



Increasing Adoption of Weather & Turbulence Observations

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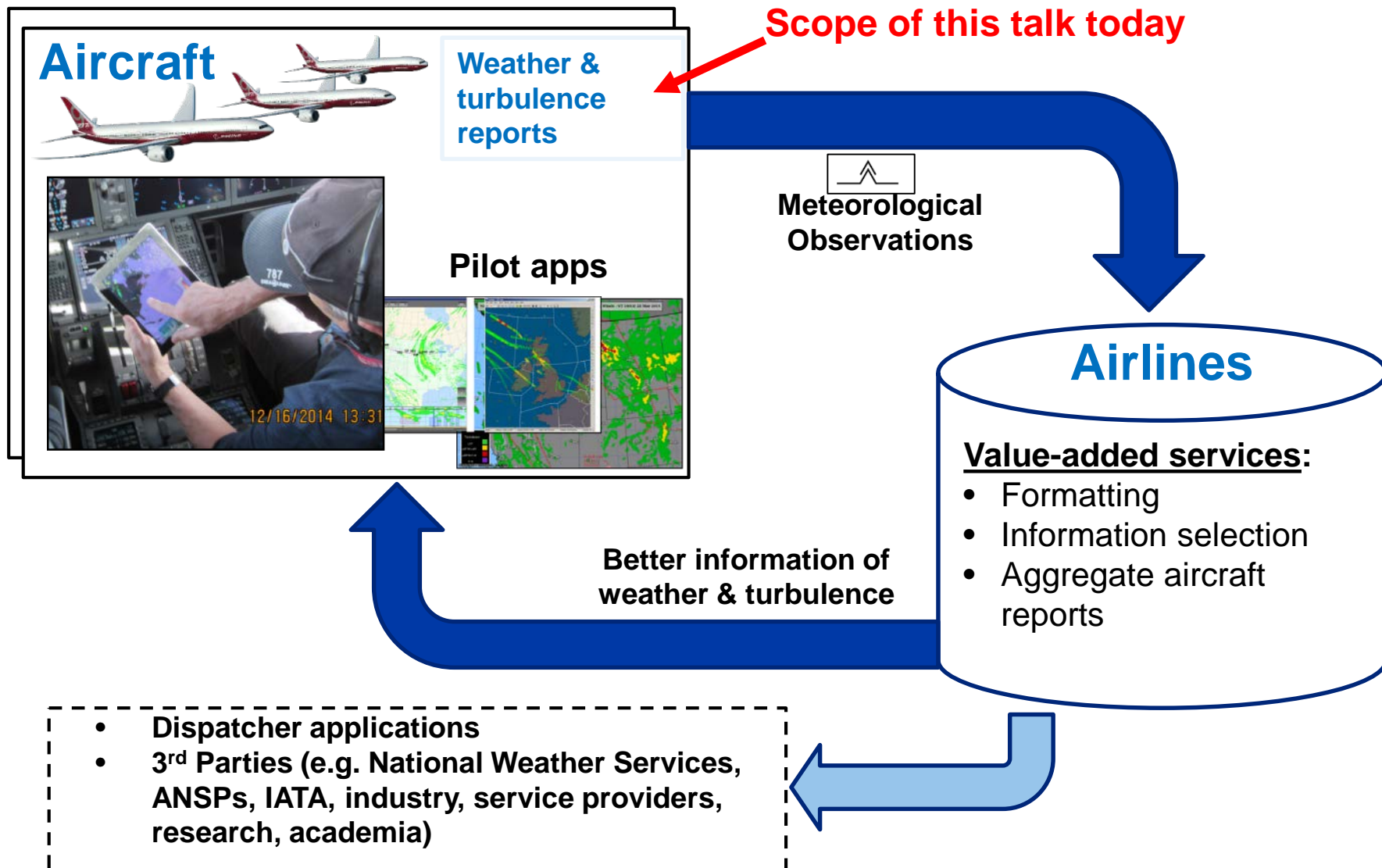
Agenda

- ❑ Scope & concept of operations
- ❑ Recent progress
- ❑ Current availability from Boeing
- ❑ *Some* Analysis of observations
- ❑ Use at United Airlines & future outlook
- ❑ Q&A

