4.8 Integrating Convective Weather Forecasts With the Traffic Management Advisor (TMA)

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1. INTRODUCTION

Embry Riddle Aeronautical University with ENSCO, Lockheed Martin, CSC and others recently demonstrated a concept for the integration of predictive weather into TMA. The demonstration was sponsored by the FAA.

Air traffic controllers use TMA to maximize arrival rates at busy airports. Coupled with the En-Route Automation Modernization (ERAM) system, TMA helps controllers avoid wasting arrival slots and keeps traffic moving as efficiently as possible.

When convective weather enters the picture however, TMA and ERAM can't compensate for the delays introduced when aircraft have to deviate around thunderstorms. While TMA has upper-level wind and temperature information to help it calculate aircraft trajectories, it has no information about thunderstorms. Typically when thunderstorm activity occurs, the ARTCC traffic managers can no longer rely on TMA and have to revert to much less efficient traffic flow programs like "miles-in-trail."

For this demonstration, thunderstorm forecasts were inserted into TMA using the weather research and forecast (WRF) model. TMA and ERAM then used these forecasts to adjust the aircraft sequencing and thus keep arrival rates at a maximum.

The demonstration domain was the Ocala arrival sector and its neighboring sectors to the north that feed aircraft into the Orlando Terminal Radar Approach Control (TRACON) (Fig 1). The weather forecasts used for the demonstration came from real weather cases gathered during the summer of 2008. The air traffic came from the same days as the weather and included the actual flight plans and amendments filed that day.

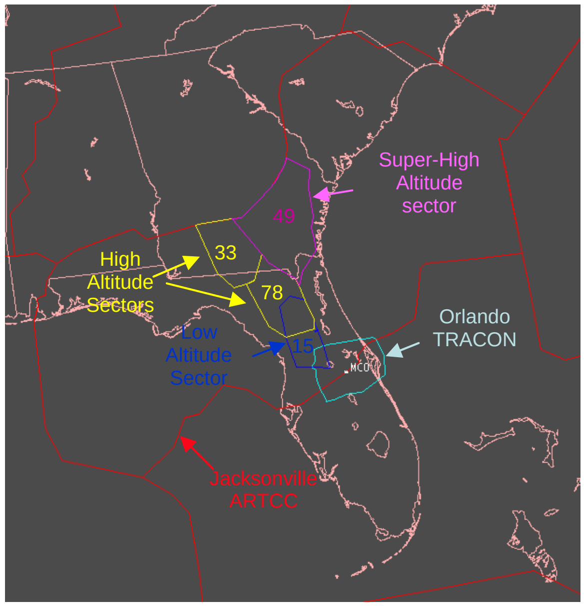

Fig 1 Jacksonville ARTCC sectors used in the demonstration. These sectors feed the Orlando TRACON which controls traffic as it approaches Orlando International Airport.

2. TMA

TMA is a decision support tool to assist traffic management personnel in arrival, en-route and departure flow management. Its purpose is to reduce delays by maximizing capacity at specified metering points. Metering is performed for both arrival points (e.g., runways, meter fixes) and en-route points (e.g., metering points near facility boundaries). TMA is used to schedule departing flights by determining release times that will work with the schedules for other flights, reducing airborne delay.

TMA receives flight plan data from the ARTCC systems (Host or ERAM) to calculate the route of

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flight and determine which flights are in the same stream at metering points. TMA uses departure restrictions from Enhanced Traffic Management System (ETMS) and actual departure information from the ARTCC systems to generate more accurate times. Track data is received from the ARTCC and TRACON systems to update times using a flight's current position and heading. TMA can have interfaces to multiple ARTCCs and TRACONs, in order to have data early enough to develop schedules and coordinate the release of departure aircraft.

