ANSP Measures of Flight Descent Performance

An Evaluation of CDO and Managed Descent

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***Abstract* – Air Navigation Service Providers (ANSPs) aim to report on Continuous Descent Operations (CDOs) in their administered airspace to evaluate and monitor flight descent efficiency. However, the widely used methodology employed for measuring CDO, by assessing the presence of level segments, does not fully capture flight inefficiencies from the perspective of the aircraft operator. This paper evaluates a more suitable performance measure by identifying a managed descent that characterizes whether a CDO was executed by the aircraft's automation, i.e. the Flight Management System (FMS). This measure is presented for Australian airports before and after the onset of the COVID-19 pandemic, providing insight on operational performance in both high and low traffic scenarios. During low traffic demand, the managed descent measure shows a 60% optimization margin, as opposed to 30% using the conventional measure for some airports. Therefore, ANSPs can use this measure as a Key Performance Indicator (KPI) to develop strategies to optimize CDO for aircraft operators and increase the benefits associated with CDO in their administered airspace. Although this study focuses on the Australian flight region, the managed descent measure is equally relevant to ANSPs and organisations around the world, like SESAR, that aim to assess and optimize flight operations.**

Keywords – Flight Efficiency; CDO; Managed Descent; KPI; ANSP Performance; Airport; COVID-19

I. INTRODUCTION

In aviation, Continuous Descent Operations (CDO) are important for minimizing fuel burn, emissions, and noise during operations [1, 2, 3]. The technique is conducted by aircraft operators but is enabled by airspace and procedural design, and facilitated by Air Navigation Service Providers (ANSPs). ANSPs evaluate and monitor the proportion of CDO through performance measures in order to understand how flight efficiency can be optimised in their administered airspace. Performance measures have been developed by Eurocontrol to assess CDO through harmonized definitions, metrics and parameters for application at the international level [4] and can be used by ANSPs. Generally, the method of identifying a CDO is by measuring whether an aircraft descended without any level-off segments [5, 6, 7]. However, from the aircraft operator perspective, there is more to consider in terms of flight efficiency than only measuring level-off segments.

A measure of level segments during a descent does not reveal whether the aircraft operator conducted a CDO with the airborne automation in control of the aircraft, like that of which is provided by the Flight Management System (FMS). Often when subject to tactical intervention by Air Traffic Control (ATC), flight operators are required to revert to manual operating modes which decouples the flight from FMS. This intervention reduces the benefits of investments made in advanced airborne automation, as throttling can occur during descent which produces more fuel burn, even if the profile was continuous. Therefore, a more suitable measure of CDO has been proposed by these authors [8] which provides ANSPs with a better performance measure to optimize descents for aircraft operators by identifying aircraft conducting CDO in managed mode.

The aforementioned authors refer to a 'managed descent', when a CDO is specifically performed using a pre-determined plan by the aircraft's FMS in a predictable manner [8]. Firstly, to conduct CDO, an aircraft must descend continuously using minimum engine thrust prior to the final approach fix [9, 10], preferably in low drag configuration. Additionally, a known lateral path from an aircraft's cruise position to the runway threshold is essential for planning a CDO. Secondly, a managed descent is based on the fundamental idea that an efficient descent operation is dependent on effective management of an aircraft's energy. For medium to large jet aircraft, this is achieved by manipulating drag forces and gravity for ideal deceleration and reduction of altitude in the descent profile, which can be achieved by the aircraft automation. These concepts have been used to formulate a managed descent measure [8] that goes beyond classifying CDO by level segments, and includes whether a CDO was performed in a predictable and efficient manner, like that of which is provided by aircraft automation.

In practice, the execution of CDO can be hindered by traffic levels where ATC sequencing is required to balance demand with capacity. Tactical intervention can be applied by ATC in the form of speed control or vectoring that interrupts operator planning for execution of CDO. Although CDO can be re-established during flight, there are many factors to consider in order to regain a CDO which can increase workload for ATC and operators. Therefore, the impact of ATC intervention in different traffic scenarios needs to be investigated by ANSPs in order minimize disruption to CDO without compromising throughput in high density scenarios. There have been solutions that aim to enable CDO during high density traffic by vectoring aircraft in a more predictable manner, like SESAR's point merge solution [17], and to minimise disruptions from conventional tactical intervention techniques. These implemented solutions for improving CDO can be evaluated by managed descent Key Performance Indicators (KPIs) and used to monitor ongoing descent performance.

