technical note

Evaluating Integrated Arrival/Departure Control Services Using Fast-Time Simulation

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16. Abstract

This document describes the objective, method, analysis, and results of a fast-time simulation study to evaluate the capacity and efficiency impacts associated with the IADCS concept. This modeling activity examined the use of flexible routing structures within the Atlanta area Air Traffic Control (ATC) facilities including the Atlanta Air Route Traffic Control Center (ZTL) and A80, the Atlanta Terminal Radar Approach Control (TRACON). The work quantified the benefits associated with the tools offered by the IADCS concept for rerouting aircraft during periods of convective weather. To measure the benefits of the IADCS flexible routing toolset, baseline scenarios representing current operations were compared against IADCS scenarios during convective weather events. Efficiency and capacity output metrics from these simulations were compared to determine the benefits of the IADCS toolset as applied to the focus areas of the Atlanta airspace.

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Executive Summary

In today's National Airspace System (NAS), airspace is highly structured and inflexible. As a result, during periods of high traffic volume or convective weather, the continuity of traffic flow is often interrupted resulting in increased delay. The Integrated Arrival/Departure Control Services (IADCS) team is focused on maintaining the continuity of traffic flow during periods of higher than typical traffic volumes and/or convective weather. To accomplish this, the IADCS concept proposes tools designed to dynamically adjust airspace and/or routing to meet the changing conditions around the nation's airports.

The objective of this fast-time simulation study was to evaluate the capacity and efficiency impacts associated with the IADCS concept. This modeling activity examined the use of flexible routing structures within the Atlanta area Air Traffic Control (ATC) facilities including the Atlanta Air Route Traffic Control Center (ZTL) and A80, the Atlanta Terminal Radar Approach Control (TRACON). The efficiency of the airport, airspace and flights and the capacity of the airport were examined to determine the potential benefits associated with the IADCS tools.

This study quantified the potential impacts of eight IADCS plays involving a short, isolated weather event which blocked arrival routes in the Northeast or Northwest airspace. Using today's operations, Northeast and Northwest arrival flights are rerouted to the southern arrival routes to avoid weather; this causes flights to experience delays and burn more fuel while interrupting the flow of an airport's hourly throughput. In the IADCS plays, arrival flights are rerouted to a new arrival route that overlaps an existing departure route. The IADCS concept proposes three options to ensure separation between all flights: a bi-directional flow in which arrival flights are flying the new arrival route at least 1,000 feet below departures that are flying the existing departure route, referred to as the Low scenario; another bi-directional flow where arrival flights are flying the new arrival route at least 1,000 feet above departure flights on the departure route, referred to as a High scenario; or the departure route can be closed and its departure flights moved to the next departure route so that arrival and departure flights are separated laterally, referred to as a Lateral scenario.

Results show that introducing IADCS operations will provide benefits to arrival flights that were rerouted to avoid weather and to other flights impacted by these reroutes. All of the eight IADCS scenarios simulated in this study provided benefits to the distance flown, duration of flight, and amount of fuel burned for rerouted arrival flights. Rerouted flights could save up to 200 NM of flight distance, 30 minutes in flight time, and 6,500 lbs of fuel with the implementation of IADCS. In general, Low scenarios produced more benefit than their High scenario counterparts; Lateral scenarios typically provided similar benefits as their associated High scenarios. Introducing IADCS procedures can reduce the added flight distance, delay, and fuel burn in daily operations. Results show that IADCS can help save up to 5,660 NM of total flight distance, 15 hours and 27 minutes of delay, and 64,780 lbs of total fuel burned in a 24-hour period. Increased benefits for daily operations may be seen when the weather event is present for longer periods or is blocking a larger section of airspace. Finally, the continuity of arrival throughput at ATL was maintained in the IADCS scenarios whereas it was interrupted in the baseline scenarios. In summary, this simulation study quantifies the significant benefits of the IADCS concept and warrants further investigation.

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1 Introduction

Fast-time simulation and modeling exercises are performed to examine system performance including benefits assessment (e.g., delay, fuel burn, time/distance flown) and the analysis of capacity, safety, risk and efficiency. They are often employed in the early stages of validation efforts to obtain preliminary ideas of potential benefits. Fast-time and modeling studies are also useful for identifying potential problem areas where real-time simulation studies are necessary for further exploration1.

The objective of this fast-time simulation study was to evaluate the capacity and efficiency benefits associated with the Integrated Arrival/Departure Control Services (IADCS) concept. This modeling activity examined the use of flexible routing structures within the Atlanta area Air Traffic Control (ATC) facilities including the Atlanta Air Route Traffic Control Center (ZTL) and A80, the Atlanta Terminal Radar Approach Control (TRACON). The work quantified the benefits associated with the tools offered by the IADCS concept for rerouting aircraft during periods of convective weather.

1.1 Purpose

The objective of this study was to investigate the system performance effects of implementing flexible routing during a weather event. The efficiency of the airport, airspace and flights and the capacity of the airport were examined to determine the potential benefits or problems associated with the IADCS tools.

1.2 Background

In today's National Airspace System (NAS), airspace is highly structured and inflexible. As a result, during periods of high traffic volume or convective weather the continuity of traffic flow is often interrupted, resulting in increased delay due to:

- Excessive Traffic Management Initiatives (TMIs)
- Route and airspace gate closures
- Ground Stops at multiple airports
- "No notice" holding patterns
- Pass-back restrictions resulting in static holding patterns far from the airport
- Excessive reroutes to an arrival gate not impacted by weather

The IADCS team is focused on maintaining the continuity of traffic flow during periods of higher than typical traffic volumes and/or convective weather. To accomplish this, the IADCS concept proposes tools designed to dynamically adjust airspace and/or routing to meet the changing conditions around the nation's airports. These tools and procedures are especially useful in, but not limited to, the nation's large metropolitan areas (i.e., metroplex environments).

IADCS tools include bi-directional routing, ATC assigned routing, dynamic sectorization, and an expansion of the 3 Nautical Mile (NM) separation rule. Flexible, bi-directional routing allows a segment of or an entire existing route structure to accommodate both arrival and departure flows (see Figures 2-1 and 2-2). The IADCS concept also allows for new temporary routes to be assigned by ATC in lieu of, or in addition to, existing routes in order to maintain the continuity of traffic flow during less than optimal conditions (see Figure 2-3). Dynamic sectorization enables controllers and traffic management units (TMUs) to change sector designations and/or boundaries as needs require (see Figure 2-4). The IADCS concept also includes an expansion of the 3 NM separation rule into En Route airspace.

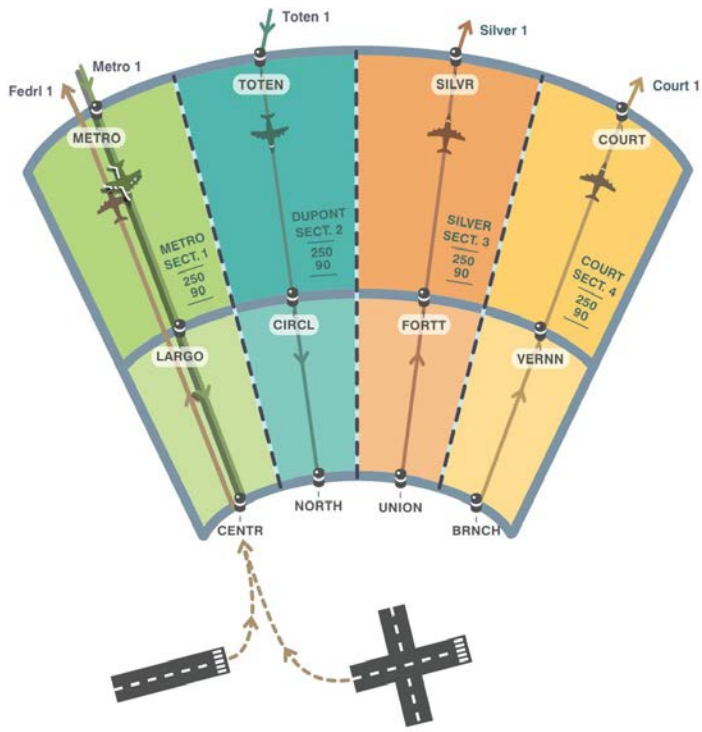

Figure 1. Full-Length Bi-Directional Route

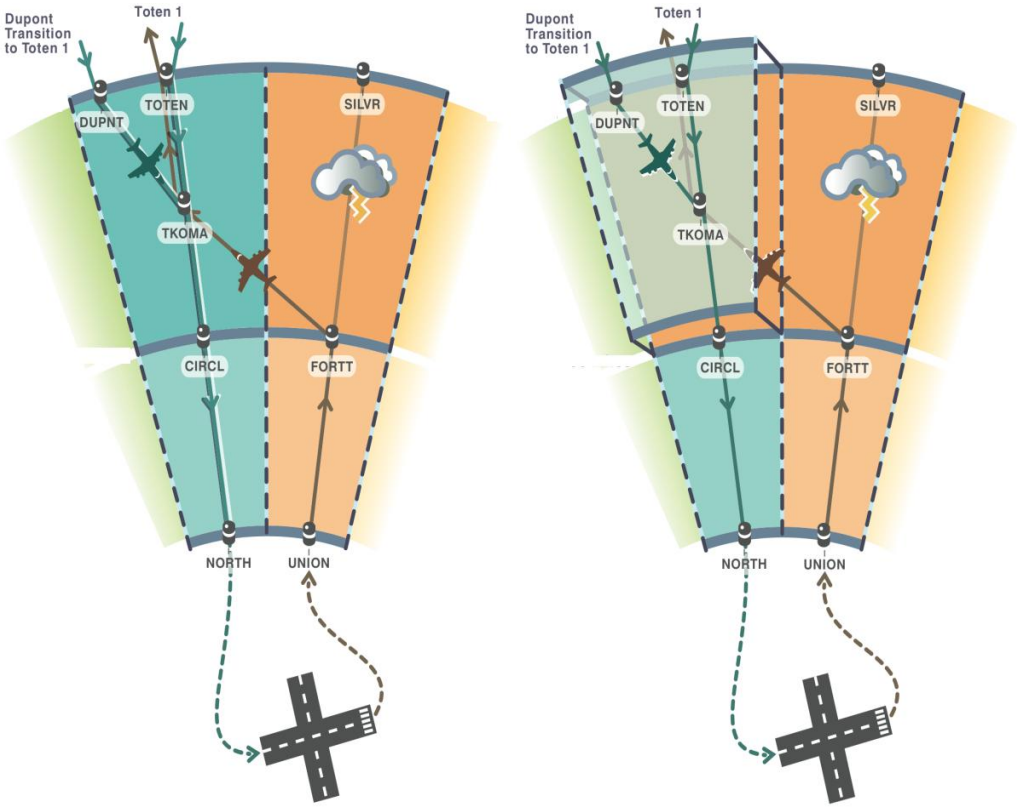

Figure 2. Segmented Bi-Directional Route

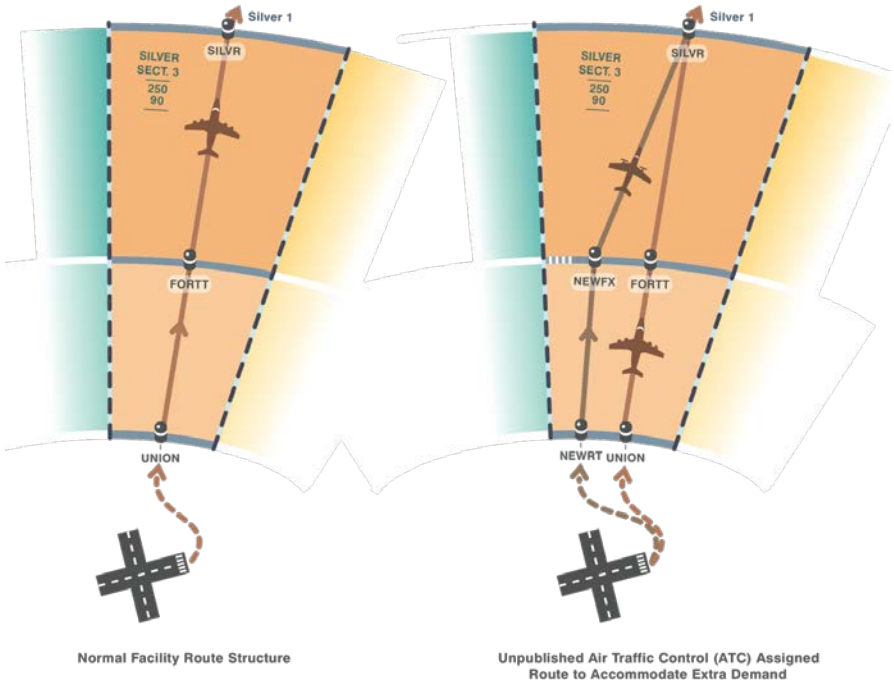

Figure 3. ATC Assigned Route

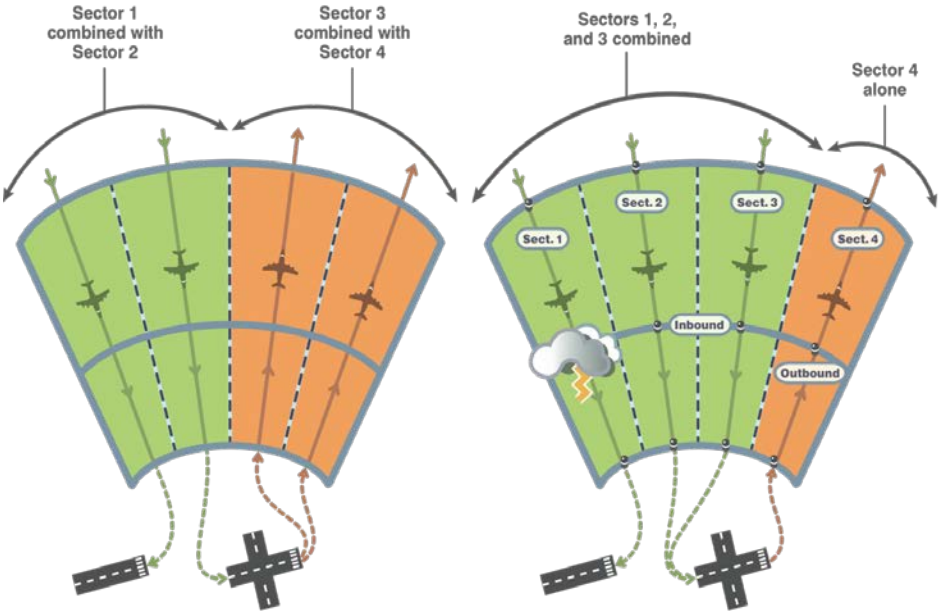

Figure 4. Dynamic Sectorization

1.3 Document Organization

The remainder of this document provides details on the methodology used to conduct this study, the results of the analysis, and conclusions and next steps for IADCS fast-time simulations.

Section 2 provides detailed information on the study metrics and analysis design. The scope of the study is defined and a list of tools and data utilized in the study is provided. Also, modeling assumptions and limitations are acknowledged, and simulation scenarios are defined in detail. The analytical methods and results are included in Section 3, and conclusions drawn from the analyses and future sets of IADCS simulations are discussed in Section 4.

This document includes two Appendices. Appendix A includes figures showing IADCS tools in Atlanta airspace. In Appendix B, visual depictions of the simulation scenarios are provided.

2 Study Methodology

The objective listed in section **Error! Reference source not found.** was examined using fast-time modeling and simulation methods. Initial parameter estimates for the model were derived from previously conducted information gathering activities including: interviews with SMEs, visits to Atlanta area ATC facilities, a cognitive walkthrough[2] conducted with Atlanta facility controllers, and other data analysis activities (e.g., historical trend analyses). Scenarios and other design assumptions were coordinated with the real-time HITL simulation team, when possible.

To measure the benefits of the IADCS flexible routing toolset, baseline scenarios representing current operations were compared against IADCS scenarios during convective weather events. Efficiency and capacity output metrics from these simulations were compared to determine the benefits of the IADCS toolset as applied to the focus areas of the Atlanta airspace.

2.1 Metric Selection

Changes in efficiency and capacity resulting from the use of the IADCS toolset were objectively quantified by measuring variations in the following metrics as compared to baseline conditions.

- Efficiency
  - Total Flight Duration
  - Total Fuel Burned
  - Total Distance Flown
- Capacity
  - Airport Throughput
    - Arrival Rate per Hour
    - Departure Rate per Hour

2.2 Analysis Design

2.2.1 Models and Tools

The Concept Analysis Branch has a number of fast-time simulation models and tools to assess the benefits of proposed concepts. The following tools were chosen for this analysis based on the individual study questions.

2.2.1.1 AirTOp Fast-Time Simulation Model

AirTOp is a multi-agent simulation tool that captures many aspects of the Air Traffic Management domain. AirTOp can model controller roles, tasks and workload for radar controllers, planning controllers and airport controllers. The tool includes a user defined rule-based system to define en-route restrictions, re-routing, approach and departure sequencing, and runway dependencies. For this analysis, AirTOp was used to simulate operations using today's procedures as well as IADCS tools during periods of convective weather, and collect the data needed to measure the potential efficiency and capacity benefits of these operations.

2.2.1.2 TARGETS

Terminal Area Route Generation Evaluation and Traffic Simulation (TARGETS) is a program used to develop and assess the flyability of Area Navigation (RNAV) routes. In the IADCS fast-time modeling study, TARGETS was used to obtain airspace structure and routing information.

2.2.1.3 JMP Statistical Software

The statistical software product JMP is used in combination with Microsoft Excel to analyze the simulation output data. JMP, a product of the SAS Institute, provides a user-friendly graphical interface which facilitates the manipulation of data tables, execution of simple and complex statistical analyses, and creation of meaningful graphs.

2.2.2 Scope

A full day's worth of traffic (i.e., 24 operational hours) was simulated in each scenario created for this activity. Eight operational scenarios using IADCS tools were developed by SMEs for the East and West quadrants of the airspace and simulated to assess their potential benefits and/or problems during a convective weather situation. Each scenario was compared against a baseline specific to the airspace quadrant and airport flow (East or West) represented.

The use of expanded 3 NM separation rules was validated as a beneficial concept in a previous simulation study on Big Airspace[3] and was not represented in this activity. Dynamic sectorization was also eliminated from the current simulation as its effects primarily impact controller roles and workload; however, exploration into controller roles and workload during a functional change in airspace will be conducted in an upcoming IADCS HITL simulation. ATC assigned routes were also excluded from this phase of the fast-time simulations but will be included in the HITL simulation. Additional sets of fast-time simulations will be conducted to further test IADCS flexible routings. Appendix A includes figures demonstrating each of the IADCS tools in the Atlanta airspace.

2.2.2.1 Airport

Hartsfield-Jackson Atlanta International Airport (ATL) was chosen as the airport to model in the IADCS fast-time study. ATL has five runways that alternate between an Eastern and Western traffic flow and can accommodate triple arrival or triple departure runways depending on the traffic situation. For this simulation study, triple arrival runways were used. Some of the scenarios required enough distance for departures to reach a high altitude at the departure waypoints; thus, the airport flow configuration for each scenario was chosen based on these requirements. A Western flow of ATL is shown in Figure 3-1, whereas an Eastern flow is shown in Figure 3-2. Ground operations at ATL were not simulated in detail as it was not the focus of the study; however, typical runway assignment rules were set to accurately represent operations utilizing the Standard Instrument Departures (SIDs) and Standard Terminal Arrival Routes (STARs) at ATL.

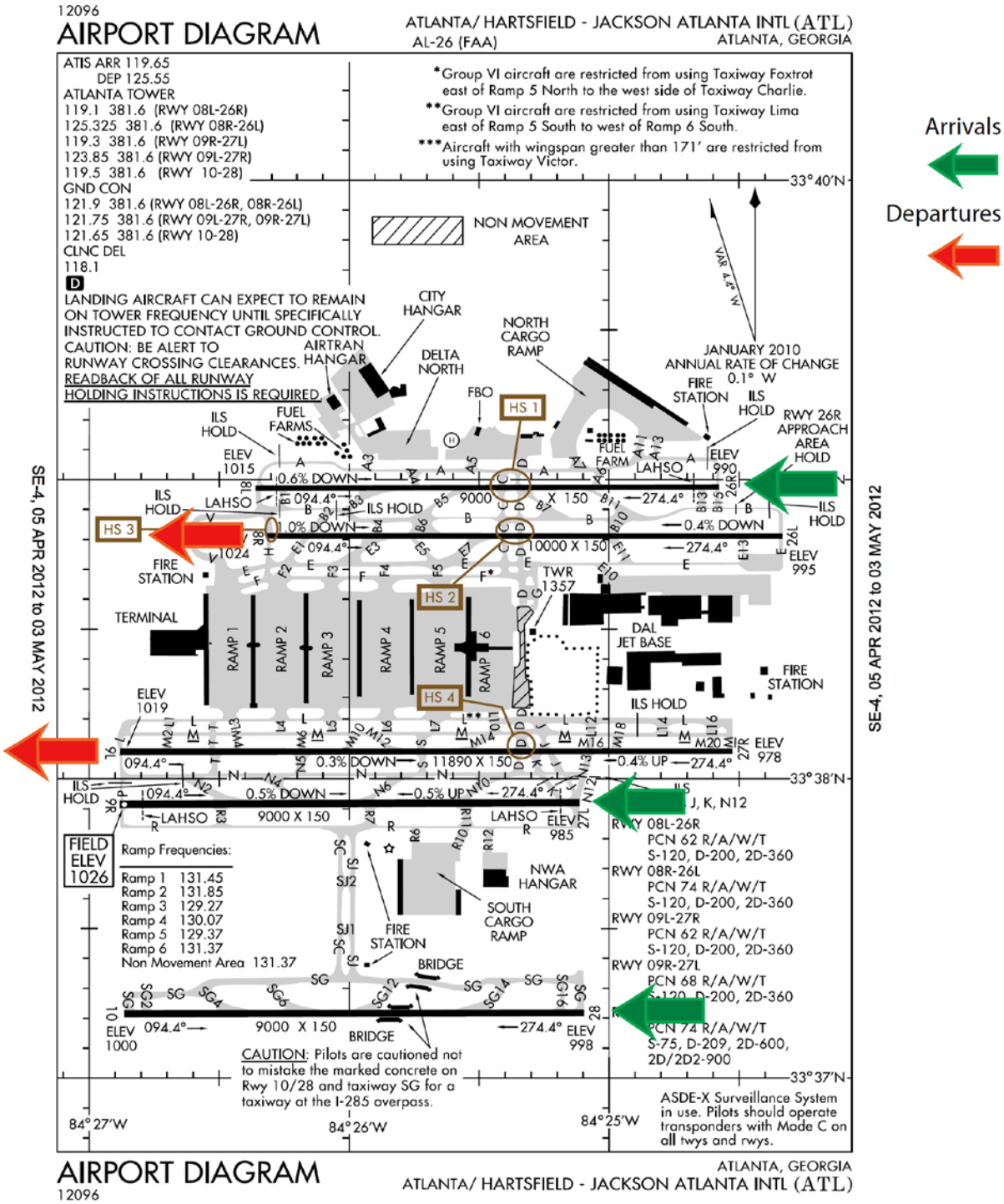

Figure 5. ATL in West Flow with Triple Arrival Runways

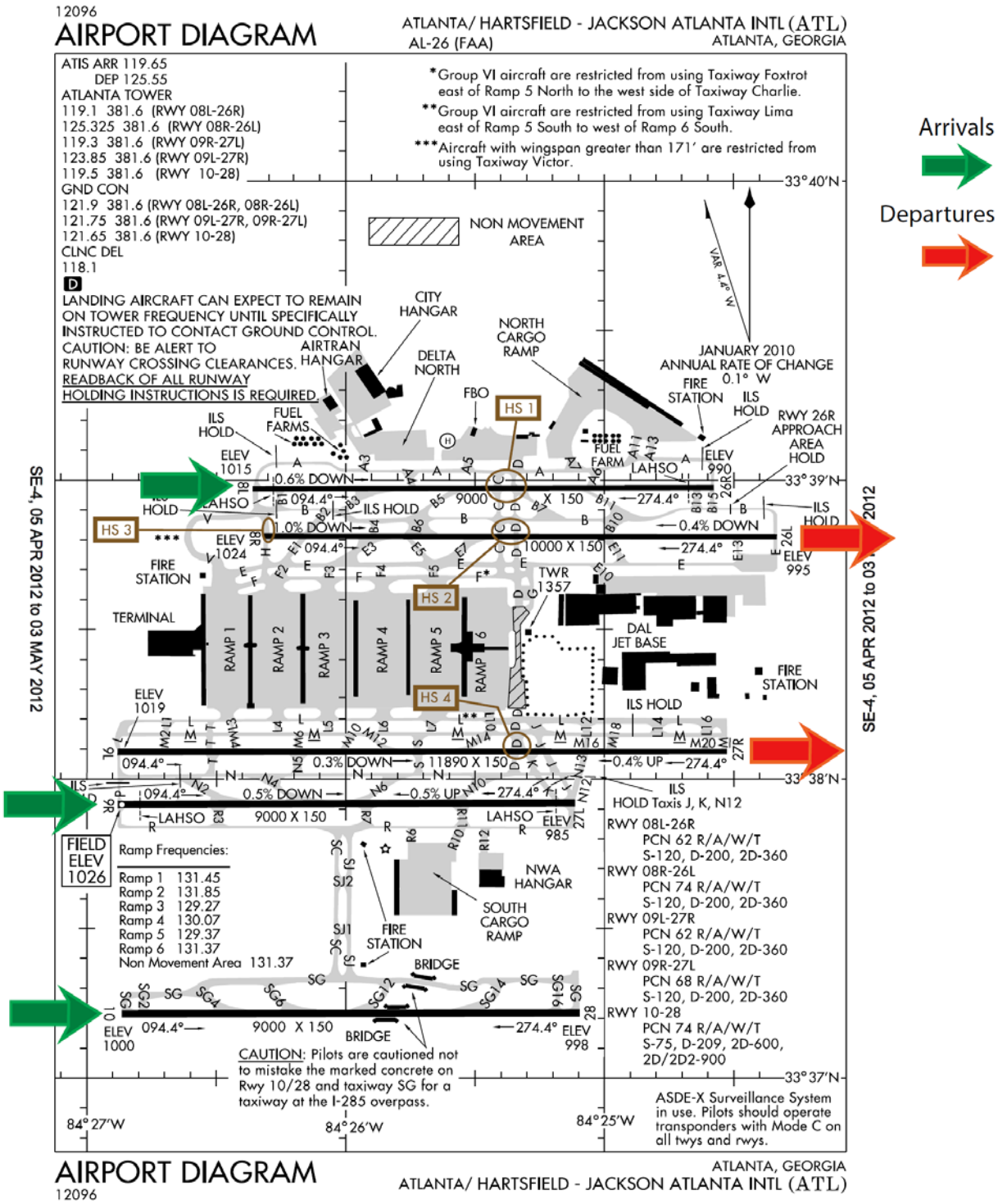

Figure 6. ATL in East Flow with Triple Arrival Runways

2.2.2.2 Airspace

This study simulated flight operations in the ATL TRACON airspace referred to as A80 as well as in the En Route airspace of ZTL. Figure 3-3 below shows the sectors of ZTL; the red, circular sector represents the A80 TRACON airspace. Airspace boundaries were obtained through the NAS Adaptation Services Environment (NASE) website. Since metrics were only measured in ZTL airspace, flight routes were trimmed to the ZTL boundary.

