



**CAR/SAM Regional Planning and Implementation Group (GREPECAS)
Twenty-First Scrutiny Working Group Meeting (GTE/21)**

Zoom Meeting, 23-26 August 2021

Agenda Item 2: Review of the results of the large height deviation (LHD) analysis

2.3 Results of the safety assessment project in RVSM airspace of the CAR and SAM Regions

SAFETY ASSESSMENT IN RVSM AIRSPACE OF THE CAR/SAM FIRs

(Presented by CARSAMMA)

EXECUTIVE SUMMARY

This paper presents a summary of large height deviation (LHD) reports received by CARSAMMA, and their analysis using the SMS methodology advocated by ICAO and reasserted at a GREPECAS meeting as a recommendation to be applied by CARSAMMA in the CAR/SAM Regions.

| | |
|------------------------------|--|
| Action: | The suggested action is shown in section 5. |
| <i>Strategic objectives:</i> | <ul style="list-style-type: none">• Safety |
| <i>References:</i> | <ul style="list-style-type: none">• ICAO SMS Manual• 2019 large height deviation (LHD) report |

1. Introduction

1.1. The CAR/SAM Regional Planning and Implementation Group (GREPECAS) delegated to the Caribbean and South American Monitoring Agency (CARSAMMA) the implementation of the SMS methodology for the analysis of LHDs.

1.2. The SMS is used for estimating the risk value of the system. A significant improvement in the use of the SMS methodology for the analysis of LHDs is the system for risk assessment and rapid identification of trends and critical points where they occur, reducing the time required for conducting the system safety analysis.

1.3. This paper aims to provide a summary of the safety assessment in RVSM airspace of the CAR/SAM FIRs. The safety assessment was carried out over a period of twelve continuous months.

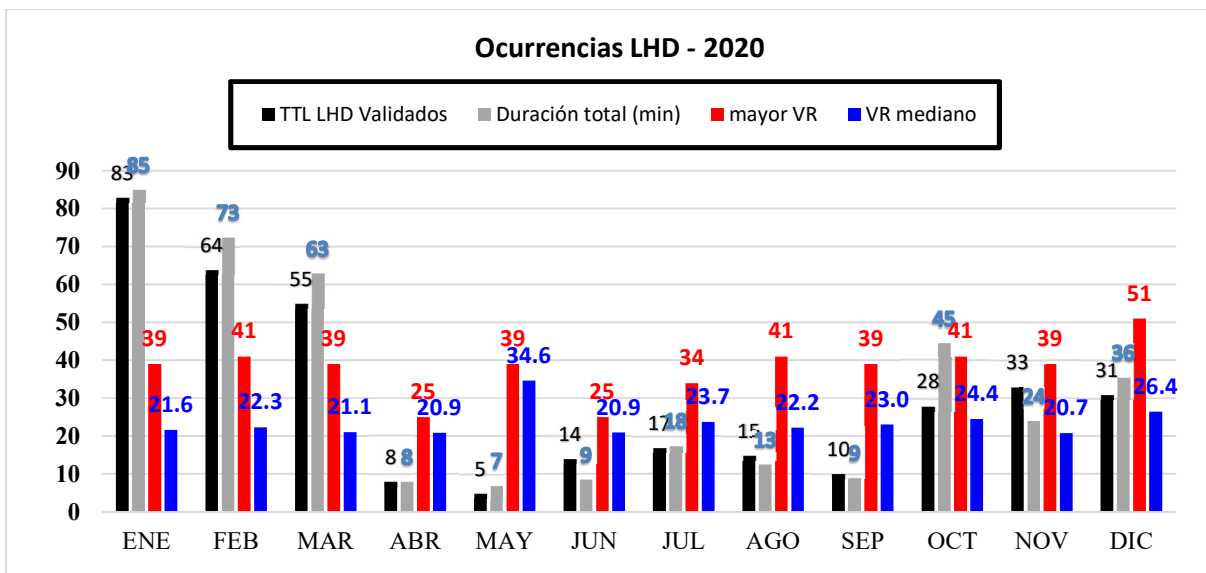
2. Context

2.1. LHD reports over a 12-month were used in this safety assessment. The period covers January through December 2020.

2.2. **Table 1 and Graph 1** summarize of validated LHD occurrences and the duration (in minutes) associated with the monthly LHDs that arrived at CARSAMMA.

| MONTH | NUMBER OF LHDs | DURATION Total (min.) | DURATION Average (min.) | RISK Average | Highest RISK |
|--------------|----------------|-----------------------|-------------------------|--------------|--------------|
| JANUARY | 83 | 85 | 1.02 | 21.6 | 39 |
| FEBRUARY | 64 | 73 | 1.13 | 22.3 | 41 |
| MARCH | 55 | 63 | 1.14 | 21.1 | 39 |
| APRIL | 8 | 8 | 1.00 | 20.9 | 25 |
| MAY | 5 | 7 | 1.40 | 34.6 | 39 |
| JUNE | 14 | 9 | 0.61 | 20.9 | 25 |
| JULY | 17 | 18 | 1.03 | 23.7 | 34 |
| AUGUST | 15 | 13 | 0.83 | 22.2 | 41 |
| SEPTEMBER | 10 | 9 | 0.90 | 23.0 | 39 |
| OCTOBER | 28 | 45 | 1.59 | 24.4 | 41 |
| NOVEMBER | 33 | 24 | 0.73 | 20.7 | 39 |
| DECEMBER | 31 | 36 | 1.15 | 26.4 | 51 |
| TOTAL | 363 | 387 | 1.07 | 22.5 | |

Table 1. LHD occurrences, with the duration, average duration, average risk, and highest risk per month



Graph 1. LHD occurrences, with the average duration, average risk, and highest risk per month

2.3. In October, two (2) events were recorded, which together lasted 19 minutes of the total of 44.5 minutes for the month, the two alone accounting for 43% of the duration. The two occurred in the Curaçao FIR, report 343 (VR = 41), position AMBIN, due to lack of coordination by the Kingston ACC, 17 minutes, and the other, in position BEROX, due to lack of coordination by the Santo Domingo ACC, report 334 (VR = 21), 2 minutes.

2.4. In December, two (2) occurrences together lasted 9 minutes of the total of 35.5 minutes of the failures occurred in the month, the two alone accounting for 25% of the duration. The reports occurred in the Piarco FIR, position TRAPP (50 NM NORTH), due to lack of coordination by the Paramaribo ACC, 7 minutes, report 423 (VR = 51), the longest of the year and in the Mendoza FIR,

position UMKAL (LATERAL DE GUVOL), due to lack of coordination by the Santiago ACC, 2 minutes, report 403 (VR = 31).

2.5. In August, one (1) occurrence lasted 3 minutes of the total of 12.5 minutes of the failures occurred in the month, that single report accounting for 24% of the duration. The report occurred in the Panama FIR, ALPON position, due to lack of coordination by the Barranquilla ACC, report 295 (VR = 41).

2.6. In February, five (5) events occurred, which together lasted 17 minutes of the total 72.5 minutes for the month, accounting for 23% of the duration. The reports occurred in the Cayenne FIR, one (1) report due to failure of coordination in the Amazónica ACC, 3 minutes, ARNAM position, report 101 (VR = 29), in the Panama FIR, due to failure and lack of coordination in the Bogotá ACC, three (3) reports, lasting 3 minutes each, for a total of 9 minutes, reports 110 (VR = 29), position ILTUR, report 126 (VR=41), position KAKOL, report 170 (VR=34), position DAKMO, and in the Barranquilla ACC, due to coordination failure, 4 minutes, report 136 (VR = 34), position 1228N 07725W.

2.7. In 2020, several LHD reports were identified in which the Guayaquil FIR was at risk due to failure in the Bogotá ACC, mainly due to coordination errors, lack of coordination or transfer issues caused by the equipment, where the TCPs involved were UGUI (41), BOKAN (19), PULTU (13), ENSOL (12), ANRAX (4), VAMOS (4) and AKTAB (1), a total of 94 failures in the Bogotá ACC.

2.8 During the period of analysis, several reports were identified in which the Guayaquil FIR generated risk for the Bogotá FIR in the same TCPs, UGUI (9), ENSOL (9), BOKAN (5) and, GAVUT (1), for a total of 24 events.

Figure 1 shows the TCPs reported in the previous paragraph and the number of reports that occurred in each TCP. It is recommended that the necessary mitigation measures be taken.

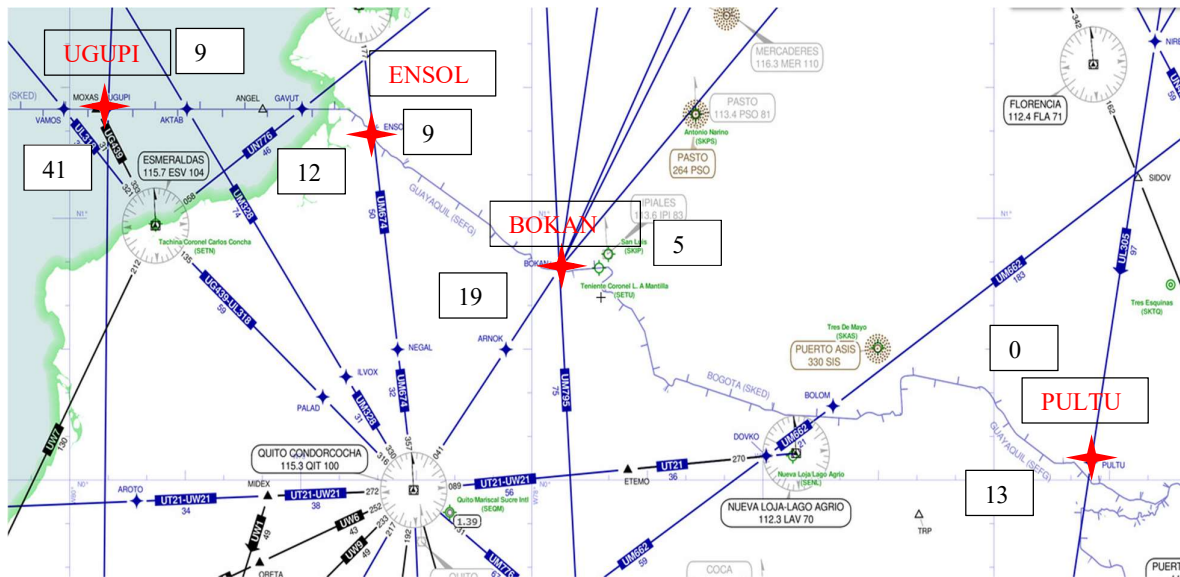


Figure 1. LHD occurrences at the most reported points between the Guayaquil FIR and the Bogotá FIR

2.9. In 2020, several LHD reports were identified in which the Amazónica FIR was at risk due to failure in the Bogotá ACC due to coordination errors, lack of coordination, or transfer issues caused by the equipment. The TCPs involved were ABIDE (6), ARUXA (3), BRACC (3), ASAPA (1) and, LET (1), with a total of 14 failures. Likewise, in the Amazónica ACC, similar errors were identified in the same TCPs with the Bogotá FIR, ABIDE (4) and, BRACC (1), with a total of 5 failures. **Figure 2** shows all the TCPs

reported in the previous paragraph and the number of reports in each TCP. It is recommended that the necessary mitigation measures be taken.

