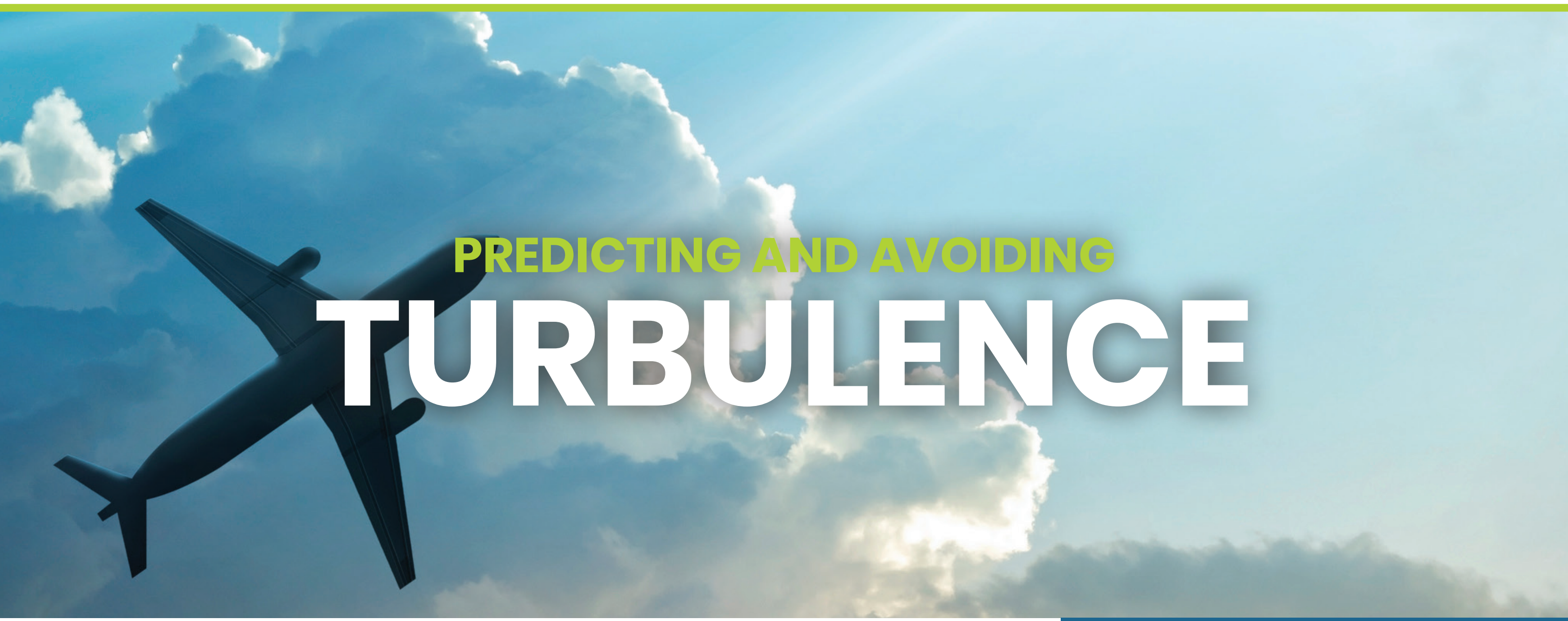

PREDICTING AND AVOIDING TURBULENCE

Far Reaching Support

For over 25 years, NCAR's Aviation Applications Program has conducted research aimed at improving our fundamental understanding of the nature and causes of turbulence affecting aviation and has developed new techniques for better observing and forecasting turbulence.

Turbulence encounters by general and commercial aviation continue to pose significant safety and flight efficiency concerns. According to some estimates, turbulence encounters account for well over 75% of all weather-related injuries on commercial aircraft and amount to at least $200M annually in costs due to passenger and crew injuries and aircraft damage.

IN SITU TURBULENCE MEASUREMENTS

Understanding the nature and genesis of aviation-scale atmospheric turbulence is complex and requires reliable observational data. Until recently, verbal pilot reports (PIREPs) have typically been the only source of routine turbulence information. These reports are incomplete since reporting is voluntary, and subjective to what one pilot views as "moderate," "light," or "severe."

To improve observations of turbulence, NCAR scientists and engineers developed the *in situ* EDR (Energy Dissipation Rate) system, an automated turbulence observation and reporting system. This *in situ* EDR software package is currently implemented

Benefits & Impacts

- *In situ* and remote sensing turbulence detection
- Tactical short term turbulence predictions
- Longer term regional to global predictions
- Low-level prediction algorithm for UAS