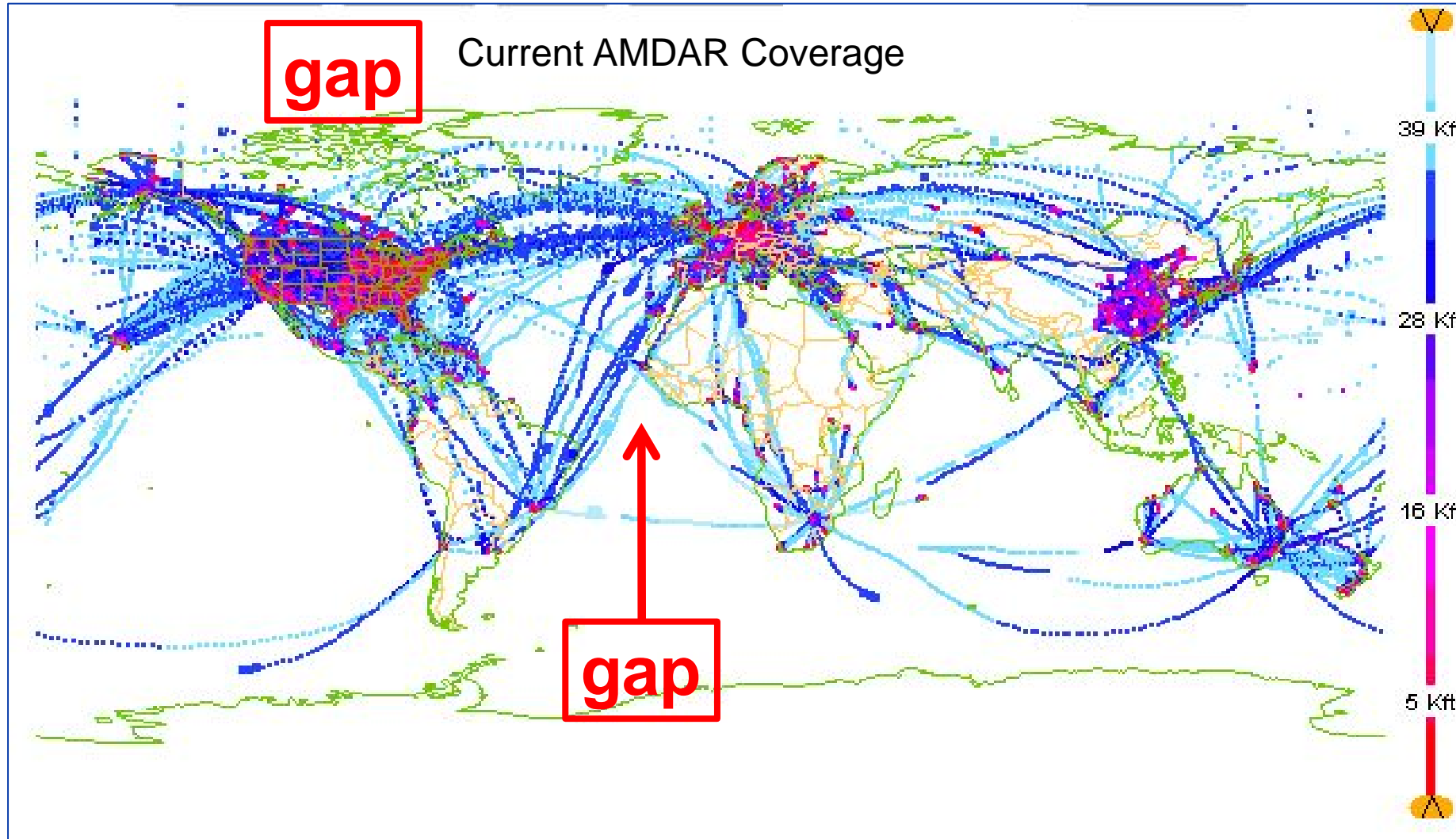
Scope & Concept of Operations

Concept of Operations & Information Flow

Generate meteorological data to support airline world-wide operations



Recent Progress



<https://sites.google.com/a/wmo.int/amdar-news-and-events/newsletters/volume-10-october-2015>

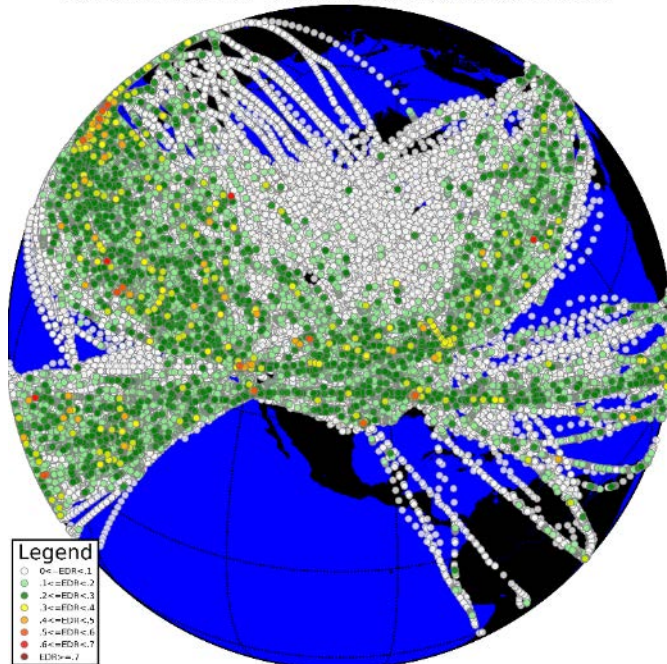
From FAA Presentation - January 2018, AMS

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

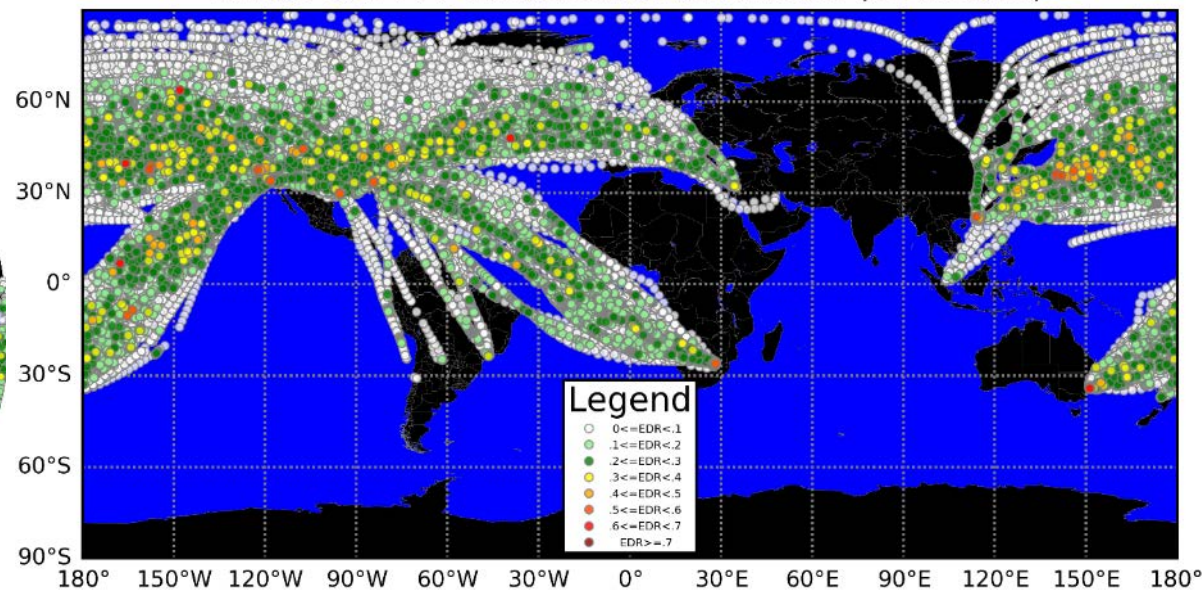
- B777: installed on 777-300ERs and 777-200LRs thus far
- B787: installing on all UAL 787s
- B737MAX: installing all UAL 737MAX aircraft **[** New Update! **]**

The reported data from UAL and DAL routes greatly expands the geographic coverage over the Arctic and Southern Hemisphere

UAL & DAL 777 EDR Turbulence Observations (all of 2017)



UAL & DAL 777 Turbulence Observations (all of 2017)



