Increasing Adoption of Weather & Turbulence Observations

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Agenda

- Scope & concept of operations
- Recent progress
- Current availability from Boeing
- *Some* Analysis of observations
- Use at United Airlines & future outlook
- Q&A
Scope & Concept of Operations
Concept of Operations & Information Flow
Generate meteorological data to support airline world-wide operations

- **Aircraft**
  - Pilot apps
    - Weather & turbulence reports

- **Meteorological Observations**

- **Airlines**
  - Value-added services:
    - Formatting
    - Information selection
    - Aggregate aircraft reports

- **Better information of weather & turbulence**

- **Dispatcher applications**
- **3rd Parties** (e.g. National Weather Services, ANSPs, IATA, industry, service providers, research, academia)

Scope of this talk today
Recent Progress
Current AMDAR Coverage

As a result of the EDR Tech Transfer collaboration, Boeing is now able to offer the EDR algorithm as an option to their customers, including UAL and DAL

- **B777**: installed on 777-300ERs and 777-200LRs thus far
- **B787**: installing on all UAL 787s
- **B737MAX**: installing all UAL 737MAX aircraft [**New Update!**]

The reported data from UAL and DAL routes greatly expands the geographic coverage over the **Arctic and Southern Hemisphere**
Current Availability from Boeing
Boeing Model Current Availability

Boeing offers an airplane option applicable to:
- 777-200/-200LR/-300/-300ER/Freighter/-8/-9
- 787-8/-9/-10
- 737-7, 737-8, 737-8200, 737-9, 737-10

The content includes: observation date and time, aircraft identification, flight number, departure, destination, latitude, longitude, altitude, static air temperature, wind direction, wind speed, icing, and mean/peak eddy dissipation rate (EDR) turbulence, and provisions for humidity & cloud properties on certain models.

If interested: Please contact Boeing to request incorporation of the new aircraft weather and turbulence reporting option.
April 24, 2018: The 3 Boeing models reporting for UAL
Analysis of Observations

(this is a start!)
UAL 777 (362367 observations)

UAL 777s EDR Turbulence Observations thru 8/31/18

Legend:
- 0<=EDR<1
- 1<=EDR<2
- 2<=EDR<3
- 3<=EDR<4
- 4<=EDR<5
- 5<=EDR<6
- 6<=EDR<7
- EDR >= 7

- Moderate Turbulence (yellow)
- Light Turbulence (green)
- Severe Turbulence (red)
UAL 737MAX Observations

UAL 737s EDR Turbulence Observations thru 8/31/18

Just Starting!
Methodology for analysis of the reported EDR (per RTCA DO-370)

Customers expect verification of installed software for correctly reporting the appropriate values (winds, temperature, icing, EDR turbulence, etc.)

Post-installation analyses over many flights (perhaps thousands of individual observations) help evaluate an aircraft implementation.

Statistical analysis of the reported EDR using a probability distribution function (PDF) derived from a histogram of the EDR can be used to help verify that the results are reasonable.

- The binned EDR data over a period of time can indicate problems with the algorithm performance.
- Note that the exact distribution of the data will be affected by an aircraft’s operation, including but not limited to:
  - Altitude
  - Geography
  - Season, time-of-day
  - Logic for periodic and threshold reporting
  - Operator’s weather and turbulence avoidance culture and procedures

[adapted from Sharman, et al., 2014, Fig. 10]
• At this time, we see reasonable agreement between UAL 777s and 787s.

• It will be interesting to revisit once both of UAL’s 787s and 777s are over 1 million observations (in 2019)

• We don’t expect anything too different from what NCAR has seen on 737/757/767s for many years.

• But, keep in mind the operational altitude differences of 777 vs 787 [see next slides]
Reminder: Tropopause levels vary with latitude

Example: Below tropopause range is FL300-FL500+ (boxes in High Level SigWx)
Operational Altitude

- Design altitude for 787s and 777s are different
- In time, we'll see if 787 operations in lower stratosphere make a statistical difference for reported EDR magnitude.

UAL 777s and 787s altitude (May-Aug 2018 heartbeat reports)

- # 777 reports: 97930
- # 787 reports: 125936
- Mean 777 alt: 32746 ft
- Mean 787 alt: 36345 ft
• UAL notes the differences between 787-8 and 787-9 operational altitude is also worth mentioning

**UAL 787-8 and 787-9 altitude (May-Aug 2018 heartbeat reports)**

- # 787-8 reports: 36604
- # 787-9 reports: 89332
- Mean 787-8 alt: 37181 ft
- Mean 787-9 alt: 36002 ft
Use at United Airlines & future outlook
Monthly UAL 777, 787, and 737Max Observations
UAL 777/787/737Max Monthly Observations thru 7/31/18

Rapid Growth June-July

UAL uses:
- Flight deck
- Dispatch
- Analysis

737s just starting
U.S. Carriers: >1,100 equipped aircraft (as of 8/27/2018)
  DAL: ~364 (B-737/767/777, A-320/330)
  UAL: ~57 (B-777/787/737MAX)
  SWA: ~710 (B-737)
Foreign carriers joining program
  • Qantas, Lufthansa/Swiss Air, Air Lingus, Air France, etc.