The Graphical Turbulence Guidance Nowcast (GTGN) Product

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NCAR | RESEARCH APPLICATIONS LABORATORY

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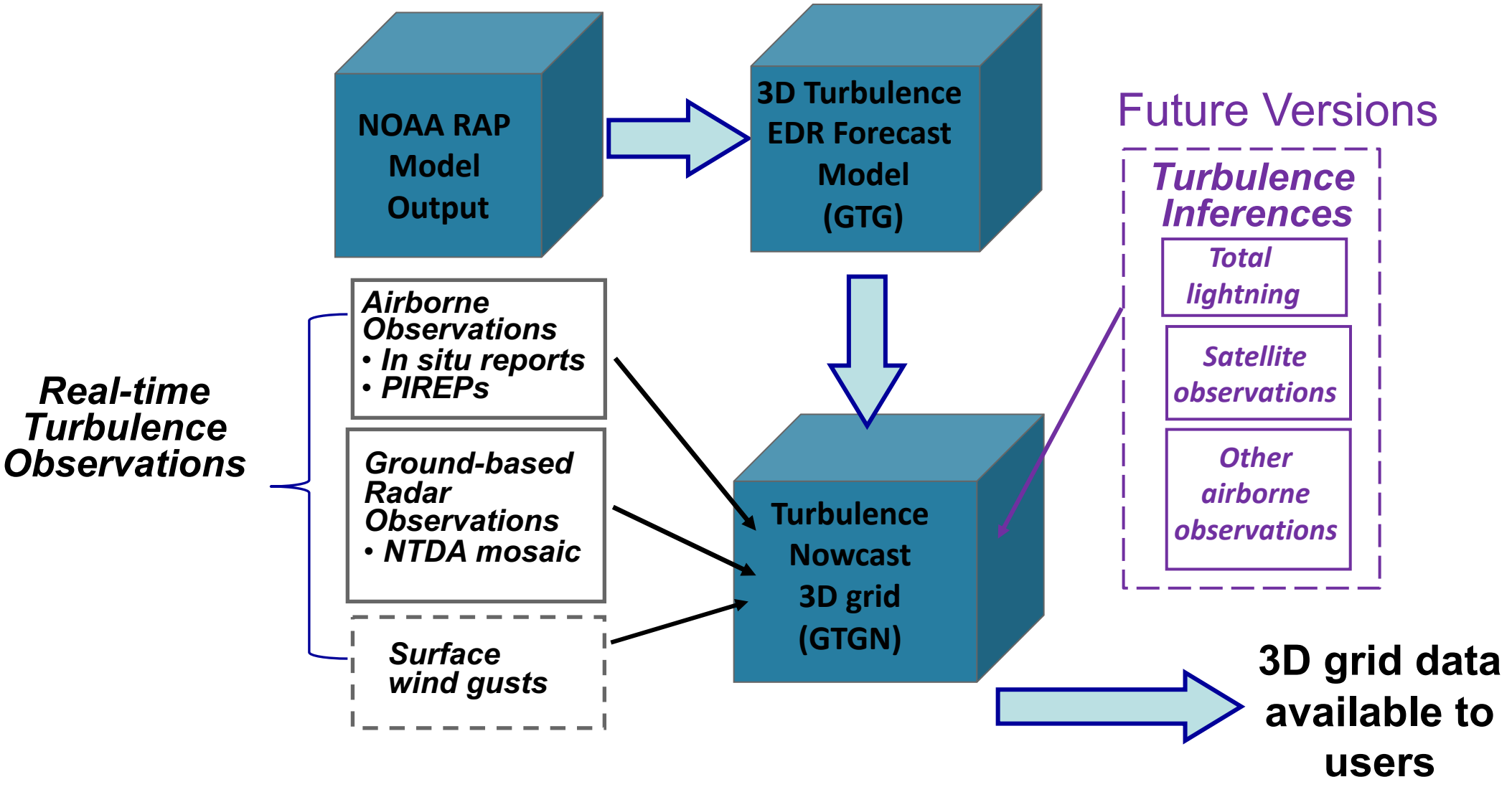
GTGNowcast (GTGN) Overview

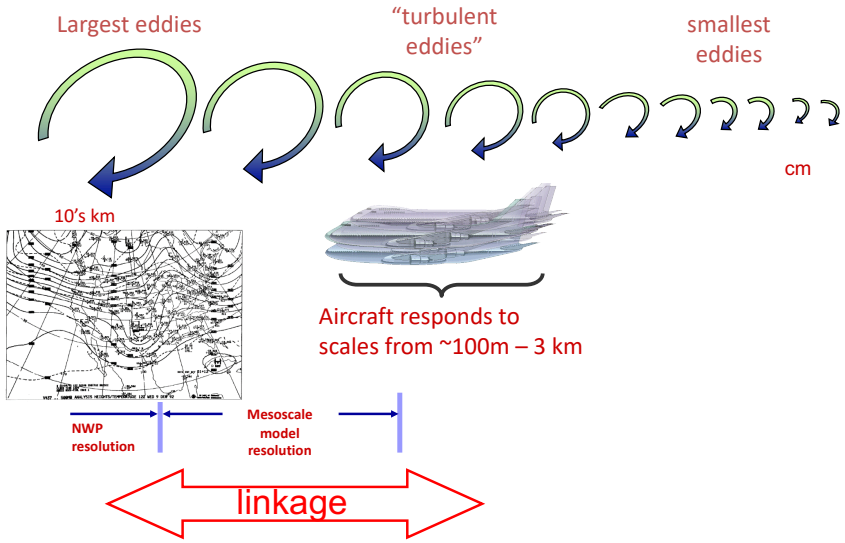
- Nowcast – tactical turbulence avoidance product
  - Rapid update cycle of 15 minutes, valid for next 15 minutes
- Current GTGN version 1 uses Graphical Turbulence Guidance System version 3 (GTG3) output grid as a basis for the nowcast
  - Most recent 1- or 2-hr forecast valid closest to nowcast valid time
- Observation-centric
  - Nudges turbulence forecasts to be more consistent with recent turbulence observations
  - Uses both airborne (PIREPs, in situ EDR) and ground based (NTDA) observations; lightning data input in development
- All sources of turbulence are represented
  - Low-level, clear-air, mountain wave, and in- and near-cloud turbulence
- Outputs 3D grid of Eddy Dissipation Rate (EDR; $\varepsilon^{1/3}$ $m^{2/3}$ / s)
  - Energy Dissipation Rate (EDR) is an atmospheric, aircraft independent, turbulence metric

