P3.7

CONTINUAL EVOLUTION OF CCFP – USER NEEDS FOR EXTENDED RANGE PREDICTION

Tom Fahey*
Northwest Airlines, Minneapolis, Minneapolis

Dave Rodenhuis
FAA, System Operations, Herndon, Virginia

1. INTRODUCTION

During the mid 1990's members of the air traffic management and meteorology communities began to realize that there was a need for more detailed forecasts of convection. By 1997 independent efforts by Air Transport Association (ATA) Collaborative Decision Making (CDM) Working Group; National Center for Atmospheric Research (NCAR); National Weather Service - Aviation Weather Center (NWS-AWC); and Small Aircraft Manufacturers Association (SAMA) began to converge. Rodenhuis, et.al. (1999) describes this convergence of ideas from the NWS-AWC perspective. Simultaneously and independently, the FAA, Air Traffic control System Command Center (ATCSCC) desired a national convective forecast product as a basis for their daily strategic planning. Thus, one of AWC's 3 separate efforts (to improve the Convective Outlook portion of the Significant Meteorological Information (SIGMET) product) was soon to deliver significant results.

By 1998 an urgent need was recognized for forecasts of organized convection beyond 2 hours, extending out 6-8 hours. These forecasts were needed to help plan adjustments to en route air traffic flows in the National Airspace System (NAS). As a result, the first operational test of, what was then called, the Collaborative Thunderstorm Forecast Product (CTFP) (Figure 1) was conducted in 1998. From the viewpoint of the FAA, the major benefit of single, national forecast product was to reduce arguments based on locally-generated, conflicting forecasts---in addition to actually providing a skillful prediction of intense convection.

Fahey, et.al. (1999) describe Commercial/General Aviation, Federal Aviation Administration (FAA) and NWS motivations for beginning the test and the goals of the effort. The uniting factor, in 1998 and still today, is that when convection develops, aviation operations suffer. Similarly, over the last 7 convective seasons (1998-2004), the goal has been to increase efficiencies for all involved.

* *Corresponding author address:* Thomas H. Fahey, III, Northwest Airlines, F7050, 7200 34th Ave, South Minneapolis, MN. 55450; email: Tom.Fahey@nwa.com.

2. CCFP: NAME, COMPONENTS & PROCESSES

By the 1999 thunderstorm season, this new product was being called the Collaborative Convective Forecast Product (CCFP). The responsibility for the name lays with Fred Foss, former Chief of the Operations Branch, AWC, who whimsically used 4 consonants to render the acronym absolutely unpronounceable.

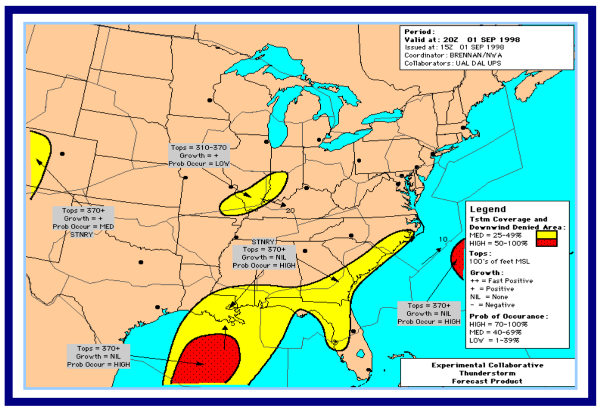

Figure 1 – Example of a CTFP map for 01 Sept. 1998

From a meteorologist's perspective there are 3 components to the CCFP product suite: Collaboration, the Forecast and the Applications. A radically new idea was being tested: collaboration between meteorological experts to challenge the "first guess" and cooperatively develop the best possible forecast. In 1999 leadership for CCFP production was transferred from the Northwest Airlines forecaster to the AWC forecasters. Participation in the Collaboration effort by the airlines, as well as by the Center Weather Service Units (CWSUs) NWS, was expanded.

