Analysis of Two Turbulence Forecast Indicies Using Synoptic-Scale Pattern Recognition and Eddy Dissipation Rate

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Abstract

The purpose of this study is to assist and improve the verification process of the Graphical Turbulence Guidance (GTG) product currently in use by the Aviation Weather Center (AWC). One of the components of the GTG algorithm involves the incorporation of the Eddy Dissipation Rate (EDR). EDR is an in situ measurement in units of turbulent kinetic energy and is based on a transformation of the observed vertical acceleration of the aircraft to obtain a measurement of atmospheric turbulence that is independent of aircraft characteristics and motions.

Research Question

How well is the current forecast index performing for the Graphical Turbulence Guidance (GTG2) in certain synoptic-scale weather patterns?

Overview of Methodology

Matched position of aircraft reports of at least MODERATE turbulence with nearest aircraft equipped with EDR sensors.

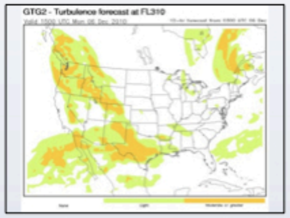
Not all aircraft are equipped with EDR, so I allowed a 15-30 minute buffer on either side of report and 2,000 feet altitude differential both above and below reported turbulence.

PIREPS of turbulence were then plotted over Ellrod and Ellrod-Knox output from AWC and then compared to EDR reports.

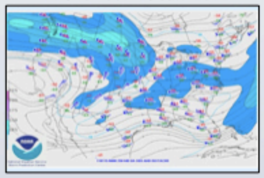
How is EDR Used in Operational WX?

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)

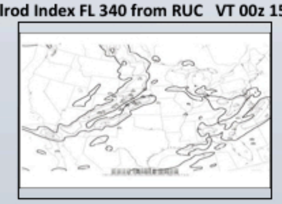
Graphical Turbulence Guidance (GTG) uses Ellrod and Ellrod-Knox equations in forecast algorithm



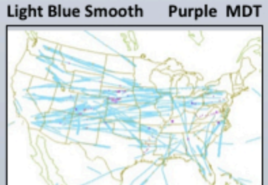
FL 340 00z 15 Jan 2011



PIREPS of MDT turbulence plotted on 6 hour Ellrod Index FL 340 from RUC VT 00z 15 Jan



Aircraft equipped with EDR
Light Blue Smooth Purple MDT



Two Turbulence Forecast Indicies Analyzed

The turbulence index used in the original GTG algorithm is the Ellrod Index and is calculated based on the product of horizontal deformation and vertical wind shear derived from numerical model forecast winds aloft.

A: Stretching = D_{ST} = $(\Delta u/\Delta x - \Delta v/\Delta y)$

B: Shearing = D_{SH} = $(\Delta v/\Delta x + \Delta u/\Delta y)$

C: Vertical Wind Shear = V_{WS} = $(\Delta V/\Delta Z)$

Ellrod : $TI = [\Delta u/\Delta x - \Delta v/\Delta y)^2 + (\Delta v/\Delta x + \Delta u/\Delta y)^2] (\Delta V/\Delta Z)$

To improve TI by accounting for rapidly changing divergent flows, a simplified "divergent trend" term (DVT) was obtained, defined as:

$$DVT = C [(\Delta u/\Delta x + \Delta v/\Delta y)_{h2} - (\Delta u/\Delta x + \Delta v/\Delta y)_{h1}]$$

The DVT was then added to TI to create the Divergence-modified turbulence Index DTI, also known as Ellrod –Knox Index:

$$DTI = TI + DVT$$

Observation Period 5 Different Synoptic Patterns	Dec 1 – Mar 31		Turb Reports TI	DTI
SHORT WAVE	7,26,29,30 14,18,23 7,14,24,26,28 11,14	December January February March	138	138
LONG WAVE	11,12,26,30,31 2,7 9,10,14,30,31	December February March	149	149
DOWNSLOPE	11 18	December January	16	16
ANTI-CYCLONIC	28 17 5	December January February	33	33
MERGING JETS	6 ,7	January	35	35

Pattern	Index	Fcst Value	EDR/MDT Turb
SHORT WAVE	TI	8 - 16	.15 to .25
	DTI	8 - 16	.15 to .25
LONG WAVE	TI	4 - 8	.15
	DTI	4 - 16	.15
DOWNSLOPE	TI	8 - 16	.25
	DTI	8 - 16	.25
ANTI-CYCLONIC	TI	4 - 16	.25
	DTI	8 - 16	.25
MERGING JETS	TI	4 - 8	.05
	DTI	4 - 8	.05

Conclusions and Suggestions

After recognizing the synoptic-scale pattern that exists, a forecaster can then evaluate the TI and DTI output at different levels from either the RUC or NAM available on the AWC Aviation Testbed Experimental Display page, (http://aviationweather.gov/exp/ellrod/ruc) and cross-reference both PIREPS and EDR data.

This study has shown NO conclusive evidence exists that SHORTWAVE troughs are forecasted better by either the Ellrod or Ellrod-Knox Index. EDR values associated with MDT turb occurred between 0.15 to 0.25.

However, THERE IS conclusive evidence that LONGWAVE troughs are forecasted better by DTI (Ellrod-Knox) since this index "captured" more PIREPS and EDR data indicating MDT turbulence. This is due to the improved index capable of predicting large scale divergent flow. EDR values associated with MDT turb occurred generally near 0.15.

Results were inconclusive as to which index was better for Downslope and Anti-Cyclonic flow due to a limited data source, however, it was CONCLUSIVE that higher values of EDR are associated with MDT turb.

Both indices performed poorly spatially with MERGING JETSTREAMS due to the potential deeper layer of wind shear spread over a larger region. Also, EDR values associated with MDT turb were near 0.05.