NextGen Weather Systems

_Turbulence Requirements_

Presented to:  Turbulence Impact Mitigation Workshop

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Purpose

• Provide FAA NextGen Weather Systems perspective on turbulence impact mitigation

• Address following questions:
  – What are aviation user requirements for turbulence impact mitigation?
  – What current NextGen Weather products support turbulence mitigation?
  – What are remaining R&D gaps?
NextGen Weather Systems
FAA Legacy Weather

Weather for Traffic Flow Management

Integrated Terminal Weather System

CoSPA: Consolidated Storm Prediction for Aviation

ITWS: Integrated Terminal Weather System

CIWS: Corridor Integrated Weather System

WARP: Weather and Radar Processor

8-hr Predictions (prototype)

Enroute Controllers’ Mosaics
NWP Consolidation and Modernization

Weather for Traffic Flow Management

Consolidated coverage domains

Integrated Terminal Weather System

CIWS

Guam

Alaska

CoSPA

Hawaii

CONUS

CONUS*

8-hr Predictions (prototype)

Enroute Controllers’ Mosaics

ITWS

WARP
NWP Addresses Unmet User Needs

• “Common weather picture”
  – Available to all stakeholders
  – No conflicting weather information from multiple sources
  – System-wide availability of Terminal and Enroute products

• Improved safety:
  – More accurate storm location, size, shape, height, intensity
  – More timely weather hazard information (25 sec updates)

• Improved efficiency:
  – Anticipation of airspace capacity impacts
  – Route availability and flow constrained areas
  – Support precise traffic flow initiatives
    • Miles-in-Trail restrictions, Ground Delay Programs and Airspace Flow Programs
NWP Aviation Weather Display

- AWD dedicated and web displays share the same Angular Material framework

Desktop browser

Phone browser

Tablet browser
NextGen Wx Turbulence Products
NextGen Weather Turbulence Categories

• **Clear air turbulence**
  – Wind and thermal gradients aloft
    • Jet stream flank, tropopause folding, etc.
  – Mountain waves

• **Convective turbulence**
  – *Growing* thunderstorms - turbulent regions at / above cloud tops
  – *Mature* thunderstorms - downstream turbulence wakes
  – Mid-latitude cyclones - vertical shear (of horizontal wind) layers

• **Low-altitude turbulence**
  – Atmospheric fronts
    • Gust front, sea breeze, synoptic fronts, orographic flows
  – Wake vortices
Clear Air Turbulence
GTG3 Turbulence Contours in NextGen Weather

- Contours represent flexible composite turbulence layer
- Example shows two contours [MOD & HVY] overlaid on 3-hr Precip Forecast
- Turbulence also available as gridded base product
Turbulence above Growing Thunderstorms

- Flight over rapidly-growing convective cells
- Hazard evolves in a matter of minutes
- Turbulence results from strong updraft that perturbs atmosphere above the storm
- Updraft strength (vertical motion), updraft height, upper air winds and stability important

July 21, 2010 in Missouri
Radar Images ~5 min apart
00:08 – 00:31 UTC
NextGen Weather Growth Trends

- NextGen Weather “Growth Trends” predicted convective turbulence aircraft encounters

100720_UAL967_divert_Denver
150515_AA_near_Memphis
150808_Delta_near_Denver
160811_JetBlue_near_RapidCity
170325_GA_Breakup_Alabama
170515_N220N_Caribbean
170620_UA1031_east_of_Cancun
170710_DAL685_near_Daytona
170805_AAL759_into_Philly
170822_AmerEagle_3167_near_StLouis
180413_extreme_turb_hail_Nebraska
180604_AAL1897_hailstrike_near_ElPaso

- Helped drive requirement for rapid update (25 sec) Growth Trends
- Growth signature ~ 5-15 min in advance of aircraft impact
  - Send product directly to cockpit
- Growth Trends signature is complementary to Precip
  - Disappears once storm is mature
Example of Growth Trends “Warning”

Severe Turbulence & Hail Encounter
Delta 1889 - August 8, 2015
BOS to SLC, landed in DEN
1 passenger to hospital
NWP 3D Mosaics - Vertical Cross-Sections

Cross-section Composite from NWP Echo Tops and Bottoms
Perspective of pilot approaching the gap, with southern storm on left

Delta 1889 Turbulence and Hail Encounter

- NWP mosaics produced every 25 seconds w/ 1Kft vertical resolution
- Tailored, real-time flight path cross-sections could be enabled
Turbulence Downstream of Mature Thunderstorms

- Downstream turbulence results when updraft acts as obstacle for upper level wind flow
  - Turbulence results in downstream wake
- ATC users on early CIWS user panel were well aware of this downstream turbulence hazard
  - Additional CIWS graphical product to highlight downstream wake turbulence was deemed “a nuisance”
- Consider including downstream turbulence in Convective Weather Avoidance Fields
Convective Turbulence: Vertical Wind Shear

All 45 Terminal Winds grids are generated in central Domain processors

- 2-D horizontal winds
- 25 vertical levels
- 0 to 25 Kft altitude
- 2 km horizontal res.
- 5 min update rate

Terminal Winds

NEXRAD
Surface Stations

TDWR
LLWAS

Aircraft Obs
RAP

Top: 100 mb
400 mb
~25 mb
Bottom: 1000 mb

COMPOSITE REFLECTIVITY & VELOCITY VECTORS 0000Z-2115Z
## Legacy vs. NextGen Weather Wind Profiles

