NextGen Weather Systems

Turbulence Requirements

Presented to: Turbulence Impact Mitigation Workshop

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Purpose

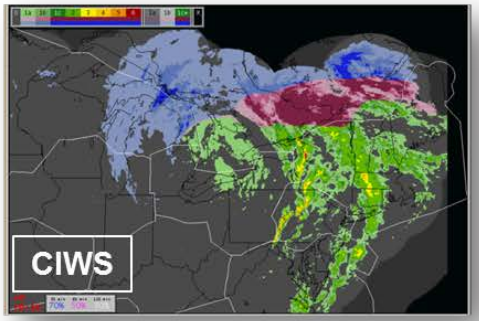
- **Provide FAA NextGen Weather Systems perspective on turbulence impact mitigation**

- **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?

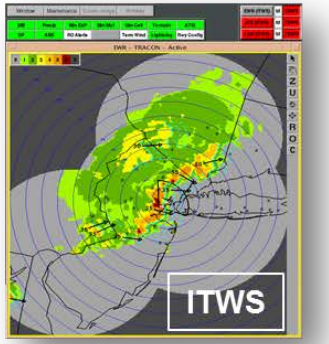
NextGen Weather Systems

FAA Legacy Weather

Weather for Traffic Flow Management

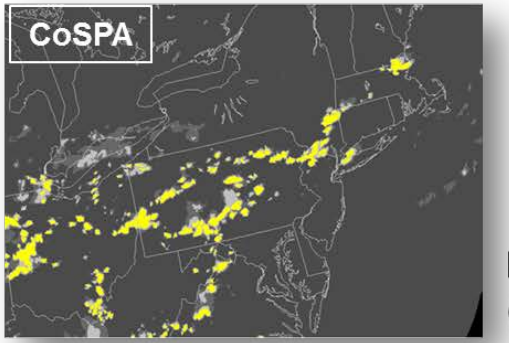


Integrated Terminal Weather System



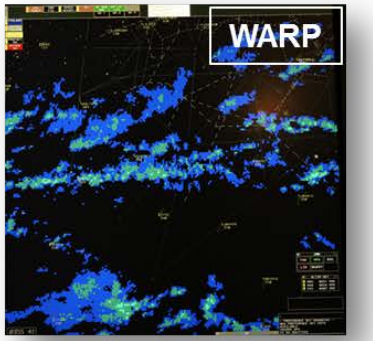
NextGEN WEATHER

Improving Safety and Efficiency in the National Airspace System



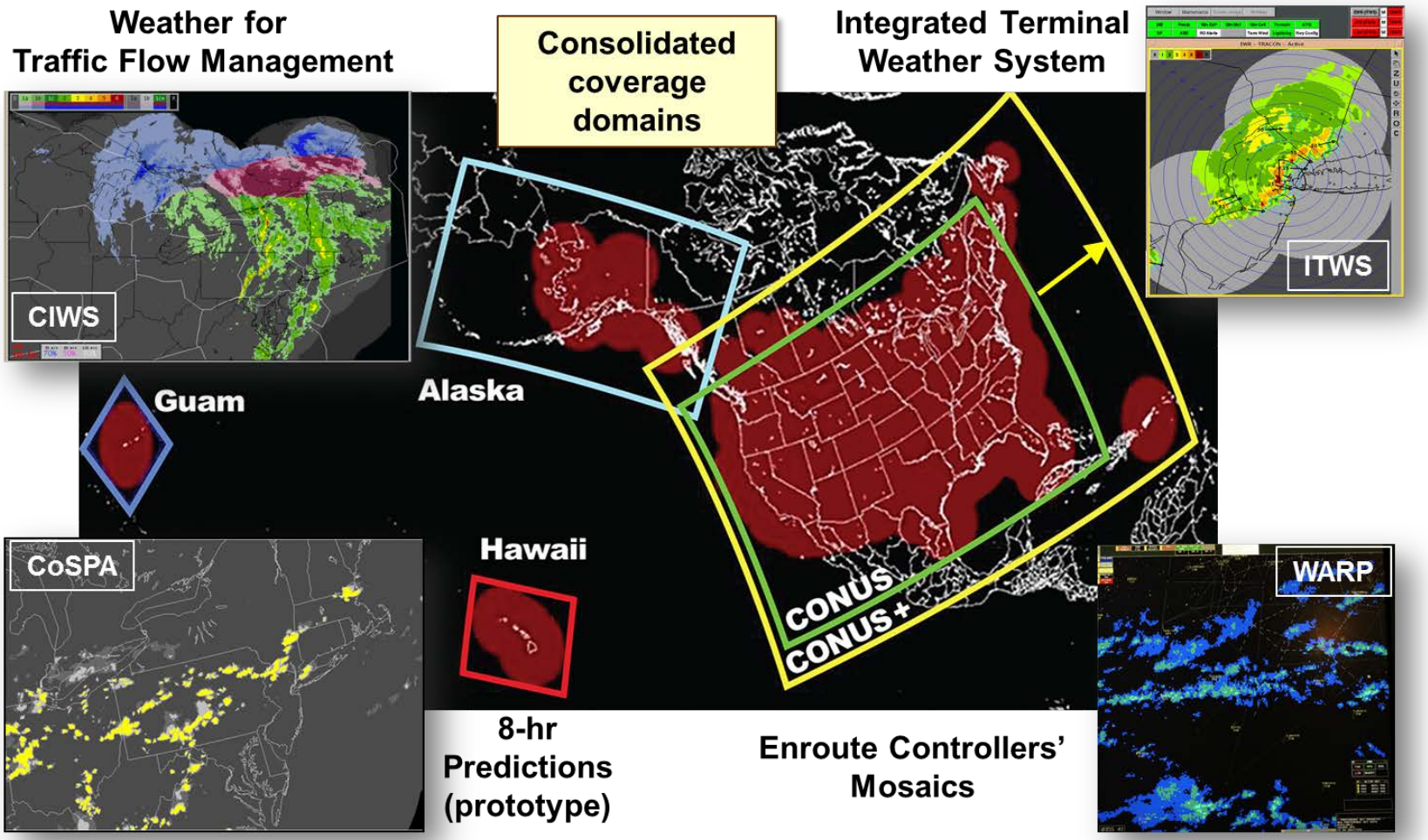
8-hr Predictions (prototype)

