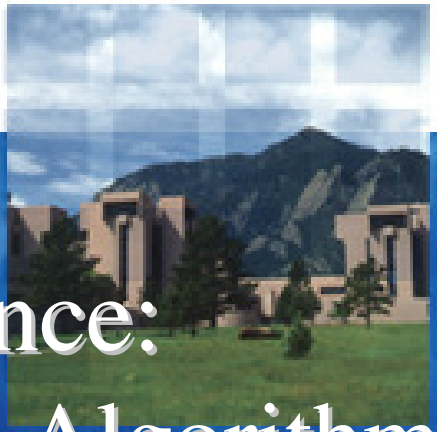


Measuring In-cloud Turbulence: The NEXRAD Turbulence Detection Algorithm

John K. Williams, Greg Meymaris, Jason Craig, Gary Blackburn, Wiebke Deierling, and Frank McDonough

AMS 15th Conference on Aviation, Range and Aerospace Meteorology

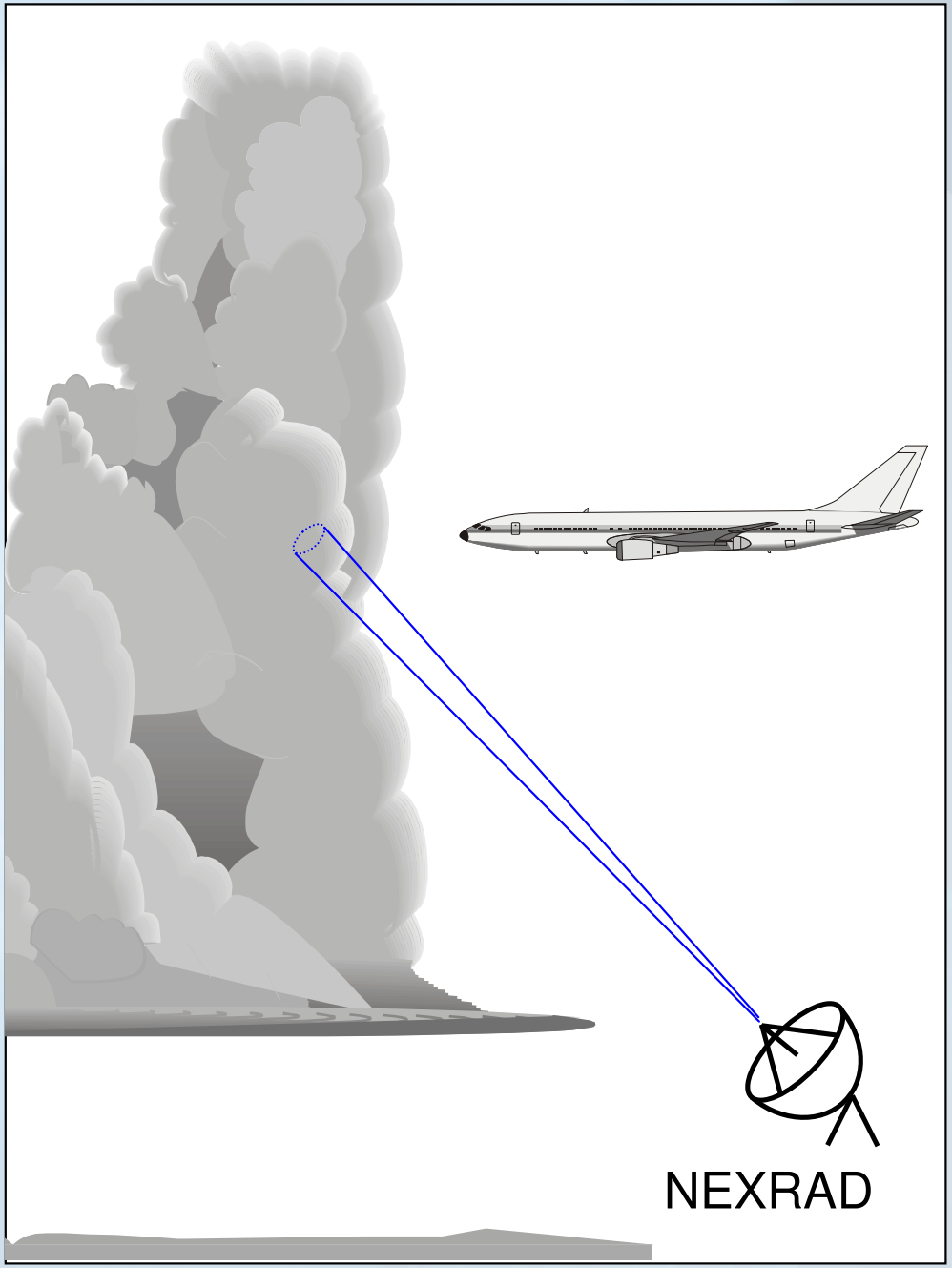
Los Angeles, CA

August 1, 2011

National Center for Atmospheric Research

What is the NTDA?

- The NEXRAD Turbulence Detection Algorithm uses Doppler weather radar data to measure turbulence in clouds, complementing radar reflectivity.



What does NTDA measure?

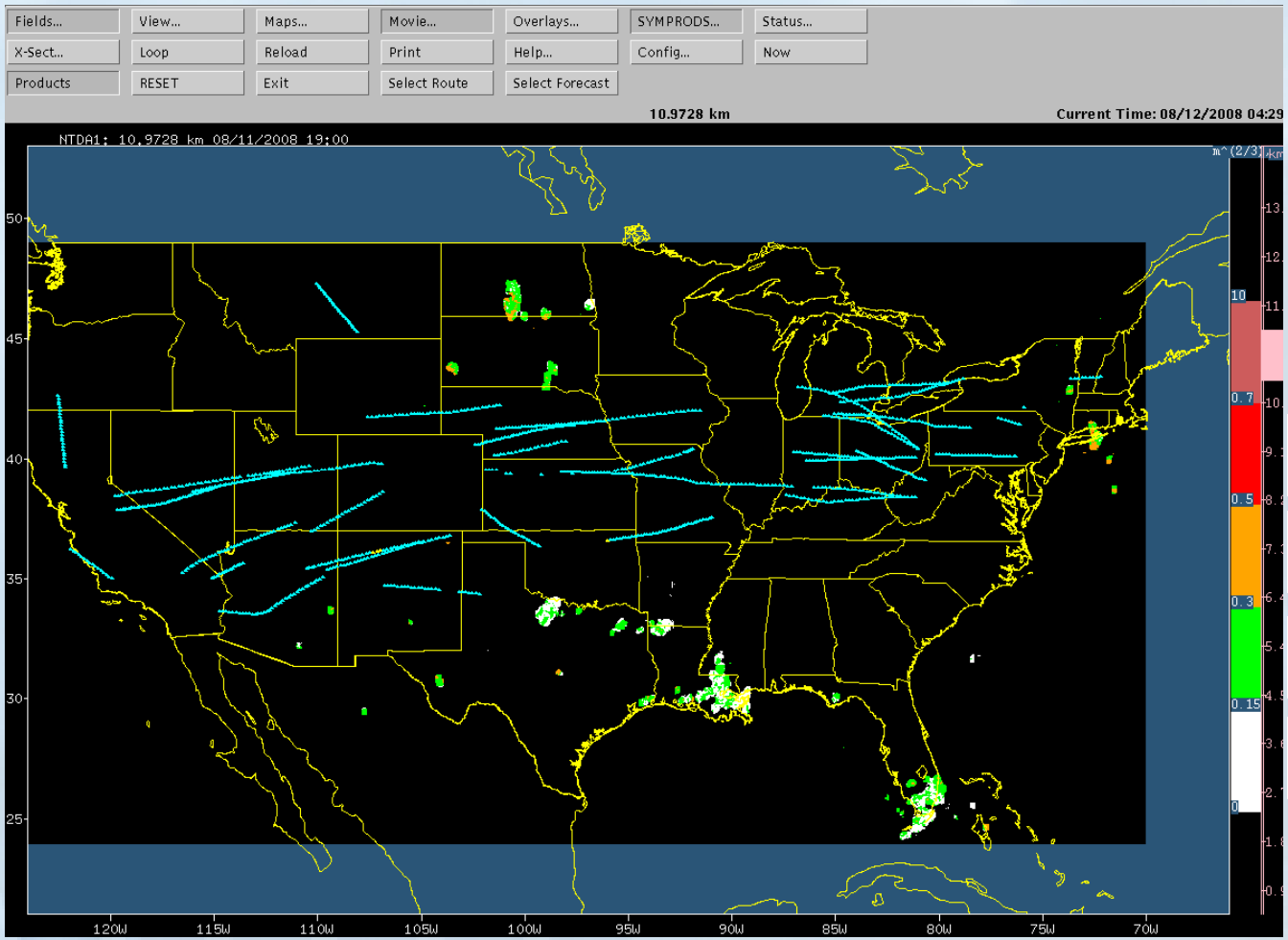
- Atmospheric turbulence: eddy dissipation rate (EDR), $\varepsilon^{1/3}$, $m^{2/3}\,s^{-1}$
  - EDR can be converted to the impact on an aircraft (RMS-g) based on the aircraft type and flight parameters
- Uses spectrum width, which represents radial wind variability within the measurement volume
- NTDA only measures turbulence where sufficient wind-tracing reflectors exist, i.e., in clouds and storms
  - Focus on in-cloud convectively-induced turblence

How rapidly does NTDA update?

- NTDA runs on each sweep of NEXRAD data as it becomes available
- Regions are rescanned every 4 – 8 minutes depending on the volume coverage pattern (VCP) being employed
- Our real-time 3-D mosaic currently runs every 5 minutes, but that's configurable
  - Mosaic algorithm "pushes" measurements onto a 3-D grid, minimizing gaps between sweeps

How fast does turbulence evolve?

