

## Forecasting low level vertical wind shear over Chhatrapati Shivaji International (C. S. I.) Airport Mumbai

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**सार** – जब कभी सतही पवन, वर्षण के साथ,  $\geq 15$  नॉट्स (झोंको सहित) होती है तब निम्न स्तर ऊर्ध्वाधर पवन अपरूपण (एल. एल. डब्ल्यू. एस.) का 1000 फीट से कम में पूर्वानुमान किया जा सकता है। शुष्क मौसम के दौरान यदि सतह तथा 500 फीट और 5000 फीट से कम की पवन के किन्ही दो क्रमागत स्तरों के बीच 9 नॉट्स का अंतर होता है तब निम्न स्तर ऊर्ध्वाधर पवन अपरूपण (एल. एल. डब्ल्यू. एस.) का पूर्वानुमान किया जा सकता है।

**ABSTRACT.** Whenever surface wind is reported  $\geq 15$  knots (including gusts), with precipitation, Low Level Vertical Wind Shear can be forecast below 1000 ft. During dry weather, if there is a difference of 9 knots between surface and 500 ft. winds and any two consecutive level winds below 5000 ft., Low Level Vertical Wind Shear can be forecast.

**Key words** – Surface wind  $\geq 15$  knots, precipitation, below 1000 ft., Difference of 9 knots, Dry weather, Two consecutive levels, Below 5000 ft.

### 1. Introduction

Low Level Vertical Wind Shear (LLWS) between runway level and 500 metre (1600 feet) above that level is very crucial for take off, landing or during circling operations of an aircraft [International Civil Aviation Organization (ICAO, 2007) and IMD, 2006]. The landing aircraft may overshoot or undershoot due to the presence of LLWS whereas required vertical clearance may be affected while taking off. Reihl (1965) had stated that the speed of the aircraft will be retarded when there is a cross wind. Rao and Rao (1974) have observed that maximum wind speed at touch down during landing is another critical parameter that affects the performance of an aircraft. According to Kumar and Patkar (1993), sea breeze and land breeze circulation and their transition from one to the other are expected to lead to considerable wind shear in lower levels over C. S. I. Airport, Mumbai. Till an aircraft is equipped with observing LLWS, aircraft reports serve as database to alert all subsequent aircrafts. Wind shear warning for arriving aircraft and/or departing

aircraft shall be cancelled when aircraft reports indicate that wind shear no longer exists or alternatively after an elapsed time of two hours (IMD, 2006). Wind shear alerts should be updated at every minute (wherever facility is available). The wind shear alert should be cancelled as soon as the headwind/ tailwind change falls below 15 knots, (ICAO, 2007). The aim of this study is to analyze the LLWS reports received at C. S. I. Airport, Mumbai with a view to explore a suitable method by which LLWS could be anticipated and forecast.

### 2. Data

LLWS data for C. S. I. Airport Mumbai for the period 1987-2000 have been collected from current weather registers of Meteorological Office (M. O.) Mumbai and upper air wind data of 950 hPa for M. O. Mumbai for 0000 and 1200 UTC from 1987-2000 have been received from Additional Director General of Meteorology, Pune. Upper air wind data for 500 and 1000 ft for 0000 and 1200 UTC from 1997-2000 and Pilot

**TABLE 1**  
**Frequency of wind shear reported over C. S. I. Airport Mumbai during 1987-2000**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987	0	2	8	12	0	11	16	8	0	1	12	4	74
1988	5	1	3	0	2	2	8	3	5	3	11	10	53
1989	1	9	6	1	3	12	24	9	0	3	4	9	82
1990	6	8	3	2	3	2	24	6	2	0	7	5	67
1991	3	2	3	1	2	7	24	11	4	5	11	12	85
1992	7	4	5	1	0	4	12	3	1	2	9	4	53
1993	4	11	1	3	0	6	6	10	9	7	7	5	70
1994	6	8	11	2	4	15	42	0	8	5	14	17	132
1995	11	6	7	9	2	2	11	1	6	5	8	7	75
1996	12	7	2	2	2	22	13	11	1	8	8	2	90
1997	6	5	16	2	2	11	36	17	1	4	4	3	170
1998	1	10	5	2	3	14	21	4	8	7	4	11	87
1999	7	15	16	3	4	12	21	17	2	13	7	7	124
2000	5	3	4	0	12	13	17	7	6	4	13	24	109
Total	74	91	90	40	39	133	275	107	53	67	119	120	1208

Balloon Observations for 0600 and 1800 UTC for 500 and 1000 ft from 1999 to 2000 have been collected from RS/RW Office Mumbai.

