EUR/SAM Corridor:
2018 Collision Risk Assessment

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Approvals

Prepared by:	Reviewed by:	Approved by:
Visado en gestor documental	*Visado en gestor documental*	*Visado en gestor documental*
Juan Miguel Delgado Sagardoy INECO AT Department of Research and Definition of Air Navigation Advanced Systems	Mª Mar Tabernero Serrano Head of Department of Research and Definition of Air Navigation Advanced Systems	Nicolás Martín Martín Head of Navigation and Surveillance Division

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3	Mª Mar Tabernero	Head of Department of Research and Definition of Air Navigation Advanced Systems	ENAIRE
4		SATMA Group	

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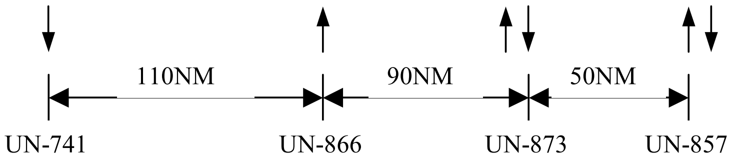
Executive Summary

This report presents the 2018 collision risk assessment made for the EUR/SAM Corridor. It assesses the current and projected lateral and vertical collision risk in the Corridor, where RNP10 and RVSM are implemented, for flight levels between FL290 and FL410.

Two quantitative risk assessments, based on suitable versions of the Reich Collision Risk Model, have been carried out. The first assessment corresponds to the lateral collision risk whilst the second one concerns the vertical collision risk. The vertical collision risk assessment has been split into two parts. The first part considers the risk due to technical causes, whilst the second one considers the complete risk due to all causes, including the operational ones.

The analysed scenario is the airspace where RNP10 and RVSM are implemented. The current route network structure is composed of four nearly parallel north-south routes, being the two easternmost bidirectional and the other two, unidirectional. Traffic on the DCT Area, placed to the west of the current UN-741, has not been considered in the analysis.



Current route network

As far as crossing traffic is concerned, apart from the traffic on the published routes that crosses the Corridor in SAL, Dakar and Recife (UR-976/UA-602, UL-435 and UL-695/UL-375, respectively), traffic that crosses the Corridor using non-published routes with carry more than 50 flights per year have been considered.

The internal software tool CRM, used in previous studies, has been updated and used to obtain the different parameters of the Reich Collision Risk Model in each one of the UIRs crossed by the Corridor.

The CRM program uses flight plan data obtained from Palestra, Enaire's database for the Canaries, and traffic data from the samples provided by SAL, Dakar and Atlantic-Recife. Real data from the Canaries has been available for the complete year 2018. However not all the data from the rest of the FIRs/UIRs was available at the end of the year. The traffic samples used to perform this analysis are the ones from 1st March 2018 to 31st March 2018. This month has been selected as it was the one with the higher number of flights from the months with all the information available. The number of flights and the flight time for the complete year 2018, required for some of the calculations, have been extrapolated.

Besides, extrapolation of traffic data has been necessary in some cases in order to obtain the traffic distribution along the Corridor and on crossing routes. Therefore, trajectories and information at required waypoints (i.e., time and FL) have been assumed, considering the most logical routes and speeds. This may have an influence on the results, as several assumptions have been made due to the incompleteness and inconsistencies, in some cases, of the provided data.

Considering a number of parameters such as probabilities of lateral and vertical overlaps, lateral, vertical and crossing occupancies, average speed, average relative velocities and aircraft dimensions, the lateral, technical vertical and total vertical collision risks have been assessed and compared with the maximum Target Level of Safety (TLS) values allowed, $TLS = 5 \cdot 10^{-9}$, $TLS = 2.5 \cdot 10^{-9}$ and $TLS = 5 \cdot 10^{-9}$, respectively.

The risk has been evaluated in 6 different locations along the Corridor and an estimation of the collision risk for the next 10 years has been calculated, assuming a traffic growth rate of 3.3% per year.

The results obtained are very similar in all the locations and the risk associated to the Corridor is the largest of all the values obtained.

Assuming that the traffic levels of March 2018 are representative of the whole year, the calculated lateral collision risk is $2.6845*10^{-9}$, whilst the lateral collision risk estimated for 2028 with an annual traffic growth rate of 3.3% is $3.7142*10^{-9}$. These values do not take into account traffic on the DCT Area routes.

As far as the technical vertical risk is concerned, the value of the collision risk for 2018 (assuming traffic levels of March 2018 are representative of the whole year), is estimated to be $1.9301*10^{-13}$ and the technical vertical collision risk estimated for 2028 with an annual traffic growth rate of 3.3%, $2.6704*10^{-13}$. Both values are below the TLS.

Regarding the vertical risk due to large height deviations, it has been calculated using the LHD notifications reported by the four involved States. Taking these LHDs into account, the total vertical risk in the Corridor is $4.3259*10^{-8}$, which greatly exceeds the TLS.

In previous safety assessments, such as [Ref. 3], [Ref. 5], [Ref. 8], [Ref. 9] or [Ref. 10], it was remarked that all the deviations received had been due to coordination errors between ATC units and not related to RVSM operations. In the same way, it was also explained that none of those reports received indicated that there had existed any traffic in conflict. This is also the case of this study.

Given that coordination errors continue to be the main cause of occurrence of LHD, the use of adequate corrective actions to reduce this type of errors should be applied as soon as possible in order to reduce the risk levels.

1. Introduction

This report presents the 2018 collision risk assessment made for the EUR/SAM Corridor. It assesses the current and projected lateral and vertical collision risk in the Corridor, where RNP10 and RVSM are implemented, with real data of traffic between FL290 and FL410 collected from 1st March 2018 to 31st March 2018 and with the number of flights and the flight time required for some of the calculations extrapolated for the complete year 2018.

For this study, the program CRM has been updated and used to obtain the different parameters of the Reich Collision Risk Model in each one of the UIRs crossed by the Corridor. Taking these values into account and the traffic forecast for the future, it has been possible to estimate the collision risk for the following years.

To perform the present study, the procedure has been the one described in [Ref. 33]. Any change with respect to that document will be explained and detailed in the present document.

2. Airspace description

The airspace description is the one presented in [Ref. 33], where the changes or new information regarding the airspace in the year 2018 are included.

2.1. Data sources and software

For this study, flight progress data from the Canaries, SAL, Dakar and Atlantic ACCs, between FL290 and FL410, have been made available from 1st March 2018 to 31st March 2018. When data, such as the number of flights or flight time for the rest of 2018 has been necessary, it has been extrapolated using information from Canaries as a basis.

Data for the complete year 2018 from the Canaries are based on the flight progress information stored in Palestra, Enaire's database. It consists of initial flight plan data updated by the controllers with pilot position reports.

The analysed Palestra flight plans have been those which cover the time period from 1st January 2018 to 31st December 2018. They include reports for all waypoints in the Canaries UIR.

Besides data from Palestra, traffic samples from SAL, Dakar and Atlantic-Recife have also been available for this assessment for all 2018, although not all of them was available at the moment of performing this assessment. Data provided by States include information from all aircraft overflying the airspace on the four main routes of the Corridor.

Regarding crossing routes, SAL and Dakar provide traffic information from airways UR-976/UA-602 and UL-435, respectively. On the other hand, Recife provides crossing traffic data from route UL-375/UL-695.

2.2. Aircraft population

The most common aircraft types, the number of flights per type and the proportion of these types over the total of flights detected during 2018 between FL290 and FL410 have been analysed.

Table 1 shows the values obtained for the Canaries UIR in 2018 together with the geometric dimensions of these aircraft types. Similar results have been obtained for the rest of UIRs.

Aircraft type	Count	% AC	Length (m)	Wingspan (m)	Height (m)
A332	5906	19,023%	63.70	60.03	16.74
B738	3134	10,095%	39.47	34.31	12.50
B77W	2566	8,265%	73.90	60.90	18.50
B763	2285	7,36%	47.60	54.90	15.90
B752	2131	6,894%	47.32	38.05	13.60
A320	1933	6,226%	37.57	34.10	11.76
A333	1856	5,978%	63.70	60.03	16.74
A343	1686	5,431%	63.70	60.30	16.74
B772	1288	4,149%	63.70	60.90	18.50
B789	1257	4,049%	62.80	60.10	16.90
A346	1229	3,959%	74.37	63.60	17.80
B788	963	3,102%	56.70	60.10	16.90
B748	761	2,451%	76.30	65.45	19.50
A321	550	1,772%	37.57	34.10	11.76
A359	485	1,562%	66.80	64.75	17.05
B38M	449	1,446%	39.50	35.90	12.30
A319	387	1,247%	33.84	34.10	11.76
B744	347	1,118%	70.70	64.40	19.40
B77L	209	0,673%	67.78	61.68	18.50
B762	206	0,664%	48.50	47.60	15.80
E35L	126	0,406%	26.33	21.17	6.76
A21N	111	0,358%	44.51	35.80	11.76
B737	100	0,322%	33.60	34.30	12.50
FA7X	84	0,271%	22.82	25.80	7.74
CL60	75	0,242%	20.86	19.35	6.28
GLEX	73	0,235%	30.30	28.65	7.57
A20N	62	0,2%	37.57	35.80	11.76
A400	58	0,187%	42.40	45.10	14.70
F2TH	58	0,187%	20.21	19.33	7.55
F900	57	0,184%	20.20	19.30	7.60
C17	52	0,167%	53.00	51.80	16.80
FA8X	45	0,145%	24.46	26.29	7.94
GLF5	44	0,142%	29.42	28.50	7.87
GLF4	39	0,126%	26.90	23.79	7.64
A345	36	0,116%	67.90	63.45	17.10
E190	34	0,11%	36.24	28.72	10.57

Aircraft type	Count	% AC	Length (m)	Wingspan (m)	Height (m)
A310	25	0,081%	46.40	43.89	15.80
A339	21	0,068%	63.66	64.00	16.79
GL5T	21	0,068%	28.69	28.65	7.70
GLF6	21	0,068%	30.41	30.36	7.72
FA50	20	0,064%	18.52	18.96	6.97
G280	20	0,064%	20.30	19.20	6.50
WW24	18	0,058%	15.90	13.70	4.80
LJ35	16	0,052%	14.71	11.97	3.71
LJ60	13	0,042%	17.89	13.35	4.44
CL30	12	0,039%	20.90	18.40	6.10
IL96	12	0,039%	69.10	73.30	20.78
IL76	11	0,035%	46.59	50.50	14.76
GALX	10	0,032%	18.99	17.71	6.52
C680	9	0,029%	11.22	14.95	4.56
C750	9	0,029%	22.05	19.38	5.84
E135	9	0,029%	26.33	20.04	6.76
LJ45	9	0,029%	17.68	14.58	4.30
E195	8	0,026%	38.65	28.72	10.55
ASTR	7	0,023%	16.94	16.05	5.54
E550	6	0,019%	20.74	20.25	6.44
E75L	6	0,019%	31.68	28.65	9.86
A124	5	0,016%	69.10	73.30	20.78
CL35	5	0,016%	20.90	21.00	6.10
CRJX	5	0,016%	39.01	26.02	7.50
C56X	4	0,013%	15.80	17.00	5.20
CRJ2	4	0,013%	26.80	21.21	6.30
E290	4	0,013%	36.20	33.70	11.00
H25C	4	0,013%	16.40	15.70	5.20
MD11	4	0,013%	61.20	51.70	17.60
A318	3	0,010%	31.40	34.10	12.60
E170	3	0,010%	29.90	26.00	9.67
H25B	3	0,010%	15.60	15.70	5.40
A30B	2	0,006%	53.60	44.80	16.50
B777	2	0,006%	67.78	61.68	18.50
C550	2	0,006%	13.30	14.40	4.40
C650	2	0,006%	14.29	15.91	4.57
FA10	2	0,006%	13.86	13.08	13.08
IL62	2	0,006%	53.12	43.30	12.35
LJ55	2	0,006%	16.80	13.30	4.50

Aircraft type	Count	% AC	Length (m)	Wingspan (m)	Height (m)
PC12	2	0,006%	14.40	16.20	4.30
B757	1	0,003%	49.70	38.05	13.50
B767	1	0,003%	54.94	50.26	16.50
B787	1	0,003%	56.70	60.10	16.90
C30J	1	0,003%	29.80	40.40	11.84
C560	1	0,003%	14.90	13.80	4.20
E145	1	0,003%	29.87	20.04	6.75
A350	1	0,003%	66.80	64.75	17.05
A342	1	0,003%	59.39	60.30	16.74
A340	1	0,003%	59.39	60.30	16.70
G150	1	0,003%	17.30	16.94	5.82
K35R	1	0,003%	41.50	39.90	12.70
A330	1	0,003%	63.60	60.30	16.70
B735	1	0,003%	31.01	28.88	11.10
DC9	1	0,003%	35.78	28.26	8.38
E3CF	1	0,003%	46.60	45.00	12.70
GLF3	1	0,003%	25.30	23.70	7.40
Unknown	5	0,016%	----	----	----

Table 1.
Aircraft population and number of flights per type during 2018 in the Canaries UIR.

The data sample in the Canaries UIR includes 31046 flights of 95 different aircraft types. The population is dominated by large and medium airframes such as A330-200, B737-800, B757-200, A320, B777-300ER, B767-200, A330-300 or A340-300. These 8 types make up about 69.24% of the total number of flights. The next 12 types, which also belong to the Airbus and Boeing families, make up another 26.17% and the rest 4.59% is distributed among the other 75 aircraft types.

2.3. Temporal distribution of flights

Several graphs, showing the temporal distribution of flights, will be displayed in this section. The first one, Figure 1, shows the distribution of the number of flights per day in EDUMO, TENPA, IPERA and GUNET from 1st January 2018 to 31st December 2018, differentiating between northbound (NB) and southbound (SB) traffic. Next, Figure 2 shows the distribution of the number of flights per day in the Canaries for the traffic sample selected in this study: from 1st March 2018 to 31st March 2018.

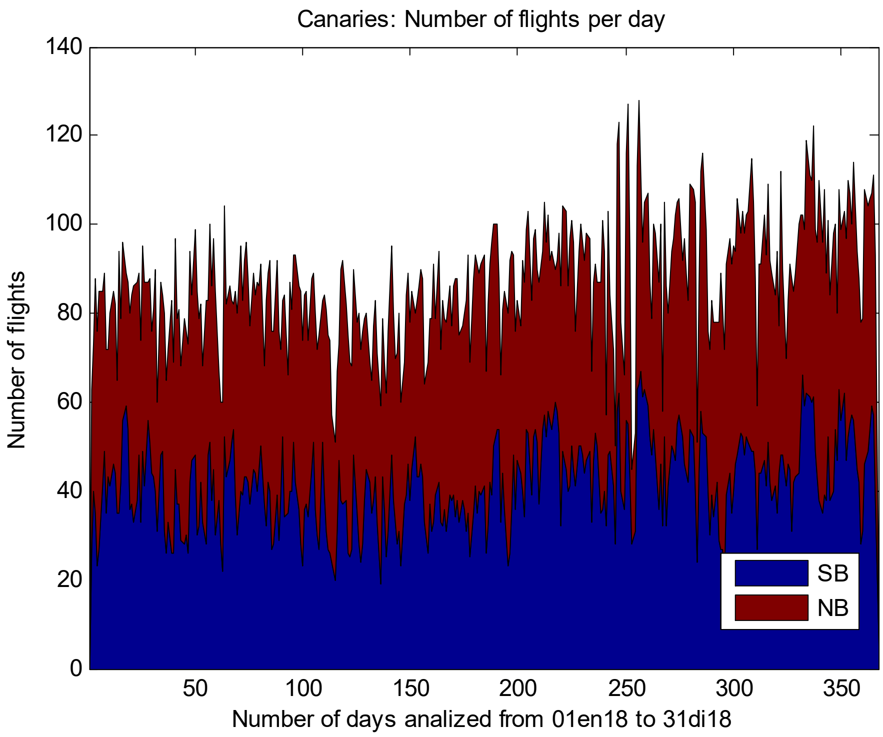


Figure 1.
Number of flights per day in the Canaries. Year 2018

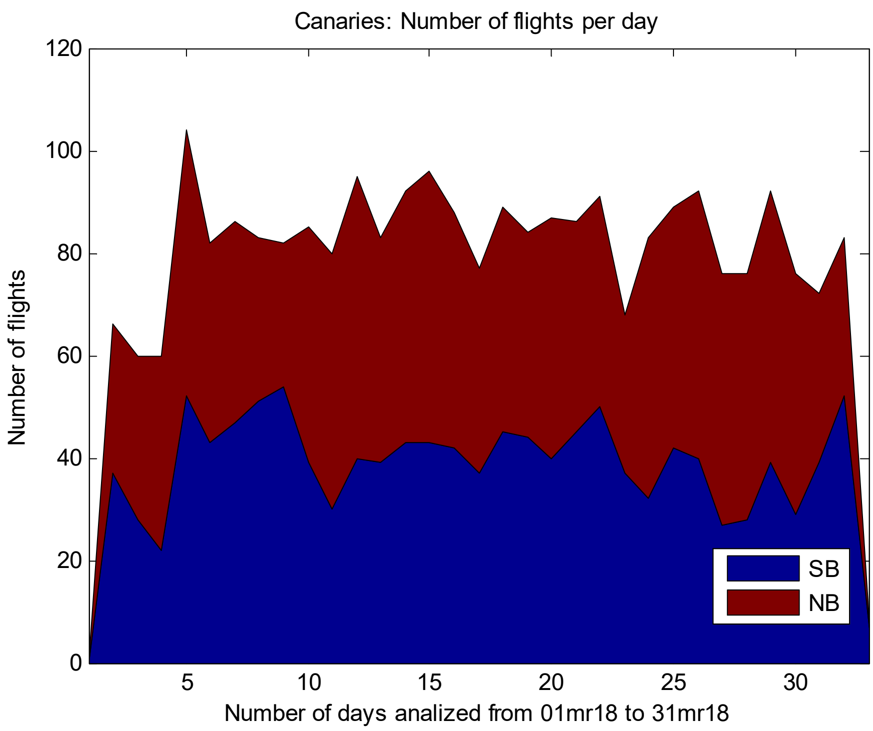


Figure 2.
Number of flights per day in the Canaries. March 2018

The overall average traffic for 2018 is 85.06 flights per day with a standard deviation of 15.06 flights per day, while in March the average is 80.87 with a standard deviation of 21.01 flights per day. So, March can be considered as a representative month of the whole year.

Figure 3 shows the distribution of the yearly traffic over the days of the week.

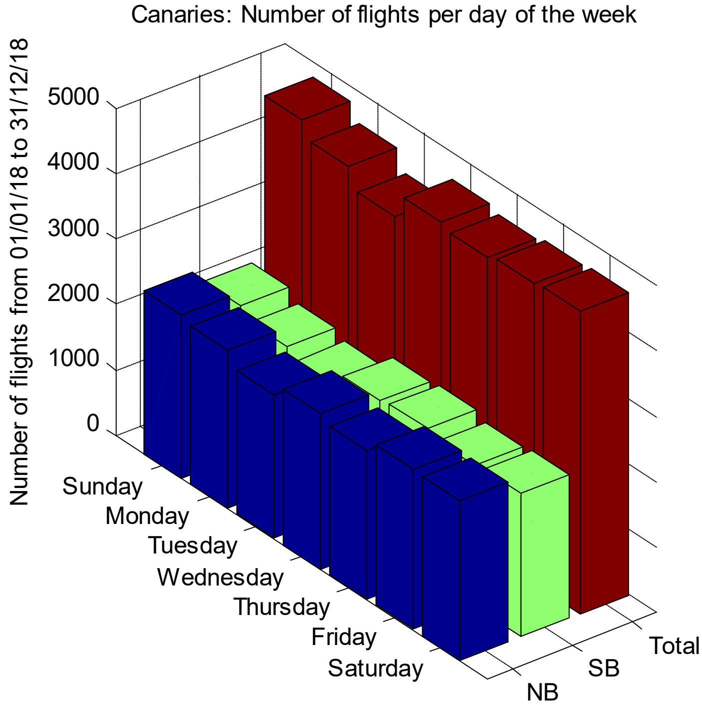


Figure 3.
Number of flights per day of the week in the Canaries. Year 2018

The distributions of flights per half-hour are shown in the following figures. The first one shows the distribution of flights obtained with the time of waypoint crossing in EDUMO, TENPA, IPERA and GUNET (Canaries) during 2018.

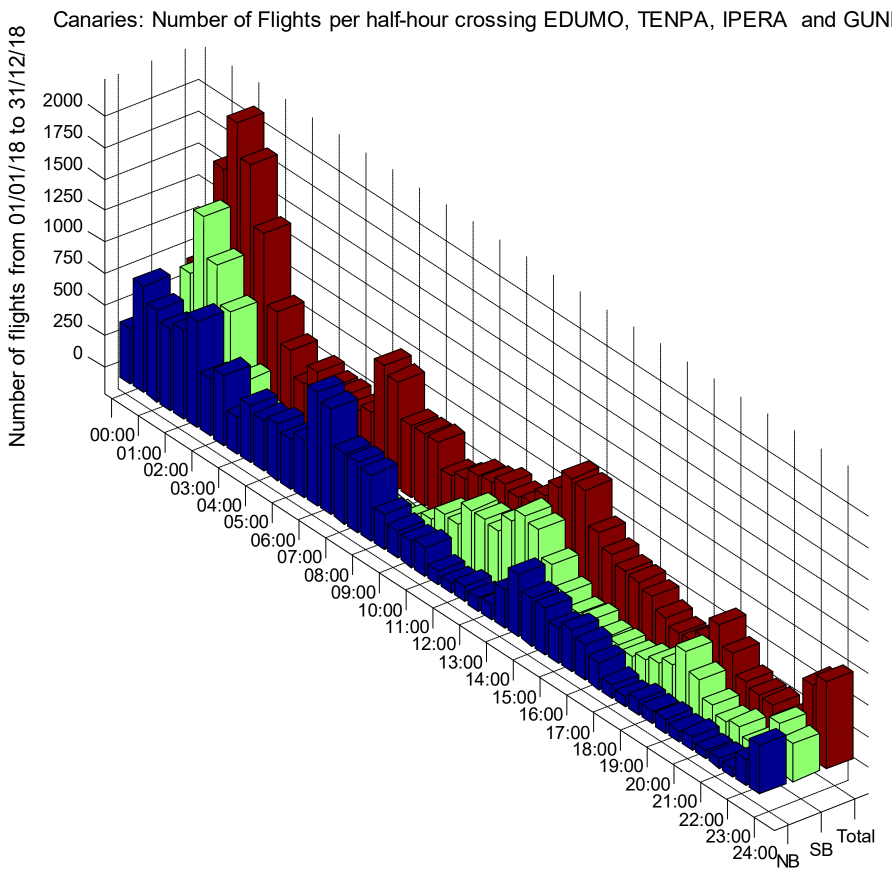


Figure 4.
Number of flights per half-hour crossing EDUMO, TENPA, IPERA and GUNET. Year 2018

It can be seen that during 2018, in the Canaries, it is from 00:00h to 3:00h and from 11:00 to 15:00h when the highest concentration of southbound flights occurs, while most of the northbound aircraft concentrate from 00:00h to 10:00h.