This study will build on previous work by these authors [8] and evaluate the application of the managed descent measure presented for Australian airports before and after the onset of the COVID-19 pandemic. The effect of the pandemic on air traffic offers a unique opportunity to study the difference between methods of measuring CDO under both high and low traffic conditions, and can be adopted by ANSPs to develop strategies during and after the recovery of traffic to optimize CDO. Although the methodology is applied to the Australian flight region, it is equally relevant to other regions around the world that aim to evaluate and optimize CDO.

Section II further describes the methodology adopted from [8] to detect whether a descent was managed, by a proxy measure.

II. Methodology

A managed descent would ideally be classified as such using information from on-board the aircraft via, for example, FMS downlinks. However, as this data source is generally unavailable to ANSPs, a proxy measurement can be used to identify a managed descent for medium and large jet operations (e.g. Airbus A320/Boeing 737 and larger). This proxy measure includes identifying (1) whether there were no level segments and (2) whether there were speed deviations from a characteristic speed profile. Large speed variations typically point to ATC intervention by request of a speed-up or slow down during the descent..

Firstly, a standard jet[1] aircraft descent has a target speed profile consisting of a constant Mach segment crossing over into a constant calibrated airspeed (CAS) segment for the performance path of the descent, which is typically above 10,000ft. This characteristic speed profile can be identified from a piecewise regression of airspeed profiles [8] for both the constant Mach and constant CAS segments. For medium-heavy jet aircraft in managed mode, the constant Mach and constant CAS descent segment is ideally executed with idle thrust and limited speed brake usage. Fig. 1 illustrates the characteristic speed profile (green dots) adopted as a baseline to compare against the airspeed data of a descent.

Secondly, speed deviations from the characteristic speed profile can be measured by the root mean squared deviation (RMSD) and absolute maximum deviation along both the constant Mach and constant CAS segment. For most jet aircraft, speed limits are considered to have been exceeded if the FMS detects a deviation of 15 – 20kts [12, 13, 14]. These values are also in line with typical values when auto-throttle and speed brakes are required [12, 13]. Therefore, based on the jet aircraft standards, this study assumes that the maximum speed deviation can vary up to 15kts for a flight to be classified as a managed descent. Additionally, the threshold of RMSD values, 7.5kts, is adopted from reference [8] and is a conservative estimation that will require investigation for future applications. In summary, the assumed thresholds for a managed descent are applied as follows:

$$\text{RMSD} < 7.5\ [\text{kts}]\ \text{AND}\ |\text{Max. Dev}| < 15\ [\text{kts}]$$

