National Transportation Safety Board

Office of Aviation Safety
Washington, D.C. 20594-2000
April 19, 2017

ATTACHMENT 4 to the METEOROLOGY GROUP FACTUAL REPORT
DCA16LA214

United Airlines recurrent training, Spring 2015, auto-PIREPs alerting & Graphical Turbulence Guidance.

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NTSB, AS-30

New WSI Turbulence Products

Auto-PIREPs Alerting

Limitations of Traditional PIREPs

- Many reports are discussed verbally between flight crews and ATC controllers without direct notification to dispatch. Additional workload on flight crew and ATC to document and disseminate verbal reports.
- Reports may no longer be relevant if issued well after an encounter when crew has time to communicate.
- Dispatcher workload may not allow timely dissemination of PIREPs to other impacted flights.

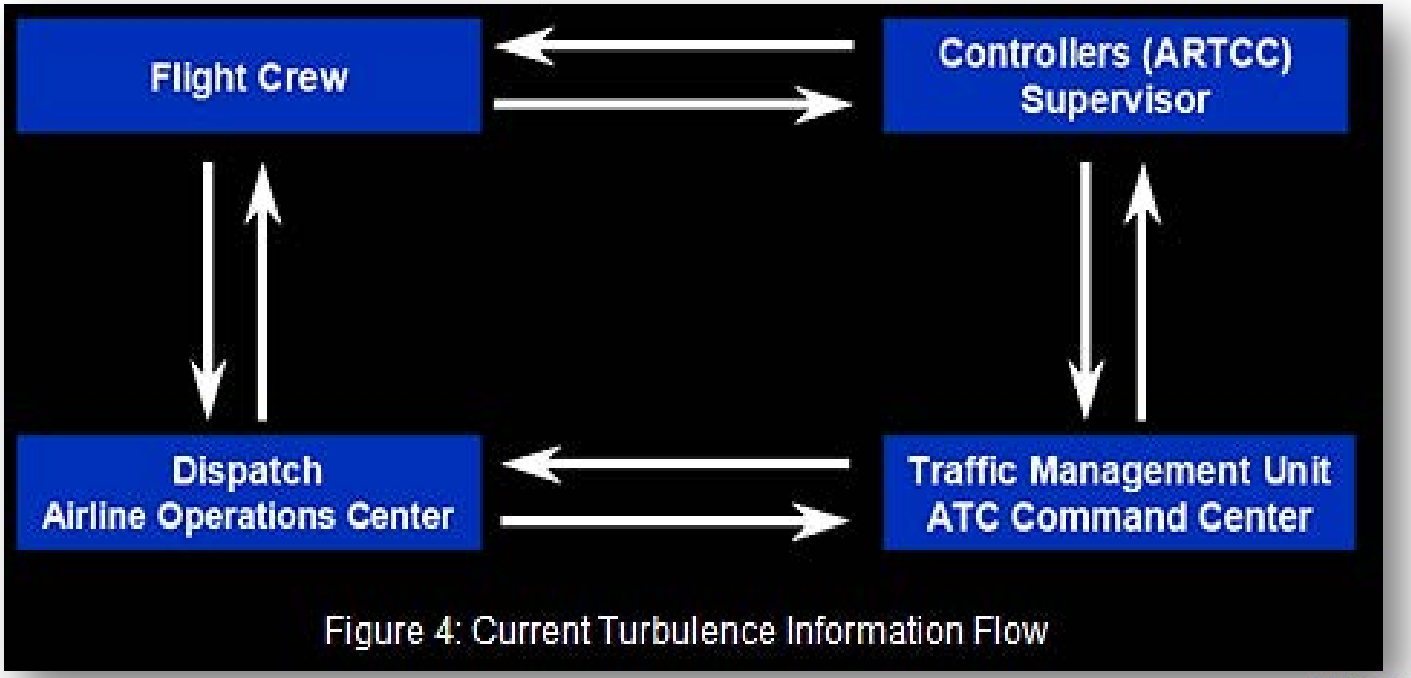


Figure 4: Current Turbulence Information Flow

Turbulence Auto-PIREP System (TAPS)

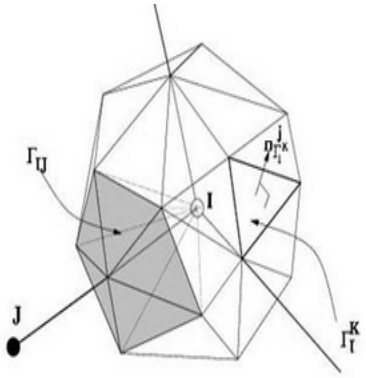
<u>Goal</u>: improve situational awareness of location and severity of turbulence hazards without increasing workload of pilots, dispatchers, and controllers.

