International Civil Aviation Organization
CAR/SAM Regional Planning Implementation Group (GREPECAS)
First Meeting of the Communications, Navigation and Surveillance / Air Traffic Management Subgroup (CNS/ATM/SG/1)
(Lima, Peru, 15 to 19 March 2010)

Agenda Item 4: **Review to pending matters of the ATM/CNS/SG, ATM/COMM, CNS/COMM and respective Task Forces, for consideration in the CNS/ATM Subgroup work programme**

Safety Assessment Post-Implementation of RVSM at the Caribbean and South American Airspace – CAR/SAM – Statistical/Mathematical Analysis – Monitoring Phase IV

(Presented by CARSAMMA)

SUMMARY

The objective of this document is to demonstrate if the safety criteria defined at ICAO's document 9574 are being satisfied in the airspace of the Caribbean and South America Regions.
It constitutes the fifth report of safety assessment of the CAR/SAM regions airspace post implementation of the RVSM and it should be submitted to revision of the SAM/WG group coordination. The revised version shall be presented for a timely discussion at the next meeting of the GREPECAS ATM/CNS subgroup.

References:

- See item 6

ICAO Strategic Objectives:	*A - Safety* *D - Efficiency*

1. Introduction

This paper presents the results of the safety assessment in the operational phase of the implementation of a Reduced Vertical Separation Minimum of 300 m (1000 ft) in the airspace of the Caribbean and South American regions (CAR/SAM). This step is a continuation of the implementation strategy from the *"Manual on Implementation of a 300 m (1000 ft) Vertical Separation Minimum between FL 290 and FL 410 inclusive, ICAO, Montreal, Doc 9574, 2nd Edition 2002"*, (Reference 1). It should be made to ensure that operations in the RVSM airspace have not induced an increase in collision risk and that the overall vertical risk does not exceed the safety objectives established.

Special attention will be required to ensure that:

1) All aircraft operating in the airspace where a reduced vertical separation minimum is applied, are RVSM approved;

2) The RVSM approval process remains effective;

3) The TLS of 2.5 x 10^{-9} fatal accidents per aircraft flight hour (relating to technical height-keeping performance monitored from a representative sample of the aircraft population) continues to be satisfied according to a predetermined level of statistical confidence.

If the Technical TLS is not satisfied in accordance with global system performance specification, verify if it is necessary and sufficient to consider a balance between the parameters of the Collision Risk Method used in monitoring;

4) The introduction of the RVSM does not increase the level of risk due to operational errors and in-flight contingency according to a predetermined level of statistical confidence;

5) Be effective the additional safety measures introduced to reduce the risk and meet the safety objectives due to operational errors and in-flight contingency;

6) There is evidence of stability of the altimetry system error (ASE); and

7) The Air Traffic Control procedures remain effective.

The methodological procedures used are based on the experience acquired with the implementation of RVSM as presented in References 2 to 16. The main evaluation data, the main conclusions inferred and the recommendations are summarized below.

The Airspace

The airspace of the CAR/SAM regions consists of 34 Flight Information Regions (FIR) constituted by the following States: Antigua, Argentina, Barbados, Barbuda, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, El Salvador, Ecuador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nevis, Nicaragua, Panama, Paraguay, Peru, St. Barthelemy, St. Kitts, St. Lucia, St. Vincent, Suriname, Trinidad & Tobago, Uruguay and Venezuela.

To facilitate the analysis, the airspace was evaluated by regions: a single region comprising the Caribbean and the South America (CAR/SAM), Caribbean Region (CAR), South America Region (SAM), Chile-Cuba Corridor, Amazonia-Port au Prince Corridor and Guayaquil-Piarco Corridor. Each part of the airspace was treated as an isolated system, in other words, with its own statistical parameters.

It were analyzed flight data of: 2346 report points, 3242 route segments, and 38904 flight levels belonging to the route segments of 336 routes of 32 FIR.

Traffic Movement Data Collection

The sample used to estimate the passing frequency and the physical and dynamic parameters of the typical aircraft for the collision risk assessment was collected during the period from 7 until 20 of March of 2009, in compliance with the determination of the conclusion of the sixth ATM/CNS/SG/6 meeting that took place at Santo Domingo, Dominican Republic, in the period from 30 of June until 4 of July of 2008.

From the 34 FIR of the CAR/SAM regions, it were treated the data received from: eight FIR from the Caribbean region (Havana, Central America, Kingston, Panama, Curacao, Piarco, Santo Domingo and Port au Prince), and twenty four FIR from the South American region (Brasilia, Curitiba, Recife, Amazonica, Atlantico, Lima, Santiago, Punta Arenas, Antofagasta, Puerto Montt, Guayaquil, Bogota, Barranquilla, Maiquetia, Montevideo, Mendoza, Cordoba, Resistencia, Comodoro Rivadavia, Asuncion, Ezeiza, Georgetown, Paramaribo and Rochambeau). The number of flight hours for each FIR, region and corridor is presented on Tables 1 to 4. From the considered sampling, note in Table 1 the percentage contribution on the flight hours of each region: CAR (27.92%), SAM (72.08%). The **Chile-Cuba Corridor** has 33.40% of the total movement from the CAR/SAM regions and comprises the following FIR: Punta Arenas, Puerto Montt, Santiago, Antofagasta, Lima, Guayaquil, Panama, Central America, Kingston and Havana (see Table 2 below). The **Amazonia-Port au Prince Corridor** has 16% of the total movement from the CAR/SAM regions and comprises the following FIR: Amazonica, Maiquetia, Curacao, Santo Domingo and Port au Prince (see Table 3 below). The Guayaquil-Piarco Corridor has

12.07% of the total movement from the CAR/SAM regions and comprises the following FIR: Guayaquil, Bogota, Barranquilla, Maiquetia and Piarco (see Table 4 below).

Aircraft Population

According to the orientation guide for the RVSM implementation, is essential that 100% of the RVSM approved aircraft population satisfies the RVSM requirements. However, it was noted evidence of a large amount of non-compliant aircraft flying in the RVSM airspace. Unfortunately, the Caribbean and South American Monitoring Agency (CARSAMMA) is not yet provided of an aircraft monitoring capability that proves such evidence. This activity is part of a technical performance monitoring program of aircraft in flight that is not established at CAR/SAM regions yet. On Table 5 it is shown the aircraft population which flew in the CAR/SAM regions with their respective dimensions and flight hours percentage, including the one for a typical aircraft.

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FIR	Flight Hours	%
HAVANA	4158.2167	7.97%
CENTRAL AMERICA	2751.8333	5.28%
PANAMA	2209.5051	4.24%
KINGSTON	1895.7476	3.63%
CURACAO	1464.8500	2.81%
PIARCO	1461.2825	2.80%
PORT AU PRINCE	337.9833	0.65%
SANTO DOMINGO	283.2833	0.54%
SUBTOTAL 1 (CAR Region)	**14562.7018**	**27.92%**
RECIFE and ATLANTICO	6160.3630	11.81%
BRASILIA	7620.2573	14.61%
AMAZONICA	4777.3873	9.16%
CURITIBA	5018.2574	9.62%
LIMA	2760.3659	5.29%
SANTIAGO and ANTOFAGASTA	2342.3667	4.49%
BOGOTA	1553.8645	2.98%
GUAYAQUIL	1005.5333	1.93%
MAIQUETIA	1480.6306	2.84%
CORDOBA	842.6833	1.62%
BARRANQUILLA	793.2415	1.52%
COMODORO RIVADAVIA	467.4764	0.90%
RESISTENCIA	430.5277	0.83%
PUNTA ARENAS	120.9500	0.23%
ROCHAMBEAU	254.6333	0.49%
ASUNCION	331.7785	0.64%
GEORGETOWN	147.4167	0.28%
PUERTO MONTT	177.3333	0.34%
PARAMARIBO	132.1567	0.25%
MONTEVIDEO	465.7535	0.89%
EZEIZA	216.9833	0.42%
MENDOZA	503.8000	0.97%
SUBTOTAL 2 (SAM Region)	**37603.7602**	**72.08%**
TOTAL CAR/SAM Regions	**52166.4620**	**100.00%**

Table 1 – Total Number of Flight Hours of the FIR in the CAR/SAM Regions (14 days sample)

FIR	Flight Hours	%
HAVANA	4158.2167	7.97%
KINGSTON	1895.7476	3.63%
PANAMA	2209.5051	4.24%
CENTRAL AMERICA	2751.8333	5.28%
GUAYAQUIL	1005.5333	1.93%
LIMA	2760.3659	5.29%
SANTIAGO and ANTOFAGASTA	2342.3667	4.49%
PUERTO MONTT	177.3333	0.34%
PUNTA ARENAS	120.9500	0.23%
TOTAL	**17421.85**	**33.40%**

Table 2 – Total Number of Flight Hours of the FIR in the CHILE-CUBA Corridor

FIR	Flight Hours	%
AMAZONICA	4777.3873	9.16%
MAIQUETIA	1480.6306	2.84%
CURACAO	1464.8500	2.81%
SANTO DOMINGO	283.2833	0.54%
PORT AU PRINCE	337.9833	0.65%
TOTAL	**8344.1345**	**16.00%**

Table 3 – Total Number of Flight Hours of the FIR in the AMAZONIA-PORT AU PRINCE Corridor

FIR	Flight Hours	%
GUAYAQUIL	1005.5333	1.93%
BOGOTA	1553.8645	2.98%
BARRANQUILLA	793.2415	1.52%
MAIQUETIA	1480.6306	2.84%
PIARCO	1461.2825	2.80%
TOTAL	**6294.5524**	**12.07%**

Table 4 – Total Number of Flight Hours of the FIR in the GUAYAQUIL-PIARCO Corridor