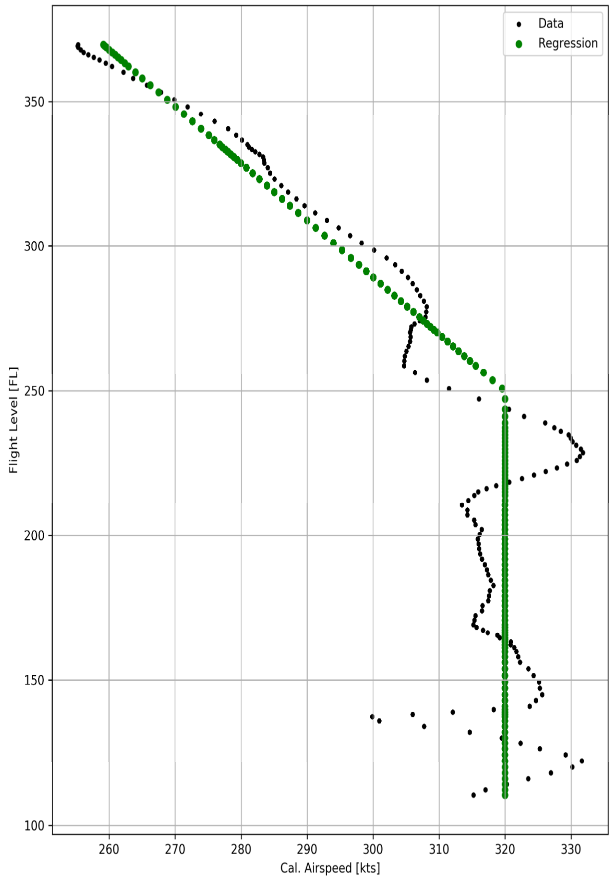

Figure 1. Example airspeed profile of a non-managed descent (black) with the characteristic speed profile from piecewise regression (green).

Additionally, the managed descent definition requires both altitude and speed conditions to be met to classify a CDO, whereas the conventional method simply defines CDO as the absence of level segments from top of descent (TOD) to landing. These measures are summarised in Table 1. Examples of a non-managed and managed descent by proxy are shown in Fig.1 and Fig.2, respectively. Both of these profiles are classified as CDO by the conventional measure, as there were no level segments during the descent.

[1] Only includes medium and large jets that typically conduct a constant MACH/CAS descent.

TABLE I. METHODS FOR DEFINING CDO

Condition	*Conventional*	*Managed Descent*
Altitude	No level segments[a]	No level segments[a]
Speed	-	RMSD[b], |Max. Dev|[b]

a. Applies from TOD to landing, where level segments must be less than 2.5NM.

c. Applies from TOD to 11000 ft. The lower limit is to exclude speed variations near deceleration to 250kts CAS at 10000 ft.

In this study, the proxy measure of a managed descent uses airspeed estimated from combining surveillance data and meteorological forecast data to resolve the groundspeed to the airspeed, as airspeed data was not available. The groundspeed was sourced from ADS-B surveillance data which typically has less noise than that of radar surveillance data. However, there can also be errors in the meteorological forecast data used (World Area Forecast Center in this study) which affects the estimated airspeed accuracy and is a point of investigation for future applications. In summary, airspeed data from ADS-B or Mode-S should be used where available instead of airspeed estimation to avoid the introduction of errors.

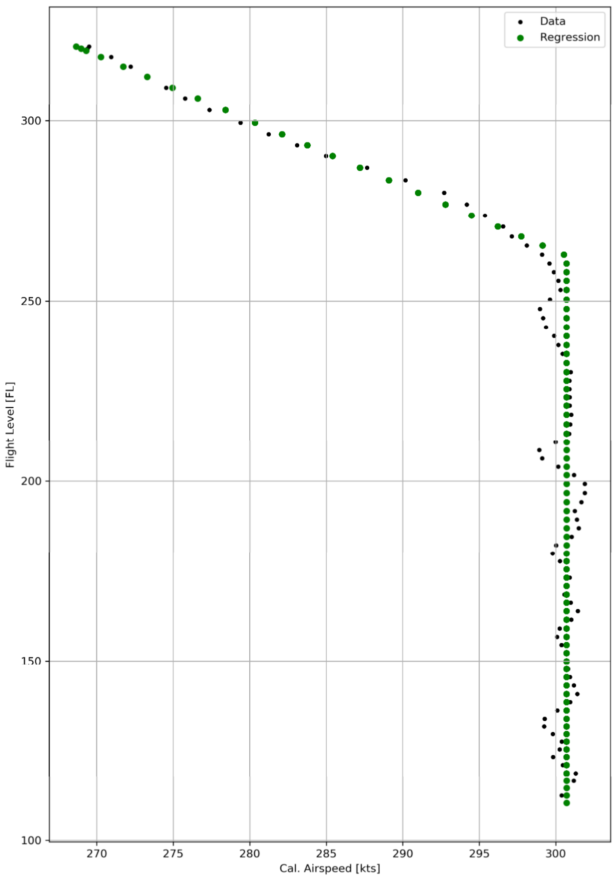

Figure 2. Example airspeed profile of a managed descent (black) with the characteristic speed profile from piecewise regression (green).

