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ASSESSING THE UTILITY OF AN AUTOMATED 0-1 h THUNDERSTORM PRODUCT TO AIR TRAFFIC MANAGERS

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1. INTRODUCTION

NOAA Forecast Systems Laboratory, in conjunction with the NWS Prototype Aviation Collaborative Effort (PACE), evaluated the utility of a tactical convective hazard product (TCHP) at the Fort Worth Air Route Traffic Control Center (ARTCC – operationally designated ZFW) during a portion of the warm season of 2003. The TCHP graphically depicts current hazardous thunderstorms and a 1-h extrapolation forecast of hazardous thunderstorm positions. This automated product, generated every five minutes, is intended to support tactical air traffic decision-making.

Responding to requirements referenced below, our goal in creating the TCHP is to consolidate all relevant thunderstorm information into a single graphical product, thereby mitigating possible effects of multiple products that could contain redundant or contradictory information. The TCHP is designed to capitalize on development of advanced products from the FAA Aviation Weather Research Program (AWRP: AUA-430) and to optimize the use of conventional advisories. The version of TCHP that we evaluated consists of detection and forecast information contained in the National Convective Weather Forecast (NCWF) and Convective SIGMETs. FAA AWRP developed NCWF and NWS/Aviation Weather Center forecasters produce Convective SIGMETs.

The TCHP evaluation was designed to create a functional definition of a graphical tactical thunderstorm product for use by air traffic managers. Through the process of familiarizing the users with the characteristics of the product, demonstrating the product in an operational setting, and evaluating the product through feedback from the ZFW Traffic Management Unit (TMU) participants, recommendations for the content and presentation of a TCHP are refined and its utility to operations is affirmed.

The sponsors of this project are:

- FAA Air Traffic System Requirements (ARS-100)
- FAA Aviation Weather Research Program (AUA-430)
- FAA Southwest Region Headquarters
- National Weather Service Southern Region Headquarters

Participants in this evaluation represent a multi-agency collaboration. The NWS Southern Region Headquarters PACE project provided computer hardware and a high-speed (DSL) Internet connection; FSL provided software development and meteorological support; ZFW Management hosted the evaluation and endorsed the participation of TMU traffic managers and supervisors; and the ZFW Center Weather Service Unit (CWSU) provided an area for PACE

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Operations. The common goals of PACE and of the FAA TMU Weather Needs Project allowed beneficial leveraging of resources. FSL Aviation Division's participation is in response to requirements and funding by the FAA Aviation Weather Research Program (AUA-430).

2. BACKGROUND

2.1 Reference Documents

Two documents have guided this work. FAA 1999 documents the results of an in-depth user needs analysis of weather information used in tactical air traffic decision making. FAA 2002 sets forth requirements (Master, Supporting, and Interim) for tactical convective forecasts for FAA Traffic Managers. TCHP is an initial step towards addressing unmet or newly identified weather information requirements of the Traffic Management Unit.

2.2 Requirements

A TMU Weather Needs Core Working Group was formed to address the above documented weather information requirements, beginning with convection products. The core working group includes:

- Kevin Browne, FAA ARS-100
- Craig Goff, AvMet/FAA ARS-100
- Lynn Sherretz, Chief, FSL Aviation Program Development Branch
- Greg Pratt, Chief, FSL Aviation Systems Development and Deployment Branch
- Dennis Rodgers, FSL Development Meteorologist
- Thomas Amis, ZFW CWSU Meteorologist-in-Charge (MIC); Chief, PACE Operations
- Paul Witsaman, Regional Aviation Meteorologist, NWS Southern Region Headquarters
- Kathleen Schlachter, NWS Headquarters

At a meeting at ZFW in October 2002, the Core Working Group determined that initial requirements for a TCHP shall include 5-min updated graphical depictions of:

- C-SIGMET Nowcast
- C-SIGMET 1-h forecast
- C-SIGMET text
- NCWF Detection
- NCWF 1-h forecast
- NCWF Tops and Movement

Another NWS product, which was considered for inclusion in TCHP, is the Center Weather Advisory (CWA). The CWA, issued by CWSUs, is a weather warning for conditions meeting or approaching AIRMET, SIGMET, or Convective SIGMET criteria. CWAs may be issued for a number of adverse weather conditions including thunderstorms, and contain free-form text. Therefore decoding is necessary to discriminate thunderstorm CWAs from the rest. The decision was made to postpone inclusion of the CWA until it can be produced in a standardized machine-readable format.