An un-delayed aircraft trajectory for each flight, consisting of Estimated Time of Arrival (ETA) at points along the route of flight, is calculated based on flight plan data, track data, aircraft characteristics, and flight level winds. This results in a 4D trajectory model, including ascent and descent profiles. TMA then develops schedules at the metering points, both arrival and en route. The Scheduled Time of Arrival (STA) at each point is calculated based on the ETAs and scheduling constraints entered by the Traffic Management Coordinator (TMC). These scheduling constraints reflect real world constraints (e.g. airport configuration, runway/airport/fix acceptance rates, maximum delay that can be absorbed in sectors). The schedules for departure flights to the TMA arrival airport/fixes and en route metering points are based on the planned departure times determined using TMA.

Resulting schedules are displayed to the traffic management personnel at the ARTCC, TRACON, and towers so that all users have a coordinated schedule. The schedules are then displayed to the sector controllers at the ARTCC where TMA is located and at adjacent ARTCC, in metering lists on the ERAM R-position display consoles. This results in a time based metering solution where controllers can more efficiently handle aircraft instead of enforcing miles-in-trail for each stream.

The TMC within the ARTCC Traffic Management Unit (TMU) can choose from three TMA displays. These include the Timeline Graphical User Interface (TGUI), Plain-view Graphical User Interface (PGUI), and the TMA load graph.

The TGUI (Fig 2) consist of two columns of aircraft call signs displayed on either side of a timeline. The timeline is in terms of minutes into the future. The left column list the aircraft call signs in order of their ETA to the selected meter fix. The right column shows these same aircraft but sorted according to their STA at the meter fix. Next to each call sign in the right column is a single digit number that indicates how much that aircraft must be delayed to be in the proper sequence for arrival at the meter fix. For example, in Fig 2 aircraft EGF894 needs to absorb 6 minutes of delay to assume its proper position in line. This information is sent to ERAM and displayed next to the aircraft data block on the sector controller's display.

The PGUI (Fig 3) gives a birds-eye view of the aircraft en-route to the given meter fix. It is very similar to the ERAM R-position display, except it is used by the TMC instead of the sector controllers.

The TMA Load Graph (Fig 4) gives as summary of the actual and planned arrival rates along with the arrival capacity. In the case shown, some aircraft must be delayed to keep arrival rate within capacity.

3. ERAM

The ERAM system supports en-route air traffic control (ATC) services around the clock. An ATC sector is staffed by one or more air traffic controllers who ensure safe, efficient flow of air traffic through the sector. Air traffic controller tasks include:

- Separating air traffic using surveillance information or manual procedures
- Sequencing and spacing traffic
- Detecting and resolving potential conflicts (supported by decision support tools and tactical alert software, e.g., aircraft-to-aircraft, aircraft-to-airspace, and aircraft-to-terrain)
- Monitoring and updating flight data
- Scanning flight data for potential conflicts between aircraft inbound to the sector
- Posting, sequencing, and updating flight information
- Providing inter- and intra-facility coordination
- Accepting and initiating handoffs
- Obtaining and disseminating weather and Notice to Airmen (NOTAM) information
- Supporting routine and special military aircraft operations

The ERAM system allows air traffic operations to comply with both national and international flight plan standards. Sector-level ATC continues to be handled as two distinct but interrelated activities: tactical and strategic. Tactical ATC involves monitoring and controlling the real-time position and movement of aircraft to ensure that separation standards are maintained; strategic ATC directly supports tactical control by predicting separation conflicts and helping to resolve them, updating flight plans, and staging traffic. Tactical ATC focuses on safety, while strategic ATC focuses on efficiency.

