ESTIMATING THE LIKELIHOOD OF SUCCESS IN DEPARTURE MANAGEMENT STRATEGIES DURING CONVECTIVE WEATHER

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Abstract

The presence of convective weather (thunderstorms) in terminal and nearby en route airspace of major metroplex areas can have significant impacts on departure operations. Traffic on departure routes impacted by convective weather may be constrained by miles-in-trail (MIT) restrictions, to allow controllers the time needed to maneuver individual flights around thunderstorms that pilots wish to avoid. When the workload required to manage traffic flows becomes too great, departure routes may be closed. Departures still on the ground that are filed on closed or restricted routes may face significant delays as they wait for clearance on their filed route, or for a viable reroute to be implemented. The solution proposed in concepts such as the Integrated Departure Route Planning tool (IDRP) [1] is the use of weather and departure demand forecasts to plan and implement reroutes to avoid weather and volume congestion proactively, well in advance of route restrictions or closures.

As traffic management concepts propose longer forecast horizons for proactive planning, they must account for the considerable uncertainty inherent in air traffic management during convective weather. The Route Availability Planning Tool (RAPT) [2], a departure management decision support tool that forecasts convective weather impacts on departure routes, has been used in both New York and Chicago to proactively plan reroutes of pending departures to avoid weather impacts. However, even with RAPT, there is uncertainty in predicting convective weather impacts, wheels-off times for pending departures, and demand for different departure resources, particularly when schedules are disrupted by weather impacts. These uncertainties can limit the planning horizon and reduce the effectiveness of proactive rerouting.

Air traffic managers with the primary responsibility for departure route management at current RAPT prototype sites (the traffic management units (TMU) in ZNY in New York and ZAU in Chicago) employ many tactics (including, but not restricted to, proactive rerouting) to mitigate convective weather impacts while accounting for the limits of forecast certainty. This paper presents convective weather impact mitigation tactics observed in departure management during RAPT field evaluations in New York [3, 4] and Chicago [5], proposes objective characteristics that may be used to define success and failure in reroute decisions, examines the probabilities of different outcomes based on weather-avoiding reroute strategies, and explores the factors that affect the choice of departure management tactics and outcomes.

Convective Weather Impact Mitigation Tactics

Four tactics - ground delay, pilot avoidance, fix merging, and rerouting - have been observed in New York and Chicago operations during RAPT evaluations [3-5]. These tactics are described below. Other potentially useful tactics – departure fix metering and surface sequencing and scheduling – are currently not in use in the either New York or Chicago.

Tactical Ground Delay

If the filed departure route is unavailable, the flight is delayed on the ground and staged for departure once the filed route is forecast to become available. The advantage is that the flight can stay on its preferred route, and by staging departures in anticipation of clearing impacts, ground delay can be minimized. There is no workload to reroute the flight. However, there must be somewhere to hold waiting departures, and there may be considerable uncertainty about when the filed route will become available. The ability to hedge uncertainty is dependent on surface flexibility and rapid coordination of reroutes between the tower and Air Route Traffic Control Center (ARTCC); if weather impacts are more prolonged than anticipated, the tower must quickly coordinate a reroute with the

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ARTCC and expedite the rerouted flight's entry into the departure queue.

Pilot Avoidance

Pilot avoidance is usually the first response to weather impacts. Controllers allow pilots to deviate to avoid weather along their filed flight plan, so long as they are comfortable that they can maintain safe separation between aircraft. There are several benefits: there is no need to coordinate a reroute, impacted airspace continues to be used, and traffic flows and schedules remain largely intact. However, if a pilot refuses to take the route, several traffic flows may be disrupted as the pilot is maneuvered to avoid the weather. The route is often then closed without warning, potentially leaving several departures in taxi without a cleared departure route. The key uncertainties are the willingness of pilots to accept the route, and the ability of the controller to maintain traffic flows with deviating aircraft. Uncertainty is hedged by implementing mile-in-trail (MIT) restrictions, to give controllers additional time and space to manage deviating aircraft. Figure 1 illustrates an example of pilot avoidance.

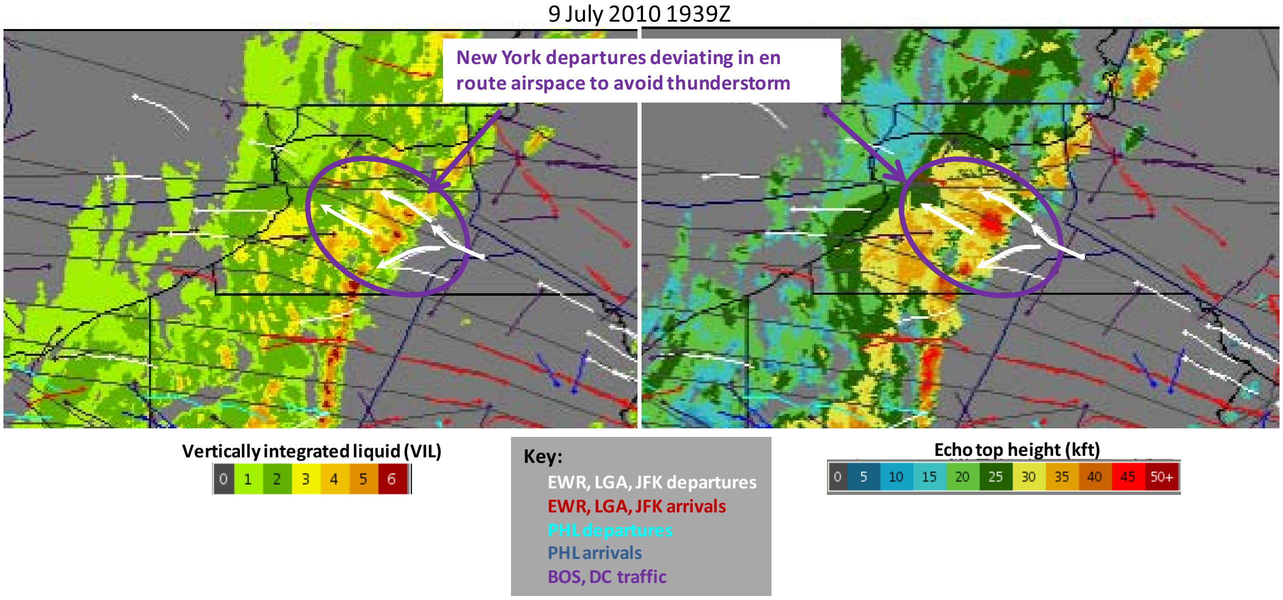


Figure 1. Pilots Maneuvering To Avoid Convective Weather

Fix Merging

In fix merging, departures filed through one or more weather-impacted departure fixes are merged with traffic flows through a neighboring, unimpacted departure fix, and then returned to their originally filed route (Figure 2). Fix merging can be highly efficient: reroute coordination workload is avoided, weather impacts remain local, and air traffic control can adjust flows as the weather changes. However, fix merging can only be done for fixes in the same departure gate, and where flights can be returned to their filed routes without significant coordination. Weather forecast uncertainty is the primary risk. If impacts unexpectedly disrupt the unimpacted fix, they may be restricted or shut off. Uncertainty may be hedged by imposing MIT on the merged flow