- Software developed in conjunction with NASA research using aircraft accelerometer data.
- An algorithm is applied to accelerometer g-loads to derive a ***standardized turbulence metric*** and automatically relay it in real time via ACARS.
- WSI now exclusively licenses TAPS as a key component of their commercial product called “Total Turbulence”.

$$\frac{d}{dt}\int_{\dot{\Omega}_I} U d\Omega \approx \frac{d}{dt}\left[V^I U^I\right]$$

$$\int_{\dot{\Gamma}_I} F_j n_j d\Gamma \approx \sum_{J\in\Gamma_I} \frac{C_j^{IJ}}{2}\left(F_j^I + F_j^J\right)$$

$$\int_{\dot{\Gamma}_I} G_j n_j d\Gamma \approx \sum_{J\in\Gamma_I} \frac{C_j^{IJ}}{2}\left(G_j^I + G_j^J\right)$$



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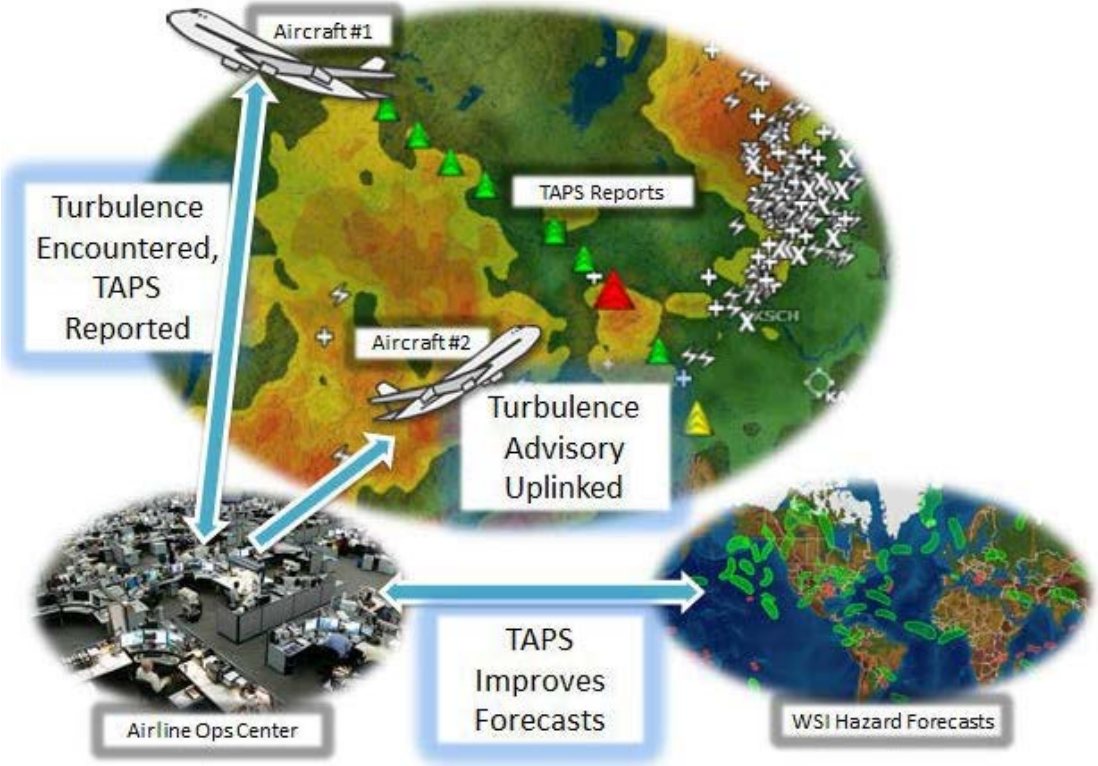
WSI TAPS Concept

- Software installed in avionics system interacts with ACARS to automatically relay TAPS events and alerts to dispatch, nearby flights, maintenance, and WSI Meteorologists.
- TAPS provides the Dispatcher with access to frequent, real-time turbulence reports and advisories that help validate existing WSI turbulence FPGs or SIGMETs.
- The Airbus A320/319 fleet will be the launch fleet for TAPS at United.



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TAPS Turbulence Metric

- **EDR**: Eddy Dissipation Rate → atmospheric "sea state" around aircraft
- **RMS-g**: Root mean square of vertical loads → vertical accelerations experienced by actual aircraft

	RMS-G	EDR
Definition	Root mean square (RMS) of vertical acceleration	Eddy Dissipation Rate (EDR)
Description	• Aircraft-derived • Measures severity of vertical acceleration variance, experienced by an aircraft in turbulence. • Measurement is more "robust" than raw accelerometer data.	• Atmospheric state • A measure of the state of the atmosphere. • Describes the turbulence "activity" level of the air.
Application	• Describes the severity of turbulence encounters (light, moderate, severe) per FAA AIM. • Scales a reported turbulence encounter from one aircraft type to another.	• Is used in numerical and probabilistic forecasting models.

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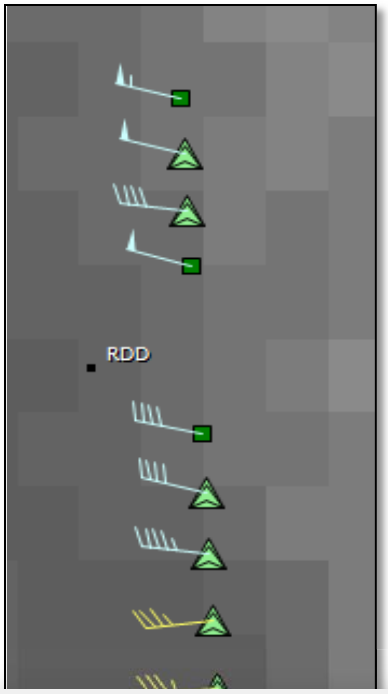
TAPS Reports

- TAPS Reports based on peak RMS g-load threshold values met over 30 sec period.
- Reports contain the following information:
  - Time of occurrence
  - Aircraft's position
  - Altitude
  - Aircraft Type
  - Flight Call Sign
  - Wind parameter
  - EDR Parameter
  - RMS/G parameter *(from accelerometer)*
- "Heartbeat" reports (blue squares) issued every 20 min for system status monitoring in smooth air.
- TAPS reports automatically scaled to aircraft type before being displayed.



