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Evaluation of the NCAR Auto-Nowcaster during the NWS Ft. Worth Operational Demonstration

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1. INTRODUCTION

During the spring of 2005 the NCAR[1] automated, short-term (0-1 hour), thunderstorm nowcasting system (Mueller et al. 2003) was deployed to the NWS forecast office in Ft. Worth Texas as part of a two year NWS Man In The Loop (MITL) nowcasting demonstration. The NCAR short-term thunderstorm nowcasting system (hereafter referred to as Auto-Nowcaster) combines human forecaster situational awareness and convergence boundary identification skills with a fuzzy logic based automated forecast process. The Auto-Nowcaster ingests level-2 data in real-time from 7 radar installations across the southern plains, METAR and surface mesonet reports, observed and derived satellite data, output from automated feature detection algorithms, a boundary layer model and its adjoint, and operational Rapid Update Cycle (RUC) gridded NWP output. These data, in addition to the forecaster-supplied boundary information are used to produce predictor fields, which are weighted and summed in a fuzzy logic engine to produce nowcasts of thunderstorm initiation, growth and decay.

The MITL demonstration is a new effort in the NWS to emphasize the role of the human forecaster in the production of automated short-term (0-6 hour) forecast products for the aviation community and the general public (Roberts et al. 2005). Inspiration for the MITL demonstration comes from the verification statistics of the FAA funded Regional Convective Weather Forecast (RCWF) demonstration which showed increased forecast skill was achieved when real-time boundary information was entered into the Auto-Nowcaster by a human forecaster (Roberts et al. 2003). The MITL demonstration seeks to build upon the RCWF results by placing the Auto-Nowcaster in a NWS forecast office and using on-duty forecasters to enter convergence boundary information. Nowcasts incorporating information supplied by the on-duty forecaster is made available to the forecast office on a local display and also to the Ft. Worth Center Weather Service Unit (CWSU) via a regularly updating webpage. Full details of the MITL demonstration are available in Roberts et al. (2005).

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2. FORECASTER SUPPLIED BOUNDARY CHARACTERISTICS

The Auto-Nowcaster uses automated feature detection algorithms run on single-site radar data to identify boundaries based on reflectivity finelines and velocity shear signatures. The algorithm has difficulty identifying boundaries in situations where clear-air returns are minimal and at extended ranges from the radar when the radar beam is no longer in close proximity to the surface. Human forecasters are not constrained to using only one source of data when identifying convergence boundaries. Forecasters with adequate situational awareness assimilate large and diverse data sets in a short amount of time to determine boundary location, and motion. Thus, they are able to identify boundaries in areas where radar information alone is insufficient. Also, large scale boundaries that extend over many radar domains are more easily identified in its entirety by a human rather than the automated feature detection algorithm which may only detect small portions close to the radar.

The Auto-Nowcaster allows a forecaster to display the observations and predictor fields used by the algorithms. These data aid in the job of identifying convergence boundaries. The display comes equipped with an interactive draw-tool that allows the forecaster to draw a boundary location on an underlay of any available data. In essence, the forecaster is using the mouse to draw boundaries on the Auto-nowcaster display as simply as he/she might use a colored pencil to draw a boundary on a printed weather chart. Additionally the Auto-Nowcaster has the ability to track and extrapolate forecaster entered boundaries. After entering an initial boundary position, the forecaster must enter the boundary again at a different time in order to obtain the boundary motion (speed and direction). Once the boundary has been inserted and the motion known, the system will track and extrapolate the boundary indefinitely until the forecaster chooses to discard the boundary feature. Large scale boundaries such as cold fronts or drylines are typically entered by the forecaster every 2-3 hours, while smaller scale boundaries such as gust fronts may be entered more frequently. Thus, boundary entry is not intended to be a major time sink for on-duty forecasters.