Figure 5 shows the temporal distribution for the 2507 aircraft detected in Canaries during March 2018. Following, Figure 6 shows the temporal distribution of the 1953 aircraft detected over this period in Recife, according to the time of day at which they crossed DIKEB, OBKUT, ORARO and NOISE waypoints. They also distinguish between northbound (NB) and southbound (SB) traffic.

In this figure, it can be seen that in Recife the highest traffic concentration occurs between 00:00h and 7:00h and, in a lower extent, from 15:00h to 24:00h.

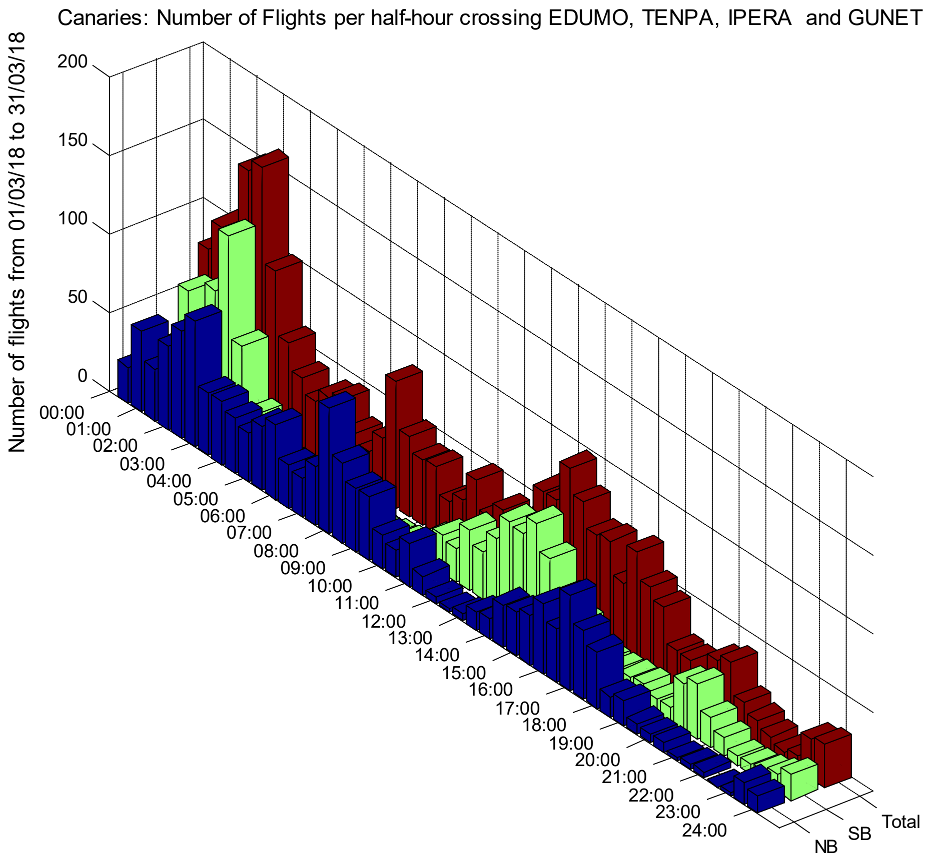


Figure 5.
Number of flights per half-hour crossing EDUMO, TENPA, IPERA and GUNET. March 2018

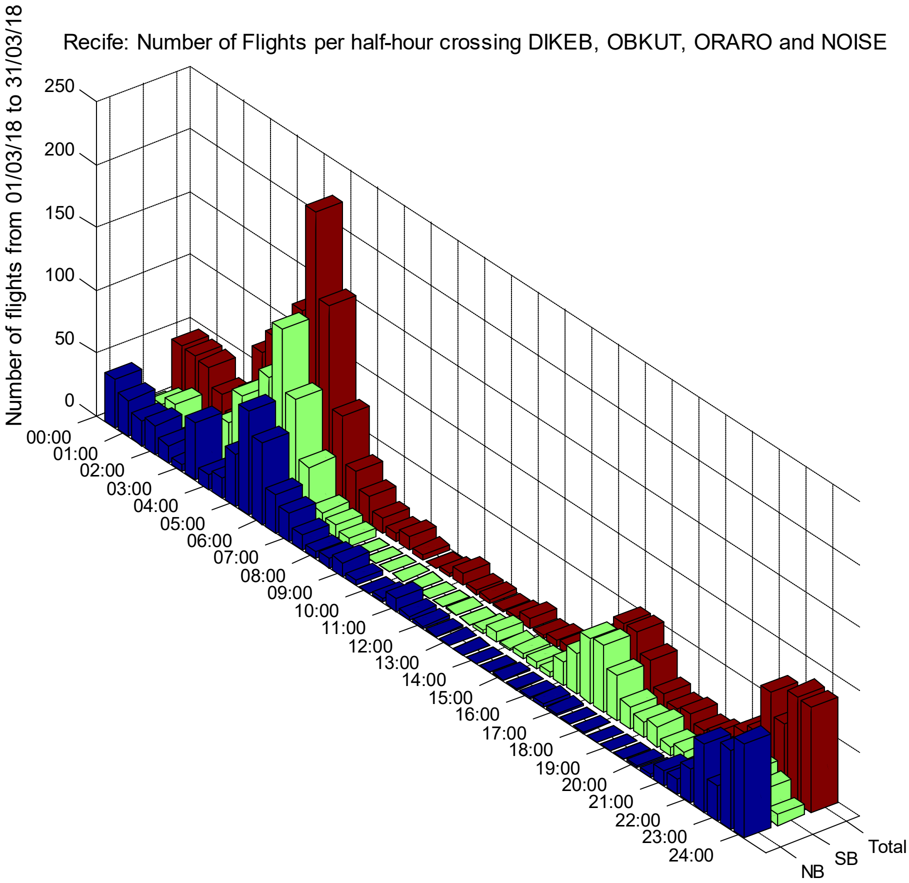


Figure 6.
Number of flights per half-hour crossing DIKEB, OBKUT, ORARO and NOISE. March 2018

2.4. Traffic distribution per flight level

Traffic distribution per flight level during 2018 will be depicted in the graphics of this section. Figure 7 shows the total amount of traffic for the main routes in the Canaries, distributed by route and flight level. Figure 8 and Figure 9 are similar, but they only include the southbound and the northbound traffic, respectively.

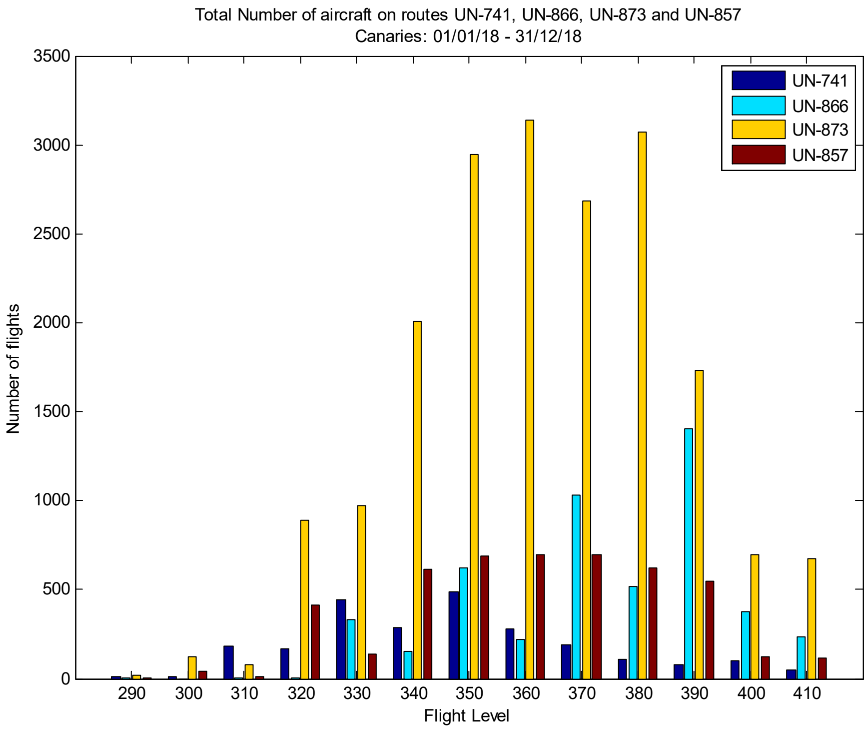


Figure 7.
Number of aircraft on routes UN-741, UN-866, UN-873 and UN-857 in the Canaries

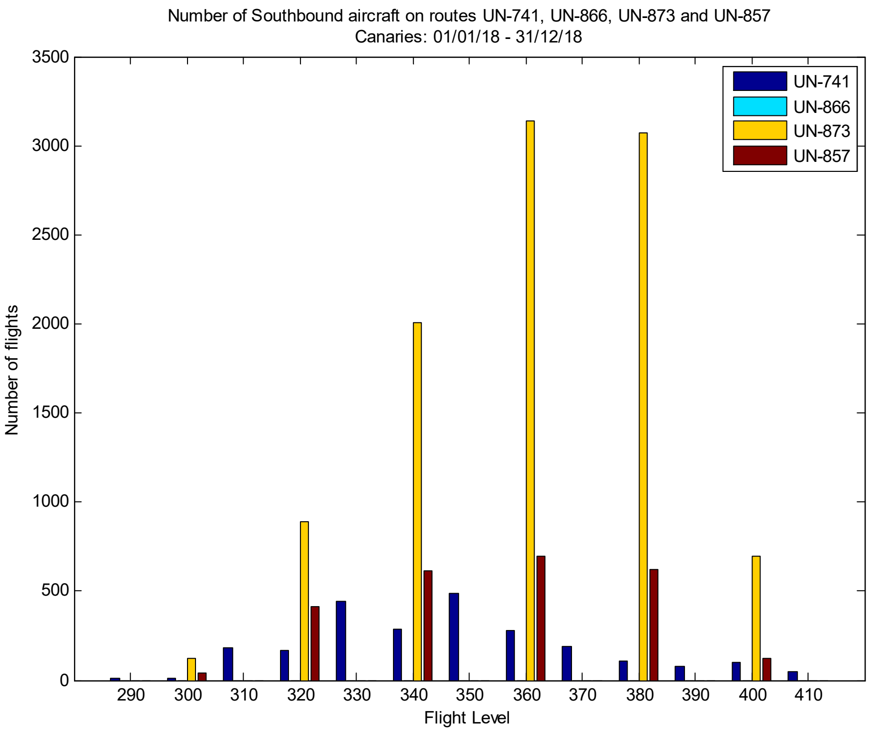


Figure 8.
Number of Southbound aircraft on routes UN-741, UN-866, UN-873 and UN-857 in the Canaries

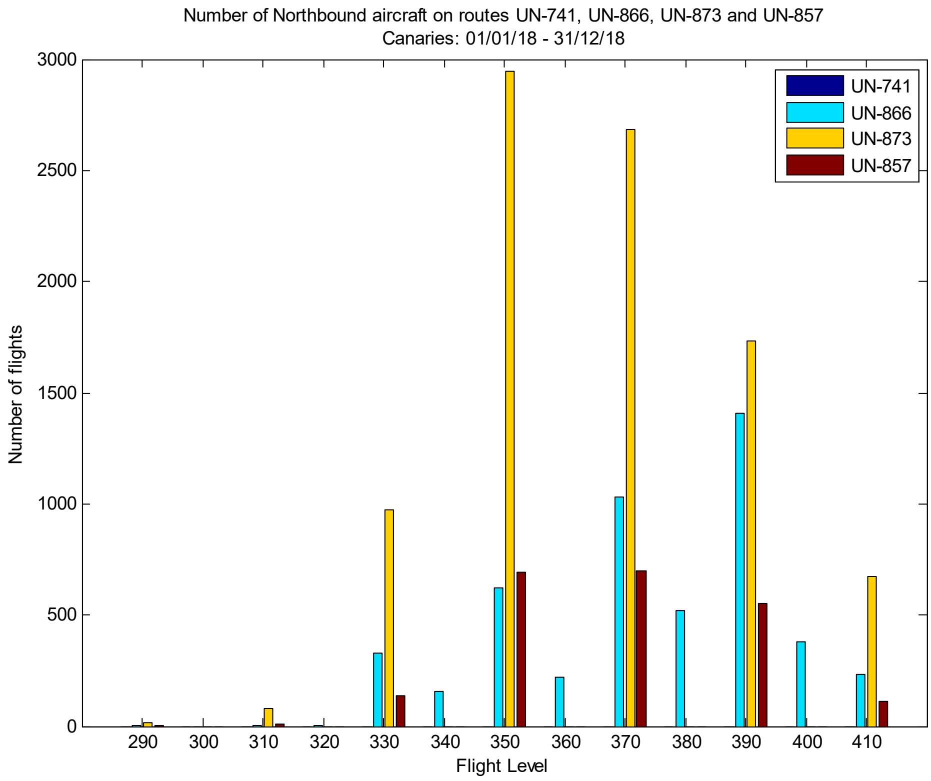


Figure 9.
Number of Northbound aircraft on routes UN-741, UN-866, UN-873 and UN-857 in the Canaries

3. Lateral collision risk assessment

As it has been said, the Reich model to calculate lateral collision risk is explained in [Ref. 33]. In the following sections all the parameters required for the calculation (those that appear in Equation 1) will be analysed.

$$N_{ay} = P_y(S_y) \cdot P_z(0) \cdot \frac{\lambda_y}{S_x} \cdot \left\{ E_{y_{same}} \cdot \left[\frac{|\Delta \bar{v}|}{2 \cdot \lambda_x} + \frac{|\overline{\dot{y}}|}{2 \cdot \lambda_y} + \frac{|\overline{\dot{z}}|}{2 \cdot \lambda_z} \right] + E_{y_{opposite}} \cdot \left[\frac{2 \cdot |\bar{v}|}{2 \cdot \lambda_x} + \frac{|\overline{\dot{y}}|}{2 \cdot \lambda_y} + \frac{|\overline{\dot{z}}|}{2 \cdot \lambda_z} \right] \right\}$$

Equation 1.

3.1. Average aircraft dimensions: $\lambda_x, \lambda_y, \lambda_z$

In previous Table 1, the dimensions of the aircraft types found in the Canaries UIR during the studied period were presented. Using this information, the average aircraft dimensions have been calculated with the dimensions of each aircraft type and the proportions of flights by type as weighting factors. These data are shown in Table 2.

Location	Value Length (λ_x) (ft)	Wingspan (λ_y) (ft)	Height (λ_z) (ft)
Canaries	179.82	165.15	50.25
SAL1	210.18	195.80	56.22
SAL2	207.35	192.92	55.54
Dakar1	208.08	191.41	55.23
Dakar2	206.25	191.62	55.29
Recife	206.37	193.51	55.99

Table 2.
Average aircraft dimensions

3.2. Probability of vertical overlap: $P_z(0)$

In this collision risk assessment, the values for $P_z(0)$ and $P_z(1000)$ (see 4.1.5) have been calculated using the Eurocontrol RVSM Tool. In the case of Pz(0), the obtained result has been $P_z(0)=0.47748$.

3.3. Average ground speed: v

Using the limitation to 575 kts explained in [Ref. 33], the speed of each aircraft that flew during the analysed period of time on each route in the Canaries UIR is shown in the following graphs:

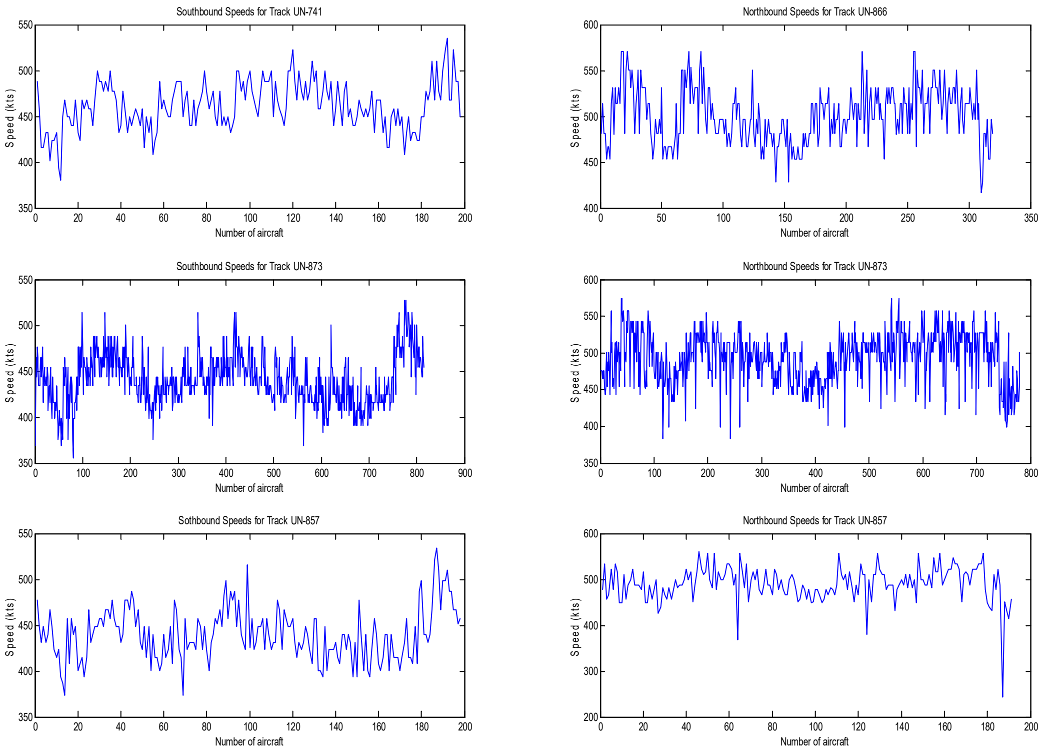


Figure 10.
Speeds limited to 575 kts in the current scenario in the Canaries

Similar graphs can be obtained for the rest of locations.

From these speeds, the average ground speed obtained in the different locations is shown in Table 3:

Location	Average speeds		
	Southbound (kts)	Northbound (kts)	Average (kts)
Canaries	447.9	497.1	472.5
SAL1	440.3	478.7	459.5
SAL2	438.2	485.6	461.9
Dakar1	474.5	491.1	482.8
Dakar2	463.2	461.5	462.4
Recife	456.4	468.1	462.2

Table 3.
Average speeds

3.4. Average relative longitudinal, lateral and vertical speeds: Δv, $\bar{\dot{y}}$ and $\bar{\dot{z}}$

The results obtained for the current scenario for relative longitudinal speeds can be seen in Table 4. The value considered in the collision risk assessment is the one shown in the last column of the table.

Location	Average relative longitudinal speeds		
	Southbound (kts)	Northbound (kts)	Average (kts)
Canaries	15.4	19.1	17.2
SAL1	20.1	25.6	22.8
SAL2	61.5	24.2	42.9
Dakar1	4.9	22.9	14.0
Dakar2	41.1	8.4	24.7
Recife	49.3	22.5	35.9

Table 4.
Average relative longitudinal speeds

As far as the average relative lateral and vertical speeds are concerned, in this study, the values considered have been$|\bar{\dot{y}}| = 42\ kts$ and $|\bar{\dot{z}}| = 1.5\ kts$, respectively, as it is described in[Ref. 33], in previous risk assessments and as it was considered in [Ref. 2].

3.5. Lateral overlap probability: $P_y(S_y)$

To calculate the weighting factor α it has been used as a reference the Appendix A of the study made by ARINC [Ref. 2], summarized in Annex 1 of [Ref. 33]. In 2018, only one lateral deviation was reported in Canaries. SAL, Dakar and Recife did not report any lateral deviation. Information about this considered deviation is shown in Table 5.

FIR/UIR	Date	Entry point	Non-expected flown segment	Deviation
Canaries	070118	GUNET	GUNET-ETIBA	0 NM[1]

Table 5.
Lateral deviations reported in 2018

Therefore, the same assumptions made in [Ref. 2] and [Ref. 6] can be considered, i.e., conservatively, one aircraft experiencing a lateral navigation anomaly has been observed in each FIR/UIR, and the value of α can be obtained using next equation:

$$\alpha = 1 - 0.05^{1/n}$$

Equation 2.

where n is the annual number of flights. As only this number is available for Canaries, extrapolations have been performed to estimate the annual flights for the other UIR/FIRs, using the number of flights of August. Table 6 shows the number of aircraft in August in each FIR and the number of aircraft estimated using the correspondence with the Canaries FIR. Data in cursive indicates if the value is estimated.

Considered period	Canaries	SAL1	SAL2	Dakar1	Dakar2	Recife
March 2018	2507	1825	1608	1767	1958	1953
Jan-Dic 2018	31060	*22610*	*19922*	*21892*	*24258*	*24196*

Table 6.
Number of aircraft considered for the α calculation

Using Equation 2 and taking the number of aircraft indicated in Table 6, different values of α have been calculated for each FIR. Table 7 summarizes the assumptions and the obtained results.