Details

Reported: 03/27/2015 18:21
Aircraft type: B752
Altitude: 368
Turbulence: Light
EDR: 0.1756 g
RMS: 0.0620 g
Wind speed: 61 knots
Wind dir: 265 degrees
Temperature: -45 °C

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TAPS Severity Levels

Intensity	Icon	Hazard Metric (rms-g)	WSI Enroute Hazard Criteria	Aircraft Reaction (AIM)	Reaction Inside Aircraft (AIM)
Smooth		< 0.075g	No SIGMET or FPG	No turbulence that causes airspeed and/or altitude variations.	No impact on crew services or passenger comfort
Ride Quality		0.075g to ≤ 0.1g	No SIGMET FPG Guidance: OCNL LGT	Turbulence that causes little or no airspeed and/or altitude variations.	Occupants feel discomfort if exposed for more than 15 minutes. Food service may be conducted and no difficulty is encountered in walking.
Light		0.1g to < 0.2g	No SIGMET FPG Guidance: LGT LGT OCNL MDT	Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude.	Occupants may feel a slight strain against seatbelts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking.
Moderate		0.2g to < 0.3g	SIGMET & FPG: MDT MDT OCNL SVR	Turbulence that is similar to light turbulence but of greater intensity. Changes in altitude and/or attitude occur but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed.	Occupants feel definite strains against seatbelts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.
Severe		> 0.3g	SIGMET & FPG: SVR EXTM	Turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in indicated airspeed or momentary loss of control.	Occupants are forced violently against seatbelts or shoulder straps. Unsecured objects are tossed about. Food service and walking are impossible.

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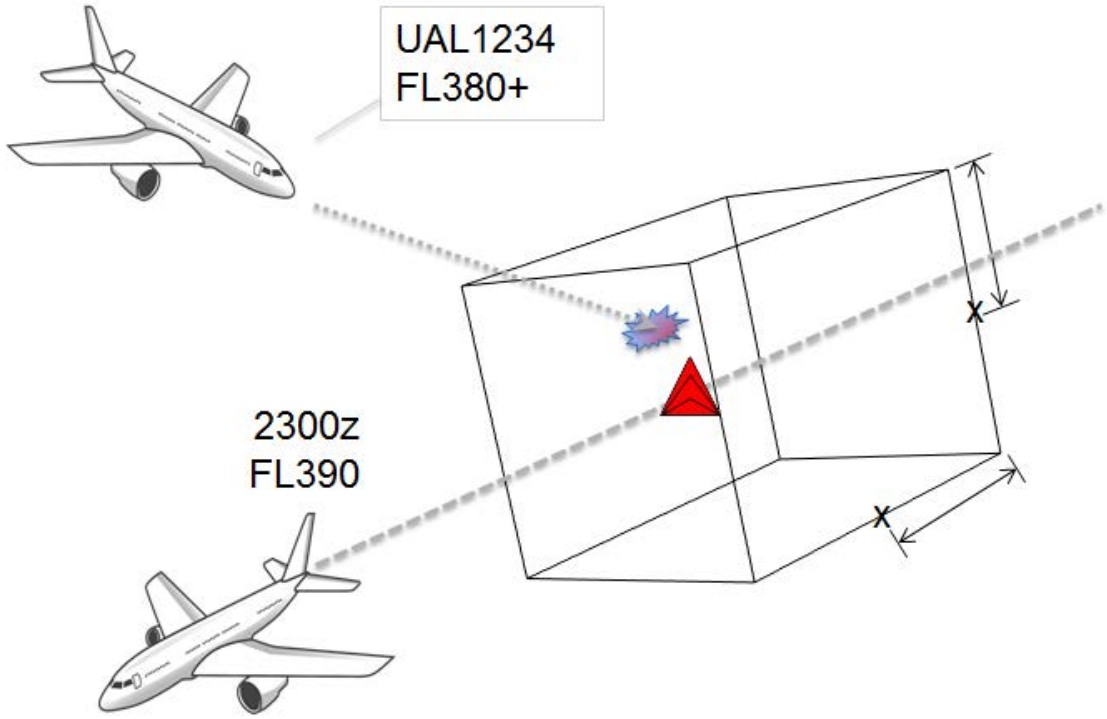
TAPS Report – Automatic Alerting Engine

- Automatic reporting and alerting ensures reports are ***consistent***, ***timely***, and ***objective*** without increasing workload.
- TAPS report alerts automatically sent to other flights passing within:
  - **50 NM** radius from report
  - **+/- 2000 FT** from report
  - **30 minutes** of report issuance