Once a boundary has been entered by the forecaster, it is combined with any preexisting forecaster entered boundaries and also the boundaries detected by the automated detection algorithm. The merged boundary dataset is used to generate a set of boundary-characteristic predictor fields (boundary relative steering flow, boundary lifting; see Mueller et al. 2003), then combined with predictor fields from other datasets (satellite, RUC, surface analyses, etc.), and converted into likelihood fields. The values of the likelihood fields range from -1 (no likelihood for thunderstorms) to +1 (highest likelihood for thunderstorms). These likelihood fields are then weighted and summed in the fuzzy logic engine. The end result is a final thunderstorm initiation likelihood field. Figure 1 shows the influence of the forecaster entered boundary on the final initiation nowcast. Areas shaded with pink or red colors in Figure 1 represent areas where new thunderstorms are expected to initiate while the blue shades indicate areas where storms are not expected to initiate. Areas shaded in green are not expected to initiate storms in this nowcast, but forecasters should monitor those regions for increased initiation likelihood in subsequent nowcasts.

3. FORECASTER INSERTED POLYGONS

A new tool has been added to the previous configuration of the Auto-Nowcaster (Saxen et al. 2004) which enables the forecaster to increase or decrease the thunderstorm initiation likelihood assigned to any geographic area within the Auto-Nowcaster domain. The new polygon tool lets the forecast add value to the forecast being produced without actually changing any of the internal configuration or fuzzy logic weights used to create the nowcast.

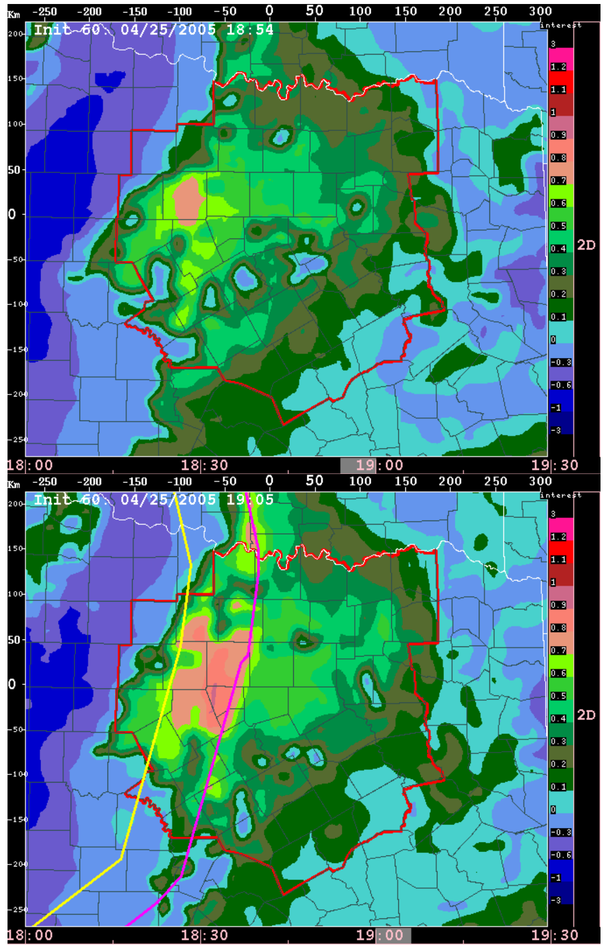

Figure 1. Auto-nowcaster final initiation likelihood fields for July 25th. Pinks and Red colors represent areas where thunderstorm initiation is expected to occur. The red polygon shows the area of responsibility for the Ft. Worth forecast office. Top: forecast before human entered boundary at 18:54 UTC; Bottom: forecast with human entered boundary (yellow) and 1 hour boundary extrapolation (magenta) at 19:05 UTC.

