Analysis of Satellite Signatures, Pattern Recognition, and Eddy Dissipation Rate in Determining Potential Areas of Convectively Induced Turbulence

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Abstract

This study assists and improves the procedures of aircraft avoidance of turbulence near thunderstorms. Convectively induced turbulence (CIT) and near cloud turbulence (NCT) represents a significant hazard for the aviation industry and are responsible for over 60% of turbulence-related aircraft accidents. Current Federal Aviation Administration (FAA) avoidance guidelines do not properly address any formal tactical procedures when aircraft are more than 20 miles from a thunderstorm. However, CIT and NCT, often occur 200-300 miles downwind of large mesoscale convective systems (MCS).

Research Question

How can short-term analysis of satellite signature and Eddy Dissipation Rate (EDR) be utilized in certain synoptic patterns to predict CIT and NCT?

Overview of Methodology

The satellite signatures of convectively induced turbulence associated with 3 cases of meso-scale convective systems (MCSs) during the warm season of 2011 from April to August are examined. EDR observations and PIREPS will be co-plotted over GOES-12 visible and infrared satellite imagery along with wind data from the Aircraft Meteorological Data Relay system (AMDAR). Two subsets will be reviewed to show how differences in the sub-synoptic environment can play a crucial role in identifying and understanding the different temporal and spatial relationships of turbulence intensity and frequency

How is EDR Used in Operational WX?

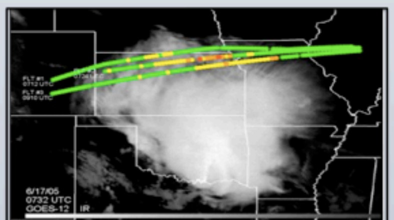
0.05 to 0.15	Smooth to Light
0.15 to 0.25	Light to Moderate
0.25 to 0.35	Moderate
0.35 to 0.45	Moderate to Severe
0.45 to 0.65	Severe
0.75	Boundary Layer (not used)

Overview of Eddy Dissipation Rate

EDR uses existing sensors, avionics, and communication networks to produce and disseminate a state of the atmosphere turbulence metric. EDR values are in units of turbulent kinetic energy, ($\varepsilon^{1/3}$) and are one of the key components of the Graphical Turbulence Guidance (GTG) product used by the AWC.

EDR is based on the turbulent state of the atmosphere, not the aircraft's reaction to turbulent flows. Therefore, EDR is aircraft-independent. This means that an EDR measurement for given turbulent conditions produces the same value whether measured by a Cessna or a Boeing 777. That value might translate to "severe" turbulence for the smaller aircraft but only "light" turbulence for the larger one.

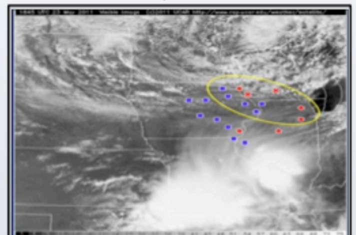
Sub-plot of EDR (0.35) at FL 280. Aircraft reported moderate to severe turbulence. AMDAR also displays temperature and wind information. Only United, Southwest and Delta B757 and B737 aircraft are equipped with EDR sensors.



Turbulence measurements along the tracks of three EDR equipped aircraft superimposed on (GOES-12) infrared satellite image. Color-coded dots represent intensity of turbulence (in cirrus outflow induced transverse bands) related to EDR values; green: none, yellow: light, orange: moderate and red: moderate to severe (From Trier and Sharman, 2008). Maddox and Fritch, 1980, showed that turbulence often occurs due to enhanced wind flow on the northern flank of MCSs.

MCSs and Short-Wave Troughs

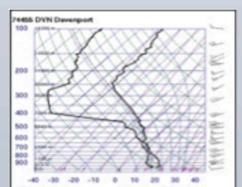
Two cases of turbulence, 23 May and 16 June 2011, associated with a short-wave trough adjacent to the northern outflow portion of an MCS are examined. Each MCS existed during the time frame 12 - 21 UTC with initial development between 12 - 14 UTC. .



MCS moving east with cirrus outflow and transverse bands move northward into lower level cyclonic flow 23 May 2011, superimposed with EDR reports of 0.15 to 0.35 (BLUE squares) and PIREPS (RED circles). Red X's indicate moderate to severe and severe turbulence FL 270 – 290, 1914 to 1928 UTC.

NOTE: Significant NCT occurred well north of core of MCS. Transverse bands interacting with short-wave trough deepened layer of turbulence. Also, 12 EDR vs 6 PIREPS!

AMDAR winds indicated a 50-60 kt increase in 6 hrs between FL 290 – 390 in vicinity of turb. NOTE: DVN sounding below.



Southern Flank Outflow May 29 2011

While radar imagery is extremely helpful in identifying intense areas of precipitation, it can be misleading to most operational aviation specialists when trying to determine safe route of aircraft travel in non-turbulent air. Nearly 20 PIREPS and 10 EDR reports of moderate turbulence occurred between FL 340 - 400 within a six-hour period in the oval area as the MCS moved almost due easterly.

This event shows that convectively induced turbulence is possible several hundred miles from the leading edge of the heaviest precipitation core in rapidly developing MCSs. What is more interesting is the massive turbulence outbreak on the southern flank in relatively weak winds aloft.

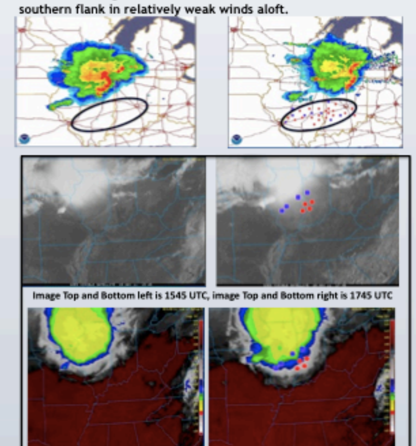


Image Top and Bottom left is 1545 UTC, image Top and Bottom right is 1745 UTC

Note how well the IR satellite depicted the leading edge of the anvil and subsequent turbulence compared to visible imagery. EDR reports are in BLUE and PIREPS in RED.

Conclusions and Suggestions

It is very difficult to objectively determine the vertical proximity of aircraft relative to transverse bands without precise knowledge of the cloud height and band vertical thickness. However, it is possible using these three cases combining EDR, AMDAR wind data, identifying certain cloud signatures relating to a developing MCS and sub-synoptic pattern recognition, a developing turbulence event can be better identified.

Current FAA guidelines suggest aircraft avoid by at least 20 miles any thunderstorm identified as severe or giving an intense radar echo. Recent research, (Bedka et al, 2008, Lenz et al, 2009, Williams et al, 2008, Lane et al, 2012) and the results of this study have shown that turbulence primarily of convective origin, especially that associated with an MCS, can occur well outside of those regions defined by the FAA guidelines. The guidelines do not reflect the current understanding of relevant NCT processes and should be updated.