Section III compares the managed descent metric, as calculated by proxy, to the conventional CDO metric in a case study of Australian airports with a terminal control unit, i.e. Sydney Kingsford Smith (YSSY), Melbourne (YMML), Brisbane (YBBN), Perth (YPPH), Adelaide (YPAD), and Canberra (YSCB). The study is limited to medium and heavy jets which typically conduct a constant MACH/CAS descent.

III. RESULTS & DISCUSSION

The emergence of the COVID-19 virus has affected the civil aviation industry globally, with ICAO reporting a drastic reduction in international (61%) and domestic (23%) traffic between 2019 and 2020. Airports, aircraft operators, and ANSPs have seen disruptions to the delivery and planning of services due to the abrupt decline in air traffic. In Australia, there was a 79% decline in traffic from 10 March 2020 due to the onset of the COVID-19 pandemic (Fig. 3), when comparing the 6 months before and after the onset of the pandemic. Although the pandemic has caused disruption globally, this presents a unique opportunity for ANSPs to investigate descent operations, and whether CDO performance has been impacted at airports of varying capacity. This evaluation can help ANSPs to strategically plan for the delivery of services in the short and long term, as air traffic recovers from the impact of the COVID-19 pandemic.

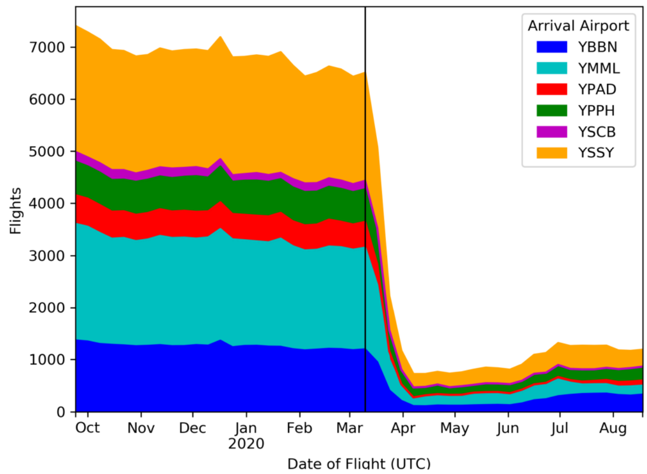

Figure 3. Weekly airport arrivals 6 months before and after the date of the COVID-19 pandemic onset (on 10 March 2020).

Both the conventional CDO and managed descent measures can be used as KPIs to evaluate and monitor ongoing descent performance. For Australian airports, an example of monthly CDO KPIs using the conventional CDO and managed descent measure are shown in Fig. 4 and Fig. 5, respectively. In general, the optimization margin by the conventional CDO measure is much lower than that of the managed descent measure. For example, for YMML pre-pandemic period, the average proportion of CDO by the conventional measure is ~70% whereas the proportion of managed descents by proxy measure is ~40%. This shows that there is a margin of ~60% to be gained from investigation of the managed descent measure, as opposed to ~30% for the CDO by conventional measure, and provides an additional level of detail to measure descent performance.

When the CDO measures for particular airports are compared, there are differences in trends. For example, at YMML (cyan lines), the proportion of CDO by the conventional measure showed no increase from March to May 2020 after the traffic decline due to the pandemic (10 March 2020). However, in contrast, the managed descent measure (Fig. 5) showed a steep increase as traffic declined from March to May 2020. This is a notable result as the managed descent measure can be associated with the traffic decline, leading to less tactical intervention for sequencing traffic and impacting on speed deviations. Overall, the turnaround month was June 2020 for both measures, coinciding with the initial recovery of traffic after the onset that led to a downturn in CDO performance. This shows that improvements in CDO and managed descents at YMML can be achieved only during very low traffic where tactical intervention is minimal and is an opportunity for CDO optimization for higher traffic scenarios.