- Moderate or severe turbulence in storms may appear quickly and last as little as a few minutes



CIDD research display: NTDA mosaic 6-hr loop on 11 August 2008, 36,000 ft.

Overlaid are *in situ* EDR measurements from United Airlines B-757s

Sev

Mod

Light

Null

How can NTDA data be used?

- Tactical decision support for en-route aircraft
  - Improve situational awareness, airspace utilization, and safety.
  - May help obviate the need for “pathfinder” aircraft after airspace closures
- Measurements may be assimilated into turbulence nowcasts
- May be used as verification “truth” data for turbulence forecasts
- Provides a tool for investigating storm dynamics and turbulence climatology

What is the status of NTDA?

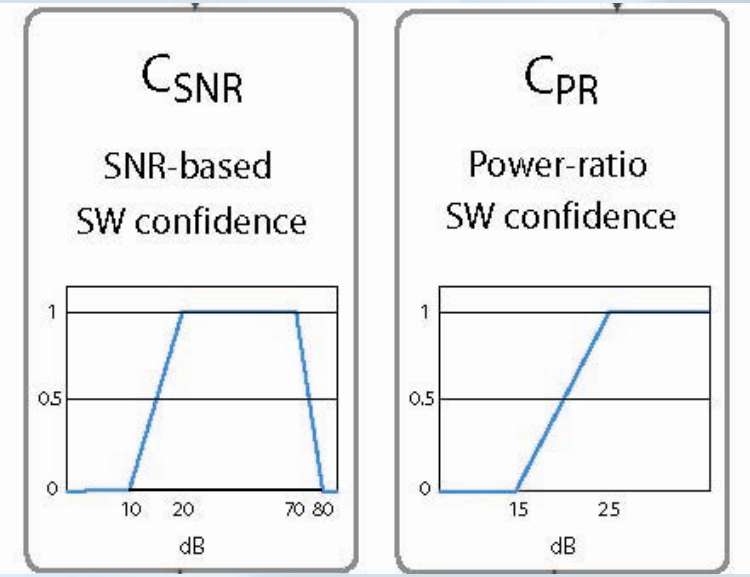
- NTDA-1 demonstrated in real-time 2005 – 2007
  - Displayed to dispatchers and en-route uplinks
- NTDA-1 deployed as part of NEXRAD Open Radar Products Generator Build 10 in 2008
- CONUS NTDA processing and 3-D mosaic running at NCAR since 2008
  - Test deployment to Aviation Weather Center in September 2010
- NTDA-2.5 (dual-pol capable) is being tested
  - Possible 2012 deployment

How does NTDA work?

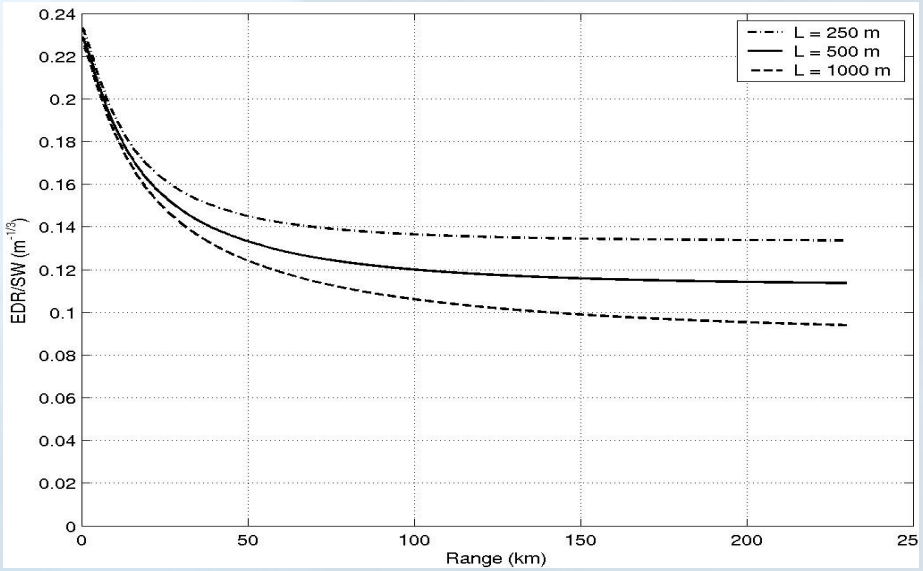
- Contaminated data (sun spikes, artifacts) are detected and censored
- SW measurement quality assessed via fuzzy logic, based on
  - Operational mode for that sweep
  - Signal-to-noise ratio (SNR)
  - Overlaid Power Ratio (PR)
  - Clutter and overlaid clutter contamination
  - Insect contamination
- SW is "scaled" to EDR:

$$\mathrm{EDR}_{\mathrm{raw}}(r) = \mathrm{SW}(r)\, f(r, L_0)$$

- Local confidence-weighted averages are computed



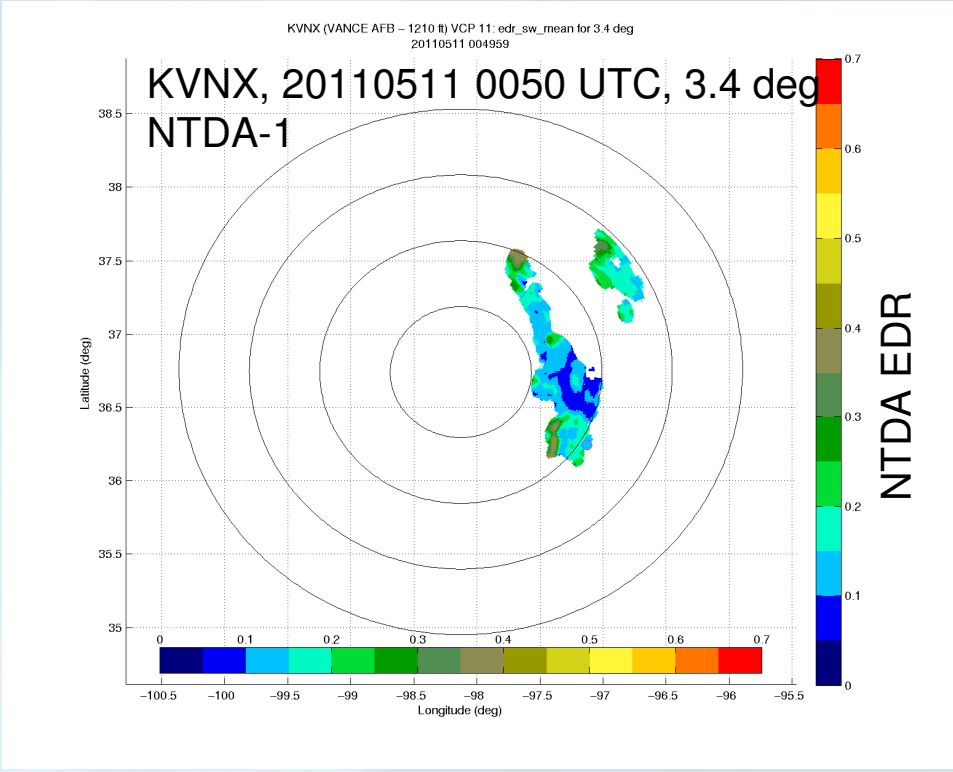
Example confidence "interest maps"

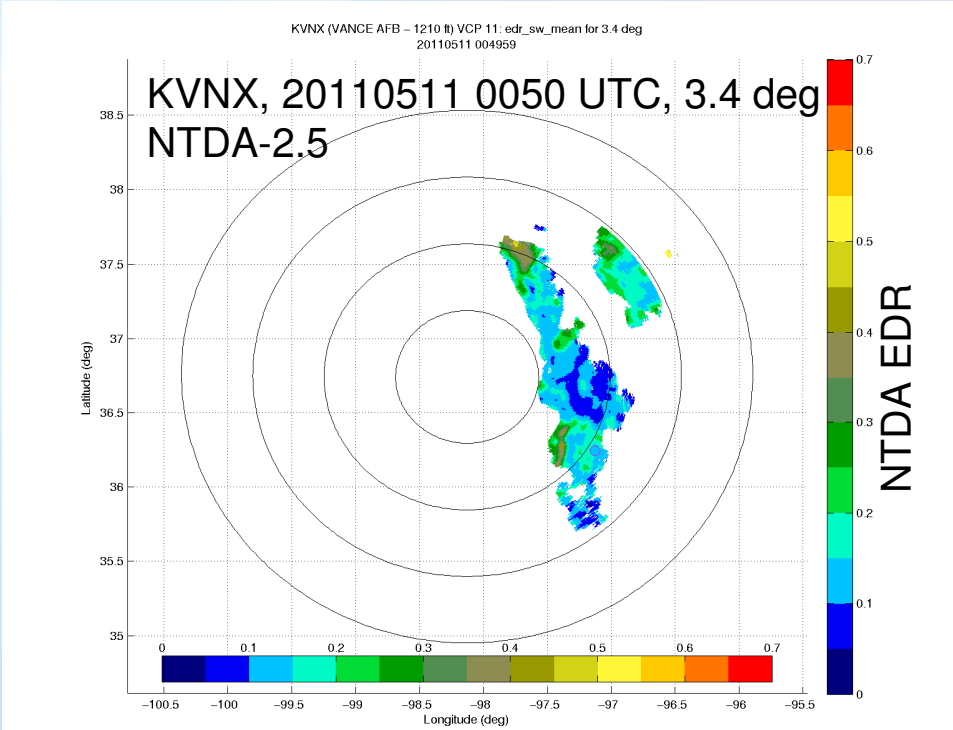


Theoretical NEXRAD "scaling" function, *f*(*r*)

How has NTDA been improved?

