Australian Enhanced Flight Tracking Evaluation

Performance Report

August 2015

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1.0 Executive Summary

In May 2014 ICAO convened a multi-disciplinary meeting to discuss the first key steps in making global aircraft tracking a priority, and to reach an agreement on the need to track flights and coordinate industry initiatives. Attendees included States, industry, related specialists, chairs, and co-chairs of several ANC panels.

As a result of this meeting, the Air Navigation Service Provider (ANSP) Airservices Australia (Airservices) invited Inmarsat to participate in an aircraft tracking capability evaluation *'to work together to implement a flight tracking initiative in order to make some immediate improvements to aircraft tracking and share the results of a trial with the international community.'*

Future Air Navigation Systems (FANS-1/A) Automatic Dependent Surveillance – Contract (ADS-C) has been used to track aircraft operating in oceanic areas for more than 20 years and so the primary goal of this evaluation was to demonstrate that this existing system, including supporting data and satellite communications, could be adapted to deliver Global Flight Tracking (GFT).

The evaluation assessed a reduction in ADS-C satellite position report intervals to 15 minutes or less and also examined message latency at the reduced interval to determine any variation against criteria established in the ICAO Global Operational Data Link Document (GOLD) and the effect on the Inmarsat network.

As a means of detecting non-normal aircraft operation, lateral and vertical compliance monitoring in the aircraft Flight Management System (FMS) is used to detect deviation from the ATC approved flight path and non-compliance automatically notified to the ATC automation system. In the Airservices automation system, this automatically further reduces the reporting interval and notifies the controller. ATC Procedures for handling alerts (missed message, path deviation, and altitude deviation) are in place and interface to Alerting and Search and Rescue procedures.

The evaluation was conducted in several phases to better monitor the data communications load and performance:

- Phase 1(30 Jan 2015 – 31 May 2015) initiated the Global Flight Tracking (GFT) concept with Qantas and Virgin Australia wide-body aircraft. The service commenced on Friday 30 January 2015, operating east of Australia in the Brisbane Flight Information Region (FIR). The data and satellite communications analysis showed negligible (if any) increase in aggregate ADS-C message rate and no degradation of the data or satcom performance.
- Phase 2 (1 May – 28 May 2015) expanded GFT to all ADS-C equipped aircraft operating in the Brisbane, Honiara, and Nauru FIRs.
- Phase 3 (29 May 2015 – present) expanded GFT to all ADS-C equipped aircraft operating in the Melbourne, Brisbane, Honiara and Nauru FIRs.

Several key findings emerged from this evaluation:

- The evaluation demonstrated that increasing ADS-C reporting to 14 minute intervals allowed airlines to comply with Global Flight Tracking (GFT) recommendations for 91.9% of passenger hours flying oceanic to/from Australia with little (if any) increase in data communication costs.
- Analysis shows that no deterioration in ADS-C communication performance occurred during the evaluation. Both ADS-C messaging and Controller Pilot Datalink Communications (CPDLC) variations were within expected daily and monthly expectations.
- The 14 minute reporting period supports the 30/30 nautical mile separation service with potential to improve access to preferred altitudes, decrease fuel consumption and emissions and this provides a sound economic basis for the use of ADS-C.

- The FMS flight path monitoring can provide useful automatic detection of non-normal aircraft operation; and
- ADS-C provides a robust aircraft tracking system, using existing technology, which can be used in oceanic airspace to meet the normal tracking requirements defined by ICAO.

This report confirms that ADS-C could be used to comply with the 15 minute normal GFT requirement for suitably equipped aircraft. Based on the results, Airservices Australia has adopted the 14 minute reporting requirement as part its standard operating procedure.

Results of the evaluation were shared with stakeholders including ICAO and neighbouring ANSPs during the phased implementation. Airways New Zealand introduced 14 minute ADS-C reporting in the New Zealand FIR on 29 May 2015. The FAA introduced 14 minute ADS-C reporting in the Anchorage (north Pacific) and Oakland (south Pacific) FIRs on 25 June 2015.

Inmarsat and Airservices agree to share the results of the initiative to illustrate the flight tracking benefits of increased ADS-C position reports in oceanic airspace. This report has been prepared to provide guidance and advice to ICAO, IATA, and CANSO for incorporation into guidance and briefing materials.

2.0 Background

The ICAO meeting in May 2014 produced a recommendation to develop a draft Concept of Operations (CONOPS) on aircraft tracking, including a clear definition and objective. The CONOPS was designed to ensure that information is provided in a timely fashion to the appropriate parties in order to support search and rescue, recovery and accident investigation activities in the event of a serious incident or accident, as well as enhanced flight situational awareness to Air Traffic Control (ATC) and Airline Operational Centres (AOC).

ICAO formed an ad-hoc working group to develop the CONOPS for the Global Aeronautical Distress & Safety System (GADSS). The goal of the GADSS is to increase the effectiveness of the current alerting and search and rescue services by addressing a number of key improvement areas and by developing and implementing a globally integrated system. GADSS aims to address the sequence of events before and after the occurrence of an accident, which should include all identified phases of such a sequence:

- Detection of an abnormal situation
- Alert phase
- Distress phase
- Search and rescue activities

The following figure provides an overview of the GADSS and identifies its main components:

- Aircraft tracking under normal and abnormal conditions
- Autonomous Distress Tracking
- Automatic Deployable Flight Recorder
- GADSS Procedures and Information Management

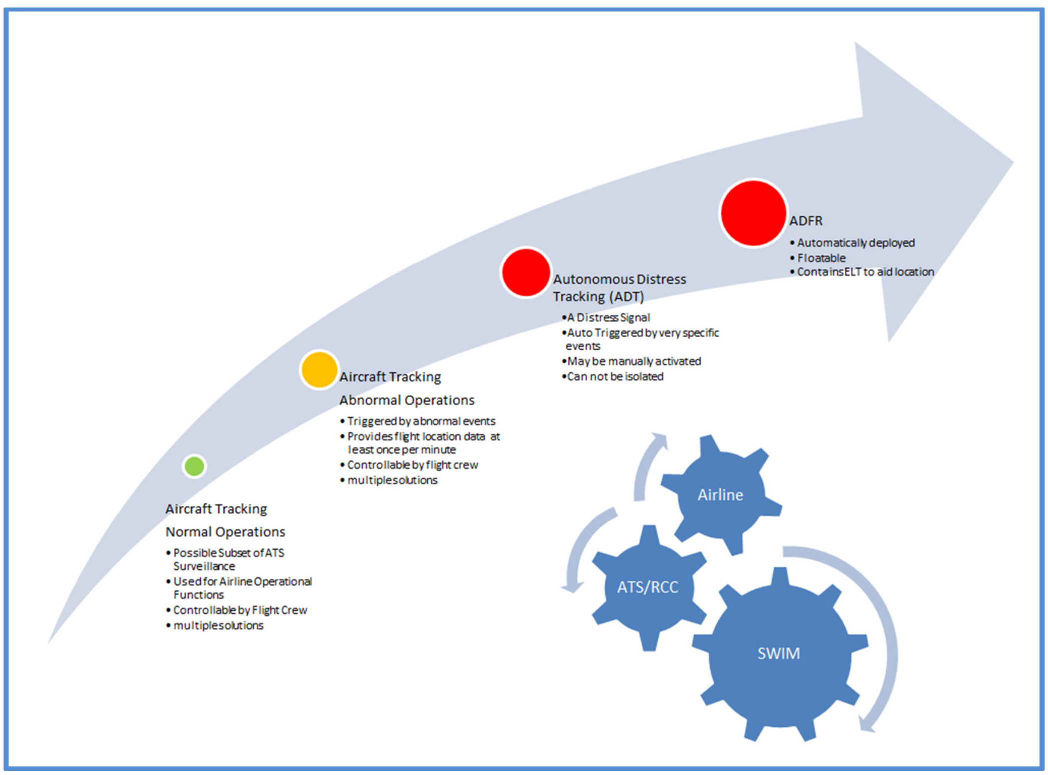

Figure 1: ICAO GADSS Components

The full GADSS concept will be phased in through the execution of actions in the short, medium, and long term. Each action will produce distinct benefits. The first phase of the GADSS process is to implement a 15 minute reporting interval for aircraft flying under normal conditions. These solutions address near term and voluntary aircraft tracking using existing technology, aircraft avionics, and existing infrastructure to support global tracking for current and suitably equipped aircraft operating outside radar and ADS-B coverage.

ADS-C can be used to address the tracking and detection of non-normal aircraft operation and interface to the Alerting and Search and Rescue procedures.

3.0 Evaluation Outline and Objectives

The primary goal of this evaluation was to explore the use of ADS-C and associated data and satcom systems to provide Global Flight Tracking to aircraft operating in oceanic airspace areas consistent with the intent of the emerging ICAO standard.

ADS-C is an automatic position reporting system that has been used with aircraft operating across the Pacific and Indian Oceans and elsewhere for 20 years to support reduced separation standards (30/30NM), the development of Flex Tracks, dynamic re-routes, and User Preferred Routes. ADS-C involves a contract between the ground ATC automation system and the aircraft Flight Management System (FMS). A typical contract requires the aircraft to periodically report position, altitude, velocity, etc. The contract can also require immediate reporting of events such as deviation from the route or level in the FMS .

ADS-C data exchange between the aircraft and the ATC automation system may be carried on various communications links. Over land, Very High Frequency (VHF) of High Frequency (HF) datalink is typically used; over the ocean, satellite communications such as Inmarsat Classic Aero satellite communications (satcom) is generally used. As satcom is often perceived as expensive, one objective of the evaluation was to demonstrate that ADS-C global tracking could be achieved without significant increase in cost.

3.1 Concept of Operations

The significant concepts of the proposed GADSS CONOPS are described in this section.

3.1.1 Normal Tracking

ICAO has proposed that aircraft operating normally should report their position every 15 minutes or less. In this evaluation, ADS-C was used to provide periodic position reports at this frequency to confirm aircraft operations were normal.

This evaluation initially used a 10 minute update period (recommendation from the global tracking meeting May 2014). However, following the recommendation of the High Level Safety Conference in February 2015, a 14 minute update period was implemented.

A 14 minute update period meets or exceeds two requirements:

- ICAO recommended GFT normal tracking rate; and
- Surveillance to support ATC 30/30NM Procedural Separation.

Availability of 30/30NM separation increases the capacity of oceanic airspace and allows a greater use of lateral aircraft separation, increasing the probability of aircraft receiving optimal level with the associated reduction in fuel consumption, operating costs and emissions.

3.1.2 Detection of Abnormal Aircraft Operation

Many (not all) events that jeopardise safe operation of an aircraft result in the aircraft departing from the cleared flight path laterally or vertically. The ADS-C contract may be set up to include FMS detection and immediate reporting of deviations from cleared routes and altitudes. The controller receives event reports that indicate possible non-normal operation of the aircraft. The ATC Automation System detects missed position reports and alerts the Controller.