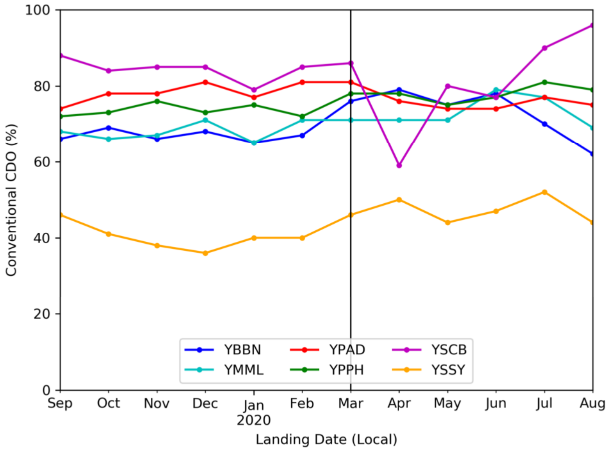

Figure 4. Conventional CDO measure by monthly KPI, with periods of before and after the date of the COVID-19 pandemic onset (on 10 March 2020).

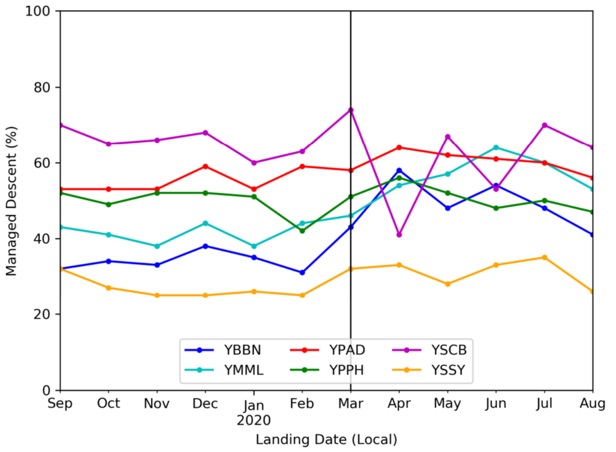

Figure 5. Managed descent measure by monthly KPI, with periods of before and after the date of the COVID-19 pandemic onset (on 10 March 2020).

Looking further at YPPH, the the number of managed descents after the onset of the pandemic was not significantly changed, as also CDO by conventional measure (green lines). There was a significant reduction in international traffic at YPPH due the pandemic onset, but domestic traffic was still present with flights continuing Fly-In Fly-Out operations within the state. This resulted in compressions of demand during the morning and afternoon peak hours which was not unlike the the pre-pandemic period. Additionally, Air Traffic Flow Management procedures for reducing airborne delay (i.e. Ground Delay Program) were cancelled due to lower demand, which would have resulted in more tactical handling by ATC. As a result of these combined factors, ATC intervention was still required at YPPH during peak hours to sequence aircraft onto metering fixes, resulting in speed deviations as evidenced by the managed descent measure.

For YSSY, the trend between the CDO and managed descent measures after the onset of the pandemic was similar (orange lines). Additionally, the monthly measures for CDO and managed descent were both lower than all the other airports shown. This can be attributed to a number of operational factors at YSSY such as higher compression of demand during peak hours, larger proportion of international flights (than any other major Australian port) not subject to Ground Delay Programs, and open STAR designs that require vectoring.

For YBBN a new airspace design was introduced in May 2020 which would have impacted CDO and managed descent performance. Further investigation can reveal whether there are limiting factors in airspace design or tactical operations, etc., that impact on CDO performance. Although not explored here, the difference in procedure design and operating environments between airports are an important factor in enabling and facilitating CDO [11].

For the lower capacity airports, YPAD (red lines) and YSCB (purple lines) showed little change before and after the pandemic onset in both CDO and managed descent measures. The traffic decline had less of an impact at these airports than that of larger capacity airports which require more sequencing by ATC to manipulate traffic flows. Nonetheless, the number of CDO and managed descents conducted at these airports during a low traffic scenario suggests that there is an improvement to be gained in increasing descent performance. Additionally, between July and August 2020 at YSCB, the conventional CDO measure shows an increase of 90 to 96% but the managed descent measure shows a decrease of 70 to 64% between the same months. Therefore, the managed descent measure highlights additional trends not shown using the conventional CDO measure, which is important information for ANSPs to identify areas to improve CDO for aircraft operators. A further investigation may reveal where improvements can made in either airspace/procedure design, aircraft operations, or ATFM/ATC procedures in order to better enable and facilitate CDO.