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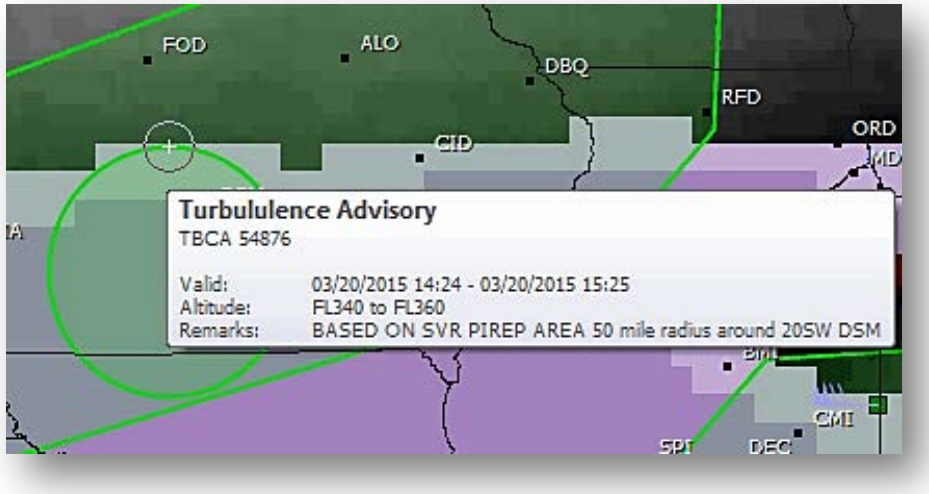
WSI Turbulence Advisory

- Advisory of significant turbulence based on TAPS event(s) or PIREP outside of or worse than existing SIGMETs and/or FPGs
- **Enables Continuous Real-Time Validation**
  - WSI Mets monitor variances and issue advisory as event evolves
  - Reduces “Nowcasting”
- **Timely, Concise, Specific**
  - Cylinder in shape
  - Radius: up to 200nm,
  - Vertical: +/- 2000 FT from report
  - Valid: 30-60 min
  - Contain a discussion/cause



- Included in automatic ACARS alerting for intersecting flights

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Integration with Dispatch View

- TAPS Intersection Alerts automatically sent to responsible Dispatcher(s) ACARS or PIREPs message queues for flights within the alert area, including the reporting aircraft.
- Aircraft outside of the alert threshold will need this information sent via ACARS per current methods.

```
FLIGHT UAL1234 INTERSECTS MODERATE TAPS EVENT
AT 1222Z FL350
A/C: B738
REPORTED:  20/1201Z
LOCATION:  5609N03116W
ALTITUDE:  FL360
RPT LOAD:  0.26 RMS/G
```

Line 1: Who/What/When - This is the flight that is impacted, not the flight that generated the event

