



Update on FAA Turbulence Work

Friends and Partners of Aviation Weather (FPAW)

Summer 2018 Meeting

July 17, 2018

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FAA

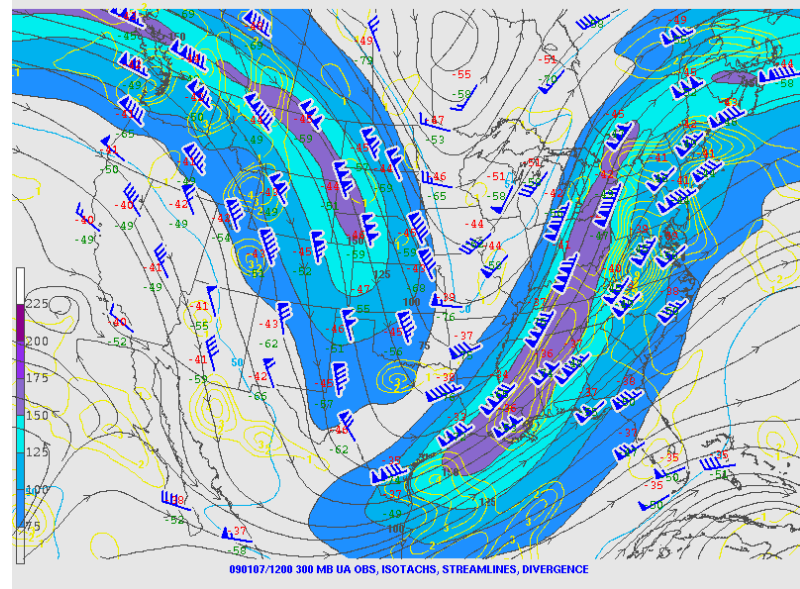
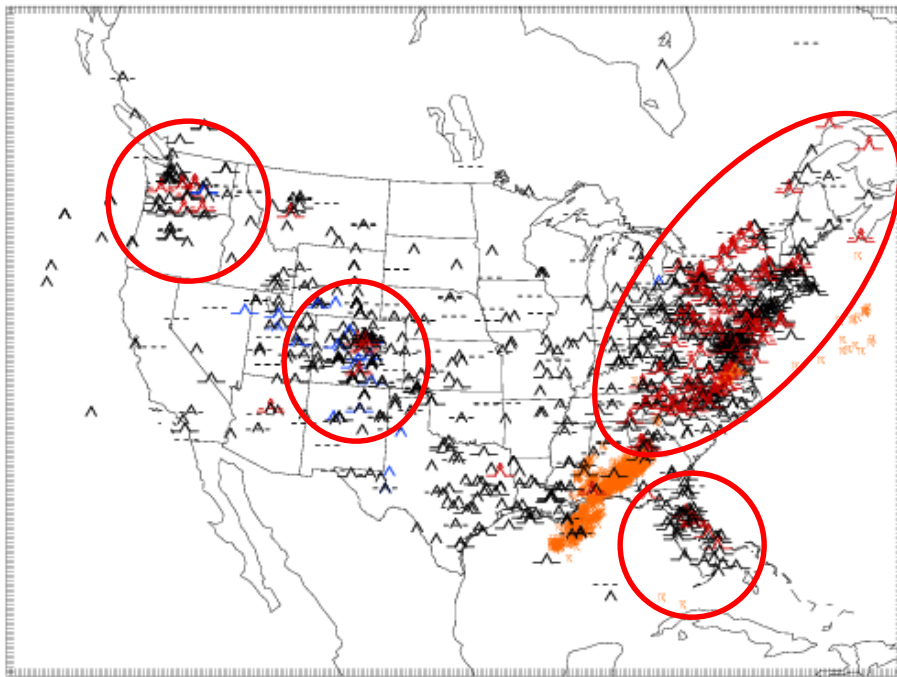
Update on FAA Turbulence Work Overview

- *In situ* Turbulence Detection – Government-Industry Collaboration Successes
- Graphical Turbulence Guidance Nowcast (GTGN) Operational Evaluations
- Turbulence Reporting Standards Development
- September Turbulence Workshop

Turbulence

Why do we care?

pireps for 07 jan 2009 0000 to 2400 UTC
flight levels(ft) = 1. to 65000.