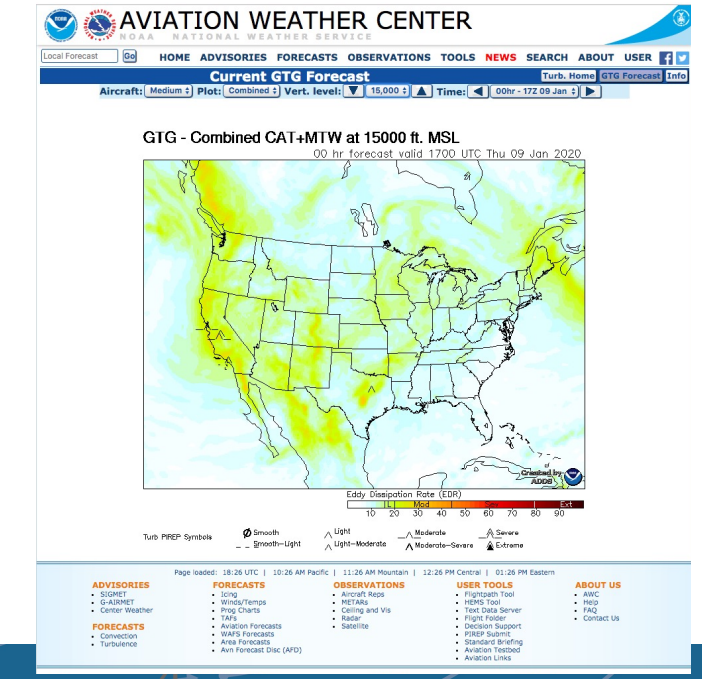
Aviation Turbulence Nowcast System: GTGN Architecture



GTGN1 Input: Graphical Turbulence Guidance

- Forecast system is called the Graphical Turbulence Guidance (GTG)*
  - GTG based on various models that include RAP, GFS, global FV3, UK-Met, ARPEGE, HRRR, etc.
  - Current GTGN inputs short term GTG forecasts based on NOAA's RAP
- Provides strategic turbulence forecasts of turbulence intensity metric termed "EDR" (energy dissipation rate$^{1/3}$)
- Assumes large scale NWP model resolved turbulence sources linked to aircraft scale turbulence
- Computes suite of turbulence diagnostics for MWT, CAT and LLT forecasts and in the very near future also CIT
- Outputs 3D Mosaic of a ***combined*** turbulence forecast field as well as ***MWT & CAT*** categories
  - 13km horizontal grid spacing, 1000ft vertical grid spacing

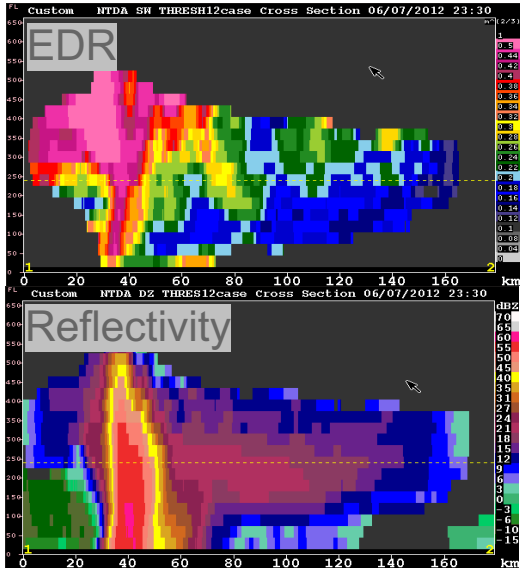


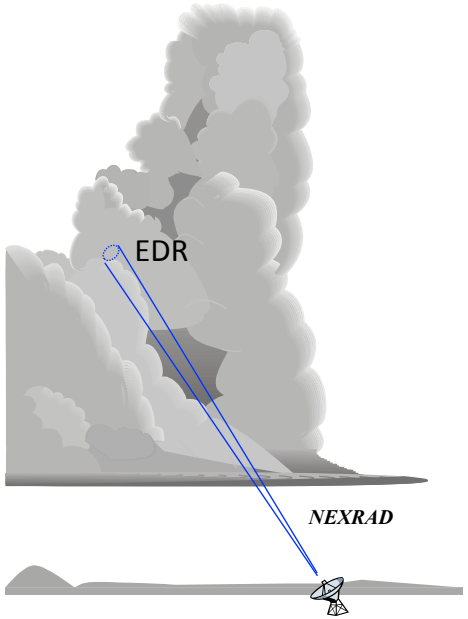


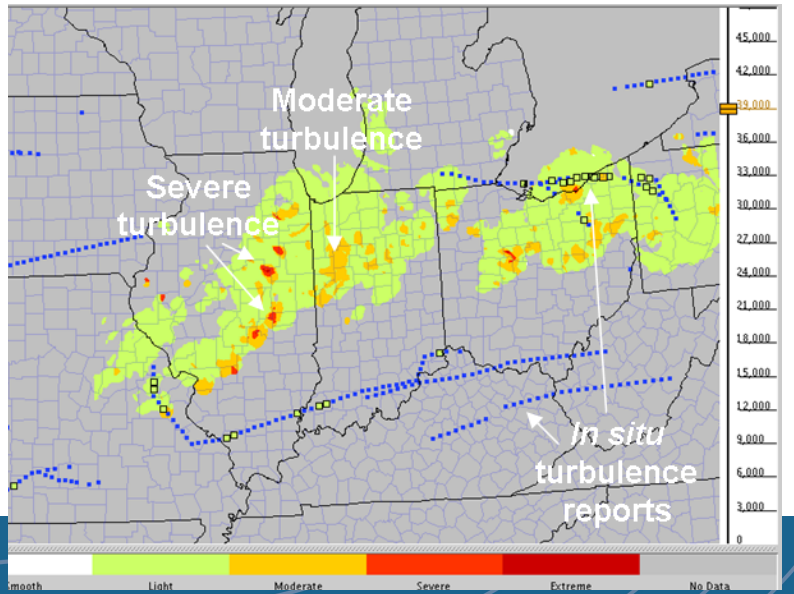
Sharman et al. *Weather & Forecasting,* 2006
Sharman and Pearson, *J Appl Met Climate*, 2017
Pearson and Sharman, *J Appl Met Climate*, 2017

GTGN1 Input: NCAR Nexrad Turbulence Detection Algorithm (NTDA)

