Central Region Technical Attachment
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Linear Convection and Air Traffic Decision Support: April 12, 2015

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Introduction and Background

Linear convection, particularly that which is oriented north to south across a wide portion of the continental United States, presents an effective barrier to the safe and efficient flow of air traffic and represents an important forecasting challenge to be resolved and communicated. In such situations, short-term strategic routing decisions often weigh heavily on an automated, blended-model Collaborative Convective Forecast Product (CCFP) and forecaster-generated Collaborative Aviation Weather Statement (CAWS), both supplied by the Aviation Weather Center (AWC)[1]. However, tactical decision making on the regional scale tends to rely more heavily on meteorological input provided by on-site meteorologists located at the various Air Route Traffic Control Centers (ARTCCs) operated by the Federal Aviation Administration (FAA). Additionally, in situations where longer-term forecasts provided by the CCFP are deemed inaccurate or too generic, these embedded meteorologists within the air traffic infrastructure assist managers in making appropriate routing decisions based on their mesoscale analyses and understanding of the unfolding synoptic and mesoscale situation. The motivation behind having meteorologists providing on-site, on-demand interagency support was driven by the crash of Southern Airways Flight 242 in April 1977, which was violently impacted by thunderstorms en route. According to National Transportation Safety Board findings from the crash investigation, "…contributing to the cause were the inadequacies of the Federal Aviation Administration's air traffic control system which precluded the dissemination of real-time hazardous weather information to the flight crew."

Synoptic Overview

Early on the morning of 12 April 2015, a surface cold front extended from the northern Plains into the central Rockies, with a warm front situated from western Kansas into northeast Texas, as shown in Figure 1. Aloft, a modest shortwave trough across the Rockies was ejecting eastward. As the day progressed, the southeastward-moving cold front began overtaking the warm front. Given the time of year and seasonally warm temperatures in the 70s F across the Plains, thunderstorm development along and just ahead of the front would be a reasonable expectation during the late afternoon as surface-based instability increased. There were no apparent outflow

[1] These products, disseminated by the Aviation Weather Center (AWC), were both pilot projects which have since been superseded by the traffic flow management convective forecast (TCF) based on partner feedback from events such as this one from the 2015 and 2016 convective seasons.

boundaries or remnant mesoscale convective vortices from antecedent convection across the Plains.

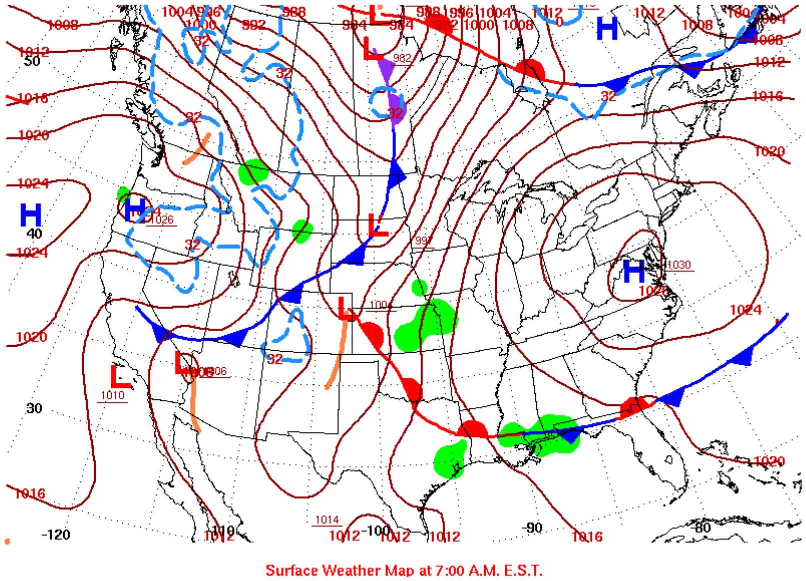

Figure 1. Weather Prediction Center's surface analysis for 1200 UTC 12 April 2015.