ATC procedures require the controller to respond to each of the above indications. Generally, the response is to communicate with the pilot, clarify the situation, and respond appropriately. If communication cannot be established with the pilot, the ATC Lost Communications Procedure is invoked; ultimately this leads to invoking search and rescue.

3.1.3 Non-Normal Tracking

The Airservices' ATC Automation System, upon receiving an event message that might indicate non-normal aircraft operations, automatically changes the ADS-C contract with the aircraft FMS to implement a non-normal 5 minute tracking period. A non-normal tracking period shorter than 5 minutes will also be explored. The controller has the authority and a console function to change the Tracking Period at any time. Similarly, the controller can also request a single position report at any time.

3.2 Initial Research

3.2.1 Candidate Aircraft

Aircraft operating terrestrially are usually under ATC surveillance by radar or ADS-B. A review of passenger aircraft operating to/from Australia to overseas destinations showed that 64% of the flights were by wide-body ADS-C equipped aircraft and 36% by narrow-body non-ADS-C equipped aircraft. The wide-body aircraft, which are used on the longer routes, each carried a greater number of passengers.

The review concluded that using ADS-C in this manner would bring compliance with the ICAO recommendation to 91.9% of passenger hours flown oceanic to and from Australia.

3.2.2 Data Communications Implications

The use of ADS-C for GFT can potentially increase data communications costs, including satcom costs.

A study of the ADS-C data communication for December 2014 was undertaken by Inmarsat and Airservices to understand satellite communications costs. A sample of 828 flights was analysed and a simulated fixed reporting period of 14 minutes was used to determine the expected effect on ADS-C communications. The resulting increase in periodic position reports was offset by a reduction in message rate change messages. The study concluded that a 4% increase in aggregate downlinks from the aircraft could be expected.

3.2.3 Participants and Stakeholders

The primary stakeholders participated in Phase 1 of the evaluation:

- Airservices Australia
- Inmarsat Global
- Qantas Airways
- Virgin Australia

Activities with other key stakeholders during Phase 1 of the evaluation included:

- Consultation with Rockwell Collins Information Management Services (RCIMS) (formerly ARINC) and SITA OnAir prior to commencement of operations
- Briefings to the Civil Aviation Safety Authority (CASA), Australian aviation regulator
- Briefings to the Australian Transport Safety Bureau (ATSB), Australian Safety Investigator
- Information during each stage of the evaluation was provided to the International Civil Aviation Organization (ICAO)
- Results of the evaluation were provided to neighbouring ANSPs (Airways New Zealand introduced 14 minute ADS-C tracking in the New Zealand FIR on 28 May 2015)

3.2.4 Phased Implementation

The evaluation incrementally phased in the increase in reporting to allow an analysis of the effect the increase in reporting would have on the Inmarsat network and the air traffic controller workload.

Phase 1

Phase 1 introduced GFT with Qantas and Virgin wide body aircraft operating in oceanic airspace to the east of Australia (OTS East). Aircraft involved were:

- Virgin Australia aircraft:
  - B777 x5
  - A330 x6 (included but seldom operated in the Global Tracking service area)
- Qantas
  - A380 x12;
  - B744 x12
  - A330 x22

The service commenced on Friday 30 January 2015, operating in the oceanic area to the east of Australia in the Brisbane, Nauru, and Honiara FIRs. (Australia provides upper airspace management in the Nauru and Honiara FIRs under contract).

Results:

- The normal reporting rate was set to one report per 10 minutes, in line with the ICAO recommendation from the Global Tracking Meeting in May 2014. The non-normal rate was left at one report every 5 minutes.
- Data communications monitoring showed no deterioration in performance and little (if any) increase in aggregate ADS-C message rate.
- The use of a constant reporting rate increased the number of Period Position Messages which was offset by a reduction in ADS-C Reporting Rate Change messages.

Phase 2

Following successful Phase 1 operations, Global Tracking was expanded on Friday 1 May 2015 to all ADS-C equipped aircraft operating in the Brisbane, Honiara, and Nauru FIRs.

Results:

- The normal reporting rate was set to once per 14 minutes. The non-normal reporting rate was set to once per 5 minutes in line with the ICAO recommendation from the ICAO High Level Safety Conference in February 2015.
- Operations normal reporting rate of once per 14 minutes supports both GFT and ATC 30/30NM procedural separation.
- The need for the controller to manually manage an ADS-C 14 minute update period when applying 30/30 NM separation was removed; a small but worthwhile reduction in controller workload.
- Data communications monitoring showed no deterioration in performance and little (if any) increase in aggregate ADS-C message rate.

Phase 3

Following successful Phase 2 operations, GFT was expanded on Friday 29 May 2015 to all ADS-C equipped aircraft operating in the Melbourne, Brisbane, Honiara and Nauru FIRs. The use of 14 minute normal rates and 5 minute non normal rates continued during Phase 3.

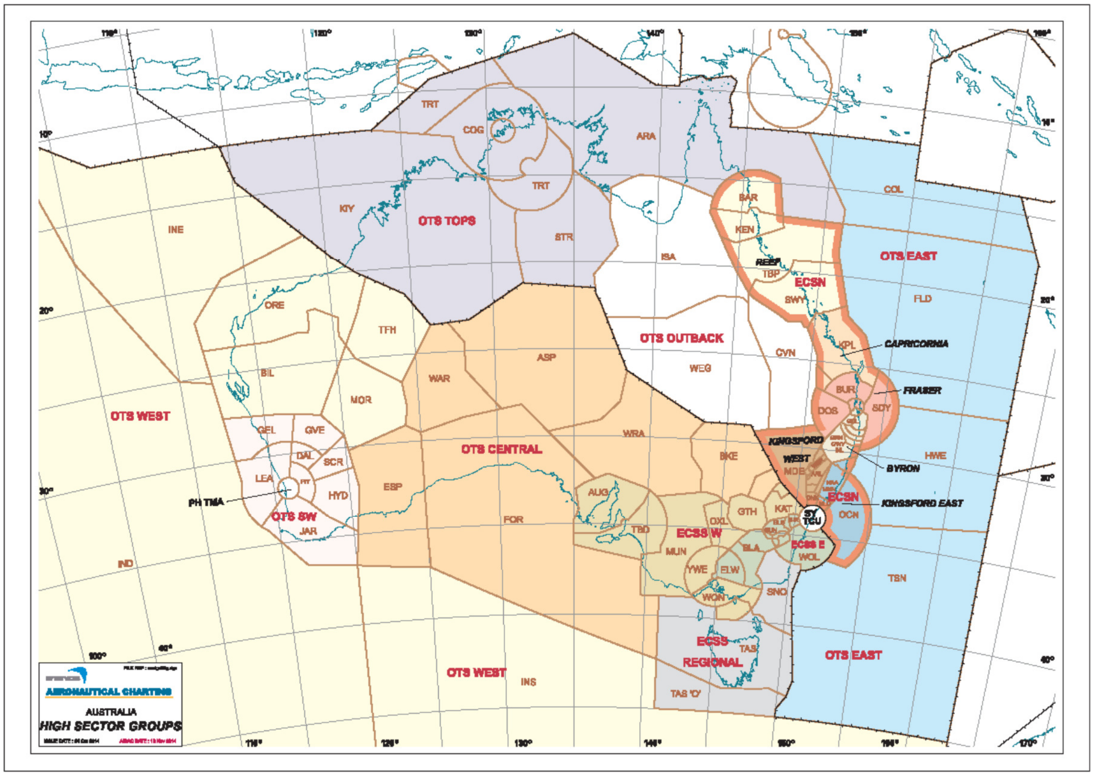

Figure 2: The Australian Flight Information Regions (FIRs)

4.0 Data Link Performance

As the evaluation utilised data link to provide the position report messaging, the performance of the systems was assessed against the requirements described in the ICAO Global Operational Data Link Document (GOLD). The GOLD provides guidance and information concerning data link operations and is intended to facilitate the uniform application of Standard and Recommended Practices (SARPs) contained in the following materials:

- Annex 2 - Rules of the Air
- Annex 10 - Aeronautical Telecommunications
- Annex 11- Air Traffic Services, the provisions in the Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444) and, when necessary, the Regional Supplementary Procedures (Doc 7030).

GOLD describes CPDLC as a data link application that supports the exchange of data messages directly between a controller and a flight crew. GOLD describes ADS-C as using various systems on board the aircraft to automatically provide aircraft position, altitude, speed, intent and meteorological data, which can be sent in a report to an Air Traffic Service Unit (ATSU) and/or an Airline Operational Control (AOC) facility ground system for surveillance and route conformance monitoring.

The criteria described in the GOLD include Required Communications Performance (RCP) and Required Surveillance Performance (RSP) specifications. Of specific relevance to this evaluation are the requirements for RCP 240 and RSP 180 operations. The RCP 240 performance requirement applies when CPDLC is the normal means of communications and ADS-C is the normal means of surveillance, supporting the application of separation minima predicated on communication performance (e.g. 30 NM lateral and 30 NM or 50 NM longitudinal).

The GOLD specifies the key performance criteria with regard to message latency and continuity. Appendix B in the GOLD describes the RCP and RSP specifications and key criteria. The specific criteria have not been reproduced in this report but are referenced in relevant sections of this report. The full GOLD document can be found at the following web address:

http://www.icao.int/APAC/Documents/edocs/GOLD_2Edition.pdf.

Future Air Navigation System 1/A data link system relies on the ground-based ACARS distribution networks, which are provided and maintained by a number of Communications Service Providers (CSPs), including Rockwell Collins ARINC and SITA OnAir.

The GOLD specifies the ANSP performance criteria in section 3.1, including:

- A validation process that confirms that the ANSPs equipment and procedures meets system integrity requirements;
- Identifying failure conditions;
- Assigning levels of criticality;
- Determining probabilities for occurrence;
- Identifying mitigating measures; and
- Integration test results confirming interoperability for operational use of the aircraft and ground systems.

5.0 ANSP Perspective

Data communications load and performance were assessed following the implementation of each phase. Results are stated below:

- The change in the data traffic was found to be within the normal fluctuation and with no adverse effect on the air traffic control data processing system.
- Analysis indicates that no deterioration in ADS-C communication performance occurred.

The evaluation demonstrated that increasing ADS-C reporting to 14 minute intervals allowed airlines to comply with GFT recommendations for 91.9% of passenger hours flying oceanic to/from Australia with little (if any) increase in data communication costs.

Standardization to a 14 minute position reporting rate also reduced complexity for controllers by removing the requirement to manually increase reporting rates to support a 30/30 NM separation at times that this was required.

6.0 Satcom Provider Perspective

Inmarsat uses analytical software applications to support message analysis and enable message latency charting and counting. The software has been used to analyse the Australian Brisbane FIR (BNECAYA) and Melbourne FIR (MELCAYA) data traffic before and during the evaluation.

Inmarsat collects operational data from its satellite networks and uses extraction tools and methodologies to assess RSP and RCP performance against the specifications in the ICAO GOLD standard. This section provides both data and conclusions on the performance of the Inmarsat satcom network. The availability of data before and after the evaluation period has made it possible to benchmark the performance of the system.