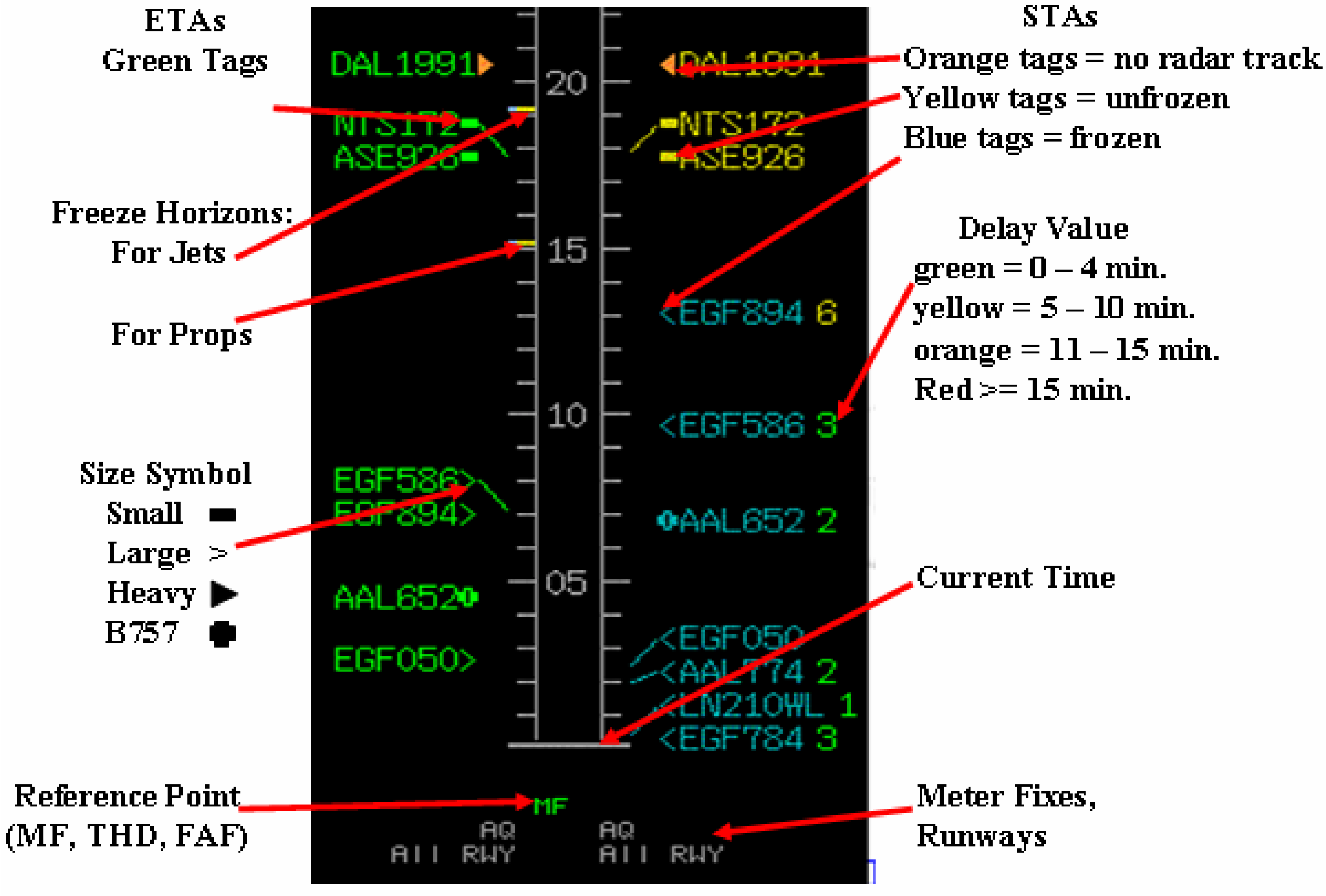

Fig 2 TMA Timeline Graphical User Interface (TGUI) (from Kim, 2006)

