



*International Civil Aviation Organization*

**EIGHTEENTH MEETING OF THE METEOROLOGY  
SUB-GROUP (MET SG/18) OF APANPIRG**

ICAO Regional Sub-Office, Beijing, China  
18 – 21 August 2014

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**Agenda Item 7: Research, development and implementation issues in the MET field**

**7.1 WAFS**

**VERIFICATION OF THE HARMONIZED  
WAFS GRIDDED FORECAST OF CAT POTENTIAL**

(Presented by Hong Kong, China)

**SUMMARY**

This paper presents an update on the verification of the harmonized WAFS gridded forecast of clear air turbulence potential using special air-reports received in the Hong Kong Flight Information Region and using flight data from flights landed/departed from Hong Kong, China.

**1. Introduction**

1.1 Verification of the WAFS harmonized gridded forecasts of clear-air turbulence (CAT) potential by China was reported at the seventh and eighth meetings of the WAFSOPSG in 2012 and 2013 respectively and at the sixteenth meeting of CNS/MET SG in 2012. Results of the verification by China raised concern that the verification by the WAFC Provider States were performed for a selected portion of the globe only and might not fully reflect its performance, in particular in relation to turbulence caused by mountain waves, in other parts of the world.

1.2 In this paper, the verification of the harmonized CAT potential is extended to cover up to May 2014. As in CNS/MET SG/16 WP-56 and CNS/MET SG/16 IP-40, the verification was done by using (a) the special air-reports received in the Hong Kong Flight Information Region (HKFIR) and (b) using the flight data from flights landed/departed from Hong Kong.

**2. Discussion**

2.1 Verification against special air-reports

2.1.1 The verification of the WAFS gridded CAT potential against pilot report for the period from 29 November 2011 to 30 May 2012 was covered in the previous study. In this study, the verification was done by using special air-reports of turbulence over the HKFIR during the 24-month period from 1 June 2012 to 31 May 2014. The same verification criteria were adopted to evaluate the

performance of the harmonized WAFC gridded forecasts of CAT potential. Moreover, the hit rates were compared with those found by WAFCs (published in Table 6 of the “Guidance on the Harmonized WAFS Grids for Cumulonimbus Cloud, Icing and Turbulence Forecasts, Ver 2.5”, the Guide) to see if the hit rates in the Guide could be generally applied.

2.1.2 After screening to ensure that the event occurred in clear air<sup>1</sup>, there were 119 special air-reports of moderate or higher intensity turbulence within the 24 month study period. As the CAT potential forecast, which is available every 6 hours, is mainly used for flight planning, the T+21 or T+24 forecast value (whichever was closer to the event time) was selected for the verification.

2.1.3 The reported turbulence intensity, together with the mean and maximum CAT potential forecasts for the grid box covering the location of the special air-report is listed in Table 1. The distributions of the mean and maximum CAT potential forecasts, in bins of 0.5, are shown in Figure 1. It is noted that over one third of the cases the forecast value of the mean and maximum CAT potential were both zero. The maximum CAT potential range from 0 to 9.1, with 39% meeting the suggested threshold value of  $> 4$ .

2.1.4 The hit rates for the present study for a range of maximum CAT potential are compared against that given in the Guide (see Table 2). It is noted that the hit rates for this study are lower than the corresponding reported hit rates in the Guide based on the verification by the WAFC Provider States. Taking the threshold value of 4 as an example, the hit rate for the harmonized maximum CAT verified by accelerometer readings is 0.626, while the hit rate verified by pilot reports is 0.387.

2.1.5 Noting that the Guide suggested the users to use the mean grid to ascertain confidence in the max grid, in particular “the closer the mean is to the max, the higher the level of confidence a user should have in the max”, the ratio of the mean and maximum CAT potential for these reported events is also calculated and tabulated in Table 1. It is noted that the ratio tends in the range of 0.1 – 0.3. More guidance on establishing the level of confidence of the forecast is thus required.

