NextGen Weather Products: Key Improvements

October 29, 2024

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Outline

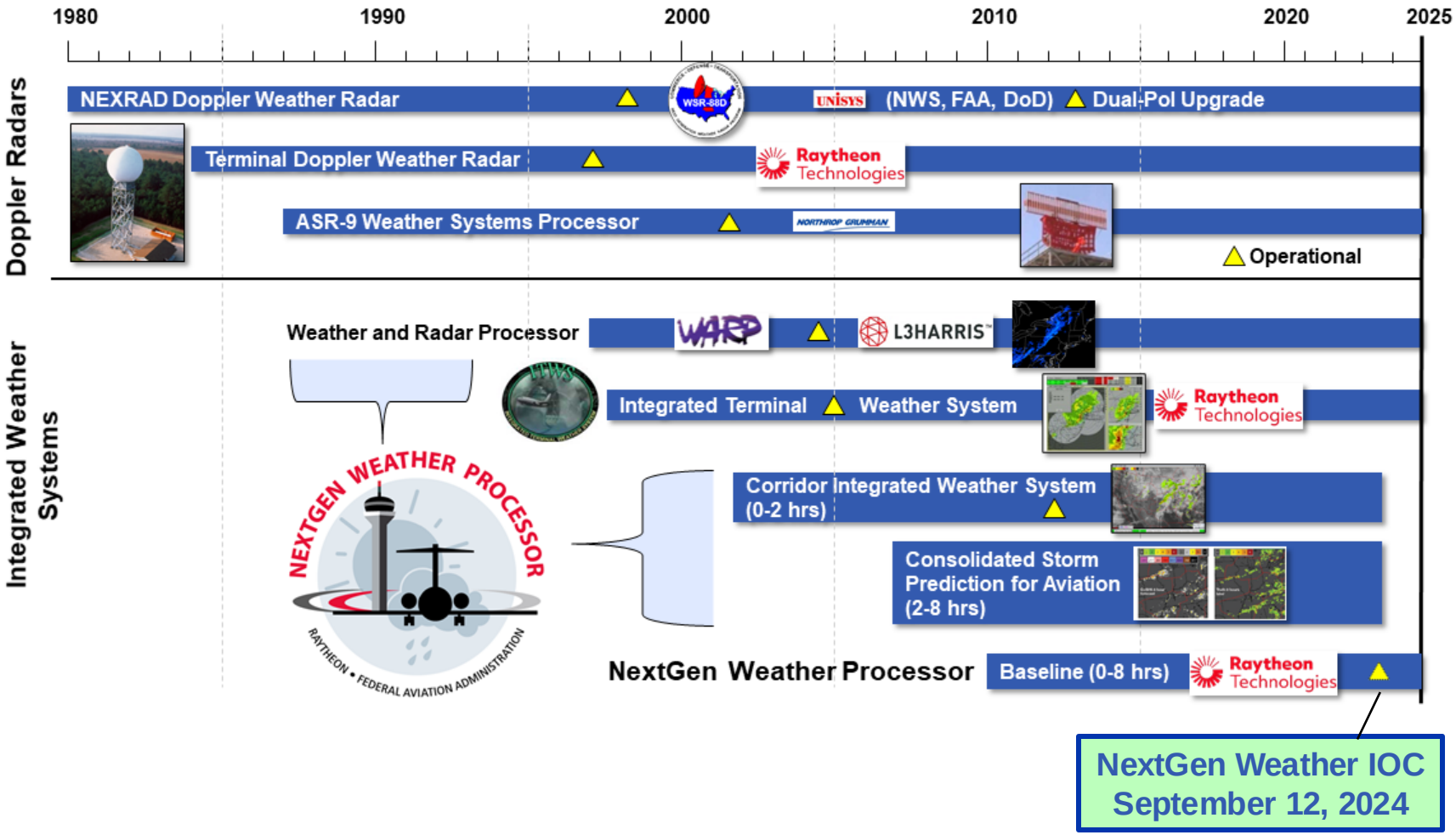
- NextGen Weather background & tech transfer at MIT LL
  - Unmet user needs in the National Airspace System
  - MIT Lincoln Laboratory's role in development
- Accurate radar mosaics
  - Domain coverage
  - Requirement for 25 sec update rate
  - Detail on generation of NextGen Weather mosaics
  - Comparison of 25 sec products with legacy mosaics
    - Comparisons with/without motion compensation
- Example of rapid storm development on the AWD
  - Illustrate importance of rapid update Growth Trends
- Additional NextGen Weather product improvements
- Summary

AWD = NextGen Weather Aviation Weather Display

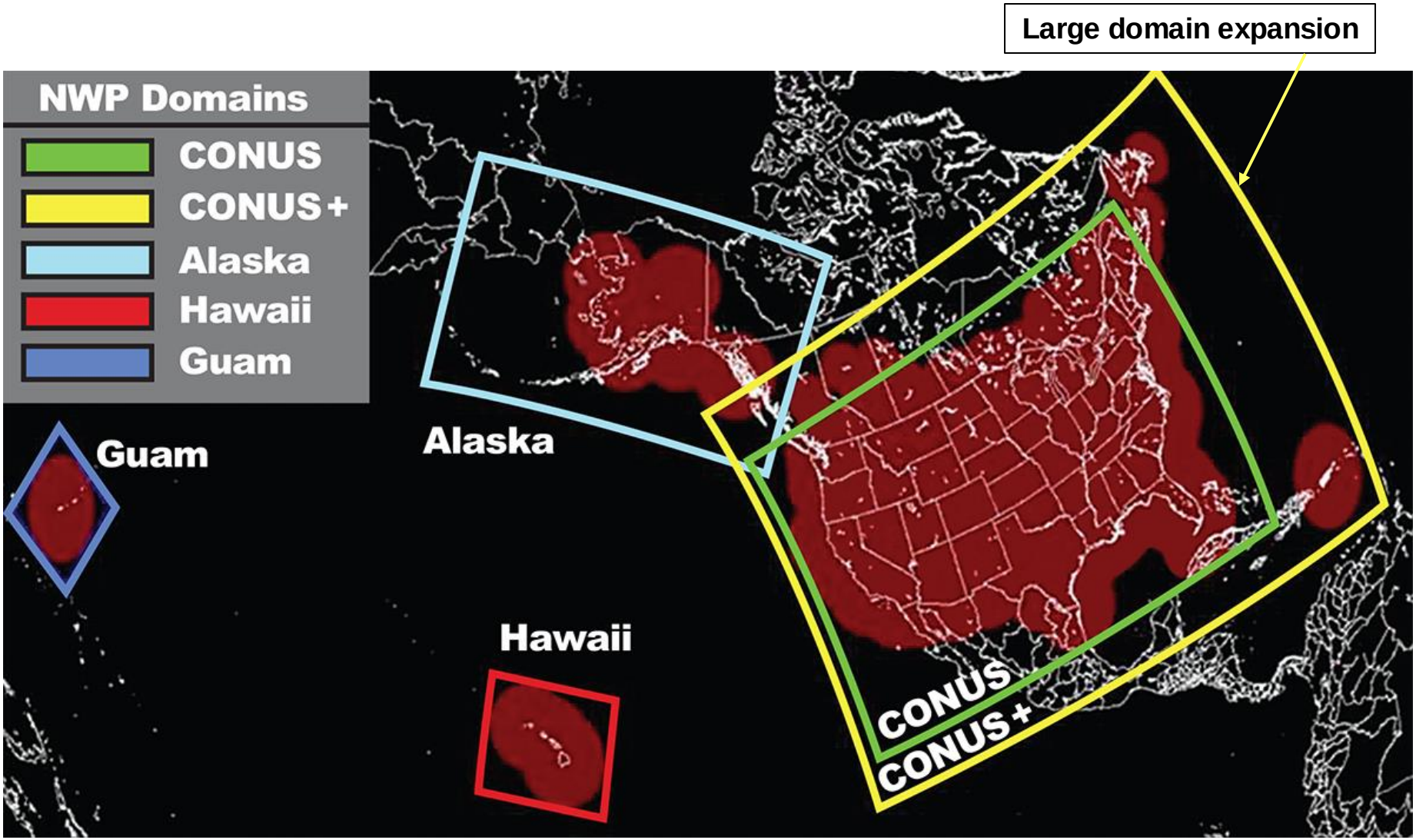
NextGen Weather Addresses Unmet User Needs

- "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
  - Prediction of route availability and flow constrained areas
  - Support development of precise traffic flow initiatives
    - Miles-in-Trail restrictions, Ground Delay Programs and Airspace Flow Programs