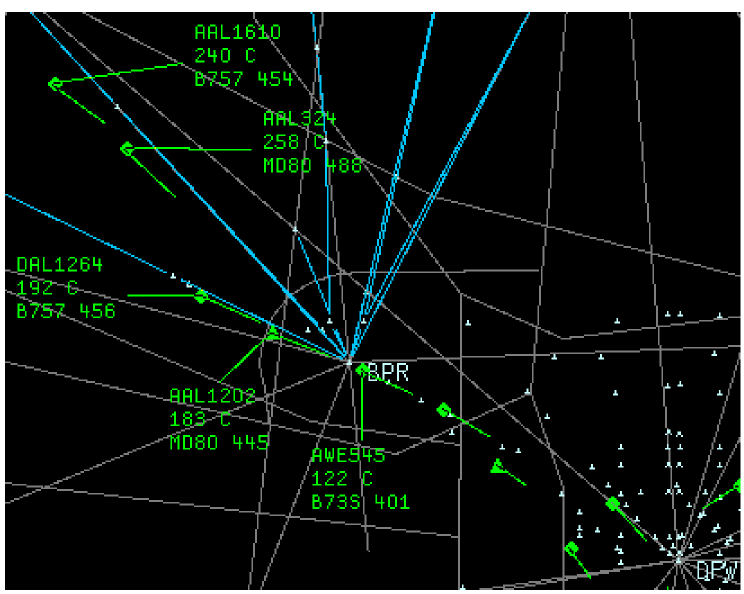

Fig 3 TMA Plain view Graphical User Interface (PGUI) Graph (from NASA Ames, 2008)

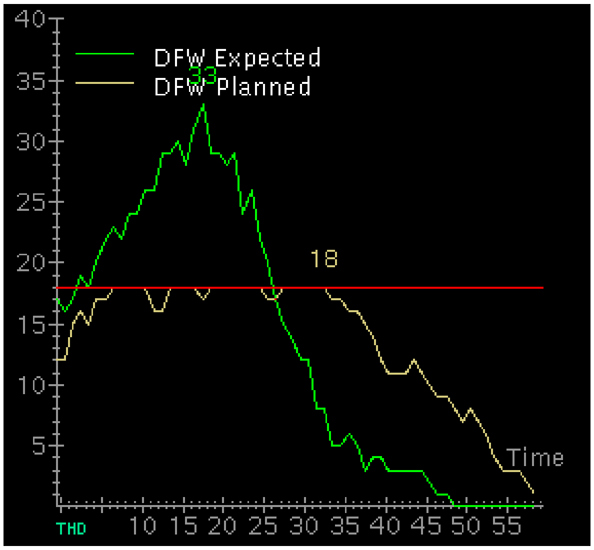

Fig 4 Sample TMA Load Graph (from NASA Ames, 2008)

ERAM integrates new tools to support tactical and strategic tasks and to help the evolution of en-route ATC. ERAM provides controller and operational supervisory personnel with a seamless Computer-Human Interface (CHI) that integrates basic surveillance and flight data automation capabilities with new and evolving automated decision tools. Effectively integrating a variety of different systems and tools is critical to accommodating greater numbers of aircraft operating in less-structured airspace without increasing controller workload or compromising safety.

Controllers can operate in the traditional manner with an R- and D-position console in which the R controller is responsible for tactical separation and the D controller is responsible for strategic separation. The consoles can also be configured to allow a one-person configuration to access both strategic and tactical data and decision support tools. Views provide the traditional situation display, display control and status, time, aircraft lists, flight plan readouts, and trial planning. Window sizing, hiding, and positioning minimize clutter on the glass. Tool bars, pull down menus, and templates minimize the amount of data the controllers must enter to access information and update flight data. Paper flight strips are supported for non-radar operations that have not been converted to electronic flight data. A-position support is provided with the ability to interact with flight data and flight strips

The Tracker position, also known as the Hand-off or H-position, is provided for additional controller support at a busy sector and requires sharing of the R-position console display with the R controller. Flight data from the adjacent D-position console is also available for viewing by the controller at the Tracker position.

ERAM provides support for the AT Supervisor, Flight Data Communication Specialists, Traffic Flow Management and Military Specialists with AT Specialist workstations. The AT Supervisor is provided with information on weather, sector usage, beacon codes, Sign-in/Sign-out status, Special Activity Airspace (SAA) status and schedules, restrictions, sector configuration, NOTAMs, hold times, and immediate aircraft alerts. In addition, the AT Supervisor can receive and send General Information (GI) messages, turn on and off SAA and restrictions, and receive search and rescue information.