## 2.2 Verification against flight data

2.2.1 Noting the subjective nature of pilot reports, the harmonized CAT potential were also verified against the “sky truth” based on the eddy dissipation rate (EDR) calculated from quick access recorder (QAR) data from flights landed/departed from the Hong Kong International Airport. During the 22-month study period (1 June 2012 to 31 March 2014), a total of about 300 flights were available, providing over 6000 data points for verification of the harmonized gridded CAT potential for 6, 12, 18 and 24 hour of forecasts.

2.2.2 Similar to the previous study, forecast CAT potential values were verified along the flight path within 1.25 x 1.25 degree latitude/longitude grid boxes in the area of 0-43N, 86E-136E. Vertical levels range from 400 hPa to 150 hPa at intervals of 50 hPa. Figure 2(a) and 2(b) show the respective ROC curves for mean EDR ( $\varepsilon^{1/3} > 0.1 \text{ m}^{2/3} \text{ s}^{-1}$ ) and maximum EDR ( $\varepsilon^{1/3} > 0.4 \text{ m}^{2/3} \text{ s}^{-1}$ ). The former represents light turbulence or greater on average, and the latter moderate turbulence or greater for the peak turbulence (Section 2.6 of Appendix 4, ICAO Annex 3).

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<sup>1</sup> Event is considered to occur in clear air if no significant convection was identified within 1 degree from the location of special air-report of turbulence and the flight concerned was not in cloud.

2.2.3 It could be readily seen that, for the current data set, ROC curves generally lay close to (or occasionally below) the diagonal line with Area Under the Curve (AUC) values no greater than 0.50, indicating very limited skill level for the Asia-Pacific region during the study period.

### **3. Conclusion**

3.1 Based on the special air-reports of turbulence of moderate or above intensity, over one third of the cases the mean and maximum CAT potential forecast were both zero, offer limited hint of turbulence potential. The hit rates for the different thresholds were lower than the corresponding ones given in the Guide.

3.2 Based on the EDR calculated from the QAR data, the harmonized gridded CAT potential forecast continued to demonstrate very limited skill for both light turbulence or above, and moderate turbulence or above events, as indicated by AUCs of 0.50 or below.

3.3 Performance of the CAT potential in the Asian sub-tropical is still lower than that given in the Guide.

### **4. Action by the Meeting**

4.1 The meeting is invited to note the information contained in this paper.

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**Table 1:** The intensity of reported turbulence together with the corresponding value of gridded forecast of mean and maximum CAT potential of the grid box covering the location of report with valid time (T+21 or T+24) closest to the report time

Gridded forecast based on time at (UTC)	Forecast Hour	3-D grid box covering location of special air-report of CAT and centre at			Mean CAT Potential Forecast	Maximum CAT Potential Forecast	Mean /Max ratio	Intensity of Reported Turbulence
		Lat (°N)	Long (°E)	Altitude (FL)				
20120601 1200	21	18.75N	112.50E	390	0.3	3.8	0.1	Moderate
20120610 1800	21	21.25N	117.50E	340	0.7	6	0.1	Moderate
20120610 1800	24	20.00N	113.75E	390	1.6	4.6	0.3	Moderate
20120619 1200	21	20.00N	116.25E	390	0	0	-	Moderate
20120619 1200	24	17.50N	113.75E	340	0	0	-	Moderate
20120621 1200	21	18.75N	115.00E	340	0	0	-	Moderate
20120621 1200	24	20.00N	113.75E	270	1.6	5.2	0.3	Moderate
20120621 1800	21	22.50N	117.50E	390	0	3.7	0.0	Moderate
20120621 1800	24	22.50N	117.50E	340	0.1	0.9	0.1	Moderate
20120621 1800	24	18.75N	112.50E	300	0	0	-	Moderate
20120623 0600	24	21.25N	113.75E	340	0	0	-	Moderate
20120623 1200	21	21.25N	113.75E	300	1	4.1	0.2	Moderate
20120623 1200	21	20.00N	112.50E	340	0.2	1.1	0.2	Moderate
20120627 1200	24	20.00N	116.25E	390	0.6	4	0.2	Moderate
20120709 0000	24	21.25N	116.25E	340	0	0	-	Moderate
20120710 0600	24	21.25N	113.75E	340	0.9	4.1	0.2	Moderate
20120716 1200	21	20.00N	113.75E	340	0	0	-	Moderate
20120717 0600	21	21.25N	115.00E	270	0	0	-	Moderate
20120719 0600	21	22.50N	116.25E	340	1	4	0.3	Moderate
20120730 1200	21	18.75N	113.75E	390	0.6	3.8	0.2	Moderate
20120808 1200	21	21.25N	115.00E	340	0	0	-	Moderate
20120820 1800	21	22.50N	117.50E	390	0	0	-	Moderate
20120826 1200	21	20.00N	113.75E	390	0	0	-	Moderate
20120830 0600	24	18.75N	113.75E	390	0	0	-	Moderate
20120906 0000	21	18.75N	115.00E	390	0.3	1.8	0.2	Moderate
20120906 0000	24	21.25N	116.25E	340	0	0	-	Moderate
20120908 1800	21	22.50N	116.25E	390	0.2	3.8	0.1	Moderate
20120918 1800	21	22.50N	116.25E	270	0	0	-	Moderate
20120921 1200	24	18.75N	115.00E	340	0	0	-	Moderate
20120930 1800	21	22.50N	117.50E	340	0	0	-	Moderate
20121001 1800	21	18.75N	115.00E	340	0.1	3.6	0.0	Moderate
20121028 0000	24	20.00N	116.25E	390	0.2	4.4	0.0	Moderate