Aircraft Type	Hours	% ACFT Pop	Length [NM]	Width [NM]	Height [NM]
A320	8082.111	15.49	0.0202860000	0.0184130000	0.0063500000
B763	6233.007	11.95	0.0296440000	0.0257020000	0.0075590000
B738	5594.638	10.72	0.0213280000	0.0185210000	0.0067490000
B737	4200.524	8.05	0.0188980000	0.0185210000	0.0067490000
A319	2671.061	5.12	0.0182720000	0.0184130000	0.0063500000
B752	2554.727	4.9	0.0255510000	0.0207880000	0.0073220000
A332	2322.531	4.45	0.0317490000	0.0325590000	0.0093950000
B772	2150.150	4.12	0.0343950000	0.0328830000	0.0099890000
E190	1325.567	2.54	0.0195680350	0.0155075590	0.0057073430
B733	1269.009	2.43	0.0172790000	0.0161990000	0.0064790000
B762	1122.983	2.15	0.0261880000	0.0257020000	0.0075590000
A343	1047.094	2.01	0.0343410000	0.0325590000	0.0090980000
B744	1018.447	1.95	0.0381750000	0.0347730000	0.0104750000
A318	669.5833	1.28	0.0169820000	0.0184130000	0.0067820000
B767	661.7353	1.27	0.0331530000	0.0280240000	0.0090710000
A346	651.6601	1.25	0.0406590000	0.0342600000	0.0093410000
B764	630.8894	1.21	0.0331530000	0.0280240000	0.0075590000
F100	609.7189	1.17	0.0191846700	0.0151619900	0.0045896300
A321	596.8016	1.14	0.0240330000	0.0184130000	0.0063500000
MD11	541.6333	1.04	0.0332613400	0.0280777500	0.0094654400
DC10	529.6030	1.02	0.0299946000	0.0255669500	0.0094654400
A306	515.3167	0.99	0.0292120000	0.0242120000	0.0089310000
MD80	512.9229	0.98	0.0243520500	0.0177375800	0.0051295900
B732	445.1000	0.85	0.0161990000	0.0156590000	0.0064790000
B735	349.2667	0.67	0.0167930000	0.0156050000	0.0059940000
A330	300.7499	0.58	0.0343412500	0.0325594000	0.0090874700
B773	287.3974	0.55	0.0399030000	0.0328830000	0.0099890000
B722	274.9975	0.53	0.0219220000	0.0177650000	0.0055620000
A340	242.0333	0.46	0.0406590000	0.0342600000	0.0093410000
B77W	206.7500	0.40	0.0343952480	0.0349892010	0.0100431970
A342	195.4782	0.37	0.0320680000	0.0325590000	0.0090170000
LJ35	191.6333	0.37	0.0080075590	0.0065010800	0.0020140390
CRJ9	185.3500	0.36	0.0195460000	0.0125810000	0.0040500000
B777	182.4000	0.35	0.0343952480	0.0349892010	0.0100431970
CL60	168.8333	0.32	0.0112580990	0.0105885530	0.0034017280
Others	-	6.96	-	-	-
Weighted Average			**0.02439009**	**0.02198885**	**0.007153745**
TOTAL	**52166.46**	**100.00**			

Table 5 – Aircraft that Flew in the CAR/SAM Regions between FL 290 and FL 410 Inclusive

On Technical Vertical Deviation Data

These data should be provided by a monitoring program of the aircraft height-keeping performance error. It has never been obtained for the CAR/SAM region because of lack of an appropriate capacity established in States. The Scrutiny Working Group (SWG) that assists CARSAMMA at the Large Height Deviation (LHD) reports analysis rarely have detected errors due to the altimetry system (ASE) and to the height-keeping performance system (AAD). In the assessments prior to 2009, CARSAMMA used ASE data provided by EUROCONTROL, but for the year of 2009, the data was not provided by any monitoring agency and, even if it had been done, it would not serve to estimate the vertical collision probability, since the data corresponding to errors due to the height-keeping performance system (AAD) were not provided either. The lack of these data incapacitates CARSAMMA to comment on or even try to give any explanation about the history of the behavior of the technical performance of any aircraft flying in the CAR/SAM regions airspace.

Demonstration of the Technical Feasibility of the RVSM Application in the CAR/SAM Regions

Basically this is the assessment of the results from the monitoring of the values of the parameters of the Reich collision risk model, passing frequency (N_x), vertical overlap probability [$P\left(S_z\right)$] and the lateral overlap probability [$P_y\left(0\right)$], to check if the following targets were attained:

a) Provide confidence on the technical TLS satisfaction;

b) Provide guidance on the efficacy of the MASPS RVSM and the effectiveness of modifications on the altimetry system; and

c) Provide evidence on ASE stability.

Conditions which Quantify the Global System Performance Specification

Passing Frequency, N_x – is the parameter of the airspace which characterizes the aircraft exposure to vertical collision risk. The estimation of the equivalent passing frequency was made considering aircrafts flying on same direction and on opposite directions. The passing frequency was individually determined for each route segment, route, FIR and corridor within the CAR/SAM regions airspace, at a total of 3242 route segments belonging to 336 routes from 32 FIR.

For Table 6 the thirty route segments which presented the highest peaks of equivalent passing frequency are shown, on decreasing order, together with their respective number of flight hours presented on Table 7. The flight hours per flight level are presented on Figures 1 to 11 for the main route segments, routes and FIR considered important for argumentation of evidences. The values are relative to CAR/SAM airspace system which is represented by the 32 FIR considered. The passing frequency peaks indicate the places with greater collision risk potential. It is important to emphasize that de passing frequencies reported in Tables 6 to 9 were calculated using the total flight hours in the CAR/SAM regions. Some observations follow:

Route Segments: main discrepancies of flight distribution per level

- The highest peak of passing frequency which represents the highest exposure to the vertical collision risk is at the route section DOBKO-SAGAZ of route UW58 in the Brasilia FIR occupying the second place on the total number of flight hours (385 h), see Figure 1.0;
- The segment URSUS-UCA of route UA301 in the Havana FIR is the one that presents the highest number of flight hours (538 h), but only the second highest passing frequency, second highest exposure to the vertical collision risk, see Figure 2.0;

- The segment GONZA-LIBRA of route UW58 in the Recife FIR presents the third highest passing frequency and the seventh place on the total number of flight hours (280 h), see Figure 1.1;
- The segment UCL-UVA of route UG448 in the Havana FIR presents the fourth place on the passing frequency and on the total number of flight hours (334 h), see Figure 3.0;
- The segment LIBRA-SAGAZ of route UW58 in the Recife FIR presents the fifth highest passing frequency and the fortieth place on the total number of flight hours (128 h), see Figure 1.2;
- The segment CONDE-SVD of route UW58 in the Brasilia FIR presents the 26th highest passing frequency and the 145th place on the total number of flight hours (70 h), see Figure 1.3;
- The segment TTZ3-BGI of route TTZP3 in the Piarco FIR presents the 47th highest passing frequency and the third place on the total number of flight hours (356 h). It presents the best distribution of flights per level and best explores the sub-utilization of the airspace from the safety point of view, see Figure 4.0;

Conclusion: in terms of exposure to the vertical collision risk, distributions of flights per level of several route segments do not present according to a logic optimization.

<u>Route</u>: main discrepancies presented by the distributions of flights per level

- The route UW58 presents the highest exposure to the vertical collision risk (highest passing frequency) with lesser flight hours (2206 h) than the route UL780 (2281 h); (segments sub-utilized and with flights poorly distributed among the levels in terms of exposure to the vertical collision risk). See Figure 1.4;
- The route UG448 presents the second highest exposure to the vertical collision risk and the ninth place on the total number of flight hours (885 h). It presents poor distribution of flights per level, principally from the FL 340, see Figure 3.1;
- The route UA301 presents the fourth highest exposure to the vertical collision risk and also the fourth place on the total number of flight hours (1186 h). This route presents a flight distribution per level relatively better than the UG448 and UW58 routes, but still has room for improvement, see Figure 2.1;
- The route TTZP3 presents the 35th highest contribution to exposure to the vertical collision risk and the 40th place on the total number of flight hours. It presents the best flight distribution per level and exploits better the sub-utilization of the airspace, see Figure 4.1.

Conclusion: in terms of exposure to the vertical collision risk, distributions of flights per level of several routes/airways are not done according to a logic optimization.

<u>FIR</u>

- The Havana FIR (Figure 5) presents higher exposure to the vertical collision risk than the Brasilia FIR (Figure 7) which has a lot more flight hours, see Figure 5;
- The Curitiba FIR presents the 14th highest exposure to the vertical collision risk and is the second place on the total number of flight hours (see Figure 10). The passing frequency is ten times lesser than the one from the Havana FIR, which has less flight hours;
- The Kingston, Havana and Port au Prince FIR presents approximately the same vertical collision risk exposure, relative to their air traffic flow;

- Taking the Curitiba FIR as a reference, all FIR can significantly improve the aircraft exposure to the vertical collision risk by redistributing the flights per level, including the Ezeiza FIR which presents the lowest passing frequency and is the 29th place on the total number of flights hours among the 34 FIR, see Figure 11;
- It is observed that, in general, the flight distribution per level follow the fuel economy at almost every FIR. The parameter that represents the aircraft exposure to the vertical collision risk is ignored.

Conclusion: use of airspace is not optimized in terms of aviation safety. The CAR/SAM regions airspace claim an optimization of the flight level occupancy taking into account the parameter that represents the exposure of aircraft to the vertical collision risk (equivalent passing frequency).

Route Segments		**Airway**	**Equivalent Passing Frequency**	**Total Number of Flight Hours**	**FIR**
Fix A	**Fix B**		**Monitoring Phase IV**		
DOBKO	SAGAZ	UW58	0.0167063	384.98904	SBBS/SBRE
URSUS	UCA	UA301	0.0111262	537.56382	KZMA/MUFH
GONZA	LIBRA	UW58	0.0092401	280.30887	SBRE
UCL	UVA	UG448	0.0074080	333.54779	MUFH
LIBRA	SAGAZ	UW58	0.0053614	128.29165	SBRE
UVA	TADPO	UG448	0.0052551	239.21706	KZMA/MUFH
CROOK	DOBKO	UW58	0.0052305	122.45154	SBBS
NISTI	CROOK	UW58	0.0050404	117.73992	SBBS
JUDAS	GONZA	UW58	0.0038481	183.86589	SBRE
ATUVI	UCL	UG448	0.0036059	226.83455	MUFH/MKJK
SIA	BEREX	UG430	0.0033555	199.31458	MKJK
SEKMA	ARNAL	UL465	0.0027128	288.05574	MKJK/MPZL
DEPOT	NISTI	UW58	0.0025839	64.60128	SBBS
UCA	PUTUL	UG430	0.0023467	315.67659	MUFH/MKJK
ALOBO	EMASA	UL465	0.0023283	201.16596	MKJK
PUTUL	SIA	UG430	0.0023055	136.17975	MKJK
ACJ	NICAR	UW58	0.0022353	114.69384	SBRE
UGUPI	GYV	UL780	0.0022184	211.45379	SKED/SEGU
BUXOS	UGUPI	UL780	0.0022144	211.11667	MPZL/SKED
BEREX	KILER	UG430	0.0021035	124.94347	MKJK
GAXER	DAGUD	UL780	0.0019081	267.03333	MUFH/MKJK
CANOA	VINKA	UB646	0.0018112	191.19086	KZMA/MUFH
VAKUD	TRU	UL780	0.0016524	192.35626	SEGU/SPIM
POTRO	ORAGO	UW58	0.0015263	162.57015	SBBR
UCA	GONIS	UG437	0.0014228	154.91730	MUFH
CONDE	SVD	UW58	0.0013512	70.37624	SBBR
UCL	SELEK	UG439	0.0012960	129.55711	MUFH
MARMA	DAGUD	UL780	0.0012871	198.09133	MKJK/MPZL
ELASA	ATEDA	UL302	0.0012611	157.99362	SCFZ
PIGBO	URSUS	UL780	0.0012523	141.54583	KZMA/MUFH