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Courtesy of UAL and DAL

Current Availability from Boeing

Boeing Model Current Availability

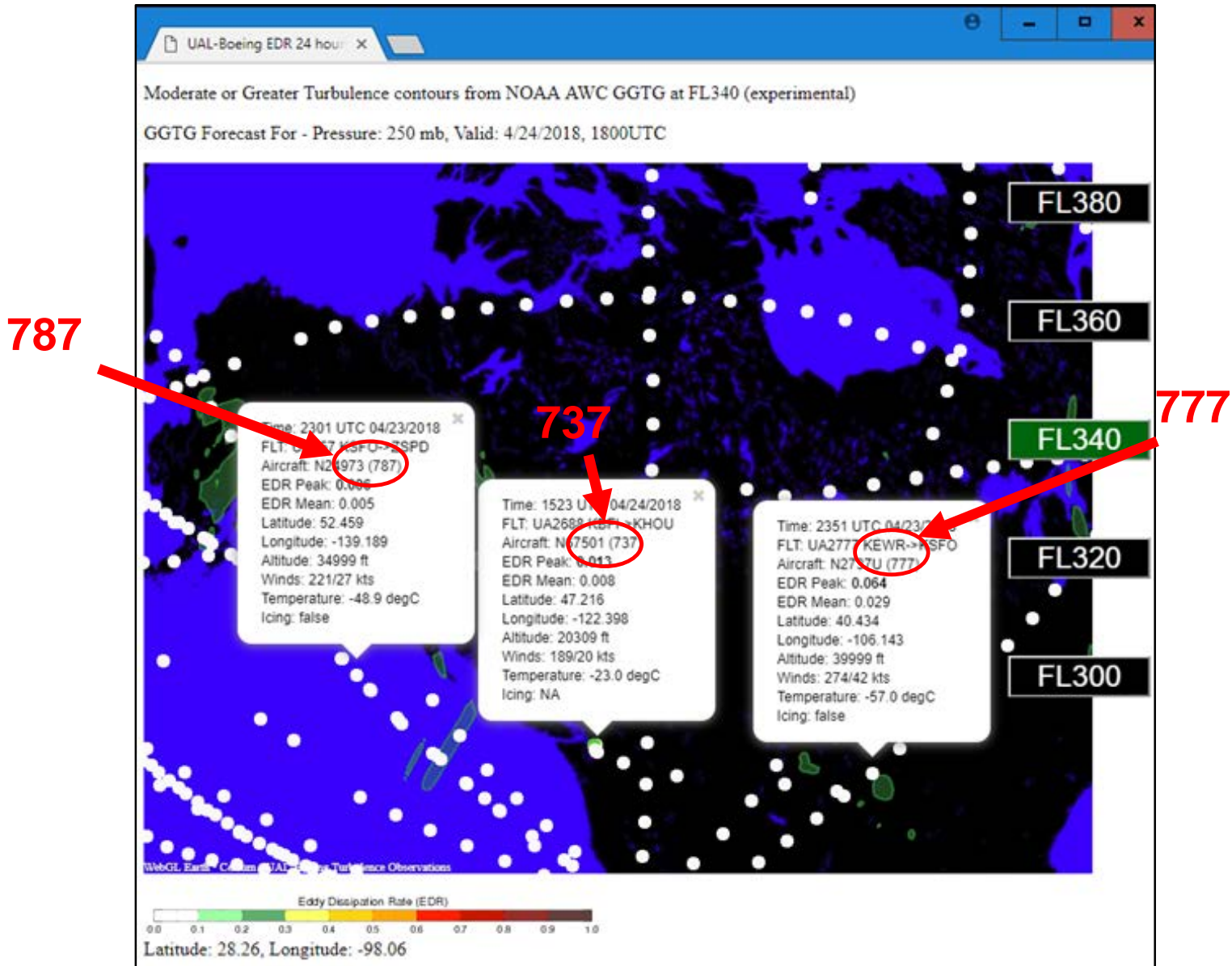
Boeing offers an airplane option applicable to:

- 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

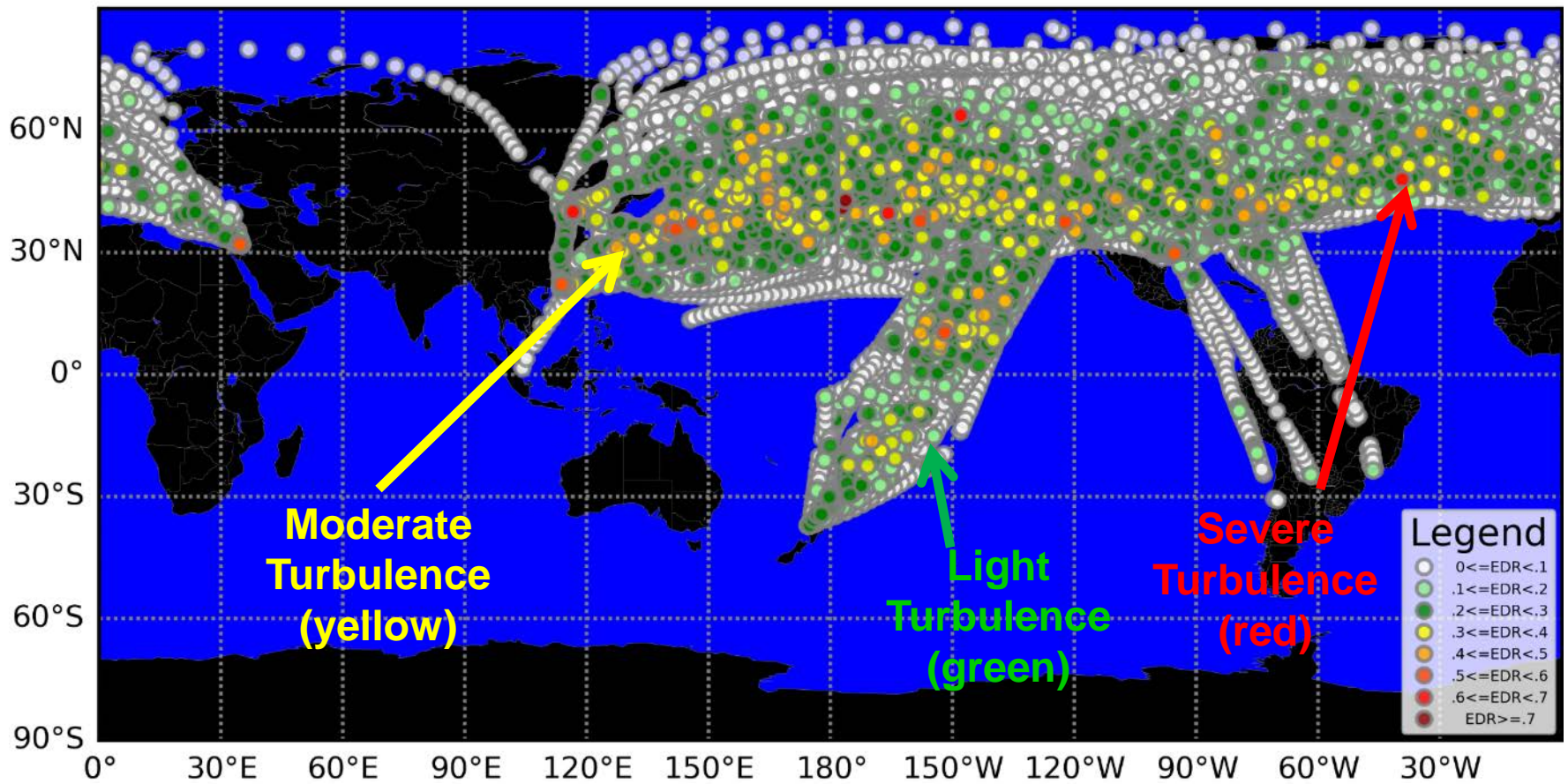


Analysis of Observations

(this is a start!)

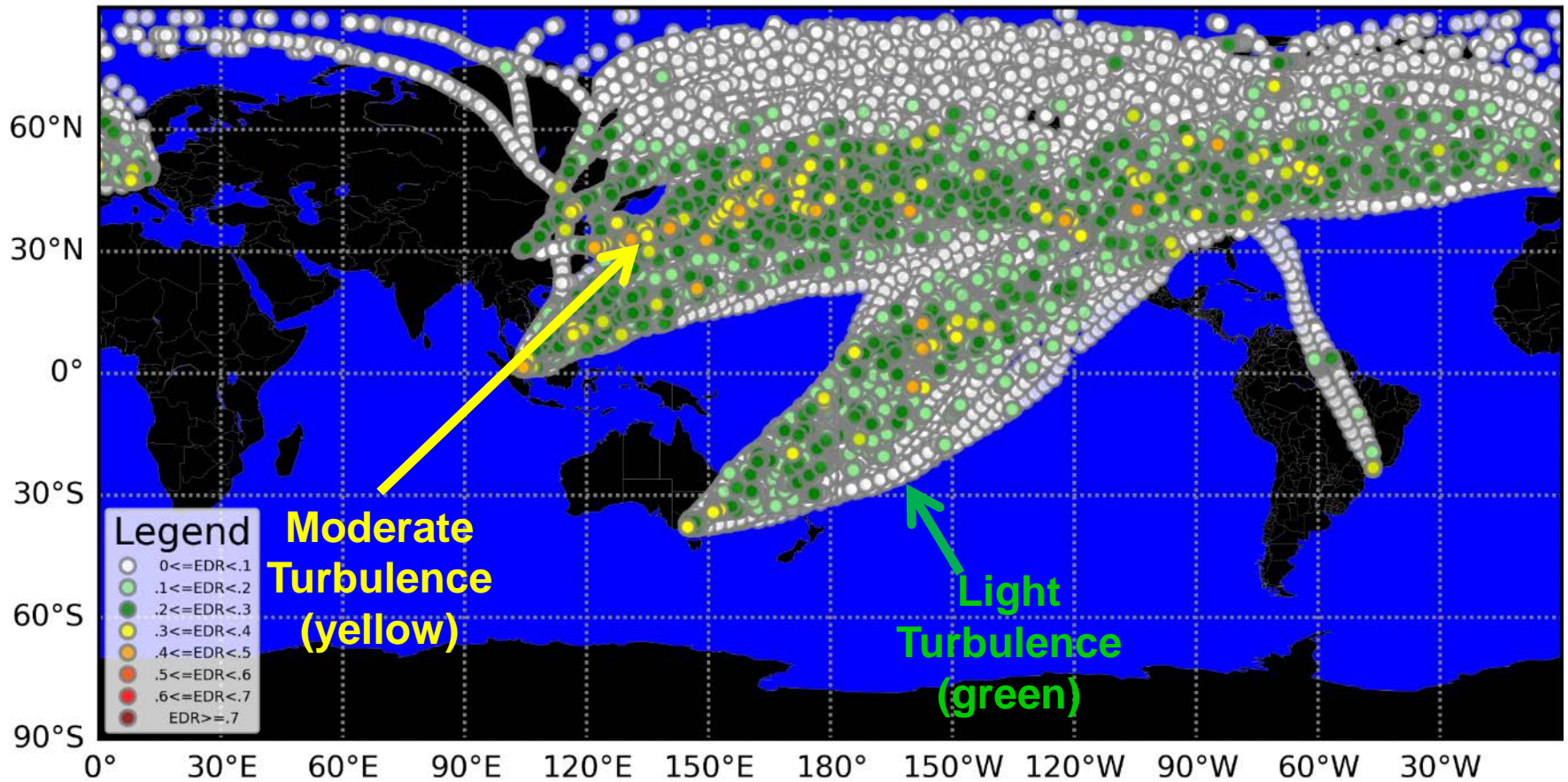
UAL 777 (362367 observations)

