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Graphical Turbulence Guidance Nowcast (GTGN) Update

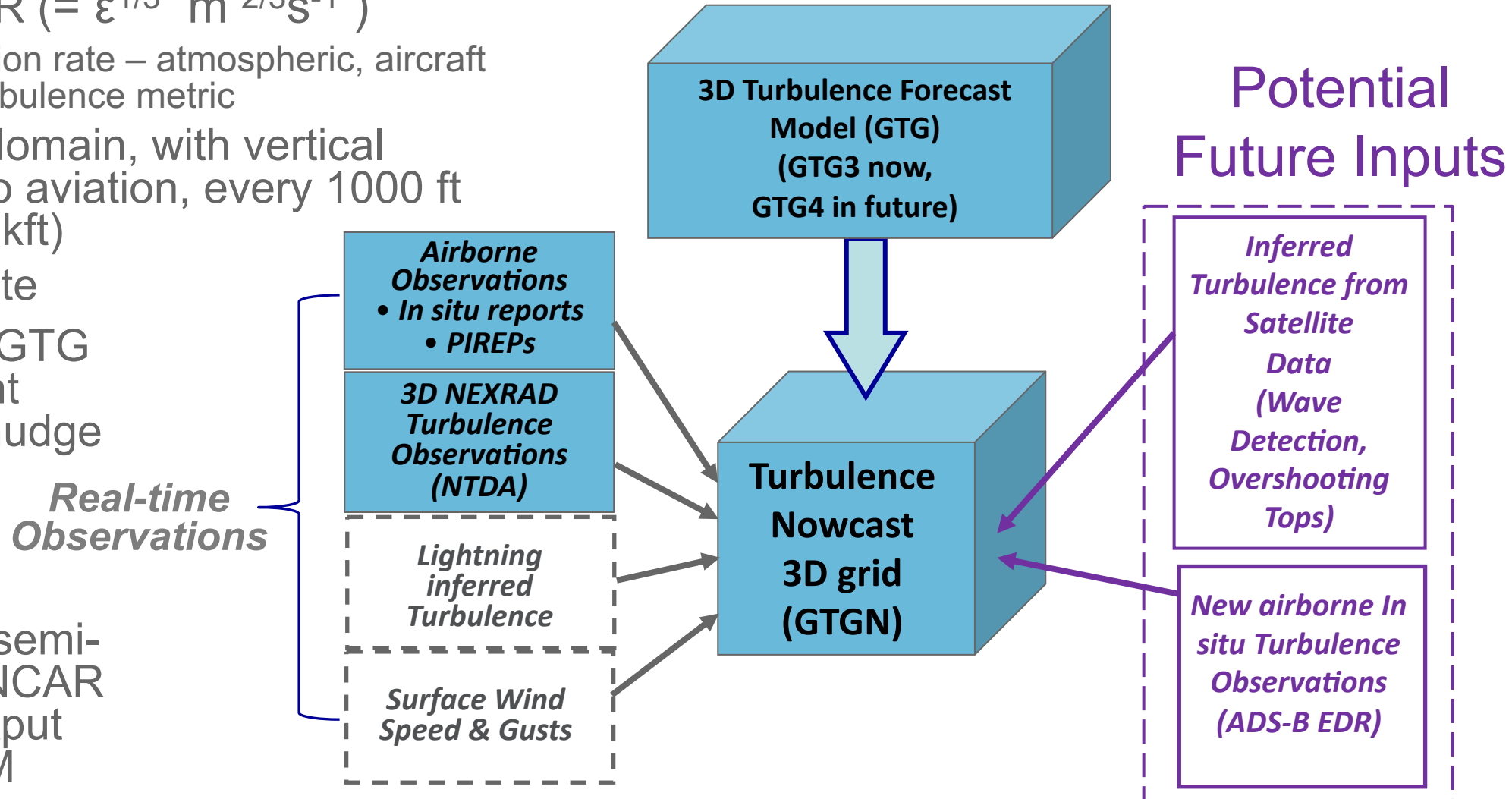
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Sharman

National Center for Atmospheric Research

- The Graphical Turbulence Guidance Nowcast (GTGN)
 - tactical turbulence product
 - help dispatchers and pilots make short-term routing and operational decisions
 - avoid turbulence hazards
 - enhance safety in the National Airspace System (NAS).
- In this talk we will describe GTGN
 - Overview of the current semi-operational algorithm GTGN 1.0:
 - Description of the input data
 - Including case studies to illustrate current capability
 - Describe additional data inputs for version 2.0
 - Case studies showing the benefit of adding:
 - Lightning data
 - Higher resolution model input
 - Summary and path to operations

Graphical Turbulence Guidance Nowcast (GTGN) Overview: Aviation Nowcast System

- Provides 3D short-term nowcasts of turbulence in EDR ($= \epsilon^{1/3} \text{ m}^{2/3} \text{ s}^{-1}$)
 - Energy dissipation rate – atmospheric, aircraft independent turbulence metric
- Output on GTG domain, with vertical levels pertinent to aviation, every 1000 ft (Flight levels >18kft)
- 15-min update rate
- Uses short-term GTG forecasts + recent observations to nudge GTG forecast
- GTGN1 running semi-operationally at NCAR with real time output available via LDM