Air traffic congestion reached a peak during the summer of 2000, and the CCFP was accepted and utilized as the

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cornerstone weather product for traffic flow management (TFM); (Hudson and Foss, 2002). However, it was quite another matter to make successful decisions to reroute air traffic when the forecast was so uncertain, imprecise, and sometimes, inconsistent. A plausible argument is made by Evans (2002) that a fraction of the delays during that year were caused by improper application of the CCFP forecast, as well as because of an impediment of the convection itself.

From another perspective it could be said that there are two processes resulting in two different products: 1st, production of the forecast product by the meteorology community and 2nd, application of the information by the air traffic management community at the FAA and at aircraft operator facilities during the development of a strategic plan for air traffic flow (See Table 1). In the later case it was necessary to inform traffic managers on the practical meaning of the forecast product without reference to meteorological concepts.

PROCESS	RESPONSIBLE	=> PRODUCT
Collaboration	Producers/Meteorologists	=> Forecast
Application	Users/Air Traffic Mgr.'s	=> Strategic Plan

Table 1. Successful CCFP concept

Thus, it is important to recognize that a successful CCFP requires both of the two processes producing both of the two products.

3. WEATHER PRODUCTS FOR ATC

The development of extended range forecasts for use in Traffic Flow Management (TFM) is distinct from the traditional development of short-range (tactical) products for use by Air Traffic Control (ATC). Because of the need for precision by ATC in the separation of air traffic, there is a corresponding desire for precision in the weather forecast, in particular, for convection. This can only be achieved by the use of current observations and/or short-range forecasts based on very recent observations; i.e., "nowcasting". In this regard in the past, the national coverage of the NWS network of Weather Surveillance Radar – 1988 Doppler (WSR-88D, also called NEXRAD (NEXt generation RADar)) has been the cornerstone for ATC and nowcasting efforts involved only extrapolation of current observed features.

Two weather forecast products that are now operational and were developed using in part, WSR-88D radar data mosaics, are the National Convective Weather Product (NCWF), (Megenhardt and Mueller, 2002) and the Terminal Convective Weather Forecast (TCWF), (Dupree, et.al. 2002). They are part of the NWS-AWC and ITWS suite of products respectively. Nowcasting has now come to imply not only extrapolation but also includes efforts to anticipate initiation, growth and dissipation of storms (Mueller, et al., 2002).

Rather recently (Evans, et.al. 2002), the automated forecast technology of the TCWF has been adapted for the Corridor Integrated Weather System (CIWS). However, the skill of CIWS's Regional Convective Weather Forecast (RCWF) falls off rapidly after approximately 30 minutes (Boldi, et al., 2002), since this is the lifetime of a convective cell.

In contrast, the CCFP covers the extended range (2-6 hours) and are produced manually. Meteorologists representing the AWC, CWSU's and commercial airlines are expected to utilize their knowledge of physical principles, atmospheric structure and stability, numerical weather model output, as well as subjective experience to create a forecast. The skill does not fall off rapidly; it is already modest, but this skill is sustained, approximately, over the range of lead times being used (Mahoney, et. al., 2004).

Evans (2002) has emphasized that strategic forecasts cannot be used alone. A traffic manager who perfectly applies a perfect forecast in the extended time range, will still perform "tactical adjustment" of air traffic around inevitable obstacles of weather and conflicts with aircraft. Therefore the existence of distinct time scales for strategic planning, tactical adjustment, and reactive-tactics require applications and procedures that integrate different information that each product provides. Notice that it is not the products by themselves that need integration.

4. EXTENDED RANGE PREDICTION FOR TFM

The development of a new weather forecast product for the extended range (2-6 hours) became necessary only because "tactical adjustment" proved to be an unsuccessful strategy when the NAS operates at near capacity. Weather forecasts for convection were needed that would support strategic planning and traffic flow management. The CCFP is the first implementation of a weather forecast to meet that objective. Subsequently, other methodologies will follow, but they will have to surpass the standards for skill (accuracy, precision, and reliability) that has been established by CCFP.

The development of CCFP started with only an idea (Rodenhuis, et.al., 1999)—without budget or personnel. How did this product attract the attention, resources and users that would support evolution? Can these concepts be applied to other projects?

4.1 A Program of Attraction

With the knowledge that we could not attract resources simply with ideas and proposals, a strategy was chosen: to build a program of attraction. That is, we were convinced that doing good work that serves the needs of specific users would attract resources.