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



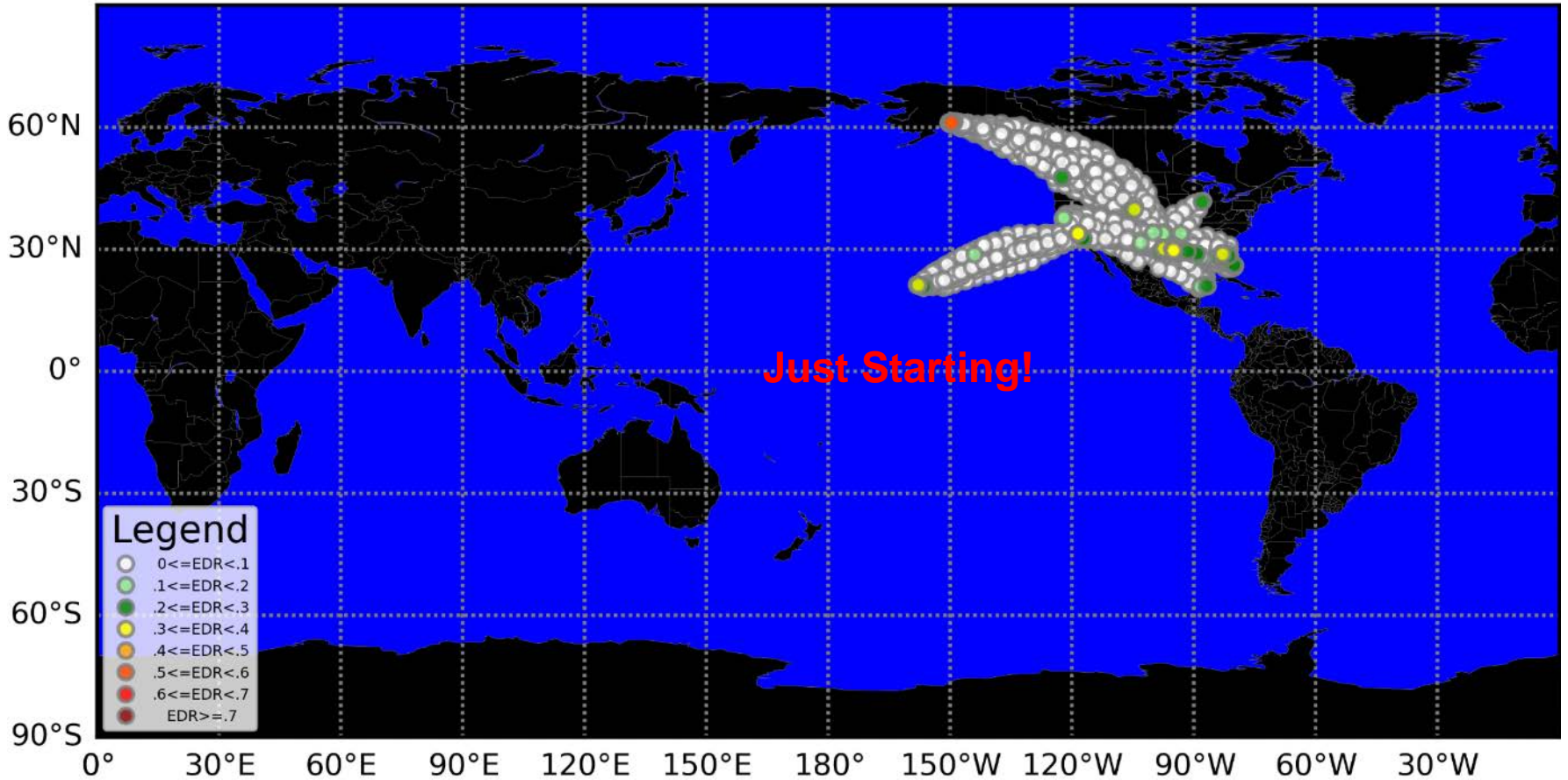
UAL 787 (214956 observations)

UAL 787s EDR Turbulence Observations thru 8/31/18



UAL 737MAX Observations

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



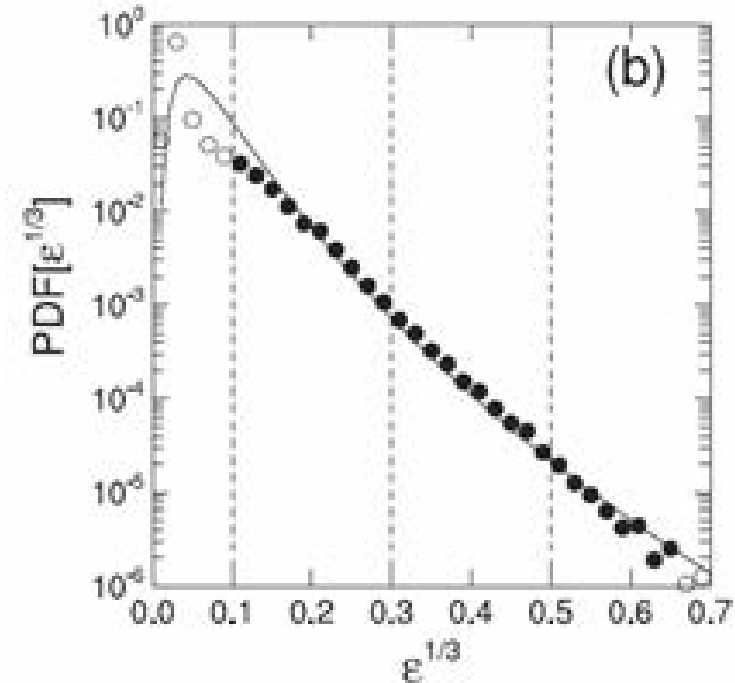
Methodology for analysis of the reported EDR (per RTCA DO-370)