Enroute Controllers' Mosaics



WARP: Weather and Radar Processor
ITWS: Integrated Terminal Weather System
CIWS: Corridor Integrated Weather System
CoSPA: Consolidated Storm Prediction for Aviation

NWP Consolidation and Modernization



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

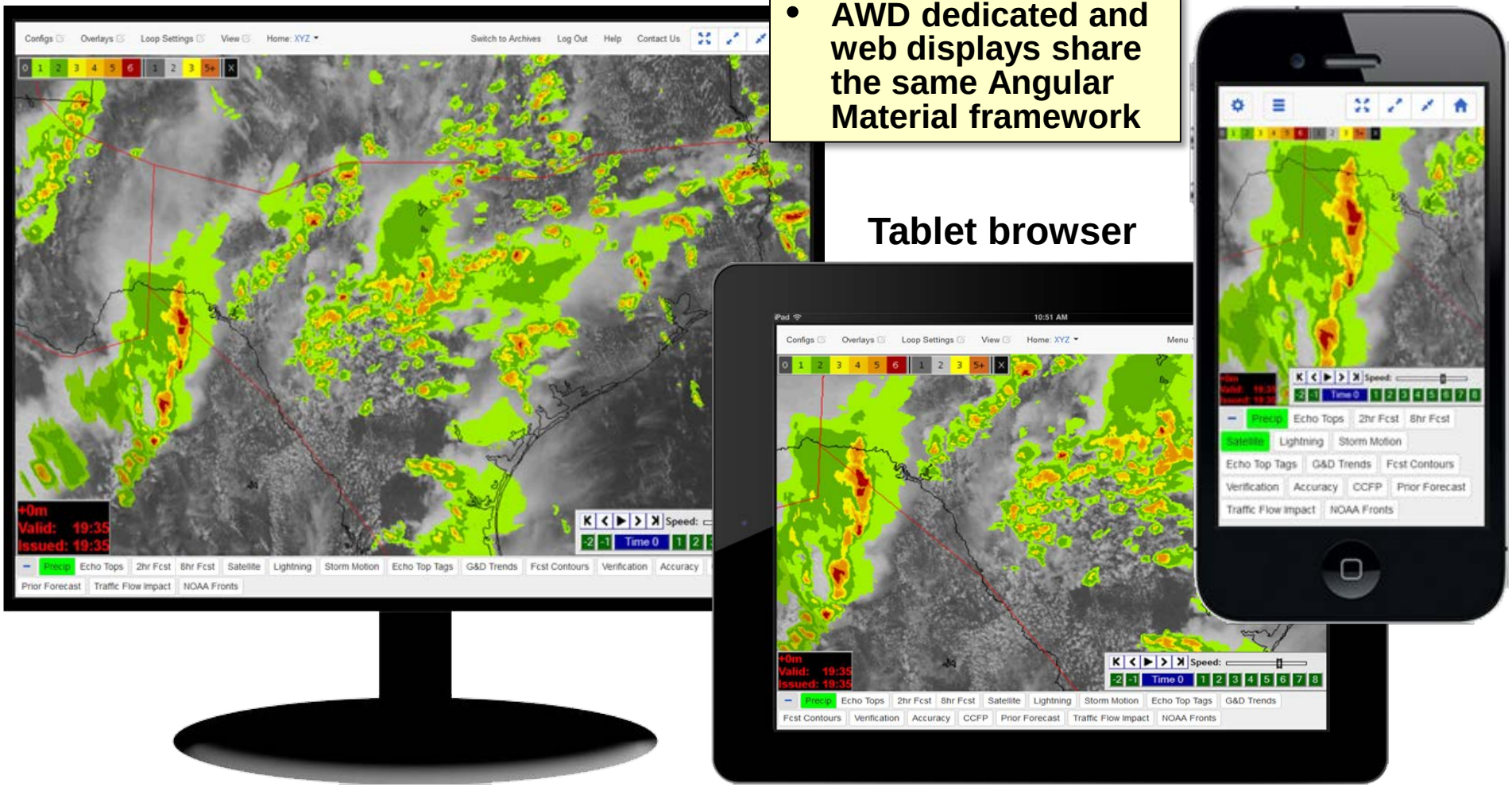