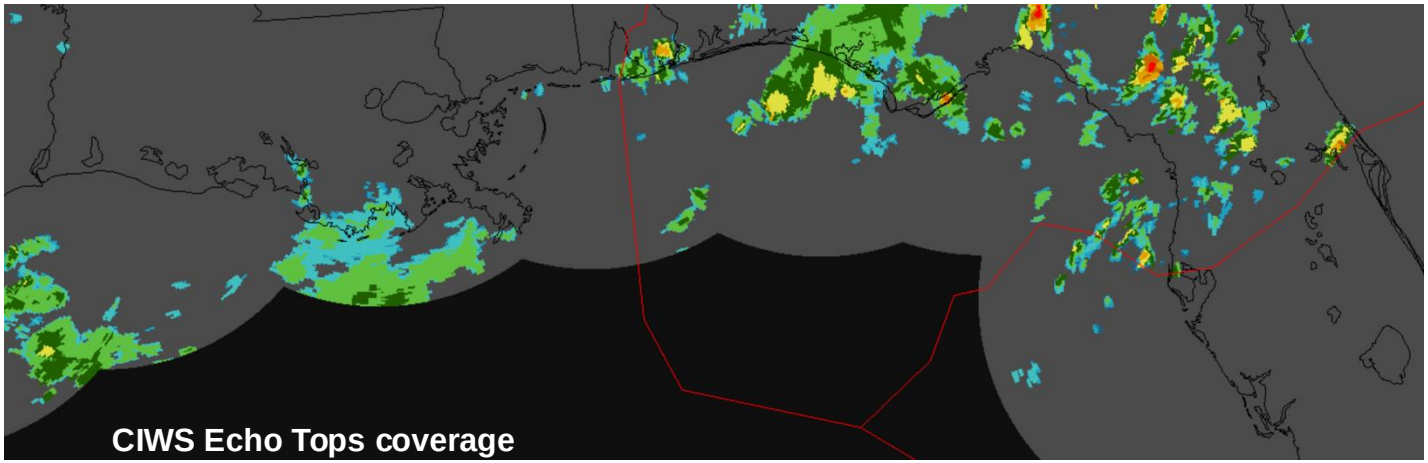
FAA Weather Program Timeline at MITLL

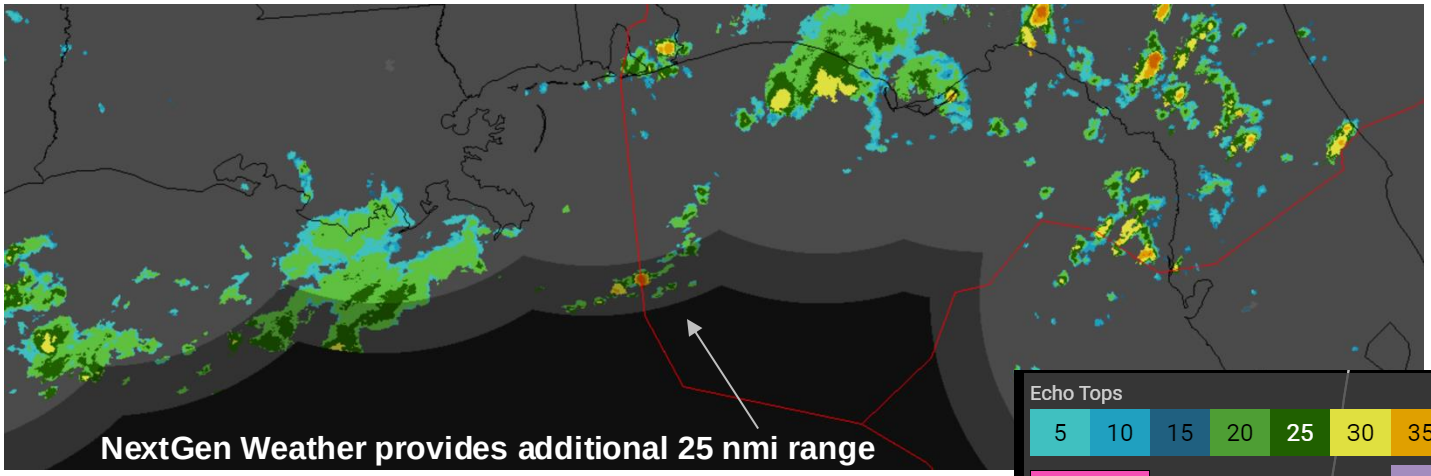


NextGen Weather Coverage

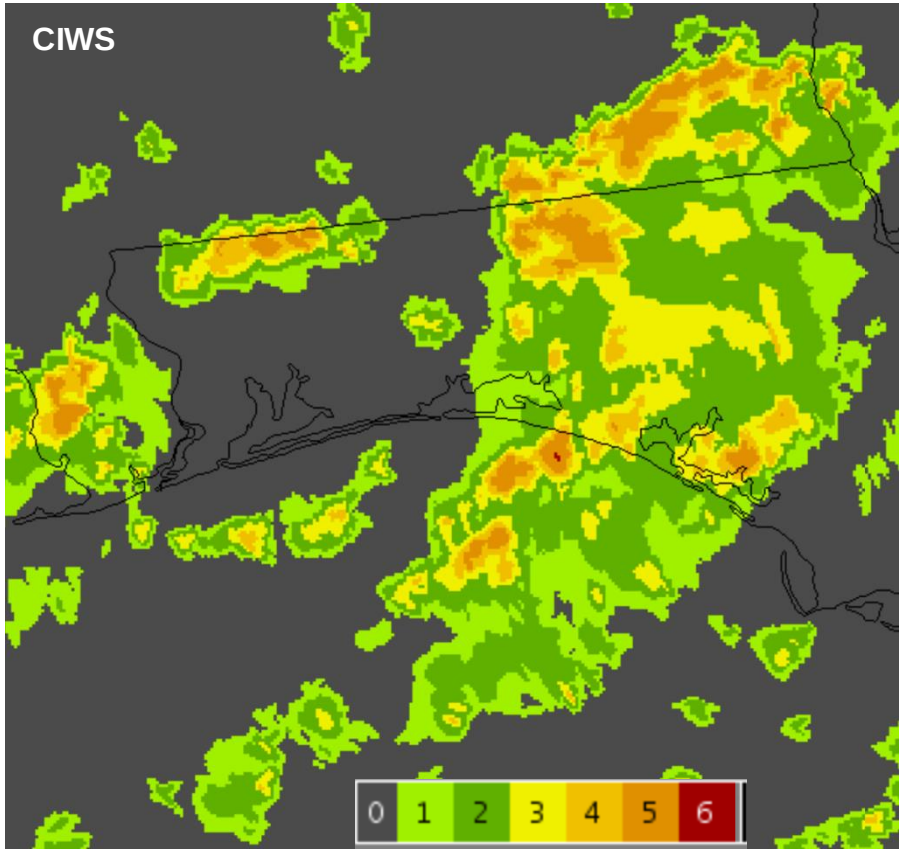


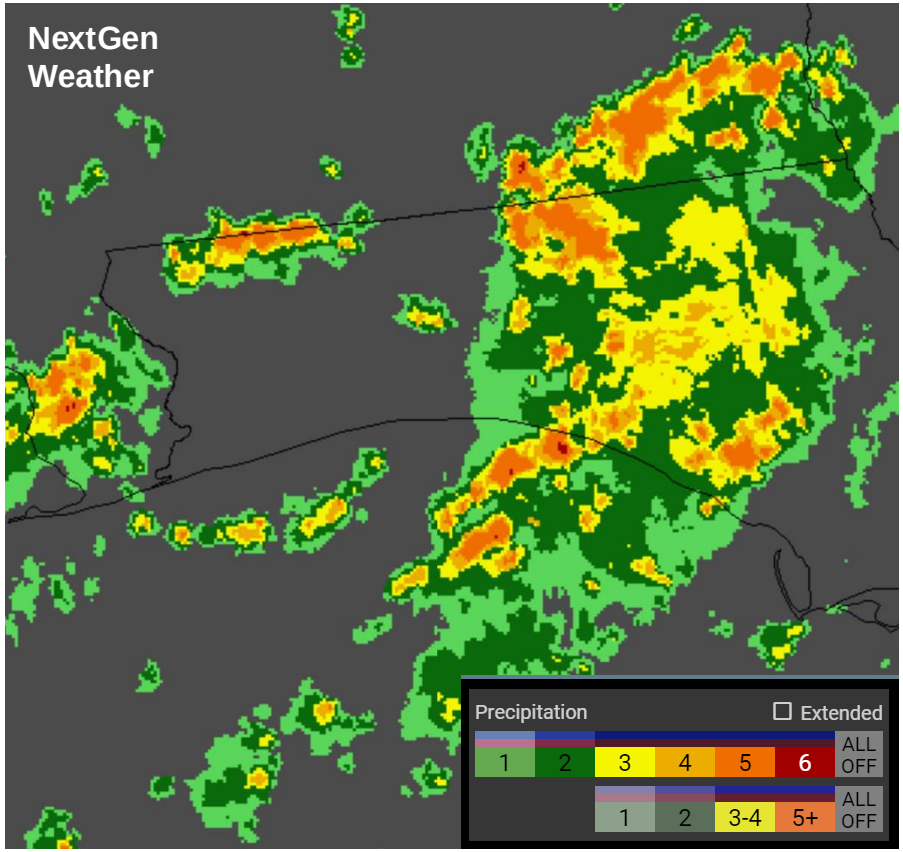
CIWS vs NextGen Wx Echo Tops Coverage





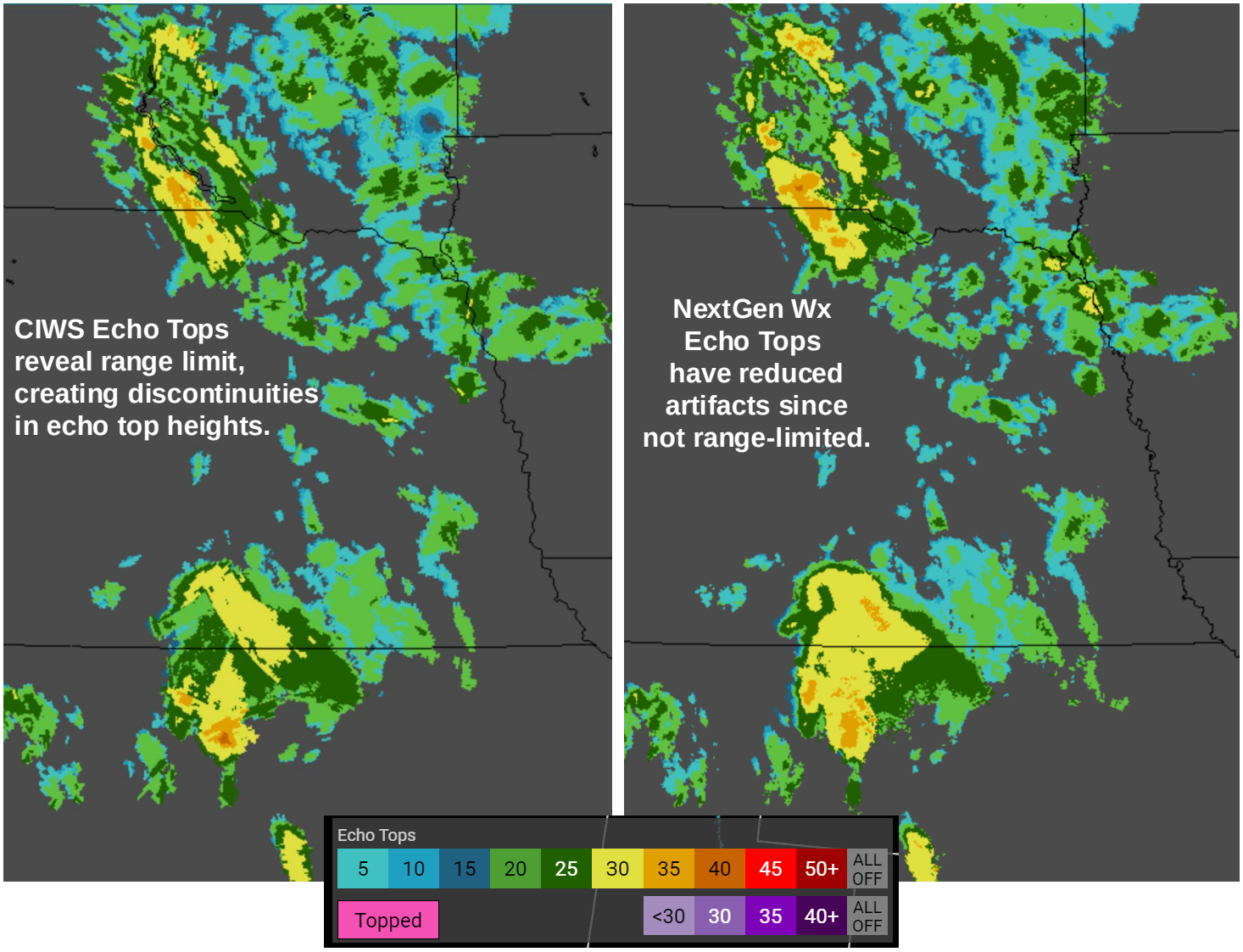
CIWS vs NextGen Wx Precip



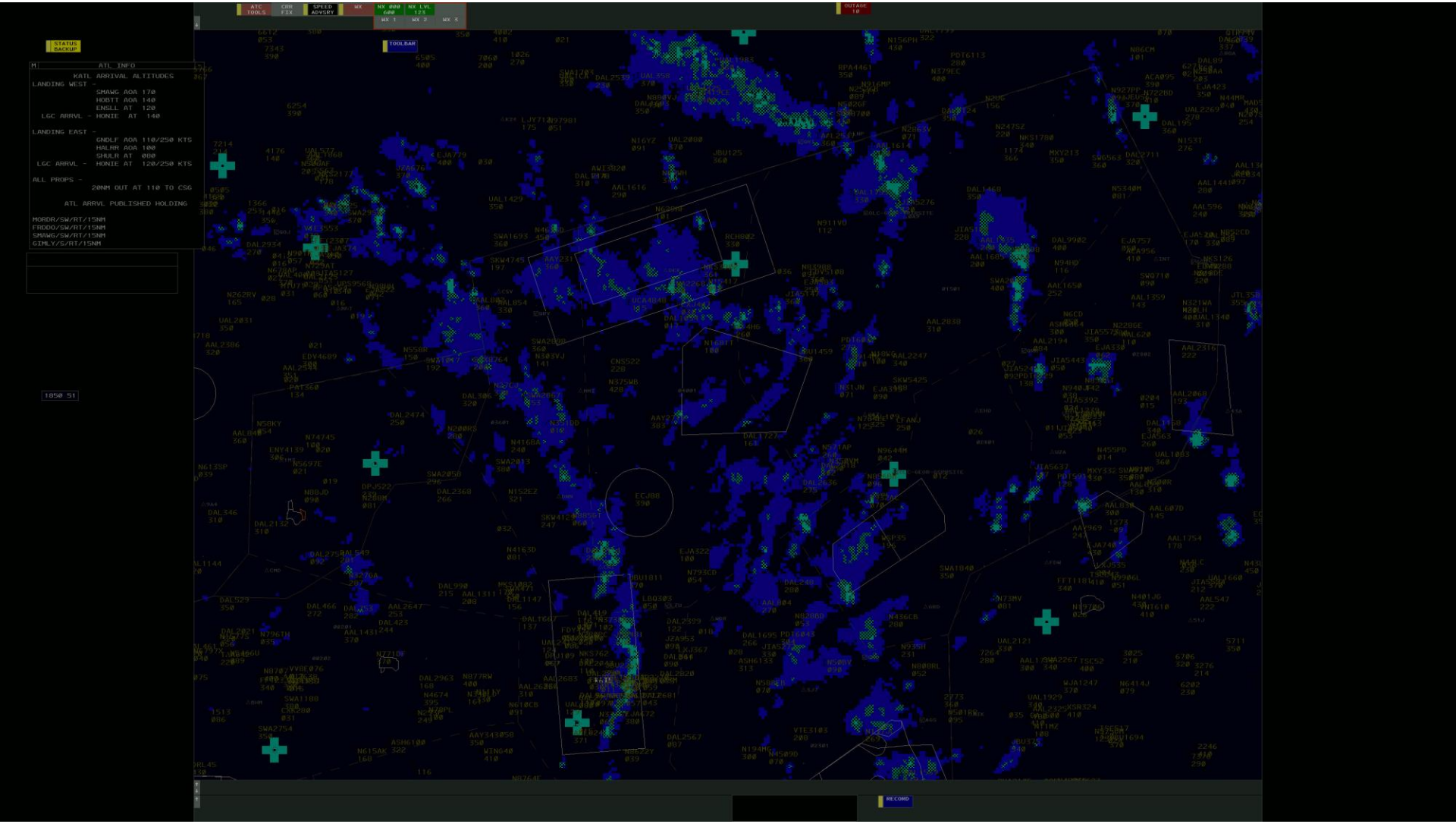


NextGen Weather provides more discrete storm coverage, and portrays new storms earlier than CIWS

CIWS vs NextGen Wx Echo Tops

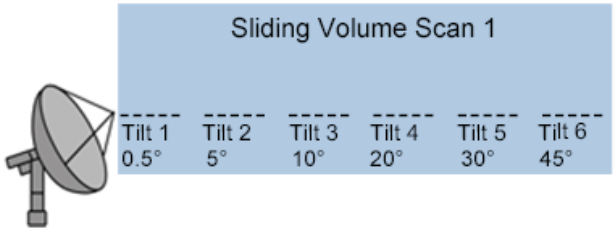


ATC Requirement for 25 sec Mosaic Update Rate



Aircraft move very quickly relative to weather, so weather must be as timely as possible.

