SESAR 2020 VLD - AAL2 Demonstration Report – Appendix J, K and L

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Table of Contents

Appendix J EXE-VLD-V4-200 Weather Impact Analysis on EFVS Operations *7*

J.1 Objectives, scope and assumptions of the study **7**

J.2 Analysis of the low Visibility situations **10**

J.3 Potential benefit of the EFVS to land concept of operation **25**

J.4 Method for supporting EFVS business case: example of Antwerp **29**

Appendix K EXE-VLD-V4-200 De-generalizing Instrument Approach Minima to Non-Instrument Runways *38*

Appendix L EXE-VLD-V4-200 Performance Prediction Analysis *39*

L.1 Performance of EFVS in Low Vis Situation resulting from pollutant **39**

L.2 EFVS performances on LED vs incandescent lights **42**

List of Tables

Table 1: EFVS-L and CAT II increase of aerodrome accessibility 29

List of Figures

Figure 1: Map of aerodromes selected for EFVS to land weather impact study 9

Figure 2: Aerodromes characteristics.. 10

Figure 3: Proportion of Low Visibility situations for all QFUs.. 12

Figure 4: Proportion of Low Visibility Situations for Main QFUs.. 12

Figure 5: cause of Low Vis Situations 13

Figure 6: causes of Low Vis Situations for main QFUs.. 13

Figure 7: proportion of Low Vis Situations for main QFUs.. 14

Figure 8: causes of Low Vis Situations for each airport 15

Figure 9: Proportion of Low Vis Situations versus published Minima for each airport 16

Figure 10: Proportion of Low Vis Situation for Unrestricted CATI airports.. 17

Figure 11: causes of Low Vis Situations for unrestricted CATI airports 18

Figure 12: proportion of Low Vis Situations for airports with published RVR less than 1 000 m 19

Figure 13: causes of Low Vis Situations for airports with published RVR less than 1 000 m 20

Figure 14: Distribution of RVR.. 21

Figure 15: proportions of RVR for each airport 22

Figure 16: distribution of ceilings 23

Figure 17: distribution of ceiling for each airport 24

Figure 18: potential benefit of EFVS-L versus CATII concept of operations.. 26

Figure 19: potential benefit of EFVS-L versus CATII concept of operations for each airport 27

Figure 20: number of Low Vis Situations 2008-2018 30

Figure 21: Antwerp, distribution and cause of Low Vis Situations over seasons................................ 33

Figure 22: Antwerp: Distribution of low Vis Situations over time of the day 36

Figure 23: Antwerp: Distribution of RVR of Low Vis Situations.. 37

Figure 24: Natural Pilot Eye simulation 41

Figure 25: EFVS Falcon Eye simulation 41

Appendix J EXE-VLD-V4-200 Weather Impact Analysis on EFVS Operations

This Appendix J to the SESAR 2020 AAL2 Demonstration Report for Augmented Approaches to Land 2 project analyses the weather impact on landing operations performed by a CATI aircraft/ crew and determines to what extent the EFVS to land concept of operation can expand the accessibility in degraded weather conditions.

In the perspective of the deployment of the EFVS to land operation (defined in EASA NPA 2016-08) in Europe, this study is a key input to assist all the stakeholders in their assessment of the real benefit of that new operational capacity (i.e. aircraft manufacturer, AIR operator, aerodrome operator, ANSP and CAA).

The Appendix is structured in the following way:

- Objective and Scope of the study
- Global Analysis of Low Visibility situations (number and causes)
- Potential benefit of EFVS to land concept of operation
- Detailed analysis of Low Visibility situations: example of Antwerp

J.1 Objectives, scope and assumptions of the study

J.1.1 Objectives of the study

This analysis determines what extent a CATI aircraft/ crew will be unable to land due to limited RVR or too low CEILING (or both). It estimates the proportion of situations the RVR or / and the CEILING are below the published minima (RVR and DA/H).

In this report, we will refer to the generic wording “Low Visibility situations” to address the situations described here above.

J.1.2 Scope of the study

1. Volume of data

This weather study has been conducted in continuation of the previous SESAR AAL weather study (2016-2017). Based on the experience of SESAR AAL, it is focused on limited number, but well-chosen European aerodromes and it covers a much longer period of time for giving more confidence in the results.

The analysis has been conducted:

- on 52 QFUs of 29 aerodromes of interest including the four aerodromes intended for the VLD (Antwerp, Le Bourget, Périgueux and Payerne).

- over a period of ten years (01/01/2008 to 31/12/2018)
- and for opening hours from 04h00 to 23h00 (UTC) to address most of operations

With respect to weather data, in total, a sample of 10 000 000 of METAR slots were collected and analyzed (which represents five more data than for SESAR AAL study).

2. Aerodromes and Approach Minima

Aerodromes:

Special attention was paid to the selection of the Aerodromes to ensure a high level of operational relevance of the study. Following criteria were applied for the selection:

- Aerodrome is fitted with an Instrument Approach Procedures (IAP) suitable for EFVS to land operations (according to NPA 2016-08) and
- Aerodromes is frequently used by Business aviation and Regional aviation and
- Aerodrome have relatively low level of infrastructure resulting in relatively high published minima, and
- Aerodrome is facing to “a priori” degraded weather conditions based on general knowledge of Weather at these locations

In consistency with the objective of the study and EFVS intended use for business and regional aviation, none of aerodrome selected in the Study is capable of CATII/III operations.

The list of aerodromes and their relevant information for the study (location and published minima) is given here below:

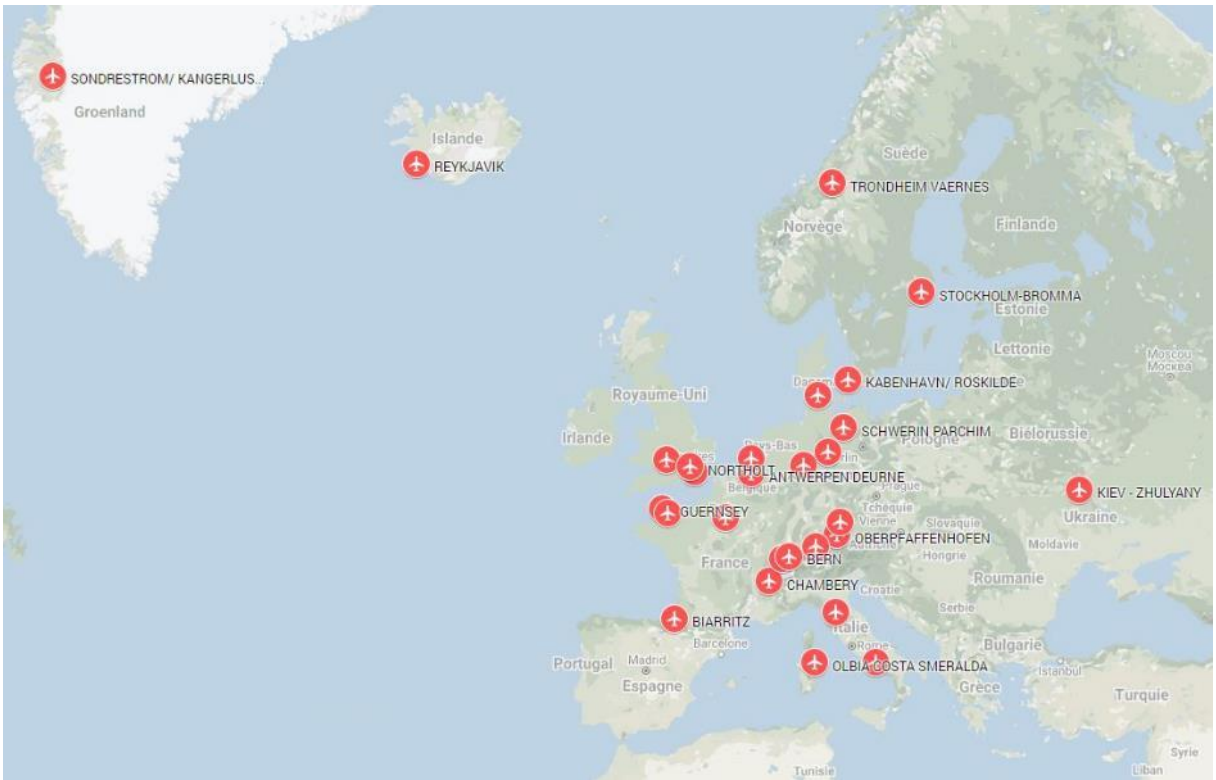


Figure 1: Map of aerodromes selected for EFVS to land weather impact study

MINIMA:

In order to figure out the best level of accessibility permitted by each aerodrome, only the lowest MINIMA corresponding to the most performant IAP (available in 2019) will be considered for each runway.

The Fig here below describes the list of IAP, and associated MINIMA considered in the study.

ICAO CODE	AIRPORT NAME LOCATION	COUNTRY	Type of airport	airport opening hours (UTC)		case 1				case 2			
				from	to	runway (preffered One)	IAC type	RVR (m)	DH (ft)	runway	IAC type	RVR (m)	DH (ft)
BIRK	REYKJAVIK	ICELAND	CAT 1	4	23	19	ILS	1000	200	13	LNAV/VNAV	1800	389
BGSF	SONDRESTROM/ KANGERLUSSUAQ	GREENLAND	CAT 1	4	23	9	LOC CDFA	1200	350				
EBAW	ANTWERPEN DEURNE	BELGIUM	CAT1	4	23	29	ILS	750	200	11	LPV	900	294
EDLP	PADERBORN/ LIPPSTADT	GERMANY	ILS cat 1	4	23	6	ILS/ LPV	550	200	24	ILS/LPV	750	200
EDMO	OBERPFAFFENHOFEN	GERMANY	ILS cat 1	4	23	22	ILS	1000	200	22	LPV	1500	250
EDOP	SCHWERIN PARCHIM	GERMANY	CAT 1	4	23	24	ILS	550	200				
EDVE	BRAUNSCHWEIG	GERMANY	CAT1	4	23	26	ILS	550	200	8	LNAV/VNAV	750	310
EGBJ	GLOUCESTERSHIRE	UK	CAT 1	4	23	27	ILS	1000	203	9	RNAV CDFA (VGP)	1700	406
EGJJ	JERSEY	UK	CAT 1	4	23	26	ILS/ LPV	550	200	8	ILS/ LPV	1000	200
EGKB	BIGGIN HILL	UK	CAT1	4	23	21	ILS	800	229				
EGLF	FARNBOROUGH CIV	UK	CAT1	4	23	6	ILS	550	200	*24*	*ILS*	*550*	*200*
EGWU	NORTHOLT	UK	CAT 1	4	23	25	ILS	1200	260				
EHRD	ROTTERDAM	NETHERLANDS	CAT1	4	23	24	ILS	550	200	6	ILS	750	200
EKRK	KABENHAVN/ ROSKILDE	DENMARK	CAT 1	4	23	11	ILS	550	200	*21*	*ILS*	*550*	*200*
EKSB	SOENDERBORG	DENMARK	CAT1	4	23	32	ILS	550	212	14	RNAV LPV	800	250
ENVA	TRONDHEIM VAERNES	NORWAY	CAT 1	4	23	9	ILS	800	217	27	ILS	800	247
ESSB	STOCKHOLM-BROMMA	SWEDEN	CAT 1	4	23	12	ILS	550	200	30	ILS	750	200
ETSI	INGOLSTADT/ MANCHING	GERMANY	CAT 1	4	23	07R	RNAV GNSS (VGP)	1200	359	25L	ILS	550	200
LFBZ	BIARRITZ	FRANCE	CAT1	4	23	27	ILS	1200	200	9	LPV	800	250
LFLB	CHAMBERY	FRANCE	CAT1	4	23	18	ILS 8%	1000	310				
LFPB	PARIS LE BOURGET	FRANCE	CAT1	4	23	27	ILS	800	200	7	ILS	1000	320
LIEO	OLBIA COSTA SMERALDA	ITALY	CAT 1	4	23	5	ILS	650	294	23	ILS5%	1300	370
LIRN	NAPOLI CAPODICHINO	ITALY	CAT 1	4	23	6	ILS	1400	395	24	ILS	1000	317
LIRQ	FIRENZE/PERETOLA	ITALY	CAT 1	4	23	5	ILS	2200	532				
LSMP	PAYERNE	SWITZERLAND	CAT1	4	23	5	ILS	1500	500	*23*	*ILS*	*1500*	*500*
LSZB	BERN	SWITZERLAND	CAT1	4	23	14	ILS 7%	1800	500	32	Ciding	5000	2327
LSZR	ALTENRHEIN	SWITZERLAND	CAT1	4	23	10	ILS	2300	500				
EGJB	GUERNSEY	UK	CAT 1	4	23	9	ILS	550	200	*27*	*ILS*	*550*	*200*
UKKK	KIEV - ZHULYANY	UKRAINE	CATI	4	23	8	ILS	600	220	26	ILS	800	200

Figure 2: Aerodromes characteristics

Note 1: Some aerodrome that were initially intended to be part of the study had to be removed due to the unavailability of the weather record during the considered period.

J.2 Analysis of the low Visibility situations

J.2.1 Methodology/ Analysis of Data

Low Visibility situations are determined by comparing the Visibility/ RVR and Ceiling weather information with the published MINIMA. Weather information are extracted from METAR report records that are issued by airport met Offices in half-hourly intervals.

These analyses consist in:

- The estimation of the number of Low Visibility situations that prevent landing,
- The determination of the proportion of either too low visibility or too low ceiling (or combination of both factors) as causes of the Low Visibility situation

This analysis gives a global number based on the full set of aerodromes over the full period of time of the study.

However, because the situations may significantly vary from an airport to another depending on its location or/ and its level of infrastructure, numbers for each airport have also been determined.

J.2.2 Assumptions

Important Note: As per ICAO annex 3 definition, ceiling is set if OVC 8/8 or BKN 5/8 to 7/8 nebulosity conditions are reported.

The weather data:

a) The RVR records used for analysis are those delivered by the RVR sensors installed along the runways. RVR is reported in steps of 25m up to 400m, 50m up to 800m and 100m beyond this value. Values are rounded down to the nearest lower reporting step in the scale. In case of several RVR sensor are installed on the runway (which is not common for non CATII/III airports), the RVR threshold value is considered.

b) The cloud height is associated to the different types of cloud and is computed by the ceilometers installed over the airport area. Cloud height is provided in steps of 30m up to 3000m and as it is for RVR, values are rounded to the nearest lowest step, which means that a 150ft cloud height will be rounded at 30m/100ft in the data provided. In consistency with ICAO definition for ceiling (note 2), and because the likelihood of landing is high in case of cloud density such as FEW (cloud coverage of 1/8 to 2/8) or SCT (3/8 to 4/8), only cloud cover density of OVC (8/8) or BKN (5/8 to 7/8) will be considered as limiting factor in this study. In case several BKN or OVC cloud layers are reported at different altitudes, the lowest one is finally selected in computation.

Estimation of Time of operation: Time of operation is computed in the study assuming a METAR report is carried out at half-hourly intervals (full hour + 20 and full hour + 50 minutes). This gives is optimistic figures for the time computation because intermediate METAR labelled as SPECI are posted in case of significant of weather change occur in the half hourly interval.

