Insert Title Here

Presented by:
Steve Abelman
Manager of Weather Technology, American Airlines

September 5, 2018

I Really Can't Figure Out a Good Title for this Turbulence Workshop Presentation

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Topics of Discussion

- During the next 30 minutes, here are the hot turbulence topics and issues I would like to discuss:
  - American Airlines Turbulence Task Force and other 121 carrier initiatives
  - Status and future of short and long term turbulence forecasting
  - Automated PIREPS
  - The future of standard PIREPS
  - Turbulence implications in GA
  - Sharing of PIREP data and the IATA initiative
  - Cockpit pilot applications for 121 carriers
  - Cockpit pilot applications for other carriers
  - The need for objective data to develop better turbulence statistics
  - Case studies of turbulence encounters
  - Trends in passenger and flight attendant injuries
  - Convectively Induced turbulence
  - Mountain Wave turbulence
  - Low level windshear
  - Wake turbulence
  - And I am just getting started…

Well that's not really true… ☺

- The point here is during the next 2 days, many, if not, all of these topics will be discussed if one form or another. As we in the research and operations community listen to what is presented, we should be cognizant of the following:
  - User needs vary widely. Respect for this has made this workshop successful and keeps it alive!
  - Research to operations considerations are critical.
  - What can ATC use and how can we help them?
  - Additional bandwidth in the cockpit opens up a new world, but lots of challenges as well.
  - How much more time and effort should we spend on getting the "perfect" objective turbulence measure and "killing" the standard PIREP?

The Real Topics of Discussion

Here is what I really want to touch on:

- American Airlines Turbulence Task Force
- The need for objective data to develop better turbulence statistics
- Trends in turbulence event statistics and flight attendant injuries
- Some thoughts on the state of turbulence forecasting

Why an American Airlines Turbulence Task Force?

- **American Airlines is huge since the merger with U.S Airways:**

- While statistics tend to show that turbulence events are not increasing, little progress being made on injury reduction to Flight Attendants.
- Passenger injuries have declined since pilots urging to "…remain seated with you seat belts fastened even when seat belt sign is off…"
- AA Senior Leadership established the Turbulence Task Force (TTF) in 2016

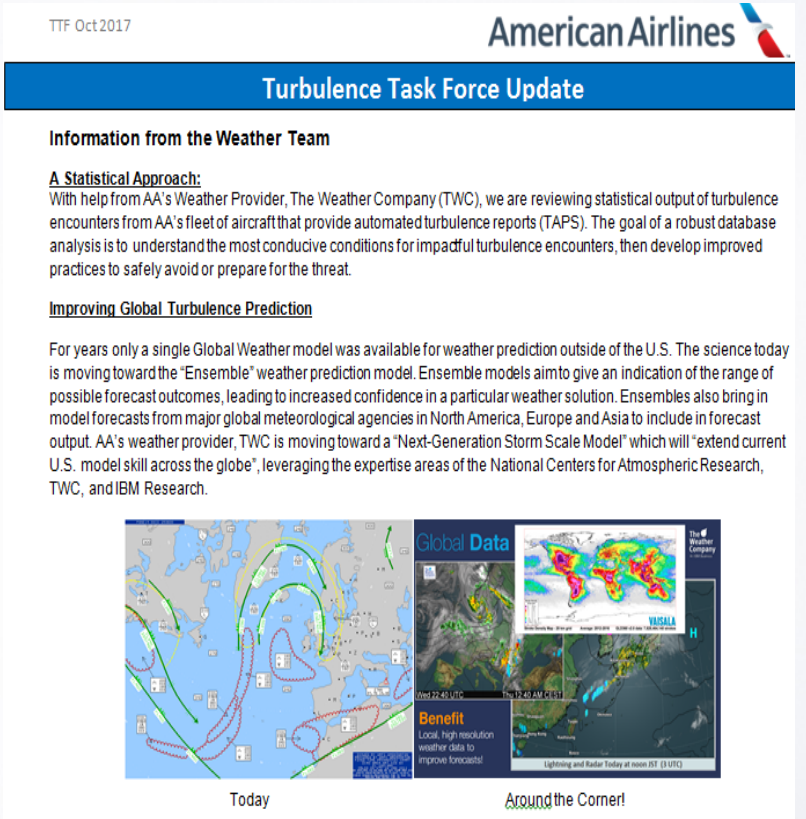
TTF Objectives

- Reduce Turbulence Injuries
  - Curtail costly litigation
  - Reduce missed crew time
  - Stay out of the news!