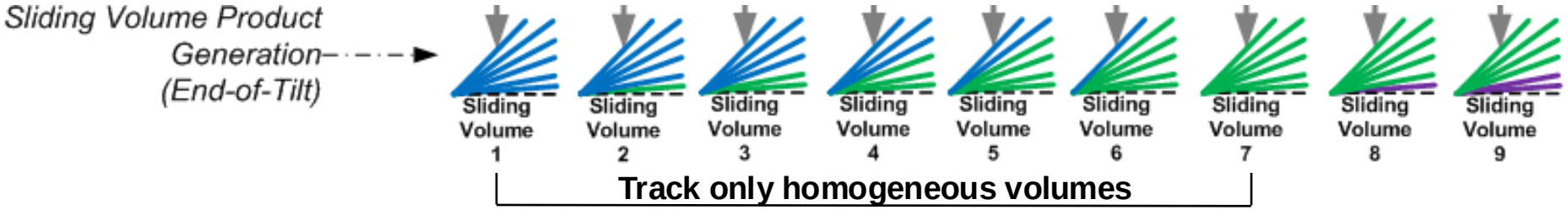
NWP Rapid Update Mosaic Techniques



NWP Mosaic Techniques

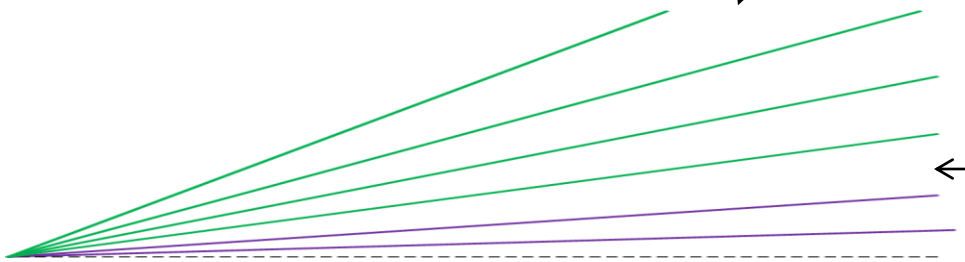
- **<u>Sliding Volume updates</u>: Compute new radar volume with every new tilt (15-40 sec)**

NWP Rapid Update Mosaic Techniques



NWP Mosaic Techniques

- **Sliding Volume updates: Compute new radar volume with every new tilt (15-40 sec)**
- **Time-align tilts: Track storms; time-align tilts; compute per-radar volume products**



Tilt time-alignment problem

"Hidden" time gap
(~ 4-5 min)

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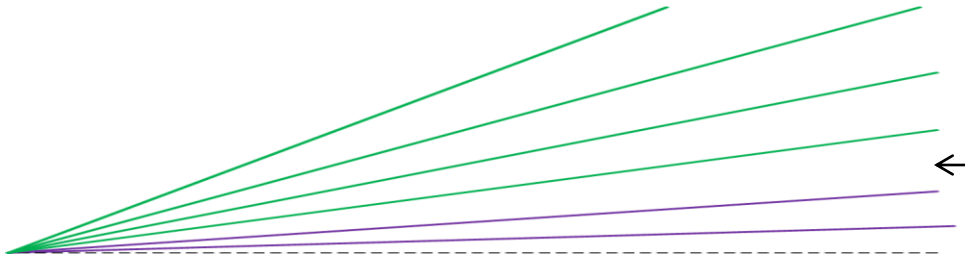
- **Time-align tilts: Track storms; time-align tilts; compute per-radar volume products**
- **Respect radar scan strategy: Compute trends only from "like" volumes**



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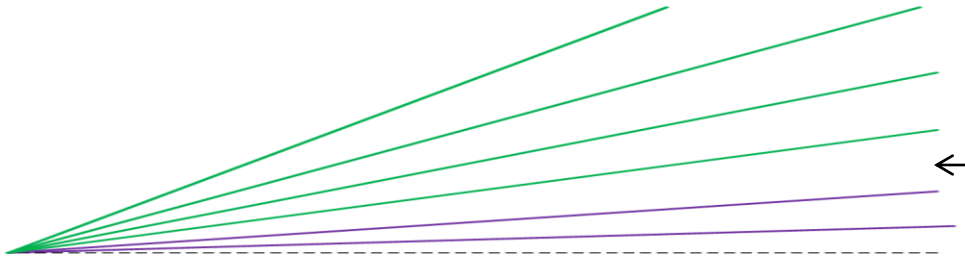
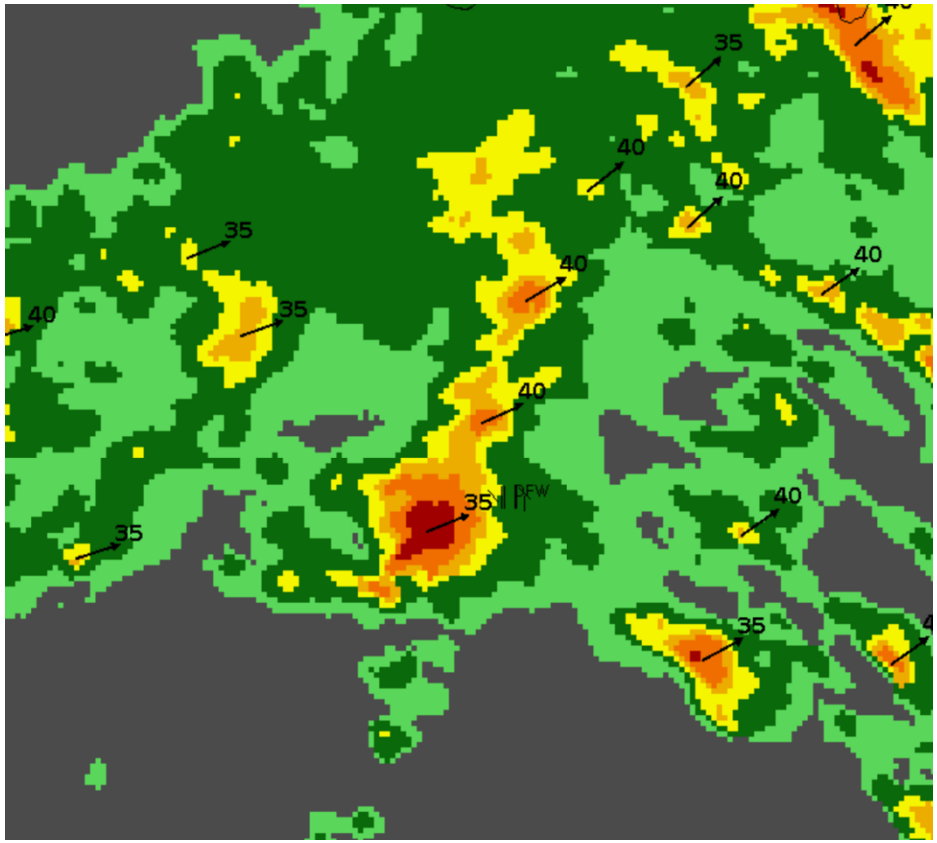
- **Time-align tilts: Track storms; time-align tilts; compute per-radar volume products**
- **Respect radar scan strategy: Compute trends only from "like" volumes**
- **Make mosaics: Motion-compensate all volumes to common mosaic time**



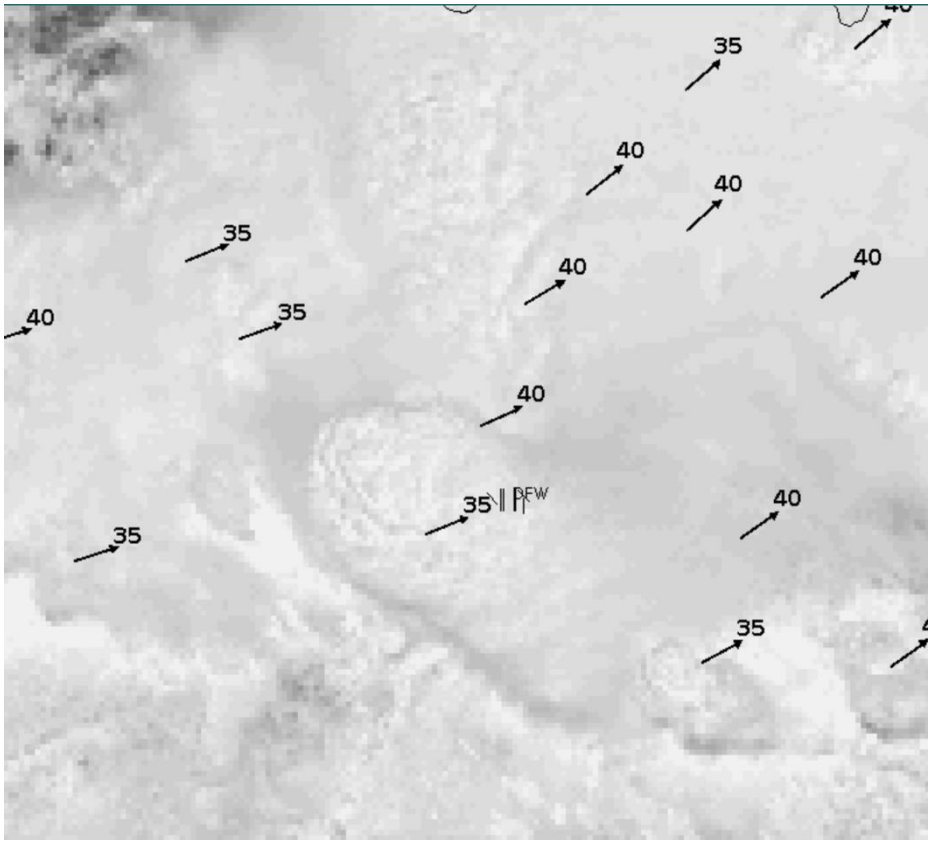
Tilt time-alignment problem

"Hidden" time gap (~ 4-5 min)

DFW Storm Motion = 35-40 kts

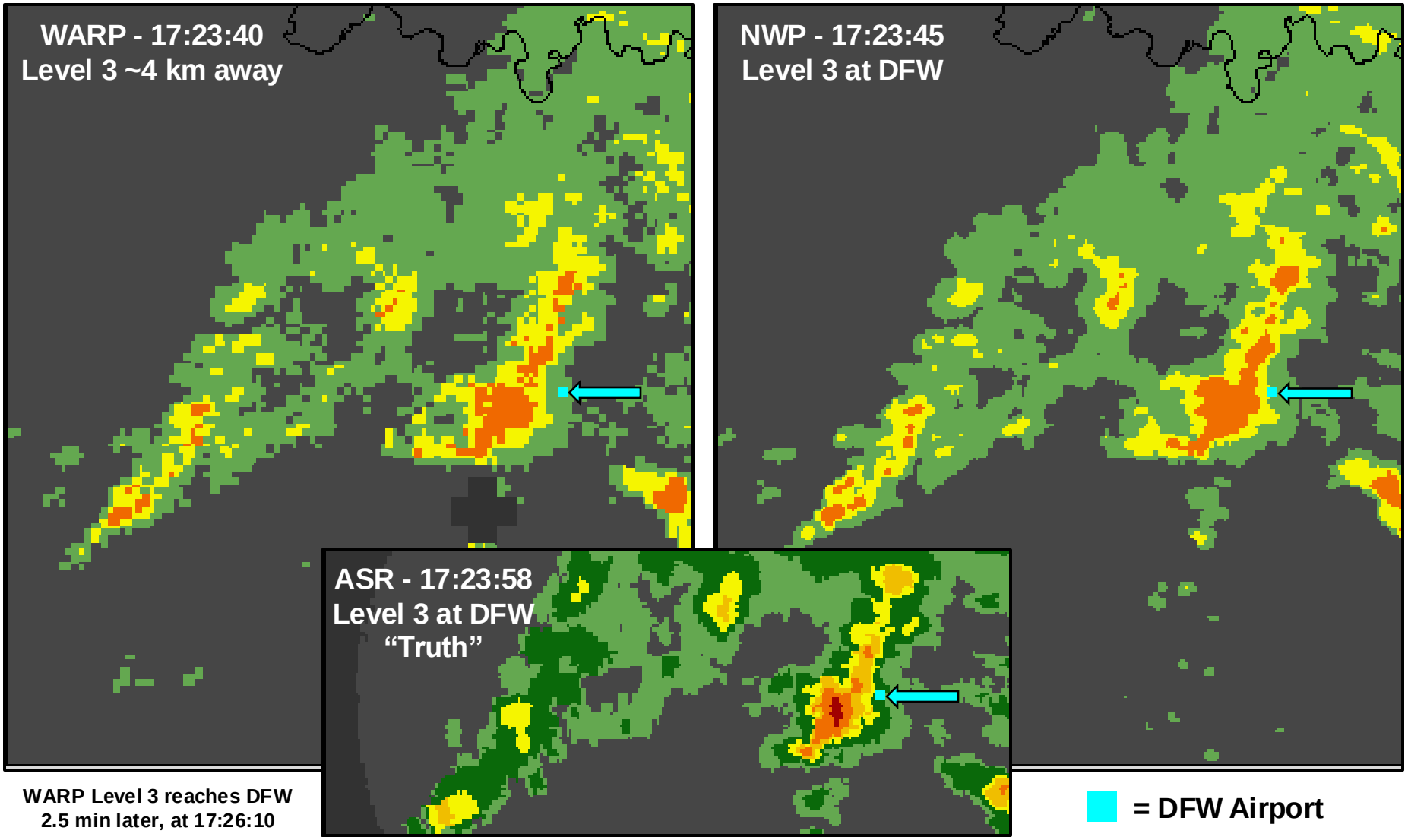


Precip Mosaic



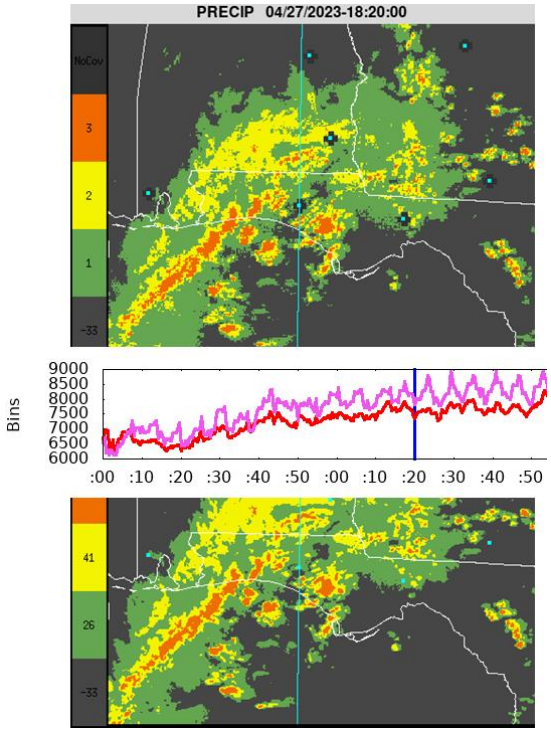
Satellite Mosaic

Comparison: Motion Compensation



Comparison: Motion Compensation

- **Mosaics without Motion Compensation exhibit “inch-worm” effect**
- **Illustrate with movie comparing 3-color CompRefl**
  - **April 27, 2023 – Atlanta Center – ERAM Demo #1**
  - **WARP: 3-color CompRefl mosaic (0-60 kft layer)**
    - **Updates mosaic with each new tilt**
    - **No motion compensation**
  - **NWP: 3-color CompRefl mosaic (1-70 kft layer)**
    - **Updates entire radar volume with each new tilt**
    - **Mosaics generated every 25 sec w/ latest volumes**
    - **Includes motion compensation (tilts and volumes)**
  - **Graph: Shows count of 50+ dBZ (Extreme) bins**
    - **WARP curve is magenta, on top**
    - **NWP curve is red, on bottom**