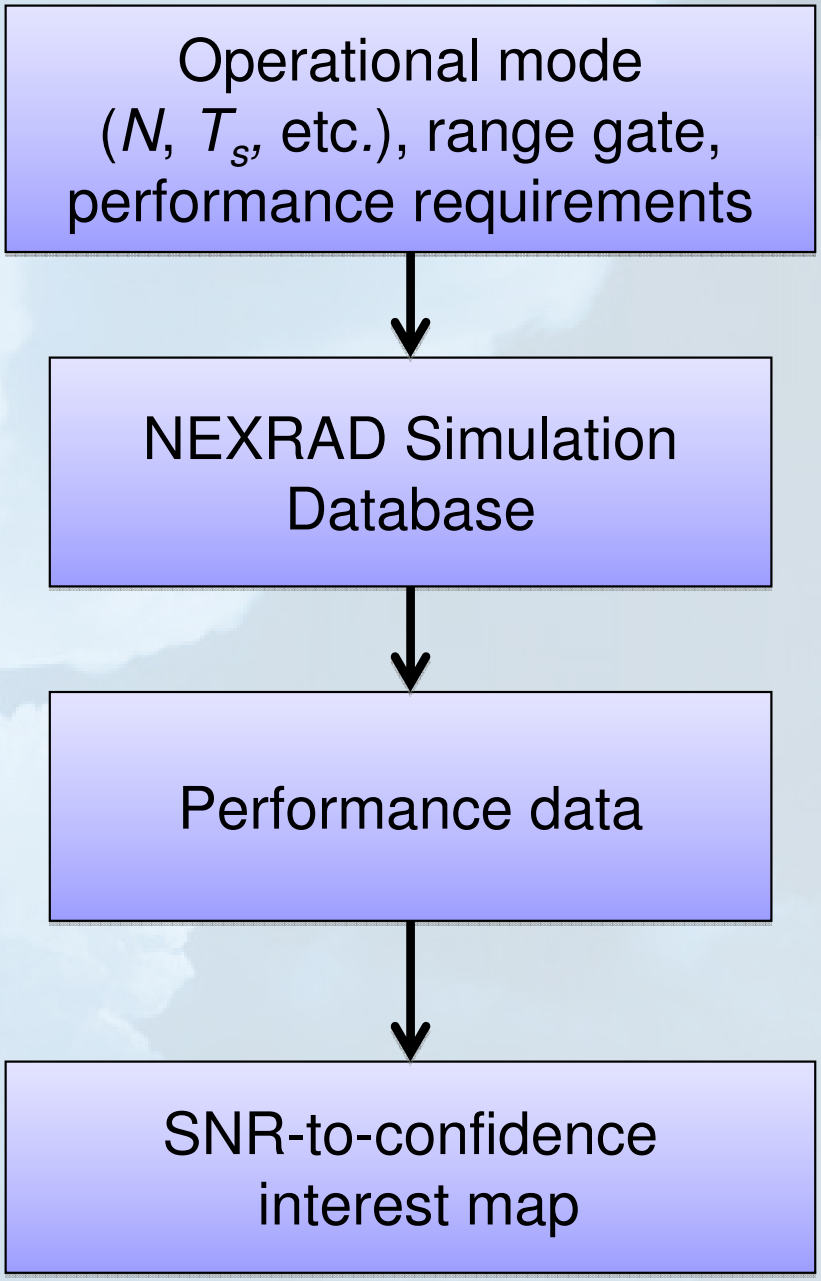
- Code faster and uses less computer memory
- Supports NEXRAD changes (super-resolution, Sachi-Zrnic phase coding, multi-PRF VCPs, dual-pol)
- Provides improved coverage thanks to more refined quality control, e.g., based on SNR





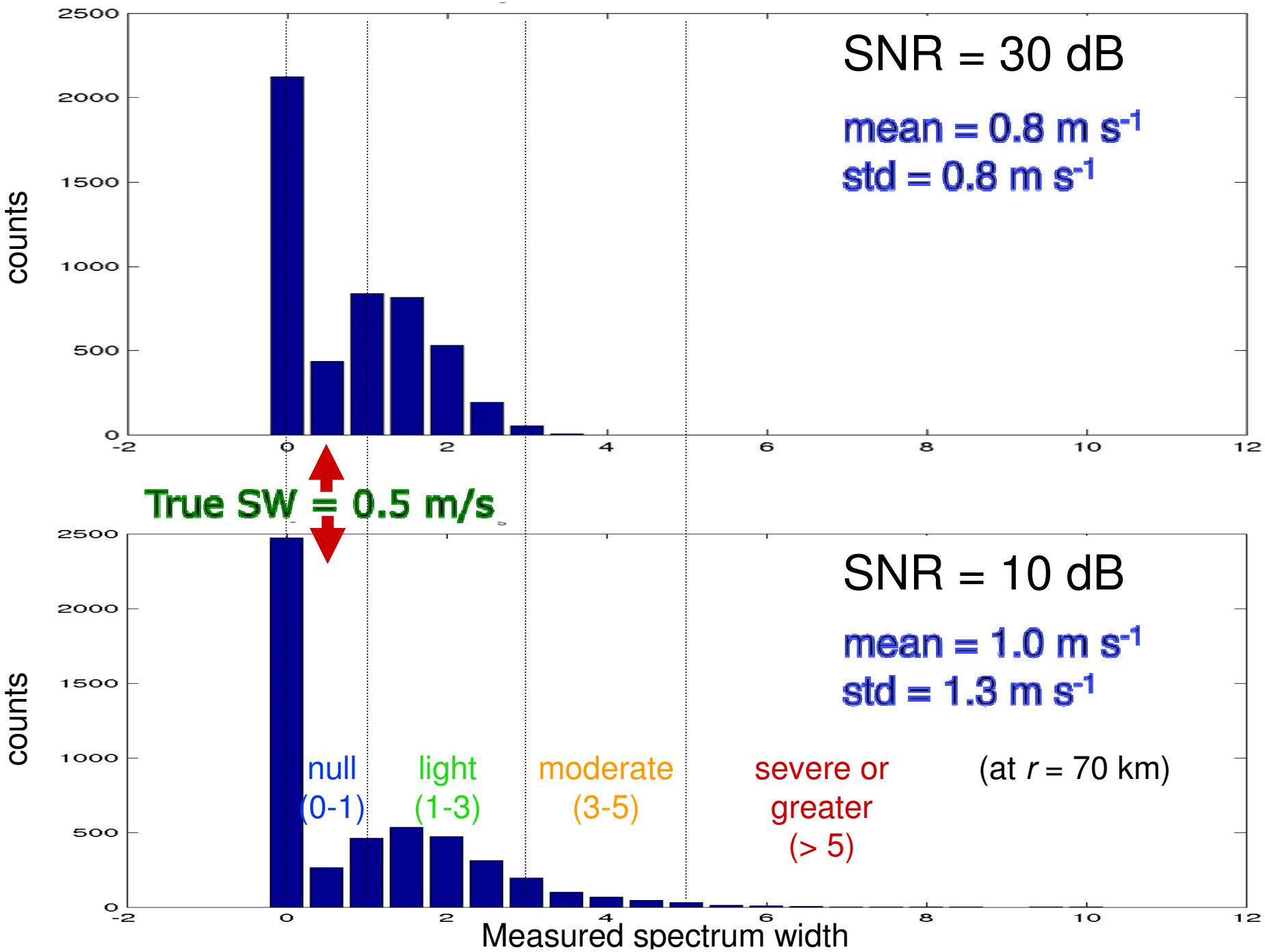
How did the SNR QC improve?

- Replaced previous interest maps that were based on "worst case" for each VCP
- Now compute maps "on the fly" based on exact operational mode (from metadata that accompanies the NEXRAD sweep data)
- Many future NEXRAD changes (e.g., new SW estimation method) may now be handled via simulation database update



