P1.12 Utility of Total Lightning Measurements for very Short Term Forecasts of Convection Growth and Decay at White Sands Missile Range.

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1. Introduction

The 4DWX program operated by the National Center for Atmospheric Research[1] Research Applications Laboratory supports the forecasting and nowcasting needs of the Army Test and Evaluation Command (ATEC) White Sands Missile Range (WSMR; Lui et al., 2008). The NCAR Auto-Nowcaster (ANC) is a component of the 4DWX program that provides very short-term forecasts of thunderstorm initiation, growth, decay and lightning potential to the forecasters at the WSMR meteorology branch since 1997 (Mueller et al., 2003; Saxen et al., 2008.) The purpose of this paper is to examine the utility of total lightning data available at WSMR to improve convection growth and dissipation forecasts within the ANC.

2. NCAR Auto-Nowcaster

Through the years, the ANC has been deployed and run in a wide variety of locations. Currently the ANC is being run in real-time by NCAR for the Forecaster Over the Loop Demonstration at the NWS office Ft. Worth Texas (Roberts et al., 2005), WSMR, and by the Beijing Meteorological Bureau, for nowcasting over the Beijing metropolitan area (Wilson et al., 2007.) Each installation of the ANC is uniquely configured and tuned to ingest data, optimize performance, and meet user needs. The meteorology branch at WSMR is particularly sensitive to lightning hazards owing to the danger a lightning discharge poses to equipment, fuel and munitions that may be on or over the range, while the NWS office in Ft. Worth is particularly interested in convection initiation forecasts. Based on user needs, a lightning potential product was added at WSMR (Saxen 2002) and user selectable fuzzy logic regimes for convection initiation were added to the Ft. Worth demonstration (Nelson et al., 2008).

While the specific datasets may be different at each location, the basic inputs into the ANC remain fairly uniform. The ANC requires volumetric radar data, numerical weather prediction output, satellite, surface and upper-air observations to drive the analysis and predictor fields that go into the fuzzy logic engine that produces the nowcasts for the end-user. For growth and decay nowcasts, volumetric radar data is ingested and analyzed in the Thunderstorm Initiation, Tracking, Analysis and Nowcasting (TITAN; Dixon and Wiener 1993). TITAN is used to identify and track cells larger than 10 km^2 and greater than 35 dbz and also 45 dbz. Normalized area growth rates for each threshold of reflectivity are computed and used as predictor fields in the fuzzy logic engine. Additionally, an altitude weighted terrain predictor field and boundary relative steering flow (Wilson and Megenhardt, 1997) also contribute to the growth and decay nowcasts in the operational configuration running at WSMR. The reader is referred to Mueller et al., (2003) and Saxen et al., (2008) for full details on the fuzzy logic data fusion process used in the ANC.

The ANC is flexible enough to accommodate unique datasets when available. Wilson et al., (2006) examined the benefits of using total lightning data available from the Lightning Detection and Ranging (LDAR II) VHF time-of-arrival 3D mapping network (Demetriades et al., 2002) centered on Dallas Ft. Worth International Airport. Flash extent density (Lojou and Cummins, 2005) and normalized area growth rate of flash extent density, when included in the growth and decay forecast logic, improved the nowcast performance.

3. Methodology

In this study, we use total lightning data detected by the Lightning Mapping Array (LMA; Thomas et al., 2004) that is permanently installed at WSMR (Saxen et al., 2008). We

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added two total lightning predictor fields to the existing NCAR ANC growth and decay forecast logic, total lightning densities and total lightning density rate of change. Total lightning densities are the lightning source counts every 2 minutes (over a 5 minute accumulation period) per square kilometer, and the rate of change of lightning densities is computed every two minutes. Initial membership functions for these two predictor fields were chosen such that small changes in lightning activity do not have a huge impact (to maintain forecast consistency) but the general trend of the lightning activity would have influence on the growth and decay nowcasts (Figs 1 and 2). 30-minute nowcasts between 1800 UTC and 2359 UTC are validated and grid statistics presented.

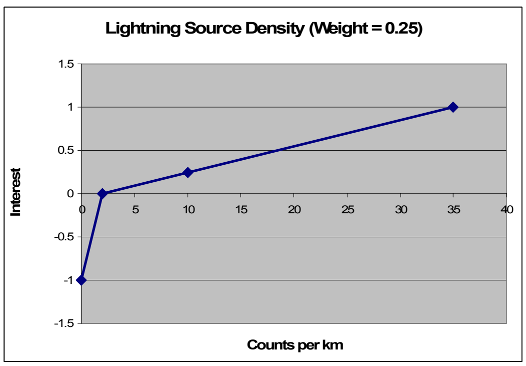

Figure 1. ANC membership function and weight for lightning source density.