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

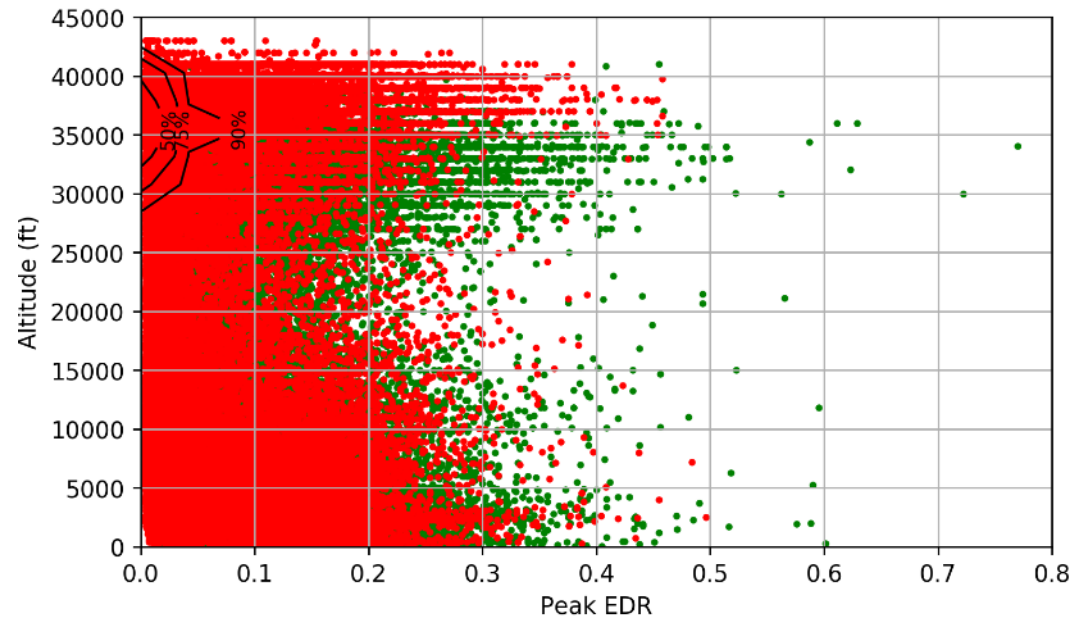
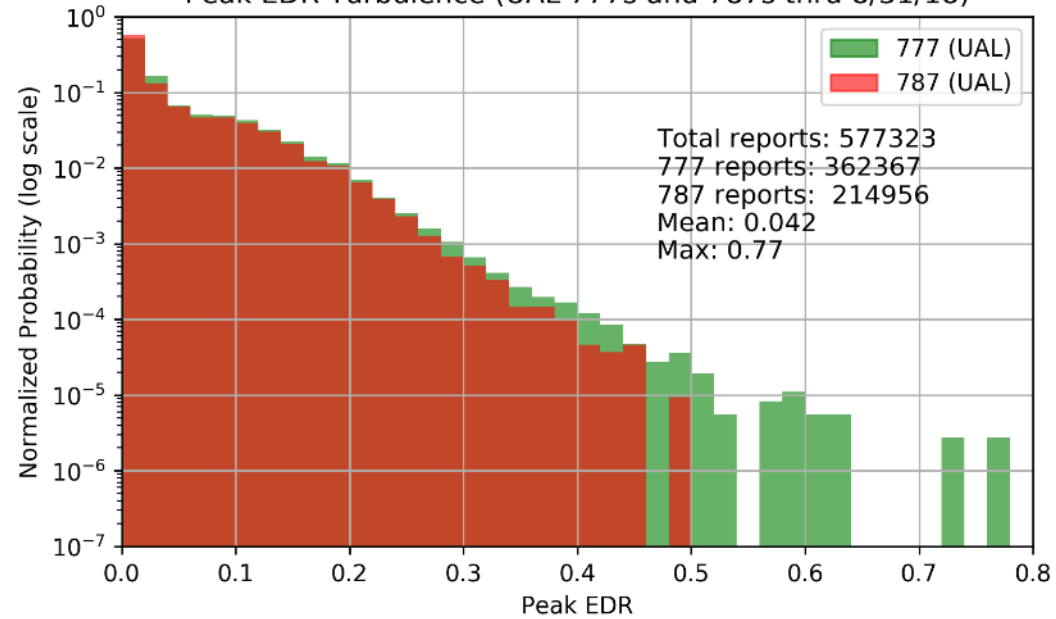


[adapted from Sharman, et al., 2014, Fig. 10]

Turbulence Performance Results

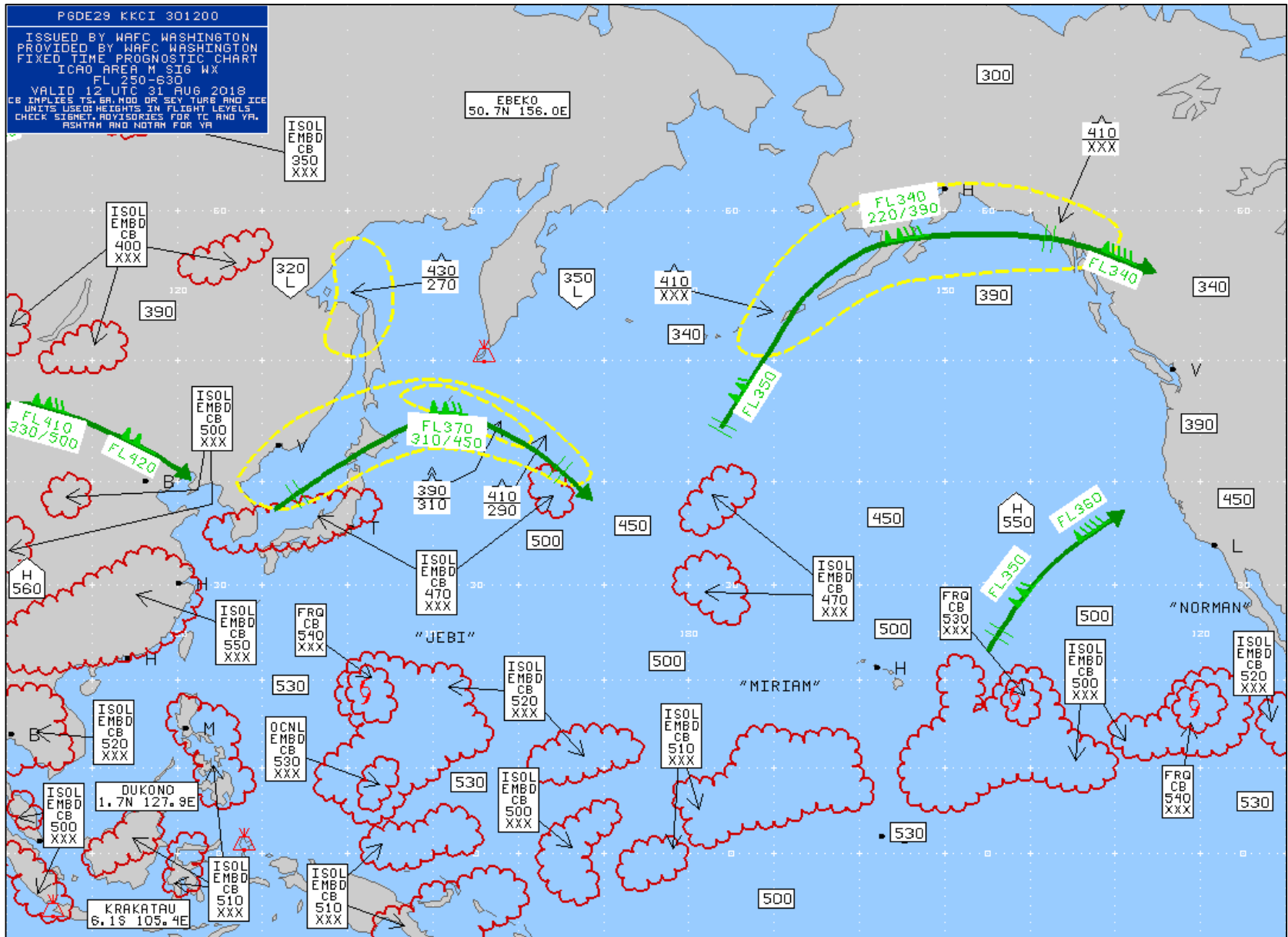
Peak EDR Turbulence (UAL 777s and 787s thru 8/31/18)