FIR	α
Canaries	$9.6445*10^{-5}$
SAL1	$1.5970*10^{-4}$
SAL2	$1.5803*10^{-4}$
Dakar1	$1.4349*10^{-4}$
Dakar2	$1.4375*10^{-4}$
Recife	$1.2902*10^{-4}$

Table 7.
α for each FIR

[1] Information confirmed by Canaries ATC

Using Equation 11 of [Ref. 33], the lateral overlap probability obtained for the different lateral separations between routes existing in the Corridor are the following ones:

RNP10 S_{ymin}=50NM	$P_y(50)$	$P_y(90)$	$P_y(110)$	$P_y(140)$
Canaries	$5.8767*10^{-8}$	$1.7321*10^{-8}$	$1.1611*10^{-8}$	$6.3721*10^{-9}$
SAL1	$1.0015*10^{-7}$	$3.4176*10^{-8}$	$2.2909*10^{-8}$	$1.2573*10^{-8}$
SAL2	$9.7895*10^{-8}$	$3.3322*10^{-8}$	$2.2336*10^{-8}$	$1.2259*10^{-8}$
Dakar1	$9.0362*10^{-8}$	$3.0020*10^{-8}$	$2.0123*10^{-8}$	$1.1044*10^{-8}$
Dakar2	$9.0581*10^{-8}$	$3.0107*10^{-8}$	$2.0181*10^{-8}$	$1.1076*10^{-8}$
Recife	$8.4192*10^{-8}$	$2.7174*10^{-8}$	$1.8215*10^{-8}$	$9.9971*10^{-9}$

Table 8.
Lateral overlap probability for different separations between routes with RNP10

The probability increases when the spacing between the routes decreases, as it was expected.

3.6. Lateral occupancy

As it was described in [Ref. 33], the next occupancy values must be computed:

- $E_{y_{same}}$: same direction occupancy for routes UN-873/UN-857
- $E^{*}_{y_{same}}$: same direction occupancy for routes UN-866/UN-873
- $E^{**}_{y_{same}}$, same direction occupancy for routes UN-866/UN-857
- $E_{y_{opposite}}$: opposite direction occupancy for routes UN-866/UN-873
- $E^{*}_{y_{opposite}}$: opposite direction occupancy for routes UN-741/UN-866
- $E^{**}_{y_{oppposite}}$, opposite direction occupancy for routes UN-866/UN-857

3.6.1. Traffic growth hypothesis

This study presents the collision risk calculated from data corresponding from 1st March 2018 to 31st March 2018, but it also presents an estimate of the collision risk over a 10 years horizon.

To do that, it is necessary to know the traffic forecast for that period of time in the studied airspace. Taking into account the last data given by STATFOR-EUROCONTROL for the high-growth scenario, [Ref. 21], the annual traffic growth rate for the traffic flows in the Canary Islands airspace would be 3.3%.

3.6.2. Lateral occupancy obtained values

This section presents the same direction and opposite direction lateral occupancy values provided by the CRM programme for the current time and an estimate of the occupancy until 2028, with the annual traffic growth rate indicated before, 3.3%.

Table 9 shows the number of aircraft and the number of same and opposite direction proximate pairs detected on the four routes, from 1st March 2018 till 31st March 2018 in the Canaries, SAL, Dakar and Recife UIR/FIRs.

Number of flights March 2018	Canaries	SAL1	SAL2	Dakar1	Dakar2	Recife
Number of flights on UN-741	198	162	138	232	216	477
Number of flights on UN-866	322	308	306	304	307	291
Number of flights on UN-873	1596	797	849	882	892	893
Number of flights on UN-857	391	247	237	267	267	213
Total number of flights	2507	1514	1530	1685	1682	1874
Number of same direction proximate pairs for tracks UN-866/UN-873	28	22	31	33	31	32
Number of same direction proximate pairs for tracks UN-866/UN-857	9	10	9	12	12	5
Number of same direction proximate pairs for tracks UN-873/UN-857	69	44	44	50	52	42
Number of opposite direction proximate pairs for tracks UN-741/UN-866	6	5	0	1	4	9
Number of opposite direction proximate pairs for tracks UN-866/UN-873	7	4	3	3	7	2
Number of opposite direction proximate pairs for tracks UN-866/UN-857	3	4	0	0	0	0

Table 9.
Lateral occupancy parameters in the Corridor FIR/UIRs

Assuming an annual traffic growth rate of 3.3%, the occupancies for the next 10 years are summarized in Table 10. It holds that occupancy is approximately proportional to traffic flow rate:

3.3% annual traffic growth		Canaries 2018-2028	SAL1 2018-2028	SAL2 2018-2028	Dakar1 2018-2028	Dakar2 2018-2028	Recife 2018-2028
Same direction lateral occupancy	UN-873/UN-857 (E_{ysame})	0.0550-0.0762	0.0581-0.0812	0.0575-0.0796	0.0593-0.0821	0.0618-0.0855	0.0448-0.0620
	UN-866/UN-873 (E^{*}_{ysame})	0.0223-0.0309	0.0291-0.0402	0.0405-0.0561	0.0392-0.0542	0.0369-0.0510	0.0342-0.0473
	UN-866/UN-857 (E^{**}_{ysame})	0.0072-0.0099	0.0132-0.0183	0.0118-0.0163	0.0142-0.0197	0.0143-0.0197	0.0053-0.0074
Opposite direction lateral occupancy	UN-866/UN-873 ($E_{yopposite}$)	0.0056-0.0077	0.0053-0.0073	0.0039-0.0054	0.0036-0.0049	0.0083-0.0115	0.0021-0.0030
	UN-741/UN-866 ($E^{*}_{yopposite}$)	0.0048-0.0066	0.0066-0.0091	0.0000-0.0000	0.0012-0.0016	0.0048-0.0066	0.0096-0.0133
	UN-866/UN-857 ($E^{**}_{yopposite}$)	0.0024-0.0033	0.0053-0.0073	0.0000-0.0000	0.0000-0.0000	0.0000-0.0000	0.0000-0.0000

Table 10.
Lateral occupancy estimate for the Canaries until 2028 with an annual traffic growth rate of 3.3%

3.7. Lateral collision risk

Once all the parameters are obtained, it is possible to calculate the lateral collision risk for the current scenario. This value must not exceed the maximum allowed, for which the system is considered to be safe. This threshold, denominated TLS (Target Level of Safety), has been set to $TLS = 5 \cdot 10^{-9}$. It means that $5 \cdot 10^{-9}$ accidents per flight hour are the maximum accepted.

3.7.1. Lateral collision risk obtained values

In the current system, with RNP10, two unidirectional routes and two bidirectional routes, the collision risk values obtained until 2028 in the different locations are the ones shown in the following table and figures.

Lateral collision risk	3.3% annual traffic growth					
	Canaries	SAL1	SAL2	Dakar1	Dakar2	Recife
2018	$1.2461*10^{-9}$	$2.6845*10^{-9}$	$2.3702*10^{-9}$	$1.6920*10^{-9}$	$2.5580*10^{-9}$	$1.9113*10^{-9}$
2019	$1.2872*10^{-9}$	$2.7731*10^{-9}$	$2.4484*10^{-9}$	$1.7479*10^{-9}$	$2.6424*10^{-9}$	$1.9744*10^{-9}$
2020	$1.3297*10^{-9}$	$2.8646*10^{-9}$	$2.5292*10^{-9}$	$1.8055*10^{-9}$	$2.7296*10^{-9}$	$2.0395*10^{-9}$
2021	$1.3736*10^{-9}$	$2.9592*10^{-9}$	$2.6127*10^{-9}$	$1.8651*10^{-9}$	$2.8197*10^{-9}$	$2.1068*10^{-9}$
2022	$1.4189*10^{-9}$	$3.0568*10^{-9}$	$2.6989*10^{-9}$	$1.9267*10^{-9}$	$2.9128*10^{-9}$	$2.1764*10^{-9}$
2023	$1.4657*10^{-9}$	$3.1577*10^{-9}$	$2.7880*10^{-9}$	$1.9902*10^{-9}$	$3.0089*10^{-9}$	$2.2482*10^{-9}$
2024	$1.5141*10^{-9}$	$3.2619*10^{-9}$	$2.8800*10^{-9}$	$2.0559*10^{-9}$	$3.1082*10^{-9}$	$2.3224*10^{-9}$
2025	$1.5640*10^{-9}$	$3.3695*10^{-9}$	$2.9750*10^{-9}$	$2.1238*10^{-9}$	$3.2108*10^{-9}$	$2.3990*10^{-9}$
2026	$1.6156*10^{-9}$	$3.4807*10^{-9}$	$3.0732*10^{-9}$	$2.1939*10^{-9}$	$3.3167*10^{-9}$	$2.4782*10^{-9}$
2027	$1.6690*10^{-9}$	$3.5956*10^{-9}$	$3.1746*10^{-9}$	$2.2663*10^{-9}$	$3.4262*10^{-9}$	$2.5599*10^{-9}$
2028	$1.7240*10^{-9}$	$3.7142*10^{-9}$	$3.2794*10^{-9}$	$2.3410*10^{-9}$	$3.5392*10^{-9}$	$2.6444*10^{-9}$

Table 11.
Lateral collision risk for the period 2018-2028 in the Corridor

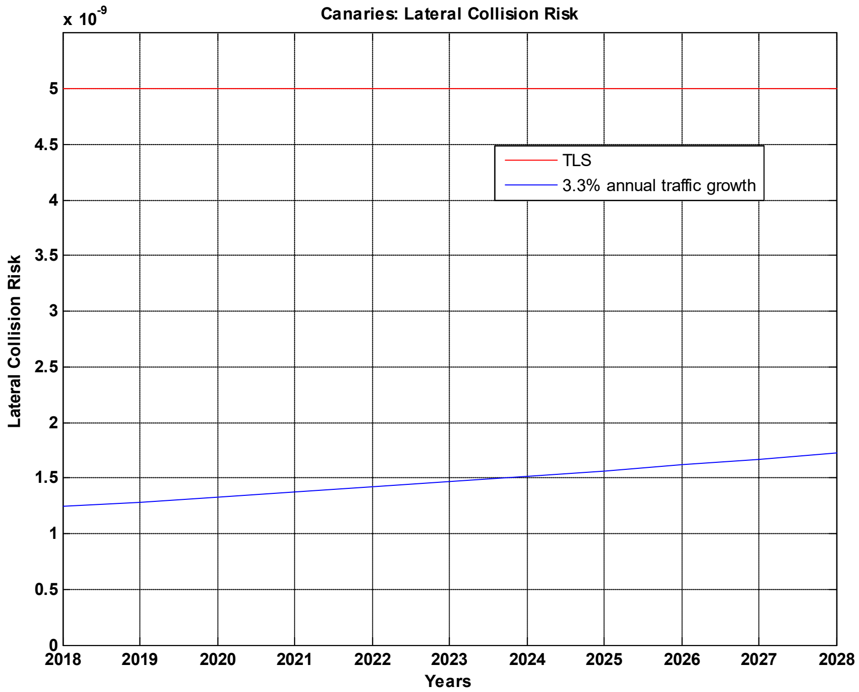


Figure 11.
Lateral collision risk for the period 2018-2028 in the Canaries

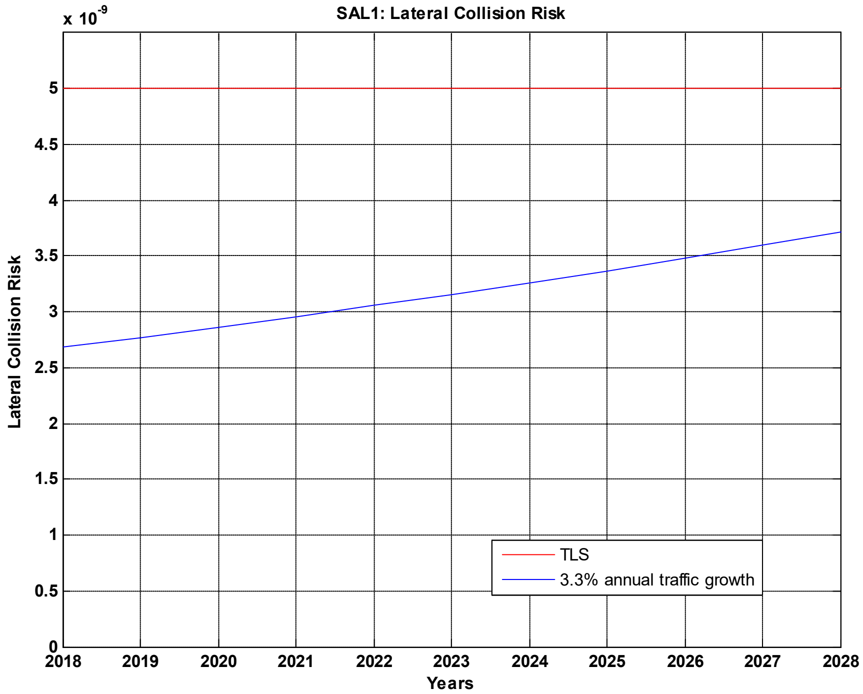


Figure 12.
Lateral collision risk for the period 2018-2028 in SAL1

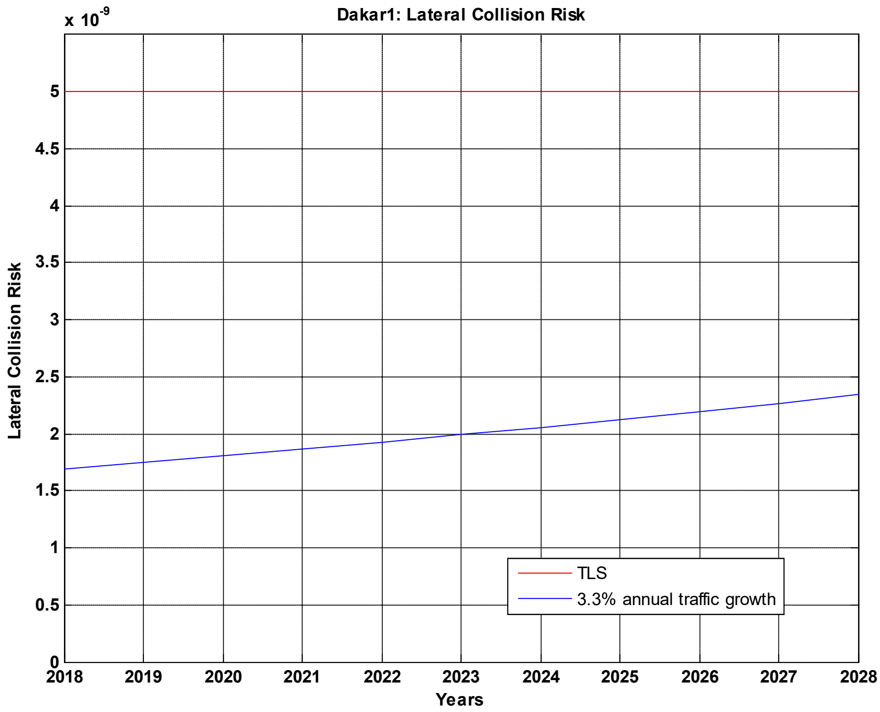


Figure 13.
Lateral collision risk for the period 2018-2028 in SAL2

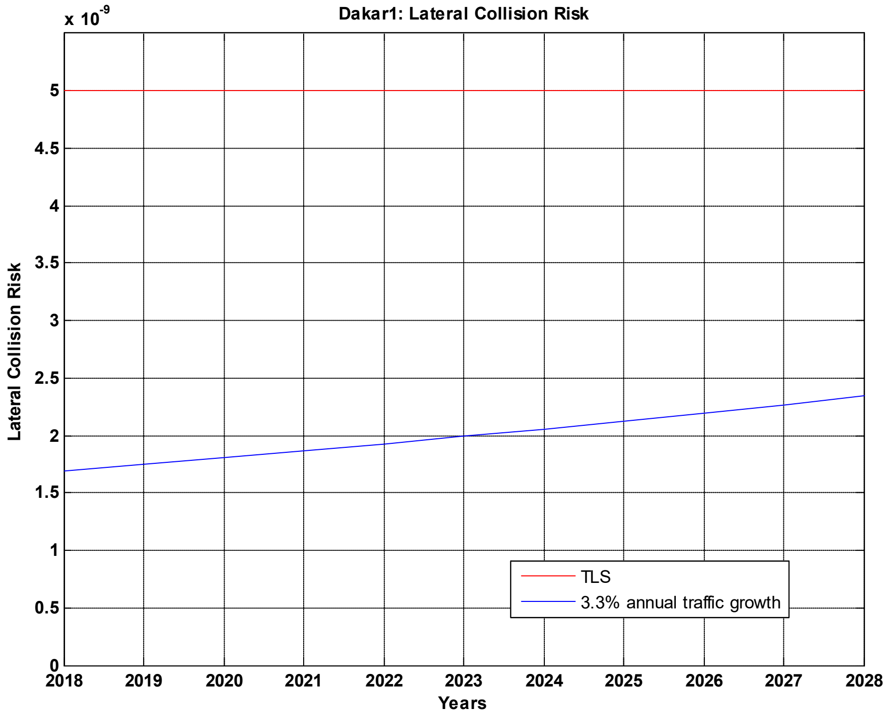


Figure 14.
Lateral collision risk for the period 2018-2028 in Dakar1

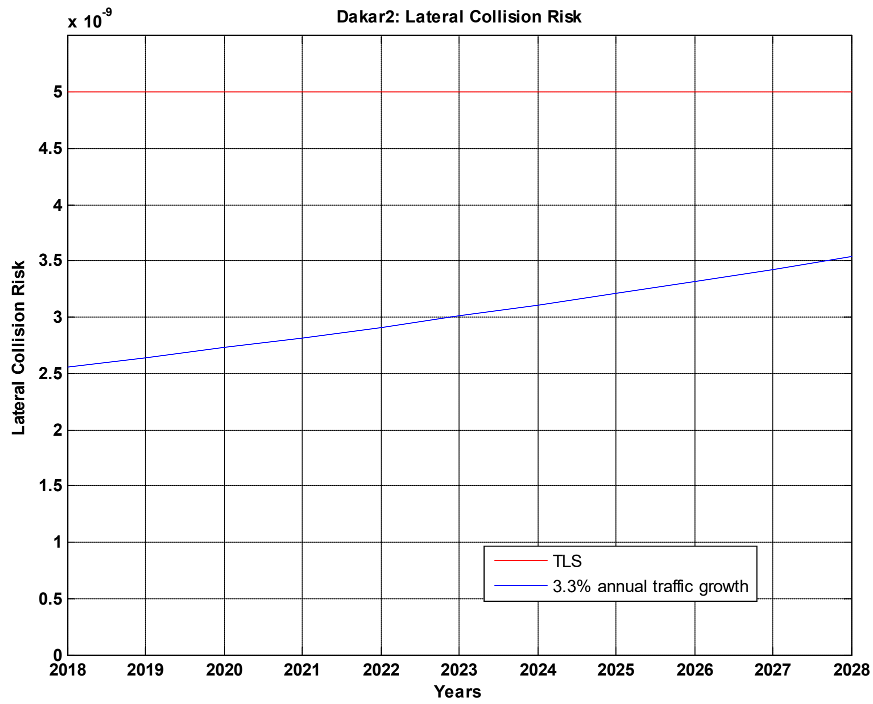


Figure 15.
Lateral collision risk for the period 2018-2028 in Dakar2

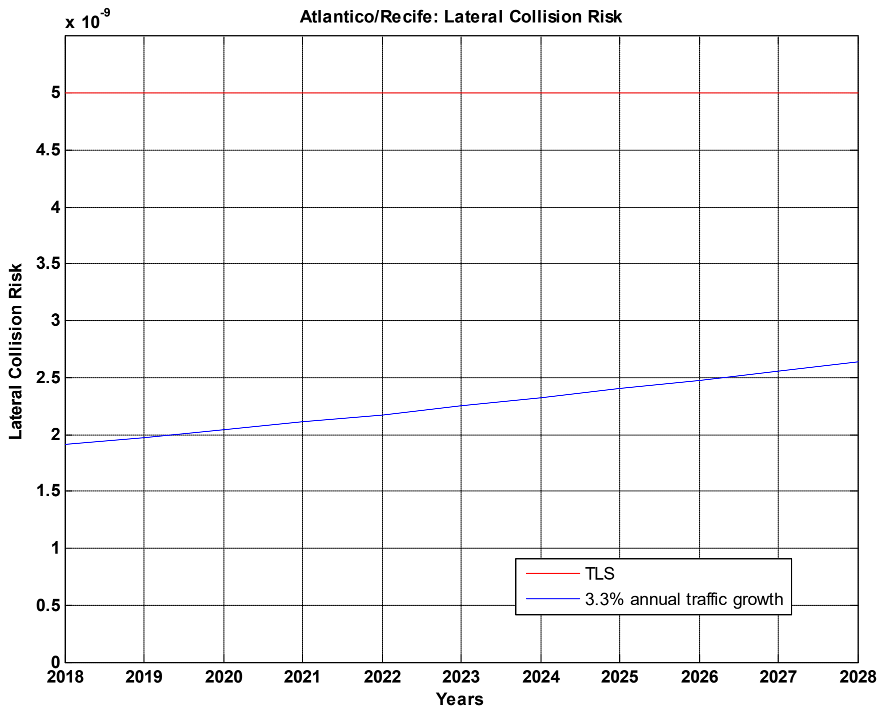


Figure 16.
Lateral collision risk for the period 2018-2028 in Recife

3.7.2. Considerations on the results

Lateral collision risk is below the $TLS = 5 \cdot 10^{-9}$ with the current traffic flow and it is estimated that, considering 3.3% as the annual traffic growth rate, the TLS would not be exceeded in the period under consideration.

The values obtained for the lateral collision risk are similar to those ones presented in the previous collision risk assessments, [Ref. 5] to [Ref. 9]. It has also been confirmed that the results are similar in all the analysed locations.