FAA

Motivations for FAA Turbulence Research

- **SAFETY:** In non-fatal accidents, turbulence is leading cause of injuries to passengers and flight crews for Part 121 Air Carriers¹
 - ✦ 1998-2013: 432 turbulence events; 225 serious injuries; 1,109 minor²
- **CAPACITY:** Turbulence is the 2nd leading cause of impact to NAS capacity
- **ECONOMY:** Cost to U.S. airlines ~\$100 million/year³
- **FUEL CONSUMPTION/EMISSIONS:** Turbulence related pilot initiated altitude deviations significantly increase airline fuel burn and carbon emissions
 - ✦ Estimates of fuel wasted by U.S. airlines as high as 160 million gallons/year⁴

¹http://www.faa.gov/passengers/fly_safe/turbulence

²NTSB Briefing to Turbulence Workshop, Washington DC, September, 2014

³<http://news.delta.com/groundbreaking-app-helps-delta-pilots-avoid-turbulence>

⁴NASA Turbulence Reporting Technologies In-Service Evaluation: Delta Air Lines Report Out, April 2007



Motivations

Shortfalls in Pilot Reports (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 2014 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

*Sharman, R. D., L. B. Cornman, G. Meymaris, J. Pearson, and T. Farrar, 2014:
Description and derived climatologies of automated *in situ* eddy dissipation rate reports of atmospheric turbulence.
J. Appl. Meteor. Climatol., **53**, 1416-1432, doi:10.1175/JAMC-D-13-0329.1

FAA Research

Automated In Situ Eddy Dissipation Rate (EDR) Reporting

- Research and development by National Center for Atmospheric Research under FAA's Aviation Weather Research Program (AWRP)
- An algorithm in 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 *state of the atmosphere*
- Aircraft independent, not a direct measurement of g-loads
- Provides atmospheric turbulence metric: Eddy Dissipation Rate (EDR), actually $\varepsilon^{1/3}$ (m^{2/3} / s), scaled 0.0-1.0
- International Civil Aviation Organization (ICAO) standard metric for turbulence reporting



EDR

Government-Industry Collaboration Success

EDR Tech Transfer (EDR TT) Package Development

- Under funding from the FAA's Weather Technology in the Cockpit (WTIC) program, NCAR developed an EDR TT package that allows airlines and airframe manufacturers to independently implement EDR reporting
- Development Approach: Modify the EDR algorithm to expand the capabilities of on-board and ground-based verification and tuning software
- The package then required evaluation and refinement to ensure it was complete and usable for new airframe types
- Key project participants: The Boeing Company, Teledyne Controls, Delta Air Lines, United Airlines
 - ✦ Others: Meteostar, Lufthansa, Swiss Air, AirDatTek, GoGo

Government-Industry Collaboration Success

EDR Tech Transfer (EDR TT) Package Development

U.S. Carriers: >1000 equipped aircraft (as of 7/16/2018)