- Establish AA as a leader in industry standards for turbulence safety
- Harmonize all departments to establish better operational practices. Includes dedicated participation from Pilots, flight attendants, dispatchers, safety representatives, meteorology, Workman's Compensation, and more…

How Do We Meet These Objectives:
Improve Communication

- Outreach to all impacted parties via memos, safety preflight alerts, manual updates, and TTF Bulletins
- Emphasize the criticality of robust communication between pilots, flight attendants, dispatch, and meteorology to include all possible detail



TTF Oct 2017

American Airlines

Turbulence Task Force Update

Information from the Weather Team

A Statistical Approach:

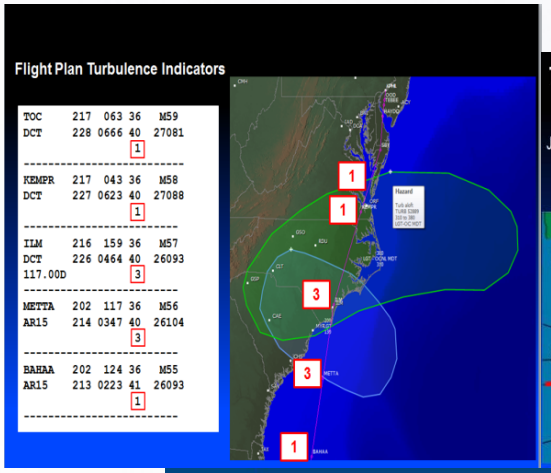
With help from AA's Weather Provider, The Weather Company (TWC), we are reviewing statistical output of turbulence encounters from AA's fleet of aircraft that provide automated turbulence reports (TAPS). The goal of a robust database analysis is to understand the most conducive conditions for impactful turbulence encounters, then develop improved practices to safely avoid or prepare for the threat.

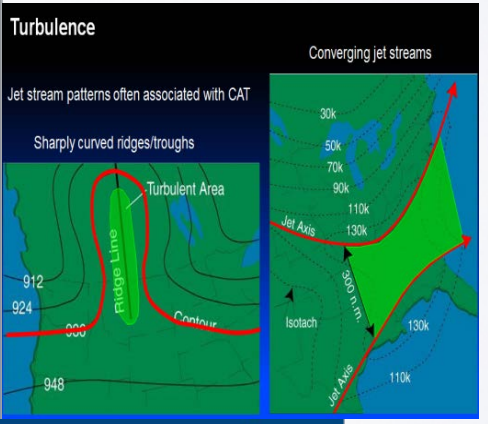
Improving Global Turbulence Prediction

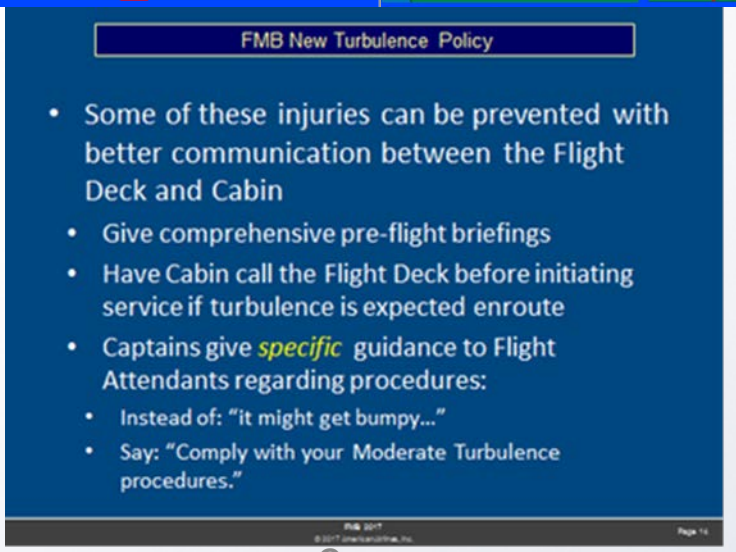
For years only a single Global Weather model was available for weather prediction outside of the U.S. The science today is moving toward the "Ensemble" weather prediction model. Ensemble models aim to give an indication of the range of possible forecast outcomes, leading to increased confidence in a particular weather solution. Ensembles also bring in model forecasts from major global meteorological agencies in North America, Europe and Asia to include in forecast output. AA's weather provider, TWC is moving toward a "Next-Generation Storm Scale Model" which will "extend current U.S. model skill across the globe", leveraging the expertise areas of the National Centers for Atmospheric Research, TWC, and IBM Research.

