12th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference and 14th AIAA/ISSM
17 - 19 September 2012, Indianapolis, Indiana

AIAA 2012-5501

Consideration of Strategic Airspace Constraints for Dynamic Weather Routes

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This paper describes analysis of strategic airspace constraints related to flights selected for dynamic weather routes. Dynamic weather routes slightly modify a flight's currently active flight plan. They are applied from the aircraft's current location to a flight plan fix downstream, while avoiding forecasted convective weather regions using up to two additional waypoints. Air traffic congested sectors and Special Use Airspaces are the two types of airspace constraints that are considered in this study. The sector traffic counts are predicted to avoid congestion downstream along the dynamic weather routes. A comparison of congested sectors for actual tracks flown and aircraft simulated to fly on dynamic weather routes is shown using five days of data from the Fort Worth Center. Also, a qualitative measure of goodness of the dynamic weather route is presented. This score indicates the difference of flying the actual tracks versus flying the dynamic weather route from a sector congestion point of view. Current analysis indicates that proposing dynamic weather routes helps save time, and consequently fuel, and alleviates congestion overall. For the cases considered, it also appears that the suggested routes could route aircraft away from congestion, helping traffic managers take aircraft away from congested areas. The dynamic weather route suggestions are also evaluated for traversal through Special Use Airspaces. The Special Use Airspace impact is presented as an advisory for selection of the routes by aircraft operators.

I. Introduction

DURING convective weather events, aircraft are routed around weather cells by the Federal Aviation Administration (FAA) traffic managers. Often, these reroutes introduce large deviations from the nominally filed flight plans. Some of the reroutes could have been implemented four to six hours before the flight gets near the constrained location, and are either unnecessary or are excessive as the weather and traffic conditions evolve. Dispatchers planning the flight an hour and a half to two hours before departure time with presumably less accurate weather information may have filed some of these routes with larger than necessary deviations around projected weather. It is possible to find shorter routes for a few of the flights, which can result in significant savings of time and fuel for the flight operator. To do so would also be beneficial for the environment due to reduced emissions. Until now, research has not been conducted to study the downstream sector congestion impact of sending these aircraft on more direct routes, e.g., to a downstream fix within their currently active flight plan.

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McNally, et al.[1] have conducted research on a weather avoidance concept for near-term, trajectory-based operations. In that research, benefits of removing excessive deviations from filed flight plans and sending flights on more direct routes are presented. That concept proposes sending flights on reroutes, which are deviations from the direct route between two waypoints along the filed flight plan. The deviation is introduced through the use of one or two additional or auxiliary waypoint(s) to route around a forecasted convective weather model region. The aircraft operator would benefit from the smaller deviation around weather for fuel and time savings, and improved schedule integrity.[2] The air traffic manager would find this beneficial, since during severe weather events, regions of airspace in the vicinity of weather become congested. The proposed weather avoidance concept helps alleviate congestion by directing some flights along dynamically generated weather routes.

In this paper, strategic airspace constraint analysis is presented for dynamic weather routes. Two types of airspace constraints are considered: congested sectors and Special Use Airspaces. Sector congestion is addressed with three metrics. For five days of data, the following three main parameters were studied. First, a comparison is presented between the number of congested sectors for actual operations, and congested sectors if all flights were allowed to fly on their dynamic weather routes. Second, a score is presented for each of the flights indicating whether it was beneficial to recommend a dynamic weather route. The basis for this score is whether an aircraft flew through a congested sector (i.e., number of aircraft was over nominal capacity for that sector) or would have flown through a congested sector if allowed to fly on the dynamic weather route. The last is the aircraft location at each point as compared to the location of congested sectors. For each of these cases, the Special Use Airspace traversal was also monitored.

The rest of the paper is as follows. Section II presents the Dynamic Weather Routes operational concept and the process for creating these routes. In Section III, the integrated software used for the analysis is described. The air traffic data scenarios and the results of analyses conducted are presented in Section IV. The paper ends with a description of future work and concluding remarks in Sections V and VI, respectively.

II. Dynamic Weather Routes (DWR)

A. Operational Concept

A trajectory automation system was developed that continuously analyzes post-departure aircraft in en-route airspace to find time and fuel saving corrections to convective weather avoidance reroutes. The system could help airline dispatchers and FAA traffic managers and controllers find more efficient routes around convective weather. Simple reroutes called Dynamic Weather Routes (DWR) are automatically proposed to an airline dispatcher and updated every 12 seconds using the Center TRACON Automation System (CTAS).[3,4] Flights where a reroute can save more than a user-specified amount of wind-corrected flying time, e.g., 5 minutes, are posted to a reroute advisory list on the dispatcher's display. An interactive trial planner function enables users to visualize the proposed reroute, modify it if necessary, and evaluate critical parameters such as potential flying time savings[*], proximity to current and predicted weather, traffic conflicts, and downstream sector congestion. The last two are computed using the Future ATM Concepts Evaluation Tool (FACET)[5]. Both CTAS and FACET are described in detail in the Integrated System Description Section (III). The DWR system is ideal for air/ground data link communication but can be used with current operational procedures.

The three main assumptions of the DWR system are as follows:

1. It is not always necessary to fly a weather avoidance reroute completely as planned. If weather has changed, or a more efficient route around weather exists, then a flight could request a reroute.

2. Airline dispatchers, FAA traffic managers and controllers are busy during weather events, and without automation, might not notice opportunities for more efficient weather- avoidance routes.

3. Named fixes or waypoints may be communicated by voice, but auxiliary waypoints defined in fix-radial-distance (FRD or latitude/longitude) format are prone to voice communication error and may be communicated only via data link.