Strategic Forecasts

The Storm Prediction Center (SPC) highlighted the area of concern as early as 10 April in their Day 3 Convective Outlook, painting the Plains at heightened risk for convection. However, it was not until the 0600 UTC Day 1 Convective Outlook was issued that there was an expressed concern for organized storms assuming a linear mode late in the period as storms congealed along the incoming frontal boundary, as shown in Figure 2.

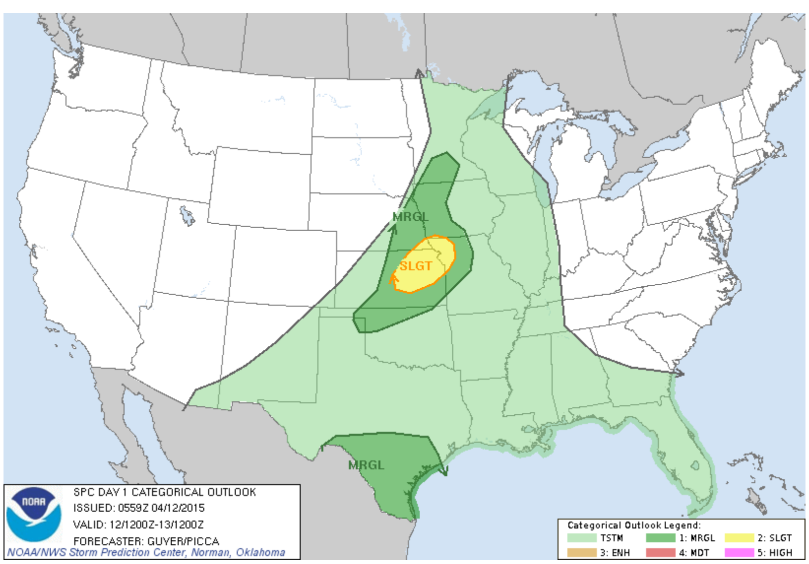

Figure 2. Storm Prediction Center's 0600 UTC Day 1 Convective Outlook indicating the potential for extensive north-to-south-oriented convection across the Plains.

Based on this SPC forecast, and subsequent issuances, little actionable information could be garnered as far as the timing of convective initiation, as well as its duration, mode, tops, and specific location at any one time. The CCFP provides additional information to help air traffic managers assess these parameters and make air routing decisions beneficial to the smooth operation of the National Airspace System (NAS). Beginning in spring 2015, the CCFP shifted from a forecaster-produced entity to an automated one, derived entirely from the output of several high-resolution models. The resultant product shows a snapshot at a specific time of expected thunderstorm location, coverage, tops, and confidence in its occurrence; this forecast is issued every two hours, with forecast panels at 2, 4, 6, and 8 hours into the future. The first forecast suggesting the potential for extensive linear convection was issued at 1500 UTC, for a valid time at 2300 UTC, as depicted in Figure 3.

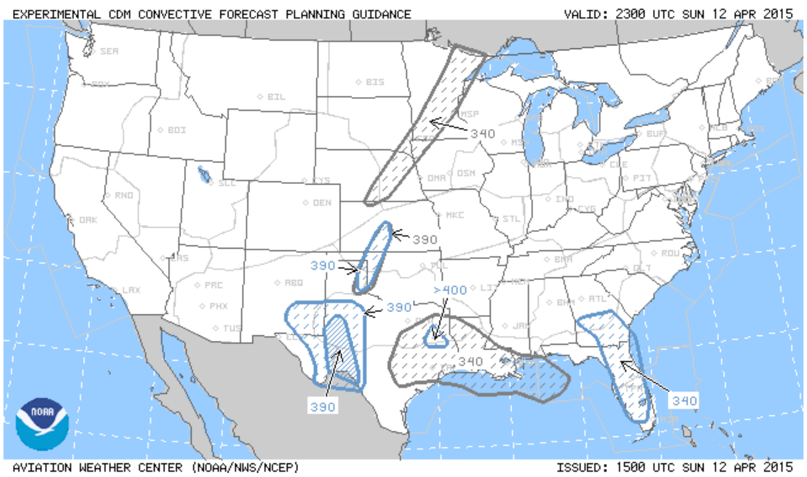

Figure 3. Aviation Weather Center’s 8-hour forecasted CCFP image, issued at 1500 UTC, is the first to show the potential of significant restrictions to transcontinental air traffic.