Gridded forecast based on time at (UTC)	Forecast Hour	3-D grid box covering location of special air-report of CAT and centre at			Mean CAT Potential Forecast	Maximum CAT Potential Forecast	Mean /Max ratio	Intensity of Reported Turbulence
		Lat (°N)	Long (°E)	Altitude (FL)				
20121101 0000	24	21.25N	113.75E	340	1.6	4.3	0.4	Moderate
20121103 0600	24	21.25N	115.00E	390	0	0	-	Moderate
20121204 0600	21	20.00N	115.00E	340	0.2	3.6	0.1	Moderate to Severe
20121204 0600	24	22.50N	117.50E	390	1.5	3.8	0.4	Moderate
20121204 1200	21	18.75N	113.75E	340	0.7	3.9	0.2	Moderate
20121204 1200	21	20.00N	112.50E	340	1.3	4.4	0.3	Moderate
20121204 1800	21	21.25N	115.00E	340	2.4	6.1	0.4	Moderate
20121205 0000	24	22.50N	113.75E	340	0.4	3.7	0.1	Moderate
20121205 0600	21	21.25N	116.25E	340	1.9	4.4	0.4	Moderate
20121205 0600	24	22.50N	116.25E	390	0	0	-	Moderate
20121205 0600	24	21.25N	115.00E	340	0.9	3.9	0.2	Moderate
20121205 1800	21	22.50N	116.25E	300	0	0	-	Moderate
20121206 0600	24	20.00N	115.00E	340	2.4	6.6	0.4	Severe
20121206 1200	24	20.00N	116.25E	390	2.5	7.9	0.3	Moderate
20121207 0000	24	20.00N	116.25E	340	1	6.9	0.1	Moderate
20121207 0600	21	20.00N	116.25E	340	0.1	5.3	0.0	Moderate
20121217 0600	24	21.25N	116.25E	390	0	0	-	Moderate
20121226 0600	24	22.50N	116.25E	340	0	0	-	Moderate
20121226 1800	21	20.00N	115.00E	340	0	0	-	Moderate
20121227 0600	21	20.00N	113.75E	390	0.1	0.9	0.1	Moderate
20130103 0000	21	20.00N	115.00E	390	2.1	7.1	0.3	Moderate
20130103 0000	21	18.75N	112.50E	450	2.0	4.4	0.5	Moderate
20130103 0600	24	20.00N	115.00E	340	4.2	7.9	0.5	Moderate
20130103 1200	24	20.00N	113.75E	390	2.6	6.6	0.4	Moderate
20130103 1200	24	22.50N	116.25E	390	1.8	5.3	0.3	Moderate
20130112 0000	21	20.00N	112.50E	390	0.8	4	0.2	Moderate
20130112 0000	21	20.00N	112.50E	390	0.8	4	0.2	Moderate
20130112 0000	21	20.00N	113.75E	340	0	0	-	Moderate
20130112 0600	24	18.75N	112.50E	390	0.2	2.7	0.1	Severe
20130122 0600	24	20.00N	113.75E	390	1.9	4.2	0.5	Moderate
20130128 0000	24	21.25N	116.25E	390	4.3	6.4	0.7	Moderate
20130202 0600	24	18.75N	112.50E	340	0	0	-	Moderate
20130205 0000	24	22.50N	116.25E	340	1.4	3.7	0.4	Moderate
20130220 1200	21	20.00N	112.50E	340	0.3	2.8	0.1	Moderate
20130305 0600	24	21.25N	112.50E	340	0.1	0.9	0.1	Moderate