*of a total of 3342 route sections

Table 6 – Route Sections Which Present the Highest Values of Passing Frequency Peaks (decreasing order)

Order	Fix A	Fix B	Route	Flight Hours
1	URSUS	UCA	UA301	537.5638
2	DOBKO	SAGAZ	UW58	384.9890
3	TTZ3	BGI	TTZP3	356.1572
4	UCL	UVA	UG448	333.5478
5	UCA	PUTUL	UG430	315.6766
6	SEKMA	ARNAL	UL465	288.0557
7	GONZA	LIBRA	UW58	280.3089
8	GAXER	DAGUD	UL780	267.0333
9	UVA	TADPO	UG448	239.2171
10	ATUVI	UCL	UG448	226.8345
11	SAISOOO1	ENTSOOO1	SOOO1	220.0000
12	LOGON	VUMPI	UL795	217.9917
13	URSUS	GELOG	UL795	212.5667
14	MOXES	TRU	UL780	212.4374
15	TEXAS	KOLVI	UW13	211.6883
16	UGUPI	GYV	UL780	211.4538
17	BUXOS	UGUPI	UL780	211.1167
18	ESIPO	DIBOK	UL795	201.8667
19	ALOBO	EMASA	UL465	201.1660
20	SIA	BEREX	UG430	199.3146
21	MARMA	DAGUD	UL780	198.0913
22	VAKUD	TRU	UL780	192.3563
23	CANOA	VINKA	UB646	191.1909
24	JUDAS	GONZA	UW58	183.8659
25	CURSE	PNG	UM788	179.9017
26	SILEN	SELMO	UT106	169.1084
27	CRV	UTRUN	UA570	169.0321
28	OPRAM	PCL	UW2	163.6394
29	POTRO	ORAGO	UW58	162.5702
30	PPR	TTZ1	TTZP1	161.0661
31	ELASA	ATEDA	UL302	157.9936
32	UCA	GONIS	UG437	154.9173
33	FOF	TTZ2	TTZP2	153.1332
34	NANDU	PONCA	UM540	153.0549
35	OTAMO	MLY	UA301	149.5211
36	MAXIM	ANALI	UG765	149.4631
37	PIGBO	URSUS	UL780	141.5458
38	SORTA	MOXES	UL780	140.8885
39	LOMID	MLO	UA308	138.4095
40	PUTUL	SIA	UG430	136.1797
41	ANALI	NUKAN	UG765	135.9869
42	VERME	ARX	UW2	134.4327
43	ENAMO	UNV	UB503	134.4281
44	BONOS	SELEK	UZ403	130.3994
45	VTN	TOY	UW200	129.8499
46	UCL	SELEK	UG439	129.5571
47	LIBRA	SAGAZ	UW58	128.2917
... 145	... CONDE	... SVD	... UW58	… 70.3800

Table 7 – Route Sections with the Highest Numbers of Flight Hours (decreasing order)

Order	Route/Airway	Passing Frequency			Total Number of Flight Hours
		Same Direction	Opposite Direction	Equivalent	
1	UW58	1.9981991E-05	5.6887291E-02	5.6916422E-02	2206.1287
2	UG448	1.0458330E-04	1.7237362E-02	1.7383506E-02	884.9922
3	UL780	8.6620500E-07	1.5731689E-02	1.5733553E-02	2281.7406
4	UA301	1.5735705E-05	1.2902254E-02	1.2937732E-02	1185.9546
5	UG430	0.0000000E+00	1.0111925E-02	1.0111925E-02	790.5494
6	UA315	1.0882798E-04	7.6315452E-03	7.8234065E-03	935.9802
7	UL465	2.2482880E-06	7.1468525E-03	7.1502543E-03	703.8669
8	UL302	0.0000000E+00	4.9953927E-03	4.9953927E-03	650.1727
9	UL795	1.3772272E-05	4.9503613E-03	4.9844569E-03	1465.5798
10	UL417	1.3676240E-06	4.8576818E-03	4.8601358E-03	1057.4627
11	UG437	1.4919350E-06	4.6098445E-03	4.6122890E-03	919.3785
12	UW6	2.3381350E-06	4.4283690E-03	4.4320168E-03	663.5117
13	UL550	8.9529000E-08	4.3169062E-03	4.3170820E-03	682.1180
14	UW10	6.7816000E-07	3.3739286E-03	3.3751041E-03	761.8260
15	UA317	3.0001151E-05	2.8502366E-03	2.8980907E-03	1068.8157
16	UA321	3.1100660E-06	2.5077411E-03	2.5134438E-03	674.1832
17	UB646	2.7455000E-08	2.0945350E-03	2.0946825E-03	242.3111
18	UG436	9.6277740E-06	2.0036711E-03	2.0234227E-03	553.7458
19	UA314	4.4809920E-06	1.9009501E-03	1.9075820E-03	743.7516
20	UN873	1.5237780E-06	1.6846434E-03	1.6872046E-03	617.9944
21	UA570	1.7754260E-06	1.5874348E-03	1.5895109E-03	261.3000
22	UB503	3.3427300E-05	1.5034314E-03	1.5549561E-03	304.5188
23	UG426	1.9960050E-06	1.5208468E-03	1.5241619E-03	420.3790
24	UW33	4.0526300E-07	1.5189223E-03	1.5199042E-03	422.7782
25	UG439	4.2706890E-06	1.4444245E-03	1.4529779E-03	406.6445
26	UA550	4.3216528E-05	1.3619056E-03	1.4279765E-03	593.7716
27	UG765	2.4827000E-08	1.2476501E-03	1.2476838E-03	330.7500
28	UA319	5.6339020E-06	1.1008938E-03	1.1149716E-03	302.7991
29	UW43	1.3180000E-08	1.1073357E-03	1.1073619E-03	286.4667
30	UZ17	0.0000000E+00	1.0561228E-03	1.0561228E-03	227.0406
…	…	…	…	…	…
35	ZZTP3	9.1E-09	0.000801	0.000802	356.1572

Table 8 – Highest values of Passing Frequency of the Main Routes/Airways from the CAR/SAM Regions (decreasing order)

FIR	Passing Frequency			Total Number of Flight Hours
	Opposite Direction	Same Direction	Equivalent	
HAVANA	4.0822537E-02	1.6752776E-04	4.0566065E-02	4158.2167
RECIFE & ATLANTICO	3.7289010E-02	5.6262304E-05	3.7161050E-02	6160.3630
BRASILIA	3.3815127E-02	4.5565196E-04	3.3175254E-02	7620.2573
KINGSTON	1.7635542E-02	1.2531200E-07	1.7635325E-02	1895.7476
PANAMA	1.1599855E-02	4.9655640E-06	1.1592147E-02	2209.5051
LIMA	1.0254301E-02	1.2951490E-06	1.0252036E-02	2760.3659
AMAZONICA	8.9551205E-03	1.2112493E-05	8.9323741E-03	4777.3873
SANTIAGO & ANTOFAGASTA	6.5380794E-03	5.9147150E-06	6.5295335E-03	2342.3667
BOGOTA	6.1312784E-03	4.6239240E-06	6.1238364E-03	1553.8645
CURACAO	4.9828185E-03	1.8745720E-04	4.6323221E-03	1464.8500
GUAYAQUIL	4.9351135E-03	2.1831570E-06	4.9315964E-03	1005.5333
MAIQUETIA	4.5978213E-03	4.5475794E-05	4.5285547E-03	1480.6306
CENTRAL AMERICA	4.0994002E-03	4.9317929E-05	4.0055658E-03	2751.8333
CURITIBA	3.2253377E-03	1.8629886E-04	2.9475596E-03	5018.2574
PORT AU PRINCE	3.1211355E-03	2.3539200E-06	3.1179159E-03	337.9833
CORDOBA	3.0689214E-03	2.8895820E-06	3.0646975E-03	842.6833
BARRANQUILLA	3.0394154E-03	6.4525700E-07	3.0383433E-03	793.2415
PIARCO	2.7025108E-03	1.8525300E-07	2.7000588E-03	1461.2825
SANTO DOMINGO	2.1484771E-03	3.2254000E-08	2.1484308E-03	283.2833
COMODORO RIVADAVIA	1.6207000E-03	2.6371430E-06	1.6164093E-03	467.4764
RESISTENCIA	1.6000265E-03	8.3573900E-07	1.5988212E-03	430.5277
PUNTA ARENAS	6.8660723E-04	8.8317300E-07	6.8520731E-04	120.9500
ROCHAMBEAU	4.9492547E-04	0.0000000E+00	4.9492547E-04	254.6333
ASUNCION	4.5115863E-04	4.8480580E-06	4.4524053E-04	331.7785
GEORGETOWN	3.7324407E-04	2.1155600E-07	3.7296277E-04	147.4167
PUERTO MONTT	2.8693251E-04	0.0000000E+00	2.8693251E-04	177.3333
PARAMARIBO	2.2651312E-04	8.8274000E-08	2.2627749E-04	132.1567
MONTEVIDEO	1.0882308E-04	5.5611657E-05	6.0862440E-06	465.7535
EZEIZA	5.4318641E-05	7.3971000E-08	5.3862309E-05	216.9833
MENDOZA	4.4470147E-05	8.2109670E-06	2.4405346E-05	503.8000
TOTAL (CAR/SAM Region)	**0,2129**	**0.001259**	**0.21491**	**52166.462**

Table 9 –Passing Frequencies for the FIR in the CAR/SAM Regions (decreasing order)

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In the following some figures that show the number of flight hours per flight levels for route segments, routes and FIR are presented.

