The NEXRAD Turbulence Detection Algorithm (NTDA): An Aviation Weather Application

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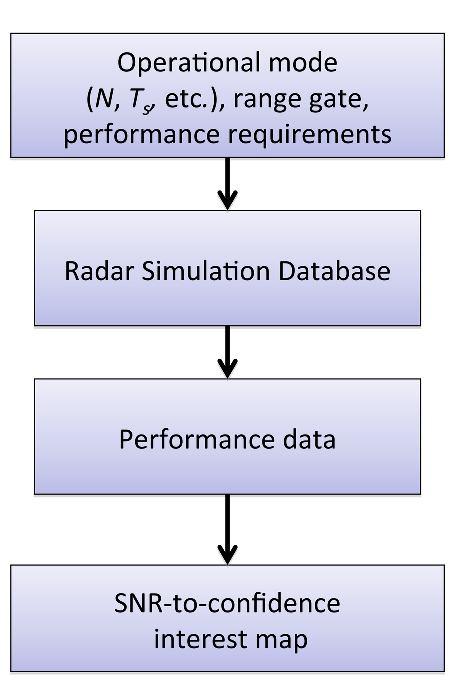
Introduction

Turbulence associated with thunderstorms poses a significant hazard to aviation [1]; in fact, convective turbulence has been identified as responsible for a significant proportion of all turbulence-related aircraft accidents [2,3]. The FAA-sponsored automated turbulence forecast product, Graphical Turbulence Guidance (GTG, [4]), does not forecast convective turbulence, and radar reflectivity does not indicate its location or severity. The NEXRAD Turbulence Detection Algorithm (NTDA) uses information from the U.S. network of WSR-88D (NEXRAD) radars to provide rapid-update, 3-D mosaics of in-cloud turbulence. NTDA was deployed on all NEXRADs in ORPG Build 10 (ca. 2008) and has since been updated to accommodate ORDA changes. NTDA turbulence maps are suitable for tactical use by pilots and airline dispatchers, and will help provide a new GTG Nowcast capability for the nation's next-generation air transportation system (NextGen). It may also provide useful information about storm dynamics.

Algorithm

NTDA processes data from each NEXRAD tilt, deriving turbulence as eddy dissipation rate (EDR) from spectrum width (SW) measurements. SW is very sensitive to contamination, so NTDA also utilizes reflectivity, radial velocity and metadata to perform extensive quality control. The steps are as follows:

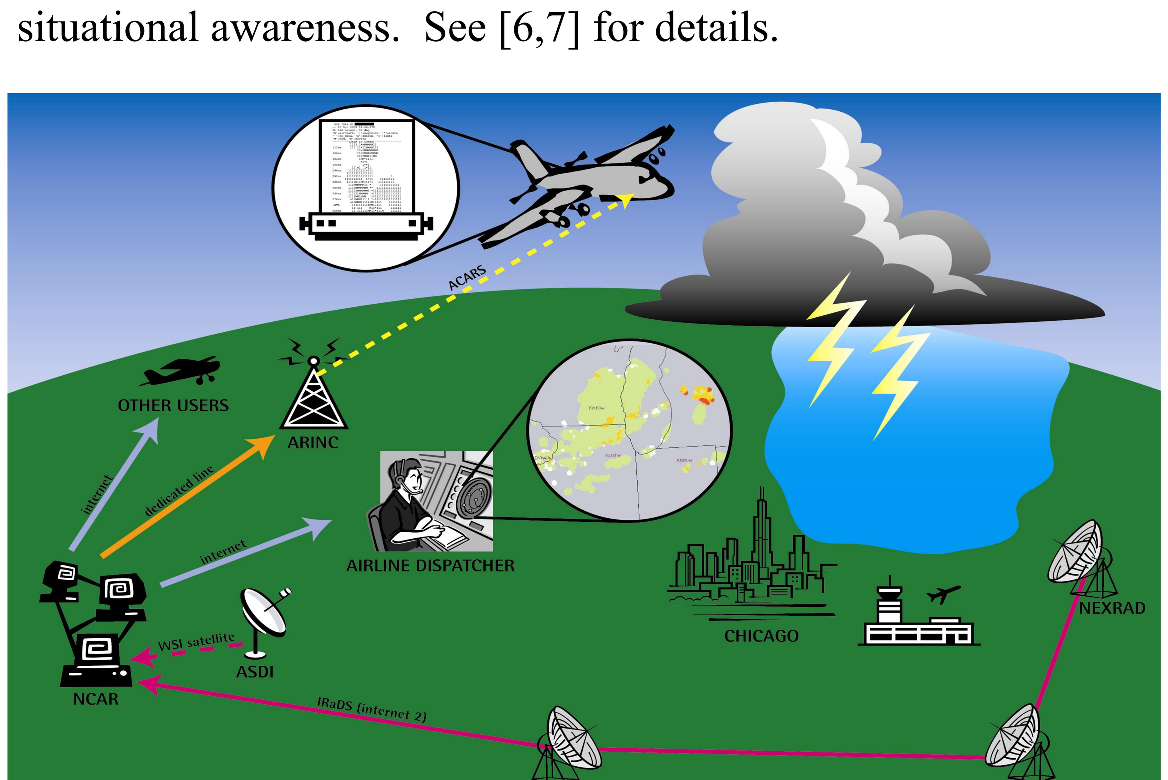
1. Contaminated data (e.g., sun spikes, artifacts) are identified and censored
2. Each spectrum width (SW) measurement is assigned a "confidence" based on
   - Operational mode (VCP, tilt)
   - Signal-to-noise ratio (SNR)
   - Overlaid Power Ratio (PR)
   - Clutter and overlaid clutter contamination
   - Insect contamination
   - Etc.
3. Each SW is "scaled" to EDR using a range-dependent function
4. Final EDR is computed from a local confidence-weighted mean
5. Final EDR confidence (EDC) is assigned based on SW confidences and local coverage.