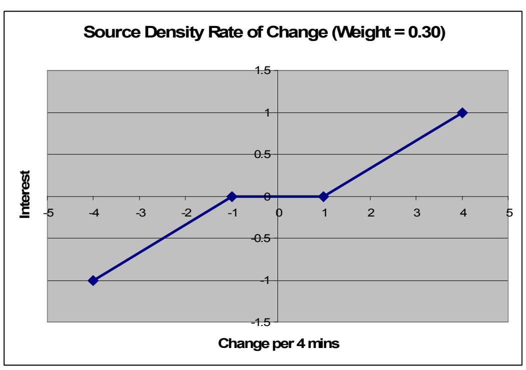

Figure 2. ANC membership function and weight for source density rate of change.

4. Results

During the afternoon of 12 July 2007, thunderstorms moved across the WSMR nowcast domain. Figure 3 shows the storms over the northern part of the range at 2030 UTC. Figure 4 shows the growth and decay interest field that includes LMA predictors at the same time, with grayscale colors showing dissipation interest, and blues through reds indicating areas of increasing storm growth interest.

Figures 5-8 show the validation statistics for the period of 1800 UTC through 2359 UTC on 12 July 2007 for both the nowcasts generated in real-time (ANC-RT) and the post analysis nowcasts that include the LMA predictors in the growth and decay forecast logic (ANC-LMA).

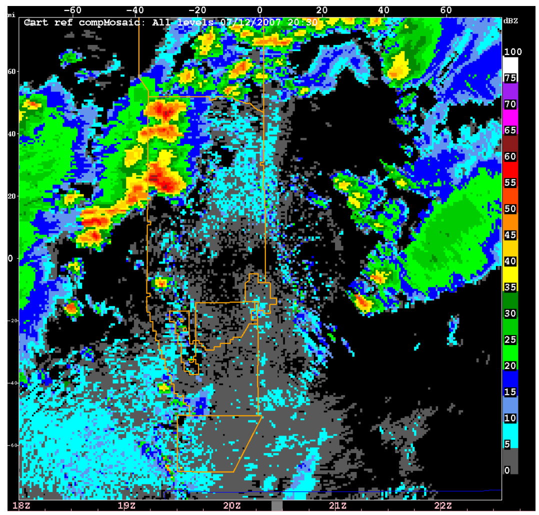

Figure 3. Composite mosaic radar reflectivity over the WSMR domain. Orange outline denotes the boundaries of WSMR, Fort Bliss and Holloman AFB.

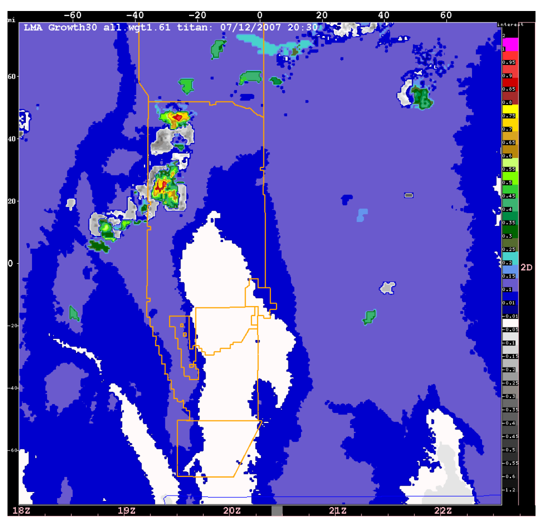

Figure 4. ANC growth and decay interest field. Grayscale colors indicate areas of dissipation interest while blues through reds show areas of growth interest.

Probability of Detection (POD) results are similar or somewhat better for the real-time ANC runs, with the mean difference in POD over the time period of .01 in favor of the real-time nowcasts (Fig 5). However, the False Alarm Ratio (FAR) shows clear improvement in the nowcasts that included LMA predictor fields. Mean differences in the FAR show an improvement of 0.1 for the nowcasts with LMA data (Fig 6). Critical Success Index (CSI) reveals that the nowcasts the include the LMA predictors are almost as good or better than the real-time results (Fig 7). When averaging the improvements in the individual nowcasts, the CSI for LMA included nowcasts is typically better by .04. Forecast bias reveals that ANC forecasts with LMA predictors are producing smaller forecast areas than what was observed in real-time. The average difference in bias for this case was 0.72.