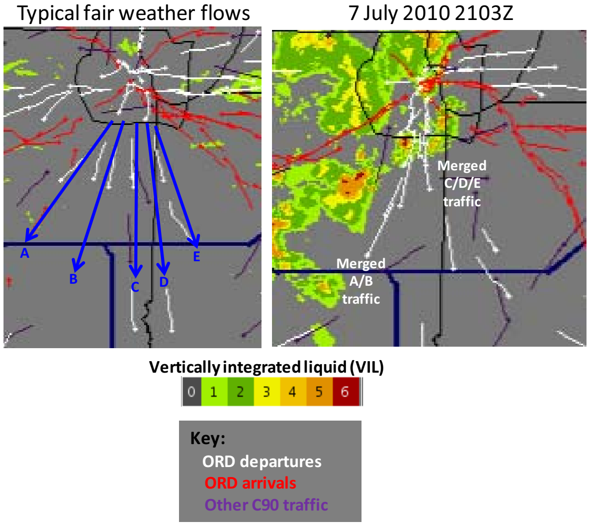


Figure 2. Fix Merging To Avoid Convective Weather

Rerouting

Rerouting is employed to avoid weather impacts that cannot be mitigated using the other tactics described above. Pilot avoidance or fix merging may be followed by reroutes if weather impacts are expected to increase in severity, or if the current tactics cannot be maintained. Proactive rerouting can enable traffic managers to maintain more predictable traffic flows by moving departure traffic out of impacted airspace, where uncertainty in forecasts of weather impact and pilot response can lead to unexpected traffic disruptions, into unimpacted airspace, where impact uncertainties are not a factor. In some airspaces, a reroute may also require a change in departure runway, and proactive reroute planning provides terminal controllers advance notice if runway changes are needed.

However, proactive rerouting has some drawbacks. Frequently, traffic filed on the unimpacted departure fix must be rerouted to make room for weather-avoiding reroutes, and MIT restrictions may be put in place to manage congestion on the unimpacted route. Furthermore, as the planning horizon increases, so does weather forecast and wheels-off prediction uncertainty. If forecasted weather impacts do not materialize, proactive reroutes may result in unused capacity and departures needlessly rerouted to less preferred routes. Traffic managers typically hedge these uncertainties by waiting until pending departures are in taxi to implement proactive reroutes, by rerouting flights only after other tactics have been tried, and by not rerouting large numbers of flights at a time. Evaluating the outcome of a reroute decision can be challenging, given the difficulty in estimating capacity on weather-impacted routes [6].

Unlike pilot avoidance and fix merging, which tend to increase controller workloads, rerouting increases the workload of traffic managers who must coordinate reroutes. Figure 3 illustrates an example of departure rerouting, recorded by observers in the Chicago ARTCC (ZAU) in the summer of 2010.

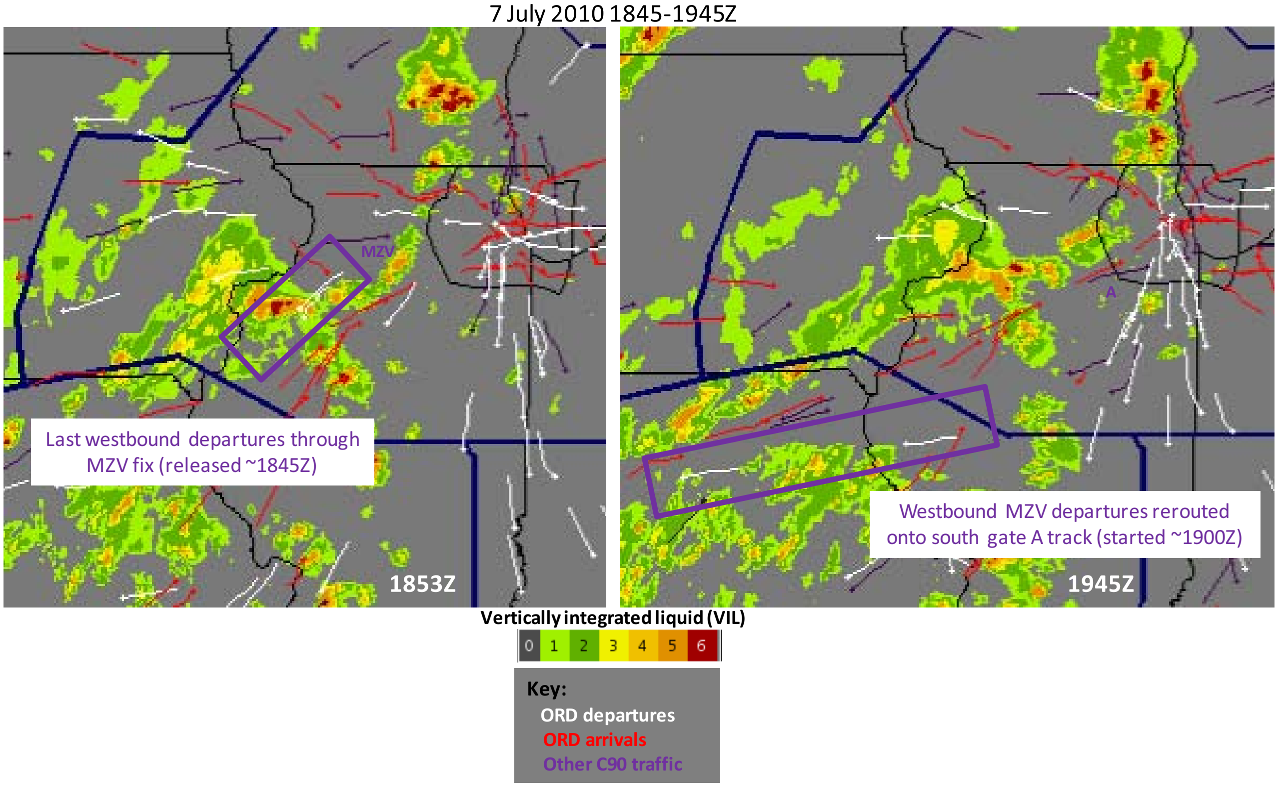
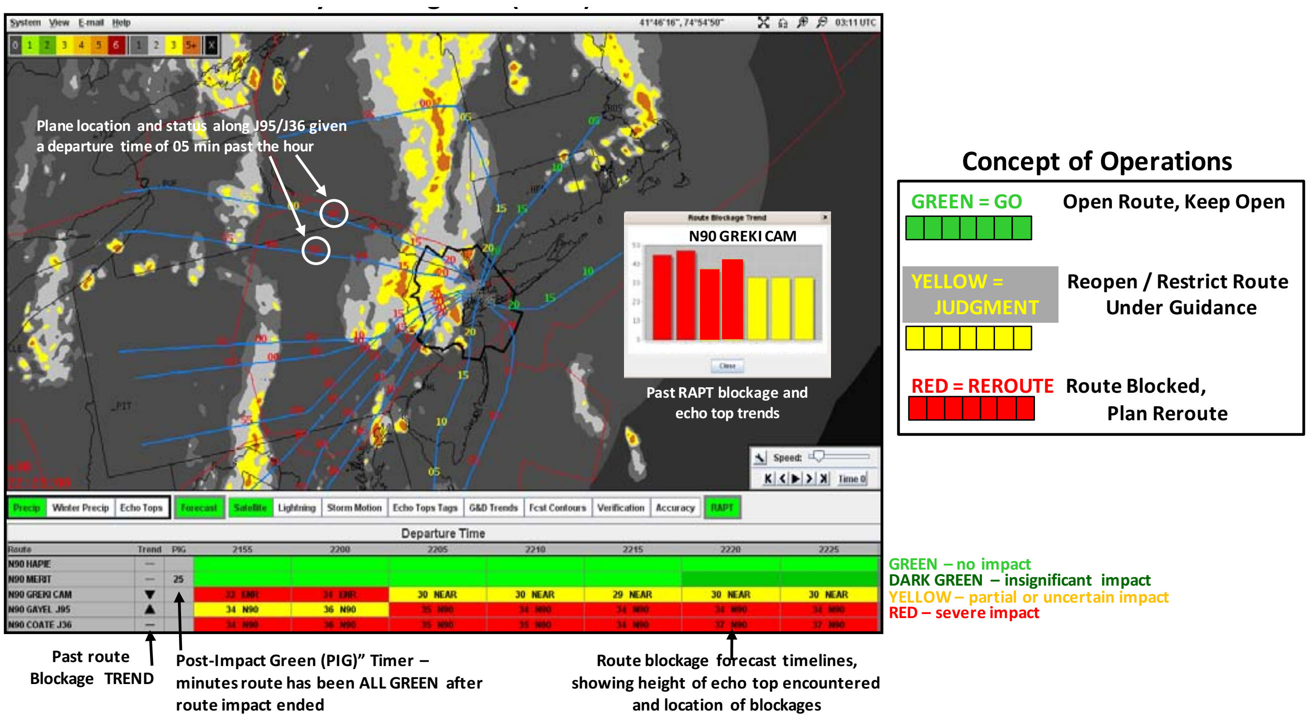