NIL METAR: Some METAR are reported as NIL meaning no METAR has been posted in time (too late or forgotten. NIL is not due to maintenance). NIL is properly taken into account in the study, i.e. they are accounted for total number of cases.

The published Minima: The published MINIMA considered in this study are those applicable to a CAT C aircraft.

Note 2: Per ICAO ANNEX 2, the ceiling is defined as "the height above the ground or water of the base of the lowest layer of cloud below 6 000 meters (20 000 feet) covering more than half the sky", which corresponds to OVC and BKN

J.2.3 Results

1. Global proportion of Low Visibility situations

This section quantifies the global number of Low Visibility situations, i.e. ceiling, low visibility or both combined in a single category, over the full period restricted to opening hours considered for the study (see here above section J.1.2).

The figures here below show that the average proportion of low Visibility situations is 1% counting all QFUs of all aerodromes and respectively 0,9% counting only the 29 main QFUs.

These numbers are not significantly different. The lowest number for main QFU is consistent with the fact it corresponds to the best equipped runway.

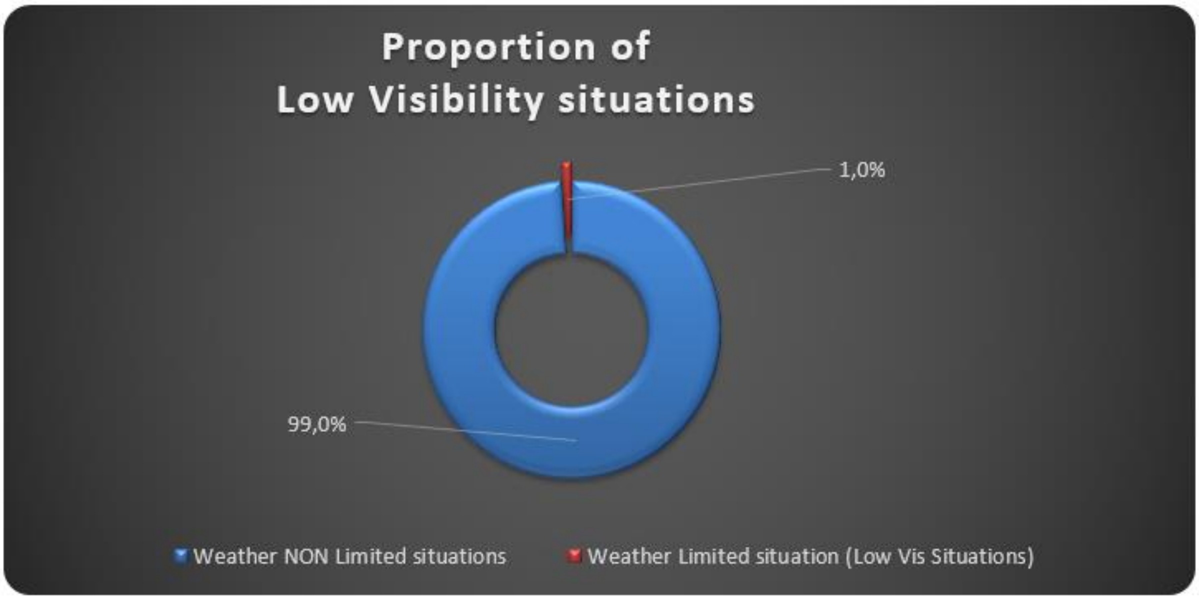


Figure 3: Proportion of Low Visibility situations for all QFUs

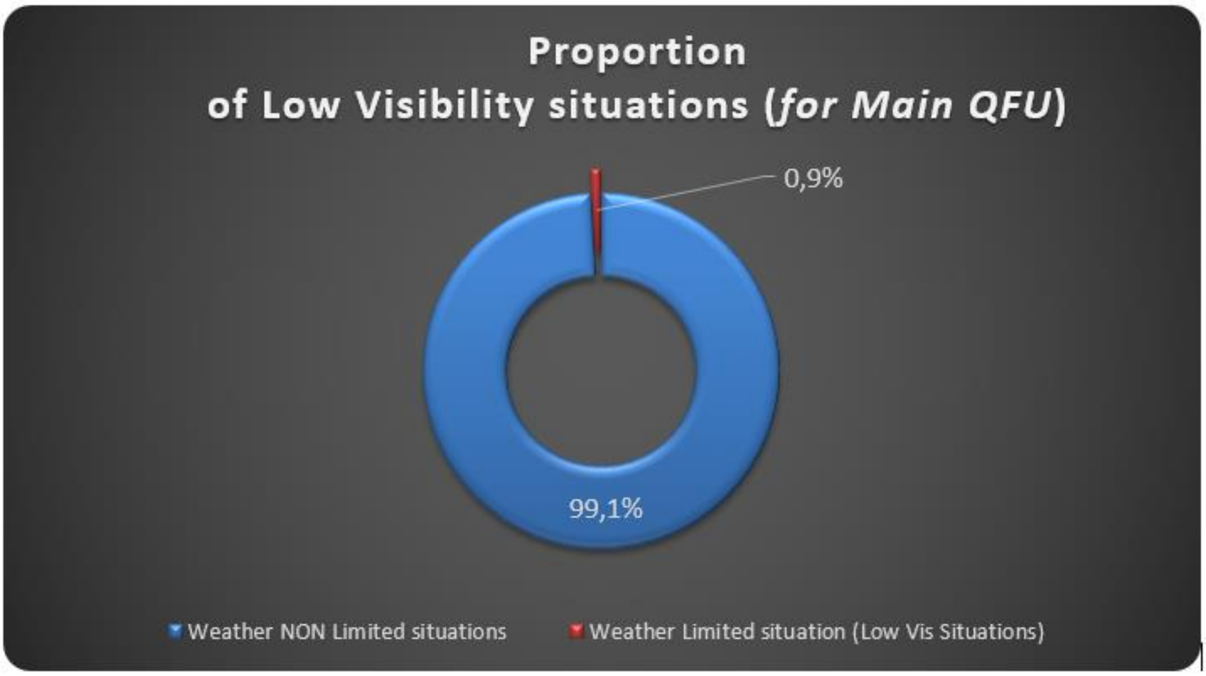


Figure 4: Proportion of Low Visibility Situations for Main QFUs

2. Causes of Global Low Visibility situations

From a global standpoint, the Figures here below indicate that the main cause of these Low Visibility situations is the CEILING.

The average proportion of CEILING for main QFUs is 57%, reaching 69% in case all QFUs are considered. RVR is a limiting factor in 36% of the Low Visibility situations for main QFUs (respectively 25% for all

QFU). Reduced RVR or low CEILING are observed in combination in only 7% of the amount of time (respectively 6% for all QFUs).

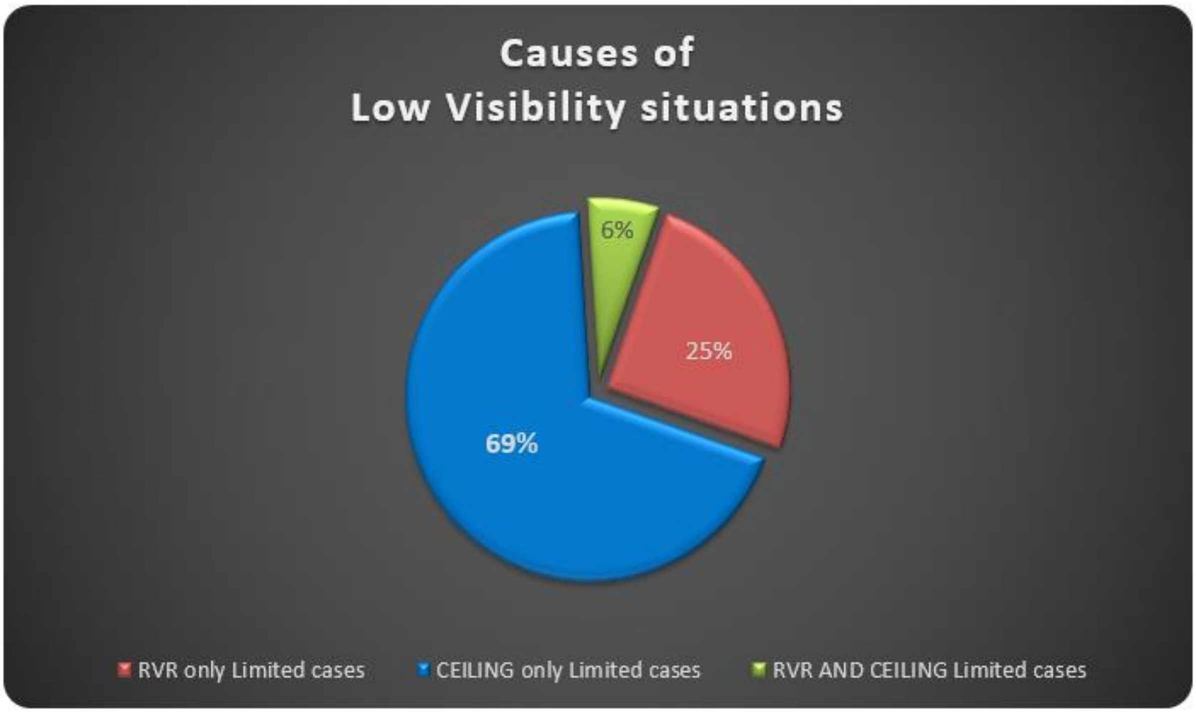


Figure 5: cause of Low Vis Situations

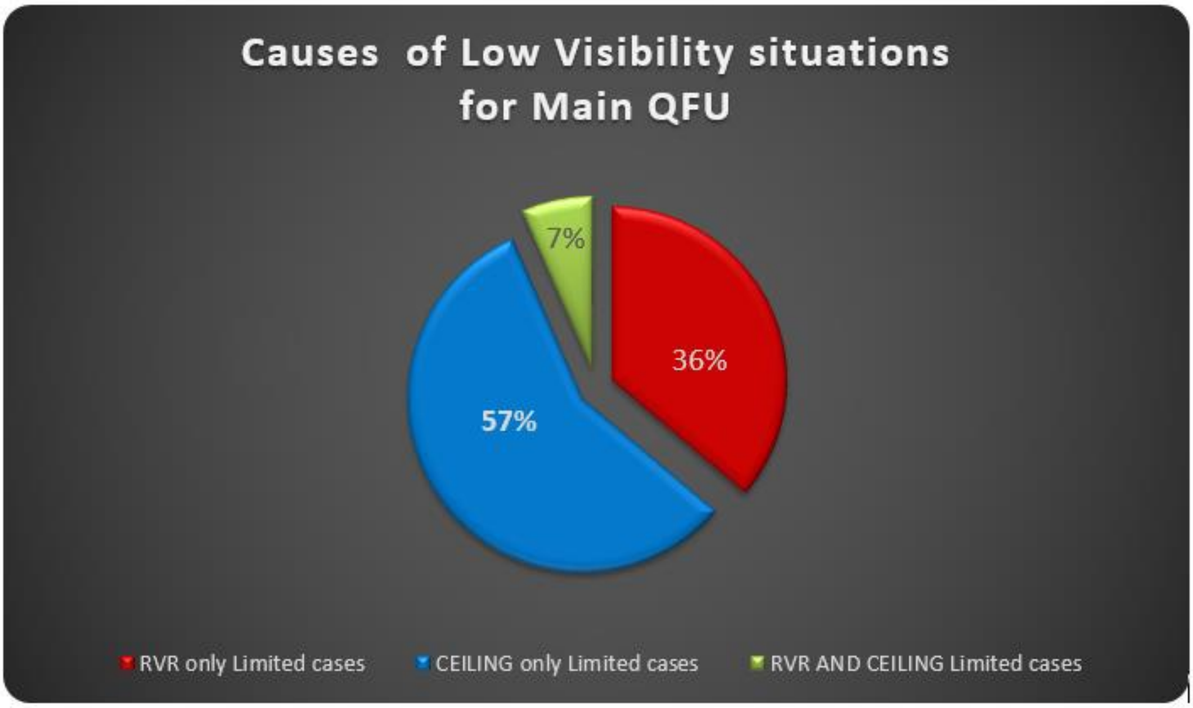


Figure 6: causes of Low Vis Situations for main QFUs

3. Aerodromes variations

a. Proportion of low Visibility situations

Beyond the global tendency presented in previous section, the analysis of the proportion of low Visibility situations for main QFU of each aerodrome show a significant dispersion. Data vary in a proportion of 1 to 3 reaching 3,2%.

On one hand, four aerodromes such as NAPOLI (LIRN) or OLBIA (LIEO) are almost never limited by low Visibility situations (<0,1%).

On the other hand, 17% of aerodromes such as GUERNSEY (EGJB), KYIV (UKKK) or BERNE (LSZB) reveals that they are subject to Low Visibility situations in a proportion up to 3 times the average rate.

45% of aerodromes considered have higher than average rate (1%) for low visibility situations.

Note: the sections here below will show that these aerodromes have relatively high published minima.

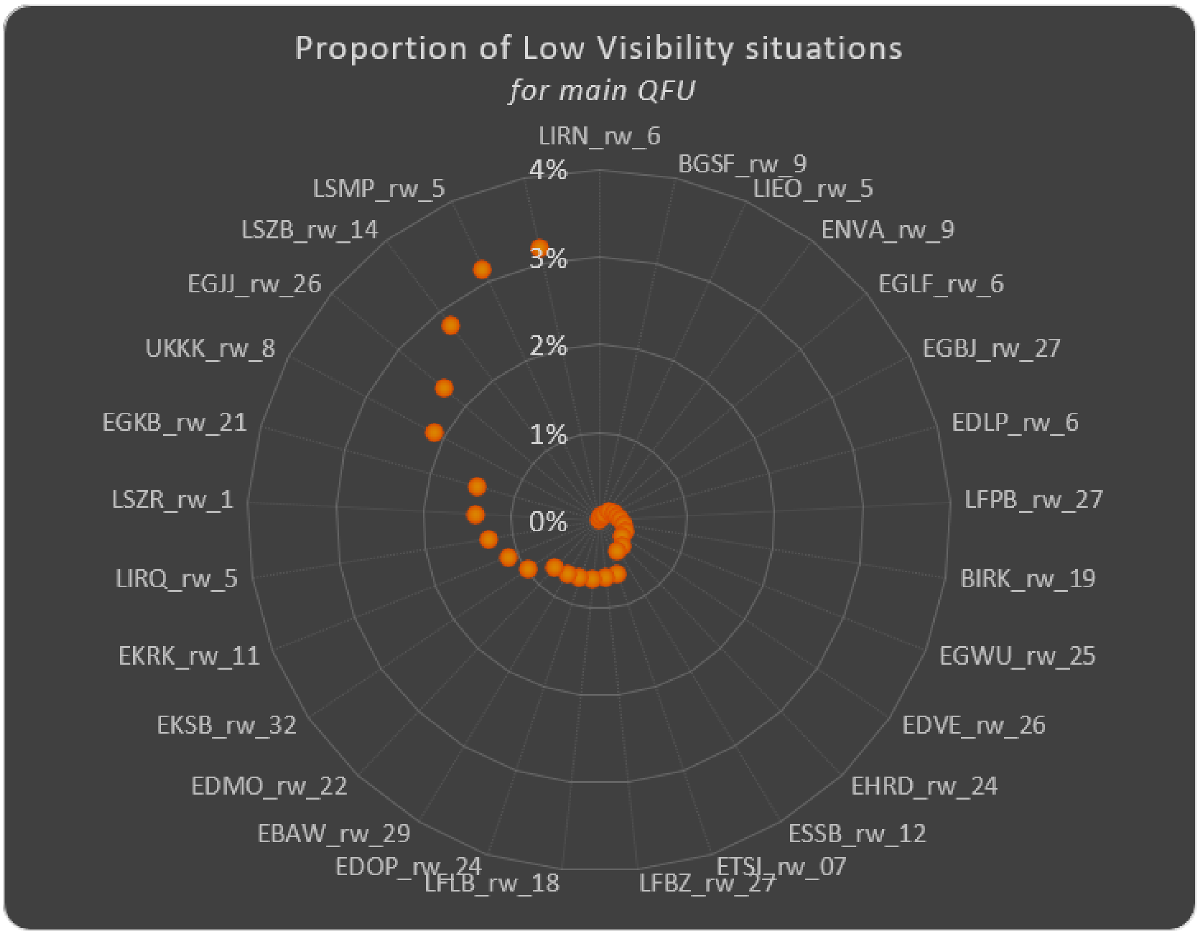


Figure 7: proportion of Low Vis Situations for main QFUs

b. Causes of Low Visibility situations

As for general proportion of Low Visibility situations, large variations are also observed regarding the contribution factors.