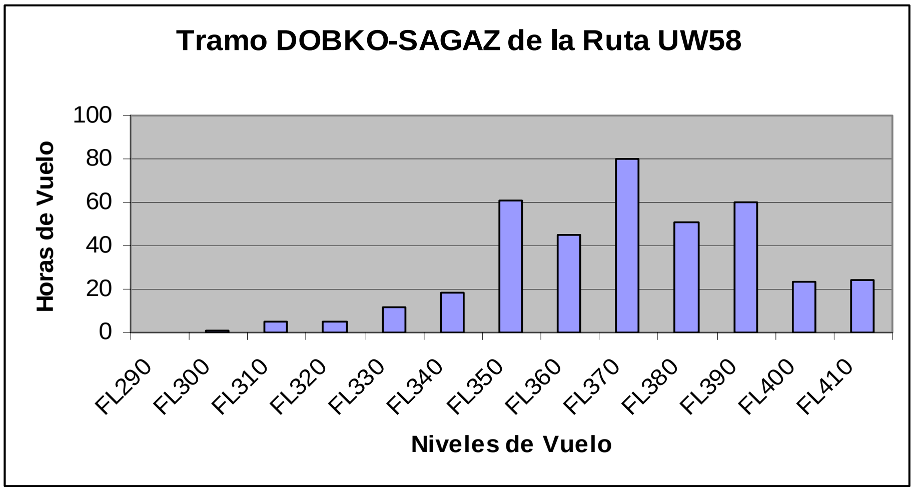

Figure 1.0 – Flight Hours per Flight Level for Route Segment DOBKO-SAGAZ

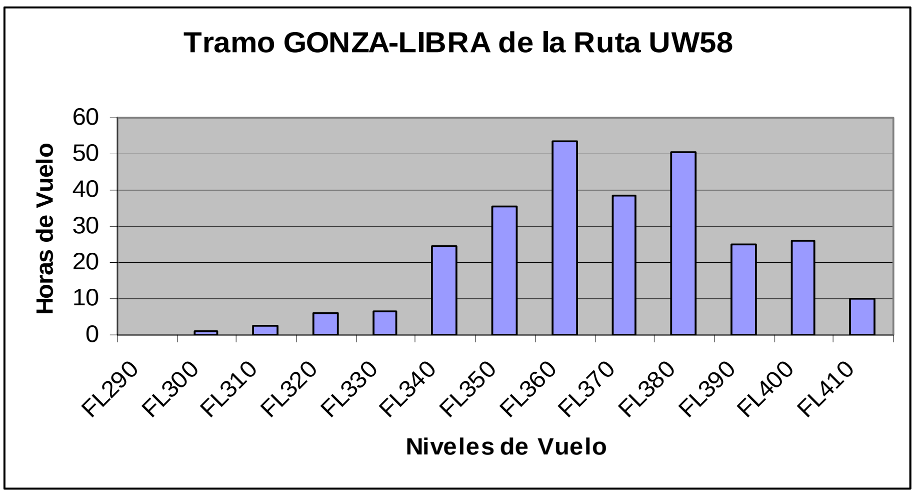

Figure 1.1 – Flight Hours per Flight Level for Route Segment GONZA-LIBRA

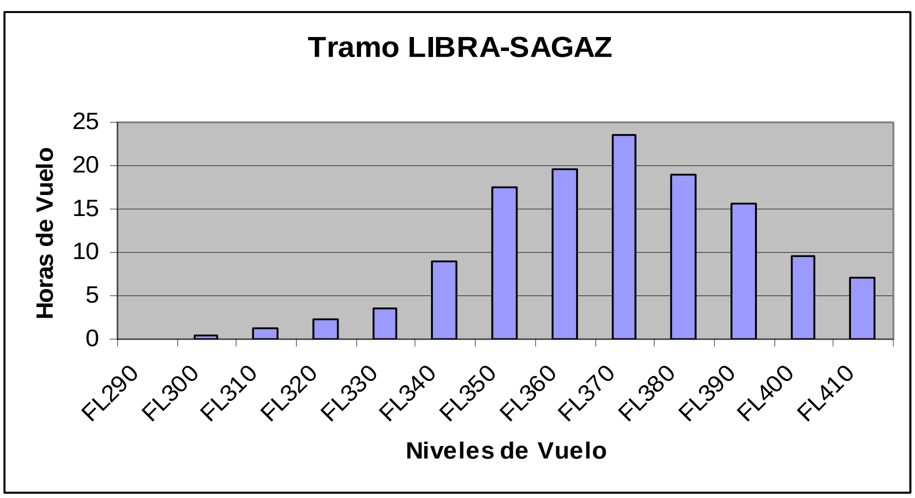

Figure 1.2 – Flight Hours per Flight Level for Route Section LIBRA-SAGAZ in Route UW58

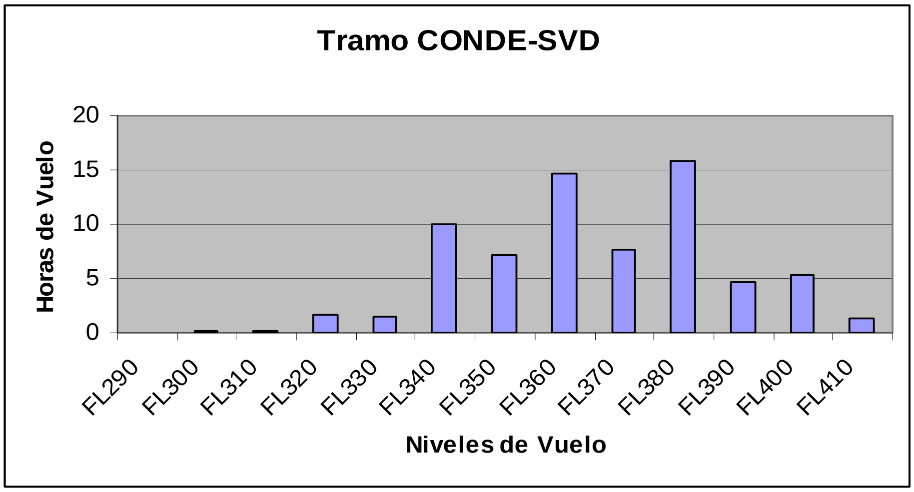

Figure 1.3 – Flight Hours per Flight Level for Route Segment CONDE-SVD in Route UW58