### 3. Frequencies of LLWS

It can be seen from Table 1 that out of 1208 cases of LLWS reported by the aircraft over C. S. I. Airport Mumbai during 14 years (1987-2000), 568 (47%) cases were reported during southwest monsoon season (June-September). July has the highest frequency of occurrence of LLWS (23%) followed by June. Incidentally it may be mentioned that maximum rainfall has been experienced during July over Mumbai. Biswas (2006) has observed that maximum number of CB cells (6 km) develops around C. S. I. Airport Mumbai during July followed by June. Kumar *et al.* (2007) have also observed that maximum number of heavy rainfall ( $\geq 65$  mm) cases over Mumbai occur during July followed by June. These suggest that the maximum LLWS frequency during July may be due to convection and strengthening of low level westerlies. A few cases of cross winds have been also

reported as LLWS by the aircraft. During southwest monsoon season, the direction of cross wind is southerly, whereas between November and February it is northerly. Tail winds at 500 ft or 1000ft were reported in maximum numbers during northeast monsoon season. Tail winds are also reported when thunderstorms develop to the east of the station (Mumbai) over the hills.

### 4. Monthly diurnal distribution of LLWS

Table 2 shows the frequency of LLWS reported over different period of time on a day. While there is no appreciable diurnal variation in LLWS frequencies during southwest monsoon season, [Table 2(a)], maximum occurrence (68%) has been noticed during evening and night time during rest of the year, [Table 2 (b)].

### 5. Intensity of LLWS

It has been found that out of 1208 cases, intensity has been reported only in about 50% of cases and that too

TABLE 2

## Diurnal variability of LLWS frequencies over CSI Airport, Mumbai, 1987-2000

	0000-0600	0600-1200	1200-1800	1800-2400	Total	Frequency per month
<b>(a) Southwest monsoon season</b>						
Jun	32	30	35	36	133	9.5
Jul	56	69	72	78	275	19.6
Aug	22	34	32	19	107	7.6
Sep	7	9	18	19	53	3.8
Total	117	142	157	152	568	10.1
<b>(b) Rest of the Year</b>						
Jan	13	4	32	25	74	5.3
Feb	16	14	32	29	91	6.5
Mar	4	15	55	16	90	6.4
Apr	2	10	23	5	40	2.9
May	6	14	14	5	39	2.8
Oct	15	12	10	30	67	4.8
Nov	26	10	36	47	119	8.5
Dec	36	8	28	48	120	8.6
Total	118	87	230	205	640	5.7

TABLE 3

## LLWS intensity reported by the aircraft over CSI Airport, Mumbai, 1987- 2000

Month	Light	Moderate	Strong	Severe	Total
Jan	1	7	14	17	39
Feb	5	12	10	22	49
Mar	5	14	4	21	44
Apr	0	6	2	9	17
May	4	2	7	8	21
Jun	9	11	7	31	58
Jul	6	26	16	83	131
Aug	5	11	5	23	44
Sep	0	3	3	8	14
Oct	2	5	5	14	26
Nov	5	17	21	38	81
Dec	3	18	20	39	80
Total	45	132	114	313	604

PS : Report was purely based on qualitative observation

qualitatively in majority of cases. Based on these reports it is found that severe LLWS has occurred on maximum occasions during July followed by November and December (Table 3). At times aircraft had reported change in wind speed as light (0-4 knots inclusive per 30m), moderate (5-8 knots inclusive per 30 m), strong (8-12 knots inclusive per 30 m) and severe (above 12 knots inclusive per 30m) wind shear without giving exact wind speed. In 50% cases aircraft had reported "wind shear/ marked wind shear/ tail wind at final approach". This type of reporting cannot be put into any category.

## 6. Reporting of LLWS

LLWS has been reported by pilots over C. S. I. Airport, Mumbai between surface and 3700 ft. Generally LLWS is reported very frequently between surface and 500/ 1000 ft (78%). Only 12 cases of wind shear have been reported below 950 hPa (below 2500 ft) and not even a single case of wind shear could be forecast by using 950 hPa upper air data as either shear was not observed between two consecutive layers or data were not available for the particular observation in a layer of appropriate thickness between surface and 950 hPa. In majority of cases (59%) pilot did not inform the height at which they experienced the wind shear. Maximum numbers of LLWS have been reported by the pilots while landing at final approach over runway 27. As runway 27 is the main runway, only a few cases of LLWS have been reported over RWY 09 and RWY 14. LLWS has never been reported by any aircraft while taking off presumably due to high concentration at the time of take off.

## 7. Method of forecasting

During southwest monsoon season winds from 500 to 1000 ft. are found to be very strong even on non-rainy days. During 1997-2000, 70 cases of LLWS were reported when it was not raining, of these 36 cases were reported between June and September. In all these cases upper air winds at 500/1000 ft. were observed as strong. Kishan (1979) had observed that land breeze is generally light over Mumbai. During northeast monsoon season (October- December), 0000 UTC upper air observation and at times 1800 UTC pilot balloon observations report strong easterly component at 500/1000 ft. while surface wind may be light or calm between 1800 and 2400 / 0200 UTC.