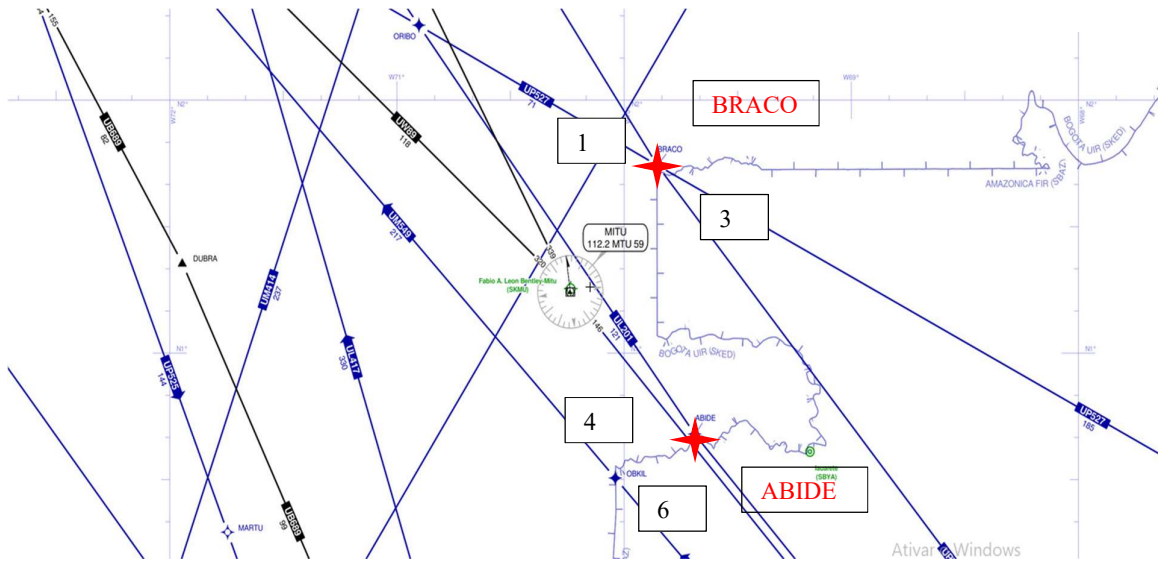


Figure 2. LHD occurrences at the most reported points between the Amazonica FIR and the Bogotá FIR

2.10. During 2020, several LHDs were reported in which the Lima FIR was at risk due to failures in the Guayaquil ACC, mainly due to coordination errors, lack of coordination, or transfer problems caused by the equipment. The TCPs involved were VAKUD (4) and PABOB (4), ANPAL (2) and LOBOT (1), with a total of 11 failures. Events were also identified where the Lima ACC generated risk to the Guayaquil FIR in VAKUD (7), TOSES (5), ARNEL (5), PABOB (2), AMERO (1), and TERAS (1), with a total of 21 failures. Figure 3 shows the TCPs, and the number of reports occurred in each TCP. It is recommended that the necessary mitigation measures be taken.

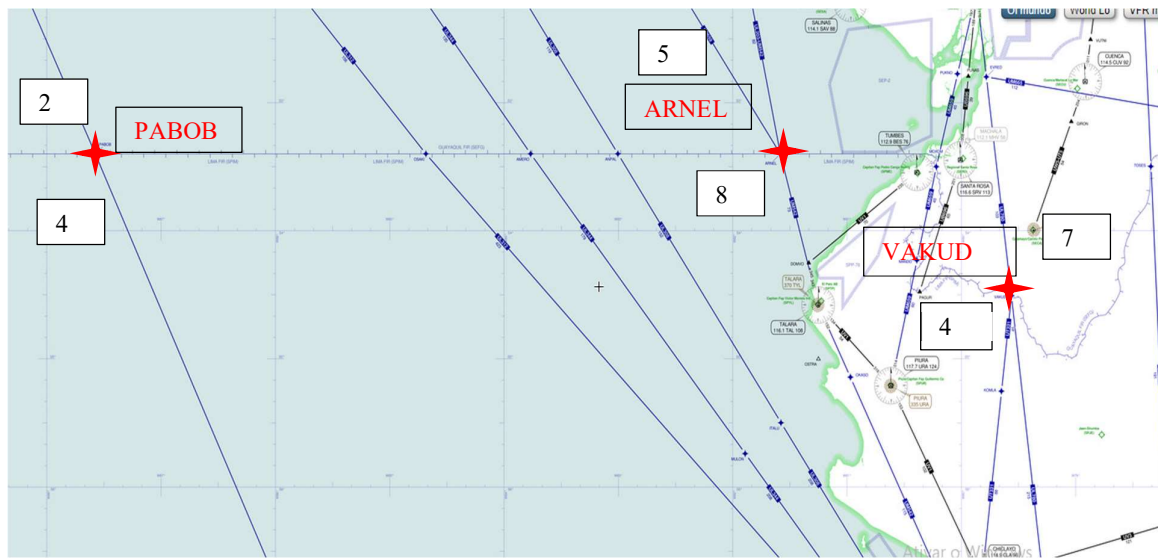


Figure 3. LHD occurrences at the most reported points between the Lima FIR and the Guayaquil FIR

2.11. During 2020, several LHDs were reported in which the Bogotá FIR was at risk due to errors in the Panama ACC, with a total of fourteen events (14) at BUXOS (5), DAKMO (3), ARORO (1), BUSMO (1), ILTUR (1), IVROS (1), TINPA (1) and TOKUT (1).. During this period, events were identified

where the Bogotá ACC generated risk to the Panama FIR, at DAKMO and BUXOS (3), ILTUR (2), BOLDO, KAKOL, and TOKUT (1) with a total of eleven (11) errors.

2.12. Several LHDs were reported in which the Bogotá FIR was at risk due to failures/errors of the Maiquetia ACC, seven (7) failures at ENPUT and three (3) KIKAS and one at (1) OPRUS. . During this period, events were identified in which the Bogotá ACC generated risk to the Maiquetia FIR, at ENPUT, CUC, KIKAS, and OPRUS one event in each TCP for a total of 4 failures.

2.13. During 2020, LHD reports were received in which the Lima FIR was at risk due to failures/errors in the Bogotá ACC, eight (8) failures at ROLUS (5), ILMUX, PLG and TERAS (1). No events were reported where the Bogotá FIR generated risk to the Lima FIR.

2.14. In 2020, LHD reports were received in which the Lima FIR was at risk due to failures/errors from La Paz ACC, 8 failures in DOBRI, ELAKO (2), OBLIR, ORALO, PDO and RAXUN (1). The Lima ACC also generated risk to La Paz FIR in DOBNI and ORALO (2), with a total of 4 failures.

2.15. During 2020, LHD events were reported in which the La Paz FIR was at risk due to failures/errors in the Amazónica ACC, five (5) events in RCO (5). During the period, events were reported in which the La Paz ACC generated risk at RCO (2), with the Amazónica FIR.

2.16. In 2020, LHD reports were received in which the Amazónica FIR was at risk due to failures/errors in the Maiquetia ACC, 12 failures at the POVLA (5), VUMPI (3), PAKON (2), AKPEP (1) and VAGAN (1) TCPs. No reports were received in which the Amazónica FIR generated risk to the Maiquetia FIR.

2.17. During the assessment period, LHDs were identified in which the Santo Domingo FIR was at risk due to failures/errors in the Port-au-Prince ACC, 6 failures at DCR (3), RETAK (2), and PIGBI (1). A total of two events caused by the Santo Domingo ACC were identified at PIGBI (1) and RETAK (1), which generated risk to the Port-au-Prince FIR.

2.18. In 2020, LHD reports were received in which the Port-au-Prince FIR was at risk due to failures/errors in the Miami ACC, 6 failures at the JOSES (3), DODLO, ALBEE and BOTES TCPs (1 each). No reports were received from the Miami FIR regarding events of risk generated by the Port-au-Prince ACC in 2020.

2.19. During 2020, LHD reports were received in which the Santo Domingo FIR was at risk due to failures/errors in the Curacao ACC, eight (8) failures at KARUM (3), PALAS (2) and VESKA (2) and BEROX (1); likewise, a total of 3 events were identified where the Santo Domingo ACC generated risk to the Curacao FIR, at BEROX (2) and PALAS (1).

2.20. During 2020, several LHD reports were identified in which the Kingston FIR was at risk due to failures/errors in the Barranquilla ACC, 9 events in total at OTAMO (4), KILER (3), BOBKA (1) and EDROD (1). During the period, no occurrences were identified in which the Kingston ACC generated risk to the Barranquilla FIR.