2.3 Development Environment

Development of the TCHP was preceded by establishing the PACE Facility within the ZFW CWSU. In order to perform exploratory development in a rapid prototyping environment, a meteorological workstation isolated from ZFW operational systems was necessary. The FSL visualization platform called FX-Connect (FXC) was installed at the CWSU with a high-speed Internet connection to servers at FSL. Descriptions of FXC and PACE can be found in FSL 2002 and Rodgers and Amis 2002. NWS 2002 describes the concept of operations of PACE at ZFW.

The first software engineering requirement involved decoding and creating AWIPS graphics for the TCHP components. Next, those products were integrated into the FXC menus and data stream, and FXC was enhanced with aviation map selections and tailored for use in ZFW airspace. PACE's FXC display system could then be used to test and validate early versions of the product.

The PACE exploratory development facility proved to be an effective test bed for the TCHP development. Before the product was made available to TMU traffic managers, the PACE Chief and CWSU forecasters were able to examine TCHP components in their preliminary state on FXC. Based on their initial feedback, and comments solicited from TMU supervisors, new requirements were defined to change the background and map overlay colors to be consistent with the Integrated Terminal Weather System (ITWS) display. A second requirement was to provide animation. These modifications were implemented before the beginning of the evaluation. By incorporating the initial feedback from PACE, we were able to increase the likelihood that the product would be acceptable to the TMU users.

This iterative development/feedback process represents rapid prototyping in a spiral software development model. In the spiral development model, an initial build is presented, feedback is gathered, requirements are added or modified, and improvements are incorporated at phased intervals. The TCHP is an evolutionary prototype in this development model. An evolutionary prototype, by definition, is built in a quality manner, experienced by the users, and evolved to better meet needs. The process is repeated as needed. This type of prototyping is flexible in that changing or added requirements and improvements in technology may be incorporated quickly and efficiently.

The PACE FXC system provided powerful capabilities to the evaluation. For the first time anywhere on any display system, we had the ability to view all of the TCHP components together with animating NEXRAD mosaic images as well as observations and analyses from the NWS AWIPS data stream. This allowed the CWSU/PACE meteorologists to examine TCHP performance, and to verify comments made by the TMU users regarding movement and forecast information from the NCWF. These unique animated displays also revealed skill in the C-SIGMET 1-h forecast when subjectively compared to the observations from the NEXRAD mosaic and NCWF detection field animations.

3. TCHP DESCRIPTION

3.1 TCHP Web-based Viewer

We made the TCHP available for viewing on a password-protected web site accessible via the Internet. This approach is cost effective and poses no impact to ZFW operational systems. Links are available on the home page to documentation, publications, and a project contact list. In the center of the home page, a link invokes the Tactical Convective Hazards Product Viewer. The TCHP Viewer initializes with a default display on the ARTCC scale, including State, ARTCC, and TRACON boundaries, VOR identifiers, and sets of selectors for CONUS, Houston Center, or TRACON displays, as well as a selection of data and map overlays, and a selector for an animated view.

3.2 TCHP Graphical Content

The evaluated version of the TCHP graphical display contains the following components:

- NCWF Detection Field
- NCWF 1-hr forecast
- Hazard Tops and Movement
- C-SIGMET Nowcast
- C-SIGMET 1-hr forecast
- C-SIGMET Text
- Impacted Jet Route Display

Components of the TCHP may be displayed in any combination. The default display includes Hazard Detection, Tops & Mvmt, and NCWF 1-hr Fcst (Fig. 1). The three selectable C-SIGMET overlays on the TCHP selector menu are graphics derived from the conventional text Convective SIGMET. The C-SIGMET Nowcast graphic is the area polygon, line, or point as issued in the operational text Convective SIGMET. The C-SIGMET 1-h forecast, unique to this project, is a graphic produced on the NCWF 5-min cycle, depicting the extrapolated position of the C-SIGMET polygon one hour from the current clock time, time-matched to the current NCWF 1-h forecast. In other words, the C-SIGMET 1-h forecast positions are valid at one hour after issue time and updated every five minutes to be valid up to one hour 55 minutes after issue time. The latest C-SIGMET 1-h Fcst is valid at the same time as the latest NCWF 1-h forecast. The extrapolated position of the C-SIGMET 1-h forecast is based on the thunderstorm area movement given in the operational Convective SIGMET text. The C-SIGMET Text graphic overlay contains the observed and/or forecasted phenomena portion of the original text message.