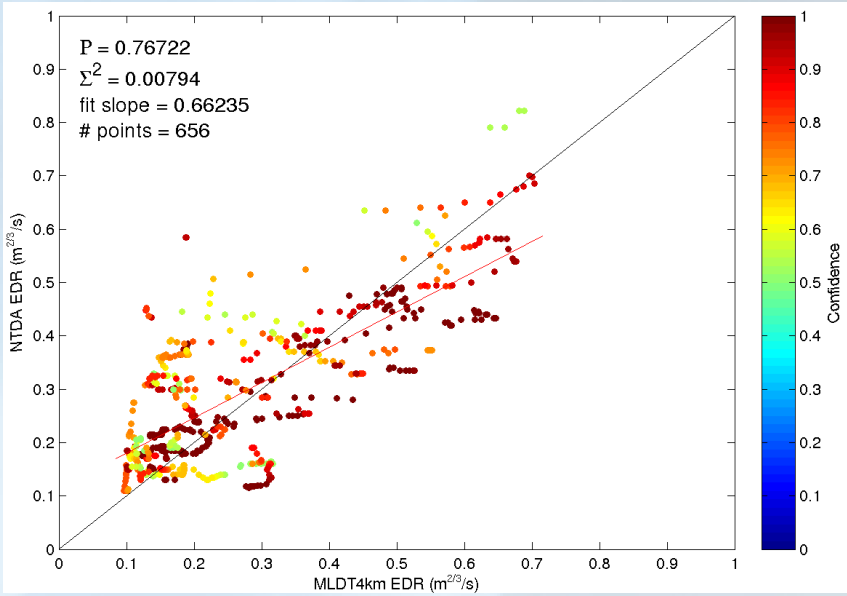
Example: simulation results for VCP 12

N = 40 pulses, T_s = 988μs, SW = 0.5 m s^{-1}, 5000 runs

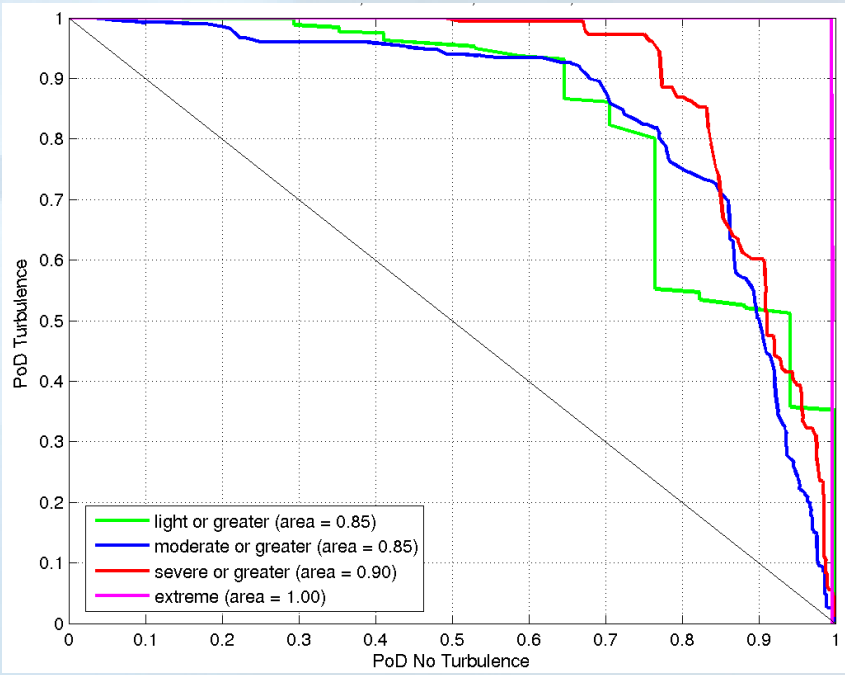


How well does NTDA work?

- Evaluated via
  - Field program data
  - Comparisons with *in situ* EDR data
  - Case studies, including accidents
  - Airline dispatcher feedback
  - Pilot feedback
- NTDA appears to work well, subject to limitations



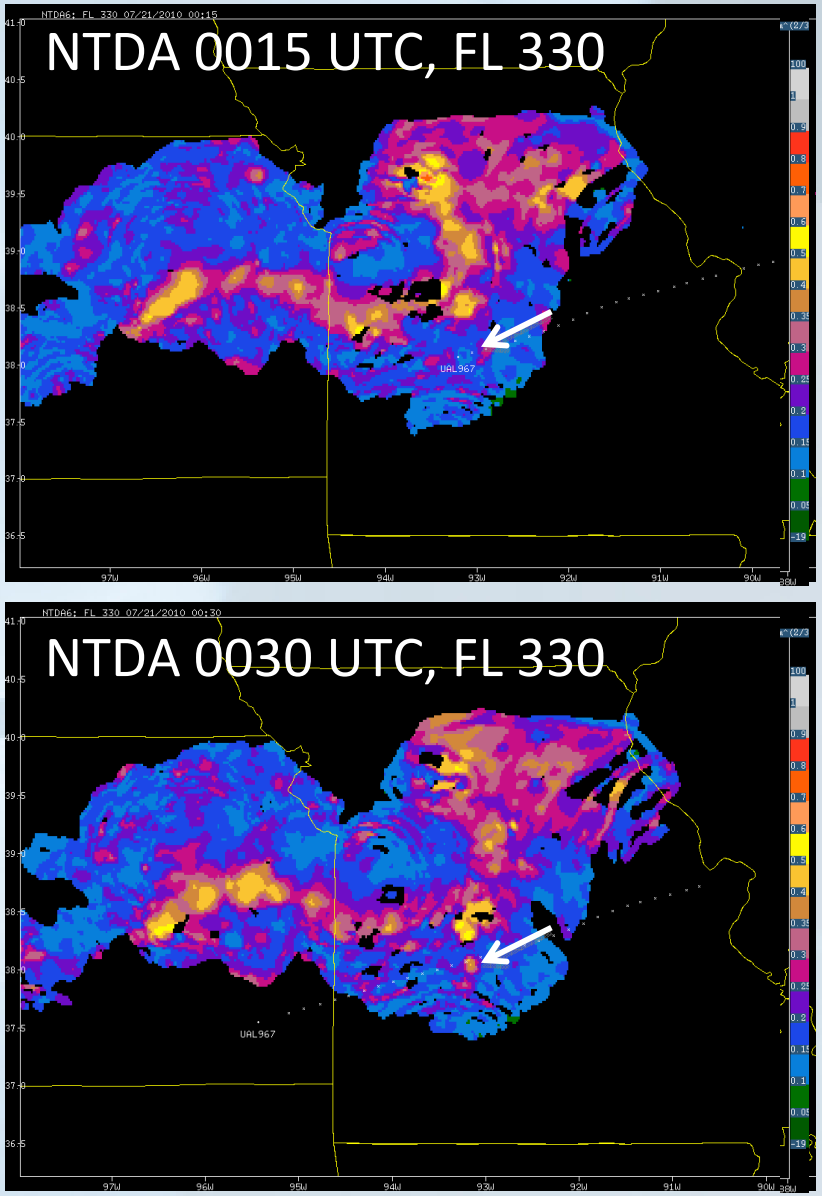
NTDA EDR vs. aircraft EDR from NASA B 757 flight tests (2002)



ROC skill curves for light, moderate, severe and extreme turb.

What are some limitations of NTDA?

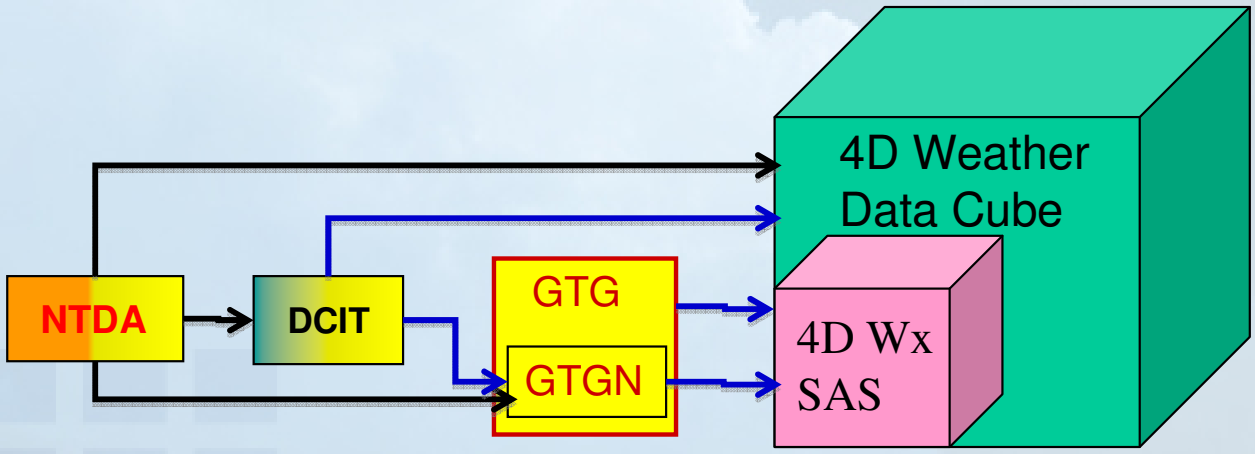
- Coverage is poor near the ground
- Thin shear layers and other phenomena may cause spurious high measurements
- Does not adjust for hydrometeor inertial effects
- Does not detect organized air motions that can also upset aircraft



United 967 turb. encounter,
21 July 2010 00:14 UTC

How will NTDA fit into NextGen?

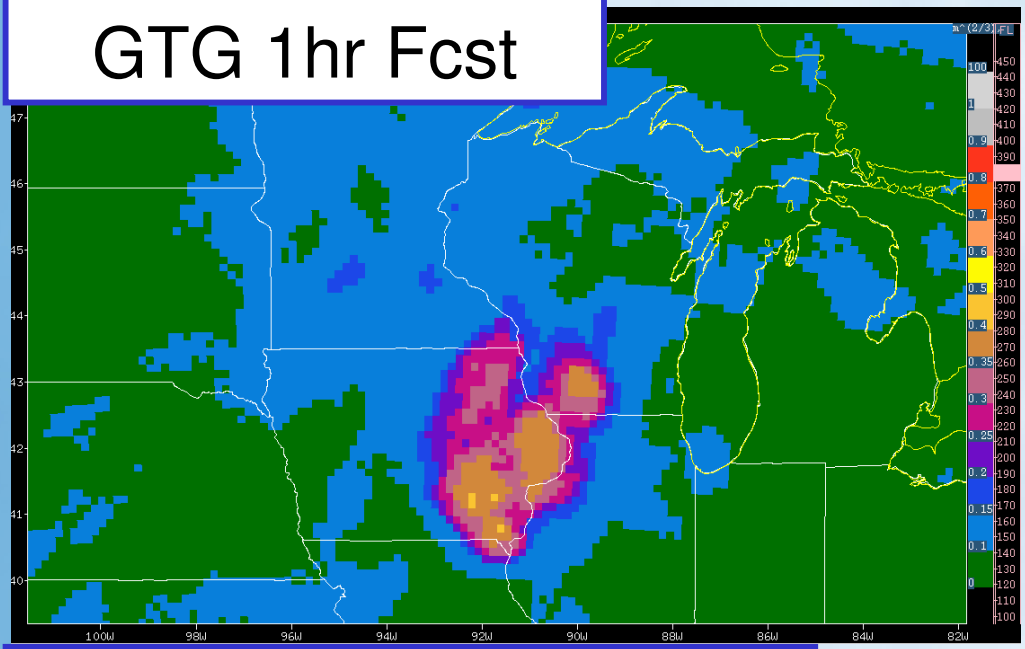
- NTDA 3-D mosaics may be included in the "4-D data cube"
- NTDA 3-D mosaic data are assimilated into the Graphical Turbulence Guidance Nowcast
- May be a candidate for Weather Technology in the Cockpit demonstration



