Progress in Development and Validation of WSR-88D Turbulence Algorithm

FAA AWRP Science Review
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National Center for Atmospheric Research
Need for Turbulence Remote Sensing

• Convective turbulence can be localized, variable, highly dynamic, and hard to forecast precisely.
• Tactical turbulence products based upon ground-based and airborne remote sensing could effectively augment in-situ sensors.
• WSR-88D and TDWR radars offer excellent coverage of the CONUS, making an effective turbulence algorithm highly desirable.
• NASA Flight tests: significant convective turbulence often occurs in low reflectivity regions
• **Goal:** Detect operationally significant convective turbulence events in low-reflectivity regions
Case study: 17 November 2002, 2300 UTC

- Canadair CL-600-2B19 (CRJ-2) encountered extreme turbulence in descent to Washington National Airport.
  - Wing down bending limit exceeded by 10%.
  - No structural damage and no injuries.
- Pilots: Airborne radar on, nothing painted (< 20 dBZ)
- Greg Salottolo, NTSB, contacted NCAR to consult; provided KAKQ and FDR data.
  - The investigation is ongoing—no cause or probable cause of the incident has been determined.
  - The FDR data provided by NTSB are preliminary.
  - For Official Use Only. Not for public release.
Case study: CRJ aircraft

Canadair CL-600-2B19 (CRJ-2)
Case study: Synoptic situation

GOES 8 infrared image (Channel 4), 2302Z.
(Annotation by Tara Jensen.)
Case study: SIGMET from Flight Release

SIGMET issued November 17, 2002 at 1920Z and valid until 2320Z.

Occasional severe turbulence between 13,000 and 28,000 feet due to windshear associated with jetstream and middle / upper trough.
Case study: ITFA diagnosis (FL180)

ITFA  Powell optimized wts
flight level(ft) =18000.
score= 1.563 count= 24 PODY,N,TSS= 0.667 0.000 -0.333

ITFA values for 18,000 ft and time 2300Z.
Case study: FDR data - accelerations

-0.5 to +0.5 g

-1.6 to +3.4 g in 2 seconds

Lateral (top) and Normal accelerations (bottom)
Case study: FDR data – Alt. and airspeed

Altitude (top) and Airspeed (bottom)
Case study: FDR data – Temp. and $\sigma_g$

Temperature (top) and stdev. normal load (bottom)
Case study: Radar data - reflectivity

NEXRAD reflectivity (dB) at 2.4°
Case study: Radar data - reflectivity

NEXRAD reflectivity (dB) at 2.4°
Case study: Radar data – velocity

NEXRAD radial velocity (m/s) at 2.4°
(KAKQ – 22:00:30 Z)
Case study: Radar data – velocity

NEXRAD radial velocity (m/s) at 2.4°
(KAKQ – 22:00:30 Z)
Case study: Radar data – spectrum width

NEXRAD spectrum width (m/s) at 2.4°
Case study: Radar data – spectrum width

NEXRAD spectrum width (m/s) at 2.4° (KAKQ – 22:00:30 Z)
Case study: Radar data – NCAR EDR

NCAR 2nd moment EDR (m/s) from 2.4° SW (KAKQ – 22:49, 22:55; 22:06, 22:12 Z)
Case study: Radar data – NCAR EDR

NCAR 2nd moment EDR (m/s) from 2.4° SW
(KAKQ – 22:00:30 Z)
Case study: Radar data – stdev. velocity

NEXRAD stdev. radial velocity (m/s) at 2.4° (KAKQ – 22:00:30 Z)
CASE STUDY:

SUMMARY

• Operationally significant turbulence encountered
• Low reflectivity case – no warning from airborne radar
• NEXRAD radar 105 km away detected turbulence
• WSR-88D turbulence algorithm would have had clear tactical value
WSR-88D Level-II Data

Computed quantities

SNR
signal-to-noise ratio

VE confidence

SW confidence

EDR estimation methods

Second moment
Scaled second-moment method

Combined
First and second moment combined method

Dimensional
Various dimensionally-correct quantities

Structure function
Velocity structure functions fit to theoretical curves

Final product

Aviation Hazard Map

“Fuzzy logic” algorithm methodology
Problem: SW field contains too many zero values
Mitigation: Omit all zero values
Problem: “Glitches” in SW and VE fields
Mitigation: Use trimmed statistics; assign confidence based on local SW variance
Example: SW Confidence

SW confidence as a function of SNR

SW confidence as a function of $\sigma$(SW)

SW confidence as a function of SW
All-flight EDR comparison: NCAR combined first and second-moment EDR (1 km disc) vs. in-situ EDR; with minimal QC
All-flight EDR comparison: NCAR combined first and second-moment EDR (1 km disc) vs. in-situ EDR; with more extensive QC
- Ongoing verification of NCAR's WSR-88D algorithm using various field program data sets & NTSB cases
- Presentation of NCAR algorithm design and preliminary results to NE X RAD TAC.
- Adapting NCAR algorithm to run on TD WR
  - With Lincoln Labs, use ITWS data to identify turbulence cases for analysis
- (Long term) Development of data quality enhancements using I, Q data and spectral processing.
Persistent Hazard Detection
1:07, 15 km before encounter
Reflectivity < 20 dBZ
Viability of Radar TRS, cont.

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<td>228-04 - u</td>
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<td>I</td>
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<td>230-08 - 2 m</td>
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**Key**
- r - registration poor
- u - underestimate
- o - overestimate
- m - marginal miss
- 0 - no tilt only
- 1 - 1 tilt only
- ? - not enough data
- n - non-validated detection (moved off)
- - consensus agreement

**Statistics**

- **PODyes**
  - $\text{PODyes} = \frac{34}{34+8}$
  - $\text{PODyes} = 80.95\%$

- **NAR**
  - $\text{NAR} = \frac{4}{34+4}$
  - $\text{NAR} = 10.53\%$

- **PODno**
  - $\text{PODno} = \frac{9}{4+9}$
  - $\text{PODno} = 69.23\%$

- **% correct**
  - $\text{% correct} = \frac{(34+9)}{(34+9+4+8)}$
  - $\text{% correct} = 78.18\%$

*NASA 2002 flight test contingency table*
The End