Figure 3. Departure Reroutes

Measuring Weather Impact and Impact Forecast Probabilities

RAPT provides an objective forecast of convective weather impact on a particular departure route as a function of wheels-off time. The impact is represented as a route impact status color: GREEN and DARK GREEN indicate no or negligible weather impacts, RED indicates significant impacts, and YELLOW indicates partial or uncertain impacts. GREEN and DARK GREEN routes are expected to carry full fair weather capacity, unless non-weather-related issues require constraints. The impacts on RED routes are considered severe enough that route capacity may be severely restricted or zero. YELLOW routes may support a range of capacities, depending on additional factors, such as echo top heights, spatial organization and location of storms, etc. The concept of operations states that routes previously closed due to convective weather impacts should be fully reopened when the departure status turns GREEN or DARK GREEN (a post-impact GREEN, or PIG). When routes turn RED, traffic managers should begin planning reroutes for pending departures. On YELLOW, traffic managers use past RAPT status and echo top trend information and weather forecast animations to determine if the constraints on a route should be increased, reduced, or remain in place. For instance, experienced traffic managers in New York often reopen closed routes when the status is YELLOW, the impact trend is stable or improving, and the echo tops are low. Operational RAPT prototypes are running in both New York (since 2003) and Chicago (since 2010) with wheels-off look-ahead times that extend out to 30 minutes into the future. Figure 4 illustrates the RAPT user interface and concept of operations.



Departure Time

Route	Trend	PIG	2155	2200	2205	2210	2215	2220	2225
N90 HAPIE	—		🟩	🟩	🟩	🟩	🟩	🟩	🟩
N90 MERIT	—	25	🟩	🟩	🟩	🟩	🟩	🟩	🟩
N90 GREKI CAM	▼		33 EWR	34 EWR	30 NEAR	30 NEAR	29 NEAR	30 NEAR	30 NEAR
N90 GAYEL J95	▲		34 N90	36 N90	35 N90	34 N90	34 N90	34 N90	34 N90
N90 COATE J36	—		34 N90	36 N90	35 N90	35 N90	34 N90	37 N90	37 N90

Past route Blockage TREND

Post-Impact Green (PIG)" Timer – minutes route has been ALL GREEN after route impact ended

Route blockage forecast timelines, showing height of echo top encountered and location of blockages

Concept of Operations

GREEN = GO 🟩🟩🟩🟩🟩🟩🟩	Open Route, Keep Open
YELLOW = JUDGMENT 🟨🟨🟨🟨🟨🟨🟨	Reopen / Restrict Route Under Guidance
RED = REROUTE 🟥🟥🟥🟥🟥🟥🟥	Route Blocked, Plan Reroute

GREEN – no impact
DARK GREEN – insignificant impact
YELLOW – partial or uncertain impact
RED – severe impact

Figure 4. RAPT User Interface and Concept of Operations

RAPT was developed for supporting traffic managers in making coarse-grained decisions about departure route availability. Nonetheless, automation can assign a RAPT status forecast to individual flights; for instance, IDRP automatically identifies individual RED departures and suggests possible reroutes. However, in such applications, one must consider the impacts of uncertainty due to errors in prediction of RAPT status and wheels-off time, and uncertainty in pilot response to the weather.

RAPT status prediction errors are estimated by comparing RAPT status, based on actual weather, to the forecast RAPT status. The comparison gives the odds of a particular status outcome, given its predicted status and look-ahead time. Route status outcome probabilities have been calculated for New York and Chicago for look-ahead times of 15 and 30 minutes, based on data from 12 severe weather avoidance program (SWAP) days in 2010 and 2011. Figure 5 presents the accuracy of RAPT forecast status predictions from New York; statistics from Chicago are similar. In general, RAPT status forecast accuracy is good and consistent across airspaces. Extreme errors (forecast RED / true GREEN and forecast GREEN / true RED) are rare. GREEN forecast accuracy is generally very good. There is also a bias toward over-forecasting impacts.