In Figure 2 we see that the forecaster on duty has drawn a polygon over a section of a boundary that had already been entered. In this instance, the forecaster felt that there was a greater likelihood of thunderstorm initiation along a small section of the boundary (a dryline) and used the polygon tool to moderately increase thunderstorm initiation likelihood in that area. The increase in likelihood set by the forecaster yielded a nowcast containing a thunderstorm initiation area, where previously likelihood values were not high enough to qualify as a positive thunderstorm initiation nowcast. Since thermodynamic and kinematic properties are often heterogeneous along boundaries, the polygon tool allows the forecaster to highlight small sections along the boundary that exhibit conditions more conducive for convection initiation.

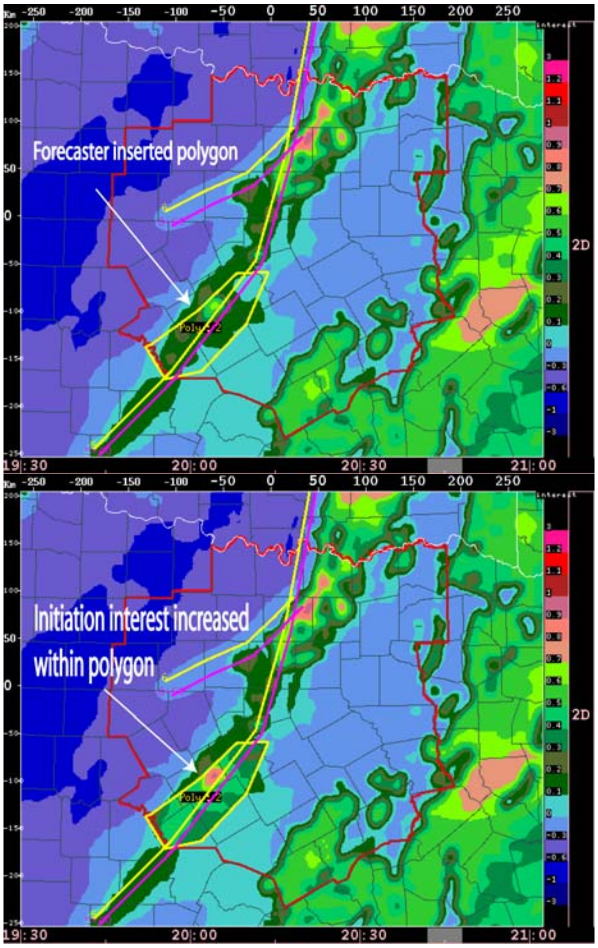

Figure 2. The final thunderstorm initiation likelihood field for April 5 at 20:38 UTC. The yellow polylines are boundaries entered by the forecaster and the magenta lines are the 60 minute extrapolations of those boundaries. The yellow polygon has been entered by the forecaster. Top: initiation likelihood field without increased likelihood from polygon applied to final forecast. Bottom: final forecast with likelihood applied from forecaster polygon.

The polygon tool has also been used, in the presence or absence of a forecaster supplied boundaries, to decrease the initiation likelihood. The most common situation for suppressing initiation likelihood with a polygon is when large quantities of negative buoyant energy (CIN) are present but not diagnosed in the RUC predictor fields, reducing nowcast false alarms. Similarly, polygons have been used to heighten likelihood values in regions where no boundaries were analyzed to better forecast convection initiation. This practice is applicable when convective initiation may be achieved by reaching convective temperature. Although the Auto-Nowcaster was not explicitly designed for elevated convection nowcasting, the forecaster on-duty has used the polygon tool to enhance thunderstorm initiation likelihood to better capture elevated convection initiation.

4. EVALUATION AND FEEDBACK

The MITL demonstration has 3 different performance measuring methodologies in progress. Grid based verification statistics are computed on a daily basis. Qualitative feedback from the forecasters on-duty are obtained through a real-time logging application and also through post event surveys. A new quantitative object based verification approach is being employed. The object based verification method for the Auto-Nowcaster demonstration in Ft. Worth is presented in Halley-Gotway 2005 and will not be discussed here.