How Do We Meet These Objectives:
Improve Training

- Recurrent training for pilots, dispatch, flight attendants, and meteorologists. Possible topics include:
  - Turbulence avoidance procedures (pilots)
  - Understanding and using turbulence forecasts (pilots and dispatch)
  - Procedures during ascent and descent when convective weather is present (pilots and FAs)
  - Improvements in short term model forecasting and improving SIGMET quality (meteorologists)

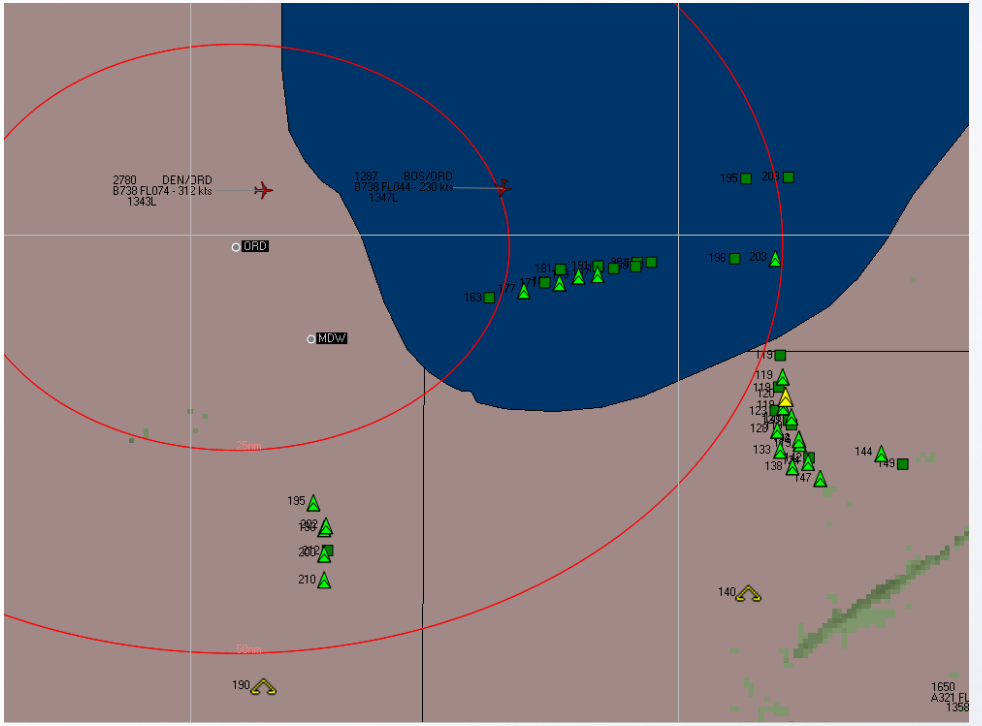






How Do We Meet These Objectives:
Improve Technology

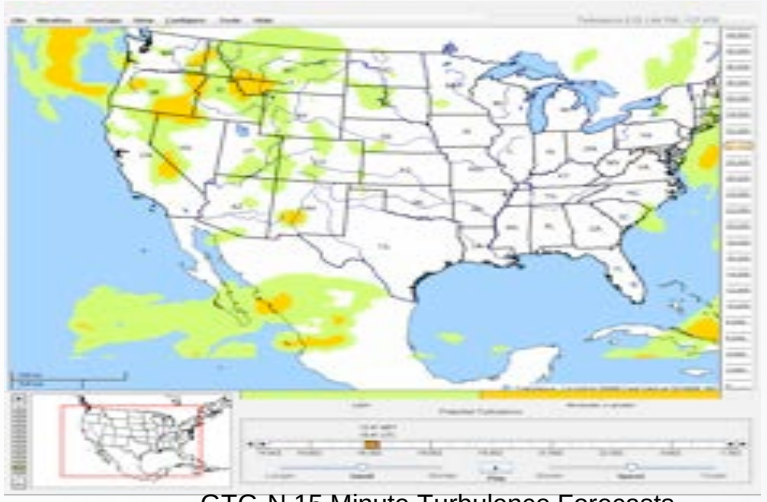
- Increase TAPs equipped aircraft
  - Currently around 400 B737, B757, and B767 aircraft equipped with Turbulence Auto-PIREP system (TAPs) for objective turbulence measurement (RMSg)
  - Airbus fleet will double equipped aircraft to nearly 800 (early 2019?)
  - B777 fleet adds another 67 aircraft and fills badly needed international gaps (late 2018)
- Calibrate TAPs reports to crew experience
  - While research was done to calibrate RMSg reports to “LGT”, “MDT”, and “SVR”, more work needs to be done
  - Significant variance depending on location in aircraft during an event
  - Am 100% convinced that this issue will exist with any “objective” turbulence measure