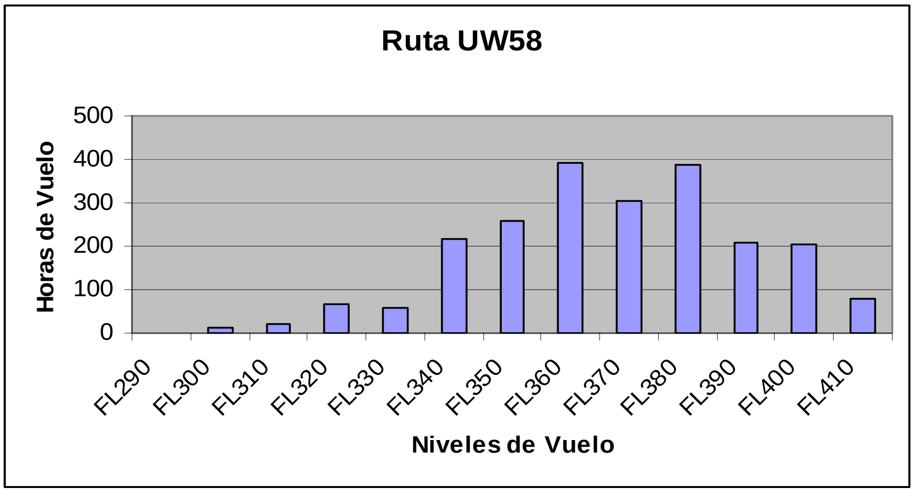

Figure 1.4 – Flight Hours per Flight Level for Route UW58

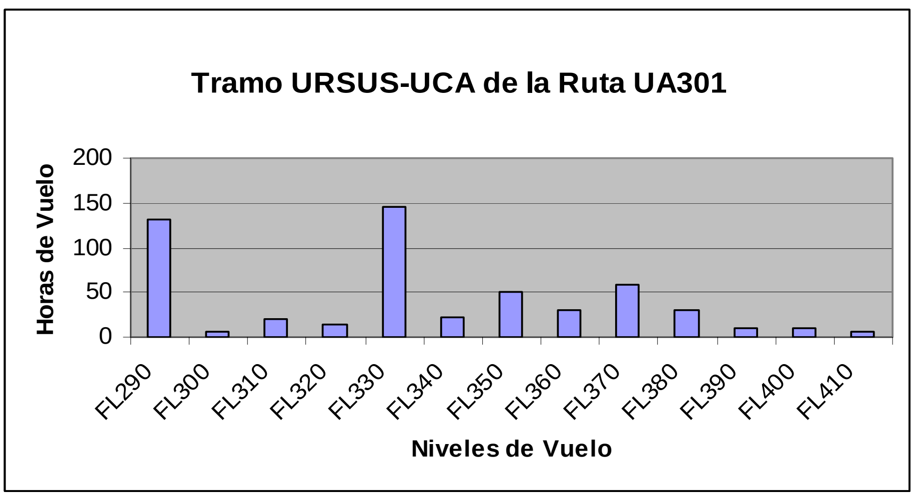

Figure 2.0 – Flight Hours per Flight Level for route Segment URSUS-UCA

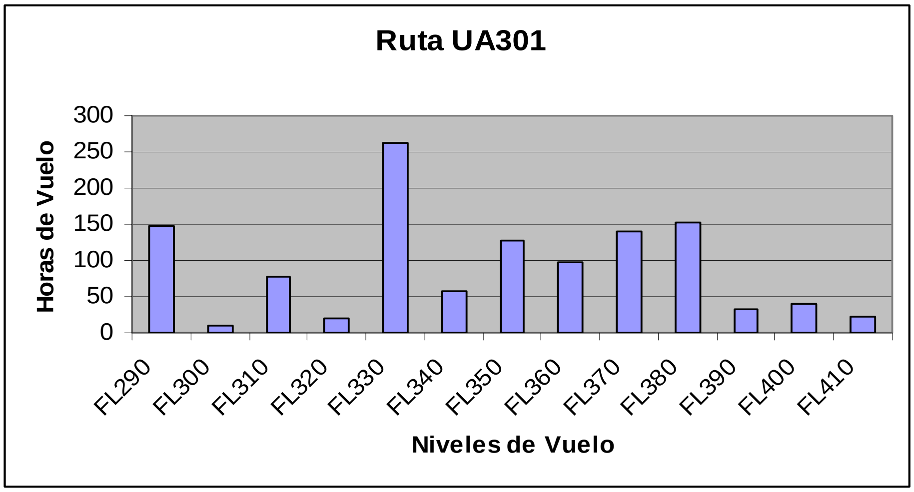

Figure 2.1 – Flight Hours per Flight Level for Route UA301

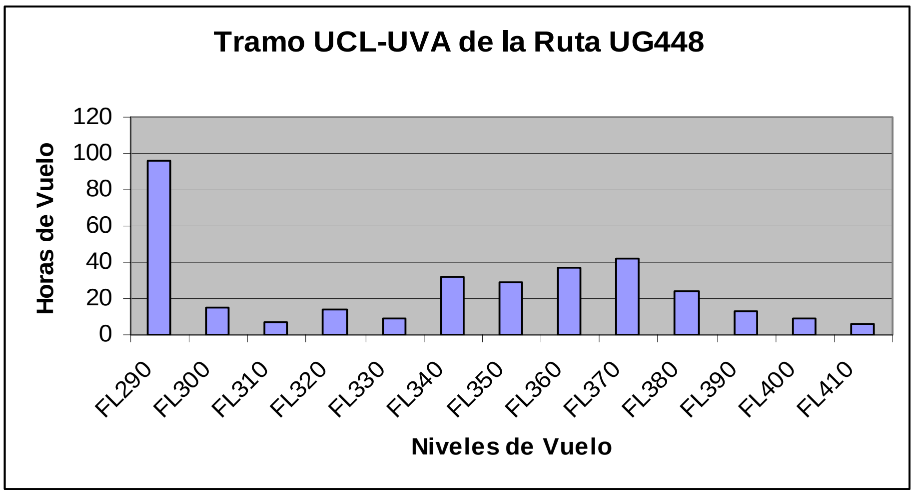

Figure 3.0 – Flight Hours per Flight Level for Route Segment UCL-UVA

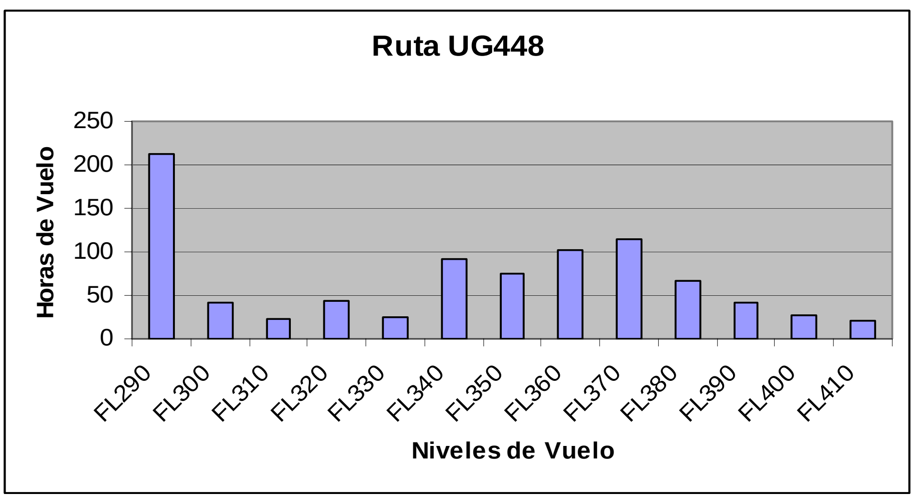

Figure 3.1 – Flight Hours per Flight Level for Route UG448

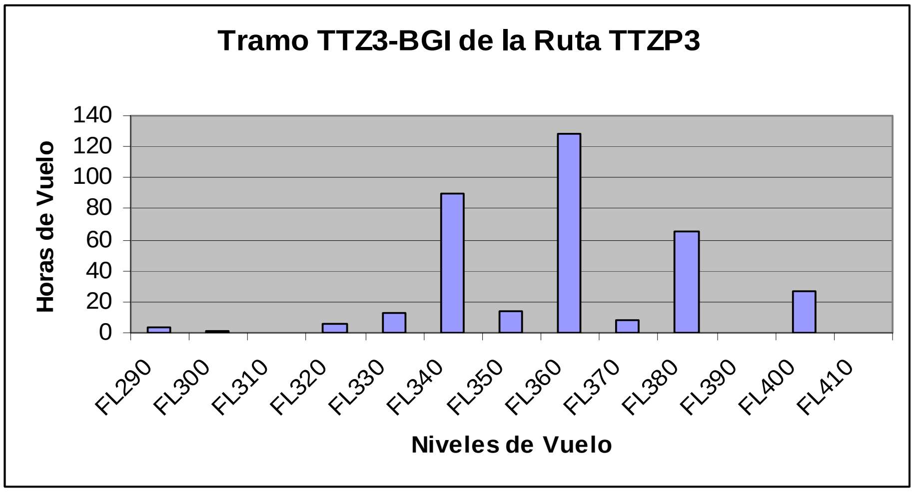

Figure 4.0 – Flight Hours per Flight Level for Route Segment TTZ3-BGI

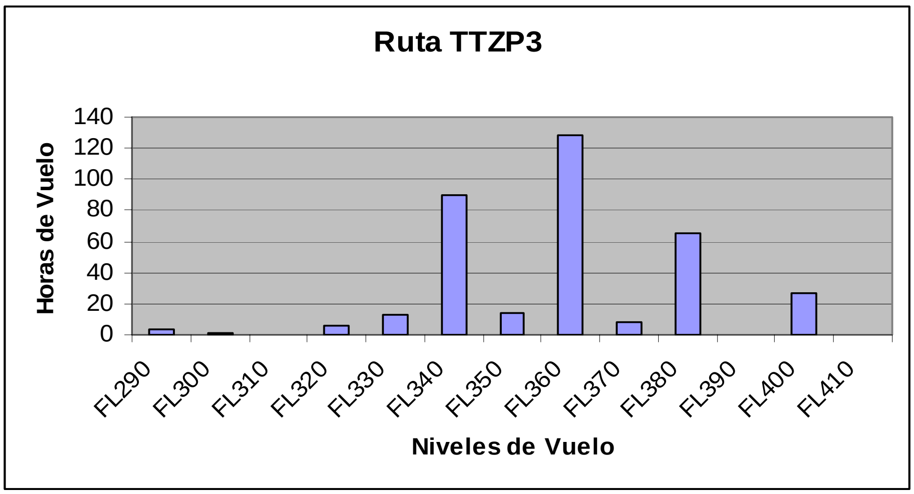

Figure 4.1 – Flight Hours per Flight Level for Route TTZP3

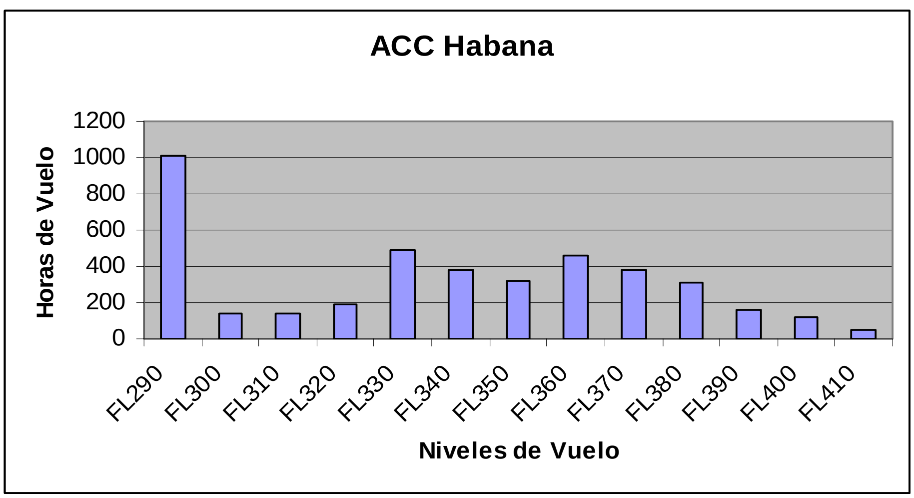

Figure 5.0 – Flight Hours per Flight Level for Havana FIR

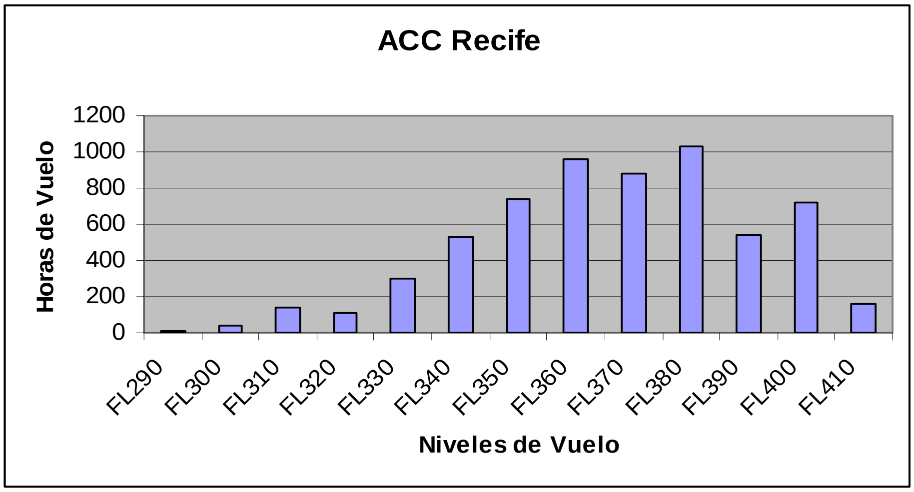

Figure 6 – Flight Hours per Flight Level for Recife FIR

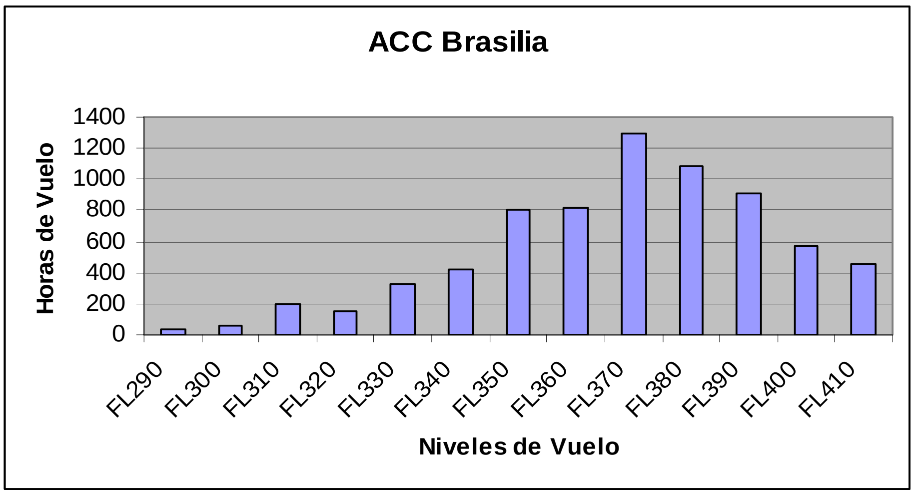

Figure 7 – Flight Hours per Flight Level for Brasilia FIR

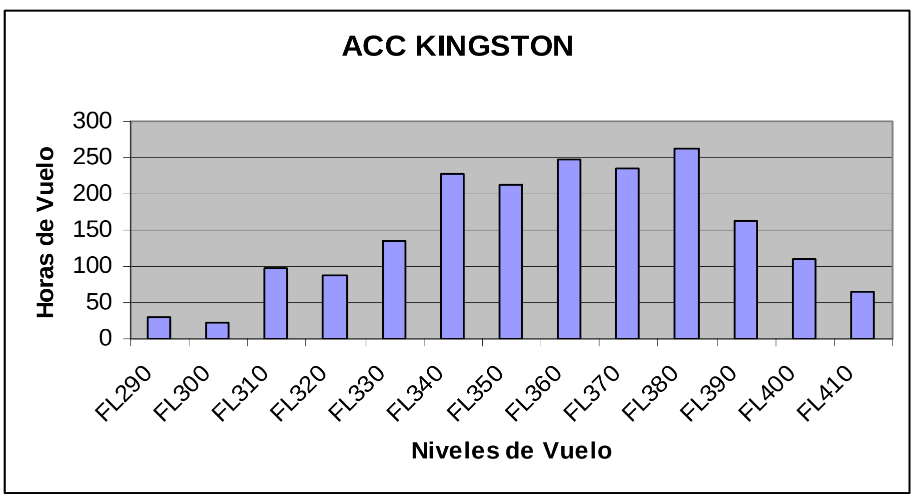

Figure 8 – Flight Hours per Flight Level for Kingston FIR

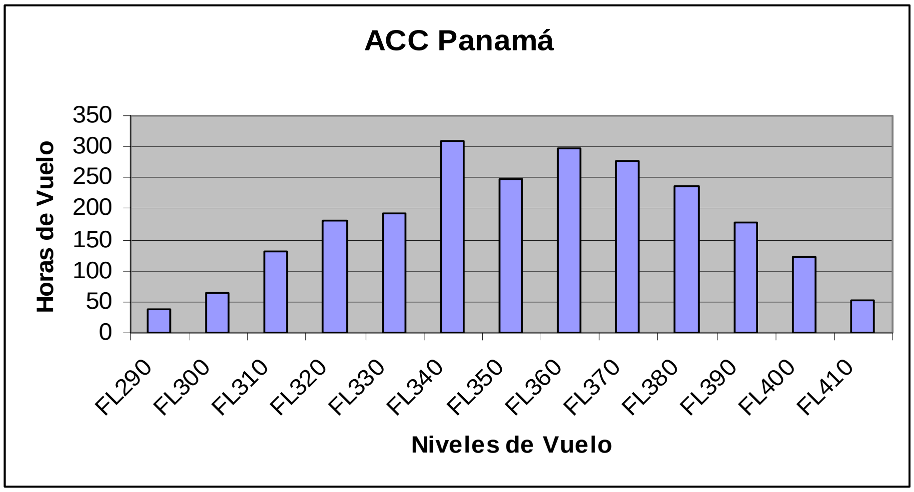

Figure 9 – Flight Hours per Flight Level for Panama FIR

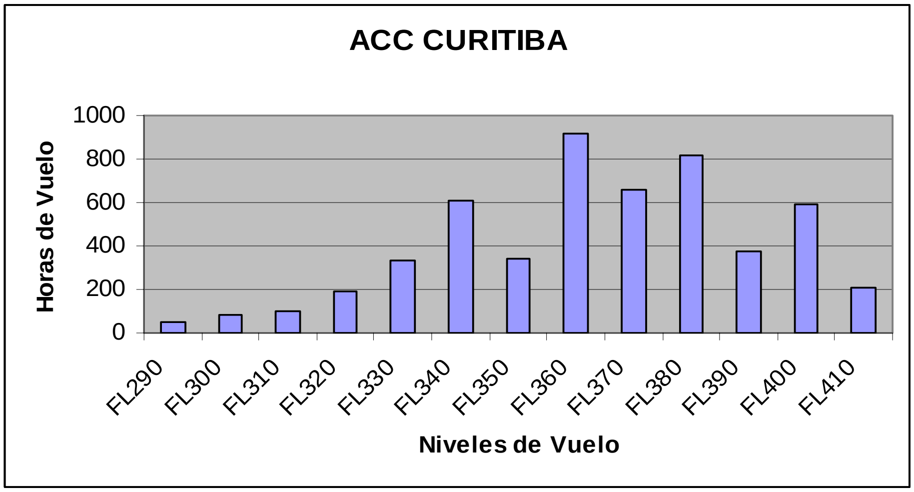

Figure 10 – Flight Hours per Flight Level for Curitiba FIR

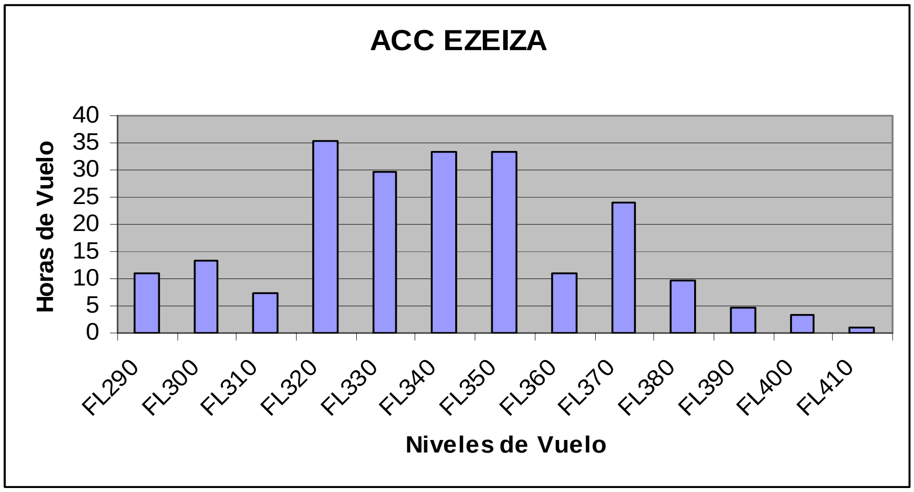

Figure 11 – Flight Hours per Flight Level for Ezeiza FIR

Lateral Overlap Probability [$P_y(0)$]

It was not possible to monitor this parameter. According to ICAO Document 9574, the lateral overlap probability should be periodically assessed. However, the agency cannot perform the monitoring because it does not have the necessary infrastructure to do so. This parameter measures the lateral path-keeping performance.

In order to make the operational collision risk assessment, it was considered that $P_y(0)$ does not exceed the value of 0.058, in accordance to ICAO recommendation (Ref. 1).

Vertical Overlap Probability [$P_z(1000)$]

It was not possible to monitor this parameter. CARSAMMA also cannot perform the monitoring of the vertical deviation (TVE) because it is not capable of doing so, for not having the necessary infrastructure to do so. As a consequence, it was not possible to obtain the result of the vertical overlap probability for the CAR/SAM regions airspace.

The estimate value for $P_z(1000)$ should not exceed $1,7\times10^{-8}$, in accordance to ICAO recommendation (Ref. 1).

<u>Verification of the Global Height-keeping Performance Specification</u>

It was not possible to verify. The estimation of the four TVE proportions could not be carried out because it was not possible to obtain the TVE distribution function due to the nonexistence of a vertical error monitoring program.

<u>Verification of the MASPS criteria</u>

For the same reasons, **it was not possible to verify** that:

- The mean of the Altimetry System Error (ASE) of the group does not exceed ±25 m (±80 ft);
- The sum of the absolute value of the ASE mean for the group and three standard deviations of the ASE distribution in the group does not exceed 75 m (245 ft); and