4. Vertical collision risk assessment

4.1. Technical vertical collision risk assessment

Technical vertical risk represents the risk of a collision between aircraft on adjacent flight levels due to normal or typical height deviations of RVSM approved aircraft. It is attributable to the height-keeping errors that result from the combination of altimetry system errors (ASE) and autopilot performance in the vertical dimension.

As it has been indicated, the Reich model to calculate technical vertical collision risk is explained in [Ref. 33]. In the following sections all the parameters required for the calculation (those that appear in Equation 3) will be analysed.

$$N_{az} = P_z(S_z) \cdot P_y(0) \cdot \frac{\lambda_x}{S_x} \cdot \left\{ E_{z_{same}} \cdot \left[\frac{|\Delta \bar{v}|}{2 \cdot \lambda_x} + \frac{\overline{|\dot{y}|}}{2 \cdot \lambda_y} + \frac{\overline{|\dot{z}|}}{2 \cdot \lambda_z} \right] + E_{z_{opposite}} \cdot \left[\frac{2 \cdot |\bar{v}|}{2 \cdot \lambda_x} + \frac{\overline{|\dot{y}|}}{2 \cdot \lambda_y} + \frac{\overline{|\dot{z}|}}{2 \cdot \lambda_z} \right] \right\} +$$
$$+ P_z(S_z) \cdot \sum_{1}^{n} P_h(\theta_i) \cdot E_z(\theta_i) \cdot \left\{ \frac{v_{rel}(\theta_i)}{\frac{\pi \lambda_h}{2}} + \frac{\overline{|\dot{z}|}}{2 \cdot \lambda_z} \right\}$$

Equation 3.

4.1.1. Average aircraft dimensions: λ_x, λ_y, λ_z, λ_h

Table 2 showed the average aircraft dimensions for the lateral collision risk model. Clearly, the same dimensions apply to the vertical model. In addition, the vertical model for crossing traffic needs the average diameter of a cylinder enveloping the aircraft (λ_h), which is the largest of the average aircraft wingspan or fuselage length. Table 12 shows the pertinent average aircraft dimensions.

Location	Value Length (λ_x) (ft)	Wingspan (λ_y) (ft)	Height (λ_z) (ft)
Canaries	179.82	165.15	50.25
SAL1	210.18	195.80	56.22
SAL2	207.35	192.92	55.54
Dakar1	208.08	191.41	55.23
Dakar2	206.25	191.62	55.29
Recife	206.37	193.51	55.99

Table 12.
Average aircraft dimensions for the vertical collision risk model

4.1.2. Probability of lateral overlap: $P_y(0)$

As it is indicated in [Ref. 33], the most conservative assumption consists of assuming that the full aircraft population are using GNSS, α=1. Thus, taking the probability density as Gaussian2, with 0 mean and 0.06123 NM standard deviation, the value obtained for the lateral overlap probability is: $P_y(0) = 4.6071 * 2\lambda_y$, with λ_y expressed in NM.

4.1.3. Probability of horizontal overlap: $P_h(\theta)$

As it was previously explained, in the EUR/SAM Corridor there is traffic crossing the Corridor in published routes in SAL, Dakar and Recife, but there is also some traffic crossing the Corridor in non-published routes or changing from one route to another.

Probability of horizontal overlap has been calculated for all these routes using Equation 37 in [Ref. 33]. The values of S_h and σ_{rc} considered are the same that are used in the CAR/SAM region, i.e., $S_h = 80\ NM$ and $\sigma_{rc} = 0.3\ NM$ (this last value is the one established in the Doc 9574, [Ref. 15]). This probability has only been calculated whenever proximate events have been detected, as it will be seen in 4.1.6.

The obtained results are shown in Table 13 and Table 14.

Horizontal overlap probability				
Location	**Diameter (λ_h)**	**Route (Point)**	**Angles (º)**	**$P_h(\theta)$**
Canaries	0.0296 NM	ISOKA-APASO (ISOKA)	151-29	$9.0752*10^{-7}$
SAL1	0.0346 NM	UR-976/UA-602 (GAMBA)	95-85	$5.9268*10^{-7}$
		ULTEM-LUMPO (IRENE)	91-89	$5.9035*10^{-7}$
		BAMUX-SEPOM (BS001)	102-78	$6.0447*10^{-7}$
		BAMUX-ILGAS (BI001)	95-85	$5.9268*10^{-7}$
		ULTEM-ILGAS (RL001)	108-72	$6.2299*10^{-7}$
		EDUMO-BI002 (BI002)	127-53	$7.4989*10^{-7}$
		CVS-BS004 (CVS)	152-28	$1.2943*10^{-6}$
		NEMDO-BI003 (BI003)	154-26	$1.3873*10^{-6}$
		IREDO-BL003 (BL003)	134-46	$8.3638*10^{-7}$
		CVS-UGAMA (CVS)	101-79	$6.0216*10^{-7}$
		CVS-UGAMA (UGAMA)	98-82	$5.9650*10^{-7}$
		CARME-PISPU (PISPU)	145-35	$1.0558*10^{-6}$

Table 13.
Horizontal overlap probabilities in Canaries and SAL1

[2] *As the calculation of $P_y(0)$ is dominated by the core of the densities, the choice of the type of the probability density is less critical than for the calculation of $P_y(S_y)$.*

Horizontal overlap probability				
Location	**Diameter (λ_h)**	**Route (Point)**	**Angles (º)**	**$P_h(\theta)$**
SAL2	0.0341 NM	CARME-KENOX (KENOX)	149-31	$1.1466*10^{-6}$
		BAMUX-KENOX (KENOX)	162-18	$1.9200*10^{-6}$
		BULBO-ORABI (BULBO)	157-23	$1.5164*10^{-6}$
		BULBO-ORABI (ORABI)	155-25	$1.4010*10^{-6}$
Dakar1	0.0339 NM	UL-435 (DIGUN)	98-82	$5.7444*10^{-7}$
		ENUGO-APIGU (ENUGO)	96-84	$5.7179*10^{-7}$
		APOXA-GONSA (GONSA)	92-88	$5.6879*10^{-7}$
		XUVIT-DIGUN (DIGUN)	158-22	$1.5656*10^{-6}$
		TARIM-DIGUN (DIGUN)	169-11	$3.0777*10^{-6}$
		LIRAX-MESAB (LIRAX)	154-26	$1.3359*10^{-6}$
		SAGRO-BUXON (SAGRO)	124-56	$6.9431*10^{-7}$
		TARIM-SAGRO (SAGRO)	167-13	$2.6112*10^{-6}$
		SAGRO-MOSOK (MOSOK)	137-43	$8.5115*10^{-7}$
		KENOX-RIXAD (KENOX)	127-53	$7.2215*10^{-7}$
Dakar2	0.0340 NM	IP007-NANIK (NANIK)	160-20	$1.7175*10^{-6}$
		IP008-NANIK (NANIK)	169-11	$3.0810*10^{-6}$
		IRAVU-MESAB (MESAB)	153-27	$1.2908*10^{-6}$
		DIGUN-MOVGA (DIGUN)	146-34	$1.0446*10^{-6}$
Recife	0.0343 NM	UL-695 (DIKEB)	97-83	$5.8391*10^{-7}$
		ERETU-PUGSA (ERETU)	165-15	$2.3125*10^{-6}$

Table 14.
Horizontal overlap probabilities in SAL2, Dakar1, Dakar2 and Recife

4.1.4. Relative velocities

Equation 27 in [Ref. 33] contains four relative speed parameters, $2|\bar{v}|$, $|\Delta\bar{v}|$, $|\overline{\dot{y}}|$ and $|\overline{\dot{z}}|$ for the same/opposite vertical risk and relative speeds for each one of the crossing pairs of routes, $v_{rel}(\theta_i)$.

The average along track speed $2|\bar{v}|$ is taken as in the lateral collision risk model.

Regarding $|\Delta\bar{v}|$, it has been calculated, as in the lateral case, from the differences between the speeds of all the pairs of aircraft that constitute a vertical proximate pair in the same direction.

Location	Vertical average relative longitudinal speeds		
	Southbound (kts)	Northbound (kts)	Average (kts)
Canaries	13.6765	26.1244	19.9005
SAL1	19.4597	26.1358	22.7977
SAL2	48.4790	11.4194	29.9492
Dakar1	3.1040	21.2506	12.1773
Dakar2	12.7335	13.2701	13.0018
Recife	23.0494	27.7601	25.4048

Table 15.
Vertical average relative longitudinal speeds

For the vertical collision risk model, $\overline{|\dot{y}|}$ is the mean of the modulus of the relative cross-track speed between aircraft on the same track. Consequently, there is no operational reason why this relative speed should have a particularly large value. As it was presented in the previous studies, [Ref. 3] to [Ref. 9], a conservative value, 20 kts, was used based on the assessment made by ARINC in [Ref. 2] and on the AFI Region Assessment, [Ref. 23]. This value has been taken here too.

The mean relative vertical speed of the vertical collision risk model applies to aircraft that have lost their assigned vertical separation minimum of S_z. The value $\overline{|\dot{z}|} = 1.5\ kts$ will be taken here as in the lateral collision risk assessment.

As far as relative speed in crossing routes is concerned, it is obtained by:

$$v_{rel}(\theta_i) = \sqrt{v_1^2 + v_2^2 - 2v_1v_2\cos(\theta_i)}$$

Equation 4.

where v_1 and v_2 are the average speeds in each one of the routes and θ, the intersection angle. The relative speeds used in this study are summarized in Table 16 and Table 17. V1 refers to the average speed on the corresponding parallel route and V2, to the crossing route. As it was said before, this velocity is only calculated if proximate pairs for the crossing route are detected.

Location	Crossing route (Point)	V_1 (kts)	V_2 (kts)	θ (º)	$V_{rel}(\theta)$ (kts)
Canaries	ISOKA-APASO (ISOKA)	472.47	395.69	29	229.73
				151	840.72
SAL1	UR-976/UA-602 (GAMBA)	459.51	471.49	85	629.04
				95	686.46
	ULTEM-LUMPO (IRENE)	459.51	450.85	89	638.11
				91	649.34
	BAMUX-SEPOM (BS001)	459.51	467.06	78	583.14
				102	720.10
	BAMUX-ILGAS (BI001)	459.51	458.86	85	620.44
				95	677.10
	ULTEM-ILGAS (RL001)	459.51	448.02	72	533.51
				108	734.24
	EDUMO-BI002 (BI002)	459.51	434.16	53	399.40
				127	799.86
	CVS-BS004 (CVS)	459.51	491.73	28	232.24
				152	923.02
	NEMDO-BI003 (BI003)	459.51	471.24	26	209.68
				154	906.90
	IREDO-BL003 (BL003)	459.51	458.80	46	358.82
				134	845.31
	CVS-UGAMA (CVS)	459.51	468.74	79	590.48
				101	716.28
	CVS-UGAMA (UGAMA)	459.51	468.74	82	609.03
				98	700.58
	CARME-PISPU (PISPU)	459.51	364.76	35	263.82
				145	786.64
SAL2	CARME-KENOX (KENOX)	461.90	400.25	31	237.93
				149	830.96
	BAMUX-KENOX (KENOX)	461.90	475.73	18	147.31
				162	926.08
	BULBO-ORABI (BULBO)	461.90	425.71	23	180.48
				157	869.82
	BULBO-ORABI (ORABI)	461.90	425.71	25	195.33
				155	866.60

Table 16.
Relative speeds in crossings (Canaries and SAL)

Location	Crossing route	V_1 (kts)	V_2 (kts)	θ (º)	$V_{rel}(\theta)$ (kts)
Dakar1	UL-435 (DIGUN)	482.81	480.69	82	632.11
				98	727.16
	ENUGO-APIGU (ENUGO)	482.81	483.19	84	646.37
				96	717.87
	APOXA-GONSA (GONSA)	482.81	483.84	88	671.49
				92	695.35
	XUVIT-DIGUN (DIGUN)	482.81	486.55	22	185.00
				158	951.55
	TARIM-DIGUN (DIGUN)	482.81	477.16	11	92.18
				169	955.55
	LIRAX-MESAB (LIRAX)	482.81	464.23	26	213.80
				154	922.77
	SAGRO-BUXON (SAGRO)	482.81	478.68	56	451.40
				124	848.94
	TARIM-SAGRO (SAGRO)	482.81	475.73	13	108.74
				167	952.38
	SAGRO-MOSOK (MOSOK)	482.81	477.05	43	351.83
				137	893.07
	KENOX-RIXAD (KENOX)	482.81	452.79	53	418.32
				127	837.40
Dakar2	IP007-NANIK (NANIK)	462.36	485.17	20	166.06
				160	933.14
	IP008-NANIK (NANIK)	462.36	481.74	11	82.52
				169	939.75
	IRAVU-MESAB (MESAB)	462.36	486.16	27	222.63
				153	922.33
	DIGUN-MOVGA (DIGUN)	462.36	495.86	34	281.98
				146	916.40
Recife	UL-695 (DIKEB)	462.21	465.36	83	614.63
				97	694.71
	ERETU-PUGSA (ERETU)	462.21	483.59	15	125.26
				165	937.71

Table 17.
Relative speeds in crossings (Dakar and Recife)

4.1.5. Vertical overlap probability: $P_z(S_z)$

With 2018 traffic and height-keeping performances information, the probability of vertical overlap has been calculated by means of Equation 43 in [Ref. 33], using the Eurocontrol RVSM Tool, being the resulting values $P_z(1000) = 9.87916 \cdot 10^{-13}$ and $P_z(0) = 0.47748$.

4.1.6. Vertical occupancy

As it is explained in [Ref. 33], vertical occupancy can be defined for same and opposite direction traffic in the same way as lateral occupancy.

This section presents the vertical occupancy values provided by the CRM program for the current time and an estimate of the occupancy until 2028, with the annual traffic growth rate previously indicated, 3.3%.

4.1.6.a. Canaries

Table 18 shows some results on same and opposite vertical occupancy in Canaries location, based on traffic levels representative of 2018.

Vertical occupancy	March 2018
Number of flights on UN-741	198
Number of flights on UN-866	322
Number of flights on UN-873	1596
Number of flights on UN-857	391
Total number of flights on main airways	2507
Number of same direction vertical proximate pairs for tracks UN-741	12
Number of same direction vertical proximate pairs for tracks UN-866	24
Number of opposite direction vertical proximate pairs for tracks UN-873	102
Number of opposite direction vertical proximate pairs for tracks UN-857	9
Total number of same direction proximate events	36
Total number of opposite direction proximate events	111
Same direction vertical occupancy (S_x=80NM)	0.0287
Opposite direction vertical occupancy (S_x=80NM)	0.0886

Table 18.
Vertical occupancy due to same and opposite direction traffic in the Canaries location with current traffic levels

Apart from the traffic on the main routes, in the Canaries airspace there are some non-published crossing trajectories, as it was explained before. The number of flights on these routes can be found in the following table:

Number of flights	March 2018
Number of flights on crossing flight ISOKA-APASO	2
Total number of flights on main routes (UN-741, UN-866, UN-873 and UN-857)	2507
Total number of flights	2507

Table 19.
Number of flights in Canaries airspace

All the flights on the non-published routes are already included in the number of flights on the main routes. Therefore, the total number of flights is 2507.

To calculate crossing occupancies, it is necessary to obtain the number of proximate pairs, i.e., the number of pairs for which horizontal separation is less than S_h. The value selected for S_h is set to the value used in the CAR/SAM study, [Ref. 19], i.e. $S_h = 80NM$.

Proximate events can be obtained comparing differences of passing times at the crossing point. The time window to be used in each case depends on the speeds and intersection angle of the routes, as it is explained in Annex 2 of [Ref. 33]. The values obtained for the Canaries are shown in Table 20, where v1 refers to the average speed on the corresponding parallel route, v2 refers to the average speed on the crossing route, and θ1 and θ2 are the two possible crossing angles, depending on the headings. With these time windows, the number of proximate pairs obtained can also be seen in Table 20. It is to be noted that only data for the crossing routes for which proximate pairs have been detected are presented.

Time windows for crossing routes						**Number of proximate events due to crossing traffic**	
Route	**Point**	**v1 (kts)**	**v2 (kts)**	**θ (º)**	**t (min)**	**At the same FL**	**At adjacent FL**
ISOKA-APASO	ISOKA	472.47	395.69	151º	45	0	4
				29º	13	0	0

Table 20.
Time windows for crossing occupancies and number of proximate events in the Canaries.

Once vertical occupancy is calculated based on current traffic levels, it is possible to estimate the occupancy in the following years taking into account the forecasted annual traffic growth rate. Vertical occupancy values from 2018 to 2028 with an annual traffic growth rate of 3.3% are shown in Table 21.

3.3% annual traffic growth			**2018**	**2020**	**2022**	**2024**	**2026**	**2028**
Same direction vertical occupancy			0.0287	0.0306	0.0327	0.0349	0.0372	0.0397
Opposite direction vertical occupancy			0.0886	0.0945	0.1008	0.1076	0.1148	0.1225
Crossing occupancy	ISOKA-APASO	151º	0.0032	0.0034	0.0036	0.0039	0.0041	0.0044
		29º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 21.
Vertical occupancy estimate for the Canaries until 2028 with an annual traffic growth rate of 3.3%

4.1.6.b. SAL1

Table 22 collects some results on same and opposite vertical occupancy in SAL1, obtained with data from March 2018.

Number of flights	March 2018
Number of flights on UN-741	162
Number of flights on UN-866	308
Number of flights on UN-873	797
Number of flights on UN-857	247
Total number of flights	1514
Number of same direction vertical proximate pairs for tracks UN-741	12
Number of same direction vertical proximate pairs for tracks UN-866	24
Number of opposite direction vertical proximate pairs for tracks UN-873	13
Number of opposite direction vertical proximate pairs for tracks UN-857	2
Total number of same direction proximate events	36
Total number of opposite direction proximate events	15
Same direction vertical occupancy (S_x=80NM)	0.0476
Opposite direction vertical occupancy (S_x=80NM)	0.0198

Table 22.
Vertical occupancy due to same and opposite direction traffic in SAL1 location with current traffic levels

Apart from the traffic on the main routes, in SAL1 there is also some traffic crossing the Corridor on routes UR-976/UA-602 and on non-published routes. The number of flights on these routes can be found in the following table:

Number of flights	March 2018
Number of flights on UR-976/UA-602	103
Number of flights on ULTEM-LUMPO	68
Number of flights on BAMUX-SEPOM	30
Number of flights on BAMUX-LUMPO	1
Number of flights on BAMUX-ILGAS	34
Number of flights on ULTEM-ILGAS	6
Number of flights on BL001-BS002	1
Number of flights on IREDO-BL003	4
Number of flights on IPERA-BI004	2
Number of flights on EDUMO-BI002	22
Number of flights on NEMDO-BI003	22
Number of flights on IRENE-KESIK	7
Number of flights on CVS-UGAMA	63
Number of flights on CVS-BL002	5
Number of flights on CVS-BS004	2
Number of flights on PISPU-CARME	6
Number of flights on main routes (UN-741, UN-866, UN-873 and UN-857)	1514
Total number of flights	1825

Table 23.
Number of flights in SAL1 airspace

All the flights on the non-published routes are already included in the number of flights on the main routes, except for the flights on the trajectories that cross the complete corridor (311 flights). Therefore, the total number of flights is 1825.

The time windows to obtain proximate pairs and the number of proximate events are, in this case, the ones shown in Table 24. It is to be noted that only data for crossing routes for which proximate events have been detected are presented.

Time windows for crossing routes						**Number of proximate events due to crossing traffic**	
Route	**Point**	**v1 (kts)**	**v2 (kts)**	**θ (º)**	**t (min)**	**At the same FL**	**At adjacent FL**
UR-976/UA-602	---	459.51	471.49	95º	16	10	16
				85º	14	0	8
ULTEM-LUMPO	---	459.51	450.85	91º	15	5	9
				89º	15	17	16
BAMUX-SEPOM	---	459.51	467.06	102º	17	4	3
				78º	14	0	8
BAMUX-ILGAS	---	459.51	458.86	95º	16	3	4
				85º	15	7	15
ULTEM-ILGAS	---	459.51	448.02	108º	18	0	2
				72º	14	0	0
IREDO-BL003	BL003	467.47	458.80	134º	28	0	2
				46º	12	0	0
EDUMO-BI002	BI002	430.17	434.16	127º	25	0	3
				53º	13	0	0
CVS-BS004	CVS	467.47	491.73	152º	41	0	1
				28º	11	0	0
NEMDO-BI003	BI003	467.47	471.24	154º	46	0	2
				26º	11	0	11
CVS-UGAMA	CVS	467.47	468.74	101º	16	0	4
				79º	14	4	5
	UGAMA	463.78	468.74	98º	16	0	1
				82º	14	1	1
PISPU-CARME	PISPU	467.47	364.76	145º	40	0	3
				35º	14	2	0

Table 24.
Time windows for crossing occupancies and number of proximate events in SAL1

It can be seen that some proximate events involve aircraft at the same flight level. 36 of these events at the same level involve aircraft within 15 minutes or less of each other. Several reasons are possible for this apparent violation of the required separation, such as:

- A tactical flight level change to separate crossing traffic was not included in the provided data;
- There was an error in the time provided in the data;
- The air traffic controller did not register a flight level change;
- The aircraft made contact too late to allow an action by the air traffic controller;
- There was an operational error that was not registered by the air traffic controller and/or by the aircraft;
- Passing times at the crossing point are not precise, due to the need of extrapolation of the traffic data.

Further analysis would be required for these cases to identify whether they are in fact proximate events at the same level or not. No more information is available for further clarification and no deviation reports have been received. Therefore, in this assessment, for the purpose of accounting for these events in the collision risk model, the "same flight level" crossing proximity events are counted as "adjacent flight level" proximity events. This approach was also followed by ARINC in [Ref. 2]. Nevertheless, if it could be shown that these events were in fact violations of the vertical separation standard, then these events should be treated as large height keeping deviations and be accounted for in the total vertical collision risk.

With these considerations, vertical occupancy values from 2018 to 2028 with an annual traffic growth rate of 3.3% are shown in Table 25. Only crossings different from zero have been shown.