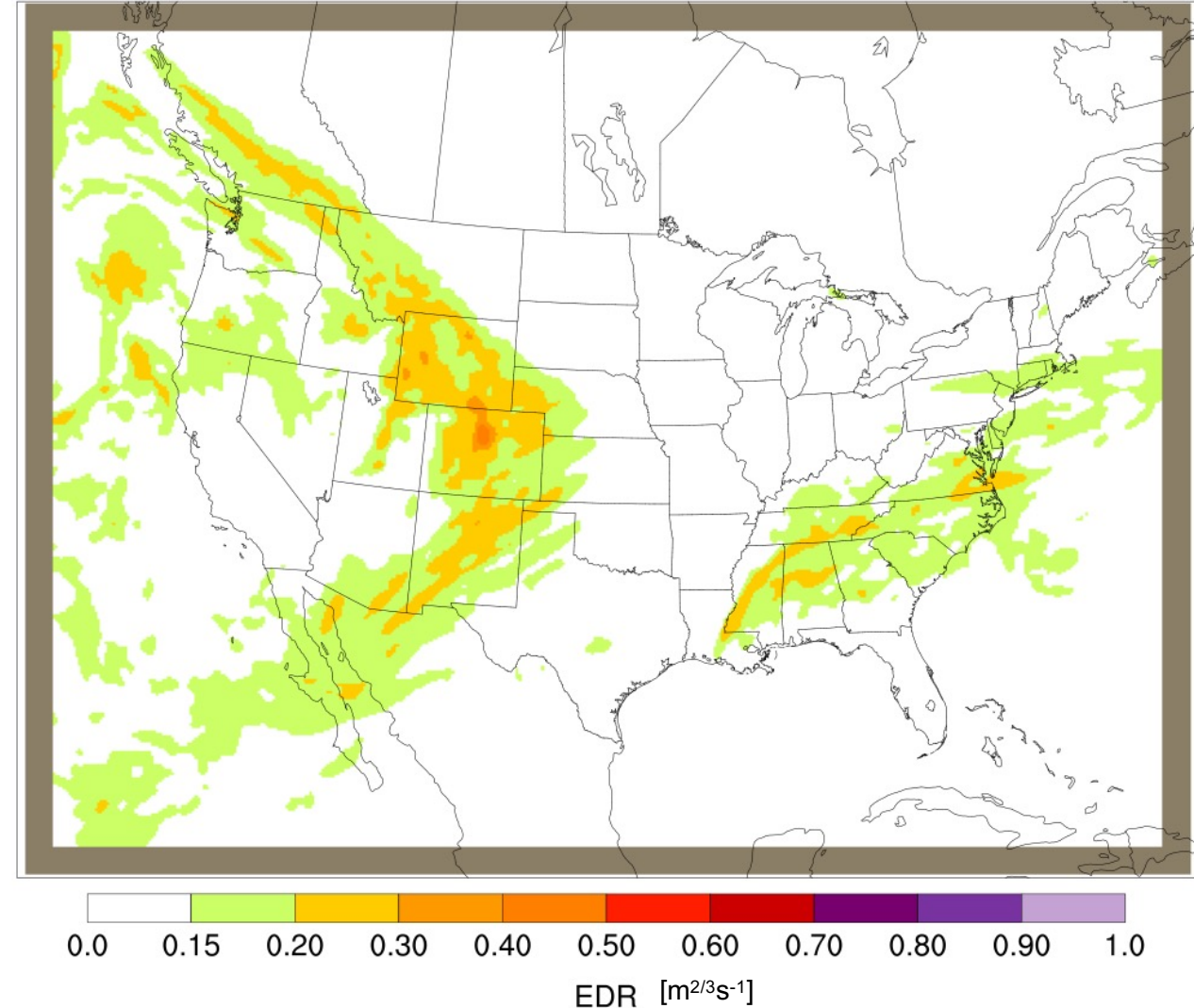
GTGN overview:

Inputs: GTG Aviation Turbulence Forecasts

- GTG provides turbulence forecasts using data from NWP models
 - GTG3: operational - RAP (13 km) Model over CONUS
 - GTG4 under development and will run on HRRR and then RRFS (3 km) models
 - Provides 3D forecasts of EDR ($\epsilon^{1/3}$)
 - CONUS domain; every 1000 ft (FL above 18kft)
 - Initialized every hour and outputs forecasts similar to NWP models
 - i.e. 0,1,2,3,6,9,12,15,18 Hour forecasts
 - 1 or 2 hour forecast used in GTGN
 - Calculates an ensemble of turbulence diagnostics (Structure functions, TKE, etc) that are converted to EDR and combined to create final forecasted EDR grid

EDDY DISSIPATION RATE at FL 370

2/11/2021 1700 UTC



GTGN Overview:

Inputs: Airborne Observations

Pilot Reports of Turbulence (PIREPs):

- Subjective, aircraft-dependent Pilot's assessment of the level of turbulence, null to extreme
- PIREP intensity converted to EDR using a parabolic equation based on the type of reporting aircraft
- ~ 550 per day on average