DAL: ~312, UAL: ~51, SWA: ~684

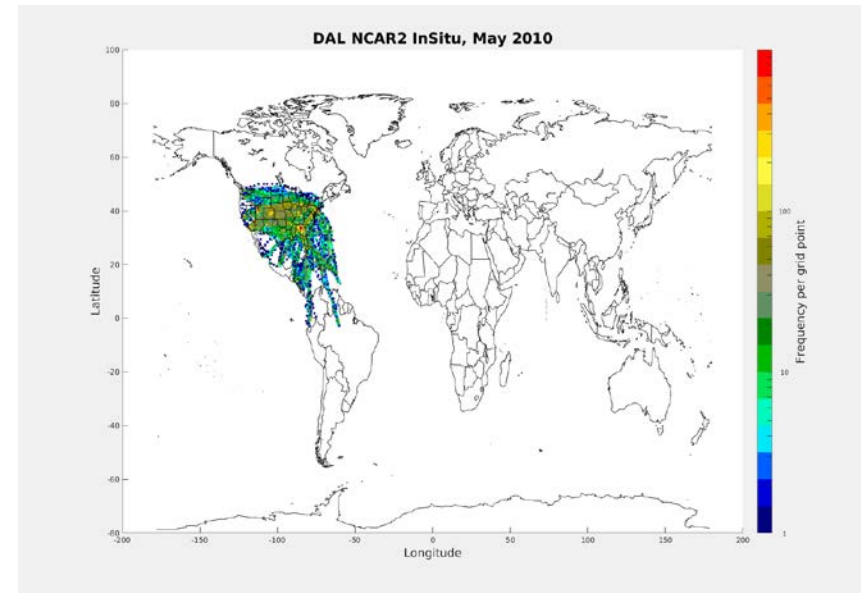
Foreign carriers joining program

- Qantas, Lufthansa/Swiss Air, Air Lingus, Air France

Recent Accomplishments

- Upgraded in-situ core ingest/QC software to accommodate additional airline data (e.g. A330) and added this capability to tech transfer package version.
- Monitored calibrations of different fleets
- In process of adding in situ data from several airlines
- Improvements to tuning methodology

Global Delta Airlines EDR Observations 2010-2018

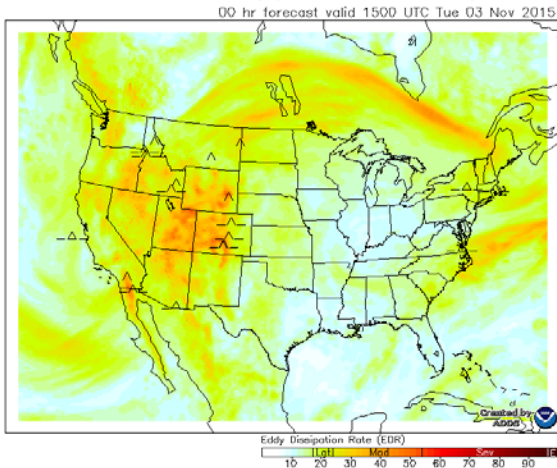


FAA Research

Graphical Turbulence Guidance (GTG) Forecast

Aircraft: Heavy Plot: Combined
Vertical level: max Forecast time: 0hr - 15Z 03 Nov

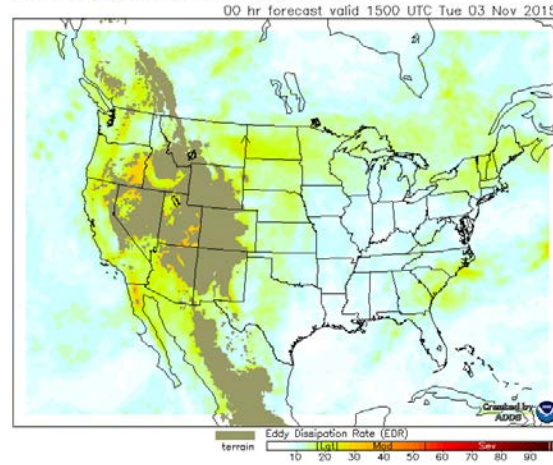
GTG - Max combined intensity (1000 ft. MSL to FL500)



Max Intensity CAT+MWT All Levels

Aircraft: Heavy Plot: Combined
Vertical level: 5,000 Forecast time: 0hr - 15Z 03 Nov

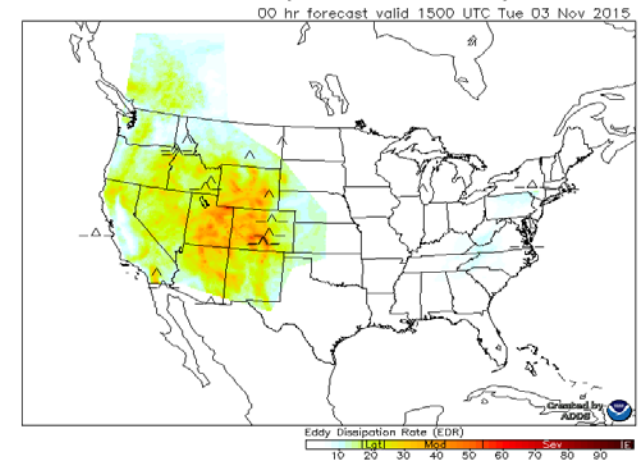
GTG - Combined CAT+MTW at 5000 ft. MSL



CAT+MWT Low Levels (GA Users)

Aircraft: Heavy Plot: Mtn Wave
Vertical level: max Forecast time: 0hr - 15Z 03 Nov

GTG - Max mountain wave (1000 ft. MSL to FL500)



