5.4 TACTICAL WEATHER DECISION SUPPORT TO COMPLEMENT "STRATEGIC" TRAFFIC FLOW MANAGEMENT FOR CONVECTIVE WEATHER

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1. OVERVIEW†

Delay increases during the months of the year characterized by thunderstorms have been the principal cause of the dramatic delay growth in the US aviation system over the past 3 years as shown in Figure 1.

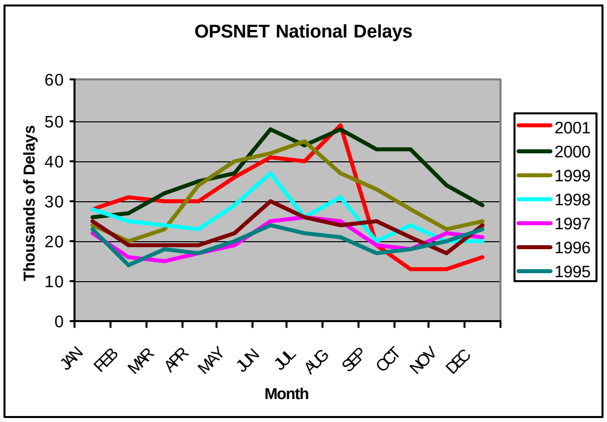

Figure 1. Number of aircraft delayed more than 15 minutes in at least one ATC facility within the US National Air System (NAS) by month.

In 2000 the key new initiative for reducing convective weather delays was "strategic" traffic flow management (TFM) through the Collaborative Convective Forecast Product (CCFP)[1], the Strategic Planning Team, and Collaborative Routing (CR). The CCFP forecasts were compared to predetermined "play books" [2]to decide the best strategy for rerouting planes to minimize disruptions from the anticipated weather.

This "strategic" approach has been quite successful in improving operations in many cases. However, in congested airspace, the inability to accurately forecast convective weather impacts requires a complementary tactical weather decision support capability. This paper describes tactical weather prediction systems plus traffic flow management and automation decision support tools to provide this tactical capability.

2. CHALLENGES ENCOUNTERED USING ONLY A "STRATEGIC" APPROACH TO CONVECTIVE WEATHER TRAFFIC MANAGEMENT

Recent experience has shown three major challenges in using strategic traffic management alone to handle convective weather:

1. route decision making when the CCFP has spatially large regions with a relatively low predicted likelihood of weather impact to the various routes within the regions,
2. managing situations where weather unexpectedly occurs in critical locations, and
3. deciding what to do when weather is not present at the forecast times and locations.

To illustrate the relative frequency of these issues, we analyzed the CCFP and the actual weather between 11Z and 01Z in the Great lakes corridor for August 2001.[3] We found that tactical responses were required about 97% of the time when convective weather occurred. The most common problem was a lack of specificity on the exact region in which convective weather would occur (e.g., nearly all forecasts were for an expected weather coverage of 25-49%). Operationally significant weather outside the CCFP forecast region occurred about 25% of the time.

3. "NEAR TERM" TACTICAL CONVECTIVE WEATHER DECISION SUPPORT

Thus, there must be a complementary tactical convective weather decision support capability. But what is the essence of this capability and how does it relate to the strategic approach?

We propose assuming an effective tactical capacity for regions that may be impacted and planning to

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[1] Information on the CCFP is available at http://www.FSL.GOV/TBD.

[2] The "play book" consists of collaboratively determined routes assuming that there are various hypothesized regions of weather that must be totally avoided by aircraft.

[3] Note (fig. 1) that August 2001 had the most delays of any month in the past 6 years.

dynamically reroute using tactical weather products and ATM decision support tools. The tactical capacity depends critically on the tactical weather products, ATM decision support tools and, capability of the air traffic controller team and pilots/dispatch.

Contemporary Terminal Weather Capabilities

A major improvement to tactical convective weather decision support system is provided by the Integrated Terminal Weather System (ITWS), which has been used operationally for over 7 years at four major terminal complexes (New York, Dallas, Orlando and Memphis). The ITWS provides high update (30 second) 3D information on storms by integrating ASR-9, NEXRAD and lightning data to provide 20-minute forecasts of storm movements and gust fronts that may cause airport reconfiguration. The Terminal Convective Weather Forecast (TCWF) 30-60 minute predictions for the future location of organized convection such as squall lines are being evaluated at the ITWS demonstration sites (Wolfson, et. al 2000).