3.3% annual traffic growth				**2018**	**2020**	**2022**	**2024**	**2026**	**2028**
Same direction vertical occupancy				0.0476	0.0507	0.0542	0.0579	0.0617	0.0658
Opposite direction vertical occupancy				0.0198	0.0211	0.0226	0.0241	0.0257	0.0274
Crossing occupancy	UR-976/UA-602	---	95º	0.0252	0.0269	0.0287	0.0306	0.0327	0.0349
			85º	0.0088	0.0094	0.0100	0.0107	0.0114	0.0121
	ULTEM-LUMPO	---	91º	0.0121	0.0129	0.0137	0.0146	0.0156	0.0167
			89º	0.0219	0.0234	0.0250	0.0266	0.0284	0.0303
	BAMUX-SEPOM	---	102º	0.0055	0.0058	0.0062	0.0067	0.0071	0.0076
			78º	0.0088	0.0094	0.0100	0.0107	0.0114	0.0121
	BAMUX-ILGAS	---	95º	0.0044	0.0047	0.0050	0.0053	0.0057	0.0061
			85º	0.0197	0.0210	0.0225	0.0240	0.0256	0.0273
	ULTEM-ILGAS	---	108º	0.0022	0.0023	0.0025	0.0027	0.0028	0.0030
			72º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	IREDO-BL003	BL003	134º	0.0022	0.0023	0.0025	0.0027	0.0028	0.0030
			46º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	EDUMO-BI002	BI002	127º	0.0033	0.0035	0.0037	0.0040	0.0043	0.0045
			53º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	CVS-BS004	CVS	152º	0.0011	0.0012	0.0012	0.0013	0.0014	0.0015
			28º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	NEMDO-BI003	BI003	154º	0.0022	0.0023	0.0025	0.0027	0.0028	0.0030
			26º	0.0121	0.0129	0.0137	0.0146	0.0156	0.0167
	CVS-UGAMA	CVS	101º	0.0044	0.0047	0.0050	0.0053	0.0057	0.0061
			79º	0.0088	0.0094	0.0100	0.0107	0.0114	0.0121
		UGAMA	98º	0.0011	0.0012	0.0012	0.0013	0.0014	0.0015
			82º	0.0022	0.0023	0.0025	0.0027	0.0028	0.0030
	PISPU-CARME	PISPU	145º	0.0033	0.0035	0.0037	0.0040	0.0043	0.0045
			35º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 25.
Vertical occupancy estimate for SAL1 until 2028 with an annual traffic growth rate of 3.3%

4.1.6.c. SAL2

Table 26 collects some results on same and opposite vertical occupancy in SAL2, obtained with data from the March 2018.

Number of flights	March 2018
Number of flights on UN-741	138
Number of flights on UN-866	306
Number of flights on UN-873	849
Number of flights on UN-857	237
Total number of flights	1530
Number of same direction vertical proximate pairs for tracks UN-741	13
Number of same direction vertical proximate pairs for tracks UN-866	20
Number of opposite direction vertical proximate pairs for tracks UN-873	27
Number of opposite direction vertical proximate pairs for tracks UN-857	1
Total number of same direction proximate events	33
Total number of opposite direction proximate events	28
Same direction vertical occupancy (S_x=80NM)	0.0431
Opposite direction vertical occupancy (S_x=80NM)	0.0366

Table 26.
Vertical occupancy due to same and opposite direction traffic in SAL2 location with current traffic levels

Apart from the traffic on the main routes, in SAL2 there is also some traffic crossing the Corridor on non-published routes. The number of flights on these routes can be found in the following table:

Number of flights	March 2018
Number of flights on XIBOT-MOGSA	1
Number of flights on SNT-BOTNO	26
Number of flights on BAMUX-KENOX	15
Number of flights on VEPOP-KENOX	1
Number of flights on CARME-KENOX	10
Number of flights on SVT-KENOX	10
Number of flights on BULVO-ORABI	10
Number of flights on MARIA-IREDO	15
Number of flights on EXTER-CARME	2
Number of flights on CVS-INESS	1
Number of flights on CARME-PISPU	6
Number of flights on main routes (UN-741, UN-866, UN-873 and UN-857)	1530
Total number of flights	1608

Table 27.
Number of flights in SAL2 airspace

All the flights on the crossing routes are already included in the number of flights on the main routes except for 78 of them. Therefore, the total number of flights in this case is 1608.

The time windows to obtain proximate pairs and the number of proximate events are, in this case, the ones shown in Table 28. It is to be noted that only data for crossing routes for which proximate events have been detected are presented.

Time windows for crossing routes						**Number of proximate events due to crossing traffic**	
Route	**Point**	**v1 (kts)**	**v2 (kts)**	**θ (º)**	**t (min)**	**At the same FL**	**At adjacent FL**
BAMUX-KENOX	KENOX	447.19	475.73	162º	66	0	0
				18º	11	0	1
BULBO-ORABI	BULBO	458.90	425.71	157º	54	0	6
				23º	12	3	0
	ORABI	458.78	425.71	155º	51	0	2
				25º	12	2	0
CARME-KENOX	KENOX	447.19	400.25	149º	43	0	0
				31º	12	0	1

Table 28.
Time windows for crossing occupancies and number of proximate events in SAL2

Here again, as it happened in SAL1, there are 5 proximate events at the same flight level within 15 minutes of each other. The same reasons explained before are of application here.

No deviation reports have been received for these cases either, and therefore, the hypothesis of considering proximate events at the same flight level as proximate at adjacent flight levels will also be made for this location. Nevertheless, this hypothesis should be verified.

With these considerations, once vertical occupancy is calculated based on current traffic levels, it is possible to estimate the occupancy in the following years taking into account the forecasted annual traffic growth rate. Vertical occupancy values from 2018 to 2028 with an annual traffic growth rate of 3.3% are shown in Table 29. Only data for crossing trajectories in which proximate events have been detected are included.

3.3% annual traffic growth				**2018**	**2020**	**2022**	**2024**	**2026**	**2028**
Same direction vertical occupancy				0.0431	0.0460	0.0491	0.0524	0.0559	0.0597
Opposite direction vertical occupancy				0.0366	0.0391	0.0417	0.0445	0.0475	0.0506
Crossing occupancy	BAMUX-KENOX	KENOX	162º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			18º	0.0012	0.0013	0.0014	0.0015	0.0016	0.0017
	BULBO-ORABI	BULBO	157º	0.0075	0.0080	0.0085	0.0091	0.0097	0.0103
			23º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		ORABI	155º	0.0025	0.0027	0.0028	0.0030	0.0032	0.0034
			25º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	CARME-KENOX	KENOX	149º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			31º	0.0012	0.0013	0.0014	0.0015	0.0016	0.0017

Table 29.
Vertical occupancy estimate for SAL2 until 2028 with an annual traffic growth rate of 3.3%

4.1.6.d. Dakar1

Table 30 collects some results on same and opposite vertical occupancy in Dakar1, obtained with data from March 2018.

Number of flights	March 2018
Number of flights on UN-741	232
Number of flights on UN-866	304
Number of flights on UN-873	882
Number of flights on UN-857	267
Total number of flights	1685
Number of same direction vertical proximate pairs for tracks UN-741	24
Number of same direction vertical proximate pairs for tracks UN-866	23
Number of opposite direction vertical proximate pairs for tracks UN-873	51
Number of opposite direction vertical proximate pairs for tracks UN-857	4
Total number of same direction proximate events	47
Total number of opposite direction proximate events	55
Same direction vertical occupancy (S_x=80NM)	0.0558
Opposite direction vertical occupancy (S_x=80NM)	0.0653

Table 30.
Vertical occupancy due to same and opposite direction traffic in Dakar1 location with current traffic levels

Apart from the traffic on the main routes, in Dakar1 there is also some traffic crossing the Corridor on route UL-435 and on non-published trajectories (including those that cross the complete Corridor and those that correspond to changes between routes). The number of flights on these routes can be found in the following table:

Number of flights	March 2018
Number of flights on UL-435	30
Number of flights on ENUGO-APIGU	8
Number of flights on APOXA-GONSA	3
Number of flights on GARKO-LIRAX	1
Number of flights on XUVIT-DIGUN	29
Number of flights on XUVIT-SAGRO	1
Number of flights on TARIM-SAGRO	5
Number of flights on TARIM-GARKO	2
Number of flights on TARIM-DIGUN	23
Number of flights on SAGRO-BUXON	6
Number of flights on SAGRO-MOSOK	21
Number of flights on LIRAX-IRAVU	10
Number of flights on KENOX-RIXAD	4
Number of flights on ENUGO-IP007	2
Number of flights on main routes (UN-741, UN-866, UN-873 and UN-857)	1685
Total number of flights	1767

Table 31.
Number of flights in Dakar1 airspace

The flights on the crossing routes are already included in the number of flights on the main routes except for those that fly on any of the trajectories that cross the whole Corridor and those that join the main routes from the DCT area (which amount 82 flights). Therefore, the total number of flights in this case is 1767.

The time windows to obtain proximate pairs and the number of proximate events are, in this case, the ones shown in Table 32. It is to be noted that only data for crossing routes for which proximate events have been detected are presented.

Time windows for crossing routes						**Number of proximate events due to crossing traffic**	
Route	**Point**	**v1 (kts)**	**v2 (kts)**	**θ (º)**	**t (min)**	**At the same FL**	**At adjacent FL**
UL-435	---	482.81	480.69	98º	16	13	5
				82º	14	0	2
ENUGO-APIGU	---	482.81	483.19	96º	15	2	2
				84º	14	5	1
APOXA-GONSA	---	482.81	483.84	92º	15	0	0
				88º	14	0	4
XUVIT-DIGUN	DIGUN	476.60	486.55	158º	52	0	0
				22º	10	0	2
TARIM-DIGUN	DIGUN	476.60	477.16	169º	107	0	0
				11º	11	1	1
LIRAX-IRAVU	LIRAX	476.79	464.23	154º	46	0	2
				26º	11	0	0
SAGRO-BUXON	SAGRO	476.60	478.68	124º	21	0	1
				56º	11	0	0
TARIM-SAGRO	SAGRO	476.60	475.73	167º	85	0	1
				13º	11	0	0
SAGRO-MOSOK	MOSOK	475.92	477.05	137º	28	0	0
				43º	11	2	0
KENOX-RIXAD	KENOX	476.60	452.79	127º	23	0	2
				53º	12	0	0

Table 32.
Time windows for crossing occupancies and number of proximate events in Dakar1

Here again, as it happened in the locations previously analyzed, there are 10 proximate events at the same flight level within 15 minutes of each other. The same reasons explained before are of application here.

Given that no deviation reports have been received for these aircraft, it will be assumed that they are due to the extrapolation of data and the lack of data regarding flight level changes in the traffic data provided, and they will be considered as adjacent level proximate events. Nevertheless, this hypothesis should be verified when more information is available, because it may have an impact on the results in case that any of the proximate events were, in fact, at the same flight level.

With these considerations, once vertical occupancy is calculated based on current traffic levels, it is possible to estimate the occupancy in the following years taking into account the annual traffic growth rate forecasted. Vertical occupancy values from 2018 to 2028 with an annual traffic growth rate of 3.3% are shown in Table 33.

3.3% annual traffic growth				**2018**	**2020**	**2022**	**2024**	**2026**	**2028**
Same direction vertical occupancy				0.0558	0.0595	0.0635	0.0678	0.0723	0.0772
Opposite direction vertical occupancy				0.0653	0.0697	0.0743	0.0793	0.0846	0.0913
Crossing occupancy	UL-435	---	98º	0.0204	0.0217	0.0232	0.0248	0.0264	0.0282
			82º	0.0023	0.0024	0.0026	0.0028	0.0029	0.0031
	ENUGO-APIGU	---	96º	0.0045	0.0048	0.0052	0.0055	0.0059	0.0063
			84º	0.0068	0.0072	0.0077	0.0083	0.0088	0.0094
	APOXA-GONSA	---	92º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			88º	0.0045	0.0048	0.0052	0.0055	0.0059	0.0063
	XUVIT-DIGUN	DIGUN	158º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			22º	0.0023	0.0024	0.0026	0.0028	0.0029	0.0031
	TARIM-DIGUN	DIGUN	169º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			11º	0.0011	0.0012	0.0013	0.0014	0.0015	0.0016
	LIRAX-IRAVU	LIRAX	154º	0.0023	0.0024	0.0026	0.0028	0.0029	0.0031
			26º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	SAGRO-BUXON	SAGRO	124º	0.0011	0.0012	0.0013	0.0014	0.0015	0.0016
			56º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	TARIM-SAGRO	SAGRO	167º	0.0011	0.0012	0.0013	0.0014	0.0015	0.0016
			13º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	SAGRO-MOSOK	MOSOK	137º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			43º	0.0023	0.0024	0.0026	0.0028	0.0029	0.0031
	KENOX-RIXAD	KENOX	127º	0.0023	0.0024	0.0026	0.0028	0.0029	0.0031
			53º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 33.
Vertical occupancy estimate for Dakar1 until 2028 with an annual traffic growth rate of 3.3%

4.1.6.e. Dakar2

Table 34 collects some results on same and opposite vertical occupancy in Dakar2, obtained with data from March 2018.

Number of flights	March 2018
Number of flights on UN-741	216
Number of flights on UN-866	307
Number of flights on UN-873	892
Number of flights on UN-857	267
Total number of flights	1682
Number of same direction vertical proximate pairs for tracks UN-741	17
Number of same direction vertical proximate pairs for tracks UN-866	22
Number of opposite direction vertical proximate pairs for tracks UN-873	84
Number of opposite direction vertical proximate pairs for tracks UN-857	9
Total number of same direction proximate events	39
Total number of opposite direction proximate events	93
Same direction vertical occupancy (S_x=80NM)	0.0464
Opposite direction vertical occupancy (S_x=80NM)	0.1106

Table 34.
Vertical occupancy due to same and opposite direction traffic in Dakar2 location with current traffic levels

Apart from the traffic on the main routes, in Dakar2 there is also some traffic crossing the Corridor on non-published routes. The number of flights on these routes can be found in the following table:

Number of flights	March 2018
Number of flights on MOSAD-MIKOL	1
Number of flights on IP006-NANIK	6
Number of flights on IP007-NANIK	66
Number of flights on IP008-NANIK	190
Number of flights on IP008-MOSAD	1
Number of flights on IRAVU-MESAB	10
Number of flights on DIGUN-MOVGA	13
Number of flights on DIGUN-ENOTO	4
Number of flights on main routes (UN-741, UN-866, UN-873 and UN-857)	1682
Total number of flights	1958

Table 35.
Number of flights in Dakar2 airspace

All the flights on the non-published routes are already included in the number of flights on the main routes except for 276 of them. Therefore, the total number of aircraft in this case is 1958.

The time windows to obtain proximate pairs and the number of proximate pairs are, in this case, the ones shown in Table 36. It is to be noted that only data for crossing routes for which proximate events have been detected are presented.

Time windows for crossing routes						Number of proximate events due to crossing traffic	
Route	**Point**	**v1 (kts)**	**v2 (kts)**	**θ (º)**	**t (min)**	**At the same FL**	**At adjacent FL**
IP007-NANIK	NANIK	468.07	485.17	160º	58	0	0
				20º	11	1	5
IP008-NANIK	NANIK	468.07	481.74	169º	110	0	0
				11º	11	2	31
IRAVU-MESAB	MESAB	459.19	486.16	153º	44	0	6
				27º	11	0	0
DIGUN-MOVGA	DIGUN	468.07	495.86	146º	35	0	0
				34º	11	2	5

Table 36.
Time windows for crossing occupancies and number of proximate events in Dakar2

Here again, as it happened in the locations previously analysed, there are 5 proximate events at the same flight level within 15 minutes of each other. The same reasons explained before are of application here.

No deviation reports have been received for these cases either, and therefore, the hypothesis of considering proximate events at the same flight level as proximate at adjacent flight levels will also be made for this location. Nevertheless, this hypothesis should be verified.

With these considerations, once vertical occupancy is calculated based on current traffic levels, it is possible to estimate the occupancy in the following years taking into account the annual traffic growth rate forecasted. Vertical occupancy values from 2018 to 2028 with an annual traffic growth rate of 3.3% are shown in Table 37.

3.3% annual traffic growth				2018	2020	2022	2024	2026	2028
Same direction vertical occupancy				0.0464	0.0495	0.0528	0.0563	0.0601	0.0642
Opposite direction vertical occupancy				0.1106	0.1180	0.1259	0.1344	0.1434	0.1530
Crossing occupancy	IP007-NANIK	NANIK	160º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			20º	0.0061	0.0065	0.0070	0.0074	0.0079	0.0085
	IP008-NANIK	NANIK	169º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			11º	0.0337	0.0360	0.0384	0.0410	0.0437	0.0466
	IRAVU-MESAB	MESAB	153º	0.0061	0.0065	0.0070	0.0074	0.0079	0.0085
			27º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	DIGUN-MOVGA	DIGUN	146º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			34º	0.0072	0.0076	0.0081	0.0087	0.0093	0.0099

Table 37.
Vertical occupancy estimate for Dakar2 until 2028 with an annual traffic growth rate of 3.3%

4.1.6.f. Recife

Table 38 collects some results on same and opposite vertical occupancy in Recife, using data from March 2018.

Number of flights	March 2018
Number of flights on UN-741	477
Number of flights on UN-866	291
Number of flights on UN-873	893
Number of flights on UN-857	213
Total number of flights	1874
Number of same direction vertical proximate pairs for tracks UN-741	78
Number of same direction vertical proximate pairs for tracks UN-866	14
Number of opposite direction vertical proximate pairs for tracks UN-873	98
Number of opposite direction vertical proximate pairs for tracks UN-857	2
Total number of same direction proximate events	92
Total number of opposite direction proximate events	100
Same direction vertical occupancy (S_x=80NM)	0.0982
Opposite direction vertical occupancy (S_x=80NM)	0.1067

Table 38.
Vertical occupancy due to same and opposite direction traffic in Recife location with current traffic levels

Apart from the traffic on the main routes, in Recife there is also some traffic crossing the Corridor on routes UL-695/UL-375 and on non-published routes. The traffic on these routes can be found in the following table:

Number of flights	March 2018
Number of flights on UL-695/UL-375	27
Number of flights on ERETU-PUGSA	51
Number of flights on main routes (UN-741, UN-866, UN-873 and UN-857)	1874
Total number of flights	1953

Table 39.
Number of flights in Recife airspace.

The time windows to obtain proximate pairs are, in this case, the ones shown in Table 40. All the flights on the non-published routes are already included in the number of flights on the main routes except for 79 of them. Therefore, the total number of aircraft in this case is 1953.

Time windows for crossing routes						Number of proximate events due to crossing traffic	
Route	**Point**	**v1 (kts)**	**v2 (kts)**	**θ (º)**	**t (min)**	**At the same FL**	**At adjacent FL**
UL-695	---	462.21	465.36	97º	16	2	3
				83º	14	1	8
ERETU-PUGSA	ERETU	453.78	483.59	165º	82	0	7
				15º	11	0	0

Table 40.
Time windows for crossing occupancies and number of proximate events in Recife

As it occurred in other locations, there is one proximate event at the same flight level within 15 minutes of each other.

As no large height deviation reports have been received for these events, it will be considered that they are proximate events at adjacent flight levels, as it has been done in other locations, assuming that they are due to the need of extrapolation and the lack of data about flight level changes. Nevertheless, this hypothesis should be verified, because it may have an impact on the results, as it has been explained before.

With these considerations, once vertical occupancy is calculated based on current traffic levels, it is possible to estimate the occupancy in the following years taking into account the annual traffic growth rate forecasted. Vertical occupancy values from 2018 to 2028 with an annual traffic growth rate of 3.3% are shown in Table 41.

3.3% annual traffic growth				**2018**	**2020**	**2022**	**2024**	**2026**	**2028**
Same direction vertical occupancy				0.0982	0.1048	0.1118	0.1193	0.1273	0.1359
Opposite direction vertical occupancy				0.1067	0.1139	0.1215	0.1297	0.1384	0.1477
Crossing occupancy	UL-695	---	97º	0.0051	0.0055	0.0058	0.0062	0.0066	0.0071
			83º	0.0092	0.0098	0.0105	0.0112	0.0120	0.0128
	ERETU-PUGSA	ERETU	165º	0.0072	0.0076	0.0082	0.0087	0.0093	0.0099
			15º	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 41.
Vertical occupancy estimate for Recife until 2028 with an annual traffic growth rate of 3.3%

4.1.7. Technical vertical collision risk

The technical vertical collision risk values obtained until 2028 in the different locations are the ones summarized in the following table, considering that the traffic growth factor is 3.3% per annum. These results can also be seen in Figure 17 to Figure 28.

