Enhanced Descent Wind Forecast for Aircraft

Facilitation of Continuous Descent Arrivals with Improved Efficiency and Predictability by the use of Tailored Descent Wind Forecasts

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We realized the difficulties of flying in so high a wind, but estimated that the added dangers in flight would be partly compensated for by the slower speed in landing.

— The Wright brothers
Presentation Overview

• Introduction
• Future Air Navigation Systems Data Analysis
• FMS Forecast Model for Descent
• Tailored Descent Winds (TDW)
• TDW Evaluation
• Conclusions
• Discussion
Best system in the world, however…

**Figure 1.1:** Air passenger movements through Australia’s capital city airports


How to handle this increased traffic?
Application of more constraints?
What if we could
Allow aircraft to continue to fly standard speed and profile, conduct a CDA and not impact on efficiency?

To do this we would need to:
• Know what the FMS is thinking
• Have a confidence in the trajectory prediction including aircraft derived information?
How can we extract trajectory predictions made by the FMS using current day technology?

FANS

Implemented in most wide body aircraft since early 90’s
CPDLC
ADS-C
» Position report
» Observed weather
» Intent Data
Data Collection

Aircraft estimates are compared to actual time over to analyse estimate error.

Different points of interest analysed:
- Cruise waypoint
- TOD
- Metering fix

This is only one flight…
Example:

- 179 estimates
evolutions for waypoints on cruise
- Airbus A340-500
Example:

- 68 estimates evolutions for Top of Descent
- Airbus A340-500
Example:

» 56 estimates evolutions for Feeder Fix (TMA Entry)
» Airbus A340-500
» Increased variance on descent
» Bias created on descent

→ descent forecast held by FMS?
FMS Descent Forecast Winds

- Limited number of winds are selected from WAFC vertical wind profile at the destination (red arrows)
- Winds used far outside of validity region
- Currently airlines use fixed levels, e.g. F410 (cruise), F350, F250, F100
• FMS subsequently linearly interpolates between these levels to form the predicted wind over complete descent. Zero wind conditions on the surface are assumed by the FMS.

• This means that sometimes the FMS does not have a good representation of the winds it will fly though on descent.

• Consequently descents will not be an efficient CDA with the aircraft either above or below FMS calculated path.

Why not tailor the 4 levels such that the wind profile is best represented?
Tailored Descent Winds Proposal

- Apply high resolution forecast
- Apply arrival trajectory to forecast and select winds appropriate to this arrival
- Tailor the four winds such that the forecast profile along the arrival trajectory is optimal represented.

Area of 6 x 6 degrees around Melbourne Airport

- WAFC GRIB: ~5x5x10 = 230 grid points
- MESOLAPS: 49x49x29 = 69629 grid points
- 300 times more grid points!!

- ~360nm 49 cells
- ~60,000ft 29plvls
- ~280nm 49cells
Fix upper level at cruise altitude for FMS to be able to accurately place TOD

- 3 free levels remaining that are chosen such that prediction error is minimised (The line is a better fit).
- Animation shows only one degree of freedom (level). TDW algorithm also tailors wind speed and wind direction to find the best fit.
- Still not perfect but will provide better information to the FMS about the descent wind profile and enable it to calculate a better geometric path for an efficient CDA

Q. How will we know if it is a better solution?
A. By reduced use of speedbrake or throttle on descent.
The daily data sample

Two flights each day

1. EK406 arrived each morning using normal winds

2. EK408 arrived each evening using TDW

Both untouched by ATC or flight crew and operated in LNAV VNAV

56 suitable flights

27 suitable flights
Analysis

Inputs
- WAFC forecasts
- MesoLAPS forecasts
- Downlinked actual WX
- FANS intent
- Aircraft QAR data

We Compared
- Actual WX to GRIB forecast
- Actual WX to MesoLAPS forecast
- TDW to standard level descent winds
- Estimate accuracy standard & TDW

We Found
- Good Results but..
- Interesting behaviour
Results Matrix

Prediction error in base forecast

-3kts

Error due not applying trajectory to forecast grid

-1kts

Interpolation error

Wind profile prediction error

-3kts

Error in predicted projection of TAS along lateral path

0kts

Error in predicted aerodynamic path angle and drift angle

0kts

Error in predicted tailwind

-3kts

Error in predicted groundspeed and geometric path

Feeder Fix estimate error

Max 15sec reduction in standard deviation

Energy management actions (deficiencies)

No significant benefits (likely obscured)

Components of the wind profile prediction error to the FMS

Effects of wind profile pred. error on accuracy of geometric descent path build by FMS

Inaccurate geometric path affects the aircraft’s groundspeed

Disturbances to the groundspeed affect accuracy of TP and flight efficiency
Observations from TDW QAR data

- Untouched CDA
- Slower than target CAS
- Use of throttle (*Even when forecast correct*)
Target Speed Deviations

- 75% of flights flew slower than the target speed!
- Most likely cause of the bias observed in the Feeder Fix ETA
Conclusions and Findings

<table>
<thead>
<tr>
<th>Finding</th>
<th>Detail</th>
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<tbody>
<tr>
<td>GRIB is on average more accurate than MesoLAPS</td>
<td>GRIB appeared 1kts (~11%) more accurate than MesoLAPS for TDW sample</td>
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<td>There is a benefit of tailoring the descent winds for an</td>
<td>1kts improvement</td>
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<td>aircraft</td>
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<tr>
<td>There is a benefit of applying aircraft trajectory to the</td>
<td>3kts improvement</td>
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<td>forecast</td>
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<td>Reduced variance in error for Feeder Fix estimates</td>
<td>Standard deviation in error for Feeder Fix estimates reduced by 15 seconds.</td>
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<td>Aircraft largely deviating from target speed</td>
<td>75% of sampled flights descended at slower than expected speeds which obscured any efficiency benefits</td>
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