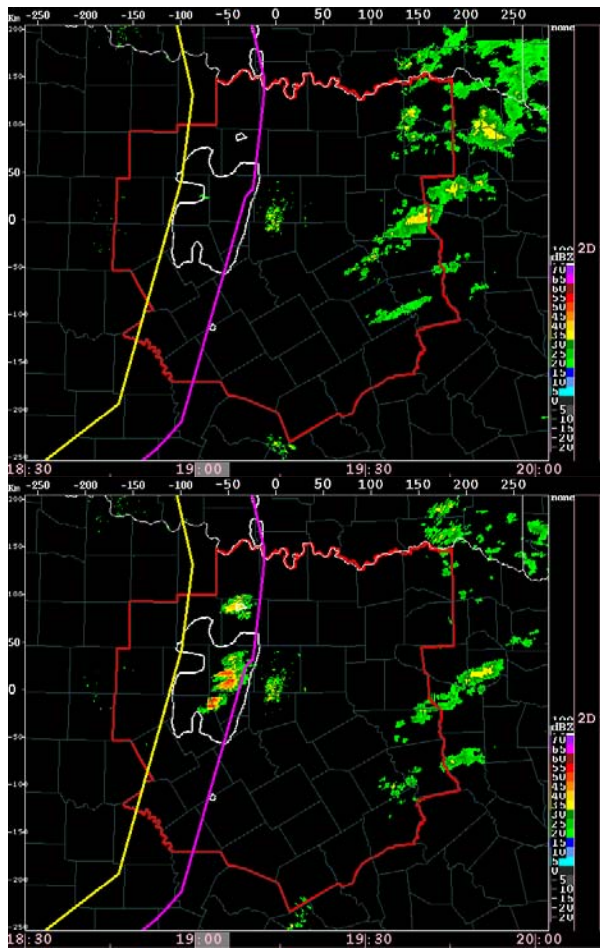

Figure 3. Forecaster entered boundaries and 60 min extrapolations (yellow and magenta polylines) with white contours of forecast thunderstorm initiation areas. Top: Reflectivity at forecast issuance. Bottom: Reflectivity at forecast valid time

4.1 Quantitative Performance

Grid-based verification statistics are computed every morning on the previous 24 hours of Auto-nowcaster output. False Alarm Ratio (FAR), Probability of Detection (POD) and Critical Success Index (CSI) are computed and plotted as times series graphs. Viewed via a webpage, both the on-duty forecasters in Ft. Worth and the scientific development team at NCAR can assess the Auto-Nowcaster performance in relatively short order. Bulk verification statistics, and statistics comparing performance with and with out human interaction will not be computed until after the convective weather season ends. Two active weather events are provided to show performance of the Auto-nowcaster with forecaster interaction.

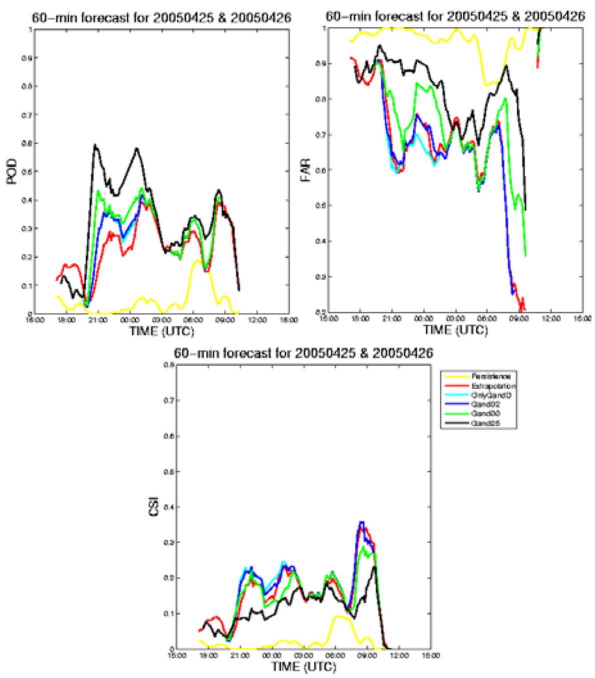

Figure 4. Time series plots of statistics for the April 25 event. Areal coverage POD, FAR, and CSI are shown. The yellow line represents the persistence forecast, the red line extrapolation forecasts, the cyan is the Auto-nowcaster Growth and Decay forecast, the blue green and black lines are the forecasts including the Growth and Decay component and 3 successive levels of initiation likelihood