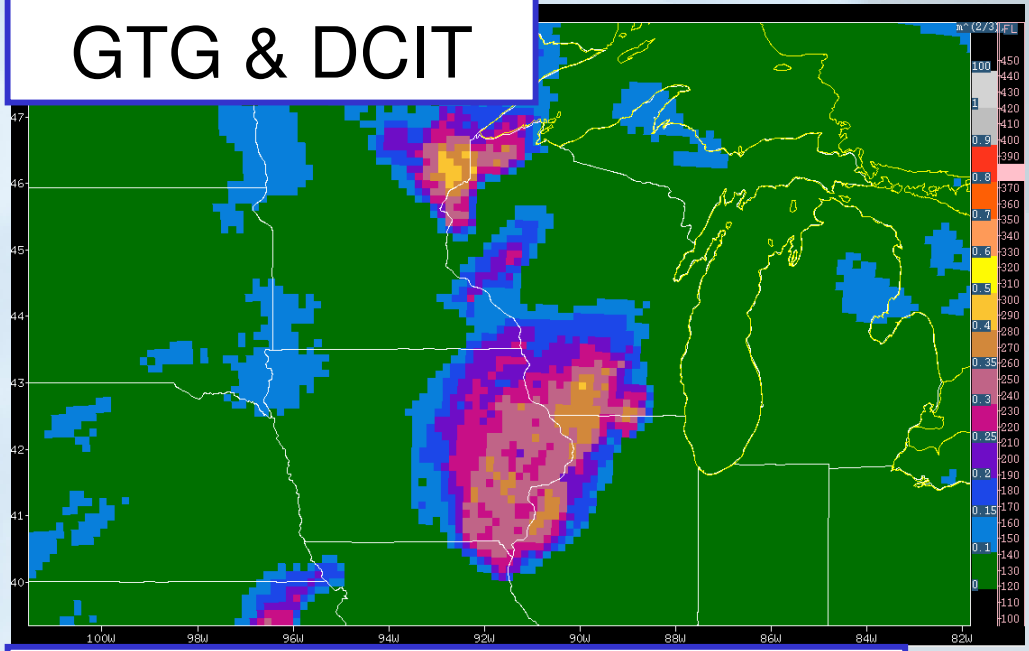
How much does NTDA contribute to GTGN's performance?