- NTDA is a radar based remote sensing technique that can identify small-scale turbulence in cloud that can evolve quickly
- Reflectivity (dBZ) is NOT a reliable indicator of turbulence intensity or location
- NTDA uses radar spectral width measurements converted to EDR to identify in-cloud turbulence
- Individual radars are mosaicked to produce 3D grids of EDR and "confidence"
  - 5 minute update rate
  - 2 km horizontal x 3,000 ft vertical resolution
  - Verified with in situ turbulence measurements and PIREPS







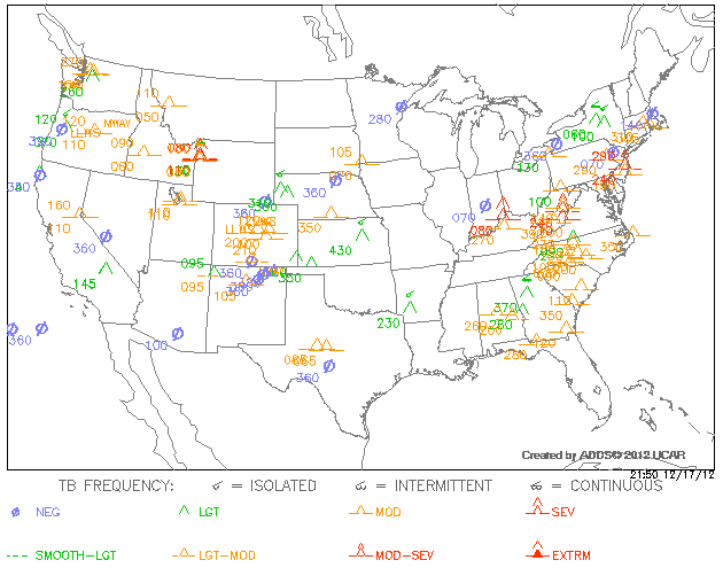
GTGN1 Input: In situ EDR and Pireps

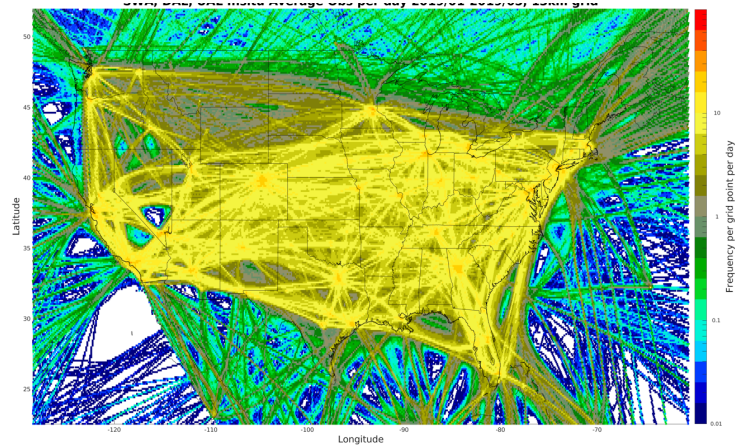
Pilot Reports of Turbulence (PIREPs):

- Subjective, aircraft-dependent assessment of the level of turbulence, null to extreme
- Include time of report (minute resolution) and position
- GTGN ingtest PIREPS converted into EDR

In situ EDR reports:

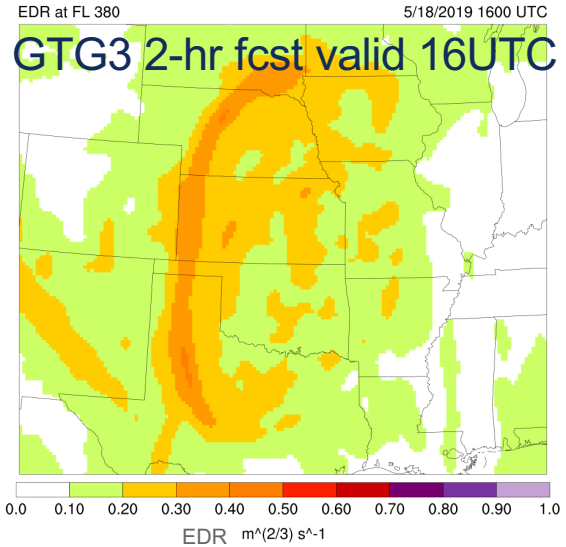
- Automated, aircraft independent measure of turbulence, includes time, position and aircraft type of aircraft.
- Eddy dissipation rate, EDR (= $\varepsilon^{1/3}$ m $^{2/3}s^{-1}$) reports routinely (heartbeats) and when there is significant turbulence (triggered)
- Reported EDR is peak and mean over the previous minute of flight.
- GTGN ingests heartbeat, triggered and interpolated null in situ EDR reports





Average in situ observation frequency per day, 13 km grid

GTGN1 Overview Continued: Example 18 May 2019 at 16UTC, FL380



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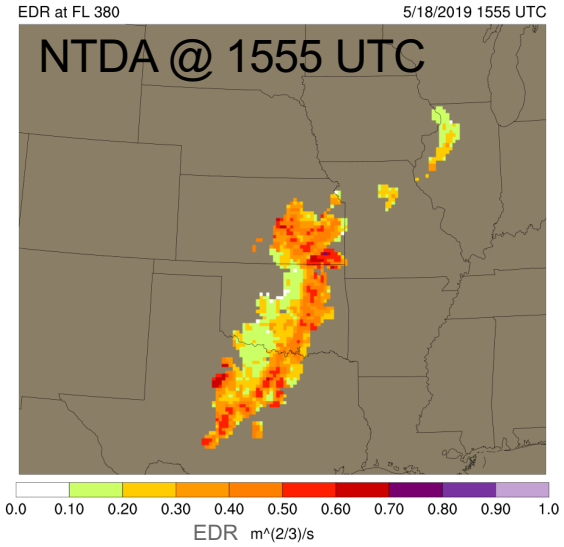