Two hours later, the CCFP forecast for 2300 UTC was little changed from the earlier issuance, suggesting good continuity among high-resolution models and thus greater confidence in the potential weather impacts. The newest 8-hour forecast panel, valid at 0100 UTC, suggests the evolution of late-day convection may block off significant portions of usable airspace for east-west transcontinental traffic during the evening, as noted in Figure 4.

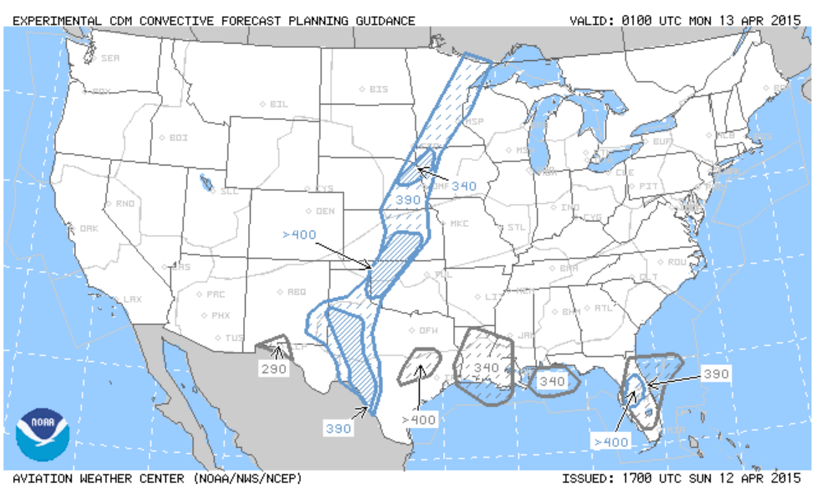

Figure 4. Aviation Weather Center’s 8-hour forecasted CCFP image, issued at 1700 UTC, suggests high confidence of thunderstorm coverage across the Plains.

Tactical Forecasts & Event

Introduction of the CAWS took place several weeks earlier as an operational bridging concept to spatially and temporally address, both in text and graphical form, areas of heightened concern to air traffic flow and impact that were not adequately depicted in the automated CCFP; while this product is forecaster-prepared and disseminated by the AWC, meteorologists at impacted ARTCCs typically provide input and refinement to the product before final issuance. The CAWS numbering scheme is sequential for the local calendar day; AWC issued their first CAWS for this event at 1800 UTC, highlighting increased confidence of linear thunderstorm development across southwestern Texas over the following several hours. The forecasted thunderstorm timing, coverage and tops appeared to verify well. An additional CAWS was issued shortly thereafter, forecasting the development of a couple of different line segments across Kansas and Nebraska, as shown in Figure 5. This CAWS was issued primarily due to CCFP suggesting only sparse thunderstorm coverage across this area with no fine detail which could be used to make actionable decisions. Of particular interest from a traffic management standpoint is the gap shown across Kansas between the two lines of thunderstorms as the event is predicted to evolve.