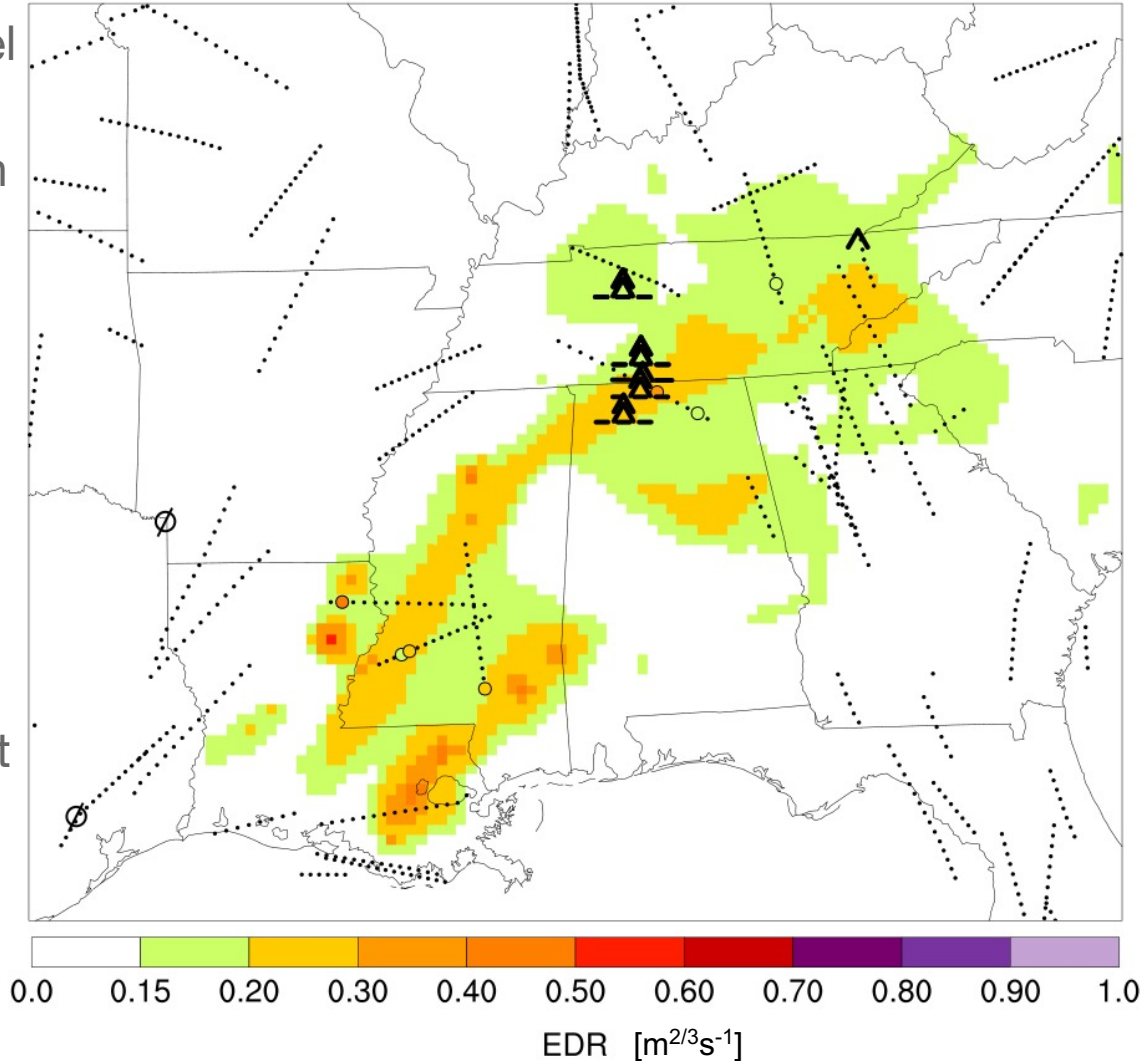
NEG (0)	LGT (2)	MOD (4)	SEV (6)
SMOOTH-LGT (1)	LGT-MOD (3)	MOD-SEV (5)	EXTRM (8)

In situ EDR reports:

- Automated, aircraft independent measure of turbulence
- Algorithm calculates peak and mean EDR every minute of flight (0-1 scale)
- Include more precise time and position information of aircraft than PIREPs.
- ~35k per day on average
- MOG turbulence approximately > 0.20 EDR for medium sized aircraft
 - Orange, Red, Purple colors