- 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]



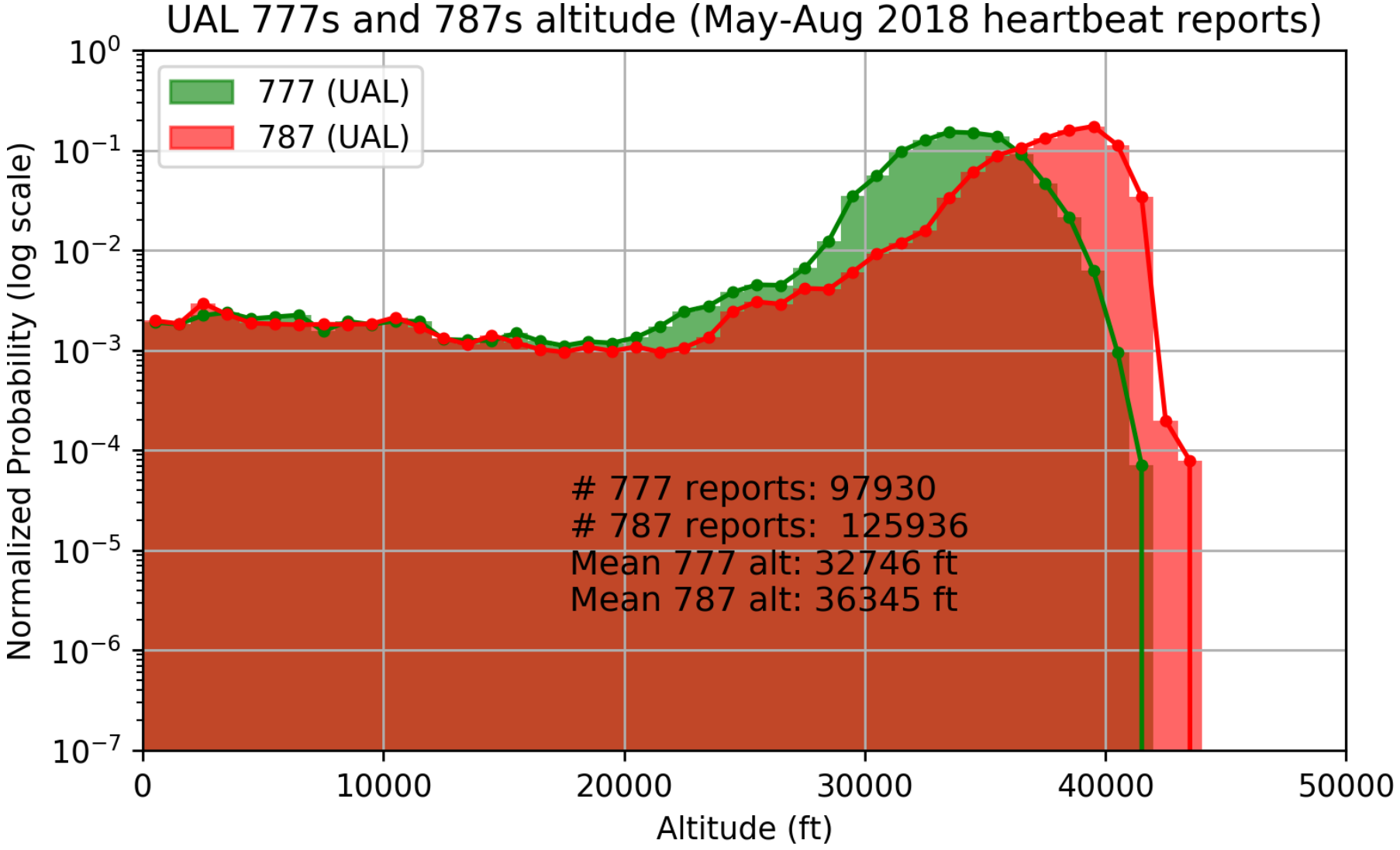
Reminder: Tropopause levels vary with latitude