To deliver this report in a timely manner to the key stakeholders, these results focus on the changes that were implemented in the Brisbane FIR on 30 April 2015. Airservices Australia and Inmarsat agreed that the number and types of operations were appropriate for assessing the performance of the evaluation and the underlying supporting systems. The data is based on a comparison of before and after 30 April 2015. The Brisbane FIR ADS-C contract rate change occurred on 30 April 2015 between 03:00 and 04:00 local time.

The following section includes two message “latency charts.” For each month plotted, the line chart shows the percentage of ADS-C messages received (y-axis) plotted against the receipt time (x-axis): i.e., the time the GES received the ADS-C message subtracted from the time it was generated in the aircraft. For the satellite sub-network, 95% of ADS-C messages should be delivered within 84 seconds, with a target of 99.9% of ADS-C messages to be delivered within 170 seconds. These are allocations made by Inmarsat in compliance with the end-to-end RSP and RCP requirements in the ICAO GOLD document.

This document’s appendix also provides a range of data and graphs which further reinforce the results and findings in this section.

6.1 Brisbane ADS-C Rate Comparison

The Brisbane airspace ADS-C contract rate change occurred on 30th April 2015 between 03:00 and 4:00 local time.

ADS-C Latency Performance Post 14 minute ADS-C Contract Rate Introduction

For each month, the chart shows the percentage of ADS-C messages received (y-axis) plotted against the time elapsed since the message was sent (x-axis). The minimum ICAO GOLD RSP requirement is for 95% of ADS-C messages to be delivered within 84 seconds, with a target for 99.9% of ADS-C messages to be delivered within 170 s.

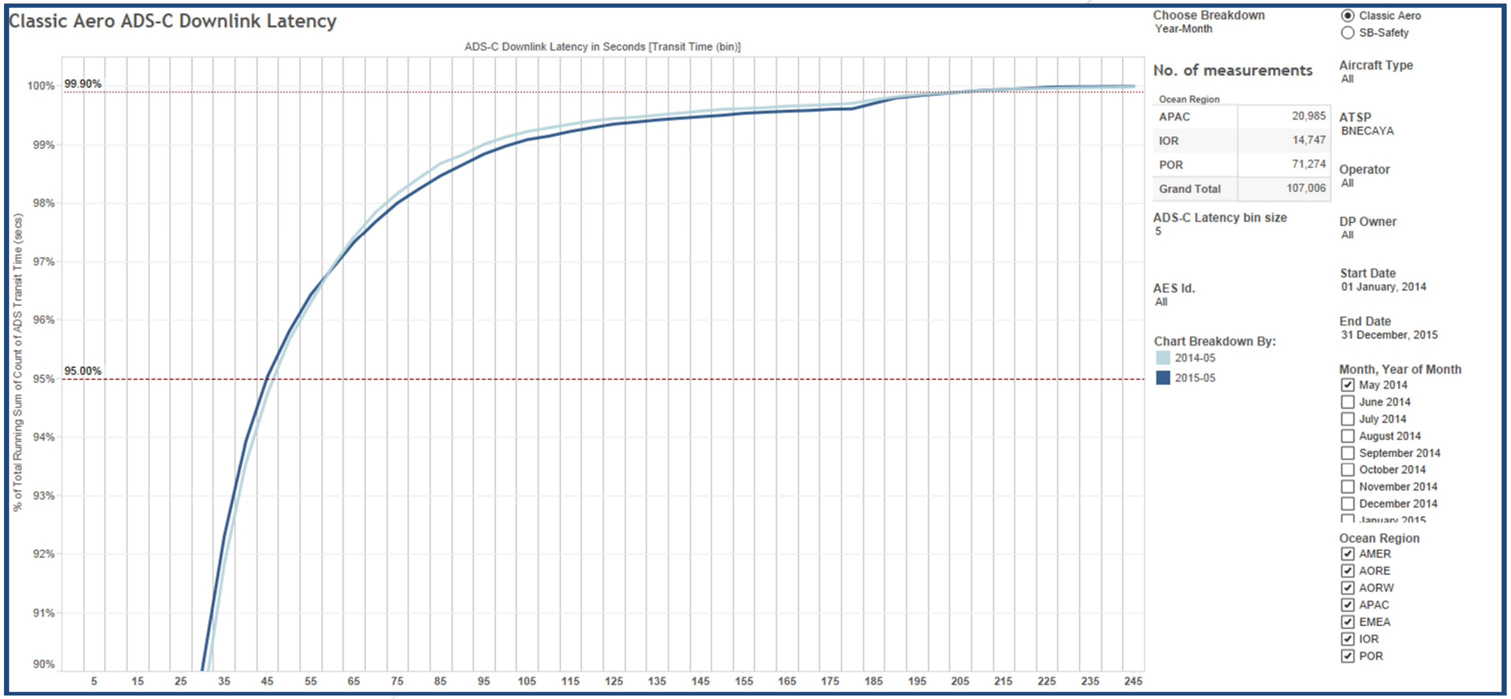

Figure 3: ADS-C Latency – May 2014

Analysis: The comparison in the chart confirms that the changes in Brisbane have had minimal impact on latency performance, and that following the change in Brisbane FIR the network continues to meet the standards specified in the GOLD.

ADS-C Latency Performance - January 2014 to December 2015

This graph depicts the ADS-C message latency performance in Brisbane FIR, comparing the month by month ADS-C performance from January 2014 to May 2015. For each month the chart shows the percentage of ADS-C messages received (y-axis) plotted against the time since the message was sent (x-axis). The minimum ICAO GOLD RSP requirement is for 95% of ADS-C messages to be delivered within 84 seconds, with a target for 99.9% of ADS-C messages to be delivered within 170 s.

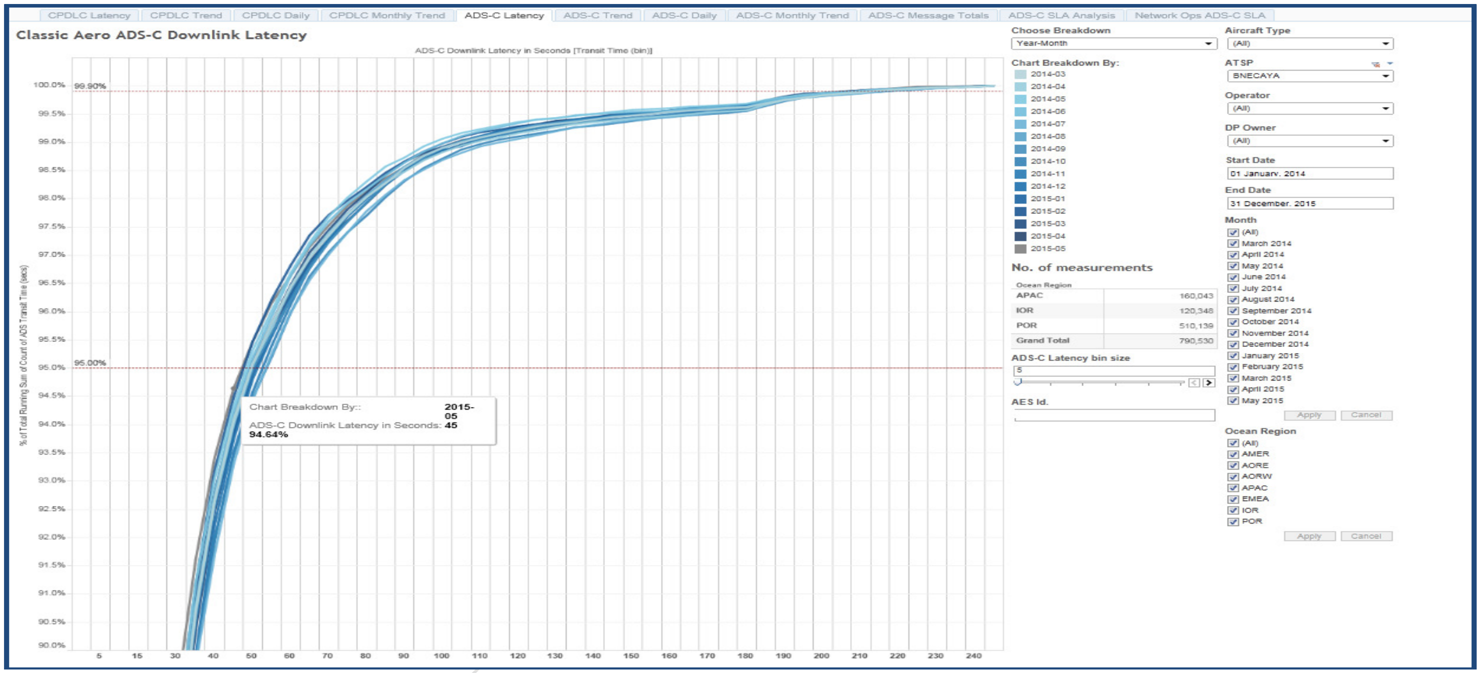

Figure 4: ADS-C Latency – January 2014 to May 2015

Analysis and Conclusion

The comparative monthly variation also confirms that the changes in Brisbane have had minimal impact of latency performance and after the change in Brisbane FIR the network continues to meet the standards specified in the ICAO GOLD.

The initial results show unchanged 95% ADS-C downlink performance and virtually unchanged 99.9% downlink performance. The magnitude of the change was within normal daily variation, and the normal commercial growth in messages over the last 12 months is well within the expected variation parameters. These results conclude that no sustained variations or peaks occurred outside expected daily or cyclical variation.

6.2 Brisbane Airspace CPDLC Performance

The Brisbane airspace ADS-C contract rate change occurred on 30th April 2015 between 03:00 and 4:00 local time.

CPDLC Latency performance - January 2014 to May 2015

This graph depicts the CPDLC message latency performance in Brisbane FIR, comparing the month by month CPDLC performance from January 2014 to May 2015. For each month the chart shows the percentage of CPDLC message responses received (y-axis) plotted against the time elapsed since the request message was sent by the ground controller (x-axis) (excluding the pilot response time). The minimum ICAO GOLD RSP requirement is for 95% of CPDLC message responses to be received within 100 seconds, with a target for 99.9% of CPDLC message responses to be received within 120 seconds.