B. DWR Automation Process

Figure 1 describes the DWR creation process. The solid line shows the current active flight plan that the aircraft is flying. The middle dotted line is the direct route between the current location of aircraft and a downstream return capture fix. The dashed line is the newly created DWR with one auxiliary waypoint, which could be a FRD point or a nearby named fix. The integrated DWR system analyzes the current active flight plan for a "dog-leg" and looks for

[*] In the DWR system, flying time savings or delay figures are all wind-corrected.

opportunities to reduce the travel time while avoiding forecasted convective weather model polygons. The process is described in detail below.

1. Weather modeling

Convective weather forecasts for DWR are based on Corridor Integrated Weather System (CIWS) and Convective Weather Avoidance Model (CWAM)[6], both developed at MIT Lincoln Laboratory. CIWS uses vertically integrated liquid (VIL) data and echo top data from NexRad weather radars to compute a 2-hour national convection forecast that is updated every 5 minutes and includes a 5-minute forecast time step.

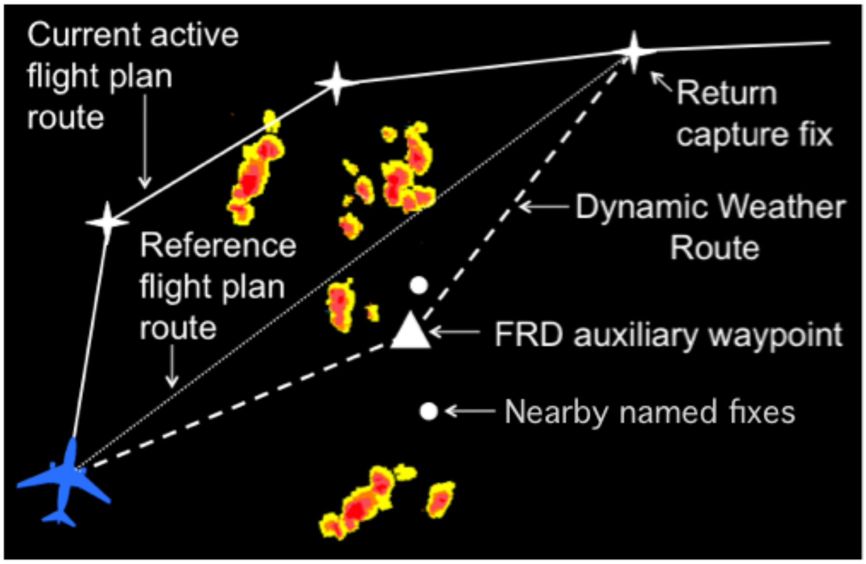


Figure 1. DWR automation schematic.

CWAM processes CIWS data to predict the probability of pilot deviation for weather as a function of storm intensity, echo-tops, look-ahead time, and altitude. For a given CIWS forecast, pilot deviation probability is quantified using Weather Avoidance Fields (WAF)[7], where a WAF defines a region around a weather cell that a specified percentage of pilots are expected to avoid. For example, 60% of pilots are expected to deviate around a 60% WAF. For a given weather cell and altitude, 70% WAF polygons are generally smaller with their boundaries closer to the weather cells than are 60% WAF polygons. Fig. 2 shows CIWS weather cells (VIL) and their corresponding current time (nowcast) 60, 70, and 80% CWAM polygons at FL330.

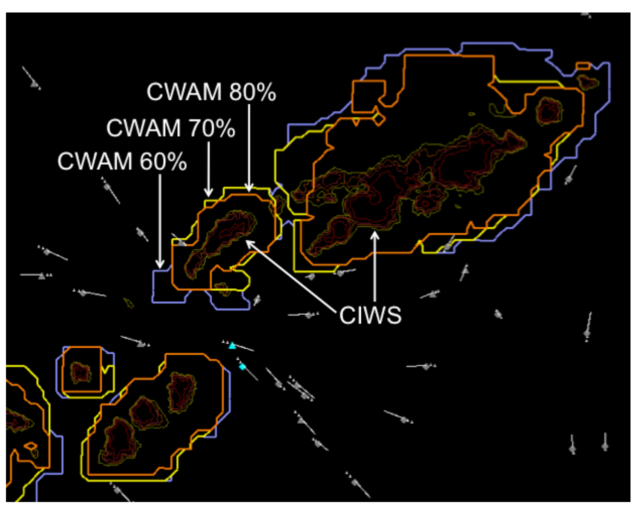


Figure 2. DWR system screen capture showing CIWS cell (VIL) and corresponding nowcast 60, 70, & 80% CWAM polygons for FL330.

CWAM updates are read into CTAS every 5 minutes, and integrated with the trajectory modeling and automation such that conflicts between nominal or trial plan trajectories, and WAF polygons are automatically detected correctly accounting for the movement of traffic and weather over time. The default WAF for this analysis is 70%.

2. Dynamic Route Creation Process

The DWR system display is shown in Fig. 3. The large window on the left shows the current flight plan route and the DWR with one auxiliary waypoint. The small window above the text "DWR list" (upper left) is the current DWR suggested list. Clicking the second check box on the 'DWR List' initializes the two routes (DWR and current flight plan) for that flight. The long window at the bottom provides the flight details. The two windows on the right show the current and future DWR sector congestion information. In this example, the DWR relieves forecasted