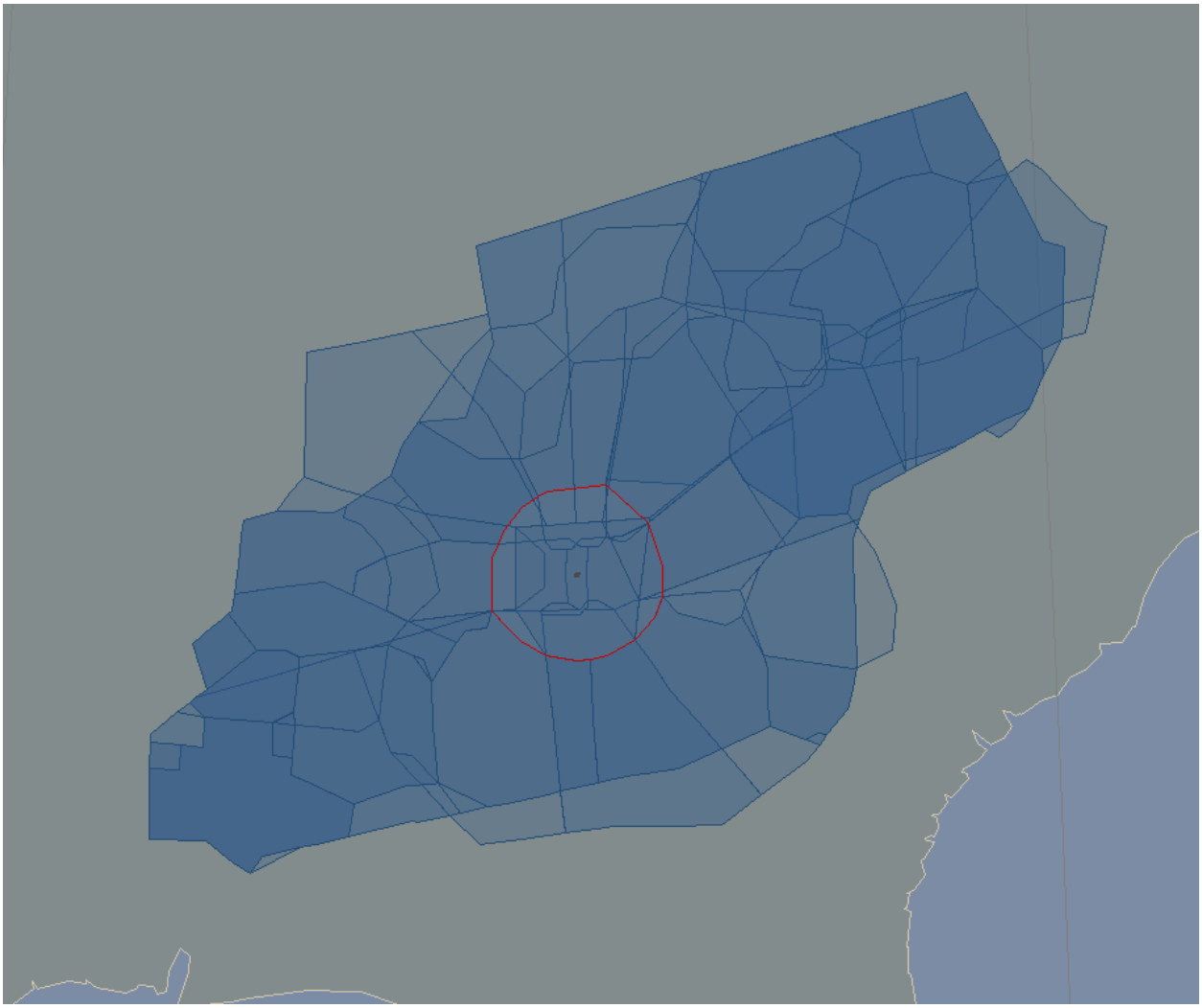

Figure 7. ZTL Airspace Sectors

Figure 3-4 shows the AirTOp representation of the SIDs (shown in red) and STARs (shown in dark blue) at ATL during a Western flow. It was assumed that the PECHY and HERKO STARs (not depicted) were not used on the day represented in the model. Arrival vectoring areas are depicted by the dark blue, triangular spaces. Waypoints shown in green are arrival fixes, whereas those in orange are departure fixes. The light blue circle in Figure 3-4 indicates the location of the A80 TRACON airspace. Figure 3-5 illustrates the same information when ATL is in an Eastern flow.

The SID and STAR definitions were obtained from the TARGETS system and applied in the baseline scenario. The definitions were also modified to characterize various IADCS procedures in IADCS scenarios for comparison. The approach vectoring areas were developed within AirTOp using recorded field data. These represent areas where the controller typically vectors flights to properly sequence arriving aircraft. Performance Data Analysis and Reporting System (PDARS) track data was displayed in AirTOp and used to determine the location and size of the vectoring areas. The initial vectoring areas in each STAR were required to maintain proper sequencing in the model and avoid artificial holding at the approach fixes.

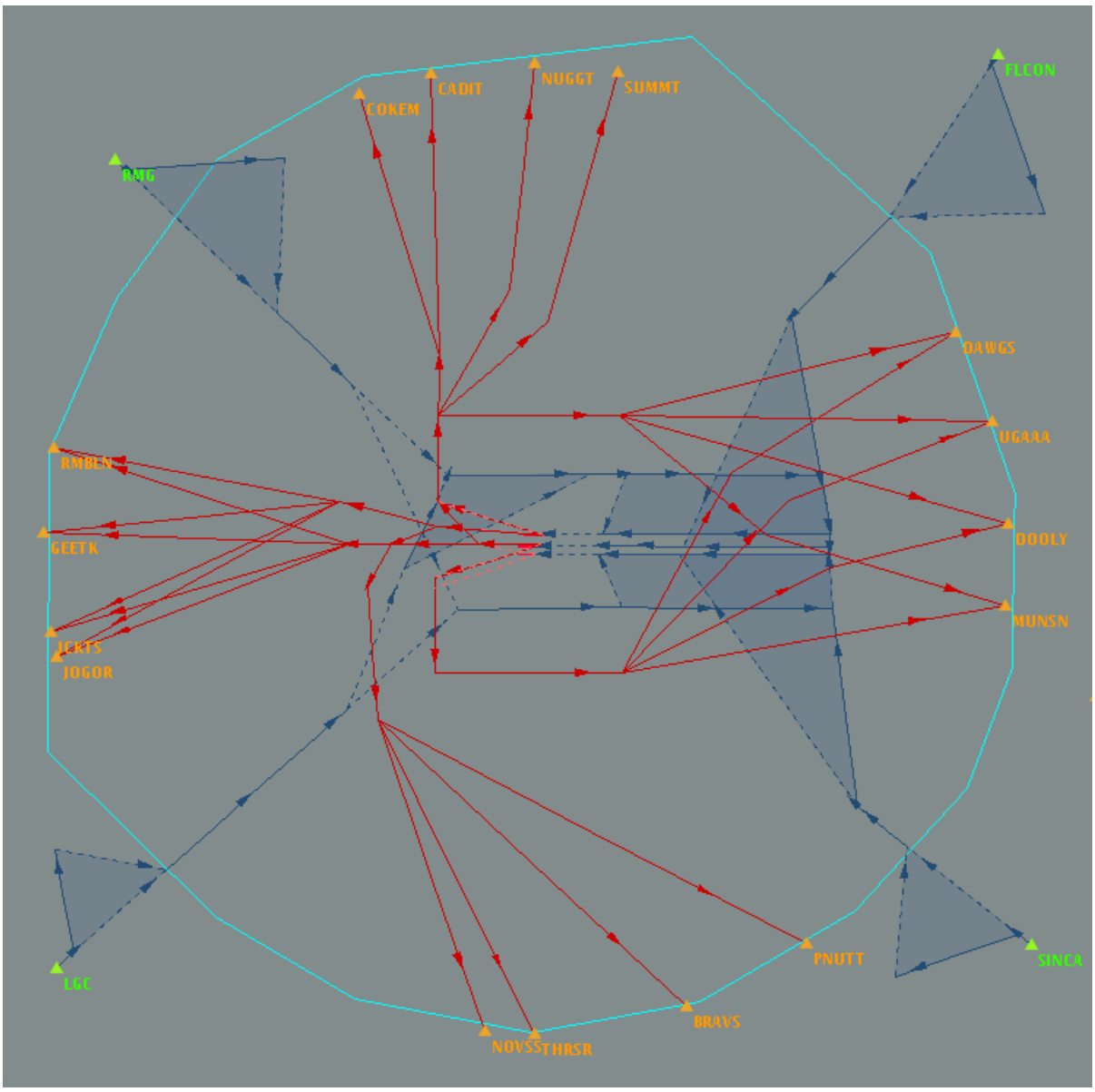

Figure 8. ATL SIDs and STARs in AirTOp (West Flow)

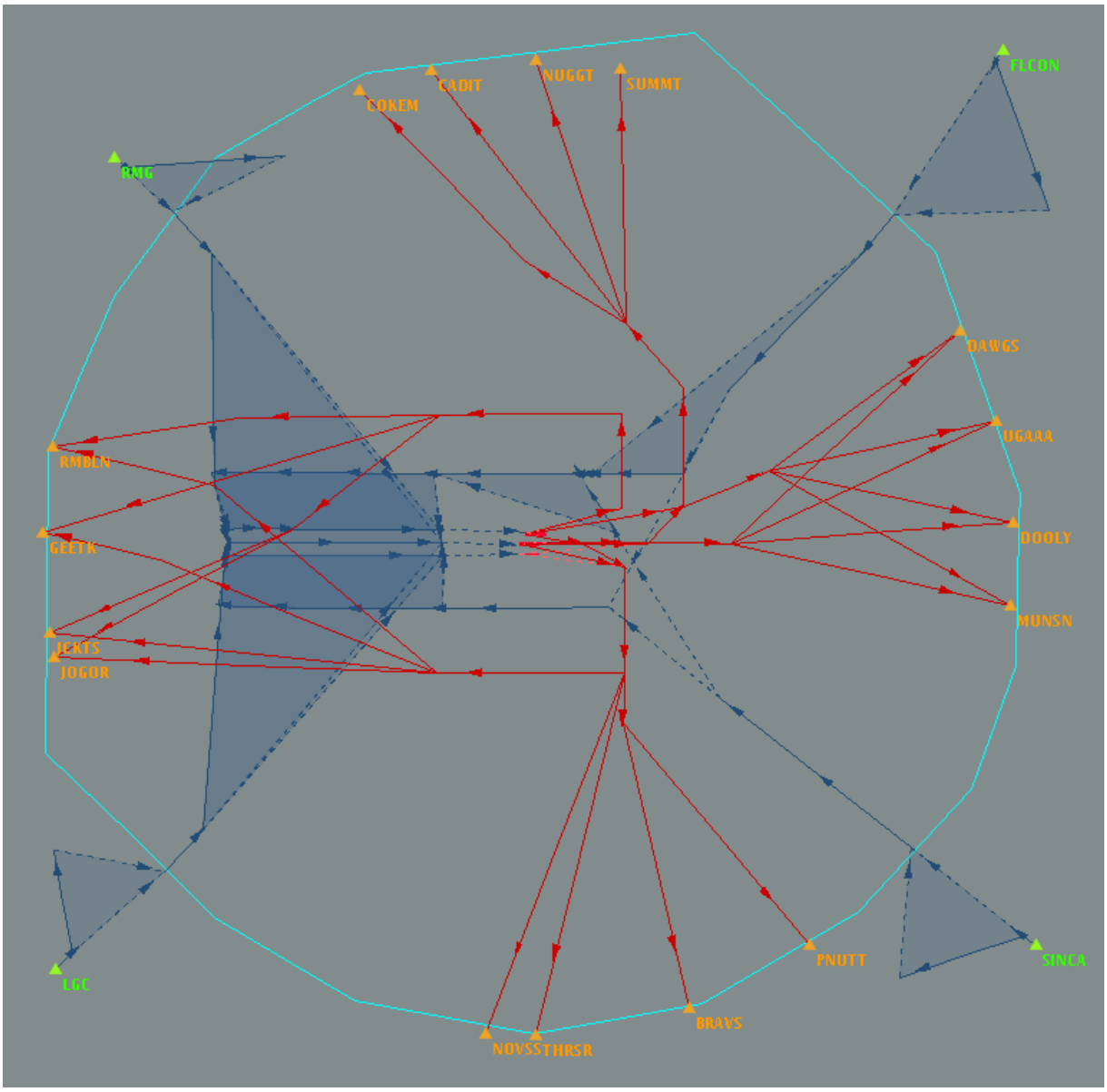

Figure 9. ATL SIDs and STARs in AirTOp (East Flow)

2.2.2.3 Traffic

The traffic sample used for the simulations was based on operational traffic from July 21, 2011. The research team chose this day because it is a fairly clear weather day at ATL airport in which few delays were attributed to weather. This traffic was used for all simulations in this activity and was obtained through the PDARS data system. The set of simulations documented in this report modeled current traffic levels; a future set of simulations will model a forecasted traffic level for the year 2020. There were 2,612 flights included in each of the simulation runs.

It was assumed that all aircraft in the traffic schedule were RNAV and Required Navigation Performance (RNP) equipped. Also, as high altitude traffic and satellite traffic was not the focus of the study, the

scenarios included only flights departing from or arriving at ATL airport. For simplicity in the simulation of approach routes, only jet aircraft were included.

2.2.2.4 Weather

Two weather patterns were represented in the scenarios and varied with the quadrant being simulated. On the East side of the airport, weather blocked the FLCON arrival from 14:00 to 15:00 Eastern Standard Time (EST); similarly, on the West side of the airport, weather blocked the RMG arrival from 07:00 to 08:00 EST. These times were chosen because they reflect the highest demand on the arrival routes in these quadrants. The short, isolated weather events represented in the simulations only blocked arrival routes in the appropriate quadrant.

Additionally, one clear weather day was simulated in East and West flows of ATL as an overall baseline for comparisons. It was used to measure the impact of a short, isolated weather event on airport hourly throughput (arrival and departure rates) in current and IADCS operations.

2.2.2.5 Procedures

In the baseline scenarios, current procedures and operations were simulated. Traffic patterns were reviewed and assessed to determine typical procedures (e.g., reroutes) employed during convective weather situations. These were represented in the baseline scenarios and included traffic reroutes, sequencing at approach waypoints, and holding patterns. Figure 3-6 shows the reroutes taken by flights on the Northeast (NE) during weather; Figure 3-7 shows the reroutes taken by flights on the Northwest (NW). In both the NE and NW, arrival flights were rerouted to the southern STARs (LGC on the West or SINCA on the East). All scenarios utilized the standard 5 NM separation in En Route airspace and 3 NM separation in the TRACON.

The change from today's procedures to IADCS flexible routings may best be described using a flight example. Suppose flight DAL1234 flies from Chicago O'Hare International Airport (ORD) to ATL with a planned arrival time of 07:30 EST. DAL1234 will enter ATL airspace in the Northwest and is planned to fly the RMG arrival. However, weather is blocking the RMG arrival at the time DAL1234 is supposed to be on the arrival route. Once the flight enters ZTL airspace, it is rerouted to the LGC arrival route on the Southwest via the waypoints VUZ and OBXAY (shown in Figure 3-7).

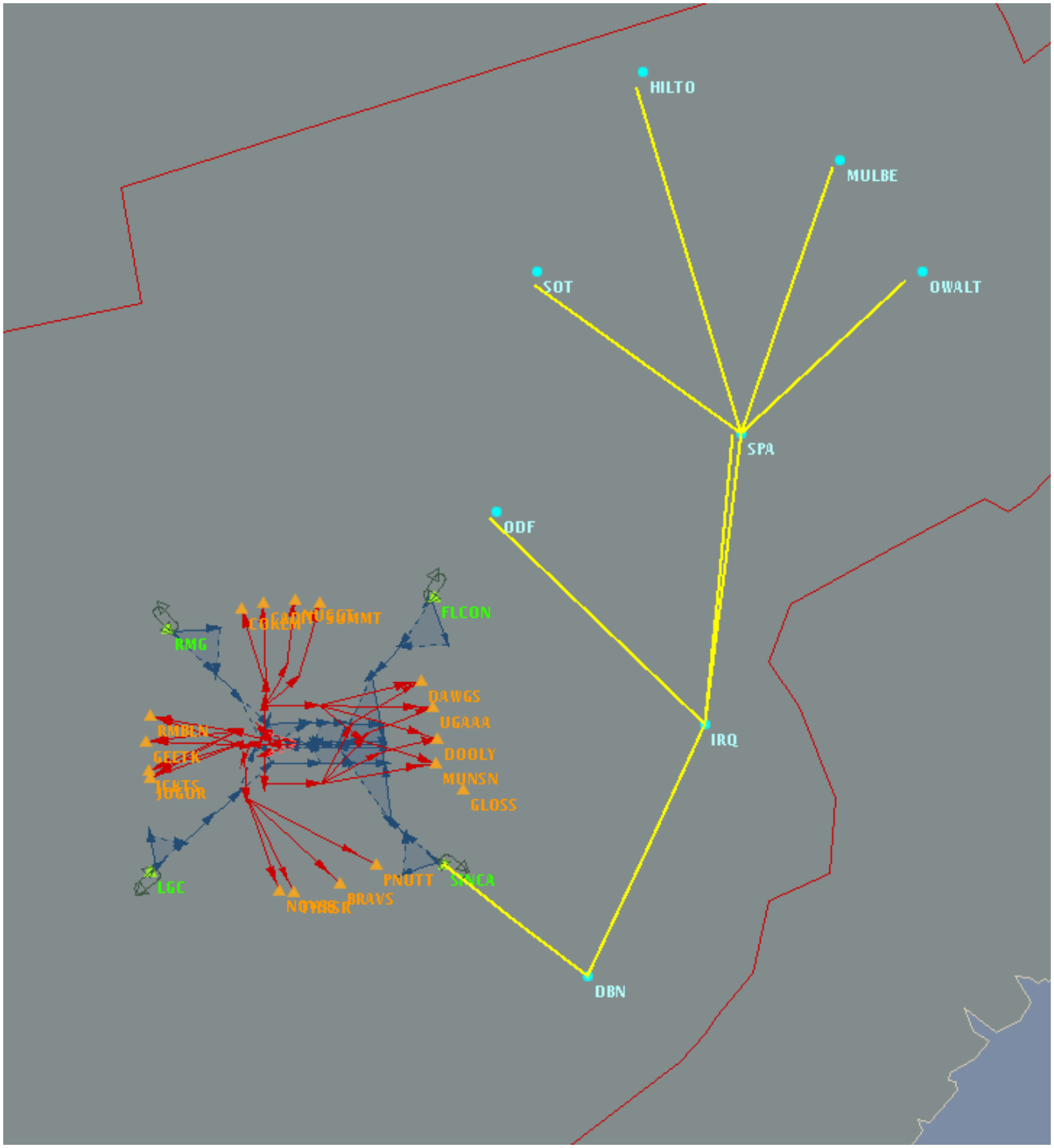

Figure 10. Current Weather Reroutes on NE in AirTOp

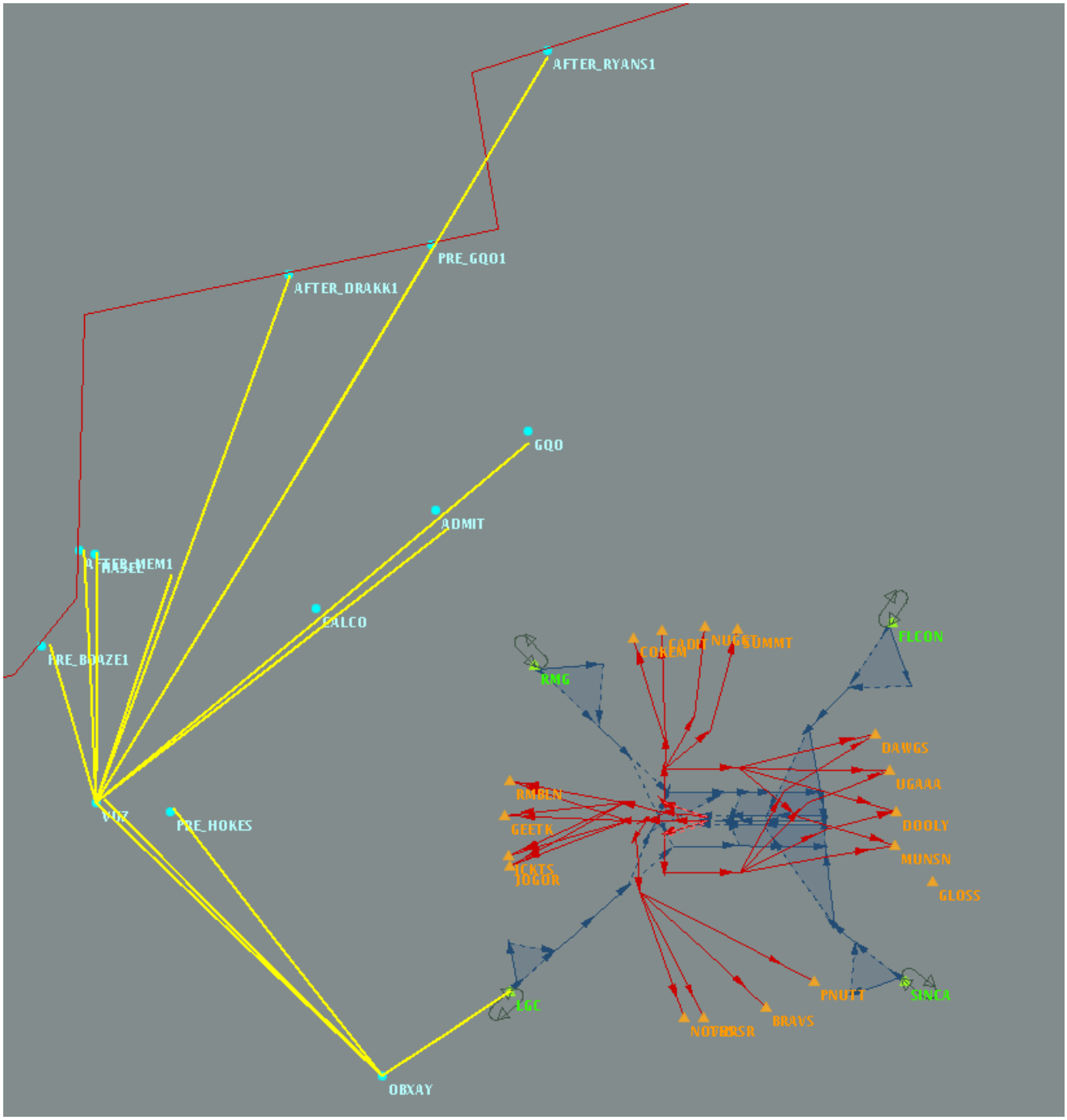

Figure 11. Current Weather Reroutes on NW in AirTOp

Using IADCS procedures, controllers and TMU personnel can coordinate to open existing routes for bi-directional flows in optimal locations to minimize flight duration and maximize the throughput of the airport during convective weather. These procedures were developed by controller SMEs and represented for evaluation in the eight IADCS scenarios.