Flight Data Communication Specialists are provided the capability to enter and update flight plans for flights that need plans to be entered or corrected for proper processing in the system. Many of the automation tools, such as flight plan templates provided at the D-position, are available for the Flight Data Communication Specialists.

ERAM provides support for Traffic Flow Management personnel at the R- and D-position consoles that are located in the TMU area. The R-position consoles are used for situational awareness, tactical planning, and metering functions. The D-position consoles are used for flight plan updates and more strategic planning. An AT Specialist workstation is provided in the TMU area for access to current and proposed flight plans and for updating those plans, as necessary. Automation is provided to improve coordination between Traffic Flow Management and en-route ATC on restrictions, SAA management, and TFM reroutes for weather and other unscheduled activities. ERAM also produces traffic volume and traffic flow off-line reports that aid in analysis and future planning activities.

4. WEATHER FOR THE DEMONSTRATION

For this demonstration convective weather, or thunderstorms, were treated as no-fly zones. To define the no-fly zone area, model output from the Weather and Research Forecast (WRF) model were used. This model provided forecasts of radar composite reflectivity (CR) and echo tops (ET).

CR is defined as the maximum radar reflectivity within a vertical column. This is a good indicator of the thunderstorm intensity. The ET is the highest altitude for which the reflectivity is at least 18 dBZ.