Explicit MWT Forecasts

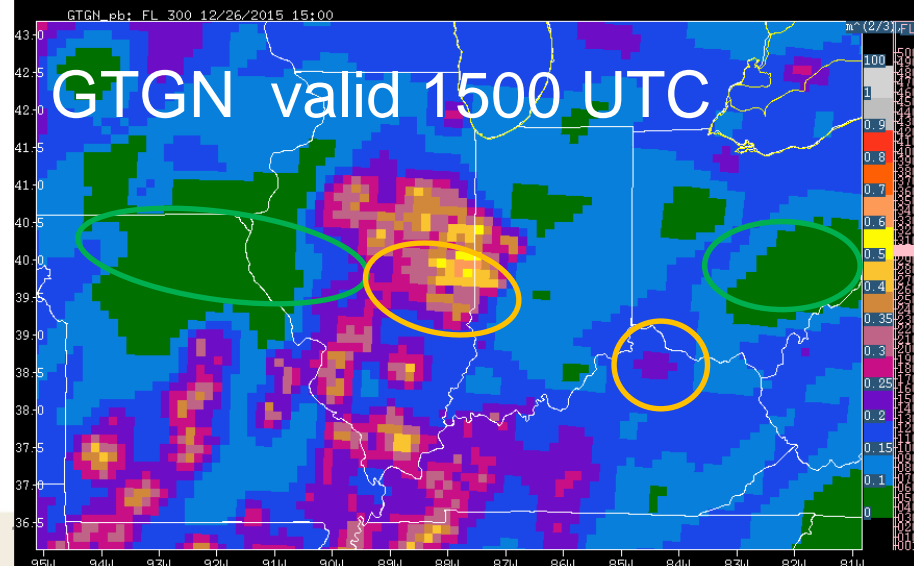
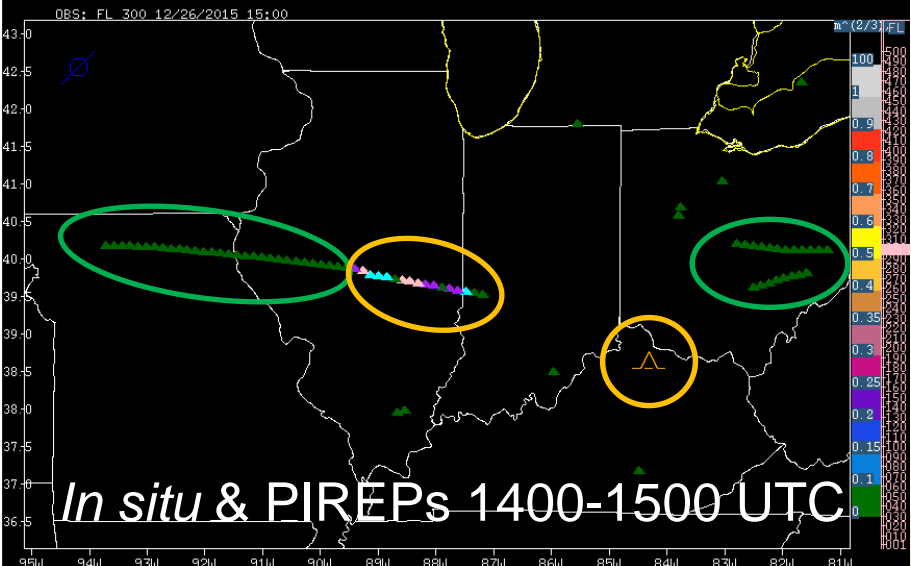
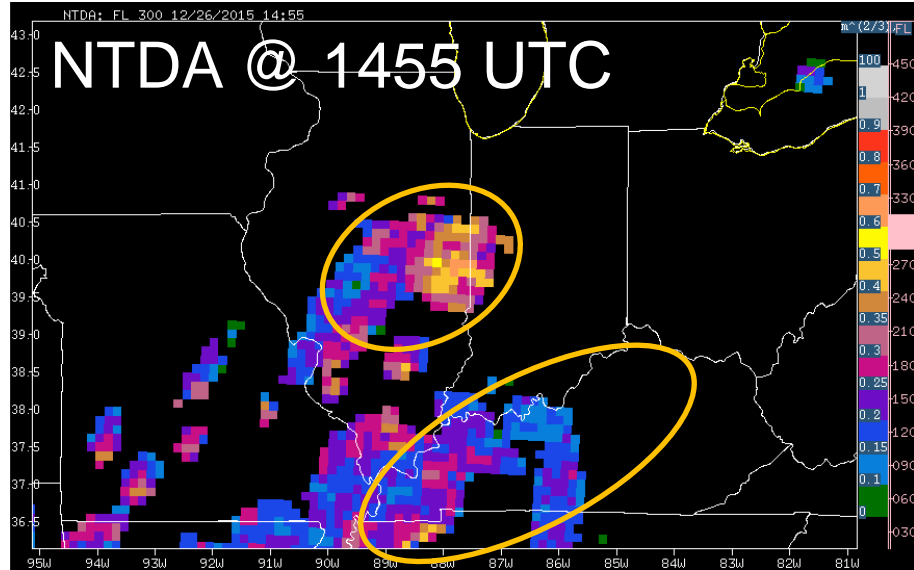
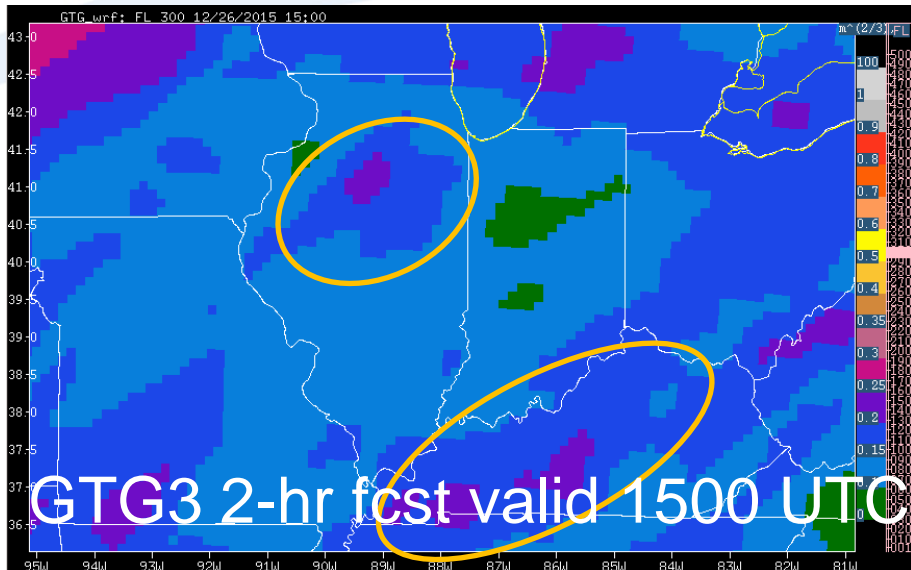
- Based on NOAA's RAP NWP model
- Publically available on <https://www.aviationweather.gov/turbulence/gtg>
- Forecast output in EDR [x100] with additional label of subjective intensity categories
- User selectable display for specific aircraft weight class (light, medium, heavy)
- Includes explicit forecasts for Mountain Wave Turbulence (MWT)
- Forecasts issued for Surface to FL 450
- Hourly forecasts extend out 0-18 hours, updated hourly