Some aerodromes such as JERSEY or NORTHOLT or STOCKOHLM are exclusively limited by CEILING which the major contributor factor of Low Visibility situations. In contrast, although none of the aerodrome is only affected at 100% by RVR, BIARRITZ, LE BOURGET and REYKJAVIK are mainly affected by limited RVR (>85%).

These differences result from the combination of two factors:

- The major type of the weather that take place at these different airport locations. These conditions may be very different as they are strongly affected by local geographical factors such as the presence of mountain, water area, urban area, or vegetation…. For example, FIRENZE is more subject to fog and JERSEY more frequently exposed to low ceiling.
- And/ or the adequacy of the Published Minima (RVR and DA/H) for each aerodrome (see next section)

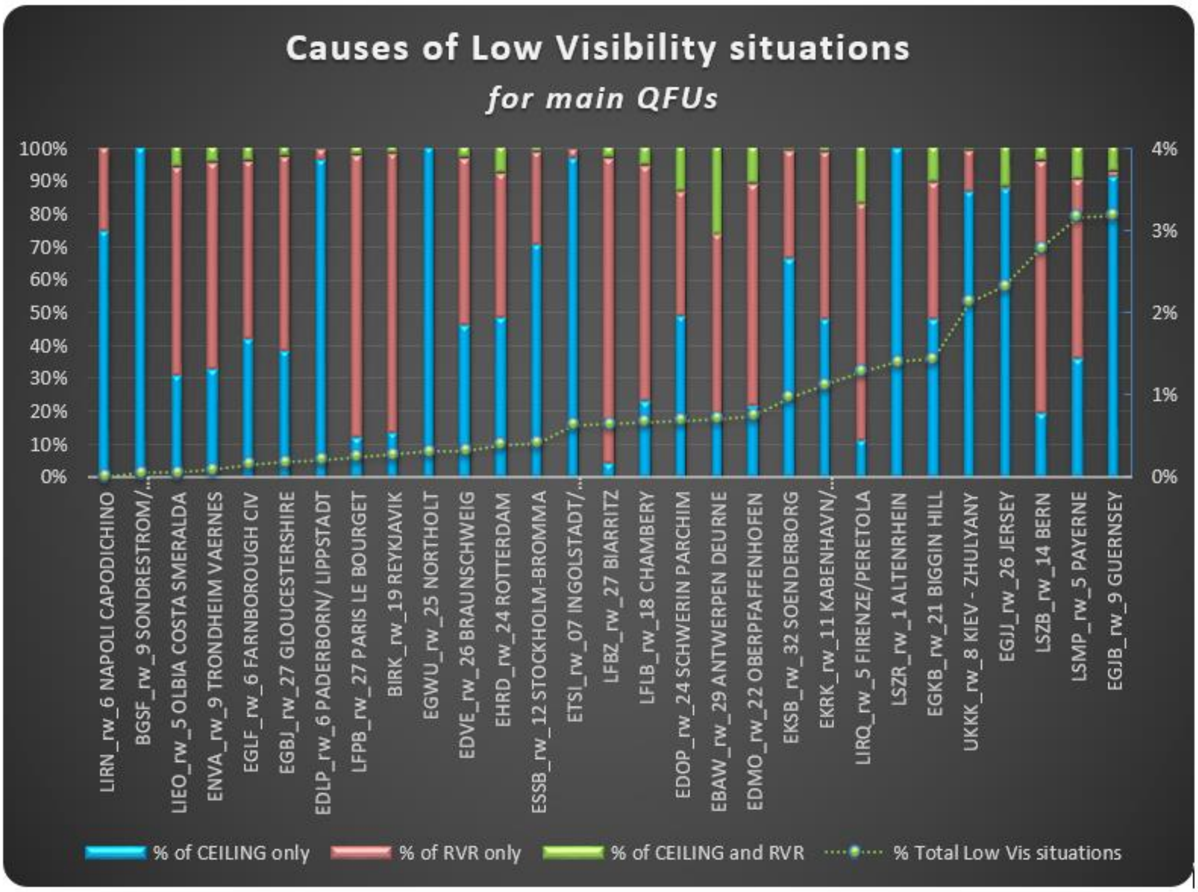


Figure 8: causes of Low Vis Situations for each airport

c. Causes of Low Visibility situations and Minima

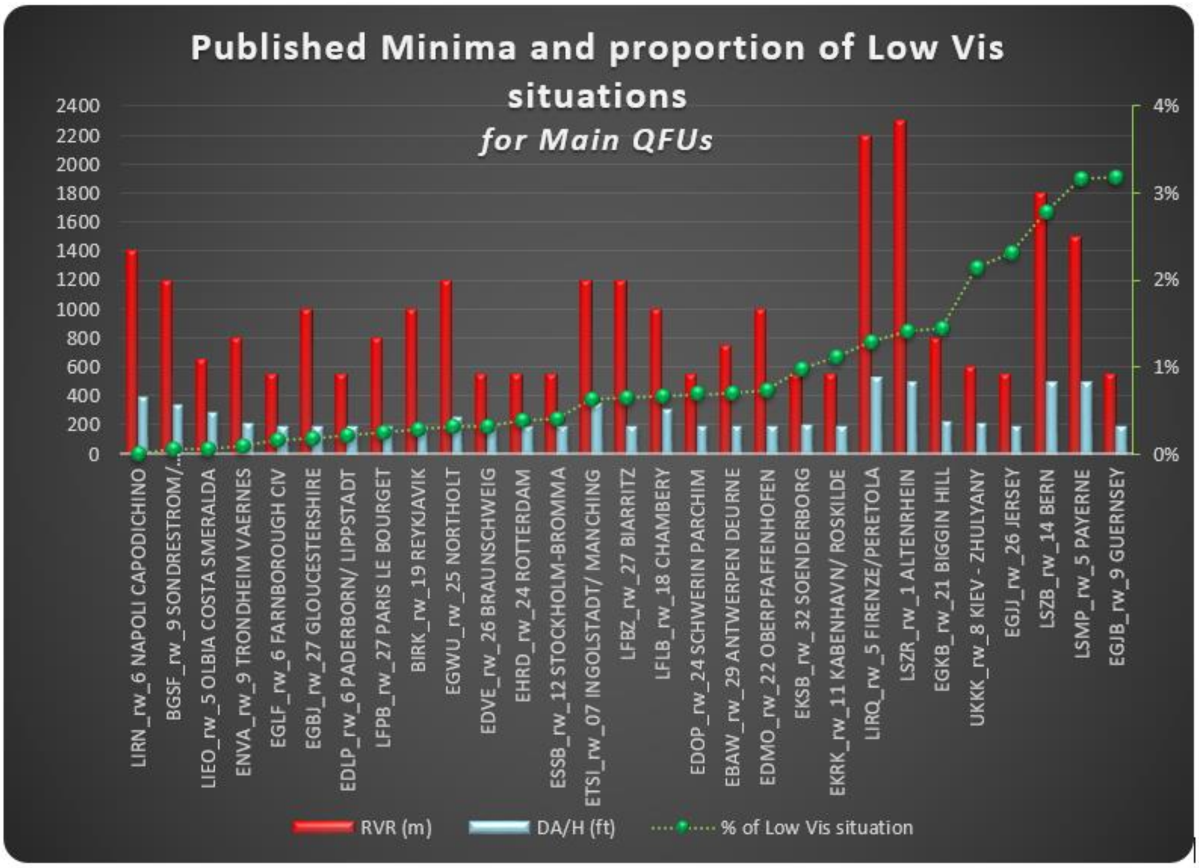


Figure 9: Proportion of Low Vis Situations versus published Minima for each airport

This section analyses the relation between the contribution factors of low visibility situations with regard to published Minima (RVR and DA/H).

Comparison of the graph of the previous section (depicting causes of low visibility situations for each aerodrome) with the graph here below (representing the published minima – RVR in red and DA/H in blue) show that there is apparently no obvious correlation between these two factors.

Some airports with High value of published RVR are however mainly limited by the ceiling (for example EGWU, LSZR, ETSI).

i. The case of unrestricted CATI runways

First of all, 36% of these 11 "best served" aerodromes present a proportion of Low Visibility situation equal or greater than the average value (1%) and 1/3 (27%) have a proportion twice higher than the average value.

The analysis of the "best served" runways where the lowest CAT 1 published minima are available (i.e. an RVR 550m and a DA/DH of 200ft) reveals that the ceiling is the main limiting factor for most of them (>55%). Ceiling limitation may even reach almost 100% for the 3 aerodromes that are the most frequently exposed to low visibility situations.

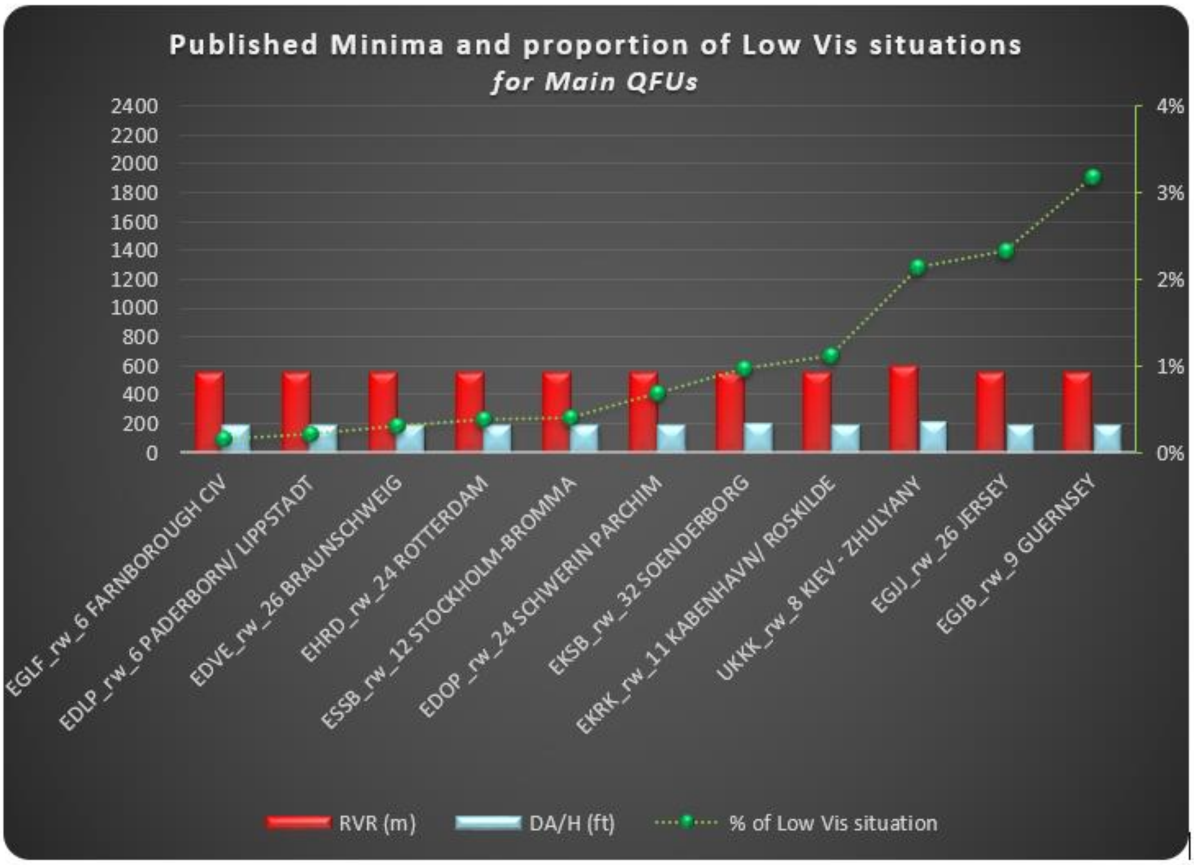


Figure 10: Proportion of Low Vis Situation for Unrestricted CATI airports

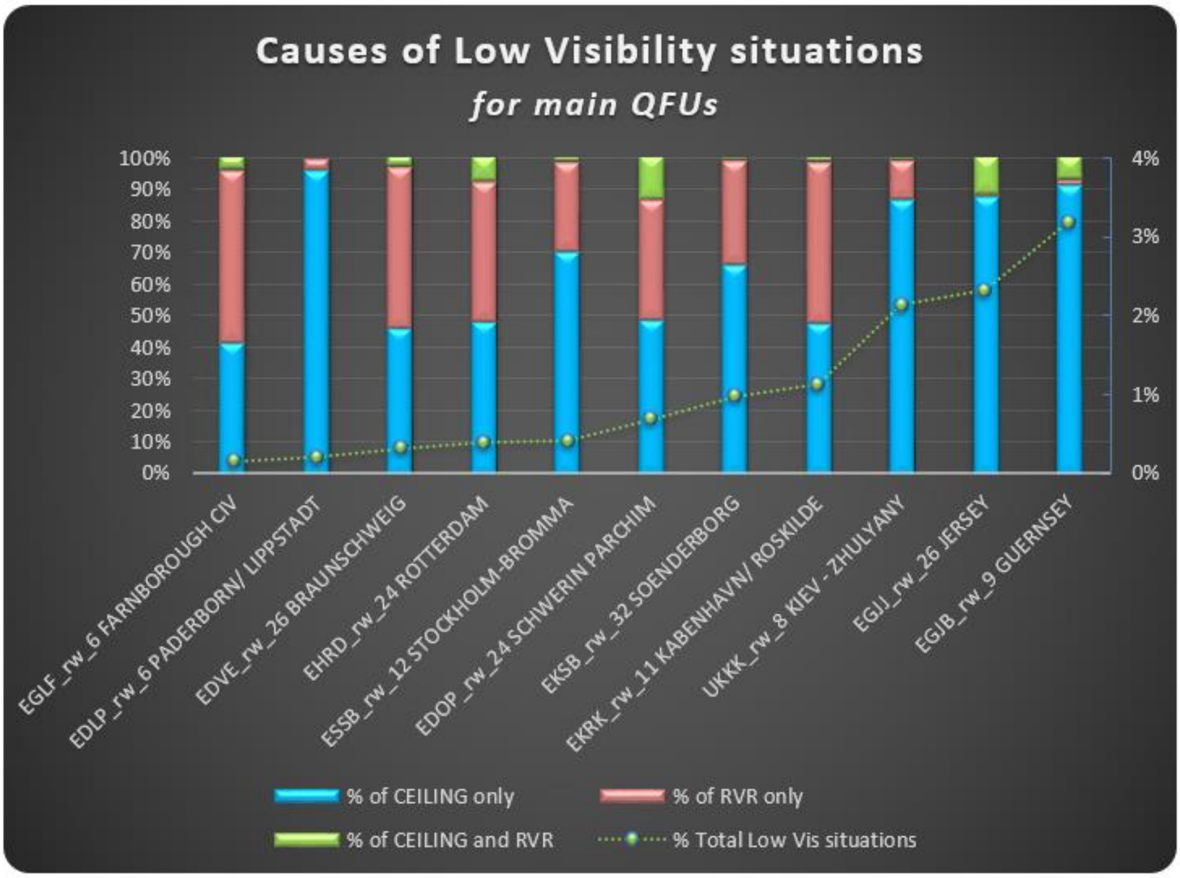


Figure 11: causes of Low Vis Situations for unrestricted CATI airports

ii. Case of runways with RVR minima less than 1 000 m

Aerodrome with RVR Minima of 800m – 1 000 m is very common as the reduced RVR most of the time reflect the fact the aerodrome is not equipped with costly full lighting systems.