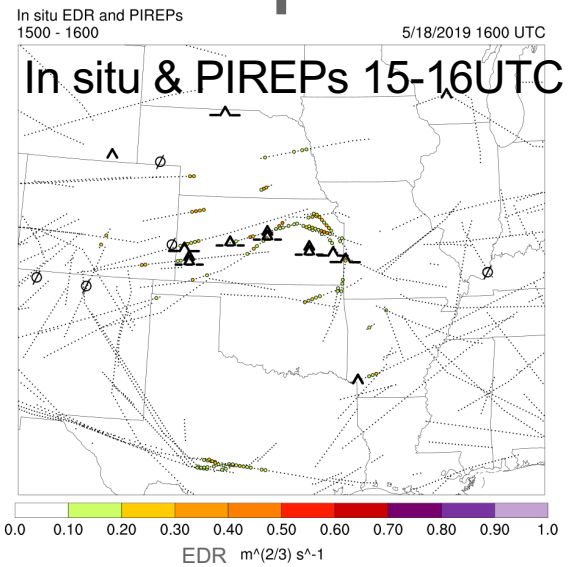

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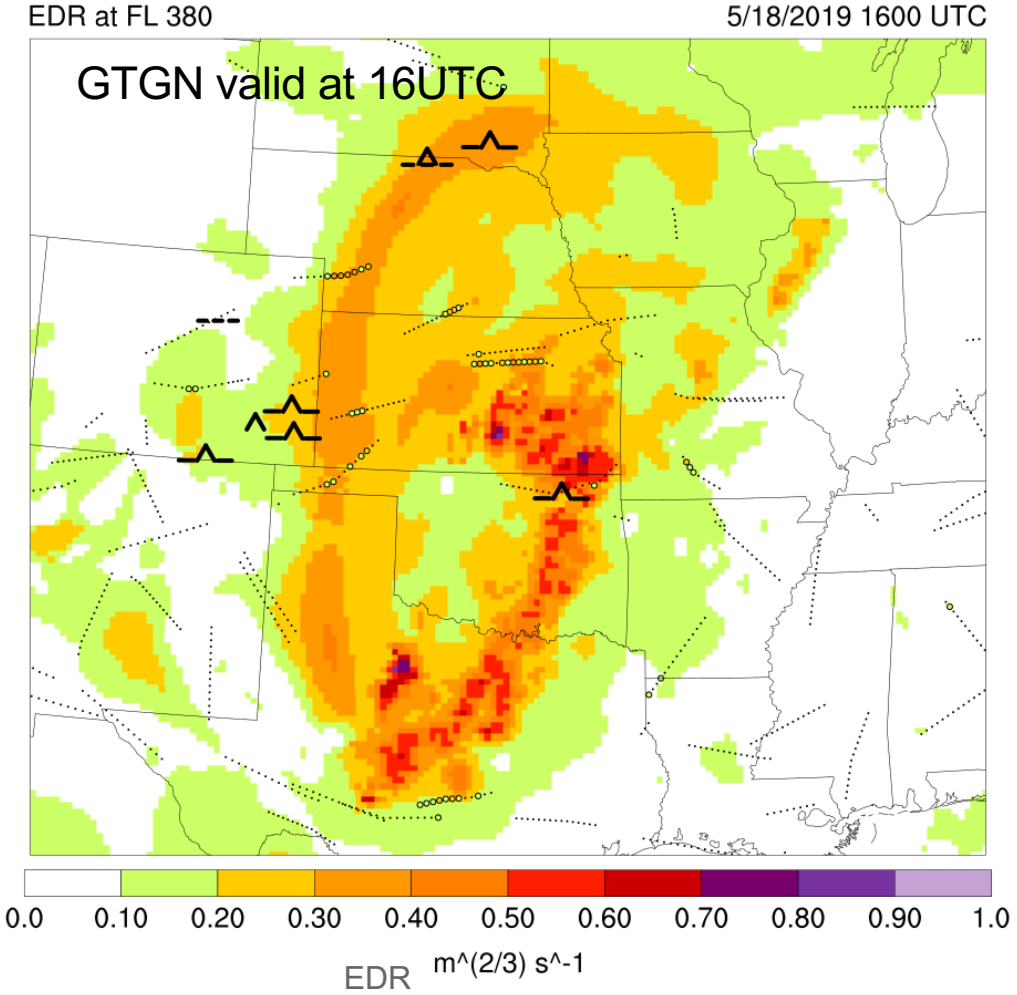