A recent study of weather delay reduction at the New York terminal area (Allen, et. al, 2001) found that the NY ITWS with the TCWF capability achieves an <u>annual convective weather delay reduction of over 1.2 million minutes per year.</u> This is accomplished by enabling traffic flow managers and terminal facility supervisors to:

1. Achieve higher departure rates during convective activity by optimizing the use of gaps in the convective weather
2. Anticipate runway shifts,
3. Utilize shorter routes for arrivals and departures, and
4. Proactively end severe weather avoidance plans (SWAPs)

The national deployment of the ITWS would yield an annual delay reduction with an equivalent monetary value of over $ 500 M per year. This illustrates the very significant delay reductions that can be accomplished by tactical means in a situation where the workload associated with flight path amendments and traffic flow management considerations are not critical factors in the tactical response.

Contemporary En Route Capabilities

The Weather and Radar Processor (WARP) currently provides displays of NEXRAD mosaics to ARTCC meteorologists, traffic flow managers (TMC) and sector supervisors. The en route controllers should receive these mosaics on their DSR displays in 2002. WARP currently does not provide any accurate, automated short-term forecasts of future storm locations. The Aviation Weather Center provides the National Convective Weather Forecast (NCWF) (Muller, et. al 2000) with 1-hour forecast contours based on application of the TCWF technology to a "composite" storm intensity product generated from vendor supplied reflectivity data and cloud-to-ground (CG) lightning data. The EMS display used by enroute TMC uses vendor NEXRAD mosaics with Cloud-to-ground lightning data provided as strike locations.

The FAA is currently operationally evaluating the Corridor Integrated Weather System (CIWS) concept that would take advantage of the high density of existing FAA and NWS weather sensors in the congested en route corridors, and, the forecast technology developed for the ITWS program (Figure 2).

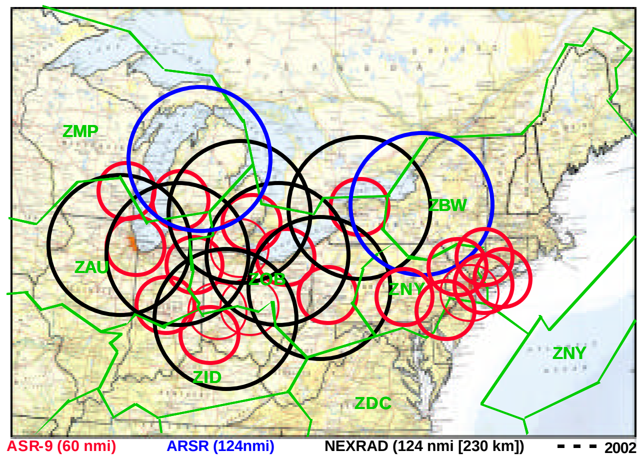

Figure 2. CIWS coverage in early summer 2002. Large circles are NEXRADs or ARSR4s; small circles are ASR9s.

Both terminal and en route weather sensors are used to create the CIWS products: the rapid update rate of the ASR-9 and ARSR-4 radar weather products (30–60 seconds) helps detect rapidly growing cells, while the NEXRAD provides 3-D storm information using AP edited vertical integrated liquid (VIL) as a measure of storm severity. Data from lightning sensors (not shown) is also integrated with the radar data. A Regional Convective Weather Forecast (RCWF) provides a TCWF like 30-60 minute forecast capability with regional performance scoring.

This use of the existing <u>terminal</u> sensors for <u>en route</u> tactical decision provides much higher update rates than could be provided by NEXRAD alone, redundancy when NEXRADs are out of service, and (most importantly) the ability to forecast new storm development through much better sensing of the critical boundary layer[4]. It is anticipated that the CIWS will commence providing 2-hour forecasts that include forecasts of cell development in 2002.

The CIWS commenced operations in the summer of 2001. It was learned that the en route system could effectively utilize the CIWS products near major terminals, but had much greater difficulty in responding

[4] In particular, the CIWS will use TDWR and NEXRAD to estimate surface wind convergence.

tactically for "over flights" due to air traffic management system issues that are described below. Given this difficulty in being "agile", longer lead time predictions were needed to take advantage of gaps in the weather. The physical extent of the storms in a number of cases resulted in traffic from within the CIWS domain needing to be rerouted into regions that did not have CIWS products; hence, it was found also to be necessary to increase the spatial coverage of the CIWS system

As a result of the summer 2001 operational experience, the CIWS demonstration in 2002 will seek to extend the forecast periods out to two hours through explicit growth/decay forecasting, significantly increase the spatial coverage and, integrate the CIWS with contemporary ATM decision support systems.

4. "NEAR TERM" TACTICAL AIR TRAFFIC MANAGEMENT (ATM) SUPPORT FOR CONVECTIVE WEATHER

The CIWS experience in 2001 has shown that air traffic management tools that can utilize the tactical weather decision support products are critical to improved handling of traffic when there is convective weather in congested airspace. Key issues include reducing controller workload, unambiguously identifying regions of airspace that pilots will seek to avoid and, addressing the traffic flow management consequences of tactical rerouting to avoid convective weather.