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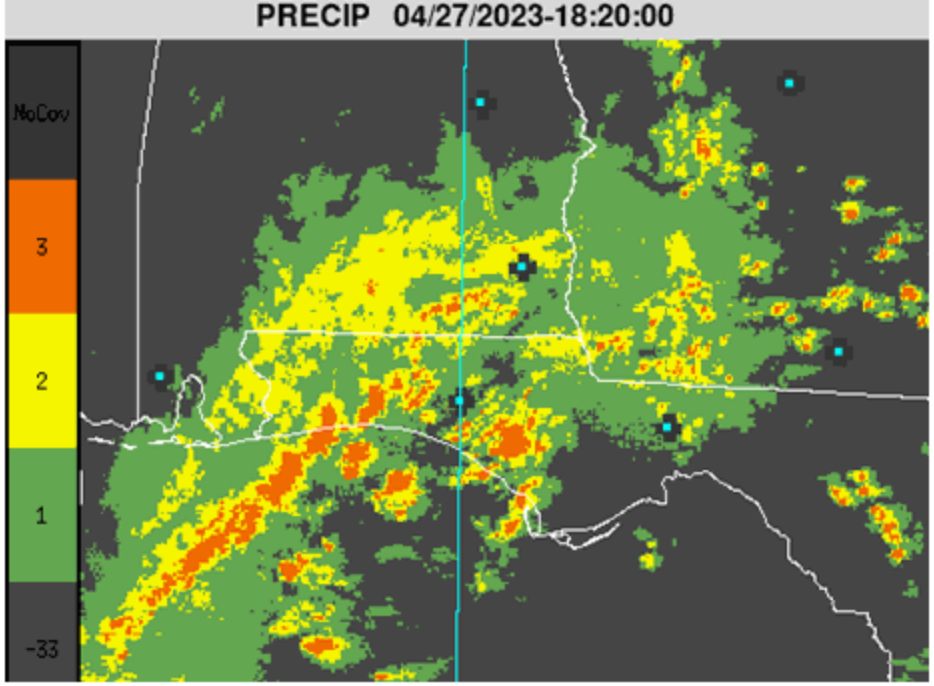
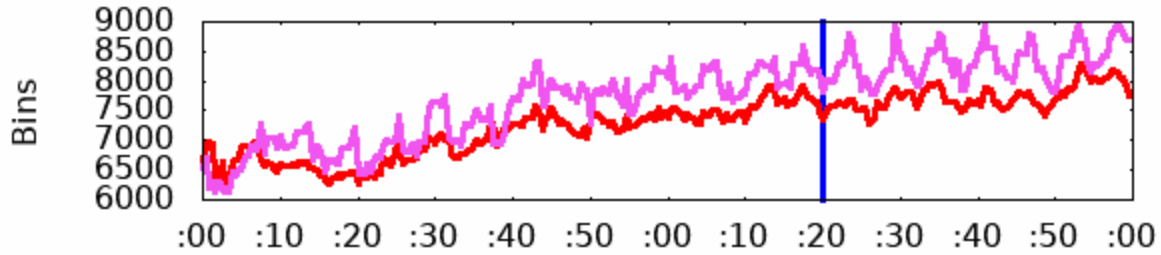
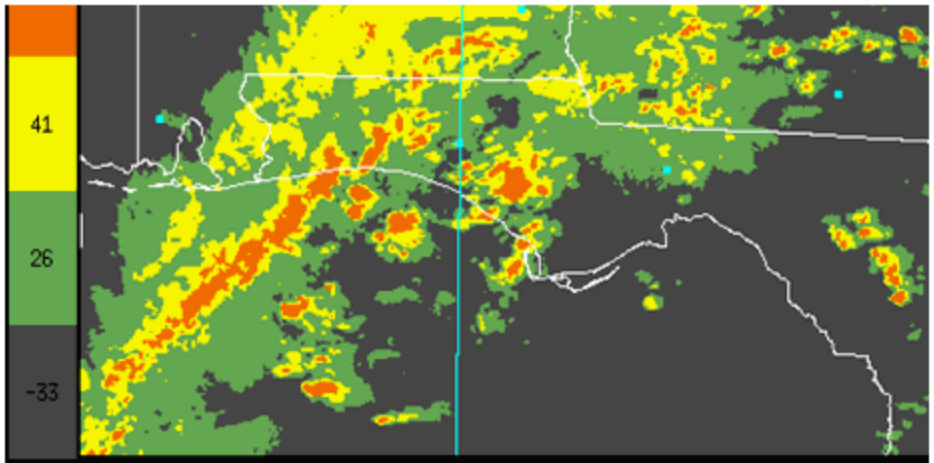


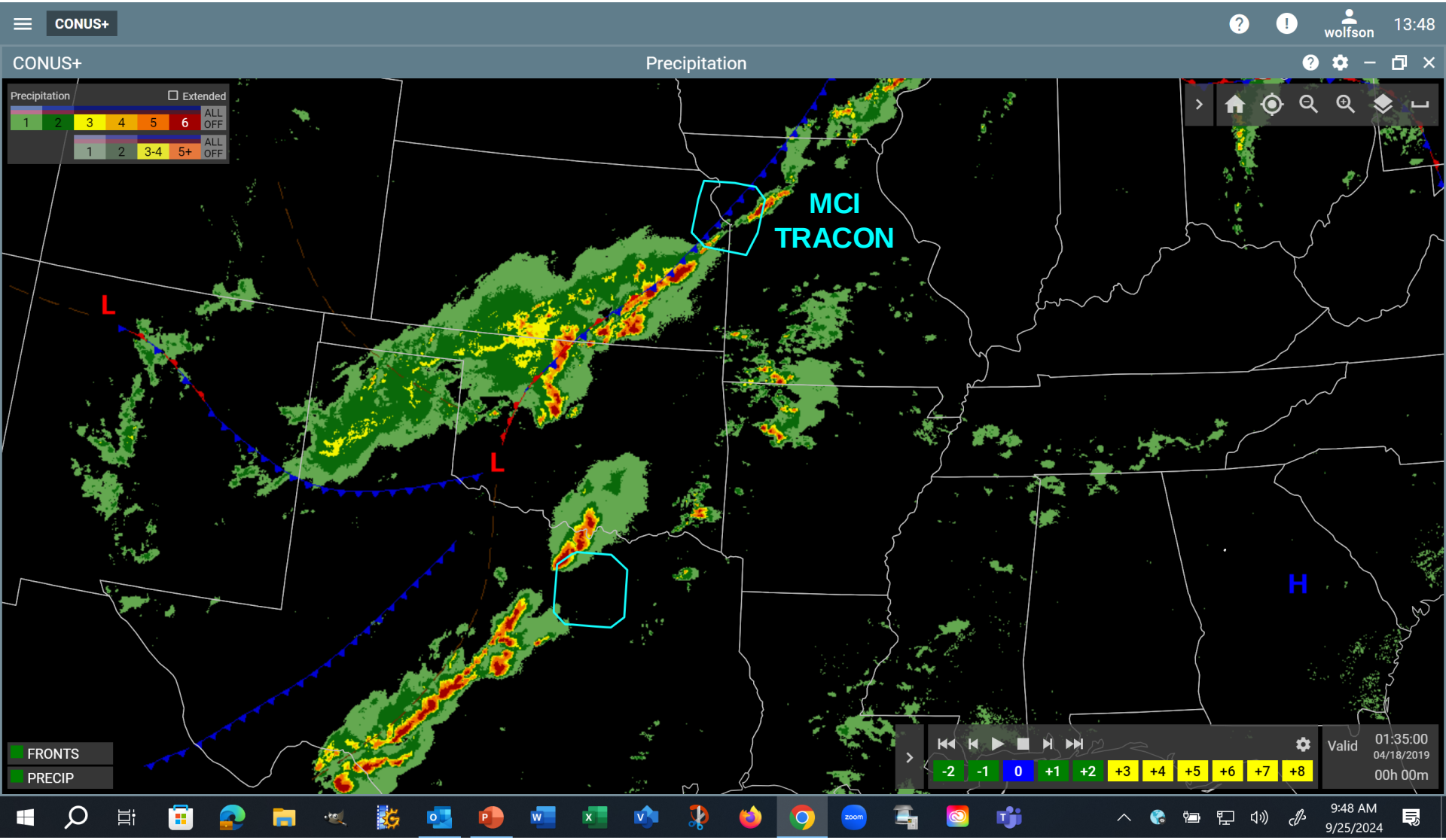
WARP CompRefl
0-60 kft





NWP CompRefl
1-60 kft
24-radar playback
MaxPortion = 0.6875
3x3 Median Filter

Rapid Growth Scenario – Frontal Forcing



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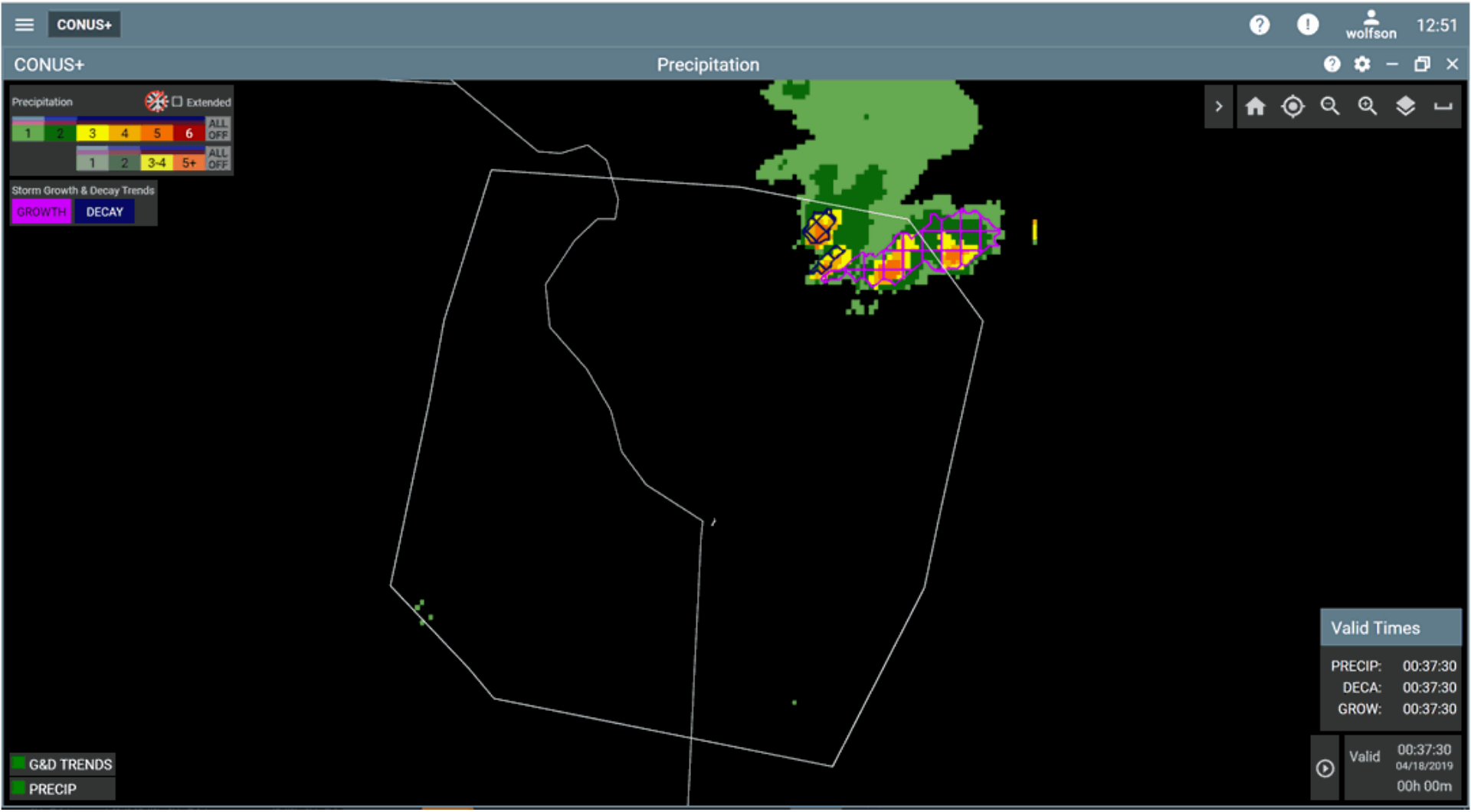
Rapid Storm Growth on the Aviation Weather Display