2.21. **Table 2** quantifies the events described in the paragraphs above, including the FIRs with the **most** reported TCPs in 2020.

| FIR AT RISK | FIR THAT CAUSED THE FAILURE | REPORTS SUBMITTED | TCP | NUMBER OF EVENTS BY FIR | TOTAL |
|-----------------|-----------------------------|-------------------|--------|-------------------------|------------|
| GUAYAQUIL | BOGOTÁ | 41 | UGUPI | 92 of 94 | 109 of 115 |
| | | 19 | BOKAN | | |
| | | 13 | PULTU | | |
| | | 12 | ENSOL | | |
| | LIMA | 7 | VAKUD | 17 of 21 | |
| | | 5 | ARNEL | | |
| 5 | | TOSES | | | |
| BOGOTÁ | GUAYAQUIL | 9 | UGUPI | 23 of 24 | 44 of 53 |
| | | 9 | ENSOL | | |
| | | 5 | BOKAN | | |
| | MAIQUETIA | 3 | KIKAS | 6 of 7 | |
| | | 3 | ENPUT | | |
| | PANAMA | 5 | BUXOS | 8 of 14 | |
| | | 3 | DAKMO | | |
| CENTRAL AMERICA | 3 | BOLDO | 3 of 3 | | |
| AMAZONICA | 4 | ABIDE | 4 of 4 | | |
| LIMA | GUAYAQUIL | 4 | VAKUD | 8 of 12 | 23 of 35 |
| | | 4 | PABOB | | |
| | BOGOTÁ | 5 | ROLUS | 5 of 7 | |
| | ANTOFAGASTA | 2 | ALDAX | 2 of 3 | |
| | LA PAZ | 2 | DOBNI | 4 of 8 | |
| | | 2 | ELAKO | | |
| AMAZONICA | 4 | LET | 4 of 4 | | |
| AMAZÓNICA | BOGOTÁ | 6 | ABIDE | 12 of 14 | 24 of 33 |
| | | 3 | ARUXA | | |
| | | 3 | BRACO | | |
| | LA PAZ | 2 | RCO | 2 of 2 | |
| | MAIQUETIA | 5 | POVLA | 10 of 12 | |
| | | 3 | VUMPI | | |
| 2 | | PAKON | | | |
| PANAMA | BOGOTÁ | 3 | BUXOS | 8 of 11 | 9 of 16 |
| | | 3 | DAKMO | | |
| | | 2 | ILTUR | | |
| | BARRANQUILLA | 1 | AGUJA | 1 of 4 | |
| MAIQUETIA | BOGOTÁ | 1 | ENPUT | 1 of 4 | 2 of 5 |
| | BARRANQUILLA | 1 | SEMDO | 1 of 1 | |
| LA PAZ | AMAZONICA | 5 | RCO | 5 of 5 | 11 of 12 |
| | ASUNCION | 2 | SIDAK | 2 of 2 | |
| | LIMA | 2 | DOBNI | 4 of 4 | |
| | | 2 | ORALO | | |

NOTE: Note that 3 FIRs are almost always present (in blue, red and green).

| FIR AT RISK | FIR THAT CAUSED THE FAILURE | REPORTS SUBMITTED | TCP | NUMBER OF REPORTS BY FIR | TOTAL |
|----------------|-----------------------------|-------------------|-------|--------------------------|----------|
| CURACAO | BARRANQUILLA | 2 | OROSA | 2 of 3 | 6 of 8 |
| | KINGSTON | 1 | AMBIN | 1 of 1 | |
| | PORT AU PRINCE | 1 | LENOM | 1 of 1 | |
| | SANTO DOMINGO | 2 | BEROX | 2 of 3 | |
| SANTO DOMINGO | CURACAO | 3 | KARUM | 7 of 8 | 12 of 14 |
| | | 2 | PALAS | | |
| | | 2 | VESKA | | |
| | PORT-AU-PRINCE | 3 | DCR | 5 of 6 | |
| | | 2 | RETAK | | |
| PORT-AU-PRINCE | HAVANA | 2 | URLAM | 2 of 2 | 9 of 13 |
| | KINGSTON | 3 | KEBET | 3 of 3 | |
| | MIAMI | 3 | JOSES | 3 of 6 | |
| | SANTO DOMINGO | 1 | PIGBI | 1 of 2 | |
| KINGSTON | BARRANQUILLA | 4 | OTAMO | 7 of 9 | 8 of 10 |
| | | 3 | KILER | | |
| | HAVANA | 1 | KATAL | 1 of 1 | |

Table 2. Points of LHD occurrences, indicating FIRs involved – Most reported points

2.22. **Table 3** and **Figure 4** show the reported points, involving the Colombian FIRs (Barranquilla and Bogotá) with the adjacent FIRs.

| FIX | NUMBER | TOTAL RV FOR EACH POINT | FIX | NUMBER | TOTAL RV FOR EACH POINT | FIX | NUMBER | TOTAL RV FOR EACH POINT |
|-----------------|--------|-------------------------|-------|--------|-------------------------|--------------|------------|-------------------------|
| 1228N 07725W | 1 | 34 | BUSMO | 1 | 22 | LET | 1 | 22 |
| ABIDE | 10 | 212 | BUXOS | 8 | 172 | OPRUS | 2 | 44 |
| AGUJA | 1 | 22 | CUC | 1 | 18 | OROSA | 2 | 44 |
| AKTAB | 1 | 27 | DAKMO | 6 | 126 | OTAMO | 4 | 77 |
| ALPON | 1 | 41 | EDROD | 1 | 22 | PLG | 1 | 18 |
| ANRAX | 4 | 89 | ENPUT | 4 | 95 | PULTU | 13 | 271 |
| ARORO | 1 | 18 | ENSOL | 21 | 465 | ROLUS | 5 | 107 |
| ARUXA | 3 | 62 | GAVUT | 1 | 22 | SELAN | 1 | 18 |
| ASAPA | 1 | 22 | ILMUX | 1 | 18 | SEMDO | 1 | 13 |
| BOBKA | 1 | 18 | ILTUR | 3 | 60 | TINPA | 1 | 18 |
| BOGAL | 1 | 21 | IVROS | 1 | 22 | TOKUT | 2 | 40 |
| BOKAN | 24 | 590 | KAKOL | 1 | 41 | UGUPI | 50 | 1170 |
| BOLDO | 5 | 190 | KIKAS | 4 | 80 | VAMOS | 4 | 88 |
| BRACO | 4 | 84 | KILER | 3 | 63 | TOTAL | 201 | 4.586 |

Table 3. Points of LHD occurrence involving the Colombian FIRs with adjacent FIRs

2.22 A total of 201 reports (56.5%) were identified of a total of 356 validated reports for the CAR/SAM Regions involving 41 fixes whose RV added up to 4,586 points, accounting for 57.2% of the total RV obtained for the entire CAR/SAM Regions (8,019 points).

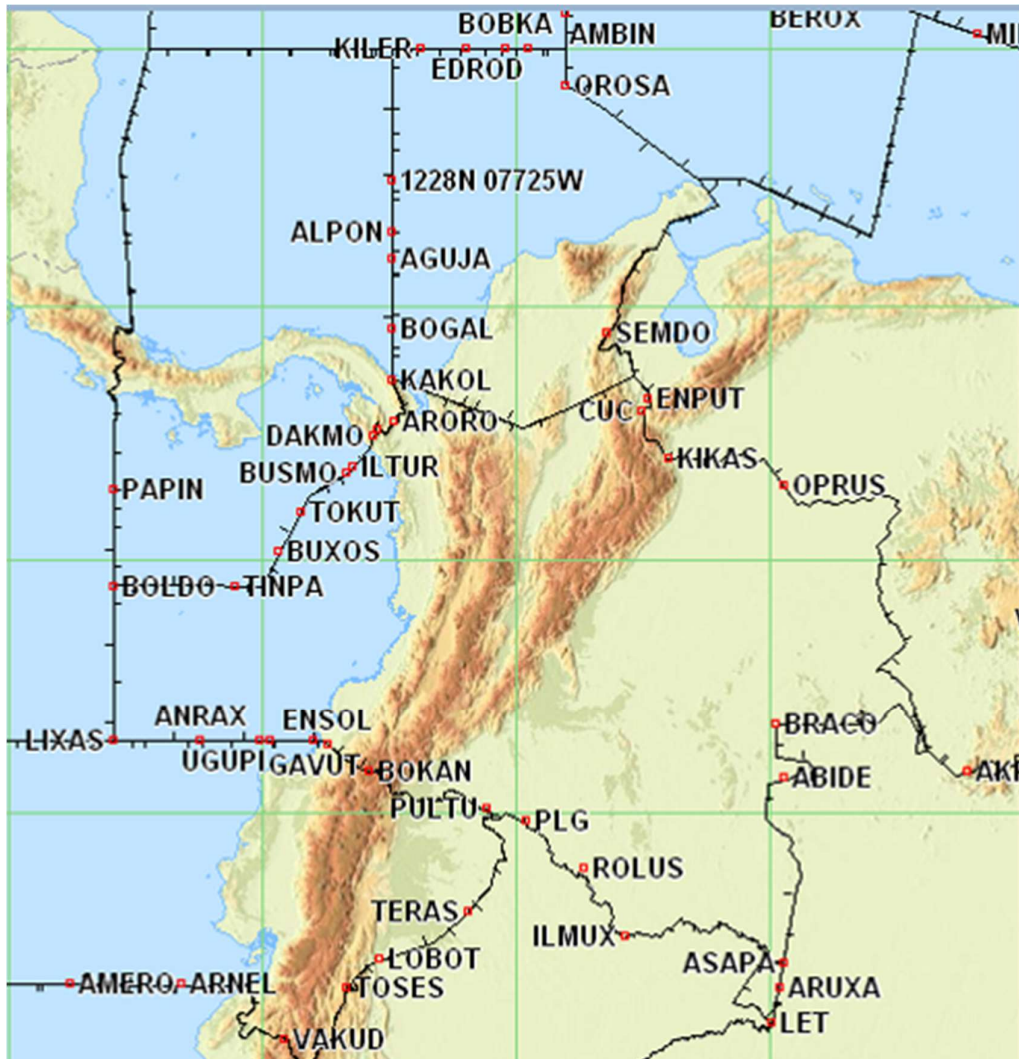


Figure 4. LHD occurrences at points shared by the Colombian FIRs and the adjacent FIRs