Technical Vertical Collision risk	**3.3% annual traffic growth**					
	Canaries	**SAL1**	**SAL2**	**Dakar1**	**Dakar2**	**Recife**
2018	$1.3458*10^{-13}$	$3.9851*10^{-14}$	$6.7553*10^{-14}$	$1.2056*10^{-13}$	$1.9260*10^{-13}$	$1.9301*10^{-13}$
2019	$1.3902*10^{-13}$	$4.1166*10^{-14}$	$6.9782*10^{-14}$	$1.2454*10^{-13}$	$1.9896*10^{-13}$	$1.9938*10^{-13}$
2020	$1.4361*10^{-13}$	$4.2524*10^{-14}$	$7.2085*10^{-14}$	$1.2865*10^{-13}$	$2.0552*10^{-13}$	$2.0596*10^{-13}$
2021	$1.4835*10^{-13}$	$4.3927*10^{-14}$	$7.4463*10^{-14}$	$1.3290*10^{-13}$	$2.1231*10^{-13}$	$2.1275*10^{-13}$
2022	$1.5324*10^{-13}$	$4.5377*10^{-14}$	$7.6921*10^{-14}$	$1.3728*10^{-13}$	$2.1931*10^{-13}$	$2.1977*10^{-13}$
2023	$1.5830*10^{-13}$	$4.6874*10^{-14}$	$7.9459*10^{-14}$	$1.4181*10^{-13}$	$2.2655*10^{-13}$	$2.2703*10^{-13}$
2024	$1.6353*10^{-13}$	$4.8421*10^{-14}$	$8.2081*10^{-14}$	$1.4649*10^{-13}$	$2.3403*10^{-13}$	$2.3452*10^{-13}$
2025	$1.6892*10^{-13}$	$5.0019*10^{-14}$	$8.4790*10^{-14}$	$1.5133*10^{-13}$	$2.4175*10^{-13}$	$2.4226*10^{-13}$
2026	$1.7450*10^{-13}$	$5.1670*10^{-14}$	$8.7588*10^{-14}$	$1.5632*10^{-13}$	$2.4973*10^{-13}$	$2.5025*10^{-13}$
2027	$1.8025*10^{-13}$	$5.3375*10^{-14}$	$9.0478*10^{-14}$	$1.6148*10^{-13}$	$2.5797*10^{-13}$	$2.5851*10^{-13}$
2028	$1.8620*10^{-13}$	$5.5136*10^{-14}$	$9.3464*10^{-14}$	$1.6681*10^{-13}$	$2.6648*10^{-13}$	$2.6704*10^{-13}$

Table 42.
Technical vertical collision risk for the period 2018-2028 in the Corridor

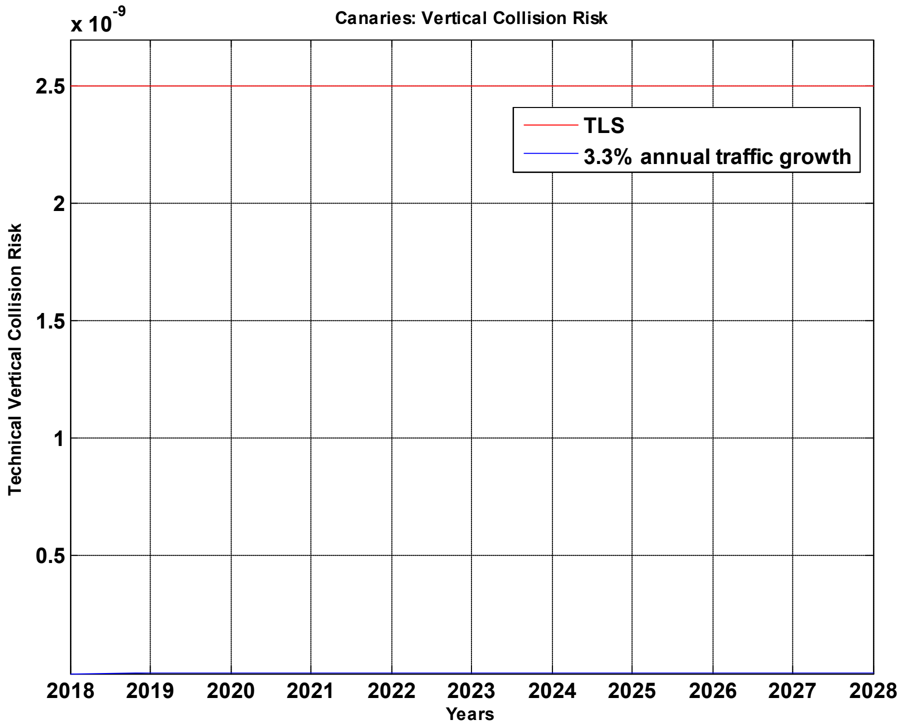


Figure 17.
Technical vertical collision risk for the period 2018-2028 in the Canaries

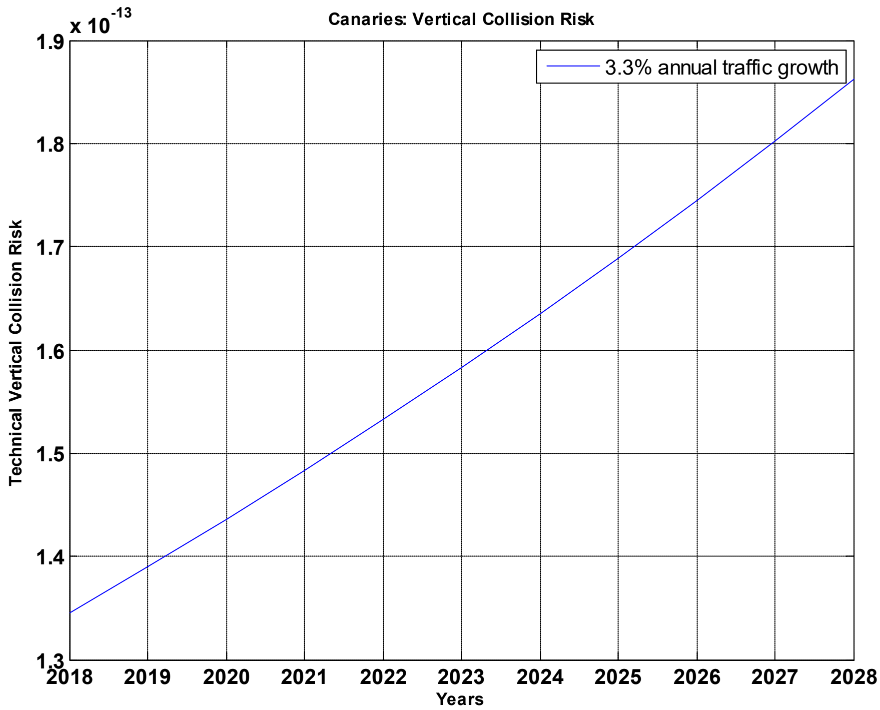


Figure 18.
Technical vertical collision risk for the period 2018-2028 in the Canaries (enlarged)

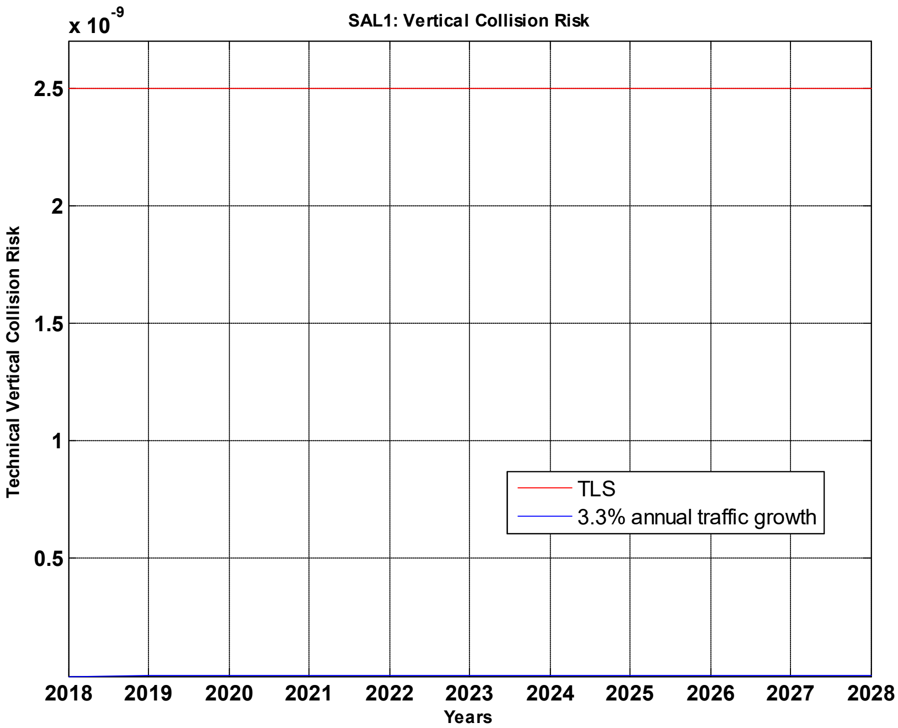


Figure 19.
Technical vertical collision risk for the period 2018-2028 in SAL1

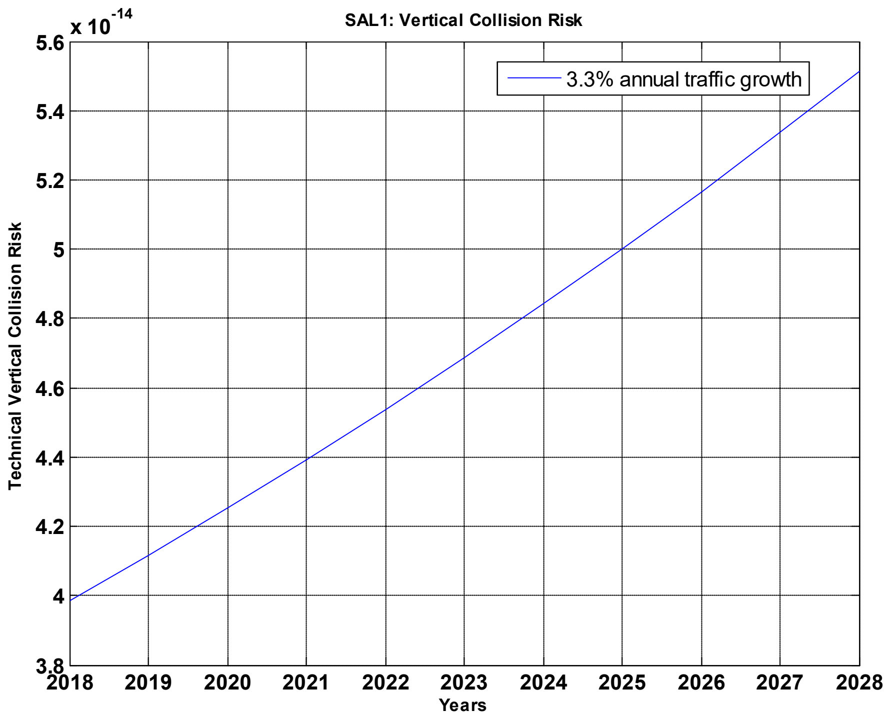


Figure 20.
Technical vertical collision risk for the period 2018-2028 in SAL1 (enlarged)

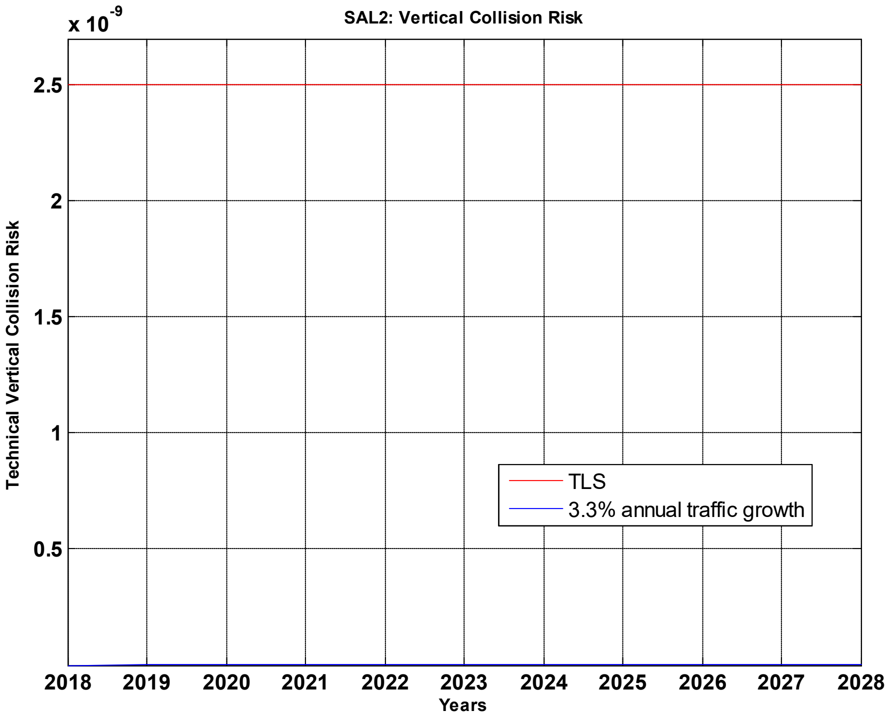


Figure 21.
Technical vertical collision risk for the period 2018-2028 in SAL2

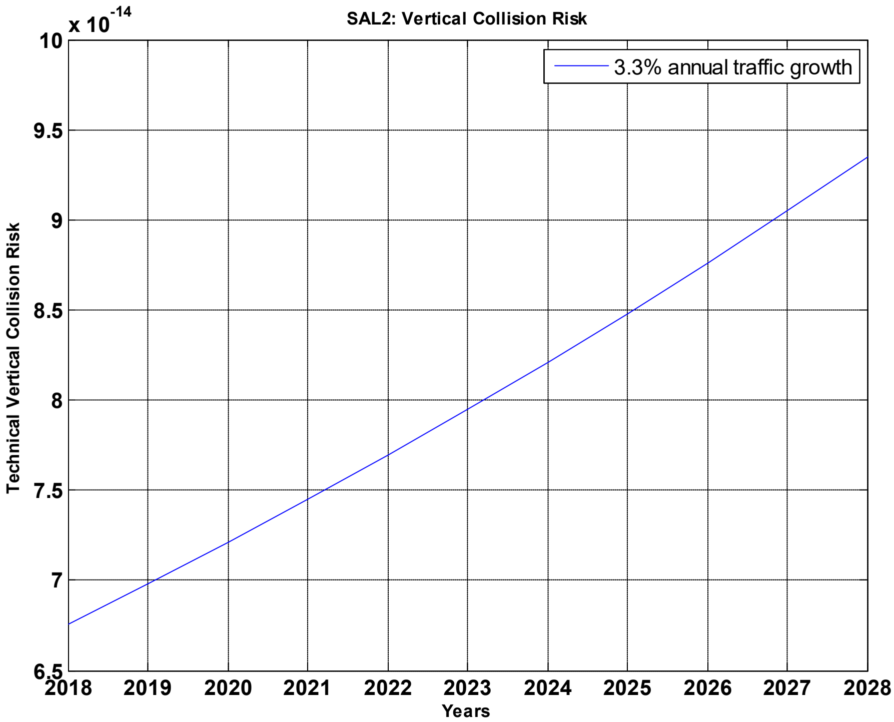


Figure 22.
Technical vertical collision risk for the period 2018-2028 in SAL2 (enlarged)

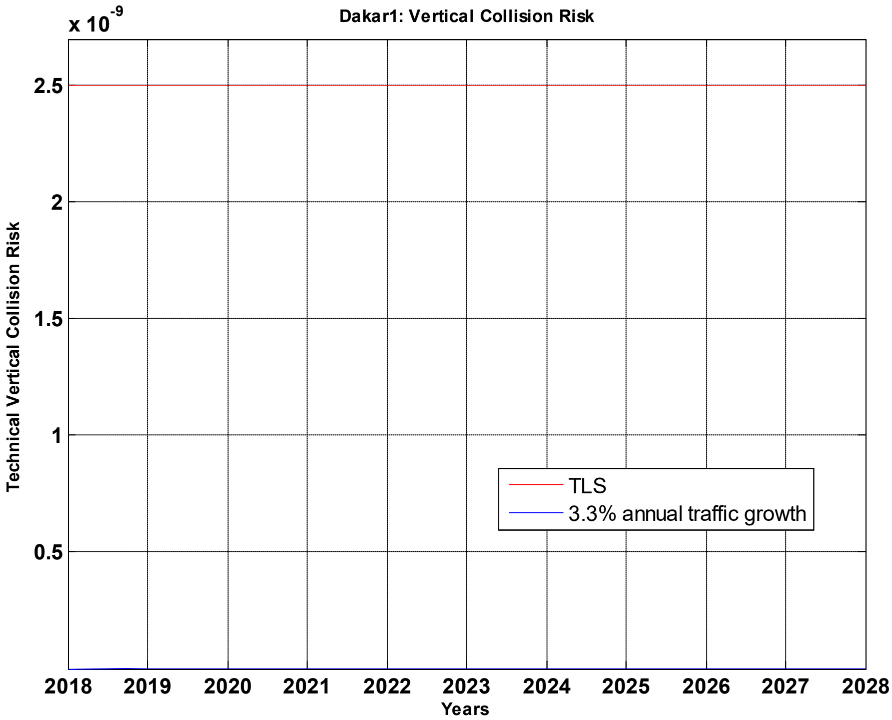


Figure 23.
Technical vertical collision risk for the period 2018-2028 in Dakar1

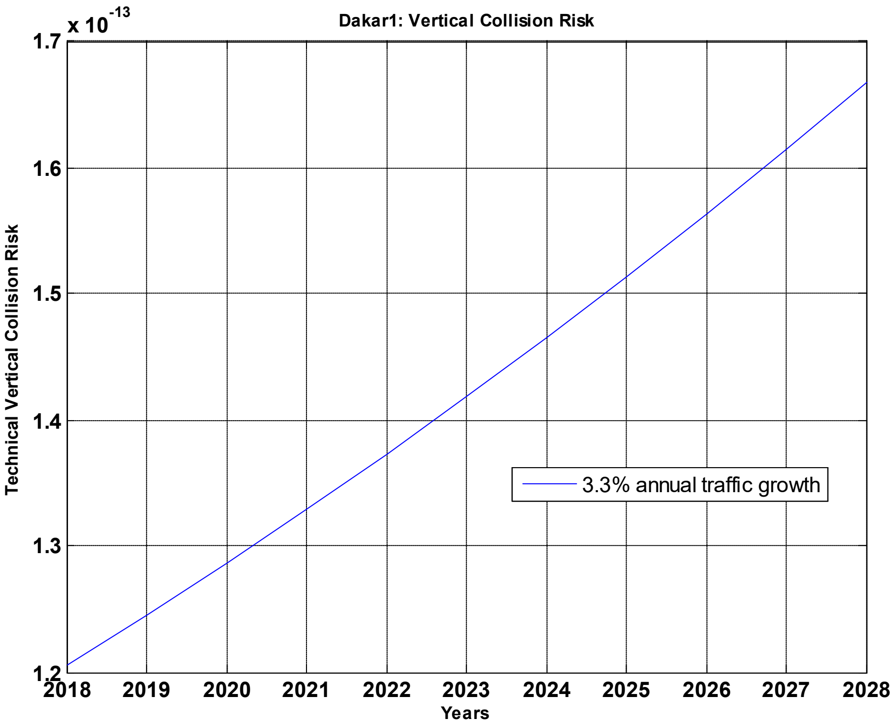


Figure 24.
Technical vertical collision risk for the period 2018-2028 in Dakar1 (enlarged)

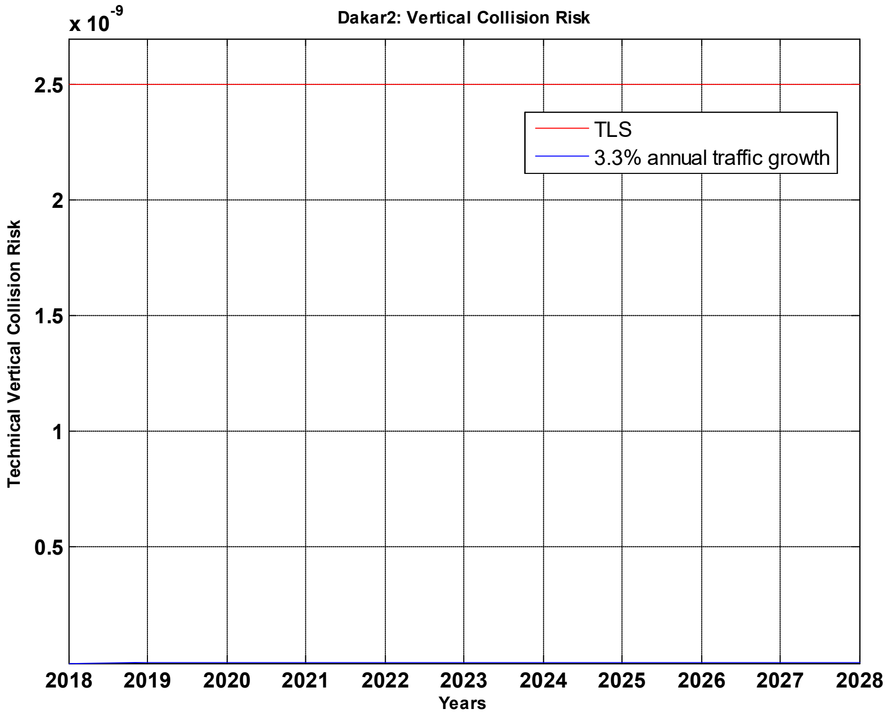


Figure 25.
Technical vertical collision risk for the period 2018-2028 in Dakar2

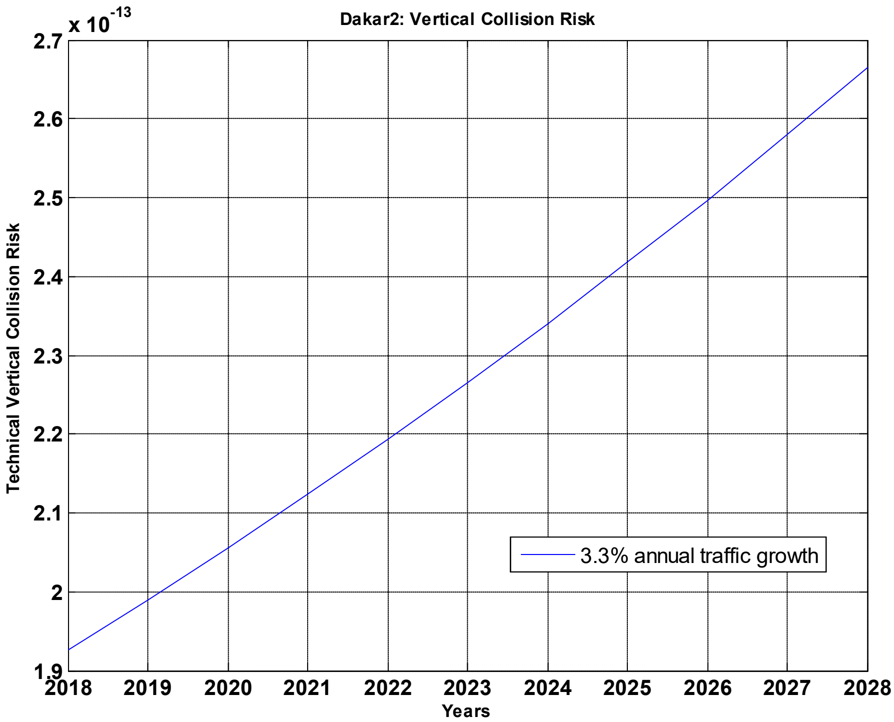


Figure 26.
Technical vertical collision risk for the period 2018-2028 in Dakar2 (enlarged)