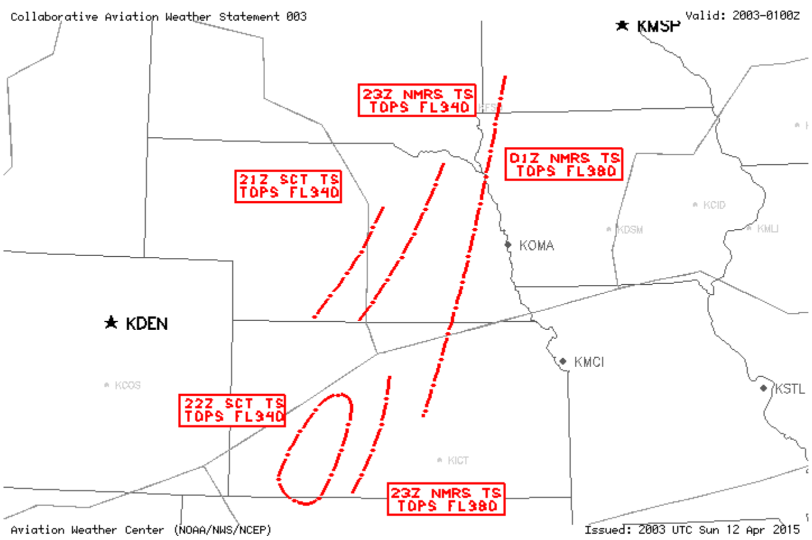

Figure 5. CAWS 003 for expected thunderstorm mode, geography, and tops for the central Plains.

Outside of the ongoing convection across west Texas, thunderstorms first developed and assumed a linear mode across central Minnesota and central Nebraska by 2130 UTC, however these were minimal in their extent and impact, consisting of narrow and short line segments in relatively lesser-travel routes. However, with the Storm Prediction Center's 2203 UTC issuance of their Mesoscale Discussion, it was recognized that significant new development was imminent across the central and southern Plains, eventually transitioning into eastward-propagating lines. This was the first of six Mesoscale Discussions that would be issued for the central and southern Plains that evening, highlighting the rather extensive area affected.

The AWC issued its first CAWS specifically addressing this area at 2256 UTC, as shown in Figure 6. In the narrative, the forecaster states that while the underlying CCFP guidance is good, the CAWS is being issued to provide more detail for impacts. An additional CAWS had also been issued farther north, to address impacts around the Minneapolis area.

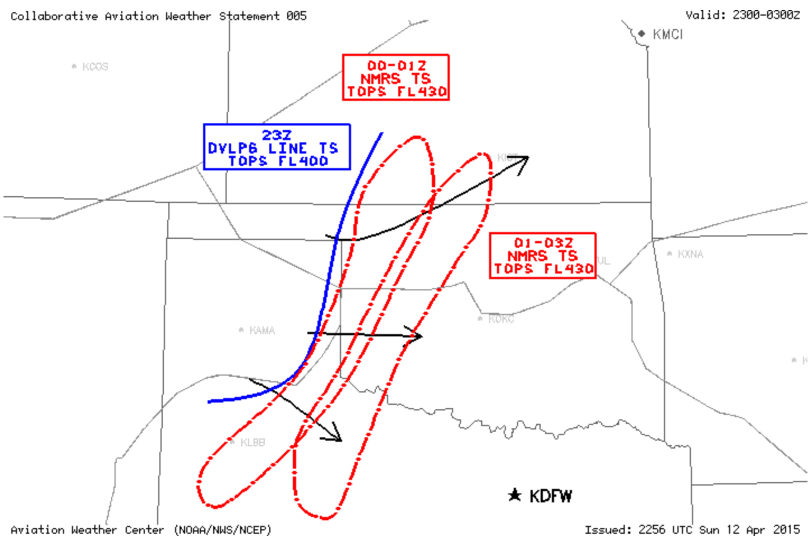

Figure 6. CAWS 005 for expected thunderstorm mode, geography, and tops for the southern Plains.

By 0000 UTC, line segments, while still narrow, were at least broken in coverage from the Arrowhead of Minnesota southwest into eastern Nebraska, with additional scattered to numerous convection developing from southwestern Kansas into the Big Bend area of Texas. Harris Corporation's Weather and Radar Processor, used extensively in FAA en route facilities for meteorological interrogation and briefing chart composition, showed the large obstructions to air traffic due to thunderstorms occurring at 0146 UTC 13 April in Figure 7. In this screen capture, yellow represents cloud-to-ground lightning strikes recorded within the previous 15 minutes, while gray indicates cloud-to-ground lightning strikes occurring from 15 to 30 minutes in the past; lightning polarity is also indicated with a "+" or "-" sign. These data are sourced from the National Lightning Detection Network (NLDN; Orville 2008). Significant Meteorological Information statements, also known as SIGMETs to the aviation community, are indicated by rectangular areas in the graphic and are issued by the AWC to highlight ongoing significant convective activity.