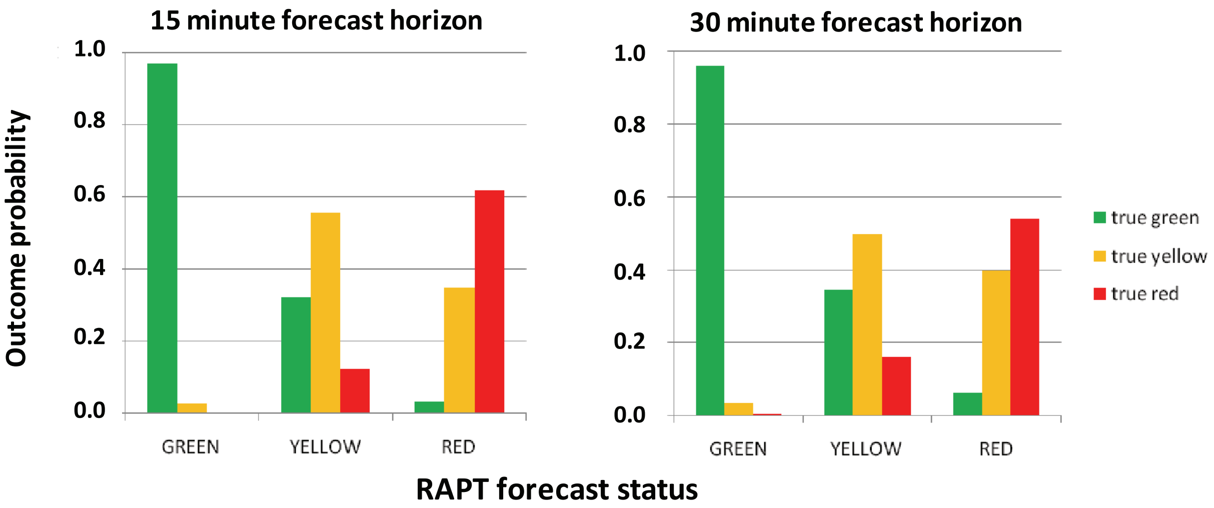
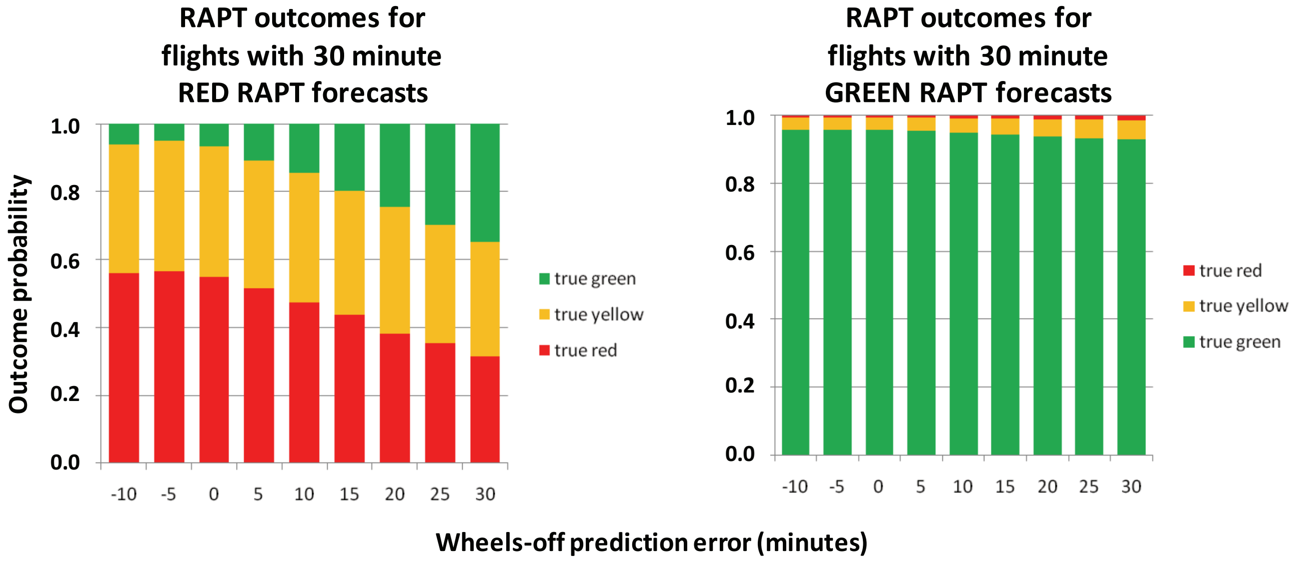


Figure 5. RAPT Status Forecast Accuracy In New York

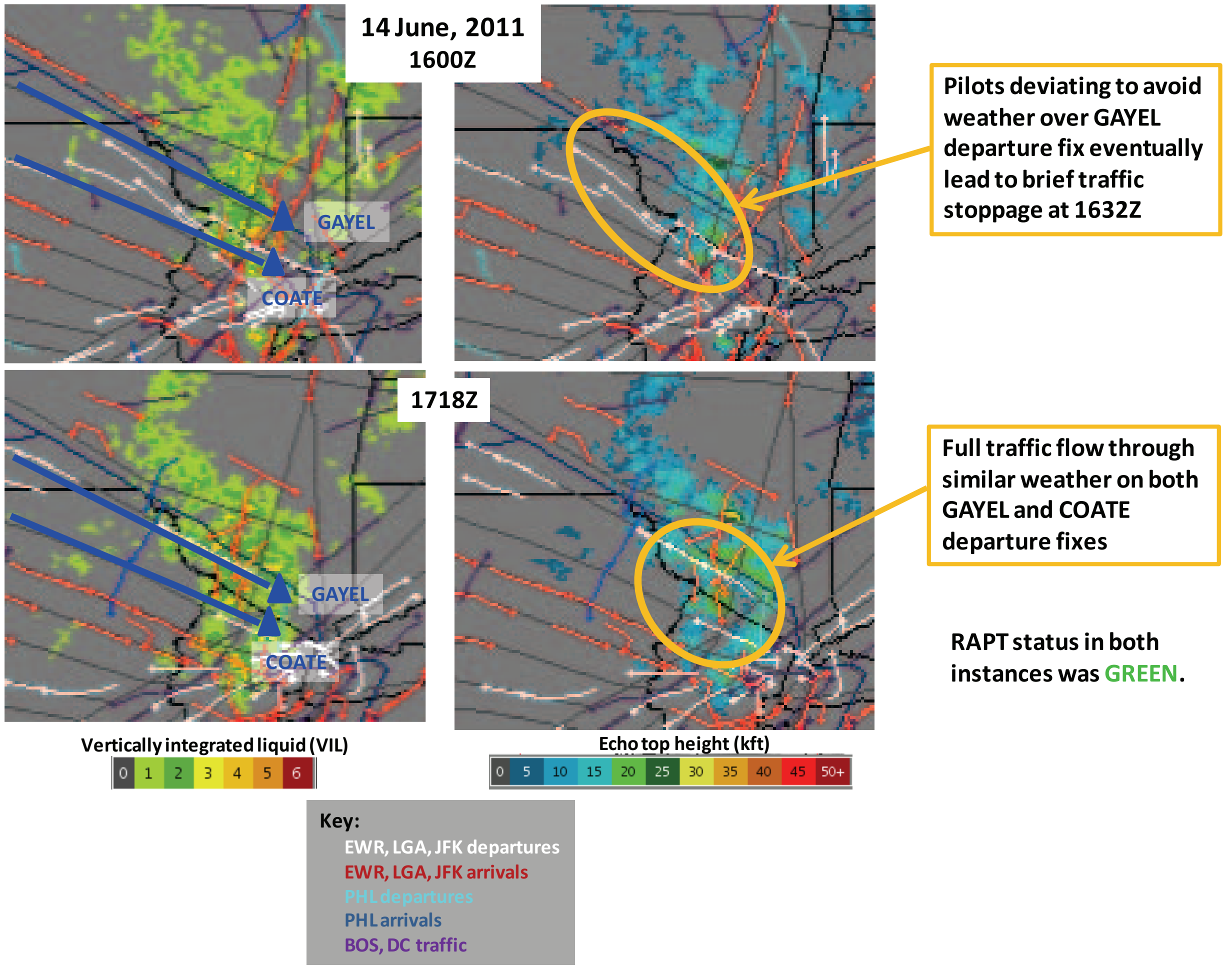
This study did not attempt to quantify the uncertainty in predicting wheels-off times. RAPT status forecast errors were simply parameterized by error in wheels-off time predictions. Figure 6 presents the probabilities of different route status outcomes as a function of wheels-off forecast error and RAPT look-ahead time, taken from the same set of 12 SWAP days analyzed in Figure 5. To understand the probabilities presented in Figure 6, consider the following example. The departure route status for a flight whose wheels-off is predicted to be 30 minutes into the future is RED. If the actual wheels-off time is 10 minutes later than predicted (i.e., 40 minutes into the future), the route status outcome probabilities are given by the 't+10' column in Figure 6. To some extent, the probabilities in figure 6 depend on the persistence of true RAPT REDs, which is related to the scale, longevity, and motion of the convection. The decrease in true RAPT RED outcomes, from 56% at 30 minutes to 32% at 60 minutes (t+30) suggests that as many as 2 in 5 RAPT REDs that are correctly predicted 30 minutes in advance do not persist beyond one hour. Figure 6 also suggests that RAPT GREEN status is likely to be long-lived.