Line 2: Time and altitude the impacted flight intersects the event

Line 3: Line break

Line 4: Aircraft type which reported the event

Line 5: Date and time the event was reported

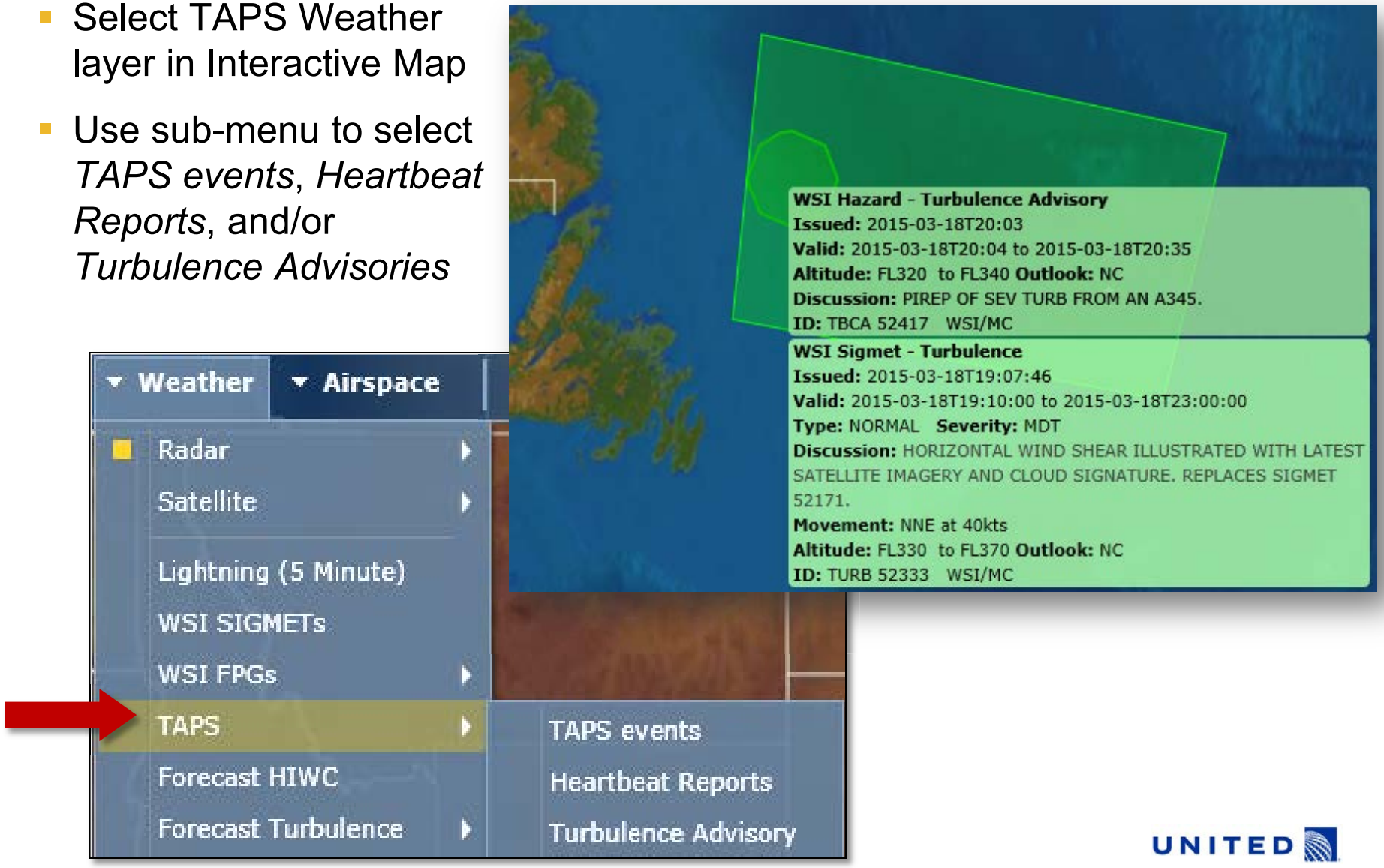
Line 6: Where it was reported

Line 7: Altitude it was reported

Line 8: Reported RMS/G (turbulence) load on the aircraft

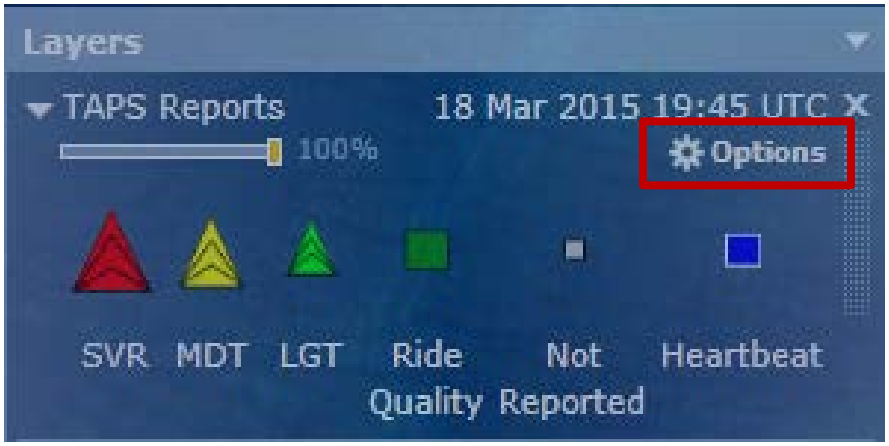
TAPS in WSI Pilotbrief Optima

- Select TAPS Weather layer in Interactive Map
- Use sub-menu to select *TAPS events*, *Heartbeat Reports*, and/or *Turbulence Advisories*



WSI Optima TAPS

- Refer to **Layers** legend in lower right corner to decode TAPS symbols and color codes.



- Click **Options** selection to access intensity filter and toggle on/off wind barbs.