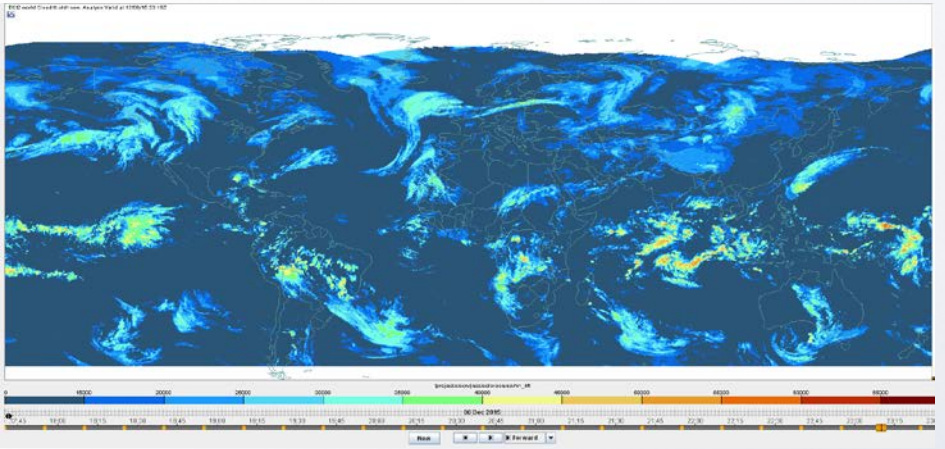
TAPs reports overlaid on WSI Fusion

How Do We Meet These Objectives:
Improve Technology cont'd

- Faster and more efficient WiFi
  - Allows for consideration of shorter term forecasts, higher quality graphics, faster updates, and more
- Enhancements to Dispatch and Pilot Tools
  - Alarm/Alert type capability to notify crews/dispatch of rapidly changing turbulence conditions
  - Vertical profile forecasts which include TAPs reports for improved strategic and tactical planning
  - Integration of 15 minute forecasts of turbulence (GTG-N or similar)



GTG-N 15 Minute Turbulence Forecasts



Global Cloud Tops from FAA ROMIO project

How Do We Meet These Objectives:

Establish and demonstrate success through quantifiable metrics

- Collaboratively develop and update statistics to demonstrate if TTF (or TAPs, or new technology, etc…) is indeed making a difference. Could include:
  - Number of incidents, injury, phase of flight, geographical region, aircraft type, and more…
- Goal here is maximize success by going for improvement in the areas where most events occur or where the trend is not positive