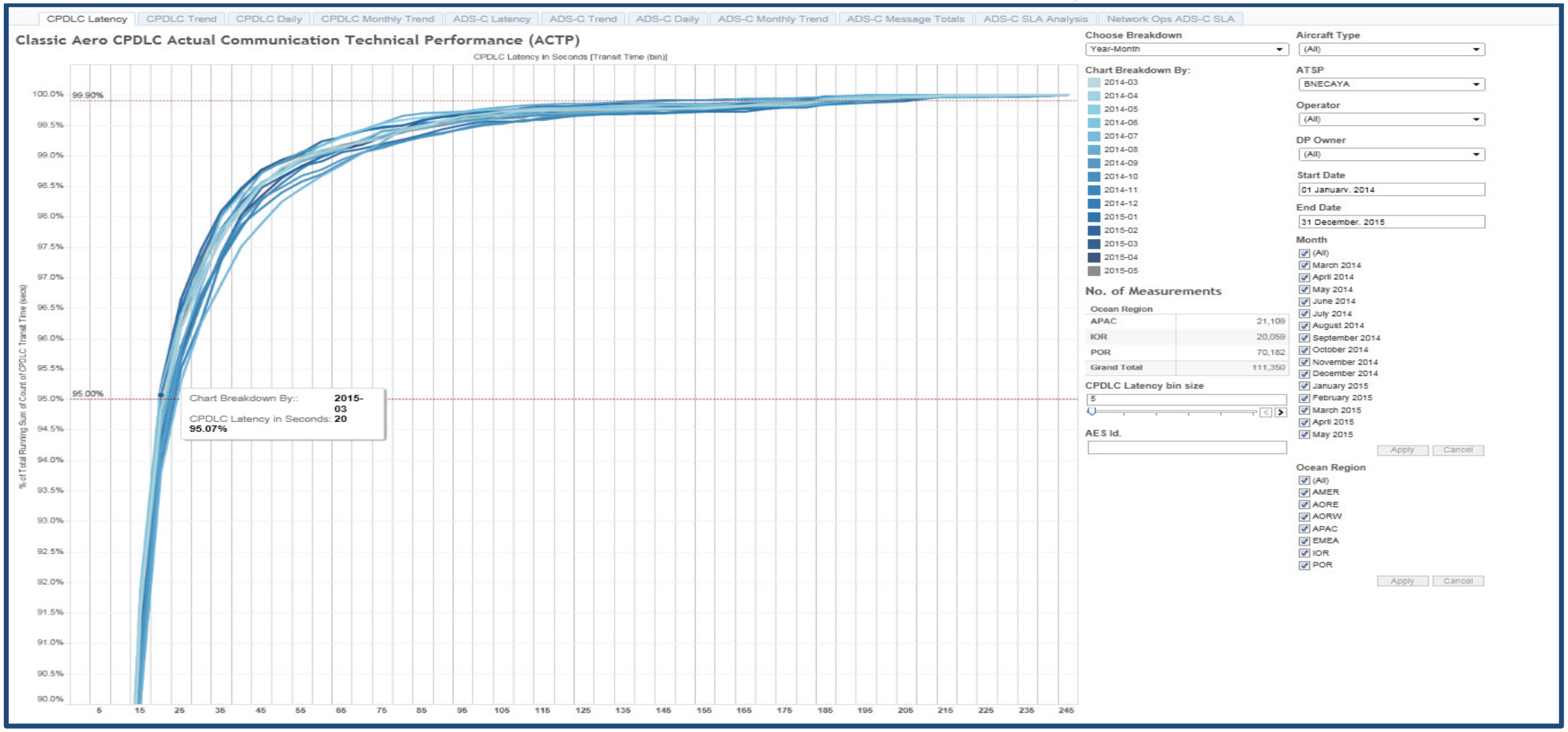

Figure 5: CPDLC Performance – January 2014 to May 2015

Analysis: Consistent with the ADS-C messaging performance, the monthly CPDLC variation is within expected daily and monthly variation.

7.0 Change Management Considerations

This section provides guidance and considerations for the introduction of flight tracking from a satcom perspective.

- Any adjustment to existing reporting rates should be carefully planned. While this trial concluded that a 14 minute reporting interval had no impact outside typical daily variance, any proposals to increase the rate should be preceded with appropriate planning and assessment.
- ANSPs and intermediate service vendors should consult the satcom provider when developing implementation plans and schedules. This precautionary approach ensures that infrastructure and network preparation can be conducted in a systematic and planned manner.
- The introduction of flight tracking is more effectively managed when all stakeholders in the value chain participate in the planning and execution.

8.0 Conclusions and Findings

The Inmarsat Classic Aero satcom network performed well within expected parameters and met or exceeded all standards stipulated in the GOLD. The following appendix provides graphs and analysis to support this conclusion.

The key conclusion is that ADS-C provides a robust aircraft tracking system, using existing technology, which can be used in oceanic airspace to meet the normal tracking requirements defined by ICAO. This report confirms that this regional trial could be used as an oceanic aircraft tracking system for suitably equipped aircraft globally.

Key conclusions:

- ADS-C meets the requirements of the ICAO normal tracking guidance.
- ADS-C meets all latency and continuity measures specified in the GOLD manual.
- The variation in message load and volume was within acceptable daily variation based on comparison historical data.
- The statistically insignificant variation means that operating costs will generally not increase.

9.0 Recommendations

Key recommendations are as follows:

- ADS-C provides a highly suitable solution that utilises existing and proven technology.
- The scale of oceanic ADS-C/satcom coverage is extensive, making this a good solution for ANSPs to provide flight tracking on behalf of their customer operators.
- Consultation with all contributing stakeholders and local regulators is important.
- Technical assessments are required when new or altered services are introduced and agreement should be reached on lead in times and phasing based on expert technical advice.
- Normal risk management processes should be applied.
- Third party vendors must ensure that they consult all parties in the satcom supply chain when agreeing to supply new or enhanced services.
- While ADS-C and CPDLC are proven and very reliable services, any changes or enhancements should be subject to the rigours of safety and risk management to identify and mitigate risks to an acceptable standard.
- Monitoring of performance should be planned and in place prior to and for an agreed period of time after the introduction of a higher rate of ADS-C reporting.

Since no issues were identified during the evaluation, the 14 minute reporting interval has now been adopted as part of Airservices' standard operating procedure.

10.0 Contacts Information

Further information and briefings can be requested to the following contacts:

Inmarsat
Stephen Angus Inmarsat
stephen.angus@inmarsat.com
+61 481 496039

Airservices Australia
Andreas Marcelja
andreas.marcelja@airservicesaustralia.com
+61 2 6268 5721

Appendix

The charts in this appendix further validate that the trial met all latency and continuity measures specified in the GOLD manual; the variation in message load and volume was within acceptable daily variation based on comparison historical data; and, the statistically insignificant variation means that operating costs will generally not increase.

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Brisbane Airspace ADS-C Evaluation
The Brisbane airspace ADS-C contract rate change occurred on 30th April 2015 between 03:00 and 4:00 local time.

ADS-C latency performance prior to 30th April 2015
This graph depicts the ADS-C message latency performance in Brisbane FIR, comparing the ADS-C performance over a selected sample of months from June 2014 to March 2015. For each month the chart shows the percentage of ADS-C messages received (y-axis) plotted against the time since the message was sent (x-axis). The minimum ICAO GOLD RSP requirement is for 95% of ADS-C messages to be delivered within 84 seconds, with a target for 99.9% of ADS-C messages to be delivered within 170 seconds.

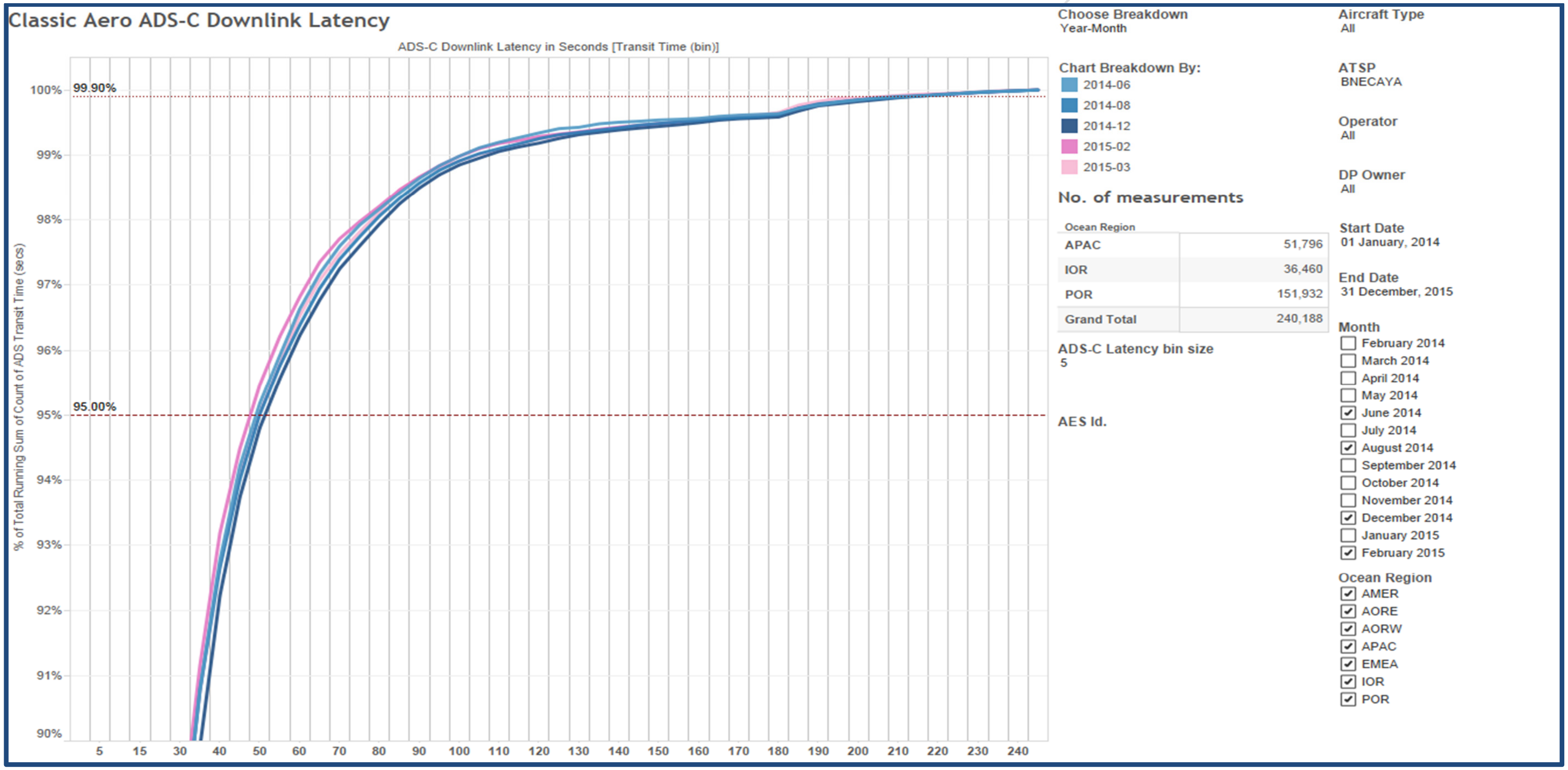

Figure 6: Historic Brisbane ADS-C latency performance

Phase 1: ADS-C Rate Comparison

The following figure shows two charts. The upper chart shows the total number of active aircraft per month using ADS-C in the Brisbane FIR over the period from March 2014 to April 2015. The lower chart shows the total number of ADS-C messages per month in the Brisbane FIR over the period from March 2014 to April 2015. For each chart, a forecast range is also depicted for the future months from May 2015 to November 2015.