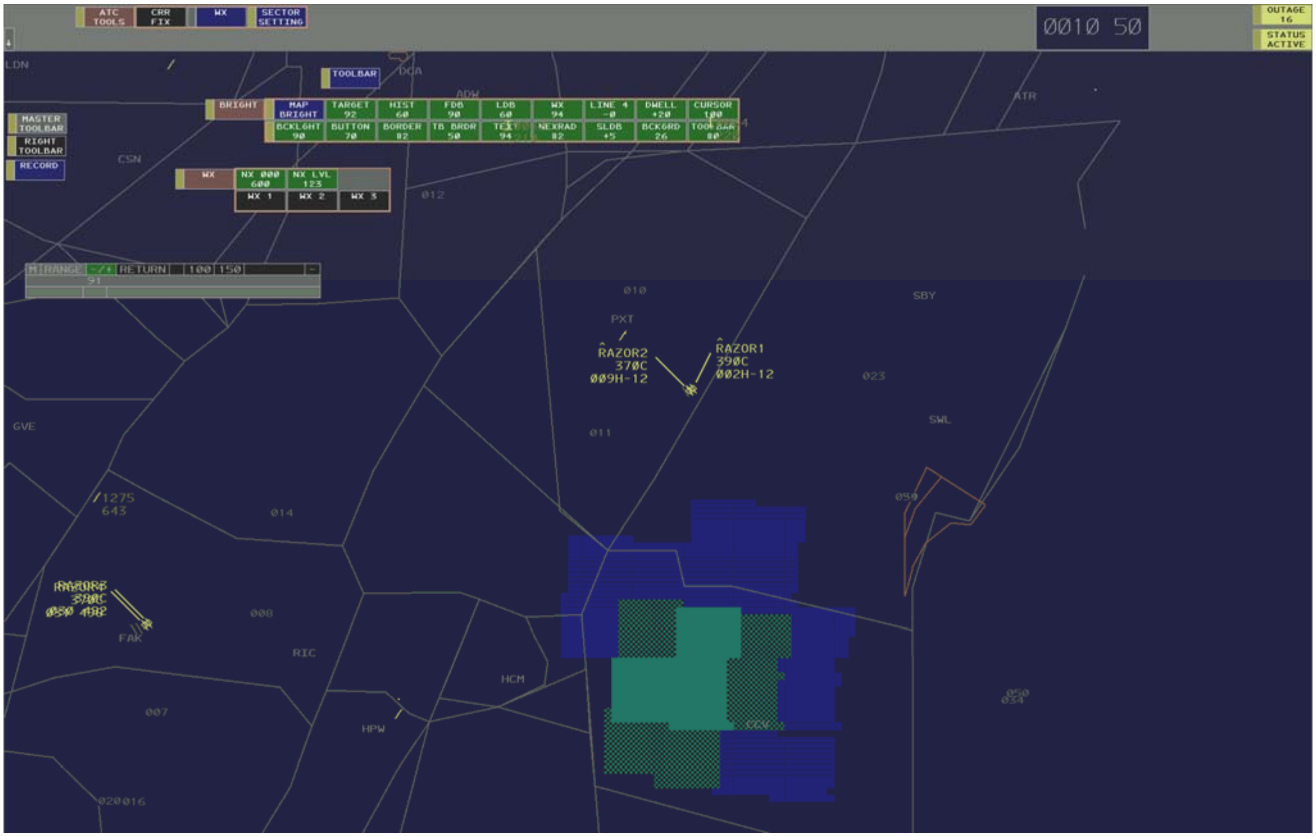

Fig 5 Sample ERAM R-position display.