EDR at FL 370

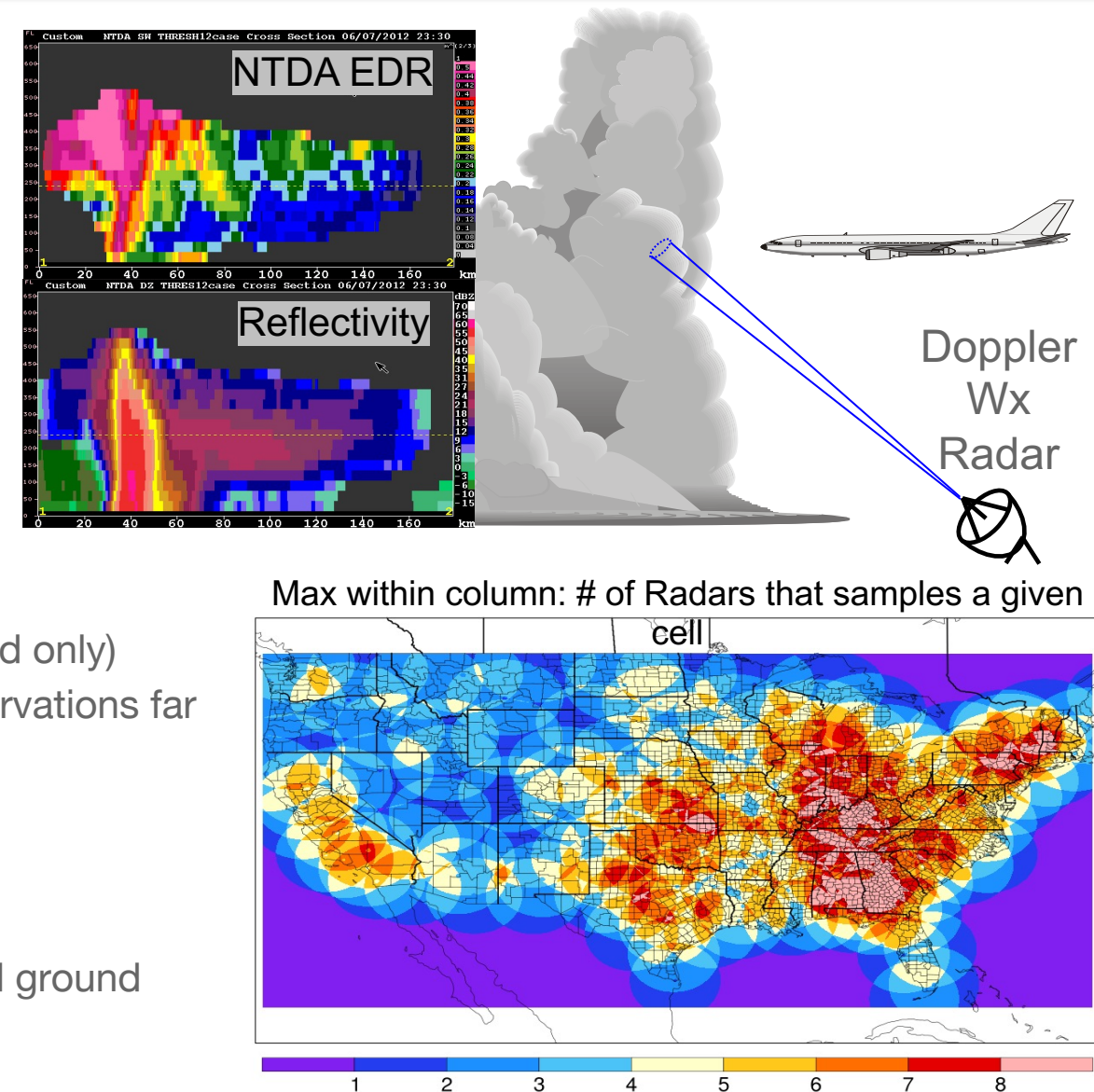
2/11/2021 1645 UTC



GTGN Overview:

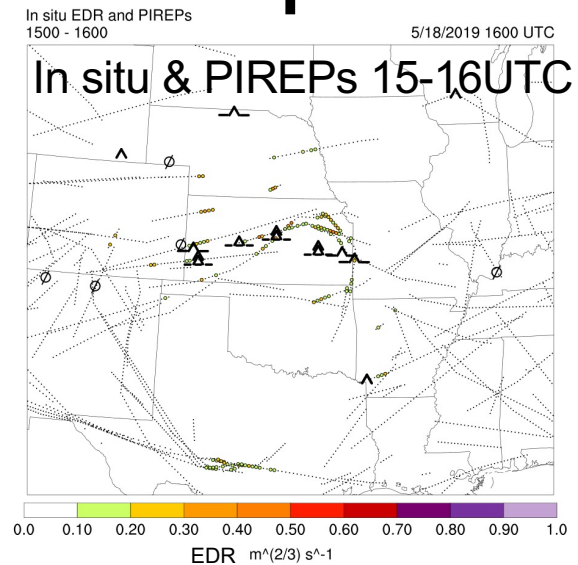
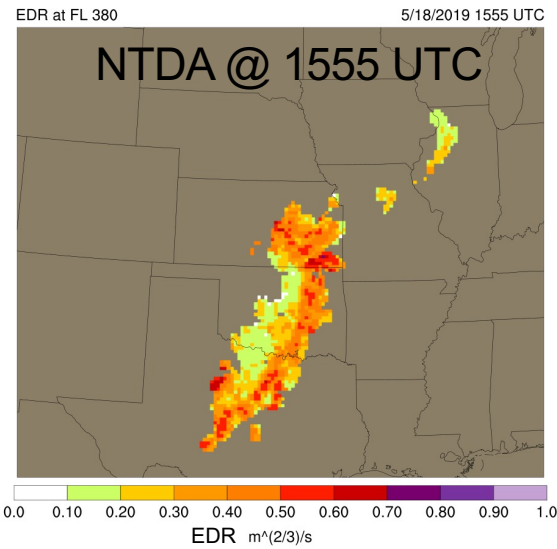
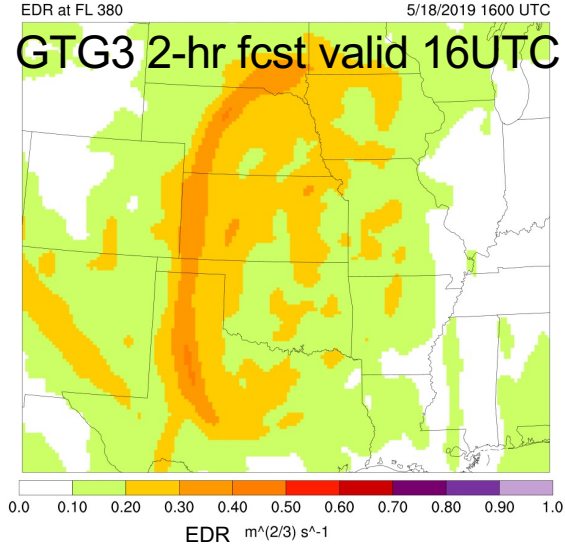
Inputs: NEXRAD/NCAR Turbulence Detection Algorithm (NTDA)

- NEXRAD/NCAR Turbulence Detection Algorithm
 - Using data from ~140 radars in US
 - Measures: Energy Dissipation Rate (EDR), from spectrum width estimates (radial wind variability within measurement volume)
- NTDA only **measures turbulence** where sufficient wind-tracing reflectors exist, i.e., **in clouds and storms**
- Output grid: 3-D, 2-km lat-lon grid, every 3,000 vertical feet to 45,000ft over CONUS, every 5 minutes
- Benefits:
 - Can measure turbulence remotely, in particular CIT (in cloud only)
 - Spatial and temporal coverage of in-cloud turbulence observations far greater than aircraft reports (PIREPs and *in situ* EDR)
 - Measurements route independent
- Limitations:
 - Limited to radar coverage; Sparse sampling in west
 - Coverage near the ground is limited by radar geometry and ground clutter