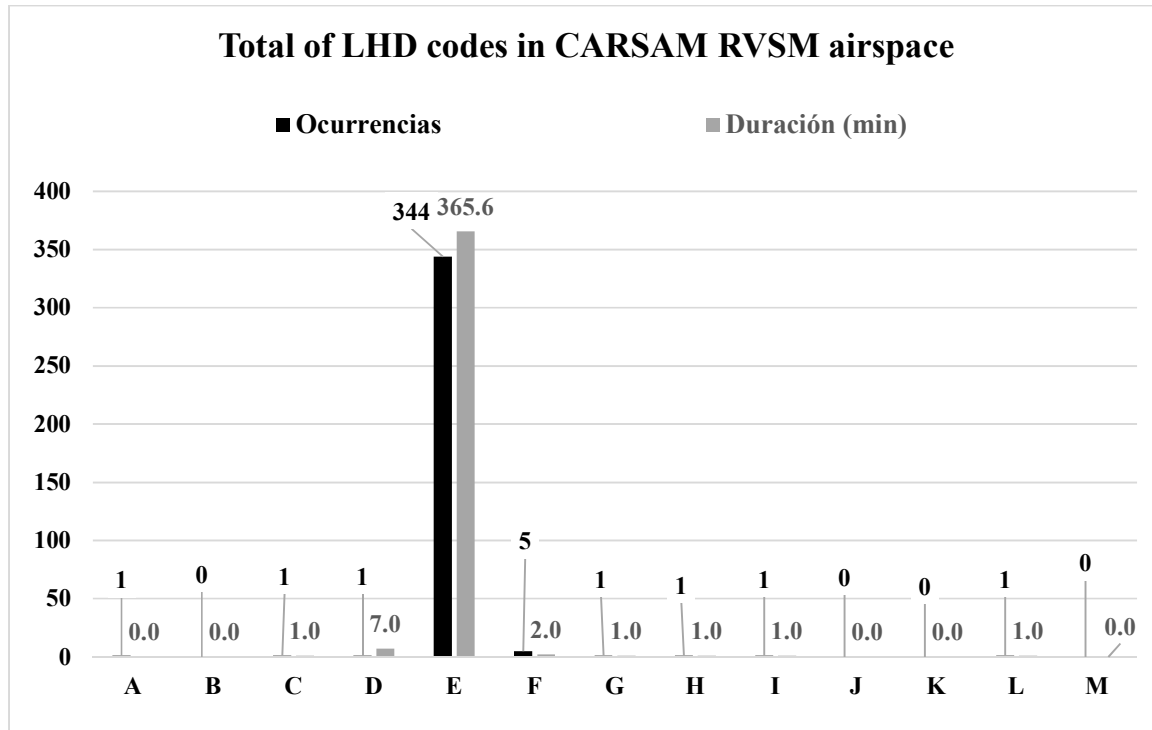
- 2.23. The reports received show long-duration LHD events of four (4) minutes or more.
- i. According to report no. 343, in October, at the Curacao FIR, there was an occurrence that lasted 17 minutes, due to lack of coordination in the Kingston ACC, with a RV = 41.
 - ii. In the La Paz FIR, in March, report no. 226 showed an occurrence that lasted 12 minutes, due to lack of coordination in the Asuncion ACC, with an RV = 39.
 - iii. In the Piarco FIR, in January, report no. 13 showed an occurrence that lasted 7 minutes, due to pilot error, with an RV = 37.
 - iv. In the Piarco FIR, in December, report no. 423 showed an occurrence that lasted 7 minutes, due to lack of coordination of the Paramaribo ACC, with an RV = 51, the highest observed in 2020.

- v. In the Cayenne FIR, in February, report no. 101 showed an occurrence that lasted 4 minutes due to poor coordination by the Amazónica FIR, with an RV = 29.
- vi. In February in the Panama FIR, , report no. 136 showed an occurrence that lasted 4 minutes due to poor coordination in the Barranquilla ACC, with an RV = 34.

2.24. **Table 4 and Graph 2** summarise the number of reported LHD occurrences, the duration (in minutes) associated with the LHD code, and the number of flight levels crossed without clearance, from 1 January to 31 December 2020 inclusive, in CAR/SAM RVSM airspace.

| LHD Code | LHD code description | No. of LHD occurrences | Duration of LHD (min) | Levels crossed without clearance |
|--------------|--|------------------------|-----------------------|----------------------------------|
| A | Failure to climb/descend as cleared. | 1 | 0.0 | 2 |
| B | Climb/descend without ATC clearance. | 0 | 0.0 | 0 |
| C | Incorrect operation or interpretation of airborne equipment (e.g., incorrect operation of fully functional FMS, incorrect transcription of ATC clearance or re-clearance, flight plan followed rather than re-clearance, etc.) | 1 | 1.0 | 0 |
| D | ATC system loop error (e.g., ATC issues incorrect clearance or flight crew misunderstands clearance message) | 1 | 7.0 | 2 |
| E | Coordination error in ATC-to-ATC transfer of control due to human factor issues (e.g., late or non-existent coordination; incorrect time estimate/actual time; flight level, ATS route, etc. not in accordance with agreed parameters) | 344 | 365.6 | 343 |
| F | Coordination errors in ATC-to-ATC transfer of control due to equipment outage or technical issues | 5 | 2.0 | 0 |
| G | Deviation due to aircraft contingency leading to sudden inability to maintain assigned flight level (e.g., pressurization failure, engine failure) | 1 | 1.0 | 0 |
| H | Deviation due to airborne equipment failure leading to unintentional or undetected change of flight level | 1 | 1.0 | 0 |
| I | Deviation due to turbulence or other weather-related cause | 1 | 1.0 | 1 |
| J | Deviation due to TCAS resolution advisory, flight crew correctly following the TCAS resolution advisory | 0 | 0.0 | 0 |
| K | Deviation due to TCAS resolution advisory, flight crew incorrectly following the TCAS resolution advisory | 0 | 0.0 | 0 |
| L | An aircraft being provided with RVSM separation while not being RVSM approved (e.g., flight plan indicates RVSM approval but aircraft not approved, ATC misinterpretation of flight plan) | 1 | 1.0 | 0 |
| M | Other - this includes situations of flights operating (including climbing/descending) in airspace where flight crews are unable to establish normal air-ground communications with the responsible ATS unit | 0 | 0.0 | 0 |
| Total | (Jan 2020 – Dec 2020) | 356 | 379.6 | 348 |

Table 3. Summary of LHD occurrences and duration by LHD code

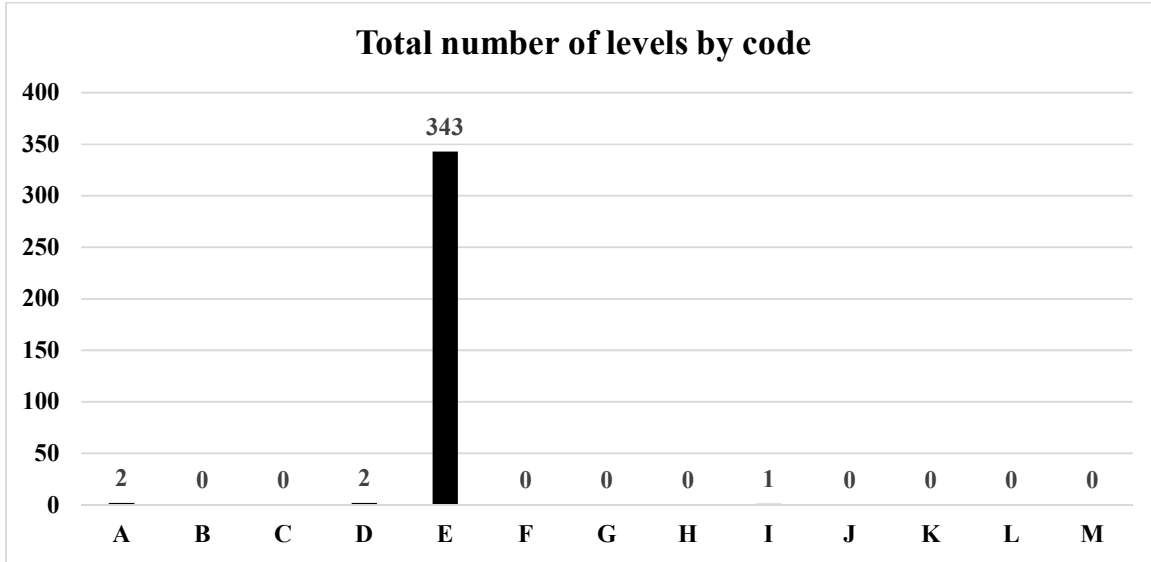


Graph 2. Total of LHD codes in CAR/SAM RVSM airspace

2.25. Once again, “E”-coded LHD reports (ATC-to-ATC coordination error) were the most frequent in 2020, with 34 events, followed by codes “F” (5), “A”, “C”, “D”, “G”, “H”, “I” and “L” (all with 1). The high number of code “E” reports reveals the need for better coordination between adjacent ATC units, which could be achieved through awareness-raising and training on coordination between controllers. It is essential to mention that “F”-coded events decreased compared to 2018 and 2019. The 2020 behaviour is mainly because on 14 April and 14 May 2019, at the two teleconferences held with the POCs of the region, it was agreed that events related to this code were not caused by equipment failure but by ATC operational problems. Accordingly, a review of all the 2019 reports was requested, and the change was made to “E1” and “E2”.