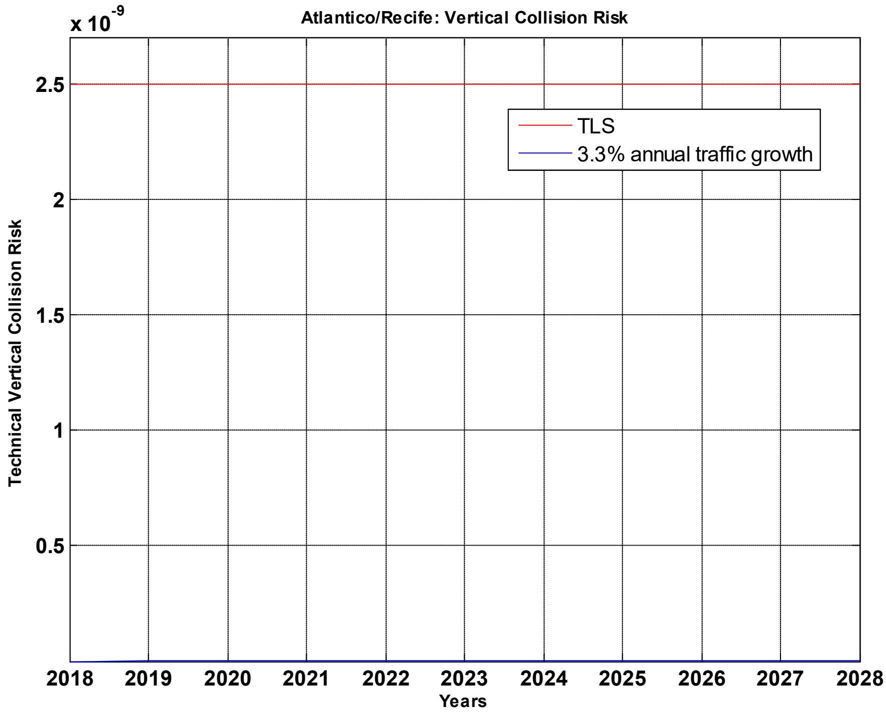


Figure 27.
Technical vertical collision risk for the period 2018-2028 in Recife

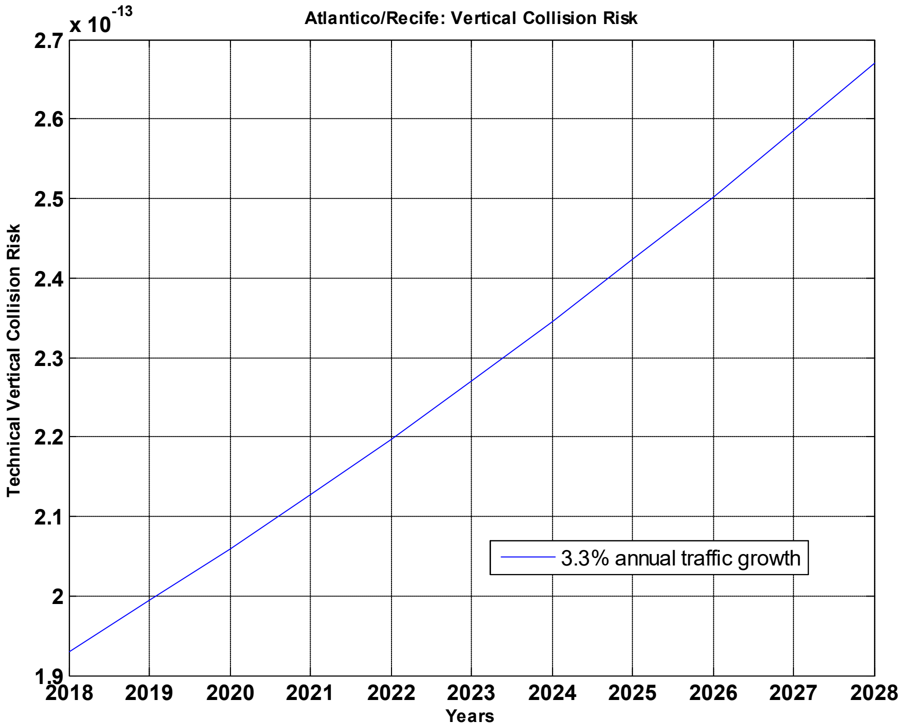


Figure 28.
Technical vertical collision risk for the period 2018-2028 in Recife (enlarged)

4.1.8. Considerations on the results

It can be seen that the estimates of the technical vertical risk are below the technical TLS even in 2028 in all the locations, and similar to the values obtained in the last year assessment ([Ref. 9]).

4.2. Total vertical collision risk assessment

In order to assess the total vertical risk, the risk due to large, atypical height deviations[3] must be assessed and added to the technical vertical risk.

In accordance with the ICAO recommendations ([Ref. 32]), large height deviations can be classified as reflected in Table 43. This classification has been used in the EUR/SAM Corredor.

LHD types	
Code	LHD Description
A	Flight crew fails to climb or descend the aircraft as cleared
B	Flight crew climbing or descending without ATC clearance
C	Incorrect operation or interpretation of airborne equipment
D	ATC system loop error
E	ATC transfer of control coordination errors due to human factors
F	ATC transfer of control coordination errors due to technical issues
G	Aircraft contingency leading to sudden inability to maintain level
H	Airborne equipment failure and unintentional or undetected level change
I	Turbulence or other weather related cause
J	TCAS resolution advisory and flight crew correctly responds
K	TCAS resolution advisory and flight crew incorrectly responds
L	Non-approved aircraft is provided with RVSM separation
M	Other

Table 43.
LHD classification according to ICAO

4.2.1. Data on EUR/SAM large height deviations

As it has been explained in [Ref. 33], data needed for the different models should be obtained from the large height deviation reports received from the different UIRs.

The information that has been made available for this assessment can be seen in the following tables, where the time spent at an incorrect flight level, necessary to calculate the risk due to an aircraft levelling off at a wrong level, had to be estimated in the major part of the LHDs, since it was not included in the reports. Therefore, it has been necessary to use default values according to the following set of criteria:

[3] *A RVSM large height deviation (LHD) is defined as any vertical deviation of 90 metres/300 feet or more from the flight level expected to be occupied by the flight.*

- Coordination error (no notification of the transfer or transfer at unexpected flight level) and detection of the aircraft when entering the UIR: 5 minutes.
- Coordination error (no notification of the transfer) and undetected aircraft in the UIR. The duration of the flight in that UIR, taking into account its speed.

Table 44 indicates the months for which LHD reports have been received before March 15th, 2019[4]. From these LHDs, only those affecting the four main routes have been considered[5]. Table 45, Table 46 and Table 47, show the details of the deviations reported in the Canaries, SAL, Dakar and Atlantic-Recife, respectively. It can happen that a State reports an LHD that affects another. In this case, the LHD will be included only in the table of the affected FIR.

Months	Canarias UIR	SAL Oceanic UIR	Dakar Oceanic UIR	Atlántico-Recife FIR/UIR
Jan-18	Available	Available	Available	"No deviation" report received
Feb-18	Available	Not available	"No deviation" report received	Available
Mar-18	"No deviation" report received	Available	Available	"No deviation" report received
Apr-18	Available	Available	Available	"No deviation" report received
May-18	"No deviation" report received	Available	Available	"No deviation" report received
Jun-18	Available	Available	Available	"No deviation" report received
Jul-18	Available	Not available	Available	"No deviation" report received
Aug-18	Available	Available	Available	"No deviation" report received
Sep-18	"No deviation" report received	Available	Available	"No deviation" report received
Oct-18	"No deviation" report received	Available	"No deviation" report received	"No deviation" report received
Nov-18	Available	Available	Available	"No deviation" report received
Dec-18	"No deviation" report received	"No deviation" report received	Available	"No deviation" report received

KEY: Available | Not available | "No deviation" report received

Table 44.
Received data from January 2018 to December 2018

Although in Table 44 it is indicated that there are reports associated with Recife, these are deviations not related to the Corridor, so they have not been considered in the study and are not shown in the following tables

[4] *The deadline agreed for all States to send their information is January 31th of the year after the one studied.*

[5] *The considered LHDs have been those that have taken place in the main routes and in incorporations to the main routes coming from the DCT area. It is to be noted that a larger number of deviations has been reported by States. However, not all of them concerned lateral or vertical deviations and not all of them affected the main routes or the RVSM flight levels. These deviations have not been included in the assessment and are not presented in this report.*

Date	Route	Duration	Coordinated FL	Observed FL	Deviation	Cause	Category
240118	UN866	0.08333 h	FL370	FL390	2000 ft	Coordination Error	E
150218	UN866	0.08333 h	FL380	FL360	2000 ft	Coordination Error	E
120318	UN873	0.08333 h	FL330	FL330	0	Coordination Error	E
200318	UN873	0.08333 h	FL270	FL370	10000 ft	Coordination Error	E
060418	UN873	0.08333 h	FL350	FL370	2000 ft	Coordination Error	E
060418	UN866	0.08333 h	FL390	FL390	0	Coordination Error	F
260418	UN866	0.08333 h	FL370	FL370	0	Coordination Error	F
040618	UN873	0.08333 h	FL350	FL370	2000 ft	Coordination Error	E
040618	UN873	0.08333 h	FL325	FL330	500 ft	Coordination Error	E
060718	UN873	0.08333 h	FL390	FL370	2000 ft	Coordination Error	E
110818	UN873	0.08333 h	FL330	FL350	2000 ft	Coordination Error	E
200818	UN857	0.08333 h	FL390	FL390	0	Coordination Error	F
041118	UN873	0.35000 h	FL390	FL390	0	Coordination Error	E
041118	UN873	0.01667 h	FL370	FL370	0	Coordination Error	E

Table 45.
Large height deviations reported in the Canaries

Date	Route	Duration	Coordinated FL	Observed FL	Deviation	Cause	Category
180318	UN873	0.08333 h	FL380	FL360	2000 ft	Coordination Error	E
200318	UN873	0.08333 h	FL340	FL340	0	Coordination Error	E
090418	UN873	0.08333 h	FL370	FL390	2000 ft	Coordination Error	E
240418	UN857	0.08333 h	FL370	FL390	2000 ft	Coordination Error	E
110918	UN873	0.08333 h	FL320	FL320	0	Coordination Error	E
120918	UN873	0.08333 h	FL400	FL400	0	Coordination Error	E
120918	UN873	0.08333 h	FL360	FL360	0	Coordination Error	E
101018	UN866	0.08333 h	FL370	FL370	0	Coordination Error	E
041118	RANDOM	0.08333 h	FL380	FL380	0	Coordination Error	E
271118	UN857	0.08333 h	FL380	FL380	0	Coordination Error	E

Table 46.
Large height deviations reported in SAL

Date	Route	Duration	Coordinated FL	Observed FL	Deviation	Cause	Category
160118	UN873	0.08333 h	FL360	FL340	2000 ft	Coordination Error	E
140318	UN873	0.08333 h	FL360	FL380	2000 ft	Coordination Error	E
280318	RANDOM	0.08333 h	FL330	FL350	2000 ft	Coordination Error	E
290318	RANDOM	0.08333 h	FL340	FL360	2000 ft	Coordination Error	E
300318	UN741	0.08333 h	FL370	FL380	1000 ft	Coordination Error	E
140518	UN866	0.01666 h	FL350	FL370	2000 ft	Coordination Error	E
240518	UN873	0.01666 h	FL370	FL350	2000 ft	Coordination Error	E
290518	UN741	0.08333 h	FL360	FL340	2000 ft	Coordination Error	E
160818	UN873	0.08333 h	FL400	FL380	2000 ft	Coordination Error	E

Table 47.
Large height deviations reported in Dakar

After an analysis of the deviation reports, it can be concluded that all of the registered deviations are due to errors in coordination between adjacent ATC units, resulting in either no notification of the transfer or in transfer at an unexpected flight level.

4.2.2. Total vertical collision risk

The total vertical risk is the sum of the technical risk and the risks due to large height deviations involving whole numbers of flight levels (both climbing/descending aircraft and level flight aircraft) and the risk due to large height deviations not involving whole numbers of flight levels. So,

$$N_{az}^{total} = N_{az}^{tech} + N_{az}^{wl} + N_{az}^{cl/d} + N_{az}^{*}$$

Equation 5.

Technical risk has already been calculated in 4.1.7.

Regarding the risk due to large height deviations, as it can be seen in Table 45, Table 46 and Table 47, there are no reports due to large height deviations not involving whole numbers of flight levels and $N_{az}^{*} = 0$.

All deviations reported are due to coordination errors between ATC units for which there is not enough information it is assumed that the level change, if any, took place in the transferring UIR following appropriate clearances and, when the aircraft entered the new UIR, the aircraft was already established at the incorrect flight level. Therefore, in these cases, the number of crossed levels is zero. Deviations that involve entering a new UIR before than the coordinated time have also been considered.

Consequently, the terms to be calculated are the risk due to an aircraft levelling off at a wrong level and not the risk due to an aircraft climbing or descending through a flight level without a proper clearance.

Most of the parameters used to calculate these two risks have already been presented within the vertical technical collision risk section (4.1). The new values required are the ones necessary to calculate the probabilities of vertical overlap and the relative vertical speed for an aircraft climbing or descending.

In the following table, relevant data for these calculations, based on traffic levels representative for the year 2018, have been gathered, namely: the time spent at a wrong level, the number of crossed levels and the total flight time within those months in which a LHD or a "no LHD" reports have been received for each location. As the annual flight time information is only available for the Canaries FIR, the annual flight time in each FIR has been estimated relating the flight time in August in each FIR with the one calculated in the Canaries and applying the same proportion to the complete year.

Number of flights	Jan-Dec 2018			
	Canaries	**SAL**	**Dakar**	**Recife**
Same direction time at incorrect level (h)	1.3666	0.7500	0.9166	0
Opposite direction time at incorrect level (h)	0	0.0833	0	0
Same direction number of crossed levels (N)	0	0	0	0
Opposite direction number of crossed levels (N)	0	0	0	0
Total FIR/UIR flight time (h)	20872.73	24166.89	34125.13	23486.71
Total Corridor flight time (h)	102651.46	102651.46	102651.46	102651.46
Wrong level, same direction vertical overlap probability	$3.1262*10^{-5}$	$1.4818*10^{-5}$	$1.2826*10^{-5}$	0
Wrong level, opposite direction vertical overlap probability	0	$1.6464*10^{-6}$	0	0
Climb/descend, same direction vertical overlap probability	0	SAL 1 0 SAL 2 0	Dakar 1 0 Dakar 2 0	0
Climb/descend, opposite direction vertical overlap probability	0	SAL 1 0 SAL 2 0	Dakar 1 0 Dakar 2 0	0
Climb/descend relative vertical speed (kts)	15	15	15	15

Table 48.
Operational vertical collision risk parameters in the Corridor

Table 49 shows the estimate of the total vertical collision risk, sum of the technical vertical risk and the operational vertical risk, considering that the traffic growth factor is 3.3% per annum. These results can also be seen in Figure 29 to Figure 34.

Total Vertical Collision risk	3.3% annual traffic growth					
	Canaries	**SAL1**	**SAL2**	**Dakar1**	**Dakar2**	**Recife**
2018	$6.7431*10^{-8}$	$1.4141*10^{-7}$	$1.7560*10^{-7}$	$5.7046*10^{-8}$	$4.8489*10^{-8}$	$1.9301*10^{-13}$
2019	$6.9656*10^{-8}$	$1.4607*10^{-7}$	$1.8139*10^{-7}$	$5.8929*10^{-8}$	$5.0089*10^{-8}$	$1.9938*10^{-13}$
2020	$7.1955*10^{-8}$	$1.5090*10^{-7}$	$1.8738*10^{-7}$	$6.0873*10^{-8}$	$5.1742*10^{-8}$	$2.0596*10^{-13}$
2021	$7.4329*10^{-8}$	$1.5587*10^{-7}$	$1.9356*10^{-7}$	$6.2882*10^{-8}$	$5.3449*10^{-8}$	$2.1257*10^{-13}$
2022	$7.6782*10^{-8}$	$1.6102*10^{-7}$	$1.9995*10^{-7}$	$6.4957*10^{-8}$	$5.5213*10^{-8}$	$2.1977*10^{-13}$
2023	$7.9316*10^{-8}$	$1.6633*10^{-7}$	$2.0655*10^{-7}$	$6.7101*10^{-8}$	$5.7035*10^{-8}$	$2.2703*10^{-13}$
2024	$8.1934*10^{-8}$	$1.7182*10^{-7}$	$2.1337*10^{-7}$	$6.9315*10^{-8}$	$5.8917*10^{-8}$	$2.3452*10^{-13}$
2025	$8.4637*10^{-8}$	$1.7749*10^{-7}$	$2.2041*10^{-7}$	$7.1603*10^{-8}$	$6.0861*10^{-8}$	$2.4226*10^{-13}$
2026	$8.7430*10^{-8}$	$1.8335*10^{-7}$	$2.2768*10^{-7}$	$7.3966*10^{-8}$	$6.2870*10^{-8}$	$2.5025*10^{-13}$
2027	$9.0316*10^{-8}$	$1.8940*10^{-7}$	$2.3519*10^{-7}$	$7.6406*10^{-8}$	$6.4945*10^{-8}$	$2.5851*10^{-13}$
2028	$9.3296*10^{-8}$	$1.9565*10^{-7}$	$2.4296*10^{-7}$	$7.8928*10^{-8}$	$6.7088*10^{-8}$	$2.6704*10^{-13}$

Table 49.
Total vertical collision risk for the period 2018-2028

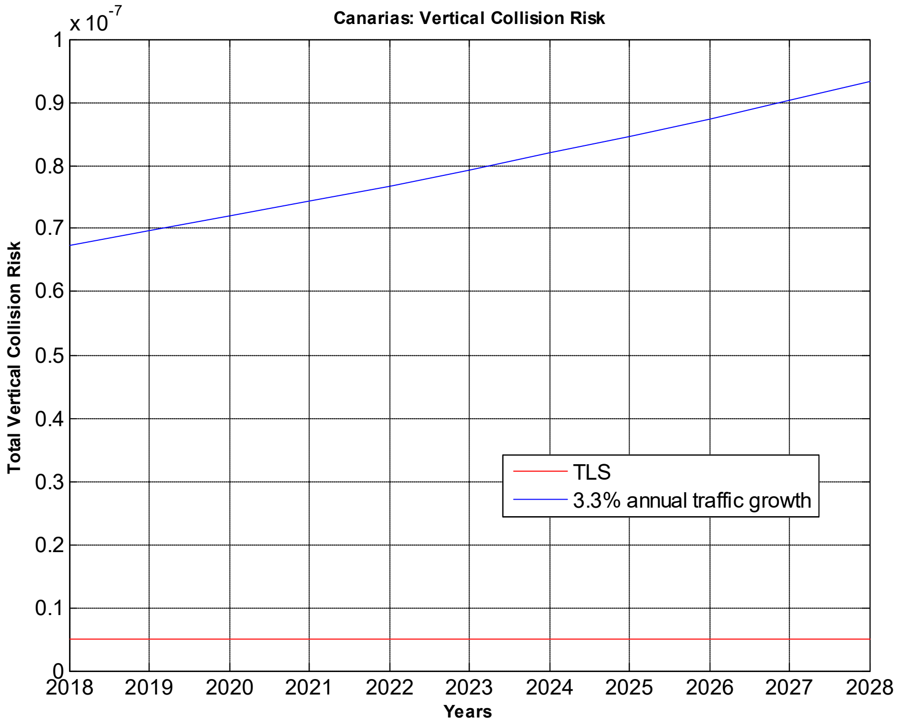


Figure 29.
Total vertical collision risk for the period 2018-2028 in the Canaries