In the IADCS procedures simulated in this study, arrival flights are rerouted to a new STAR that overlaps an existing SID. The IADCS concept proposes three options to ensure separation between all flights: a bi-directional flow in which arrival flights are flying the new STAR at least 1,000 feet below departures that are flying the existing SID (a Low scenario shown in Figure 3-8); another bi-directional flow where arrival flights are flying the new STAR at least 1,000 feet above departure flights on the SID (a High scenario shown in Figure 3-9); or the SID can be closed and its departure flights moved to the next SID so that arrival and departure flights are separated laterally (a Lateral scenario shown in Figure 3-10).

Again, take flight DAL1234 from ORD to ATL as an example. The flight is once again rerouted to avoid weather at RMG as soon as it enters ZTL airspace. DAL1234 is rerouted to a new approach route overlapping the RMBLN departure route and will get there via a new waypoint RLTDE which acts as a merge point for different arrival flows. A new arrival route has been developed below the RMBLN departure route (referred to as the RMBLN Low play). This means that DAL1234 will be flying at least 1,000 feet below ATL departure flights using the RMBLN SID. If the RMBLN High play had been used for arrival flights, DAL1234 would have been flying at least 1,000 feet above ATL departure flights on the RMBLN SID; and, if the RMBLN/GEETK play was in place, only arrival flights like DAL1234 would be flying over RMBLN since departures would be using the nearby GEETK departure route.

The three NW scenarios described above are depicted in the figures below. Light blue waypoints indicate trigger points for reroutes to a new STAR, and the yellow lines are the paths taken by the reroutes. Appendix B contains figures showing all of the AirTOp scenarios used in this study.

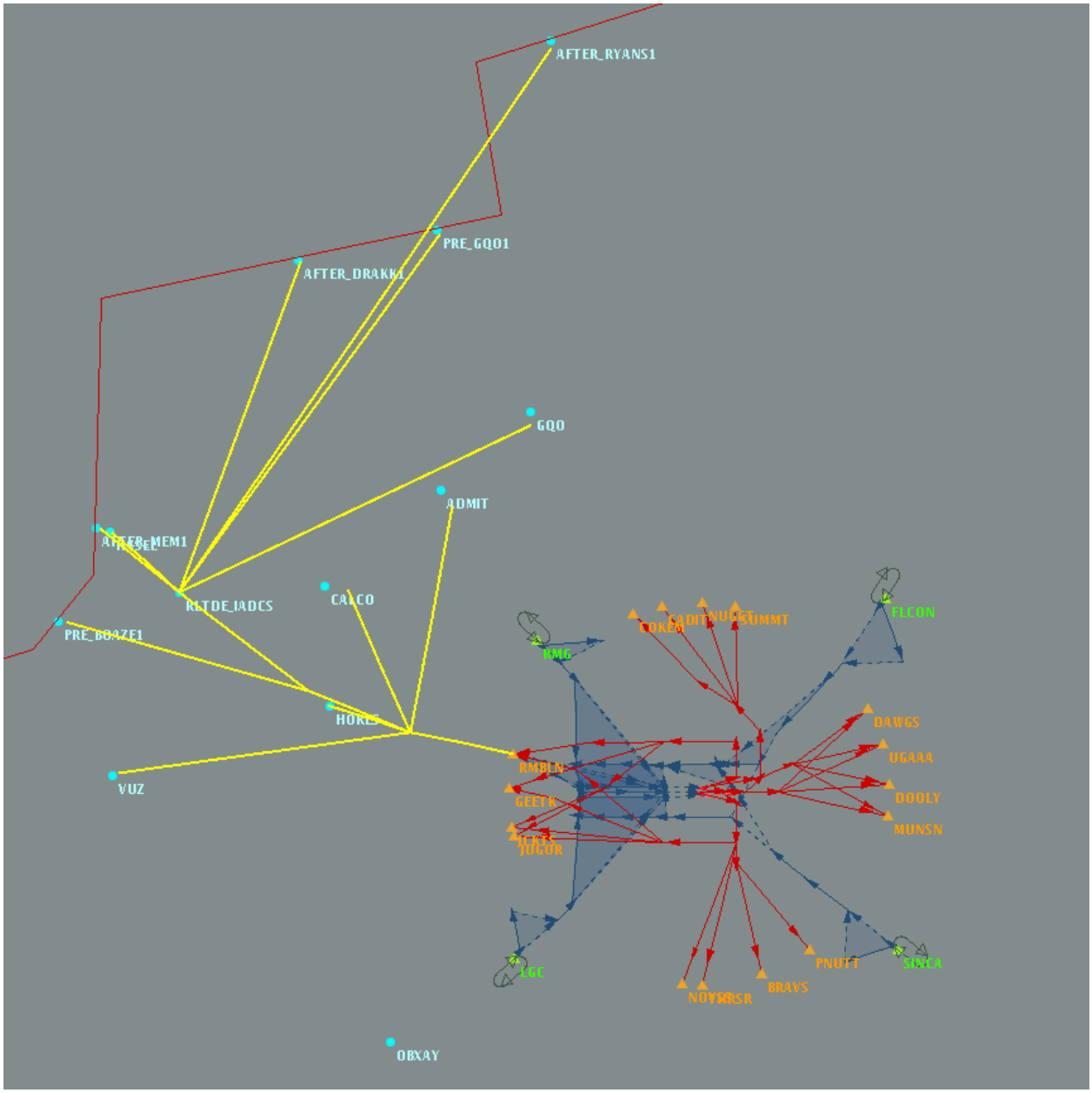

Figure 12. RMBLN Low Scenario in AirTOp

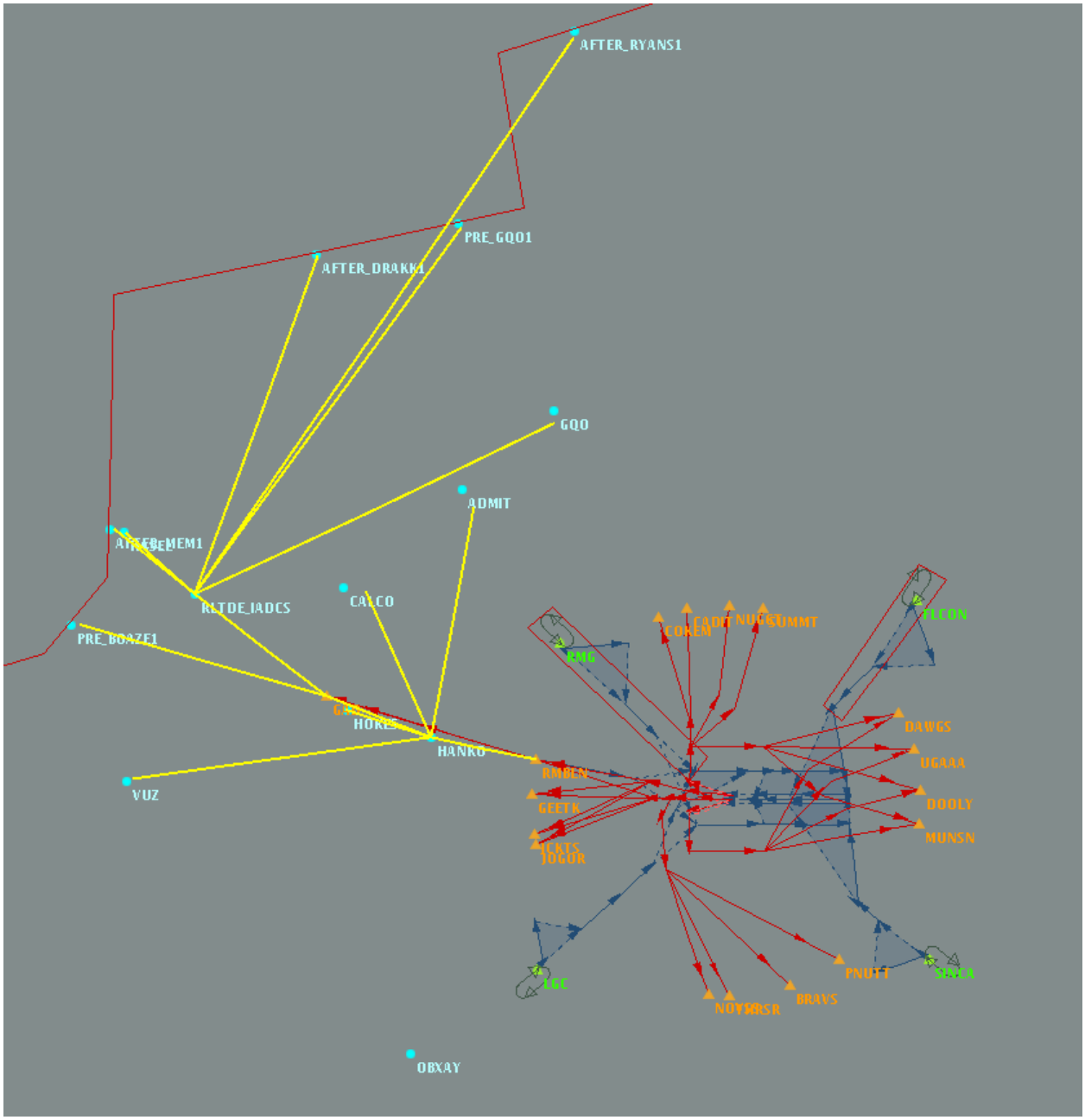

Figure 13. RMBLN High Scenario in AirTOp

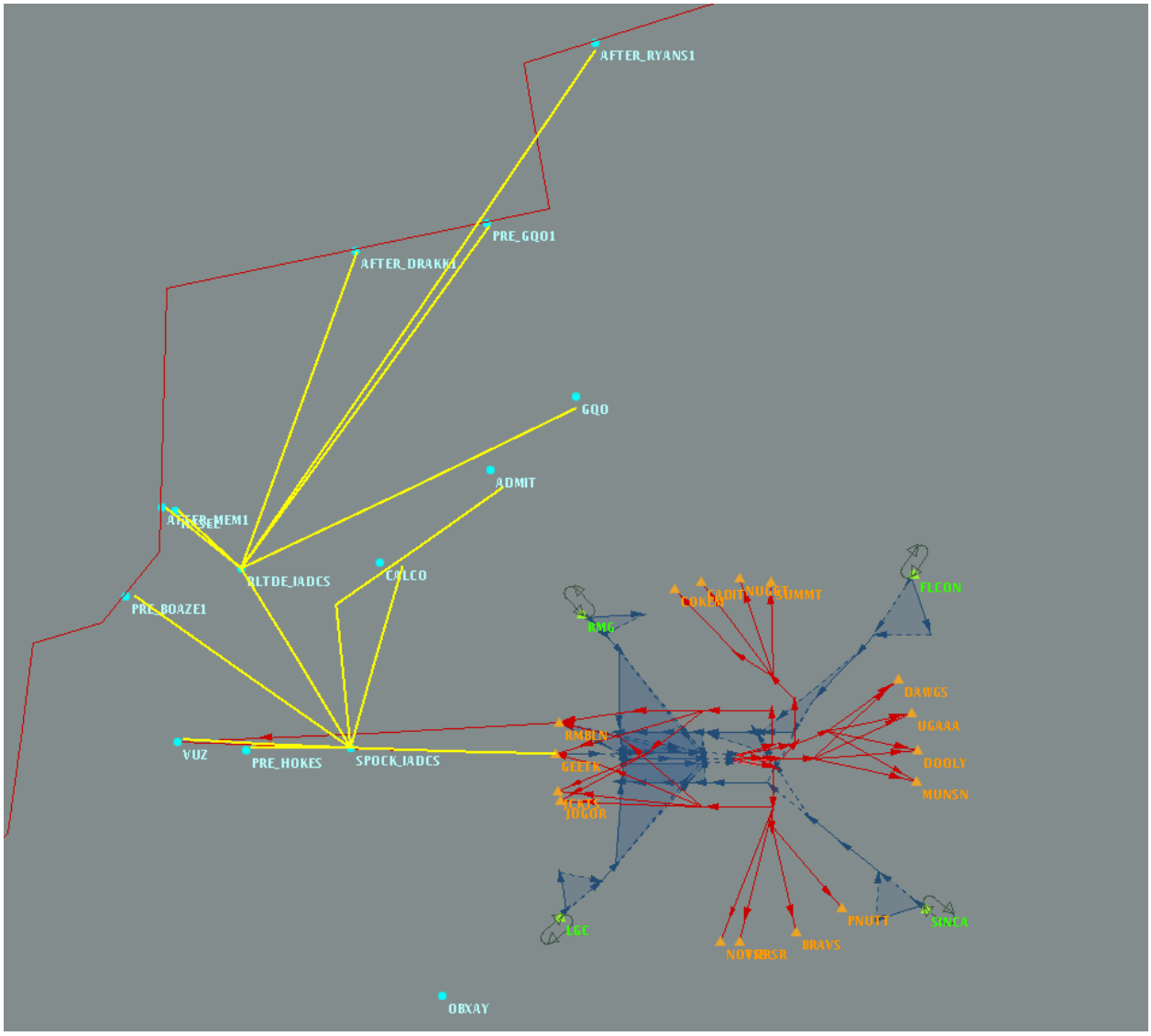

Figure 14. RMBLN (Departures)/GEETK (Arrivals) Lateral Scenario in AirTOp

2.2.3 Assumptions and Limitations

This fast-time simulation activity is limited in its ability to measure changes in human performance with the introduction of IADCS tools; a HITL is necessary to test the human factors element of the concept.

As with any modeling activity, there were several assumptions that influence the design and outcomes of the simulation. The following is a list of assumptions made to conduct this fast-time modeling activity:

- Traffic management decisions were not impacted by controller workload.
- ATL ground constraints did not affect airborne flight delays.
- All aircraft flying into or out of ATL airport were RNAV/RNP equipped.
- Only jet aircraft were represented in the airspace affected by the IADCS procedures.
- One isolated, hour-long weather event was present on the NE or NW and only blocked the airspace quadrant's arrival route at its busiest time of day. No departure routes were blocked by the weather event.
- No ground stops were utilized at any airports in the simulations.
- Reroutes of ATL flights due to weather began in ZTL airspace. In real operations, reroutes may begin outside of ZTL airspace; however, this simulation was limited to only modeling controller actions within ZTL. For flights originating outside of ZTL, simulated reroutes were initiated as close to the ZTL boundary as possible.
- The climb profile of ATL departure flights were not restricted by TRACON sector altitudes. Departures climbed unrestricted once they were no longer crossing the approach routes. No other change in procedures or airspace boundaries was represented.
- Overflight traffic and satellite airports such as PDK did not impact ATL arrivals or departures.
- Aircraft were separated by 5 NM in En Route airspace and 3 NM in the TRACON for all scenarios.
- Offload arrival routes, PECHY and HERKO, were not utilized in the simulations.

2.2.4 Scenarios

The following tables list the baseline and IADCS simulation scenarios modeled in this activity. The data obtained from these simulations was used to quantify benefits for the IADCS concept. Additional fast-time simulations are planned as a follow-up activity and will be documented in an addendum to this report.

Scenario Name	Airport Flow Configuration	Airspace Quadrant	Description
BASELINE SCENARIOS			
West Clear Baseline	Western	All	Current operations and procedures on a clear weather day while ATL is in a Western flow.
East Clear Baseline	Eastern	All	Current operations and procedures on a clear weather day while ATL is in an Eastern flow
West NE Weather Baseline	Western	NE	Current operations and procedures when convective weather is blocking the FLCON arrival flow; ATL is in a Western flow; Reroute paths are shown in Figure 3-6 and B-1.
West NW Weather Baseline	Western	NW	Current operations and procedures when convective weather is blocking the RMG arrival flow; ATL is in a Western flow; Reroute paths are shown in Figure 3-7 and B-2.
East NE Weather Baseline	Eastern	NE	Current operations and procedures when convective weather is blocking the FLCON arrival flow; ATL is in an Eastern flow; Reroute paths are shown in Figure 3-6 and B-1.
East NW Weather Baseline	Eastern	NW	Current operations and procedures when convective weather is blocking the RMG arrival flow; ATL is in an Eastern flow; Reroute paths are shown in Figure 3-7 and B-2.

Table 1. Baseline Fast-Time Simulation Scenario Matrix

Scenario Name	Airport Flow Configuration	Airspace Quadrant	Description
IADCS SCENARIOS			
DAWGS Low	Western	NE	Convective weather is blocking the FLCON arrival flow, and these arrivals are rerouted to a new STAR over DAWGS; Departures continue to fly the DAWGS SID, making this path bi-directional with arrivals flying beneath departures; ATL is in a Western flow so that departures can gain enough altitude to fly above the arrivals safely; Reroute path from waypoint ODF to DAWGS approach is shown in Figure B-3.
DAWGS High	Eastern	NE	Convective weather is blocking the FLCON arrival flow, and these arrivals are rerouted to a new STAR over DAWGS; Departures continue to fly the DAWGS SID, making this path bi-directional with arrivals flying above departures; ATL is in an Eastern flow, and departures will be step climbing to ensure proper separation from arrivals; Reroute path from waypoint ODF to DAWGS approach is shown in Figure B-4.
DAWGS /UGAAA Lateral	Western	NE	Convective weather is blocking the FLCON arrival flow; the arrival flights are rerouted to a new STAR over DAWGS while all DAWGS departures are moved to the UGAAA SID, providing lateral separation for the arrivals and departures; ATL is in a Western flow; Reroute path from waypoint ODF to DAWGS approach is shown in Figure B-5.
RMBLN Low	Eastern	NW	Convective weather is blocking the RMG arrival flow, and these arrivals are rerouted to a new STAR over RMBLN; Departures continue to fly the RMBLN SID, making this path bi-directional with arrivals flying beneath departures; ATL is in an Eastern flow so that departures can gain enough altitude to fly above the arrivals safely; Reroute paths to RMBLN approach are shown in Figure 3-8 and B-6.
RMBLN High	Western	NW	Convective weather is blocking the RMG arrival flow, and these arrivals are rerouted to a new STAR over RMBLN; Departures continue to fly the RMBLN SID, making this path bi-directional with arrivals flying above departures; ATL is in a Western flow, and departures will be step climbing to ensure proper separation from arrivals; Reroute paths to RMBLN approach are shown in Figure 3-9 and B-7.
RMBLN /GEETK Lateral	Eastern	NW	Convective weather is blocking the RMG arrival flow; the arrival flights are rerouted to a new STAR over RMBLN while all RMBLN departures are moved to the GEETK SID, providing lateral separation for the arrivals and departures; ATL is in an Eastern flow; Reroute paths to RMBLN approach are shown in Figure 3-10 and A-8.
COKEM Low	Eastern	NW	Convective weather is blocking the RMG arrival flow, and these arrivals are rerouted to a new STAR over COKEM; Departures continue to fly the COKEM SID, making this path bi-directional with arrivals flying beneath departures; ATL is in an Eastern flow so that departures can gain enough altitude to fly above the arrivals safely; Reroute paths to COKEM approach are shown in Figure B-9.
COKEM High	Western	NW	Convective weather is blocking the RMG arrival flow, and these arrivals are rerouted to a new STAR over COKEM; Departures continue to fly the COKEM SID, making this path bi-directional with arrivals flying above departures; ATL is in a Western flow, and departures will be step climbing to ensure proper separation from arrivals; Reroute paths to COKEM approach are shown in Figure B-10.

Table 2. IADCS Fast-Time Simulation Scenario Matrix

3 Analysis

3.1 Methods of Analysis

Output from the AirTOp model was collected from files created during the simulations. These files included data on distance flown, flight duration and fuel burn per flight as well as airport throughput per hour. The results of the IADCS scenarios were compared against baseline scenarios to determine the potential impact of implementing IADCS plays.

Three sets of analyses were conducted for each IADCS scenario: a calculation of impact to the rerouted flights, impact to other flights affected by the weather event, and impact to the overall daily operations in each scenario. While it is anticipated that the flights which rerouted to avoid weather will experience a large reduction in distance flown, flight duration, and fuel burn with the introduction of IADCS flexible routings, the impact of the reroutes on other flights at ATL must also be quantified. The impact on overall operations at ATL is quantified to demonstrate the impact of IADCS on the efficiency of daily operations and on the capacity of ATL airport in each scenario.

All scenarios involve 2,612 total flights; however, the simulation model removes a small number of flights (range 0-5) from three of the weather baseline simulations because the holding patterns used to manage the additional rerouted flights were full. No comparison to the IADCS scenarios is possible for these flights, so they are excluded from the analysis.

3.2 Results

Results for the first two analyses, impact on rerouted flights and impact on other flights affected by weather, report arrivals and departures separately because they were affected differently depending on the IADCS scenario. All scenarios involve a changed route for the arrivals. In the Low scenarios (DAWGS Low, RMBLN Low, and COKEM Low), the departures function the same way as in the weather baselines. Departures in the High scenarios (DAWGS High, RMBLN High, and COKEM High) follow the same route as in the weather baselines but have restricted altitudes to ensure vertical separation from arrivals at a higher altitude.

It is important to note that the following results represent potential impacts due to implementing IADCS during a short, isolated weather event. Changes to the assumptions made for this activity, such as weather location and duration, can greatly affect the calculated impact of IADCS. For example, if the weather event blocked an arrival route for a longer period and impacted more flights, it is likely that a greater amount of miles flown, time, and fuel would be saved by using IADCS procedures.

3.2.1 Impact of IADCS on Rerouted Flights

Three metrics (distance flown, flight duration, and fuel burned) were used to quantify the benefits of IADCS for the flights that were rerouted during the simulated weather event and those impacted by the reroutes. In scenarios where weather was assumed to be blocking the NW arrival route at ATL (RMG arrival) during a peak arrival time, thirty-three (33) flights were rerouted to avoid the weather. Likewise, when weather was blocking the NE arrival route (FLCON arrival) during a peak arrival time, twenty-eight (28) flights were rerouted.

In every IADCS scenario, the rerouted flights saved a large amount of distance, time, and fuel compared to current operations in the baselines. Table 3 shows the average and range of these savings while Figure 4-1 illustrates the average savings per scenario in a chart. Rerouted flights in the Low scenarios saved more fuel than their associated High scenarios (ex. average fuel savings in DAWGS Low is 2,009.02 lbs compared to the savings in DAWGS High at 1,936.00 lbs). This slight difference was expected since departure flights were kept at low altitudes in the High scenarios and allowed to climb freely to their requested altitude in the Low scenarios, while the altitude of arrival flights typically only differed by 2,000 feet between the Low and High scenarios. Also, the Low scenarios yielded larger benefits than the High scenarios or Lateral scenarios (RMBLN/GEETK and DAWGS/UGAAA) for the RMBLN and DAWGS sets.