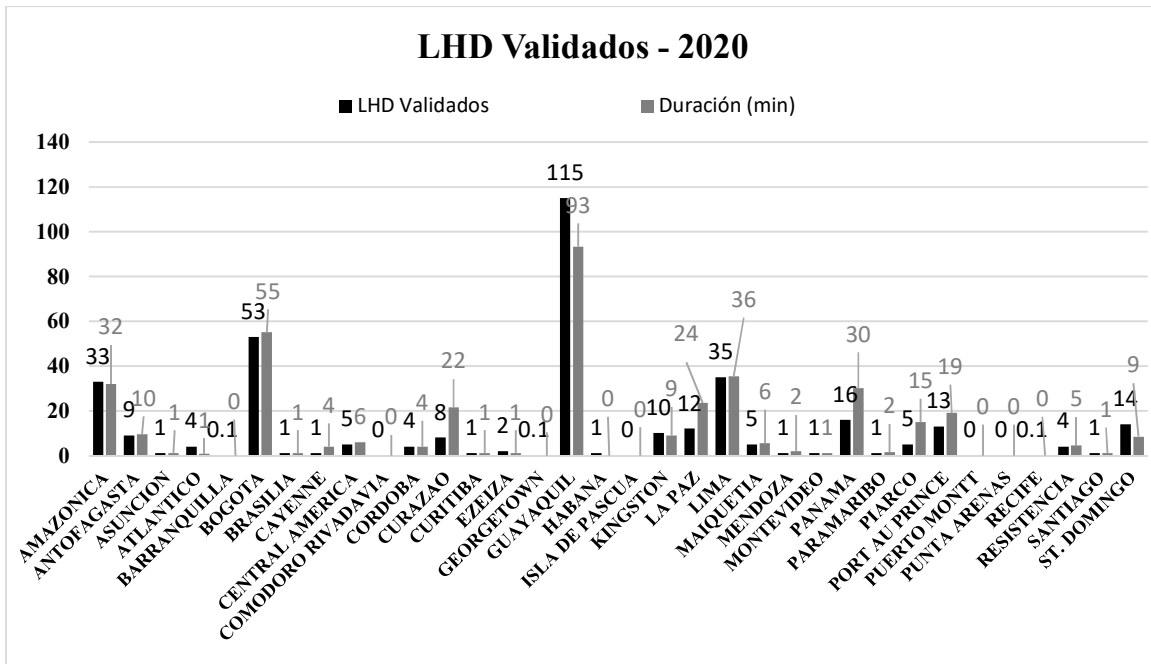
2.26 **Graph 2** shows the significant duration of “E”-coded LHD reports, with a total duration of 21,935 seconds or 365.6 minutes or 6.1 hours. This is an important consideration as it has a direct impact on safety (total “E”-coded events: “E1” poor coordination - 162 reports, and “E2” lack of coordination- 182 reports).

2.27. **Graph 3** shows the total number of levels, by code, where level crossings occurred without clearance received from air traffic control. In this case, “E”-coded LHD reports were the most prominent, with 343 level crossings.



Graph 3. Total number of levels by code

Graph 4 shows the total number of validated LHD reports, by FIR. It should be noted that the Guayaquil, Bogotá, Lima, Amazónica and Panama FIRs have the largest absolute duration in minutes.



Graph 4. Summary of LHD occurrences by FIR

3. Risk value (RV) assessment

3.28. This section updates the results of the safety assessment of RVSM airspace in the CAR/SAM FIRs. The SMS methodology was applied to the internationally accepted safety assessment of this airspace.

3.29. Risk Value parameter estimates - The initial material for estimating the value of each parameter inherent to the internationally accepted risk value (RV) that was used for assessing safety in RVSM airspace is summarised in the following formula and described in **Table 5**.

$$VR = (P \times D \times S) + R + W + T, \text{ donde:}$$

| Parameter | Description | Value |
|-----------|-----------------------------|---|
| RV | Risk value | To be estimated |
| P | Probability of the position | Varies from 1 to 5 |
| D | Duration of the occurrence | Varies from 1 to 3 |
| S | Severity of the occurrence | Varies from 1 to 5 |
| R | With or without RADAR/ADS | With=5 or Without=10 |
| W | Meteorological conditions | VMC=0 or IMC=5 |
| T | Other traffic (if any) | Range varies from 5 (with radar) to 10 (without radar) |
| | TOTAL | Maximum 100 points |

Table 5. Calculation of risk value parameters

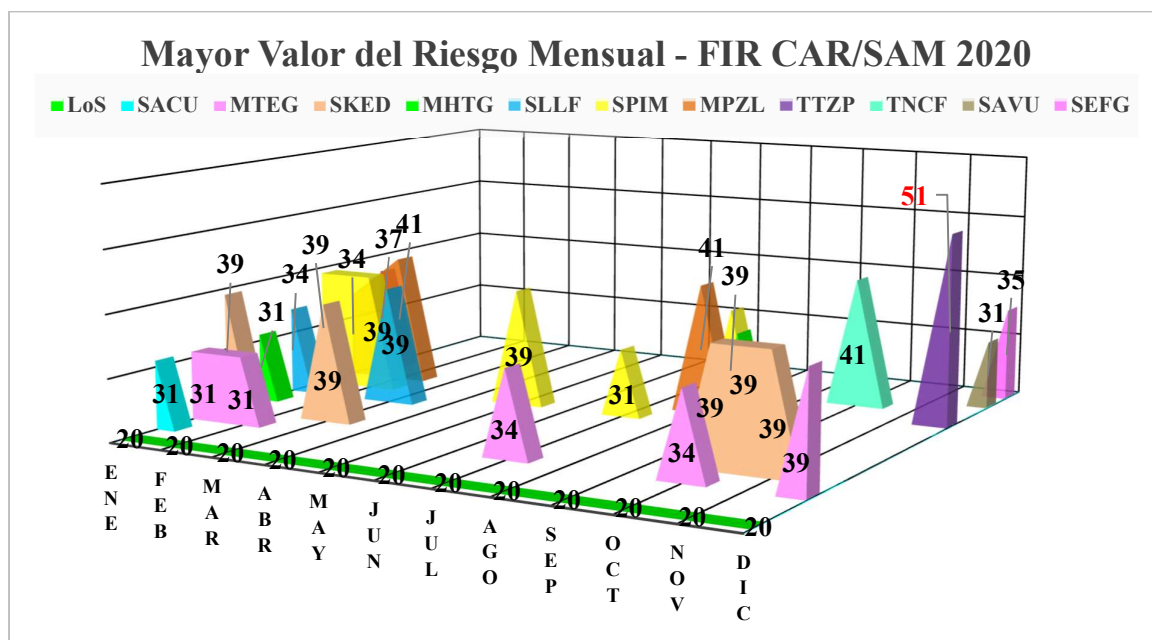
3.30. Safety assessment – The results of the safety assessment of RVSM airspace in CAR/SAM FIRs are shown in Table 6 and Figure 5 (FIRs with LHD reports with RV>30. The LoS limit was established at the ICAO GTE/11 meeting held in 2011 (Lima, Peru).

| | LoS | SA CU | MT EG | SK ED | MH TG | SL LF | SP IM | MP ZL | TT ZP | TN CF | SA VU | SE FG |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| JAN | 20 | 31 | 31 | 39 | 31 | 34 | 39 | 34 | 37 | | | |
| FEB | 20 | | 31 | | | | 39 | 41 | | | | |
| MAR | 20 | | | 39 | | 39 | | | | | | |
| APR | 20 | | | | | | | | | | | |
| MAY | 20 | | | | | | 39 | | | | | |
| JUN | 20 | | | | | | | | | | | |
| JUL | 20 | | 34 | | | | 31 | | | | | |
| AUG | 20 | | | | | | | 41 | | | | |
| SEP | 20 | | | | | | 39 | | | | | |
| OCT | 20 | | 34 | 39 | 39 | | | | | 41 | | |
| NOV | 20 | | | 39 | | | | | | | | |
| DEC | 20 | | 39 | | | | | | 51 | | 31 | 35 |

Table 6. Estimates of the highest risk value for the LHD for each month

3.31. In January 2020, there was still a "normal" volume of operations; however, several reports had high RVs. The Bogotá (SKED) and Lima (SPIM) FIRs had the highest RV (39). In February, still with a high level of traffic, the highest RV (41) occurred in the Panama FIR (MPZL). In March, with reduced traffic, the Bogotá (SKED) and the La Paz (SLLF) FIRs had the highest RV (41) (39). In April, all RVs were below the studied value. In May, the Lima FIR (SPIM) had the highest RV (39). In June, all RVs were below the studied value. In July, the Port-au-Prince FIR (MTEG) had the highest RV (34). In August, the Panama FIR (MPZL) had the highest RV (41). In September, the Lima FIR (SPIM) had the highest RV (39). In October, the Curacao FIR (TNCF) had the highest RV (41). In November, the Bogotá FIR (SKED) had the highest RV (39). In December, the Piarco FIR (TTZP) had the highest RV (51).

- 3.32. LHD report 423, submitted by the Piarco FIR in December 2020, with failure of the Paramaribo FIR, accounted for 6.23% of the risk assessment for that month, with an RV = 51, the largest in the sample.
- 3.33. LHD report 126, submitted by the Panama FIR in February, upon failure of the Bogotá FIR, accounted for 2.90% of the risk assessment for this month, with an RV = 41.
- 3.34. LHD report 295, submitted by the Panama FIR in August 2020, with failure of the Barranquilla FIR, accounted for 13.36% of the risk assessment for this month, with an RV = 41.
- 3.35. LHD report 343, submitted by the Curaçao FIR in October 2020, with failure of the Kingston FIR, accounted for 5.99% of the risk assessment for this month, with an RV = 41 and a duration of 1,020 seconds, the largest in the sample.
- 3.36. LHD reports 80 and 82, submitted by the Bogotá and Lima FIRs in January 2020, upon failure of Central America and La Paz FIRs, respectively, accounted for 4.44% of the risk assessment of this month, with an RV = 39 for each of the two reports.
- 3.37. LHD reports 106 and 123, submitted by the Lima FIR in February 2020, with failure of the La Paz and Guayaquil FIRs, respectively, accounted for 5.52% of the risk assessment for this month with an RV = 39 for each of the two reports.
- 3.38. LHD reports 203 and 226, submitted by the Bogotá and La Paz FIRs in March 2020, with failure of the Guayaquil and Asuncion FIRs, respectively, accounted for 6.92% of the risk assessment for this month, with an RV = 39 for each of the two reports.
- 3.39. LHD reports 245, 247, and 250, submitted by the Lima FIR in May 2020, with failure of the Guayaquil FIR in all three, accounted for 67.63% of the risk assessment for this month, with an RV = 39 for each of the three reports.
- 3.40. LHD report 318, submitted by the Lima FIR in September 2020, with failure of the La Paz FIR, accounted for 16.95% of the risk assessment for this month, with an RV = 39.
- 3.41. LHD report 342, submitted by the Bogotá FIR in October 2020, with failure of the Central America FIR, accounted for 5.70% of the risk assessment for this month, with an RV = 39.
- 3.42. LHD report 361, submitted by the Bogotá FIR in November 2020, with failure of the Central America FIR, accounted for 6.01% of the risk assessment for this month, with an RV = 39.
- 3.43. LHD report 433, submitted by the Port-au-Prince FIR in December 2020, with failure of the Havana FIR, accounted for 4.76% of the risk assessment for this month, with an RV = 39.
- 3.44. **Graph 5** shows the most significant risk values (RVs) that occurred in all months, based on LHD reports from 1 January to 31 December 2020.