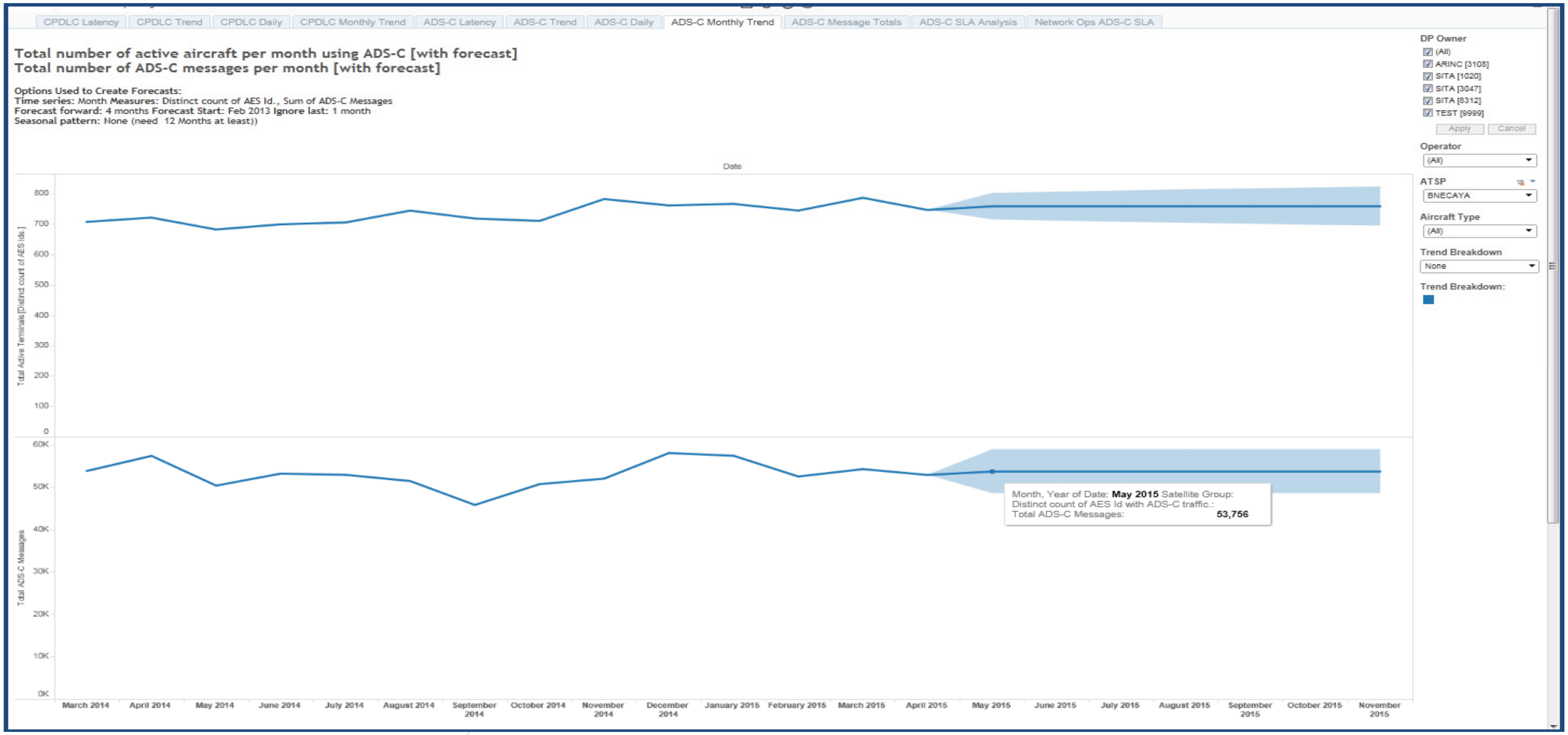

Figure 7: ADS-C Rate Comparison

Phase 2: ADS-C Rate Comparison

The following figure shows two charts. The upper chart shows the total number of ADS-C latency measurements per day in the Brisbane FIR, comparing the month of April 2014 with the months of April and May 2015. The lower chart shows the total number of aircraft actively using ADS-C per day in the Brisbane FIR, comparing the month of April 2014 with the months of April and May 2015.

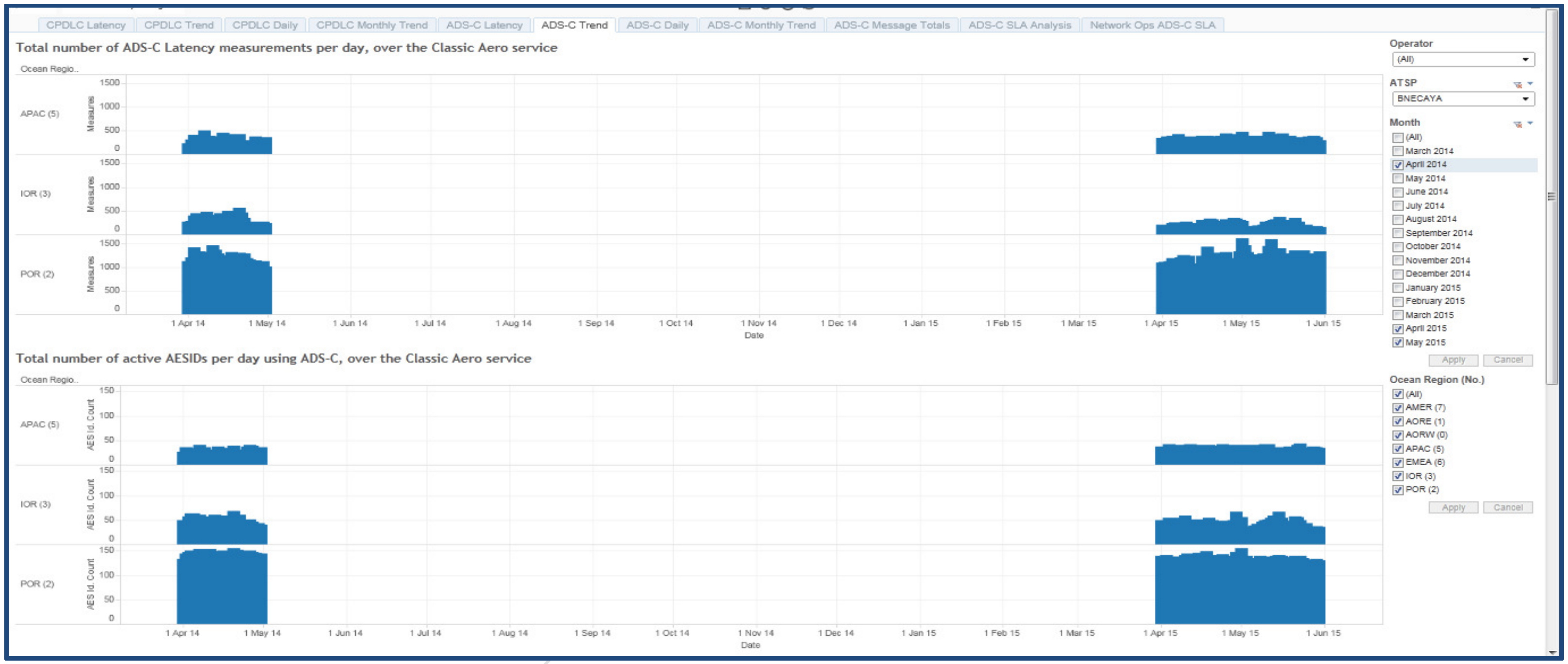

Figure 8: ADS-C Rate Comparison

Brisbane ADS-C Plots Before and After Rate Change

The following two figures compare the geographic distribution of ADS-C position reports before and after the rate change in the Brisbane FIR. Figure 9 shows aircraft positions derived from ADS-C over the Brisbane FIR over 5 days between the 26th and the 30th April 2015, which is the period immediately prior to the ADS-C rate change. Figure 10 shows aircraft positions derived from ADS-C over the Brisbane FIR over 5 days between the 17th and the 21st May 2015, which is after the ADS-C rate change.