The probability that RAPT route status will correctly predict pilot behavior and controller workload is difficult to evaluate. Qualitative analyses, based on the review of field operations and weather and traffic data, suggest that RAPT status generally reflects operational decision making and pilot behavior [3-5]. Statistical analysis of observed departure route traffic as a function of RAPT status shows a sensible relationship between RAPT status and observed traffic counts [4]. While RAPT status approximates weather impact reasonably well, significant uncertainty remains in the prediction of pilot behavior and controller response. Figure 7 illustrates differences in pilot behavior and air traffic response on RAPT routes with similar status.


RAPT outcomes for flights with 30 minute RED RAPT forecasts

RAPT outcomes for flights with 30 minute GREEN RAPT forecasts

Figure 6. Changes In RAPT Status Forecast Outcomes As A Function Of Wheels-Off Prediction Error


14 June, 2011
1600Z

1718Z

Pilots deviating to avoid weather over GAYEL departure fix eventually lead to brief traffic stoppage at 1632Z

Full traffic flow through similar weather on both GAYEL and COATE departure fixes

RAPT status in both instances was GREEN.

Figure 7. Differences In Pilot And Air Traffic Control Response To Similar Weather In New York Departure Airspace

Defining Criteria for Success

Table 1 suggests some criteria for judging the outcome of a reroute decision. The term ‘filed’ indicates the departure route initially filed, and ‘target’ indicates the route onto which the flight is rerouted.

A successful reroute strategy will result in a high likelihood of good reroute outcomes, and will be based on reroute targets that are acceptable. Given such criteria and metrics, it is possible to estimate the probability of success that will result from a particular reroute decision strategy.

Weather Impact Criteria

RAPT outcome probabilities can be used to assess the likelihood that a reroute strategy will successfully reduce weather impact. Consider the reroute strategy, ‘reroute all forecast RED filed routes to forecast GREEN targets’ (reroute-RED-to-GREEN). Table 2 gives the probabilities of each possible filed / target true status outcome, given a RED 15 minute RAPT forecast for the filed route, a GREEN forecast for the reroute target, and a perfect wheels-off prediction. Table 2 cells colored blue indicate good outcomes, purple cells indicate poor outcomes, and gray indicate outcomes that require more information to assess because the weather impact status on both the filed route and reroute target are the same (‘unknown’ outcome). Summing up different outcome probabilities, one can ascertain the likelihood of success or failure of the reroute-RED-to-GREEN strategy. The same set of probabilities was calculated for the 30 minute RAPT forecast, and for a reroute-RED-to-YELLOW strategy.

Table 1. Criteria for Evaluating the Success of a Reroute Decision

Criteria	Objective metric	Good	Poor	Comments
Weather impact	True RAPT status (based on actual weather)	RAPT route status less severe on target than on filed	RAPT route status more severe on target than on filed	If target and filed impacts are similar, other factors must be considered.
Volume congestion	Fair weather and weather-impacted fix capacity	Target free of congestion after reroute	Rerouted flight creates / increases congestion on target	Congestion must be considered in light of weather impacted-capacity.
Operator acceptability	Target within envelope of reroute acceptability	Meets operator requirements (fueling, schedule, etc.)	Unacceptable to operator	There are likely to be ‘exceptional cases’, but these should not form the basis of a general strategy.

Table 2. Reroute Weather Impact Outcome Probabilities

Reroute RED-to-GREEN Strategy (15 minute planning horizon)				
		Filed forecast RAPT RED		
	Truth	**GREEN**	**YELLOW**	**RED**
Reroute target forecast RAPT GREEN	**GREEN**	**0.03**	**0.34**	**0.60**
	YELLOW	**0.00**	**0.01**	**0.02**
	RED	**0.00**	**0.00**	**0.00**

More stringent weather impact criteria require that a successful reroute not only reduce the weather impact, but also reroute away from a filed route that is very likely to be closed, i.e., the filed route should be RED. Applying this additional 'necessity' criterion, only the top two outcomes in the RED column represent successful outcomes.

Volume Congestion

Volume congestion results when the demand for a departure fix or route exceeds the capacity. When demand exceeds capacity, air traffic control must reduce traffic volume quickly via means such as airborne holding and short notice volume stops, which can be disruptive. Resource capacity is a function of controller workload, which is related to the degree of weather impact. No data are available for fix and route congestion prediction probabilities like those reported in Table 2.

Figure 8 compares outcome probabilities based on weather criteria only for reroute-RED-to-GREEN and reroute-RED-to-YELLOW options. When the necessity criterion is not included, the reroute-RED-to-GREEN option has a very high probability of success (> 90% for both 15 and 30 minute planning horizons) and a very low failure probability (< 1% for both planning horizons), due largely to RAPT's very high success rate in predicting GREEN and the very low likelihood that forecast RAPT REDs will turn out GREEN. The reroute RED-to-YELLOW strategy has a high probability of success (66% at 15 minutes, 59% at 30 minutes), which is enhanced by the fact that RAPT tends to over-forecast impacts (forecast YELLOWs are more likely to be GREEN than RED when RAPT is in error). The higher percentage of failures, and the increase in failure rate as the planning horizon increases from 15 to 30 minutes (6.5% to 10.6%) reflect the reliance of outcomes on more uncertain YELLOW impact predictions.