NTDA's quality control mapping from SNR to confidence is obtained dynamically for each tilt using a simulation database and specification of performance requirements.

Evaluation

NTDA has been verified through comparisons with aircraft measurements of EDR from research flights and in-service commercial aircraft [5], retrospective analyses of accident cases, and a cockpit uplink demonstration to select United Airlines flights in which pilots noted its ability to improve their situational awareness. See [6,7] for details.

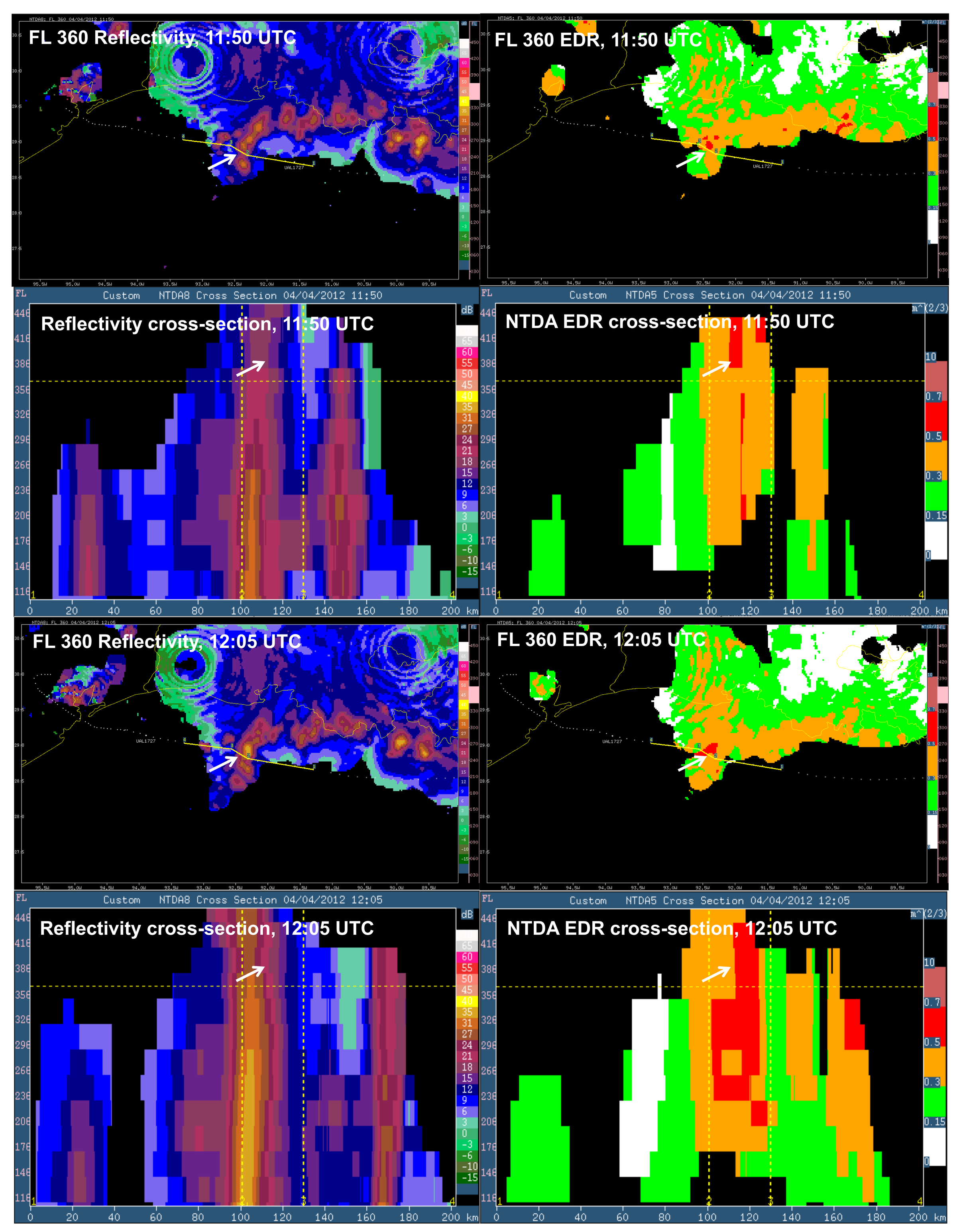


Concept of operations for the NTDA cockpit uplink demonstration.