For all these aerodromes of the list, the main limiting factor is the RVR.

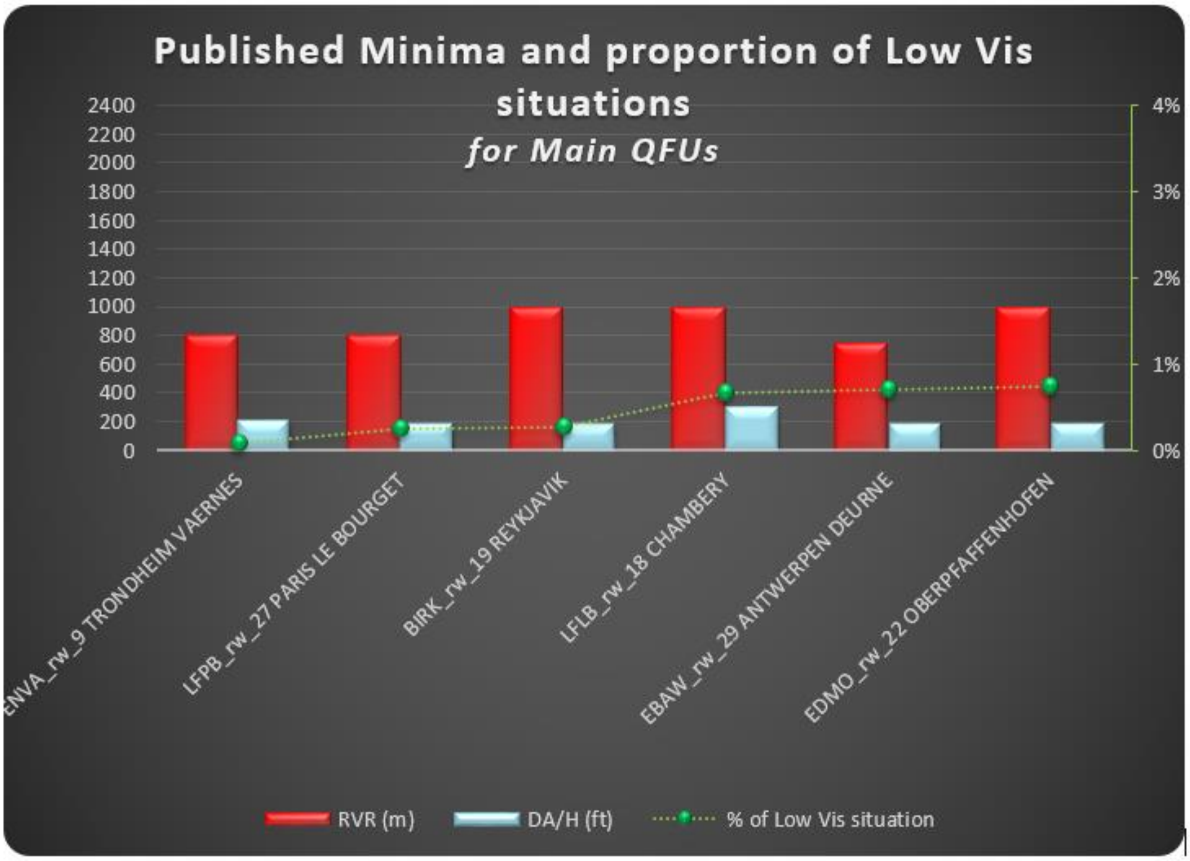


Figure 12: proportion of Low Vis Situations for airports with published RVR less than 1 000 m

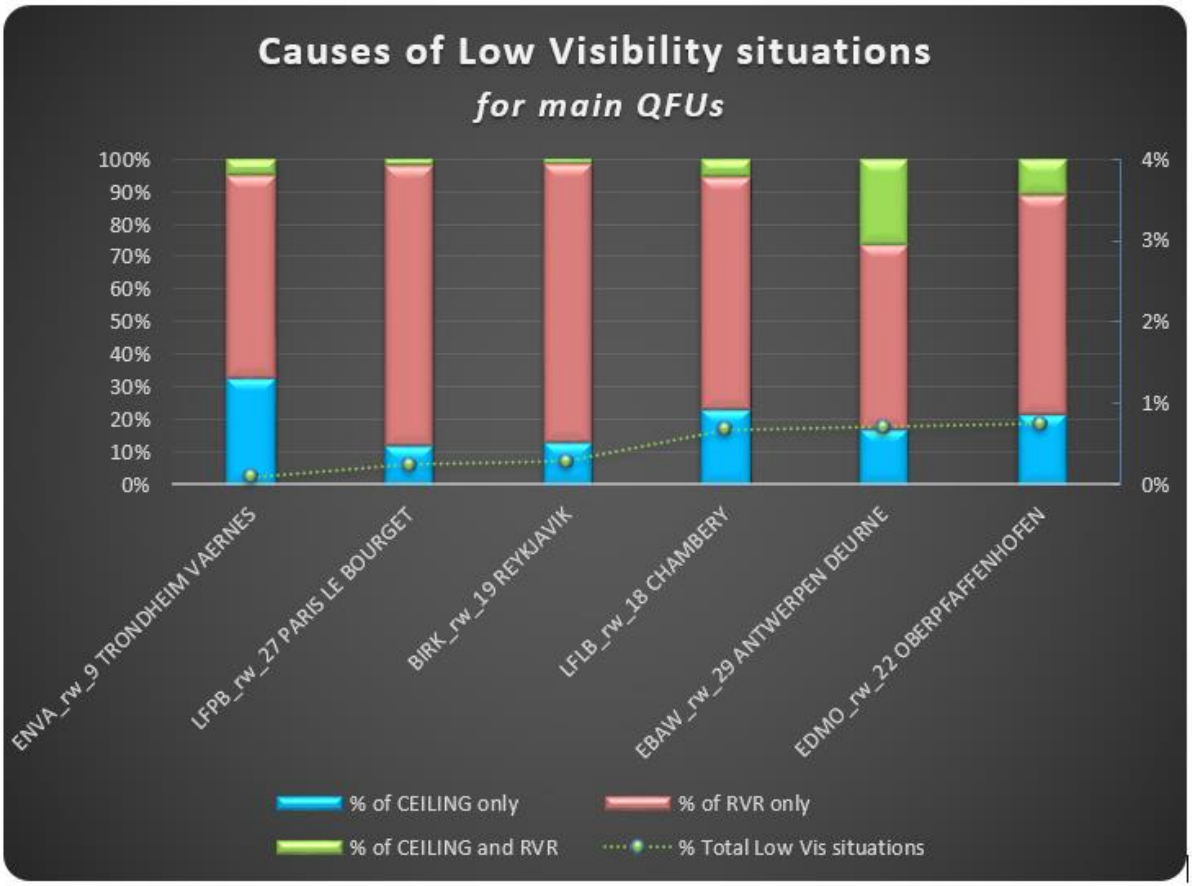


Figure 13: causes of Low Vis Situations for airports with published RVR less than 1 000 m

iii. Distribution of ceiling and RVR

This section analyses the distribution of ceiling and RVR in the range they mainly affect the landing operations.

The range of 0-1499m for RVR and 0-400ft for CEILING have been selected as they cover most of the operational situations.

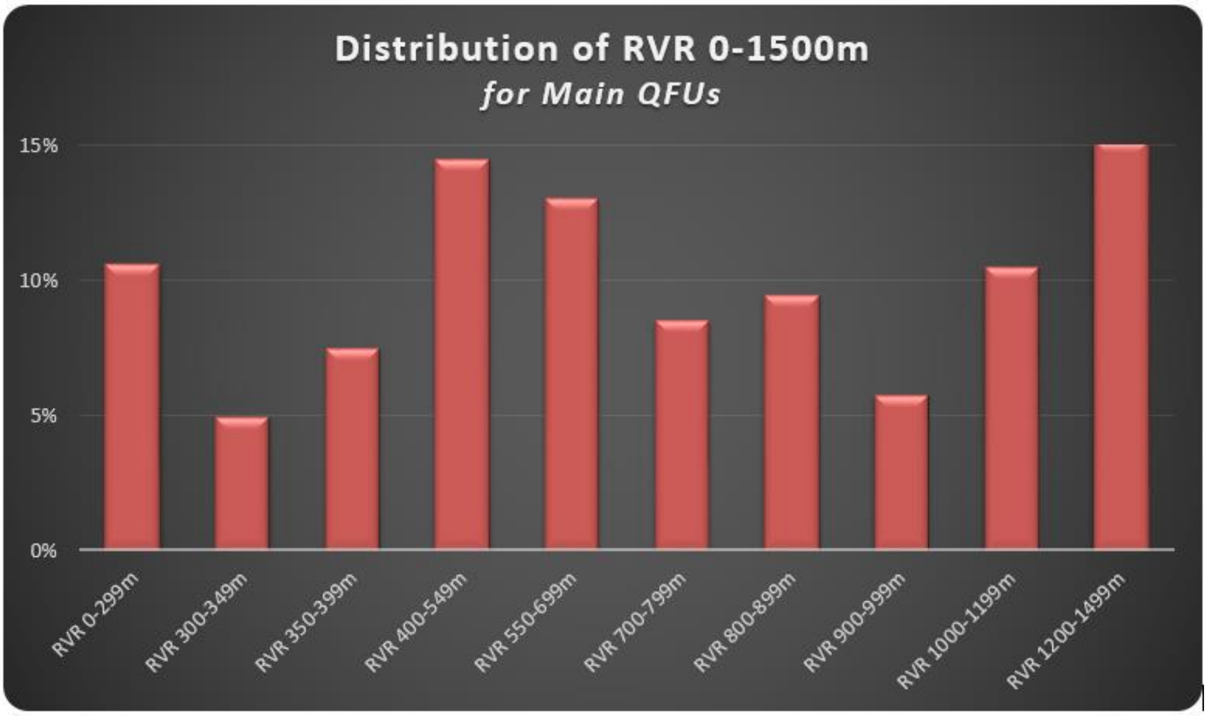
1. RVR

The Analysis of the RVR value in the range 0-1499m for main QFU shows a peak in the range 400-700m with relatively high proportion of RVR below 300m.

With respect to EFVS concepts, the cumulated histogram indicates that 37% of the 0-1499m RVR are below 550m which is the limit of CAT I operation.

10% of RVR observed are still below 300m which is the bottom limit for EFVS operations (same as CATII).

The third Fig here below shows large variation depending on aerodromes. In ROTTERDAM, for example, the proportion of RVR of less than 550m is more than 46% for ROTTERDAM or JERSEY or of RVR below 1499m. 28% of RVR less than 1499m are equal or less than 300m in GUERNSEY.