NWP Aviation Weather Display

Desktop browser

Phone browser

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

Tablet browser



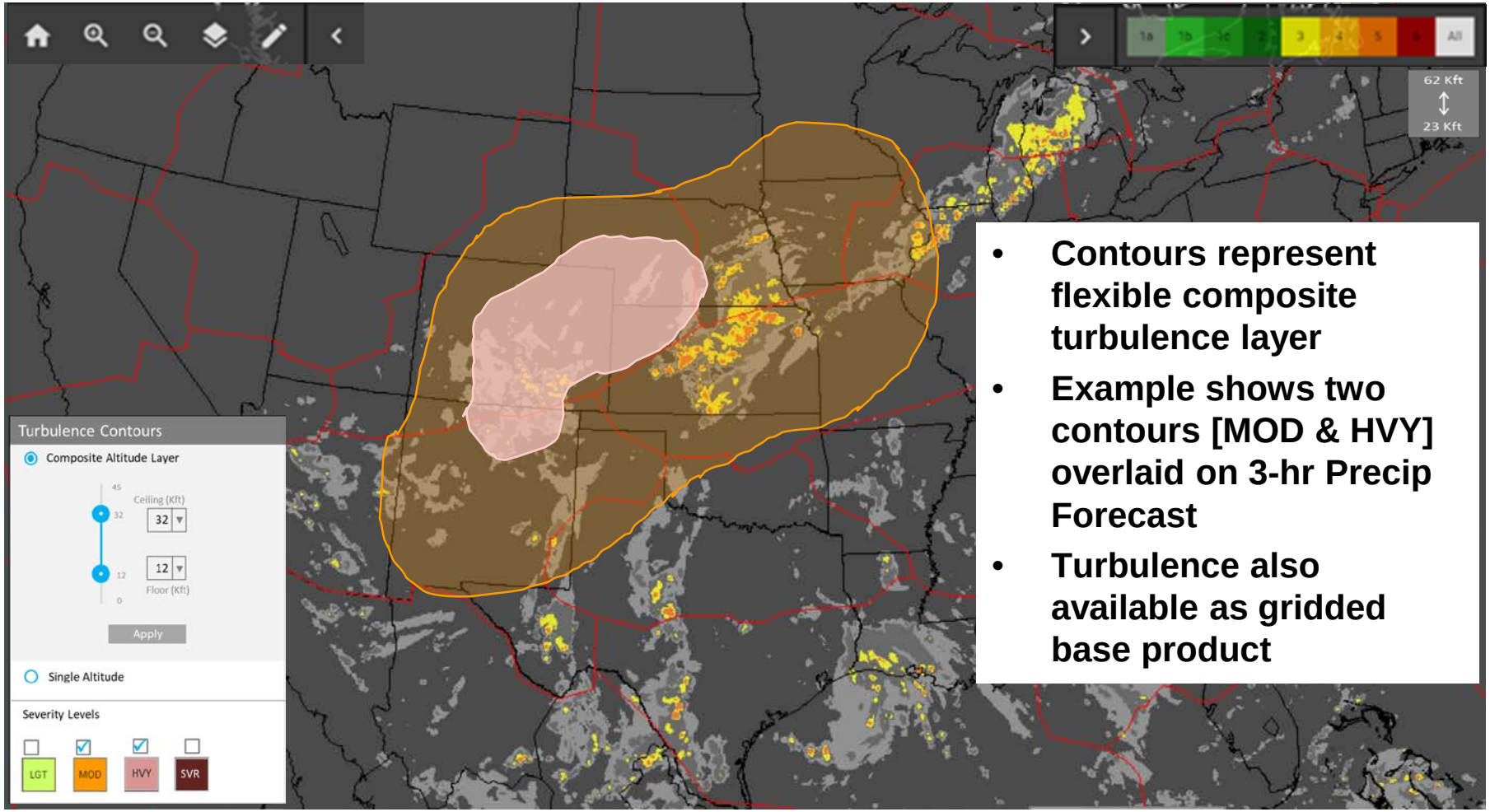
NextGen Wx Turbulence Products

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

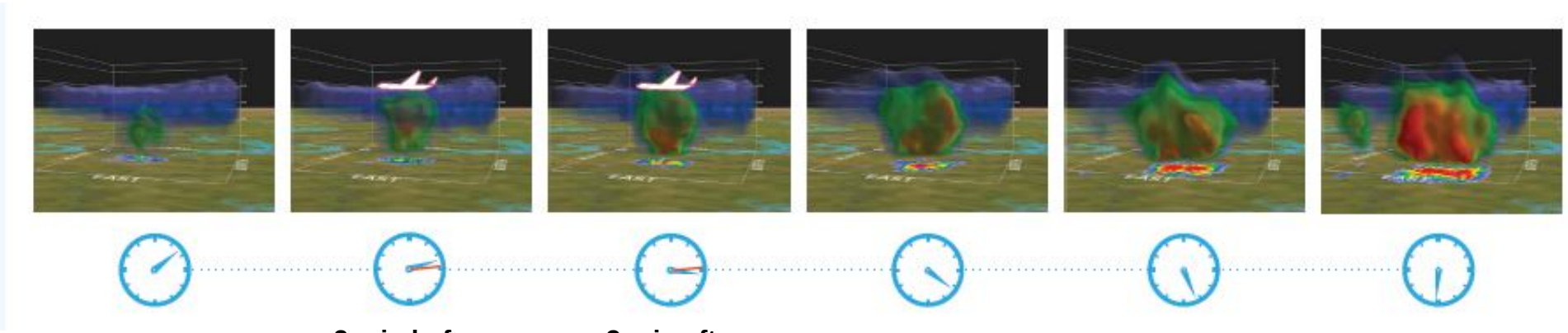
GTG3 Turbulence Contours in NextGen Weather