Gridded forecast based on time at (UTC)	Forecast Hour	3-D grid box covering location of special air-report of CAT and centre at			Mean CAT Potential Forecast	Maximum CAT Potential Forecast	Mean /Max ratio	Intensity of Reported Turbulence
		Lat (°N)	Long (°E)	Altitude (FL)				
20130305 1200	24	20.00N	115.00E	340	2.5	4.9	0.5	Moderate
20130322 0600	21	20.00N	113.75E	340	0	0	-	Moderate
20130328 0000	24	22.50N	116.25E	340	5.2	9.1	0.6	Moderate
20130328 0600	21	22.50N	115.00E	300	2.1	4.6	0.5	Moderate
20130328 1800	21	20.00N	115.00E	340	0.1	3.6	0.0	Moderate
20130411 0600	21	22.50N	116.25E	340	0.9	4.5	0.2	Moderate
20130516 1200	24	20.00N	115.00E	340	0	0	-	Moderate
20130702 1200	21	21.25N	116.25E	340	3.6	7.2	0.5	Moderate
20130702 1800	24	20.00N	113.75E	390	4.5	8.9	0.5	Moderate
20130704 0000	21	22.50N	116.25E	390	2.8	4.6	0.6	Moderate
20130703 1200	21	18.75N	115.00E	390	0.1	1.9	0.1	Moderate
20130809 1200	24	22.50N	113.75E	390	3	4.7	0.6	Moderate
20131026 0000	21	21.25N	115.00E	340	0	0	-	Moderate
20131127 0600	24	21.25N	116.25E	340	0	0	-	Moderate
20131206 0000	24	21.25N	112.50E	390	0.8	3.9	0.2	Moderate
20131217 0000	24	22.50N	115.00E	240	0	0	-	Moderate
20131217 0000	24	22.50N	116.25E	240	0.6	3.6	0.2	Moderate
20131219 0600	24	21.25N	116.25E	340	0	0	-	Moderate
20131222 0600	21	21.25N	116.25E	340	0.9	4.7	0.2	Moderate
20131222 1200	21	22.50N	117.50E	340	0	0	-	Moderate
20131223 1200	21	21.25N	111.25E	390	0	0	-	Moderate
20131224 1200	24	21.25N	116.25E	390	0.9	4	0.2	Moderate
20131225 1200	21	22.50N	115.00E	390	0	0	-	Moderate
20140112 1800	21	22.50N	116.25E	340	0.5	3.8	0.1	Moderate
20140112 1200	21	22.50N	117.50E	390	2.4	4.4	0.5	Moderate
20140112 1200	24	20.00N	113.75E	390	2	5.2	0.4	Moderate
20140112 1200	24	21.25N	111.25E	390	1.2	4.3	0.3	Moderate
20140114 0600	24	18.75N	112.50E	390	2.1	4.4	0.5	Moderate
20140115 1800	21	20.00N	113.75E	390	3	5.2	0.6	Moderate
20140118 0600	24	18.75N	112.50E	390	0	0	-	Moderate
20140120 0600	21	20.00N	113.75E	270	0.5	4.3	0.1	Severe
20140120 1200	24	21.25N	112.50E	340	0.5	3.7	0.1	Moderate
20140120 0600	21	22.50N	117.50E	390	0	0	-	Moderate
20140120 1800	24	21.25N	115.00E	270	3.9	4.7	0.8	Severe
20140121 0600	24	21.25N	116.25E	390	1.7	6	0.3	Moderate