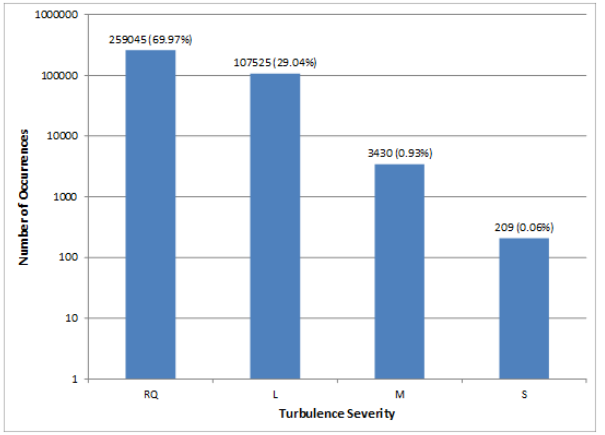


Figure 2: Turbulence Severity Breakdown – 2017

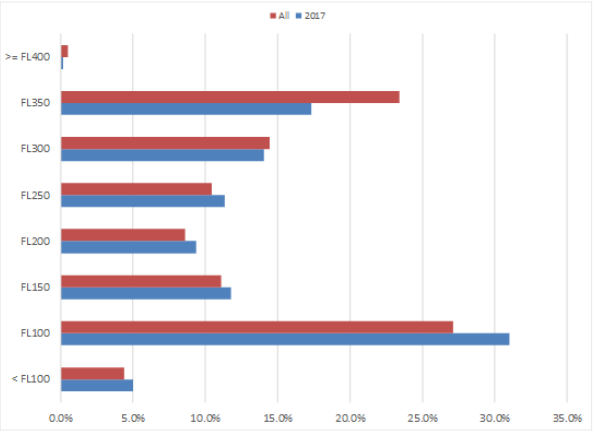


Figure 3: Turbulence Report Flight Level Breakdown

More on Metrics and Stats

- AA is not the only 121 carrier that is looking at this issue
- As more objective data becomes available, databases are being populated with a variety of data…minus some of the subjectivity of a manual PIREP
- AA collecting data on turbulence intensity, location, phase of flight, injuries, maintenance, favorite TV meteorologist and more!
- So what are we seeing…
- Not yet, let's play a little game of true/false first!

Question 1

- True or False: Most MDT or SVR turbulence reports occur at cruise altitudes
  - Answer…False!
  - Our objective data unequivocally shows that over 70% of documented TAPs reports of MDT or greater occur below 20,000FT, with over 50% below 15,000FT.

Question 2

- True or False: Most MDT or SVR turbulence reports occur in Clear Air Turbulence
  - Answer…False!
  - Though we are still working on objective methods to evaluate proximity to convection, we believe at least 50% of these reports are related to convection.

Question 3

- True or False: Most Flight Attendants (FAs) are injured in Light or Light to Moderate Turbulence
  - Answer…True!
  - With improved CAT forecasts more FAs are encouraged to be seated in known or forecast areas of significant turbulence. The surprise factor seems to be at play here. And of course carts, coffee pots, and other moving objects play a major role.

And one more...

- True or False: Too many Flight Attendants (FAs) are injured during the decent phase when conditions/forecasts should have given a hint to the potential
  - Answer…True!
  - An obviously loaded question and a high priority in TTF to assess current procedures and communications between pilots and FAs.

Quick Look at some AA limited statistics

- Thanks to our collaboration with Jason Prince at The Weather Company (formally WSI), monthly statistics are produced for our TAPs fleet.
- Also thanks to the collaboration with our Workman's Comp Folks, we have compiled FA injury data as well

Reports from AA TAPS equipped Aircraft

Table 1: Turbulence Severity Breakdown – 2018

Month	Ride Quality	Light	Moderate	Severe
January	23,960	8,480	210	8
February	25,319	10,791	291	14
March	29,025	12,287	323	28
April	27,971	12,734	397	23
May	27,107	12,571	354	38
June	24,565	10,746	291	28
July	21,541	9,004	355	21

Summary

The following information and figures show a summary of reports from 2018.

1. Total Turbulence Reports – 258,482
    a. Moderate or Greater – 2,381
2. Total Heartbeat Messages – 1,945,857
3. Estimated Number of Flight Hours – 648,619
4. Estimated Number of Turbulence Reports per Flight Hour – 0.40
    a. Moderate or Greater (per 100 flight hours) – 0.37