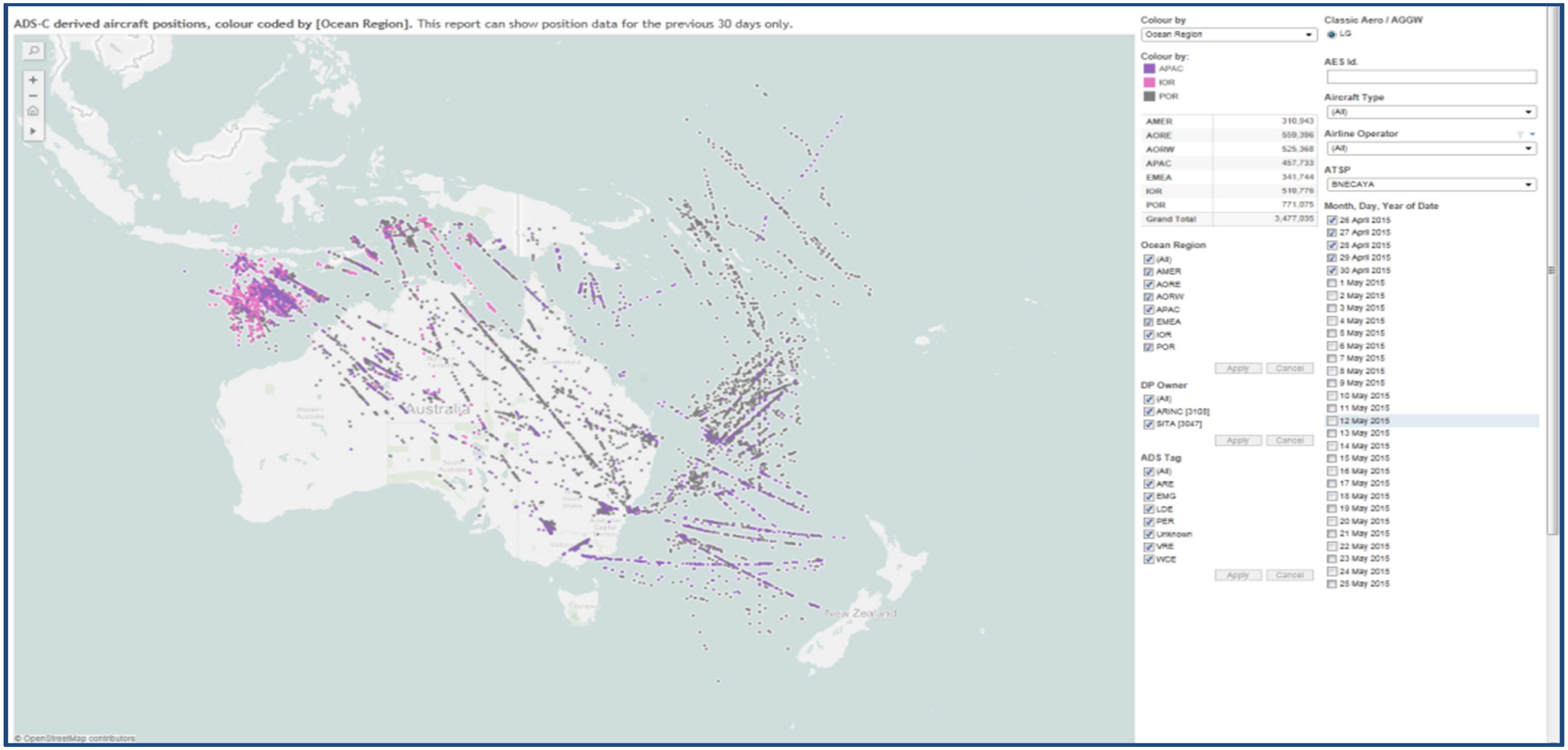

Figure 9: ADS-C Coverage in Brisbane 26th – 30th April

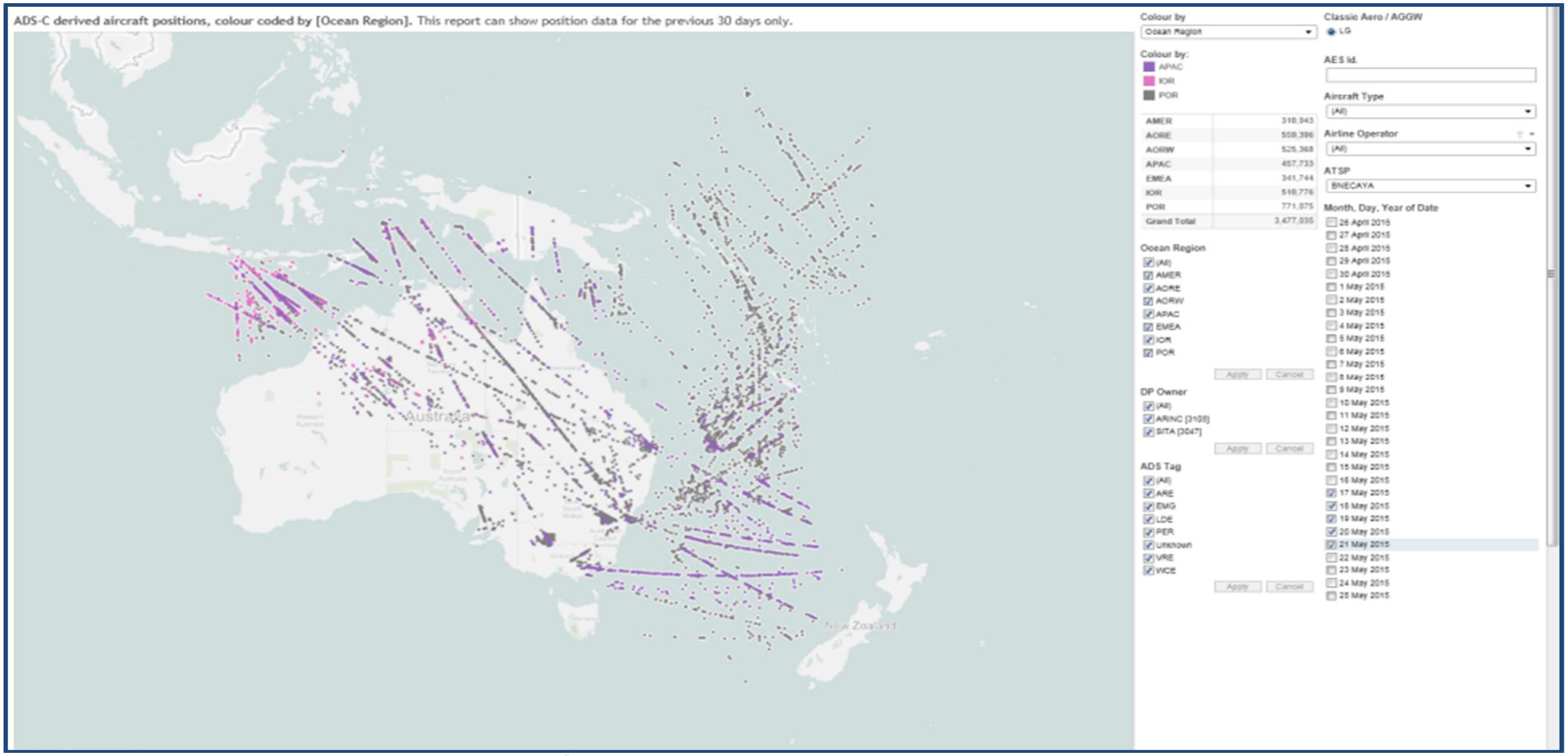

Figure 10: ADS-C Coverage in Brisbane 17th – 21st May

Brisbane ADS-C Message Count History May 2014 – June 2015

The following figure shows two charts. The upper chart shows the total number of ADS-C latency measurements per day in the Brisbane FIR from May 2014 to the start of June 2015. The lower chart shows the total number of aircraft actively using ADS-C per day in the Brisbane FIR from May 2014 to the start of June 2015.

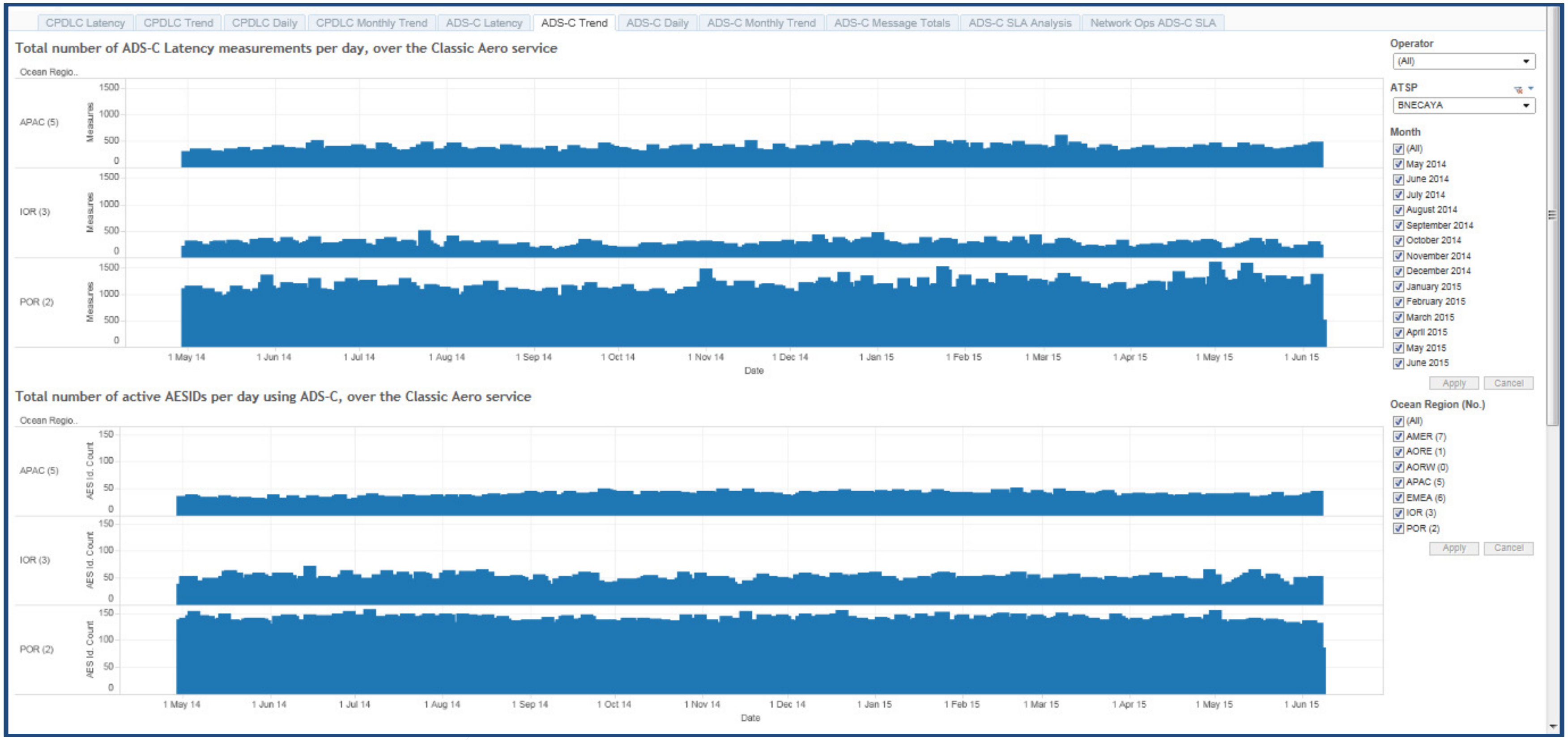

Figure 11: Brisbane ADS-C message count history May 2014 – June 2015

Brisbane ADS-C Message Count History - March 2015 – June 2015

The following figure shows two charts. The upper chart shows the total number of ADS-C latency measurements per day in the Brisbane FIR from March 2015 to the start of June 2015. The lower chart shows the total number of aircraft actively using ADS-C per day in the Brisbane FIR from March 2014 to the start of June 2015.

Figure 12: Brisbane ADS-C message count history - Feb 2015 – June 2015

Brisbane Latency - April 2 2015 – June 1 2015

The following figure shows two charts. The upper chart shows the total number of ADS-C latency measurements per day in the Brisbane FIR from the start of April 2015 to the end of May 2015. The lower chart shows the total number of aircraft actively using ADS-C per day in the Brisbane FIR from the start of April 2015 to the end of May 2015.