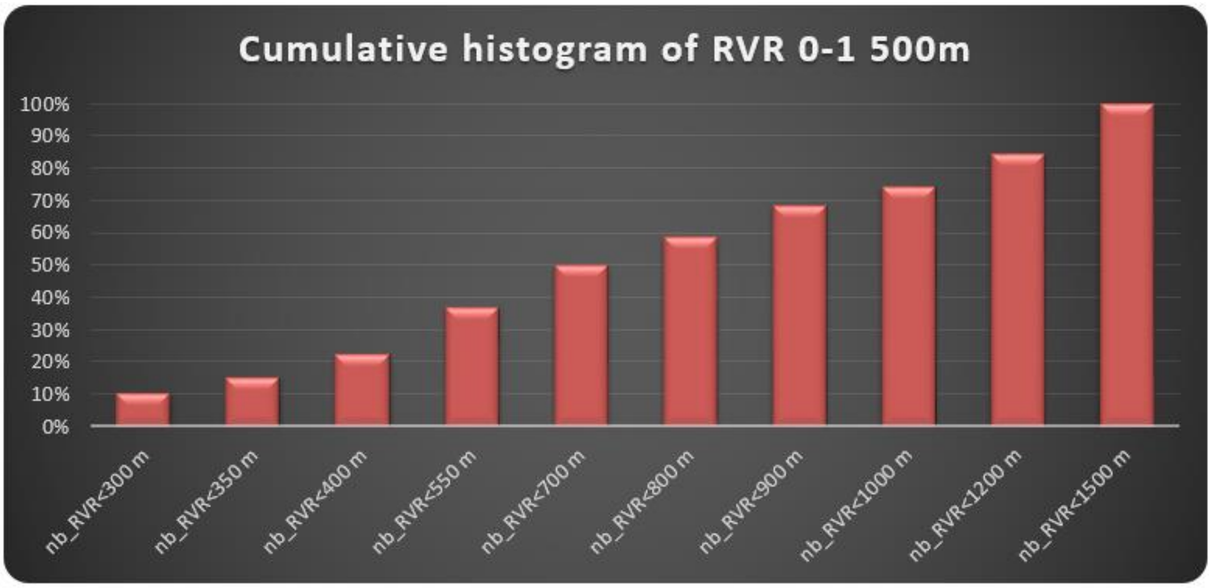


Figure 14: Distribution of RVR

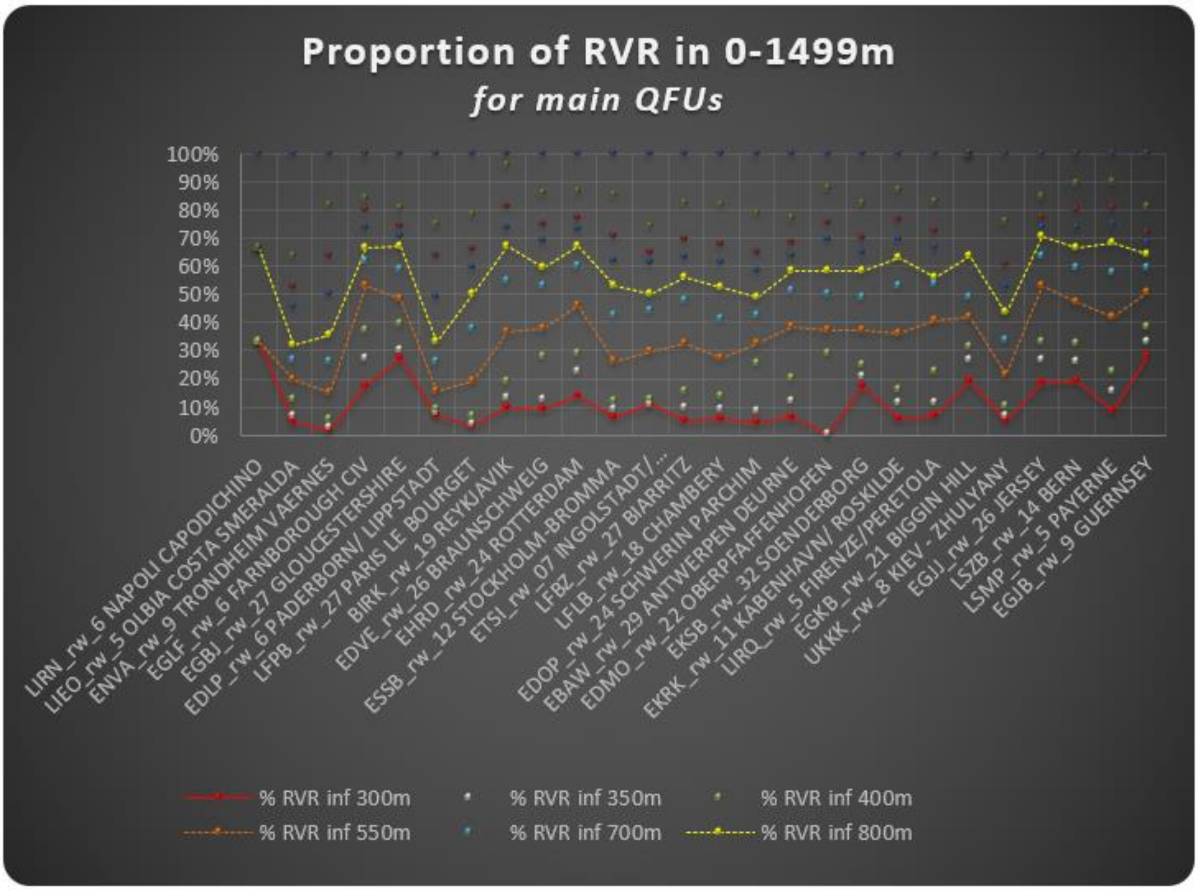
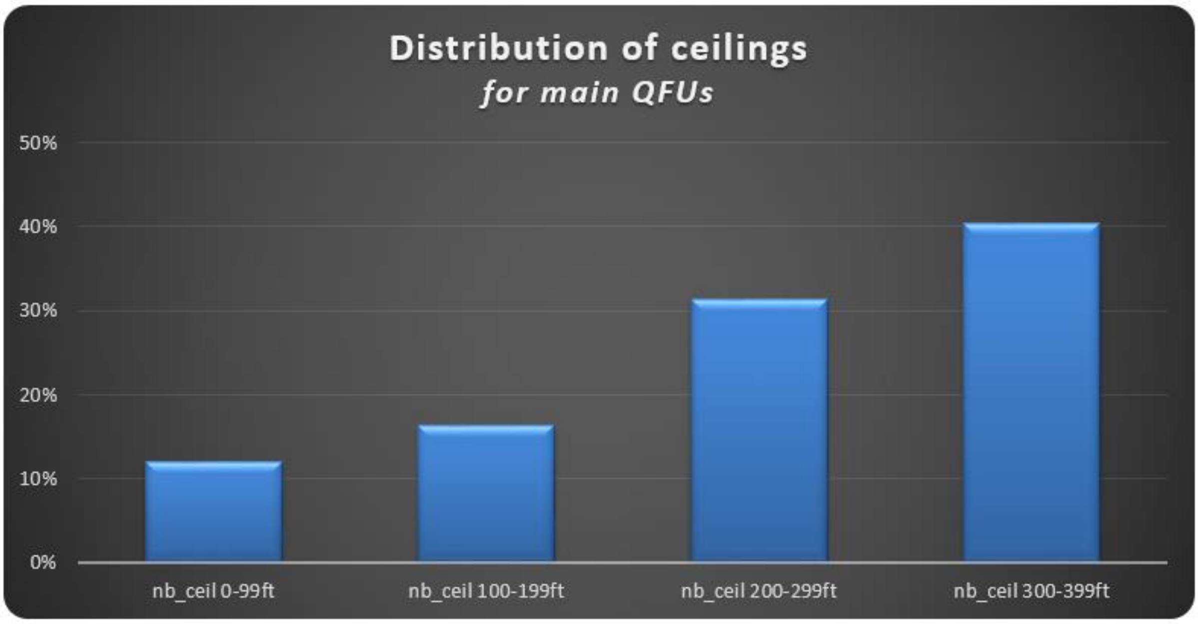


Figure 15: proportions of RVR for each airport

2. Ceiling

Although 12% of ceiling in the range 0-400ft are equal or below 100ft, 86% of the 29 aerodromes have a proportion of ceiling lower than 100ft. In contrast, JERSEY and GUERNSEY have very high proportion of ceiling below 100ft (40%).



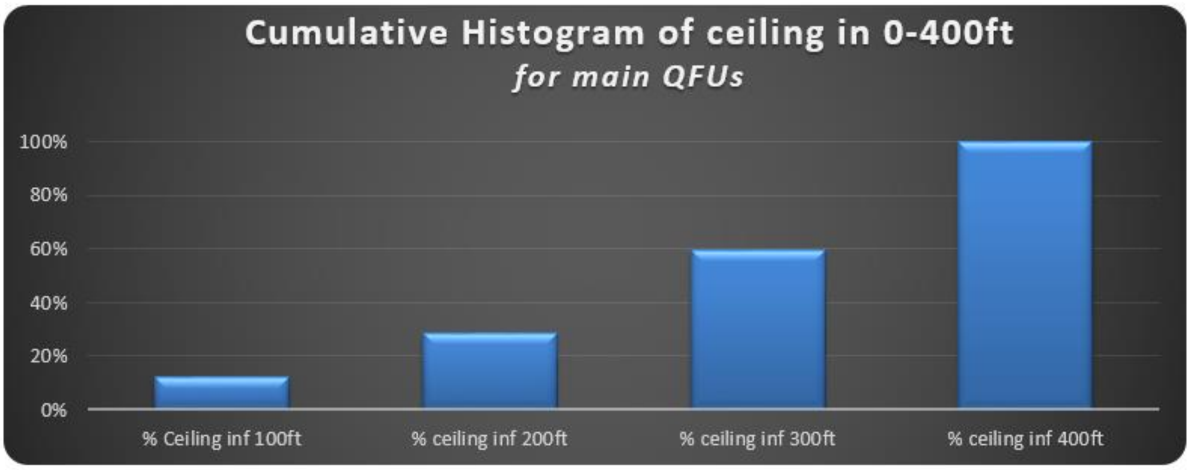


Figure 16: distribution of ceilings

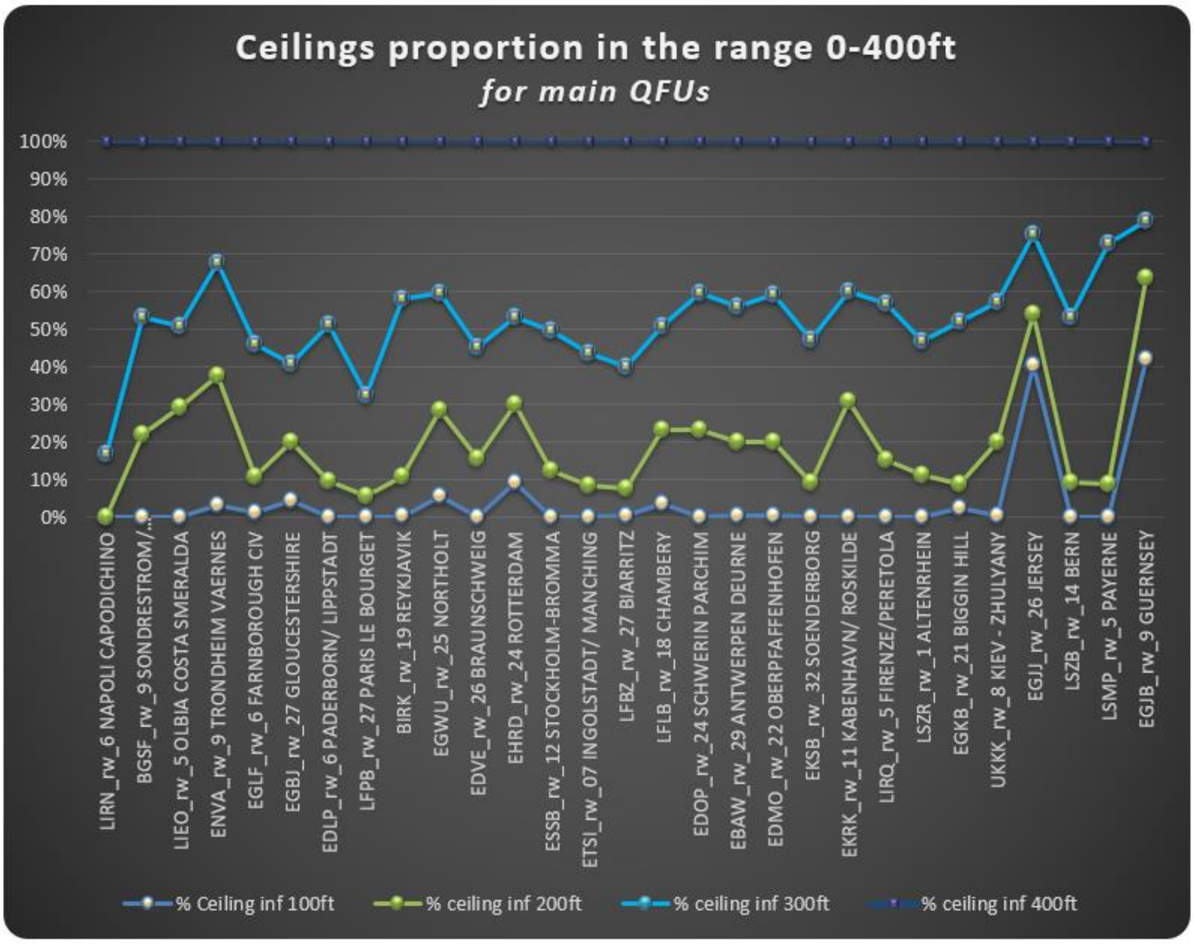


Figure 17: distribution of ceiling for each airport

J.3 Potential benefit of the EFVS to land concept of operation

This section assesses to what extent an aircraft equipped with an EFVS system and operating according to the new EASA EFVS to land concept of operation would have been capable to land.

Numbers are presented in comparison to CATII concept of operation:

- EFVS to land post 2025 figuring out foreseen improvement of technology is capable of RVR of 300m.
- CATII is capable of RVR of 300m and ceiling of 100ft.

J.3.1 Methodology

The estimation of the amount of time that would have been saved by an EFVS to land concept of operation can be determined

- by doing the same kind of analysis as those described in previous section
- and by applying the OPS credit permitted by EFVS instead of published Minima

J.3.2 Global Results

The graph here below illustrates the potential benefit of the EFVS to land concept assuming 2025 technology taking into account the 29th aerodromes of the project over 10 years by considering the most performant published Minima for each of them. Comparison is made with CATII concept of operation highlighting the fact this concept is only applicable a very limited number of aerodromes.

Results shows that EFVS to land concept is more performant than the CATII concept as it allows to cover more limiting situations. In particular, it would allow to erase the 100ft ceiling situation the CATII concept cannot. Moreover, the EFVS to land concept could be deployed at much more than just the few CATII capable aerodromes and without significant effort/ investment.

This study shows that EFVS top land concept would have erased 95% of low Visibility situation that occurred in the period 2008-2018 for the 29 relevant aerodromes considered.

EFVS to land concept	**RVR limit**	**Ceiling limit**	**Estimated amount of time the EFVS increases the accessibility of the aerodrome** per airport and per year	**Estimated amount of time the aerodrome remains NOT accessible** per airport and per year
EFVS to land 2025	300m	no	158 hours	9 hours
CAT II	300m	100ft	134 hours	32 hours

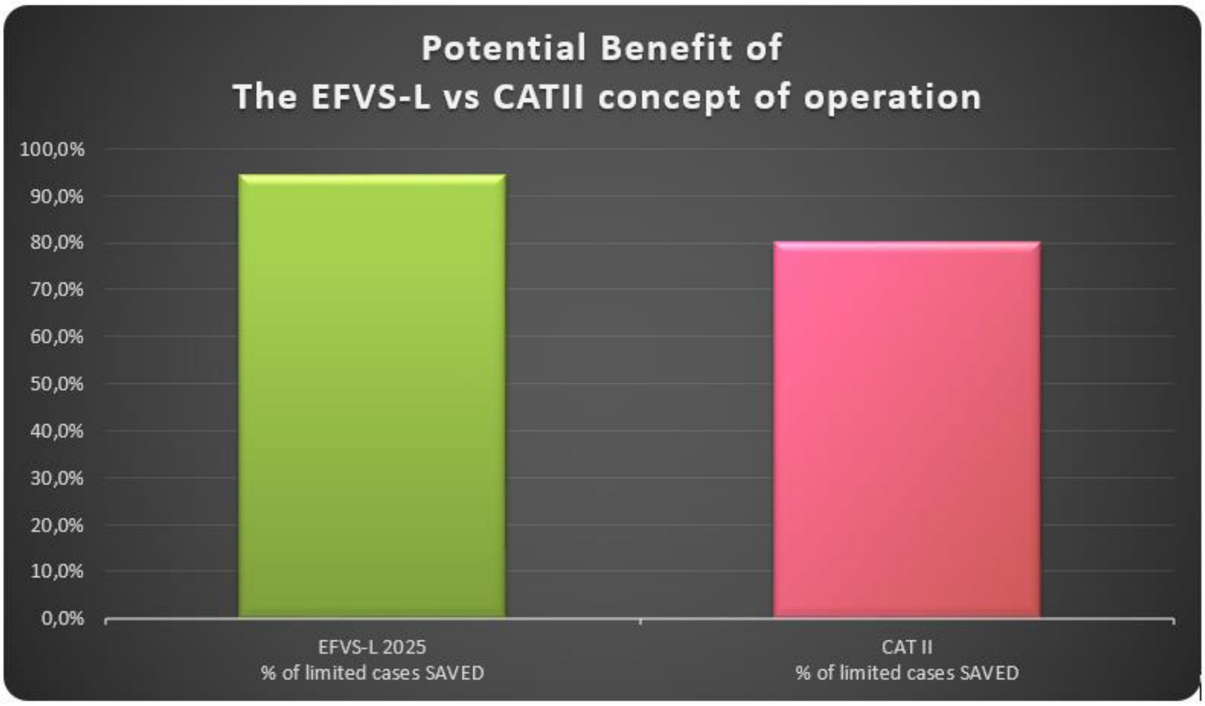


Figure 18: potential benefit of EFVS-L versus CATII concept of operations

J.3.3 Results by aerodromes

The Fig here below gives presents for each aerodrome the proportion of the Low Visibility situations that would have been saved by an EFVS to land concept. Results are compared to a CATII concept of operation.

