VextGEN

Friends and Partners of Aviation Weather (FPAW) 2016 Application of Turbulence Data in Flight Operations Introduction: The Turbulence Problem

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FPAW

Application of Turbulence Data in Flight Operations

Panelists

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The Turbulence Problem and Advancements in Mitigation Overview

- Motivations
- Automated In Situ Turbulence Reporting
- Turbulence Forecasts/Nowcasts
- Integration of Turbulence Information into Flight Operations
- Future challenges





Motivations

Turbulence impacts on NAS Operations

- SAFETY: In non-fatal accidents, turbulence is leading cause of injuries to passengers and flight crews for Part 121 Air Carriers¹
 ²1998-2013: 432 turbulence events; 225 serious injuries; 1,109 minor
- CAPACITY: Turbulence is the 2nd leading cause of impact to NAS capacity
 - Degraded acceptance/departure rates from terminals
 - Reroutes, delays, diversions, cancellations
 - Increased controller workload

• FUEL CONSUMPTION/EMISSIONS: Pilot initiated altitude deviations

- ATC "Chat Room" Pilots & controllers on center frequencies drive often unnecessary altitude deviations as pilots seek smoother rides
- + Significantly reduces airline fuel economy and increases carbon emissions.
 - Estimates that 40-159 million gallons of fuel are wasted annually³

¹<u>http://www.faa.gov/passengers/fly_safe/turbulence</u>
 ²NTSB Briefing to Turbulence Workshop, Washington DC, September, 2014
 ³NASA Turbulence Reporting Technologies In-Service Evaluation: Delta Air Lines Report Out, April 2007





Motivations User Turbulence Concerns

• • • • •	Flight Crews Multiple data sources (ATC "Chat" room, dispatchers, company-specific forecast products, on-board radar) Strategic vs tactical decisions Reporting subjectivity, inaccuracy Cabin management Varied tolerance for risk Company policies	 Dispatchers Multiple data sources Subjectivity, inaccuracy Varied tolerance for risk Workload
•	ATC No access to real-time turbulence data at work area Reporting subjectivity, inaccuracy PIREPs communicated via "sneaker net" Ride reports passed from controller to controller during shift change Altitudes "blocked" out with repeated turbulence reports, can persist for hours	 Flight Attendants Cabin management Insufficient info from flight crews Obligation to continue duties when seatbelt sign is on 300 lb beverage cart Uncooperative passengers

Motivations Shortfalls in Manual Turbulence PIREPS

- Wright Brothers' Technology?
- PIREPS are subjective in nature
- PIREP thresholds are aircraft-dependent
- Due to various reasons, manual turbulence PIREPs are often inaccurate in space and time:
 - A 2012 study by the NCAR found*:
 - 1. PIREPS, on average, have distance errors of 35-45 km
 - 2. Average PIREP timing error can range from a few seconds to a few minutes

*Pearson, J. and Sharman, R., 2013: "Calibration of in situ eddy dissipation rate (EDR) severity thresholds based on comparisons to turbulence pilot reports (PIREPs)", presentation at 93rd American Meteorological Society Annual Meeting, 16th Conference on Aviation, Range, and Aerospace Meteorology, Austin, Texas.





Automated In Situ Turbulence Reporting NCAR EDR Algorithm

 Development began in 1990s under FAA's Aviation Weather Research Program (AWRP)



- Software loaded on the Aircraft Condition Monitoring System (ACMS); uses existing sensors (accelerometer, winds, pressure, etc) and inputs derived from sensors (angle of attack, roll angle, etc) to calculate a measure of the turbulent <u>state of the atmosphere</u>
- Aircraft independent, not a direct measurement of g-loads
- Provides atmospheric turbulence metric: Eddy Dissipation Rate (EDR)
- International Civil Aviation Organization (ICAO) standard for turbulence reporting





Automated In Situ Turbulence Reporting NCAR EDR Algorithm (As of Oct 6, 2016)



🎯 FAA

U.S. Carriers: ~85 reporting a/c

•DAL – 84 (B-737/767s)

A-330/321s, B-777s in progress

Within next 3-4 months, 284 total

Within 12 months, potential for 270 additional

•SWA – Currently 0 (B-737s)

Undergoing avionics upgrade

Potential for >600

•UAL - 1 (B-757)

Foreign carriers

- •XiamenAir (China): ~~59 B-737s, possible plans for B-787s
- •Qantas (Australia), Air France, Lufthansa (Germany) all interested

In Situ Turbulence Reporting Other Developers

• Panasonic (TAMDAR): 296 current installations, 136 more under contract

- 10 active participating airlines, plus future B737 operator in Asia:
 - AeroMexico Connect (Mexico); Embraer ERJ145s, EMB190s
 - AirAsia (Southeast Asia); Airbus A320s
 - Republic Airways (Eastern US); Embraer ERJ145s
 - Piedmont Airlines (Eastern US); Bombardier Dash-8 100/300s
 - Peninsula Airways (Alaska & Eastern US); Saab 340s & 2000s
 - Silver Airways (Eastern US); Saab 340s
 - Ravn Alaska (Alaska mainland); Bombardier Dash-8 100s and Beechcraft 1900Cs
 - Icelandair (US and Europe); Boeing B-757s
 - Horizon Airlines (Western US); Bombardier Q400s
 - Flybe (Europe); Bombardier Q400s and Embraer EMB195s