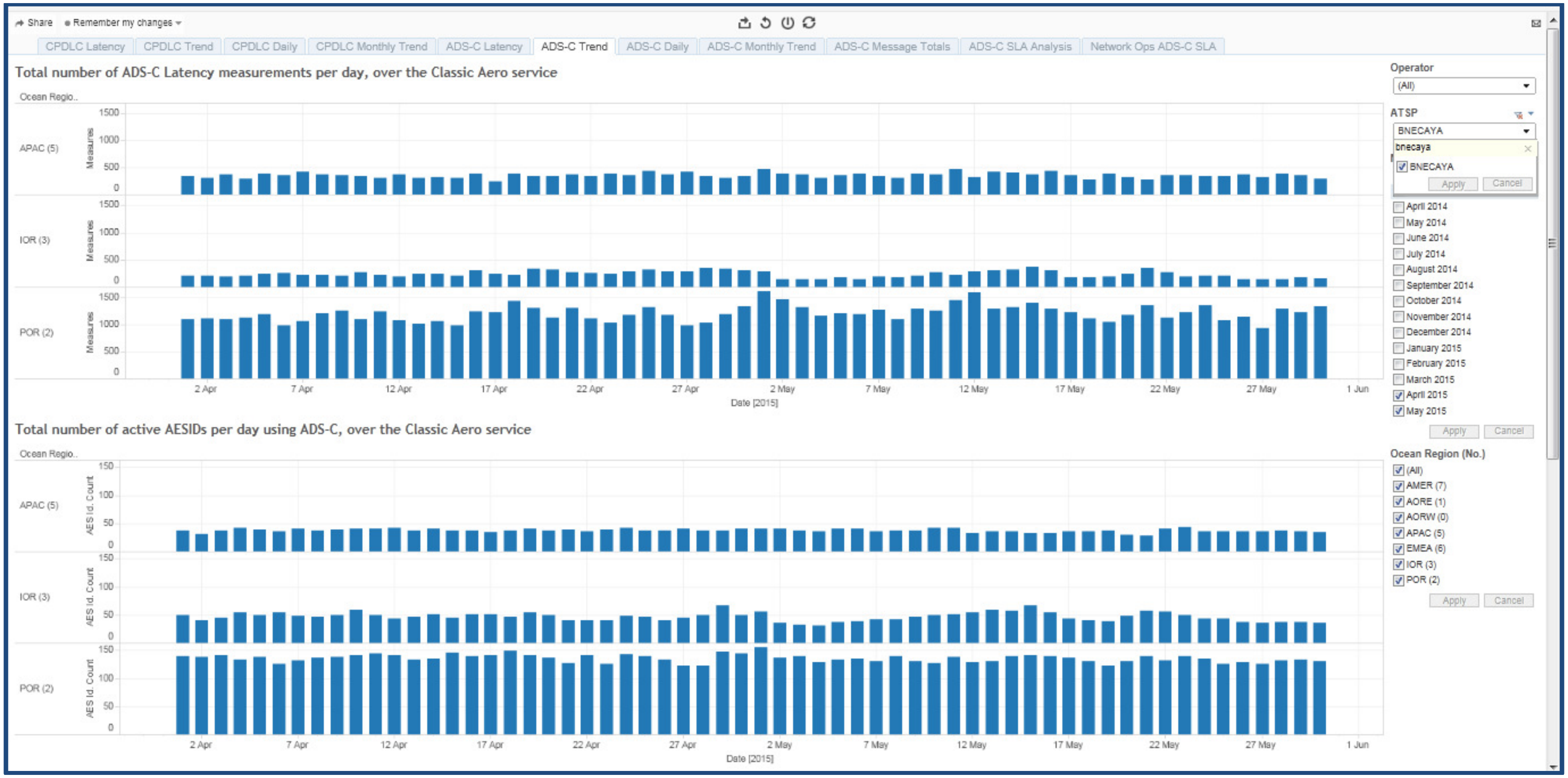

Figure 13: Brisbane latency - April 2 2015 – June 1 2015

Brisbane Latency Performance History

The following latency performance charts for April and May of 2015 provide a baseline comparison prior to the commencement of the 14 minute operation.