It shows the EFVS to land concept allows to erase more than 78% (average 94%) of Low Visibility situation within the 2008-2018 period.

The EFVS to land concept would even be much more beneficial than a standard CATII concept for JERSEY and GUERNSEY which are two of the most critical aerodromes regarding low visibility situations and in particular low ceiling situations.

Results are is sorted in ascending order by occurrence of low Visibility situation over the full period.

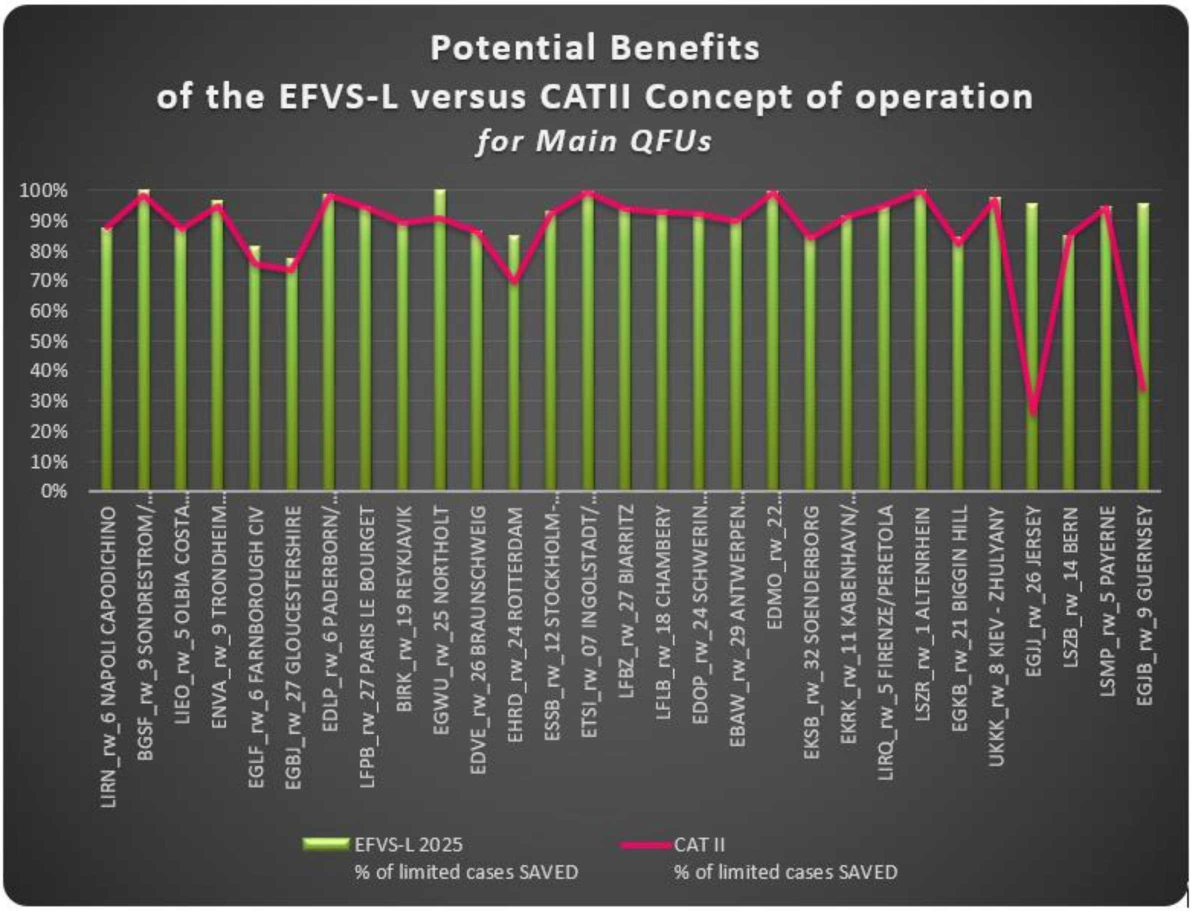


Figure 19: potential benefit of EFVS-L versus CATII concept of operations for each airport

	EFVS to land 2025	CAT II
Aerodrome ⇩	**Estimated amount of time the EFVS increases the accessibility of the aerodrome** per airport and per year (hours)	**Estimated amount of time the EFVS increases the accessibility of the aerodrome** per airport and per year (hours)
LIRN_rw_6	0,35	0,35

BGSF_rw_9	3,2	3,15
LIEO_rw_5	4,5	4,5
ENVA_rw_9	8,35	8,2
EGLF_rw_6	4,95	4,6
EGBJ_rw_27	13,65	13
EDLP_rw_6	18,4	18,35
LFPB_rw_27	22,15	22,15
BIRK_rw_19	12,15	12,1
EGWU_rw_25	30,9	28,05
EDVE_rw_26	23,5	23,45
EHRD_rw_24	49,7	40,75
ESSB_rw_12	36,6	36,25
ETSI_rw_07	64,05	64
LFBZ_rw_27	59,05	58,95
LFLB_rw_18	61,4	60,8
EDOP_rw_24	44,7	44,7
EBAW_rw_29	61,25	60,85
EDMO_rw_22	63,6	63,3

EKSB_rw_32	81,4	81,05
EKRK_rw_11	100,35	100,1
LIRQ_rw_5	116,95	116,95
LSZR_rw_1	135,5	135,45
EGKB_rw_21	116,95	113,6
UKKK_rw_8	214,75	212,75
EGJJ_rw_26	209,2	56
LSZB_rw_14	229,15	229,1
LSMP_rw_5	136	135,95
EGJB_rw_9	291,75	104,3

Table 1: EFVS-L and CAT II increase of aerodrome accessibility

Numbers in green in the table show a significant difference between the CATII ops concept and the EFVS to land concept.

J.4 Method for supporting EFVS business case: example of Antwerp

The weather study is part of key elements for supporting the assessment of the real benefit of the deployment of EFVS operation capacity for an aerodrome.

As illustrated on the here above sections, results may significantly vary from an aerodrome to another and it is essential to conduct a specific study for an intended aerodrome.

If proportion of low visibility situations and associated causes can be quantified as proposed in the previous section of this appendix, temporal situation must be however further analyzed. In particular, it should be paid attention to the duration of the low visibility conditions periods, the season and time the adverse conditions occur for the intended aerodrome. In addition, the wind can also be considered as it drives the choice of the runway for landing.

J.4.1 Global number: reminder

As determined in the previous section, the proportion of low visibility situations for EBAW runway 29 is estimated at 0,7% over ten years. The proportion of causes is as follows:

- 17% associated to too low ceiling only,
- 57% associated to reduced RVR only,
- and 26% associated to both too low ceiling and reduced RVR

For that aerodrome, the reduced visibility conditions resulted from FOG (87%) or MIST (13%).

J.4.2 Temporal analysis

In the graphs here below, the threshold is indicated in ft and the RVR in meters.

1. Number of cases over years

An average of 123 (median is 107) cases of Low Visibility situations were observed per year.

The minimum number of cases is 40 (2008) and the max is six times more (in 2016). In 2018, 146 cases were observed.

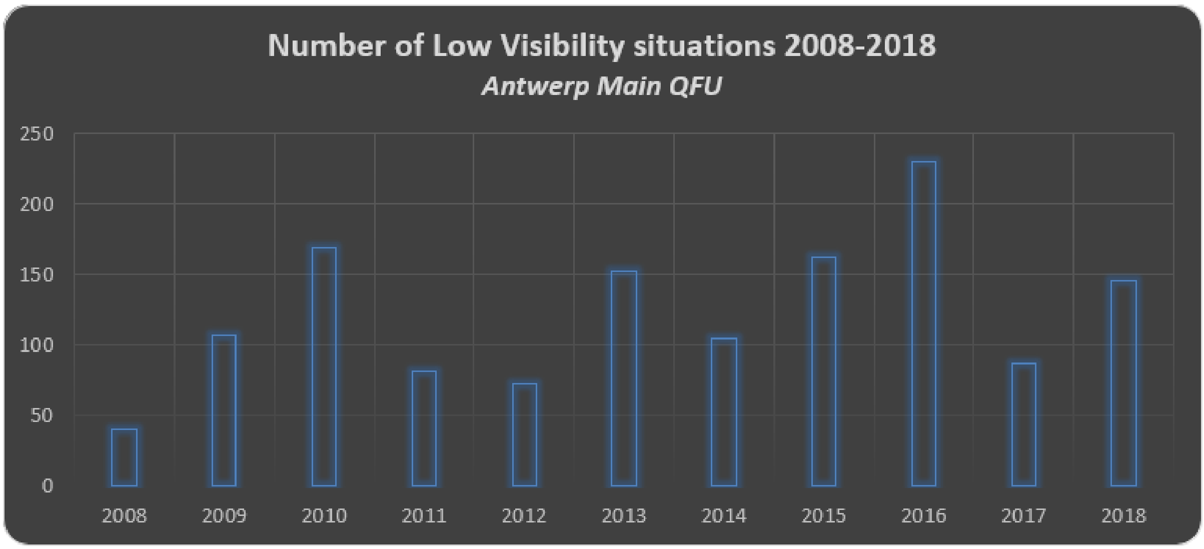
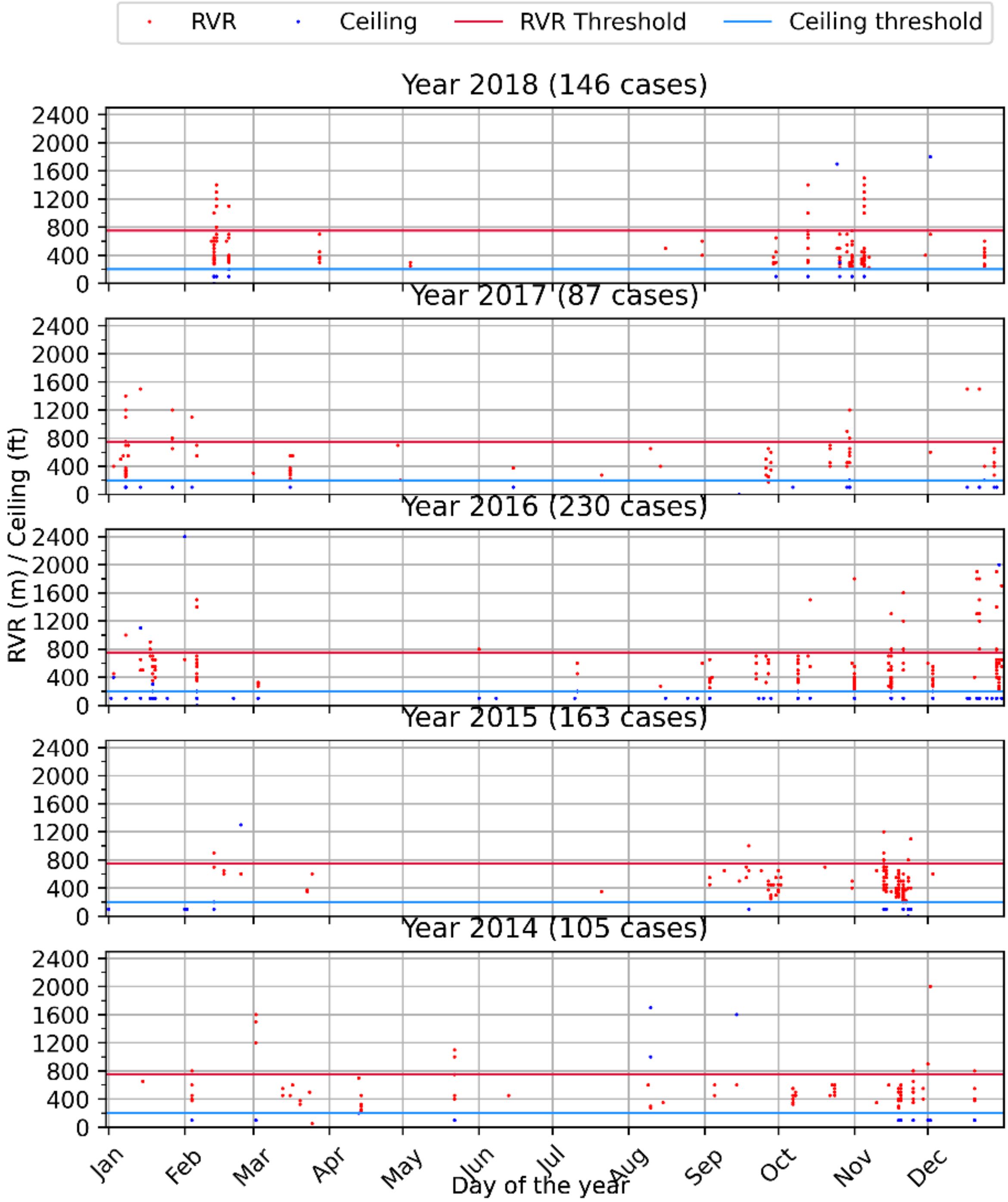
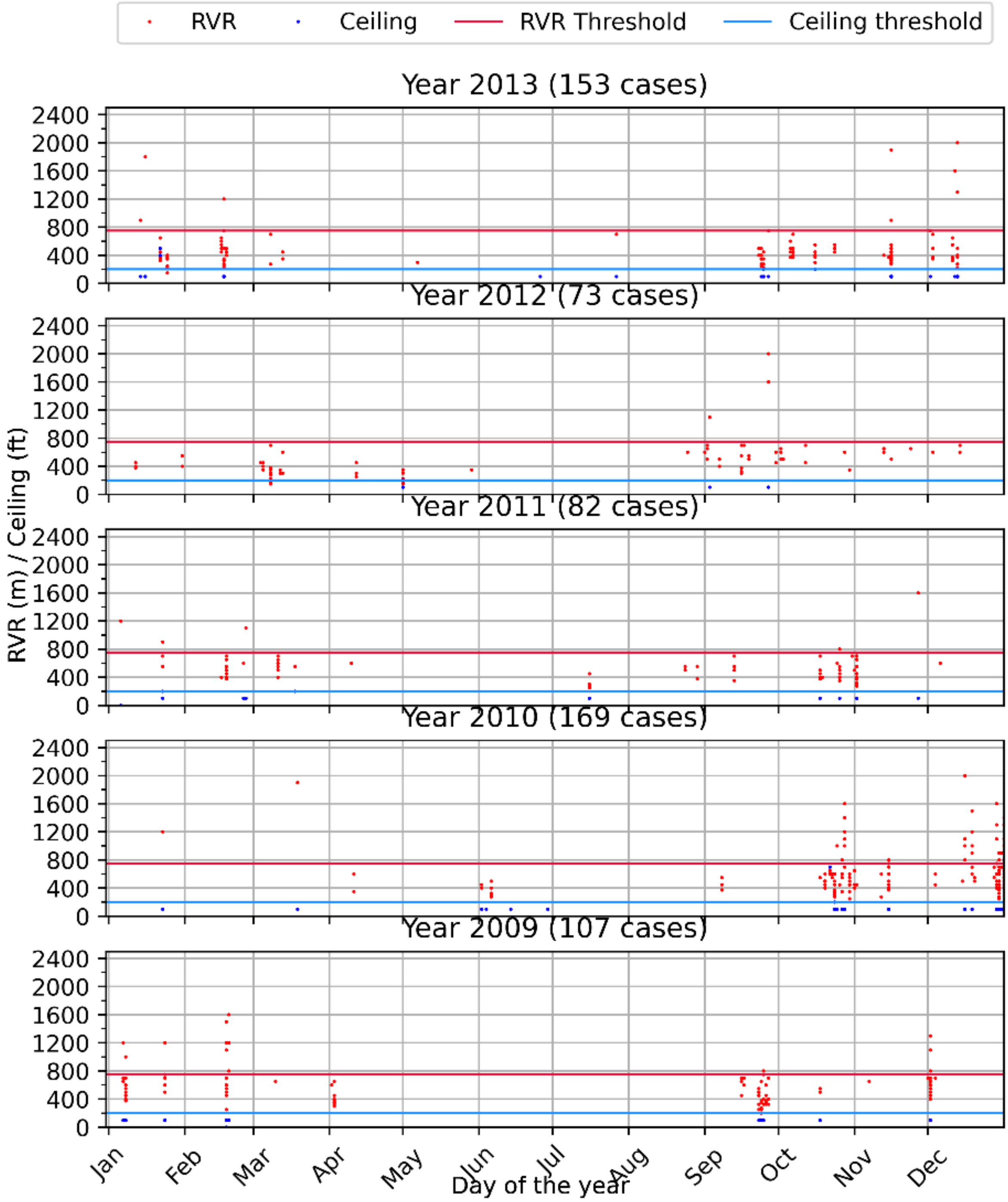