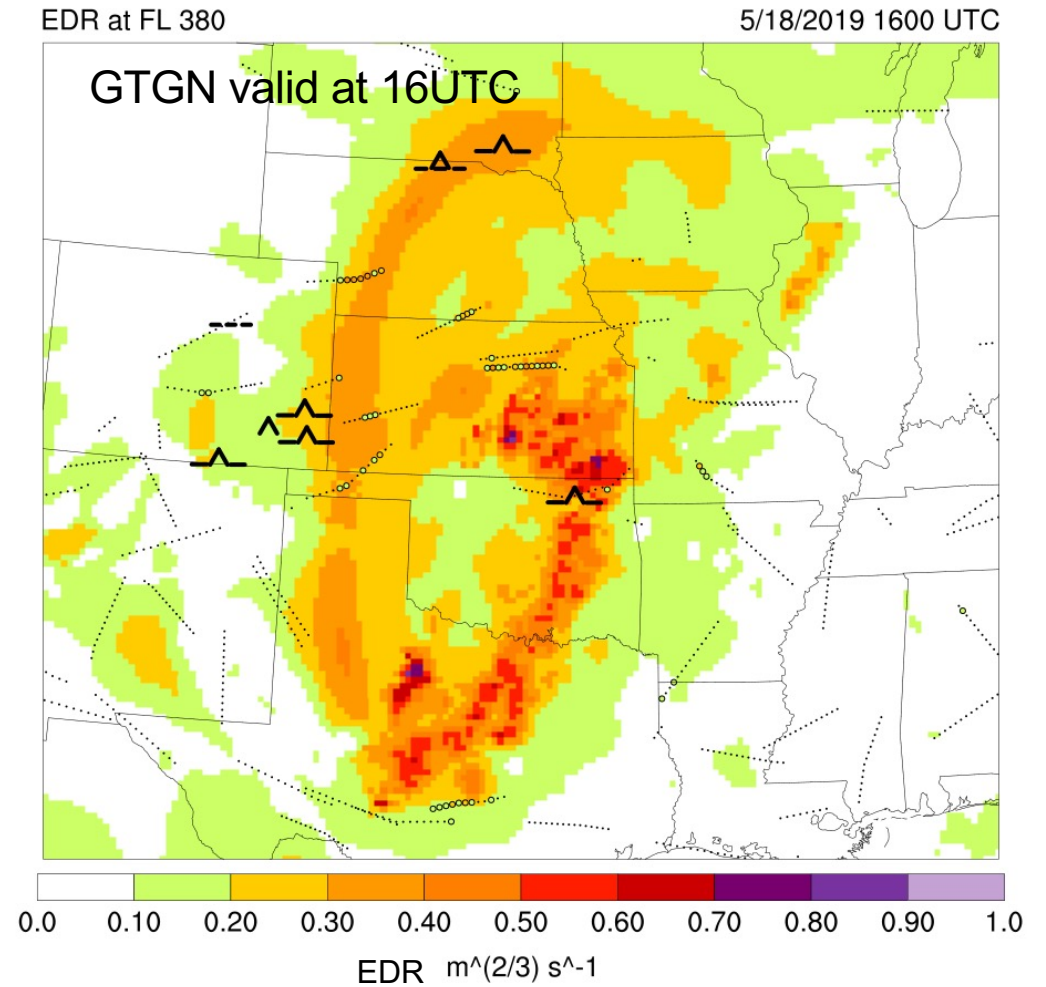


GTGN1 Overview:

Example 18 May 2019 at 16UTC, FL380

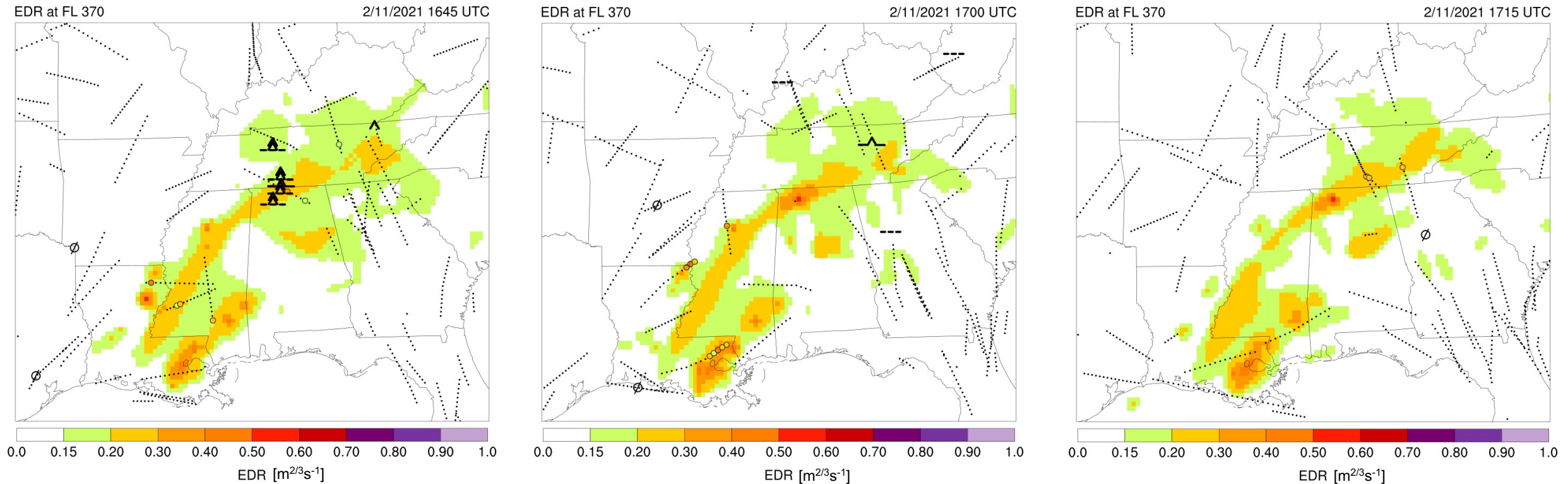


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Verification Obs 1600-1615

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

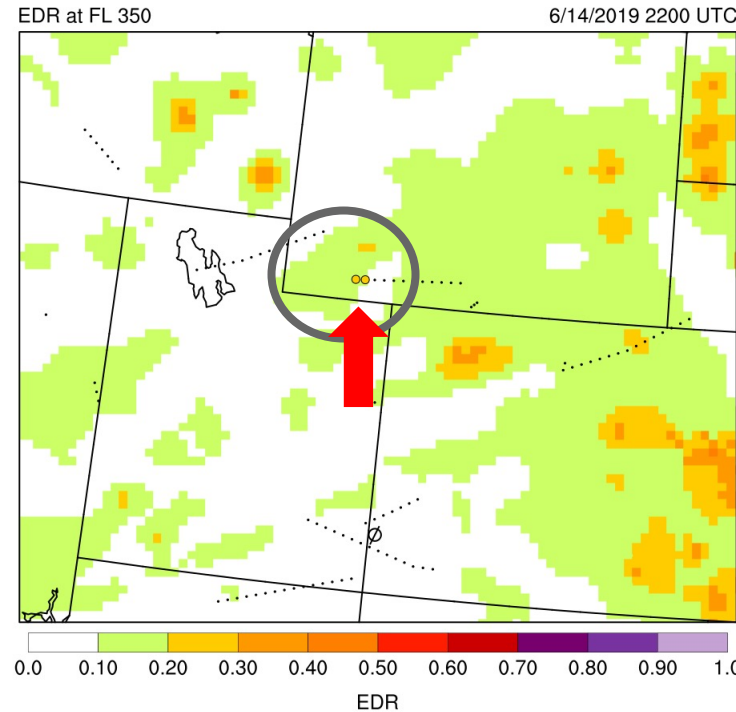


- GTGN real time output at 1645, 1700, 1715 UTC, FL370. Observations from 1645 – 1730 shown in 15 minute valid ranges +/- 2100 ft around FL370 for the 3 plots
- GTGN shows areas of MOG turbulence corresponding to the precise locations of several Mod and Mod-Sev PIREPs, as well as numerous elevated in situ EDR reports in LA, MS and TN over this time window.
- Null in situ EDR reports around these events are in areas GTGN shows as null to light turbulence.
- These times show skill in correctly identifying narrow regions of MOG turbulence and adjacent null turbulence.

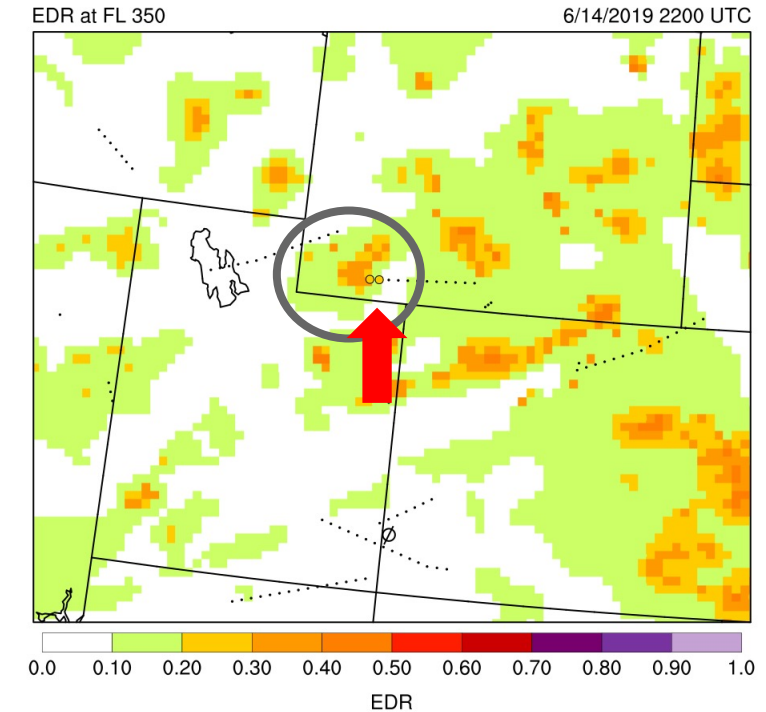
GTGN2: Addition of Lightning data

- Our research has shown that:
 - Lightning characteristics correlate with in-cloud turbulence
 - As lightning frequency increases (intensive convection) so does EDR intensity
- NTDA is currently the main contributor of in-cloud convectively induced turbulence (CIT) in GTGN1
 - Limited by radar coverage
 - sparser radar coverage over the Western US which can result in misses of CIT in these regions
- Lightning Observations are available:
 - over CONUS to fill in where NTDA has sparse coverage
 - Over oceans and globally allowing for GTGN with CIT over expanded domains

Improves nowcast of turbulence in the mountainous western US where Radar coverage is limited