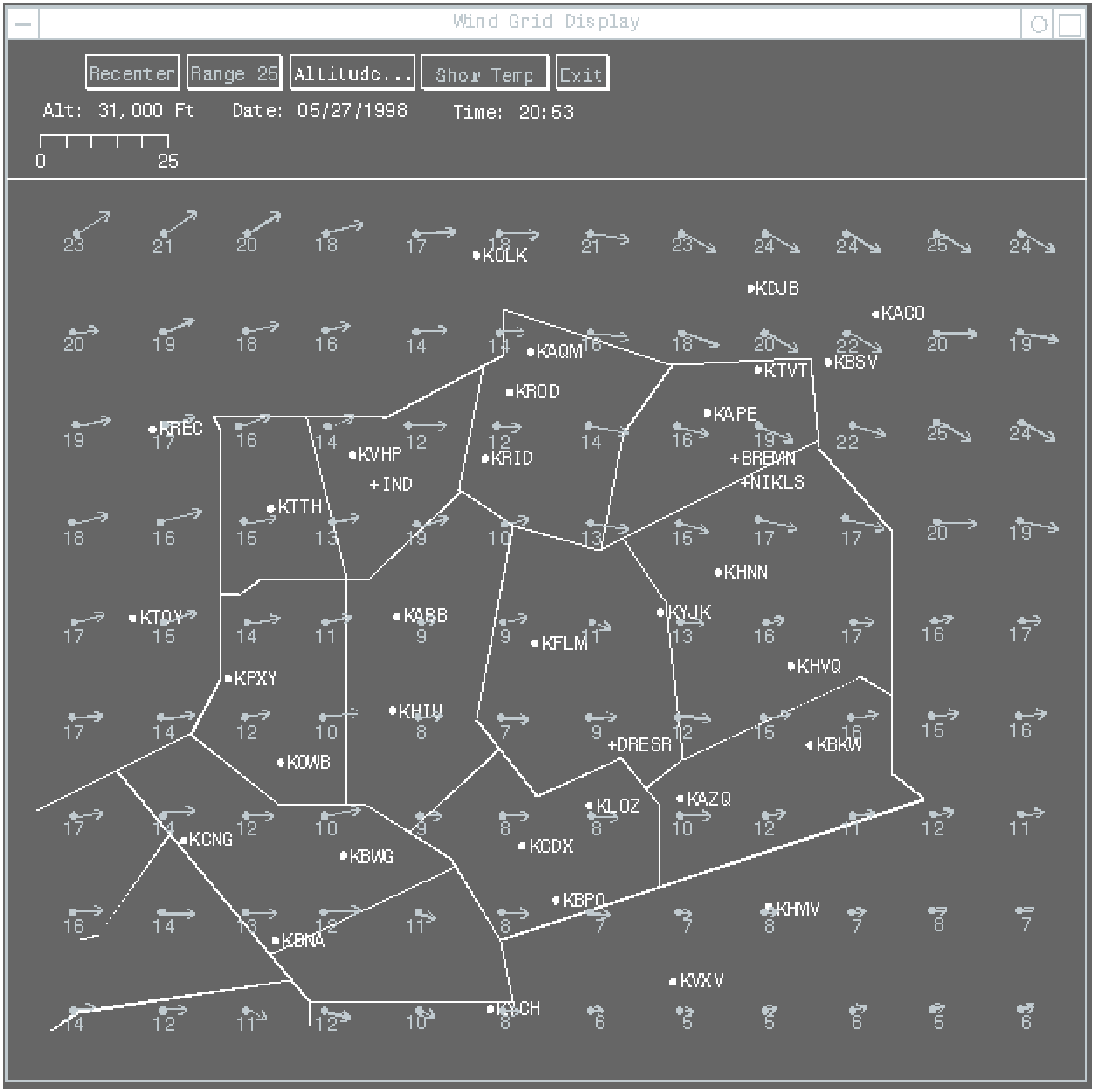

Fig 6 Sample ERAM D-position wind display.

Each thunderstorm no-fly zone was defined by a horizontal polygon. The bottom of the no-fly zone was the ground. The top of the no-fly zone was the highest echo top within the polygon area. These CR polygons and ET created “layer-cakes” of no fly zones like those shown in (Fig 7).

Fig 7 Layer-cake depiction of model-generated thunderstorm over Florida peninsula.

The WRF model output these polygons in 5-minute forecast increments. It ran once every three hours, creating a new set of forecasts.

The resultant polygons were formatted to match a System Wide Information Management (SWIM)-like network capability for use by ERAM and TMA. It should be noted that defining the no-fly zones as polygons with a single flat top may not be optimal in the long run. It is well suited to this first attempt to put convective forecasts into ERAM, since ERAM is already equipped to deal with no-fly polygons such as special use airspace.

The version of WRF used for this demonstration was the model Ensco, Inc. routinely runs over the Florida peninsula to support operations at the Kennedy Space Center. This version contained 42 vertical levels and had a horizontal resolution of 4 km. Ingested observation data included NEXRAD radar reflectivity.

5. THE DEMONSTRATION

Fig 8 shows an example of the airspace schematic used in TMA. The TRACON controls aircraft within the inner circle while the ARTCC controls aircraft in the outer area. The metering fixes for this example are the ARTCC/TRACON handoff points and the final approach fix for the runway. TMA assists the ARTCC controllers in sequencing aircraft toward the metering fix. The freeze horizon (not shown) is the distance where the aircraft position in the sequence is frozen. Notice in the example in Fig 2 the jet freeze horizon is 19 minutes flight time before the meter fix and the prop freeze horizon is 15 minutes flight time before the meter fix.

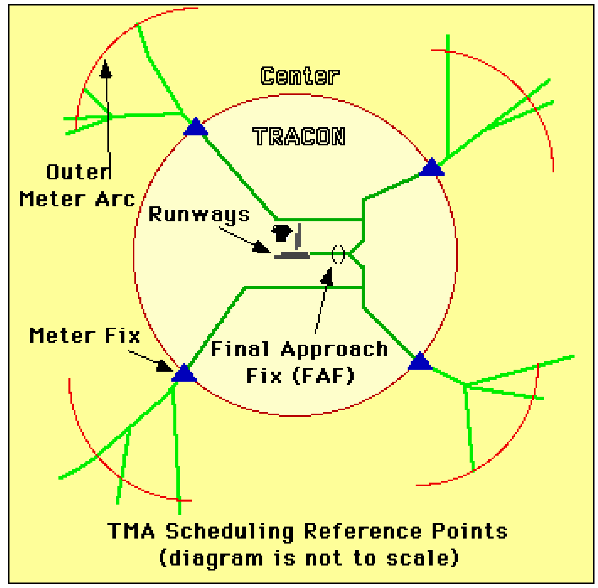

Fig 8 Airspace schematic used by TMA, (from NASA Ames, 2008).