Excellent storm tracking allows accurate diagnosis of Trends

Precip updates: 2.5 min
Trend updates: 25 sec

Comparison of Radar Mosaics During Growth Phase

- **Rapid growth over 3.75 minutes shown below**
  - **NextGen Weather: 25 sec VIL mosaics**
  - **ASR Mosaic: 28 sec "VIL" truth**
  - **ITWS Mosaic: 150 sec Mosaics only include new data at <u>end</u> of radar volumes**

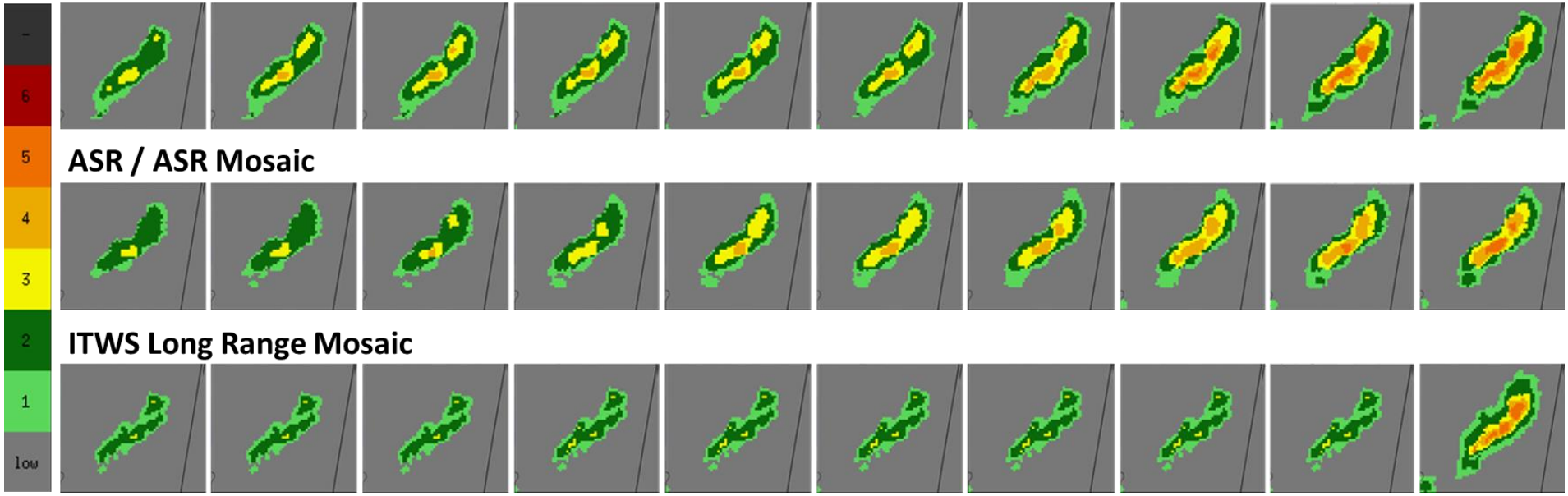
Terminal Controller Workstation (TCW)

Tower Display Workstation (TDW)

- **Terminal Automation considering using NextGen Weather mosaics in place of ASR radars STARS* displays**

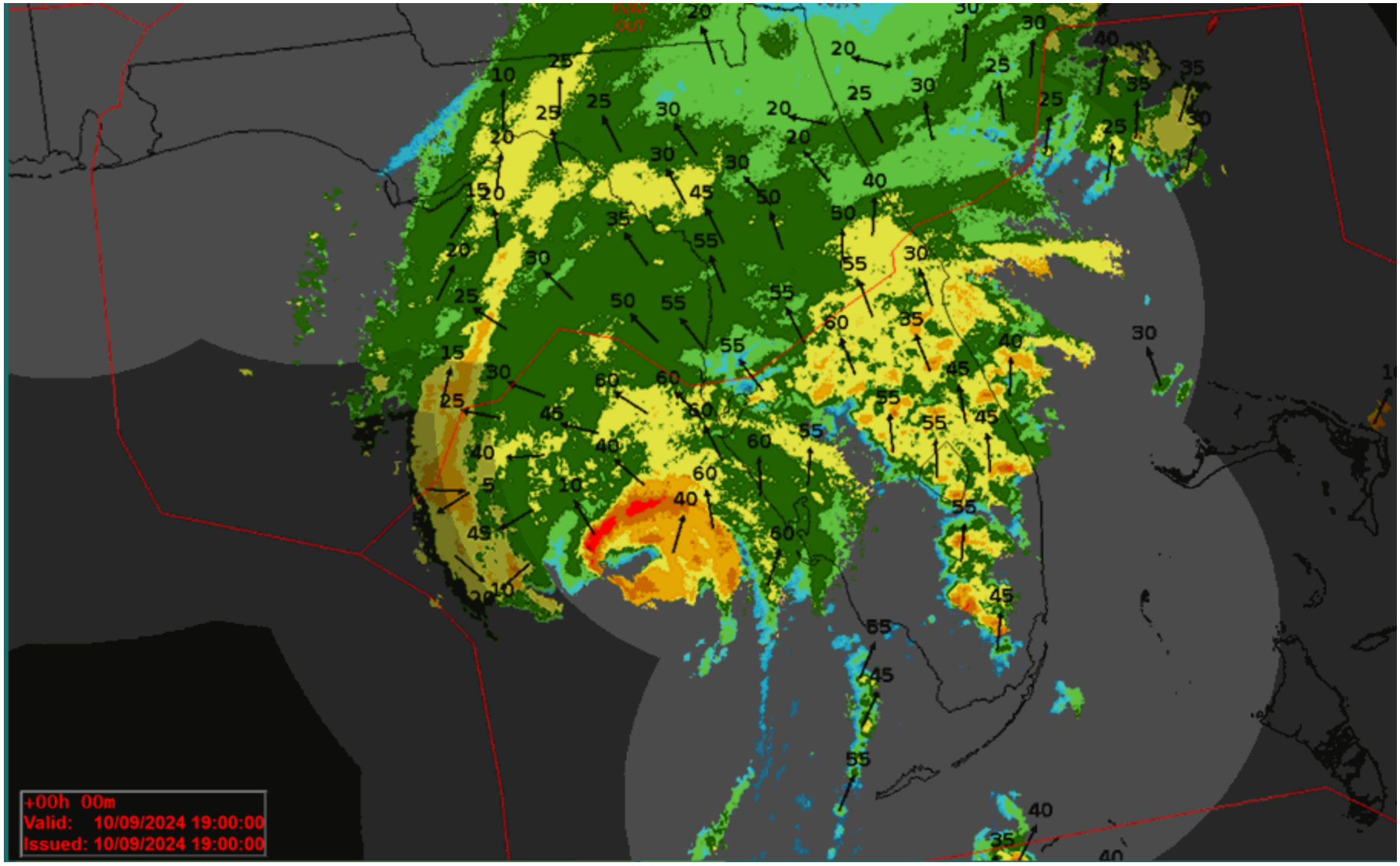
NextGen Weather Mosaic

MCI TRACON (Kansas City) – 4/18/2019

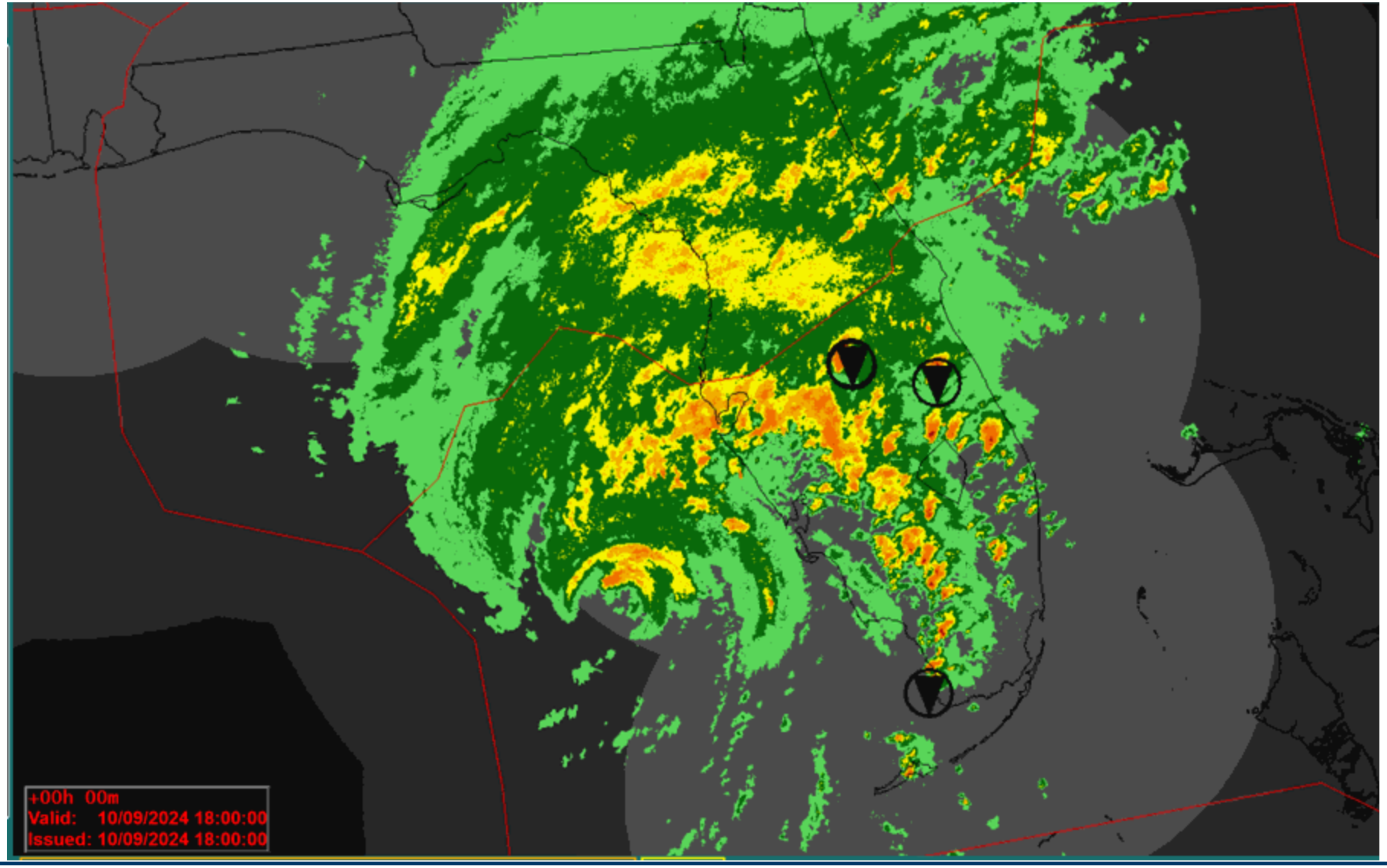


***STARS** is the Standard Terminal Automation Replacement System used by Terminal Air Traffic Control to show aircraft and weather