As the need for ATC intervention is largely dependent on the flow of traffic presented and can be exacerbated by the compression of demand, the managed descent measure can be evaluated for hours of operation in Fig. 6. For some airports, there are particular hours of the day where managed descent performance is much lower (e.g. YSSY, 0900L) which can be used to further evaluate the extent of intervention. For example, at YSSY there is typically higher demand during both the morning (0700-1100L) and afternoon (1700-2000L) periods. The extent of intervention is more prominent in the morning period when YSSY typically sees a compression of domestic and off-schedule international traffic causing disruption to traffic flows and requiring more ATC sequencing action. Therefore, the managed descent measure can be used to evaluate these hours to investigate areas for optimizing CDO.

A further investigation can be conducted on the hours with the lowest managed descent performance. For example, the 1000L hour at YBBN is typically part of the morning peak period whereby intervention is employed for sequencing aircraft. Evidence of this intervention action is reflected in the managed descent performance of 19% for the 1000L hour in Fig. 6. An example of the speed profile for a YBBN flight in the 1000L hour is shown in Fig. 1. This flight was not classified as a managed descent as the speed deviation was beyond the defined thresholds of the managed descent measure.

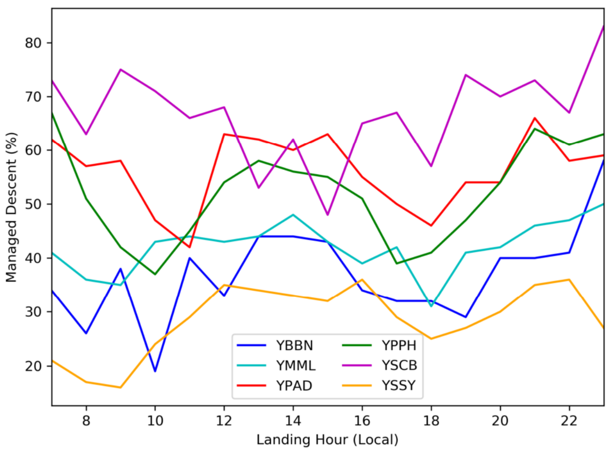

Figure 6. Managed descent proportion by local hour, for all data in this study. Only hours 0700L-2300L are shown.

Evidence of speed variation is shown on the aforementioned descent profile when compared to the characteristic MACH/CAS speed profile in Fig. 7. The profile illustrates the speed deviations before the aircraft crosses the metering fix (ENLIP) and after the aircraft enters the terminal control area of Brisbane airport (ZBNTV), where ATC tactical intervention is typically used to manage the aircraft during the arrival. For a managed descent, the aircraft should ideally be allowed to descend with optimal management of energy without disruptions in altitude or speed, and at commencement of TOD. In this example, the speed deviations are concentrated to the latter parts of the descent, i.e. before the metering fix and in the terminal control area, which impacts on operator planning for execution of CDO. Evidence of lateral intervention is further shown in tracking in Fig. 8, where there is deviation from the flight planned path (dotted line) via track shortening occurring during TOD and also when entering the terminal control area of Brisbane airport. In particular, the track shortening after waypoint ANSOR occurs later into the descent and it was likely that the crew had to manage the descent tactically, leading to large speed deviations seen in Fig. 7. This suggests that facilitation of the flight according to the pre-planned trajectory is an important factor when evaluating CDO, as there can be inefficiencies associated with managing speed when there is lateral intervention. ATC sequencing methods should ideally be implemented before commencement of TOD to allow for aircraft to descend without interruption [11]. Therefore, the managed descent measure can be investigated for individual flights or particular arrival routes which may reveal where there are further opportunities for ANSPs to improve the management of arrival flows for CDO.