The Impacted Jet Route graphic (Fig. 2) is a proof-of-concept exercise involving a modest investment of developer time to produce a simple, "quick-look" graphic indicating thunderstorm-impacted air space. In this simplified presentation of the TCHP information, current and forecasted impact to specific jet routes can be determined at a glance. A subset of high-use jet routes are depicted in one of three colors: Green jet route segments indicate no direct impact from NCWF detected or forecast thunderstorms; Red jet route segments indicate impact from NCWF Detection level 3 or greater touching the jet route segment; Yellow jet route segments indicate a NCWF forecast polygon touching the jet route. This display concept offers a "red light/green light" simplified graphic display of weather impacted airspace, and could be easily extended to highlight sectors, approach/departure corridors and gates, etc. in addition to jet routes. Other automated, gridded hazardous weather

diagnostic and forecast products (for example, icing and turbulence) could also be integrated into this type of display. This experimental display was included with the TCHP for traffic manager comments.

3.3 Display Interface

The left side of the TCHP Viewer contains controls for user-selectable data and map overlays, and five "radio buttons" for the five geographic areas; CONUS, ZFW ARTCC, ZHU ARTCC, DFW TRACON, IAH TRACON. Above the scale selector buttons, two sets of check boxes allow the user to select/deselect data and map overlays. A link below the scale selector buttons initializes an animation of the TCHP. The animation automatically loads and refreshes 6 detection images at 15 min intervals, providing 90 minutes of history. The seventh frame shows the most recent Detection with the most recent NCWF 1-h forecast and Tops & Movement overlays.

The web-based TCHP viewer enabled TMU staff to experience the TCHP concept and content, but was not intended to be a comprehensive display system including all necessary operational functionality such as extensive map overlay selections and aircraft situation information. The TMU participants mentioned those capabilities frequently as requirements. Nevertheless, the web display was an adequate cost-effective way to gather necessary feedback on the thunderstorm information content and presentation of the TCHP.

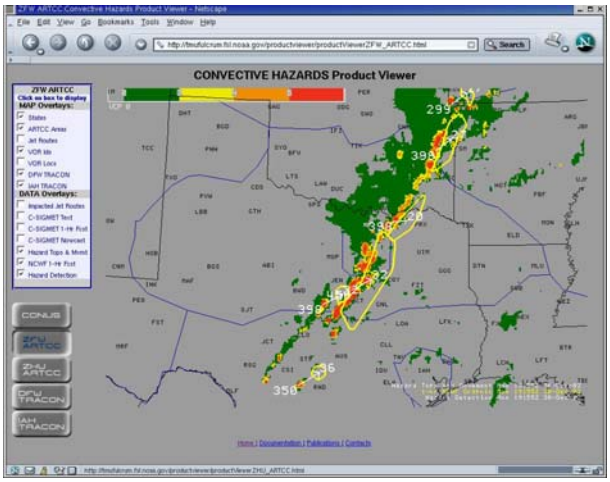

Figure 1 TCHP default display.

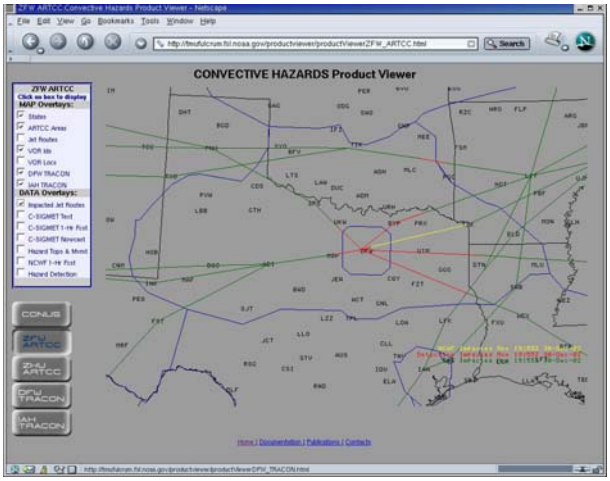

Figure 2 Impacted Jet Route Product.