Case Studies

United Airlines Flight 1727

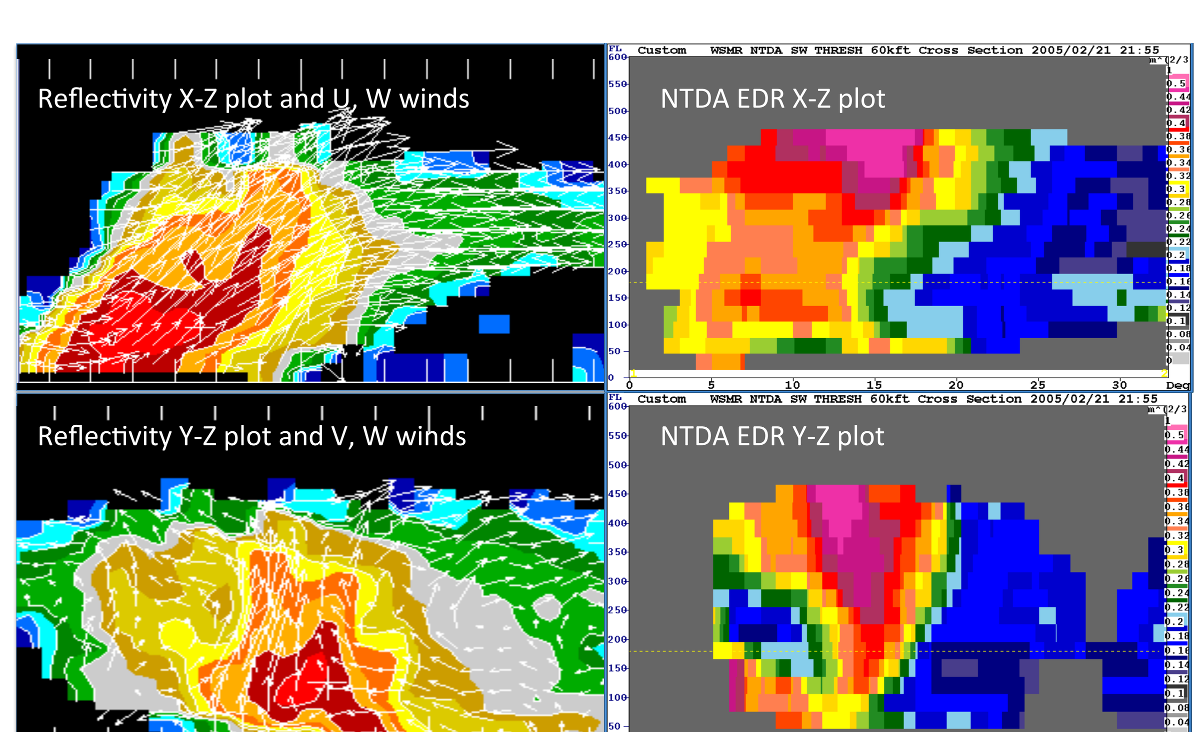
At 11:57 UTC on 4 April 2012, UA Flight 1727, a Boeing 737 en-route from Tampa to Houston with 146 passengers, encountered turbulence over the Gulf of Mexico south of Louisiana. Flight track data show that the aircraft's altitude declined from flight level 380 (38,000 ft) to FL 321. The pilots declared an emergency, and a UA spokesman reported that five passengers and two flight attendants were injured.



Plan views and vertical cross-sections from 3-D reflectivity (left) and NTDA turbulence (right) near the time of the UA 1727 accident.

Dual-Doppler Comparison

NTDA EDR measurements often show V-shaped areas of moderate and severe turbulence above the highest reflectivity region in a storm cell. The following plots show a comparison with a dual-Doppler analysis that suggests that elevated turbulence occurs where the updraft interacts with the tropopause. Other studies have compared NTDA EDR volumes with total lightning measurements, suggesting correlation between the two. NTDA also detects patches of turbulence in anvil well away from the updraft region.



Comparison of radar reflectivity cross-sections with dual-Doppler wind vectors overlaid (left) with NTDA EDR cross sections (right). The top row shows west-east cross-sections, and the bottom row shows south-north cross-sections. The case is taken from 21 February 2005 near Huntsville.