- The height-keeping errors are symmetric with respect to the mean of 0 m (0 ft); the standard deviation is not greater than 13 m (43,7 ft); and the error frequency decreases with the increase of the error magnitude at an exponential rate.

<u>Provide evidence of the ASE stability</u>

Because of the lack of the establishment of a monitoring program, CARSAMMA does not have a monitoring database of the aircraft in the CAR/SAM regions. As a consequence, it cannot perform an assessment of the history of the technical performance behavior. In summary, CARSAMMA is not yet capable of verifying the continued airworthiness and, consequently, to be aware of deviations and interact with the operators to ensure that aircraft maintenance procedures are being executed in conformity with the safety rules.

<u>Identification of the Causes of the Inconsistency of the Height-keeping Errors</u>

It was not possible to identify any causes because there is no information on the vertical technical errors. A monitoring program of the Altimetry System Errors (ASE) would allow CARSAMMA to identify which of the following most common probable causes (identified during the monitoring program executed by EUROCONTROL) apply to the CAR/SAM regions:

- dirty or defective Pitot tubes;
- static system defective;
- defective Air Data Computer (ADC);
- inadequate calibration of the Pitot-static system;
- defective transponder;
- defective static probe;
- defective static system drain;
- erosion or damage to the static probes;
- deficient calibration of the static system;
- eventual incorrect connections of the electric wires after maintenance;
- problems at the fan attack angle;
- corrosion at static port bearings;
- static system leak;
- static port inadequate flush;
- system pressure leak;
- Pitot head contamination;
- STBY identification system failure;
- aircraft sold and disqualified for RVSM flights;
- abrupt variation of the meteorological conditions; and
- etc..

According to what was presented at the fourth RMA Special Meeting in Canberra, Australia (Ref. 16), the HMU systems provide, on regular operation, about 20000 monitoring results monthly to EUROCONTROL. From these, approximately 250 results are submitted to an intense control, and, monthly, the Scrutiny Working Group of the Monitoring Agency finds and reviews about 50 aircraft which present deviation from the validated data of more or less than 180 feet. Usually, from 2 to 3 aircrafts require investigations to take place.

Technical TLS Verification

The Technical TLS could not be verified. In order to verify the Technical TLS, is required that all necessary activities to demonstrate the safety objectives have proved the corresponding evidences that they have been based on. The presentation of the evidences related to the parameters of the vertical overlap probability [$P_z\left(S_z\right)$] and lateral overlap probability ($P_y(0)$) will only be possible after the establishment of the monitoring program of the vertical and lateral deviations.