Graph 5. Highest risk value for RVSAM airspace in CAR/SAM FIRs. The Green line is the LoS RV (20).

4. LHD safety analysis (SMS)

4.28. **Appendix A** lists all LHD reports identified during the 12 months of 2020, whose operational failures or errors were analysed at teleconferences or by CARSAMMA in conjunction with the POCs of the FIRs involved, and considered to be of a risk greater than 20 (> 20).

4.29. **Table 7** shows the FIRs that sustained risk or generated risk

| FIR | Sustained risk | % | Generated risk | % |
|--------------------|----------------|------|----------------|------|
| AMAZONICA | 33 | 9.3 | 15 | |
| ANTOFAGASTA | 9 | | 4 | |
| ASUNCION | 1 | | 4 | |
| ATLANTICO | 4 | | 1 | |
| BARRANQUILLA | 0 | | 17 | 5.0 |
| BOGOTÁ | 53 | 14.9 | 131 | 38.5 |
| BRASILIA | 1 | | 2 | |
| CAYENNE | 1 | | 0 | |
| CENTRAL AMERICA | 5 | | 4 | |
| COMODORO RIVADAVIA | 0 | | 0 | |
| CORDOBA | 4 | | 1 | |
| CURACAO | 8 | | 8 | |
| CURITIBA | 1 | | 1 | |
| EZEIZA | 2 | | 2 | |
| GEORGETOWN | 0 | | 3 | |
| GUAYAQUIL | 115 | 32.3 | 39 | 11.5 |
| HAVANA | 1 | | 3 | |
| EASTER ISLAND | 0 | | 0 | |
| KINGSTON | 10 | | 5 | |
| LA PAZ | 12 | | 14 | |
| LIMA | 35 | 9.8 | 32 | 9.4 |
| MAIQUETIA | 5 | | 19 | 5.6 |

| | | | | |
|---|------------|-----------------------|------------|-----------------------|
| MENDOZA | 1 | | 0 | |
| MONTEVIDEO | 1 | | 1 | |
| PANAMA | 16 | 4.5 | 14 | |
| PARAMARIBO | 1 | | 2 | |
| PIARCO | 5 | | 0 | |
| PORT-AU-PRINCE | 13 | | 7 | |
| PUERTO MONTT | 0 | | 0 | |
| PUNTA ARENAS | 0 | | 0 | |
| RECIFE | 0 | | 1 | |
| RESISTENCIA | 4 | | 4 | |
| SANTIAGO | 1 | | 1 | |
| ST. DOMINGO | 14 | | 5 | |
| TOTAL | 356 | 70.8 | 340 | 70.0 |
| NOTE 1: Total reports filed/filled by CAR FIRs = 56; filed/filled by SAM FIRs = 300. | | | | |
| NOTE 2: In the column “sustained risk”, these 5 FIRs alone sustained 70.8% of the CAR/SAM Regions risk. All from the SAM Region. | | | | |
| NOTE 3: In the column “generated risk”, these 5 FIRs alone generated 70.0% of the CAR/SAM Regions. All from the SAM Region risk. | | | | |
| ADJACENT FIRs OTHER (*) (**) | | Sustained risk | | Generated risk |
| ABIDJAN | | 0 | | 2 |
| AIRCRAFT | | 0 | | 2 |
| LA PAZ APP | | 0 | | 1 |
| LUANDA | | 0 | | 1 |
| MERIDA | | 0 | | 1 |
| MIAMI | | 0 | | 6 |
| PILOT (**) | | 0 | | 3 |
| TOTAL | | 0 | | 16 |

Table 7. FIRs that sustained and generated risk (LHD) in 2020.

4.30. The FIRs that suffered the most from failures of adjacent FIRs were: Guayaquil 115 events, Bogotá 53 events, Lima 35 events, Amazónica 33 events, Panama 16 events; these 5 FIRs filed a total of 252 LHD reports accounting for 70.8% of all reports received from the region.

4.31. The FIRs that contributed the most failures to adjacent FIRs were: Bogotá 131 events, Guayaquil 39 events, Lima 32 events, Maiquetia 19 events, Barranquilla 17 events; these 5 FIRs generated a total of 238 LHD reports accounting for 70.0% of all failures observed in the region. These failures generated risk for the neighbouring FIRs. Given the above data, it is recommended that consideration be given to the adoption of urgent mitigation measures.

4.32. The Barranquilla FIR generated 17 risk events to neighbouring FIRs, mainly to the Kingston FIR, with nine (9) errors/failures, followed by the Panama FIR, with four (4) errors/failures, the Curacao FIR, with three (3) errors/failures, and finally the Maiquetia FIR, with one (1) error/failure.

4.33. Secondly, the Georgetown FIR generated three (3) risk events to neighbouring FIRs, mainly to the Piarco FIR, with two (2) errors/failures, and then to the Paramaribo FIR, with one (1) error/failure.

4.34. Thirdly, the Asuncion FIR generated 4 risk events to the neighbouring FIRs, mainly to the La Paz FIR, with 2 errors/failures, then to the Curitiba and Resistencia FIRs, with 1 error/failure each.

4.35. Fourthly, the Maiquetia FIR, despite being present in only 5 LHD reports from adjacent FIRs, generated 19 risk events to neighbouring FIRs, mainly to the Amazónica FIR, with 12 errors/failures, followed by the Bogotá FIR, with 7 errors/failures.

4.36. In fifth place, the Havana FIR generated 3 risk events to neighbouring FIRs, mainly to the Port-au-Prince FIR, with 2 errors/failures, followed by the Kingston FIR, with 1 error/failure.

4.37. In sixth place, the Bogotá FIR generated 131 risk events to the neighbouring FIRs, mainly the Guayaquil FIR, with 94 errors/failures, then the Amazónica FIR, with 14 errors/failures, then the Panama FIR, with 11 errors/failures, then the Lima FIR, with 7 errors/failures, then the Maiquetia FIR, with 4 errors/failures, and finally the Central America FIR, with 1 error/failure.

4.38. Part of the analysis included a detailed review of certain operational errors/failures, to identify contributing factors and ensure that procedures and processes are implemented by the safety authorities of the CAR/SAM FIRs to reduce the likelihood of recurrence of errors.

4.39. In the case of RVSM airspace, CARSAMMA assessed the individual operational errors identified by the LHD reports submitted by the 34 FIRs in its geographical area of coverage, grouped by FIR and then by State, using the following statistical tools:

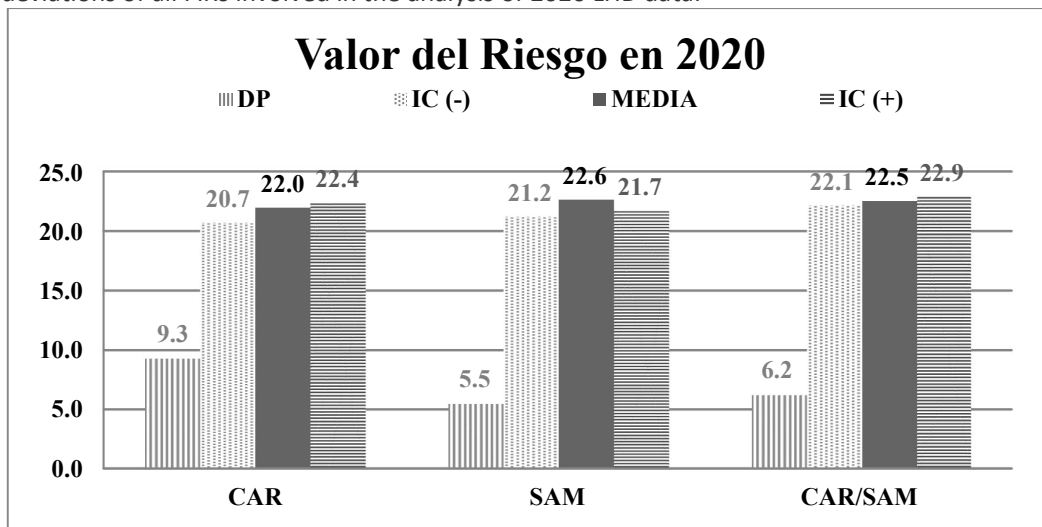
Mean of the risk value $\Rightarrow \bar{x} = \sum VR / n ;$