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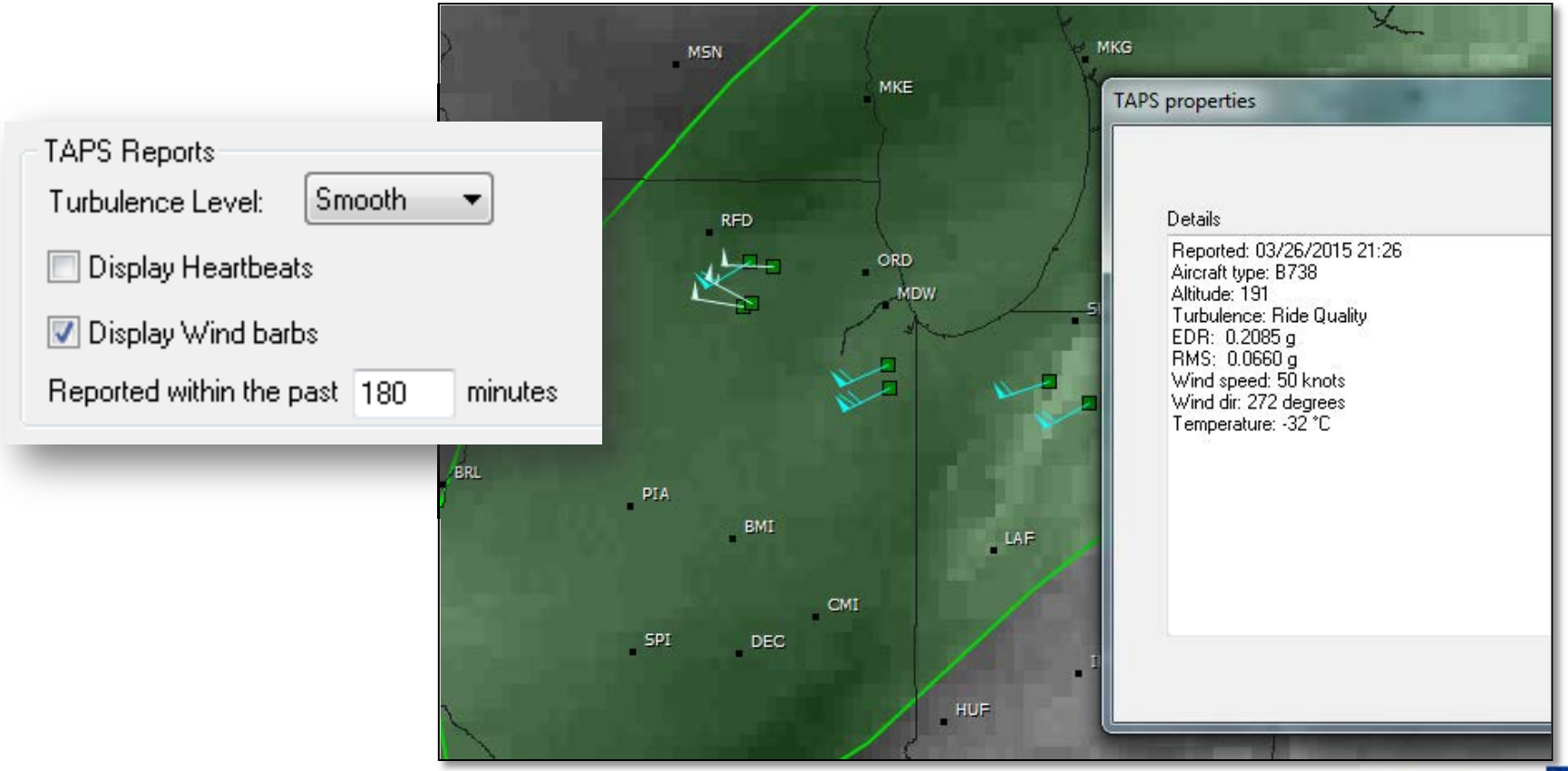
Flight Explorer TAPS – eff. v14.1 in June 2015

- Able to view last 3 hrs of TAPS reports but animation not enabled.
- Wind barbs will be color-coded based on strength of winds.
- Properties dialog enabled for individual TAPS reports
- Intensity filter and toggles available in User Defined Settings.



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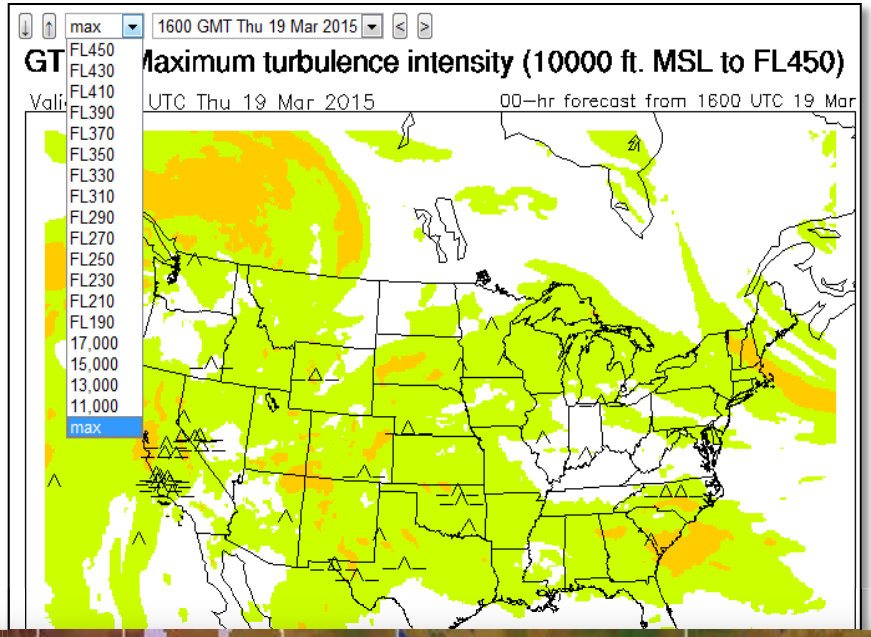
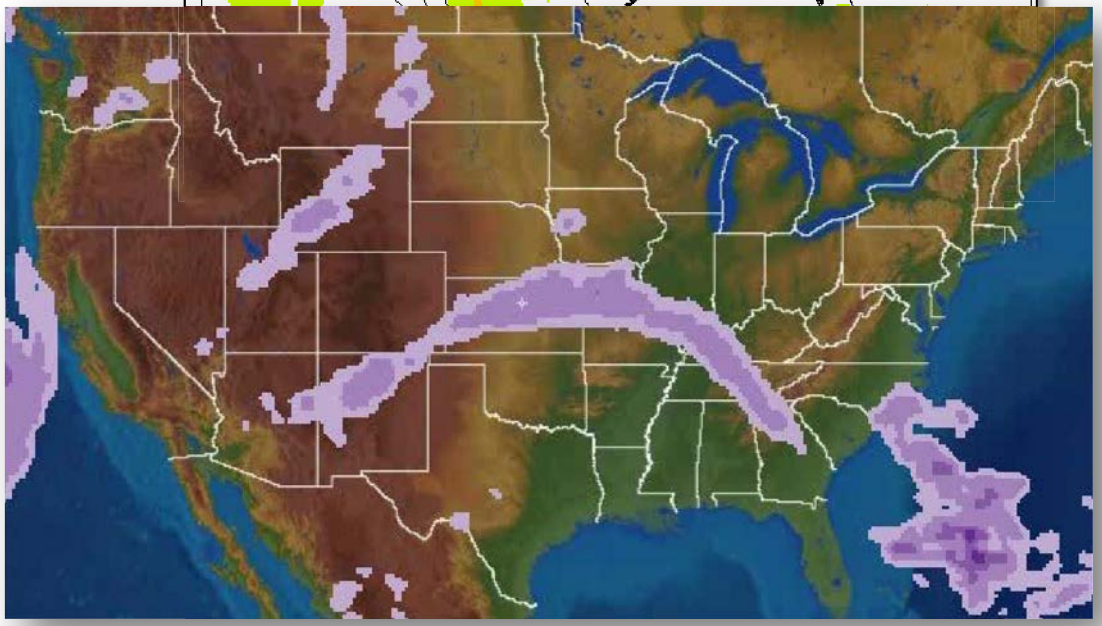
WSI Turbulence Forecast