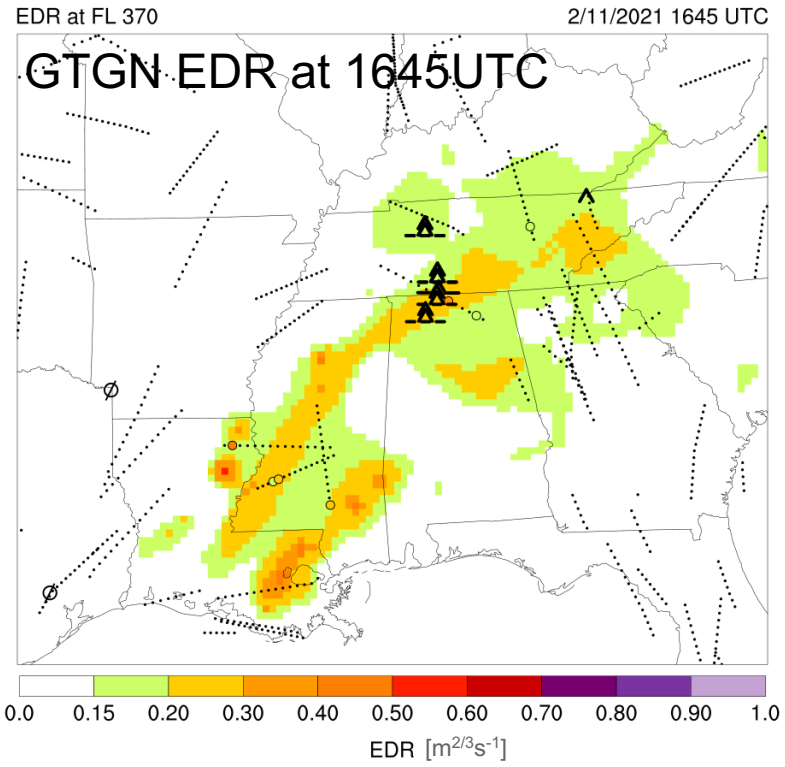
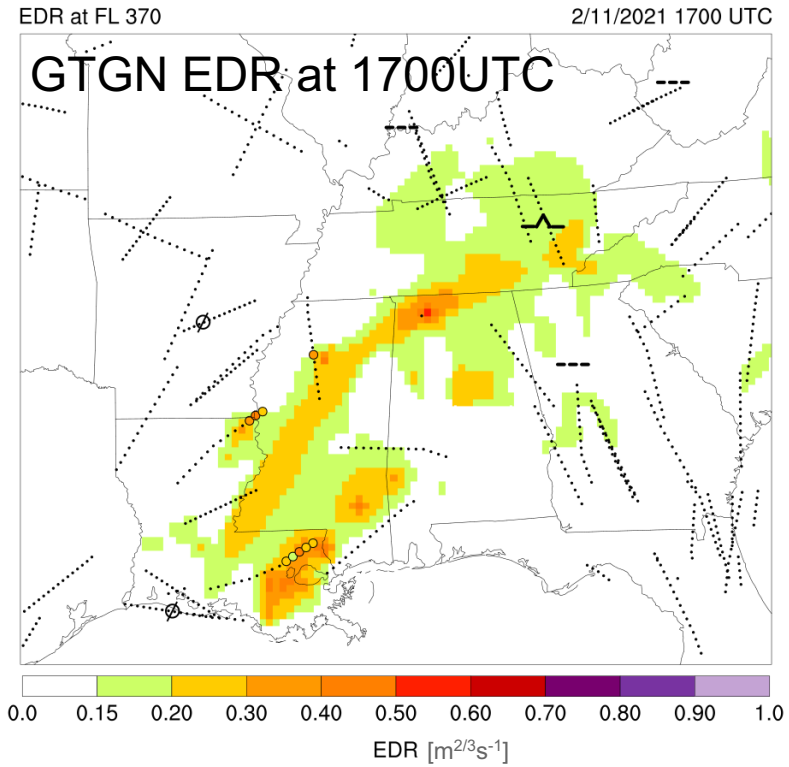
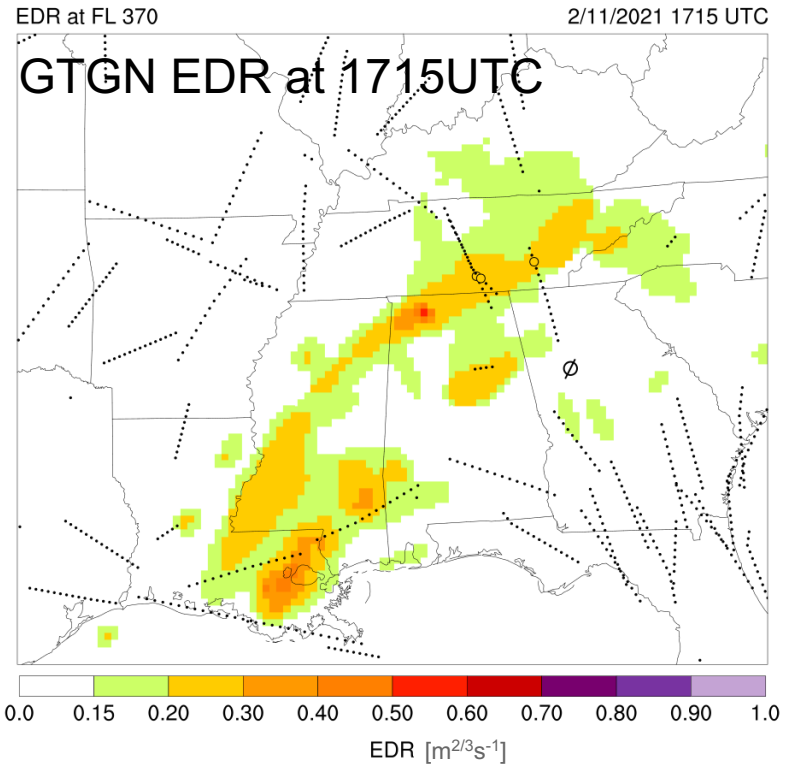