<u>Assessment of the RVSM Impact on the Risk due to Operational Errors and Flight Contingencies</u>

According to ICAO Doc 9574, the large errors identified through the incident reports may be due to operational procedures, adverse meteorological conditions or, yet, emergency maneuvers due to failure of engine or pressurization, and can be divided into four groups:

1) *ATC-pilot loop errors and incorrect clearances;*
2) *Aircraft contingency events;*
3) *Deviations due to meteorological effects; and*
4) *Deviations due to ACAS.*

These height deviation categories permit the causes to be identified in an easier way. The definition of errors according to its causes should be based on the classification suggested by ICAO Doc 9574 according to a decision taken during The Eleventh Meeting/Workshop of Air Traffic Management (ATM) Authorities and Planners (AP/ATM/11), Lima, 25-29 of September of 2005. The deviations types and causes are described on Table 10, below:

Code	**Large Height Deviations Causes (LHD)**
A	Failure to climb/descend as cleared
B	Climb/descend without ATC clearance
C	Entry into airspace at an incorrect flight level
D	Deviation due to turbulence or other weather related cause
E	Deviation due to equipment failure
F	Deviation due to collision avoidance system (ACAS/TCAS) resolution advisories
G	Deviation due to contingency event
H	Aircraft not approved for operation in RVSM restricted airspace
I	ATC system loop error; (e.g. pilot misunderstands clearance message or ATC issues incorrect clearance)
J	Equipment control error encompassing incorrect operation of fully functional FMS or navigation system (e.g. by mistake the pilot incorrectly operates INS equipment)
K	Incorrect transcription of ATC clearance or re-clearance into the FMS
L	Wrong information faithfully transcribed into the FMS (e.g. flight plan followed rather than ATC clearance or original clearance followed instead of re-clearance)
M	Error in ATC-unit-to-ATC-unit transition message
N	Negative transfer received from transitioning ATC-unit
O	Other

Table 10 – Codes Used to Define the Cause of Each Reported LHD

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<u>Large Height Deviation Reports</u>

Below, on Table 11, the types of errors quantified per State from January until December of 2008 are shown:

	Number of Large Height Deviations by Code													
States	**A**	**B**	**C**	**D**	**E**	**F**	**H**	**I**	**J**	**M**	**N**	**O**	**P**	**Total**
Netherlands Antilles		1								9	15		1	**26**
Argentina											6			**6**
Brazil	5	4		4	5	2	3	3	2	35	9	1		**73**
Chile	1	1								20	5			**27**
COCESNA					1					16	3		1	**21**
Colombia								1		1	2			**4**
Ecuador						1				39	24			**64**
French Guyana										4	7	1		**12**
Jamaica				1						6	3			**10**
Paraguay		1	1							4	2			**8**
Peru		1				2		4		21	1	1		**30**
Dominican Republic					1					34	15			**50**
Trinidad & Tobago	1		1					1		30	35			**68**
Uruguay										16	4			**20**
Venezuela										17	13			**30**
Total	**7**	**8**	**2**	**5**	**7**	**5**	**3**	**9**	**2**	**25 2**	**14 4**	**3**	**2**	**449**

Table 11 – Deviations Quantified per State

On Table 12, it is presented the gradual development of the parameters of the Large Height Deviation through the year of 2008, times that aircraft spent at wrong level and the number of flight level crossed without clearance:

Month	**Time Spent Same Direction [s]**	**Time Spent Opposite Direction [s]**	**Levels Crossed Same Direction**	**Levels Crossed Opposite Direction**
January/2008	14170	90	37	39
February/2008	1805	240	22	27
March/2008	4280	2580	44	47
April/2008	1810	240	20	18
May/2008	2345	1640	16	18
June/2008	2961	2490	26	29
July/2008	2960	25	36	36
August/2008	2195	25	19	21
September/2008	3030	240	35	38
October/2008	4305	90	29	28
November/2008	2980	150	19	20
December/2008	7100	180	32	31
TOTAL	**49941**	**7990**	**335**	**352**

Table 12 – Gradual Development of the Parameters of the Operational Error

Estimation of the Global Collision Risk

On Table 13, the groups of physical and dynamical parameters applied in the Reich's Collision Risk Model, as well as the main monitoring parameters, the vertical and lateral overlap probabilities and the passing frequency are presented. All the parameters were determined considering each region of the airspace as an isolated system.

	AIRSPACE SYSTEM					
Parameters	**Guayaquil Piarco**	**Amazonia P. Prince**	**Chile Cuba**	**CAR**	**SAM**	**CAR/SAM**
T^{*}	162,598	218,084	456,219	382,256	978,731	1,360,986
$P_y(0)$	0.058	0.058	0.058	0.058	0.058	0.058
$P_z(0)$	0.57	0.57	0.57	0.57	0.57	0.57
$P_z(1000)$	?	?	?	?	?	?
λ_x^{**}	0.0272400	0.025809	0.023324	0.024298	0.024425	0.0249010
λ_y^{**}	0.0244542	0.023235	0.020871	0.021416	0.022212	0.0219889
λ_z^{**}	0.0076518	0.007371	0.006928	0.007044	0.007196	0.0071537
λ_h^{**}	0.0272400	0.025809	0.023324	0.024298	0.024425	0.0249010
$\overline{\lvert V \rvert}^{***}$	453.05	444.94	449.65	443.84	439.44	440.68
$\overline{\lvert \Delta V \rvert}^{***}$	44.75	32.69	38.22	33.76	40.81	38.12
$\overline{\lvert \dot{y} \rvert}^{***}$	20	20	20	20	20	20
$\overline{\lvert \dot{z} \rvert}^{***}$	1.5	1.5	1.5	1.5	1.5	1.5
$\overline{\lvert \dot{z}_c \rvert}^{***}$	10	10	10	10	10	10
$N_{x(oppos)}$	0.1741	0.1454	0.2892	0.3097	0.1751	0.2129
$N_{x(same)}$	0.0004	0.0015	0.0007	0.0014	0.0012	0.0013
$N_{x(equiv)}$	0.1748	0.1482	0.2903	0.3123	0.1822	0.2150
$E_{z(Xssing)}$						
S_x	80	80	80	80	80	80

*Hours [h]; **Nautical Miles [NM]; ***Nautical Miles per Hour [NM/h]

Table 13 – Summary of the Parameters Used in the Reich's Collision Risk Model for each Airspace System

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The estimated values for the collision risk model are shown on Table 14, where:

- N_{az}^{tec} is the **technical vertical risk**,

Which could not be estimated because, in the following equation

- $N_{az}^{tec} = P_y(0) \times P_z(S_z) \times N_x(equivalent) \times CONSTANT$,

The lateral overlap probability [$P_y(0)$] and the vertical overlap probability [$P_z(S_z)$] were not monitored in any of the mentioned regions.

- N_{az}^{ACAS} is the **vertical risk due to incidents related to the Airborne Collision Avoidance System (ACAS)**;

It was not possible to estimate for the same reasons above, the lateral performance and the height-keeping performance were not monitored.

- N_{az}^{ne} is the **vertical risk due to aircraft leveling at a wrong level**;

It was only possible to estimate this parameter, assuming a value for a lateral standard deviation of 0.3 NM for the probability distribution function representative of an aircraft population equipped with a compatible area navigation (RNAV) equipment, and also, the highest value already considered in other airspaces for the probability of two aircrafts assigned to fly at a same level being within a vertical distance of λ_z (average aircraft height) from each other, $P_z(0) = 0,57$.

- N_{az}^{nc} is the **vertical risk due to aircraft crossing levels without clearance**;

This is the same of the previous justification.

- N_{az}^{op} is the **operational collision risk**, $N_{az}^{ne} + N_{az}^{nc}$;

- N_{az}^{Total} is the **vertical collision risk due to all causes or total risk**.

It was not possible to calculate because of the previous justifications.

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	COLISION RISK RESULTS					
AIRSPACE SYSTEMS	N_{az}^{tec} [×10^{-9}]	N_{az}^{ACAS} [×10^{-9}]	N_{az}^{ne} [×10^{-9}]	N_{az}^{nc} [×10^{-9}]	N_{az}^{op} [×10^{-9}]	N_{az}^{Total} [×10^{-9}]
Guayaquil Piarco	?	?	**8.52**	**12.08**	**20.60**	?
Amazonia P. Prince	?	?	**9.64**	**6.03**	**15.67**	?
Chile Cuba	?	?	**32.75**	**12.81**	**45.56**	?
CAR	?	?	**18.35**	**63.40**	**81.75**	?
SAM	?	?	**5.02**	**3.09**	**36.1**	?
CAR/SAM	?	?	**43.2**	**8.04**	**51.6**	**?**

Reference Value: *TLS = 5.0 x 10^{-9}*

Table 14 – Collision Risk Results for the Regions

It is noticed that the collision risk for any of the regions is higher than the reference TLS of 5.0 x 10^{-9} fatal accidents per aircraft flight hour. The operational risk for the CAR region is a lot higher than the reference value, i.e. $N_{az}^{op} = 81.79 \times 10^{-9}$, or ~16 times the TLS. For SAM region it was ~7 times the TLS. CAR/SAM system presents an operational risk of ~10 times the TLS and the Chile-Cuba corridor ~9 times the TLS.

The safety is being compromised because of the occurrence of operational errors of all types classified by ICAO, and continues to be affected principally by common procedure errors of ATC-unit to ATC-unit transition message (code M) and negative transfer received from transitioning ATC-unit (code N). Attention should also be given to the type of errors of codes A, B, C, D, E, F, H, I, J, O and P, see Table 11.

2. Corrective Actions

To take corrective actions to eliminate all errors listed on Table 11.

To give special attention to corrective actions in order to eliminate the LHD that occurs along the routes which present higher exposure to the collision risk. On Table 15, below, the routes which present the highest number of LHD and the corresponding relative position on the exposure to the vertical collision risk rank are presented.

In conjunction with the action to eliminate the LHD causes, it is recommended that an optimization of the distribution of flights per flight level (FL) be done, with the objective of lowering the passing frequency (collision risk exposure), since the estimated collision risk value is directly proportional to the value of the passing frequency parameter.

Especial care should be given to the combination of a high number of LHD and a high value of passing frequency, particularly at routes UL780, UA315, UA550, UW58, UG436, UL550, UG437, UL795 and UL302.

A redistribution of routes and flights per flight level is strongly recommended, principally at CAR region and Brazil, particularly at the Brasilia and Recife FIR.

Rank	Routes	N^{o} of LHD	Collision Risk Exposure Rank
1st	UL780	35	3rd
2nd	UA315	30	6th
3rd	UA550	29	13th
4th	UG437	12	11th
5th	UG436	12	17th
6th	UA567	12	41st
7th	UL795	11	9th
8th	UL550	11	13th
9th	UG426	10	23rd
10th	UL302	10	8th
11th	UA561	9	173rd
12th	UG449	8	55th
13th	UG442	8	68th
14th	UA551	8	129th
15th	UA319	7	27th
16th	UL304	7	70th
17th	UW58	6	1st
18th	UN741	5	16th
19th	UG439	5	25th
20th	UL305	5	39th
21st	UW50	5	60th

Table 15 – Routes Which Present the Highest Number of LHD and Their Corresponding Exposure to the Vertical Collision Risk

3. Conclusions and Recommendations

On the Air Traffic Movement Data

From the 34 FIR of the CAR/SAM regions, the data received from: 8 FIR from the Caribbean region and 24 FIR from the South American region were treated.