Figure 7. NLDN-observed cloud-to-ground lightning strikes over a 30-minute period ending at 0146 UTC 13 April.

At 0012 UTC, CAWS 003 for the central Plains was replaced by CAWS 006, better reflecting where the gap in convective lines was taking shape, shown in Figure 8.

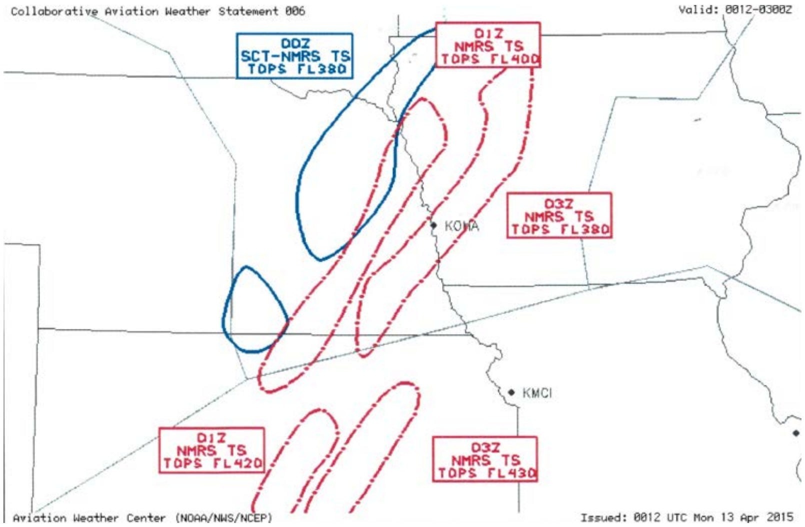

Figure 8. CAWS 006 issued at 0012 UTC, highlighting the gap between lines of thunderstorms across the central Plains.

Impacts

Sunday evening air traffic tends to be somewhat higher than the average evening across the week, due to the combination of increased business travelers en route to their meetings and the tendency of vacationers to begin or conclude their journeys during the weekend. Over the course of the entire day, Kansas City ARTCC worked 4,004 aircraft on this particular Sunday, in comparison to the Sunday seasonal average of 3,863. According to local air traffic managers, while the relatively small numerical increase in operations was due to the severely compromised transcontinental routes that took much of the evening traffic through Kansas City airspace, the temporal and spatial compression of traffic imposed by the convection seriously strained operations across large sections of the NAS and resulted in a high-impact traffic management event for controllers working the few sectors not impacted by thunderstorms. As an example, Figure 9 provides a snapshot of high-altitude air traffic across one sector of north-central Kansas at 0050 UTC 13 April. Notice the fairly large spread in airplanes at this time, before convection significantly restricted airspace in this region. In contrast, the same high-altitude sector at 0202 UTC shows only a tiny corridor of navigable airspace remaining as the gap between lines of thunderstorms closes. In order to maintain safety for the aircraft and their occupants, as well as reduce complexity and workload for air traffic controllers, specific initiatives are adopted by traffic managers including “miles-in trail,” which mandates predetermined and universal spacing distance between aircraft; this snapshot is shown in Figure 10.