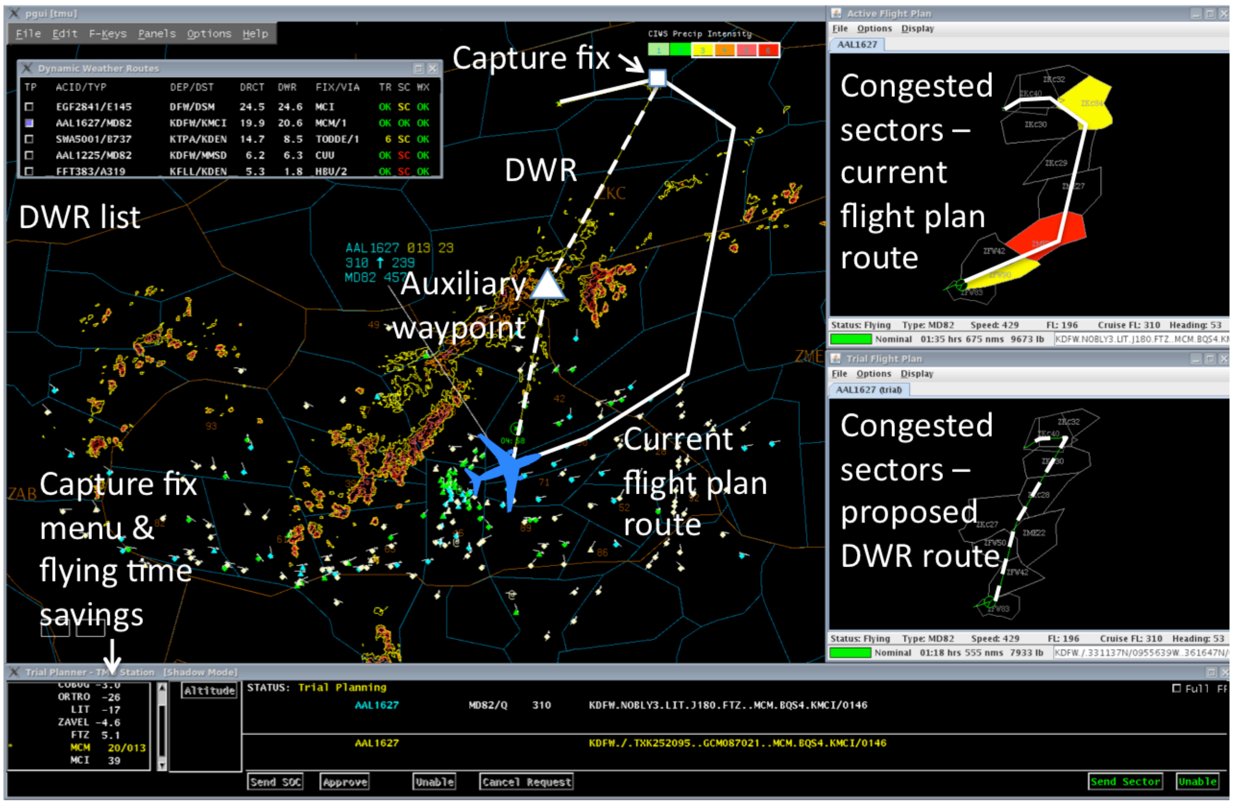


Figure 3. A snapshot of main DWR display.

congestion (shown in the upper right window). Six steps are followed for creating a DWR. Briefly, they are: finding candidate flights, detecting weather and traffic conflicts, resolving these conflicts, computing flying time savings, presenting downstream airspace constraints and posting final list of flights to the DWR list. Determining the downstream or strategic airspace constraints and the definitions behind the red and yellow sectors are described in *Step 5*, is the main focus of this paper. The steps are described in detail next.

Step 1. Find Candidate Flights. DWR automatically analyzes the most recent trajectory updates to find flights that could potentially benefit from more efficient routing around weather. The presence of a large "dog-leg" in a downstream route of flight is a strong indication that the flight is on a route previously implemented for constraint avoidance. The return capture fix is an existing fix on the current route of flight. The reference flight plan route is the basis for resolving weather and traffic conflicts.

The reference flight plan could be a direct route or a wind-optimal route to a suitable downstream fix or a route to a more efficient standard arrival route (STAR) into the destination airport, or some other user-preferred route. In this analysis the direct route is used and the associated trajectory automation[4] as implemented in CTAS is applied to identify flights with large "dog-legs" in their current flight plan route. The Direct-To algorithm automatically finds direct routes to downstream fixes that can save one-minute or more wind-corrected flying time. For the DWR system, a flight with a large "dog-leg" is one where the flying time savings to a downstream fix within a 700x1000 nmi limit rectangle that surrounds a Center is greater than a critical trigger value, e.g., 5 minutes.

Step 2. Detect Weather and Traffic Conflicts. Any direct route trajectory that meets the limit rectangle and time savings criteria described in Step 1 is automatically tested for conflict with modeled weather and traffic. If no weather or traffic conflicts exist, Steps 3-4 are skipped, the direct route is tested for strategic airspace constraints (*Step 5*) and the DWR advisory is posted to the DWR List (*Step 6*) as a reroute direct to the downstream capture fix.

Step 3. Resolve Weather and Traffic Conflicts. If weather or traffic conflicts are detected on the reference flight plan trajectory in Step 2, the resolution software[8] automatically attempts to find a minimum-delay reroute, relative to the reference flight plan. In the current implementation two DWR solutions are attempted. The first resolves modeled weather only, and the second computes an integrated solution that resolves both weather and traffic separation conflicts. Weather conflicts are resolved on a 60-minute time horizon and traffic conflicts are resolved on a 12-minute time horizon. *Steps 4-6* are followed before posting a solution on the DWR list.

DWRs are formed by inserting up to two auxiliary waypoints between the current track position and the downstream capture fix. Candidate solutions are sent to the CTAS trajectory engine and tested for flying time delay relative to reference flight plan. The solution with the minimum flying time delay relative to the reference flight plan and which meets the weather, or weather and traffic constraints, is selected for further analysis.

Step 4. Flying Time Savings. The DWR solutions are checked for potential flying time savings relative to the actual current flight plan trajectory. If the time to fly along the DWR saves more than 5 minutes, continue on to *Steps 5* and *6*. If not, this flight is not posted on the DWR List.