Scenario	N	Avg Distance Savings (NM)	Range of Distance Savings (NM)	Avg Duration Savings (mm:ss)	Range of Duration Savings (mm:ss)	Avg Fuel Savings (lbs)	Range of Fuel Burn Savings (lbs)
RMBLN /GEETK	33	112.16	63.57 - 151.04	17:32	07:44 - 23:47	1131.25	613.44 - 4415.21
RMBLN Low	33	126.07	94.98 - 163.41	19:13	13:25 - 27:42	1270.13	713.11 - 4865.16
RMBLN High	33	114.43	66.88 – 152.33	17:41	07:22 – 22:58	719.17	152.52 - 1701.42
COKEM Low	33	126.78	29.01 - 190.50	18:37	02:52 - 28:40	1329.22	316.74 - 6043.61
COKEM High	33	130.31	35.50 - 194.80	20:01	05:09 - 29:10	1301.14	343.33 - 6541.5
DAWGS /UGAAA	28	111.16	93.19 - 178.81	18:07	13:45 - 27:29	1313.92	547.01 - 2969.89
DAWGS High	28	124.33	75.45 - 204.52	17:34	07:41 - 30:28	1936.00	723.51 - 5498.48
DAWGS Low	28	136.38	100.94 - 184.20	20:09	14:20 - 27:33	2009.02	806.45 - 5622.31

Table 3. Simulation Results for Rerouted Flights in Each Scenario

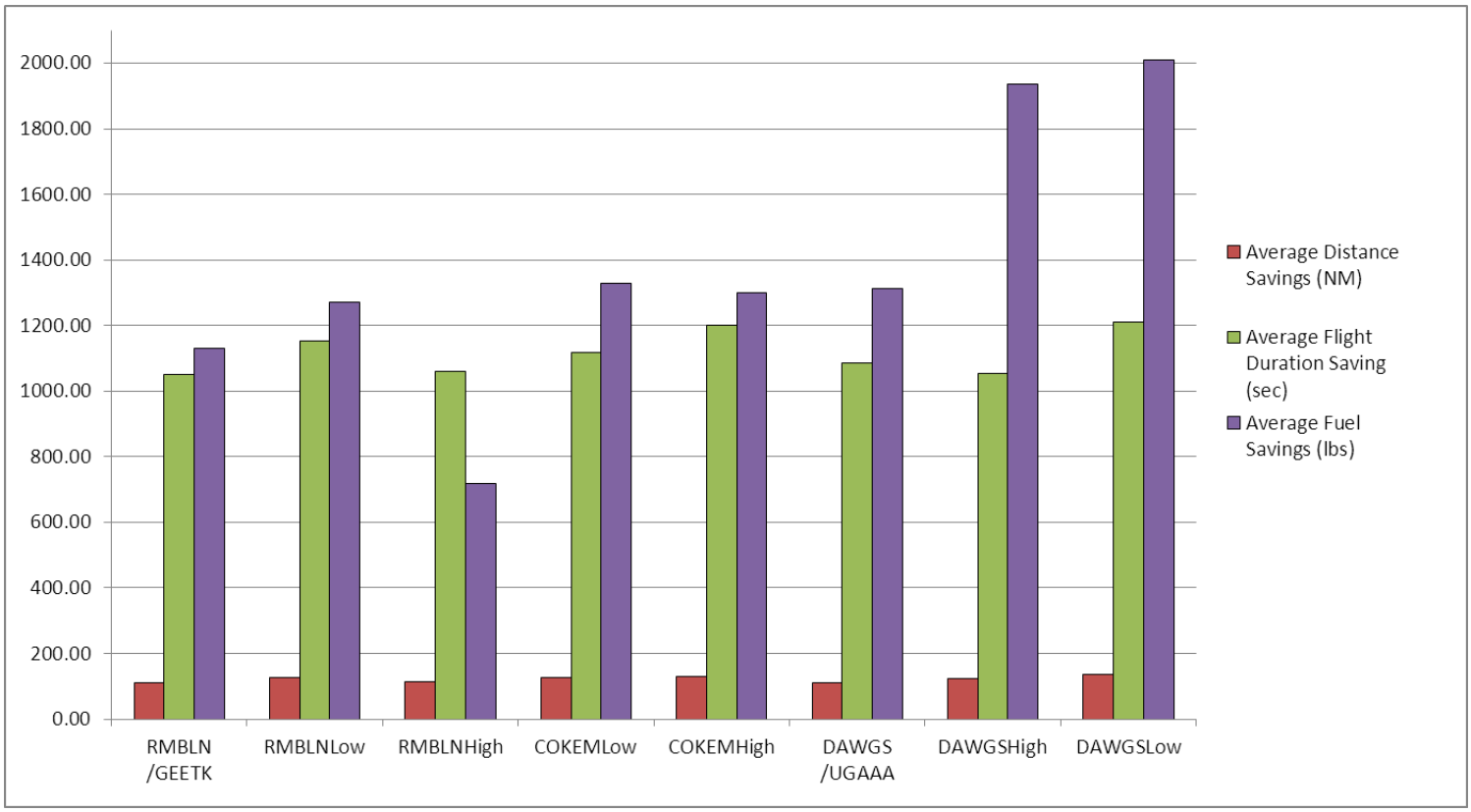

Figure 15. Simulation Results for Rerouted Flights in Each Scenario

3.2.2 Impact of IADCS on Other Flights Affected by Weather

When arrival flights are rerouted to avoid weather today, they are redirected to another STAR and must be sequenced with the planned arrival flights for that STAR. As a result, the rerouted flights travel much farther to reach an arrival route, and other arrival flights are impacted by the rerouted arrivals during and shortly after the weather event. This can cause many flights to hold since two streams of traffic are merging into one, and this effect can last an hour or longer after the weather event has passed. The flexible routing options in IADCS scenarios could minimize this impact on rerouted and other flights; however, impacts to departure flights may exist in some IADCS scenarios. Therefore, it is necessary to examine the effects that rerouted flights have on other arrival and departure flights during and shortly after the weather event.

The weather events represented in the fast-time simulations occurred in the NW from 07:00 EST to 08:00 EST and in the NE from 14:00 EST to 15:00 EST. The results in this section include arrival flights (excluding rerouted flights) that entered the TRACON airspace between 06:45 EST and 09:00 EST (NW) or 13:45 EST and 16:00 EST (NE) as well as departure flights that left the TRACON airspace between 06:45 EST and 08:15 EST (NW) or 13:45 EST and 15:15 EST (NE). The impact of the rerouted flights is thought to last longer on the arrivals than on departure flights.

Table 4 and Figures 4-2, 4-3, and 4-4 show the total distance, time, and fuel savings of all arrival flights impacted by the weather, excluding the rerouted flights. Positive values in the tables and graphs indicate that the total distance flown, time spent, and fuel consumed is larger in the baseline scenario than the condition scenario for the flights of interest. Results are shown for Northwest (RMG), Southwest (LGC), Northeast (FLCON), and Southeast (SINCA) arrival routes. As a reminder, in scenarios where the Northeast STAR was blocked by weather, arrivals were rerouted to the Southeast STAR in today's operations and to DAWGS or UGAAA in IADCS procedures. Likewise, when the Northwest STAR was blocked by weather, all arrivals were rerouted to the Southwest STAR in today's operations and to RMBLN, GEETK, or COKEM in IADCS procedures.

This analysis was also performed on departure flights during the weather events. Results are shown in Table 5 and Figures 4-5, 4-6, and 4-7 for the North (COKEM, CADIT, NUGGT, and SUMMT), South (NOVSS, THRSR, BRAVS, and PNUTT), East (DAWGS, UGAAA, DOOLY, and MUNSN), and West (RMBLN, GEETK, JCKTS, and JOGOR) departure routes.

Metric	Condition	Arrivals			
		Northwest	Southwest	Northeast	Southeast
Total Distance Saved (NM)	DAWGS Low	79.19	118.31	759.5	3.39
	DAWGS High	215.05	121.61	678.02	232.15
	DAWGS /UGAAA	-76.77	-20.12	544.27	27.94
	RMBLN Low	231.45	577.49	57.41	136.85
	RMBLN High	196.07	527.17	5.28	343.91
	RMBLN /GEETK	214.43	624.66	110.6	175.9
	COKEM Low	248.31	600.21	6.88	179.14
	COKEM High	319.9	621.16	4.67	390.11
Total Duration Saved (mm:ss)	DAWGS Low	33:04	32:05	108:56	-10:16
	DAWGS High	49:06	31:01	89:38	63:41
	DAWGS /UGAAA	-11:29	-05:43	86:12	-02:00
	RMBLN Low	46:32	109:18	24:44	34:22
	RMBLN High	35:23	87:05	-00:40	79:07
	RMBLN /GEETK	44:08	117:50	34:29	47:08
	COKEM Low	42:57	111:38	06:15	48:12
	COKEM High	65:17	111:27	-00:02	95:17
Total Fuel Saved (lbs)	DAWGS Low	1036.3	761.65	5259.72	803.56
	DAWGS High	2567.99	1334.99	4895.03	2405.35
	DAWGS /UGAAA	337.26	84.88	3162.13	309.57
	RMBLN Low	9425.99	5589.77	746.31	1286.64
	RMBLN High	5288.99	5032.77	-46.08	3570.78
	RMBLN /GEETK	9073.4	6042.38	960.02	1473.77
	COKEM Low	10730.5	5706	371.54	1504.39
	COKEM High	11085.73	5573.35	-46.76	4109.54

Table 4. Simulation Results for Arrival Flights (Excluding Reroutes) During Weather Event

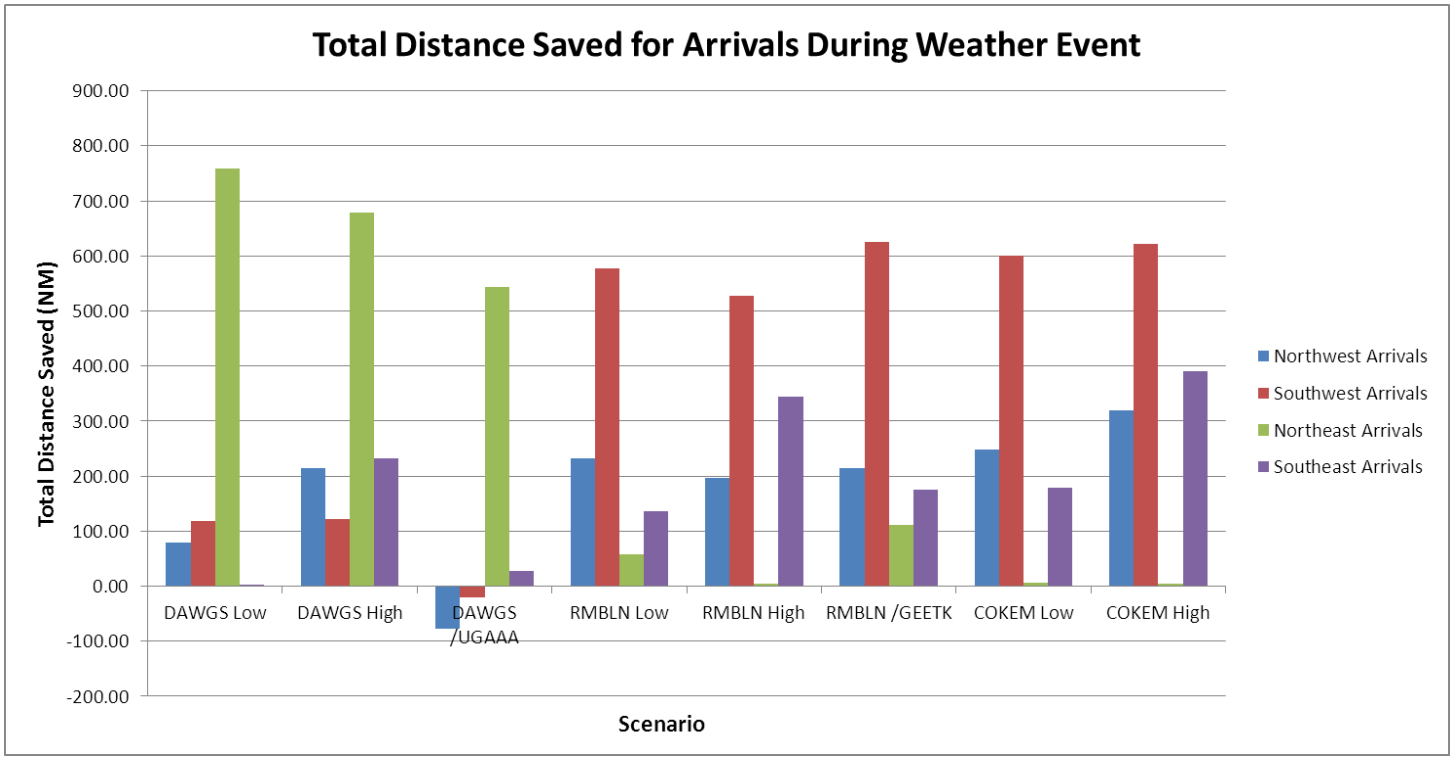

Figure 16. Total Distance Saved for Arrivals During Weather Event

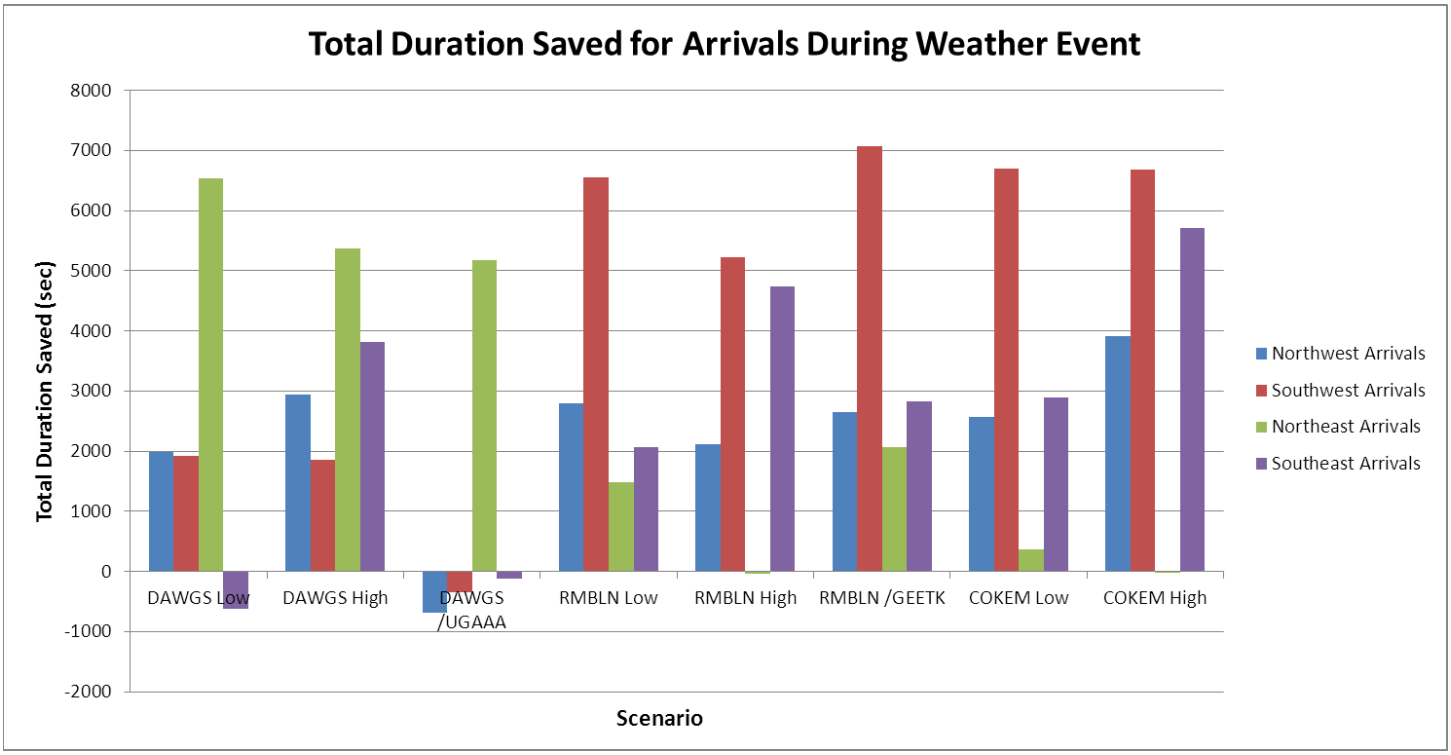

Figure 17. Total Duration Saved for Arrivals During Weather Event

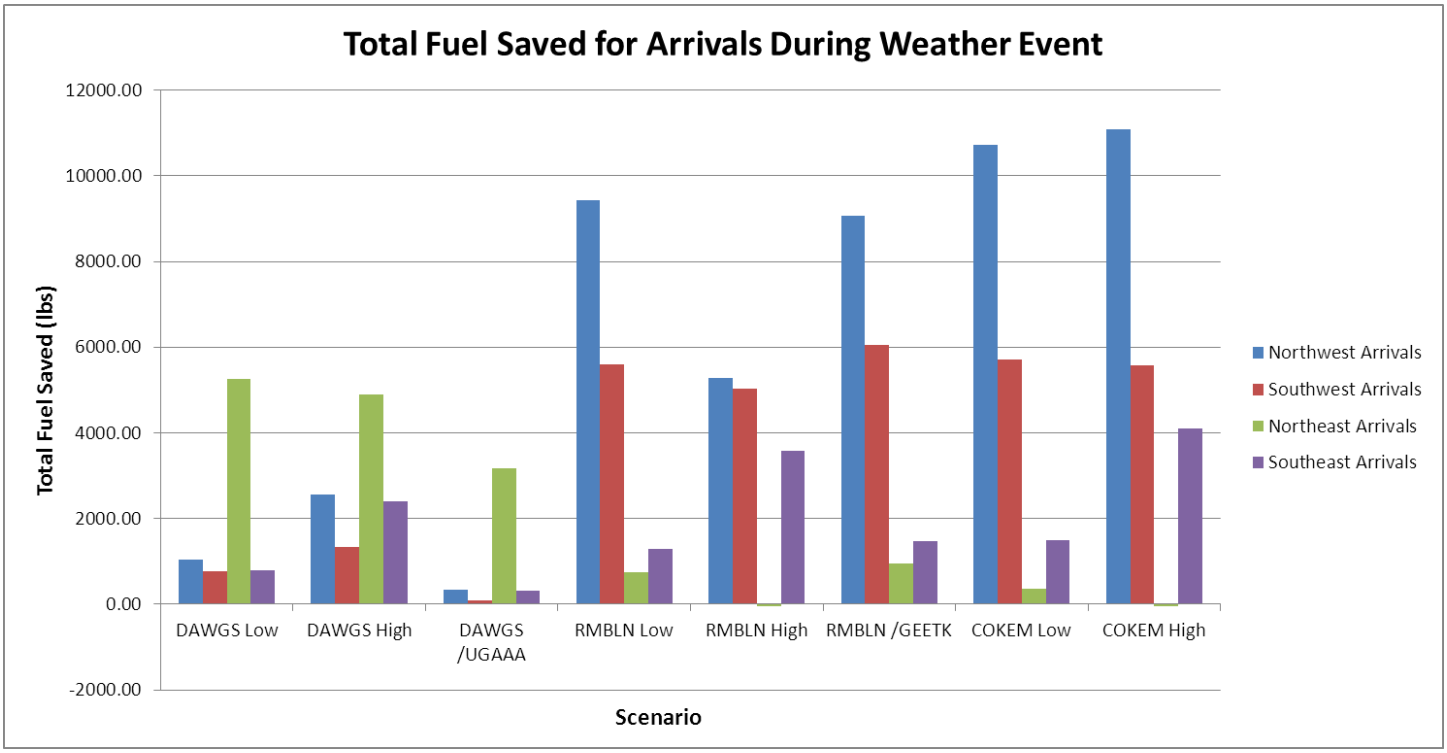

Figure 18. Total Fuel Saved for Arrivals During Weather Event

Results for the DAWGS and RMBLN scenarios largely supported expectations as a significant benefit was seen for distance, time and fuel for arrival flights in the Southeast and Southwest quadrants, respectively. These flights were directly impacted by rerouted flights in the baseline scenarios, whereas they were minimally affected in the IADCS scenarios because rerouted flights were directed to a different airspace. Additionally, many of the IADCS scenarios showed a benefit on the South side of the airport opposite the location of the weather. For example, the RMBLN High scenario involved weather blocking the Northwest, and a large savings in distance, time and fuel was experienced by flights in the Southeast. This is most likely because of the logic used in the simulations to assign arrival flights to runways. Flights using the Southern arrival routes (LGC and SINCA) are assigned to the Southern runway, 10/28. In today's operations, when flights in the NE or NW are rerouted to the South, more aircraft are being assigned to the Southern runway. This impacts flights using the other Southern arrival route and causes holding and/or additional vectoring to meet sequencing requirements. Using the IADCS procedures simulated in this activity, the extra demand for the Southern runway is eliminated and a normal flow of arrivals is maintained in the South.