Acknowledgements

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Use in GTG-Nowcast

To supplement the strategic forecasts produced by GTG, the rapid-update GTG Nowcast merges information from GTG and observations every 15 minutes to create timely snapshots of turbulence suitable for tactical use [8]. The GTG Nowcast is expected to join GTG in providing "single authoritative source" turbulence information for NextGen. Case studies and statistical evaluations show that the information provided by NTDA significantly improves the accuracy of the GTG Nowcast. The statistical verification results shown below are particularly impressive considering that pilots already attempt to avoid regions of convective turbulence.

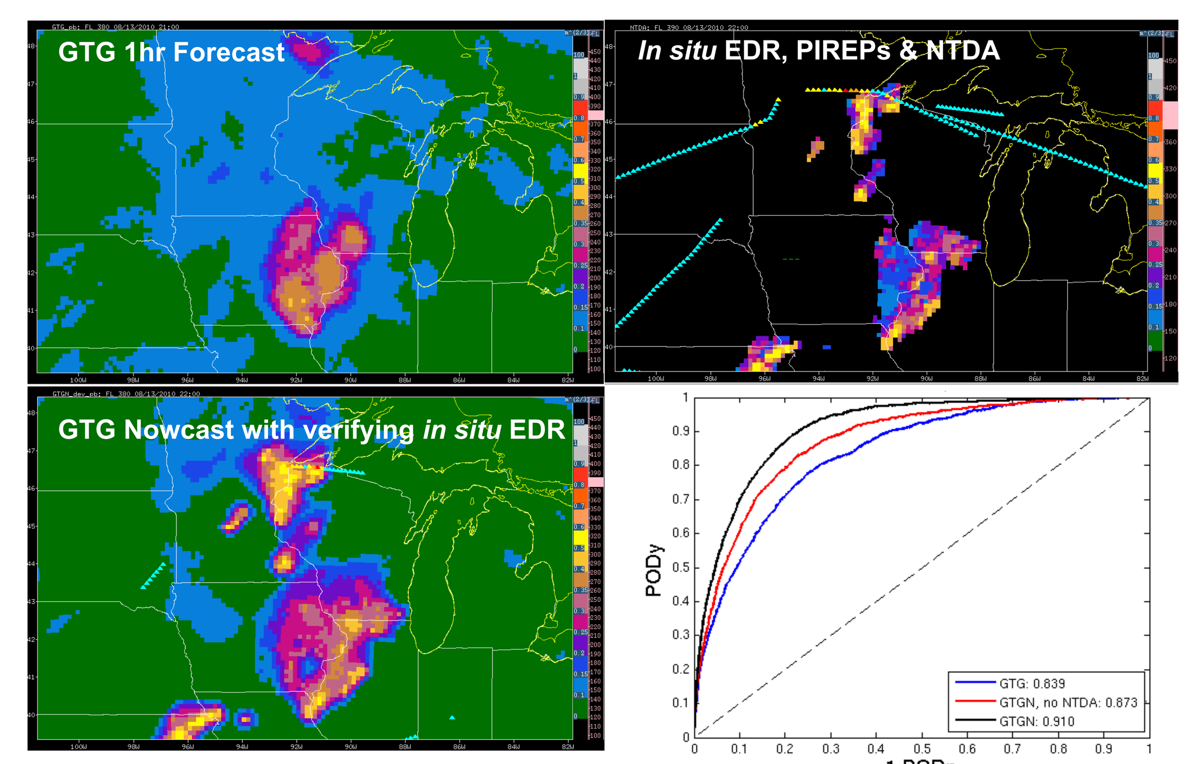

Illustration of NTDA's use in the GTG Nowcast. (Upper left) GTG 1-hr forecast; (upper right) NTDA EDR, with aircraft turbulence observations overlaid; (lower left) the GTG Nowcast, with *in situ* EDR measurements from the following 15 minutes overlaid; (lower right) receiver operating characteristic curves for GTG, GTG Nowcast without NTDA, and GTG Nowcast with NTDA based on statistical comparisons with *in situ* EDR data from commercial aircraft.

Summary and Plans

The NTDA has been developed to provide tactical turbulence information for aviation weather users. The algorithm runs on data from each NEXRAD, producing estimates of EDR and associated confidence on a polar grid for each tilt. A prototype system at NCAR ingests Level II data from 133 NEXRADs, runs NTDA, and merges the results to produce a CONUS mosaic every 5 minutes at 2 km horizontal and 3,000 ft vertical resolution. These data are used in a GTG Nowcast prototype and to investigate storm dynamics. A future version of NTDA will use dual-pol data for improved quality control. A graphical cockpit uplink demonstration is being planned. NTDA is also being adapted for use in the Taiwan aviation weather system.

References

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