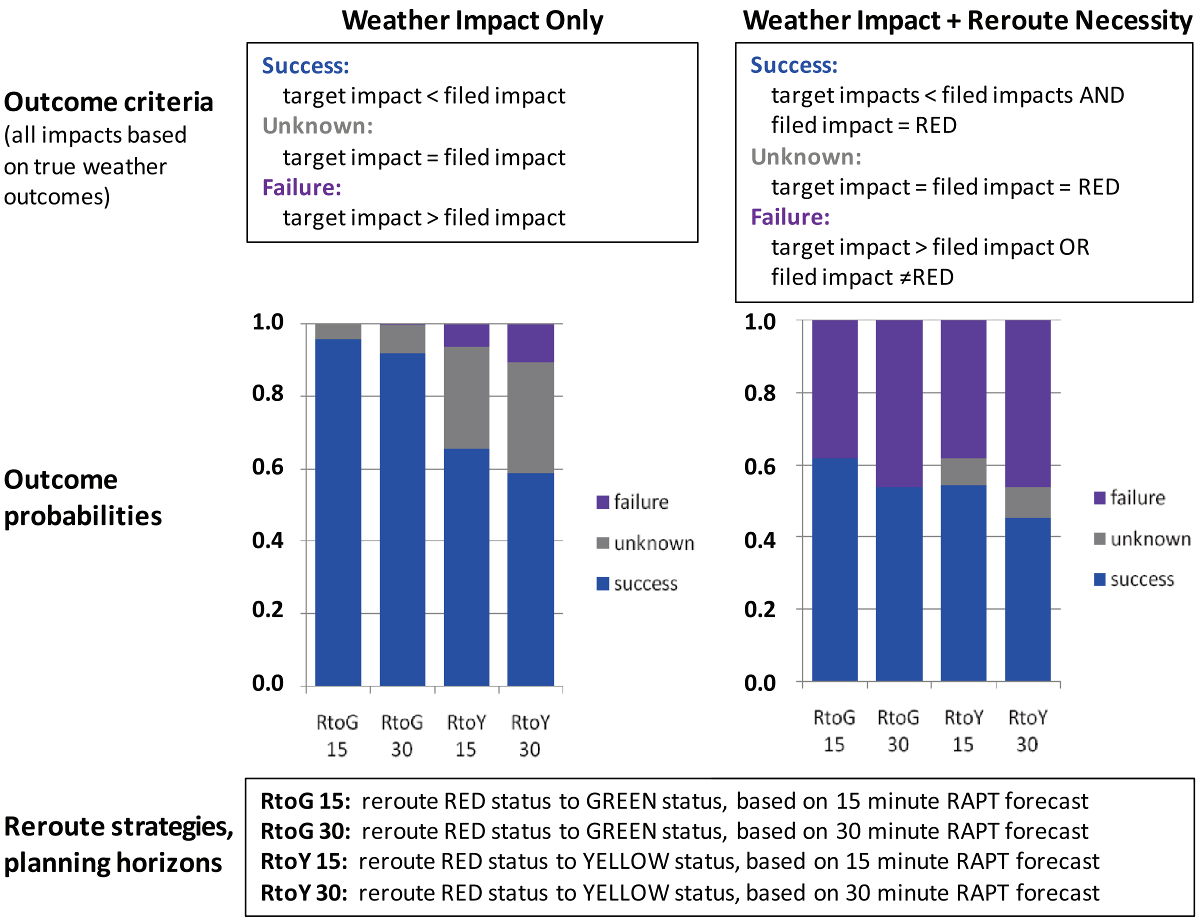


Figure 8. Reroute Outcome Probabilities Based on Different Weather Impact Criteria

The likelihood of a successful reroute outcome is considerably reduced when the necessity criterion (reroute did reduce weather impact and filed route was RED) is applied. The large reduction in successful outcomes is due to the RAPT RED forecast errors; approximately 38% of RAPT 15 minute RED forecasts are incorrect, increasing to approximately 46% for RAPT 30 minute RED forecasts. The probability of an 'unknown' outcome is drastically reduced, since the only unknown outcome (filed and target routes both RED) is very rare.

Can unnecessary rerouting be reduced by the use of tactical ground delay? The analysis illustrated in figure 6 of the previous section shows that the probability of true RAPT RED on a route whose 30 minute RAPT forecast is RED decreases from approximately 56% for an on-time departure (i.e., 30 minutes into the future) to approximately 44% if the departure is delayed 15 minutes (the t+15 bar in the Figure 6). This suggests that as many as one in five weather avoiding reroutes may be averted by taking a 15 minute ground delay on the initial filed route. The identification of circumstances where tactical ground delay will be successful is dependent upon the ability to differentiate between RAPT REDs that are likely to be long-lived and those that are likely to dissipate quickly.