On April 25, a dryline had become established in the western part of the Ft. Worth County Warning Area (CWA) during the morning. The short-term forecaster on-duty entered the dryline into the Auto-nowcaster around 19z (as shown in Fig. 1) with thunderstorm initiation occurring by 20z. In the top panel of Figure 3 white polygons outlining the areas of positive convective initiation forecast are overlaid on the regional radar reflectivity mosaic valid at the nowcast issuance, where in the bottom panel of Figure 3 the radar mosaic is shown for the nowcast valid time. It is shown that convection initiation was correctly forecast for several counties along the eastward advancing dryline.

Daily grid based verification statistics (Fig. 4) show that the Auto-Nowcaster had forecast skill (as shown by the POD graph), but suffered from false alarm problems, likely due to over forecasting the aerial extent of convective initiation. The bottom panel of Figure 3 shows the discrepancy between the forecast area and the area of convective initiation that occurred.

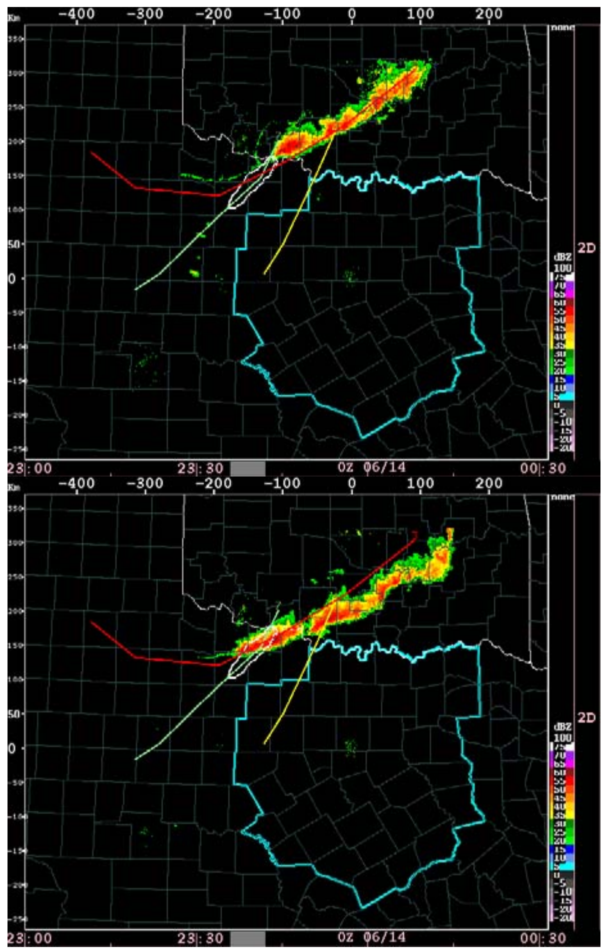

Figure 5. Forecast entered boundaries (red green and yellow polylines) and white contour of highest initiation likelihood. Top: Reflectivity as observed at forecast issuance. Bottom: Reflectivity as observed at forecast valid time, 00:40 UTC on June 14.