Verification Observations 1600-1615

GTGN1 Operational Output Case Analysis: 11 Feb 2021, FL370, 1645 – 1715 UTC

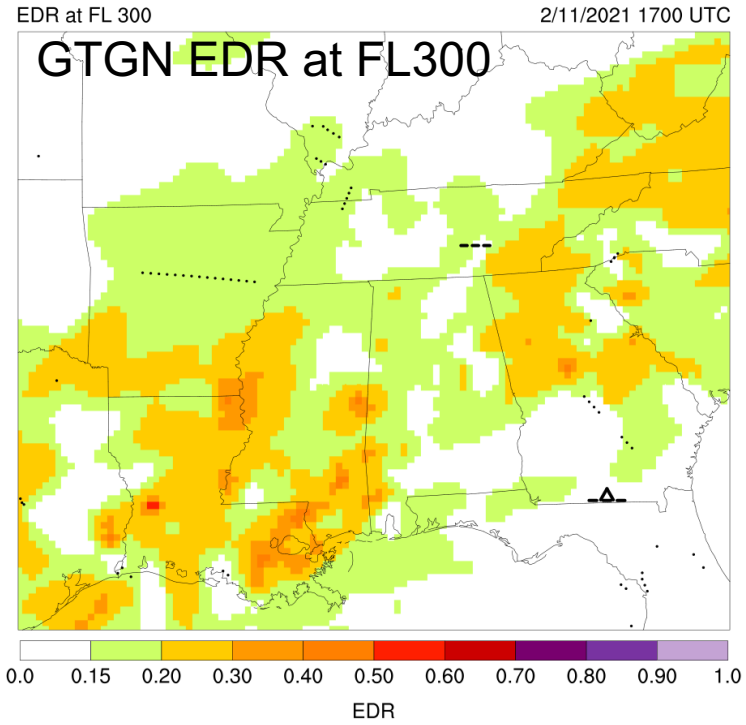


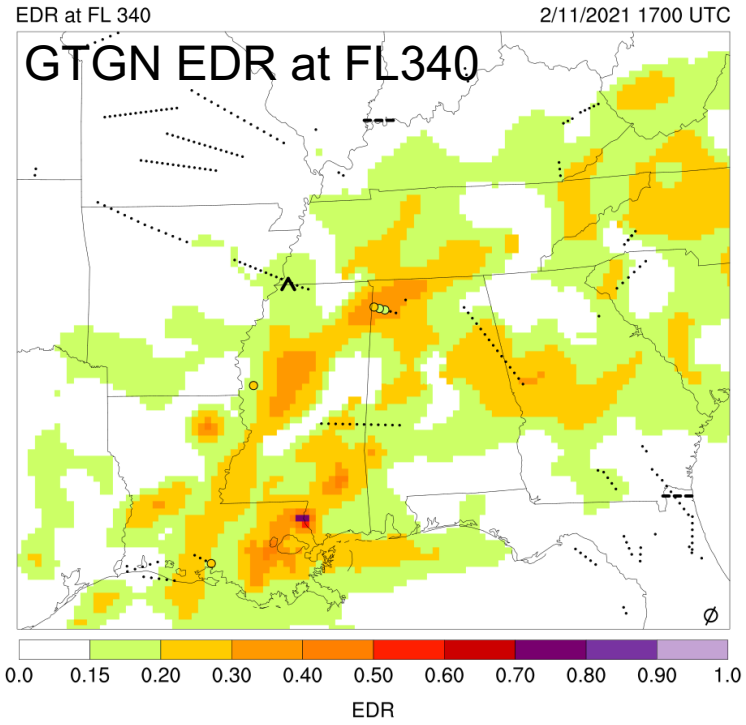


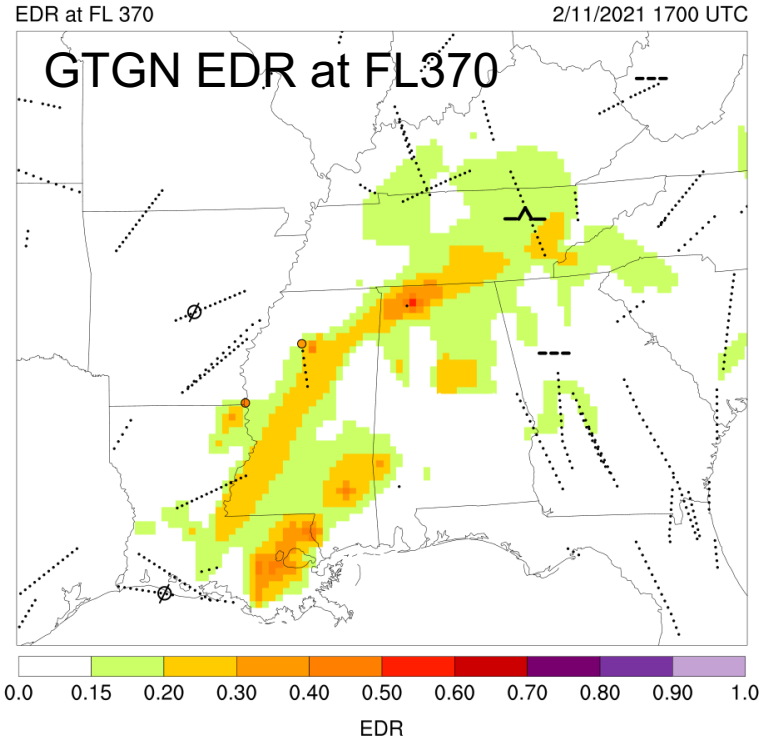


- GTGN real time output at 1645, 1700, 1715 UTC, FL370. Observations from 1645 – 1730 shown in 15 minute valid ranges +/- 2100 ft around FL370 for the 3 plots
- GTGN shows areas of MOG turbulence corresponding very well to locations of several MOG PIREPs & in situ EDR reports in LA, MS and TN over this time window.
- GTGN shows null to light turbulence in areas with null in situ EDR reports around these events
- Event illustrates GTGN skill in correctly identifying narrow regions of MOG turbulence and adjacent null turbulence.

11 Feb 2021 Case Analysis: GTGN1 at 1700 UTC, Different Flight Levels



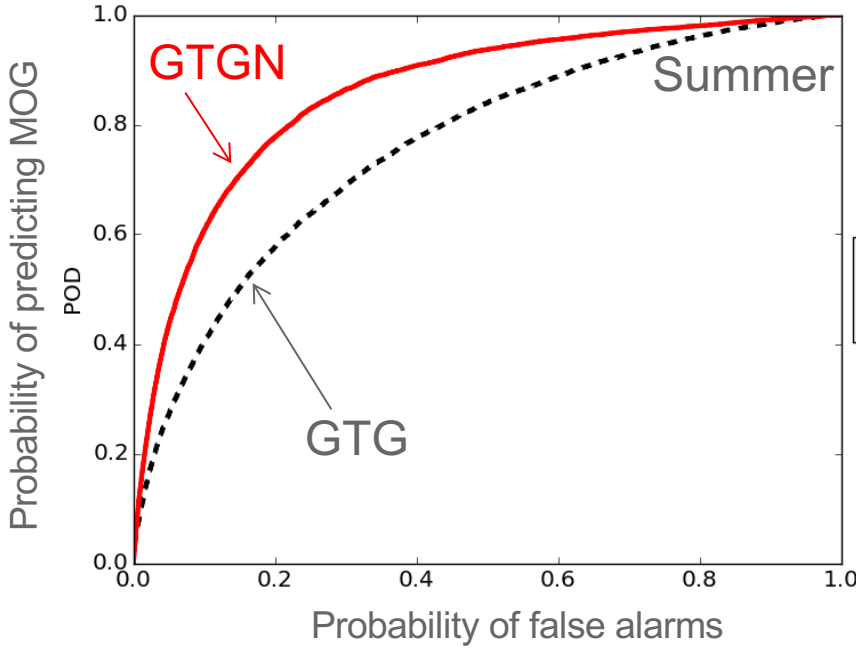


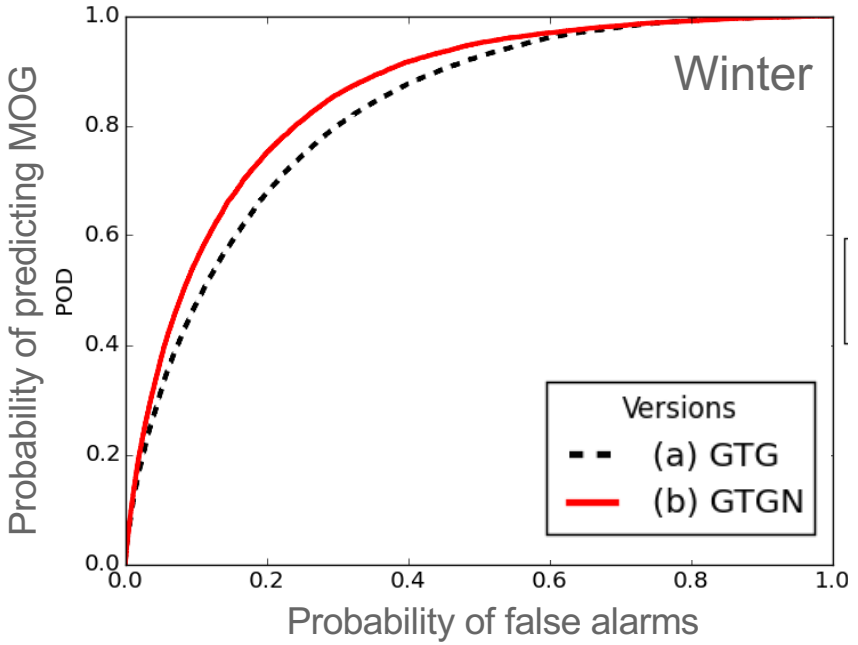


- Alarm Volume changes significantly with altitude
- Observations shown are +/- 1100ft of FL