Metric	Condition	Departures			
		North	South	East	West
Total Distance Saved (NM)	DAWGS Low	0	0	0	0
	DAWGS High	0	0	6.47	0
	DAWGS /UGAAA	0	0	-0.12	0
	RMBLN Low	0	0	0	0
	RMBLN High	0	0	-46.15	-2.12
	RMBLN /GEETK	0	0	0	-22.7
	COKEM Low	0	0	0	0
	COKEM High	20.69	0	-0.08	0
Total Duration Saved (mm:ss)	DAWGS Low	0	0	0	0
	DAWGS High	0	0	00:05	0
	DAWGS /UGAAA	0	0	0	0
	RMBLN Low	0	0	0	0
	RMBLN High	0	0	-06:10	-34:32
	RMBLN /GEETK	0	0	0	-02:33
	COKEM Low	0	0	0	0
	COKEM High	-06:40	0	-00:35	0
Total Fuel Saved (lbs)	DAWGS Low	0	0	1844.16	23.88
	DAWGS High	0.02	0.04	55.49	0.07
	DAWGS /UGAAA	-0.02	0.07	2.65	0.11
	RMBLN Low	-959.3	-863.44	-830.02	831.89
	RMBLN High	29.21	25.53	-322.14	-3570.03
	RMBLN /GEETK	0	0	0	-347.23
	COKEM Low	0	0	0	0
	COKEM High	-421.19	0	-14.44	0

Table 5. Simulation Results for Departure Flights During Weather Event

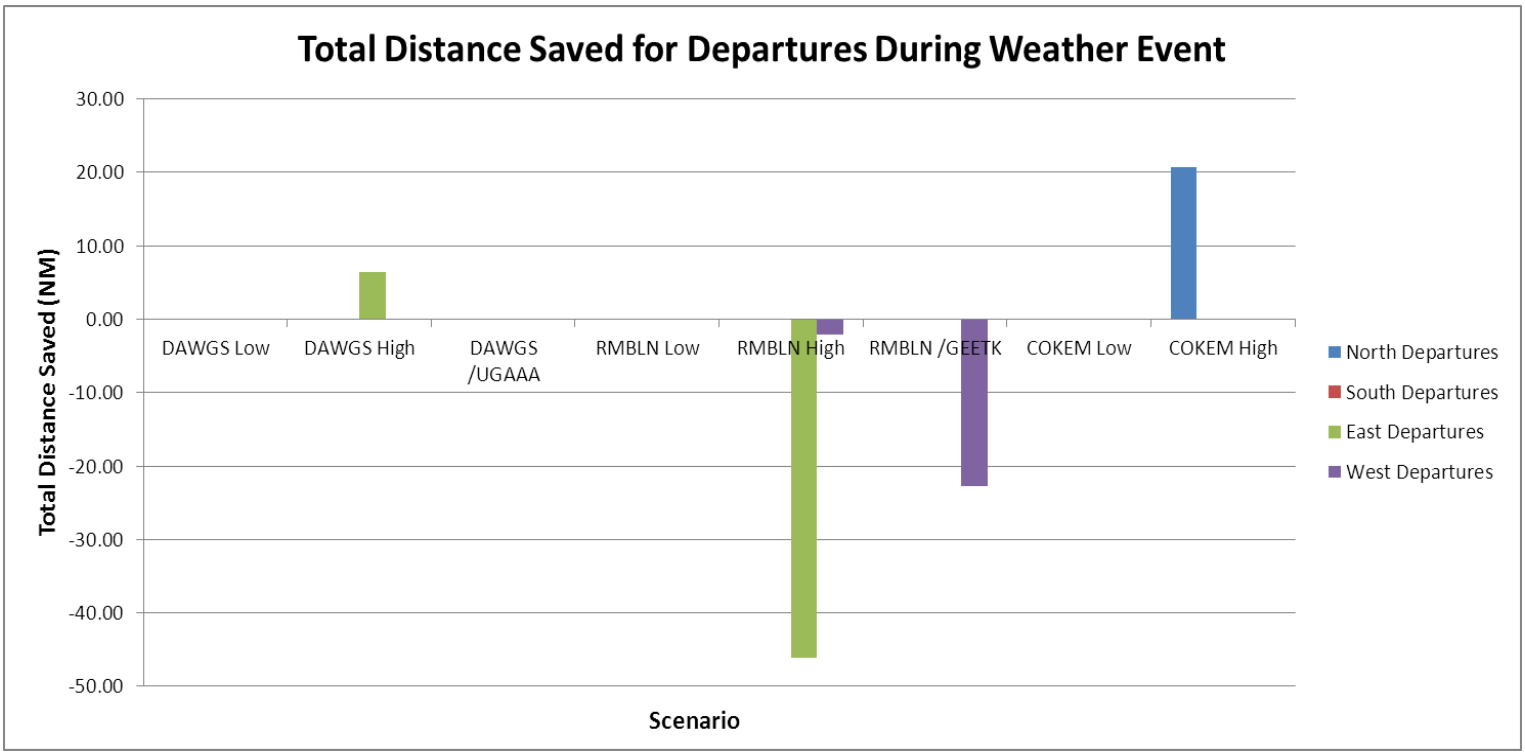

Figure 19. Total Distance Saved for Departures During Weather Event

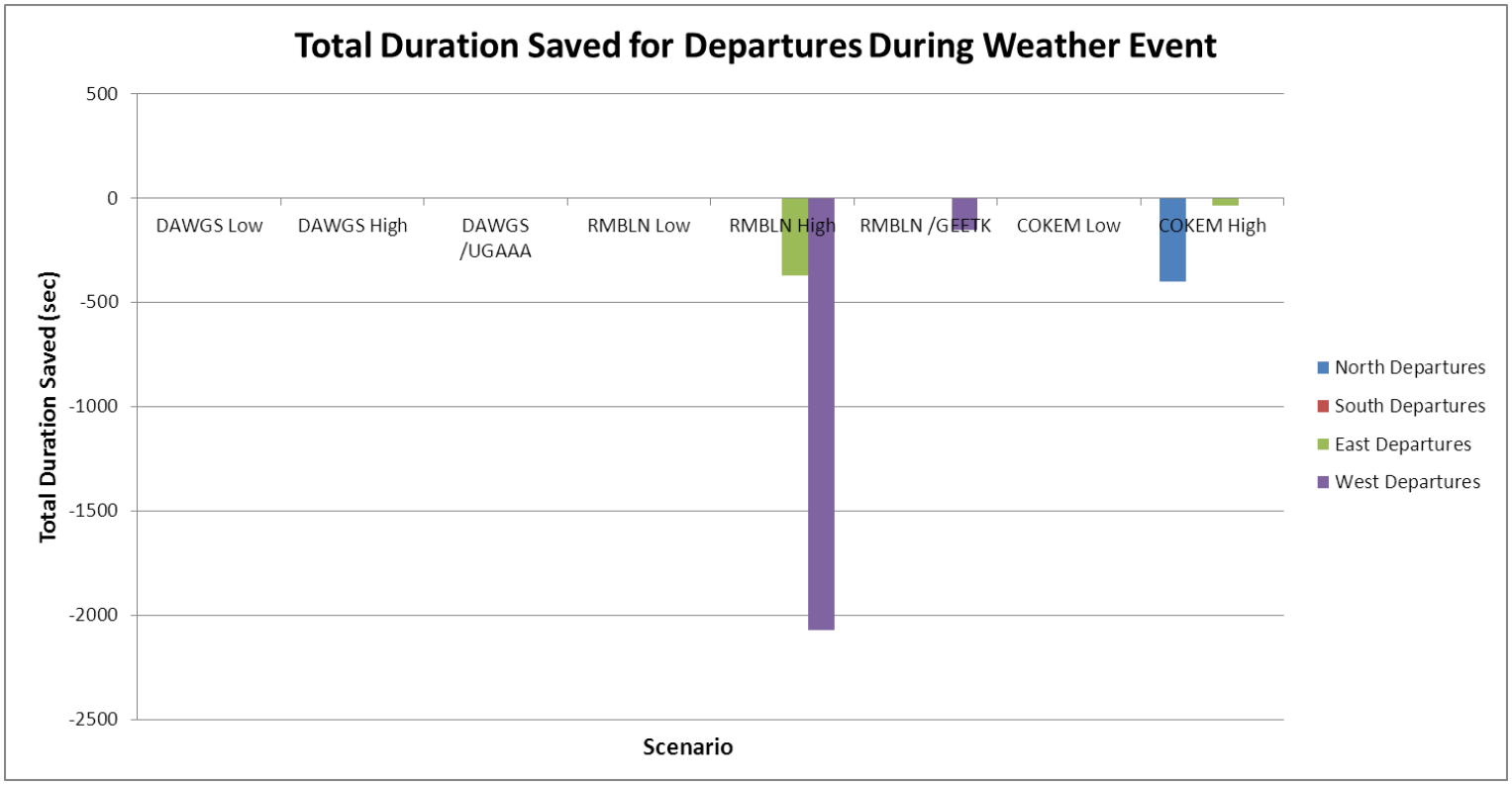

Figure 20. Total Duration Saved for Departures During Weather Event

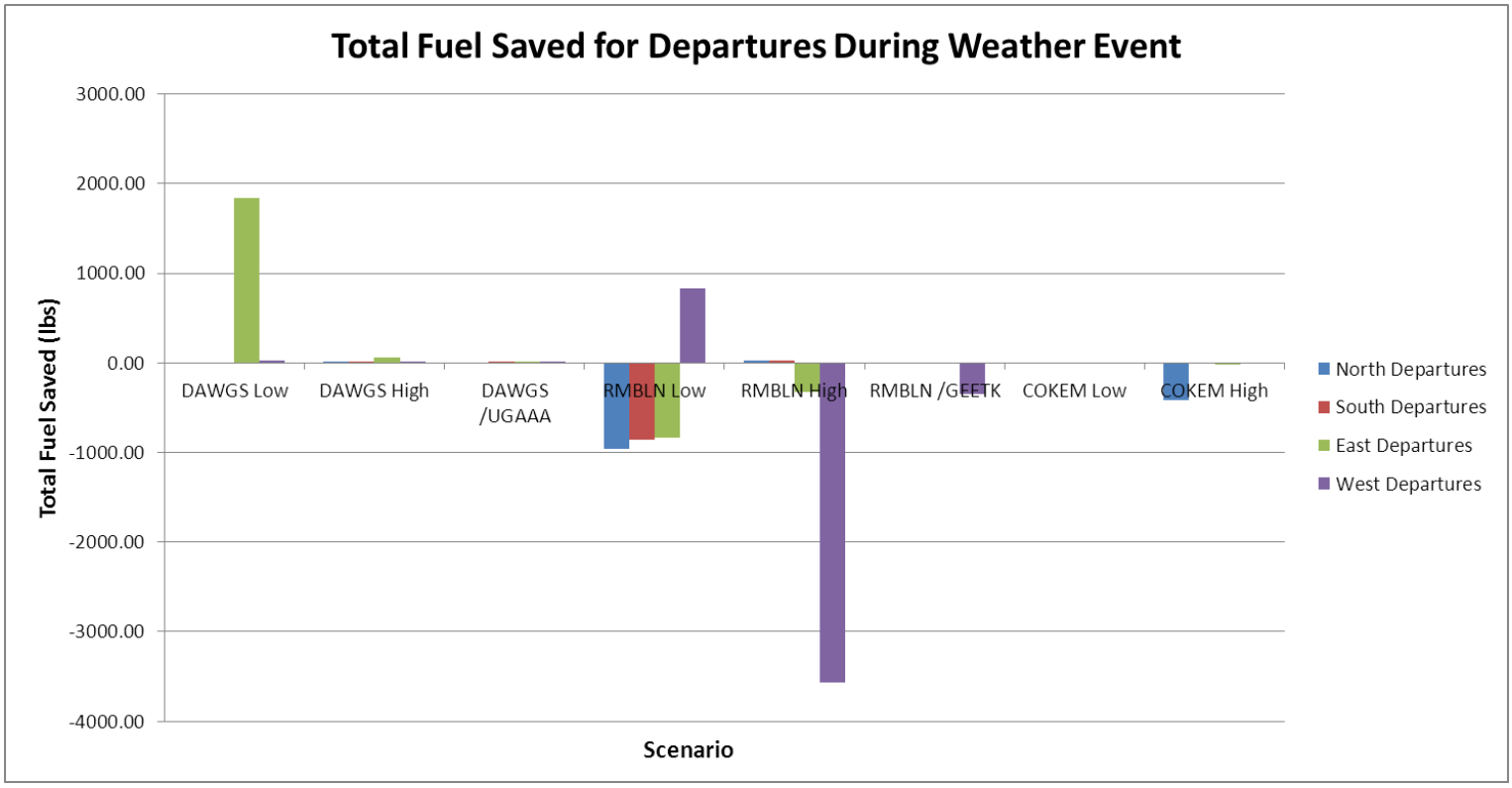

Figure 21. Total Fuel Saved for Departures During Weather Event

None of the IADCS scenarios provided a significant benefit to the total flight distance or duration of the departures during the weather events, and most have no effect on the amount of fuel burned. In general, the Low scenarios showed no difference for departures impacted by weather in the baseline and IADCS procedures. However, the RMBLN Low scenario caused more fuel to be burned than was burned in the baseline for departures in the North, South and East. Interestingly, the RMBLN High scenario showed that more fuel and time is used by the West departures than in the baseline. This is likely because the RMBLN High scenario forced departures taking the RMBLN SID to stay at lower, non-optimal altitudes. While this hypothesis was supported by the fuel savings in the COKEM High scenario, results for the DAWGS High scenario showed no change in fuel usage from the baseline.

It is important to note that conclusions about potential impacts of IADCS on departure flights cannot accurately be stated given the lack of ground stops in the simulations. Using today's procedures during a weather event, a ground stop would be implemented at ATL and other airports, and departure flights would be stuck on the ground accruing huge delays. IADCS would likely allow departure operations to continue without a ground stop at ATL and nearby airports. Since the ground at ATL was not simulated in this activity, this potential benefit may only be assumed. Future real-time and fast-time simulation activities may address this shortcoming.

3.2.3 Impact of IADCS on Daily Operations

Each IADCS scenario is compared against its corresponding weather baseline where the airspace quadrant and airport flow configuration are the same (ex. DAWGS Low involves the NE quadrant and uses the Western flow at ATL so it is compared against the baseline titled West NE Weather Baseline). The additional distance flown, flight delay, and fuel burned due to the weather event is calculated for the weather baselines and IADCS scenarios, and these metrics are compared to determine savings in distance, fuel, and delay that can be attributed to implementing IADCS.

Figure 4-8, Figure 4-9, Figure 4-10, and Table 7 show that IADCS procedures provide a benefit to overall daily operations on a day in which a short weather event occurs. Savings may be higher on a typical weather day in the NAS.

Weather events can potentially have a large impact on the hourly arrival and departure rates at a busy airport like ATL. IADCS operations may minimize this effect and allow the airport to maintain arrival and departure rates closer to those experienced in clear weather conditions. Figures 4-11 and 4-12 illustrate the change in hourly arrival rates in today's operations and in IADCS operations as compared to the clear weather baseline; Figures 4-13 and 4-14 show the same for hourly departure rates. IADCS operations improve ATL's hourly arrival rates in both East and West flow as the rates more closely match those experienced in clear weather conditions than the rates in the convective weather baseline scenarios. The same cannot be said for the hourly departure rates. The hourly departure rates are not affected by the weather event in the baseline scenarios (today's operations); they have the exact same hourly rates as those seen in the clear weather baselines. The hourly departure rates seen in the IADCS scenarios involving DAWGS are also not affected by the weather event. However, the RMBLN and COKEM scenarios produce a different pattern of hourly rates as soon as the NW weather event begins at 07:00 EST.

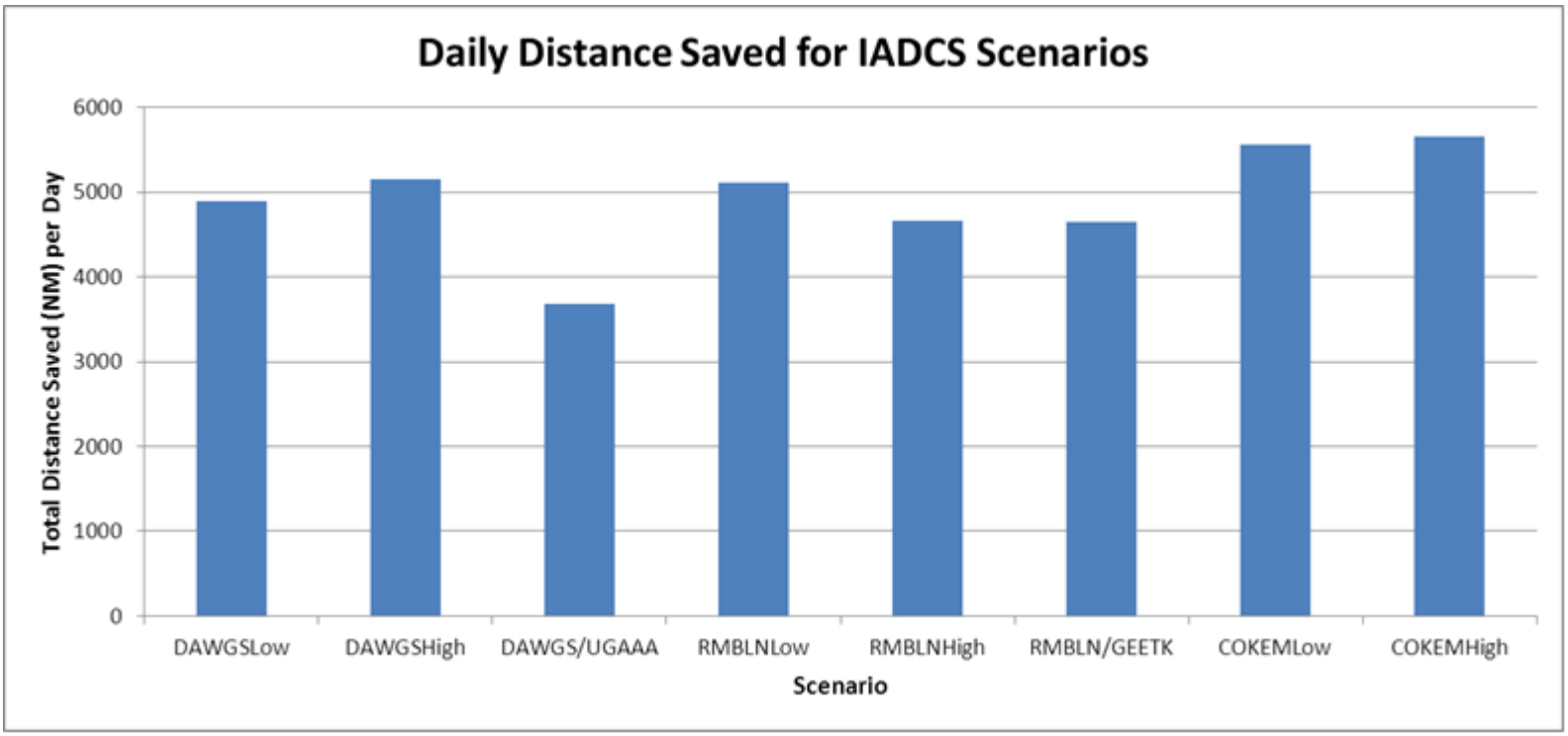

Figure 3-8. Total Daily Distance Saved in Each IADCS Scenario

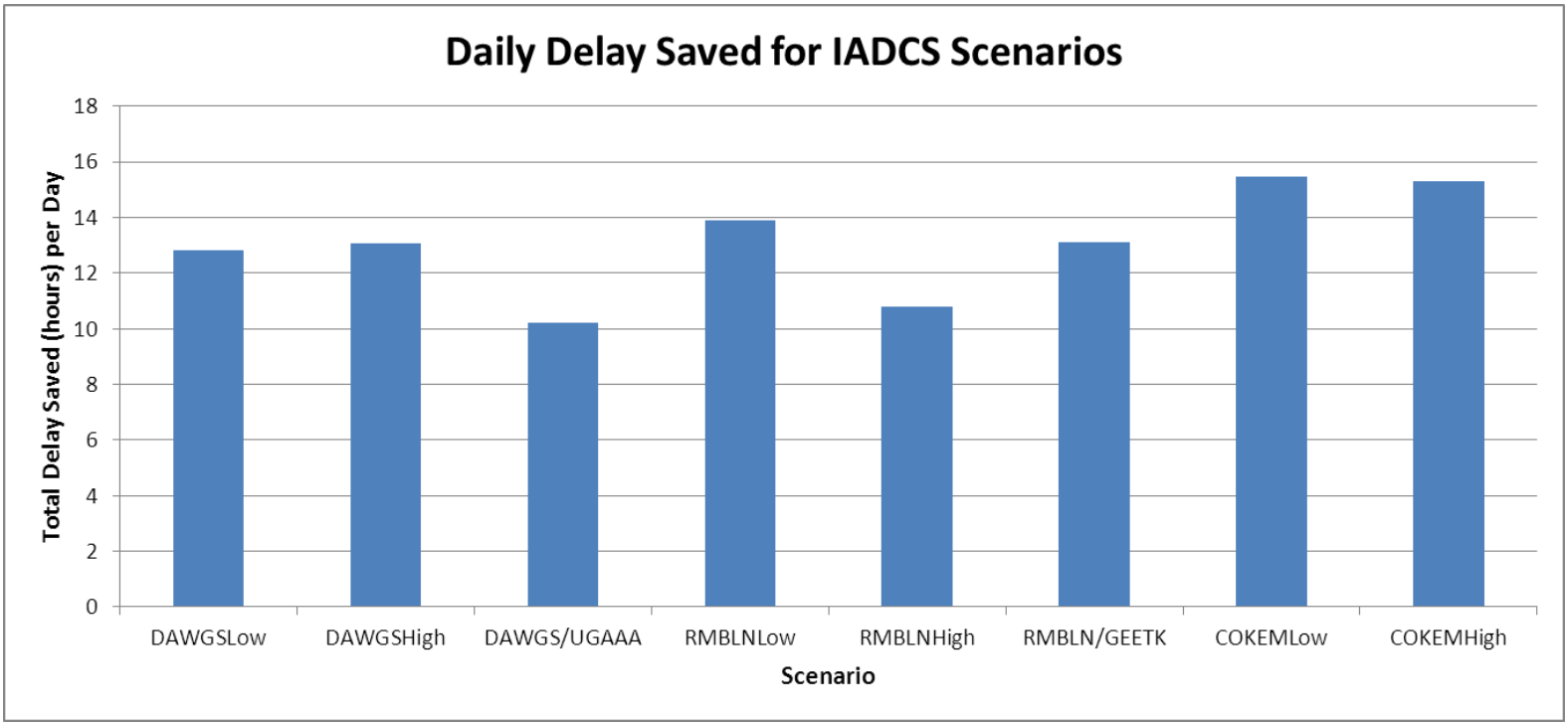

Figure 3-9. Total Daily Delay Savings in Each IADCS Scenario

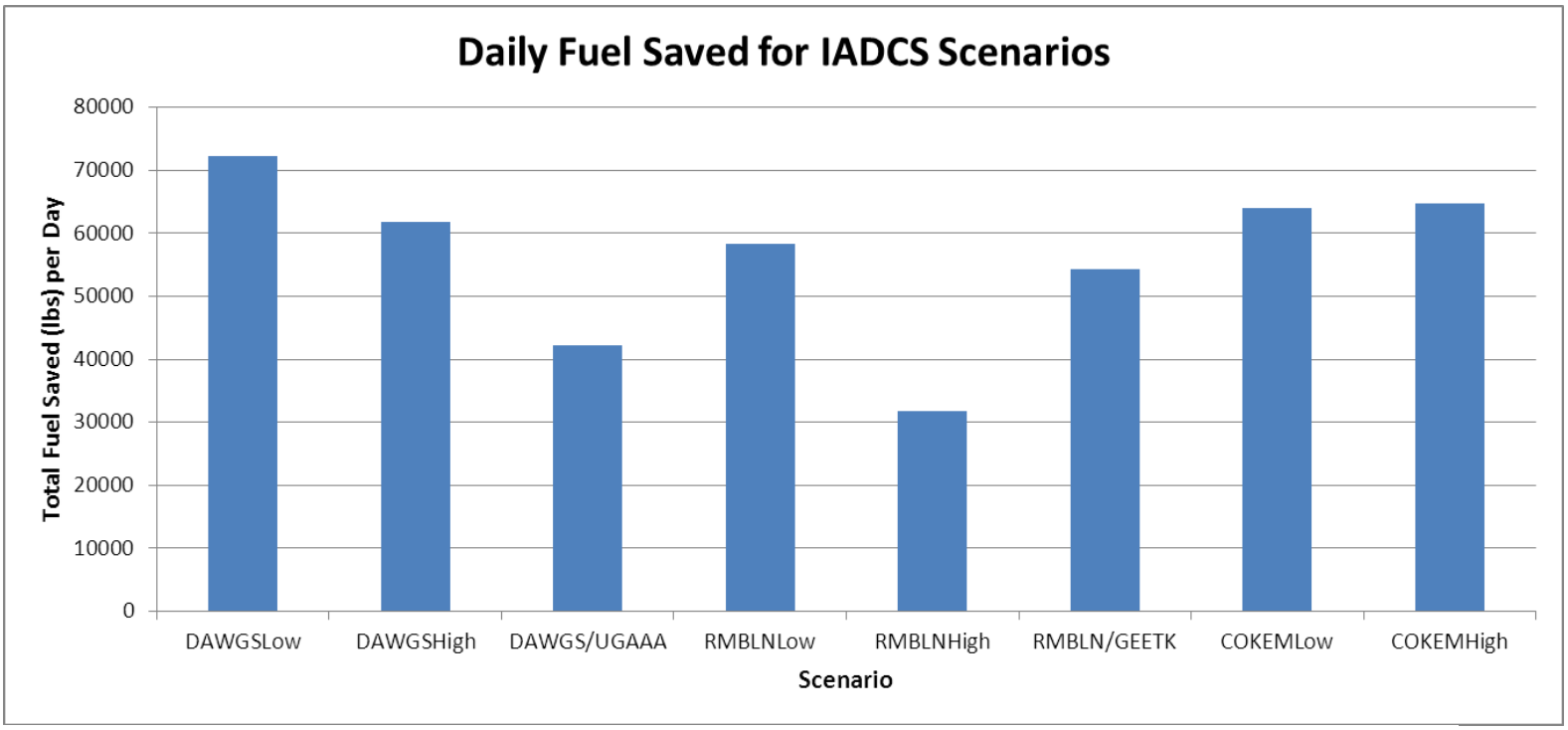

Figure 3-10. Total Daily Fuel Saved in Each IADCS Scenario

Scenario	Total Daily Savings		
	Distance Saved (NM)	Delay Saved (hh:mm:ss)	Fuel Saved (lbs)
DAWGSLow	4,894.23	12:49:06	72,168.74
DAWGSHigh	5,149.37	13:04:53	61,753.99
DAWGS/UGAAA	3,685.29	10:12:24	42,203.72
RMBLNLow	5,110.84	13:54:12	58,400.47
RMBLNHigh	4,660.54	10:46:24	31,729.35
RMBLN/GEETK	4,651.98	13:05:52	54,355.77
COKEMLow	5,565.19	15:27:23	64,000.96
COKEMHigh	5,658.26	15:17:01	64,788.45