4. EVALUATION DESCRIPTION

4.1 Training

Nearly all traffic managers, traffic management coordinators and the CWSU meteorologists have completed training to become familiar with the use and interpretation of the thunderstorm products included in the TCHP. Additionally, participants were briefed on the evaluation plan and trained in the use of the project's TMU web site to view the TCHP and associated displays. Once they became familiar with the components of the TCHP, TMU and CWSU participants were asked to provide feedback on the utility of the TCHP and suggestions for improvements.

Training of TMU traffic managers began on June 04 and was completed on 27 June, with a total of 23 participants attending a PowerPoint presentation individually or in pairs. The training sessions averaged 45 minutes in duration. The CWSU MIC completed some initial training in February and March 2003 but that training was limited to two TMU supervisors to facilitate early feedback gathering. Further training at that point had limited success due to changes in the TMU staff, changes in the TCHP web design, and the management duties of the MIC.

4.2 Schedules and Location

The location of the TCHP evaluation is the Fort Worth, TX ARTCC (ZFW). This site was selected due to the high volume of air traffic, technological advances, thunderstorm climatology, and location with respect to NWS/FAA regional headquarters.

The CWSU is located within the Display System Replacement (DSR) Control Room next to the Operations Manager and TMU. This design facilitates a rapid flow of air traffic and weather data for use in tactical and strategic planning. The ARTCC operations floor is divided into two main areas: the DSR control room containing radar and monitor positions for controllers; and the traffic management area, in which TMU controllers, supervisors, and operations managers oversee all facets of air traffic through ZFW airspace. The CWSU operates as part of the traffic management team.

As agreed on by the project participants, the evaluation was conducted Monday through Friday from 0500 to 2145 local time when significant convection occurred. This provided the greatest opportunity for full participation by the PACE Chief, CWSU meteorologists, ZFW TMU personnel and FSL developers.

4.3 TCHP displays in an Operational Setting

In general, the TCHP was displayed in the TMU alongside the Convective Collaborative Forecast Product (CCFP) during Strategic Planning telephone conference calls in which strategic and tactical planning of aircraft movement through the National Airspace System (NAS) is conducted. TMU supervisors and coordinators viewed TCHP at the TMU supervisory position, which is the hub of information flow within the TMU. This is where coordination of all traffic flow from the en-route airspace into the Dallas/Fort Worth (DFW) Terminal Approach Control (TRACON) and terminal airspace occurs.

In the CWSU, TCHP was displayed at the PACE operations computer and desk top computers with Internet connectivity. Occasionally, TCHP was displayed via a large screen plasma monitor to the traffic management and control room supervisory staff during daily operational briefings.

4.4 Data Collection and Analysis Method

The following information was obtained through one-on-one interviews with TMU traffic managers and supervisors, and through comments and discussions that occurred during training. Each individual respondent has been trained and had ample opportunity to view the TCHP in real time during several active thunderstorm periods in June.

Fourteen TMU traffic managers or supervisors (out of the 23 trained) have provided feedback used in this report, representing 60% of the ZFW TMU staff. The CWSU MIC recorded their responses on a web-based TCHP evaluation form. Responses recorded on the evaluation web site were compiled and tallied, and combined with user comments to provide the substance of this report.

5. FINDINGS AND RECOMMENDATIONS

5.1 Findings

Several significant findings resulted from this operational assessment.

- Traffic managers unanimously endorse the TCHP concept and most approved of the TCHP graphical display
- The NCWF is subject to erroneous motion vectors and extrapolated storm positions and, therefore, was considered insufficiently reliable to use in air traffic management decisions.
- Traffic managers do not use Convective SIGMETs.
- C-SIGMET 1-h extrapolated forecast graphic showed utility when combined with NCWF Detection.
- A direct benefit of conducting this evaluation is risk reduction in the operational implementation of a TCHP. A secondary benefit is the opportunity to “fine tune” the content and presentation of a graphic product prior to national implementation.