Flight data from: 2346 notification points, 3242 route segments, and 38904 flight levels belonging to segments of 336 routes and 32 FIR were analyzed.

On the Aircraft Population

An indication of a large amount of non compliant aircraft flying at the RVSM airspace exists. The CARSAMMA agency does not have the necessary infrastructure for monitoring aircraft in order to prove such evidences. A technical monitoring program of aircraft in flight needs to be established at the CAR/SAM regions.

From the samples collected at Brazil and at the Chile-Cuba corridor, which together correspond to almost 80% of the total flight hours of the CAR/SAM regions, it was noticed that the total number of aircraft that flew in these regions represents approximately 100% of the aircraft that flew in the CAR/SAM regions. From this it was concluded that a height-keeping performance monitoring program covering the Flight Information Regions (FIR) of Brazil and Santiago-Havana would be sufficient to monitor 99.5% of aircraft that fly in the CAR/SAM regions.

On the Technical Vertical Deviation

The States of the CAR/SAM regions do not provide CARSAMMA with data about the technical vertical deviation for not having appropriate capacity of monitoring the height-keeping performance of the aircraft.

CARSAMMA, after analyzing the assessments of previous years done with data from other regions, concluded that it is not a useful practice for the CAR/SAM regions. This practice, actually, prevented CARSAMMA to take the necessary actions to ensure the safety objectives to be satisfied, since, the errors, when they existed, were corrected at the source region and, as a consequence, the errors of the CAR/SAM regions, still exist and are unknown.

On the Monitoring of the Aircraft System Errors

The same conclusions and recommendations made at the last safety assessment report presented at the meetings AP/ATM/13 (2007) and ATM/COMM/6 (2008) in regard to the data of the vertical deviation (ASE and AAD) and the data from the lateral deviation remain valid.

On the Distribution of Flights per Flight Level

From the vertical collision risk exposure point of view, generally, the routes present poor distribution of flights per level and the subutilization of the airspace it is not explored from the safety point of view.

A redistribution of routes and flights per flight level is strongly advised, principally in CAR region and Brazil, especially at the Brasilia and Recife FIR.

The distribution of flights per level seeks the fuel economy and the parameter that represents the exposure of the aircraft to the collision risk is being ignored.

An intelligent optimization of the flight level occupation in favor of safety will take, inevitably, to the reduction of the equivalent passing frequency, and, as a consequence, to the reduction of the vertical collision risk.

On the Vertical Technical Performance

It was not possible to verify the parameters lateral overlap probability [$P_y(0)$] and vertical overlap probability [$P_z(1000)$], and, as a consequence, it was not possible to verify: the global height-keeping performance specification; the MASPS criteria; the evidences of the ASE stability; the causes of the inconsistency of the height-keeping error; and the technical TLS.

On the Operational Performance

It was not possible to determine the Total Collision Risk, but it was possible to estimate the operational collision risks (due to the errors that lead the aircraft to level at a wrong level and to cross levels without clearance), assuming the maximum values of $P_y(0)$ and $P_z(0)$ considered in the safety assessment in other regions.

Results

The values of the collision risk for all the considered parts of the airspace from the CAR/SAM regions are exposing: at the CAR region the risk is 16.4 x TLS; at the SAM region the risk is 7.2 x TLS; at the CAR/SAM regions the risk is 10.32 x TLS; at the Chile-Cuba corridor the risk is 9.1 x TLS; at the Guayaquil-Piarco corridor the risk is 4.12 x TLS; and at the Amazonia-Port au Prince corridor the risk is 3.13 x TLS.

The Large Height Deviations (LHD)

The main operational errors are related to ATC-unit to ATC-unit transition message (252 codes M) and negative transfer received from transitioning ATC-unit (144 codes N).

The States should become aware that every error needs a corrective action to be taken independently of any result of the risk assessment. Therefore, corrective measures should be adopted to eliminate the errors of the types listed on Table 10, i.e., errors type A, B, C, D, E, F, G, H, I, J, K, L, M, N, besides the unknown error types O and P.

LHD Code	VP 2004	IOP 2005	MP-I 2006	MP-II 2007	MP-III 2008	MP-IV 2009
A	2	2	2	0	1	7
B	3	6	0	1	8	8
C	0	0	0	0	1	2
D	0	0	0	0	6	5
E	0	0	0	0	2	7
F	0	0	1	0	2	5
H	0	0	1	0	1	3
I	0	0	6	31	2	9
J	0	0	0	0	0	2
M	16	4	56	76	197	252
N	0	0	0	1	63	144
O	0	0	0	1	0	3
P	0	0	3	3	1	2
Total	**21**	**12**	**68**	**113**	**284**	**449**

VP – Verification Phase; IOP – Initial Operational Phase; Monitoring Phase I; Monitoring Phase II; Monitoring Phase III; Monitoring Phase IV

Table 16 – Gradual Development of the Large Height Deviation (LHD)

The gradual development of the LHD presented on Table 16, corroborates the conclusions with respect to the possibility of collision at the CAR/SAM regions. Therefore, vigorous efforts are needed so that the States feel encouraged to apply additional safety measures.

On the Location of the Monitoring Facilities

It should be emphasized that, among the strategic positions chosen to install the monitoring unit system, the corridor Chile-Cuba and Brazil should be considered as strong candidates as they cover practically the entire aircraft population (listed on Table 5) flying in the CAR/SAM regions.

On the CAR/SAM Monitoring Agency

CARSAMMA is endowed with sufficient expertise to assess the safety of the airspaces. It has expertise to fulfill its obligations in regard to monitoring the airspace of the CAR/SAM regions. However, the establishment of a capacity to generate data from height keeping monitoring systems depends on a joint initiative of the States.

4. Special Recommendation

To the fulfillment of the resolution of the Fifth Meeting/Workshop of the Scrutiny Working Group (GTE/5), written below:

"2.2 Also, the meeting recalled that GREPECAS took note that RVSM post-implementation safety assessment carried considering the technical risk plus the risk for all the other causes, shows that the total risk for the CAR/SAM Regions is greater than the TLS agreed and that this total risk is influenced by large-height deviations (LHD).

2.3 Taking into consideration that the Scrutiny Group (SG) in analyzing the LHD, verified that errors are not caused by RVSM operation but for common procedures in aircraft transference from an ATC unit to another one. For this reason, new corrective actions at short and midterm were proposed, therefore, GREPECAS/13 considered that these measures are additional to those contained in Conclusion 13/61.

2.4 In addition to the short-term actions, to find a solution to the identified LHD cause, GREPECAS encouraged States and International Organizations to implement a safety management system and as far as possible, as a technological defense, to gradually implement data communications between ATS (AIDC).

2.5 On the other hand, GREPECAS/14 considered that in order to significantly reduce the occurrence of this type of errors, CAR/SAM States and International Organizations should, as an urgent matter, commit to adopt the measures referred in Conclusion GREPECAS 13/61 "Measures to reduce operational errors in the ATC coordination loop between adjacent ACCs", and particularly the error prevention programme in ATC coordination cycle between adjacent ATS units, associated to the referred conclusion and additional measures previously described (See Appendix B to this part of the report)."

5. Additional Recommendations

All the recommendations made in the assessment of 2007, which are transcribed below, remain valid:

The recommendations described in this section have the objective of helping in the efforts that will be required by the next tasks associated with the collision risk evaluation after the RVSM implementation in the CAR/SAM regions.

***Data on the Traffic Flow** – approximately 40% of the received data could not be treated due to different reasons: from lack of understanding on how the data should be transcribed to the spreadsheets to inconsistency of data. It is advisable that, before the collection of data, States pay attention to the guidelines developed for this procedure and approved by the RVSM TF.*

***Data on Technical Vertical Deviation** – a planning effort should be made to define the best methodology of data collection on technical vertical deviation. Additionally, a work program should be elaborated to show that the Altimetry System Error (ASE) for RVSM-approved aircraft remains steady. This task could be carried out along with the implementation of a monitoring program of the aircraft altimetry system performance. Such program will have to foresee the monitoring of the mentioned system of altimetry at least each two years or after 1000 flight hours per aircraft (whichever occurs later).*

***On Altimetry System Monitoring** - the CAR/SAM regions will have to establish a program for implantation of monitoring units for the verification of aircraft altimetry system. This program will have to be composed of a system of independent monitoring units (AGHME) installed in positions strategically located in the areas of higher traffic flow density. The objective is to monitor the largest possible number of aircraft for verification of the stability of the altimetry system error (ASE) and to check if the technical risk remains compatible with the agreed TLS of 2.5E-9.*

***Data on Vertical Deviations due to Operational Errors** - Information on these types of events is obtained through ATC or pilot's reports. Unfortunately important data on these deviations, like number of crossed flight levels and time spent at non-authorized flight level, are rarely informed. As these deviations are consequences of errors or contingency actions, States should develop a work plan to obtain these data with a high level of confidence and share them with CARSAMMA.*

States/International Organizations and airlines should continue to apply their best efforts toward obtaining and informing to CARSAMMA of LHD events.

On Deviation Due to the Collision Avoidance System (ACAS/TCAS) Resolution Advisories

The monitoring of the deviation due to the collision avoidance system should be effective in order to check the operational performance.

6. References

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7. List of Acronyms

AAD – Assigned Altitude Deviation

ACAS – Airborne Collision Avoidance System

ACC – Area Control Center

ASE – Altimetry System Error

ATC – Air Traffic Control

ATS – Air Traffic Service

CAR/SAM – Caribbean/South America Region

CARSAMMA – Caribbean/South America Region Monitoring Agency

CRM – Collision Risk Model

EUR – European Region

FIR – Flight Information Region(s)

FL – Flight Level

FTE – Flight Technical Error

MASPS – Minimum Aircraft System Performance Specification

MNPS – Minimum Navigation Performance Specifications

NAT – North Atlantic Region

NM – Nautical Mile

RGCSP – Review of General Concept of Separation Panel

RA – Resolution Advisory (generated by TCAS)

RMA – Regional Monitoring Agency

RNAV – Area Navigation

RNP –Required Navigation Performance

RVSM – Reduced Vertical Separation Minimum of 300m (1000 ft)

TCAS – Traffic Alert Collision Avoidance System

TLS – Target Level of Safety

TVE – Total Vertical Error

VP - Verification Phase

WG – Working Group

- END -