Table 6. Total Daily Savings per IADCS Scenario

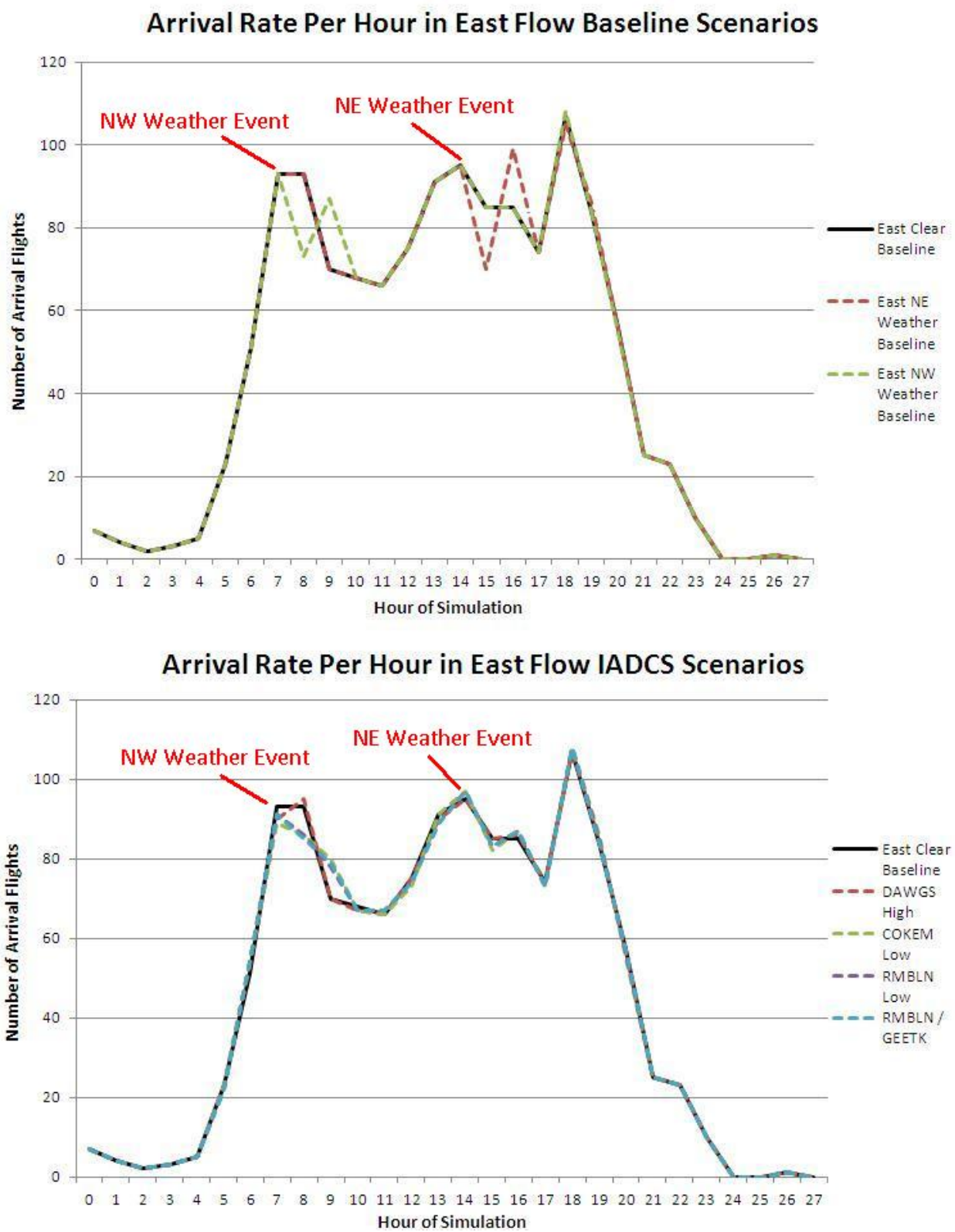

Figure 25. Arrival Rates per Hour Comparison (East Flow Scenarios)

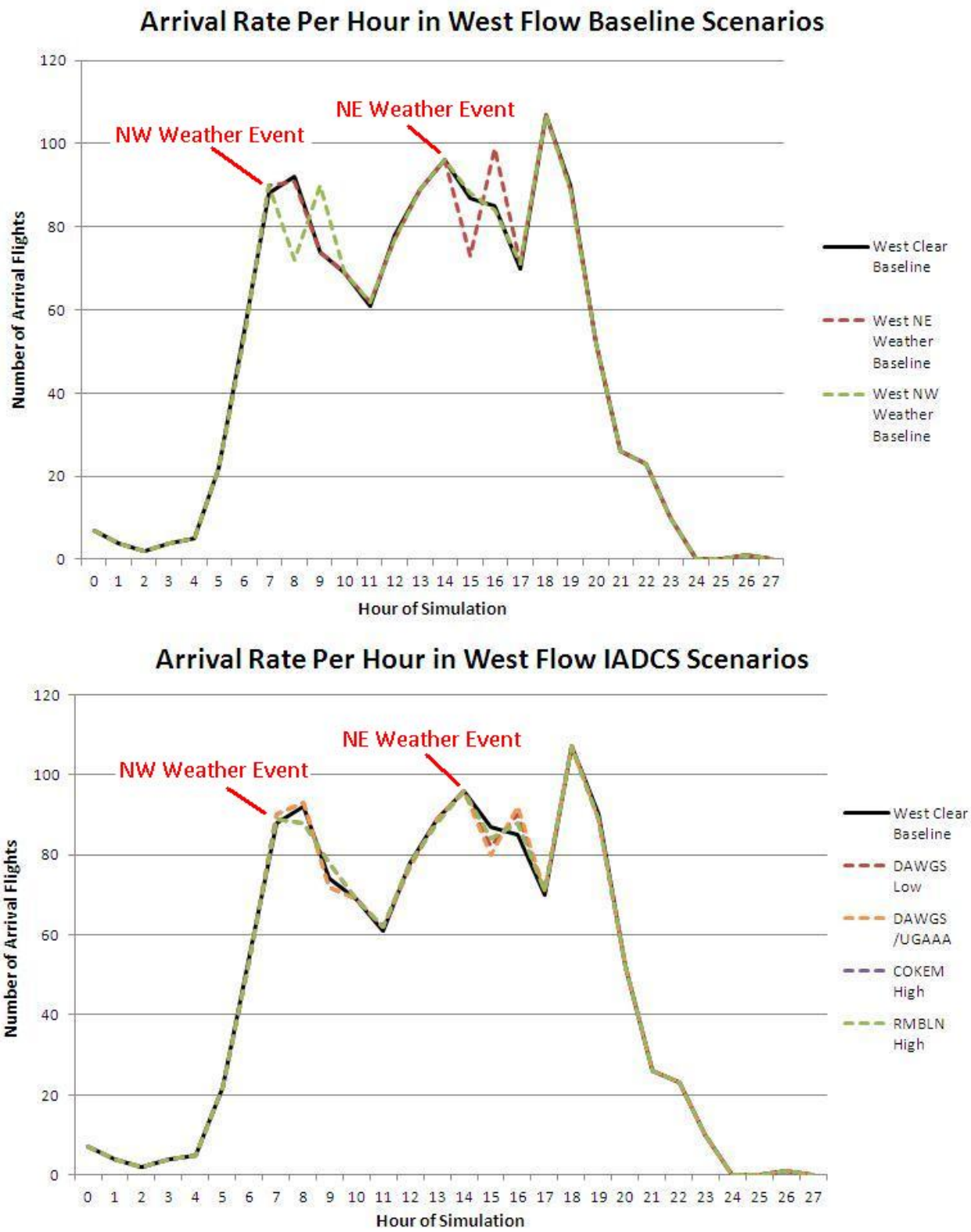

Figure 26. Arrival Rates per Hour Comparison (West Flow Scenarios)

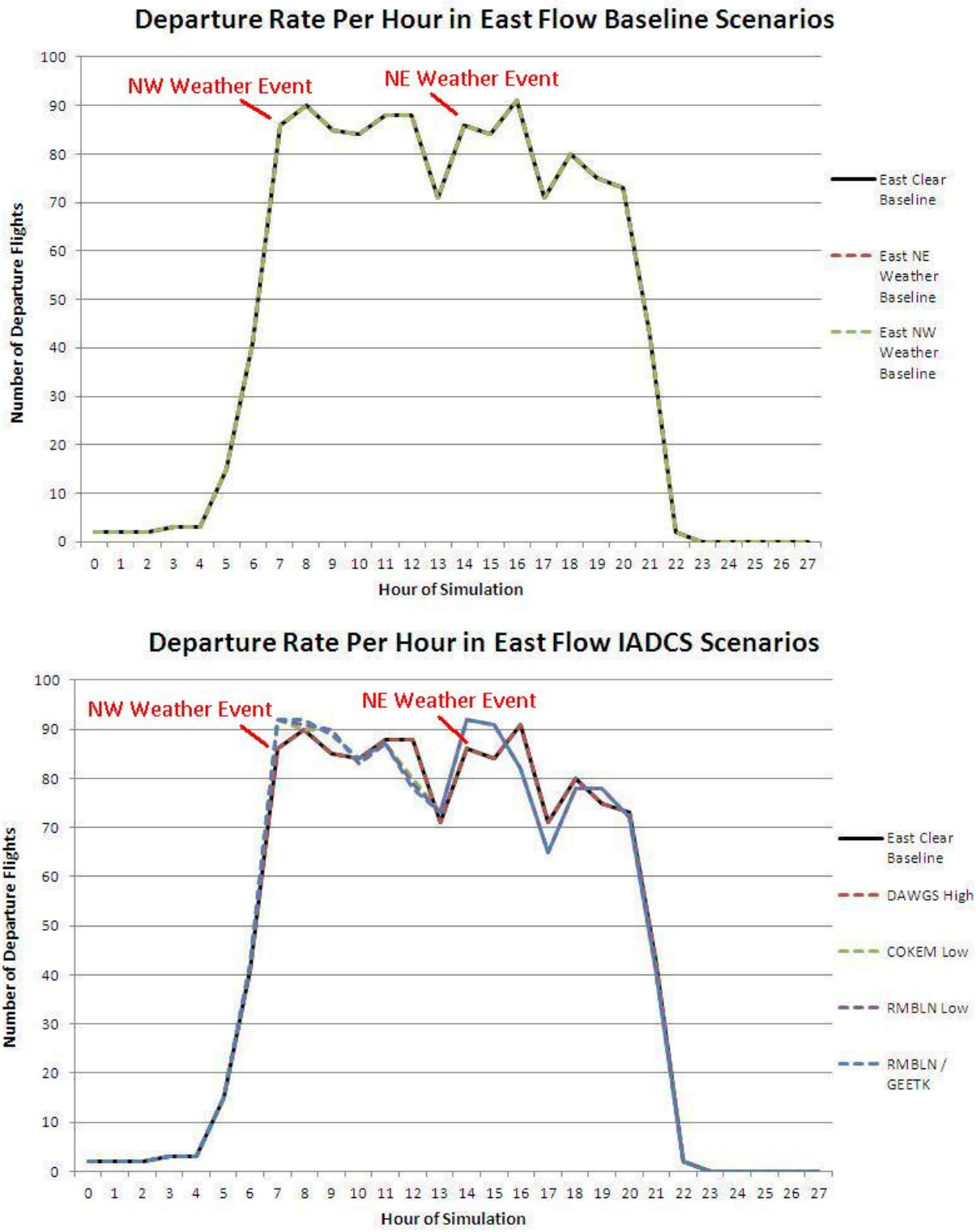

Figure 27. Departure Rates per Hour Comparison (East Flow Scenarios)

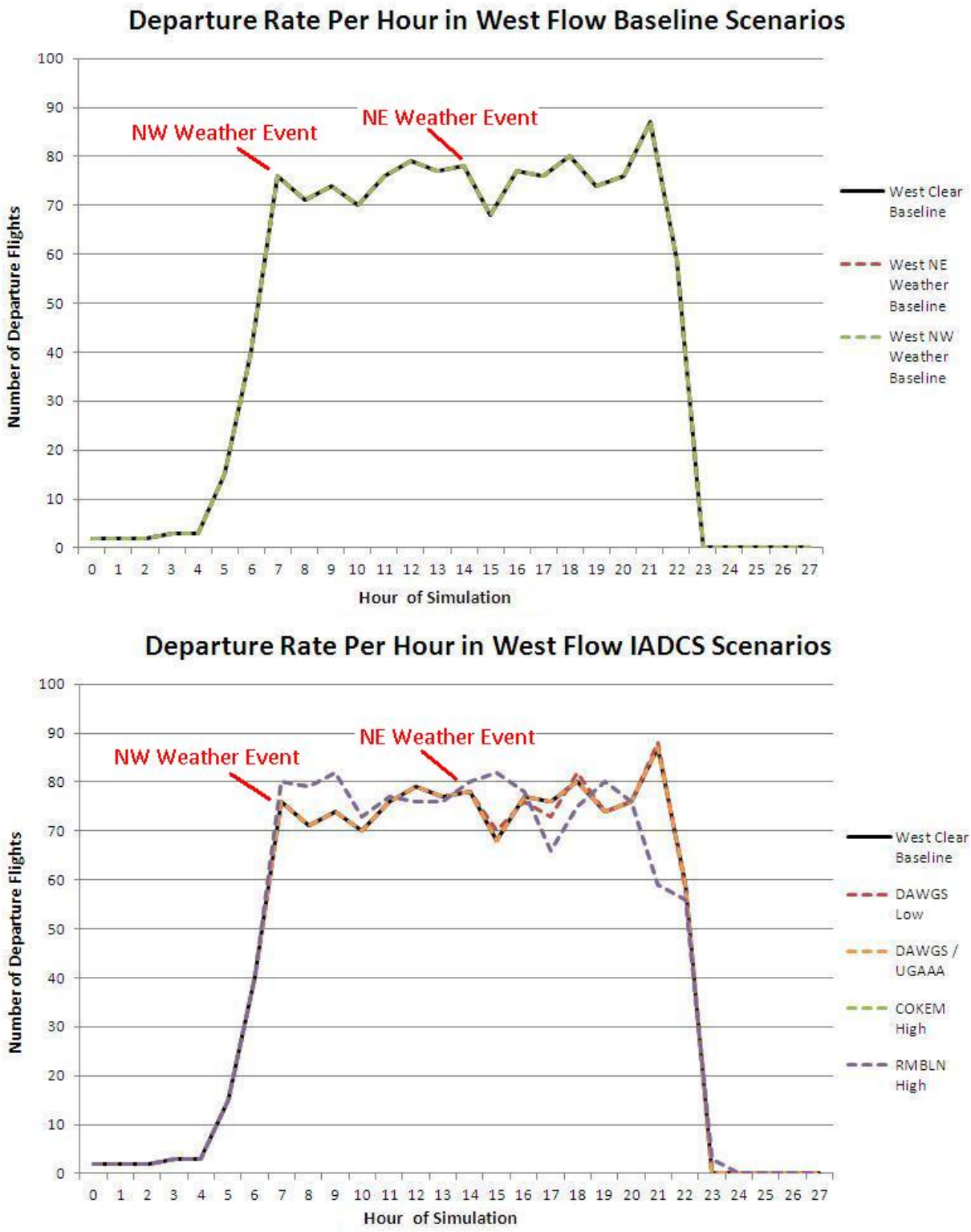

Figure 28. Departure Rates per Hour Comparison (West Flow Scenarios)

4 Conclusions and Next Steps

Current weather avoidance operations cause flights to experience delays and burn more fuel and interrupt the flow of an airport's hourly throughput. IADCS operations will help to minimize any additional distance and time required for flights to reroute around weather. This activity quantified the potential benefits associated with IADCS operations through the use of fast-time simulation.

Introducing IADCS operations will provide undeniable benefits to arrival flights that are rerouted to avoid weather and to other flights impacted by these reroutes. In the eight potential IADCS scenarios simulated in this study, all provided large benefits to the distance flown, duration of flight, and amount of fuel burned for rerouted arrival flights. Rerouted flights could save up to 200 NM of flight distance, 30 minutes in flight time, and 6,500 lbs of fuel with the implementation of IADCS. In general, Low scenarios produced more benefit than their High scenario counterparts; this result was expected since departures were penalized more in the High scenarios than the arrivals were in the Low scenarios. Increased benefits to daily operations may be seen when the weather event is present for longer periods or is blocking a larger section of airspace. Finally, the continuity of arrival throughput at ATL was maintained in the IADCS scenarios whereas it was interrupted in the baseline scenarios.

Following this fast-time simulation activity, a real-time HITL will be performed to measure controller reactions to the IADCS toolset. A future forecasted traffic level will be used in the HITL, and it will involve the DAWGS scenarios used in the fast-time simulation and a scenario that includes an ATC assigned route. In an effort to synchronize the fast-time and HITL experiments, additional sets of fast-time simulations will be performed to test the benefit of an ATC assigned route and to test all of the scenarios with the same future traffic level as used in the HITL. Also, future simulations could include additional IADCS plays, fully simulated ground operations, and higher altitude traffic in ZTL Center to identify any potential problems such as a conflict between departure traffic from the Charlotte Douglas International Airport (CLT) using the "Big Red" SID and arrivals using a DAWGS or UGAAA arrival path.

List of Acronyms

A80	Atlanta TRACON
AirTOp	Air Traffic Optimization (fast-time simulation model)
ATC	Air Traffic Control
ATL	Hartsfield-Jackson Atlanta International Airport
BL	Baseline (fast-time scenarios representing today's operations)
CLT	Charlotte Douglas International Airport
EST	Eastern Standard Time
FAA	Federal Aviation Administration
HITL	Human-in-the-Loop
hh:mm:ss	Hours : Minutes : Seconds (measure of flight duration)
IADCS	Integrated Arrival/Departure Control Services
lbs	Pounds (measure of fuel)
NAS	National Airspace System
NASE	NAS Adaptation Services Environment
NE	Northeast
NM	Nautical Mile (measure of flight distance flown)
NW	Northwest
ORD	Chicago O'Hare International Airport
PDARS	Performance Data Analysis and Reporting System
PDK	DeKalb-Peachtree Airport
RNAV	Area Navigation
RNP	Required Navigation Performance
SID	Standard Instrument Departure
SME	Subject Matter Expert
STAR	Standard Terminal Arrival Route
TARGETS	Terminal Area Route Generation Evaluation and Traffic Simulation
TMI	Traffic Management Initiative
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control
ZTL	Atlanta Air Route Traffic Control Center (ARTCC)

References

[1] Federal Aviation Administration and EUROCONTROL, Operational Concept Validation Strategy Document, edition 2.0a, March 2008.

[2] Federal Aviation Administration, Integrated Arrival/Departure Control Service Cognitive Walkthrough Final Report, May 2012.

[3] Federal Aviation Administration, Integrated Arrival/Departure Control Service (Big Airspace) Concept Validation, September 2007.

Appendix A: IADCS Toolset in Atlanta

The following figures illustrate the IADCS toolset implemented in the NE quadrant of ATL airspace.