Standard deviations

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (x - \bar{x})^2}$$

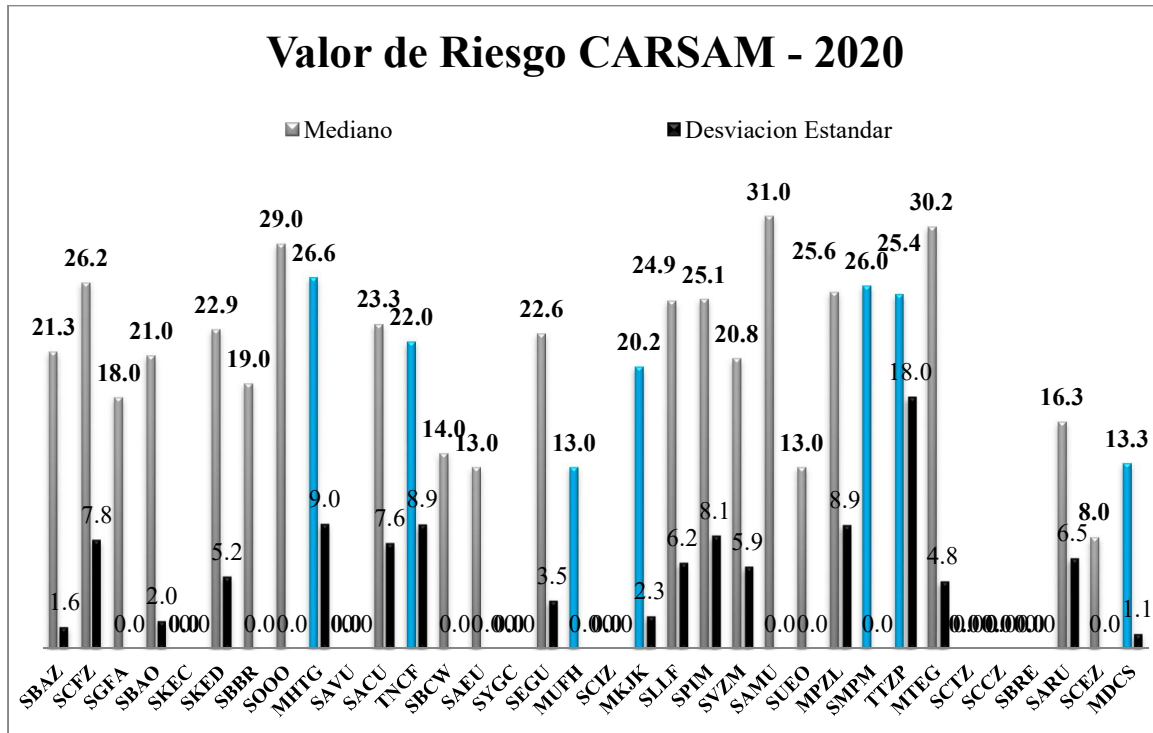
Confidence interval of 95% for the analysis (= 1.96).

4.40. **Graph 6** presents all these values, the average value, the standard deviation, and the confidence interval of the risk values assigned to operational errors reported in the large altitude deviations of all FIRs involved in the analysis of 2020 LHD data.



Graph 6. Average value, standard deviation and confidence interval of the CAR and SAM Regions

4.41. **Graph 7** below identifies the average values and standard deviations of the results of this analysis, with the risk value contribution assigned to the operational errors of large altitude deviations, by FIR involved in the analysis of 2020 LHD data.



Graph 7. Contribution of mean values and standard deviations by FIR involved in the risk

4.42. **Figure 5** illustrates the geographical location of risk points (RV ≥ 31) of LHD reports with 27 points, and 40 reports in the 12 consecutive month dataset of 2020 issued by the CAR/SAM FIRs. The illustration is intended to provide a means of identifying specific risk points related to RVSM operations.



Figure 5. CAR/SAM FIRs - Points with the highest RV in large height deviations (LHDs) January – December 2020

4.43. The **black** point, indicated by the arrow, is the point with the highest RV (51), generated by lack of coordination in the Paramaribo ACC with the Piarco ACC (#423). The following factors were identified, *inter alia*, as contributors to this value: Lack of coordination by the adjacent ACC, where another ACC performed such coordination.. The aircraft entered and only made contact when it was 50 NORTH of the TRAPP position and the event lasted 5 minutes (300 seconds) in Piarco FIR airspace.

4.44. **Table 8** shows some points with the number of reports where the RV was equal to or above 31, number of occurrences reported, maximum RVs and FIRs involved.

| POINT | NUMBER OF REPORTS | RISK VALUE (MAX) | FIRs INVOLVED (Sustained X Generated) |
|--------------|-------------------|------------------|---------------------------------------|
| 1150N 05312W | 1 / 1 | 37 | Piarco X Pilot |
| 1228N 07725W | 1 / 1 | 34 | Panama x Barranquilla |
| ALBEE | 1 / 1 | 31 | Port-au-Prince x Miami |
| ALPON | 1 / 1 | 41 | Panama x Barranquilla |
| AMBIN | 1 / 1 | 41 | Curacao x Kingston |
| BODLO | 1 / 1 | 31 | Port-au-Prince x Miami |

| | | | |
|-------|--------|---------|------------------------------|
| BOLDO | 1 / 1 | 39 | Central America x Bogotá |
| BOLDO | 1 / 1 | 34 | Panama X Bogotá |
| BOLDO | 3 / 3 | 39 | Bogotá x Central America |
| BOTES | 1 / 1 | 31 | Port-au-Prince x Miami |
| DAKMO | 0 / 3 | - | Bogotá x Panama |
| DAKMO | 1 / 3 | 34 | Panama x Bogotá |
| DOBNI | 1 / 2 | 34 | La Paz x Lima |
| DOBNI | 2 / 2 | 31 y 39 | Lima x La Paz |
| ELAKO | 2 / 2 | 39 | Lima x La Paz |
| ENSOL | 1 / 9 | 39 | Bogotá x Guayaquil |
| ENSOL | 0 / 12 | - | Guayaquil x Bogotá |
| JOSES | 3 / 3 | 31 | Port-au-Prince x Miami |
| KAKOL | 1 / 1 | 41 | Panama x Bogotá |
| KEBET | 2 / 3 | 31 y 34 | Port-au-Prince x Kingston |
| LIXAS | 1 / 2 | 31 | Central America x Guayaquil |
| OBLIR | 1 / 1 | 31 | Lima x La Paz |
| PABOB | 0 / 2 | - | Guayaquil x Lima |
| PABOB | 4 / 4 | 39 | Lima x Guayaquil |
| PUBUM | 1 / 2 | 31 | Córdoba x La Paz |
| RETAK | 1 / 3 | 39 | Port-au-Prince x St. Domingo |
| RETAK | 0 / 2 | 34 | St. Domingo x Port-au-Prince |
| ROLUS | 1 / 5 | 31 | Lima x Bogotá |
| SIDAK | 1 / 2 | 39 | La Paz x Asunción |
| TERAS | 1 / 1 | 31 | Lima x Guayaquil |
| TERAS | 0 / 1 | - | Guayaquil x Lima |
| TRAPP | 1 / 1 | 51 | Piarco x Paramaribo |
| UGUPI | 0 / 9 | - | Bogotá x Guayaquil |
| UGUPI | 1 / 41 | 35 | Guayaquil x Bogotá |
| UMKAL | 1 / 1 | 31 | Mendoza x Santiago |
| URLAM | 1 / 2 | 39 | Port-au-Prince x Havana |

Table 8. CAR/SAM FIRs- RVSM large height deviation (LHD) risk points
January – December 2020

4.45. The table above shows that in 2020 there were some reports with high values, mainly between the Curacao FIR and the Kingston FIR, between the Panama FIR and the Barranquilla FIR, and between the Panama FIR, and the Bogotá FIR, with an RV = 41.

4.46. It may also be noted that reports with RV=39 were filed in 2020, mainly between the Bogotá FIR and the Central America FIR, between the Bogotá FIR and the Guayaquil FIR, between the Central America FIR and the Bogotá FIR, between the La Paz FIR and the Asuncion FIR, between the Lima FIR and the Guayaquil FIR, between the Lima FIR and the La Paz FIR (2 events), between the Port-au-Prince FIR and the Havana FIR, and between the Port-au-Prince FIR and the Santo Domingo FIR. Likewise, an occurrence was reported in 2020 with an RV=37 between the Piarco FIR and a pilot failure.

4.47. Table 8 shows that occurrences were reported in 2020 with an RV=34, mainly between the La Paz FIR and the Lima FIR, between the Panama FIR and the Barranquilla FIR, between the Panama FIR and the Bogotá FIR (2 events), between the Port-au-Prince FIR and the Kingston FIR, and between the Santo Domingo FIR and the Port-au-Prince FIR.

4.48. We can also note reports in 2020 with an $RV=31$, mainly between the Central America FIR and the Guayaquil FIR, between the Cordoba FIR and the La Paz FIR, between the Lima FIR and the Bogotá FIR (2 events), between the Lima FIR and the La Paz FIR (2 events), between the Mendoza FIR and the Santiago FIR, between Port-au-Prince FIR and the Kingston FIR, and between the Port-au-Prince FIR and the Miami FIR (4 events).

4.49 Based on the information provided under 4.18, 4.19, 4.20, 4.21 and 4.22, we can conclude that:

- a. The FIRs that sustained the highest risk, considering reports with $RV \geq 31$, were: Mendoza with 100%, Piarco with 69.3%, Port-au-Prince with 67.9%, Central America with 52.6, Panama with 45.0%, Cordoba with 33.3%, Lima with 27.5%, La Paz with 24.4%, Curacao with 23.3%, Santo Domingo with 18.3%, Bogotá with 6.4%, and Guayaquil with 1.4% of the total risk to their FIRs.
- b. Another factor to be noted is that the FIRs that generated the higher risks with reports of $RV \geq 31$ were: Santiago with 100%, Kingston with 75.2%, Panama with 69.8%, Miami with 66.7%, Havana with 47.6%, Asuncion with 44.8%, La Paz with 44.8%, Curacao with 38.0%, Port-au-Prince with 37.4%, Santo Domingo with 32.5%, Central America with 28.1%, Barranquilla with 20.1%, Lima with 15.8%, Guayaquil with 8.3%, and Bogotá with 8.0%.

4.49. Among the TCPs that had already been reported in 2019 with high RVs and reported again in 2020 are: AMBIN, BOLDO, DAKMO, ELAKO, PABOB, PUBUM and SIDAK. FIRs adjacent to these TCPs should urgently take mitigating measures to reduce the RV.