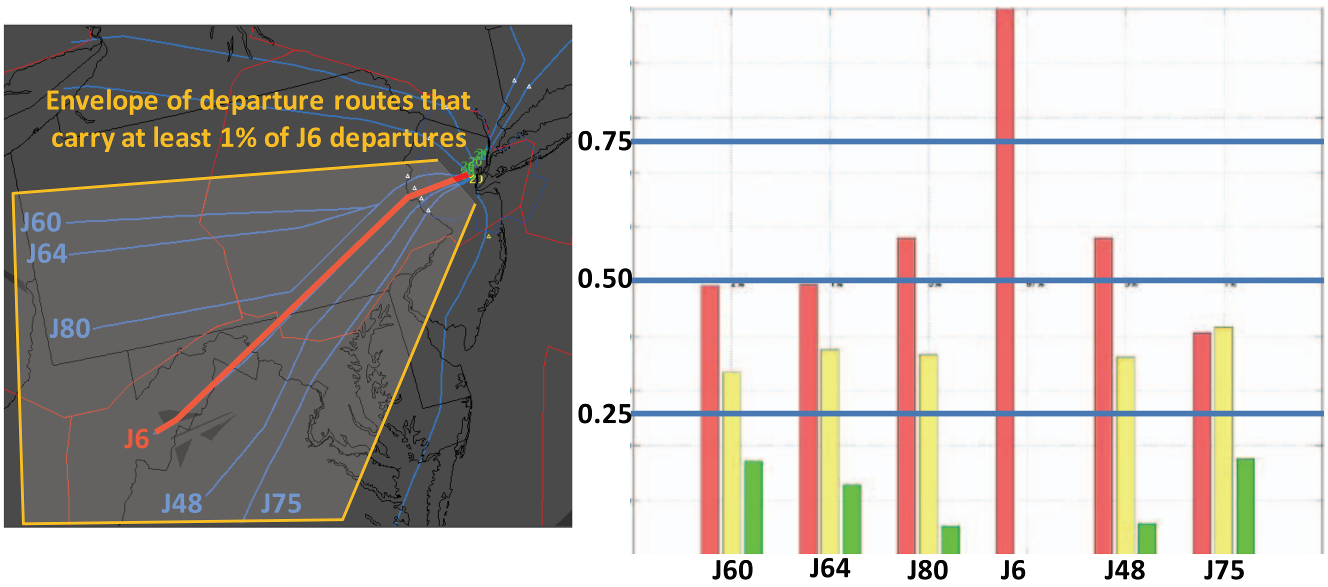
Operator Acceptability

An analysis of reroutes of departing flights from La Guardia Airport (LGA), John F. Kennedy International Airport (JFK), and Newark Liberty International Airport (EWR) in June and July of 2010 was performed to identify the envelope that bounded the majority of reroutes off of filed routes that are part of the RAPT departure route set. For a given RAPT route, all alternative routes that carried at least 1% of the departure traffic normally filed on the route are identified – this set of alternative routes defines the 'reroute envelope'. The observed probability of RAPT RED, YELLOW, and GREEN status on each alternative was calculated for all times when the filed route was RED. The probability that at least one alternative within the reroute envelope was GREEN (or YELLOW) was also calculated.

Results for the RAPT EWR departure route (J6) are illustrated in Figure 9. Although there are several options for departures filed on J6, the alternative routes are often RED when J6 is RED. The likelihood of one alternative being GREEN is 31%; YELLOW is 77%. The limitations of the reroute envelopes suggest that RED-to-YELLOW reroutes may be the only option available in many circumstances, unless much longer reroutes, outside of the reroute envelope, are considered. The use of RED-to-YELLOW reroutes may also require secondary reroutes, in which flights filed on the YELLOW reroute target are rerouted to make room for the RED-to-YELLOW weather avoiding rerouted flights. This 'double reroute' tactic is not uncommon in air traffic management, but it increases the complexity, workload, and extent of the impact of weather avoidance mitigation.

Volume Congestion

In order to consider uncertainty in congestion predictions and its effect on the likelihood of success in reroute strategies, one requires a validated model for capacity and congestion prediction on impacted routes. Such a model is still in development.



Probability of at least one GREEN = .31
Probability of at least one YELLOW = .77

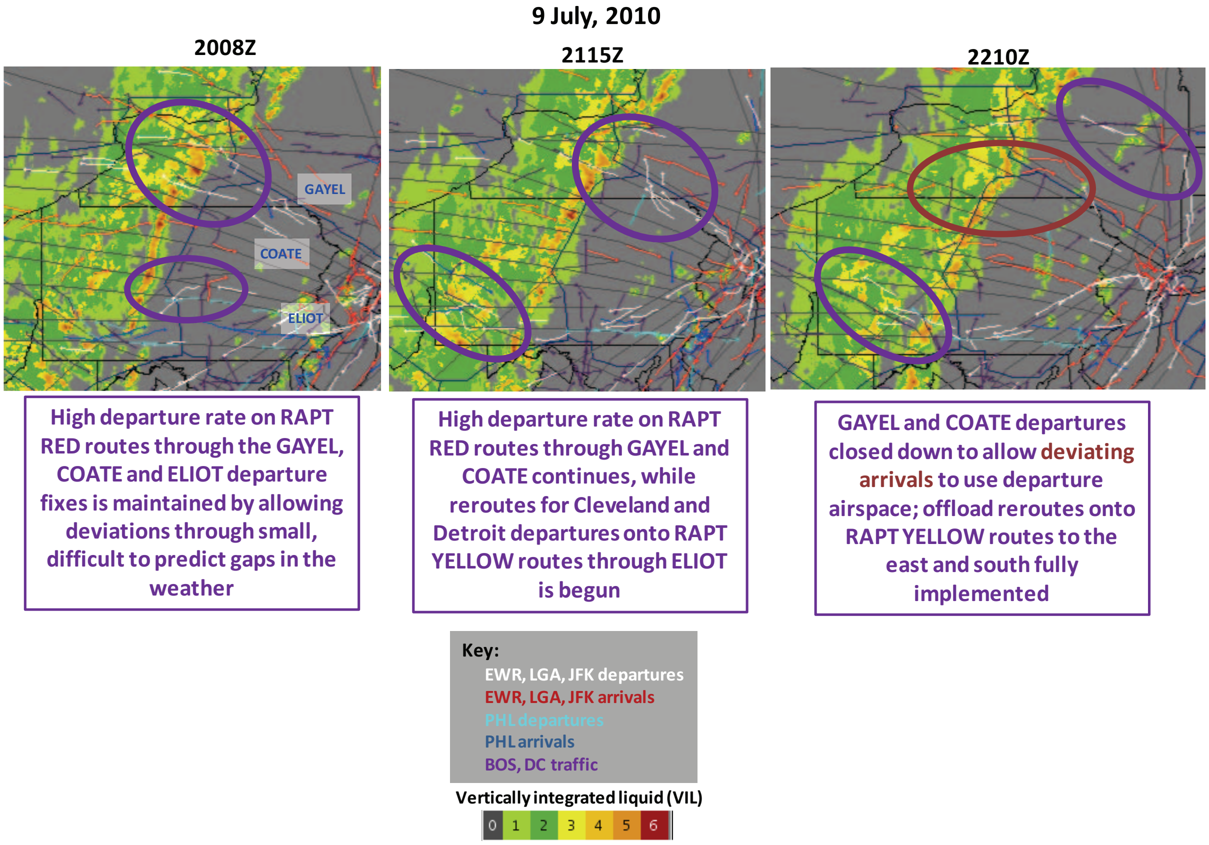
Figure 9. Most Common Reroutes for Departures Filed on J6 from EWR Airport (Left) and Likelihood of RAPT Status When J6 Is Forecast RED (Right)

Other Factors to Consider in Reroute Decision Making

Traffic managers have frequently used RAPT in both ZNY and ZAU to successfully plan weather avoiding reroutes. These instances share several common characteristics:

- The evolution of the weather impacts follows a pattern that is common in the airspace.
- Prior to implementing reroutes, departures are maneuvered around weather on their filed routes, even as impacts change the RAPT route status to RED. This enables the traffic managers to calibrate RAPT guidance to current operations.
- Reroutes are implemented with short look-ahead times for departures that are already in taxi.
- Reroute targets are within the acceptable reroute envelope.
- Routes that are closed due to weather impacts are reopened once weather impacts are forecasted to clear.