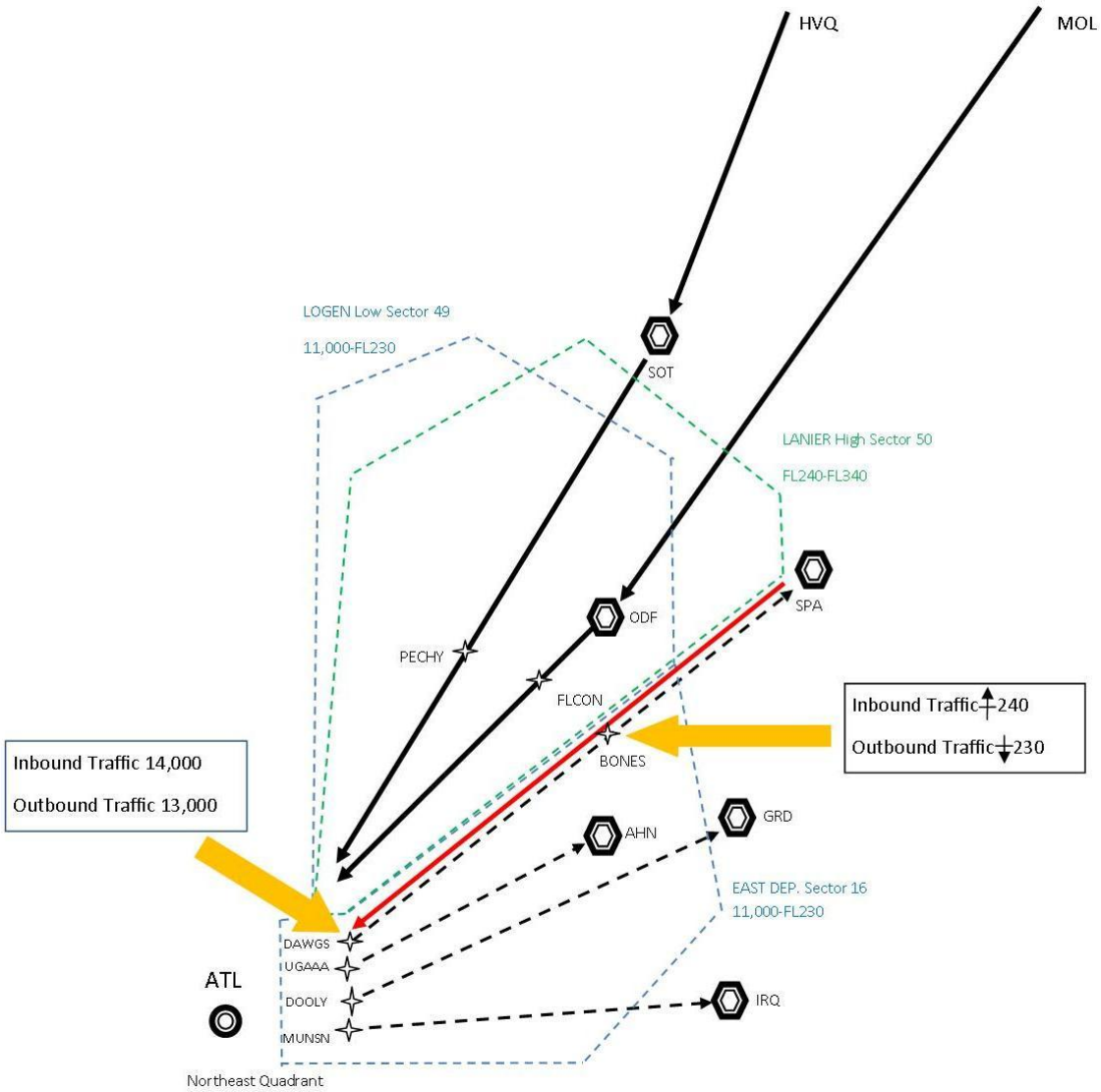

Figure 29. Bi-Directional Route at ATL

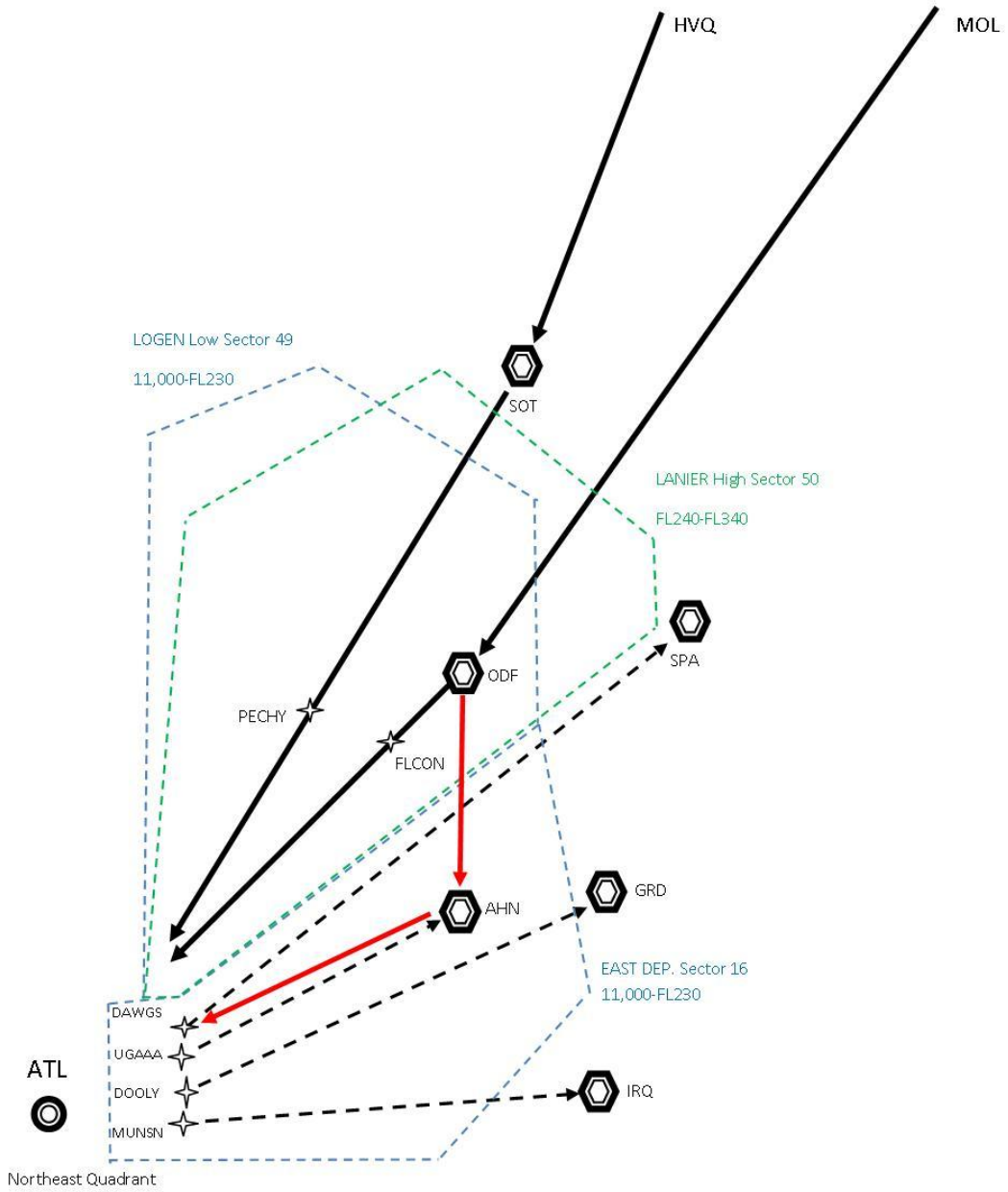

Figure 30. Bi-Directional Gate at ATL

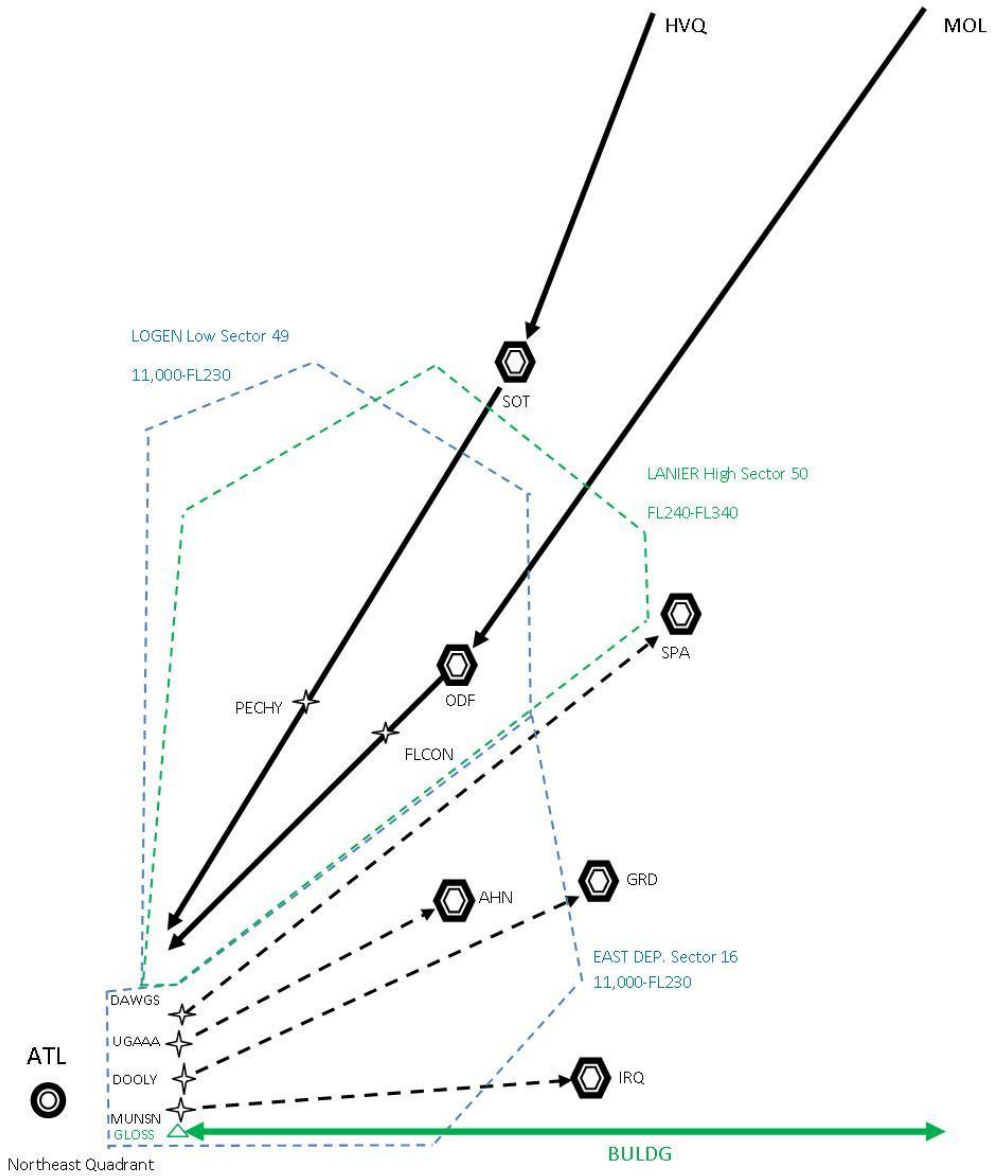

Figure 31. ATC Assigned Route at ATL

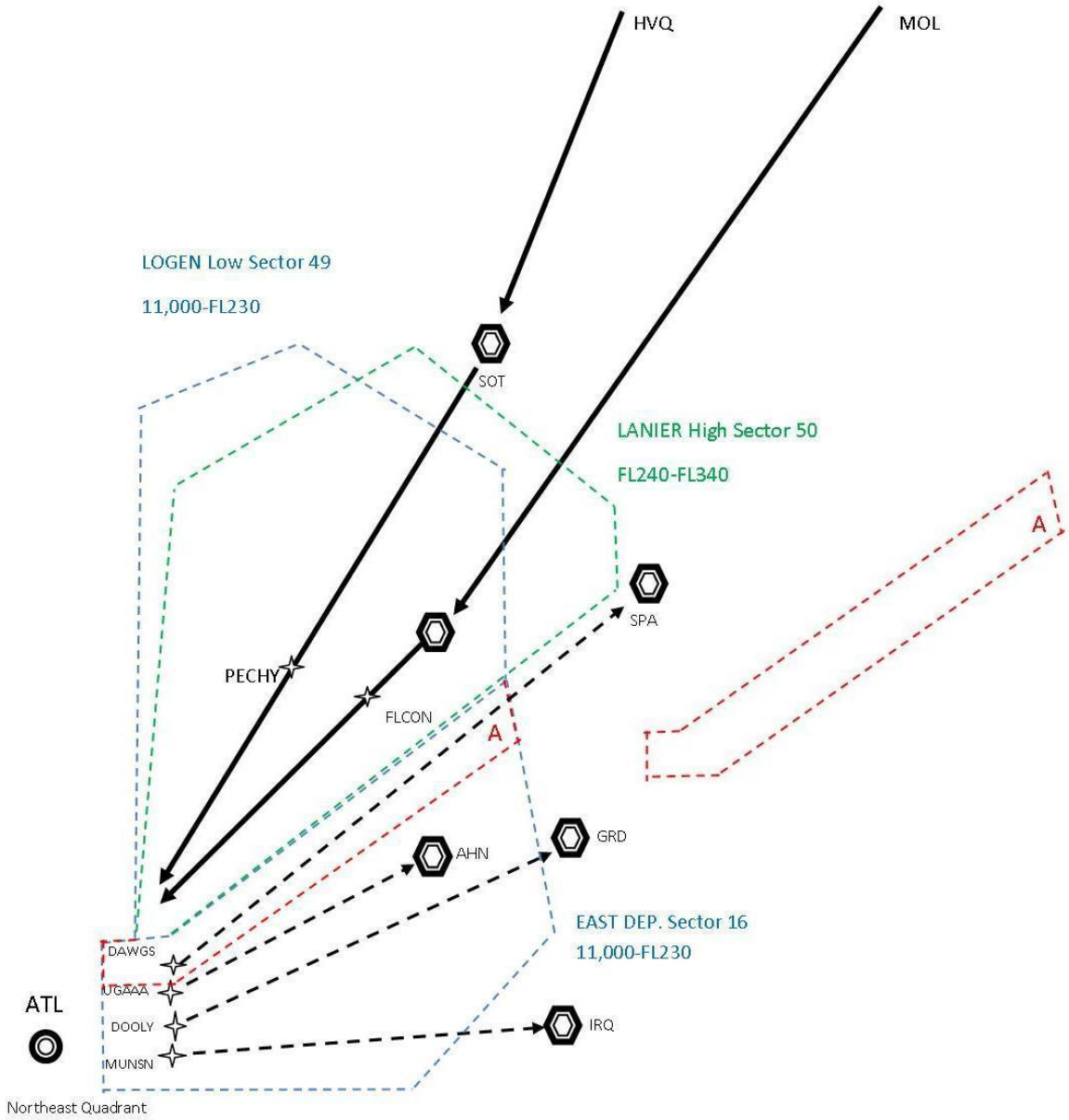

Figure 32. Dynamic Airspace at ATL

Appendix B: AirTOp Scenarios

The figures below show the path of rerouted flights in the baseline and IADCS scenarios. The yellow lines in the following figures represent the paths taken by flights rerouted from trigger points that are shown in light blue.