Figure 20: number of Low Vis Situations 2008-2018

2. Distribution of the Low visibility situation over the seasons

The graphs here below give an accurate indication of the proportion of low visibility situation over the period of the year. It shows that Low Visibility situations mainly occur in the sept to March period.


RVR
Ceiling
RVR Threshold
Ceiling threshold
Year 2018 (146 cases)
Year 2017 (87 cases)
Year 2016 (230 cases)
Year 2015 (163 cases)
Year 2014 (105 cases)
RVR (m) / Ceiling (ft)
0
400
800
1200
1600
2000
2400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Day of the year


RVR
Ceiling
RVR Threshold
Ceiling threshold
Year 2013 (153 cases)
Year 2012 (73 cases)
Year 2011 (82 cases)
Year 2010 (169 cases)
Year 2009 (107 cases)
RVR (m) / Ceiling (ft)
2400
2000
1600
1200
800
400
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Day of the year

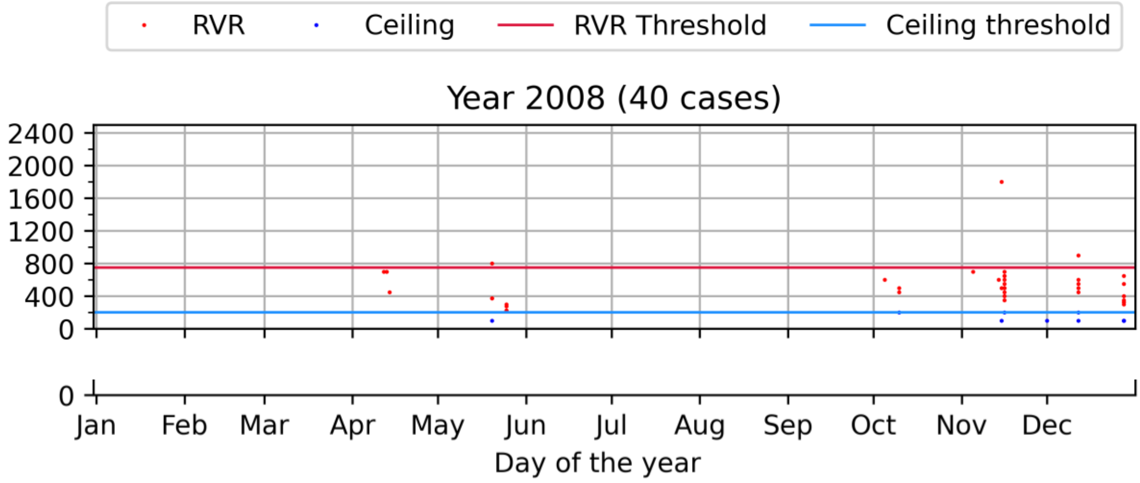
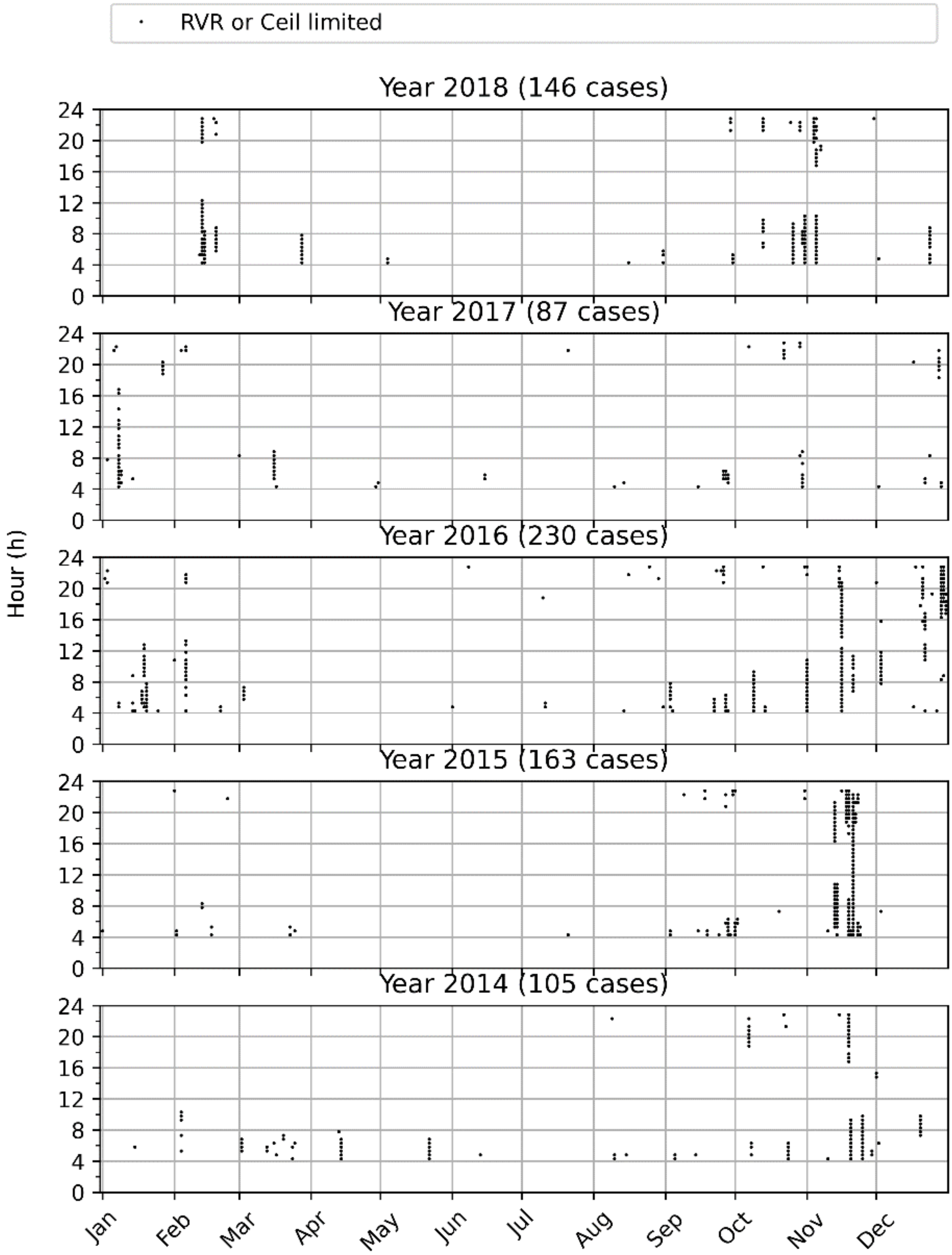
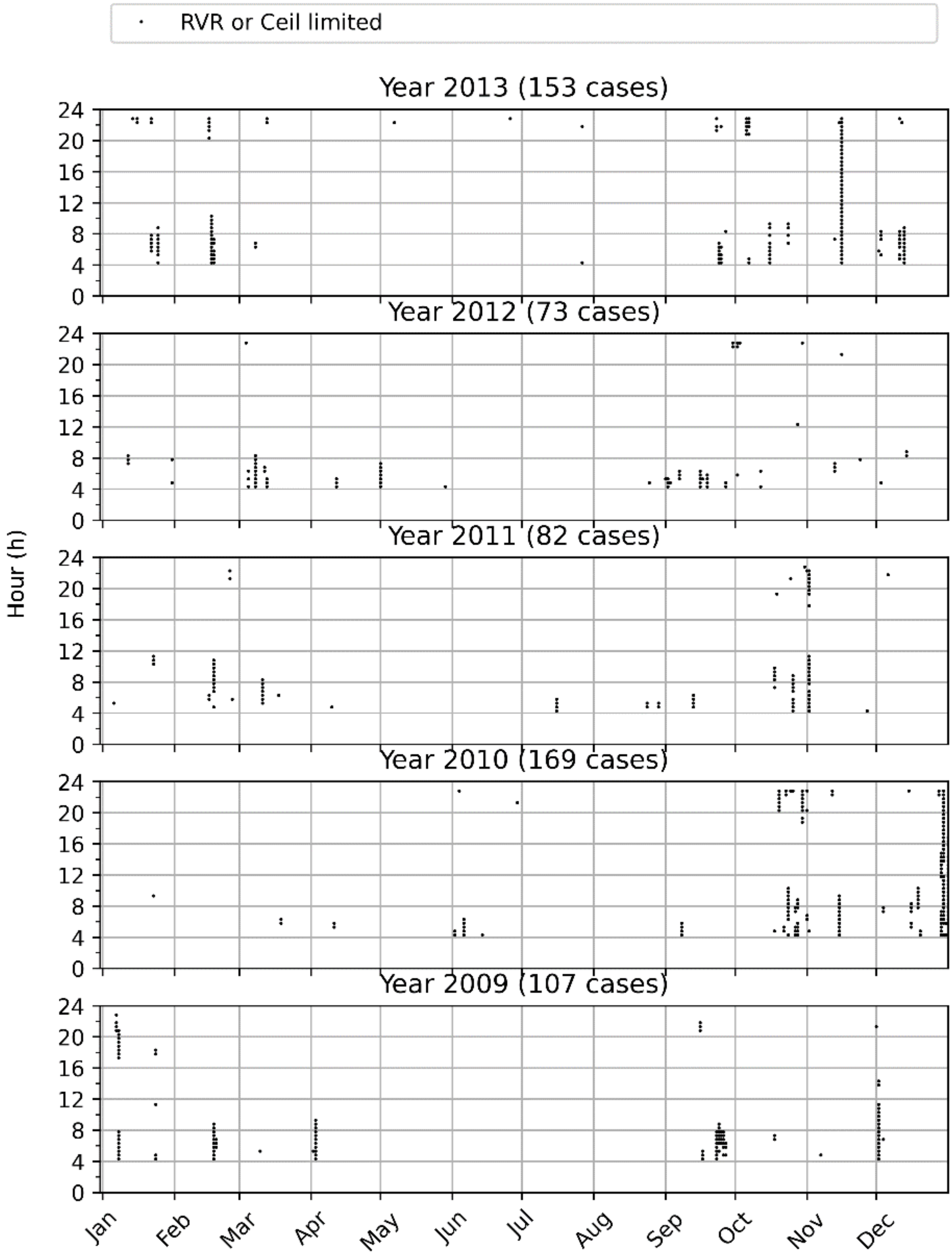


Figure 21: Antwerp, distdistribution, cause of Low Vis Situations over seasons

3. Distribution of the Low Visibility situations over the time of the day

The graph here below presents the Low Visibility events in regard to the time of the day. Data reveals that most of the events mainly occurred in the morning, or late in the evening. It shall be also noticed that some Low Visibility situation are reported during several hours.


RVR or Ceil limited
Year 2018 (146 cases)
Year 2017 (87 cases)
Year 2016 (230 cases)
Year 2015 (163 cases)
Year 2014 (105 cases)
Hour (h)
0
4
8
12
16
20
24
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


RVR or Ceil limited
Year 2013 (153 cases)
Year 2012 (73 cases)
Year 2011 (82 cases)
Year 2010 (169 cases)
Year 2009 (107 cases)
Hour (h)
0
4
8
12
16
20
24
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

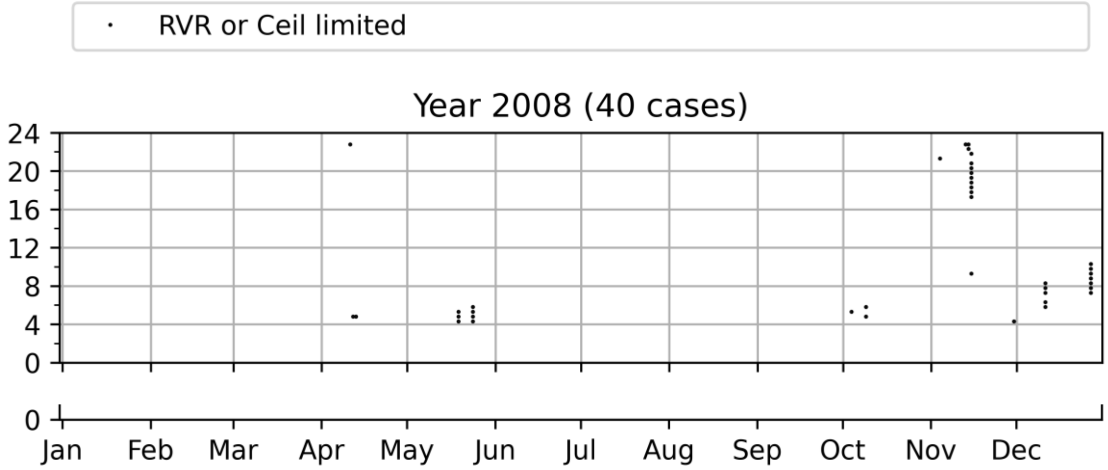


Figure 22: Antwerp: Distribution of low Vis Situations over time of the day

4. Distribution of RVR for all limited cases

The graph here below presents the distribution of RVR for the Low Visibility situations.