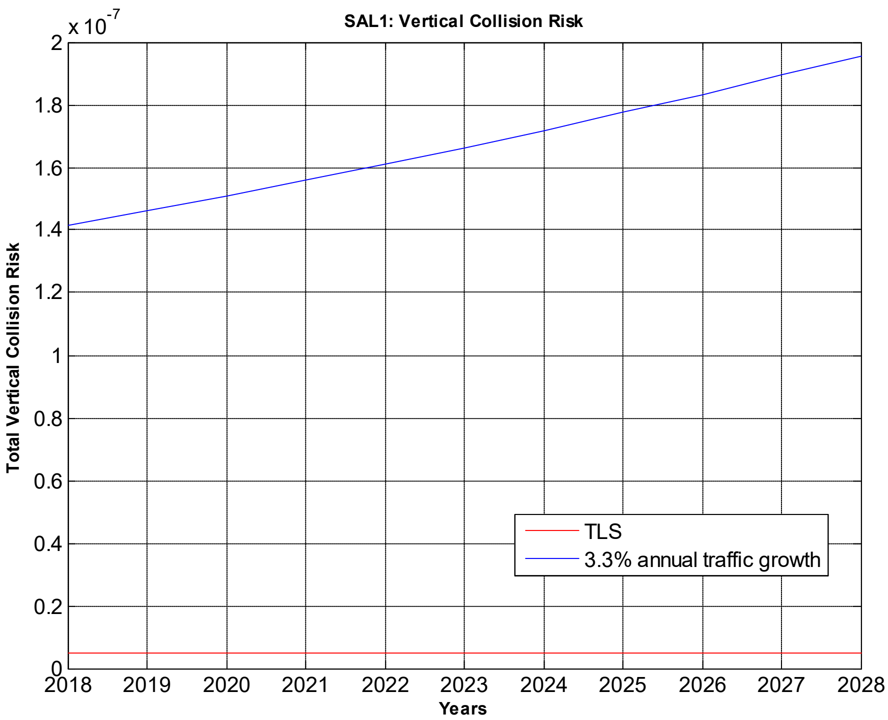


Figure 30.
Total vertical collision risk for the period 2018-2028 in SAL1

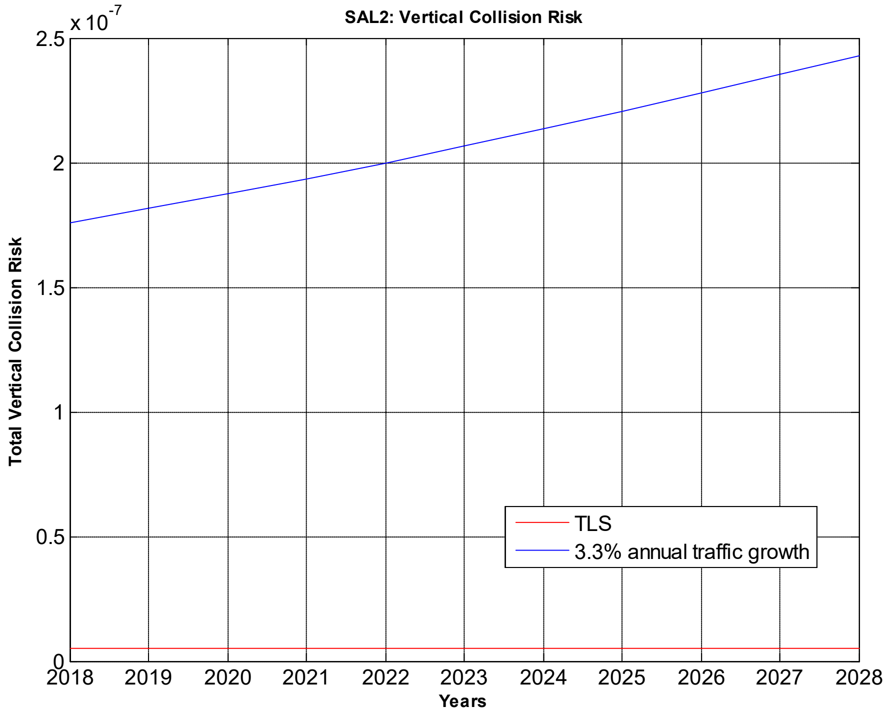


Figure 31.
Total vertical collision risk for the period 2018-2028 in SAL2

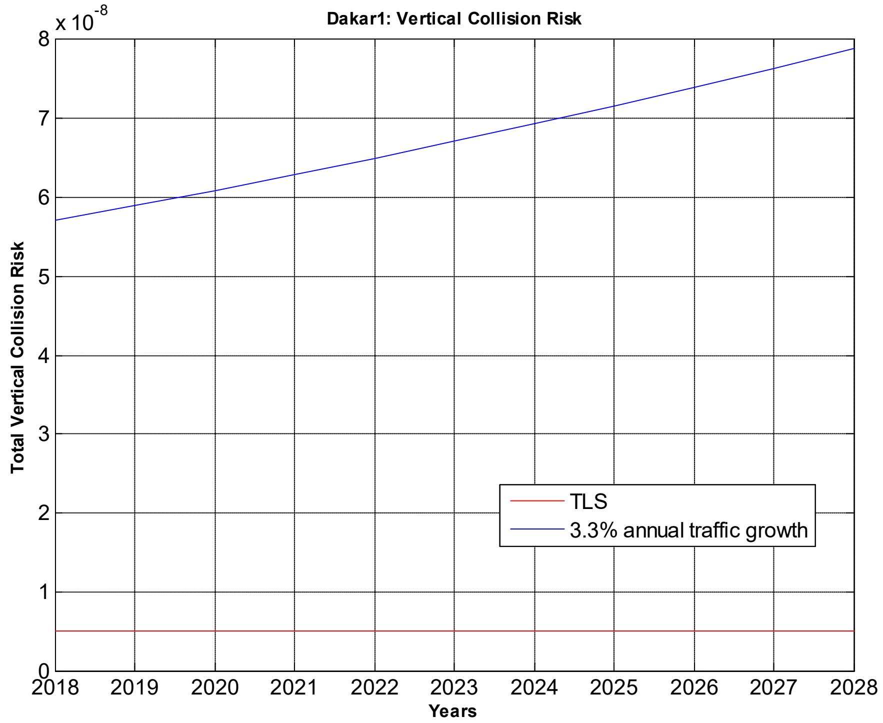


Figure 32.
Total vertical collision risk for the period 2018-2028 in Dakar1

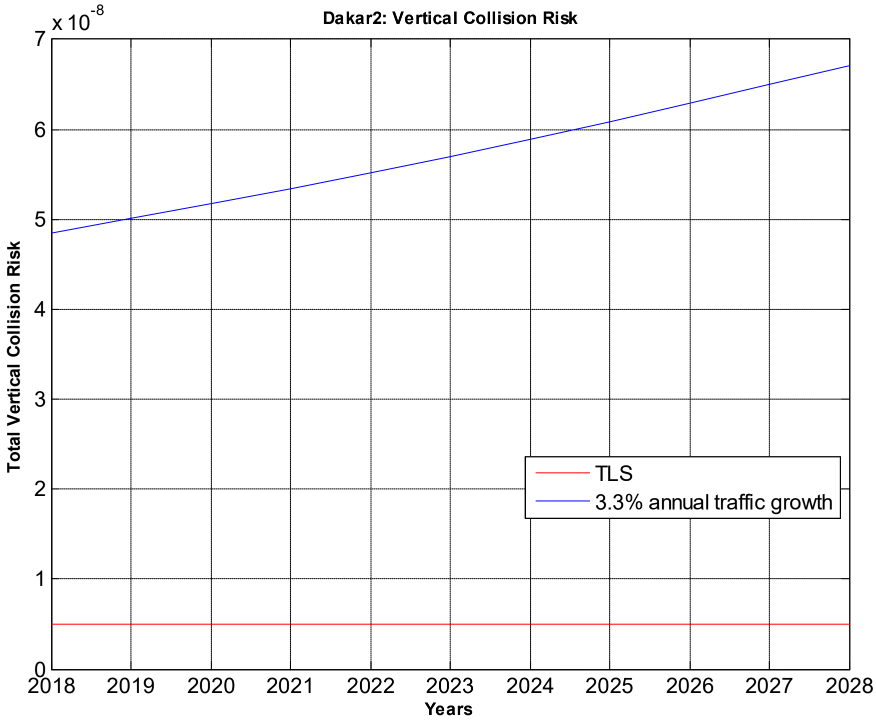


Figure 33.
Total vertical collision risk for the period 2018-2028 in Dakar2

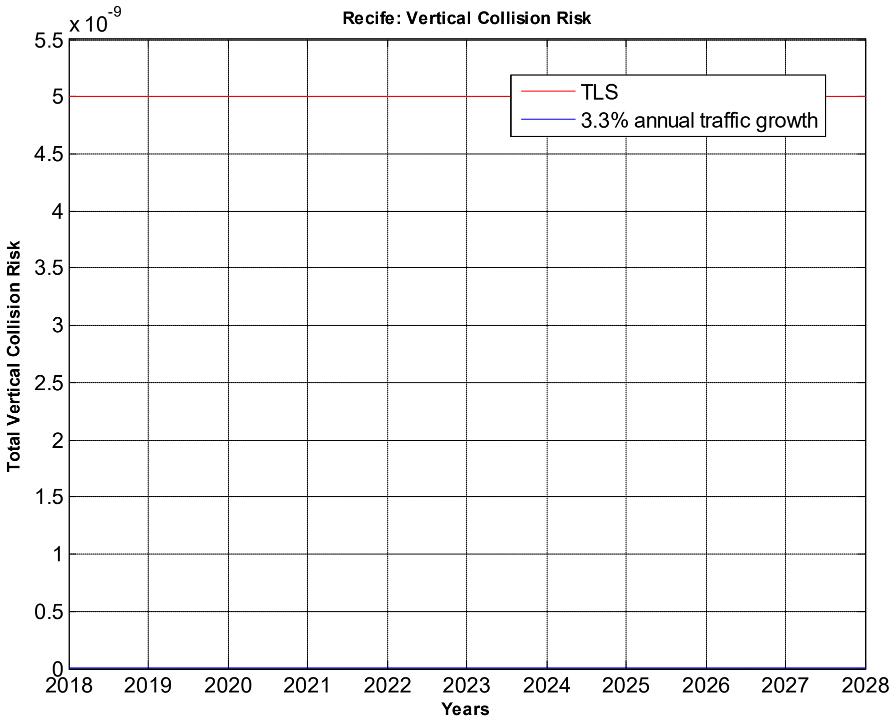


Figure 34.
Total vertical collision risk for the period 2018-2028 in Recife

4.2.3. Considerations on the results

The total vertical risk calculated using the deviations reported by the States is higher than the TLS in all locations except in the Recife FIR because in this case, no deviations were reported in the corridor (some deviations were reported not related to the corridor and not taken into account in this analysis).

In previous safety assessments, such as [Ref. 3], [Ref. 5], [Ref. 8], [Ref. 9] or [Ref. 10], it was remarked that all the received deviations had been due to coordination errors between ATC units and not related to RVSM operations. In the same way, it was also explained that the deviation reports indicated that there was not any traffic in conflict. That is also the case of this study.

The same problem, the collision risk being higher than the TLS if coordination errors are taken into account, was already identified in the previous safety assessments and the corresponding conclusions were presented. Nevertheless, it is also advisable to insist on the need of implementing adequate corrective actions to reduce operational errors in the Corridor.

4.2.3.a. Influence of the $P_y(0)$ value

As it was indicated in 4.1.2, the selected value of $P_y(0)$ could be overly conservative, having this parameter a direct influence on the vertical collision risk results. Alternative calculations have also been made using a value of $P_y(0)=0.059$, which is more similar to the ones used in European studies and in the Collision Risk Assessments performed by other Regional Monitoring Agencies ([Ref. 29], [Ref. 30] and [Ref. 31]).

Using this value of $P_y(0)=0.059$, the obtained results are shown in Table 50.

FIR/UIR	Vertical risk	
	Technical risk	Total vertical risk
Canaries	$3.1903*10^{-14}$	$1.7221*10^{-8}$
SAL1	$9.0761*10^{-15}$	$4.3259*10^{-8}$
SAL2	$1.3873*10^{-14}$	$3.8764*10^{-8}$
Dakar1	$2.4877*10^{-14}$	$1.6366*10^{-8}$
Dakar2	$3.9418*10^{-14}$	$1.3931*10^{-8}$
Recife	$3.9266*10^{-14}$	$1.9301*10^{-13}$

Table 50.
Technical and total vertical risk using Py(0)=0.059

As it can be seen in Table 50, even if a value of $P_y(0)=0.059$ were used, the results for the total vertical risk would still be above the TLS except in the Recife FIR.

5. Conclusions

Given that not all the traffic data from the different UIRs for the required period of time were available at the end of the year, only real traffic data for one month from all Corridor UIRs have been used for this study. Besides, some information was still missing and some inconsistencies have been detected. However, more information is available for large height deviation reports, as information for all FIR/UIR and months has been received. Nevertheless, some conservative assumptions had to be made regarding the modelling of probability densities and the extrapolation of traffic data.

Taking this into account, the following conclusions can be extracted from the analysis in the six different locations considered (the risk associated to the Corridor is considered to be the largest of the values calculated for each location):

- Lateral collision risk assessment:
  - The probability of lateral overlap increases as the separation between routes decreases, as it was expected. The value obtained for $S_y = 50\,NM$ is between $P_y(50) = 1.0015 \cdot 10^{-7}$ and $P_y(50) = 9.7895 \cdot 10^{-8}$, depending on the location, whilst the lateral overlap probability obtained for $S_y = 90\,NM$ is between $P_y(90) = 1.7321 \cdot 10^{-8}$ and $P_y(90) = 3.4176 \cdot 10^{-8}$.
  - For current traffic levels, the lateral collision risk obtained is $2.6845*10^{-9}$, whilst the lateral collision risk estimated for 2028 with an annual traffic growth rate of 3.3% is $3.7142*10^{-9}$. These values do not take into account traffic on the DCT Area route.
  - It should be remarked that the values of lateral technical collision risk for 2018 and the projection to the next 10 years, are similar to those obtained in previous collision risk assessments.

- Vertical risk assessment:
  - Vertical risk is split into two parts, one for the technical vertical risk and the second one for the vertical risk due to all causes. The same collision risk model is used for both. The differences are the value of the vertical overlap probability and the relative vertical speed to use in each one.
  - The probability of vertical overlap due to technical causes was based on the probability distribution of Total Vertical Error (TVE). This was obtained by convoluting probability distributions of Altimetry System Errors (ASE) and typical Assigned Altitude Deviation (AAD). In the absence of any direct monitoring data from the EUR/SAM Corridor, 2018 height-keeping data and models from the EUR airspace provided by Eurocontrol have been used.
  - The value of the vertical overlap probability calculated by means of EUROCONTROL RVSM tool with traffic data from the Canaries for 2018, for S_z=1000 ft is $P_z(1000) = 9.87916 \cdot 10^{-13}$.
  - The lateral overlap probability for aircraft nominally flying at adjacent flight levels of the same path, $P_y(0)$ has been obtained conservatively assuming that all aircraft are using GNSS and that their lateral path-keeping errors standard deviation is 0.0612 NM. The value obtained for $P_y(0)$ is between 0.2492 and 0.2969 depending on the location, which is much higher than the value assumed by the RGCSP, 0.059.
  - The value of the vertical technical collision risk for the current traffic levels is estimated to be $1.9301*10^{-13}$. The technical vertical collision risk estimated for 2028 with an annual traffic growth rate of 3.3% is $2.6704*10^{-13}$. Both values are below the TLS.

- The technical vertical risk obtained in this study is similar to the one obtained in the previous safety assessment although slightly higher than in 2017.
- The vertical risk due to large height deviations has been calculated using the deviations reported by the States. The total vertical risk calculated using these deviations is much higher than the TLS, except in the Recife FIR because in this case, no deviations were reported in the corridor.
- All the deviations received were due to a coordination error or resulted in a coordination error, and they are not related to RVSM operations.
- The same problem, the collision risk being higher than the TLS if coordination errors are taken into account, was already identified in the previous safety assessments.

It can be concluded that lateral and technical vertical collision risks are below the TLS. Nevertheless, the validity of these results depends on the validity of the assumptions made.

Regarding the total vertical risk, the risk greatly exceeds the TLS even with current traffic levels (except in Recife FIR). In any case, as the main problem, coordination errors, is clearly identified, the use of adequate corrective actions to reduce coordination errors in the Corridor would reduce the risk. These measures should be applied as soon as feasible.

As the accuracy of the assessment greatly depends on the availability and accuracy of the data provided, it is recommended that for next assessments:

- Accurate flight progress data from all FIR/UIRs be made available, including as much information as possible in the traffic samples, to facilitate the verification of traffic flows, distribution and passing frequencies used in the analysis.
- Data on lateral and vertical deviations obtained from radar data and incident reports should be provided in order to improve the estimation of overlap probabilities (a continuous monitoring process is required to obtain a representative data sample on deviations for future assessments).
- All LHDs should be reported before the deadline and better information about LHDs must be made available, as not always complete information about them has been provided.

6. Reference documentation

[Ref. 1] Atlas South Atlantic Crossing 57C, 22 Dec 05. Air navigation Chart

[Ref. 2] Risk Assessment of RNP10 and RVSM in the South Atlantic Flight Identification Regions Including an Assessment for Limited Implementation of RVSM on RN741. (ARINC)

[Ref. 3] EUR/SAM Corridor: "Double unidirectionality" post-implementation collision risk assessment. NIVY-IDSA-INF-001-1.0-09. January 2009.

[Ref. 4] First approach to 2009 Collision Risk Assessment within the EUR/SAM Corridor. NYVI-IDSA-INF-008-1.0/10. May 2010.

[Ref. 5] EUR/SAM Corridor: 2009 Collision risk assessment. NYVI-IDSA-INF-036-1.0/10. December 2010.

[Ref. 6] EUR/SAM Corridor: 2010 Collision risk assessment. NYVI-IDSA-INF-003-1.0/12. February 2012.

[Ref. 7] EUR/SAM Corridor: 2014 Collision risk assessment. NYVI-IDSA-INF-007-1.0/16. February 2016.

[Ref. 8] EUR/SAM Corridor: 2015 Collision risk assessment. NYVI-IDSA-INF-074-1.0/16. February 2017.

[Ref. 9] EUR/SAM Corridor: 2016 Collision risk assessment. NYVI-IDSA-INF-017-1.0/17. June 2017.

[Ref. 10] EUR/SAM Corridor: 2017 Collision risk assessment. NYVI-IDSA-INF-019-1.0/18. June 2018.

[Ref. 11] AIP Spain. AIS. AIC 17/Jan/01

[Ref. 12] Separation and Airspace Safety Panel. A New Parameter for Gross Lateral Errors (SASP-WG/A/2-WP/4, 21/10/01)

[Ref. 13] Manual on airspace planning methodology for the determination of separation minima (ICAO Doc 9689-AN/953)

[Ref. 14] Air Traffic Services Planning manual. Doc 9426 OACI

[Ref. 15] ICAO Document 9574 (2nd edition). Manual on Implementation of a 300m (1000ft) Vertical Separation Minimum between FL290 and FL410 inclusive.

[Ref. 16] RVSM Safety Assessment of the Australian Airspace for the period 1 Jan 2004 through 31 Dec 2004.-RASMAG/3-WP/16 06/06/2005. OACI

[Ref. 17] Summary of the Airspace Safety Review for the RVSM Implementation in Asia Region.- RASMAG/4-WP11 25/10/2005. OACI

[Ref. 18] The EUR RVSM Mathematical Supplement.-MDG/21 DP/01 August 2001.

[Ref. 19] CAR/SAM-Course on Introduction to Safety Assessment. Lima, 19-23/06/06 (www.lima.icao.int)

[Ref. 20] SAT/12-TF/1 Report. Appendix A to the Report on Agenda Item 2: An Update to the Summary of Reduced Vertical Separation Minimum (RVSM) Safety Assessment to Reflect the Operations Safety after the RVSM Implementation in CAR/SAM airspace in January 20th.- 5-9/09/06

[Ref. 21] STATFOR. Eurocontrol Seven-Year Forecast. February 2018

[Ref. 22] EUR/SAM Risk Assessments. DNV-ADS-INF-23-0.2/06. December 2006

[Ref. 23] Revised Pre-Implementation Collision Risk Assessment for RVSM in the Africa Indian Ocean Region. NLR-CR-2007-637. February 2007

[Ref. 24] Application of offset tracks. NLR. September 2007

[Ref. 25] AIC NR 13/A/08GO 30 October 2008. Bureau NOTAM International de L'Ouest Africain. Pre-Operational Implementation of AFDP, FPASD, ADS and CPDLC within Dakar and Niamey FIRs.

[Ref. 26] AIS-ESPAÑA. AIC 10 May 07. New route orientation on airways UN-741 and UN-866 (Corridor EUR/SAM)

[Ref. 27] AIS-ESPAÑA. AIC 30 July 09. ADS/CPDLC Operational implementation of the SACCAN FANS 1/A System in the Canarias FIR/UIR

[Ref. 28] Updated RMA Manual. SASP/13-WP/44. May 2008

[Ref. 29] "Airspace Safety Review of RVSM in Australian, Nauru, Papua New Guinea and Solomon Islands Airspace. January 2014 to December 2014", "Airspace Safety Review of the RVSM Implementation in Indonesian Airspace. January 2014 To December 2014".

[Ref. 30] "Airspace Safety Review for the RVSM operation In the airspace of Chinese Flight Information Regions. January 2012 - December 2012".

[Ref. 31] "Airspace Safety Review for the RVSM Implementation in Fukuoka Flight Information Region". Jan 2014 To Dec 2014"

[Ref. 32] ICAO Doc 9937 Manual of Operating Procedures and Practices for Regional Monitoring Agencies

[Ref. 33] Description of the methodology for the Collision Risk Assessment in the EUR/SAM Corridor. ENAIRE. NYVI-IDSA-INF-018-18-1.0. June 2018

7. Acronyms

AAD	ASSIGNED ALTITUDE DEVIATION
ADS	AUTOMATIC DEPENDENT SURVEILLANCE
ASE	ALTIMETRY SYSTEM ERROR
ATC	AIR TRAFFIC CONTROL
ATS	AIR TRAFFIC SERVICES
DE	DOUBLE EXPONENTIAL DISTRIBUTION
EUR/SAM	EUROPE/SOUTH AMERICA
FIR	FLIGHT INFORMATION REGION
FL	FLIGHT LEVEL
FMC	FLIGHT MANAGEMENT COMPUTER
FTE	FLIGHT TECHNICAL ERROR
G	GAUSSIAN DISTRIBUTION
GL	GENERALISED LAPLACE DISTRIBUTION
HFDL	HIGH FREQUENCY DATA LINK
HMU	HEIGHT MONITORING UNIT
kts	KNOTS
MASPS	MINIMUM AVIATION SYSTEM PERFORMANCE STANDARDS
MDG	MATHEMATICS DRAFTING GROUP (EUROCONTROL)
NAT	NORTH ATLANTIC
NM	NAUTICAL MILE
RGCSP	REVIEW OF THE GENERAL CONCEPT OF SEPARATION PANEL
RNP	REQUIRED NAVIGATION PERFORMANCE
RVSM	REDUCED VERTICAL SEPARATION MINIMUM
SAT	SOUTH ATLANTIC
SATCOM	SATELLITE COMMUNICATIONS
SATMA	SOUTH ATLANTIC MONITORING AGENCY
STATFOR	AIR TRAFFIC STATISTICS AND FORECASTS (EUROCONTROL)
TVE	TOTAL VERTICAL ERROR
UIR	UPPER FLIGHT INFORMATION REGION