Graphical Turbulence Guidance

WSI Graphical Turbulence Guidance (GTG)

- NWS GTG limited to CONUS only
- WSI runs ***global*** GTG model using in-house RPM model.
- Output available for 11 flight levels in 1-hr forecast increments out to 36 hrs.
- Updated 4x daily
- WSI GTG complements FPGs & SIGMETs by narrowing down areal coverage and time window of turbulence areas.





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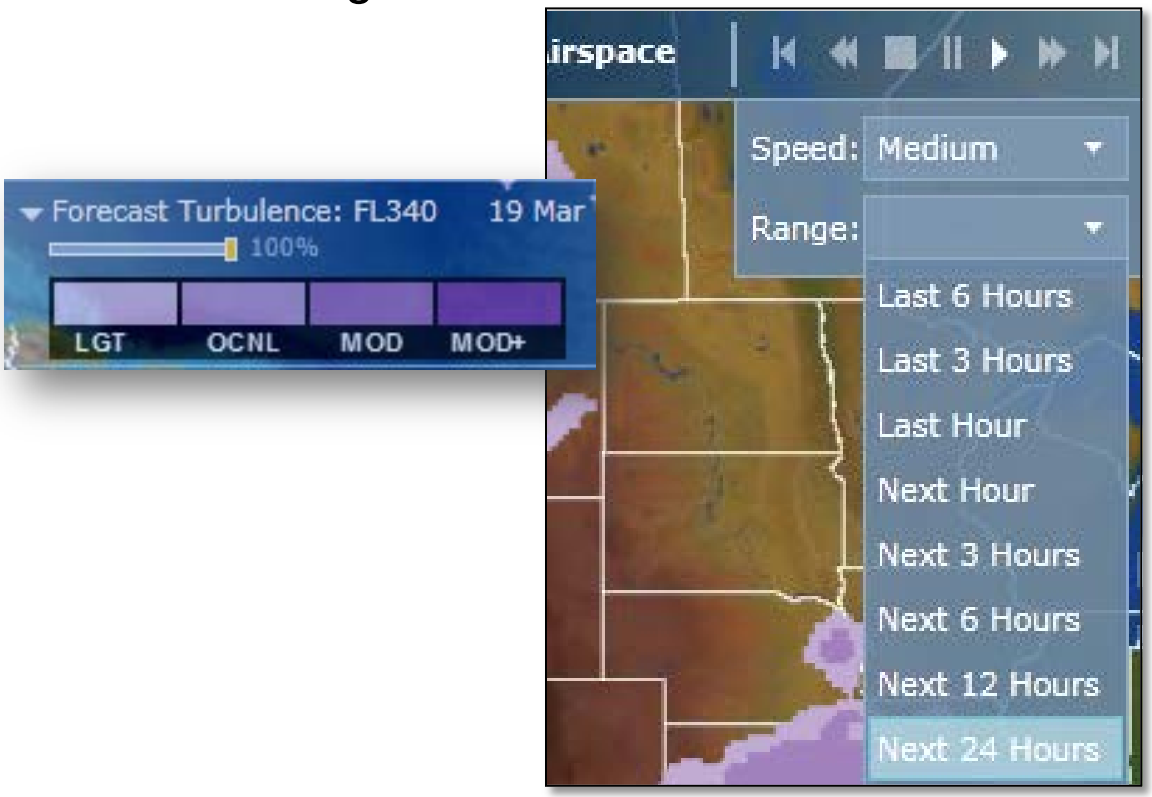
WSI Turbulence Forecast in Optima