Gridded forecast based on time at (UTC)	Forecast Hour	3-D grid box covering location of special air-report of CAT and centre at			Mean CAT Potential Forecast	Maximum CAT Potential Forecast	Mean /Max ratio	Intensity of Reported Turbulence
		Lat (°N)	Long (°E)	Altitude (FL)				
20140121 0000	24	21.25N	115.00E	270	3.8	4.7	0.8	Moderate
20140121 0600	21	18.75N	115.00E	270	1.5	4.3	0.3	Moderate
20140123 1800	21	20.00N	113.75E	390	0	0	-	Moderate
20140130 0600	24	20.00N	113.75E	390	3.5	4.8	0.7	Moderate
20140131 0600	21	20.00N	116.25E	390	0.1	2.7	0.0	Moderate
20140131 1800	21	22.50N	116.25E	340	1.9	6	0.3	Moderate to severe
20140202 0000	24	22.50N	116.25E	340	1.4	4	0.4	Moderate
20140207 1200	21	21.25N	112.50E	390	0.1	1.8	0.1	Moderate
20140212 1800	21	22.50N	116.25E	390	0	0	-	Moderate
20140215 1200	24	20.00N	113.75E	390	0	0	-	Moderate
20140313 0000	24	21.25N	117.50E	390	1.4	5	0.3	Moderate
20140313 0000	24	20.00N	113.75E	390	1.3	4.3	0.3	Moderate
20140328 0000	24	17.50N	113.75E	300	0	0	-	Moderate
20140406 0600	24	21.25N	116.25E	390	1.6	5	0.3	Moderate
20140408 0000	24	21.25N	115.00E	390	0	0	-	Moderate
20140408 0600	21	22.50N	116.25E	300	1	4.2	0.2	Moderate
20140408 0600	21	21.25N	116.25E	340	0	0	-	Moderate

**Table 2:** Hit rate for a range of thresholds of harmonized maximum CAT from accelerometer readings on aircraft and based on pilot reports for moderate or greater turbulence

Threshold	Hit Rate for Harmonized Maximum CAT from accelerometer readings on aircraft for moderate or greater turbulence [1]	Hit Rate for Maximum CAT Potential T+ 21 or T+24 Forecast
1.00	0.811	0.630
2.00	0.773	0.597
3.00	0.709	0.571
4.00	0.626	0.387
5.00	0.523	0.160
6.00	0.431	0.092
7.00	0.370	0.050
8.00	0.304	0.017
9.00	N/A	0.008
10.00	0.200	0.000

Note [1]: Figures copied from Guidance on the Harmonized WAFS Grids for Cumulonimbus Cloud, Icing and Turbulence Forecasts (Version 2.5; 13 September 2012): “Table 6: Verification scores for a range of thresholds of harmonized maximum CAT from accelerometer readings on aircraft for moderate or greater turbulence. *Note: There were insufficient observations above 10 to calculate scores. 641,783 Observations.*”