- 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**



2-min before encounter

3-min after encounter

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

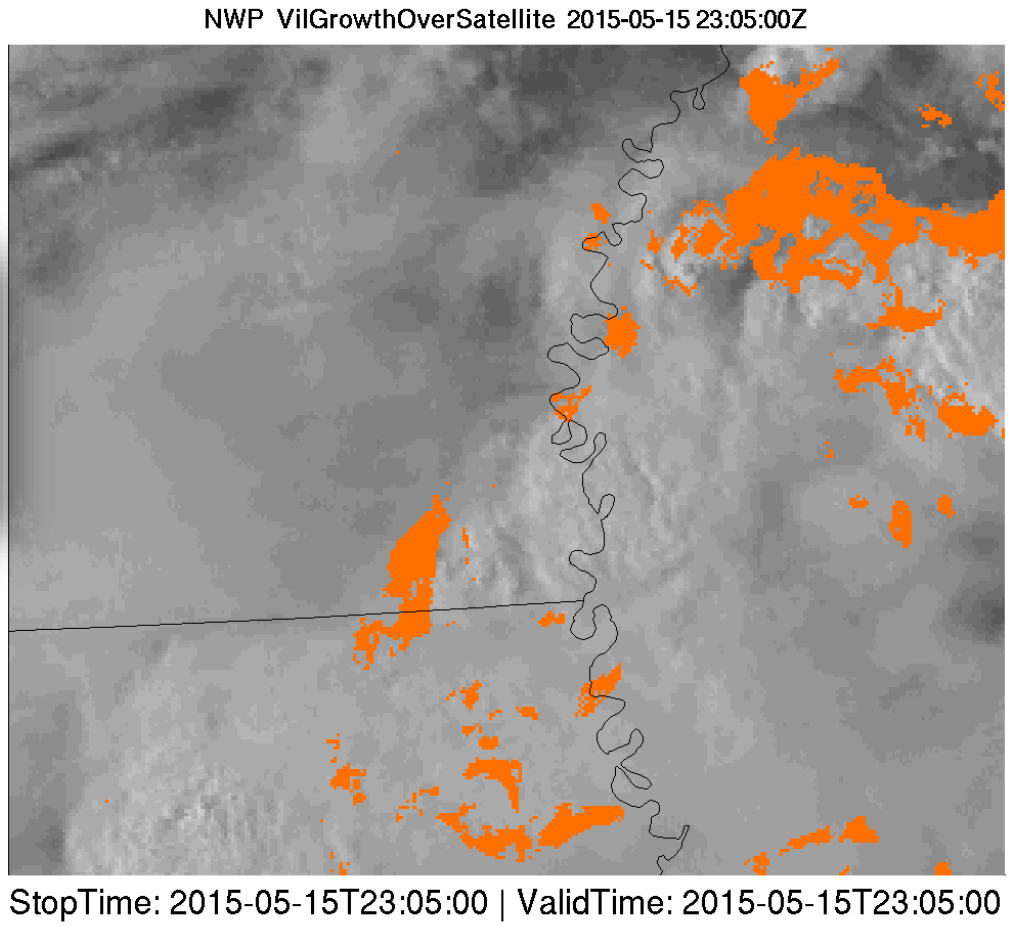
NextGen Weather Growth Trends

- **NextGen Weather "Growth Trends" predicted convective turbulence aircraft encounters**

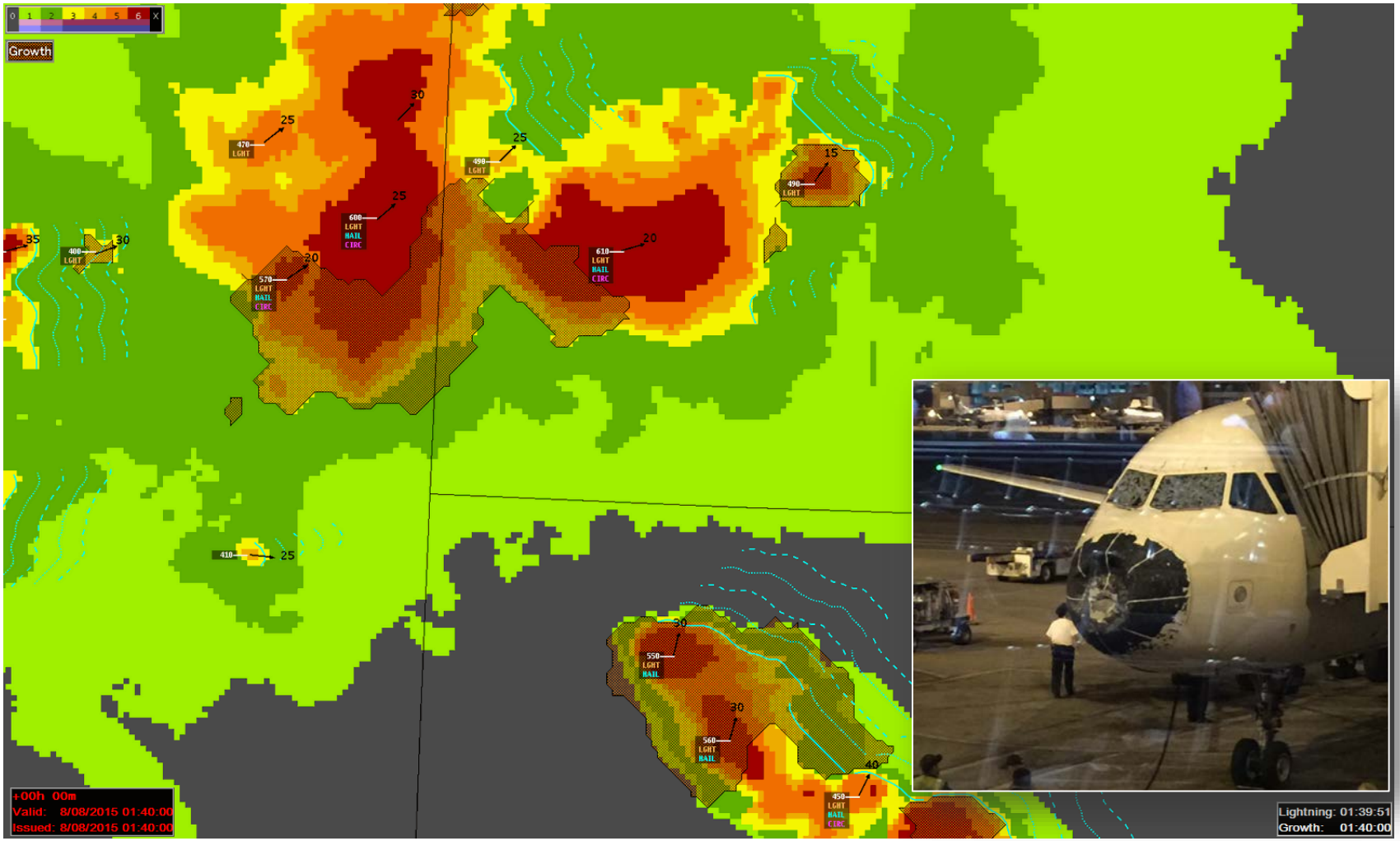
100720_UAL967_divert_Denver
150515_AA_near_Memphis
150808_Delta_near_Denver
160811_JetBlue_near_RapidCity
170325_GA_Breakup_Alabama
170515_N220N_Caribbean