The progression of tactics – recognizing common patterns of storm development and motion, initially responding to weather impacts by managing pilot deviations and / or departure fix merging, short planning horizons – provides vital situational awareness that reduces uncertainty while enabling traffic managers to continue using capacity in weather impacted airspace. Reroutes are implemented when it becomes clear that impacts will soon close down routes, and the transition of traffic flows from impacted filed routes to reroute targets is often efficient. As the weather impacts clear, closed routes are reopened quickly and reroutes of pending departures on the previously impacted route are stopped, ensuring that available capacity is put to use as quickly as possible and reroute workload to undo reroutes that are no longer necessary is avoided. The potential risk in this scenario is that traffic managers will wait too long to begin reroutes (see Figures 10 and 11). While there is ample anecdotal information about the potential rewards and risks of the 'progressive' scenario described above, there is little objective data that provides insight into the likelihood of success, and the cost and frequency of failure.

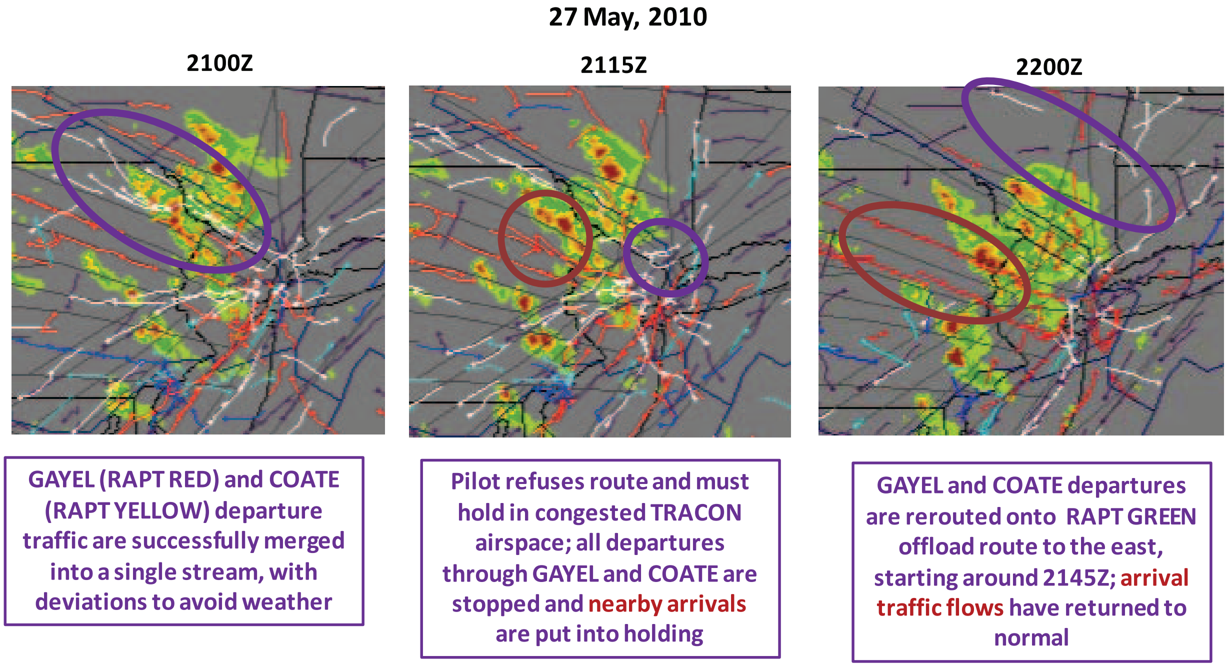


High departure rate on RAPT RED routes through the GAYEL, COATE and ELIOT departure fixes is maintained by allowing deviations through small, difficult to predict gaps in the weather

High departure rate on RAPT RED routes through GAYEL and COATE continues, while reroutes for Cleveland and Detroit departures onto RAPT YELLOW routes through ELIOT is begun

GAYEL and COATE departures closed down to allow deviating arrivals to use departure airspace; offload reroutes onto RAPT YELLOW routes to the east and south fully implemented

Figure 10. Successful Progression from Pilot Deviation to Weather-Avoiding Reroutes



GAYEL (RAPT RED) and COATE (RAPT YELLOW) departure traffic are successfully merged into a single stream, with deviations to avoid weather

Pilot refuses route and must hold in congested TRACON airspace; all departures through GAYEL and COATE are stopped and nearby arrivals are put into holding

GAYEL and COATE departures are rerouted onto RAPT GREEN offload route to the east, starting around 2145Z; arrival traffic flows have returned to normal

Figure 11. Failure to Anticipate Pilot Refusal Results in 30 Minute Disruption of Departure and Arrival Traffic

Summary and Future Work

Proactive rerouting of departures to avoid convective weather and volume congestion impacts has been proposed as a means to reduce departure delay in convective weather. Reroute planning requires forecasts of weather impacts and departure demand that are subject to considerable uncertainty in the pilot response to weather, controller response to pilot deviations, and forecast uncertainty in both the weather impact and wheels-off predictions. As the planning horizon increases, the uncertainty increases, and the likelihood of a 'good' reroute decision decreases. In order to evaluate the effectiveness of proactive rerouting, it is necessary to understand the limits of certainty in reroute planning: when forecasts are sufficiently accurate to support longer reroute planning horizons, and when forecast uncertainty dictates shorter planning horizons and the use of other tactics that enable air traffic managers to hedge uncertainty while maintaining traffic flows in impacted airspace. Such tactics include the use of ground delay, allowing traffic to deviate around storms in impacted airspace, and merging of multiple departure streams into one or two flows that can be maneuvered around weather.

This paper examined tactics used in the mitigation of weather impacts in departure airspace. It proposed criteria for evaluating the success of reroute strategies based on RAPT route blockage. By defining a successful rerouting decision as one that results in a reduction of weather impact and is necessary to avoid severe weather impacts on the originally filed route, the analysis estimates the likelihood that a reroute planned 30 minutes in advance of wheels-off will be successful approximately 56% of the time if there is no error in the wheels-off time estimate. That likelihood falls to 44% if the actual wheels-off time is 15 minutes later than predicted. The analysis identifies the need for a comprehensive reroute success metric that accounts for weather impact, volume congestion, and effects on total departure throughput. Finally, the observed 'progression of tactics' used to successfully hedge uncertainty in departure management, was described.

Additional research is needed in several areas to develop decision support, procedures, and user training that can increase the likelihood of success in proactive rerouting:

- Characterize the errors in wheels-off and departure demand prediction. Since impacts on Terminal Radar Approach Control (TRACON) and en route airspace begin at wheels-off, it is critical to understand the consequences of and tolerance for errors in wheel-off prediction times.
- Improve RAPT RED forecasts. There are three subtasks: improve the prediction of RAPT REDs, develop models to identify which RAPT REDs are likely to persist and which are likely to dissipate beyond the 30 minute RAPT forecast horizon, and improve the RED blockage characterization to increase the likelihood that RAPT RED really means that a route is unusable.
- Create models for resource capacity (departure fix, route) during weather impacts (e.g., RAPT YELLOW).
- Develop concepts and tools for flexible pre-flight and surface management. When uncertainty is high and the reliable planning horizon shrinks, efficient operations can be maintained if pending departure demand can be quickly organized to take advantage of capacity as it becomes available.
- Create comprehensive metrics for departure management efficiency and reroute effectiveness.

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