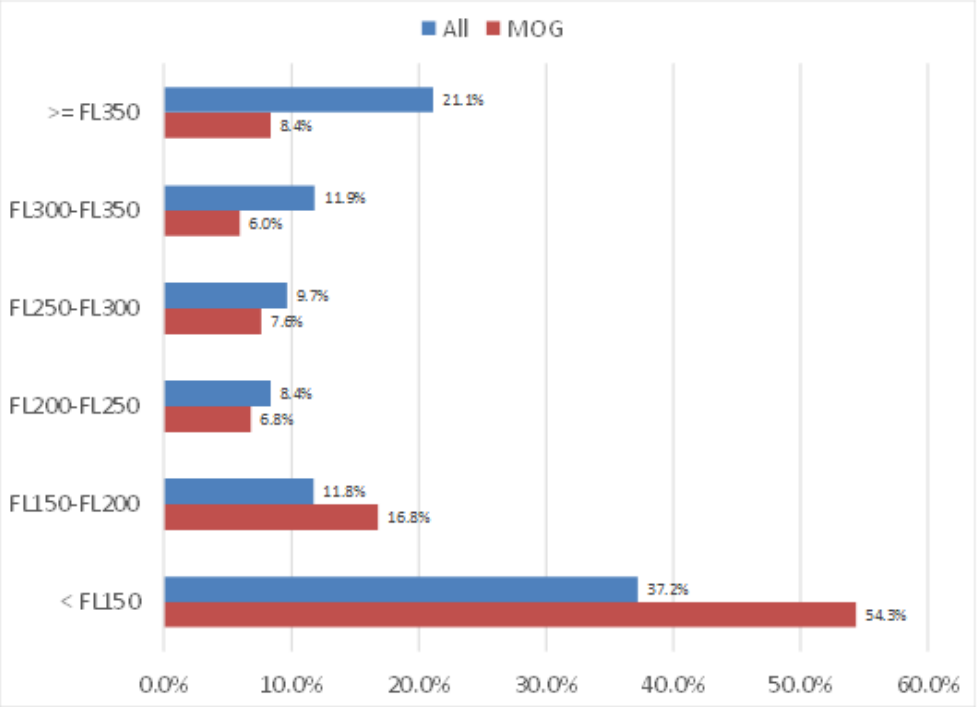


Figure 2: Turbulence Report Flight Level Breakdown

Reports from AA TAPS equipped Aircraft

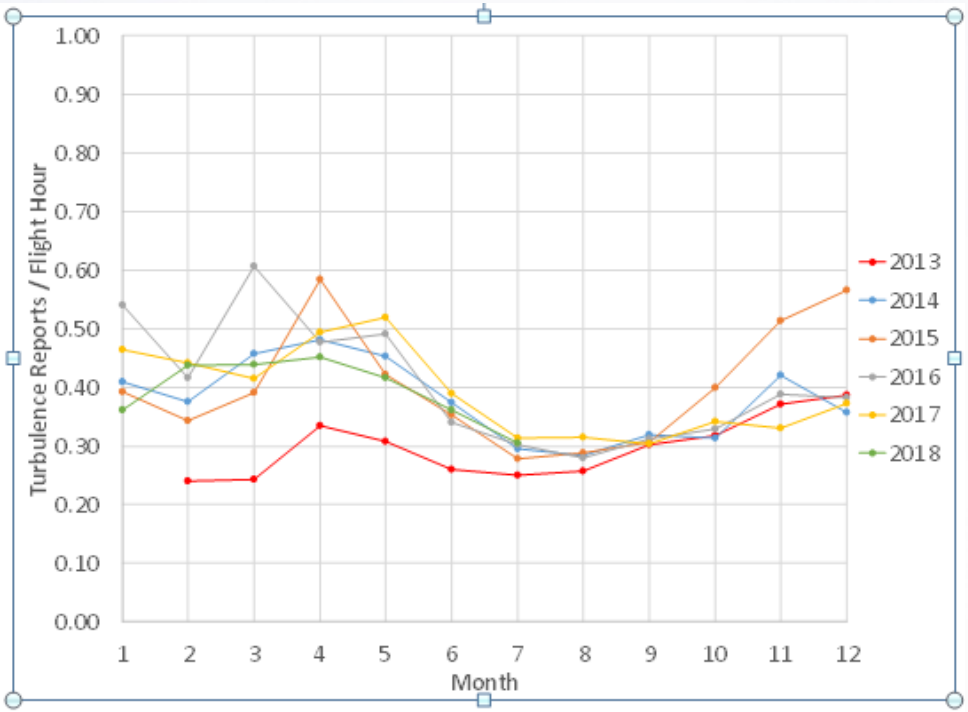