Late on 13 June 2005, a cold front was moving southeast over southern Oklahoma and northwest Texas. The cold front intersected a slow westward moving dryline just northwest of the Ft. Worth CWA. Convection initiated on the cold front in

Oklahoma and was propagating southeast. Figure 5 shows the locations of the cold front (red polyline), dryline (green polyline), and a third confluent boundary (yellow polyline) as entered by the forecaster on duty. The white polyline contours the highest initiation level nowcast at 23:40 UTC. While the existing convection was not in the forecast area for the Ft. Worth office (cyan outline in Fig. 5), the cell motions indicated the potential for the storms to affect the northern portion of their CWA. The bottom panel of Figure 5 shows the initiation nowcast with the reflectivity at the forecast valid time. It shows that additional cell development occurred near the cold front dryline intersection, where the Auto-nowcaster had the highest likelihood for initiation. Figure 6 shows the grid based verification statistics for June 13-14. Extrapolation dominates the later forecasts, but early in the period the initiation forecasts (blue, green and black lines) show quite a bit of improvement in POD over extrapolation and persistence forecasts.

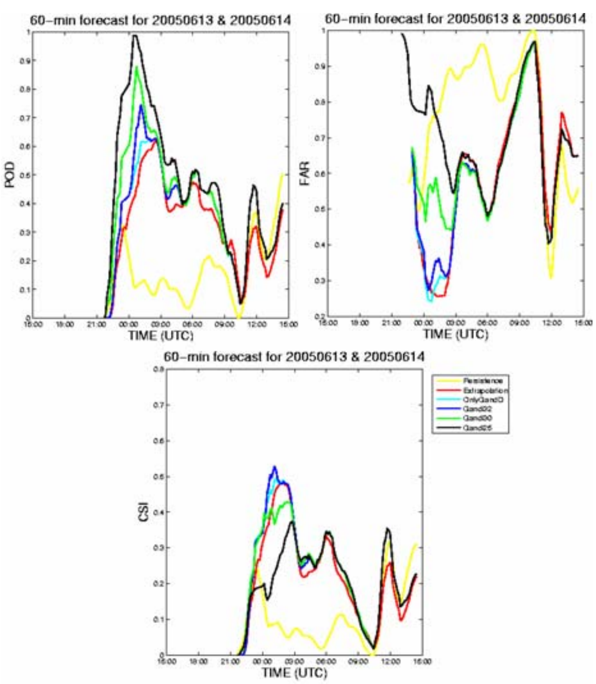

Figure 6. Time series plots of statistics for the June13th event.

4.2 Qualitative Evaluation

Active participation and feedback from the WFO forecasters is greatly desired. The facilitate dialogue, a graphic user interface (GUI; Figure 7) was designed and implemented on the Auto-Nowcaster display. This feedback interface provides a selection of buttons that allows the forecaster on-duty to "login" with his or her respective identification number at the beginning of their shift. Identifying impacts on normal NWS operations is important in evaluating the MITL effort. To accomplish this, several commonly issued products or tasks are listed on the GUI. When a forecaster issues one of the products listed (Area Weather Update, Significant Weather update, Terminal Aerodrome Forecast -TAF, and Short Term Forecast) either solely or in part based on Auto-nowcaster output, the appropriate button is clicked and the type of product and time is submitted to the log file. It's been observed that nowcasts have been useful in activating or standing-down weather spotter networks in the CWA. Thus, in addition to the common text products a button has been provided for phone briefings based on Auto-nowcaster output. Next, a row of buttons is provided to let the forecaster subjectively evaluate the Auto-Nowcaster forecasts. Five buttons let the forecaster rate the nowcasts from Very Poor to Very Good. When an evaluation is submitted, it is time stamped so that more thorough analysis of the nowcast can be done after the active weather has abated. Finally, a line is provided where the forecaster can record brief comments about any aspect of the Auto-nowcaster system, ranging from forecast quality and usefulness to technical difficulties encountered.

During active weather, a few brief comments entered in the GUI may not be sufficient to fully convey the thoughts and ideas of the forecaster. So to supplement the GUI, a longer post-event web survey was created. Intended to be completed after the forecaster's shift, the web survey, uses a mixture of rating questions and comment boxes that allow the user to rate individual aspects of the nowcaster system and its nowcasts, and provide feedback on usefulness and impacts to operations.