NCAR

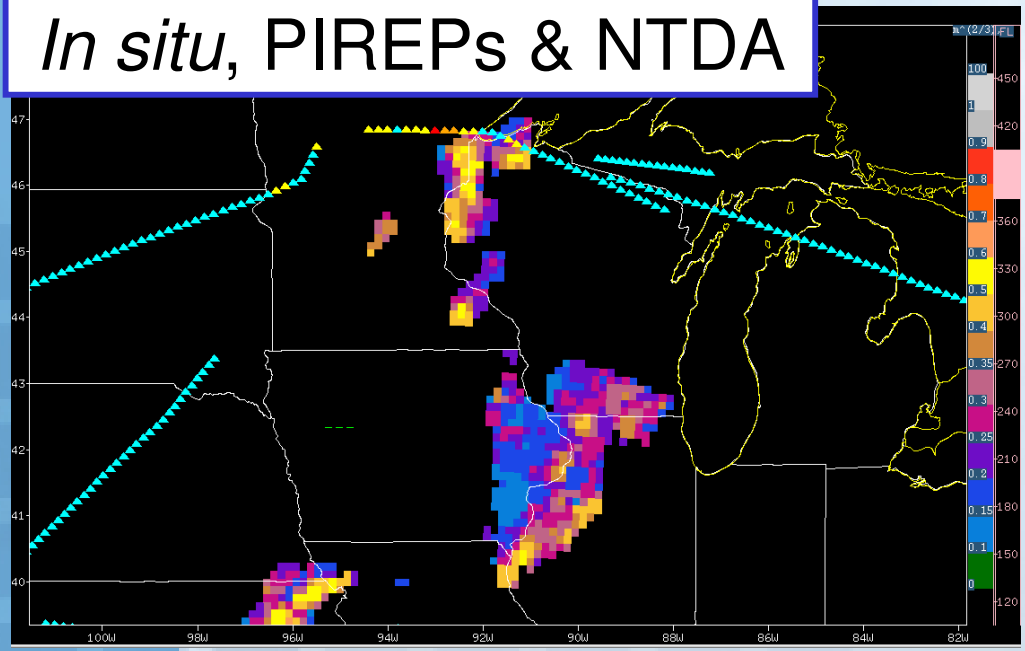
GTG 1hr Fcst



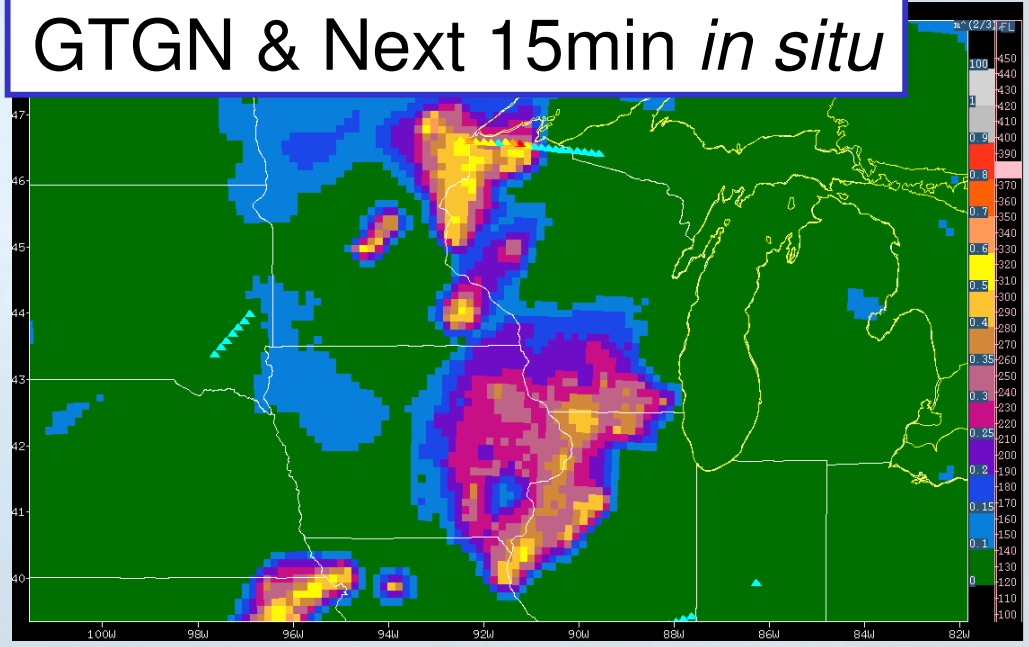
GTG & DCIT



In situ, PIREPs & NTDA



GTGN & Next 15min *in situ*

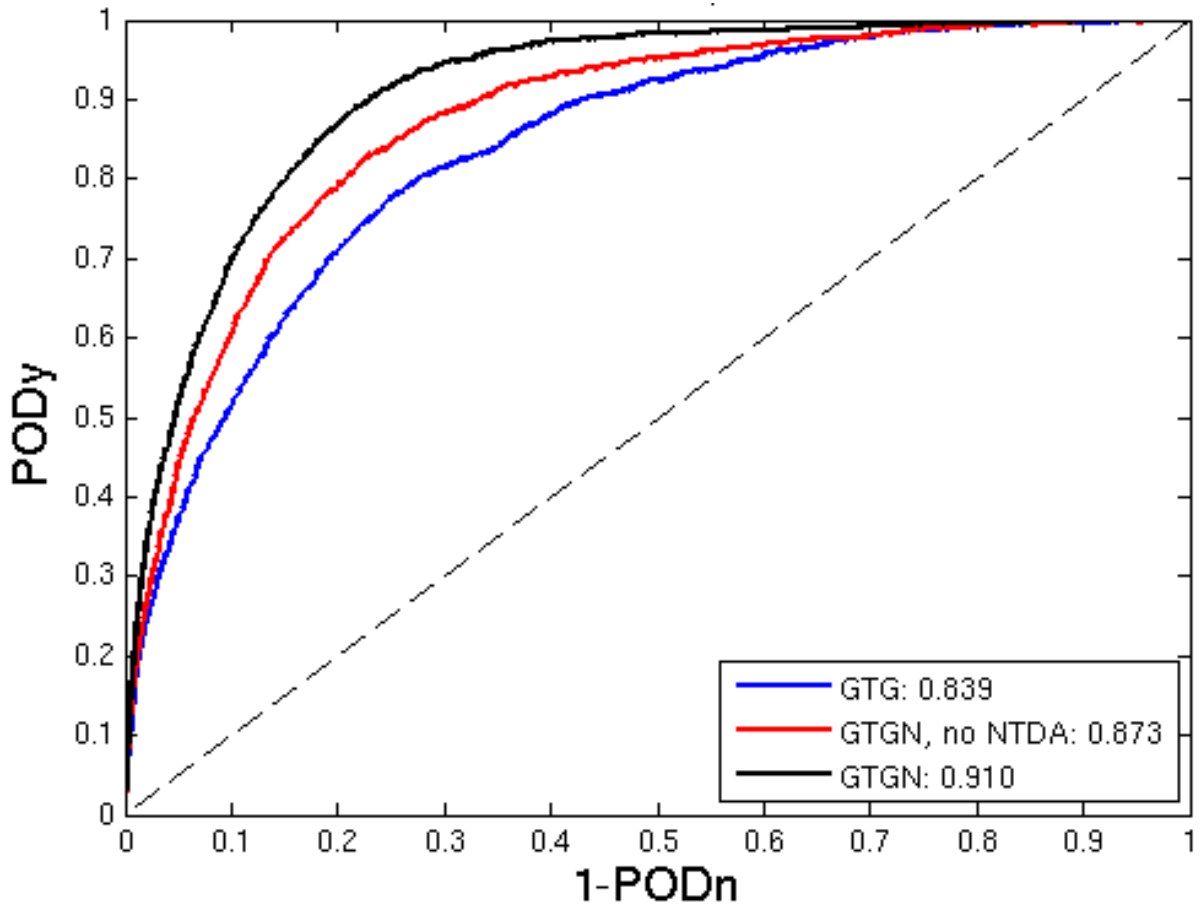


Courtesy of Julia Pearson

NTDA contributions to GTGN

Verification via *in situ* EDR reports

- Evaluation shows that adding NTDA considerably improves GTG Nowcasts

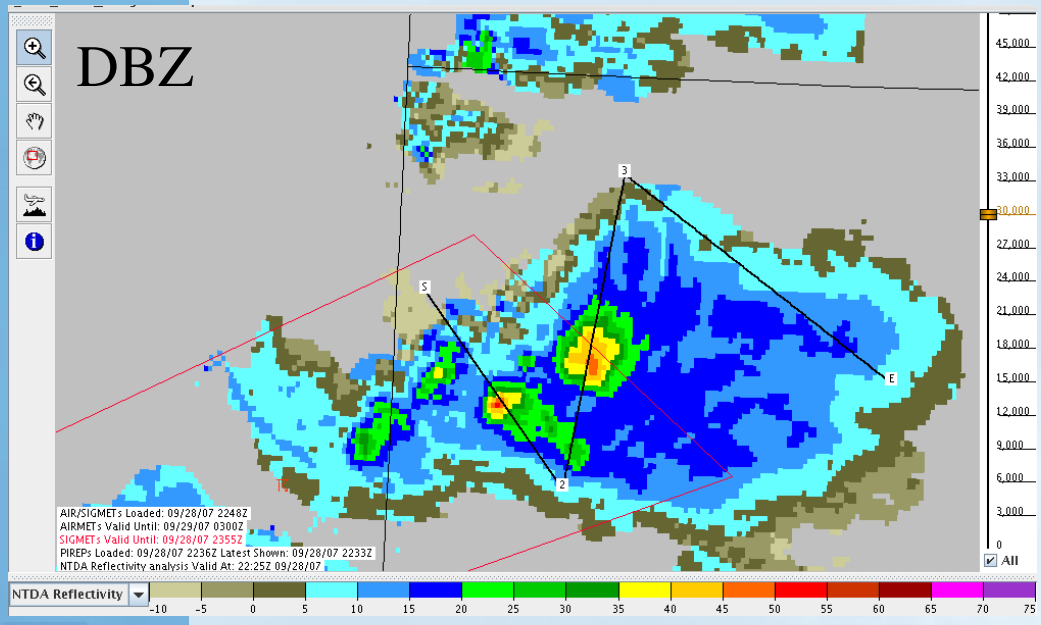


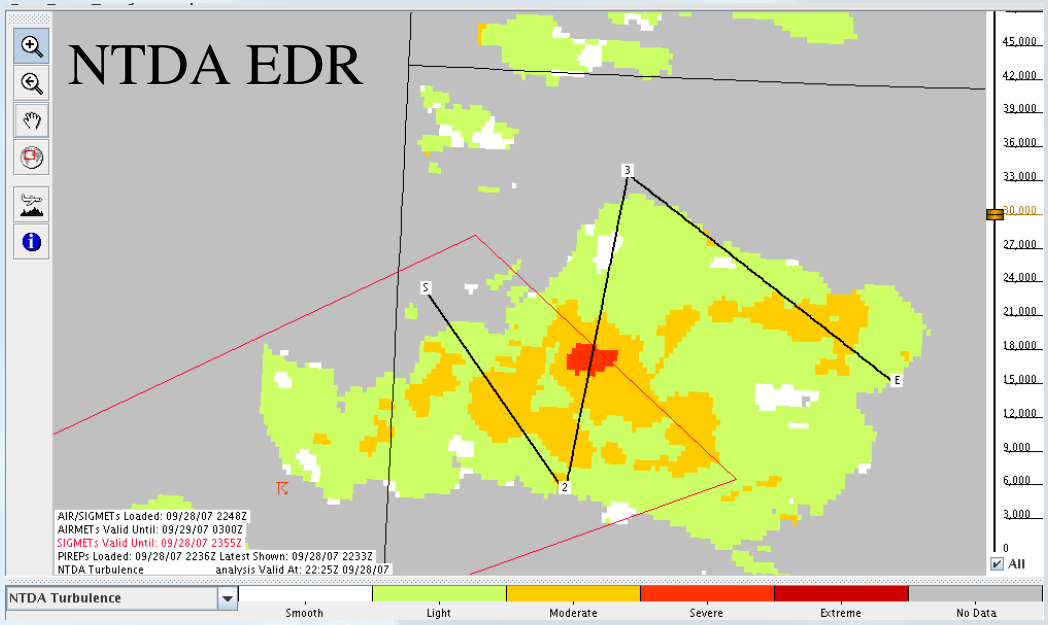
Courtesy of Julia Pearson

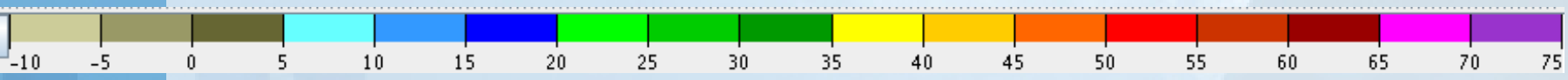
How is turbulence related to reflectivity?

NCAR

- Example: 28 September 2007
  (Flight Level 300; 2 km horizontal resolution)