4.2 Rapid Prototyping

From our experience, grand plans are not rewarded, and federal initiatives are not funded. Rather than form a committee, we organized a small Task Force and made a commitment to rapid prototyping (Rodenhuis, et.al., 1999).

4.3 Collaborative Forecasting

The traditional development of a weather forecast depends on individual insight and experience of a high priest of meteorology—the forecaster. Quite often the name of the forecaster indicates that professional ownership, much like a piece of art. However, in developing the CCFP forecast we had to bridge both commercial and federal forecast expertise—they are all Producers. For the first time a collaborated forecast was designed (Fahey, et.al., 1999). This forecast is not the average of many contributions; it is the best forecast that the AWC forecasters can make, and they have to defend their choices.

4.4 Forecast and Applications

Even under hypothetical conditions when a forecast that is agreeable to all the meteorological Producers, the *value* of the forecast, as well as the skill is of paramount importance. This is not just a problem for the Users to solve. For the CCFP we are equally committed to developing a concept of use for the application of the weather forecast, as we are to doing the forecast itself. From the meteorologist's perspective, the CCFP has 3 components: collaboration, the forecasts, and applications.

4.5 Training

Anyone who is part of the community who flies or supports aviation understands the value of training. However, compared to ATC, traffic flow management (TFM) is a relatively new concept that requires knowledge of weather forecasting as well as flight dispatching or TFM. Furthermore, the traditional training for weather forecasters does not include anything about ATC or TFM. For these reasons, the concept of use is required on which to build a repetitive training with professional standards.

4.6 Verification and Evaluation

On principle, a professional forecaster is distinguished from speculators by committing to verification of the forecast. Furthermore, verification is an essential element for making improvements in methodology or discovering new details. Beyond an excellent weather forecast lie the question of utility for decision-making and the value of the forecast information. Evaluation is done by the users and is an extra step that drives the evolution of the CCFP.

4.7 Monitoring and User Feedback

It is essential to break the routine of operational forecasting by providing feedback---both on forecast skill, and also on the value. The latter comes from Users, and it must be timely, even if it is not quantitative. Daily feedback; weekly feedback, seasonal feedback, annual feedback of verification and evaluation forces the evolution of the forecast and improves the training.

4.8 Continual Evolution

It is not a central idea of CCFP to continuously improve, it is the *consequence* of all the concepts on which CCFP is built. Continual evolution is sustained prototyping of the product and depends on adaptation and change from the people that produce it. In that regard, the professional aviation weather forecaster works between automated "nowcasting" and "model output". Aviation users need skillful forecasts for lead times of 2-6 hours. Since convection is the most important weather parameter for TFM all WAWG resources have focused on this hazard. The potential remains to develop collaborative forecast processes for all other weather hazards, but if and only if Users (Air Traffic Managers at the FAA and at aircraft operators) are committed to developing processes for application.

5 CCFP EVOLUTION

5.1 1998 – Prototype Test

Curiously, the successful merging of efforts such as the NWS-AWC Task Force to Commercial Aviation occurred at a meeting unrelated to this effort held 6-10 April 1998 in Anchorage, Alaska. It was during breaks at that meeting that discussions were held between David Rodenhuis (NWS), Paul Fiduccia (SAMA) and Tom Fahey (NWA) that resulted in finalizing the commitment by the NWS to support a prototype test. Subsequently, Bill Failor (ATCSCC), Dale Branch (ZMP), and Fred Foss (AWC) contributed substantially to the design and testing of the product.

A limited test of forecast collaboration was lead by NWA using telephone conference calls, Monday through Friday from 06 July through 01 Sept. 1998. Meteorologists from the Minneapolis Air Route Traffic Control Center (ZMP) CWSU as well as 4 other airlines (United, UPS, Delta and American) participated. The NWS-AWC participated for 6 weeks during the test. The application of the forecast to traffic management decision making was tested for one week in August. (Rodenhuis, et.al., 1999; Fahey, et.al., 1999; Hudson and Mosher, 1999)

The Forecast System Lab and NWA jointly developed verification procedures at this time also (Schultz and Hartsough, 1999).