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

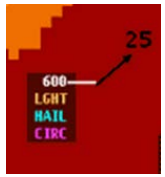
- **Helped drive requirement for rapid update (25 sec) Growth Trends**
- **Growth signature ~ 5-15 min in advance of aircraft impact**
  - **Send product directly to cockpit**
- **Growth Trends signature is *complementary* to Precip**
  - **Disappears once storm is mature**



Example of Growth Trends “Warning”



Benefits of Terminal & Enroute Wx Consolidation



Storm Info Tags & Tornado Icon

→ Terminal Safety

Growth Trends (rapid update)

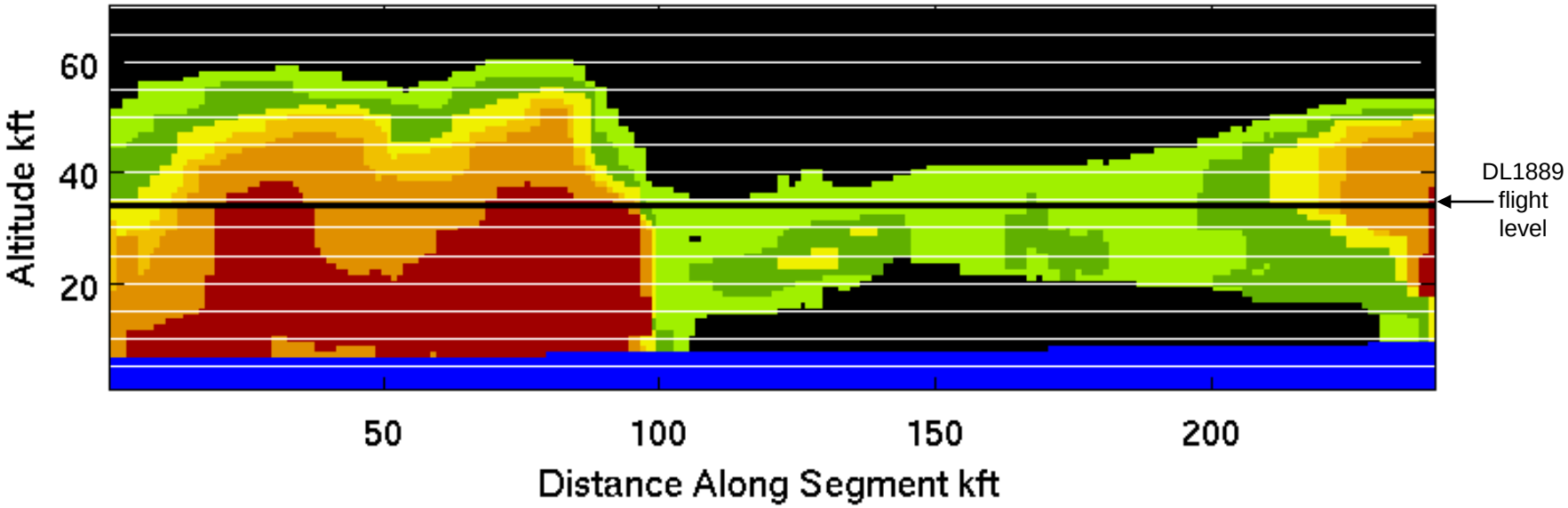
→ Enroute ATC 25 sec update

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

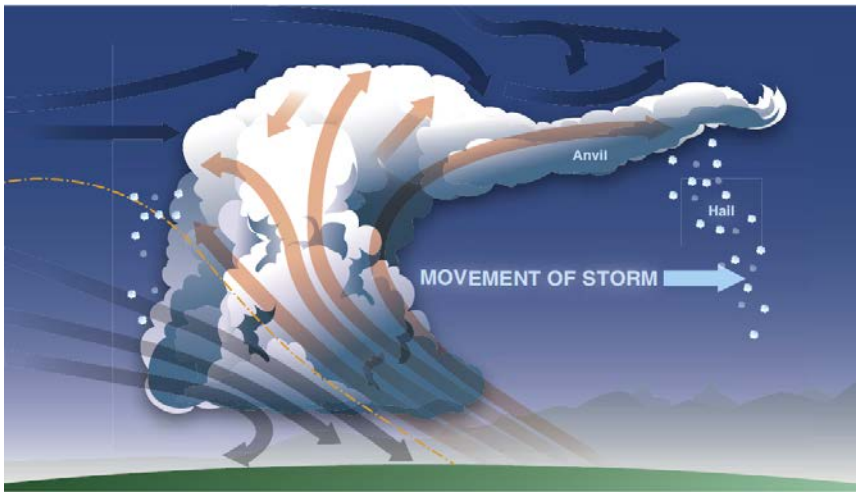


- **NWP mosaics produced every 25 seconds w/ 1Kft vertical resolution**
- **Tailored, real-time flight path cross-sections could be enabled**

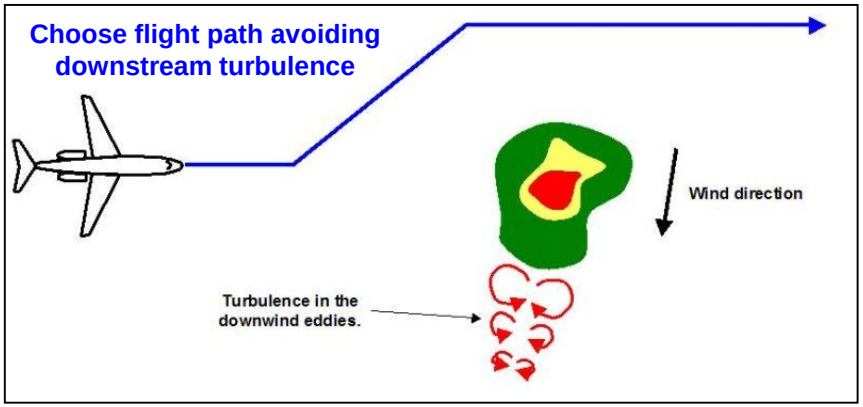