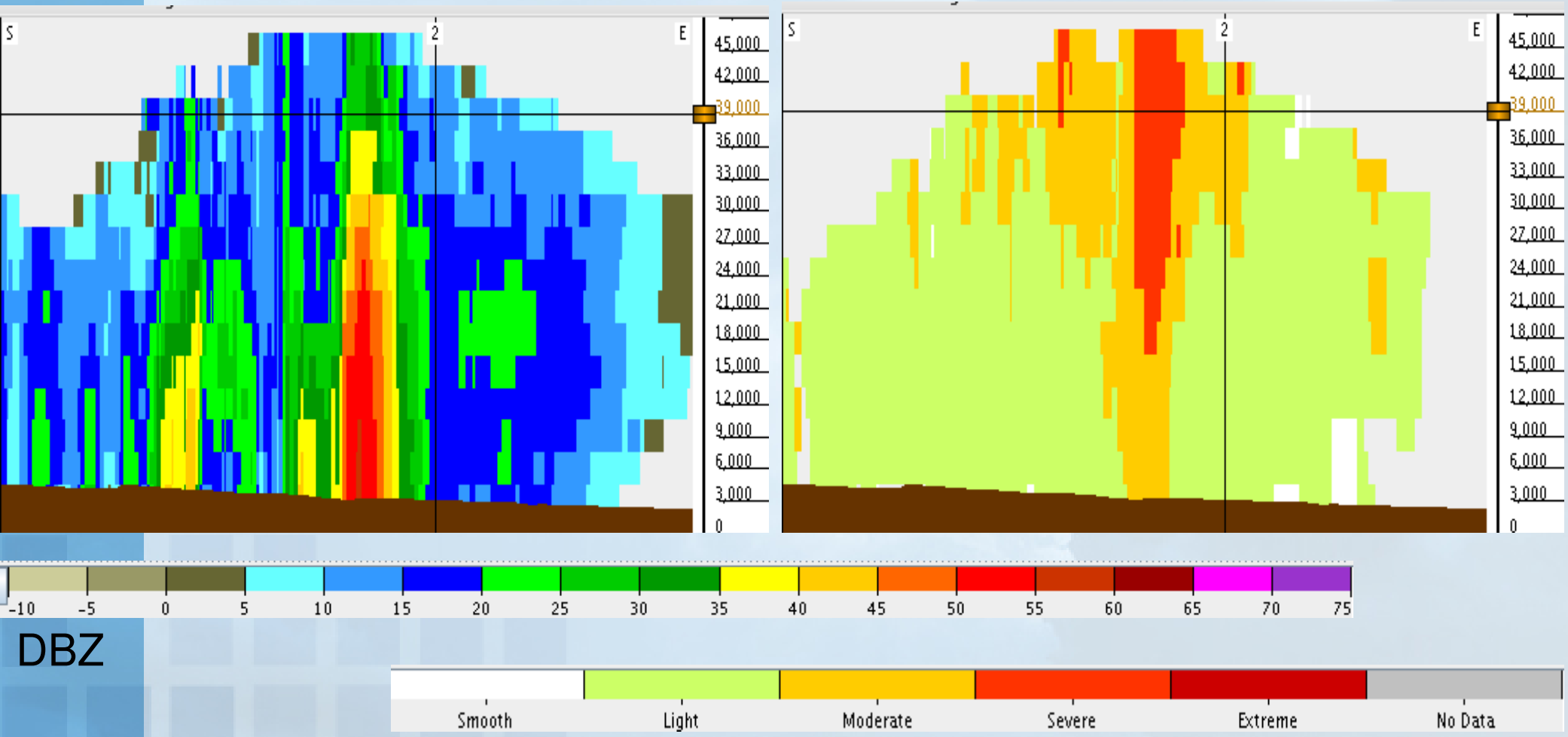
DBZ

NTDA EDR

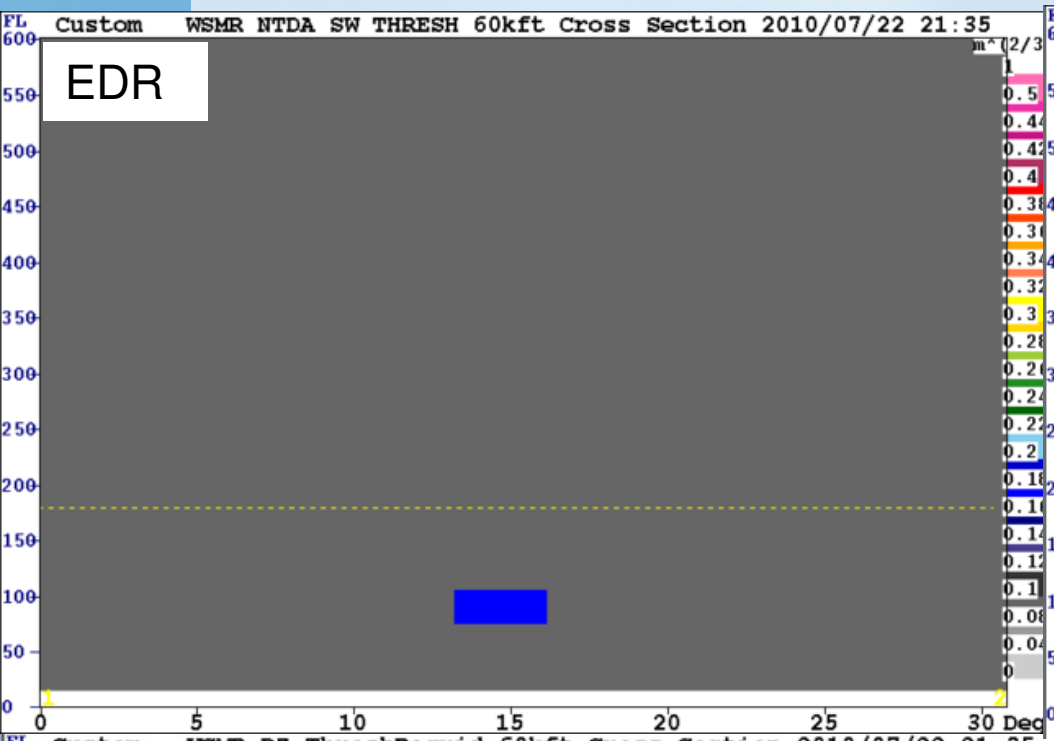
How is turbulence related to reflectivity?

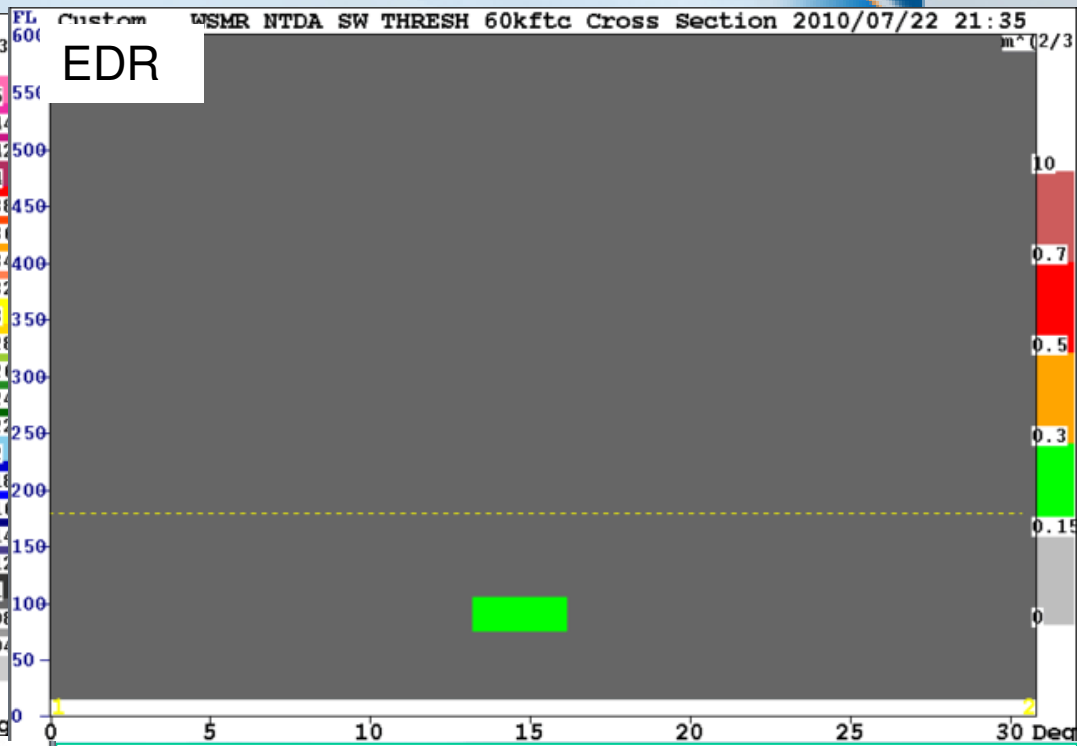
NCAR

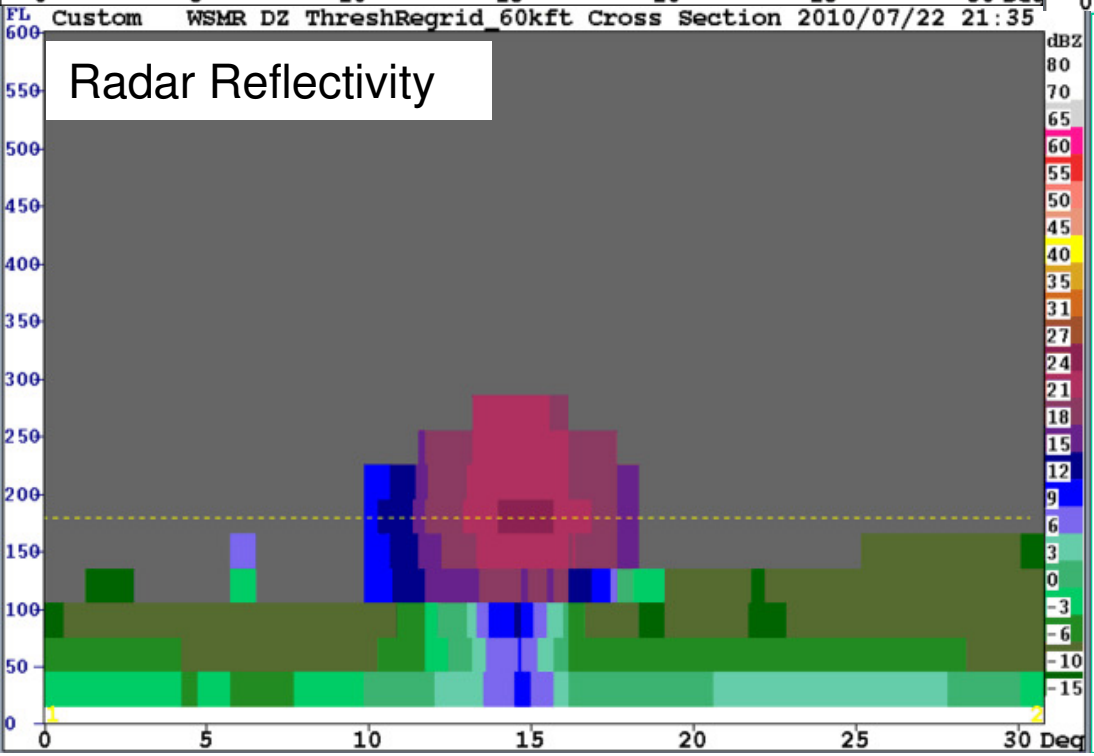
- Example: 28 September 2007
  (3,000 ft vertical resolution)

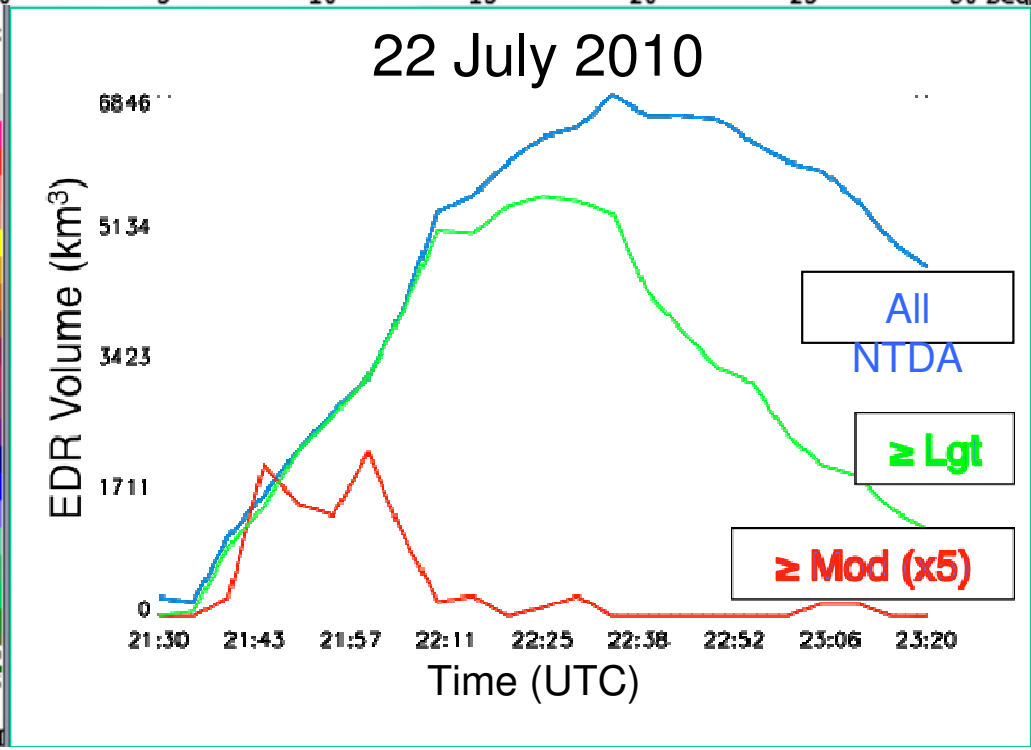


How is turbulence related to storm lifecycle?