Hurricane Milton – 2.5 min Echo Tops

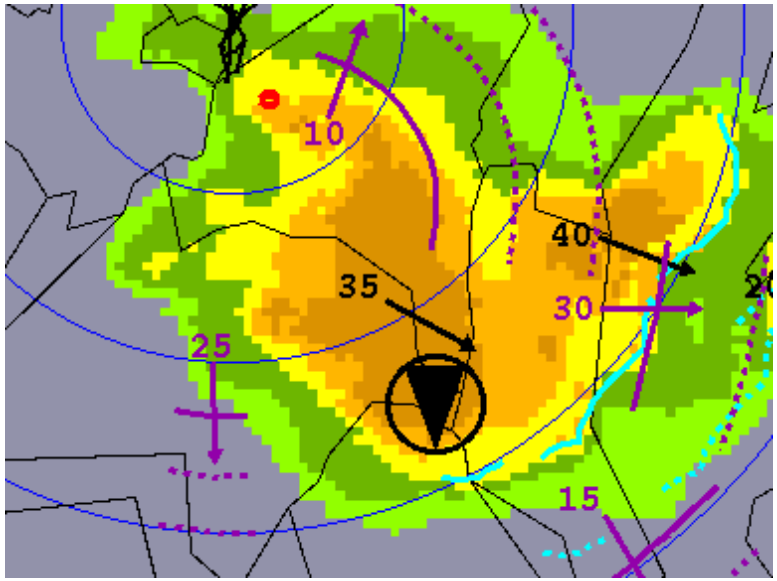


Hurricane Milton – 25 sec CompRefl



Tornado Detections

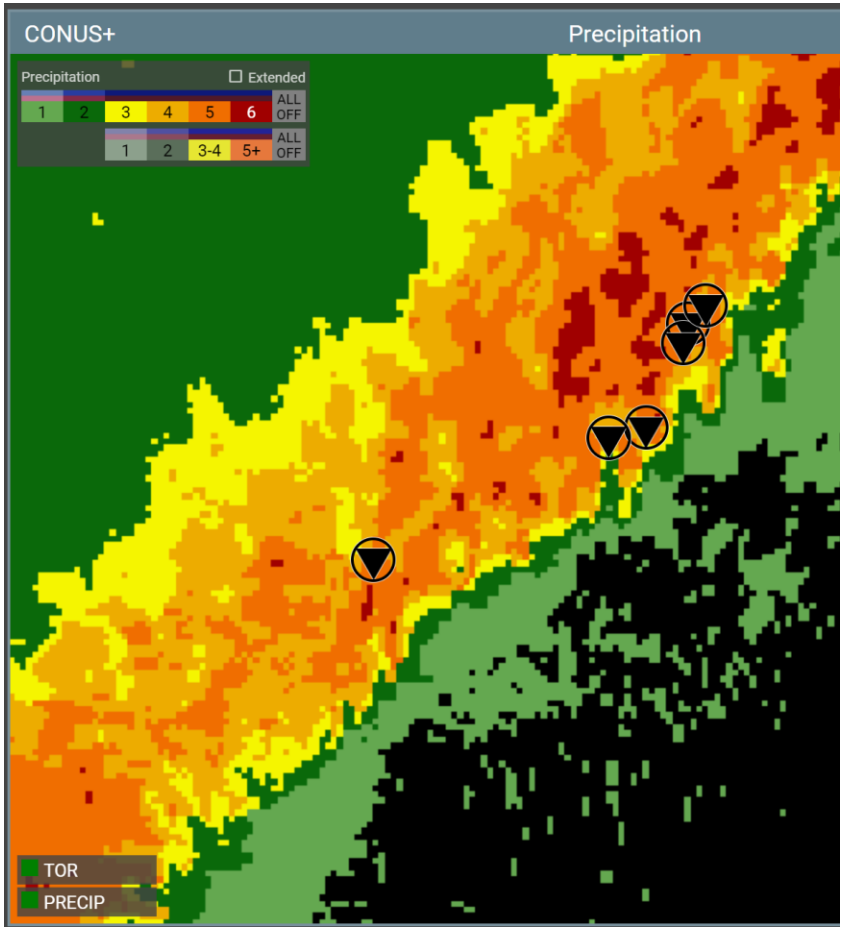
ITWS Tornado Detections



Available within each ITWS
34 Long Range Mosaics
with 1-3 NEXRADs each

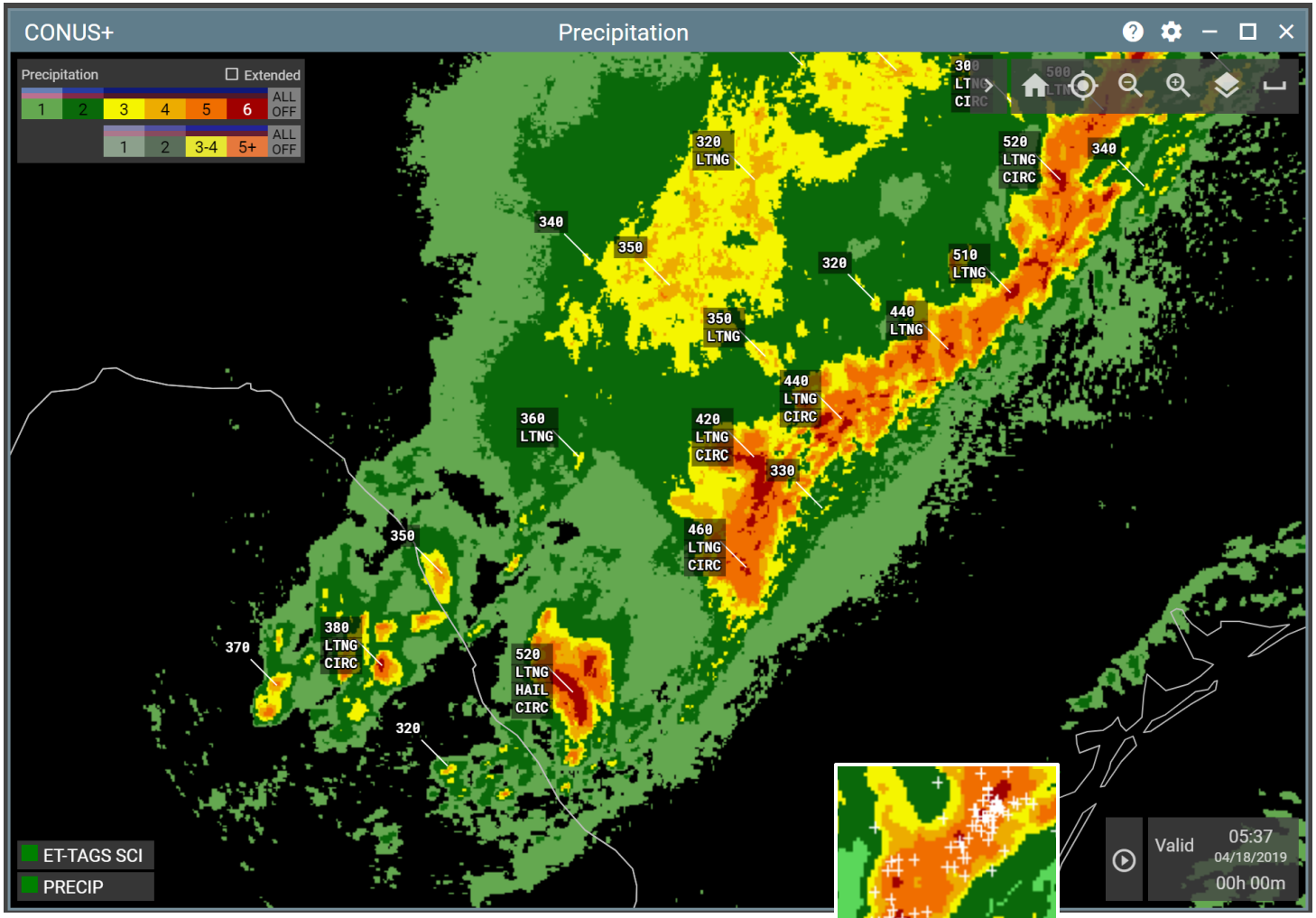
Based on NEXRAD Tornado Vortex Signature Product

NextGen Weather Tornado Detections



Available throughout all NWP domains

Storm Hazard Tags



In addition to Echo Tops Tags, NextGen Weather provides Storm Hazard Tags as selectable option

LTNG
(from FAA contract Lightning feed)

HAIL
(based on Nexrad Hail product)

CIRC
(based on Nexrad Mesocyclone product)

←Alternative lightning display (Can obscure Precip in severe lightning)

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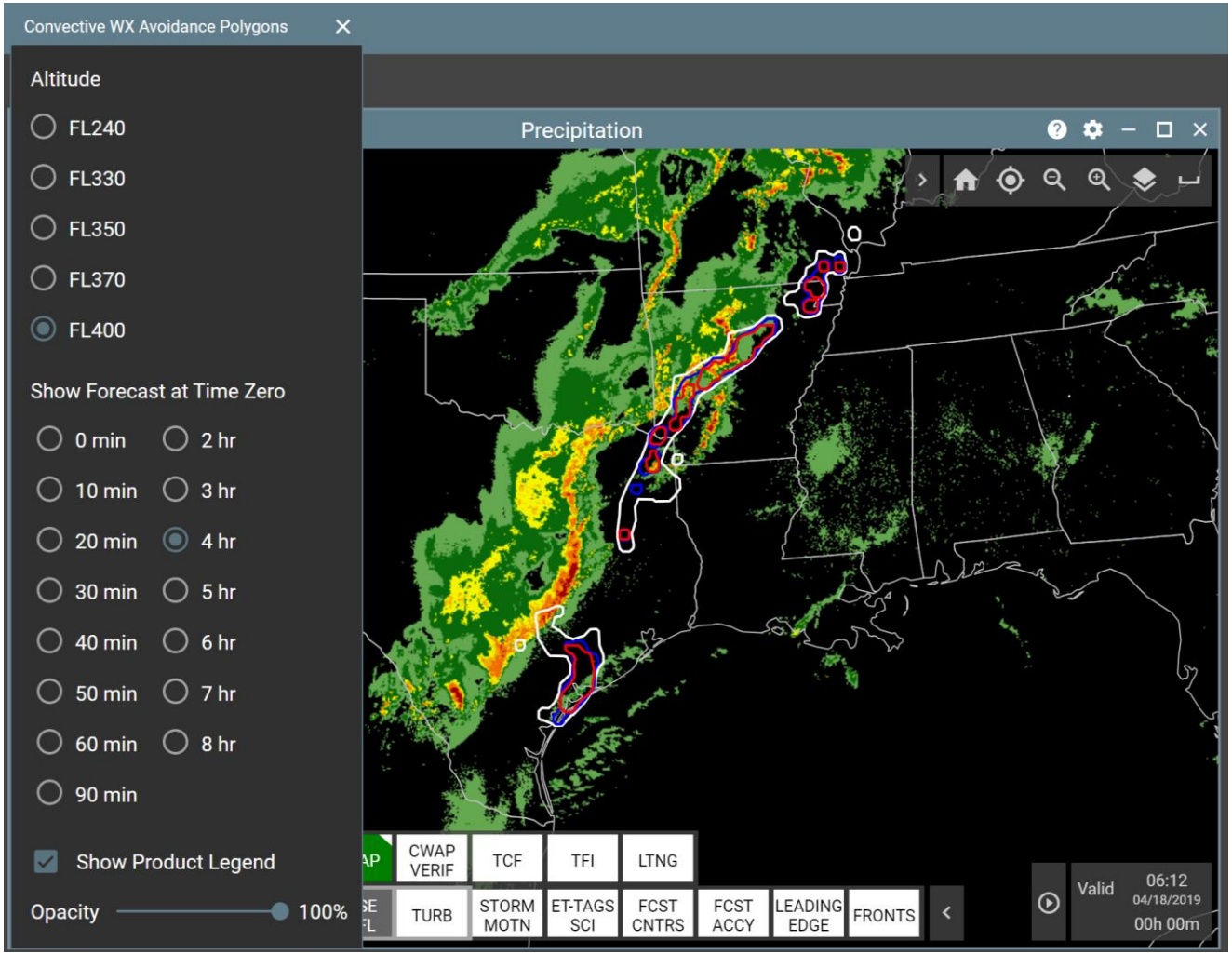
Convective Weather Avoidance Polygons



NextGen Weather includes the NASA-developed Convective Weather Avoidance Polygons (CWAP) to provide up to 8-hr look ahead for regions pilots will avoid flying.

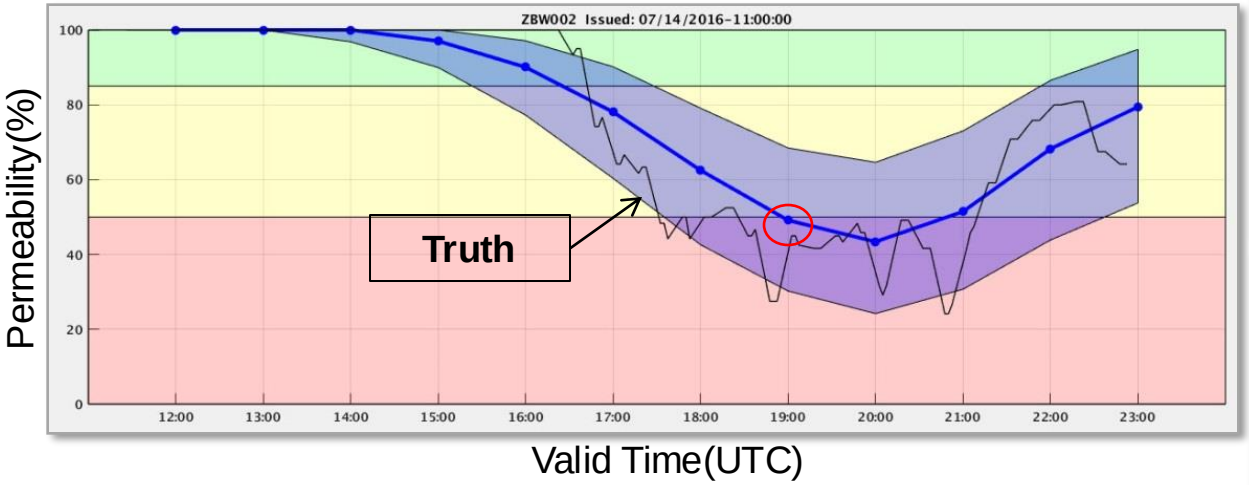
CWAP is available at 5 different altitudes Flight Levels:

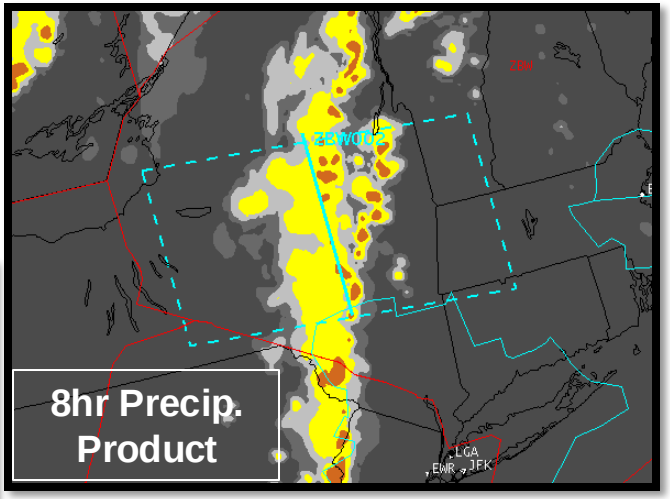
- **240 (24,000 ft)**
- **330**
- **350**
- **370**
- **400**

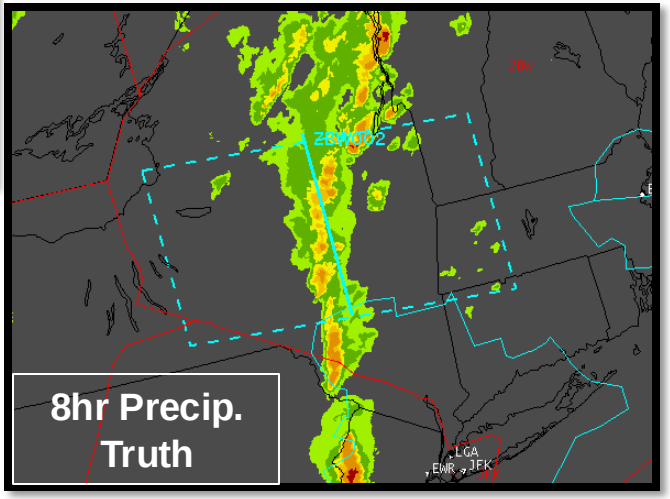
The contours represent Low, Medium & High probability of pilot avoidance.