A. ATC workload reduction

A major problem in executing a highly adaptive, flexible approach to handling of convective en route weather is the controller and TFM workload associated with coordination and filing of flight path amendments. The flight path amendment problem becomes particularly acute when reroutes must be coordinated across multiple sectors and ARTCCs.

Rerouting would be far simpler if there were electronic flight strip coordination tools that check for conflicts and traffic flow management constraints automatically. Both the User Request Evaluation Tool (URET) developed by MITRE and the "Direct To" tool developed at NASA Ames significantly improves the capability to reroute planes; but has not yet been interfaced to convective weather decision support systems nor integrated with traffic flow management tools (see the next section) and flight dispatch decision support systems.

B. Addressing capacity limitations

In congested airspace, traffic flow management (TFM) constraints become particularly important when convective weather has reduced the capacity of various routes and sectors thus increasing the demand on other routes and sectors. Hence, determining the viability of candidate reroute strategies would be greatly facilitated by appropriate TFM decision support tools .

The Collaborative Routing Coordination Tool (CRCT) has been effective at key en route centers in assessing the impacts of reroutes on downstream traffic flow management (TFM) systems (see Sherry, et. al, 2001). However, at this point, the CRCT software in use does not extend across multiple ARTCCs. CRCT currently requires the users to input the areas of weather impacts and, does not automatically generate sets of solutions for the projected weather impacts. Also, it is essential that dispatchers be able to interact with the proposed reroutes in real time.

5. A "NEXT GENERATION" INTEGRATED CONVECTIVE WEATHER SYSTEM

In the discussion above, we have identified a number of current technologies that could be utilized to provide a tactical weather/ATM capability that would complement the current "strategic " weather/ATM capability. However, a far more robust system could be developed if the tactical and strategic capabilities were developed jointly as opposed to separately.

The current "strategic" ATM approach essentially assumes that one can forecast the convective weather perfectly. We argue that generating deterministic forecasts with prediction times > 2 hours that would permit accurate determination of routes and capacity in congested airspace is simply not feasible in the near future.

Rather, it will be important to generate probabilistic forecasts that can be related in a natural way to predicting capacities and determining the initial routing strategies. The challenge here is the development of a stochastic model that can:

1. address the space/time correlation for convective weather of various types, and
2. smoothly transition to a largely deterministic model for short prediction times (e.g., 30 minutes) and,
3. be matched to route optimizing algorithms (see, e.g., Nilim, et. al, 2001)

These probabilistic forecasts would then be used by route optimizing and traffic flow management optimization algorithms to determine candidate rerouting strategies for aircraft over extensive regions of airspace[5]. Since the rerouting will generally extend over multiple ARTCC's, it would need to be accomplished nationwide by a central location. This will necessitate that the central facility have access to very high space/time resolution forecasts in congested airspace. The resulting reroute recommendations would then need to be reviewed very rapidly by TMCs from the impacted ATC facilities and airline dispatchers.

5 In particular, the spatial region covered must include areas with no operationally signficiant weather that is being utilized for reroutes.

The approach suggested above could be viewed as centralized paradigm for route planning that sharply conflicts with current decentralized approach where each airline dispatcher generates flight plans more or less independently and in which there is some degree of conflict resolution through FAA/airline discussions.

To facilitate collaborative interaction between various ATC facilities and airline dispatch, we recommend that the algorithms which generate rerouting strategies for aircraft in flight and on the ground be "community" property that can be run by various ATC facilities and airlines for "what if" studies.

This heavily automated rerouting capability is principally needed in highly congested airspace. In less congested airspace where there is much more flexibility to reroute individual aircraft with minimal or no traffic flow management constraints, the current approaches would probably suffice. How these two approaches might jointly exist in the air system in spatially adjacent regions might be a candidate near term for the large scale US air system simulation proposed for the NASA AvSTAR program.

6. SUMMARY AND RECOMMENDATIONS

Convective weather has become a major cause of US aviation delays due to the major effective capacity reductions that are caused by thunderstorms. Convective activity is a particularly difficult challenge in congested airspace because it is not possible to accurately forecast operationally significant convective weather far enough in advance to avoid in flight adjustments of aircraft routes.

In the near term, it is possible to make a major improvement in the convective weather decision support capability by a combination of the ITWS/TCWF/RCWF weather prediction technology integrated with contemporary automation and traffic flow management tools to generate and evaluate rerouting options on an ongoing basis. We emphasize that it is essential that we provide ATM tools that will enable the air traffic users to utilize the available weather forecast technology if we are to be successful at reducing the adverse impact of convective weather on congested airspace.

It will also be necessary to commence work on a new paradigm for convective weather decision support based on probabilistic strategic forecasts that smoothly transition to deterministic forecasts for short prediction lead times and are coupled to appropriate ATM decision support tools. This is a very challenging task that will require creative approaches by both the meteorologists and the ATM system designers.

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