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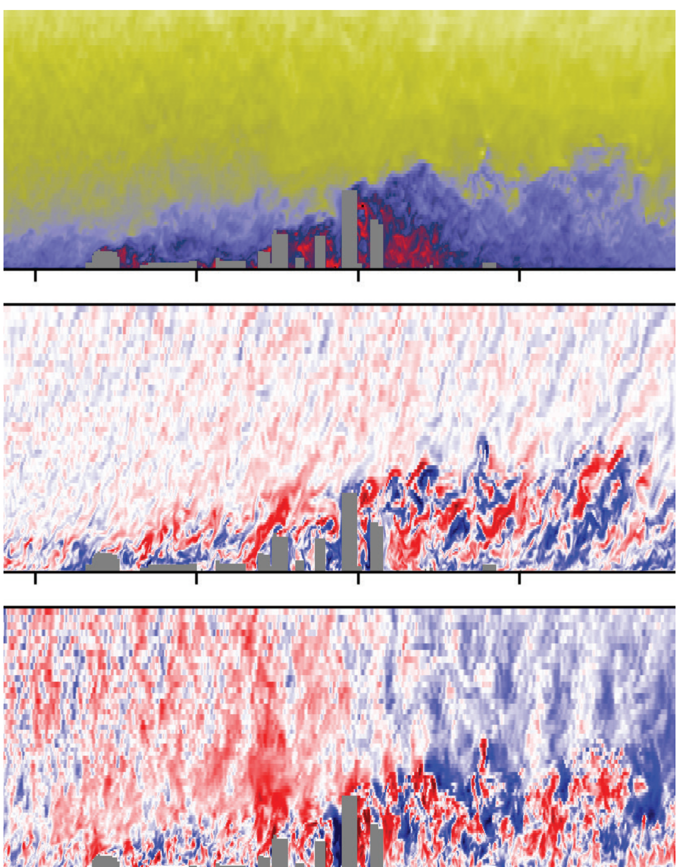
on Delta, United and Southwest Airlines aircraft, providing roughly 65,000 reports per day, and is expected to be implemented on other aircraft in the coming years. Some of these implementations will be on laptops in the cockpit available via WIFI.

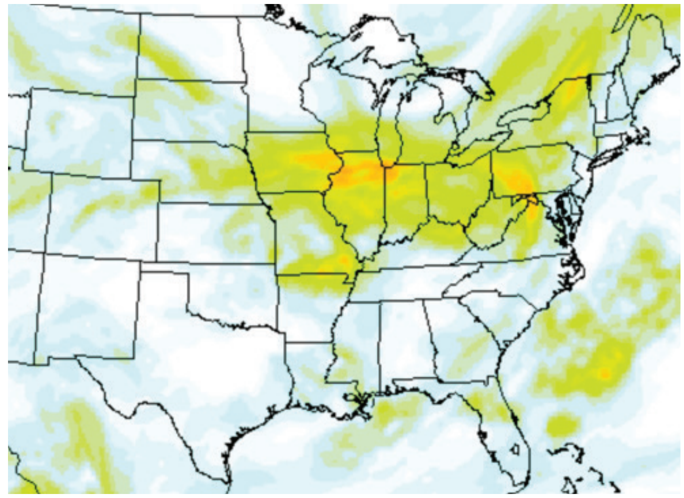
REMOTE SENSING MEASUREMENTS

In order to give pilots better information on potentially hazardous regions of turbulence in clouds, particularly thunderstorms, NCAR scientists developed the NEXRAD Turbulence Detection Algorithm (NTDA) which uses ground-based Doppler radar data from the NEXRAD WSR-88D network to remotely detect turbulence within clouds.

The algorithm makes use of radar spectrum width measurements from the NEXRAD WSR- 88D radars to estimate EDR. These EDR estimates are mapped on a 3D grid with chosen flight altitudes. Continued advancements are being made to the NTDA to increase its coverage, accuracy, speed and maintainability, and to accommodate NEXRAD changes.



High-resolution simulations



GTG 2–hour Turbulence Forecast

FORECASTING AND NOWCASTING

NCAR has developed a turbulence diagnosis and forecast system covering the continental U.S. and, more recently, the globe. The Graphical Turbulence Guidance (GTG) product provides forecasts out to 18 hours, is updated hourly, and provides an ensemble weighted mean of various turbulence diagnostics. Development of a global version of GTG has also been completed and has been implemented at the U.S. National Centers for Environmental Prediction and the UK Meteorological Office.

In addition to the GTG forecast system, NCAR is currently developing a nowcast system, GTG-N, which provides rapid (every 15 min) updates that make heavy use of the latest available turbulence observations from the *in situ* EDR estimates, PIREPs, NTDA, and other sources (e.g., METARs gust information) on a GTG background. This product is intended to provide enhanced pilot situational awareness for clear air, mountain wave and convectively induced turbulence.

TURBULENCE CHARACTERIZATION

Fundamental research aimed at characterizing different sources of turbulence continues to be a focus of NCAR scientists. Substantial effort has been invested in developing a better physical understanding convectively induced (CIT), clear-air (CAT), low level (LLT) and mountain wave (MWT) turbulence with the long-term goal of providing better operational turbulence forecasts, specifically making use of high-resolution nested (WRF) numerical simulations.

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