Traffic Flow Impact Predictions

11z Traffic Flow Impact Prediction

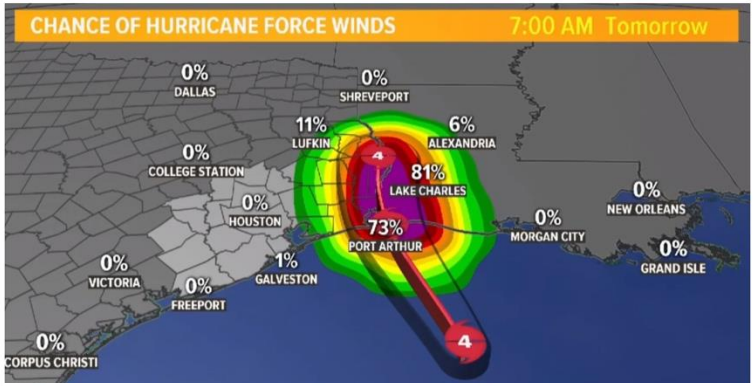


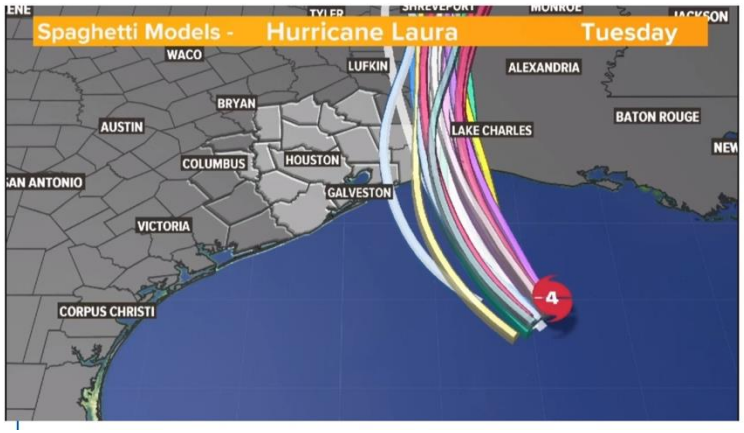




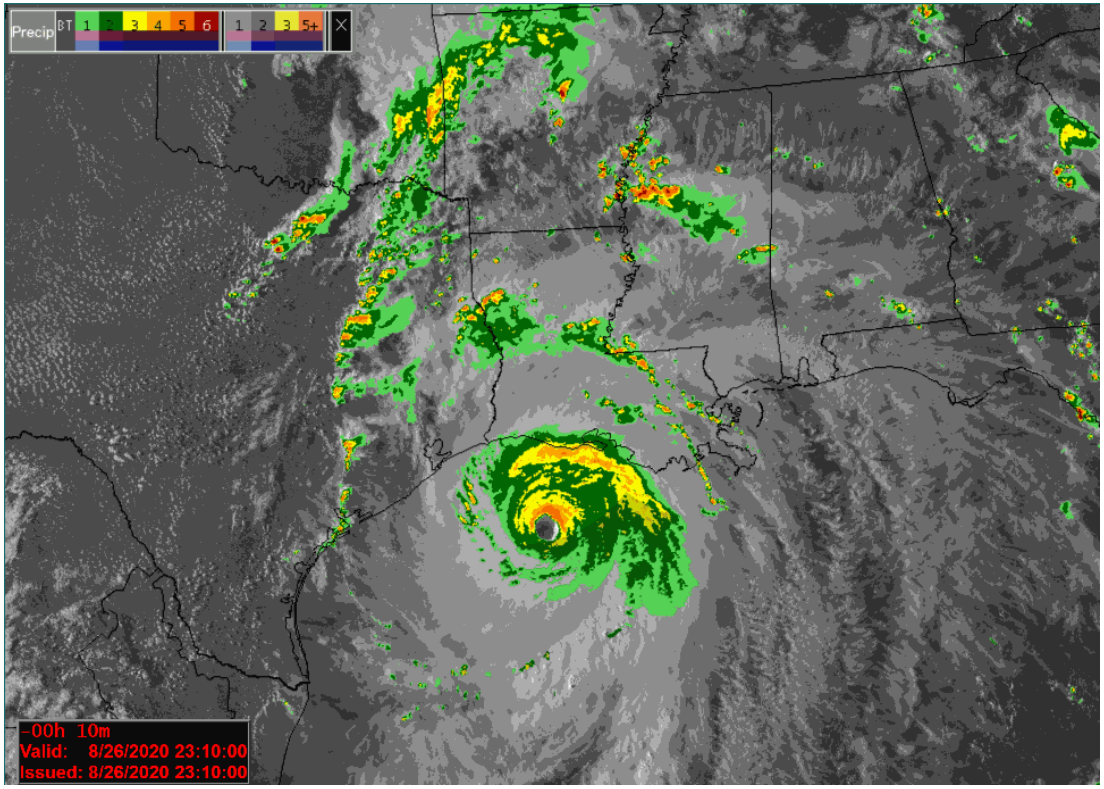
Initial product: 8-hr predictions
Future system release: 12-hr predictions