Step 5. Present Downstream Airspace Constraints. As mentioned earlier, this step is the focus of analysis presented in this paper. For all flights that meet the minimum flying time savings criteria in *Step 4*, their DWR trajectories and their actual current flight plan trajectories are probed for downstream sector congestion and SUA traversal. If a DWR would take an aircraft directly into a congested sector or an active SUA, the reroute would likely be unacceptable from an air traffic controller perspective. Alternatively, if the current active flight plan has the aircraft flying into congested airspace, while the DWR takes the flight out of congested airspace, the DWR is preferable and helps ease congestion. Flight plans are not filed into active SUA regions.

As mentioned above, FACET is used for computing downstream sector congestion. The aircraft location at each one-minute step for a two-hour period is added to corresponding sector counts. Each aircraft's current flight plan and the DWR proposed route is checked for travel through congested sectors. The result can be seen in Fig. 3. The upper right window shows the current flight plan traversing through one red and two yellow sectors. The sector is depicted red if the number of aircraft predicted to traverse the sector is at or above Monitor Alert Parameter (MAP), and at least MAP number of aircraft are airborne at the time the prediction is made. If some of the aircraft are on the ground but the total number of aircraft traveling through a sector is at or over MAP value, then the sector is depicted yellow. The bottom right window in Fig. 3 shows that the proposed DWR does not encounter any congestion. As soon as a DWR is computed by CTAS, FACET computes and provides the sector congestion information indicated in the two windows on the right (Fig. 3). The user (either a flight dispatcher or a traffic manager) at this point can view the congestion information and decide whether the DWR is acceptable based on a target or anticipated level of congestion. If the proposed DWR traverses an active SUA, it is displayed on the right top and bottom windows as well. This is described in further detail in Section IV.D below.

Step 6. Post Flights to DWR List. In the last step, the flight ID, potential flying time savings, and other pertinent information are posted to a list on the user's display (DWR List). This is the smaller window in the top left of Fig. 3. Options to display advisories and enable trial planning from the flight data block are also available and well suited to air traffic control displays. The alerting value for posting a solution to the DWR List is adjustable by the user based on workload, potential flying time savings benefit, and other factors.

3. Trial planner

The Trial Planner is the user's primary tool for evaluating DWR advisories. An interactive rapid-feedback trial planner tool enables users to quickly and easily visualize the proposed DWR and modify it if necessary. Trial planning functions are common in air traffic management automation applications and are integral parts of many automation systems. A point and click action in the DWR List initializes the trial planner with the advised DWR.

III. Integrated System Description

In order to analyze the feasibility of dynamic weather routes for traffic management, CTAS[3,4] was integrated with FACET[5]. Both these software tools have been in development at NASA Ames Research Center for many years. CTAS and FACET software are connected through an interface, which allows them to communicate bi-directionally to exchange flight plans and sector congestion information. Both of these systems are briefly described below.

CTAS is a high fidelity simulation environment handling aircraft within a single center of the National Airspace System (NAS). It includes real-time traffic conflict and convective weather conflict detection and resolution, time-based metering, and efficient descent advisory functions, all of which are supported by a single common CTAS trajectory engine. CTAS is configured for en-route Center operations and is the trajectory automation software baseline for Dynamic Weather Routes. CTAS computes 4D trajectory predictions (x, y, h, and time) for all Center flights using live or recorded data feeds. The primary inputs to CTAS are Center Host surveillance radar track messages updated every 12 sec, Center Host route and altitude flight plan intent messages as entered and updated by controllers, National Oceanic and Atmospheric Administration (NOAA) Rapid Refresh (RR) atmospheric data, including wind forecasts, updated every 1 hour, and a database of aircraft performance models. The 12 sec Host track and flight plan updates are essential so that flight plan intent is up to date and traffic conflict detections are reliable. Trajectories include modeled top-of-climb and top-of-descent points and incorporate hourly Rapid Refresh wind updates which include wind variation with altitude.

FACET is a NAS-based medium level fidelity data analysis and simulation system, which reads in FAA provided air traffic data. The capacities of airspace sectors and other parameters are obtained from the FAA's Enhanced Traffic Management System (ETMS)[9] or what is now called the Traffic Flow Management System (TFMS). Thousands of aircraft are simulated, with NOAA RR one, two, three, and six-hour forecast winds, to fly along their nominal flight plans as filed with the FAA, using the Base of Aircraft Data (BADA)[10] look up tables for aircraft performance. The MAP values are obtained for each sector from the FAA. For the aircraft under consideration, FACET computes sector congestion data for filed flight plan and the dynamic weather route received from CTAS through the interface. Active Special Use Airspace (SUA) times are obtained from the FAA, and FACET searches for any active SUA intersections.

IV. DWR Data and Analysis

The focus of the analysis presented here is that associated with *Step 5* in previous Section. To analyze the strategic feasibility of the dynamic weather routes concept, two airspace constraint parameters were studied: the predicted downstream congestion and the active Special Use Airspace (SUA) traversal. The results of the analyses are presented below.

In all, five days of data were used for the analysis. These are shown in Table 1 below. All these five days had considerable convective weather in and around Ft. Worth Center (ZFW). Also listed is the total number of DWRs proposed for flights on various days.

Table 1. DWR analysis dates, times and number of flights for which DWRs were suggested.

Date	Day	Start Time (UTC)*	End Time (UTC)*	Number of DWR flights
May 14, 2010	Monday	1400Z	1900Z	32
June 9, 2010	Wednesday	1700Z	2200Z	48
June 24, 2010	Thursday	2000Z	2400Z	11
September 2-3, 2010	Thursday-Friday	2300Z	0400Z	40
March 19-20, 2012	Monday-Tuesday	2300Z	0400Z	33

(* Note: Ft. Worth Center (ZFW) for these days was on Central Daylight Time, which is UTC – 4 hours)

The DWR system is generally run in live mode. The DWRs are presented based on current traffic conditions. The analysis described here was conducted by playing back recorded data in post operations. A sample flight case is shown in Fig. 4 to describe this post-operations analysis. The actual (black), the active flight plan (cyan) and proposed DWR (pink) tracks for flight AAL1157 on May 14, 2010 from 14:00 to 15:59 UTC are presented in Fig. 4. The flight flew from Dallas/Ft. Worth airport to Seattle airport but tracks stop when the flight reaches the Denver Center (ZDV) and Salt Lake Center (ZLC) boundary. In all subsequent discussion, only two hours of flight data (from the flight's current location) are processed. All the analysis data presented here are comparisons of actual trajectory (black crosses) against DWR route (pink triangles). Note how the flight stays on the current flight plan (cyan) until it gets close to the ZFW/Albuquerque (ZAB) boundary and then flies a shorter route between the current and DWR flight plan. This is because an en-route flight plan modification was implemented in ZAB, sending the aircraft direct to Grand Junction (JNC) in ZDV. JNC is located where all three routes meet and is shown with a black square.