- WSI GTG available in Optima Interactive Map Weather overlays under the title “**Forecast Turbulence**”.
- Select a future **Range** under animation controls and click play to view loop of 1-hr forecasts up to 24 hrs.
- A legend will be displayed in the Layers Control to depict the forecasted light to severe turbulence



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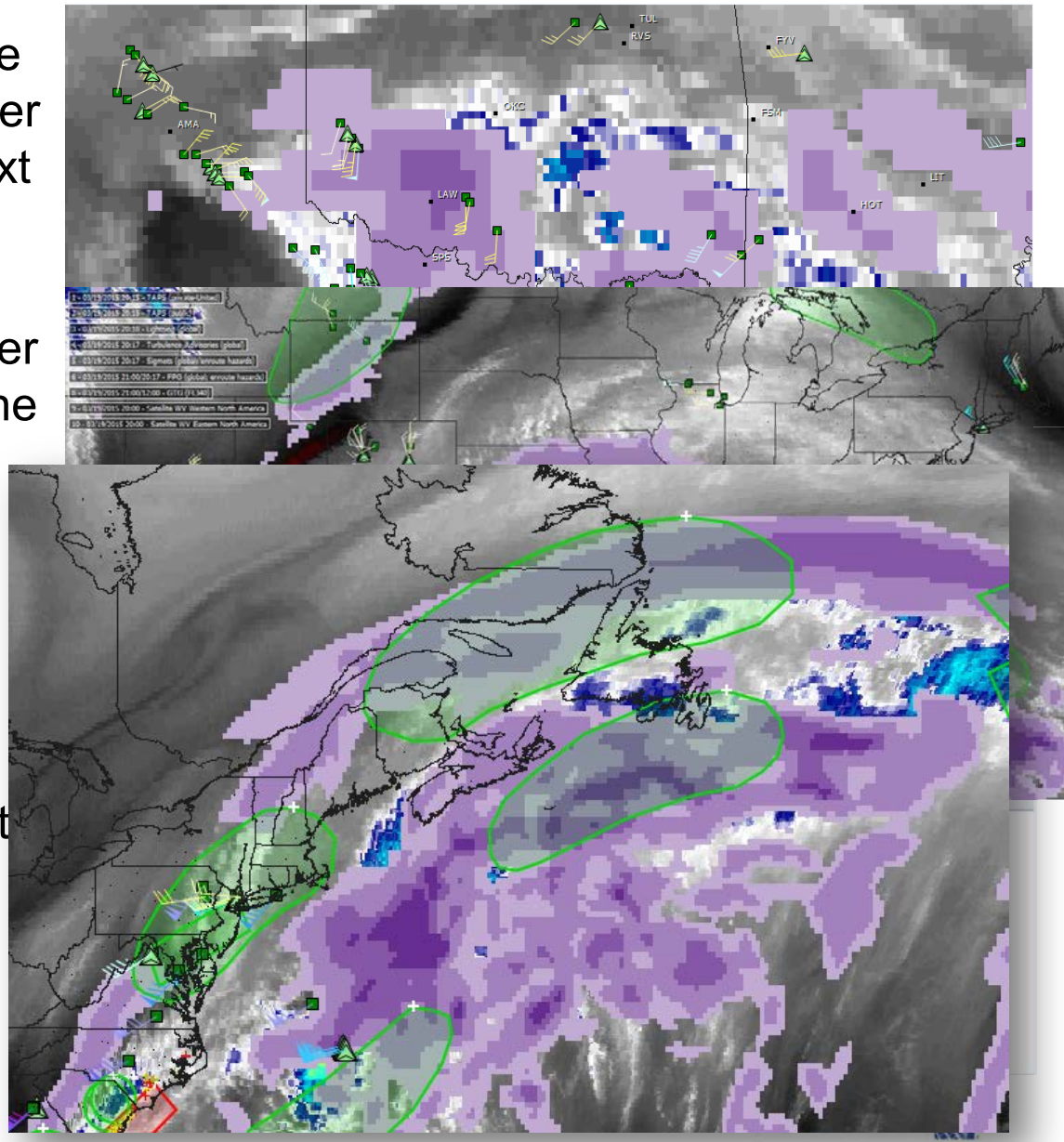
WSI GTG in Flight Explorer

- The WSI GTG product will be available in the Flight Explorer product beginning on the next update in June 2015
- The GTG product can be displayed in the same manner as the TAPS reports using the group by Product Types.
- GTG can be analyzed for different altitudes for a psuedo-three dimensional view.
- GTG can be animated to determine the trend going int the future.



Conclusion

TAPS & GTG Benefits

Benefits to Operating Priorities

WSI TAPS and GTG products provide dispatch with additional integrated tools to enhance our operating priorities:

- Reduce injuries to flight crews and passengers through enhanced turbulence awareness.
- Improve collaboration and operational decision-making between pilots and dispatchers in mitigating turbulence hazards.
- Improve ability to select altitudes that best balance safety and operational efficiency.
- Enable more judicious use of airspace leading to potential fuel savings

Vastly Improved Turbulence Forecasting

Hi-density PIREPs **>>** observations ingested into computer models **>>** validate and improve turbulence forecasts (e.g. GTG) **>>** more accurate forecasts improve user confidence **>>** better decision-making **>>** **safer, more efficient flights**.