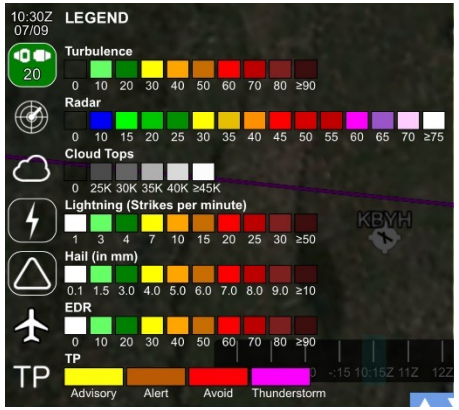
GTGN1 Evaluation

- Evaluation: ROC curve comparison of GTG versus GTGN for **summer and winter months**





GTGN1 Evaluation from FAA & Delta Airlines



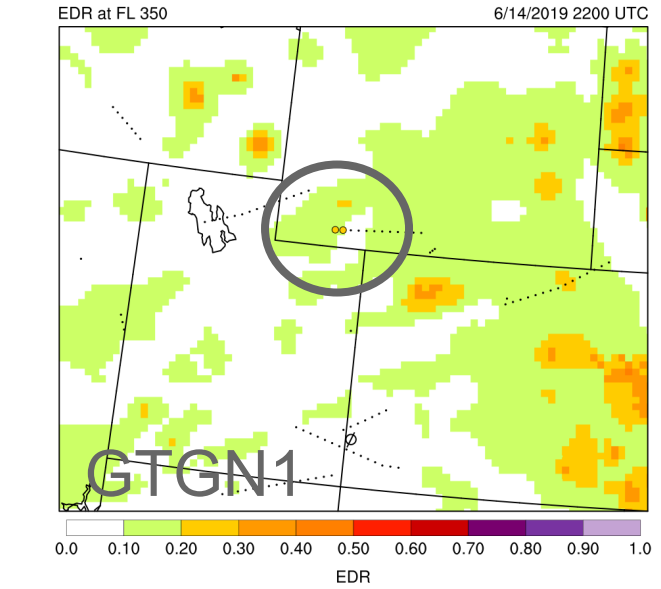
GTGN displayed via App on Tablet for use in the cockpit

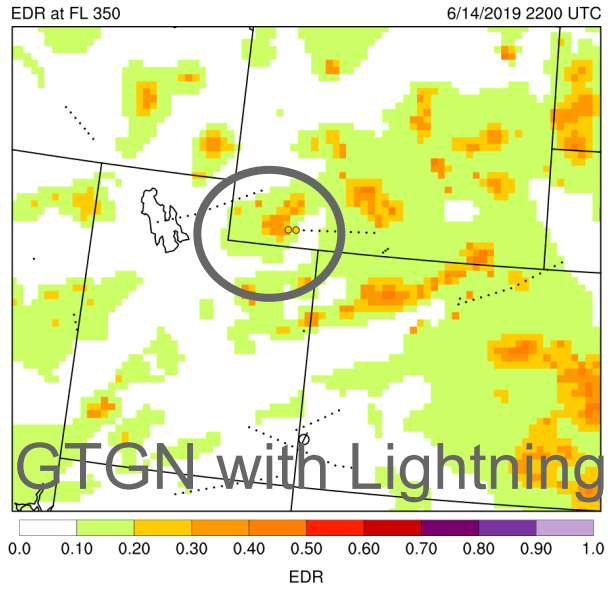
Courtesy Delta Airlines

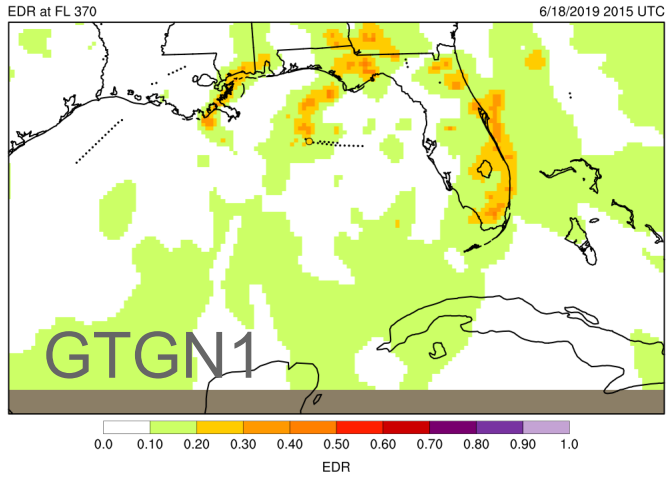
GTGN Version2: Addition of Lightning Data

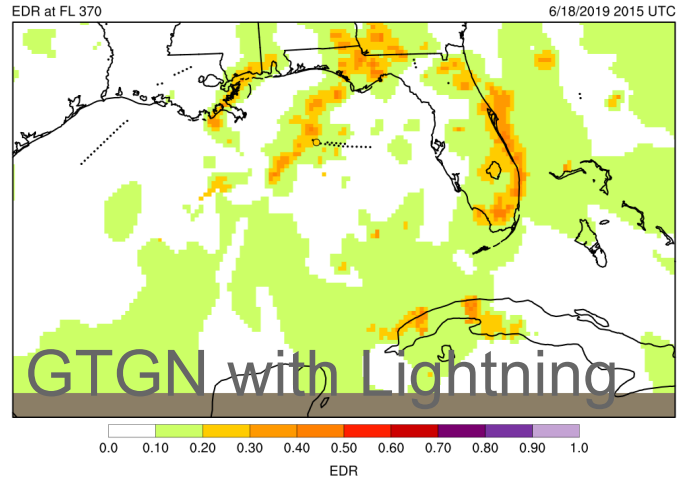
Improves nowcast where radar coverage is limited

- Our research has shown that:
  - Lightning characteristics correlate with in-cloud turbulence
- Various lightning observations are available:
  - Over CONUS to fill in where NTDA has sparse coverage
  - Over oceans and globally allowing for a GTGN with current in-cloud convective turbulence over expanded domains