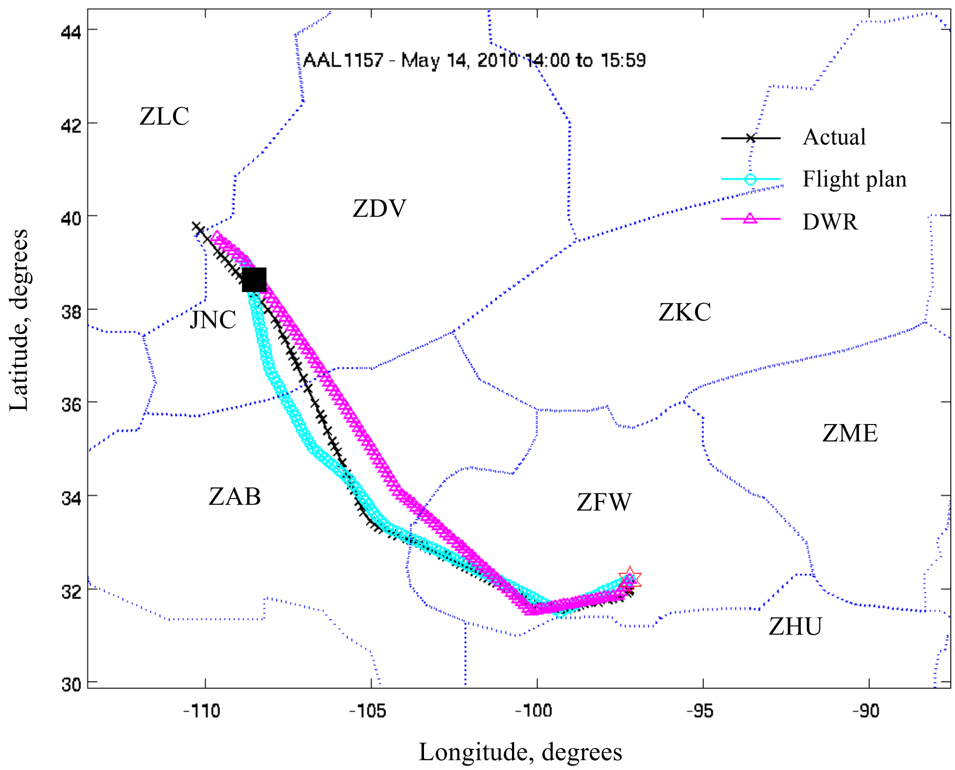


Figure 4. Display of tracks for actual data (black), active flight plan (cyan) and DWR (pink).

A. Downstream Sector Congestion

An important question from a traffic manager's perspective often is, if he or she were to accept all of the proposed dynamic weather routes, what would happen to sector congestion in various sectors in Ft. Worth and neighboring Centers? Figure 5 shows data to answer that question. For Ft. Worth (ZFW) center and its four neighboring centers, Albuquerque (ZAB), Kansas City (ZKC), Memphis (ZME), and Houston (ZHU), several sectors are shown in Fig. 5. These are all the sectors that were at or above nominal capacity (represented by the MAP value). The red bars represent the number of one-minute instances when the sector was over MAP with actual air traffic data for May 14, 2010 between 1400Z and 1900Z. The DWR flights were then removed from actual data and were flown along the suggested dynamic weather routes. The blue bar numbers (computed in post-operations) represent the number of one-minute instances over MAP when the selected flights were simulated on DWRs, with all other aircraft flying as they did on that day. The figure shows that for all sectors, the blue bars are always equal to or lower than red bars. This implies that the number of times any sector went over capacity is lower when flights were flying along DWRs. It should be noted that there was no active control applied with CTAS/FACET to minimize sector congestion and the red bars represent what happened on May 14, 2010.

Figure 6 shows the data shown in Fig. 5 as a function of time instead of individual sectors. The number of one-minute instances of sectors going over capacity is shown. The cases with actual tracks (red) and with DWRs (blue) show that DWRs represented lower congested sectors at all times. The congested sectors from the same five Centers from Fig. 5 are used for Fig. 6. Therefore, the total number of red sectors from Fig. 5 and Fig. 6 are the same.