5.2 1999 – Prototype

The NWS-AWC began chairing the collaboration process. What was now being called the CCFP was produced 2 times per day, at 15 and 19 Universal Time Coordinated (UTC) and valid 1, 3, 5 hours and 3, 5, 7 hours respectively (Fike, 2000).

5.3 2000 – Launch Operational Production

The CCFP had become an operational 16-hour per day product for 7 months (April - October). The FAA provided the NWS-AWC with resources for 3 meteorologist-forecast positions and NWS-NCEP committed another 2 positions to support CCFP production. A User Needs Analysis was completed by the FAA and delivered to the NWS (ARS 2000). An evaluation of participation in the Weather Chatroom was initiated, and the first Technical Briefing for training users was developed by AvMet Applications under contract to FAA, ARS organization.

5.4 2001 – Improve Training

In 2001 the production was expanded to 24 hours. Six times per day (every 4 hours) a suite of 3 CCFPs valid 2, 4 and 6 hours were produced. The forecasting season continued to run for 7 months (Apr. – Oct.). A training module was revised and distributed and the FAA's 2nd User Needs Analysis was produced (ARS, 2001).

5.5 2002 – Increased Frequency (12 / day)

The CCFP forecast season was started 1 month earlier (March - October) for a total of 8 months. At this same time a CCFP Project Team under the sponsorship of CDM was established. One of the first requests of the CDM users was to provide an updated CCFP prior to each Strategic Planning Team telcon (every 2 hours). In the face of significant resource issues by mid-summer (July 2002), the frequency of CCFP forecasts was increased from 6 per day (every 4 hours) to 12 per day. As part of this same effort, in July 2002 the NWS suspended the outlook section of the Convective SIGMET and the CCFP took its place. In 2002 the first formalized Statement of User Needs was prepared by the FAA, Memorandum dated 6/27 by ATT-100.

5.6 2003 – Add Canadian Airspace

The CCFP Project Team was established permanently as the Weather Applications Work Group (WAWG) of CDM. The CCFP was expanded to cover eastern Canada south of 48 deg. North latitude, between Minnesota and Maine. As a result of CCFP expansion, NavCanada began participating in the WAWG. An ATCSCC Training Department representative was also added to the WAWG. The Statement of User Needs (WAWG, 2003) documents other changes for 2003 which include: the forecast object (convection) and the forecast criteria were more clearly defined; "probability" was redefined as forecaster confidence; the forecast frequency was reduced 12 to 11 per day to allow for more efficient production by AWC; training graphics were upgraded; and Operational Feedback Reports were initiated.

5.7 2004 – Added Verification Needs

The Statement of User Needs (WAWG, 2004) clarified forecast "tops" in relation to radar echo heights and added a future expectation to examine forecasting and verification of tops. Verification of the concept of forecast consistency was added (in addition to accuracy and precision). In addition 3 tools for active training were developed and distributed.

5.8 2005 – More Intuitive Graphics

The first substantial change in product format is anticipated for 2005: 2 colors representing confidence. and 3 "fills" representing coverage (See Figure 2)

6 EXPECTATIONS

Several developments will affect extended range forecasting in the next few years. First, there are encouraging results from Evans, et.al. (2002) that CIWS will be able to provide skillful forecasts out to 2 hours. Those results, like those from NCWF (Megenhardt and Mueller, 2002) depend on extrapolation of the position of current radar (filtered) observations. Their skill at the 2-hour lead-time will be rigorously compared with the CCFP at the same lead-time.

Second, numerical weather prediction models, especially the Rapid Update Cycle (RUC) model (Benjamin, et.al., 2002) show real promise for use in the CCFP forecast. However, the RUC will only change the forecast method, not the collaboration or application that will continue to be an essential element of extended range forecasting. This transition will enable the meteorologist to redirect efforts toward quality control and potentially also, the application component.

Third, weather forecasters universally desire to express their forecasts uncertainty in terms of probability. This term is distinct from the current parameter used in CCFP, *confidence*. The difference is the result of some extra effort that should not be taken for granted: 1) conducting independent verification, and 2) changing the forecast to conform to the verification results. Before aviation weather forecasts become probabilistic, the Producers must work with the Users to solve an additional problem: How should the probabilistic forecasts be applied to deterministic strategic traffic management and tactical adjustment?