Graphical Turbulence Guidance Nowcast (GTGN) Operational Evaluations

- Designed for use as a tactical turbulence avoidance product
 - Rapid update cycle of 15 minutes, valid for next 15 minutes
- Observation-centric:
 - Nudges GTG3 to better agree with most recent turbulence obs
 - Uses both airborne (PIREPS, in situ EDR) and ground-based (NEXRAD Turbulence Detection Algorithm-NTDA) observations
- Outputs all sources of turbulence – Low level, mountain wave, in cloud in a 3D map of EDR, same grid as GTG3
- Product received unanimous approval from a Technical Review Panel comprised of FAA, NWS, and airline met representatives in March 2016

GTG-Nowcast

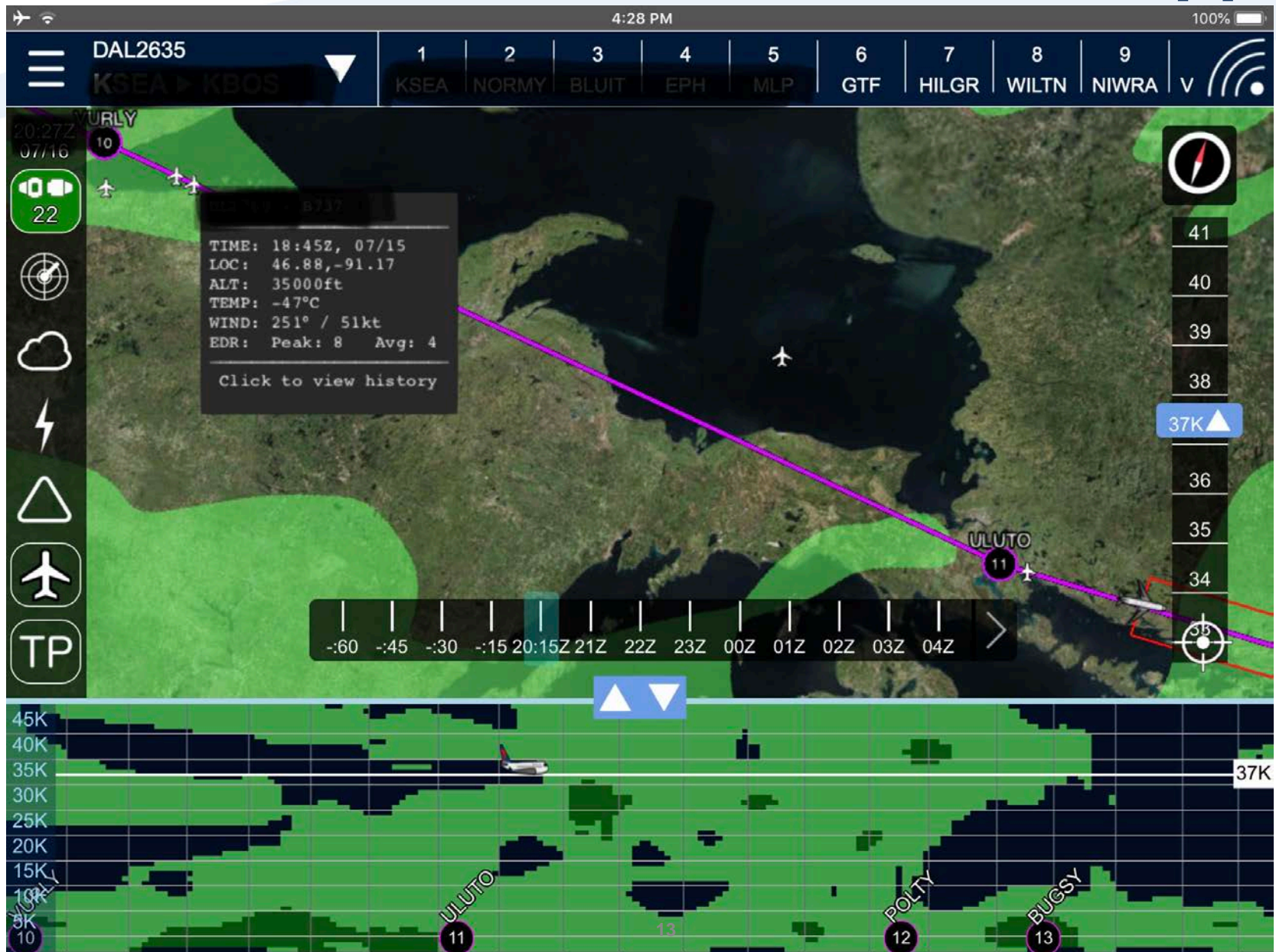
Example: Dec 26, 2015, valid at 1500UTC FL3000



Graphical Turbulence Guidance Nowcast (GTGN) Operational Evaluations

- GTGN available in real-time to AWC Testbed and Delta Air Lines to have flight crews and other users assess and evaluate the potential uses of the GTGN product in operations
- >12,000 DAL pilots with tablets containing “Flight Weather Viewer” application
 - ✦ Provides real-time graphics of GTG and EDR, along with company-specific products
- Crew reactions: “Industry game changer”; “...incredible leap forward in safety and customer comfort”
- If interested in helping evaluating GTGN, let us know and we will get you access to AWC Testbed.