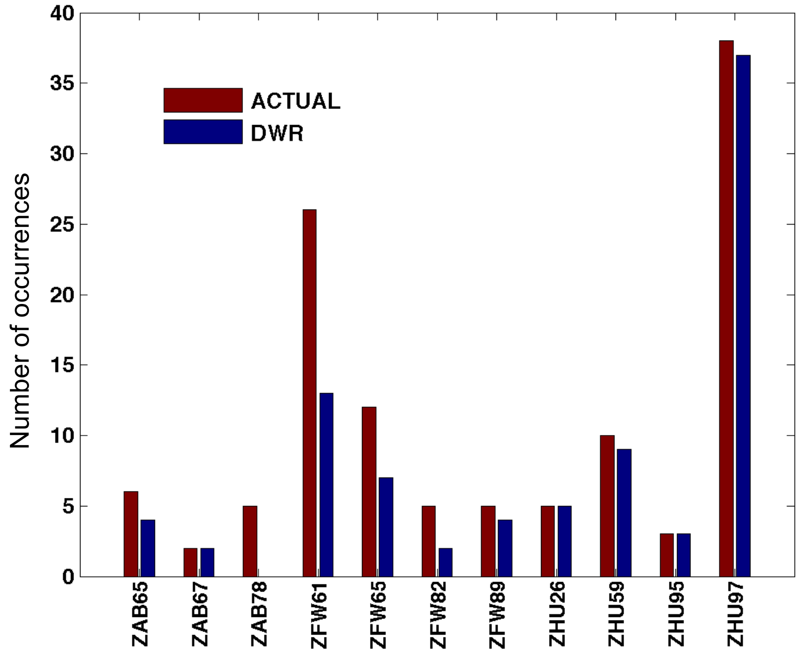


Figure 5. A comparison of congested sectors in actual data (red) and with DWRs (blue).

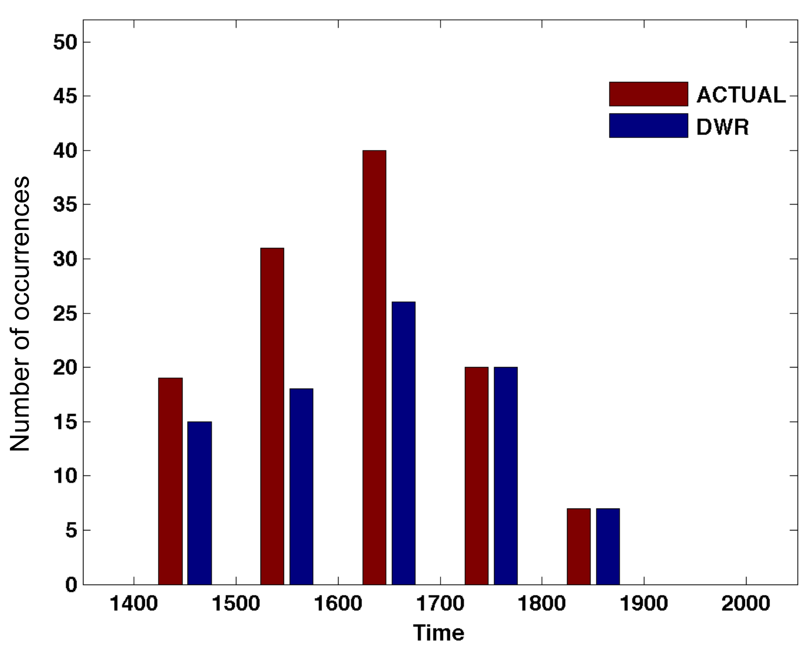


Figure 6. A temporal comparison of congested sectors in actual data (red) and with DWRs (blue).

Table 2 below provides a summary of all the five days listed in Table 1. On each day, the number of one-minute instances of congested sectors is presented for the actual tracks (column 3) as well as when flights were flown on the suggested DWRs (column 4). The number of flights with a suggested DWR is shown in Column 2. Other than on June 24, 2010 for two one-minute instances, DWR overall reduced sector congestion by 18% compared to what the aircraft actually flew. This is attributable to the fact that DWRs tend to move aircraft from the FAA imposed structured routes.

Table 2. Congested sectors with actual tracks and DWR, and the corresponding % improvement with DWR.

Date	Number of DWR flights	Congested Sectors (Actual)	Congested Sectors (DWR)	% Improvement using DWR
May 14, 2010	32	117	86	27
June 9, 2010	48	36	34	6
June 24, 2010	11	49	51	-4
September 2-3, 2010	40	91	55	40
March 19-20, 2012	33	130	119	8
Total	**164**	**423**	**345**	**18**

B. DWR Score

In the generation of dynamic weather routes, sector congestion is not included as a constraint but is presented for the flight dispatcher's consideration. Therefore, goodness of a DWR from a sector congestion perspective is needed. One metric used in post-operations is to assess if an aircraft flew through a congested sector. If so, one can compute if the suggested DWR would have traversed non-congested sectors. Figure 7 represents a score for such a situation. The DWR for a flight is given a +1 score (blue) if that flight flew through congestion but the DWR did not take the flight through any congested sectors. On the other hand, if the DWR simulation flew a flight through a congested sector, while the actual aircraft did not encounter congested sectors, DWR is given a -1 score (red). If a flight's actual track did not go through congestion nor did the simulated DWR go through congestion, the flight's DWR score is 0. The score is always an integer value between -1 and 1. Since this score requires the congestion information for the actual flight, it can be computed in post-operations only.

For the May 14, 2010 data shown in Fig. 5, one flight shown in red (AAL1157) did not go through congestion that day but could have encountered congested sectors if it had flown along the suggested dynamic weather route. On the other hand, seven flights (shown in blue) went through congested sectors that day but could have flown free of congestion if they had traveled along the DWR. Over all five days, there were 164 flights, out of which 46 flights

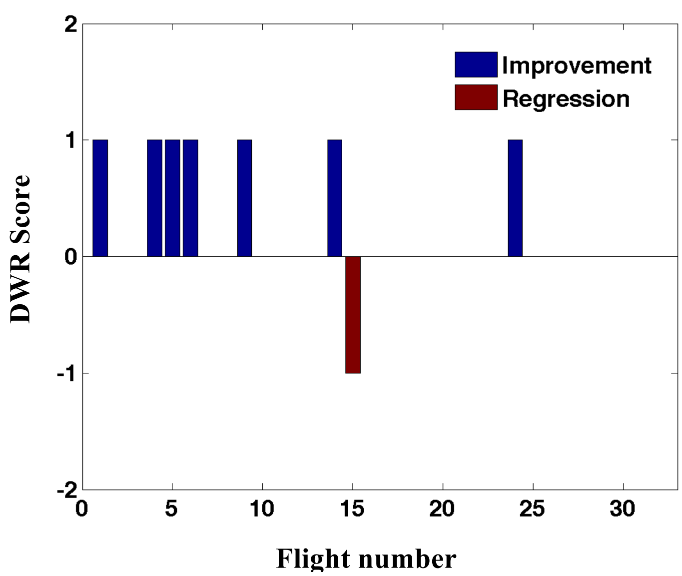


Figure 7. The DWR score for each flight to show the goodness of proposing dynamic weather route.