### Profile ID

**EWR_220010**

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### Winds: altitude (ft.*100) direction speed (kts)

### History (when applicable, in last 15 minutes):

- Speed increase >= 10 kts
- Speed decrease >= 10 kts
- Direction change >= 60 deg

### Color coding:

- **GREEN**  No warning
- **ORANGE** Wind speed > 30 kts.
  (Altitude <= 6000 ft. only)
- **RED** Vertical shear between levels of >= 20 kts. (color both levels)

*(RED takes precedence over ORANGE)*
Low Altitude Turbulence – Fronts (0-2 hr)

- **Fronts issued by NOAA**
  - Includes set of fronts valid at one “synoptic” time
  - Updates every 3 hours
  - Arrives ~1.5 hours after valid time

- **NextGen Weather time-aligns fronts**
  - Projects ahead every 5 min out to 2 hours
  - Re-aligns and updates every 5 min
Low Altitude Turbulence – Gust Fronts

• Detection and forecast
  – Solid purple line for current position and dashed lines for 10/20 min forecasts

• Wind shift estimate
  – Purple numeral and arrow indicate wind shift estimate behind gust front passage

• 1 minute update, within 30 NM of TDWR; can trigger wind shear gain alerts

• Impact timer
  – Estimated time until gust front airport impact
  – Not a countdown; recomputes impact time based on updated gust front position
General Turbulence Priorities
General Turbulence Priorities

• **Top priorities**
  – Coverage in US National Airspace and Canada (MOA)
  – Safety of aircarrier and general aviation flights
  – Efficiency of strategic traffic flow planning
  – Coordination outside FAA with Airlines, DoD and NWS

• **Secondary priorities**
  – Global coverage
  – Unmanned air systems
  – Coordination outside FAA with international aviation agencies
NextGen Weather Turbulence Wish List

• **Coordinate new product development within agency**
  – Integrate ongoing development & assets within FAA
  – Leverage new product development & agency technology refresh
  – Ensure “Common Weather Picture” desired by users

• **Utilize high resolution rapid refresh numerical models**
  – Highest resolution available in space and time

• **Develop accurate products consistent with NextGen Weather offerings**
  – Precise locations
  – Ultra low false alarm rates
  – Independent, complementary information
### NextGen Weather Turbulence Mitigation Summary

<table>
<thead>
<tr>
<th>Product</th>
<th>Details</th>
<th>NextGen Weather Work Package 1</th>
<th>WP1 Analysis &amp; Forecast</th>
<th>Remaining R&amp;D Gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Air Turbulence</td>
<td>Flexible layers 0-45 kft</td>
<td>GTG3 CAT only for users (MW available – not used)</td>
<td>0-8 hrs</td>
<td>Separate CAT &amp; MW Turb; offer improved combo; increase horizontal resolution</td>
</tr>
<tr>
<td>Convective Turbulence Growing Thunderstorms</td>
<td>Growth Trends</td>
<td>25 sec update rate Contours (x,y)</td>
<td>Analysis only</td>
<td>In-situ verification; quantification; tailored uplink to cockpit &amp; warn; radar-forward predictions coupled with Conv Weather Avoidance Field</td>
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<td>Convective Turbulence Mature Thunderstorms</td>
<td>Downstream Wake diagnosis</td>
<td><em>Not valued by early CIWS user group – potential nuisance</em></td>
<td>3-D radar forecast &amp; Upper level winds available in WP1</td>
<td>0th order prototype &amp; display options for user feedback; if valuable, prototype 1st order R&amp;D; couple w/ Conv Weather Avoidance Field</td>
</tr>
<tr>
<td>Convective Turbulence Mid-latitude cyclones</td>
<td>Vertical shear of horizontal winds</td>
<td>Terminal Winds - Profiles include color coded shear layers (45 terminals)</td>
<td>Analysis only</td>
<td>Path-based shear &amp; Airport Arrival Rate (AAR) estimates from 0-2 hr Twinds (new); AAR strategic planning product for &gt; 2 hrs; include Mode S EHS aircraft wind obs</td>
</tr>
<tr>
<td>Low Altitude Turbulence Atmospheric Fronts</td>
<td>0-2hr Fronts; Gust Fronts, thin lines</td>
<td>Time aligned &amp; extrapolated Fronts; ITWS Gust Fronts (45 airports)</td>
<td>GF – Analysis only 0-2 hr Fronts - 5 min CONUS+ only</td>
<td>Expand 0-2 hr Fronts to include AK &amp; Oceanic; combine with 0-2 hr Terminal Winds (new) for quantitative turbulence/wind shift estimates; incorporate GF from NEXRAD, ASR WSP, Canada (new)</td>
</tr>
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<td>Low Altitude Turbulence Wake vortices</td>
<td>No NextGen Weather algorithms</td>
<td>Terminal Winds grids &amp; profiles (25 mb vertical layers), 0-2hr Fronts, Gust Fronts</td>
<td>Terminal Winds, GF: Analysis only 0-2 hr Fronts – 5 min</td>
<td>0-2 hr Terminal Winds with 1 kft vertical layers for altitude precision and quantitative wind shift estimates</td>
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