Figure 3: Estimated Turbulence Reports per Flight Hour by Year

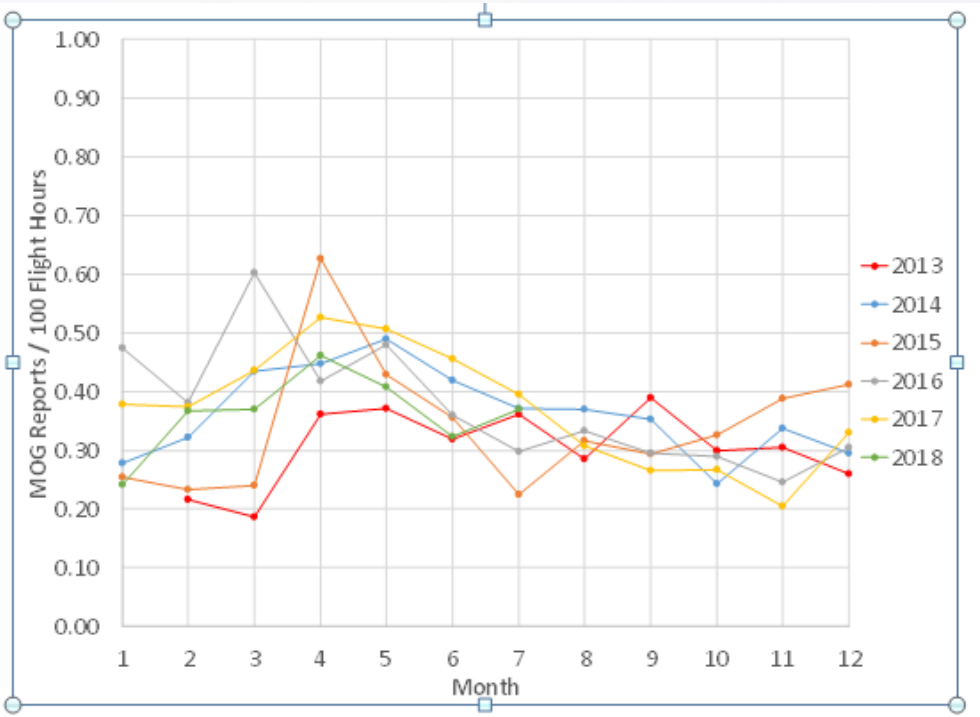
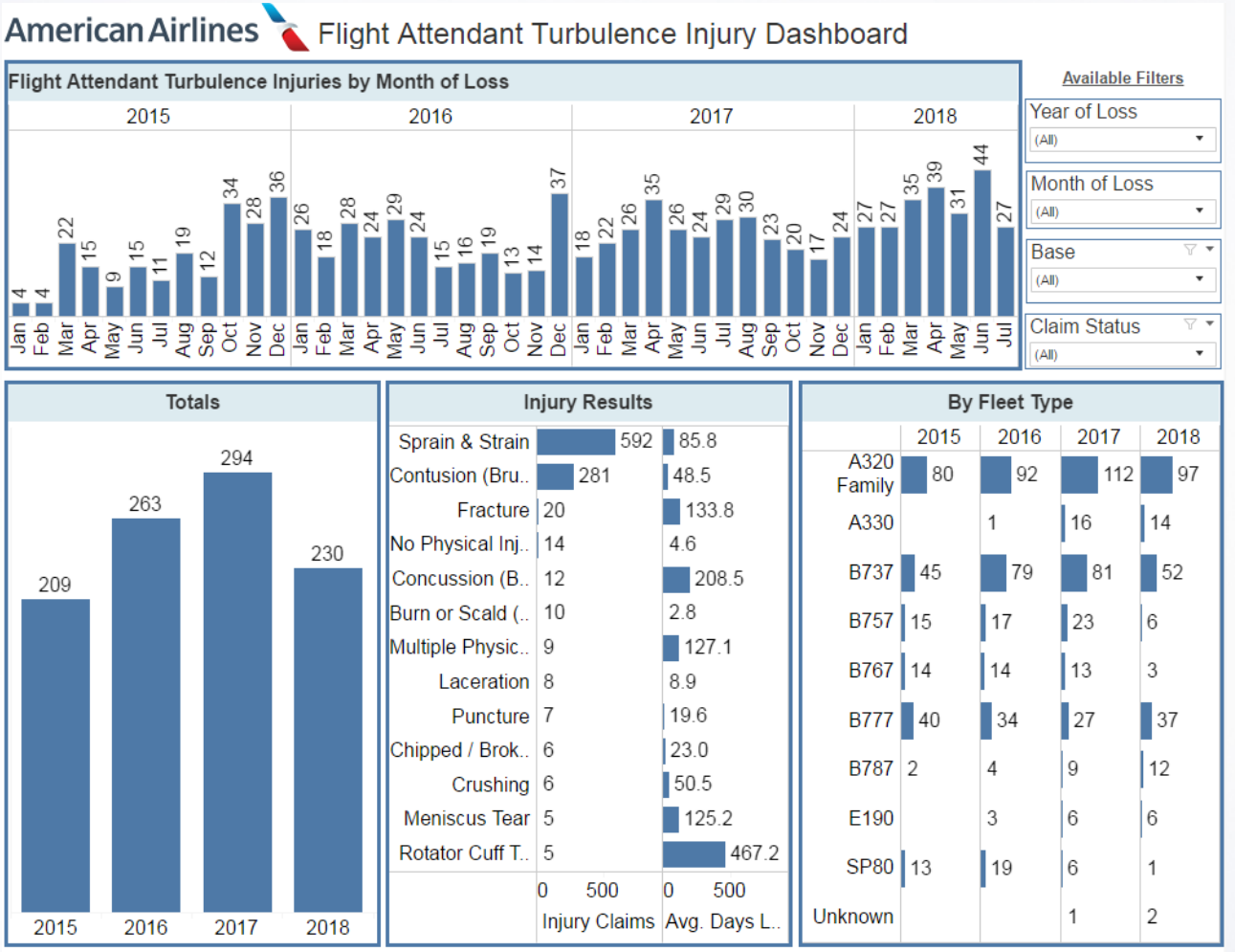