Delta Air Lines Weather Viewer App



Turbulence Reporting Standards Development

- RTCA DO-370 published in January 2018: Guidelines for Eddy Dissipation Rate (EDR) Algorithm Performance
 - ✦ Guidelines for developers to evaluate whether their algorithm performs as expected in strict testing environment
 - ✦ Actual operational implementations are much more complex
- Combined Surveillance Committee, Weather Surveillance Working Group (CSC WxS) - Determine which weather surveillance requirements and recommendations are to be implemented via ADS-B and/or Mode-S, and develop appropriate Minimum Operational Performance Standard (MOPS) requirements.
- Next step: Development of a Service Description for GTGN, to include inputs, update rates, etc, for use in the Minimum Aviation System Performance Standards (MASPS) for Aeronautical Information and Meteorological Data Link Services, RTCA DO-364A.
 - ✦ Will require harmonization with EUROCAE
 - ✦ Soliciting participation from industry – See Tammy Flowe or Eldridge Frazier

Turbulence Workshop III

September 5-6, 2018

**Co-Sponsored by the MITRE Corporation and
the National Center for Atmospheric
Research (NCAR)**

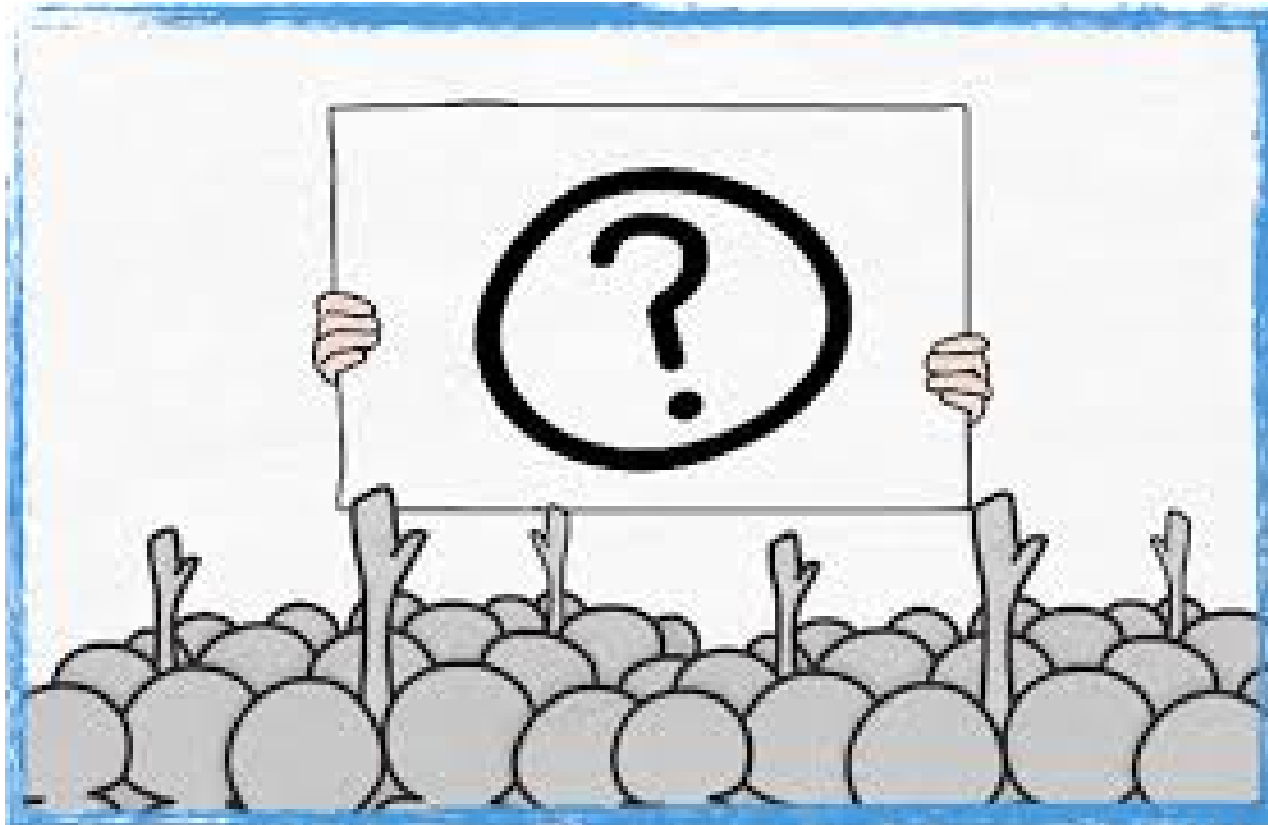
Location: MITRE, McLean, Virginia

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NextGEN



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Next**GEN**

Next GEN



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