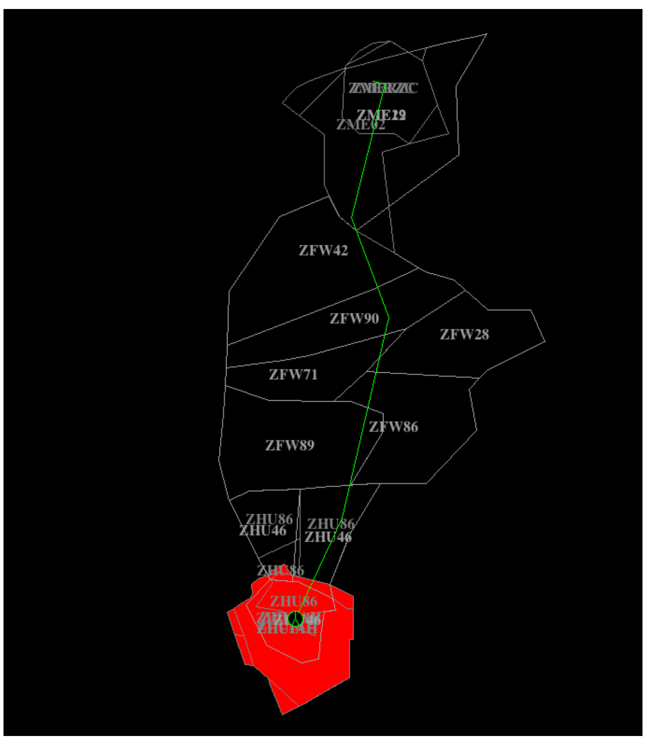
were blue and only 2 were red. Meaning, 28% of the DWR suggested flights could have saved time and could have helped the traffic manager and controller by reducing excessive traffic through their sectors. The vast majority of the other flights did not encounter congestion in actual tracks nor would have traversed congested sectors on suggested DWRs.

C. Aircraft Location Relative to Congested Sectors

Although not a constraint for DWR suggestion, the location of aircraft relative to congested sectors was also computed. If an aircraft is currently in a sector where the number of aircraft is at or above the MAP value, a DWR should not be requested. Despite considerable past research, no realistic metric for controller workload is used in operations currently. Therefore, it is assumed that if the sector is red, the traffic controller is busy with higher workload. This factor of aircraft being in a red sector will be used in the future to filter flights from being on the DWR list.

Figure 8 (left) below shows an aircraft within a red congested sector. Figure 8 (right) shows a list of sectors within two hours of a flight's path (going north). In general, flights are required by the FAA to file their flight plans 45-minutes prior to departure. For DWR to be useful and acceptable in practice, it is suggested that a user not request the DWR trial plan while in a congested sector or approaching a predicted red sector within 45 minutes. This particular flight plan already is in a red sector currently (time 22:11 from Fig. 8 right, top). If any of the sectors in the flight's path in the next 45 minutes were congested (before 22:56 and until entry into Sector ZME19) then that would be an even stronger indication for not requesting this DWR from a traffic manager or controller.

During five days considered for this study, there were 18 instances where a DWR was suggested while the aircraft was in a congested sector. There were 7 instances where a DWR was proposed when an aircraft was beyond 15 minutes but within 45 minutes of a congested sector. This is over the total 164 flights for which DWRs were suggested. Again, it should be noted that there was no active control applied with CTAS/FACET to minimize sector congestion and the red sectors represent what happened on May 14, 2010. Based on current analysis, this parameter will be included with the advisory in a future DWR system. Predicted aircraft positions at 15- and 45-minute values will be marked for the user's benefit.



Sector	In	Out	Duration	Count	Capacity
ZHUIAH	22:11	22:16	00:06	28	20
ZHU86	22:17	22:22	00:06	12	15
ZHU46	22:23	22:27	00:05	11	15
ZFW89	22:28	22:36	00:09	12	16
ZFW86	22:37	22:39	00:03	18	18
ZFW28	22:40	22:40	00:01	13	16
ZFW71	22:41	22:42	00:02	3	18
ZFW90	22:43	22:47	00:05	13	18
ZFW42	22:48	22:53	00:06	11	18
ZME19	22:54	22:58	00:05	7	18
ZME22	22:59	23:01	00:03	3	18
ZME02	23:02	23:04	00:03	2	12
ZMERZC	23:05	23:10	00:06	4	20

Figure 8. An aircraft located in a congested sector and the predicted sector list with entry/exit times.