GTGN 1.0

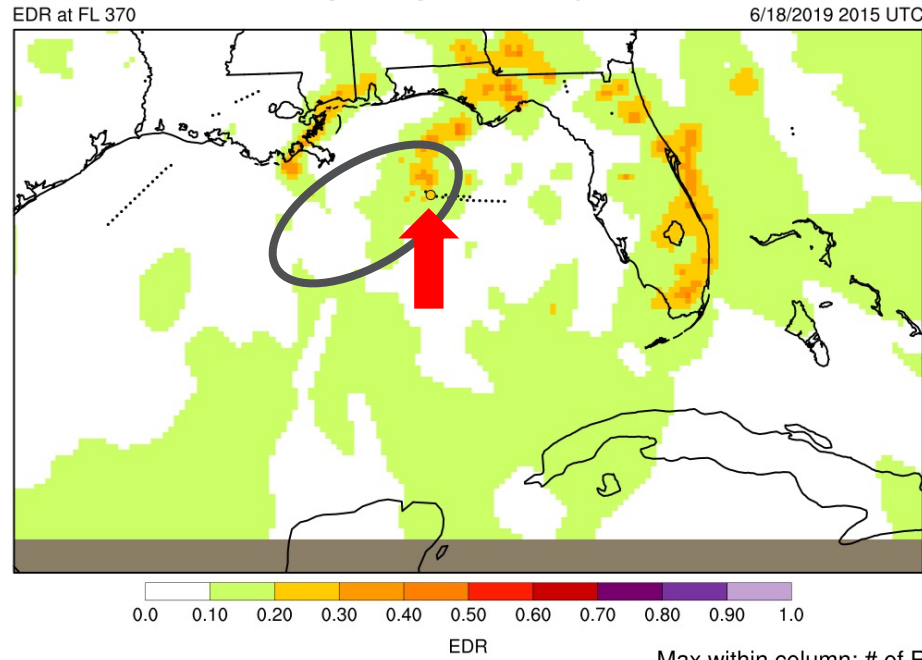


GTGN with Lightning

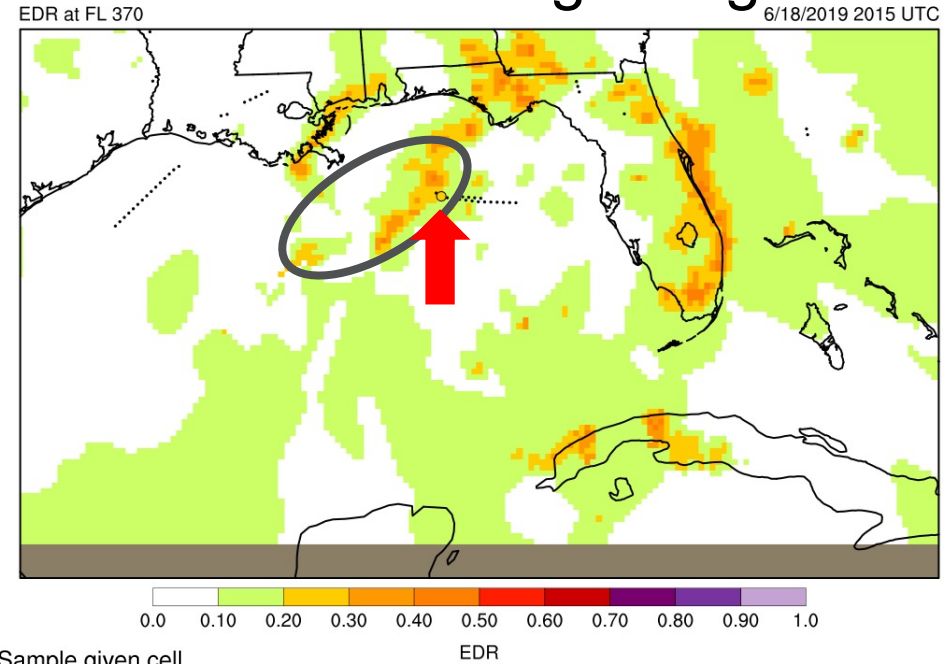
With next 15 minutes of in situ & PIREP observations