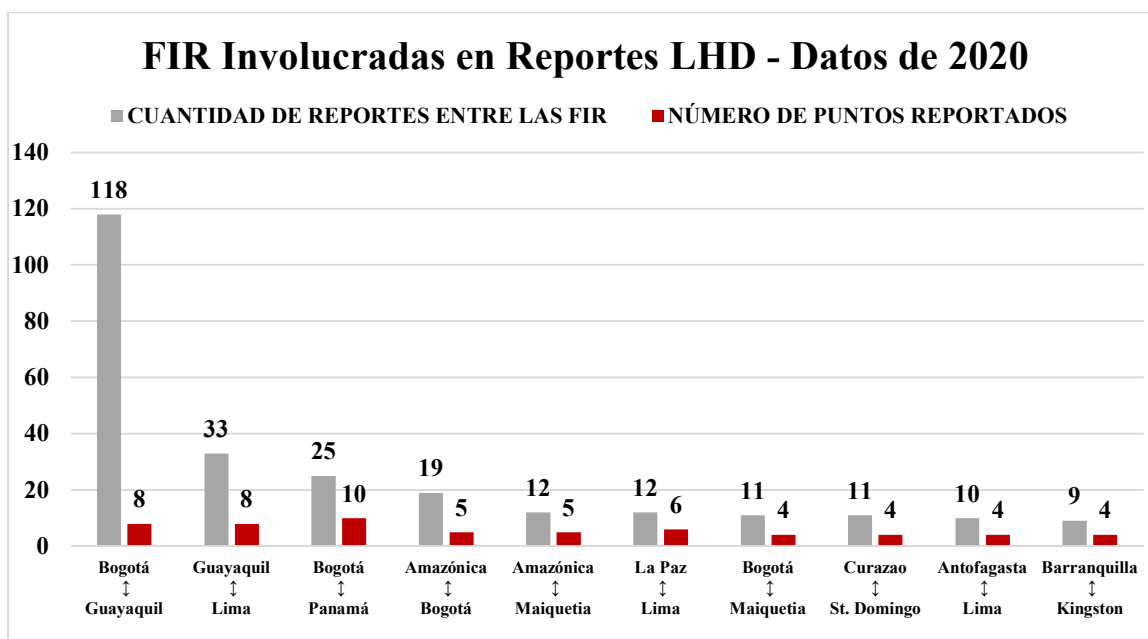
4.50. **Table 9** shows the top 30 FIR pairs with the highest number of reports, the total number of reports between them and the total number of points/fixes reported.

| FIRs INVOLVED | NUMBER OF REPORTS | NUMBER OF POINTS REPORTED |
|------------------------------|-------------------|---------------------------|
| Bogotá ↔ Guayaquil | 118 | 8 |
| Guayaquil ↔ Lima | 33 | 8 |
| Bogotá ↔ Panama | 25 | 10 |
| Amazónica ↔ Bogotá | 19 | 5 |
| Amazónica ↔ Maiquetía | 12 | 5 |
| La Paz ↔ Lima | 12 | 6 |
| Bogotá ↔ Maiquetía | 11 | 4 |
| Curacao ↔ St. Domingo | 11 | 4 |
| Antofagasta ↔ Lima | 10 | 4 |
| Barranquilla ← Kingston | 9 | 4 |
| Port-au-Prince ↔ St. Domingo | 8 | 3 |
| Amazónica ↔ La Paz | 7 | 1 |
| Bogotá ↔ Lima | 7 | 3 |
| Port-au-Prince → Miami | 6 | 4 |
| Havana ← Port-au-Prince | 7 | 5 |
| Amazónica ↔ Lima | 4 | 1 |
| Barranquilla ← Panama | 4 | 4 |
| Bogotá ↔ Central America | 4 | 3 |
| Ezeiza ↔ Resistencia | 4 | 3 |
| Barranquilla ← Curacao | 3 | 2 |
| Central America ↔ Guayaquil | 3 | 2 |
| Amazónica → Brasilia | 2 | 2 |

| | | |
|-----------------------|---|---|
| Antofagasta → Córdoba | 2 | 2 |
| Asunción → Curitiba | 2 | 2 |
| Asunción ↔ La Paz | 1 | 1 |
| Atlántico → Abidjan | 2 | 1 |
| Córdoba ↔ La Paz | 2 | 1 |
| Georgetown ↔ Piarco | 2 | 2 |
| Havana ← Kingston | 2 | 2 |
| Piarco → Pilot | 2 | 2 |

Table 9 - CAR/SAM FIRs - Number of reports between them and total number of points reported

4.51. **Graph 8** shows the 10 top FIR pairs with the highest number of reports.



Graph 8. CAR/SAM FIRs - Number of reports between them and number of points reported

4.52. **Table 10** shows the top FIR pairs with the highest number of reports, with the respective points/fixes reported.

| FIRs INVOLVED | NAME OF POINTS/FIXES REPORTED |
|------------------------------|---|
| Bogotá ↔ Guayaquil | UGUPI – BOKAN – PULTU – ENSOL – ANRAX – VAMOS – AKTAB – GAVUT |
| Guayaquil ↔ Lima | VAKUD – ARNEL – TERAS – PABOB – TOSES – ANPAL – LOBOT – AMERO |
| Bogotá ↔ Panama | ARORO – BOLDO – BUSMO – BUXOS – DAKMO – ILTUR – IVROS – KAKOL – TINPA – TOKUT |
| Amazónica ↔ Bogotá | ABIDE – ARUXA – ASAPA – BRACO – LET |
| Amazónica ↔ Maiquetía | AKPEP – PAKON – POVLA – VAGAN – VUMPI |
| La Paz ↔ Lima | DOBNI – ELAKO – OBLIR – ORALO – PDO – RAXUM |
| Bogotá ↔ Maiquetía | CUC – ENPUT – KOKAS – OPRUS |
| Curacao ↔ St. Domingo | BEROX – KARUM PALAS – VESKA |
| Antofagasta ↔ Lima | ALDAX – ESDIN – IREMI – SORTA |
| Barranquilla ↔ Kingston | BOBKA – EDROD – KILER – OTAMO |
| Port-au-Prince ↔ St. Domingo | DCR – PIGBI – RETAK |

| | |
|-----------------------------|------------------------------------|
| Amazónica ↔ La Paz | RCO |
| Bogotá ↔ Lima | ILMUX – OLG - ROLUS |
| Port-au-Prince → Miami | ALBBE – DODLO – BOTES - JOSES |
| Havana ← Port-au-Prince | URLAM – KEBET |
| Amazónica ↔ Lima | LET |
| Barranquilla ← Panama | 1228N 07725W – AGUJA – ALPON BOGAL |
| Bogotá ↔ Central America | BOLDO |
| Ezeiza ↔ Resistencia | KORTA – OPNIN - TODES |
| Barranquilla ← Curacao | OROSA - SELAN |
| Central America ↔ Guayaquil | LIXAS - UGADI |
| Amazónica → Brasilia | BURLO - OPNUP |
| Antofagasta → Córdoba | GEKAL - KONRI |
| Asunción → Curitiba | REBOX - REMEK |
| Asunción ↔ La Paz | SIDAK |
| Atlántico → Abidjan | SBAODIII1 |
| Córdoba ↔ La Paz | PUBUM |
| Georgetown ↔ Piarco | KORTO - MINDA |
| Havana ← Kingston | ATUVI - KATAL |
| Piarco → Pilot | 1135N 06016W – 1150N 05312W |

Table 10 - CAR/SAM FIRs - Name of points reported between FIRs

4.53. The following images show all the fixes and/or TCPs reported in this working paper.

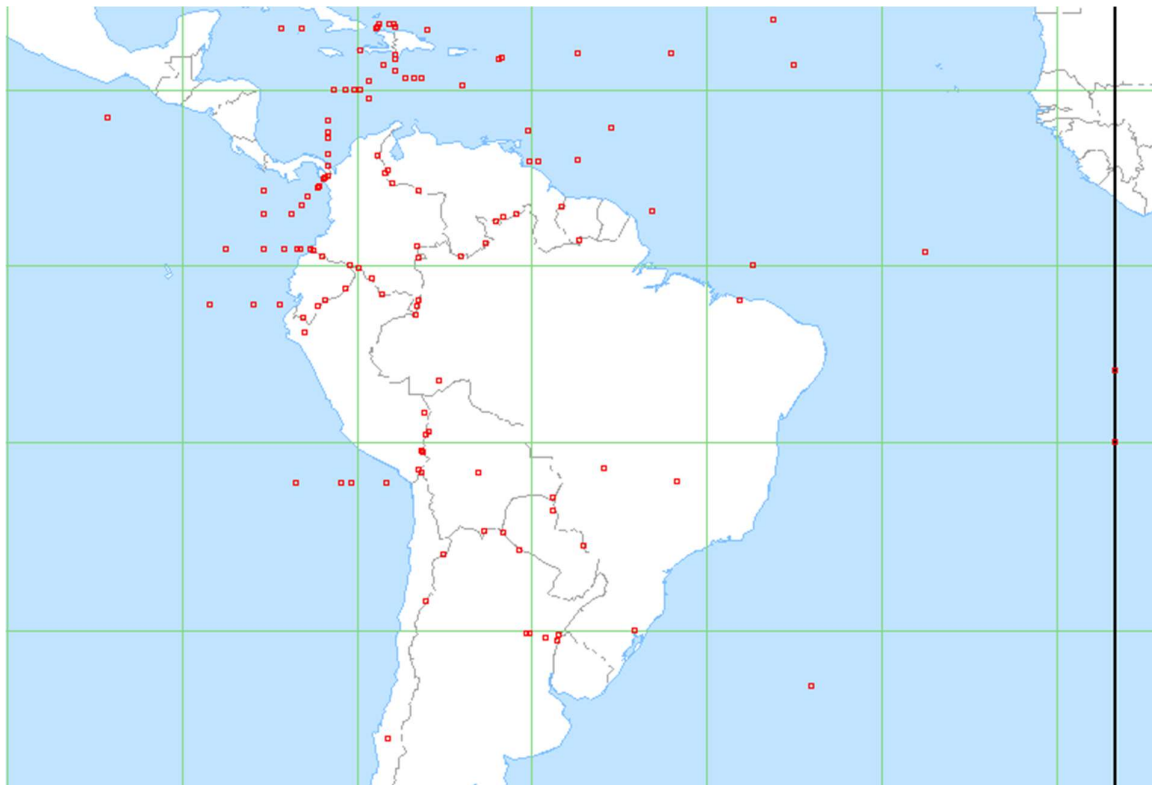


Figure 6. CAR/SAM FIRs - Risk points reported in large height deviations (LHDs), with no mention of FIR January – December 2020