Figure 3: Estimated Moderate or Greater (MOG) Reports per 100 Flight Hours

Notable:

- Only AA TAPS equipped aircraft included. How much aircraft type and configuration contributes to turbulence susceptibility of interest
- TAPS calibration to LGT, MDT, SVR of interest. Trends seem to indicate that LGT reports (.10 RMSg) is too high and SVR reports (.30 RMSg is too low)

Flight Attendant Injury Data



Noteworthy:

- Injury data not yet normalized by flight hour, so some of the steady increase due to more flights
- As noted earlier, while number of incidents seems to be on a steady state, injuries to FAs may be increasing
- This is relatively new and we are very interested in adding attributes like phase of flight, length of flight, intensity of turbulence encounter (not always available), regional analysis, and more…
- We are deep diving into injuries occurring on TAPS equipped aircraft where more objective data is available.
- Flight attendant and pilot reporting is not standard and we still do lots of manual analysis

The State of Turbulence Forecasting (to promote discussion during the next 2 days)

- I think we all agree that CAT and Mountain Wave forecasts have improved from more accurate numerical modeling, better diagnostics and ensembles, vendor solutions, GOES-16, forecaster knowledge, and probably more. Congratulations to you all!
- I also think we agree that forecast performance degrades over time and AA believes that drop off after 12-15 hours is pretty substantial (which impacts international flight planning)
- There is lots of interest in convective turbulence forecasts, but we must analyze the performance of these forecasts
  - Clearly products like GTG-N have demonstrated value in very short term forecasts
  - Not so sure beyond an hour or two and this concern is most obviously based on our ability to forecast convection with the necessary precision

The State of Turbulence Forecasting (to promote discussion during the next 2 days)

- I suspect there will be quite a few opinions and suggestions about probabilistic forecasts during the next 2 days. Maybe you didn't ask, but here is what I think:
  - Frequent consumers of turbulence forecasts understand that considerable uncertainty exists in these forecasts
  - Validating strictly probabilistic forecasts, like we do point convective forecasts is a nightmare!
  - Terminology such as "confidence", "risk", or "threat" might be better suited for relaying uncertainty in the forecasts of the future
- Finally, cockpit weather and inflight connectivity opens up all sorts of opportunity to make better decisions in more tactical turbulence avoidance
  - But…pilots are really busy and can't be looking at a display that dynamically changes every minute.
  - Alerts and alarms can help, the POD/FAR ratio needs to be reasonable. (Can't over-alert)
  - Even 15 minute turbulence products will have uncertainty in the forecast!

This Marks the End of…
"I Really Can't Figure Out a Good Title for this Turbulence Workshop Presentation"

Thanks so much for your attention and enjoy the workshop!

I close with a couple turbulence event reviews from the world's best airline. The obvious and the not so obvious. Red triangle is position of reported SVR turbulence: