where,

$g$ = Acceleration due to gravity,

$\theta$ = Potential temperature,

and $dv/dz$ = Wind shear.

We know the turbulence sets in for $R_i$=1/4 and continues up to the value 1.

Now let us take the following data :

Surface pressure = 1000 hPa

Surface temperature = 15°C

Intensity of inversion = 12°C/km

Thickness of inversion = 400m

For turbulence to start, *i.e.*, $R_i$ to be 0.25 we get wind shear = 3 kt/30m. Thus, this turbulence explains only light LLWS. This shear should be for any magnitude of rise in surface temperature.

In case of 3°C rise, the air must have come down from 136 m above the ground for the above intensity of inversion. When there is displacement of air in the vertical in a stable layer Brunt Vaisala wave is generated. It is given by :

$$h = a \sin k\, t$$

where, $h$ is the displacement in the vertical in time $t$ and $a$ is the amplitude and

$$k^2 = g(\gamma' - \gamma)/T$$

where, $\gamma'$ = Dry adiabatic lapse rate=10°C/km

$\gamma$ = Environmental lapse rate=12°C/km

$T$ = Mean temperature of the layer in which the wave is working.

(We have assumed it to be same as surface temperature).

For a descent from 136 m, we may take this height to be the double amplitude. In that case $a$ = 68m. We know that period $\tau$ is given by :

$$\tau = 2\pi \sqrt{\frac{T}{g(\gamma' - \gamma)}}$$

Putting the above values we get $\tau$ = 229 sec. The maximum velocity of the wave is given by

$$w_m = a\sqrt{g(\gamma' - \gamma)/T}$$

We get under the conditions given above :

$$w_m = 1.86 \text{ m/s}$$

The average velocity will be :

$$4\, a/\tau = 136 \times 2/229 = 1.19 \text{ m/s}$$

The velocities are in vertical direction.

Consider an aircraft is landing with air speed 140 kt against a head wind of 20 kt and the angle of declination is 3°. For a downward velocity of 1.86 m/s we find that the angle of declination will increase by 1° (ICAO 1987). This would also happen if the headwind suddenly decreases by 7 kt. The pilot will, therefore, feel as if a shear of 3+7=10 kt/30 m has occurred. Thus, he would report a strong shear. If we count the average downward velocity this comes to 7 kt/30 m which is moderate LLWS. For a surface temperature rise of 5°C the LLWS comes to >13 kt/30 m or a severe LLWS.

Dayakishan (1977) showed that such rise in surface temperature occurs at Bombay in the wake of the passage of a strong western disturbance over northwest India. First strong northnorthwesterly wind invades Bombay followed by strong northeasterly winds at 300 m a.s.l. Otherwise, the prevailing wind is northeasterly.

With the cooling of the surface, inversion sets in which helps the development of considerable amount of wind shear. Thus, LLWS increases as the night proceeds to early morning. At Bombay the sea breeze ceases at about 2100 IST. After that urban wind, which is northerly over Bombay airport, sets in (Mukherjee and Daniel 1976). At Bombay land breeze sets in two instalments (Mukherjee *et al.* 1987). The first change is northwesterly to northerly. The wind is light. The second one is northerly to northeasterly when wind becomes a bit stronger. According to Dayakishan the rise in temperature of the magnitudes he studied happen when the land breeze and strong synoptic wind come in phase. Thus, after the sea breeze ceases, with suitable synoptic condition we should first note when the change to northerly occurs. Within two to four hours LLWS should develop and then the land breeze should set in. Thus, we can determine the period when the LLWS is liable.

After the turbulence sets in, wave should gradually subside and the LLWS would decrease. Thus LLWS, significant for aircraft operations, is a transient phenomenon.

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