GTGN2: Lightning Data Example

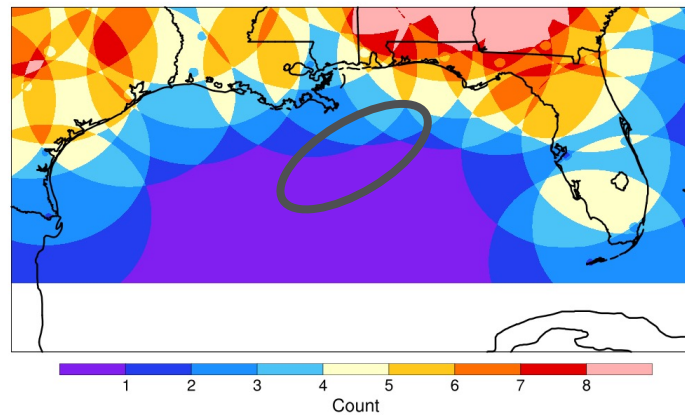
GTGN 1.0



GTGN with Lightning

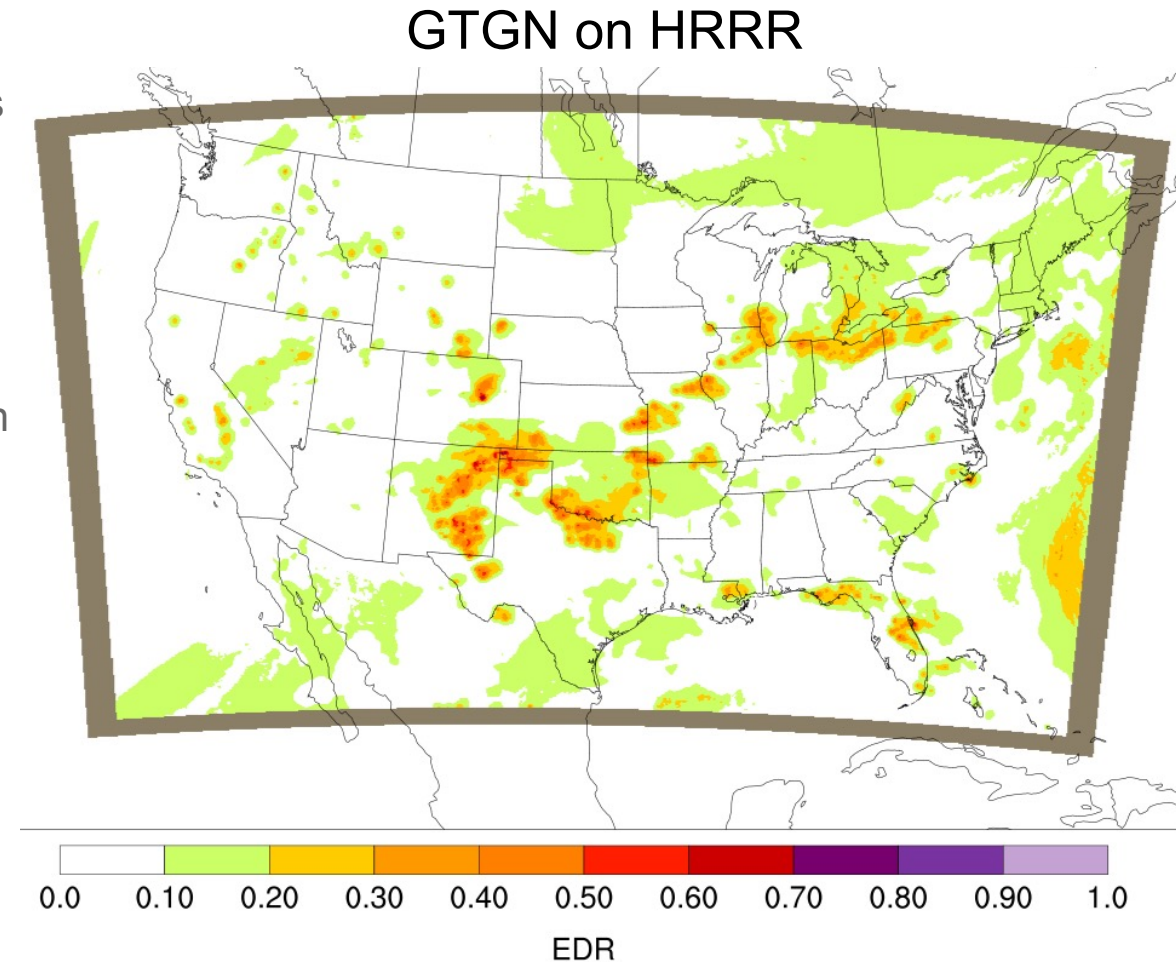
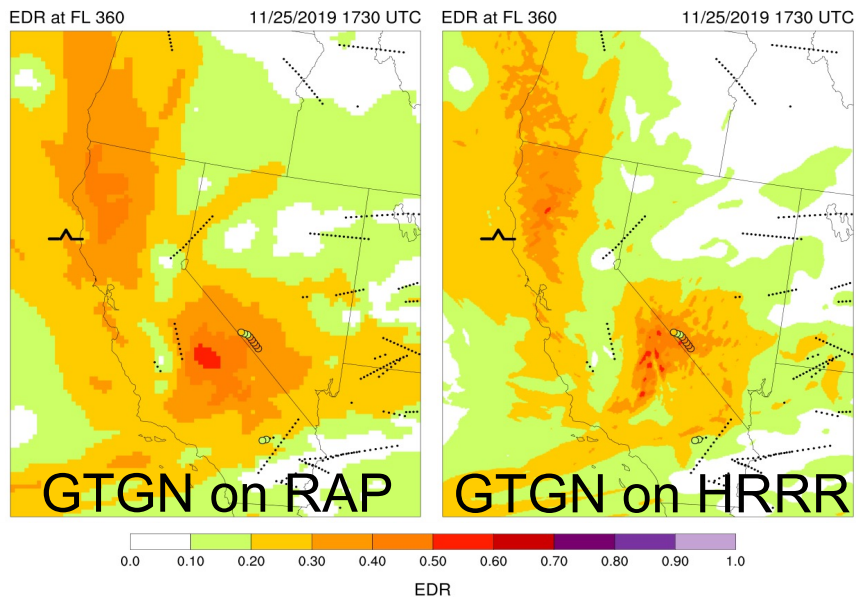


Max within column: # of Radars that Sample given cell



GTGN2: Higher resolution domain

- GTGN2 utilizes:
 - Short term GTG4 forecasts 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

- The Graphical Turbulence Guidance Nowcast (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 pertinent to aviation users
- Rapid updates and real time ingest of turbulence observations provide immediate feedback to aviation users on the state of the atmosphere
- Real time cases show GTGN was able to pinpoint specific regions of MOG turbulence and adjacent areas of null turbulence
- GTGN 1.0 underwent the FAA's TRP and SRM processes and its output is available on a semi-operational basis through LDM feed from NCAR
- Under development at NCAR, GTGN 2.0 will include lightning and higher resolution inputs
- 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!
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