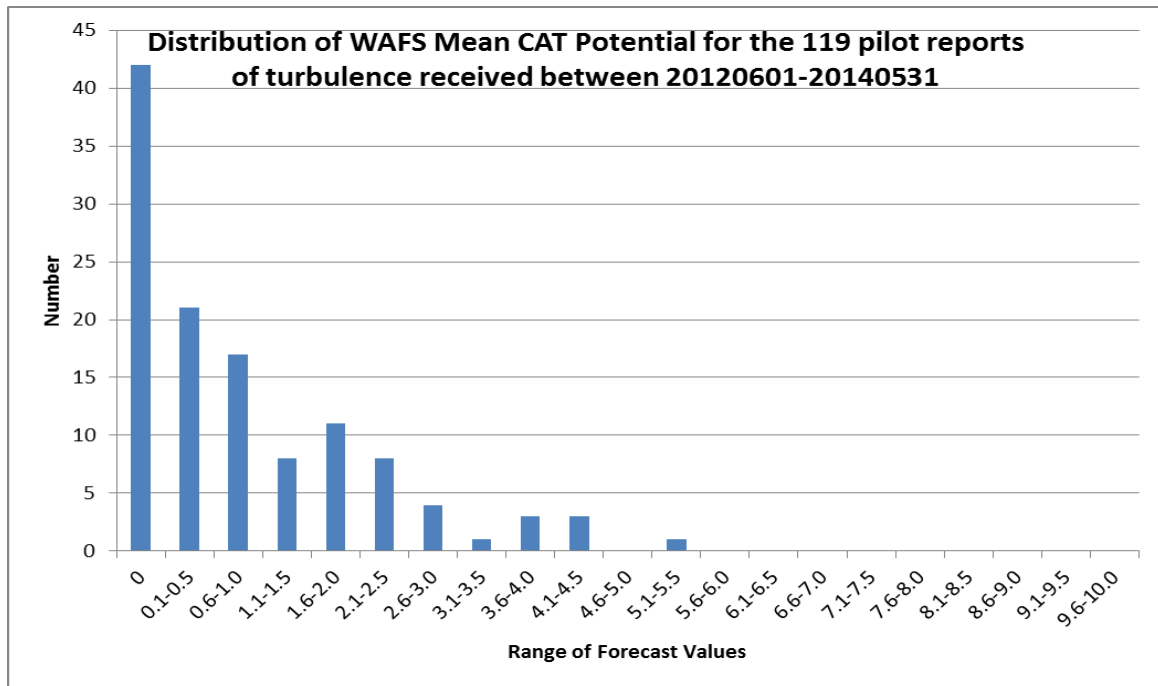


Figure 1A

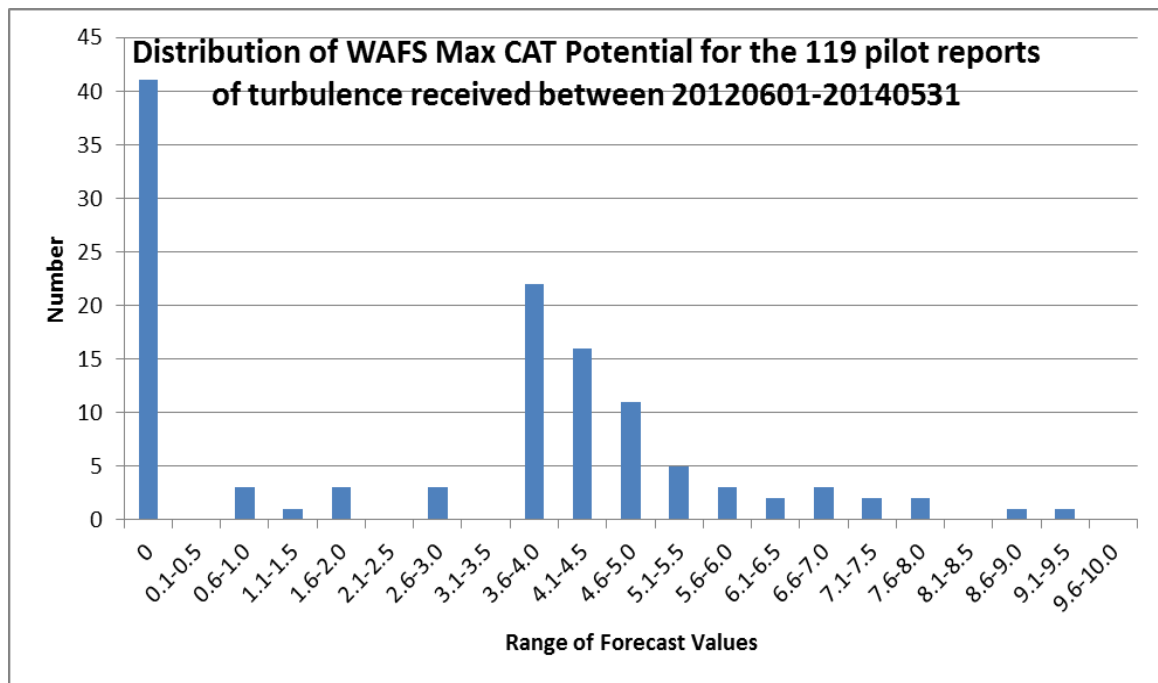
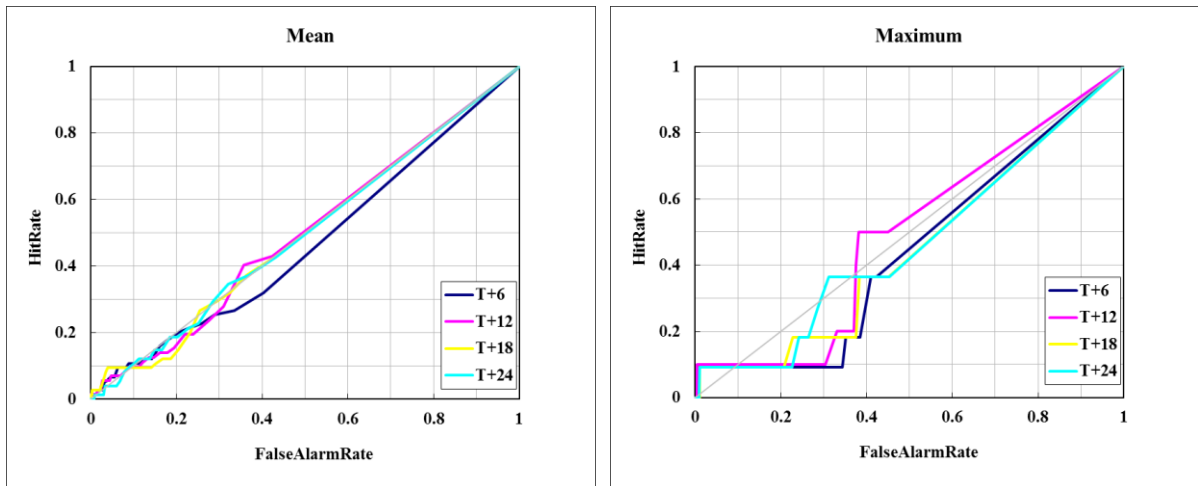


Figure 1B

Figure 1 Distribution (number of occurrence) of WAFS Mean (Figure 1A) and Maximum (Figure 1B) CAT Potential forecast for the grid box covering the location of special air-report of turbulence.





	T+6	T+12	T+18	T+24
D	6861	6730	6843	6776
T	75	72	75	75
F	1.09	1.07	1.10	1.11
A	0.47 (0.59)	0.50 (0.64)	0.50 (0.64)	0.50 (0.66)

	T+6	T+12	T+18	T+24
D	6861	6730	6843	6776
T	11	10	10	11
F	0.16	0.15	0.16	0.16
A	0.46 (0.47)	0.49 (0.52)	0.49 (0.60)	0.50 (0.54)

Figure 2 ROC curves of (a) mean EDR  $\varepsilon^{1/3} > 0.1 \text{ m}^{2/3}\text{s}^{-1}$  and (b) maximum EDR  $\varepsilon^{1/3} > 0.4 \text{ m}^{2/3}\text{s}^{-1}$  for the harmonized CAT potential forecasts at T+6, 12, 18 and 24 hours. Number of data points, number of turbulence events exceeding the respective EDR  $\varepsilon^{1/3}$  thresholds, the observed frequency of turbulence (in %), and the area under the curve (AUC) are denoted by D, T, F and A respectively. Values inside brackets () denote corresponding AUC scores in the previous study.