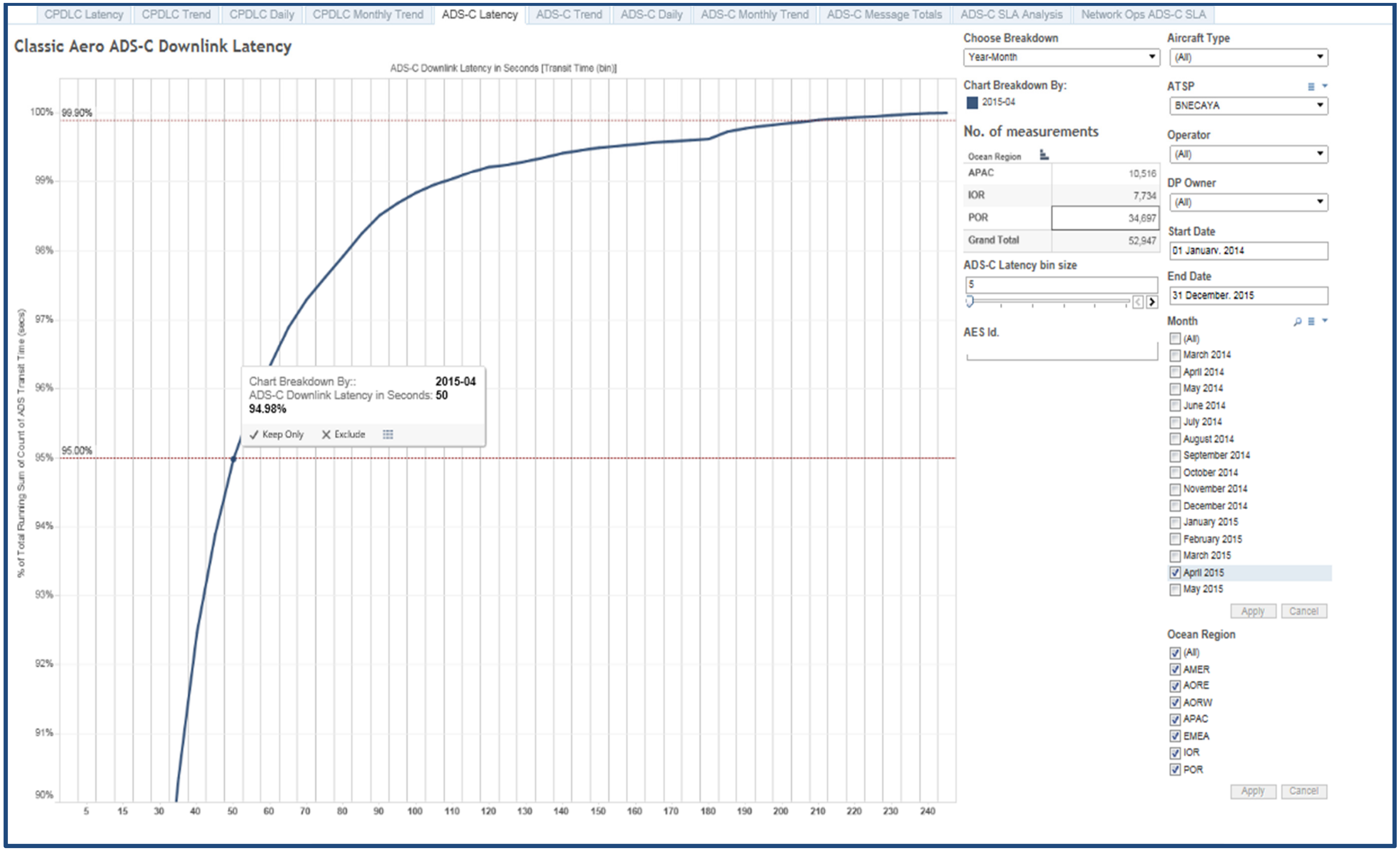

Figure 14: Historic Brisbane ADS-C latency performance April 2015

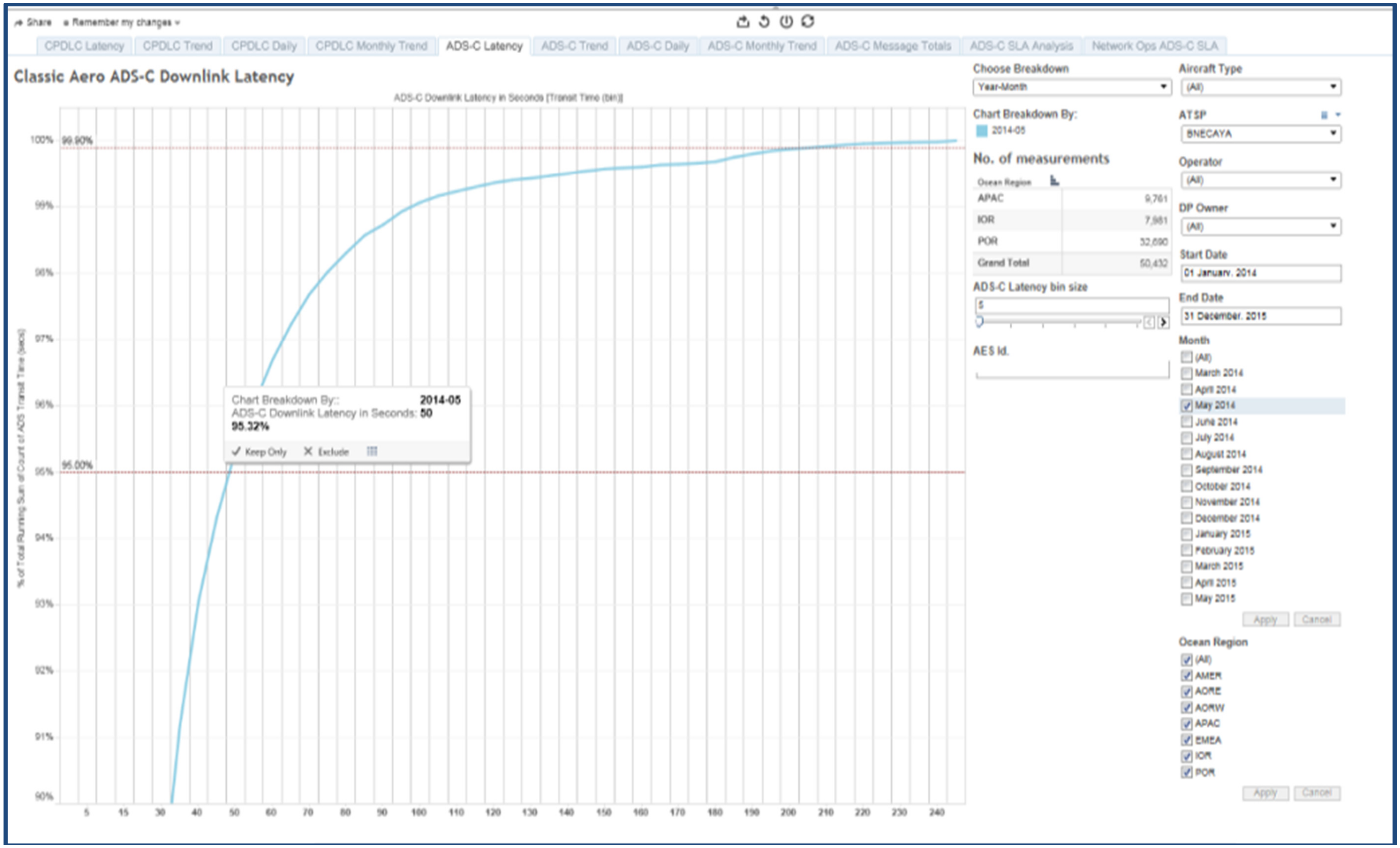

Figure 15: Historic Brisbane ADS-C latency performance May 2015

Brisbane Latency Performance History – May 2014

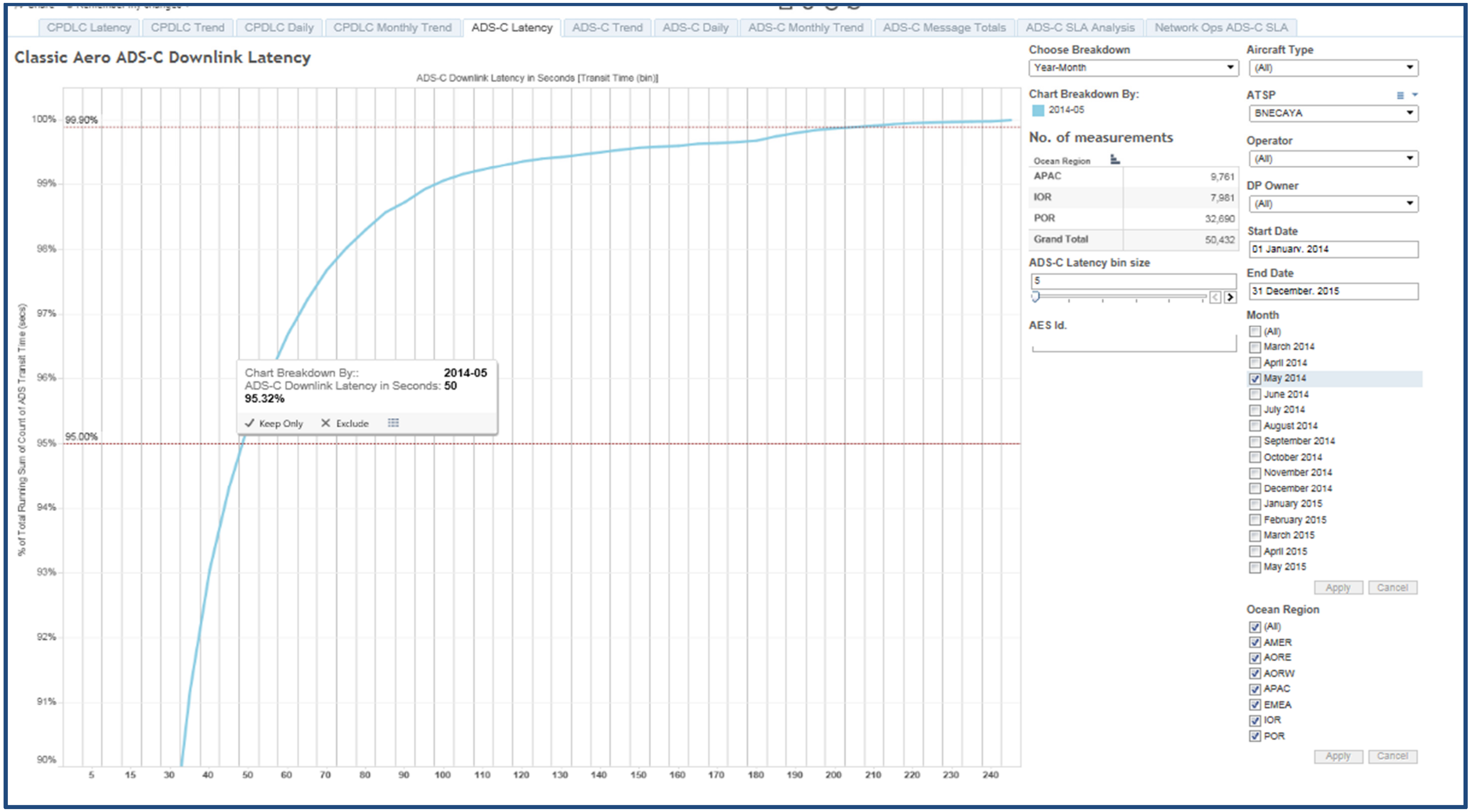

Figure 16: Historic Brisbane ADS-C Latency Performance May 2014

Brisbane Latency performance history – March 2015

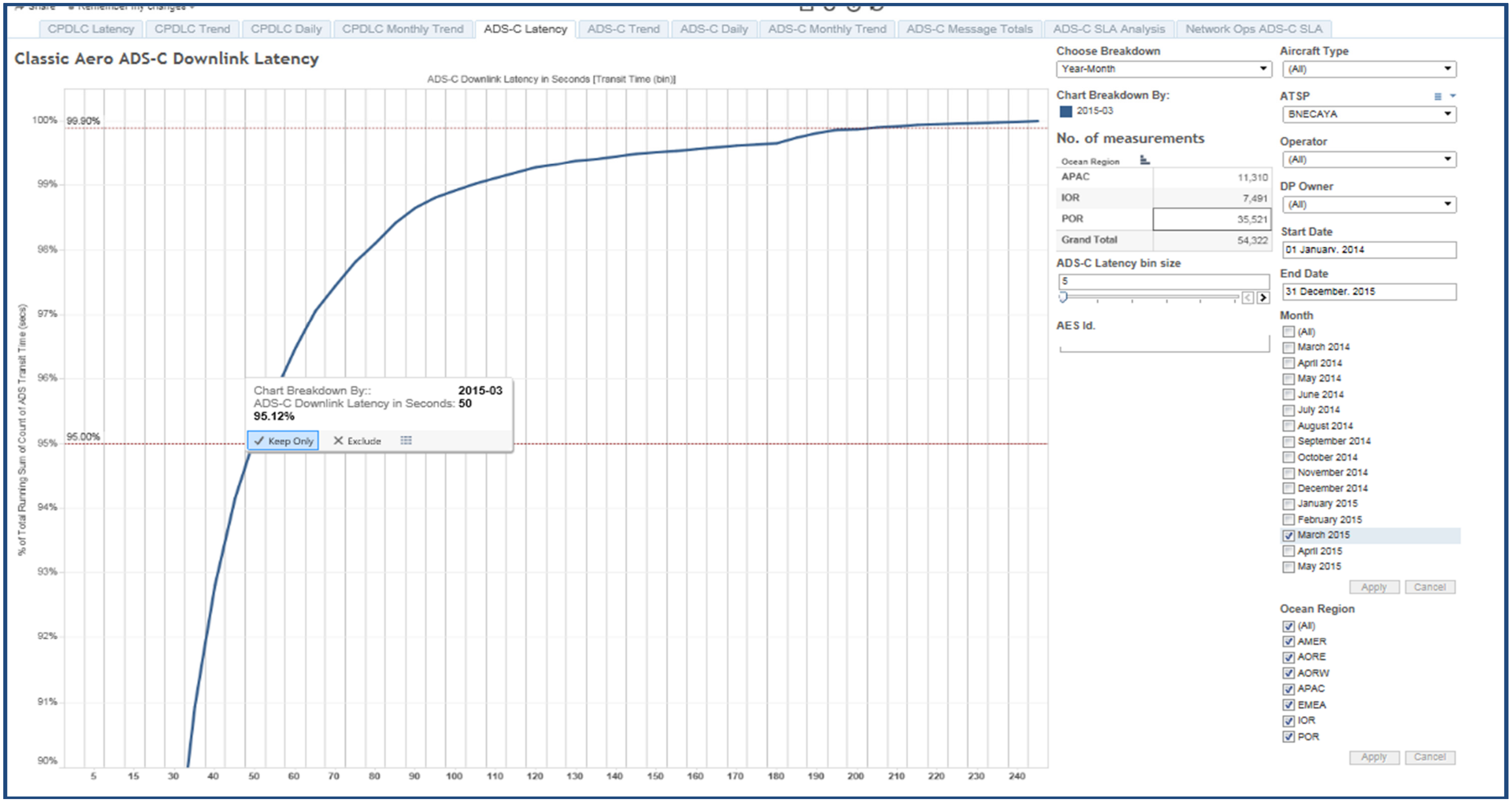

Figure 17: Brisbane ADS-C Latency Performance March 2015

Brisbane Latency performance history – April 2015

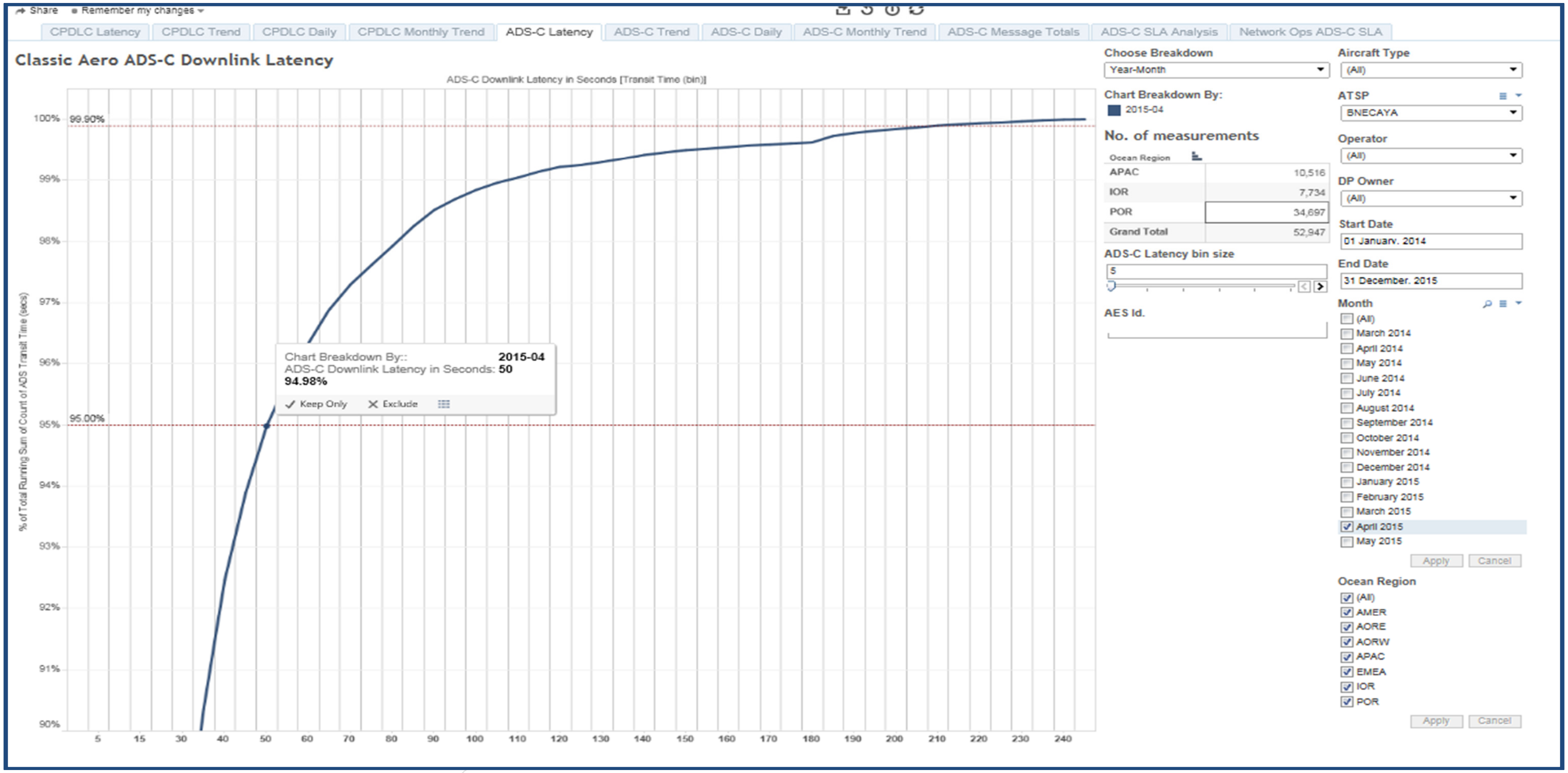

Figure 18: Brisbane ADS-C Latency Performance April 2015