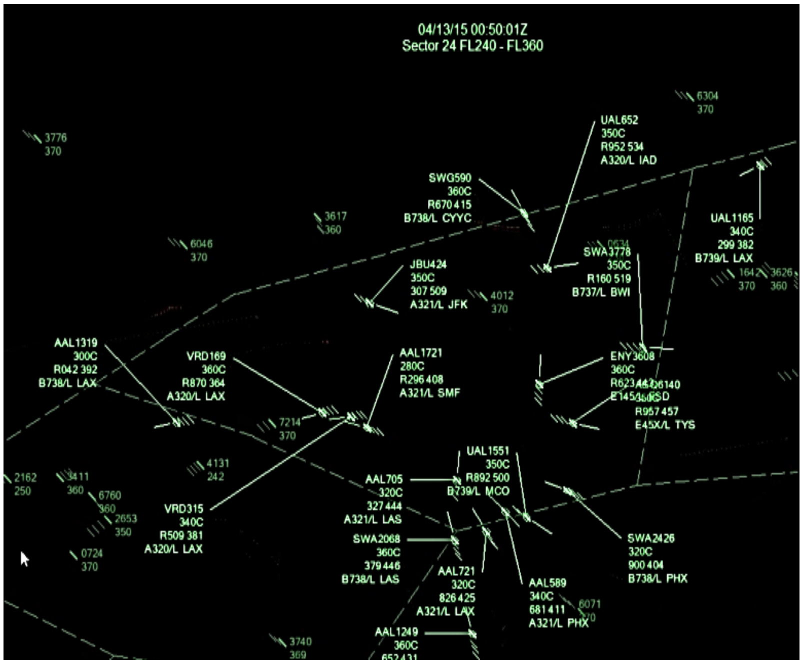

Figure 9. High-altitude sector of air traffic at 0050 UTC 13 April.

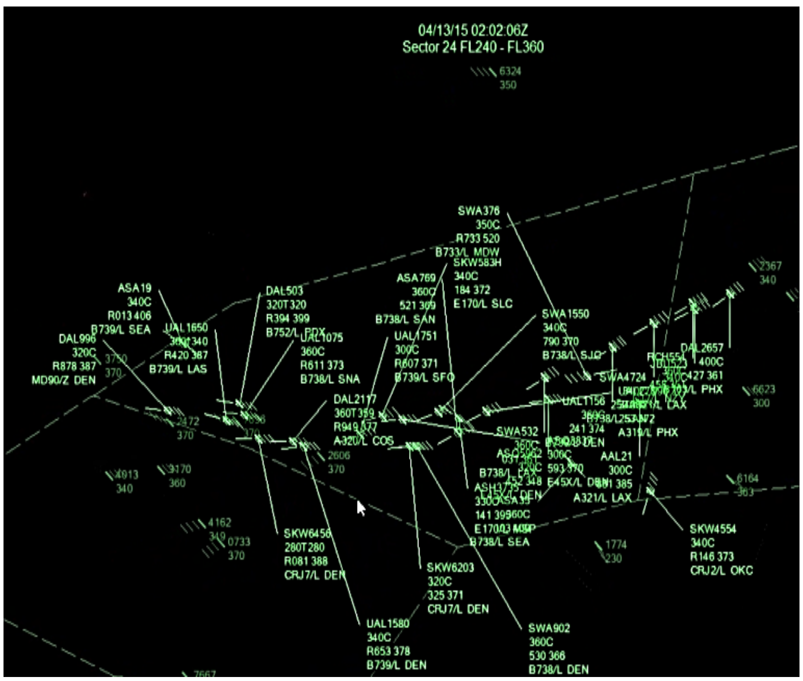

Figure 10. The same high-altitude sector shown previously, but at 0202 UTC.

Decision Support

At Kansas City ARTCC, the meteorologists compose planning forecasts out to four days which are shown at various briefings daily. These charts indicate the anticipated spatial coverage of convection across the central third of the continental US, thunderstorm tops, and convective mode. The main intent of these forecasts is to assist front-line FAA supervisors and traffic managers in making staffing decisions for upcoming days and approving or denying of leave and overtime, as required, based on the projected weather conditions and likely impact on air traffic.

In particular, effort is made to indicate whether thunderstorm tops and mode are likely to block off the airspace in its entirety (high-topped solid thunderstorm lines covering the entire airspace), which would actually require less staff to manage, versus convection where gaps in thunderstorm lines are likely to occur across the airspace, which often leads to higher-than-normal traffic, requiring additional staffing. The latter situation was the case in the event showcased herein. Thus, the ability to accurately predict where these gaps occur in the hours and days leading up to the event has significant economic value and safety consideration in appropriately balancing staffing resources against the safe and efficient flow of air traffic.