By displaying the data such a way, it is easy to see where weather impacts the general public.
This illustrates the potential of a concept of operation regarding the RVR distribution and considering the published minima.

For Antwerp, the graph shows in particular that an important part of RVR in the range 300-499m limits the operations and usually occur with too low ceiling conditions.

Graph also indicate that significant part of too low ceiling conditions is associated to high value of RVR.

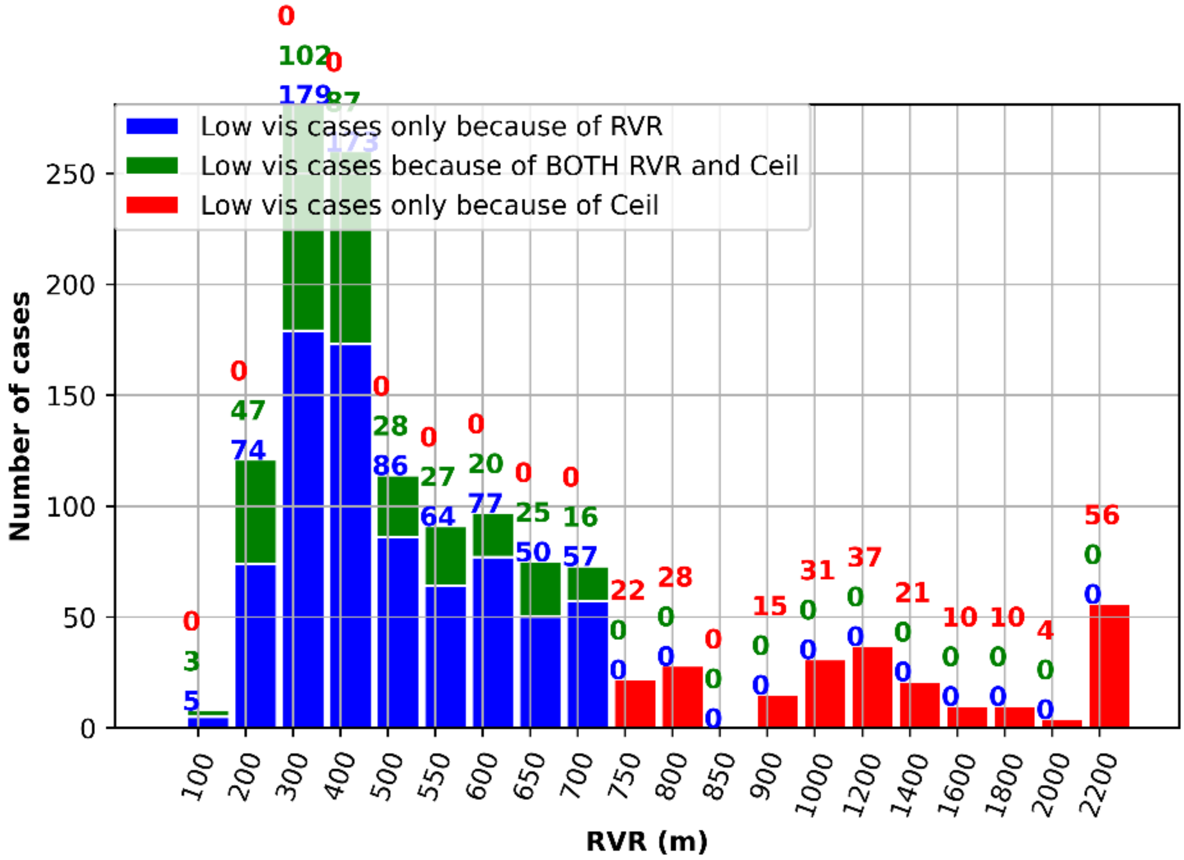


Figure 23: Antwerp: Distribution of RVR of Low Vis Situations

Appendix K EXE-VLD-V4-200 De-generalizing Instrument Approach Minima to Non-Instrument Runways

EXE-VLD-V4-200_De
generalizing Instrun

Appendix L EXE-VLD-V4-200 Performance Prediction Analysis

AAL2 flight demos were performed in limited visibility conditions resulting from fog and at aerodromes fitted with incandescent approach lights.

This appendix deals with the characterisation of the performance of EFVS for other than those most standard situations. The study is focused on two situations:

- Performance of the EFVS in low visibility conditions resulting from pollutant instead of humidity made of water droplets.
- Performance of the EFVS on LED lights compared to standard incandescent lights

The EFVS system used for the study is the FalconEye EVS installed on Dassault Falcon aircraft. This system is representative of Visual-IR based technology available in 2020.

L.1 Performance of EFVS in Low Vis Situation resulting from pollutant

As demonstrated in AAL2, EFVS systems are capable to provide visual advantage over natural vision in atmosphere conditions made of water droplets (Fog for visibility lower than 1000 meters and haze for higher visibility). Significant visual advantage has also been demonstrated (out of SESAR AAL2) in Snow conditions.

A short survey of operational revealed that reduced visibility resulting from pollutant may affect landing operations (especially wood & coal for cooking and heating smoke or palm tree fire). Such events are frequent in Asia or in India for example around industrial towns.

In the frame of SESAR AAL2, it has been tried to assess the visual advantage that an EFVS could achieve in these particular conditions.

In order to quantify the performance of the EFVS for a given approach, Dassault Aviation uses proprietary advanced simulation tool (developed out of SESAR).

L.1.1 EFVS Dassault Aviation Simulation tool

A physical video generation tool developed by Dassault along the Falconeye EFVS development allow to play or replay approaches and to generate for a given airport/ALS (Approach Lighting system) /trajectory/atmosphere condition, some videos representative of:

- natural pilot eye
- EFVS Falcon Eye

The tool relies on state of the art following third party software:

- OKTAL-SE for image / video rendering (ray tracing)
- MODTRAN: US reference atmosphere code.
- MATISSE: ONERA French aerospace lab atmosphere code.

The process of generation of sensor video of an approach is in three steps presented in the following sections.

1. Generation of Atmospherical using MODTRAN or MATISSE

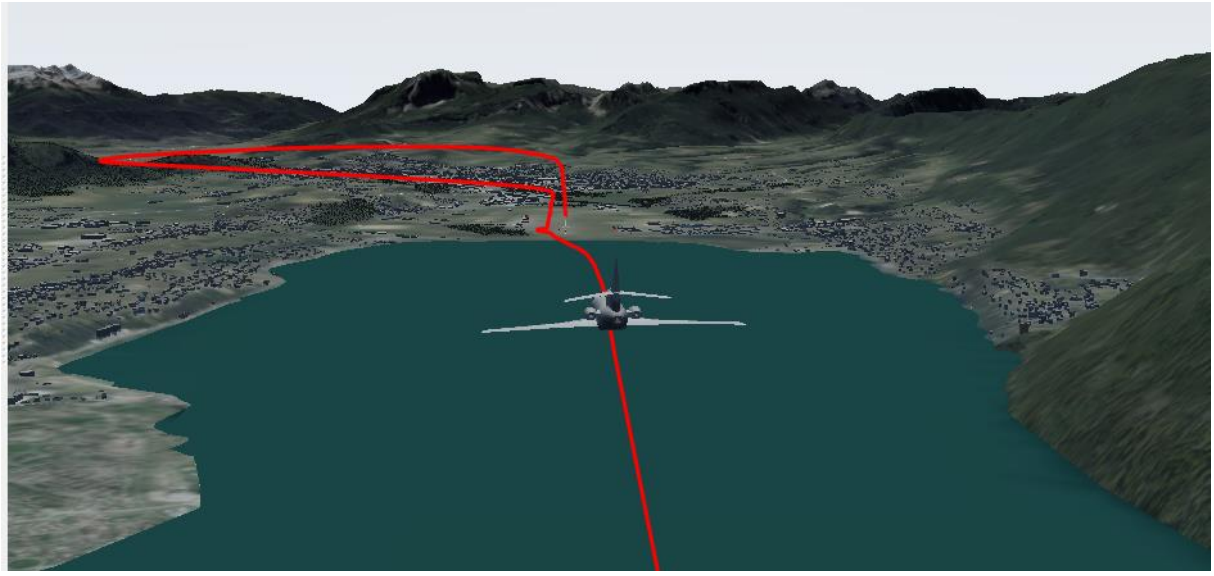
MODTRAN offers the capacity to define parameters such as:

- atmosphere model (among Mid Latitude Summer/Winter, Tropical, …),
- type of aerosol (among rural, maritime, urban, radiative fog, advective fog, desert, …),
- visibility in km,
- ambient lighting conditions such as day/ night, hour of the DAY,
- latitude/longitude of observer.

2. Generation of “realistic” images using OKTAL-SE

“Realistic” Images are generated using OKTAL-SE software.

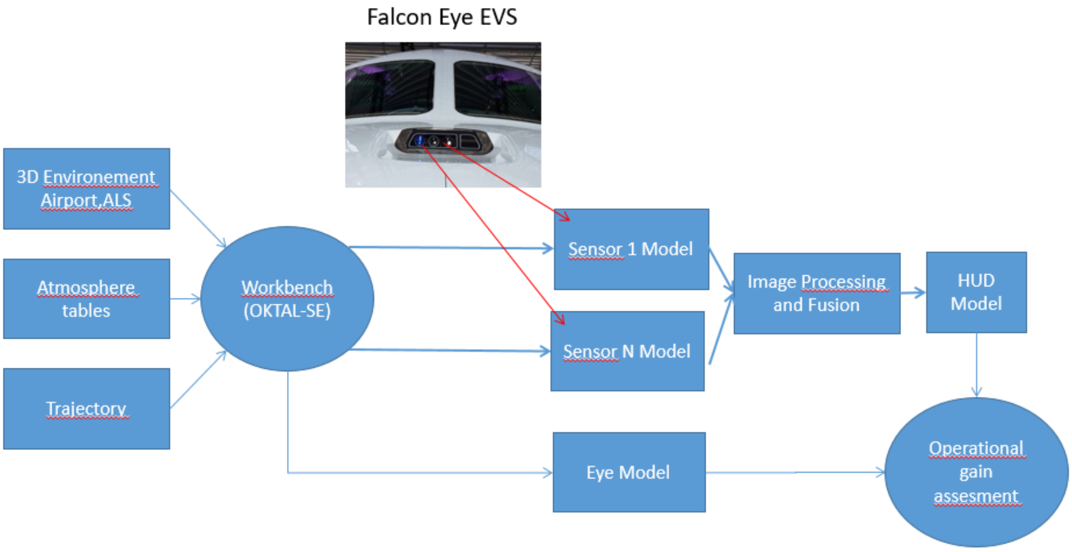
3D model of the scene ALS, trajectory of Aircraft, table of atmosphere previously computed and sensor parameters (among Field of view, resolution, spectral response) are used to compute these images.



3. Application of Sensor model

Sensor model are applied to “perfect images” to take into account the performance of sensor (sensitivity, …) as well as the complex image processing / fusion algorithms.

A summary sketch of the global process is given hereafter:



L.1.2 2) simulation validation process

Representativeness of the Simulation has been validated using replay of EFVS flights, some of them being performed in low visibility conditions (fog conditions).

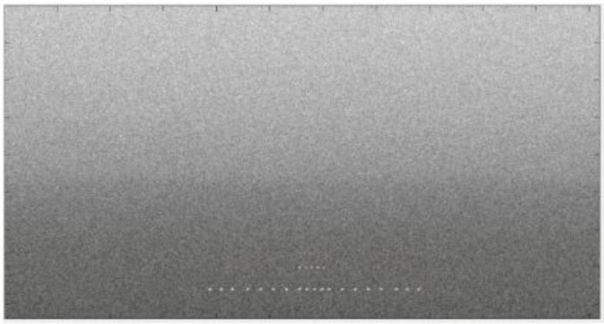


Figure 24: Natural Pilot Eye simulation

Figure 25: EFVS Falcon Eye simulation

L.1.3 SESAR AAL2 simulation results.

In order to assess visual advantage of EFVS in industrial / urban polluted atmosphere, simulations have been launched in these conditions.

MODTRAN has been used to generate atmosphere tables considering URBAN aerosol and visibility has been set from 300 meters to 800 meters. Realistic videos of approaches were generated.

The result is such that the very low atmosphere radiance is observed whatever the hour of the day. It looks as if images had been generated at night. Resulting video are very low contrasted.

Therefore, the conclusion is that low visibility industrial atmosphere cannot be modelled properly using MODTRAN predefined aerosol.

A potential solution could be to use the MATISSE atmospheric code from ONERA with predefined smoke / industrial atmosphere setting. Preliminary discussions with OKTAL-SE and ONERA about the use of MATISSE are promising. However, it requires some customization in the way MATISSE is interfaced with OKTAL-SE software. Moreover, further technical discussion would be needed with ONERA experts in order to define in detail what has to be modelled and what can be modelled. Such simulations using MATISSE requiring extensive cooperation between multiple partners were not possible to be performed in the frame of SESAR AAL2 project.

Determination of EFVS visual advantage in these conditions would require complementary studies conducted in cooperation with ONERA and OKTAL-SE for modeling industrial atmospheres

L.2 EFVS performances on LED vs incandescent lights.

Dassault Aviation EFVS simulation tool allows to determine the EVS performance for approaches in different meteorological conditions for different ALS and for incandescent light as well as LED Light.

L.2.1 LED Light modelling

LED light spectral intensity has been modelled according to spectral measurements performed by the STAC aeronautical laboratory on 20 000 Cd LED Light.

L.2.2 Incandescent light modelling

Incandescent light spectral intensity has been modelled based on black body law and on:

- Average intensity in visible spectrum (20 000 Cd),
- Electrical power of light 300 W
- Efficiency.

L.2.3 Simulation

This spectrum has been used to replay approach perform in real flight and has been taken into account in verification of representativeness of Dassault Simulation.

Simulation of EVS light detection range has been performed as per methodology described in previous sections both for LED and incandescent light.

L.2.4 Results

Simulations performed in the frame of SESAR AAL2 show that LED and Incandescent light detection ranges are similar (lower than 10% relatively for 300 m visibility).

To compensate the lack of readiness demos (see deviation section in the main AAL2 report), ground test measurements achieved in other than SESAR program in similar conditions were compared to the simulation and confirm the conclusion.

Note: Falcon Eye EVS system has dedicated sensors for detection of LED light vs Incandescent Light.

Flight test on LED approach lights remain to be performed in degraded visibility conditions (and especially at night) in order to consolidate these results.