Turbulence Downstream of Mature Thunderstorms

- **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**

Side View



Top View



Convective Turbulence: Vertical Wind Shear

All 45 Terminal Winds grids are generated in central Domain processors

NEXRAD

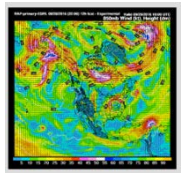
Surface Stations

TDWR

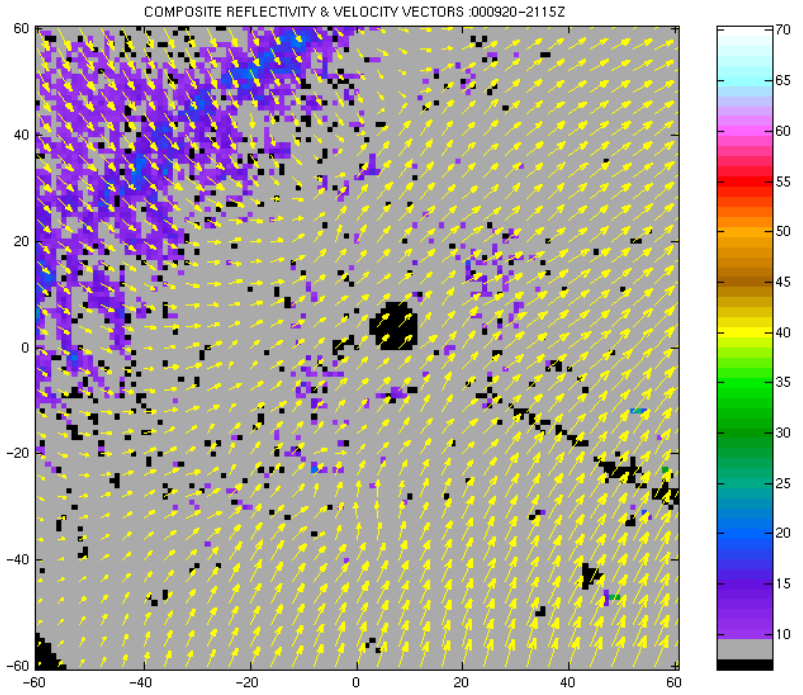
LLWAS

Aircraft Obs

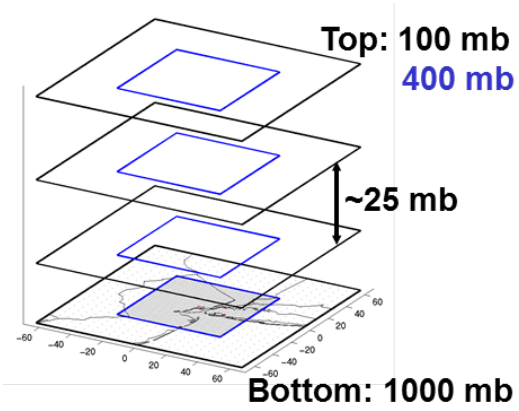
RAP



Terminal Winds



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



Legacy vs. NextGen Weather Wind Profiles

EWR_220010		
040	200	30
030	170	32
020	130	15

EWR_220010		
040	200	30
030	170	32+
020	130	15

EWR_040010		
040	190	52
030	190	50
020	180	41

EWR_040010		
040	190	52
030	190	50
020	180	41

SBJ_VOR		
060	240	31
050	220	25
040	130	20

SBJ_VOR		
060	240	31
050	220	25
040	130	20 *

Profile ID

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

History (when applicable, in last 15 minutes):