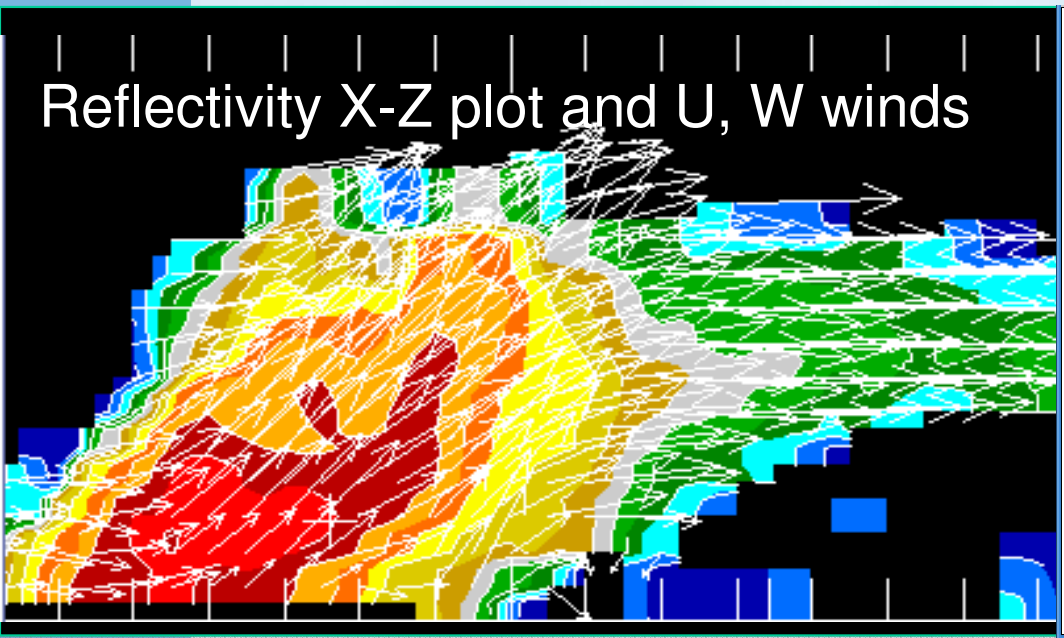


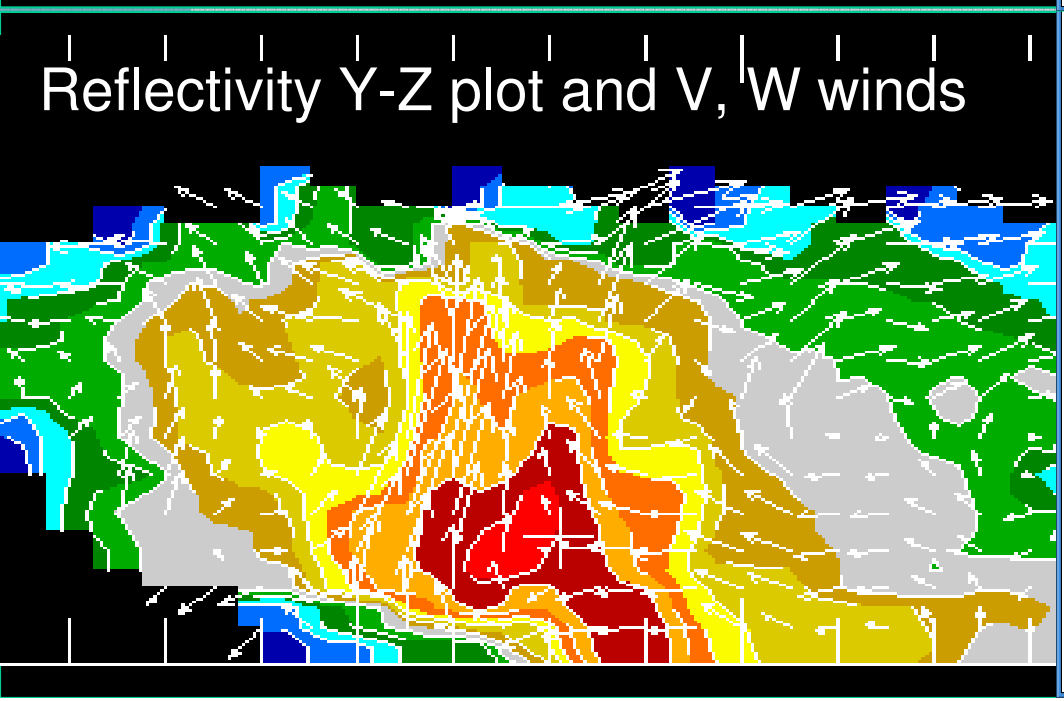


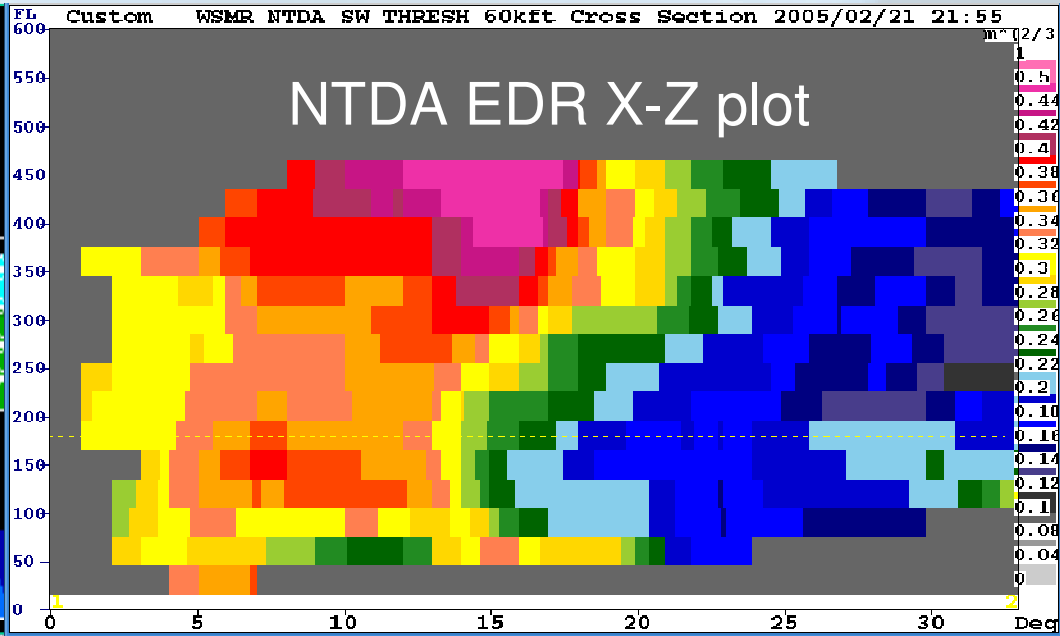


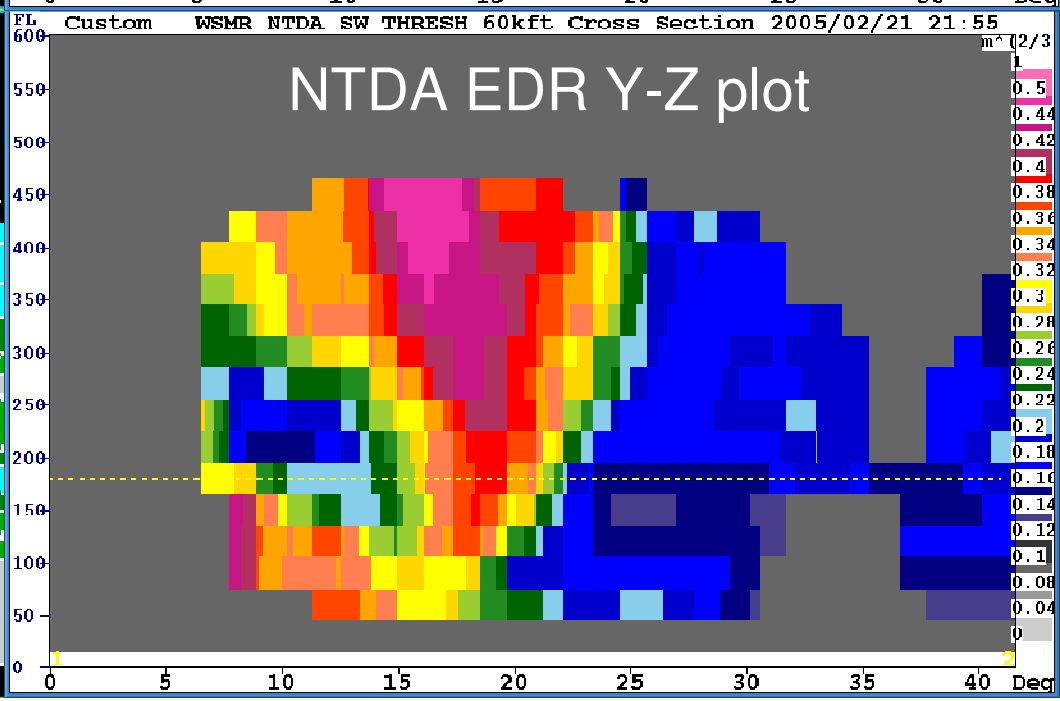
How does turbulence relate to updrafts?

- Example: 21 February 2005, Huntsville, dual-Doppler









How is turbulence related to lightning?

- See Wiebke Deierling's talk in this session, 2.3: "The relationship of in-cloud convective turbulence to total lightning"

What are plans for NTDA?

- NTDA-2.5 testing to be completed in 2012, system prepared for deployment to the Aviation Weather Center
- NTDA-3 would adapt to NEXRAD changes and use dual-pol information to provide low-level quality control, enabling additional coverage
- CONUS NTDA processing and 3-D EDR mosaic demonstration continue at NCAR

Acknowledgement

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