INTEGRATED TURBULENCE FORECASTING ALGORITHM ASSESSMENT

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1.0 INTRODUCTION

The Federal Aviation Administration (FAA) Aviation Weather Research Program (AWRP) has provided funding to the National Center for Atmospheric Research (NCAR) to develop a forecasting tool that mitigates the dangers to commercial and general aviation aircraft from unexpected, hazardous, clear-air turbulence (CAT). This effort is within the domain of the Turbulence Product Development Team (PDT). The PDT includes meteorological experts from private, government and academic organizations and receives its overall funding and direction from the AWRP. In response to the direction provided, NCAR has developed the Integrated Turbulence Forecasting Algorithm (ITFA), which produces CAT forecasts for the contiguous United States.

In support of ITFA's development in 2002, the FAA William J. Hughes Technical Center (WJHTC) Weather Processors and Sensors Group (ACB-630) performed a user assessment of the ITFA. The assessment examined the utility and benefit of ITFA to airline dispatchers and meteorologists. The assessment included participation from one major and one regional airline; United Airlines (UAL) and Comair Airlines, respectively. Users included forecasters from UAL's Weather Center Unit and dispatchers from Comair's Flight Operations Center. A usability study was employed to evaluate the extent to which the ITFA was used, valued, and supportive to meteorological and dispatch operations. Other aspects investigated included: ease of use, the extent the displayed data is interpretable, value added benefit, workload effects, and perceptions of ITFA's accuracy, and performance in detecting and forecasting CAT.

As part of the assessment, ACB-630 meteorologists reviewed ITFA on a daily basis in order to identify trends in model output and performance. In addition, user feedback was used to indicate conditions where ITFA did and did not perform well. Identified trends were further examined in regards to the underlying meteorological conditions. Results of the assessment will be used in making enhancements to ITFA. Final demonstration results, conclusions, and recommendations will be presented to NCAR and the AWRP.

2.0 ALGORITHM OVERVIEW

2.1 Algorithm Processing

ITFA generates predictions of CAT produced by upper level influences (e.g., jet stream and upper fronts) above 15,000 ft. ITFA does not produce forecasts for CAT resulting from nearby convection, mountain waves or turbulence of any type below 15,000 ft. To create CAT forecasts, ITFA relies on several indices and algorithms, each having strengths and weaknesses as CAT predictors. These indices and algorithms are listed in Table 1. ITFA uses the forecasted fields of the Rapid Update Cycle (RUC) gridded forecast model to compute each index and algorithm. The outputs are assigned weighting factors based on turbulence observations obtained from pilot reports. The output and weighing factors are integrated, with the resulting final output displayed as graphical forecasts of CAT (Sharman et al., 2000).

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Table 1. ITFA resident indices and algorithms.

Brown 2
Colson Panofsky
Ellrod 1
Richardson Number
TKE_KH3 (DTF3)
Endlich
NGM1
Horizontal Shear
Vorticity Squared
Horizontal Divergence
Temperature Gradient

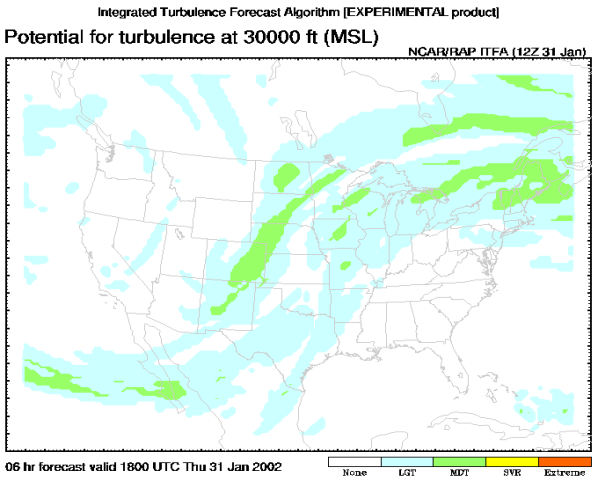
2.2 Algorithm Output

The ITFA is run every three hours in conjunction with the RUC model run. Output includes 0, 3, 6, 9 and 12- hour CAT forecasts for each 3,000-ft interval between 15,000 and 45,000 ft (listed in Table 2). A composite product that displays the greatest value predicted in any layer is also created. Figure 1 contains a sample of the ITFA 6-hour forecast product.

Table 2. The ITFA Forecast Flight Levels.

ITFA Forecast Flight Levels (In Feet)
45,000
42,000
39,000
36,000
33,000
30,000
27,000
24,000
21,000
18,000
15,000
Composite – All Forecast Levels

Figure 1. ITFA 6-hr forecast.



The ITFA output contains turbulence predictions ranging from none to extreme; higher values imply the likelihood of turbulence of a higher intensity. Table 3 provides an approximate correlation of the ITFA predictions to operational turbulence interpretations. A final determination of the relationship between ITFA predictions and operational interpretations will come after future intensive evaluations.

Table 3. Range of ITFA forecasts vs. operational interpretations.