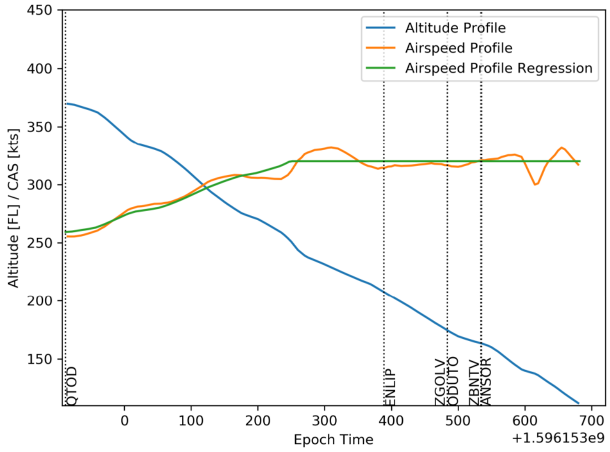

Figure 7. Altitude and airspeed profiles of a non-managed descent (blue and orange, respectively), along with the characteristic speed profile from piecewise regression (green). Vertical lines show the times of certain points during the trajectory (e.g. TOD, waypoints, and sector crossings).

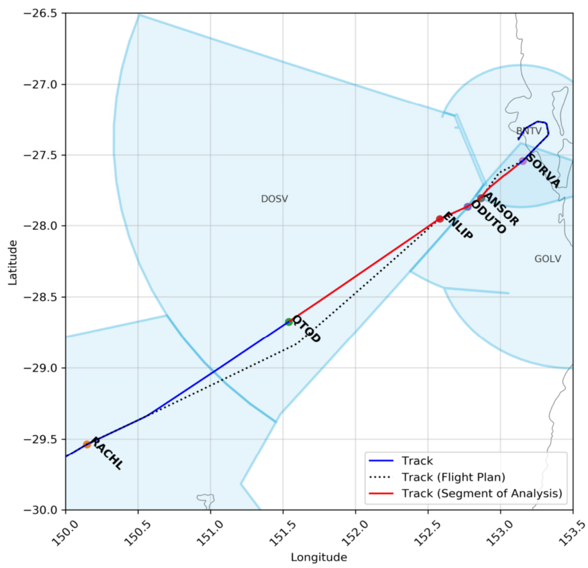

Figure 8. Track of a non-managed descent (blue) showing the segment of analysis (red) and the corresponding flight plan track (dotted). Shaded areas show sectors, and markers show certain points during the trajectory (e.g. TOD, waypoints).

IV. Conclusion

CDO is applicable to a range of airspaces and is endorsed by Eurocontrol and the Federal Aviation Administration (FAA) due to the benefits in efficiency and cost savings in fuel, emissions, workload, and noise [16]. However, in order to optimize CDO for operators, ANSPs require a CDO performance measure that identifies whether a CDO was performed in a predictable and efficient manner, like that of which is provided by aircraft automation. Generally, FMS downlinked trajectory data is not available to ANSPs to determine whether an aircraft descended in such a manner. Therefore, the methodology adopted in this study specifically utilises data accessible to ANSPs, in the absence of FMS downlinked trajectory data, and can be easily adapted by any ANSPs that aim to evaluate and optimise CDOs in their airspace.

An application of a managed descent performance measure showed how ANSPs can evaluate and optimize for CDOs according to the operator's preferences, as opposed to conventional CDO measures. The benefits of the managed descent measure were described in a case study of Australian airports before and after the onset of the COVID-19 pandemic. This provided insight on CDO performance in both low and high traffic scenarios. The study found that even during low traffic demand, the managed descent measure shows a larger optimization margin (60%) as opposed to using the conventional CDO measure (30%). The benefit of this measure is further demonstrated when considering an airport-by-airport basis, where the differences in the operational context can provide further information on where ANSPs can concentrate efforts to optimize CDO for aircraft operators. Through CDO implementation guidelines [11] and development in measuring CDO performance, such as managed descents, ANSPs can optimize services in current and future scenarios to maximize the benefits of CDO to the aviation industry.

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