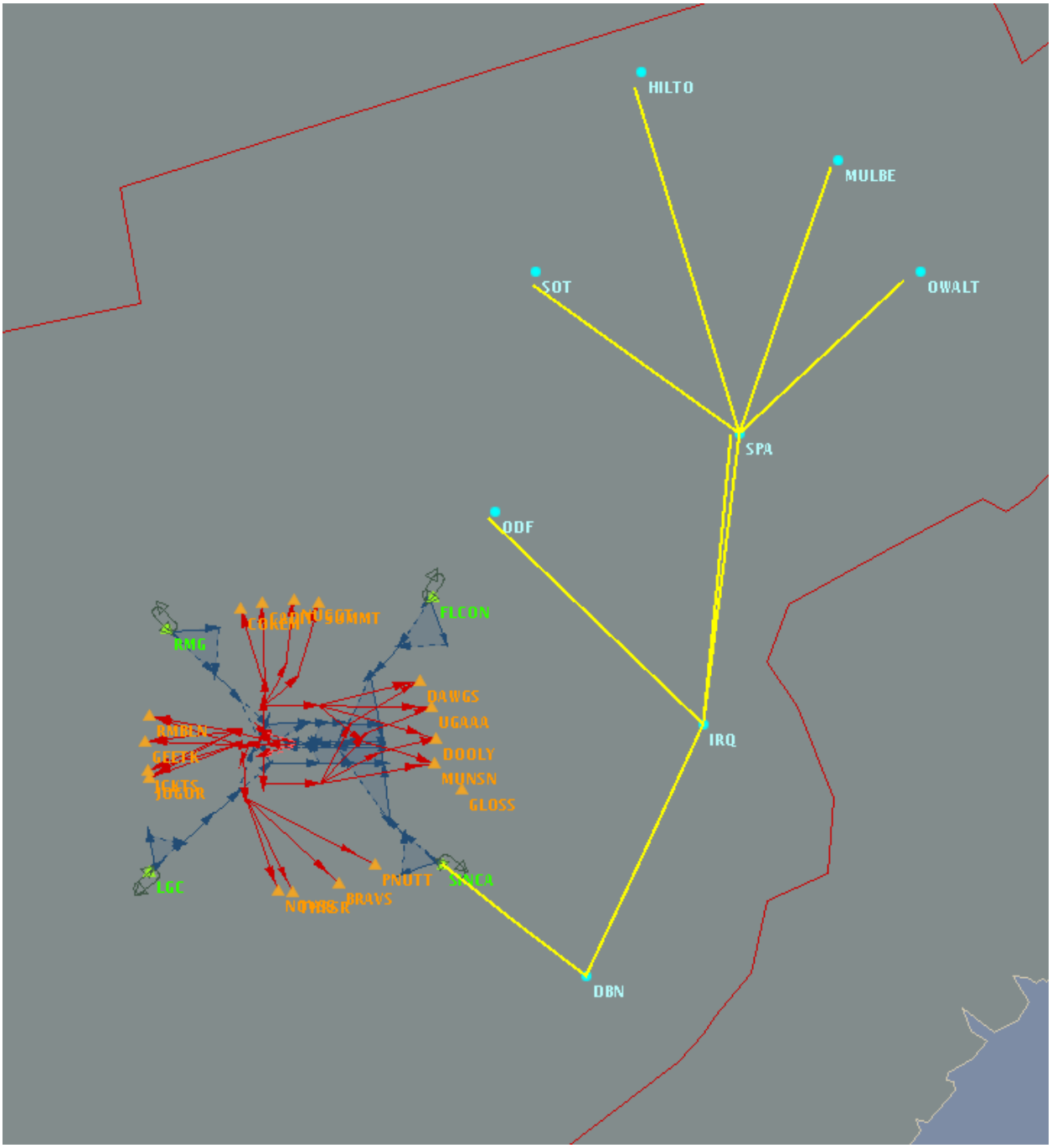

Figure 33. NE Weather Baseline Scenario in AirTOp

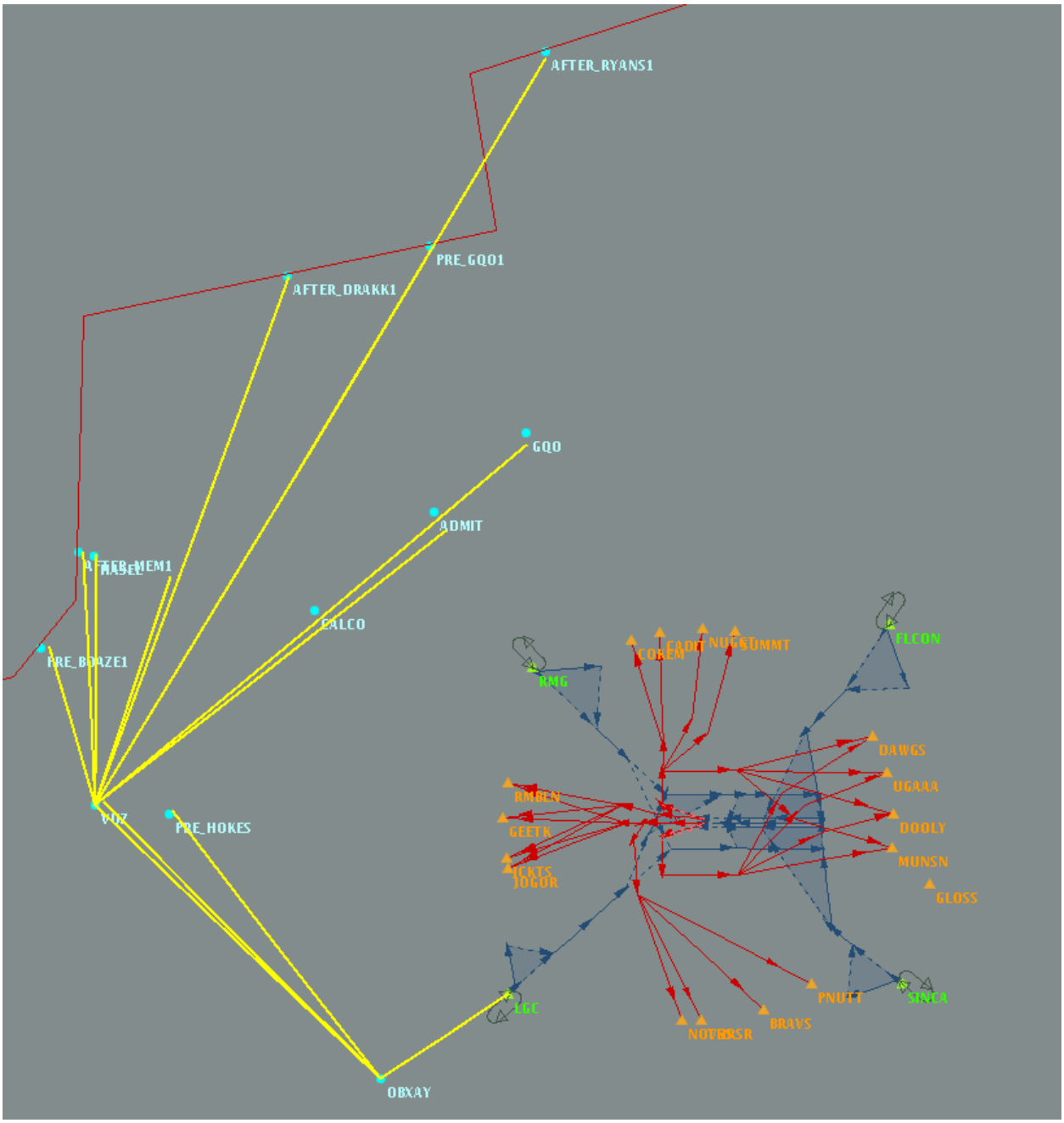

Figure 34. NW Weather Baseline Scenario in AirTOp

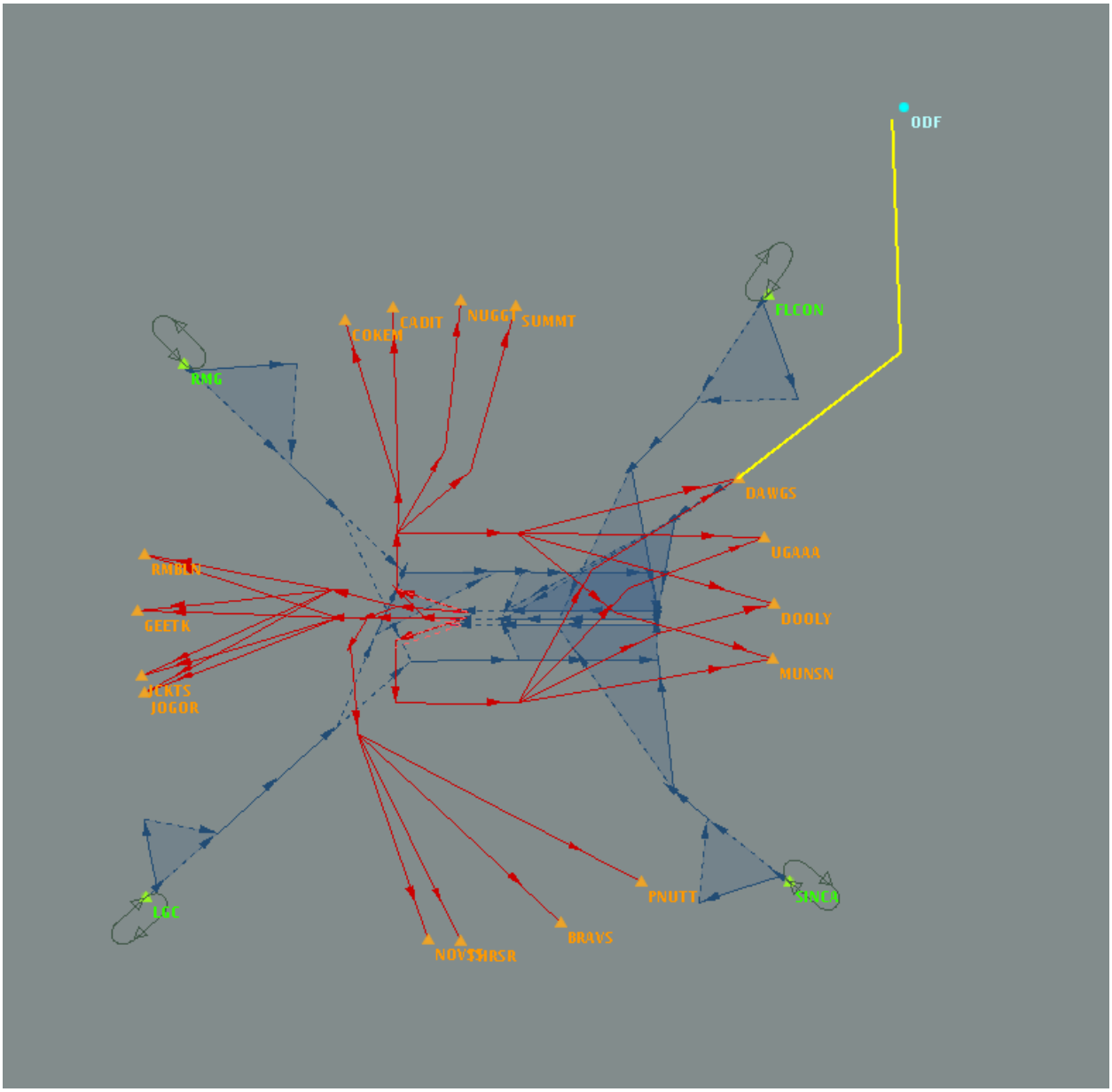

Figure 35. DAWGS Low Scenario in AirTOp

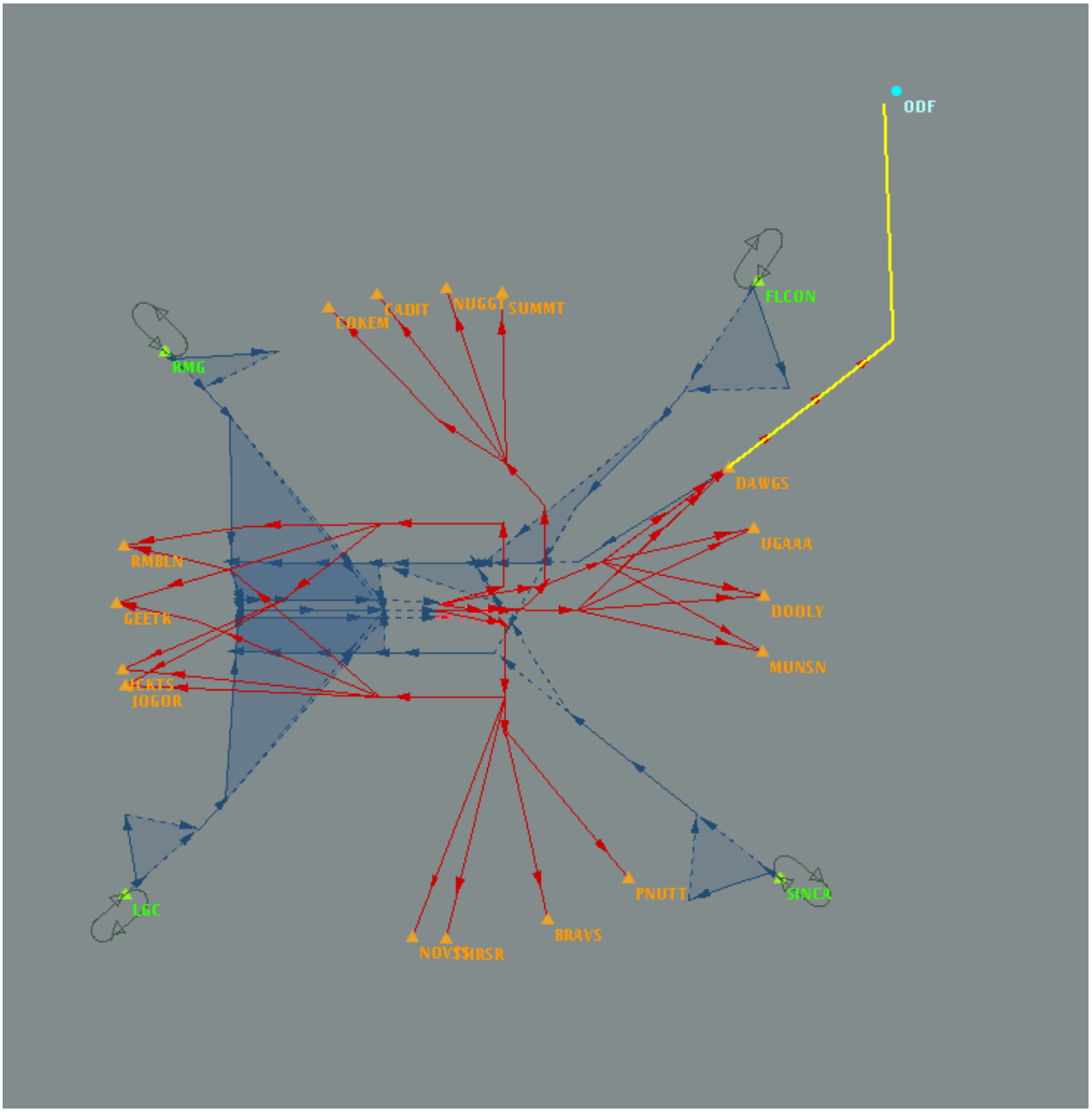

Figure 36. DAWGS High Scenario in AirTOp

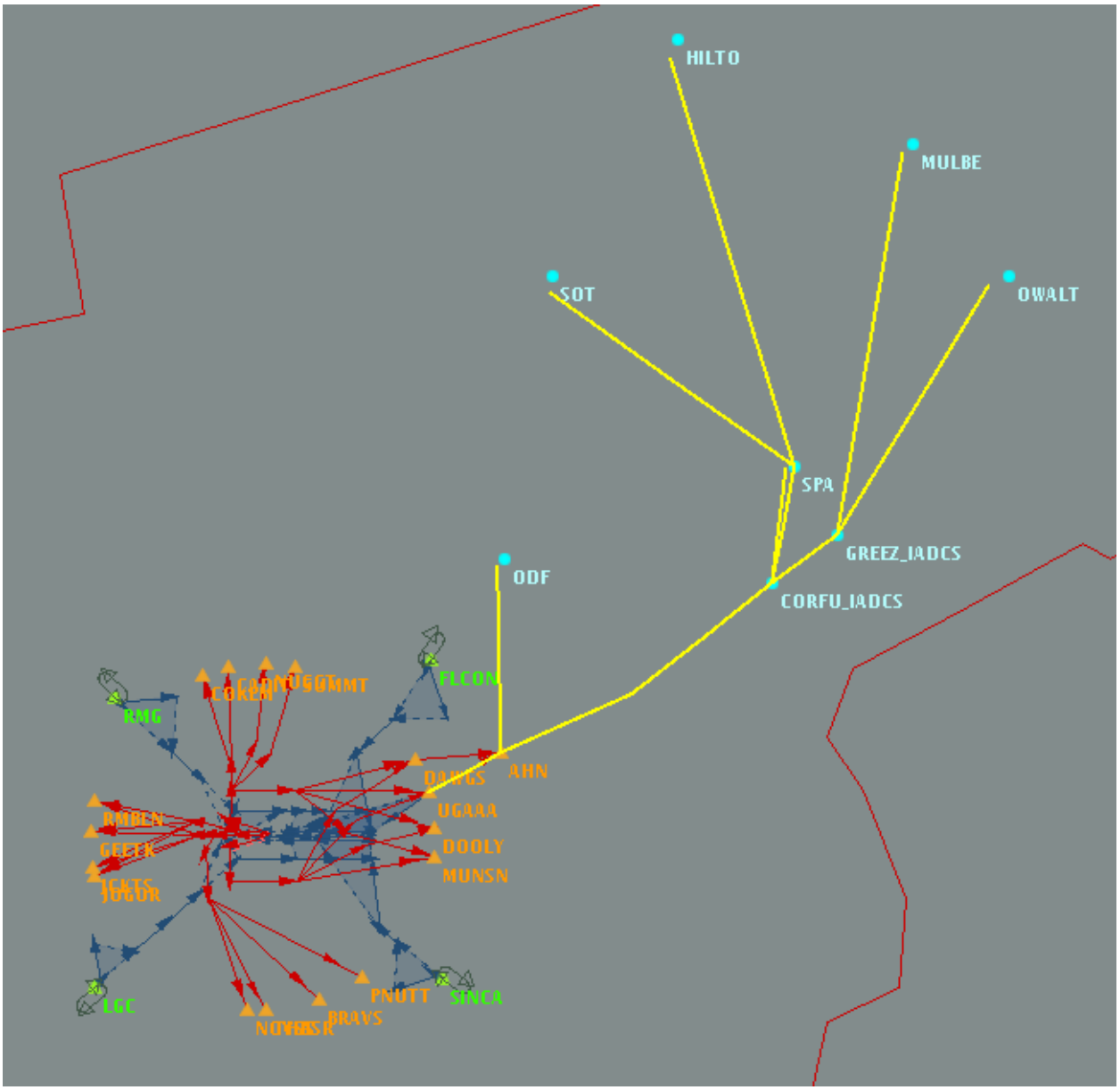

Figure 37. DAWGS (Departures)/UGAAA (Arrivals) Lateral Scenario in AirTOp

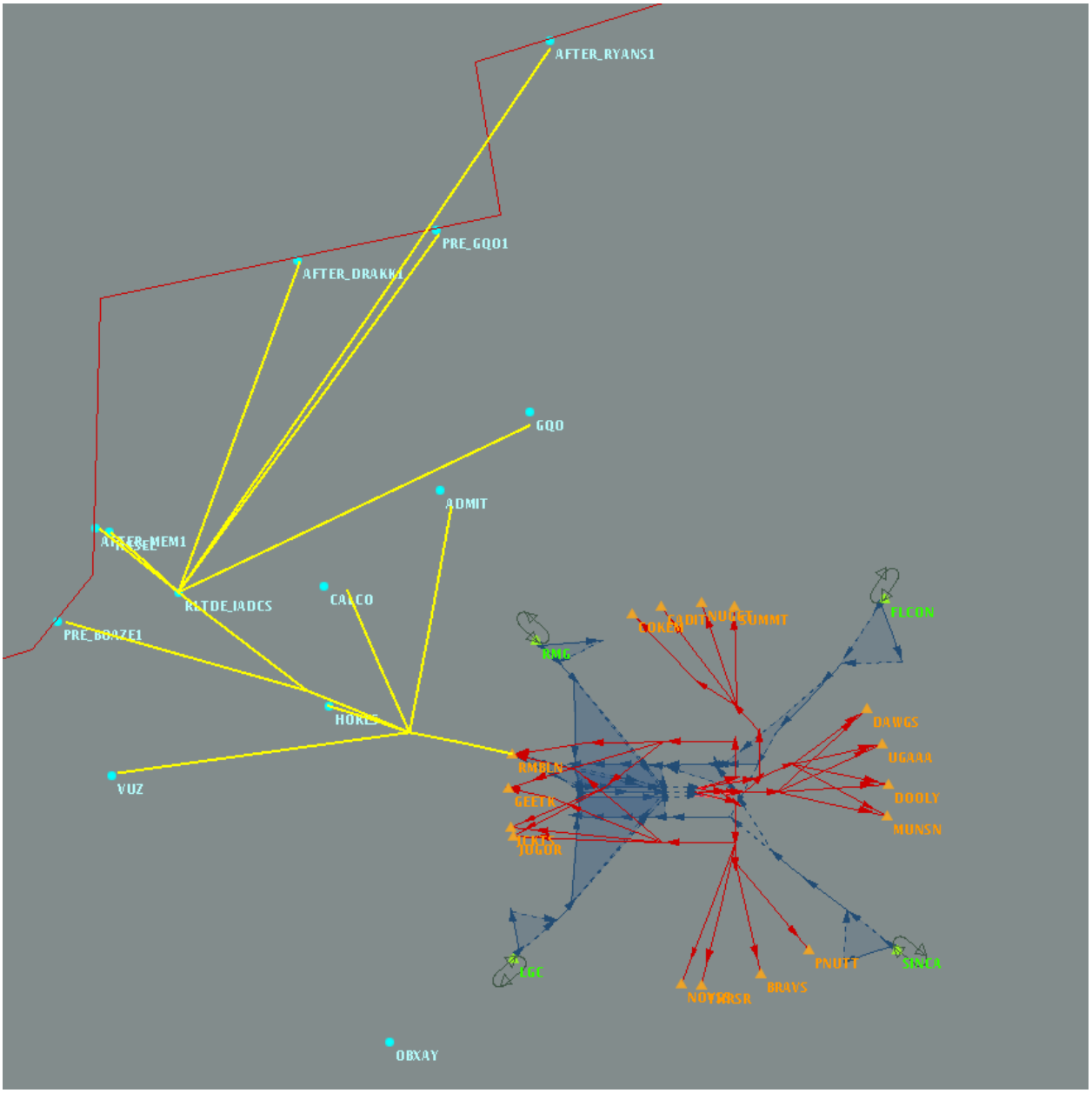

Figure 38. RMBLN Low Scenario in AirTOp

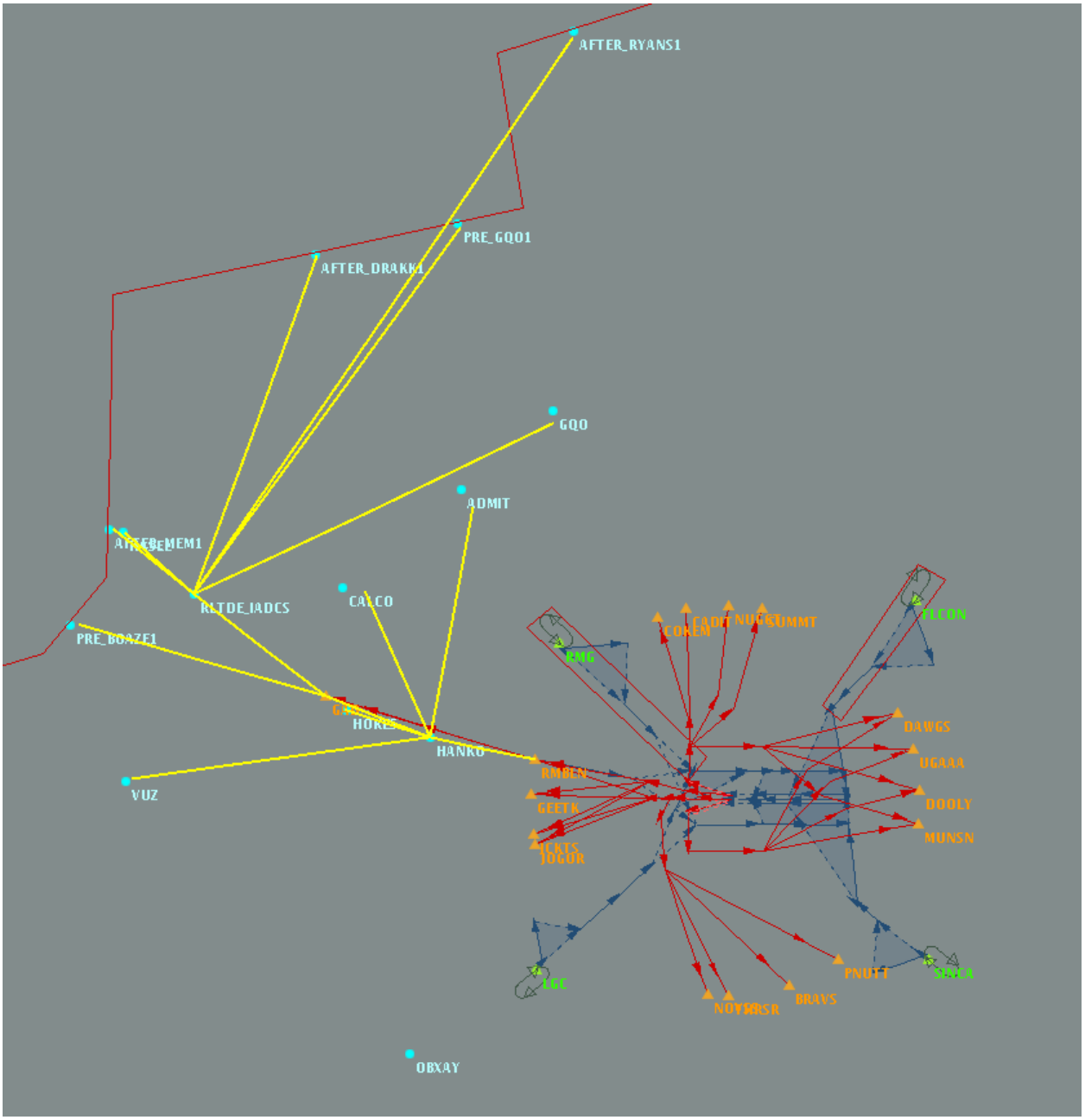

Figure 39. RMBLN High Scenario in AirTOp

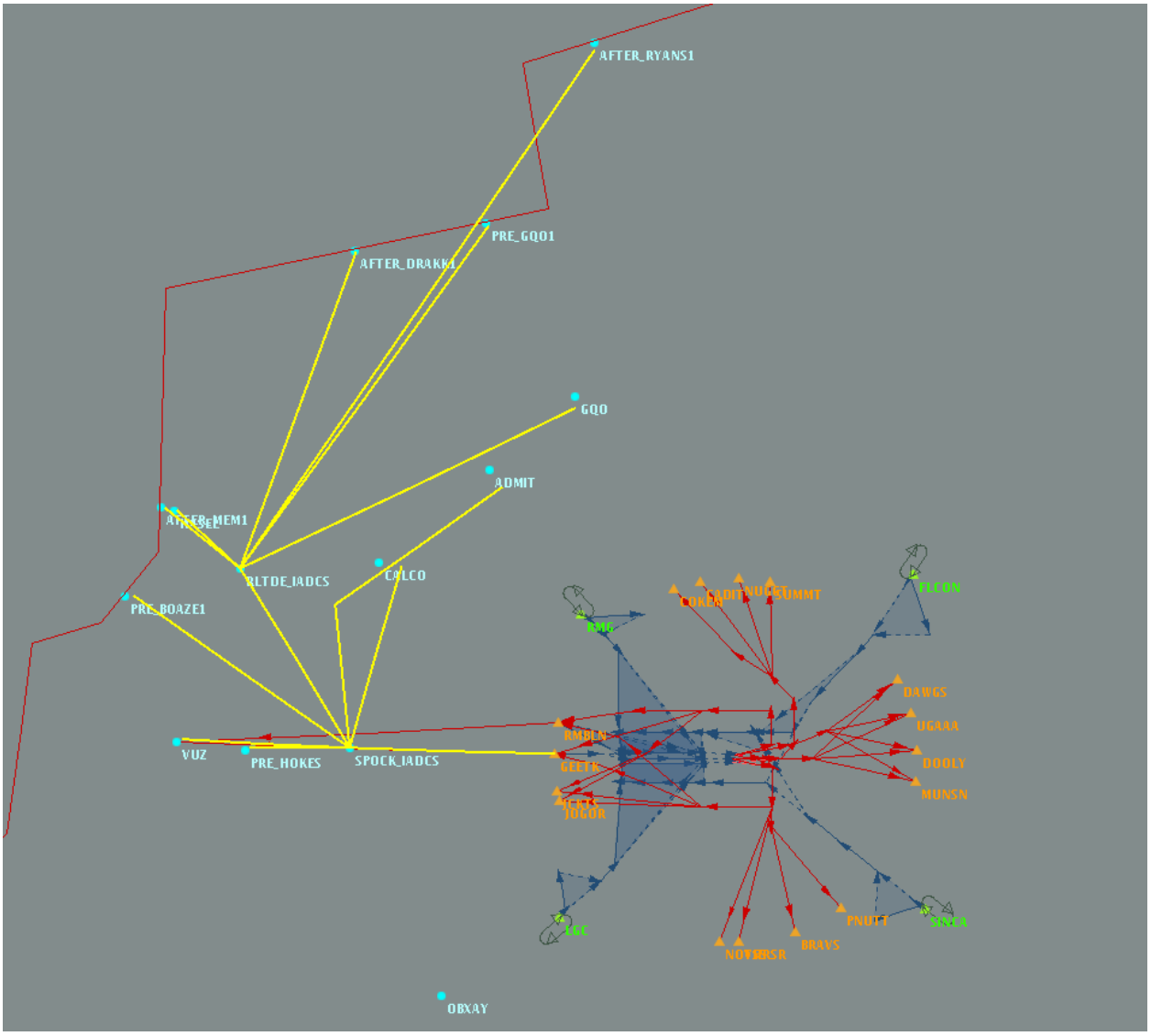

Figure 40. RMBLN (Departures)/GEETK (Arrivals) Lateral Scenario in AirTOp

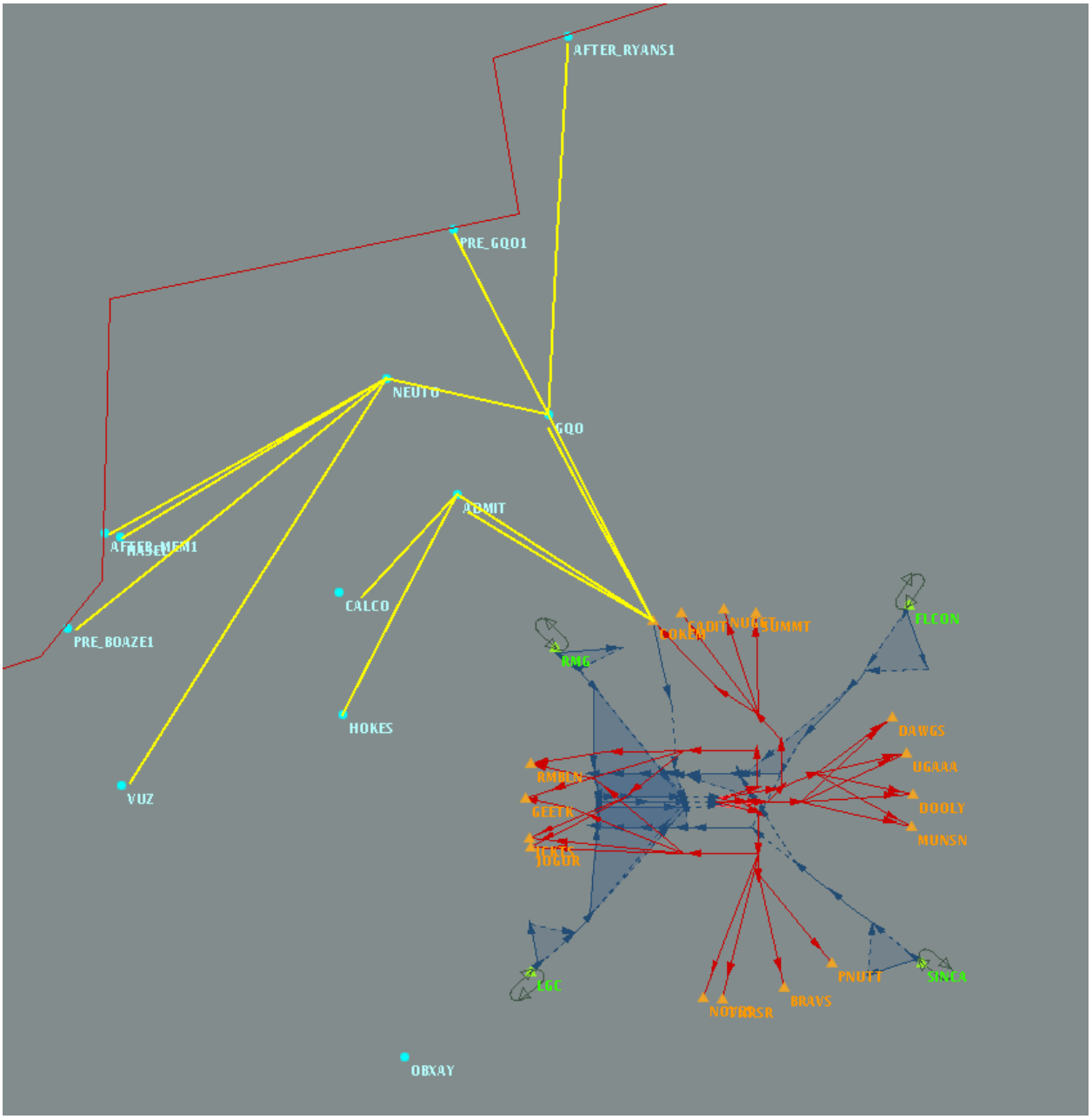

Figure 41. COKEM Low Scenario in AirTOp

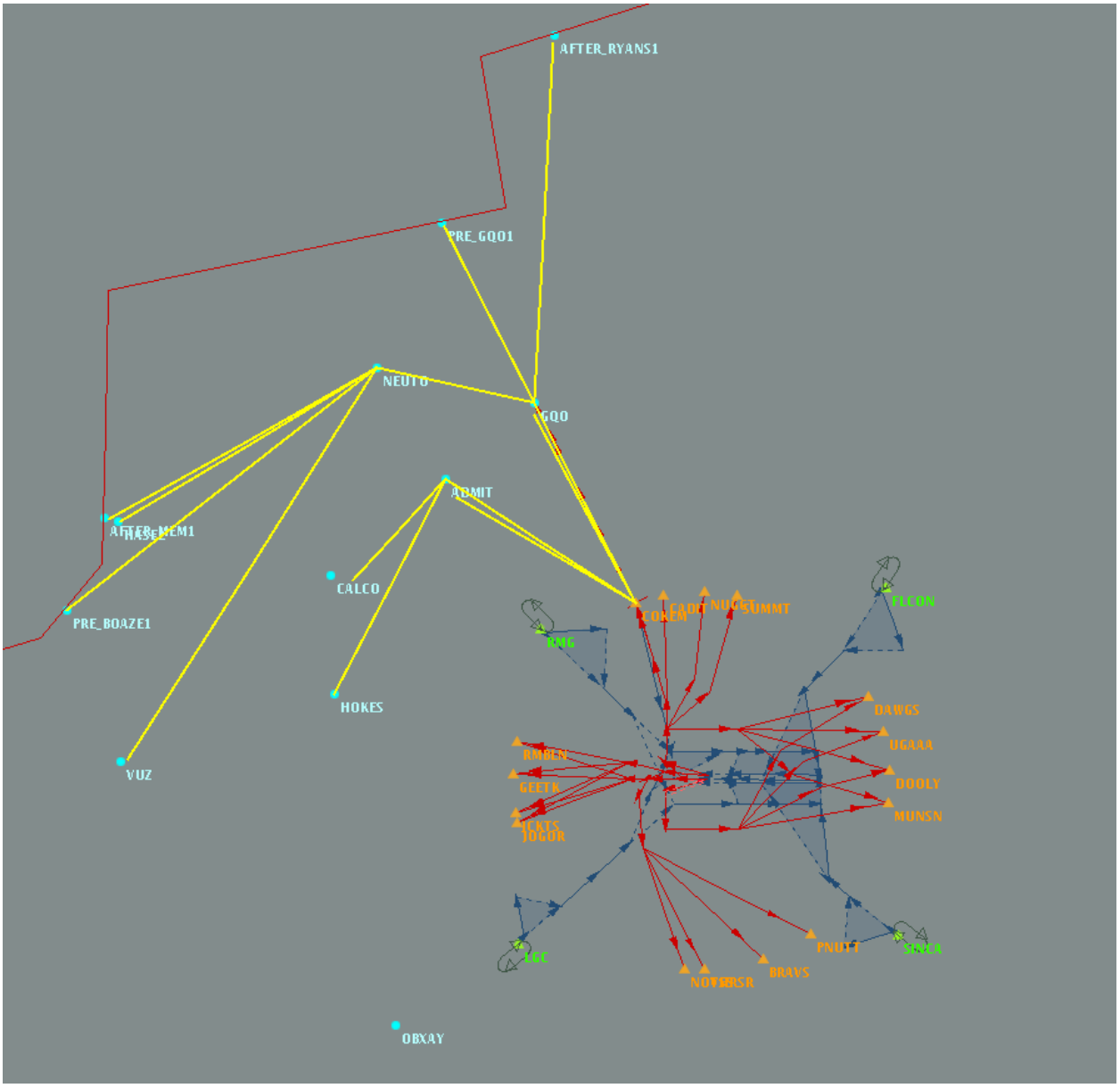

Figure 42. COKEM High Scenario in AirTOp