“Radar-Forward” Predictions for ATC Users

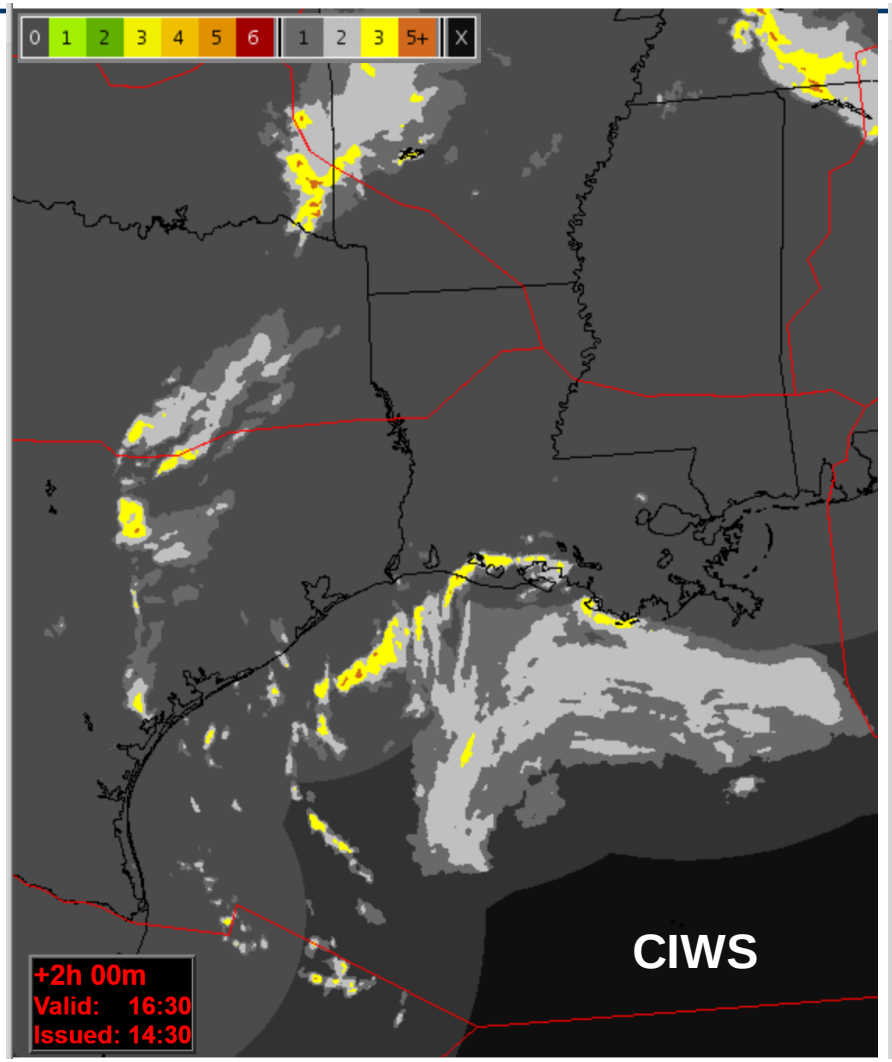


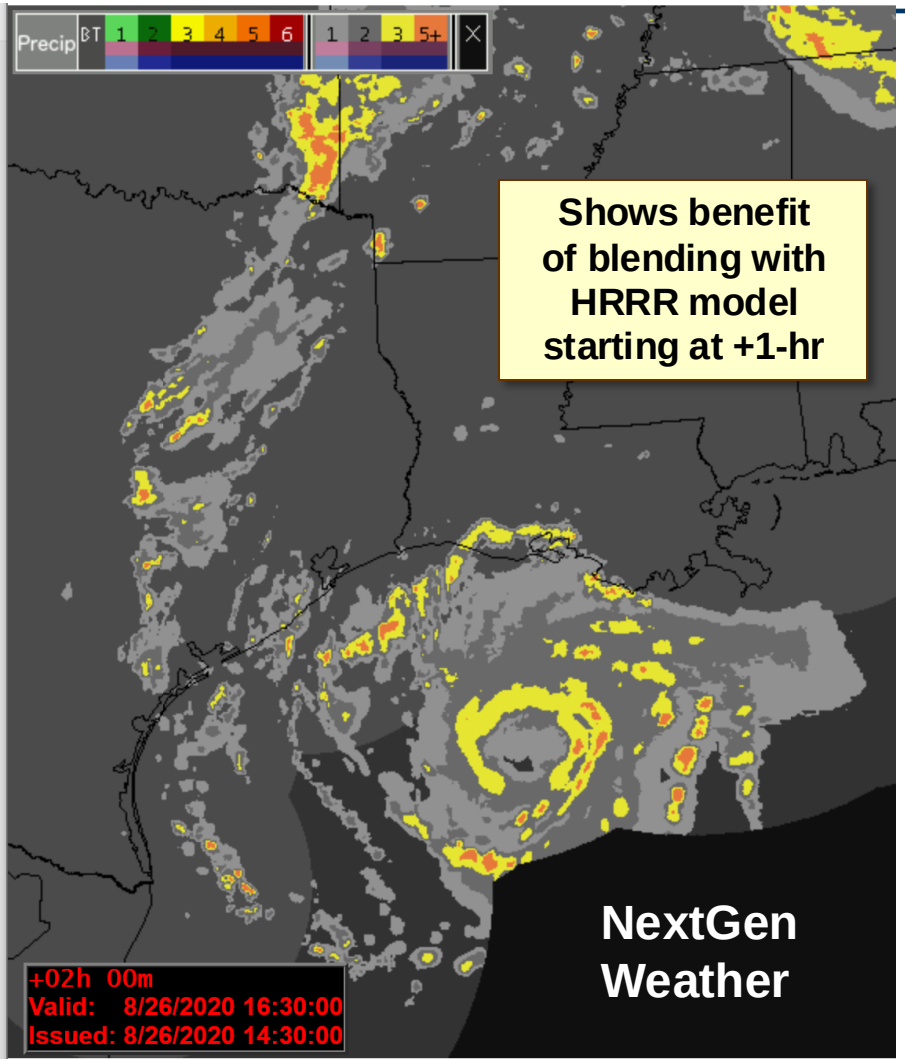


Images courtesy of National Weather Service KHOU

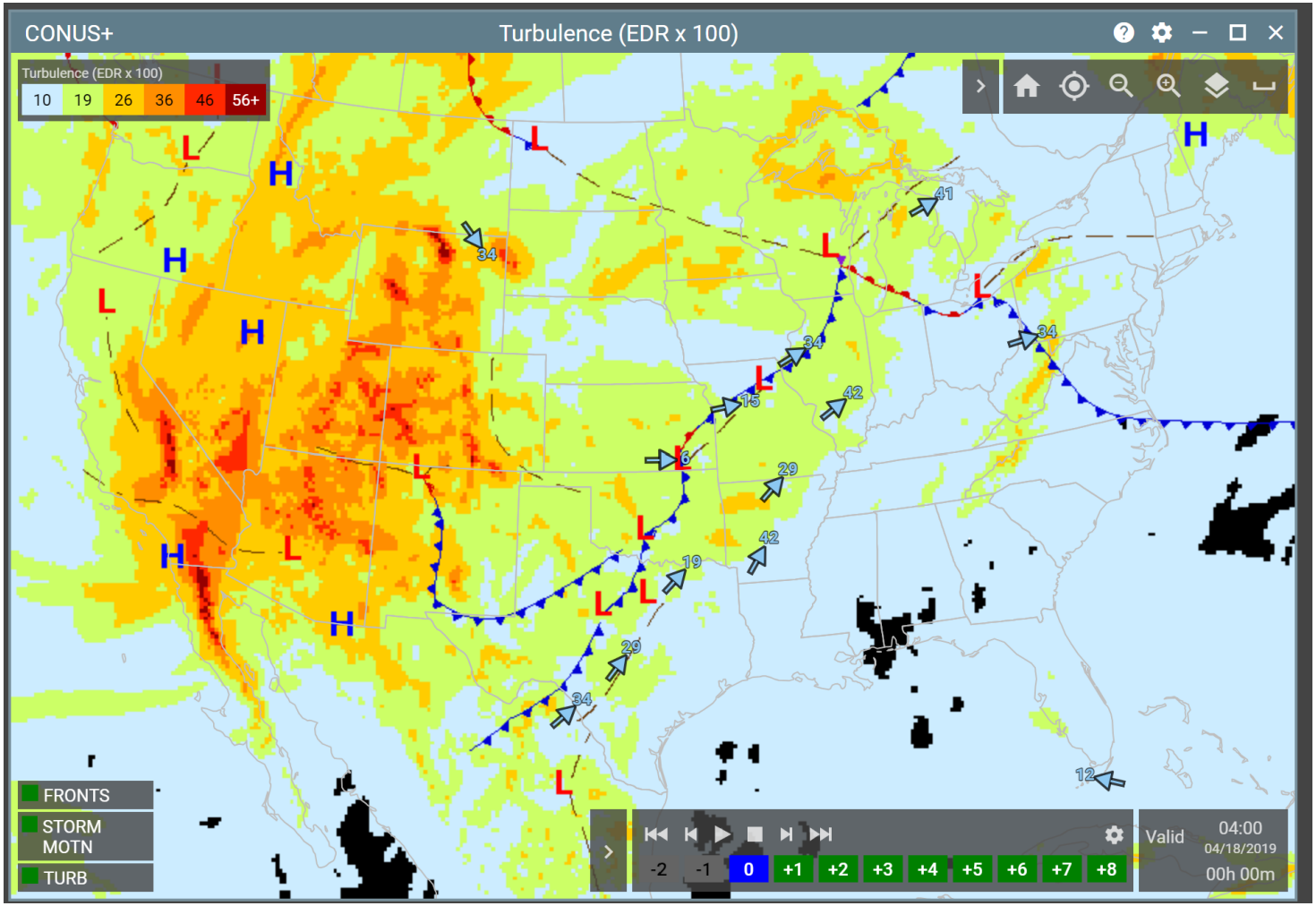


2-hr Hurricane Prediction Comparison





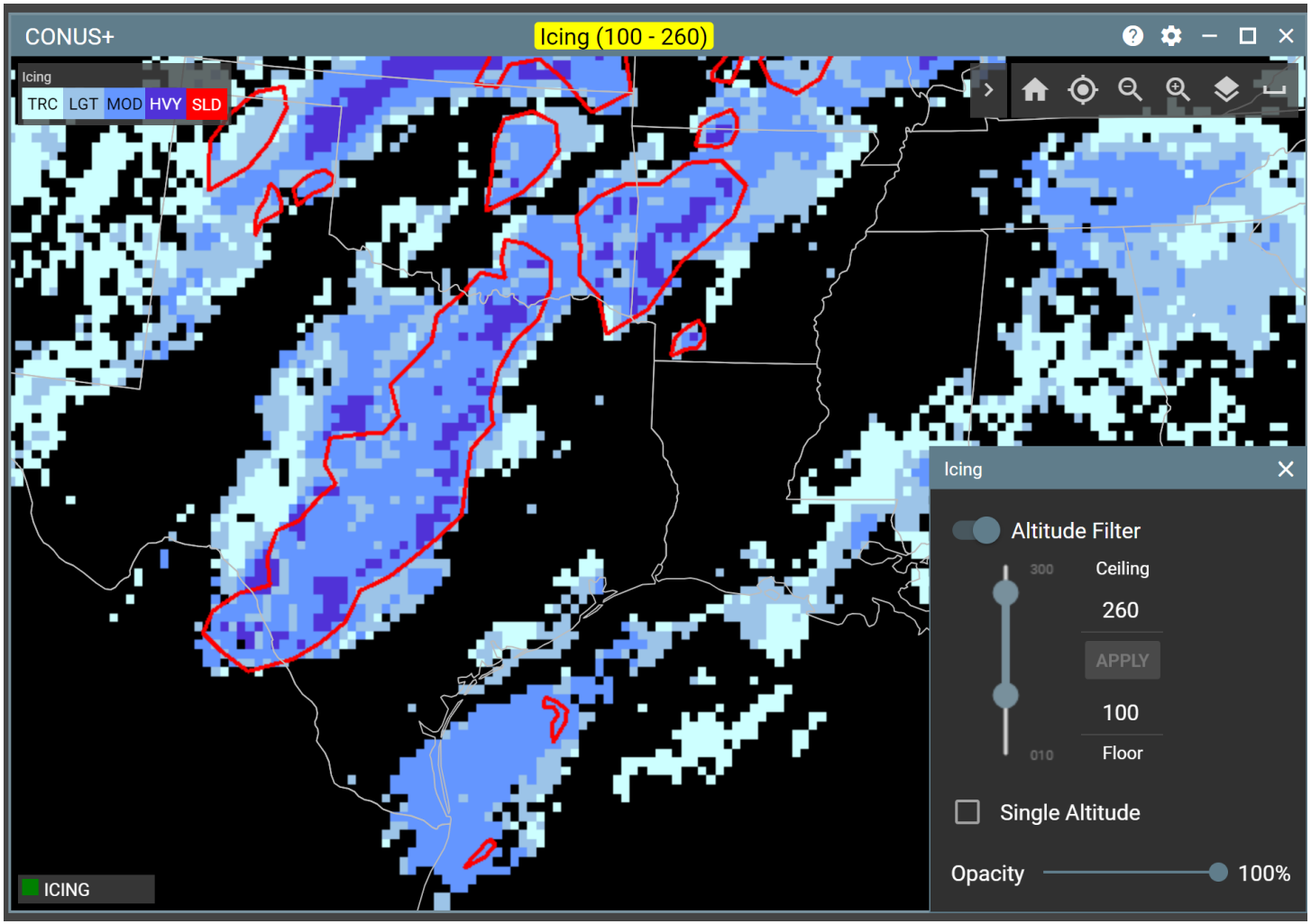
NWS Turbulence w/ NextGen Weather



NextGen Weather integrates NWS Turbulence on the Aviation Weather Display

Shown here are NextGen Weather 0-2 hr Fronts and Storm Motion Vecs overlaid on NWS Turbulence map

NWS Icing w/ NextGen Weather

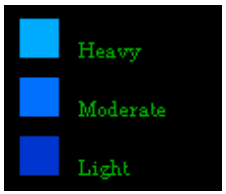


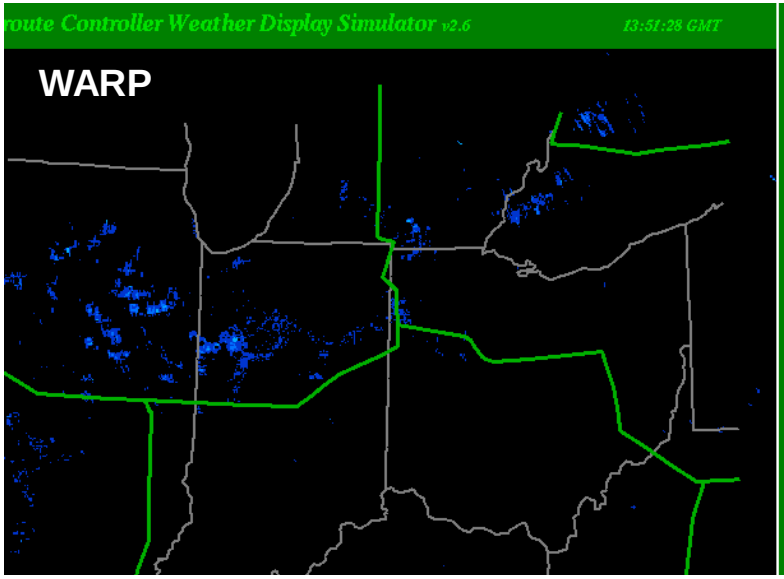
NextGen Weather integrates NWS Icing and provides Layer selection option (floor/ceiling) for:

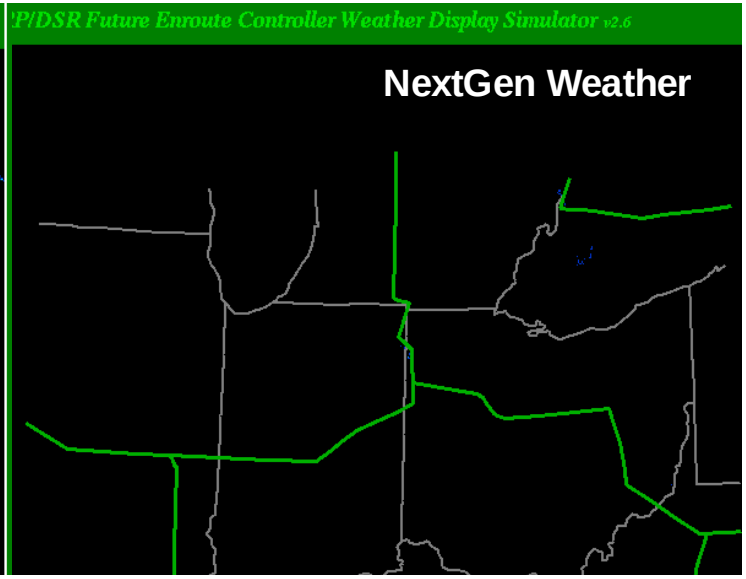
- NWS Icing (shown here)
- NWS Turbulence
- NextGen Weather Composite Reflectivity

Red contour indicates regions of super-cooled large droplets, known to cause aircraft icing

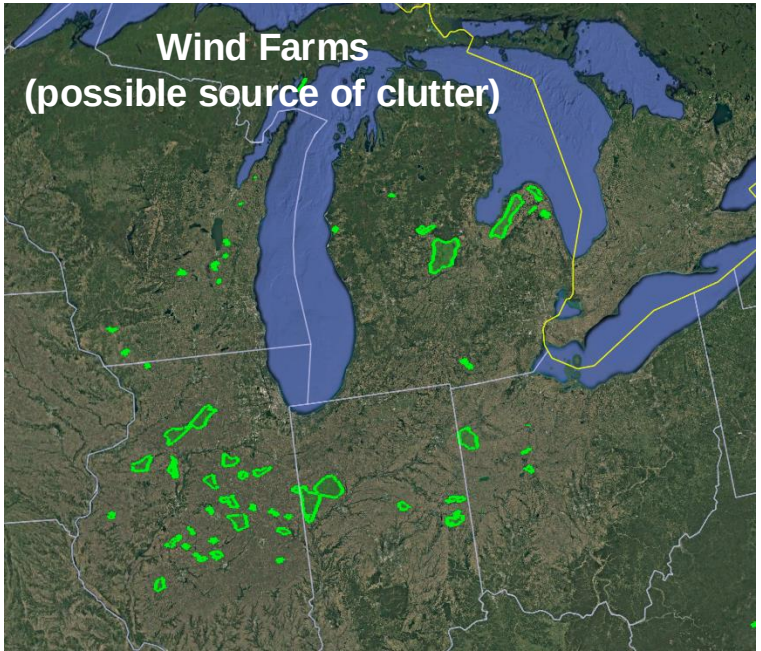
Newsflash: Users Report Clutter on ERAM Mitigated by NextGen Weather

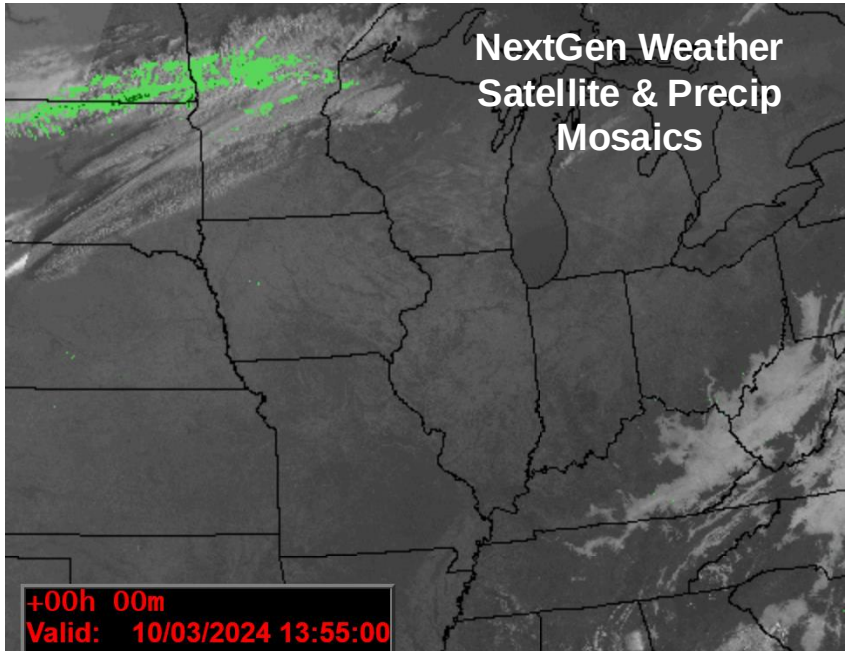






Courtesy of Tri Nguyen and Dave Keifer ERAM CHI 10/3/2024





Summary

- **NextGen Weather:**
  - **Consolidates FAA legacy weather processors**
    - **WARP, CIWS, CoSPA** *(ITWS, ASR-WSP remain)*
  - **Provides "common weather picture"**
    - **Available to all stakeholders**
    - **Very timely and accurate**
  - **Represents a long term, multi-agency investment**
    - **Processes weather radar data within the NAS for aviation use**
    - **Augments products using National Weather Service models & observations**
    - **New requirements driven by FAA, airline & CWSU users**
- **NextGen Weather products:**
  - **Update rapidly with high accuracy – comparable to actual 28 sec radar**
  - **Improve upon current operational weather for ATC**
    - **Based on quantitative comparisons with**

      WARP-ERAM, ASR-STARS, CIWS/CoSPA and ITWS
  - **Lead to improved safety and efficiency in the NAS**