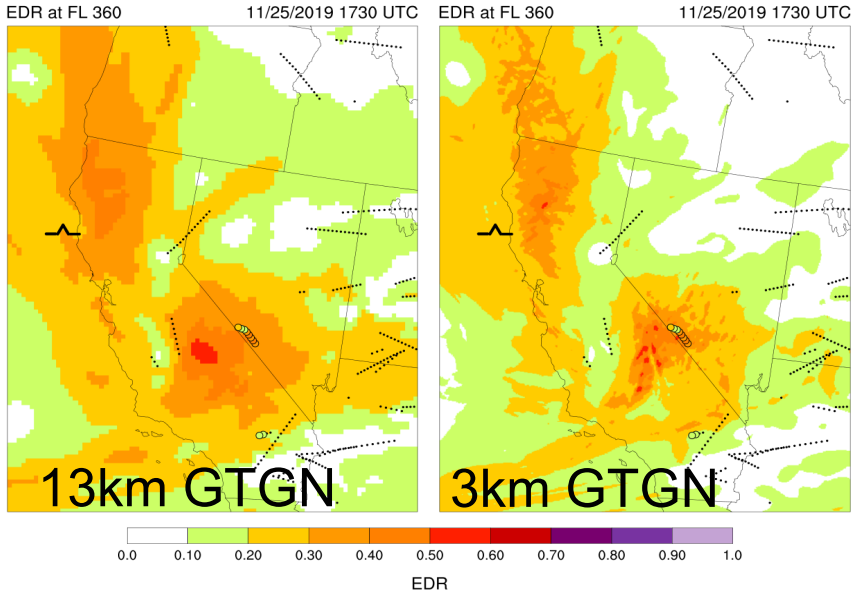




With next 15 minutes of in situ & PIREP observations

GTGN Version2: Higher Resolution Domain

- GTGN version2 utilizes
  - GTG4 short term forecasts based on NOAA's HRRR/RRFS models
    - 3 km grid spacing
      - More detail in turbulence features
      - Less volume of MOG forecast
    - GTG4 will include a CIT forecast
  - CONUS domain similar to GTGN1
  - NTDA on the higher resolution domain (3 vs 13km) results in more precise in-cloud turbulence input into GTGN



Summary and Next Steps

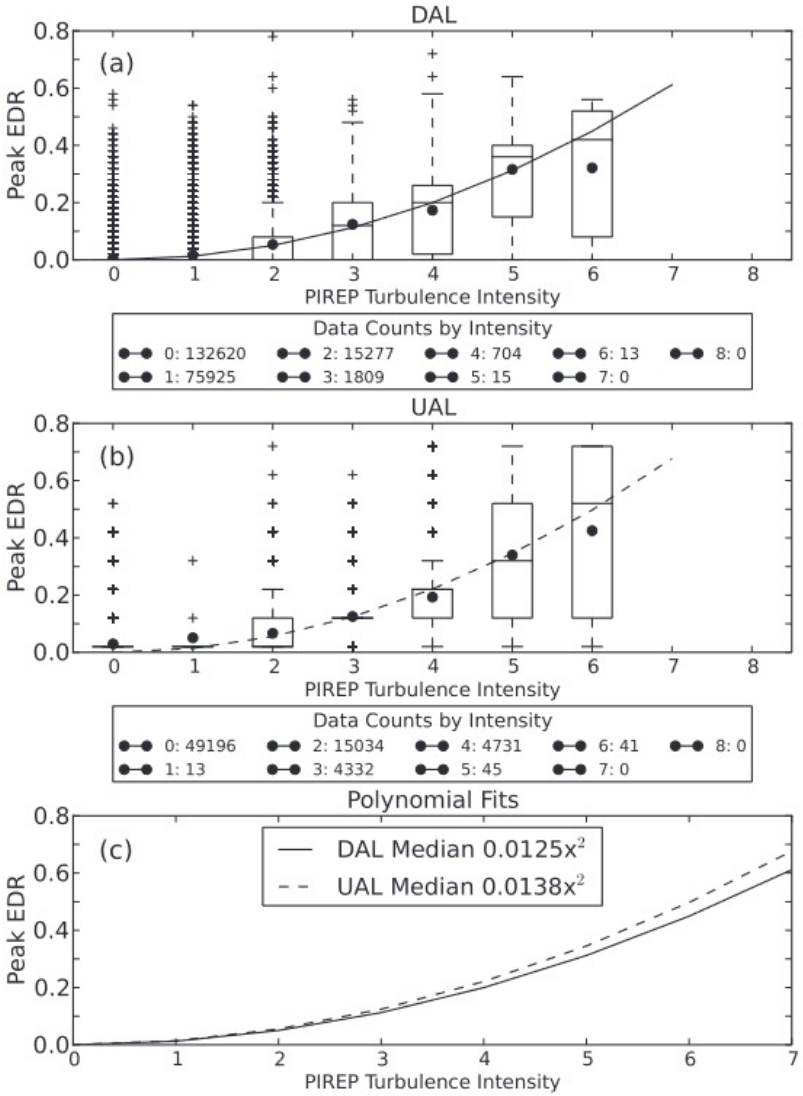
- GTGN is a tactical turbulence avoidance aid to aviation developed under research funding provided by the FAA.
- GTGN is a 3D product that identifies turbulent layers in the atmosphere on flight levels with an update time of 15 minutes, ingests turbulence observations and short term forecast
- Real time cases show GTGN was able to pinpoint specific regions of MOG turbulence and adjacent areas of null turbulence
- GTGN1 underwent the FAA's TRP and SRM processes, GTGN1 output is available on a semi-operationally basis through LDM feed from NCAR: *https://ral.ucar.edu/solutions/products/graphical-turbulence-guidance-nowcast-gtgn*
- Under development at NCAR, GTGN version 2 will include higher resolution short term turbulence forecasts and other observational data such as lightning
- NTSB recently published recommendations to operationalize turbulence nowcasts such as GTGN
  - GTGN is planned to be transitioned to NOAA/NCEP for operations

Questions

- Thank you!
- Contact info:
  - Julia Pearson and Wiebke Deierling
  - jpearson@ucar.edu; deierlin@ucar.edu

Backup Slides

PIREPs & *Insitu* EDR Comparisons



Based on 60,000 UAL757 matches, 50,000 DAL737 matches

"Light"=0.15 $m^{2/3}s^{-1}$

"Moderate"=0.22 $m^{2/3}s^{-1}$

"Severe"=0.34 $m^{2/3}s^{-1}$

These are lower than ICAO "standard" thresholds

"None" < 0.1 $m^{2/3}s^{-1}$

"Light" 0.1-0.3 $m^{2/3}s^{-1}$

"Moderate" 0.3-0.5 $m^{2/3}s^{-1}$

"Severe" > 0.5 $m^{2/3}s^{-1}$

Sharman, R. D., L. B. Cornman, G. Meymaris, J. Pearson, and T. Farrar, 2014: Description and Derived Climatologies of Automated in situ eddy dissipation rate reports of atmospheric turbulence. *J. Appl. Meteor. Climatol.*, **53**, 1416–1432, doi:10.1175/JAMC-D-13-0329.1.