As mentioned in the introduction, this demonstration’s domain included the Jacksonville ARTCC sectors that feed the Orlando TRACON from the north (Fig 9). The TMA freeze zone was set at 120 nm. Controllers used TMA and ERAM to optimize traffic flow into three transition fixes, BUGGZ, PIGLT, and LEESE (Fig 9).

The demonstration included three scenarios, (1) a fair weather day , (2) an active thunderstorm day using the existing TMA and ERAM and (3) the same active thunderstorm day, but using the enhanced TMA and ERAM.

Scenario 1 demonstrated how TMA and ERAM work together to optimize traffic flow into a busy airport during fair weather conditions. It demonstrated the best-case-scenario for using today’s TMA.

Scenario 2 demonstrated how the current TMA and ERAM are unable to keep up when aircraft are forced to deviate around thunderstorms. During this scenario, the TMC eventually had to revert to a much less efficient approach by imposing “miles-in-trail” restrictions and basically abandoning the use of TMA.

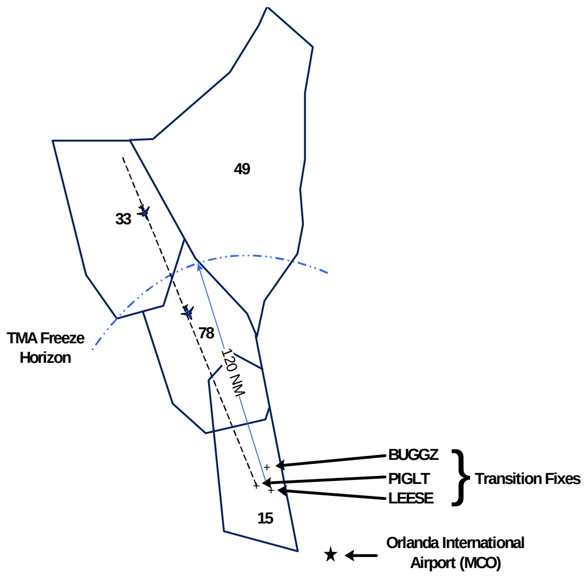

Fig 9 Jacksonville ARTCC sectors and meter fixes used in the demonstration.

In scenario 3 the added convective weather forecast information enabled the sector controller and TMC to stay on top of the situation and keep TMA functioning, even as the aircraft were deviating around the weather. Here's how it worked:

- The TMC could view the convective forecast polygons on the TMA PGUI and thus anticipate possible aircraft deviations.
- The D-side sector controller, using the ERAM D-position display, could also see where thunderstorms were likely to impact traffic. He/she could perform trial plan reroutes by point-and-click around the weather polygons. He/she could also use a slide bar to display aircraft and thunderstorm positions 60 minutes into the future.
- After an appropriate reroute was determined, the R-side controller would issue appropriate instructions to the pilot.
- ERAM would also send the updated flight plan information to TMA which would then recalculate the STA and ETA, update the metering lists and return that information back to ERAM for display on the R-position.

6. CONCLUSION

This demonstration showed how convective forecasts could be used to optimize traffic flow into a busy airport. TMA and ERAM could be modified to perform this function, provided they receive the appropriate convective weather forecasts.

However, the WRF model may not be the best choice for providing very short lead-time convective forecast for TMA and ERAM. We chose the WRF model for this demonstration because it was already running over this region and it took very little effort to generate the CR and ET polygons. Also, in the early planning stages of the project, the forecast lead times were expected to be several hours.

In a real-time operational environment requiring very short range convective forecasts like these, an extrapolation-based system like the Corridor Integrated Weather System (CIWS) may be a better choice.

7. REFERENCES

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