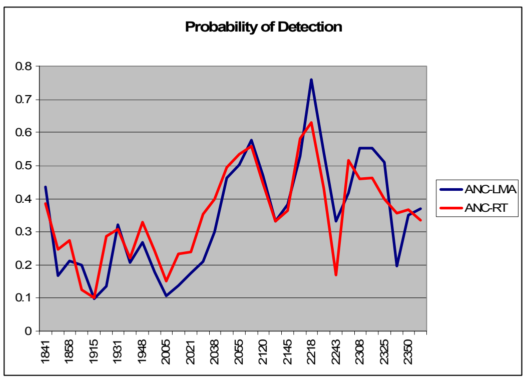

Figure 5. Probablilty of Detection for each nowcast from the real-time run (in red) and the nowcasts with LMA predictor fields (in blue).

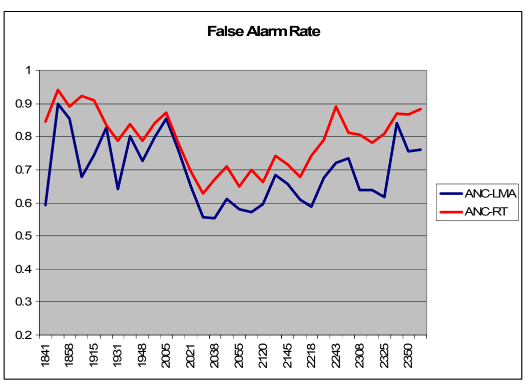

Figure 6. False Alarm Rate. Same colors as previous figure.

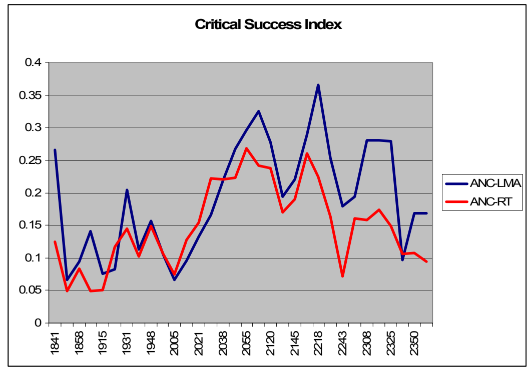

Figure 7. Critical Success Index. Colors are the same as Figure 5.

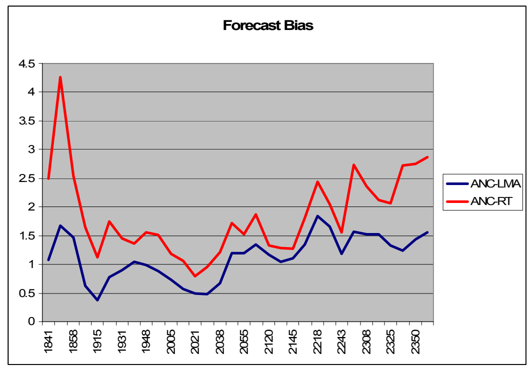

Figure 8. Forecast Bias. Colors are the same as Figure 5.

5. Discussion and Future Work

Using the LMA data for the 12 July 2007 case, we were able to increase the performance of the nowcasts by decreasing the false alarms and forecast area without sacrificing significantly in POD. This result is encouraging; however, much more work is necessary before the real-time ANC is configured to use the LMA predictors explored in this case. Additional case studies are needed ascertain if the improvements observed for this case are consistent for many cases or are an anomaly. Further refinement of the membership functions and weights for the source density and the source density rate of change will occur as additional cases are processed.

Additional predictor fields will be evaluated to determine if they will further enhance the WSMR ANC nowcasts. LMA data will be further analyzed. Flash rate and the rate of change of flash rate will be added to the forecast logic to determine if those predictors add value to the nowcast. Radar and cloud-to-ground lightning strike climatologies will be constructed and examined to see if they can be used in conjunction with or in-lieu of the existing altitude weighted terrain predictor field. Finally, there is a desire to examine the performance of the ANC growth and decay nowcasts when only LMA based predictors are used. Such a configuration could be used in the event of a failure of the nearby radar at Holloman AFB or if external data ingest is interrupted at WSMR.

6. Acknowledgements

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