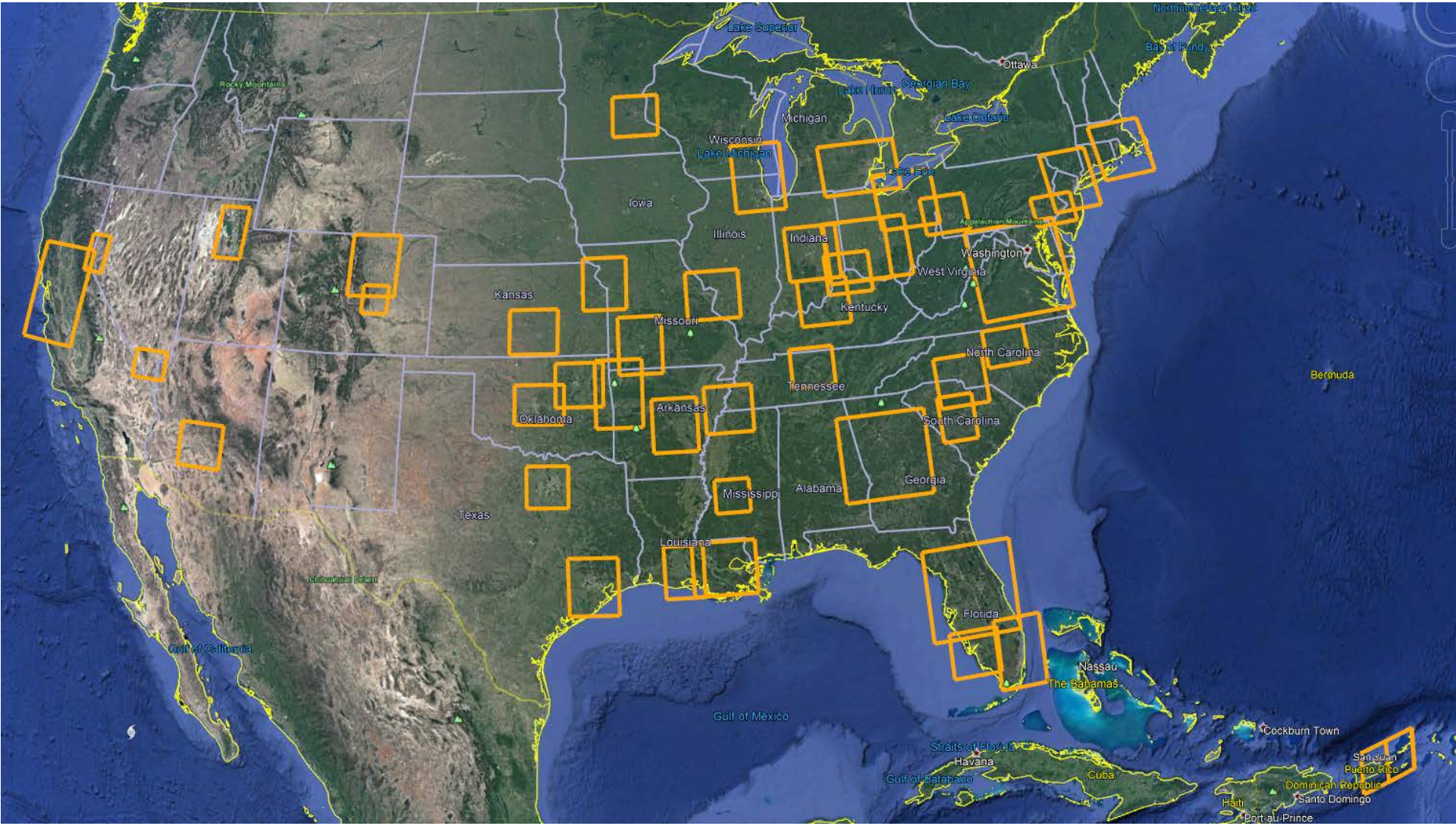
+	Speed increase >= 10 kts
-	Speed decrease >= 10 kts
*****	Direction change >= 60 deg

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)