Inspection of the staffing report from the evening shift indicates personnel strength of only 84% of that prescribed for a typical April Sunday evening for the facility, with western Kansas sectors only at 75% and north-central Kansas, where sector 24 resides as shown in Figures 9 and 10, at 90% these prescribed, historical staffing levels. Despite lower controller staffing, actionable weather information in the hours leading up to the event prompted local traffic management staff to issue a "playbook" at 2350 UTC, setting up a structured routing plan to direct air traffic through the very limited navigable airspace effective from 0100 UTC through 0500 UTC. This initiative, seen in Figure 11, was issued based on weather forecasts issued locally and provides an effective way to route westbound transcontinental traffic through the weather.

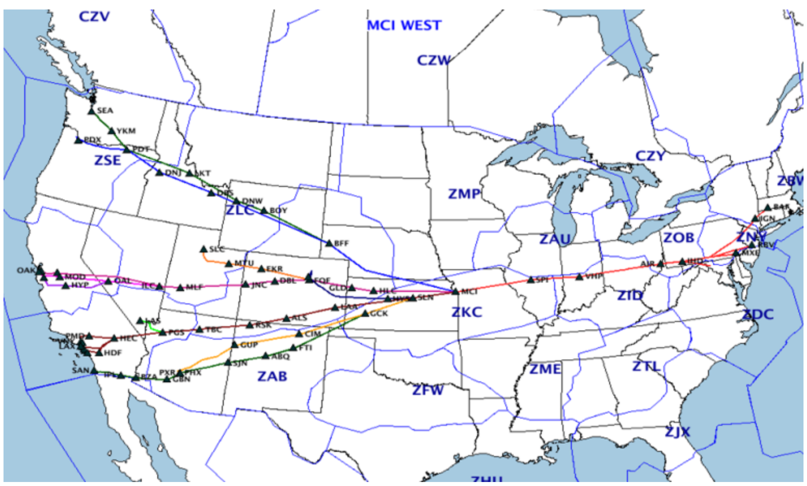

Figure 11. MCI West playbook preemptively issued to provide structure to westbound traffic to utilize gap through north-south thunderstorm lines.

As is often the case with higher-impact local events, a Traffic Management Review (TMR) was conducted by FAA personnel to ensure operations unfolded nominally and as a synopsis for other stakeholders, especially commercial airlines. Among documents reviewed included the official traffic management log, noted in real time by personnel principally responsible for utilizing meteorological and staffing information to implement playbooks and other strategic planning initiatives as well as coordinating with the national FAA Command Center, who serves as the final arbiter of the National Airspace System. The following is an excerpt summarizing the shift from this log:

> "Very difficult shift. Amazing amount of help from first tier facilities, weather developed as projected…weather initially closed down to two small openings east to west; one north of HLC [Hill City, Kansas] and one around HYS [Hays, Kansas]. ZMP [Minneapolis ARTCC] did a spectacular job making sure aircraft stayed inside their airspace when possible helping us manage the volume through

> us. ZMP WX eventually closed leaving us with the main transcon route. MIT [miles-in-trail] and routes issued to ZDV [Denver], ZAU [Chicago], ZFW [Fort Worth], ZID [Indianapolis], ZME [Memphis] to assist with the volume."

As noted in the description, besides the MCI West playbook issued, other initiatives were also in place to help mitigate traffic volume across the Kansas City ARTCC and provide for optimal routing decisions across the nation.

Conclusion

Thunderstorms, especially linear convective modes favoring north-to-south orientation, present a formidable challenge to safely and efficiently managing air traffic across the continental United States. The availability and proficiency of increasingly high-resolution temporal and spatial models are one factor in successfully meeting this challenge, particularly on a tactical level; on a strategic level, tailored meteorological forecasts extending out up to several days provides another critical element, allowing decision makers to adequately address personnel considerations well in advance to ensure traffic management complexity is ideally staffed. Finally, as this event showcases, having a cadre of meteorologists embedded within the air traffic infrastructure who are familiar with its vagaries allows constant communication and the ability to be nimble when changes occur or are required to best meet the needs and safety of the flying public.

Reference

Orville, R.E., 2008: Development of the National Lightning Detection Network. *Bull. Amer. Meteor. Soc.*, **89**, 180-190.

Acknowledgments

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