ITFA Prediction by color	**Turbulence Interpretation**
White	No Turbulence Likely
Blue	Light Turbulence Likely
Green	Moderate Turbulence Likely
Yellow	Severe Turbulence Likely
Red	Extreme Turbulence Likely

The ITFA forecasts are presented graphically on a contoured national map that coincides with the RUC model domain. Initial 0-hr forecast products include plots of Pilot Reports (PIREPs) received during the 90 minutes previous to the corresponding RUC model run. These PIREPs are plotted on the ITFA 0-hour forecasts.

3.0 Methodology

In order to meet demonstration objectives, the ITFA Assessment employed a usability study using questionnaires, structured interviews, and telephone interviews. ACB-630 meteorologists monitored ITFA on a daily basis to identify trends in model output and performance, and to assist ACB-630 human factors specialists in determining CAT conditions. In addition to the user feedback, ACB-630 personnel subjectively examined ITFA meteorological performance. User feedback identified times when ITFA tended to perform well or not. These times will be further analyzed in regard to the meteorological environment.

3.1 Participants

To gain a broader prospective on the utility of ITFA, two different types of users were solicited. Each give a different prospective based on their experience and their perceived utility of the product. A major airline and a regional airline were chosen. One set of participants were dispatchers from Comair Airlines, a regional airline based at the Cincinnati/Northern Kentucky International Airport, in Covington, KY. There are approximately 40 dispatchers involved in flight planning at Comair Airline's Flight Operations Center. User objectives were to assess ITFA for the following: flight planning task benefit, the value of ITFA compared to existing CAT information sources, the utility of ITFA for dispatcher operations, the reliability of ITFA, perceived ITFA accuracy, the perceptions of ITFA's accuracy, user confidence in ITFA, acceptability of ITFA interfaces, the integration of ITFA in the dispatcher's work environment, and the perceived operator mental workload.

The other set of participants in this assessment were meteorologists from UAL, a major airline, whose world headquarters is based in Chicago, IL. These participants were the 6 meteorologists that staff the Turbulence Desk at UAL's Weather Center Unit, which is a new addition to the unit. Assessment objectives for the turbulence desk were to evaluate: ITFA's CAT forecasting task benefit, ITFA's comparison to existing CAT information sources, assess the utility of ITFA for meteorological operations; reliability of ITFA, perceived accuracy of ITFA, perceived ITFA performance, confidence in ITFA, the acceptability of ITFA interfaces, the integration of ITFA in a turbulence forecaster's work environment; and perceived operator mental workload

3.2 Phased ITFA Data Collection Approach

The objectives of the ITFA Demonstration were achieved by obtaining feedback from airline dispatch and meteorological users. Data collection metrics were the same for both user groups, however, based on different user needs, tasking, functions, and expertise (dispatchers vs. meteorologists), questions were sometimes dissimilar.

The Demonstration period was divided into two data collection Phases. Phase 1 occurred near the end of February 2002. The users were familiar with and used the ITFA enough to form preliminary impressions of the product's usefulness and performance. At this point, based on user feedback, issues surrounding ITFA began to surface. Identifying them early on in the Demonstration allowed evaluators to fine-tune the data collection approach for Phase 2 in order to better assess some of the more critical issues. Phase 2 final data collection occurred around mid-April 2002.

3.2.1 Questionnaires

Questionnaires were administered during Phases 1 and 2. Demonstration participants rated various aspects of the ITFA based on their perceptions of product utility, ease of use, readability, and accuracy. ITFA was rated on a 5-point scale. The questionnaire also included open-ended questions that allowed users to identify aspects of ITFA products/components and CAT forecast/detection capabilities they felt needed improvement. Information on how frequently ITFA was used was also solicited.

3.2.2 Structured Interviews

ACB-630 conducted structured interviews during both data collection phases. The goal of interviews during Phase 1 was to gain general feedback regarding the utility of the ITFA as well as identifying additional areas of utility. Therefore, Phase 1 questions were more exploratory in nature. Interviews during Phase 2 data collection were used as a supplementary data collection method. These interviews were used to follow up issues that arose as a result of

questionnaire responses and comments/issues identified.

3.2.3 Telephone Interviews

ACB-630 meteorologists monitored CAT conditions along UAL and Comair domestic flight routes. If significant CAT was expected, the ACB-630 Human Factors Specialist called one or more Comair dispatchers (between 8:00 a.m. and 5:00 p.m. eastern time), and the morning and afternoon shift Turbulence Desk meteorologists at UAL. The interview consisted of a few short questions regarding the CAT event, information sources used to predict/detect the event, and perceived accuracy and performance of ITFA.

4.0 Results

At the current time, data analysis and results are being completed. Complete results will be presented at the 19th Conference on Weather Analysis and Forecasting. In addition, all information will be documented in a report available from ACB-630.

5.0 Conclusions

Results will be presented to the Turbulence PDT for the improvement of ITFA. Final results and conclusions will be documented in an ACB-630 report and presented at the 19th Conference on Weather Analysis and Forecasting.

6.0 ACKNOWLEDGEMENTS

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7.0 REFERENCES

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