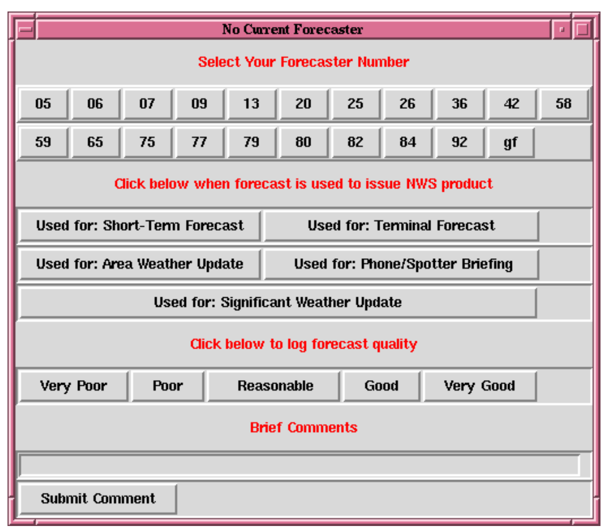

Figure 7. The real-time forecast log graphic user interface.

Both evaluation utilities were used by the forecaster to submit feedback and evaluate the 13 June 2005 case that was discussed in an earlier section. The feedback GUI was used in real-time to subjectively evaluate the Auto-nowcaster output twice between 00:00 and 01:00 UTC on 14 June. The forecaster rated the forecasts as “Very Good” and “Good” within that period. The next day, the forecaster who was on duty during the active weather submitted a web survey with additional comments and information on the Auto-nowcaster performance and impact on operations. Below are excerpts from the web survey.

“*Convection was developing rapidly along the cold front as it moved south toward the Red River. [Auto-nowcaster] had a very good handle on convective initiation along the front…especially around 00Z when it showed new initiation on the western edge of the front. Convection did form and intensify in this area.”*

In a subsequent section of the survey the forecaster briefly described the operational impacts of the Auto-nowcaster output.

“[The Auto-Nowcaster] system was useful for determining when and if storms would form on the western portion of the cold front. We used the initiation forecasts to write a short-term forecast around 00Z to inform the counties in the path of the developing storms.”

5. DISCUSSION AND FUTURE IMPROVMENTS

Interaction with the Auto-nowcaster has been added to the duties of the short-term forecaster at the NWS forecast office in Ft. Worth without a corresponding decrease in other responsibilities of the position. As a result, during active weather, the short-term forecaster may be unable to give the Auto-nowcaster the necessary attention required to enter or update boundaries to the detriment of the nowcasts being produced. This scenario often plays out when the office begins issuing severe weather warnings, and the number of demands placed on the time of all on-duty forecasters increases significantly. However, feedback from the forecasters indicates that the nowcasts being produced by the system are often beneficial and have a positive impact on operations. In year two of the MITL demonstration, the impact of the Auto-nowcaster forecasts on aviation products issued by the Ft. Worth CWSU will be investigated.

The feedback received from the forecasters has contributed to improvements to the Auto-Nowcaster. For instance, the input from the forecasters has led to changes in the forecast production logic to increase weights of convective inhibition and vertical velocity predictor fields from the RUC. Other suggestions relating to the boundary entry methods are currently being explored and may be implemented for the next convective weather season.

The example events provided shows that NWS forecaster interaction with Auto-Nowcaster produces nowcasts with increased skill in prediction convention initiation. One of the drawbacks of the system noted by the forecasters is that the Auto-nowcaster resides on a platform independent of AWIPS, which all of the forecasters are intimately familiar with. Work is ongoing to integrate parts of the Auto-nowcaster system into the AWIPS infrastructure and should lead to even greater interaction between the forecasters and the Auto-Nowcaster. Collaboration will also continue to improve the logic and methodologies in the Auto-nowcaster and in the end yield even better nowcasts.

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