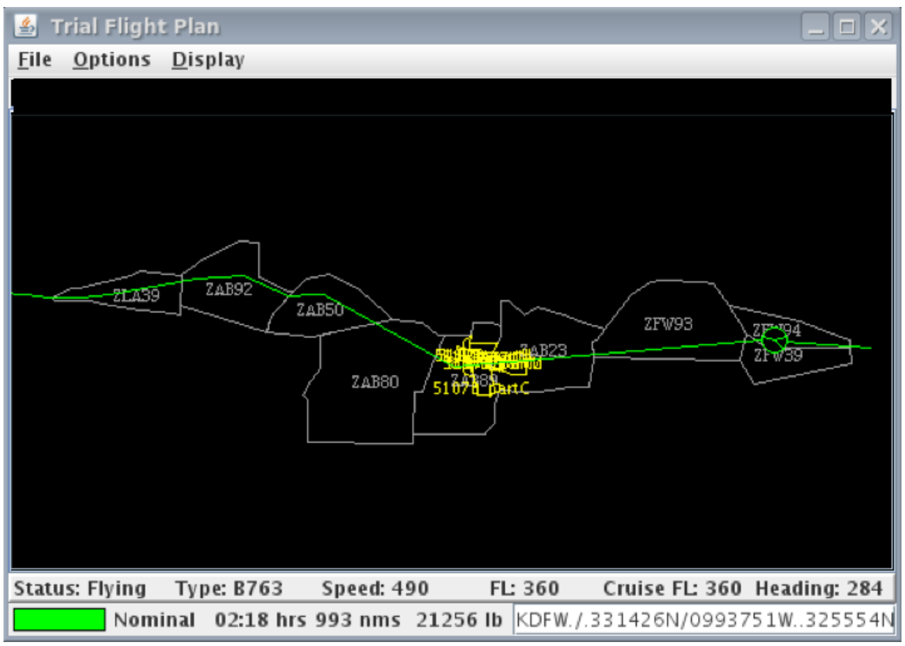
D. Special Use Airspace Evaluation

One of the factors that affect the acceptance of a DWR is its traversal through a Special Use Airspace (SUA) region. Within the United States, there are several types of SUAs. These are mainly categorized as Regulatory and Nonregulatory. The regulatory SUAs are the Restricted and Prohibited Special Use Areas. The nonregulatory SUAs are Military Operations Area (MOA), Alert Areas, Warning Areas, and National Security Areas. There are Air Traffic Control Assigned Areas (ATCAA) through which aircraft are restricted to fly as well. Also present in the airspace are Temporary Flight Restrictions, which are dynamic airspace regions for handling of sensitive flights.

For this study, the restricted, prohibited, MOA, alert, warning Special Use Airspaces and ATCAAs were considered. The active (hot) times information for these were obtained from the FAA's SUA web site. The data were downloaded every 15-minutes and processed by FACET software. When any active flight plan or DWR trial flight plan intersected any of the SUAs considered, it is displayed with the SUA name in yellow on the sector congestion window, as shown in Fig. 9 (a). FACET software checked for aircraft being within those SUAs at the appropriate times and altitudes.

As displayed in Fig. 9 (a), if the aircraft were to intersect a number of closely located SUAs, their names are available in a list of SUA names. This list, shown in Fig. 9 (b), consists of the SUA name, the time the aircraft would enter and exit the SUA, and the duration of transit through it.

To create Fig. 9 (a), a sample trial plan was created for an actual flight to generate intersection with multiple SUAs. Clearly, the sample trial plan was rejected. Most of the flights did not have any SUA intersections. Therefore, if ever, an empty yellow polygon showed up in the window, it was cause for checking the suggested DWR.



(a)

File

FCA	In	Out	Duration
5107B_partM	16:45	16:46	00:02
5107B_partL	16:45	16:46	00:02
5107B_partI	16:47	16:48	00:02
5107B_partH	16:47	16:48	00:02
5107F	16:45	16:48	00:04
5107B_partC	16:49	16:49	00:01
5111A	16:50	16:51	00:02

(b)

Figure 9. (a) Display of Special Use Airspace information along a DWR route, (b) list of SUAs with the entry/exit times.

Generally, an additional waypoint can be introduced outside of the SUA and a new SUA-crossing free route can be created. Even though there was no active control applied with CTAS/FACET to remove SUA intersections, there were no suggested DWRs that intersected any active SUAs during the five days of analyzed data. There was one flight with actual tracks that entered an active Warning SUA at 0225 UTC. The SUA was deactivated at 0230 UTC.

V. Future Work

Currently, the DWR system is being assessed for time and fuel savings, along with avoiding additional burden to air traffic controllers. There are several enhancements that have surfaced as a result of this study. Some of these are display of location markers of aircraft in 15- and 45-minutes, use of congested sectors within 45-minutes as a part of the advisory, use of SUA traversal as a part of the advisory, and the dynamic sector configuration information. The location markers would help the user know where the flight is predicted to be in 15- and 45-minutes. If there were any displayed red sectors within that time, the user would be better off not requesting a reroute from a busy air traffic controller. Even though the active SUAs are displayed clearly in the DWR trial plan window, it would be better to simply not alert the user with that route. The dynamic sector configuration is critical for an accurate representation of congestion information. In the current study, the airspace sectorization (4 pm Eastern Daylight Time due to peak traffic) is used for all sectors. In the future, the dynamic sector definitions obtained from the FAA will be implemented. Since only the sector congestion and SUA constraints were considered, other airspace initiatives like severe weather avoidance reroutes/coded departure routes (or a host of other reroutes that the FAA employs), miles- or minutes-in-trail, arrival/departure rate constraints at airports, will be considered in the future.

VI. Concluding Remarks

A preliminary airspace constraint analysis of dynamic weather routes is presented in this study. Dynamic weather routes are generated for flights that can save time, and consequently fuel, during convective weather events. Two different air traffic simulation systems, the Center TRACON Automation System (CTAS) and the Future ATM Concepts Evaluation Tool (FACET) were integrated to study the feasibility of dynamic weather routes from a downstream airspace constraint perspective. Sector congestion and Special Use Airspace (SUA) constraints were considered in this study. Based on the current results, in addition to saving time and fuel for flight operators, dynamic weather routes can help alleviate sector congestion by about 18% during severe weather events. About 28% of the flights would have saved time and fuel, while reducing the congestion observed in sectors.

Acknowledgments

The authors wish to thank Dr. Banavar Sridhar, Dr. Shon Grabbe and Mr. William Chan for discussions on feasibility of dynamic weather routes concept from traffic flow management and weather avoidance perspectives. Thanks are also due to Mr. Scott Sahlman for help with the DWR flight analysis and to the FACET/CTAS development team for continuous support of the integrated system.

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