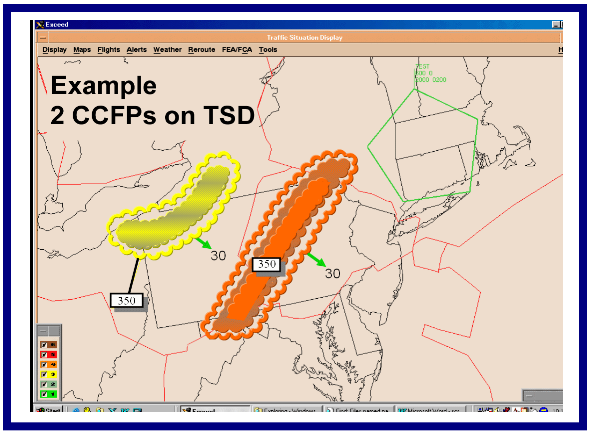

Figure 2 – 2005 CCFP prototype for more intuitive graphics on the FAA's Traffic Situation Display (TSD).

Exploring this third issue further, it is important to note that currently the application of the CCFP to produce a strategic plan for TFM is exclusively the role of the Air Traffic Managers. And due to both perceived and actual limitations to the CCFP, strategic plans for the 4-6 hour time period are often not developed. Future increases in CCFP skill will result in the potential for more frequent application. Before more vigorous applications can be realized, the WAWG has recommended that thresholds for likelihood of occurrence (probability) cross referenced with potential impact to the NAS be developed jointly by the meteorology and ATM communities (WAWG, 2004c)

Fourth, users have identified 3 CCFP variables that need to be displayed graphically: coverage, forecaster confidence and tops. Coverage has been provided graphically since 1998 and it is anticipated that a graphical depiction of forecaster confidence will be added in 2005. This is also a convenient way of expressing probability information. The graphical depiction of the tops of the convection will also need to be addressed.

Fifth, meteorological verification of the CCFP, providing quantified measurements, is well developed. But evaluations of the value of the CCFP as it relates to the operation of the NAS are just beginning and only subjective to date. Quantified measurements, evaluating the value of the CCFP are needed. As a first step toward this goal, the WAWG has explored the concept of Convective Constrained Areas (CCA's), (WAWG 2003b & 2004b). Mahoney, et.al., 2004 describe current status of the effort. Additional work & funding is required to compare CCA's with flight track information.

In addition, when measuring the value of the CCFP, focus on addressing the perception that CCFP collaborators sometimes are influenced by traffic flow managers within their organization (FAA or aircraft operators) will be important in future evaluations.

Sixth, enhancements to the Collaboration process such as use of Internet for virtual meeting capability in addition to Internet chat are important.

Seventh, preliminary discussions have begun with some users regarding the need for more detailed, extended range forecasts for TFM strategic planning in the airport terminal area.

7 CONCLUSIONS

The history of the development of the CCFP offers concepts that were used successfully to attract resources for the Producers and meet expectations (albeit imperfectly) of Users. As a consequence of these concepts, a continual evolution has occurred in the forecast content, collaboration, skill, value, and training. Moreover, the CCFP product has demonstrated 2 concepts for the first time: collaborative forecasting, and continual evolution of an operational product.

ACKNOWLEDGEMENTS

The start of NWA meteorology's efforts with the CCFP concept began as a hallway discussion in the spring of 1997. Bill Leber, with his CDM perspective and in his endearing manner, insisted that convective forecasting for ATM purposes be addressed immediately. From a much broader perspective the authors want to acknowledge the joint efforts of a community of technical and scientific experts, operational forecasters and traffic managers, project leaders and supervisors—both within the commercial aviation industry, and at the FAA and the NWS—all who helped develop CCFP and sustain its evolution. We know who you are. We especially want to acknowledge the leadership of Jim Weatherly, CDM who provided resources early in the development of the CCFP. Sincere gratitude is also extended to the critics of the CCFP process. Your efforts have helped encourage continual evolution. You know who you are.

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