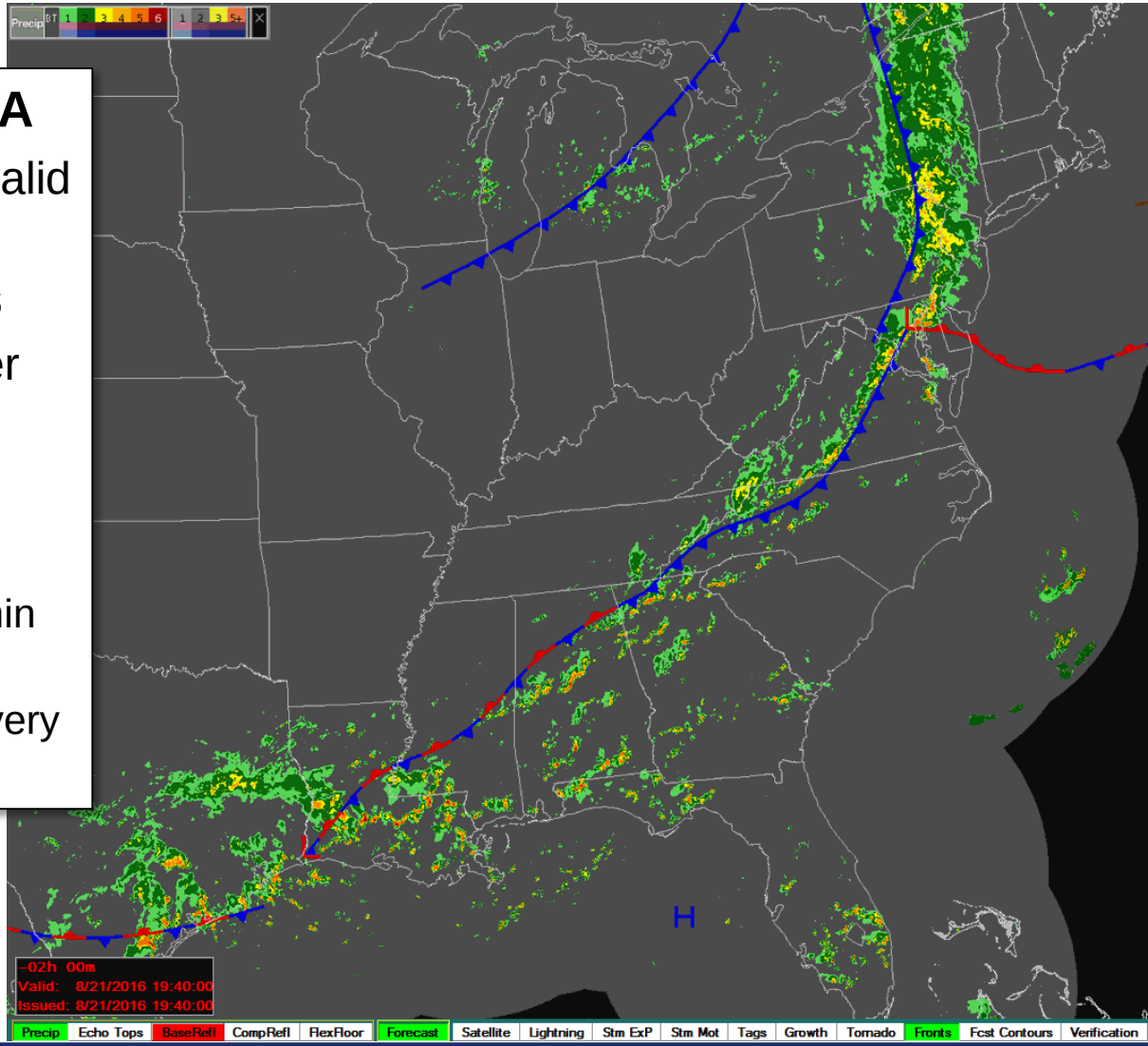
(RED takes precedence over ORANGE)

NextGen Weather Terminal Winds Grids



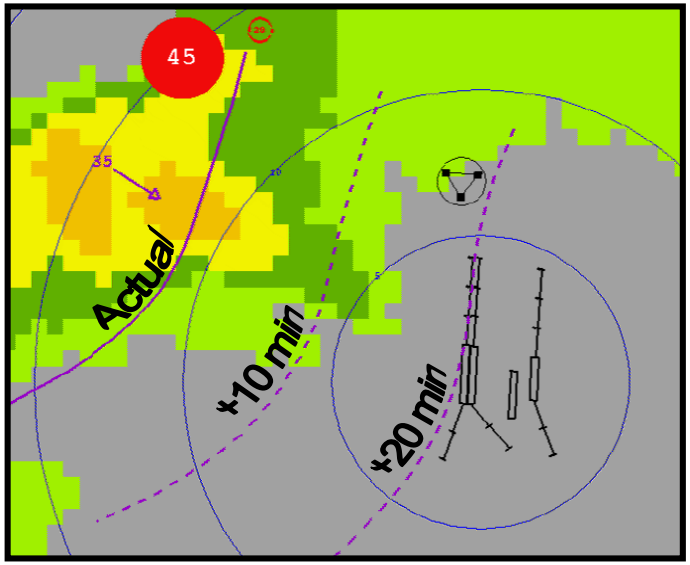
Low Altitude Turbulence – Fronts (0-2 hr)

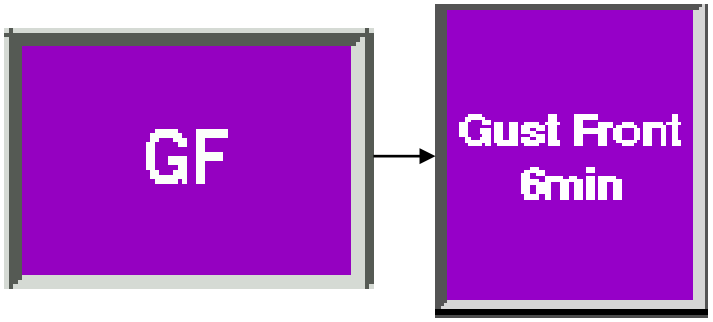
- **Fronts issued by NOAA**
  - Includes set of fronts valid at one “synoptic” time
  - Updates every 3 hours
  - Arrives ~1.5 hours after valid time
- **NextGen Weather time-aligns fronts**
  - Projects ahead every 5 min out to 2 hours
  - Re-aligns and updates every 5 min



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

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