Jayanthi and Raman (1993) had observed for that out of 76% thunderstorm related wind shear cases, 24% were associated with down draft accompanied by heavy rainfall

reducing the visibility to less than 2000 metres over Chennai airport. Generally thundershowers over Mumbai occur during pre-monsoon (just before onset of southwest monsoon), on the day of revival of monsoon just after break and during post monsoon season. Once the monsoon is established thundershowers are rare. Kumar and Patkar (1993) had observed that most of the low level wind shear at Mumbai Airport is associated with thunderstorm and strong gusty winds during monsoon and post monsoon seasons.

Generally strong surface wind during southwest monsoon season is observed over Mumbai whenever there is a low pressure area over northeast Arabian Sea and neighbourhood or a cyclonic circulation over Gujarat region and neighbourhood. Whenever surface wind is reported 15 knots or more (including gusts: variation from the mean wind speed during past 10 minutes shall be reported when the maximum wind speed exceeds the mean wind speed by 10 knots or more: IMD, 2006) with precipitation, wind shear has been reported by the aircraft at the time of landing. Under this category, 46 cases of LLWS, observed during 1989, 1991, 1992, 1994, 1995, 1996, 1997, 1998, 1999 and 2000 have been considered as data base. The above criteria have been verified for 70 cases reported during 2001. "D" is considered as zero in view of very large value of 24 hours current weather observations in comparison to 25 reported cases of LLWS. The details of LLWS forecast verification for 2001 are as under:

Observed	Forecast	
	Yes	No
Yes	A(19)	B(6)
No	C(45)	D(0)

$$\text{Probability Of Detection (POD)} = A/(A+B) = 0.76$$

$$\text{False Alarm Ratio (FAR)} = C/(C+A) = 0.7$$

$$\text{Miss Rate (MR)} = B/(B+A) = 0.24$$

$$\text{Critical Success Index (CSI)} = A/(A+B+C) = 0.27$$

In the second category, it has been observed that whenever there is a difference of 9 knots (4.5 mps) between surface and 500 feet winds (0.15 km, upper air observation) or any two consecutive levels below 5000 feet, WS has been reported by the aircraft at the time of landing during dry weather. Under this category 33 cases

of reported LLWS have been considered as data base for the years 1987, 1988 and 1999, for which upper air observations for 0.15/0.3 km (500/1000 ft) heights are available, which have been verified for 28 cases for the year 2000. LLWS forecast verification for the year 2000 is as under:

Observed	Forecast	
	Yes	No
Yes	A(11)	B(14)
No	C(3)	D(0)

$$\text{POD} = 0.44, \text{FAR} = 0.2, \text{MR} = 0.56, \text{CSI} = 0.39$$

## 8. Discussion

After examining wind shear cases mentioned, it appears that all aircraft do not report wind shear in large number of cases. Generally when severe thunderstorm with rain (+TSRA) / heavy rain (+RA) is reported, the airport is surrounded by CB clouds from almost all around. During these conditions general visibility reduces to 500 m or even goes up to 50 m. C. S. I. Airport, Mumbai comes under Category I operation. Any precision approach operation with a minimum decision height of 60 m (200ft) and with a minimum general visibility of 800 m or Runway Visual Range (RVR) not less than 550 m is considered as Category I operation. As a result many aircraft may not land under these conditions.

On 26<sup>th</sup> June 2002, current weather observation at 0210 UTC reported surface wind as 23013G23 knots. Moderate wind shear between surface and 500 feet had been forecast. Aircraft confirmed the forecast through 0440 UTC current weather observation and wind shears had been continuously reported till 1410 UTC. However, surface winds were reported less than 15 knot after 1010 UTC. The main reason for occurrence of LLWS during strong surface wind with precipitation is based on the observed fact that significant downdraft speeds may exist at levels as low as 300 to 400 feet above the terrain. As a result significant difference between surface and 500 feet winds is observed.

## 9. Co-ordination with Pilots, flight dispatchers and Tower officials

Suresh (2004) has observed that feedback received from pilots and flight dispatchers after issue of wind shear alert at Chennai airport is poor. It has been already

mentioned in this study that more than 50% of the reported wind shear messages at CSI airport Mumbai are incomplete. Not even a single case of wind shear was reported during take off phase.

## 10. Conclusion

(i) Whenever surface wind is reported 5 knots (including gusts) with precipitation, LLWS can be forecast below 1000 ft. This method has a CSI of 0.27. Though the POD is 0.76, this method has a FAR of 0.70 which is very high in operational set up. Hence this method may be tried with a probability only.

(ii) Whenever there is a difference of 9 knots (4.5 mps) between surface and 500 ft winds or any two consecutive level winds below 5000 ft during dry weather, LLWS can be forecast. This has a CSI of 0.39 and FAR 0.2.

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