A conceptual approach to differentiating thunderstorm information into tactical and strategic categories is described in the documents cited in Sec 2.1. For this exercise, the TCHP provided an explicit 1-h forecast location of NCWF Level 3 or greater storms. Beyond this tactical time frame, strategic thunderstorm information is operationally provided (by the operational CCFP) as a range of percentage of area coverage with a categorical probability of storms meeting the minimum area coverage threshold. An assumption was made that these two categories of thunderstorm forecasts are best presented as separate products; otherwise users might be confused by the differing graphical presentations. Results from this assessment indicate that the TMU user group is capable of assimilating and applying thunderstorm information presented in both manners, and a number of participants suggested combining them. Several

traffic managers commented that the CCFP is used heavily for transcontinental overflight traffic decision-making, and requested that the time frame of the TCHP be extended by including the CCFP as a selectable overlay on the display, providing 0-6 hours of thunderstorm information on one display.

Our approach was to create one graphical display, which merged all relevant, operational thunderstorm information in the tactical time and space scales. The challenge is to present complex, detailed information in simple, easy-to-digest, stand-alone graphics that may then be integrated into decision support systems. We feel that the Impacted Jet Route product is a step in this direction. However, the responses from traffic managers in this TCHP evaluation demonstrate the need to provide as much flexibility as possible to the users to view tactical thunderstorm information within the context of their familiar display systems, complete with all of the user interactivity, map overlays, and aircraft targets routinely used by traffic managers.

5.2 Recommendation for a Tactical Convective Hazard Product

Based on the unanimous positive response of our sample group of ZFW TMU traffic managers and supervisors, implementation of a graphical tactical thunderstorm product is recommended, but additional prototyping is recommended to ensure maximum utility. The findings of this assessment indicate that this tactical product should include the following characteristics or attributes:

- 0-2 hour time frame for tactical applications
- NCWF detection field with existing intensity levels and colors
- Enhanced NCWF forecast graphic (1-h initially; 2-h when approved by Aviation Weather Technology Transfer Board)
- Tops and Movement graphic
- Selectable NCWF Performance graphic
- Selectable Convective SIGMET 1-h forecast graphic showing extrapolated positions time-matched to the NCWF production cycle.
- Selectable CCFP 2, 4, 6-h graphics
- Selectable sector and jet route map backgrounds (similar to ETMS or ITWS capabilities)
- Selectable aircraft locations graphic
- Typical user interactivity, e.g., zoom, pan, animate
- Graphic presentation that is visually consistent with ITWS displays (neutral gray background; consistent map overlay selections and colors; etc.)

The evaluation team suggests including a performance graphic as is found on the ADDS (http://adds.aviationweather.gov) javascript presentation of NCWF. By including a performance graphic with the TCHP and providing the capability to overlay a time-matched extrapolated C-SIGMET forecast, uncertainties or gaps in forecast information with the automated product may be “filled in” with the less frequent human product, or flagged by the performance graphic. The performance graphic originally included in the NCWF graphics package provides a simple, visual method for quickly assessing the "goodness" of the NCWF in a given situation. This strategy maximizes the utility of both the conventional human-generated advisories and the frequently updated automated product.

TMU respondents to the evaluation questionnaire indicated that the TCHP is most useful on the ARTCC scale, including a 150 nautical mile buffer outside of the ARTCC airspace. A Conterminous US graphic would be useful with zoom and roam capability, applied to transcontinental overflight traffic decision-making. Most felt that ITWS is a superior display for gate and terminal area decision-making.

The evaluation team recommends that work continue to improve the reliability of the storm motion and forecast position information provided by NCWF or subsequent versions of NCWF.

Due to the number of comments regarding NCWF forecast reliability, the team recommends that the next phase of the evaluation include the enhanced version of the NCWF. The next phase should also explore the utility of including the CCFP.

Since the NCWF Detection is a hybrid product containing derived radar information and lightning, and differs in appearance and information content from a conventional radar reflectivity display, some training for users is strongly indicated.

5.3 General Recommendations

Based on the findings of this assessment, the evaluation team recommends that all future automated forecast products should include real time performance information as part of the operational graphics package as a requirement for

AWTT Level D5 approval. A performance graphic, such as is found on the ADDS javascript presentation of NCWF, or a similar real-time verification graphic, facilitates the intelligent application of, and confidence in, the product by end users.

Based on the limited positive responses from users, justification exists to refine the Impacted Jet Route product according to the feedback obtained, and repeat an evaluation of its utility in tactical decision making.

6. ACKNOWLEGEMENTS

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