•AeroTech Research U.S.A., Inc.: Turbulence Auto-PIREP System (TAPS), licensed by WSI "As of January 2014, three WSI-client airlines (including American Airlines) were operating 465 Boeing and Airbus equipped with TAPS." [Rosenkrans, W., 2014: Smooth Operators. *AeroSafety World*, 14-19.]





9



Turbulence Forecasting Graphical Turbulence Guidance (GTG3)



Max Intensity CAT+MWT All Levels CAT+MWT Low Levels (GA Users)

Explicit MWT Forecasts

- Graphical product; available on Aviation Digital Data Service (ADDS) <u>https://www.aviationweather.gov/turbulence/gtg</u>
- Forecast output in EDR with additional label of subjective intensity categories
- User selectable display for specific aircraft weight class (light, medium, heavy)
- Includes explicit forecasts for Mountain Wave Turbulence (MWT)
- Forecasts issued for 1,000 ft to FL 450
- Low-level forecasts (1,000 10,000 ft) incorporated for use by General Aviation
- Hourly forecasts extend out 0-18 hours, updated hourly

Turbulence Forecasting Graphical Turbulence Guidance "Nowcast"

- Nowcast: Designed for use as a tactical turbulence avoidance product
 - Rapid update cycle of 15 minutes, valid for next 15 minutes
- Outputs a 3D map of EDR, same grid as GTG3
- Product received unanimous approval of Technical Review Panel comprised of FAA, NWS, and airline met representatives on 3/23/2016
- Collaborative (FAA/DAL) operational validation begins late 2016







Integration of Turbulence Information into NAS Operations

In 2008, DAL approached FAA with proposal to jointly conduct "Proof of Concept" demonstrations, integrating automated turbulence information into airline flight operations.

Dispatch Demo
<u>Sep 2008-Jan 2010</u>
Focused on:
• Dispatchers
•Flight Operations
•Atlanta Air Route Traffic Control Center Weather Support Unit (CWSU)
Flight crews did not have direct access to the data. Demo was strategic in nature, not tactical.

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Uplink Demo May 2013-Jul 2014

Operational flight demonstrations of the turbulence tablet with Line Check Airmen in the cockpit.

- Is it feasible to provide and displaying the information on the flight deck through existing WiFi link?
- •What human factors considerations exist?
- •Can we quantify the efficiency and capacity benefits to the NAS?

Conclusion: Overwhelming approval by LCA. DAL recommends implementation airline-wide as supplementary information.

Integration of Turbulence Information into NAS Operations

Delta Air Lines Flight Weather Viewer

- Updated tablet application is now in use in the cockpit by over 12,000 DAL pilots through the GoGo WiFi network
- Depicts graphical views of forecast and actual turbulence along route of flight

14

- Greatly enhances cockpit situational awareness
- Reduction in ATC workload





Global Expansion of Program EDR Tech Transfer Package Development

- Under FAA Weather Technology in the Cockpit (WTIC) funding, NCAR is developing an EDR Technical Transfer (EDR TT) package that will allow airlines to more readily implement the EDR algorithm
 - Both onboard data processing software and ground-based software to provide tuning and verification
 - Testing is being done in collaboration with Delta Air Lines (B-777s) and Boeing



 Still a prototype, but maturing quickly



Current Efforts and Challenges

- NextGen and Weather Avoidance Fields
 - Under the FAA's NextGen program, weather information will be translated into <u>weather</u> <u>avoidance fields</u> for integration into decision support tools (for example, traffic flow management systems)
 - Metron Aviation is developing a Turbulence Avoidance Model (TAM) for FAA which will produce avoidance fields generated using pilot behavior models
- Standardization
 - + The three major EDR algorithm implementations (NCAR, WSI, Panasonic) all use different computational methods; Industry needs assurance output is "operationally comparable"
 - RTCA Special Committee 206, Aeronautical Information and Meteorological Data Link Services; drafting EDR Minimum Operational Performance Standards (MOPS)
- Data Access/Sharing
 - + EDR data is considered proprietary by the airlines and private commercial vendors
 - Efforts underway to process and store the NCAR EDR data on National Weather Service's MADIS system
 - Potential for cost-sharing/more open data access agreements between the gov't and airlines?





16

Summary

- Turbulence has pronounced effect on flight operations and air traffic management.
- The U.S. has growing turbulence and forecasting programs.
- U.S. airlines are beginning to incorporate the data into their operations and seeing real benefits.
- There are challenges ahead, but the future is promising and we are hopeful the programs can be expanded worldwide.