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



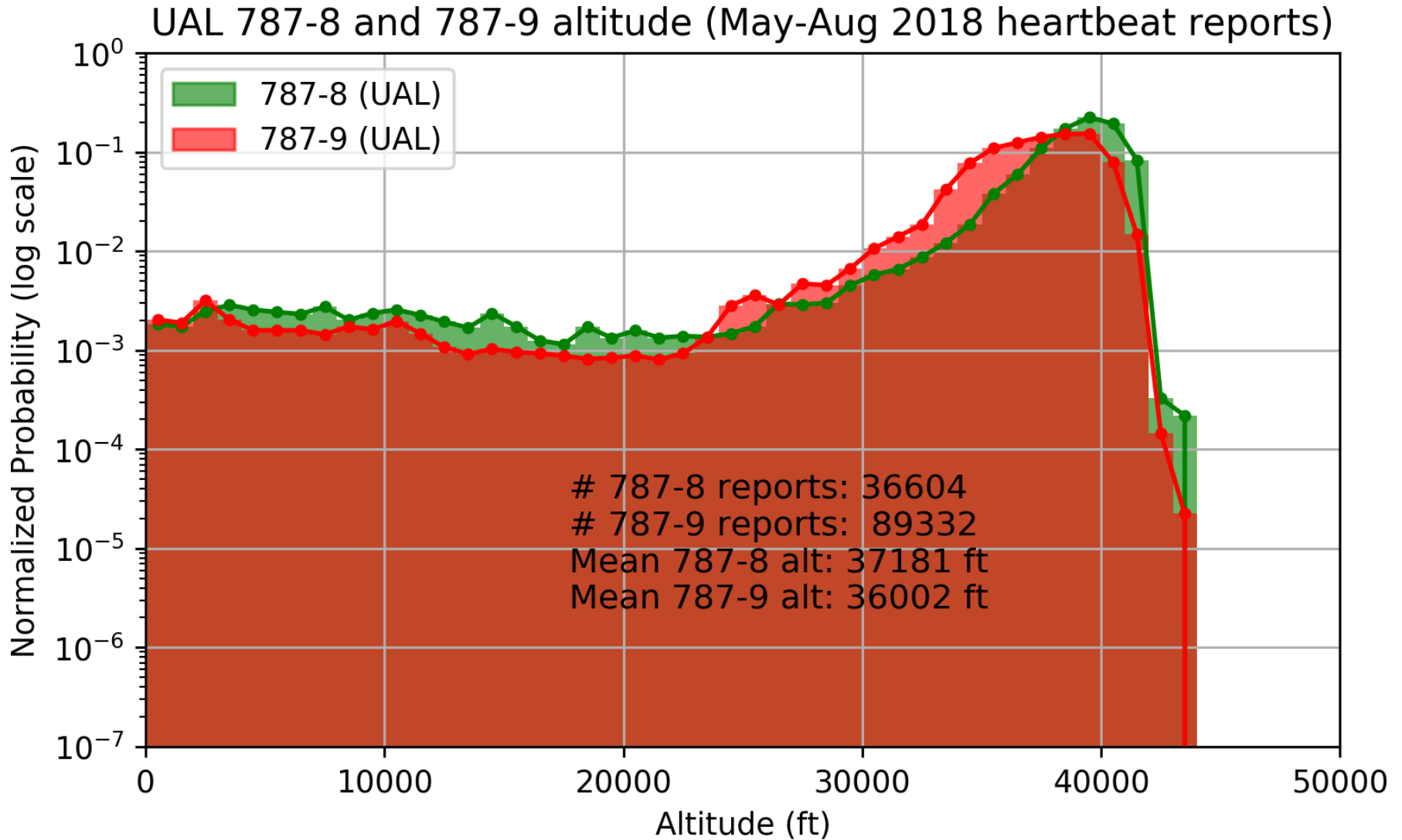
Operational Altitude

- 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.



Operational Altitude

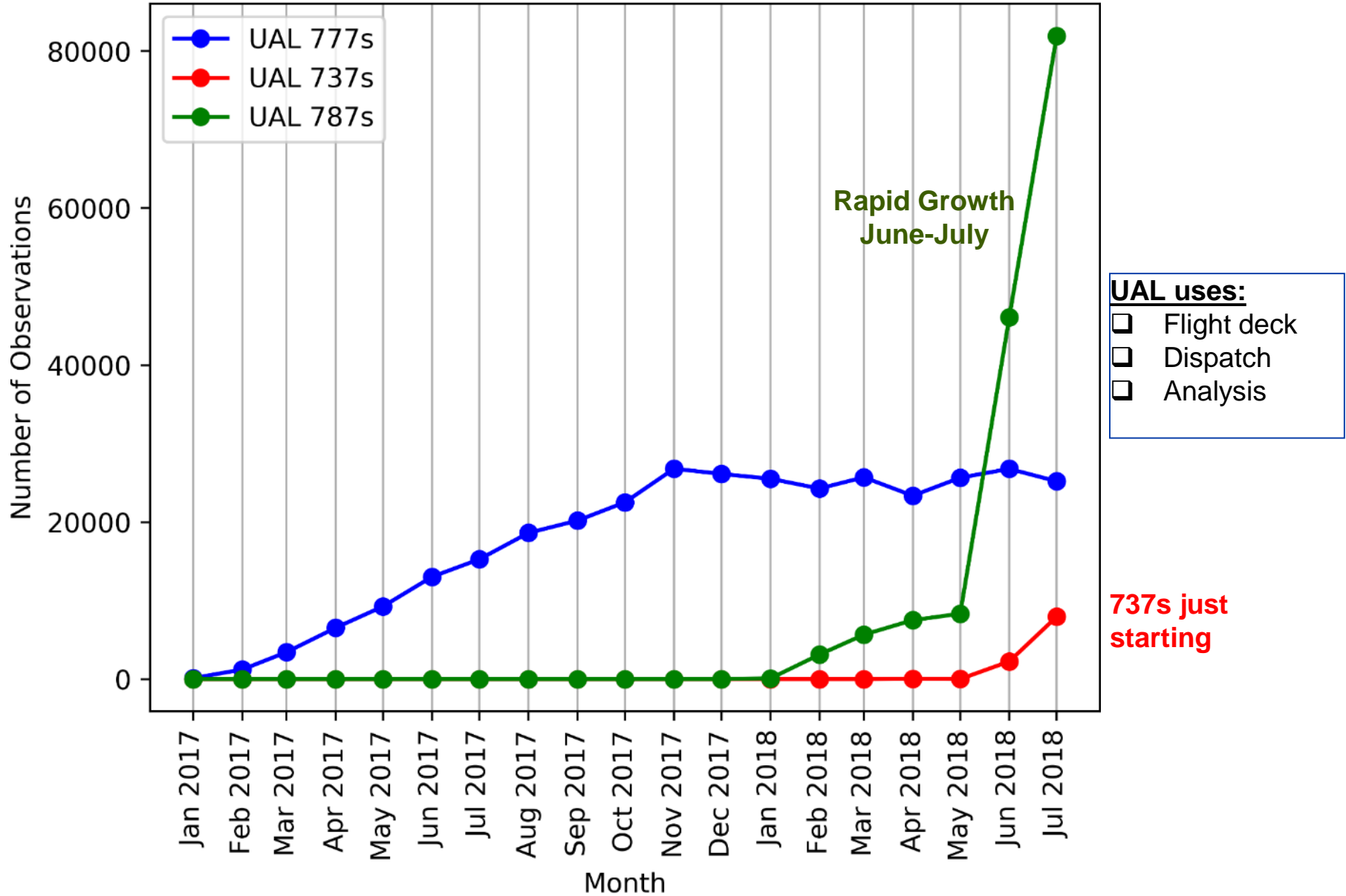
- UAL notes the differences between 787-8 and 787-9 operational altitude is also worth mentioning



Use at United Airlines & future outlook

Monthly UAL 777, 787, and 737Max Observations

UAL 777/787/737Max Monthly Observations thru 7/31/18





Automated *In situ* Turbulence Detection

Government-Industry Collaboration Success

Updated
FAA Slide

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.*

Global Delta Airlines EDR Observations 2010-2018

